

Review of particle properties

Particle Data Group

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This review of the properties of leptons, mesons, and baryons is an updating of Review of Particle Properties, Particle Data Group [Phys. Lett. **75B** (1978)]. Data are evaluated, listed, averaged, and summarized in tables. Numerous tables, figures, and formulae of interest to particle physicists are also included. A data booklet is available.

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I. INTRODUCTION, CREDITS, CONSULTANTS

This review is an updating through December 1979 of our previous review of particle properties [Particle Data Group (1978)]. As in previous editions we have attempted to make the text as complete and self-contained as possible.

As usual, the results of our compilation are presented in two sections, the Tables of Particle Properties and the Data Card Listings. The Tables summarize the properties of only those particles whose existence is in our judgment experimentally well founded and which have a large probability of standing the test of time. This is a conservative judgment, and surely some genuine resonances are omitted, awaiting confirmation (see section V below).

The Data Card Listings give up-to-date information, with references, on all reported particles, whether considered well established or not. The Listings also contain mini-reviews on questions of interest.

A history of the Particle Data Group, with a discussion of procedures and problems, has been given by Rosenfeld (1975) and a short survey of the history of some of the constants we compile can be found in Appendix IV.

We have maintained in this review the statistical procedure introduced in 1976, i.e., we give simultaneously in the Listings the old (labeled "AVG") and new (labeled "STUDENT") average values and errors. Details may be found in Sec. VII.

A pocket-sized Particle Properties Data Booklet, containing the Tables and a reprint of the figures and formulae from the first part of the review, is available on request. For North and South America, Australia, and the Far East, write to Technical Information Department, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA. For all other areas, write to CERN Scientific Information Service, CH-1211 Geneva 23, Switzerland.

As usual, we wish to emphasize that we compile the experimental results of others. It is inappropriate to give us the credit for their countless hours of effort. We urge that references be given directly to the original data, and we provide complete references in the Data Card Listings for that purpose.

The responsibilities for the various sections can be broken down as follows:

(1) *Stable particles*: N. Barash-Schmidt, C. P. Horne, M. J. Losty, T. Shimada, and T. G. Trippe.

(2) *Meson resonances*: C. Dionisi, M. J. Losty, M. Mazzucato, L. Montanet, and M. Roos.

(3) *Baryon resonances*: C. Bricman, R. L. Crawford, C. P. Horne, R. L. Kelly, M. J. Losty, and C. G. Wohl.

(4) *General, including text*: All authors.

Consultants: To overcome unavoidable gaps in our

coverage, both intellectual and geographical, we have solicited the help of consultants:

- U. Amaldi (CERN),
- W. B. Atwood (SLAC),
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- R. E. Shriock (SUNY Stony Brook),
- K. Shizaya (Lawrence Berkeley Laboratory),
- B. N. Taylor (U. S. National Bureau of Standards).

The usefulness of this compilation depends in large part on the interaction between the users and the authors and consultants. We appreciate comments, criticisms, and suggestions for improvements of all stages of data retrieval, processing, evaluation, and presentation.

II. SELECTION OF DATA

All particles are considered to fall into one of the three groups:

- (1) Stable particles, immune to decay via the strong interaction, including the η and the photon and the leptons.
- (2) Meson resonances.
- (3) Baryon resonances.

The charmed, charmonium, and other new flavor particles have been merged into these groups.

These groups are maintained within the two main parts of the compilation:

- (1) Tables of Particle Properties.
- (2) Data Card Listings.

The Data Card Listings contain the original information (data, references, etc.), weighted averages, comments, and "mini-reviews". Immediately preceding the Data Card Listings is an illustrative key thereto. We attempt to give complete Data Card Listings up to our closing date (January 1, 1980) for all journals listed in the Illustrative Key. We also include preprints and unpublished conference reports that have come to our attention, but make no claim to completeness.

Roughly 40% of our encoded results, those set off in parentheses, are not used for averaging. The reasoning is then often given in a footnote below the data. If the reason is not given, it is one of the following:

- The result was presented with no error stated.
- The result comes from a preprint or conference report. It is our experience that such results (and

particularly the errors) often change before final publication. Accordingly we keep these new results in parentheses until they are published (or explicitly verified to us by the authors).

- It involves some assumptions that we do not wish to incorporate.
- It is of poor quality, e.g. bad signal-to-noise ratio.
- It is inconsistent with other results, e.g. because of different methods employed, rendering averaging meaningless.
- It is not independent of other results, e.g. it is a result from one of several partial-wave analyses all using the same data, again rendering averaging meaningless.

When the data for a particle have received special treatment or present special problems, this is noted in a mini-review in the Data Card Listings.

The Tables of Particle Properties represent the output of weighted averages and some critical judgment. The extent to which "blind" averaging has been tempered with judgment is explained in footnotes to the Tables. In general, however, the footnotes are less complete than is the collection of notes and mini-reviews in the Data Card Listings. The reader is thus encouraged to become familiar with the Data Card Listings and, ultimately, with the original references.

III. NOMENCLATURE

A. Quantum numbers

The symbols $I^G(J^P)C_n$ represent:

- I = isospin,
- G = G parity,
- J = spin (also s),
- P = space parity,
- C_n = charge-conjugation parity for the neutral member of the isospin multiplet.

We also use:

- B = baryon number,
- S = strangeness,
- C = charm,
- l = orbital angular momentum.

1. Mesons

The charge-conjugation operator C turns particle into antiparticle and has eigenvalues ± 1 only for neutral states; so it is useful to define an operator G which has eigenvalues for charged states too. This is usually¹ defined by

$$G = C \exp(i\pi I_y). \quad (1)$$

A neutral nonstrange, noncharmed state is an eigenstate of $\exp(i\pi I_y)$ with eigenvalue $(-1)^I$. Then we can write the eigenvalue equation for the whole multiplet as

$$G = C_n (-1)^I, \quad (2)$$

where C_n (n for neutral) is the eigenvalue C would have

¹Most texts define it as in Eq. (1); see e.g. Gasiorowicz (1966); however, sometimes the rotation is taken about I_x . The difference between the two conventions is mentioned in a footnote in Källén (1964).

if applied to the neutral member of the multiplet. Thus, for a π^0 , C has the eigenvalue $+1$, and since $I=1$, $G = -1$. For a charged pion, there are no eigenvalues corresponding to C and to the isospin rotation, but Eqs. (1) and (2) still give $G = -1$.

Consider a meson as a bound state of fermion-antifermion, e.g. quark-antiquark $\bar{q}q$, with orbital angular momentum l , and with the two fermion spins coupling to give a spin s . Then one can show that the charge-conjugation eigenvalue [defined as in Eq. (2)] is

$$C_n = (-1)^{l+s}. \quad (3)$$

Eqs. (2) and (3) combine to give

$$G = (-1)^{l+s+I}. \quad (4)$$

The parity is

$$P = -(-1)^l. \quad (5)$$

Eqs. (3) and (5) combine to give

$$C_n P = -(-1)^s, \quad (6)$$

so all singlets ($^1S_0, ^1P_1, \dots$) have $C_n P = -1$, and all triplets ($^3S_1, \dots$) have $C_n P = +1$. For proofs of the above, see our 1969 text [Particle Data Group (1969)] and Appendix by C. Zemach.

If, instead of $\bar{q}q$, we consider the meson as a state of *boson-antiboson* (e.g. $A_2 \rightarrow \bar{K}K$), it turns out that some signs cancel, and Eqs. (3) and (4) (not Eq. (5)!) apply *unchanged*. Of course, the mesons are often spinless, so s is zero, but the equations are more general. Eqs. (3) and (4) can be considered as selection rules forbidding many decays.

We now use Eqs. (3) and (4) to introduce the concept of "Abnormal- C_n " mesons, i.e. mesons that cannot be composed of $\bar{q}q$. For this, it is sufficient to consider the SU(3) subgroup of the full unitary group of flavors, containing the u , d , and s quarks in a $\{3\}$ representation.

This triplet of quarks is of course defined to have isospin and hypercharge properties such that $\bar{q}q$ can combine (according to the SU(3) relations $\{3\} \otimes \{3\} = \{8\} \oplus \{1\}$) so as to form only octets and singlets. The non-observation of "exotic" mesons (i.e., mesons in larger SU(3) representations, or mesons requiring at least a $q\bar{q}q\bar{q}$ structure) is of course a direct consequence of the naive quark model. States coupling directly to proton-antiproton channels are sometimes interpreted as "baryonium", requiring $q\bar{q}q\bar{q}$ structure, but this interpretation is model-dependent, and no manifestly exotic mesons have been found. It is slightly less obvious that even some *octets* are forbidden by the model, namely those with $(J^P)C_n = (0^+)-, (1^-)+, (2^+)-, \dots$. Such states are not observed, and this is an additional success of the naive quark model classification scheme.

In what follows, do not confuse "Abnormal- C_n " with "Normal" or "Abnormal" J^P , both of which are allowed by the quark model. The series $J^P = 0^+, 1^-, 2^+, \dots$ is called Normal because $P = (-1)^J$ as for normal spherical harmonics, and $J^P = 0^-, 1^+, \dots$ is called Abnormal.

The top part of Table 1 shows all the low angular momentum states that can be formed from $\bar{q}q$. Note that half of the J^P states can be formed by both a triplet and a singlet $\bar{q}q$ state, e.g. $^3P_1, ^1P_1$, or $^3D_2, ^1D_2$.

TABLE I. Orbital excitations of the $\bar{q}q$ system, and corresponding mesons. For the distinction between Abnormal J^P and Abnormal C_n , see text following Eq. (6) in Section III. Strange and charmed mesons share the same values of J^P as the $I=0$ and 1 states shown, but are not eigenstates of G . The second column, which gathers together $(J^P)_N$ or AC_nP , is a redundant intermediate step intended to make the table easier to read. The table repeats itself for each radial excitation.

$\bar{q}q$ State		$(J^P)_{C_nP}$ Normal or abnormal	$I^G(J^P)C_n$	Examples of ground state mesons		
C_n^P -	C_n^P +			Non-strange, Non-charmed $S=C=0$	Strange $|S|=1$ ($I=\frac{1}{2}$)	Charmed $|C|=1$ ($I=\frac{1}{2}$)
NORMAL- C_n STATES THAT CAN COME FROM $\bar{q}q$ MODEL						
Parity -	$1S_0$	$(0^-)_{A^-}$	$\left\{ \begin{array}{l} 0^+(0^-)+ \\ 1^-(0^-)+ \end{array} \right.$	η, η' π	K	D(1870)
	$3S_1$	$(1^-)_{N^+}$	$\left\{ \begin{array}{l} 0^-(1^-)- \\ 1^+(1^-)- \end{array} \right.$	$\omega, \phi, J/\psi(3100)$ ρ	$K^*(892)$	$D^*(2010)$
Parity +	$1P_1$	$(1^+)_{A^-}$	$\left\{ \begin{array}{l} 0^-(1^+)- \\ 1^+(1^+)- \end{array} \right.$	B		
	$3P_0$	$(0^+)_{N^+}$	$\left\{ \begin{array}{l} 0^+(0^+)+ \\ 1^-(0^+)+ \end{array} \right.$	$\epsilon, S^*, X(3415)$ δ	κ	
	$3P_1$	$(1^+)_{A^+}$	$\left\{ \begin{array}{l} 0^+(1^+)+ \\ 1^-(1^+)+ \end{array} \right.$	D A_1	Q1	
	$3P_2$	$(2^+)_{N^+}$	$\left\{ \begin{array}{l} 0^+(2^+)+ \\ 1^-(2^+)+ \end{array} \right.$	f, f' A_2	$K^*(1430)$	
Parity -	$1D_2$	$(2^-)_{A^-}$	$\left\{ \begin{array}{l} 0^+(2^-)+ \\ 1^-(2^-)+ \end{array} \right.$	A_3		
	$3D_1$	$(1^-)_{N^+}$	same as $3S_1$	$\psi(3770)$		
	$3D_2$	$(2^-)_{A^+}$	$\left\{ \begin{array}{l} 0^-(2^-)- \\ 1^+(2^-)- \end{array} \right.$	Regge recurrence of the Abnormal- C_n state $(J^P)C_n = (0^-)-$		
	$3D_3$	$(3^-)_{N^+}$	$\left\{ \begin{array}{l} 0^-(3^-)- \\ 1^+(3^-)- \end{array} \right.$	$\omega(1670)$ g	$K^*(1780)$	
Parity +	$1F_3$	$(3^+)_{A^-}$	$\left\{ \begin{array}{l} 0^-(3^+)- \\ 1^+(3^+)- \end{array} \right.$			
	$3F_2$	$(2^+)_{N^+}$	same as $3P_2$			
	$3F_3$	$(3^+)_{A^+}$	$\left\{ \begin{array}{l} 0^+(3^+)+ \\ 1^-(3^+)+ \end{array} \right.$			
	$3F_4$	$(4^+)_{N^+}$	$\left\{ \begin{array}{l} 0^+(4^+)+ \\ 1^-(4^+)+ \end{array} \right.$	h		
ABNORMAL- C_n STATES THAT CANNOT COME FROM $\bar{q}q$ MODEL						
Abnormal C_n states Have no $\bar{q}q$ model	$(0^-)_{A^+}$	$\left\{ \begin{array}{l} 0^-(0^-)- \\ 1^+(0^-)- \end{array} \right.$	All except $J^P = 0^-$ are $J^P = \text{normal},$ $C_n^P = -1$			
	$(1^-)_{N^-}$	$\left\{ \begin{array}{l} 0^+(1^-)+ \\ 1^-(1^-)+ \end{array} \right.$				
	$(0^+)_{N^-}$	$\left\{ \begin{array}{l} 0^-(0^+)- \\ 1^+(0^+)- \end{array} \right.$				
	$(2^+)_{N^-}$	$\left\{ \begin{array}{l} 0^-(2^+)- \\ 1^+(2^+)- \end{array} \right.$				
	$(3^-)_{N^-}$	$\left\{ \begin{array}{l} 0^+(3^-)+ \\ 1^-(3^-)+ \end{array} \right.$				

Equation (3) shows that 3P_1 and 1P_1 have opposite C_n , so the $\bar{q}q$ model allows both. But the states 3P_0 and 3P_2 have no 1P counterparts. According to Eq. (6) they have $C_n P = +1$, and with the $\bar{q}q$ model there is no way to form a state with a J^P of ${}^3P_{0,2}$ (i.e. $J^P = \text{Normal}$) and with $C_n P = -1$. As mentioned, such octets have not shown up. With the help of Table I one can also see that the special state 1S_0 , $C_n P = +1$, cannot be formed, so has Abnormal C_n .

When, in addition to the l -excitation, there are radial excitations of the $\bar{q}q$ system, Table I repeats itself, and we need a radial quantum number n for each repetition ($n=1$ for the ground state). Examples of first radial excitations, $n=2$, are ρ' (1600), ψ (3685), and Υ' (10060). Examples of further possible radial excitations can be found in the ψ and Υ families.

2. General remarks

Well-established quantum numbers are underlined in the Tables of Particle Properties (except for stable particles, where most of the quantum numbers are established). We have used what evidence is available (sometimes flimsy) to guess many of the remaining ones, and we have indicated with “?” ones (in the Baryon Table) for which there is almost no evidence.

As is customary, we define antiparticles as the result of operating with CPT on particles, so both share the same spins, masses, and mean lives. Whenever there is a particularly interesting test of CPT invariance we include it in the Stable Particles Table.

B. Particle names

If a meson has a well-accepted colloquial name, we use it. If not, we name it by a single symbol which specifies its baryon number B ($=0$ for mesons), its isospin I , its strangeness S and charm C , and, for a non-strange, non-charmed meson, its G parity.

The name conventions for mesons are given in the first part of Table II.

TABLE II. Particle name conventions.

Name	I	S	C	G
Mesons				
η	0	0	0	+
ω, ϕ, ψ, T^a	0	0	0	-
ρ	1	0	0	+
π	1	0	0	-
K	1/2	± 1	0	
D	1/2	0	± 1	
F	0	± 1	± 1	
Baryons				
N	1/2	0	0	
Δ	3/2	0	0	
Z_0, Z_1	0, 1	+1	0	
Λ	0	-1	0	
Σ	1	-1	0	
Ξ	1/2	-2	0	
Ω	0	-3	0	
Λ_c	0	0	1	
Σ_c	1	0	1	

^a We use the symbol ω for those $I^G = 0^-$ mesons which are mainly $u\bar{u}$ and $d\bar{d}$ quark states; ϕ for those which are mainly $s\bar{s}$ quark states, ψ for mainly $c\bar{c}$ states, and T for mainly $b\bar{b}$ (hypothesized) states.

For some pairs of mesons with supposedly identical quantum numbers, we also use primes; e.g. $\eta, \eta'; f, f'; \rho, \rho'$. Note that primes and subscripts do not carry any further specific meaning.

For baryons no attempt has been made to attach a subscript about J and P . The name conventions are given in the second part of Table II. For stable baryons of each I and S we use the symbol standing alone; for resonances, the mass is in parentheses [i.e. $N(1688), \Lambda(1405), \Sigma(1765)$, etc.]. The J^P assignments are reported in the Baryon Table as $\frac{1}{2}^+, \frac{3}{2}^-, \frac{5}{2}^+$, etc., and also by the symbols P_{11}, D_{13}, F_{15} , which refer to the πp or Kp partial-wave amplitude in which the resonant state occurs (the first subscript refers to the isospin state: $2 \times I$ for N and Δ and just I for Z, Λ , and Σ). When two or more baryons have identical quantum numbers we warn the reader by adding primes to the spectroscopic symbol as explained in footnote (a) of the Baryon Table.

IV. CONVENTIONS AND PARAMETERS FOR STRONG INTERACTIONS

A. Partial-wave amplitudes and resonance parameters

The vast majority of information concerning baryon resonances comes in the form of partial-wave analyses. In addition data concerning meson resonances ($\pi\pi, K\pi, \pi\pi\pi$) are, with increasing frequency, being subjected to partial-wave analyses. We thus find it natural to introduce the resonance parameters which we compile in terms of a Breit-Wigner approximation for the partial-wave amplitude.

In general the elastic amplitude for a given angular momentum l may be written as

$$T_{11} = \frac{\eta \exp(2i\delta) - 1}{2i}, \tag{1}$$

where η is the absorption parameter ($0 \leq \eta \leq 1$) and δ is the phase shift. The subscripts 11 on T denote scattering from channel 1 to channel 1 (e.g. $\pi\pi \rightarrow \pi\pi$ or $\bar{K}K \rightarrow \bar{K}K$).

In Fig. 1 we show an Argand plot of the elastic partial wave amplitude T_{11} . It illustrates geometrically how the real parameters η and δ are related to the real and imaginary parts of T_{11} . Many examples of such Argand plots may be found in the Baryon Data Card Listings.

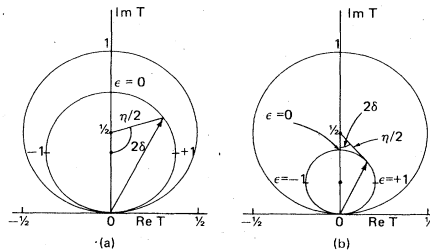


FIG. 1. Argand plots for the elastic partial wave amplitude T_{11} . The outer circles are the unitarity bound ($\eta=1$). The inner circles correspond to the Breit-Wigner approximation of Eq. (2) for (a) $x_1 = \Gamma_1/\Gamma = 0.75$ and (b) $x_1 = 0.4$. Note: $\epsilon = \sqrt{2}(M - E)/\Gamma$.

Consider the so-called non-relativistic Breit-Wigner approximation for T_{11} :

$$T_{11} = \frac{1}{2} \Gamma_1 / (M - E - \frac{1}{2} i\Gamma), \quad (2)$$

where E is the c.m. energy or invariant mass, Γ_1 and Γ are the *elastic* and *total* widths, and M is the *resonance mass*. Equation (2) is, of course, not the only possible description of a resonant amplitude; but it suffices to illustrate the properties of partial-wave amplitudes which we associate with resonance behavior in the absence of any background in the same partial wave (see, e.g., the $\pi N D_{15}$ and F_{15} waves in the Baryon Data Card Listings). Usually the widths contain barrier-penetration factors which can vary rapidly with energy. Near threshold, $\Gamma_1(E)$ should start up as q^{2l+1} (also true for the inelastic width Γ_β). Various E dependences are then used for Γ_1 , mostly of the form

$$\Gamma_1(E) \propto \frac{(qR)^{2l+1}}{\text{const} + \dots + (qR)^{2l}}; \quad (3)$$

see Jackson (1964), Pišut and Roos (1968), and Barbaro-Galtieri (1968).

The BW approximation to the amplitude for an inelastic process leading from channel 1 to channel β ($\pi\pi \rightarrow \bar{K}K$ or $\bar{K}N \rightarrow \Sigma\pi$, for example) is

$$T_{1\beta} = \frac{1}{2} (\Gamma_1 \Gamma_\beta)^{1/2} / (M - E - \frac{1}{2} i\Gamma) \quad (4)$$

$$= (x_1 x_\beta)^{1/2} [\frac{1}{2} \Gamma / (M - E - \frac{1}{2} i\Gamma)],$$

where

$$\Gamma = \sum_1^N \Gamma_\beta, \quad x_\beta = \Gamma_\beta / \Gamma, \quad (5)$$

and x_1 (called the elasticity) is often written x_e . (Note that in the Data Card Listings we use the symbol P_β to denote x_β .) The channel cross section $\sigma_{1\beta}$ for the reaction $1 \rightarrow \beta$, for spin 0-spin 1/2 scattering, is

$$\sigma_{1\beta} = 4\pi \lambda^2 (J + \frac{1}{2}) |T_{1\beta}|^2, \quad (6)$$

where $J = l \pm \frac{1}{2}$.

The important features of Eq. (4) which characterize resonant behavior in the Argand diagram ($\text{Im } T_{1\beta}$ versus $\text{Re } T_{1\beta}$) are:

energy variation given by circles with diameter $(x_1 x_\beta)^{1/2}$ and maximum amplitude at $E = M$ of

$$T_{1\beta}^{\text{max}} = i(x_1 x_\beta)^{1/2}; \quad (7)$$

a maximum in the speed near resonance, given approximately by

$$\text{“Speed” (res)} = \left| dT_{1\beta} / dE \right|_{E=M} = \frac{2(x_1 x_\beta)^{1/2}}{\Gamma(E)}, \quad (8)$$

for slowly varying $\Gamma(E)$. These features may be related to the η, δ representation of T_{11} . Thus when $E = M$, δ is either 90° ($x_1 > \frac{1}{2}$) or 0° ($x_1 < \frac{1}{2}$) and η dips to its minimum value.

These simple properties can be used to judge the presence or absence of resonance behavior in an Argand plot, but do not necessarily constitute the criteria we use (see Sec. V). It must also be kept in mind that Eqs. (2) and (4) are only approximations to the “true” amplitude. The simple picture given above can be distorted by various effects:

the presence of “background” in the same partial wave as the resonance,

two resonances in the same partial wave overlapping in energy,

the resonant energy M being close to an inelastic channel threshold, in which case a K -matrix-like parametrization is more appropriate,

the speed of the resonance being very slow so that the resonance is very broad, and the Breit-Wigner formula a bad approximation.

B. Sign conventions for resonance couplings

Consider the partial width Γ_β of a resonance decaying into the channel β . We can always define a coupling constant such that

$$\Gamma_\beta \propto G_\beta^2.$$

In this case the inelastic amplitude in the Breit-Wigner approximation, Eq. (4), will go as

$$T_{1\beta} \propto G_1 G_\beta / (M - E - \frac{1}{2} i\Gamma),$$

where G_1 is the coupling constant for the elastic channel. In the context of exact SU(3) symmetry the relative signs of the product $G_1 G_\beta$ for different resonances are often useful as a consistency check on SU(3) assignment of baryon resonances. See Appendix II for further details.

In the Data Card Listings for baryon resonances, we tabulate measured values for $(x_1 x_\beta)^{1/2} \propto G_1 G_\beta$. When the sign of the amplitude is determined, it is given; absence of an explicit sign indicates that it is undetermined (*not* that it is positive). For Λ and Σ resonances, the signs are chosen according to the convention advocated by Levi-Setti (1969) and used in the table of SU(3) Isoscalar Factors presented in this review. Thus the signs multiplying the Breit-Wigner amplitudes for $\bar{K}N \rightarrow \Sigma(1385) \rightarrow \Sigma\pi$, $\Lambda\pi$ and $\bar{K}N \rightarrow \Lambda(1405) \rightarrow \Sigma\pi$ are simply the product of the phases of the appropriate isoscalar factors. This convention is shown in Fig. 2, adapted from Levi-Setti (1969).

C. Types of partial-wave analyses

Partial-wave analyses (PWA) are classified into three categories in the Data Card Listings: energy-independent partial-wave analyses (IPWA), energy-dependent partial-wave analyses (DPWA), and model-dependent partial-wave analyses (MPWA), in increasing order of the number of explicit supplementary hypotheses that are used to extract the amplitudes from experimental data.

In an IPWA, data at different energies are analyzed separately. Usually each partial wave included in the fit is allowed to vary freely (subject to unitarity constraints) over some large region, and waves whose angular momenta are above some cutoff value are assumed to be negligible. The sharp cutoff in angular momentum resolves continuum ambiguities in the solution (such as the overall phase ambiguity), but there remains a finite number of indistinguishable “best” solutions (i.e., solutions corresponding to identical physical observables) which have been codified by Barrelet (1972). In addition, there are generally some

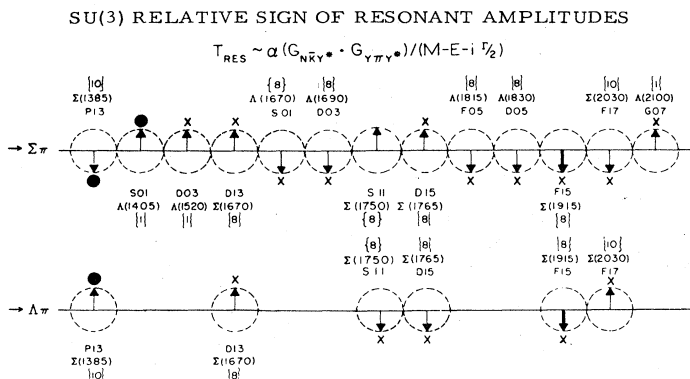


FIG. 2. Plot adapted from Levi-Setti (1969) showing the sign convention adopted here for the $\Sigma\pi$ and $\Lambda\pi$ amplitudes. Once the signs of one $I=0$ and one $I=1$ amplitude are fixed, the others can be measured relative to these two. Arrows here indicate signs predicted by SU(3); \times marks indicate the observed phases; \bullet indicates phase chosen according to sign convention described in text. The $\Sigma(1915)$ predictions have been changed from Levi-Setti's original figure.

nearby solutions (and their associated Barrelet ambiguities) which have chi-squared values close to the minimum one.

At the end of the analysis a choice is made among these many solutions, usually on the basis of energy continuity. A popular criterion for making this choice is the shortest path technique in which the total "length" of the preferred solution is chosen to be a minimum. The definition of "length" used here is not universal but is usually closely related to the total geometrical length of the lines representing the various partial-wave amplitudes in Argand plots (see the baryon section of the Data Card Listings for examples of Argand plots). Various other criteria which are also used in some analyses are, e.g., matching with known solutions at low energies, the presence of known resonances in the final results, and limited inelasticity in high partial waves.

In a DPWA, data at different energies are fit simultaneously by using an energy dependent parametrization of the partial-wave amplitudes. The parametrization is usually chosen to include both resonances and nonresonant background of some sort and an attempt is made to keep it as "model independent" as possible. Often the data are grouped into several energy bins which are fit separately rather than trying to fit the whole energy range under consideration simultaneously. One of the main advantages of DPWA over IPWA is that sparse data spread over many different energies can be analyzed, e.g., nearly all $S=-1$ analyses are DPWA. In addition, the built-in energy continuity helps to resolve the ambiguities that plague IPWA and eases the problems associated with resonance parameter extraction. The price one pays for these advantages lies in the danger of systematic error in the amplitudes and poor fits to the data if the parametrization is poorly chosen or insufficiently flexible.

An MPWA also uses an energy-dependent parametrization, but one based on explicit model-dependent theoretical assumptions such as Regge exchanges. This technique is usually applied to reactions where the data are incomplete. There is, of course, no sharp distinction between DPWA and MPWA, and a well chosen MPWA parametrization may actually be less biased than a model-independent but poorly chosen DPWA parametrization.

D. Production of resonances

Hereby, we mean the observation of statistically significant peaks in invariant mass plots or, loosely, in integrated cross sections. Many meson resonances are of this type. We expect most of these peaks to be associated with Breit-Wigner behavior in appropriate Argand plots; thus the ρ meson peak in $\pi\pi$ mass plots is firmly related to the $I=1, l=1$ $\pi\pi$ phase shift passing through 90° .

From mass plots we can determine M , Γ , and the approximate branching ratios

$$x_\alpha/x_\beta = \Gamma_\alpha/\Gamma_\beta. \tag{9}$$

In the case of total cross sections, the peak above background gives us, using the optical theorem, the product $(J + \frac{1}{2})x_e$:

$$\sigma^{\text{tot}}(E=M) = 4\pi\lambda^2 (J + \frac{1}{2})x_e. \tag{10}$$

V. CRITERIA FOR RESONANCES

An experimentalist who sees indications of a resonance in some energy (or mass) region will of course want to know what has been seen in that region in the past; hence, we strive to have the Data Card Listings serve as an archive for all substantial claims for resonances.

For the Tables of Particle Properties, on the other hand, we wish to be more conservative and to include only those peaks or resonances which we feel have a large chance of survival. An arrow (\rightarrow) at the left of the Tables of Particle Properties indicates that a questionable candidate has been omitted from the Table, but that it can be found in the corresponding part of the Data Card Listings. One's betting odds for survival are of course subjective; therefore no precise criteria can be defined. Very slow speeds (ϵ and κ) make it quite difficult to decide what is a resonance and what is not. For more detailed discussions, see the mini-reviews in the Listings. In what follows we shall attempt to specify some guidelines.

(a) When energy-independent partial-wave analyses are available (mostly for N^*s), approximate Breit-Wigner behavior of the amplitude appears to us to be the most satisfactory test for a resonance. We can check that the Argand plot follows roughly a lefthand

circle, and that the "speed" of the amplitude also shows a maximum near the resonance energy; further, there should be data well above the resonance, showing that the speed again decreases. Indeed proper behavior of the partial-wave amplitude could accredit a resonance even if its elasticity is too small to make a noticeable peak in the cross section.

Of course even if Argand plots are available, it may still be a matter of opinion as to what behavior constitutes a resonance. Such an example is the $Z_0(1780)$ state seen in KN total cross-section experiments and in partial-wave analysis. The partial-wave analyses of Giacomelli (1974) and Martin (1975) find preferred solutions which exhibit a resonance-like loop in the P_{01} wave near 1740 MeV. However, Giacomelli *et al.* and Martin point out that, despite the resonantlike appearance of the loop, the evidence for resonant energy dependence is inconclusive. Thus we omit the $Z_0(1780)$ from the Baryon Table. A similar quandary has existed for some time concerning the $Z_1(1900)$, and it too has been omitted from the Tables.

(b) When there are insufficient data to perform energy-independent analyses, one often resorts to energy-dependent partial-wave analyses (mostly for Y^*s). In this case Breit-Wigner behavior is an input. We therefore require that resonance solutions be found by several different analyses, preferably in different channels ($\bar{K}N \rightarrow \bar{K}N$, $\pi\Sigma$, etc.), before putting the claim in the table.

(c) Partial-wave analyses of three-body final states ($\pi N \rightarrow \pi\pi N$) are now available. While these analyses are based on the isobar model ($\pi N \rightarrow \rho N$, $\pi\Delta$, etc.) and are subject to theoretical objections of varying importance, they provide increasingly reliable information on inelastic decay modes of otherwise established resonances.

(d) Most mesons, Ξ^* peaks, and high mass N^* and Y^* peaks fall into a category for which no partial-wave analyses exist. In general we accept such peaks if they are experimentally reliable, of high statistical significance or observed in several different production processes.

Thus, we enter into the Tables of Particle Properties only states for which there is experimentally convincing evidence, and we expect that most of these will be confirmed as resonances.

VI. CONVENTIONS AND PARAMETERS FOR WEAK AND ELECTROMAGNETIC DECAYS

A. Muon-decay parameters

The μ -decay parameters describe the momentum spectrum (ρ and η), the asymmetry (ξ and δ), and the helicity (h) of the electron in the process $\mu^\pm \rightarrow e^\pm + \nu + \bar{\nu}$. Assuming a local and lepton-conserving interaction, the matrix element may be written as

$$\sum_i \langle \bar{e} | \Gamma_i | \mu \rangle \langle \bar{\nu} | \Gamma_i (C_i + C_i' \gamma_5) | \nu \rangle,$$

where the summation is taken over $i=S, V, T, A, P$. Using the definitions and sign conventions of Kinoshita and Sirlin (1957), we have for the momentum parameters

$$\rho = [3g_A^2 + 3g_V^2 + 6g_T^2]/D,$$

$$\eta = [g_S^2 - g_P^2 + 2g_A^2 - 2g_V^2]/D,$$

for the asymmetry parameters:

$$\xi = \frac{6g_S g_P \cos\phi_{SP} - 8g_A g_V \cos\phi_{AV} + 14g_T^2 \cos\phi_{TT}}{D},$$

$$\delta = [-6g_A g_V \cos\phi_{AV} + 6g_T^2 \cos\phi_{TT}]/D\xi,$$

and for the parameter describing the helicity of the electron:

$$h = \frac{2g_S g_P \cos\phi_{SP} - 8g_A g_V \cos\phi_{AV} - 6g_T^2 \cos\phi_{TT}}{D}.$$

Here

$$D = g_S^2 + g_P^2 + 4g_V^2 + 6g_T^2 + 4g_A^2,$$

$$g_i^2 = |C_i|^2 + |C_i'|^2,$$

and

$$\cos\phi_{ij} = \text{Re}(C_i^* C_j + C_i' C_j').$$

The quantities g_i are defined to be real non-negative numbers, and the ϕ_{ij} are phase angles between the i -type and j -type interactions. Under the assumption of two-component neutrinos $C_i' = -C_i$ and $C_j' = -C_j$, the S , P , and T terms vanish, and ϕ_{AV} is the phase angle between C_A and C_V in the complex plane.

By using the above equations and the experimental determinations of ρ , η , ξ , δ , and h , limits can be placed on g_S/g_V , g_A/g_V , g_T/g_V , g_P/g_V , and ϕ_{AV} . The results, given in the Data Card Listings, assume neither two-component neutrinos nor time-reversal invariance. If, however, two-component neutrinos are assumed, then $\sin\phi_{AV}$ is the amplitude of time-reversal violation. Note that most experiments study only the upper end of the spectrum where ρ and η are highly correlated, so they can only report ρ for $\eta=0$ and η for $\rho=3/4$. The values for ρ and η we use here were obtained by combining measurements of both upper and lower ends of the spectrum and turn out to be nearly uncorrelated.

Note also that the radiative corrections are unambiguous only when $g_S = g_T = g_P = 0$. The same limits on g_A/g_V and ϕ_{AV} are obtained, however, as when g_S , g_T , and g_P are left free.

Current values for the asymmetry parameters as well as $|g_A/g_V|$ and ϕ_{AV} are given in the Addendum to the Stable Particle Table. In addition, upper limits on $|g_S/g_V|$, $|g_T/g_V|$ and $|g_P/g_V|$ are given in the μ section of the Stable Particle Data Card Listings.

B. K -decay parameters

1. Dalitz plot for $K \rightarrow 3\pi$ decays

The Dalitz plot distribution for the τ mode ($K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\mp$), the τ' mode ($K^\pm \rightarrow \pi^0 \pi^0 \pi^\pm$), and the τ^0 mode ($K_L^0 \rightarrow \pi^+ \pi^- \pi^0$) of K decay can be parametrized by a series expansion such as that introduced by Weinberg (1960).

We use the form

$$|M|^2 \propto 1 + g \frac{s_3 - s_0}{m_{\pi^+}^2} + h \left(\frac{s_3 - s_0}{m_{\pi^+}^2} \right)^2 + j \frac{s_2 - s_1}{m_{\pi^+}^2} + k \left(\frac{s_2 - s_1}{m_{\pi^+}^2} \right)^2 + \dots, \quad (1)$$

where $m_{\pi^+}^2$ has been introduced so as to make the coefficients g , h , j , and k dimensionless, and

$$s_i = (P_K - P_i)^2 = (m_K - m_i)^2 - 2m_K T_i, \quad i = 1, 2, 3,$$

$$s_0 = \frac{1}{3} \sum_i s_i = \frac{1}{3} (m_K^2 + m_1^2 + m_2^2 + m_3^2).$$

Here the P_i are 4-vectors, m_i and T_i are the mass and kinetic energy of the i th pion, and the index 3 is used for the odd pion.

The coefficient g is a measure of the slope in the variable s_3 (or T_3) of the Dalitz plot, while h and k measure the quadratic dependence on s_3 and $(s_2 - s_1)$, respectively. The coefficient j is related to the asymmetry of the plot and must be zero if CP invariance holds (C stands for charge conjugation throughout the discussion in this section). Note also that if CP is good, g must be the same for τ^+ and τ^- , and similarly for h and k .

Since different experiments use different forms for $|M|^2$, in order to compare the experiments we have converted to g , h , j , and k whatever coefficients have been measured. See the mini-review in the K^+ section of the Stable Particle Data Card Listings for details on this point. The results are given in the Addendum to the Stable Particle Table and in the K^+ and K_L^0 sections of the Stable Particle Data Card Listings.

Relations among τ^+ , τ'^+ , and τ^0 are predicted by the $\Delta I = \frac{1}{2}$ rule. See Appendix I for these relations and a discussion of this rule.

2. Form factors in $K_{\mu 3}$ leptonic decays

Assuming that only the vector current contributes to these decays, we write the matrix element as

$$M \propto f_+(t) [(P_K + P_\pi)_\mu \bar{u}_i \gamma_\mu (1 + \gamma_5) u_\nu] + f_-(t) [m_l \bar{u}_i (1 + \gamma_5) u_\nu], \quad (2)$$

where P_K and P_π are the four momenta of K and π mesons; m_l is the lepton mass; f_+ and f_- are dimensionless form factors which can depend only on $t = (P_K - P_\pi)^2$, the square of the four-momentum transfer to the leptons. f_+ and f_- are relatively real if time-reversal invariance holds for these decays. $K_{\mu 3}$ experiments measure f_+ and f_- , while $K_{e 3}$ experiments are sensitive only to f_+ because the presence of the lepton mass makes the f_- term negligible.

(a) $K_{\mu 3}$ experiments.

Analyses of $K_{\mu 3}$ data frequently assume a linear dependence of f_+ and f_- on t , i.e.

$$f_\pm(t) = f_\pm(0) [1 + \lambda_\pm(t/m_\pi^2)]. \quad (3)$$

Most $K_{\mu 3}$ data are adequately described by Eq. (3) for f_+ and a constant f_- (i.e. $\lambda_- = 0$). There are two equivalent parametrizations commonly used in these analyses:

(1) λ_+ , $\xi(0)$ parametrization. Analyses of $K_{\mu 3}$ data often introduce the ratio of the two form factors

$$\xi(t) = f_-(t)/f_+(t).$$

The $K_{\mu 3}$ decay distribution is then described by the two parameters λ_+ and $\xi(0)$ (assuming time reversal

invariance and $\lambda_- = 0$). These parameters can be determined by three different methods:

Method A. By studying the Dalitz plot or the pion spectrum of $K_{\mu 3}$ decay. The Dalitz plot density is [see, e.g. Chounet *et al.* (1972)]:

$$\rho(E_\pi, E_\mu) \propto f_+^2(t) [A + B\xi(t) + C\xi(t)^2],$$

where

$$A = m_K(2E_\mu E_\nu - m_K E'_\pi) + m_\mu^2 (\frac{1}{4} E'_\pi - E_\nu),$$

$$B = m_\mu^2 (E_\nu - \frac{1}{2} E'_\pi),$$

$$C = \frac{1}{4} m_\mu^2 E'_\pi,$$

$$E'_\pi = E_\pi^{\max} - E_\pi = \frac{m_K^2 + m_\pi^2 - m_\mu^2}{2m_K} - E_\pi.$$

Here E_π , E_μ , and E_ν are respectively the pion, muon, and neutrino energies in the kaon center of mass. The density ρ is fit to the data to determine the values of λ_+ , $\xi(0)$, and their correlation.

Method B. By measuring the $K_{\mu 3}/K_{e 3}$ branching ratio and comparing it with the theoretical ratio [see, e.g., Fearing *et al.* (1970)] as given in terms of λ_+ and $\xi(0)$, assuming μ - e universality:

$$\Gamma(K_{\mu 3}^+)/\Gamma(K_{e 3}^+) = 0.6457 + 1.4115\lambda_+ + 0.1264\xi(0) + 0.0192\xi(0)^2 + 0.0080\lambda_+\xi(0),$$

$$\Gamma(K_{\mu 3}^0)/\Gamma(K_{e 3}^0) = 0.6452 + 1.3162\lambda_+ + 0.1246\xi(0) + 0.0186\xi(0)^2 + 0.0064\lambda_+\xi(0).$$

This cannot determine λ_+ and $\xi(0)$ simultaneously but simply fixes a relationship between them.

Method C. By measuring the muon polarization in $K_{\mu 3}$ decay. In the rest frame of the K , the μ is expected to be polarized in the direction \mathbf{A} with $\mathbf{P} = \mathbf{A}/|\mathbf{A}|$, where \mathbf{A} is given [Cabibbo and Maksymowicz (1964)] by

$$\mathbf{A} = a_1(\xi) \mathbf{p}_\mu - a_2(\xi) \left\{ \frac{\mathbf{p}_\mu}{m_\mu} \left[m_K - E_\pi + \frac{\mathbf{p}_\pi \cdot \mathbf{p}_\mu}{|\mathbf{p}_\mu|^2} (E_\mu - m_\mu) \right] + \mathbf{p}_\pi \right\} + m_K \text{Im} \xi(t) (\mathbf{p}_\pi \times \mathbf{p}_\mu).$$

If time-reversal invariance holds, ξ is real, and thus there is no polarization perpendicular to the K -decay plane. Polarization experiments measure the weighted average of $\xi(t)$ over the t range of the experiment, where the weighting accounts for the variation with t of the sensitivity to $\xi(t)$.

(2) λ_+ , λ_0 parametrization. Some of the more recent $K_{\mu 3}$ analyses have parametrized in terms of the form factors f_+ and f_0 which are associated with vector and scalar exchange respectively to the lepton pair. f_0 is related to f_+ and f_- by

$$f_0(t) = f_+(t) + [t/(m_K^2 - m_\pi^2)] f_-(t).$$

Here $f_0(0)$ must equal $f_+(0)$ unless $f_-(t)$ diverges at $t=0$. The earlier assumption that f_+ is linear in t and f_- is constant leads to f_0 linear in t :

$$f_0(t) = f_0(0) [1 + \lambda_0(t/m_\pi^2)].$$

With the assumption that $f_0(0) = f_+(0)$, the two parametrizations, $(\lambda_+, \xi(0))$ and (λ_+, λ_0) are equivalent as

long as correlation information is retained. (λ_+, λ_0) correlations tend to be less strong than $(\lambda_+, \xi(0))$ correlations.

The experimental results for $\xi(0)$ and its correlation with λ_+ are listed in the K^\pm and K_L^0 sections of the Stable Particle Data Card Listings in Sec. XIA, XIB, or XIC depending on whether method *A*, *B*, or *C* discussed above was used. The corresponding values of λ_+ are listed in subsection L+M.

Because current experiments tend to use the (λ_+, λ_0) parametrization, we have added a subsection L0 for λ_0 results. Wherever possible we have converted $\xi(0)$ results into λ_0 results and vice versa.

(b) K_{e3} experiments.

Analysis of K_{e3} data is simpler than that of $K_{\mu 3}$ because the second term of the matrix element assuming a pure vector current [Eq. (2) above] can be neglected. Here f_+ is usually assumed to be linear in t , and the linear coefficient λ_+ of Eq. (3) is determined.

If we remove the assumption of a pure vector current, then the matrix element for the decay, in addition to the terms in Eq. (2), would contain

$$+2m_K(f_S\bar{u}_i(1+\gamma_5)u_\nu + (2f_T/m_K)(P_K)_\lambda(P_\tau)_\mu\bar{u}_i\sigma_{\lambda\mu}(1+\gamma_5)u_\nu),$$

where f_S is the scalar form factor, and f_T is the tensor form factor. In the case of the K_{e3} decays where the f_- term can be neglected, experiments have yielded limits on $|f_S/f_+|$ and $|f_T/f_+|$.

The K_{e3} results for λ_+ , $|f_S/f_+|$, and $|f_T/f_+|$ are listed in the subsections *L+M*, *FS*, and *FT*, respectively of the K^\pm and K_L^0 sections of the Stable Particle Data Card Listings.

See also the Note on K_{13}^\pm and K_{13}^0 Form Factors in the K^\pm section of the Stable Particle Data Card Listings for additional discussion of the $K_{\mu 3}^0$ parameters, correlations, and conversion between parametrization and also for a comparison of the experimental results.

3. CP violation in K^0 decays

We list parameters for four different reactions in which *CP* can be tested [for details, see Okun and Rubbia (1967), Steinberger (1969), and Wolfenstein (1969)].

(a) $K_S \rightarrow \pi^+\pi^-\pi^0$.

The quantity measured here is the ratio of amplitudes

$$A_S(K_S \rightarrow \pi^+\pi^-\pi^0)/A_L(K_L \rightarrow \pi^+\pi^-\pi^0) \equiv x + iy. \quad (4)$$

If *CPT* invariance holds and there is no $I=3$ state present, then x can be neglected and *CP* violation would be observed as a nonzero y . We give the result for Eq. (4) in the K_L^0 section of the Stable Particle Table and under Branching Ratio *R4* in the K_S^0 section of the Stable Particle Data Card Listings. Our procedure is to assume that $x=0$, and to list $(A_S/A_L)^2$ in the form of a branching ratio.

(b) Charge asymmetry in $K_L \rightarrow 3\pi$ decays.

As mentioned above, the presence of a term in $(s_2 - s_1)$ in expression (1) describing the Dalitz plot distribution for τ^\pm, τ^0 decays of K mesons would be an indication of *CP* violation. Experimenters have used

several forms for this *CP*-violation term. As described in the mini-review in the K^\pm section of the Stable Particle Data Card Listings, we have converted all results to coefficient j in Eq. (1) above. The latter is listed among the *CP*-violating parameters at the back of the K_L^0 section of the Stable Particle Data Card Listings. Note that only upper limits have been reported for this quantity.

(c) Asymmetry in the $K_L \rightarrow \pi^+\pi^-\nu$ decays.

The quantity measured and compiled here is

$$\delta = \frac{\Gamma(K_L \rightarrow \pi^+\pi^-\nu) - \Gamma(K_L \rightarrow \pi^-\pi^+\nu)}{\Gamma(K_L \rightarrow \pi^+\pi^-\nu) + \Gamma(K_L \rightarrow \pi^-\pi^+\nu)}.$$

This asymmetry violates *CP* invariance. If *CPT* is good, for a pure K_L^0 beam, δ can be written as

$$\delta = 2[(1 - |x|^2)/(|1 - x|^2)] \text{Re}\epsilon,$$

where x is the $\Delta S = \Delta Q$ -violating parameter defined in section B.4, and ϵ is the parameter of the expansion

$$|K_L\rangle = [(1 + \epsilon)|K\rangle - (1 - \epsilon)|\bar{K}\rangle]/[2(1 + |\epsilon|^2)]^{1/2}, \quad (5a)$$

$$|K_S\rangle = [(1 + \epsilon)|K\rangle + (1 - \epsilon)|\bar{K}\rangle]/[2(1 + |\epsilon|^2)]^{1/2}. \quad (5b)$$

We give δ in the Addendum to the Stable Particle Table. In addition, in the K_L^0 *CP*-violation section of the Stable Particle Data Card Listings, we list δ separately for $K_L^0 \rightarrow \pi\mu\nu$ and $K_L^0 \rightarrow \pi e\nu$.

(d) $K_L \rightarrow 2\pi$ decay.

The relevant parameters are

$$\eta_{+-} = A(K_L \rightarrow \pi^+\pi^-)/A(K_S \rightarrow \pi^+\pi^-)$$

$$= |\eta_{+-}| \exp(i\phi_{+-}),$$

$$\eta_{00} = A(K_L \rightarrow \pi^0\pi^0)/A(K_S \rightarrow \pi^0\pi^0)$$

$$= |\eta_{00}| \exp(i\phi_{00}),$$

ϵ , defined in Eqs. (5) above, and

$$\epsilon' = \frac{1}{2} i\sqrt{2} \exp[i(\delta_2 - \delta_0)] \text{Im}(A_2/A_0).$$

Here, A_i and δ_i are the amplitude and phase of $\pi\pi$ scattering at the K mass, defined by

$$\langle I=0 | T | K \rangle = \exp(i\delta_0) A_0,$$

$$\langle I=2 | T | K \rangle = \exp(i\delta_2) A_2.$$

Wu and Yang (1964) have derived the relationships

$$\eta_{+-} = \epsilon + \epsilon', \quad \eta_{00} = \epsilon - 2\epsilon'.$$

We give η_{+-} , η_{00} , ϕ_{+-} , and ϕ_{00} in the Addendum to the Stable Particle Table. The phases are measured directly, whereas the magnitudes η_{+-} and η_{00} are derived parameters. We use, as far as we can, the directly measured quantities as input and calculate η_{+-} and η_{00} from the values given by our constrained fits. Therefore, if one looks at the Data Card Listings, most of the $|\eta|$ measurements appear in the form of branching ratios, with appropriate comments. We then give the values of η_{+-} and $|\eta_{00}|^2$ in a separate list at the end of the *CP*-violating parameters section of the K_L^0 section of the Stable Particle Data Card Listings.

4. $\Delta S = \Delta Q$ rule in K^0 decays

The relative amount of $\Delta S \neq \Delta Q$ component present is measured by the parameter x , defined as

$$x = A(\bar{K}^0 \rightarrow \pi^- l^+ \nu) / A(K^0 \rightarrow \pi^- l^+ \nu).$$

We list $\text{Re}\{x\}$ and $\text{Im}\{x\}$ for both K_{e3} and $K_{\mu 3}$ at the end of the Stable Particle Data Card Listings and give values in the Addendum to the Stable Particle Table.

C. η -decay parameters

1. C -violation in η decays

As a test of possible C -violation in electromagnetic interactions, a number of experiments have looked for possible charge asymmetries in the decays $\eta \rightarrow \pi^+ \pi^- \pi^0$ and $\eta \rightarrow \pi^+ \pi^- \gamma$. We list the following parameters:

(a) The left-right asymmetry

$$A = (N^+ - N^-) / (N^+ + N^-),$$

where $N^{(\pm)}$ means the number of events with the $\pi^{(\pm)}$ energy greater than the $\pi^{(*)}$ energy in the η rest frame.

(b) The sextant asymmetry

$$A_s = \frac{N_1 + N_3 + N_5 - N_2 - N_4 - N_6}{N_1 + N_2 + N_3 + N_4 + N_5 + N_6}$$

for the decay $\eta \rightarrow \pi^+ \pi^- \pi^0$. The numbers refer to the sextants of the Dalitz plot [see, for example, Layter (1972)]. A_s is sensitive to an $I=0$ C -violating asymmetry.

(c) The quadrant asymmetry A_q , defined in a similar way as A_s , but with each sector of the Dalitz plot now containing $\pi/2$ rather than $\pi/3$ radians. A_q is sensitive to an $I=2$ C -violating final state.

(d) The d -wave contribution to the C -violating amplitude in the decay $\eta \rightarrow \pi^+ \pi^- \gamma$. The upper limit for this contribution is measured by the parameter β , defined by

$$dN/d|\cos\theta| \propto \sin^2\theta(1 + \beta \cos^2\theta),$$

where θ is the angle between the π^+ and the γ in the dipion center of mass. A term proportional to $\cos^2\theta$ could also be due to p - and f -wave interference.

We list A for the decay modes $\eta \rightarrow \pi^+ \pi^- \pi^0$ and $\eta \rightarrow \pi^+ \pi^- \gamma$, A_s and A_q for the decay $\eta \rightarrow \pi^+ \pi^- \pi^0$, and β for the decay $\eta \rightarrow \pi^+ \pi^- \gamma$ in the η section of the Stable Particle Data Card Listings.

2. Dalitz plot for $\eta \rightarrow \pi^+ \pi^- \pi^0$

The Dalitz plot for the decay $\eta \rightarrow \pi^+ \pi^- \pi^0$ may be fit by the distribution

$$|M(x, y)|^2 \propto 1 + ay + by^2 + cx + dx^2 + exy.$$

Here,

$$x = \sqrt{3} (T_+ - T_-) / Q, \quad y = (3T_0 / Q) - 1,$$

T_+ , T_- , T_0 are the kinetic energies of the π^+ , π^- , and π^0 in the η rest system, and $Q = m_\eta - m_{\pi^+} - m_{\pi^-} - m_{\pi^0}$. The coefficient of the term linear in x is sensitive to C -violation due to an $I=0$ or $I=2$ final state. We list papers presenting determinations of the parameters a , b , c , and d in the η section of the Stable Particle

Data Card Listings. However, we do not tabulate values of these parameters because the assumptions made by different authors are not compatible and do not allow comparison of the numerical values.

3. Dalitz plot for $\eta \rightarrow \pi^+ \pi^- \gamma$

The Dalitz plot for the decay $\eta \rightarrow \pi^+ \pi^- \gamma$ may be fit to the expression

$$|M|^2 \propto 1 + 2\alpha z,$$

where

$$z = \frac{2}{3} \sum_{i=1}^3 \left[\frac{3}{m_\eta - 3m_\pi} (E_i - \frac{1}{3} m_\eta) \right]^2 = \frac{\rho^2}{\rho_{\max}^2}.$$

Here E_i is the energy of the i th pion in the η rest frame, and ρ is the distance to the center of the Dalitz plot. We list the parameter α in the η section of the Stable Particle Data Card Listings.

D. Baryon-decay parameters

1. A/V ratio for baryon leptonic decays

Consider the decay

$$B_i \rightarrow B_f + l + \nu.$$

Assuming V, A theory, neglecting "induced" scalar, "induced" pseudoscalar, and axial weak-magnetism terms, and neglecting the q^2 dependence of the form factors, the baryon part of the matrix element for these decays may be written [Goldberger and Treiman (1958)] as

$$\langle B_f | \gamma_\lambda (g_V - g_A \gamma_5) + (g_W / m_{B_i}) \sigma^{\lambda\nu} q_\nu | B_i \rangle,$$

where B_i and B_f represent initial and final baryons, g_A and g_V the axial and vector coupling constants, g_W the weak magnetism coupling constant, and q_ν the sum of the lepton momenta. Here the Pauli representation is used for the γ matrices. The ratio g_A/g_V may be written as

$$g_A/g_V = |g_A/g_V| \exp(i\phi),$$

where ϕ is $0 + n\pi$ if time reversal holds [see Jackson *et al.* (1957)].

Experiments on the leptonic decays of baryons other than the neutron have generally assumed ϕ to be either 0 or π , and have thus measured the magnitude and sign of g_A/g_V . In studying neutron beta decay, however, experiments have been sensitive enough to measure ϕ more precisely, and we include the phase angle in our Listings for this case. It is consistent with time-reversal invariance, and by using the above definition of the matrix element with the Pauli representations, the value of g_A/g_V in neutron beta decay is negative.

Due to statistical limitation the weak magnetism form factor g_W is usually assumed from CVC and $SU(3)$, so only g_A and g_V are determined experimentally. This determination is accomplished in a variety of ways.

(a) The lepton-neutrino angular correlation provides a measure of the absolute value of g_A/g_V [for relevant formulas, see, e.g., Albright (1959)].

(b) The up-down asymmetry of the lepton from polarized baryon decays provides a measure of g_A/g_V with its sign [for relevant formulas, see, e.g., Albright

(1959)].

(c) The lepton spectrum, given enough statistics, provides a measure of g_A/g_V with its sign [for relevant formulas, see, e.g., Bender (1968)].

(d) The polarization of the decay baryon, from polarized or unpolarized initial baryon, also provides g_A/g_V with its sign [for formulas, see, e.g., Willis and Thompson (1968)].

(e) The presence of a term proportional to

$$\sigma_{B_i} \cdot (\mathbf{p}_e \times \mathbf{p}_\nu),$$

where the initial baryon is polarized or

$$\sigma_{B_f} \cdot (\mathbf{p}_e \times \mathbf{p}_\nu),$$

where the polarization of the decay baryon is observed provides a measure of the deviation of ϕ from 0 or π , and is thus a test of time-reversal invariance [see, e.g., Willis and Thompson (1968)].

We compile the ratio g_A/g_V with its sign, for those decays for which it has been measured.

All the coupling constants and decay rates for baryon leptonic decays are related by Cabibbo's theory [Cabibbo (1963)], extended to six quarks (and three mixing angles) by Kobayashi and Maskawa (1973). A recent fit to this theory has been done by Shrock and Wang (1978).

2. Asymmetry parameters in nonleptonic hyperon decays

The transition matrix for the hyperon decay may be written as

$$M = s + p(\sigma \cdot \mathbf{q}), \quad (6)$$

where s and p are the parity-changing and the parity-conserving amplitudes, respectively; σ is the Pauli spin operator, and \mathbf{q} is a unit vector along the direction of the decay baryon in the hyperon rest frame.

The asymmetry parameters are defined by the relations

$$\begin{aligned} \alpha &= 2 \operatorname{Re}(s^*p) / (|s|^2 + |p|^2), \\ \beta &= 2 \operatorname{Im}(s^*p) / (|s|^2 + |p|^2), \\ \gamma &= (|s|^2 - |p|^2) / (|s|^2 + |p|^2). \end{aligned}$$

With the transition matrix (6), the angular distribution of the decay baryon, in the hyperon rest system, is of the form

$$I = 1 + \alpha \mathbf{P}_Y \cdot \mathbf{q},$$

where $\mathbf{P}_Y = \langle Y | \boldsymbol{\sigma} | Y \rangle$ is the hyperon polarization.

In the notation of Lee and Yang (1957) the polarization \mathbf{P}_B of the decay baryon is²

$$\mathbf{P}_B = \frac{(\alpha + \mathbf{P}_Y \cdot \mathbf{q})\mathbf{q} + \beta(\mathbf{P}_Y \times \mathbf{q}) + \gamma\mathbf{q} \times (\mathbf{P}_Y \times \mathbf{q})}{1 + \alpha \mathbf{P}_Y \cdot \mathbf{q}},$$

where \mathbf{P}_B is defined in that rest system of the baryon obtained by a Lorentz transformation along \mathbf{q} from the hyperon rest system in which \mathbf{q} and \mathbf{P}_Y are defined.

²Note that Lee and Yang (1957) contains a misprint. The minus sign in the definition of β should be replaced by a 2. In addition, our unit vector \mathbf{q} is the direction of the baryon, whereas their unit vector \mathbf{p} is the direction of the pion.

Note that α is the helicity of the decay baryon for unpolarized hyperons.

The three parameters α , β , and γ satisfy the relation

$$\alpha^2 + \beta^2 + \gamma^2 = 1.$$

It is then convenient to describe hyperon nonleptonic decays in terms of the two independent parameters α and the angle ϕ defined by

$$\begin{aligned} \beta &= (1 - \alpha^2)^{1/2} \sin \phi, \\ \gamma &= (1 - \alpha^2)^{1/2} \cos \phi, \end{aligned}$$

which has a more nearly gaussian distribution than β or γ . Evidently

$$\begin{aligned} -\frac{1}{2}\pi &\leq \phi \leq \frac{1}{2}\pi \text{ for } \gamma > 0, \\ +\frac{1}{2}\pi &\leq \phi \leq \frac{3}{2}\pi \text{ for } \gamma < 0. \end{aligned}$$

In discussing time-reversal invariance, the quantity of interest is Δ , defined by

$$\begin{aligned} \alpha &= 2 |s| |p| \cos \Delta / (|s|^2 + |p|^2), \\ \beta &= -2 |s| |p| \sin \Delta / (|s|^2 + |p|^2); \end{aligned}$$

that is, Δ is the phase angle of s relative to p . Evidently

$$\begin{aligned} -\frac{1}{2}\pi &\leq \Delta \leq \frac{1}{2}\pi \text{ for } \alpha > 0, \\ +\frac{1}{2}\pi &\leq \Delta \leq \frac{3}{2}\pi \text{ for } \alpha < 0. \end{aligned}$$

Under the assumption of time-reversal invariance, the angle Δ must satisfy the relation

$$\Delta = \delta_s - \delta_p,$$

modulo π , where δ_s and δ_p are the pion-baryon scattering phase shifts at the appropriate energy and for the appropriate isospin state. For Λ decay, assuming the validity of the $|\Delta I| = \frac{1}{2}$ rule,

$$\Delta = \delta_s - \delta_p = (7.0 \pm 1.0) \text{ deg.}^3$$

In the Stable Particle Data Card Listings we give α and ϕ for each decay since they are the most closely related to the experiments and are essentially uncorrelated. Whenever necessary we have changed the signs of the reported values, so as to agree with our conventions. In the Stable Particle Table we give α , ϕ , and Δ with errors; and for convenience we also give the central value of γ , without an error.

VII. STATISTICAL PROCEDURES

We divide this discussion on obtaining averages and errors into two sections:

- A. the unconstrained case, or "simple averaging", and
- B. the constrained case.

In what follows, the term "error" means one standard deviation (1σ); that is, for central value \bar{x} and error $\delta\bar{x}$, the range $\bar{x} \pm \delta\bar{x}$ constitutes a 68.3% confidence interval.

³This value for $\delta_s - \delta_p$ is derived from the phase-shift analyses by Ayed (1976). The error is our estimation of the uncertainty allowing for possible correlations.

A. Unconstrained averaging

We first describe the standard procedure we have used for several years to determine averages and errors. We then discuss a second method, which we feel offers a less conservative, but possibly more accurate, estimate of errors.

1. Standard procedure—Gaussian distribution with scale factor

We begin by assuming that measurements of a given quantity obey a gaussian distribution, and thus we calculate a weighted average and error

$$\bar{x} \pm \delta\bar{x} = \left(\frac{\sum_i w_i x_i}{\sum_i w_i} \right) \pm \left(\frac{\sum_i w_i}{\sum_i w_i} \right)^{-1/2}, \quad (1)$$

$$w_i = [1/(\delta x_i)^2],$$

where x_i and δx_i are the value and error, respectively, reported by the i th experiment, and the sums run over N experiments. We also calculate χ^2 and compare it with its expectation value of $N - 1$.

If $\chi^2/(N - 1)$ is less than or equal to 1, and there are no known problems with the data, we accept the above results.

If $\chi^2/(N - 1)$ is very large, or if there is prior knowledge of extremely large inconsistencies between experiments, we may choose not to average the data at all. Alternatively, we may quote the calculated average, but then give an educated guess as to the error; such a guess is generally a quite conservative estimate designed to take into account known problems with the data.

Finally, if $\chi^2/(N - 1)$ is greater than 1, but not to such a large extent, we still average the data, but then try to make up for this fact in two ways:

(i) We plot an ideogram to guide the reader in deciding which data might be rejected before selected averages are made. An example of such an ideogram is given in Fig. 3 below. Each experiment appearing

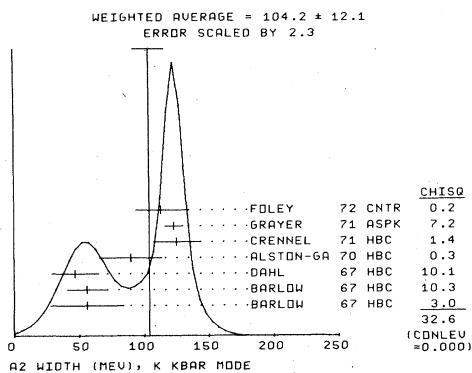


FIG. 3. Ideogram of early measurements of the A_2 width, as determined from the $K\bar{K}$ mode. The vertical line indicates the position of the weighted average, while the horizontal bar atop the line gives the error in the average after scaling by the SCALE factor. Only those experiments indicated by + error flags were precise enough to be accepted in the calculation of the SCALE factor; the column on the far right gives the χ^2 contribution of each of these experiments. Occasionally, less precise experiments are included in the calculation of the weighted average, but not SCALE; they have \perp error flags.

in the plot is represented by a gaussian with central value x_i , error δx_i , and area proportional to $1/\delta x_i$. The choice of area is a somewhat arbitrary one; it is based on the assumption that an experimenter will work to reduce his (or her) systematic errors until they are slightly smaller (but seldom much smaller) than the statistical errors. Thus, as a bubble chamber physicist gets more events, he (or she) will use them both to reduce the statistical errors and to study the biases. Our confidence that a significant systematic error has not been made in a given experiment, as compared with other contradictory experiments, then tends to go up as $1/\delta x_i$.

But why not assign a weight $1/\delta x_i^2$, as is done when computing a weighted average? We feel that this is equivalent to assuming that large systematic errors are as infrequent as large statistical fluctuations, and that this is unrealistic.

We emphasize the difference between least-squares averaging (where the weighting factor is the inverse square of the error) and the ideograms prepared for visual display. The former arithmetic is of course best if one has statistically distributed input, and yields a narrow gaussian distribution centered at the weighted mean. The ideogram (often multip peaked and certainly not gaussian) is based on the opposite hypothesis that some of the input is systematically in error. The idea behind least-squares averaging is that experiments 1, 2, 3, etc., are *all* valid (so we should multiply their probabilities). Our *ideograms* are based on the assumption that 1 *or* 2 *or* 3, etc., is valid, "hedged" with $1/\delta x_i$ betting odds; we then add their probabilities. Both approaches cannot simultaneously be right; we leave it to the reader to choose. A glance at the ideogram will show, however, that the discrepancy is often not severe for reasonably distributed input.

(ii) The second way in which we try to take account of $\chi^2/(N - 1)$ being greater than 1 is to scale up our quoted error $\delta\bar{x}$ in Eq. (1) by a factor

$$\text{SCALE} = [\chi^2/(N - 1)]^{1/2}. \quad (2)$$

Our reasoning is as follows. Since we do not know which one or more of the experiments are wrong, we assume that all experimentalists underestimated their errors by the same scale factor (2). If we scale up all input errors by this factor, χ^2 returns to $N - 1$, and of course the output error scales up by the same factor.

If all the experiments have errors of about the same size, the above (straightforward) procedure for calculating SCALE is carried out. If, however, we are to combine experiments with widely varying errors, we must modify the procedure slightly. This is because it is the more precise experiments that most influence not only the average value \bar{x} , but also the error $\delta\bar{x}$. Now, on the average, the low-precision experiments each contribute about unity to *both* the numerator and the denominator of SCALE, hence the χ^2 contribution of the sensitive experiments is diluted, i.e., reduced. Therefore, we evaluate SCALE by using *only* experiments for which the errors are not much greater than those of the more precise experiments. Explicitly, to calculate SCALE we use only the most sensitive experiments, i.e., those with errors less than δ_0 , where

the ceiling δ_0 is (arbitrarily) chosen to be

$$\delta_0 = 3N^{1/2}\delta\bar{x}.$$

Here $\delta\bar{x}$ is the unscaled error of the mean of all the experiments. Note that if each experiment had the same error δx_i , then $\delta\bar{x}$ would be $\delta x_i/N^{1/2}$, so each individual experiment would be well under the ceiling on SCALE.

This scaling approach has the property that if there are two values with comparable errors separated by much more than their stated errors (with or without a number of other experiments of lower accuracy), the error on the mean value $\delta\bar{x}$ is increased so that it is approximately half the interval between the two discrepant values.

We wish to emphasize the fact that our scaling procedures for errors in no way affect central values. In addition, if one wishes to recover the unscaled error $\delta\bar{x}$, one need only divide the given error by the SCALE factor for that error.

2. A second procedure—Student's distribution

The second method of averaging data, described in detail in Roos *et al.* (1975), relies upon an empirical determination of the distribution of the residuals for the ensemble of data appearing in the Review. The residual for the i th measurement of a quantity with average value \bar{x} is defined as

$$h_i = (x_i - \bar{x})/\delta x_i.$$

Roos *et al.* select several different subsamples of the data, and show that the residuals for each subsample have approximately the same properties; in particular, their first few even moments are similar. Since the distributions have longer tails than a gaussian, the authors choose to represent them by a distribution function having such a property, namely the Student distribution

$$S_n(h/c) = K \left[1 + \frac{(h/c)^2}{n} \right]^{-(n+1)/2}. \quad (3)$$

Here K is a normalization constant, and n and c are parameters which the authors then fit to the combined sample of data. The resulting empirical distribution is

$$S_{10}(h/1.11) = 0.351 \left[1 + \frac{(h/1.11)^2}{10} \right]^{-11/2}. \quad (4)$$

Note that the shape of S_{10} is somewhere between that of a gaussian ($=S_\infty$) and that of a Breit-Wigner ($=S_1$).

The proposed method of averaging the data for a given quantity then consists of finding the value of \bar{x} which maximizes the log-likelihood function

$$\log \mathcal{L}(\{x_i\}|\bar{x}) = \sum_i \log \left[S_{10} \left(\frac{x_i - \bar{x}}{1.11\delta x_i} \right) \right]; \quad (5)$$

the sum here is again taken over all N measurements of x . The error $\delta\bar{x}$ is determined by finding the variation in \bar{x} needed to decrease the log-likelihood by 1/2:

$$\log \mathcal{L}(\{x_i\}|\bar{x}) - \log \mathcal{L}(\{x_i\}|\bar{x} \pm \delta\bar{x}) = \frac{1}{2}. \quad (6)$$

3. Comparison of procedures

Both of the procedures described above adopt a partially empirical approach to the problem that measured values for the quantities tabulated in this Review do not exhibit the gaussian behavior naively expected. (This problem, it should be noted, persists even when careful attempts are made to resolve difficulties and inconsistencies in the data prior to averaging.)

The first approach operates on a quantity-by-quantity basis and adjusts the error in each case so that no scaled $\chi^2/(N-1)$ is greater than 1. This is obviously rather conservative, since even if the data obeyed a gaussian distribution, about half of the quantities would be expected to have $\chi^2/(N-1) > 1$.

The second approach, on the other hand, assumes that (provided we first eliminate quantities with obvious, known problems) all quantities have the same theoretical distribution function, namely the fairly long-tailed $S_{10}(h/1.11)$. With this supposition, if a particular quantity has a large χ^2 , it is assumed to be just a happenstance, occasioned by a random fluctuation into the long tails, and no special scaling for this quantity is done. This procedure thus results in generally smaller, or less conservative, error estimates for quantities having $\chi^2/(N-1) > 1$. (However, it should be noted that, because of the overall scale of 1.11 appearing in the empirical Student's distribution, the errors for quantities with $\chi^2/(N-1) \leq 1$ are actually increased by about 10%.) Table 3 shows some comparisons of sample results from the two procedures, using data from the 1978 edition of the Review. Shifts in both \bar{x} and $\delta\bar{x}$ can be observed, especially where SCALE > 1 .

Since the second procedure is a significant departure from the traditional method, we have repeated the previously adopted approach: in the Data Card Listings we give the average-and-error for each quantity cal-

TABLE III. Comparison of procedures (data from 1978 edition).

Particle property	Pure gaussian	Standard method:		Proposed method:
	$\bar{x} \pm \delta\bar{x}$	gaussian + scale factor	Scale	Student's distribution
		$\bar{x} \pm \delta\bar{x}$		$\bar{x} \pm \delta\bar{x}$
ρ^0 mass (MeV)	770.23 \pm 0.65	770.23 \pm 0.88	1.3	770.25 \pm 0.82
η' mass (MeV)	957.57 \pm 0.25	957.57 \pm 0.25	1.0	957.57 \pm 0.28
ϕ mass (MeV)	1019.62 \pm 0.16	1019.62 \pm 0.24	1.5	1019.68 \pm 0.21
K_L^0 mean life (10^{-8} s)	5.158 \pm 0.042	5.158 \pm 0.042	1.0	5.158 \pm 0.046
ν^+ mean life (10^{-10} s)	0.8015 \pm 0.0053	0.8015 \pm 0.0053	1.0	0.8015 \pm 0.0058
χ^- mean life (10^{-10} s)	1.483 \pm 0.011	1.483 \pm 0.015	1.4	1.481 \pm 0.012
$K^+ \rightarrow \pi^+\pi^+\pi^-$ (%)	5.521 \pm 0.075	5.521 \pm 0.098	1.3	5.533 \pm 0.089
$\Lambda \rightarrow p\pi^-$ (%)	63.99 \pm 0.49	63.99 \pm 0.49	1.0	63.98 \pm 0.55

culated both ways; the standard way is labelled at the left with the code "AVG", while the second way is labelled "STUDENT". In the Tables of Particle Properties, we continue to use the standard procedure—gaussian with SCALE factor. As in the past, a SCALE factor greater than 1 is indicated by the appearance of "S=..." next to the value and error.

B. Constrained fits

Except for trivial cases, all branching ratios and rate measurements are analyzed by the computer program AHR. This program makes a simultaneous least-squares fit to all the data, and outputs the partial-decay fractions \bar{P}_i , width Γ , partial widths Γ_i , and their error matrix.

The original version of AHR was written by J. Peter Berge. It is documented separately, and we wish here only to give the simplest nontrivial example that permits us to comment on the error matrix and the scale factor.

Assume that a state has only three partial-decay fractions, P_1 , P_2 , and P_3 ($\sum P_i = 1$), which have been measured in four different ratios, R_1, \dots, R_4 , where, e.g., $R_1 = P_1/P_2$, $R_2 = P_1/P_3$, etc.⁴ Further assume that each ratio has been measured by N experiments (we designate each experiment with a subscript x , e.g., R_{1x}). Then AHR finds the best values of P_1 , P_2 , and P_3 by minimizing χ^2 , namely

$$\chi^2 = \sum_{r=1}^4 \left[\sum_{x=1}^N \left(\frac{R_{rx} - R_r(P_1, P_2, P_3)}{\delta R_{rx}} \right)^2 \right]. \quad (7)$$

In addition to the fitted values \bar{P}_i , the program calculates an error matrix $\langle \delta \bar{P}_i \delta \bar{P}_j \rangle$. We tabulate the diagonal elements $\delta \bar{P}_i = \langle \delta \bar{P}_i \delta \bar{P}_i \rangle^{1/2}$ (except that some errors are scaled according to Eq. (2) as discussed below). In the listings we give the complete error matrix; we also calculate the fitted value of each ratio, for comparison with the input data, and list it below the relevant input, along with a simple unconstrained average of the same input.

Two further comments on the example above.

(1) There was no connection between measurements of the width and the branching ratios. But often we also have information on partial widths Γ_i as well as total width Γ . In this case AHR must introduce Γ as a parameter into the fit, along with the relations $\Gamma_i = \Gamma P_i$, $\sum \Gamma_i = \Gamma$. When appropriate, we tabulate the Γ_i along with the P_i , and give error matrices in the listings.

(2) Note that we do *not* allow for correlations between input data. We *do* try to pick those ratios and widths which are as independent and as close to the original data as possible.

In *asymmetric* errors, we use a continuous function of $\delta(P)^+$ and $\delta(P)^-$ in the fitting. When no errors are reported, we merely list the data for inspection.

Hyperon-decay parameters. The program AHR handles any type of input, α , ϕ , Δ , β , or γ , according to the definitions of Sec. VI. If for a particular hyperon decay there are data for more than two of the decay

⁴We can handle any R of the form $R = \sum \alpha_i P_i / \sum \beta_i P_i$, where α_i and β_i are constants, usually 1 or 0.

parameters, they are analyzed by using the constraint

$$\alpha^2 + \beta^2 + \gamma^2 = 1.$$

Inconsistent constrained data. According to our simple example, which led to Eq. (7), the double sum for χ^2 is summed over experiments $x = 1$ to N , leaving a single sum over ratios

$$\chi^2 = \sum_r \chi_r^2.$$

Even before fitting, some of the χ_r^2 may be too large. But if we scaled them before fitting, then the scaling would move the central value, contrary to our policy. So we do not scale until after the first fit; then, knowing the fitted χ_r^2 and its expectation value $\langle \chi_r^2 \rangle$ we form SCALE factors (just as before), i.e.,

$$(\text{SCALE})_r^2 = \chi_r^2 / \langle \chi_r^2 \rangle,$$

and if any $(\text{SCALE})_r$ is greater than 1, all N of the measurements of that particular ratio are equally penalized by having their errors increased by $(\text{SCALE})_r$. Program AHR then recycles on all the data, those with errors unchanged as well as those with errors increased. We then get new values, $\delta \bar{P}'_i$ for the errors in the partial decay modes.

Because of the constraint ($\sum P_i = 1$) some SCALE factors may still be greater than 1 even after this second pass. If this is so, the whole procedure (i.e., increasing errors by the new SCALE factors and recycling through AHR) is repeated.

At the end of AHR's final pass we have two measures of the errors for the \bar{P}_i . One is, of course, the $\delta \bar{P}'_i$, i.e., the errors in the final fitted values \bar{P}'_i which include the effects of scaling the input errors. The other measure of the errors is $(\bar{P}_i - \bar{P}'_i)$, i.e., the *shift* in the central values of the i th mode between the first (unscaled) fit and the final (scaled) fit. In practice we find that on the average these two measures of the uncertainty are about equal. Rather than selecting just one or the other, our tabulated errors are given by the combination

$$(\delta \bar{P}_i)_{tab} = [\delta \bar{P}'_i{}^2 + (\bar{P}_i - \bar{P}'_i)^2]^{1/2},$$

where \bar{P}_i is the fitted value of the i th partial-decay mode before scaling, \bar{P}'_i is its value after scaling, and $\delta \bar{P}'_i$ is the error in \bar{P}'_i . The SCALE factors we finally list in such cases are defined by

$$(\text{SCALE})_i = (\delta \bar{P}_i)_{tab} / \delta \bar{P}_i.$$

However, in line with our policy of not letting SCALE affect the central values, we give the values of \bar{P}_i obtained from the original (unscaled) fits. (The differences between the \bar{P}_i calculated with either the scaled or the unscaled errors are, of course, always within the tabulated errors, $(\delta \bar{P}_i)_{tab}$.)

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TABLES OF PARTICLE PROPERTIES

April 1980

N. Barash-Schmidt, C. Bricman, R. L. Crawford, C. Dionisi, C. P. Horne, R. L. Kelly, M. J. Losty, M. Mazzucato, L. Montanet, A. Rittenberg, M. Roos, T. Shimada, T. G. Trippe, C. G. Wohl, G. P. Yost

(Closing date for data: Jan. 1, 1980)

Stable Particle Table

For additional parameters, see Addendum to this table.

Quantities in italics have changed by more than one (old) standard deviation since April 1978.

Particle	$I^G(J^P)C_n^a$	Mass (MeV) Mass ² (GeV) ²	Mean life (sec) τ (cm)	Partial decay mode		
				Mode	Fraction ^b	p or Pmax ^c (MeV/c)
PHOTON						
γ	0,1(1 ⁻)	0(<6×10 ⁻²²)	—	stable		
LEPTONS						
ν_e	$J=\frac{1}{2}$	0(<0.00006)	stable (>3×10 ⁸ m _e (MeV))	stable		
e	$J=\frac{1}{2}$	0.5110034 ±.0000014	stable (>5×10 ²¹ y)	stable		
ν_μ	$J=\frac{1}{2}$	0(<0.57)	stable (>2.6×10 ⁴ m _{ν_μ} (MeV))	stable		
μ	$J=\frac{1}{2}$	105.65946 ±.00024 m ² =0.01116392 m _{μ} -m _{π} ±=-33.9074 ±.0012	2.197120×10 ⁻⁶ ±.000077 τ =6.5868×10 ⁴	$\mu^- \rightarrow$ e ⁻ $\bar{\nu}_e$ ν_μ (98.6 ±0.4)% e ⁻ $\bar{\nu}_e$ ν_μ (1.4 ±0.4)% e ⁻ γ γ (<4)×10 ⁻⁶ % e ⁻ e ⁺ e ⁻ (<1.9)×10 ⁻⁹ % e ⁻ γ (<1.9)×10 ⁻¹⁰ % e ⁻ ν_e $\bar{\nu}_\mu$ (<25)%	53 53 53 53 53	
τ	$J=\frac{1}{2}^f$	1764 ±4 m ² =3.18	<2.3×10 ⁻¹² τ <0.07	$\tau^- \rightarrow$ μ ⁻ $\bar{\nu}_\mu$ ν_τ (17.9 ±1.5)% e ⁻ $\bar{\nu}_e$ ν_τ (17.0 ±1.1)% hadron ⁻ neutrals (33 ±10)% π ⁻ ν (8.2 ±2.6)% ρ ⁻ ν (22 ±4)% K ⁻ neutrals (small) e ⁻ γ +μ ⁻ γ (<12)% 3(hadron [*]) neutrals (35 ±11)% π ⁻ ρ ⁰ ν (4.2 ±1.3)% π ⁻ π ⁻ π ⁰ ν (incl.πρν) (7 ±5)% π ⁻ π ⁻ π ⁰ ν (≥0π ⁰) (18 ±7)% (≥3chgd.) neutrals (32 ±5)% e ⁻ chgd.parts. +μ ⁻ chgd.parts. (<4)%	889 892 887 723 892 715 864 864	
NONSTRANGE MESONS^g						
π^\pm	1 ⁻ (0 ⁻)	139.5669 ±.0012 m ² =0.0194789	2.6030×10 ⁻⁸ ±.0023 τ =780.4 (τ^+ - τ^-)/ $\bar{\tau}$ = (0.05±0.07)% (test of CPT)	$\pi^\pm \rightarrow$ μ [±] ν 100% e [±] ν (1.267±0.023)×10 ⁻⁴ % μ [±] ν γ (1.24±0.25)×10 ⁻⁴ % e [±] ν π^0 (1.02±0.07)×10 ⁻⁸ % e [±] ν γ (5.6 ±0.7)×10 ⁻⁸ % e [±] ν e [±] e ⁻ (<5)×10 ⁻⁹ %	70 30 30 5 70 70	
π^0	1 ⁻ (0 ⁺)	134.9626 ±.0039 m ² =0.0182149 m _{π^\pm} -m _{π^0} =4.6043 ±.0037	0.828×10 ⁻¹⁶ ±.057 S=1.8* τ =2.5×10 ⁻⁶	$\pi^0 \rightarrow$ $\gamma\gamma$ (98.85±0.05)% γ e [±] e ⁻ (1.15±0.05)% $\gamma\gamma\gamma$ (<1.5)×10 ⁻⁶ % e [±] e ⁻ e [±] e ⁻ (3.32)×10 ⁻⁵ % $\gamma\gamma\gamma$ (<4)×10 ⁻⁵ % e [±] e ⁻ (2.2 ±2.4 / -1.1)×10 ⁻⁷ %	67 67 67 67 67	
η	0 ⁺ (0 ⁺)	548.8 ±0.6 S=1.4* m ² =0.3012	Γ =(0.85±0.12)keV Neutral decays (71.0±0.7)% S=1.1* Charged decays (29.0±0.7)% S=1.1*	$\eta \rightarrow$ π ⁰ $\gamma\gamma$ (38.0 ±1.0)% S=1.2* 3π ⁰ (3.1 ±1.1)% S=1.2* π ⁺ π ⁻ π ⁰ (29.9 ±1.1)% S=1.1* π ⁺ π ⁻ π ⁰ (23.6 ±0.6)% S=1.1* π ⁺ π ⁻ γ (4.89±0.13)% S=1.1* e [±] e ⁻ γ (0.50±0.12)% e [±] e ⁻ π ⁰ (<4)×10 ⁻⁵ % π [±] π [∓] π ⁰ (<0.15)×10 ⁻⁵ % e [±] e ⁻ π [±] π [∓] π ⁰ (<0.1 ±0.1)% π [±] π [∓] π ⁰ γ (<0.2)×10 ⁻⁴ % π [±] π [∓] $\gamma\gamma$ (<0.2)×10 ⁻⁴ % μ [±] μ [∓] γ (2.2 ±0.8)×10 ⁻⁵ % μ [±] μ [∓] γ (1.5 ±0.8)×10 ⁻⁴ % μ [±] μ [∓] π ⁰ (<5)×10 ⁻⁴ % e [±] e ⁻ (<3)×10 ⁻⁴ %	274 258 180 175 236 274 258 236 236 175 236 253 253 211 274	

Stable Particle Table (cont'd)

Particle	$I^G(J^P)C_n^a$	Mass (MeV) Mass ² (GeV) ²	Mean life (sec) cr (cm)	Mode	Partial decay mode Fraction ^b	p or Dma ^c (MeV/c)			
STRANGE MESONS*									
K^\pm	$\frac{1}{2}(0^-)$	493.669 ± 0.015 $m^2 = 0.24371$ $m_{K^+} - m_{K^0} = -4.01$ ± 0.13 $S = 1.1^*$	1.2371×10^{-8} ± 0.0026 $S = 1.9^*$ $\tau = 370.9$ $(\tau^+ - \tau^-) / \tau =$ $(.11 \pm .09)\%$ (test of CPT) $S = 1.2^*$	$K^+ \rightarrow d$					
				$\mu^+ \nu$	(63.50 \pm 0.16) %	236			
				$\pi^+ \pi^0$	(21.16 \pm 0.15) %	205			
				$\pi^+ \pi^+ \pi^-$	(5.59 \pm 0.03) %	$S = 1.1^*$ 125			
				$\pi^+ \pi^0 \pi^0$	(1.73 \pm 0.05) %	$S = 1.3^*$ 133			
				$\mu^+ \nu \pi^0$	(3.20 \pm 0.09) %	$S = 1.7^*$ 215			
				$e^+ \nu \pi^0$	(4.82 \pm 0.05) %	$S = 1.1^*$ 228			
				$e^+ \nu \gamma$	$e(5.8 \pm 3.5) \times 10^{-3}$	236			
				$e^+ \nu \pi^0 \pi^0$	(1.8 \pm 2.4) $\times 10^{-5}$	207			
				$e^+ \nu \pi^+ \pi^-$	(3.90 \pm 0.15) $\times 10^{-5}$	203			
				$e^+ \nu \pi^+ \pi^+$	(< 5) $\times 10^{-7}$	203			
				$\mu^+ \nu \pi^+ \pi^-$	(0.9 \pm 0.4) $\times 10^{-5}$	151			
				$\mu^+ \nu \pi^+ \pi^+$	(< 3.0) $\times 10^{-6}$	151			
				$e^+ \nu$	(1.54 \pm 0.09) $\times 10^{-5}$	247			
				$e^+ \nu \gamma (SD)^j$	(1.52 \pm 0.23) $\times 10^{-5}$	247			
				$e^+ \nu \gamma (SD)^j$	(< 1.0) $\times 10^{-4}$	247			
				$\pi^+ \pi^0$	$j.e(2.75 \pm 0.16) \times 10^{-4}$	205			
				$\pi^+ \pi^+ \pi^- \gamma$	$e(1.0 \pm 0.4) \times 10^{-4}$	125			
				$\mu^+ \nu \pi^0 \gamma$	$e(< 6) \times 10^{-5}$	215			
				$e^+ \nu \pi^0 \gamma$	$e(3.7 \pm 1.4) \times 10^{-4}$	228			
				$e^+ e^- \pi^+$	(2.6 \pm 0.5) $\times 10^{-7}$	227			
				$e^+ e^- \pi^-$	(< 1) $\times 10^{-8}$	227			
				$\mu^+ \mu^- \pi^+$	(< 2.4) $\times 10^{-6}$	172			
				$\pi^+ \gamma \gamma$	$e(< 3.5) \times 10^{-5}$	227			
				$\pi^+ \gamma \gamma \gamma$	$e(< 3.0) \times 10^{-4}$	227			
				$\pi^+ \nu \nu$	(< 0.6) $\times 10^{-6}$	227			
				$\pi^+ \gamma$	(< 4) $\times 10^{-6}$	227			
				$e^+ \mu^+ \pi^+$	(< 7) $\times 10^{-9}$	214			
				$e^+ \mu^+ \pi^+$	(< 5) $\times 10^{-9}$	214			
				$e^+ \nu \nu \bar{\nu}$	(< 6) $\times 10^{-5}$	247			
				$\mu^+ \nu \nu \bar{\nu}$	(< 6) $\times 10^{-6}$	236			
				$\mu^+ \nu e^+ e^-$	(11 \pm 3) $\times 10^{-7}$	236			
				$\mu^- \nu e^+ e^+$	(< 2.0) $\times 10^{-8}$	236			
$e^+ \nu e^+ e^-$	(2 \pm 2) $\times 10^{-7}$	247							
K^0 \bar{K}^0	$\frac{1}{2}(0^-)$	497.67 ± 0.13 $S = 1.1^*$ $m^2 = 0.24768$	50% KShort, 50% KLong						
				K_S^0	$\frac{1}{2}(0^-)$	0.8923 $\times 10^{-10}$ ± 0.0022 $\tau = 2.675$	$\pi^+ \pi^-$	(68.61 \pm 0.24) %	$S = 1.1^*$ 206
							$\pi^0 \pi^0$	(31.39 \pm 0.24) %	209
$\mu^+ \mu^-$	(< 3.2) $\times 10^{-7}$	225							
$e^+ e^-$	(< 3.4) $\times 10^{-4}$	249							
$\pi^+ \pi^- \gamma$	$e(1.85 \pm 0.10) \times 10^{-3}$	206							
$\gamma \gamma$	(< 0.4) $\times 10^{-3}$	249							
K_L^0	$\frac{1}{2}(0^-)$	5.183 $\times 10^{-8}$ ± 0.040 $\tau = 1554$ $m_{K_L} - m_{K_S} = 0.5349 \times 10^{10} \text{ h sec}^{-1}$ ± 0.0022		$\pi^0 \pi^0 \pi^0$	(21.5 \pm 0.7) %	$S = 1.3^*$ 139			
				$\pi^+ \pi^- \pi^0$	(12.39 \pm 0.18) %	$S = 1.2^*$ 133			
				$\pi^+ \mu^+ \nu$	(27.0 \pm 0.5) %	$S = 1.1^*$ 216			
				$\pi^+ e^+ \nu$ (incl. $\pi e \nu \gamma$)	(38.8 \pm 0.5) %	$S = 1.1^*$ 229			
				$\pi e \nu \gamma$	$e(1.3 \pm 0.8)$	229			
				$\pi^+ \pi^-$	$k(0.203 \pm 0.005)$ %	206			
				$\pi^0 \pi^0$	$k(0.094 \pm 0.018)$ %	$S = 1.5^*$ 209			
				$\pi^+ \pi^- \gamma$	$e(6.0 \pm 2.0) \times 10^{-5}$	206			
				$\pi^0 \gamma \gamma$	(< 2.4) $\times 10^{-4}$	231			
				$\gamma \gamma$	(4.9 \pm 0.5) $\times 10^{-4}$	249			
				$e \mu$	(< 2.0) $\times 10^{-9}$	238			
				$\mu^+ \mu^-$	(9.1 \pm 1.9) $\times 10^{-9}$	225			
				$\mu^+ \mu^- \gamma$	(< 7.8) $\times 10^{-6}$	225			
				$\mu^+ \mu^- \pi^0$	(< 5.7) $\times 10^{-5}$	177			
				$e^+ e^-$	(< 2.0) $\times 10^{-9}$	249			
				$e^+ e^- \gamma$	(< 2.8) $\times 10^{-5}$	249			
				$\pi^+ \pi^- e^+ e^-$	(< 8.8) $\times 10^{-6}$	206			
				$\pi^0 \pi^+ e^+ \nu$	(< 2.2) $\times 10^{-3}$	207			
CHARMED MESONS*									
D^\pm	$\frac{1}{2}(0^-)^f$	1868.3 ^f ± 0.9 $m^2 = 3.491$ $m_{D^\pm} - m_{D^0} = 5.0$ ± 0.8	$(2.5^{+3.5}_{-1.5}) \times 10^{-13}$ $\tau = 0.007$	$D^+ \rightarrow d$					
				K^- anything	(10 \pm 7) %				
				$\dagger [K^- \pi^+ \pi^+ (\text{incl. } K^* \pi)]$	(3.9 \pm 1.0) %	845			
				$\dagger [K^* (892)^0 \pi^+]$	(seen)	456			
				$\dagger [K^- K^+ \pi^+]$	(< 0.6) %	743			
				K^0 anything	(39 \pm 29) %				
				$\dagger [\bar{K}^0 \pi^+]$	(1.5 \pm 0.6) %	862			
				e^+ anything	$m(8.2 \pm 1.2)$ %				
				$\pi^+ \pi^+ \pi^-$	(< 0.31) %	908			
				K^+ anything	(6 \pm 6) %				
$K^+ \pi^+ \pi^-$	(< 0.20) %	845							
D^0 \bar{D}^0	$\frac{1}{2}(0^-)^f$	1863.1 ^f ± 0.9 $m^2 = 3.471$ $\frac{\Gamma(D^0 \rightarrow \bar{D}^0 \rightarrow K^+ \pi^-)}{\Gamma(D^0 \rightarrow K \pi)} < 0.16$	$(3.5^{+3.5}_{-1.7}) \times 10^{-13}$ $\tau = 0.01$	$D^0 \rightarrow d$					
				K^+ anything	(35 \pm 10) %				
				$\dagger [K^- \pi^+]$	(1.8 \pm 0.5) %	860			
				$\dagger [K^- \pi^+ \pi^0]$	(12 \pm 6) %	843			
				$\dagger [K^- \pi^+ \pi^+ \pi^-]$	(3.5 \pm 0.9) %	812			
				K^0 anything + K^0 any	(57 \pm 26) %				
				$\dagger [\bar{K}^0 \pi^0 + K^0 \pi^0]$	(< 6) %	859			
				$\dagger [\bar{K}^0 \pi^+ \pi^- + K^0 \pi^+ \pi^-]$	(4.4 \pm 1.1) %	841			
				e^+ anything	$m(8.2 \pm 1.2)$ %				
				$\pi^+ \pi^-$	(5.9 \pm 3.2) $\times 10^{-4}$	921			
$K^+ K^-$	(2.0 \pm 0.8) $\times 10^{-3}$	790							

Stable Particle Table (cont'd)

Particle	$I^G(J^P)C_n^a$	Mass (MeV) Mass ² (GeV) ²	Mean life (sec) τ (cm)	Partial decay mode		
				Mode	Fraction ^b	p or Pmax ^c (MeV/c)
NONSTRANGE BARYONS^a						
p	$\frac{1}{2}(\frac{1}{2}^+)$	938.2796 ± 0.0027 $m^2 = 0.880369$	stable ($>10^{30}$ y)	stable	$|q_p| - |q_e| < 10^{-21}|q_e|^n$	
n	$\frac{1}{2}(\frac{1}{2}^+)$	939.5731 ± 0.0027 $m^2 = 0.882798$ $m_p - m_n = -1.29343$ ± 0.00004	917 ± 14 $\tau = 2.75 \times 10^{13}$	$p e^- \bar{\nu}$ $p \nu \bar{\nu}$ (chg. noncons.)	(100 %) (< 3) $\times 10^{-19}$	1 1
STRANGENESS -1 BARYONS^a						
Λ	$0(\frac{1}{2}^+)$	1115.60 ± 0.05 $S = 1.2^*$ $m^2 = 1.2446$ $m_\Lambda - m_{\Sigma^0} = -76.86$ ± 0.08	2.632×10^{-10} ± 0.020 $S = 1.6^*$ $\tau = 7.89$	$p \pi^-$ $n \pi^0$ $p e^- \bar{\nu}$ $p \mu^- \bar{\nu}$ $p \pi^- \gamma$	(64.2 ± 0.5)% (35.8 ± 0.5)% (8.07 ± 0.28) $\times 10^{-4}$ (1.57 ± 0.35) $\times 10^{-4}$ (0.85 ± 0.14) $\times 10^{-3}$	100 104 163 131 100
Σ^+	$1(\frac{1}{2}^+)$	1189.36 ± 0.06 $S = 1.8^*$ $m^2 = 1.4146$ $m_{\Sigma^+} - m_{\Sigma^-} = -7.98$ ± 0.08 $S = 1.2^*$	0.800×10^{-10} ± 0.004 $\tau = 2.40$	$p \pi^0$ $n \pi^+$ $p \gamma$ $n \pi^+ \gamma$ $\Lambda e^+ \nu$ $\Lambda \mu^+ \nu$ $\Lambda e^+ e^-$ $\Lambda \mu^+ e^-$	(51.64 ± 0.30)% (48.36 ± 0.30)% (1.24 ± 0.18) $\times 10^{-3}$ (0.93 ± 0.10) $\times 10^{-3}$ (2.02 ± 0.47) $\times 10^{-5}$ (< 3.0) $\times 10^{-5}$ (< 0.5) $\times 10^{-5}$ (< 7) $\times 10^{-6}$	189 185 S=1.4* 185 71 202 224 225
Σ^0	$1(\frac{1}{2}^+)^p$	1192.46 ± 0.08 $m^2 = 1.4220$	5.8×10^{-20} ± 1.3 $\tau = 1.7 \times 10^{-9}$	$\Lambda \gamma$ $\Lambda e^+ e^-$ $\Lambda \gamma \gamma$	100 % (5.45 ± 0.1) $\times 10^{-3}$ (< 3) %	74 74 74
Σ^-	$1(\frac{1}{2}^+)$	1197.34 ± 0.05 $m^2 = 1.4336$ $m_{\Sigma^0} - m_{\Sigma^-} = -4.88$ ± 0.06	1.482×10^{-10} ± 0.11 $S = 1.3^*$ $\tau = 4.44$	$n \pi^-$ $n e^- \bar{\nu}$ $n \mu^- \bar{\nu}$ $\Lambda e^- \bar{\nu}$ $n \pi^- \gamma$	100 % (1.08 ± 0.04) $\times 10^{-3}$ (0.45 ± 0.04) $\times 10^{-3}$ (0.61 ± 0.05) $\times 10^{-4}$ (4.6 ± 0.6) $\times 10^{-4}$	193 230 210 79 193
STRANGENESS -2 BARYONS^a						
Ξ^0	$\frac{1}{2}(\frac{1}{2}^+)^q$	1314.9 ± 0.6 $m^2 = 1.7290$ $m_{\Xi^0} - m_{\Xi^-} = -6.4$ ± 0.6	2.90×10^{-10} ± 1.0 $\tau = 8.69$	$\Lambda \pi^0$ $\Lambda \pi^+$ $\Sigma^0 \gamma$ $p \pi^-$ $p e^- \bar{\nu}$ $\Sigma^+ e^- \bar{\nu}$ $\Sigma^+ \mu^- \bar{\nu}$ $\Sigma^+ e^- \nu$ $\Sigma^+ \mu^- \nu$ $\Sigma^0 \mu^- \nu$	100 % (0.5 ± 0.5)% (< 7) % (< 3.6) $\times 10^{-5}$ (< 1.3) $\times 10^{-3}$ (< 1.1) $\times 10^{-3}$ (< 0.9) $\times 10^{-3}$ (< 1.1) $\times 10^{-3}$ (< 0.9) $\times 10^{-3}$ (< 0.9) $\times 10^{-3}$ (< 1.3) $\times 10^{-3}$	135 184 117 299 323 120 112 64 49 309
Ξ^-	$\frac{1}{2}(\frac{1}{2}^+)^q$	1321.32 ± 0.13 $m^2 = 1.7459$	1.641×10^{-10} ± 0.16 $\tau = 4.92$	$\Lambda \pi^-$ $\Lambda e^- \bar{\nu}$ $\Sigma^0 e^- \bar{\nu}$ $\Lambda \mu^- \bar{\nu}$ $\Sigma^0 \mu^- \bar{\nu}$ $n \pi^-$ $n e^- \bar{\nu}$ $n \mu^- \bar{\nu}$ $\Sigma^- \gamma$ $p \pi^- \pi^-$ $p \pi^- e^- \bar{\nu}$ $p \pi^- \mu^- \bar{\nu}$ $\Xi^0 e^- \bar{\nu}$	100 % (2.8 ± 1.2) $\times 10^{-4}$ (< 5) $\times 10^{-4}$ (3.1 ± 1.2) $\times 10^{-4}$ (< 8) $\times 10^{-4}$ (< 1.1) $\times 10^{-3}$ (< 3.2) $\times 10^{-3}$ (< 1.5) % (< 1.2) $\times 10^{-3}$ (< 4) $\times 10^{-4}$ (< 4) $\times 10^{-4}$ (< 4) $\times 10^{-4}$ (< 2.3) $\times 10^{-3}$	139 190 123 163 70 303 327 313 118 223 304 250 6
STRANGENESS -3 BARYON^a						
Ω^-	$0(\frac{1}{2}^+)^q$	1672.22 ± 0.31 $m^2 = 2.7963$	0.82×10^{-10} ± 0.03 $\tau = 2.5$	ΛK^- $\Xi^0 \pi^-$ $\Xi^- \pi^0$ $\Xi^0 e^- \bar{\nu}$ $\Xi(1530)^0 \pi^-$ $\Lambda \pi^-$ $\Xi^- \gamma$	(68.6 ± 1.3)% (23.4 ± 1.3)% (8.0 ± 0.8)% (~ 1) % (~ 2) $\times 10^{-3}$ (< 1.3) $\times 10^{-3}$ (< 3.1) $\times 10^{-3}$	211 293 290 319 15 449 314
NONSTRANGE CHARMED BARYON^a						
Λ_c^+	$0(\frac{1}{2}^+)^r$	2273 ± 6 $S = 1.6^*$ $m^2 = 5.17$	$\sim 7 \times 10^{-13}$ $\tau \sim 0.02$	$\Lambda \pi^+ \pi^+ \pi^-$ $p K^+ \pi^+$ $p K^+(892)^0$ $\Delta(1232)^+ K^-$	(seen) (2.2 ± 1.0)% (seen) (seen)	798 814 567 700

ADDENDUM TO
Stable Particle Table

Magnetic moment					
e	1.001 159 652 41 $\frac{e\hbar}{2m_e c}$ ±.000 000 000 20	μ Decay parameters^a			
μ	1.001 165 924 $\frac{e\hbar}{2m_\mu c}$ ±.000 000 009	$\rho = 0.752 \pm 0.003$ $\xi = 0.972 \pm 0.013$ $|g_A/g_V| = 0.86^{+0.33}_{-0.11}$	$\eta = -0.12 \pm 0.21$ $\delta = 0.755 \pm 0.009$ $\phi = 180^\circ \pm 15^\circ$	$h = 1.00 \pm 0.13$	
η	Mode $\pi^+\pi^-\pi^0$ $\pi^+\pi^-\gamma$	Left-right asymmetry (0.12±.17)% (0.88±.40)%	Sextant asymmetry (0.19±0.16)%	Quadrant asymmetry (-0.17±0.17)%	$\beta = 0.047 \pm 0.062$
K±	Mode $\mu\nu$ $\pi\pi^0$ $\pi\pi^+\pi^-$ $\pi\pi^0\pi^0$ $\mu\pi^0\nu$ $e\pi^0\nu$	Partial rate (sec⁻¹) (51.33±0.17)×10 ⁶ (17.10±0.13)×10 ⁶ (4.52±0.02)×10 ⁶ (1.40±0.04)×10 ⁶ (2.58±0.07)×10 ⁶ (3.90±0.04)×10 ⁶	S=1.2* S=1.1* S=1.1* S=1.3* S=1.7* S=1.1*	Slope parameters for K → 3π[±] $K^+ \rightarrow \pi^+\pi^+\pi^-$ $g = -0.215 \pm 0.004$ S=1.4* $K^- \rightarrow \pi^-\pi^-\pi^+$ $g = -0.217 \pm 0.007$ S=2.5* $K^\pm \rightarrow \pi^0\pi^0\pi^\pm$ $g = 0.607 \pm 0.030$ S=1.3* $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ $g = 0.670 \pm 0.014$ S=1.6* $K_S^0 \rightarrow \pi^+\pi^-\pi^0$ $g = 0.670 \pm 0.014$ S=1.6* $K_S^0 \rightarrow \pi^0\pi^0\pi^0$ $g = 0.670 \pm 0.014$ S=1.6* See Data Card Listings for quadratic coefficients.	
K_S⁰	$\pi^+\pi^-\pi^0$ $\pi^0\pi^0\pi^0$	$k(0.7689 \pm 0.0033) \times 10^{10}$ $k(0.3517 \pm 0.0029) \times 10^{10}$	S=1.1*	$K_{13}^+ \left\{ \begin{array}{l} \lambda_{13}^+ = 0.029 \pm 0.004 \\ \lambda_{13}^0 = 0.026 \pm 0.008 \\ \lambda_{13}^- = -0.003 \pm 0.007 \end{array} \right. S=1.5^*$ $K_{13}^0 \left\{ \begin{array}{l} \lambda_{13}^+ = 0.0301 \pm 0.0016 \\ \lambda_{13}^0 = 0.034 \pm 0.006 \\ \lambda_{13}^- = 0.020 \pm 0.007 \end{array} \right. S=2.5^*$ See Data Card Listings for ξ , f_S , and f_L .	
K_L⁰	$\pi^0\pi^0\pi^0$ $\pi^+\pi^-\pi^0$ $\pi\mu\nu$ $\pi e\nu$ $\pi^+\pi^-$ $\pi^0\pi^0$	(4.14 ± 0.15)×10 ⁶ (2.39 ± 0.04)×10 ⁶ (5.21 ± 0.10)×10 ⁶ (7.49 ± 0.11)×10 ⁶ $k(3.91 \pm 0.10) \times 10^4$ $k(1.81 \pm 0.35) \times 10^4$	S=1.3* S=1.2* S=1.1* S=1.1* S=1.5*	CP violation parameters u, k $|\eta_{+-}| = (2.274 \pm 0.022) \times 10^{-3}$ $|\eta_{00}| = (2.33 \pm 0.08) \times 10^{-3}$ S=1.1* $\phi_{+-} = (44.6 \pm 1.2)^\circ$ $\phi_{00} = (54 \pm 5)^\circ$ $|\eta_{+-}| < 0.12$ $|\eta_{00}|^2 < 0.28$ $\delta = (0.330 \pm 0.012) \times 10^{-2}$ ΔS = -ΔQ Re x = 0.009 ± 0.020 S=1.4* Im x = -0.004 ± 0.026 S=1.1*	
Magnetic moment (eħ/2m_pc)	Decay parameters^v				
		Measured	Derived	$\frac{g_A}{g_V}$	$\frac{g_V}{g_A}$
		α	γ		
		$\phi(\text{degree})$	$\Delta(\text{degree})$		
P	2.7928456 ±.0000011				
n^w	-1.91304184 ±.00000088	$pe^- \nu$		-1.254 ± 0.007 $\delta = (180.11 \pm 0.17)^\circ$	
Λ^w	-0.614 ±.005	$p\pi^-$ 0.642 ± 0.013 $n\pi^0$ 0.646 ± 0.044 $pe\nu$	(-6.5 ± 3.5)° 0.76 S=1.1*	(7.7 ^{+4.0} _{-4.1})° -0.62 ± 0.05 S=1.2*	
Σ⁺	2.33 ±.13	$p\pi^0$ -0.979 ± 0.016 $n\pi^+$ +0.068 ± 0.013 $p\gamma$ -1.03 ^{+0.52} _{-0.42}	(36 ± 34)° (167 ± 20)° S=1.1*	0.17 (187 ± 6)° -0.97 (-72 ⁺¹³² ₋₁₁)°	
Σ⁻	-1.41 ±.25	$n\pi^-$ -0.068 ± 0.008 $ne^- \nu$ $\Lambda e^- \nu$	(10 ± 15)° 0.98 S=1.1*	(249 ⁺¹² ₋₁₁₅)° ±(0.385 ± 0.070) S=2.3* 0.10 ± 0.22 S=1.5*	
Ξ⁰	-1.20 ±.06	$\Lambda\pi^0$ -0.47 ± 0.05	(21 ± 12)° S=1.3*	0.84 (216 ⁺¹³ ₋₁₉)°	
Ξ⁻	-1.85 ±.75	$\Lambda\pi^-$ -0.403 ± 0.017	(2 ± 6)° S=1.1*	0.92 (185 ± 13)°	
Ω⁻		ΛK^- -0.26 ± 0.33	S=1.5*		

Stable Particle Table (cont'd)

- Indicates an entry in the Stable Particle Data Card Listings not entered in the Stable Particle Table. This is the case for ν_τ , for the charmed-strange meson F^* , and for listings of searches for heavy leptons other than τ^* , intermediate boson searches, quark searches, magnetic monopole searches, charm searches, and other particle searches.
- * $S = \text{Scale factor} = \sqrt{\chi^2/(N-1)}$, where $N \approx$ number of experiments. S should be ≈ 1 . If $S > 1$, we have enlarged the error of the mean, $\delta\bar{x}$; i.e., $\delta\bar{x} \rightarrow S\delta\bar{x}$. This convention is still inadequate, since if $S \gg 1$ the experiments are probably inconsistent, and therefore the real uncertainty is probably even greater than $S\delta\bar{x}$. See text, and ideograms in Stable Particle Data Card Listings.
- † Square brackets indicate a subreaction of the previous (unbracketed) decay mode.

- a. The baryon number B , strangeness S , and charm C of the hadrons which appear in the tables are as follows:

Mesons ($B=0$)	S	C	Baryons ($B=1$)	S	C
π, η	0	0	p, n	0	0
K^+, K^0	+1	0	Λ, Σ	-1	0
K^-, \bar{K}^0	-1	0	Ξ	-2	0
D^+, D^0	0	+1	Ω^-	-3	0
D^-, \bar{D}^0	0	-1	Λ_c^+	0	+1

- b. Quoted upper limits correspond to a 90% confidence level.
- c. In decays with more than two bodies, p_{max} is the maximum momentum that any particle can have.
- d. For simplicity, decay mode charge states are written for the particle shown. For antiparticle modes all particles must be charge conjugated.
- e. See Stable Particle Data Card Listings for energy limits used in this measurement.
- f. Quantum numbers shown are favored but not yet established. See Data Card Listings.
- g. Theoretical value; see also Stable Particle Data Card Listings.
- h. See note in Stable Particle Data Card Listings.
- i. Structure-dependent part with positive (SD+) and negative (SD-) photon helicity.
- j. The direct emission branching fraction is $(1.56 \pm 35) \times 10^{-5}$.
- k. The $K_S^0 \rightarrow \pi\pi$ and $K_L^0 \rightarrow \pi\pi$ rates (and branching fractions) are from independent fits and do not include results of $K_L^0 - K_S^0$ interference experiments. The $|\eta_{+-}|$ and $|\eta_{00}|$ values given in the addendum are these rates combined with the $|\eta_{+-}|$ and $|\eta_{00}|$ results from interference experiments.
- l. Error does not include 0.13% uncertainty in the absolute SPEAR energy calibration. Assumes $m_\psi = 3095$ MeV.
- m. This is a weighted average of D^* (44%) and D^0 (56%) branching fractions.
- n. Limit from neutrality-of-matter experiments. Assumes $|q_n| = |q_p| - |q_e|$.
- p. J^P not measured for Σ^0 . Assumed same as Σ^* to allow isotriplet association.
- q. P for Ξ and J^P for Ω^- not yet measured. Values shown are SU(3) predictions.
- r. J^P for Λ_c^+ not yet measured. Values shown are SU(4) predictions.
- s. $|g_A/g_V|$ defined by $g_A^2 = |C_A|^2 + |C'_A|^2$, $g_V^2 = |C_V|^2 + |C'_V|^2$, and $\Sigma(\bar{u}\Gamma_1\mu)(\bar{u}\Gamma_2(C_1+C'_1)\gamma_5)\nu$; ϕ defined by $\cos \phi = -\text{Re}(C_A^*C_V + C'_A C'_V)/g_A g_V$ [for more details, see text Section VI A].
- t. The definition of the slope parameter of the Dalitz plot is as follows [see also text Section VI B.1]:

$$|M|^2 = 1 + g \left(\frac{s_3 - s_0}{m_{\pi^+}^2} \right)$$

- u. The definition for the CP violation parameters is as follows [see also text Section VI B.3]:

$$\eta_{+-} = |\eta_{+-}| e^{i\phi_{+-}} = \frac{A(K_L^0 \rightarrow \pi^+\pi^-)}{A(K_S^0 \rightarrow \pi^+\pi^-)} \quad \eta_{00} = |\eta_{00}| e^{i\phi_{00}} = \frac{A(K_L^0 \rightarrow \pi^0\pi^0)}{A(K_S^0 \rightarrow \pi^0\pi^0)}$$

$$\delta = \frac{\Gamma(K_L^0 \rightarrow \ell^+\ell^-) - \Gamma(K_L^0 \rightarrow \ell^-\ell^-)}{\Gamma(K_L^0 \rightarrow \ell^+\ell^-) + \Gamma(K_L^0 \rightarrow \ell^-\ell^-)}, \quad |\eta_{+-}|^2 = \frac{\Gamma(K_S^0 \rightarrow \pi^+\pi^-\pi^0)_{\text{CP viol.}}}{\Gamma(K_L^0 \rightarrow \pi^+\pi^-\pi^0)}, \quad |\eta_{00}|^2 = \frac{\Gamma(K_S^0 \rightarrow \pi^0\pi^0\pi^0)_{\text{CP viol.}}}{\Gamma(K_L^0 \rightarrow \pi^0\pi^0\pi^0)}$$

- v. The definition of these quantities is as follows [for more details on sign convention, see text Section VI B]:

$$\alpha = \frac{2|s||p|\cos\Delta}{|s|^2 + |p|^2} \quad \beta = \sqrt{1 - \alpha^2} \sin\phi \quad \left| \begin{array}{l} g_A/g_V \text{ defined by } (B_1\gamma_\lambda(g_V - g_A\gamma_5))B_1 \\ \delta \text{ defined by } g_A/g_V = |g_A/g_V|e^{i\phi} \end{array} \right.$$

$$\beta = \frac{-2|s||p|\sin\Delta}{|s|^2 + |p|^2} \quad \gamma = \sqrt{1 - \alpha^2} \cos\phi$$

- w. For limits on electric dipole moment of n and Λ , see Data Card Listings.

Meson Table

April 1980

In addition to the entries in the Meson Table, the Meson Data Card Listings contain all substantial claims for meson resonances. See Contents of Meson Data Card Listings below.

Quantities in italics are new or have changed by more than one (old) standard deviation since April 1978.

Name $\frac{G}{-} \frac{I}{+} \frac{0}{1} \frac{1}{\pi}$ $\frac{+}{-} \frac{1}{\eta} \frac{1}{\rho}$	$I^G(J^P)C_{\eta}$ estab.	Mass M (MeV)	Full Width Γ (MeV)	M^2 $\pm \Gamma M^{(a)}$ (GeV) ²	Partial decay mode		
					Mode	Fraction (%) [Upper limits are 1 σ (%)]	P or Pmax ^(b) (MeV/c)
NONSTRANGE MESONS							
π^{\pm}	$1^-(0^-)+$	139.57	0.0	0.019479			
π^0		134.96	7.95 eV ± 55 eV	0.018215		See Stable Particle Table	
η	$0^+(0^-)+$	548.8 ± 0.6	0.85 keV ± 12 keV	0.301 ± 0.000	Neutral Charged	71.0 29.0	See Stable Particle Table
$\rho(770)$	$1^+(1^-)-$	776 ^(f) $\pm 3^g$	158 ^(f) $\pm 5^g$	0.602 ± 123	$\pi\pi$ $\pi\gamma$ e^+e^- $\mu^+\mu^-$ $\eta\gamma$	≈ 100 0.024 \pm .007 0.0043 \pm .0005 (d) 0.0067 \pm .0012 (d) seen ^(f)	362 375 388 375 194
M and Γ from neutral mode:					For upper limits, see footnote (e)		
$\omega(783)$	$0^-(1^-)-$	782.4 ± 0.2 S=1.1*	10.1 ± 3	0.612 ± 0.008	$\pi^+\pi^-\pi^0$ $\pi^+\pi^-$ $\pi^0\gamma$ e^+e^- $\eta\gamma$	89.8 \pm 0.5 1.4 \pm 0.2 8.8 \pm 0.5 0.0076 \pm .0017 seen ^(f)	327 365 380 391 199
					For upper limits, see footnote (f)		
$\eta'(958)$	$0^+(0^-)+^{\ddagger}$	957.57 ± 0.25	0.28 ± 0.10	0.917 ± 0.0003	$\eta\pi\pi$ $\rho^0\gamma$ $\omega\gamma$ $\gamma\gamma$	65.6 \pm 1.6 29.8 \pm 1.6 2.7 \pm 0.5 1.9 \pm 0.2	231 164 159 479
					For upper limits, see footnote (g)		
$\delta(980)$	$1^-(0^+)+$	981 ^(h) ± 3	52 ^(h) ± 8	0.962 ± 0.051	$\eta\pi$ K \bar{K}	seen seen ^(f)	319
$S^*(980)$	$0^+(0^+)+$	$\sim 980^{(c)}$ $\pm 10^g$	40 ^(c) $\pm 10^g$	0.960 ± 0.039	K \bar{K} $\pi\pi$	seen ^(f) seen	470
See note on $\pi\pi$ and K \bar{K} S-wave ^(f) .							
$\phi(1020)$	$0^-(1^-)-$	1019.6 ± 0.1 S=1.3*	4.1 ± 2	1.040 ± 0.004	K^+K^- $K_L^0K_S^0$ $\pi^+\pi^-\pi^0$ (incl. $\rho\pi$) $\eta\gamma$ $\pi^0\gamma$ e^+e^- $\mu^+\mu^-$	48.6 \pm 1.2 35.2 \pm 1.2 14.7 \pm 0.7 1.5 \pm 0.2 0.14 \pm 0.05 .031 \pm .001 .025 \pm .003	S=1.3* S=1.5* S=1.2* 362 501 S=1.1* 499
					For upper limits, see footnote (i)		
$A_1(1100-1300)$	$1^-(1^+)+$	1100 ^(f) to 1300	$\sim 300^{(f)}$	1.44 ± 0.36	$\rho\pi$ $\pi(\pi\pi)$ S-wave	dominant seen	329 558
$B(1235)$	$1^+(1^+)-$	1231 $\pm 10^g$	129 $\pm 10^g$	1.52 ± 0.16	$\omega\pi$ [D/S amplitude ratio = .29 \pm .05] For upper limits, see footnote (j)	only mode seen	348
$f(1270)$	$0^+(2^+)+$	1273 ^(g) $\pm 5^g$	178 ^(g) $\pm 20^g$	1.62 ± 0.23	$\pi\pi$ $2\pi^+2\pi^-$ K \bar{K} $\pi^+\pi^-2\pi^0$	83.1 \pm 1.9 2.9 \pm 0.3 2.8 \pm 0.3 seen	S=1.4* S=1.1* S=1.3* 561
					For upper limits, see footnote (k)		
$D(1285)$	$0^+(1^+)+$	1284 $\pm 10^g$	27 $\pm 10^g$	1.65 ± 0.03	K $\bar{K}\pi$ $\eta\pi\pi$ [$\frac{\delta\pi}{4\pi}$ (prob. $\rho\pi\pi$)]	10 \pm 2 49 \pm 6 36 \pm 7 41 \pm 13	303 483 239 564
$\epsilon(1300)$	$0^+(0^+)+$	~ 1300	200-400		$\pi\pi$ K \bar{K}	~ 90 ~ 10	635 423
See note on $\pi\pi$ and K \bar{K} S wave ^(f) .							
$A_2(1310)$	$1^-(2^+)+$	1317 ^(g) $\pm 5^g$	102 ^(g) $\pm 5^g$	1.73 ± 0.13	$\rho\pi$ $\eta\pi$ $\omega\pi\pi$ K \bar{K} $\eta'\pi$ $\pi\gamma$	70.0 \pm 2.2 14.6 \pm 1.1 10.6 \pm 2.5 4.8 \pm 0.5 <1 0.45 \pm 0.11	414 534 360 434 285 651

Meson Table (cont'd)

Name	$\frac{G}{\Gamma} \frac{1}{\omega} \frac{1}{\pi} \frac{1}{\rho}$	$I^G(J^P)C_n$ estab.	Mass M (MeV)	Full Width Γ (MeV)	M^2 $\pm \Gamma M^{(a)}$ (GeV) ²	Partial decay mode		P or P _{max} ^(b) (MeV/c)
						Mode	Fraction (%) [Upper limits are 1 σ (%)]	
E(1420)		$0^+(1^+)_{+}$	$1418_{\pm 10}^{\text{§}}$	$50_{\pm 10}^{\text{§}}$	2.01 ± 0.07	$K\bar{K}\pi$ (prob. $K^*\bar{K} + \bar{K}^*K$) $\eta\pi\pi$ $\dagger[\delta_{\pi\pi}]$	seen possibly seen possibly seen	423 565 350
f'(1515)		$0^+(2^+)_{+}$	$1516_{\pm 12}^{\text{§}}$	$67_{\pm 10}^{\text{§}}$	2.30 ± 0.10	$K\bar{K}$ $\pi\pi$ For upper limits, see footnote (k)	dominant seen	572 745
ρ' (1600)		$1^+(1^-)_{-}$	$\sim 1600^{\text{¶}}$	$\sim 300^{\text{¶}}$	2.56 ± 0.48	4π (incl. $\rho\pi^+\pi^-$) $\pi\pi$	~ 85 ~ 15	738 788
A ₃ (1660)		$1^-(2^-)_{+}$	$1660_{\pm 10}^{\text{§}}$	$200_{\pm 50}^{\text{§}}$	2.76 ± 0.33	$f\pi$ $\rho\pi$ $\pi(\pi\pi)_{\text{S-wave}}$	~ 60 ~ 30 ~ 10	320 640 802
ω (1670)		$0^-(3^-)_{-}$	1666 ± 5	$166_{\pm 15}^{\text{§}}$	2.78 ± 0.28	$\rho\pi$ 3π 5π $\dagger[\omega\pi\pi]$ (prob. B π)	seen possibly seen seen seen	644 805 739 614
g(1700) [¶]		$1^+(3^-)_{-}$	$1700_{\pm 20}^{\text{§}}$	$200_{\pm 20}^{\text{§}}$	2.89 ± 0.34	2π 4π (incl. $\pi\pi\rho, \rho\rho, A_2\pi, \omega\pi$) $K\bar{K}\pi$ (incl. $K^*\bar{K}$) $K\bar{K}$	24.0 ± 1.3 72.1 ± 1.6 2.4 ± 0.7 1.5 ± 0.3	838 792 651 689
J ^P , M and Γ from the 2π and $K\bar{K}$ modes.								
S(1935) [¶]			$1936_{\pm 5}^{\text{§}}$		3.74	$N\bar{N}$	seen	236
Not a well established resonance. [¶]								
h(2040)		$0^+(4^+)_{+}$	$2040_{\pm 20}^{\text{§}}$	$150_{\pm 50}^{\text{§}}$	4.16 ± 0.31	$\pi\pi$ $K\bar{K}$	seen seen	1010 890
+++++								
J/ψ(3100)		$0^-(1^-)_{-}$	3097 ± 1	0.063 ± 0.009	9.598 ± 0.000	e^+e^- $\mu^+\mu^-$ hadrons \dagger [all stables]	7 ± 1 7 ± 1 86 ± 2	1549 1545
						$2(\pi^+\pi^-)\pi^0$ $3(\pi^+\pi^-)\pi^0$ $\pi^+\pi^-\pi^0 K^+K^-$ $\pi^+\pi^-K^+K^-$ $4(\pi^+\pi^-)\pi^0$ $p\bar{p}\pi^+\pi^-$ $2(\pi^+\pi^-)$ $3(\pi^+\pi^-)$ $\Xi^+\Xi^-$ $2(\pi^+\pi^-)K^+K^-$ $K_S^0 K_S^0 \pi^+\pi^-$ $p\bar{p}\eta$ $p\bar{p}\eta$ or $\bar{p}n\pi^+$ $p\bar{p}$ $n\bar{n}$ $p\bar{p}\pi^+\pi^-\pi^0$ $\Sigma^0 \bar{\Sigma}^0$ $\Lambda\bar{\Lambda}$ $p\bar{p}\pi^0$	3.7 ± 0.5 2.9 ± 0.7 1.2 ± 0.3 0.72 ± 0.23 0.9 ± 0.3 0.55 ± 0.06 0.4 ± 0.1 0.4 ± 0.2 0.32 ± 0.08 0.31 ± 0.13 0.26 ± 0.07 0.23 ± 0.04 0.21 ± 0.02 0.22 ± 0.02 0.18 ± 0.09 0.16 ± 0.06 (n) 0.13 ± 0.04 0.11 ± 0.02 0.11 ± 0.01	1496 1433 1368 1407 1345 1107 1517 1466 818 1320 1440 948 1174 1232 1231 1033 988 1074 1176
						\dagger [with resonances]	1.2 ± 0.1 0.85 ± 0.34 0.84 ± 0.45 0.68 ± 0.19 0.67 ± 0.26 0.61 ± 0.08 0.29 ± 0.07 0.23 ± 0.08 0.21 ± 0.09 0.18 ± 0.06 0.18 ± 0.08 0.16 ± 0.03 0.16 ± 0.10 0.10 ± 0.06	1448 1392 1124 1435 1007 1373 1300 1144 1365 596 1176 768 1265 1320
						\dagger [radiative decays]	0.25 ± 0.06 0.15 ± 0.05	1400 1287
For smaller branching ratios and upper limits see listing. [¶]								

Meson Table (cont'd)

Name	$\frac{G}{\omega} \frac{I}{\pi} \frac{0}{\pi} \frac{1}{\pi}$ + | π | p	$I^G(J^P)C_n$ estab.	Mass M (MeV)	Full Width Γ (MeV)	M^2 $\pm \Gamma M^{(a)}$ (GeV) ²	Partial decay mode		p or Pmax (MeV/c) ^(b)
						Mode	Fraction (%) [Upper limits are 1σ]	
χ(3415)		$0^+(0^+)_{\pm}$	3414±4		11.655	2(π ⁺ π ⁻) (incl. ππρ) π ⁺ π ⁻ K ⁺ K ⁻ (incl. πK ⁺ K ⁻) γJ/ψ(3100) 3(π ⁺ π ⁻) π ⁺ π ⁻ K ⁺ K ⁻ ppπ ⁺ π ⁻	4.6±0.9 3.7±0.9 2.7±1.0 (m) 1.9±0.7 0.9±0.2 0.9±0.2 0.6±0.2	1678 1580 302 1632 1701 1634 1319
P _C or χ(3510)		$0^+(A)_{\pm}$	3507±4		12.299	γJ/ψ(3100) 3(π ⁺ π ⁻) 2(π ⁺ π ⁻) (incl. ππρ) π ⁺ π ⁻ K ⁺ K ⁻ (incl. πK ⁺ K ⁻) π ⁺ π ⁻ pp	31.5±5.2 2.7±1.1 2.0±0.6 1.1±0.4 0.17±0.11	S = 1.3* 386 1681 1726 1650 1379
		J ^P = 1 ⁺ preferred.						
χ(3550)		$0^+(N)_{\pm}$	3551±5		12.610	γJ/ψ(3100) 2(π ⁺ π ⁻) (incl. ππρ) π ⁺ π ⁻ K ⁺ K ⁻ (incl. πK ⁺ K ⁻) 3(π ⁺ π ⁻) π ⁺ π ⁻ and K ⁺ K ⁻ π ⁺ π ⁻ pp	15.4±2.4 2.4±0.6 2.1±0.6 1.3±0.8 0.27±0.11 0.37±0.14	425 1748 1654 1704 1407
		J ^P = 2 ⁺ preferred.						
ψ(3685)		$0^-(1^-)_{-}$	3685±1 S=1.1*	0.215±0.040	13.579 ±0.001	e ⁺ e ⁻ μ ⁺ μ ⁻ hadrons +[J/ψ π ⁰ π ⁰] +[J/ψ π ⁰ π ⁰] +[J/ψ η] +[2(π ⁺ π ⁻)π ⁰] +[π ⁺ π ⁻ K ⁺ K ⁻] +[ppπ ⁺ π ⁻] +[2(π ⁺ π ⁻)] +[γ χ(3415)] +[γ χ(3510)] +[γ χ(3550)]	0.9±0.1 0.8±0.2 98.1±0.3 33±2] 17±2] 3.7±0.4] 0.4±0.2] 0.16±0.04] 0.08±0.02] 0.05±0.01] 7±2] 7±2] 7±2]	1842 1839 476 480 194 1798 1725 1490 1816 261 174 132
		$m_{\psi(3685)} - m_{\psi(3100)} = 588.2 \pm 0.9$ S=1.2*						
		For smaller branching ratios and upper limits see Listings. ^{††}						
ψ(3770)		$(1^-)_{-}$	3768 ±3	25 ±3	14.198 ±0.094	e ⁺ e ⁻ DD	0.0013±0.0002 dominant	1884 243
		$m_{\psi(3770)} - m_{\psi(3685)} = 82.5 \pm 3.7$ S=2.2*						
ψ(4030)		$(1^-)_{-}$	4030 ^{±6} _{±6} [§]	52±10	16.241 ±0.210	e ⁺ e ⁻ hadrons	0.0014±0.0004 dominant	2015
ψ(4160)		$(1^-)_{-}$	4159±20	78±20	17.297 ±0.324	e ⁺ e ⁻ hadrons	0.0010±0.0004 dominant	2079
ψ(4415)		$(1^-)_{-}$	4415±6	43±20 [§]	19.492 ±1.190	e ⁺ e ⁻ hadrons	0.0010±0.0003 dominant	2207
T(9460)		$(1^-)_{-}$	9458±6	~ 0.080	89.454 ±0.0006	μ ⁺ μ ⁻ e ⁺ e ⁻	2.2±2.0 2.5±2.1	4728 4729
T(10020)		$(1^-)_{-}$	10016±14	< 12	100.320	μ ⁺ μ ⁻ e ⁺ e ⁻	seen seen	5007 5008
		$m_T(10020) - m_T(9460) = 559 \pm 7$						
		Additional structure at m = 10410±30 is seen. ^{††}						
STRANGE MESONS								
K ⁺ K ⁰		$1/2(0^-)$	493.67 497.67		0.244 0.248	See Stable Particle Table		
K ⁺ (892)		$1/2(1^-)$	891.8 ±0.4 S=1.1*	50.3 ±0.8	0.795 ±0.045	Kπ K ⁰ π Kγ	≈ 100 < 0.07 0.15±0.07	288 216 309
		M and Γ from charged mode; m ⁰ - m [±] = 6.7±1.2 MeV.						
Q ₁ (1280)		$1/2(1^+)_{\pm}$	~ 1280	~ 120	1.64 ±.15	Kππ +[Kρ] +[K ⁺ π] Kω	dominant large] possibly seen possibly seen	501 62 307
Q ₂ (1400)		$1/2(1^+)_{\pm}$	~ 1400	~ 150	1.96 ±.21	Kππ +[K ⁺ π] +[Kρ]	dominant large] possibly seen]	576 399 286

Meson Table (cont'd)

Name $\frac{G}{+} \frac{I}{-} \frac{C}{+} \frac{P}{-} \frac{C_n}{+}$	$I^G(J^P)C_n$ → estab.	Mass M (MeV)	Full Width Γ (MeV)	M^2 $\pm \Gamma M^{(a)}$ (GeV) ²	Mode	Partial decay mode		p or Pmax ^(b) (MeV/c)
						Mode	Fraction (%) [Upper limits are 1σ · (%)]	
K* (1430)	$1/2(2^+)$	1434 ^S ±5 ^S	100 ^S ±10 ^S	2.06 ±.14	Kπ	49.1±1.6	S=1.1*	623
					K*π	27.0±2.2		424
					K*ππ	11.2±2.5		374
					Kω	6.6±1.5		327
					Kη	3.7±1.6		320
						2.5±2.6	492	
κ (1500)	$1/2(0^+)$	~1500	~250	2.25 ±.36	Kπ	seen		661
See note on Kπ S wave [¶] .								
L region	$1/2$	1600 to 2000			Kππ	seen		
Not a well established resonance [¶] .								
K* (1780) [¶]	$1/2(3^-)$	1785 ±6	126 _a ±20 ^S	3.19 ±.22	Kππ	large		798
					[Kω]	large]		619
					[K*π]	large]		660
					Kπ	19±5 ^S		817
CHARMED, NONSTRANGE MESONS								
D*	$1/2(0^-)$	1868.3		3.491	See Stable Particle Table			
D ⁰		1863.1		3.471				
D*+ (2010)	$1/2(1^-)$	2008.6 ±1.0 m _{D*+} - m _{D⁰} = 145.3 ± 0.4 MeV	< 2.0	4.034	D ⁰ π ⁺	64±11		40
					D*π ⁰	28±9		37
					D*γ	8±7		135
D* ⁰ (2010)	$1/2(1^-)$	2006.0 ±1.5	< 5	4.024	D ⁰ π ⁰	55±15		45
					D ⁰ γ	45±15		138

Contents of Meson Data Card Listings

Non-strange (S = 0, C = 0)				Strange (|S| = 1, C = 0)	
entry	$I^G(J^P)C_n$	entry	$I^G(J^P)C_n$	entry	I (J ^P)
π	1 ⁻ (0 ⁺) ⁺	A ₂ (1310)	1 ⁻ (2 ⁺) ⁺	+ e ⁺ e ⁻ (1100-3100)	K 1/2(0 ⁻)
η	0 ⁺ (0 ⁺) ⁺	E (1420)	0 ⁺ (1 ⁺) ⁺	+ X (2830)	K* (892) 1/2(1 ⁻)
ρ (770)	1 ⁺ (1 ⁻) ⁻	+ X (1410-1440)		+ U (2980)	Q ₁ (1280) 1/2(1 ⁺)
ω (783)	0 ⁻ (1 ⁻) ⁻	f' (1515)	0 ⁺ (2 ⁺) ⁺	J/ψ (3100)	0 ⁻ (1 ⁻) ⁻
+ M (940-953)		+ F ₁ (1540)	1 (A)	X (3415)	0 ⁺ (0 ⁺) ⁺
η' (958)	0 ⁺ (0 ⁺) ⁺	ρ' (1600)	1 ⁻ (2 ⁻) ⁻	+ X (3455)	
δ (980)	1 ⁻ (0 ⁺) ⁺	A ₃ (1660)	1 ⁺ (1 ⁻) ⁻	P _C or χ (3510)	0 ⁺ (A) ⁺
S* (980)	0 ⁺ (0 ⁺) ⁺	ω (1670)	0 ⁻ (3 ⁻) ⁻	X (3550)	0 ⁺ (N) ⁺
+ H (990)		g (1700)	1 ⁺ (3 ⁻) ⁻	+ X (3590)	
φ (1020)	0 ⁻ (1 ⁻) ⁻	+ X (1690)		ψ (3685)	0 ⁻ (1 ⁻) ⁻
+ M (1033-1040)		+ A ₄ (1900)	1 ⁻	ψ (3770)	(1 ⁻) ⁻
+ N (1080)	0 ⁺ (N) ⁺	+ A ₂ (1900)	1 ⁻ (4 ⁺) ⁺	ψ (4030)	(1 ⁻) ⁻
+ M (1150-1170)		S (1935)		ψ (4160)	(1 ⁻) ⁻
A ₁ (1100-1300)	1 ⁻ (1 ⁺) ⁺	h (2040)	0 ⁺ (4 ⁺) ⁺	ψ (4415)	(1 ⁻) ⁻
B (1235)	1 ⁺ (1 ⁺) ⁻	+ T0 (2150)	0 ⁺ (2 ⁺) ⁺	T (9460)	(1 ⁻) ⁻
+ ρ' (1250)	1 ⁺ (1 ⁻) ⁻	+ T1 (2190)	1	T (10020)	(1 ⁻) ⁻
f (1270)	0 ⁺ (2 ⁺) ⁺	+ X (2200)		T (10400)	(1 ⁻) ⁻
+ η (1275)	0 ⁺ (0 ⁺) ⁺	+ U0 (2350)	0		
D (1285)	0 ⁺ (1 ⁺) ⁺	+ U1 (2400)	1		
e (1300)	0 ⁺ (0 ⁺) ⁺	+ NN (1400-3600)			
		+ X (1900-3600)			
Charmed (|C| = 1)					
					D (1870) 1/2(0 ⁻)
					D* (2010) 1/2(1 ⁻)
					+ F (2030)
					+ F* (2140)
					+ Exotics

Meson Table (cont'd)

- Indicates an entry in Meson Data Card Listings not entered in the Meson Table. We do not regard these as established resonances. All the entries in the Listings can be found in the Table of Contents of Meson Data Card Listings.
- ¶ See Meson Data Card Listings.
- * Quoted error includes scale factor $S = \sqrt{\chi^2/(N-1)}$. See footnote to Stable Particle Table.
- + Square brackets indicate a subreaction of the previous (unbracketed) decay mode(s).
- § This is only an educated guess; the error given is larger than the error of the average of the published values. (See Meson Data Card Listings for the latter.)
- (a) ΓM is approximately the half-width of the resonance when plotted against M^2 .
- (b) For decay modes into ≥ 3 particles, p_{\max} is the maximum momentum that any of the particles in the final state can have. The momenta have been calculated by using the averaged central mass values, without taking into account the widths of the resonances.
- (c) From pole position $(M - i\Gamma/2)$.
- (d) The e^+e^- branching ratio is from $e^+e^- \rightarrow \pi^+\pi^-$ experiments only. The $\omega\rho$ interference is then due to $\omega\rho$ mixing only, and is expected to be small. See note in Meson Data Card Listings. The $\mu^+\mu^-$ branching ratio is compiled from 3 experiments; each possibly with substantial $\omega\rho$ interference. The error reflects this uncertainty; see notes in Meson Data Card Listings. If $e\mu$ universality holds, $\Gamma(\rho^0 \rightarrow \mu^+\mu^-) = \Gamma(\rho^0 \rightarrow e^+e^-) \times 0.99785$.
- (e) Empirical limits on fractions for other decay modes of $\rho(770)$ are $\pi^+\pi^- < 0.8\%$, $\pi^+\pi^-\pi^0 < 0.15\%$, $\pi^+\pi^+\pi^-\pi^0 < 0.2\%$.
- (f) Empirical values of fractions for other decay modes of $\omega(783)$ are $\pi^+\pi^-\gamma < 5\%$, $\pi^0\pi^0\gamma < 1\%$, $\eta + \text{neutral}(s) < 1.5\%$, $\mu^+\mu^- < 0.02\%$, $\pi^0\mu^+\mu^- = (9 \pm 5) \times 10^{-5}$.
- (g) Empirical values of fractions for other decay modes of $\eta'(958)$: $\pi^+\pi^- < 2\%$, $\pi^+\pi^-\pi^0 < 5\%$, $\pi^+\pi^+\pi^-\pi^0 < 1\%$, $\pi^+\pi^+\pi^-\pi^-\pi^0 < 1\%$, $6\pi < 1\%$, $\pi^+\pi^-\rho^0 < 0.6\%$, $\pi^0\rho^0 < 1.3\%$, $\eta e^+e^- < 1.1\%$, $\pi^0\rho^0 < 4\%$, $\mu^+\mu^-\gamma = (8 \pm 4) \times 10^{-5}$.
- (h) The mass and width are from the $\eta\pi$ mode only. If the $K\bar{K}$ channel is strongly coupled, the width may be larger.
- (i) Empirical limits on fractions for other decay modes of $\phi(1020)$ are $\pi^+\pi^- < 0.03\%$, $\pi^+\pi^-\gamma < 0.7\%$, $\omega\gamma < 5\%$, $\rho\gamma < 2\%$, $2\pi^+2\pi^-\pi^0 < 1\%$, $2\pi^+2\pi^- < 0.1\%$.
- (j) Empirical limits on fractions for other decay modes of $B(1235)$: $\pi\pi < 15\%$, $K\bar{K} < 2\%$, $4\pi < 50\%$, $\phi\pi < 1.5\%$, $\eta\pi < 25\%$, $(\bar{K}K)^+\pi^0 < 8\%$, $K_S K_S \pi^{\pm} < 2\%$, $K_S K_L \pi^{\pm} < 6\%$.
- (k) Empirical limits on fractions for other decay modes of $f'(1515)$ are $\eta\eta < 50\%$, $\eta\pi\pi < 30\%$, $K\bar{K}\pi + K^+\bar{K} < 35\%$, $2\pi^+2\pi^- < 32\%$.
- (l) Empirical limits on fractions for other decay modes of $f(1270)$ are $\eta\pi\pi < 1\%$, $K^0\bar{K}^+\pi^+ + \text{c.c.} < 1\%$, $\eta\eta < 2\%$.
- (m) Preliminary results from the Crystal Ball experiment give an upper limit of 0.007, see Meson Data Card Listings.
- (n) Includes $p\bar{p}\pi^+\pi^-\gamma$ and excludes $p\bar{p}\eta$, $p\bar{p}\omega$, $p\bar{p}\eta'$.

Established Nonets, and octet-singlet mixing angles from Appendix IIB, Eq. (2'). Of the two isosinglets, the 'mainly octet' one is written first, followed by a semicolon.

$(J^P)C_n$	Nonet members	$\theta_{\text{lin.}}$	$\theta_{\text{quadr.}}$
$(0^-)^+$	$\pi, K, \eta; \eta'$	$-24 \pm 1^\circ$	$-10 \pm 1^\circ$
$(1^-)^-$	$\rho, K^*, \phi; \omega$	$38 \pm 1^\circ$	$40 \pm 1^\circ$
$(2^+)^+$	$\Lambda_2, K^*(1430), f'; f$	$25 \pm 4^\circ$	$26 \pm 4^\circ$

Baryon Table

April 1980

The following short list gives the status of all the Baryon States in the Data Card Listings. In addition to the status, the name, the nominal mass, and the quantum numbers (where known) are shown. States with three- or four-star status are included in the main Baryon Table; the others have been omitted because the evidence for the existence of the effect and/or for its interpretation as a resonance is open to considerable question.

N(939) P11 ****	$\Delta(1232)$ P33 ****	$\Lambda(1115)$ P01 ****	$\Sigma(1193)$ P11 ****	$\Xi(1317)$ P11 ****
N(1470) P11 ****	$\Delta(1550)$ P31 **	$\Lambda(1330)$ Dead	$\Sigma(1385)$ P13 ****	$\Xi(1530)$ P13 ****
N(1520) D13 ****	$\Delta(1650)$ S31 ****	$\Lambda(1405)$ S01 ****	$\Sigma(1480)$ *	$\Xi(1630)$ **
N(1535) S11 ****	$\Delta(1670)$ D33 ****	$\Lambda(1520)$ D03 ****	$\Sigma(1560)$ **	$\Xi(1680)$ S11 **
N(1540) P13 *	$\Delta(1690)$ P33 ***	$\Lambda(1600)$ P01 **	$\Sigma(1580)$ D13 **	$\Xi(1820)$ 13 ***
N(1650) S11 ****	$\Delta(1890)$ F35 ****	$\Lambda(1670)$ S01 ****	$\Sigma(1620)$ S11 **	$\Xi(1940)$ **
N(1670) D15 ****	$\Delta(1900)$ S31 **	$\Lambda(1690)$ D03 ****	$\Sigma(1660)$ P11 ***	$\Xi(2030)$ 1 ***
N(1688) F15 ****	$\Delta(1910)$ P31 ****	$\Lambda(1800)$ S01 ***	$\Sigma(1670)$ D13 ****	$\Xi(2120)$ *
N(1700) D13 ****	$\Delta(1950)$ F37 ****	$\Lambda(1800)$ P01 **	$\Sigma(1670)$ **	$\Xi(2250)$ *
N(1710) P11 ****	$\Delta(1960)$ P33 **	$\Lambda(1800)$ G09 *	$\Sigma(1690)$ **	$\Xi(2370)$ 1 **
N(1810) P13 ****	$\Delta(1960)$ D35 ***	$\Lambda(1800)$ *	$\Sigma(1750)$ S11 ***	$\Xi(2500)$ **
N(1990) F17 **	$\Delta(2160)$ ***	$\Lambda(1815)$ F05 ****	$\Sigma(1765)$ D15 ****	
N(2000) F15 **	$\Delta(2300)$ H39 *	$\Lambda(1830)$ D05 ****	$\Sigma(1770)$ P11 *	$\Omega(1672)$ P03 ****
N(2040) D13 **	$\Delta(2420)$ H311***	$\Lambda(1860)$ P03 ***	$\Sigma(1840)$ P13 **	
N(2100) S11 *	$\Delta(2500)$ G39 *	$\Lambda(2010)$ *	$\Sigma(1880)$ P11 **	$\Lambda_c(2260)$ ***
N(2100) D15 **	$\Delta(2750)$ I313*	$\Lambda(2020)$ F07 *	$\Sigma(1915)$ F15 ****	
N(2190) G17 ****	$\Delta(2850)$ ****	$\Lambda(2100)$ G07 ****	$\Sigma(1940)$ D13 ***	$\Sigma_c(2430)$ **
N(2200) G19 ****	$\Delta(2950)$ K315**	$\Lambda(2110)$ F05 ***	$\Sigma(2000)$ S11 *	
N(2220) H19 ****	$\Delta(3230)$ ****	$\Lambda(2325)$ D03 *	$\Sigma(2030)$ F17 ****	
N(2600) I111***		$\Lambda(2350)$ ****	$\Sigma(2070)$ F15 *	Dibaryons
N(2700) K113*		$\Lambda(2585)$ ***	$\Sigma(2080)$ P13 **	S = 0 *
N(2800) G19 *	Z0(1780) P01 *		$\Sigma(2100)$ G17 *	S = -1 **
N(3030) ****	Z0(1865) D03 *		$\Sigma(2250)$ ****	S = -2 *
N(3245) *	Z1(1900) P13 *		$\Sigma(2455)$ ***	
N(3690) *	Z1(2150) *		$\Sigma(2620)$ ***	
N(3755) *	Z1(2500) *		$\Sigma(3000)$ **	
			$\Sigma(3170)$ *	

- **** Good, clear, and unmistakable.
- *** Good, but in need of clarification or not absolutely certain.
- ** Needs confirmation.
- * Weak.

[See notes on N's and Δ 's, Z's, Λ 's and Ξ 's, Ξ 's, and dibaryons at the beginning of those sections in the Baryon Data Card Listings; also see notes on individual resonances in the Baryon Data Card Listings.]

Particle ^a	I (J ^P) ^a estab.	π or K beam ^b P _{beam} (GeV/c) $\sigma = 4\pi\lambda^2$ (mb)	Mass M ^c (MeV)	Full Width Γ^c (MeV)	M ² $\pm \Gamma M^b$ (GeV ²)	Partial decay mode ^f		
						Mode	Fraction %	p or d P _{max} (MeV/c)
S=0 I=1/2 NUCLEON RESONANCES (N)								
p	$1/2(1/2^+)$		938.3		0.880			
n			939.6		0.883			See Stable Particle Table
N(1470)	$1/2(1/2^+)P'_{11}$	p = 0.66 $\sigma = 27.8$	1400 to 1480	120 to 350 (200)	2.16 ± 0.29	N π N η N $\pi\pi$	50-65 ~18 ~25	420 d 368
						[N π [$\Delta\pi$ [N ρ	~7] ^e ~23] ^e ~7] ^e	d 177 d
N(1520)	$1/2(3/2^-)D'_{13}$	p = 0.74 $\sigma = 23.5$	1510 to 1530	100 to 140 (125)	2.31 ± 0.19	N π N $\pi\pi$	~55 ~45	456 410
						[N π [N ρ [$\Delta\pi$ N η	<5] ^e ~19] ^e ~23] ^e <1	d d 228 d
N(1535)	$1/2(1/2^-)S'_{11}$	p = 0.76 $\sigma = 22.5$	1520 to 1560	100 to 250 (150)	2.36 ± 0.23	N π N η N $\pi\pi$	~40 ~55 ~5	467 182 422
						[N ρ [N π [$\Delta\pi$	~3] ^e ~2] ^e ~1] ^e	d d 243
N(1650)	$1/2(1/2^-)S''_{11}$	p = 1.05 $\sigma = 14.3$	1620 to 1680	100 to 200 (150)	2.72 ± 0.25	N π N $\pi\pi$	~60 ~30	547 511
						[N π [N ρ [$\Delta\pi$ ΛK ΣK N η	<10] ^e 7-21] ^e 4-15] ^e ~10 2-7 ~1	d d 344 161 d 346

Baryon Table (cont'd)

Particle ^a	I (J ^P) ^a estab.	π or K beam ^b P _{beam} (GeV/c) $\sigma = 4\pi\lambda^2$ (mb)	Mass ^c M (MeV)	Full Width ^c Γ (MeV)	M ² $\pm\Gamma M$ ^b (GeV ²)	Partial decay mode ^f		
						Mode	Fraction ^c %	p or d P _{max} (MeV/c)
N(1670)	$1/2(5/2^-)D_{15}^+$	p = 1.00 $\sigma = 15.6$	1660 to 1690	120 to 180 (155)	2.79 ± 0.26	N π N $\pi\pi$ [$\Delta\pi$ [N ρ [ΣK N η	~40 ~60 ~50] ^e ~5] ^e < 0.3 < 0.5	560 525 360 d 200 368
N(1688)	$1/2(5/2^+)F_{15}^+$	p = 1.03 $\sigma = 14.9$	1670 to 1690	110 to 140 (130)	2.85 ± 0.22	N π N $\pi\pi$ [N ρ [$\Delta\pi$ N η	~60 ~40 ~22] ^e ~13] ^e ~18] ^e < 0.3	572 538 340 d 375 388
N(1700)	$1/2(3/2^-)D_{13}^+$	p = 1.05 $\sigma = 14.3$	1670 to 1730	70 to 120 ^g (120)	2.89 ± 0.20	N π N $\pi\pi$ [N ρ [$\Delta\pi$ [ΣK N η	~10 ~90 < 40] ^e < 5] ^e 15-40] ^e < 1 ~ 4	580 547 355 d 385 250 400
N(1710)	$1/2(1/2^+)P_{11}^+$	p = 1.20 $\sigma = 12.2$	1680 to 1740	100 to 140 ^h (120)	2.92 ± 0.21	N π N $\pi\pi$ [N ρ [$\Delta\pi$ [ΣK N η	~20 > 50 15-40] ^e 40-65] ^e 10-20] ^e < 5 ~10 2-20 ⁱ	587 554 d d 393 264 138 410
N(1810)	$1/2(3/2^+)P_{13}^+$	p = 1.26 $\sigma = 11.5$	1690 to 1800	150 to 250 (200)	3.28 ± 0.36	N π N $\pi\pi$ [N ρ [$\Delta\pi$ [ΣK N η	~17 ~70 ~20] ^e 45-70] ^e ~20] ^e 1-4 ~ 2 < 5	652 624 468 297 471 386 307 503
N(1990)	$1/2(7/2^+)F_{17}^+$	p = 1.62 $\sigma = 8.35$	1950 to 2050	100 to 400 (250)	3.96 ± 0.50	N π N η [ΣK [ΣK	~5 ~3 seen seen	772 655 562 506
N(2190)	$1/2(7/2^-)G_{17}^-$	p = 2.07 $\sigma = 6.21$	2120 to 2180	<400 (250)	4.80 ± 0.55	N π N η [ΣK	~15 ~ 2 < 1	888 790 712
N(2200)	$1/2(9/2^-)G_{19}^-$	p = 2.10 $\sigma = 6.12$	2130 to 2270	200 to 350 (250)	4.84 ± 0.55	N π N η	~10 ~ 2	894 810
N(2220)	$1/2(9/2^+)H_{19}^+$	p = 2.14 $\sigma = 5.97$	2150 to 2300	~300 (300)	4.93 ± 0.67	N π N η	~20 ~ 1	905 811
N(2600)	$1/2(11/2^-)I_{111}^-$	p = 3.26 $\sigma = 3.67$	2580 to 2700	>300 (400)	6.76 ± 1.04	N π	~ 5	1014
N(3030)	$1/2(?)$	p = 4.41 $\sigma = 2.62$	~3030	~400 (400)	9.18 ± 1.21	N π	(J + 1/2) ^x < 0.1 ^k	1366

Baryon Table (cont'd)

Particle ^a	I (J ^P) ^a estab.	π or K beam ^b P _{beam} (GeV/c) $\sigma = 4\pi\lambda^2$ (mb)	Mass ^c M (MeV)	Full Width ^c Γ (MeV)	M ² $\pm\Gamma M$ ^b (GeV ²)	Partial decay mode ^f		
						Mode	Fraction %	P or d ^d P _{max} (MeV/c)
S=0 I=3/2 DELTA RESONANCES (Δ)								
$\Delta(1232)$	$3/2(3/2^+)P_{33}^+$	p = 0.30 $\sigma = 94.3$	1230 to 1234	110 to 120 (115)	1.52 ± 0.14	N π N $\pi^+\pi^-$	~ 99.4 ~ 0	227 80
		$\Delta(++)$ Pole position: ^z $\Delta(0)$ Pole position: ^z	M - i $\Gamma/2 = (1211.0 \pm 0.8) - i(49.9 \pm 0.6)$ M - i $\Gamma/2 = (1210.5 \pm 1.0) - i(52.9 \pm 1.0)$					
$\Delta(1650)$	$3/2(1/2^-)S_{31}^-$	p = 0.96 $\sigma = 16.4$	1600 to 1650	120 to 160 (140)	2.72 ± 0.23	N π N $\pi\pi$ [N ρ] [$\Delta\pi$]	~ 32 ~ 65 < 50 ^e ~ 40 ^e	547 511 d 344
$\Delta(1670)$	$3/2(3/2^-)D_{33}^-$	p = 1.00 $\sigma = 15.6$	1630 to 1740	190 to 300 (200)	2.79 ± 0.33	N π N $\pi\pi$ [N ρ] [$\Delta\pi$]	~ 15 ~ 85 ~ 40 ^e < 50 ^e	560 525 d 361
$\Delta(1690)$	$3/2(3/2^+)P_{33}^+$	p = 1.03 $\sigma = 14.9$	1500 to 1900 ^m	150 to 350 (250)	2.86 ± 0.42	N π N $\pi\pi$ [N ρ] [$\Delta\pi$]	~ 20 ~ 80 < 10 ^e $30-45$ ^e	573 540 d 377
$\Delta(1890)$	$3/2(5/2^+)F_{35}^+$	p = 1.42 $\sigma = 9.88$	1890 to 1930	250 to 400 (250)	3.57 ± 0.47	N π N $\pi\pi$ [N ρ] [$\Delta\pi$] ΣK	~ 15 ~ 80 ~ 60 ^e $10-30$ ^e < 3	704 677 403 531 400
$\Delta(1910)$	$3/2(1/2^+)P_{31}^+$	p = 1.46 $\sigma = 9.54$	1850 to 1950	200 to 330 (220)	3.65 ± 0.42	N π N $\pi\pi$ [N ρ] [$\Delta\pi$] ΣK	20-25 > 40 < 40 ^e small ^e 2-20	716 691 429 545 420
$\Delta(1950)$	$3/2(7/2^+)F_{37}^+$	p = 1.54 $\sigma = 8.90$	1910 to 1950	200 to 340 (240)	3.80 ± 0.47	N π N $\pi\pi$ [N ρ] [$\Delta\pi$] ΣK	~ 40 > 30 ~ 20 ^e ~ 30 ^e < 1	741 716 471 574 460
$\Delta(1960)$	$3/2(5/2^-)D_{35}^-$	p = 1.56 $\sigma = 8.75$	1890 to 1940	150 to 300 (200)	3.84 ± 0.39	N π ΣK	4-12 < 10	748 469
$\Delta(2160)^n$	$3/2(?^-)$	p = 2.00 $\sigma = 6.46$	2150 to 2280	200 to 440 (300)	4.67 ± 0.65	N π	(J+1/2) _x = 0.2 - 1.2 k	870
$\Delta(2420)$	$3/2(11/2^+)H_{311}^+$	p = 2.64 $\sigma = 4.68$	2380 to 2450	300 to 500 (300)	5.86 ± 0.73	N π	~ 10	1023
$\Delta(2850)$	$3/2(?^+)$	p = 3.85 $\sigma = 3.05$	2800 to 2900	~ 400 (400)	8.12 ± 1.14	N π	(J+1/2) _x ~ 0.25 k	1266
$\Delta(3230)$	$3/2(?)$	p = 5.08 $\sigma = 2.25$	3200 to 3350	~ 440 (440)	10.43 ± 1.42	N π	(J+1/2) _x ~ 0.05 k	1475

^z* Evidence for states with strangeness +1 is inconclusive.
See the Baryon Data Card Listings for data and discussion.

Baryon Table (cont'd)

Particle ^a	I (J) ^P _{stab.} ^a	π or K beam ^b P _{beam} (GeV/c) $\sigma = 4\pi\lambda^2$ (mb)	Mass M ^c (MeV)	Full Width Γ^c (MeV)	M ² $\pm\Gamma^b$ (GeV ²)	Partial decay mode ^f		
						Mode	Fraction ^e %	P or \bar{d} P _{max} (MeV/c)
S=-1 I=0 LAMBDA RESONANCES (Λ)								
Λ	$0(1/2^+)$		1115.6		1.245	See Stable Particle Table		
$\Lambda(1405)$	$0(1/2^-)S'_{01}$	Below K^-p threshold	1405 $\pm 5^o$	40 $\pm 10^o$ (40)	1.97 ± 0.06	$\Sigma\pi$	100	142
$\Lambda(1520)$	$0(3/2^-)D'_{03}$	p = 0.389 $\sigma = 84.5$	1519.5 $\pm 1.5^o$	15.5 $\pm 1.5^o$ (16)	2.31 ± 0.02	$N\bar{K}$ $\Sigma\pi$ $\Lambda\pi\pi$ $\Sigma\pi\pi$	46 ± 1 42 ± 1 10 ± 1 0.9 ± 0.1	234 258 250 140
$\Lambda(1670)$	$0(1/2^-)S''_{01}$	p = 0.74 $\sigma = 28.5$	1660 to 1680	20 to 60 (40)	2.79 ± 0.07	$N\bar{K}$ $\Lambda\eta$ $\Sigma\pi$	15-25 15-35 20-60	410 64 393
$\Lambda(1690)$	$0(3/2^-)D''_{03}$	p = 0.78 $\sigma = 26.1$	1690 $\pm 10^o$	50 to 70 (60)	2.86 ± 0.10	$N\bar{K}$ $\Sigma\pi$ $\Lambda\pi\pi$ $\Sigma\pi\pi$	20-30 20-40 ~25 ~20	429 409 415 352
$\Lambda(1800)$	$0(1/2^-)S'''_{01}$	p = 1.16 $\sigma = 14.2$	1700 to 1850	200 to 400 (300)	3.50 ± 0.56	$N\bar{K}$ $\Sigma\pi$ $\Sigma(1385)\pi$ $N\bar{K}^*(892)$	25-40 seen seen seen	525 488 346 d
$\Lambda(1815)$	$0(5/2^+)F'_{05}$	p = 1.05 $\sigma = 16.7$	1820 $\pm 5^o$	70 to 90 (80)	3.29 ± 0.15	$N\bar{K}$ $\Sigma\pi$ $\Sigma(1385)\pi$	55-65 5-15 5-10	542 508 362
$\Lambda(1830)$	$0(5/2^-)D_{05}$	p = 1.09 $\sigma = 15.8$	1810 to 1830	60 to 110 (95)	3.35 ± 0.17	$N\bar{K}$ $\Sigma\pi$ $\Sigma(1385)\pi$	<10 35-75 >15	554 519 375
$\Lambda(1860)$	$0(3/2^+)F'_{03}$	p = 1.14 $\sigma = 14.7$	1850 to 1920	60 to 200 (100)	3.46 ± 0.19	$N\bar{K}$ $\Sigma\pi$ $\Sigma(1385)\pi$ $N\bar{K}^*(892)$	15-40 3-10 seen seen	576 534 396 162
$\Lambda(2100)$	$0(7/2^-)G_{07}$	p = 1.68 $\sigma = 8.68$	2080 to 2120	100 to 300 (250)	4.41 ± 0.53	$N\bar{K}$ $\Sigma\pi$ $\Lambda\eta$ EK $\Lambda\omega$ $N\bar{K}^*(892)$	~30 ~5 <3 <3 <8 10-20	748 699 617 483 443 514
$\Lambda(2110)$	$0(5/2^+)F''_{05}$	p = 1.70 $\sigma = 8.48$	2080 to 2140	150 to 250 (200)	4.45 ± 0.42	$N\bar{K}$ $\Sigma\pi$ $N\bar{K}^*(892)$ $\Lambda\omega$ $\Sigma(1385)\pi$	5-25 <40 20-60 seen seen	756 709 524 454 589
$\Lambda(2350)$	$0(9/2^+)$	p = 2.29 $\sigma = 5.85$	2340 to 2420	100 to 250 (120)	5.52 ± 0.28	$N\bar{K}$ $\Sigma\pi$	~12 ~10	913 865
$\Lambda(2585)$	$0(?)$	p = 2.91 $\sigma = 4.37$	~2585	~300 (300)	6.68 ± 0.78	$N\bar{K}$	(J+1/2) _x ~1.0 K	1058
S=-1 I=1 SIGMA RESONANCES (Σ)								
Σ	$1(1/2^+)$		(+)1189.4 (0)1192.5 (-)1197.3		1.415 1.422 1.434	See Stable Particle Table		
$\Sigma(1385)$	$1(3/2^+)F'_{13}$	Below K^-p threshold	(+)1382.3 ± 0.4 s = 1.6 P (-)1387.5 ± 0.6 s = 1.0 P (0)1382.0 ± 2.5 s = 1.6 P	(+)35 ± 2 s = 2.2 P (-)40 ± 2 s = 1.9 P (35)	1.92 ± 0.05	$\Lambda\pi$ $\Sigma\pi$	88 ± 2 12 ± 2	208 117

Baryon Table (cont'd)

Particle ^a	I (J ^P) ^a estab.	π or K beam ^b P _{beam} (GeV/c) $\sigma = 4\pi\lambda^2$ (mb)	Mass M ^c (MeV)	Full Width Γ ^c (MeV)	M ² ±ΓM ^b (GeV ²)	Partial decay mode ^f		
						Mode	Fraction %	P or d P _{max} (MeV/c)
Σ(1660) ^q	1(1/2 ⁺)F ₁₁ '	p = 0.72 σ = 30.1	1580 to 1690	30 to 200 (100)	2.76 ±0.17	N \bar{K} Σπ Λπ	<30 seen seen	402 383 440
Σ(1670)	1(3/2 ⁻)D ₁₃ "	p = 0.74 σ = 28.5	1675 ±10 ^o	40 to 60 (50)	2.79 ±0.08	N \bar{K} Σπ Λπ	5-15 20-60 < 20	410 387 447
Σ(1750)	1(1/2 ⁻)S ₁₁ "	p = 0.91 σ = 20.7	1730 to 1820	50 to 160 (75)	3.06 ±0.13	N \bar{K} Λπ Σπ Ση	10-40 5-20 < 8 15-55	483 507 450 54
Σ(1765)	1(5/2 ⁻)D ₁₅	p = 0.94 σ = 19.6	1774 ±7 ^o	105 to 135 (120)	3.12 ±0.21	N \bar{K} Λπ Λ(1520)π Σ(1385)π Σπ	~41 ~14 ~19 ~ 9 ~ 1	496 518 187 315 461
Σ(1915)	1(5/2 ⁺)F ₁₅ '	p = 1.25 σ = 13.0	1905 to 1930	70 to 160 (100)	3.67 ±0.19	N \bar{K} Λπ Σπ Σ(1385)π	5-15 10-20 seen < 5	612 619 568 437
Σ(1940) ^q	1(3/2 ⁻)D ₁₃ "	p = 1.32 σ = 12.0	1900 to 1950	150 to 300 (220)	3.76 ±0.43	N \bar{K} Λπ Σπ Λ(1520)π Δ(1232) \bar{K} NK*(892) Σ(1385)π	<20 seen seen seen seen seen seen	678 680 589 370 410 320 461
Σ(2030)	1(7/2 ⁺)F ₁₇	p = 1.52 σ = 9.93	2020 to 2040	120 to 200 (180)	4.12 ±0.37	N \bar{K} Λπ Σπ ΣK Λ(1520)π Σ(1385)π Δ(1232) \bar{K} NK*(892)	~20 ~20 5-10 < 2 10-20 5-15 10-20 < 5	700 700 652 412 429 530 498 438
Σ(2250) ^q	1(?) ^p	p = 2.04 σ = 6.76	2200 to 2300	50 to 150 (100)	5.06 ±0.22	N \bar{K} Λπ Σπ	< 10 seen seen	849 841 801
Σ(2455)	1(?)	p = 2.57 σ = 5.09	~2455	~120 (120)	6.03 ±0.29	N \bar{K}	(J+1/2) _x ~0.2 _K	979
Σ(2620)	1(?)	p = 2.95 σ = 4.30	~2600	~200 (200)	6.86 ±0.52	N \bar{K}	(J+1/2) _x ~0.3 _K	1064
S=-2 I=1/2 CASCADE RESONANCES (Σ)								
Σ	1/2(1/2 ⁺)		(0)1314.9 (-)1321.3		1.729 1.746		See Stable Particle Table	
Σ(1530)	1/2(3/2 ⁺)P ₁₃		(0)1531.8±0.3 S = 1.3 P (-)1535.0±0.6	(0)9.1±0.5 (-)10.1±1.9 (10)	2.34 ±0.02	Σπ	100	144
Σ(1820)	1/2(3/2 ⁻)		1823 ±6 ^o	20 ⁺¹⁵ ₋₁₀ (20)	3.31 ±0.04	Λ \bar{K} Σ(1530)π Σ \bar{K} Σπ	~45 ~45 ~10 small	396 234 306 413
Σ(2030)	1/2(?)		2024 ±6 ^o	16 ⁺¹⁵ ₋₅ (16)	4.12 ±0.03	Σ \bar{K} Λ \bar{K} Σπ Σ(1530)π	~80 ~20 small small	524 587 573 418
Ω ⁻	0(3/2 ⁺)		1672.2±0.3		2.796		See Stable Particle Table	
Λ _c ⁺	0(1/2 ⁺)		2273±6		5.17		See Stable Particle Table	

Baryon Table (cont'd)

For convenience all Baryon States for which information exists in the Baryon Data Card Listings are listed at the beginning of the Baryon Table. States with only a one or two star (*) rating in that list have been omitted from the main Baryon Table; each omitted state is indicated by an arrow in the left-hand margin of the Table. In the Listings there is an arrow under the name of each state omitted from the Table.

- a. The names of the Baryon States in Col. 1 [such as N(1470)] contain a nominal mass which is primarily for purposes of identification. See Col. 4 for actual mass values. The convention for using primes in the spectroscopic notation for the quantum numbers in Col. 2 (such as P_{11}) is as follows: no prime is attached when the Data Card Listings include only one resonance in the given partial wave; when there is more than one resonance, the first has been designated with a prime, the second with a double prime, etc. The name and the quantum numbers for each state are also given in large print at the beginning of the Data Card Listings for that state. See footnote a. of the Stable Particle Table for the strangeness quantum numbers of the baryons; in addition to the names listed there, we also use N and Δ for $S=0$ baryons, and Z^* for $S=+1$ baryons.
- b. The numbers in Col. 3 and Col. 6 are calculated using the nominal mass (see a. above) for M and the nominal width (see c. below) for Γ .
- c. For masses, widths, and branching fractions of most baryons we report here a range instead of an average. Averages are appropriate if each result is based on independent measurements, but inappropriate where the spread in parameters arises because different models or procedures have been applied to a common set of data. The ranges given in the Table are generally chosen to be *conservatively large*. See the Data Card Listings for the individual values obtained in specific analyses. A single value with an approximation sign (\sim) indicates that there is not enough data to give a meaningful interval. A nominal width is included in parentheses in Col. 5; this nominal width is used to calculate the value of ΓM given in Col. 6.
- d. For two-body decay modes we give the momentum, p , of the decay products in the decaying baryon rest frame. For decay modes into ≥ 3 particles we give the maximum momentum, p_{\max} , that any of the particles in the final state can have in this frame. The momenta are calculated using the nominal mass (see a. above) of the decaying baryon, and of any isobars in the final state. Some decays which would be energetically forbidden for the nominal masses actually occur because of the finite widths of the decaying baryon and/or isobars in the final state. In these cases, the decay momentum is omitted from Col. 9 and replaced with a reference to this footnote.
- e. Square brackets around an isobar decay mode indicate that it is a sub-reaction of the previous unbracketed decay mode.
- f. Many of the branching fractions in the Table are extracted from significantly more accurate results, on \sqrt{xx} type couplings obtained in partial-wave analyses. The original \sqrt{xx} values are given in the Baryon Data Card Listings. For information on radiative decays of N 's and Δ 's, see the mini-review preceding the Baryon Data Card Listings.
- g. The range given here does not include the widths of several hundred MeV reported by LONGACRE 75 and LONGACRE 77.
- h. The range given here does not include the width of 550 MeV reported by SAXON 80.
- i. The range given here does not include the branching ratio of approximately 80% reported by FELTESSE 75.
- k. This state has been seen only in an energy-dependent fit to total, channel, or fixed angle cross-section data. J is not known; x is Γ_{e1}/Γ .
- l. See note on determination of resonance parameters in the Baryon Data Card Listings. Values of mass and width are dependent upon resonance shape used to fit the data. The pole position is much less dependent upon the parametrization used. The pole positions given here are taken from results (in the Data Card Listings) of fits to phase shifts without Coulomb corrections.
- m. There may be more than one P_{33} resonance in or near this mass range.
- n. There is probably more than one Δ resonance near 2160 MeV. The parameter ranges in the Table include the various possibilities. See the Baryon Data Card Listings.
- o. The error given here is only an educated guess; it is larger than the error of the average of the published values (see the Baryon Data Card Listings for the latter).
- p. Quoted error includes a S (scale) factor. See second footnote to Stable Particle Table.
- q. Because the elastic branching fraction of this resonance is poorly determined, it is not possible to extract inelastic branching fractions from partial-wave couplings. See the Baryon Data Card Listings for the partial-wave couplings.
- r. Recent partial-wave analyses of the College de France-Saclay group find evidence for a $5/2^-$ and a $9/2^-$ Σ resonance at this mass. See the Baryon Data Card Listings.

PHYSICAL AND NUMERICAL CONSTANTS*

<u>PHYSICAL CONSTANTS</u>		Uncert. (ppm)
N_A	$= 6.022\,045(31) \times 10^{23} \text{ mole}^{-1}$	5.1
V_m	$= 22413.83(70) \text{ cm}^3 \text{ mole}^{-1} = \text{molar volume of ideal gas at STP}$	31
c	$= 2.997\,924\,58(1.2) \times 10^{10} \text{ cm sec}^{-1}$	0.004
e	$= 4.803\,242(14) \times 10^{-10} \text{ esu} = 1.602\,189\,2(46) \times 10^{-19} \text{ coulomb}$	2.9; 2.9
1 MeV	$= 1.602\,189\,2(46) \times 10^{-6} \text{ erg}$	2.9
$\hbar = h/2\pi$	$= 6.582\,173(17) \times 10^{-22} \text{ MeV sec} = 1.054\,588\,7(57) \times 10^{-27} \text{ erg sec}$	2.6; 5.4
$\hbar c$	$= 1.973\,285\,8(51) \times 10^{-11} \text{ MeV cm} = 197.32858(51) \text{ MeV fermi}$	2.6; 2.6
$(\hbar c)^2$	$= 0.389\,385\,7(20) \text{ GeV}^2 \text{ mb}$	5.2
α	$= e^2/\hbar c = 1/137.03604(11)$	0.82
$k_{\text{Boltzmann}}$	$= 1.380\,662(44) \times 10^{-16} \text{ erg } ^\circ\text{K}^{-1}$	32
	$= 8.61735(28) \times 10^{-11} \text{ MeV } ^\circ\text{K}^{-1} = 1 \text{ eV}/11604.50(36) \text{ } ^\circ\text{K}$	32; 31
$\sigma_{\text{Stef. Boltz.}}$	$= 5.67032(71) \times 10^{-5} \text{ erg sec}^{-1} \text{ cm}^{-2} \text{ } ^\circ\text{K}^{-4}$	125
	$= 3.53911(44) \times 10^7 \text{ eV sec}^{-1} \text{ cm}^{-2} \text{ } ^\circ\text{K}^{-4}$	125
m_e	$= 0.511\,003\,4(14) \text{ MeV} = 9.109\,534(47) \times 10^{-28} \text{ g}$	2.8; 5.1
m_p	$= 938.2796(27) \text{ MeV} = 1836.15152(70) m_e = 6.722\,795(61) m_{\pi^\pm}$	2.8; 0.38; 9.0
	$= 1.007\,276\,470(11) \text{ amu}$	0.011
1 amu	$= 1/12 m_{C^{12}} = 931.5016(26) \text{ MeV}$	2.8
m_d	$= 1875.6280(53) \text{ MeV}$	2.8
r_e	$= e^2/m_e c^2 = 2.817\,938\,0(70) \text{ fermi} (1 \text{ fermi} = 10^{-13} \text{ cm})$	2.5
λ_e	$= \hbar/m_e c = r_e \alpha^{-1} = 3.861\,590\,5(64) \times 10^{-11} \text{ cm}$	1.6
$a_\infty \text{ Bohr}$	$= \hbar^2/m_e e^2 = r_e \alpha^{-2} = 0.529\,177\,06(44) \text{ \AA} (1 \text{ \AA} = 10^{-8} \text{ cm})$	0.82
σ_{Thomson}	$= (8/3)\pi r_e^2 = 0.665\,244\,8(33) \text{ barn} (1 \text{ barn} = 10^{-24} \text{ cm}^2)$	4.9
μ_{Bohr}	$= e\hbar/2m_e c = 0.578\,837\,85(95) \times 10^{-14} \text{ MeV gauss}^{-1}$	1.6
μ_N	$= e\hbar/2m_p c = 3.152\,451\,5(53) \times 10^{-18} \text{ MeV gauss}^{-1}$	1.7
μ_p/μ_{Bohr}	$= 0.001\,521\,032\,209(16)$	0.011
$1/2\omega_{\text{cyclotron}}^e$	$= e/2m_e c = 8.794\,024(25) \times 10^6 \text{ rad sec}^{-1} \text{ gauss}^{-1}$	2.8
$1/2\omega_{\text{cyclotron}}^p$	$= e/2m_p c = 4.789\,378(14) \times 10^3 \text{ rad sec}^{-1} \text{ gauss}^{-1}$	2.8
Hydrogen-like atom (nonrelativistic, $\mu = \text{reduced mass}$):		
	$\frac{v}{c} r_{\text{rms}} = \frac{z\alpha}{n}; E_n = \frac{\mu}{2} v^2 = \frac{\mu}{2} \left(\frac{c z \alpha}{n}\right)^2; a_n = \frac{n^2 \hbar}{\mu z c \alpha}$	
$R_\infty = m_e e^4/2\hbar^2$	$= m_e c^2 \alpha^2/2 = 13.605\,804(36) \text{ eV (Rydberg)}$	2.6
	$= m_e c \alpha^2/2h = 109\,737.3177(83) \text{ cm}^{-1}$	0.075
$pc = 0.3 \text{ H}\rho (\text{MeV, kilogauss, cm})$		
1 year (sidereal)	$= 365.256 \text{ days} = 3.1558 \times 10^7 \text{ sec} (\approx \pi \times 10^7 \text{ sec})$	
density of dry air	$= 1.204 \text{ mg cm}^{-3} (\text{at } 20^\circ\text{C, } 760 \text{ mm})$	
acceleration by gravity	$= 980.62 \text{ cm sec}^{-2} (\text{sea level, } 45^\circ)$	
gravitational constant	$= 6.6720(41) \times 10^{-8} \text{ cm}^3 \text{ g}^{-1} \text{ sec}^{-2}$	.615
1 calorie (thermochemical)	$= 4.184 \text{ joules}$	
1 atmosphere	$= 1.01325 \text{ bar} (1 \text{ bar} = 10^6 \text{ dynes cm}^{-2})$	
1 eV per particle	$= 11604.50(36) \text{ } ^\circ\text{K} (\text{from } E = kT)$	.31

NUMERICAL CONSTANTS

π	$= 3.141\,592\,7$	1 rad	$= 57.295\,779\,5 \text{ deg}$	$\sqrt{\pi}$	$= 1.772\,453\,85$
e	$= 2.718\,281\,8$	1/e	$= 0.367\,879\,4$	$\sqrt{2}$	$= 1.414\,213\,6$
$\ln 2$	$= 0.693\,147\,2$	$\ln 10$	$= 2.302\,585\,1$	$\sqrt{3}$	$= 1.732\,050\,8$
$\log_{10} 2$	$= 0.301\,030\,0$	$\log_{10} e$	$= 0.434\,294\,5$	$\sqrt{10}$	$= 3.162\,277\,7$

*Revised April 1980 by Barry N. Taylor. Originally prepared by Stanley J. Brodsky, based mainly on the "1973 Least-Squares Adjustment of the Fundamental Constants," by E. R. Cohen and B. N. Taylor, *J. Phys. Chem. Ref. Data* 2, 663 (1973). The figures in parentheses correspond to the one-standard-deviation uncertainty in the last digits of the main number. The equivalent uncertainty in parts per million (ppm) is given in the last column. Note that the uncertainties of the output values of a least-squares adjustment are in general correlated, and the general law of error propagation must be used in calculating additional quantities.

The set of constants resulting from the 1973 adjustment of Cohen and Taylor has been recommended for international use by CODATA (Committee on Data for Science and Technology), and is the most up-to-date, generally accepted set currently available. However, since the publication of the 1973 adjustment, a number of new experiments have been completed, yielding improved values for some of the constants: $N_A = 6.022\,097\,8(63) \times 10^{23} \text{ mole}^{-1}$ (1.04 ppm); $\alpha^{-1} = 137.035\,963(15)$ (0.11 ppm) [obtained using the Josephson effect]; and $R_\infty = 109\,737.314\,76(32) \text{ cm}^{-1}$ (0.003 ppm). But it must be realized that, since the output values of a least-squares adjustment are related in a complex way and a change in the measured value of one constant usually leads to corresponding changes in the adjusted values of others, one must be cautious in carrying out calculations using both the output values from the 1973 adjustment and the results of more recent experiments. A new adjustment is planned for completion by early 1982.

CLEBSCH-GORDAN COEFFICIENTS, SPHERICAL HARMONICS, AND d FUNCTIONS

Note: A $\sqrt{\quad}$ is to be understood over every coefficient; e.g., for $-8/15$ read $-\sqrt{8/15}$.

Notation: $\begin{matrix} J & J & \dots \\ M & M & \dots \end{matrix}$

$$1/2 \times 1/2$$

1	0	0
+1/2	0	0
+1/2	-1/2	1/2
-1/2	1/2	-1/2
-1/2	-1/2	1

$$Y_1^0 = \sqrt{\frac{3}{4\pi}} \cos\theta$$

$$Y_1^1 = -\sqrt{\frac{3}{8\pi}} \sin\theta e^{i\phi}$$

$$Y_2^0 = \sqrt{\frac{5}{4\pi}} \left(\frac{3}{2} \cos^2\theta - \frac{1}{2} \right)$$

$$Y_2^1 = -\sqrt{\frac{15}{8\pi}} \sin\theta \cos\theta e^{i\phi}$$

$$Y_2^2 = \frac{1}{4} \sqrt{\frac{15}{2\pi}} \sin^2\theta e^{2i\phi}$$

$$2 \times 1/2$$

5/2	3/2	1/2
+5/2	3/2	1/2
+2	1/2	1
+2	-1/2	1/5
+1	1/2	4/5
+1	-1/2	5/2
0	1/2	3/2
0	-1/2	3/5
0	1/2	2/5
0	-1/2	3/5
0	1/2	5/2
0	-1/2	3/2

m_1	m_2	J	J	\dots
m_1	m_2	M	M	\dots
Coefficients				

$$1 \times 1/2$$

3/2	1/2	1/2
+3/2	1/2	1/2
+1	1/2	1/2
+1	-1/2	1/3
0	1/2	2/3
0	-1/2	2/3
0	1/2	1/3
0	-1/2	2/3

$$3/2 \times 1/2$$

2	1	1/2
+2	1	1/2
+3/2	1/2	1
+3/2	-1/2	1/4
+1/2	1/2	3/4
+1/2	-1/2	3/4
0	1/2	1
0	-1/2	1
0	1/2	1/2
0	-1/2	1/2

$$2 \times 1$$

3	2	1
+3	2	1
+2	1	1
+2	0	1/3
+1	1	2/3
+1	0	2/3
0	1	1/3
0	0	2/3

$$3/2 \times 1$$

5/2	3/2	1/2
+5/2	3/2	1/2
+3/2	1	1
+3/2	0	2/5
+1/2	1	3/5
+1/2	0	3/5
0	1	1/5
0	0	4/5

$$1 \times 1$$

2	1	1
+2	1	1
+1	1	1
+1	0	1/2
0	1	1/2
0	0	1
0	1	1/2
0	0	1/2

1	1/5	1/2	3/10
+1	-1	1/5	1/2
0	1	3/5	0
0	0	2/5	3/10
-1	1	1/5	-1/2
-1	0	3/5	0
-1	-1	1/5	-1/2
0	-1	6/15	1/2
0	0	8/15	1/6
0	1	6/15	-1/2
0	0	1/15	1/3
0	1	1/15	1/3
0	0	1/15	-1/3
0	1	1/15	-1/3

2	1	1
+2	1	1
+3/2	1/2	1
+3/2	-1/2	1/4
+1/2	1/2	3/4
+1/2	-1/2	3/4
0	1/2	1
0	-1/2	1
0	1/2	1/2
0	-1/2	1/2

$$Y_\ell^{-m} = (-1)^m Y_\ell^m$$

$$d_{m,0}^\ell = \sqrt{\frac{4\pi}{2\ell+1}} Y_\ell^m e^{-im\phi}$$

$$\langle j_1 j_2 m_1 m_2 | j_1 j_2 J M \rangle = (-1)^{J-j_1-j_2} \langle j_2 j_1 m_2 m_1 | j_2 j_1 J M \rangle$$

$$d_{m',m}^{j_1} = (-1)^{m-m'} d_{m,-m'}^{j_1} = d_{-m,-m'}^{j_1}$$

$$3/2 \times 3/2$$

3	2	1
+3	2	1
+3/2	1/2	1
+3/2	-1/2	1/2
+1/2	1/2	1/2
+1/2	-1/2	1/2
0	1/2	1
0	-1/2	1
0	1/2	1/2
0	-1/2	1/2

$$d_{1/2,1/2}^{1/2} = \cos\frac{\theta}{2} \quad d_{1/2,-1/2}^{1/2} = -\sin\frac{\theta}{2}$$

$$2 \times 3/2$$

7/2	5/2	3/2
+7/2	5/2	3/2
+2	1/2	1
+2	0	1/3
+1	1/2	2/3
+1	0	2/3
0	1/2	1/3
0	0	2/3

$$d_{1,1}^1 = \frac{1+\cos\theta}{2} \quad d_{1,0}^1 = -\frac{\sin\theta}{\sqrt{2}}$$

$$d_{1,-1}^1 = \frac{1-\cos\theta}{2}$$

$$2 \times 2$$

4	3	2
+4	3	2
+2	1	1
+2	0	1/2
+1	1	1/2
+1	0	1
0	1	1/2
0	0	1

$$d_{0,0}^1 = \cos\theta$$

$$d_{3/2,3/2}^{3/2} = \frac{1+\cos\theta}{2} \cos\frac{\theta}{2}$$

$$d_{3/2,1/2}^{3/2} = -\sqrt{3} \frac{1+\cos\theta}{2} \sin\frac{\theta}{2}$$

$$d_{3/2,-1/2}^{3/2} = \sqrt{3} \frac{1-\cos\theta}{2} \cos\frac{\theta}{2}$$

$$d_{3/2,-3/2}^{3/2} = -\frac{1-\cos\theta}{2} \sin\frac{\theta}{2}$$

$$d_{1/2,1/2}^{3/2} = \frac{3\cos\theta-1}{2} \cos\frac{\theta}{2}$$

$$d_{1/2,-1/2}^{3/2} = -\frac{3\cos\theta+1}{2} \sin\frac{\theta}{2}$$

$$d_{2,2}^2 = \left(\frac{1+\cos\theta}{2} \right)^2$$

$$d_{2,1}^2 = -\frac{1+\cos\theta}{2} \sin\theta$$

$$d_{2,0}^2 = \frac{\sqrt{6}}{4} \sin^2\theta$$

$$d_{2,-1}^2 = -\frac{1-\cos\theta}{2} \sin\theta$$

$$d_{2,-2}^2 = \left(\frac{1-\cos\theta}{2} \right)^2$$

$$d_{1,1}^2 = \frac{1+\cos\theta}{2} (2\cos\theta-1)$$

$$d_{1,0}^2 = -\sqrt{\frac{3}{2}} \sin\theta \cos\theta$$

$$d_{1,-1}^2 = \frac{1-\cos\theta}{2} (2\cos\theta+1)$$

$$d_{0,0}^2 = \left(\frac{3}{2} \cos^2\theta - \frac{1}{2} \right)$$

Sign convention is that of Wigner (Group Theory, Academic Press, New York, 1959), also used by Condon and Shortley (The Theory of Atomic Spectra, Cambridge Univ. Press, New York, 1953), Rose (Elementary Theory of Angular Momentum, Wiley, New York, 1957), and Cohen (Tables of the Clebsch-Gordan Coefficients, North American Rockwell Science Center, Thousand Oaks, Calif., 1974). The signs and numbers in the current tables have been calculated by computer programs written independently by Cohen and at LBL. (Table extended April 1974.)

SU(3) ISOSCALAR FACTORS

The most commonly used isoscalar factors, corresponding to the singlet, octet, and decuplet content of $8 \otimes 8$ and $10 \otimes 8$, are displayed at the right. The notation uses particles names to identify the coefficients, so that the pattern of relative couplings can be seen at a glance. We illustrate the use of the coefficients by example; see J. J. de Swart, Rev. Mod. Phys. 35, 916 (1963) for detailed explanation and phase conventions.

A $\sqrt{\quad}$ is understood over every integer in the matrices; the exponent $\frac{1}{2}$ is a reminder of this. For example, in de Swart's notation the $\Xi \rightarrow \Omega K$ element of our $10 \rightarrow 10 \otimes 8$ matrix reads

$$\begin{pmatrix} 10 & 8 & 10 \\ 0 & -2 & \frac{1}{2} & 1 & \frac{1}{2} & -1 \end{pmatrix} = \frac{-\sqrt{6}}{\sqrt{24}}$$

Intra-multiplet relative decay strengths can be read directly from our matrices. Thus, the partial widths for $\Delta^* \rightarrow (N\pi)_{I=3/2}$ and $\Omega^* \rightarrow (\Xi K)_{I=0}$ are in the ratio

$$\frac{\Gamma(\Omega^* \rightarrow (\Xi K)_{I=0})}{\Gamma(\Delta^* \rightarrow (N\pi)_{I=3/2})} = \frac{12}{6} \times (\text{threshold factors})$$

Supplying isospin Clebsch-Gordan coefficients one obtains, e.g.,

$$\frac{\Gamma(\Omega^{*-} \rightarrow \Xi^0 K^-)}{\Gamma(\Delta^{*+} \rightarrow p\pi^0)} = \frac{1/2}{2/3} \times \frac{12}{6} \times \text{tf} = \frac{3}{2} \times \text{tf}$$

Partial widths for $8 \rightarrow 8 \otimes 8$ involve a linear superposition of 8_1 (symmetric) and 8_2 (anti-symmetric) couplings. For example,

$$\Gamma(\Xi^* \rightarrow \Xi\pi) \sim \left(-\sqrt{\frac{9}{20}} g_1 + \sqrt{\frac{3}{12}} g_2 \right)^2$$

The relation between g_1, g_2 (with de Swart's normalization) and the standard D,F couplings appearing in the interaction Lagrangian,

$$\mathcal{L} = -\sqrt{2} D \text{Tr}([\bar{B}, B]_+ M) + \sqrt{2} F \text{Tr}([\bar{B}, B]_- M)$$

is

$$D = \frac{\sqrt{30}}{40} g_1, \quad F = \frac{\sqrt{6}}{24} g_2$$

Thus, $\Gamma(\Xi^* \rightarrow \Xi\pi) \sim (1 - 2\alpha)^2$

where $\alpha \equiv D/(D+F)$.

$1 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} \Lambda \end{pmatrix}_1 \rightarrow \begin{pmatrix} N\bar{K} & \Sigma\pi & \Lambda\eta & \Xi K \end{pmatrix}_{8 \otimes 8} = \frac{1}{\sqrt{8}} \begin{pmatrix} 2 & 3 & -1 & -2 \end{pmatrix}^{\frac{1}{2}}$$

$8_1 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix}_{8_1} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Xi\eta & \Xi K \\ N\bar{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \end{pmatrix}_{8 \otimes 8} = \frac{1}{\sqrt{20}} \begin{pmatrix} 9 & -1 & -9 & -1 \\ -6 & 0 & 4 & -6 \\ 2 & -12 & -4 & -2 \\ 9 & -1 & -9 & -1 \end{pmatrix}^{\frac{1}{2}}$$

$8_2 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix}_{8_2} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Xi\eta & \Xi K \\ N\bar{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \end{pmatrix}_{8 \otimes 8} = \frac{1}{\sqrt{12}} \begin{pmatrix} 3 & 3 & 3 & -3 \\ 2 & 8 & 0 & 0 & -2 \\ 6 & 0 & 0 & 6 \\ 3 & 3 & 3 & -3 \end{pmatrix}^{\frac{1}{2}}$$

$10 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix}_{10} \rightarrow \begin{pmatrix} N\pi & \Sigma K \\ N\bar{K} & \Sigma\pi & \Lambda\pi & \Xi\eta & \Xi K \\ \Sigma\bar{K} & \Lambda\bar{K} & \Xi\pi & \Xi\eta \\ \Xi\bar{K} \end{pmatrix}_{8 \otimes 8} = \frac{1}{\sqrt{12}} \begin{pmatrix} -6 & 6 \\ -2 & 2 & -3 & 3 & 2 \\ 3 & -3 & 3 & 3 \\ 12 \end{pmatrix}^{\frac{1}{2}}$$

$8 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix}_8 \rightarrow \begin{pmatrix} \Delta\pi & \Sigma K \\ \Delta\bar{K} & \Sigma\pi & \Xi\eta & \Xi K \\ \Sigma\pi & \Xi K \\ \Sigma\bar{K} & \Xi\pi & \Xi\eta & \Omega K \end{pmatrix}_{10 \otimes 8} = \frac{1}{\sqrt{15}} \begin{pmatrix} -12 & 3 \\ 8 & -2 & -3 & 2 \\ -9 & 6 \\ 3 & -3 & -3 & 6 \end{pmatrix}^{\frac{1}{2}}$$

$10 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix}_{10} \rightarrow \begin{pmatrix} \Delta\pi & \Delta\eta & \Sigma K \\ \Delta\bar{K} & \Sigma\pi & \Xi\eta & \Xi K \\ \Sigma\bar{K} & \Xi\pi & \Xi\eta & \Omega K \\ \Xi\bar{K} & \Omega\eta \end{pmatrix}_{10 \otimes 8} = \frac{1}{\sqrt{24}} \begin{pmatrix} 15 & 3 & -6 \\ 8 & 8 & 0 & -8 \\ 12 & 3 & -3 & -6 \\ 12 & -12 \end{pmatrix}^{\frac{1}{2}}$$

SU(n) Multiplicities

The table below gives the multiplicities of the multiplets that occur in qq, q \bar{q} , and qqq systems in various SU(n). Normal mesons are q \bar{q} systems, and normal baryons are qqq systems. Also given are the multiplicities that occur in meson-baryon scattering when the meson multiplet is the one to which the pion belongs and the

baryon multiplet is the one to which the proton belongs. Complex-conjugate representations are indicated by a bar. The two 20-dimensional representations of SU(4) are indicated as 20 (which contains the SU(3) decuplet) and 20' (which contains the SU(3) octet). The C(N,M)'s are the binomial coefficients N!/M!(N-M)!.

qq	
SU(2):	$2 \otimes 2 \rightarrow 3 \oplus 1$
SU(3):	$3 \otimes 3 \rightarrow 6 \oplus \bar{3}$
SU(4):	$4 \otimes 4 \rightarrow 10 \oplus 6$
SU(n):	$n \otimes n \rightarrow n(n+1)/2 \oplus n(n-1)/2$

q \bar{q} (Mesons)	
SU(2):	$2 \otimes \bar{2} \rightarrow 3 \oplus 1$
SU(3):	$3 \otimes \bar{3} \rightarrow 8 \oplus 1$
SU(4):	$4 \otimes \bar{4} \rightarrow 15 \oplus 1$
SU(n):	$n \otimes \bar{n} \rightarrow (n^2-1) \oplus 1$

qqq (Baryons)	
SU(2):	$2 \otimes 2 \otimes 2 \rightarrow 4 \oplus 2 \oplus 2$
SU(3):	$3 \otimes 3 \otimes 3 \rightarrow 10 \oplus 8 \oplus 8 \oplus 1$
SU(4):	$4 \otimes 4 \otimes 4 \rightarrow 20 \oplus 20' \oplus 20' \oplus \bar{4}$
SU(n):	$n \otimes n \otimes n \rightarrow C(n+2,3) \oplus 2C(n+1,3) \oplus 2C(n+1,3) \oplus C(n,3)$

Meson-Baryon Scattering	
SU(2):	$3 \otimes 2 \rightarrow 4 \oplus 2$
SU(3):	$8 \otimes 8 \rightarrow 27 \oplus 10 \oplus \bar{10} \oplus 8 \oplus 8 \oplus 1$
SU(4):	$15 \otimes 20' \rightarrow 140 \oplus 60 \oplus 36 \oplus 20 \oplus 20' \oplus 20' \oplus \bar{4}$

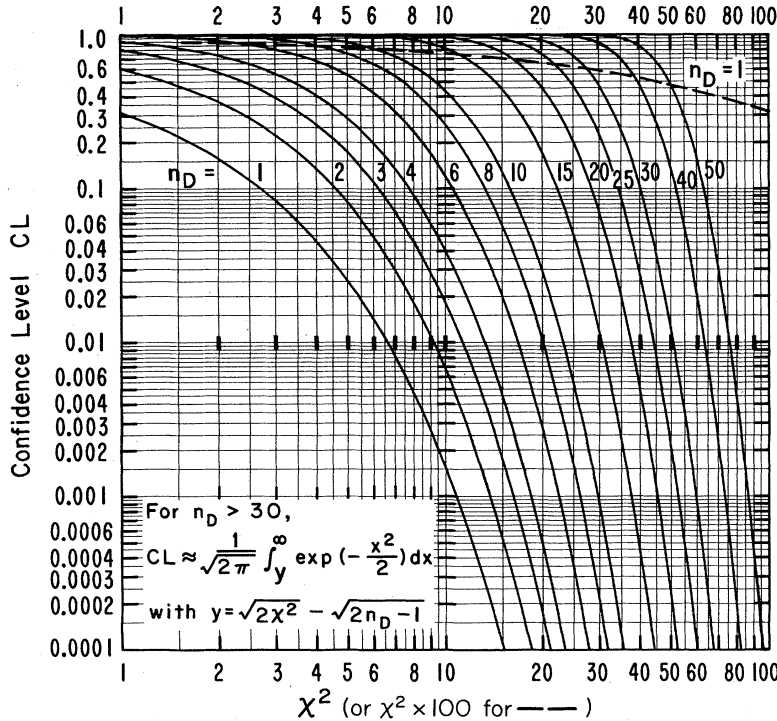
PROBABILITY AND STATISTICS

A. PROBABILITY DISTRIBUTIONS AND CONFIDENCE LEVELS

We give here properties of the three probability distributions most commonly used in high energy physics: Normal (or Gaussian), Chi-squared, and Poisson. We warn the reader that there is no universal convention for the term "confidence level"

as used by physicists; thus, explicit definitions are given for each distribution, and we have attempted to choose definitions that correspond to common usage. It is explained below how confidence levels for all three distributions can be extracted from the following figure.

χ^2 Confidence Level vs. χ^2 for n_D Degrees of Freedom

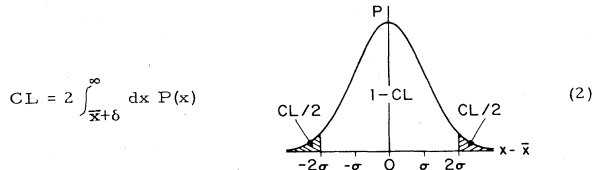


A.1. Normal Distribution

The normal distribution with mean \bar{x} and standard deviation σ (variance σ^2) is:

$$P(x)dx = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\bar{x})^2/2\sigma^2} dx. \quad (1)$$

The confidence level associated with an observed deviation from the mean, δ , is the probability that $|x-\bar{x}| > \delta$, i. e.,



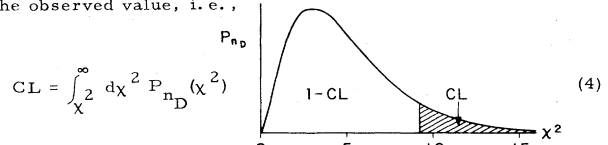
[The small figure in Eq. (2) is drawn with $\delta = 2\sigma$.] CL is given by the ordinate of the $n_D = 1$ curve in the figure at $\chi^2 = (\delta/\sigma)^2$. The confidence level for $\delta = 1\sigma$ is 31.7%; 2σ , 4.6%; 3σ , 0.3%. The central confidence interval, $1-CL$, (which is also sometimes called confidence level) for $\delta = 1\sigma$ is 68.3%; 2σ , 95.4%; 3σ , 99.7%. The odds against exceeding δ , $(1-CL)/CL$, for $\delta = 1\sigma$ are 2.15:1; 2σ , 21:1; 3σ , 370:1; 4σ , 16,000:1; 5σ , 1,700,000:1. Relations between σ and other measures of the width: probable error (CL = 0.5 deviation) = 0.67σ ; mean absolute deviation = 0.80σ ; RMS deviation = σ ; half width at half maximum = 1.18σ .

A.2. Chi-squared Distribution

The chi-squared distribution for n_D degrees of freedom is:

$$P_{n_D}(\chi^2) d\chi^2 = \frac{1}{2^h \Gamma(h)} (\chi^2)^{h-1} e^{-\chi^2/2} d\chi^2 \quad (\chi^2 \geq 0), \quad (3)$$

where h (for "half") = $n_D/2$. The mean and variance are n_D and $2n_D$, respectively. In evaluating Eq. (3) one may use Stirling's approximation: $\Gamma(h) = (h-1)! \approx 2.507 e^{-h} h^{(h-1/2)} \sqrt{\pi} (1 + 0.0833/h)$ which is accurate to $\pm 0.1\%$ for all $h \geq 1/2$. The confidence level associated with a given value of n_D and an observed value of χ^2 is the probability of chi-squared exceeding the observed value, i. e.,



[The small figure in Eq. (4) is drawn with $n_D = 5$ and $CL = 10\%$.] CL is plotted as a function of χ^2 for several values of n_D in the above figure. For large n_D , χ^2 becomes normally distributed about n_D . Thus,

$$y_1 = (\chi^2 - n_D)/\sqrt{2n_D} \quad (5)$$

becomes normally distributed with unit standard deviation. A better approximation, due to Fisher,¹ is that χ , not χ^2 , becomes normally distributed, specifically

$$y_2 = \sqrt{2}\chi^2 - \sqrt{2n_D - 1} \quad (6)$$

approaches normality with unit standard deviation. For small CL's in particular, y_2 is much more accurate than y_1 . Thus, for $n_D = 50$ and $\chi^2 = 80$, the true CL = 0.45%, but y_1 is 3.0 corresponding to a CL of 0.13%, while y_2 is 2.7 corresponding to a CL of 0.35%.

PROBABILITY AND STATISTICS (Cont'd)

A.3. Poisson Distribution

The Poisson distribution with mean \bar{n} is:

$$P_{\bar{n}}(n) = \frac{e^{-(\bar{n})} (\bar{n})^n}{n!} \quad (n = 0, 1, 2, \dots) \quad (7)$$

The variance is equal to the mean. Confidence levels for Poisson distributions are usually defined in terms of quantities called "upper limits" as follows: The confidence level associated with a given upper limit N and an observed value n_0 of n is the probability that $n > n_0$ if $\bar{n} = N$, i. e.,

$$CL = \sum_{n=n_0+1}^{\infty} P_N(n) = 1 - \sum_{n=0}^{n_0} P_N(n) \quad (8)$$

[The small figure in Eq. (8) is drawn with $n_0 = 2$ and $CL = 90\%$.] A useful relation between Poisson and chi-squared confidence levels allows one to look up this quantity on the above figure. Specifically, the quantity $1-CL$ is given by the ordinate of the $n_D = 2(n_0+1)$ curve at $\chi^2 = 2N$. Thus, 90% confidence level upper limits for $n_0 = 0, 1,$ and 2 are given by half the χ^2 value corresponding to an ordinate of 0.1 on the $n_D = 2, 4,$ and 6 curves, respectively; the values are $N = 2.3, 3.9,$ and 5.3 .

Tables of confidence levels for all three of these distributions, the relation between Poisson and chi-squared confidence levels, and numerous other useful tables and relations may be found in Ref. 2.

B. STATISTICS

We consider here the situation in which one is presented with N independent data, $y_n \pm \sigma_n$, and it is desired to make some inference about the "true" value of the quantity represented by these data. For this purpose we interpret each datum y_n as a single sample point drawn randomly (and independently of the other data) from a distribution having mean \bar{y}_n (which we wish to estimate) and variance σ_n^2 . (Identification of the true σ_n with the σ_n datum is an approximation which may become seriously inaccurate when σ_n is an appreciable fraction of y_n .) Some methods of estimation commonly used in high energy physics are given below; see Ref. 3 for numerous applications. Section B.1. deals with the case in which all \bar{y}_n are the same, e. g., several different measurements of the same quantity; Sec. B.2. deals with the case in which $\bar{y}_n = \bar{y}(x_n)$, where x_n represents some set of independent variables, e. g., cross-section measurements at various values of energy and angle, $x_n = \{E_n, \theta_n\}$.

B.1. Single Mean and Variance Estimates

(1) If the y_n represent a set of values all supposedly drawn from a single distribution with mean \bar{y} and variance σ^2 (i. e., the σ_n are all the same, but their common value is unknown) then

$$\bar{y}_e = \frac{1}{N} \sum y_n \quad \text{and} \quad (9)$$

$$\sigma_e^2 = \frac{1}{N-1} \sum (y_n - \bar{y}_e)^2 = \frac{N}{N-1} \left[\left(\bar{y}^2 \right)_e - \bar{y}_e^2 \right] \quad (10)$$

are unbiased estimates of \bar{y} and σ^2 . The variance of \bar{y}_e is σ^2/N . If the parent distribution is normal and N is large, the variance of σ_e^2 is $2\sigma^4/N$.

(2) If the \bar{y}_n all have the common value \bar{y} and the σ_n are known, then the weighted average

$$\bar{y}_e = \frac{1}{w} \sum w_n y_n, \quad (11)$$

where $w_n = 1/\sigma_n^2$ and $w = \sum w_n$, is an appropriate unbiased estimate of \bar{y} . This choice of weighting factors in Eq. (11) minimizes the variance of the estimate; the variance is $1/w$.

B.2. Linear Least Squares Fit

A least squares fit of the function $y(x) = \sum_i a_i f_i(x)$ to independent data $y_n \pm \sigma_n$ at points x_n (e. g., a Legendre fit in which the f_i are Legendre polynomials and the a_i are Legendre coefficients) gives the following estimates of the parameters a_i :

$$a_{e,i} = \frac{\sum_{j=1}^N V_{ij} f_j(x_n) y_n}{\sigma_n^2} \quad (12)$$

Here V is the covariance matrix of the fitted parameters

$$V_{ij} = (\bar{a}_{e,i} - \bar{a}_{e,i}) (\bar{a}_{e,j} - \bar{a}_{e,j}), \quad (13)$$

which is given by

$$(V^{-1})_{ij} = \sum_{k=1}^N f_i(x_k) f_j(x_k) / \sigma_k^2 \quad (14)$$

The variance of an interpolated or extrapolated value of y at point x, $y_e = \sum a_{e,i} f_i(x)$, is:

$$(y_e - \bar{y}_e)^2 = \sum_{ij} V_{ij} f_i(x) f_j(x) \quad (15)$$

For the case of a straight line fit, $y(x) = a + bx$, one obtains the following estimates of a and b,

$$a_e = (S_y S_{xx} - S_x S_{xy}) / D, \quad (16)$$

$$b_e = (S_1 S_{xy} - S_x S_y) / D,$$

where

$$S_1, S_x, S_y, S_{xx}, S_{xy} = \sum (1, x_n, y_n, x_n^2, x_n y_n) / \sigma_n^2 \quad (17)$$

$$D = S_1 S_{xx} - S_x^2$$

The covariance matrix of the fitted parameters is:

$$\begin{pmatrix} V_{aa} & V_{ab} \\ V_{ab} & V_{bb} \end{pmatrix} = \frac{1}{D} \begin{pmatrix} S_{xx} & -S_x \\ -S_x & S_1 \end{pmatrix} \quad (18)$$

The variance of an interpolated or extrapolated value of y at point x is:

$$(y_e - \bar{y}_e)^2 = \frac{1}{S_1} + \frac{S_1}{D} \left(x - \frac{S_x}{S_1} \right)^2 \quad (19)$$

C. ERROR PROPAGATION

We consider here the situation in which one wishes to calculate the value and error of a function of some other quantities with errors, e. g., in a Monte Carlo program. Let {y} be a set of random variables with means $\{\bar{y}\}$ and covariance matrix V. Then the mean and variance of a function of these variables are approximately (to second order in $\{y-\bar{y}\}$):

$$\bar{f} \approx f(\{\bar{y}\}) + \frac{1}{2} \sum_{mn} V_{mn} \left(\frac{\partial^2 f}{\partial y_m \partial y_n} \right)_{\{y\}=\{\bar{y}\}} \quad (20)$$

$$(f - \bar{f})^2 = \sum_{mn} V_{mn} \left(\frac{\partial f}{\partial y_m} \right)_{\{y\}=\{\bar{y}\}} \left(\frac{\partial f}{\partial y_n} \right)_{\{y\}=\{\bar{y}\}} \quad (21)$$

E. g., the mean and variance of a function of a single variable with mean \bar{y} and variance σ^2 are:

$$\bar{f} \approx f(\bar{y}) + \frac{1}{2} \sigma^2 f''(\bar{y}), \quad (22)$$

$$(f - \bar{f})^2 = \sigma^2 f'(\bar{y})^2 \quad (23)$$

Note that these equations will usually be applied by substituting some measured quantities, $\{\tilde{y}\}$ say, for the true means, $\{\bar{y}\}$. If, as is often the case, $\tilde{y}_n - \bar{y}_n$ is of order $\sqrt{V_{nn}}$, then there is no point in keeping the second order terms in Eq. (20) or (22) since the substitution itself introduces first order errors.

1. R. A. Fisher, Statistical Methods for Research Workers (Oliver and Boyd, Edinburgh and London, 1958).
2. M. Abramovitz and I. Stegun, eds., Handbook of Mathematical Functions (National Bureau of Standards, Applied Mathematics Series, Vol. 55, Washington, 1964).
3. W. T. Eadie, D. Drijard, F. E. James, M. Roos, and B. Sadoulet, Statistical Methods in Experimental Physics (North-Holland, Amsterdam and London, 1971).

Revised and expanded April 1974.

RELATIVISTIC KINEMATICS

I. BASICS

(a) Lorentz transformations -- Let E and \vec{p} be the energy and 3-momentum of a particle or system as seen from a certain inertial frame, and let E^* and \vec{p}^* be the same quantities as seen from a second inertial frame that moves with velocity $\vec{\beta}$ relative to the first. Then starred and unstarred quantities are related by

$$\begin{pmatrix} E^* \\ \vec{p}^*_{\parallel} \end{pmatrix} = \begin{pmatrix} \gamma & -\gamma\beta \\ -\gamma\beta & \gamma \end{pmatrix} \begin{pmatrix} E \\ \vec{p}_{\parallel} \end{pmatrix}, \quad p^*_{\perp} = p_{\perp}.$$

Here $\gamma = (1 - \beta^2)^{-1/2}$, and subscripts \parallel and \perp indicate components of \vec{p} or \vec{p}^* that are parallel or perpendicular to $\vec{\beta}$ (often η is used for $\gamma\beta$). The inverse transformation is given by changing β to $-\beta$. A particle of mass m at rest in the second frame, so that it is moving at velocity $\vec{\beta}$ relative to the first, has $E^* = m$ and $\vec{p}^* = 0$, so here

$$E = \gamma m, \quad \vec{p} = \gamma \vec{\beta} m.$$

In any frame, the energy, momentum, and mass are related by

$$E^2 = p^2 + m^2.$$

(b) Four momenta; scalar products -- The 4-momentum vector of a particle or system having energy E and 3-momentum \vec{p} is

$$q = (E, \vec{p}) = (E, p_x, p_y, p_z).$$

Conservation of energy and the components of 3-momentum for any process $a + b + \dots \rightarrow 1 + 2 + \dots$ may then be written as

$$q_a + q_b + \dots = q_1 + q_2 + \dots$$

Although the components of a 4-momentum are different in different frames, the scalar product of any two 4-momenta q and q' , defined as

$$q \cdot q' = EE' - \vec{p} \cdot \vec{p}',$$

is an invariant; i.e., in numerical calculations the same result is obtained in any frame, and in algebraic calculations results obtained in different frames may be equated. For a particle of mass m , the scalar product $q \cdot q$ is

$$q \cdot q = q^2 = E^2 - \vec{p}^2 = m^2.$$

The invariant mass M (or total c.m. energy) of an n -particle system is given by

$$M^2 = \left(\sum_{i=1}^n q_i \right)^2 = \left(\sum_i E_i \right)^2 - \left(\sum_i \vec{p}_i \right)^2,$$

where $q_i = (E_i, \vec{p}_i)$ is the 4-momentum of the i^{th} particle.

(c) Electric and magnetic forces -- In Gaussian cgs units, the force on a particle with charge q moving with velocity \vec{v} in electric and magnetic fields \vec{E} and \vec{B} is

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B},$$

where $\vec{\beta} = \vec{v}/c$. The units are \vec{F} in dynes, q in esu, \vec{E} in statvolts/cm, and \vec{B} in gauss. In mksa units, the force is

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B},$$

where the units are \vec{F} in newtons ($1 \text{ N} = 10^5$ dynes), q in coulombs ($1 \text{ C} \approx 3 \times 10^9$ esu; each 3 in this section is really 2.9979...), \vec{E} in volts/m ($1 \text{ V} \approx 1/300$ statvolt), and \vec{B} in tesla ($1 \text{ T} = 10^4$ G). The force is zero if \vec{E} and \vec{B} are at right angles, $\vec{\beta}$ (or \vec{v}) is in the direction $\vec{E} \times \vec{B}$, and $\beta = E/B$ (cgs) or $v = E/B$ (mksa).

In a uniform, static magnetic field, the path of a charged particle is a helix of constant radius R and constant pitch angle λ , with the axis of the helix being along \vec{B} . The momentum is related to the other quantities by

$$p \cos \lambda \approx 3 \times 10^{-4} qBR,$$

where the units (very mixed!) are p in GeV/c, q in multiples of the electronic charge e , B in kG, and R in cm. The angular velocity about the axis of the helix is

$$\omega \approx 3 \times 10^{-4} qB/\gamma m,$$

where the units are ω in rad/sec, q in multiples of the electronic charge e , B in kG, and the energy γm in GeV.

II. DECAYS

(a) Survival probabilities -- Let a particle have mass m and proper mean life τ_0 . In a frame in which its 4-momentum is (E, \vec{p}) , the probability that it survives a time greater than t before decaying is

$$\text{Prob.}(>t) = \exp(-t/\gamma\tau_0) = \exp(-mt/E\tau_0).$$

The probability that it goes a distance greater than x before decaying is

$$\text{Prob.}(>x) = \exp(-x/\gamma\beta c\tau_0) = \exp(-mx/pc\tau_0);$$

values of $c\tau_0$ (in cm) are given in the Stable Particle Table. If the particle has charge $\pm e$ and is in a uniform magnetic field \vec{B} [see I(c)], then the probability that the projection of its helical path on the plane perpendicular to \vec{B} turns through an angle greater than θ before decaying is

$$\text{Prob.}(>\theta) = \exp(-Cm\theta/B\tau_0),$$

where, if m is in GeV, θ in deg, B in kG, and τ_0 in sec, then C is numerically 1.942×10^{-9} . This last distribution is independent of p or the helical pitch angle λ ; its only dependence is geometrical.

(b) Two-body decays -- A particle of mass m decays into two particles, masses m_1 and m_2 . In the rest frame of m , the energies of m_1 and m_2 are

$$\epsilon_1 = (m^2 + m_1^2 - m_2^2)/2m$$

$$\epsilon_2 = (m^2 + m_2^2 - m_1^2)/2m.$$

In this frame, the 3-momenta of m_1 and m_2 are equal and opposite and of magnitude

$$k = (\epsilon_1^2 - m_1^2)^{1/2} = (\epsilon_2^2 - m_2^2)^{1/2}$$

$$= \{[m^2 - (m_1 + m_2)^2][m^2 - (m_1 - m_2)^2]\}^{1/2}/2m.$$

See also the third paragraph of III(b).

(c) Three-body decays -- A particle of mass m decays into three particles, masses m_1 , m_2 , and m_3 . The invariant masses m_{ij} of the 2-particle systems, where $m_{ij}^2 = (q_i + q_j)^2$, satisfy the relation

$$m_{12}^2 + m_{13}^2 + m_{23}^2 = m^2 + m_1^2 + m_2^2 + m_3^2,$$

so that only two of the three m_{ij} 's are independent. In a rectangular Dalitz plot, m_{13}^2 (say) is plotted against m_{12}^2 . The kinematic boundaries may be calculated as follows: (i) The lower and upper limits on m_{12}^2 are $(m_1 + m_2)^2$ and $(m - m_3)^2$. (ii) For any m_{12}^2 between these limits, the lower and upper limits on m_{13}^2 are given by taking the + and - signs in

$$m_{13}^2 = (E_1 + E_3)^2 - (p_1 \pm p_3)^2,$$

where

$$E_1 = (m_{12}^2 + m_1^2 - m_2^2)/2m_{12}$$

$$E_3 = (m^2 - m_{12}^2 - m_3^2)/2m_{12}$$

$$p_1 = (E_1^2 - m_1^2)^{1/2}$$

$$p_3 = (E_3^2 - m_3^2)^{1/2}.$$

(These are the energies and momenta of particles 1 and 3 in the rest frame of m_{12} .) The phase-space density is uniform over the areas of both the above and the following form of the Dalitz plot.

In a triangular Dalitz plot, the kinetic energies T_1 , T_2 , and T_3 of the final-state particles in the rest frame of m are plotted as the distances inward from the sides of an equilateral triangle whose altitude is the energy Q released by the decay:

$$Q = T_1 + T_2 + T_3 = m - m_1 - m_2 - m_3.$$

The kinetic energies are related to the 2-particle invariant masses by

$$2mT_1 = (m - m_1)^2 - m_{23}^2 = (m_{23}^{\text{max}})^2 - m_{23}^2,$$

etc.

RELATIVISTIC KINEMATICS (Cont'd)

(d) **Four-body decays** -- A particle of mass m decays into four particles, masses $m_1, m_2, m_3,$ and m_4 . In a **triangle** (or Goldhaber) **plot**, the invariant mass of two of the particles is plotted against that of the other two, say m_{34} versus m_{12} , where $m_{ij}^2 = (q_i + q_j)^2$. The kinematic boundaries of this plot are the sides of the triangle whose vertices are at the points $(m_{12}, m_{34}) = (m_1 + m_2, m_3 + m_4), (m_1 + m_2, m - m_1 - m_2),$ and $(m - m_3 - m_4, m_3 + m_4)$. The phase-space density is not uniform over the enclosed area.

III. REACTIONS (MAINLY 2-BODY)

(a) **Initial state** -- Two particles, masses m_1 and m_2 , interact. In the lab frame, where particle 2 is at rest, the 4-momenta are (E_1, \vec{p}_1) and $(m_2, 0)$. In the c.m. frame, where the 3-momenta are equal and opposite, the 4-momenta are (ϵ_1, \vec{k}) and $(\epsilon_2, -\vec{k})$. Then the total c.m. energy E is given by

$$E^2 = (\epsilon_1 + \epsilon_2)^2 = m_1^2 + m_2^2 + 2E_1 m_2.$$

The c.m. energies of particles 1 and 2 are

$$\epsilon_1 = (m_1^2 + E_1 m_2)/E = (E^2 + m_1^2 - m_2^2)/2E$$

$$\epsilon_2 = (m_2^2 + E_1 m_2)/E = (E^2 + m_2^2 - m_1^2)/2E.$$

The c.m. momentum k is

$$k = p_1 m_2 / E.$$

See also the expression in II(b) for k , in which replace m with E .

The velocity of the c.m. relative to the lab is

$$\beta = p_1 / (E_1 + m_2).$$

The parameters for the Lorentz transformation between these frames [see I(a)] are

$$\gamma = (E_1 + m_2)/E$$

and

$$\gamma\beta = p_1/E.$$

(b) **Two-body final states** -- In the reaction $1 + 2 \rightarrow 3 + 4$, let the masses be m_i and the final-state c.m. 4-momenta be (ϵ_3, \vec{k}') and $(\epsilon_4, -\vec{k}')$. Then

$$\epsilon_3 = (E^2 + m_3^2 - m_4^2)/2E$$

$$\epsilon_4 = (E^2 + m_4^2 - m_3^2)/2E;$$

and

$$k' = (\epsilon_3^2 - m_3^2)^{1/2} = (\epsilon_4^2 - m_4^2)^{1/2} \\ = \{[E^2 - (m_3 + m_4)^2][E^2 - (m_3 - m_4)^2]\}^{1/2}/2E.$$

Let Θ_3 be the lab production angle of particle 3 (the angle between \vec{p}_3 and \vec{p}_1), and let θ_3 be the c.m. production angle (the angle between \vec{k}' and \vec{k}). These angles are related by

$$\tan \Theta_3 = \frac{p_{3\perp}}{p_{3\parallel}} = \frac{\sin \theta_3}{\gamma (\cos \theta_3 + \beta/\beta_3)},$$

where $p_{3\perp}$ and $p_{3\parallel}$ are the components of \vec{p}_3 perpendicular and parallel to \vec{p}_1 , and $\beta_3 = k'/\epsilon_3$ is the c.m. velocity of particle 3. [See III(a) for γ and β .] If $\beta > \beta_3$, then particle 3 can only go forward in the lab, the maximum Θ_3 being given by

$$\tan \Theta_3^{\max} = \beta_3 \left(\frac{1 - \beta^2}{\beta^2 - \beta_3^2} \right)^{1/2}.$$

The components of \vec{p}_3 satisfy

$$\left(\frac{p_{3\parallel} - \gamma\beta\epsilon_3}{\gamma k'} \right)^2 + \left(\frac{p_{3\perp}}{k'} \right)^2 = 1,$$

which is the equation of an ellipse with semi-major axis $\gamma k'$ and semi-minor axis k' . Thus the possible lab momenta of particle 3 are the vectors to the ellipse from the point a distance $\gamma\beta\epsilon_3$ back along the major axis from the center of the ellipse.

The results of the preceding paragraph also apply to 2-body decay. Just set $m_2 = 0$, in which case $E = m_1$. [The decay-product masses are here m_3 and m_4 , not m_1 and m_2 as in II(b).]

The **Mandelstam variables** $s, t,$ and u are the Lorentz scalars defined in terms of the particle 4-momenta q_i as

$$s = (q_1 + q_2)^2 = (q_3 + q_4)^2$$

$$t = (q_1 - q_3)^2 = (q_2 - q_4)^2$$

$$u = (q_1 - q_4)^2 = (q_2 - q_3)^2.$$

They satisfy the relation

$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2,$$

so that only two of the three are independent. Evaluating s in the c.m. frame gives

$$s = (\epsilon_1 + \epsilon_2)^2 = E^2,$$

and evaluating t and u , the 4-momentum-transfer-squared variables, in this frame gives

$$t = m_1^2 + m_3^2 - 2\epsilon_1\epsilon_3 + 2kk' \cos \theta_3$$

$$= t_0 - 4kk' \sin^2(\theta_3/2)$$

$$u = m_1^2 + m_4^2 - 2\epsilon_1\epsilon_4 + 2kk' \cos \theta_4$$

$$= u_0 - 4kk' \sin^2(\theta_4/2),$$

where θ_4 is the c.m. production angle of particle 4 ($\theta_3 + \theta_4 = \pi$), and

$$t_0 = t(\theta_3 = 0) = (\epsilon_1 - \epsilon_3)^2 - (k - k')^2$$

$$u_0 = u(\theta_4 = 0) = (\epsilon_1 - \epsilon_4)^2 - (k - k')^2.$$

The differences $\Delta t = t_0 - t_\pi$ and $\Delta u = u_0 - u_\pi$, where $t_\pi = t(\theta_3 = \pi)$ and $u_\pi = u(\theta_4 = \pi)$, are

$$\Delta t = \Delta u = 4kk'.$$

For **elastic scattering**, where $m_1 = m_3 = m$ and $m_2 = m_4 = M$, t_0 is zero and

$$t = -2k^2(1 - \cos \theta_3) = -4k^2 \sin^2(\theta_3/2).$$

And now

$$u_0 = (m^2 - M^2)^2/s.$$

Evaluating t in the lab frame gives

$$t = -2MT_4,$$

where $T_4 = E_4 - M$ is the lab kinetic energy of particle 4. For small-angle elastic scattering,

$$(-t)^{1/2} \approx k\theta_3 \approx p_1\theta_3 \approx p_4,$$

where $p_1, \theta_3,$ and p_4 are lab quantities.

IV. OTHER VARIABLES

(a) **Rapidity** -- For a system of energy E and momentum \vec{p} , the rapidity y is given by

$$y = \frac{1}{2} \ln \left(\frac{E + p_{\parallel}}{E - p_{\parallel}} \right) = \tanh^{-1} \left(\frac{p_{\parallel}}{E} \right) = \ln \left(\frac{E + p_{\parallel}}{m_1} \right),$$

where p_{\parallel} is the component of \vec{p} along a particular axis (the "rapidity axis", chosen, for example, parallel to the direction of an incoming beam), and $m_1 = (m^2 + p_{\perp}^2)^{1/2}$. Inverting these equations, we find

$$E = m_1 \cosh y$$

$$p_{\parallel} = m_1 \sinh y.$$

The shape of a rapidity distribution is invariant under a Lorentz transformation between inertial frames with relative motion parallel to the rapidity axis. Such a transformation is given by

$$y^* = y - \ln[\gamma(1 + \beta)] = y - \frac{1}{2} \ln \left(\frac{1 + \beta}{1 - \beta} \right),$$

where the sign of β is positive in the direction of increasing rapidity and p_{\parallel} .

RELATIVISTIC KINEMATICS (Cont'd)

(b) Scaling variable, hadron reactions -- In the inclusive reaction $h + 2 \rightarrow 3 + X$, with h any hadron, Feynman's x for particle 3 is defined as

$$x = k'_3/k'_{\max},$$

where k' is the c.m. momentum of particle 3. k'_{\max} is obtained [see Sec. III(b)] using the smallest mass m_X [called m_4 in III(b)] consistent with quantum conservation laws. At high energies, $k'_{\max} \approx \sqrt{s}/2$. Rapidity and x are related at large \sqrt{s} by

$$x \approx \frac{2m_1}{\sqrt{s}} \sinh y^*,$$

where y^* is evaluated in the c.m.

(c) Scaling variables, lepton reactions -- For the inclusive reaction $l + 2 \rightarrow l' + X$, with particles l and l' leptons, we define the 4-vector

$$q = (p_l - p_{l'})$$

so that

$$Q^2 \equiv -q^2 = 2E_l E_{l'} - 2|\vec{p}_l||\vec{p}_{l'}| \cos \theta - m_l^2 - m_{l'}^2 \geq 0$$

where θ is the $l \rightarrow l'$ scattering angle, and the preceding relation is valid in any frame. Also useful are

$$\nu = p_2 \cdot q / m_2 = [E_l - E_{l'}]_{\text{LAB}} = [E_X - m_2]_{\text{LAB}}$$

and

$$W = \sqrt{p_X^2} = (-Q^2 + 2m_2\nu + m_2^2)^{1/2} = m_X.$$

Q^2 , ν , and W are Lorentz invariants, and the notation "LAB" refers to the reference frame with particle 2 at rest. (Note: ν is sometimes written $\nu = p_2 \cdot q$, leading to the replacement of $m_2\nu$ with ν throughout.)

Scaling variables in common use include

$$x \equiv \omega^{-1} = Q^2/2m_2\nu, \quad 0 \leq x \leq 1$$

and

$$y = m_2\nu/p_l \cdot p_2 = [(E_l - E_{l'})/E_l]_{\text{LAB}}, \quad 0 \leq y \leq 1.$$

Both x and y are dimensionless.

Cross sections for inclusive reactions in the energy region where masses are negligible can be written in terms of E_l and certain pairs of these variables, usually Q^2 and ν , x and y , or Q^2 and x . If, in any frame, $|\vec{p}_l||\vec{p}_{l'}| \approx E_l E_{l'}$ and $E_l E_{l'} \sin^2(\theta/2) \gg m_l^2$ and $m_{l'}^2$ (i.e., $m_l, m_{l'}$ small), then

$$Q^2 \approx 4E_l E_{l'} \sin^2(\theta/2)$$

and

$$x \approx \frac{2E_l E_{l'} \sin^2(\theta/2)}{m_2\nu}.$$

†Inequality sometimes violated unless $m_X \geq m_2$ and $m_{l'} \geq m_l$.

LORENTZ INVARIANT PHASE SPACE FORMULAE

For a system of n particles with overall four-momentum p and final four momenta p_1, \dots, p_n [$p_i = (E_i, \vec{p}_i)$],

Lorentz Invariant Phase Space is given by

$$d \text{LIPS}(s; p_1, \dots, p_n) = (2\pi)^4 \delta^4(p - \sum_i p_i) \frac{1}{(2\pi)^{3n}} \prod_{i=1}^n \frac{d^3 \vec{p}_i}{2E_i}. \quad (1)$$

$$\text{For 2-body: } d \text{LIPS}(s, p_1, p_2) = \frac{1}{(2\pi)^2} \delta^4(p - p_1 - p_2) d^4 p \frac{|\vec{p}_1^{\text{cm}}|}{4\sqrt{s}} d\Omega_1^{\text{cm}}. \quad (2)$$

$$\text{For 3-body: } d \text{LIPS}(s, p_1, p_2, p_3) = \frac{1}{(2\pi)^5} \delta^4(p - p_1 - p_2 - p_3) d^4 p \frac{1}{32s} ds_{12} ds_{23} d\alpha d\beta d\gamma, \quad (3)$$

where α, β , and γ are Euler angles.

For $a + b \rightarrow n$ particles or $X \rightarrow n$ particles, in general $|i\rangle \rightarrow |f\rangle$,

$$\sigma_{if} = \frac{1}{4F} \int |\mathcal{M}_{if}|^2 d \text{LIPS}(s; p_1, \dots, p_n), \quad (4)$$

or

$$\Gamma_{if} = \frac{1}{2m_X} \int |\mathcal{M}_{if}|^2 d \text{LIPS}(m_X^2; p_1, \dots, p_n), \quad (5)$$

where \mathcal{M}_{if} is an invariant matrix element. F is Møller's invariant flux factor, $F^2 = (p_a \cdot p_b)^2 - m_a^2 m_b^2$. If a is beam, b , target ($\vec{p}_b^{\text{lab}} = 0$), then $F = |\vec{p}_a^{\text{lab}}| m_b = |\vec{p}_a^{\text{cm}}| \sqrt{s}$.

For elastic scattering in c.m., $|\vec{p}_a^{\text{cm}}| = |\vec{p}_1^{\text{cm}}|$, and (2) and (4) yield

$$\frac{d\sigma}{d\Omega} = \frac{|\mathcal{M}|^2}{(8\pi)^2 s} \quad \text{or} \quad \frac{d\sigma}{dt} = \frac{|\mathcal{M}|^2}{64\pi |\vec{p}_a^{\text{cm}}|_s}. \quad (6)$$

The normalization is such that the optical theorem reads

$$\text{Im } \mathcal{M}|_{t=0} = 2 |\vec{p}_a^{\text{cm}}| \sqrt{s} \sigma_{\text{tot}}. \quad (7)$$

The choice of Eq. (4) implies a particular normalization of any spinors that may occur in \mathcal{M} . The advantage of this normalization is that it greatly simplifies the structure of \mathcal{M} by putting factors such as $\frac{1}{(2\pi)^3} \frac{1}{2E}$ into the phase space where they really belong. In addition, the labels, i, f , refer to specific spin (helicity) states, so that the usual "average and sum" rule is implicit.

WEAK INTERACTIONS OF QUARKS AND LEPTONS

The "standard" SU(2) ⊗ U(1) model^{1,2} is described here for six quarks and six leptons in left-handed doublets of SU(2)_{weak} and right-handed singlets of SU(2)_{weak} (T₃ = third component of weak isospin):

$$T_3 = +1/2 \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L, \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_L, \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_L, \begin{pmatrix} u \\ d' \end{pmatrix}_L, \begin{pmatrix} c \\ s' \end{pmatrix}_L, \begin{pmatrix} t \\ b' \end{pmatrix}_L$$

$$T_3 = -1/2 \begin{pmatrix} e^- \\ \mu^- \\ \tau^- \\ u_R \\ d_R \\ c_R \\ s_R \\ t_R \\ b_R \end{pmatrix}$$

Mixing occurs between quarks d, s, b of charge -1/3 (by convention the charge 2/3 quarks, u, c, t, are unmixed) and is expressed by the Kobayashi-Maskawa (KM) mixing matrix²

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} c_1 & s_1 c_3 & s_1 s_3 \\ -s_1 c_2 & c_1 c_2 c_3 + s_2 s_3 e^{i\delta} & c_1 c_2 s_3 - s_2 c_3 e^{i\delta} \\ -s_1 s_2 & c_1 s_2 c_3 - c_2 s_3 e^{i\delta} & c_1 s_2 s_3 + c_2 c_3 e^{i\delta} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

where c_i = cos θ_i, s_i = sin θ_i, i=1,2,3. In the limit θ₂=θ₃=δ=0, this reduces to the usual Cabibbo mixing with θ₁ the Cabibbo angle.

The interaction Lagrangian is

$$\mathcal{L}_{int} = e \left[\bar{\psi} \gamma_\alpha J_\alpha^em + \frac{1}{\sin\theta_W \cos\theta_W} Z^\alpha J_\alpha^N + \frac{1}{\sqrt{2} \sin\theta_W} (W^+ J_\alpha^C + W^- J_\alpha^{C\dagger}) \right]$$

Here θ_W is the weak mixing angle in the relations

$$W^0 = Z \cos\theta_W + A \sin\theta_W$$

$$B = -Z \sin\theta_W + A \cos\theta_W$$

which relate the physical fields A (photon) and Z (neutral weak gauge boson) to W⁰ (SU(2)_{weak} partner of W⁺ and W⁻) and B (U(1) gauge field). The charged current is written

$$J_\alpha^C = (\bar{\nu}_e \bar{\nu}_\mu \bar{\nu}_\tau) \left[\gamma_\alpha \frac{(1-\gamma_5)}{2} \right] \begin{pmatrix} e^- \\ \mu^- \\ \tau^- \end{pmatrix} + (\bar{u} \bar{c} \bar{t}) \left[\gamma_\alpha \frac{(1-\gamma_5)}{2} \right] \begin{pmatrix} KM \\ \text{matrix} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

i.e., V-A structure. The neutral current is written

$$J_\alpha^N = (\bar{\nu}_e \bar{\nu}_\mu \bar{\nu}_\tau) \left[\frac{1}{2} \gamma_\alpha \frac{(1-\gamma_5)}{2} \right] \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} + (\bar{e} \bar{\mu} \bar{\tau}) \left[-\frac{1}{2} \gamma_\alpha \frac{(1-\gamma_5)}{2} + \sin^2\theta_W \gamma_\alpha \right] \begin{pmatrix} e \\ \mu \\ \tau \end{pmatrix} + (\bar{u} \bar{c} \bar{t}) \left[\frac{1}{2} \gamma_\alpha \frac{(1-\gamma_5)}{2} - \frac{2}{3} \sin^2\theta_W \gamma_\alpha \right] \begin{pmatrix} u \\ c \\ t \end{pmatrix} + (\bar{d} \bar{s} \bar{b}) \left[-\frac{1}{2} \gamma_\alpha \frac{(1-\gamma_5)}{2} + \frac{1}{3} \sin^2\theta_W \gamma_\alpha \right] \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

where for fermion f the coupling [Γ_α^f] has a V-A term depending on T₃^f and a vector term depending on charge Q_f:

$$[\Gamma_\alpha^f] = \left[T_3^f \gamma_\alpha \frac{(1-\gamma_5)}{2} - Q_f \sin^2\theta_W \gamma_\alpha \right]$$

The effective Lagrangian for exchange of W[±] and Z between two currents reduces at low q² to

$$\mathcal{L}_{weak} = \frac{G}{\sqrt{2}} 4 \left(J_\alpha^C J_\alpha^{C\dagger} + 2\rho J_\alpha^N J_\alpha^N \right)$$

with G/√2 = πα/(2M_W²sin²θ_W), α = e²/(4π), and ρ = M_W²/(M_Z²cos²θ_W). Assuming the simplest Higgs structure, ρ=1, and the W and Z masses are related by M_Z = M_W/cosθ_W. Currently reported values of the weak interaction parameters are

$$\left. \begin{aligned} |\cos\theta_1| &= 0.9737 \pm 0.0025 \\ |\sin\theta_1 \cos\theta_3| &= 0.219 \pm 0.011 \end{aligned} \right\} \text{Ref. 3 ;}$$

$$|\sin\theta_1 \sin\theta_3| = 0.06 \pm 0.06 \left. \vphantom{|\sin\theta_1 \cos\theta_3|} \right\} \text{Refs. 3,4 ;}$$

$$\left. \begin{aligned} \theta_2 \text{ and } \delta \text{ not determined without} \\ \text{additional theoretical input} \end{aligned} \right\} \text{Ref. 5 ;}$$

$$G = G_\mu = (1.16632 \pm 0.00004) \times 10^{-5} \text{ GeV}^{-2} \left. \vphantom{G} \right\} \text{Refs. 3,6 ;}$$

$$\left. \begin{aligned} \sin^2\theta_W &= 0.218 \pm 0.025, \quad \rho = 0.985 \pm 0.026 \\ \sin^2\theta_W &= 0.228 \pm 0.010, \quad \rho \equiv 1 \text{ (fixed)} \end{aligned} \right\} \text{Ref. 7 .}$$

The resulting mass estimates for W[±] and Z are M_W = 37.3 GeV/sinθ_W = 78.1 ± 1.7 GeV, and M_Z = 88.9 ± 1.4 GeV, where the numerical values are obtained using the simplest Higgs structure (ρ ≡ 1).

Lepton-Nucleon Inclusive Scattering

For reactions ℓ+N → ℓ'+X, differential cross sections can be written using several choices of independent variables. These are related by

$$\frac{d^2\sigma}{dx dy} = 2ME_\ell^2 y \frac{d^2\sigma}{d\nu dQ^2} = 2ME_\ell^2 x \frac{d^2\sigma}{dx dQ^2} = \frac{2\pi ME_\ell^2 y}{|\vec{p}_\ell| |\vec{p}_\ell'|} \frac{d^2\sigma}{d\nu dE_\ell'}$$

$$\cong \frac{2\pi ME_\ell y}{E_\ell} \frac{d^2\sigma}{d\nu dE_\ell'}$$

where ν, Q², x, and y are defined in the Relativistic Kinematics section IV(c), E_ℓ, p_ℓ and E_{ℓ'}, p_{ℓ'} are the incident and outgoing lepton lab energies and momenta, and M is the target nucleon mass.

Structure Functions^{8,9}

For charged current (C.C.) and neutral current (N.C.) reactions, we have

$$\frac{d^2\sigma^{\nu(\bar{\nu})}}{dx dy} = \frac{G^2 M E_\ell}{\pi} \left[\left(1 - y - \frac{M}{2E_\ell} xy \right) F_2^{\nu(\bar{\nu})}(x, Q^2) + \frac{y^2}{2} 2x F_1^{\nu(\bar{\nu})}(x, Q^2) \pm \left(y - \frac{y^2}{2} \right) x F_3^{\nu(\bar{\nu})}(x, Q^2) \right],$$

where the upper and lower signs refer to ν and ν̄ scattering, respectively, and F₃ is defined as a positive quantity. The other common structure functions W_i are related by MW₁ = F₁, νW₂ = F₂, and νW₃ = -F₃. For electron and muon scattering, F₃=0, and G² is replaced by 8π²α²/(Q²)².

WEAK INTERACTIONS OF QUARKS AND LEPTONS (Cont'd)

The ratio of the longitudinally to transversely polarized photon absorption cross section is

$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{2xF_1(x, Q^2)} \left[F_2(x, Q^2) - 2xF_1(x, Q^2) + \frac{4M^2x^2}{Q^2} F_2(x, Q^2) \right].$$

To compare with the parton-model predictions below, we write for $E_Q \gg M$:

$$\frac{d^2\sigma^{V(\bar{V})}}{dx dy} = \frac{G^2 ME_\ell}{\pi} \left[\frac{1}{2} (2xF_1^{V(\bar{V})} \pm xF_3^{V(\bar{V})}) + \frac{1}{2} (1-y)^2 (2xF_1^{V(\bar{V})} \mp xF_3^{V(\bar{V})}) + (1-y) (F_2^{V(\bar{V})} - 2xF_1^{V(\bar{V})}) \right],$$

$$\frac{d^2\sigma^{e, \mu}}{dx dy} = \frac{8\pi\alpha^2 ME_\ell}{(Q^2)^2} \left[\frac{1+(1-y)^2}{2} 2xF_1^{e, \mu} + (1-y) (F_2^{e, \mu} - 2xF_1^{e, \mu}) \right].$$

The Free-Quark-Parton-Model Predictions¹⁰

For this model in the Bjorken limit ($Q^2, \nu \rightarrow \infty$ with x fixed), $F_i(x, Q^2) \rightarrow F_i(x)$.^{8,9} For spin- $\frac{1}{2}$ quark partons, we have $2xF_1(x) = F_2(x)$, the Callan-Gross relation. Thus, in this approximation, $R=0$ and there is no $(1-y)$ term in the cross section.

$$\bullet \text{ (C.C.) } \frac{d^2\sigma^{VN \rightarrow \mu^+ X}}{dx dy} = \frac{G^2 ME_\ell}{\pi} 2x \sum_q \left[f_q(x) + f_{\bar{q}}(x) (1-y)^2 \right].$$

For $\bar{\nu}N \rightarrow \mu^+ X$, interchange $f_q(x)$ and $f_{\bar{q}}(x)$ in the formula. Here $f_q(x) dx$ is the number of quarks q in the target nucleon with momentum fraction x to $x+dx$. We include $f_q(x)$ and $f_{\bar{q}}(x)$ in the sum only for negative (positive) charged quarks and antiquarks in $\nu(\bar{\nu})$ reactions.

$$\bullet \text{ (N.C.) } \frac{d^2\sigma^{VN \rightarrow \nu X}}{dx dy} = \frac{G^2 ME_\ell}{\pi} 2\rho^2 x \sum_q \left\{ (\epsilon_L^q)^2 [f_q(x) + f_{\bar{q}}(x) (1-y)^2] + (\epsilon_R^q)^2 [f_q(x) (1-y)^2 + f_{\bar{q}}(x)] \right\},$$

and the sum runs over all quarks. Here the neutral-current coupling is decomposed according to

$$\Gamma_\alpha^q = \epsilon_L^q \gamma_\alpha \frac{(1-\gamma_5)}{2} + \epsilon_R^q \gamma_\alpha \frac{(1+\gamma_5)}{2}$$

with left- and right-handed coupling constants ϵ_L^q and ϵ_R^q . In the "standard" $SU(2) \otimes U(1)$ model

$$\epsilon_L^q = T_3^q - Q_q \sin^2 \theta_W, \quad \epsilon_R^q = -Q_q \sin^2 \theta_W.$$

For $\bar{\nu}N \rightarrow \bar{\nu} X$, interchange ϵ_L^q and ϵ_R^q in the cross-section formula.

$$\bullet \text{ (E.M.) } \frac{d^2\sigma^{e, \mu}}{dx dy} = \frac{8\pi\alpha^2 ME_\ell}{(Q^2)^2} x \sum_q Q_q^2 [f_q(x) + f_{\bar{q}}(x)] \frac{1+(1-y)^2}{2}.$$

Comparison with earlier structure function formulas gives:

$$\text{(C.C.) } F_2(x) = 2x \sum_q [f_q(x) + f_{\bar{q}}(x)],$$

$$xF_3(x) = 2x \sum_q [f_q(x) - f_{\bar{q}}(x)];$$

$$\text{(N.C.) } F_2(x) = 2\rho^2 x \sum_q [(\epsilon_L^q)^2 + (\epsilon_R^q)^2] [f_q(x) + f_{\bar{q}}(x)],$$

$$xF_3(x) = 2\rho^2 x \sum_q [(\epsilon_L^q)^2 - (\epsilon_R^q)^2] [f_q(x) - f_{\bar{q}}(x)],$$

$$F_1^{V(\bar{V})}(x) = F_1^{V(\bar{V})}(x);$$

$$\text{(E.M.) } F_2(x) = x \sum_q Q_q^2 [f_q(x) + f_{\bar{q}}(x)].$$

In the examples below, $u(x)$, $\bar{u}(x)$, $d(x)$, $\bar{d}(x)$, etc., mean f_q ($f_{\bar{q}}$) for the individual quark (antiquark) in the proton (for neutron, interchange $u(x)$ and $d(x)$). Charm production is taken into account.

$$\bullet \quad F_2^{\nu p \rightarrow \mu^+ X} = 2x [d(x) + s(x) + \bar{u}(x) + \bar{c}(x)],$$

$$F_2^{\bar{\nu} p \rightarrow \mu^+ X} = 2x [u(x) + c(x) + \bar{d}(x) + \bar{s}(x)],$$

$$xF_3^{\nu p \rightarrow \mu^+ X} = 2x [d(x) + s(x) - \bar{u}(x) - \bar{c}(x)],$$

$$xF_3^{\bar{\nu} p \rightarrow \mu^+ X} = 2x [u(x) + c(x) - \bar{d}(x) - \bar{s}(x)].$$

Hereafter we neglect small contributions of the s , \bar{s} , c , \bar{c} quarks in the sea.

$$\bullet \text{ For charge-symmetric nuclei with } q(x) = u(x) + d(x), \bar{q}(x) = \bar{u}(x) + \bar{d}(x),$$

$$F_2^{\nu N \rightarrow \mu^+ X} = F_2^{\bar{\nu} N \rightarrow \mu^+ X} = x [q(x) + \bar{q}(x)],$$

$$xF_3^{\nu N \rightarrow \mu^+ X} = x F_3^{\bar{\nu} N \rightarrow \mu^+ X} = x [q(x) - \bar{q}(x)].$$

$$\bullet \quad F_2^{ep, \mu p}(x) = x \left[\frac{4}{9} (u(x) + \bar{u}(x)) + \frac{1}{9} (d(x) + \bar{d}(x)) \right]$$

$$F_2^{ed}(x) \cong \frac{5}{18} F_2^{V(\bar{V})d} \text{ C.C.}$$

$$\left(\frac{5}{18} : \text{average squared charge of } u, d \text{ quarks} \right).$$

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PARTICLE DETECTORS, ABSORBERS, AND RANGES*

A. DETECTOR PARAMETERS

In this section we give various parameters for common detectors. The quoted numbers represent at best an order of magnitude, and are useful only for preliminary design. A more detailed introduction to detectors can be found in "A Consumer's Guide to Particle Detectors," by D. J. Miller, Rutherford Lab Report RL-76-072, July 1976.

A.1 Scintillators: Photon yield $\approx 1\gamma/100$ eV in plastic scintillator¹ and $\approx 1\gamma/25$ eV in NaI.^{1,2}

A.2 Čerenkov:³ Half-angle θ_c of cone aperture in terms of velocity β and index of refraction n :

$$\theta_c = \arccos\left(\frac{1}{\beta n}\right) \sim \sqrt{2\left(1 - \frac{1}{\beta n}\right)}$$

Threshold velocity: $\beta_t = 1/n$; $\gamma_t = 1/\sqrt{1 - \beta_t^2}$.

Therefore, $\beta_t \gamma_t = 1/\sqrt{2\delta + \delta^2}$, where $\delta = n-1$. Values of δ for various commonly used gases are given as a function of pressure and wavelength in Ref. 4; for values at atmospheric pressure, see the Table of Atomic and Nuclear Properties following.

Number of photons N per cm:

$$N = \frac{\alpha}{c} \int \left(1 - \frac{1}{\beta^2 n^2}\right) 2\pi \nu d\nu = \frac{\alpha}{c} \beta^2 \int \left(\frac{1}{\beta_t^2 \gamma_t^2} - \frac{1}{\beta^2 \gamma^2}\right) 2\pi \nu d\nu$$

$$\approx 500 \sin^2 \theta_c / \text{cm} \quad (\text{visible spectrum})$$

A.3 Photon Collection: In addition to the photon yield, one should take into account the light collection efficiency ($\lesssim 10\%$ for typical 1-cm-thick scintillator), attenuation length (≈ 1 to 4 m for typical scintillators⁵), and quantum efficiency of the photomultiplier cathode ($\lesssim 25\%$).

A.4 Bubble, Streamer, Wire Chambers:

Chamber Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble	$\pm 75\mu$	≈ 1 ms	$\approx 1/20$ s ^d
Streamer	$\pm 300\mu$	≈ 2 μ s	≈ 100 ms
Optical spark	$\pm 200\mu$ ^b	≈ 2 μ s	≈ 10 ms
Magnetostrictive Spark	$\pm 500\mu$	≈ 2 μ s	≈ 10 ms
Proportional	$\geq \pm 300\mu$ ^{c,d}	≈ 50 ns	≈ 200 ns
Drift	± 50 to 300μ	≈ 2 ns ^e	≈ 100 ns

^aMultiple pulsing time.
^b60 μ for high pressure.
^c300 μ is for 1 mm pitch.
^dDelay line cathode readout can give $\pm 150\mu$ parallel to anode wire.
^eFor two chambers.

A.5 Shower Detectors: Typical energy resolutions (FWHM) for incident electron in the 1 GeV range, E in GeV. For a fixed number of radiation lengths, FWHM in the last three detectors would be expected to be proportional to \sqrt{E} for t (= plate thickness) ≥ 0.2 radiation lengths.⁶

NaI (20 rad. lengths):⁷ $\frac{2\%}{E^{1/4}}$

Lead Glass (14 rad. lengths):⁸ $\frac{10-12\%}{\sqrt{E}}$

Lead-Liquid Argon (15.75 rad. lengths):⁶ $\frac{16\%}{\sqrt{E}}$
 (42 cells: lead, 2 mm liquid argon, \sqrt{E}
 lead-G10, 2 mm liquid argon)

Lead-Scintillator Sandwich (14 rad. lengths):⁹ $\frac{22\%}{\sqrt{E}}$
 (35 cells: 2 mm lead,
 12.7 mm scintillator)

Proportional Wire Shower Chamber (17 rad. lengths):¹⁰ $\frac{40\%}{\sqrt{E}}$
 (36 cells: 0.474 rad. length type-metal + Al,
 9.5 mm 80% Ar - 20% CH₄ gas)

A.6 Proportional Chamber Wire Instability: The limit on the voltage V for a wire tension T , due to mechanical effects when the electrostatic repulsion of adjacent wires exceeds the restoring force of wire tension, is given by¹¹

$$V \leq \frac{sT^{1/2}}{\ell C}$$

where s , ℓ , and C are the wire spacing, length, and capacitance per unit length. An approximation to C for chamber half-gap t and wire diameter d (good for $s \leq t$) gives¹²

$$V \leq 59T^{1/2} \left[\frac{t}{\ell} + \frac{s}{\pi \ell} \ln \left(\frac{s}{\pi d} \right) \right]$$

where V is in kV, and T is in grams.

A.7 Proportional and Drift Chamber Potentials: Potential distributions and fields for an array of parallel line charges q (coul./m) along z and located at $y=0$, $x = 0, \pm a, \pm 2a, \dots$, can usually be calculated with good accuracy from (MKSA):

$$V(x,y) = -\frac{q}{4\pi\epsilon_0} \ln \left\{ 4 \left[\sin^2 \left(\frac{\pi x}{a} \right) + \sinh^2 \left(\frac{\pi y}{a} \right) \right] \right\}$$

B. COSMIC RAY FLUXES

The fluxes of particles of different types depend on the latitude, their energy, and the conditions of measurement. Some typical sea-level values¹³ are given below:

- I_V flux per unit solid angle about vertical direction crossing unit horizontal area
- J_1 perpendicular component of total flux crossing unit horizontal area from above
- J_2 total flux crossing unit horizontal area

	Total Intensity	Hard Component	Soft Component	
I_V	1.1×10^{-2}	0.8×10^{-2}	0.3×10^{-2}	cm ⁻² sec ⁻¹ sterad ⁻¹
J_1	1.8×10^{-2}	1.3×10^{-2}	0.5×10^{-2}	cm ⁻² sec ⁻¹
J_2	2.4×10^{-2}	1.7×10^{-2}	0.7×10^{-2}	cm ⁻² sec ⁻¹

Very approximately, about 75% of all particles at sea-level are penetrating, and are muons. The absolute flux of protons⁵ at sea-level, in a momentum range 700-1100 MeV/c, is 1.5×10^{-5} cm⁻² sec⁻¹ sterad⁻¹, or $\sim 0.1\%$ of all particles.

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

C. PASSAGE OF PARTICLES THROUGH MATTER

C.1 Energy Loss Rates for Heavy Charged Projectiles: A heavy projectile (much more massive than an electron) of charge $Z_{inc}e$, incident at speed βc ($\beta \gg 1/137$) through a slowing medium, dissipates energy principally via interactions with the electrons of the medium. The mean rate of such energy loss per unit path length x may be written as:¹⁴

$$\left(\frac{dE}{dx}\right)_{inc} = \frac{D \rho_{med} Z_{med}}{A_{med}} \left(\frac{Z_{inc}}{\beta}\right)^2 \times \left[\ln \left(\frac{2m_e \gamma^2 \beta^2 c^2}{I} \right) - \beta^2 - \frac{\delta}{2} - \frac{C}{Z_{med}} \right] \{1 + \nu\},$$

where $D = 4\pi N_A r_e^2 m_e c^2 = 0.3070 \text{ MeV cm}^2/\text{g}$ (see Physical and Numerical Constants Table).

Here Z_{med} and A_{med} are the charge and mass numbers of the medium and ρ_{med} is the mass density of the medium; I , δ , C , and ν are phenomenological functions. Frequently, the values of δ , C , and ν are negligibly small; the parameter I characterizes the binding of the electrons of the medium. As a rule of thumb, we may estimate I for an idealized medium as $I \approx 16 (Z_{med})^{0.9} \text{ eV}$ when $Z_{med} > 1$. For realistic media the value of I will vary at the 10% level from this estimate; for H_2 , $I = 20.0 \text{ eV}$. We may approximately treat media which are chemical mixtures or compounds by computing

$$\frac{dE}{dx} \approx \sum_{n=1}^N \left(\frac{dE}{dx}\right)_n$$

with $(dE/dx)_n$ appropriate to the n^{th} chemical constituent (using $\rho_{med}^{(n)}$ as the partial density).¹⁵

The function δ represents the density effect upon the energy loss rate; it is non-negligible only for highly relativistic projectiles in dense media.¹⁶ For ultra-relativistic projectiles, δ approaches $2\ln\gamma + \text{constant}$, where the value of the constant depends upon the density of the medium and its chemical composition.

The function C represents shell corrections to the energy loss rate.¹⁴ These effects are non-negligible only for projectiles with speeds not much faster than the speeds of the fastest electrons bound in the medium.

The function ν represents corrections due to higher-order electrodynamics.¹⁷ These effects become important when $|Z_{inc}/\beta|$ is comparable to 137. For relativistic unit-charge projectiles, $|\nu|$ is of the order of 1%; positively charged projectiles lose energy more rapidly than do their charge conjugates.^{17,18}

$(dE/dx)_{inc}$ falls rapidly with β until reaching a minimum around $\beta = 0.96$ (almost independent of medium), followed by a slow rise. Because of the density effect, the quantity in square brackets approaches $\ln\gamma + \text{constant}$ for large γ .

The value $(dE/dx)_{inc} \delta x$ is the mean total energy loss via interactions with electrons of the medium in a layer of thickness δx . For any finite δx , Poisson fluctuations can cause the actual energy loss to deviate from the mean. For thin layers, the distribution is broad and skewed, being peaked below $(dE/dx) \delta x$, and having a long tail toward large energy losses.¹⁹ Only for a very thick layer [$(dE/dx) \delta x \gg 2m_e \beta^2 \gamma^2 c^2$] will the distribution of energy losses become nearly Gaussian. The large fluctuations of the total energy loss rate from the mean are due to a small number of collisions with large energy transfers. The fluctuations are greatly reduced for the so-called restricted energy loss rate, described in section C.3.

C.2 Energetic Knock-On Electrons: For a spinless point-charge projectile, the production of high energy (kinetic energy $T \gg I$) electrons is given by (neglecting the spin of the electron):

$$\frac{dN}{dTdx} = \frac{1}{2} D \left(\frac{Z_{med}}{A_{med}}\right) \left(\frac{Z_{inc}}{\beta}\right)^2 \rho_{med} \frac{1}{T^2}$$

$$\text{for } I \ll T \leq T_{max}; T_{max} = \frac{2m_e \beta^2 \gamma^2 c^2}{1 + 2\gamma \frac{m_e}{M_{inc}} + \left(\frac{m_e}{M_{inc}}\right)^2}$$

where M_{inc} is the mass of the incident projectile and all other quantities are as in section C.1. This formula does not differ significantly from the precise result, incorporating spin effects, for any projectile (including e^+) in the restricted range $I \ll T \ll T_{max}$; more accurate formulae are available for various projectiles.^{20,21} Our formula is inaccurate for T close to I ; for $2I \leq T \leq 10I$, the $1/T^2$ dependence above becomes $\approx T^{-\eta}$ with $3 \leq \eta \leq 5$.²²

C.3 Rates of Restricted Energy Loss for Charged Projectiles:

The variability of energy loss for heavy projectiles is due primarily to the variability in the production of energetic knock-on electrons. Bremsstrahlung and pair production processes make this variability even greater for electrons than for heavy particles as projectiles (see, e.g., the figure "Fractional Energy Loss for e^+ and e^- in Lead"). If an instrument is capable of isolating these high-energy-loss interactions, then it is appropriate to consider the rate of energy loss excluding them, i.e., a restricted energy loss rate. The mean energy loss rate via all collisions which have energy transfer T such that $T \leq E_{max} \ll T_{max}$ is:¹⁴

$$\left(\frac{dE}{dx}\right)_{\leq E_{max}} = \frac{D}{2} \frac{Z_{med} \rho_{med}}{A_{med}} \left(\frac{Z_{inc}}{\beta}\right)^2 \times \left[\ln \left(\frac{E_{max} T_{max}}{I^2} \right) - \beta^2 - \delta - \frac{2C}{Z_{med}} \right]$$

Notice the overall factor of $1/2$.

The density effect causes the restricted energy loss rate to approach a constant, the Fermi plateau value, for the fastest projectiles.

C.4 Multiple Coulomb Scattering through Small Angles: As a charged particle traverses a medium it is deflected via many independent small-angle Coulomb scatterings. The bulk of this deflection is due to scattering from the nuclei in the medium. The non-projected (space) and projected (plane) distributions are given approximately²³ by the Gaussian forms:

$$f(\theta_{space}) d\Omega \approx \frac{1}{\pi \theta_0^2} \exp\left(-\frac{\theta_{space}^2}{\theta_0^2}\right) d\Omega$$

$$g(\theta_{plane}) d\theta_{plane} \approx \frac{1}{\sqrt{\pi} \theta_0} \exp\left(-\frac{\theta_{plane}^2}{\theta_0^2}\right) d\theta_{plane}$$

where

$$\theta_0 = \frac{20 \text{ MeV}/c}{p\beta} Z_{inc} \sqrt{\frac{L}{L_R}} \left[1 + \frac{1}{9} \log_{10} \left(\frac{L}{L_R} \right) \right] \text{ (radians),}$$

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

p , β , and Z_{inc} are the momentum (in MeV/c), velocity, and charge number of the incident particle, and L/L_R is the thickness, in radiation lengths, of the scattering medium. L_R for certain materials is given in the Table of Atomic and Nuclear Properties of Materials. The $1/e$ angle, θ_0 , is a fit to Moliere²⁴ theory accurate to about 5% for $10^{-3} < L/L_R < 10$ except for very light elements or low velocity where the error is about 10 to 20%. In this Gaussian approximation, θ_0 has the meaning

$$\theta_0 = \theta_{space}^{rms} = \sqrt{2} \theta_{plane}^{rms}$$

Beyond angles of about $2\theta_0$, the true distribution function has a long tail which contributes at the level of roughly 1% of peak height, slowly descending, beyond the point at which the Gaussian would be negligible, to the height expected for single large-angle Rutherford or nuclear scatters.

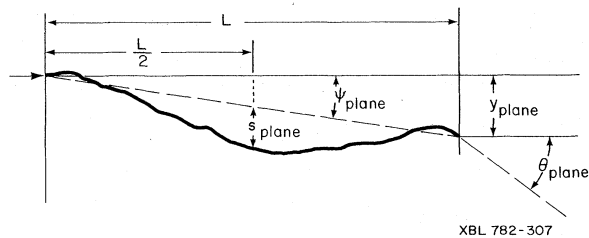
Other quantities are sometimes used to describe the amount of multiple Coulomb scattering: the auxiliary quantities ψ_{plane} , y_{plane} , and s_{plane} (see the figure) obey:

$$\psi_{plane}^{rms} = \frac{1}{\sqrt{3}} \theta_{plane}^{rms}$$

$$y_{plane}^{rms} = \frac{1}{\sqrt{3}} L \theta_{plane}^{rms}$$

and

$$s_{plane}^{rms} = \frac{1}{4\sqrt{3}} L \theta_{plane}^{rms}$$



All the quantitative estimates in this section apply only in the limit of small θ_{plane}^{rms} and in the absence of large-angle scatters.

C.5 Electron Range in Lead, Copper, Carbon, and Hydrogen: See figure following.

C.6 Fractional Energy Loss for Electrons and Positrons in Lead: See figure following.

C.7 Contributions to Photon Cross Section in Lead: See figure following.

C.8 Photon Mass Attenuation Coefficients, Energy Deposition: See figure following.

D. ATOMIC AND NUCLEAR PROPERTIES OF MATTER

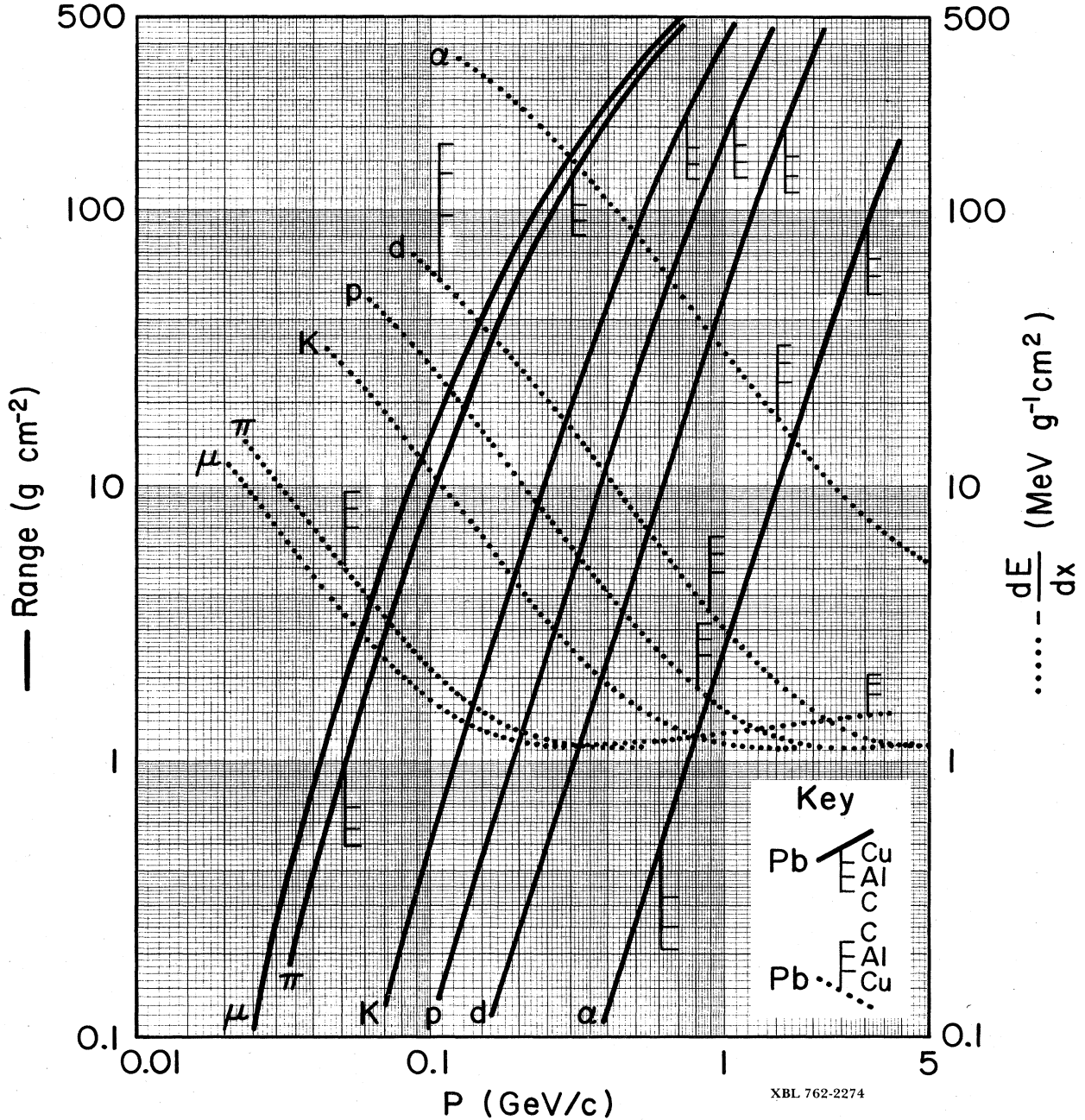
See Table following.

*Prepared April 1974 by Sherwood Parker and Bernard Sadoulet. Revised April 1980 by Sherwood Parker and Ray Hagstrom.

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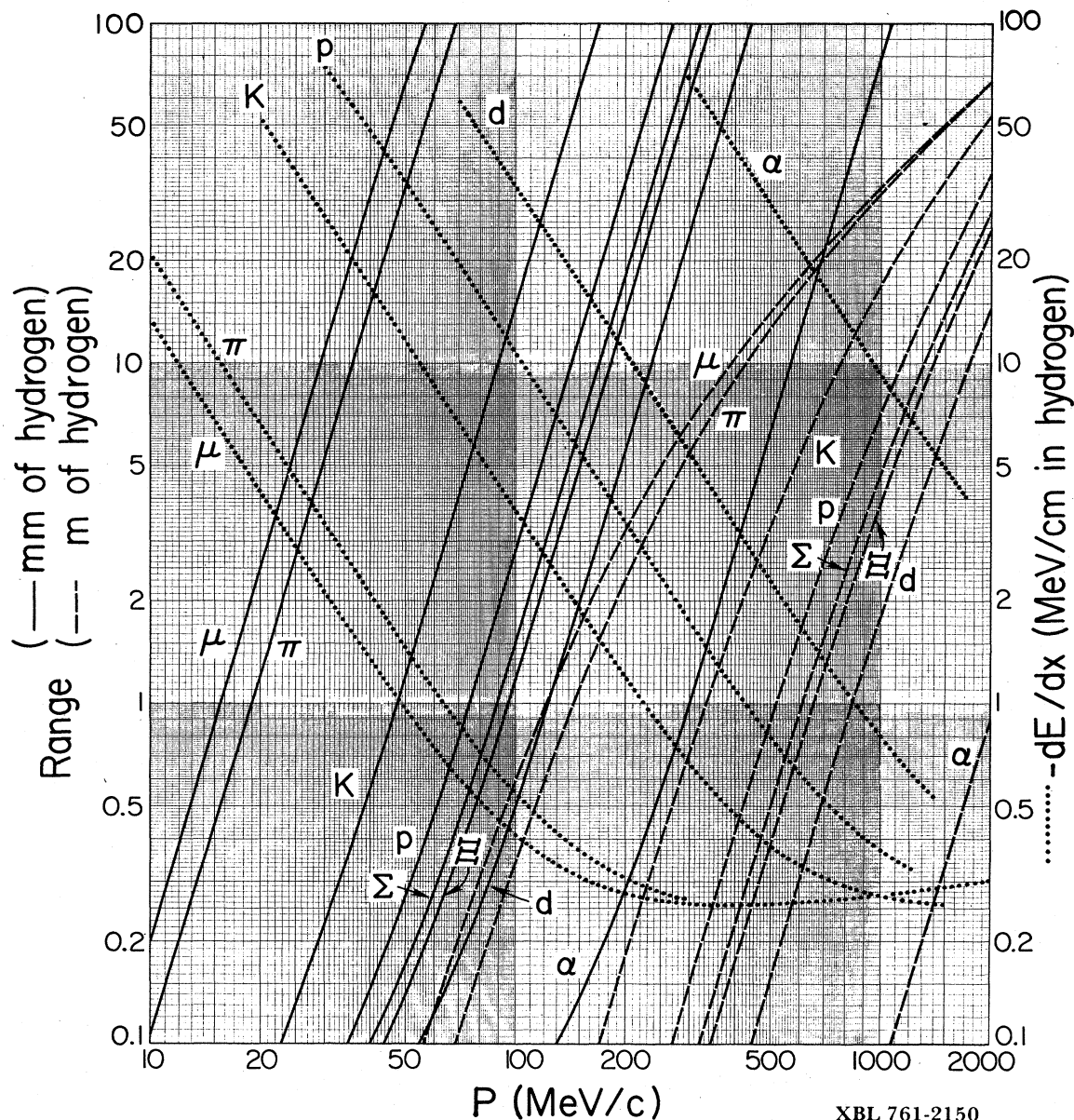
Mean Range and Energy Loss in Lead, Copper, Aluminum, and Carbon



Mean range and energy loss due to ionization for the indicated particles in Pb, with scaling to Cu, Al, and C indicated, using Bethe-Bloch equation (Section C.1 above) with corrections. Calculated using program of Hans Bichsel (UCRL-17538), with density correction added (Hans Bichsel, private communication). See also Joseph F. Janni [Air Force Weapons Laboratory Technical Report No. AFWL-TR-65-150 (1966)]. The average ionization potentials (I) assumed were: Pb (820 eV), Cu (320 eV), Al (166 eV), and C (77.5 eV). Figure indicates total path length; observed range may be smaller (by $\sim 1\% - 2\%$ in heavy elements) due to multiple scattering, primarily from small energy-loss collisions with nuclei. The functional forms have not been experimentally verified to better than roughly $\pm 1\%$. For higher energies refer to discussion by Cobb ["A Study of Some Electromagnetic Interactions of High Velocity Particles with Matter," University of Oxford Report HEP/T/55 (1973)] and by Turner ["Penetration of Charged Particles in Matter: A Symposium", National Academy of Sciences, Washington D. C. (1970), p. 48]. Scaling to other beam particles is, to a good approximation, described by the expression on the next page.

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

Mean Range and Energy Loss in Liquid Hydrogen



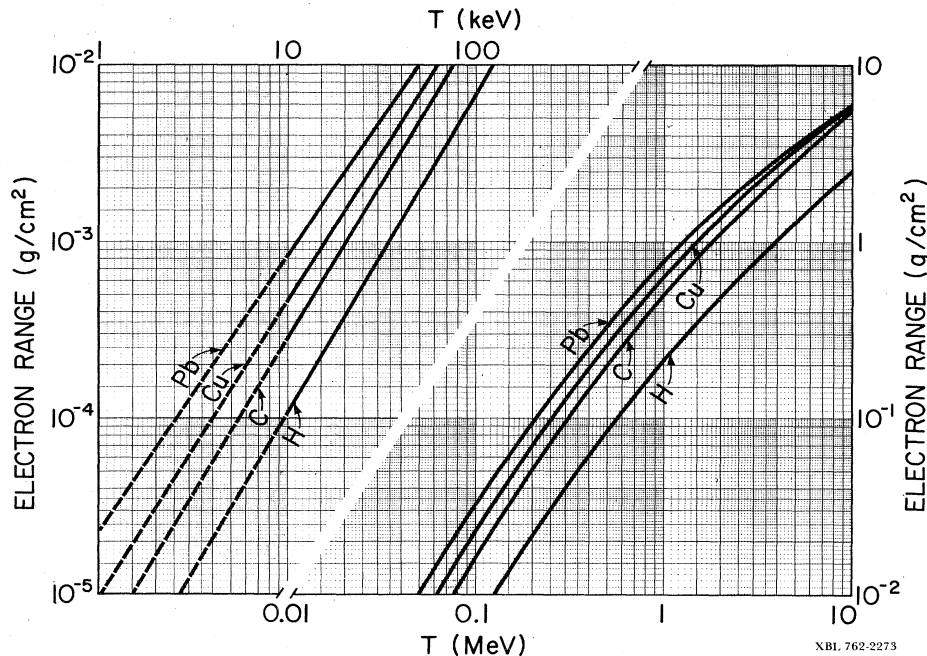
Range and energy loss in liquid hydrogen bubble chamber, based on Bethe-Bloch equation (Section C.1 above), using an average ionization potential for H_2 of $I = 20.0$ eV, which is an approximate average of the experimental result of Garbincius and Hyman [Phys. Rev. **A2**, 1834 (1970)] and the theoretical result of Ford and Browne [Phys. Rev. **A7**, 418 (1973)]. Bubble chamber conditions are chosen to be those of Garbincius and Hyman: parahydrogen of density = 0.0625 g/cm³ (note: range $\propto 1/\text{density}$), with vapor-pressure 60.8 lb/in² (absolute) and temperature 26.2°K . The functional dependence of the Bethe-Bloch equation is not experimentally verified to better than about $\pm 1\%$ over large momentum ranges. It should be noted that the number of bubbles per cm of a track in a bubble chamber is nearly proportional to $1/\beta^2$, not dE/dx . For the linear portions of the range curves, $R \propto p^{3.6}$. Scaling law for particles of other mass or charge (except electrons): for a given medium, the range R_b of any beam particle with mass M_b , charge z_b , and momentum P_b is given in terms of the range R_a of any other particle with mass M_a , charge z_a , and momentum $P_a = P_b M_a / M_b$ (i.e., having the same velocity) by the expression:

$$R_b(M_b, z_b, P_b) = \left[\frac{M_b/M_a}{z_b^2/z_a^2} \right] R_a(M_a, z_a, P_a = P_b M_a / M_b)$$

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

Mean Electron Range in Lead, Copper, Carbon, and Liquid Hydrogen

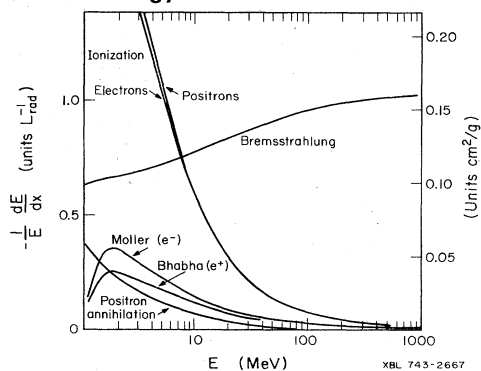
Mean range of electrons in the continuous-slowing-down approximation, taking into account energy loss by collisions with atomic electrons and by bremsstrahlung; strong fluctuations are to be expected for individual tracks. This range is the total path length; the "practical range" - a common measure of straight-line penetration distance - is shorter because of multiple Coulomb scattering, which becomes increasingly important as the electron slows down. E.g., for a fast electron the rms projected angle due to multiple Coulomb scattering reaches 1 radian by the time the electron has slowed to 0.4 MeV in hydrogen, 1.5 MeV in carbon, 9 MeV in copper, and 24 MeV (off scale) in lead. Electron energy deposition and penetration probability vs. range are discussed by L. V. Spencer, "Energy Dissipation by Fast Electrons," NBS Monograph #1, 1959, and S. M. Seltzer, "Transmission of Electrons through Foils," NBSIR 74, 457 (1974). Electrons which have energy less than 0.2 MeV in Ar, 1.5 MeV in Cu, 3.5 MeV in Sn, and 5 MeV in Pb are likely to deposit 10% of their energy behind their starting plane. The practical range, R_p , is defined as that absorber thickness obtained by extrapolating to zero the linearly decreasing part of the curve of penetration probability vs. absorber thickness. Data for Al in the T range of the figure are available, and fit (to ~10%) $R_p = AT[1-B/(1+CT)]$ mg cm⁻² [a form suggested by K.-H. Weber, Nucl. Inst. Meth. 25, 261 (1964)], with $A=0.55$ mg cm⁻² keV⁻¹, $B=0.9841$, and $C=0.0030$ keV⁻¹. At this penetration depth, 90-95% of the incident electrons have stopped. Data for other elements are sketchy, but suggest that higher-Z (≤ 50) elements have $1 \lesssim R_p/R_p(Al) \lesssim 1.4$ below ~10 keV, and $0.6 \lesssim R_p/R_p(Al) \lesssim 1$ above ~100 keV. The "critical energy" (above which the energy loss due to bremsstrahlung exceeds that due to ionization, and showering becomes important) is 400 MeV for hydrogen, 100 MeV for carbon, 25 MeV for copper, and 10 MeV for lead. The mean positron range may differ from the mean electron range by several percent. See Berger and Seltzer, NASA SP-3012 (1964) and SP-3036, and P. Trower, UCRL-2426, Vol. III, Rev. (1966). 1-10 keV range was obtained by linear extrapolation; in this region the true range may actually lie above the curves.



XBL 762-2273

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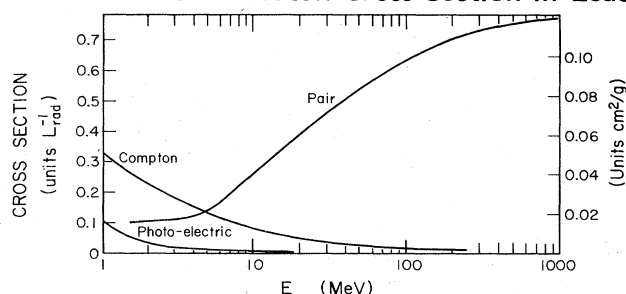
Fractional Energy Loss for e⁺ and e⁻ in Lead



XBL 743-2667

Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Moller (Bhabha) scattering when it is above.

Contributions to Photon Cross Section in Lead



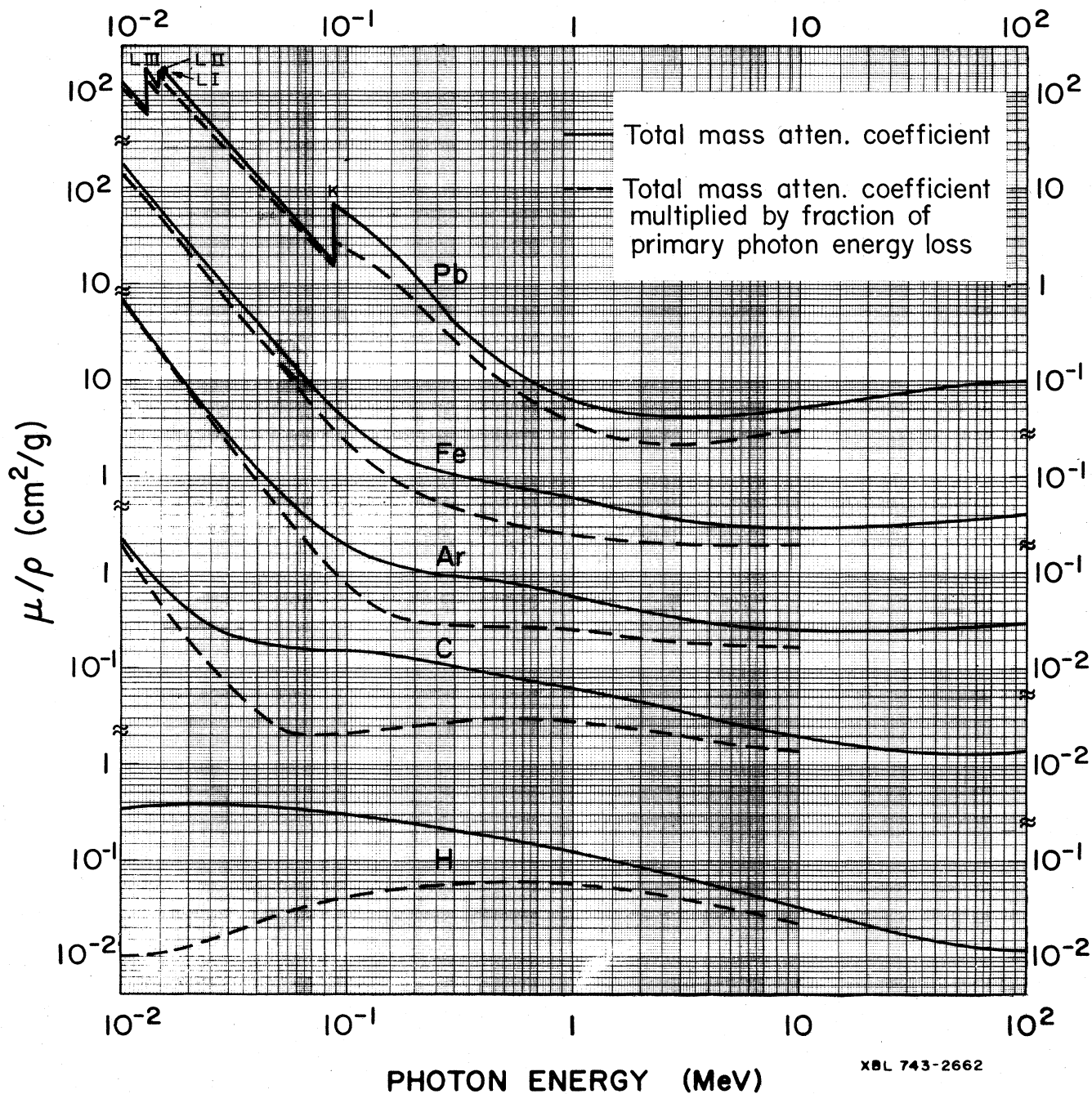
XBL 743-2668

Photon cross section in lead in inverse radiation lengths as a function of photon energy. The intensity of photons can be expressed as $I = I_0 \exp(-\sigma x)$, where σ is read above and x is the path length in radiation lengths. See also figure following.

These figures are adapted from Fig. 3.2 and Fig. 3.3 from Messel and Crawford, *Electron-Photon Shower Distribution Function Tables for Lead, Copper and Air Absorbers*, Pergamon Press, 1970. Messel and Crawford use $L_r(Pb) = 5.82$ g/cm², but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials (following), namely $L_r(Pb) = 6.4$ g/cm². The development of electron-photon cascades is approximately independent of absorber when the results are expressed in terms of inverse radiation lengths (i. e., scales on left of plots).

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

Photon Mass Attenuation Coefficients, Energy Deposition



The photon mass attenuation coefficient for various absorbers as a function of photon energy (solid curves). For a homogeneous medium of density ρ , the intensity I remaining after traversal of thickness t is given by $I = I_0 \exp(-\mu t)$. The accuracy is a few percent. Interpolation to other Z should be done in the cross section $\sigma = (\mu/\rho) M/N_A \text{ cm}^2/\text{atom}$, where M is the atomic weight of the absorber material and N_A is Avogadro's number. For a chemical compound or mixture, use $(\mu/\rho)_{\text{eff}} \approx \sum_i w_i (\mu/\rho)_i$, accurate to a few percent, where w_i is the proportion by weight of the i th constituent. The dashed curve is the mass energy-absorption coefficient, giving μ/ρ multiplied by the fraction of photon energy deposited in a small volume (assumed large enough to contain the ranges of most secondary electrons) about the interaction. This fraction is smaller than 1.0 because such processes as Compton scattering and electron bremsstrahlung imply radiation of some of the energy away from the immediate area. From J. H. Hubbell, NSRDS-NBS 29(1969).

PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

Atomic and Nuclear Properties of Materials*

Material	Z	A	Nuclear cross section σ^a [barns]	Nuclear collision length L_{coll}^b [g/cm ²]	Nuclear collision length L_{coll}^b [cm]	Absorption length λ^b [cm]	dE/dx min ^c [MeV/g/cm ²] [MeV/cm]		Radiation length L_{rad}^d [g/cm ²] [cm]		Density ^e [g/cm ³] () is for gas [g/l]	Refractive index n_r^e () is $(n-1) \times 10^6$ for gas
H ₂	1	1.01	0.039	43.0	607	790	4.12	0.292	63.05	890	{ 0.0708 (0.090)	{ 1.112 (140)
D ₂	1	2.01	0.074	45.1	273	342	2.07	0.342	126.1	764	0.163	1.128
He	2	4.00	0.134	49.6	397	478	1.94	0.243	94.32	755	{ 0.125 (0.178)	{ 1.024 (35)
Li	3	6.94	0.215	53.6	100.4	120.6	1.65	0.881	82.76	155	0.534	-
Be	4	9.01	0.270	55.4	30.0	36.7	1.61	2.97	65.19	35.3	1.848	-
C	6	12.01	0.340	58.7	≈37.8	49.9	1.78	≈2.76	42.70	≈27.5	≈1.55 ^f	-
N ₂	7	14.01	0.390	59.7	73.8	99.4	1.82	1.47	37.99	47.0	{ 0.808 (1.25)	{ 1.205 (300)
Ne	10	20.18	0.520	64.4	53.7	74.9	1.73	2.08	28.94	24.0	{ 1.207 (0.90)	{ 1.092 (67)
Al	13	26.98	0.650	68.9	25.5	37.2	1.62	4.37	24.01	8.9	2.70	-
Ar	18	39.95	0.890	74.5	53.2	80.9	1.51	2.11	19.55	14.0	{ 1.40 (1.78)	{ 1.233 (283)
Fe	26	55.85	1.160	79.9	10.2	17.1	1.48	11.6	13.84	1.76	7.87	-
Cu	29	63.54	1.270	83.1	9.3	14.8	1.44	12.9	12.86	1.43	8.96	-
Sn	50	118.69	2.040	96.6	13.2	22.8	1.28	9.4	8.82	1.21	7.31	-
W	74	183.85	2.810	108.6	5.6	10.3	1.17	22.6	6.76	0.35	19.3	-
Pb	82	207.19	3.080	111.7	9.8	18.5	1.13	12.8	6.37	0.56	11.35	-
U	92	238.03	3.380	116.9	≈6.2	12.0	1.09	≈20.7	6.00	≈0.32	≈18.95	-
Air				60.2	50000 ^g	67500 ^g	1.82	0.0022 ^g	36.20	30050 ^g	{ 0.001205 ^g (1.29)	{ 1.000273 ^g (293)
H ₂ O				58.3	58.3	78.8	2.03	2.03	36.08	36.1	1.00	1.33
H ₂ (bubble chamber 26°K) ^h				43.0	≈683	887	4.12	≈0.26	63.05	≈1000	≈0.063 ^h	1.112
D ₂ (bubble chamber 31°K) ^h				45.1	≈322	403	2.07	≈0.29	126.1	≈900	≈0.140 ^h	1.110
H-Ne mixture (50 mole percent) ⁱ				62.9	154.5	215	1.84	0.75	29.70	73.0	0.407	1.092
Propane (C ₃ H ₈) ^j				55.0	134	176	2.28	0.98	45.38	111	{ 0.41 ^j (2.0)	{ 1.25 ^j (1005)
Freon 13B1 (CF ₃ Br) ^j				74.3	≈49.5	73.5	1.52	≈2.3	16.53	≈11	{ ≈1.50 ^j (8.71)	{ 1.238 ^j (750)
Ilford emulsion				88.1	23.1	36.7	1.44	5.49	11.02	2.94	3.815	-
NaI				91.9	25.0	41.3	1.32	4.84	9.49	2.59	3.67	1.775
LiF				61.1	23.1	30.7	1.69	4.46	39.25	14.9	2.64	1.394
Polyethylene (CH ₂)				55.7	≈59.6	78.4	2.09	≈1.95	44.78	≈48	0.92-0.95	-
Mylar (C ₅ H ₄ O ₂)				58.5	42.1	56.1	1.91	2.65	39.95	28.7	1.39	-
Polystyrene, scintillator (CH) ^k				57.0	55.2	68.5	1.97	2.03	43.8	42.9	1.032	1.581
Lucite, Plexiglas (C ₅ H ₈ O ₂)				57.7	≈48.9	65.0	1.97	≈2.32	40.55	≈34.5	1.16-1.20	≈1.49
Spark or proportional chamber ^l					0.030%	0.022%	-	0.034		0.067%	0.019	-
Shielding concrete ^m				65.5	26.2	36.8	1.70	4.25	26.7	10.7	2.5	-
CO ₂ ⁿ				60.4	33800	46000	1.82	0.0033	36.2	20210	(1.79) ⁿ	(410) ⁿ
Freon 12 (CCl ₂ F ₂) ⁿ				68.1	13800	20200	1.64	0.0081	23.7	4810	(4.93) ⁿ	(1080) ⁿ
Freon 13 (CClF ₃) ⁿ				66.0	15000	21400	1.70	0.0072	27.15	6380	(4.26) ⁿ	(720) ⁿ
Silica Aerogel ^o				62.3	≈311	430	1.82	≈0.36	30	≈150	0.1-0.3	1.0+0.25 ρ

*) Table revised April 1980 by J. Engler and F. Mönig. For details, see CERN NP Internal Report 74-1.

a) σ of neutrons ($\approx \sigma$ of protons) at 20 GeV from Landolt-Bornstein, New Series I, Vol. 5. Energy dependence for all nuclei $\approx 1/2$ percent/GeV (from 5-25 GeV).

b) $L_{coll} = A/(N\sigma)$. In the absorption length the elastic scattering is subtracted.

c) For a minimum-ionizing, singly-charged particle in the material. From W.H. Barkas and M.J. Berger, Tables of Energy Losses and Ranges of Heavy Charged Particles, NASA-SP-3013 (1964).

d) From Y.S. Tsai, Rev. Mod. Phys. **46**, 815 (1974).

e) Values for solids, or the liquid phase at boiling point, except where noted. Values in parentheses for gaseous phase STP (0°C, 1 atm.), except where noted.

f) Density variable.

g) Gas at 20°C.

h) Density may vary about $\pm 3\%$, depending on operating conditions.

i) Values for typical working condition with H₂ target: 50 mole percent, 29°K, 7 atm.

j) Values for typical chamber working conditions: Propane $\sim 57^\circ\text{C}$, 8-10 atm. Freon 13B1 $\sim 28^\circ\text{C}$, 8-10 atm.

k) Typical scintillator; e.g. PILOT B and NE 102A have an atomic ratio H/C = 1.10.

l) Values for typical construction: 2 layers 50 μm Cu/Be wires, 8 mm gap, 60% argon, 40% isobutane or CO₂; 2 layers 50 μm Mylar/Aclar foils.

m) Standard shielding blocks, typical composition O₂ 52%, Si 32.5%, Ca 6%, Na 1.5%, Fe 2%, Al 4% plus reinforcing iron bars. Attenuation length $l = 115 \pm 5$ g/cm², also valid for earth (typical $\rho = 2.15$) from CERN-LRL-RHEL Shielding exp. UCRL 17841 (1968).

n) Used in Čerenkov counters, value at 26°C and 1 atm. Indices of refraction from E.R. Hayes, R.A. Schluter, and A. Tamosaitis, ANL-6916 (1964).

o) n(SiO₂) + 2n(H₂O) used in Čerenkov counters, ρ = density in g/cm³. From M. Cantin et al., Nucl. Instr. Meth. **118**, 177 (1974).

ELECTROMAGNETIC RELATIONS

Maxwell's Equations

Quantity	CGS (statcoul., statamp., sec cm ⁻¹)	MKSA (coul., amp., ohm)
Potentials:	$V = \sum \frac{q}{r}$ $\vec{A} = \frac{1}{c} \sum \frac{\vec{I}}{r}$ c = speed of light in vacuum	$V = \frac{1}{4\pi\epsilon_0} \sum \frac{q}{r}$ $\vec{A} = \frac{\mu_0}{4\pi} \sum \frac{\vec{I}}{r}$ $\epsilon_0 = \frac{1}{36\pi} 10^{-9}$ MKSA $\mu_0 = 4\pi 10^{-7}$ MKSA
Fields:	$\vec{E} = -\vec{\nabla}V - \frac{1}{c} \frac{\partial \vec{A}}{\partial t}$ $\vec{B} = \vec{\nabla} \times \vec{A}$	$\vec{E} = -\vec{\nabla}V - \frac{\partial \vec{A}}{\partial t}$ $\vec{B} = \vec{\nabla} \times \vec{A}$
Materials:	$\vec{D} = \epsilon \vec{E}, \vec{B} = \mu \vec{H}$	$\vec{D} = \epsilon \vec{E}, \vec{B} = \mu \vec{H}$
Force:	$\vec{F} = q(\vec{E} + \frac{\vec{v}}{c} \times \vec{B})$	$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$
Maxwell:	$\vec{\nabla} \cdot \vec{D} = 4\pi\rho$ $\vec{\nabla} \times \vec{E} = -\frac{1}{c} \frac{\partial \vec{B}}{\partial t}$ $\vec{\nabla} \cdot \vec{B} = 0$ $\vec{\nabla} \times \vec{H} = \frac{4\pi\vec{j}}{c} + \frac{1}{c} \frac{\partial \vec{D}}{\partial t}$	$\vec{\nabla} \cdot \vec{D} = \rho$ $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ $\vec{\nabla} \cdot \vec{B} = 0$ $\vec{\nabla} \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$
Relativistic transformations:	$\vec{E}'_{\parallel} = \vec{E}_{\parallel}$ $\vec{E}'_{\perp} = \gamma(\vec{E}_{\perp} + \frac{1}{c} \vec{v} \times \vec{B})$ $\vec{B}'_{\parallel} = \vec{B}_{\parallel}$ $\vec{B}'_{\perp} = \gamma(\vec{B}_{\perp} - \frac{1}{c} \vec{v} \times \vec{E})$	$\vec{E}'_{\parallel} = \vec{E}_{\parallel}$ $\vec{E}'_{\perp} = \gamma(\vec{E}_{\perp} + \vec{v} \times \vec{B})$ $\vec{B}'_{\parallel} = \vec{B}_{\parallel}$ $\vec{B}'_{\perp} = \gamma(\vec{B}_{\perp} - \frac{1}{c^2} \vec{v} \times \vec{E})$

Impedances: Alternating Currents (MKSA)

Ohm's law: $V = ZI, V = V_0 e^{i\omega t}$

- Impedance of self-inductance L: $Z = i\omega L$
- Impedance of a capacitor of capacitance C: $Z = \frac{1}{i\omega C}$
- Impedance of a flat conductor of width w at high frequency:
 $Z = \frac{(1+i)\rho}{w\delta}$

ρ = resistivity in $10^{-8} \Omega\text{m}$:

- ~1.7 for Cu
- ~2.4 for Au
- ~2.8 for Al
- (Al alloys may have up to double this value.)
- ~5.5 for W
- ~73 for SS 304
- ~100 for Nichrome

δ = effective skin depth

$$= \sqrt{\frac{\rho}{\pi\nu\mu}} \approx \frac{6.6 \text{ cm}}{\sqrt{\nu(\text{sec}^{-1})}} \text{ for Cu}$$

- Impedance of free space: $Z = \sqrt{\mu_0/\epsilon_0} = 376.7\Omega$

Capacitance C and Inductance L per Unit Length (MKSA)

- For flat plates of width w, separated by $d \ll w$:

$$C = \frac{\epsilon w}{d}, \quad L = \mu \frac{d}{w}$$

- For coax cable of interior and exterior radii r_1 and r_2 :

$$C = \frac{2\pi\epsilon}{\ln(r_2/r_1)}; \quad L = \frac{\mu}{2\pi} \ln(r_2/r_1);$$

ϵ = dielectric constant { 2 to 6 for plastics;
4 to 8 for porcelain, glasses;
 μ = magnetic susceptibility.

Transmission Lines (No Loss) (MKSA)

Velocity = $1/\sqrt{LC} = 1/\sqrt{\mu\epsilon}$

Impedance = $\sqrt{L/C}$

L and C are inductance and capacitance per unit length.

Synchrotron Radiation (CGS)

Energy loss/revolution = $\frac{4\pi}{3} \frac{e^2}{\rho} \beta^3 \gamma^4$, ρ = orbit radius.

For electrons ($\beta \approx 1$), $\frac{\Delta E(\text{MeV})}{\text{rev.}} = 0.0885 [E(\text{GeV})]^4 / \rho(\text{meter})$

Critical frequency: $\omega_c = 3\gamma^3 \frac{c}{\rho}$

Frequency spectrum (for $\gamma \gg 1$):

$$I(\omega) \approx 3.3 \frac{e^2}{c} \left(\frac{\omega\rho}{c}\right)^{1/3}, \quad \omega \ll \omega_c$$

$$I(\omega) \approx (1.0, 1.6, 1.6, 0.5, 0.08) \frac{e^2\gamma}{c} \text{ at } \frac{\omega}{\omega_c} = 0.01, 0.1, 0.2, 1.0, 2.0, \text{ respectively;}$$

$$I(\omega) \approx \sqrt{3\pi} \frac{e^2\gamma}{c} \left(\frac{\omega}{\omega_c}\right)^{1/2} e^{-2\omega/\omega_c}, \quad \omega \gtrsim 2\omega_c$$

The radiation is confined to angles $\lesssim 1/\gamma$ relative to the instantaneous direction of motion.

See J. D. Jackson, Classical Electrodynamics, 2nd edition (John Wiley & Sons, New York, 1975) for more formulae and details (Prepared April 1974; revised April 1980.)

RADIOACTIVITY AND RADIATION PROTECTION

Unit of activity = Curie:

1 Ci = 3.7×10^{10} disintegrations/sec

Unit of exposure dose for x and γ radiation = Roentgen:

1 R = $1 \text{ esu/cm}^2 = 87.8 \text{ erg/g}$ ($5.49 \times 10^7 \text{ MeV/g}$) of air

Unit of absorbed dose = rad:

1 rad = 100 erg/g ($6.25 \times 10^7 \text{ MeV/g}$) in any material

Unit of dose equivalent (for protection) = rem:

rems (Roentgen equivalents for man) = rads \times QF,

where QF (quality factor) depends upon the type of radiation and other factors. For γ rays and HE protons, QF \approx 1; for thermal neutrons, QF \approx 3; for fast neutrons, QF ranges up to 10; and for α particles and heavy ions, QF ranges up to 20.

Maximum permissible occupational dose for the whole body:

5 rem/year (maximum 3 rem/calendar quarter)

Fluxes (per cm²) to liberate 1 rad in carbon:

3.5×10^{17} minimum ionizing singly charged particles

4.0×10^9 photons of 1 MeV energy

(These fluxes are correct to within a factor of 2 for all materials.)

Natural background: 120 to 130 millirem/year

cosmic radiation (charged particles + neutrons) ~ 25

cosmic radiation (γ rays) ~ 25

radiation from rocks and air (γ rays) ~ 73

Cosmic ray background in counters: $\sim 1/\text{min/cm}^2/\text{ster}$

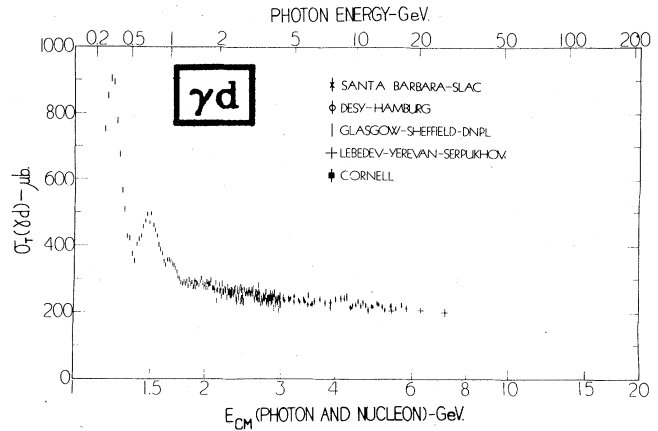
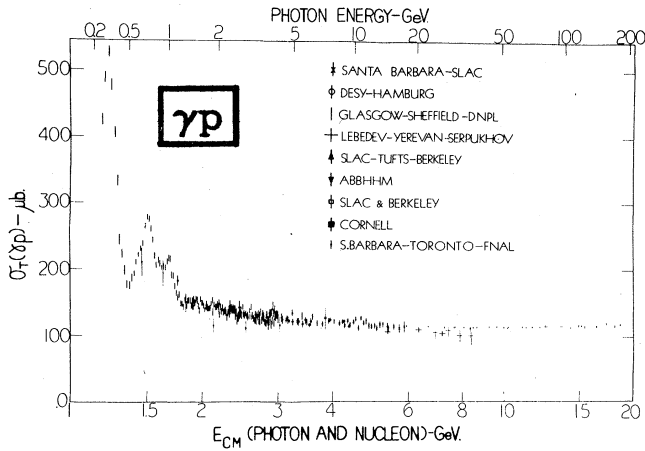
mrem/yr

C.M. ENERGY AND MOMENTUM VS. BEAM MOMENTUM

E_cm dE_cm = m_p dT_beam = m_p v_beam dp_beam ≈ m_p dp_beam

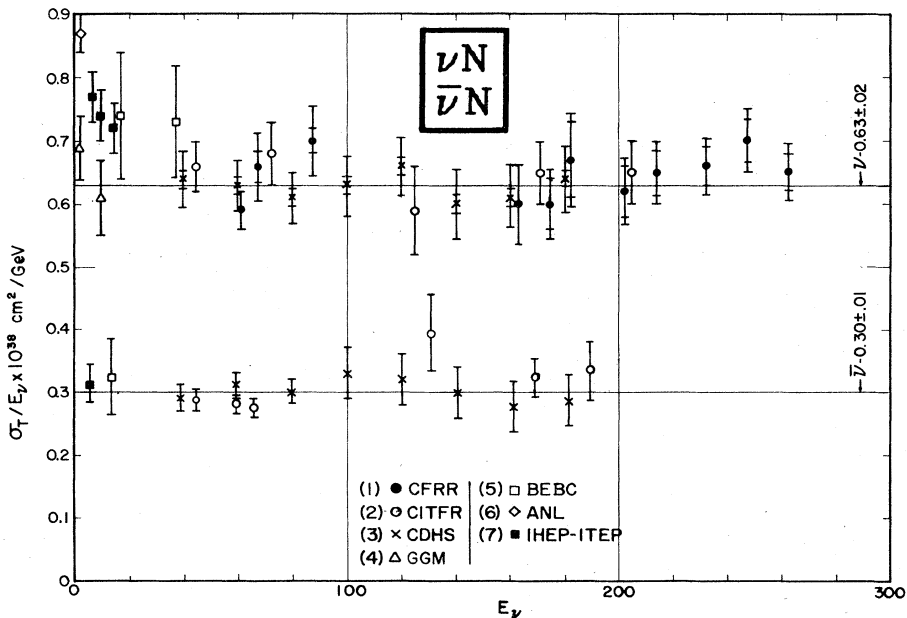
Table with 12 columns: PBEAM (GEV/C), C.M. ENERGY (GEV), MOMENTUM IN C.M. (GEV/C), PBEAM (GEV/C), C.M. ENERGY (GEV), MOMENTUM IN C.M. (GEV/C), PBEAM (GEV/C), C.M. ENERGY (GEV), MOMENTUM IN C.M. (GEV/C). Each column contains a series of numerical values for different particle types and beam momenta.

CROSS SECTION PLOTS



γp total cross section versus photon energy (top scale) and photon-plus-nucleon total center-of-mass energy (lower scale). References: SANTA BARBARA-SLAC: D.O.Caldwell et al., Phys. Rev. D7, 1362 (1973); DESY-HAMBURG: H.Meyer et al., Phys. Lett. 33B, 189 (1970); GLASGOW-SHEFFIELD-DNPL: T.A.Armstrong et al., Phys. Rev. D5, 1640 (1972); LEBEDEV-YEREVAN-SERPUKHOV: A.S.Belousov et al., Preprint 19, Moscow (1973), A.S.Belousov et al., Sov. Phys. Doklady 19, 123 (1974), and A.S.Belousov et al., Sov. J. Nucl. Phys. 21(3), 289 (1975); SLAC-BERKELEY-TUPTS: J.Ballam et al., Phys. Rev. D5, 545 (1972); ABBHHM: H.G.Hilpert et al., Phys. Lett. 27B, 474 (1968); SLAC and BERKELEY: J.Ballam et al., Phys. Rev. Lett. 21, 1544 (1968), and H.H.Bingham et al., Phys. Rev. D8, 1277 (1973); CORNELL: S.Michalowski et al., Phys. Rev. Lett. 39, 737 (1977); SANTA BARBARA-TORONTO-FNAL: D.O.Caldwell et al., Phys. Rev. Lett. 40, 1222 (1978). Courtesy Gething M. Lewis, Glasgow.

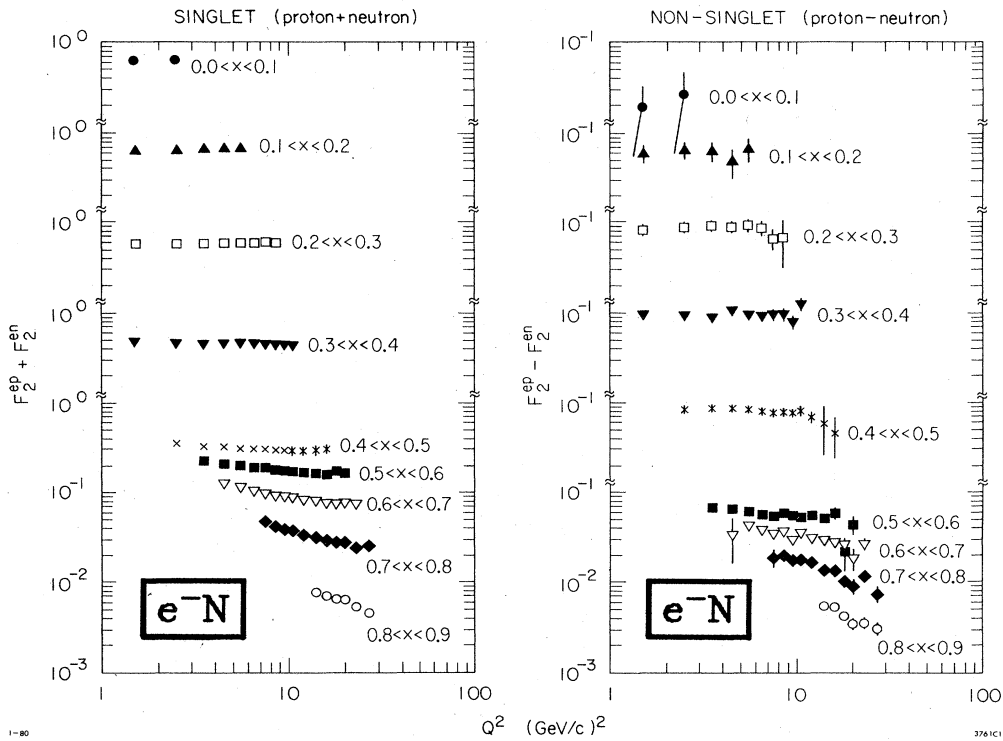
γd total cross section versus photon energy (top scale) and photon-plus-single-nucleon total center-of-mass energy (lower scale). References: SANTA BARBARA-SLAC: D.O.Caldwell et al., Phys. Rev. D7, 1362 (1973); DESY-HAMBURG: H.Meyer et al., Phys. Lett. 33B, 189 (1970); GLASGOW-SHEFFIELD-DNPL: T.A.Armstrong et al., Nucl. Phys. B41, 445 (1972); LEBEDEV-YEREVAN-SERPUKHOV: A.S.Belousov et al., Sov. J. Nucl. Phys. 21(3), 289 (1975); CORNELL: S.Michalowski et al., Phys. Rev. Lett. 39, 737 (1977). Courtesy Gething M. Lewis, Glasgow.



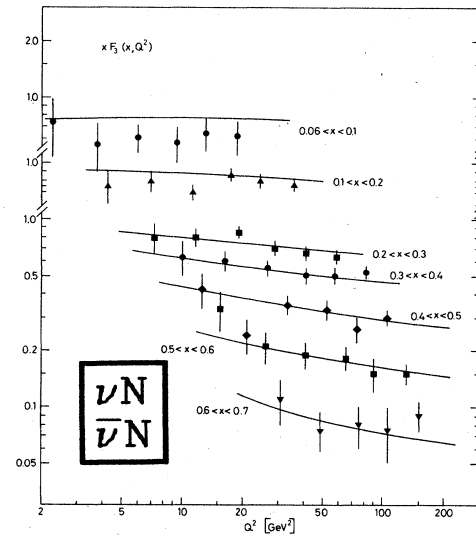
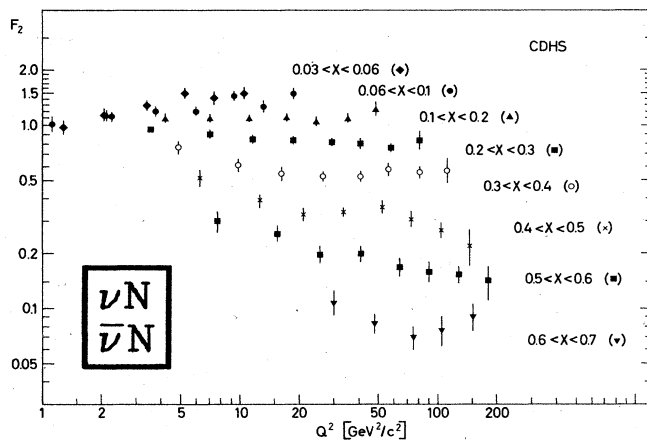
σ_T/E_ν for the muon neutrino and antineutrino charged-current total cross section as a function of neutrino energy. The straight lines are averages of all data. (1) B.Barish et al., Cal Tech preprint CALT 68-734 (1979); (2) B.C.Barish et al., Phys. Rev. Lett. 39, 1595 (1977); (3) J.G.H.de Groot et al., Z. Physik C - Particles and Fields 1, 143 (1979); (4) S.Ciampolillo et al., Phys. Lett. 84B, 281 (1979); (5) D.C.Colley et al., Z. Physik C - Particles and Fields 2, 187 (1979); (6) S.J.Barish et al., Phys. Rev. D19, 2521 (1979); (7) A.E.Asralyan et al., Phys. Lett. 76B, 239 (1978), and A.E.Muklin, Serpukhov preprint SERP-4-45 (1979). Courtesy D. Theriot, FNAL.

CROSS SECTION PLOTS (Cont'd)

Structure Functions

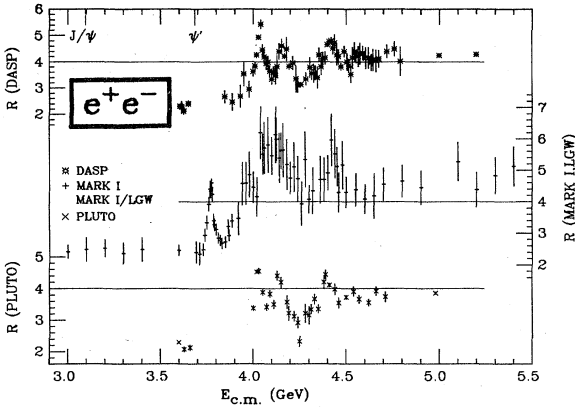


F_2 structure functions derived from inelastic electron-nucleon data taken at SLAC¹⁻⁴ with recoil mass >2 GeV and four-momentum transfer squared $Q^2 > 1(\text{GeV}/c)^2$ are shown. For definitions of F_2 , x , and Q^2 , see the "Relativistic Kinematics" section and the "Weak Interactions of Quarks and Leptons" section. $R \equiv \sigma_L/\sigma_T = 0.21^3$ was assumed. Systematic errors are comparable in size to the data point symbols. Corrections for nucleon motion in deuterium have been made. These corrections are small except for $x > 0.7$. No error was included to account for uncertainties in this correction. References: 1) A. Bodek et al., Phys. Rev. D20, 1471 (1979); 2) W.B. Atwood, SLAC Report No. 185 (1975); 3) M.D. Mestayer, SLAC Report No. 214 (1978); 4) S. Stein et al., Phys. Rev. D12, 1884 (1975). Courtesy W. B. Atwood, SLAC.

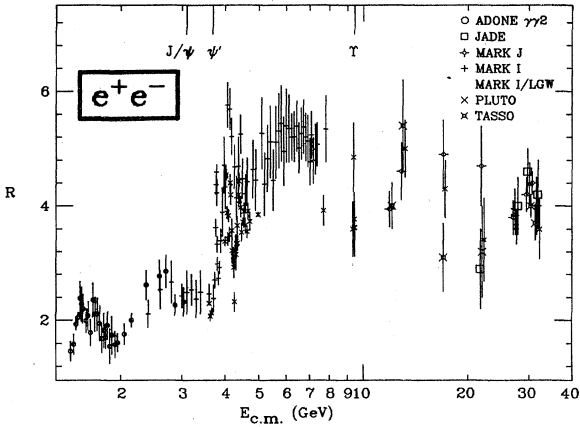


Nucleon structure functions as measured by the CDHS collaboration in high energy (30-200 GeV) charged-current neutrino- and anti-neutrino-nucleon scattering [J.G.H. de Groot et al., Z. Physik C - Particles and Fields 1, 143 (1979); reproduced by permission]. Definitions, and a discussion of the significance of these structure functions, may be found in the above reference, and also in the "Weak Interactions of Quarks and Leptons" section of the present work. See de Groot et al., for a discussion of experimental details, including corrections, etc. Curves are based on a QCD parametrization of Buras and Gaemers [Nucl. Phys. B132, 249 (1978)].

CROSS SECTION PLOTS (Cont'd)



An expanded view of R measurements around charm threshold. See the caption for the figure below for details (we have not combined any data points in this figure). We have arbitrarily added a horizontal line at R=4 as an aid to visual comparison of the three sets of data.

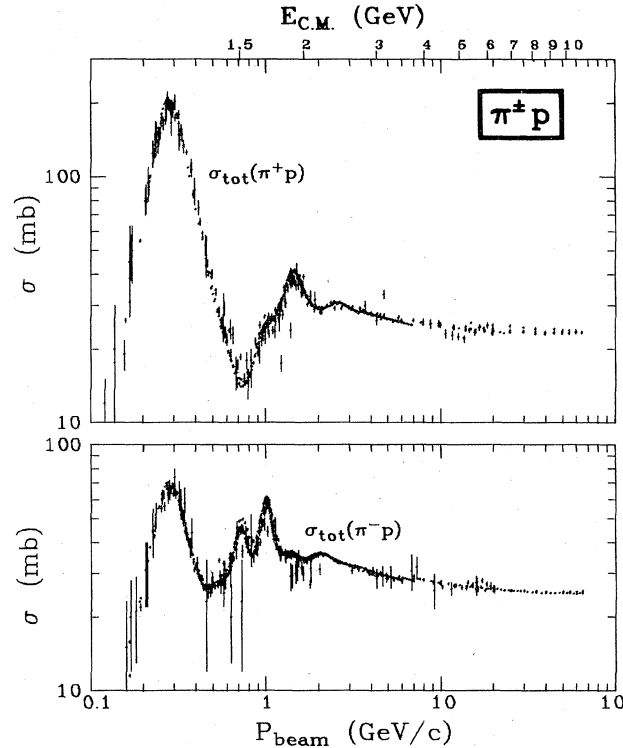


Measurements of $R \equiv \sigma(e^+e^- \rightarrow \text{hadrons})/\sigma(e^+e^- \rightarrow \mu^+\mu^-)$, where the annihilation proceeds via one photon. The denominator is a calculated quantity:

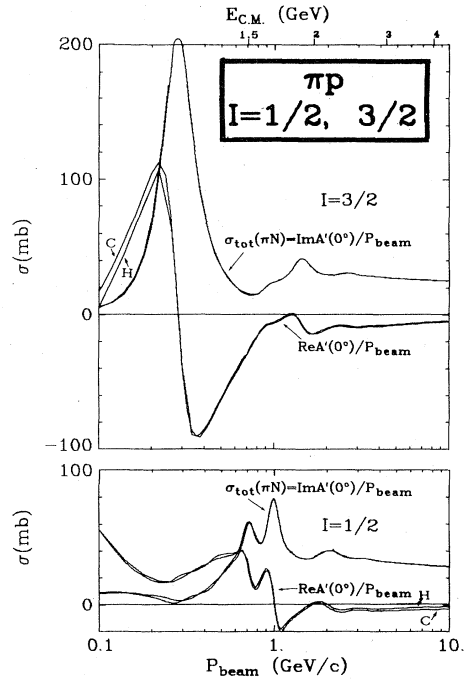
$$\sigma(e^+e^- \rightarrow \ell^+\ell^-) = (hc)^2 \frac{\alpha^2}{4E_{cm}^2} \beta_\ell \int_{(4\pi)} d\Omega_{cm} (2 - \beta_\ell^2 \sin^2 \theta_{cm})$$

$$\beta_{\ell=1} = \frac{4\pi}{3} (hc)^2 \frac{\alpha^2}{E_{cm}^2} = \frac{86.8}{[E_{cm}(\text{GeV})]^2} \text{ nb}; \quad \beta_\ell = \frac{v_\ell^{cm}}{E_{cm}};$$

for $e^+e^- \rightarrow \mu^+\mu^-$, $\beta_\mu \cong 1$ for energies shown. Radiative corrections and, where important, corrections for two-photon processes have been made. The J/ψ , ψ' , and T values are offscale at the positions indicated. Note the suppressed zero. The ADONE data is for ≥ 3 hadrons only, and the points in the ψ' region are from the MARK I - Lead Glass Wall (LGW) experiment. For clarity, some of the data points for $E_{cm} < 10$ GeV have been combined by us, and some of the points above 10 GeV have been shifted slightly ($< 2\%$) in E_{cm} . Systematic errors (not included in the figure) are typically between 10% and 20%. The horizontal extent of the plot symbols has no special significance. References: ADONE Y72: C. Bacci et al., PL 86B, 234 (1979); DASP: R. Brandelik et al., PL 75B, 361 (1978); JADE: W. Bartel et al., PL 88B, 171 (1979); MARK J: D.P. Barber et al., MIT Laboratory for Nuclear Science report #107 (1979), submitted to Nucl. Phys. B, H. Newman (private communication); MARK I: J.-E. Augustin et al., PRL 34, 764 (1975), W. Chinowsky, Ann. Rev. Nucl. Sci. 27, 393 (1977); MARK I + Lead Glass Wall: P.A. Rapidis et al., PRL 39, 526 (1977), P.A. Rapidis, Thesis, SLAC-Report-220 (1979); PLUTO: A. Bäcker, Thesis, Gesamthochschule Siegen, DESY F33-77/03, C. Gerke, Thesis, Hamburg University (1979), Ch. Berger et al., PL 81B, 410 (1979), Ch. Berger et al., PL 86B, 413 (1979); TASSO: R. Brandelik et al., DESY 79/74 (1979), submitted to Physics Letters. Courtesy F.C. Porter, Cal Tech.

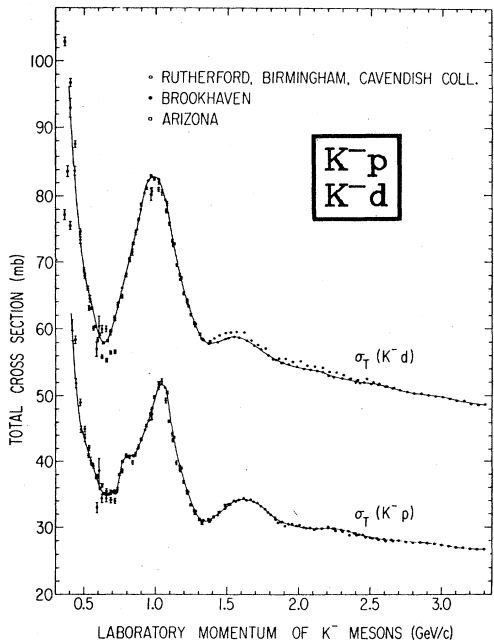


$\pi^\pm p$ total cross-section data from the Particle Data Group compilation "NN Two-Body Scattering Data," LBL-63 (1973).

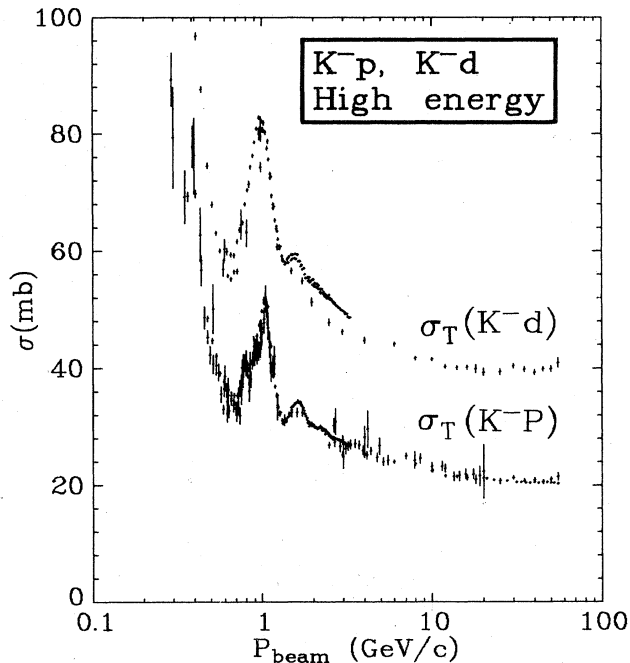


Interpolations of πN total cross sections for $I=3/2$ and $1/2$, and the corresponding real parts of the forward amplitudes as calculated from dispersion relations by A. A. Carter and J. R. Carter (RHEL preprint RL-73-024, 1973; labeled C above), and by G. Höhler and H. P. Jakob (private communication, 1972; labeled H above). The normalization of the curves for each value of I is such that the sum of their squares divided by 19.6 gives $d\sigma/dt$ at 0° in $\text{mb}/(\text{GeV}/c)^2$. For visual purposes, these old analyses are fine; for quantitative purposes, refer to G. Höhler et al., Handbook of Pion-Nucleon Scattering, Physik Daten Series No. 12-1 (1979), Fachinformationzentrum, Karlsruhe, Germany.

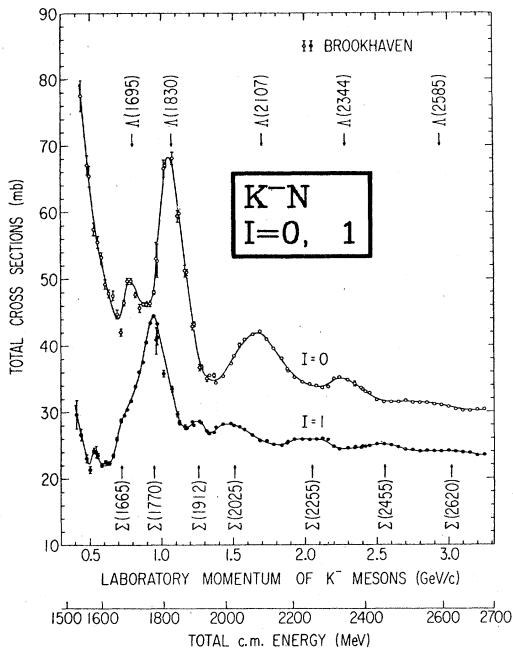
CROSS SECTION PLOTS (Cont'd)



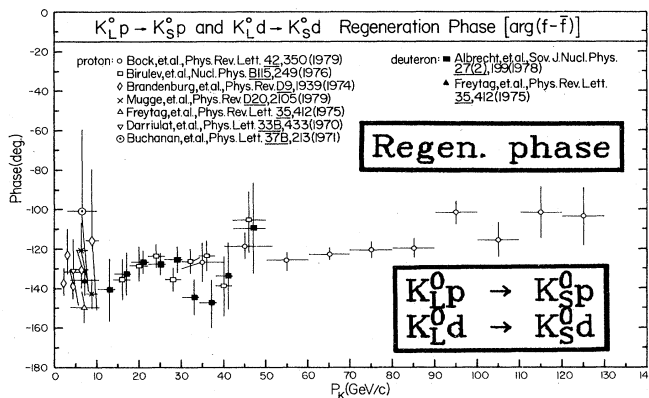
K^-p and K^-d total cross-section data compiled by Li et al., Proc. 1973 Purdue Conf. on Baryon Resonances. The solid curve passes through the Brookhaven data.



K^-p and K^-d total cross-section data. Compilation sources: E. Bracci et al., CERN/HERA 72-2, K^-p ; G.R. Lynch, K^-d (<3 GeV/c); Particle Data Group, K^-d (>3 GeV/c). The BNL data below 1 GeV/c are not included.

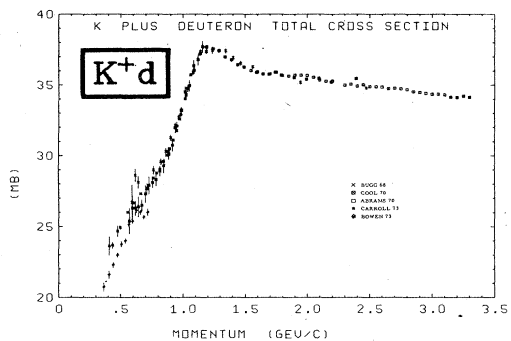
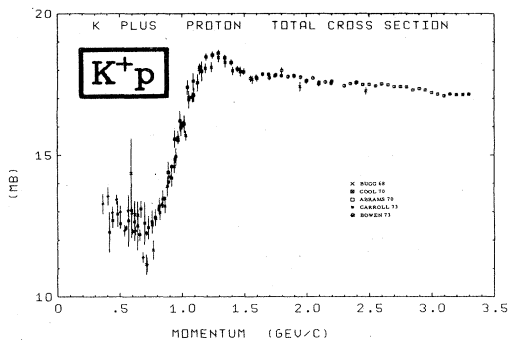


K^-N total cross sections for $I=0$ and $I=1$ below 3.3 GeV/c. Compiled and unfolded by Li et al., Proc. 1973 Purdue Conf. on Baryon Resonances.

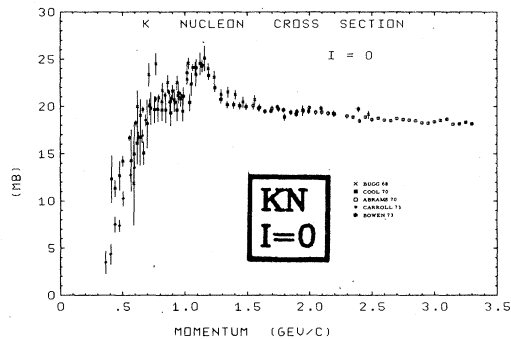


Phases of forward amplitudes for $K_L^0 p \rightarrow K_S^0 p$ (open symbols) and $K_L^0 d \rightarrow K_S^0 d$ (solid symbols). Courtesy S. Aronson, Brookhaven National Laboratory.

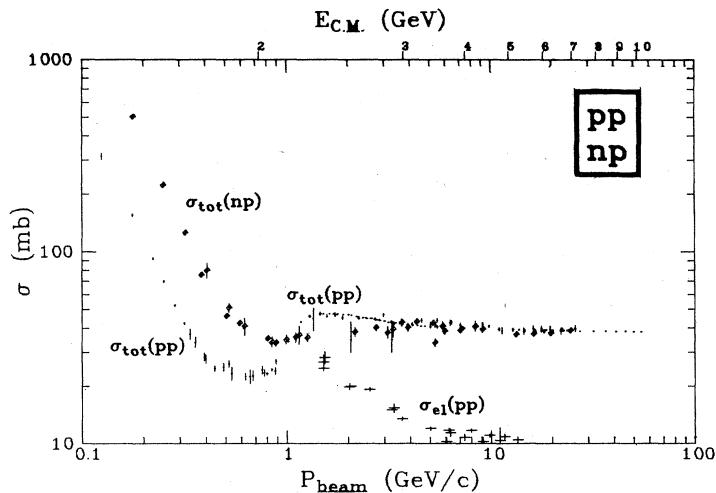
CROSS SECTION PLOTS (Cont'd)



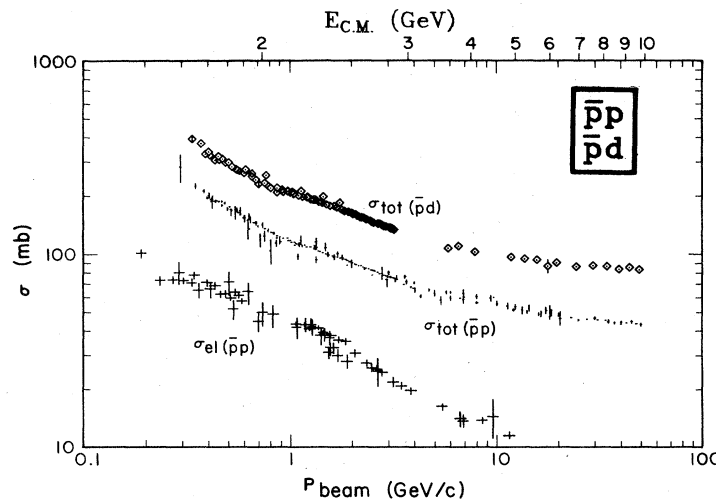
Compilation of K^+p and K^+d total cross-section measurements. References can be found in the Baryon Data Card Listings.



Total cross section for isospin zero KN system. Unfolding of the BUGG 68 and BOWEN 70 and 73 data was done by G. R. Lynch (as in Proc. of 1970 Duke Conference). Tables of σ_0 were provided by the BNL authors. Lynch and BNL use the same method of unfolding; the BOWEN 73 unfolded distribution is obtained by a different method [see plot in Z^+ mini-review in the 1976 edition of this review, Particle Data Group, Rev. Mod. Phys. 48, 1 (1976)].



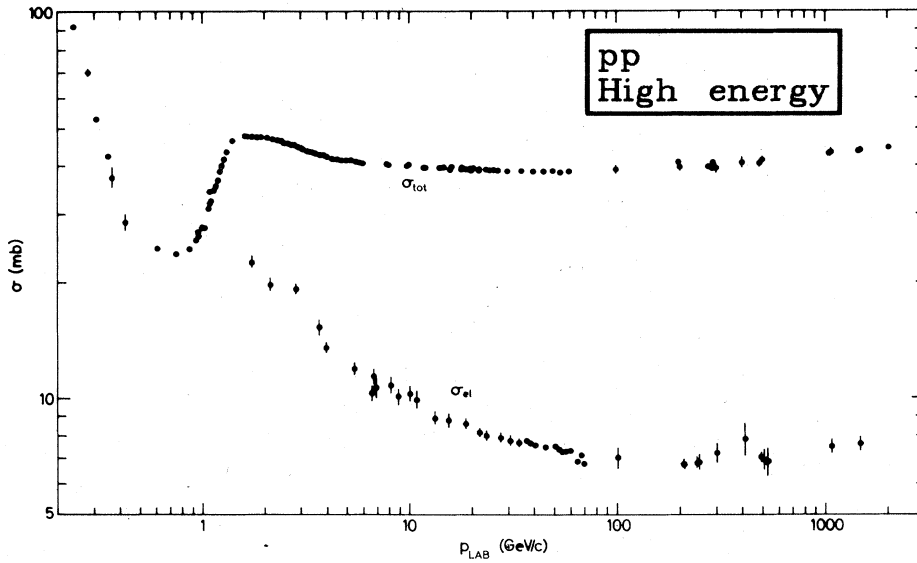
pp and np cross sections from Particle Data Group, "NN and ND Interactions -- A Compilation", UCRL-20 000 NN (August 1970); some points at higher energies added since original compilation.



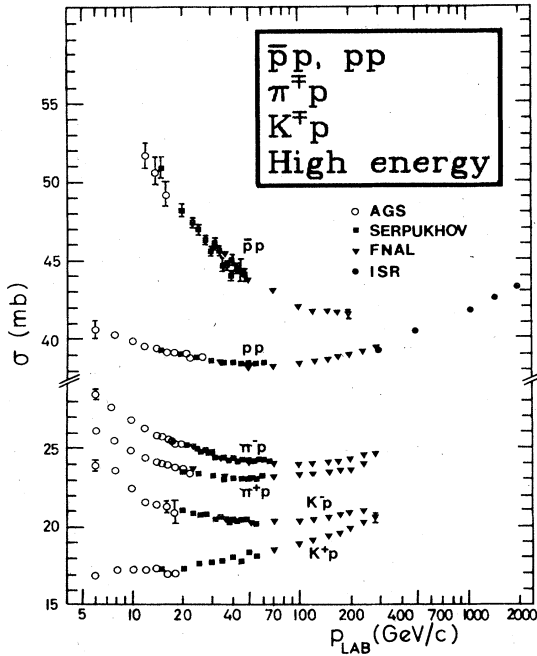
XBL 743-2661

$\bar{p}p$ and $\bar{p}d$ cross sections from Particle Data Group, "A Compilation of NN and ND Reactions," LBL-58 (1972); some points added since original compilation.

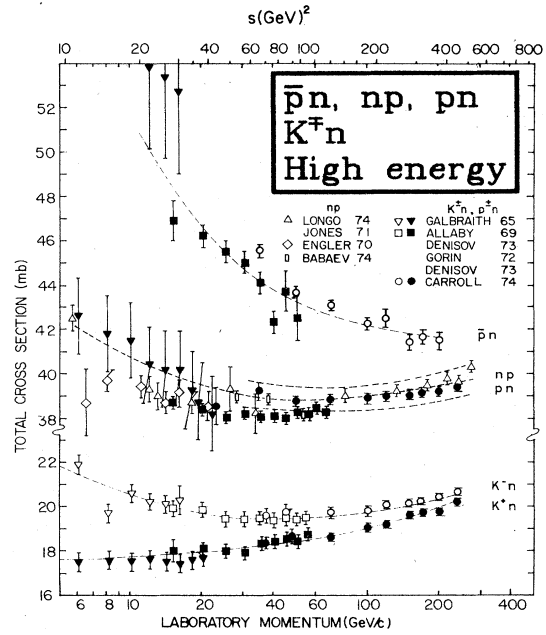
CROSS SECTION PLOTS (Cont'd)



Total and elastic pp cross-section data compiled by U. Amaldi, CERN.



$\bar{p}p$, pp , $\pi^- p$, $\pi^+ p$, $K^- p$, and $K^+ p$ total cross sections versus $s (\approx 2m_p p_{lab})$, as compiled by U. Amaldi, CERN.



$\bar{p}n$, np , pn , $K^- n$, and $K^+ n$ total cross sections versus $s (\approx 2m_p p_{lab})$, as compiled by G. Giacomelli, CERN.

DATA CARD LISTINGS

Illustrative Key

Name of particle as it appears in table. **XX(1200)**

Arrow indicates this particle omitted from table. **74 XX MESON (1200, JPC= -) I=1**

Quantity tabulated below. **74 XX(1200) MASS (MEV)**

M	1216.	11.	MERRILL	66 HBC	0 3.2 K-P	7/66
M	1192.	(16.)	LYNCH	67 HBC +-	2.7 PI-P	6/67
M	1198.	10.	PIERCE	68 ASPK +	2.1 K-P	9/68
M	(1208.)	7.	FENNER	69 HBC	0 4.2 PI+P	9/69
M	80 1210.	8.	SMITH	70 MMS	- 3.5 PI-P	2/79*
M	SUPERSEDES EARLIER RESULT					
M	AVG	1206.9	5.1		AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	

Code for quantity tabulated (M=mass, W=width, etc.)

Symbols used to key together data card and related comments.

Number of events above background.

Measured values (parentheses indicate value not used in average).

± Error in measured value (- field blank if error symmetric; parentheses on error only indicate data not used in average due to problems with error estimation).

Average value (and error) of quantity measured.

Vertical bar indicates average; width of horizontal bar on top is error (scaled) in average.

Value and error for each experiment.

Reaction producing particle, or comments.

Date this result punched (asterisk indicates result added or changed since previous edition).

Scale factor > 1 indicates inconsistent data.

Ideogram to display inconsistent data; curve is sum of Gaussians, one for each experiment (area of Gaussian = 1/error; width of Gaussian = ± error).

Contribution of experiment to χ^2 (if no entry present, experiment not used in calculating χ^2 or scale factor because of large error).

Partial decay mode (labeled by P_i).

Decay masses

Representative masses of decay products (used for calculating last column of Particle Property Tables)

Branching ratio (labeled by R_j).

Value (and error) of quantity measured, as determined from constrained fit (using all measured branching ratios for this particle).

Branching ratio R_j in terms of partial decay mode fractions P_i above.

Author(s)

References listed by year, then author.

Abbreviated reference form used on data cards above.

Journal, report, preprint, etc. (see abbreviations on next page).

Quantum number determinations in this reference

Institution(s) of author(s) (see abbreviations on next page).

74 XX(1200) MASS (MEV)

74 XX(1200) WIDTH (MEV)

74 XX(1200) PARTIAL DECAY MODES

74 XX(1200) BRANCHING RATIOS

REFERENCES FOR XX(1200)

Illustrative Key (cont'd)

Abbreviations

Journals

APAH	Acta Phys. Acad. Hungarica
ADVP	Advances in Physics
AMP	Annals of Physics
ARNS	Annual Review of Nuclear Science
ARPS	Bulletin of the Amer. Phys. Soc.
CJJP	Canadian Journal of Physics
JAP	Journal of Applied Physics
JETP	English Transl. of Soviet Physics JETP
JETPL	Letters of Soviet Physics JETP
JFA	Journal of Physics A
JPG	Journal of Physics G
JPSJ	Journal of the Phys. Soc. of Japan
LNC	Letters to Nuovo Cimento
NC	Nuovo Cimento
NIM	Nuclear Instruments and Methods
NP	Nuclear Physics
PL	Physics Letters
PN	Particles and Nuclei
PSL	Proc. of the Phys. Soc. of London
PR	Physical Review
PRAM	Pramana
PRL	Physical Review Letters
PRSE	Proc. of the Royal Soc. of Edinburgh
PRSL	Proc. of the Royal Soc. of London
PTP	Progress of Theoretical Physics
RMP	Reviews of Modern Physics
RRP	Revue Romaine de Physique
SJNP	Soviet Journal of Nuclear Physics
SPU	Soviet Physics - Uspekhi
ZNAT	Zeitschrift fur Naturforschung
ZPHY	Zeitschrift fur Physik

Conferences

Conferences are referred to by the location in which they were held (e.g., DUBNA, BOULDER, LUND, etc.).

Institutions

AACH	Technische Univ. Aachen	Aachen, Germany
AARH	Aarhus Univ.	Aarhus, Denmark
ABO	Abo Akademi	Abo, Finland
ADEL	Adelphi Univ.	Garden City, N. Y., USA
AERE	Atomic Energy Res. Estab.	Harwell, Berks., England
AICHI	Aichi Educational Univ.	Toyota, Aichi Pref., Japan
ALBA	State Univ. of New York at Albany	Albany, N. Y., USA
ALBE	Alberta Univ., NRC	Edmonton, Canada
AMST	Univ. of Amsterdam	Amsterdam, Netherlands
ANKA	Middle East Technical Univ.	Ankara, Turkey
ANL	Argonne National Lab.	Argonne, Ill., USA
ARIZ	Univ. of Arizona	Tucson, Ariz., USA
ATEN	Nuclear Res. Centre Demokritos	Athens, Greece
ATHU	Univ. of Athens	Athens, Greece
AUCK	Univ. of Auckland	Auckland, New Zealand
BARC	Univ. de Barcelona	Barcelona, Spain
BARI	Univ. di Bari	Bari, Italy
BART	Bartol Research Foundation	Swarthmore, Pa., USA
BASL	Basel Univ.	Basel, Switzerland
BEDF	Bedford College	London, England
BELG	Inst. Interuniv. des Sci. Nuc.	Bruxelles, Belgium
BELL	Bell Labs.	Murray Hill, N. J., USA
BERG	Univ. of Bergen	Bergen, Norway
BERL	Inst. Hochenergiephys. DAW	Zeuthen/Berlin, DDR
BERN	Univ. Bern	Bern, Switzerland
BGNA	Univ. di Bologna	Bologna, Italy
BING	State Univ. of New York at Binghamton	Binghamton, N. Y., USA
BIRM	Birmingham Univ.	Birmingham, England
BNL	Brookhaven National Lab.	Upton, L.I., N. Y., USA
BOHR	Niels Bohr Inst.	Copenhagen, Denmark
BOIS	Boise State Univ.	Boise, Idaho, USA
BONN	Univ. Bonn	Bonn, Germany
BORD	Univ. de Bordeaux	Bordeaux, France
BOST	Boston Univ.	Boston, Mass., USA
BRAN	Brandeis Univ.	Waltham, Mass., USA
BRCC	Univ. of British Columbia	Vancouver, Canada
BRIIS	H. H. Willis Phys. Lab., U. of Bristol	Bristol, England
BROW	Brown Univ.	Providence, R. I., USA
BRUX	Univ. Libre de Bruxelles	Bruxelles, Belgium
BUCH	Bucharest State Univ.	Bucharest, Rumania
BUDA	Central Research Inst. of Physics	Budapest, Hungary
BUFF	State Univ. of New York at Buffalo	Buffalo, N. Y., USA
CAEN	Lab. de Phys. Corpusculaire	Caen, France
CAMB	Cambridge Univ.	Cambridge, England
CANB	Australian National Univ.	Canberra, Australia
CARL	Carleton Univ.	Ottawa, Canada
CARN	Carnegie-Mellon Univ.	Pittsburgh, Pa., USA
CASE	Case Western Reserve Univ.	Cleveland, Ohio, USA
CATH	Catholic Univ. of America	Washington, D. C., USA
CAVE	Cavendish Lab., Cambridge Univ.	Cambridge, England
CCAC	Community College of Allegheny County	Pittsburgh, Penn., USA
CDEF	College de France	Paris, France
CEA	Cambridge Electron Accel.	Cambridge, Mass., USA
CENG	CEN, Grenoble	Grenoble, France

Measurement Techniques

ASPK	Automatic spark chambers
CC	Cloud chamber
CNTR	Counters
DASP	DESY double-arm spectrometer
DBC	Deuterium bubble chamber
DLCO	SLAC-SPEAR DELCO detector
DPWA	Energy-dependent PWA
ELEC	Electronic combination
EMUL	Emulsions
FBC	Freon bubble chamber
FRAB	ADONE BB Group detector
FRAG	ADONE YY Group detector
FRAM	ADONE MEA Group detector
HBC	Hydrogen bubble chamber
HEBC	Helium bubble chamber
HLBC	Heavy liquid bubble chamber
HYBR	Hybrid: BC + electronics
IPWA	Energy-independent PWA
MMS	Missing mass spectrometer
MPWA	Model-dependent PWA
NEUL	Neuland large-angle ν spectrometer
OMEG	CERN OMEGA spectrometer
OSPK	Optical spark chamber
PBC	Propane bubble chamber
PLAS	Plastic detector
PLUT	DESY PLUTO detector
PWA	Partial-wave analysis
RVUE	Review of previous data
SFM	CERN split field magnet
SMAG	SPEAR magnetic detector
SMK2	SLAC Mark II detector
SPEC	Spectrometer
SPRK	Spark chamber
STRC	Streamer chamber
WIRE	Wire chamber
XEBC	Xenon bubble chamber

CERN	European Org. for Nuclear Research	Geneva, Switzerland
CHIC	Univ. of Chicago	Chicago, Ill., USA
CINC	Univ. of Cincinnati	Cincinnati, Ohio, USA
CIT	Calif. Inst. of Technology	Pasadena, Calif., USA
CNRC	Canadian National Research Council	Ottawa, Canada
COLO	Univ. of Colorado	Boulder, Colo., USA
COLU	Columbia Univ.	New York, N. Y., USA
CORN	Cornell Univ.	Ithaca, N. Y., USA
COSU	Colorado State Univ.	Fort Collins, Colo., USA
CRAC	Inst. for Nuclear Research	Cracow, Poland
CUNY	City Univ. of New York	New York, N. Y., USA
CURI	Laboratoire Joliot-Curie	Paris, France
DARE	Daresbury Nuclear Physics Lab.	Daresbury, England
DART	Dartmouth College	Hanover, N. H., USA
DESY	Deutsches Elektronen-Synchrotron	Hamburg, Germany
DORT	Univ. Dortmund	Dortmund, Germany
DUKE	Duke Univ.	Durham, N. C., USA
DURH	Univ. of Durham	Durham, England
DUUC	University College	Dublin, Ireland
EDIN	Univ. of Edinburgh	Edinburgh, Scotland
EFT	Enrico Fermi Inst. for Nucl. Studies	Chicago, Ill., USA
EPOL	Ecole Polytechnique	Paris, France
ETH	Swiss Federal Inst. of Technology	Zurich, Switzerland
FIRZ	Univ. di Firenze	Firenze, Italy
FISK	Fisk Univ.	Nashville, Tenn., USA
FLOR	Univ. of Florida	Gainesville, Fla., USA
FNAL	Fermi National Accelerator Lab.	Batavia, Ill., USA
FOM	Found. for Fundamental Res. on Matter	Utrecht, Netherlands
FRAS	Lab. Nazionali del C.N.E.N.	Frascati, Italy
FREI	Univ. of Freiburg	Freiburg, Germany
FSU	Florida State Univ.	Tallahassee, Fla., USA
GENO	Univ. di Genova	Genova, Italy
GESC	General Electric Res. and Dev. Center	Schenectady, N. Y., USA
GEVA	Univ. de Geneve	Geneva, Switzerland
GLAS	Univ. of Glasgow	Glasgow, Scotland
GRAZ	Univ. Graz	Graz, Austria
GREEN	Inst. des Sci. Nuc., Univ. de Grenoble	Grenoble, France
GSCO	Geological Survey of Canada	Ottawa, Canada
HAIF	Technion - Israel Inst. of Technology	Haifa, Israel
HAMB	Univ. Hamburg	Hamburg, Germany
HARV	Harvard Univ.	Cambridge, Mass., USA
HAWA	Univ. of Hawaii	Honolulu, Hawaii, USA
HEID	Univ. Heidelberg	Heidelberg, Germany
HELS	Helsingin Yliopisto	Helsinki, Finland
HIRO	Hiroshima Univ.	Hiroshima, Japan
HOUS	Univ. of Houston	Houston, Texas, USA
IBM	International Business Machines	Palo Alto, Calif., USA
IIT	Illinois Inst. of Tech.	Chicago, Ill., USA
ILL	Univ. of Illinois	Urbana, Ill., USA
ILLC	Univ. of Illinois at Chicago	Chicago, Ill., USA
ILLG	Inst. Laue-Langevin	Grenoble, France
IND	Univ. of Indiana	Bloomington, Ind., USA
INNS	Phys. Inst., Univ. Innsbruck	Innsbruck, Austria
IOWA	Univ. of Iowa	Iowa City, Iowa, USA

Illustrative Key (cont'd)

Abbreviations (cont'd)

Institutions (cont'd)

IPN	Inst. de Phys. Nucleaire	Orsay, France	OXF	Oxford Univ.	Oxford, England
IPNP	Inst. de Physique Nucleaire	Paris, France	PADO	Univ. di Padova	Padova, Italy
IPPC	Inst. for Particle Physics of Canada	Montreal, Canada	PATR	Univ. of Patras	Patras, Greece
IRAD	Inst. du Radium	Paris, France	PAVI	Univ. di Pavia	Pavia, Italy
ISU	Iowa State Univ.	Ames, Iowa, USA	PENN	Univ. of Pennsylvania	Philadelphia, Pa., USA
ITEP	Inst. for Theor. and Exp. Phys.	Moscow, USSR	PISA	Univ. di Pisa	Pisa, Italy
IUPUI	Indiana U. - Purdue U. at Indianapolis	Indianapolis, Ind., USA	PITT	Univ. of Pittsburgh	Pittsburgh, Pa., USA
JAGL	Jagellonian Univ.	Cracow, Poland	PPA	Princeton-Penn. Proton Accel.	Princeton, N. J., USA
JHU	Johns Hopkins Univ.	Baltimore, Md., USA	PRAG	Inst. of Physics, CSAV	Prague, Czechoslovakia
JINR	Joint Inst. for Nucl. Research	Dubna, USSR	PRIN	Princeton Univ.	Princeton, N. J., USA
KANS	Univ. of Kansas	Lawrence, Kansas, USA	PSLL	Physical Science Lab.	Lafayette, Ind., USA
KARL	Univ. Karlsruhe	Karlsruhe, Germany	PURD	Purdue Univ.	Rehovoth, Israel
KEK	Nat. Lab for High Energy Phys., Japan	Tsukuba-gun, Japan	REHO	Weizmann Inst. of Sci.	Chilton, Did., Berks., England
KENT	Kent Univ. at Canterbury, Kent	Canterbury, England	RHEL	Rutherford High Energy Lab.	Houston, Texas, USA
KEYN	Open Univ.	Milton Keynes, England	RICE	William Marsh Rice Univ.	Roskilde, Denmark
KIAE	Kurchatov Inst. of Atomic Energy	Moscow, USSR	RISO	Research Estab. Riso	Chilton, Did., Berks., England
KIEV	Physical-Technical Inst.	Kiev, USSR	RL	Rutherford Lab. (formerly RHEL)	Shrivenham, England
KINK	Kinki Univ.	Osaka, Japan	RMCS	Royal Military College of Science	Rochester, N. Y., USA
KNTY	Univ. of Kentucky	Lexington, Ky., USA	ROCH	Univ. of Rochester	New York, N. Y., USA
KONA	Konan Univ.	Kobe, Japan	ROCK	Rockefeller Univ.	Roma, Italy
KONS	B. P. Konstantinov Inst. of Nucl. Phys.	USSR	ROMA	Univ. di Roma	Terre Haute, Ind., USA
LALO	Linear Accelerator Lab, Orsay	Orsay, France	ROSE	Rose Polytechnic Inst.	New Brunswick, N. J., USA
LANC	Lancaster Univ.	Lancaster, England	RUTG	Rutgers Univ.	GiF-sur-Ivette, France
LAPP	Lapp Univ.	Annecy, France	SACL	Cntr. d'Etudes Nucl. Saclay	Saga, Japan
LASL	U. C. Los Alamos Scientific Lab.	Los Alamos, N. M., USA	SAGA	Saga Univ.	Roma, Italy
LAUS	Univ. of Lausanne	Lausanne, Switzerland	SANI	Ist. Superiore di Sanita	San Bernardino, Calif., USA
LBL	U. C. Lawrence Berkeley Lab.	Berkeley, Calif., USA	SBER	San Bernardino State College	Seattle, Wash., USA
LCGT	Lab. di Cosmo-Geofisica del CNR	Torino, Italy	SEAT	Seattle Pacific College	Vienna, Austria
LEBD	Lebedev Physics Inst.	Moscow, USSR	SEB	Research Center Selbersdorf	Serpukov, USSR
LEED	Univ. of Leeds	Leeds, England	SERP	Inst. of High Energy Physics	South Orange, N. J., USA
LEHI	Lehigh Univ.	Bethlehem, Pa., USA	SETO	Seton Hall Univ.	Tampa, Fla., USA
LEID	Inst. Lorentz	Leiden, Netherlands	SFLA	Univ. of South Florida	Sheffield, England
LENI	Inst. of Nucl. Phys., USSR Acad. Sci.	Leningrad, USSR	SHEF	Univ. of Sheffield	Southampton, England
LIBH	Lab. Interuniv. Belge High Eng.	Bruxelles, Belgium	SHMP	Univ. of Southampton	Siberia, USSR
LINZ	Linz Inst. fur Physik, Kepler Hoch.	Linz, Austria	SIBE	Inst. of Nucl. Phys., USSR Acad. Sci.	Huttental, Germany
LIVP	Liverpool Univ.	Liverpool, England	SIEG	Gesamthochschule Siegen	Villigen, Switzerland
LLL	Lawrence Livermore Lab.	Livermore, Calif., USA	SIN	Swiss Inst. of Nuclear Research	Stanford, Calif., USA
LOIC	Imperial Col. of Sci. and Tech.	London, England	SLAC	Stanford Linear Accel. Center	North Dartmouth, Mass., USA
LOQM	Queen Mary College	London, England	SMAS	Southeastern Massachusetts Univ.	Sofia, Bulgaria
LOUC	University College	London, England	SOFI	Bulgarian Acad. of Sci.	Stanford, Calif., USA
LOWC	Westfield College	London, England	STAN	Stanford Univ.	Hoboken, N. J., USA
LPNP	Lab. de Phys. Nucl. et Hautes Energies	Paris, France	STEV	Stevens Inst. of Tech.	St. Louis, Mo., USA
LPTP	Lab. de Phys. Theor. et Hautes Energies	Paris, France	STLO	St. Louis Univ.	Stockholm, Sweden
LRL	U. C. Lawrence Berkeley Lab.	Berkeley, Calif., USA	STOH	Stockholm Univ.	Stony Brook, L.I., N. Y., USA
LSU	Louisiana State Univ.	Baton Rouge, La., USA	STON	State Univ. of New York at Stonybrook	Strasbourg, France
LUND	Univ. I Lund	Lund, Sweden	STRB	Centre des Res. Nucleaires	Surrey, England
MADR	Junta de Energia Nuclear	Madrid, Spain	SURR	Univ. of Surrey	Falmer, Brighton, England
MADU	Univ. Autonome de Madrid	Madrid, Spain	SUSS	Univ. of Sussex	Syracuse, N. Y., USA
MANH	Mamhattan College	New York, N. Y., USA	SYRA	Syracuse Univ.	College Station, Texas, USA
MANI	Univ. of Manitoba	Winnipeg, Canada	TAMU	Texas A and M Univ.	Bombay, India
MANZ	Univ. Mainz	Mainz, Germany	TATA	Tata Inst. of Fundamental Research	Tel-Aviv, Israel
MASA	Univ. of Massachusetts	Amherst, Mass., USA	TELA	Univ. of Tel-Aviv	Philadelphia, Pa., USA
MASB	Univ. of Massachusetts	Boston, Mass., USA	TEMP	Temple Univ.	Knoxville, Tenn., USA
MCGI	McGill Univ.	Montreal, Canada	TENN	Univ. of Tennessee	Austin, Texas, USA
MCHS	Univ. Manchester	Manchester, England	TEXA	Univ. of Texas	Tomsk, USSR
MELB	Univ. of Melbourne	Parkville, Australia	TMSK	Nucl. Phys. Inst., Tomsk Polytech Inst.	Toronto, Canada
MHGO	Mount Holyoke College	South Hadley, Mass., USA	TWTO	Univ. of Toronto	Sendai, Japan
MICH	Univ. of Michigan	Ann Arbor, Mich., USA	TOHO	Tohoku Univ.	Tokyo, Japan
MILA	Univ. di Milano	Milano, Italy	TOKY	Univ. of Tokyo	Torino, Italy
MINN	Univ. of Minnesota	Minneapolis, Minn., USA	TORI	Univ. di Torino	Vancouver, Canada
MIOH	Miami Univ.	Oxford, Ohio, USA	TRIU	TRIUMF, Univ. of British Columbia	Trieste, Italy
MIT	Massachusetts Inst. of Technology	Cambridge, Mass., USA	TRST	Univ. di Trieste	Medford, Mass., USA
MODE	Ist. di Fisica dell Univ.	Modena, Italy	TUFT	Tufts Univ.	Tokyo, Japan
MONP	Univ. de Montpellier	Montpellier, France	TWAS	Waseda Univ.	Belgrade, Yugoslavia
MONS	Univ. de l'Etat, Mons	Mons, Belgium	UBEL	Univ. of Belgrade	Berkeley, Calif., USA
MONT	Univ. de Montreal	Montreal, Canada	UCB	Univ. of Calif. at Berkeley	Davis, Calif., USA
MOSU	Moscow State Univ.	Moscow, USSR	UCD	Univ. of Calif. at Davis	Irvine, Calif., USA
MPEI	Moscow Phys. Eng. Inst.	Moscow, USSR	UCI	Univ. of Calif. at Irvine	Los Angeles, Calif., USA
MPHI	Max Planck Inst. fur Phys.--Astrophys.	Heidelberg, Germany	UCLA	Univ. of Calif. at Los Angeles	Oak Ridge, Tenn., USA
MPIM	Max Planck Inst. fur Phys.--Astrophys.	Munich, Germany	UCND	Union Carbide Nuclear Division	Riverside, Calif., USA
MSNA	Ist. di Fisica dell Univ.	Messina, Italy	UCR	Univ. of Calif. at Riverside	Santa Barbara, Calif., USA
MSU	Michigan State Univ.	East Lansing, Mich., USA	UCSB	Univ. of Calif. at Santa Barbara	Santa Cruz, Calif., USA
MTHO	Mt. Holyoke College	South Hadley, Mass., USA	UCSC	Univ. of Calif. at Santa Cruz	La Jolla, Calif., USA
MULH	Centre Univ. du Haut-Rhin	Mulhouse, France	UCSD	Univ. of Calif. at San Diego	College Park, Md., USA
MUNC	Univ. of Munich	Munich, Germany	UMD	Univ. of Maryland	Schenectady, N. Y., USA
MURA	Midwestern Univ. Research Assoc.	Stroughton, Wisc., USA	UNCS	Union College	Durham, N. H., USA
NAGO	Nagoya Univ.	Nagoya, Japan	UNH	Univ. of New Hampshire	East Orange, N. J., USA
NAPL	Univ. di Napoli	Napoli, Italy	UPNJ	Uppsala College	Uppsala, Sweden
NASA	NASA, Goddard Space Flight Center	Greenbelt, Md., USA	UPPS	Gustaf Werner Inst.	Salt Lake City, Utah, USA
NDAM	Univ. of Notre Dame	Notre Dame, Ind., USA	UTAH	Univ. of Utah	Utrecht, Netherlands
NEAS	Northeastern Univ.	Boston, Mass., USA	UTRE	Univ. of Utrecht	Nashville, Tenn., USA
NEUC	Univ. de Neuchatel	Neuchatel, Switzerland	VAND	Vanderbilt Univ.	Victoria, Canada
NEVI	Nevis Lab.	Irvington-on-Hudson, N. Y., USA	VICT	Univ. of Victoria	Vienna, Austria
NIJM	R. K. Univ. Nijmegen	Nijmegen, Netherlands	VIRG	Inst. for High Energy Physics, A. A. S.	Charlottesville, Va., USA
NIU	Northern Illinois Univ.	De Kalb, Ill., USA	VPI	Virginia Polytechnic Inst.	Warsaw, Poland
NORD	Nordisk Inst. for Theor. Atomfys.	Copenhagen, Denmark	WARS	Univ. of Warsaw	Seattle, Wash., USA
NOVO	Inst. of Nucl. Phys.	Novosibirsk, USSR	WASH	Univ. of Washington	Wien, Austria
NPOL	Northern Polytechnic	London, England	WIEN	Univ. of Washington	Williamsburg, Va., USA
NRL	Naval Research Laboratory	Washington, D.C., USA	WILL	College of William and Mary	Madison, Wisc., USA
NWES	Northwestern Univ.	Evanston, Ill., USA	WISC	Univ. of Wisconsin	Woodstock, Md., USA
NYU	New York Univ.	New York, N. Y., USA	WOOD	Woodstock College	Wuppertal, Germany
OHIO	Ohio Univ.	Athens, Ohio, USA	WUPG	Gesamthochschule Wuppertal	Wuppertal, Germany
OREG	Univ. of Oregon	Eugene, Ore., USA	WUPP	Univ. Wuppertal	St. Louis, Mo., USA
ORNL	Oak Ridge National Lab.	Oak Ridge, Tenn., USA	WUSL	Washington Univ.	Laramie, Wyoming, USA
ORSA	Univ. de Paris, Fac. des Sci.	Orsay, France	WYOM	Univ. of Wyoming	New Haven, Conn., USA
OSAK	Osaka Univ.	Osaka, Japan	YALE	Yale Univ.	Yokohama, Japan
OSKC	Osaka City Univ.	Osaka, Japan	YOKO	Yokohama Univ.	Amsterdam, Netherlands
OSLO	Oslo Univ.	Oslo, Norway	ZEMM	Zeeman Lab., Univ. of Amsterdam	Zurich, Switzerland
OSU	Ohio State Univ.	Columbus, Ohio, USA	ZURI	Univ. Zurich	
OTTA	Univ. of Ottawa	Ottawa, Canada			

Stable Particles

Data Card Listings

ν, ν_e, e, ν_μ

For notation, see key at front of Listings.

1968), p.367. See also S. Glashow, Nucl. Phys. 22, 579 (1961); S. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D2, 1285 (1970); and, for the n=3 case, M. Kobayashi and T. Maskawa, Prog. Theor. Phys. 49, 652 (1973).

- 2. See, e.g., B. W. Lee and R. E. Shrock, Phys. Rev. D16, 1444 (1977).
3. J. Yang et al., Astrophys. J. 227, 697 (1979); see also footnote 4 in G. Steigman et al., Phys. Rev. Lett. 43, 239 (1979).
4. K. Berkvist, Nucl. Phys. B39, 317 (1972).
5. M. Daum et al., Phys. Rev. D20, 2692 (1979).

nu_e

1 E-NEUTRINO (0,J=1/2)

1 E-NEUTRINO MASS (KEV)

Table with columns for particle name, mass limits, and references. Includes entries for Langer, Hamilton, Friedman, Beck, Daris, Bergkvist, Cowsik, Rode, Clark, and Vasiliev.

1 (E-NEUTRINO) - (E-ANTINEUTRINO) MASS DIFF. (KEV)

Table with columns for particle name, mass difference, and references. Includes entry for Clark.

1 E-NEUTRINO MEAN LIFE/MASS (UNITS SEC/EV)

Table with columns for particle name, mean life/mass, and references. Includes entries for Reines, Falk, and others.

REFERENCES FOR E-NEUTRINO

Table listing references for E-neutrino, including authors like Langer, Hamilton, Friedman, Beck, Daris, Bergkvist, Cowsik, Rode, Clark, Reines, and Falk.

e

3 ELECTRON(0.5,J=1/2)

3 ELECTRON MASS (MEV)

Table with columns for particle name, mass, and references. Includes entries for Cohen, Taylor, and Cohen.

3 ELECTRON MEAN LIFE (UNITS 10**21 YR)

Table with columns for particle name, mean life, and references. Includes entries for Moe, Steinfeld, Kovalchuk, and Steinfeld.

Table with columns for particle name, magnetic moment, and references. Includes entries for Schupp, Wilkison, Cohen, Moe, Rich, Taylor, Wesley, Gilleland, Rich, Cohen, Walls, Steiner, Serednya, and Vandyck.

3 ELECTRON ELECTRIC DIPOLE MOMENT(UNITS 10**23 E-CM) TEST OF P OR T VIOLATION IN THE EM INTERACTION

Table with columns for particle name, dipole moment, and references. Includes entries for Weisskopf and Vasiliev.

REFERENCES FOR ELECTRON

Table listing references for electron, including authors like Schupp, Wilkison, Cohen, Moe, Rich, Taylor, Wesley, Gilleland, Rich, Cohen, Walls, Steiner, Serednya, Vandyck, Vasiliev, and Kovalchuk.

nu_mu

2 MU-NEUTRINO(0,J=1/2)

2 MU-NEUTRINO MASS (MEV)

Table with columns for particle name, mass, and references. Includes entries for Barkas, Dudziak, Feinberg, Alldcock, Bardon, Shrum, Cowsik, Backenstoss, Daum, and others.

2 (MU-NEUTRINO) - (MU-ANTINEUTRINO) MASS DIFF. (MEV)

Table with columns for particle name, mass difference, and references. Includes entry for Clark.

2 MU-NEUTRINO MEAN LIFE/MASS (UNITS SEC/EV)

Table with columns for particle name, mean life/mass, and references. Includes entries for Bellotti, Barnes, Cowsik, Falk, and others.

2 MU-NEUTRINO VELOCITY-C: ABS((V-C)/C) (UNITS 10**4) EXPECTED TO BE ZERO FOR MASSLESS NEUTRINO

Table with columns for particle name, velocity, and references. Includes entries for Vasiliev and others.

REFERENCES FOR MU-NEUTRINO

Table listing references for mu-neutrino, including authors like Barkas, Dudziak, Feinberg, Alldcock, and Bardon.

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

v, mu

SHAHER 65 PRL 14 923 R E SHAHER, CROWE, JENKINS (LRL)
BOOTH, JOHNSON, WILLIAMS, WORMALD (LIVERPOOL)
HYMAN 67 PL 258 376 +LOKEN, PEWITT, MCKENZIE+ (ANL+CARN+NMES)
BACKENSTOSS, DANIEL, KOCH+ (CERN, KARL, HEID)
SHRUM 71 PL 378 114 E V SHRUM, O H ZIOCK (UNIV OF VIRGINIA)
CGHSIK 72 PRL 29 669 R CGHSIK, J MC CLELLAND (UCB)
BACKENSTOSS, DANIEL, KOCH+ (CERN+KARL+MUNICH)
CLARK 74 PR 09 533 +EL IOFF, FRISCH, JOHNSON, KERTH, SHEN + (LBL)
AL SPECTOR 76 PRL 36 837 +ALSPECTOR + (BNL+PURD+CIT+FNAL+ROCK)
BELLOTTI 76 LNC 17 553 +CAVALLI, FIORINI, ROLLIER (MILA)
DAUM 76 PL 608 380 +DUBAL, EATON, FROSCH, MCCULLOCH+ (SIN+ETH)
BARNES 77 PRL 38 1049 +CARMONY, DAUWE, FERNANDEZ + (PURD+ANL)
CGHSIK 77 PRL 39 784 R. CGHSIK (MPIM+TATA)
ALSO 79 PR D19 2219 R. CGHSIK (TATA)
ALSO 79 PR D19 2215 GOLDMAN, STEPHENSON (LASL)

BLIETSCH 78 NP B133 205 AACH+LIBH+CERN+EPOL+MIL+A+OR SA+LOUC
DAUM 78 PL 748 126 +EATON, FROSCH, HIRSCHMANN, MCCULLOCH+ (SIN)
FALK 78 PL 79B 511 S. FALK, D. SCHRAMM (EPF)

KALBFLEI 79 PRL 43 1361 KALBFLEI SCH, BAGGETT, FOWLER+(FNAL+PURD+BELL)

4 MUON(106, J=1/2)
4 MUON MASS (MEV)
M (105.659) (0.002) FEINBERG 63 RVUE
M (105.659) (0.0014) TAYLOR 69 141R USING NEW E/H 7/70
M C (105.6597) (0.0005) CRANE 71 CNTR INCLUDED IN COHEN73 1/73
M D (105.6594) (0.0004) CROWE 72 CNTR INCLUDED IN COHEN73 2/72
M 105.65948 0.00035 COHEN 73 RVUE 3/74
M A 105.65945 0.00033 CASPERSON 77 CNTR + 12/77
M C CRANE 71 GIVES MU/ME=206.76878(85). WE USE ME=.5110041(16)MEV. 1/73
M D CROWE 72 GIVES MU/ME=206.7682(5) AND USES ME=.5110041(16)MEV. 1/73
M A CASPERSON 77 GIVES MU/ME=206.76859(29). WE USE ME=.5110034(14)MEV. 12/77
M AVG 105.65946 0.00024 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M STUDENT 105.65946 0.00026 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
M FIT 105.65946 0.00024 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

4 MUON MEAN LIFE (UNITS 10**--6)
T 2.198 0.001 0.001 FARLEY 62 CNTR
T 2.203 0.004 LUNDY 62 CNTR CONLEV=.98 11/67
T 2.202 0.003 0.003 ECKHAUSE 63 CNTR
T 2.197 0.005 0.002 MEYER 63 CNTR +
T 2.198 0.002 0.002 MEYER 63 CNTR - 7/66
T W (2.20026)(0.00081) WILLIAMS 72 CNTR + 2/76
T 2.1973 0.0003 DUCLOS 73 CNTR + 1/76
T 2.19711 0.00008 BALANDIN 74 CNTR + 1/76
T 2.1948 0.0010 BAILEY2 77 CNTR - STORAGE RINGS 2/79*
T 2.1966 0.0020 BAILEY2 77 CNTR + STORAGE RINGS 2/79*
T W WILLIAMS 72 MEAN LIFE MEASUREMENT WAS NOT THE PRIMARY PURPOSE OF 1/76
T W THEIR EXPERIMENT AND DISAGREES STRONGLY WITH LATER EXPTS. NOT AVGD. 1/76
T AVG 2.197120 0.000077 0.000077 AVERAGE (ERROR INCL. SCALE FACTOR OF 1.0)
T STUDENT 2.197123 0.000083 0.000083 AVG BY STUDENT10(H/1.11) -- SEE MAIN TEXT

4 MU+MU- MEAN LIFE RATIO
DT 1.000 0.001 MEYER 63 CNTR MEAN LIFE MU+/MU- 7/66
DT 1.0008 0.0010 BAILEY 79 CNTR STORAGE RING 7/79*
DT AVG 1.00040 0.00071 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
DT STUDENT 1.00040 0.00077 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

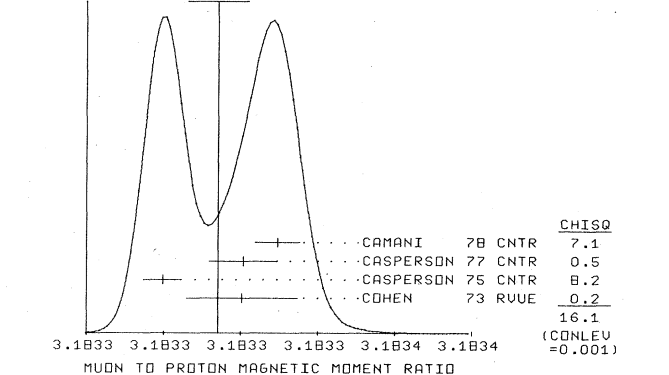
4 MUON ANOMALOUS MAGN. MOMENT (10**--6*(E/2MU MASS))
MM SEE RICH 72 AND COMBLEY 74 FOR A REVIEW OF THEORY AND EXPERIMENTS.
MM (1162.0) (5.0) CHARPAK 62 CNTR +
MM B (1165.75) (6.71) BAILEY 68 CNTR + STOR. RINGS 5/69
MM B (1166.25) (0.24) BAILEY 68 CNTR - STOR. RINGS 5/69
MM B ERRORS STATISTICAL, VALUES COMBINED TO GIVE MU+- VALUE BELOW 5/69
MM 1166.16 0.31 BAILEY 68 CNTR +- STOR. RINGS 5/69
MM 1060. 67. HENRY 69 CNTR + 1/77
MM IA (1165.895) (0.027) BAILEY 75 CNTR + STORAGE RING 11/75
MM IA (1165.922) (0.009) BAILEY 77 CNTR +- STORAGE RING 11/77
MM I (1165.911) (0.011) BAILEY 79 CNTR + STORAGE RING 7/79*
MM I (1165.937) (0.012) BAILEY 79 CNTR + STORAGE RING 7/79*
MM I 1165.924 0.0085 BAILEY 79 CNTR +- STORAGE RING 7/79*
MM A BAILEY 77 INCLUDES RESULTS OF BAILEY 75. 11/77
MM I BAILEY 79 IS FINAL RESULT. INCLUDES BAILEY 75 AND 77 DATA. 7/79*
MM I THIRD BAILEY 79 RESULT IS FIRST TWO COMBINED. 7/79*
MM AVG 1165.9242 0.0085 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
MM STUDENT 1165.9242 0.0092 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

4 MUON ELECTRIC DIPOLE MOMENT (UNITS 10**--19 E-CM)
EDM B (8.6) (4.5) BAILEY 78 CNTR + STORAGE RINGS 2/79*
EDM B (0.8) (4.3) PAILEY 78 CNTR - STORAGE RINGS 2/79*
EDM B 3.7 3.4 BAILEY 78 CNTR +- STORAGE RING 2/79*
EDM B BAILEY 78 YIELDS EDM < 1.05*10**--18 WITH CL=.95. THIRD RESULT IS FIRST TWO COMBINED. ASSUMING CPT. 2/79*

4 MUON TO PROTON MAGNETIC MOMENT RATIO
MMR THIS RATIO IS USED TO OBTAIN PRECISE VALUES OF THE MUON MASS. 3/72
MMR SEE CROWE 72. 3/72
MMR (3.18351) (0.0022) COFFIN 58 CNTR + SPIN RESONANCE 2/72
MMR (3.1830) (0.011) LUNDY 58 CNTR + PRECESSION STROB 2/72
MMR (3.176) (0.013) LUNDY 58 CNTR - PRECESSION STROB 2/72
MMR (3.1834) (0.002) GARWIN 60 CNTR + PRECESSION PHASE 2/72
MMR (3.18336) (0.0007) BINGHAM 63 CNTR + PRECESSION STROB 2/72
MMR (3.1808) (0.004) BINGHAM 63 CNTR - PRECESSION STROB 2/72
MMR (3.18338) (0.0004) HUTCHINS 63 CNTR + PRECESSION PHASE 2/72
MMR D (3.183351) (0.00016) EHRlich 69 CNTR HFS SPLITTING 2/72
MMR C (3.183314) (0.00034) THOMPSON 69 CNTR HFS SPLITTING 2/72
MMR (3.183301) (0.00064) HUTCHINS 70 CNTR + PRECESSION PHASE 2/72
MMR H (3.183347) (0.00009) HAGUE 70 CNTR + PRECESSION PHASE 2/72
MMR C (3.183361) (0.00013) CRANE 71 CNTR HFS SPLITTING 2/72
MMR D (3.183349) (0.00015) DEVOE 71 CNTR HFS SPLITTING 1/73

MMR F (3.183326) (0.00013) FAVART 71 CNTR HFS SPLITTING 2/72
MMR H (3.1833467) (0.000082) CROWE 72 CNTR + PRECESSION PHASE 2/72
MMR R THE RESULTS THROUGH 1972 ARE INCLUDED IN COHEN73. 3/74
MMR 3.1833402 -0.000072 COHEN 73 RVUE 3/74
MMR 3.1833299 -0.000029 CASPERSON 75 CNTR 2/76
MMR 3.1833403 -0.000044 CASPERSON 77 CNTR + HFS SPLITTING 12/77
MMR 3.1833448 -0.000029 CAMANI 78 CNTR + PRECESSION STROB 7/79*
MMR C CRANE 71 SUPERSEDES THOMPSON 69. THIS IS NOT A DIRECT MEASUREMENT. 1/73
MMR H CROWE 72 SUPERSEDES HAGUE 70.
MMR F FAVART 71 ASSUMES A ZERO VALUE FOR THE PROTON POLARIZABILITY. 1/73
MMR D DEVOE 71 SUPERSEDES EHRlich 69. THIS IS NOT A DIRECT MEASUREMENT. 1/73
MMR D WE GIVE A NEW VALUE WHICH CONTAINS A THEORETICAL CORRECTION OF 1/73
MMR D -7.8+-2.3 PPM, AS DISCUSSED IN FOOTNOTE 35A OF CROWE 72. 1/73

MMR AVG 3.18333710.000039 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)
MMR STUDENT 3.18333820.000032 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)



4 MUON PARTIAL DECAY MODES
P1 MUON INTO E ANTI(E-NEU) (MU-NEU) .5+ 0+ 0
P2 MUON INTO E GAMMA .5+ 0+ 0
P3 MUON INTO SELECTIONS .5+ .5+ .5
P4 MUON INTO E GAMMA .5+ 0 0
P5 MUON INTO E (E-NEU) ANTI(MU-NEU) .5+ 0+ 0
P6 MUON INTO E ANTI(E-NEU) (MU-NEU) GAMMA .5+ 0+ 0+ 0

4 MUON BRANCHING RATIOS
R1 MUON INTO E+2GAMMA (IN UNITS OF 10**--5) (P2)/(P1)
R1 1.6 OR LESS CL=.90 FRANKEL 63 OSPK +
R1 P 0.4 OR LESS CL=.90 POUTISSOU 74 CNTR + 12/75
R1 P POUTISSOU 74 LIMIT APPLIES TO SUM OF ALL NEUTRINOLESS MU+ DECAYS. 1/76
R2 MUON INTO 3E (IN UNITS OF 10**--7) (P3)/(P1)
R2 F 5.0 OR LESS CL=.90 PARKER 62 CNTR
R2 F 1.3 OR LESS CL=.90 ALIKHANDOV 62 OSPK
R2 F 1.5 OR LESS CL=.90 FRANKEL2 63 CNTR
R2 F 1.2 OR LESS CL=.90 BABAEV 63 OSPK
R2 K 0.062 OR LESS CL=.90 KORENCH2 71 OSPK 2/72
R2 K 0.019 OR LESS CL=.90 KORENCHEN 76 SPEC + 6/77
R2 F FOUR ABOVE EXPERIMENTS EVALUATED UPPER LIMITS ASSUMING A SECOND ORDER W-A NEUTRINO LOOP DIAGRAM. LIMITS NOT SIGNIFICANTLY CHANGED BY ASSUMING A CONSTANT MATRIX ELEMENT. 10/77
R2 K THESE EXPERIMENTS ASSUME A CONSTANT MATRIX ELEMENT.
R3 MUON INTO E+GAMMA (IN UNITS OF 10**--8) (P4)/(P1)
R3 4.3 OR LESS CL=.90 FRANKEL 63 OSPK
R3 2.2 OR LESS CL=.90 PARKER 64 OSPK
R3 2.9 OR LESS CL=.90 KORENCH1 71 OSPK + 10/71
R3 0.36 OR LESS CL=.90 DEPCAMHER 77 CNTR + 12/77
R3 0.11 OR LESS CL=.90 PDEL 77 ELEC + 1/79*
R3 0.019 OR LESS CL=.90 BOHMAN 79 SPEC + 7/79*
R4 MUON+ INTO (E-(E-ANTI NEU)) (MU-NEU) (P5)/(P1)
R4 FORBIDDEN BY ADDITIVE CONSERVATION LAW FOR MUON NUMBER.
R4 MULTIPLICATIVE LAW PREDICTS R4=0.5
R4 0.25 OR LESS CL=.90 EICHTEN 73 HLBC + 11/75
R5 MUON INTO E ANTI(E-NEU) (MU-NEU) GAMMA (P6)/(P1)
R5 27 EVENTS SEEN ASHKIN 59 CNTR 1/78
R5 1.4E-2 0.4E-2 CRITTENDE 61 CNTR T(GAM) GT 10 MEV 1/78
R5 3.3E-3 1.3E-3 CRITTENDE 61 CNTR T(GAM) GT 20 MEV 1/78
R5 862 EVENTS SEEN BOGART 67 CNTR T(GAM) GT 14.5 MEV 1/78

4 MUON DECAY PARAMETERS
RELATED TEXT SECTION VI A
RHO RHO PARAMETER (V-A THEORY PREDICTS RHO=0.75)
RHO C (0.741) (0.027) DUDZIAK 59 CNTR + 20-53 MEV E+ 10/69
RHO P 0.745 0.025 PLANO 60 HBC + WHOLE SPECTRUM 10/69
RHO P TWO PARAMETER FIT TO RHO AND ETA.
RHO C 2276 (0.751) (0.034) BLOCK 62 HBC - WHOLE SPECTRUM 10/69
RHO D (0.64) (0.04) BARLOW 64 CNTR - WHOLE SPECTRUM 10/69
RHO D (0.661) (0.016) BARLOW 64 CNTR + WHOLE SPECTRUM 10/69
RHO D (0.867) (0.035) PGNETCORV 64 CC - 10/69
RHO D RESULTS IN DOUBT.
RHO C 800K (0.7503) (0.0026) PEOPLES 66 ASPK + 20-53 MEV E+ 10/69
RHO C 280K (0.760) (0.009) SHERWOOD 67 ASPK + 25-53 MEV E+ 10/69
RHO C 170K (0.762) (0.008) FRYBERGER 68 ASPK + 25-53 MEV E+ 10/69
RHO C ETA CONSTRAINED =0-. THESE VALUES INCORPORATED INTO A TWO PARAMETER
RHO C FIT TO RHO AND ETA BY DERENZO 69.
RHO 0.7518 0.0026 DERENZO 69 RVUE 10/69
RHO
RHO AVG 0.7517 0.0026 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
RHO STUDENT 0.7517 0.0028 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

τ^\pm, π^\pm

P10 TAU+- INTO NEU(TAU) A1(1100)+- 0+1100
P11 TAU+- INTO K+- NEUTRALS
P12 TAU+- INTO NEU(TAU) P1+- 0+ 139
P13 TAU+- INTO NEU(TAU) 2P1+- PI+- (INCL. P9, P10) 0+ 139+ 139+ 139
P14 TAU+- INTO NEU(TAU) 2P1+- PI+- (PIOS) (INCL. P13) 0+ 139+ 139+ 139
P15 TAU+- INTO NEU(TAU) AND 3 OR MORE CHGD. PARTICLES
P16 TAU+- INTO NEU(TAU) RHO+- 0+ 776

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i +/- delta P_i, where delta P_i = sqrt(delta P_i^2), while the off-diagonal elements are the normalized correlation coefficients (delta P_i delta P_j) / (delta P_i delta P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table with 7 columns (P1 to P7) and 7 rows (P1 to P7) showing branching fractions and correlation coefficients.

35 TAU BRANCHING RATIOS

R1 TAU+- INTO (MU+- NEU(MU) NEU(TAU))/TOTAL (P1)
R1 220 (0.15) (0.03) BURMEST1 77 PLUT ASSUMES V-A DECAY 12/77
R1 220 (0.19) (0.04) BURMEST1 77 PLUT ASSUMES V+A DECAY 12/77
R1 0.175 0.040 PERL 77 SMAG E+E- TO MU+- X-+ 12/77
R1 0.22 0.10 0.07 CAVALLISF 77 SPEC E+E- TO MU+- X-+ 1/78
R1 S 11 0.22 0.07 0.08 SMITH 78 SPEC E+E- TO MU+- X0 7/79*

R2 TAU+- INTO (E+- NEU(E) NEU(TAU))/TOTAL (P2)
R2 B 459 0.160 0.013 BACIN02 78 DLCO E+E- ECM=3.1-7.4GEV 1/79*
R2 B BACIN02 78 VALUE COMES FROM FIT TO EVENTS WITH E+- AND 1 OTHER 1/79*
R2 B NONELECTRON CHARGED PRONG. 1/79*

R3 TAU+- INTO (L+- NEU(L) NEU(TAU))/TOTAL (P3)
R3 WHERE L MEANS E OR MU. EQUALITY OF E AND MU SQRTS IS ASSUMED.
R3 P 105 0.17 0.06 0.03 PERL 76 SMAG 3/77
R3 B 144 0.186 0.030 PERL 77 SMAG 12/77
R3 B 21 0.224 0.055 BARBARO-G 77 SMAG 11/77
R3 B 13 0.182 0.031 BRANDELIK 78 DASP ASSUMES V-A DECAY 3/78
R3 B 13 (0.206) (0.036) BRANDELIK 78 DASP ASSUMES V+A DECAY 3/78
R3 B WE HAVE COMBINED STATISTICAL AND SYSTEMATIC ERRORS QUADRATICALLY. 3/78
R3 P ASSUMES V-A COUPLING, TAU MASS=1.8 GEV, TAU NEUTRINO MASS=0.
R3 B ASSUMES V-A COUPLING, TAU MASS=1.9 GEV, TAU NEUTRINO MASS=0.
R3 AVG 0.186 0.018 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R3 STUDENT 0.186 0.020 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
R3 FIT 0.1744 0.0085 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R4 TAU+- INTO (E+- NEU(E) NEU(TAU)/MU+- NEU(MU) NEU(TAU))(P2)/(P1)
R4 PREDICTED TO BE 1 FOR SEQUENTIAL LEPTON, 2 FOR PARAELECTRON,
R4 AND 1/2 FOR PARAMUON. PARAELECTRON ALSO RULED OUT BY HEILE 78.
R4 21 0.92 0.37 BURMEST2 77 PLUT ASSUMES V-A DECAY 12/77
R4 21 (0.67) (0.28) BURMEST2 77 PLUT ASSUMES V+A DECAY 12/77
R4 B 18 1.09 0.38 BRANDELIK 78 DASP E+E- 3.1-5.2GEV ECM 12/78*
R4 B BRANDELIK 78 QUOTES THE INVERSE OF THIS RATIO AS .92+- .32. 12/78*

R5 TAU+- INTO (MU+- NEU(MU) NEU(TAU))*(E+- NEU(E) NEU(TAU)) (P1)*(P2)
R5 0.034 0.006 ABRAMS 79 SMAG 12/79*
R5 B 20 0.034 0.009 BACIN01 79 DLCO E+E- ECM=3.6-7.4GEV 1/79*
R5 B BACIN01 79 QUOTES BR(MU)=0.21+-0.0581 STAT.+SYST. ERRORS COMBINED IN 1/79*
R5 B QUADRATURE) ASSUMING BR(E)=0.16. WE MPY. BY 0.16 TO GET ABOVE VAL. 1/79*

R6 TAU+- INTO (E+- GAMMA(S) + MU+- GAMMA(S))/TOTAL (P3+P4)
R6 B 0.12 OR LESS CL=.90 BURMEST2 77 PLUT E+E- 4-5 GEV ECM 12/77
R6 B ASSUMES SAME MU,E MOM. SPEC. AS (MU E+ NOTHING DETECTED). 12/77

R7 TAU+- INTO (E+- CHARGED PRONG + MU+- CHARGED PRONG)/TOTAL (P5+P6)
R7 B 0.04 OR LESS CL=.90 BURMEST2 77 PLUT E+E- 4-5 GEV ECM 12/77
R7 B ASSUMES SAME MU,E MOM. SPEC. AS (MU E+ NOTHING DETECTED). 12/77

R8 TAU+- INTO (HADRON+- NEUTRALS)/TOTAL (P7)
R8 19 0.45 0.19 BARBARO-G 77 SMAG 11/77
R8 0.29 0.11 BRANDELIK 78 DASP ASSUMES V-A DECAY 3/78
R8 (0.21) (0.10) BRANDELIK 78 DASP ASSUMES V+A DECAY 3/78
R8 AVG 0.330 0.095 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R8 STUDENT 0.33 0.10 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

R9 TAU+- INTO (K+- NEUTRALS)/TOTAL (P11)
R9 B SMALL BRANDELIK 77 DASP 3.6-5.2ECM E+E- 1/78
R9 B BRANDELIK 77 FINDS 0.07+-0.06 K+- PER EVT IN E+E- --> E+- PRONG+- 1/78

R10 TAU+- INTO (3 HADRONS+- NEUTRALS)/TOTAL (P8)
R10 0.35 0.11 BRANDELIK 78 DASP ASSUMES V-A DECAY 3/78
R10 (0.38) (0.11) BRANDELIK 78 DASP ASSUMES V+A DECAY 3/78

R11 TAU+- INTO (NEU RHO0 PI+-)*(E+- NEU NEU) (P9)*(P2)
R11 A 21 0.0072 0.0021 ALEXAND1 78 PLUT E+E- 4-5 GEV ECM 3/78
R11 A ALEXANDER1 78 REPORTS BR(NEU RHO0 PI)=0.045+-0.013 FOR 3/78
R11 A BR(NEU NEU)=0.16 AND M(TAU)=1.8 GEV. WE MPY. BY 0.16 TO GET 3/78
R11 A ABOVE VAL. 3/78
R11 FIT 0.0072 0.0021 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R12 TAU+- INTO (NEU A1(1100)+-)/TOTAL (P10)
R12 A 21 (0.10) (0.03) ALEXAND1 78 PLUT E+E- 4-5 GEV ECM 12/78*
R12 A NOT INDEPENDENT OF ALEXANDER1 78 R11 VALUE ABOVE. ASSUMES THAT ALL 12/78*
R12 A (NEU RHO0 PI+-) EVENTS ARE (NEU A1+-) AND THAT BR(E+- NEU NEU)=16. 12/78*

R13 TAU+- INTO (NEU 2P1+- PI+-)*(PIOS)*(MU+- NEU NEU) (P14)*(P1)
R13 J 33 0.032 0.012 JAROS 78 SMAG E+E- ECM > 6 GEV 1/79*
R13 J JAROS 78 FINDS BR(NEU 3PI (PIOS))=18+-0.65 ASSUMING BR(MU)=0.18. 1/79*
R13 J WE MULTIPLY TO OBTAIN ABOVE VALUE.
R13 FIT 0.032 0.012 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R14 TAU+- INTO (NEU 2P1+- PI+-)*(MU+- NEU NEU) (P13)*(P1)
R14 J 13 0.013 0.009 JAROS 78 SMAG E+E- ECM > 6 GEV 1/79*
R14 J JAROS 78 FINDS BR(NEU 3PI)=0.07+-0.05 ASSUMING BR(MU)=0.18. WE 1/79*
R14 J MULTIPLY TO OBTAIN ABOVE VALUE. EVENTS CONSISTENT WITH BEING
R14 J RHO PI OR A1.
R14 FIT 0.0130 0.0090 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R15 TAU+- INTO (NEU(TAU) .GE. 3 CHARGED PARTICLES)/TOTAL (P15)
R15 692 0.32 0.05 BACIN02 78 DLCO E+E- ECM=3.1-7.4GEV 1/79*
R16 TAU+- INTO (NEU(TAU) PI+-)*(E+- NEU(E) NEU(TAU)) (P12)*(P2)
R16 A 23 0.015 0.006 ALEXAND02 78 PLUT E+E- ECM=3.6-5 GEV 2/79*
R16 B 10 0.013 0.006 BACIN01 79 DLCO E+E- ECM=3.6-7.4GEV 1/79*
R16 A ALEXANDER2 78 QUOTE BR(PI)=0.09+-0.038(STAT.+SYST.ERRORS COMBINED IN 2/79*
R16 A QUADRATURE) USING BR(E)=167+-0.10. WE MPY. BY 1.67 TO GET ABOVE VAL. 2/79*
R16 B BACIN01 79 QUOTES BR(PI)=0.080+-0.035(STAT.+SYST.ERRORS COMBINED IN 1/79*
R16 B QUADRATURE) ASSUMING BR(E)=0.16. WE MPY. BY 0.16 TO GET ABOVE VAL. 1/79*

R17 TAU+- INTO (NEU(TAU) RHO+-)*(E+- NEU(TAU) NEU(E)) (P16)*(P2)
R17 0.0421 0.0090 ABRAMS 79 SMAG 12/79*
R17 FIT 0.0369 0.0089 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R18 TAU+- INTO (NEU(TAU) RHO+-)*(MU+- NEU(TAU) NEU(MU)) (P16)*(P1)
R18 0.0329 0.0100 ABRAMS 79 SMAG 12/79*
R18 FIT 0.0389 0.0072 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

***** REFERENCES FOR TAU(1800) HEAVY LEPTON *****
PERL 75 PRL 35 1489 +ABRAMS,BOYARSKI,BREIDENBACH + (LBL+SLAC)
PERL 76 PL 638 466 +FELDMAN,ABRAMS,ALAM,BOYARSKI + (SLAC+LBL)
BARBARO-77 PRL 39 1058 +BARBARO-GALTIERI+ (LBL+NWES+SLAC+HAWA)
BRANDEL1 77 PL 708 125 BRANDEL1K + (AACH+DESY+HAMB+MPI+TCKY)
BURMEST1 77 PL 688 297 BURMESTER,CRIGEEE + (DESY+HAMB+SIEG+MUPG)
BURMEST2 77 PL 688 301 BURMESTER,CRIGEEE + (DESY+HAMB+SIEG+MUPG)
CAVALLISF 77 LNC 20 337 CAVALLI-SFORZA,GOGGI + (PAVI+PRIN+UMD)
PERL 77 PL 708 487 +FELDMAN,ABRAMS,ALAM,BOYARSKI+ (SLAC+LBL)
ALEXAND1 78 PL 738 99 ALEXANDER,CRIGEEE+ (DESY+AACH+SIEG+MUPG)
ALEXAND2 78 PL 788 162 ALEXANDER* (DESY+AACH+HAMB+SIEG+MUPG)
BACIN02 78 PRL 41 13 +FERGUSON,NODULMAN + (UCLA+SLAC+UCI+STON)
BARTEL 78 PL 778 331 +DITTMANN,QUINKER,DLSSCN,ONEILL+(DESY+HEID)

BRANDEL1 78 PL 738 109 BRANDEL1K + (AACH+DESY+HAMB+ MPI+TCKY)J
HEILE 78 NP B138 189 +PERL,ABRAMS,ALAM,BOYARSKI+ (SLAC+LBL)
JAROS 78 PRL 40 1120 +ABRAMS,ALAM+ (SLAC+LBL+NWES+HAWA)
SMITH 78 PR D18 1 +FORO,MORSE,MANN,RESVANIS+ (COLO+PENN+MISC)
ABRAMS 79 PRL 43 1555 +ALAM,BLOCKER,BOYARSKI+ (SLAC+LBL)
ALEXAND0 79 PL 819 84 +ALEXANDER + (DESY+AACH+HAMB+SIEG+MUPG)
BACIN01 79 PRL 42 6 +FERGUSON,NODULMAN + (UCLA+SLAC+UCI+STON)
BACIN02 79 PRL 42 749 +FERGUSON,NODULMAN+ (UCLA+SLAC+UCI+STON)

REVIEW'S
PERL2 77 HAMBURG SYMP. ALSO ISSUED AS SLAC-PUB-2022, M.PERL (SLAC)
FLUGGE 77 MESON CONF.BOSTON ALSO ISSUED AS DESY 77-35, G.FLUGGE (DESY)
AZIMOV 78 SPU 21 225 +FRANKFURT,KHOZE (LENI)
FELDMAN 78 SLAC-PUB-2224 G.J.FELDMAN (TOKYO CONF.1978) (SLAC)
PERL 78 SLAC-PUB-2219 M.L.PERL (KARLSRUHE SUMMER INST.1978) (DESY)
FLUGGE 79 JP C1 121 G.FLUGGE (DESY)
KIRKBY 79 SLAC-PUB-2419 J.KIRKBY (SLAC)
***** CHARGED PION I=0, JP=0-1 I=1 *****
***** CHARGED PION MASS (MEV) *****
M 139.37 0.20 CROWE 54 CNTR -
M 139.68 0.15 BARKAS 56 ENUL +
M S (139.577) (0.013) SHAFER 67 CNTR - MESONIC ATOMS 6/68
M B (139.549) (0.008) BACKENSTO 71 CNTR - MESONIC ATOMS 10/71
M S 139.566 0.013 SHAFER 72 CNTR - MESONIC ATOMS 1/73
M B 139.569 0.008 BACKENSTO 73 CNTR - MESONIC ATOMS 1/73
M 139.571 0.010 BRANDAGD 76 CNTR - MESONIC ATOMS 1/77
M 139.568 0.0020 CARTER 76 CNTR - MESONIC ATOMS 6/78
M 139.5667 0.0024 MARUSHENK 76 CNTR - MESONIC ATOMS 12/77
M D (139.5652) (0.0019) DAUM 78 SPEC + PI+ -> MU+ NEU 2/78
M S SHAFER 72 UPDATES SHAFER67 WITH NEW ALPHA AND NEW CALIB. LINE ENER. 1/73
M B BACKENSTOSS 73 CORRECTS BACKENSTOSS 71 WITH NEW VACUUM POL. CALC. 1/73
M M THIS MARUSHENKO 76 VALUE USED AT AUTHORS REQUEST BECAUSE IT USES 3/78
M M ACCEPTED SET OF CALIBRATION GAMMA ENERGIES. ERROR INCREASED FROM 3/78
M M .0017 TO INCLUDE QED CALC. ERROR OF .0017 (12 PPM). 3/78
M D DAUM 78 VALUE DEPENDS ON ASSUMED MU+ MASS M(MU)=105.65948+-0.0035 2/78
M D ENTERS OUR FIT VIA PI-MU MASS DIFF. BELOW WHICH IS INDEP. OF M(MU). 2/78
M AVG 139.5679 0.0015 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M STUDENT 139.5679 0.0016 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
M FIT 139.5669 0.0012 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

Stable Particles

π^\pm, π^0

Data Card Listings

For notation, see key at front of Listings.

Table with 4 columns: D, DT, D STUDENT, D FIT. Rows include mass difference (MEV) for (P1+) - (MU+) and average error including scale factor of 1.0.

Table with 4 columns: DM, DT, D STUDENT, D FIT. Rows include mass difference (PERCENT) for ((P1+) - (P1-))/AVG..

Table with 4 columns: T, DT, D STUDENT, D FIT. Rows include charged pion mean life (UNITS 10**--9) and systematic errors in calibr. in this exp. discussed by Norrberg 67.

Table with 4 columns: DT, D STUDENT, D FIT. Rows include mean life diff. (PERCENT) for ((P1+) - (P1-))/AVG..

Table with 4 columns: DT, D STUDENT, D FIT. Rows include quantity as a measure of CPT invariance in W.I. for above 15 TFE most conservative value quoted by authors.

Table with 4 columns: P1, P2, P3, P4, P5, P6. Rows include decay masses for charged pion partial decay modes.

Table with 4 columns: R1, R2, R3, R4, R5, R6. Rows include charged pion branching ratios for pion into mu and pion into e.

Table with 4 columns: R3, R4, R5, R6. Rows include charged pion branching ratios for pion into pi and pion into gamma.

Table with 4 columns: R4, R5, R6. Rows include charged pion branching ratios for pion into e and pion into gamma.

Table with 4 columns: BARKAS, CROWE, DEFORMMII, DEFORMM12, BARTLETT, DI CAPUA. Rows include references for charged pion.

Table with 4 columns: BACASTOW, BERTRAM, DUNAITSSE, ECKHAUSE, BARDON, DORE, DORFAN, KRIEGER, KUTYIN, PROKOSHIN, RASUVAEV, SIMONOV, KINSEY, LOBKOWICZ, NORDBERG, LOBKOWICZ, MEL ISSINGS, NAGASHIMA, HYMAN, NORDBERG, SHAFER. Rows include various particle data entries.

Table with 4 columns: DEFORMMIE, PETRUKHI, AYRES, BACKENSTOSS, DANIEL, KOCH, KORENCHENKO, KOSTIN, MICELMACHER, SHAFER, BACKENSTOSS, DANIEL, KOCH, BACKENSTOSS, DANIEL, KOCH, DUNAITSSE, BRYMAN, BRANDAD, CARTER, KORENCHENKO, KOSTIN, MICELMACHER, MARUSHEN, MARUSHEN, DAUM, STETZ. Rows include various particle data entries.

Table with 4 columns: CARTWRIG, MERRISON, SHAPIRO, CZIRR, CARRIGAN, WILKIN. Rows include various particle data entries.

Table with 4 columns: D, DT, D STUDENT, D FIT. Rows include neutral pion mass difference (MEV) for (P1+) - (P10) and average error including scale factor of 1.0.

Table with 4 columns: T, DT, D STUDENT, D FIT. Rows include neutral pion mean life (UNITS 10**--16) and average error including scale factor of 1.0.

Table with 4 columns: P1, P2, P3, P4, P5, P6. Rows include neutral pion partial decay modes.

Table with 4 columns: R1, R2, R3, R4, R5, R6. Rows include neutral pion branching ratios for pion into gamma and pion into e.

Data Card Listings

Stable Particles

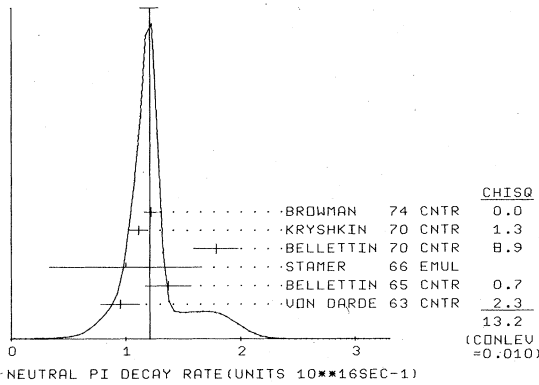
For notation, see key at front of Listings.

π^0, η

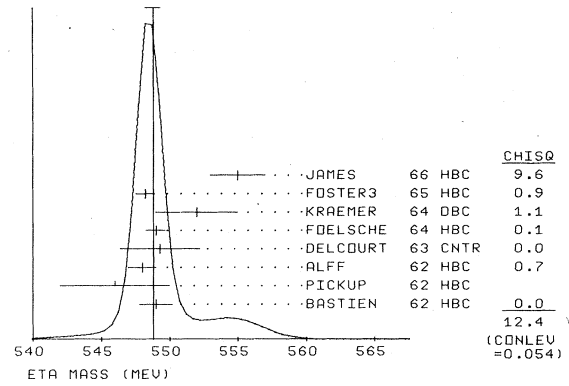
R2 PIO INTO (3 GAMMA)/TOTAL (UNITS 10**-6) (P4)
R2 D 0 4.9 OR LESS CL=.90 DUCLOS 65 CNTR 6/66
R2 D 4.9 OR LESS CL=.90 KUTIN 65 CNTR 3/68
R2 D THESE EXPTS. GIVE BR(3GAMMA/2GAMMA)<5.0*10**-6.
R2 0 1.5 OR LESS CL=.90 AUERBAC1 78 CNTR 1/79*

14 ETA(549, JPG=0-+) I=0
14 ETA MASS (MEV)
M 53 549.0 1.2 BASTIEN 62 HBC
M 35 546.0 4.0 PICKUP 62 HBC
M 91 548.0 1.0 ALFF 62 HBC
M 549.3 2.9 DELCOURT 63 CNTR
M 148 549.0 0.7 FOELSCHKE 64 HBC
M 325 552.0 3.0 KRAEMER 64 DBC
M 548.2 0.65 FOSTER3 65 HBC 7/66
M 250 555.0 2.0 JAMES 66 HBC 6/66

WEIGHTED AVERAGE = 1.207 ± 0.080
ERROR SCALED BY 1.8



WEIGHTED AVERAGE = 548.82 ± 0.56
ERROR SCALED BY 1.4



9 NEUTRAL PION ELECTROMAGNETIC FORM FACTOR
THE AMPLITUDE FOR THE PROCESS P0 -> E+ E- GAMMA CONTAINS A
FORM FACTOR GAMMA(X**2) AT THE (PIO GAMMA GAMMA) VERTEX
WHERE X=MASS(E+E-)/MASS(PIO). THE PARAMETER A IN THE LINEAR
EXPANSION GAMMA(X**2)=1+A*(X**2) IS LISTED BELOW.
A LINEAR COEFFICIENT OF P0 ELECTROMAGNETIC FORM FACTOR
A (-0.15) (0.10) KOBRAK 61 HBC NO RAD. CORR. 2/80*

14 ETA WIDTH
ETA WIDTH DETERMINED FROM MASS SPECTRUM (UNITS MEV)
W 91 (10.0) OR LESS ALFF 62 HBC
W 148 (10.0) OR LESS FOELSCHKE 64 HBC
W 31 (12.0) OR LESS JAMES 66 HBC
W (4.0) OR LESS BALYAY 66 DBC
W (1.9) OR LESS CL=.95 JONES 66 CNTR
ETA WIDTH DETERMINED FROM DECAY RATE (UNITS KEV)
THIS IS THE PARTIAL DECAY RATE (W1) FOR THE MODE (ETA INTO 2GAMMA)
DIVIDED BY THE FITTED BRANCHING FRACTION (P1) FOR THAT MODE.
W FIT 0.85 0.12 FROM FIT

REFERENCES FOR NEUTRAL PION
PANOF SKY 51 PR 81 565 W K H PANOF SKY, R L AAMODT, J HADLEY (LRL)
CHINDOWSK 54 PR 93 586 W CHINDOWSKY, J STEINBERGER (COLUMBIA)
CASSELS 59 PPS 74 92 CASSELS, JONES, MURPHY, O'NEILL (LIVERPOOL)
HADDOCK 59 PRL 3 478 HADDOCK, ABASHIAN, CROWE, CZIRR (LRL)
HILLMAN 59 NC 14 887 HILLMAN, MIDDELKOOP, YAMAGATA, ZAVATTINI (CERN)
BUDA GOV 60 JETP 11 755 BUDA GOV, VIKTOR, DZHELEPOV, ERMOLOV + (JINR)
JOSEPH 60 NC 16 597 D W JOSEPH (EFI)
SAMIOS 60 NC 18 154 N P SAMIOS (COLUMBIA)
GLASSER 61 PR 123 1014 R G GLASSER, N SEEMAN, B STILLER (NRL)
KOBRAK 61 NC 20 1115 H. KOBRAK (EFI)
SAMIOS 61 PR 121 275 N P SAMIOS (COLUMBIA+BNL)
SAMIOS 62 PR 126 1844 SAMIOS, PLANO, PRODELL + (COLUMBIA+BNL)
TIETGE 62 PR 127 1324 J TIETGE, W PUESCHEL (MAX PLANCK INST)
CZIRR 63 PR 130 341 JOHN B CZIRR (LRL)
KOLLER 63 NC 27 1405 E L KOLLER, S TAYLOR, T HUETTER (STEVENS)
ALSO 66 STAMER
PETRUKHI 63 SIENA CONF 208 V I PETRUKHIN, YU D PROKOSHKIN (JINR)
VCN DARD 63 PL 4 51 VON DARDEL, DEKKERS, MERMOD, VAN PUTTEN (CERN)
SHWE 64 PR 1368 1839 H SHWE, F N SMITH, W H BARKAS (LRL)
BELLETTINI 65 NC 40 A 1139 BELLETTINI, BEMPORAD, BRACCINI + (PISA+FRENZE)
DUCLOS 65 PL 19 253 DUCLOS, FREYTAG, HEINTZE + (CERN+HEIDELBERG)
EVANS 65 PR 139 B 982 D A EVANS (OXFORD)
KUTIN 65 JETP LETT 2 243 KUTIN, PETRUKHIN, PROKOSHKIN (JINR)
STAMER 66 PR 151 1108 STAMER, TAYLOR, KOLLER, HUETTER + (STEVENS)
VASTILEVS 66 PL 23 281 VASTILEVSKY, VISHNYAKOV, DUMAITSEV + (DUBNA)
DEVONS 69 PR 184 1354 +NEMENTHY, NISSIM-SABAT, DI CAPUA + (COLU+RGM)
BELLETTINI 70 NC 66A 243 BELLETTINI, BEMPORAD, LUBELSMY + (PISA+BCNN)
KRYSHKIN 70 JETP 30 1037 +STERLIGOV, USOV (TCMSK POLYTECH. INST.)
ABRAMS 73 PL 458 66 +CARROLL, KYCIA, LI, MICHAEL, MCKEET + (BNL)
MIYAZAKI 73 PR D8 2051 T. MIYAZAKI, E. TAKASUGI (TOKY)
BROWMAN 74 PRL 33 1400 +DEWIRE, GITTELMAN, HANSON + (CORN+B ING)
CAVIES 74 NC 244 324 +GUY, ZIA (BIRM+RHEL+SHMP)
AUERBAC1 78 PRL 41 275 +AUERBACH, HIGHLAND, JOHNSON, + (TEMP+LASL)
AUERBAC2 78 PL 788 353 +AUERBACH, HIGHLAND, JOHNSON, + (TEMP+LASL)
FISCHER1 78 PL 738 359 +EXTERMANN, GUI SAN, MERMOD, + (TEVA+SACL)
FISCHER2 78 PL 738 364 +EXTERMANN, GUI SAN, MERMOD, MOREL + (TEVA+SACL)

14 ETA PARTIAL DECAY MODES
P1 ETA INTO 2GAMMA 0+ 0
P2 ETA INTO 3PIO 134+ 134+ 134
P3 ETA INTO P1+ P1- PIO 139+ 139+ 134
P4 ETA INTO P1+ P1- GAMMA 139+ 139+ 0
P5 ETA INTO E+ E- PIO (VIOLATES C IN E.M.I.) 134+ .5+ .5
P6 ETA INTO E+ E- P1+ P1- 139+ 139+ .5+ .5
P7 ETA INTO P1O 2GAMMA 134+ 0+ 0
P8 ETA INTO E+ E- GAMMA .5+ .5+ 0
P9 ETA INTO 2PIO GAMMA (VIOLATES C) 134+ 134+ 0
P10 ETA INTO P1+ P1- PIO GAMMA 139+ 139+ 134+ 0
P11 ETA INTO P1+ P1- 2GAMMA 139+ 139+ 0+ 0
P12 ETA INTO MU+ MU- 105+ 105 0
P13 ETA INTO MU+ MU- GAMMA 105+ 105+ 134
P14 ETA INTO MU+ MU- PIO 139+ 139
P15 ETA INTO P1+ P1- 139+ 139
P16 ETA INTO E+ E- .5+ .5

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS
The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± delta P_i, where delta P_i = sqrt(delta P_i^2 + delta P_i^2), while the off-diagonal elements are the normalized correlation coefficients (delta P_i delta P_j) / (delta P_i delta P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.
P 1 P 2 P 3 P 4 P 7 P 8
P 1 .3799+-0.0098
P 2 -.2691 .2990+-0.106
P 3 -.3224 -.2353 .2358+-0.0056
P 4 -.2866 -.2095 -.8201 .0489+-0.0013
P 7 -.4271 -.5781 -.0939 -.0801 .0314+-0.0109
P 8 -.0434 -.0326 -.0494 -.0501 -.0036 .0050+-0.0012

Stable Particles

η

Data Card Listings

For notation, see key at front of Listings.

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., $G_i = \Gamma_i = \Gamma_{total} P_i$, in appropriate units. In analogy to the matrix above, the diagonal elements are $G_i \pm \delta G_i$, where $\delta G_i = \sqrt{(\delta G_i \delta G_i)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta G_i \delta G_j) / (\delta G_i \delta G_j)$. Note that, because of the error in Γ_{total} , the errors and correlations here are not directly derivable from those above.

Table with 6 columns (G1-G6) and 6 rows (G1-G6) showing fitted partial decay mode rates and correlation coefficients.

14 ETA DECAY RATES

Table listing decay rates for eta into 2 gamma (units keV) with various experimental data points and fit results.

14 ETA BRANCHING RATIOS

Table listing branching ratios for eta into neutrals/charged and eta into 2 gamma/charged, including experimental data and fit results.

Note on $\eta \rightarrow \pi^0 \gamma \gamma$

The discrepancies between various measurements of branching ratios involving $\eta \rightarrow \pi^0 \gamma \gamma$ are displayed in the ideogram below, in which all relevant experiments have been converted to a common ratio, $\pi^0 \gamma \gamma / \text{neutrals}$. Our branching ratio fit does not include DIGIUGNO 66, FELDMAN 67, or the upper limit measurements. See page 43 of "Review of Particle Properties", Physics Letters 39B, No. 1 (1972) for more discussion.

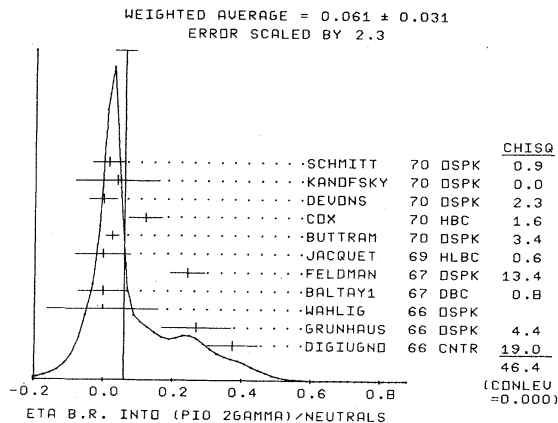


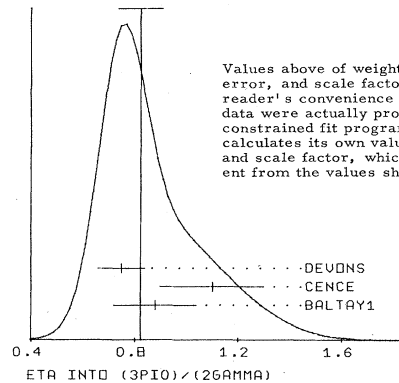
Table listing experimental data for eta into 2 gamma neutrals, including authors like DIGIUGNO 66, GRUNHAUS 66, and FITZPATRICK 67.

Table listing experimental data for eta into pi+ pi- gamma / pi+ pi- pi0, including authors like FOELSCH 64, PAULI 64, and CRAWFORD 66.

Table listing experimental data for eta into 3 pi0 + 2/3(pi0 2 gamma) / pi+ pi- pi0, including authors like CRAWFORD 63, FOELSCH 64, and FOSTER 65.

Table listing experimental data for eta into 3 pi0 or more, including authors like CHRETIEN 62, BALYAY 67, and DEVONS 70.

WEIGHTED AVERAGE = 0.024 +/- 0.005
ERROR SCALED BY 1.2



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of \bar{x} , $\delta \bar{x}$, and scale factor, which are different from the values shown here.

Table listing CHISO values for various experiments: DEVONS 70 DSPK (0.7), CENCE 67 DSPK (1.9), BALYAY 67 DBC (0.1), and CDNLEU (0.259).

Table listing experimental data for eta into 2 gamma / (pi+ pi- pi0), including authors like FOSTER 65, BAGLIN 69, and FITZPATRICK 67.

Table listing experimental data for eta into neutral / (pi+ pi- pi0), including authors like KRAEMER 64, PAULI 64, FLATTE 67, and AGUILAR-B 72.

Table listing experimental data for eta into (e+e-pi0) / (pi+ pi- pi0) (units 10^-4), including authors like PRICE 65, ALFF-STELI 66, BAGLINI 67, BILLING 67, and JANEI 75.

Data Card Listings

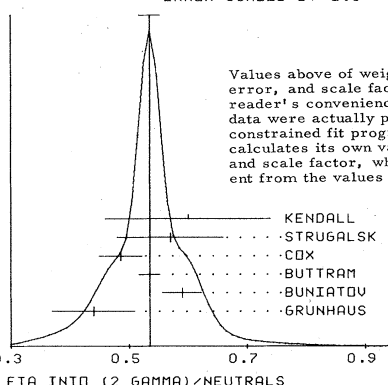
Stable Particles

For notation, see key at front of Listings.

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R10 ETA INTO (E+E-PI+PI-)/TOTAL (UNITS 10**=-2) (P6)
R11 ETA INTO (E+E-PI+PI-)/(PI+PI-GAMMA) (P6)/(P4)
R12 ETA INTO 2 GAMMA/NEUTRALS (P1)/(P1+P2+P7)
R12 S (0.416) (0.044) DIGIUGNO 66 CNTR ERROR DOUBLED 6/66
R12 .44 .07 GRUNHAUS 66 OSPK 8/67
R12 S (.575) (.052) FELDMAN 67 OSPK 8/67
R12 S SEE THE NOTE ON ETA DECAY INTO NEUTRALS ABOVE.
R12 T (0.39) (0.06) JONES 66 CNTR 8/67
R12 T THIS RESULT FROM COMBINING CROSS SECTIONS FROM TWO DIFFERENT EXPTS.
R12 .59 .033 BUNIATOV 67 OSPK 11/67
R12 .535 .018 BUTTRAM 70 OSPK 12/70
R12 .486 .026 COX 70 HBC 6/70
R12 0.57 0.09 STRUGALSK 71 HLBC 5/71
R12 113 0.60 0.14 KENDALL 74 OSPK 12/75
R12 AVG .535 .018 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R12 STUDENT 0.535 0.016 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R12 FIT 0.535 0.013 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
(SEE IDEOGRAM BELGW)

WEIGHTED AVERAGE = 0.535 ± 0.018
ERROR SCALED BY 1.3



R13 ETA INTO 3PI0/NEUTRALS (P2)/(P1+P2+P7)
R13 S (0.209) (0.054) DIGIUGNO 66 CNTR ERROR DOUBLED 6/66
R13 R (.29) (.10) GRUNHAUS 66 OSPK 8/67
R13 S (.177) (.035) FELDMAN 67 OSPK 8/67
R13 S SEE THE NOTE ON ETA DECAY INTO NEUTRALS ABOVE.
R13 .41 .033 BUNIATOV 67 OSPK 11/67
R13 R REDUNDANT INFORMATION FROM THIS EXPERIMENT.
R13 R (.439) (.024) BUTTRAM 70 OSPK 12/70
R13 .392 .042 COX 70 HBC 6/70
R13 0.32 0.09 STRUGALSK 71 HLBC 5/71
R13 75 0.40 0.14 KENDALL 74 OSPK 12/75
R13 AVG .397 .025 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R13 STUDENT 0.397 0.027 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R13 FIT 0.421 0.014 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R14 ETA INTO P10 (2 GAMMA)/2GAMMA (P7)/(P1)
R14 (.5) OR LESS CL=.90 WAHLIG 66 SPRK 7/66
R14 0.0 0.4 BALTAY 67 DBC 11/67
R14 P (0.05) (0.04) BONAMY 67 SPRK PRELIMINARY RESULT 11/67
R14 FIT .083 .030 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)

R15 ETA INTO (E+E-PI0)/TOTAL (UNITS 10**=-2) (P5)
R15 0.7 OR LESS RITTENBER 65 HBC 6/66
R15 0.084 OR LESS CL=.90 BAZIN 68 DBC 6/68
R15 0 0.016 OR LESS CL=.90 MARTYNOV 76 HLBC 6/77

R16 ETA INTO 2GAMMA/(3PI0 + P10 2GAMMA) (P1)/(P2+P7)
R16 0.80 .25 BACCI 63 CNTR 7/66
R16 FIT .1150 .060 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)

R17 ETA INTO (PI+PI-PI0 GAMMA)/(PI+PI-PI0) (UNITS 10**=-2) (P10)/(P3)
R17 7.0 OR LESS FLATTE 67 HBC 8/67
R17 0.9 OR LESS PRICE 67 HBC 8/67
R17 1.6 OR LESS CL=.95 BALTAY2 67 DBC 11/67
R17 1.7 OR LESS CL=.90 ARNOLD 68 HLBC 9/68
R17 0 0.24 OR LESS CL=.90 THALER 73 ASPK 6/73

R18 ETA INTO (PI+PI- 2GAMMA)/(PI+PI-PI0) (P11)/(P3)
R18 .309 OR LESS PRICE 67 HBC 8/67
R18 .016 OR LESS CL=.95 BALTAY2 67 DBC 11/67

R19 ETA INTO 3PI0/(PI+ PI- PI0) (P2)/(P3)
R19 1.3 .4 BAGLIN2 67 HLBC 8/67
R19 1.47 0.20 0.17 BULLOCK 68 HLBC 9/68
R19 199 1.50 .15 .29 EAGLIN 69 HLBC 7/69
R19 AVG 1.46 0.13 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R19 STUDENT 1.46 0.14 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R19 FIT 1.268 0.060 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R20 ETA INTO 2GAMMA/(13PI0)+2/3(P10 2GAMMA) (P1)/(P2+3P7)
R20 1.10 0.5 MULLER 63 DBC 7/66
R20 FIT .1187 .058 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)

R21 ETA INTO NEUTRALS/TOTAL (P1+P2+P7)
R21 .79 .08 BUNIATOV 67 OSPK 11/67
R21 16K .705 .008 BASILE 71 CNTR MM SPECTROMETER 8/71
R21 AVG 0.7058 0.0080 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R21 STUDENT 0.7058 0.0086 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R21 FIT 0.7103 0.0068 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R22 ETA INTO (PI0 2GAMMA)/TOTAL (P7)
R22 .12 OR LESS CL=.95 JACQUET 69 HLBC 6/70
R22 FIT .0031 .0011 FROM FIT
R23 ETA INTO MU+MU-/TOTAL (UNITS 10**=-5) (P12)
R23 0 2. OR LESS CL=.95 WEHMAN 68 OSPK 4/68
R24 ETA INTO MU+MU-PI0/TOTAL (UNITS 10**=-4) (P14)
R24 5. OR LESS WEHMAN 68 OSPK 4/68
R25 ETA INTO MU+MU-/2GAMMA (UNITS 10**=-5) (P12)/(P1)
R25 5.9 2.2 HYAMS 69 OSPK 7/69
R26 ETA INTO (PI0 2GAMMA)/(13PI0 + P10 2GAMMA) (P71)/(P2+P7)
R26 N 0.1 0.3 KANFOSKY 70 OSPK 2/71
R26 N WE HAVE CHANGED THE ERROR ON THIS EXPERIMENT FROM +0.3,-0.1
R26 N TO THE ABOVE +0.3,-0.2 SINCE IT IS CLEAR FROM FIGURE 7 IN THE
R26 N ARTICLE THAT A CENTRAL VALUE OF 0.0 IS ABOUT AS PROBABLE AS THE
R26 N QUOTED VALUE OF 0.1.
R26 FIT .0095 .0032 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
R27 ETA INTO (PI+ PI-)/TOTAL (UNITS 10**=-2) (P15)
R27 0 0.15 OR LESS THALER 73 ASPK CON. LEV. NOT GIVEN 6/73
R28 ETA INTO (E+E-GAMMA)/(PI+PI-PI0) (UNITS 10**=-2) (P8)/(P3)
R28 J 80 2.1 0.5 JANEZ 75 OSPK 2/76
R28 J VALUE CHANGED BY ERRATUM.
R28 FIT .211 0.50 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)
R29 ETA INTO (E+ E-)/TOTAL (UNITS 10**=-4) (P16)
R29 D 3. OR LESS CL=.90 DAVIES 74 RVUE 2/78
R29 D DAVIES 74 EXTRACTS THIS INFORMATION FROM ESTEN 67.
R30 ETA INTO (MU+ MU- GAMMA)/TOTAL (UNITS 10**=-4) (P13)
R30 100 1.5 0.75 BUSHNIN 78 SPEC 2/799
R30 2/799

14 ETA C-NONCONSERVING DECAY PARAMETERS

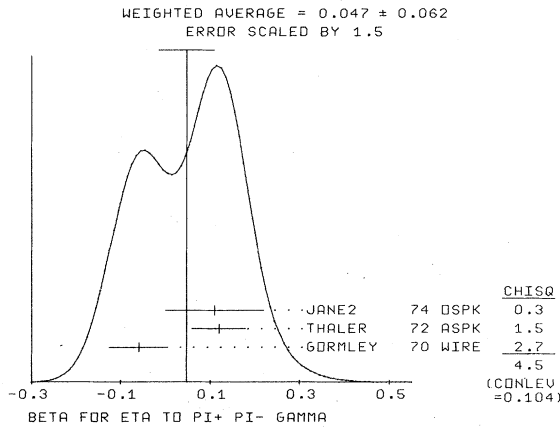
RELATED TEXT SECTION VI C.1
A1 LEFT-RIGHT ASYMMETRY PARAMETER FOR PI+ PI- PI0 (UNITS 10**=-2)
A1 1351 7.2 2.8 BALTAY 66 DBC 8/66
A1 1300 5.8 3.4 CLPHY 66 HBC 8/66
A1 10665 (0.3) (1.0) CNOPS 66 OSPK REPL BY MULLER 69 8/67
A1 705 .04 4.0 LARRIBE 66 HBC 8/67
A1 G36800 (1.5) (.5) GORMLEY3 68 ASPK 6/68
A1 10709 .3 1.1 MULLER 69 OSPK 9/69
A1 1138 -1.4 3. CARPENTR 70 HBC 6/70
A1 349 3.2 5.4 DANBURG 70 DBC 2/71
A1 220K -0.05 0.22 LAYER 72 ASPK 8/72
A1 165K 0.28 0.26 JANEZ 74 OSPK 3/74
A1 G GORMLEY3 68 ASYMMETRY PROBABLY DUE TO UNMEASURED (E X B) SPK. CH. 3/74
A1 G EFFECTS. NEW EXPTS. WITH (E X B) CNTRLS DONT OBSERVE ASYMMETRY. 3/74
A1 AVG 0.12 0.17 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
A1 STUDENT 0.11 0.19 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
A2 LEFT-RIGHT ASYMMETRY PARAMETER FOR PI+ PI- GAMMA (UNITS 10**=-2)
A2 33 -2. 17. CRAWFORD 66 HBC 11/66
A2 -4. 8. LITCHEL 67 DBC 8/67
A2 N 1620 1.5 2.5 MULLER 69 OSPK 9/69
A2 7257 1.22 1.56 GORMLEY 70 ASPK 6/70
A2 36K 0.5 0.6 THALER 72 ASPK 8/72
A2 35K 1.2 0.6 JANEZ 74 OSPK 3/74
A2 N MULLER 69 IS SENSITIVE ONLY TO UPPER .4 OF GAMMA-RAY SPECTRUM.
A3 AVG 0.88 0.40 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
A3 STUDENT 0.88 0.45 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
AS SEXTANT ASYMMETRY PARAMETER FOR PI+ PI- PI0 (UNITS 10**=-2)
AS 1300 6.8 3.3 CLPHY 66 HBC 12/75
AS 705 -2.4 4.0 LARRIBE 66 HBC 12/75
AS 37K 0.5 0.5 GORMLEY3 68 WIRE 12/75
AS 220K 0.10 0.22 LAYER 72 ASPK 12/75
AS 165K 0.20 0.25 JANEZ 74 OSPK 12/75
AS AVG 0.19 0.16 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
AS STUDENT 0.19 0.17 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
AQ QUADRANT ASYMMETRY PARAMETER FOR PI+ PI- PI0 (UNITS 10**=-2)
AQ 220K -0.07 0.22 LAYER 72 ASPK 12/75
AQ 165K -0.30 0.25 JANEZ 74 OSPK 12/75
AQ AVG -0.17 0.17 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
AQ STUDENT -0.17 0.18 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
BET BETA FOR ETA TO PI+ PI- GAMMA. SENSITIVE TO D-WAVE CONTRIBUTION.
BET 7250 -0.060 0.065 GORMLEY 70 WIRE 12/75
BET L 0.12 0.06 THALER 72 ASPK 12/75
BET 35K 0.11 0.11 JANEZ 74 OSPK 12/75
BET L AUTHORS DONT BELIEVE THIS TO INDICATE D-WAVE BECAUSE DEPENDENCE OF
BET L BETA ON GAMMA ENERGY INCONSISTENT WITH THEIR PREDICTION. 12/75
BET L COS**2 DEPENDENCE MAY ALSO COME FROM P AND F-WAVE INTERFERENCE. 12/75
BET AVG 0.047 0.062 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
BET STUDENT 0.053 0.059 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
(SEE IDEOGRAM BELGW)
14 ENERGY DEPENDENCE OF ETA DALITZ PLOT
DP RELATED TEXT SECTION VI C.2
DP THE FOLLOWING EXPTS FIT TO ONE OR MORE OF THE COEFFICIENTS
DP A+B+C*D, OR E FOR ETA TO PI+ PI- PI0
DP MATRIX ELEMENT**2 1 + A**Y + B*(Y**2) + C*X + D*(X**2) + E*X**Y
DP 1300 SEE TEXT SEC VI C.2 CLPHY 66 HBC 12/75
DP 705 SEE TEXT SEC VI C.2 LARRIBE 66 HBC 12/75
DP 1710 SEE TEXT SEC VI C.2 CNOPS 68 OSPK 12/75
DP 37K SEE TEXT SEC VI C.2 GORMLEY3 68 WIRE 12/75
DP 526 SEE TEXT SEC VI C.2 BAGLIN 69 HLBC 12/75
DP 1138 SEE TEXT SEC VI C.2 CARPENTR 70 HBC 12/75
DP 349 SEE TEXT SEC VI C.2 DANBURG 70 DBC 12/75
DP 7250 SEE TEXT SEC VI C.2 GORMLEY 70 WIRE 12/75
DP 220K SEE TEXT SEC VI C.2 LAYER 72 ASPK 12/75
DP 81K SEE TEXT SEC VI C.2 LAYER 73 ASPK 12/75
AO ALPHA PARAMETER FOR ETA TO 3 PI0
AO MATRIX ELEMENT **2 = 1 + 2*ALPHA**2 (SEE TEXT SEC VI C.3) 12/75
AO 192 -0.32 0.37 BAGLIN 70 HLBC 12/75

Stable Particles

η, K^\pm

Data Card Listings

For notation, see key at front of Listings.



REFERENCES FOR ETA

PEVSNER 61 PRL 7 421	PEVSNER, KRAEMER, NUSSBAUM, RICHARDSON + (JHU)
ALFF 62 PRL 9 322	ALFF, BERLEY, COLLEY, BRUGGER + (COLU+RUTGERS)
BASTIEN 62 PRL 8 114	BASTIEN, BERGE, DAHL, FERRO-LUZZI + (LRL)
CHRETIEN 62 PRL 9 127	CHRETIEN + (BRAN+BRON+HARVARD+MIT+PADOVA)
PICKUP 62 PRL 8 329	E PICKUP, ROBINSON, SALANT (UCR+BNL)
SHAFER 62 CERN CONF 307	J SHAFER, FERRO-LUZZI, MURRAY + (CNC+LRL)
BACCI 63 PRL 11 37	BACCI, PENSO, SALVINI + (ROMA+FRAS)
BUSCHBECK 63 SIENA CONF 1 166	BUSCHBECK-GIAPPACOPPER + (VIENNA, CERN, AMST)
CRAWFORD 63 PRL 10 546	F S CRAWFORD, LLOYD, FOWLER (LRL+DUKE)
ALSO 66 PRL 16 907	F S CRAWFORD, L LLOYD, E FOWLER (LRL+DUKE)
DEL COURT 63 PL 7 215	DEL COURT, LEFRANCOIS, PEREZ Y JORBA + (ORSAY)
MULLER 63 SIENA CONF 99	MULLER, PAULI + (SACL+RCHA)
FOELSCH 64 PR 134 B 1138	H W FOELSCH, H L KRAYBILL (YALE)
KRAEMER 64 PR 136 B 496	KRAEMER, MADANSKY, FIELDS + (JHU+WES+WCOO)
PAULI 64 PL 13 351	E PAULI, A MULLER (SACLAY)
FOSTER1 65 PR 138 B 652	FOSTER, PETERS, MEER, LOEFFLER + (WISC+PURDUE)
FOSTER2 65 ATHENS	FOSTER, GODD, MEER (WISCONSIN)
FOSTER3 65 THESIS	M.C. FOSTER (WISCONSIN)
PRICE 65 PRL 15 123	L.R. PRICE, F.S. CRAWFORD (LRL)
RITTENBERG 65 PRL 15 556	RITTENBERG, KALBFLEISCH (LRL+BNL)
ALFF-STE 66 PR 145 1072	ALFF-STEINBERGER, BERLEY + (COLUMBIA+RUTGERS)
BALTY 66 PRL 16 1224	+FRANZINI, KIM, KIRSCH + (COLUMBIA+STONY BROOK)
CLPAY 66 PR 149 1044	COLUMBIA, LRL, PURDUE, WISCONSIN, YALE
CNDPS 66 PL 22 546	CNDPS, FINOCCHIARO, LASSALLE, + (CERN, ETH, SACL)
CRAWFORD 66 PRL 16 333	F.S. CRAWFORD, L.R. PRICE (LRL)
DIGIUGNO 66 PRL 16 767	DIGIUGNO, GIORGI, SILVESTRI + (NAPL, TRST, FRAS)
GROSSMAN 66 PR 146 993	R GROSSMAN, L PRICE, F CRAWFORD (LRL)
GRUNHAUS 66 THESIS	J. GRUNHAUS (COLUMBIA)
JAMES 66 PR 142 896	F E JAMES, H L KRAYBILL (YALE+BNL)
WNEIS 66 PL 23 597	JONES, BINNIE, DUANE, HORSLEY, MASON, (LICI, RHEL)
LARRIBE 66 PL 23 600	LARRIBE, LEVEQUE, MULLER, PAULI, + (SACL+RHEL)
WAHLIG 66 PRL 17 221	WAHLIG, SHIBATA, MANNELLI (MIT+PISA)
BAGLIN 67 PL 248 637	BAGLIN, BEZAUQUET, DEGRANGE, + (EPOL+UCB)
BAGLIN2 67 BAPS 12 567	BAGLIN, BEZAUQUET, DEGRANGE, + (EPOL+UCB)
BALTY1 67 PRL 19 1495	BALTY, FRANZINI, KIM, NEWMAN + (COLU+BRAN)
BALTY2 67 PRL 19 1458	BALTY, FRANZINI, KIM, NEWMAN + (COLU+STON)
BEMPORAD 67 PL 258 380	BEMPORAD, BRACCINI, FOA, LUBELSMY + (PISA, BCNN)
ALSO PRIVATE COMMUNICATION	
BILLING 67 PL 258 435	BILLING, BULLOCK, ESTEN, GOVAN, + (LOUC, OXF)
BCNAMY 67 HEIDELBERG CONF.	BONAMY, SGNOREGGER (SACLAY)
BOWEN 67 PL 248 206	BOWEN, CNDPS, +FINOCCHIARO, + (CERN+ETH+SACL)
BUNIATOV 67 PL 258 560	BUNIATOV, ZAVATTINI, DEINET, + (CERN+KARL)
CENCE 67 PRL 19 1393	CENCE, PETERSON, STENGER, CHIU + (HAWAII+LRL)
ESTEN 67 PL 248 115	+GOVAN, KNIGHT, MILLER, TOVEY + (LOUC+OXF)
FELDMAN 67 PRL 18 868	FELDMAN, FRATTI, GLEESON, HALPERN, + (PERN)
FLATTE 67 PRL 18 976	S.M. FLATTE (LRL)
FLATTE2 67 PR 163 1441	S.M. FLATTE AND C.G. WOHL (LRL)
LITCHFIELD 67 PL 248 486	LITCHFIELD, RANGAN, SEGAR, SMITH + (RHEL+SACLAY)
PRICE 67 PRL 18 1207	L.R. PRICE, F.S. CRAWFORD (LRL)
ARNOLD 68 PL 278 466	+PATY, BAGLIN, BINGHAM + (STRB+MADR+EPOL+UCB)
BAZIN 68 PRL 20 895	BAZIN, GOSHAW, ZACHER, + (PRINCETON, QUEENS)
BULLOCK 68 PL 278 402	+ESTEN, FLEMING, GOVAN, HENDERSON, OWEN + (LOUC)
GORMLEY3 68 PRL 21 402	GORMLEY, HYMAN, LEE, NASH, PEOPLES + (COLU+BNL)
WEHMANN 68 PRL 20 748	WEHMANN, ENGELS, + (HARV+CASE+SLAC+CORN+MGILL)
BAGLIN 69 PL 298 445	BAGLIN, BEZAUQUET, + (EPOL+UCB, MADR, STRB)
ALSO 70 NP 822 66	+BEZAUQUET, DEGRANGE, MUSSET + (EPOL+MADR, STRB)
HYAMS 69 PL 298 128	HYAMS, KOCH, POTTER, VON LINDERN, + (CERN, MPIM)
JACQUET 69 NC 58 743	JACQUET, NGUYEN-KHAC, HAA TUFT + (EPOL, BERG)
MULLER 69 THESIS	ARMAND MULLER (STRB)
BAGLIN 70 NP 822 66	+BEZAUQUET, DEGRANGE, MUSSET + (EPOL+MADR+STRB)
BUTTRAM 70 PRL 25 1358	+KREISLER, MITSCHKE (PRIN)
CARPENTER 70 PR D1 1303	CARPENTER, BINKLEY, CHAPMAN, COX, DAGAN + (DUKE)
COX 70 PRL 24 534	COX, FORTNEY, GOLSON (DUKE)
DANBURG 70 PR D2 2564	+ABOLINS, DAHL, DAVIES, HOCH, KIRZ, + (LRL)
DEVONS 70 PR D1 1936	+GRUNHAUS, KOZLOWSKI, NEMETHY + (COLU, SYRA)
GORMLEY 70 PR D2 501	GORMLEY, HYMAN, LEE, NASH, PEOPLES + (COLU+BNL)
ALSO 70 NEVIS 181 (THESIS)	MICHAEL GORMLEY (COLU)
KANOFSKY 70 NC 68 413	A. KANOFSKY (LEHI)
SCHMITT 70 PL 328 638	+BUNIATOV, ZAVATTINI, DEINET + (CERN, KARL)

BASILE 71 NC 3A 796	+BOLLINI, DALPIAZ, FRABETTI + (CERN, BGNA, STRB)
STRUGALS 71 NP 827 429	+CHUVILO, GEMESTY, IVANOVSKAYA + (JINR)
AGUILAR 72 PR D6 29	AGUILAR-BEKTEZ, CHUNG-ETSNER, SAMIOS (BNL)
BLOODWORTH 72 NP 839 525	BLOODWORTH, JACKSON, PRENTICE, YOON (TORONTO)
LAYER 72 PRL 29 316	+APPEL, KOTLEWSKI, LEE, STEIN, THALER (COLU)
THALER 72 PRL 29 313	+APPEL, KOTLEWSKI, LAYER, LEE, STEIN (CLLU)
LAYER 73 PR D7 2565	+APPEL, KOTLEWSKI, LEE, STEIN, THALER (COLU)
THALER 73 PR D7 2569	+APPEL, KOTLEWSKI, LAYER, LEE, STEIN (COLU)
BROWMAN 74 PRL 32 1067	+DEWIRE, GITTELMAN, HANSON, LOH + (CORN+BING)
DAVIES 74 NC 24A 324	+GU, ZIA (BIRM+RHEL+SHMP)
JANE1 74 PL 48B 260	+JONES, LIPMAN, OWEN, PENNEY + (RHEL+LDC+SUSS)
JANE2 74 PL 48B 265	+JONES, LIPMAN, OWEN, PENNEY + (RHEL+LDC+SUSS)
KENDALL 74 NC 21A 387	+LANOU, MASSIMO, SHAPIRO + (BROV+BARI+MIT)
JANE1 75 PL 59B 99	+GRANNIS, JONES, LIPMAN, OWEN + (RHEL+LDC)
JANE2 75 PL 59B 103	+GRANNIS, JONES, LIPMAN, OWEN + (RHEL+LDC)
ALSO 76 PL (TO BE PUBL.)	ERRATUM, H.R. JANE, PRIVATE COMMUNICATION.
MARTYNOV 76 SJNP 23 48	+SALTYKOV, TARASOV, UZHINSKII (JINR)
BUSHNIN 78 PL 79B 147	+DZHEL'YADIN, GOLDOVKIN, GRITSUK + (SERP)
ALSO 78 SJNP 28 775	BUSHNIN, GOLDOVKIN, GRITSUK, DZHEL'YADIN + (SERP)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA CARDS

BASTIEN 62 PRL 8 114	BASTIEN, BERGE, DAHL, FERRO-LUZZI, MILLER + (LRL)
CARMONY 62 PRL 8 117	D CARMONY, A ROSENFELD, VAN DE WALLE (LRL)
ROSENFELD 62 PRL 8 293	A ROSENFELD, D CARMONY, VAN DE WALLE (LRL)

K[±] 10 CHARGED K (494, JP=0-) I=1/2

10 CHARGED K MASS (MEV)

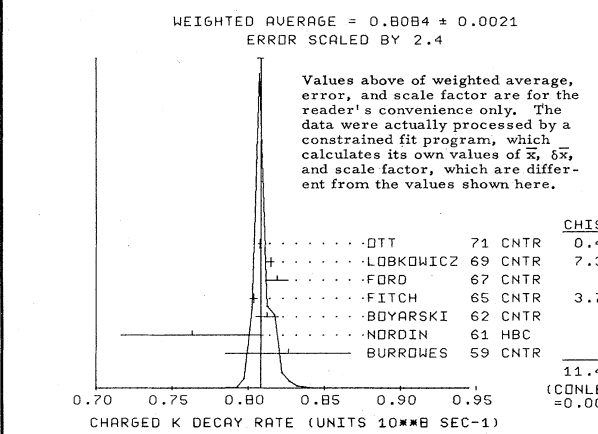
M	493.9	0.2	COHEN	57 RVUE +
M	493.7	0.3	BARKAS	63 EMUL -
M	493.78	0.17	GREINER	65 EMUL + VIA TAU DECAY
M A	(493.871)	(0.19)	KUNSELMAN 71 CNTR	- KAONIC ATOMS 10/71
M	493.691	0.040	JACKENSTO 73 CNTR	- KAONIC ATOMS 1/73
M A	493.662	0.19	KUNSELMAN 74 CNTR	- KAONIC ATOMS 3/74
M	493.657	0.020	CHENG	75 CNTR - KAONIC ATOMS 6/77
M	493.670	0.029	BARKOV	79 EMUL +- E+E- -> K+ K- 7/79*
M A	KUNSELMAN 74 UPDATES	KUNSELMAN 71 WITH IMPROVED KAONIC ATOM CALC.	3/74	
M	AVG	493.668	0.015	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M	STUDENT	493.668	0.017	AVERAGE USING STUDENT(10/1.11) -- SEE MAIN TEXT
M	FIT	493.669	0.015	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

10 (K+) - (K-) MASS DIFFERENCE (MEV)

DM F 1.5M	-0.032	0.090	FORD	72 ASPK +- 4/72
DM F	FORD 72 USES M(PI+)-M(PI-)	= +284- TO KEV.		1/73

10 CHARGED K MEAN LIFE (UNITS 10**=-8)

T	CHAR. K MEAN LIFE			
T 0	(0.95)	(0.36)	(0.25)	ILOFF 56 EMUL
T 0 52	(1.60)	(0.3)	(0.3)	EISENBERG 58 EMUL
T	1.21	0.06	0.06	BURROWES 59 CNTR
T 0 33	(1.38)	(0.24)	(0.24)	FREDEN 60 EMUL
T 0	(1.25)	(0.22)	(0.17)	BARKAS 61 EMUL
T 0 51	(1.27)	(0.36)	(0.23)	BHOWMIK 61 EMUL
T	2.93	1.31	0.08	NORDIN 61 HBC -
T	(1.24)	(0.07)		NORDIN 61 RVUE -
T	1.231	0.011	0.011	BOYARSKI 62 CNTR +
T	1.243	0.0038		FITCH 65 CNTR + K AT REST 6/66
T	1.221	0.011		FORD 67 CNTR +- 8/67
T	1.2272	0.0036		LOBKOWICZ 69 CNTR + K IN FLIGHT 9/66
T	3M	1.2380	0.0016	OTT 71 CNTR + STOPPING K 2/71
T 0	OLD EXPERIMENTS WITH LARGE ERRORS EXCLUDED FROM AVERAGING			2/71
T	AVG	1.2370	0.0032	0.0032 AVERAGE (ERROR INCL. SCALE FACTOR OF 2.4)
T	STUDENT	1.2374	0.0016	0.0016 AVG BY STUDENT(10/1.11) -- SEE MAIN TEXT
T	FIT	1.2371	0.0026	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.9) (SEE IDEOGRAM BELOW)



Data Card Listings

Stable Particles

For notation, see key at front of Listings.

K±

Table with columns: DT, N, THIS QUANTITY IS A MEASURE OF CPT INVARIANCE IN W.I., DT, N, THIS QUANTITY IS A MEASURE OF CPT INVARIANCE IN W.I., DT, N, THIS QUANTITY IS A MEASURE OF CPT INVARIANCE IN W.I.

Table with columns: P1, CHAR., K INTO MU NEU, K MU2, 105+ 0, P2, CHAR., K INTO PI P10, K PI2, 139+ 134, P3, CHAR., K INTO PI P1+ PI-, TAU, 139+ 139+ 139, P4, CHAR., K INTO PI P2I0, TAU PRIME, 139+ 134+ 134, P5, CHAR., K INTO MU PI0 NEU, K MU3, 105+ 134+ 0, P6, CHAR., K INTO E P10 NEU, K E3, .5+ 134+ 0, P7, K+ INTO PI+ PI- E+ NEU, K E+ 4, 139+ 139+ .5+ 0, P8, K+ INTO PI+ PI+ E- NEU, K E- 4, 139+ 139+ .5+ 0, P9, K+ INTO PI+ PI- MU+ NEU, K+MU+ 4, 139+ 139+ 105+ 0, P10, K+ INTO PI+ PI+ MU- NEU, K+MU- 4, 139+ 139+ 105+ 0, P11, CHAR., K INTO E NEU, K E2, .5+ 0, P12, CHAR., K INTO MU NEU GAMMA, K MU RAD, 105+ 0+ 0, P13, CHAR., K INTO PI P10 GAMMA, K PI RAD, 139+ 134+ 0, P14, CHAR., K INTO PI P1+ PI- GAMMA, TAU RAD, 139+ 139+ 139+ 0, P15, CHAR., K INTO PI E+ E-, PI E E, 135+ .5+ .5, P16, CHAR., K INTO PI MU+ MU-, PI MU MU, 139+ 105+ 105, P17, CHAR., K INTO PI GAMMA GAMMA, PI GAM GAM, 139+ 0+ 0, P18, CHAR., K INTO P10 E NEU GAMMA, PI E NEU GAM, 134+ .5+ 0+ 0, P19, K+ INTO PI+ E+ E-, PI+E+E-, 139+ .5+ .5, P20, CHAR., K INTO PI NEU NEU, PI MU NEU, 139+ 0+ 0, P21, CHAR., K INTO E NEU GAMMA, K E2 RAD, .5+ 0+ 0, P22, CHAR., K INTO PI GAMMA, K PI GAM, 139+ 0, P23, CHAR., K INTO PI 3GAMMA, PI 3GAM, 139+ 0+ 0+ 0, P24, C+R, K INTO P10 P10 E NEU, K E4 2P10, 134+ 134+ .5+ 0, P25, K+ INTO PI+ E+ MU+, PI+E+MU+, 139+ .5+ 105, P26, K+ INTO PI+ E+ MU-, PI+E+MU-, 139+ .5+ 105, P27, CHAR., K INTO MU NEU NEU NEUBAR, MU 3NEU, 105+ 0+ 0+ 0, P28, CHAR., K INTO P10 MU NEU GAMMA, PI MU NEU GAM, 134+ 105+ 0+ 0, P29, K+ INTO PI+ MU+ E-, PI+MU+E-, 139+ 105+ .5, P30, CHAR., K INTO MU NEU E+ E-, MU NEU E+E-, 105+ 0+ .5+ .5, P31, K+ INTO MU+ NEU E+ E-, MU+ NEU 2E+, 105+ 0+ .5+ .5, P32, CHAR., K INTO NEU E E E, NEU 3E, 0+ .5+ .5+ .5, P33, CHAR., K INTO E NEU NEU NEUBAR, E 3NEU, .5+ 0+ 0+ 0

CHARGED K CONSTRAINED FIT
OVERALL FIT OF MEAN LIFE, WIDTHS AND BRANCHING RATIOS USES 59 DATA POINTS TO DETERMINE SIX QUANTITIES. OVERALL FIT HAS CHISQ=78.0. MAIN CONTRIBUTION (13.2) COMES FROM R19 OF HAIDT 71 (WE SEE NO REASON TO REJECT THIS EXPERIMENT AT THIS TIME)

Table with columns: P1, P2, P3, P4, P5, P6. Fitted partial decay mode branching fractions.

Table with columns: G1, G2, G3, G4, G5, G6. Fitted partial decay mode rates.

Table with columns: W1, CHAR., K INTO MU NEU (UNITS 10**6 SEC-1), W1, CHAR., K INTO PI P1+ PI- (UNITS 10**6 SEC-1), W2, F, CHAR., K INTO PI P1+ PI- (UNITS 10**6 SEC-1), W2, F, THE LAST IS THE COMBINED RESULT OF FORD 67 AND FORD 70, W3, CHAR., K INTO (TAU) - (TAU PRIME) (UNITS 10**6 SEC-1), W3, USED FOR DELTA I = 1/2 TEST.

Table with columns: W4, CHAR., K INTO (MU P10 NEU) + (E P10 NEU) (UNITS 10**6 SEC-1), W4, USED FOR DELTA I = 1/2 TEST., W4, FIT, 6.484, 0.089, FROM FIT

Table with columns: D1, DIFFERENCE IN K MU2 RATES ((G1+)-(G1-))/G1, D1, DIFFERENCE IN TAU RATES ((G3+)-(G3-))/G3, D2, F, 3.2M, (0.10), (0.14), D2, S, (-0.02), (0.16), D2, F, SECOND FORD 70 VALUE IS FIRST FORD 70 COMBINED WITH FORD 67.

Table with columns: D3, DIFFERENCE IN TAU PRIME RATES ((G4+)-(G4-))/AVERAGE, D3, 1802, -1.1, 1.8, D3, 0.08, 0.58, D3, AVG, 0.07, 0.12, D3, STUDENT, 0.07, 0.13

Table with columns: D4, DIFFERENCE IN K PI2 RATES ((G2+)-(G2-))/AVERAGE, D4, 0.8, 1.2, D5, DIFFERENCE IN K PI RAD RATES ((G13+)-(G13-))/AVERAGE, D5, 24, 0.0, 24.0, D5, 4000, 1.0, 4.0, D5, 2461, 0.8, 5.8

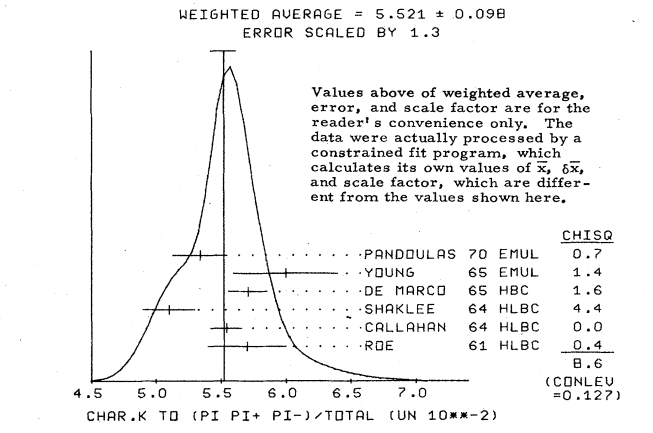
Table with columns: D5, AVG, 0.9, 3.3, D5, STUDENT, 0.9, 3.5

10 CHARGED K BRANCHING RATIOS

Table with columns: R1, CHAR., K INTO (MU NEU)/TOTAL (UNITS 10**6 SEC-1), R1, O, (58.5), (3.0), R1, O, (56.9), (2.6), R1, O, GLD EXPERIMENTS NOT INCLUDED IN AVERAGING, R1, 62K, 63.24, 0.44, R1, FIT, 63.50, 0.16

Table with columns: R2, CHAR., K INTO (PI P10)/TOTAL (UNITS 10**6 SEC-1), R2, O, (27.7), (2.7), R2, O, (23.2), (2.2), R2, O, EARLIER EXPERIMENTS NOT AVERAGED, R2, (21.0), (0.6), R2, 16K, (21.6), (0.6), R2, 16K, 21.18, 0.28, R2, FIT, 21.16, 0.15

Table with columns: R3, CHAR., K INTO (PI P1+ PI-)/TOTAL (UNITS 10**6 SEC-1), R3, O, (5.6), (0.4), R3, O, (6.8), (0.4), R3, O, (5.2), (0.3), R3, O, EARLIER EXPERIMENTS NOT AVERAGED, R3, 5.7, 0.3, R3, 2332, 5.54, 0.12, R3, 540, 5.1, 0.2, R3, 5.71, 0.15, R3, 44, 6.0, 0.4, R3, 693, 5.34, 0.21, R3, C, 2330, (5.56), (0.20), R3, C, THIS VALUE IS NOT INDEPENDENT OF CHIANG 72 R1,R2,R4,R5, AND R6, R3, P, INCLUDES EVENTS OF TAYLOR 59., R3, AVG, 5.521, 0.098, R3, STUDENT, 5.533, 0.089, R3, FIT, 5.588, 0.030

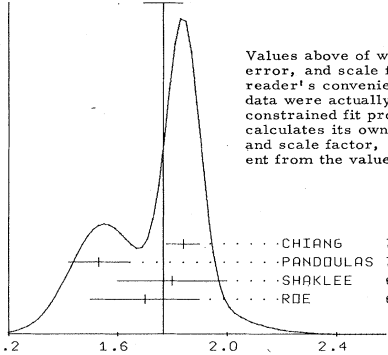


Stable Particles

K±

Table with columns for particle ID (R4), characteristics (CHAR.), and experimental details (K INTO (PI 2PI0)/TOTAL (UNITS 10**2)). Includes names like BIRGE, ALEXANDER, TAYLOR, ROE, SHAKLEE, PANDOULAS, CHIANG.

WEIGHTED AVERAGE = 1.767 ± 0.071
ERROR SCALED BY 1.4



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of X, 6x, and scale factor, which are different from the values shown here.

Table listing individual data points with columns for name (CHIANG, PANDOULAS, SHAKLEE, ROE), counts (72 DSPK, 70 EMUL, 64 HLBC, 61 HLBC), and CHISO values (1.5, 4.6, 0.0, 0.1).

CHAR. K INTO (PI 2PI0)/TOTAL (UN 10**2)

Table with columns for particle ID (R5), characteristics (CHAR.), and experimental details (K INTO (MU P10 NEU)/TOTAL (UNITS 10**2)). Includes names like BIRGE, ALEXANDER, TAYLOR, CHIANG.

Table with columns for particle ID (R6), characteristics (CHAR.), and experimental details (K INTO (E P10 NEU)/TOTAL (UNITS 10**2)). Includes names like BIRGE, ALEXANDER, ROE, SHAKLEE, CHIANG.

Table with columns for particle ID (R7), characteristics (CHAR.), and experimental details (K INTO (PI2 + MU3)/TOTAL (UNITS 10**2)). Includes names like ROE, SHAKLEE.

Table with columns for particle ID (R8), characteristics (K+ INTO (PI+ PI+ E- NEU)/TOTAL (UNITS 10**7)), and experimental details. Includes names like BIRGE, ELY, SCHWEINBE.

Table with columns for particle ID (R9), characteristics (K+ INTO (PI+ PI- MU+ NEU)/TOTAL (UNITS 10**5)), and experimental details. Includes name CLINE.

Table with columns for particle ID (R10), characteristics (K+ INTO (PI+ PI+ MU- NEU)/TOTAL (UNITS 10**6)), and experimental details. Includes name BIRGE.

Table with columns for particle ID (R11), characteristics (CHAR. K INTO (E NEU)/TOTAL (UNITS 10**5)), and experimental details. Includes name BORREANI.

Table with columns for particle ID (R12), characteristics (CHAR. K INTO (PI GAMMA GAMMA)/TOTAL (UNITS 10**4)), and experimental details. Includes names CHEN, KLEMS, EDWARDS, ABRAMS.

Table with columns for particle ID (R13), characteristics (CHAR. K INTO (PI P10 GAMMA)/TOTAL (UNITS 10**4)), and experimental details. Includes names CLINE, EMERSON, MALTSEV, ABRAMS, EDWARDS, LJUNG, SMITH, WIRE.

Table with columns for particle ID (R14), characteristics (CHAR. K INTO (PI PI+ PI- GAMMA)/TOTAL (UNITS 10**4)), and experimental details. Includes name STAMER.

Table with columns for particle ID (R15), characteristics (CHAR. K INTO (PI E+ E-)/TOTAL (UNITS 10**6)), and experimental details. Includes names CAMERINI, BISI, CLINE2, BEIER, CENCE.

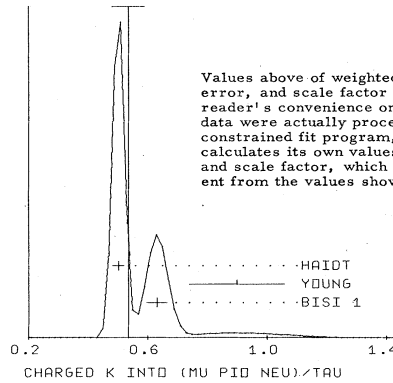
Table with columns for particle ID (R16), characteristics (CHAR. K INTO (PI MU+ MU-)/TOTAL (UNITS 10**6)), and experimental details. Includes names CAMERINI, BISI.

Table with columns for particle ID (R17), characteristics (CHAR. K INTO (PI P10)/TAU), and experimental details. Includes names YOUNG, CALLAHAN.

Table with columns for particle ID (R18), characteristics (CHAR. K INTO (PI 2PI0)/TAU), and experimental details. Includes names BISI, YOUNG.

Table with columns for particle ID (R19), characteristics (CHAR. K INTO (MU P10 NEU)/TAU), and experimental details. Includes names BISI 1, YOUNG, EICHTEN, HAIDT.

WEIGHTED AVERAGE = 0.536 ± 0.054
ERROR SCALED BY 3.2



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of X, 6x, and scale factor, which are different from the values shown here.

Table listing individual data points with columns for name (HAIDT, YOUNG, BISI 1), counts (71 HLBC, 65 EMUL, 65 H+HL), and CHISO values (3.1, 10.5, 7.5).

Table with columns for particle ID (R20), characteristics (CHAR. K INTO (E P10 NEU)/TAU), and experimental details. Includes names BORREANI, YOUNG, BELLOTT2.

Table with columns for particle ID (R21), characteristics (K+ INTO (PI+ PI- E+ NEU)/TAU (UNITS 10**4)), and experimental details. Includes names BIRGE, ELY, BOURQUIN, SCHWEINBE, ROSSELET.

Table with columns for particle ID (R22), characteristics (K+ INTO (PI+ PI- MU+ NEU)/TAU (UNITS 10**4)), and experimental details. Includes names GREINER, BISI.

Table with columns for particle ID (R23), characteristics (CHAR. K INTO (E P10 NEU)/(MU2+PI2) (UNITS 10**2)), and experimental details. Includes names CESTER, ESCHSTRUT, WEISSENBERG, KNU2, KP12.

Table with columns for particle ID (R24), characteristics (K+ INTO (PI+ PI- MU+ NEU)/TAU (UNITS 10**4)), and experimental details. Includes names GREINER, BISI.

Table with columns for particle ID (R25), characteristics (CHAR. K INTO (E P10 NEU)/(MU2+PI2) (UNITS 10**2)), and experimental details. Includes names CESTER, ESCHSTRUT, WEISSENBERG, KNU2, KP12.

Table with columns for particle ID (R26), characteristics (CHAR. K INTO (E P10 NEU)/(MU2+PI2) (UNITS 10**2)), and experimental details. Includes names CESTER, ESCHSTRUT, WEISSENBERG, KNU2, KP12.

Table with columns for particle ID (R27), characteristics (CHAR. K INTO (E P10 NEU)/(MU2+PI2) (UNITS 10**2)), and experimental details. Includes names CESTER, ESCHSTRUT, WEISSENBERG, KNU2, KP12.

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

K±

Table of particle data listings for K mesons, including entries for K INTO (PI P10)/(MU NEU), K INTO (PI P10)/(MU NEU)/KE3, K INTO (PI P10)/(MU NEU)/TAU, and K INTO (PI P10)/(MU NEU)/TAU PRIME. Each entry includes numerical values, error bars, and descriptive text.

Table of particle data listings for K mesons, including entries for K INTO (PI P10)/(MU NEU)/KE3, K INTO (PI P10)/(MU NEU)/TAU, and K INTO (PI P10)/(MU NEU)/TAU PRIME. Each entry includes numerical values, error bars, and descriptive text.

Note on Slope Parameter for K → 3π Decays

As was discussed in Section VI B.1 of the text, for the 3π decays of the K mesons we list the slope parameter "g" which is defined, as in that section, by

Equation defining the slope parameter g: |M|^2 ∝ 1 + g * (s3 - s0) / m_pi^2 + h * ((s3 - s0) / m_pi^2)^2 + j * (s2 - s1) / m_pi^2 + k * ((s2 - s1) / m_pi^2)^2 + ... (1)

where

Stable Particles

 K^\pm

$$s_i = (\underline{p}_K - \underline{p}_i)^2 = (m_K - m_i)^2 - 2m_K T_i \quad (2)$$

$$s_0 = \frac{1}{3} \sum s_i = \frac{1}{3} (m_K^2 + m_1^2 + m_2^2 + m_3^2) \quad (3)$$

$\underline{p}_K, \underline{p}_i$ are the four-vectors for the K and the i^{th} pion, and the index 3 refers to the odd pion, i.e., the third pion in the decays listed below. (4)

We refer to the three possible charged decays as $\tau, \tau',$ and τ^0 :

$$\begin{array}{ll} \tau^\pm & K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\mp \\ \tau'^\pm & K^\pm \rightarrow \pi^0 \pi^0 \pi^\pm \\ \tau^0 & K_L^0 \rightarrow \pi^+ \pi^- \pi^0 \end{array}$$

The measurements of g vary considerably beyond the authors' quoted errors as can be seen in the ideograms associated with the GT+, GT-, and GTP subsections of the K^\pm Data Card Listings and the GTO subsection of the K_L^0 Listings. Appendix I discusses tests of the $\Delta I = 1/2$ rule utilizing these slopes.

There is no indication of a CP-violating asymmetry in K_L^0 decay as measured by the coefficient j given in subsection JTO of the K_L^0 Listings.

The high-statistics τ^0 -decay experiment of MESSNER 74 finds significant non-zero quadratic coefficients h and k . CHO 77, a lower-statistics τ^0 experiment, obtains results in agreement with MESSNER 74 but can also obtain good fits with a linear term (g) only. The correlation between the linear and quadratic coefficients changes the CHO 77 g_{τ^0} from 0.629 ± 0.017 (linear fit) to 0.681 ± 0.024 (quadratic fit). Another experiment, PEACH 77, does not observe this correlation and is in agreement only with the linear fit of CHO 77.

There is some evidence for a non-zero k coefficient from τ^\pm experiments. FORD 72 (1.5M events) have studied $K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\mp$ and find that the χ^2/DF goes from 1.38 to 1.20 for $DF \approx 150$ when the second order and CP-violation terms are added. However, the authors state that since their Coulomb

Data Card Listings

For notation, see key at front of Listings.

correction is larger than the experimental errors and is not well known, it is difficult to interpret these results. DEVAUX 77 also finds a non-zero k .

Because of the above evidence for quadratic terms, and for consistency in our treatment of τ^0 and τ^\pm decay, we now include in our averages only those τ^0 and τ^\pm experiments for which we have information on the three coefficients $g, h,$ and k . Correlations prevent us from comparing fits which do not include these three parameters. For τ^\pm decays we compile g and h only since no experiments measure k .

Parametrizations

In the literature *other definitions* of slope parameters have appeared. We have converted to the definitions of g, h, j and k in Eq. (1) from whatever experimental quantity has been reported. We give the conversion to the definition (1) for the most widely used parametrizations and tabulate the conversion factors for the reader's convenience.

a) For analysis of charged K's and some K^0 experiments, the expression often used is:

$$|M|^2 = 1 + a_Y Y + b_Y Y^2 + d_X X + e_Y X^2$$

with

$$Y = \frac{3T_3 - Q}{Q}$$

$$X = \frac{\sqrt{3} (T_1 - T_2)}{Q}$$

$$Q = m_K - \sum m_i$$

The relevant formulae are:

$$Y = -\frac{3}{2} \frac{s_3 - s_0}{m_K Q} + \Delta, \quad X = \frac{\sqrt{3}}{2} \frac{s_2 - s_1}{m_K Q}$$

with

$$\Delta = \frac{m_1 - m_3}{Q} \left(2 - \frac{m_3 + m_1}{m_K} \right)$$

and

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

K[±]

$$\begin{aligned}
 g &= \frac{-c_y(a_y + 2b_y\Delta)}{1 + a_y\Delta + b_y\Delta^2} , \\
 h &= \frac{c_y^2 b_y}{1 + a_y\Delta + b_y\Delta^2} , \\
 j &= \frac{c_y d_y}{\sqrt{3} (1 + a_y\Delta + b_y\Delta^2)} , \\
 k &= \frac{c_y^2 e_y}{3(1 + a_y\Delta + b_y\Delta^2)} ,
 \end{aligned}$$

with

$$c_y = \frac{3}{2} \frac{m_{\pi^+}^2}{m_K Q}$$

b) For the analysis of some K⁰ experiments the expression used is

$$\begin{aligned}
 |M|^2 &= 1 + 2a_t \frac{m_K}{m_{\pi^+}} (2T_3 - T_{3\max}) \\
 &+ b_t \left(\frac{m_K}{m_{\pi^+}} \right)^2 (2T_3 - T_{3\max})^2 ,
 \end{aligned}$$

with

$$T_{3\max} = \frac{(m_K - m_3)^2 - (m_1 + m_2)^2}{2m_K}$$

The relevant transformations are

$$T_3 = -\frac{s_3 - s_0}{2m_K} + \frac{Q}{3} (1 + \Delta)$$

and

$$\begin{aligned}
 g &= \frac{-2a_t - b_t c_t}{1 + a_t c_t + \frac{b_t c_t^2}{4}} , \\
 h &= \frac{b_t}{1 + a_t c_t + \frac{b_t c_t^2}{4}} ,
 \end{aligned}$$

with

$$c_t = \frac{2m_K}{m_{\pi^+}} \left[\frac{2}{3} Q(1 + \Delta) - T_{3\max} \right] .$$

c) Other K⁰ authors use the same form of matrix element as given in b) above with a linear

term only, but define

$$T_{\max} = \frac{2}{3} Q .$$

The relevant transformation is then

$$g = \frac{-2a_u}{1 + a_u c_u} ,$$

with

$$c_u = \frac{4m_K}{3m_{\pi^+}^2} Q\Delta .$$

d) Older K⁰ analyses were done using

$$|M|^2 = 1 + a_v \frac{T_3}{m_K}$$

The relevant transformation is then

$$g = \frac{-c_v a_v}{1 + d_v a_v}$$

with

$$c_v = \frac{m_{\pi^+}^2}{2m_K^2}$$

and

$$d_v = \frac{Q}{3m_K} (1 + \Delta) .$$

e) The CP-violating term in |M|² for K_L⁰ → π⁺π⁻π⁰ experiments has been parametrized in several ways. BLANPIED 68 and SCRIBANO 70 use the parametrization given in (b) above with no quadratic term and with an additional CP violating term. BLANPIED 68 parametrizes the CP-violating term as

$$2\sigma_B \frac{m_K}{m_{\pi^+}} (T_1 - T_2) .$$

The relevant transformation is then

$$j = \frac{\sigma_B}{1 + c_t a_t}$$

with c_t as defined in (b) above. SCRIBANO 70 parametrizes the CP-violating term as

$$\frac{2}{\sqrt{3}} \sigma_S \frac{T_1 - T_2}{T_{12\max}}$$

where T_{12max} is the maximum kinetic energy of particle 1 or 2, the charged π's, given by

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$$T_{12max} = \frac{(m_K - m_1)^2 - (m_2 + m_3)^2}{2m_K}$$

The resulting transformation is then

$$j = \frac{m_{\pi^+}^2}{\sqrt{3} m_K T_{12max}} \frac{\sigma_S}{(1 + c_t a_t)}$$

SMITH 70 gives the asymmetry

$$\alpha = \frac{N_+ - N_-}{N_+ + N_-}$$

where N₊ is the number of events with T₁ > T₂ and N₋ is the converse. BLANPIED 68 gives the relation σ_B = α/1.16 which allows us to use the transformation to j given above for BLANPIED 68.

For the reader's convenience we give a table of numerical values for Q, T_{3max}, T_{12max}, Δ, c_y, c_t, c_u, c_v, and d_v, obtained using the masses from the current edition.

	τ [±]	τ [±]	τ ⁰
Q	74.97	84.18	83.57
T _{3max}	48.08	53.20	53.89
T _{12max}	48.08	53.99	53.12
Δ	0.0000	-0.0790	0.0798
c _y	0.7895	0.7031	0.7025
c _t	0.0962	-0.0769	0.3204
c _u	0.0000	-0.2247	0.2272
c _v	0.0400	0.0400	0.0393
d _v	0.0506	0.0523	0.0604

References

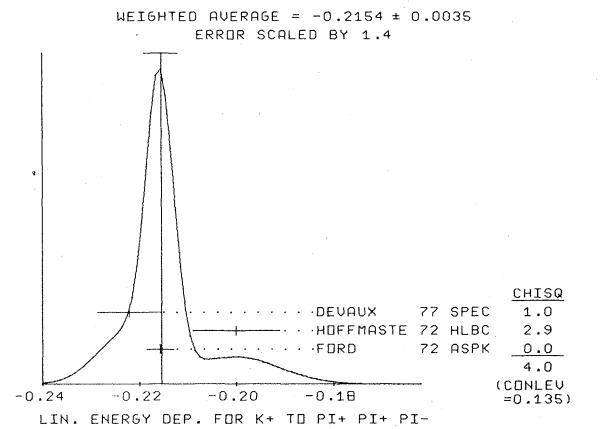
See the reference sections of the K[±] and K_L⁰ Data Card Listings.

See also the review of T. J. Devlin and J. O. Dickey, Rev. Mod. Phys. 51, 237 (1979), which contains an analysis of K → 2π and K → 3π data in terms of transition amplitudes with appropriate energy dependence.

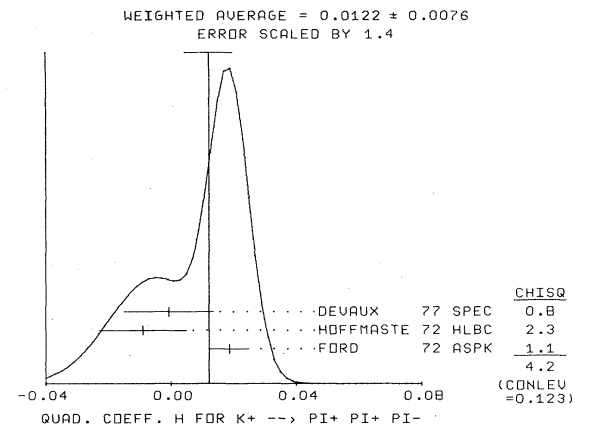
Data Card Listings

For notation, see key at front of Listings.

10 CHARGED K ENERGY DEPENDENCE OF DALITZ PLOT
 RELATED TEXT SECTION VI B.1, APPENDIX I, AND MINI-REVIEW ABOVE
 MATRIX ELEMENT SQUARED = 1 + G*U + H*U**2 + K*V**2 1/79*
 WHERE U=(S3-S0)/(MPI**2) AND V=(S1-S2)/(MPI**2) 1/79*
 GT+ LINEAR COEFFICIENT G FOR TAU DECAYS K+ --> PI+ PI+ PI- 1/79*
 GT+ SOME EXPTS USE DALITZ VARIABLES X AND Y. WE GIVE AY=COEFF OF Y 1/79*
 GT+ TERM AT RIGHT. SEE MINI-REVIEW ABOVE. 1/79*
 GT+ZL 5428 (-0.22) (0.024) ZINGHENKO 67 HBC + AY=0.28+-03 10/69
 GT+ L 9994 (-0.218) (0.016) BUTLER 68 HBC + AY=0.277+-020 10/69
 GT+ G17898 (-0.196) (0.032) GRAUMAN 70 HLBC + AY=0.228+-030 8/70
 GT+ 750K -0.2157 0.0028 FORD 72 ASPK + AY=0.2734+-0035 1/79*
 GT+H 39819 -0.200 0.009 HOFFMASTE 72 HLBC + 1/79*
 GT+ 225K -0.2221 0.0065 DEVAUX 77 SPEC + AY=0.2814+-0082 1/79*
 GT+ L EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE. 3/78
 GT+ Z ALSO INCLUDES DBC EVENTS
 GT+ G EMULS. DATA ADDED - ALL EVENTS INCLUDED BY HOFFMASTE 72 1/71
 GT+H HOFFMASTE 72 INCLUDES GRAUMAN 70 DATA. 1/79*
 GT+
 GT+ AVG -0.2154 0.0035 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
 GT+ STUDENT -0.2156 0.0028 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)



HT+ QUADRATIC COEFF. H FOR K+ --> PI+ PI+ PI- 1/79*
 HT+ 750K 0.0187 0.0062 FORD 72 ASPK + 1/79*
 HT+ 39819 -0.009 0.014 HOFFMASTE 72 HLBC + 1/79*
 HT+ 225K -0.0006 0.0143 DEVAUX 77 SPEC + 1/79*
 HT+
 HT+ AVG 0.0122 0.0076 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)
 HT+ STUDENT 0.0124 0.0065 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)



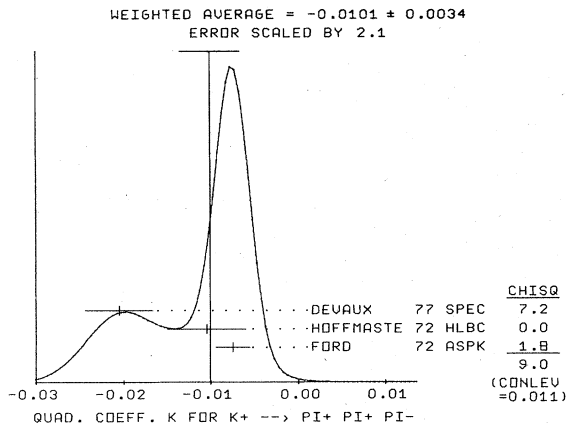
KT+ QUADRATIC COEFF. K FOR K+ --> PI+ PI+ PI- 1/79*
 KT+ 750K -0.0075 0.0019 FORD 72 ASPK + 1/79*
 KT+ 39819 -0.0105 0.0045 HOFFMASTE 72 HLBC + 1/79*
 KT+ 225K -0.0205 0.0039 DEVAUX 77 SPEC + 1/79*
 KT+
 KT+ AVG -0.0101 0.0034 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.1)
 KT+ STUDENT -0.0094 0.0021 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

Data Card Listings

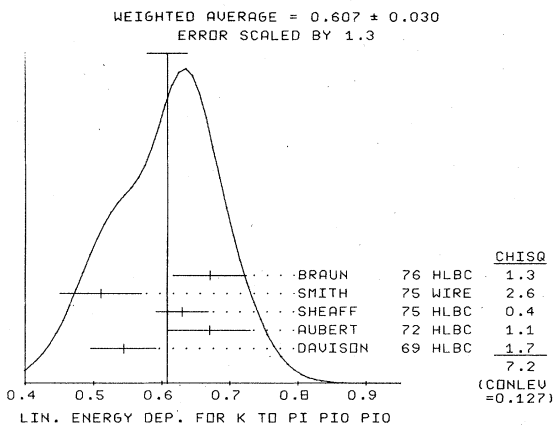
For notation, see key at front of Listings.

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K±



GT- L LINEAR COEFFICIENT G FOR TAU DECAYS K- --> PI- PI- PI+
GT- FOR DEFINITION OF AY SEE NOTE IN SECTION GT+ ABOVE.
GT- F 1347 (-0.220) (0.035) FERRO-LUZ 61 HBC - AY=0.28+-0.045 10/69
GT-ML 5778 (-0.190) (0.023) MOSCOSO 68 HBC - AY=0.24+-0.029 10/69
GT- 50919 -0.193 0.010 MAST 69 HBC - AY=0.24+-0.013 1/79*
GT- 750K -0.2186 0.0028 FORD 72 ASPK - AY=0.2770+-0.0035 1/79*
GT- Q 81K (-0.199) (0.008) LUCAS1 73 HBC - AY=0.252+-0.011 10/72
GT- F NO RADIATIVE CORRECTIONS INCLUDED.
GT- L EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE. 3/78
GT- M ALSO INCLUDES DBC EVENTS.
GT- Q QUADRATIC DEPENDENCE IS REQUIRED BY KL EXPTS. FOR COMPARISON WE 1/79*
GT- Q AVERAGE ONLY THOSE K+ EXPERIMENTS WHICH QUOTE QUADRATIC FIT VALUES. 1/79*
GT- AVG -0.2167 0.0066 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.5)
GT- STUDENT -0.2173 0.0031 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
HT- QUADRATIC COEFF H FOR K- --> PI- PI- PI+ 1/79*
HT- 50919 -0.001 0.012 MAST 69 HBC - 1/79*
HT- 750K 0.0125 0.0062 FORD 72 ASPK - 1/79*
HT- AVG 0.0097 0.0055 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
HT- STUDENT 0.0098 0.0061 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
KT- QUADRATIC COEFF K FOR K- --> PI- PI- PI+ 1/79*
KT- 50919 -0.014 0.012 MAST 69 HBC - 1/79*
KT- 750K -0.0083 0.0019 FORD 72 ASPK - 1/79*
KT- AVG -0.0084 0.0019 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
KT- STUDENT -0.0084 0.0020 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
DG ((GT+)-(GT-))/(GT+)+(GT-) IN PERCENT
DG A NON-ZERO VALUE FOR THIS QUANTITY INDICATES CP VIOLATION
DG 3.2M -0.70 0.53 FORD 70 ASPK 11/70
GTP LINEAR COEFFICIENT G FOR TAU PRIME DECAYS CHAR. K --> PI PI0 PI0.
GTP UNLESS OTHERWISE STATED, ALL EXPTS INCLUDE TERMS QUADRATIC IN
GTP (S3-S0)/(MP1*2). SEE MINI-REVIEW ABOVE.
GTP K 1792 (0.48) (0.04) KALMUS 64 HLBC + 1/79*
GTP K 1874 (0.586) (0.098) BISI 65 HLBC + ALSO HBC 1/79*
GTP 4048 0.544 0.048 DAVISON 69 HLBC + ALSO EMUL 1/79*
GTP L 198 (0.527) (0.102) PANDOLAS 70 EMUL + 1/79*
GTP 1365 0.67 0.06 AUBERT 72 HLBC + 1/79*
GTP K 574 (0.484) (0.084) LUCAS2 73 HBC - DALITZ PRS ONLY 1/79*
GTP 5625 0.630 0.038 SHEAFF 75 HLBC + 1/79*
GTP 27K 0.510 0.060 SMITH 75 WIRE + 1/79*
GTP L 4639 (0.806) (0.220) BERTRAND 76 EMUL + 1/79*
GTP 3263 0.670 0.054 BRAUN 76 HLBC + 1/79*
GTP K AUTHORS GIVE LINEAR FIT ONLY.
GTP L EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.
GTP AVG 0.607 0.030 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
GTP STUDENT 0.610 0.027 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
(SEE IDEOGRAM BELOW)



HTP QUADRATIC COEFF H FOR CHAR K --> PI PI0 PI0. SEE MINI-REVIEW ABOVE. 1/79*
HTP 4048 0.026 0.050 DAVISON 69 HLBC + ALSO EMUL 1/79*
HTP L 198 (0.018) (0.124) PANDOLAS 70 EMUL + 1/79*
HTP 1365 -0.01 0.08 AUBERT 72 HLBC + 1/79*
HTP 5635 0.041 0.030 SHEAFF 75 HLBC + 1/79*
HTP 27K 0.009 0.040 SMITH 75 WIRE + 1/79*
HTP L 4639 (0.164) (0.121) BERTRAND 76 EMUL + 1/79*
HTP 3263 0.152 0.082 BRAUN 76 HLBC + 1/79*
HTP L EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE. 1/79*
HTP AVG 0.034 0.020 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
HTP STUDENT 0.033 0.022 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

Note on $K_{\ell 3}^{\pm}$ and $K_{\ell 3}^0$ Form Factors

Definitions of the parameters λ_+ , $\xi(0)$, λ_0 , $|f_S/f_+|$ and $|f_T/f_+|$ and a general discussion of the methods of analysis are given in Section VI B.2 of the text.

This note describes the contents of the Data Card Listings for the two $K_{\mu 3}$ parametrizations, $(\lambda_+, \xi(0))$ and (λ_+, λ_0) , which were discussed in the text. Problems related to our data entries for individual experiments are discussed and a comparison of results is given.

$K_{\mu 3}$ Experiments

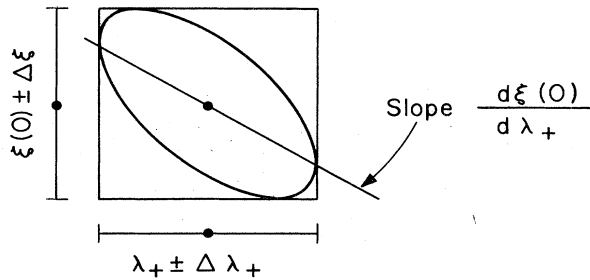
The matrix element for $K_{\mu 3}$ decay, assuming a pure vector current, is given by Eq. (2) in Section VI B.2 of the text. Most experiments appear to be compatible with the assumption that f_+ depends linearly on t and that f_- is constant. Only DALLY 72 ($K_{\mu 3}^0$) appears to require $\lambda_- \neq 0$ (by about three standard deviations). A single data bin at low q^2 seems to be responsible. The effect is not observed in the high-statistics experiment of DONALDSON2 74 (also $K_{\mu 3}^0$).

$\lambda_+, \xi(0)$ Parametrization: λ_+ data from $K_{\mu 3}$ decay are entered into the K_{ℓ}^{\pm} and K_{ℓ}^0 sections of the Data Card Listings in subsection L+M. The corresponding $\xi(0)$ values are entered in subsection XIA, XIB, or XIC, depending on whether Method A, B, or C, discussed below and in the text, was used. The data cards contain the values, one-standard-deviation errors $\Delta\lambda_+$ and $\Delta\xi(0)$, as well as the correlation $d\xi(0)/d\lambda_+$, all indicated on the $e^{-1/2}$ likelihood contour below. The correlations are given on the right side of the $\xi(0)$ data cards.

λ_+, λ_0 Parametrization: This parametrization is used in recent $K_{\mu 3}$ analyses. To facilitate comparison between experiments, we convert earlier experiments from the $(\lambda_+, \xi(0))$ parametrization to (λ_+, λ_0) whenever possible (i.e., when λ_+ and $\xi(0)$ values, errors, and correlations are given). The

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K^\pm



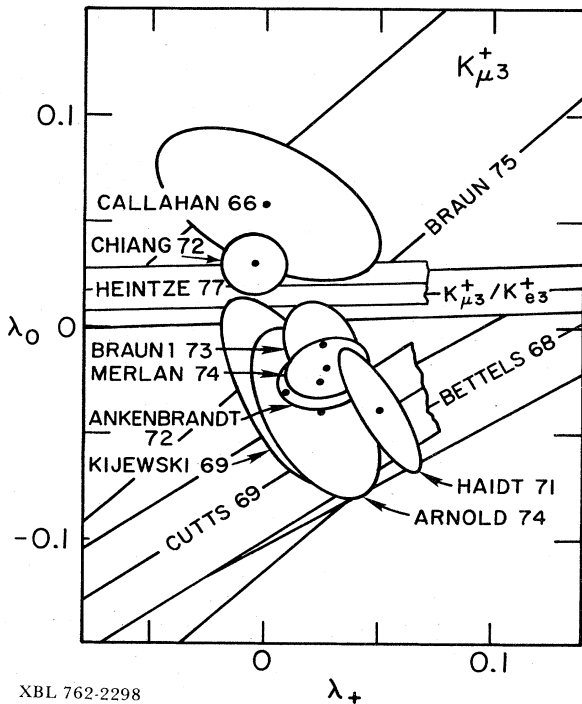
transformation between these parametrizations is:

$$\lambda_0 = \lambda_+ + a\xi(0) ,$$

$$\Delta\lambda_0^2 = (1 + 2a \frac{d\xi(0)}{d\lambda_+}) \Delta\lambda_+^2 + a^2 \Delta\xi^2 ,$$

$$\frac{d\lambda_0}{d\lambda_+} = 1 + a \frac{d\xi(0)}{d\lambda_+} ,$$

where $a = m_\pi^2 / (m_K^2 - m_\pi^2)$. The λ_0 value, the one-standard-deviation error $\Delta\lambda_0$, and the correlation $d\lambda_0/d\lambda_+$ are given in subsection L0 of the data cards.



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Fig. 1. One-standard-deviation ($e^{-1/2}$) likelihood contours in the (λ_+, λ_0) plane for $K_{\mu 3}^+$.

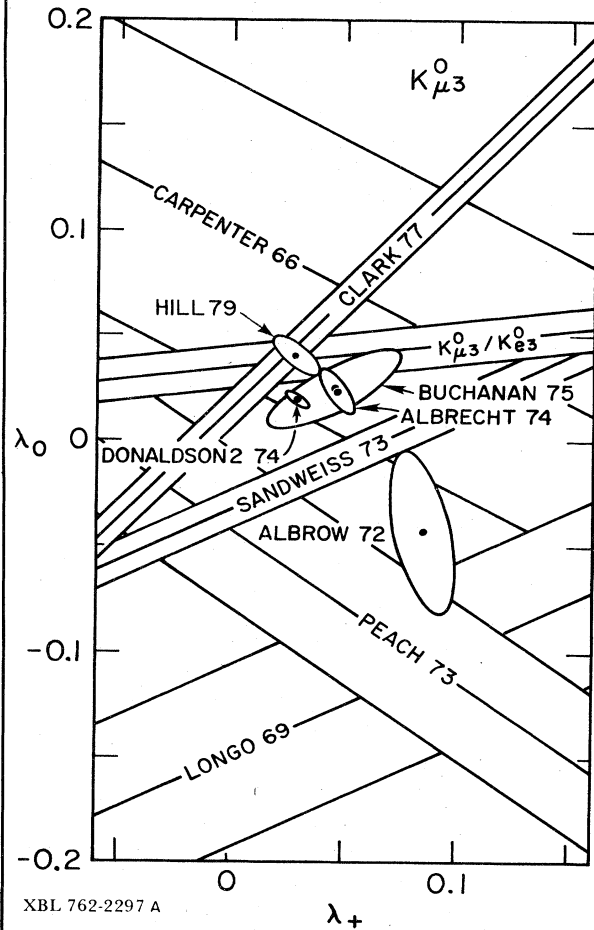
Data Card Listings

For notation, see key at front of Listings.

We also convert (λ_+, λ_0) results into the $(\lambda_+, \xi(0))$ parametrization whenever possible so that subsection L0 is essentially equivalent to the three subsections XIA, XIB, and XIC.

Individual analyses have used a variety of parametrizations. Problems arise when trying to express their results in terms of the parametrizations used here. The discussion of these problems is divided into three sections corresponding to the three methods of analyses discussed in the text.

Method A: Dalitz plot analyses and pion spectrum analyses usually determine λ_+ and $\xi(0)$ (or λ_0) values, errors, and correlation. Such measurements are entered in the L+M, XIA, and L0 subsections. They give rise to the error ellipses shown in Figs. 1 and 2. These are approximations to likelihood contours.



XBL 762-2297 A

Fig. 2. One-standard-deviation ($e^{-1/2}$) likelihood contours in the (λ_+, λ_0) plane for $K_{\mu 3}^0$.

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

K[±]

Some analyses of this type fix λ_+ and determine $\xi(0)$, e.g., CARPENTER 66 and PEACH 73 (both $K_{\mu 3}^0$). We enter $\xi(0)$ and $d\xi(0)/d\lambda_+$ in the XIA section and give the fixed λ_+ value in the data card footnote. The $\xi(0)$ error is parenthesized because it does not include the uncertainty in the value of λ_+ . These results, transformed to λ_0 measurements, give rise to bands in Fig. 2. These bands are also approximations to the likelihood contours. The actual likelihood bands would not be straight.

In some cases, we alter an error from its published value in order to obtain an error ellipse with a width which matches the error in $\xi(0)$ for fixed λ_+ . These adjustments are noted in the $\xi(0)$ data card footnotes, e.g., for CALLAHAN1 66 and HAIDT 71 (K⁺ subsection XIA), where the published errors and correlation violate the constraint $|C_{\lambda\xi}| < 1$ on the normalized correlation coefficient $C_{\lambda\xi}$ given by

$$C_{\lambda\xi} = \frac{\Delta\lambda_+}{\Delta\xi} \frac{d\xi(0)}{d\lambda_+} .$$

In some cases, e.g., BRAUN1 73, the parametrization used is λ_+ , $\xi(0)$, $\xi(t^*)$, where t^* is the weighted average of t with weighting according to the sensitivity to ξ . In this case we do not use $\xi(0)$. It is a badly determined parameter comparable to λ_- or the slope of $\xi(t)$. Instead, we use

$$\xi(0) = \xi(t^*) (1 + \lambda_+ t^*) ,$$

$$\frac{d\xi(0)}{d\lambda_+} = \frac{d\xi(t^*)}{d\lambda_+} (1 + \lambda_+ t^*) + \xi(t^*) t^* .$$

With the BRAUN1 73 values, $\lambda_+ = 0.027$, $\xi(6.6) = -0.34 \pm 0.20$, and $d\xi(6.6)/d\lambda_+ = -14$, we obtain

$$\xi(0) = (-0.40 \pm 0.24) - 19(\lambda_+ - 0.027) ;$$

or for their fitted $\lambda_+ = 0.025 \pm 0.017$, we get $\xi(0) = -0.36 \pm 0.40$.

Method B: Branching ratio experiments cannot determine λ_+ and $\xi(0)$ simultaneously, but simply fix a relationship between them, given in Section VI B.2 of the text. Results are usually quoted as values of $\xi(0)$ at fixed λ_+ . We list these results in subsection XIB, but we do not average them because the λ_+ values differ. Instead, we compute

a combined result by using the relations in the text and our fitted values of $\Gamma(K_{\mu 3}^{\pm})/\Gamma(K_{e 3}^{\pm})$ and $\Gamma(K_{\mu 3}^0)/\Gamma(K_{e 3}^0)$, which include the branching ratios from these experiments. The branching ratios from our current edition and the results for $\xi(0)$ and λ_0 evaluated at $\lambda_+ = 0.030$ are

	K [±]	K _L ⁰
$\Gamma(K_{\mu 3}^{\pm})/\Gamma(K_{e 3}^{\pm})$	0.663 ± 0.018 (S=1.7)	0.695 ± 0.017
$\xi(0)$	-0.20 ± 0.15 (S=1.7)	+0.08 ± 0.13
$d\xi(0)/d\lambda_+$	-11.9	-10.3
λ_0	+0.014 ± 0.012 (S=1.7)	+0.037 ± 0.011
$d\lambda_0/d\lambda_+$	+0.04	+0.12

The scale factor S is the amount by which the error has been multiplied in order to compensate for discrepancies in the branching ratios. These λ_0 results give rise to the $K_{\mu 3}/K_{e 3}$ bands in Figs. 1 and 2.

Method C: Polarization experiments measure $\langle \xi(t) \rangle$, the weighted average of $\xi(t)$ over the t range of the experiment, where the weighting accounts for the variation with t of the sensitivity to $\xi(t)$. Such measurements are entered in subsection XIC.

To reinterpret these results in the $(\lambda_+, \xi(0))$ parametrization, we recognize that $\lambda_+ = 0$ corresponds to $\xi(t)$ constant (always assuming $\lambda_- = 0$) so that

$$\xi(0) \Big|_{\lambda_+=0} \equiv \langle \xi(t) \rangle .$$

The correlation with λ_+ is given by the following relations (valid for small λ_+):

$$\xi(0) \approx \langle \xi(t) \rangle (1 + \lambda_+ \langle \frac{t}{m_\pi^2} \rangle) ,$$

$$\frac{d\xi(0)}{d\lambda_+} \approx \langle \xi(t) \rangle \langle \frac{t}{m_\pi^2} \rangle ,$$

where $\langle t/m_\pi^2 \rangle$ is the average value of t weighted by the sensitivity to $\xi(t)$. These results, transformed to λ_0 and $d\lambda_0/d\lambda_+$ values, are entered in subsection L0 and give rise to bands in Figs. 1 and 2.

In Figs. 1 and 2, we disregard those polarization measurements for which $d\xi(0)/d\lambda_+$ is not

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obtainable. Also we disregard MERLAN 73 because the signs of $\xi(0)$ and $d\xi(0)/d\lambda_+$ are opposite, whereas the above equation requires them to be the same (since $t > 0$).

Comparison of K_{μ3} Experiments: Figures 1 and 2 show the likelihood contours in the (λ_+, λ_0) plane for K_{μ3}⁺ and K_{μ3}⁰ respectively.

The K_{μ3}⁺ Dalitz plot results (ellipses) shown are fairly consistent and appear to cluster between the K_{μ3}⁺/K_{e3} result and the polarization results of BETTELS 68 and CUTTS 69. The K_{μ3}⁰ results are much less consistent with a small cluster appearing in the neighborhood of the DONALDSON2 74 result.

χ^2 fits to the results shown in Fig. 1 and Fig. 2 yield the following values for λ_+ and λ_0 . The corresponding values of $\xi(0)$ are also given.

	K _{μ3} ⁺	K _{μ3} ⁰
λ_+	+0.026 ± 0.008*	+0.034 ± 0.005*
λ_0	-0.003 ± 0.007*	+0.022 ± 0.006*
$d\lambda_0/d\lambda_+$	-0.11	-0.30
χ^2/DF	40/19	76/14
S*	1.5	2.3
.....		
$\xi(0)$	-0.35 ± 0.14*	-0.14 ± 0.11
$d\xi(0)/d\lambda_+$	-14.	-15.

*All errors have been increased by the scale factor S = $(\chi^2/DF)^{1/2}$ to take into account the discrepancies between measurements.

In view of the large χ^2/DF of these fits, especially K_{μ3}⁰, the fit results should be taken with a grain of salt. The largest contributors to χ^2 in the K_{μ3}⁺ case are CHIANG 72 with 8.1, and the polarization results, BETTELS 68 with 6.8 and CUTTS 69 with 5.5. In the K_{μ3}⁰ case the largest contributors are the polarization results of SANDWEISS 73 with 18, LONGO 69 with 14, and CLARK 77 with 10, and the Dalitz plot results of ALBROW 72 with 11, ALBRECHT 74 with 5.9, and PEACH 73 with 5.5. All other χ^2 values were less than 5.

The DONALDSON2 74 result

Data Card Listings

For notation, see key at front of Listings.

$$\lambda_+ = 0.030 \pm 0.003$$

$$\lambda_0 = 0.019 \pm 0.004$$

clearly dominates the statistics in the K_{μ3}⁰ case. The λ_+ value is consistent with the K_{e3} value of λ_+ , and with the pole approximation

$$f_+(t) = f_+(0) \frac{m_{K^*}^2}{m_{K^*}^2 - t}$$

Their $f_0(t)$ extrapolates linearly to the Callan-Treiman point. It is less than two standard deviations from the K_{μ3}⁺/K_{e3} result.

K_{e3} Experiments

The f_- term of the matrix element [Eq. (2) text Section VI B.2] can be neglected for K_{e3} because it is proportional to the lepton mass. The f_+ term is usually assumed to be linear in $t = q^2 = (P_K - P_\pi)^2$, the square of the four-momentum transfer, i.e., the effective mass of the lepton pair. We quote the linear coefficient λ_+^e (L+E on the data cards). There has been some suggestion of departure from linearity [CHIEN 71 (K_{e3}⁰) and Chounet, Gaillard, and Gaillard¹ - Review] but no compelling evidence. The λ_+ results are fairly consistent and the average values are

$$K_{e3}^+: \lambda_+ = 0.0285 \pm 0.0043$$

$$K_{e3}^0: \lambda_+ = 0.0301 \pm 0.0016 \quad (S=1.2)$$

where the K_{e3}⁰ error has been multiplied by the scale factor 1.2 to compensate for inconsistencies (see ideogram in K_L⁰ section L+E).

See also the excellent reviews of Gaillard and Chounet,¹ Chounet, Gaillard, and Gaillard,² and Pondrom.³

References

1. M. K. Gaillard and L. M. Chounet, "K_{L3} Form Factors," CERN 70-14 (May 1970), and Phys. Letters **32B**, 505 (1970).
2. L. M. Chounet, J. M. Gaillard, and M. K. Gaillard, Physics Reports **4C**, 199 (1972).
3. L. G. Pondrom, "Weak Decay Processes," Proc. Particles and Fields 1976, BNL, Oct. 6-8, 1976.

Stable Particles

K[±], K⁰

Data Card Listings

For notation, see key at front of Listings.

TRILLING 65 UCRL 14473 GEORGE H TRILLING (LRL)
 UPDATED FROM 1965 ARGONNE CONF. PAGE 5.
 YOUNG 65 UCRL 16362 POH-SHUNG YOUNG (THIS IS, BERKELEY) (LRL)
 ALSO 67 PR 156 1464 P-S YOUNG, W. Z. OSBORNE, W. H. BARKAS (LRL)

CALLAHAN 66 PR 150 1153 CALLAHAN, CAMERINI + (WISC., LRL, RIVERSIDE, BAR) (WISCONSIN)
 CALLAHAN 66 NC 44A 90 A C CALLAHAN (WISCONSIN)
 CESTER 66 PL 21 343 CESTER, ESCHSTRUTH, ONEILL + (PRINCETON-PENN)
 ALSO 67 AUERBACH, FOOTNOTE 1

AUERBACH 67 PR 155 1505 +DOBBS, MANN, MCFARLANE, WHITE + (PENN., PRIN)
 74 PR 09 3216 ERRATUM
 BELLOTTI 67 HEIDELBERG CONF BELLOTTI, PULLIA (MILAN)
 BELLOTTI 67 NC 52A 1287 BELLOTTI, FORINI, PULLIA (MILAN)
 ALSO 66 PL 20 690 BELLOTTI, FORINI, PULLIA + (MILAN)
 BISI 67 PL 258 572 BISI, CESTER, CHIESA, VIGONE (TORINO)

BOTTERILL 67 PRL 19 982 BOTTERILL, BROWN, CORBETT, CULLIGAN + (OXFORD)
 68 BOTTERILL 68 BOTTERILL (OXFORD)
 BOWEN 67 PR 154 1314 BOWEN, MANN, MCFARLANE, HUGHES + (PENN-PRINCETON)
 CLINE 67 HEIDELBERG CONF CLINE, HAGGERTY, SINGLETON, FRY + (WISCONSIN)
 CLINE 67 HERCEG NOVJ TBL. 4 D. CLINE, PROC. INTL. SCH. ON ELEM. PART. PHYSICS

FLETCHER 67 PRL 19 98 FLETCHER, BEIER, EDWARDS, + (ILLINOIS)
 FORD 67 PRL 18 1214 +LEMONICK, NAUENBERG, PIRQUE (PRINCETON)
 IMLAY 67 PR 160 1203 IMLAY, ESCHSTRUTH, FRANKLIN + (PRINCETON)
 KALMUS 67 PR 159 1187 KALMUS, KERMAN (LRL)
 ZINGHENK 67 RUTGERS (THIS IS) ZINGHENKO (RUTGERS)

BETTELS 68 NC 56A 1106 AACHEN-BARI-BERGEN-CERN-EP-NIJMEGEN-ORSAY +
 ALSO 71 HAIDT
 BOTTERILL 68 PR 171 1402 BOTTERILL, BROWN, CLEGG, CORBETT + (OXFORD)
 BOTTERILL 68 PR 174 1661 BOTTERILL, BROWN, CLEGG, CORBETT + (OXFORD)
 BOTTERILL 68 PR 21 766 BOTTERILL, BROWN, CLEGG, CORBETT + (OXFORD)
 BUTLER 68 UCRL-18420 +BLAND, GOLDBERGER, GOLDBERGER, HIRATA + (LRL)
 CHANG 68 PRL 20 510 CHANG, YUDD, EHRLICH, PLANO + (MARYLAND, RUTGERS)

CHEN 68 PRL 20 73 CHEN, COTTI, KJEWSKI, STIENING + (LRL, MIT)
 EICHEN 68 PR 169 586 AACHEN-BARI-CERN-EP-ORSAY-PADOVA-VALENCIA
 EISLER 68 PR 169 1090 EISLER, FUNG, MARATECK, MEYER, PLANO (RUTGERS)
 ESCHSTRU 68 PR 165 1487 ESCHSTRUTH, FRANKLIN, HUGHES + (PRINCETON, PENN)
 GARLAND 68 PR 167 1225 +STIPS, DEVONS, ROSEN + (COLUMBIA, RUTG., WISC)
 MOSCOSO 68 THE SIS M L MOSCOSO (UNIV PARIS ORSAY)

CUTTS 69 PR 184 1380 +STIENING, WIEGAND, DEUTSCH (LRL, MIT)
 ALSO 68 PRL 20 955 CUTTS, STIENING, WIEGAND, DEUTSCH (LRL, MIT)
 DAVISON 69 PR 180 1333 +BACASTOW, BARKAS, EVANS, FUNG, PORTER + (UCR)
 ELY 69 PR 180 1319 ELY, GIDAL, HAGOPIAN, KALMUS + (LOUC+WISC+LRL)
 EMMERSON 69 PRL 23 393 EMMERSON, QUIRK (OXFORD)

HERZO 69 PR 186 1403 +BANNER, BEIER, BERTRAM, EDWARDS + (ILL)
 KIJEWSKI 69 UCRL-18433 THESIS P K KIJEWSKI (LRL)
 LOBKOWIC 69 PR 185 1676 +MELISSINOS, NAGASHIMA, TEWKSBURY + (ROCH., BNL)
 ALSO 66 PRL 17 548 LOBKOWICZ, MELISSINOS, NAGASHIMA (ROCH+BNL)
 MACEK 69 PRL 22 32 MACEK, MANN, MCFARLANE, ROBERTS + (PENN, TEMPLE)
 MAST 69 PR 183 1200 +GERSHWIN, ALSTON-GARNJOST, BANGERTER + (LRL)
 ZELLER 69 PR 182 1420 ZELLER, HADDOCK, HELLAND, PAHL + (UCLA, LRL)

BOTTERILL 70 PL 318 325 +BROWN, CLEGG, CORBETT, CULLIGAN + (CXF)
 FORD 70 PRL 25 1370 +PIRQUE, REMMEL, SMITH, SOUDER (PRIN)
 GRAUMAN 70 PR 01 1277 +KOLLER, TAYLOR, PANDOULAS + (STEV, SETO, LEHI)
 ALSO 69 PRL 23 737 +KOLLER, TAYLOR, PANDOULAS + (STEV, SETO, LEHI)
 MACEK 70 PR 01 1249 +MANN, MCFARLANE, ROBERTS (PENN)
 MALTSEV 70 SJNP 10 678 +PASTERLAK, SLODOVNIKOVA, FADEEV + (JINR)
 PANDOUULA 70 PR 02 1205 +TAYLOR, KOLLER, GRAUMAN + (STEV, SETO)

BASTILE 71 PL 368 619 +BREHIN, DIAMANT-BERGER, KUNZ + (SACL+GEVA)
 BOURQUIN 71 PL 368 615 +BOYMOND, EXTERMANN, MARASCO + (GEVA, SACL)
 HAIDT 71 PR 03 10 AACHEN+BARI+CERN+EP+NIJMEGEN+ORSAY+PADOVA+
 ALSO 69 PL 29B 691 +AACH, BARI, CERN, EPOL, NIJM, ORSAY, PADO, TORI
 KLEMS 71 PR 04 66 +HILDEBRAND, STIENING (CHIC, LRL)
 ALSO 70 PRL 24 1386 +HILDEBRAND, STIENING (LRL, CHIC)
 ALSO 70 PRL 25 473 KLEMS, HILDEBRAND, STIENING (LRL, CHIC)

KUNSELMA 71 PL 348 485 R. KUNSELMAN (WYOMING)
 QTT, PRITCHARD (LQW)
 ROMANO 71 PL 368 525 +RENTON, AUBERT, BURBAN-LUTZ (BARI, CERN, ORSA)
 SCHWEINB 71 PL 368 246 AACHEN+BELGIUM+CERN+NIJMEGEN+PADOVA+COLLAB
 STEINER 71 PL 368 521 AACHEN+BARI+CERN+EPOL+ORSAY+NIJMEGEN+PADO+TORIN

ABRAMS 72 PRL 29 1118 +CARROLL, KYCIA, LI, MENES, MICHAEL + (BNL)
 ANKENBRA 72 PRL 28 1472 ANKENBRANDT, LARSEN + (BNL+LASL+FNAL+YALE)
 AUBERT 72 NC 12A 509 +HEUSSE, PASCAUD, VIALLE + (ORSA+BRUX+EPOL)
 BEIER 72 PRL 29 678 +BUGHDOLZ, MANN, PARKER (PENNSYLVANIA)
 CHIANG 72 PR 06 1254 +ROSEN, SHAPIRO, HANDLER, GLSEN + (ROCH+WISC)

CLARK 72 PRL 29 1274 +CORK, ELIOFF, KERTH, MCREYNOLDS, NEWTON + (LBL)
 EDWARDS 72 PR 05 2720 +BEIER, BERTRAM, HERZO, KOESTER + (ILL)
 FORD 72 PL 380 335 +PIRQUE, REMMEL, SMITH, SOUDER (PRINCETON)
 HOFFMAST 72 NP 836 1 HOFFMASTER, KOLLER, TAYLOR + (STEV+SETO+LEHI)

ABRAMS 73 PRL 30 500 +CARROLL, KYCIA, LI, MENES, MICHAEL + (BNL)
 BACKENST 73 PL 438 431 BACKENSTOSS, BAMBERGER + (CERN+KARL+HEID+STOH)
 BEIER 73 PRL 30 399 +BUGHDOLZ, MANN, PARKER, ROBERTS (PENN)
 BRAUN 73 PL 478 182 AACHEN+BARI+BRUSSELS+CERN COLLABORATION
 ALSO 75 BRAUN
 BRAUN 73 PL 478 185 AACHEN+BARI+BRUSSELS+CERN COLLABORATION
 ALSO 75 BRAUN

CABLE 73 PR 08 3807 +HILDEBRAND, PANG, STIENING (EF1+LBL)

LJUNG 73 PR 08 1307 D. LJUNG, D. CLINE (WISC)
 ALSO 72 PRL 28 523 D. LJUNG (WISC)
 ALSO 72 PRL 28 1287 D. CLINE, D. LJUNG (WISC)
 LUCAS 73 PR 08 719 CAMERINI, LJUNG, SHEAFF, CLINE (WISC)
 LUCAS 73 PR 08 719 LUCAS, TAFT, WILLIS (YALE)
 PANG 73 PR 08 1989 +HILDEBRAND, CABLE, STIENING (EF1+LBL)
 ALSO 72 PL 40B 699 CABLE, HILDEBRAND, PANG, STIENING (EF1+LBL)
 SMITH 73 NP 860 411 +BOOTH, RENSHALL, JONES + (GLAS+LIVP+OXF+RHEL)

ARNOLD 74 PR 09 1221 C. L. ARNOLD, B. P. ROE, D. SINCLAIR (MICH)
 BRAUN 74 PL 518 393 +CORNELIUSSEN, MARTYN + (AACH+BARI+BRUX+CERN)
 CENCE 74 PR 010 776 +HARRIS, JONES, MORGADO + (HAMA+LBL+WISC)
 ALSO 73 THE SIS (UNPUBL.) D B CLARKE (WISC)
 KUNSELMA 74 PR 09 2469 R. KUNSELMAN (WYOM)
 MERLAN 74 PR 09 107 +KASHA, HANDLER, ADALR + (YALE+BNL+LASL)
 WEISSENB 74 PL 488 474 WEISSENBERG, EGOROV, MINERVINA + (ITEP+LEBD)

BLOCH 75 PL 568 201 +BREHIN, BUNCE, DEVAUX + (SACL+GEVA)
 BRAUN 75 NP 889 210 +CORNELIUSSEN, MARTYN + (AACH+BARI+BRUX+CERN)
 CHENG 75 NP 825 381 +ASANO, CHEN, DUGAN, HU, WU, HUGHES + (COLU+YALE)
 HEARD 75 PL 558 324 +HEINTZE, HEINZELMANN + (CERN+HEID)
 HEARD 75 PL 558 327 +HEINTZE, HEINZELMANN + (CERN+HEID)
 SHEAFF 75 PR 012 2570 W. SHEAFF (WISC)
 SMITH 75 NP 891 45 +BOOTH, RENSHALL, JONES + (GLAS+LIVP+OXF+RHEL)

BERTRAND 76 NP B114 387 +SACTON + (BRUX+UBEL+DUUC+LOUC+WARS)
 BLOCH 76 PL 60B 393 +BUNCE, DEVAUX, DIAMANT-BERGER + (GEVA+SACL)
 BRAUN 76 LNC 17 521 +MARTYN, ERRIQUEZ + (AACH+BARI+BEL+CERN)
 DIAMANT 76 PL 62B 485 DIAMANT-BERGER, BLOCH, DEVAUX + (SACL+GEVA)
 HEINTZE 76 PL 60B 302 +HEINZELMANN, IGO-KEMENES, HUNDENKES + (HEID)
 SMITH 76 NP B109 173 +BOOTH, RENSHALL, JONES + (GLAS+LIVP+OXF+RHEL)
 WEISSENB 76 NP B115 55 WEISSENBERG, EGOROV, MINERVINA + (ITEP+LEBD)

ABRAMS 77 PR 015 22 +CARROLL, KYCIA, LI, MICHAEL, MCKEY + (BNL)
 DEVAUX 77 NP B126 11 +BLOCH, DIAMANT-BERGER, MALLARD + (SACL+GEVA)
 HEINTZE 77 PL 70B 482 +HEINZELMANN, IGO-KEMENES, + (HEID+CERN)
 ROSSELET 77 PR 015 574 +EXTERMANN, FISCHER, GUISSAN + (GEVA+SACL)
 BARKOV 79 NP B148 53 +VASSERMAN, ZOLOTOREV, KRUPIN + (SIBERIA+KAE)
 HEINTZE 79 NP B149 365 +HEINZELMANN, IGO-KEMENES + (HEID+CERN)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA CARDS

BLOCK 62 CERN CONF 371 BLOCK, LENDINARA, MONARI (NWES+BOLOGNA)

PAPERS NOT REFERRED TO IN DATA CARDS

BRENE 61 NP 22 553 BRENE, EGARDT, QVIST (NCRD)
 BIRGE 63 PRL 11 35 BIRGE, ELY, GIDAL, CAMERINI + (LRL+WISC+BARI)
 ADAIR 64 PL 12 67 ADAIR, LEIPUNER (YALE, BNL)
 CABIBBO 64 PL 9 352 CABIBBO, MAKSYMOWICZ (CERN)
 ALSO 64 PL 11 360 CABIBBO, MAKSYMOWICZ (CERN)
 ALSO 65 PL 14 72 CABIBBO, MAKSYMOWICZ (CERN)

CABIBBO 66 BERKELEY CONF 33 CABIBBO (CERN)
 GINSBERG 67 PR 162 1570 EDWARD S GINSBERG (U. MASS BOSTON)
 WILLIS 67 HEIDELBERG 273 W J WILLIS -RAPPORTEUR TALK (YALE)
 CRONIN 68 VIENNA CONF 241 RAPPORTEUR TALK (PRINCETON)
 HAIDT 2 69 PL 29B 696 + (AACH+BARI+CERN, EPOL, NIJM, ORSA, PADO, TCRI)

BARDIN 70 PL 32B 121 BARDIN, BILENKY, PONTECORVO (JINR)
 BECHERRA 70 PR 01 1452 T. BECHERRA (ROCH)
 FEARING 70 PR 03 542 +FISCHBACK, SMITH (STON+BOHR)
 GAILLARD 70 CERN 70-14 M K GAILLARD, L M CHOUNET (CERN+ORSA)
 GINSBERG 70 PR 01 229 E S GINSBERG (MIT HAIFA)

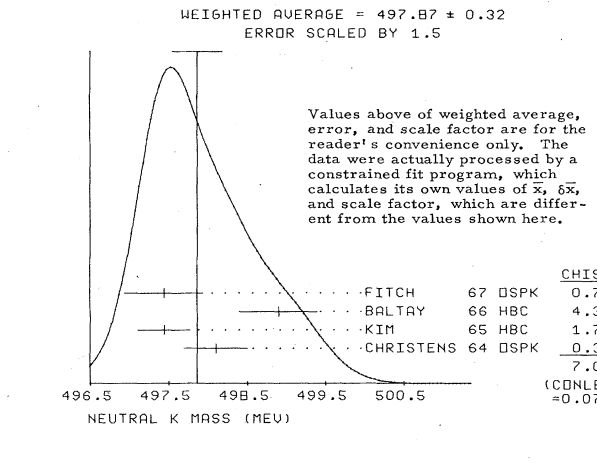
GINSBERG 71 PR 04 2893 E S GINSBERG (MIT)
 CHOUNET 72 PL 4C 199 (PHYS. REPTS.) CHOUNET, 2*GAILLARD (ORSA+CERN)

 K⁰ 11 NEUTRAL K(498, JP=0-) I=1/2

11 NEUTRAL K MASS (MEV)

M	2223	498.1	0.4	CHRISTENS 64 OSPK	
M	4500	497.44	0.33	KIM 65 HBC	KO FROM PBAR P 6/66
M		498.9	0.5	BALTAY 66 HBC	KO FROM PBAR P 6/66
M		497.44	0.50	FITCH 67 OSPK	11/67
M	AVG	497.87	0.32	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)	
M	STUDENT	497.83	0.26	AVERAGE USING STUDENT(10/1.11) -- SEE MAIN TEXT	
M	FIT	497.67	0.13	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1) 2/80*	

(SEE IDEOGRAM BELOW)



11 (K⁰) - (K[±]) MASS DIFFERENCE (MEV)

D	3.9	0.6	ROSENFELD 59 HBC	-
D	5.4	1.1	CRAWFORD 59 HBC	-
D	9	0.25	BURNSTEIN 65 HBC	-
D	7	3.71	KIM 65 HBC	K- P TO K ⁰ N 6/68
D	417	3.95	HILL 68 HBC	K+ D TO KOPP 3/68
D	AVG	3.92	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
D	STUDENT	3.91	AVERAGE USING STUDENT(10/1.11) -- SEE MAIN TEXT	
D	FIT	4.01	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1) 2/80*	

 REFERENCES FOR NEUTRAL K
 CRAWFORD, CRESTI, GODO, STEVENSON, TICHQ (LRL)
 ROSENFELD 59 PRL 2 110 A H ROSENFELD, F SOLMITZ, R D TRIPP (LRL)
 CHRISTEN 64 PRL 13 138 CHRISTENSON, CRONIN, FITCH, TURLAY (PRINCETON)
 BURNSTEIN 65 PR 13 B 895 R A BURNSTEIN, H A RUBIN (MARYLAND)
 KIM 65 PR 140 B 1334 J K KIM, L KIRSCH, D MILLER (COLUMBIA)

Stable Particles

K_S⁰, K_L⁰

BOTT-BODENHAUSEN, DE BOUARD, CASSEL+ (CERN) DONALD, EDWARDS, NISAR+ (LIVP, CERN, LPNP, CDEF) HILL, ROBINSON, SAKITT+ (BNL, CARNEGIE) ... BOTT-BODENHAUSEN, DE BOUARD, CASSEL+ (CERN) DONALD, EDWARDS, NISAR+ (LIVP, CERN, LPNP, CDEF) HILL, ROBINSON, SAKITT+ (BNL, CARNEGIE) ...

K_L⁰

13 LONG-LIVED NEUTRAL K(498, JP=0-) I=1/2 WE GIVE (KOL-KOS MASS DIFFERENCE / HBAR) IN UNITS OF 10**10 SEC-1 ... D X (2.29) (0.55) FITCH 61 CNTR ...

Data Card Listings

For notation, see key at front of Listings.

C CAMERINI 62 VALUE CHANGED FROM 1.7 (SEE TABLE 1 OF CAMERINI 66) 8/67 D A CHRISTENSON 65 CORRECTED FOR INTERFERENCE BY FITCH 65 FOOTNOTE 1/71 D V VISHNEVSKY 65 NOT CORRECTED FOR INTERFERENCE EFFECTS. 3/68 D N CANTER 66 ERROR IGNORES UNCERTAINTY OF PHASE SHIFTS. THESE EVENTS 10/71 D N ARE USED IN HILL 71. 10/71 D B BOTT-BODENHAUSEN 69 IS A REEVALUATION OF BOTT-BODENHAUSEN 66. 1/71 D F FAISSNER 69 HAS ADDNL. SYSTEMATIC ERROR LESS THAN TWO PERCENT. 1/71 D R ARONSON 70 AND CARNEGIE 71 USE KOS MEAN LIFE = .862+- .006 E-10 SEC. 11/75 D R WE HAVE NOT ATTEMPTED TO ADJUST THESE VALUES FOR THE SUBSEQUENT 2/76 D R CHANGE IN THE KOS MEAN LIFE OR IN ETA+- 2/76 D H HILL 71 PRIMARY RESULT IS THAT DM IS POSITIVE. 10/71 D H THE MAGNITUDE MAY HAVE AN ADDITIONAL SYSTEMATIC ERROR OF ABOUT 0.12 10/71 D S NOT AVERAGED BECAUSE ERROR IS LARGE AND SYSTEMATICS NOT DISCUSSED. 2/76

13 KOL MEAN LIFE (UNITS 10**8 SEC) T KOL MEAN LIFE T 34 8+1 3.2 2.4 BARON 58 CNTR T ASSUMED DS=DQ AND DELTA I=1/2 CRAWFORD 59 HBC T 15 5.1 2.4 1.3 DARNOR 62 FBC T 5.3 0.6 FUJII 64 OSPK T 1700 6.1 1.5 1.2 ASTBURY 65 CNTR T 5.15 0.14 DEVLIN 67 CNTR T L (5-0) (0.5) LOWNY 67 HBC T .4M 5.154 0.044 VOSBURGH 72 CNTR T L SUM OF PARTIAL DECAY RATES. T AVG 5.158 0.042 AVERAGE (ERROR INCL. SCALE FACTOR OF 1.0) T STUDENT 5.158 0.046 AVG BY STUDENT10(H/1.1) -- SEE MAIN TEXT T FIT 5.183 0.040 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

13 KOL PARTIAL DECAY MODES P1 KOL INTO 3P10 TAU 0 PRIME 134+ 134+ 134+ P2 KOL INTO PI+ PI- P10 TAU 0 139+ 139+ 134+ P3 KOL INTO PI MU NEUTRINO KL MU3 135+ 105+ 0 P4 KOL INTO PI E NEUTRINO KL E3 139+ .5+ 0 P5 KOL INTO PI+ PI- GAMMA KL PI+ PI- 139+ 139+ P6 KOL INTO MU+ MU- GAMMA KL MU 105+ 105+ P7 KOL INTO E+ E- GAMMA KL E2 .5+ .5 P8 KOL INTO E MU GAMMA KL EMU .5+ 105 P9 KOL INTO TWO GAMMAS KL 2GAMMA 0+ 0 P10 KOL INTO PI+ PI- GAMMA KL PI+ G 139+ 139+ 0 P11 KOL INTO P10 P10 KL P10 134+ 134+ 0 P12 KOL INTO PI E NEU GAMMA KL E3GAM 139+ .5+ 0+ 0 P13 KOL INTO P10 TWO GAMMAS KL P10GAMMA 134+ 0+ 0 P14 KOL INTO E+ E- GAMMA KL 2EGAM .5+ .5+ 0 P15 KOL INTO MU+ MU- GAMMA KL 2MUGAM 105+ 105+ 0 P16 KOL INTO MU+ MU- P10 KL 2MUP10 105+ 105+ 134+ P17 KOL INTO PI+ PI- E+ E- KL 2PI2E 139+ 139+ .5+ .5 P18 KOL INTO P10 PI+ E+ NEU KL 2PIE10 134+ 139+ .5+ 0 P19 KOL INTO (PI MU ATOM) NEU KL (PI MU)NEU

NEUTRAL K CONSTRAINED FIT OVERALL FIT OF MEAN LIFE, WIDTHS AND BRANCHING RATIOS USES 64 DATA POINTS TO DETERMINE SIX QUANTITIES. OVERALL FIT HAS CHI-SQUARED=69.8 3/78 3/78

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± δP_i, where δP_i = √(δP_i² + δP_j²), while the off-diagonal elements are the normalized correlation coefficients (δP_iδP_j)/(δP_i·δP_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table with 6 columns: P 1, P 2, P 3, P 4, P 5, P 11. Values include .2147+- .0073, -.5340, .1239+- .0018, .1869, .2701+- .0048, -.0711, .2212, -.1788, .3884+- .0054, -.3361, .4867, .1379, .1627, .0020+- .0001, .1719, -.1061, -.1115, -.1312, -.0665, .0009+- .0002

FITTED PARTIAL DECAY MODE RATES

The matrix below is the branching fraction matrix above, transformed into rate space; i.e., G_i = Γ_i = Γ_{total} P_i, in appropriate units. In analogy to the matrix above, the diagonal elements are G_i ± δG_i, where δG_i = √(δG_i² + δG_j²), while the off-diagonal elements are the normalized correlation coefficients (δG_iδG_j)/(δG_i·δG_j). Note that, because of the error in Γ_{total}, the errors and correlations here are not directly derivable from those above.

Table with 6 columns: G 1, G 2, G 3, G 4, G 5, G 11. Values include .0414+- .0015, -.3285, .0239+- .0004, -.3816, .2970, .0521+- .0010, -.4277, .3439, -.0029, .0749+- .0011, -.2206, .5284, .2112, .2440, .0004+- .0000, .1814, -.0706, -.0798, -.0896, -.0471, .0002+- .0000

13 KOL DECAY RATES

W1 KOL INTO P10 P10 P10 (UNITS 10**6 SEC-1) (G1) W1 54 5.22 1.03 0.84 BEHR. 66 HLBC ASSUMES CP 8/66 W1 FIT .414 .015 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

K⁰

W2 KOL INTO PI+ PI- P0 (UNITS 10**6 SEC-1) (G2)
W2 18 3.26 0.77 ANDERSON 65 HBC 8/66
W2 14 1.4 0.4 FRANZINI 65 HBC 8/66
W2 136 2.62 0.28 0.27 BEHR 66 HLBC ASSUMES CP 8/66
W2 53 2.20 0.35 WEBBER 70 HBC ASSUMES CP 10/71
W2 99 2.71 0.28 CHO 71 DBC ASSUMES CP 4/71
W2 J 98 (2.51) (0.3) JAMES 71 HBC ASSUMES CP 6/71
W2 50 2.12 0.33 MEISNER 71 HBC ASSUMES CP 10/71
W2 J 180 2.35 0.20 JAMES 72 HBC ASSUMES CP 1/73
W2 192 2.32 0.13 0.15 BALDOCEOL 75 HLBC ASSUMES CP 1/76
W2 IN THE OVERALL FIT THIS RATE IS WELL DETERMINED BY THE MEAN LIFE AN
W2 THE BRANCHING RATIO R2. FOR THIS REASON THE DISCREPANCY BETWEEN THE
W2 R2 MEASUREMENTS DOES NOT AFFECT THE SCALE FACTOR OF THE OVERALL FIT
W2 J JAMES 72 IS A FINAL MEASUREMENT AND INCLUDES JAMES 71. 11/73
W2
W2 AVG 2.34 0.11 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
W2 STUDENT 2.35 0.10 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
W2 FIT 2.391 0.038 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
(SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 2.34 ± 0.11
ERROR SCALED BY 1.2

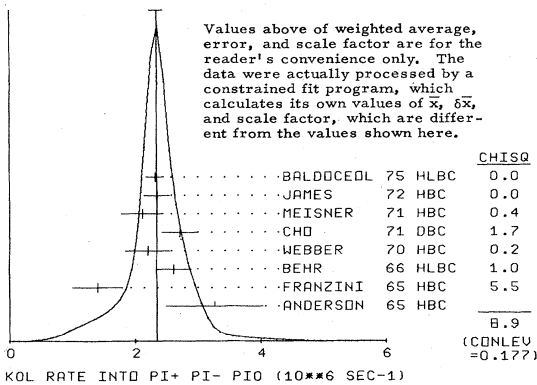


Table with 2 columns: Name and CHISO value. Includes entries for BALDOCEOL, JAMES, MEISNER, CHO, WEBBER, BEHR, FRANZINI, ANDERSON, and B.9 (CONLEV = 0.177).

W3 KOL INTO PI E NEUTRINO (UNITS 10**6 SEC-1) (G4)
W3 7.52 0.85 0.72 AUBERT 65 HLBC DS=DQ,CP ASSUMED 8/67
W3 620 7.81 0.56 CHAN 71 HBC 2/72
W3
W3 AVG 7.71 0.46 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
W3 STUDENT 7.71 0.49 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
W3 FIT 7.49 0.11 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

WEIGHTED AVERAGE = 11.60 ± 0.65
ERROR SCALED BY 1.5

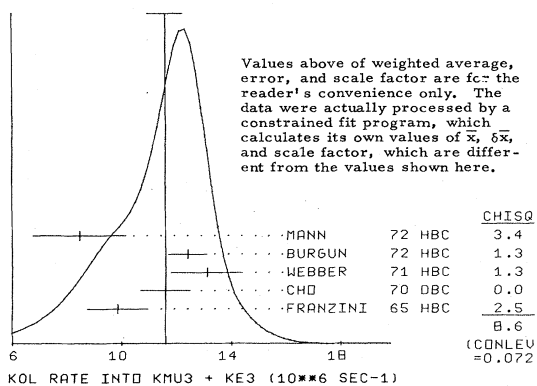


Table with 2 columns: Name and CHISO value. Includes entries for MANN, BURGUN, WEBBER, CHO, and FRANZINI, and B.6 (CONLEV = 0.072).

W6 KOL INTO PI MU NEUTRINO UNITS 10**6 SEC-1 (G3)
W6 19 4.54 1.24 1.08 LOWYS 67 HLBC 8/67
W6
W6 FIT 5.211 0.100 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

13 KOL BRANCHING RATIOS
R1 KOL INTO (PIO P10)/CHARGED (P1)/(P2+P3+P4)
R1 24 0.24 0.08 ANIKINA 64 CC 6/66
R1 549 0.251 0.014 BUDAGOV 68 HLBC OPSAY MEASUR. 10/68
R1 444 0.277 0.021 BUDAGOV 68 HLBC EC. POLYTEC.MEAS 10/68
R1 29 0.31 0.07 0.06 KULYUKINA 68 CC 2/71
R1
R1 AVG 0.260 0.011 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R1 STUDENT 0.260 0.013 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
R1 FIT 0.274 0.012 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)

R2 KOL INTO (PI+ PI- P10)/CHARGED (P2)/(P2+P3+P4)
R2 59 0.185 0.038 ASTIER 61 CC 8/66
R2 79 0.151 0.020 ADAIR 64 HBC 8/66
R2 75 0.157 0.03 0.04 LUERS 64 HBC 8/66
R2 66 0.15 0.03 0.04 ASTBURY1 65 CC 8/66
R2 326 0.159 0.015 ASTBURY2 65 CC 6/66
R2 566 0.178 0.017 GUIDONI 65 HBC 6/66
R2 1729 (0.144) (0.004) HOPKINS 65 HBC SEE HOPKINS 67 6/66
R2 126 0.162 0.015 HAWKINS 66 HBC 6/66
R2 0.161 0.005 HOPKINS 67 HBC 8/67
R2 1402 0.167 0.016 KULYUKINA 68 CC 2/71
R2 1590 0.1605 0.0038 ALEXANDER 73 HBC 1/74
R2 3200 0.146 0.004 BRANDENBU 73 HBC 1/74
R2 558 0.159 0.010 EVANS 73 HLBC 1/73
R2 6499 0.163 0.003 CHO 77 HBC 11/77
R2
R2 AVG 0.1587 0.0024 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)
R2 STUDENT 0.1600 0.0022 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
R2 FIT 0.1584 0.0020 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)
(SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 0.1587 ± 0.0024
ERROR SCALED BY 1.3

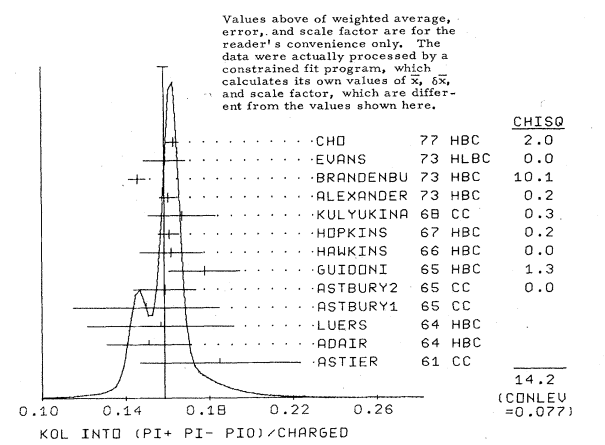


Table with 2 columns: Name and CHISO value. Includes entries for CHO, EVANS, BRANDENBU, ALEXANDER, KULYUKINA, HOPKINS, HAWKINS, GUIDONI, ASTBURY1, ASTBURY2, LUERS, ADAIR, and ASTIER, and B.9 (CONLEV = 0.077).

R3 KOL INTO (PI MU NEUTRINO)/CHARGED (P3)/(P2+P3+P4)
R3 C 251 (0.356) (0.07) LUERS 64 HBC 7/66
R3 C 172 (0.391) (0.08) (0.10) ASTBURY1 65 CC 2/71
R3 C 330 (0.335) (0.055) KULYUKINA 68 CC 2/71
R3 C THIS MODE NOT MEASURED INDEPENDENTLY FROM R2 AND R4

R4 KOL INTO (PI E NEUTRINO)/CHARGED (P4)/(P2+P3+P4)
R4 24 0.46 0.11 NEAGU 61 CC 2/76
R4 153 0.487 0.05 LUERS 64 HBC 2/71
R4 202 0.46 0.08 0.10 ASTBURY1 65 CC 7/66
R4 500 0.498 0.052 KULYUKINA 68 CC 2/71
R4
R4 AVG 0.485 0.032 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R4 STUDENT 0.485 0.034 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
R4 FIT 0.4964 0.0051 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R5 KOL INTO (PI E NEU)/(PI E NEU)+(PI MU NEU) (P4)/(P3+P4)
R5 320 0.415 0.120 ASTIER 61 CC
R5 FIT 0.5898 0.0059 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R6 KOL INTO (PI+ PI- P10)/TOTAL (P2)
R6
R6 FIT 0.1239 0.0018 FROM FIT

R7 KOL INTO (LEPTON PI NEUTRINO)/TOTAL (P3+P4)
R7
R7 FIT 0.6584 0.0066 FROM FIT

R8 KOL INTO (2 GAMMA)/TOTAL (UN. 10**4) (P9)
R8 C (1.3) (0.6) CRIGEE 66 DSPK 8/66
R8 32 6.7 2.2 TODOROFF 67 DSPK REPL. CRIGEE66 11/68
R8 K 33 (7.4) (1.6) CRONIN 1 67 DSPK 11/67
R8 90 5.5 1.1 KUNZ 68 DSPK NORM.TO 3PI(C+N) 2/71
R8 23 4.5 1.0 ENSTROM 71 DSPK KOL 1.5-9 GEV/C 2/72
R8 R 5.0 (1.0) REPELLIN 71 DSPK 11/71
R8 B 4.54 0.84 BANNERZ 72 DSPK 8/72
R8 B THIS VALUE USES (E00/E+-)**2=1.05+0.14. IN GENERAL, S13R8 = 8/72
R8 B (4.32+0.55)*(10**4)*((E00/E+-)**2). TO EVALUATE 11/71
R8 R ASSUMES REGEN AMPL IN COPPER AT 2GEV IS 22 MB. TO EVALUATE 11/71
R8 R FOR A GIVEN REGEN AMPL AND ERROR, MULTIPLY BY (REGEN AMPL/22MB)**2 11/68
R8 C CRIGEE 66 REPLACED BY TODOROFF 67 11/68
R8 K CRONIN 67 REPLACED BY KUNZ 68 2/71
R8
R8 AVG 4.88 0.54 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R8 STUDENT 4.88 0.59 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

Stable Particles

K_L⁰

Data Card Listings

For notation, see key at front of Listings.

R9 KOL INTO (PI+ PI-)/CHARGED (UNIT 10**--3) (P5)/(P2+P3+P4)
R9 O 45 (2.0) (0.4) CHRISTENS 64 OSPK ETA +- = 1.95+-0.20 2/76
R9 O 54 (2.08) (0.35) GALBRAITH 65 OSPK ETA +- = 1.99+-0.16 2/76
R9 C (1.93) (0.26) BASILE 66 OSPK ETA +- = 1.92+-0.13 2/76
R9 G (1.993) (0.090) BOTT-BODE 66 OSPK ETA +- = 1.95+-0.04 2/76
R9 M 4200 (2.60) (0.07) MESSNER 73 ASPK ETA +- = 2.23+-0.05 6/73
R9 C OLD EXPERIMENTS EXCLUDED FROM FIT. SEE SUBSECTION E+- BELOW FOR 2/76
R9 O AVERAGE ETA+- OF THESE EXPERIMENTS AND FOR NOTE ON DISCREPANCY. 2/76
R9 M FROM SAME DATA AS R27 MESSNER 73,BUT WITH DIFFERENT NORMALIZATION. 6/73
R9 FIT 2.589 0.060 FROM FIT

R10 KOL INTO (PI MU NEU)/(PI E NEU) (P3)/(P4)
R10 0.81 0.19 ADAIR 64 HBC 6/66
R10 0.82 0.10 DEBOUARD 67 OSPK 11/67
R10 273 0.7 0.2 HANKINS 67 HBC 8/67
R10 0.81 0.08 HOPKINS 67 HBC 8/67
R10 770 0.71 0.05 BUDAGOV 68 HLBC 10/68
R10 K (0.67) (0.13) KULYUKINA 68 CC 3/74
R10 B 569 (0.71) (0.04) BELLIERE 69 HLBC 10/69
R10 1309 (0.648) (0.030) EVANS 69 HLBC REPL. BY EVANS 73 1/73
R10 3548 0.68 0.08 BASILE 70 OSPK 10/70
R10 6700 0.741 0.023 BRANDENBU 73 HBC 1/74
R10 1309 0.662 0.030 EVANS 73 HLBC 1/73
R10 10K 0.662 0.037 WILLIAMS 74 ASPK 10/74
R10 K KULYUKINA 68 R10 IS NOT MEASURED INDEPENDENTLY FROM R2 AND R4. 1/74
R10 B BELLIERE 69 IS A SCANNING EXPT USING SAME EXPOSURE AS BUDAGOV 68
R10
R10 AVG 0.695 0.019 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
R10 STUDENT 0.695 0.021 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R10 FIT 0.695 0.017 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R11 KOL INTO (MU+MU-)/CHARGED (UNITS 10**--6) (P6)/(P2+P3+P4)
R11 100.0 OR LESS ANIKINA 65 CC 6/66
R11 250.0 OR LESS CL=90 ALFF-STEI 66 OSPK 9/66
R11 35.0 OR LESS CL=90 BOTT-BODE 67 OSPK 8/67
R11 35.0 OR LESS CL=90 FITCH 67 OSPK 3/68

R12 KOL INTO (PI+ PI- GAMMA)/TOTAL (UNITS 10**--3) (P10)
R12 0 15.0 OR LESS ANIKINA 65 CC 6/66
R12 0 5.0 OR LESS BELLOTTI 66 HLBC GAM KE 40-130 MV 8/67
R12 1 3.0 OR LESS NEFKENS 66 OSPK GAM KE 120 MEV 6/66
R12 0.4 OR LESS CL=90 THATCHER 68 OSPK GAM KE 20-170 MV 2/71
R12 3.2 OR LESS CL=90 BOBISUT 74 HLBC GAM KE GT 40 MEV 12/75
R12 D 24 0.62 0.07 DOITLSDI 74 SPEC 10/76
R12 0.46 OR LESS CL=90 WOO 74 SPEC 12/75
R12 D USES KOL TO PI+PI-PI0/ALL KOL DECAYS = 0.126 10/74

R13 KOL INTO (E+ E-)/CHARGED (UNITS 10**--6) (P7)/(P2+P3+P4)
R13 1000.0 OR LESS ANIKINA 65 CC 6/66
R13 200.0 OR LESS CL=90 ALFF-STEI 66 OSPK 6/66
R13 23.0 OR LESS CL=90 BOTT-BODE 67 OSPK 8/67

R14 KOL INTO (E MU)/CHARGED (UNITS 10**--4) (P8)/(P2+P3+P4)
R14 10.0 OR LESS ANIKINA 65 CC 6/66
R14 1.0 OR LESS CL=90 CARPENTER 66 OSPK 8/66
R14 0.1 OR LESS CL=90 BOTT-BODE 67 OSPK 8/67
R14 0.08 OR LESS CL=90 FITCH 67 OSPK 3/68

R15 KOL INTO (E+ PI- NEU)/(E- PI+ NEU)
R15 O 97 (0.90) (0.18) NEAGU 61 CC
R15 O (1.01) (0.16) LUERS 64 HBC 8/66
R15 O 894 (0.99) (0.023) KULYUKINA 66 CC 9/66
R15 O 1539 (1.06) (0.05) VERHEY 66 OSPK 8/67
R15 O LOW PRECISION EXPTS NOT AVERAGED. FOR MORE PRECISE VALUE,
SEE S13A2 (BENNETT 70, MARX 70)

R16 KOL INTO (MU+ PI- NEU)/(MU- PI+ NEU)
R16 1M 1.0081 0.0027 DORFAN 67 OSPK 11/67
R16 SEE ALSO S13A2 AND S13AL IN THE CP VIOLATION SECTION 2/71

R17 KOL INTO (PI0 PI0)/TOTAL (UNITS 10**--3) (P11)
R17 C 7 (1.2) (1.5) (1.2) CRIEGEE 66 OSPK 7/66
R17 C CRIEGEE EXPT NOT DESIGNED TO MEASURE 2 PI0 DECAY MODE
R17 G 189 (2.5) (0.8) GAILLARD 69 OSPK E00=3.6+-0.6 5/69
R17 G LATEST RESULT OF THIS EXPERIMENT GIVEN BY FAISSNER 7C R19 1/71
R17 FIT 0.94 0.18 FROM FIT

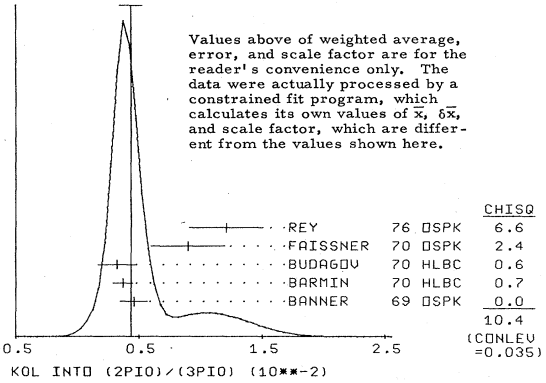
R18 KOL INTO (3PI0)/(PI+PI-PI0) (P11)/(P2)
R18 188 2.0 0.6 ALEKSANYA 64 FBC 9/66
R18 1010 1.80 0.13 BUDAGOV 68 HLBC 10/68
R18 883 (1.65) (0.07) BARMIN 72 HLBC ERROR STAT. ONLY 3/74
R18 AVG 1.81 0.13 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R18 STUDENT 1.81 0.14 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R18 FIT 1.733 0.076 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)

R19 KOL INTO (2PI0)/(3PI0) (UNITS 10**--2) (P11)/(P1)
R19 C 109 (1.89) (0.31) CRONIN 1 67 OSPK ETA00=4.9+-0.5 8/67
R19 C (1.36) (0.18) CRONIN 2 67 OSPK ETA00=3.92+-0.3 11/67
R19 C CRONIN2 IS FURTHER ANALYSIS CRONIN1 +NDM BOTH WITHDRAWN 11/68
R19 NO EVENTS SEEN BARTLETT 68 OSPK SEE E00 BELOW 11/68
R19 57 0.46 0.11 BANNER 69 OSPK ETA00=2.2+-0.3 2/72
R19 R 133 (1.31) (0.31) CENCE 69 OSPK ETA00=3.7+-0.5 10/69
R19 29 0.37 0.08 BARMIN 70 HLBC ETA00=2.02+-0.23 12/70
R19 30 0.32 0.15 BUDAGOV 70 HLBC ETA00=1.94+-0.5 10/70
R19 F 172 0.90 0.30 FAISSNER 70 OSPK ETA00=3.2+-0.5 12/70
R19 R 150 1.21 0.30 REY 76 OSPK ETA00=3.8+-0.5 8/76
R19 F FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69 R17
R19 R CENCE 69 EVENTS ARE INCLUDED IN REY 76. 1/77
R19 AVG 0.437 0.092 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
R19 STUDENT 0.425 0.065 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
R19 FIT 0.437 0.083 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)
(SEE IDEOGRAM BELOW)

R20 KOL INTO (PI+ PI-)/(KES + KMUS) (UNITS 10**--3) (P5)/(P3+P4)
R20 C 309 (2.51) (0.23) DEBOUARD 67 OSPK ETA+-=2.00+-0.09 2/76
R20 C 525 (2.38) (0.19) FITCH 67 OSPK ETA+-=1.94+-0.08 2/76
R20 2703 3.04 0.14 DEVIE 77 SPEC ETA+-=2.25+-0.05 11/77
R20 C OLD EXPERIMENTS EXCLUDED FROM FIT. SEE SUBSECTION E+- BELOW FOR 2/76
R20 C AVERAGE ETA+- OF THESE EXPERIMENTS AND FOR NOTE ON DISCREPANCY. 2/76
R20
R20 FIT 3.076 0.075 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R21 KOL INTO (2GAMMA)/(3 PI0) (UNITS 10**--3) (P9)/(P1)
R21 16 5 ARNO 68 HLBC VACUUM DECAY 11/68
R21 \$ BANNER 69 IS NEW EXPT. NOT TO BE CCONF WITH 88 OF CRONIN1 67 2/72
R21 115 2.24 0.28 BANNER 69 OSPK 11/68
R21 28 2.13 0.43 BARMIN 71 HLBC 8/71
R21
R21 AVG 2.24 0.27 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R21 STUDENT 2.24 0.24 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

WEIGHTED AVERAGE = 0.437 ± 0.092
ERROR SCALED BY 1.6



R22 KOL INTO (MU+MU-)/(PI+PI-) (UNITS 10**--6) (P6)/(P5)
R22 0 140.0 OR LESS CL=90 FOETH 69 SPEC 5/70
R22 0 18.0 OR LESS CL=90 DARRIULAT 70 SPEC 11/70
R22 A 0 (1.53) OR LESS CL=90 CLARK 71 SPEC 2/76
R22 C 9 5.8 2.3 1.5 CARITHERS 73 SPEC 2/76
R22 F 3 4.2 5.1 2.6 FUKUSHIMA 76 SPEC 2/76
R22 15 4.0 1.4 0.9 SHOCHET 79 SPEC 7/79*
R22 A CLARK 71 LIMIT RAISED FROM 1.2 E-06 BY FIELD 74 REANALYSIS. 2/76
R22 A NOT IN AGREEMENT WITH SUBSEQUENT EXPTS. SO NOT AVERAGED. 2/76
R22 C CARITHERS 73 ERRORS ARE AT CL=0.68, W-CARITHERS, PRV.V.COMM. 1979. 2/76
R22 F FUKUSHIMA 76 ERRORS ARE AT CL=90 PERCENT. 2/76
R22
R22 AVG 4.47 0.95 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R22 STUDENT 4.5 1.0 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

R23 KOL INTO (E+ E-)/(PI+PI-) (UNITS 10**--5) (P7)/(P5)
R23 0 10.0 OR LESS CL=90 FOETH 69 ASPK 5/70
R23 0.10 OR LESS CL=90 CLARK 71 ASPK 6/71

R24 KOL INTO (E MU)/(PI+PI-) (UNITS 10**--5) (P8)/(P5)
R24 0.10 OR LESS CL=90 CLARK 71 ASPK 6/71

R25 KOL INTO (PI E NEU GAM)/(KL E3) (UNITS 10**--2) (P12)/(P3)
R25 10 3.3 2.0 PEACH 71 HLBC GAM KE GT 15 MEV 6/71

R26 KOL INTO (PI0 TWO GAMMAS)/(3PI0) (UNITS 10**--3) (P13)/(P1)
R26 0 1.1 OR LESS CL=90 BANNER 69 OSPK 2/72

R27 KOL INTO (PI+ PI-)/TAU (UNITS 10**--2) (P5)/(P2)
R27 4200 1.64 0.04 MESSNER 73 ASPK ETA +- = 2.23 6/73
R27 FIT 1.635 0.036 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R28 KOL INTO (E+ E- GAMMA)/(3PI0) (UNITS 10**--4) (P14)/(P1)
R28 0 1.3 OR LESS CL=90 BARMIN1 72 HLBC 3/74

R29 KOL INTO (MU+ MU- GAMMA)/TOTAL (UNITS 10**--6) (P15)
R29 D 7.81 OR LESS CL=90 DONALDSON 74 SPEC 12/75
R29 D USES KOL TO PI+PI-PI0/ALL KOL DECAYS = 0.126 6/77

R30 KOL INTO (MU+ MU- PI0)/TOTAL (UNITS 10**--5) (P16)
R30 D 5.66 OR LESS CL=90 DONALDSON 74 SPEC 12/75
R30 D USES KOL TO PI+PI-PI0/ALL KOL DECAYS = 0.126 6/77

R31 KOL INTO (PI+PI+E-)/TOTAL (UNITS 10**--6) (P17)
R31 30.0 OR LESS ANIKINA 76 STAR 3/78
R31 D 8.81 OR LESS CL=90 DONALDSON 76 SPEC 6/77
R31 D USES KOL TO PI+PI-PI0/ALL KOL DECAYS = 0.126 6/77

R32 KOL INTO (PI0 PI+- E+- NEU)/TOTAL (UNITS 10**--3) (P18)
R32 D 2.2 OR LESS CL=90 DONALDSON 74 SPEC 12/75
R32 D USES KOL TO PI+PI-PI0/ALL KOL DECAYS = 0.126 6/77

R33 KOL INTO (PI MU ATOM) NEU/TOTAL (UNITS 10**--7) (P19)
R33 18 SEEN COOMBS 76 WIRE 6/77

13 KOL ENERGY DEPENDENCE OF DALITZ PLOT
RELATED TEXT SECTION VI B.1, APPENDIX I, AND MINI-REVIEW ON SLOPE
PARAMETERS IN THE CHARGED K SECTION OF THE DATA CARD LISTINGS ABOVE
MATRIX ELEMENT SQUARED = 1 + G*U + H*U**2 + J*V + K*V**2
WHERE U=(S3-S0)/(MPI**2) AND V=(S1-S2)/(MPI**2)

Table with columns: GTO, LINEAR COEFFICIENT G FOR KL --> PI+ PI- PI0 MATRIX ELEMENT SQUARED, and values for various experiments like ADAIR, LUERS, ASTBURY1, etc.

Data Card Listings

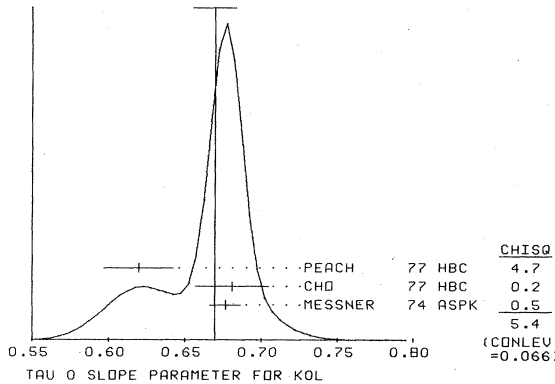
For notation, see key at front of Listings.

Stable Particles

KI

GTO Q QUADRATIC DEPENDENCE REQUIRED BY SOME EXPERIMENTS (SEE SECTIONS GTO Q HTO AND KTO BELOW). CORRELATIONS PREVENT US FROM AVERAGING RESULTS...

WEIGHTED AVERAGE = 0.670 ± 0.014
ERROR SCALED BY 1.6



HTO QUADRATIC COEFF. K FOR KL --> P+ P- P0 MATRIX ELEMENT SQUARED
HTO Q 29K (-0.011) (0.018) ALBROW 70 ASPK 1/79*
HTO Q 4400 (0.043) (0.052) SMITH 70 OSPK 1/79*
HTO 509K 0.079 0.007 MESSNER 74 ASPK 3/78
HTO 6499 0.024 0.010 CHD 77 HBC 3/78
HTO 4709 0.048 0.036 PEACH 77 HBC 3/78
HTO SEE NOTES IN SECTION GTO ABOVE. 1/79*
HTO AVG 0.0786 0.0067 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
HTO STUDENT 0.0787 0.0073 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT 1/79*

13 KOL FORM FACTORS
RELATED TEXT SECTION VI B.2 AND MINI-REVIEW ON FORM FACTORS IN THE CHARGED K SECTION OF THE DATA CARD LISTINGS ABOVE.
IN THE FORM FACTOR COMMENTS, THE FOLLOWING ABBREVIATIONS ARE USED.
F+ AND F- ARE FORM FACTORS FOR THE VECTOR MATRIX ELEMENT.
FS AND FT REFER TO THE SCALAR AND TENSOR TERM.
FO = (F+) + (F-) * (K**2 - M**2)
L+, L- AND LO ARE THE LINEAR EXPANSION COEFFS. OF F+, F- AND FO.
L+ REFERS TO THE KMU3 VALUE EXCEPT IN THE KE3 SECTIONS.
DXI/DL IS THE CORRELATION BETWEEN XI(O) AND L+ IN KMU3.
DLO/DL+ IS THE CORRELATION BETWEEN LO AND L+ IN KMU3.
T = MOMENTUM TRANSFER TO THE PI IN UNITS OF MPI**2.
DP = DALITZ PLOT ANALYSIS
PI = PI SPECTRUM ANALYSIS
MU = MU SPECTRUM ANALYSIS
POL = MU POLARIZATION ANALYSIS
BR = KMU3/KE3 BRANCHING RATIO ANALYSIS
E = POSITRON OR ELECTRON SPECTRUM ANALYSIS
RC = RADIATIVE CORRECTIONS

XIA XIA = F-/F+ (DETERMINED FROM SPECTRA)
XIA L1341 +1.2 (0.8) CARPENTER 66 OSPK DP, DXI/DL=-18 1/74
XIA B 3140 (-0.9) (0.4) BASILE 70 OSPK DP, INDEP OF L+ 1/74
XIA C 16K (-0.68) (0.12) (0.20) CHIEN 70 ASPK DP, DXI/DL=-26 1/74
XIA A A9086 -1.5 0.7 ALBROW 72 ASPK DP, DXI/DL=-28 1/74
XIA C 16K (+0.50) (0.61) DALLY 72 ASPK DP, DXI/DL UNKN. 1/74
XIA P1395 -1.00 (0.45) PEACH 73 HLBC DP, DXI/DL=-20 1/74
XIA D 82K -0.26 (0.21) ALBRECHT 74 WIRE DP, DXI/DL=-24 11/75
XIA D 82K (-2.41) (0.17) ALBRECHT 74 WIRE DP, DXI/DL=-9.4 11/75
XIA E1.6M -0.11 0.07 DONALD52 74 SPEC DP, DXI/DL=-17 11/75
XIA F 32K -0.25 0.22 BUCHANAN 75 SPEC DP, DXI/DL=-5.9 2/76
XIA L CARPENTER 66 XI(O) IS FOR L+=0. DXI/DL IS FROM FIG. 9. 1/74
XIA B BASILE 70 IS INCOMPATIBLE WITH ALL OTHER RESULTS. AUTHORS SUGGEST 1/74
XIA B THAT EFFICIENCY ESTIMATES MIGHT BE RESPONSIBLE. 1/74
XIA A ALBROW 72 FIT HAS L- FREE, GETS L=-.030+-0.060 OR L+=+1.5+-1.7-11. 1/74
XIA C CHIEN 70 ERRORS ARE STATISTICAL ONLY. DXI/DL FROM FIG.4. 1/74
XIA C DALLY 72 IS A REANALYSIS OF CHIEN 70. THE DALLY 72 RESULT IS 1/74
XIA C NOT COMPATIBLE WITH ASSUMPTION L=0 SO NOT INCLUDED IN OUR FIT. 2/76
XIA C THE NON-ZERO L- VALUE AND THE RELATIVELY LARGE L+ VALUE FOUND BY 1/74
XIA C DALLY 72 COME MAINLY FROM A SINGLE LOW T BIN (FIGS.1,2). 1/74
XIA C THE (F+ XI) CORRELATION WAS IGNORED. 1/74
XIA C WE ESTIMATE FROM FIG. 2 THAT FIXING L=0 WOULD GIVE XI(O)=-1.4+-0.3 1/74
XIA C AND WOULD ADD ID TO CHI SQUARED. DXI/DL IS NOT GIVEN. 1/74
XIA D ALBRECHT 74 IS CALCULATED BY US FROM LO, L+ AND DLO/DL+. THEY FIND 11/75
XIA D TWO SOLUTIONS. THE FIRST HAS L+=+0.46+-0.08 IN AGREEMENT WITH KE3. 3/74
XIA P PEACH 73 GIVES XI(O)=-.95+-0.45 FOR L+=L=-0.25. THE ABOVE VALUE IS 1/74
XIA P FOR L=0. K.PEACH, PRIVATE COMMUNICATION(1974). 1/74
XIA E DONALDSON2 74 GIVES XI=-.11+-0.02 NOT INCLUDING SYSTEMATICS. ABOVE 11/75
XIA E ERROR AND DXI/DL WERE CALCULATED BY US FROM LO AND L+ ERRORS (WHICH 1/75
XIA E INCLUDE SYSTEMATICS) AND DLO/DL+. 11/75
XIA F BUCHANAN 75 IS CALCULATED BY US FROM LO, L+ AND DLO/DL+ BECAUSE 2/76
XIA F THEIR APPENDIX A NOTE -20+-22 ASSUMES XI(T) CONSTANT, I.E. L-=L+. 2/76
XIA FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN K+- SECTION OF DATA CARDS.

XIB XIB = F-/F+ (DETERMINED FROM KMU3/KE3)
XIB THE KMU3/KE3 BRANCHING RATIO FIXES A RELATIONSHIP BETWEEN XI(O) 1/74
XIB AND L+. WE QUOTE THE AUTHORS XI(O) AND ASSOCIATED L+ BUT DO NOT 1/74
XIB AVERAGE BECAUSE THE L+ VALUES DIFFER. THE FIT RESULT AND SCALE 1/74
XIB FACTOR GIVEN IN THE NOTE ON KL3 FORM FACTORS IN THE K+- SECTION OF 2/76
XIB THE DATA CARDS ARE NOT OBTAINED FROM THESE XIB VALUES. INSTEAD 2/76
XIB THEY ARE OBTAINED DIRECTLY FROM THE FITTED KMU3/KE3 RATIO (R10). 2/76
XIB 389 +1.1 1.1 ADAIR 64 HBC BR, L+=0 1/74
XIB +0.66 0.9 1.3 LUERS 64 HBC BR, L+=0 1/74
XIB +0.2 0.8 1.2 KULYUKINA 68 CC BR, L+=0 1/74
XIB 569 +0.45 0.28 BEILLIERE 69 HLBC BR, L+=0 1/74
XIB E 1309 (-0.22) (0.30) EVANS 69 HLBC BR, L+=.02+-0.015 1/74
XIB 354R -0.5 0.5 BASILE 70 OSPK BR, L+=.02 1/74
XIB 6700 0.5 0.4 BRANDEBU 73 HBC BR, L+=.019+-0.013 1/74
XIB E1309 -0.8 0.25 EVANS 73 HLBC BR, L+=.02 1/74
XIB E EVANS 73 REPLACES EVANS 69. 1/74
XIB FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN K+- SECTION OF DATA CARDS.

XIC XIC = F-/F+ (DETERMINED FROM MU POLARIZATION IN KMU3)
XIC THE MU POLARIZATION IS A MEASURE OF XI(T). NO ASSUMPTIONS ON L+- 1/74
XIC NECESSARY. T (WEIGHTED BY SENSITIVITY TO XI) SHOULD BE SPECIFIED. 1/74
XIC IN L+, XI(O) PARAMETERIZATION THIS IS XI(O) FOR L+=0. DXI/DL=XI(T). 1/74
XIC FOR RAD. CORR. TO MUON POLARIZATION IN KMU3, SEE GINSBERG 73. 2/72
XIC T 2608 (-1.2) (0.5) AUERBACH 66 OSPK POLARIZATION 8/67
XIC T 638 (-1.6) (0.5) ABRAMS 68 SPK POLARIZATION 5/69
XIC L -1.81 0.50 0.26 LONGO 69 CNTR POL, T=3.3 1/74
XIC S2.2M -0.385 0.105 SANDWEISS 73 CNTR POL, DXI/DL=-6 1/74
XIC H207K +0.178 0.105 CLARK 77 SPEC POL, DXI/DL+=.68 11/77
XIC T VALUE NOT GIVEN. 1/74
XIC L LONGO 69 T=3.3 CALC. FROM DXI/DL=-6.0 (TABLE 1) DIVIDED BY XI=-1.81 1/74
XIC S SANDWEISS 73 IS FOR L+=0 AND T=0. 1/74
XIC H CLARK 77 T=+3.80, DXI/DL=XI(T)*T=-178*3.80+=.68. 11/77
XIC FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN K+- SECTION OF DATA CARDS.

IXI IMAGINARY PART OF XI (TEST OF T REVERSAL)
IXI -0.2 0.6 ABRAMS 68 OSPK POLARIZATION 10/69
IXI -0.02 0.08 LONGO 69 CNTR POL, T=3.3 11/69
IXI 2.2M -0.060 0.045 SANDWEISS 73 CNTR POL, T=0 1/74
IXI S2.2M -0.085 0.064 SANDWEISS 73 CNTR POL, T=0 12/79*
IXI C207K 0.35 0.30 CLARK 77 SPEC POL, T=0 11/77
IXI 0.012 0.026 SCHMIDT 79 CNTR POLARIZATION 12/79*
IXI S SANDWEISS 73 VALUE CORRECTED FROM VALUE QUOTED IN THEIR PAPER DUE 12/79*
IXI S TO NEW VALUE OF RE(XI). SEE FNOTE 4 OF SCHMIDT 79. 12/79*
IXI C CLARK 77 VALUE HAS ADDITIONAL XI(O) DEPENDENCE +0.21*RE(XI(O)). 11/77
IXI AVERAGE 0.021 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
IXI STUDENT -0.013 0.024 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

L+M LAMBDA + (LINEAR ENERGY DEPENDENCE OF F+ IN KMU3 DECAY)
L+M SEE ALSO THE CORRESPONDING ENTRIES AND NOTES IN SECTION XIA AND LO. 3/74
L+M FOR RAD. COR. OF KMU3 DP SEE GINSBURG 70 AND BEGHERARY 70. 11/75
L+M C 16K (0.07) (0.02) CHIEN 70 ASPK DP 1/74
L+M A9086 0.085 0.015 ALBROW 72 ASPK DP 1/74
L+M C 16K (0.11) (0.04) DALLY 72 ASPK DP 1/74
L+M D 82K 0.046 0.008 ALBRECHT 74 WIRE DP 11/75
L+M D 82K (0.076) (0.004) ALBRECHT 74 WIRE DP 11/75
L+M 1.6M 0.030 0.003 DONALD52 74 SPEC DP 10/74
L+M 32K 0.046 0.030 BUCHANAN 75 SPEC DP 9/75
L+M Z 129K (0.037) (0.0033) DZHORDZHA 77 SPEC DP 12/79*
L+M 16K +0.028 0.011 HILL 79 STRC DP 12/79*
L+M C CHIEN 70 VALUE AND ERROR HAVE BEEN CHANGED FROM 0.08 +- 0.01 TO 3/71
L+M C INCLUDE SYSTEMATIC EFFECTS. DALLY 72 IS A REANALYSIS OF CHIEN 70. 3/71
L+M C SEE NOTE IN SECTION XIA. 1/74
L+M D ALBRECHT 74 FINDS TWO SOLUTIONS. THE FIRST AGREES WITH KE3. 11/75
L+M Z DZHORDZHADE 77 IS COMBINED ANALYSIS OF THE 82K ALBRECHT 74 EVENTS 12/79*
L+M Z AND 47K KE3 EVENTS OF BIRULEV 76. 12/79*
L+M FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN K+- SECTION OF DATA CARDS.

LO LAMBDA 0 (LINEAR ENERGY DEPENDENCE OF FO IN KMU3 DECAY)
LO WHEREVER POSSIBLE, WE HAVE CONVERTED THE ABOVE VALUES OF XI(O) INTO 1/74
LO VALUES OF LO USING THE ASSOCIATED L+M AND DXI/DL. 1/74
LO L 1371 +0.08 (0.07) CARPENTER 66 OSPK DP, DLO/DL+=-0.54 1/74
LO L -0.140 (0.043) (0.022) LONGO 69 CNTR POL, DLO/DL+=.49 1/74
LO B 3140 (-0.333) (0.034) BASILE 70 OSPK DP, DLO/DL+=+1. 1/74
LO A 9086 -0.043 0.052 ALBROW 72 ASPK DP, DLO/DL+=+1.39 1/74
LO C 16K (-0.67) (0.227) DALLY 72 ASPK DP, DLO/DL+ UNKN. 1/74
LO R 6700 +0.061 (0.03) BRANDEBU 73 HBC BR, L+=.019+-0.013 1/74
LO P 1385 -0.060 (0.038) PEACH 73 HLBC DP, DLO/DL+=-0.71 1/74
LO L 2.2M -0.018 (0.009) SANDWEISS 73 CNTR POL, DLO/DL+=+.49 1/74
LO D 82K -0.024 0.011 ALBRECHT 74 WIRE DP, DLO/DL+=-1.06 11/75
LO D 82K (-0.130) (0.014) ALBRECHT 74 WIRE DP, DLO/DL+=+0.20 11/75
LO E 1.6M +0.019 0.004 DONALD52 74 SPEC DP, DLO/DL+=-0.47 10/74
LO F 32K +0.025 0.019 BUCHANAN 75 SPEC DP, DLO/DL+=+0.5 2/76
LO L 207K +0.047 (0.009) CLARK 77 SPEC POL, DLO/DL+=+1.06 11/77
LO Z 47K (+0.0485) (0.0076) DZHORDZHA 77 SPEC DP, DLO/DL+=-0.93 12/79*
LO 16K +0.039 0.010 HILL 79 STRC DP, DLO/DL+=-0.67 12/79*
LO L LO VALUE IS FOR L+=0.03 CALCULATED BY US FROM XIO AND DXI/DL. 1/74
LO B BASILE 70 LO IS FOR L+=0. CALCULATED BY US FROM XIA WITH DXI/DL=0. 1/74
LO B THAT EFFICIENCY ESTIMATES MIGHT BE RESPONSIBLE. 1/74
LO A ALBROW 72 LO IS CALCULATED BY US FROM XIA L+ AND DXI/DL. THEY GIVE 1/74
LO A L+=.043+-0.039 FOR L=0. WE USE OUR LARGER CALCULATED ERROR. 1/74
LO C DALLY 72 GIVES FO=-1.20+-0.35, L+=-0.80+-0.27, L-OPRIME=-.006+-0.045. 1/74
LO C BUT WITH A DIFFERENT DEFINITION OF LO. OUR QUOTED LO IS HIS LO/FO. 1/74
LO C WE CANNOT CALCULATE TRUE LO ERROR WITHOUT HIS (LO/FO) CORRELATIONS. 1/74
LO C SEE ALSO NOTE C IN SECTION XIA. 1/74
LO P PEACH 73 ASSUMES L+=0.025. CALCULATED BY US FROM XIO AND DXI/DL+. 1/74
LO R FIT FOR LO DOES NOT INCLUDE THIS VALUE BUT INSTEAD INCLUDES THE 2/76
LO R KMU3/KE3 RESULT FROM THIS EXPERIMENT. 2/76
LO D ALBRECHT 74 FINDS TWO SOLUTIONS. THE FIRST HAS L+=.046+-0.008 IN 11/75
LO D AGREEMENT WITH KE3. DLO/DL+ OBTAINED FROM FIG.2.C. 11/75
LO E DONALDSON 74 DLO/DL+ OBTAINED FROM FIG.1.B. 11/75
LO F BUCHANAN 75 VALUE IS FROM THEIR APPENDIX A AND USES ONLY KMU3 DATA. 2/76
LO F DLO/DL+ WAS OBTAINED BY PRIVATE COMMUNICATION, C.BUCHANAN, 1976. 2/76
LO Z DZHORDZHADE 77 IS COMBINED ANALYSIS OF THE 82K ALBRECHT 74 EVENTS 12/79*
LO Z AND 47K KE3 EVENTS OF BIRULEV 76. 12/79*

LO FIT DISCUSSED IN NOTE ON KL3 FORM FACTORS IN K+- SECTION OF DATA CARDS.

Stable Particles

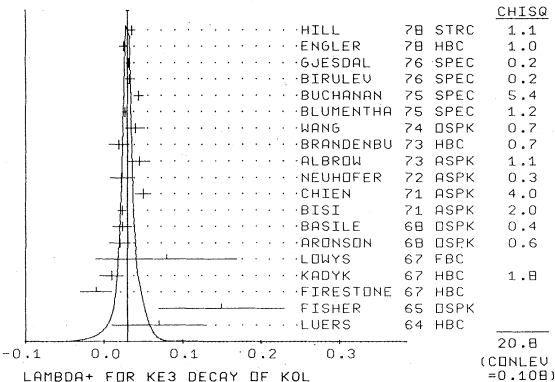
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Data Card Listings

For notation, see key at front of Listings.

LAMBDA+ (LINEAR ENERGY DEPENDENCE OF F+ IN K0 E3 DECAY) -----
 FOR RAD. COR. OF KE3 DP SEE GINSBURG 67 AND BECHERRAWY 70. 3/74
 L+E 153 +0.07 .06 LUERS 64 HBC DP, NO RC 8/67
 L+E 577 +0.15 .08 FISHER 65 OSPK DP, NO RC 8/67
 L+E 762 -0.01 .02 FIRESTONE 67 HBC DP, NO RC 8/67
 L+E 591 +0.01 .015 KADYK 67 HBC EPI, NO RC 8/67
 L+E 240 +0.08 .10 .08 LOWYS 67 FBC PI, USES RC 8/67
 L+E 1000 0.02 0.013 ARONSON 68 OSPK PI 5/69
 L+E 4800 +0.023 0.012 BASILE 68 OSPK DP, NO RC 3/68
 L+E 42K 0.023 0.005 BISI 71 ASPK DP, USES RC 12/71
 L+E 16K 0.05 0.01 CHIEN 71 ASPK DP, NO RC 6/71
 L+E 1910 0.022 0.014 NEUHOFER 72 ASPK PI, USES RC 1/73
 L+E 5600 0.045 0.014 ALBROW 73 ASPK DP, USES RC 9/73
 L+E 1871 0.019 0.013 BRANDENBU 73 HBC PI TRANSV., RC 1/74
 L+E 2171 0.040 0.012 WANG 74 OSPK DP, USES RC 7/74
 L+E 25K 0.0270 0.0028 BLUMENTHA 75 SPEC DP 7/75
 L+E 24K 0.04 0.006 BUCHANAN 75 SPEC DP, USES RC 7/75
 L+E 48K 0.032 0.0042 BIRULEV 76 SPEC DP, USES RC 1/78
 L+E 500K 0.0312 0.0025 GJESDAL 76 SPEC DP, USES RC 1/77
 L+E 12K 0.025 0.005 ENGLER 78 HBC DP, USES RC 7/79*
 L+E 18K 0.0348 0.0044 HILL 78 STRC DP, USES RC 6/78*
 L+E AVG 0.0301 0.0016 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)
 L+E STUDENT 0.0300 0.0016 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
 (SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 0.0301 ± 0.0016
 ERROR SCALED BY 1.2



FS FS/F+ RATIO OF SCALAR TO F+ COUPLINGS FOR KE3 DECAY (ABS. VALUE)-----
 FS 5600 0.19 OR LESS CL=.95 ALBROW 73 ASPK 10/69
 FS 25K 0.04 OR LESS CL=.68 BLUMENTHA 75 SPEC 7/75
 FS 48K 0.07 OR LESS BIRULEV 76 SPEC CL NOT GIVEN 1/78
 FS 18K 0.095 OR LESS CL=.95 HILL 78 STRC 6/78*
 FT FT/F+ RATIO OF TENSOR TO F+ COUPLINGS FOR KE3 DECAY (ABS. VALUE)-----
 FT 5600 1.0 OR LESS CL=.95 ALBROW 73 ASPK 9/73
 FT 25K 0.23 OR LESS CL=.68 BLUMENTHA 75 SPEC 7/75
 FT 48K 0.34 OR LESS BIRULEV 76 SPEC CL NOT GIVEN 1/78
 FT 18K 0.40 OR LESS CL=.95 HILL 78 STRC 6/78*

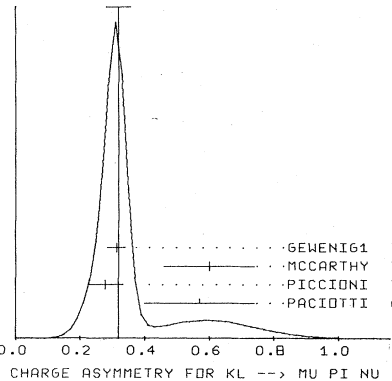
13 CP VIOLATION PARAMETERS IN K0L DECAYS
 RELATED TEXT SECTION VI 8.3 AND MINI-REVIEW BELOW

13 CHARGE ASYMMETRY IN TAU DECAYS-----
 JTO COEFF OF TERM (S1-S2)/(MP12) IN MATRIX ELEMENT DEFINED AT BEGINNING
 JTO OF SECTION 6 TO ABOVE. SEE ALSO MINIREVIEW ON SLOPE PARAMETERS IN
 JTO CHGD K SECTION AND TEXT SEC. VI 8.1. THIS SECTION REPLACES CHARGE
 JTO ASYMMETRY PARAMETER SECTION(A) IN THE 1978 AND EARLIER EDITIONS.
 JTO 238K 0.001 0.004 BLANPIED 68 1/79*
 JTO 3M 0.0013 0.0009 SCRIBAND 70 1/79*
 JTO 4400 0.00 0.017 SMITH 70 OSPK 1/79*
 JTO 6499 0.001 0.011 CHO 77 1/79*
 JTO 4709 -0.001 0.003 PEACH 77 1/79*
 JTO AVG 0.00110 0.00084 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
 JTO STUDENT 0.00111 0.00091 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

13 CHARGE ASYMMETRY IN LEPTONIC DECAYS (PERCENT)-----
 TEXT SECTION VI 8.3 C
 SUCH ASYMMETRY VIOLATES CP. IT IS RELATED TO REAL(EPSILON).
 A1 KOL INTO (MU+PI-NU) - (MU-PI+NU) / (MU+PI-NU) + (MU-PI+NU) (PERCENT)
 A1 D 1M (0.403) (0.134) DORFAN 67 OSPK DERIVED FROM R16 11/67
 A1 D 1M 0.57 0.17 PACIOTTI 69 OSPK 1/73
 A1 7.7M 0.278 0.051 PICCIONI 72 ASPK 1/73
 A1 4.1M 0.60 0.14 MCCARTHY 73 CNTR 6/73
 A1 19K 0.313 0.029 GENENIGI 74 ASPK 7/74
 A1 D PACIOTTI 69 IS A REANALYSIS OF DORFAN 67 AND IS CORRECTED FOR
 A1 D MU+ NU- RANGE DIFFERENCE IN MC CARTHY 72. 1/73
 A1 AVG 0.319 0.038 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)
 A1 STUDENT 0.316 0.027 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
 (SEE IDEOGRAM BELOW)

A2 KOL INTO (E+PI-NU) - (E-PI+NU) / (E+PI-NU) + (E-PI+NU) (PERCENT)
 A2 B 10M (0.224) (0.036) BENNETT 67 CNTR 11/67
 A2 B 10M 0.246 0.059 SAAL 69 CNTR 10/70
 A2 10M 0.346 0.033 MARX 70 CNTR 10/70
 A2 600K 0.36 0.18 ASHFORD 72 ASPK 2/72
 A2 40M 0.318 0.038 FITCH 73 ASPK 12/73
 A2 34M 0.341 0.018 GENENIGI 74 ASPK 7/74
 A2 B SAAL 69 IS A REANALYSIS OF BENNETT 67
 A2 AVG 0.333 0.014 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
 A2 STUDENT 0.334 0.016 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

WEIGHTED AVERAGE = 0.319 ± 0.038
 ERROR SCALED BY 1.5



AL KOL INTO ((L)-(L-))/((L)+(L-)) (COMBINED A1 AND A2) (PERCENT)
 AL B 10M 0.246 0.059 SAAL 69 CNTR KE3 2/71
 AL D 1M 0.57 0.17 PACIOTTI 69 OSPK KMU3 1/73
 AL 10M 0.346 0.033 MARX 70 CNTR KE3 2/71
 AL 600K 0.36 0.18 ASHFORD 72 ASPK KE3 2/72
 AL 7.7M 0.278 0.051 PICCIONI 72 ASPK KMU3 1/73
 AL 40M 0.318 0.038 FITCH 73 ASPK KE3 12/73
 AL 4.1M 0.60 0.14 MCCARTHY 73 CNTR KMU3 6/73
 AL 33M 0.333 0.050 WILLIAMS 73 ASPK KMU3+KE3 12/73
 AL 15M 0.313 0.029 GENENIGI 74 ASPK KMU3 7/74
 AL 34M 0.341 0.018 GENENIGI 74 ASPK KE3 7/74
 AL SEE FOOTNOTES IN SECTIONS A1 AND A2 ABOVE. 1/73
 AL AVG 0.330 0.012 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
 AL STUDENT 0.330 0.013 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

13 PARAMETERS FOR KOL INTO 2PI DECAY-----
 TEXT SECTION VI 8.3 D

ETA+- = A(KL TO PI+PI-)/A(KS TO PI+PI-)
 ETA00 = A(KL TO PI0PI0)/A(KS TO PI0PI0)
 THE FITTED VALUES OF ETA+- AND ETA00 GIVEN BELOW ARE THE RESULTS
 OF A FIT TO ETA+-, ETA00 AND ETA00/ETA+- RESULTS. THE VALUES LISTED
 BELOW WHICH ARE NOT PARENTHESIZED ENTER THE FIT AS SHOWN. THE
 VALUES WHICH ARE PARENTHESIZED AND BEAR THE FOOTNOTE X DO NOT ENTER
 THE FIT AS SHOWN. THESE EXPERIMENTS GIVE BRANCHING RATIOS AND ENTER
 THE FIT VIA THE QUANTITY ACTUALLY MEASURED -- BRANCHING RATIOS
 R9, R20 AND R27 (ETA+-) AND R17 AND R19 (ETA00). THESE BRANCHING
 RATIOS ARE COMBINED WITH CURRENT NORMALIZATIONS AND CURRENT KL AND KS
 MEAN LIVES TO OBTAIN PI PI RATES. THE ETA+- AND ETA00 VALUES OBTAINED
 FROM THESE RATES ARE ENTERED BELOW WITH THE NAME *GKL/GKS*.

E0S (ETA00)**2 = (A(KL TO 2PI0)/A(KS TO 2PI0))**2 (UNITS 10**-6) ---
 E0S X 0 (1.2) (7.0) BARTLETT 68 OSPK 10/69
 E0S X 57 (4.9) (1.2) BANNER 69 OSPK 2/72
 E0S XR 133 (14.1) (3.4) CENCE 69 OSPK 10/69
 E0S XF 180 (13.) (4.) GAILLARD 69 OSPK 10/69
 E0S X 29 (4.08) (0.9) BARNIN 70 HLBC 12/70
 E0S X 30 (3.61) (1.9) BUDAGOV 70 HLBC 10/70
 E0S C 8.7 3.7 CHOLLET 70 OSPK CU REG., 4 GAMMAS 2/72
 E0S XF 172 (9.9) (3.4) FAISSNER 70 OSPK 12/70
 E0S C 56 7.4 2.0 WOLFF 71 OSPK CU REG., 46 GAMMAS 12/71
 E0S XR 150 (14.1) (3.4) REY 76 OSPK 8/76
 E0S C 54.3 0.84 CHRISTEL 79 ASPK 12/79*
 E0S X 5.1 1.0 GKL/GKS 78 RVUE BR SCALE FACTOR=1.5 2/80*
 E0S X SEE NOTE ABOVE REGARDING FITTED VALUES OF ETA+- AND ETA00.
 E0S R CENCE 69 EVENTS ARE INCLUDED IN REY 76. 1/77
 E0S F FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69
 E0S C CHOLLET 70 GIVES ETA00=(1.23+-0.24)*(REGEN AMPL, 2GEV/C CU)/10000MB 2/72
 E0S C WOLFF 71 GIVES ETA00=(1.13+-0.12)*(REGEN AMPL, 2GEV/C CU)/10000MB 2/72
 E0S C WE COMPUTE BOTH ETA00**2 VALUES FOR (REGEN AMPL, 2GEV/C CU)=24+-2MB. 2/72
 E0S C THIS REGEN AMPL RESULTS FROM AVERAGING OVER FAISSNER 69. 2/72
 E0S C EXTRAPOLATED USING OPTICAL MODEL CALCULATIONS OF BOHM ET AL. 2/72
 E0S C PL 278 594 (1968) AND THE DATA OF BALATS 71. (FROM H. FAISSNER, 2/72
 E0S C PRIVATE COMMUNICATION)
 E0S F FAISSNER 70 CONTAINS SAME 2PI0 EVENTS AS GAILLARD 69 2/72
 E0S
 E0S AVG 5.58 0.60 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
 E0S STUDENT 5.56 0.66 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
 E0S FIT 5.41 0.38 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1) 2/80*
 E0S THIS FIT VALUE CORRESPONDS TO ETA00=2.325+-0.082 2/80*

E+- ETA+- = A(KL TO PI+PI-)/A(KS TO PI+PI-) UNITS 10**-3 -----
 E+- X 45 (1.95) (0.20) CHRISTENS 64 OSPK 2/76
 E+- X 54 (1.99) (0.16) GALLBRATH 65 OSPK 2/76
 E+- X (1.92) (0.13) BASILE 66 OSPK 2/76
 E+- X (1.95) (0.04) BOTT-BODE 66 OSPK 2/76
 E+- X (2.00) (0.09) DEBOUGH 67 OSPK 2/76
 E+- X (1.94) (0.08) FITCH 67 OSPK 2/76
 E+- X (1.95) (0.03) GKL/GKS 71 RVUE EXPTS. BEFORE 71 2/76
 E+- A AVERAGE OF ABOVE EXPERIMENTS. THESE ARE EXCLUDED FROM THE GKL/GKS, 1/80*
 E+- A AVERAGE, AND FIT VALUES BELOW SINCE THEY DO NOT AGREE WITH MORE 1/80*
 E+- A RECENT PRECISE AND IN PRINCIPLE SUPERIOR EXPERIMENTS. 1/80*
 E+- X 4200 (2.23) (0.05) MESSNER 73 ASPK 11/75
 E+- 2.30 0.035 GENENIGI 74 ASPK 3/74
 E+- X 2703 (2.25) (0.05) DEVOTE 77 SPEC 11/77
 E+- 2.27 0.12 CHRISTE2 79 ASPK 12/79*
 E+- X (1.94) (0.08) GKL/GKS 71 RVUE BR EXP. AFTER 71 2/78
 E+- X SEE NOTE ABOVE REGARDING FITTED VALUES OF ETA+- AND ETA00.
 E+-
 E+- AVG 2.273 0.022 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
 E+- STUDENT 2.272 0.025 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
 E+- FIT 2.274 0.022 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

K_L⁰

ER	RATIO OF ETA00 OVER ETA+-								
ER	124	1.03	0.07	BANNER1	72	OSPK			8/72
ER	167	1.00	0.06	HOLDER	72	ASPK			8/72
ER	C	(1.00)	(0.09)	CHRISTE1	79	ASPK			2/80*
ER	C	NOT INDEPENDENT OF F+- AND EOS VALUES WHICH ARE INCLUDED IN FIT.							2/80*
ER	AVG	1.013	0.04	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)					
ER	STUDENT	1.013	0.049	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT					
ER	FIT	1.023	0.036	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)					
F+-	PHASE OF ETA +- (DEGREES)								
F+-	THE DEPENDENCE OF THE PHASE ON THE KOL-KOS MASS DIFFERENCE								
F+-	IS GIVEN FOR EACH EXPERIMENT IN THE COMMENTS BELOW, WHERE DM IS								
F+-	(MASS DIFF./HBAR) IN UNITS 10**10 SEC-1. WE HAVE EVALUATED THESE								
F+-	PHASE DEPENDENCES USING OUR APRIL 1978 VALUE, DM=0.5349+-0.0022								
F+-	TO OBTAIN THE VALUES AND AVERAGE QUOTED BELOW. WE ALSO GIVE THE								
F+-	REGENERATOR PHASE FR IN THE COMMENTS BELOW.								
F+-	D	(45.0)	(50.0)	FITCH	65	OSPK	BE	REGEN	11/67
F+-	O	(30.0)	(45.0)	FIRESTONE	66	HBC	C	REGEN	11/67
F+-	C	(70.0)	(21.0)	BOTT-BODE	67	OSPK	C	REGEN	11/67
F+-	O	(25.0)	(35.0)	MISCHKE	67	OSPK	CU	REGEN	7/68
F+-	C	OLD EXPERIMENTS WITH LARGE ERRORS NOT INCLUDED IN AVERAGE.							2/76
F+-	N	(51.0)	(11.0)	BENNETT2	68	CNTR	CU	REG. USES	8/68
F+-	C	34.2	10.0	BENNETT	69	CNTR	CU	REGEN	2/71
F+-	B	45.3	12.0	BOHM	69	OSPK	VACUUM	REGEN	2/71
F+-	F	45.2	7.4	FAISSNER	69	ASPK	CU	REGEN	2/71
F+-	J	40.6	4.2	JENSEN	70	ASPK	VACUUM	REGEN	2/71
F+-	D	37.2	12.0	BALATS	71	OSPK	CU	REGEN	9/71
F+-	P	36.2	8.1	CARNEGIE	72	ASPK	CU	REGEN	1/73
F+-	G	46.5	1.6	GEWENIG2	74	ASPK	VACUUM	REGEN	3/74
F+-	H	45.5	2.8	CARITHERS	75	SPEC	C	REGEN	7/75
F+-		41.7	3.5	CHRISTE2	79	ASPK			12/79*
F+-	AVG	44.6	1.2	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)					
F+-	STUDENT	44.6	1.4	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT					
F+-	FIT	44.6	1.2	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)					
F+-	COMMENTS								
F+-	N	BENNETT 69 IS A REEVALUATION OF BENNETT2 68.							11/69
F+-	C	BENNETT 69 USES MEASUREMENT OF (F+-)-(PHIF) OF ALFF-STEINBERGER 66.							2/71
F+-	C	BENNETT 69 F+-=(34.9+-10.0)+ 69*(DM-.545) DEG. FR=-49.9+-5.4 DEG.							2/71
F+-	B	BOHM 69 F+-=(41.0+-12.0)+479*(DM-.526) DEG. FR=-49.9+-5.4 DEG.							2/71
F+-	F	FAISSNER 69 ERROR ENLARGED TO INCLUDE ERROR IN REGENERATOR PHASE.							11/69
F+-	F	FAISSNER 69 F+-=(49.3+-7.4)+205*(DM-.555) DEG. FR=-42.7+-5.0 DEG.							2/71
F+-	J	JENSEN 70 F+-=(42.2+-4.0)+576*(DM-.538) DEG. FR=-43.0+-4.0 DEG.							9/71
F+-	D	BALATS 71 F+-=(39.0+-12.0)+198*(DM-.544) DEG. FR=-56.2+-5.2 DEG.							1/73
F+-	P	CARNEGIE 72 F+- IS INSENSITIVE TO DM. FR=-56.2+-5.2 DEG.							3/74
F+-	G	GEWENIG2 74 F+-=(49.0+-1.0)+56*(DM-.540) DEG. FR=-40.9+-2.6 DEG.							11/75
F+-	H	CARITHER 75 F+-=(45.5+-2.8)+224*(DM-.5348) DEG. FR=-40.9+-2.6 DEG.							11/75
F00	PHASE OF ETA 00 (DEGREES)								
F00	FIRST QUADRANT PREFERRED								
F00	C	51.0	30.0	GOBBI	69	OSPK			11/69
F00	W 56	38.0	25.0	CHOLLET	70	OSPK	CU	REG., 4 GAMMAS	10/70
F00				WOLFF	71	OSPK	CU	REG., 4 GAMMAS	12/71
F00	AVG	43.3	19.2	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)					
F00	STUDENT	43.3	20.7	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT					
F00	C	55.7	5.8	CHRISTE1	79	ASPK			12/79*
F00	C	CHOLLET 70 USES REGENERATOR PHASE FR=-46.5+-4.4 DEG.							1/73
F00	W	WOLFF 71 USES REGENERATOR PHASE FR=-48.2+-3.5 DEG.							1/73
F00	FIT	54.5	5.3	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)					
DF	PHASE DIFFERENCE F00 - F+- (DEGREES)								
DF	B	7.6	18.0	BARBIELLI	73	ASPK			7/73
DF	C	(12.6)	(6.2)	CHRISTE1	79	ASPK			2/80*
DF	B	INDEPENDENT OF REGENERATOR MECHANISM, DM, AND LIFETIMES.							7/73
DF	C	NOT INDEPENDENT OF F+- AND F00 VALUES WHICH ARE INCLUDED IN FIT.							2/80*
DF	AVG	8.8	5.4	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)					

The above predictions can be compared with the experimental values

$$|\eta_{00}/\eta_{+-}| = 1.023 \pm 0.036$$

$$\phi_{+-} = (44.6 \pm 1.2)^\circ$$

$$\phi_{00} = (54.5 \pm 5.3)^\circ$$

$$\text{Re}\epsilon = (1.621 \pm 0.088) \times 10^{-3}$$

where Re ϵ has been computed using the relation

$$\text{Re}\epsilon = \frac{\delta}{2} \left(\frac{|1-x|^2}{1-|x|^2} \right)$$

and our current values of the charge asymmetry parameter for leptonic K_L⁰ decay $\delta = (0.330 \pm 0.012)\%$ and the $\Delta S = -\Delta Q$ amplitude (Rex, Imx) = (0.009 ± 0.020, -0.004 ± 0.026).

The superweak predictions are in agreement with the data except for the measured value of ϕ_{00} , which is two standard deviations above the prediction. This results primarily from the recent CHRISTENSON1 79 measurement $\phi_{00} = (55.7 \pm 5.8)^\circ$.

References

1. L. Wolfenstein, Phys. Lett. **13**, 562 (1964).
2. T. D. Lee and L. Wolfenstein, Phys. Rev. **138B**, 1490 (1965).

Superweak Model Predictions for $|\eta_{00}/\eta_{+-}|$, ϕ_{+-} , and Re ϵ

In terms of the parameters defined in the text, Sec. VI B(d), the superweak model¹ predicts that²

$$|\eta_{00}/\eta_{+-}| = 1$$

$$\phi_{+-} = \phi_{00} = \tan^{-1} \left(\frac{2\Delta m \tau_S}{\hbar} \right)$$

and

$$\text{Re}\epsilon = |\eta_{+-}| \left[1 + \left(\frac{2\Delta m \tau_S}{\hbar} \right)^2 \right]^{-1/2}$$

The latter two expressions and the values of the K_L⁰ - K_S⁰ mass difference $\Delta m = (0.5349 \pm 0.0022) \times 10^{10} \hbar \text{ sec}^{-1}$, the K_S⁰ mean life $\tau_S = (0.8923 \pm 0.0022) \times 10^{-10} \text{ sec}$, and the magnitude of the K_L⁰ $\rightarrow \pi^+ \pi^- / K_S^0 \rightarrow \pi^+ \pi^-$ amplitude ratio $|\eta_{+-}| = (2.274 \pm 0.022) \times 10^{-3}$, all from the current edition, result in the predictions that

$$\phi_{+-} = \phi_{00} = (43.67 \pm 0.14)^\circ$$

and

$$\text{Re}\epsilon = (1.645 \pm 0.016) \times 10^{-3}$$

13 X = (DS=-DQ AMPLITUDE)/(DS=+DQ AMPLITUDE)

RELATED TEXT SECTION VI B.4

REX	REAL PART OF X								
REX	C 152	0.06	0.18	0.44	BALDO-CE	65	HLBC	K+ CHARGE EXCHNG	11/67
REX	196	0.035	0.11	0.13	AUBERT	65	HLBC	K+ CHARGE EXCHNG	11/67
REX	F 109	-0.08	0.16	0.28	FRANZINI	65	HBC	PBAR P	11/67
REX	116	0.17	0.16	0.35	FELDMAN	67	OSPK	P1-P TO K0 LMBDA	11/67
REX	N 335	(0.17)	(0.10)		MANN	72	HBC	K+P TO K0BAR N	9/72
REX	B	(0.03)	(0.03)		BENNETT1	68	CNTR	K+D YIELDS KOPP	7/68
REX	121	0.09	0.07	0.09	JAMES	68	HBC	PBAR P	5/69
REX	B	-0.020	0.025		BENNETT	69	CNTR	CHAR ASYM+ CU RE	10/69
REX	686	0.09	0.14	0.16	LITTENBER	69	OSPK	K+N TO KOP	4/69
REX	N 215	0.12	0.09		CHO	70	DBC	K+D TC KOPP	10/70
REX	U 222	(0.04)	(0.07)	(0.08)	BURGUN	71	HBC	K+P TO KOPPI+	2/72
REX	252	0.25	.07	.09	WEBBER	71	HBC	K-P TO KBAR N	10/69
REX	U 410	0.03	0.06	0.06	BURGUN	72	HBC	K+P TO KOPPI+	1/73
REX	126	0.26	0.10	0.14	MANN	72	HBC	K+P TO K0BAR N	9/72
REX	G 342	(-0.13)	(0.11)		MANTSCH	72	OSPK	KE3 FROM KO LMB	2/72
REX	G 100	(0.04)	(0.10)	(0.13)	GRAHAM	72	OSPK	KMU3 FROM KO LMB	2/72
REX	G 442	-0.05	0.09		GRAHAM	72	OSPK	P1-P TO K0 LMBDA	2/72
REX	1757	-0.008	0.044		FACKLER	73	OSPK	KE3 FROM KO	9/73
REX	1367	-0.03	0.07		HART	73	OSPK	KE3 FROM KO LMB	2/74
REX	1079	-0.070	0.036		MALLARY	73	OSPK	KE3 FROM KO LM +	6/73
REX	4724	0.04	0.03		NIEBERGA	74	ASPK	X+P TO KOPPI+	7/74
REX	79	0.10	0.18	0.19	SMITH	75	WIRE	P1-P TO K0 LMBDA	8/76
REX	C	BALDO-CE 65 GIVES X AND THETA CONVERTED BY US TO REX AND IMX.							11/67
REX	F	FRANZINI 65 GIVES X AND THETA FOR REX AND IMX SEE SCHMIDT 67.							11/67
REX	N	CHO 70 IS ANALYSIS OF UNAMBIGUOUS EVENTS IN NEW DATA AND HILL 67.							10/70
REX	U	BURGUN 72 IS A FINAL RESULT WHICH INCLUDES BURGUN 71.							11/73
REX	B	BENNETT 69 IS A REANALYSIS OF BENNETT1 68.							10/69
REX	G	SECOND GRAHAM 72 VALUE IS FIRST GRAHAM 72 VALUE COMBINED WITH							2/72
REX	G	MANTSCH 72.							2/72
REX	AVG	0.009	0.020	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)					
REX	STUDENT	0.008	0.017	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT					
				(SEE IDEOGRAM BELOW)					

Stable Particles

Data Card Listings

K_L⁰

For notation, see key at front of Listings.

WEIGHTED AVERAGE = 0.009 ± 0.020
ERROR SCALED BY 1.4

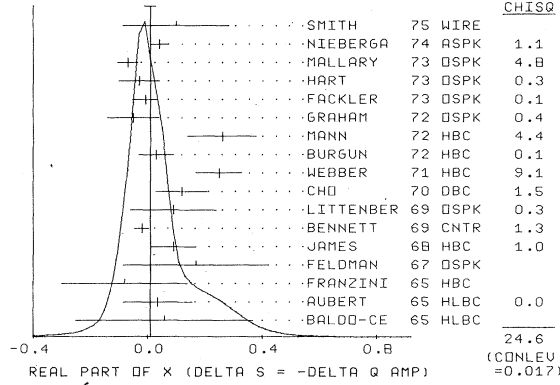


Table listing authors and their associated numerical values for the real part of X. Includes authors like SMITH, NIEBERGA, MALLARY, HART, FACKLER, GRAHAM, MANN, BURGUN, WEBBER, CHO, LITTENBER, BENNETT, JAMES, FELDMAN, FRANZINI, AUBERT, BALDO-CE, etc.

Table listing authors and their associated numerical values for the real part of X. Includes authors like GRIEGER, FIRESTON, FUJII, HAWKINS, JOVANOVICH, KULYUKIN, MEISNER, NEFKENS, VERHEY, BENNETT, BOTT-BOD, CANTER, CRONIN, DEBOUARD, DEVLIN, DORFAN, FELDMAN, FIRESTON, FITCH, HAWKINS, HILL, HOPKINS, KADOK, KULYUKIN, LOWY, MISCHKE, NEFKENS, TODOROFF, ABRAMS, ARNOLD, ARNOLDSON, EALATZ, BARTLETT, BASILE, BENNETT, BERNETT, BLANPEDI, BUDAGOV, CARNEGIE, JAMES, KULYUKIN, MELHOP, THATCHER, BANNER, BEILLIER, BENNETT, BOHM, BOTT-BOD, CENCE, EVANS, FAISSNER, FOETH, GAILLARD, GOBBI, LITTENBERG, LONGO, PACIOTTI, SAAL, ALBROW, ARNSON, BARMIN, BASILE, BUCHANAN, CHEN, CHOI, CHOLLET, CULLEN, DARRULA, FAISSNER, JENSEN, MARX, SCRIBAN, SMITH, WEBBER, BALATS, BARMIN, BISI, BURGON, CARNEGIE, CHAN, CHIEN, ZALTY.

REFERENCES FOR K_L⁰

Table listing references for K_L⁰ from various authors. Includes authors like M. BARDOU, ASTIER, FITCH, GOOD, NEAGU, CAMERINI, ADAIR, ALEKSANY, ANIKINA, CHRISTEN, FUJII, LUERS, ANIKINA, ANDERSON, ASTBURY, AUBERT, BALDO-CE, CHRISTEN, FISHER, FITCH, FRANZINI, GALBRAIT, GUIDONI, HOPKINS, VISINSKY, ALFF-STE, ANIKINA, AUERBACH, AUERBACH, BALDO-CE, BEHR, BELLUCCI, BOTT-BOD, CAMERINI, CANTER, CARPENTE, CHANG.

Table listing references for K_L⁰ from various authors. Includes authors like HOPKINS, KADOK, KULYUKIN, LOWY, MISCHKE, NEFKENS, TODOROFF, ABRAMS, ARNOLD, ARNOLDSON, EALATZ, BARTLETT, BASILE, BENNETT, BERNETT, BLANPEDI, BUDAGOV, CARNEGIE, JAMES, KULYUKIN, MELHOP, THATCHER, BANNER, BEILLIER, BENNETT, BOHM, BOTT-BOD, CENCE, EVANS, FAISSNER, FOETH, GAILLARD, GOBBI, LITTENBERG, LONGO, PACIOTTI, SAAL, ALBROW, ARNSON, BARMIN, BASILE, BUCHANAN, CHEN, CHOI, CHOLLET, CULLEN, DARRULA, FAISSNER, JENSEN, MARX, SCRIBAN, SMITH, WEBBER, BALATS, BARMIN, BISI, BURGON, CARNEGIE, CHAN, CHIEN, ZALTY.

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

K⁰, D[±]

CHO 71 PR D3 1557 +DRALLE,CANTER,ENGLER,FISK+ (CERN,BNL,CASE)
CLARK 71 PR 26 1667 +ELLIOTT,FIELD,FRISCH,JOHNSON,KERTH+ (LRL)
ALSO 70 UCRL 19709-THESIS
ALSO 71 UCRL 20264-THESIS
ALSO 74 SLAC-PUB-1498 R.C.FIELD (SLAC)

PAPERS NOT REFERRED TO IN DATA CARDS
ALEXANDE 62 PRL 9 69 G ALEXANDER,S ALMEIDA,F CRAWFORD (LRL)
JOVANOVI 63 BNL CONF 42 JOVANOVI,F FISCHER,BURRIS + (BNL+MARYLAND)
STERN 64 PRL 12 459 STERN,BINWORLD,LINDO,ANDERSON + (WISC+LRL)

Stable Particles

D±, D0, F±

Data Card Listings

For notation, see key at front of Listings.

Table with columns for particle name, mass, and other properties. Includes entries for D+ AND DO INTO (E+ ANYTHING)/(TOTAL D+ AND DO) and R8 STUDENT.

Table with columns for particle name, mass, and other properties. Includes entries for R9 D+ INTO (K- ANYTHING) and R10 D+ INTO (K0BAR ANYTHING).

***** REFERENCES FOR CHARGED D *****

Table listing references for charged D particles, including authors like Goldhaber, Brandelik, and Feller.

***** REVIEWS *****

Table listing reviews for charged D particles, including authors like Barabard and Kirckby.



32 NEUTRAL D(1863,JP=0) I=1/2

32 NEUTRAL D MASS (MEV)

Table showing mass measurements for neutral D(1863,JP=0) with columns for mass, error, and reference.

32 NEUTRAL D MEAN LIFE (UNITS 10**-13 SEC)

Table showing mean life measurements for neutral D(1863,JP=0) with columns for mean life, error, and reference.

32 NEUTRAL D WIDTH FROM MASS SPECTRUM (MEV)

Table showing width measurements for neutral D(1863,JP=0) with columns for width, error, and reference.

32 NEUTRAL D PARTIAL DECAY MODES

Table showing partial decay modes for neutral D(1863,JP=0) with columns for mode, branching fraction, and reference.

DOBAR MODES ARE CHARGE CONJUGATES OF ABOVE MODES

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± δP_i, where δP_i = √(δP_i δP_i), while the off-diagonal elements are the normalized correlation coefficients (δP_i δP_j) / (δP_i δP_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table with columns P1, P2, P3, P5, P7 and rows for various particle decays.

32 NEUTRAL D BRANCHING RATIOS

Table showing branching ratios for neutral D(1863,JP=0) with columns for mode, ratio, error, and reference.

Table showing DOBAR modes for neutral D(1863,JP=0) with columns for mode, ratio, error, and reference.

Table showing mass measurements for neutral D(1863,JP=0) with columns for mass, error, and reference.

REFERENCES FOR NEUTRAL D

Table listing references for neutral D particles, including authors like Goldhaber, Fiedman, and Scherre.

Table listing reviews for neutral D particles, including authors like Barabard and Kirckby.

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA CARDS

Table listing quantum number determinations for neutral D(1863,JP=0).

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

F[±], p, n

34 F--(2030) BRANCHING RATIOS
R1 F-- INTO (ETA PI+)/(ETA ANYTHING) (P1)/(P2)
R1 6 0.09 0.06 BRANDELIK 79 DASP E+E- ECM=4.42GEV 1/80*

REFERENCES FOR F--(2030)
BRANDEL I 77 PL 708 132 BRANDEL I K + (AACH+DESY+HAMB+MPI+TCKY)
BRANDEL I 79 PL 808 412 BRANDEL I K + (AACH+DESY+HAMB+MPI+TCKY)

16 PROTON (938,J=1/2) I=1/2
16 PROTON MASS (MEV)
M (938.256) (0.005) COHEN 65 RVUE 7/66
M (938.2592) (0.0052) TAYLOR 69 RVUE 7/70
M 938.2796 0.0027 COHEN 73 RVUE 3/74

16 ANTI-PROTON MASS (MEV)
M1 938.3 0.5 BAMBERGER 70 CNTR 12/79*
M1 938.179 0.058 HU 75 CNTR EXOTIC ATOMS 12/79*
M1 938.229 0.049 ROBERSON 77 CNTR 12/79*
M1 938.30 0.13 ROBERTS 78 CNTR 6/78*

16 PROTON MEAN LIFE (UNITS 10**26 YR)
T (.000001) OR MORE GOLDHABE 54 TH 232 FISS.MODE INDEPEN
T (.002) OR MORE FLEROV 57 TH 232 FISS.MODE INDEPEN
T B (1.5) OR MORE BACKENSTO 60 CNTR
T B (60.0) OR MORE KROPP 65 CNTR
T (200.0) OR MORE GURR 67 CNTR DEP. CN DECAY MODE
T (1300.0) OR MORE BERGAMASC 74 CNTR 12/75
T R (23000.0) OR MORE REINES 74 CNTR 12/75
T 10300.0 OR MORE LEARNED 79 CNTR 12/79*

16 ANTI-PROTON MEAN LIFE (HOURS)
T1 B (3.3 E-8) OR MORE CL=.95 GANGULI 78 HBC 6/78*
T1 B (32.) OR MORE BREGMAN 78 7/79*
T1 E (1700.) OR MORE CL=.90 BELL 79 ICE PBAR-->E- P10 1/80*
T1 G 1.67 YR CR MORE GOLDEN 79 SPEC 12/79*

16 PROTON MAGNET. MOMENT (E/2MP)
MM (2.79276) (.00002) COHEN 65 RVUE 7/70
MM (2.792782) (.000017) TAYLOR 69 RVUE 7/70
MM 2.7928456 .0000011 COHEN 73 RVUE 3/74

16 ANTI-PROTON MAGNETIC MOMENT (E/2MP)
MM1 O (-1.81) (1.2) BUTTON 62 CNTR 11/75
MM1 R (-2.83) (0.10) FOX 72 CNTR 7/75
MM1 R (-2.819) (0.056) ROBERTS 74 CNTR 6/78*

16 PROTON ELECTRIC DIPOLE MOMENT (UNITS 10**23 E CM)
EDM 16 700. 900. HARRISON 69 MBR 10/69
EDM 55000. OR LESS KHRIPLOV I 76 1/78

16 PROTON ELECTRON CHARGE DIFFERENCE (UNITS E)
DQ D 1.0E-21 OR LESS DYLLA 73 NEUTRALITY OF SF6 2/80*
DQ D ASSUMES THAT Q(NEUTRON)=Q(PROTON)-Q(E-). SEE DYLLA 73 FOR A 2/80*
DQ D SUMMARY OF EXPERIMENTS ON THE NEUTRALITY OF MATTER. 2/80*

REFERENCES FOR PROTON
GOLDHABE 54 PR 96 1157 FN07E2 GOLDHABER, F. REINES+ (LOS ALAMOS,BNL)
FLEROV 57 SOV PHYS DOK 3 79 FLEROV, KLOCHKOV, SKOBKIN, TERENTEV (USSR)

BERGAMASC 74 LNC 11 636 BERGAMASC, PICCHI (TORI+FRAS)
REINES 74 PRL 32 493 +CROUCH (UCI+CASE)
ROBERTS 74 PRL 33 1181 +COX, ECKHAUSE+ (WILL+VPI+CARN+WYOM+CIT+BNL)
ALSO 75 PR D12 1232 ROBERTS, COX + (WILL+VPI+CARN+WYOM+CIT+BNL)
HU 75 NP A254 403 +ASANO, CHEN, CHENG, DUGAN+ (COLU+YALE)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN THE DATA CARDS
KALOGERO 76 PRL 37 1037 KALOGERPOULOS, CHIU, SUDARSHAN (SYRA+TEXA) P
FRANKLIN 77 PR D16 910 JERROLD FRANKLIN (HAIF) P

17 NEUTRON (939,J=1/2) I=1/2
17 NEUTRON MASS (MEV)
M T (939.5527) (0.0052) TAYLOR 69 RVUE USING NEW E/H 7/70
M T 939.5791 0.0027 COHEN 73 RVUE 3/74
M T THESE DETERMINATIONS OF NEUTRON MASS NOT INDEPENDENT OF 7/70
M T NEUTRON-PROTON MASS DIFFERENCE MEASUREMENTS BELOW. 7/70

17 (NEUTRON) - (PROTON) MASS DIFFERENCE (MEV)
D M (1.29344) (0.00007) MATTAUCH 65 RVUE 3/71
D (1.293429 0.000036 COHEN 73 RVUE 3/74
D M WE HAVE CONVERTED MATTAUCH NEUTRON-HYDROGEN MASS DIFFERENCE TO 3/71
D M NEUTRON-PROTON MASS DIFFERENCE USING CURRENT VALUE OF ELECTRON MASS 3/71
D M AND A HYDROGEN BINDING ENERGY OF 13.6 EV. 3/71

17 NEUTRON MEAN LIFE (UNITS 10**3 SEC)
THE MEASUREMENT OF THE NEUTRON MEAN LIFE BY SOSNOVSKI 59 HAS BEEN DISCARDED SINCE 1. IT DISAGREES WITH THE BETTER AND MORE RECENT RESULT OF CHRISTENSEN 67. 2. THE VALUE OF GA/GV DE- RIVED FROM THE NEW VALUE OF THE MEAN LIFE AGREES WELL WITH THE GA/GV VALUE OBTAINED FROM THE FREE NEUTRON DATA.
T E (1.012) (0.021) SOSNOVSKI 59 PILE 7/68
T (0.935) (0.014) CHRISTENS 67 PILE REPL BY CHRISTENS72 3/68
T 0.918 0.014 CHRISTENS 72 PILE 6/72
T 0.877 0.078 BONDARENK 78 PILE 1/80*

17 NEUTRON MAGNETIC MOMENT (MAGNETONS, 938.2 MEV)
MM (-1.913148 0.000066) COHEN 56 RVUE 7/66
MM (-1.91304211 0.0000088) GREENE 77 MRS 3/78
MM -1.91304164 0.0000088 GREENE 79 MRS 12/79*

17 NEUTRON ELECTRIC DIPOLE MOMENT (UNITS 10**23 E CM)
TEST OF CP OR T VIOLATION IN THE EM INTERACTION
EDM M (-20.) (30.) MILLER 67 MRS 1/78
EDM M +24. 39. SHULL 67 CNTR 1/78
EDM M (30.) OR LESS DRESS 68 MRS ABSOLUTE VALUE 1/78
EDM M (5.) OR LESS BAIRD 69 MRS INCLUDED IN DRESS73 10/69
EDM - 2. 39. APDSTOLS 70 MRS 1/78
EDM 0.32 0.75 DRESS 73 MRS .LT. 10**23 CL=.80 6/73
EDM D 0.04 0.15 DRESS 77 MRS 6/77
EDM M DRESS 68 INCLUDES DATA OF MILLER 67. 1/78
EDM D THE DRESS 77 RESULT IS EQUIV TO EDM < 3 E-24 (CL=.90) 6/77

17 NEUTRON CHARGE
SEE SECTION DQ IN THE PROTON DATA CARD LISTINGS ABOVE

17 NEUTRON PARTIAL DECAY MODES
P1 NEUTRON INTO PROTON E- ANTI(NUE) 938+ .5+ 0 DECAY MASSES
P2 NEUTRON INTO PROTON NUE ANTI(NUE) 938+ 0+ 0 DECAY MASSES

17 NEUTRON BRANCHING RATIOS
R1 NEUTRON INTO (PROTON NUE ANTI(NUE)) / (PROTON E- ANTI(NUE) (P2)/(P1)
R1 S 3. E-17 OR LESS SUNYAR 60 CNTR RB87-->SR87M+NEUTRL 2/80*
R1 S 3. E-19 OR LESS NORMAN 79 CNTR RB87-->SR87M+NEUTRL 2/80*
R1 S WE HAVE CONVERTED SUNYAR 60 MEAN LIFE LIMIT FOR (N -> P + NEUTRS) 2/80*
R1 S AS DESCRIBED IN NORMAN 79.

Stable Particles

n, Λ

Data Card Listings

For notation, see key at front of Listings.

17 NEUTRON BETA DECAY PARAMETERS

RELATED TEXT SECTION VI D.1

GA/GV (SEE TEXT FOR SIGN CONVENTION)

AV C (-1.250) (0.044) CONFORTO 67 RVUE SEE NOTE C BELOW

AV EP (-1.231) (0.011) CHRISTENS 67 CNTR N DECAY FT VALUE 11/68

AV P (-1.221) (0.081) GRIGOREV 68 CNTR E-NEU ANG CORREL 10/71

AV P (-1.261) (0.021) CHRISTENS 70 CNTR PE,NEUT SPIN CORREL 10/71

AV EP (-1.271) (0.025) EROZOLIMS 71 CNTR PE,NEUT SPIN CORREL 10/71

AV EP (-1.239) (0.011) CHRISTENS 72 CNTR N DEC.+ FT VALUE 1/73

AV P (-1.263) (0.016) KROPP 73 RVUE N DECAY ALONE 1/73

AV P (-1.259) 0.009 KROPP 73 RVUE N DEC.+ FT VALUE 1/73

AV ES (-1.250) (0.036) DOBROZEMS 75 CNTR E-NEU ANG CORREL 12/75

AV K (-1.253 0.021 KRHN 75 CNTR PE,NEUT SPIN CORREL 1/77

AV (-1.263 0.015 EROZOLIMS 77 CNTR PE,NEUT SPIN CORREL 1/78

AV E S (-1.259) 0.017 STRATOWA 78 CNTR PROTON RECOIL SPECT 7/79*

AV C CONFORTO 67 COMBINES FREE NEUTRON DATA TO 1967. REPL. BY KROPP 73. 1/73

AV E THESE EXPERIMENTS MEASURE THE ABSOLUTE VALUE OF GA/GV ONLY 10/71

AV P KROPP 73 VALUE OBTAINED BY FITTING ALL DATA THROUGH 1972. 1/73

AV K KRHN 75 PAPER GIVES -1.258--0.15 INCLUDING EVENTS OF CHRISTENS 70. 1/78

AV K THE VALUE QUOTED ABOVE IS DERIVED FROM HIS A,BASED ON NEW EXPT ONLY 1/77

AV S STRATOWA 78 IS FINAL RESULT OF DOBROZEMS 75 EXPT. 7/79*

AV * * * * *

AV AVG -1.2543 0.0067 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

AV STUDENT -1.2542 0.0073 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

F PHASE ANGLE OF GA RELATIVE TO GV (DEGREES)

F P (175.) (10.) BURGY 60 CNTR POLAR. NEUTRONS 6/77

F P (139.) (27.) CLARK 60 CNTR POLAR. NEUTRONS 6/77

F C (176.1) (6.4) CONFORTO 67 RVUE POLAR. NEUTRONS 11/68

F P (181.3) (1.3) EROZOLIMS 70 CNTR POLAR. NEUTRON 10/69

F P 181.1 1.3 KROPP 73 RVUE N DECAY 1/73

F 180.35 0.43 EROZOLIMS 74 CNTR POLAR. NEUTRONS 6/77

F 180.14 0.22 STEINBERG 74 CNTR POLAR. NEUTRONS 6/77

F 179.71 0.39 EROZOLIMS 78 CNTR POLAR. NEUTRONS 7/79*

F C CONFORTO 67 COMBINES FREE NEUTRON DATA TO 1967. REPL. BY KROPP 73. 1/73

F P KROPP 73 VALUE OBTAINED BY FITTING ALL DATA THROUGH 1972. 1/73

F * * * * *

F AVG 180.11 0.17 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

F STUDENT 180.11 0.19 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

D1 THREE-VECTOR CORRELATION COEFFICIENT 7/76

D1 D1 MEASURES COMPONENT OF NEUTRON SPIN PERPENDICULAR TO THE DECAY 7/76

D1 PLANE IN BETA DECAY. SHOULD BE ZERO IF T-INVARIANCE NOT 7/76

D1 VIOLATED. SEE TEXT SEC VI D. 7/76

D1 -0.31 .01 EROZOLIMS 70 CNTR POLAR. NEUTRONS 7/76

D1 -0.0327 .0033 EROZOLIMS 74 CNTR POLAR. NEUTRONS 7/76

D1 -0.0011 .0017 STEINBERG 74 CNTR POLAR. NEUTRONS 7/76

D1 +0.0022 .0030 EROZOLIMS 78 CNTR POLAR. NEUTRONS 7/79*

D1 * * * * *

D1 AVG -0.0009 0.0013 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

D1 STUDENT -0.0009 0.0015 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

REFERENCES FOR NEUTRON

COHEN 56 PR 104 283 V W COHEN, CORNGOLD, RAMSEY (BNL+HARVARD)

SCSNVSK 59 JETP 9 717 SOSNOVSKII, SPIVAK, PROKOFEV + (IAE MOSCOW)

BURGY 60 PR 129 1829 *KROHN, MOVEY, RINGO (ANL+CHIC)

CLARK 60 CJP 38 693 *ROBSON

SUNYAR 60 PR 120 871 A.W.SUNYAR, M.GOLDHABER (BNL)

MATTAUCH 65 NP 67 1 *THIELE, WAPSTRA (MAX PLANCK INST. CHEM.)

CHRISTEN 67 PL 268 11 CHRISTENSEN, NIELSON, BAHNSEN, BROWN+ (RISO)

CONFORTO 67 AP4H 22 15 G. CONFORTO (CERN)

MILLER 67 PRL 19 381 *DRESS, BAIRD, RAMSEY (ORNL+HARV)

SHULL 67 PRL 19 384 C.G. SHULL, R. NATHANS (MIT+BNL)

DRESS 68 PR 170 1200 *BAIRD, MILLER, RAMSEY (ORNL+HARV)

GRIGOREV 68 SUNP 6 239 *GRISHIN, VLADIMIRSKII, NIKOLAEVSKII + (ITEP)

BAIRD 69 PR 179 1285 *MILLER, DRESS, RAMSEY (ORNL, HARV)

TAYLOR 69 RMP 41 375 *PARKER, LANGENBERG (PRINCETON)

APOSTOLE 70 RRP 15 343 APOSTOLESCU, IONESCU, IONESCU-BUJOR + (BUCH)

CHRISTEN 70 PR C1 1693 CHRISTENSEN, KRHN, RINGO (ANL)

ERZOLIM 70 SUNP 11 583 EROZOLIMSKI, BONDARENKO, + (KIAE)

ALSO PL 278 557 EROZOLIMSKY, BONDARENKO + (KIAE)

ERZOLIM 71 JETPL 13 252 EROZOLIMSKII, BONDARENKO + (KIAE)

CHRISTEN 72 PR D5 1628 CHRISTENSEN, NIELSON, BAHNSEN, BROWN+ (RISO)

COHEN 73 J. PHYS. CHEM. REF. DATA 2, P. 663, E. R. COHEN, B. N. TAYLOR

DRESS 73 PR D7 3147 DRESS, MILLER, RAMSEY (ORNL+HARV)

KROPP 73 ZPHY TO BE PUBL. A KROPP, H. PAUL (LINZ)

ALSO 70 NP A154 160 H. PAUL (VIEN)

ERZOLIM 74 JETPL 20 345 EROZOLIMSKII, MOSTOVOI, FEDUNIN, FRANK+ (KIAE)

STEINBERG 74 PRL 33 41 STEINBERG, LIAUD, VIGNON, HUGHES (YALE+GREN)

ALSO 76 PR D13 2469 STEINBERG, LIAUD, VIGNON, HUGHES (YALE+GREN)

DOBROZEM 75 PR D11 510 DOBROZEMSKY, KERSCHBAUM, MORAW, PAUL + (SEIB)

KRHN 75 PL 558 175 KRHN, RINGO (ANL)

DRESS 77 PR D15 9 *MILLER, PENDLEBURY, PERRIN+ (ORNL+GREN+HARV)

ERZOLIM 77 JETPL 23 663 EROZOLIMSKII, FRANK, MOSTOVOI+ (KIAE)

GREENE 77 PL 718 297 *RAMSEY, MAMPE+ (HARV+ILLG+SUSS+ORNL+CENG)

ERZOLIM 78 SUNP 28 48 EROZOLIMSKII, MOSTOVOI, FEDUNIN, FRANK+ (KIAE)

STRATOWA 78 PR D18 3970 *DOBROZEMSKY, WEINZIERL (SEIB)

BONDAREN 78 JETPL 28 303 BONDARENKO, KURGUZOV, PROKOFEV+ (KIAE)

GREENE 79 PR D20 2139 *RAMSEY, MAMPE+ (HARV+ILLG+SUSS+ORNL+CENG)

NORHAN 79 PRL 43 1226 E.B. NORMAN, A.G. SEAMSTER (WASH)

PAPERS NOT REFERRED TO IN DATA CARDS

JACKSON 57 PR 106 517 JACKSON, TREIMAN, WYLD (PRINCETON)

COHEN 65 RMP 37 537 *DUMOND (IN AMER. AVIATION SCIENCE CENT., CIT)

BHALLA 66 PL 19 691 C P BHALLA (ALABAMA)

A

18 LAMBDA(1115, JP=1/2+) I=0

18 LAMBDA MASS (MEV)

M N SINCE OUR FINAL VALUES FOR THE SIGMA AND LAMBDA MASSES COME FROM

M N DOING AN OVERALL FIT TO ALL MEASURED MASSES AND MASS DIFFERENCES,

M N WE HAVE USED THE UNCORRELATED MEASUREMENTS FROM SCHMIDT 65 RATHER

M N THAN THE ONES COMING FROM THE OVERALL FIT REPORTED IN THAT PAPER.

M N SINCE THERE SEEMS TO BE NO CONVINCING ARGUMENT AS TO WHY ONE SHOULD

M N IGNORE DATA USING RANGE MEASUREMENTS, WE HAVE INCLUDED HERE VALUES

M N DEPENDING ON PROTON AND PION RANGES. THE SCHMIDT 65 MASSES HAVE

M N BEEN REEVALUATED USING OUR APRIL 1973 PROTON AND CHARGED K AND PI

M N MASSES. P. SCHMIDT, PRIVATE COMMUNICATION, (1974).

M 1115.44 0.12 BHOWMIK 63 RVUE + SEE NOTE L BELOW

M L ABOVE LAMBDA MASS HAS BEEN RAISED 35 KEV TO ACCOUNT FOR 46 KEV

M L INCREASE IN PROTON MASS AND 11 KEV DECREASE IN CHARGED PION MASS.

M S 935(1115.86) (0.09) BALTAY 65 HBC ERROR IS STATIS. 6/66

M 488 1115.65 0.07 SCHMIDT 65 HBC SEE NOTE N 3/74

M S 1147(1115.74) (0.04) CHIEN 66 HBC 6.9 PBAR P 9/67

M S 972(1115.69) (0.05) CHIEN 66 HBC 6.9 PBAR P,ANTIL 9/67

M 1115.6 0.4 LONDON 66 HBC 6/66

M (1115.0) (0.2) BADIER 67 HBC 2.4 PBAR P,LLBAR 8/67

M 195 1115.39 0.12 MAYEUR 67 EMUL 11/67

M B 1524(1115.52) (0.03) BOHM 70 EMUL 3/72

M 935 1115.59 0.08 HYMAN 72 HBC 3/72

M B AVERAGE OF VERY INCONSISTENT DATA. ERROR STATISTICAL ONLY. AUTHORS

M B DETECT SYSTEMATIC EFFECT OF ABOUT .15 MEV, WHICH THEY ATTRIBUTE

M B TO ERROR IN RANGE-ENERGY RELATIONS, IN REGION BETA=0.6-0.7. 3/72

M B THIS EFFECT, IF CONFIRMED, WOULD AFFECT VERY LITTLE THE VALUES OF

M B BHOWMIK 63 AND MAYEUR 67. 3/72

M S ERROR PURELY STATISTICAL.

M * * * * *

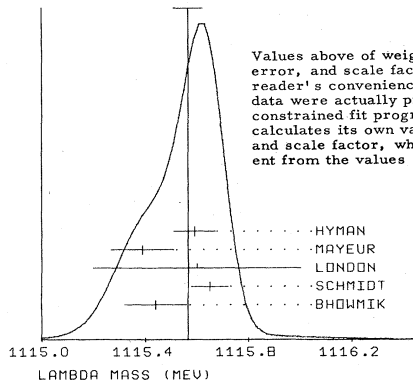
M AVG 1115.566 0.096 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.3)

M STUDENT 1115.568 0.053 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

M FIT 1115.596 0.046 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2) 2/80*

(SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 1115.566 ± 0.056
ERROR SCALED BY 1.3



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of \bar{x} , $\delta\bar{x}$, and scale factor, which are different from the values shown here.

18 LAMBDA - ANTILAMBDA MASS DIFFERENCE (MEV)

DM 0.05 0.06 CHIEN 66 HBC 6.9 PBAR P 9/67

DM 0.29 0.15 BADIER 67 HBC 2.4 PBAR P 8/67

DM * * * * *

DM AVG 0.083 0.083 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)

DM STUDENT 0.080 0.063 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

18 LAMBDA MEAN LIFE (UNITS 10** -10)

T 0 188 (2.63) (0.21) (0.21) BOLDT 58 CC

T 0 825 (2.72) (0.16) (0.16) CRAWFORD 59 HBC

T 0 140 (2.72) (0.29) (0.27) BOWEN 60 CC

T 0 186 (2.60) (0.28) (0.20) CHANG 62 HBC

T 0 799 (2.69) (0.11) (0.11) HJMPHREY 62 HBC

T 0 2239 (2.36) (0.06) (0.06) BLOCK 63 HBC

T 0 706 (2.76) (0.20) CHRETIEN 63 HBC

T 0 754 (2.59) (0.09) HUBBARD 64 HBC

T 0 2260 (2.31) (0.10) KREISLER 64 OSPK

T 0 1378 (2.59) (0.07) SCHWARTZ 64 HBC

T 0 635 (2.91) (0.16) BALTAY 65 HBC

T 0 2534 (2.61) (0.11) HILL 65 OSPK

T 0 916 (2.35) (0.09) BURAN 66 HBC

T S 1147 (2.50) (0.14) CHIEN 66 HBC 6.9 PBAR P 9/67

T S 972 (2.70) (0.20) CHIEN 66 HBC 6.9 PBAR P,ANTI 9/67

T 0 2213 (2.452) (0.056) (0.056) ENGELMANN 66 HBC 9/66

T 0 585 (2.68) (0.13) (0.11) AUERBACH 67 OSPK 8/67

T 0 (2.44) (0.15) BADIER 67 HBC 2.4 PBAR P 6/68

T 0 (2.55) (0.15) BADIER 67 HBC 2.4 PBAR P,ANTIL 6/68

T 0 8342 (2.55) (0.05) GRIMM 68 HBC 6/68

T 0 2600 (2.47) (0.08) HEPP 68 HBC 8/68

T 0 1059 (2.39) (0.10) DEMIDOV 70 HBC PI-P, 3.86 GEV/C 12/70

T 0 4572 (2.54) (0.04) BALTAY 71 HBC K-P AT REST 6/71

T 0 6582 (2.69) (0.05) ALTHOFF2 73 OSPK PI+K TO K+LAMBDA 2/74

T 0 36K 2.626 0.020 POUJARO 73 HBC K-P,KMOM +4T02.3 9/73

T 0 34K 2.611 0.020 CLAYTON 75 HBC K-P,KMOM +96-1.4 1/77

T 0 53K 2.69 0.03 ZECH 77 SPEC NEUTRAL HYP. BEAM 12/77

T 0 OLD LOWER STATISTICS EXPERIMENTS NOT INCLUDED IN AVERAGE. 1/78

T S ERROR PURELY STATISTICAL.

T * * * * *

T AVG 2.632 0.020 0.020 AVERAGE (ERROR INCL. SCALE FACTOR OF 1.6)

T STUDENT 2.630 0.015 0.015 AV BY STUDENT10(H/1.11) -- SEE MAIN TEXT

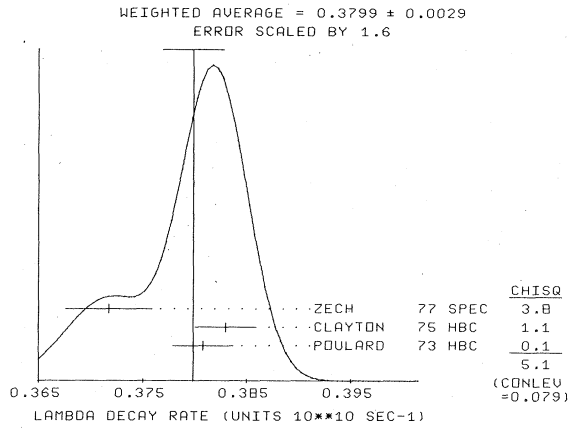
(SEE IDEOGRAM BELOW)

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

A



18 (LAMBDA - ANTILAMBDA)/AVG., MEAN LIFE DIFFERENCE						
DT	0.044	0.085	BADIER	67 HBC	2.4 PBAR P	8/67

18 LAMBDA MAGNETIC MOMENT (MAGNETONS, 938.26 MEV)						
MM	-1.5	0.5	COOL	62 OSPK		
MM	0.0	0.6	KERNAN	63 CC		
MM	8553	-1.39	ANDERSON	64 HBC		
MM	151	-0.5	CHARRIERE	65 EMUL		
MM	49	(-0.67)	(0.31)	(0.37)	BARKOV 71 EMUL	PRELIM. RESULT 2/72
MM	1300	-0.66	0.07	DAHLJENSE	71 EMUL	MAG FIELD=200KG 6/71
MM	3868	-0.73	0.18	HILL	71 OSPK	10/71
MM	57	-0.65	0.28	BARKOV	72 EMUL	INCLUDES BARKOV 71 3/78
MM	1.2M	-0.57	0.05	BUNCE	76 SPEC	1/78
MM	350K	-0.59	0.07	HELLER	77 SPEC	1/78
MM	3M	-0.6138	0.0047	SCHACHING	78 SPEC	1/79*
MM	AVG	-0.6136	0.0047	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
MM	STUDENT	-0.6136	0.0050	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

18 LAMBDA ELECTRIC DIPOLE MOMENT (UNITS 10**14 E CM)						
NONZERO VALUE IMPLIES VIOLATION OF T AND P						
EDM	5.0	OR LESS	CL=95	GIBSON	66 EMUL	2/72
EDM B	1.0	OR LESS	CL=95	BARONI	71 EMUL	2/72
EDM B	BARONI MEASURES (-5.9+-2.9)*10**15 E CM					2/72

18 LAMBDA PARTIAL DECAY MODES						
P1	LAMBDA INTO PROTON PI-				DECAY MASSES	
P2	LAMBDA INTO NEUTRON P0				938+ 139	
P3	LAMBDA INTO PROTON MU- NEUTRINO				938+ 105+ 0	
P4	LAMBDA INTO PROTON E- NEUTRINO				938+ .5+ 0	
P5	LAMBDA INTO PROTON PI- GAMMA				938+ 139+ 0	

18 LAMBDA BRANCHING RATIOS						
R1	LAMBDA INTO (P PI-)/(P PI-)+(N P10)				(P1)/(P1+P2)	
R1	0.627	0.031	CRAWFORD	59 HBC		
R1	0.65	0.05	COLUMBIA	60 HBC		
R1	0.685	(0.017)	ANDERSON	62 HBC		
R1 U	903	0.643	0.016	HUMPHREY	62 HBC	
R1 U	6736	0.635	0.007	DOYLE	69 HBC	PI-P TO LAM. KO 2/71
R1	4572	0.646	0.008	BALTAY	71 HBC	K-P AT REST 6/71
R1	ANDERSON RESULT NOT PUBLISHED, EVENTS ADDED TO DOYLE SAMPLE.					2/71
R1	AVG	0.6399	0.0049	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R1	STUDENT	0.6398	0.0055	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R1	FIT	0.6419	0.0049	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R2	LAMBDA INTO (N P10)/(P PI-)+(N P10)				(P2)/(P1+P2)	
R2	0.23	0.09	EISLER	57 HLBC		
R2	0.43	0.14	CRAWFORD	59 HBC		
R2	0.28	0.08	BAGLIN	60 HLBC		
R2	0.35	0.05	BROWN	63 HLBC		
R2	75	0.291	0.034	CHRETIEN	63 HLBC	
R2	AVG	0.304	0.025	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R2	STUDENT	0.304	0.028	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R2	FIT	0.3581	0.0049	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)		

R3 LAMBDA INTO (P E- NEU)/TOTAL (UNITS 10**3) (P4)/(P1+P2)						
R3 O	15	(2.0)	(0.5)	HUMPHREY	61 RVUE	
R3 O	8	(2.9)	(1.5)	AUBERT	62 FBC	
R3 N	150	(0.82)	(0.12)	ELY	63 FBC	K- AT REST
R3 N	102	(0.78)	(0.12)	(0.13)	BAGLIN	64 FBC K- AT 1.45 GEV/C
R3 C	20	(1.55)	(0.34)	LIND	64 HBC	
R3 N	143	(0.90)	(0.08)	MALONEY	69 HBC	
R3 N	86	(0.78)	(0.09)	CANTER	71 HBC	K-P AT REST 4/71
R3 N	218	(0.88)	(0.10)	LINDQUIST	71 OSPK	PI- P TO KO LAM 2/72
R3 N	THESE VALUES HAVE BEEN CHANGED BY US INTO RATIOS TO PROTON PI-					3/72
R3 N	BECAUSE THAT IS THE DIRECTLY MEASURED QUANTITY. SEE R5 BELOW					3/72
R3 O	LOW STATISTICS EXPERIMENTS. NOT AVERAGED					7/70

R4	LAMBDA INTO (P MU- NEU)/TOTAL (UNITS 10**4)	(P3)/(P1+P2)				
R4	1	(0.2)	OR MORE	GOOD	62 HBC	
R4	1	(1.0)	OR LESS	ALSTON	63 HBC	
R4	2	(1.0)	OR LESS	KERNAN	64 FBC	
R4	BETWEEN 1.3 AND 6.0			LIND	64 HBC	
R4	3	1.3	0.7	LIND	64 RVUE	7/66
R4	2	1.5	1.2	RONNE	64 FBC	
R4	9	2.4	0.8	CANTER1	71 HBC	STOPPED K-P 7/71
R4	14	1.4	0.5	BAGGETT2	72 HBC	STOP K- 8/72
R4	AVG	1.57	0.35	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R4	STUDENT	1.56	0.38	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

R5	LAMBDA INTO (P E- NEU)/(P PI-) (UNITS 10**3)	(P4)/(P1)				
R5	150	1.23	0.20	ELY	63 FBC	2/72
R5	120	1.17	0.18	BAGLIN	64 FBC	2/72
R5	143	1.20	0.12	MALONEY	69 HBC	2/72
R5	1076	1.31	0.06	ALTHOFF1	71 OSPK	2/72
R5 C	86	1.17	0.13	CANTER	71 HBC	K-P AT REST 3/72
R5 LC	218	(1.32)	(0.15)	LINDQUIST	71 OSPK	PI-P TO KO LAM 3/72
R5	544	1.23	0.11	LINDQUIST	77 SPEC	PI-P TO KO LAM 12/77
R5 C	CALCULATED BY US FROM R3 ASSUMING THE AUTHORS USED (P PI-)/TD=2/3					3/72
R5 L	LINDQUIST 77 INCLUDES DATA OF LINDQUIST 71.					12/77
R5	AVG	1.257	0.043	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R5	STUDENT	1.256	0.048	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

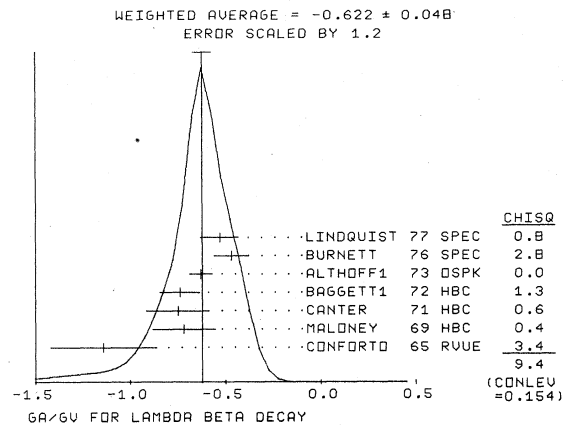
R6	LAMBDA INTO (P PI- GAMMA)/(P PI-) (UNITS 10**3)	(P5)/(P1)				
R6	72	1.32	0.22	BAGGETT3	72 HBC	PI- MOM LT 95 MEV/C 1/73

18 LAMBDA DECAY PARAMETERS						
RELATED TEXT SECTION VI D AND APPENDIX III						
A-	ALPHA LAMBDA-	(LAMBDA INTO PI-	PROTON)			
A-	1156	0.62	0.07	CRONIN	63 CNTR	LAMBDA FROM PI-P 8/67
A-		(0.663)	(0.022)	BERGE	66 RVUE	INCLUDES ABOVE 9/66
A-	10130	0.645	0.017	OVERSETH	67 OSPK	LAMBDA FROM PI-P 8/67
A-	M 2529	(0.747)	(0.086)	MERRILL	68 HBC	REPL BY DAUBER 68 6/68
A-	3520	0.67	0.06	DAUBER	69 HBC	FROM XI DECAY 6/68
A-	10325	0.649	0.023	CLELAND	72 OSPK	LAMBDA FROM PI-P 5/72
A-	8500	0.584	0.046	ASTURRY	75 SPEC	LAMBDA FROM PI-P 2/78
A-	AVG	0.642	0.013	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
A-	STUDENT	0.642	0.014	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

A0	ALPHA /ALPHA-	FOR LAMBDA (L INTO P10 N/L INTO PI- P)				
A0	4760	1.10	0.27	CORK	60 CNTR	
A0 D	4760	1.000	0.068	DLSEN	70 OSPK	PI+N TO K+ LAMBDA 5/70
A0	AVG	1.006	0.066	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
A0	STUDENT	1.006	0.071	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
A0 D	DONE BY CMPARING PROTON DISTR. WITH N DISTR. FROM LAMBDA DECAY.					

F-	PHI ANGLE (SIN(PHI)/COS(PHI)=BETA/GAMMA)	(DEGREES)				
F-	1156	13.0	17.0	CRONIN	63 OSPK	LAMBDA FROM PI-P 11/67
F-	10130	-8.0	6.0	OVERSETH	67 OSPK	LAMBDA FROM PI-P 11/67
F-	7377	(-9.2)	(5.2)	CLELAND	67 OSPK	REPL BY CLELAND 72 5/72
F-	10325	-7.0	4.5	CLELAND	72 OSPK	LAMBDA FROM PI-P 5/72
F-	AVG	-6.5	3.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
F-	STUDENT	-6.6	3.8	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

AV	GA/GV FOR LAMBDA BETA DECAY (SEE TEXT SEC. VI D.1 FOR SIGN CONV.)					
AV	C 22	(-1.03)	LIND	64 HBC	6/68	
AV	C 102	(0.6)	OR MORE	BAGLIN	65 HLBC	NO SIGN GIVEN 1/71
AV	C	BETW 0. AND -1.1	BARLOW	65 OSPK	6/68	
AV	C 102	(0.7)	OR MORE	CL=95	ELY	65 HLBC ABS. VALUE 1/71
AV	C	EXPERIMENTS INCLUDED IN CONFORTO 65, RVUE				6/68
AV		-1.14	0.23	0.33	CONFORTO	65, RVUE 11/67
AV	M 148	-0.72	0.14	0.19	MALONEY	69 HBC 10/69
AV	A 1078	(-0.62)	(0.08)	(0.09)	ALTHOFF2	71 OSPK POLARIZED LAMBDA 7/73
AV	H 141	-0.75	0.15	0.18	CANTER	71 HBC LAMBDA FROM PI-P 4/71
AV	L 173	(-0.40)	(0.13)	(0.17)	LINDQUIST	71 OSPK E-NEU AND UP-DOWN 9/71
AV	M 352	-0.74	0.09	0.12	BAGGETT1	72 HBC STOP-K- 2/72
AV	A 817	-0.63	0.06	ALTHOFF1	73 OSPK POLARIZED LAMBDA 7/73	
AV	405	-0.47	0.09	BURNETT	76 SPEC E-NEU AND SPIN 2/78	
AV	L 441	-0.53	0.09	0.11	LINDQUIST	77 SPEC POL LAMBDA, 3 ASYMM 12/77
AV	A	ALTHOFF1 73	INCLUDES DATA OF ALTHOFF2 71.	USES	PROT SPECTRUM AND	7/73
AV	A	THREE SPIN ASYMMETRIES.				7/73
AV	M	EXPT MEASURES ONLY THE ABSOLUTE VALUE OF A/V				7/73
AV	L	LINDQUIST 77 INCLUDES DATA OF LINDQUIST 71.				12/77
AV	AVG	-0.622	0.048	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)		
AV	STUDENT	-0.624	0.045	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)		



Stable Particles

Data Card Listings

Λ, Σ^+

For notation, see key at front of Listings.

REFERENCES FOR LAMBDA

EISLER, PLANO, SAMIOS, SCHWARTZ + (COLU+BNL)
BOLDT, D O CALDWELL, Y PAL (MIT)
CRAWFORD, CRESTI, DOUGLASS, GOOD + (LRL)

BAGLIN, BLOCH, BRISSEN, HENNESSY + (EPOL)
BOWEN, HARDY, REYNOLDS, SUN + (PRINCE TON)
CORK, KERTH, WENZEL, CRONIN + (LRL+PRIN+BNL)
M SCHWARTZ + (COLUMBIA)
HUMPHREY, KIRZ, ROSENFELD, RHEE + (LRL+SYRA)

ANDERSON, CRAWFORD, GOLDEN, LLOYD + (LRL)
AUBERT, BRISSON, HENNESSY, SIX + (EPOL)
CHUEN CHUEN CHANG (DUKE)
COOL, HILL, MARSHALL + (BNL+MIT+NYU+ANL)
M L GOOD, V G LIND (WISCONSIN)
W E HUMPHREY, R R ROSS (LRL)

ALSTON, KIRZ, NEUFELD, SOLMITZ, WOHLMUT (LRL)
B BHOWMIK, D P GOYAL (DELHI)
BLOCK, GESSAROLI, RATTI + (INNES+BGNA+SYRA+ORNL)
BROWN, KADYK, TRILLING, ROE + (LRL+MICH)
CHRETIEN, CROUCH + (BRAN+BROWN+HARVAR+MIT)
J W CRONIN, G E OVERSETH + (PRINCE TON)
ELY, GIDAL, KALMUS, OSWALD, POWELL + (LRL)
KERNAN, NOVEY, MARSHAM, MATTENBERG (ANL+ILL)

J A ANDERSON, F S CRAWFORD (LRL)
BAGLIN, BINGHAM + (EPOL+CERN+LOUC+RHEL+BERG)
HUBBARD, BERGE, KALBFLEISCH, SHAFER + (LRL)
KERNAN, POWELL, SANDLER + (LRL+LOUC)
M N KREISLER, O OVERSETH, J CRONIN (PRIN)
LIND, BINFORD, GOOD, STERN (WISCONSIN)
RONNE + (CERN+EPOL+LOUC+UNIV. BERGEN)
JOSEPH ADAM SCHWARTZ (LRL)

BAGLIN + (EPOL, CERN, LOUC, RHEL, BERGEN)
BALTAY, SANDWEISS, CULWICK, KOPP + (YALE+BNL)
J BARLOW, BLAIR, CCONFORTO + (CERN+RHEL+PENN)
CHARRIERE, GIBSON + (EPOL+BRIS+CERN+MPIH)
CHARRIERE, GIBSON + (EPOL, BRIS, CERN, MPIH)
G CONFORTO (CERN)
ELY, GIDAL, KALMUS, POWELL + (LRL, LOUC)
HILL, LI, JENKINS, KYCIA, RUDERMAN (MIT, BNL)
P SCHMIDT (COLUMBIA)

BERGE, CABIBBO ((RVUE) LRL, CERN)
BURAN, EIVINDSON, SKJEGGE STAD, TOFTE + (OSLO)
+LACH, SANDWEISS, TAFT, YEH, OREN + (YALE+BNL)
ENGELMANN, FILTHUTH, ALEXANDER + (HEID, RHEID)
W M GIBSON, K GREEN (BRIS)
LONDON, RAU, GOLDBERG, LICHTMAN + (BNL, SYRA)

AUERBACH, BOWEN, DOBBS, LANDE, MANN + (PENN)
+BONNET, BRIANDET, SADOULET (EPOL)
CLELAND, BIRNLEIN, CONFORTO + (CERN+GEVA+LUND)
C MAYEUR, E, TOMPA, J, WICKENS (BELG, LOUC)
O E OVERSETH, R F ROTH (MICH+PRIN)
H J GRIMM (HEIDELBERG)
V HEPP, H, SCHLEICH (HEIDELBERG)
MERRILL, SHAFER (LRL)

+BERGE, HUBBARD, MERRILL, MILLER (LRL)
J.C. DOYLE (LRL)
MALONEY, SECHI-ZORN (UNIV MARYLAND)
+ KRECKER + (BERL+BRUX+DUUC+LOUC+WARS)
+KIRILLOV, UGRYUMOV, PONDISOV, PROTASOV + (ITEP)
+PONDISOV, HANDLER, LIMON, SMITH + (WISC, MICH)

+BROWN, FREYTAG, HEARD, HEINTZE + (CERN, HEID)
+BROWN, FREYTAG, HEARD, HEINTZE + (CERN, HEID)
+BRIDGMAN, COPPER, HABIBI + (COLU+BNL)
+GUREVICH, MAKARINA, MARTEMYANOV + (ITEP)
G BARONI, S PETRERA, G ROMANO (RMA)
+COLE, LEE-FRANZINI, LOVELESS + (STON-COLL)

+COLE, LEE-FRANZINI, LOVELESS + (STON-COLL)
DAHL-JENSEN + (CERN+ANKA+LAUS+MPIH+RMA)
+LI, JENKINS, KYCIA, RUDERMAN (MIT, BNL)
HILL, LI, JENKINS, KYCIA, RUDERMAN (MIT, BNL)
LINDQUIST, SUMNER + (EFI, MUSL, OSU, ANL)

+BAGGETT, EISELE, FILTHUTH, FRESHE + (HEID)
+BAGGETT, EISELE, FILTHUTH, FRESHE + (HEID)
+BAGGETT, EISELE, FILTHUTH, FRESHE, HEPP + (HEID)
+GUREVICH, MAKARINA, MARTEMYANOV + (ITEP)
+CONFORTO, EATON, GERBER + (CERN+GEVA+LUND)
+BUNNELL, DERRICK, FIELDS, KATZ + (ANL+CARN)

+BROWN, FREYTAG, HEARD, HEINTZE + (CERN+HEID)
+BROWN, FREYTAG, HEARD, HEINTZE + (CERN+HEID)
+GIVERNAUD, BORG (SACL)

+GALLIVAN, JAFAR + (LOIC+CERN+ETHS+AACL)
+BACON, BUTTERWORTH, WATERS + (LOIC+RHEL)
+HANDLER, MARCH, MARTIN + (WISC+MICH+RUTG)
+INNES, MASEK, MAUNG, MILLER, RUDERMAN + (UCSC)

+OVERSETH, BUNCE, DYDAK + (MICH+WISC+HEID)
LINDQUIST, SWALLOW, SUMNER + (EFI+OSU+ANL)
LINDQUIST, SWALLOW, SUMNER + (EFI+OSU+ANL)
+DYDAK, NAVARRIA + (SIEG+CERN+OORT+HEID)
SCHACHINGER, BUNCE, COX + (MICH+RUTG+WISC)

PAPERS NOT REFERRED TO IN DATA CARDS

ARMENTEROS + (CERN+EPOL+LOIC+BIRM+CEN-SACLAY)
BALTAY, FOWLER, SANDWEISS, CULWICK + (YALE+BNL)
BERGE 63 THESIS (BERKELEY) J PETER BERGE (LRL)

Σ^+

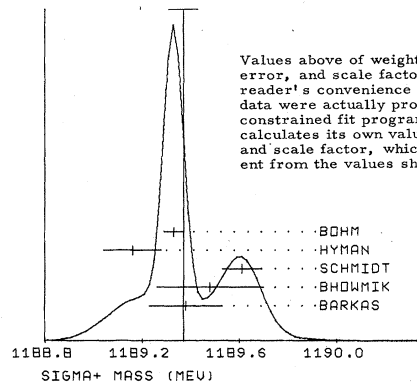
19 SIGMA+(1189, JP=1/2+) I=1

19 SIGMA+ MASS (MEV)

M N SEE NOTE PRECEDING LAMBDA MASS LISTINGS

Table with columns for mass (MEV), error, and source. Includes entries for BARKAS, SCHMIDT, HYMAN, BOHM, and BOHM 72 UPDATED WITH PDG APR. 73.

WEIGHTED AVERAGE = 1189.371 ± 0.060
ERROR SCALED BY 1.8



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of x-bar, delta x-bar, and scale factor, which are different from the values shown here.

Table with columns for source, mass (MEV), and error. Includes entries for BOHM 72 EMUL, HYMAN 67 HBC, SCHMIDT 65 HBC, BHOWMIK 64 EMUL, and BARKAS 63 EMUL.

19 SIGMA+ MEAN LIFE (UNITS 10**-10)

Table with columns for source, mean life, error, and scale factor. Includes entries for GLASER, PUSCHEL, EVANS, FREDEN, KAPLON, CHIESA, BERTHELOT, CARAYAN, CHANG, HUMPHREY, BHOWMIK, BALTAY, CARAYAN, CHANG, CHIEN, CHEN, CDOK, BARLOUETA, K-E P, K-E P AT REST, BAKKER, CONFORTO, HARRAFFIN, and C. CHANGE ERROR.

19 SIGMA+ MAGNETIC MOMENT (MAGNETONS, 938.26 MEV)

Table with columns for source, magnetic moment, error, and scale factor. Includes entries for COOK, KOTELCHUK, SULLIVAN, COMBE, MAST, ALLEY, SAHA, DOBLE, SETTLER, and SETTLER 79 INCLUDES DOBLE 77 DATA.

19 SIGMA+ PARTIAL DECAY MODES

Table with columns for decay mode, branching ratio, and error. Includes entries for SIGMA+ INTO PROTON P, SIGMA+ INTO NEUTRON P, SIGMA+ INTO NEUTRON P + GAMMA, SIGMA+ INTO LAMBDA E+ NEU, SIGMA+ INTO PROTON GAMMA, SIGMA+ INTO NEUTRON NU + NEUTRINO, SIGMA+ INTO NEUTRON E+ NEUTRINO, and SIGMA+ INTO PROTON E+ E-.

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

Σ+

19 SIGMA+ BRANCHING RATIOS

Table with columns for particle ID, name, and branching ratios. Includes entries for R1 through R4, covering various decay channels and experimental data.

WEIGHTED AVERAGE = 0.240 ± 0.035
ERROR SCALED BY 1.4

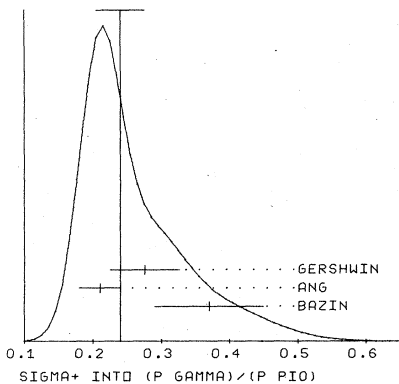


Table with 2 columns: Name and Value. Includes GERSHWIN 69 HBC 0.5, ANG 69 HBC 1.0, BAZIN 65 HBC 2.6, and a total of 4.1.

Table with columns for particle ID, name, and branching ratios. Includes entries for R5 through R9, covering various decay channels and experimental data.

Table with columns for particle ID, name, and branching ratios. Includes entries for R10 through R12, covering various decay channels and experimental data.

19 SIGMA+ DECAY PARAMETERS

Table with columns for particle ID, name, and decay parameters. Includes entries for A+ through F+, covering various decay channels and experimental data.

REFERENCES FOR SIGMA+

Table with columns for author names and references. Includes entries for CORK, EVANS, FREDEN, KAPLON, PUSCHEL, BARKAS, BERTHELO, CHIESA, BEALL, GRARD, GALTIERI, HUMPHREY, TRIPP, BARKAS, ALSO, BHOWMIK, CARRARA, MURPHY, NAUENBERG, WILLIS, BALTAY, BAZIN, GARAYAN, QUARENTI, SCHMIDT, BANGERTER, CHANG, CHIEN, COOK, BAGGETT, BARASH, EISELE, HYMAN, KOTELCHUK, SULLIVAN, CORK, KERTH, WENZEL, CRONIN, COOL, BRIST, BRUSS, IAS, U. COL, DUBLIN, LCN, MILAN, PAD, S, FREDEN, H, KORNBLUM, R, WHITE, M, KAPLON, A, MELISSINOS, YAMANOUCHI, W, PUSCHEL, (MAX PLANCK INST), BARKAS, DYER, MASON, NICHOLS, SMITH, BERTHELO, DAUDIN, GOUSSU, (SACLAY+ORSAV), CHIESA, QUASSIATI, RINAUDO, (INFN-TURIN), BEALL, CORK, KEEFE, MURPHY, WENZEL, GRARD, G, A, SMITH, GALTIERI, BARKAS, HECKMAN, PATRICK, SMITH, W, E, HUMPHREY, R, ROSS, R, D, TRIPP, M, B, WATSON, M, FERRO-LUZZI, W, H, BARKAS, J, N, DYER, H, H, HECKMANN, JOHN, DYER, (THIS PAPER, BERKELEY), B, BHOWMIK, P, JAIN, P, MATHUR, LAKSHMI, CARRARA, CRESTI, GRIGOLETTO, PERUZZO, (PADOVA), COURANT, FILITUTHI, (GERN-HEID+UMD+NR+BNL), C, THORNTON, MURPHY, NAUENBERG, MARATECK, (COLL+RUTG+PRIN), WILLIS, COURANT, ENGELMAN, (BNL, CERN, HEID, UMD), BALTAY, SANDWEISS, CULWICK, KOPP, (YALE+BNL), BAZIN, BLUMENFELD, NAUENBERG, (PRIN+COLL), BAZIN, PLAND, SCHMIDT, (PRIN, RUTG, COLL), GARAYAN, CARAYANPOULGOS, TAUFFET, WILLMANN, (PURDUE), QUARENTI, CARTACCI, (BGNA, FIRZ, GENO, PARM), SCHMIDT, (COLUMBIA), BANGERTER, GALTIERI, BERGE, MURRAY, (LRL), BERLEY, (LRL), +HERZBACH, KOFLER, YAMAMOTO, (BNL+MASA+YALE), CHANG, CHUNG YUN CHANG, (COLUMBIA), ALSO 65 NEVIS 145 THESIS, CHUNG YUN CHANG, (COLUMBIA), CHIEN, LACH, SANDWEISS, TAFT, YEH, DREN, (YALE+BNL), COOK, V, COOK, EWART, MASEK, ORR, PLATNER, (WASHINGTON), BAGGETT, DAY, GLASSER, KEHOE, KNOP, (MARYLAND), ALSO 68 VIENNA ABS. 374, BAGGETT, KEHOE, (MARYLAND), ALSO 68 PRIVATE COMM., BARASH, DAY, GLASSER, KEHOE, KNOP, (MARYLAND), EISELE, ENGELMAN, FILITUTH, FOLISH, HEPP, (THEO), HYMAN, LOKEN, PENNITT, MCKENZIE, (LANL+CARN+MWS), KOTELCHUK, GOZA, SULLIVAN, ROSS, (VANDERBILT), SULLIVAN, MCINTURFF, KOTELCHUK, (VANDERBILT), ALSO 64 PRL 13 246, A, D, MCINTURFF, C, E, ROSS, (VANDERBILT)

Data Card Listings

For notation, see key at front of Listings.

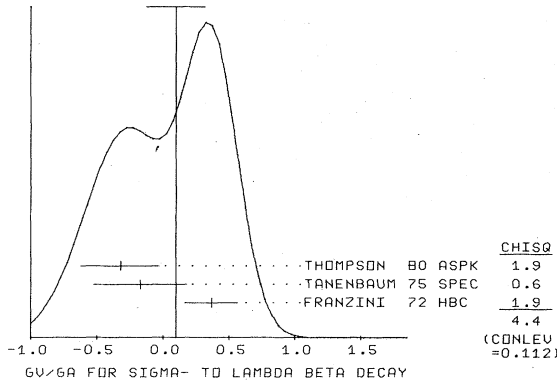
Stable Particles

Σ^-, Σ^0

PHI ANGLE (SIN(PHI)/COS(PHI)=BETA/GAMMA) (DEGREES)
F- O 1036 (+22.) (30.) BERLEY 67 HBC K-P TO SIG- PI+ 11/67
F- 1385 14. 19. BANGERT1 69 HBC 10/69
F- C1092 +5. 23. BERLEY 70 HBC NEUTRON RESCATT. 11/69
F- C CHANGED FROM -5 TO +5 TO AGREE WITH SIGN CONVENTION
F- AVG 10.3 14.6 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
F- STUDENT 10.4 15.8 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

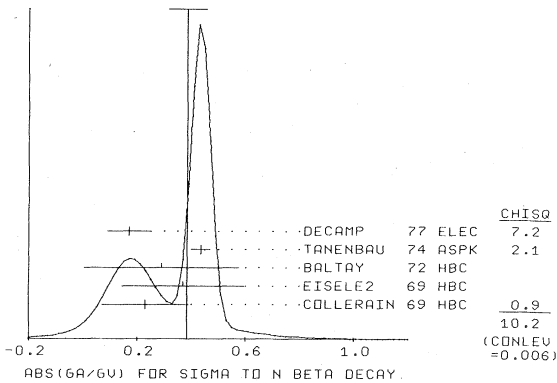
GV/GA FOR SIGMA TO LAMBDA BETA DECAY (TEXT SEC VI 0.1 FOR SIGN CONV)
PREDICTED TO BE ZERO BY CONSERVED VECTOR CURRENT THEORY
AV FB 45 (0.31) (0.30) BARASH 67 HBC 11/67
AV FS 51 (0.7) (0.4) BALTAY 69 HBC USING SIG+- 4/69
AV FS 81 (+0.27) (0.28) EISELE1 69 HBC 10/68
AV F S 186 0.37 0.20 FRANZINI 72 HBC USING SIG+- 1/73
AV T 55 -0.17 0.35 TANENBAUM 75 SPEC 12/75
AV T 115 -0.32 0.30 THOMPSON 80 ASPK HYPERON BEAM 2/80*

WEIGHTED AVERAGE = 0.10 ± 0.22
ERROR SCALED BY 1.5



GA/GV FOR SIGMA TO NEUTRON BETA DECAY (TEXT SEC VI 0.1 FOR SIGN CONV)
AV1 57 (0.051) (0.23) (0.32) GERSHWIN 68 HBC REPLACED BY GER.69 6/68
AV1 61 +0.19 0.20 0.17 GERSHWIN 69 HBC POLARIZED SIGMAS 10/69
AV1 63 -0.33 0.30 0.85 BOGERT 70 HBC K-P AT 400 MEV/G 10/70
AV1 43 -0.4 0.52 1.5 ELLIS 72 ASPK POLARIZED SIGMAS 10/71
AV1 E (+0.10) (0.11) ELLIS 72 RVUE SUM LIKEL.(+SOL) 10/71
AV1 E (-0.27) (0.15) (0.17) ELLIS 72 RVUE SUM LIKEL.(-SOL) 10/71
AV1 E ELLIS 72 HAS COMBINED THE MAXIMUM LIKELIHOODS OF COLLERAINE 69, 3/72
AV1 E EISELE2 69, GERSHWIN 69, ELLIS 72, AND GETS TWO POSSIBLE VALUES. 3/72
AV1 AVG 0.13 0.17 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
AV1 STUDENT 0.13 0.19 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT

WEIGHTED AVERAGE = 0.385 ± 0.070
ERROR SCALED BY 2.3



BROWN 58 CERN CONF 270
EISLER 58 NC SERIO 10 150
BARKAS 61 PR 124 1209
CHIESA 61 NC 19 1171
HUMPHREY 62 PR 127 1305
TRIPP 62 PRL 9 66
BARKAS 63 PRL 11 26
BURNSTEI 64 PRL 13 66
COURANT 64 PR 136 B 1791
MILLER 64 PL 11 262
MURPHY 64 PR 154 B 188
NAUMBER 64 PRL 12 679
BAZIN 65 PR 140 B 1358
DOSCH 65 PL 14 239
ALSO 65 PR 151 1081
SCHMIDT 65 PR 140 B 1328
BANGERT E 66 PRL 17 495
CHANG 66 PR 151 1081
CHIEN 66 PR 152 1171
BARASH 67 PRL 19 181
BERLEY 67 PRL 19 979
BIERMAN 68 PRL 20 1459
GERSHWIN 68 PRL 20 1270
HEPP 68 ZPHY 214 71
WHITESID 68 NC 54A 537

ANG 1 69 ZPHY 223 103
ANG 2 69 ZPHY 228 151
BAGGETT 69 PRL 23 249
BALTAY 69 PRL 22 615
BANGERT E 69 UCRL-19244
BANGERT I 69 PR 187 1821
BARLOUTA 69 NP B14 153
COLLERAINE 69 PRL 23 198
EISELE 69 ZPHY 221 1
EISELE2 69 ZPHY 223 487
GERSHWIN 69 UCRL-19246
BERLEY 70 PR D1 2015
BOGERT 70 PR D2 6
EISELE 70 ZPHY 238 372
BAKKER 71 LNC 1 37
COLE 71 PR D4 631
ALSO 69 NEVIS-175 THESIS
TOYEE 71 NP B33 493
BALTAY 72 PR D5 1569
BOHM 72 NP B48 1
ELLIS 72 PR B39 77
FRANZINI 72 PR D6 2417
ROBERTSO 72 THESIS
EBENHOH 73 ZPHY 264 413
FOX 73 PRL 31 1084
SECHIZOR 73 PR D8 12
EBENHOH 74 ZPHY 266 367
ROBERTS 74 PRL 32 1265
ALSO 74 PRL 33 122
ALSO 75 PR D12 1232
TANENBAU 74 PRL 33 175
ALSO 75 TANENBAUM
DUGAN 75 NP A254 396
TANENBAU 75 PR D12 1871
COMFORTO 76 NP B135 189
DECAMP 77 PL 66B 295
HANSL 78 NP B132 465
HERBERT 78 PR 40 1230
MARRAFFI 80 PR D (TO BE PUB.)
THOMPSON 80 PR D (TO BE PUB.)

REFERENCES FOR SIGMA-
BROWN, GLASER, GRAVES, PERL, CRONIN + (MICH)
EISLER, BASSI, CONVERSIT + (COLU, BNL, BGNA, PISA)
BARKAS, DYER, MASON, NICKOLS, SMITH (LRL)
A M CHIESA, B QUASSIATI, G RINAUDO (TURIN)
W E HUMPHREY, R R ROSS (LRL)
R D TRIPP, M WATSON, M FERRO-LUZZI (LRL)
H H BARKAS, J N DYER, H H HECKMAN (LRL)
BURNSTEIN, DAY, KEHOE, SECHI ZORN, SNOW (UMD)
COURANT, FILTHUTH + (CERN+HEID+UMD+NRL+BNL)
MILLER, STANNARD, BEZAGUE + (LOUC, EPUL+BERG)
C THORNTON MURPHY (MILSCON SIN)
NAUMBERG, SCHMIDT, MARATECK + (COLU+RUTG+PRIN)

BAZIN, PLANO, SCHMIDT + (PRIN+RUTG+COLU)
DOSCH, ENGELMANN, FILTHUTH, HEPP, KLUGE + (HEID)
CHUNG YUN CHANG (COLUMBIA)
P SCHMIDT (COLUMBIA)
BANGERTER, GALTIERI, BERGE, MURRAY + (LRL)
CHUNG YUN CHANG (COLUMBIA)
+LACH, SANDWEISS, TAFT, YEH, OREN + (YALE+BNL)
BARASH, DAY, GLASSER, KEHOE, KNOP + (MARYLAND)
BERLEY, HERTZBACH, KOFLER + (BNL, MASA, YALE)
BIERMAN, KOUNDSU, NAUMBERG + (PRINCETON)
GERSHWIN, ALSTON-GARAJOST, BANGERTER + (LRL)
V. HEPP, H. SCHLEICH (HEIDELBERG)
H. WHITESIDE, J. GCLLUB (OBERLIN)
ANG, EISELE, ENGELMANN, FILTHUTH + (HEID)
+EBENHOR, EISELE, ENGELMANN, FILTHUTH + (HEID)
BAGGETT, KEHOE, SNOW (UNIV MARYLAND)
BALTAY, FRANZINI, NEWMAN, NORTON + (COLU, STON)
BANGERTER, GELLER, BANGERTER (THESIS) (LRL)
BANGERTER, GARNJOST, GALTIERI, GERSHWIN + (LRL)
BARLOUTAUD, BELLEFON, GRANET + (SACL+CERN+HEID)
COLLERAINE, DAY, GLASSER, KNOP + (UNIV MARYLAND)
+ENGELMANN, FILTHUTH, FOHLISCH, HEPP + (HEID)
EISELE, ENGELMANN, FILTHUTH, FOHLISCH + (HEID)
LAWRENCE KENNETH GERSHWIN (THESIS) (LRL)
+YAMIN, HERTZBACH, KOFLER + (BNL, MASA, YALE)
+LUCAS, TAF T, WILLIS, BERLEY + (BNL, MASA, YALE)
+FILTHUTH, HEPP, PRESSER, ZECH (HEIDELBERG)
+ SABRE COLLAB. (ZEEM+SACL+BGNA+REHOE+COLU)
+LEE-FRANZINI, LOVELESS, BALTAY + (STON, COLU)
HERBERT NORTON (COLUMBIA)
LOUC, BELGRADE, BERL, BRUX, DOUBLIN, WARS COLLAB
+FEINMAN, FRANZINI, NEWMAN, YEHI + (COLU+STON)
BERLIN+BELGRADE+BRUX+DOUBLIN+LOUC+WARS SAH
OXF+AERE+RHEL+LOQM+LYON+NWES+ITEP COLLABOR
COLUMBIA+HEIDELBERG+MARYLAND+STONY BROOK
R.M. ROBERTSON (IIT)
+EISELE, FILTHUTH, HEPP, LEITNER, THOUW + (HEID)
+LAM, EARNE, EISENSTEIN + (BNL+VPI+WILL+WYOM)
B. SECHI-ZORN, G. SNOW (UMD)
+EISELE, ENGELMANN, FILTHUTH, HEPP + (HEID)
WILL+VPI+CARN+WYOM+CIT COLLABORATION
ERRATUM TO ROBERTS 74
+GERSHWIN, COX + (WILL+VPI+CARN+WYOM+CIT+BNL)
TANENBAUM, HUNGERBUHELER + (YALE+FNAL+BNL)
+ASANO, CHEN, CHENG, HU, LIDOF SKY + (COLU+YALE)
TANENBAUM, HUNGERBUHELER + (YALE+FNAL+BNL)
+GOPAL, KALMUS, LICHTFIELD, ROSS + (RHEL+LOIC)
+BADIER, BLAND, CHOLLET, GAILLARD + (LALOE+POL)
+MANZ, MATT, REICROFT, SETTLER + (MPI+VAND)
+CLELAND, COOPER, DRIS, ENGELS + (PITT+ENL)
MARRAFFINO, REUCROFT, ROSS, WATER S + (VAND+MPI)
+CLELAND, COOPER, DRIS, ENGELS + (PITT+ENL)

Table with 2 columns: D1 N and SEE NOTE PRECEDING LAMBDA MASS LISTINGS. It lists data points for Sigma- mass difference and includes a weighted average calculation.

Table with 2 columns: DL N and SEE NOTE PRECEDING LAMBDA MASS LISTINGS. It lists data points for Sigma0 mass difference and includes a weighted average calculation.

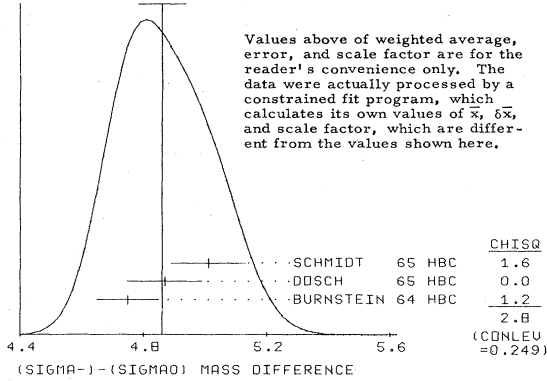
Stable Particles

Σ^0, Ξ^-

Data Card Listings

For notation, see key at front of Listings.

WEIGHTED AVERAGE = 4.860 ± 0.076
ERROR SCALED BY 1.2



21 SIGMA0 MEAN LIFE (UNITS 10**19 SEC)

T	(E-14 OR LESS)	DAVIS	62 EMUL	6/77	
T	0.58	0.13	DYDAK	77 SPEC PRIMAKOFF EFFECT	6/77

21 SIGMA0 PARTIAL DECAY MODES

P1	SIGMA0 INTO LAMBDA GAMMA	DECAY MASSES
P2	SIGMA0 INTO LAMBDA + E-	1115+ 0
P3	SIGMA0 INTO LAMBDA GAMMA GAMMA	1115+ .5+ .5
		1115+ 0+ 0

21 SIGMA0 BRANCHING RATIOS

R1	SIGMA0 INTO (LAMBDA E+ E-)/TOTAL	(P2)/(P1+P2)	9/66
R1	(0.00545) THEORET. CAL. FEINBERG	58	QUANTUM ELECT.
R2	SIGMA0 INTO (LAMBDA GAMMA GAMMA)/(LAMBDA GAMMA)	(P3)/(P1)	12/75
R2	0.33 OR LESS CL=90	COLAS	75 HLBC

REFERENCES FOR SIGMA0

FEINBERG 58 PR 109 1019
 DAVIS 62 PR 127 605
 BURNSTEIN 64 PRL 13 66
 DOSCH 65 PL 14 235
 SCHMIDT 65 PR 140 B 1328

G.FEINBERG (BNL)
 D DAVIS, R SETTI, M RAYMOND, G TOMASIN (EPJ)
 BURNSTEIN, DAY, KEOHE, SECHI ZORN, SNOW (UMD)
 DOSCH, ENGE LMANN, FILTHUTH, HEPP, KLUGE+ (HEID)
 P SCHMIDT (COLUMBIA)

CGLAS 75 NP B91 253
 OYDAK 77 NP B118 1

+FARWELL, FERRER, SIX (ORSA)
 +NAVARRIA, CVERSETH, STEFFEN+ (CERN+DDRT+HEID)

PAPERS NOT REFERRED TO IN DATA CARDS

COURANT 63 PRL 13 409 COURANT, FILTHUTH, FRANZINI+ (CERN+UMD+NRL)

QUANTUM NUMBER DETERMINATIONS NOT REFERRED TO IN DATA CARDS

ALFF 65 PR 137 B1105 ALFF, GELFAND, NAUENBERG+ (COLUMBIA+RJT G+BNL JP)



22 XI-(1321, JP=1/2) I=1/2

22 XI- MASS (MEV)

M	H	(1321, 0)	(2, 2)	WANG	61 HLBC
M	H	18(1317, 9)	(1, 9)	FWLER	61 HLBC
M	H	(OLD DATA AND LOW STATISTICS DROPPED ON SUGGESTION OF J R HUBBARD)			
M		517 1321.4	0.4	JAUNEAU	63 FBC
M		62 1321.1	0.65	SCHNEIDER	63 HBC
M		241 1321.1	0.3	BADIERI	64 HBC
M		ALL MASSES ABOVE WERE RAISED 0.09 MEV BECAUSE LAMBDA MASS RAISED			
M		149 1321.3	0.4	PJERROU	65 HBC
M		8 1321.67	0.52	CHIEN	66 HBC
M		299 1321.6	1.1	LONDON	66 HBC
M	G	195 1321.87	0.51	GOLOWASSE	70 HBC
M	G	USES LAMBDA MASS OF 1115.58-M(XI) IS 1322.18 IF M(LAMBDA)=1115.84			
M		268 1321.12	0.41	WILQUET	72 HLBC
M		632 1321.69	0.34	DIBIANCA	75 DBC
M		AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)			
M	AVG	1321.34	0.14	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
M	STUDENT	1321.34	0.16	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT	
M	FIT	1321.32	0.13	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)	
M		THE FIT ASSUMES XI AND ANTI-XI MASSES EQUAL.			

22 ANTI-XI+ MASS (MEV)

M1	I	(1322, 0)	(1, 3)	BROWN	62 HBC	ANTI-XI-	7/66
M1		5 1320.69	0.93	CHIEN	66 HBC	+ 6.9 PBAR P, ANTI	9/67
M1	S	12(1321, 7)	(0, 9)	SHEN	67 HBC	ANTI-XI-	10/67
M1		34 1321.2	0.4	STONE	70 HBC		10/70
M1		35 1321.6	0.8	VOTRUBA	72 HBC	10 GEV/C K+ P	11/72
M1	S	THE ERROR IS STATISTICAL ONLY					
M1		AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)					
M1	AVG	1321.20	0.33	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)			
M1	STUDENT	1321.20	0.36	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			
M1	FIT	1321.32	0.13	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)			
M1		THE FIT ASSUMES XI AND ANTI-XI MASSES EQUAL.					

22 (XI-) - (ANTI-XI+) MASS DIFFERENCE (MEV)

DM	1.0	1.1	CHIEN	66 HBC	6.9 PBAR P	9/67
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22 XI- MAGNETIC MOMENT (MAGNETONS, 938.26 MEV)

MM	2724	-0.1	2.1	BINGHAM	70 OSPK	- 1.8 GEV/C K-P	2/71
MM	2436	-2.1	0.8	COOL	74 OSPK	- 1.8 GEV/C K-P	10/74
MM	AVG	-1.85	0.75	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)			
MM	STUDENT	-1.86	0.82	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			

22 XI- MEAN LIFE (UNITS 10**10)

T	H	11	(3.5)	(3.4)	(1.23)	WANG	61 HLBC	
T	H	18	(1.28)	(0.41)	(0.25)	FWLER	61 HLBC	
T	H	(OLD DATA AND LOW STATISTICS DROPPED ON SUGGESTION OF J R HUBBARD)						
T		517	1.86	0.15	0.14	JAUNEAU	63 FBC	
T		62	1.95	0.31	0.31	SCHNEIDER	63 HBC	
T		356	(1.77)	(0.12)		CARMONY	64 HBC	
T		794	1.69	0.07		HUBBARD	64 HBC	
T		246	1.70	0.12		PJERROU	65 HBC	
T	S	6	(1.37)	(0.51)		CHIEN	66 HBC	
T	S	299	1.80	0.16		LONDON	66 HBC	
T	S	2610	1.61	0.04		BURGUM	68 HBC	
T		680	1.73	0.08	0.07	MAYEUR	72 HLBC	
T		4303	1.63	0.03		BALTAY	74 HBC	
T	S	2436	(1.637)	(0.050)		COOL	74 OSPK	
T		4286	1.609	0.028		DIBIANCA	75 DBC	
T		41K	1.665	0.065		HEMINGWAY	78 HBC	
T	S					BOURQUIN	79 SPEC	
T		THE ERROR IS STATISTICAL ONLY						
T	AVG	1.641	0.016	0.016	AVERAGE (ERROR INCL. SCALE FACTOR OF 1.0)			
T	STUDENT	1.640	0.019	0.018	AVG BY STUDENT10(H/1.11) -- SEE MAIN TEXT			

22 ANTI-XI+ MEAN LIFE (UNITS 10**10)

T1	S	5	(1.51)	(0.55)	CHIEN	66 HBC	+ 6.9 PBAR P, ANTI	9/67
T1	S	12	(1.9)	(0.7)	(0.5)	SHEN	67 HBC	ANTI-XI-
T1		34	1.6	0.3		STONE	70 HBC	
T1	S	35	(1.55)	(0.35)	(0.20)	VOTRUBA	72 HBC	10 GEV/C K+ P
T1	S	THE ERROR IS STATISTICAL ONLY						

22 XI- PARTIAL DECAY MODES

P1	XI- INTO LAMBDA PI-	DECAY MASSES
P2 <td>XI- INTO LAMBDA E- NEUTRINO</td> <td>1115+ .5+ 0</td>	XI- INTO LAMBDA E- NEUTRINO	1115+ .5+ 0
P3 <td>XI- INTO NEUTRON PI-</td> <td>939+ 139</td>	XI- INTO NEUTRON PI-	939+ 139
P4 <td>XI- INTO LAMBDA MU- NEUTRINO</td> <td>1115+ 105+ 0</td>	XI- INTO LAMBDA MU- NEUTRINO	1115+ 105+ 0
P5 <td>XI- INTO SIGMA E- NEUTRINO</td> <td>1192+ .5+ 0</td>	XI- INTO SIGMA E- NEUTRINO	1192+ .5+ 0
P6 <td>XI- INTO SIGMA MU- NEUTRINO</td> <td>1192+ 105+ 0</td>	XI- INTO SIGMA MU- NEUTRINO	1192+ 105+ 0
P7 <td>XI- INTO NEUTRON E- NEUTRINO</td> <td>939+ .5+ 0</td>	XI- INTO NEUTRON E- NEUTRINO	939+ .5+ 0
P8 <td>XI- INTO NEUTRON MU- NEUTRINO</td> <td>939+ 105+ 0</td>	XI- INTO NEUTRON MU- NEUTRINO	939+ 105+ 0
P9 <td>XI- INTO SIGMA GAMMA</td> <td>1197+ 0</td>	XI- INTO SIGMA GAMMA	1197+ 0
P10 <td>XI- INTO PROTON PI- PI-</td> <td>938+ 139+ 139</td>	XI- INTO PROTON PI- PI-	938+ 139+ 139
P11 <td>XI- INTO PROTON PI- E- NEUTRINO</td> <td>938+ 139+ .5+ 0</td>	XI- INTO PROTON PI- E- NEUTRINO	938+ 139+ .5+ 0
P12 <td>XI- INTO PROTON PI- MU- NEUTRINO</td> <td>938+ 139+ 105+ 0</td>	XI- INTO PROTON PI- MU- NEUTRINO	938+ 139+ 105+ 0
P13 <td>XI- INTO XIO E- NEUTRINO</td> <td>1314+ .5+ 0</td>	XI- INTO XIO E- NEUTRINO	1314+ .5+ 0

22 XI- BRANCHING RATIOS

R1	XI- INTO (LAMBDA E- NEU)/(LAMBDA PI-) (UNITS 10**3)	(P2)/(P1)	11/67
R1	1	155 EFFECTIVE DENOM.	CARMONY 63 HBC
R1	0	260 EFFECTIVE DENOM.	JAUNEAU 63 HBC
R1	0	220 EFFECTIVE DENOM.	BERGE 66 HBC
R1	1	155 EFFECTIVE DENOM.	LONDON 66 HBC
R1	0	717 EFFECTIVE DENOM.	TRIPPE 67 HBC
R1	2	1976 EFFECTIVE DENOM.	HUBBARD 68 HBC
R1	H	4 (1.15) (0.90) (0.55)	HUBBARD 68 RVUE
R1	H	HUBBARD 68 (RVUE) INCLUDES ALL ABOVE EVENTS	
R1		0.24	0.24
R1		0.30	0.14
R1		YEH 74 HBC	
R1		THOMPSON 80 ASPK	
R1		HYPERON BEAM	
R1	AVG	0.28	0.12
R1	STUDENT	0.28	0.13
R1		AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
R1		AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT	

XI- INTO (NEUTRON PI-)/(LAMBDA PI-) (UNITS 10**3)

R2	XI- INTO (NEUTRON PI-)/(LAMBDA PI-) (UNITS 10**3)	(P3)/(P1)	6/68
R2	5.0 OR LESS	FERRO-LU2 63 HBC	
R2	1.1 OR LESS	DAUBER 69 HBC	
R2	0 3.0 OR LESS CL=90	YEH 74 HBC	
R2		760 EFF. DENOM.	

XI- INTO (LAMBDA MU- NEUTRINO)/TOTAL (UNITS 10**3)

R3	XI- INTO (LAMBDA MU- NEUTRINO)/TOTAL (UNITS 10**3)	(P4)	6/68
R3	12.0 OR LESS	BERGE 66 HBC	
R3	1.3 OR LESS	DAUBER 69 HBC	
R3	1 0.35 0.35	YEH 74 HBC	
R3	H 11 0.31 0.13	HERBERT 78 ASPK	
R3	H	WE HAVE INCLUDED IN THE ERROR A 20 PCNT SYSTEMATIC ERROR IN HYPERON BEAM	
R3	H	ADDITION TO THE STATISTICAL ERROR OF .11 QUOTED IN HERBERT 78.	
R3	AVG	0.31	0.12
R3	STUDENT	0.31	0.13
R3		AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
R3		AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT	

XI- INTO (SIGMA E- NEUTRINO)/TOTAL (UNITS 10**3)

R4	XI- INTO (SIGMA E- NEUTRINO)/TOTAL (UNITS 10**3)	(P5)	6/68
R4	3.0 OR LESS	BERGE 66 HBC	
R4	0.5 OR LESS	DAUBER 69 HBC	
R4	0 0.53 OR LESS CL=90	YEH 74 HBC	
R4		4363 EFF. DENOM.	

XI- INTO (SIGMA MU- NEU)/(LAM PI-) (UNITS 10**3)

R5	XI- INTO (SIGMA MU- NEU)/(LAM PI-) (UNITS 10**3)	(P6)/(P1)	7/66
R5	0 0.76 OR LESS CL=90	YEH 74 HBC	
R5		3026 EFF. DENOM.	

Data Card Listings

Stable Particles

For notation, see key at front of Listings.

E-, E0

R7 XI- INTO (SIGMA0 E- NEU + LAMBDA E- NEU)/TOTAL (10**3) (P2+P5)
R7 17 0.68 0.22 DUCLOS 71 O5PK SEE NOTE D 10/71
R7 D THIS EXPERIMENT CANNOT DISTINGUISH SIGMA0 FROM LAMBDA. THE CABIBBO
R7 D THEORY PREDICTS SIGMA0 RATE ABOUT A FACTOR 6 SMALLER THAN THE
R7 D LAMBDA. TO GET A VALUE FOR THE TABLE R7 HAS BEEN AVERAGED WITH R1.

22 XI- DECAY PARAMETERS
RELATED TEXT SECTION VI D AND APPENDIX III

A ALPHA XI-
A 0 0.44 (0.12) JAUNEAU 63 FBC SEE NOTE D BELOW 6/68
A 0 62 (-0.73) (0.23) SCHNEIDER 63 HBC SEE NOTE D BELOW 6/68
A 240 -0.5 0.38 EADIERI 64 HBC SEE NOTE D BELOW 6/68
A 356 -0.62 0.13 CARMENY 64 HBC SEE NOTE D BELOW 6/68
A 1004 -0.365 0.068 BERGE 66 HBC SEE NOTE D BELOW 6/68
A L 364 -0.47 0.13 LONDON 66 HBC SEE NOTE D BELOW 6/68
A (-0.391) (0.032) BERGE 2 66 RVUE INCLUDES ALL ABOVE 9/66
A M 2529 (-0.375) (0.051) MERRILL 68 HBC
A 2781 -0.391 0.045 DAUBER 69 HBC SEE NOTE A BELOW
A 2724 -0.383 0.065 BINGHAM 70 O5PK 10/70
A 820 -0.42 0.11 MAYEUR 72 HLBC 2.1 GEV/C K- 1/73
A 4303 -0.376 0.038 BALTAY 74 HBC 1.75 GEV/C K- 3/74
A 2436 -0.39 0.05 COOL 74 O5PK - 1.8 GEV/C K-P 10/74
A B 414 -0.43 0.19 DIBIANCA 75 DBC 4.9 GEV/C K-0 1/77
A 6599 -0.370 0.032 HEMINGWAY 78 HBC 4.2 GEV/C K-P 7/79*
A -0.49 0.04 CLELAND 80 ASPK HYPERON BEAM 2/80*

REFERENCES FOR XI-

FOWLER 61 PRL 6 134 FOWLER, BERGE, EBERHARD, ELY, GODD, POWELL+(LRL)
WANG 61 JETP 13 512 K WANG, T WANG, VI RYASOV, TING, SOLOVIEV+(JINR)
BRQWN 62 PRL 8 255 BROWN, GULWICK, FOWLER, GAILLOUD + (BNL+YALE)
CARMENY 63 PRL 10 381 CARMENY, PJERROU (UCLA)
FERRU-LU 63 PR 133 1568 FERRU-LUZZI, ALSTON, ROSENFELD, WOJCICKI (LRL)
JAUNEAU 63 SIENA CONF 4 JAUNEAU+ (EPOL+CERN+LOUC+RHEL+BERGEN)
ALSD 63 PL 5 261 JAUNEAU,+ (EPOL,CERN,LOUC,RHEL,BERGEN)
SCHNEIDE 63 PL 4 360 H SCHNEIDER (CERN)
CARMENY 64 PRL 12 482 CARMENY, PJERROU, SCHLEIN, SLATER, STORK+(UCLA) J
BADIERI 64 DUBNA CONF I 593 BADIERI, DEMCULI N, BARLOUTAUD+ (EPOL, SACL, ZEEM)
HUBBARD 64 PR 135 B 183 HUBBARD, BERGE, KALBFLEISCH, SHAFER + (LRL)
BINGHAM 65 PRL 285 202 H H BINGHAM (CERN)
PJERROU 65 PRL 14 275 + SCHLEIN, SLATER, SMITH, STORK, TICHQ (UCLA)
G M PJERROU (UCLA)
BERGE 66 PR 147 945 BERGE, EBERHARD, HUBBARD, MERRILL + (LRL)
BERGE 2 66 BERKELEY CONF 46 BERGE, CABIBBO (LRL+CERN+RVUE)
LONDON 66 PR 143 1034 LONDON, RAU, GOLDBERG, LICHTMAN+(BNL+SYRACUSE)
+LACH, SANDWEISS, TAFT, YEH, OREN + (YALE+BNL)
CHEN 66 PR 152 1171 B.C. SHEN, A. FIRESTONE, G. GOLDBER (UCB+LRL)
SHEN 67 PL 25 B 443 T. TRIPPE (UCLA)
TRIPPE 67 PRIV. COMM.
BURGUN 68 NP 88 447 +MEYER, PAULI, TALLINI, + (SACL+CDEF+RHEL)
HUBBARD 68 PRL 20 465 HUBBARD, BERGE, DAUBER (LRL)
MERRILL 68 PR 167 1202 MERRILL, SHAFER (LRL)
DAUBER 69 PR 179 1262 +BERGE, HUBBARD, MERRILL, MILLER (LRL)
BINGHAM 70 PR D1 3010 +COOK, HUMPHREY, SANDER, WILLIAMS+(UCSD,WASH)
GOLDWASS 70 PR D1 1960 GOLDWASSER, SCHULTZ (JIL)
STONE 70 PL 32B 515 +BEKINGHIERI, BROMBERG, COHEN, FERBEL+(CERN)
DUCLOS 71 NP 832 493 +FREYTAG, HEINTZE, HEINZELMAN, JONES+(CERN)
MAYEUR 72 NP 847 333 +VAN BINST, WILQUET+ (BRUX+CERN+TUFT+LOUC)
VOTRUBA 72 NP 845 77 VOTRUBA, SARDER, RATLOFF (BIRM+EDIN)
WILQUET 72 PL 428 372 +FLIAGINE, GUY, KNIGHT + (BRUX+CERN+TUFT+LOUC)
BALTAY 74 PR D9 49 +BRIDGEWATER, COOPER, GER SHWIN+ (COLU+BNL)
COOL 74 PR D13 792 +GIACOMELLI, JENKINS, KYCIA, LEONTIC, LI+(BNL)
ALSD 72 PRL 29 1630 COOL, GIACOMELLI, JENKINS, KYCIA, LEONTIC+(BNL)
YEH 74 PR D13 3545 +GAIAGLAS, SMITH, ZENDLE, EALTY + (BING+COLU)
DIBIANCA 75 NP 898 137 F.A. DIBIANCA, R. J. ENDORF (CARN)

HEMINGWAY 78 NP 8142 205 HEMINGWAY, ARMENTEROS+ (CERN+ZEEM+NIJM+DXF)
HERBERT 78 PRL 40 1230 +CLELAND, COOPER, DRIS, ENGELS + (PITT+BNL)
BOURQUIN 79 PL 87B 297 (BRIS+GEVA+HEID+ORS+RHEL+STRB+CERN+MELB)
CLELAND 80 PR D (TO BE PUB.) +COOPER, DRIS, ENGELS, HERBERT+ (PITT+BNL)
THOMPSON 80 PR D (TO BE PUB.) +CLELAND, COOPER, DRIS, ENGELS+ (PITT+BNL)



23 XI0(1314, JP=1/2) I=1/2

23 XI0 MASS (MEV)
M 1 1313.4 1.8 PALMER 68 HBC 3/68
M 49 1315.2 0.92 WILQUET 72 HLBC 1/73
M AVG 1314.83 0.82 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M STUDENT 1314.84 0.91 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
M FIT 1314.91 0.55 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

23 (XI-) - (X10) MASS DIFFERENCE (MEV)
D 23 6.8 1.6 JAUNEAU 63 FBC
D 45 (6.1) (1.6) CARMONY 64 HBC REP BY PJERROU 65
D 88 6.1 0.9 PJERROU 65 HBC 11/67
D 29 6.9 2.2 LONDON 66 HBC 6/66
D AVG 6.34 0.74 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
D STUDENT 6.34 0.80 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
D FIT 6.41 0.55 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0) 2/80*

23 XI0 MEAN LIFE (UNITS 10**10)
T 24 3.9 1.4 0.80 JAUNEAU 63 FBC
T 45 (3.5) (1.0) (0.8) CARMONY 64 HBC REP BY PJERROU 65
T 101 2.5 0.4 0.3 HUBBARD 64 HBC
T 80 3.0 0.5 PJERROU 65 HBC 11/67
T 340 3.07 0.22 0.20 DAUBER 69 HBC 6/68
T B 469 (2.85) (0.20) (0.18) BRIDGEWATER 72 HBC 1.75 GEV/C K-P 1/73
T M 157 2.90 0.32 0.27 MAYEUR 72 HLBC 2.1 GEV/C K- 1/74
T B 652 2.88 0.21 0.19 BALTAY 74 HBC 1.75 GEV/C K- 3/74
T Z 6300 2.77 0.16 ZECH 77 SPEC NEUTRAL HYP. BEAM 12/77
T H MAYEUR 72 VALUE MODIFIED BY ERRATUM.
T B BALTAY 74 INCLUDES BRIDGEWATER 72. 3/74
T Z ZECH 77 VALUE IS FOR LAMBDA LIFETIME=2.69E-10. FOR LAM LIFETIME 12/77
T Z DIFFERENT FROM THIS, TAUXI0=(2.77-(TAULAMBDA-2.69)E-10. 12/77
T AVG 2.903 0.099 0.093 AVERAGE (ERROR INCL. SCALE FACTOR OF 1.0)
T STUDENT 2.90 0.11 0.10 AVG BY STUDENT10(H/1.11) -- SEE MAIN TEXT

23 XI0 MAGNETIC MOMENT (MAGNETONS, 938.26 MEV)
MM 42K -1.20 0.06 BUNCE 79 SPEC 1/80*

23 XI0 PARTIAL DECAY MODES
P1 XI0 INTO LAMBDA P10 1115+ 134
P2 XI0 INTO PROTON P1- 938+ 139
P3 XI0 INTO PROTON E- NEU 938+ 5+ 0
P4 XI0 INTO SIGMA+ E- NEU 1189+ 5+ 0
P5 XI0 INTO SIGMA- E+ NEU 1197+ 5+ 0
P6 XI0 INTO SIGMA+ MU- NEUTRINO 1189+ 105+ 0
P7 XI0 INTO SIGMA- MU+ NEUTRINO 1197+ 105+ 0
P8 XI0 INTO PROTON MU- NEUTRINO 938+ 105+ 0
P9 XI0 INTO LAMBDA GAMMA 1115+ 0
P10 XI0 INTO SIGMA GAMMA 1192+ 0

23 XI0 BRANCHING RATIOS

R1 XI0 INTO (PROTON P1-)/(LAMBDA P10) (UNITS 10**5) (P2)/(P1)
R1 2700. OR LESS TICHQ 63 HBC 6/68
R1 500. OR LESS HUBBARD 66 HBC 6/68
R1 90. OR LESS DAUBER 69 HBC 6/68
R1 0 180. OR LESS CL=90 YEH 74 HBC 1300 EFF. DENOM. 11/75
R1 3.6 OR LESS CL=90 GEWENIGER 75 SPEC 11/75
R2 XI0 INTO (PROTON E- NEU)/(LAMBDA P10) (UNITS 10**3)
R2 27.0 OR LESS TICHQ 63 HBC (P3)/(P1) 6/68
R2 6.0 OR LESS HUBBARD 66 HBC 6/68
R2 1.3 OR LESS DAUBER 69 HBC 6/68
R2 0 3.4 OR LESS CL=90 YEH 74 HBC 670 EFF. DENOM. 11/75
R3 XI0 INTO (SIGMA+ E- NEU)/(LAMBDA P10) (UNITS 10**3)
R3 13.0 OR LESS TICHQ 63 HBC (P4)/(P1) 6/68
R3 7.0 OR LESS HUBBARD 66 HBC 6/68
R3 1.5 OR LESS DAUBER 69 HBC 6/68
R3 0 1.1 OR LESS CL=90 YEH 74 HBC 2100 EFF. DENOM. 11/75
R4 XI0 INTO (SIGMA- E+ NEU)/(LAMBDA P10) (UNITS 10**3) (P5)/(P1)
R4 6.0 OR LESS HUBBARD 66 HBC 6/68
R4 1.5 OR LESS DAUBER 69 HBC 6/68
R4 0 0.9 OR LESS CL=90 YEH 74 HBC 2500 EFF. DENOM. 11/75
R5 XI0 INTO (SIGMA+ MU- NEU)/TOTAL (UNITS 10**3) (P6)
R5 7.0 OR LESS HUBBARD 66 HBC 6/68
R5 1.5 OR LESS DAUBER 69 HBC 6/68
R5 0 1.1 OR LESS CL=90 YEH 74 HBC 2100 EFF. DENOM. 11/75
R6 XI0 INTO (SIGMA- MU+ NEU)/TOTAL (UNITS 10**3) (P7)
R6 6.0 OR LESS HUBBARD 66 HBC 6/68
R6 1.5 OR LESS DAUBER 69 HBC 6/68
R6 0 0.9 OR LESS CL=90 YEH 74 HBC 2500 EFF. DENOM. 11/75
R7 XI0 INTO (PROTON MU- NEU)/TOTAL (UNITS 10**3) (P8)
R7 6.0 OR LESS HUBBARD 66 HBC 6/68
R7 1.3 OR LESS DAUBER 69 HBC 6/68
R7 0 3.5 OR LESS CL=90 YEH 74 HBC 664 EFF. DENOM. 11/75

Stable Particles

Data Card Listings

Ξ^0, Ω^-

For notation, see key at front of Listings.

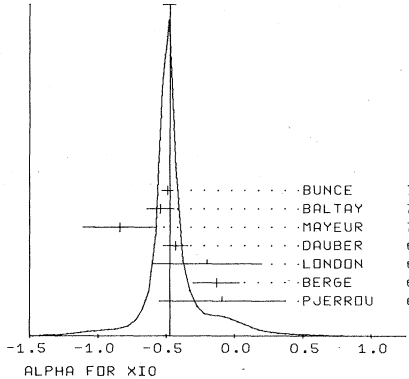
R8 XIO INTO (LAMBDA GAMMA)/(LAM P10) (UNITS 10**-3) (P9)/(P1)
R8 1 5. 5. YEH 74 HBC 200 EFF.DENOM. 11/75
R9 XIO INTO (SIGMA GAMMA)/(LAM P10) (UNITS 10**-2) (P10)/(P1)
R9 0-1 6.5 OR LESS CL=90 YEH 74 HBC 60 EFF.DENOM. 11/75

23 XIO DECAY PARAMETER

RELATED TEXT SECTION VI D AND APPENDIX III

Table with columns for parameter name, value, and reference. Includes entries for ALPHA XI 0, LONDON, MERRILL, BRIDGEWATER, BALTAY, BUNCE, etc.

WEIGHTED AVERAGE = -0.474 ± 0.045
ERROR SCALED BY 1.3



CHISO

Table listing CHISO values for various experiments: BUNCE (7B SPEC, 0.1), BALTAY (74 HBC, 0.4), MAYEUR (72 HLBC, 1.8), DAUBER (69, 0.2), LONDON (66 HBC, 6.6), BERGE (66 HBC, 4.1), PJERRU (65 HBC, 6.8).

Table with columns for parameter name, value, and reference. Includes entries for PHI ANGLE, LONDON, MERRILL, BRIDGEWATER, BALTAY, BUNCE, etc.

REFERENCES FOR XIO

List of references for XIO, including authors like ALVAREZ, JAUNEAU, TICHOU, CARMONY, HUBBARD, PJERRU, BERGE, LONDON, MERRILL, PALMER, DAUBER, BRIDGEWATER, MAYEUR, WILQUET, BALTAY, YEH, GENENIEZ, ZECH, BUNCE, etc.



24 OMEGA-(1672, JP=3/2+) I=0
QUANTUM NUMBERS ASSIGNED FROM SU3
SPIN 1/2 EXCLUDED BY DEUTSCHMANN 78

24 OMEGA- MASS (MEV)

Table listing mass measurements for OMEGA- in MeV. Columns include experiment name, value, error, and reference. Includes entries for EISENBERG, FRY, ABRAMS, PALMER, SCHULTZ, SCOTTER, SPEITH, ABCLV, DIBIANCA, HEMINGWAY, etc.

24 ANTI-OMEGA+ MASS (MEV)

Table listing mass measurements for ANTI-OMEGA+ in MeV. Columns include experiment name, value, error, and reference. Includes entry for FIRESTONE (71 HBC, 12 GEV/C K+D, 3/71).

Note on Ω- Mean Life

The value of the Ω- mean life quoted in our 1978 edition was determined from the result of two large-statistics bubble chamber experiments, DEUTSCHMANN 78 and HEMINGWAY 78, with samples of 101 and 39 events, respectively. The result of HEMINGWAY 78 is about 2.5 standard deviations below that of DEUTSCHMANN 78 (see the Data Card Listings below). Another recent bubble chamber experiment with a sample of 40 events (BAUBILLIER 78) obtains a mean life consistent with the value of HEMINGWAY 78.

This year the first results from the CERN hyperon beam experiment are available. BOURQUIN 79 collected a total of some 2400 Ω- events and were able to make a very accurate measurement of the mean life. Their value is in agreement with BAUBILLIER 78 and HEMINGWAY 78.

The origin of the discrepancy with DEUTSCHMANN 78 is not known. It could be connected with the fact that the data of DEUTSCHMANN 78 is bubble chamber data at relatively high energy where contamination from Ξ- decays might present a problem. In our calculation of the average Ω- mean life below, we do not include the value of DEUTSCHMANN 78.

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

Ω^-, Λ_c^+

24 OMEGA- MEAN LIFE (UNITS 10**-10 SEC)

Table with columns for particle name, mean life values, and source references. Includes entries for ABRAMS, BARNES, COLLEY, RICHARDSON, SCHULTZ, SCOTTER, DEUTSCHMANN, HEMINGWAY, BOURQUIN, and KOCHER.

24 OMEGA- PARTIAL DECAY MODES

Table listing decay modes such as OMEGA- INTO LAMBDA K-, OMEGA- INTO X10 PI-, OMEGA- INTO X1- PI0, OMEGA- INTO LAMBDA PI-, OMEGA- INTO X1- GAMMA, OMEGA- INTO X1*(1530)0 PI-, and OMEGA- INTO X10 E- NEU.

24 OMEGA- BRANCHING RATIOS

Table detailing branching ratios for various decay channels, including event counts and source references. Includes entries for R1 through R7.

24 OMEGA- DECAY PARAMETERS

Table showing decay parameters like ALPHA FOR OMEGA- TO K- LAMBDA, with values and source references. Includes entries for AL and AL AVG.

REFERENCES FOR OMEGA-

Table of references for Omega- particles, listing authors like EISENBERG, FRY, SCHNEPS, SWAMI, ACHENBERG, BURNSTEIN, GLASSER, BARNES, COLLETT, COLLEY, RICHARDSON, SAMIOS, PALMER, SCHULTZ, SCOTTER, SPETH, FIRESTONE, ABCLV, ALVAREZ, KOCHER, and DIBIANCA.

Table listing authors and their affiliations for the Omega- data, including BAUBILLIE, DEUTSCHMANN, HEMINGWAY, and BOURQUIN.

WEIGHTED AVERAGE = -0.26 ± 0.33
ERROR SCALED BY 1.5

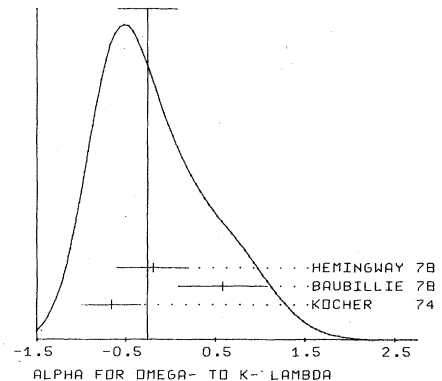


Table with CHISQ values for different sources: HEMINGWAY 78 HBC (0.0), BAUBILLIE 78 HBC (2.8), KOCHER 74 (1.5), and CDNLEU (0.116).



33 LAMBDA/C+(2260, JP=) 1
FOR (SIGMA/C) - (LAMBDA/C) MASS DIFFERENCE SEE THE SIGMA/C SECTION OF THE BARYON DATA CARD LISTINGS

33 LAMBDA/C+ MASS (MEV)

Table listing mass measurements for Lambda_c+ particles from various experiments and sources, including CAZZOLI, SUGIMOTO, KNAPP, BARISH, ANGELINI, BALTAY, CNOPS, GIBONI, ABRAMS, and KERNAN.

WEIGHTED AVERAGE = 2272.9 ± 6.5
ERROR SCALED BY 1.6

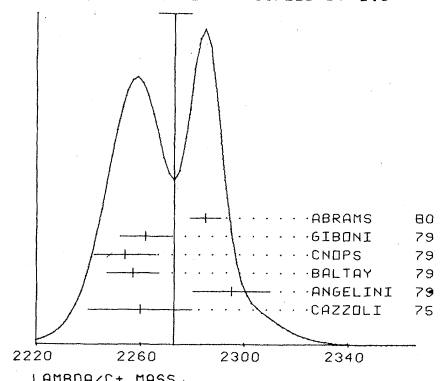


Table with CHISQ values for different sources: ABRAMS 80 SMK2 (4.0), GIBONI 79 SPEC (1.2), CNOPS 79 DBC (2.5), BALTAY 79 HLBC (2.5), ANGELINI 79 HYBR (2.2), and CAZZOLI 75 HBC (0.4). CDNLEU = 0.025.

Stable Particles

Λ_c^\pm , HEAVY LEPTON SEARCHES

33 LAMBDA/C+ MEAN LIFE (UNITS 10**9-12 SEC)

T	S	1	(4.5)	SUGIMOTO	75	EMUL	INTO	SIGMA	P10	3/77	
T	S	1	(0.68)	SUGIMOTO	75	EMUL	INTO	SIGMA	ETA0	3/77	
T	S	1	0.73	ANGELINI	79	HYBR	INTO	P	K- P1+	12/79*	
T	S			SUGIMOTO	75	VALUES ASSUME DECAY TRACK IDENTIFICATION AS SIGMA+.				3/77	
T	S			VALUES TAKEN FROM GAISSER	76	TABLE 3.				VERY SPECULATIVE.	3/77

33 LAMBDA/C+ WIDTH FROM MASS SPECTRUM

W	C	60	75.	OR LESS	KNAPP	76	SPEC	-	ANTILAM	2P1-	P1+	3/77
W	C			KNAPP	76	MEASURES WIDTH 40+-20MEV CONSISTENT WITH THEIR EXPT						3/77
W	C			RESOLUTION (30MEV) FOR A ZERO WIDTH STATE.								3/77

33 LAMBDA/C+ PARTIAL DECAY MODES

				DECAY MASSES	
P1	LAMBDA/C+ INTO LAMBDA P1+ P1- P1-			1115+	139+ 139+ 139
P2	LAMBDA/C+ INTO SIGMA+ P10			1189+	134
P3	LAMBDA/C+ INTO SIGMA+ ETA			1189+	548
P4	LAMBDA/C+ INTO P P1- P10 K0 E+ NEU			938+	139+ 134+ 497+
P5	LAMBDA/C+ INTO LAMBDA P1+			1115+	139
P6	LAMBDA/C+ INTO P KOBAR			938+	497
P7	LAMBDA/C+ INTO P KOBAR P1- P1+			938+	497+ 139+ 139
P8	LAMBDA/C+ INTO K- P1+ P			492+	139+ 938
P9	LAMBDA/C+ INTO K*(892)0 P			892+	938
P10	LAMBDA/C+ INTO K- N*3/2(1232)++			493+	1232
P11	LAMBDA/C+ INTO P K*(892)- P1+			938+	892+ 139

NOTE ON VERY TENTATIVE MODES P2, P3, AND P4
 THESE MODES ARE VERY TENTATIVE. P2 AND P3 ARE FROM SUGIMOTO 75
 (SEE GAISSER 76 REVIEW) AND P4 IS FROM BARISH 77. EACH IS FROM A
 SINGLE EVENT.

33 LAMBDA/C+ BRANCHING RATIOS

R#	Mode	Seen	Ratio	Source	Year	Ref	
R1	LAMBDA/C+ INTO (LAMBDA P1+ P1- P1-)/TOTAL			(P1)			
R1	1 SEEN	CAZZOLI	75	HBC	NEU	BROADBAND	2/80*
R1	60 SEEN	KNAPP	76	SPEC	NEU	WIDEBAND	2/80*
R1	2 SEEN	BALTAY	79	HLBC	NEU	WIDEBAND	2/80*
R1	12 SEEN	GIBONI	79	SPEC	P P	AT 63 GEV ECM	12/79*
R1	18 SEEN	LOCKMAN	79	SPEC	P P	AT 53+62 GEVECM	12/79*
R2	LAMBDA/C+ INTO (K- P1+ P1)/TOTAL			(P8)			
R2	90 SEEN	DRIJARD	79	SFM	P P	AT 62.8 GEV ECM	12/79*
R2	98 SEEN	GIBONI	79	SPEC	P P	AT 63 GEV ECM	12/79*
R2	18 SEEN	LOCKMAN	79	SPEC	P P	AT 53+62 GEVECM	12/79*
R2	39 0.022 0.010	ABRAMS	80	SMK2	E4E-	5.2 GEV ECM	1/80*
R3	LAMBDA/C+ INTO (K*(892)0 P)			(P9)			
R3	1 SEEN	ANGELINI	79	HYBR	NEU	300 GEV WIDE	12/79*
R3	47 SEEN	DRIJARD	79	SFM	P P	AT 52.5 GEV ECM	12/79*
R4	LAMBDA/C+ INTO (K- N*3/2(1232)++)			(P10)			
R4	40 SEEN	DRIJARD	79	SFM	P P	AT 52.5 GEV ECM	12/79*
R5	LAMBDA/C+ INTO (LAMBDA P1+)			(P5)			
R5	6 SEEN	BALTAY	79	HLBC	NEU	WIDEBAND	2/80*
R6	LAMBDA/C+ INTO (P KOBAR)			(P6)			
R6	5 SEEN	BALTAY	79	HLBC	NEU	WIDEBAND	2/80*
R7	LAMBDA/C+ INTO (P K*(892)- P1+)			(P11)			
R7	1 SEEN	CNOPS	79	DBC	NEU	BROADBAND	2/80*

 REFERENCES FOR LAMBDA/C+
 CAZZOLI 75 PRL 34 1125 +CNOPS,CONNOLLY,LOUTTIT,MURTAGH+ (BNL)
 SUGIMOTO 75 PTP 53 1540 +SATO,SAITO (TWS+TKCY)
 KNAPP 76 PR D15 82 +LEE,LEUNG,SMITH+ (COLU+HAWA+ILL+FNAL)
 BARISH 77 PR D15 1 +DERRICK,DOMBECK,MUSGRAVE+ (ANL+PURD)
 ANGELINI 79 PL 848 150 (ANKA+LIB+ CERN+DUJG+LOUC+KEYN+PISA+ROMA+)
 BALTAY 79 PRL 42 1721 +CAROUNBALIS,FRENCH,HIBBS,HYLTON+(COLU+BNL)
 CNOPS 79 PRL 42 197 +CONNOLLY,KAHN,KIRK,MURTAGH,PALMER+ (BNL)
 DRIJARD 79 PL 858 452 +FISCHER+ (CERN+CDEF+DORT+HEID+LAPP+WARS)
 GIBONI 79 PL 858 437 +DIBITONTO+ (AACH+CERN+HARV+MUNC+NWES+UCR)
 KERMAN 79 LEPTON CONF.FNAL AL KERMAN (UCR)
 LOCKMAN 79 PL 858 443 +MEYER,RANDER,SCHLEIN,WEBB+ (UCLA+SACL)
 ABRAMS 80 PRL 44 10 +ALAM,BLOCKER,BOYARSKI+ (SLAC+LBL)
 THEORY AND REVIEW
 DERJAJULA 75 PR D12 147 +GEORGI,GLASHOW (HARV)
 GAISSER 76 PR D14 3153 T.R.GAISSER,F.HALZEN (BART+NSC)
 LEE 77 PR D15 157 +QUIGG,ROSNER (FNAL)
 MULLER 79 CERN/EP 79-148 F.MULLER (CARGESE LEC.1979) (CERN)

HEAVY LEPTON SEARCHES

Data on the τ^\pm (1800) heavy lepton are listed in a separate section above, following the e and μ listings.

The following section contains information on searches for heavy leptons of other types and searches for the τ^\pm in collisions other than e^+e^- .

Data Card Listings

For notation, see key at front of Listings.

Several types of heavy leptons (that is, non-strongly-interacting fermions other than e and μ) have been proposed. In the Data Card Listings we distinguish four types.^{1,2} Each has a corresponding antiparticle with opposite charge and lepton number. For convenience we omit writing the antiparticles in the following descriptions. The four types are:

Sequential Leptons (L^-, ν_L). Such a pair is assumed to have its own separately strictly conserved lepton number $n_L = +1$. This means that the radiative decays

$$\left. \begin{aligned} L^- &\rightarrow e^- \gamma \\ L^- &\rightarrow \mu^- \gamma \end{aligned} \right\} \text{are forbidden,}$$

while the weak decays (assuming m_L sufficiently massive)

$$\left. \begin{aligned} L^- &\rightarrow \nu_L e^- \bar{\nu}_e \\ L^- &\rightarrow \nu_L \mu^- \bar{\nu}_\mu \\ L^- &\rightarrow \nu_L \text{ hadrons} \end{aligned} \right\} \text{are allowed.}$$

There could be an increasing mass sequence of such pairs. It is frequently assumed that the neutrinos are massless.

Decay rates are assumed calculable from conventional weak interactions theory. For L^- mass between 1 and 3 GeV, the branching fraction to each of the two leptonic modes should be roughly 10% to 20%. For L^- mass above 1 GeV, the mean life should be $\leq 10^{-12}$ sec, too short to be observed in a track chamber.¹

Paraleptons (E^+, E^0) and (M^+, M^0). These pairs have the same lepton numbers as the opposite-charge ordinary leptons, i.e., e^- and μ^- , respectively. Radiative decays are again forbidden and decays similar to those allowed for L^- are allowed here, e.g.,

$$\begin{aligned} M^+ &\rightarrow \nu_\mu e^+ \nu_e \\ \text{or} \quad M^+ &\rightarrow \nu_\mu \mu^+ \nu_\mu \end{aligned}$$

However, the lightest member is not stable as is the case for sequential leptons, so that bizarre decay schemes such as (assuming $m_{E^0} < m_{E^+}$)

$$\begin{aligned} E^+ &\rightarrow E^0 \mu^+ \nu_\mu \\ &\quad \downarrow \\ &\quad e^- e^+ \nu_e \end{aligned}$$

Data Card Listings

For notation, see key at front of Listings.

Stable Particles HEAVY LEPTON SEARCHES

are allowed.

Heavy leptons of this type (and/or a neutral intermediate boson Z^0) are desired in unified gauge theories of weak and electromagnetic interactions to cancel unphysical high energy behavior in such processes as $e^+e^- \rightarrow W^+W^-$.

Ortho-leptons (F^- and N^-). These have the same lepton numbers as e^- and μ^- , respectively. They may or may not have associated neutral leptons. Radiative decays are allowed in addition to weak modes similar to those of sequential leptons. The radiative mode can dominate or can be relatively unimportant depending on the model.⁴ Decays such as

$$F^- \rightarrow e^- + \text{hadrons}$$

are also allowed.

Long-Lived Penetrating Particles. Heavy leptons could have long mean lives under certain circumstances. For example, if $m_{\nu_L} > m_{L^-}$, then L^- , the sequential lepton, is completely stable since its lepton number is conserved.

Experimental Results. The results are summarized in the Data Card Listings below. Mass limits for all types are listed together in subsection M. Mass information on the τ^+ (1800) is no longer included here but has been moved into the new τ^+ (1800) section.

The Listings also contain cross-section upper limits reported as results of unsuccessful searches. We no longer list cross sections for anomalous ep events in e^+e^- collisions. These cross sections are consistent with coming from $e^+e^- \rightarrow \tau^+\tau^-$ where the τ^+ (1800) is assumed to be a spin-1/2 Dirac point particle with a mass about 1800 MeV.

References

1. M. L. Perl and P. Rapidis, SLAC-PUB-1496 (October 1974).
2. C. H. Llewellyn Smith, Invited paper presented at the Royal Society Meeting on New Particles and New Quantum Numbers, 11 March 1976, Oxford Ref. 33/76.
3. J. D. Bjorken and C. H. Llewellyn Smith, Phys. Rev. **D7**, 887 (1973).
4. F. Wilczek and A. Zee, Nucl. Phys. **B106**, 461 (1976).

PROPERTIES OF THE TAU+(1800) HEAVY LEPTON AND ITS ASSOCIATED NEUTRINO ARE LISTED SEPARATELY ABOVE FOLLOWING THE E AND MU LISTINGS. THE FOLLOWING SECTION CONTAINS INFORMATION ON SEARCHES FOR HEAVY LEPTONS OF OTHER TYPES AND SEARCHES FOR TAU+ IN COLLISIONS OTHER THAN E+E-. WE LIST MASS LIMITS AND CROSS SECTION UPPER LIMITS REPORTED AS NEGATIVE SEARCH RESULTS. WE NO LONGER LIST CROSS SECTIONS FOR THE ESTABLISHED PROCESS E+ E- -> TAU+ TAU- AS WAS DONE IN OUR 1977 SUPPLEMENT.

HEAVY LEPTON MASS LIMITS (GEV)						
M	H	0	1.0	OR MORE	BEHREND 65 SPEC - ORTHOELECTRON(F)	6/77
M	T	NONE	BETWEEN .12	AND .57	BETOURNE 65 SPEC - ORTHOELECTRON(F)	6/77
M	U	NONE	BETWEEN .3	AND .7	BUDNITZ 66 SPEC - ORTHOELECTRON(F)	6/77
M	R	NONE	BETWEEN .2	AND .92	BARNA 68 CNTR - LONG-LIVED	6/77
M	R	NONE	BETWEEN .97	AND 1.03	BARNA 68 CNTR - LONG-LIVED	6/77
M	Y	NONE	BETWEEN .1	AND 1.3	BOLEY 68 SPEC - ORTHOELECTRON(F)	6/77
M	L	NONE	BETWEEN .2	AND .6	LIBERMAN 69 DSPK - ORTHOMUON(N)	6/77
M	W		.490	OR MORE	ROTHER 69 RVUE	6/77
M	I	NONE	BETWEEN .26	AND 1.32	LICHTENST 70 SPEC - ORTHOELECTRON(F)	6/77
M	M	20	(.424)	(.013)	(.002)RAMM 70 HLBC 0 ORTHOMUON(N)	6/77
M	M	22	(.431)	(.004)	RAMM 71 HLBC - ORTHOMUON(N)	6/77
M	S	0	0.1	OR MORE	ANSORGE 73 HBC - LONG-LIVED	6/77
M	B	0	0.6	OR MORE	BACCI 73 ELEC +- ORTHOELECTRON(F)	1/76
M	B	0	2.2	OR MORE	BACCI 73 ELEC +- ORTHOELECTRON(F)	1/76
M	C	0	2.0	OR MORE	CL=.90 BARISH 73 ASPK C PARAMUON (M)	3/74
M	D	0	1.8	OR MORE	CL=.95 BERNARDIN 73 ASPK +- ANY NON-RAD TYPE	2/74
M	D	0	1.0	OR MORE	CL=.95 BERNARDIN 73 ASPK +- ANY NON-RAD TYPE	2/74
M	N	NONE	BETWEEN 0.55	AND 4.5	BUSHNIN 73 CNTR - LONG-LIVED	2/74
M	E	0	2.4	OR MORE	CL=.90 EICHTEN 73 HLBC + PARAMUON (M)	3/74
M	O	0	1.15	OR MORE	CL=.95 ORTIO 74 ASPK +- ANY NON-RAD TYPE	11/75
M	A	1.8	OR MORE	CL=.90	ASRATYAN 74 HLBC +- ORTHOMUON (N)	11/75
M	F	8.4	OR MORE	CL=.90	BARISH 74 SPEC + PARAMUON (M)	7/74
M	G	NONE	BETWEEN 0	AND 2.0	GITTLESON 74 SPEC ORTHOMUON (N)	12/77
M	K	NONE	BETWEEN 0.25	AND 2.3	CL=.95 BACCI 77 SPEC +- ORTHOELECTRON(F)	12/77
M	C	2.4-4.6			COX 77 NEUTRAL -> MU-MU+NU	12/79*
M	C	6.9-8.1			MEYER 77 CHARGED -> NEUTRAL MU-ANU	12/79*
M	P	1.2	OR MORE		GOX 77 SMAG 0 NEUTRAL	12/77
M	Y	10.3	OR MORE	CL=.98	ASRATYAN 78 - ORTHOMUON (N)	1/79**
M	Q	7.5	OR MORE		CNOP5 78 HLBC - ORTHOMUON (N)	8/78*
M	Q	9.0	OR MORE		CNOP5 78 HLBC + PARAMUON (M)	8/78*
M	Z	10.0	OR MORE		ERIQUEZ 78 BEBC	1/79*
M	V	12.	OR MORE	C=.90	HOLDER 78 + PARAMUON (M)	6/78*
COMMENTS						3/77
LIMITS APPLY ONLY TO HEAVY LEPTON TYPE GIVEN IN COMMENT AT RIGHT ON						3/77
DATA CARD. SEE REVIEW ABOVE FOR DESCRIPTION OF TYPES.						3/77
IN COMMENT BELOW: ALL BEAMS ARE MU TYPE NEUTRINO OR ANTINEUTRINO.						3/77
L,E,M,F,N STAND FOR SEQUENTIAL LEPTON, PARA-ELECTRON, PARA-MUON,						3/77
OR THO-ELECTRON, OR THO-MUON RESPECTIVELY.						3/77
M	H	BEHREND 65 IS DESY EXPT. LOOKS FOR E P-->F P, F-->E GAMMA.				6/77
M	H	THIS MASS LIMIT CORRESPONDS TO A LIMIT ON LAMBDA**2 OF 6.25*10**4.				6/77
M	T	BETOURNE 65 IS ORSAY EXPT. LOOKS FOR E P -->F P. MASS OF .12				6/77
M	T	CORRESPONDS TO COUPLING CONSTANT LAMBDA**2 GT .0016, MASS OF .57				6/77
M	U	LAMBDA**2 GT .31.				6/77
M	U	BUDNITZ 66 IS CEA EXPT. LOOKS FOR E P-->F P.				6/77
M	R	BARNA 68 IS SLAC PHOTOPRODUCTION EXPT.				6/77
M	Y	BOLEY 68 IS CEA EXPT. LOOKS FOR E P-->F P. MASS OF .1 CORRESPONDS				6/77
M	Y	TO COUPLING CONSTANT LAMBDA**2 GT 3*10**4, MASS LIMIT OF 1.3 TO				6/77
M	Y	LAMBDA**2 GT .01.				6/77
M	L	LIBERMAN 69 IS A BNL EXPT MEASURING MUON BREMSSTRAHLUNG.				6/77
M	W	ROTHER 69 EXAMINES PREVIOUS DATA ON MU PAIR PROD AND PI AND K DECAYS				6/77
M	I	LICHTENSTAM TO IS CORNELL EXPT MEASURING E BREMSSTRAHLUNG.				6/77
M	I	MASS LIMIT DEPENDS ON COUPLING CONSTANT. FIRST VALUE ABOVE IS FOR				6/77
M	I	LAMBDA**2 GT .17, SECOND IS FOR LAMBDA**2 GT .42.				6/77
M	M	RAMM 70 FINDS PEAK IN MU PI COMBINED MASS PRODUCED BY NEUTRINO				6/77
M	M	INTERACTIONS. HE ALSO CLAIMS EVIDENCE FOR THIS IN KOMU5 DECAYS IN				6/77
M	M	HBC WHERE PI MU COMBINED MASS PEAKS IN SAME REGION. CLARK 72 FINDS				6/77
M	M	NO EVIDENCE FOR PI MU PEAK IN HIGH STATISTICS KOL3 EXPT.				6/77
M	M	RAMM 71 SEES PEAK IN MU GAMMA COMBINED MASS PRODUCED BY NEUTRONS.				6/77
M	S	ANSORGE 73 LOOKS FOR ELECTRON PAIR PROD AND ELECTRON-LIKE BREMS.				6/77
M	B	BACCI 73 IS FRASCATI E+E- EXPT. LOOKS FOR F-->E GAMMA.				1/76
M	B	MASS LIMIT DEPENDS ON COUPLING CONSTANT LAMBDA FOR THIS DECAY.				1/76
M	B	FIRST VALUE ABOVE IS FOR LAMBDA**2 GT 9*10**5, 2ND IS FOR				1/76
M	B	LAMBDA**2 GT 10**3.				1/76
M	C	BARISH 73 IS FNAL 50.145 GEV NEU EXPT. LOOKS FOR (NEU NUCLEON -->				3/77
M	C	+ ANYTHING) WITH BR=.3.				3/77
M	D	BERNARDINI 73 IS FRASCATI E+E- EXPT. FIRST VALUE ASSUMES UNIVERSAL				2/74
M	D	COUPLING TO ORDINARY LEPTONS. SECOND VALUE ALSO ASSUMES COUPLING				2/74
M	D	TO HADRONS.				2/74
M	N	BUSHNIN 73 IS SERPUKOV TO GEV P EXPT. MASSES ASSUME MEAN LIFE ABOVE				2/74
M	N	7E-10 AND 3E-8 RESPECTIVELY. CALCULATED FROM CROSS SEC(DC BELOW)				2/74
M	N	AND 30 GEV MUON PAIR PRODUCTION DATA.				2/74
M	E	EICHTEN 73 IS CERN 1-10GEV NEU EXPT. LOOKS FOR M+ PRODUCED IN				2/76
M	E	NEU NUCL --> M+ HADRONS ASSUMING 15 PERCENT DECAY TO E+ NEU NEU.				2/76
M	J	HANSON 73 LOOK FOR DEVIATIONS FROM QED IN E+ E- -->2 GAMMA. THEY				6/77
M	J	MEASURE THE PRODUCT OF THE F MASS * THE COUPLING CONSTANT LAMBDA,				6/77
M	J	WHICH IS THE VALUE QUOTED ABOVE.				6/77
M	A	ASRATYAN 74 USES EICHTEN 73 DATA ON NEU NUCL --> E- HADRONS AND				2/76
M	A	ANTINEU NUCL --> E+ HADRONS TO SET LIMITS ON ORTHOMUON PRODUCTION.				2/76
M	F	BARISH 74 IS FNAL 50.135 GEV NEU EXPT. LOOKS FOR (NEU NUCLEON -->				7/74
M	F	M+ ANYTHING). ASSUMES (M+ -->MU+ NEU NEU) WITH BR=.3.				7/74
M	G	GITTLESON 74 IS NU P --> P ORTHOMUON SEARCH. COUPLING CONSTANT				12/77
M	G	LAMBDA**2 IS <.01 FOR MASS UP TO .7 GEV, LIMIT ON LAMBDA**2 RISES				12/77
M	G	TO <.1 FOR MASS OF 2.0 GEV.				12/77
M	O	ORTIO 74 LOOKED FOR H+H- PAIRS GIVING MU-E PAIRS. MASS LIMIT REFERS				3/74
M	O	TO ANY NON-RADIATIVE TYPE HEAVY LEPTON: L, E, M, F, N.				3/74
M	D	COUPLING TO HADRONS ASSUMED FROM THEORETICAL MODELS.				3/74
M	K	LAMBDA**2 LIMIT OF 4*10**5, UPPER VALUE IS FOR LAMBDA**2 LIMIT OF				12/77
M	K	1.5*10**3.				12/77
M	C	COX 77 ASSUMES TRIMUON EVENTS OF BENVENUTI 77 ARE A NEGATIVE HEAVY				12/79*
M	C	LEPTON DECAYING TO NEUTRAL HEAVY LEPTON MU- NUBAR.				12/79**
M	Z	ERIQUEZ 78 IS CERN SP5 EXPT. LOOKS FOR MU MU NUCLEON --> MU- E+ X.				1/79**
M	Z	FINDS CS FOR PRODUCING HWY LEPT --> E+ <.7*10**3 %C.C. CS.				1/79**
M	V	HOLDER 78 IS A CERN NEU EXPT LOOKING FOR NEU MU NUCLEON --> MU+ ANY				6/78*
M	V	THING. ASSUMES M+ --> MU+ 2NEUMU WITH BR=0.2.				6/78*
COS COSMOLOGICAL LIMITS ON MASS OF NEUTRAL HEAVY LEPTONS						12/79*
COS		NONE TO 20 EV TO 23 MEV	SATO	77	MASSIVE NEUTRINOS	12/79*
COS		NONE TO 30 EV TO 2.5 GEV	VYSOTSKII 77			12/79*
COS		NONE TO 50 EV TO 100 KEV	DIGUS	78	RADIATIVE DECAY	12/79*
COS		NONE TO 3 EV TO 10 GEV	SCHRAMM	78		12/79*
COS		60 GEV OR LESS	HUT	79	HEAVY NEUTRINOS	12/79*

Stable Particles

INTERMEDIATE BOSON, QUARK SEARCHES

NEU HEAVY LEPTON EVIDENCE (NEUTRINO NUCLEON)
SEE ALSO SECTION 'Y' IN 'CHARMED HADRON SEARCHES' AND
SECTION 'T' IN 'OTHER NEW PARTICLE SEARCHES'.

DC HEAVY LEPTON PRODUCTION DIFF. CROSS SEC. (P NUCLEON) (CM**2/SR-GEV)
DC B 0 1.6E-37 OR LESS CL=90 BUSHNIN 73 CNTR-70GEV P, SERPUKHOV
DC B 0 4.4E-38 OR LESS CL=90 GOLSHNIN 73 CNTR-70GEV P, SERPUKHOV

IC INVARIANT HEAVY LEPTON PROD. CROSS SEC. (P NUCLEON) (CM**2/GEV**2)
IC S 0 5.4E-39 OR LESS CL=90 CRONIN 74 SPEC - M=1-6.8 GEV
IC B 0 6.4E-35 OR LESS CL=90 BINTINGER 75 SPEC +- M=1-5 GEV

CN NEUTRAL HEAVY LEPTON PRODUCTION CROSS SECTION (CM**2)
CN K 5 (1, E-37 OR MORE) KRISHNASWAMY 75 CNTR-70- M=2-5 GEV
CN B 0 BENVENUTI 75 SPEC 0
CN K KRISHNASWAMY 75 IS KOLAR GOLD MINE COSMIC RAY EXPT. TYPICAL EVENT

N EVIDENCE FOR NEUTRAL HEAVY LEPTON PRODUCED IN NEUTRINO INTERACTIONS
N B 1 SEEN BARANOV 77 HLBC 0 SERPUKHOV
N A 2 SEEN BARANOV 79 HLBC 0 SERPUKHOV
N B BARANOV EVENT INTERPRETED AS NEU N -> P 2PIO NEUTRAL H. LEPTON WITH

MM UNEXPLAINED MISSING NEUTRAL (HEAVY LEPTON?) MOMENTUM /TOTAL MOMENTUM
MM E 0.05 0.03 ELLIOT 77 CALD
MM E ELLIOT 77 IS SLAC 10.5 GEV P1+0 -> P N2+- NEUTRALS. FINDS THAT

CP NEUTRAL HEAVY LEPTON PROD. CROSS SEC. (PROTON NUCLEON) (CM**2)
CP F 0 1.4E-29 OR LESS FAISSNER 76 HLBC 0
CP B 0 2.8E-35 OR LESS CL=90 BECHIS 78 SPEC 0
CP F FAISSNER 76 LIMIT ASSUMES STABLE NEUTRAL WEAKLY INTERACTING LEPTON.

NE NEUTRAL HEAVY LEPTON PROD. CROSS SECTION (E+ E-) (CM**2)
NE M 4.5E-36 OR LESS CL=90 MEYER 77 SMAG E+E- 6.8 GEV (ECM)
NE M MEYER 77 EXPT LOOKS FOR NARROW NEUTRAL RESONANCE IN E-P1 AND MU-P1

REFERENCES FOR HEAVY LEPTON SEARCHES

- BEHREND 65 PRL 15 900 +BRASSE, ENGLER, GANSSAUGE+ (DESY+KARL)
BETOURNE 65 PL 17 70 +NGUYEN NGOC, PEREZ Y JORBA+ (ORSAS)
BUJNITZ 66 PR 141 1313 +BAKER, KRZYSINSKI, NEALE, RUSHBROOKE+ (CANE)
BARNA 68 PR 173 1391 +COX, MARTIN, PERL, TAN, TONER, ZIPF+ (SLAC+STAN)
BOLEY 68 PR 167 1275 +ELIAS, FRIEDMAN, HARTMANN, KENDALL+ (MIT+CEA)

Data Card Listings

For notation, see key at front of Listings.

BENVENUTI 75 PRL 35 1486 BENVENUTI, CLINTE, FORD+ (HARV+PENN+WISC+FNAL)
BINTINGER 75 PRL 34 982 BINTINGER, CURRY+ (EFI+HARV+PENN+WISC)
BACCI 77 PL 718 227 +DEZORZI, PENSO, STELLA+ (ROMA+FRAS)
KRISHNASWAMY 75 PL 578 105 KRISHNASWAMY, MENDN+ (BOMBAY+OSAKA)

CAVALLIS 77 LNC 29 337 CAVALLIS-SFORZA, GOGGI+ (PAVI+PRIN+UMD)
COX 77 PR D16 2897 PAUL COX, ASIM YILDIZ (UNH+HARV)
ELLIOT 77 PR D15 1851 +FORTNEY, GOSHAW, LAMSA, LEOS+ (DUKE+ALBA)
MEYER 77 PL 708 469 +NGUYEN, ABRAMS, ALAM+ (SLAC+BL+NWES+HAWA)
SATO 77 PTP 58 1775 +KOBAYASHI (KYOTO)
VYSOTSKI 77 JETPL 26 188 VYSOTSKI, DOLGOV, ZELDOVICH (ITEP)

INTERMEDIATE BOSON SEARCHES

M W BOSON MASS LIMITS (GEV)
M B 0 1.7 OR MORE CL=.99 BERNARDINI 65 HYBR + NEU N, CERN 2/74
M B 0 2.0 OR MORE CL=.90 BURNS 65 OSKP + NEU N, BNL 2/74
M C 0 3.8 OR MORE CL=.90 BARISH 73 ASPK + W TO LEP+NEU-2 2/74

C W BOSON PRODUCTION CROSS SECTION (10**-36 CM**2)
C A 0 6.0 OR LESS ANKENBRANDT 71 CNTR +- W TO (MU NEU) 1.0 2/74
C A ANKENBRANDT 71 LOOKED FOR (P N) IN (HADRON S), W TO (MU NEU) AT NAL. 2/74
C A THIS ASSUMES BR OF W TO MU NEU IS 1. IN GENERAL THIS VALUE IS 2/74
C A 6.0/BR, WHERE BR=(W TO MU NEU)/(W TO ALL).

S SCALAR BOSON MASS LIMITS (GEV)
S C 0 10.0 OR MORE CL=90 CONVERSI 73 ASPK 0 E+E- FRASCATI 3/74
S C CONVERSI 73 LOOKED FOR QED VIOLATION IN E+E- SCATTERING AT 2.8 GEV 3/74
S C AND ASSUMED W BOSON MASS=10 GEV. FOR MW=15 GEV, MS LIMIT= 6.5 GEV 3/74

REFERENCES FOR INTERMEDIATE BOSON SEARCHES

- BERNARDINI 65 NC 38 608 BERNARDINI, BIENLEIN, BOHM, DARDOL,+ (CERN)
BURNS 65 PRL 15 42 +GOLLIANOS, HYMAN, LEDERMAN, LEE + (COLU+YALE)
ANKENBRANDT 71 PR D3 2582 ANKENBRANDT, LARSEN, LEIPUNER+ (BNL+BNL)

QUARK SEARCHES

SEARCHES FOR INTERCALLY CHARGED QUARKS APPEAR ALONG WITH OTHER SIMILAR SEARCHES IN 'OTHER NEW PARTICLE SEARCHES' SECTION BELOW.

Since the last edition, two more instances of charge +/-1/3 have been claimed by the Stanford group (LARUE 79) using magnetic levitation of heat-treated niobium beads. There has now been 15 no independent confirmation of the existence of free quarks.

The best searches for quarks in cosmic rays yield upper limits on the flux of quarks of about

Data Card Listings

For notation, see key at front of Listings.

Stable Particles QUARK SEARCHES

$10^{-11} \text{ cm}^{-2} \text{ ster}^{-1} \text{ sec}^{-1}$. Cross-section upper limits established from proton accelerator experiments and calculations based on production models¹ imply that free quarks, if they exist, have a mass greater than about 5 GeV. Mass limits from photon and electron beam searches are slightly lower, but more reliable, depending only on the QED calculations for quark pair production. Limits on free quark concentrations in stable matter vary enormously depending on the source of matter and the technique.

The largely negative result of quark searches does not prove that free quarks do not exist, but indicates that they are hard to find. De Rujula, Giles, and Jaffe² have considered the question of unconfined quarks in a framework of a renormalizable, spontaneously broken version of QCD, and conclude that: (1) production cross sections are small, (2) interaction cross sections with nucleons are very large, and (3) the physical masses of quarks are probably very large. On this basis, primordial quarks would be expected to be non-integrally charged, superheavy nucleon complexes.

We group quark searches by experimental technique - proton beams, photon beams, neutrino beams, electron beams, cosmic rays, and stable matter. Proton beam experiments generally measure quark production cross sections (we quote these in section C), differential cross-section ratios (section AF), or differential cross sections (sections IC and D). The photon beam experiment measures cross section per equivalent quanta (section DC), and the neutrino experiment measures the ratio of quark events over total events (section NEU). Searches with electron beams may measure differential cross sections (section G) and set limits on the quark mass (section M). Cosmic ray experiments measure quark flux (section F), and searches in stable matter measure quark concentration (section RHO). Most of the accelerator and cosmic ray experiments have searched for fractionally charged particles, but some have searched for massive stable particles which would have low velocity. The latter searches are usually sensitive to a range of charges and may appear in the section below on Other New Particle Searches.

We have relied heavily on the review of

L. W. Jones³ for data prior to April 1977.

References

1. T. K. Gaisser and F. Halzen, Phys. Rev. **D11**, 3157 (1975).
2. A. de Rujula, R. C. Giles, and R. L. Jaffe, Phys. Rev. **D17**, 285 (1978).
3. L. W. Jones, Rev. Mod. Phys. **69**, 717 (1977).

C	QUARK PRODUCTION CROSS SECT. FROM PROTON BEAM EXPTS. (CM**2)			
0	2.0E-34 OR LESS	CL=90	BINGHAM 64	HBC Q= -1/3 M=5-2.0GEV 3/77
0	1.0E-34 OR LESS	CL=90	BINGHAM 64	HBC Q= -2/3 M=5-2.5GEV 3/77
0	2.0E-35 OR LESS		BLUM 64	HBC Q= -1/3 M=0-2.5GEV 3/77
0	9.5E-36 OR LESS		HAGOPIAN 64	HBC Q= +1/3 M=5-2.5GEV 3/77
0	1.0E-34 OR LESS		LEIPUNER 64	CNTR Q= -1/3 M=0-2.0GEV 3/77
0	1.0E-34 OR LESS		MORRISON 64	HBC Q= -1/3 M=5-2.5GEV 3/77
0	1.0E-34 OR LESS		MORRISON 64	HBC Q= -2/3 M=5-2.5GEV 3/77
0	2.0E-35 OR LESS		FRANZINI 65	CNTR Q= -2/3 M=0-2.5GEV 3/77
0	3.2E-39 OR LESS	CL=90	ALLYBY 69	CNTR Q= -1/3 M=2GEV 1/76
0	5.5E-38 OR LESS	CL=90	ALLYBY 69	CNTR Q= -2/3 M=2GEV 1/76
0	1.4E-34 OR LESS		ALLYBY 69	CNTR Q= +1/3 M=2GEV 1/76
0	1.0E-35 OR LESS	CL=90	ALLYBY 69	CNTR Q= +2/3 M=2GEV 1/76
0	4.0E-37 OR LESS	CL=90	ANTIPOV1 69	CNTR Q= -2/3 M=0-5GEV 2/74
0	3.0E-39 OR LESS	CL=90	ANTIPOV2 69	CNTR Q= -1/3 M=4.5-5GEV 1/76
0	1.0E-35 OR LESS	CL=90	ANTIPOV2 69	CNTR Q= -2/3 M=2-5GEV 1/76
0	1.0E-36 OR LESS	CL=90	ANTIPOV 71	CNTR Q= -4/3 M=4GEV 1/76
0	3.0E-34 OR LESS		BOTT-BODE 72	CNTR Q=+1/3 M=0-2GEV 2/74
0	6.0E-34 OR LESS		BOTT-BODE 72	CNTR Q=+2/3 M=0-13GEV 2/74
0	1.0E-32 OR LESS	CL=90	ALPER 73	SPEC Q= 2/3 M=4-24 GEV 1/76
0	1.0E-32 OR LESS	CL=90	ALPER 73	SPEC Q= 4/3 M=4-24 GEV 1/76
0	1.0E-35 OR LESS		LEIPUNER 73	CNTR Q= 1/3 M=0-12GEV 2/74
0	1.0E-35 OR LESS		LEIPUNER 73	CNTR Q= 2/3 M=0-12GEV 2/74
0	5.0E-31 OR LESS		LEIPUNER 73	CNTR Q= 4/3 M=0-12GEV 2/74
0	5.0E-39 OR LESS	CL=90	NASH 74	CNTR Q= -1/3 M=4-9GEV 2/77
0	5.0E-38 OR LESS	CL=90	NASH 74	CNTR Q= -2/3 M=4-11GEV 2/77
0	4.0E-35 OR LESS	CL=90	FABJAN 75	CNTR Q= 1/3 M=0-20 GEV 1/77
0	8.0E-35 OR LESS	CL=90	FABJAN 75	CNTR Q= 2/3 M=0-20 GEV 1/77
0	1.0E-35 OR LESS	CL=90	BASILEI 78	SPEC Q=+1/3 M=0-20 GEV 2/79*
0	1.0E-33 OR LESS	CL=90	BASILEI 78	SPEC Q=+1/3 M=0-26 GEV 2/79*
Z	HAGOPIAN 64 CROSS SECTION INFERRED FROM FLUX DATA.			3/77
W	FRANZINI 65 CROSS SECTION INFERRED FROM FLUX DATA.			3/77
Y	ALLYBY 69 IS A CERN 27 GEV P+BE EXPT. STUDIES MASSES 0-2.7GEV			1/76
N	THEY DO NOT CLAIM THIS AS A QUARK.			2/78
Y	CROSS SECTIONS AT 26EV ARE GIVEN HERE. SEE FIG.9 FOR MASS DEPEN.			1/76
A	ANTIPOV1 69 IS A SERPUKHOV 70 GEV P EXPT. MASS LIMIT FROM NN=NNQ.			2/74
A	ANTIPOV1 69 AND ANTIPOV2 69 ARE SERPUKHOV 70GEV P EXPTS. ANTIPOV2			1/76
A	GIVES RESULTS FOR M=2-5GEV ASSUMING NN-->NNQ, HADRONIC OR LEPTONIC			1/76
A	QUARKS. WE QUOTE TYPICAL VALUES.			1/76
V	ANTIPOV 71 IS A SERPUKHOV 70 GEV P+AL EXPT. STUDIES DIQUARK MASSES			1/76
V	1.9-4.4GEV. WE SHOW 4GEV VALUE. SEE THEIR FIG.2 FOR MASS DEPEN.			1/76
B	BOTT-BODENHAUSEN 72 IS A CERN ISR 26+26 GEV P+P EXPERIMENT.			2/74
A	ALPER 73 IS CERN ISR 26+26 GEV P+P EXPT. ASSUMES ISOTROPIC C.M.			1/76
P	PRODUCTION. SENSITIVE TO ANY Q2/3.			1/76
L	LEIPUNER 73 IS AN AL 300 GEV P EXPERIMENT.			2/74
N	NASH 74 IS FINAL EXPT USING 200 AND 300 GEV PROTONS. SEE FIG 2, PG861			2/77
N	FOR OTHER MASS VALUES AND VARIOUS PRODUCTION MECHANISMS.			2/77
F	FABJAN 75 IS CERN ISR P+P EXPT. INCLUDES RESULTS OF BOTT-BODE 72			1/77
F	EXPT. RESULTS ARE FOR ECM=53 GEV.			1/77
S	BASILEI 78 IS CERN-ISR EXPT WITH ECM=52.5 GEV.			2/79*
X	THE ABOVE RESULT IS FOR ECM=62 GEV, FROM AN EARLIER EXP (BASILE 77)			2/79*
AF	QUARK PRODUCTION FLUX (FLUX QUARKS / FLUX CHARGED PARTICLES)			
F	0 6.2E-10 OR LESS		FABJAN 75	CNTR M=0-20 GEV 2/80*
B	0 1.78E-9 OR LESS	CL=90	BASILEI 77	SPEC Q= +1/3 M=0-26GEV 1/78
A	0 1.0E-9 OR LESS	CL=90	BASILEI 77	SPEC Q= -1/3 M=0-26GEV 1/78
A	0 5.11E-10R OR LESS	CL=90	BASILEI 78	SPEC Q=+1/3 M=0-21 GEV 2/79*
D	0 4.E-11 OR LESS		BOZZOLI 79	CNTR Q=-2/3, 1<M<3 12/79*
A	0 2.E-11 OR LESS		BOZZOLI 79	CNTR Q=-4/3, 2<M<6 12/79*
D	0 3.E-11 OR LESS		BOZZOLI 79	CNTR Q=+2/3, 1<M<3 12/79*
D	0 3.E-10 OR LESS		BOZZOLI 79	CNTR Q=+4/3, 2<M<6 12/79*
F	FABJAN 75 REPORTS BOTH FLUX AND CROSS SECTION (ABOVE)			
B	BASILE 77 IS A CERN-ISR PP EXP AT ECM=62.2 GEV COVERING PT UP TO 1			2/78
B	GEV BASILE 77 FIND ONE QUARK CANDIDATE WITH M .LT. .169 GEV.			2/78
B	THEY DO NOT CLAIM THIS AS A QUARK.			2/78
A	BASILE 78 IS CERN-ISR EXPT WITH ECM=52.5 GEV.			2/79*
AF	D BOZZOLI 79 SEARCHED FOR QUARKS WITH LIFETIME > 1.E-8 SEC IN 200			12/79*
AF	GEV/C P BE INTERACTIONS USING RF SEPARATOR AS MASS SPECTROMETER.			12/79*
IC	QUARK INVARIANT PRDD. CRDSS SECT. FROM PROTON BEAMS (CM**2/GEV**2)			
T	0 5.1E-39 OR LESS	CL=90	ANTREASYA 77	SPEC Q= +1/3 M=0-6.3 GEV 11/77
T	0 8.8E-39 OR LESS	CL=90	ANTREASYA 77	SPEC Q= -1/3 M=0-6.3 GEV 11/77
T	0 1.3E-39 OR LESS	CL=90	ANTREASYA 77	SPEC Q= +2/3 M=0-8 GEV 11/77
T	0 2.2E-39 OR LESS	CL=90	ANTREASYA 77	SPEC Q= -2/3 M=0-8 GEV 11/77
S	0 4. E-39 OR LESS	CL=90	STEVENSON 79	CNTR Q= 2/3 M=5 GEV 12/79*
S	0 5. E-38 OR LESS	CL=90	STEVENSON 79	CNTR Q= 1/3 M=5 GEV 12/79*
T	ANTREASYA 77 LOOKS FOR HIGH TRANSVERSE MOM QUARKS IN 400 GEV P-CU			11/77
IC	INTERACTIONS AT FNAL.			11/77
S	STEVENSON 79 IS 300 GEV P-CU EXPT AT FNAL, SENSITIVE TO PARTICLES			12/79*
S	WITH LIFETIMES BETWEEN 2.5E-5 AND 1.E-3 SEC.			12/79*
D	QUARK PRDD. DIFF. CROSS SEC. FROM PROTON BEAM EXPTS. (CM**2/SR-GEV)			
D	0 1.5E-36 OR LESS		DORFAN 65	CNTR BE TARG M=3-7GEV 2/74
D	0 3.0E-36 OR LESS		DORFAN 65	CNTR FE TARG M=3-7GEV 2/74
D	0 7.2E-39 OR LESS	CL=90	ALLYBY 69	CNTR Q=-1/3 THETA=0 MR 1/76
D	0 5.2E-38 OR LESS	CL=90	ALLYBY 69	CNTR Q=-2/3 THETA=0,5MR 1/76
D	0 2.4E-35 OR LESS	CL=90	ALLYBY 69	CNTR Q=+1/3 THETA=44 MR 1/76
D	0 1.3E-35 OR LESS	CL=90	ALLYBY 69	CNTR Q=+2/3 THETA=44 MR 1/76
D	0 7.0E-38 OR LESS	CL=90	ANTIPOV2 69	CNTR Q=-1/3 M=0-5GEV 1/76
A	0 4.0E-38 OR LESS	CL=90	ANTIPOV2 69	CNTR Q=-2/3 M=0-2.5GEV 1/76
D	0 3.8E-36 OR LESS	CL=90	ANTIPOV 71	CNTR Q=-4/3 THETA=47 MR 1/76
D	0 3.8E-36 OR LESS	CL=90	ANTIPOV 71	CNTR Q=-4/3 THETA=47 MR 1/76
N	0 5.6E-36 OR LESS	CL=90	NASH 74	CNTR Q=-1/3 2/77
N	0 5.0E-35 OR LESS	CL=90	NASH 74	CNTR Q=-2/3 M GT 1.76 2/77
N	0 8.9E-35 OR LESS	CL=90	NASH 74	CNTR Q=-2/3 H LT 1.76 2/77
L	0 1.6E-33 OR LESS	CL=90	ALBROW 75	SPEC Q=+4/3 M=5-20 GEV 1/77
J	0 5.0E-34 OR LESS	CL=90	JOVANOVIC 75	CNTR Q=1/3 M=7-15 GEV 2/76
J	0 2.0E-34 OR LESS	CL=90	JOVANOVIC 75	CNTR Q=1/3 M=15-26 GEV 11/75
J	0 1.3E-34 OR LESS	CL=90	JOVANOVIC 75	CNTR Q=2/3 M=10-26 GEV 11/75
D	0 8.0E-35 OR LESS	CL=90	JOVANOVIC 75	CNTR Q=4/3 M=10-26 GEV 11/75
D	0 3.9E-36 OR LESS	CL=90	BALDIN 76	CNTR Q=2/3 M=1.4-6 GEV 1/77
D	0 2.0E-36 OR LESS	CL=90	BALDIN 76	CNTR Q=-4/3 M=2.7-12GEV 1/77

Stable Particles

Data Card Listings

QUARK SEARCHES

For notation, see key at front of Listings.

D D DORFAN 65 IS A 30 GEV/C P EXPERIMENT AT BNL. V=18-.995 2/74
 Y SEE FOOTNOTE Y IN SUBSECTION C ABOVE. 2/76
 D A SEE FOOTNOTE A IN SUBSECTION C ABOVE. 2/76
 D V FIRST ANTIPOV 71 VALUE IS FOR M=1.9-2.3+2.7-4.4GEV, SECOND IS FOR M=2.3-2.7GEV. SEE ALSO NOTE V IN SECTION C ABOVE. 1/76
 D N NASH 74 IS FINAL EXPT USING 200 AND 300 GEV PROTONS. VALUES ARE FOR D N A 1 MRAD LAB PROD. ANGLE AND OUTGOING MOMENTUM AT MAX OF FOUR BODY D N PHASE SPACE FOR QUARK-PAIR PROD. SEE TABLE 1 PG. 860 FOR OTHER D N LIMITS. 2/77
 D L ALBROW 75 IS A CERN ISR EXPT WITH ECM=53 GEV. THETA=40 MR. SEE D L FIG. 5 FOR MASS RANGES UP TO 25 GEV. 1/77
 D J JOVANDVICH 75 FIG.4 COVERS RANGES Q=1/3 TO 2 AND M=3 TO 26 GEV. 11/75
 D B BALDIN 76 IS A 70 GEV SERP EXP. VALUES ARE PER AL NUCLEUS AT D B THETA=0. ASSUMES STABLE PARTICLE INTERACTING WITH MATTER IN SAME D B MANNER AS ANTIPOV. 1/77
 DG QUARK PROD. DIFF. CROSS SEC. FROM PHOTOPROD. (CM**2/SR-EQUIV.QUANTA) 1/76
 DG G 5.0E-35 OR LESS CL=.90 GALIK 74 CNTR THETA=1.2,7 DEG. 11/76
 DG G GALIK 74 IS 20 GEV(IMAX) GAMMA QU EXPT. USING SLAC 20 GEV SPRMETER. 11/76
 NEU QUARK PRODUCTION IN NEUTRINO BEAMS (QUARK EVS./TOTAL EVS.) 7/79*
 NEU Q (5.0E-31) OR LESS CL=.90 BASILEZ 78 CNTR NUMJ BEAM AT SPS 7/79*
 M LIMIT ON QUARK MASS FROM ELECTRON BEAMS (GEV/C**2)
 M *LEP QUARK INDICATES LEPTONIC QUARK
 M *STR QUARK INDICATES STRONG QUARK
 M .85 OR MORE CL=.99 BATHOW 67 CNTR Q=1/3 *LEP QUARK 3/77
 M .90 OR MORE CL=.99 BATHOW 67 CNTR Q=2/3 *LEP QUARK 3/77
 M .70 OR MORE CL=.90 FOSS 67 CNTR Q=1/3 *LEP QUARK 3/77
 M .84 OR MORE CL=.90 BELLAMY 68 CNTR Q=2/3 *LEP QUARK 3/77
 M 1.0 OR MORE BELLAMY 68 CNTR Q=1/3 *LEP QUARK 3/77
 M 1.5 OR MORE BELLAMY 68 CNTR Q=2/3 *LEP QUARK 3/77
 M 0.5 OR MORE BELLAMY 68 CNTR Q=1/3 *STR QUARK 3/77
 M .75 OR MORE BELLAMY 68 CNTR Q=2/3 *STR QUARK 3/77
 M G 3.6 OR MORE CL=.90 GALIK 74 CNTR Q=1/3 *STR QUARK 7/76
 M G 4.5 OR MORE CL=.90 GALIK 74 CNTR Q=2/3 *STR QUARK 7/76
 M G 1.4 OR MORE CL=.90 GALIK 74 CNTR Q=1/3 *LEP QUARK 7/76
 M G 1.8 OR MORE CL=.90 GALIK 74 CNTR Q=2/3 *LEP QUARK 7/76
 M G FIRST TWO MASS LIMITS ARE FOR STRONGLY INTERACTING QUARKS; INFERRED
 M G FROM CROSS-SEC LIMITS USING DRELL MODEL. LAST TWO ARE FOR LEPTONIC
 M G QUARKS. EXPT USES PHOTOPRODUCTION ON COPPER. 7/76
 F QUARK FLUX FROM COSMIC RAY EXPERIMENTS (NUMBER/CM**2-SR-SEC)
 F *TD IN THE RIGHT HAND COLUMNS INDICATES A SEARCH FOR MASSIVE
 F QUARKS USING TIME DELAY AFTER AIR SHOWERS, SENSITIVE TO A RANGE
 F OF CHARGES
 F *AS IN THE RIGHT HAND COLUMNS INDICATES A SEARCH IN AIR SHOWERS
 F ALL SEARCHES ARE AT SEA LEVEL UNLESS OTHERWISE INDICATED
 F 0.16E-8 OR LESS CL=.90 BOWEN 64 CNTR Q=-1/3 ALT=2750M 3/77
 F 0.20E-7 OR LESS CL=.90 SUNYAR 64 CNTR Q=1/3 3/77
 F 0.87E-9 OR LESS CL=.90 DELISE 65 CNTR Q=1/3 ALT=2750M 3/77
 F 0.18E-10 OR LESS CL=.90 MASSAM 65 CNTR Q=2/3 ALT=2750M 3/77
 F 5.0E-8 OR LESS CL=.90 MASSAM 65 CNTR Q=2/3 3/77
 F V 0.14E-10 OR LESS BARTON 66 CNTR Q=2/3 3/77
 F 0.15E-9 OR LESS CL=.90 BUHLER-BR 66 CNTR Q=1/3 ALT= 450M 3/77
 F 0.15E-9 OR LESS CL=.90 BUHLER-BR 66 CNTR Q=2/3 ALT= 450M 3/77
 F 0.26E-9 OR LESS KASHA 66 CNTR Q=1/3 3/77
 F 0.21E-9 OR LESS KASHA 66 CNTR Q=2/3 3/77
 F 0.45E-10 OR LESS CL=.90 LAMB 66 CNTR Q=1/3 3/77
 F 0.16E-10 OR LESS CL=.90 LAMB 66 CNTR Q=2/3 3/77
 F W 0.14E-10 OR LESS BARTON 67 CNTR Q=1/3 3/77
 F Q 0.16E-7 OR LESS BUHLER-1 67 CNTR Q=4/3 ALT= 450M 3/77
 F Q 0.45E-10 OR LESS CL=.90 BUHLER-2 67 CNTR Q=1/3 ALT= 450M 3/77
 F Q 0.17E-10 OR LESS BUHLER-2 67 CNTR Q=2/3 ALT= 450M 3/77
 F Q 0.17E-10 OR LESS CL=.90 GOMEZ 67 CNTR Q=1/3 3/77
 F Q 0.34E-10 OR LESS CL=.90 GOMEZ 67 CNTR Q=2/3 3/77
 F 0.20E-9 OR LESS CL=.90 KASHA 67 CNTR Q=2/3 3/77
 F C 0.30E-10 OR LESS BJORNBOE 68 CNTR M=5GEV OR MORE *TD 2/74
 F 0.18E-10 OR LESS CL=.90 BRIATORE 68 CNTR Q=1/3 5/76
 F R 0.18E-10 OR LESS CL=.90 BRIATORE 68 CNTR Q=2/3 5/76
 F R 0.37E-8 OR LESS CL=.90 BRIATORE 68 CNTR Q=4/3 5/76
 F Y 0.22E-8 OR LESS FRANZINI 68 CNTR V=-.5-.9C M=2GEV UP 2/74
 F 0.64E-11 OR LESS CL=.95 GARMIRE 68 CNTR Q=1/3 3/77
 F 0.84E-11 OR LESS CL=.95 GARMIRE 68 CNTR Q=2/3 3/77
 F 0.31E-10 OR LESS CL=.90 HANAYAMA 68 CNTR Q=1/3 3/77
 F 0.24E-8 OR LESS CL=.95 KASHA 68 OSPK V=-.5-.75C M=5-15GEV 2/74
 F 0.12E-10 OR LESS CL=.90 KASHAZ 68 CNTR Q=2/3 3/77
 F 0.13E-10 OR LESS CL=.90 KASHAZ 68 CNTR Q=4/3 3/77
 F Z 0.50E-11 OR LESS CAIRNS 69 CC Q=2/3 3/77
 F F 0.50E-11 OR LESS CL=.90 FUKUSHIMA 69 CNTR Q=1/3 2/74
 F F 0.75E-10 OR LESS CL=.90 FUKUSHIMA 69 CNTR Q=2/3 2/74
 F M 1 EVENT CLAIMED MCCUSKER 69 CC Q=2/3 *AS 2/74
 F 0.50E-10 OR LESS BOSIA 70 CNTR Q=1/3 ALT=3500M 1/78
 F 0.25E-10 OR LESS BOSIA 70 CNTR Q=2/3 ALT=3500M 1/78
 F U 1 EVENT CLAIMED CHU 70 HLBC *AS 5/76
 F 0.19E-9 OR LESS CL=.90 FAISSNER 70 CNTR Q=1/3 3/77
 F 0.94E-11 OR LESS CL=.90 KRIDER 70 CNTR Q=1/3 ALT=750M 3/77
 F 0.16E-10 OR LESS CL=.90 KRIDER 70 CNTR Q=2/3 ALT=750M 3/77
 F 0.13E-10 OR LESS CL=.90 CHIN 71 CNTR Q=1/3 3/77
 F 0.57E-11 OR LESS CL=.90 CHIN 71 CNTR Q=1/3 ALT=2770M 3/77
 F 0.30E-10 OR LESS CL=.90 CLARK 71 CC Q=1/3 *AS 3/77
 F 0.30E-11 OR LESS CL=.90 CLARK 71 CC Q=2/3 *AS 3/77
 F 0.10E-10 OR LESS CL=.90 HAZEN 71 CC Q=1/3+2/3 *AS 2/77
 F 0.41E-10 OR LESS BEUCHAMP 72 CNTR Q=4/3 ALT=2750M 3/77
 F 0.10E-10 OR LESS CL=.90 BOHM 72 CNTR Q=1/3 *AS 2/74
 F 0.10E-10 OR LESS CL=.90 BOHM 72 CNTR Q=2/3 *AS 2/74
 F 0.83E-11 OR LESS CL=.90 COX 72 ELEC Q=1/3 ALT=2750M 3/77
 F 0.96E-11 OR LESS CL=.90 COX 72 ELEC Q=2/3 ALT=2750M 3/77
 F 0.22E-10 OR LESS CL=.90 CROUCH 72 CNTR Q=2/3 *TD 3/77
 F X 0.30E-9 OR LESS DARDO 72 *TD 3/77
 F 0.40E-9 OR LESS CL=.95 EVANS 72 CC Q=1/3 *AS 1/77
 F 0.15E-9 OR LESS TONWARR 72 CNTR M.GT.10GEV *TD 3/77
 F 0.80E-11 OR LESS ASHTON 73 CNTR Q=1/3 *AS 3/77
 F H 0.17E-8 OR LESS CL=.90 HICKS 73 CNTR Q=1/3 1/76
 F H 0.17E-8 OR LESS CL=.90 HICKS 73 CNTR Q=2/3 1/76
 F 0.10E-7 OR LESS CL=.90 CLARK 74 CC Q=1/6 *AS 1/77
 F 0.70E-10 OR LESS CL=.90 CLARK 74 CC Q=1/4 *AS 1/77
 F 0.80E-11 OR LESS CL=.90 CLARK 74 CC Q=1/3 *AS 1/77
 F K 0.30E-10 OR LESS CL=.95 KIFUNE 74 CNTR Q=1/3 7/76
 F 0.12E-11 OR LESS CL=.90 HAZEN 75 CC Q=1/3 *AS 7/76
 F 0.70E-11 OR LESS CL=.90 KRISOR 75 CNTR Q=1/3 3/77
 F 0.50E-11 OR LESS CL=.90 KRISOR 75 CNTR Q=2/3 GAMMA = 10 3/77
 F 0.15E-10 OR LESS CL=.90 KRISOR 75 CNTR Q=2/3 GAMMA GT100 3/77
 F 0.10E-9 OR LESS BRIATORE 76 ELEC *TD 1/77
 F 0 3 EVENTS CLAIMED YOCK 78 CNTR 2/79*
 F V BARTON 66 20 22000 G/C**2 EXTRA SHIELDING 3/77
 F W BARTON 67 HAD 6000 G/C**2 EXTRA SHIELDING 3/77
 F Q BUHLER-1 67 AND BUHLER-2 67 HAD 760 G/C**2 EXTRA SHIELDING 3/77
 F C BJORNBOE 68 TWO EXPERIMENTS HAVING 1650 AND 3600 G/C**2 SHIELDING 3/77
 F R BRIATORE 68 SEARCHES FOR LEPTONIC QUARKS WITH 6300 G/C**2 SHIELDING 3/77
 F R BRIATORE 68 SEARCHES FOR LEPTONIC QUARKS WITH 6300 G/C**2 SHIELDING 3/77
 F Z CAIRNS 69 OBSERVED 4 POSSIBLE QUARK CANDIDATES 3/77
 F Y FRANZINI 68 MEASURES VELOCITY DIRECTLY BY TOP 3/77
 F F FUKUSHIMA 69 DOES NOT RULE OUT QUARKS HEAVIER THAN 10 GEV. 7/76
 F M MCCUSKER 69 CLAIMS 1 CANDIDATE. LATER SIMILAR EXPTS. SEE NONE. 2/74

F U Q=2/3 IF MASS LT 6.5 GEV, Q=1/3 IF MASS = 8 GEV. 5/76
 F U COULD BE AN EARLY-TIME NORMALLY CHARGED COSMIC RAY. SEE ALLISON 70. 2/77
 F X DARDO 72 HAD 7000 G/C**2 EXTRA SHIELDING 3/77
 F H HICKS 73 LOOKED AT LARGE ZENITH ANGLES, THUS USING THE ATMOSPHERE 1/76
 F H AS AN EXTENDED FILTER FOR HADRONIC QUARKS. THEIR SEARCH PUTS AN 1/76
 F H UPPER LIMIT ON LEPTONIC QUARK FLUX IN COSMIC RAYS. 1/76
 F K KIFUNE 74 LOOKED AT LARGE ZENITH ANGLES. FROM THEIR FLUX LIMIT, THEY 7/76
 F K GET A LOWER LIMIT ON QUARK MASS OF 20 GEV. 7/76
 F O YOCK 78 EVENTS HAVE TAU > 10**=-8 SEC, CHARGES OF +-70, +-68, +-42, 2/79*
 F O AND MASSES 24.4, 4.8, AND 20 GEV RESPECTIVELY. MEASURES BETA AND 2/79*
 F O DE/DX IN OSPK-SCINTILLATOR COSMIC RAY TELESCOPE. IF TAKEN AS QUARK, 2/79*
 F O THE OBSERVED FLUX WOULD BE 2.4E-9. 7/79*
 RHO QUARK CONCENTRATION IN MATTER (QUARKS PER NUCLEON)
 RHO S 0.10E-22 OR LESS HILLAS 59 3/77
 RHO R 0.10E-10 OR LESS BENNETT 66 SOLAR SPECTRUM 3/77
 RHO P 0.10E-17 OR LESS CHUPKA 66 METORITES 3/77
 RHO 0.10E-16 OR LESS GALLINARO 66 GRAPHITE LEVITOMETER 3/77
 RHO 0.40E-19 OR LESS STOVER 67 IRON LEVITOMETER 2/74
 RHO 0.10E-17 OR LESS BRAGINSKI 68 GRAPHITE LEVITOMETER 3/77
 RHO 0.10E-20 OR LESS RANK 68 DIL DRUPS 3/77
 RHO T 0.10E-18 OR LESS RANK 68 SEA WATER 3/77
 RHO T 0.10E-17 OR LESS RANK 68 SEA SALT, ETC. 3/77
 RHO T 0.10E-18 OR LESS RANK 68 LAKE WATER 3/77
 RHO V 0.10E-24 OR LESS COOK 69 SEAWATER 2/74
 RHO 0.10E-23 OR LESS COOK 69 GCK SAMPLES 3/77
 RHO V 0.50E-23 OR LESS COOK 69 LAVA 3/77
 RHO 0.10E-15 OR LESS ELBERT 70 ION SPECTROMETER 3/77
 RHO 0.50E-19 OR LESS MURPORGO 70 GRAPHITE LEVITOMETER 3/77
 RHO Z 0.10E-21 OR LESS STEVENS 76 DEEP OCEAN SEDIMENT 3/77
 RHO Z 0.10E-22 OR LESS STEVENS 76 LUNAR SOIL 3/77
 RHO B 0.30E-18 OR LESS BLAND 77 TUNGSTEN BEADS 8/77
 RHO 0.30E-21 OR LESS GALLINARO 77 IRON LEVITOMETER 7/77
 RHO L 1 EVENT Q=0.337+-009 LARUE 77 NIOBIUM-TUNGSTEN LEVITOM 7/77
 RHO L 1 EVENT Q=-0.331+-070 LARUE 77 NIOBIUM-TUNGSTEN LEVITOM 7/77
 RHO M 012. E-19) OR LESS MULLER 77 CNTR 2.5CM*7.7 GEV/C2 12/79*
 RHO M 011. E-13) OR LESS MULLER 77 CNTR FOR MC-3 12/79*
 RHO M 019. E-15) OR LESS MULLER 77 CNTR .3CM*2.5 GEV/C2 12/79*
 RHO -015.0E-28) OR LESS OGRODNIK 77 SEAWATER 12/79*
 RHO 015.0E-27) OR LESS OGRODNIK 77 SEDIMENT, LAVA 12/79*
 RHO O 0.50E-15 OR LESS BOYD 78 TUNGSTEN IONS 8/78*
 RHO Y 015.0E-16) OR LESS CL=.67 BOYD2 78 HYDROGEN 1/79*
 RHO L LARUE 77 SEES RESIDUAL CHARGE IN TUNGSTEN BEADS 2/79*
 RHO H 0.10E-22 OR LESS SCHIFFER 78 NIOBIUM, TUNGSTEN+IRON 2/79*
 RHO D 016.4E-16) OR LESS CL=.67 BOYD 79 HELIUM 12/79*
 RHO 2 EVENTS Q=0.345+-035 LARUE 79 NIOBIUM BALL LEVITATION 7/79*
 RHO 4.7E-21 QUARKS/NUCLEON LARUE 79 NIOBIUM BALL LEVITATION 7/79*
 RHO S HILLAS 59 WAS INSENSITIVE TO QUARKS ACCORDING TO SUNYAR 64. 3/77
 RHO R BENNETT 66 LIMIT INFERRED BY JONES 76. 3/77
 RHO T RANK 68 USES O.V. SPECTROSCOPY. 3/77
 RHO V COOK 69 USES MOLECULAR BEAMS. 3/77
 RHO Z STEVENS 76 USES AN ION SPECTROMETER. 3/77
 RHO B BLAND 77 IS A MILLIKAN OIL-DROP TYPE EXPT USING TUNGSTEN PARTICLES. 8/77
 RHO B NO FRACTIONAL CHARGE WAS FOUND ON A TOTAL SAMPLE OF 3.07E-7 GRAMS 8/77
 RHO L LARUE 77 SEES RESIDUAL CHARGE IN TUNGSTEN BEADS TRANSFERRED TO A 7/77
 RHO L NIOBIUM BALL FROM A TUNGSTEN SUBSTRATE, CORRESPONDING TO A DENSITY 7/77
 RHO L OF 1. E-23. 7/77
 RHO M MULLER 77 SEARCHES FOR CHARGE 1 QUARKS IN HYDROGEN USING A 12/79*
 RHO M MULLER 77 SEARCHES FOR CHARGE 1 QUARKS IN HYDROGEN USING A 12/79*
 RHO M BOYD 78 USES VAN-DE-GRAFF AS MASS SPECTROMETER TO SEARCH FOR Q=1/3 8/78*
 RHO Y BOYD2 78 USES VAN-DE-GRAFF AS MASS SPECTROMETER TO SEARCH FOR Q=1 1/79*
 RHO Y WITH MASS < 1.75 GEV. 1/79*
 RHO Y STABLE CHARGE 1 QUARKS WITH MASS < 1.75 GEV. 1/79*
 RHO Y LISTED ABOVE TRANSFERRED TO A 2/79*
 RHO H SCHIFFER 78 LOOKS FOR QUARKS ACCELERATED BY A 1 MEV ELECTROSTATIC 2/79*
 RHO H FIELD ONTO A SI DETECTOR FROM HEATED W, FE AND NB FILAMENTS. 2/79*
 RHO D BOYD 79 USES HE BEAM WITH A VAN-DE-GRAFF AS MASS SPECTROMETER. 12/79*

 REFERENCES FOR QUARK SEARCHES
 HILLAS 59 NATURE 184 892 HILLAS, CRANSHAW (AERE)
 BINGHAM 64 PL 9 201 +DICKINSON, DIEBOLD, KOCH, LEITH+ (CERN)+EPOL
 BLUM 64 PRL 13 353A +BRANDT, COCCONI, CZYZEWSKI, DANYSZ+ (CERN)
 BOWEN 64 PRL 13 728 BOWEN, DELISE, KALBACH, MORTARA (ARIZ)
 HAGOPIAN 64 PRL 13 280 +SELOVE, EHRICH, LEBOY, LANZA, RAHM+ (PENN+CAL)
 LEIPUNER 64 PRL 12 423 LEIPUNER, CHU, LARSEN, ADAIR (BNL+YALE)
 MORISON 64 PL 9 199 MORISON, LEIPUNER, TRISCHKA (YRNL)
 SUNYAR 64 PR 1368 1157 SUNYAR, SCHWARZSCHILD, CCNNORS (CERN)
 DELISE 65 PR 1408 458 DELISE, BOWEN (ARIZ)
 DORFAN 65 PRL 14 999 +EADES, LEDERMAN, LEE, TING (CGLU)
 FRANZINI 65 PRL 14 196 +LEONTEIC, RAHM, SAMIOS, SCHWARTZ (BNL+CGLU)
 MASSAM 65 NC 404 589 MASSAM, MULLER, ZICHICH (CERN)
 BARTON 66 PL 21 360 BARTON, STOCKEL (INPOL)
 BENNETT 66 PRL 17 1196 W.R. BENNETT (YALE)
 BUHLER-B 66 NC 454 520 BUHLER-BROGELIN, FOR TUNATO, MASSAM+ (CERN)
 CHUPKA PRL 17 60 CHUPKA, SCHIFFER, STEVENS (ANL)
 GALLINARO 66 PL 23 609 GALLINARO, MURPORGO (GENO)
 KASHA 66 PR 150 1140 KASHA, LEIPUNER, ADAIR (BNL+YALE)
 LAMB 66 PRL 17 1068 LAMB, LUNDY, NOVEY, JOVANDVICH (ANL)
 BARTON 67 PRSL 90 87 BARTON (INPOL)
 BATHOW 67 PL 258 163 BATHOW-FREYTAG, SCHULZ, TESCH (DESY)
 BUHLER-1 67 NC 494 209 BUHLER-BROGELIN, DALPIAZ, MASSAM, ZICHICH(CERN)
 BUHLER-2 67 NC 514 937 BUHLER-BROGELIN, DALPIAZ, MASSAM, ZICHICH(CERN)
 FOSS 67 PL 258 166 +GARELICK, HOMMA, LUBAR, OSBORNE, UGLUM (MIT)
 GOMEZ 67 PRL 18 1022 +KOBRAK, MOLINE, ORTH, VANPUTTEN+ (CIT)
 KASHA 67 PR 154 1263 +LEIPUNER, WAGLER, AL SPECTOR, ADAIR (BNL+YALE)
 STOVER 67 PR 164 1599 +MORAN, TRISCHKA (SYRAC)
 BELLAMY 68 PR 166 1391 +HOFSTADTER, LAKIN, PERL, TONER (STAN+SLAC)
 BJORNBOE 68 NC 853 241 +DAMGARD, HANSEN, CHATTERJEE+ (BOHR+BERN)
 BRAGINSKI 68 JETP 27 51 BRAGINSKI I, ZELODVICH, MARYNOV (MOSU)
 BRATON 68 NC 856 950 +CASTAÑOL, I. BOLLINI, MASSAM+ (TOR+CERN)
 FRANZINI 68 PRL 21 1013 FRANZINI, SHULMAN (CGLU)
 GARMIRE 68 PR 166 1280 GARMIRE, LEONG, SREEKANTAN (MIT)
 HANAYAMA 68 CJP 46 5734 +HARA, HIGA SHI, KITAMURA, MIYONO+ (OSAK)
 KASHA 68 PR 172 1297 +STEFANSKI (BNL+YALE)
 KASHA2 68 PRL 20 217 KASHA, LARSEN, LEIPUNER, ADAIR (BNL+ALEJ)
 KASHA3 68 CJP 46 5730 KASHA, LARSEN, LEIPUNER, ADAIR (BNL+YALE)
 RANK 68 PR 176 1635 D.M. RANK (MICH)
 ALLABY 69 NC 644 75 +BIANCHINI, DIDDENS, DOBSON, HARTUNG+ (CERN)
 ANTIPOV1 69 PL 298 245 +KARPOV, KHROMOV, LANDSBERG, LAPS HIN+ (SERP)
 ANTIPOV2 69 PL 308 576 +BOLOTOV, DEVISHVILI, DEVISHVILI, SAKOVA+ (SERP)
 CAIRNS 69 PR 186 1394 +MCCUSKER, PEAK, WOODCOTT (SYDNEY)
 COOK 69 PR 188 2092 +DEPASQUALI, FRAUENFELDER, PEACOCK+ (ILL)
 FUKUSHIMA 69 PR 178 2058 FUKUSHIMA, KIFUNE, KONDO, KOSHIBA+ (TOKY)
 MCCUSKER 69 PRL 23 658 MCCUSKER, CAIRNS (SYDNEY)

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

MAGNETIC MONOPOLE, CHARM SEARCHES

Table listing particle data for various experiments including BOSIA, CHU, ELBERT, FAISSNER, KRIDER, MORPURGO, ANTIPOV, CHIN, CLARK, HAZEN, BEUCHAMP, BOHM, BOTT-BODT, COX, CROUCH, DAKDO, EVANS, TONNAR, ALPER, ASHTON, HICKS, LEIPUNER, CLARK, GALIK, KIFUNE, NASH, ALBROW, FABJAN, HAZEN, JOVANDVI, KRISOR, BALDIN, BRIATORE, STEVENS, ANTREASY, BASILE, BLAND, GALLINAR, LARUE, MULLER, OGDORNDI, BASILE1, BASILE2, BOVD, BOVD2, PUTT, SCHIFFER, YOCK, BOVD, BOZZOLI, LARUE, STEVENSO, ZAITSEV, JONES.

REVIEW ARTICLES

MAGNETIC MONOPOLE SEARCHES

Table listing magnetic monopole searches with columns for experiment name, production method, cross section, and search details. Includes entries for AMALDI, GOTO, PETUKHOV, PURCELL, CARITHERS, FLEISCHER, SCHATTEN, KOLM, GUREVICH, CARRIGAN, ROSS, GIACOMELLI, BURKE, PRICE, CARRIGAN, OFFMAN, HOFFMAN.

Table listing magnetic monopole searches with columns for experiment name, production method, cross section, and search details. Includes entries for CARITHERS, FLEISCHER, ROSS, PRICE, SCHATTEN, KOLM, GUREVICH, CARRIGAN, ROSS, GIACOMELLI, BURKE, PRICE, CARRIGAN, OFFMAN, HOFFMAN.

REFERENCES FOR MAGNETIC MONOPOLE SEARCHES

Table listing references for magnetic monopole searches, including authors and publication details. Includes names like BARONI, MANFREDINI, BRADNER, KOLM, FORD, YAKIMENKO, COLLINS, FUJII, HORNBOSTEL, TURKOT, CARITHERS, STEFANSKI, ADAR, FLEISCHER, HART, JACOBS, GUREVICH, SCHATTEN, KOLM, GUREVICH, WARE, CARRIGAN, ROSS, ALVAREZ, WATT, NEZRICK, STRAUSS, GUSTAFSON, JONES, LONGO, NEZRICK, CARRIGAN, NEZRICK, ROSS, TAYLOR, ALVAREZ, OBERLACK, GIACOMELLI, ROSSI, SHIRK, OSBORNE, PINSKY, LUIS ALVAREZ, PHILIPPE EBERHARD, R.L. FLEISCHER, R.M. WALKER, M.W. FRIEDLANDER, RONALD ROSS, PRICE HAGSTROM, RAY, SHIRK, OSBORNE, PINSKY, LUIS ALVAREZ, PHILIPPE EBERHARD, CARRIGAN, HOFFMAN, STRAUSS, GIACOMELLI, KANTARDJIAN.

CHARM SEARCHES

Data on specific charmed states are listed in separate sections in the appropriate places in the Data Card Listings: D, F, and Lambda_c - Stable Particles; D*, F* - Mesons; Sigma_c - Baryons.

Data Card Listings

For notation, see key at front of Listings.

Stable Particles

CHARM SEARCHES

CPI U BUNNELL 76 IS A SLAC 15.5 GEV P1+P EXPT. ALL POSSIBLE 2 TO 5-BODY... CP A 0 1. E-33 OR LESS AUBERT 75 SPEC P1+ K- 2/76... CP A 0 4. E-33 OR LESS AUBERT 75 SPEC K+ P1- 2/76... CP A 0 1. E-33 OR LESS AUBERT 75 SPEC K+ K- 2/76... CP A 0 2. E-33 OR LESS AUBERT 75 SPEC P1+ P1- 2/76... CP A 0 7. E-33 OR LESS AUBERT 75 SPEC P K- 2/76... CP A 0 2. E-33 OR LESS AUBERT 75 SPEC K+ PBAR 2/76... CP A 0 4. E-32 OR LESS AUBERT 75 SPEC P1 2/76... CP A 0 2. E-33 OR LESS AUBERT 75 SPEC P1+ PBAR 2/76... CP H 0 20. 10 TO 35. E-30 OR LESS AHAHLN 76 HBC BARYON, M LT 2GEV 2/77... CP H 0 15. TO 100. E-30 OR LESS AHAHLN 76 HBC BARYON, M 2-3 GEV 2/77... CP H 0 10. TO 35. E-30 OR LESS AHAHLN 76 HBC MESON, M 1-2 GEV 2/77... CP L 0 3.05 TO 1.35E-27 OR LESS ALBROW 76 SPEC K P1, K P 1/78... CP J 0 2. 3.0E-31 OR LESS BRANTING 76 SPEC M+ GEV/C#2 1/77... CP B 0 5. E-32 OR LESS BINTINGER 76 SPEC M+ GEV/C#2 1/77... CP C 0 9. E-30 OR LESS CL=95 ALDER 77 SPEC D -> K- P1+ 12/77... CP C 0 8. E-30 OR LESS CL=95 ALDER 77 SPEC DOBAR -> K+ P1- 12/77... CP C 0 3.6E-31 OR LESS CL=95 DITZLER 77 SPEC DO -> NOTE S BELOW 7/77... CP D 0 2.9E-31 OR LESS CL=95 DITZLER 77 SPEC DOBAR -> K- P1+ 1/78... CP U 0 7.6E-29 OR LESS CL=95 BAUM 78 SPEC PP -> DO BAR ANYTHING 2/79#... CP R 32 (7.0E-31E-29) CLARK 78 SPEC PP -> DO BAR ANYTHING 2/79#... CP T 0 1.0E-31 OR LESS LAUTERBERG 78 SPEC D+ DO TO K MU NU 12/79#... CP K 2.6E-29 OR LESS CL=95 BRANSON 79 PP -> DO DOBAR + D+ 12/79#... CP K 5.9E-29 OR LESS CL=95 BRANSON 79 PP -> DO DOBAR + D+ 12/79#... CP W (1.3 TO 6.3)E-29 BROWN 79 SPEC C RILTINGAR 79 SPEC D DOBAR INCLUSIVE 12/79#... CP M (7 TO 20)E-30 DIAMANTBE 79 CNTR D, DOBAR -> MUCNS 12/79#... CP I 6.7E-28 OR LESS CL=95 DISHAW 79 CALD 430 GEV PP -> DOBAR 12/79#... CP E 9211.5-20)E-28 DRJAROD 79 SFM D+ -> X- P1+ P1+ 12/79#... CP E (3.0 TO 6.2)E-30 DRJAROD 79 SFM LAM/C+ TO KOBAR# 12/79#... CP E (6.3 TO 6.7)E-30 DRJAROD 79 SFM LAM/C+ TO K- DEL+ 12/79#... CP G (6.07 TO 1.8)E-30 GIBONI 79 SPEC LAM/C+ -> K- P1+ 12/79#... CP G (0.3 TO 0.7)E-30 GIBONI 79 SPEC LAM/C+ -> LAM (3P1) 12/79#... CP N (2.34-0.3)E-30 LOCKMAN 79 SPEC LAM/C+ -> X- P1+ P1+ 12/79#... CP N (2.34-0.3)E-30 LOCKMAN 79 SPEC LAM/C+ -> LAM (3P1) 12/79#... CP A AUBERT 75 IS A BNL 30 GEV EXPT. LOOKS FOR P BE -> JPRIME ANYTHING 2/76... CP A WHERE JPRIME DECAYED VIA THE CHANNEL SHOWN. ABOVE VALUES ARE 2/76... CP A FOR M=2.25GEV AND ASSUME A WIDTH SMALL COMPARED TO THE RESOLUTION. 2/76... CP A UPPER LIMITS ARE ALSO GIVEN FOR THE ABOVE CHANNELS AND P BAR FOR 2/76... CP A M=3 AND 2. THOSE LIMITS RANGE FROM 7E-36 TO 4E-33. 2/76... CP A MA 77 SAYS AUBERT 75 LIMITS SHOULD BE AN ORDER OF MAG. LARGER. 2/77... CP H AHAHLN 76 IS A 19 GEV/C P-P EXPT AT CERN. VALUES GIVEN ARE CL=975. 2/77... CP H SEE TABLE 28, PG 479 FOR INDIVIDUAL LAMBDA (OR KS) +P1CNS CHANNELS. 2/77... CP L ALBROW 76 IS ISR EXPT. ECM=59GEV. SEE THEIR TABLE 28, PG 317 FOR 1/78... CP L INDIVIDUAL MESON AND BARYON CHANNELS. EXAMINES MASS RANGE 2-4 GEV. 1/78... CP B BINTINGER 76 IS CROSS-SEC TIMES BR INTO K- P1+. WE SHOW TWO VALUES 1/77... CP B FROM THEIR FIG.4 WHICH COVERS MASS RANGE 1.7-4 GEV. SIMILAR LIMITS 1/77... CP B ARE GIVEN FOR K+ P1- AND P1+ P1- CHANNELS. LIMITS ARE PROPORTIONAL 1/77... CP B TO C5*BR FOR J/PSI INTO MU+ MU-, TAKEN-LONGB FOR ABOVE VALUES. 1/77... CP C ALDER 77 IS CERN-ISR EXPT AT ECM=53 GEV. 12/77#... CP S BRANSON 77 MEASURES (P1 NUC -> J C C BAR) / (P NUC -> ANYTHING) WITH 7/77... CP S J,C, AND C BAR ALL DECAYING TO MUONS. FINAL EXPT USING 225 GEV/C BEAM. 7/77... CP S DITZLER 77 IS FINAL 400 GEV P EXPT. ABOVE LIMITS ARE FOR 1/78... CP D BRK P1+ SIGMA/OY AT Y(CM)=0.4. 1/78... CP U BAUM 78 IS ISR EXPT AT ECM=55 GEV. MEASURES C5*BR(D -> X) BR(D -> MU) 1/78... CP U <.92 MICRONS AT THIS ENERGY. 2/79#... CP R CLARK 78 IS CERN-ISR EXPT LOOKING FOR E+ - MU+ - EVENTS. ERROR IS 2/79#... CP R STATISTICAL ONLY. ASSUMES THE SEMILEPTONIC BRANCHING FRACTIONS OF 2/79#... CP R THE D INTO ELECTRONS AND MUONS AS 10 PERCENT EACH. 2/79#... CP T LAUTERBERG 78 RESULT BASED ON POLARIZATION OF PROMPT MUONS IN 400 12/79#... CP T GEV P-NUCLEON INTERACTIONS. IN A FIELD OF D -> MU+ .07, CS#7 E-31. 12/79#... CP K FIRST BRANSON 79 VALUE IS AT ECM=54.4 GEV, SECOND AT ECM=27.4 GEV. 12/79#... CP W BRWON 79 SEES PROMPT 1 MUON SIGNAL IN 400 GEV PROTONS ON STEEL. 12/79#... CP V UNCERTAINTY IN C.S. IS DUE TO MODEL DEPENDENCE. 12/79#... CP V WILCHINSKY 79 ANALYZE CERN ISR EXPT AT 53 AND 63 GEV ECM FOR LOW 12/79#... CP N MASS LEPTON PAIR PRODUCTION. VALUE ABOVE IS C.S. PER UNIT OF 12/79#... CP V RAPIDITY NEAR Y=0. 12/79#... CP M DIAMANTBERGER 79 USES 400 GEV PROTONS CN FE AND LOOKS FOR MISSING 12/79#... CP M ENERGY IN MU+ MU- PRODUCTION INDICATIVE OF FINAL STATE NEUTRINOS. 12/79#... CP E DRJAROD 78 IS CALORIMETRIC EXPT AND LOOKS FOR LOW ENERGY TAIL OF 12/79#... CP I ENERGY DISTRIBUTIONS DUE TO ENERGY LOST TO WEAKLY INTERACTING 12/79#... CP I PARTICLES. ASSUMES SEMILEPTONIC B.R.=0.11. 12/79#... CP E DRJAROD 79 IS CERN-ISR EXPERIMENT AT ECM=53 GEV. FOUND A PEAK AT 12/79#... CP E DMASS (K+ P1+ P1+ MASS DISTRIBUTION WHEN MASS OF AT LEAST ONE OF 12/79#... CP E TWO (K+ P1+) PAIRS IS REQUIRED INSIDE THE K*(890) REGION. CORRECTED 12/79#... CP E FOR BRANCHING RATIO. SEE TABLE 3 FOR C.S. ESTIMATION. 12/79#... CP E DRJAROD 79 IS CERN ISR EXPT AT 53 GEV ECM. SEES MASS ENHANCEMENT 12/79#... CP E AT 2.26 GEV IN BOTH CHANNELS. RANGE IN VALUES DUE TO MODEL 12/79#... CP G DEPENDENCE VALUES ARE SHOWN FOR MODES SHOWN. 12/79#... CP G GIBONI 79 IS CERN ISR EXPT AT 63 GEV ECM. SEES MASS ENHANCEMENT NEAR 12/79#... CP G 2.255 GEV IN BOTH CHANNELS. VALUES ARE SIGMA*BR FOR MODES SHOWN. 12/79#... CP N LOCKMAN 79 IS A CERN ISR EXPT AT 53 AND 62 GEV ECM. SEES A MASS 12/79#... CP N ENHANCEMENT AT 2.29 GEV IN BOTH CHANNELS. VALUES ARE SIGMA*BR FOR 12/79#... CP N MODES SHOWN AND FOR 0.75X<0.90 IN ONE HEMISPHERE. 12/79#...

CHARMED HADRON PRODUCTION CROSS SECTION (N NUCLEON) (CM**2) B 0 1.9E-31 OR LESS BLESER 75 SPEC K P1+, M=1.8 GEV 2/77... B 0 1.0E-31 OR LESS BLESER 75 SPEC K P1+, M=2.5 GEV 2/77... B 0 1.0E-31 OR LESS BLESER 75 SPEC K- P1+, M=2.5 GEV 2/77... W 0 2.5E-29 OR LESS CL=975 WARD 75 HBC KS P1+ P1- 1/77... A 0 6. E-32 OR LESS ABOLINS 76 SPEC P1+ P1- 1/77... A 0 7. E-32 OR LESS ABOLINS 76 SPEC PBAR P 1/77... A 0 6. E-32 OR LESS ABOLINS 76 SPEC K- P1 1/77... G 0-2 SEE COMMENT G BELOW BINKLEY 76 SPEC 1/77... L 0 1.10E-31 OR LESS ABOLINS 78 SPEC C+ TO LAMBDA P1+ 6/78#... T 0 2.8E-31 OR LESS CL=90 BDMPSST 78 SPEC D+ -> K- P1+ 12/79#... T 0 2.5E-31 OR LESS CL=90 BDMPSST 78 SPEC D+ -> KO P1+ 12/79#... P 0 3.4E-31 OR LESS CL=95 LIPTON 78 SPEC 8/78#... S 0 2.0E-31 OR LESS CL=95 SLEBRING 78 SPEC K+ P1-, M=1.86GEV 8/78#... D 0 3.8E-31 OR LESS CL=90 BDMPSST 79 SPEC DO -> K- P1+ 12/79#... D 0 3.2E-31 OR LESS CL=90 BDMPSST 79 SPEC DO -> K P1+ 12/79#... D 0 1.3E-30 OR LESS CL=90 BDMPSST 79 SPEC D+ -> K- P1+ P1- 12/79#... D 0 1.1E-30 OR LESS CL=90 BDMPSST 79 SPEC D+ -> K P1+ P1- 12/79#... D 0 5.9E-31 OR LESS CL=90 BDMPSST 79 SPEC F -> K+ K- P1+ 12/79#... D 0 4.8E-31 OR LESS CL=90 BDMPSST 79 SPEC F -> K+ K- P1+ 12/79#... D 0 1.3E-30 OR LESS CL=90 BDMPSST 79 SPEC LAM/C+ -> K- P1+ 12/79#... D 0 2.3E-31 OR LESS CL=90 BDMPSST 79 SPEC LAM/C+ -> P KOBAR 12/79#... B BLESER 75 USES NEUTRONS UP TO 300 GEV/C. BE TARGET. EXAMINES MASS 2/77... B RANGE UP TO 3.5 FOR KP1, UP TO 4.0 FOR K P1. VALUES ARE CROSS-SEC/NUC 2/77... B PBAR P. POSSIBLE K+ P1+ PEAK AT 2.29 SEEN IN ABOLINS DOBAR -> K P1+ 6/78#... W RANGE 1.5-2.5 GEV. SEE TABLE 1 PG 31 FOR UPPER LIMITS ON C++C+, 1/77... W C0+D0, D0, D- DECAYS INTO VARIOUS FINALSTATES IN MASS RANGE 1.5-5.0GEV, 1/77... W UPPER LIMIT FOR SEEING DECAY OF CHGD CHARMED PARTICLE INTO VO FOR 1/77... W TAU GT 10**11 SEC GIVEN AS 1.5E(PT) FOR VO - LAMBDA OR SIGMA, AND 1/77... W 3.0E(PT) FOR VO=KO. HERE, T=10**11/TAU, CS GIVEN IN MICROBARS. 1/77... W A ABOLINS 76 IS FINAL EXPT. USES NEUTRONS UP TO 300 GEV/C ON BE TARG. 1/77... W A TYPICAL VALUES ABOVE ARE FOR M=3.0 GEV. SEE FIG 4 FOR MASS RANGE 1/77... W A 2-4 GEV. OBSERVES POSSIBLE K+ P1+ ENHANCEMENT AT 2.29. 12/79#... G BINKLEY 76 MEASURES BR(G) TO MU OTHERS; WHERE R IS THE RATIO OF 1/77... G THE CROSS-SEC FOR PRODUCING THE J/PSI TOGETHER WITH A C-BAR PAIR 1/77... G TO THE TOTAL CROSS-SEC FOR PRODUCING THE J/PSI AT THIS ENERGY. THE 1/77... G EXPT WAS A 300 GEV FINAL RUN, AND SAW 2 TRI-MUON EVENTS. THIS GAVE 1/77... G A +0.01 CL UPPER LIMIT OF .003 FOR THE MEASURED QUANTITY DESCRIBED 1/77... G ABOVE. 1/77... L ABOLINS 78 IS A 250 GEV/C N-BE EXPT LOOKING FOR NARROW ENHANCEMENTS 6/78#... L IN RANGE 1.7-3.5 GEV. CHANNELS EXAMINED ARE P1+P1-, K- P1+, K P, 6/78#... L PBAR P. POSSIBLE K+ P1+ PEAK AT 2.29 SEEN IN ABOLINS 76 NOT SEEN 6/78#... L HERE. STATISTICS HERE ARE 5 TIMES ABOLINS 76 STATISTICS. 6/78#... L IF SAME PSI PRODUCTION MODEL WERE ASSUMED HERE AS WAS USED IN 6/78#... L ABOLINS 76, THE 78 LIMITS WOULD BE SMALLER BY A FACTOR OF 3. 6/78#... L BDMPSST 78 IS A SERP EXPT USING 45 GEV NEUTRONS (LIMITS CS/NUC FOR 8/78#... L LIPTON 78 IS 300 GEV N-BE EXPT. FINAL. QUOTED IS CS/NUC FOR 8/78#... P ASSOC CHARM PROD WITH ONE CHARMED PARTICLE -> ELECTRON AND THE 8/78#... P OTHER -> MUON. 8/78#... S SLEBRING 78 IS 300 GEV N-BE EXPT AT FINAL. VALUE QUOTED IS CS/NUC 8/78#... R PROD OF DO AND ANOTHER CHARGED PART. DO -> K P1 AND 8/78#... S SECOND CHARMED PARTICLE DECAYING TO PROMPT MUON. 8/78#... D BDMPSST 79 IS SAME EXPERIMENT AS BDMPSST 78. 12/79#... CAP CHARMED HADRON PRODUCTION CROSS SECTION (P NUCLEON) (CM**2) CAP C 0 3. E-29 OR LESS CL=95 CARLSSON 75 HBC PBAR P ANYTHING 2/77... CAP C 0 3. E-29 OR LESS CL=95 CARLSSON 75 HBC PBAR P P1+ P1- 2/77... CAP E 0 .8 TO 4.4 E-30 OR LESS CESTER 76 SPEC 12.4 TO 15 GEV/C 2/77... CAP J 0 .15 TO 1. E-29 OR LESS JACHOLKOW 78 BEBC 12GEV/C PBAR P 12/79#... CAP C CARLSSON 78 IS A 9GEV PBAR P CERN EXPT. LIMITS ARE FOR P BAR PEAK 2/77... CAP C IN CHANNELS INDICATED. K KBAR CHANNELS CHECKED BUT NO LIMITS GIVEN. 2/77... CAP E CESTER 76 LOOKS AT MASS RANGE 1.8 TO 2.5 GEV. SEE TABLE 1 FOR 2/77... CAP E INDIVIDUAL CHANNELS. VALUES GIVEN ARE CROSS-SEC/NUCLEON ON CARBON. 2/77... CAP J JACHOLKOWSKA 78 IS CERN EXPT LOOKING FOR NARROW PEAKS IN COBALT-60 1/79#... CAP J AND LAMBDA+PI0NS SPECTRA. SEE TABLES 1 AND 2 FOR INDIVID CHANNELS. 1/79#... BD BEAM DUMP EXPTS SEARCHING FOR NEUTRAL PENETRATING PARTICLES AND 6/78#... BD PROMPT NEUTRONS FROM UNKNOWN SOURCES 6/78#... A ALIBRAN 78 IS CERN SPS EXPT. SEE EXCESS PROD OF PROMPT ENU AND 6/78#... A ENEUBAR EVENTS. COULD BE EXPLAINED BY (CHARMED D PRODUCTION C.S.) 6/78#... A #BR(D -> X+ NEU X) = 32+157-10 MICROBARS. 6/78#... B ASRATYAN 78 CALD ASRATYAN 78 ESTIMATE (D DOBAR PROD. C.S.)#BR(D -> X) AS (1.9+1.5) 1/80#... B SD (0.5+0.4) MICROBAR FOR A**1.5 OR A**1 RESPECTIVELY. 1/80#... B B BOSETTI2 78 IS CERN SPS EXPT. BOSETTI2 PROMPT NEUTRONS WITH EQUAL 6/78#... B BOULETS OF NEU AND NEUBAR OF BOTH E AND MU TYPES COULD COME FROM 6/78#... B DECAY OF SHORT-LIVED LIGHT PARTICLES OF NEW TYPE. TAU LEPTONS AND 6/78#... B AXIONS EXCLUDED. CHARM (D DOBAR) PRODUCTION WOULD HAVE TO HAVE 6/78#... B 100-400 MICROBAR CROSS SECTION TO EXPLAIN RESULTS. 6/78#... B H HANSL 78 IS CERN SPS EXPT. SEES PROMPT NEUTRINO FLUX CONSISTENT 6/78#... H WITH EQUAL AMOUNTS OF ENU, ENEUBAR, MUNEU, MUNEUBAR. COULD BE 6/78#... H EXPLAINED AS CHARM(D DOBAR) PRODUCTION WITH ABOUT 30 MICROBAR 6/78#... B CROSS SECTION. 6/78#... B COTEU 79 IS BNL EXPT. SEES NO EXCESS N.C. RATE IN BEAM DUMP. SETS 7/79#... B CLIMIT FOR CS(PROD)*CS(INT) OF PENETRATING PARTICLES < 5E-68 CM**4. 7/79#... Y CHARMED HADRON EVIDENCE IN NEUTRINO NUCLEON -> 2 LEPTONS ANYTHING 7/79#... Y ALSO SEE SECTION 'NEUS' IN 'HEAVY LEPTON SEARCHES' AND VO AND VOA BELOW. 7/79#... Y SECTION 'TA' IN 'OTHER NEW PARTICLE SEARCHES' AND VO AND VOA BELOW. 7/79#... Y B 14MU+MU- 0MU+MU- 0MU+MU+ BENVENUTI 75 SPEC PREDOM. NEU BEAM 2/76... Y B 51MU+MU- 7MU+MU- 3MU+MU+ BENVENUTI 75 SPEC 6/77 NEU BEAM 2/76... Y B 5MU+MU- 0MU+MU- 2MU+MU+ BENVENUTI 75 SPEC 9/10ANTINEU BEAM 2/76... Y S 4MU+MU- 4 OTHER MU PAIRS BARISH 76 SPEC NEU BEAM 1/76... Y S 32 DIMUON EVENTS ASRATYAN 77 SPEC NEU BEAM 1/78... Y A 4MU+E- 6MU+E- BALLAGH 77 HLBC .95 NEUBAR. 4.5 NEU 12/77... Y L 81 EVENTS MU+E+ BALYATY 77 HLBC PREDOM. NEU BEAM 8/77... Y K 1 EVENT MU+E+ BARISH 77 DBC NEU BEAM 3/77... Y R 67 MU+MU- BARISH72 77 SPEC FNAL 45-205GEV NEU 1/78... Y Z 28 MU+MU- BARISH72 77 SPEC FNAL 45-205 ANTINEU 1/78... Y Z 17 EVENTS MU+E+ BOSETTI2 77 HYBR 7/77... Y D 11 MU+E+ DEDED 77 HLBC 12/77... Y D 15 MU+MU- HADY 77 HLBC 1/78... Y I 257MU+MU- HOLDER 77 SPEC INCIDENT NEU 12/77... Y I 58MU+MU- HOLDER 77 SPEC INCIDENT ANEU 12/77... Y J 47 MU+MU- HOLDER2 77 SPEC NEU BEAM 12/77... Y J 9 MU+MU- BARISH72 77 SPEC NEU BEAM 12/77... Y C 46 MU+MU- 199 MU+ MU- BENVENUTI 78 SPEC PREDOM. NEU BEAM 1/79#... Y C 2 MU+MU+ 49 MU+ MU- BENVENUTI 78 SPEC PREDOM. NEUBAR BEAM 1/79#... Y E 10MU+MU- 3MU+MU- 5MU+E+ BOSETTI11 78 HYBR NEU BEAM 6/78#... Y E 2MU+MU- 1MU+E- BOSETTI11 78 HYBR NEUBAR BEAM 6/78#... Y E 15 MU+ E+ BARISH72 78 BEBC NEU BEAM 1/79#... Y M 94 MU+MU- ARMENISE 79 HYBR NEU BEAM 1/80#... Y X 12 MU+E- BERGE 79 HLBC NEUBAR BEAM 7/79#... Y G 67 MU+MU- DEGRDOT 79 SPEC NEU BEAM 1/80#... Y G 19 MU+MU- DEGRDOT 79 SPEC NEUBAR BEAM 1/80#... Y N 34 MU+MU- 35 MU E BALLAGH 80 HYBR NEU BEAM 2/80#...

Stable Particles
CHARM SEARCHES

Data Card Listings
For notation, see key at front of Listings.

Y B BENVENUTI 75 ARE FINAL NEUTRINO NUCLEON EXPERIMENTS WHICH LOOKED FOR 2/76
 Y B TWO OR MORE MUONS IN THE FINAL STATE. NO TRIMUON EVENTS WERE SEEN. 2/76
 Y B AUTHORS STATE THAT THESE DIMUON EVENTS REQUIRE THE EXISTENCE OF ONE 2/76
 Y B OR MORE NEW PARTICLES WITH M=2-4GEV AND TAU=10**-.10SEC. OR LESS. 2/76
 Y B BENVENUTI 75 SHOW THAT THE OBSERVED PROPERTIES OF THESE EVENTS 2/76
 Y B DO NOT AGREE WITH HYPOTHESES OF HEAVY LEPTON OR INTERMEDIATE VECTOR 2/76
 Y B BOSON. THEY SUGGEST A HADRON (Y1 WITH A NEW QUANTUM NUMBER. 2/76
 Y S ASRAYTAN 77 IS SERPKOVH EXPT. FINDS R=(DIMUONS/SINGLE MUON EVENTS) 1/78
 Y S GT (6.2+-1.7)E-3 FOR NEU BEAM AND LT .011 FOR NEUBAR BEAM. 1/78
 Y A BALLAGH 77 IS AN FINAL EXPT. MEASURES (NEUMU N-->MU+ E+ X)/(ALL NUMU 12/77
 Y C.C.1=1.24+-23-.13)*10**-.2 AND (NEUMUOR N-->MU+ E+ X)/(ALL NUMUBAR 12/77
 Y C.C.1=1.15+-14-.08)*10**-.2. RATIO OF ANTINEU TO NEU FRACTIONS IS 12/77
 Y (0.45+-0.6+-0.3). 12/77
 Y L BALTAY 77 IS FINAL EXPT IN NEON-H2 MIXTURE. 8/77
 Y K BARIISH 77 EVENT COULD BE NEU P TO MU+ B**+. SEE CHARMED BARYON NOTE 3/77
 Y K AND LAMBDA/C+ SECTION ABOVE. 3/77
 Y R BARIISH 77 FINDS DIMUON TO SINGLE MUON RATE CONSISTENT WITH CHARM. 1/78
 Y Z BLETZACKER 77 EXPLAINS TRIMUON AND LIKE SIGN DIMUON PROD AS ASSOC 12/77
 Y Z PROD OF CHARM. 12/77
 Y C BOSETTI 77 IS FINAL 15-FT CHAMBER EXPT. 1/77
 Y D DEDEN 77 IS CERN WIDE BAND EXPT. EMAX=2 GEV.11+-5 EVENTS ABOVE A 12/77
 Y D BACKGROUND OF 6 EVENTS. 12/77
 Y H HAIDT 77 IS SAME EXPT AS VONKROGH 76 LISTED UNDER S29V0. MEASURES 1/78
 Y H (NEUMU N-->MU+ E+ X)/(NEUMU N-->MU+ X)=1.63+--.21E-2 FOR T(E+)>.8 GEV. 1/78
 Y THESE EVENTS HAVE AN AVERAGE OF 2.0+-0.6 KO PER EVENT. 1/78
 Y I HOLDER 77 IS CERN NARROW-BAND BEAM EXPT IN WHICH ALL MOMENTA ARE 12/77
 Y I MEASURED ENERGY SPECTRA, ANG. CORRELATIONS, PT DISTRIBUTIONS ALL IN 12/77
 Y I AGREEMENT WITH PROD AND DECAY OF CHARMED PARTICLE. 12/77
 Y J HOLDER 77 IS 200GEV NARROW BAND EXPT. AFTER BACKGROUND SUBTRACTION 12/77
 Y J THE RATE OF LIKE-SIGN DIMUON EVENTS TO CHARGED CURRENT EVENTS IS 12/77
 Y J (3+-2)*10**-.4. MAY COME FROM ASSOC PROD OF CHARM-ANTI CHARM PAIR. 12/77
 Y C BENVENUTI 78 IS FINAL EXPT. MEASURE PROMPT DIMUON RATIO 1/79
 Y C (MU+MU+)->0 FOR P(MU+)>5 GEV/C AND E-12+-05 FOR 1/79
 Y C (MU+MU+)>10 GEV/C. (MU-MU-) MAY COME FROM ASSOCIATED CHARM PRODUCTION. 1/79
 Y C ABOVE 80 GEV, THE RATIO OF DIMUON TO SINGLE-MUON EVENTS IS 1/79
 Y C (0.65+-0.13)*10**-.2 FOR NEU AND (0.70+-0.25)*10**-.2 FOR NEUBAR. 1/79
 Y C FOR PNU 75 5 GEV/C. 1/79
 Y E BOSETTI 78 IS A CERN NE-H2 EXPT USING 200 GEV NARROW BAND BEAM. 6/78
 Y E RATE FOR (MU+ E+ + MU+ MU-)/MU- IN NEU BEAM IS 0.013+-0.004. 6/78
 Y E RATE FOR (MU+ E+ + MU+ MU-)/MU+ IN NEUBAR BEAM IS 0.012+-0.005. 6/78
 Y E ERRIQUEZ 78 IS CERN SPS EXPT. FINDS (NUMU N-->MU+ E+ X)/(ALL NUMU 1/79
 Y C.C.1=1.41+-15*10**-.2 (E+>36EV). DIRECT E+ PROD. VIA N.C. IS 1/79
 Y E <0.2 TIMES C.C. LIFETIME OF POSSIBLE E+ PARENT PARTICLE IS LESS 1/79
 Y E THAN 3*10**-.12 SEC. 1/79
 Y M ARMEISE 79 IS A CERN SPS EXPT. FINDS R=(MU+MU-)/(SINGLE MU- EVTS) 1/80
 Y M =0.72+-0.14E-2. UPPER LIMIT FOR D LIFETIME IS 0.8 E-12SEC(CI=0.9) 1/80
 Y BERGE 79 IS FINAL EXPT IN 15 FT CHAMBER USING H-NE MIXTURE. RATE FOR 1/79
 Y X (MU+ E- X)/(MU+ X)=0.36+-0.11. 1/79
 Y G DEGRODT 79 IS CERN WIDE BAND EXPT. RATES ARE (MU-MU-)/(LMU-)= 1/80
 Y G (3.4+-1.8)E-5, (MU-MU-)/(MU+MU+)=(.041+-0.021), (MU+MU-)/(LMU-)= 1/80
 Y G (4.4+-2.3)E-5. (MU+MU-)/(MU+MU+)=(.042+-0.023) 1/80
 Y N BALLAGH 80 EVENTS INCLUDE DIRECT OBSERVATION OF PROD. AND VISIBLE 1/80
 Y N SEMI-LEPTONIC DECAY OF SHORT-LIVED PARTICLES (1 CHGD, 2 NEUTRAL, 1/80
 Y N AND 1 UNDETERMINED CHARGE). 1/80
 VO NUMBER OF VOS PER EVENT IN NEUTRINO NUCLEON--> MU- E+ VO ANYTHING 11/79
 VO WHERE THE VO IS A KOS OR A LAMBDA (SEE ALSO SECTION Y AND VO) 11/79
 VO B 1 DEDEN 75 HLBC 2/76
 VO B 1 BLIETSCHAU 76 HLBC 2/76
 VO V 4 VONKROGH 76 HLBC 2/76
 VO 15 0.6 0.2 BALTAY 77 HLBC 1/79
 VO 11 1.84 0.63 0.53 BOSETTI 77 HYBR KOS/(MU+E+)EVENT 11/79
 VO D 3 DEDEN 77 HLBC 12/77
 VO 8 1.7 3.7 BOSETTI 78 HYBR KOS/(MU-L+)EVENT 11/79
 VO 5 1.2 0.5 ERRIQUEZ 78 BEBC 1/79
 VO A 9 0.53 0.25 0.20 ARMEISE 79 HYBR K0/(MU+MU-)+EVENT 1/80
 VO A 3 0.03 0.06 0.04 ARMEISE 79 HYBR LAMBDA/(MU+MU-)+EV 1/80
 VO S 1 BARANOV 79 EVENT 1/79
 VO B THE DEDEN 75 AND BLIETSCHAU 76 EVENTS ARE FROM CERN 2/76
 VO B GARGAMELLE NEUTRINO EXPOSURES. THE MASSES OF THE E+ VO SYSTEM FOR 2/76
 VO B THE TWO EVENTS ARE 1.24, 1.91 GEV FOR LAMBDA OR 0.65, 1.57 FOR KO. 2/76
 VO V THE VON KROGH 76 EVENTS ARE FROM AN FINAL 15 FT NEON BUBBLE CHAMBER 2/76
 VO H EXPOSURE. ALL FIDUCIAL EVENTS FOUND HAVE ASSOCIATED KOS. 2/76
 VO D DEDEN 77 EVENTS INCLUDE THOSE OF DEDEN 75 AND BLIETSCHAU 76. 12/77
 VO A ARMEISE 79 IS A CERN SPS EXPT. 1/80
 VO S BARANOV 79 EVENT FROM SKAT(SERPKOVH). MAY BE LAMBDA/C+ TO E+NEU 1/79
 VO S LAMBDA. 1/79
 VO 1/79
 VO AVG 0.11 0.12 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.5) 12/79
 VO STUDENT 0.97 0.66 AVERAGE USING STUDENT(10/H/1.1) -- SEE MAIN TEXT 12/79
 VO A NUMBER OF VOS PER EVENT IN ANTI NEUTRINO NUCLEON--> MU+ E+ VO ANYTHING 12/79
 VO WHERE VO IS A KOS, LAMBDA OR LAMBDA BAR (SEE ALSO SECTION Y AND VO) 12/79
 VO E 0 BERGE 77 HLBC 3/77
 VO B 8 1.8 0.7 BERGE 79 HLBC 12/79
 VO A BERGE 77 USED FINAL 15 FT CHAMBER FILLED WITH H-NEON. SAW TWO 3/77
 VO A POSSIBLE MU E EVENTS, COMMENSURATE WITH PREDICTED BACKGROUND. 3/77
 VO A NEITHER WITH ASSOCIATED VO. 3/77
 VO A BERGE 79 QUOTES 21+-8 NEUTRAL STRANGE PARTICLES FOR 12(MU+ E-). WE 12/79
 VO A DIVIDE. 12/79
 R1 CHARMED HADRON BRANCHING RATIO INTO (MU NEU ANYTHING)/TCTAL 12/77
 R1 B 8 A FEW PERCENT BENVENUTI 75 SPEC FINAL NEUTRINO NU 2/76
 R1 H 315 APPROX 0.15 HOLDER 77 SPEC 12/77
 R1 A 0.19 OR LESS BAUM 77 12/77
 R1 D 3 .15 .18 .07 DEDEN 77 HLBC 1/78
 R1 B BENVENUTI 75 LOOKS AT ANTI NEUTRINO NUCLEON --> MUON HADRONS. SEES 2/76
 R1 B EXCESS EVENTS ABOVE INCIDENT ENERGY 30 GEV. COMPARES BENVENUTI 75 2/76
 R1 B DIMUON EVENTS WITH EXCESS EVENTS TO GET BRANCHING RATIO. 2/76
 R1 H HOLDER 77 VALUE IS FROM NEU AND ANEU INDUCED DIMUON EVENTS OF 12/77
 R1 H OPPOSITE SIGN. SEE SEC. Y LISTING ABOVE. BR CALCULATED USING EFF 12/77
 R1 H BASED ON DECAY OF D+(1850) TO KO MU+ NEU. 12/77
 R1 A BAUM 77 PUTS UPPER LIMIT ON E-- MU+ PROD AT ISR. INFERS BR ABOVE 12/77
 R1 A FROM THIS, ASSUMING THAT ALL DIRECT ELECTONS COME FROM THE D. 12/77
 R1 D DEDEN 77 IS FOR CHARMED BARYON --> LAMBDA LEPTON+ NEU ANYTHING. 1/78
 R1 D SEES 3 NEU N --> MU+ E+ X EVENTS AND EXCESS OF 42+-20 NEU N --> 1/78
 R1 D MU+ LAMBDA X EVENTS OVER EXPECTED ASSOC. PROD.. SUGGESTS CHRM.BAR. 1/78
 R2 CHARMED HADRON (ASSOC. VO) BRANCHING RATIO INTO SEMILEPTONICS/ALL 2/76
 R2 B 2 0.1 OR MORE BLIETSCHAU 76 HLBC M=2.5-4 GEV 2/76
 R2 B THIS BR.RATIO AND MASS ARE REQD. BY OBSERVED RATE AND CHARM SCHEME. 2/76
 R3 CHARMED HADRON BRANCHING RATIO INTO (E NEU ANYTHING) 12/77
 R3 B 0.11 0.03 BRANDEL 77 SPEC E+ E- 4-5.2 GEV(CM) 12/77
 R3 B 0.16 0.06 BRANDEL 77 SPEC E+ E- 4-5.2 GEV(CM) 12/77
 R3 B 0.082 0.019 FELLER 78 SMAG E+ E- 3.9-7.4GEV ECM 11/79
 R3 B FIRST BRANDELKIT VALU USES INCLUSIVE ELECTRON EVENTS. SECOND 12/77
 R3 B VALUE(ERROR STAT ONLY) USES EVENTS WITH A SECOND ELECTRON. 12/77

CC CHARMED HADRON EVIDENCE IN COSMIC RAYS 71 EMUL 9/76
 CC N 1 EVENT TADOKI 75 9/76
 CC N NIU 71 DETECTS CHGD PARTICLE DECAYING INTO HADRON+PIO. MASS=1.78GEV 9/76
 CC N AND TAU=2.2 E-14 IF SECONDARY IS PION. MASS=2.95 GEV AND TAU=2.6 9/76
 CC N E-14 IF IT IS PROTON. POSSIBLE EVIDENCE OF PAIR PRODUCTION. 9/76
 CC T 8 EVENTS TASAKA 75 EMUL 9/76
 CC CC SAME TYPE AS NIU EVENT. TAU BETH 1.5 AND 175 E-13. 9/76
 CC S 1 EVENT SUGIMOTO 75 EMUL 1/77
 CC S SAME TYPE AS NIU EVENT. TWO SUCH PARTICLES PRODUCED TOGETHER. 1/77
 CC S TAU1=6.E-13, DECAYS TO CHARGED PRONG + ETA. TAU2=4.E-12, DECAYS TO 1/77
 CC S CHARGED PRONG + PIO. MASSES OF BOTH PARTICLES ARE ABOUT 2.0 GEV IF 1/77
 CC S DECAY PRONG IS PROTON. 1.7 IF DECAY PRONG IS KADN. AND 1.55 IF 1/77
 CC S DECAY PRONG IS PI. COMBINED MASS OF THE TWO NEW PARTICLES = 4.1 GEV 1/77
 CC S OR 3.8 GEV ASSUMING THE DECAY PRONGS TO BE KADNS OR PIONS 1/77
 CC S RESPECTIVELY. CONSISTENT WITH LAMBDA/C+ LAMBDA BAR/C- .5EE GAISSER 76 1/77
 CC A 4 EVENTS SAKAYANAG 79 EMUL 1/80
 CC A SAKAYANAG 79 ANALYZE BRAZIL-JAPAN COLLAB DATA AT MT. CHACALATA. 1/80
 CC A THE VERY HIGH RATE 4/24 OF X-PARTICLE EVENTS MAY BE DUE TO HIGH 1/80
 CC A ENERGY OF THE INCIDENT HADRONS (APPROXIMATELY 10**5 GEV). 1/80
 EM CHARMED HADRON CROSS SEC. IN MISC. EMUL. EXPTS. WHERE LIFETIME SEEN 3/77
 EM J 1 EVENT JAIN 75 EMUL TAU APPROX. 10E-13 2/77
 EM K 2 EVENTS KCMAR 75 EMUL TAU LT. E-15 4/77
 EM B 1 EVENT BURKH 76 EMUL TAU APPROX E-13 3/77
 EM C 0.1SE-30 OR LESS CL=90 COREMANS 76 EMUL TAU E-12 TO E-14 3/77
 EM N 3 EVENTS (SEMILEPTONIC) BANIK 77 EMUL TAU E-13 TO E-15 12/79
 EM A 1 EVENT BANIK2 77 EMUL TAU APPROX E-14 12/79
 EM Z 0.7E-30 OR LESS CL=90 BOZZOLI 77 300,400 GEV P-NUCL 1/78
 EM M 0.0018 OR LESS CL=90 MUNDRA 77 EMUL TAU E-12 TO E-14 1/78
 EM A 9 EVENTS KOMAR 78 EMUL TAU=1.2 E-14 1/80
 EM U 1 EVENT PAIR PROD USHIDA 78 EMUL 400 GEV P-NUCLEUS 2/79
 EM L 3 EVENTS ALLASTA 79 HYBR TAU APPROX E-13 12/79
 EM K KOMAR 77 IS FINAL 200 GEV/C PROTON EXPT. AT CERN. APPROX 1E-28 CM**2. 12/79
 EM N 2 ANGELINI 79 HYBR NEU BEAM 1/80
 EM F 1 EVENT (SEMILEPTONIC) FUCHI 79 EMUL TAU APPROX E-13 12/79
 EM I 1 EVENT PAIR PROD FUCHI 79 EMUL 400 GEV P-NUCLEUS 12/79
 EM I 9 EVENTS KOMAR 79 EMUL 400 GEV P-NUCLEUS 12/79
 EM R 1 EVENT BURKH 79 EMUL 200 GEV P-NUCLEUS 12/79
 EM J JAIN 75 IS A FINAL 300 GEV PROTON EXPT. EVENT SHOWS DECAY OF NEUTRAL 2/77
 EM J INTO HADRON-E-NEU, TAKING PLACE .019 CM FROM THE PROD VERTEX. 2/77
 EM J BE LEPTONIC DECAY OF CHARMED PARTICLE. 4/77
 EM K ANGELINI 79 EVENTS INCLUDE LAM/C+ -->PI+K- P WITH ESTIMATED DECAY 4/77
 EM K ELECTRON EMITTED FROM NEAR INTERACTION. SEE 2 EVENTS WITH SINGLE 2/77
 EM B BURKH 76 EXPT DONE AT FERMILAB HIGH ENERGY NEUTRINO BEAM. USED A 3/77
 EM B COMBINATION OF EMULSION AND SPARK CHAMBERS. THEY SEE A PARTICLE 3/77
 EM B WITH TAU-ABOUT 6 E-13 SEC DECAYING TO VO + 3 CHGD TRACKS. DECAY 3/77
 EM B MODE APPEARS DIFFERENT FROM PREVIOUSLY OBSERVED MODES OF CHARGED 3/77
 EM B HADRON DECAYS. SEE READ 79 FOR FURTHER ANALYSIS AND DISCUSSION. 7/79
 EM C COREMANS 76 USED 300 GEV/C PROTONS, AND LOOKED FOR ABOVE LIFETIMES. 3/77
 EM N DANNIK 77 USES 70 GEV PROTON BEAM AT SERPKOVH. MASS APPROX 2.4 GEV. 12/79
 EM K ANGELINI 79 USES 400 GEV P-NUCL BEAM AT SERPKOVH. MASS APPROX 2.4 GEV. 12/79
 EM Z BOZZOLI 77 IS FINAL EXPT LOOKING FOR ASSOC PROD OF CHARMED PARTICLES 1/78
 EM Z WITH TAU=3E-15 TO 3E-13 SECONDS AND MASS LT 4.5 GEV. 1/78
 EM M MUNDRA 77 IS FINAL 400GEV P EXPT. ABOVE VALUE IS RATIO TO PI+- PROD. 1/78
 EM A KOMAR 78 IS 400 GEV/C PROTON EXPT AT FINAL. C.C. APPROX 1E-28 CM**2. 1/80
 EM U USHIDA 78 SEES TWO NEUTRALS WITH TAU=3.02E-14 AND 1.18E-12 IF 2/79
 EM U MESONS, 4.21E-14 AND 1.23E-12 IF BARYONS. ASSUMES MESON DECAY MODES 2/79
 EM U K+E+NU AND PIO KO, BARYON DECAY MODES XI+E+NU AND PIO XIO. 2/79
 EM L ALLASTA 79 USES WIDE BAND NEU BEAM AT CERN. SEES DECAY OF NEUTRAL 12/79
 EM B SHORT-LIVED PARTICLE. 12/79
 EM A ANGELINI 79 IS NEU BEAM EXP AT CERN-SPS. SEE ALSO BURKH 76. 12/79
 EM N ANGELINI 79 EVENTS INCLUDE LAM/C+ -->PI+K- P WITH ESTIMATED DECAY 1/80
 EM N TIME (7.3+-0.1)*E-13 SEC. 1/80
 EM F FUCHI 79 IS 400 GEV P NUCLEUS EXPT AT CERN. 12/79
 EM I FUCHI 79 EVENT GIVES TAU 2.8-4.4E-13. SEE ALSO USHIDA 78. 12/79
 EM P KOMAR 79 EVENTS GIVE TAU APPROX 1.5E-14 SEC. CS/NUCLEON=1.2E-28. 12/79
 EM R KOMAR 79 EVENT MAY BE CHARMED BARYON TO E+- HADRONS VIA N.C. 12/79
 D CHARMED HADRON PRODUCTION IN NEU NUCLEON INTERACTIONS(RATIO TO C.C.) 1/79
 D B 64 .007 .002 EALTAY 78 HLBC D--> KO PI+ PI- 1/79
 D B 11 .001 .001 BALTAY 78 HLBC D--> KO K0 + 1/79
 D E .01 OR LESS BERGE 78 HBC DECAY TO LAMBDA PIS 12/79
 D E .02 OR LESS BERGE 78 HBC DECAY TO KO PIONS 12/79
 D L 2 0.041 0.024 BLIETSCHAU 79 HBC D** PRODUCT I/O/C.C. 1/80
 D B BALTAY 78 IS FINAL EXPT. NO DO SEEN IN N.C. EVENTS. 1/79
 D E BERGE 79 ALSO SET NEU P --> MU- DI--> KO N(PI1) X/C.C. <0.01 AT 12/79
 D E CL=0. 12/79
 D L BLIETSCHAU 79 IS CERN BEBC EXPT. SEES ONE EVENT NEU P-->MU+ P D** 1/80
 D L AND ONE EVENT NEU P-->MU- P O** PI+ PI-, WHERE D**=DO PI+ IN BOTH 1/80
 D L CASES. 1/80
 D 1/79
 D AVG 0.0023 0.0024 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.7) 12/79
 D STUDENT 0.0020 0.0012 AVERAGE USING STUDENT(10/H/1.1) -- SEE MAIN TEXT 12/79
 ***** 12/79 *****
 REFERENCES FOR CHARMED HADRON SEARCHES
 NIU 71 PTP 46 1644 +MIKUMI,MAEDA (TOKY+YOKOHAMA)
 TASAKA 73 PTP 50 1879 +YANAMOTO (KONA)
 AUBERT 75 PRL 35 416 +BECKER,BIGGS,BURGER,CHEN+ (MIT+BNL)
 ALSO 77 MA
 BALTAY 75 PRL 34 1118 +CAUTIS,COHEN,CSORNA,KALELKAR + (COLU+BNB)
 BENVENUTI 75 PRL 34 419 +BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
 BENVENUTI 75 PRL 34 597 +BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
 ALSO 74 PRL 33 984 AUBERT,BENVENUTI+ (HARV,PENN,WISC,FNAL)
 BENVENUTI 75 PRL 35 1199 +BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
 BENVENUTI 75 PRL 35 1249 +BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
 BLESER 75 PRL 35 76 +GOBBI,KENAH,KEREN+ (FNAL+MNS+ROCH+SLV)
 CARLSSON 75 NP 899 451 +EKSPONG,HOLMGREN,NILSSON+ (STOH+LIVP)
 DEDEN 75 PL 588 361 (IACH+BRUX+CERN+EPOL+MILA+ORSA+LUC)
 JAIN 75 PRL 34 1238 P. L. JAIN, B. GIRARD
 KOMAR 75 JETPL 21 239 +ORLOVA,TRETYAKOVA,CHERNYASKII (LEBO)
 ALSO 76 SJNS 24 275 KOMAR,ORLOVA,TRETYAKOVA,CHERNYASKII (LEBO)
 SUGIMOTO 77 PTP 53 1540 +SAITO SAITO (TMS+TKY)
 WARD 75 NP 8101 29 +ANSORGE,CARTER,MOUNT,NEALE+ (CAVE)
 AALIN 76 NP B107 476 +ALPGARD,ANDERSEN,BERGVAATN+(OSLO+STOH+HLS)
 ARLOFF 76 PRL 37 417 +CARDIMONA,MATTHEWS,SIODEN+ (WU+CGU+ARL)
 ALBROW 76 NP B114 365 +CERN+DARE+FOM+LANC+LIVP+MCHS+RHEL+UTR+LUND)
 APEL 76 SJNP 24 507 +BERTOLUCCI,VIKTOROV,VINCELLI+ (SERP+CERN)
 BARIISH 76 PRL 36 939 +BARTLETT,BODEK,BROWN,BUCHHOLZ + (CIT+FNAL)
 BINKLEY 76 PRL 37 578 +GAINES,PEOPLE,KNAPP+ (FNAL+COLU+HAWA+ILL)
 BINTINGER 76 PRL 37 732 +BINTINGER,LUNDY,AKERLOF+ (FNAL+MICH+PROD)
 BLIETSCH 76 PL 608 207 (IACH+BRUX+CERN+EPOL+MILA+ORSA+LUC)
 BUNNELL 76 PRL 37 85 +CHENG,DELPAPE,DORFAN,DEUNGVAN+ (UGCS+SLC)
 BURKH 76 PL 658 299 +LUDG+CERN+MICH+ORSA+STRB+ (LUDG+FNAL+BELG+DUIG+CERN+MICH+ORSA+STRB+)
 CESTER 76 PRL 37 1178 +FITZ,KADEL,WEBB,WHITAKER + (PRIN+BNL)

Stable Particles

Data Card Listings

OTHER STABLE PARTICLE SEARCHES

For notation, see key at front of Listings.

MU D1- AND TRI-MUON PRODUCTION IN MU NUCLEON INTERACTIONS
 CS 11 TRIMUON EVENTS CHANG 77 SPEC 12/77
 CS 32 DIMUON EVENTS CHANG 77 SPEC 12/77
 MU C CHANG 77 DIMUON RATE IS GT 5*10**4 THAT OF INCLUSIVE MUON RATE. 12/77
 MU C CROSS SECTION UNCORRECTED FOR ACCEPTANCE IS 5*10**36 CM**2/NUCLEON 12/77

CH HEAVY PARTICLE PRODUCTION CROSS SECTION (CM**2)
 CH L 0 1.E-31 OR LESS LEIPUNER 73 CNTR +- M=3-11 GEV 5/76
 CH C 2.1-1.3E-31 OR LESS CARROLL 78 SPEC M=2-2.5 GEV 1/779
 CH L LEIPUNER 73 IS AN ANAL 300 GEV P EXPT. WOULD HAVE DETECTED PARTICLES 4/76
 CH L WITH LIFETIME GREATER THAN 200 NSEC. 4/76
 CH C CARROLL 78 LOOK FOR NEUTRAL, S=2 DIHYPERON RESONANCE IN 1/779
 CH C P F -> 2K+ X. G.S. VARIES WITHIN ABOVE LIMITS OVER MASS RANGE AND 1/779
 CH C PLAB=5.1-5.9 GEV/C. 1/779

CS HEAVY PARTICLE PRODUCTION CROSS-SECTION (CM**2/NUCLEON)
 CS C 0 2.5E-35 OR LESS GUSTAFSON 76 CNTR O TAU GT 10**+7 1/777
 CS C GUSTAFSON 76 IS 200 GEV FINAL EXPT LOOKING FOR HEAVY (M GT 2 GEV) 1/777
 CS G LONGLIVED NEUTRAL HADRONS IN THE M4 NEUTRAL BEAM, THE ABOVE TYPICAL 1/777
 CS G VALUE IS FOR M=3 GEV AND ASSUMES AN INTERACTION CROSS SECTION OF 1/777
 CS G 1 MB. VALUES AS A FUNCTION OF MASS AND INTERACTION CROSS SECTION 1/777
 CS G ARE GIVEN IN FIG. 2. 1/777

D HEAVY PARTICLE PRODUCTION DIFFERENTIAL CROSS SECTION (CM**2/SR-GEV)
 D D 0 1.5E-36 OR LESS DORFAN 65 CNTR BE TARGET M=3-7GEV 5/76
 D D 0 3.0E-36 OR LESS DORFAN 65 CNTR FE TARGET M=3-7GEV 5/76
 D D 0 2.4E-35 OR LESS CL=90 BINON 69 CNTR Q=- M1=1.8 GEV 3/77
 D S 0 2.4E-35 OR LESS CL=90 ANTIPOV1 71 CNTR Q=- M1,2-1.7,2-1-4 3/77
 D T 0 1.2E-35 OR LESS CL=90 ANTIPOV2 71 CNTR Q=- M=2,2-2.8 3/77
 D L 0 5.8E-34 OR LESS CL=90 ALPER 73 SPEC +- M=1.5-2.4 GEV 5/76
 D O 0 1.E-31 OR LESS CL=90 APPEL 76 CNTR +- M=3.2-7.2 GEV 2/76
 D W 0 2.1E-33 OR LESS CL=90 ALBROW 75 SPEC Q+-1 M=4-15 GEV 1/77
 D W 0 1.2E-33 OR LESS CL=90 ALBROW 75 SPEC Q+-2 M=6-27 GEV 1/77
 D J 0 8.E-35 OR LESS CL=90 JOVANOVI 75 CNTR +- M=15-26 GEV 2/76
 D J 0 1.5E-35 OR LESS CL=90 JOVANOVI 75 CNTR Q+- M=10-26 GEV 2/76
 D J 0 1.E-35 OR LESS CL=90 JOVANOVI 75 CNTR Q+- M=10-26 GEV 2/76
 D B 0 2.6E-36 OR LESS CL=90 BALDIN 76 CNTR Q=-1, M=2.1-9.4 GEV 1/77
 D D DORFAN 65 IS A 30 GEV/C P EXPT AT BNL. UNITS ARE PER GEV MOMENTUM 5/76
 D D PER NUCLEUS. 5/76
 D S ANTIPOV1 71 LIMIT INFERRED FROM FLUX RATIO. 7C GEV P EXPERIMENT. 3/77
 D T ANTIPOV2 71 IS FROM SAME 70 GEV P EXP. AS ANTIPOV1 71 AND BINON 69. 3/77
 D L ALPER 73 IS CERN ISR 26+26 GEV P+P EXPT. P>.9 GEV, <.2 BETA <.65. 5/76
 D A APPEL 74 IS ANAL 300 GEV P+W EXPERIMENT. STUDIES FORWARD PRODUCTION 2/76
 D A OF HEAVY (UP TO 24 GEV) CHARGED PARTICLES WITH MOMENTA 24-200GEV(-) 2/76
 D A AND 40-150GEV (+CHG). ABOVE TYPICAL VALUE IS FOR 75 GEV AND IS 5/76
 D A PER GEV MOMENTUM PER NUCLEON. 5/76
 D W ALBROW 75 IS A CERN ISR EXPT WITH ECM=53 GEV. THETA=40 MR. SEE 1/77
 D W FIG. 5 FOR MASS RANGES UP TO 35 GEV. 1/77
 D J JOVANOVI 75 IS A CERN ISR 26+26 AND 15+15 GEV P+P EXPERIMENT. 2/76
 D J FIG.4 COVERS RANGES Q=1/3 TO 2 AND M=3 TO 26 GEV. 2/76
 D J VALUE IS PER GEV MOMENTUM. 5/76
 D B BALDIN 76 IS A 70 GEV SERP EXP. VALUE IS PER AL NUCLEUS AT 1/77
 D B THETA=0. FOR OTHER CHARGES IN RANGE -0.5 TO +3.0. CL=90 LIMIT IS 1/77
 D B (2.6E-36)/ABS(CHARGE) FOR MASS RANGE (2.1 TO 9.4GEV)*ABS(CHARGE). 1/77
 D B ASSUMES STABLE PARTICLE INTERACTING WITH MATTER AS DO ANTIPTONS. 1/77

ICH LONGLIVED HEAVY PARTICLE INVARIANT C.S. (CM**2/GEV**2/NUCLEON) 1/779
 ICH C 0 1.1E-37 OR LESS CL=90 CUTTS 78 CNTR MASS=4-10 GEV 1/779
 ICH V 0 3.0E-37 OR LESS CL=90 VIDAL 78 CNTR MASS=4.5-6 GEV 12/779
 ICH A 0 6.E-33 OR LESS CL=90 ARMITAGE 79 SPEC M=1.87 GEV 7/779
 ICH A 1.5E-33 OR LESS CL=90 ARMITAGE 79 SPEC M=1.5-3.0 GEV 7/779
 ICH B 0 BOZZOLI 79 CNTR Q=+(2/3,1,4/3,2) 1/800
 ICH C CUTTS 78 IS P BE EXPT AT FNAL SENSITIVE TO PARTICLES OF TAU=5E-8SEC 1/779
 ICH C VALUE IS FOR -1.3<XCO AND PT=0.175. 1/779
 ICH V VIDAL 78 IS FNAL 400 GEV PROTON EXPT. VALUE IS FOR X=0 AND PT=0. 2/779
 ICH V PUTS LIFETIME LIMIT OF <5*10**8 SEC ON PARTICLE IN THIS MASS RANGE 2/779
 ICH A ARMITAGE 79 IS CERN-ISR EXPT AT ECM=53 GEV. VALUE IS FOR X=0 AND 7/779
 ICH A PT=0.15. OBSERVED PARTICLES AT M=1.87 GEV ARE FOUND ALL CONSISTENT 7/779
 ICH A WITH BEING ANTIIDEUTERONS. 7/779
 ICH B BOZZOLI 79 IS CERN-SPS 200 GEV P N EXPERIMENT. LOOKS FOR PARTICLE 1/800
 ICH B WITH TAU LARGER THAN 10**+8 SEC. SEE THEIR FIG.11-18 FOR PRODUCTION 1/800
 ICH B CROSS SECTION UPPER LIMITS VS MASS. 1/800

CA CROSS-SEC FOR PRD AND CAPT OF LONG-LIVED MASSIVE PARTICLES (CM**2)
 CA F 0 1.1E-36 OR LESS FRANKEL 74 CNTR TAU=1 TO 1000 HRS 7/76
 CA R 0 1.4E-36 OR LESS FRANKEL 75 CNTR TAU=50 MS TO 10 HRS 2/77
 CA A 0 2.2E-34 OR LESS ALEKSEE1 76 ELEC TAU=100 MS TO 1 DAY 4/77
 CA A 0 2.2E-34 OR LESS ALEKSEE2 76 ELEC TAU=5 MS TO 1 DAY 3/77
 CA F FRANKEL 74 LOOKS FOR PARTICLES PRODUCED IN THICK AL TARGETS BY 7/76
 CA F 300-400 GEV/C PROTONS. 7/76
 CA R FRANKEL 75 IS EXTENSION OF FRANKEL 74. 2/77
 CA A ALEKSEEV(1,2) 76 ARE 61-70 GEV P SERP EXPT. CS IS PER PB NUCLEUS. 3/77

F HEAVY PARTICLE FLUX IN COSMIC RAYS (NUMBER/CM**2-SEC-SR)
 F 0 3.0E-10 OR LESS BJORNBOE 68 CNTR M ABOVE 5 GEV 4/77
 F 0 5.0E-11 OR LESS CL=90 JONES 67 ELEC M=5 TO 15 GEV 3/77
 F 0 3.0E-8 OR LESS DARDU 72 CNTR M GT 10 GEV 4/77
 F 0 1.5E-9 OR LESS TONNAR 72 CNTR M GT 10 GEV 4/77
 F Y 5 6.E-9 OR MORE YOCK 74 CNTR M GT 6 GEV 1/76
 F 0 7.E-10 OR LESS CL=90 YOCK 75 ELEC +- Q GT 7 OR LT -7E 9/76
 F 0 1.0E-9 OR LESS BRIATORE 76 ELEC 4/77
 F B 0 7.8E-9 OR LESS CL=90 BOZZOLI 78 CNTR +- M GT 1 GEV 1/800
 F 3 4.3+1.3 E-11 GOODMAN 79 ELEC M=2+5 GEV 7/79
 F Y YOCK 74 EVENTS COULD BE TRITONS. 1/76
 F B BHAT 78 IS AT KDLAR GOLD FIELDS. LIMIT IS FOR TAU > 10**+6 SEC. 1/800

C LIGHT (BETWEEN MU AND E MASSES) PARTICLE MASS (UNITS=ELECTRON MASSES)
 C 0 NONE BETWEEN 6 AND 25 BELOUSOV 60 CNTR SPINOR,TAU>1 E=8 5/76
 C 0 NONE BETWEEN 2 AND 25 GORBUNOV 60 CC SPINOR,TAU>1 E=9 5/76
 C 0 NONE BETWEEN 5 AND 175 COWARD 63 CNTR SPINOR,TAU>2 E=10 5/76
 C 0 NONE BETWEEN 5 AND 175 COWARD 63 CNTR SCALAR,TAU>6 E=10 5/76
 C D 0 NONE BETWEEN 2 AND 13 BLAGOV 75 CNTR SPINOR,TAU>2E-10SEC 2/76
 C D 0 NONE BETWEEN 2 AND 10.6 BLAGOV 75 CNTR SCALAR,TAU>2E-10SEC 2/76
 C C 75 0 NONE BETWEEN 120 AND 190 VIERTEL 78 CNTR TAU >2.E-5 SEC 1/800
 C D BLAGOV 75 BOUNDS ON LIFETIME DEPEND ON MASS AND IMPROVE AS MASS 1/777
 C D DECREASES. AT 2 GEV THE EXPERIMENT IS SENSITIVE TO TAU>3E-11 SEC 4/77
 C D FOR SPINOR, TAU>5E-11 SEC FOR SCALAR. 4/77
 C V VIERTEL 78 SEARCHES FOR MU ->X+ NEU. FINDS BR<2.E-6 IN MASS 1/800
 C V RANGE GIVEN ABOVE (CL=.90) 1/800

CCN CONCENTRATION OF HEAVY STABLE PARTICLES IN MATTER 7/779
 CCN 2.E-22 TO 1.E-21 OR LESS SMITH 79 SPEC WATER,M=6-350 MPROT 7/779

REFERENCES FOR OTHER NEW PARTICLE SEARCHES
 BELOUSOV 60 JETP 11 1143 +RUSAKOV,TAMM,CERENKOV (LEBD)
 GORBUNOV 60 JETP 11 51 +SPIRIDONOV,CERENKOV (LEBD)
 COWARD 63 PR 131 1782 +GITTELMAN,LYNCH,RIESEN (STAN)
 DORFAN 65 PRL 14 999 +EADES,LEDERMAN,LEE,TING (CCLU)
 JONES 67 PR 164 1584 (MICH+MISC+BL+UCLA+MINN+CO SU+COLO+MURA)

BJORNBOE 68 NC 853 241 +DAMGARD,HANSEN,CHATTERGEE+ (BOHR+BERN)
 BINON 69 PL 308 510 DUTEIL,KACHANOV,KHROMOV,KUTYIN+ (SERP)

ANTIPOV1 71 PL 348 164 +DENISOV,DONSKOV,GORIN,KACHANDV+ (SERP)
 ANTIPOV2 71 NP 831 235 +DENISOV,DONSKOV,GORIN,KACHANDV+ (SERP)
 DARDU 72 NC 9A 319 DARDO,NAVARRA,PEENGO,SITTE (TCRI)
 TONNAR 72 JPA 5 569 TONNAR,NARANAN,SREKANTAN (TATA)
 ALPER 73 PL 468 265 (CERN+LIVPA+LUND+BOHR+RHEL+STCH+BERG+LUCU)
 LEIPUNER 73 PRL 31 1226 +LARSEN,SESSOMS,SMITH,WILLIAMS+ (BNL+YALE)

APPEL 74 PRL 32 428 +BOURQUIN,GAINES,LEDERMAN,PAAR+ (COLU+FNAL)
 FRANKEL 74 PR D9 1932 +FRATI,RESVANIS,YANG,NEZRICK (PENN+FNAL)
 YOCK 74 NP 876 175 P.C.M. YOCK (UNIV OF AUCKLAND)

ALBROW 75 NP 897 189 +BARBER,BENZ+(CERN+OARE+FOU+LANC+MCHS+UTRE)
 APEL 75 PL 568 190 +AUGENSTEIN,BERTOLUCCI,DONSKOV,+ (SERP+CERN)
 BOYARSKI 75 PRL 34 762 +BREIDENBACH,BULOS,FELDMAN+ (SLAC+LBL)
 BLAGOV 75 YAD.F1Z. 21,300 +KOMAR,MURASHOVA,SYREISHCHIKOVA+ (LEBD)
 FRANKEL 75 PR D12 2561 +FRATI,RESVANIS,YANG,NEZRICK (PENN+FNAL)
 JOVANOVI 75 PL 568 105 JOVANOVI+CH+ (MANI+AAACH+CERN+GENO+HARV+TORI)
 YOCK 75 NP 886 216 P.C.M. YOCK (UNIV OF AUCKLAND+SLAC)

ALEKSEE1 76 SUNP 22 531 ALEKSEEV,ZAITSEV,KALINI NA,KRUGLOV+ (JINR)
 ALEKSEE2 76 SUNP 23 633 ALEKSEEV,ZAITSEV,KALINI NA,KRUGLOV+ (JINR)
 BACCI 76 PL 568 190 +BIIDOLI,PENSO,STELLA+ (ROM+FERAS)

BALDIN 76 SUNP 22 264 +VYTOGRADOV,VISHNEVSKI,I,GRISHKEVICH+(JINR)
 BARBIELL 76 PL 648 395 BARBIELLINI,NICOLETTI+(FRAS+ANPL+PIS+ROMA)
 BRIATORE 76 NC 31A 553 +DARDO,PIAZZOLI,MANNOCCI+ (LCT+FRAS+FREI)
 EARTLY 76 PRL 36 1355 +GIACOMELLI,I,PRETZL (FNAL+BNL+MPI)
 ESPOSITO 76 PL 648 362 +FELICETTI,MARINI,+ (FRAS+ROMA+PAD+ANPL)
 GUSTAFSO 76 PRL 37 474 GUSTAFSON,AYRE,JONES,LONGO,MURPHY (MICH)

HOMI 76 PRL 36 1236 +LEDERMAN,PARR,SNYDER+ (COLU+FNAL+STON)
 HOM2 76 PRL 37 1374 +LEDERMAN,PARR,SNYDER,+ (COLU+FNAL+STON)
 THEODOSI 76 PRL 37 126 THEODOSIOU,GITTELMAN,HANSON,LARSON+ (CCRN)

ASCHMAN 77 PRL 39 124 +COVNE,GROOM+ (PRIN+PAVI+UMD+UCSD+SLAC)
 BARISH2 77 PRL 38 577 +BARILETT,BODEK,BROWN+ (CIT+FNAL+ROCK)
 BENVENUT 77 PRL 38 1110 BENVENUTI,CLINE+ (FNAL+HARV+PENN+RUTG+WISC)
 BENNINGE 77 NP B119 77 BLETZACKER,NIEH,SONE (ISTON+UCS B)
 (BRAN+BNL+CARN+CINC+CUNY+MASA+PENN+SMAS+)

CHANG 77 PRL 39 519 +CHEN,VAN GINNEKEN (MSU+FNAL)
 HOLDER 77 PL 708 393 +KNOBLOCH,MAY+ (CERN+DORT+HEID+SACL+BGNA)

ALBRIGHT 78 PR D18 108 +SMITH,VERMASEREN (FNAL+STON+PURD)
 ALIBRAN 78 PL 748 134 AACH+BAR+BERG+BRUX+CERN+EPOL+MILA+ORSA+ (ITEP+SERP)
 ASRAYAN 78 PL 798 497 +EPSTEIN,FAKHROUDINOV+ (MILA)
 BELLOTTI 78 PL 768 225 +FIORINI,ZANOTTI (FNAL+HARV+PENN+RUTG+WISC)
 BENVENUT 78 PRL 40 488 BENVENUTI+ (FNAL+HARV+PENN+RUTG+WISC)
 BHAT 78 PRAM 10 115 +RAMANA MURTY (TATA)
 BOSETTI 78 PL 748 143 +DEDEN+ (AACH+BOHN+CERN+LOIC+DFX+SACL)

CARROLL 78 PRL 41 777 +CHIANG,JOHNSON,KYCIA,KI+ (BNL+PRIN)
 ALIBRAN 78 PL 41 363 +DULUDE+ (BROU+FNAL+ILL+BARI+MIT+WARS)
 DONNELLY 78 PR D18 1607 +FREEDMAN,LYTE,PECCICI,SCHWARTZ (STAN)
 ALSO 76 PRL 37 315 REINES,GURR,SOBEL
 ALSO 74 PRL 39 179 GURR,REINES,SOBEL
 HANSL 78 PL 748 139 +HOLDER,KNOBLOCH+(CERN+DORT+HEID+SACL+BGNA)
 HANSL2 78 PL 778 114 +HOLDER,KNOBLOCH+(CERN+DORT+HEID+SACL+BGNA)
 ALSO 78 NP B142 381 HANSL,HOLDER+ (CERN+DORT+HEID+SACL+BGNA)

HOLDER 78 PL 738 105 +KNOBLOCH,MAY+ (CERN+DORT+HEID+SACL+BGNA)
 LOVELESS 78 PL 788 505 +BENADA+CAMERINI+ (WISC+LBL+FNAL+HAWA+WASH)
 MICELMAC 78 LNC 21 441 MICELMACHER,POINTECORVO (JINR)
 MORI 78 PRL 40 432 +BENVENUTI+ (FNAL+HARV+PENN+RUTG+WISC)
 VIDAL 78 PL 778 344 +HERB,LEDERMAN,SNYDER+ (COLU+FNAL+STON+UCB)
 VIERTEL 78 LNC 22 235 +HAHN,SCHACHER (BERN)
 VYSOTSSK 78 JETPL 27 502 VYSOTSSKI+(INST.APPL.MATH.,USSR ACA. SCI.)

ARMITAGE 79 NP B150 87 +BENZ,BORBIN+ (CERN+OARE+FOU+MCHS+UTRECHT)
 BENVENUT 79 PRL 42 1024 BENVENUTI+ (FNAL+HARV+OSU+PENN+RUTG+WISC)
 BOZZOLI 79 NP B155 363 +BUSSIERE,GIACOMELLI (BGNA+CERN+LAPP+SACL)

COTEUS 79 PRL 42 1438 +DIESBURG,FINE,LEE,SOKLORSKY+ (COLU+ILL+BNL)
 DEGROD 79 PL B58 131 +HANSL,HOLDER+ (CERN+DORT+HEID+SACL+BGNA)
 DISHAW 79 PL B58 142 +DIAMANT-BERGER,FAESSLER,LIU+ (SLAC+CIT)
 GODDMAN 79 PR D19 2572 +ELLSWORTH,ITO,MACFALL,STOHAN+ (UMD)
 SMITH 79 NP B149 525 +BENNETT (RHEL)

Data Card Listings

For notation, see key at front of Listings.

Mesons

$\pi^\pm, \pi^0, \eta, \rho(770)$

S=0, C=0 MESON STATES

π^\pm
 8 CHARGED PION(140, JPC=0--) I=1
 SEE STABLE PARTICLE DATA CARD LISTINGS

π^0
 9 NEUTRAL PION(135, JPC=0--) I=1
 SEE STABLE PARTICLE DATA CARD LISTINGS

η
 14 ETA(549, JPC=0+-) I=0
 SEE STABLE PARTICLE DATA CARD LISTINGS

$\rho(770)$
 9 RHO(770, JPC = 1--) I=1

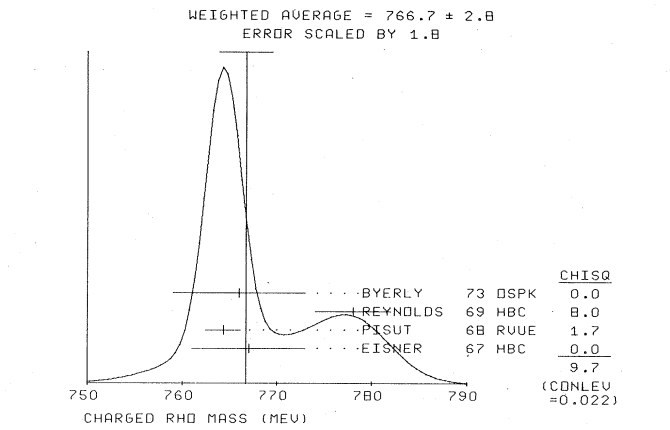
Note on the ρ^0 Mass and Width

Because of the broadness of the ρ meson, determinations of the resonance parameters are beset with many difficulties. In physical-region fits, it is well known that the ρ line shape does not correspond to a relativistic Breit-Wigner function with a P-wave width, but requires one further shape parameter (PISUT 68). The same remark applies to the energy dependence of the phase shift δ_1^1 . Different ways of introducing the shape parameter lead to systematic differences in addition to the systematic errors due to different ways of accounting for the background in physical-region fits, or due to different ways of projecting out the partial waves in phase-shift analyses.

We consider phase-shift analyses more reliable than physical-region fits.

All phase-shift analyses can now be summarized by two pairs of parameters which agree: in an analysis of the BATON 70, HYAMS 73, and PROTOPEPSCU 73 phase shifts, ROOS 75 obtains $M(\rho^0) = (776.3 \pm 0.4)$ MeV, $\Gamma(\rho^0) = (154.5 \pm 1.0)$ MeV; combining the HYAMS 73 data with more recent data on polarized protons, BECKER2 79 obtains $M(\rho^0) = (776.1 \pm 2.6)$ MeV, $\Gamma(\rho^0) = (161.8^{+7.6}_{-7.2})$ MeV. We base our "educated guess" on these values.

M CHARGED ONLY			
M	(748.0)	KENNEY	62 HBC - 1.2 PI-P
M	130 (775.0)	GUIRAGOSS	63 HBC - 3.3 PI-P
M	R (760.0) (9.0)	CARMONY	64 HBC + 3.5 PI+P, TCUT 4
M	R (768.0) (5.0)	BLIEDEN	65 MMSP - 3.5 PI-P 6/66
M	R (765.0) (5.0)	ALFF-STEI	66 HBC + 2.3 PI+P 6/66
M	R (760.0) (5.0)	HAGOPIANI	66 HBC - 3.0 PI-P 6/66
M	R (765.0) (5.0)	HAGOPIAN2	66 HBC - 2.14 PI-T, TCUT12 9/67
M	R 2775 (753.5) (10.5)	JACOBS	66 HBC - 2.3PI-T, CUT 20 6/68
M	R (758.0) (10.0)	JAMES	66 HBC + 2.1 PI+, TCUT2.5 8/66
M	R (749.0) (3.0)	WEST	66 HBC - 2.1 PI-P 10/66
M	Z 900 767. 6.	EISNER	67 HBC - 4.2 PI-T, CUT10 1/73
M	R (768.0) (5.0)	MILLER	67 HBC - 2.7 PI-T, CUT20 9/66
M	R (773.0) (2.0)	BATON	68 HBC - 2.8 PI-T, CUT13 7/69
M	1700 (782.1) (5.1)	FOSTER	68 HBC +- PBAR P AT REST 1/73
M	9650 764.3 1.9	1.8 PISUT	68 RVUE - 1.7-3.2PI-T, CT10 6/68
M	A 9650 (764.3) (19.2) (3.3)	PISUT	68 RVUE - 1.7-3.2PI-T, CT10 6/68
M	1300 778.0 4.0	REYNOLDS	69 HBC - 2.26 PI-P 12/78*
M	X 6500 766. 7.	BYERLY	73 OSK - 5.1 PI-P 2/74
M	AVG 766.7 2.8	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.8)	
M	STUDENT 766.0 2.0	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)	



MO NEUTRAL ONLY			
MO	190 (750.0) (20.0)	SAMIOS	62 HBC 0 4.7 PI-P
MO	R 300 (760.0) (10.0)	ABOLINS	63 HBC 0 2.5 PI+P
MO	160 (775.0)	GUIRAGOSS	63 HBC 0 3.3 PI-P
MO	R 500 (770.0) (10.0)	GOLDHABER	64 HBC 0 3.7 PI+P
MO	R (750.0) (5.0)	ALFF-STEI	66 HBC 0 2.3 PI-P 6/66
MO	R (775.0) (5.0)	HAGOPIANI	66 HBC 0 3.0 PI-P 6/66
MO	R (770.1) (5.1)	HAGOPIAN2	66 HBC 0 2.1 PI-T, CUT 12 2/67
MO	R 4207 (758.0) (7.5)	JACOBS	66 HBC 0 2-3PI-T, CUT 20 6/68
MO	R (765.0) (8.0)	JAMES	66 HBC 0 2.1 PI+P 6/66
MO	R (760.0) (3.0)	WEST	66 HBC 0 2.1 PI-P 10/66
MO	P 4000 (765.1) (5.0)	ASBURY 2	67 CNTR 0 GAMMA + PB 1/73
MO	R (768.0) (2.0)	BACCN	67 HBC 0 1.7 PI-P 9/67
MO	R (761.1) (3.1)	HUME	67 HBC 0 2.4 PI-P 7/67
MO	R (770.0) (4.0)	MILLER	67 HBC 0 2.7 PI-T, CUT20 9/66
MO	R (775.0) (2.0)	ARMENISE	68 DBC 0 5.1 PI+D 6/68
MO	1900 (776.1) (5.1)	FOSTER	68 HBC 0 PBAR P AT REST 1/73
MO	2250 775.0 3.0	HYAMS	68 OSK 0 11.2 PI-P 9/68
MO	13300 766.7 2.8	PISUT	68 RVUE 0 1.7-3.2PI-T, CT10 1/73
MO	B (754.0) (9.0)	AUSLENDER	69 OSK 0 +-E- COLL.BEAMS 2/74
MO	R (768.4) (2.4)	MALAMUD	69 RVUE 0 2-4 PI-P 1/73
MO	1700 774.0 3.0	REYNOLDS	69 HBC 0 2.26 PI-P 12/78*
MO	C 759.0 7.0	SCHAREN	69 HBC 0 2-4 PI-P 1/73
MO	P (765.0) (10.0)	ALVENSLEB	70 CNTR 0 GAMMA A, TCUT.01 1/73
MO	C12630 (760.0)	BATON	70 HBC 0 2.8 PI-P 1/71
MO	140K 767.7 1.9	BIGGS	70 CNTR 0 PHCTOPRGD. 1/73
MO	C 140K 761.0 5.0	BATLLEN	72 ASK 0 15. PI-P 1/73
MO	1930 767.0 4.0	BALLAM	72 HBC 0 2.8 GAMMA P 1/73
MO	2430 770.0 4.0	BALLAM	72 HBC 0 4.7 GAMMA P 1/73
MO	B (775.4) (7.3)	BENAKSAS	72 OSK 0 +-E- COLL.BEAMS 2/74
MO	Z 11200 773.5 1.7	BENAKSAS	72 RVUE 0 +-E- COLL.BEAMS 2/74
MO	6800 764.0 3.0	JACOBS	72 HBC 0 2.8 PI-P 1/73
MO	P (775.1) (5.1)	RATCLIFF	72 ASK 0 15. PI-P, TCUT.3. 2/74
MO	H (778.1) (2.1)	GLADNING	73 CNTR 0 2.9-4.7 GAMMA P 2/74
MO	C 32000 775.0 4.0	HYAMS	73 ASK 0 17. PI-P, PI+PI-N 1/74
MO	4100 767. 4.	PROTOPEP	73 HBC 0 7.1 PI+P, TCUT.4 2/74
MO	H (770.1) (9.1)	ENGLER	74 DBC 0 6. PI+P, PI+PI-P 12/75
MO	G (771.1) (1.1)	ESTABROOK	74 RVUE 0 17. PI-P, PI+PI-N 12/75
MO	D (776.3) (0.4)	GRAY	74 ASK 0 17. PI-P, PI+PI-N 2/74
MO	76000 768.0 1.0	ROOS	75 RVUE 0 PHASE SHIFTS 12/75
MO	X 767.6 2.7	DEUTSCHMA	76 HBC 0 16. PI+P 4/78*
MO	769.0 3.0	BARTALUCC	78 CNTR 0 BREMS, E+P 12/77
MO	766.1 2.6	WICKLUND	78 ASK 0 3.4, 6 PI+PN 4/78*
MO	769.11 0.86	BECKER	79 ASK 0 17. PI-P PLCLARIZ 12/79*
MO	STUDENT 769.11 0.78	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)	
		AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)	

9 RHO MASS (MEV)
 WE NO LONGER LIST S-WAVE BREIT-WIGNER FITS, PEAR P DATA WITH HIGH COMBINATORIAL BACKGROUND, AND INSIGNIFICANT OR DOUBTFUL DATA. SEE ALSO THE MINI-REVIEW ABOVE.
 MIXED CHARGES
 240 (752.0) ALITTI 63 HBC -0 1.6 PI-P
 290 (755.0) CHADWICK 63 HBC +-0 0.0 PBAR P

NOTES
 A ERRORS ARE 2 STD AND INCLUDE SYSTEMATIC UNCERTAINTIES FROM THEORY
 B INCLUDED IN BENAKSAS 72 RVUE VALUE
 C FROM PLE EXTRAPOLATION
 D INCLUDES BATON 70, HYAMS 73, PROTOPEPSCU 73
 E INCLUDED IN BECKER 79 ANALYSIS
 G FROM PHASE SHIFT ANALYSIS OF GRAYER 74 DATA.
 H FROM PHOTOPRODUCTION, MODEL DEPENDENT.
 I INCLUDED IN PISUT 68 RVUE
 X SYSTEMATIC ERRORS ADDED CORRESP. TO SPREAD OF DIFFERENT FITS.
 Z MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N), SEE K* TYPED NOTE

Mesons
rho(770)

Data Card Listings

For notation, see key at front of Listings.

WEIGHTED AVERAGE = 769.42 +/- 0.86
ERROR SCALED BY 1.5

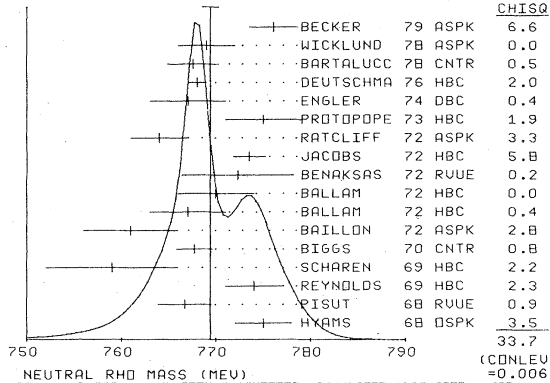


Table listing data points for the rho(770) mass distribution. Columns include the name of the source (e.g., BECKER, WICKLUND), the particle type (e.g., ASPK, HBC), and the mass difference in MeV (e.g., 6.6, 0.0).

Table 9: (RHOO) - (RHO++) MASS DIFFERENCE (MEV). Lists various sources and their measured mass differences, including average values and error scales.

FROM QUOTED MASSES OF CHARGED AND NEUTRAL MODES

9 RHO WIDTH (MEV)

WE NO LONGER LIST S-WAVE BREIT-WIGNER FITS. PBAR P DATA WITH HIGH COMBINATORIAL BACKGROUND, AND INSIGNIFICANT OR DOUBTFUL DATA. SEE FURTHER MINI-REVIEW ABOVE.

Table 9: RHO WIDTH (MEV). Lists various sources and their measured widths, including average values and error scales.

Table listing various meson decays and their properties. Columns include the meson name, decay mode, and associated parameters like branching ratios and lifetimes.

NOTES

W B INCLUDED IN BENAKSAS T2 REVUE VALUE
W C FROM POLE EXTRAPOLATION
W D INCLUDES BATON 70, HYAMS 73, PROTOPOPOSCU 73
W G INCLUDED IN BECKER 79 ANALYSIS
W H FROM PHASE SHIFT ANALYSIS OF GRAYER 74 DATA.
W P FROM PHOTOPRODUCTION, MODEL DEPENDENT.
W R INCLUDED IN PISUT 68 RVUE
W X SYSTEMATIC ERRORS ADDED CORRESP. TO SPREAD OF DIFFERENT FITS.
W Z WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N); SEE K* TYPED NOTE

9 RHO PARTIAL DECAY MODES

Table listing partial decay modes of the rho meson, including decay masses and branching ratios for various channels like RHO INTO 2PI and RHO INTO PI+ PI-.

9 RHO BRANCHING RATIOS

Table listing branching ratios for various rho meson decays, including RHO INTO 4PI/2PI and RHO INTO PI GAMMA/2PI.

Note on the e+e- and mu+mu- Decays

Extraction of a ratio for rho0 to e+e- is complicated by interference with omega decay. In photoproduction, YA to e+e-A, there is substantial interference between the allowed (rho0, omega) to e+e- decays. The interference in the colliding-beam reaction e+e- to pi+pi- is due to G-parity-violating mixing of the overlapping rho0 and omega resonances; it alters the results for the rate Gamma(rho0 to e+e-) only by a small amount. Therefore at present we average only the values from the e+e- to pi+pi- experiments.

The same comment applies to the decay rho0 to mu+mu-.

Table listing various meson decays and their properties, including branching ratios and lifetimes for channels like RHO INTO (E+ E-)/(PI+ PI-).

Data Card Listings

For notation, see key at front of Listings.

Mesons
rho(770), omega(783)

R5 H HYAMS MASS RESOL. IS 20 MEV. THE OMEGA REGION WAS EXCLUDED.
R5 R POSSIBLY LARGE RHO-OMEGA INTERFERENCE LEADS US TO INCREASE
R5 R THE MINUS ERROR
R5 W RESULT CONTAINS (11 +- 1) PER CENT CORRECTION USING SU(3)
R5 W FOR CENTRAL VALUE. THE ERROR ON THE CORRECTION TAKES ACCOUNT
R5 W OF POSSIBLE RHO-OMEGA INTERFERENCE AND THE UPPER LIMIT AGREES
R5 W WITH THE UPPER LIMIT OF OMEGA INTO MU+ MU- FROM THIS EXPT.

REFERENCES FOR RHO
ANDERSON 61 PRL 6 365
ERWIN 61 PRL 6 628
KENNEY 62 PRL 126 736
SAMIOS 62 PRL 9 139
XUCING 62 PRL 128 1849
ABLINS 63 PRL 11 381
ALITTI 63 NC 29 515
CHADWICK 63 PRL 62 63
GURRACOS 63 PRL 11 85
SACLAY 63 SIENA CONF 1 239
BONDAR 64 NC 31 729
CARMONY 64 DUBNA CONF 1 486
GOLDHABER 64 PRL 12 336
ALYEA 65 PL 15 82
ARMENSE 65 NC 37 361
BLIEDEN 65 PL 19 444
CLARK 65 PR 139 B 1556
GUTAY 65 NC 39 381
LANZEROT 65 PRL 15 210
ZDANIS 65 PRL 14 721

ACCENS 66 PL 20 557
ALFF-STE 66 PR 145 1072
BALTAY 66 PR 145 1103
BLIEDEN 66 NC 43 71
CAMBRIDGE 66 PR 146 994
CASON 66 PR 148 1282
DEUTSCHM 66 PR 155 82
FERBEL 66 PL 21 111
FIDECCARO 66 PL 23 163
HAGOPIAN 66 PR 145 1128
HAGOPIAN 66 PR 152 1183
HUSON 66 PL 20 91
JACOBS 66 UCRL-16877
JAMES 66 PR 142 896
WEST 66 PR 149 1089

ALLES-BO 67 NC 50 A 776
ASBURY 1 67 PR 189 809
ASBURY 2 67 PRL 19 865
BACON 67 PR 126 635
BANNER 67 PL 25 B 300
BARLOW 67 NC 50A 701
BATON 67 PL 25 B 419
ALSO 67 NP 3 349
ELEAR 67 NC 49A 399
DANYSZ 67 NC 51 A 801
EISNER 67 PR 164 1699
FRENCH 67 NC 52A 442
HERTZBACH 67 PR 155 1461
ALSO 67 ZDANIS
HUWE 67 PL 248 252
HYAMS 67 PL 248 634
MILLER 67 PR 153 1423
POIRIER 67 PR 163 1462

ABC COLL 68 NP 84 501
ARMENSE 68 NC 54 999
ASTVACAT 68 PL 27 B 45
BATON 68 PR 176 1574
BLECHSCH 68 NC 53 A 1045
ALSO 68 NC 52 A 1348
CHUNG 68 PR 165 1491
DONALD 68 NP 8 6 179
FOSTER 68 NP 8 6 107
HUSON 68 PL 288 208
HYAMS 68 NP 8 7 1
JONES 68 PR 166 1405
JOHNSON 68 PR 176 1651
KEY 68 PR 166 1430
LAMSA 68 PR 166 1399
LANZEROT 68 PR 166 1365
MARATECK 68 PRL 21 1613
PISUT 68 NP 8 6 325

AUGUSTIN 69 PL 28 B 508
AUGUSTIN 69 LNC 2 214
AUSLENDE 69 SJNP 9 69
GERMAN C 69 PR 188 2060
HAISSINSKI 69 ARGONNE CONF. 373
JUHALLA 69 PR 189 1461
MALAMUD 69 ARGONNE CONF. P.93
MILLER 69 PR 178 2061
MOTT 69 PR 177 1966
REYNOLDS 69 PR 184 1424
ROOS 69 NP 8 10 563
ROTHWELL 69 PRL 23 1521
SCHAREN 69 ARGONNE CONF. 306
WEHMANN 69 PR 178 2095

ALVENSLEB 70 PRL 24 786
BATON 70 PL 33 B 528
BIGGS 70 PRL 24 1197
BINGHAM 70 PR 184 955
GALLOWAY 70 PR D 1 3077
ABRAMS 71 PR D 4 653
BLOODMOR 71 NP 8 35 133
DEERY 71 PR D 3 635

BAILLON 72 PL 38 B 555
BALLAM 72 PR D 5 545
BRADSWAN 72 PL 41 B 178
BENAKSAS 72 PL 39 B 289
DRIVER 72 NP 8 38 1
EISENBERG 72 PR D 5 15
GRAYER 72 PHIL. CONF. PROC. 5
GRAYER 72 NP 8 50 29
JACOBS 72 PR D 6 1291
RATCLIFF 72 PL 38 B 345
TAKAHASHI 72 PR D 6 1266

BYERLY 73 PR D 7 637
CHARLESW 73 NP 8 65 253
GLADDING 73 PR D 8 3721
HYAMS 73 NP 8 64 134
PROTOPOP 73 PR D 7 1280

ROOS 75 NP 8 97 165
M. ROOS (HELS)

DEUTSCHM 76 NP 8 103 426
ANDREWS 77 PRL 38 198

BALTAY 78 PR D 17 62
BARTALUC 78 NC 44 A 587
WENZLER 78 PL 76 B 512
QUICKLUND 78 PR D 17 1197

BECKER 79 NP 8 151 46

omega(783)

1 OMEGA(783, JP G=1-1) I=0

1 OMEGA MASS (MEV)

Table with columns for particle name, mass, and other properties. Includes entries like ARMENTERO, ALFF, BARTALUC, etc.

M AVG 782.44 0.22 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)

M STUDENT 782.48 0.24 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

M B OBSERVED BY THRESHOLD-CROSSING TECHNIQUE. MASS RESOL.=4.8 MEV FWHM
M C FROM TOTAL SAMPLE OF COYNE 71. THEY OBSERVE AN IMPORTANT
M C CORRELATION BETWEEN SIGMA OF EXP. RESOLUTION AND THE MEAS. MASS.

M D FROM RESOLUTION SAMPLE OF COYNE 71
M F FROM OMEGA-RHO INTERFERENCE IN THE PI+PI- MASS SPECTRUM
M F ASSUMING OMEGA WIDTH 12.6 MEV.
M R INCLUDED IN ROOS 77,79 RVUE
M S ERROR INCLUDES 0.5 MEV MASS SCALE ERROR

1 OMEGA FULL WIDTH (MEV)

Table with columns for particle name, full width, and other properties. Includes entries like MILLER D, BARASH, ABRAMOVIC, etc.

M AVG 10.11 0.31 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

M STUDENT 10.10 0.35 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

M B OBSERVED BY THRESHOLD-CROSSING TECHNIQUE. MASS RESOL.=4.8 MEV FWHM

M C UNFOLDED BY COYNE 71
M E ERROR TAKES ACCOUNT OF SYSTEMATICS ADDED LINEARLY

Mesons

$\omega(783)$

Data Card Listings

For notation, see key at front of Listings.

1 OMEGA PARTIAL DECAY MODES
DECAy MASSES
P1 OMEGA INTO P1+ P1- P10 139+ 139+ 134
P2 OMEGA INTO P1+ P1- (VICILATES G) 139+ 139+ 134
P3 OMEGA INTO P10 GAMMA 134+ 0
P4 OMEGA INTO P1+ P1- GAMMA 139+ 139+ 0
P5 OMEGA INTO 2P10 GAMMA 134+ 134+ 0
P6 OMEGA INTO ETA GAMMA 548+ 0
P7 OMEGA INTO E+ E- 5+ 5
P8 OMEGA INTO MU+ MU- 105+ 105
P9 OMEGA INTO ETA P10 (VICILATES C) 548+ 134
P10 OMEGA INTO 3 GAMMA 0+ 0+ 0
P11 OMEGA INTO P10 MU+ MU- 134+ 105+ 105

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± 6P_i, where 6P_i = sqrt(6P_i*6P_i), while the off-diagonal elements are the normalized correlation coefficients (6P_i*6P_j)/(6P_i*6P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Matrix of branching fractions and correlations for P1, P2, P3.

1 OMEGA BRANCHING RATIOS

Table of branching ratios for various decay modes including neutrals, eta, and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of branching ratios for eta and gamma decays.

Table of Omega into eta+ eta- total units and branching fractions.

Table of Omega into eta+ eta- total units and branching fractions.

Table of Omega into neutrals / total and branching fractions.

Table of Omega into eta gamma / all neutrals and branching fractions.

Table of Omega into eta gamma / all neutrals and branching fractions.

Table of Omega into eta gamma / all neutrals and branching fractions.

Table of Omega into eta gamma / all neutrals and branching fractions.

Table of Omega into eta gamma / all neutrals and branching fractions.

***** REFERENCES FOR OMEGA *****

List of references for Omega meson decays, including authors and journal information.

Data Card Listings

Mesons

For notation, see key at front of Listings.

$\omega(783)$, $M(940-953)$, $\eta'(958)$

DEINET 69 PL 30 B 426
ERWIN 69 NP B 9 364
GOLDHABE 69 PRL 23 1351
JACQUET 69 NC 63 A 743
MILLER 69 PR 178 2061
STRUGALS 69 PL 29 B 532
WILSON 69 PRIVATE COMM.

*MENZIONE, MULLER, BUNIATCV+ (KARL+CERN)
*WALKER, GOSHAU, WEINBERG (WI SC+PRIN+VAND)
*BUTLER, COYNE, HALL, MACNAUGHTON, TRILING(LRL)
*NGUYEN-KHAC, HAATUFT, HALSTEIN(LI(EPOL+BERG)
R. MILLER, LICHTMAN, WILLMANN (PURDUE)
*CHUVILO, FENYVES,+ (WARS+JINR+BUOA)
RICHARD WILSON (SEE ALSO PR 178 2095)(HARV)

ABRAMOV I 70 NP B 20 209
BIZZARRI 70 PRL 25 1385
ALLISON 70 PRL 24 618
ATHERTON 70 NP B 18 221
BIGGS 70 PRL 24 1201
CASON 70 PR D 1 851
CHAPMAN 70 NP B 24 445
DANBURG 70 PR D 2 2564
FLATTE 70 PR D 1 1
GOLDHABE 70 PHILA. CNF. P. 59
HAGOPIAN 70 PRL 25 1050
ROOS 70 DNPL/R7 P. 173

ABRAMOVICH, BLUMENFELD, BRUYANT,+ (CERN)
*CIAPETTI, DORE, GASPERO, GUIDONI,+ (ROMA+SYRA)
*COOPER, FIELDS, RHINE+ (ANL)
*BLAIR, CELNIKER, DOMINGO, FRENCH+ (CERN+IPN)
*CLIFFT, GABATHULER, KITCHING, RAND (DARE)
*ANDREWS, BISWAS, GROVES, HARRINGTON,+ (NDAM)
*DAVIDSON, GREEN, LYS, ROE, VANDER VELDE (MICH)
*ADOLINS, DAHL, DAVIES, HOCH, KIRZ, MILLER+(LRL)
STANLEY M. FLATTE (LRL)
GERSON GOLDHABER, REVIEW (LRL)
S. AND V. HAGOPIAN, BOGART, SELOVE (FSU+PENN)
PROC. DARESBURY STUDY WEEKEND NO 1. (CERN)

ABRAMS 71 PR D 4 653
ALVENSLE 71 PRL 27 888
ANGELOW 71 SJNP 12 427
BALDIN 71 SJNP 13 758
BARADIAN 71 PR D4 2711
BEHREND 71 PRL 27 61
BIZZARRI 71 NP B 27 140
BLGDORH 71 NP B 35 133
CHAPMAN 71 PR D 3 38
COYNE 71 NP B 32 333
FIELDS 71 PRL 27 1749
MATTHEWS 71 PRL 26 400
MOFFEIT 71 NP B 25 349

*BARNHAM, BUTLER, COYNE, GOLDHABER, HALL,+ (LBL)
ALVENSLE BEN, BECKER, BUSZA, CHEN, COHEN,+ (DESY)
*GRAMENI TSKY, KANA SIR SKY, KERATS CHEW,+ (JINR)
*YER GAROV, TREBUKHOVSKY, SHI SHOV (IITP)
BARADIAN, OTWINOWSKA, HOFMOKL, MICHEJDA+(WARS)
*LEE, NORDBERG, WEHMAN,+ (ROCH+CORN+PAL)
*MONTANET, NILSSON, D-ANDLAU,+ (CERN+CDEF)
BLGDORH, JACKSON, PRENTICE, YGON (TORONTO)
*DORNEY, FOWLER (DUKE)
*BUTLER, FANG-LANDAU, MACNAUGHTON (LRL)
*COOPER, RHINE S, ALLISON (ANL+CXF)
*PRENTICE, YDON, CARROLL, WALKER,+ (TNTD+ISC)
*BINGHAM, FREYTER, BALLAM+(LRL+UCB+SAC+TUFT)

AGUILAR 72 PR D 6 29
APEL 72 PL 41 B 234
BASILE 72 PHIL. CNF. PROC153
BENKASAS 72 PL 39 B 289
BENKASAS172 PL 42 B 507
BENKASAS272 PL 42 B 511
BRDHN 72 PL 42 B 117
DAKIA 72 PR D 6 2321
EISENBERG 72 PR D 5 15
RATCLIFF 72 PL 38 B 345
BORENSTEIN 72 PR D 5 1559

AGUILAR-BENITEZ, CHUNG, EISNER, SAMIOS (BNL)
*AUSLANDER, MULLER, BERTOLUCCI,+ (KARL+PISA)
*BOLLINI, BROGLINI, DALPIAZ, FRABETTI,+ (CERN)
*COSME, JEAN-MARIE, JULLIAN, LAPLANCHE,+ (ORSA)
*COSME, JEAN-MARIE, JULLIAN, LAPLANCHE+(ORSA)
*COSME, JEAN-MARIE, JULLIAN, LAPLANCHE+(ORSA)
*DOWLING, HOLLOWAY, HULD, BERNSTEIN+(ILL+LILC)
*HAUSER, KRUISLER, MISCHKE (PRINCETON)
EISENBERG, BALLAM, DAGAN,+ (REHO+SAC+TELA)
*BULOS, CARNEGIE, KLUGE, LEITH, LYNCH,+ (SLAC)
BORENSTEIN, DANBURG, KALBFLEISCH,+ (BNL+MICH)

BINNIE 73 PR D 8 2789
BURNS 73 PR D 7 1310
ESTABROO 74 NP B 81 73
GREGORIO 74 NC 20 A 437
KRAMER 74 PRL 33 505
OREN 74 NP B 71 189

*CARR, DEBENHAM, DUANE, GARBUTT,+ (LOIC+SHMP)
*CONDON, XI, MANDELKERN, PRICE, SCHULTZ (UCI)
ESTABROOKS, HYAMS, JONES, BLUM, (CERN+MPIM)
M. A. GREGORIO (ICTP-TRIESTE)
*AYRES, DIEBOLD, GREENE, PAWLICKI+ (ANL)
*COOPER, FIELDS, RHINE S, ALLISON+ (ANL+OXF)

EMMS 75 NP 898 1
KALBFLEI 75 PR D 11 987
ROOS 75 NP B 97 165
BRANDENB 76 NP B 104 413
KRAMER 76 PR D 14 28
ALSO 73 BINNIE

*KINSON, STACEY, BELL, DALE,+ (BIRM+DURH+RHEL)
KALBFLEISCH, STRAND, CHAPMAN (BNL+MICH)
M. ROOS (HELS)
BRANDENBURG, CARNEGIE, CA SHMORE, DAVIER+ (SLAC)
*BINNIE, CARR, DEBENHAM, GARBUTT,+ (LOIC+SHMP)

ANDREWS 77 PRL 38 198
BARTKE 77 NP B 118 360
GESSAROL 77 NP B 126 382
HOLMGREN 77 PL 66 B 191
LYLNS 77 NP B 125 207
ROOS 77 LNC 19 419

*FUKUSHIMA, HARVEY, LOBKOWICZ, MAY,+ (RGGH)
*IAAC+BERL+BONN+CERN+CRAC+LOIC+WIEN+WARS)
GESSAROL, I,+ (BGN+FRIZ+GENO+MILA+OXF+PAVI)
*JONGE JANS, ENGELN,+ (CERN+AMST+NIJM+CXF)
*COOPER, CLARK (OXF)
M. ROOS (HELSINKI)
VAN APELDOORN, GRUNDEMAN, HARTING,+ (ZEEM)
*GURTU, MONTANET,+ (TATA+CERN+CDEF+MADR)
*RIBES, RUMPF, BERTRAND, EIZOT, CHASE,+ (LALD)
*AYRES, DIEBOLD, GREENE, KRAMER, PAWLICKI (ANL)

APELDOOR 78 NP B 133 245
COOPER 78 NP B 146 1
QUENZER 78 PL 76 B 512
WICKLUND 78 PRD 17 1197
BENKHEIR 79 NP B 150 268
CORRIER 79 LAL-7971
DZHELJAD 79 PL 84 B 143
ROOS 79 LNC

BENKHEIR, EISENSTEIN,+ (EPOL+CERN+CDEF+LALO)
*DELCOURT, ESCHSTRUTH, FLUDA,+ (LALD)
DZHELJADIN, GOLDOVITN, GRITSUK,+ (SERP)
*PELLINEN (HELS)

M(940-953)

66 M(940-953)
THE CLAIM FOR A NARROW RESONANCE AT 940 MEV BY CHESHIRE 72 HAS NOT BEEN CONFIRMED BY BINNIE 72, 74, GRAY 74, BUTTRAM 75. OMITTED FROM TABLE. THE CLAIM FOR A RESONANCE M(953) IN THE P1+ P1- GAMMA CHANNEL (AGUILAR 70) HAS NOT BEEN CONFIRMED. OMITTED FROM TABLE.

REFERENCES FOR M(940-953)

AGUILAR 70 PRL 25 1635
MAGLICH 71 PRL 27 1479
ROSNER 71 PRL 26 933
AGUILAR 72 PR D 6 29
CHESHIRE 72 PRL 28 520
BINNIE 72 PL 39 B 275
BINNIE 74 PRL 32 392
BUTTRAM 75 PRL 35 970
GRIGERIA 75 NP 891 232

AGUILAR-BENITEZ, BASSANO, SAMIOS, BARNES+(BNL)
*DOOSTENS, BRODY, CVI JANDVICH (RUTG+PENN+UPNJ)
J. L. ROSNER, E. W. COLGLAZIER (MINN+CIT)
AGUILAR-BENITEZ, CHUNG, EISNER, SAMIOS (BNL)
*HOFFMAN, GARFINKEL,+ (IDW+ANL+PURD)
*CAMILLETTI, DUANE, GARBUTT, BURTON+(LOIC+SHMP)
*CAMILLETTI, CARR, DEBENHAM,+ (LOIC+SHMP)
*CRAMLEY, DUKE, LAMB, LEEPER, PETERSSON (ISU)
GRIGORIAN, LADAGE, MELLEMA, RUDNICK,+ (UGLA)

$\eta'(958)$

2 ETA PRIME(958, JP=0-+) I=0

Note on the J^P Assignment of $\eta'(958)$

From the Dalitz plot analyses of the $\eta' \rightarrow \pi\pi\pi$ and $\eta' \rightarrow \pi^+\pi^-\gamma$ decays and from the observation of an $\eta' \rightarrow \gamma\gamma$ decay mode, all assignments except $J^P = 0^{-+}$ and 2^{-+} are excluded. The Dalitz plot analyses favor spin 0, but cannot rule out spin 2. The indication of anisotropy in the decay of very forward-produced η' (KALBFLEISCH 73) has not been confirmed by BALTAY 74, thus again favoring spin 0, but still not ruling out spin 2 (LEDNICKY 77).

Two recent analyses, however, seem to have finally established the spin 0 assignment of the η' .

CERRADA 77 perform a partial-wave analysis of the $\eta\pi\pi$ system produced in the reaction $K^-p \rightarrow \eta'\Lambda$, taking into account the η' and Λ joint decay angular correlations. They conclude that J^P is unambiguously 0^{-} (see also DELAGUILA 77).

ROUSSARIE 77 analyze a large sample of events from the reaction $\pi^-p \rightarrow \eta'n$ at beam momenta just above threshold. They verify that the η' is produced in a relative S-wave state, and thus the Adair condition is satisfied by their total sample of some 1800 events. The decay angular distribution of the η' is consistent with isotropy, and thus ROUSSARIE 77 conclude that the spin cannot be 2.

2 ETA PRIME MASS (MEV)						
M	C	ONLY EXPERIMENTS GIVING ERROR LESS THAN 2 MEV KEPT FOR AVERAGING	12/75			
M	85	(957.0) DAUBER 64 HBC 1.95 K-P				
M	K	(958.0) (1.0) KALBFLEI 64 HBC 2.7 K-P	6/66			
M	K	KALBFLEISCH 64 SUPERSEDED BY RITTENBERG 69				
M	O	(957.0) (3.0) BADIER 65 HBC 3.0 K-P				
M	O	8 (960.0) (2.0) TRILLING 65 HBC 3.65 P1+ P	12/75			
M	O	7 (955.0) (10.0) COHN 66 DBC 3.3 P1+D	6/66			
M	O	(959.0) (3.0) LONDON 66 HBC 2.2 K-P	6/66			
M	O	(960.0) (5.0) MOTT 69 HBC 4.1-5.5 K-P	7/69			
M	O	957. 1. RITTENBERG 69 HBC 1.7-2.7 K-P	9/69			
M	O	(956.0) (2.0) AGUILAR 70 HBC 3.9-4.6 K-P	12/75			
M	3415	956.1 1.1 BASILEI 71 CNTR 1.6 P1- P,N XO	11/71			
M	535	957.4 1.4 BASILEI 71 CNTR 1.6 P1- P,N XO	11/71			
M	1414	958.2 0.5 DANBURG 73 HBC 2.2 K-P, LAM XO	2/74			
M	400	558. 1. JACOBS 73 HBC 2.9 K-P, LAM XO	1/74			
M	957.46	0.33 DUANE 74 MMS P1- P,N MM	1/74			
M	AVG	957.57 0.25 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)				
M	STUDENT	957.57 0.28 AVERAGE USING STUDENT(10(H,1,11)) -- SEE MAIN TEXT				

2 ETA PRIME WIDTH (MEV)						
W	85	(4.0) OR LESS	DAUBER 64 HBC 1.95 K-P			
W	3415	(8.) OR LESS	CL=.90 BASILEI 71 CNTR 1.6 P1- P,N XO	11/71		
W	514	(4.7) OR LESS	CL=.95 DANBURG 73 HBC 2.2 K-P, LAM XO	2/74		
W	(0.8) OR LESS	CL=.95	DUANE 74 MMS P1- P,N MM	1/74		
W	1000	0.28 0.10	BINNIE 79 MMS 0 P1- P,N MM	12/79*		

Mesons

$\eta'(958)$

Data Card Listings

For notation, see key at front of Listings.

Table with 2 columns: Mode and Decay Masses. Rows include P1, P2, P3, P4, P5, P6, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS. Matrix of branching fractions P1-P5.

Note on $\eta'(958)$ Branching Fractions. In our calculation of the branching fractions of the $\eta'(958)$, we use the decay modes $\eta\pi\pi$ (including $\eta\pi^0\pi^0$), $\rho^0\gamma$, $\omega\gamma$, and $\gamma\gamma$. It is assumed that the rate $\eta \rightarrow$ neutrals is 71.0%.

In the fit we do not use the constraint $R = \frac{\Gamma(\eta' \rightarrow \eta\pi^+\pi^-)}{\Gamma(\eta' \rightarrow \eta\pi^0\pi^0)} = 2$

from I-spin conservation. The result of the fit is in agreement with it: $R = 1.8 \pm 0.2$.

2 ETA PRIME PARTIAL WIDTHS (KEV). Table with 2 columns: Mode and Width.

2 ETA PRIME BRANCHING RATIOS. Table with 2 columns: Mode and Ratio. Includes sub-section SEE MINI-REVIEW ABOVE.

Table with 2 columns: Mode and Data. Rows include R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26.

Data Card Listings

For notation, see key at front of Listings.

Table with columns for particle name, parameters, and references. Includes entries for R27 ETA PRIME INTO, R27 K, R27 P, R28 ETA PRIME INTO, R29 ETA PRIME INTO.

2 ETA PRIME C-NONCONSERVING DECAY PARAMETER

Table with columns for decay parameter, value, and reference. Includes entries for A DECAY ASYMMETRY PARAMETER, A S, A P, A AVG, A STUDENT.

REFERENCES FOR ETA PRIME

Large table of references for eta prime decays, listing authors, journals, and years. Includes names like DAUBER, GOLDBERG, KALBFLEI, etc.

delta(980) 36 DELTA(980, JPC=0+-) I=1

Observations of missing-mass peaks in the 960 MeV mass region are mostly controversial and are therefore not listed here.

- 1. eta pi decays, peaking slightly below the KK threshold. This defines I^G = 1^- and J^P = normal.
2. A KK threshold enhancement with I = 1.

This association is justified by the remark (ASTIER 67) that the KK threshold enhancement may be due to a virtual bound state also coupled to the eta pi system.

The low Q-value of the KK threshold enhancement and decay distributions of the eta pi system favor J^P = 0^+. Additional evidence (LIPKIN 69) comes from the absence of a rho eta decay mode (GRASSLER 77).

36 DELTA(980) MASS (MEV)

Table of mass measurements for delta(980) in MeV, listing authors and values with errors.

36 DELTA(980) WIDTH (MEV)

Table of width measurements for delta(980) in MeV, listing authors and values with errors.

Mesons

$\delta(980)$, $S^*(980)$

W F USING A TWO CHANNEL RESONANCE PARAMETRIZATION OF GAY 76 DATA.
W J SEE NOTE J ABOVE.
W N THE ERROR IN THE PAPER IS WRONGLY QUOTED AT ONE POINT
W R FROM D(1285) DECAY
W W WEAK EVIDENCE ONLY FOR DELTA+ PRODUCTION.
W K KEAR ONLY, SEE THE TYPED NOTE ABOVE
W 143 (57.0) 13.0+SYSTEMATIC ROSENFELD 65 RVUE +- 8/66
W 100 (25.) APPROX. ASTIER 67 HBC +- SEE NOTE A ABOVE 9/67
W M (120.) APPROX. MORGAN 75 RVUE 1.2 PBAR P 12/75
W M FROM COUPLED CHANNEL FIT TO DUBOC 72 DATA

36 DELTA(980) PARTIAL DECAY MODES

Table with 3 columns: P1, P2, P3; Delta(980) into eta pi, rho pi, k kbar; Decay masses 548+134, 497+134, 497+497

36 DELTA(980) BRANCHING RATIOS

Table with 3 columns: R1, R2, R2 L; Delta(980) into rho pi/eta pi, k kbar/eta pi; Branching ratios like 70 HBC, 11/77, 4/78*

***** REFERENCES FOR DELTA(980) *****

Extensive list of references for Delta(980) decays and branching ratios, including authors like Collins, Armenteros, Daloz, etc.

S*(980)

3 S*(980, JP=0++) I=0

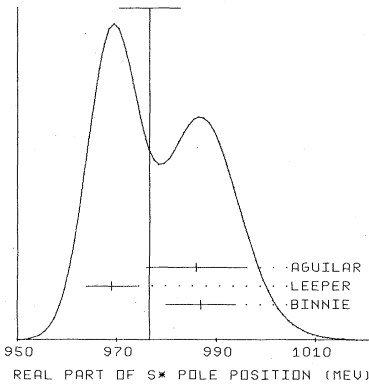
UNDER THIS ENTRY WE LIST PARAMETERS OF THE POLE IN THE ISOSCALAR S WAVE. FOR A MINI-REVIEW SEE UNDER EPSILON. POSSIBLE EVIDENCE OF D-WAVE PI PI INTERACTIONS IN THIS REGION IS LISTED SEPARATELY UNDER ETA N(1080).

FOR EARLY WORK USING BREIT-WIGNER OR SCATTERING LENGTH PARAMETRIZATION IN FITS TO THE K KBAR MASS SPECTRUM, SEE REFERENCE SECTION AND OUR 1972 EDITION.

3 REAL PART OF THE S* POLE POSITION (MEV)

Table listing real part of S* pole position with columns for author, year, value, and decay mode.

WEIGHTED AVERAGE = 976.6 +/- 6.2
ERROR SCALED BY 1.6



3 NEGATIVE IMAG. PART OF THE S* POLE POSITION (MEV)

Table listing negative imaginary part of S* pole position with columns for author, year, value, and decay mode.

3 S*(980) PARTIAL DECAY MODES

Table with 3 columns: P1, P2; S*(980) into k kbar, pi pi; Decay masses 497+497, 139+139

***** REFERENCES FOR S* *****

Extensive list of references for S*(980) decays and branching ratios, including authors like Wang, Bigi, Erwin, etc.

Data Card Listings

For notation, see key at front of Listings.

Mesons

S*(980), H(990), phi(1020)

Table of particle data cards for H(990) and phi(1020) mesons, listing authors, institutions, and experimental parameters.

H(990)

35 H(990, JPC=A-) I=0
THE EVIDENCE OF BENSON 66 HAS DISAPPEARED AFTER RE-ANALYSIS (CHAUDHARY 70). NO SIGNIFICANT OTHER EVIDENCE HAS BEEN PUBLISHED. OMITTED FROM TABLE.

REFERENCES FOR H

Table of references for H(990) meson, listing authors and publication details.

phi(1020)

4 PHI(1020, JPC=1--) I=0
WE ONLY AVERAGE MASS AND WIDTH VALUES WHEN THE SYSTEMATIC ERRORS HAVE BEEN EVALUATED.

Table of particle data cards for phi(1020) meson, listing authors, institutions, and experimental parameters.

Table of particle data cards for S*(980) meson, listing authors, institutions, and experimental parameters.

WEIGHTED AVERAGE = 1019.631 +/- 0.094
ERROR SCALED BY 1.3

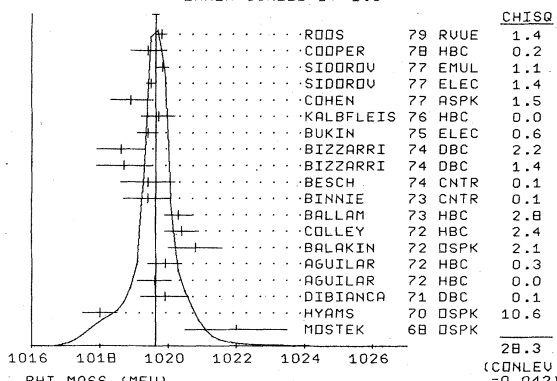


Table of particle data cards for phi(1020) meson, listing authors, institutions, and experimental parameters.

4 PHI MASS (MEV)
WE ONLY AVERAGE MASS AND WIDTH VALUES WHEN THE SYSTEMATIC ERRORS HAVE BEEN EVALUATED.

Table of particle data cards for phi(1020) meson, listing authors, institutions, and experimental parameters.

4 PHI PARTIAL DECAY MODES
DECAY MASSES

Mesons
phi(1020)

Data Card Listings
For notation, see key at front of Listings.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i +/- delta P_i, where delta P_i = sqrt(delta P_i delta P_i), while the off-diagonal elements are the normalized correlation coefficients (delta P_i delta P_j) / (delta P_i delta P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table with 4 columns: P 1, P 2, P 3, P 4. Values include .4861+-.0116, .8014-.3517+-.0123, etc.

4 PHI BRANCHING RATIOS

Main data table for phi(1020) branching ratios. Columns include R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15. Rows list various decay modes like PHI INTO (K+ K-)/(K KBAR + PI+ PI- P0), PHI INTO (K L KS)/(K KBAR), etc.

Table with columns: R16, PHI INTO (E+ E-)/TOTAL (UNITS 10**+4), (P5). Values include 5 (6.6) (4.4), 27 (7.2) (3.9), etc.

R16 A ERROR OF ASTVACATUROV 68 DOES NOT INCLUDE SIGMA(PHI) UNCERTAINTY. USING TOTAL WIDTH 4.2 MEV, THEY DETECT 3 PI MODE AND OBSERVE R16 E SIGNIFICANT INTERFERENCE WITH OMEGA TAIL. THIS IS ACCOUNTED FOR IN THE RESULT QUOTED ABOVE

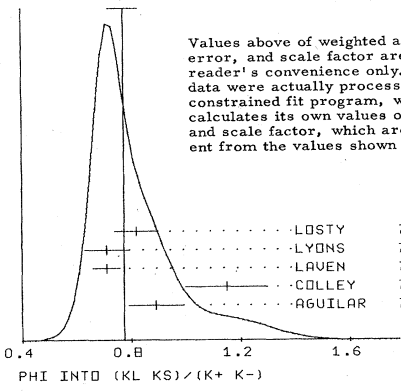
Table with columns: R17, PHI INTO (PI0 GAMMA)/(TOTAL), (P7). Values include 7 (0.0025) (0.0012), 32 (0.0014) (0.0005), etc.

Table with columns: R18, PHI INTO (PI+ PI-)/(TOTAL) (UNITS 10**+4), (P8). Values include (50.) OR LESS CL=.95, (80.) OR LESS CL=.95, etc.

Table with columns: R19, PHI INTO (K L KS)/(K+ K-), (P2)/(P1). Values include 144 0.89 0.10, 125 1.15 0.15, etc.

R19 AVG 0.774 0.055 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6) R19 STUDENT 0.768 0.042 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT R19 FIT 0.724 0.061 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5) (SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 0.774 +/- 0.055 ERRDR SCALED BY 1.6



Values above of weighted average, error, and scale factor are for the reader's convenience only. The data were actually processed by a constrained fit program, which calculates its own values of xi, xi-bar, and scale factor, which are different from the values shown here.

Table with columns: R20, PHI INTO (PI+ PI- P0)/(K+ K-), (P3)/(P1). Values include 34 0.28 0.09, 0.302 0.018 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1), etc.

REFERENCES FOR PHI
BERTANZA 62 PRL 9 180
GELFAND 63 PRL 11 438
SCHLEIN 63 PRL 10 368
BADIERY 65 PRL 17 337
GALTIERI 65 PRL 14 279
LINDSEY 65 PRL 15 221
GRAY, L 66 PRL 17 501
LINDSEY 66 PR 147 913
LINDSEY 66 PR 20 93
LONDON 66 PR 143 1034
ABRAMS 67 MO TECH REP 720
BARLON 67 NC 50A 701
CHASE 67 PRL 18 710
DAHL 67 PR 163 1377
HERTZBACH 67 PR 155 1461
KHACHATU 67 PL 248 349
BERTANZA, BRISSON, CONNOLLY, HART + (BNL+SYRA)
GELFAND, MILLER, NUSSBAUM, KIRSCH + (COLU+WUTG)
SCHLEIN, SLATER, SMITH, STORK, TICHO (UCLA)
BADIERY, DEMCULIN, BARLOUTAUD + (SACL+AMST)
D BERLEY, N GELFAND (BNL+COLUMBIA)
A BARBARO GALTIERI, R D TRIPP (LRL)
JAMES S LINDSEY, GERALD A SMITH (LRL)
MILLER D 65 CU-237(NEVIS 131) DAVID C MILLER (THESIS) (COLUMBIA)
+HAGERTY, BIZZARRI, CIAPETTI + (SYRA+RCMAJ) PG
JAMES S LINDSEY, GERALD A SMITH (LRL)
J. S. LINDSEY, G. A. SMITH (LRL)
IN LINDSEY 66 ABOVE
LONDON, RAU, SAMIOS, GOLDBERG + (BNL+SYRACUSE)
GERALD ABRAMS, THESIS (MARYLAND)
+LILLETSTOL+MONTANET + (CERN+CDEF+IRAD+IVP)
R. C. CHASE, P. ROTHWELL, R. WEINSTEIN (CEA+NEAS)
+HARDY+HESS+KRAMER+MILLER (LRL)
HERTZBACH, KRAEMER, MADANSKI, ZDANIS+ (LJH+BNL)
KHACHATURYAN+AZIMOV+BALDIN+BELOUSOV+ (DUBNA)
+GLASSER, KEHOE, SECHI-ZORN, WOLSKY (MARYLAND)
ASTVACATUROV, AZIMOV, BALDIN + (JINR+MOSCOW)
ASBURY, BECKER, BERTRAM, TING + (DESY+COLUMBIA)
+BERTRAM, BINLEY, JORDAN, KNAUSEL + (DESY+MIT)
+DUANE+FARUQI+HORSERY + (LOIC+RHUL)
+BUHLER, DALPIAZ, MASSAM + (CERN+BGNA+STRB)
+EISENHANDLER+MCLELLAN, MISTRY + (CORNELL)
+ENGELS + (HARVARD+CASE+SLAC+CORNELL+MCGILL)

Data Card Listings

For notation, see key at front of Listings.

M(1033-1040), $\eta_N(1080)$, M(1150-1170), A_1

MOUSTIN 69 PL 28 B 517 MOY 69 THESIS SCOTTER 69 NC 62 A 1057	+BI ZOT, BUON, DELCOURT, HAISS INSK I, + (ORSAY) KEN MIN MOY (NORTHEASTERN UNIVERSITY) +ERSKINE, PALER, + (BIRM+GLAS+LOIC+MPIM+DXF)
BIZOT 70 PL 32 416 ALSO 69 PEREZ-Y-JORBA, LIVERPOOL SYM-F.69 BIZOT 70 LNC 4 1273 EARLES 70 PRL 25 1312 HYAMS 70 NP B 22 189	+BUON, CHATELUS, JEANJEAN, LALANNE, + (ORSA) +DELCOURT, JEANJEAN, LALANNE, + (ORSAY) +FAISSLER, GETTNER, LUTZ, MOY, TANG, + (NEAS) +KOCH, POTTER, V. LINDERN, LORENZ, LUTJENS (CERN)
ALVENSLEB 71 PRL 27 441 EALAKIN 71 PL 34 B 328 CHATELUS 71 LAL 1247(THESIS) Y. ALSO 70 BIZOT DIEIANCA 71 NP B 35 13 HAYES 71 PR D 4 899 STOTTLEMYER 71 ORD 2504 170	ALVENSLEBEN, BECKER, BUSZA, CHEN, + (MIT+DESY) +BUDKER, PAKHTUSOVA, SIDOROV, SKRINSKY, + (NGVO) Y. CHATELUS (STRASBOURG) +EINSCHLAG, ENDORF, ENGLER, FISK, + (CORN) +IMLAY, JOSEPH, KEIZER, STEIN (CORN) A. R. STOTTLEMYER, THESIS (MARYLAND)
AGUILAR 72 PR D 6 29 ALVENSLEB 72 PRL 28 66 BALAKIN 72 PL 40 B 431 BASILE 72 NP B 44 605 BENAKSAS 72 PL 42 B 511 BORENSTEIN 72 PR D 5 1559 CGLLEY 72 NP B 50 1	AGUILAR-BENITEZ, CHUNG, EISNER, SAMIOS (BNL) ALVENSLEBEN, BECKER, BIGGS, BINKLEY+ (MIT+DESY) +BOKIN, PAKHTUSOVA, SIDOROV, + (NOVOSIBIRSK) +DALPIAZ, FRABETTI, ZICHICHI+ (CERN+BGNA+STRB) +COSME, JEAN-MARIE, JULLIAN, LAPLANCHE+ (ORSAY) BORENSTEIN, DANBURG, KALBFLEISCH, + (BNL+MICH) +JOBES, RIDDIFORD, GRIFFITHS, + (BIRM+GLAS)
BALLAM 73 PR D 7 3150 BINNIE 73 PR D 8 2789	+CHADWICK, EISENBERG, BINGHAM, + (SLAC+LBL) +CARR, DEBENHAM, DUANE, GARBUZZI, + (LOIC+SHMP)
AYRES 74 PRL 32 1463 BECHT 74 NP 870 257 EIZZARRI 74 NC 20A 353 COSME 1 74 PL 48 B 155 COSME 2 74 PL 48 B 159 DE GROOT 74 NP B74 77	+DIEBOLD, GREENE, KRAMER, LEVINE, + (ANL) +HARTMANN, KUSE, KRAUTSCHNEIDER, PAUL, + (BONN) +LAURETTI, ODNESI, OORE, GASPERO + (RIMA) +JEAN-MARIE, JULLIAN, LAPLANCHE, + (ORSAY) +JEAN-MARIE, JULLIAN, LAPLANCHE, + (ORSAY) +HOOGLAND, JONGEJANS, MEIZGER+ (AMST+NIJM)
BUKIN 75 IYAF 75-64 KALBFLEI 75 PR D11 987	+DERBENEV, KONDRATENKO, KURDADZE, + (NCVO) KALBFLEISCH, STRAND, CHAPMAN (BNL+MICH)
COSME 76 PL 63 B 352 KALBFLEI 76 PR D 13 22 PAFROURI 76 PL 63 B 357 PAFROUR2 76 PL 63 B 362	+COURAU, DUDELZAK, GRELAUD, JEAN-MARIE (ORSAY) KALBFLEISCH, STRAND, CHAPMAN (BNL+MICH) +GRELAUD, COSME, COURAU, DUDELZAK, + (ORSAY) +GRELAUD, COSME, COURAU, DUDELZAK, + (ORSAY)
AKERLOF 77 PRL 39 861 ANDREWS 77 PRL 38 198 BALDI 77 PL 68 B 381 CERRADA 77 NP B 126 241 COHEN 77 PR D 38 269 COURANT 77 PR D 16 1 EVANGEL 77 NP B 127 384 LAYEN 77 NP B 127 43 LYONS 77 NP B 125 207 SIDOROV 77 Tbilisi VOL-2 B13 V. A. SIDOROV	+ALLEY, BINTINGER, DITZLER, + (FNAL+MICH+PURD) +FUKUSHIMA, HARVEY, LOBKOWICZ, MAY, + (RCH) +BOHRINGER, DORSZAK, HUNGERBUHLER, + (GENEVA) +BLOCKZIJL, HEINEN, + (AMST+CERN+NIJM+DXF) +AYRES, DIEBOLD, KRAMER, PAWICKI, WICKLUND (ANL) +MOKOSI, MARSHAK, PETERSGN, RUDTICK, + (MINN) EVANGELIST A, + (BARI+BONN+CERN+OARE+GLAS+) +OTTER, KLEIN, + (AACH+BERL+CERN+LOIC+WIEN) +COOPER, CLARK (OXF) V. A. SIDOROV (NCVO)
BARTALUC 78 NC 44 A 587 COOPER 78 NP B 146 1 LOSTY 78 NP B 133 38	BARTALUCCI, BASINI, BERTOLUCCI+ (DESY+FRAS) +GURU, MCANETAN, + (TATA+CERN+COEF+MADR) +HOLMGREN, BLOCKZIJL, + (CERN+AMST+NIJM+CXF)
CORDER 79 PL B 81 389 ROOS 79 LNC	+DELCOURT, ELSCHTRUTH, FULDO, + (LALO) +PELLINEN (HEL)

M(1033-1040)

67 M(1033-1040)
THE CLAIM FOR A NARROW RESONANCE AT 1033 MEV BY GARFINKEL 72 HAS NOT BEEN CONFIRMED BY BINNIE 74, GRAY 74, BUTTRAM 75. OMITTED FROM TABLE.
THE CLAIM FOR AN OMEGA PI RESONANCE AT 1040 MEV BY DEFOIX 73 HAS NOT BEEN CONFIRMED BY DIAZ 74. OMITTED FROM TABLE.

REFERENCES FOR M(1033-1040)

GARFINKEL 72 PRL 29 1477 DEFOIX 73 PL 43 B 141 BINNIE 74 PRL 32 392 DIAZ 74 PRL 32 260 GRAY 74 NP B 75 189 BUTTRAM 75 PRL 35 973	GARFINKEL, HOFFMAN, JACOBEL, + (PURD+ANL+IDWA) +DOBRYNSKI, ESPIGAT, NASCIMENTO, + (COEF) +CAMILLERI, GARR, DEBENHAM, + (LOIC+SHMP) +DIBIANCA, FICKINGER, ANDERSON, + (CASE+CERN) +HYAMS, JONES, BLUM, DIETL, KOCH+ (CERN+MPIM) +CRAWLEY, DUKE, LAMB, LEEPER, PETERSON (ISU)
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$\eta_N(1080)$

30 $\eta_N(1080, J^P = N^+)$ I=0 J GREATER THAN 1
SOME EXPERIMENTS SUGGEST $J^P = 2^-$. NOT CONFIRMED BY GRAY 74, FROGGATT 77. OMITTED FROM TABLE.

30 η_N MASS (MEV)					
M	1060.0	15.0	MILLER 68 HBC	4.0 PI - P	9/68
M	70 1085.0	10.0	WHITEHEAD 68 ASPK	3.1-3.6 PI-P	10/67
M	1120.0	100.0	OH 69 HBC	7. PI - P, PI + D	9/69
M	1112.0	16.0	CLAYTON 70 HBC	2.5 PBAR P, 4 PI	1/71
M	(1100.0)		DIAZ 70 HBC	0. PBAR P, 4 PI	5/70
M	1070.0	20.0	REYNOLDS 70 HBC	2.26-2.36 PI - P	1/71
M	.....	.....	
M	AVG 1083.3	9.8	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)		
M	STUDENT 1085.0	8.3	AVERAGE USING STUDENT 10H/1.11 -- SEE MAIN TEXT		

30 η_N WIDTH (MEV)					
W	(70.0)	OR LESS	MILLER 68 HBC	4.0 PI - P	9/68
W	(25.0)	OR LESS	WHITEHEAD 68 ASPK	3.1-3.6 PI-P	10/67
W	150.0	100.0	OH 69 HBC	7. PI - P, PI + D	9/69
W	(80.0)		CLAYTON 70 HBC	2.5 PBAR P, 4 PI	1/71
W	(80.0)		DIAZ 70 HBC	0. PBAR P, 4 PI	5/70
W	85.0	35.0	REYNOLDS 70 HBC	2.26-2.36 PI - P	1/71
W	.....	.....	
W	AVG 57.7	34.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
W	STUDENT 57.7	34.5	AVERAGE USING STUDENT 10H/1.11 -- SEE MAIN TEXT		

Mesons

MILLER 68 PRL 21 1489 WHITEHEAD 68 NC 53 A 817 OH 69 PRL 23 331 CLAYTON 70 NP B 22 85 DIAZ 70 NP B 16 239 REYNOLDS 70 NP B 21 77 WHITEHEAD 72 NP B 48 365 DIAMOND 73 PR D 7 1977 GRAY 74 NP B 75 189 FROGGATT 77 NP B 129 89	+GUTAY, JOHNSON, KENNEY+ (PURDUE+NDAM+SLAC) C. WHITEHEAD + (AERE+SHMP+LCIC) +WALKER, RHELL, FIREBAUGH, + (WISC+INTO) +MASON, MUIRHEAD, RIGDPOULOS, + (LIVP+ATEN) +GAVILLET, LABROSSE, MONTANET, + (CERN+CDEF) +ALBRIGHT, BRADLEY, + (OHIO+SU+MINN+GLO) WHITEHEAD, AULD, + (AERE+RHEL+SHMP+LUC) +BINKLEY, + (WISC+DUKE+COLD+TNTD+DHI) +HYAMS, JONES, BLUM, DIETL, KOCH+ (CERN+MPIM) +PETERSEN (GLASGOW+COPENHAGEN)
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REFERENCES FOR η_N

M(1150-1170) 68 M(1150-1170)
THIS ENTRY LISTS REFERENCES TO PEAKS OF LOW STATISTICAL SIGNIFICANCE IN THE 3 PI SYSTEM BETWEEN THE A1 AND A2, AS WELL AS A CLAIM FOR A NARROW RESONANCE AT 1150 MEV BY JACOBEL 72. NOT CONFIRMED BY BUTTRAM 75. OMITTED FROM TABLE.

REFERENCES FOR M(1150-1170)

BUTTRAM 67 HEIDELB. CONF. P. 28 CASON 67 PRL 18 880 ASCOLI 68 PRL 21 113 DONALD 68 PL 26 B 327 VGN KRUG 68 PL 27B 253 JURKMAN 68 NP B8 671 ARMENSE 69 LNC 2 501 GALLOWAY 70 PR D 1 3077 JACOBEL 72 PRL 29 671 NORSE 72 NP B 43 77 BUTTRAM 75 PRL 35 970 CORDEN 78 NP B 136 77	REVIEW TALK ON MESONS AT HEIDELBERG CONF. +LAMS, BISHOP, DERADO, GROVES, + (INDREAME) +CRAWLEY, KRUSE, MORRIS, SCHAFFER, + (ILLINGIS) +FRODESEN, BETTINI, + (LIVERPOOL, OSLO, PADUA) +MIYASHITA, KOPELMAN, MARSHALL LIBBY (CLO) +CGCOTI+ (AACH+BERL+BONN+CERN+MARS) +GHIDINI, FRINO, CARTACCI+ (BARI+BGNA+FRIZ) +MOTT, ALEYA, LEE, MARTIN, PRICKETT (IND) +GARFINKEL, HOFFMAN, + (IOWA+PURD+DND) +OH, WALKER, JOHNSTON, YOON (WISC+INTO) +CRAWLEY, DUKE, LAMB, LEEPER, PETERSON (ISU) +DOWELL, GARVEY, JOBS, + (BIRM+RHEL+TEL+LWCJ) JP
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REFERENCES FOR $A_1(1100-1300)$

$A_1(1100-1300)$ 10 $A_1(1100-1300, J^P = 1^-)$ I=1

The peak in the $(3\pi)^{\pm}$ mass distribution near the $\rho\pi$ threshold was discovered by BELLINI 63 in very forward π^- scattering on carbon without nuclear break-up, thus coherent diffractive $\rho\pi$ production.

Until 1977, all the significant observations of a $\rho^0\pi^{\pm}$ peak near 1100 MeV were made in the reaction $\pi^{\pm}N \rightarrow (\pi\pi\pi)^{\pm}N$. At small momentum transfer, the diffraction-like mechanism without quantum number exchange in the t channel contributes to this reaction. The dominant effect is a broad $J^P = 1^+$ enhancement in the S-wave $\rho\pi$ system, its width being ~300 MeV (ANTIPOV 73, OTTER 74, KRUSE 74, TABAK 74, THOMPSON 74, EMMS 75, BALTAY 77, PERNER 78, ROBERTS 78, DAUM 80). The position of the maximum intensity falls in the range 1100 to 1300 MeV and varies with t (DAUM 80).

Most of these experiments have been partial-wave analyzed by the method of ASCOLI 70. Assuming that, for a given momentum transfer t, the 3π vertex is independent of the NN vertex, the 3π vertex is composed, in the spirit of the non-unitary isobar model, of quasi-two-body $\pi\rho$ and $\pi\pi$ amplitudes. The waves contributing to the diffractive 3π final state are (at most) the $0^-P, 1^+S, 1^+D, 2^-P, 3^+D, 1^-P$, and 2^+D $\rho\pi$ waves and the $0^-S, 1^+P$, and 2^-D $\pi\pi$ waves. Here ϵ stands for a pole simulating the non-resonant $J^P = 0^+$ $\pi\pi$ interaction in the 700 to 900 MeV region [see the review of

Mesons

 $A_1(1100-1300)$

S-wave $\pi\pi$ interactions under $\epsilon(1300)$.

The results of these analyses have shown that the phase of the 1^+S wave displays little variation relative to the 0^-S ($\epsilon\pi$), 1^+P ($\epsilon\pi$), and 2^-P ($\rho\pi$) waves (ANTIPOV1 73, OTTER 74, TABAK 74, THOMPSON 74, BALTAY 77). As the 2^+D wave exhibits a clear Breit-Wigner-like phase change in the A_2 region (ASCOLI 70, ANTIPOV1 73, OTTER 74, TABAK 74, THOMPSON 74, BALTAY 77), the above results have been interpreted to imply that no resonant A_1 is needed. Unitarity corrections to the isobar model did not change this conclusion (ASCOLI 75, AITCHISON 75).

More recent analyses, however, have provided new evidence for an A_1 resonance. BOWLER 75 demonstrated that the small variation in the 1^+S phase could be due to a phase difference between the Deck amplitude and the direct A_1 resonance production amplitude. This small phase variation also could be due to inelasticity, because of the coupling of $\rho\pi$ to the $\epsilon\pi$ and $K^*\bar{K}$ channels, or to rescattering (BRAYSHAW 76, LONGACRE 76,77). SCHULT 77 reanalyzed the ANTIPOV1 73 data using three-pion-state amplitudes which satisfy both unitarity and analyticity, and found a solution with considerably more phase variation than originally had been observed.

BASDEVANT 77 performed an analysis of the $\rho\pi$ waves exclusively, ignoring the $\epsilon\pi$ waves as being meaningless in an isobar analysis since the ϵ could not be considered a bona fide particle. Their full amplitude is properly analytic and unitary, and it includes: the Deck amplitude (resonant as well as background elastic $\rho\pi \rightarrow \rho\pi$ scattering), rescattering corrections, inelasticity due to the $K^*\bar{K}$ channel, and direct diffractive A_1 production. They take the 1^+S phase from the difference of the known A_2 phase and the observed 2^+D-1^+S phase difference (ANTIPOV1 73). BASDEVANT 77 show that the ANTIPOV1 73 data are consistent with a resonance at $M = 1300 \pm 150$ MeV, $\Gamma = 400 \pm 100$ MeV, and that the data are rather inconsistent with the hypothesis of no resonance.

New light has been shed on the existence of the A_1 by the PERNEGR 78 data on coherent π scattering on nuclei. For the first time these data contain information on the 1^+S-0^-P phase difference.

Data Card Listings

For notation, see key at front of Listings.

Although this phase-shift analysis is ambiguous between two solutions, one solution exhibits a 1^+S-0^-P phase increase of 90° from threshold up to 1400 MeV, together with a peak in the 1^+S intensity around 1100 MeV. The energy dependence of the 1^+S-0^-P phase difference is in fact exactly as predicted by BASDEVANT 77 on the basis of the ANTIPOV1 73 data. Overwhelming confirmation now comes from the very large DAUM 80 experiment on a proton target. They find a unique and stable solution which exhibits not only the 1^+S-0^-P phase increase up to 1400 MeV, but, by comparing with the A_2 phase, they are able to show unambiguously that the 1^+S , 1^+P , and 0^-S phases all increase with mass, the forward motion of the 1^+S phase being $\approx 80^\circ$ in the 1100 to 1500 MeV region.

A long-standing problem of the A_1 has been its non-observation in non-diffractive processes (for a review of the situation up to 1976, see HABER 77). Here also the situation is completely changed due to new observations.

GAVILLET 77 have analyzed backwardly produced 3π events in the reaction $K^-p \rightarrow \Sigma^- \pi^+ \pi^+ \pi^-$ in sufficient number to project out the different partial waves. An A_1 peak seen in the total 3π mass distribution can be attributed to the 1^+S partial wave. The Breit-Wigner parameters of the peak are $M = 1041 \pm 13$ MeV, $\Gamma = 230 \pm 50$ MeV. The SU(3) assignment of an A_1 with these parameters to the $J^{PC} = 1^{++}$ nonet together with the Q 's, the D(1285), and the E(1420) is not completely satisfactory and may indicate that the experimental masses are far from the pole positions on the second sheet (MAZZUCATO 79, DIONISI 80). A possible confirmation of backward A_1 production by pions has been obtained by FERRER 78. The observed peak has the resonance parameters $M \approx 1050$ MeV, $\Gamma \approx 200 \pm 50$ MeV, but nothing is known about the partial-wave composition. The production cross sections at the two different beam momenta of FERRER 78 agree with limits set by earlier, less significant experiments (ANDERSON 69, ABASHIAN 75).

On the other hand, no evidence for the A_1 is found in the charge-exchange reactions $\pi^+n \rightarrow \pi^+\pi^-\pi^0p$ (EMMS2 75), $\pi^+p \rightarrow \pi^+\pi^-\pi^0\Delta^{++}$ (WAGNER 75, BALTAY 77), $\pi^-p \rightarrow \pi^+\pi^-\pi^0n$ (CORDEN 78), or $K^-p \rightarrow \pi^+\pi^-\pi^0\Lambda^0$ (CERRADA 77). However, the number of partial waves

Data Card Listings

For notation, see key at front of Listings.

is greater in charge exchange due to the two possible values of isospin, and thus the analysis is more complicated.

Other non-diffractive channels, such as $\bar{p}p$ annihilation, have not produced consistent results of sufficiently high statistical significance. At best, an A_1 shoulder has been seen in the $(3\pi)^-$ spectrum from $\bar{p}d \rightarrow p\pi^+\pi^-\pi^0$. However no A_1^0 is observed. The effect is interpretable as interference between various resonance channels (KASPER 79).

Finally, the semileptonic decay $\tau^\pm \rightarrow A_1^\pm \nu$ seems to have been discovered at PLUTO (ALEXANDER 78, WAGNER 79) and confirmed at SLAC-LBL (JAROS 78). The PLUTO $\pi^+\pi^-\pi^\pm$ mass distribution with a $\rho^0\pi^\pm$ selection shows a peak centered at $M \lesssim 1200$ MeV, $\Gamma \sim 400$ to 500 MeV, very unlike phase space. The Dalitz plot distribution is consistent with 1^+S . However, with only 27 events in the plot, it is not possible to rule out all other possible waves.

To summarize, most of the data now seem to require the presence of an A_1 resonance, but the quantitative details are far from being determined exactly. BASDEVANT 78 used the data of ALEXANDER 78 and JAROS 78 to restrict the range of solutions for the A_1 resonance parameters obtained in their analysis of diffractive A_1 production (BASDEVANT 77). The values they obtain, when expressed as second-sheet pole parameters rather than as simple Breit-Wigner parameters are $M \approx 1180 \pm 50$ MeV, $\Gamma = 400 \pm 50$ MeV.

DAUM 80, fitting simultaneously the 1^+S intensity and the phase relative to the 2^+D wave above 1 GeV with model amplitudes similar to the ones used by BOWLER 75 and BASDEVANT 77, find for the A_1 parameters: $M \approx 1280$ MeV, $\Gamma \approx 300$ MeV. This is not in complete agreement with PERNEGR 78, GAVILLET 77, FERRER 78, ALEXANDER 78, and JAROS 78, who find the peak of the 1^+S intensity around 1100 MeV. Thus, if the A_1 can finally be considered as a well established meson, the determination of its parameters is far from settled.

10 A1 MASS (MEV)	
M PRODUCED BY PI +	
M (1080.0)	
M (1090.0) APPROX.	ADERHOLZ 64 HBC 4.0 PI+P 6/68
M (1095.0) (6.0)	BOESEBECK 68 HBC + 8 PI+ P 2/67
M F (1119.0) (30.)	ARMENISE 70 HBC 0.9 PI+ N -- A1 P 1/71
	THOMPSON 74 HBC + 13 PI+P, P(3PI)+ 12/75

Mesons

$A_1(1100-1300)$

M PRODUCED BY PI -	
M (1080.0)	ASCOLI 68 HBC - 0.5 PI-P 6/68
M (1089.0) (12.0)	BALLAM 68 HBC - 16.0 PI-P 9/68
M (1090.0) APPROX.	CHUNG 68 HBC - 3.2, 4.2 PI-P 2/67
M (1095.0) (6.0)	JUNKMANN 68 HBC - 16. PI- P, 5PI 9/69
M S (1119.0) (30.)	KEY 68 HBC - 3 PI-P 9/68
M S SHOULDER ON A2 ONLY	
M (1069.0) (7.0)	CASO 70 HBC - 11.2PI-P 5/70
M (1120.0)	CRENNELL 70 HBC - 6. PI- P, F PI 5/70
M F T (1150.0)	ANTIPOVI 73 CNTR - 25., 40. PI- P 1/74
M T MASS AND WIDTH SEEN TO DEPEND ON T, UNIQUE DET. IMPOSSIBLE	1/74
M (1152.0) (9.0)	BALTAY 77 HBC 0.15 PI- P, P 3PI 12/77
M P (1100.0)	PERNEGR 78 CNTR - 9+13+15 PI- NUC. 4/78*
M PD (1280.0) (30.0)	DAUM 80 CNTR 63.94 PI- P 12/79*
M P PHASE VARIATION OBSERVED BETWEEN (1+S) AND (0-P) WAVES	
M D FROM A MODEL DEPENDENT FIT.	
M PRODUCED BY PICNS, BACKWARDS SCATT.	
M (1115.0) (20.0)	ANDERSON 69 MMS - 16 PI- P, BACKW9 8/69
M J (1050.0) (11.0)	FERRER 2 78 OMEG - 9+12 PI- P, P 3PI 4/78*
M J NO JP DETERMINATION ATTEMPTED	
M PRODUCED BY PBARS.	
M (1054.0) (7.0)	DANYSZ 67 HBC +- 3, 3.6 PBAR P 7/67
M (1042.0) (21.0)	FRIDMAN 68 HBC +- 5.7 PBAR P 6/68
M A (1076.0) (5.0)	ATHERTON 73 HBC +- 5.7 PBAR P 1/74
M A JP ANALYSIS GIVES SOME EVIDENCE FOR RHO PI D-WAVE	
M PRODUCED BY K-.	
M (1111.0) (10.0)	ALLISON 67 HBC + 6 K-P, LAM +5 PI 1/68
M (1117.0) (30.0)	ALLISON 67 HBC + 6 K-P, LAM +4 PI 1/68
M (1060.0) (15.0)	JUHALA 67 HBC 0.4, 6-5 K-P, 5BODY 1/68
M PRODUCED BY K+.	
M K+ (1060.0) (20.0)	ALEXANDER 69 HBC + 9 K+P 9/69
M K+ (1030.0) (20.0)	BERLINGHI 69 HBC + 0.12.7 K+ P 9/69
M K+ FOR CONTRADICTIONARY EVIDENCE SEE RABIN 70.	
M PRODUCED BY K-, BACKWARDS SCATTERING	
M F (1041.0) (13.0)	GAVILLET 77 HBC + 4.2 K- P, S 3PI 12/77
M F FROM A FIT TO JP=1+ RHO PI PARTIAL WAVE	
M PRODUCED IN TAU DECAY	
M 42(1100.0) APPROX.	JAROS 78 SMAG +- E+E-, MU+- 3PI 12/78*
M 27(1200.0) OR LESS	WAGNER 79 PLUT +- E+E-, E(MU) 3PI 12/79*
M AVERAGING NOT MEANINGFUL	

10 A1 WIDTH (MEV)

W PRODUCED BY PI +	
W (80.0)	ADERHOLZ 64 HBC 4.0 PI+P 6/68
W (130.0) APPROX.	BOESEBECK 68 HBC + 8 PI+ P 1/71
W (50.0) OR LESS	ARMENISE 70 HBC 0.9 PI+ N -- A1 P 6/78
W F (300.0) APPROX.	RINAUDO 71 HBC + 5. PI+P, P(3PI)+ 11/71
W (367.0) (30.0)	THOMPSON 74 HBC + 13 PI+P, P(3PI)+ 12/75
W PRODUCED BY PI -	
W (140.0) (31.0)	BALLAM 68 HBC - 16.0 PI- P 9/68
W (125.0) APPROX.	CHUNG 68 HBC - 3.2, 4.2 PI-P 2/67
W (177.0) (17.0)	JUNKMANN 68 HBC - 16. PI- P, 5PI 9/69
W K (76.0) (46.0)	KEY 68 HBC - 3.0 PI- P 11/67
W K SHOULDER ON A2 ONLY	
W (99.0) (15.0)	CASO 70 HBC - 11.2PI-P 5/70
W F T (300.0)	ANTIPOVI 73 CNTR - 25., 40. PI- P 1/74
W T MASS AND WIDTH SEEN TO DEPEND ON T, UNIQUE DET. IMPOSSIBLE	1/74
W (264.0) (11.0)	BALTAY 77 HBC 0.15 PI+ P, P 3PI 12/77
W P (300.0)	PERNEGR 78 CNTR - 9+13+15 PI- NUC. 4/78*
W PD (300.0) (30.0)	DAUM 80 CNTR 63.94 PI- P 12/79*
W P PHASE VARIATION OBSERVED BETWEEN (1+S) AND (0-P) WAVES	
W D FROM A MODEL DEPENDENT FIT.	
W PRODUCED BY PICNS, BACKWARDS SCATT.	
W (198.0) (45.0) (20.0)	ANDERSON 69 MMS - 16 PI- P, BACKW9 8/69
W J (195.0) (32.0)	FERRER 2 78 OMEG - 9+12 PI- P, P 3PI 4/78*
W J NO JP DETERMINATION ATTEMPTED	
W PRODUCED BY PBARS.	
W (33.0) (19.0)	DANYSZ 67 HBC +- 3, 3.6 PBAR P 7/67
W (130.0) APPROX.	FRIDMAN 68 HBC +- 5.7 PBAR P 6/68
W A (36.0) (20.0) (15.0)	ATHERTON 73 HBC +- 5.7 PBAR P 1/74
W A JP ANALYSIS GIVES SOME EVIDENCE FOR RHO PI D-WAVE	
W PRODUCED BY K-.	
W (50.0) (50.0)	ALLISON 67 HBC + 6 K-P, LAM +4 PI 1/68
W (50.0) (25.0)	ALLISON 67 HBC + 6 K-P, LAM +5 PI 1/68
W (120.0) (15.0)	JUHALA 67 HBC 0.4, 6-5 K-P, 5BODY 1/68
W PRODUCED BY K+.	
W (160.0) (20.0)	ALEXANDER 69 HBC + 9 K+P 9/69
W B (120.0) (30.0)	BERLINGHI 69 HBC 12.7 K+ P 8/69
W K+ FOR CONTRADICTIONARY EVIDENCE SEE RABIN 70.	
W (130.0) (20.0)	BERLINGHI 69 HBC + 0.12.7 K+ P 9/69
W PRODUCED BY K-, BACKWARDS SCATTERING.	
W F (230.0) (50.0)	GAVILLET 77 HBC + 4.2 K- P, S 3PI 12/77
W F FROM A FIT TO JP=1+ RHO PI PARTIAL WAVE	
W PRODUCED IN TAU DECAY	
W 42(200.0) APPROX.	JAROS 78 SMAG +- E+E-, MU+- 3PI 12/78*
W 27 400. TO 500.	WAGNER 79 PLUT +- E+E-, E(MU) 3PI 12/79*
W AVERAGING NOT MEANINGFUL	

10 A1 PARTIAL DECAY MODES

P1	A1 INTO RHO PI	DECAY MASSES
P2	A1 INTO KBAR K	776+ 139
P3	PI (PI PI) S WAVE	493+ 497
		139+ 139+ 139

10 A1 BRANCHING RATIOS

R1	A1 INTO (KBAR K)/(RHO PI)	(P2)/(P1)
R1	(0.0025) OR LESS	DAHL 67 HBC - 4.0 PI- P .10/66

Mesons

A₁(1100-1300), B(1235)

Data Card Listings

For notation, see key at front of Listings.

REFERENCES FOR A1

Table listing references for A1 mesons, including authors like Bellini, Adersholz, Goldhaber, and various institutions like CERN, FNAL, and SLAC.

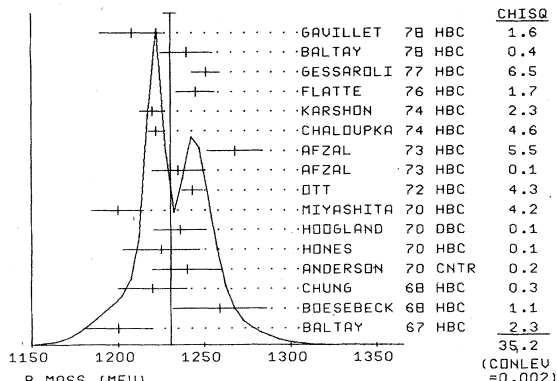
B(1235)

11 B(1235, JP=1++) I=1

11 B MASS (MEV)

Table listing B meson mass measurements from various experiments, including authors like Abolins, Goldhaber, Baltay, and institutions like CERN, FNAL, and SLAC.

WEIGHTED AVERAGE = 1230.6 ± 3.7
ERROR SCALED BY 1.5



11 B WIDTH (MEV)

Table listing B meson width measurements from various experiments, including authors like Abolins, Goldhaber, Baltay, and institutions like CERN, FNAL, and SLAC.

Data Card Listings

For notation, see key at front of Listings.

Mesons

B(1235), rho'(1250), f(1270)

11 B PARTIAL DECAY MODES

Table with columns for particle ID (P1-P7), decay mode (e.g., B INTO OMEGA+PI), and decay masses (e.g., 782+ 139).

11 B BRANCHING RATIOS

Table with columns for particle ID (R10-R17), decay mode (e.g., D/S RATIO FOR B(1235) INTO OMEGA PI), and branching ratios (e.g., 0.3, 0.1).

Table with columns for particle ID (R1-R6), decay mode (e.g., B INTO (4PI)/(OMEGA PI)), and branching ratios (e.g., (0.5) OR LESS).

REFERENCES FOR B(1235)

List of references for B(1235) meson, including authors like ABOLINS, LANDER, MEHLHOP, XUONG, YAGER, etc.

rho'(1250)

Table for rho'(1250) meson, including RHO PRIME(1250) MASS (MEV) and RHO PRIME(1250) WIDTH (MEV) data.

Table for rho'(1250) meson, including RHO PRIME(1250) WIDTH (MEV) data.

REFERENCES FOR RHO PRIME(1250)

List of references for rho'(1250) meson, including authors like ANDERSON, PODOLSKY, FRENKIEL, etc.

f(1270)

Table for f(1270) meson, including F(1270, JPC=2+-) I=0 and F MASS (MEV) data.

Table for f(1270) meson, including F MASS (MEV) data.

EVIDENCE FOR A STRUCTURE CLAIMED IN BECKER 79 ANALYSIS. USES S.C. DATA AS HYAMS 75. ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS.

Table for f(1270) meson, including F WIDTH (MEV) data.

Mesons f(1270)

Data Card Listings

For notation, see key at front of Listings.

Table with columns for W, T, I, G, M, N, S, A, V, and student values, and corresponding author names and dates.

W E EVIDENCE FOR A STRUCTURE CLAIMED
W G INCLUDED IN BECKER 79 ANALYSIS
W H USES SAME DATA AS HYAMS 75
W I ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
W J JOHNSON 68 INCLUDES BONDAR 63, LEE 64, DERADO 65, EISNER 67.
W T WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SORT(N), SEE K* TYPED NOTE

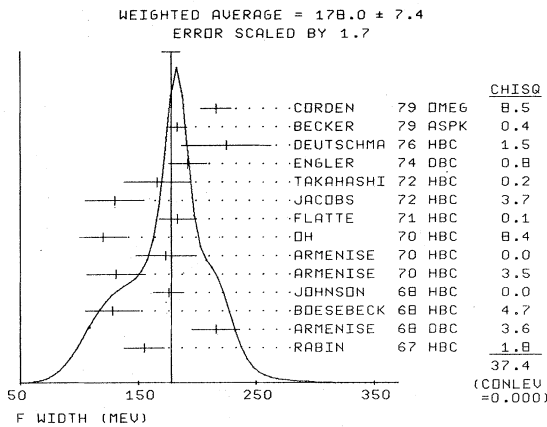


Table with columns for P1-P8, F INTO (PI PI), and DECAY MASSES.

Table with columns for W1, F INTO GAMMA GAMMA (KEV), and authors.

Table with columns for R1-R11, F INTO (2P1+2P1-)/(PI PI), and branching ratios.

Table with columns for R2-R3, F INTO (PI+PI-2PI0)/(PI PI), and F INTO (K KBAR)/(PI PI).

R3 C THIS DETERMINATION HAS QUANTITATIVELY ACCOUNTED FOR BOTH F-PRIME
R3 C AND A2 INTERFERENCE EFFECTS.
R3 M TAKES INTO ACCOUNT THE F-F* INTERFERENCE
R3 N BY EXTRAPOLATION TO THE PION POLE
R3 W USING F PRIME WIDTH = 40 MEV

WEIGHTED AVERAGE = 0.0339 +/- 0.0033
ERROR SCALED BY 1.3

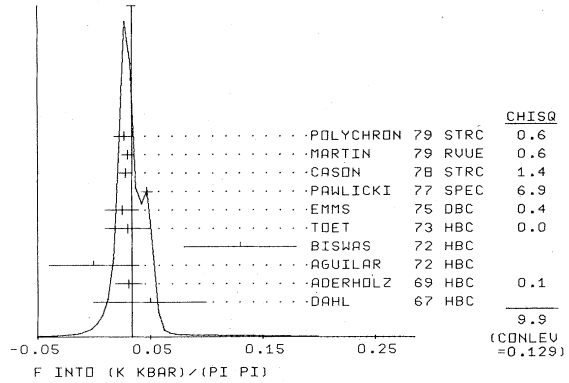


Table with columns for R4-R6, F INTO (K0 K- PI+ AND C.C.)/(PI PI), F INTO (ETA PI PI)/(PI PI), and F INTO (ETA PI PI)/(PI PI).

R10 G INCLUDED IN BECKER 79 ANALYSIS
R10 H USES SAME DATA AS HYAMS 75
R10 I ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS

WEIGHTED AVERAGE = 0.831 +/- 0.019
ERROR SCALED BY 1.4

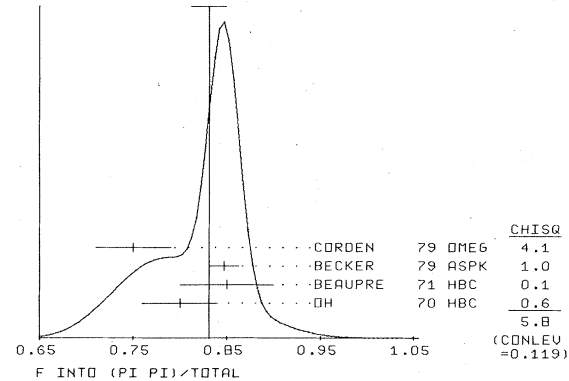


Table with columns for author names and references for F mesons.

Data Card Listings

Mesons

For notation, see key at front of Listings.

f(1270), η(1275), D(1285)

ACCENSI 66 PL 20 557
JACOBS 66 UCRL-16877
WAHLIG 66 PR 147 941

BAKLOW 67 NC 50A 701
BEUSCH 67 PL 25 B 357
DAHL 67 PR 163 1377
EISNER 67 PR 164 1699
POIRIER 67 PR 163 1462
RABIN 67 THESES

ARMENISE 68 NC 54 A 999
ASCOLI 68 PRL 21 1712
BOESEBECK 68 NP B 4 501
FOSTER 68 NP B 6 107
JOHNSON 68 PR 176 1651
LANSA 68 PR 166 1395
WHITEHEA 68 NC 53A 817

ADERHOLZ 69 NP B 11 259
AGUILAR 69 PL 29 B 241
ARMENISE 69 LNC 2 501
CASO 69 NC 62 A 755
DONALD 69 NP B 11 551

AGUILAR 70 PRL 25 58
ARMENISE 70 LNC 4 199
BADIER 70 NP B 22 512
OH 70 PR 0 1 2494
STUNTEBE 70 PL 32 B 391

BARDAIN 71 PR D4 2711
BEAUPRE 71 NP B 28 77
FARBER 71 NP B 29 237
FLATTE 71 PL 34 B 551

AGUILAR 72 PR D 6 29
BISWAS 72 PR D 5 1564
FOGLI 72 NC 8 A 670
GRAYER 72 PHL CONF. PROC. 5
JACOBS 72 PR D 6 1291
KEMP 72 NC 8 A 611
SCAROTT 72 LNC 3 271
TAKAHASHI 72 PR D 6 1266
WHITEHEA 72 NP B 48 365

ANDERSON 73 PRL 31 562
BUGG 73 PR D 7 3264
CHARLESW 73 NP B 65 253
HYAMS 73 NP B 64 134
TOET 73 NP B 63 248

EISENBERG 74 PL 52B 239
ENGLER 74 PR D10 2070
GRAYER 74 NP B 75 189
HOLLOWAY 74 PR D9 1161
LOUIE 74 PL 48B 385

EMMS 75 NP B96 155
ESTABROO 75 NP B95 222
HYAMS 75 NP B100 205
PAWLICKI 75 PR D12 631

DEUTSCHM 76 NP B 103 426
WETZEL 76 NP B 115 208

ALEXANDE 77 NP B 131 365
ANTIPOV 77 NP B 119 45
PAWLICKI 77 PR D 15 3196

SALTAY 78 PR D 17 62
CASON 78 PRL 41 271

ACCENSI, ALLES-BORELLI, FRENCH, FRISK+ (CERN)
L.D. JACOBS, THESES (LRL)
+SHIBATA, GORDON, FRISCH, MANNELLI (MIT+PISA) J

+LILLETSTOL+MONTANET+ (CERN+CDEF+IRAD+LIVP)
+FISCHER, GCBBI, ASTBURY+ (ETH+CERN)
+HARDY+HES+KIRZ+MILLER (LRL)
+JOHNSON+KLEIN+PETERS+SAHNI+YEN+ (PURDUE)
+BISWAS, CASON, DERADO, KENNEY+ (NDAM+PENN)
+M. RABIN (RUTGERS)

+FORINCO+CARTEGGI+ (BARI+BGNA+FIRENZE+ORSAY)
G. ASCOLI, H. B. CRAWLEY, D. W. MORTARA+ (ILL)
BOESEBECK, DEUTSCHMANN+ (AACHEN+BERLIN+CERN)
+GAVILLET+LABROSSE+MONTANET+ (CERN+CDEF)
+POIRIER, BISWAS, GUTAY+ (NDAM+PURD+SLAC)
+CASON+BISWA S+DE RADO+GROVES+ (NOTREDAME)
+MCEWEN, OTT, AITKEN+ (AERE+SIMP+LUC)

+BARTSCH, + (AACH+BERL+CERN+JAGL+WARS)
M. AGUILAR-BENITEZ, J. BARLOW, + (CERN+CDEF)
+GHIDINI+FORINO, CARTEGGI+ (BARI+BGNA+FRIZ)
+CONTI, BENZI+ (GENO+DESY+HAMB+MILA+SACL)
+EDWARDS, BURAN, BETTINI, + (LIVP+OSLO+PAOD)

AGUILAR-BENITEZ, BARNES, BASSANO, + (BNL+SYRA)
+GHIDINI+FORINO, CARTEGGI+ (BARI+BGNA+FRIZ)
+BONNET, DREVILLON, BAUBILLIER, + (EPFL+IPNP)
+GARFINKEL, MORSE, WALKER, PRENTICE (WISC+INTJ)
STUNTEBECK, KENNEY, DEERY, BISWAS, CASON+ (NDAM)

BARDAIN+GTHINOWSKA, HOFMOKL, + (WARS)
+DEUTSCHMANN, GRAESSLER, + (AACH+BERL+CERN)
+DE PINTO, BISWAS, CASON, DEERY, KENNEY, + (NDAM)
+ALSTON-GARNJUST, BARBARO-GALTIERI, + (LBL)

AGUILAR-BENITEZ, CHUNG, EISNER, SAMIOS (BNL)
+CASON, HARRINGTON, KENNEY, SHEPHARD (NDAM)
FOGLI-MUCIACCIA, PICCARELLI (BARI)
+HYALES+JONES, SCHLEIN, BLUM, DIETL+ (CERN+MPIIM)
L.D. JACOBS (SACLAY)
+MAJOR, CONTRI, + (DURH+GENO+MILA+EPOL+LPP)
SCAROTT, KEMP (DURHAM)
TAKAHASHI, BARISH, + (TOHO+PENN+NDAM+ANL)
WHITEHEA, AULD, + (AERE+RHEL+SIMP+LUC)

+ENGLER, KRAEMER, TOAF, DIAZ, + (CERN+CASE)
+CONDO, HART, CGHN, ENDORF, + (TENN+ORNL+C INC)
CHARLESWORTH, EMMS, BELL, + (RHEL+BRIM+DURH)
+JONES, WEILHAMMER, BLUM, DIETL, + (CERN+MPIIM)
+THUAN, MAJOR, RINAUDO, + (NIJM+BONN+DURH+TCRI)

EISENBERG, ENGLER, HABER, KARSHON+ (REHO)
+KRAEMER, TOAFF, WEISSER, DIAZ+ (CERN+CASE)
G. GRAYER, HYAMS, BLUM, DIETL, + (CERN+MPIIM)
+HULD, JORDAN, KOETZ, BERNSTEIN+ (ILL+LILL)
+ALITTI, GANDDIS, CHALOUKPA+ (SACL+CERN)

+KINSON, STACEY, VOTRUBA+ (BIRM+DURH+RHEL)
P. ESTABROOKS, A. D. MARTIN (DURH)
+JONES, WEILHAMMER, BLUM, DIETL+ (CERN+MPIIM)
+AYRES, DIEBOLD, GREENE, KRAMER, WICKLUND (ANL)

+KIRK, + (AACH+BERL+BONN+CERN+CRAC+HEID+WARS)
+FREUNDREICH, BEUSCH, + (ETH+CERN+LUC)
ALEXANDER, CORDEN, + (TELA+BIRM+RHEL+LWIC)
+BUSNELLO, DAMGAARD, KIENZLE, + (SERP+GEVA)
+AYRES, COHEN, DIEBOLD, KRAMER, WICKLUND (ANL)

+CAUTIS, COHEN, CSORNA, SMITH, YEY, + (COLU+BIN)
+BAUMBAUGH, BISHOP, BISWAS, KENNEY, + (NDAM+ANL)
+ALAM, BLOCKER, BOYARSKI, + (SLAC+LBL)
+BLANAR, BLUM, GERDA, + (MPIIM+CERN+ZEEM+CRAC)
+HOWELL, GARVEY, JONES, + (BIRM+RHEL+TELA+LWIC)
+NICZYPOUR, RZANSKA+ (CRAC+MPIIM+CERN+ZEEM)
+ARMENTEROS, DIONISII+ (CERN+CDEF+MADR+STOH)
+GZMUTLU (DURH)
POLYMERONAKIS, CASON, BISHOP+ (NDAM+ANL)

REFERENCES FOR ETA(1275)
STANTON 79 PRL 42 346 +BROCKMAN, DANKOWYCH, + (OSU+CARL+MCGI+TNT) JP

D(1285)

8 D(1285, JPG=1++) I=0

Table with columns for mass (MEV), particle name, and various parameters. Includes entries for BARLOW, DAHL, D-ANDLAW, etc.

Table with columns for width (MEV), particle name, and various parameters. Includes entries for DAHL, D-ANDLAW, DEFOIX, etc.

Table with columns for partial decay modes, particle name, and various parameters. Includes entries for D INTO K KBAR, D INTO PI PI RHO, etc.

Table with columns for branching ratios, particle name, and various parameters. Includes entries for D INTO (PI PI RHO) / (K KBAR PI), etc.

Table with columns for decay masses, particle name, and various parameters. Includes entries for D INTO K KBAR, D INTO PI PI RHO, etc.

η(1275)

37 ETA(1275, JPG=0++) I=0
SEEN IN PHASE SHIFTS ANALYSIS OF THE ETA PI+ PI- SYSTEM WITH PI+ PI- IN AN S-WAVE (STANTON 79). WAIT CONFIRMATION. OMITTED FROM TABLE.

37 ETA(1275) MASS (MEV)
M (1275.) APPROX. STANTON 79 CNTR 0 8.4PI-P, ETA 2PI 12/79*

37 ETA(1275) WIDTH (MEV)
W (70.) APPROX. STANTON 79 CNTR 0 8.4PI-P, ETA 2PI 12/79*

37 ETA(1275) PARTIAL DECAY MODES
P1 ETA(1275) INTO DELTA PI 981+ 139
P2 ETA(1275) INTO ETA PI+ PI- 548+ 134+ 139

37 ETA(1275) BRANCHING RATIOS.
R1 ETA(1275) INTO DELTA PI (P1) STANTON 79 CNTR 0 8.4PI-P, ETA 2PI 12/79*

Rev. Mod. Phys., Vol. 52, No. 2, Part II, April 1980

Mesons

D(1285), $\epsilon(1300)$

Data Card Listings

For notation, see key at front of Listings.

REFERENCES FOR D

D-ANDLAU 65 PL 17 347
 MILLER 65 PRL 14 1074
 BARLOW 67 NC 50 A 701
 DAHL 67 PR 163 1377
 C-ANDLAU 68 NP B 5 693
 DEFOIX 68 PL 28 B 353

CAMPBELL 69 PRL 22 1204
 DCNALD 69 NP B 11 551
 LORSTAD 69 NP B 14 63
 OTWINOWSKI 69 PL 29 B 529

AMMAR 70 PR D2 430

BARADIN 71 PR D4 2711
 ROSEBEC 71 PL 34 B 659
 GOLDBERG 71 LNC 1 627

BERENVI 72 NP B 37 621
 CHAPMAN 72 NP B 42 1
 DEFOIX 72 NP B 44 125
 DUBOC 72 NP B 46 429
 THUN 72 PRL 28 1733

VUILLEMI 75 LNC 14 165
 WELLS 75 NP B 101 333

HANDLER 76 NP B 110 173
 VUILLEMI 76 NC 33A 133

GRASSLER 77 NP B 121 189

CORDEN 78 NP B 144 253
 IRVING 78 NP B 139 327
 NACASCH 78 NP B 135 203

GURTU 79 NP B 151 181
 STANTON 79 PRL 42 346

DIONISI 80 CERN-EP 80/1

+BARLOW, ADAMSON,+ (CDEF+CERN+IRAD+LIVP)
 +CHUNG, DAHL, HESS, HARDY, KIRZ,+ (LRL+UCB)
 +MONTANET, D-ANDLAU+ (CERN+CDEF+IRAD+LIVP)
 +HARDY, HESS+KIRZ+MILLER (LRL) I JP
 +ASTIER, BARLOW+ (CDEF+CERN+IRAD+LIVP) I JP
 +RIVET, SIAUD, CONFORTO+ (CDEF+IPNP+CERN)

+LICHTMAN,+ (PURD)
 +EDWARDS, BURAN, BETTINI,+ (LIVP+OSLO+PADO) JP
 B. LORSTAD, D-ANDLAU, ASTIER,+ (CDEF+CERN) JP
 S. OTWINOWSKI (WARSAW)

+KROPAC, DAVIS, DERRICK+ (KANS+NWES+ANL+WISC)

BARADIN-COTWINOWSKA, HOFMOKL, MICHEJDA+(WARS)
 (AACH+BERL+BONN+CERN+CRAC+HEID+WARS)
 +MAKOWSKI, TOUCHARD, DONALD,+ (IPNP+LIVP) JP

+PRENTICE, STEENBERG, YOON, WALKER (TNTD+NISC)
 +CHURCH, LYS, MURPHY, RING, VANDER VELDE (MICH)
 +NASCIMENTO, BIZZARRI,+ (CDEF+CERN)
 +GOLDBERG, MAKOWSKI, DONALD,+ (LPNP+LIVP)
 +BLIEDEN, FINOCCHIARO, BOWEN,+ (STON+NEAS)

VUILLEMIN,+ (LAUS+NEUC+LPNP+LIVP+GLAS) JP
 +RADOJICIC, ROSCOE, LYONS,+ (OXF)

+PLANO, BRUCKER, KOLLER+ (RUTG+STEV+SETO)
 VUILLEMIN+ (LAUS+NEUC+LPNP+LIVP+GLAS)

+ (AACHEN+BERLIN+BONN+CERN+CRAC+HEID+WARS)

+CORBETT, ALEXANDER,+ (BIRM+RHEL+TELA+LCNC) JP
 A. C. IRVING, H. R. SEPPANGI (LIVP)
 +DEFDIX, DOBRZYNSKI,+ (PARIS+MADRID+CERN)

+GAVILLET, BLOKZIJL,+ (CERN+ZEEM+NIJUM+CKF)
 +BROCKMAN, DANKOWYCH,+ (DSU+CARL+MGI+TNTD) JP

+GAVILLET, ARMENTEROS+ (CERN+MA CR+CDEF+STOH)

$\epsilon(1300)$

14 EPSILON(1300, JPG=D+*) I=0

S-Wave $\pi\pi$ and $K\bar{K}$ Interactions

In this note we discuss information on the non-strange $I^G_{J^P} = 0^+_{0^{++}}$ partial wave (S wave) coupled to the $\pi\pi$ and $K\bar{K}$ systems.

Near the $\pi\pi$ threshold the S wave shows no resonant behavior. For a discussion of the relevant scattering lengths and various resonance-like kinematic effects, see our 1978 edition.

Up to the ρ meson mass region, the phase shift δ^0_0 is (qualitatively) uniquely determined: it rises monotonically and reaches 60° to 70° near 700 MeV (SONDEREGGER 69, BATON 70, BAILLON 72, CARROLL 72, FRENKIEL 72, GAIDOS 72, PROTOPOESCU 73, HYAMS 73, OCHS 73, ENGLER 74, ESTABROOKS 74,75, GRAYER 74).

In the early phase-shift analyses two solutions for δ^0_0 were found (the "up-down ambiguity") in the 700 to 900 MeV region. The "up" solution corresponds to an ϵ resonance under the ρ meson with mass and width similar to the ρ meson, the $\epsilon(800)$. The "down" solution is characterized by an approximately energy-independent phase shift of almost 90° , showing no resonant behavior. This ambiguity was considered resolved in favor of the "down" solution by the observation of a very rapid decrease in the modulus of the S-wave amplitude between 900 MeV and the $K\bar{K}$ threshold, followed by a sharp drop in the elasticity. δ^0_0 is $\sim 90^\circ$ at about 900 MeV and reaches $\sim 180^\circ$ around 990 MeV (FLATTE 72, GAIDOS 72, HYAMS 73,

BINNIE 73, ENGLER 74). However, the region is complicated by the simultaneous presence of the S^* resonance and the opening of the $K\bar{K}$ channel, permitting almost discontinuous jumps from one solution to another.

Without polarization information, the reaction $\pi N \rightarrow \pi\pi N$ cannot be analyzed unambiguously due to the fact that there are more helicity amplitudes than observables (see, e.g., DONOHUE 75). Thus one is obliged to make some supplementary assumptions.

An amplitude analysis (ESTABROOKS 74) of the largest $\pi^- p$ (unpolarized) $\rightarrow \pi^+ \pi^- n$ experiment (HYAMS 73, GRAYER 74) still finds both the "up" and the "down" solutions. This analysis assumes both spin coherence (the unnatural-parity-exchange, s-channel helicity amplitudes are nucleon spin-flip, i.e., no A_1 -like exchange) and phase coherence (the S-wave amplitude and the unnatural-parity-exchange, meson helicity-zero P-wave amplitude have the same phase). These assumptions may tend to bias the results (MORGAN 74, DONOHUE 75,79).

The advent of $\pi^- p$ (polarized) $\rightarrow \pi^+ \pi^- n$ data (BECKER 79) has made both the spin coherence and phase coherence assumptions unnecessary. Analyzing their data in a model-independent way, BECKER 79 also find both the "up" and the "down" solutions.

The reaction $\pi^+ p \rightarrow \pi^+ \pi^- \Delta^{++}$ has been analyzed in the region 660 to 860 MeV (OWENS 76, DONOHUE 79) and in the region 600 to 920 MeV (GELFAND 78), using all the information carried by the Δ^{++} decay. The conclusion from both analyses is that the $\epsilon(800)$ of the "up" solution cannot be ruled out.

In a coupled-channel fit of various pole parametrizations to both $\pi\pi \rightarrow \pi\pi$ (ESTABROOKS 74) and $\pi\pi \rightarrow K\bar{K}$ data (CASON 76, PAWLICKI 77), ESTABROOKS 79 finds a pole located at 720 to 800 MeV with a width of 800 to 1000 MeV. Note that the "down" solution of ESTABROOKS 74 was used as input to this analysis. Further indirect information comes from elastic $\pi\pi$ scattering in the crossed channel (ELVEKJAER 72, NIELSEN 70,72) in agreement with the "down" solution, but not with the "up" solution.

The only way to rule out the "up" solution at present is to study the $\pi^0 \pi^0$ system, where the "up" solution predicts a ρ -meson-like bump unmasked by the ρ meson. With the exception of one experiment (DAVID 77), all the $\pi^0 \pi^0$ experiments agree that no

Data Card Listings

For notation, see key at front of Listings.

Mesons

 $\epsilon(1300)$

such bump is present and that the "down" solution describes the data well (DEINET 69, BENSINGER 71, APEL 72,79, BRAUN 73, SKUJA 73, RIESTER 75, BORREANI 79).

The region of elastic $\pi\pi$ scattering is known to extend to about 990 MeV, near the $K\bar{K}$ threshold (BATON 70, CARROLL 72, PROTOPODESCU 73, HYAMS 73, OCHS 73). Beyond 1 GeV we therefore have to consider the two channels $\pi\pi$ and $K\bar{K}$. In addition, the solutions have inherent ambiguities related to the Barrelet zeros of the amplitudes. Thus HYAMS 75 find four solutions in the region 1.0 to 1.8 GeV, ESTABROOKS 74 find eight solutions, and CORDEN 79, extending the $\pi\pi$ analysis to 2.08 GeV, find another eight solutions.

In the past many of these solutions have been ruled out by imposing continuity in various ways, as well as analyticity and unitarity (FROGGATT 75,77, COMMON 76, MARTIN 78).

Now that data on π^-p (polarized) $\rightarrow \pi^+\pi^-n$ are available (BECKER 79), there is no need for such arguments. The model-independent partial-wave analysis of BECKER 79 selects solution β' of MARTIN 78 and possibly solution β .

The β and β' amplitudes describe the experimental moments in each bin without any explicit smoothing; they are analytic in s and approximately analytic in $\cos\theta$. They take into account all waves up to $\ell=4$. The β solution has a highly elastic S wave, whereas the S wave of solution β' is somewhat inelastic (MARTIN 78). The unique solution of FROGGATT 77, which has explicit smoothness built in and which takes account only of $\ell \leq 3$ waves, is rather similar to β . However, it has problems with unitarity, apparently because of the neglected G wave (MARTIN 78).

The S wave is clearly resonant in the data of BECKER 79. In the 1150 to 1400 MeV region both the S-P and S-D phase differences show the presence of a broad resonance, and the intensity of the S wave confirms this by exhibiting a peak at about 1300 MeV with a width of about 300 MeV; see Fig. 1(a).

The amplitude analysis of the $\pi^-p \rightarrow \pi^+\pi^-n$ experiment of CORDEN 79 has two preferred solutions which are close to β and β' , giving some support for an $\epsilon(1300)$. Also the S wave in the $\pi^0\pi^0$ system

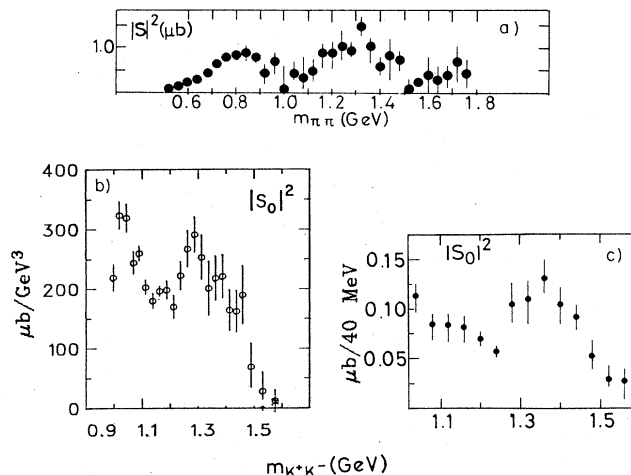


Fig. 1. (a) The absolute intensity (in μb) of the $\pi^+\pi^-$ S wave in 40 MeV bins (without dividing by the bin size), as given by the "down" solution of BECKER 79. (b) Absolute intensity (in $\mu\text{b}/\text{GeV}^3$) of the K^+K^- S wave, as given by the favored solution of COHEN 78, for $|t| < 0.08 \text{ GeV}^2$. (c) The absolute intensity (in $\mu\text{b}/40 \text{ MeV}$ bin) of the K^+K^- S wave, as given by the favored solution of GORLICH 79.

tends to confirm the $\epsilon(1300)$ by staying near its unitarity limit around 1200 MeV (APEL 79).

Independent evidence for the $\epsilon(1300)$ comes from studies of the $K\bar{K}$ systems. In the reaction $\pi^-p \rightarrow K_S^0 K_S^0 n$, the S wave exhibits a large intensity in the 1300 MeV region (WETZEL 76, LOVERRE 79), with some evidence for a bump. Moreover, the $\langle Y_0^2 \rangle$ moment shows a large negative excursion indicating S-D interference (CASON 76, WETZEL 76, LOVERRE 79, POLYCHRONAKOS 79). The main problem is the isospin of the bump: if OPE were the only mechanism, $I=0$ would be assured. However, an $I=1$ non-OPE contribution in the same region cannot be excluded. Moreover, the $I=1$ K^-K^0 system does show some peaking (MARTIN 79), so one will possibly have to disentangle two resonances in the $K_S^0 K_S^0$ bump.

In agreement with this, the K^+K^- system produced in π^-p , π^+n , and π^-p (polarized) scattering clearly shows the S wave peaking at 1300 MeV; again, both $I=0$ and $I=1$ may be present. While PAWLICKI 77, COHEN 78, and GORLICH 79 favor $I=0$, MARTIN 79 concludes that the isospin cannot be assigned unambiguously. The experiments disagree on the strength of the $\epsilon(1300)$ coupling to $K\bar{K}$.

Data Card Listings

For notation, see key at front of Listings.

Mesons

ε(1300), A₂(1310)

ESTABROO 79 PR D 19 2678 P, ESTABROOKS (CARL)
GORLICH 79 CER/EP 79-139 +NICZYDRAK, ROZANSKA+ (CRAC+MPIM+CERN+ZEEM)
GREENHUT 79 PR D 20 2326 +INTEMANN (SETO)
LOWERRE 79 CER/EP 79-162 +ARMENTEROS, DIONISI+ (CERN+CDEF+MADR+STOH)I, JP
MARTIN 79 NP B 158 520 +OZMUTLU (DURHI, JP)
POLYCHRO 79 PR D 19 1317 POLYCHRONAKOS, CASON, BISHOP+ (NDAM+ANL11, JP)

A₂(1310)

12 A2(1310, JP=2+-) I=1

WE LIST THE A2 AS AN ORDINARY BREIT-WIGNER RESONANCE. FOR DISCUSSION OF THE REPORTED SPLITTING, SEE OUR APRIL 72 AND APRIL 73 EDITION.

Table with columns for mass (MEV), 3PI mode, and various experimental data points. Includes entries like ADERHOLZ 64 HBC 4.0 PI+ P, GOLDHABER 64 HBC +- 3.7 PI+- P, etc.

12 A2 MASS (MEV), K KBAR MODE

Table with columns for mass (MEV), K Kbar mode, and various experimental data points. Includes entries like BARLOW 67 HBC +- 1.2 PBAR P, BEUSCH 67 OSPK 0 5-12 PI-P, K1K1, etc.

12 A2 MASS (MEV), ETA PI MODE

Table with columns for mass (MEV), eta pi mode, and various experimental data points. Includes entries like ALSTON 70 HBC + 7.0 PI+P, PI ETA, CASO 70 HBC - 11.2 PI-P, PI ETA, etc.

WEIGHTED AVERAGE = 1310.5 ± 1.6
ERROR SCALED BY 1.4.

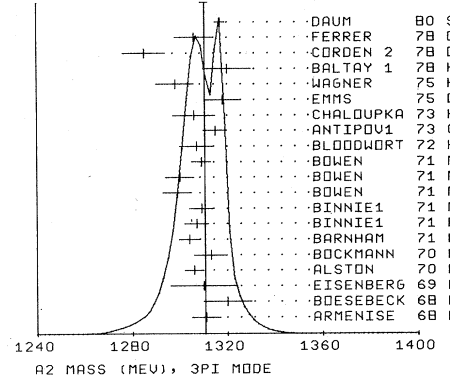


Table listing experiments and their associated CHISQ values for the A2(1310) 3PI mode. Includes entries like DAUM 80 SPEC 10.6, FERRER 78 OMEG 0.3, etc.

WEIGHTED AVERAGE = 1317.47 ± 0.89
ERROR SCALED BY 1.2

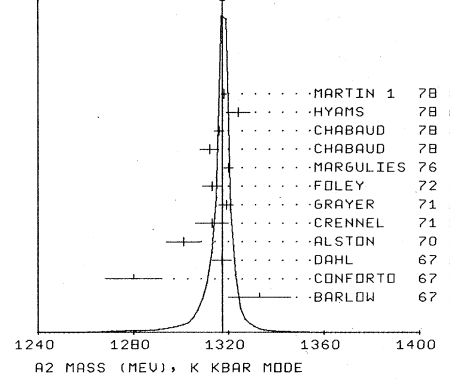


Table listing experiments and their associated CHISQ values for the A2(1310) K Kbar mode. Includes entries like MARTIN 1 78 SPEC 0.3, HYAMS 78 ASPK 1.7, etc.

WEIGHTED AVERAGE = 1305.3 ± 5.8
ERROR SCALED BY 1.6

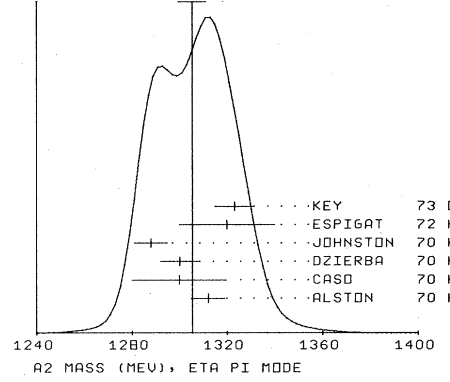


Table listing experiments and their associated CHISQ values for the A2(1310) eta pi mode. Includes entries like KEY 73 OSPK 4.9, ESPIGAT 72 HBC 0.5, etc.

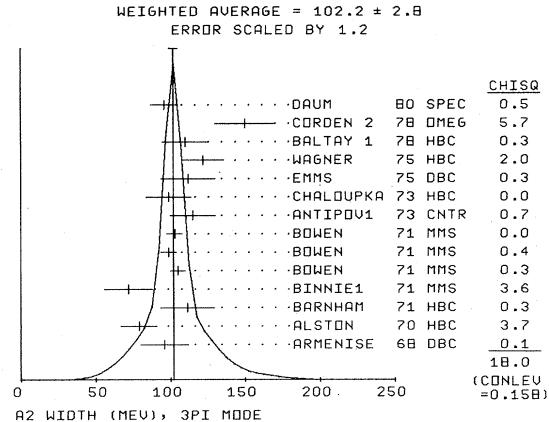
Mesons
A₂(1310)

Data Card Listings

For notation, see key at front of Listings.

12 A2 WIDTH (MEV), 3PI MODE

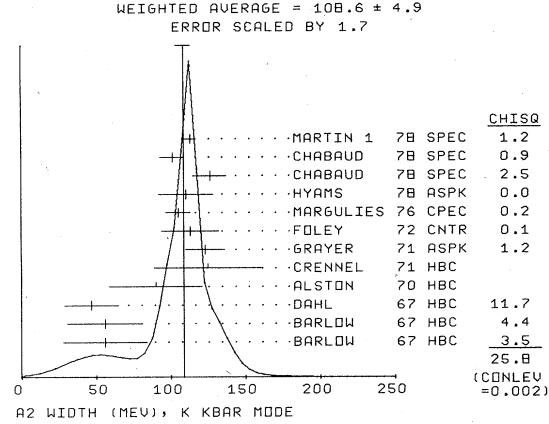
W	(100.0)		ADERHOLZ	64	HBC	4.0	PI+P			
W	(90.0)	(10.0)	GOLDBERGER	64	HBC	3.7	PI+-P	12/75		
W	1425	99.0	LEFEBVRES	65	MSP	6.0	PI-P	1/73		
W	(70.0)	(10.0)	BARNES	66	HBC	6.0	PI-P	2/73		
W	(100.0)	(15.0)	BENSON	66	DBC	0.3	65 PI+D	12/75		
W	1060	58.0	LEVRAT	66	MMS	6.7	PI-P	1/73		
W	O 4000	(90.0)	CHIKOVANI	67	MMS	7.1	PI-P	12/75		
W	O 260	96.0	ARMENISE	68	DBC	0.5	1.1 PI+D	9/67		
W	O 120	(56.0)	BOESEBECK	68	HBC	0.8	PI+P	1/73		
W	O (80.0)	(20.0)	CHUNG	68	HBC	2.7	4.5 PI-P	5/68		
W	O (40.0)	(25.0)	VON KROGH	68	HBC	6.7	PI-P	9/68		
W	A (52.0)	(16.0)	JUNKMANN	68	HBC	1.6	PI-P, 3PI	1/73		
W	D (50.0)	(10.0)	ANDERSON	69	MMS	1.6	PI-P, BACKW	12/75		
W	AE 241	(164.0)	ARMENISE	69	DBC	5.1	PI+D, 3PI+-	5/70		
W	O (80.0)	(30.0)	EISENBERG	69	HBC	4.3	5.3 GAMMA P	12/69		
W	941	79.0	ALSTON	70	HBC	7.0	PI+P, 3PI P	1/71		
W	O 280	(70.0)	BOCKMANN	70	HBC	0.5	PI+P, A20	5/70		
W	A 581	(115.0)	CASO	70	HBC	11.2	PI-P, PI RHO	1/73		
W	O (90.0)	(20.0)	DIAZ	70	HBC	0.1	PBAR P, 4 PI	5/70		
W	D (35.0)	(35.0)	GARFINKEL	70	DBC	4.5	K-D, LAMBDA	1/71		
W	360	111.4	BARNHAM	71	HBC	3.7	PI+P, 3PI+	11/71		
W	10000	(100.0)	BINNIE1	71	MMS	PI-P NEAR A2 THR	12/71			
W	5000	72.0	BINNIE1	71	MMS	PI-P NEAR A2 THR	11/71			
W	28000	105.0	BOWEN	71	MMS	5.1	PI-P	11/71		
W	24000	99.0	BOWEN	71	MMS	5.1	PI+P	11/71		
W	17000	105.0	BOWEN	71	MMS	7.1	MMS	11/71		
W	O 160	(72.0)	BLOODWORT	72	HBC	5.4	5.1 PI+P, 3PI	12/72		
W	P 115.0	15.0	ANTIPOV1	73	CNTR	25.0	PI-P	1/74		
W	P 1580	99.0	CHALOUKPA	73	HBC	3.9	PI-P, P, A2	2/73		
W	P 1600	112.0	EMMS	75	DBC	0.4	PI+N, P, A20	11/75		
W	P S1200	122.0	WAGNER	75	HBC	0.7	PI+P, DEL+ A2	11/75		
W	P 3000	(130.0)	GHIDINI	77	OMEG	1.2	PI-P, P, 3PI	12/77		
W	1097	110.0	BALTAY 1	78	HBC	0.1	15 PI+P, P, 4PI	4/78*		
W	P 490	(115.0)	BALTAY 1	78	HBC	0.1	15 PI+P, DEL 3PI	4/78*		
W	O 150.0	20.0	CORDEN 2	79	OMEG	12.1	PI-P, 3PI N	4/78*		
W	P 25000	56.0	DAUM	80	SPEC	63.9	PI-P, 3PI	12/79*		
W	AVG	102.2	2.8	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)						
W	STUDENT	102.2	2.7	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT						
				(SEE IDEOGRAM BELOW)						



W O ONLY EXPERIMENTS GIVING MASS ERROR LT. 15 MEV KEPT FOR AVERAGING
 W E BACKGROUND SUBTRACTION MODEL-DEPENDENT.
 W D MAY BE DIFFERENT OBJECT, ALTHOUGH JPC=2+-. COMPARE CRENNELL 69.
 W A ANALYSIS COMPLICATED BY NEARBY PEAK (A1,5) AND/OR A1
 W S WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NOTE
 W P FROM A FIT TO JP=2+ RHO PI PARTIAL WAVE

12 A2 WIDTH (MEV), K KBAR MODE

WK	60	56.0	28.0	BARLOW	67	HBC	1.2	PBAR P, KK	9/67	
WK	S 80	56.0	25.0	BARLOW	67	HBC	1.2	PBAR P, KK	9/67	
WK	N (88.0)	(23.0)	(22.0)	BEUSCH	67	OSPK	0.5	1.2 PI-P, K1K1	11/71	
WK	130	(90.0)		CONFORTO	67	HBC	0.1	PBAR P IN KK	9/67	
WK	47.0	18.0		DAHL	67	HBC	2.7	4.5 PI-P	8/67	
WK	N (80.5)	(36.5)		DAHL	67	HBC	0.2	7.4 5 PI-P	11/71	
WK	N (21.0)	(10.0)	(6.0)	CRENNELL	68	HBC	0.6	0.1 PI-P, K1K1	11/71	
WK	S 132	90.0	31.0	ALSTON	70	HBC	7.0	PI+P, K+KS P	1/71	
WK	S 150	125.0	36.0	CRENNELL	71	HBC	4.5	PI-P, KSK-P	11/71	
WK	S1500	123.0	13.0	GRAYER	71	ASPK	17.2	PI-P, K-KS P	11/71	
WK	730	113.0	19.0	FOLEY	72	CNTR	20.3	PI-P, K-KS	12/72	
WK	S2724	105.0	8.0	MARGULIES	76	CPEC	23.1	PI-P, K-KS	12/77	
WK	350	110.0	18.0	HYAMS	78	ASPK	12.7	PI+P, K+KS P	4/78*	
WK	S 190	126.0	11.0	CHABAUD	78	SPEC	9.8	PI-P, K-KS P	4/78*	
WK	4730	101.0	8.0	CHABAUD	78	SPEC	18.8	PI-P, K-KS P	4/78*	
WK	P S 113.0	4.0		MARTIN 1	78	SPEC	10.1	PI P, KS K-P	4/78*	
WK	4000	(116.0)	(4.0)	CHABAUD	79	SPEC	17.1	NUCLEI, KSK-	12/79*	
WK	AVG	108.6	4.9	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)						
WK	STUDENT	109.5	3.4	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT						
				(SEE IDEOGRAM BELOW)						



WK P FROM A FIT TO JP=2+ PARTIAL WAVE.
 WK N THE NEUTRAL MODE CAN INTERFERE WITH THE F-MESON
 WK S WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NOTE

12 A2 WIDTH (MEV), ETA PI MODE

W	189	103.0	20.0	ALSTON	70	HBC	7.0	PI+P, PI ETA	1/71	
W	(120.0)			CASO	70	HBC	11.2	PI-P, PI ETA	5/70	
W	32	(41.0)	(20.0)	DZIERBA	70	HBC	8.1	PI-P, PI ETA	11/70	
W	T 30	(38.0)	(30.0)	JOHNSTON	70	HBC	7.1	PI-P, PI ETA P	1/73	
W	1000	108.0	9.0	ESPIGAT	72	HBC	0.1	PBAR P, ETA 2PI	11/71	
W	M 6200	(104.0)	(9.0)	KEY	73	OSPK	6.1	PI-P, PI ETA	1/74	
W				CONFORTO	73	OSPK	0.1	PI-P, P, MMS-	1/74	
W	AVG	108.1	7.9	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)						
W	STUDENT	108.0	8.5	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT						
W	M	MISSING MASS WITH ENRICHED MMS=ETA PI-, ETA = 2 GAMMA								
W	T	WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NOTE								

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i , as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i^2)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta P_i \delta P_j) / (\delta P_i \delta P_j)$. For the definitions of the individual P_i , see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

	P 1	P 2	P 3	P 4
P 1	.7004+-0.0217			
P 2	.1210	.0479+-0.0049		
P 3	-.0506	-.0382	.1458+-0.0114	
P 4	-.8714	-.2858	-.4049	.1058+-0.0250

12 A2 PARTIAL DECAY MODES

P1	A2 INTO RHO PI	776+ 139
P2	A2 INTO K KBAR	493+ 497
P3	A2 INTO ETA PI	548+ 139
P4	A2 INTO OMEGA PI PI	139+ 139+ 782
P5 S	A2 INTO PI+ PI- PI0 EXCL. RHO PI	139+ 139+ 134
P6 S	A2 INTO PI+ PI- PI- EXCL. RHO PI	139+ 139+ 139
P7 S	A2 INTO PI GAMMA	139+ 0
P8 S	A2 INTO ETA PRIME PI	957+ 139
P9 S	A2 INTO GAMMA GAMMA	0+ 0
P S	SMALL, NOT USED IN THE FIT	

12 A2 PARTIAL WIDTHS

W1	A2 INTO GAMMA GAMMA (KEV)					
W1 F	(2.5) OR LESS CL=0.95	ABRAMS	79	SMAG	E+ E-	12/79*
W1 F	FROM RHO PI DECAY MODE					
W1 D	(17.0) OR LESS CL=0.95	ABRAMS	79	SMAG	E+ E-	12/79*
W1 D	FROM K+ K- DECAY MODE					

Data Card Listings

For notation, see key at front of Listings.

Mesons

A₂(1310)

12 A2 BRANCHING RATIOS

Table with columns for particle name, mass, width, and various branching ratios. Includes entries for A2(1310) and A2(1640) with detailed decay data and references.

REFERENCES FOR A2

Table listing references for the A2 meson, including authors and publication details.

Table listing references for the A2(1310) meson, including authors and publication details.

Mesons

A₂(1310), E(1420), X(1410-1440), f'(1515)

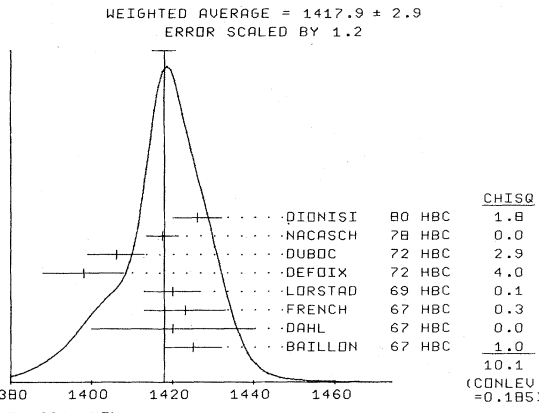
Data Card Listings

For notation, see key at front of Listings.

BALTAY 1 78 PR D 17 62 +CAUTIS, COHEN, CSORNA, SMITH, YEH, + (COLU+ BING)
BALTAY 2 78 PRL 40 87 +CAUTIS, KALELKHAR (COLU) JP
CHABAUD 78 NP B 145 349 +HYAMS, JONES, WEILHAMMER, BLUM, + (CERN+MPIM)
CORDEN 1 78 NP B 136 77 DOWELL, GARVEY, JOBS, + (BIRM+RHEL+TELA+LWGC) JP
CORDEN 2 78 NP B 138 235 +CORBETT, ALEXANDER, + (BIRM+RHEL+TELA+LWGC) JP
FERRER 78 PL 74 B 287 +TRELLE, RIVET + (ORSAY+CERN+CDEF+LNP)
HYAMS 78 NP B 146 303 +JONES, WEILHAMMER, BLUM, + (CERN+MPIM+ATEN)
MARTIN 1 78 PL 74 B 417 +OZMUTLU, BALDI, BOHRINGER, DORSAZ, + (DURH+GEVA) JP
MARTIN 2 78 NP B 140 158 +OZMUTLU, BALDI, BOHRINGER, DORSAZ, + (DURH+GEVA) JP
ABRAMS 79 SLAC-PUB 2421 +ALAM, BLOCKER, BOYARSKI, + (SLAC+LBL)
CHABAUD 79 CERN/EP 79-159 +HYAMS, PAPPADPOULOU, + (CERN+MPIM+AMST) JP
DAUM 80 PL 89 B 276 +HERTZBERGER, + (AMST+CERN+CRAC+MPIM+OXF+RHEL) JP

E(1420) 6 E(1420, JPC=1++) I=0

Table with columns: M, E MASS (MEV), BAILLON, DAHL, FRENCH, LORSTAD, DEFOIX, DUBOC, CORDEN, NACASCH, DIONISI, 80 HBC, 0. PBAR P, 11/66, etc.



6 E WIDTH (MEV)
W 80. 10. BAILLON 67 HBC 0. PBAR P 11/66
W 60.0 20.0 DAHL 67 HBC 1.6-4.2 PI- P 10/66
W 45. 20. FRENCH 67 HBC 3-4 PBAR P 6/67
W 310 60. 20. LORSTAD 69 HBC 7PB P, 4, 5-BODY 9/69
W 170 50. 10. DEFOIX 72 HBC 0.7 PBAR P, 7 PI 1/73
W 280 50. 12. DUBOC 72 HBC 1.2 PBAR P, 2K4PI 12/72
W 36 (45.0) (30.0) CORDEN 78 OMEG 1.2-15PI-P, K+K-PI 4/78*
W 55. 20.0 NACASCH 78 HBC +.7, .76 PBAR P . 4/78*
W 221 40.0 15.0 DIONISI 80 HBC 4. PI-P, K K PI N 12/79*

6 E PARTIAL DECAY MODES
P1 E INTO K K*(892) 497+ 892
P2 E INTO K KBAR PI 497+ 497+ 139
P3 E INTO PI PI RHO 134+ 134+ 776
P4 E INTO DELTA PI 981+ 139
P5 E INTO ETA PI PI 548+ 139+ 139
P6 E INTO 4 PI 139+ 139+ 139+ 139

6 E BRANCHING RATIOS
R1 E INTO (KBAR K*(892) + C.C.)/(K KBAR PI) (P1)/(P2)
R1 M .50 .10 BAILLON 67 HBC 0.0 PBAR P N 12/78*
R1 N 0.86 0.12 DIONISI 80 HBC 4. PI-P, K K PI N 12/79*
R1 M FROM JP=0 SOLUTION
R1 N FROM JP=1 SOLUTION
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 2.3)
R2 E INTO (PI PI RHO) / (K KBAR PI) (P3)/(P2)
R2 (1.5) OR LESS CL=.95 DAHL 67 HBC 0.1.6-4.2 PI- P .10/66
R2 (0.3) OR LESS CL=.95 CORDEN 78 OMEG 12-15PI-P 4/78*

R4 E INTO (DELTA PI)/(ETA PI PI) (P4)/(P5)
R4 0.4 0.2 DEFOIX 72 HBC 0.7 PBAR P, 7 PI 1/73
R4 NOT SEEN IN EITHER MODE CORDEN 78 OMEG 12-15PI-P 4/78*
R5 E INTO (4PI)/(KBAR K*(892) + C.C.) (P6)/(P1)
R5 (10.9) OR LESS CL=.95 DIONISI 80 HBC 4. PI-P, K K PI N 12/79*

REFERENCES FOR E
BAILLON 67 NC 50A 393 +EDWARDS+D-ANDLAU+ASTIER+ (CERN+CDEF+IRAD)
BARASH 67 PR 156 1399 BARASH, NIRSCH, MILLER, TAN (COLUMBIA)
DAHL 67 PR 163 1377 +HARDY+HESS+KIRZ+MILLER (LRL) JP
ALSO 65 PRL 14 1074 MILLER, CHUNG, DAHL, HESS, HARDY, KIRZ, (LRL+UGB)
FRENCH 67 NC 52A 438 +KINSON+MCDONALD+RIDDI FORD+ (CERN+BIRM)
FOSTER 68 NP B 8 174 +GAVILLET, LABROSSE, MONTANET, + (CERN+CDEF)
BETTINI 69 NC 62 A 1038 +CRESTI, LIMENTANI, BERTAUZA, BIGI+ (PADO+PISA) IC
LORSTAD 69 NP B 14 63 B. LORSTAD, D-ANDLAU, ASTIER, + (CDEF+CERN) JP
DEVONS 71 PRL 27 1614 +KOZLOWSKI, HORWITZ, + (COLU+SYRA)
CHAPMAN 72 NP B 42 1 +CHURCH, LYS, MURPHY, RING, VANDER VELDE (MICH)
DEFOIX 72 NP B 44 125 +NASCIMENTO, BIZZARRI, + (CDEF+CERN)
DUBOC 72 NP B 46 429 +GOLDBERG, MAKOWSKI, DONALD, + (LNP+LIVP)
VUILLEMI 75 LNC 14 165 VUILLEMIN, + (LAUS+NEUC+LNP+LIVP+GLAS) JP
HANDLER 76 NP B 110 173 +PLANO, BRUCKER, KOLLER+ (RUTG+STEV+SETO)
VUILLEMI 76 NC 33A 133 +VUILLEMIN, + (LAUS+NEUC+LNP+LIVP+GLAS)
EDWARDS 77 PREPRINT +LEGACEY+TOTTAWA+NONTREAL+COLUMBUS+TORONTO)
GRASSLER 77 NP B 121 189 +AACHEN+BERLIN+BOHN+CERN+CRACON+HEID+MARS)
CORDEN 78 NP B 144 253 +CORBETT, ALEXANDER, + (BIRM+RHEL+TELA+LWGC)
IRVING 78 NP B 139 327 A.C. IRVING, H.R. SEPANGI (LIVP)
NACASCH 78 NP B 135 203 +DEFOIX, DOBRZYNSKI, + (PARIS+MADRID+CERN)
STANTON 79 PRL 42 346 +BROCKMAN, DANKOWYCH, + (OSU+CARL+MGI+TNT) JP
DIONISI 80 CERN/EP 80-1 +GAVILLET, ARMENTEROS + (CERN+MACR+CDEF+STOH) I, JP

X(1410-1440) 38 X(1410-1440)

THIS ENTRY LIST PEAKS OF LOW STATISTICAL SIGNIFICANCE, SEEN IN RHO RHO OR K KBAR. OMITTED FROM TABLE.

38 X(1410-1440) MASS (MEV)
M -----RHOO RHOO MODE-----
M (1410.0)
M KS KS MODE BETTINI 66 DBC 0 0. PBAR N, 5 PI 2/74
M POSSIBLY SEEN ABRAMS 67 HBC 4.25 K- P 5/67
M THE AUTHOR'S ASSOCIATE THE PEAK WITH THE F PRIME, BUT BACKGROUND
M ESTIMATION IS DIFFICULT (LIVP)
M 1412. 23. BARLOW 67 HBC 1.2 PBAR P 5/67
M 1439.0 5.0 6.0 BEUSCH 67 OSPK 5.7, 12 PI-P 9/67
M (1425.0) FOLEY 71 CNTR - 20.3 PI- P, K- KS 2/71
M (1405.) DEFOIX 73 HBC 0 0.7 PBAR P, 7 PI 1/74
M PL 5.
M AVG 1437.5 5.3 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M STUDENT 1437.7 5.9 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

38 X(1410-1440) WIDTH (MEV)
W -----RHOO RHOO MODE-----
W (90.0) BETTINI 66 DBC 0 0. PBAR N, 5 PI 2/74
W KS KS MODE
W 100. 70. BARLOW 67 HBC 1.2 PBAR P 5/67
W 43.0 17.0 18.0 BEUSCH 67 OSPK 5.7, 12 PI-P 9/67
W (20.1) OR LESS FOLEY 71 CNTR - 20.3 PI- P, K- KS 2/71
W (40.) DEFOIX 73 HBC 0 0.7 PBAR P, 7 PI 1/74
W PL 5.
W AVG 46.4 17.0 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
W STUDENT 46.2 18.5 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

REFERENCES FOR X(1410-1440)
BETTINI 66 NC 42A 695 +CRESTI, LIMENTANI, LORIA, PERUZZO+(PADO+PISA)
ABRAMS 67 PRL 18 620 +KEHOE, GLASSER, SECHI-ZORN, WOLSKY (MARYLAND)
BARLOW 67 NC 50 A 701 +MONTANET, D-ANDLAU+ (CERN+CDEF+IRAD+LIVP)
BEUSCH 67 PL 25 B 357 +FISCHER, GOBBI, ASTBURY, + (ETH+CERN)
DONALD 69 NP B 11 551 +EDWARDS, BURAN, BETTINI, + (LIVP+OSLO+PADO)
FOLEY 71 PRL 26 413 +LOVE, OZAKI, PLATNER, LINDENBAUM, + (BNL+CUYU)
DEFOIX 73 PL 43 B 141 +DOBRZYNSKI, ESPIGAT, NASCIMENTO, + (CDEF)
POLYCHRO 79 PR D 19 1317 POLYCHRONAKOS, CASON, BISHOP, (NDAM+ANL)

f'(1515) 13 F PRIME(1515, JPC=2++) I=0

13 F PRIME MASS (MEV)
M P 14(1480.0) CRENNELL 66 HBC 6.0 PI- P 8/66
M B 5(1460.) (10.) ABRAMS 67 HBC 4.25 K- P, K KS 5/67
M BACKGROUND ESTIMATION DIFFICULT.
M P (1515.0) (7.0) ANMAR 67 HBC 5.5 K-P, K KBAR 9/67
M P 100(1519.) (7.) AGUILAR 72 HBC 3.9, 4.6 K-, K KB 12/72
M P 46(1514.) (4.) COLLEY 72 HBC 10.4 P, K+ K- 12/72
M P 47(1521.) (7.) VIDEAU 72 HBC 4.4 K- P, K KBAR 12/72
M EP 120(1527.0) (6.0) BRANDENBU 76 ASPK 13.4 K-, K+K- 7/77
M 123 1522.0 6.0 BARREIRO 77 HBC 4.15 K+, K KS 7/77
M 166 1528. 7.0 EVANGELIS 77 OMEG 10 K- P 12/77
M C 1506.0 5.0 PAWLICKI 77 SPEC 6.1 PI, N, K+K- 12/77*
M N (1502.0) (25.0) CORDEN 79 OMEG 12-15PI-P, N 2PI 12/79*
M (1492.0) (29.0) GORLICH 79 ASPK 0 17 PI- P, POLARIZ 12/79*
M PL 5.
M AVG 1516.1 6.7 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)
M STUDENT 1517.1 4.9 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
(SEE IDEOGRAM BELOW)

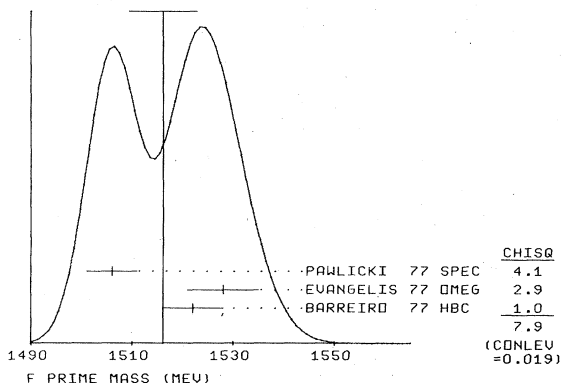
Data Card Listings

For notation, see key at front of Listings.

Mesons

$f'(1515)$, $F_1(1540)$, $\rho'(1600)$

WEIGHTED AVERAGE = 1516.1 ± 6.7
ERROR SCALED BY 2.0



M C WITH A PHASE SHIFT ANALYSIS
M E MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N), SEE K* TYPED NCTE.
M N FROM AN AMPLITUDE ANALYSIS WHERE THE F PRIME WIDTH AND ELASTICITY ARE IN COMPLETE DISAGREEMENT WITH VALUES OBTAINED FROM KKBAR CHANNEL MAKING THE SOLUTION DUBIOUS.
M P F=A2-F PRIME INTERFERENCE IN K+K- FINAL STATE NOT ACCOUNTED FOR.

13 F PRIME WIDTH (MEV)

W B	5 (53.)	(18.)	ABRAMS	67 HBC	4.25 K- P, K KS	5/67
W B	BACKGROUND ESTIMATION DIFFICULT.					
W P	(35.0)	(25.0)	AMMAR	67 HBC	5.5 K-P, K KBAR	9/67
W P	100 (69.)	(22.)	AGUILAR	72 HBC	3.9, 4.6 K-P, K KB	12/72
W P	46 (28.)	(15.)	COLLEY	72 HBC	10. K+ P, K+ K-	12/72
W EP	47 (40.)	(20.)	VIDEAU	72 HBC	4. K- P, K KBAR	12/72
W EP	120 (61.0)	(22.0)	BRANDENBU	76 ASPK	13. K-P, K+K-	7/77
W	123 62.0	19.0	BARREIRO	77 HBC	4.15 K-P, K KS	7/77
W	186 72.0	25.0	EVANGELIS	77 OMEG	10 K-P	12/77
W C	66.0	10.0	PAWLICKI	77 SPEC	6. PI N, K+K-	12/77
W N	(165.0)	(42.0)	CORDEN	79 OMEG	12-15PI-P, N 2PI	12/79*
W	(150.0)	(83.0)	GORLICH	79 ASPK	0 17 PI-P, POLARIZ	12/79*
W M	92.0	39.0	POLYCHRON	79 STRC	7. PI-P, K KS N	12/79*
W	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)					
W AVG	67.4	7.8				
W STUDENT	67.3	8.4	AVERAGE USING STUDENT(10/1.11) -- SEE MAIN TEXT			

M C WITH A PHASE SHIFT ANALYSIS
M E WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NCTE.
M N FROM A FIT TO THE D WAVE WITH F-F PRIME INTERFERENCE. MASS FIXED AT 1516 MEV.
M N FROM AN AMPLITUDE ANALYSIS WHERE THE F PRIME WIDTH AND ELASTICITY ARE IN COMPLETE DISAGREEMENT WITH VALUES OBTAINED FROM KKBAR CHANNEL MAKING THE SOLUTION DUBIOUS.
M P F=A2-F PRIME INTERFERENCE IN K+K- FINAL STATE NOT ACCOUNTED FOR.

13 F PRIME PARTIAL DECAY MODES

P1	F PRIME INTO PI PI	139+ 139	DECAY MASSES
P2	F PRIME INTO K KBAR	497+ 497	
P3	F PRIME INTO K K*(892)	493+ 892	
P4	F PRIME INTO ETA ETA	548+ 548	
P5	F PRIME INTO PI PI ETA	139+ 139+ 548	
P6	F PRIME INTO PI K KBAR	139+ 497+ 497	
P7	F PRIME INTO PI+ PI+ PI- PI-	139+ 139+ 139+ 139	
P8	F PRIME INTO GAMMA GAMMA	0+ 0	

13 F PRIME PARTIAL WIDTHS

W1	F PRIME INTO GAMMA GAMMA (KEV)		12/78*
W1 B	(1.2) OR LESS CL=0.95	ABRAMS	79 SMAG E+ E-
W1 B	USING BRANCHING RATIO F PRIME INTO K KBAR = 1.		12/79*

13 F PRIME BRANCHING RATIOS

R1	F PRIME INTO (PI PI)/TOTAL	(P1)	
R1 C	(0.0086) OR LESS	BEUSCH	75 OSPK 8.9 PI-P, KO KO N 12/77
R1	(0.063) OR LESS CL=0.90	BRANDENBU	76 ASPK 13. K-P, K+K- 7/77
R1	(0.045) OR LESS CL=0.95	BARREIRO	77 HBC 4.15 K-P, K KS 7/77
R1 C	0.012 (0.004)	PAWLICKI	77 SPEC 6. PI N, K+K- 12/77
R1 N	(0.19) (0.03)	CORDEN	79 OMEG 12-15PI-P, N 2PI 12/79*
R1 C	(0.027) (0.071) (0.013)	GORLICH	79 ASPK 0 17, 18 PI-P POLAR 12/79*
R1 C D	0.0075 0.0025	MARTIN	79 RVUE 12/79*
R1 C	ASSUMING THAT THE F PRIME IS PRODUCED BY AN OPE PRODUCTION MECHANISM.		
R1 D	MARTIN 79 USES THE PAWLICKI 77 DATA WITH DIFFERENT INPUT VALUE OF THE F INTO K KBAR BRANCHING RATIO.		
R1	AVERAGE 'MEANINGLESS' (SCALE FACTOR = 1.0)		
R3	F PRIME INTO (ETA ETA)/(K KBAR)	(P4)/(P2)	
R3	(0.50) OR LESS	BARNES	67 HBC 4.6, 5.0 K- P 10/67
R4	F PRIME INTO (PI PI ETA)/(K KBAR)	(P5)/(P2)	
R4	(0.3) OR LESS CL=.67	AMMAR	67 HBC 10/67
R4 A	(0.25) (0.13)	BARNES	67 HBC 4.6, 5.0 K- P 10/67
R4 A	SUPERSEDED BY AGUILAR 72		
R4	(0.41) OR LESS CL=.95	AGUILAR	72 HBC 3.9, 4.6 K- P 12/72
R5	F PRIME INTO (PI K KBAR + K K*(892))/(K KBAR)	(P6+P3)/(P2)	
R5	(0.41) OR LESS CL=.67	AMMAR	67 HBC 10/67
R5	(0.35) OR LESS CL=.55	AGUILAR	72 HBC 3.9, 4.6 K- P 12/72

R6 F PRIME INTO (PI+ PI- PI- PI-)/(K KBAR) (P7)/(P2)
R6 (0.32) OR LESS CL=.95 AGUILAR 72 HBC 3.9, 4.6 K- P 12/72

REFERENCES FOR F PRIME

BARNES	65 PRL 15 322	+CULWICK, GUIDONI, KALBFLEISCH, GOZ+ (BNL+SYRA)
CRENNELL	66 PRL 16 1025	+ KALBFLEISCH, LAI, SCARR, SCHUMANN + (BNL) I
ABRAMS	67 PRL 18 620	+KEHDE, GLASSER, SECHI-ZORN, WOLSKY (MARYLAND)
AMMAR	67 PRL 19 1071	+DAVIS, HHANG, DAGAN, DERRICK + (NYES+ANL) JP
BARNES	67 PRL 19 964	+DORRAN, GOLDBERG, LEITNER + (BNL+SYRACUSE) ICJP
ALITTI	68 PRL 21 1705	+BARNES, CRENNELL, FLAMINIO, GOLDBERG, + (BNL)
LORSTAD	69 NP B 14 63	B. LORSTAD, D-ANDLAU, ASTIER, + (CDEF+CERN)
SCOTTER	69 NC 62 A 1057	+ERSKINE, PALER, + (BIRM+GLAS+LOIC+MPI+OXF)
AGUILAR	72 PR D 6 29	AGUILAR-BENITEZ, CHUNG, EISNER, SAMIOS (BNL)
COLLEY	72 NP B 50 1	+JOBES, RIDDIFORD, GRIFFITHS, + (BIRM+GLAS)
VIDEAU	72 PL 41 B 213	+VIDEAU, ROUGE, BARRETE, DEBRION, + (EPOL+SLAC)
BEUSCH	75 PL 60 B 101	+BIRMAN, WEBSDALE, WETZEL (CERN+ETH)
BRANDENB	76 NP B 104 413	BRANDENBURG, CARNEGIE, CASHMORE, DAVIER + (SLAC)
BARREIRO	77 NP B 121 237	+DIAZ, GAY, HEMINGWAY, + (CERN+AMST+NIJ+OXF)
EVANGELI	77 NP B 127 384	EVANGELI STA, + (BARI+BONN+CERN+DARE+GLAS+) JP
LAVEN	77 NP B 127 43	+OTTER, KLEIN, + (AACH+BERL+CERN+LOIC+WIEN)
PAWLICKI	77 PR D 15 3156	+AYRES, COHEN, DIEBOLD, KRAMER, WICKLUND (ANL) I JP
ABRAMS	79 SLAC-PUB 2421	+ALAM, BLOCKER, BOYARSKI, + (SLAC+LBL)
BECKER	79 NP B 151 46	+BLANAR, BLUM, CERRADA + (MPI+CEM+ZEM+CRAC)
CORDEN	79 NP B 157 250	+DOWELL, GARVEY, JOBES, + (BIRM+RHEL+TEL+LWU) JP
GORLICH	79 CERN/EP 79-139	+NICZYDORUK, ROZANSKA + (CRAC+MPI+CEM+ZEM)
MARTIN	79 NP B 158 520	+OZMUTLU (DURH)
POLYCHRO	79 PR D 19 1317	POLYCHRONAKOS, CASON, BISHOP + (NDAM+ANL)

F₁(1540) 47 F₁(1540, J_P= 1-1)
JP = 2-, 1+ FAVORED.
A NEW EXPERIMENT (CERRADA 77, MONTANET 77) WITH 5 TIMES THE STATISTICS OF AGUILAR 65 DOES NOT CONFIRM THE F₁. OMITTED FROM TABLE.

47 F₁ MASS (MEV)

M	10(1490.0)	(20.0)	ADERHOLZ	69 HBC + 8 PI+ P, KKBARPI	11/69
M	142 1540.0	5.0	AGUILAR	69 HBC 0. 7PBAR P, KKBARPI	11/69
M	25(1543.0)	(3.0)	DUBOC	71 HBC 0 1.1-1.2 PBAR P	2/72
M B	70(1557.1)	(10.1)	BAKKEN	75 HBC + 19 PP, PN3PI	12/75

M B DUBIOUS BACKGROUND SUBTRACTION

47 F₁ WIDTH (MEV)

W	10 (85.0)	(39.0)	ADERHOLZ	69 HBC + 8 PI+ P, KKBARPI	11/69
W	142 40.0	15.0	AGUILAR	69 HBC 0. 7PBAR P, KKBARPI	11/69
W	25 (16.0)	(10.0)	DUBOC	71 HBC 0 1.1-1.2 PBAR P	2/72
W B	70 (40.)	(10.)	BAKKEN	75 HBC + 19 PP, PN3PI	12/75

W B DUBIOUS BACKGROUND SUBTRACTION

47 F₁ PARTIAL DECAY MODES

P1	F ₁ INTO K KBAR PI	134+ 497+ 457	DECAY MASSES
P2	F ₁ INTO K*(892) KBAR	892+ 497	
P3	F ₁ INTO 3 PI	139+ 139+ 139	

REFERENCES FOR F₁

ADERHOLZ	69 NP B 11 259	+BARTSCH, + (AACH+BERL+CERN+CRAC+WAR)
AGUILAR	65 PL 29 B 379	+BARLOW, JACOBS, D-ANDLAU, ASTIER + (CERN+CDEF)
AGUILAR	69 NP B 14 195	+BARLOW, JACOBS, D-ANDLAU, ASTIER + (CERN+CDEF)
DUBOC	71 PL 34 B 343	+GOLDBERG, MAKOWSKI, TOUCHARD, + (IPNP+LIVP)
CHAPMAN	72 NP B 42 1	+CHURCH, LYS, MURPHY, RING, VANDER VELDE (MICH)
DUBOC	72 NP B 46 429	+GOLDBERG, MAKOWSKI, DONALD, + (LPNP+LIVP)
BAKKEN	75 NP B90 227	+JACOBSEN, OLSSON, SKJEVLING (OSLOIG--)
CERRADA	77 PREPR. BUDAPEST C	+DIAZ, FERRAND, GARZON+ (MADR+TATA+CERN+CDEF)
MONTANET	77 PRIVATE COMMUN.	L. MONTANET (CERN)
MINNAERT	78 NP B 132 88	+BILLY, + (BORD+LPNP+LAUS+NEUC+LIVP+GLAS) JP

ρ'(1600) 65 RHO PRIME(1600, J_P=1-) = 1

The $\rho'(1600)$ was first seen in the $\pi^+\pi^-\pi^-$ system, or its $\rho^0\pi^+\pi^-$ subsystem, in photoproduction (BINGHAM 72, DAVIER 73, SCHACHT 74, ALEXANDER 75, LEE 75, ATIYA 79, RICHARD 79) and in e^+e^- annihilation (BARBARINO 72, CONVERSI 74, CORDIER 79, COSME 79). The $\pi^+\pi^-$ system in the $\rho^0\pi^+\pi^-$ final state is apparently in an S wave, although no ϵ resonance at

Mesons
rho'(1600)

Data Card Listings

For notation, see key at front of Listings.

sufficiently low mass exists to make this final state a quasi-two-body rho pi system. For this reason all rho pi analyses have difficulties and all mass fits are strongly parametrization dependent (SMADJA 72, BUDNEV 77, CORDIER 79). Moreover, other mechanisms exist that can simulate a resonance peak in e+e- annihilations to 4pi (HIRSCHFELD 74) and in photo-production (SCHACHT 74).

Evidence for a 2pi decay mode has been looked for in phase-shift analyses of the pi-pi to pi+pi- reaction, as well as in photoproduction and e+e- annihilations. The decay rho' to pi+pi- has been reported in photoproduction (ATIYA 79, RICHARD 79) with a branching ratio of 16 +/- 5% (RICHARD 79). This information can now be used to distinguish between the various phase-shift solutions.

As noted in the mini-review on S-wave pi pi interactions, the solutions denoted beta' and beta of MARTIN 77 fit the data of BECKER 79 best, with a slight preference for solution beta' in the rho' region, 1.5 to 1.7 GeV. Both solutions require a rho' at 1575 MeV. However, solution beta has a branching ratio to 2pi of 30%, while beta' has a branching ratio of only 15%. Thus the photoproduction data also select beta'.

The unique solution of FROGGATT 77 and the solution B of CORDEN 79 are similar to solution beta (having, however, problems with the unitarity of the S wave).

Further support for the rho'(1600) comes from an analysis of the pion form factor (GENSINI 78). No rho'(1250) is required in e+e- to pi+pi- when the analysis is extended well outside the rho'(1600) region. The rho'(1250) resonance, claimed mainly by vector dominance arguments to explain the nucleon form factors, is also not found in any of the phase-shift solutions. The J^P = 1^- partial wave of the omega pi system is expected to contribute to the pion form factor (ROOS 75, COSTAL 77); it is indeed strong in the 1250 MeV region, but does not exhibit a resonance behavior (CHUNG 73,75, CHALOUKKA 74, BUDNEV 77, GESSAROLI 77).

The rho'(1600) is most explicitly seen in e+e- annihilations into three or more hadrons (BACCI 79). Some support for a rho'(1600) decay into e+e- has been claimed in pp annihilation (BASSOMPIERRE 76).

Table with 10 columns: M, H, M, M, M, M, M, M, M, M. Contains data for RHO PRIME MASS (MEV) with values like 400 1430, 1590, 1550, 160 1590, 340 1450, 65 1570, 1610, 1540, (1575), 1600.0, 1558.0, 1533.0, (1600.0) APPROX., 1650.0.

AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)
INCLUDED IN BECKER 79 ANALYSIS
WITH ONLY ONE BREIT WIGNER FIT.
FROM PHASE SHIFT ANALYSIS OF HYAMS 73 DATA
AN ADDITIONAL 40 MEV UNCERTAINTY IN BOTH THE MASS AND WIDTH
IS PRESENT DUE TO THE CHOICE OF THE BACKGROUND SHAPE.

Table with 10 columns: W, H, W, W, W, W, W, W, W, W. Contains data for RHO PRIME WIDTH (MEV) with values like 400 450, (180.), 360., 160 400., 340 850., 65 340., 300., 220., (340.), 283.0, 175.0, 202.0, 230.0, 710.0.

AVERAGE MEANINGLESS (SCALE FACTOR = 1.6)
WIDTH ERRORS ENLARGED BY US TO 4*WIDTH/SQRT(N), SEE K* TYPED NCTE
INCLUDED IN BECKER 79 ANALYSIS
WITH ONLY ONE BREIT WIGNER FIT.
WITH TWO BREIT WIGNER FIT.
FROM PHASE SHIFT ANALYSIS OF HYAMS 73 DATA
AN ADDITIONAL 40 MEV UNCERTAINTY IN BOTH THE MASS AND WIDTH
IS PRESENT DUE TO THE CHOICE OF THE BACKGROUND SHAPE.

Table with 2 columns: P1, P2, P3, P4, P5, P6, P7. Contains data for RHO PRIME PARTIAL DECAY MODES with values like 139+ 139+ 776, 139+ 139+ 139+ 139, 776+ 776, 139+ 139, 493+ 493, 139+ 782, 139+ 139+ 134+ 134.

Table with 2 columns: R1, R2, R3, R4, R5, R6, R7, R8, R9, R10. Contains data for RHO PRIME BRANCHING RATIOS with values like 500 0.7 0.1, (1.2) OR LESS 2 SIGMA BINGHAM 72 HBC 0 9.3 GAM P,P 4PI 1/73, (0.14) OR LESS ESTIMATE DAVIER 73 STRC 0 6-18 G P,P 4PI 1/74, 0.16 0.05 RICHARD 79 OMEG 20-70 GAM P,2PI 12/79*.

Table with 2 columns: ALVENSLE, BRAUN, BULOS, BACCI, BARBARIN, BARTOLI, BINGHAM. Contains references for RHO PRIME with values like 71 PRL 26 273, 71 NP B30 213, 71 PRL 26 149, 72 PL 388 551, 72 LNC 3 689, 72 PR D 6 2374, 72 PL 418 635.

Data Card Listings

For notation, see key at front of Listings.

Mesons

ρ(1600), A₃(1660)

Table of data cards for various mesons, including authors, dates, and experimental details. Includes entries for BRAMON, DIEBOLD, EISENBERG, LAYSSAC, SMADJA, CERADINI, CHUNG, DAVIER, EISENBERG, HYAMS, KREUZER, OCHS, MONTANET, PARK, BALLAM, BERNABEI, CHALCUPK, CONVERSI, ESTABROO, FERDEL, GRAYER, HIRSHFELD, SCHACHT, ALEXANDE, CHUNG, ESTABROO, FROGGATT, HYAMS, LANS, LANGACKER, LEE, RGDOS, BASSOMPI, COMMON, JOHNSON, BUDNEY, COSTA, FROGGATT, GESSARDOL, LAPLANCH, GENSTIN, MARTIN, ATIYA, BACCI, BECKER, CORDEN, CORRIER, CCSME, RICHARD, SPINETTI, +GRECO, +DIEBOLD, +EISENBERG, +LAYSSAC, +BINGHAM, +CONVERSI, +PROTOPOPESCU, +DERADO, +EISENBERG, +HYAMS, +JONES, +KREUZER, +MONTANET, +PARK, +CHADWICK, +ANGELLO, +CHALCUPKA, +COLUCCI, +ESTABROOKS, +FERBEL, +GRAYER, +HIRSHFELD, +DERADO, +ALEXANDER, +ALLES, +CHUNG, +ESTABROO, +FROGGATT, +HYAMS, +LANS, +LANGACKER, +LEWY, +BASSOMPI, +COMMON, +JOHNSON, +BUDNEY, +COSTA, +FROGGATT, +GESSARDOL, +LAPLANCHE, +GENSTIN, +MARTIN, +ATIYA, +BACCI, +BECKER, +CORDEN, +CORRIER, +CCSME, +RICHARD, +SPINETTI.

resonant in the S-wave ππ system as well as in the P-wave ρπ system and in the D-wave επ system.

Beyond the A₃ meson, the J^P = 2⁻ phase seems to continue to increase, indicating the possible existence of a second resonance in this wave at M = (2000 ± 100) MeV, Γ ≈ 400 MeV (DAUM 80).

Table 34 A3 MASS (MEV) listing various experimental measurements of the A3 meson mass. Columns include author, mass value, error, and other parameters. Includes entries for FORING, VETLITSKY, BALTAY, BARTSCH, LAMSA, ARMENISE, CASO, HARRISON, GRENNELL, MIYASHITA, BEKETOV, PALER, CASO, THOMPSON, KALEKAR, BALTAY, GHIDINI, PERNEGR, DAUM.

M B SAME EXPERIMENT AS BALTAY 77
M D CLEAR PHASE ROTATION SEEN IN (2-S), (2-P), (2-D) WAVES.
M E EVIDENCE FOR A ROTATION OF THE PHASE CLAIMED.
M F FIT ASSUMES AN ADDITIONAL PEAK AT 1830 MEV.
M M BACKGROUND SUBTRACTION DIFFICULT.
M P FROM A FIT TO JP=2- S (F PI) PARTIAL WAVE
M R CLEAR PHASE ROTATION SEEN IN (2-S) AND (2-P) WAVES

Table 34 A3 WIDTH (MEV) listing various experimental measurements of the A3 meson width. Columns include author, width value, error, and other parameters. Includes entries for VETLITSKY, BALTAY, BARTSCH, LAMSA, ARMENISE, CASO, HARRISON, GRENNELL, MIYASHITA, BEKETOV, PALER, CASO, THOMPSON, KALEKAR, BALTAY, GHIDINI, PERNEGR, DAUM.

M B SAME EXPERIMENT AS BALTAY 77
M D CLEAR PHASE ROTATION SEEN IN (2-S), (2-P), (2-D) WAVES.
M E EVIDENCE FOR A ROTATION OF THE PHASE CLAIMED.
M F FIT ASSUMES AN ADDITIONAL PEAK AT 1830 MEV.
M M BACKGROUND SUBTRACTION DIFFICULT.
M P FROM A FIT TO JP=2- F PI PARTIAL WAVE
M R CLEAR PHASE ROTATION SEEN IN (2-S) AND (2-P) WAVES

Table 34 A3 PARTIAL DECAY MODES listing decay channels and branching ratios. Columns include decay mode, partial width, and total width. Includes entries for A3 INTO 3 PI, A3 INTO RHO PI, A3 INTO ETA PI, A3 INTO 5 PI, A3 INTO K K*(892), A3 INTO K BAR PI, A3 INTO K BAR, A3 INTO F PI, A3 INTO OMEGA PI PI, A3 INTO 3 PI.

Table 34 A3 BRANCHING RATIOS listing branching ratios for various decay modes. Columns include decay mode, branching ratio, and other parameters. Includes entries for A3+ INTO (PI+ RHO0)/(ALL PI+ PI+ PI-), A3+ INTO (PI+ F)/(ALL PI+ PI+ PI-), A3+ INTO (PI+ RHO0)/(ALL PI+ PI+ PI-), A3+ INTO (PI+ F)/(ALL PI+ PI+ PI-).

A₃(1660)

Evidence for the existence of the A₃ meson was previously confused due to its appearance near ππ threshold in the diffractive-like process πN → πππN, much like the A₁ meson. While everybody agreed that there was a ≈300 MeV wide fπ enhancement in the J^P_{LM} = 2⁻₅₀ partial wave at about 1650 MeV, some claimed non-resonant status (ANTIPOV1 73, ASCOLI1 73, BALTAY 77, GHIDINI 77), while others saw evidence for a resonance in the phase variation with respect to other partial waves (OTTER 74, THOMPSON 74).

In the non-diffractive charge-exchange reaction π⁺p → π⁺π⁰Δ⁺⁺ (WAGNER 75, BALTAY 77, CAUTIS 77) and in the hypercharge exchange reaction K⁻p → π⁺π⁰Λ at 4.2 GeV/c (CERRADA 77), there is no evidence for A₃ production.

Definitive proof for the resonant nature of the A₃ has been given by PERNEGR 78 using 60,000 3π events, diffractively produced by incident π⁻ on nuclei, and by DAUM 80 in an analysis of nearly 600,000 events of the reaction π⁻p → π⁻π⁰π⁺. A partial-wave analysis shows the 3π system to be

Mesons

A₃(1660), ω(1670), g(1700)

Data Card Listings

For notation, see key at front of Listings.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for A3+ and A3- mesons with various decay modes and branching ratios.

Table containing 'REFERENCES FOR A3' and a list of references for the A3 meson, including authors like GESSAROLI, CERN MISSING MASS, etc.

ω(1670) 45 OMEGA(1670, JPC=3--) I=0. THIS RESONANCE OVERLAPS IN ITS 3PI MODE WITH THE A3, BUT IN SOME EXPERIMENTS ONE CAN ESTABLISH THE DECAY MODE RHO0 P10, THUS I=0. WAGNER 75 FIND JP=3- UNICUELY.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for ω(1670) and A3 mesons with various decay modes and branching ratios.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for E 110(1700,0) APPROX., P E 430 1673.0, etc.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for 45 OMEGA(1670) PARTIAL DECAY MODES.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for 45 OMEGA(1670) BRANCHING RATIOS.

Table with columns for particle name, quantum numbers, and experimental data. Includes entries for REFERENCES FOR OMEGA(1670).

g(1700) 15 G(1700, JPC=3-+) I=1

The g meson is uniquely established near 1700 MeV in the I G J P = 1 + 3 - partial wave of the pi+ pi- system (HYAMS 75, MARTIN3 78, BECKER 79, CORDEN 79), in the K+ K- system (GORLICH 79), and in the K- K0 system (MARTIN1,2 78). Its branching ratio into pi pi is unanimously in the range 23-26%, whereas determinations of the ratio K K-bar / pi pi are conflicting: 19.1% in a model-independent analysis of the K+ K- system (GORLICH 79), but only 5.6% in K- K0 (MARTIN1,2 78). It is clear from these numbers, however, that the g decays predominantly into channels other than pi pi or K K-bar, such as 4 pi, omega pi, rho pi pi, A2 pi, and K K-bar pi.

Data Card Listings

For notation, see key at front of Listings.

Mesons
g(1700)

15 G MASS (MEV)

WE AVERAGE ONLY THE 2PI AND KKBAR MODES WHICH HAVE LARGE STATISTICS

Table listing experimental data for the 2PI mode, including mass values, error bars, and researcher names like BELLINI, FORINO, GOLDBERG, etc.

MASS ERRORS ENLARGED BY US TO WIDTH/SQRT(N), SEE K* TYPED NOTE
USES SAME DATA AS HYAMS 75
INCLUDED IN BECKER 79 ANALYSIS
FROM PHASE-SHIFT ANALYSIS
ERROR TAKES ACCOUNT OF SPREAD OF DIFFERENT PHASE-SHIFT SOLUTIONS
FROM A PHASE SHIFT SOLUTION CONTAINING A F PRIME WIDTH TWO TIMES LARGER THAN THE K KBAR RESULT.

Table listing experimental data for the K KBAR + K KBAR PI MODE, including mass values and researcher names like EHRlich, FRENCH, CRENNELL, etc.

K OBSERVED IN NEUTRAL(K* KBAR) MODE (G-PARITY UNKNOWN)
L THEY CANNOT DISTINGUISH BETWEEN G AND OMEGA(1670).
FROM A FIT TO JP=3- PARTIAL WAVE.
SYSTEMATIC ERROR ON MASS SCALE SUBTRACTED

AVG 1693.2 5.5 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)
STUDENT 1691.0 3.8 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

Table listing experimental data for the (4PI)+- MODE, including mass values and researcher names like BALTAY, JOHNSTON, BARTSCH, etc.

AVG 1675.2 11.1 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.9)
STUDENT 1674.9 7.8 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

F FROM (RHO+- RHO0) MODE
NOT SEPARATED FROM 2 PI DECAY

Table listing experimental data for the RHO0 RHO0 MODE, including mass values and researcher names MAURER, BRAUN.

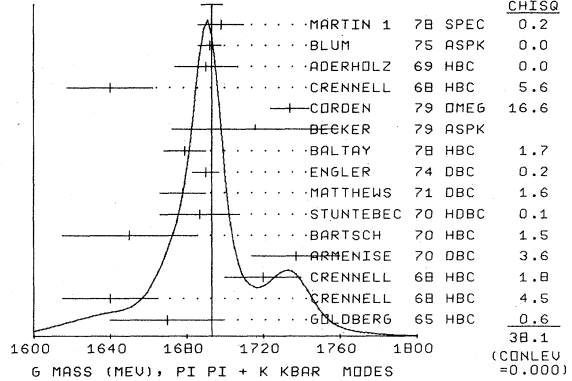
Table listing experimental data for the OMEGA PI MODE, including mass values and researcher names BARNHAM, CASO, etc.

AVG 1663.4 13.8 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)
STUDENT 1665.7 10.2 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

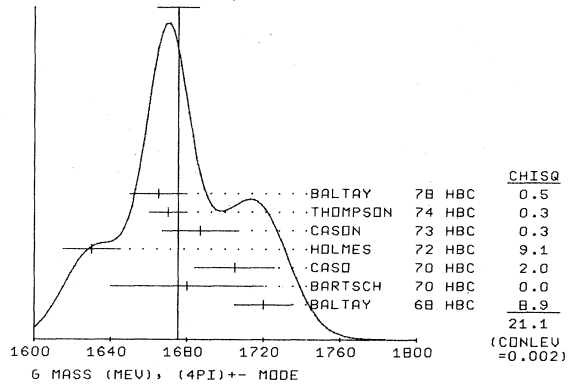
R PEAKS FROM MMS. (FOR DIFFICULTIES WITH MMS EXPTS. SEE THE A2 MINI-REVIEW IN THE 1973 EDITION)

Table listing experimental data for the R peaks from MMS, including mass values and researcher names FOCACCI, ANDERSON.

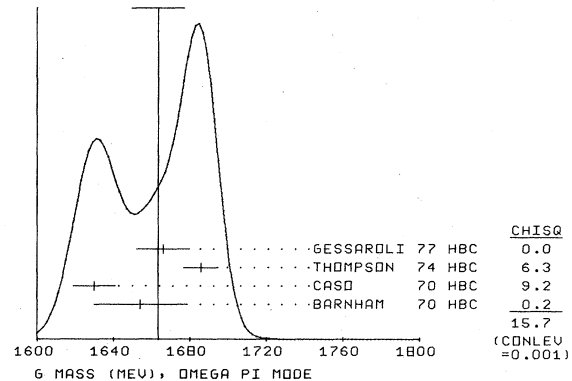
WEIGHTED AVERAGE = 1693.2 ± 5.5
ERROR SCALED BY 1.7



WEIGHTED AVERAGE = 1675.2 ± 11.1
ERROR SCALED BY 1.9



WEIGHTED AVERAGE = 1663.4 ± 13.8
ERROR SCALED BY 2.3



Data Card Listings

Mesons

For notation, see key at front of Listings.

g(1700), X(1690), A₄(1900)

R11 G+ INTO (PI PHI)/(4 PI) CHARGED (P9)/(P11) BALTAY 68 HBC + 7,8.5 PI+P 6/68
R12 G+ INTO (PI+ 2PI+ 2PI- PI0)/(4 PI) CH. (0.15) OR LESS BALTAY 68 HBC + 7,8.5 PI+ P 6/68
R13 G+ INTO (PI ETA)/(4 PI) CHARGED (P10)/(P11) THOMPSON 74 HBC + 13 PI+ P 12/75
R14 G+ INTO (K KBAR)/TOTAL (P4) R14 B 0.013 0.004 MARTIN 2 78 SPEC -10 PI P,K S K- P 4/78*

64 X(1690) WIDTH (MEV)
W N (38.) (18.) DANYSZ 67 HBC 0 3,3.6 PBAR P 1/73
W N NOT SEEN IN HIGH STATISTICS EXP. OF OREN 74
W (50.0) (15.0) YOST 68 HBC 04.3 K-P,LMBD.5PI. 1/73
W 90. 20. BARNES 69 HBC 0 4.6 K-P,OMEG2PI 1/73

REFERENCES FOR X(1690)
DANYSZ 67 NC 51 A 801 DANYSZ+FRENCH+SIMAK (CERN)
YOST 68 UMD T.REPORT 849 +YODH+EINSCHLAG,DAY,GLASSER (UMD)
BARNES 69 PRL 23 142 +CHUNG,EISNER,FLAMINIO,+ (BNL)
OREN 74 NP B71 189 +COOPER,FIELDS,RHINES,WHITMORE,+ (ANL+CXF)

REFERENCES FOR G
BELLINI 65 NC 40 A 948 BELLINI,DI CERATO,DUIMIG,FIORINI (MILANO)
DEUTSCHMANN 65 PL 18 351 M.DEUTSCHMANN ET AL (AACHEN+BERLIN+CERN)
FORINO 65 PL 19 65 FORINO,GESSAROLI + (BOLOGNA+ORSAY+SACLAY)
GOLDBERG 65 PL 17 354 GOLDBERG+ (CERN+EPOL+ORSAY+MILANO+CEA-SACL)

A4(1900) 43 A4(1900,JP= -) I=1
THIS ENTRY CONTAINS THE DIFFRACTIVE-LIKE 3PI AND 5PI BUMPS IN THE REGION OF 1900 MEV, AS WELL AS VARIOUS PEAKS NEARBY. NOTE THAT THE EXISTENCE OF AN S-WAVE GPI THRESHOLD BUMP (IN ANALOGY TO A1 AND A3) IS NOT UNEXPECTED. OMITTED FROM TABLE.

R. EHRLICH,W.SELOVE,H.YUTA (PENNSYLVANIA)
CERN MISSING MASS SPECTROMETER GROUP (CERN)
CERN MISSING MASS SPECTROMETER GROUP (CERN)
CERN MISSING MASS SPECTROMETER GROUP (CERN)
+KEHOE+GLASSER+SECHI-ZORN+WOLSKY (MARYLAND)
+FRENCH+KINSON+SIMAK+ (CERN+LIVERPOOL)
+FOCACCI+KINZON+LECHANDINE+LEVRAT+ (CERN)
L. DUBAL (GENEVE)
+KINSON+MCDONALD+RIDDIFORD+ (CERN+BIRM)

43 A4 MASS (MEV)
M (1900.) HUSCN 68 HLBC - 16.PI-A,A 5PI 2/74
M (1830.) SALZBERG 72 HBC - 13,20 PI-P,P 3PI 2/74
M B 40(1960.) (30.) BASTIEN 73 DBC - 15.PI-D,D 3PI 2/74
M (1800.) DEUTSCHM 75 HBC + 16.PI+P,P 3PI 12/75
M C 208(280.) (40.) KALELKAR 75 HBC + 15.PI+P,P 3PI 12/75
M (2100.) APPROX. ANTIPOV 77 C1BS - 25PI-P,P 3PI 12/77
M (2214.) (15.) BALTAY 77 HBC 0 15PI-P,DEL+3PI 12/77
M K VARIOUS PEAKS (1820.) (12.) FRENCH 67 HBC 0 3,3.6 PBAR P 7/67

+FORINO+CARACCIO+(BARI+BGNA+FIRENZE+ORSAY)I
+KUNZ+VENHOFERBEL+ (COLU+ROCH+RUTG+VALE)I=1
+CASON,DZIERBA,GROVES,KENNEY,+ (NDAM)
BOESEBECK,DEUTSCHMANN,+ (AACHEN+BERLIN+CERN)
+CONTE+CORDS+DIAZ+ (GENOVA+HAMB+MILA+CEA+SACL)
+KARSHON,LAI,SCARR,SKILLICORN (BNL)
+PRENTICE,STEEBERG,YOON (TORONTO+ISC)IJP

43 A4 WIDTH (MEV)
W B (130.) SALZBERG 72 HBC - 13,20 PI-P,P 3PI 2/74
W B 40 (200.) BASTIEN 73 DBC - 15.PI-D,D 3PI 2/74
W C 208 (340.) (80.) KALELKAR 75 HBC + 15.PI+P,P 3PI 12/75
W (355.) APPROX. ANTIPOV 77 C1BS - 25PI-P,P 3PI 12/77
M (2100.) (21.) BALTAY 77 HBC 0 15PI-P,DEL+3PI 12/77
W K VARIOUS PEAKS (50.) (20.) FRENCH 67 HBC 0 3-4 PBAR P 7/67
W B MARGINAL STATISTICAL SIGNIFICANCE.
W C SAME EXPERIMENT AS BALTAY 77
W K OBSERVED IN (KS KO P10...) MODE (G-PARITY UNKNOWN)

+CHADWICK,GUFRAGOSIAN,JOHNSON,+ (SLAC)
+FRIDMAN,GERBER,CIVERNAUD,KAHN,+ (STRB)
+HYAMS+JONES,SCHLEIN,BLUM,+ (CERN+MPIIM)JP3-
+PRENTICE,YOON,CARROLL,+ (TNTO+ISC)JP3-

43 A4 PARTIAL DECAY MODES
P1 A4 INTO 3PI DECAY MASS ES 139+ 139+ 139
P2 A4 INTO RHO PI 776+ 139
P3 A4 INTO G PI 1273+ 139
P4 A4 INTO G PI 1700+ 139

+OHIDINI,FORINO,CARTACCI,+ (BARI+BGNA+FIRZ)
+COLLEY,JOBES,KENYON,PATHAK,RIDDIFORD(BIRM)
+KRAUS,TSANOS,GROTE,KOTZAN+(AACH+BERL+CERN)
+CONTE,TOMASINI,CORDS+(GENOVA+HAMB+MILA+SACL)
+BAR TON,GUTAY,LICHTMAN,MILLER,+ (PURDUE)
G. MAURER (STRASSBOURG)
STUNTEBECK,KENNEY,DEERY,BISWAS,CASON+(NDAM)

43 A4 BRANCHING RATIOS
R1 A4 INTO (G PI)/(ALL 3PI) KALELKAR 75 HBC + 15 PI+P,P 3PI 12/75

REFERENCES FOR A4
DANYSZ 67 NC 51 A 801 DANYSZ+FRENCH+SIMAK (CERN)
FRENCH 67 NC 52 A 442 +KINSON+MCDONALD+RIDDIFORD+ (CERN+BIRM)
HUSGN 68 PL 28 B 208 +LUBATTI,BELLINI,BINGHAM,+ (ORSAY+MILA+LBL)
BEMPCRAD 71 NP B 33 397 +DUFETY,COOLING,+ (CERN+ETH+LOIC+MILA)
CLAYTON 72 NP B 47 81 +MASON,MUIRHEAD,RIGOPOLDS,+ (LIVP+PATR)
HARRISON 72 PRL 28 775 +HEYDA,JOHNSON,KIM,LAW,MUELLER,+ (HARV)
SALZBERG 72 NP B 41 397 +HARRISON,HEYDA,JOHNSON,KIM,LAW,+ (HARV)
BASTIEN 73 UPPSALA CONF. 73 +DUNN,HARRIS,LUBATTI,BINGHAM,+ (SEAT+UCB)
OREN 74 NP B71 189 +COOPER,FIELDS,RHINES,WHITMORE,+ (ANL+CXF)
DEUTSCHM 75 NP B99 397 DEUTSCHMANN,+ (ABBCCHW COLLABORATION)
KALELKAR 75 THESES(NEVIS 207) M.S.KALELKAR (COLU)I=1
ANTIPOV 77 NP B 119 45 +BUSNELLO,DAMGAARD,KIENZLE+ (CERN+SERP)
BALTAY 77 PRL 39 591 +CAUTIS,KALELKAR (COLUMBIA) JP
CAUTIS 77 THESES NEVIS 221 C.V.CAUTIS (COLUMBIA) JP
BALTAY 78 PR D 17 52 +CAUTIS,COHEN,CSORNA,KALELKAR+ (COLU+BING)

X(1690) 64 X(1690)
THIS ENTRY CONTAINS OMEGA PI PI PEAKS AROUND 1690 MEV. EVIDENCE NOT COMPELLING. OMITTED FROM TABLE.

64 X(1690) MASS (MEV)
M N (1689.) (10.) DANYSZ 67 HBC 0 3,3.6 PBAR P 2/74
M N NOT SEEN IN HIGH STATISTICS EXP. OF OREN 74
M (1670.0) (18.0) YOST 68 HBC 04.3 K-P,LMBD.5PI. 2/74
M 1655.0 20.0 BARNES 69 HBC 0 4.6 K-P,OMEG2PI 2/74

Data Card Listings

For notation, see key at front of Listings.

Mesons

S(1935), h(2040)

Table with columns for channel number, S channel, NBAR, N, and various experimental details for the S(1935) meson.

Table for S(1935) partial decay modes, listing P1, S into PBAR P, and decay masses.

Table of references for S(1935) from various experiments and publications, including authors and journal information.

h(2040)

16 H(2040, JPC=4++) I=0. APEL 75 AND BLUM 75 ESTABLISH JP AS 4+ AND I=0. ADDITIONAL EVIDENCE FOR THE H MESON IS REPORTED IN WAGNER 74.

Table for h(2040) 16 H MASS (MEV) listing various decay channels and masses.

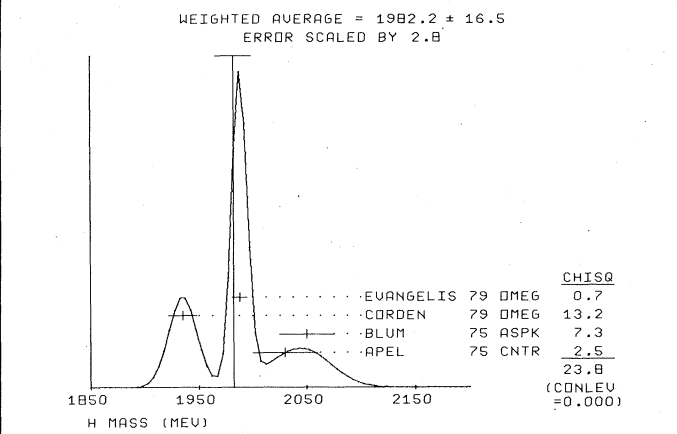


Table for h(2040) 16 H WIDTH (MEV) listing various decay channels and widths.

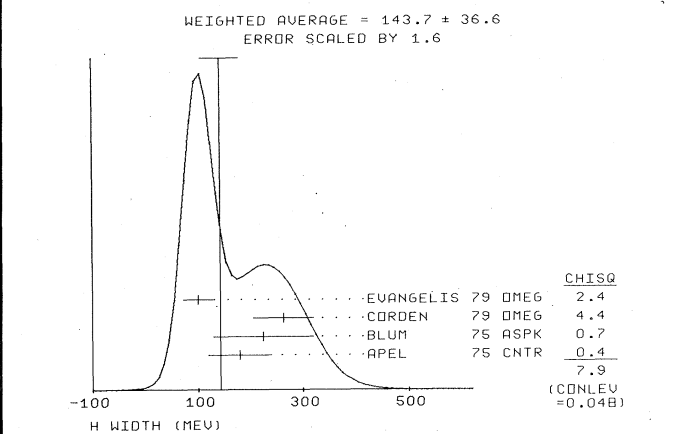


Table for h(2040) 16 H PARTIAL DECAY MODES listing P1, H into P1 P1, and H into K KBAR.

Table for h(2040) 16 H BRANCHING RATIOS listing R1, H into (P1 P1)/TOTAL, and (P1).

Table of references for h(2040) from various experiments and publications, including authors and journal information.

Mesons

T AND U REGIONS, T0(2150), T1(2190)

Data Card Listings

For notation, see key at front of Listings.

Note on T and U Regions

The observation of broad enhancements at 2190 and 2350 MeV comes from pp total cross-section measurements (ABRAMS 67), pp annihilation measurements (ALSPECTOR 73), pp elastic cross-section measurements (COUPLAND 77), and from pp charge-exchange cross-section measurements (CUTTS 78).

The comparison of pp and pd total cross sections (ABRAMS 67) suggests I=1 for the 2190 MeV enhancement, called T1, whereas I=0 and I=1 are both present in the 2400 MeV mass region, which we call U0 and U1, respectively.

Partial-wave analysis of pp annihilation into pi+pi- (CARTER 77) and into pi0pi0 (DULUDE 78) have shown that resonances are formed in the pi pi annihilation channels in the 2100-2500 MeV mass region (no statistically significant data are available outside this mass region). The analysis of MARTIN 78 which combines the pi+pi- data of EISENHANDLER 75 and CARTER 77 and the pi0pi0 data of DULUDE 78 finds evidence for a JP=2+, IG=0+ resonance near 2150 MeV, called T0, and for a JP=5-, IG=1+ resonance near 2450 MeV, which may be too high in mass to be associated to the U1 bump observed in the pp total cross section. The pi pi partial-wave analysis gives ambiguous results on the I=1 component in the T region, favoring however, JP=1-, and on both I=0 and I=1 components in the U (2350-2450 MeV) mass region, where resonances with spin three and four may be present.

Model-dependent partial-wave analyses of the pp system produced with incident pion beams and relying on one-pion-exchange mechanisms suggest the presence of resonances with spin 2, 3, 4, and 5 in the 2100 to 2500 MeV mass region (EVANGELISTA 79, ROZANSKA 79).

T0(2150) 42 T0(2150, JPC=2++) I=0
THIS ENTRY CONTAINS THE I=0 STRUCTURES FOUND BY AMPLITUDE ANALYSES OF PBAR P INTO PI PI OR KB K AND BY MOMENTS ANALYSES OF THE PBAR P SYSTEM PERIPHERALLY PRODUCED BY INCIDENT PIONS. WE LIST ALSO THE BUMPS FOUND IN S-CHANNEL NBAR N OF UNDEFINED ISOSPIN. SEE ALSO S,T,U MINI-REVIEWS. OMITTED FROM TABLE.

42 T0(2150) MASS (MEV)
M S CHANNEL NBAR N ABRAMS 70 CNTR S CHANNEL PBAR N 1/73
M B L 2190. 10. SEEN AS BUMP IN I=1 STATE. SEE ALSO COOPER 68.
M B PEASLEE 75 CONFIRM PBAR P RESULTS OF ABRAMS 70, NO NARROW STRUCTURE
M I 2193. 2. ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
M E I 2155.0 15.0 COUPLAND 77 CNTR 0.7-2.4PB-P,PB-P 12/77
M E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M I (2190.0) APPROX. CUTTS 78 CNTR .97-3. PB P,NB N 12/78*
M I ISOSPINS 0 AND 1 NOT SEPARATED

M PBAR P INTO PI PI OR KB K
L (2150.0) APPROX. DULUDE 2 78 OSK 1.-2.PB P,PIOPIO 12/78*
L IG=0+,JP=2+ FROM PARTIAL WAVE AMPLITUDE ANALYSIS
M P (2150.0) APPROX. MARTIN 79 RVUE 12/79*
M P I=0,JP=2+ FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO
P WITH THE PARTIAL-WAVE EXPANSION TRUNCATED IN J.
M PBAR P PRODUCTION EXPERIMENTS
M 2180.0 10.0 ROZANSKA 80 SPRK 18.PI-P,P PB N 12/79*
M I=0,JP=2+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE.
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

42 T0(2150) WIDTH (MEV)
W S CHANNEL NBAR N ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
W I 98. 8. COUPLAND 77 CNTR 0.7-2.4PB-P,PB-P
W E I 135.0 75.0 FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W I ISOSPINS 0 AND 1 NOT SEPARATED
M PBAR P INTO PI PI OR KB K
L (2150.0) APPROX. DULUDE 2 78 OSK 1.-2.PB P,PIOPIO 12/78*
L IG=0+,JP=2+ FROM PARTIAL WAVE AMPLITUDE ANALYSIS
M P (2150.0) APPROX. MARTIN 79 RVUE 12/79*
M P I=0,JP=2+ FROM SIMULTANEOUS ANALYSIS OF P PB --> PI-PI+ AND PIO PIO
P WITH THE PARTIAL-WAVE EXPANSION TRUNCATED IN J.
M PBAR P PRODUCTION EXPERIMENTS
M 270.0 10.0 ROZANSKA 80 SPRK 18.PI-P,P PB N 12/79*
M I=0,JP=2+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
M AVERAGE MEANINGLESS (SCALE FACTOR = -13.4)

REFERENCES FOR T0(2150)
ALSPECTO 73 PRL 30 511 ALSPECTOR, COHEN, CVIJANOVICH,+ (RUTG+UPNJ)
COUPLAND 77 PL 71 B 460 +EISENHANDLER, GIBSON, ASTBURY,+ (LOQM+RHEL)
CUTTS 78 PR D 17 16 +GOOD, GRANNIS, GREEN, LEE, PITTMAN+(STON+WISC)
DULUDE 1 78 PL 79 B 329 +LANOU, MASSIMO, PEASLEE+ (BROW+MIT+BARI)
DULUDE 2 78 PL 79 B 335 +LANOU, MASSIMO, PEASLEE+ (BROW+MIT+BARI)
BOWCOCK 79 PREP. BIRMINGH. J. E. BOWCOCK, D. C. HODGSON (BIRM)
MARTIN 79 PL 86 B 93 A. D. MARTIN, M. R. PENNINGTON (DURH)
ALSO 80 DURHAM PREPRINT A. D. MARTIN, M. R. PENNINGTON (DURH)
ROZANSKA 80 NP B 162 505 +BLUM, DIETL, GRAYER, LORENZ+ (MPI+CERN)

T1(2190) 32 T1(2190, JPC=) I=1.
THIS ENTRY CONTAINS THE I=1 BUMP OBSERVED IN S-CHANNEL NBAR N AND THE STRUCTURES FOUND BY AMPLITUDE ANALYSES OF PBAR P INTO PI PI OR KB K AND BY THE MOMENTS ANALYSES OF THE PBAR P SYSTEM PERIPHERALLY PRODUCED BY INCIDENT PIONS. SEE ALSO S,T,U MINI-REVIEWS. OMITTED FROM TABLE.

32 T1(2190) MASS (MEV)
M S CHANNEL NBAR N ABRAMS 70 CNTR S CHANNEL PBAR N 1/73
M B L 2190. 10. SEEN AS BUMP IN I=1 STATE. SEE ALSO COOPER 68.
M B PEASLEE 75 CONFIRM PBAR P RESULTS OF ABRAMS 70, NO NARROW STRUCTURE
M I 2193. 2. ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
M E I 2155.0 15.0 COUPLAND 77 CNTR 0.7-2.4PB-P,PB-P 12/77
M E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M I (2190.0) APPROX. CUTTS 78 CNTR .97-3. PB P,NB N 12/78*
M I ISOSPINS 0 AND 1 NOT SEPARATED
M PBAR P INTO PI PI OR KB K
M J (2150.0) APPROX. CARTER 1 77 CNTR 0.7-2.4PB P,PIPI 12/77
M J I=1,JP=3- FROM AMPLITUDE ANALYSIS.
M K (2140.0) APPROX. CARTER 2 78 CNTR 0.7-2.4PB P,K-K+ 12/78*
M K I=0,1,JP=3- FROM BARRELET ZERO'S ANALYSIS.
M PBAR P PRODUCTION EXPERIMENTS
M R (2110.0) APPROX. EVANGELIS 79 OMEG 10,16 PI-P,PB P 12/79*
M R I=1,JP=3- FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
M R SOLUTION A.
M N 2110.0 10.0 ROZANSKA 80 SPRK 18.PI-P,P,PB N 12/79*
M N I=1,JP=3- FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
M AVERAGE MEANINGLESS (SCALE FACTOR = 5.8)

32 T1(2190) WIDTH (MEV)
W S CHANNEL NBAR N ABRAMS 67 CNTR S CHANNEL PBAR N 7/67
W B (85.1)
W B SEE NOTE B ABOVE.
W I 98. 8. ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
W E I 135.0 75.0 COUPLAND 77 CNTR 0.7-2.4PB-P,PB-P 12/77
W E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W I ISOSPINS 0 AND 1 NOT SEPARATED
M PBAR P INTO PI PI OR KB K
M J (200.0) APPROX. CARTER 1 77 CNTR 0.7-2.4PB P,PIPI 12/77
M J I=1,JP=3- FROM AMPLITUDE ANALYSIS.
M K (150.0) APPROX. CARTER 2 78 CNTR 0.7-2.4PB P,K-K+ 12/78*
M K I=0,1,JP=3- FROM BARRELET ZERO'S ANALYSIS.
M PBAR P PRODUCTION EXPERIMENTS
M R (330.0) APPROX. EVANGELIS 79 OMEG 10,16 PI-P,PB P 12/79*
M R I=1,JP=3- FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
M R SOLUTION A.
M N 190.0 10.0 ROZANSKA 80 SPRK 18.PI-P,P,PB N 12/79*
M N I=1,JP=3- FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
M AVERAGE MEANINGLESS (SCALE FACTOR = 7.2)

Data Card Listings

For notation, see key at front of Listings.

Mesons

T1(2190), X(2200), U0(2350)

32 SIGMA (MB) FOR FORMATION BY NUCLEON ANTINUCLEON
CS A (5.5) ABRAMS 70 CNTR S CHANNEL PBAR N 1/71
FOR I=1 NBAR N 0.13 0.08 ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
CS 2,3

32 T1(2190) PARTIAL DECAY MODES
P1 T INTO PBAR P 938+ 938
P2 T INTO PI PI 139+ 139

REFERENCES FOR T1(2190)
+COOL, GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL)
+HYMAN, MANNER, MUSGRAVE, VOYVODIC (ANL)
+FERRO-LUZZI, BIZARD, + (CERN+CAEN+SACL)
+COOL, GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL)
+BUTTERWORTH, MILLER, PHELAN, + (RHEL+LIVP)
+COOPER, RHINES, ALLISON (ANL+OXF)
+BARI SH, CARROLL, LOBKOVICZ+ (CIT+BNL+RGCH)
ALEXANDER, BAR-NIR, BEVARY, DAGAN, + (TEL)
+CONDO, HART, COHN, ENDORF, + (TENN+ORNL+CINC)
+MASON, MUIRHEAD, RIGOPoulos, + (LIVP+PATR)
+GALLETT, EDWARDS, DE BILLY, + (LIVP+LBNP)
ALSPECTOR, COHEN, CVI JANOVICH, + (RUTG+UPNJ)
+GARNJOST, BIGI, + (PADM+BL+PARIS+TORI)
+EARLES, FAISSLER, BLIEDEN, + (INEAS+STON)
+EASTMAN, OH, PARKER, SMITH, SPRAFKA (MSU)
NICHOLSON, DELORME, CARROLL, + (CIT+ROCH+BNL)
+BIGI, CASALI, LARICCIA, + (PISA+PADO+TORI)
+JONES, WEILHAMMER, BLUM, + (CERN+MPIM)
A. DONNACHIE, P. R. THOMAS (MANCHESTER)
EISENHANDLER, GIBSON, + (LOQM+LIVP+DARE+RHEL)
+COUPLAND, ATKINSON, ARNISON, + (LOQM+DARE+RHEL)
+GARNJOST, ROSS, + (LBL+PADO+PISA+TORI)
+DEMARZO, GUERRIERO, + (CANB+BARI+BROW+MIT)
+MEINGERET, BOGDANSKI, + (NEUC+LAUS+LIVP+MSU)
+HENG MA, MOUNTZ, SMITH (MICH)
+COUPLAND, EISENHANDLER, ASTBURY, + (LOQM+RHEL) JP
+COUPLAND, ATKINSON, ARNISON, + (LOQM+DARE+RHEL) JP
+EISENHANDLER, GIBSON, ASTBURY, + (LQCM+RHEL)
M. D. JONES, R. J. PLAND (RUTG)
L. MONTANET (CERN)
A. A. CARTER (LQCM) JP
A. A. CARTER (LQCM)
+GOOD, GRANNIS, GREEN, LEE, PITTMAN, + (STON+WISC)
+LANDU, MASSIMO, PEASLEE, + (BROW+MIT+BARI)
+LANGU, MASSIMO, PEASLEE, + (BROW+MIT+BARI)
EVANGELI 79 NP B 153 253 + (BARI+BCNN+CERN+DARE+GLAS+LIVP+MILA+WIEN)
MARTIN 79 PL 86 B 93 A. D. MARTIN, M. R. PENNINGTON (DURH)
ALSO 80 DURHAM PREPRINT A. D. MARTIN, M. R. PENNINGTON (DURH)
ROZANSKA 80 NP B 162 505 +BLUM, DIETL, GRAYER, LORENZ+ (MPIM+CERN)

X(2200)

44 X(2200, JPC=) I=
SEEN IN K+, K- MASS SPECTRUM FROM PI- P INTERACTIONS
AT 10 GEV. (EVANGELI 79). NEEDS CONFIRMATION.
OMITTED FROM TABLE.

44 X(2200) MASS. (MEV)
M 2210.0 79.0 21.0 EVANGELIS 79 OMEG 10. PI-P, K+ K- N 12/79*

44 X(2200) WIDTH. (MEV)
W (203.0) APPROX. EVANGELIS 79 OMEG 10. PI-P, K+ K- N 12/79*

44 X(2200) PARTIAL DECAY MODES
P1 X(2200) INTO PI+ PI- DECAY MASSES 139+ 139
P2 X(2200) INTO K+ K- 493+ 493

44 X(2200) BRANCHING RATIOS
R1 X(2200) INTO (K+ K-)/TOTAL (P2)
R1 SEEN EVANGELI 79 OMEG 0 10 PI- P, K+ K- 12/79*

REFERENCES FOR X(2200)
EVANGELI 79 NP B 153 381 + (BARI+BCNN+CERN+DARE+GLAS+LIVP+MILA+WIEN)

U0(2350) 41 U0(2350, JPC=) I=0
THIS ENTRY CONTAINS THE BROAD I=0 BUMP OBSERVED
IN THE S-CHANNEL NBAR N AND THE STRUCTURE FOUND
BY AMPLITUDE ANALYSES OF PBAR P INTO PI PI OR KB K
AND BY AMPLITUDE ANALYSES OF PBAR P SYSTEMS
PERIPHERALLY PRODUCED BY INCIDENT PIONS.
SEE ALSO S, T, U MINI-REVIEWS.
OMITTED FROM TABLE.

41 U0(2350) MASS
M 2375. 10. ABRAMS 70 CNTR S CHANNEL NBAR N 1/71
M I (2359.) (2.) ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
M EI (2345) (15.0) COUPLAND 77 CNTR 0 .7-2.4PB-P, PB-P 12/77
M E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
M I (2380.0) APPROX. CUTS 78 CNTR .97-3. PB P, NB N 12/78*
M I ISOSPINS 0 AND 1 NOT SEPARATED
M PBAR P INTO PI PI OR KB K
M J (2310.0) CARTER 1 77 CNTR 0 .7-2.4PB P, PIP 12/77
M J I=0, JP=+ FROM AMPLITUDE ANALYSIS.
M K (2340.0) APPROX. CARTER 2 78 CNTR 0 .7-2.4PB P, K+K- 12/78*
M K I=0, JP=+ FROM BARRELET ZERO'S ANALYSIS
M PBAR P PRODUCTION EXPERIMENTS
M R (2260.0) APPROX. EVANGELIS 79 OMEG 10, 16 PI-P, PB P 12/79*
M R I=0, JP=+ FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
M R SOLUTION A.
M M 2380.0 10.0 ROZANSKA 80 SPRK 18, PI-P, P, PB N 12/79*
M M I=0, JP=+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

41 U0(2350) WIDTH
W I (190.) (165.) (18.) (8.) ABRAMS 70 CNTR S CHANNEL NBAR N 1/71
W EI (135.0) (150.0) (65.0) COUPLAND 77 CNTR 0 .7-2.4PB-P, PB-P 12/77
W E FROM A FIT TO THE TOTAL ELASTIC CROSS SECTION.
W I ISOSPINS 0 AND 1 NOT SEPARATED
W PBAR P INTO PI PI OR KB K
W J I=0, JP=+ FROM AMPLITUDE ANALYSIS.
W J (210.0) APPROX. CARTER 1 77 CNTR 0 .7-2.4PB P, PIP 12/77
W K (150.0) APPROX. CARTER 2 78 CNTR 0 .7-2.4PB P, K+K- 12/78*
W K I=0, JP=+ FROM BARRELET ZERO'S ANALYSIS
W PBAR P PRODUCTION EXPERIMENTS
W R (440.0) APPROX. EVANGELIS 79 OMEG 10, 16 PI-P, PB P 12/79*
W R I=0, JP=+ FROM A MASS DEPENDENT PARTIAL WAVE ANALYSIS TAKING
W R SOLUTION A.
W M 380.0 20.0 ROZANSKA 80 SPRK 18, PI-P, P, PB N 12/79*
W M I=0, JP=+ FROM AMPLITUDE ANALYSIS ASSUMING ONE PION EXCHANGE

41 U0(2350) SIGMA (MB) FOR FORMATION EXPERIMENTS
CS (2.5) ABRAMS 70 CNTR S CHANNEL PBAR P 1/71
CS I (2.1) (0.2) (0.1) ALSPECTOR 73 CNTR S CHANNEL PBAR P 1/74
CS I ISOSPINS 0 AND 1 NOT SEPARATED

41 U0 PARTIAL DECAY MODES
P1 U INTO PBAR P 938+ 938
P2 U INTO PI PI 139+ 139

REFERENCES FOR U0(2350)
BRICMAN 69 PL 29 B 451 +FERRO-LUZZI, BIZARD, + (CERN+CAEN+SACL)
ABRAMS 70 PR D 1 1917 +COOL, GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL)
EASTMAN 72 NP B 51 29 +MING MA, OH, PARKER, SMITH, SPRAFKA (MSU)
MING MA 72 NP B 51 77 +EASTMAN, OH, PARKER, SMITH, SPRAFKA (MSU)
ALSPECTOR 73 PR 30 511 ALSPECTOR, COHEN, CVI JANOVICH, + (RUTG+UPNJ)
NICHOLSON 73 PR D 7 2572 NICHOLSON, DELORME, CARROLL, + (CIT+ROCH+BNL)

HYAMS 74 NP B 73 202 +JONES, WEILHAMMER, BLUM, + (CERN+MPIM)
MING MA 74 NP B 68 214 +MOUNTZ, ZEMANY, SMITH (MICH)
DONNACHI 75 NC 26 A 317 A. DONNACHIE, P. R. THOMAS (MANCHESTER)
EISENHANDLER, GIBSON, + (LOQM+LIVP+DARE+RHEL)
CARTER 1 77 PL 67 B 117 +COUPLAND, EISENHANDLER, ASTBURY, + (LQCM+RHEL) JP
CARTER 2 77 PL 67 B 122 A. A. CARTER (LQCM) JP
CARTER 3 77 NP B 127 202 +COUPLAND, ATKINSON, ARNISON, + (LOQM+DARE+RHEL) JP
COUPLAND 77 PL 71 B 460 +EISENHANDLER, GIBSON, ASTBURY, + (LOQM+RHEL)
MONTANET 77 BOSTON CONF. L. MONTANET (CERN)

CARTER 1 78 NP B 132 176 A. A. CARTER (LQCM) JP
CARTER 2 78 NP B 141 467 A. A. CARTER (LQCM)
CUTTS 78 PR D 17 16 +GOOD, GRANNIS, GREEN, LEE, PITTMAN, + (STON+WISC)
DULUDE1 78 PL 79 B 329 +LANDU, MASSIMO, PEASLEE, + (BROW+MIT+BARI)
DULUDE2 78 PL 79 B 335 +LANDU, MASSIMO, PEASLEE, + (BROW+MIT+BARI)

BOWCOCK 79 PREP. BIRMINGHAM. J. E. BOWCOCK, D. C. HODGSON (BIRM)
EVANGELI 79 NP B 153 253 + (BARI+BCNN+CERN+DARE+GLAS+LIVP+MILA+WIEN)
MARTIN 79 PL 86 B 93 A. D. MARTIN, M. R. PENNINGTON (DURH)
ALSO 80 DURHAM PREPRINT A. D. MARTIN, M. R. PENNINGTON (DURH)
ROZANSKA 80 NP B 162 505 +BLUM, DIETL, GRAYER, LORENZ+ (MPIM+CERN)

Mesons

U1(2400), NN(1400-3600)

Data Card Listings

For notation, see key at front of Listings.

U1(2400) 33 U1(2400,JP=) I=1
THIS ENTRY CONTAINS THE BROAD I=1 BUMP OBSERVED IN THE S-CHANNEL NEAR N AND THE STRUCTURE FOUND BY AMPLITUDE ANALYSES OF PBAR P INTO PI PI OR KB K AND BY AMPLITUDE ANALYSES OF PBAR P SYSTEMS PERIPHERALLY PRODUCED BY INCIDENT PIONS. SEE ALSO S,T,U MINI-REVIEWS. OMITTED FROM TABLE.

33 U1(2400) MASS (MEV)
M S CHANNEL NBAR N
M A 2350. 10. ABRAMS 70 CNTR S CHANNEL NBAR N 1/73
M N FOR I=1 NBAR N
M N (2360.0) (25.0) OH 70 HDBC -OPBAR(P,N),K*K2P1 1/73
M N NO EVIDENCE FOR THIS BUMP SEEN IN THE PBAR P DATA OF CHAPMAN 71
M N NARROW STATE NOT CONFIRMED BY OH 73 WITH MORE DATA.

33 U1(2400) WIDTH (MEV)
W S CHANNEL NBAR N
W N (140.) ABRAMS 67 CNTR S CHANNEL PBAR N 1/73
W N (60.0) OR LESS OH 70 HDBC -OPBAR(P,N),K*K2P1 1/71
W N NO EVIDENCE FOR THIS BUMP SEEN IN THE PBAR P DATA OF CHAPMAN 71
W N NARROW STATE NOT CONFIRMED BY OH 73 WITH MORE DATA.

33 SIGMA (MB) FOR FORMATION BY NUCLEON ANTINUCLEON
CS A (3.2) ABRAMS 70 CNTR S CHANNEL NBAR N 1/71
CS A FOR I=1 NBAR N
CS I (2.1) (0.2) (0.1) AL SPECTOR 73 CNTR S CHANNEL PBAR P 1/74
CS I ISOSPINS 0 AND 1 NOT SEPARATED

REFERENCES FOR U1(2400)
ABRAMS 67 PRL 18 1209 +CODL,GIACOMELLI,KYCIA,LEONTIC,LI,+ (BNL)
BKICMAN 69 PL 29 B 451 +FERRO-LUZZI,BIZARD,+ (CERN+CAEN+SACL)
CASO 69 LNC 3 707 +CONTE,BENZ,+ (GENO+DESY+HAMB+MILA+SACL)
ABRAMS 70 PR D 1 1917 +CODL,GIACOMELLI,KYCIA,LEONTIC,LI,+ (BNL)
OH 70 PRL 24 1257 +PARKER,EASTMAN,SMITH,SPRAFKA,MA (MSU)

MARTIN 80 DURHAM PREPRINT A.D. MARTIN,M.R. PENNINGTON (DURH)
ROZANSKA 80 NP B 162 505 +BLUM,DIETL,GRAYER,LORENZ+ (MPI+ CERN)

NN(1400-3600) 51 NBAR N(1400-3600)
THIS ENTRY CONTAINS VARIOUS HIGH MASS, NON-STRANGE STRUCTURES COUPLED TO THE BARYON-ANTIBARYON SYSTEM AS WELL AS QUASI-NUCLEAR BOUND STATES BELOW THRESHOLD. SEE ALSO S,T,U DATA CARD LISTINGS AND MINIREVIEWS. EVIDENCE FOR STRUCTURES COUPLED TO THE ANTI-HYPERON NUCLEON (OR C.C.) SYSTEM IS LISTED UNDER K*(2200), OMITTED FROM TABLE.

51 NBAR N(1400-3600) MASSES AND WIDTHS (MEV)
M W G (1395.) PAVLOPOUL 78 CNTR STOPPED PBARS 1/78
M W G (1646.) PAVLOPOUL 78 CNTR STOPPED PBARS 1/78
M W G (1684.) PAVLOPOUL 78 CNTR STOPPED PBARS 1/78
G OBSERVED WIDTHS CONSISTENT WITH EXPERIMENTAL RESOLUTION. THEY LOOKED FOR RADIATIVE TRANSITIONS TO BOUND P PBAR STATES, MONO-ENERGETIC GAMMA RAYS DETECTED.

M D (1794.5) (1.4) GRAY 71 DBC - 0.PBAR D 1/72
W D (8.) OR LESS CL=95 GRAY 71 DBC - 0.PBAR D 1/72
D DECAYS TO FOUR OR MORE PIONS,I=1.
M Z (1897.) (1.) KALOGERO 75 DBC - PBAR N ANNIH 12/75
W Z (25.) (6.) KALOGERO 75 DBC - PBAR N ANNIH 12/75
Z NOT SEEN BY ALBERI 79 WITH COMPARABLE STATISTICS.

M I 1949. 10. DEFOIX 80 HBC 0 0-1.2 PB P,5 PI 12/79*
W I 80. 20. DEFOIX 80 HBC 0 0-1.2 PB P,5 PI 12/79*
I ISOSPIN = 1 FAVOURED
M 153(2020.0) (3.0) BENKHEIRI 77 OMEG 0 9,12PI-P,PPBP1- 12/77
W 153 (24.0) (12.0) BENKHEIRI 77 OMEG 0 9,12PI-P,PPBP1- 12/77

M K (2190.) (17.0) KALBFLEIS 69 HBC 0 5-CHANNEL PBAR P 7/69
W K (110.0) (82.0) KALBFLEIS 69 HBC 0 5-CHANNEL PBAR P 7/69
K NOT SEEN BY BACON 73,NOR BY ZEMAN 76
M E (2200.)
W E (150.)
E SEE TO(2150) AND TI(2190) ABOVE

M 58(2204.0) (5.0) BENKHEIRI 77 OMEG - 9,12PI-P,PPBP1-12/77
W 58 (16.) OR LESS BENKHEIRI 77 OMEG - 9,12PI-P,PPBP1- 12/77
M A (227.) (13.) ALLES-BOR 67 HBC 0 5.7 PBAR P 12/66
W A (62.) (52.) ALLES-BOR 67 HBC 0 5.7 PBAR P 12/66
A ALLES-BORELLI 67 SEE NEUTRAL MODE ONLY (PI+PI-PI0)
M S (2141.) DONALD 73 HBC 0 S CHANNEL PBAR P 1/74
W S (14.) DONALD 73 HBC 0 S CHANNEL PBAR P 1/74
S SEEN IN FINAL STATE (OMEGA PI+ P1-)

Data Card Listings

Mesons

For notation, see key at front of Listings.

X(1900-3600), e+e-(1100-3100)

M Z (3600.) (20.) ALEXANDER 72 HBC 0 6.94 PBAR P 1/73
W Z (140.) (20.) ALEXANDER 72 HBC 0 6.94 PBAR P 1/73
Z DECAYS TO 4PI+ 4PI-

***** REFERENCES FOR NBAR N(1400-3600) *****
ALLES-BO 67 NC 50 A 776 ALLES-BORELLI, FRENCH, FRISK, + (CERN+BCNNIG--
KALDFEI 69 PL 29 B 259 C, KALDFEISCH, R. STRAND, V. VANDERBURG (BNL)
ALEXANDER 70 PRL 25 63 *BAR-NIR, DAGAN, SIDAL, GRUNHAUS, + (TEL-AVIV)
KALDFEI 70 PHILAD. CONF. P. 409 G, KALDFEISCH AND D. MILLER REVUES (BNL)
GRAY 71 PRL 26 1491 +HAGERT, KALGEROPOULOS (SYRA)
ALEXANDER 72 NP B 45 29 ALEXANDER, BAR-NIR, BEVARY, DAGAN, + (TELA)
BOGDANOV 72 PRL 28 1418 BOGDANOV, DALKAROV, SHAPIRO (ITEP)
DONALD 73 NP B 61 333 +EDWARDS, GIBBINS, BRIAND, DUBOC, + (LIVP+LPNP)
GRAY 73 PRL 30 1091 +PAPADOPOULOU, KARAGEROPOULOS, + (ATEN+SYRA)
NICHOLSON 73 PR D 7 2572 NICHOLSON, DELGRME, CARROLL, + (CIT+ROCH+BNL)
HYAMS 74 NP B 73 202 +JONES, WEIHLAMMER, BLUM, + (CERN+MPIM)
DANNACHI 75 NC 26 A 317 A. DONNACHI, P. R. THOMAS (MANCHESTER)
EISENHAN 75 NP B 96 109 EISENHANDLER, GIBSON, + (LOQM+LIVP+DARE+RHEL)
KALGEGE 75 PRL 34 1947 KALGEROPOULOS, TZANAKOS (SYRA)
ABASHIAN 76 PR D 13 5 +WATSON, GELFAND, BUTTRAM, (ILL+ANL+CHIC+ICWA)
BRAUN 76 PL B 60 481 +BRICK, FRIDMAN, GERBER, JUILLOT, MAURER, (STRB)
BENKHEIR 77 PL B 68 483 BENKHEIR, BOUCROT, + (CERN+CDEF+EPDL+LALO)
CARTER 77 PL 67 B 117 *COUPLAND, EISENHANDLER, ASTBURY, + (LOQM+RHEL)
EVANGELI 77 PL B 72 139 EVANGELISTA, (BART+BONN+CERN+DARE+GLAS+)
BALTAY 78 PR D 17 52 +CAUTIS, COHEN, CSORNA, KALELKAR, + (CGLU+BING)
BENKHEIR 78 LAL-78/30 BENKHEIR, BOUCROT, + (CERN+CDEF+EPDL+LALO)
CARTER 78 NP B 141 467 A. A. CARTER (LIGM)
PAVLOPOU 78 PL 72 B 415 PAVLOPOULOS, (KARL+BASL+CERN+STOH+STRB)
MARTIN 78 NP B 137 77 M. R. PENNINGTON (CERN)
ALBERTI 79 PL 83 B 247 +ALVEAR, CASTELLI, POROPAT, + (TRST+CERN+RHO)
ALSTON-G 79 PRL 43 1901 ALSTON-GARNJOST, HAMILTON, + (LBL+MHD+BNL)
ARMSTRON 79 PL B 85 304 ARMSTRONG, (AACH+BARI+BONN+CERN+GLAS+LIVP+)
BENKHEIR 79 PL 81 B 380 BENKHEIR, BOUCROT, + (EPOL+LALO+CDEF+BNL)
BOWCOCK 79 PREP. BIRMINGH. J. E. BOWCOCK, D. C. HODGSON (BJRM)
CARROLL 79 PR D 19 1950 +CHIANI, KYCIA, LI, LITTEBERG, + (BNL+RCH)
DELCOURT 79 PL B 86 395 +DERADO, BERTHANO, BISELL, G. RIZOT, BUON, + (LALO)
EVANGELI 79 NP B 153 253 + (BAR+BONN+CERN+DARE+GLAS+LIVP+MILA+WIEN)
GIBBARD 79 PRL 42 1593 +AHRENS, BERKELMAN, CASSEL, DAY, HARDING, (CORN)
MARTIN 79 PL B 86 93 A. D. MARTIN, M. R. PENNINGTON (DURH)
DEFOIX 80 NP B 162 12 +DOBRYZNSKI, ANGELINI, BIGI, + (CDEF+ISA)
HAMILTON 80 PRL +PUN, TRIPP, LAZARUS, NICHOLSON (LBL+BNL+MHO)
ROZANSKA 80 NP B 162 505 +BLUM, DIETL, GRAYER, LORENZ, + (MPIM+CERN)

X(1900-3600) 46 X(1900-3600)
THIS ENTRY CONTAINS VARIOUS HIGH-MASS NON-STRANGE PEAKS. OMITTED FROM TABLE.

The high mass region is covered nearly continuously by evidence for peaks of various widths and decay modes. As a satisfactory grouping into particles is not yet possible, we list all the Y=0 bumps coupled neither to NN nor to e+e-, and having M > 1900 MeV, together, ordered by increasing mass. Note that ANTIPOV 72 (pi-p -> p MM- at 25 and 40 GeV/c) see no narrow bumps.

Table with columns: Particle Name, Mass (MeV), Width (MeV), Decay Mode, Reference. Includes entries for THOMPSON 74 HBC, BOESEBECK 68 HBC, CHLIAPIKOV 79 HBC, CASC 70 HBC, KRAMER 70 HBC, TAKAHASHI 72 HBC, etc.

M (2500.0) (32.0) ANDERSON 69 MMS - 16 PI- P, BACKW9 8/69
W (87.0) ANDERSON 69 MMS - 16 PI- P, BACKW9 8/69
M 550(2620.) (20.) BAUD 69 MMS - 8-10. PI- P 9/69
W 550 (85.) (30.) BAUD 69 MMS - 8-10. PI- P 9/69
M (2676.0) (27.0) CASC 70 HBC - 11.2PI- P, NOTE C 5/70
W (150.0) CASC 70 HBC - 11.2PI- P, NOTE C 5/70
C SEEN IN RHO- PI+ PI- (OMEGA AND ETA ANTISELECTED IN 4 PI SYSTEM)
M 640(2800.) (20.) BAUD 69 MMS - 8-10. PI- P 9/69
W 640 (46.) (10.) BAUD 69 MMS - 8-10. PI- P 9/69
M C 15(2820.) (10.) SABAU 71 HBC + 8. PI+ P 11/71
W C 15 (50.1) (10.) SABAU 71 HBC + 8. PI+ P 11/71
C SEEN IN (K KBAR PI PI) MASS DISTRIBUTION
M 230(2880.) (20.) BAUD 69 MMS - 8-10. PI- P 9/69
W 230 (15.) OR LESS BAUD 69 MMS - 8-10. PI- P 9/69
M Y 43(3013.) (5.) YOST 71 HBC + 11.PI+ P, P(8PI) 11/71
W Y 43 (40.) OR LESS YOST 71 HBC + 11.PI+ P, P(8PI) 5/71
Y 4.2 S.D. EFFECT - DECAY TO 7 PIONS
Y NOT SEEN BY KALELKAR 75 WITH 5 TIMES MORE DATA
M (3025.0) (20.0) BAUD 70 MMS - 10.5-13 PI- P 5/70
W (25.0) APPROX. BAUD 70 MMS - 10.5-13 PI- P 5/70
M (3075.0) (20.0) BAUD 70 MMS - 10.5-13 PI- P 5/70
W (25.0) APPROX. BAUD 70 MMS - 10.5-13 PI- P 5/70
M (3145.0) (20.0) BAUD 70 MMS - 10.5-15 PI- P 5/70
W (10.0) OR LESS BAUD 70 MMS - 10.5-15 PI- P 5/70
M (33475.0) (20.0) BAUD 70 MMS - 14-15.5 PI- P 5/70
W (30.0) APPROX. BAUD 70 MMS - 14-15.5 PI- P 5/70
M (3535.0) (20.0) BAUD 70 MMS - 14-15.5 PI- P 5/70
W (30.0) APPROX. BAUD 70 MMS - 14-15.5 PI- P 5/70

***** REFERENCES FOR X(1900-3600) *****
CLAYTON 67 HEIDBG. CONF. P. 57 +MASON, MUIRHEAD, FILIPPAS, + (LIVERPOOL+ATHENS)
BOESEBECK 68 NP B 4 501 BOESEBECK, DEUTSCHMANN, + (AACHEN+BERLIN+CERN)
ANDERSON 69 PRL 22 1390 +COLLINS, + (BNL+CERN)
BAUD 69 PL 308 129 CERN BOSCN SPECTROMETER GROUP (CERN)
BAUD 70 PL 31 B 549 CERN BOSCN SPECTROMETER GROUP (CERN)
CASO 70 LNC 3 707 +CONTE, TOMASINI, CORO, + (GENO+HAMB+MILA+SACL)
KRAMER 70 PRL 25 396 +BARTON, GUTAY, LICHTMAN, MILLER, + (PURDUE)
SABAU 71 LNC 1 514 +URETSKY (BUCH+ANL)
YOST 71 PR D 3 642 +MORRIS, ALBRIGHT, BRUCKER, LANNUCCI (FSU)
TAKAHASHI 72 PR D 6 1266 +MORRIS, ALBRIGHT, BRUCKER, LANNUCCI (FSU)
THOMPSON 74 NP B 69 220 +GATOS, MCILWAIN, MILLER, MILLER, + (PURDUE)
BALTAY 75 PRL 35 891 +CAUTIS, COHEN, KALELKAR, PISELLO, + (COLU+BING)
KALELKAR 75 THESIS(INEVIS 207) M. S. KALELKAR (CGLU)
KEMP 75 NC 27 A 195 +LOTT, CONTRI, FEDOROV, + (DURH+GENO+MILA+LPNP)
BALTAY 78 PR D 17 52 +CAUTIS, COHEN, CSORNA, KALELKAR, + (COLU+BING)
BLANAR 79 PR D 20 615 +BOYER, EARLES, FAISSLER, GARELICK, + (NEAS)
CHLIAPIKOV 79 PREP. CHLIAPIKOV, GERDYUKOV, + (SERP+BRUX+MONS)
CLINE 79 PRL 43 1771 +DE BONTE, GATOS, LEEDOM, KEY, + (PURDUE+TNT)

e+e-(1100-3100) 7 E+ E-(1100-3100, JP6=1-) I=

THIS ENTRY CONTAINS NON-STRANGE VECTOR MESONS COUPLED TO E+ E-(PHOTON) BETWEEN PHI AND J/PSI MASS REGION. SEE ALSO RHO PRIME(1250) AND RHO PRIME(1600) MINI-REVIEW. OMITTED FROM TABLE.

Table with columns: Particle Name, Mass (MeV), Width (MeV), Decay Mode, Reference. Includes entries for BARTALUCC 79 OSKP, COSME 79 OSKP, CHLIAPIKOV 79 OSKP, CASC 70 HBC, KRAMER 70 HBC, TAKAHASHI 72 HBC, etc.

Mesons

CHARMONIUM, X(2830), U(2980)

For notation, see key at front of Listings.

REFERENCES FOR E+ E-(1100-3100)

BACCI 75 PL 58 B 481	+BIDOLI, PENSO, STELLA, BALDINI,+ (ROMA+FRAS)
BACCI 76 PL 64 B 356	+BIDOLI, PENSO, STELLA, BALDINI,+ (ROMA+FRAS)
BACCI 77 PL B 68 393	+DE ZORZI, PENSO, STELLA, BALDINI,+ (ROMA+FRAS)
BARBIELL 77 PL B 68 397	BARBIELLINI, BARLETTA,+ (FRAS+NAPL+PISA+SANI)
BARTALUC 77 NC A 35 374	BARTALUCCI, BERTOLUCCI, BRADASCHIA (DESY+FRAS)
ESPOSITO 77 PL B 68 389	+FELICETTI, MARINI,+ (FRAS+NAPL+PADO+ROMA)
AMBROSIO 78 PL 80 B 141	+CERRITO, BEMFORAD, BRUSCG,+ (NAPL+PISA+ROMA)
BALDINI 78 PL 78 B 167	+BATTISTONI, CAPON, BACCI, DEZORKI+ (FRAS+RCMA)
ESPOSITI 78 LNC 22 305	ESPOSITO, FELICETTI+ (FRAS+NAPL+PADO+ROMA)
ESPOSITO 78 LNC 23 604	ESPOSITO, FELICETTI+ (FRAS+NAPL+PADO+RCMA)
PETERSON 78 PR D 18 3955	+DIXON, EHRLICH, GALIK, LARSON+ (CORN+HARV)
BARTALUC 79 NC 49 A 207	BARTALUCCI, BASINI, BERTOLUCCI+ (DESY+FRAS)
COSME 79 NP B 152 215	+DUDELZAK, GRELAUD, JEAN-MARIE, JULLIAN+ (IPN)
DELGOURT 79 PREP. LAL-79/21	+BERTRAND, BISELLO, BIZOT, BUON, CORDIER+ (LAL)
ESPOSITO 79 LNC 25 5	+MARINI, PALLOTTA+ (FRAS+UMD+PADO+ROMA)
SPINETTI 79 PREP. LFN-79/65	N. SPINETTI (FRAS)
BACCI 80 PREP. LFN 80/2	+BALDINI, BATTISTONI, CAPON, DE ZORZI+ (FRAS)

The Charmonium System

We group into this system those meson states commonly believed to consist of charmed-quark-charmed-antiquark pairs. Since the discovery of the $J/\psi(3100)$ (AUBERT 74, AUGUSTINI 74) this family has increased to at least 13, of which we tabulate 9 as well established particles. Figure 1 shows the states of charmonium below the $\psi(3685)$, interpreted by the charmonium model, at the time of the 1979 Chicago Lepton-Photon Conference: 1) the $X(2830)$ and $X(3455) 0^{-+}$ candidates were not seen by the Crystal Ball Experiment (PARTRIDGE 79); 2) a new state, $U(2980)$, had been discovered by examining the inclusive photon spectrum at the $\psi(3685)$ mass.

X(2830)

54 X(2830, JPC=) I=

OBSERVED IN THE SEQUENTIAL RADIATIVE DECAY OF THE $J/\psi(3100)$ INTO $X(2830)$ GAMMA, $X(2830)$ INTO 2 GAMMAS BY THE DASP AND DESY-HEIDELBERG GROUPS. NOT SEEN BY THE CRYSTAL BALL (PARTRIDGE 79) WITH MUCH LARGER STATISTICS. OMITTED FROM TABLE.

REFERENCES FOR X(2830)

WIJK 75 STANFORD SYMP. 69	B.H. WIJK (DESY)
BARTEL 76 TBILISI CONF. N56	+DUINKER, OLSSON, HEINTZE,+ (DESY+HEID)
AMALDI 77 LNC 20 409	+BENEVENTANO, DELL, DOOHER+ (ROMA+BNL+ADELPHI)
BRAUNSCH 77 PL 67 B 243	BRAUNSCHWIG,+ (AACH+DESY+HAMB+MPI+TOKY)
YAMADA 77 HAMB. CONF. P. 69	YAMADA (AACH+HAMB+DESY+MUNC+TOKY)
APEL 78 PL 72 B 500	+AUGENSTEIN,+ (KARL+PISA+SERP+MIEN+CERN)
PARTRIDGE 79 SLAC-PUB 2425	PARTRIDGE, PECK,+ (CIT+HARV+PRIN+SLAC+STAN)

U(2980)

26 U(2980, JPC=) I=

OBSERVED IN THE INCLUSIVE GAMMA SPECTRUM GENERATED FROM $\psi(3685)$ DECAY. NEEDS CONFIRMATION. OMITTED FROM TABLE.

26 U(2980) MASS (MEV)

M	1624(2980.0)	(20.0)	PARTRIDGE 79 CNTR	E+E-, GAMMA INCL. 12/79*
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26 U(2980) WIDTH (MEV)

W	1624 (60.0) OR LESS	SCHARRE 79 RVUE	E+E-, GAMMA INCL. 12/79*
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REFERENCES FOR U(2980)

PARTRIDGE 79 SLAC-PUB 2425	PARTRIDGE, PECK,+ (CIT+HARV+PRIN+SLAC+STAN)
SCHARRE 79 SLAC-PUB 2426	D.L. SCHARRE

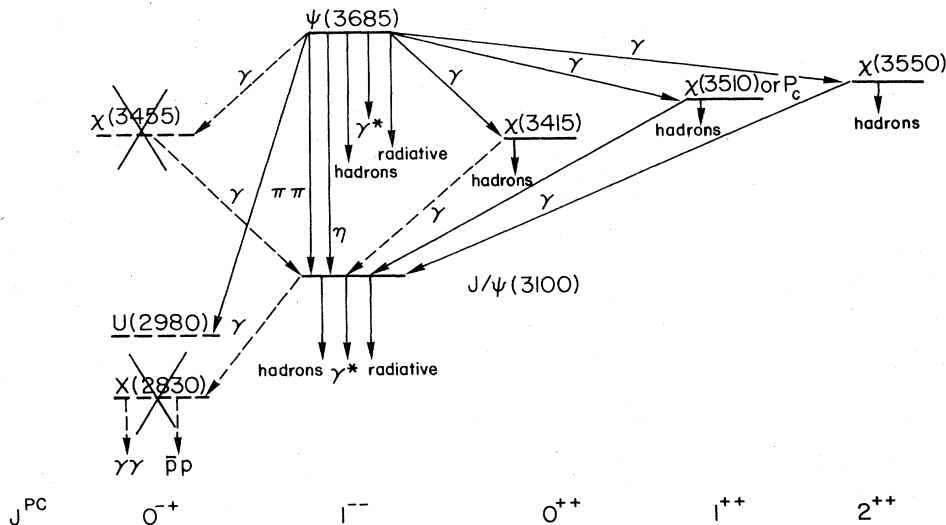


Fig. 1. The current state of knowledge of the charmonium system and transitions, as interpreted by the charmonium model. Uncertain states and transitions are indicated by dashed lines. J^{PC} quantum number assignments are in some cases tentative, but all are at least consistent with experiment; see individual particle listings for discussion. The notation γ^* refers to decay processes involving decays to e^+e^- and $\mu^+\mu^-$. The crosses correspond to the states not seen by PARTRIDGE 79.

Data Card Listings

For notation, see key at front of Listings.

Mesons

J/ψ(3100)

J/ψ(3100)

70 J/PSI(3100,JPG=1--I=0

70 J/PSI(3100) MASS (MEV)

WE USE INDEPENDENT MEASUREMENTS OF THE J/PSI(3100) MASS, THE PSI(3685) MASS AND THE MASS DIFFERENCE TO PERFORM A CONSTRAINED FIT.

Table with columns for mass measurements, including entries for AUBERT, AUGUSTIN, BOYARSKI, CRIEGEEI, PREPOST, BEMORAD, SNYDER, BARATE, and BRANDELIK. Includes average values and error factors.

70 J/PSI(3100) WIDTH (KEV)

Table with columns for width measurements, including entries for BOYARSKI, BALDINI1, ESPOSITO, and BRANDELIK. Includes average values and error factors.

70 J/PSI(3100) PARTIAL DECAY MODES

Table listing various decay modes for J/ψ(3100), such as J/PSI(3100) INTO E+ E-, J/PSI(3100) INTO MU+ MU-, and various hadronic decays. Includes branching ratios and decay masses.

70 J/PSI(3100) PARTIAL WIDTHS (KEV)

Table listing partial widths for J/ψ(3100) into various channels, including E+ E-, MU+ MU-, and hadronic channels. Includes entries for BOYARSKI, BALDINI1, ESPOSITO, and BRANDELIK.

70 J/PSI(3100) BRANCHING RATIOS

FOR THE BRANCHING RATIOS R1 - R4, SEE ALSO THE PARTIAL WIDTHS ABOVE, AND (PARTIAL WIDTHS)*R1 BELOW.

Table listing branching ratios for J/ψ(3100) into various channels, including E+ E-, MU+ MU-, and hadronic channels. Includes entries for BOYARSKI, BALDINI1, ESPOSITO, and BRANDELIK.

Mesons
J/ψ(3100)

For notation, see key at front of Listings.

R20	J/PSI(3100) INTO (RHO PI PI P1)/(2 (PI+ PI-1) P10)	JEAN-MARI 76 SMAG	E+E-	1/76
R21	J/PSI(3100) INTO (PHI PI+ PI-1)/TOTAL	FELDMAN 77 SMAG	E+E-	12/77
R22	J/PSI(3100) INTO (KOS KOL)/TOTAL (UNITS 10**4)	VANNUCCI 77 SMAG	E+E-	1/77
R23	J/PSI(3100) INTO (K+ K-1)/TOTAL (UNITS 10**4)	VANNUCCI 77 SMAG	E+E-	1/77
R23 AVG	2.15 0.78	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R23 STUDENT	2.15 0.84	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R24	J/PSI(3100) INTO (K0 K*(892)0)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R25	J/PSI(3100) INTO (K+ K*(892)-+)/TOTAL	BRAUNSCHW 76 DASP	E+E-	1/77
R25 AVG	0.00338 0.00054	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R25 STUDENT	0.00338 0.00059	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R26	J/PSI(3100) INTO (K0 K*(1430)0)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R27	J/PSI(3100) INTO (K+ K*(1420+-)/TOTAL	BRAUNSCHW 76 DASP	E+E-	1/77
R27 AVG	0.00338 0.00054	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R27 STUDENT	0.00338 0.00059	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R28	J/PSI(3100) INTO (K*(892)0 K*(892)0)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R29	J/PSI(3100) INTO (K*(1430)0 K*(1430)0)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R30	J/PSI(3100) INTO (K*(892)0 K*(1430)0)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R31	J/PSI(3100) INTO (P BAR P)/TOTAL (UNITS 10**3)	BESCH 78 CNTR	E+E-	4/78*
R31 A	331 2.2 0.2	PERUZZI 78 SMAG	E+E-	4/78*
R31 B	133 2.5 0.4	BRANDELIK 79 DASP	E+E-	12/79*
R31 AVG	2.23 0.17	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R31 STUDENT	2.23 0.18	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R32	J/PSI(3100) INTO (P BAR P)/(MU MU-)	CRIEGEE 75 PLUT	E+E-	1/76
R33	J/PSI(3100) INTO (LAMBDA ANTILAMBDA0)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, L X, LBAR L	4/78*
R34	J/PSI(3100) INTO (P P BAR P1)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB	4/78*
R34 AVG	1.05 0.14	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R34 STUDENT	1.05 0.15	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R35	J/PSI(3100) INTO (P P BAR PI+PI-1)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB 1-2PI	4/78*
R36	J/PSI(3100) INTO (P P BAR PI+ PI- P10)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB 2PI	4/78*
R37	J/PSI(3100) INTO (LAMBDA ANTISIGMA)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, LAMBDA X	4/78*
R38	J/PSI(3100) INTO (PI+ A2)/TOTAL	BRAUNSCHW 76 DASP	E+E-	1/77
R39	J/PSI(3100) INTO (OMEGA PI P1)/TOTAL	BURMESTER 77 PLUT	E+E-	12/77
R39 AVG	0.0068 0.0019	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R39 STUDENT	0.0068 0.0021	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R40	J/PSI(3100) INTO (Z+ K-1)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R41	J/PSI(3100) INTO (OMEGA K K BAR)/TOTAL	FELDMAN 77 SMAG	E+E-	12/77
R42	J/PSI(3100) INTO (PHI K K BAR)/TOTAL	FELDMAN 77 SMAG	E+E-	12/77
R43	J/PSI(3100) INTO (PHI ETA)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R44	J/PSI(3100) INTO (PHI ETA PRIME)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R45	J/PSI(3100) INTO (PHI F PRIME)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R46	J/PSI(3100) INTO (P BAR PI-1)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PI-	4/78*
R46 AVG	2.10 0.20	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R46 STUDENT	2.10 0.21	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R47	J/PSI(3100) INTO (P BAR ETA)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB 0-2PI	4/78*
R47 AVG	2.32 0.41	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R47 STUDENT	2.32 0.41	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R48	J/PSI(3100) INTO (P BAR OMEGA)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB 1-2PI	4/78*
R49	J/PSI(3100) INTO (KCS K+- PI-1)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R50	J/PSI(3100) INTO (PHI F)/TOTAL (UNITS 10**4)	VANNUCCI 77 SMAG	E+E-	1/77

R51	J/PSI(3100) INTO (PHI 2(PI+PI-1))/TOTAL	CL=0.90 VANNUCCI 77 SMAG	E+E-	1/77
R52	J/PSI(3100) INTO (OMEGA F)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R52 AVG	0.00232 0.00084	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)		
R52 STUDENT	0.00230 0.00081	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R53	J/PSI(3100) INTO (OMEGA F PRIME)/TOTAL (UNITS 10**4)	VANNUCCI 77 SMAG	E+E-	1/77
R54	J/PSI(3100) INTO (PI+PI-P10 K+K-1)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R55	J/PSI(3100) INTO (RHO A2)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R56	J/PSI(3100) INTO (OMEGA 2PI+ 2PI-1)/TOTAL	VANNUCCI 77 SMAG	E+E-	1/77
R57	J/PSI(3100) INTO (X1- ANTIX1-)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, X1-X	4/78*
R57 C	71 (3-2) (0.8)	PERUZZI 78 SMAG	E+E-, L LBAR	4/78*
R57 C	INCLUDES CHANNEL (X10 ANTIX10)			
R58	J/PSI(3100) INTO (RHO+- PI-+)/(K*(892)-+ K-+)	PIERRE 76 SMAG	E+E-	4/77
R59	J/PSI(3100) INTO (B+- PI-+)/TOTAL	BURMESTER 77 PLUT	E+E-	12/77
R60	J/PSI(3100) INTO (N NBAR)/TOTAL (UNITS 10**2)	BESCH 78 CNTR	E+E-	4/78*
R61	J/PSI(3100) INTO (SIGMA SIGMABAR0)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, L LBAR	4/78*
R62	J/PSI(3100) INTO (P P BAR ETA PRIME)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB 1-2PI	4/78*
R	J FINAL STATE 2(PI+PI-1)P10			
R A	ASSUMING ANGULAR DISTRIBUTION (1.+COS(THETA)**2)			
R	RADIATIVE DECAYS			
R71	J/PSI(3100) INTO (2 GAMMA)/TOTAL (UNITS 10**3) (P4)	CL=0.90 BARTEL 77 CNTR	E+E-	4/77
R72	J/PSI(3100) INTO (PI0 GAMMA)/TOTAL (UNITS 10**3)	BRANDELIK 79 DASP	E+ E-	12/79*
R73	J/PSI(3100) INTO (ETA GAMMA)/TOTAL (UNITS 10**3)	BARTEL 77 CNTR	E+E-, 3 GAMMA	1/77
R73 AVG	0.85 0.11	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.2)		
R73 STUDENT	0.85 0.11	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R74	J/PSI(3100) INTO (ETA PRIME GAMMA)/TOTAL (UNITS 10**3)	BACCI 76 FRAG	E+E-	4/77
R74 AVG	2.54 0.59	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R74 STUDENT	2.54 0.64	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R75	J/PSI(3100) INTO (ETA PRIME GAMMA)/(ETA GAMMA)	PARTRIDGE 79 CNTR	E+ E-, 3 GAM 2PI	12/79*
R76	J/PSI(3100) INTO (X(2830) GAMMA)/TOTAL X TO 2 GAMMA (UNITS 10**3)	BARTEL 77 CNTR	E+E-, 3 GAMMA	12/77
R76 X	(0.32) OR LESS CL=0.90	YAMADA 77 DASP	E+E-, 3 GAMMA	12/77*
R76 AVG	0.22 0.04	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R76 STUDENT	0.22 0.04	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R77	J/PSI(3100) INTO (3 GAMMA)/TOTAL (UNITS 10**3)	BRAUNSCHW 77 DASP	E+E-, 3 GAMMA	1/77
R78	J/PSI(3100) INTO (3 GAMMA)/TOTAL (UNITS 10**3)	PARTRIDGE 79 CNTR	E+E-, 3 GAMMA	12/79*
R78 U	EXISTENCE OF X(2830) IN BARTEL 2 76 DATA IS ONLY 2 STD EFFECT			3/77
R80	J/PSI(3100) INTO (GAMMA + 2 OR MORE NEUTRALS)/TOTAL (UNITS 10**3)	BARTEL 77 CNTR	E+E-	1/77
R81	J/PSI(3100) INTO (F GAMMA)/TOTAL (UNITS 10**3)	ALEXANDER 78 PLUT	0 E+E-	4/78*
R81 T	30 1.2 0.6	BRANDELIK 78 DASP	E+E-, PI+PI-GAMMA	4/78*
R81	RE-STATD BY US TO TAKE ACCOUNT OF SPREAD OF E1,M2,E3 TRANSITIONS.			
R81 AVG	1.54 0.46	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
R81 STUDENT	1.54 0.51	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
R82	J/PSI(3100) INTO (F PRIME GAMMA)/TOTAL (UNITS 10**3)	ALEXANDE 2 78 PLUT	E+E-, K+K- GAMMA	4/78*
R82 S	(0.23) OR LESS CL=0.90	BRANDELIK 79 DASP	E+E-, PI+PI-GAMMA	12/79*
R82 S	ASSUMING ISOTROPIC PRODUCTION AND DECAY OF THE F PRIME AND ISCS PIN.			
R84	J/PSI(3100) INTO (P P BAR GAMMA)/TOTAL (UNITS 10**3)	PERUZZI 78 SMAG	E+E-, P PB SHOWER	4/78*

70 J/PSI(3100) G(I)*G(E+E-)/G(TOTAL) (KEV)

THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH INTO E+E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE INTEGRATED CROSS-SECTION INTO CHANNEL(I) IN THE E+E- ANNIHILATION. WE ONLY LIST DATA NOT HAVING BEEN USED TO DETERMINE THE PARTIAL WIDTH G(I) OR THE BRANCHING RATIO G(I)/TOTAL.

G1	G(E+E-)*G(E+E-)/G(TOTAL)	BALDINI 75 FRAG	E+E-	1/76
G1 S	(.32) (.07)	BEMPORAD 75 FRAB	E+E-	1/76
G1	(.34) (.14)	ESPOSITO 75 FRAM	E+E-	1/76
G1 S	(.36) (.10)	FORD 75 SPEC	E+E-	
G1	(.35) (.02)	BRANDELIK 79 DASP	E+E-	12/79*
G1	0.35 0.02	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
G1 STUDENT	0.350 0.021	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		

Mesons

P_c or $\chi(3510)$, $\chi(3550)$

Data Card Listings

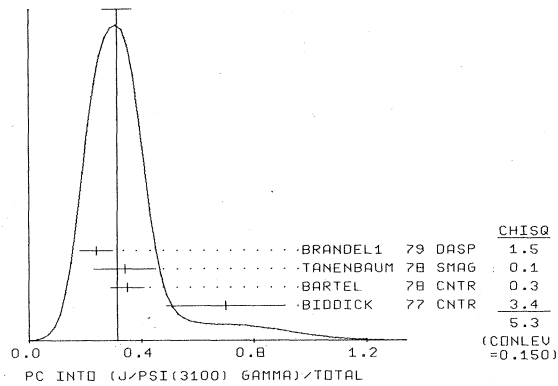
For notation, see key at front of Listings.

55 PC MASS (MEV)
M 40(3500.) (10.) TANENBAUM 75 SMAG HADRONS GAM 12/77
M W 7(3512.0) (7.0) WIIK 75 DASP E+E-, J/PSI 2 GAM 1/77
M (3510.0) (20.0) BARTEL 76 CNTR E+E-, J/PSI 2 GAM 1/77
M 3511.0 7.0 BIDDICK 77 CNTR E+E-, MONOCHR. GAM 3/77
M Z 3505.0 6.0 BARTEL 78 CNTR E+E-, J/PSI 2 GAM 4/78*

55 PC PARTIAL DECAY MODES
P1 PC INTO J/PSI(3100) GAMMA 3097+ 0
P2 PC INTO PI+ PI- 139+ 139
P3 PC INTO K+ K- 493+ 493
P4 PC INTO GAMMA GAMMA 0+ 0
P5 PC INTO 2(PI+ PI-) 139+ 139+ 139+ 139

55 PC BRANCHING RATIOS
R1 PC INTO (J/PSI(3100) GAMMA)/TOTAL
R1 T 0.70 0.21 BIDDICK 77 CNTR PSI(3685) TO GAM PC 12/77
R1 T 0.35 0.06 BARTEL 78 CNTR PSI(3685) TO GAM PC 4/78*

WEIGHTED AVERAGE = 0.315 ± 0.052
ERROR SCALED BY 1.3



CHISO
BRANDEL1 79 DASP 1.5
TANENBAUM 78 SMAG 0.1
BARTEL 78 CNTR 0.3
BIDDICK 77 CNTR 3.4
3.5
(CONLEV = 0.150)
R2 PC INTO (PI+PI- AND K+K-)/TOTAL
R2 T (0.0321) OR LESS FELDMAN 77 SMAG PSI(3685) TO GAM PC 12/77
R2 T (0.0046) OR LESS CL=0.90 BRANDEL2 79 DASP PSI(3685) TO GAM CHI 12/79*

REFERENCES FOR PC
DASP 75 PL 578 407 BRAUNSCHEWIG, KONIGS, + (AACH+DESY+MPI+TKY)
G. J. FELDMAN
HEINTZE 75 STANFORD SYMP. 39 J. HEINTZE (HEIDELBERG)
SIMPSON 75 PRL 35 699 +BERON, FORD, HILGER, HOFSTADTER, + (STAN+PENN)
TANENBAU 75 PRL 35 1323 TANENBAUM, WHITAKER, ABRAMS, + (LBL+SLAC)
WIIK 75 STANFORD SYMP. 69 B. H. WIIK (DESY)
BARTEL 76 TBILISI CONF. N75 +DUINKER, OLSSON, HEINTZE, + (DESY+HEID)
BARTEL 77 DESY 77/70 +DITTMANN, FRITSCHER, HEINTZE, + (DESY+HEID)
BIDDICK 77 PRL 38 1324 +BURNETT* (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
FELDMAN 77 PL 33 C 285 +PERL (LBL+SLAC)
YAMADA 77 HAMB. CONF. P. 69 YAMADA (DESY+TKY)
BARTEL 78 PL 79 B 492 +DITTMANN, DUINKER, OLSSON, ONEILL, + (DESY+HEID)
TANENBAU 78 PR D 17 1731 TANENBAUM, ALAM, BOVARSKI, + (SLAC+LBL)
BRANDEL1 79 ZPHY C 1 233 BRANDEL1, CORDS, + (AACH+DESY+HAMB+MPI+TKY)
BRANDEL2 79 NR B 160 426 BRANDEL1, CORDS, + (AACH+DESY+HAMB+MPI+TKY)
KIRK 79 PRL 42 619 +GODDARD, ALVERSON, + (FNAL+HARV+ILL+OXF+TUFT)
LEMOIGNE 79 D PH PE 79-16 +ABDLIN, BARATE, + (SACL+LOIC+SHMP+IND)
PARTRIDG 79 SLAC-PUB 2425 PARTRIDG, PECK, + (CIT+HARV+PRIN+SLAC+STAN)

CHI(3550) 57 CHI(3550, JPG= +) I=0
OBSERVED IN RADIATIVE DECAY OF PSI(3685) INTO
CHI(3550) GAMMA. THEREFORE C=+. THE OBSERVED DECAY INTO 4PI
AND 6PI IMPLY G=+, THUS I=0.
J=0 IS EXCLUDED BY THE ANGULAR DISTRIBUTION IN THE HADRONIC
DECAYS. JP ABNORMAL EXCLUDED BY PI+ PI- AND K+ K- DECAYS.
JP=2+ PREFERRED (FELDMAN 77).

57 CHI(3550) MASS (MEV)
M (3550.0) (10.0) TRILLING 76 SMAG E+E-, HADRONS GAM 1/77
M (3545.0) (10.0) WHITAKER 76 SMAG E+E-, J/PSI 2 GAM 1/77
M (3561.0) (7.0) BIDDICK 77 CNTR E+E-, MONOCHR. GAM 3/77
M Z 3551.0 7.0 BARTEL 78 CNTR E+E-, J/PSI 2 GAM 4/78*

57 CHI(3550) PARTIAL DECAY MODES
P1 CHI(3550) INTO PI+ PI- 139+ 139
P2 CHI(3550) INTO K+ K- 493+ 493
P3 CHI(3550) INTO 2(PI+ PI-) 139+ 139+ 139+ 139
P4 CHI(3550) INTO 3(PI+ PI-) 139+ 139+ 493+ 493
P5 CHI(3550) INTO PI+ PI- K+ K- 3097+ 0
P6 CHI(3550) INTO J/PSI(3100) GAMMA 0+ 0
P7 CHI(3550) INTO 2 GAMMA 0+ 0
P8 CHI(3550) INTO PI+ PI- P PBAR 139+ 139+ 938+ 938
P9 CHI(3550) INTO RHOO PI+ PI- 776+ 139+ 139
P10 CHI(3550) INTO K*(892) K+/- PI- +/- 892+ 493+ 139
P11 CHI(3550) INTO P PBAR 938+ 938

57 CHI(3550) BRANCHING RATIOS
R1 CHI(3550) INTO (2 GAMMA)/TOTAL
R1 T (0.0006) OR LESS CL=0.90 YAMADA 77 DASP E+ E-, 3 GAMMA 12/77
R2 CHI(3550) INTO 2(PI+ PI-)/TOTAL
R2 T .024 .006 TANENBAUM 78 SMAG PSI(3685) TO GAM CHI 12/78*
R3 CHI(3550) INTO (PI+ PI- K+ K-)/TOTAL
R3 T .021 .006 TANENBAUM 78 SMAG PSI(3685) TO GAM CHI 12/78*
R4 CHI(3550) INTO 3(PI+ PI-)/TOTAL
R4 T .013 .008 TANENBAUM 78 SMAG PSI(3685) TO GAM CHI 12/78*
R5 CHI(3550) INTO (PI+ PI- AND K+ K-)/TOTAL
R5 T .0027 .0011 TANENBAUM 78 SMAG PSI(3685) TO GAM CHI 12/78*
R6 CHI(3550) INTO (PI+ PI- P PBAR)/TOTAL
R6 T .0037 .0014 TANENBAUM 78 SMAG PSI(3685) TO GAM CHI 12/78*
R7 CHI(3550) INTO (J/PSI(3100) GAMMA)/TOTAL
R7 T 0.31 0.14 BIDDICK 77 CNTR PSI(3685) TO GAM CHI 12/77
R7 T 0.14 0.03 BARTEL 78 CNTR PSI(3685) TO GAM CHI 4/78*

Data Card Listings

For notation, see key at front of Listings.

Mesons

$\chi(3550)$, $\chi(3590)$, $\psi(3685)$

REFERENCES FOR $\chi(3590)$

Table listing references for $\chi(3590)$ with columns for author, journal, volume, page, and notes.

$\chi(3590)$

59 CHI(3590, JPC=) I= OBSERVED IN THE CASCADE RADIATIVE DECAY OF $\psi(3685)$ INTO $\chi(3590)$ GAMMA, $\chi(3590)$ INTO $J/\psi(3100)$ GAMMA (BARTEL 79). THEREFORE, C=.

59 CHI(3590) MASS (MEV)

Table with columns M, S, J, and values for mass measurements of $\chi(3590)$.

REFERENCES FOR $\chi(3590)$

Table listing references for $\chi(3590)$ with columns for author, journal, volume, page, and notes.

$\psi(3685)$

71 $\psi(3685, JPC=1--)$ I=0

71 $\psi(3685)$ MASS (MEV)

WE USE INDEPENDENT MEASUREMENTS OF THE $J/\psi(3100)$ MASS, THE $\psi(3685)$ MASS, AND THE MASS DIFFERENCE TO PERFORM A CONSTRAINED FIT.

Table with columns M, S, J, and values for mass measurements of $\psi(3685)$.

71 $\psi(3685) - J/\psi(3100)$ MASS DIFFERENCE (MEV)

Table with columns DM, OM, and values for mass difference measurements.

71 $\psi(3685)$ WIDTH (KEV)

Table with columns W, F, and values for width measurements.

71 $\psi(3685)$ PARTIAL DECAY MODES

Table listing decay modes and branching fractions for $\psi(3685)$.

HADRONIC DECAYS

Table listing hadronic decays with columns P, P1, P2, P3, P4 and associated values.

RADIATIVE DECAYS

Table listing radiative decays with columns P, P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11 and associated values.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i , as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i^2 + \delta P_j^2)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta P_i \delta P_j) / (\delta P_i \delta P_j)$.

Matrix of correlation coefficients for branching fractions.

71 $\psi(3685)$ PARTIAL WIDTHS (KEV)

Table listing partial widths for various decay channels.

71 $\psi(3685)$ BRANCHING RATIOS

Table listing branching ratios for various decay channels.

Data Card Listings

Mesons

For notation, see key at front of Listings. $\psi(3770)$, $\psi(4030)$, $\psi(4160)$, $\psi(4415)$, $T(9460)$

Table with 2 columns: P1, P2 and 2 columns: DECAY MASSES. Row 1: PSI(3770) INTO E+ E- .5+ .5. Row 2: PSI(3770) INTO D DBAR 1868+1868.

Table with 2 columns: R1, R2 and 2 columns: BRANCHING RATIOS. Row 1: PSI(3770) INTO (D DBAR)/TOTAL DOMINANT PERUZZI 77 SMAG (P2) E+E-, D DBAR 12/77. Row 2: PSI(3770) INTO (E+ E-)/TOTAL (UNITS 10**-5) RAPIDIS 77 SMAG (P1) 0 E+E- 12/77.

REFERENCES FOR PSI(3770) table listing various experiments and their results for PSI(3770) decays.

$\psi(4030)$

72 PSI(4030, JPC=1-) I= SEEN CLEARLY SEPARATED FROM THE PSI(4160) BY DASP AND CONFIRMED WITH LESS STATISTICS BY PLUTO SEEN ALSO BY MARK I, DELCO AND THE CRYSTAL BALL (KIRKBY 79).

Table with 2 columns: M, M and 2 columns: PSI(4030) MASS (MEV). Row 1: 4028.0 2.5 GOLDHABER 77 SMAG E+E- 12/77. Row 2: 4040.0 10.0 BRANDELIK 78 DASP E+E- 4/78*

Table with 2 columns: W, W and 2 columns: PSI(4030) WIDTH (MEV). Row 1: 52.0 10.0 BRANDELIK 78 DASP E+E- 4/78*

Table with 2 columns: P1, P2, P3, P4, P5, P6 and 2 columns: PSI(4030) PARTIAL DECAY MODES. Row 1: PSI(4030) INTO D DBAR 1868+1868. Row 2: PSI(4030) INTO D* DBAR AND D*BAR D 2006+1863. Row 3: PSI(4030) INTO D* DBAR 2006+2006. Row 4: PSI(4030) INTO J/PSI(3100) HADRONS. Row 5: PSI(4030) INTO E+ E- .5+ .5. Row 6: PSI(4030) INTO MU+ MU- 105+ 105.

Table with 2 columns: W1, W1 and 2 columns: PSI(4030) PARTIAL WIDTHS (KEV). Row 1: 0.75 0.15 BRANDELIK 78 DASP E+ E- 12/78*

Table with 2 columns: R1, R1, R2, R2, R3, R3, R4, R4 and 2 columns: PSI(4030) BRANCHING RATIOS. Row 1: PSI(4030) INTO (D DBAR)/(D* DBAR+D*BAR D) GOLDHABER 77 SMAG (P1)/(P2) 0 E+ E- 12/77. Row 2: PSI(4030) INTO J/PSI(3100) HADRONS BURMESTER 77 PLUT (P4) E+E- 4/77. Row 3: PSI(4030) INTO (D* DBAR)/(D* DBAR+D*BAR D) GOLDHABER 77 SMAG (P3)/(P2) 32.0 12.0 0 E+ E- 12/77. Row 4: PSI(4030) INTO (E+ E-)/TOTAL (UNITS 10**-5) FELDMAN 77 SMAG (P5) E+ E- 12/77.

REFERENCES FOR PSI(4030) table listing various experiments and their results for PSI(4030) decays.

$\psi(4160)$

25 PSI(4160, JPC=1-) I= SEEN CLEARLY SEPARATED FROM THE PSI(4030) BY DASP AND CONFIRMED WITH LESS STATISTICS BY PLUTO MARK I, DELCO AND THE CRYSTAL BALL SEE A PROMINENT SHOULDER BUT NO SEPARATION (KIRKBY 79).

Table with 2 columns: M, M and 2 columns: PSI(4160) MASS (MEV). Row 1: 4159.0 20.0 BRANDELIK 78 DASP E+E- 4/78*

Table with 2 columns: W, W and 2 columns: PSI(4160) WIDTH (MEV). Row 1: 78.0 20.0 BRANDELIK 78 DASP E+E- 4/78*

Table with 2 columns: P1, P1 and 2 columns: PSI(4160) PARTIAL DECAY MODES. Row 1: PSI(4160) INTO E+ E- .5+ .5.

Table with 2 columns: W1, W1 and 2 columns: PSI(4160) PARTIAL WIDTHS (KEV). Row 1: PSI(4160) INTO E+ E- 12/78*. Row 2: 0.77 0.23 BRANDELIK 78 DASP E+ E- 12/78*.

REFERENCES FOR PSI(4160) table listing various experiments and their results for PSI(4160) decays.

$\psi(4415)$

73 PSI(4415, JPC=1-) I=

Table with 2 columns: M, M, M, M, M, M and 2 columns: PSI(4415) MASS (MEV). Row 1: 4414. 7. SIEGRIST 76 SMAG E+E- 2/76. Row 2: (4400.) APPROX. KNIES 77 PLUT 0 E+E-, MU+ MU- 12/77. Row 3: 4417.0 10.0 BRANDELIK 78 DASP E+E- 4/78*.

Table with 2 columns: W, W, W, W and 2 columns: PSI(4415) WIDTH (MEV). Row 1: 33. 10. SIEGRIST 76 SMAG E+E- 2/76. Row 2: 46.0 15.0 BRANDELIK 78 DASP E+E- 4/78*.

Table with 2 columns: P1, P1 and 2 columns: PSI(4415) PARTIAL DECAY MODES. Row 1: PSI(4415) INTO E+ E- .5+ .5.

Table with 2 columns: W1, W1 and 2 columns: PSI(4415) PARTIAL WIDTHS (KEV). Row 1: 0.49 0.13 BRANDELIK 78 DASP E+ E- 12/78*

Table with 2 columns: R1, R1, R2, R2 and 2 columns: PSI(4415) BRANCHING RATIOS. Row 1: PSI(4415) INTO (E+ E-)/TOTAL (UNITS 10**-5) SIEGRIST 76 SMAG E+E- 2/76. Row 2: PSI(4415) INTO HADRONS/TOTAL DOMINANT SIEGRIST 76 SMAG E+E- 1/77.

REFERENCES FOR PSI(4415) table listing various experiments and their results for PSI(4415) decays.

T(9460)

49 UPSILON(9460, JPC=1-) I=

Table with 2 columns: M, M, M, M, M, M and 2 columns: UPSILON(9460) MASS (MEV). Row 1: I (9410.) (13.) INNES 77 SPEC 0 400 P+A, MU+MU- 12/77. Row 2: CB (9460.0) (10.0) BERGER 78 PLUT E+E- 4/78*.

Table with 2 columns: W, W, W, W and 2 columns: UPSILON(9460) WIDTH (MEV). Row 1: (18.0) OR LESS BERGER 78 PLUT E+E- 4/78*.

Mesons

Data Card Listings

T(9460), T(10020), T(10400), K±, K0, K*(892) For notation, see key at front of Listings.

49 UPSILON(9460) PARTIAL DECAY MODES
P1 UPSILON(9460) INTO MU+ MU- DECAY MASSES
P2 UPSILON(9460) INTO E+ E- .5+ .5

49 UPSILON(9460) PARTIAL WIDTHS (KEV)
W1 UPSILCN(9460) INTO E+ E- (G2)
W1 CBD (1.3) (0.4) BERGER 78 PLUT E+E- 4/78*

49 UPSILON(9460) BRANCHING RATIOS
R1 UPSILCN(9460) INTO(MU+ MU-)/TOTAL (P1)
R1 0.022 0.020 BERGER 79 PLUT E+E- 12/79*

T(10020) 52 UPSILON(10020, JPC=1-) I=
52 UPSILON(10020) MASS (GEV)
M I 10.060 (0.030) INNES 77 SPEC 400 P+A, MU+MU- 12/77

52 UPSILON(10020) PARTIAL WIDTHS (MEV)
W A (12.0) OR LESS BIENLEIN 78 CNTR E+E- 4/78*

52 UPSILON(10020)-UPSILON(9460) MASS DIFFERENCE (MEV)
DM C 560.0 10.0 BIENLEIN 78 CNTR E+E- 4/78*

52 UPSILON(10020) PARTIAL DECAY MODES
P1 UPSILON(10020) INTO MU+ MU- DECAY MASSES
P2 UPSILCN(10020) INTO E+ E- .5+ .5

52 UPSILON(10020) BRANCHING RATIOS
R1 UPSILCN(10020) INTO(MU+ MU-)/TOTAL (P1)
R1 SEEN HERB 77 SPEC 400 P A, MU+ MU- 12/78*

R2 UPSILON(10020) INTO (E+ E-)/TOTAL (P2)
R2 SEEN COBB 77 SPEC P P, E+ E- X 12/78*

T(10400) 48 UPSILON(10400, JPC=1-) I=
48 UPSILON(10400)-UPSILON(9460) MASS DIFFERENCE (MEV)
DM A 550.0 30.0 UENO 79 SPEC 400 P PT, MU+MU- 12/79*

S=±1, C=0 MESON STATES

K± 10 CHARGED K(494, JP=0-) I=1/2
SEE STABLE PARTICLE DATA CARD LISTINGS

K0 11 NEUTRAL K(498, JP=0-) I=1/2
SEE STABLE PARTICLE DATA CARD LISTINGS

K*(892) 18 K*(892, JP=1-) I=1/2
18 K*(892) MASS (MEV)
M CHARGED ONLY. THIS IS WHAT APPEARS ON MESON TABLE

M NEUTRAL ONLY.
M S 70 (897.0) (10.0) COLLEY 62 HBC 0 2.0 PI-P 12/75

Data Card Listings

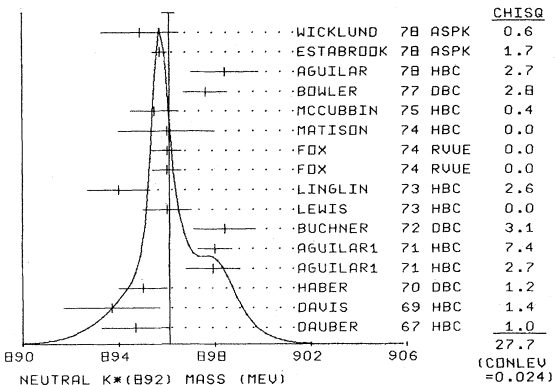
For notation, see key at front of Listings.

Mesons

K*(892)

M AS 490 (892.0)	(4.0)	GEORGE 67 HBC	0 5.0 K+ P	12/75
M SD 150 (856.0)	(4.5)	FIENEC1 68 HBC	0 1.3 K-P (K-PI+)	12/75
M SD 120 (903.0)	(5.0)	FIENEC2 68 HBC	0 2.7 K-P (K-PI+)	12/75
M S 200 (895.0)	(5.0)	SCHWEINGR 68 HBC	0 4.1 K-P(K-PI+)	12/75
M 10K 893.7	2.0	SCHWEINGR 68 HBC	0 5.5 K-P(K-PI+)	12/75
M WAD2200 (890.0)	(1.3)	KANG 68 HBC	0 4.6 K-P(K-PI+)	12/75
M W 4300 895.0	1.0	DAVIS 69 HBC	0 12. K+P(K+PI+)	12/75
M D2924 897.9	1.1	DE BAERE 69 HBC	0 5.0 K+P(K+PI+)	12/75
M D5362 898.0	0.7	HABER 70 DBC	0 3. K-N (K-PI+)	12/75
M D1760 898.4	1.3	AGUILAR1 71 HBC	0 3.9+4.6 K- P	12/75
M 3186 896.0	1.0	BUCHNER 72 DBC	0 4.6 K+ N,K+ PI-	12/72
M C 894.0	1.3	LEWIS 73 HBC	0 2.1-2.7 K+P	2/74
M 10K 896.0	0.6	LINGLIN 73 HBC	0 2-13 K+P,K+PI-	12/75
M C 896.0	2.0	FOX 74 RVUE	0 2 K+P,K+PI+P	12/75
M 3600 895.5	1.0	FOX 74 RVUE	0 2 K+N,K+PI-P	12/75
M I 22K (897.1)	(0.7)	MATISON 74 HBC	0 12 K+P,K+PI-	12/75
M 897.6	0.9	MCCUBBIN 75 HBC	0 3.6 K-P,K-PI+P	12/75
M 1180 898.4	1.4	PALER 75 HBC	0 14.3 K-P,K*0 X0	12/75
M P 895.7	0.3	BOWLER 77 DBC	0 5.4 K+0,K+PI-P	12/77
M 894.9	1.6	AGUILAR 78 HBC	0 .76 PB P,K KS PI	12/78*
M		ESTABROOK 78 ASPK	0 13 K+P,K+PI+-	12/77*
M		WICKLUND 78 ASPK	0 3,4,6 PI+PN	4/78*
M				
M AVG 896.10	0.26	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)		
M STUDENT 896.02	0.24	AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)		

WEIGHTED AVERAGE = 896.10 ± 0.26
ERROR SCALED BY 1.4



M A INCLUDED IN LINGLIN 73 WORLD K+P DST
M C FROM POLE EXTRAPOLATION.
M D MASS ERRORS ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE.
M I INCLUSIVE REACTION. COMPLICATED BACKGROUND AND PHASE-SPACE EFFECTS
M P FROM PHASE SHIFT ANALYSIS OF 15000 EVENTS.
M S DATA WITH MASS ERROR OF 3 MEV OR MORE NOT AVERAGED
M W NUMBER OF EVENTS IN PEAK REEVALUATED BY US
M X SYSTEMATIC ERROR ADDED

Note on K*(892) Masses and Mass Differences

Unrealistically small errors are reported by some experiments. We use simple "realistic" tests for the minimum errors on the determination of mass and width from a sample of N events:

$$\delta_{\min}(m) = \frac{\Gamma}{\sqrt{N}}, \quad \delta_{\min}(\Gamma) = 4 \frac{\Gamma}{\sqrt{N}}$$

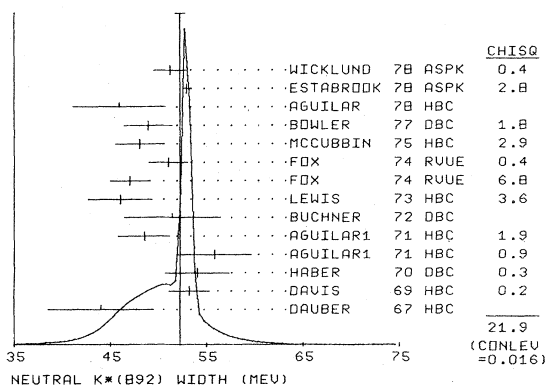
(For detailed discussion see the April 1971 edition of this note.) We consistently increase unrealistic errors before averaging.

D W 283 6.3	4.1	BARASH 67 HBC	0 PBAR P	12/75
D SD1400 (6.5)	(5.0)	FIENEC1 68 HBC	1.3 K- P	12/75
D SD1600 (9.5)	(5.0)	FIENEC2 68 HBC	2.7 K- P	12/75
D 7338 5.7	1.7	AGUILAR1 71 HBC	-0 3.9+4.6 K- P	11/71
D 2980 7.7	1.7	AGUILAR 78 HBC	+- .76 PB P,K KS PI	12/78*
D				
D AVG 6.7	1.2	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
D STUDENT 6.7	1.3	AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT		
D				
D D MASS ERRORS ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE.				
D S DATA WITH MASS ERROR OF 3 MEV OR MORE NOT AVERAGED				
D W NUMBER OF EVENTS IN PEAK REEVALUATED BY US				

W CHARGED ONLY. THIS IS WHAT APPEARS ON MESON TABLE				
W S 100 (46.0)	(8.0)	CHADWICK 63 HBC	+ 1.5 K+P(K PI)	12/75
W W D1700 46.0	5.0	WOJCIK 64 HBC	- 1.7 K-P(KO PI-)	12/75
W SD 200 (51.0)	(15.0)	ADELMAN 65 HBC	- 1.5 K-P	12/75
W SD 300 (47.0)	(11.0)	FERRER-LUZ 65 HBC	+ 3.0 K+P	12/75
W SD 300 (50.0)	(12.0)	GELSEMA 65 HBC	- 1.5 K-P(KO PI-)	12/75
W SD 190 (50.1)	(15.0)	BOMSE 67 HBC	+ 2.3 K+P(KO PI+)	12/75
W D 620 56.0	11.0	DE BAERE 67 HBC	+ 3.5 K+P(KO PI+)	12/75
W SD 260 (53.1)	(13.0)	DE BAERE 67 HBC	+ 3.5 K+P (K+ P IO)	12/75
W SD 70 (68.1)	(33.0)	SALLSTROM 67 HBC	+ 3. K+ P (KO PI+)	12/75
W SD 50 (47.1)	(27.0)	SALLSTROM 67 HBC	+ 3. K+ P (K+ P IO)	12/75
W SD 210 (44.1)	(12.0)	BARLOW 67 HBC	+ 1.2 PBAR	12/75
W D 720 42.0	9.0	BARLOW 67 HBC	+ 1.2 PBAR(KO PI)	12/75
W D 600 53.0	9.0	BARLOW 67 HBC	+ 1.2 PBAR(K PI)	12/75
W SD 430 (58.1)	(12.0)	DE WIT 68 DBC	- 3. K- D	12/75
W D 540 44.0	8.0	DE WIT 68 DBC	- 3. K- D	12/75
W S (58.1)	(16.0)	FIENEC1 68 HBC	- 1.3 K-P (K-PI)	12/75
W S (44.1)	(13.0)	FIENEC1 68 HBC	- 1.3 K-P (KOPI-)	12/75
W SD 115 (41.0)	(16.0)	SCHWEINGR 68 HBC	- 4.1 K-P(KO PI-)	12/75
W SD 341 (47.0)	(10.0)	SCHWEINGR 68 HBC	- 5.5 K-P(KO PI-)	12/75
W S (57.0)	(13.0)	FIENEC2 68 HBC	- 2.7 K- P(K-PI)	12/75
W S (48.0)	(9.0)	FIENEC2 68 HBC	- 2.7 K- P(KOPI-)	12/75
W SD 175 (52.0)	(16.0)	KANG 68 HBC	- 4.6 K- P	12/75
W D2886 53.0	4.0	FRIEDMAN 69 HBC	- 2.1 K-P(KO PI-)	12/75
W D 728 49.0	7.3	FRIEDMAN 69 HBC	- 2.45K-P(KO PI-)	12/75
W D229 46.0	3.2	FRIEDMAN 69 HBC	- 2.6 K-P(KO PI-)	12/75
W D1027 49.0	6.1	FRIEDMAN 69 HBC	- 2.7 K-P(KO PI-)	12/75
W SD 127 (50.1)	(18.0)	LIND 69 HBC	+ 9. K+ P	12/75
W D4404 56.3	3.3	AGUILAR1 71 HBC	+ 3.9+4.6 K- P	12/75
W D 765 46.3	2.0	CLARK 73 HBC	- 3.13K-P PI- KO	12/75
W D1150 48.2	5.7	CLARK 73 HBC	- 3.3 K-P PI- KO	12/75
W I 9000 (52.1)	(2.2)	PALER 75 HBC	- 14.3 K-P,K* X+	12/75
W 1800 45.8	3.6	AGUILAR 78 HBC	+- .76 PB P,K KS PI	12/78*
W 1225 43.0	8.4	BALAND 78 HBC	+- 12 PB P, INCLUSIV	4/78*
W D6706 52.0	2.5	COOPER 78 HBC	+- 76 PB P, INCLUSIV	4/78*
W 50.9	1.0	MARTIN 78 SPEC	+- 10 K+P,K S PI P	12/78*
W				
W AVG 50.34	0.77	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
W STUDENT 50.38	0.87	AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT		

W NEUTRAL ONLY.				
W SD 70 (60.0)	(29.0)	COLLEY 62 HBC	0 2.0 PI-P	12/75
W S 310 (53.1)	(13.0)	BARLOW 67 HBC	0 1.2 PBAR P	12/75
W SD 120 (34.1)	(12.5)	BARLOW 67 HBC	0 1.2 PBAR P	12/75
W D1040 46.0	5.5	DAUBER 67 HBC	0 2.0 K- P	12/75
W S (52.1)	(12.0)	FIENEC1 68 HBC	0 1.3 K-P (K-PI+)	12/75
W S (50.0)	(8.0)	FIENEC2 68 HBC	0 1.2 K-P (K-PI+)	12/75
W SD 200 (48.0)	(16.0)	KANG 68 HBC	0 4.6 K-P(K-PI+)	12/75
W SD 120 (51.0)	(19.0)	SCHWEINGR 68 HBC	0 5.5 K-P(K-PI+)	12/75
W SD 150 (53.0)	(17.5)	SCHWEINGR 68 HBC	0 4.1 K-P(K-PI+)	12/75
W D 10K 53.2	2.1	DAVIS 69 HBC	0 12. K+P(K+PI-)	12/75
M WAD2200 (58.0)	(5.0)	DE BAERE 69 HBC	0 5.0 K+P(K+PI-)	12/75
M W D4300 54.0	3.3	HABER 70 DBC	0 3. K-N (K-PI+)	12/75
M 2934 55.8	4.2	AGUILAR1 71 HBC	0 3.9+4.6 K- P	11/71
M D5362 48.5	2.7	AGUILAR1 71 HBC	0 3.9+4.6 K- P	12/75
M D1700 51.4	5.0	BUCHNER 72 DBC	0 4.6 K+ N,K+ PI-P	12/72
M D3186 46.0	3.3	LEWIS 73 HBC	0 2.1-2.7 K+P	12/75
M C (46.5)	(1.5)	LINGLIN 73 HBC	0 2-13 K+P,K+PI-	1/74
M 10K 47.0	2.0	FOX 74 RVUE	0 2 K-P,K-PI+P	12/75
M C (47.1)	(3.1)	FOX 74 RVUE	0 2 K+N,K+PI-P	12/75
M 3600 48.0	3.0	MATISON 74 HBC	0 12 K+P,K+PI-	12/75
M I 22K (50.6)	(2.5)	MCCUBBIN 75 HBC	0 3.6 K-P,K-PI+P	12/75
M 48.9 2.5		PALER 75 HBC	0 14.3 K-P,K*0 X0	12/75
M 1180 45.9	4.8	BOWLER 77 DBC	0 5.4 K+0,K+PI-P	12/77
M P 52.9 0.4		AGUILAR 78 HBC	0 .76 PB P,K KS PI	12/78*
M 51.2 1.7		ESTABROOK 78 ASPK	0 13 K+P,K+PI+-	12/77*
M		WICKLUND 78 ASPK	0 3,4,6 PI+PN	4/78*
M				
M AVG 52.23	0.52	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)		
M STUDENT 52.26	0.50	AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)		

WEIGHTED AVERAGE = 52.23 ± 0.52
ERROR SCALED BY 1.5



W A INCLUDED IN LINGLIN 73 WORLD K+P DST
W C FROM POLE EXTRAPOLATION.
W D WIDTH ERRORS ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE.
W I INCLUSIVE REACTION. COMPLICATED BACKGROUND AND PHASE-SPACE EFFECTS
W P FROM PHASE SHIFT ANALYSIS OF 15000 EVENTS.
W S DATA WITH MASS ERROR OF 3 MEV OR MORE NOT AVERAGED
W W NUMBER OF EVENTS IN PEAK REEVALUATED BY US

Mesons
K*(892), Q

Data Card Listings

For notation, see key at front of Listings.

18 K*(892) PARTIAL DECAY MODES		DECAY MASSES	
P1	K*(892) INTO K PI	493+	139
P2	K*(892) INTO K PI P1	493+	139+ 139
P3	K*(892) INTO K GAMMA	493+	0

18 K*(892) BRANCHING RATIOS		(P2)/(P1)	
R1	K*(892) INTO (K PI P1)/(K PI)	WJCICKI 64 HBC	- 1.7 K-P
R1	0 (0.002) OR LESS	JONGEJANS 78 HBC	4 K-P, P KO 2PI
R1	0 (0.0007) OR LESS	CL=0.95	4/78*
R2	K*(892) INTO (K GAMMA)/TOTAL	(UNITS 10** -3)	(P3)
R2	(1.6) OR LESS	CL=.95	BEMPORAD 72 CNTR + 10.-16. K+A, COUL
R2	1.5	0.7	CARITHERS 75 CNTR 0 8-16K0BAR A, COUL
			12/75

REFERENCES FOR K*(892)	
ALSTON 61 PRL 6 300	ALSTON, ALVAREZ, EBERHARD, GOOD, GRAZIANO+ (LRL)
ALEXANDE 62 PR 8 447	ALEXANDER, KALBFLEISCH, MILLER, G SMITH (LRL)
COLLEY 62 CERN CONF 315	D COLLEY, N GELFAND + (COLUMBIA+RUTGERS)
CHADWICK 63 PL 6 3C9	CHADWICK, CRENNELL, DAVIES, BETTINI+(OXF+PADO)
GOLDHABE 63 ATHENS CONF 92	SULAMITH GOLDHABER (LRL)
WJCICKI 64 PR 135 B 484	STANLEY G WJCICKI (LRL)
ADELMAN 65 ATHENS 527	STUART LEE ADELMAN (CAVENDISH)
FERRLO-LU 65 NC 36 1101	FERRLO-LUZZI, GEORGE, HENRI, JONGEJANS (CERN)
FERRLO-LU 65 NC 39 417	FERRLO-LUZZI, GEORGE, GOLDSCHMIDT-CLEMER (CERN)
GELSEMA 65 THESIS	E.S. GELSEMA (SEE ALSO PL 10 341) (AMSTERDAM)
WANGLER 65 PR 137 B 414	WANGLER, ERWIN, WALKER (MISCONSIN)
BARASH 67 PR 156 1399	BARASH, KIRSCH, MILLER, TAN (COLUMBIA)
BARLOW 67 NC 50 A 701	+MONTANET, D-ANDLAU+ (CERN+CDEF+IRAD+LIVP)
BOMSE 67 PR 158 1298	+BORENSTEIN+COLE+GILLESPIE+ (JOHN HOPKINS)
CONFORTO 67 NP 83 469	+MARECHAL, MONTANET+CERN+CDEF+IPN+LIVERPOOL
DAUBER 67 PR 153 1403	+SCHLEIN, SLATER, TICHO (UCLA)
DE BAERE 67 NC 51 A 401	+GOLDSCHMIDT-CLEMERONT, HENRI+ (BRUX+CERN)
FRENCH 67 NC 42A 442	+KINSON+MC DONALD+RIDDIFORD+ (CERN+BIRM)
GEORGE 67 NC 49A 9	+GOLDSCHMIDT-CLEMERONT+HENRI+ (CERN+BRUX)
SALLSTRO 67 NC 49A 348	SALLSTROM+OTTER+EKSPOG (STOCKHOLM)
DE WIT 68 THESIS	S. DE WIT (AMSTERDAM)
FICENECL 68 PR 169 1034	+HULLSIZER+SWANSON+TROWER (ILL)
FICENECL 68 PR 175 1725	FICENECL, GARDON, TROWER (ILLINOIS)
KANG 68 PR 176 1587	Y.W. KANG (IOWA)
SCHWEING 68 PR 166 1317	SCHWEINGRUBER, DERRICK, FIELDS+ (ANL+NRES)
CRENNELL 69 PRL 22 487	+KARSHON, LAI, ONEALL, SCARR (BNL)
DAVIS 69 PRL 23 1671	+DERENZO, FLATTE, ALSTON, LYNCH, SOLMITZ (LRL)
DE BAERE 69 NC 61 A 397	+GOLDSCHMIDT-CLEMERONT, HENRI,+ (BELG+CERN)
FRIEDMAN 69 UCRL-18860	J. FRIEDMAN, PH.D. THEISIS (LRL)
JUHALA 69 PR 184 1461	+LEACOCK, RHODE, KOPELMAN, LIBBY,+ (ISU+CGLD)
LIND 69 NP B 14 1	+ALEXANDER, FIRESTONE, FU, GOLDHABER (LRL) JP
ATHERTON 70 NP B 16 416	+FRANEK, FRENCH, FRISK, BEDNAR+ (CERN+PRAG)
HABER 70 NP B 17 289	+SHAPIRA, ALEXANDER+ (REHO+SACL+BGNA+EPL)
AGUILAR 71 PRL 26 466	+BARNES, BASSANO, EISNER, KINSON, SAMIOS (BNL)
AGUILAR 71 PR D 4 2583	+EISNER, KINSON (BNL)
BARNHAM 71 NP B 28 171	+COLLEY, JOBS, GRIFFITHS, HUGHES,+ (BIRM+GLAS)
BUCHNER 71 NP B 29 381	+DEHM, GOBEL, GOLDSCHMIDT,+ (IPN+CERN+BELG)
CORDS 71 PR D 4 1974	+CARMONY, ERWIN, MEIERE,+ (PURD+UCD+IUPUI)
MERCER 71 NP B32 381	+ANTICH, CALLAHAN, CHIEN, COX,+ (JOHN HOPKINS)
YUTA 71 PRL 26 1502	+DERRICK, ENGELMANN, MUSGRAVE (ANL+EFFI)
ABRAMOVICH 72 NP B 35 189	ABRAMOVICH, CHALOUPKA, CHUNG, HILPERT,+ (CERN)
BINGHAM 72 NP B 41 1	+ (INTERNATIONAL K+ COLLABORATION)
DEMPERAD 72 NP B 51 1	+BEUSCH, FREUDENREICH,+ (CERN+ETH+LIG)
BRUNET 72 NP B 37 114	+DANYSZ, GOLDSACK,+ (CDEF+SACL+LOIC+LDC)
BUCHNER 72 NP B 45 333	+DEHM, CHARRIERE, CORNET,+ (IPN+CERN+BRUX)
CRENNELL 72 PR D 6 1220	+GORDON, KWAN-WU LAI, SCARR (BNL)
DEUTSCHM 72 NP B 36 373	DEUTSCHMANN,+ (ABCLV COLLABORATION)
ENGELMAN 72 PR D 5 2162	ENGELMANN, MUSGRAVE, FORMAN,+ (ANL+EFFI)
ROUGE 72 NP B 46 29	+VIDEAL, VOLTE, DE BRION,+ (EPOL+SACL)
TIECKE 72 NP B 35 596	+GRIJNS, HEINEN, DE GROOT,+ (NIJW+AMST)
BERTHON 73 NP B 63 54	+MONTANET, PAUL, BERTRANET,+ (CERN+SACL)
CHARRIERE 73 NP B 51 317	CHARRIERE, DRI JARD, DE BAERE,+ (CERN+BELG)
CLARK 73 NP B 54 452	+LYONS, RADJICIC (OXFORD)
LEWIS 73 NP B 60 283	+ALLEN, JAGBS, DANYSZ, BORG,+ (LOWC+LOIC+CDEF)
LINGLIN 73 NP B 55 408	D. LINGLIN (CERN)
WALUCH 73 PR D 8 2837	+FLATTE, FRIEDMAN (LRL)
FOX 74 NP B80 403	G.C. FOX, M.L. GRISS (CIT)
MATISON 74 PR D9 1872	+GALTIERI, GARNJUST, FLATTE, FRIEDMAN,+ (LRL)
BRANDENB 75 PL 59 B 405	BRANDENBURG, CARNEGIE, CAMMORE, DAVIER+(SLAC)
CARITHERS 75 PRL 35 349	CARITHERS, MUEHLEMANN, UNDERWOOD,+ (ROCH+MGI)
MCCUBBIN 75 NP B86 13	N.A. MCCUBBIN, L. LYONS (OXF)
PALER 75 NP B86 1	+TOVEY, SHAH, SPIRO, CHAURAND+(RHEL+SACL+EPL)
KIRK 76 NP B 116 99	+KLEIN, COUNIHAN,+ (AACH+BERL+CERN+LOIC+WIEN)
BOWLER 76 NP B 126 31	+DAINTON, DRAKE, WILLIAMS (OXFORD)
AGUILAR 78 NP B 141 101	+FERNANDEZ, COOPER,+ (MADR+TATA+CERN+CDEF)
BALAND 78 NP B 140 220	+GRARD, JOHNSON,+ (MONS+BELG+CERN+LOIC+LALO)
BALDI 78 NP B 134 365	+BOHRINGER, DORSZ, HUNGERBUHLER+ (GEVA)
COOPER 78 NP B 136 365	+GURTY, DORZYSKI,+ (TATA+CERN+CDEF+MADR)
ENGELN 78 NP B 134 14	+JONGEJANS, HEWINGS,+ (NIJW+ZEM+CERN+CDEF)
ESTABROO 78 NP B 133 490	ESTABROOKS, CARNEGIE,+ (MONT+CARL+DURH+SLAC)
ALSO 78 PR D 17 658	ESTABROOKS, CARNEGIE+ (MONT+CARL+DURH+SLAC)
JONGEJAN 78 NP B 139 383	JONGEJANS, CERRADA,+ (ZEM+CERN+NIJW+CXF)
MARTIN 78 NP B 134 392	+SHIMADA, BALDI, BOHRINGER, DORSZ+ (DURH+GEVA)
WICKLUND 78 PR D 17 1197	+AYRES, DIEBOLD, GREENE, KRAMER, PAWICKI (ANL)

Q REGION, Kππ(1200-1400)

28 Q REGION (1200-1400) I=1/2

The main effect in the Q region is a broad bump in the Kππ spectrum between 1200 and 1400 MeV (not far above the K*(892)π threshold), produced by K beams without charge exchange. In particular, it has been observed in coherent K+d interactions (FIRESTONE 72) and in coherent interactions on heavy nuclei (BINGHAM 73). Throughout the entire region, J^P = 1⁺ and I = 1/2. FIRESTONE 72 observe a bump in the backward direction with a shape similar to that of the Q. The broad Q peak does not have a simple Breit-Wigner shape. It can be fitted at all energies by a superposition of two Breit-Wigner amplitudes. Dalitz plot analyses of the interference between the K*π and Kp modes show the relative magnitude and relative phase of the two decay amplitudes varying with Kππ mass. The Kp mode has a maximum intensity below that of K*π.

Partial-wave analyses have confirmed the rather complex situation in the Q region (DEUTSCHMANN 74, ANTIPOV 75, OTTER 75,76, TOVEY 75, BRANDENBURG 76, BEUSCH 78, VERGEEST 79). The dominant states are 1⁺S (K*π), almost entirely I = 1/2 (VERGEEST 79), and 1⁺S (Kp). Other important states are J^P = 0⁻ and J^P = 2⁺. The K*π and Kp modes are not produced coherently and have different polarization properties (BRANDENBURG 76, OTTER 76, VERGEEST 79). Whereas the Kp mode approximately conserves s-channel helicity, the K*π mode is approximately t-channel helicity conserving.

Experimentally, those data with sufficient statistics show the presence of a two-peak structure (OTTER 76, BRANDENBURG 76). BRANDENBURG 76 claim to observe sufficient phase variation to warrant proposing the existence of two J^P = 1⁺ Kππ resonances: Q₁, with a mass around 1280 MeV, a width of the order of 150 MeV, and mainly coupled to the Kp channel; and Q₂, with a mass around 1400 MeV, a width of the order of 150 MeV, and mainly coupled to the S-wave K*π channel (CARNEGIE 77). These results are experimentally confirmed by VERGEEST 79 and supported by the BOWLER 77 and BASDEVANT 79 analyses.

Data Card Listings

For notation, see key at front of Listings.

Mesons

Q

AACHEN 76 and WOHL 78 have shown some evidence for a $K\omega$ decay of the Q_1 in diffraction-like processes.

The $(K\pi\pi)^0$ system produced in the charge-exchange reaction appears to have an important $J^P = 1^+$ contribution (OTTER 75, VERGEEST 76). The $1^+(K^*\pi)$ and $1^+(K\rho)$ waves cannot be explained as decay products of a single resonance and the $K^*\pi$ wave behavior suggests a resonance contribution around 1400 MeV (VERGEEST 76).

There are a number of claims for the observation of $K\pi\pi$ resonances in the Q mass region in other non-diffractive processes (ARMENTEROS 64, CRENNEL 67,72, ASTIER 69, DAVIDSON 74, DORE 75). These data can be described in terms of a single resonance of characteristics consistent with those of the Q_1 (CONFORTO 77). A result from the hyperon-exchange reaction (GAVILLET 78) again shows the production of a $J^P = 1^+$ $K\rho$ resonance with mass and width close to those of the Q_1 . Neither ARMENTEROS 64 (nor a later analysis by ASTIER 69) nor GAVILLET 78 observe a $K^*\pi$ resonance compatible with the Q_2 . However the assignment to a $J^{PC} = 1^{++}$ SU(3) nonet of the $J^P = 1^+$ $K\rho$ resonance together with the A_1 , D(1285), and E(1420) seems to support the existence of a Q_2 (1400) with parameters compatible with those of CARNEGIE 77 (MAZZUCATO 79 and DIONISI 80).

Note that IRVING 80 discusses a model for non-diffractive Q production in which the Q_2 is suppressed relative to the Q_1 .

28 Q REGION MASS (MEV)	
M PRODUCED BY BEAMS OTHER THAN K MESONS	
M A	1242.0 9.0 10.0 ASTIER 69 HBC 0 PBAR P 9/69
M THIS IS THE C MESON.	
M	45(130.0) CRENNELL 67 HBC 0 6 PI-P, LK2PI 7/67
M	40(1300.) CRENNELL 72 HBC 0 4.5PI-P, LK2PI 12/75
M	40(1278.) (5.) DAVIDSON 74 HBC +- 1.6-2.2 PBAR P 12/75
M	43(1235.) (10.) DGRE 75 OSPK 06.2 PI-P, MM 12/75
M PRODUCED BY K-, BACKWARDS SCATTERING, HYPERON EXCHANGE	
M C	700 1275.0 10.0 GAVILLET 78 HBC + 4.2 K-P, XI-KPIPI 4/78*
M COUPLES MAINLY TO RHO K.	
M PRODUCED BY K BEAMS	
M	12(1320.0) (25.0) ALMEIDA 65 HBC + 3-5 K+ P 12/72
M C	(1230.0) (15.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
M C	35(1280.0) (10.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
M C	(1320.0) (15.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
M C SPLIT THE Q REGION INTO 3 BUMPS	
M	(1270.) APPROX. DE BAERE 67 HBC + 3.5 K+ P 7/67
M	(1335.0) (6.0) BARTSCH 68 HBC 10. K-P, K NPI 12/75
M	(1300.) APPROX. BARBARO 69 HBC + 12. K+ P (K 2PI) 9/69
M	45(1301.0) (10.0) BISHOP 69 HBC + 3.5 K+P(K* PI) 12/75
M	21(1300.0) (10.0) ERWIN 69 HBC 0 3.5 K+P(K* PI) 12/75
M	(1281.) (7.) FRIEDMAN 69 HBC - 2.6, 2.7 K- P 12/75
M	(1300.0) (10.0) ABRAMS 70 HBC + 2.5-3.2 K+ P 12/75
M	(1260.) (20.) FARBBER 70 HBC + 12.7 K+ P 12/75
M	(1325.0) DENEGR 71 DBC - 12.6 K-D, K 2PI D 12/75
M	(1296.) (5.) BARLOUTAU 73 HBC - 14.3 K-P, P K-2PI 12/75
M	(1283.) (6.) BARLOUTAU 73 HBC - 14.3 K-P, P K02PI 12/75
M	(1315.) (7.) BINGHAM 73 HBC - 5.5-12.7 COH K-A 12/75
M	(1260.) (10.) LEWIS 73 HBC + 2.1-2.7 K+ P 12/75
M	(1260.) (5.) LEWIS 73 HBC + 2.1-2.7 K+ P 12/75
M AVERAGING NOT MEANINGFUL	

28 Q LOW (Q1) MASS (MEV)	
ML FROM EXPERIMENTS SPLITTING Q REGION INTO TWO PEAKS	
ML	(1280.) SHEN 66 HBC + 0 4.6 K+P, 5 BODY 12/72
ML	(1260.0) (10.0) ALEXANDER 69 HBC 9.0 K+ P 12/75
ML	(1240.0) (5.0) BARNHAM 71 HBC + 10.0 K+P, K 2PI 12/75
ML	(1243.) (8.) GARFINKEL 71 DBC + 9. K+ D 12/75
ML	(1228.) (14.) ANDERSON 72 DBC - 7.3 K- D 12/75
ML	(1260.) DAVIS 72 HBC + 12. K+ P 12/72
ML	(1234.) (12.) FIRESTONE 72 DBC + 12. K+ D 2/73
ML C	(1300.) APPROX. BRANDENB 76 ASPK +- 13 K+-P, (KPIPI)P 12/75
ML E	(1299.0) (25.0) CARNEGIE 77 ASPK +- 13 K+-P, P KPIPI 12/77
ML	(1270.0) APPROX. OTTER 76 HBC - 10-14-16K-P 12/77
ML	(1300.0) APPROX. VERGEEST 79 HBC +- 4.2 K-P, K PI PI 12/79*
ML COUPLES MAINLY TO RHO K	
ML FROM A MODEL DEPENDENT FIT WITH GAUSSIAN BACKGROUND TO	
ML BRANDENBURG 76 DATA.	
ML AVERAGING NOT MEANINGFUL	

28 Q HIGH (Q2) MASS (MEV)	
MH FROM EXPERIMENTS SPLITTING Q REGION INTO TWO PEAKS	
MH	70(1320.0) (10.0) SHEN 66 HBC + 4.6 K+ P 12/75
MH	(1380.0) (20.0) ALEXANDER 69 HBC 9.0 K+ P 12/75
MH	(1420.0) (5.0) BARNHAM 71 HBC + 10.0 K+P, K 2PI 12/75
MH	(1344.) (8.) GARFINKEL 71 DBC + 9. K+ D 12/75
MH	(1414.) (15.) ANDERSON 72 DBC - 7.3 K- D 12/75
MH	(1420.) DAVIS 72 HBC + 12. K+ P 12/72
MH	(1368.) (18.) FIRESTONE 72 DBC + 12. K+ D 12/77
MH D	(1400.) APPROX. BRANDENB 76 ASPK +- 13 K+-P, (KPIPI)P 12/75
MH E	(1404.0) (10.0) CARNEGIE 77 ASPK +- 13 K+-P, P KPIPI 12/77
MH	(1400.0) APPROX. VERGEEST 79 HBC +- 4.2 K-P, K PI PI 12/79*
MH COUPLES MAINLY TO K* PI	
MH SEE NOTE E ABOVE.	
MH AVERAGING NOT MEANINGFUL	

28 Q REGION WIDTH (MEV)	
W PRODUCED BY BEAMS OTHER THAN K MESONS	
W	127.0 7.0 25.0 ASTIER 69 HBC 0 PBAR P 9/69
W	45 (60.) CRENNELL 67 HBC 0 6 PI-P 7/67
W	40 (60.) CRENNELL 72 HBC 0 4.5PI-P, LK2PI 12/72
W D	40 (25.) (15.) DAVIDSON 74 HBC +- 1.6-2.2 PBAR P 12/75
W D	ERROR INCREASED BY US. SEE K* TV NOTE.
W	43 (30.) (25.) (18.) DORE 75 OSPK 06.2 PI-P, L MM 12/75
W PRODUCED BY K-, BACKWARDS SCATTERING, HYPERON EXCHANGE	
W C	700 75.0 15.0 GAVILLET 78 HBC + 4.2 K-P, XI-KPIPI 4/78*
W COUPLES MAINLY TO RHO K.	
W PRODUCED BY K BEAMS	
W	12 (60.0) (20.0) ALMEIDA 65 HBC + 3-5 K+ P 12/72
W C	(60.0) (20.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
W C	35 (80.0) (20.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
W C	(60.0) (20.0) BASSOMPIE 67 HBC + 5. K+ P 11/67
W C SPLIT THE Q REGION INTO 3 BUMPS	
W	(200.) APPROX. DE BAERE 67 HBC + 3.5 K+ P 7/67
W B	(196.0) (16.0) BARTSCH 68 HBC 10. K- P, K NPI 12/75
W	250. APPROX. BARBARO 69 HBC + 12. K+ P (K 2PI) 9/69
W B NO BACKGROUND SUBTRACTION.	
W	45 (60.0) (10.0) BISHOP 69 HBC + 3.5 K+P(K* PI) 12/75
W	21 (40.0) (15.0) ERWIN 69 HBC 0 3.5 K+P(K* PI) 12/75
W	(51.) (22.) FRIEDMAN 69 HBC - 2.6, 2.7 K- P 12/75
W	(80.0) (20.0) ABRAMS 70 HBC + 2.5-3.2 K+ P 12/75
W	(180.) (28.) FARBBER 70 HBC + 12.7 K+ P 12/75
W	(180.0) (16.0) DENEGR 71 DBC - 12.6 K-D, K 2PI D 5/71
W	(326.) (17.) BARLOUTAU 73 HBC - 14.3 K-P, P K-2PI 12/75
W	(266.) (21.) BARLOUTAU 73 HBC - 14.3 K-P, P K02PI 12/75
W	(150.) (70.) LEWIS 73 HBC + 2.1-2.7 K+ P 12/75
W	(47.) (18.) LEWIS 73 HBC + 2.1-2.7 K+ P 12/75
W AVERAGING NOT MEANINGFUL	

28 Q LOW (Q1) WIDTH (MEV)	
ML F FROM EXPERIMENTS SPLITTING Q REGION INTO TWO PEAKS	
ML	(100.0) (20.0) SHEN 66 HBC + 0 4.6 K+P, 5 BODY 12/75
ML	(40.0) (10.0) ALEXANDER 69 HBC 9.0 K+ P 12/75
ML	(110.0) (15.0) BARNHAM 71 HBC + 10.0 K+P, K 2PI 12/75
ML	(70.) (26.) (18.) GARFINKEL 71 DBC + 9. K+ D 12/75
ML	(111.) (33.) ANDERSON 72 DBC - 7.3 K- D 12/75
ML	(120.) DAVIS 72 HBC + 12. K+ P 12/72
ML	(188.) (21.) FIRESTONE 72 DBC + 12. K+ D 12/75
ML C	(200.) APPROX. BRANDENB 76 ASPK +- 13 K+-P, (KPIPI)P 12/75
ML E	(150.0) (71.0) CARNEGIE 77 ASPK +- 13 K+-P, P KPIPI 12/77
ML	(150.0) APPROX. VERGEEST 79 HBC +- 4.2 K-P, K PI PI 12/79*
ML COUPLES MAINLY TO RHO K	
ML SEE NOTE E ABOVE.	
ML AVERAGING NOT MEANINGFUL	

28 Q HIGH (Q2) WIDTH (MEV)	
MH F FROM EXPERIMENTS SPLITTING Q REGION INTO TWO PEAKS	
MH	70 (80.0) (20.0) SHEN 66 HBC + 4.6 K+P 12/75
MH	(120.0) (20.0) ALEXANDER 69 HBC 9.0 K+ P 12/75
MH	(120.0) (15.0) BARNHAM 71 HBC + 10.0 K+P, K 2PI 12/75
MH	(60.) (26.) (18.) GARFINKEL 71 DBC + 9. K+ D 12/75
MH	(89.) (24.) ANDERSON 72 DBC - 7.3 K- D 12/75
MH	(80.) DAVIS 72 HBC + 12. K+ P 12/72
MH	(241.) (30.) FIRESTONE 72 DBC + 12. K+ D 12/75
MH D	(160.) APPROX. BRANDENB 76 ASPK +- 13 K+-P, (KPIPI)P 12/75
MH E	(142.0) (16.0) CARNEGIE 77 ASPK +- 13 K+-P, P KPIPI 12/77
MH	(200.0) APPROX. VERGEEST 79 HBC +- 4.2 K-P, K PI PI 12/79*
MH COUPLES MAINLY TO K* PI	
MH SEE NOTE E ABOVE.	
MH AVERAGING NOT MEANINGFUL	

Data Card Listings

For notation, see key at front of Listings.

Mesons

K*(1430)

K*(1430)

22 K*(1430, JP=2+) I=1/2
WE CONSIDER THAT PHASE-SHIFT ANALYSES PROVIDE MORE RELIABLE DETERMINATIONS OF THE MASS AND WIDTH. SEE RHO(770) MINI-REVIEW.

22 K*(1430) MASS (MEV)

Table listing mass measurements for K*(1430) from various experiments, including charged only and neutral states, with columns for experiment name, mass value, error, and reference.

Table listing mass measurements for K*(1430) with other final states, including Badiier, Dubal, Bassompie, and Friedman.

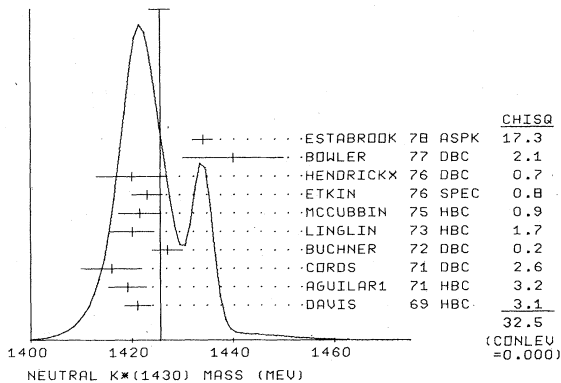
Table listing mass measurements for charged and neutral K*(1430) from Focardi and Aderholz.

Table listing mass measurements for neutral K*(1430) from various experiments including Dahl, Kang, Schweingr, Bassompie, Davis, Aguilari, Cords, Buchner, Linglin, McCubbin, Etkin, Hendrickx, Bowler, and Estabrook.

Average (error includes scale factor of 1.9) using Student's t-test: 1425.7 ± 2.0

Included in Linglin 73 world K+P DST. From pole extrapolation, using world K+P DST. Errors enlarged by us to gamma/sqrt(n). See typed note on K* from phase shift analysis. Data with mass error of 15 MeV or more not averaged. Number of events in peak reevaluated by us.

WEIGHTED AVERAGE = 1425.7 ± 2.0
ERRDR. SCALED BY 1.9



22 K*(1430) WIDTH (MEV)

Table listing width measurements for K*(1430) from various experiments, including charged only and neutral states.

Table listing width measurements for K*(1430) with other final states.

Table listing width measurements for charged and neutral K*(1430) from Focardi and Aderholz.

Table listing width measurements for neutral K*(1430) from various experiments.

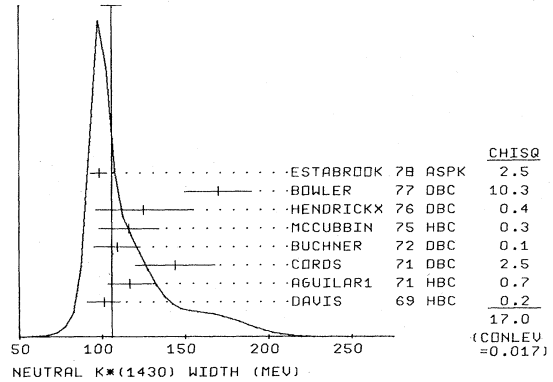
Rev. Mod. Phys., Vol. 52, No. 2, Part II, April 1980

Table listing width measurements for neutral K*(1430) from various experiments, including Dahl, Kang, Bassompie, Davis, Aguilari, Cords, Buchner, Linglin, McCubbin, Hendrickx, Bowler, and Estabrook.

Average (error includes scale factor of 1.6) using Student's t-test: 105.1 ± 4.8

Included in Linglin 73 world K+P DST. From pole extrapolation, using world K+P DST. Errors enlarged by us to 4*gamma/sqrt(n). See K* typed note. From phase shift analysis. Data with mass error of 15 MeV or more not averaged. Number of events in peak reevaluated by us.

WEIGHTED AVERAGE = 105.8 ± 5.9
ERRDR. SCALED BY 1.6



22 K*(1430) PARTIAL DECAY MODES

Table listing partial decay modes for K*(1430) into various meson pairs, including decay masses and branching fractions.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i^2/delta P_i^2, where delta P_i = sqrt(delta P_i^2), while the off-diagonal elements are the normalized correlation coefficients (delta P_i delta P_j)/(delta P_i delta P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Matrix of fitted partial decay mode branching fractions for K*(1430).

22 K*(1430) BRANCHING RATIOS

Table listing branching ratios for K*(1430) into various meson pairs, including ratios and uncertainties.

Mesons

K*(1430), κ(1500)

Table of experimental data for K*(1430) and κ(1500) mesons, including columns for particle name, mass, width, and various fit parameters.

REFERENCES FOR K*(1430)

List of references for K*(1430) meson, including authors like Badier, Chung, Focardi, Shen, Bassano, etc.

Data Card Listings

For notation, see key at front of Listings.

Table of experimental data for K*(1430) and κ(1500) mesons, continuing from the previous table with more fit parameters and references.

κ(1500)

19 KAPPA(1500, JP=0+) I=1/2

S-Wave Kπ Interactions

The Kπ interactions are reminiscent of the ππ interactions, apart from the inelastic thresholds, both for the leading J^P = 1^-, 2^+, 3^- resonances and for the S wave. The first inelastic S-wave thresholds are Kπππ and Kη, neither of these channels being known to be important below 1400 MeV.

From the Kπ threshold to ~1400 MeV, the phase shift δ_0^1 of the I(J^P) = 1/2(0^+) wave is determined uniquely by the requirements of elastic unitarity.

It grows monotonically, reaching 40° at about 900 MeV, and 90° at about 1350 MeV, being everywhere well described by an effective range formalism (MERCER 71, BINGHAM 72, FIRESTONE 71,72, MATISON 72,74, GALTIERI 73, YUTA 73, FOX 74, BAKER 75, LAUSCHER 75, BOWLER 77, ESTABROOKS 78); see Fig. 1. The ambiguous "up" solution in the region of the K*(892) has been ruled out conclusively (MATISON 72,74, GALTIERI 73, BOWLER 77, ESTABROOKS 78).

In the 1400 MeV region the analysis becomes complicated due to the largeness of δ_0^1, to the nearness of the K*(1430) and the resulting strong S-D interference, and to the opening of inelastic channels. Several groups have interpreted the slow passage of δ_0^1 through 90° as evidence for a resonance (FIRESTONE 71,72, FRATI 72, ROUGE 72, CORDS 73, LAUSCHER 75, MORGAN 75, ENGELEN 78), while others contended that δ_0^1 was large but

Data Card Listings

For notation, see key at front of Listings.

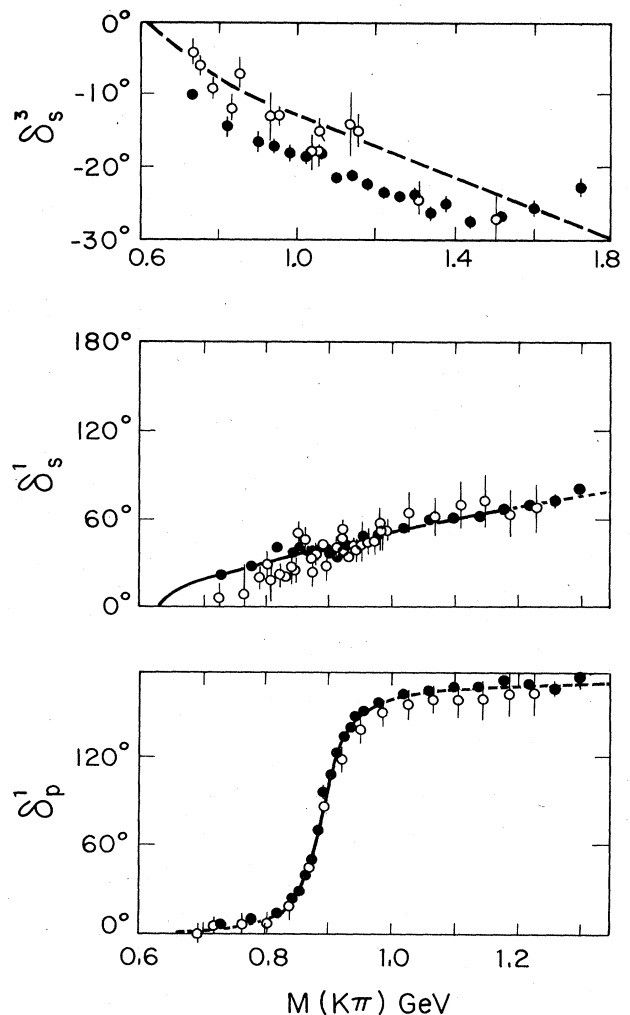
Mesons
 $\kappa(1500)$

non-resonant (AGUILAR 72, BUCHNER 72, CRENNELL 72, ENGELMANN 72, BAKER 75).

New features emerge as the phase-shift analysis is continued up to 1900 MeV on a large-statistics experiment (ESTABROOKS 78). In the inelastic region where the ambiguities cannot be solved ESTABROOKS 78 find four solutions, in all of which the S wave exhibits a rapid drop in the modulus of the amplitude near 1450 MeV; see Fig. 2. This behavior is confirmed with less statistics by BOWLER 77 and MARTIN 78, and a clear circular motion is seen in the Argand plot with a maximum speed in the region 1400-1500 MeV. Thus all four solutions provide evidence for an S-wave $0^+ K\pi$ resonance. The elasticity is greater than 0.8 in all but one solution. We call this resonance $\kappa(1500)$ and enter it into the Table. ESTABROOKS 79 performs a coupled-channel fit to the mass dependence of the S-wave magnitude and phase using various parametrizations. All the fits result in a second-sheet pole very near the $K\eta'$ threshold with $M = 1480-1570$ MeV and $\Gamma = 120-400$ MeV, depending on which of the four solutions is used as input. No additional pole is required to explain the slow passage of δ_0^1 through 90° at about 1350 MeV. We note that this situation is reminiscent of the $\pi\pi$ system, where the "down" phase shift δ_0^0 goes slowly through 90° at about 850 MeV, far below the $\epsilon(1300)$ resonance.

The present 0^+ nonet looks rather different from the one considered by MORGAN 75. The ϵ and κ both have higher masses and smaller widths than before; the ϵ in addition couples noticeably to $K\bar{K}$.

Finally, we remark that two of the four solutions of ESTABROOKS 78 provide evidence for a second P-wave resonance with mass ~ 1650 MeV, width ~ 250 MeV, and elasticity ~ 0.25 . This new state, $K^{*'}(1650)$, would, if confirmed, most probably be assigned in the quark model as a radial excitation, similarly to $\rho'(1600)$.



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Fig. 1. The solid points are the $K\pi$ phase shifts calculated in a simultaneous analysis of the SLAC 13 GeV/c neutron and Δ recoil reactions. The curves represent the effective range or resonance fits of ESTABROOKS 78, except for the dashed curve on the δ_S^3 plot which represents a constant cross section of 1.8 mb. The open circles are from MERCER 71, BINGHAM 72, BAKER 73, LINGLIN 73, and MATISON 74.

Mesons

$\kappa(1500)$, L(1580)

Data Card Listings

For notation, see key at front of Listings.

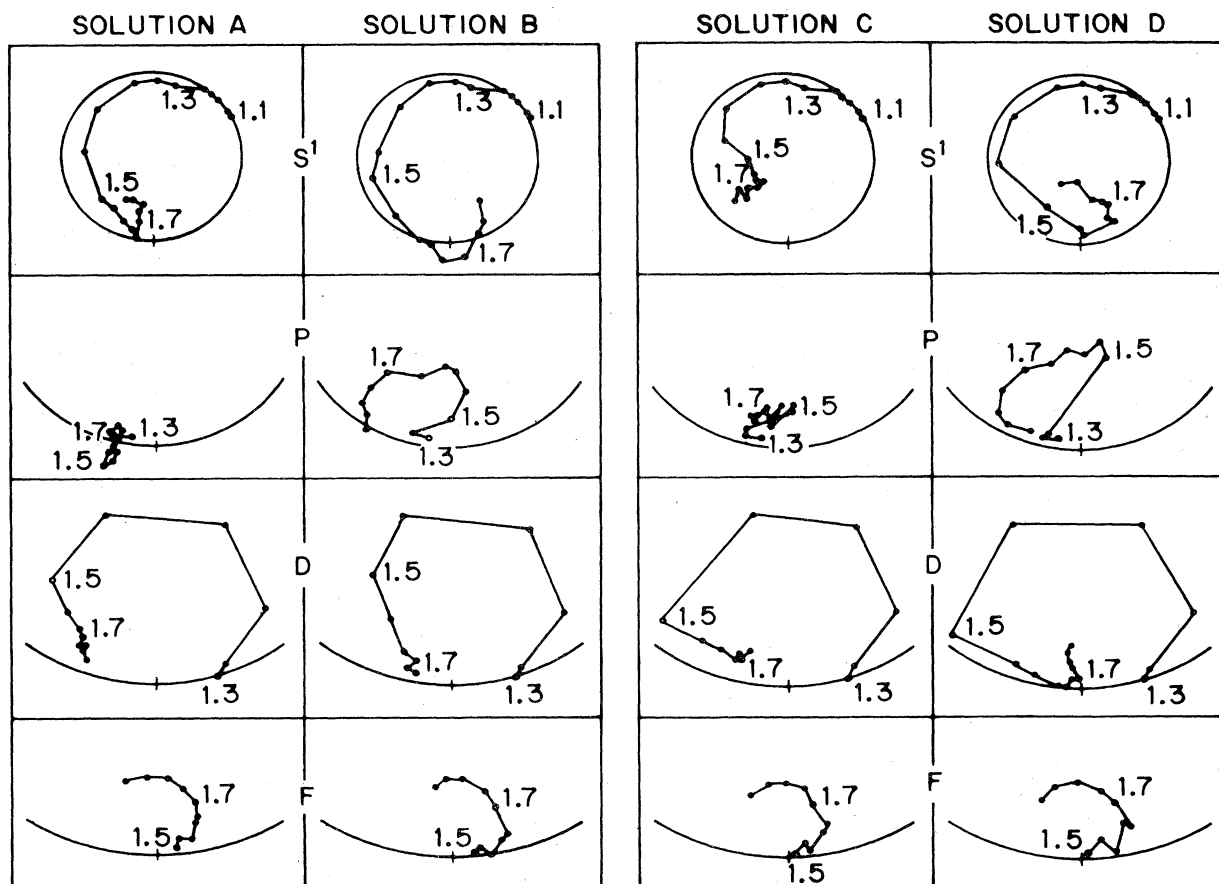


Fig. 2. Argand diagrams for the $K\pi$ partial waves of ESTABROOKS 78.

19 KAPPA MASS (MEV)
M C (1425.) APPROX. ESTABROOK 78 ASPK 13 K+- P 12/77
M (1450.0) APPROX. MARTIN 78 SPEC 10 K+-P,KS PI P 12/78*
M C FROM ELASTIC K PI PARTIAL WAVE ANALYSIS (SEE KAPPA MINI-REVIEW)

19 KAPPA WIDTH (MEV)
W C 200-300 APPROX. ESTABROOK 78 ASPK 13 K+- P 12/77
W C FROM ELASTIC K PI PARTIAL WAVE ANALYSIS (SEE KAPPA MINI-REVIEW)

REFERENCES FOR KAPPA

TRIPPE 68 PL 28 B 203 +CHIEN,MALAMUD,MELLEMA,SCHLEIN,+ (UCLA)
CRENNELL 69 PRL 22 487 +KARSHON,LAI,O'NEALL,SCARR (BNL)
DODD 69 PR 177 1994 +JOLDERSMA,PALMER,SAMIOS (BNL)
GOLDBERG 69 PL 30 B 424 SABRE COLLABOR. (SACL+AMST+BGNA+REHO+EPOL)
SCHLEIN 69 ARGONNE CONF. 446 P.SCHLEIN (UCLA)
FIRESTON 71 PRL 26 1460 A.FIRESTONE,G.GOLDBERGER,D.LISSAUER (LRL)
MERCER 71 NP 832 381 +ANTICH,CALLAHAN,CHIEN,COX,+ (JOHN HOPKINS)
YUTA 71 PRL 26 1502 +DERICK,ENGELMANN,MUSGRAVE (ANL+EFI)
AGUILAR 72 PR D 6 11 AGUILAR-BENITEZ,CHUNG,EISNER (BNL)
BINGHAM 72 NP B 41 1 + (INTERNATIONAL K+ COLLABORATION)
BUCHNER 72 NP B 45 333 +DEHM,CHARRIERE,CORNET,+ (MPIH+CERN+BRUX)
CHUNG 72 PRL 29 1570 +EISNER,AGUILAR-BENITEZ (BNL)
CRENNELL 72 PR D 6 1220 +GORDON,KWAN-WU LAI,SCARR (BNL)
DIEBOLD 72 BATAV.CONF. v.3 17R.DIEBOLD RAPORTEUR TALK (ANL)
ENGELMAN 72 PR D 5 2162 ENGELMANN,MUSGRAVE,FORMAN,+ (ANL+EFI)
FIRESTON 72 PR D 5 2198 +GOLDBERGER,LISSAUER,TRILLING (LBL+PIA)
FRATI 72 PR D 6 2361 +HALPERN,HARGIS,SHAPE,CARNAHAN,+ (PENN+CINC)
MATISON 72 LBL 1537 (THESIS) REVISED VERSION WILL GO TO PHYS.REV. LBL
ROUGE 72 NP B 46 29 +VIDEAU,VOLTE,DE BRION,+ (EPOL+SACL)
CORDS 73 NP B 54 109 +CARMONY,LANDER,MEIERE,+ (PURD+UCD+IUPUI)
GALTIERI 73 LBL 1772 +MATISON,GARNJUST,FLATTE,FRIEDMAN+ (LBL)
LINGLIN 73 NP B 55 408 D.LINGLIN (CERN)
YUTA 73 NP B 52 70 +ENGELMANN,MUSGRAVE,FORMAN,+ (ANL+EFI)

FOX 74 NP 880 403 G.C.FOX,M.L.GRISS (CIT)
MATISON 74 PR D9 1872 +GALTIERI,GARNJUST,FLATTE,FRIEDMAN,+ (LBL)
MORGAN 74 PL 518 71 D.MORGAN (RHEL)
BAKER 75 NP 899 211 +BANERJEE,CAMPBELL,ALLEN,MARCH+ (LOIC+LOWC)
LAUSCHER 75 NP 886 189 +OTTER,WIECZOREK,+ (ABCLV COLLABORATION)
MORGAN 75 ARGONNE CONF. 45 D.MORGAN (RHEL)

CHIEN 76 NP B 106 395 +FEIOCK,LUCAS,PEVSNER,ZOANIS (BALTIMORE)
BOWLER 77 NP B 126 31 +DAINTON,DRAKE,WILLIAMS (OXFORD)
SPIRO 77 NP B 125 162 +BARLOUTAUD,COMBER,PALER,+ (SACL+RHEL+EPOL)

BALDI 78 NP B 134 365 +BOHRINGER,DORSAZ,HUNGERBUHLER+ (GEVA)
ENGELEN 78 NP B 134 14 +JONGEJANS,HEMINGWAY,+ (NIJM+ZEEM+CERN+OXF)
ESTABROO 78 NP B 133 490 ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC)
MARTIN 78 NP B 134 392 +SHIMADA,BALDI,BOHRINGER,DORSAZ+(DURH+GEVA)

ESTABROO 79 PR D 19 2678 P.ESTABROOKS (CARL)
VERGEEST 79 NP B 158 265 +ENGELEN,KITTEL+ (NIJM+AMST+CERN+OXF)

L(1580) 39 L(1580,JP=2-) I=1/2
→ SEEN IN PARTIAL WAVE ANALYSIS OF THE K-PI+PI- SYSTEM (OTTER 78). SEE L(1770) MINIREVIEW. NEED CONFIRMATION OMITTED FROM TABLE.

39 L(1580) MASS (MEV)
M (1580.) APPROX. OTTER 79 - 10,14,16 K- P 12/79*

39 L(1580) WIDTH (MEV)
W (110.) APPROX. OTTER 79 - 10,14,16 K- P 12/79*

Data Card Listings

For notation, see key at front of Listings.

Mesons

L(1580), K*(1650), KN(1700), L(1770)

39 L(1580) PARTIAL DECAY MODES

Table with columns for particle ID, decay mode, and decay masses (892+139, 1434+139).

39 L(1580) BRANCHING RATIOS

Table with columns for particle ID, decay mode, and branching ratios (e.g., 79 HBC, 10,14,16 K- P).

REFERENCES FOR L(1580)

OTTER 79 NP B 147 1 +RUDOLPH, (AACH+BERL+CERN+LOIG+WIEN) JP

K*(1650)

29 K*(1650, JP=1-) I=1/2

SEEN IN K PI PHASE SHIFTS ANALYSIS (ESTABROOK 78). WAIT CONFIRMATION. OMITTED FROM TABLE.

29 K*(1650) MASS (MEV)

Table with columns for mass (1650.), approximation, and reference (ESTABROOK 78 ASKP).

29 K*(1650) WIDTH (MEV)

Table with columns for width (250-300), approximation, and reference (ESTABROOK 78 ASKP).

REFERENCES FOR K*(1650)

ESTABROOK 78 NP B 133 490 ESTABROOKS, CARNEGIE, (MONT+CARL+DURH+SLAC)

KN(1700)

27 KN(1700, JP=) I=1/2

THIS ENTRY CONTAINS VARIOUS PEAKS IN STRANGE MESON SYSTEMS REPORTED IN THE 1700 MEV REGION. EVIDENCE NOT COMPELLING. OMITTED FROM TABLE.

27 KN(1700) MASS (MEV)

Table with columns for mass (1660.0, 1660.0, 1660.0, 60(1710.), 137(1692.0)), decay modes, and references.

27 KN(1700) WIDTH (MEV)

Table with columns for width (60.0, 60.0, 60(110.), 137(26.0)), decay modes, and references.

27 KN(1700) PARTIAL DECAY MODES

Table with columns for particle ID, decay mode, and decay masses (493+139, 493+139+139, 892+139, 493+776, 1434+139, 493+782).

27 KN(1700) BRANCHING RATIOS

Table with columns for particle ID, decay mode, and branching ratios (74 HBC, 76 SPEC).

REFERENCES FOR KN(1700)

CARMONY 67 PRL 18 615 D. CARMONY, T. HENDRICKS, L. LANDER (LA JOLLA) + BASSOMPIERRE, DE BAERE + (BIRM+CERN+BRUX)

L(1770)

23 L(1770, JP=) I=1/2

The L(1770) is seen as a bump in the diffractive-like process KN -> (K pi pi) N. BARBARO 69 and FIRESTONE 72 find the decay is consistent with being entirely K*(1430) pi, whereas AGUILAR 70, BARTSCH 70, COLLEY 71, and DENEGRI 71 present evidence for alternate decay modes. For a review see EISNER 74.

Partial-wave analyses (DEUTSCHMANN 74, ANTIPOV 75, OTTER 75,79) have shown that the situation in the L region is complicated with many unnatural parity waves contributing. The 2- K*(1430) pi S wave is important, but cannot explain the whole L enhancement.

On the other hand, OTTER 79 propose the existence of a 2- resonance of mass approx 1580 MeV and width approx 110 MeV to explain the sharp rise of the 2- K*(1430) pi channel, the peak in the 2- K*(892) pi partial wave, and the observed phase variation. Further confirmation is, however, needed before considering this an established resonance.

23 L(1770) MASS (MEV)

Table with columns for mass (20(1780.), 1745.0, 1780.0, 1760.0, 1765.0, 1740.0, 1767.), decay modes, and references.

23 L(1770) WIDTH (MEV)

Table with columns for width (20(80.), 100.0, 138.0, 150.0, 90.), decay modes, and references.

23 L(1770) PARTIAL DECAY MODES

Table with columns for particle ID, decay mode, and decay masses (497+134+134, 134+1434, 497+134+134+134, 892+134, 892+776, 892+782, 892+134+134).

23 L(1770) BRANCHING RATIOS

Table with columns for particle ID, decay mode, and branching ratios (LARGE, 1.0, 0.2, LESS THAN 1.0, LESS THAN 1.0, CONSISTENT WITH 1., PRODUCED IN CONJUNCTION WITH D*, LESS THAN 1.0 SEEMS TO BE ESTABLISHED, FOR DISCUSSION OF THE EXPERIMENTAL EVIDENCE ON OTHER DECAY MODES SEE HUGHES 71, SLATTERY 71, EISNER 74).

Mesons

L(1770), K*(1780)

Data Card Listings

For notation, see key at front of Listings.

Table with columns for author names and references for L(1770). Includes entries like BARTSCH 66 PL 22 357, BERLINGHIERI + FARBER + FERBEL + FORMAN + (ROCH) + BASSOMPIERRE, DE BAERE + (BIRM-CERN-BRUX), etc.

K*(1780)

60 K*(1780, JP=3-)

Evidence for K*(1780) has been reported by a number of experiments which observe peaks of low statistical significance around 1800 MeV in the mass spectra of Kπ and Kππ systems produced both with charge exchange (CARMONY 71, AGUILAR 73, SPIRO 76, CARMONY 77, GRASSLER 77) and without charge exchange (SPIRO 76). The large variation in the measured values of the mass (see the Data Card Listings) leads GRASSLER 77 to suggest that there may be further structure at higher mass (around 1850 MeV).

Additional evidence for the K*(1780) has come from observations of structure in the charge-exchange Kπ angular distribution at ~1800 MeV (FIRESTONE 71, BRANDENBURG 76), which can be explained by a rapid rise of the F-wave amplitude interfering strongly with other waves. This behavior has been interpreted by BRANDENBURG 76 as implying the existence of a resonance with JP=3-, M~1780 MeV, and Γ~270 MeV. The existence of such a resonance has been confirmed by BALDI 76 and CHUNG 78. BALDI 76 analyze non-charge-exchange data and find significant signals at ~1780 MeV in all moments up to L=6. A clear, statistically significant peak at ~1786 MeV is observed by CHUNG 78 in their charge-exchange Kπ mass spectrum. Both of these experiments obtain narrower widths than BRANDENBURG 76. BALDI 76 finds a width of 135 ± 22 MeV and CHUNG 78 a width of 95 ± 31 MeV.

There have been two phase-shift analyses of

the Kπ system in this energy region. The energy-dependent analysis of BOWLER 77 supports the existence of a broad JP=3- resonance at ~1760 MeV with a width ~300 MeV. The problem of the width has been partly resolved by the ESTABROOKS 78 analysis of the high-statistics spectrometer data of BRANDENBURG 76. ESTABROOKS 78 find four solutions (see the Kπ S-wave mini-review), all of which are compatible with the existence of an F-wave resonance at ~1780 MeV with a width ~175 MeV and elasticity ~0.2. The Kππ decay mode has been confirmed by BEUSCH 78 with good statistics and can be considered established.

Table titled '60 K*(1780) MASS (MEV)'. Contains columns for experiment name, mass values, and decay modes. Includes entries like CARMONY 71 DBC 09 K+N,K+PI-P 11/71, FIRESTONE 71 DBC 0 12.K+ N,K+ PI-P 11/71, etc.

Table titled '60 K*(1780) WIDTH (MEV)'. Contains columns for experiment name, width values, and decay modes. Includes entries like CARMONY 71 DBC 09 K+N,K+PI-P 11/71, FIRESTONE 71 DBC 0 12.K+ N,K+ PI-P 11/71, etc.

Table titled '60 K*(1780) PARTIAL DECAY MODES'. Lists decay modes and their corresponding masses. Includes entries like K*(1780) INTO K PI 493+ 139, K*(1780) INTO K*(892) PI 892+ 139, etc.

Table titled '60 K*(1780) BRANCHING RATIOS'. Lists branching ratios for various decay modes. Includes entries like K*(1780) INTO (K*(892) PI + K RHO)/(K PI) (P2+P3)/P1, etc.

Data Card Listings

Mesons

For notation, see key at front of Listings.

K*(1780), K*(2200), I(2600), D±, D0, D*±, D*0

R4 K*(1780) INTO (K PI 1/2) TOTAL (P1)
R4 B (0.2) OR LESS BOWLER 77 DBC 0 5.4 K+D,K+PI-P P 12/77
R4 B 0.19 0.02 ESTABROO 78 ASPK 0 13 K+-P,K PI 12/77
R4 B SEE NOTE ABOVE.

C=±1 MESON STATES

REFERENCES FOR K*(1780)
CARMONY 71 PRL 27 1160 +CORDS,CLOPP,ERWIN,MEIERE,+ (PURO+UCD+IUPU)
FIRESTONE 71 PL 36 B 513 FIRESTONE,GOLDBERGER,LISSAUER,TRILLING (LBL)
AGUILAR 73 PRL 30 672 +CHUNG,EISNER,PROTOPOSCU,SAMIOS,+ (BNL)
WALUCH 73 PR D 8 2837 +FLATTE,FRIEDMAN (LBL)
BALDI 76 PL 63 B 344 +BOEHRINGER,DRSAZ,HUNGERBUHLER,+ (GENEVA) JP
BRANDEB 76 PL 60 B 478 BRANDEBURG,CARNEGIE,CASHMORE,DAVIER+(SLAC) JP
SPIRO 76 PL 60 B 389 +BARLOUTAUD,PALEK,CHAURAND+(SACL+RHUL+EPOL) JP
BOWLER 77 NP B 126 31 +DAINTON,DRAKE,WILLIAMS (OXFORD) JP
CARMONY 77 PRD 16 1251 +CLOPP,LANDER,MEIERE,YEN,+ (PURO+UCD+IUPU)
GRASSLER 77 NP B 125 189 +KLUQW,+ (AACHEN+BERLIN+CERN+LOIC+VIENNA) JP
BEUSCH 78 PL 74 B 282 +BIRMAN,KONIGS,OTTER,+ (CERN+AACH+ETH) JP
CHUNG 78 PRL 40 B 355 +ETKIN,FLAMIND+(BNL+BRAN+CUNY+MASA+PENN) JP
ESTABROO 78 NP B 133 490 ESTABROOKS,CARNEGIE,+ (MONT+CARL+DURH+SLAC) JP
ALSO 78 PR D 17 658 ESTABROOKS,CARNEGIE+ (MONT+CARL+DURH+SLAC) JP

31 CHARGED D(1868,JP=0-) I=1/2
SEE STABLE PARTICLE DATA CARD LISTINGS
32 NEUTRAL D(1863,JP=0-) I=1/2
SEE STABLE PARTICLE DATA CARD LISTINGS
62 CHARGED D*(2010,JP=1-) I=1/2

K*(2200)

40 K*(2200,JP=)
THIS ENTRY CONTAINS VARIOUS PEAKS IN STRANGE MESON SYSTEMS REPORTED IN THE 2100-2200 MEV REGION AS WELL AS ENHANCEMENTS SEEN IN ANTIHYPERON NUCLEON MASS SPECTRA. A MOMENTS ANALYSIS OF THE CLELAND 80 DATA GIVES EVIDENCE FOR TWO RESONANCES AT 2.3 AND 2.5 GEV WITH JP=2- AND 4- COUPLING TO ANTI-LAMBDA P (WITH SU+ AND LAMBDA ANTI-PROTON (WITH 50 GEV/C INCIDENT K-). INTERPRETATION UNCERTAIN. OMITTED FROM THE TABLE.

62 CHARGED D*(2010) MASS (MEV)
M G (2008.) (3.) GOLDHAB2 77 SMAG +- E+E- 12/77
M P 2008.6 1.0 PERUZZI 77 SMAG +- E+E- 12/77
M G FROM SIMULTANEOUS FIT TO D**+D*0,D+,AND D0,NOT INDEPENDENT OF
M G FELDMAN 77 MASS DIFFERENCE BELOW.
M P PERUZZI 77 MASS NOT INDEPENDENT OF FELDMAN 77 MASS DIFFERENCE
M P BELOW AND PERUZZI 77 DO MASS VALUE.

40 K*(2200) MASS (MEV)
M C 20(2240.) (20.) LISSAUER 70 HBC 9. K+ P 11/71
(2200.) APPROX. SLATTERY 71 RVUE 8-13 K+ P 11/71
M C COMPILATION OF (ANTIHYPERON-NUCLEON) MASS IN K+ P B.-13. GEV/C
M P 488(2115.) (46.) CARMONY 77 HBC 0 9 K+D,K+ PIONS 12/78*
M P JP=4+ PREFERRED FROM MOMENTS ANALYSIS.
M P 37(2147.) (4.) CHLIAPNIK 79 HBC + K+P TO LAM-BAR P 1/80*
M Q (2320.) APPROX. CLELAND 80 SPEC +- LAMBDA ANTI-P+CC 1/80*
M Q JP=2- FROM MOMENTS ANALYSIS.
M R (2510.) APPROX. CLELAND 80 SPEC +- LAMBDA ANTI-P+CC 1/80*
M R JP=4- FROM MOMENTS ANALYSIS.

62 (D**) - (D0) MASS DIFFERENCE (MEV)
DM 30 145.3 0.5 FELDMAN 77 SMAG D** TO DO PI+ 12/77
DM 2 145.2 0.6 BLIETSCH 79 BEBC NEUTRINO P 12/79*
DM AVG 145.26 0.38 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
DM STUDENT 145.26 0.41 AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT
62 (D**) - (D*0) MASS DIFFERENCE (MEV)
EM P 2.6 1.8 PERUZZI 77 SMAG +- E+E- 12/77
EM P NOT INDEPENDENT OF FELDMAN 77 MASS DIFFERENCE ABOVE, PERUZZI 77
EM P DO MASS, AND GOLDBERGER 77 D*0 MASS.

40 K*(2200) WIDTH (MEV)
W C 20 (80.) (20.) LISSAUER 70 HBC 9. K+ P 11/71
(200.) APPROX. SLATTERY 71 RVUE 8-13 K+ P 11/71
W C COMPILATION OF (ANTIHYPERON-NUCLEON) MASS IN K+ P B.-13. GEV/C
W P (300.) (200.) CARMONY 77 HBC 0 9 K+D,K+ PIONS 12/78*
W P JP=4+ PREFERRED FROM MOMENTS ANALYSIS.
W P 37 (40.) APPROX. CHLIAPNIK 79 HBC + K+P TO LAM-BAR P 1/80*
W Q (250.) APPROX. CLELAND 80 SPEC +- LAMBDA ANTI-P+CC 1/80*
W Q JP=2- FROM MOMENTS ANALYSIS.
W R (250.) APPROX. CLELAND 80 SPEC +- LAMBDA ANTI-P+CC 1/80*
W R JP=4- FROM MOMENTS ANALYSIS.

62 CHARGED D*(2010) WIDTH (MEV)
W W 18 (20.0) OR LESS PERUZZI 76 SMAG +- E+E-,PSI(4030) 1/77
30 (2.0) OR LESS CL=.90 FELDMAN 77 SMAG D** TO DO PI+ 12/77
62 CHARGED D*(2010) PARTIAL DECAY MODES
P1 D**+(2010) INTO DO PI+ DECAY MASSES 186.3+ 139
P2 D**+(2010) INTO D+ GAMMA 186.8+ 0
P3 D**+(2010) INTO D+ P10 186.8+ 134
P D**-(2010) MODES ARE CHARGE CONJUGATES OF ABOVE MODES

REFERENCES FOR K*(2200)
ALEXANDE 68 PRL 20 755 ALEXANDER,FIRESTONE,GOLDBERGER,SHEN (LRL)
LISSAUER 70 NP B 18 491 ALEXANDER,FIRESTONE,GOLDBERGER (LBL)
CARMONY 71 PRL 27 1160 +CORDS,CLOPP,ERWIN,MEIERE,+ (PURO+UCD+IND)
SLATTERY 71 UR-875-332(PREP) P.SLATTERY;A REVIEW OF STRANGE MESONS(RCCH)
CARMONY 77 PRD 16 1251 +CLOPP,LANDER,MEIERE,YEN,+ (PURO+UCD+IUPU)
CHLIAPNIK 79 NP B 150 253 CHLIAPNIKOV,GERDYUKOV+ (CERN+BEL+MONS)
CLELAND 80 PL B 89 290 +DELFOSSSE,DRSAZ+(PITT,GEVA,LAUS,CERN,DURH) JP

62 CHARGED D*(2010) BRANCHING RATIOS
R1 D**+(2010) INTO (DO PI+)/TOTAL (P1)
R1 G 0.6 0.15 GOLDHAB2 77 SMAG +- E+E- 12/77
R1 G ASSUMING THAT ISOSPIN IS CONSERVED IN THE DECAY
R2 D**+(2010) INTO (D+ GAMMA)/TOTAL (P2)
R2 0.08 0.07 KIRKBY 79 RVUE E+ E- 12/79*
R3 D**+(2010) INTO (D+ P10)/TOTAL (P3)
R3 G 0.28 0.09 KIRKBY 79 RVUE E+ E- 12/79*

I(2600)

24 I(2600)
THIS ENTRY CONTAINS HIGH-MASS, NARROW STRANGE PEAKS. OMITTED FROM TABLE.

REFERENCES FOR CHARGED D*(2010)
PERUZZI 76 PRL 37 569 +PICCOLO,FELDMAN,NGUYEN,WISS,+ (SLAC+LBL)
FELDMAN 77 PRL 38 1313 +PERUZZI,PICCOLO,ABRAMS,ALAM+ (SLAC+LBL)
PERUZZI 77 PRL 39 1301 +PICCOLO,FELDMAN,PERL,+ (SLAC,LBL,NWES+HAWA)
GOLDBERGER 77 CHICAGO APS G.GOLDBERGER (LBL+SLAC)
GOLDBERGER 77 PL 69 B 503 +WISS,ABRAMS,ALAM,BOYARSKI,+ (LBL+SLAC)

24 I MASS (MEV)
M N 130 2600.0 10.0 APOSTOLAK 77 HBC +- 12PB P,KSPIPIPI 12/77
M N NOT SEEN BY APELDOORN 78 IN THE SAME REACTION AND
M N WITH ABOUT THE SAME STATISTICS, BUT POORER RESOLUTION.
M N THE DISAGREEMENT IS AT A LEVEL OF ABOUT 2 STD.DEV.
M N ALSO NOT SEEN BY WHITMORE 78.

BLIETSCH 79 PL 86 B 108 BLIETSCHAU,+ (AACH+BONN+CERN+MPIM+OXF)
KIRKBY 79 SLAC-PUB 2419 J. KIRKBY (SLAC)

24 I WIDTH (MEV)
W N 130 (10.0) OR LESS APOSTOLAK 77 HBC +- 12PB P,KSPIPIPI 12/77
W N SEE NOTE N ABOVE.

D*0(2010) 61 NEUTRAL D*(2010,JP=1-) I=1/2
J CONSISTENT WITH 1, VALUE 0 RULED OUT (NGUYEN 77).

REFERENCES FOR I
APOSTOLAK 77 PL 66 B 185 APOSTOLAKIS,+ (CERN+MONS+LOIC+BELG+LALO)
APELDOORN 78 PL 72 B 487 APELDOORN,KARIMAKI,+ (AMST+HELSE+LIV+STOH)
WHITMORE 78 PL 76 B 649 +LACH,KITAGAKI,CANTER,+ (MSU+FNAL+TODH+TOFH)

61 NEUTRAL D*(2010) MASS (MEV)
M G 2006. 1.5 GOLDHABE 77 SMAG E+E- 12/77
M G FROM SIMULTANEOUS FIT TO D**+D*0,D+,AND D0.

61 NEUTRAL D*(2010) WIDTH (MEV)
W (5.) OR LESS GOLDHAB2 76 SMAG E+E- TO D*D* 3/77

Mesons

D*0(2010), F±, F*(2140), EXOTICS

Data Card Listings

For notation, see key at front of Listings.

61 NEUTRAL D*(2010) PARTIAL DECAY MODES

Table with columns P1, P2, D*0(2010) INTO DO P10, D*0(2010) INTO DO GAMMA, DECAY MASSES, and values like 1863+ 134, 1863+ 0.

61 NEUTRAL D*(2010) BRANCHING RATIOS

Table with columns R1, R2, D*0(2010) INTO (DO P10)/TOTAL, GOLDHABER 77 SMAG, KIRKBY 79 RVUE, and values like 0.45, 0.15, 12/77, 12/79*.

REFERENCES FOR NEUTRAL D*(2010)

Table listing references for neutral D*(2010) with authors like GOLDHABER, PIERRE, ABRAMS, ALAM, KIRKBY and journal abbreviations like PRL, SLAC CONF, J.

F±

34 F±(2030, JP=) I= SEE STABLE PARTICLE DATA CARD LISTINGS

F*(2140)

74 F*(2140, JP=) I= OMITTED FROM TABLE.

74 F* MASS (MEV)

Table with columns M, 2140.0, 60., BRANDELIK 77 DASP +- E+E-, PI 3 GAMMA, 12/77.

74 (F*+) - (F0) MASS DIFFERENCE (MEV)

Table with columns DM, 110., 46., BRANDELIK 79 DASP +- E+E-, F GAMMA, 12/79*.

74 F* PARTIAL DECAY MODES

Table with columns P1, F* INTO F GAMMA, DECAY MASSES, 2030+ 0.

74 F* BRANCHING RATIOS

Table with columns R1, F* INTO (F GAMMA)/TOTAL, BRANDELIK 77 DASP, (P1) E+E-, 12/77.

REFERENCES FOR F*(2140)

Table listing references for F*(2140) with authors like BRANDELIK, CORDS and journal abbreviations like PRL, PL.

EXOTIC MESON STATES

EXOTICS

50 EXOTICS

THE PURPOSE OF THIS ENTRY IS TO PROVIDE A LIST OF REFERENCES FOR EXOTIC MESON SEARCHES (SEE MAIN TEXT, SEC. 3 AND TABLE 1), AS WELL AS THEORETICALLY BASED SUGGESTIONS FOR EXPERIMENTS. NOTE THAT LIPKIN 73 PROPOSES EXPERIMENTS WHICH ARE CONCLUSIVE EVEN IF NEGATIVE RESULTS ARE OBTAINED.

REFERENCES FOR EXOTICS

REPORTS ON SEARCHES

Table listing references for exotic meson states with authors like ROSENFEL, DODD, CHO, GIACOMELI, ROSNER, BUHL, COHEN, DURUSOY, ALAM, COHEN, OREN, BALTAY, DAVIS, BRUNDIER, BOUCROT, HODGLAND, MOSER, ALAM, ARMSTRON, LEMOIGNE and journal abbreviations like PRL, NP, PRE.

SUGGESTIONS FOR SEARCHES

Table listing suggestions for searches with authors like ROSNER, ROSNER, FAJMAN, LIPKIN, HOLMGREN and journal abbreviations like PRL, EXP, PL, PR.

Data Card Listings

For notation, see key at front of Listings.

Baryons
N's and Δ 'sNote on N's and Δ 'sI. Determination of Resonance Parameters

Values of masses, widths, and branching ratios are obtained mainly from partial-wave analyses. In addition to a few comprehensive partial-wave analyses, there are numerous others which are based on somewhat incomplete data or cover only a limited energy range. We also include some information from production and total cross-section experiments. This can be valuable in establishing the existence of high mass bumps, but at the lower energies these experiments have limited statistics compared to formation experiments and it is seldom clear which of several states at similar masses is being observed.

There are two main problems in obtaining reliable resonance parameters. First there is often disagreement as to just what the values of the partial-wave amplitudes are. This problem is obviously related to the quality and quantity of the data and to the procedures used to determine the amplitudes. Secondly, even if smooth curves were available for the amplitudes, there would still be some parametrization-dependent ambiguity in deciding what the resonance parameters should be. From a theoretical standpoint the most unambiguously defined resonance parameters are the pole position and residue, and it has been found in practice that, given sufficiently precise partial-wave amplitudes, these quantities can be extracted in a stable and parametrization-independent way, in spite of the fact that they require an extrapolation away from the physical region. This point has been discussed in detail with regard to the $\Delta(1232)$ in previous editions of this review.^{1,2} Although the best-determined pole parameters are those of $\Delta(1232)$, there are now a number of determinations for higher lying resonances which are included in the Data Card Listings. In most cases we specify pole parameters by giving the real and imaginary parts of the pole position and residue. It should be kept in mind that these real and imaginary parts tend to be highly correlated. For the residue, in particular, it is often the case that the absolute value is better determined than the phase. For further discussion see the corresponding references, e.g.,

NOGOVA 73, SPEARMAN 74, BALL 75, LICHTENBERG 75, VASAN 76, LONGACRE 77, ZIDELL 78, CUTKOSKY 79, and MIROSHNICHENKO 79.

The following sections of this mini-review contain discussions of various new developments in experimental non-strange baryon spectroscopy. For a thorough discussion of earlier results see our 1978 edition³ and the reviews of K. Lanius⁴ and S. Ozaki.⁵

At the beginning of the Data Card Listings for N's and Δ 's, we present a table giving our evaluation of the status of the N and Δ resonances based on information contained in the Listings. In the Table of Particle Properties, we do not quote values and errors for most parameters, but give only ranges for masses and widths in order to emphasize that in some cases these parameters are quite poorly determined. When in doubt about the reliability of a particular parameter, we choose the range quoted in the Tables to be conservatively large.

References for Section I

1. Particle Data Group, Rev. Mod. Phys. **43**, S114 (1971).
2. Particle Data Group, Phys. Lett. **39B**, 103 (1972).
3. Particle Data Group, Phys. Lett. **75B**, No. 1 (1978).
4. K. Lanius, in Proceedings of the 18th International Conference on High Energy Physics, (Tbilisi, 1976), Vol. I, pg.C45.
5. S. Ozaki, in Proceedings of the 19th International Conference on High Energy Physics, (Tokyo, 1978), pg.101.

For other references see the Data Card Listings.

II. Two-Body Partial-Wave Analyses
and New Resonances

Several new partial-wave analyses have appeared, and older analyses have been published in final form, since our 1978 edition.¹ In the $\pi N \rightarrow \pi N$ reactions we have the analyses of CUTKOSKY 79, HOEHLER 79, HENDRY 78, ZIDELL 78, and Chew.² CUTKOSKY 79 analyzes $\pi N \rightarrow \pi N$ reactions in the mass range 1300-2150 MeV, and supersedes the analysis of CUTKOSKY 76 which concentrated on $I=3/2$ resonances in a narrower range. HOEHLER 79 is the published version

Baryons

N's and Δ 's

Data Card Listings

For notation, see key at front of Listings.

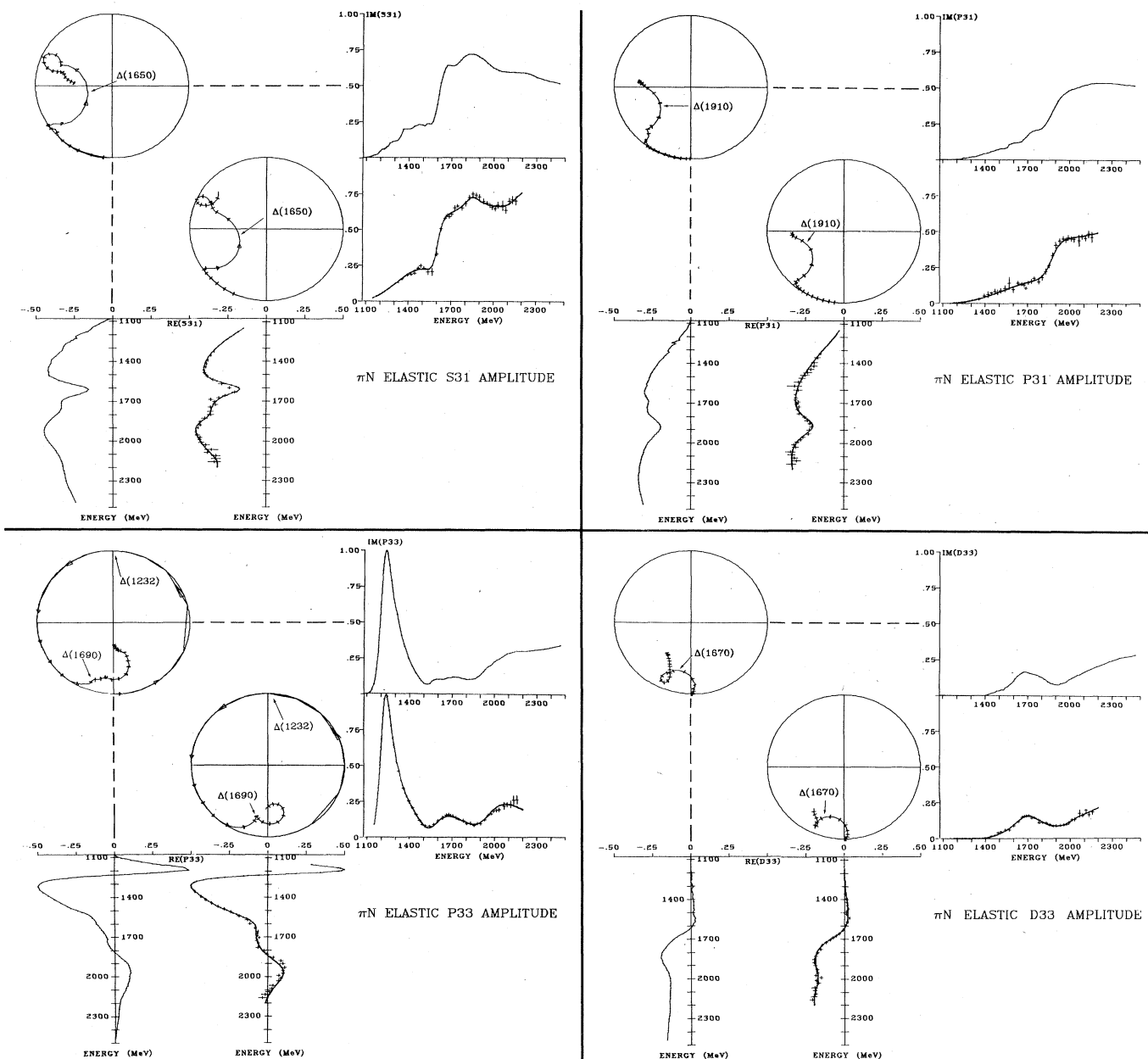


Fig. II.1. Amplitudes for $I=3/2$ πN elastic scattering in the $J=1/2$ and $J=3/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All the energy axes run from elastic threshold to 2500 MeV. The established resonances in these waves are indicated on the Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from CUTKOSKY 79 (results of energy-independent fitting are shown as data points; the curves show an energy-dependent fit). The upper plot for each wave is from HOEHLER 79.

Data Card Listings

For notation, see key at front of Listings.

Baryons

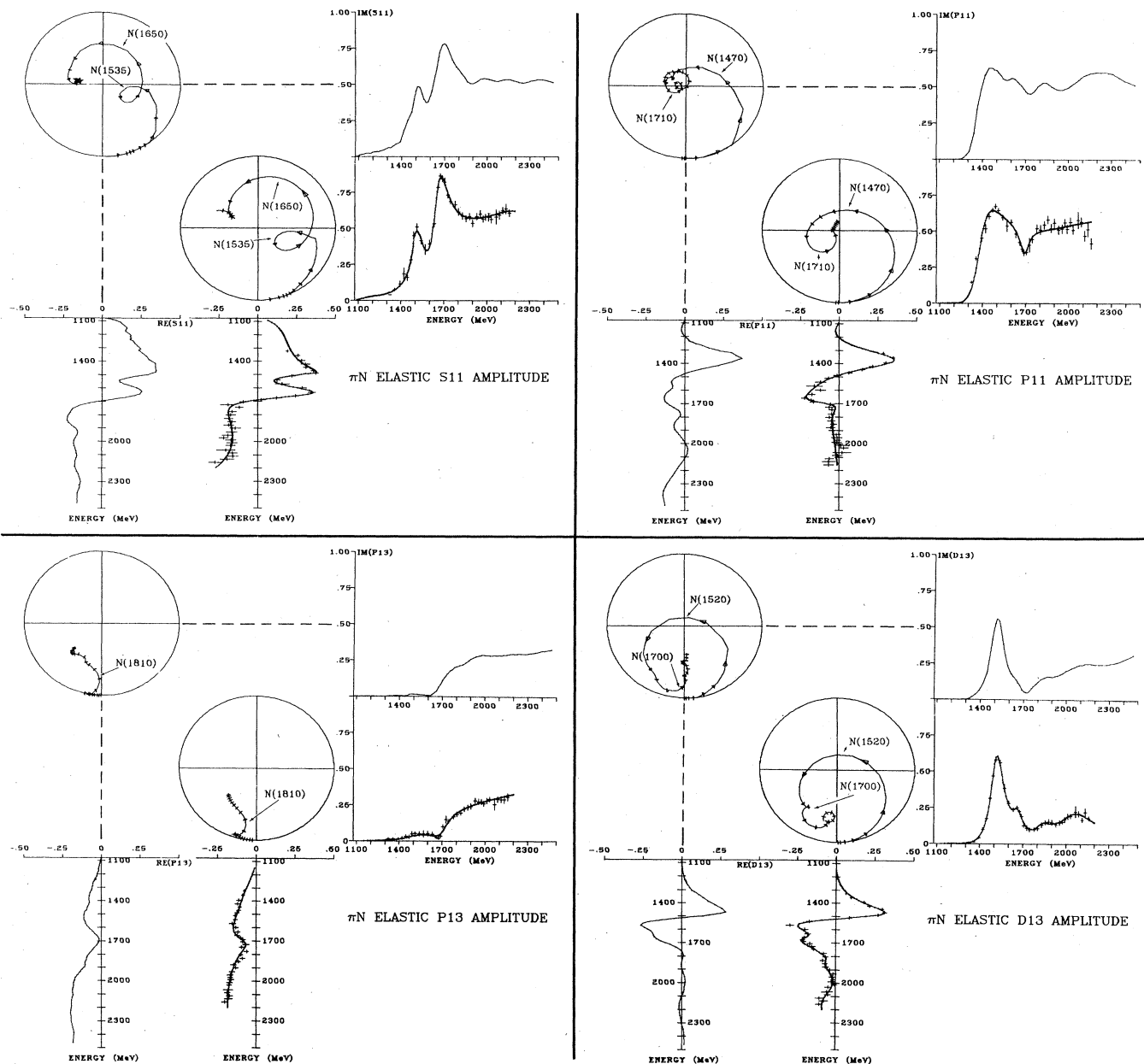
N's and Δ 's

Fig. II.2. Amplitudes for $I=1/2$ πN elastic scattering in the $J=1/2$ and $J=3/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All the energy axes run from elastic threshold to 2500 MeV. The established resonances in these waves are indicated on the Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from CUTKOSKY 79 (results of energy-independent fitting are shown as data points; the curves show an energy-dependent fit). The upper plot for each wave is from HOEHLER 79.

Baryons

N's and Δ 's

Data Card Listings

For notation, see key at front of Listings.

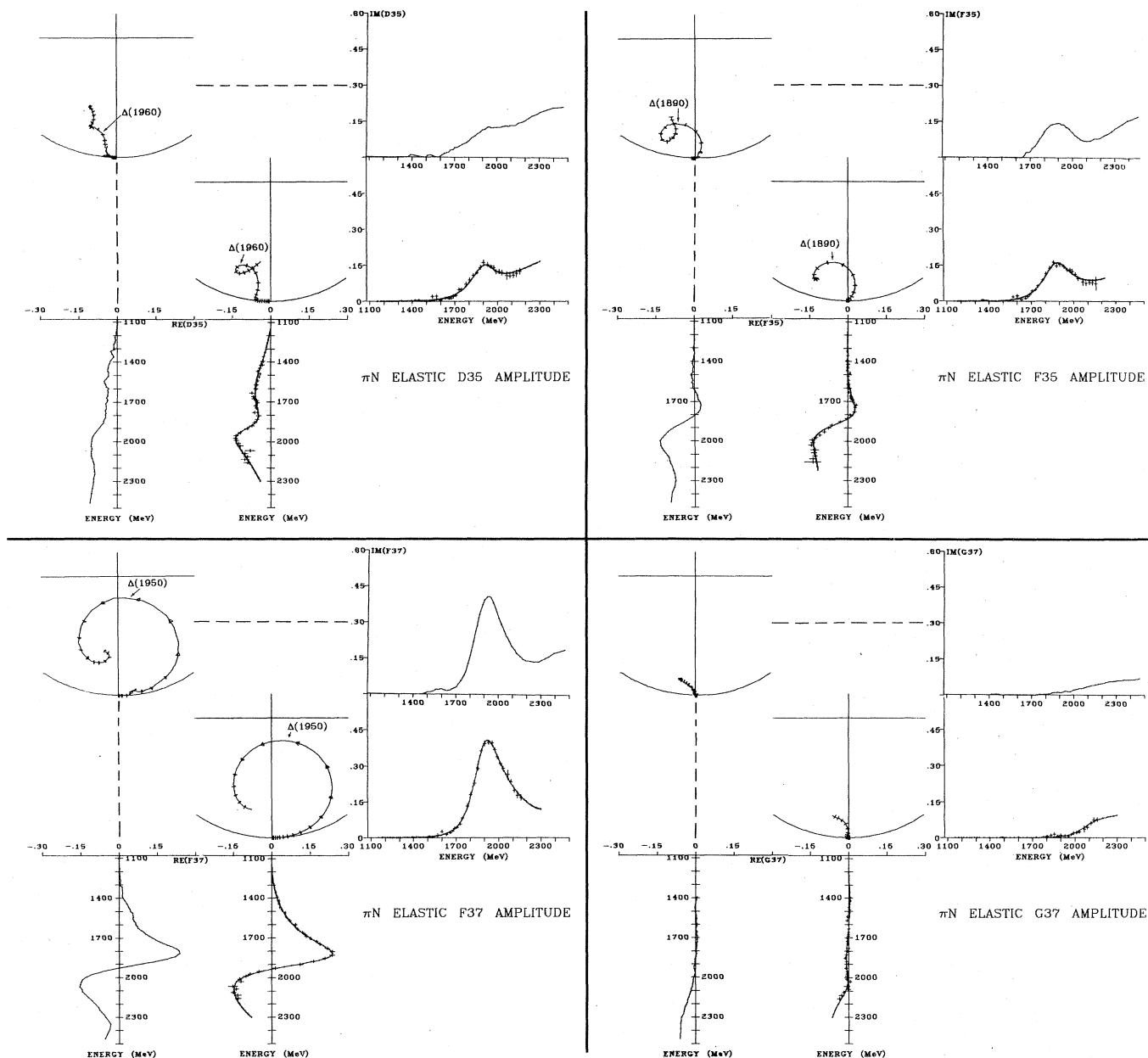


Fig. II.3. Amplitudes for $I=3/2$ πN elastic scattering in the $J=5/2$ and $J=7/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All the energy axes run from elastic threshold to 2500 MeV. The established resonances in these waves are indicated on the Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from CUTKOSKY 79 (results of energy-independent fitting) are shown as data points; the curves show an energy-dependent fit). The upper plot for each wave is from HOEHLER 79.

Data Card Listings

For notation, see key at front of Listings.

Baryons

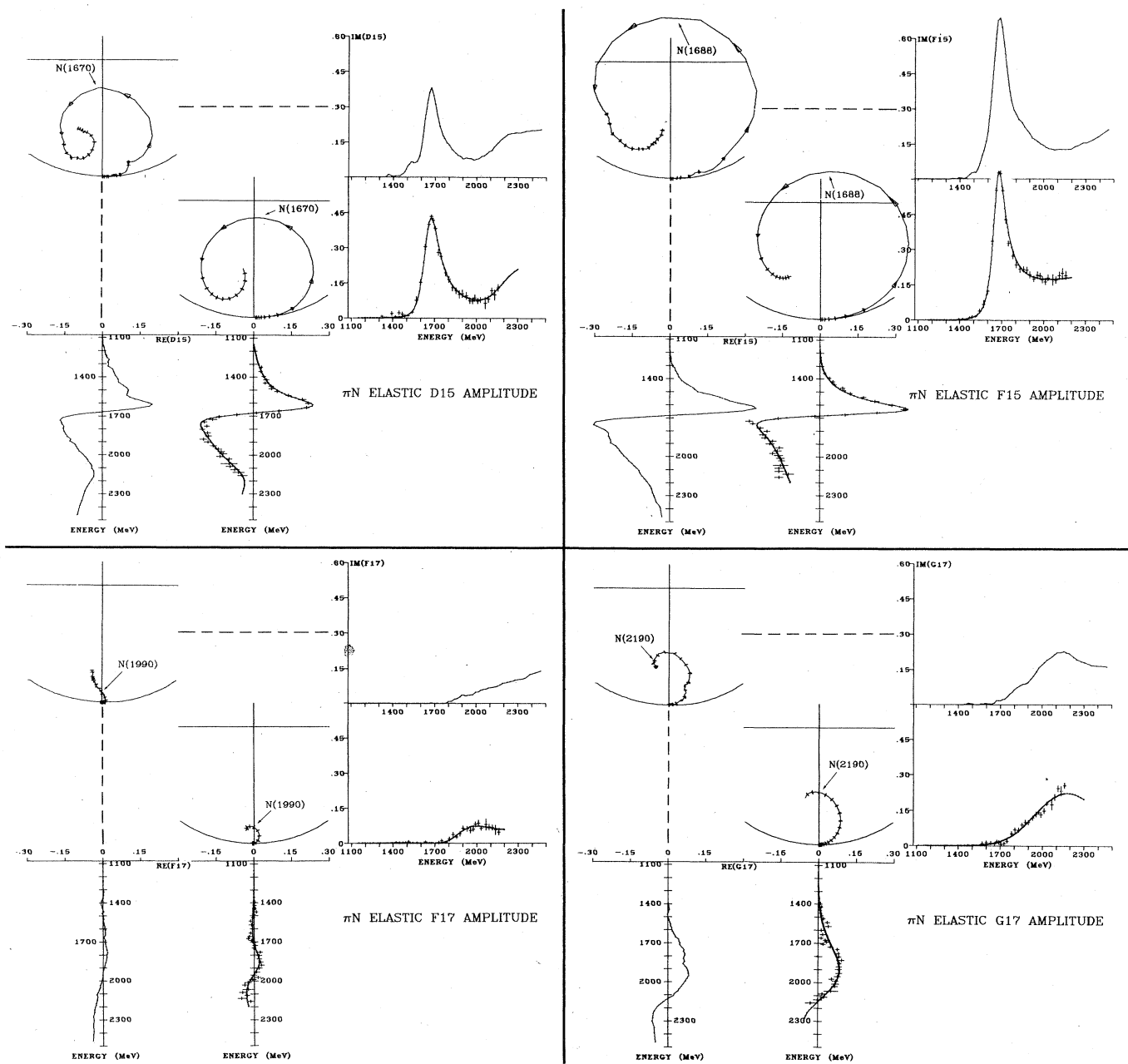
N's and Δ 's

Fig. II.4. Amplitudes for $I=1/2$ πN elastic scattering in the $J=5/2$ and $J=7/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All the energy axes run from elastic threshold to 2500 MeV. The established resonances in these waves are indicated on the Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from CUTKOSKY 79 (results of energy-independent fitting are shown as data points; the curves show an energy-dependent fit). The upper plot for each wave is from HOEHLER 79.

Baryons

N's and Δ 's

Data Card Listings

For notation, see key at front of Listings.

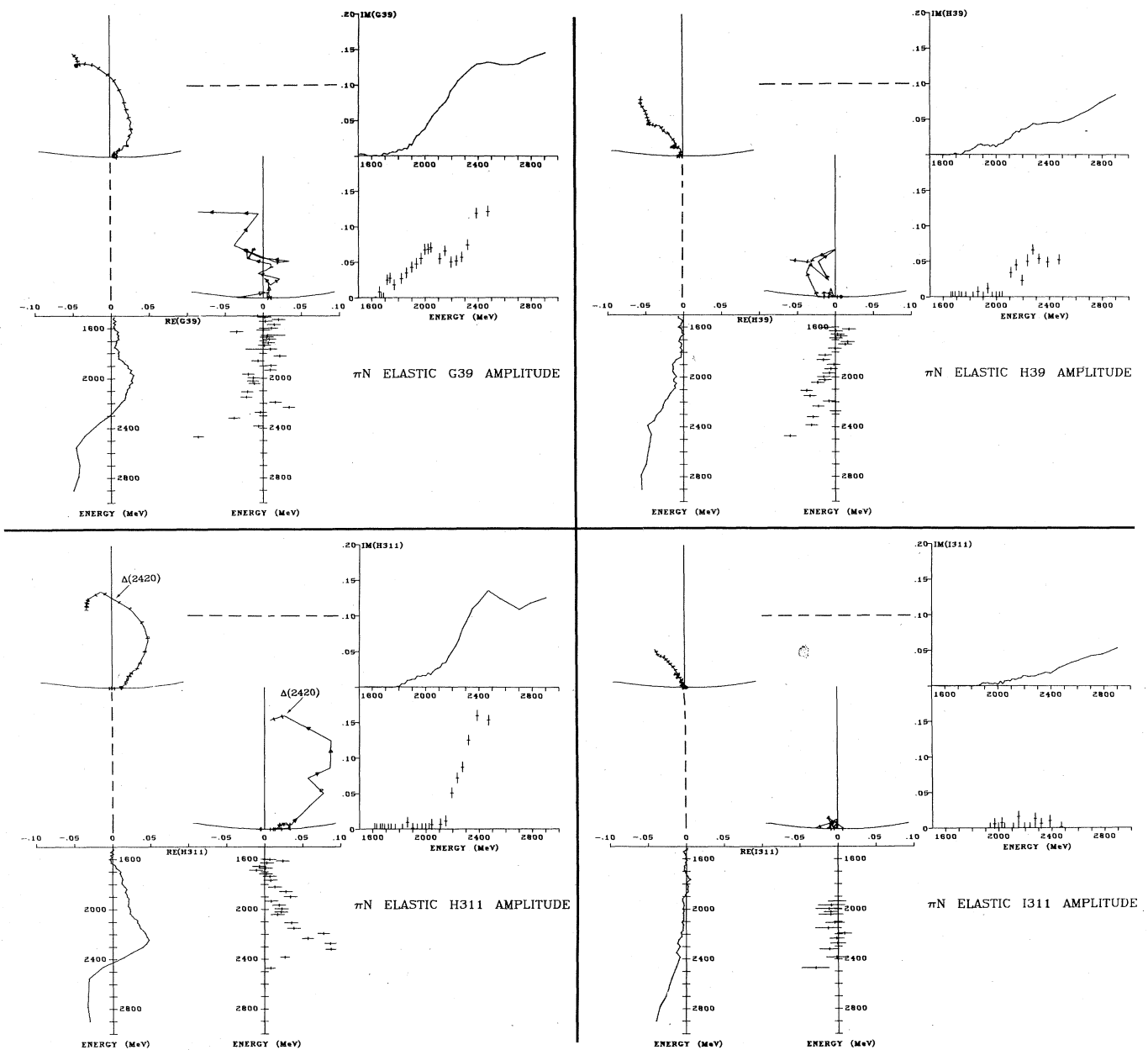


Fig. II.5. Amplitudes for $I=3/2$ πN elastic scattering in the $J=9/2$ and $J=11/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All energy axes run from 1500 to 3000 MeV. The established resonance in the H_{311} wave is indicated on its Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from AYED 76; the upper plot is from HOEHLER 79.

Data Card Listings

For notation, see key at front of Listings.

Baryons

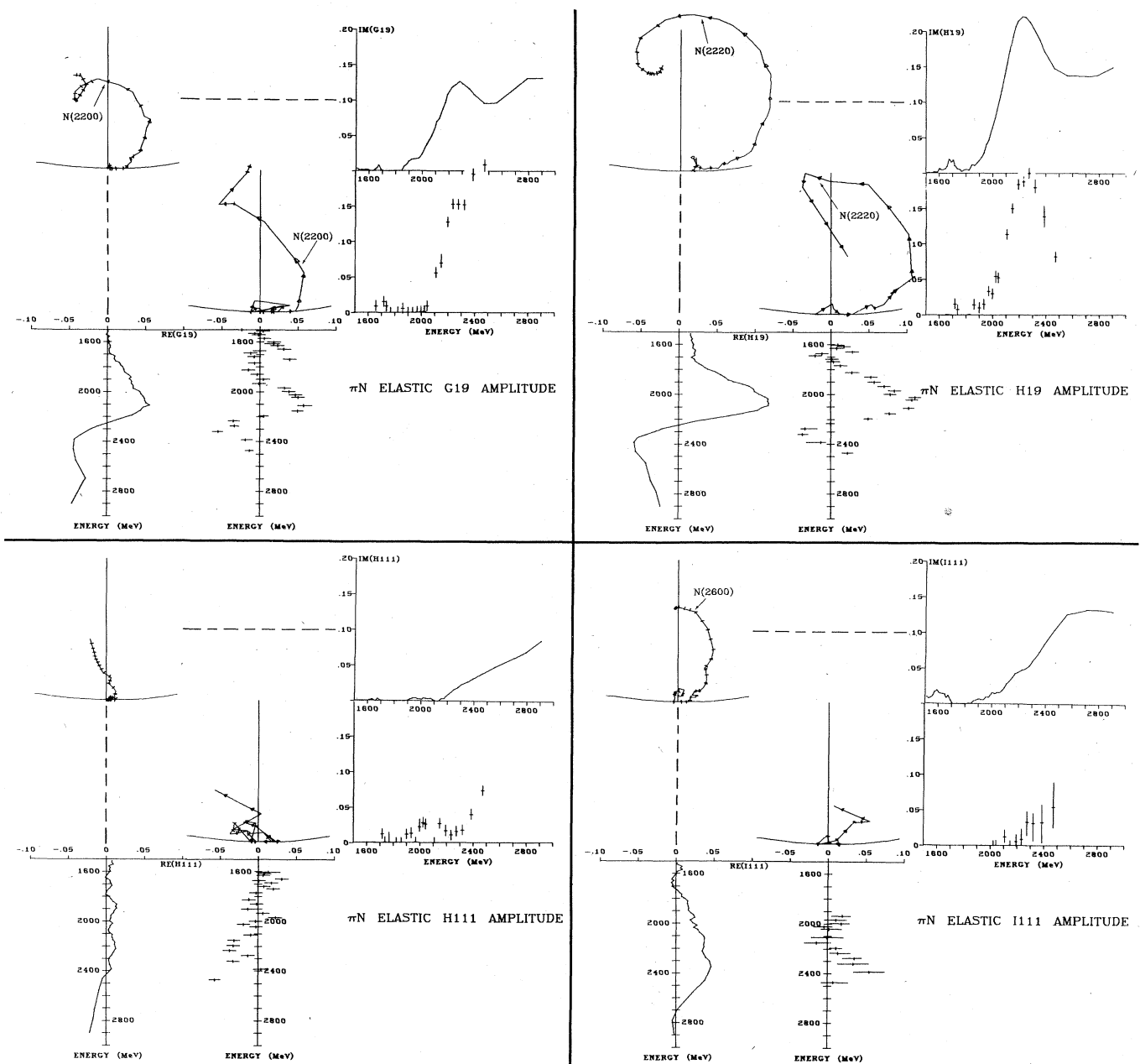
N's and Δ 's

Fig. II.6. Amplitudes for $I=1/2$ πN elastic scattering in the $J=9/2$ and $J=11/2$ waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts vs. energy, in alignment with the corresponding Argand plot. In addition, arrows are plotted on the Argand plots with bases positioned at integer multiples of 50 MeV and a base-to-tip length of 5 MeV. All the energy axes run from 1500 to 3000 MeV. The established resonances in these waves are indicated on the Argand plots. The results of two different analyses are shown; the energy axes for the two analyses are aligned for ease of comparison. The lower Argand plot for each wave is from AYED 76; the upper plot is from HOEHLER 79.

Baryons N's and Δ 's

of the analysis made available to us by Pietarinen³ for our 1978 edition, and referred to there as PIETARINEN 78. This analysis covers a wide range, with claims for resonance masses as large as 3000 MeV. Both CUTKOSKY 79 and HOEHLER 79 make extensive use of analyticity in their parametrizations, but in quite different ways. The analysis of HENDRY 78 concentrates on the most peripheral high-spin, high-mass resonances, and extracts these using a diffractive + peripheral ansatz for the high energy behavior of the $\pi N \rightarrow \pi N$ amplitudes in the impact-parameter representation. Resonances with spin as high as $21/2$ and mass as high as 4100 MeV are reported. At lower energies ZIDELL 78 report new determinations of the Δ^0 and Δ^{++} pole positions, and Chew² uses a Barrelet-zero technique to analyze $\pi^+ p \rightarrow \pi^+ p$ data below 2300 MeV.

Two analyses of inelastic reactions have also been reported. BAKER 79 analyzes $\pi^- p \rightarrow \eta n$ between 1500 and 2250 MeV, and SAXON 80 analyzes $\pi^- p \rightarrow K^0 \Lambda$ below 2300 MeV. Both are energy-dependent analyses in which the existence (and sometimes the masses and widths) of N resonances are taken from $\pi N \rightarrow \pi N$ analyses, and the couplings to the inelastic reaction are determined.

In 1978 we added five new N and Δ resonances to the Baryon Table (see Ref. 1). These have been strengthened by more recent results, and two have been promoted to 4-star status. This year we are adding one more nucleon resonance, the F17 N(1990). The results of CUTKOSKY 79 and HOEHLER 79 for this resonance are illustrated in Fig. II.4. It was also observed by BAKER 79, but not by SAXON 80.

An important change within the Listings, which does not yet appear in the Table, is the further clarification of the P33 amplitude in the range 1500-2000 MeV. The $\Delta(1690)$ was added to the Table in 1978, and it seemed likely that there was another P33 resonance near 2000 MeV. Most of the evidence for this effect was contained in the rather confused listing for the $\Delta(2160)$. This year we have been able to extract the information relevant to the P33 partial wave from $\Delta(2160)$, combine it with newer information from CUTKOSKY 79 and HOEHLER 79, and list the new 2-star P33 resonance $\Delta(1960)$. Another important change in the Listings this year is the addition of many 1-star high-spin, high-mass

Data Card Listings

For notation, see key at front of Listings.

resonances from the analyses of HOEHLER 79 and HENDRY 78.

References for Section II

1. Particle Data Group, Phys. Lett. **75B**(1) (1978).
 2. D. M. Chew, LBL-5306 and LBL-10075 (1979).
 3. E. Pietarinen, private communication (1978).
- For other references see the Data Card Listings.

III. The $\pi N \rightarrow \pi \pi N$ Channel

In general, the $2 \rightarrow 3$ -body process, $ab \rightarrow cde$, is described by the center-of-mass energy, W , three angles, $\alpha, \beta,$ and γ , and two subenergies, w_{cd} and w_{de} . Thus, unlike $2 \rightarrow 2$ -body reactions, fits at single values of W cannot be parametrized in terms of a set of constants without introducing some assumptions into the analysis. All fits to $\pi N \rightarrow \pi \pi N$ use the isobar model, which notes that almost all events for the reaction lie in bands for quasi-two-body processes in the Dalitz plot. It is therefore assumed that there is no pure three-body interaction and that the reaction proceeds by the formation of a two-body state which decays into three bodies.

The basic form used is

$$T(\pi N \rightarrow \pi \pi N) = \sum \left\{ \begin{aligned} &T_{\Delta\pi}^{JILL'}(W) BW_{\Delta}(w_{\pi N}) X_{\Delta\pi}^{JILL'} \\ &+ T_{N^*\pi}^{JILL'}(W) BW_{N^*}(w_{\pi N}) X_{N^*\pi}^{JILL'} \\ &+ T_{\rho N}^{JILL'}(W) BW_{\rho}(w_{\pi\pi}) X_{\rho N}^{JILL'} \\ &+ T_{\epsilon N}^{JILL'}(W) BW_{\epsilon}(w_{\pi\pi}) X_{\epsilon N}^{JILL'} \end{aligned} \right\},$$

where in present analyses $\Delta = \Delta(1232)$, $N^* = N^*(1470)$, $\rho = \rho(770)$, and ϵ is the S-wave, $I=0$ $\pi\pi$ enhancement (although not all the isobars may be included in the different analyses). Here, BW denotes the appropriate Breit-Wigner or corresponding two-body amplitude from πN or $\pi\pi$ analyses, and X is a well-defined function containing all the angular information. The decay of the resonances formed in the reaction is given by the partial-wave amplitudes, $T_{\Delta\pi}^{JILL'}$, etc., with J giving the total angular momentum and I the total isospin of the state formed. L and L' are respectively the orbital angular momenta of the initial two-body and final quasi-two-body states. $\vec{J} = \vec{L} + \vec{S} = \vec{L}' + \vec{S}'$, with S and S' as the initial and final total spins. In the

Data Card Listings

For notation, see key at front of Listings.

Baryons
N's and Δ 's

case of the ρN amplitude, it is necessary to add the suffix 2S', equal to 1 or 3, to indicate the total ρN spin. The partial-wave amplitudes are frequently denoted by $\Delta L L' 2I 2J$, $N^* L L' 2I 2J$, ρ_{2S} , $L L' 2I 2J$, and $\epsilon L L' 2I 2J$.

The Data Card Listings contain the results of four analyses.

LONGACRE 75 (LBL-SLAC) is an analysis using 200K events for $\pi^- p \rightarrow \pi^- \pi^0 p$, $\pi^- \pi^+ n$ and $\pi^+ p \rightarrow \pi^+ \pi^0 p$ with $1300 \text{ MeV} \leq W \leq 2000 \text{ MeV}$. Approximate unitarity constraints are imposed in the form of a simplified K-matrix formalism that links the $\pi\pi N$ channel to the πN channel. This gives smooth solutions and eliminates the overall phase ambiguity that can occur at each energy. The $\Delta\pi$, ρN , and ϵN isobar states are included. Couplings and T-matrix pole positions are given for 14 resonances. A fuller description is given in the 1974 edition of Review of Particles Properties.

LONGACRE 77 (Saclay) is a coupled-channel analysis similar to LONGACRE 75 that fits 100K events for $1380 \text{ MeV} \leq W \leq 1740 \text{ MeV}$. The couplings and pole positions of 16 resonances are measured including those of the $P_{13}(1540)$ and $P_{31}(1550)$, which are suggested for the first time in this analysis and have not yet been seen in any other channel.

NOVOSELLER 78 (California Inst. of Technology) is an analysis of $\pi^- p \rightarrow \pi^- \pi^0 p$, $\pi^- \pi^+ n$ and $\pi^+ p \rightarrow \pi^+ \pi^0 p$ for $1630 \text{ MeV} \leq W \leq 1990 \text{ MeV}$, based on the LBL-SLAC energy-independent analysis.¹ Again the $\Delta\pi$, ρN , and ϵN isobar states are used, but the resonances are fitted by a simple Breit-Wigner rather than the K-matrix formalism of LONGACRE 75. This analysis considers the criticism made of earlier analyses that they ignore the effects of one-pion-exchange with $\pi\pi$ rescattering. This is used to calculate the higher partial waves, and it is concluded that it improves the fit for $W \geq 1800 \text{ MeV}$ and helps eliminate the phase ambiguity. Another study of the importance of one-pion-exchange has been made by Aaron et al.,² who also find that it can give important corrections to the angular dependence. NOVOSELLER 78 quotes two solutions, the second including the effects of π exchange. They are given in the Data Card Listings as, respectively, fits to LONGACRE 75 and NOVOSELLER 78.

BARNHAM 79 (see also Ref. 3) is an analysis at Imperial College, London, of 44K events for $\pi^+ p \rightarrow \pi^+ \pi^0 p$, $\pi^+ \pi^+ n$ for $1440 \text{ MeV} \leq W \leq 1700 \text{ MeV}$, thus concentrating on the Δ resonances and using data not available to the other analyses. It considers that the reaction proceeds by the $\pi\Delta$, ρN , and $\pi N^*(1470)$ isobar states, the last one being necessary to account for the difference between the $\pi^+ \pi^0 p$ and $\pi^+ \pi^+ n$ cross sections. Also included is the effect of one-pion-exchange leading to the S-wave $\pi\pi$ state with $I=2$. The phase ambiguity is resolved by requiring the $\pi\Delta$ amplitude for the $D_{33}(1670)$ to have a Breit-Wigner phase. The parameters of four resonances are evaluated, including the $P_{31}(1550)$, but since some of the data used are also used by LONGACRE 77 it is not clear that the existence of this resonance is confirmed.

It is difficult to assess the accuracy with which the couplings of the resonances to the final isobar states are known, but those that are indicated in the Data Card Listings as being considered well determined in LONGACRE 77 do, in general, at least agree in sign with the values from other analyses, although some of the ρ_3 couplings have not been measured elsewhere. The group at Imperial College also claim to get a clear measurement of the signs of $\rho_1 SS31$, $\rho_1 DD33$, and $N^* PP33$.

All existing isobar models can be criticized because they neglect possible subenergy dependence of the partial-wave amplitudes and because it can be shown⁴ that this is not consistent with unitarity. This problem has been studied by Aitchison and Brehm,⁵ who derive an isobar expansion that is consistent with Bose symmetry and with subenergy analyticity and unitarity. The resulting coupled integral equations are suitable for both dynamical and phenomenological studies of $\pi N \rightarrow \pi\pi N$. They estimate the subenergy corrections to the isobar model and conclude that such corrections may not be significant for existing isobar fits but could become important with improved experimental data.⁶ A rough estimate of these corrections has also been made by the Imperial College group,³ who find that they are small.

References for Section III

1. D.J.Herndon, R.Longacre, L.R.Miller, A.H.Rosen-

Baryons N's and Δ 's

Data Card Listings

For notation, see key at front of Listings.

- feld, G.Smadja, P.Söding, R.J.Cashmore, and D.W.G.S.Leith, Phys. Rev. D11, 3183 (1975).
2. R.Aaron, R.D.Amado, R.A.Arndt, Y.Goradia, D.C.Teplitz, and V.L.Teplitz, Phys. Rev. D16, 50 (1977).
 3. K.W.J.Barnham, in Proceedings of the Topical Conference on Baryon Resonances, Oxford, 1976, edited by R.T.Ross and D.H.Saxon, pg.109.
 4. R.Aaron and R.D.Amado, Phys. Rev. Lett. 31, 1157 (1973).
 5. I.J.R.Aitchison and J.J.Brehm, Phys. Rev. D20, 1119 (1979).
 6. I.J.R.Aitchison and J.J.Brehm, Phys. Rev. D20, 1131 (1979).

IV. Photon Couplings

IVa. Photoproduction

The couplings of ΥN to N^* and Δ resonances can be studied in any formation process in which the coupling to the final strong decay channel is well known. In practice, this limits the sources of such couplings to the analysis of single-pion photoproduction, for which the final state has been extensively studied in the phase-shift analysis of elastic πN scattering. There are also more experimental data for single-pion photoproduction than for any other photoproduction reactions. All analyses rely heavily on information from πN elastic phase-shift analyses for values of the masses and widths of the resonances. These are fitted in only a few photoproduction analyses, and even in these it is necessary to rely on the πN phase-shift analyses for a prior knowledge of the existence of a resonance and for starting values for its mass and width. However, the photoproduction results are of interest since they give information for the resonance states with charge of +1.

The most important analyses of single-pion photoproduction are reviewed below. The formalism has been previously described¹ and readers are referred there for additional information. There are three basic methods of analysis. All have had to cope with the difficulty of having four independent complex spin amplitudes at any energy and production angle, and of having only up to four independent experimental measurements. The recent measurements of the G and H observables² have not

yet been used in any analysis.

(a) Simple Isobar Model

This is the simplest form of energy-dependent analysis. The partial waves are parametrized as a smooth background to which Breit-Wigner resonant structure is added. Usually, the electric, but not magnetic, Born terms are included explicitly to reproduce the forward peak in charged-pion production. This method is sufficiently flexible to give excellent fits to the experimental data, but there are, in principle, difficulties concerning the uniqueness of the solution due to the large number of partial waves that are involved. This is overcome by the form of the parametrization, but it is not clear how this may bias the solution. The most extensive analysis of this type is METCALF 74, which is an extension of the earlier Walker analysis.³ It fits $\Upsilon p \rightarrow \pi^+ n$, $\pi^0 p$ and $\Upsilon n \rightarrow \pi^- p$ from the first to the fourth resonance region. FELLER 76 fits only $\Upsilon p \rightarrow \pi^+ n$ and $\pi^0 p$ from the first to the third resonance region but uses data not available to the earlier analysis. Other isobar analyses (ROSSI 73, HEMM1 73, HEMM2 73, BENEVENTANO 74, and KRIVETS 74⁴) have been made on a significantly smaller scale using small and sometimes restricted data sets.

(b) Fixed-t Dispersion Relations (FTDR)

This technique uses the apparent resonant dominance of the photoproduction amplitudes to get a relatively simple parametrization of their imaginary parts. Fixed-t dispersion relations are used to calculate the real parts without the introduction of other free parameters, or, in some cases, with only a relatively small number of additional parameters. This significantly reduces the possibility of multiple solutions and automatically satisfies the requirements of analyticity. However, the method is relatively inflexible compared to the isobar model, giving poorer fits. Also, as has been described in NOELLE 78 and elsewhere,⁵ the divergence of the partial-wave expansions for the dispersion integrals does not allow the use of experimental data at all angles above about the third resonance region. Not all analyses include the constraints of unitarity and time-reversal invariance as given

Data Card Listings

For notation, see key at front of Listings.

Baryons
N's and Δ 's

by Watson's theorem.⁶

FTDR analyses have been made by groups at Berkeley (MOORHOUSE 73, KNIES 74, and MOORHOUSE 74), at Lancaster (DEVENISH 73, DEVENISH2 74), at Glasgow (CRAWFORD 75, BARBOUR 76, and BARBOUR 78) and at Yerevan (AZNAURYAN 77). NOELLE 78 is a hybrid analysis incorporating FTDR in a coupled-channel isobar model.

(c) Energy-Independent Analysis

These evaluate the partial waves by making independent fits over a range of essentially single energies, and are thus the least biased of all the techniques employed. It is necessary to use Watson's theorem to fix the complex phases of the partial waves in order to get a unique solution. Due to inelasticity, this becomes difficult above the first resonance region, and only BERENDS 77 extends into the second resonance region. This analysis suggests in particular that the $A_{3/2}^p$ coupling for the D_{13}^+ (1520) from the energy-dependent analyses is too large by a factor of almost two due to the omission of non-resonant background.

New Analyses in the Data Card Listings

AZNAURYAN 77 is an FTDR analysis of $\gamma p \rightarrow \pi^0 p$ from threshold to a laboratory photon energy of 1.2 GeV. NOELLE 78, as described, is a hybrid isobar and FTDR analysis of the first and second resonance regions. BARBOUR 78 is an FTDR analysis that combines a partial-wave analysis for center-of-mass energies, W , up to 2.5 GeV with an amplitude analysis at higher energies to reduce the uncertainty in the FTDR from the high energy parts of the dispersion integrals. Data at all accelerator energies are fitted, and, as in the other Glasgow analyses, the resonance masses and widths are evaluated with the couplings. MIROSHNICHENKO 79 is based on an earlier energy-independent analysis⁷ and measures the pole position of the Δ^+ , P_{33} (1232), resonance.

Resonance Couplings and Errors
in the Data Card Listings

The Data Card Listings give the results of all recent and extensive analyses. If no error is given, only a unique result has been quoted. The Berkeley analyses and CRAWFORD 75 give for the errors the spread of solutions around a central value. The

TABLE IV.1. The average of the couplings from MOORHOUSE 74, KNIES 74, METCALF 74, DEVENISH2 74, FELLER 76, BERENDS 77, and BARBOUR 78. The errors take into account both statistical errors and the variation of values over the analyses. Where no error is shown, it is considered that there are too few analyses to make a reliable estimate.

Resonance	Helicity	Helicity Couplings (GeV) ^{-1/2} × 10 ⁻³	
		A_{λ}^p	A_{λ}^n
P_{11}^+ (1470)	1/2	-77 ± 10	35 ± 22
D_{13}^+ (1520)	1/2	-11 ± 8	-75 ± 15
	3/2	151 ± 37	-131 ± 17
S_{11}^+ (1535)	1/2	60 ± 19	-56 ± 33
D_{15}^+ (1670)	1/2	20 ± 12	-30 ± 26
	3/2	20 ± 11	-54 ± 27
F_{15}^+ (1688)	1/2	-4 ± 16	24 ± 11
	3/2	133 ± 23	-20 ± 20
S_{11}'' (1700)	1/2	45 ± 21	-22 ± 17
D_{13}'' (1700)	1/2	-15 ± 35	-4 ± 45
	3/2	8 ± 25	12 ± 30
P_{11}'' (1780)	1/2	2 ± 40	9 ± 50
P_{13}'' (1810)	1/2	33 ± 54	9 ± 40
	3/2	-39 ± 43	-10 ± 55
F_{17} (1990)	1/2	40 ± ?	-69 ± ?
	3/2	4 ± ?	-72 ± ?
G_{17} (2190)	1/2	-30 ± ?	-85 ± ?
	3/2	180 ± ?	7 ± ?
		Δ_{λ}	
P_{33}^+ (1232)	1/2	-141 ± 7	
	3/2	-259 ± 10	
S_{31}^+ (1650)	1/2	39 ± 45	
D_{33} (1670)	1/2	63 ± 43	
	3/2	58 ± 39	
P_{33}'' (1690)	1/2	-8 ± 20	
	3/2	-7 ± 25	
F_{35} (1890)	1/2	35 ± 20	
	3/2	-7 ± 60	
P_{31}'' (1910)	1/2	-14 ± 23	
F_{37} (1950)	1/2	-71 ± 15	
	3/2	-101 ± 45	
D_{35} (1960)	1/2	-62 ± ?	
	3/2	19 ± ?	

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Lancaster group give as an error the change of value for each coupling that is required to increase the "best possible" χ^2 by 1%. METCALF 74, FELLER 76, and AZNAURYAN 77 quote similar errors. In BARBOUR 78, the point of view is taken that the systematic variations due to the different methods of analyses are at least as significant as the purely statistical errors that are usually given. Thus, the errors quoted are obtained by comparison with other analyses as well as from the random variation of the parameters over a number of fits.

In the compilation of couplings given in Table IV.1, the errors given are calculated in a similar manner from both the statistical errors quoted in the analyses used and from the spread of results over the analyses.

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IVb. Electroproduction in the Resonance Region (by F. Foster, Lancaster University, April 1978)

Both the quantity and quality of the data continue to improve in this interesting but somewhat unfashionable corner of the ν , Q^2 plane. Most experiments now use the coincidence technique: detecting the scattered electron to fix the energy and momentum transfer, together with one of the final state hadrons (p, π^\pm). By this method the virtual photoproduction differential cross sections for particular exclusive channels can be determined.

At the date of the 1976 Review many excellent data sets were already available. These included π^0 production in the first resonance region from DESY,^{1,2} the Lancaster-Manchester group at Daresbury,³ and Bonn University.⁴ There was

Data Card Listings

For notation, see key at front of Listings.

also good π^0 data in the second resonance region⁵ and forward π^+ data in the second and third resonance regions from Lancaster-Manchester.⁶ Much interest was generated by the η data from Daresbury, DESY, and Bonn, which is a unique indicator for the S'_{11} (1535) resonance.⁷⁻⁹ The total cross-section measurements from DESY,¹⁰ Bonn,¹¹ and Stanford¹² gave essential information on the Q^2 variation of the resonance "peak" heights in relation to the background, and demonstrated that the longitudinal-to-transverse ratio σ_L/σ_T was everywhere very close to zero.

During the past two years much new information has become available. In particular we have the detailed data sets from DESY on single π^+ and π^0 production in the second and third resonance regions^{13,14} at Q^2 values of 0.6 and 1.0 GeV^2 , and new η data near the S'_{11} (1535) from DESY^{15,16} at 0.6, 1.0, 2.0, and 3.0 GeV^2 and Bonn¹⁷ at Q^2 of 0.4 GeV^2 . By changing the virtual photon polarization, both groups have succeeded in measuring the longitudinal excitation of the S_{11} resonance with the results: $\sigma_L/\sigma_T = 0.15 \pm 0.18$ ($Q^2 = 0.6$),¹⁵ -0.06 ± 0.16 ($Q^2 = 1.10$),¹⁶ 0.16 ± 0.10 ($Q^2 = 0.4$).¹⁷ The Lancaster-Manchester group has taken a large amount of data on π^- and π^+ production from a deuterium target over the second and third resonance regions at Q^2 values 0.5 and 1.0 GeV^2 . From this data it will be possible to extract the differential cross sections $\gamma_\nu n \rightarrow p\pi^-$, which are essential to the understanding of the multipole couplings to the isospin-1/2 resonances. Preliminary data were available at the Hamburg conference¹⁸ for the π^-/π^+ ratio at $Q^2 = 0.5$ GeV^2 in the forward direction, and estimates were presented of the neutral D'_{13} (1520) multipole couplings.¹⁹

Theoretical analyses of the data sets to extract resonance multipole couplings necessarily rely on fixed- t dispersion-relation calculations which relate the real (background) and imaginary (resonant) parts of these matrix elements. R. C. E. Devenish and D. H. Lyth²⁰ incorporated the constraints into an energy-dependent fitting procedure and produced the first estimates of second and third resonance multipoles up to $Q^2 = 1.5$ GeV^2 using the Lancaster-Manchester^{5,6} and preliminary DESY π^0 , π^+ , and η data together with

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For notation, see key at front of Listings.

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total cross-section measurements. Since then, Gayler²¹ has used the final DESY data in the same fitting routines and has produced improved results on the couplings to the S'_{11} (1535), D'_{13} (1520), F'_{15} (1688), and P'_{11} (1470) resonances.

The present status of the couplings to the more prominent resonant states may be summarized as follows:

P'_{33} (1232): There is no change from previous reviews. However, Gayler remarks²¹ that while the resonance appears to be a dominantly magnetic (quark spin flip) excitation, the background, which forms an increasing fraction of the single-pion cross section as Q^2 increases, is dominantly helicity-1/2 in the $\gamma_{\nu p}$ system. This is to be expected on the basis of the quark parton model and duality.

D'_{13} (1520): It is firmly established^{6,13,14,21} that the transverse helicity-1/2 excitation increases rapidly as Q^2 increases from 0 to 1.0 GeV^2 . The rate of increase observed depends on the details of the fitting procedures used, but is consistent with the magnetic coupling falling slowly and the electric coupling falling like a "dipole," almost as one would expect from a naive harmonic oscillator quark model.²²

S'_{11} (1535): The new data¹⁴⁻¹⁷ establish beyond doubt that the excitation of this resonance falls less rapidly than its SU(6) partner D'_{13} (1520) and the excitation is dominantly transverse. At $Q^2 = 0$, contributions of the D'_{13} and S'_{11} are in the ratio 4:1, while at $Q^2 = 3.0 \text{ GeV}^2$ the ratio becomes an amazing 1:2. Thus the second resonant peak in total cross-section measurements at high Q^2 is dominated by the S'_{11} (1535) - this may account for possible small changes in the observed shape as Q^2 increases.

P'_{11} (1470): The situation here is fluid; although there are no clear signals for this resonance, some analyses²¹ do require a significant contribution at $Q^2 = 1.0 \text{ GeV}^2$. New π^0 and π^+ data from Lancaster-Manchester below the second resonance and from DESY at high Q^2 may clarify the position.

F'_{15} (1688): Here again the helicity-1/2 to helicity-3/2 ratio is observed to increase with Q^2 as we expect from the quark model.

Some progress has been made in understanding the phenomenology of resonance electroproduction within the framework of SU(6)_w symmetry.²³ Cashmore et al.,²⁴ for example, have shown that radiative transitions between the nucleon and members of the $\{70, 1^-\}$ multiplet are consistent with only three independent amplitudes, corresponding to quark orbit flip, spin flip, and simultaneous spin-orbit excitation. (Note that the spin-orbit term is normally neglected in "naive" quark model calculations.²²) It is necessary to find out if this relatively simple structure persists as Q^2 increases and, if it does, to determine the Q^2 variation of the three amplitudes. Using mainly the amplitudes connecting the proton and the charged D'_{13} and S'_{11} resonances, Foster²⁵ and Alcock et al.²⁶ have shown that all three excitation terms are necessary to describe electroproduction at Q^2 values up to 1 GeV^2 . The orbit flip term falls rapidly, while the spin flip term remains almost constant as Q^2 increases (just like the simple quark model predictions), causing the observed helicity change-over. The spin-orbit term has an intermediate variation with Q^2 and appears to be influential in causing the S'_{11} to dominate the D'_{13} at Q^2 values above 0.5 GeV^2 . To be sure that the three terms are sufficient to describe electroproduction of the $\{70, 1^-\}$ multiplet we will have to await accurate determination of more charged resonance multipoles or some measurements of the neutral isospin-1/2 resonance multipoles. The preliminary data from Lancaster-Manchester^{18,19} on the process $\gamma_{\nu n} \rightarrow \pi^- p$ near the second resonance give results for M_{2-}^n and E_{2-}^n which are in fair agreement with the SU(6)_w scheme.²⁵

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V. Production Experiments

It is difficult to draw firm conclusions about N and Δ resonance properties from production experiments because each prominent bump seen in production is generally a coherent superposition of several resonances plus non-resonant background. However, production and formation experiments are clearly closely related, and we give parameters obtained from production experiments in the Listings, although they are not used in the Tables. This section contains a brief review of the main results of recent N and Δ production experiments. We concentrate on diffractive production of πN and $\pi\pi N$ systems as this is where most of the recent experimental activity has been.

Data on the exclusive channels $NN \rightarrow NN\pi$ and

Data Card Listings

For notation, see key at front of Listings.

$NN\pi\pi$ at high energy are now available, both from FNAL (BIEL 78) and the CERN ISR (WEBB 75, DEKERRET 76, and GOGGI 79). Double diffraction dissociation reactions have also been studied at the ISR (GOGGI 78). The diffractively produced πN and $\pi\pi N$ systems have mass shapes which are remarkably similar to those observed at lower momenta.

The low mass πN system is dominated by a broad bump peaking around 1.35 GeV, on which may be superimposed other structures at 1.5 and 1.7 GeV. The 1.35 GeV bump is produced more peripherally than those at 1.5 and 1.7 GeV (DEKERRET 76, HARRIS 77, BIEL 78, and CHADWICK 78). The two higher mass peaks are probably associated with the $D_{13}^+(1520)$ and $F_{15}^+(1688)$, respectively.

There is mounting evidence for an appreciable $J^P = 1/2^-$ component in low mass $N \rightarrow N\pi$ diffractive dissociation. This is in violation of the Gribov-Morrison rule which would allow only $1/2^+$, $3/2^-$, $5/2^+$, etc. The reactions $\pi^\pm p \rightarrow \pi^\pm(p\pi^0)$ and $\pi^\pm(n\pi^+)$ have been analyzed by OCHS 75 at 14 GeV/c and OTTER 77 at 16 GeV/c [who included data on $\pi^\pm p \rightarrow \pi^0(p\pi^\pm)$]. In each case the data were fitted with coherent sums of diffractive and Δ -production amplitudes. Both analyses concluded that there is significant diffractive production of $1/2^-$ background for πN masses below 1.3 - 1.4 GeV. Moreover, the diffractively produced πN system could be described completely by $1/2^-$ and $3/2^+$ waves only (i.e., both Gribov-Morrison violating), although a sizeable $3/2^-$ contribution could not be excluded. SOTIRIOU 75 also analyzed $\pi^\pm p \rightarrow \pi^\pm(n\pi^+)$ at 16 GeV/c for $n\pi^+$ masses below 2 GeV. In addition to enhancements associated with known resonances, a 200-MeV broad bump at 1.35 GeV was found. The J^P determination at low mass was not completely unambiguous, but the bump appears to be predominantly $1/2^-$ below 1.35 GeV, and predominantly $1/2^+$ above. RUSHBROOKE 76 analyzed data on $np \rightarrow (p\pi^-)p$ from 9 to 24 GeV/c. They used a Deck-plus-resonances parametrization and found broad resonance signals in both the $1/2^-$ and $1/2^+$ waves at about 1.4 GeV, as well as a large $1/2^-$ Deck contribution peaking below 1.3 GeV. In STRACHMAN 75 the t-channel isospin-0 and isospin-1 parts of $\bar{N}N \rightarrow \bar{N}(N\pi)$ at 5.7 GeV/c were separated and the $I_t = 1$ $N\pi$ mass spectrum found to contain known resonance peaks, while the $I_t = 0$

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For notation, see key at front of Listings.

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spectrum had only a broad bump centered at 1.35 GeV.

The low mass $\pi\pi N$ system exhibits a broad enhancement below 2 GeV on which subsidiary peaks are superimposed at around 1.5 and 1.7 GeV. The production characteristics are consistent with diffraction.

Partial-wave analyses of diffractively produced $\pi\pi N$ systems have recently been carried out by CARNEY 76, BACON 77, HEINEN 77, IDSCHOK 78, and OTTER 78. All these analyses use bubble chamber data in the medium energy range. CARNEY 76 use a compilation of data on $K^+p \rightarrow K^+(p\pi^+\pi^-)$ between 7.3 and 16 GeV/c. The reaction $K^-p \rightarrow K^-(p\pi^+\pi^-)$ is studied by HEINEN 77 at 4.2 GeV/c and by OTTER 78 at 10, 14.3, and 16 GeV/c. BACON 77 analyze the 10 and 16 GeV/c data of OTTER 78 together with $\pi^{\pm}p \rightarrow \pi^{\pm}(p\pi^+\pi^-)$ at 8, 16, and 23 GeV/c. IDSCHOK 78 study $pp \rightarrow p(p\pi^+\pi^-)$ at 12 and 24 GeV/c.

All the analyses agree that the low mass $\pi\pi N$ system can be adequately described assuming a dominant contribution from partial waves having spin-parities $J^P = 1/2^+$, $3/2^-$, and $5/2^+$, and having $\Delta\pi$, $p\pi$, and, to a less extent, pp decay modes only. CARNEY 76 require $J \geq 7/2$ above about 1.7 GeV. BACON 77 cannot rule out alternative solutions completely in terms of partial waves in the series $J^P = 1/2^-, 3/2^+, 5/2^-, \text{etc.}$, although this conclusion is not supported by CARNEY 76. OTTER 78 find evidence for a small contribution (of order 20%) from $5/2^-(\ell=2)\Delta\pi$ in the mass region 1.60 - 1.75 GeV in addition to partial waves satisfying the Gribov-Morrison rule. The shape of the $5/2^-$ enhancement is consistent with a Breit-Wigner form ($M=1.67$ GeV, $\Gamma=0.15$ GeV) and is interpreted as evidence for production of D_{15}^+ (1670).

It seems clear that the enhancement at 1.5 GeV is predominantly $3/2^-(\ell=0)\Delta\pi$, although other partial waves such as $1/2^+(\ell=0)p\pi$ are contributing in this region. No evidence for a resonant nature of the 1.5 GeV enhancement could be obtained from studies of relative phases (BACON 77, HEINEN 77, IDSCHOK 78, and OTTER 78).

The situation concerning the peak at 1.7 GeV is more complex in that the different analyses come to different conclusions as to the detailed spin-parity decomposition. However, all analyses do

agree that $5/2^+$ is not the only contribution, and thus the enhancement cannot be completely associated with the F_{15}^+ (1688). CARNEY 76 are unable to conclusively identify all the waves contributing to the enhancement, but both $3/2^-(\ell=1)p\pi$ and $3/2^-(\ell=2)\Delta\pi$ are strong. On the other hand, BACON 77 find that $1/2^+(\ell=0)p\pi$ is important in the 1.7 GeV region, together with $3/2^-(\ell=1)p\pi$, $3/2^-(\ell=2)\Delta\pi$, and $5/2^+(\ell=1)\Delta\pi$. HEINEN 77 also find that spin-parity $1/2^+$ contributes, but that the decay mode is $(\ell=1)\Delta\pi$. In addition, $3/2^-(\ell=1)p\pi$ and $5/2^+(\ell=2)p\pi$ are present. Spin-parity $5/2^+$ is the most important contribution to the data of IDSCHOK 78 above 1.6 GeV, but $3/2^-(\ell=1)p\pi$ is also significant. No partial wave exhibits a phase variation. OTTER 78 also conclude that the 1.7 GeV enhancement is composed of several partial waves with spin-parities $1/2^+$ (or $1/2^-$ - the analysis cannot distinguish the two possibilities in this region), $3/2^-$, and $5/2^+$ all contributing, as well as $5/2^-(\ell=2)\Delta\pi$.

The production of the different spin-parity states depends very differently on four-momentum transfer (IDSCHOK 78). Thus the apparent disagreement concerning the exact nature of the 1.7 GeV enhancement could be due in part to the different regions of four-momentum transfer used by the various analyses.

It is interesting to note that the Gribov-Morrison rule appears to be reasonably well satisfied for diffractively produced $\pi\pi N$ systems, in contrast to the situation for πN diffraction dissociation. This could be connected with the fact that the Deck mechanism is expected to be important at low mass and that the major contribution is to S-wave states. Thus S-wave $\Delta\pi$ ($J^P = 3/2^-$) and $p\pi$ ($1/2^+$) both give rise to spin-parities in the "allowed" series, whereas S-wave πN ($1/2^-$) does not. A similar situation occurs in three-meson diffractive production, where the "allowed" series is dominant.

References for Section V

See the Data Card Listings.

Baryons

N's and Δ's, p, n, N(1470)

Data Card Listings

For notation, see key at front of Listings.

***** STATUS OF N* RESONANCES

THOSE WITH AN OVERALL STATUS OF *** OR **** ARE INCLUDED IN THE MAIN BARYON TABLE. THE OTHERS AWAIT CONFIRMATION.

STATUS AS SEEN IN --

Table with columns: PARTICLE, LIJ, OVERALL STATUS, TOTAL CR.S., PI N, ETA N, K LAM, K SIG, PI DE, GAM N, OTHER CHANN. Lists various baryon resonances like N(939), N(1470), N(1520), etc.

Table with columns: DEL, LIJ, OVERALL STATUS, TOTAL CR.S., F, R, B, I, D, E, N. Lists decuplet resonances like DEL(1232)P33, DEL(1550)P31, etc.

**** GOOD, CLEAR, AND UNMISTAKABLE.
*** GOOD, BUT IN NEED OF CLARIFICATION OR NOT ABSOLUTELY CERTAIN.
** NEEDS CONFIRMATION.
* WEAK.
ATTRIBUTED TO THE STATE CLOSEST TO WHERE THE CROSS SECTION PEAKS.

S=0 I=1/2 NUCLEON STATES (N)

p

16 PROTON(938, J=1/2) I=1/2

SEE STABLE PARTICLE DATA CARD LISTINGS

n

17 NEUTRON(939, J=1/2) I=1/2

SEE STABLE PARTICLE DATA CARD LISTINGS

N(1470)

61 N*1/2(1470, JP=1/2+) I=1/2

P11

MASS AND WIDTH ARE BEST DETERMINED FROM PARTIAL WAVE ANALYSES. WE LIST PRODUCTION EXPERIMENTS SEPARATELY -- SEE BELOW.

AYED 76 CLAIMS TWO P11 STATES IN THE 1500 MEV REGION. WE TENTATIVELY LIST BOTH HERE.

61 N*1/2(1470) MASS (MEV)

Table with columns: M, LIJ, MASS, BRANDSEN, ROPER, BAREYRE, DONNACHI, AYED, FROM ENER. DEP., DAVIES, ALMEHED, CRANFORD, LONGACRE. Lists mass and production data for N(1470).

Table with columns: M, LIJ, MASS, AYED, DONNACHI, BAREYRE, LONGACRE, FROM SOLUTION, POSITION WHICH IS FROM SOLUTIONS, SUPERSEDES, BAKER, CUTKOSKY, HOEHLER. Lists resonance data for N(1470).

61 N*1/2(1470) WIDTH (MEV)
Table with columns: W, LIJ, MASS, BAREYRE, DONNACHI, AYED, DAVIES, ALMEHED, CRANFORD, LONGACRE, BAREYRE, BAKER, CUTKOSKY, HOEHLER. Lists width data for N(1470).

61 N*1/2(1470) REAL PART OF POLE POSITION (MEV)
Table with columns: RE, LIJ, MASS, LEE, LONGACRE, CUTKOSKY. Lists real part of pole position data for N(1470).

61 N*1/2(1470) -2*IMAG PART OF PCLE POSITION (MEV)
Table with columns: IM, LIJ, MASS, LEE, LONGACRE, CUTKOSKY. Lists imaginary part of pole position data for N(1470).

61 N*1/2(1470) REAL PART OF ELASTIC POLE RESIDUE (MEV)
Table with columns: RER, LIJ, MASS, CUTKOSKY. Lists real part of elastic pole residue data for N(1470).

61 N*1/2(1470) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
Table with columns: IMR, LIJ, MASS, CUTKOSKY. Lists imaginary part of elastic pole residue data for N(1470).

61 N*1/2(1470) ABSOLUTE VALUE OF POLE RESIDUE (MEV)
Table with columns: ABS, LIJ, MASS, LEE. Lists absolute value of pole residue data for N(1470).

61 N*1/2(1470) PHASE OF POLE RESIDUE (RADIAN)
Table with columns: PH, LIJ, MASS, LEE. Lists phase of pole residue data for N(1470).

61 N*1/2(1470) PARTIAL DECAY MODES
Table with columns: P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12. Lists partial decay modes for N(1470).

61 N*1/2(1470) BRANCHING RATIOS
Table with columns: R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12. Lists branching ratios for N(1470).

Data Card Listings

For notation, see key at front of Listings.

Baryons

N(1470)

Table of particle data cards for N(1470) baryons, including columns for ID, description, parameters, and references.

61 N*1/2(1470) PHOTON DECAY AMPL(GEV**1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECA AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table of photon decay amplitudes for N*1/2(1470) baryons, listing helicity and amplitude values.

A1 N*1/2(1470) INTO GAM N, HELICITY=1/2 (GEV**1/2)

Table of gamma decay amplitudes for N*1/2(1470) baryons, listing helicity and amplitude values.

REFERENCES FOR N*1/2(1470)

Table of references for N*1/2(1470) baryons, listing author names and journal information.

Table of particle data cards for N(1470) baryons, including columns for ID, description, parameters, and references.

THE FOLLOWING ARE THEORETICAL PAPERS CONCERNING THE N*1/2(1470) --

1470 MEV REGION - PRODUCTION EXPERIMENTS

91 N*1/2(1470, JP=) I=1/2 PRODUCTION EXPERIMENTS UNDER THIS HEADING WE INCLUDE ALL BUMPS WHICH LIE WELL BELOW 1500 MEV. SEE THE MINI-REVIEW PRECEDING THE N AND DELTA LISTINGS FOR A DISCUSSION OF PRODUCTION EXPERIMENTS.

Table of production experiments for N(1470) baryons, listing experiment names, energies, and results.

Baryons

N(1470), N(1520)

Data Card Listings

For notation, see key at front of Listings.

Table listing particle properties for N(1470) and N(1520) with columns for mass, width, and various decay modes.

Table listing particle properties for N(1470) and N(1520) with columns for mass, width, and various decay modes.

Table titled '91 N*1/2(1470) WIDTH (MEV) (PROD. EXP.)' showing width measurements and production cross-sections.

Table titled '91 N*1/2(1470) PARTIAL DECAY MODES (PROD. EXP.)' showing branching ratios and decay channels.

Table titled '91 N*1/2(1470) BRANCHING RATIOS (PROD. EXP.)' showing branching ratios for various decay modes.

Table titled '62 N*1/2(1520) MASS (MEV)' showing mass measurements and cross-sections.

Table titled 'REFERENCES FOR N*1/2(1470) (PROD. EXP.)' listing references for production experiments.

Table titled '62 N*1/2(1520) WIDTH (MEV)' showing width measurements and production cross-sections.

Data Card Listings

For notation, see key at front of Listings.

Baryons
N(1520)

62 N*1/2(1520) REAL PART OF POLE POSITION (MEV) 11/75				
RE	(1514.)	LONGACRE	75 IPWA	PI N TO 2PI N
RE 8	1508. OR 1505.	LONGACRE	77 IPWA	PI N TO 2PI N
RE	(1510.)	CUTKOSKY	79 IPWA	PI N TO PI N

62 N*1/2(1520) -2*IMAG PART OF POLE POSITION (MEV) 11/75				
IM	(146.)	LONGACRE	75 IPWA	PI N TO 2PI N
IM 8	109. OR 107.	LONGACRE	77 IPWA	PI N TO 2PI N
IM	(114.)	CUTKOSKY	79 IPWA	PI N TO PI N

62 N*1/2(1520) REAL PART OF ELASTIC POLE RESIDUE (MEV) 12/79*				
RER	(34.)	CUTKOSKY	79 IPWA	PI N TO PI N

62 N*1/2(1520) IMAG PART OF ELASTIC POLE RESIDUE (MEV) 12/79*				
IMR	(-8.)	CUTKOSKY	79 IPWA	PI N TO PI N

62 N*1/2(1520) PARTIAL DECAY MODES				
P1	N*1/2(1520) INTO PI N			DECAY MASSES
P2	N*1/2(1520) INTO N*3/2(1232) PI			139+ 938
P3	N*1/2(1520) INTO N PI P1			1232+ 139
P4	N*1/2(1520)+ INTO NEUTRON PI+			938+ 139+ 139
P5	N*1/2(1520)+ INTO PROTON PI+ PI-			938+ 139+ 139
P6	N*1/2(1520) INTO N ETA			939+ 548
P7	N*1/2(1520) INTO N EPSILON			938+1300
P8	N*1/2(1520) INTO N RHO			938+ 776
P9	N*1/2(1520) INTO GAM P, HELICITY=1/2			0+ 938
P10	N*1/2(1520) INTO GAM P, HELICITY=3/2			0+ 938
P11	N*1/2(1520) INTO GAM N, HELICITY=1/2			0+ 939
P12	N*1/2(1520) INTO GAM N, HELICITY=3/2			0+ 939
P13	N*1/2(1520) INTO K LAMBDA			49+1115
P14	N*1/2(1520) INTO N*3/2(1232) PI, S-WAVE			1232+ 139
P15	N*1/2(1520) INTO N*3/2(1232) PI, D-WAVE			1232+ 139
P16	N*1/2(1520) INTO N RHO, S=3/2, S-WAVE			938+ 776

62 N*1/2(1520) BRANCHING RATIOS				
R1	N*1/2(1520) INTO (PI N)/TOTAL	(P1)		
R1 1	(0.54)	BAREYRE	68 RVUE	11/67
R1 3	(0.509)	DONNACHI	68 RVUE	6/68
R1 6	(0.593)	AYED	70 IPWA	1/71
R1 4	(0.45)	DAVIES	70 RVUE	8/69
R1 7	(0.58)	ALMEHED	72 IPWA	2/72
R1	(.56)	AYED	76 IPWA	11/77
R1	.56	CUTKOSKY	79 IPWA	12/79*
R1	.54	HOEHLER	79 IPWA	12/79*

R1 SEE THE NOTES ACCOMPANYING THE MASSES QUOTED.
R1 ALMOST THE ENTIRE INELASTICITY IS IN N PI PI (ONLY N ETA COULD COMPETE, R1 AND IT DOESN'T). THE N PI PI SEEMS TO BE MAINLY N*3/2(1232) PI, IN BOTH R1 S AND D WAVES.

R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

R2	N*1/2(1520) INTO (N*3/2(1232) PI)/TOTAL	(P4)		
R2	0.20	KIRZ	66 HBC	0 ASSUMING R1=0.72
R2	0.05	OLSSON	66 RVUE	PI P TO PI PI N
R2 D	0.40	DIEM	70 IPWA	3 BODY ANALYSIS
R2 D	0.5			1/71

R3	N*1/2(1520) INTO (N*3/2(1232) PI)/(N PI PI)	(P2)/(P3)		
R3	LARGE	THURNAUER	65 RVUE	-
R3	LARGE	NAVYSLAWS	66 RVUE	-
R3	LARGE	ROBERTS	67 RVUE	-
R3	LARGE	ROSENFELD	67 RVUE	-
R3	LARGE	MORGAN	68 RVUE	ISOBAR MODEL

R4	N*1/2(1520) INTO (N EPSILON)/TOTAL	(P7)		
R4	PROBABLY PRESENT	MORGAN	68 RVUE	ISOBAR MODEL
R4 D	0.02	DIEM	70 IPWA	3 BODY ANALYSIS
R4 D	0.5			1/71

R5	N*1/2(1520) INTO (N ETA)/TOTAL	(P6)		
R5 D	0.06	DAVIES	67 RVUE	
R5 D	0.06	DAVIES	67 RVUE	11/67
R5 B	(0.014)	BOTKE	69 MPWA	T POLE+ RESON.
R5 B	(0.005)	DEANS	69 MPWA	T POLE+ RESON.
R5 B	(0.002) OR 0.004	CARRERAS	70 MPWA	T POLE+ RESON.
R5 B	PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING	LEMOIGNE	73 DPWA	1488 TO 1685 MEV

R6	N*1/2(1520) INTO (N RHO)/TOTAL	(P8)		
R6 D	0.07	DIEM	70 IPWA	3 BODY ANALYSIS
R6 D	0.5			1/71

R7	N*1/2(1520) FROM PI N TO K LAMBDA	SQRT(PI*PI13)		
R7 C	-0.76	DEVENISH	74	0 FIXED T DISP REL
R7 C	0.32			4/75
R7 C	0.32			4/75

R8	N*1/2(1520) FROM PI N INTO N EPSILON	SQRT(PI*PI7)		
R8 L	(0.01) OR +17	LONGACRE	75 IPWA	PI N TO 2PI N
R8 L	(+1.3)	LONGACRE	77 IPWA	PI N TO 2PI N

R9	N*1/2(1520) FROM PI N TO N*3/2(1232) PI, S-WAVE	SQRT(PI*PI14)		
R9 L	(+2.7) OR +24	LONGACRE	75 IPWA	PI N TO 2PI N
R9 L	(+2.6)	LONGACRE	77 IPWA	PI N TO 2PI N
R9 L	LONGACRE 77			CONSIDER THIS COUPLING TO BE WELL DETERMINED.

R10	N*1/2(1520) FROM PI N TO N*3/2(1232) PI, D-WAVE	SQRT(PI*PI15)		
R10 L	(+2.4) OR +30	LONGACRE	75 IPWA	PI N TO 2PI N
R10 L	(+2.1)	LONGACRE	77 IPWA	PI N TO 2PI N
R10 L	LONGACRE 77			CONSIDER THIS COUPLING TO BE WELL DETERMINED.

R11	N*1/2(1520) FROM PI N TO N RHO, S=3/2, S-WAVE	SQRT(PI*PI16)		
R11 L	(+3.2) OR +24	LONGACRE	75 IPWA	PI N TO 2PI N
R11 L	(+35)	LONGACRE	77 IPWA	PI N TO 2PI N
R11 L	LONGACRE 77			CONSIDER THIS COUPLING TO BE WELL DETERMINED.

R12	N*1/2(1520) FROM PI N TO ETA N	SQRT(PI*PI6)		
R12 9	(+0.11) OR +.058	FELTESSE	75 DPWA	0 1488 TO 1745 MEV
R12 9	SUPERSEDES LEMOIGNE 73, USES M AND W OF	AYED 76;		11/77
R12	(.02)	BAKER	79 DPWA	0 PI - P TO ETA N

62 N*1/2(1520) PHOTON DECAY AMPL(GEV**1/2)
FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

A1	N*1/2(1520) INTO GAM P, HELICITY=1/2 (GEV**1/2)			
A1	0.10	DEVENISH	73 DPWA	PI N PHOTO PROD
A1	(-0.26)	HEMMIL	73	+ FWD PIO PHTOPROD
A1	-0.26	MOORHOUSE	73 DPWA	PI N PHOTO-PROD
A1	-0.09	DEVENISH	74 DPWA	PI N PHOTO-PROD
A1	-0.19	KNIES	74 DPWA	PI N PHOTO PROD
A1	-0.06	METCALF	74 DPWA	PI N PHOTO-PROD
A1	-0.00	MOORHOUSE	74 DPWA	PI N PHOTO-PROD
A1	-0.09	CRAWFORD	75 DPWA	PI N PHOTO-PROD
A1	(+0.11)	KRIVETS	75 DPWA	PI N PHOTO-PROD
A1	(-0.12)	BARBOUR	76 DPWA	PI N PHOTO-PROD
A1	-0.05	FELLER	76 DPWA	PI N PHOTO-PROD
A1	-0.00	AZNAURYAN	77 DPWA	PIO PHTPRD, SOL 1
A1	-0.30	AZNAURYAN	77 DPWA	PIO PHTPRD, SOL 2
A1	(-0.21)	BERENDES	77 IPWA	PI-N PHOTO-PROD
A1 A	-0.16	BARBOUR	78 DPWA	PI-N PHOTO-PROD
A1 N	(-0.08)	NOELLE	78	PI-N PHOTO-PROD
A1 N	CONVERTED TO OUR CONVENTIONS USING M=1.528, W=.187 FROM NOELLE 78.			1/80*
A1	AVERAGE MEANINGLESS (SCALE FACTOR = 3.5)			

A2	N*1/2(1520) INTO GAM P, HELICITY=3/2 (GEV**1/2)			
A2	-0.180	DEVENISH	73 DPWA	PI N PHOTO PROD
A2	+0.194	KNIES	73 DPWA	PI N PHOTO-PROD
A2	-0.171	DEVENISH	74 DPWA	PI N PHOTO-PROD
A2	-0.169	KNIES	74 DPWA	PI N PHOTO PROD
A2	+0.165	METCALF	74 DPWA	PI N PHOTO-PROD
A2	-0.174	MOORHOUSE	74 DPWA	PI N PHOTO-PROD
A2	+0.162	CRAWFORD	75 DPWA	PI N PHOTO-PROD
A2	(+1.38)	KRIVETS	75 DPWA	PI-N PHOTO-PROD
A2	(+1.58)	BARBOUR	76 DPWA	PI N PHOTO-PROD
A2	+0.164	FELLER	76 DPWA	PI N PHOTO-PROD
A2	+0.182	AZNAURYAN	77 DPWA	PIO PHTPRD, SOL 1
A2	+0.133	AZNAURYAN	77 DPWA	PIO PHTPRD, SOL 2
A2	(+0.075)	BERENDES	77 IPWA	PI-N PHOTO-PROD
A2 A	-0.077	BARBOUR	78 DPWA	PI-N PHOTO-PROD
A2 N	(-2.06)	NOELLE	78	PI-N PHOTO-PROD
A2 N	CONVERTED TO OUR CONVENTIONS USING M=1.528, W=.187 FROM NOELLE 78.			1/80*
A2	AVERAGE MEANINGLESS (SCALE FACTOR = 4.1)			

A3	N*1/2(1520) INTO GAM N, HELICITY=1/2 (GEV**1/2)			
A3	-0.75	DEVENISH	73 DPWA	PI N PHOTO PROD
A3	-0.085	MOORHOUSE	73 DPWA	PI N PHOTO-PROD
A3 2	+0.37	ROSSI	73 DPWA	0 GAM N TO PI - P
A3 2	CONVERTED TO OUR CONVENTIONS USING M AND W FROM ROSSI 73 AND X=.56			4/75
A3	(0.)	BENEVENT	74 DPWA	0 GAM N TO PI - R
A3	-0.089	DEVENISH	74 DPWA	PI N PHOTO-PROD
A3	-0.077	KNIES	74 DPWA	PI N PHOTO PROD
A3	-0.066	METCALF	74 DPWA	PI N PHOTO-PROD
A3	-0.088	MOORHOUSE	74 DPWA	PI N PHOTO-PROD
A3	-0.067	CRAWFORD	75 DPWA	PI N PHOTO-PROD
A3	(-0.056)	BARBOUR	76 DPWA	PI N PHOTO-PROD
A3 A	-0.055	BARBOUR	78 DPWA	PI-N PHOTO-PROD
A3 N	(-0.60)	NOELLE	78	PI-N PHOTO-PROD
A3 N	CONVERTED TO OUR CONVENTIONS USING M=1.528, W=.187 FROM NOELLE 78.			1/80*
A3	AVERAGE MEANINGLESS (SCALE FACTOR = 3.6)			

A4	N*1/2(1520) INTO GAM N, HELICITY=3/2 (GEV**1/2)			
A4	-0.126	DEVENISH	73 DPWA	PI N PHOTO PROD
A4	(-0.87)	HEMMIL	73	0 GAM N TO PI 0
A4 8	CONVERTED TO OUR CONVENTIONS USING M AND W FROM WALKER 69 AND X=.56			4/75
A4 2	-0.16	ROSSI	73 DPWA	0 GAM N TO PI - P
A4 2	-0.124	MOORHOUSE	73 DPWA	PI N PHOTO-PROD
A4 5	(-0.35)	BENEVENT	74 DPWA	0 GAM N TO PI - P
A4 5	CONVERTED TO OUR CONVENTIONS USING M=1.520 MEV, W=120 MEV, X=.56			4/75
A4	-0.155	DEVENISH	74 DPWA	PI N PHOTO-PROD
A4	-0.120	KNIES	74 DPWA	PI N PHOTO PROD
A4	-0.118	METCALF	74 DPWA	PI N PHOTO-PROD
A4	-0.119	MOORHOUSE	74 DPWA	PI N PHOTO-PROD
A4	-0.133	CRAWFORD	75 DPWA	PI N PHOTO-PROD
A4 A	(-1.36)	BARBOUR	76 DPWA	PI N PHOTO-PROD
A4 A	-0.141	BARBOUR	78 DPWA	PI-N PHOTO-PROD
A4 N	(-1.27)	NOELLE	78	PI-N PHOTO-PROD
A4 N	CONVERTED TO OUR CONVENTIONS USING M=1.528, W=.187 FROM NOELLE 78.			1/80*
A4	AVERAGE MEANINGLESS (SCALE FACTOR = 2.9)			

***** REFERENCES FOR N*1/2(1520)

SEE A PREVIOUS EDITION (RMP 37, 633, 1965) FOR EARLIER REFERENCES.

BRANDSEN 65 PR 139 B1566 +ODONNELL, MOORHOUSE (DURHAM, RHEL)JJP
 ROPER 65 PR 138 B190 LD ROPER, RM WRIGHT, BT FELD (LRL-LVM, MIT)JJP
 THURNAUE 65 PRL 14 985 P G THURNAUER (ROCHI)

KIRZ 66 PRIVATE COMM J KIRZ (LRL)
 NUMBER EXTRACTED FROM DATA DISCUSSED IN KIRZ 63. Z 63.
 NAVYSLAW 66 PR 15 1328 NAVYSLAW, RAZMI ROBERTS (ISTAN, EDIN, LMC)
 CLSSCN 66 PR 145 1309 M G OLSSON, G B YODH (WISC, UIC)

DAVIES 67 NC 52A 1112 A T DAVIES, R G MOORHOUSE (GLASGOW, RHEL)
 ROBERTS 67 PREPRINT R G ROBERTS (DURHAM)
 ROSENFEL 67 IRVINE CONF A H ROSENFELD, P SODING (LRL)

BAREYRE 68 PR 165 1731 P BAREYRE, C BRICMAN, G VILLET (SACLAY)JJP
 DONNACHI 68 PL 268 161 A DONNACHIE, R G KIRSOPP, C LOVELACE (CERN)JJP
 ALSO 68 VIENNA 139 DONNACHIE, RAPPOURTEUR-S TALK (GLAS)
 MORGAN 68 PR 166 1731 R G KIRSOPP (EDIN)
 D MORGAN (RHEL)

BOTKE 69 PR 180 1417 J C BOTKE (UCSB)
 DEANS 69 PR 185 1797 S DEANS, J WOOTEN (UNIV S FLORIDA)

AYED 70 KIEV CONF R AYED, P BAREYRE, G VILLET (SACLAY)JJP
 CARRERAS 70 NP 15 35 B CARRERAS, A DONNACHIE (DARE, MCHS)
 DAVIES 70 NP B21 359 A DAVIES (GLAS)
 DAVIES 70 KIEV CONF + SMADJA, CHAVANON, DELER, DOUBEAU+ (SACL)
 ALMEHED 72 NP B40 157 +LOVELACE (LUND, RUTG)JJP

Baryons

N(1520), N(1535)

Data Card Listings

For notation, see key at front of Listings.

Table listing various baryons and their properties, including DEVENISH, HEMMII, LEMOIGNE, MOORHOUS, ROSSI, BENEVENTA, DEVENISH, DEVENISH, KNIES, METCALF, MOORHOUS, CRAWFORD, FELTESSE, KRIVETS, LONGACRE, AYED, BARBOUR, FELLER, AZNAURYA, BERENDS, LONGACRE, BARBOUR, NOELLE, BAKER, CUTKOSKY, HOEHLER, KIRZ, BAREYRE, CROUCH, DERADO, MERLO, THE ABOVE PAPERS DISCUSS INELASTIC CHANNELS NEAR THE RESONANCE, JOHNSON, DEANS, DONNACHI, WALKER, AYED.

1520 MEV REGION - PRODUCTION EXPERIMENTS

8 N*1/2(1520, JP=) I=1/2 PRODUCTION EXPERIMENTS
SEE THE MINI-REVIEW PRECEDING THE N AND DELTA LISTINGS FOR A DISCUSSION OF PRODUCTION EXPERIMENTS.

Table listing production experiments for N(1520) with columns for mass (MEV), production method, and branching ratios.

Table listing widths (MEV) for N(1520) with columns for mass (MEV), width (MEV), and production method.

Table listing partial decay modes for N(1520) with columns for decay mode, branching ratio, and production method.

Table listing branching ratios for N(1520) with columns for decay mode, branching ratio, and production method.

Table listing references for N(1520) with columns for author, year, and journal.

PAPERS NOT REFERRED TO IN DATA CARDS
RUSHBROOK 76 PRD 13 1835
SOTIRIOU 76 NP 1107 457
BIEL 78 PR 18 3079
ALSO 76 PRL 36 504, 507
CHADWICK 78 PRD 17 1713
GOGGI 78 NP 1143 365
GOGGI 79 NP 8161 14

N(1535) 63 N*1/2(1535, JP=1/2-) I=1/2 S11
THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED. IT IS STRONGLY COUPLED TO THE ETA NEUTRON CHANNEL, WITH A BRANCHING RATIO OF 0.70 (BHANDARI 77 AND R. BHANDARI, PRIV. COMM., 1979).

Table listing masses (MEV) for N(1535) with columns for mass (MEV), production method, and branching ratios.

Table listing widths (MEV) for N(1535) with columns for mass (MEV), width (MEV), and production method.

Data Card Listings

For notation, see key at front of Listings.

Baryons

N(1535)

Table with columns for particle ID, mass, and properties. Includes entries for AYED, DAVIES, ALMEHED, HICKS, CRAWFORD, LONGACRE, etc.

Table for 63 N*1/2(1535) REAL PART OF POLE POSITION (MEV). Columns include RE, RE 8, and properties.

Table for 63 N*1/2(1535) -2*IMAG PART OF POLE POSITION (MEV). Columns include IM, IM 8, and properties.

Table for 63 N*1/2(1535) REAL PART OF ELASTIC POLE RESIDUE (MEV). Columns include RER, RER 8, and properties.

Table for 63 N*1/2(1535) IMAG PART OF ELASTIC POLE RESIDUE (MEV). Columns include IMR, IMR 8, and properties.

Table for 63 N*1/2(1535) PARTIAL DECAY MODES. Columns include P1-P10, decay masses, and properties.

Table for 63 N*1/2(1535) BRANCHING RATIOS. Columns include R1-R10, ratios, and properties.

Table for 63 N*1/2(1535) INTO (N ET A)/TOTAL. Columns include R2-R20, properties, and notes.

Table for 63 N*1/2(1535) INTO (N EPSILON)/TOTAL. Columns include R4-R40, properties, and notes.

Table for 63 N*1/2(1535) INTO (N RHO)/TOTAL. Columns include R5-R50, properties, and notes.

Table for 63 N*1/2(1535) INTO GAMMA PROTON/TOTAL. Columns include R6-R60, properties, and notes.

Table for 63 N*1/2(1535) PHOTON DECAY AMPL(GEV**1/2). Columns include R9-R12, properties, and notes.

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table for 63 N*1/2(1535) INTO GAM P, HELICITY=1/2 (GEV**1/2). Columns include A1-A10, properties, and notes.

Table for 63 N*1/2(1535) INTO GAM N, HELICITY=1/2 (GEV**1/2). Columns include A2-A20, properties, and notes.

REFERENCES FOR N*1/2(1535)

Large table of references for N*1/2(1535) with columns for author, journal, volume, page, and year.

Baryons

N(1535), N(1540), N(1650)

Data Card Listings

For notation, see key at front of Listings.

PAPERS NOT REFERRED TO IN DATA CARDS

BAREYRE 65 PL 18 342 + BRICMAN, STIRLING, VILLET (SACLAY)IJP
BRANDSEN 65 PR 139 B1566 +ODONNELL, MOORHOUSE (DURHAM, RHELI)IJP
BASIS OF NUMBERS WE QUOTE FROM HENDRY 65.
JOHNSON 67 UCL-17683 THESIS C H JOHNSON (LRL)
LOVELACE 67 HEIDELBERG C. 79 C LOVELACE (CERN)IJP
DONNACHI 69 NP 108 433 A DONNACHI, R KIRSOPP (GLAS+EDIN)
AYED 70 PL 318 598 +BAREYRE+VILLET (SACLAY)

THE FOLLOWING ARTICLES DEAL WITH THE REACTIONS PI- P TO ETA N AND GAMMA P TO ETA P NEAR THRESHOLD. THE DATA AND THE THEORETICAL ARTICLES ARE USEFUL IN UNDERSTANDING THE BEHAVIOR OF THE S11 AMPLITUDE AS DETERMINED IN PI P PHASE-SHIFT ANALYSES. FURTHER REFERENCES MAY BE FOUND IN THEM.

MAINLY EXPERIMENTAL --
BULOS 64 PRL 13 486 + (BROWN, BRANDEIS, HARVARD, MIT, PADOVA) I
BACCI 66 NC 45A 983 +PENSO, SALVINI, MENCUCINI, + (ROMA, FRASCATI)IJP
JONES 66 PL 23 597 +BINNIE, DUANE, HORSEY, MASON, + (LOIC, RHEL)
RICHARDS 66 PRL 16 1221 +CHIU, EANDI, HELMHOLDZ, KENNEY, + (LRL, HAWAII) IJ
PREPOST 67 PRL 18 82 R PREPOST, D LUNDQUIST, D QUINN (STANFORD)
BLOOM 68 PRL 21 1100 +HEUSCH, PRESCOTT, ROCHESTER (CIT)
BULOS 69 PR 187 1827 +LANOU, BORDNER, BASTIEN, (BOST+HARV+MIT+PENN)
HEUSCH 70 PRL 25 1381 +PRESCOTT, ROCHESTER, WINSTEIN (CIT)
BINNIE 73 PRD 8 2789 +CAMILLIERI, DEBENHAM, DUANE, + (LOIC, SHMP)

MAINLY THEORETICAL --
BALL 66 PR 149 1191 J S BALL (UCLA)
DOBSON 66 PR 146 1022 P N DOBSON (HAWAII)
MINAMI 66 PR 147 1123 S MINAMI (OSAKA)
DEANS 67 PR 161 1466 S R DEANS, W G HOLLADAY (VANDERBILT)
LOGAN 67 PR 153 1634 R K LOGAN, F UCHIYAMA-CAMPBELL (ILL)
MENCUCINI 67 NC 48A 579 C MENCUCINI, A REALE (FRASCATI)
MINAMI 67 PR 162 1619 S MINAMI (OSAKA)
MOSS 67 PR 163 1785 T A MOSS (LSU)
DEANS 68 PR 165 1886 S R DEANS, W G HOLLADAY (VANDERBILT)
PAL 68 PR 167 1350 B K PAL (NPL NEW DELHI)
BALL 69 PR 177 2257 +GARG+SHAW (UCLA+UCI)
LEFIEVRE 70 NC 66A 349 +LERUSTE (CDFE)

N(1540)

P13

109 N*1/2(1540, JP=3/2-) I=1/2 11/77
109 N*1/2(1540) MASS (MEV) 11/77

M 8 (1540.) LONGACRE 77 IPWA PI N TO 2PI N 11/77
M 8 ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE POSITION WHICH IS FROM SOLUTIONS S1 AND C1. 11/77

109 N*1/2(1540) WIDTH (MEV) 11/77
W 8 (200.) LONGACRE 77 IPWA PI N TO 2PI N 11/77

109 N*1/2(1540) REAL PART OF POLE POSITION (MEV) 11/77
RE 8 1935. OR 1482. LONGACRE 77 IPWA PI N TO 2PI N 11/77

109 N*1/2(1540) -2*IMAG PART OF POLE POSITION (MEV) 11/77
IM 8 207. OR 314. LONGACRE 77 IPWA PI N TO 2PI N 11/77

109 N*1/2(1540) PARTIAL DECAY MODES 11/77
P1 N*1/2(1540) INTO PI N 139+ 938
P2 N*1/2(1540) INTO N RHO, S=1/2, P=WAVE 938+ 776
P3 N*1/2(1540) INTO N RHO, S=3/2, P=WAVE 938+ 776
P4 N*1/2(1540) INTO N*3/2(1232) PI, P=WAVE 1232+ 139
P5 N*1/2(1540) INTO N EPSILON 938+1300

109 N*1/2(1540) BRANCHING RATIOS 11/77
R1 N*1/2(1540) FROM PI N TO N RHO, S=1/2, P=WAVE SQRT(P1*P2) 11/77
R1 8 (-.08) LONGACRE 77 IPWA PI N TO 2PI N 11/77
R2 N*1/2(1540) FROM PI N TO N RHO, S=3/2, P=WAVE SQRT(P1*P3) 11/77
R2 8 (.00) LONGACRE 77 IPWA PI N TO 2PI N 11/77
R3 N*1/2(1540) FROM PI N TO N*3/2(1232) PI, P=WAVE SQRT(P1*P4) 11/77
R3 8 (+.11) LONGACRE 77 IPWA PI N TO 2PI N 11/77
R4 N*1/2(1540) FROM PI N TO N EPSILON SQRT(P1*P5) 11/77
R4 8 (.00) LONGACRE 77 IPWA PI N TO 2PI N 11/77

REFERENCES FOR N*1/2(1540)

LONGACRE 77 NP B122 493 LONGACRE, DOLBEAU (SACL)IJP
ALSO 76 NP B108 365 DOLBEAU, TRIANTIS, NEVEU, CADIET (SACL)IJP

N(1650)

S11

66 N*1/2(1650, JP=1/2-) I=1/2
THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

66 N*1/2(1650) MASS (MEV)

M (1695.0) BRANDSEN 65 RVUE PHASE-SHIFT ANAL 9/66
M (1700.0) MICHAEL 66 RVUE FITS BAREYRE S11 7/66
M G (1710.0) BAREYRE 68 RVUE PHASE-SHIFT ANAL 11/67
M G WHERE CROSS SECTION IS GREATEST - EYEBALL FIT
M 3 (1710.0) DONNACHI 68 RVUE PHASE-SHIFT ANAL 8/68
M (1705.0) (10.0) ORITO 69 RVUE K LAMBDA PS ANAL 8/69
M 6 (1689.0) AYED 70 IPWA 1/71
M 6 FROM ENER. DEP. FIT OF ARGAND DIAGRAM
M 4 (1766.0) DAVIES 70 RVUE P-S ANAL SOL A 8/69
M (1678.0) SCHORSCH 70 DPWA K LAM PHOTOPRO. 10/71
M A (1685.0) WAGNER 71 IPWA PI-P TO K LAMB 1/71
M A THERE ARE 3 SIMILAR SOLUTIONS
M 7 (1670.) ALMEHED 72 IPWA 2/72
M 2 (1699.) HICKS 73 MPWA GAM P-ETA P 9/73
M 2 ONLY STATES FROM TABLE VII OF HICKS73 ARE INCLUDED IN LISTINGS. 9/73
M 2 M AND W ARE FROM SOLUTION C2, BR-SQRT(G)W WITH G FROM TABLE VII. 9/73
M 1 (1860.) LANGBEIN 73 IPWA PI N-K SIG. SOL 2 9/73
M 1 S11 AMPLITUDE LARGE BUT NOT RESONANT IN SOLUTION 1 OF LANGBEIN73 9/73
M 1 DEANS75 AND LANGBEIN73 DISAGREE WITH PI+ P TO K+ SIGMA+ DATA OF 1/78
M 1 WINNIK77 AROUND 1920 MEV. 1/78
M (1675.) KNASEL 75 DPWA 0 PI- P TO K0 LAM 11/75
M L 1675. OR 1660. LONGACRE 75 IPWA PI N TO 2PI N 11/75
M L THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75. 11/75
M (1673.) AYED 76 IPWA 11/77
M (1676.) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
M D (1700.) (5.) BAKER 77 IPWA 0 PI- P TO K LAM. 1/78
M E (1680.) BAKER 77 DPWA 0 PI- P TO K LAM. 1/78
M D THE TWO ENTRIES FOR BAKER 77 ARE FOR AN IPWA USING THE BARRELET 1/78
M E ZERO METHOD AND A CONVENTIONAL ENERGY-DEPENDENT ANALYSIS. 1/78
M 8 (1700.) LANGBEIN 77 IPWA PI N TO 2PI N 11/77
M 8 ALL LNCACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE POSITION WHICH IS FROM SOLUTIONS S1 AND C1. 11/77
M 8 (1680.) BAKER 78 DPWA 0 PI- P TO K LAM. 3/79*
M 9 (1694.) BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
M 9 SUPERSEDES BARBOUR 76.
M 1640. 30. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M 1670. 8. HOEHLER 79 IPWA PI N TO PI N 12/79*
M (1680.) SAXON 80 DPWA 0 PI- P TO K LAM 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

66 N*1/2(1650) WIDTH (MEV)

W 1 (240.0) MICHAEL 66 RVUE 7/66
W 1 (260.0) BAREYRE 68 RVUE 11/67
W 3 (300.0) DONNACHI 68 RVUE 8/69
W (104.0) (15.0) ORITO 69 RVUE 8/69
W 6 (166.0) AYED 70 IPWA 1/71
W 4 (164.0) DAVIES 70 RVUE P-S ANAL SOL A 8/69
W 4 SOL B GIVES 121 MEV (99.0)
W A (110.0)OR(140.0) SCHORSCH 70 DPWA K LAM PHOTOPRO. 10/71
W 7 (120.) WAGNER 71 IPWA PI-P TO K LAMB 1/71
W 2 (195.) ALMEHED 72 IPWA 2/72
W 1 (200.) HICKS 73 MPWA GAM P-ETA P 9/73
W L (170.) LANGBEIN 73 IPWA PI N-K SIG. SOL 2 9/73
W L 150. OR 130. KNASEL 75 DPWA 0 PI- P TO K0 LAM 11/75
W (150.) LONGACRE 75 IPWA PI N TO 2PI N 11/75
W (134.) AYED 76 IPWA 11/77
W D (130.) (10.) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
W E (90.) BAKER 77 IPWA 0 PI- P TO K LAM. 1/78
W 8 (170.) LONGACRE 77 IPWA PI N TO 2PI N 11/77
W (90.) BAKER 78 DPWA 0 PI- P TO K LAM. 3/79*
W 9 (193.) BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
W 140. 40. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
W 180. 20. HOEHLER 79 IPWA PI N TO PI N 12/79*
W H (120.) SAXON 80 DPWA 0 PI- P TO K LAM 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
SEE THE NOTES ACCOMPANYING THE MASSES QUOTED.

66 N*1/2(1650) REAL PART OF POLE POSITION (MEV) 11/75

RE (1648.) LONGACRE 75 IPWA PI N TO 2PI N 11/75
RE 8 1699. OR 1698. LONGACRE 77 IPWA PI N TO 2PI N 11/77
RE (1639.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

66 N*1/2(1650) -2*IMAG PART OF POLE POSITION (MEV) 11/75

IM 8 (117.) LONGACRE 75 IPWA PI N TO 2PI N 11/75
IM (140.) OR 173. LONGACRE 77 IPWA PI N TO 2PI N 11/77
CUTKOSKY 79 IPWA PI N TO PI N 12/79*

66 N*1/2(1650) REAL PART OF ELASTIC POLE RESIDUE (MEV)

RER (3.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

66 N*1/2(1650) IMAG PART OF ELASTIC POLE RESIDUE (MEV)

IMR (-58.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

66 N*1/2(1650) PARTIAL DECAY MODES

P1 N*1/2(1650) INTO PI N 139+ 938
P2 N*1/2(1650) INTO N ETA 938+ 548
P3 N*1/2(1650) INTO LAMBDA K 1115+ 497
P4 N*1/2(1650) INTO GAM P, HELICITY=1/2 0+ 938
P5 N*1/2(1650) INTO GAM N, HELICITY=1/2 0+ 939
P6 N*1/2(1650) INTO N PI PI 938+ 139+ 139
P7 N*1/2(1650) INTO N EPSILON 938+1200
P8 N*1/2(1650) INTO N RHO 938+ 776
P9 N*1/2(1650) INTO K SIGMA 493+1189
P10 N*1/2(1650) INTO N RHO, S=1/2, S=WAVE 938+ 776
P11 N*1/2(1650) INTO N RHO, S=3/2, S=WAVE 938+ 776
P12 N*1/2(1650) INTO N*3/2(1232) PI 1232+ 139

Data Card Listings

For notation, see key at front of Listings.

Baryons

N(1650), N(1670)

66 N*1/2(1650) BRANCHING RATIOS

R1	N*1/2(1650) INTO (PI N)/TOTAL							
R1	(1.01)	APPROX	MICHAEL	66 RVUE				7/66
R1	(0.79)		DONNACHI	68 RVUE				8/69
R1	(0.642)		AYED	70 IPWA				1/71
R1	(0.56)		DAVIES	70 RVUE	P-S ANAL	SOL A		8/69
R1	(0.51)		ALMEHED	72 IPWA				2/72
R1	(.54)		AYED	76 IPWA				11/77
R1	.60	.05	CUTKOSKY	79 IPWA	PI N TO PI N			12/79*
R1	.61	.04	HOEHLER	79 IPWA	PI N TO PI N			12/79*
R1	AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)							

R2 N*1/2(1650) FROM PI N TO K LAMBDA

R2	(.20)	(.05)	ORITO	69 RVUE	SQRT(P1*P3)			4/75
R2	(.21)OR .23		WAGNER	71 IPWA	PI- P TO K LAMB			4/75
R2	(.179)	.033	DEVENISH	74	O FIXED T DISP REL			4/75
R2	(.12)		KNASEL	75 DPWA	O PI- P TO KO LAM			11/75
R2	(.23)	(.01)	BAKER	77 IPWA	O PI- P TO K LAM			1/78
R2	(.25)		BAKER	77 DPWA	O PI- P TO K LAM			1/78
R2	(.25)		BAKER	78 DPWA	O PI- P TO K LAM			3/79*
R2	F THE (UNDETERMINED) OVERALL PHASE OF ALL COUPLINGS FROM BAKERT8							
R2	F HAS BEEN CHANGED TO AGREE WITH PREVIOUS CONVENTIONS.							
R2	(.22)		SAXON	80 DPWA	O PI- P TO K LAM			12/79*
R2	H SUPERSEDES BAKER 78.							

R3 N*1/2(1650) INTO (LAMBDA K)/TOTAL

R3	(0.028)	APPROX.	RUSH	68 MPWA	T POLE + RESON.			8/69
R3	PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING							

R4 N*1/2(1650) INTO (ETA)/TOTAL

R4	(0.013)		BOTKE	69 MPWA	T POLE + RESON.			10/69
R4	(0.03)	(0.02)	DEANS	69 MPWA	T POLE + RESON.			8/69
R4	(0.19) OR 0.27		CARRERAS	70 MPWA	T POLE + RESON.			5/70
R4	B PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING							
R4	C CARRERAS 70 USES REGGE POLES + RESONANCES. VALUES SUSPICIOUSLY LARG							

R5 N*1/2(1650) FROM GAMMA PROTON TO K LAMBDA

R5	(0.002)OR LESS		ORITO	69 CNTR	K LAM PHOTOPROD			10/71
R5	(0.072)		SCHORSCH	70 DPWA	K LAM PHOTOPROD.			10/71
R5	(0.060)		DEANS	72 MPWA	GAM P-K LM, SOL D			9/73

R6 N*1/2(1650) FROM GAMMA PROTON TO ETA PROTON

R6	(.0101)		HICKS	75 MPWA	GAM P-ETA P			9/73
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R7 N*1/2(1650) FROM PI N TO K SIGMA

R7	(.11)		LANGBEIN	73 IPWA	PI-N-K SIG, SOL 2			9/73
R7	(.046)TO .137		DEANS	75 DPWA	PI N TO K SIGMA			11/75
R7	5 RANGE GIVEN IS FROM FOUR BEST SOLUTIONS.							
R7	(.20)		KNASEL	75 DPWA	O PI- P TO KO LAM			11/75

R8 N*1/2(1650) FROM PI N TO N*3/2(1232) PI

R8	(-.16)OR -.15		LONGACRE	75 IPWA	PI N TO 2PI N			11/75
R8	(.29)		LONGACRE	77 IPWA	PI N TO 2PI N			11/77
R8	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.							

R9 N*1/2(1650) FROM PI N TO N RHO, S=1/2, S-WAVE

R9	(.23)OR +.16		LONGACRE	75 IPWA	PI N TO 2PI N			11/75
R9	(.17)		LONGACRE	77 IPWA	PI N TO 2PI N			11/77

R10 N*1/2(1650) FROM PI N TO N RHO, S=3/2, D-WAVE

R10	(-.29)		LONGACRE	77 IPWA	PI N TO 2PI N			11/77
R10	LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.							

R11 N*1/2(1650) FROM PI N TO N EPSILON

R11	(.23)OR -.25		LONGACRE	75 IPWA	PI N TO 2PI N			11/75
R11	(.00)		LONGACRE	77 IPWA	PI N TO 2PI N			11/77

R12 N*1/2(1650) FROM PI N TO ETA N

R12	(.09)		BAKER	79 DPWA	O PI- P TO ETA N			12/79*
R12	THIS COUPLING WAS FIXED DURING FITTING, BUT THE NEGATIVE SIGN							
R12	RELATIVE TO N(1535) IS WELL DETERMINED.							

66 N*1/2(1650) PHOTON DECAY AMPL (GEV**1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

A1 N*1/2(1650) INTO GAM P, HELICITY=1/2 (GEV**1/2)

A1	.024	.035	DEVENISH	73 DPWA	PI N PHOTOPROD			2/74
A1	+.066	-.042	MOORHOUSE	73 DPWA	PI N PHOTOPROD			2/73
A1	.029	-.018	DEVENISH	74 DPWA	PI N PHOTOPROD			4/75
A1	.058	-.018	KNIES	74 DPWA	PI N PHOTOPROD			2/74
A1	+.012	-.015	METCALF	74 DPWA	PI N PHOTOPROD			2/74
A1	-.054	+.005	MOORHOUSE	74 DPWA	PI N PHOTOPROD			2/74
A1	+.044	-.018	CRAWFORD	75 DPWA	PI N PHOTOPROD			1/76
A1	(+.044)		BARBOUR	76 DPWA	PI N PHOTOPROD			1/76
A1	+.068	-.009	FELLER	76 DPWA	PI N PHOTOPROD			2/77
A1	+.004	-.004	AZNAURYAN	77 DPWA	P10 PHOTOPROD, SOL 1			12/79*
A1	+.003	-.004	AZNAURYAN	77 DPWA	P10 PHOTOPROD, SOL 2			12/79*
A1	+.048	-.017	BARBOUR	78 DPWA	PI-N PHOTOPROD			3/79*
A1	AVERAGE MEANINGLESS (SCALE FACTOR = 3.8)							

A2 N*1/2(1650) INTO GAM N, HELICITY=1/2 (GEV**1/2)

A2	.010	.043	DEVENISH	73 DPWA	PI N PHOTOPROD			2/74
A2	-.072	-.066	MOORHOUSE	73 DPWA	PI N PHOTOPROD			2/73
A2	-.006	+.031	DEVENISH	74 DPWA	PI N PHOTOPROD			4/75
A2	-.015	-.035	KNIES	74 DPWA	PI N PHOTOPROD			2/74
A2	-.019	-.022	METCALF	74 DPWA	PI N PHOTOPROD			2/74
A2	-.027	-.009	MOORHOUSE	74 DPWA	PI N PHOTOPROD			2/74
A2	-.103	-.010	CRAWFORD	75 DPWA	PI N PHOTOPROD			1/76
A2	(-.022)		BARBOUR	76 DPWA	PI N PHOTOPROD			1/76
A2	-.045	-.024	BARBOUR	78 DPWA	PI-N PHOTOPROD			3/79*
A2	AVERAGE MEANINGLESS (SCALE FACTOR = 2.6)							

REFERENCES FOR N*1/2(1650)

BRANDSEN	65 PL 19 420	+ODONNELL, MOORHOUSE	(DURHAM, RHEL)IJP
MICHAEL	66 PL 21 93	C MICHAEL	(OXF)
BAREVRE	68 PR 165 1731	P BAREVRE, C BRICMAN, G VILLET	(SACLAY)IJP
DONNACHI	68 PL 268 161	A DONNACHIE, R G KIRSOPP, C LOVELACE	(CERN)IJP
ALSO	68 VIENNA 139	DONNACHIE, RAPPORTEUR.S TALK	(GLAS)
ALSO	68 THESIS	R G KIRSOPP	(EDIN)
RUSH	68 PR 173 1776	J E RUSH	(UNIV ALABAMA)

J C BOTKE (UCSB)

DEANS	69 PR 185 1797	S DEANS, J WOOTEN	(UNIV S FLORIDA)
ORITO	69 LNC 1 936	S ORITO, S SASAKI	(TKOY-OSAKA)
ORITO2	69 INS J 113	S ORITO (THESIS)	(TKOY)

AYED 70 KIEV CONF

CARRERAS	70 NP 168 35	R AYED, P BAREVRE, G VILLET	(SACL)IJP
DAVIES	70 NP B21 359	B CARRERAS, A DONNACHIE	(DARE, MCHS)
SCHORSCH	70 NP B25 179	A DAVIES	(GLAS)
		+TIETGE, WELLNBOECK	(MPIM)

WAGNER 71 NP B25 411

		F WAGNER, C LOVELACE	(CERN)
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ALMEHED 72 NP B40 157

DEANS	72 PR 6 1906	+LOVELACE	(LUND, RUTG)IJP
HICKS	73 PR D 7 2614	DEANS, JACOBS, LYONS, MONTGOMERY	(SOUTH FLA.)IJP
LANGBEIN	73 PR B53 251	DEVENISH, RANKIN, LYTH	(LDCU+BNON+LNC)IJP
MOORHOUSE	73 PL 438 44	+DEANS, JACOBS, LYONS+ (CARN+ORNL+ SOUTH FLA.)IJP	
		LANGBEIN, WAGNER	(MUNICH)IJP
		MOORHOUSE, OBERLACK	(GLAS+LBL)IJP

DEVENISH 74 NP B81 330

DEVENISH	74 PL 528 227	DEVENISH, FROGGATT, MARTIN (DESY, NORDITA, LDCU)	
KNIES	74 PR 9 2680	DEVENISH, LYTH, RANKIN	(DESY, LANG, BONN)IJP
METCALF	74 NP B76 253	KNIES, MOORHOUSE, OBERLACK	(SACL)IJP
MOORHOUSE	74 PR 9 1	W J METCALF, R L WALKER	(CIT)IJP
		MOORHOUSE, OBERLACK, ROSENFELD	(GLAS+LBL)IJP

CRAWFORD 75 NP B97 125

DEANS	75 NP B96 90	R L CRAWFORD	(GLAS)IJP
KNASEL	75 PR 11 1	+MITCHELL, MONTGOMERY, +	(SFLA, ALABAMA)IJP
LONGACRE	75 PL 558 415	+LINDQUIST, NELSON+ (CHIC, MUSL, OSU, ANL)IJP	
ALSO	78 PR D 17 1795	+ROSENFELD, LASINSKI, SMADJA+	(LBL, SLAC)IJP
		LONGACRE, LASINSKI, ROSENFELD+	(LBL, SLAC)

AYED 76 CEAN-1921

BARBOUR	76 NP B111 358	AYED (THESIS)	(SACL)IJP
FELLER	76 NP B104 219	I. M. BARBOUR, R. L. CRAWFORD	(GLAS)IJP
		+FUKUSHIMA, HORIKAWA, KAJIKAWA+ (NAGOYA+OSAKA)IJP	

AZNAURYA 77 EPI-264(57)-77

		+AKOPOV, BAGDASARYAN (YEREVAN PHYSICS INST.)IJP	
		+BLISSSET, BLOODWORTH, BROOME, HART+	(RHEL)IJP
		LONGACRE, DOLBEAU	(SACL)IJP
		DOLBEAU, TRIANTIS, NEVEU, CADIEY	(SACL)IJP

BAKER 78 NP B141 29

BARBOUR	78 NP B141 253	+BLISSSET, BLOODWORTH, BROOME+	(RL+CAMB)IJP
BAKER	79 NP B156 93	+BRONN, CLARK, DAVIES, DEPAETER, EVANS+	(RHEL)IJP
CUTKOSKY	79 PR D 20 2839	+FORSYTH, HENDRICK, KELLY	(CARN+RHL)IJP
HOEHLER	79 HANDBOOK OF PI-N	SCATTERING, PHYSIK DATEN VOL. 12-1	
		+KAISER, KOCH, PIETARINEN	/KARLSRUHE IJP
SAXON	80 NP B162 522	+BAKER, BELL, BLISSSET, BLOODWORTH+ (RHEL+BRIS)IJP	

PAPERS NOT REFERRED TO IN DATA CARDS

BAREVRE 65 PL 18 342

JOHNSON	67 UCRL-17683 THESIS	+ BRICMAN, STIRLING, VILLET	(SACLAY)IJP
DEANS	69 PR 177 2623	S R DEANS	(UNIV S FLORIDA)
DONNACHI	69 NP 108 433	A DONNACHIE, R KIRSOPP	(GLAS+EDIN)
AYED	70 PL 318 598	+BAKER, VILLET	(SACLAY)
WINNIK	77 NP B128 66	+TOAFF, REVEL, GOLDBERG, BERNY	(HAIFA)

***** ***** THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED. *****

N(1670) 64 N*1/2(1670, JP=5/2-) I=1/2 **D'15**

64 N*1/2(1670) MASS (MEV)

M	(1650.0)	APPROX	BRANDSEN	65 RVUE	PHASE-SHIFT ANAL			7/66
M	(1680.0)		BAREVRE	68 RVUE	PHASE-SHIFT ANAL			11/67
M	1		WHERE CROSS SECTION IS GREATEST - EYEBALL FIT					
M	3	(1678.0)	DONNACHI	68 RVUE	PHASE-SHIFT ANAL			6/68
M	6	(1674.0)	DUKE	68 CNTR	PI-P EL + POL			6/68
M	6	(1675.0)	AYED	70 IPWA				1/71
M	6	FROM ENER. DEP. FIT OF ARGAND DIAGRAM						
M	4	(1669.0)	DAVIES	70 RVUE	P-S ANAL	SOL A		8/69
M	7	(1683.0)	ALMEHED	72 IPWA				2/72
M	L	1652. TO 1687.	CRAWFORD	75 DPWA	PI N PHOTOPROD			1/76
M	L	1640. OR 1660.	LONGACRE	75 IPWA	PI N TO 2PI N			11/75
M	L	THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.						
M	(1660.)		AYED	76 IPWA				11/77
M	(1687.)		BARBOUR	76 DPWA	PI N PHOTOPROD			1/76
M	8	(1650.0)	LONGACRE	77 IPWA	PI N TO 2PI N			11/77
M	8	ALL LONGACRE 77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE						
M	8	POSITION WHICH IS FROM SOLUTIONS S1 AND C1.						
M	5	(1680.)	BARBOUR	78 DPWA	PI-N PHOTOPROD			3/79*
M	5	SUPERSEDES BARBOUR 76.						
M	1680.	15.	CUTKOSKY	79 IPWA	PI N TO PI N			12/79*
M	1679.	8.	HOEHLER	79 IPWA	PI N TO PI N			12/79*
M	(1670.)		SAXON	80 DPWA	O PI- P TO K LAM			12/79*
M	AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)							

64 N*1/2(1670) WIDTH (MEV)

W	1	(135.0)	BAREVRE	68 RVUE				11/67
W	3	(173.0)	DONNACHI	68 RVUE				6/68
W	6	(143.0)	AYED	70 IPWA				1/71
W	4	(115.0)	DAVIES	70 RVUE	SOL A AND B			

Baryons
N(1670)

Data Card Listings

For notation, see key at front of Listings.

64 N*1/2(1670) -2*IMAG PART OF POLE POSITION (MEV) 11/75
IM 8 (146.) LONGACRE 75 IPWA P I N TO 2P I N 11/75
IM 127. OR 127. LONGACRE 77 IPWA P I N TO 2P I N 11/77
IM (150.) CUTKOSKY 79 IPWA P I N TO P I N 12/79*

64 N*1/2(1670) REAL PART OF ELASTIC POLE RESIDUE (MEV)
RER (33.) CUTKOSKY 79 IPWA P I N TO P I N 12/79*

64 N*1/2(1670) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
IMR (-11.) CUTKOSKY 79 IPWA P I N TO P I N 12/79*

64 N*1/2(1670) PARTIAL DECAY MODES
DECAY MASSES
P1 N*1/2(1670) INTO P I N 139+ 938
P2 N*1/2(1670) INTO N ETA 939+ 548
P3 N*1/2(1670) INTO LAMBDA K 1115+ 497
P4 N*1/2(1670) INTO N*3/2(1232) P I 1232+ 139
P5 N*1/2(1670) INTO N P I P I 938+ 139+ 139
P6 N*1/2(1670) INTO GAM P, HELICITY=1/2 0+ 938
P7 N*1/2(1670) INTO GAM P, HELICITY=3/2 0+ 938
P8 N*1/2(1670) INTO GAM N, HELICITY=1/2 0+ 939
P9 N*1/2(1670) INTO GAM N, HELICITY=3/2 0+ 939
P10 N*1/2(1670) INTO SIGMA K 493+1189
P11 N*1/2(1670) INTO N*3/2(1232) P I, D-WAVE 1232+ 139
P12 N*1/2(1670) INTO N RHO, S=3/2, D-WAVE 938+ 776
P13 N*1/2(1670) INTO N EPSILON 938+1300

64 N*1/2(1670) BRANCHING RATIOS
R1 N*1/2(1670) INTO (P I N)/TOTAL (P1)
R1 1 (0.41) BAREYRE 68 RVUE 11/67
R1 3 (0.391) DONNACHI 68 RVUE 6/68
R1 6 (0.392) AYEY 70 IPWA 1/71
R1 4 (0.50) DAVIES 70 RVUE 8/69
R1 7 (0.45) ALMEHD 72 IPWA 2/72
R1 (.41) AYEY 76 IPWA 11/77
R1 .35 .06 CUTKOSKY 79 IPWA P I N TO P I N 12/79*
R1 .38 .03 HOEHLER 79 IPWA P I N TO P I N 12/79*

R2 N*1/2(1670) INTO (N ETA)/TOTAL (P2)
R2 (0.02) OR LESS TRIPP 67 RVUE 8/67
R2 8 (0.018) BOTKE 69 MPWA T POLE + RESON. 10/69
R2 8 (0.006) (0.004) DEANS 69 MPWA T POLE + RESON. 5/70
R2 8 (0.006) OR 0.012 CARRERAS 70 MPWA T POLE + RESON. 5/70
R2 8 PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING

R3 N*1/2(1670) INTO (LAMBDA K)/TOTAL (P3)
R3 (0.014) OR LESS TRIPP 67 RVUE 8/67
R3 8 (0.001) OR LESS RUSH 68 MPWA T POLE + RESON. 8/69
R3 8 PARAMETRIZATION USED COULD BE IN DANGER OF DOUBLE COUNTING
R3 (0.0028) OR LESS CL= .63 WAGNER 71 IPWA P I - P TO K LAMB 1/71

R4 N*1/2(1670) INTO (N*3/2(1232) P I)/TOTAL (P4)
R4 E 12600 0.63 0.1 BRODY 71 HBC P I - P -- 2P I N, PWA 6/70
R4 E ASSUMES ELASTIC BRANCHING RATIO 0.42+0.04

R5 N*1/2(1670) FROM P I N TO K LAMBDA SQR(I*P1*P3) 4/75
R5 (-0.03) DEVENISH 74 0 FIXED T DISP REL 4/75
R5 COUPLING TO LAMBDA K NOT REQUIRED IN THE ANALYSES OF BAKER77 AND 3/79*
R5 BAKER78. 3/79*

R6 N*1/2(1670) FROM P I N TO ETA N SQR(T*P1*P2) 11/75
R6 2 (0.0) OR (+.009) FELTESSE 75 DPWA 0 1480 TO 1745 MEV 11/75
R6 2 USES M AND W OF AYEY 76. BAKER 79 DPWA 0 P I - P TO ETA N 12/79*

R7 N*1/2(1670) FROM P I N TO K SIGMA SQR(T*P1*P10) 11/75
R7 2 LESS THAN .005 DEANS 75 DPWA P I N TO K SIGMA 11/75
R7 2 RANGE GIVEN IS FROM FOUR BEST SOLUTIONS. 11/75
R7 2 DEANS75 DISAGREES WITH P I + P TO K SIGMA+ DATA OF WINNIK77 1/78
R7 2 AROUND 1920 MEV. 1/78

R8 N*1/2(1670) FROM P I N TO N*3/2(1232) P I, D-WAVE SQR(T*P1*P11) 11/75
R8 L (-.45) OR -.50 LONGACRE 75 IPWA P I N TO 2P I N 11/75
R8 8 (-.46) LONGACRE 77 IPWA P I N TO 2P I N 11/77
R8 8 LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.
R8 N (-.5) NOVOSSELLE 78 IPWA P I N TO 2P I N 3/79*
R8 N BW FIT TO LONGACRE 75 IPWA. 3/79*

R9 N*1/2(1670) FROM P I N INTO N RHO, S=3/2, D-WAVE SQR(T*P1*P12) 11/77
R9 8 (+.15) LONGACRE 77 IPWA P I N TO 2P I N 11/77
R9 8 LONGACRE 77 CONSIDER THIS COUPLING TO BE WELL DETERMINED.

R10 N*1/2(1670) FROM P I N INTO N EPSILON SQR(T*P1*P13) 11/77
R10 8 (-.03) LONGACRE 77 IPWA P I N TO 2P I N 11/77

64 N*1/2(1670) PHOTON DECAY AMPL(GEV**1/2)
FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-
REVIEW PRECEDING THE BARYON LISTINGS.
A1 N*1/2(1670) INTO GAM P, HELICITY=1/2 (GEV**1/2) P I N PHOTO PROD 2/74
A1 .027 .030 DEVENISH 73 DPWA + FWD P I O PHTOPROD 2/74
A1 (.029) HEMMI 73 + FWD P I O PHTOPROD 2/74
A1 +.011 .012 MOORHOUSE 73 DPWA P I N PHOTO-PROD 2/74
A1 .015 .021 DEVENISH 74 DPWA P I N PHOTO-PROD 4/75
A1 .013 .014 KNIES 74 DPWA P I N PHOTO-PROD 2/74
A1 +.010 .013 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A1 .019 .007 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A1 +.027 .009 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A1 (+.004) KRIVETS 75 DPWA P I - N PHOTO-PROD 1/78
A1 (+.008) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A1 +.034 .004 FELLER 76 DPWA P I N PHOTO-PROD 2/77

A1 +.034 .003 AZNAURYAN 77 DPWA P I O PHTPRO,SOL 1 12/79*
A1 +.071 .002 AZNAURYAN 77 DPWA P I O PHTPRO,SOL 2 12/79*
A1 +.022 .010 BARBOUR 78 DPWA P I - N PHOTO-PROD 3/79*
A1 AVERAGE MEANINGLESS (SCALE FACTOR = 5.2)

A2 N*1/2(1670) INTO GAM P, HELICITY=3/2 (GEV**1/2) P I N PHOTO PROD 2/74
A2 .036 .030 DEVENISH 73 DPWA P I N PHOTO-PROD 2/73
A2 +.021 .020 MOORHOUSE 73 DPWA P I N PHOTO-PROD 4/75
A2 .014 .004 DEVENISH 74 DPWA P I N PHOTO-PROD 2/74
A2 .014 .008 KNIES 74 DPWA P I N PHOTO-PROD 2/74
A2 +.042 .024 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A2 .016 .002 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A2 +.015 .006 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A2 (+.021) KRIVETS 75 DPWA P I - N PHOTO-PROD 1/78
A2 (+.021) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A2 +.019 .009 FELLER 76 DPWA P I N PHOTO-PROD 2/77
A2 +.010 .010 AZNAURYAN 77 DPWA P I O PHTPRO,SOL 1 12/79*
A2 +.002 .021 AZNAURYAN 77 DPWA P I O PHTPRO,SOL 2 12/79*
A2 5 +.015 .006 BARBOUR 78 DPWA P I - N PHOTO-PROD 3/79*
A2 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

A3 N*1/2(1670) INTO GAM N, HELICITY=1/2 (GEV**1/2) P I N PHOTO PROD 2/74
A3 -.060 .062 DEVENISH 73 DPWA P I N PHOTO-PROD 2/73
A3 +.010 .040 MOORHOUSE 73 DPWA P I N PHOTO-PROD 4/75
A3 -.029 .023 DEVENISH 74 DPWA P I N PHOTO-PROD 2/74
A3 -.043 .006 KNIES 74 DPWA P I N PHOTO-PROD 2/74
A3 .004 .015 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A3 -.017 .004 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A3 -.052 .003 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A3 (-.058) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A3 5 -.066 .020 BARBOUR 78 DPWA P I - N PHOTO-PROD 3/79*
A3 AVERAGE MEANINGLESS (SCALE FACTOR = 4.4)

A4 N*1/2(1670) INTO GAM N, HELICITY=3/2 (GEV**1/2) P I N PHOTO PROD 2/74
A4 -.072 .022 DEVENISH 73 DPWA P I N PHOTO-PROD 2/73
A4 -.035 .014 MOORHOUSE 73 DPWA P I N PHOTO-PROD 4/75
A4 -.068 .020 DEVENISH 74 DPWA P I N PHOTO-PROD 2/74
A4 -.071 .030 KNIES 74 DPWA P I N PHOTO-PROD 2/74
A4 -.009 .029 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A4 -.049 .004 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A4 -.043 .007 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A4 (-.080) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A4 5 -.073 .014 BARBOUR 78 DPWA P I - N PHOTO-PROD 3/79*
A4 AVERAGE MEANINGLESS (SCALE FACTOR = 2.1)

REFERENCES FOR N*1/2(1670)

BRANDSEN 65 PL 19 420 +ODDNELL, MOORHOUSE (DURHAM, RHELIJ)
TRIPP 67 NP 83 10 + LEITH, + (LRL,SLAC,CERN,HEID,SLACLAY)
BAREYRE 68 PR 165 1731 P BAREYRE, C BRICMAN, G VILLET (SACLAY)IJP
DENNACHI 68 PL 268 161 A DONNACHIE, R G KIRSOPP, C LOVELACE (CERN)IJP
ALSO 68 VIENNA 139 DONNACHIE RAPPORTEUR.S TALK (GLAS)
ALSO 68 THEISIS R G KIRSOPP (EDIN)
DUKE 68 PR 166 1448 +JONES,KEMP,MURPHY,THRESHER, + (RHEL,OXF)IJP
INSIGHTFUL QUALITATIVE ARGUMENTS CONCERNING EXISTENCE AND IJP.
RUSH 68 PR 173 1776 J E RUSH (UNIV ALABAMA)
BOTKE 69 PR 180 1417 J C BOTKE (UCSB)
DEANS 69 PR 185 1797 S DEANS, J WOOTEN (UNIV S FLORIDA)
AYED 70 KIEV CONF R AYED, P BAREYRE, G VILLET (SACLAY)IJP
CARRERAS 70 NP 169 35 B CARRERAS, A DONNACHIE (DARE, MCHS)
DAVIES 70 NP B21 359 A DAVIES (GLAS)
BRODY 71 PL 348 665 +CASHMORE+..+HERNDON+.. (SLAC+LRL)
WAGNER 71 NP B25 411 F WAGNER, C LOVELACE (CERN)
ALMEHD 72 NP B40 157 +LOVELACE (LUND,RUTGI)IJP
DEVENISH 73 PL 478 53 DEVENISH,RANKIN,LYTH (LDUC+BNON+LANC)IJP
HEMMI,INAGAKI 73 PL 438 79 HEMMI,INAGAKI (KYOTO+SAGA+KEK+TKY)IJP
MOORHOUSE 73 PL 438 44 MOORHOUSE, OBERLACK (GLAS+LBL)IJP
DEVENISH 74 NP 881 330 DEVENISH,FROGGATT,MARTIN,DESY,NORDITA,L DUC
DEVENISH 74 PL 52 227 DEVENISH,LYTH,RANKIN (DESY,LANC,BNON)IJP
KNIES 74 PRD 9 2680 KNIES,MOORHOUSE,OBERLACK (LBL,GLAS)IJP
METCALF 74 NP 876 253 W J METCALF,R L WALKER (CIT)IJP
MOORHOUSE 74 PRD 9 1 MOORHOUSE,OBERLACK,ROSENFELD (GLAS+LBL)IJP
CRAWFORD 75 NP B97 125 R L CRAWFORD (GLAS)IJP
DEANS 75 NP B96 90 +MITCHELL,MONTGOMERY,+ (SFLA,ALABAMA)IJP
FELTESSE 75 NP B93 242 +AYED,BAREYRE,BORGEAUD,DAVID,ERNWEIN+(SACLAY)IJP
KRIVETS 75 SUNJ 20 430 +KIROSHICHENKO,NIKI FOROV,SANIN (KIEV)IJP
ALSO 75 SUNJ 19 112 KRIVETS,NIKI FOROV,SANIN,SHALATSKII (KIEV)IJP
LONGACRE 75 PL 558 415 +ROSENFELD,LASINSKI,SMADJA+ (LBL,SLAC)IJP
ALSO 78 PRD 17 1795 LONGACRE,LASINSKI,ROSENFELD+ (LBL,SLAC)IJP
AYED 76 CEA-N-1921 AYED (THEISIS) (GLAS)IJP
BARBOUR 76 NP B111 358 I. M. BARBOUR,R. L. CRAWFORD (SACLAY)IJP
FELLER 76 NP B104 219 +FUKUSHIMA,HORIKAWA,KAJIKAWA+INAGYA+OSAKAI)IJP
AZNAURYA 77 EFF-264(57)-77 +AKOPIVA,BAGDASARYAN (YEREVAN PHYSICS INST.)IJP
LONGACRE 77 NP B122 493 LONGACRE,DOLBEAU (SACLAY)IJP
ALSO 76 NP B108 365 DOLBEAU,TRIAINTIS,NEVEU,CADIET (SACLAY)IJP
BARBOUR 78 NP B141 253 BARBOUR,CRAWFORD,PARSONS (GLAS)
NOVOSELL 78 NP B137 509 D. E. NOVOSSELLER (CAL TECH)IJP
ALSO 78 NP B137 445 D. E. NOVOSSELLER (CAL TECH)IJP
BAKER 79 NP B156 93 +BROWN,CLARK,DAVIES,DEPAGTER,EVANS+ (RHEL)IJP
CUTKOSKY 79 NP B20 2839 +CUTKOSKY,HEMMI,KELLY (LARC+CP)IJP
HOEHLER 79 HANDBOOK OF P I - N SCATTERING, PHYSIK DATEN VOL-12-1 (LRL)
SAXON 80 NP B162 522 +KAISER,KOCH,PIETARINEN (KARLSRUHE)IJP
+BAKER,BELL,BLISSETT,BLOODWORTH+(RHL+BRIS)IJP
PAPERS NOT REFERRED TO IN DATA CARDS
BAREYRE 65 PL 18 342 + BRICMAN, STIRLING, VILLET (SACLAY)IJP
DUKE 65 PR 15 468 +JONES,KEMP,MURPHY,PRENTICE, + (RHEL,OXF)IJP
JOHNSON 67 UCL-1763 THESIS G H JOHNSON (LRL)
DEANS 69 PR 177 2623 S R DEANS (UNIV S FLORIDA)
DONNACHI 69 NP 108 433 A DONNACHIE, R KIRSOPP (GLAS+EDIN)
AYED 70 PL 318 598 +BAREYRE+VILLET (SACLAY)
BAKER 77 NP B126 365 +BLISSETT,BLOODWORTH,BROOME,HART+ (RHEL)IJP
WINNIK 77 NP B128 66 +TOAFF,REVEL,GOLDBERG,BERNY (HAIF)IJP
BAKER 78 NP B141 29 +BLISSETT,BLOODWORTH,BROOME+ (LRL+CAMB)IJP

Baryons N(1688)

Data Card Listings For notation, see key at front of Listings.

Table with columns for mass, width, real part of pole position, imaginary part of pole position, branching ratios, and decay masses. Includes sub-sections like '65 N*1/2(1688) MASS (MEV)', '65 N*1/2(1688) WIDTH (MEV)', etc.

Table with columns for helicity, photon decay amplitude, and helicity-3/2 photon decay amplitude. Includes sub-sections like '65 N*1/2(1688) PHOTON DECAY AMPL(GEV** -1/2)', '65 N*1/2(1688) HELICITY-1/2', etc.

MORE INFORMATION ON THE INELASTIC DECAY MODES OF THE 1690 MEV BUMP, AS SEEN IN PRODUCTION EXPERIMENTS, MAY BE FOUND BELOW

Baryons
N(1688), N(1700)

Data Card Listings

For notation, see key at front of Listings.

Table with columns for particle ID, mass, helicity, and references. Includes entries for N(1688) and N(1700) with various experimental data points.

REFERENCES FOR N(1/2(1688))

SEE A PREVIOUS EDITION (RMP 37, 633, 1965) FOR EARLIER REFERENCES.

Main reference table for N(1/2(1688)) listing authors, journals, and helicity values. Includes entries like BRANDSEN, HEUSCH, TRIPP, BAREVRE, etc.

PAPERS NOT REFERRED TO IN DATA CARDS

Table listing papers not referred to in data cards, including authors like CROUCH, DERADO, DUKE, etc.

N(1700)

18 N*1/2(1700, JP=3/2-) I=1/2

D13

18 N*1/2(1700) MASS (MEV)

Table listing mass measurements for N(1700) with columns for mass (MeV), helicity, and references.

Table listing mass measurements for N(1700) with columns for mass (MeV), helicity, and references.

Table listing real part of pole position (MEV) for N(1700) with columns for mass, helicity, and references.

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Table listing real part of pole position (MEV) for N(1700) with columns for mass, helicity, and references.

18 N*1/2(1700) PARTIAL DECAY MODES

Table listing partial decay modes for N(1700) with columns for mode, helicity, and branching ratios.

18 N*1/2(1700) BRANCHING RATIOS

Table listing branching ratios for N(1700) with columns for mode, helicity, and branching ratios.

Table listing branching ratios for N(1700) with columns for mode, helicity, and branching ratios.

Table listing branching ratios for N(1700) with columns for mode, helicity, and branching ratios.

Data Card Listings

For notation, see key at front of Listings.

Baryons N(1700)

R8 N*1/2(1700) FROM PI N TO N RHO,S=3/2,S=WAVE SQRT(PI*P11) 11/75
R8 L (0.1 OR (-.07) LONGACRE 75 IPhA PI N TO 2PI N 11/75
R8 8 (-.07) LONGACRE 77 IPhA PI N TO 2PI N 11/77

R9 N*1/2(1700) FROM PI N TO ETA N SQRT(PI*P12) 12/79*
R9 (.065) BAKER 79 DPWA 0 PI- P TO ETA N 12/79*

18 N*1/2(1700) PHOTON DECAY AMPL (GEV**1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

A1 N*1/2(1700) INTO GAM P, HELICITY=1/2 (GEV**1/2)
A1 -.103 .130 DEVENISH 73 DPWA PI N PHOTO PROD 2/74
A1 -.048 .050 DEVENISH 74 DPWA PI N PHOTO-PROD 4/75
A1 -.015 .040 KNIES 74 DPWA PI N PHOTO PROD 2/74
A1 (.023) METCALF 74 DPWA PI N PHOTO-PROD 2/74
A1 (-.023) MOORHOUS 74 DPWA PI N PHOTO-PROD 2/74
A1 -.012 .010 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A1 (-.005) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A1 -.014 .025 FELLER 76 DPWA PI N PHOTO-PROD 2/77
A1 +.078 .008 AZNAURYAN 77 DPWA P10 PHTPRD,SOL 1 12/79*
A1 +.038 .005 AZNAURYAN 77 DPWA P10 PHTPRD,SOL 2 12/79*
A1 4 -.033 .021 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
A1 4 SUPERSEDES BARBOUR 76. 3/79*

A1 AVERAGE MEANINGLESS (SCALE FACTOR = 4.1)

A2 N*1/2(1700) INTO GAM P, HELICITY=3/2 (GEV**1/2)
A2 -.055 .065 DEVENISH 73 DPWA PI N PHOTO PROD 2/74
A2 -.036 .014 DEVENISH 74 DPWA PI N PHOTO-PROD 4/75
A2 -.030 .040 KNIES 74 DPWA PI N PHOTO PROD 2/74
A2 .0 .029 METCALF 74 DPWA PI N PHOTO-PROD 2/74
A2 (-.035) MOORHOUS 74 DPWA PI N PHOTO-PROD 2/74
A2 -.012 .010 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A2 (-.009) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A2 .0 .014 FELLER 76 DPWA PI N PHOTO-PROD 2/77
A2 -.066 .007 AZNAURYAN 77 DPWA P10 PHTPRD,SOL 1 12/79*
A2 -.048 .007 AZNAURYAN 77 DPWA P10 PHTPRD,SOL 2 12/79*
A2 4 -.016 .025 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*

A2 AVERAGE MEANINGLESS (SCALE FACTOR = 2.6)

A3 N*1/2(1700) INTO GAM N, HELICITY=1/2 (GEV**1/2)
A3 -.013 .222 DEVENISH 73 DPWA PI N PHOTO PROD 2/74
A3 -.021 .098 DEVENISH 74 DPWA PI N PHOTO-PROD 4/75
A3 -.036 .040 KNIES 74 DPWA PI N PHOTO PROD 2/74
A3 (.028) METCALF 74 DPWA PI N PHOTO-PROD 2/74
A3 (-.015) MOORHOUS 74 DPWA PI N PHOTO-PROD 2/74
A3 +.081 .015 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A3 (+.017) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A3 4 +.050 .042 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
A3 AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)

A4 N*1/2(1700) INTO GAM N, HELICITY=3/2 (GEV**1/2)
A4 -.088 .067 DEVENISH 73 DPWA PI N PHOTO PROD 2/74
A4 -.026 .067 DEVENISH 74 DPWA PI N PHOTO-PROD 4/75
A4 .024 .024 KNIES 74 DPWA PI N PHOTO-PROD 2/74
A4 .0 .044 METCALF 74 DPWA PI N PHOTO-PROD 2/74
A4 (.028) MOORHOUS 74 DPWA PI N PHOTO-PROD 2/74
A4 +.107 .025 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A4 (+.022) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A4 4 +.035 .030 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
A4 AVERAGE MEANINGLESS (SCALE FACTOR = 1.5)

***** REFERENCES FOR N*1/2(1700) *****

DONNACHZ 68 VIENNA 139 DONNACHIE RAPPORTEUR.S TALK (GLAS)
KIRSOPP 68 THESIS R G KIRSOPP (EDIN)
WAGNER 71 NP 825 411 F WAGNER, C LOVELACE (CERN)
DEANS 72 PRD 6 1906 DEANS, JACOBS, LYONS, MONTGOMERY (SOUTH FLA.) IJP
DEVENISH 73 PL 478 53 DEVENISH, RANKIN, LYTH (LOUC+BOON+LANC) IJP
LANGBEIN 73 NP 853 251 LANGBEIN, WAGNER (MUNICH) IJP
DEVENISH 74 NP 881 330 DEVENISH, FROGGATT, MARTINIDES, MORITA, LUCIC
DEVENISH 74 PL 528 227 DEVENISH, LYTH, RANKIN (DESY, LANG, BOON) IJP
KNIES 74 PRD 9 2680 KNIES, MOORHOUS, OBERLACK (LBL, GLAS) IJP
METCALF 74 NP 876 253 W J METCALF, R L WALKER (CIT) IJP
MOORHOUS 74 PRD 9 1 MOORHOUS, OBERLACK, ROSENFELD (GLAS+LBL) IJP
CRAWFORD 75 NP 897 125 R L CRAWFORD (GLAS) IJP
DEANS 75 NP 896 90 +MITCHELL, MONTGOMERY,+ (SFLA, ALABAMA) IJP
LONGACRE 75 PL 558 415 +ROSENFELD, LASINSKI, SMADJA+ (LBL, SLAC) IJP
ALSO 78 PRD 17 1795 LONGACRE, LASINSKI, ROSENFELD+ (LBL, SLAC)

AYED 76 CEAN-1921 AYED (THISIS) (SACL) IJP
BARBOUR 76 NP B111 358 I. M. BARBOUR, R. L. CRAWFORD (GLAS) IJP
FELLER 76 NP B104 219 +FUKUSHIMA, HORIKAWA, KAJIKAWA+(NAGDYA+OSAKA) IJP
AZNAURYAN 77 EFI-264(571)-77 +AKOPOV, BAGDASARYAN (YEREVAN PHYSICS INST.) IJP
BAKER 77 NP B126 365 +BLISSET, BLOODWORTH, BROCKE, HART+ (RH) IJP
LONGACRE 77 NP B122 493 LONGACRE, DOLBEAU (SACL) IJP
ALSO 76 NP B198 365 DOLBEAU, TRANTIS, NEVEU, CADDET (SACL) IJP
BAKER 78 NP B141 29 +BLISSET, BLOODWORTH, BROOME+ (RL+CAMB) IJP
BARBOUR 78 NP B141 253 BARBOUR, CRAWFORD, PARSONS (GLAS)

BAKER 79 NP B156 93 +BROWN, CLARK, DAVIES, DEPAGTER, EVANS+ (RH) IJP
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL) IJP
HDEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 /KARLSRUHE IJP
+KAI SER, KOCH, PIETARINEN (RH+LBL+BRIS) IJP
SAXON 80 NP B162 522 +BAKER, BELLI, BLISSETT, BLOODWORTH+(RH+LBL+BRIS) IJP
PAPERS NOT REFERRED TO IN DATA CARDS
HERNDON 77 LBL 1065 +...ROSENFELD...+CASHMORE+... (LBL, SLAC)
WINNIK 77 NP B128 66 +TOAFF, REVEL, GOLDBERG, BERNY (HAIF) IJP

1700 MEV REGION - PRODUCTION EXPERIMENTS

20 N*1/2(1700, JP=) I=1/2 PRODUCTION EXPERIMENTS
SEE THE MINI-REVIEW PRECEDING THE N AND DELTA LISTINGS FOR DISCUSSION OF PRODUCTION EXPERIMENTS.

Table with columns: Particle Name, Mass (MeV), Production Experiment, and Cross-section. Includes entries for A-Borelli, Bellam, Beretov, etc.

Table with columns: Particle Name, Width (MeV), Production Experiment, and Cross-section. Includes entries for A-Borelli, Almeida, Galloway, etc.

Baryons

N(1700), N(1710)

Table listing particle properties for N(1700) and N(1710) including mass, spin, and decay modes.

20 N*1/2(1700) PARTIAL DECAY MODES (PROD. EXP.)

Table showing partial decay modes for N*1/2(1700) with columns for decay mode, branching ratio, and reference.

20 N*1/2(1700) BRANCHING RATIOS (PROD. EXP.)

Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

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Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

Table showing branching ratios for N*1/2(1700) with columns for decay mode, ratio, and reference.

SEE THE NOTES ACCOMPANYING THE MASSES QUOTED

REFERENCES FOR N*1/2(1700) (PROD. EXP.)

Table listing references for N*1/2(1700) with columns for author, journal, and year.

Table listing particle properties for various baryons including mass, spin, and decay modes.

Table listing particle properties for various baryons including mass, spin, and decay modes.

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Table listing particle properties for various baryons including mass, spin, and decay modes.

Table listing particle properties for various baryons including mass, spin, and decay modes.

Data Card Listings

For notation, see key at front of Listings.

Complex block containing a box labeled 'N(1710)' and text: '14 N*1/2(1710), JP=1/2+ I=1/2 P11 THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.'

14 N*1/2(1710) MASS (MEV)

Table listing mass values for N*1/2(1710) with columns for mass (MeV), reference, and notes.

AVERAGE MEANINGLESS (SCALE FACTOR =14.9)

Data Card Listings

For notation, see key at front of Listings.

Baryons

N(1710)

Table with columns for particle ID, mass, width, and various properties. Includes sub-header '14 N*1/2(1710) WIDTH (MEV)'.

Table with columns for particle ID, real part of pole position, and various properties. Includes sub-header '14 N*1/2(1710) REAL PART OF POLE POSITION (MEV)'.

Table with columns for particle ID, -2*imag part of pole position, and various properties. Includes sub-header '14 N*1/2(1710) -2*IMAG PART OF POLE POSITION (MEV)'.

Table with columns for particle ID, real part of elastic pole residue, and various properties. Includes sub-header '14 N*1/2(1710) REAL PART OF ELASTIC POLE RESIDUE (MEV)'.

Table with columns for particle ID, imag part of elastic pole residue, and various properties. Includes sub-header '14 N*1/2(1710) IMAG PART OF ELASTIC POLE RESIDUE (MEV)'.

Table with columns for particle ID, partial decay modes, and various properties. Includes sub-header '14 N*1/2(1710) PARTIAL DECAY MODES'.

Table with columns for particle ID, branching ratios, and various properties. Includes sub-header '14 N*1/2(1710) BRANCHING RATIOS'.

Table with columns for particle ID, parameters for various decay channels, and various properties.

Table with columns for particle ID, parameters for various decay channels, and various properties.

Table with columns for particle ID, parameters for various decay channels, and various properties.

Table with columns for particle ID, various parameters, and various properties. Includes sub-header '14 N*1/2(1710) PHOTON DECAY AMPL(GEV**1/2)'.

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table with columns for particle ID, parameters for various decay channels, and various properties.

Table with columns for particle ID, parameters for various decay channels, and various properties.

***** REFERENCES FOR N*1/2(1710) *****

Table with columns for particle ID, references for various decay channels, and various properties.

Baryons

N(1710), N(1810)

Data Card Listings

For notation, see key at front of Listings.

PAPERS NOT REFERRED TO IN DATA CARDS

DEANS 69 PR 177 2623 S R DEANS (UNIV S FLORIDA)
DONNACHI 69 NP 108 433 A DONNACHI, R KIRSOPP (GLAS+EDIN)
AYED 70 PL 318 598 +BAREYRE-VILLET (ISACLAY)
WINNIK 77 NP B128 66 +TOAFF,REVEL,GOLDBERG,BERNY (HAIF)I

N(1810) 15 N*1/2(1810, JP=3/2+) I=1/2 P13

THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

15 N*1/2(1810) MASS (MEV)

Table with columns for mass values, authors, and resonance parameters. Includes entries for M 3, M X, M 6, M A, M A P13, M 7, M 1, M 1, M L, M L, M D, M E, M E, M 8, M 8, M 5, M 5, M C, and M.

15 N*1/2(1810) WIDTH (MEV)

Table with columns for width values, authors, and resonance parameters. Includes entries for W 3, W 6, W 4, W 4, W A, W 7, W 1, W L, W D, W E, W 8, W 5, W 5, W C, and W.

15 N*1/2(1810) REAL PART OF PCLE POSITION (MEV)

Table with columns for real part of pole position, authors, and resonance parameters. Includes entries for RE 8 and RE.

15 N*1/2(1810) -2*IMAG PART OF PCLE POSITION (MEV)

Table with columns for -2*imag part of pole position, authors, and resonance parameters. Includes entries for IM 8 and IM.

15 N*1/2(1810) REAL PART OF ELASTIC POLE RESIDUE (MEV)

Table with columns for real part of elastic pole residue, authors, and resonance parameters. Includes entry for RER.

15 N*1/2(1810) IMAG PART OF ELASTIC POLE RESIDUE (MEV)

Table with columns for imag part of elastic pole residue, authors, and resonance parameters. Includes entry for IMR.

15 N*1/2(1810) PARTIAL DECAY MODES

Table with columns for partial decay modes, authors, and resonance parameters. Includes entries for P1 through P13.

15 N*1/2(1810) BRANCHING RATIOS

Table with columns for branching ratios, authors, and resonance parameters. Includes entries for R1 through R12.

15 N*1/2(1810) PHOTON DECAY AMPL(GEV**1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table with columns for photon decay amplitudes, authors, and resonance parameters. Includes entries for A1 through A5.

Table with columns for photon decay amplitudes, authors, and resonance parameters. Includes entries for A4 through A4.

Data Card Listings

For notation, see key at front of Listings.

Baryons

N(2040), N(2100), N(2190)

REFERENCES FOR N*1/2(2040)

DOONNACHI 68 PL 268 161 A DONNACHIE, R G KIRSOPP, C LOVELACE (CERN)IJP
DCNNACH2 68 VIENNA 139 DONNACHIE, RAPPORTEUR,S TALK (GLAS)
KIRSOPP 68 THESIS R G KIRSOPP (EDIN)

N(2100)

04 N*1/2(2100, JP=1/2-) I=1/2

S11

M (2070.) ROYCHOUD 71 DPWA 3/72
M 7 (2100.) ALMEHED 72 IPWA 2/72
M (2280.) AYED 76 IPWA 11/77
M 1880. 20. HOEHLER 79 IPWA PI N TO PI N 12/79*

W 7 (200.) ALMEHED 72 IPWA 2/72
W (320.) AYED 76 IPWA 11/77
W 95. 30. HOEHLER 79 IPWA PI N TO PI N 12/79*

P1 N*1/2(2100) INTO PI N DECAy MASSES 139+ 938
P2 N*1/2(2100) INTO LAMBDA K 1115+ 497

R1 N*1/2(2100) INTO (PI N)/TOTAL (P1)
R1 7 (0.5) ALMEHED 72 IPWA 2/72
R1 (1.15) AYED 76 IPWA 11/77
R1 .09 .05 HOEHLER 79 IPWA PI N TO PI N 12/79*

RCYCHOUD 71 NP B27 125 R K ROYCHOUDHURY,B H BRANSDEN (DURH)IJP
ALMEHED 72 NP B40 157 +LOVELACE (LUND,RUTG)IJP
AYED 76 CEA-N-1921 AYED (THESIS) (SACL)IJP

N(2100)

05 N*1/2(2100, JP=5/2-) I=1/2

D15

M 7 (2100.) ALMEHED 72 IPWA 2/72
M (2076.) AYED 76 IPWA 11/77
M E (1870.) BAKER 77 DPWA 0 PI- P TO K LAM. 1/78
M E IN ADDITION TO THE LISTED PARAMETERS OBTAINED IN A DPWA, BAKER 77 1/78
M E SEE A POSSIBLE EFFECT ABOVE 2000 MEV IN AN IPWA. 1/78
M 2228. 30. HOEHLER 79 IPWA PI N TO PI N 12/79*
M (1920.) SAXON 80 DPWA 0 PI- P TO K LAM 12/79*

05 N*1/2(2100) WIDTH (MEV)

W 7 (150.) ALMEHED 72 IPWA 2/72
W (206.) AYED 76 IPWA 11/77
W E (93.) BAKER 77 DPWA 0 PI- P TO K LAM. 1/78
W 310. HOEHLER 79 IPWA PI N TO PI N 12/79*
W (220.) SAXON 80 DPWA 0 PI- P TO K LAM 12/79*

05 N*1/2(2100) PARTIAL DECAY MODES

P1 N*1/2(2100) INTO PI N DECAy MASSES 139+ 938
P2 N*1/2(2100) INTO LAMBDA K 1115+ 497
P3 N*1/2(2100) INTO ETA N 939+ 548

05 N*1/2(2100) BRANCHING RATIOS

R1 N*1/2(2100) INTO (PI N)/TOTAL (P1)
R1 7 (0.2) ALMEHED 72 IPWA 2/72
R1 (1.09) AYED 76 IPWA 11/77
R1 .07 .02 HOEHLER 79 IPWA PI N TO PI N 12/79*

REFERENCES FOR N*1/2(2100)

ALMEHED 72 NP B40 157 +LOVELACE (LUND,RUTG)IJP
AYED 76 CEA-N-1921 AYED (THESIS) (SACL)IJP
BAKER 77 NP B126 365 +BLISSETT,BLOODWORTH,BROOME,HART+ (RH)EL)IJP

2100 MEV REGION - PRODUCTION EXPERIMENTS

114 N*1/2(2100, JP=) I=1/2 PRODUCTION EXPERIMENTS
RESONANCE-LIKE BUMP OBSERVED IN PP TO P(N PI+) AT CERN
ISR (DE KERRET 76). THE ENHANCEMENT SHOWS UP MORE
CLEARLY WHEN EVENTS CORRESPONDING TO TRANSVERSAL DECAYS
OF THE (N PI+) SYSTEM ARE SELECTED, CONTRARY TO WHAT
WOULD BE EXPECTED FOR A DIFFRACTIVE-LIKE EFFECT.

114 N*1/2(2100) MASS (MEV) (PROD. EXPERIMENTS)

M (2100.) DE KERRET 76 ISR + P(N PI+)E**45GEV 1/78

114 N*1/2(2100) PARTIAL DECAY MODES (PROD. EXP.)

P1 N*1/2(2100) INTO PI N DECAy MASSES 139+ 493

REFERENCES FOR N*1/2(2100) PROD. EXPERIMENTS

DEKERRET 76 PL 638 477,483 +NAGY,REGLER,BRANDT+ (CERN+HAMB+IPN+VIEN)

N(2190)

71 N*1/2(2190, JP=7/2-) I=1/2

G17

THIS RESONANCE IS WELL ESTABLISHED.

71 N*1/2(2190) MASS (MEV)

M (2190.0) DIDDENS 63 CNTR PI+ P TOTAL
M (2210.0) HOHLER 64 RVUE DATA + DISP REL 7/66
M (2190.0) APPROX YOKOSAWA 66 CNTR PI- P DSIG + PDL
M (2265.0) DONNACHI 68 RVUE PHASE-SHIFT ANAL 6/68
M (2000.0) APPROX LEA 69 CNTR PI-P ELASTIC 5/59
M 2180. 25. ANDERSON 70 MMS - PI- P TO PI- MMS 2/71
M (2158.0) AYED 70 IPWA 1/71
M 6 FROM ENER. DEP. FIT OF ARGAND DIAGRAM
M (2240.0) HULL 70 MPWA SMALL ANGLE PI-P 1/71
M (2160.0) (50.0) AMALDI 71 CNTR P P AT 24 GEV 10/71
M (2160.) BRANSDEN 71 DPWA 3/72
M (2200.) ROYCHOUD 71 DPWA 3/72
M (2225.) ALMEHED 72 IPWA 2/72
M (2190.) OIT 72 MPWA 0 PI- P BKWD ELSTC 2/73
M 1 (2208.) HICKS 73 MPWA GAM P-ETA P 9/73
M 1 ONLY STATES FROM TABLE VII OF HICKS73 ARE INCLUDED IN LISTINGS. 9/73
M 1 M AND W ARE FROM SOLUTION C2,BR-SQRT(G) W WITH G FROM TABLE VII. 9/73
M (2208.) (20.) ABE 74 + P+P->P+X, JCBN PK 4/75
M (2141.) AYED 76 IPWA 11/77
M (2117.) BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
M 2140. 40. HENDRY 78 MPWA PI N TO PI N 12/79*
M (2140.) BAKER 79 DPWA 0 PI- P TO ETA N 12/79*
M 2150. 100. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M 2140. HOEHLER 79 IPWA PI N TO PI N 12/79*
M (2180.) SAXON 80 DPWA 0 PI- P TO K LAM 12/79*

AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Data Card Listings

Baryons

For notation, see key at front of Listings.

N(2200), N(2220), N(>2500), N(2600)

REFERENCES FOR N*1/2(2200)

AYED 76 CEA-N-1921 AYED (THISIS) (SACLIIJP)
HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP
BAKER 79 NP B156 93 +BROWN, CLARK, DAVIES, DEPAGTER, EVANS+ (RHELIIJP)
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 /KARLSRUHE IJP
SAXON 80 NP B162 522 +KAISER, KOCH, PIETARINEN /KARLSRUHE IJP
+BAKER, BELL, BLISSETT, BLODOWORTH+ (RHEL+BRIS)IJP

N(2220) 90 N*1/2(2220, JP=9/2+) I=1/2 H19
THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

90 N*1/2(2220) MASS (MEV)
M (2200.) APPROX. BUSZA 67 OSPK LEG. POLYN. ANAL. 2/71
M 6 (2221.0) AYED 70 IPWA 1/71
M 6 FROM ENER. DEP. FIT OF ARGAND DIAGRAM
M (2245.0) HULL 70 MPWA SMALL ANGLE PI-P 1/71
M (2249.) AYED 76 IPWA 11/77
M 2300. 100. HENDRY 78 MPWA PI N TO PI N 12/79*
M (2350.) BAKER 79 DPWA 0 PI- P TO ETA N 12/79*
M (2250.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M 2205. 10. HOEHLER 79 IPWA PI N TO PI N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

90 N*1/2(2220) WIDTH (MEV)
W 6 (258.0) AYED 70 IPWA 1/71
W (329.0) HULL 70 MPWA SMALL ANGLE PI-P 1/71
W (347.) AYED 76 IPWA 11/77
W 450. 150. HENDRY 78 MPWA PI N TO PI N 12/79*
W (450.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
W 365. 30. HOEHLER 79 IPWA PI N TO PI N 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

90 N*1/2(2220) REAL PART OF POLE POSITION (MEV)
REE (2180.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

90 N*1/2(2220) -2*IMAG PART OF POLE POSITION (MEV)
IME (400.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

90 N*1/2(2220) REAL PART OF ELASTIC POLE RESIDUE (MEV)
RER (37.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

90 N*1/2(2220) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
IMR (-21.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

90 N*1/2(2220) PARTIAL DECAY MODES
DECAY MASSES
P1 N*1/2(2220) INTO PI N 139* 938
P2 N*1/2(2220) INTO N ETA 939* 548
P3 N*1/2(2220) INTO LAMBDA K 1115* 497

90 N*1/2(2220) BRANCHING RATIOS
R1 N*1/2(2220) INTO (PI N)/TOTAL (P1)
R1 6 (0.140) AYED 70 IPWA 1/71
R1 (0.15) HULL 70 MPWA SMALL ANGLE PI-P 1/71
R1 (.20) AYED 76 IPWA 11/77
R1 .12 .04 HENDRY 78 MPWA PI N TO PI N 12/79*
R1 (.20) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
R1 .18 .015 HOEHLER 79 IPWA PI N TO PI N 12/79*
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.4)
R2 N*1/2(2220) FROM PI N TO K LAMBDA SQRT(P1*P3) 12/79*
R2 NOT SEEN SAXON 80 DPWA 0 PI- P TO K LAM. 12/79*

REFERENCES FOR N*1/2(2220)
+DAVIS, DUFF, HEYMANN, NIMMON + (LOUC+LOWC)
R AYED, P BAREYRE, G VILLET (SACLIIJP)
J HULL, R LEACOCK (ISU)
AYED 76 CEA-N-1921 AYED (THISIS) (SACLIIJP)
HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP
BAKER 79 NP B156 93 +BROWN, CLARK, DAVIES, DEPAGTER, EVANS+ (RHELIIJP)
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 /KARLSRUHE IJP
SAXON 80 NP B162 522 +KAISER, KOCH, PIETARINEN /KARLSRUHE IJP
+BAKER, BELL, BLISSETT, BLODOWORTH+ (RHEL+BRIS)IJP
PAPERS NOT REFERRED TO IN DATA CARDS
AYED 70 PL 31B 598 +BAREYRE, VILLET (SACLIIJP)
MA 76 PRD 13 3027 E. MA, G. L. SHAW (OREG+UCII)JP

2200 MEV REGION - PRODUCTION EXPERIMENTS

111 N*1/2(2200, JP=?) I=1/2 PRODUCTION EXPERIMENTS
WE LIST HERE BUMPS OBSERVED IN THE RANGE 1900-2500 MEV.

111 N*1/2(2200) MASS (MEV) (PROD. EXP.)
M 2160. 50. AMALDI 71 SAS + P P TO P MM 1/78
M 2120. 30. APPLE 77 SPEC + P P TO P (P PI0) 1/78
M 2362. 20. APPLE 77 SPEC + P P TO P (N PI+) 1/78
M D 45 1930. 20. SUGAHARA 79 HBC +0 PI-P AT 4.5 GEV 12/79*
M D 34 2120. 10. SUGAHARA 79 HBC +0 PI-P AT 4.5 GEV 12/79*
M D SEEN IN N*3/2(1232) PI PI (NOT RHO)
M R 176(2200.) SUGAHARA 79 HBC + PI-P AT 4.5 GEV 12/79*
M R N*3/2(1232) RHO IS DOMINANT. IDENTIFIED WITH G17(2190).
M AVERAGE MEANINGLESS (SCALE FACTOR = 7.7)

111 N*1/2(2200) WIDTH (MEV) (PROD. EXP.)
W 125. 70. APPLE 77 SPEC + P P TO P (P PI0) 1/78
W 75. 50. APPLE 77 SPEC + P P TO P (N PI+) 1/78
W D 45 160. 30. SUGAHARA 79 HBC +0 PI-P AT 4.5 GEV 12/79*
W D 34 20. 30. SUGAHARA 79 HBC +0 PI-P AT 4.5 GEV 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)
SEE THE NOTES ACCOMPANYING THE MASSES QUOTED ABOVE.

REFERENCES FOR N*1/2(2200)

AMALDI 71 PL 34B 435 +BIANCASTELLI, BOSIO, MATTHIAE+ (SANI+CERN)
APPLE 77 LNC 18 167 +ASH, CHENG, COYNE, GROSSMAN+ (PRIN+PAVIA)
SUGAHARA 79 NC 52A 373 +SUZUKI, FUKAWA, KABE, KICHIMI, OCHIAI+ (KEK)

>2500 MEV REGION - FORMATION EXPERIMENTS

128 N*1/2(>2500) I=1/2
WE LIST HERE I=1/2 RESONANCES WITH MASS GREATER THAN ABOUT 2.5 GEV WHICH HAVE BEEN SEEN IN A SINGLE PARTIAL WAVE ANALYSIS ONLY. ALL RESONANCES WHICH HAVE BEEN OBSERVED IN >1 ANALYSIS AT ABOUT THE SAME MASS ARE GIVEN A SEPARATE LISTING WITH THE APPROPRIATE QUANTUM NUMBERS.

128 N*1/2(>2500) MASS (MEV)
M 3500. 200. HENDRY 78 MPWA PI N L115 12/79*
M 3800. 200. HENDRY 78 MPWA PI N M117 12/79*
M 4100. 200. HENDRY 78 MPWA PI N N119 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.5)

128 N*1/2(>2500) WIDTH (MEV)
W 1300. 200. HENDRY 78 MPWA PI N L115 12/79*
W 1600. 200. HENDRY 78 MPWA PI N M117 12/79*
W 1900. 300. HENDRY 78 MPWA PI N N119 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.2)

128 N*1/2(>2500) PARTIAL DECAY MODES
DECAY MASSES
P1 N*1/2(>2500) INTO PI N 139* 938

128 N*1/2(>2500) BRANCHING RATIOS
R1 N*1/2(>2500) INTO (PI N)/TOTAL (P1)
R1 -.055 .02 HENDRY 78 MPWA PI N L115 12/79*
R1 .040 .015 HENDRY 78 MPWA PI N M117 12/79*
R1 .030 .015 HENDRY 78 MPWA PI N N119 12/79*
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

REFERENCES FOR N*1/2(>2500)

HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP

N(2600) 120 N*1/2(2600, JP=11/2-) I=1/2 I111

120 N*1/2(2600) MASS (MEV)
M 2700. 100. HENDRY 78 MPWA PI N TO PI N 12/79*
M 2577. 50. HOEHLER 79 IPWA PI N TO PI N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.1)

Baryons

Data Card Listings

N(2600), N(2650), N(2700), N(2800), N(3030) For notation, see key at front of Listings.

120 N*1/2(2600) WIDTH (MEV)
W 900. 100. HENDRY 78 MPWA PI N TO PI N 12/79*
R 400. 100. HOEHLER 79 IPWA PI N TO PI N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 3.5)

120 N*1/2(2600) PARTIAL DECAY MODES
PI N*1/2(2600) INTO PI N DECAY MASSES
139+ 938

120 N*1/2(2600) BRANCHING RATIOS
R1 N*1/2(2600) INTO (PI N)/TOTAL (P1) 12/79*
R1 .08 .02 HENDRY 78 MPWA PI N TO PI N 12/79*
R1 .05 .01 HOEHLER 79 IPWA PI N TO PI N 12/79*
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

REFERENCES FOR N*1/2(2600)
HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL) IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN /KARLSRUHE IJP

2650 MEV REGION - MISCELLANEOUS EXPERIMENTS

72 N*1/2(2650,) I=1/2 PRODUCTION EXPERIMENTS
ROYCHUDHURY 71 CLAIM F15(2400) AND G19(2400) TO BE
POSSIBLE RESONANCES. BRANDSEN 71 FIND THE POSSIBLE
RESONANT CANDIDATES S11(2520) AND H19(2590). RECENT
PI N PWA'S ESTABLISH THE EXISTENCE OF A JP=11/2- STATE
IN THIS REGION, BUT THE POSSIBILITY THAT THERE
ARE ALSO OTHER STATES REMAINS. SEE THE MINI-REVIEW
PRECEDING THE N AND DELTA LISTINGS.

72 N*1/2(2650) MASS (MEV) (PROD. EXP.)
M (2700.0) ALVAREZ 64 CNTR P1 PHOTOPROD
M (2660.0) HOHLER 64 RVUE DATA + DISP REL
M (2600.0) APPROX WAHLIG 64 DSPK 0 PI-P CH EX
M (2635.0) BARGER 66 FIT TOTAL + CH EX 11/67
M 2649.0 10.0 CITRON 66 CNTR PI-P TOTAL 7/66

72 N*1/2(2650) WIDTH (MEV) (PROD. EXP.)
W (100.0) ALVAREZ 64 CNTR
W (200.0) HOHLER 64 RVUE 7/66
W (425.0) BARGER 66 FIT TOTAL + CH EX 11/67
W 360.0 20.0 CITRON 66 CNTR 7/66

72 N*1/2(2650) PARTIAL DECAY MODES (PROD. EXP.)
PI N*1/2(2650) INTO PI N DECAY MASSES
P2 N*1/2(2650) INTO LAMBDA K 139+ 938
P3 N*1/2(2650) INTO N PI P1 115+ 497
93+ 139+ 139

72 N*1/2(2650) BRANCHING RATIOS (PROD. EXP.)
R1 N*1/2(2650) INTO (PI N)/TOTAL (P1)
R1 ONLY (J+1/2)* (PI N)/TOTAL MEASURED FOR THIS STATE
R1 B (0.456) (0.318) BARGER 66 RVUE TOTAL + CH EXC. 11/67
R1 0.436 0.028 CITRON 66 CNTR TOTAL CROSS-SEC. 11/67
R1 B (0.30) BARGER 67 RVUE USES KORMANYOS67 11/67
R1 B USES REGGE AMP.+RESCN. TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGRE
R1 B FOR CRITICISM OF THIS METHOD, SEE DOLEN 68.
R1 D (0.24) DIKMEN 67 RVUE USES KORMANYOS66 11/67
R1 D USES ONLY RESONANCES TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGREE
R1 (0.06) KORMANYOS 67 CNTR PI-P AT 180 DEG. 11/67

REFERENCES FOR N*1/2(2650) (PROD. EXP.)
+BAR-YAM,KERN,LUCKEY,OSBORNE, + (MIT,CEA)
HOHLER 64 PL 12 149 G HOHLER, J GIESECKE (KARLSRUHE) I
+MANNELLI,SCDICKSON,FACKLER,WARD, + (MIT)
BARGER 66 PR 151 1123 V BARGER, M GLSSON (WISC)
CITRON 66 PR 144 1101 +GALBRAITH,KYCIA,LEONTIC,PHILLIPS, + (BNL) I
BARGER 67 PR 155 1792 V BARGER, D CLINE (WISC) P
DIKMEN 67 PR 18 798 F N DIKMEN (MICH)
KORMANYOS 67 PR 164 1661 KORMANYOS, KRISCH, OFALLON, + (MCH,ANL) P

PAPERS NOT REFERRED TO IN DATA CARDS
BAACKE 67 NC 51A 761 J BAACKE, M YVERT (KARLSRUHE,ORSAY)J-L
DOLEN 68 PR 166 1768 R DOLEN, D HORN, C SCHMID (CIT)
WAHLIG 68 PR 158 1915 M A WAHLIG, I MANNELLI (MIT,PISA)
FINAL VERSION OF DATA USED IN WAHLIG 64. IN CONJUNCTION WITH
CITRON 66 TOTAL CROSS SECTIONS, THIS CHARGE EXCHANGE DATA GIVES
COMPLEX ELASTIC SCATTERING AMPLITUDE AT 0 DEGREES.

BRANDSEN 71 NP 826 511 +ODGEN (DURHIJJP
ALSO 70 NP B16 461 ROYCHUDHURY,PERRIN,BRANDSEN (DURHIJJP
ROYCHUD 71 NP 827 125 R K ROYCHUDHURY, B H BRANDSEN (DURHIJJP

N(2700) 121 N*1/2(2700, JP=13/2+) I=1/2 K113

121 N*1/2(2700) MASS (MEV)
M 3000. 100. HENDRY 78 MPWA PI N TO PI N 12/79*
M 2612. 45. HOEHLER 79 IPWA PI N TO PI N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 3.5)

121 N*1/2(2700) WIDTH (MEV)
W 900. 150. HENDRY 78 MPWA PI N TO PI N 12/79*
W 350. 50. HOEHLER 79 IPWA PI N TO PI N 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 3.5)

121 N*1/2(2700) PARTIAL DECAY MODES
PI N*1/2(2700) INTO PI N DECAY MASSES
139+ 938

121 N*1/2(2700) BRANCHING RATIOS
R1 N*1/2(2700) INTO (PI N)/TOTAL (P1) 12/79*
R1 .07 .02 HENDRY 78 MPWA PI N TO PI N 12/79*
R1 .04 .01 HOEHLER 79 IPWA PI N TO PI N 12/79*
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

REFERENCES FOR N*1/2(2700)
HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL) IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN /KARLSRUHE IJP

N(2800) 122 N*1/2(2800, JP=9/2-) I=1/2 G19

122 N*1/2(2800) MASS (MEV)
M 2792. 100. HOEHLER 79 IPWA PI N TO PI N 12/79*

122 N*1/2(2800) WIDTH (MEV)
W 240. 100. HOEHLER 79 IPWA PI N TO PI N 12/79*

122 N*1/2(2800) PARTIAL DECAY MODES
PI N*1/2(2800) INTO PI N DECAY MASSES
139+ 938

122 N*1/2(2800) BRANCHING RATIOS
R1 N*1/2(2800) INTO (PI N)/TOTAL (P1) 12/79*
R1 .02 .015 HOEHLER 79 IPWA PI N TO PI N 12/79*

REFERENCES FOR N*1/2(2800)
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1
+KAISER,KOCH,PIETARINEN /KARLSRUHE IJP

N(3030) BUMPS 73 N*1/2(3030, JP=) I=1/2 PRODUCTION EXPERIMENTS

73 N*1/2(3030) MASS (MEV) (PROD. EXP.)
M (3080.0) HOHLER 64 RVUE DATA + DISP REL 7/66
M (3030.0) CITRON 66 CNTR PI-P TOTAL 7/66

73 N*1/2(3030) WIDTH (MEV) (PROD. EXP.)
W (400.0) CITRON 66 CNTR 7/66

73 N*1/2(3030) PARTIAL DECAY MODES (PROD. EXP.)
PI N*1/2(3030) INTO PI N DECAY MASSES
P2 N*1/2(3030) INTO N PI P1 139+ 938
93+ 139+ 139

Data Card Listings

For notation, see key at front of Listings.

Baryons

$N_7(3245)$, $N(3690)$, $N_7(3755)$, $\Delta(1232)$

73 N*1/2(3030) BRANCHING RATIOS (PROD. EXP.)
 R1 N*1/2(3030) INTO (PI N)/TOTAL (P1)
 R1 ONLY (J+1/2)*(PI N/TOTAL) MEASURED FOR THIS STATE
 R1 B (0.088) (0.016) BARGER 66 RVUE TOTAL + CH EXC. 11/67
 R1 (0.048) CITRON 66 CNTR TOTAL CROSS SEC. 11/67
 R1 B (0.12) BARGER 67 CNTR USES KORMANYOS66 11/67
 R1 B USES REGGE AMP.+RESON. TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGRE
 R1 B FOR CRITICISM OF THIS METHOD, SEE DOLEN 68.
 R1 D (0.016) DIKMEN 67 RVUE USES KORMANYOS67 11/67
 R1 D USES ONLY RESONANCES TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGREES

 REFERENCES FOR N*1/2(3030) (PROD. EXP.)
 HOHLER 64 PL 12 149 G HOHLER, J GIESECKE (KARLSRUHE) I
 BARGER 66 PR 151 1123 V BARGER, M OLSSON (WISC)
 CITRON 66 PR 144 1101 +GALBRAITH, KYCIA, LEONTIC, PHILLIPS, + (BNL) I
 BARGER 67 PR 155 1792 V BARGER, D CLINE (WISC) P
 DIKMEN 67 PRL 18 798 F N DIKMEN (WICH)

PAPERS NOT REFERRED TO IN DATA CARDS
 KORMANYOS 67 PR 164 1661 KORMANYOS, KRISCH, OFALLON, + (MICH, ANL) P
 DOLEN 68 PR 166 1768 R DOLEN, D HORN, C SCHMID (CIT)

**$N_7(3245)$
BUMPS**

74 N* /2(3245, JP=) PRODUCTION EXPERIMENTS
 EXISTENCE NOT CONCLUSIVELY ESTABLISHED. I-SPIN
 NOT DETERMINED, BUT THE NARROW WIDTH PRECLUDES
 IDENTIFICATION WITH THE N*3/2(3230).
 OMITTED FROM TABLE.

74 N* /2(3245) MASS (MEV) (PROD. EXP.)
 M 3245.0 10.0 KORMANYOS 67 CNTR PI-P 180 DEG EL 6/68

74 N* /2(3245) WIDTH (MEV) (PROD. EXP.)
 W (35.0) OR LESS KORMANYOS 67 CNTR 6/68

74 N* /2(3245) PARTIAL DECAY MODES (PROD. EXP.)
 P1 N* /2(3245) INTO PI N DECAY MASSES 139+ 938

74 N* /2(3245) BRANCHING RATIOS (PROD. EXP.)
 R1 N* /2(3245) INTO (PI N)/TOTAL (P1)
 R1 J IS NOT KNOWN. FOLLOWING IS (J+1/2)*(PI N)/TOTAL
 R1 (0.37) KORMANYOS 67 CNTR 6/68

 REFERENCES FOR N* /2(3245) (PROD. EXP.)
 KORMANYO 67 PR 164 1661 KORMANYOS, KRISCH, OFALLON, + (MICH, ANL) P

**$N(3690)$
BUMPS**

75 N*1/2(3690, JP=) I=1/2 PRODUCTION EXPERIMENTS
 A BUMP SEEN IN THE INVARIANT MASS OF A VERY COMPLI-
 CATED STATE (N + SEVEN PIS), SO AS EVIDENCE FOR
 A NEW RESONANCE IT IS NOT CONCLUSIVE. NOT INCLUDED
 IN TABLE.

75 N*1/2(3690) MASS (MEV) (PROD. EXP.)
 M 3690.0 10.0 BARTKE 67 HBC + PI+P 8 PRONGS 8/67

75 N*1/2(3690) WIDTH (MEV) (PROD. EXP.)
 W 50.0 30.0 BARTKE 67 HBC + 8/67

75 N*1/2(3690) PARTIAL DECAY MODES (PROD. EXP.)
 P1 N*1/2(3690) INTO N + 7 PIS DECAY MASSES

 REFERENCES FOR N*1/2(3690) (PROD. EXP.)
 BARTKE 67 PL 248 118 +CZYZEWSKI, DANYSZ, + (CRACOW, DRSAY) I

**$N_7(3755)$
BUMPS**

76 N* /2(3755, JP=) PRODUCTION EXPERIMENTS
 A SMALL PEAK IN THE (P P PBARI) INVARIANT MASS FROM
 8.4 BEV/C PI+ P TO PI+ P P BAR EVENTS. AS EVIDENCE
 FOR A NEW RESONANCE IT IS NOT CONCLUSIVE. OMITTED
 FROM TABLE.

76 N* /2(3755) MASS (MEV) (PROD. EXP.)
 M 3755.0 8.0 EHRLICH 68 HBC + PI+ P P BAR 6/68

76 N* /2(3755) WIDTH (MEV) (PROD. EXP.)
 W 40.0 20.0 EHRLICH 68 HBC + 6/68

76 N* /2(3755) PARTIAL DECAY MODES (PROD. EXP.)
 P1 N* /2(3755) INTO PI+ P P BAR DECAY MASSES 139+ 938+ 938+ 938

 REFERENCES FOR N* /2(3755) (PROD. EXP.)
 EHRLICH 68 PRL 20 686 R EHRLICH, R J PLANO, J B WHITTAKER (RUTGERS)

S=0 I=3/2 NUCLEON STATES (Δ)

$\Delta(1232)$

33 N*3/2(1232, JP=3/2+) I=3/2 P'33
 THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.
 SEE CARTER 71 AND CARTER 73 FOR PI N CROSS-SECTION
 DATA IN THIS REGION.

33 N*3/2(1232) MASS (MEV)

M (1234.) ROPER 65 DPWA ++0 PHASE SHIFT AN. 2/72
 M (1235.) ALMEHE 72 IPWA 2/74
 M 3 (1243.3) (1241.7) CHENG 73 FIT CARTER 71 2/74
 M 3 THE TWO ENTRIES ARE FROM TWO DIFFERENT PARAMETRIZATIONS OF THE 2/74
 M 3 RESONANCE CONTRIBUTION TO THE P33 PHASE SHIFT. 2/74
 M (1230.4) TSCHANG 73 FIT CARTER 71 P33 1/74
 M (1231.) AYED 76 IPWA PI N TO PI N 11/77
 M (1233.) 2. HOEHLER 79 IPWA 12/79*

M++ 1236.0 0.55 OLSSON 65 RVUE ++ TOTAL-SIGMA DATA
 M++ 2 1231.0 1.5 CARTER 71 MPWA ++ PI+P SIG. TOTAL 1/74
 M++ 1 1231.1 .2 CARTER 73 IPWA ++ PI N 88-310 MEV 9/73
 M++ 1 EXPERIMENTAL QUANTITY-SEE CARTER 73 FOR COULOMB BARRIER CORRECTIONS 9/73
 M++ 2 EXPERIMENTAL QUANTITY-SEE CARTER 71 FOR COULOMB BARRIER CORRECTIONS 3/79*

M++ AVERAGE MEANINGLESS (SCALE FACTOR = 8.4)

M+ (1231.8) BERENDS 75 IPWA + GAM P TO PI NUC 4/75
 M+ 1230.6 1.8 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
 M+ (1231.7) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
 M+ 4 (1231.2) BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
 M+ 4 SUPERSEDES BARBOUR 76. MIROSHNIC 79 + FIT PHOTO-PROD 12/79*
 M+ 1236.9 1.4
 M+ AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)

MO 1236.45 0.65 OLSSON 65 RVUE 0
 MO 1232.9 0.6 CARTER 71 MPWA 0 PI-P SIG. TOTAL 1/71
 MO
 MO AVERAGE MEANINGLESS (SCALE FACTOR = 4.0)

33 N*3/2(1232) WIDTH (MEV)

W (120.) ROPER 65 DPWA ++0 PHASE SHIFT AN. 2/72
 W (129.) ALMEHE 72 IPWA 2/74
 W 3 (152.2) (145.8) CHENG 73 FIT CARTER 71 2/74
 W (120.) TSCHANG 73 FIT CARTER 71 P33 1/74
 W (109.) AYED 76 IPWA 11/77
 W 116. 5. HOEHLER 79 IPWA PI N TO PI N 12/79*

W++ 120.0 2.0 OLSSON 65 RVUE ++
 W++ 2 111.1 1.8 CARTER 71 MPWA ++ PI+P SIG. TOTAL 1/74
 W++ 1 111.5 .4 CARTER 73 IPWA ++ PI N 88-310 MEV 9/73

W++ AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

W+ 120.2 3.9 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
 W+ (117.4) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
 W+ 4 (111.0) BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
 W+ 131.1 2.4 MIROSHNIC 79 + FIT PHOTO-PROD 12/79*
 W+ AVERAGE MEANINGLESS (SCALE FACTOR = 2.4)

WO 119.6 2.4 OLSSON 65 RVUE 0
 WO 114.7 3.0 CARTER 71 MPWA 0 PI-P SIG TOT. 1/71
 WO
 WO AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

33 (N*0) - (N+++) MASS DIFFERENCE (MEV)

D R (0.45) (0.85) OLSSON 65 RVUE
 D 2 1.3 1.9 CARTER 71 MPWA ++ PI+P SIG. TOTAL 1/74
 D 1 1.4 .4 CARTER 73 IPWA PI N 88-310 MEV 9/73
 D R REDUNDANT WITH DATA IN MASS LISTING.
 D
 D AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Baryons
Δ(1232)

Data Card Listings
For notation, see key at front of Listings.

33 N*3/2(1232) WIDTH DIFFERENCE (MEV) 9/73
WD 2 6.5 2.2 CARTER 71 MPWA ++ P1+P SIG. TOTAL 1/74
WD 1 10.3 1.3 CARTER 73 IPWA P1 N 88-310 MEV 9/73
WD AVERAGE MEANINGLESS (SCALE FACTOR = 1.5)

33 N*3/2(1232) REAL PART OF POLE POSITION (MEV)
REE M (1214.) MICHAEL 67 2/74
REE (1211.) BALL 72 2/73
REE P (1211.6 0.7) POG 72 FIT DELTA 33 2/73
REE 3 (1210.7) (1210.7) CHENG 73 FIT CARTER 71 2/74
REE (1214.5 10.) NGOOVA 73 FIT ALMEHD72 2/74
REE (1213.) SPEARMAN 74 FIT ZERO TRJCTRY 4/75

REE M FIT INCLUDES OLSSON 65 PARAMETERS PLUS SCATTERING LENGTH PLUS 6
REE M PHASE SHIFT VALUES FOR TPI=120 TO 492 MEV.
REE P ERROR EST. FROM FITS WITH SOMEWHAT VARYING ASSUMPTIONS
REE
REE AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
R++ U 1211.5 .6 BALL 75 ++ FIT CARTER 73 11/75
R++ U 1210.9 .8 LICHTENB 75 ++ FIT CARTER 73 11/75
R++ C 1209.6 .5 VASAN 76 ++ FIT CARTER 73 1/76

RE+ 1209. 2. CAMPBELL 76 + FIT PHOTO-PROD 2/77
RE+ 1206.9+-0.9 TO 1210.5+-1.8 MIROSHNIC 79 + FIT PHOTO-PROD 12/79*
REO U (1211.6) BALL 75 0 FIT CARTER 73 11/75
REO U 1210.9 1.4 LICHTENB 75 0 FIT CARTER 73 11/75
REO C 1210.75 .6 VASAN 76 0 FIT CARTER 73 1/76
REO U (1210.2) VASAN 76 0 FIT CARTER 73 1/76
REO Z 1209.5 .41 ZIDELL 78 0 FIT ZIDELL 78 3/79*

33 N*3/2(1232) -IMAG PART OF POLE POSITION (MEV)
IME M (52.) MICHAEL 67 2/74
IME (50.1) BALL 72 2/73
IME P (50.7) (50.6) CHENG 73 FIT CARTER 71 2/74
IME 3 48.6 5. NGOOVA 73 FIT ALMEHD72 2/74
IME (49.) SPEARMAN 74 FIT ZERO TRJCTRY 4/75

IM+ U 50.1 .6 BALL 75 ++ FIT CARTER 73 11/75
IM+ U 49.6 .75 LICHTENB 75 ++ FIT CARTER 73 11/75
IM+ C 50.4 .5 VASAN 76 ++ FIT CARTER 73 1/76
IM+ U (49.9) TO (50.0) VASAN 76 ++ FIT CARTER 73 1/76
IM+ Z 49.745 .14 ZIDELL 78 ++ FIT ZIDELL 78 3/79*

IM+ AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
IMQ U (53.0) BALL 75 0 FIT CARTER 73 11/75
IMQ U 53.25 1.75 LICHTENB 75 0 FIT CARTER 73 11/75
IMQ C 52.8 .6 VASAN 76 0 FIT CARTER 73 1/76
IMQ U (52.9) TO (53.1) VASAN 76 0 FIT CARTER 73 1/76
IMQ Z 52.45 .2 ZIDELL 78 0 FIT ZIDELL 78 3/79*

IMQ AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
ABS (53.) BALL 73 FIT DELTA 33 9/73
A++ C (52.4) TO (53.2) VASAN 76 ++ FIT CARTER 73 1/76
A++ U (52.1) TO (52.4) VASAN 76 ++ FIT CARTER 73 1/76
ABO C (54.8) TO (55.0) VASAN 76 ++ FIT CARTER 73 1/76
ABO U (55.2) TO (55.3) VASAN 76 ++ FIT CARTER 73 1/76

33 N*3/2(1232) ABSOLUTE VALUE OF ELASTIC POLE RESIDUE (MEV)
PH (-.81) BALL 73 FIT DELTA 33 9/73
P++ C (-.82) TO -.83 VASAN 76 ++ FIT CARTER 73 1/76
P++ U (-.82) TO -.83 VASAN 76 ++ FIT CARTER 73 1/76
PHO C (-.84) TO -.847 VASAN 76 ++ FIT CARTER 73 1/76
PHO U (-.84) TO -.856 VASAN 76 ++ FIT CARTER 73 1/76

33 N*3/2(1232) PHASE OF ELASTIC POLE RESIDUE (RADIANS)
MIP INFORMATION ON THE PHASE (AND MAGNITUDE) OF THE M1+(3/2) MULTIPLE 12/79*
MIP AMPLITUDE POLE RESIDUE IS CONTAINED IMPLICITLY IN THE PAPER OF 12/79*
MIP MIROSHNICHENKO 79. THEY FIND THAT THE PHASE IS CONSISTENT WITH 12/79*
MIP BEING EQUAL TO THAT OF THE ELASTIC POLE RESIDUE. 12/79*

33 N*3/2(1232) PHASE OF M1+(3/2) PHOTOPRODUCTION MULTIPLE AMPLITUDE POLE RESIDUE
MM (44.7) TO (46.7) NEFKENS 78 P I P TO P I P GAM 12/79*

33 N*3/2(1232) PARTIAL DECAY MODES
P1 N*3/2(1232) INTO N P1 938+ 139
P2 N*3/2(1232) INTO N GAMMA 938+ 0
P3 N*3/2(1232) INTO N P1 P1 938+ 139+ 139
P4 N*3/2(1232) INTO GAM NUCLEON, HELICITY=1/2 0+ 938
P5 N*3/2(1232) INTO GAM NUCLEON, HELICITY=3/2 0+ 938

33 N*3/2(1232) BRANCHING RATIOS
R1 N*3/2(1232) INTO (N GAMMA)/(N P1) (PERCENT) (P2)/(P1)
R1 0.55 0.02 DALITZ 66 RVUE 7/68
R1 0.53 0.025 BERENDS 71 IPWA PHOTOPROD. ANAL. 10/71

R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
R2 N*3/2(1232) INTO (N P1)/TOTAL (P1)
R2 2 (.99) CARTER 71 MPWA ++ P1+P SIG. TOTAL 1/74
R2 (1.) ARVED 76 IPWA 11/77
R2 (1.) HOEHLER 79 IPWA P I N TO P I N 12/79*

33 N*3/2(1232) PHOTON DECAY AMPLITUDE (GEV**1/2)
FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

A1 N*3/2(1232) INTO GAM NUCLEON, HELICITY=1/2 (GEV**1/2)
A1 -144 .014 DEVENISH 73 DPWA P I N PHOTO PROD 2/74
A1 -142 .006 MOORHOUSE 73 DPWA P I N PHOTO-PROD 2/73
A1 -138 .004 KNIES 74 DPWA P I N PHOTO PROD 2/74
A1 -140 .006 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A1 -142 .001 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A1 -130 .002 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A1 (-139) KRIVETS 75 DPWA P I N PHOTO-PROD 1/78
A1 (-129) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A1 -141 .004 FELLER 76 DPWA P I N PHOTO-PROD 2/77
A1 -136 .002 AZNAURYAN 77 DPWA P I O PHTRD, SOL 1 12/79*

A2 N*3/2(1232) INTO GAM NUCLEON, HELICITY=3/2 (GEV**1/2)
A2 -262 .015 DEVENISH 73 DPWA P I N PHOTO PROD 2/74
A2 -259 .016 MOORHOUSE 73 DPWA P I N PHOTO-PROD 2/73
A2 -253 .002 KNIES 74 DPWA P I N PHOTO PROD 2/74
A2 -254 .007 METCALF 74 DPWA P I N PHOTO-PROD 2/74
A2 -261 .001 MOORHOUSE 74 DPWA P I N PHOTO-PROD 2/74
A2 -248 .002 CRAWFORD 75 DPWA P I N PHOTO-PROD 1/76
A2 (-253) KRIVETS 75 DPWA P I N PHOTO-PROD 1/78
A2 (-251) BARBOUR 76 DPWA P I N PHOTO-PROD 1/76
A2 -256 .003 FELLER 76 DPWA P I N PHOTO-PROD 2/77
A2 -255 .002 AZNAURYAN 77 DPWA P I O PHTRD, SOL 1 12/79*

REFERENCES FOR N*3/2(1232)

CLSSCN 65 PRL 14 118 M G OLSSON (WISC)
ROPER 65 PR 138 B190 L D ROPER, R M WRIGHT, B T FELD (LRL+MIT) IJP
DALITZ 66 PR 146 1180 DALITZ, SUTHERLAND (OXFORD)
CONTAINS REFERENCES TO EARLIER WORK ON DELTA PHOTOPRODUCTION.
MICHAEL 67 PR 156 1677 MICHAEL (RHEL) IJP
+WEAVER (CEA, MIT, TUFT)
CARTER 71 NP 826 445 +WILLIAMS, BUGG, BUSSEY, DANCE (CAVE, RHEL)
ALMEHD 72 NP 840 157 +LOWLACE (LUND, RUTG) IJP
BALL 72 PRL 28 1143 +CAMPBELL, LEE, SHAW (UTAH, BOLS, UCI)
POG 72 PL 398 103 SODING, BARTELS, + (DESY+LBL+BRAN+GERN+HELS) IJP
BALL 73 PRD 7 2789 BALL, LEE, SHAW (UTAH+UCI) IJP
CARTER 73 NP 858 378 CARTER, BUGG, CARTER (CAVENDISH+QUEEN MARY) IJP
CHENG 73 PRD 7 2249 CHENG, LICHTENBERG (IND) IJP
DEVENISH 73 PL 478 53 DEVENISH, RANKIN, LYTH (LOUC+BOON+LANC) IJP
MOORHOUSE 73 PL 438 44 MOORHOUSE, OBERLACK (GLAS+LBL) IJP
NGOOVA 73 NP 861 445 NGOOVA, PISUT (IP SLOVAK ACAD SCI, COMENIUS) U IJP
ALSO 73 NP 865 544 NGOOVA, PISUT+ (IP SLOVAK ACAD SCI, COMENIUS) U IJP
TSCHANG 73 NP 859 445 TSCHANG, PARKINSON (FLOR+GAINESVILLE) IJP
KNIES 74 PRD 9 2680 KNIES, MOORHOUSE, OBERLACK (LBL, GLAS) IJP
METCALF 74 NP 876 253 W J METCALF, R L WALKER (CIT) IJP
MOORHOUSE 74 PRD 9 1 MOORHOUSE, OBERLACK, ROSENFELD (GLAS+LBL) IJP
SPEARMAN 74 PRD 10 1660 T D SPEARMAN (TRINITY COLLEGE, DUBLIN)
BALL 75 PRD 11 1171 J S BALL, R L GOBLE (UTAH) IJP
BERENDS 75 NP 884 342 BERENDS, DONNAGHIE (LEID, MCHS)
CRAWFORD 75 NP 897 125 R L CRAWFORD (GLAS) IJP
KRIVETS 75 SUNP 20 430 +MIROSHNICHENKO, NIKIFOROV, SANIN+ (KIEV) IJP
ALSO 74 SUNP 19 112 KRIVETS, NIKIFOROV, SANIN, SHALATSKII (KIEV) IJP
LICHTENB 75 LNC 12 616 D B LICHTENBERG (IND) IJP
AYED 76 CEA-N-1921 AYED (THESES) (SACL) IJP
BARBOUR 76 NP 811 358 I. M. BARBOUR, R. L. CRAWFORD (GLAS) IJP
CAMPBELL 76 PRD 15 2421 CAMPBELL, LEE, SHAW, BALL (BOIS+UCI) IJP
FELLER 76 NP 8104 219 +FUKUSHIMA, HORIKAWA, KAJIKAWA+ (NAGAYA+OSAKA) IJP
VASAN 76 NP 8106 535 S. S. VASAN (CARN) IJP
ALSO 76 NP 8106 526 S. S. VASAN (CARN) IJP
AZNAURYA 77 EFI-266 (57)-77 +AKOPDV, BAGDASARYAN (YEREVAN PHYSICS INST.) IJP
BARBOUR 78 NP 8141 253 BARBOUR, CRAWFORD, PARSONS (GLAS)
NEFKENS 78 PRD 18 3911 +ARMAN, BALAGH, GLODIS, HADDOCK+ (UCLA+CATH) IJP
NOELLE 78 PTP 60 778 P. NOELLE (NAGO)
ZIDELL 78 LNC 21 140 ZIDELL, ARNDT, ROPER (VP) IJP
HOEHLER 79 HANDBOOK OF P I N SCATTERING, PHYSIK DATEN VOL. 12-1
+KAISER, KOCH, PIETARINEN /KARLSRUHE IJP
MIROSHNI 79 SUNP 29 94 MIROSHNICHENKO, NIKIFOROV, SANIN+ (KHARKOV) IJP

Data Card Listings

For notation, see key at front of Listings.

Baryons

$\Delta(1232)$, $\Delta(1550)$, $\Delta(1650)$

PAPERS NOT REFERRED TO IN DATA CARDS

DCNNACHI 68 PL 268 161	DONNACHI, LOVELACE, KIRSOPP (CERN)
FGNDA 73 PR 8 353	FONDA, GHIRARDI, SHAW (ICTP-TRIESTE+TRST) IJP
HENVEY 74 PR 09 302	HENVEY, KANE (MICH) IJP
OLSSON 74 LNC 10 353	OLSSON (CERN) IJP
PFELL 74 NP 873 166	PFELL, ROLLNIK, STANKOWSKI (BCNN)
SUZUKI 74 NP 868 413	SUZUKI, KUROKAWA, KONDO (TOKYO)
GANEKO 75 SJNP 22 522	*KRIVETS, MIROSHNICHENKO, NIKIFOROV+ (KIEV) IJP
NIGRO 75 NP 884 201	NIGRO, SPILLANTI, VALENTE (PADO, FRAS)
GANEKO2 76 SJNP 24 284	*KRIVETS, MIROSHNICHENKO, NIKIFOROV+ (KIEV) IJP
GANEKOZ 76 SJNP 24 594	*GORBENKO, KRIVETS, KOLESNIKOV+ (KIEV) IJP
ZABEV 76 SJNP 24 70	ZABEV, KUZNETSOV, STUKOV (TMSK) IJP

1232 MEV REGION - PRODUCTION EXPERIMENTS

81 N*3/2(1232, JP=3/2+) I=3/2 PRODUCTION EXPERIMENTS

SEE THE MINI-REVIEW PRECEDING THE N AND DELTA LISTINGS FOR A DISCUSSION OF PRODUCTION EXPERIMENTS.

81 N*3/2(1232) MASS (MEV) (PROD. EXP.)

M	1217.	8.	ANDERSON	70 MMS	-	PI- P TO PI- MMS	2/71
M	1227.0	7.0	ELLIS	71 CNTR	MMS PP	3.7 GEV/C	10/71
M							
M	AVG	1222.7	5.3	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)			
M	STUDENT	1222.7	5.9	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			
M++	(1232.0)	(6.0)	FERRO-LUZ	65 HBC	++	K+P TO KO P PI+	
M++	(1236.0)		DEANS	66 RVUE	++	P1+P TOTAL	7/66
M++	(1233.4)	(4.4)	GIDAL	66 DBC	++	D TO NN(NN) PI	7/66
M++	(1224.0)	(2.0)	HABER	70 DBC		K-D TO 4 BOD(P)	7/70
M++	(1231.1)	(3.1)	COLTON	72 HBC	++	PP TO PI+PN 7GEV	1/73
M++	1226.0	2.0	COLTON	72 HBC	++	TO P1+P1-PP	1/73
M++	1222.0	3.0	COLTON	72 HBC	++	TO P1+P1-PIOPP	1/73
M++	1226.0	2.0	COLTON	72 HBC	++	TO P1+P1-P1-PN	1/73
M++	(1231.1)	(3.1)	LEWIS	73 HBC	++	K+ P TO K P 2PI	1/76
M++	1219.	5.	LIGHTMAN	74 HBC	++	P1+P TO 3PI P	4/75
M++	1213.	3.	LIGHTMAN	74 HBC	++	P1-P TO 3PI P	4/75
M++	(1224.)	5. TO 10.	BRAUNZ	75 BC	PBAR P AND D, 5.7	11/75	
M++	1224.	TO 1228.	ATHERTON	76 HBC	PBAR P 5.7 GEV	2/77	
M++	2K 1226.	3.	GOGG12	78 ISR	++	PP TO DELTA P PI	1/80*
M++	840 1225.	2.	APELDOORN	79 HBC	++	PBAR P 7.2 GEV/C	12/79*
M++							
M++	AVG	1226.1	2.2	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.6)			
M++	STUDENT	1225.3	1.1	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			
M+	1224.	TO 1230.	BRAUN1	75 HBC	PBAR P 5.7 GEV	11/75	
M+	1	1256.	15.	APPLE	77 SPEC	+ P P TO P (N PI+)	1/78
M+	1	NOT SEEN IN P P TO P (P PI0).					1/78
MO	1231.	11.	COOPER	74 HBC	O D P CEX	4/75	
MO	(1230.)		BRAUN1	75 HBC	PBAR P 5.7 GEV	11/75	
MO	(1220.)	5. TO 10.	BRAUNZ	75 BC	PBAR P AND D, 5.7	11/75	
M-	(1241.3)	(5.1)	GIDAL	66 DBC	-	TO P1+P1-PI-PN	7/66
M-	1239.0	5.0	COLTON	72 HBC	-	TO P1+P1-PI-PN	1/73

81 (N*-) - (N*++) MASS DIFFERENCE (MEV) (PROD. EXP.)

D	7.9	6.8	GIDAL	66 DBC
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81 N*3/2(1232) WIDTH (MEV) (PROD. EXP.)

W	115.	5.	ANDERSON	70 MMS	-	PI- P TO PI- MMS	2/71
W	105.0	7.0	ELLIS	71 CNTR	MMS PP	3.7 GEV/C	10/71
W	141.	11.	MUSGRAVE	75 HBC	K+ P TO K PI N	11/75	
W							
W	AVG	115.2	7.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.0)			
W	STUDENT	114.5	4.6	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			
W++	(125.0)	(30.0)	FERRO-LUZ	65 HBC	++		
W++	(121.0)		DEANS	66 RVUE	++		7/66
W++	(124.0)	(14.0)	GIDAL	66 DBC	++		7/66
W++	(120.0)	(8.0)	HABER	70 DBC		K-D TO 4 BOD(P)	7/70
W++	115.0	6.0	COLTON	72 HBC	++	PP TO P1+PN 7GEV	1/73
W++	127.0	5.0	COLTON	72 HBC	++	TO P1+P1-PP	1/73
W++	122.0	9.0	COLTON	72 HBC	++	TO P1+P1-PIOPP	1/73
W++	106.0	7.0	COLTON	72 HBC	++	TO P1+P1-P1-PN	1/73
W++	(146.)	(10.)	LEWIS	73 HBC	++	K+ P TO K P 2PI	1/76
W++	166.	14.	LIGHTMAN	74 HBC	++	P1+P TO 3PI P	4/75
W++	136.	7.	LIGHTMAN	74 HBC	++	P1-P TO 3PI P	4/75
W++	(110.)	10. TO 20.	BRAUNZ	75 BC	PBAR P AND D, 5.7	11/75	
W++	96.	TO 113.	ATHERTON	76 HBC	PBAR P 5.7 GEV	2/77	
W++	2K 113.	16.	GOGG12	78 ISR	++	PP TO DELTA P PI	1/80*
W++	840 100.	5.	APELDOORN	79 HBC	++	PBAR P 7.2 GEV/C	12/79*
W++							
W++	AVG	117.5	5.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.3)			
W++	STUDENT	118.5	3.8	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT			
W+	110.	TO 130.	BRAUN1	75 HBC	PBAR P 5.7 GEV	11/75	
W+	1	20.	60.	20.	APPLE	77 SPEC	+ P P TO P (N PI+)
W+	1						1/78
WO	109.	32.	25.	COOPER	74 HBC	O D P CEX	4/75
WO	(1)			BRAUN1	75 HBC	PBAR P 5.7 GEV	11/75
WO	(120.)	10. TO 20.	BRAUNZ	75 BC	PBAR P AND D, 5.7	11/75	
W-	(149.0)	(18.0)	GIDAL	66 DBC	-	TO P1+P1-PI-PN	7/66
W-	237.0	22.0	COLTON	72 HBC	-	TO P1+P1-PI-PN	1/73

REFERENCES FOR N*3/2(1232) (PRCD. EXP.)

FERRO-LU 65 NC 36 1101	FERRO-LUZZI, GEORGE, + (CERN)
DEANS 66 PREPRINT	S R DEANS, W G HOLLADAY (VANDERBILT)
GIDAL 66 PR 141 1261	G GIDAL, A KERNAN, S KIM (LRL)
ANDERSON 70 PRL 25 699	*BLESER, BLIEDEN, COLLINS++ (BNL, CERN)
HABER 70 NP 178 289	*SHAPIRA, MERRILL, MCNARI++ (SABRE COLL)
ELLIS 71 PRL 27 442	*MAGLICH, NOREM, SANNES, SILVERMAN (RUTG)
COLTON 72 PR 06 95	E COLTON, A KIRSCHBAUM (LBL)
LEWIS 73 NP 860 283	*ALLEN, JACOBSON, DANYSZ, ISLAM+ (LONC+LOIC+CCEF)

COOPER 74 NP 879 259	COOPER, SEIDL, VANDERVELDE (MICH)
LIGHTMAN 74 NP 881 31	LIGHTMAN, BISMAS, CASON, KENNEY, MCGAHAN+ (NDAM) I
BRAUN1 75 NP 895 481	*GERBER, MAURER, MICHALON, SCHIBY+ (STRB, LPNP) I
BRAUN2 75 NP 895 503	*GERBER, MAURER, MICHALON, SCHIBY+ (STRB, LPNP) I
MUSGRAVE 75 NP 887 365	*PEETERS, SCREINER, WHITMORE, YUTA (ANL)
ATHERTON 76 NP B103 381	ATHERTON, FRENCH, SKURA, BOHM+ (CERN+PRAG) I
APPLE 77 LNC 18 167	*ASH, CHENG, COYNE, GROSSMAN+ (PRIN+PAVIA)
GOGG12 78 NP B133 365	*CAVALLI-LORZA, CONTI+ (CERN+PAVI)
APELDOOR 79 NP B156 111	VAN APELDOORN, HARTING, HOLTHUIZEN+ (AMST)

PAPERS NOT REFERRED TO IN DATA CARDS	
ALEXANDE 73 NP B52 221	ALEXANDER, BENARY+ (TEL-AVIV+HEIDELBERG+DESY)
BEAUPRE 73 NP B66 93	(AACH+BERL+BONN+CERN+NDAM+PENN+TGH) I
BERLAND 74 NP B75 93	BERLAND, HABER, HODDUS, HULSIZER+, (MIT) I
ALSO 74 PL 518 187	BERLAND, HABER, HODDUS, HULSIZER+, (MIT) I
ATHERTON 75 NC 30A 505	ATHERTON, BAI-NIR, FRENCH, SKURA+ (CERN+PRAG) I
STRACHMA 75 NP B98 120	STRACHMAN, BRAUN, GERBER, MAURER+ (LNP+STRB) I

$\Delta(1550)$

110 N*3/2(1550, JP=1/2+) I=3/2 S_{31} 11/77

110 N*3/2(1550) MASS (MEV) 11/77

M 8	(1550.)	LONGACRE	77 IPWA	PI N TO 2PI N	11/77
M 8	ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE POSITION WHICH IS FROM SOLUTIONS S1 AND C1.				11/77
M	(1525.)	BARNHAM	79 IPWA	++ PI N TO 2PI N	12/79*

110 N*3/2(1550) WIDTH (MEV) 11/77

W 8	(110.)	LONGACRE	77 IPWA	PI N TO 2PI N	11/77
W	(40.)	BARNHAM	79 IPWA	++ PI N TO 2PI N	12/79*

110 N*3/2(1550) REAL PART OF POLE POSITION (MEV) 11/77

RE 8	1554. OR 1553.	LONGACRE	77 IPWA	PI N TO 2PI N	11/77
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110 N*3/2(1550) -2*IMAG PART OF POLE POSITION (MEV) 11/77

IM 8	105. OR 104.	LONGACRE	77 IPWA	PI N TO 2PI N	11/77
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110 N*3/2(1550) PARTIAL DECAY MODES 11/77

P1	N*3/2(1550) INTO PI N	DECAY MASSES
P2	N*3/2(1550) INTO N*3/2(1232) PI	1394 938
P3	N*3/2(1550) INTO N RHO, S=3/2	1232+ 139
		938+ 776

110 N*3/2(1550) BRANCHING RATIOS 11/77

R1	N*3/2(1550) FROM PI N TO N*3/2(1232) PI	SQRT(P1*P2)	11/77			
R1	8 (+.11)	LONGACRE	77 IPWA	PI N TO 2PI N	11/77	
R1	.13	.05	BARNHAM	79 IPWA	++ PI N TO 2PI N	12/79*
R2	N*3/2(1550) FROM PI N TO N RHO, S=3/2	SQRT(P1*P3)	11/77			
R2	8 (+.08)	.05	LONGACRE	77 IPWA	PI N TO 2PI N	11/77
R2	.17	.05	BARNHAM	79 IPWA	++ PI N TO 2PI N	12/79*

REFERENCES FOR N*3/2(1550)

LONGACRE 77 NP B122 493	LONGACRE, DOLBEAU (SACL) IJP
ALSO 76 NP B108 365	DOLBEAU, TRIANTIS, NEVEU, CADDET (SACL) IJP
BARNHAM 79 IC/HENP/78/3	*GLICKMAN, MIER-REDREJOWICZ+ (LGI) IJP

$\Delta(1650)$

82 N*3/2(1650, JP=1/2-) I=3/2 S_{31} 11/77

THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

82 N*3/2(1650) MASS (MEV)

M	(1648.0)	(12.0)	DEVLIN	65 CNTR	PI+ P TOTAL	
M	1	(1695.0)	BARREYRE	68 RVUE	PHASE-SHIFT ANAL	11/67
M	1				WHERE CROSS SECTION IS GREATEST - EYEBALL FIT	
M	3	(1635.0)	DONNACHI	68 RVUE	PHASE-SHIFT ANAL	6/68
M	6	(1614.0)	AYED	70 IPWA		1/71
M	6	ENER. DEP. FIT OF ARGAND DIAGRAM				
M	4	(1617.0)	DAVIES	70 RVUE	P-S ANAL SOL A	8/69
M	7	(1620.)	ALMEHD	72 IPWA		2/72
M	1622. TO 1688.		CRAWFORD	75 DPWA	PI N PHOTO-PROD	1/76
M	L 1625. OR 1600.		LONGACRE	75 IPWA	PI N TO 2PI N	11/75
M	L THE 2 SETS OF PARAMETERS ARE FROM METHODS 1 AND 2 OF LONGACRE 75.					11/75
M	(1623.)		AYED	76 IPWA		11/77
M	(1680.)		BARBOUR	76 DPWA	PI N PHOTO-PROD	1/76
M	8 (1580.)		LONGACRE	77 IPWA	PI N TO 2PI N	11/77
M	8 ALL LONGACRE77 PARAMETERS ARE FROM SOLUTION S2, EXCEPT FOR THE POLE POSITION WHICH IS FROM SOLUTIONS S1 AND C1.					11/77
M	2 (1662.)		BARBOUR	78 DPWA	PI-N PHOTO-PRD	3/79*
M	2 SUPER SEDES BARBOUR 76.					3/79*
M	5 (1620.)		BARNHAM	79 IPWA	++ PI N TO 2PI N	12/79*
M	1620.	20.	CUTKOSKY	79 IPWA	PI N TO PI N	12/79*
M	1610.	7.	HOEHLER	79 IPWA	PI N TO PI N	12/79*
M						
M	AVG	MEANINGLESS (SCALE FACTOR = 1.0)				

Baryons

$\Delta(1650)$, $\Delta(1670)$

Data Card Listings

For notation, see key at front of Listings.

Table with columns: W, #, (mass), BARYON, #, RVUE, 11/67. Includes data for $\Delta(1650)$ with various baryon assignments like BAREYRE, DONNACHI, AYES, DAVIES, ALMEHED, CRAWFORD, LONGACRE, BARBOUR, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: RE, #, (mass), REAL PART OF POLE POSITION (MEV), 11/75. Includes data for $\Delta(1650)$ with assignments like LONGACRE, CUTKOSKY.

Table with columns: IM, #, (mass), -2*IMAG PART OF POLE POSITION (MEV), 11/75. Includes data for $\Delta(1650)$ with assignments like LONGACRE, CUTKOSKY.

Table with columns: RER, #, (mass), REAL PART OF ELASTIC POLE RESIDUE (MEV), 12/79*. Includes data for $\Delta(1650)$ with assignment CUTKOSKY.

Table with columns: IMR, #, (mass), IMAG PART OF ELASTIC POLE RESIDUE (MEV), 12/79*. Includes data for $\Delta(1650)$ with assignment CUTKOSKY.

Table with columns: P1, #, N*3/2(1650) INTO PI N, DECAY MASSES, 139+ 938, 139. Includes data for $\Delta(1650)$ with assignments like LONGACRE, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: R1, #, N*3/2(1650) INTO (PI N)/TOTAL, (PI), 6/68. Includes data for $\Delta(1650)$ with assignments like DONNACHI, AYES, DAVIES, ALMEHED, AYES, CUTKOSKY, HOEHLER.

Table with columns: R2, #, N*3/2(1650) FROM PI N TO N*3/2(1232) PI, SQR(T(P1*P6)), 11/75. Includes data for $\Delta(1650)$ with assignments like LONGACRE, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: A1, #, N*3/2(1650) INTO GAM NUCLEON, HELICITY=1/2 (GEV**1/2), 2/74. Includes data for $\Delta(1650)$ with assignments like DEVENISH, HEMMI, MOORHOUS, DEVENIS2, KES, METCALF, MOORHOUS, CRAWFORD, KRIVETS, BARBOUR, FELLER, AZNAURYAN, BARNHAM.

A1 AVERAGE MEANINGLESS (SCALE FACTOR = 2.4)

Table with columns: DEVLIN, #, PRL, #, REFERENCES FOR N*3/2(1650), T J DEVLIN, J SOLOMON, G BERTSCH (PRINCETON) I. Includes data for $\Delta(1650)$ with assignments like BAREYRE, DONNACHI, AYES, DAVIES, ALMEHED, CRAWFORD, LONGACRE, BARBOUR, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: CRAWFORD, #, NP, #, 125, 11/75. Includes data for $\Delta(1650)$ with assignments like CRAWFORD, KRIVETS, LONGACRE.

Table with columns: AZNAURYAN, #, #, #, 77, 11/75. Includes data for $\Delta(1650)$ with assignments like AZNAURYAN, LONGACRE.

Table with columns: BARBOUR, #, #, #, #, 78, 11/75. Includes data for $\Delta(1650)$ with assignments like BARBOUR, BARNHAM, HOEHLER.

Table with columns: CARRUTHE, #, PRL, #, #, 60, 11/75. Includes data for $\Delta(1650)$ with assignments like CARRUTHE, DEVLIN, HELLAND, BAREYRE, JOHNSON, DONNACHI, AYES, BOWLER, DEANS.

Table with columns: DEANS, #, NP, #, #, 75, 11/75. Includes data for $\Delta(1650)$ with assignments like DEANS.

$\Delta(1670)$ 10 N*3/2(1670, JP=3/2-) I=3/2 D33
THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

Table with columns: M, #, (mass), 10 N*3/2(1670) MASS (MEV), 8/69. Includes data for $\Delta(1670)$ with assignments like DONNACHI, AYES, DAVIES, ALMEHED, CRAWFORD, GADDO, LONGACRE, BARBOUR, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: W, #, (mass), 10 N*3/2(1670) WIDTH (MEV), 8/69. Includes data for $\Delta(1670)$ with assignments like DONNACHI, AYES, DAVIES, ALMEHED, CRAWFORD, GADDO, LONGACRE, BARBOUR, BARNHAM, CUTKOSKY, HOEHLER.

Table with columns: RE, #, (mass), 10 N*3/2(1670) REAL PART OF POLE POSITION (MEV), 11/75. Includes data for $\Delta(1670)$ with assignments like LONGACRE, CUTKOSKY.

Table with columns: IM, #, (mass), 10 N*3/2(1670) -2*IMAG PART OF POLE POSITION (MEV), 11/75. Includes data for $\Delta(1670)$ with assignments like LONGACRE, CUTKOSKY.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Δ(1890), Δ(1900), Δ(1910)

11 N*3/2(1890) BRANCHING RATIOS

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890). Includes entries for R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R2 N*3/2(1890) INTO (K SIGMA)/TOTAL

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) into (K SIGMA). Includes entries for R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R3 N*3/2(1890) INTO (SIGMA K)*(PI N)/TOTAL**2

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) into (SIGMA K)*(PI N). Includes entries for R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R4 N*3/2(1890) FROM PI N TO N*3/2(1232) PI

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) from PI N to N*3/2(1232) PI. Includes entries for R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R5 N*3/2(1890) FROM PI N TO K SIGMA

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) from PI N to K SIGMA. Includes entries for R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R6 N*3/2(1890) FROM PI N TO N*3/2(1232) PI, F-WAVE

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) from PI N to N*3/2(1232) PI, F-WAVE. Includes entries for R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

R7 N*3/2(1890) FROM PI N TO N RHO, S=3/2, P-WAVE

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) from PI N to N RHO, S=3/2, P-WAVE. Includes entries for R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99, R100.

11 N*3/2(1890) PHOTON DECAY AMPL (GEV**1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) photon decay amplitudes. Includes entries for A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, A46, A47, A48, A49, A50, A51, A52, A53, A54, A55, A56, A57, A58, A59, A60, A61, A62, A63, A64, A65, A66, A67, A68, A69, A70, A71, A72, A73, A74, A75, A76, A77, A78, A79, A80, A81, A82, A83, A84, A85, A86, A87, A88, A89, A90, A91, A92, A93, A94, A95, A96, A97, A98, A99, A100.

A2 N*3/2(1890) INTO GAM NUCLEON, HELICITY=3/2 (GEV**1/2)

Table with columns for particle ID, mass, width, and branching ratios for Δ(1890) into GAM NUCLEON, HELICITY=3/2. Includes entries for A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, A46, A47, A48, A49, A50, A51, A52, A53, A54, A55, A56, A57, A58, A59, A60, A61, A62, A63, A64, A65, A66, A67, A68, A69, A70, A71, A72, A73, A74, A75, A76, A77, A78, A79, A80, A81, A82, A83, A84, A85, A86, A87, A88, A89, A90, A91, A92, A93, A94, A95, A96, A97, A98, A99, A100.

REFERENCES FOR N*3/2(1890)

Table listing references for N*3/2(1890) from various sources like DCNACH1, AYMED, ALMEHED, CRAWFORD, DEANS, LONGACRE, METCALF, RAYED, FEUERBACH, KALMUS, MEHTANI, LANGBEIN, DEVENIS2, DEVENIS1, KNIES, METCALF, CRAWFORD, BARBOUR, AZNAURYAN, BARBOUR, SUPERSEDES BARBOUR, etc.

Δ(1900) 30 N*3/2(1900, JP=1/2-) I=3/2 S31 9/73 THIS EFFECT IS SEEN IN TWO CHANNELS.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for M 2, M 3, M 4, M 5, M 6, M 7, M 8, M 9, M 10, M 11, M 12, M 13, M 14, M 15, M 16, M 17, M 18, M 19, M 20, M 21, M 22, M 23, M 24, M 25, M 26, M 27, M 28, M 29, M 30, M 31, M 32, M 33, M 34, M 35, M 36, M 37, M 38, M 39, M 40, M 41, M 42, M 43, M 44, M 45, M 46, M 47, M 48, M 49, M 50, M 51, M 52, M 53, M 54, M 55, M 56, M 57, M 58, M 59, M 60, M 61, M 62, M 63, M 64, M 65, M 66, M 67, M 68, M 69, M 70, M 71, M 72, M 73, M 74, M 75, M 76, M 77, M 78, M 79, M 80, M 81, M 82, M 83, M 84, M 85, M 86, M 87, M 88, M 89, M 90, M 91, M 92, M 93, M 94, M 95, M 96, M 97, M 98, M 99, M 100.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for W 2, W 3, W 4, W 5, W 6, W 7, W 8, W 9, W 10, W 11, W 12, W 13, W 14, W 15, W 16, W 17, W 18, W 19, W 20, W 21, W 22, W 23, W 24, W 25, W 26, W 27, W 28, W 29, W 30, W 31, W 32, W 33, W 34, W 35, W 36, W 37, W 38, W 39, W 40, W 41, W 42, W 43, W 44, W 45, W 46, W 47, W 48, W 49, W 50, W 51, W 52, W 53, W 54, W 55, W 56, W 57, W 58, W 59, W 60, W 61, W 62, W 63, W 64, W 65, W 66, W 67, W 68, W 69, W 70, W 71, W 72, W 73, W 74, W 75, W 76, W 77, W 78, W 79, W 80, W 81, W 82, W 83, W 84, W 85, W 86, W 87, W 88, W 89, W 90, W 91, W 92, W 93, W 94, W 95, W 96, W 97, W 98, W 99, W 100.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for REE (1844.), CUTKOSKY 79 IPWA, PI N TO PI N 12/79*

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for IME (142.), CUTKOSKY 79 IPWA, PI N TO PI N 12/79*

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for RER (7.), CUTKOSKY 79 IPWA, PI N TO PI N 12/79*

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for IMR (-1.), CUTKOSKY 79 IPWA, PI N TO PI N 12/79*

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for P1 N*3/2(1900) INTO PI N 139+ 938, P2 N*3/2(1900) INTO K SIGMA 493+1189

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for R1 N*3/2(1900) FROM PI N TO K SIGMA, R2 (111), R3 (-121), R4 (076), R5 DEANS 75 DPWA, R6 VALUE GIVEN IS FROM SOLUTION 1, NOT PRESENT IN SOLUTIONS 2,3,4.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for R2 N*3/2(1900) INTO PI N/TOTAL (P1), R2 (.08), R3 (.08 .03), R4 (.08 .04), R5 HOEHLER 79 IPWA, R6 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for LANGBEIN 73 NP B53 251, DEANS 75 NP B96 90, AYMED 76 CEAN-1921, LANGBEIN, WAGNER (MUNICH) IJP, MITCHELL, MONTGOMERY, + (SFLA, ALABAMA) IJP, AYMED (THIS IS) (SACL) IJP

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for CUTKOSKY 79 PRD 20 2839, HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL. 12-1, +KAISER, KOCH, PIETARINEN /KARLSRUHE IJP

Table with columns for particle ID, mass, width, and branching ratios for Δ(1900). Includes entries for WINNIK 77 NP B128 66, +TOAFF, REVEL, GOLDBERG, BERNY (HAIF) I

Δ(1910) 12 N*3/2(1910, JP=1/2+) I=3/2 P31 THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

Table with columns for particle ID, mass, width, and branching ratios for Δ(1910). Includes entries for M 3 (1934.0), M 4 (1783.0), M 5 (1914.0), M 6 (1900.), M 7 (1980.), M 8 (1950.), M 9 DEANS75 AND LANGBEIN73 DISAGREE WITH PI+ P TO K+ SIGMA+ DATA OF WINNIK77 AROUND 1920 MEV.

Baryons

$\Delta(1910)$, $\Delta(1950)$

Data Card Listings

For notation, see key at front of Listings.

Table with columns for mass, width, and various parameters for baryons. Includes entries for $\Delta(1789)$, $\Delta(1940)$, $\Delta(1790)$, $\Delta(1899)$, $\Delta(1920)$, and $\Delta(1888)$.

12 N*3/2(1910) WIDTH (MEV)

Table listing widths for $\Delta(1910)$ states. Columns include mass, width, and references. Includes entries for $\Delta(1910)$, $\Delta(1940)$, $\Delta(1790)$, $\Delta(1899)$, $\Delta(1920)$, and $\Delta(1888)$.

12 N*3/2(1910) REAL PART OF POLE POSITION (MEV)

Table listing real parts of pole positions for $\Delta(1910)$ states. Columns include mass, real part, and references.

12 N*3/2(1910) -2*IMAG PART OF POLE POSITION (MEV)

Table listing -2*imaginary parts of pole positions for $\Delta(1910)$ states. Columns include mass, imaginary part, and references.

12 N*3/2(1910) REAL PART OF ELASTIC POLE RESIDUE (MEV)

Table listing real parts of elastic pole residues for $\Delta(1910)$ states. Columns include mass, real part, and references.

12 N*3/2(1910) IMAG PART OF ELASTIC POLE RESIDUE (MEV)

Table listing imaginary parts of elastic pole residues for $\Delta(1910)$ states. Columns include mass, imaginary part, and references.

12 N*3/2(1910) PARTIAL DECAY MODES

Table listing partial decay modes for $\Delta(1910)$ states. Columns include mass, decay mode, and references.

12 N*3/2(1910) BRANCHING RATIOS

Table listing branching ratios for $\Delta(1910)$ states. Columns include mass, branching ratio, and references.

12 N*3/2(1910) INTO (K SIGMA)/TOTAL

Table listing branching ratios for $\Delta(1910)$ into $(K \Sigma)$. Columns include mass, branching ratio, and references.

12 N*3/2(1910) FROM PI N TO K SIGMA

Table listing branching ratios for $\Delta(1910)$ from πN to $K \Sigma$. Columns include mass, branching ratio, and references.

12 N*3/2(1910) FROM PI N TO N*3/2(1232) PI

Table listing branching ratios for $\Delta(1910)$ from πN to $N^*(1232) \pi$. Columns include mass, branching ratio, and references.

12 N*3/2(1910) FROM PI N TO N RHO, S=3/2

Table listing branching ratios for $\Delta(1910)$ from πN to $N \rho$. Columns include mass, branching ratio, and references.

12 N*3/2(1910) PHOTON DECAY AMPL (GEV**-1/2)

FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-REVIEW PRECEDING THE BARYON LISTINGS.

Table listing photon decay amplitudes for $\Delta(1910)$ states. Columns include mass, amplitude, and references.

REFERENCES FOR N*3/2(1910)

Table listing references for $\Delta(1910)$ states. Columns include author names and journal information.

$\Delta(1950)$

83 N*3/2(1950, JP=7/2+) I=3/2

THE EXISTENCE OF THIS RESONANCE IS WELL ESTABLISHED.

83 N*3/2(1950) MASS (MEV)

Table listing masses for $\Delta(1950)$ states. Columns include mass, width, and references.

83 N*3/2(1950) WIDTH (MEV)

Table listing widths for $\Delta(1950)$ states. Columns include mass, width, and references.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Δ(1950)

Table with columns for REE, IME, RER, IMR, R1, R2, R3, R4, R5, R6, RQ, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10. Rows include data for REAL PART OF POLE POSITION (MEV), IMAG PART OF POLE POSITION (MEV), REAL PART OF ELASTIC POLE RESIDUE (MEV), IMAG PART OF ELASTIC POLE RESIDUE (MEV), PARTIAL DECAY MODES, BRANCHING RATIOS, and PHOTON DECAY AMPL. Includes sub-sections for DECAy MASSES and BRANCHING RATIOS.

Table with columns for A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, A46, A47, A48, A49, A50, A51, A52, A53, A54, A55, A56, A57, A58, A59, A60, A61, A62, A63, A64, A65, A66, A67, A68, A69, A70, A71, A72, A73, A74, A75, A76, A77, A78, A79, A80, A81, A82, A83, A84, A85, A86, A87, A88, A89, A90, A91, A92, A93, A94, A95, A96, A97, A98, A99, A100. Rows include data for HELICITY=3/2 (GEV**1/2), REFERENCES FOR N*3/2(1950), 1950 MEV REGION - PRODUCTION AND σTOTAL EXP'TS, and 1950 MEV REGION MASS (MEV) (PROD. EXP.).

Baryons

$\Delta(1950)$, $\Delta(1960)$

Data Card Listings

For notation, see key at front of Listings.

70 N*3/2(1950) PARTIAL DECAY MODES (PROD. EXP.)
P1 N*3/2(1950) INTO PI N 139+ 938
P2 N*3/2(1950) INTO SIGMA K 1189+ 493
P3 N*3/2(1950) INTO N*3/2(1232) PI 1232+ 139
P4 N*3/2(1950) INTO Y*1(1385) K 1384+ 493
P5 N*3/2(1950) INTO N*3/2(1232) RHO 1232+ 776
P6 N*3/2(1950) INTO NEUTRON PI+ PI+ 939+ 139+ 139
P7 N*3/2(1950) INTO N*3/2(1232) PI PI (NOT RHO) 1232+ 139+ 139
P8 N*3/2(1950) INTO PROTON PI+ PI0 938+ 139+ 139
P9 N*3/2(1950) INTO PI PI N 139+ 139+ 938

70 N*3/2(1950) BRANCHING RATIOS (PROD. EXP.)
R1 N*3/2(1950) INTO (PI N)/TOTAL (P1)
R1 (0.37) (0.12) DEVLIN 65 CNTR 139+ 938
R1 (0.48) (0.15) ZEMANY 78 HBC ++ PI+P 10.3 GEV/C 1/78
R2 N*3/2(1950) INTO (SIGMA K)/(PI N) (P2)/(P1)
R2 0.059 0.024 CHINOWSKY 68 HBC ++ PP TO P SIG K 11/68
R3 N*3/2(1950) INTO N*3/2(1232) PI PI (NOT RHO) (P7)
R3 SEEN CHINOWSKY 68 HBC ++ PP TO (P 3PI) N 11/68
R3 SEEN BOGGILD 70 HBC PP TO N3PI(INTRL) 6/70
R4 N 3/2(1950) INTO (PI N)/(N*3/2(1232) PI) (P1)/(P3)
R4 (0.55) OR LESS LEE 67 HBC P1-P 3.63 BEV/C 11/67
R5 N*3/2(1950) INTO ((PI N)*(NEUTRON PI+ PI+))/TOTAL**2 (P1*P6)
R5 0.05 0.013 GALLOWAY 68 RVUE ++ PI+P TO N 2PI+ 6/68
R6 N*3/2(1950) INTO (Y*1(1385) K)/(PI N) (P4)/(P1)
R6 0.035 0.015 CHINOWSKY 68 HBC ++ PP TO P LAM K PI 11/68
R7 N*3/2(1950) INTO (N*3/2(1232) RHO)/(PI N) (P5)/(P1)
R7 (0.45) APPROX CHINOWSKY 68 HBC ++ PP TO (P 3PI) N 11/68
R7 THIS INCLUDES CORRECTION FOR UNSEEN DECAY (ISPIN FACTOR 5/3).

REFERENCES FOR N*3/2(1950) (PROD. EXP.)
COOL 56 PR 103 1082 R COOL, O PICCIGNI, D CLARK (BNL) I
BRISSON 61 NC 19 213 +DETOUF, FALK-VAIRANT, VAN ROSSUM, + (SACLAY) I
DEVLIN 65 PRL 14 1031 T, J DEVLIN, J SLOMON, G BERTSCH (PRINCETON) I
LEE 67 PR 159 1156 +MOEBS, ROE, SINGLAIR, VANDER VELDE (MICH)
YCON 67 PL 248 307 +BERENYI, KEY, PRENTICE, + (TORONTO, WISC)
CHINOWSKY 68 PR 171 1421 CHINOWSKY, GENDON, KINSEY, KLEIN, + (LRL, SLAC)
CHUNG 68 PR 165 1491 S U CHUNG, DAHL, KIRZ, MILLER (LRL)
GALLOWAY 68 PL 268 334 F GALLOWAY (INDIANA) I
BOGGILD 70 NP 816 503 +KORAE-AHO-JACOBSEN+ (BOHR+ HELS+OSLO+STOH)
COLTON 72 PR D6 45 E COLTON, A KIRSCHBAUM (LBL)
COLLEY 74 NP 869 205 COLLEY, HUQ, JOBES, KINSON, MILNE, + (BIRM+GLASG) I
BRAUN 75 NP 895 503 +GERBER, MAURER, MICHALON, SCHIBY, STORB, L'IMP I
CHUNG 75 PL 578 384 +PROTOPESCU, EISNER+ (BNL+CASE+LBL+UCSC) IJP
ALSO 75 PRD 12 693 CHUNG, PROTOPESCU, EISNER+ (BNL+CASE+UCSC) IJP
GAIDOS 75 PRD 12 2565 GAIDOS, MILLER (PURD) IJP
ZEMANY 78 NP B137 365 +BEAUFAYS, GODDARD, KEY+ (TNTO+PURD+BNL) IJP
ALSO 78 NP B138 265 GODDARD, KEY, GORDON, LAI (TNTO+BNL) I
ALSO 78 PRD 17 2888 KENNEDY, ZEMANY, BEAUFAYS, KEY, LUSTE+ (TNTO)
APELDOORN 79 NP B156 111 VAN APELDOORN, HARTING, HOLTHUIZEN+ (AMST) I
PAPERS NOT REFERRED TO IN DATA CARDS
DEUTSCHMANN+ (AACH+ BONN+ BERL+ CERN+ CRAC+ HEID)

$\Delta(1960)$ 117 N*3/2(1960), JP=3/2+ I=3/2 P33
EARLY ANALYSES FOUND EVIDENCE FOR A P33 RESONANCE NEAR 2160 MEV, THERE MAY HAVE BEEN CONFUSION WITH OTHER RESONANCES IN THAT REGION (SEE LISTING FOR N*3/2(2160)). RECENT ANALYSES AGREE THAT THE MASS IS CLOSER TO 1960 MEV.
117 N*3/2(1960) MASS (MEV)
M 3 (2160.) KIRSOPP 68 RVUE PHASE SHIFT ANAL 10/69
M (2120.) ROYCHOUD 71 DPWA 3/72
M 7 (2150.) ALMEHD 72 IPWA 2/72
M 1 (1980.) LANGBEIN 73 IPWA PI N-K SIG, SOL 1 9/73
M 1 NOT SEEN IN SOLUTION 2 OF LANGBEIN73 9/73
M 1 DEANS75 AND LANGBEIN73 DISAGREE WITH PI+ P TO K+ SIGMA+ DATA CF 1/78
M 1 WINNIK77 AROUND 1920 MEV. 1/78
M 1960. 80. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M 1860. 10. HOEHLER 79 IPWA PI N TO PI N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

117 N*3/2(1960) WIDTH (MEV)
W 3 (260.) KIRSOPP 68 RVUE PHASE SHIFT ANAL 10/69
W 7 (200.) ALMEHD 72 IPWA 2/72
W 1 (190.) LANGBEIN 73 IPWA PI N-K SIG, SOL 1 9/73
W 302. 100. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
W 220. 80. HOEHLER 79 IPWA PI N TO PI N 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

117 N*3/2(1960) REAL PART OF POLE POSITION (MEV)
REE (1933.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

117 N*3/2(1960) -2*IMAG PART OF POLE POSITION (MEV)
IME (280.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

117 N*3/2(1960) REAL PART OF ELASTIC POLE RESIDUE (MEV)
RER (-10.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

117 N*3/2(1960) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
IMR (-27.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

117 N*3/2(1960) PARTIAL DECAY MODES
P1 N*3/2(1960) INTO PI N 139+ 938
P2 N*3/2(1960) INTO K SIGMA 493+1189

117 N*3/2(1960) BRANCHING RATIOS
R1 N*3/2(1960) INTO (PI N)/TOTAL (P1)
R1 3 (0.25) KIRSOPP 68 RVUE PHASE SHIFT ANAL 10/69
R1 7 (0.3) ALMEHD 72 IPWA 2/72
R1 17 (0.4) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
R1 14 (0.4) HOEHLER 79 IPWA PI N TO PI N 12/79*
R1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
R2 N*3/2(1960) FROM PI N TO K SIGMA (P1)*2 (P1)*2
R2 1 (0.8) LANGBEIN 73 IPWA PI N-K SIG, SOL 1 9/73
R2 5 (0.048) TO 0.120 DEANS 75 DPWA PI N TO K SIGMA 11/75
R2 5 RANGE GIVEN IS FROM FOUR BEST SOLUTIONS. 11/75

REFERENCES FOR N*3/2(1960)
KIRSOPP 68 THESIS R G KIRSOPP (EDIN)
ROYCHOUD 71 NP B27 125 R K ROYCHOUDHURY, B H BRANSDEN (DURH) IJP
ALMEHD 72 NP 840 157 +LOVELACE (LUND, RUTG) IJP
LANGBEIN 73 NP 853 251 LANGBEIN, WAGNER (MUNICH) IJP
DEANS 75 NP B96 90 +MITCHELL, MONTGOMERY, + (SFLA, ALABAMA) IJP
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL) IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING: PHYSIC DATEN VOL.12-1 +KAISER, KOCH, PIETARINEN /KARLSRUHE IJP

$\Delta(1960)$ 13 N*3/2(1960), JP=5/2- I=3/2 D35

13 N*3/2(1960) MASS (MEV)
M 3 (1950.0) DONNACHI 68 RVUE PHASE-SHIFT ANAL 6/68
M 3 (1970.) KIRSOPP 68 RVUE PHASE SHIFT ANAL 10/69
M X (1950.0) APPROX LEA 69 CNTR PI-P ELASTIC 8/69
M X SEE ALSO APLIN 70
M 3 WHERE MAX. ABSORPTION IS -DONNACHI, 2, KIRSOPP EYEBALL FIT CERN 1 10/69
M 7 (2200.) ALMEHD 72 IPWA 2/72
M 1 (1960.) LANGBEIN 73 IPWA PI N-K SIG, SOL 2 9/73
M 1 NOT SEEN IN SOLUTION 1 OF LANGBEIN73 9/73
M 1 DEANS75 AND LANGBEIN73 DISAGREE WITH PI+ P TO K+ SIGMA+ DATA CF 1/78
M 1 WINNIK77 AROUND 1920 MEV. 1/78
M (1894.) 20. AYED 76 IPWA 11/77
M 1925. 20. CUTKOSKY 76 IPWA 11/77
M 4 (2024.) 20. BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
M C 1930. 20. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M C SUPERSEDES CUTKOSKY 76.
M L 1901. 15. HOEHLER 79 IPWA PI N TO PI N 12/79*
M H 2305. 26. HOEHLER 79 IPWA PI N TO PI N 12/79*
M LH HOEHLER79 FINDS A HIGHER MASS D35 RESONANCE, AS WELL AS ONE IN THIS 12/79*
M LH MASS REGION. BOTH ARE LISTED HERE, AND LABELED L AND H FOR LOW AND 12/79*
M LH HIGH, AWAITING CONFIRMATION OF THE HIGHER MASS STATE. 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 8.1)

13 N*3/2(1960) WIDTH (MEV)
W 3 (311.00) DONNACHI 68 RVUE PHASE SHIFT ANAL 8/69
W 3 (400.) KIRSOPP 68 RVUE PHASE SHIFT ANAL 10/69
W 7 (600.1) ALMEHD 72 IPWA 2/72
W 1 (190.) LANGBEIN 73 IPWA PI N-K SIG, SOL 2 9/73
W (121.) AYED 76 IPWA 11/77
W 350. 100. CUTKOSKY 76 IPWA 11/77
W 4 (462.) 20. BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
W C 280. 90. CUTKOSKY 79 IPWA PI N TO PI N 12/79*
W L 195. 60. HOEHLER 79 IPWA PI N TO PI N 12/79*
W H 300. 70. HOEHLER 79 IPWA PI N TO PI N 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
SEE THE NOTES ACCOMPANYING MASSES QUOTED

Data Card Listings

For notation, see key at front of Listings.

Baryons

Δ(1960), Δ(2160)

13 N*3/2(1960) REAL PART OF POLE POSITION (MEV)
REE C 1860. 15. CUTKOSKY 76 IPWA 11/77
(1968.) CUTKOSKY 79 IPWA 12/79*

13 N*3/2(1960) -2*IMAG PART OF POLE POSITION (MEV)
IME C 276. 40. CUTKOSKY 76 IPWA 11/77
(226.) CUTKOSKY 79 IPWA 12/79*

13 N*3/2(1960) REAL PART OF ELASTIC POLE RESIDUE (MEV)
RER C 12. 3. CUTKOSKY 76 IPWA 11/77
(13.) CUTKOSKY 79 IPWA 12/79*

13 N*3/2(1960) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
IMR C -15. 4. CUTKOSKY 76 IPWA 11/77
(2.) CUTKOSKY 79 IPWA 12/79*

13 N*3/2(1960) PARTIAL DECAY MODES
P1 N*3/2(1960) INTO PI N DECAY MASSES
P2 N*3/2(1960) INTO K SIGMA 139+ 938
493+1189

13 N*3/2(1960) BRANCHING RATIOS
R1 N*3/2(1960) INTO (PI N)/TOTAL (P1)
R1 3 (.154) DONNACHI 68 RVUE PHASE SHIFT ANA. 10/69
R1 3 (.12) KIRSOPP 68 RVUE PHASE SHIFT ANA. 10/69
R1 7 (0.25) ALMEHD 72 IPWA 2/72
R1 (.08) AYED 76 IPWA 11/77
R1 .113 .013 CUTKOSKY 76 IPWA 11/77
R1 C .12 .03 CUTKOSKY 79 IPWA 12/79*

R2 N*3/2(1960) INTO (K SIGMA)/TOTAL (P2)
R2 1 (0.013) (0.01) FEUERBACH 70 RVUE PI P TO K+ SIG+ 7/70
R2 1 ASSUME MASS, WIDTH, X(ELAST) OF DONNACHIE 68
R2 1 MODEL USED MAY DOUBLE COUNT.
R3 N*3/2(1960) FROM PI N TO K SIGMA SQRT(P1*P2) 9/73
R3 1 (.08) LANGBEIN 73 IPWA PI N-K SIG+ SOL 2 9/73
R3 2 (-0.18) .035 DEANS 75 DPWA PI N TO K SIGMA 11/75
R3 2 RANGE GIVEN IS FROM FOUR BEST SOLUTIONS. 11/75

13 N*3/2(1960) PHOTON DECAY AMPL(GEV**--1/2)
FOR DEFINITION OF GAMMA-NUCLEON DECAY AMPLITUDES, SEE MINI-
REVIEW PRECEDING THE BARYON LISTINGS.

A1 N*3/2(1960) INTO GAM NUCLEON, HELICITY=1/2 (GEV**--1/2) 1/76
A1 +.003 .016 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A1 (-.085) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A1 .062 .064 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*
A1 4 SUPERSEDES BARBOUR 76. 3/79*
A1 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)
A2 N*3/2(1960) INTO GAM NUCLEON, HELICITY=3/2 (GEV**--1/2) 1/76
A2 -.010 .032 CRAWFORD 75 DPWA PI N PHOTO-PROD 1/76
A2 (+.066) BARBOUR 76 DPWA PI N PHOTO-PROD 1/76
A2 4 +.019 .054 BARBOUR 78 DPWA PI-N PHOTO-PROD 3/79*

REFERENCES FOR N*3/2(1960)
DONNACHI 68 PL 268 161 A DONNACHIE, R G KIRSOPP, C LOVELACE (CERN)IJP
KIRSOPP 68 THESIS R G KIRSOPP (EDIN)
LEA 69 PL 298 584 LEA, OADES, WARD, COWAN, + (RHEL, BRISTOL, DARE)
FEUERBACH 70 NP 168 85 FEUERBACHER+HOLLADAY (VANDERBILT)
ALMEHD 72 NP 840 157 +LOVELACE (LUND, RUTG)IJP
LANGBEIN 73 NP 853 251 LANGBEIN, WAGNER (MUNICH)IJP
CRAWFORD 75 NP 897 125 R L CRAWFORD (GLAS)IJP
DEANS 75 NP 896 90 +MITCHELL, MCNTGOMERY, + (SFLA, ALABAMA)IJP
AYED 76 CEA-N-1921 AYED (THIS IS) (SACL)IJP
BARBOUR 76 NP B111 358 I. M. BARBOUR, R. L. CRAWFORD (GLAS)IJP
CUTKOSKY 76 PRL 37 645 CUTKOSKY, HENDRICK, KELLY (CARN+LBL)IJP
ALSO 76 OXFORD CONF. 49 CUTKOSKY, HENDRICK, CHAO+ (CARN+LBL+BRIS)IJP
BARBOUR 78 NP B141 253 BARBOUR, CRAWFORD, PARSONS (GLAS)
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 (CARN+LBL)IJP
+KAISER, KOCH, PIETARINEN /KARLSRUHE IJP
PAPERS NOT REFERRED TO IN DATA CARDS
DONNACHI 69 NP 108 433 A DONNACHIE, R KIRSOPP (GLAS+EDIN)
AYED 70 PL 318 598 +GGDEN (DURH)IJP
APLIN 71 NP 832 253 +BARREYRE+VILLLET (SACLAY)
WINNIK 77 NP B128 66 +COWAN, GIBSON, GILMORE++ (RHEL, BRISTOL)
+TOAFF, REVEL, GOLDBERG, BERNY (HAIF)I

Δ(2160)

9 N*3/2(2160), I=3/2
EARLY ANALYSES FOUND EVIDENCE FOR A RESONANCE
NEAR THIS MASS IN THE P33 PARTIAL WAVE. THESE
RESULTS ARE NOW INCLUDED WITH THE LISTING FOR
N*3/2(1960), JP=3/2+, IN ADDITION, ROYCHOUDHURY 71
FIND POSSIBLE EVIDENCE FOR P31, D33, AND D35
RESONANCES IN THIS MASS REGION. IN A SIMILAR ANALYSIS
BRANDSEN 71 FOUND SOME EVIDENCE FOR G31, D33, AND D35
RESONANCES IN THIS REGION. VON SCHLIPPE 72 SUGGESTS A G39. A PRONOUNCED
SHARP DIP IS OBSERVED IN PI+ P BACKWARD SCATTERING AT 2200 MEV BY
REY 74. DUAL INTERFERENCE MODEL ANALYSIS OF MA 75 FINDS SIGNAL FOR
P33, P31, AND D35, BUT NOT FOR G39. AYED 76 FINDS A G39 RESONANCE
IN THIS MASS REGION. CUTKOSKY 79 AND HOEHLER 79 FIND A G37 RESONANCE,
HENDRY 78 FINDS BOTH A G37 AND A G39 RESONANCE.

9 N*3/2(2160) MASS (MEV)
M 4 (2196.) (46.) (41.) REY 74 MPWA ++ PI+ P 180 DEG CS 10/74
M 4 BAKER 74 AND REY 74 FIND NEGATIVE PARITY (SPIN UNDETERMINED).
M 2 (2170.) AYED 76 IPWA 11/77
M 2 AYED 76 RESULT IS A G39 RESONANCE. 11/77
M 9 2200. 100. HENDRY 78 MPWA PI N TO PI N 12/79*
M 9 HENDRY 78 RESULT LABELED 9 IS A G39 RESONANCE. 12/79*
M 7 2280. 80. HENDRY 78 MPWA PI N TO PI N 12/79*
M 7 HENDRY 78 RESULT LABELED 7 IS A G37 RESONANCE. 12/79*
M C (2200.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
M C CUTKOSKY 79 RESULT IS A G37 RESONANCE. 12/79*
M 1 2215. 60. HOEHLER 79 IPWA PI N TO PI N 12/79*
M 1 HOEHLER 79 RESULT IS A G37 RESONANCE. 12/79*

9 N*3/2(2160) WIDTH (MEV)
W 4 (302.) (143.) REY 74 MPWA ++ PI+ P 180 DEG CS 10/74
W 2 (205.) 60. AYED 76 IPWA 11/77
W 9 450. 200. HENDRY 78 MPWA PI N TO PI N 12/79*
W 7 400. 150. HENDRY 78 MPWA PI N TO PI N 12/79*
W C (350.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
W 1 400. 100. HOEHLER 79 IPWA PI N TO PI N 12/79*
SEE THE NOTES ACCOMPANYING MASSES QUOTED

9 N*3/2(2160) REAL PART OF PCLE POSITION (MEV)
REE C (209.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

9 N*3/2(2160) -2*IMAG PART OF POLE POSITION (MEV)
IME C (294.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

9 N*3/2(2160) REAL PART OF ELASTIC POLE RESIDUE (MEV)
RER C (2.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

9 N*3/2(2160) IMAG PART OF ELASTIC POLE RESIDUE (MEV)
IMR C (-7.) CUTKOSKY 79 IPWA PI N TO PI N 12/79*

9 N*3/2(2160) PARTIAL DECAY MODES
P1 N*3/2(2160) INTO PI N DECAY MASSES
P2 N*3/2(2160) INTO K SIGMA 139+ 938
493+1189

9 N*3/2(2160) BRANCHING RATIOS
R1 N*3/2(2160) INTO (PI N)/TOTAL (P1)
R1 4 REY74 FINDS (J+1/2)X=.81+/-(.54+.39) 10/74
R1 2 (.04) AYED 76 IPWA 11/77
R1 9 .10 .03 HENDRY 78 MPWA PI N TO PI N 12/79*
R1 7 .09 .02 HENDRY 78 MPWA PI N TO PI N 12/79*
R1 C (-.05) CUTKOSKY 79 IPWA PI N TO PI N 12/79*
R1 1 -.05 .02 HOEHLER 79 IPWA PI N TO PI N 12/79*

REFERENCES FOR N*3/2(2160)
REY 74 PRL 32 908 REY, LENNOX, POIRIER, PRETZL (NDAM+MPI)IJP
ALSO 74 PRL 33 250 REY, LENNOX, POIRIER, PRETZL (NDAM+MPI)IJP
ALSO 75 PRD 11 1777 LENNOX, POIRIER, REY, SANDER+ (NDAM+FNAL+ANL)IJP
AYED 76 CEA-N-1921 AYED (THIS IS) (SACL)IJP
HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP
CUTKOSKY 79 PRD 20 2839 +FORSYTH, HENDRICK, KELLY (CARN+LBL)IJP
HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 (CARN+LBL)IJP
+KAISER, KOCH, PIETARINEN /KARLSRUHE IJP
PAPERS NOT REFERRED TO IN DATA CARDS
DONNACHI 69 NP 108 433 A DONNACHIE, R KIRSOPP (GLAS+EDIN)
BRANDSEN 71 NP 826 511 +GGDEN (DURH)IJP
ALSO 70 NP 816 461 ROYCHOUDHURY, PERRIN, BRANDSEN (DURH)IJP
ROYCHODJ 71 NP 827 125 R K ROYCHOUDHURY, B H BRANDSEN (DURH)IJP
VON SCHL 72 LNC 4 767 VON SCHLIPPE (LDWC)IJP
BAKER 74 PRL 32 251 BAKER, EARTLY, PRETAL, PRUSS, + (FNAL, ANL, NDAM)IJP
MA 75 PRD 11 1832 MA, SHAW (UCSB, SLAC)IJP
WINNIK 77 NP B128 66 +TOAFF, REVEL, GOLDBERG, BERNY (HAIF)I

Baryons

$\Delta(2300)$, $\Delta(2420)$, $\Delta(2500)$

Data Card Listings

For notation, see key at front of Listings.

$\Delta(2300)$ **H₃₉**

123 N*3/2(2300, JP=9/2+) I=3/2

M 2217. 80. HOEHLER 79 IPWA P I N TO P I N 12/79*

123 N*3/2(2300) MASS (MEV)

W 300. 100. HOEHLER 79 IPWA P I N TO P I N 12/79*

123 N*3/2(2300) PARTIAL DECAY MODES

P I N*3/2(2300) INTO P I N DECAY MASSES 139+ 938

123 N*3/2(2300) BRANCHING RATIOS

R I N*3/2(2300) INTO (P I N)/TOTAL (P I) 12/79*

R I .03 .02 HOEHLER 79 IPWA P I N TO P I N 12/79*

REFERENCES FOR N*3/2(2300)

HOEHLER 79 HANDBOOK OF P I - N SCATTERING, PHYSIK DATEN VOL.12-1 +KAI SER, KOCH, PIETARINEN /KARLSRUHE IJP

$\Delta(2420)$ **H₃₁₁**

84 N*3/2(2420, JP=11/2+) I=3/2

BOTH ROYCHOUDHURY 71 AND BRANSDEN 71 SEE A POSSIBLE RESONANT P35 IN THIS MASS REGION. IN ADDITION BRANSDEN 71 FIND A RESONANT P33 AT 2600 MEV.

84 N*3/2(2420) MASS (MEV)

M 6 (2312.0) AYED 70 IPWA 1/71

M 6 FROM ENER. DEP. FIT OF ARGAND DIAGRAM

M (2400.) BRANSDEN 71 DPWA 3/72

M (2400.) ROYCHOUD 71 DPWA 3/72

M (2400.) OTT 72 MPWA 0 P I - P BKWD ELSTC 2/73

M 1 (2404.) (63.) REY 74 MPWA ++ P I + P 180 DEG CS 10/74

M (2392.) AYED 76 IPWA 11/77

M 2400. 60. HENDRY 78 MPWA P I N TO P I N 12/79*

M 2416. 17. HOEHLER 79 IPWA P I N TO P I N 12/79*

M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

84 N*3/2(2420) WIDTH (MEV)

W 6 (347.0) AYED 70 IPWA 1/71

W 1 (484.) (79.) REY 74 MPWA ++ P I + P 180 DEG CS 10/74

W (289.) AYED 76 IPWA 11/77

W 460. 100. HENDRY 78 MPWA P I N TO P I N 12/79*

W 340. 28. HOEHLER 79 IPWA P I N TO P I N 12/79*

W AVERAGE MEANINGLESS (SCALE FACTOR = 1.2)

84 N*3/2(2420) PARTIAL DECAY MODES

P I N*3/2(2420) INTO P I N DECAY MASSES 139+ 938

P 2 N*3/2(2420) INTO SIGMA K 1197+ 493

84 N*3/2(2420) BRANCHING RATIOS

R I N*3/2(2420) INTO (P I N)/TOTAL (P I) 1/71

R I 6 (0.113) AYED 70 IPWA (DURH) IJP

R I 7 (.4) OTT 72 MPWA 0 P I - P BKWD ELSTC 2/73

R I 1 (.157) (.070) (.035) REY 74 MPWA ++ P I + P 180 DEG CS 10/74

R I 1 REY 74 DETERMINES (J+1/2) ONLY, WE HAVE DIVIDED BY 6. 10/74

R I (.091) AYED 76 IPWA 11/77

R I .11 .02 HENDRY 78 MPWA P I N TO P I N 12/79*

R I .08 .015 HOEHLER 79 IPWA P I N TO P I N 12/79*

R I AVERAGE MEANINGLESS (SCALE FACTOR = 1.2)

REFERENCES FOR N*3/2(2420)

AYED 70 KIEV CONF R AYED, P BAREYRE, G VILLET (SACL) IJP

BRANSDEN 71 NP 826 511 +ODDEN (DURH) IJP

ALSO 70 NP 916 461 ROYCHOUDHURY, PERRIN, BRANSDEN (DURH) IJP

ROYCHOUD 71 NP 827 125 R. K. ROYCHOUDHURY, B. H. BRANSDEN (DURH) IJP

OTT 72 PL 428 133 +TRISCHUK, VAVRA, RICHARDS, + (MCGI, STLO, IOWA) IJP

ALSO 72 MCGILL THESIS J. VAVRA (MCGI) IJP

REY 74 PRL 32 908 REY, LENNOX, POIRIER, PRETZL (NDAM+MPIM) IJP

ALSO 74 PRL 33 250 REY, LENNOX, POIRIER, PRETZL (NDAM+MPIM) IJP

ALSO 75 PRD 11 1777 LENNOX, POIRIER, REY, SANDER+ (NDAM+FNA+ANL) IJP

AYED 76 CEA-N-1921 AYED (THE SIS) (SACL) IJP

HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL) IJP

HOEHLER 79 HANDBOOK OF P I - N SCATTERING, PHYSIK DATEN VOL.12-1 +KAI SER, KOCH, PIETARINEN /KARLSRUHE IJP

PAPERS NOT REFERRED TO IN DATA CARDS

BELLAMY 67 PRL 19 476 +BUCKLEY, DOBINSON, + (WESTFIELD, LOUC) JP

AYED 70 PL 318 598 +BAREYRE+VILLET (SACL) Y

2420 MEV REGION - PRODUCTION AND σ_{TOTAL} EXPTS

69 N*3/2(2420, JP=) I=3/2 PRODUCTION EXPERIMENTS

SEE THE MINI-REVIEW PRECEDING THE N AND DELTA LISTINGS FOR A DISCUSSION OF PRODUCTION EXPERIMENTS.

69 N*3/2(2420) MASS (MEV) (PROD. EXP.)

M (2360.0) DIDDENS 63 CNTR P I + P TOTAL

M (2520.0) (40.0) ALVAREZ 64 CNTR P I PHOTOPROD 7/66

M (2440.0) HOHLER 64 RVUE DATA + DISP REL

M (2400.0) APPROX WAHLIG 64 OSPK 0 P I - P CH EX

M B (2452.0) BARGER 66 RVUE TOTAL + CH EX 11/67

M B USES REGGE AMP.+RESON. TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGRE

M B FGR CRITICISM OF THIS METHOD, SEE DOLEN 68.

M 2423.0 10.0 CITRON 66 CNTR P I + P TOTAL 7/66

69 N*3/2(2420) WIDTH (MEV) (PROD. EXP.)

W (200.0) DIDDENS 63 CNTR 7/66

W (245.0) HOHLER 64 RVUE 11/67

W B (275.0) BARGER 66 RVUE TOTAL + CH EX 11/67

W 310.0 20.0 CITRON 66 CNTR 7/66

69 N*3/2(2420) PARTIAL DECAY MODES (PROD. EXP.)

P I N*3/2(2420) INTO P I N DECAY MASSES 139+ 938

P 2 N*3/2(2420) INTO SIGMA K 1197+ 493

P 3 N*3/2(2420) INTO N*3/2(1232) P I 1232+ 139

P 4 N*3/2(2420) INTO NEUTRON P I + P I + 939+ 139+ 139

69 N*3/2(2420) BRANCHING RATIOS (PROD. EXP.)

R I N*3/2(2420) INTO (P I N)/TOTAL (P I) 7/66

R I (0.067) APPROX DIDDENS 63 CNTR ASSUMING J=11/2 7/66

R I 0.113 0.0036 CITRON 66 CNTR ASSUMING J=11/2 7/66

R I B (0.121) BARGER 67 FIT ASSUMING J=11/2 11/67

R I D (0.163) DIKMEN 67 FIT ASSUMING J=11/2 11/67

R I D USES ONLY RESONANCES TO CALCULATE DIF. CROSS SECTIONS AT 180 DEGREES

R I (0.06) KORMANYOS 67 CNTR ASSUMING J=11/2 11/67

R 2 N*3/2(2420) INTO (P I N)*(NEUTRON P I + P I +1)/(TOTAL*2) (P I*P 4)

R 2 0.0195 0.0048 GALLGWAY 68 RVUE 6/68

REFERENCES FOR N*3/2(2420) (PROD. EXP.)

DIODENS 63 PRL 10 262 +JENKINS, KYCIA, RILEY (BNL) I

ALVAREZ 64 PRL 12 710 +BAR-YAM, KERN, LUCKEY, OSBORNE, + (MIT, CE) A

HOHLER 64 PL 12 149 G HOHLER, J GIESECKE (KARLSRUHE) I

WAHLIG 64 PRL 13 103 +MANNELLI, SODICKSON, FACKLER, WARD, + (MIT)

BARGER 66 PR 151 1123 V BARGER, M CLISSON (WISC) P

CITRON 66 PR 144 1101 +GALBRAITH, KYCIA, LEONTIC, PHILLIPS, + (BNL) I

BARGER 67 PR 155 1792 V BARGER, D CLINE (WISC) P

DIKMEN 67 PRL 18 798 F N DIKMEN (MICH) P

KORMANYOS 67 PR 164 1661 KORMANYOS, KRISCH, OFALLON, + (MICH, ANL) P

GALLGWAY 68 PL 268 334 K F GALLGWAY (INDIANA) I

PAPERS NOT REFERRED TO IN DATA CARDS

BAACKE 67 NC 51A 761 J BAACKE, M YVERT (KARLSRUHE,GRSAY) J-L

DOBROWOL 67 PL 248 203 DOBROWOLSKI, GUSKOV, LIKHACHEV, + (DUBNA) P

DOLEN 68 PR 166 1768 R DOLEN, D HORN, C SCHMID (CIT)

WAHLIG 68 PR 168 1515 M A WAHLIG, I MANNELLI (MIT, PISA)

FINAL VERSION OF DATA USED IN WAHLIG 64, IN CONJUNCTION WITH CITRON 66 TOTAL CROSS SECTIONS, THIS CHARGE EXCHANGE DATA GIVES COMPLEX ELASTIC SCATTERING AMPLITUDE AT 0 DEGREES.

$\Delta(2500)$ **G₃₉**

124 N*3/2(2500, JP=9/2-) I=3/2

124 N*3/2(2500) MASS (MEV)

M 2468. 50. HOEHLER 79 IPWA P I N TO P I N 12/79*

124 N*3/2(2500) WIDTH (MEV)

W 480. 100. HOEHLER 79 IPWA P I N TO P I N 12/79*

124 N*3/2(2500) PARTIAL DECAY MODES

P I N*3/2(2500) INTO P I N DECAY MASSES 139+ 938

124 N*3/2(2500) BRANCHING RATIOS

R I N*3/2(2500) INTO (P I N)/TOTAL (P I) 12/79*

R I .06 .03 HOEHLER 79 IPWA P I N TO P I N 12/79*

Data Card Listings

Baryons

For notation, see key at front of Listings. Δ(2500), Δ(>2500), Δ(2750), Δ(2850), Δ(2950)

REFERENCES FOR N*3/2(2500)

HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 +KAISER,KOCH,PIETARINEN /KARLSRUHE IJP

>2500 MEV REGION - FORMATION EXPERIMENTS

127 N*3/2(>2500) I=3/2

WE LIST HERE I=3/2 RESONANCES WITH MASS GREATER THAN ABOUT 2.5 GEV WHICH HAVE BEEN SEEN IN A SINGLE PARTIAL WAVE ANALYSIS ONLY. ALL RESONANCES WHICH HAVE BEEN OBSERVED IN >1 ANALYSIS AT ABOUT THE SAME MASS ARE GIVEN A SEPARATE LISTING WITH THE APPROPRIATE QUANTUM NUMBERS.

127 N*3/2(>2500) MASS (MEV)

Table with columns: M, mass values (2450, 2850, 3200, 3300, 3700, 4100), HENDRY, 78 MPWA, PI N, H39, 1311, K313, L317, M319, N321, 12/79*

127 N*3/2(>2500) WIDTH (MEV)

Table with columns: W, mass values (500, 700, 1000, 1100, 1300, 1600), HENDRY, 78 MPWA, PI N, H39, 1311, K313, L317, M319, N321, 12/79*

127 N*3/2(>2500) PARTIAL DECAY MODES

Table with columns: P1, N*3/2(>2500) INTO PI N, DELAY MASSES, 139+ 938

127 N*3/2(>2500) BRANCHING RATIOS

Table with columns: R1, N*3/2(>2500) INTO (PI N)/TOTAL, HENDRY, 78 MPWA, PI N, H39, 1311, K313, L317, M319, N321, 12/79*

REFERENCES FOR N*3/2(>2500)

HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP

Δ(2750)

125 N*3/2(2750, JP=13/2-) I=3/2

I313

125 N*3/2(2750) MASS (MEV)

Table with columns: M, mass values (2650, 2790), HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

125 N*3/2(2750) WIDTH (MEV)

Table with columns: W, mass values (500, 350), HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

125 N*3/2(2750) PARTIAL DECAY MODES

Table with columns: P1, N*3/2(2750) INTO PI N, DELAY MASSES, 139+ 938

125 N*3/2(2750) BRANCHING RATIOS

Table with columns: R1, N*3/2(2750) INTO (PI N)/TOTAL, HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

REFERENCES FOR N*3/2(2750)

HENDRY 78 PRL 41 222 ARCHIBALD W. HENDRY (IND+LBL)IJP HOEHLER 79 HANDBOOK OF PI-N SCATTERING, PHYSIK DATEN VOL.12-1 +KAISER,KOCH,PIETARINEN /KARLSRUHE IJP

Δ(2850) BUMPS

85 N*3/2(2850, JP= +) I=3/2 PRODUCTION EXPERIMENTS

85 N*3/2(2850) MASS (MEV) (PROD. EXP.)

Table with columns: M, mass values (2870.0, 2700.0, 2850.0, 2883.), HOEHLER, WAHLIG, BARADIN, CITRON, 64 RVUE, 64 OSPK, 66 HBC, 66 CNTR, 74 MPWA, DATA + DISP REL, PI-P CH EX, N* TO P + 3 PIS, PI+ P TOTAL, PI+ P 180 DEG CS, 12/79*

85 N*3/2(2850) WIDTH (MEV) (PROD. EXP.)

Table with columns: W, mass values (150.0, 400.0, 4300.), HOEHLER, BARADIN, CITRON, 66 HBC, 66 CNTR, 74 MPWA, 40.0, (141.), (201.), PI+ P 180 DEG CS, 12/79*

85 N*3/2(2850) PARTIAL DECAY MODES (PROD. EXP.)

Table with columns: P1, N*3/2(2850) INTO PI N, N*3/2(2850) INTO P PI PI, N*3/2(2850) INTO N PI PI, DECAY MASSES, 139+ 938, 938+ 139+ 139+ 139

85 N*3/2(2850) BRANCHING RATIOS (PROD. EXP.)

Table with columns: R1, N*3/2(2850) INTO (PI N)/TOTAL, ONLY (J+1/2)* (PI N/TOTAL) MEASURED FOR THIS STATE, BARGER, CITRON, BARGER, BARGER, DIKMAN, DOBROWOLSKI, KORMANYOS, HALDORSE, REY, 67 PRL 155 1792, 67 PRL 18 798, 67 PL 248 203, 67 PR 164 1661, 72 NC 10A 468, 74 PRL 32 908, 74 PRL 33 250, 75 PRD 11 1777, G HOHLER, J GIESECKE, MANNELLI-SODICKSON, FACKLER, WARD, BARADIN-OTHINOWSKA, DANYSZ, V BARGER, M CLSSON, GALBRAITH, KYCIA, LEONTIC, PHILLIPS, V BARGER, D CLINE, F N DIKMAN, DOBROWOLSKI, GUSKOV, LIKHACHEV, KORMANYOS, KRISCH, OFALLON, HALDORSEN-JACOBSEN, REY, LENNOX, POIRIER, PRETZL, REY, LENNOX, POIRIER, PRETZL, SANDER, (KARLSRUHE) I, (MIT), (WARSAW), (WISC), (BNL) I, (WISC), (MICH), (DUBNA) P, (MICH, ANL) P, (OSLO) IJ, (NDAM+MPI)IP, (NDAM+MPI)IP, (NDAM+FNAL+ANL)IP

REFERENCES FOR N*3/2(2850) (PROD. EXP.)

HOHLER 64 PL 12 149 WAHLIG 64 PRL 13 103 BARADIN 66 PL 21 357 BARGER 66 PR 151 1123 CITRON 66 PR 144 1101 BARGER 67 PRL 155 1792 DIKMAN 67 PRL 18 798 DOBROWOLSKI 67 PL 248 203 KORMANYOS 67 PR 164 1661 HALDORSE 72 NC 10A 468 REY 74 PRL 32 908 ALSO 74 PRL 33 250 ALSO 75 PRD 11 1777 G HOHLER, J GIESECKE (KARLSRUHE) I MANNELLI-SODICKSON, FACKLER, WARD, (MIT) BARADIN-OTHINOWSKA, DANYSZ, (WARSAW) V BARGER, M CLSSON (WISC) GALBRAITH, KYCIA, LEONTIC, PHILLIPS, (BNL) I V BARGER, D CLINE (WISC) F N DIKMAN (MICH) DOBROWOLSKI, GUSKOV, LIKHACHEV, (DUBNA) P KORMANYOS, KRISCH, OFALLON, (MICH, ANL) P HALDORSEN-JACOBSEN (OSLO) IJ REY, LENNOX, POIRIER, PRETZL (NDAM+MPI)IP REY, LENNOX, POIRIER, PRETZL (NDAM+MPI)IP SANDER (NDAM+FNAL+ANL)IP

PAPERS NOT REFERRED TO IN DATA CARDS

BAACKE 67 NC 51A 761 DOLEN 68 PR 166 1768 WAHLIG 68 PR 168 1515 FINAL VERSION OF DATA USED IN WAHLIG 64. IN CONJUNCTION WITH CITRON 66 TOTAL CROSS SECTIONS, THIS CHARGE EXCHANGE DATA GIVES COMPLEX ELASTIC SCATTERING AMPLITUDE AT 0 DEGREES. J BAACKE, M YVERT (KARLSRUHE,ORSAY)J-L R DOLEN, D HORN, C SCHMID (CITI) M A WAHLIG, I MANNELLI (MIT,PNLS)

Δ(2950)

126 N*3/2(2950, JP=15/2+) I=3/2

K315

126 N*3/2(2950) MASS (MEV)

Table with columns: M, mass values (2850, 2990), HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

126 N*3/2(2950) WIDTH (MEV)

Table with columns: W, mass values (700, 330), HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

126 N*3/2(2950) PARTIAL DECAY MODES

Table with columns: P1, N*3/2(2950) INTO PI N, DECAY MASSES, 139+ 938

126 N*3/2(2950) BRANCHING RATIOS

Table with columns: R1, N*3/2(2950) INTO (PI N)/TOTAL, HENDRY, 78 MPWA, HOEHLER, 79 IPWA, PI N TO PI N, 12/79*

Data Card Listings

For notation, see key at front of Listings.

Baryons

Z₀(1780), Z₀(1865), Z₁(1900)

95 Z*0(1780) PARTIAL DECAY MODES
PI Z*0(1780) INTO K N
DECAY MASSES
493+ 939

95 Z*0(1780) BRANCHING RATIOS
R1 Z*0(1780) INTO (K N)/TOTAL
R1 W (0.95) COOL 70 CNTR + K+P, D TOTAL 1/71

REFERENCES FOR Z*0(1780)
COOL 70 DUKE CONF 47
ALSO 69 PL 308 564

EXPERIMENTS MAINLY ABOUT ELASTIC CHANNELS
GOLDHABE 62 PRL 9 135
RAY 69 PR 183 1183

EXPERIMENTS MAINLY ABOUT INELASTIC CHANNELS
GIACOMELI 77 NP 837 577
ARMITAGE 77 NP 8123 11

Z₀(1865) 96 Z*0(1865, JP=3/2-) I=0
D03
THIS EFFECT IS STRONGLY ASSOCIATED WITH THE K* N THRESHOLD.

96 Z*0(1865) MASS (MEV)
M (1860.0) (15.0) CARTER 67 THEO DISPERSION REL. 8/67

96 Z*0(1865) WIDTH (MEV)
W (200.0) (50.0) CARTER 67 THEO 8/67

96 Z*0(1865) PARTIAL DECAY MODES
P1 Z*0(1865) INTO K N
P2 Z*0(1865) INTO N K*(892)

96 Z*0(1865) BRANCHING RATIOS
R1 Z*0(1865) INTO (K N)/TOTAL
R1 (.155) (.025) CARTER 67 THEO IF J=3/2 9/73

REFERENCES FOR Z*0(1865)
A A CARTER (CAVENDISH)
HIRATA, WOHLL, GOLDHABER, TRILLING (LRL)

PAPERS NOT REFERRED TO IN DATA CARDS
HIRATA 70 DUKE 429
HIRATA 71 PRL 26 407

S=1 I=1 EXOTIC STATES (Z₁)

Z₁(1900) 97 Z*1(1900, JP=3/2+) I=1
P13
THIS EFFECT IS STRONGLY ASSOCIATED WITH THE K-DELTA THRESHOLD.

97 Z*1(1900) MASS (MEV)
M 1 (1932.0) AYED 70 IPWA P13,SOL I 6/70

97 Z*1(1900) WIDTH (MEV)
W 1 (520.0) AYED 70 IPWA K+P 6/70

97 Z*1(1900) REAL PART OF POLE POSITION
REE 3 (1787.) ARNDT 74 DPWA K+ P ELASTIC 4/75

97 Z*1(1900) -IMAGINARY PART OF POLE POSITION
IME 3 (100.) ARNDT 74 DPWA K+ P ELASTIC 4/75

97 Z*1(1900) PARTIAL DECAY MODES
P1 Z*1(1900) INTO K N
P2 Z*1(1900) INTO N*3/2(1232) K

97 Z*1(1900) BRANCHING RATIOS
R1 Z*1(1900) INTO (K N)/TOTAL
R1 (0.10) OR LESS CARTER 67 THEO DISPERSION REL. 8/67

Z*1(1900) INTO K N*3/2(1232)
R2 MAIN INELASTIC DECAY BLAND 67 HBC (P2) 8/67

REFERENCES FOR Z*1(1900)
BLAND 67 PRL 18 1077
CARTER 67 PRL 18 801

TOTAL-CROSS-SECTION EXPERIMENTS
BUGG 68 PR 168 1466
BOWEN 70 PR D2 2599

Baryons

Z₁(1900), Z₁(2150), Z₁(2500), Λ's and Σ's

Data Card Listings

For notation, see key at front of Listings.

A K-MATRIX ANALYSIS OF SOME OF THE EARLY K+P DATA ---
HITE 67 THESIS G E HITE (ILLINOIS)

THEORETICAL AND MODEL DEPENDENT ANALYSES
CARRERAS 70 NP B19 349 B CARRERAS, A DONNACHIE (DARESBURY, MCHS)
ALCOCK 73 NP B56 301 ALCOCK, COTTINGHAM (BRIS) IJP
ALCOCK 76 NP B102 173 ALCOCK, COTTINGHAM, DAVIS (BRIS) IJP
ALCOCK 78 J. PHYS. G 4 323 ALCOCK, COTTINGHAM, DAVIS (BRIS) IJP

EXPERIMENTS MAINLY ABOUT INELASTIC CHANNELS ---
BLAND 68 UCRL-18131 THESIS R W BLAND (LRL)
BLAND 69 NP B13 595 +BOWLER, BROWN, KADYK, GOLDBERGER, + (LRL)
BLAND 70 NP B18 537 +BOWLER, BROWN, GOLDBERGER, (LRL)
BLAND 69 AND BLAND 70 REPLACE BLAND 67 AND BLAND 68.
HIRATA-1 71 NP B33 445 +GOLDBERGER, HALL, SEEGER, TRILLING, WOHL (LBL)
BRUNET 72 NP B37 114 BRUNET, NARJOUX, DANYSZ+ (CDEF+SACL+LOIC+LDCW)
GRIFFITH 72 NP B38 365 +HIRATA, HUGHES, JACOB+ (BGNA, GLAS, ROMA, TRST) IJP
LCKEN 72 PR D6 2346 +BARISH, GOMEZ, DAVIES, SCHLEIN, + (GIT, UCLA)
BERTHON 73 NP B63 54 BERTHON, MONTANET, PAUL, SAETRE+ (CERN+SACL)
LEWIS 73 NP B60 283 LEWIS, ALLEN, JACOBS, DANYSZ+ (LDCW+CDEF)
LESQUOY 75 NP B99 346 +MULLER, TRIANTIS, BERTHON+ (SACL+CERN) IJP
MUSGRAVE 75 NP B87 365 +PEETERS, SCREINER, WHITMORE, YUTA (ANL)
GIACOMELLI 76 NP B111 365 GIACOMELLI+MANDRIOLI+ (BGNA+GLAS+ROMA+TRST)
ARMITAGE 77 NP B123 111 +ASTON, DUERDOTH, ELLISON, FITTON+ (MCHS+DARE)
GLASSER 77 PRD 15 1200 +SNOW, TREVETT, BURNSTEIN, FU, PETRI+ (UMD+IIT)
SAKITT 77 PRD 15 1846 +SKELLY, THOMPSON (BNL)

THE MAIN ELASTIC SCATTERING AND POLARIZATION EXPERIMENTS ---
CARROLL 68 PRL 21 1282 +FISCHER, LUNDBY, PHILLIPS, + (BNL, RCCH)
ANDERS-1 69 PL 288 611 ANDERSSON, DAUM, ERNE, LAGNAUX, + (CERN)
ANDERS-2 69 PL 308 56 ANDERSSON, DAUM, ERNE, LAGNAUX, + (CERN)
ASBURY 69 PRL 23 194 +DOWELL, KATO, LUNDQUIST, NOVEY, + (ANL, UMD)
BLAND 69 NP B13 595 R W BLAND, G GOLDBERGER, G H TRILLING (LRL)
BARBER 70 NP 328 214 +BROOME, DUFF, HEYMANN, IMRIE, + (LOUC, RHEL) IJP
GIACOMELLI 70 NP B20 301 GIACOMELLI, G. GRIFFITHS, (BGNA, GLAS, ROMA, TRST) IJP
HALL 70 DUKE 435 +BLAND, GOLDBERGER, TRILLING (LRL)
REBKA 70 REKA 160 +ROTHBERG, ETKIN, GLADIS, + (YALE) IJP
ADAMS 71 PR D4 2637 +DAVIES, DOWELL, GRAYER, HATTERS+ (BIRM+RHEL)
BARNETT 71 PL 348 655 +LAASANEN, STEINBERG + (UMD+ANL+MNS+FNAL)
EHLICH 71 PRL 26 925 +ETKIN, GLADIS, HUGHES, KONDO, LU, MORI, + (YALE)
WHITMORE 71 PR D3 1092 +ABRAMS, EISENSTEIN, KIM, DHALLORAN, + (ILL)
ADAMS 72 NAL PAPER 326 +COX, DAVIES+DOWELL, GRAYER + (BIRM+RHEL)
CHARLES 72 PL 408 289 +OWAN, EDWARDS, GIBSON, + (BRIS, RHEL, SHMP)
ALSO 72 NAL PAPER 287 CHARLES, COWAN, EDWARDS + (BRIS+RHEL+SHMP)
DANYSZ 72 NP B42 29 +PENNEY, STEWART, THOMPSON, + (LOIC, CDEF, LDCW)
ADAMS 73 NP B66 346 +ADAMS, COX, DAVIES, DOWELL, + (BIRM+RHEL) IJP
BARBER 73 NP B61 125 BARBER, BROOME, BUSZA, DAVIES, DUFF+ (LOUC+RHEL)
BARNETT 73 PRD 8 2751 BARNETT, LAASANEN+ (UMD+ANL+NWS+FNAL)
CHARLES 73 PURDUE CONF. 179 CHARLES, EDWARDS, + (SHMP+AA+RHEL+BRIS)
CAMERON 74 NP B78 93 CAMERON, HIRATA, JENNINGS, + (GLAS, BGNA, TRST) IJP
YUTA 74 NP B61 189 YUTA, BOCK, MUSGRAVE, PEETERS, SCHREINER, + (ANL) I
ABE 75 PRD 11 1719 +BARNETT, GOLDMAN, LAASANEN+ (UMD, ANL)
ADAMS 75 NP B87 41 +CARTER, COOK, GLASS, GREEN (WASH)
PATTON 75 PRL 34 975 +BARLETTA, EHLICH, ETKIN+ (YALE, TOKY, BNL)

PARTIAL-WAVE ANALYSES (SEE ALSO ADAMS 73 AND CAMERON 74)
CARRERA 70 NP B23 525 B CARRERAS, A DONNACHIE (DARE+MCHS+EDIN)
ALSO 70 DUKE 447 +DONNACHIE, KIRSOPP (DARE+MCHS+EDIN)
ERNE 70 DUKE 375 +SENS, WAGNER (CERN) IJP
LEA 71 NP B26 413 +MARTIN, THOMPSON (RHEL, LOUC) IJP
LOVELACE 71 NP B28 141 +WAGNER (CERN) IJP
CUTKOSKY 72 NAL PAPER 210 +HICKS, KELLY, SHIH, JOHNSON (CARN+ILL+ANL)
EHLICH 72 NAL PAPER 447 +ETKIN, GLADIS, HUGHES, LU, PATTON + (YALE)
MARTIN 72 PREPRINT B. R. MARTIN, C. E. MILLER (LOUC)
MARTIN 75 NP B94 413 B R MARTIN (LOUC)
CUTKOSKY 76 NP B102 139 CUTKOSKY, HICKS, KELLY, + (CARN+II+ANL) IJP
GIACOMELLI 76 NP B110 67 GIACOMELLI+MANDRIOLI (BGNA+GLAS) IJP

EARLIER ANALYSES THAT DO NOT INCLUDE RECENT POLARIZATION DATA --
LEA 68 PR 165 1770 LEA, MARTIN, OADES (RHEL, BNL, CERN)
MARTIN 68 PRL 21 1286 B R MARTIN (BNL)
CUTKOSKY 70 PR D1 2547 R E CUTKOSKY, B B DEO (CARNegie-MELLON) I

LATEST REVIEW TALKS AND PAPERS
LEVISETT 69 LUND CONF 341 R LEVI SETTI (RAPPOREUR) (CHICAGO)
GOLDBERGER 70 DUKE 407 G. GOLDBERGER (REVIEWER) (LRL)
DOWELL 72 NAL REVIEW REVIEW TALK IN BARYON SESSION (BIRM)
LOVELACE 72 NAL REVIEW RAPPOREUR'S TALK (RUTG)
DOWELL 73 PURDUE CONF. 157 DOWELL (BIRM)
CUTKOSKY 74 LCHDON CONF II-54 CUTKOSKY (CARN)
KELLY 75 ANL-HEP-G-75-58 REVIEW TALK IN BARYON SESSION (LBL)
URBAN 75 PL 608 77 URBAN (LBL)
MARTIN 76 OXFORD CONF. 409 RAPPOREUR'S TALK (LOUC)
KELLY 78 HUPD-7813 44 MTG. ON EXOTIC RESONANCES, HIROSHIMA (LBL)

Z₁(2150) BUMPS
93 Z₁(2150, JP=) I=1
A SMALL BUMP IN TOTAL CROSS SECTION AT PK=1.8 GEV/C

93 Z₁(2150) MASS (MEV)
M 2150. 20. ABRAMS 70 CNTR ++ K+P TOTAL 10/71

93 Z₁(2150) WIDTH (MEV)
W (175.) ABRAMS 70 CNTR + K+P TOTAL 10/71

93 Z₁(2150) PARTIAL DECAY MODES
P1 Z₁(2150) INTO K N DECAY MASSES 493+ 938

93 Z₁(2150) BRANCHING RATIOS
R1 Z₁(2150) INTO (K N)/TOTAL (P1)
R1 J IS NOT KNOWN, THE FOLLOWING IS (J=1/2)*P1 (LBL)
R1 (0.04) ABRAMS 70 CNTR + K+P TOTAL 10/71

REFERENCES FOR Z₁(2150)
ABRAMS 70 PR D1 1917 +COOL, GIACOMELLI, KYCIA, LEONTIC, LI + (BNL)
ALSO 67 PRL 19 257 ABRAMS, COOL, GIACOMELLI, KYCIA, LEONTIC+ (BNL)

Z₁(2500) BUMPS
94 Z₁(2500, JP=) I=1
A SMALL BUMP IN TOTAL CROSS SECTION AT PK=2.7 GEV/C

94 Z₁(2500) MASS (MEV)
M 2500. 20. ABRAMS 70 CNTR ++ K+P TOTAL 10/71

94 Z₁(2500) WIDTH (MEV)
W (160.) ABRAMS 70 CNTR ++ K+P TOTAL 10/71

94 Z₁(2500) PARTIAL DECAY MODES
P1 Z₁(2500) INTO K N DECAY MASSES 493+ 938

94 Z₁(2500) BRANCHING RATIOS
R1 Z₁(2500) INTO (K N)/TOTAL (P1)
R1 J IS NOT KNOWN, THE FOLLOWING IS (J=1/2)*P1 (P1)
R1 (0.03) ABRAMS 70 CNTR ++ K+P TOTAL 10/71

REFERENCES FOR Z₁(2500)
ABRAMS 70 PR D1 1917 +COOL, GIACOMELLI, KYCIA, LEONTIC, LI + (BNL)
ALSO 67 PRL 19 257 ABRAMS, COOL, GIACOMELLI, KYCIA, LEONTIC+ (BNL)

Z₁ CROSS SECTION LIMITS
SEE MINIREVIEW PRECEDING Z*0

CS UNITS MICROBARNS
CS LESS THAN 50. BASSOMPIERRE 68 HBC K+P TO Z*+ P1+ 10/69
CS A LESS THAN +2 +3 ANDERSON 69 ASPK + PI-P TO K-Z*+ 10/69
CS A ABOVE LIMIT FOR M=1.2 TO 1.4 GEV - CL= 99 P.C.
CS B LESS THAN 1.4 +1.9 -5 ANDERSON 69 ASPK + PI-P TO K-Z*+ 10/69
CS B ABOVE LIMIT FOR M=1.5 TO 2.5 GEV

REFERENCES FOR Z*1 CROSS SECTION LIMITS
BASSOMPI 68 PL 27B 468 BASSOMPIERRE, + (CERN, BRUXELLES)
ANDERSON 69 PL 29B 136 +BLESER, BLIEDEN, COLLINS, + (BNL, CARNegie)

PAPERS NOT REFERRED TO IN DATA CARDS
TYSON 67 PRL 19 255 +GREENBERG, HUGHES, LU, MINEHART, MORI, (YALE)
MORI 68 PL 28B 152 +GREENBERG, HUGHES, LU, ROTHBERG, + (YALE)
MORI 69 PR 185 1687 +GREENBERG, HUGHES, LU, MINEHART, + (YALE)
MORI 69 REPLACES TYSON 67 AND MORI 68.

Note on Λ's and Σ's

The number of confirmed resonances is still increasing, but very slowly; in 1978, we added three more states to the Y* portion of the Baryon Table, and there has been no further increase this year. There remains, however, a large number of proposed, but unconfirmed resonances, and some of the states we enter in the Data Card Listings may really be more than one resonance.

All the Y*'s proposed in the last few years are only weakly coupled to their two-body decay channels $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$. For this reason they appear as very small peaks or make no appearance at all in invariant mass distributions. Rather,

Data Card Listings

For notation, see key at front of Listings.

Baryons
 Λ 's and Σ 's

when the two-body reactions $\bar{K}N \rightarrow \bar{K}N$, $\bar{K}N \rightarrow \Lambda\pi$, and $\bar{K}N \rightarrow \Sigma\pi$ are partial-wave analyzed, some of the amplitudes are found to traverse resonance-like counterclockwise circles. The results of partial-wave analysis give J^P information, whereas a peak seen in an invariant mass distribution or a total cross section often cannot be analyzed for its quantum numbers. We will keep information coming from formation experiments and from production experiments separate whenever necessary.

Formation Experiments

Partial-wave analyses have been performed mainly for the channels $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$; a few results exist also for $\bar{K}K$, $\Lambda\omega$, and some quasi-two-body channels. With a few exceptions (e.g., BAILLON 75 and VANHORN 75 for the $\Lambda\pi$ channel), the great majority of the analyses done so far cover rather narrow energy ranges, usually corresponding to a single bubble chamber experiment. A disturbing feature that appears when examining the partial waves obtained in such analyses is that they do not always join smoothly with the partial waves given in analyses done for the same channel over a different energy range.

More ambitious analyses treat all channels simultaneously so that unitarity constraints are automatically obeyed and the resonances appear with the same masses and widths in the different channels. The multi-channel analyses done prior to 1974 (KIM 71, LANGBEIN 72, and LEA 73) included the three two-body channels $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$, and were carried out in the mass range 1.5 to 1.9 GeV. This is the mass range of a particular bubble chamber experiment (ARMENTEROS 68), the only one which at that time had relatively good statistical accuracy.

In recent years, additional experimental results have been obtained. Bubble chamber experiments now exist with better statistics in the mass range already considered (HEMINGWAY 75, RLIC 77) and with somewhat lower statistical accuracy up to a mass of 2.5 GeV (BELLEFON 75, 2 75, 77, and 78). However, the most important recent contributions to this field, for the $\bar{K}N$ channel at least, are from electronic counter experiments. These provide results which are difficult if not impossible to get in a conventional bubble chamber experiment.

They include high-statistics measurement of the $\bar{K}^-p \rightarrow \bar{K}^0n$ total¹ and differential cross section² at low energies, \bar{K}^-p elastic polarization measurements,³ and \bar{K}^-n elastic angular distributions (DECLAIS 77 and Ref. 4).

We may hope that improved partial-wave analyses over a wide energy range will be performed in the near future in order to disentangle the rather unsatisfactory present situation. Even though the unconfirmed resonances (one- and two-star states in Table 1) are often "seen" in several analyses with more or less compatible parameters, the corresponding partial-wave behavior is often very different in each of these analyses. Thus the confidence one has in the existence of these resonances is rather weak.

The three more recent analyses are discussed below. Two of them are multi-channel analyses, fitting data from the three channels, $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$, and covering a wide mass range.

a) In the analysis of the Rutherford Laboratory-Imperial College collaboration (RLIC 77) the mass range extends from 1480 to 2170 MeV. The data used have been carefully selected in order to eliminate inconsistencies (usually the older and statistically less accurate points have been rejected). Angular distributions were directly used in the fit except when the quality of the data was such that no loss of information occurred by using Legendre coefficients (e.g., $\bar{K}^-p \rightarrow \Sigma^0\pi^0$). In this work, a conventional energy-dependent analysis is performed first for each of the three channels ($\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$). As usual, the presence of a resonance in a partial wave is detected by comparing the goodness of the fit when this wave is parametrized as a smooth background to the alternative fit when a Breit-Wigner is added to the background. The three separate fits are then considered together in order to obtain a real multi-channel analysis. Internal consistency requires that the masses and widths of the resonances be the same in each of the three channels. The final fit has been done with these resonance parameters fixed and equal to a "weighted average" of the three values.

Some suspected resonances are confirmed by this analysis, but many other reported "resonance

Baryons

Λ 's and Σ 's

Data Card Listings

For notation, see key at front of Listings.

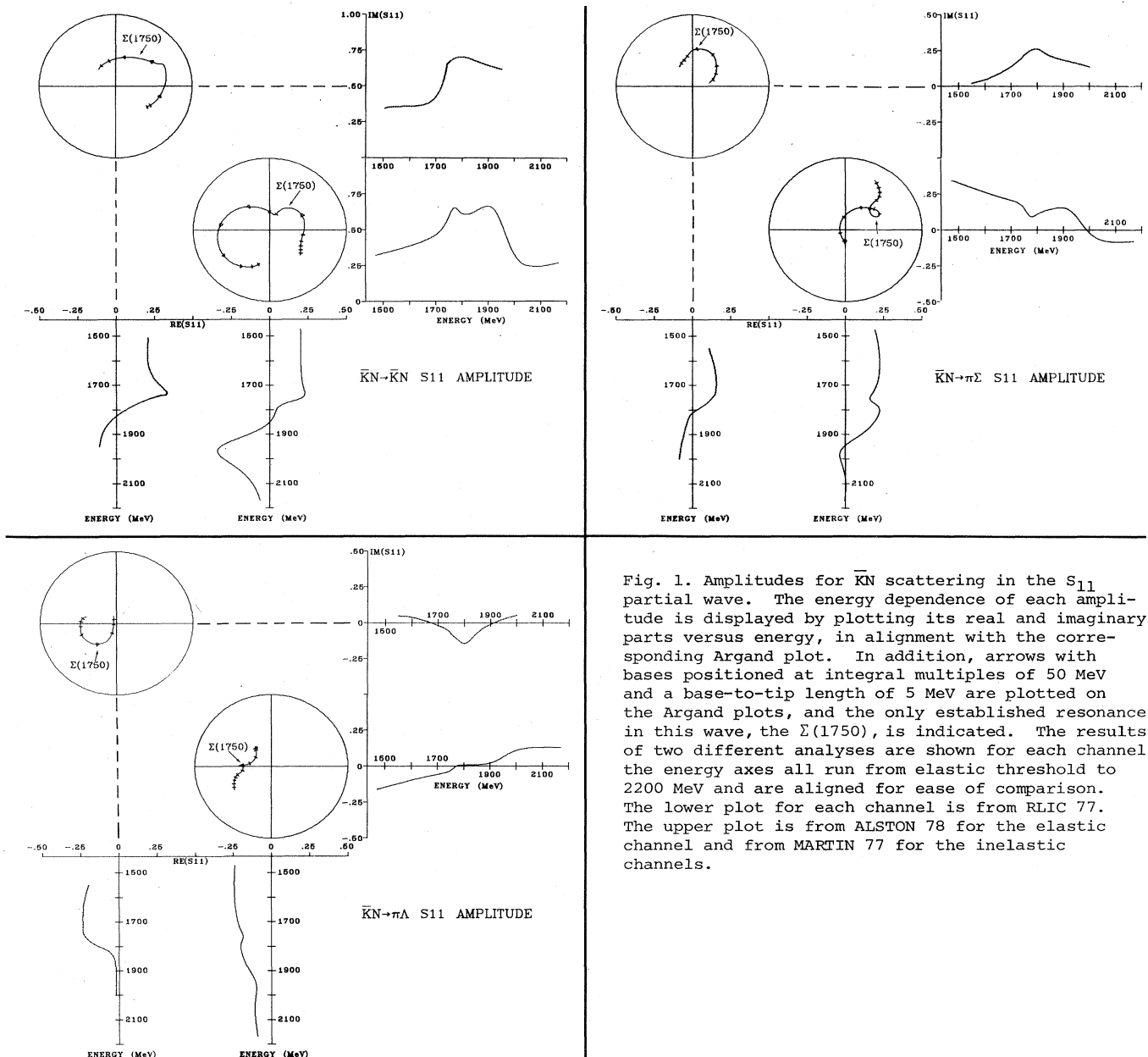


Fig. 1. Amplitudes for $\bar{K}N$ scattering in the S_{11} partial wave. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the only established resonance in this wave, the $\Sigma(1750)$, is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Λ 's and Σ 's

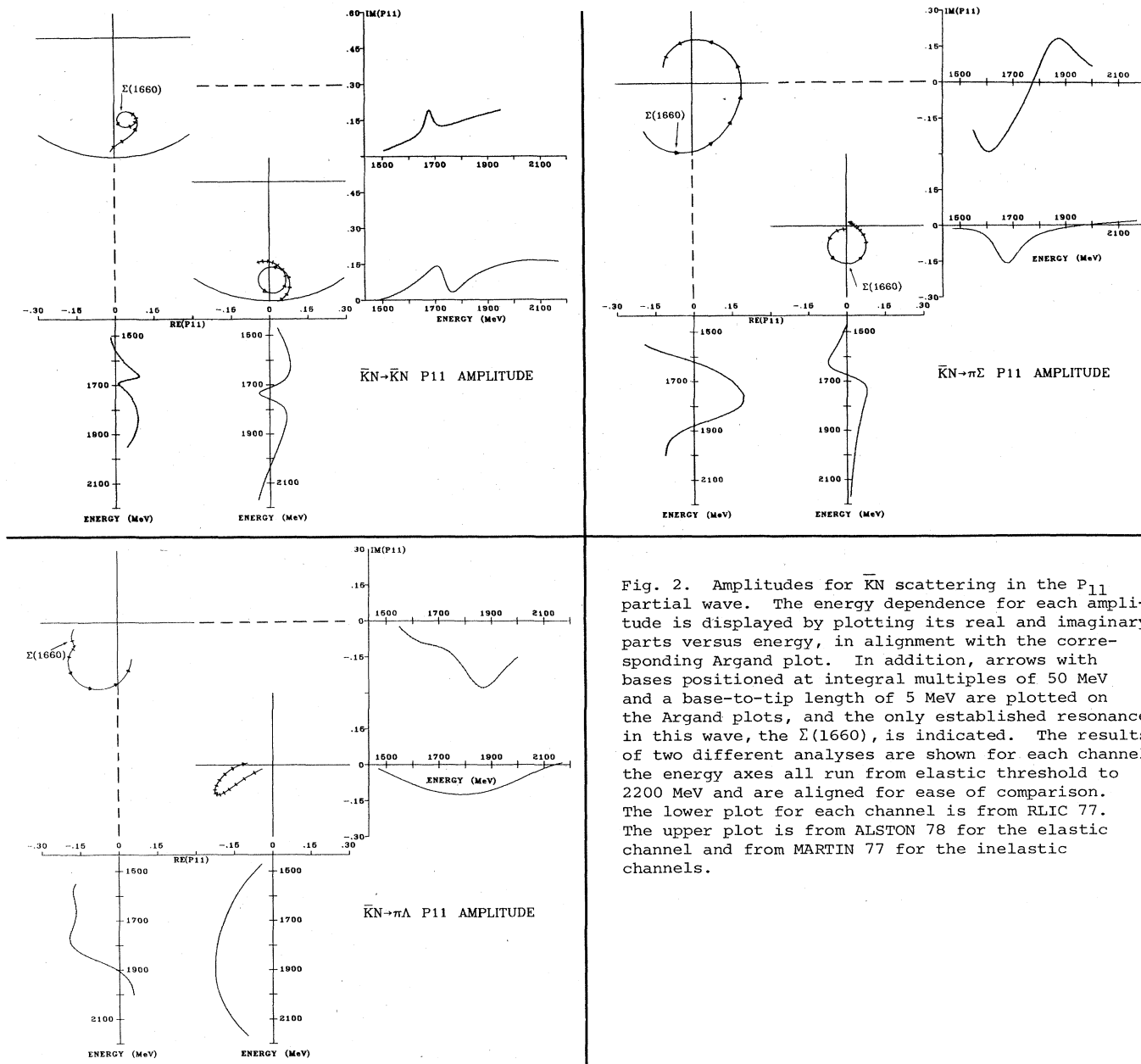


Fig. 2. Amplitudes for $\bar{K}N$ scattering in the P_{11} partial wave. The energy dependence for each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the only established resonance in this wave, the $\Sigma(1660)$, is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Baryons
 Λ 's and Σ 's

Data Card Listings

For notation, see key at front of Listings.

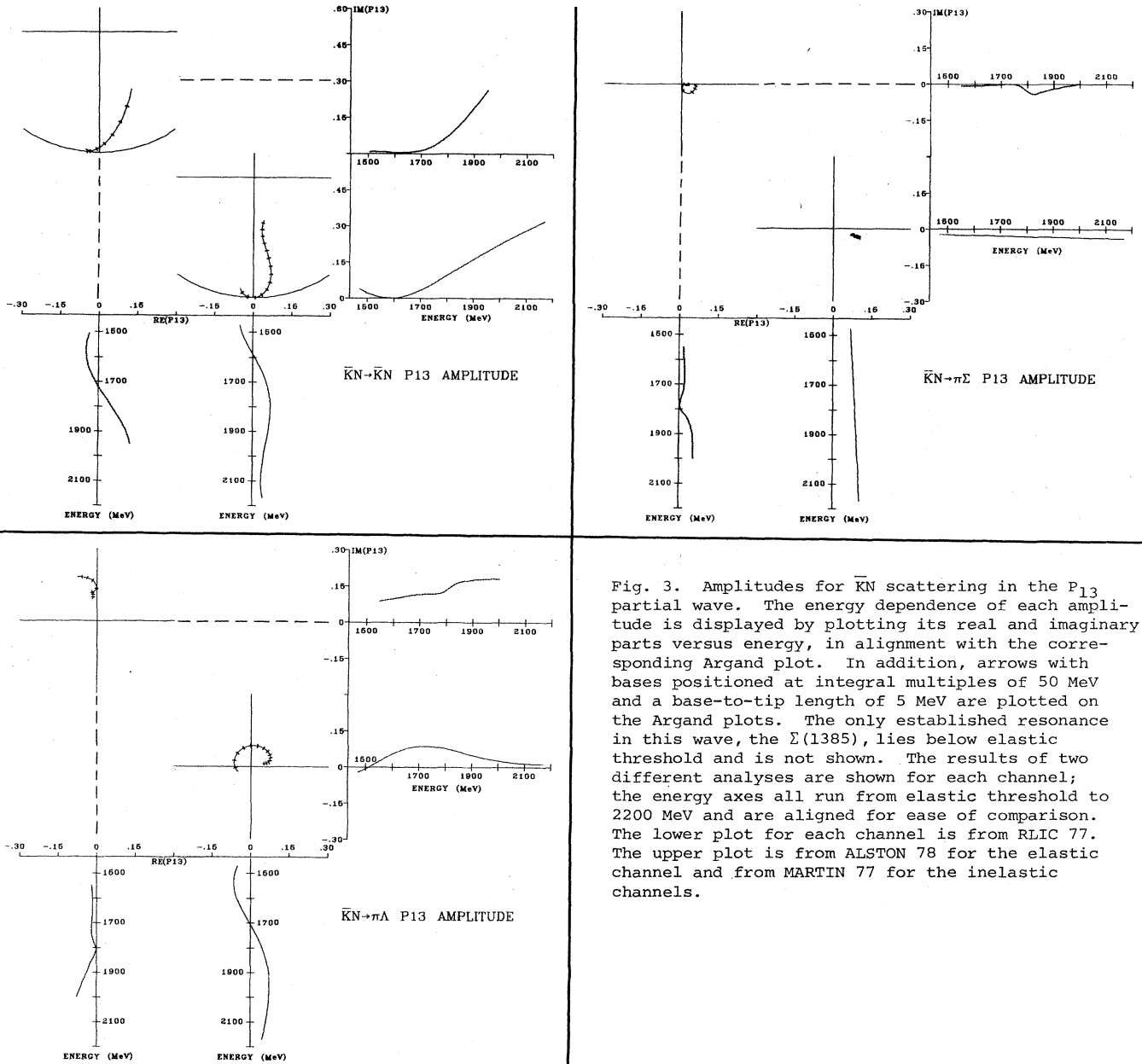


Fig. 3. Amplitudes for $\bar{K}N$ scattering in the P_{13} partial wave. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots. The only established resonance in this wave, the $\Sigma(1385)$, lies below elastic threshold and is not shown. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Λ 's and Σ 's

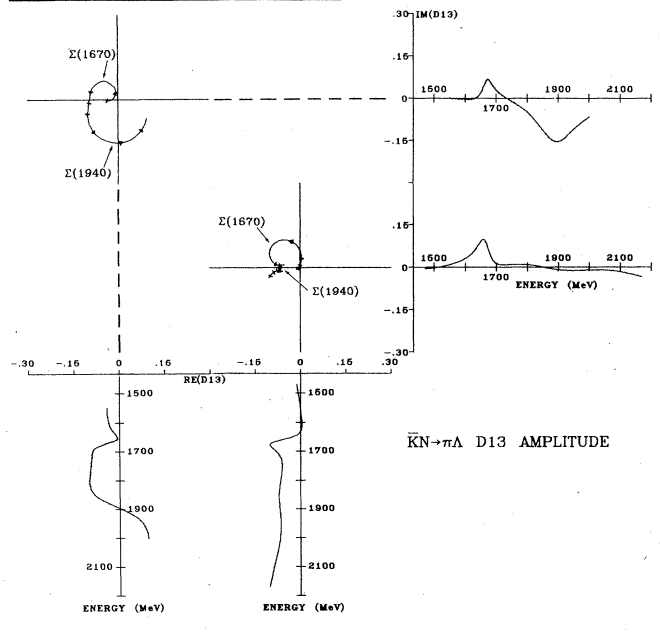
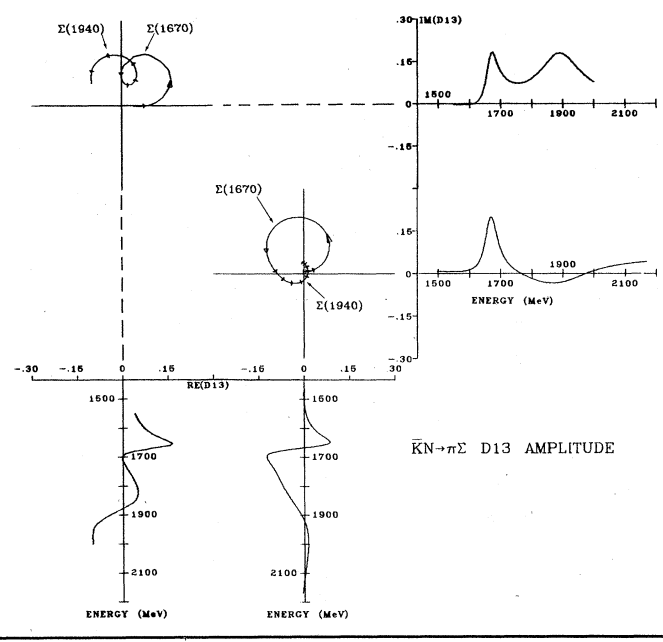
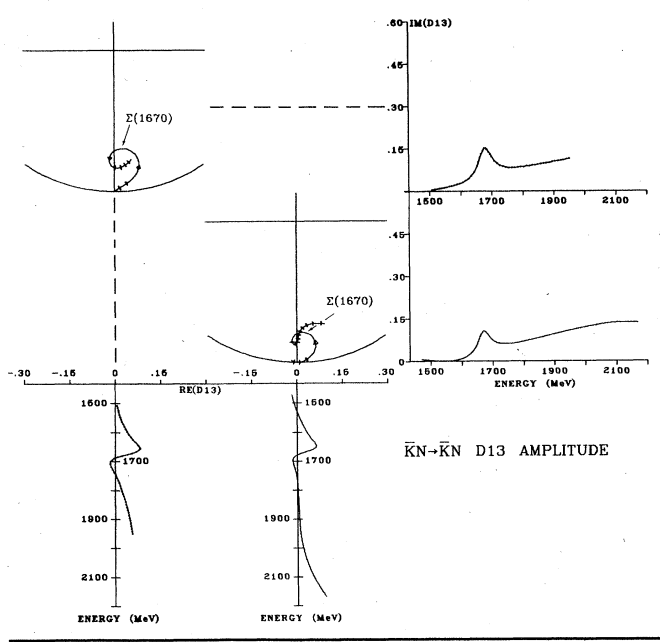


Fig. 4. Amplitudes for $\bar{K}N$ scattering in the D_{13} partial wave. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the established resonances in this wave, the $\Sigma(1670)$ and the $\Sigma(1940)$, are indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Baryons

 Λ 's and Σ 's

Data Card Listings

For notation, see key at front of Listings.

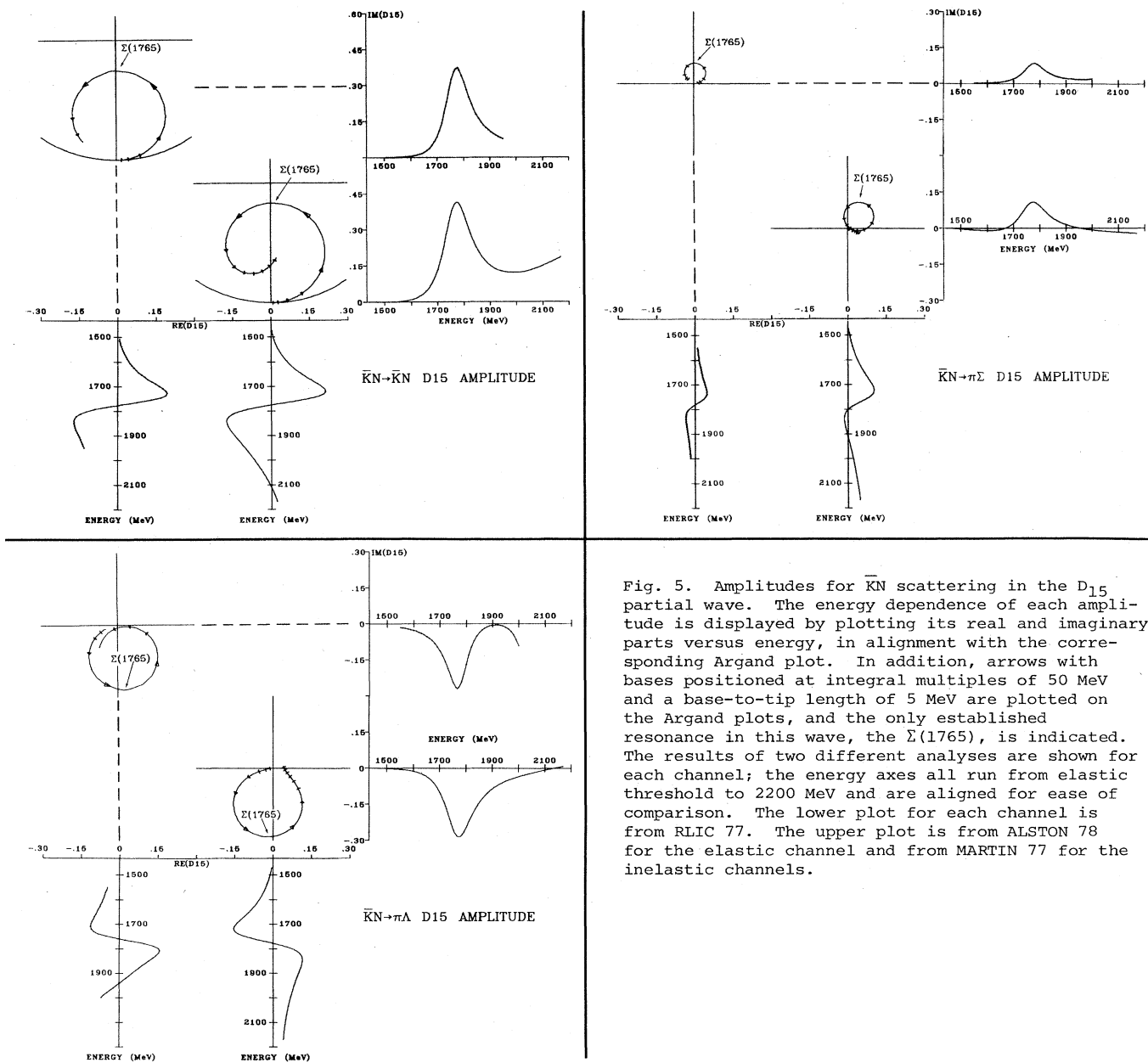


Fig. 5. Amplitudes for $\bar{K}N$ scattering in the D_{15} partial wave. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the only established resonance in this wave, the $\Sigma(1765)$, is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Λ 's and Σ 's

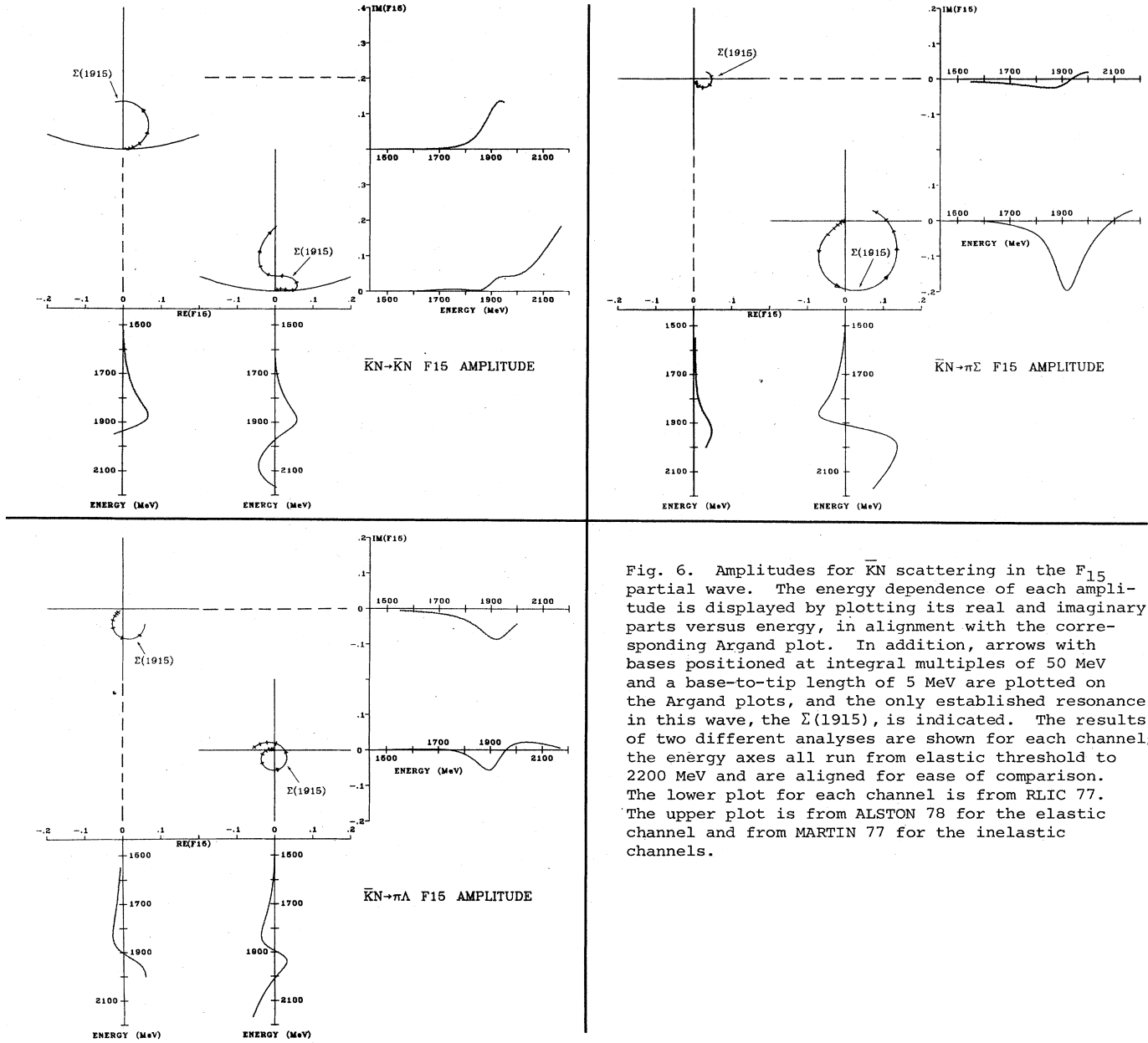


Fig. 6. Amplitudes for $\bar{K}N$ scattering in the F_{15} partial wave. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the only established resonance in this wave, the $\Sigma(1915)$, is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Baryons
Λ's and Σ's

Data Card Listings

For notation, see key at front of Listings.

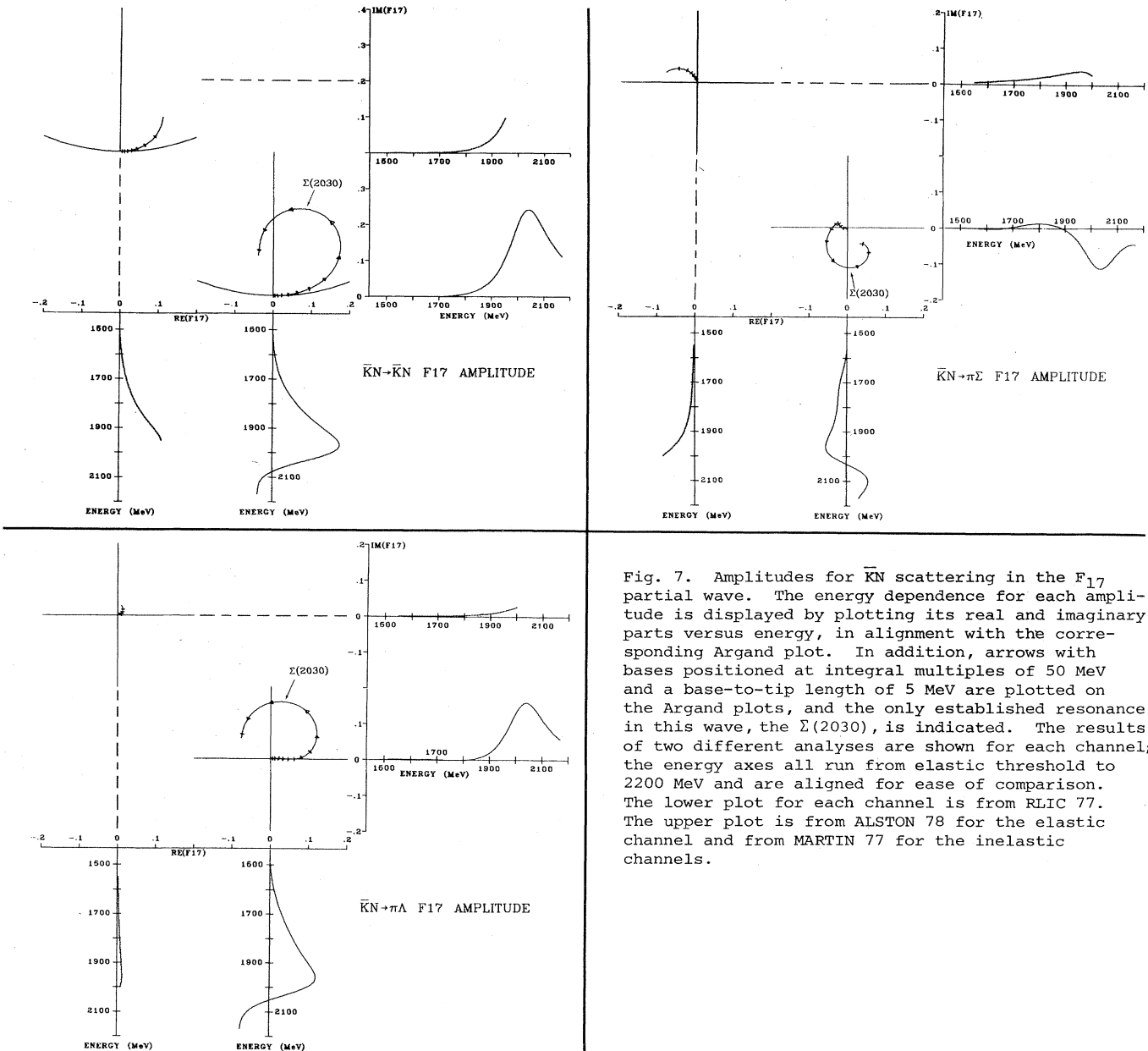


Fig. 7. Amplitudes for $\bar{K}N$ scattering in the F_{17} partial wave. The energy dependence for each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the only established resonance in this wave, the $\Sigma(2030)$, is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the inelastic channels.

Data Card Listings

For notation, see key at front of Listings.

Baryons

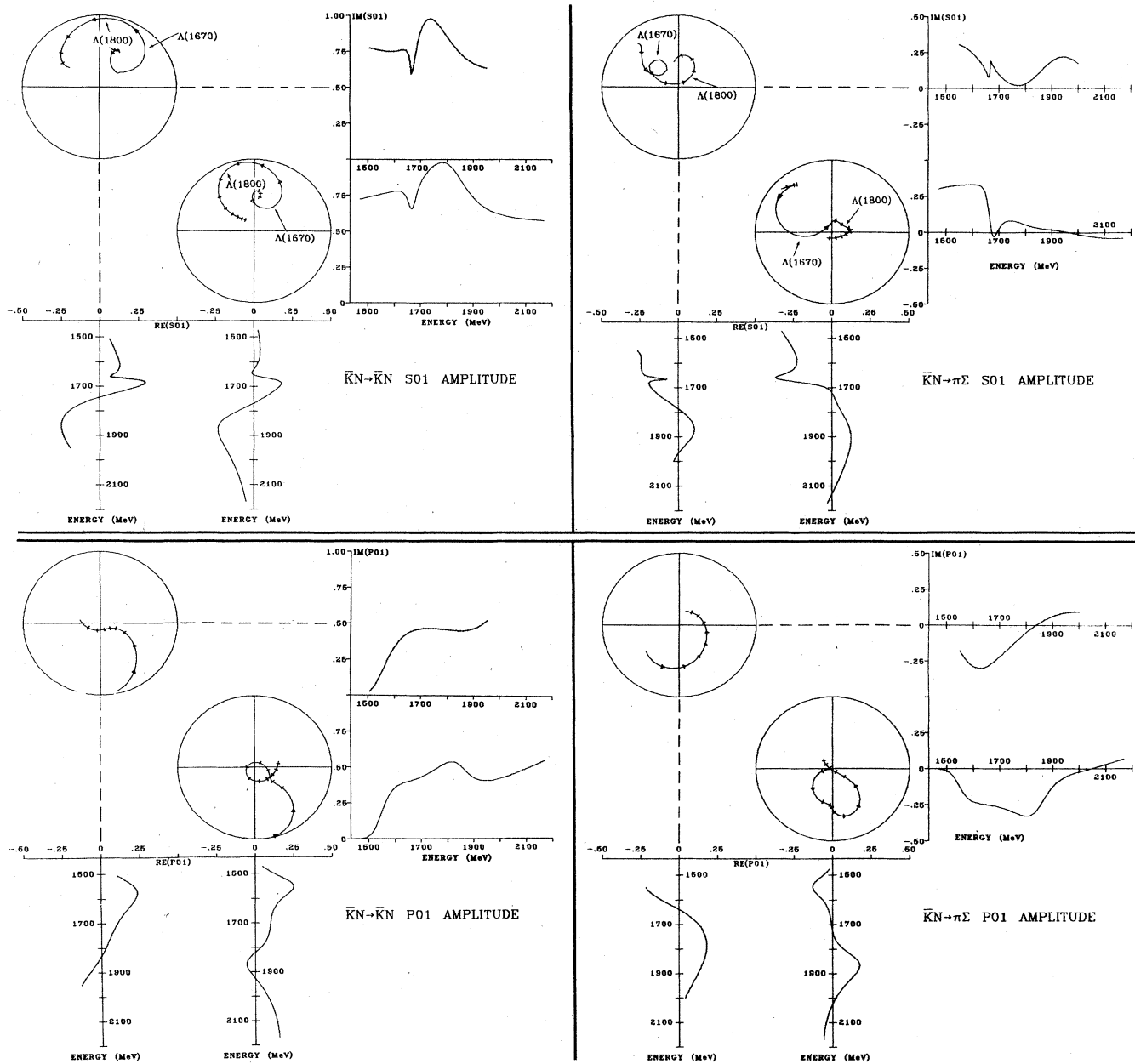
 Λ 's and Σ 's

Fig. 8. Amplitudes for $\bar{K}N$ scattering in the S_{01} and P_{01} partial waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the established resonances $\Lambda(1670)$ and $\Lambda(1800)$ are indicated. The only other established resonance in these waves is the $\Lambda(1405)$, which lies below elastic threshold in the S_{01} wave and is not shown. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the $\pi\Sigma$ channel.

Baryons

 Λ 's and Σ 's

Data Card Listings

For notation, see key at front of Listings.

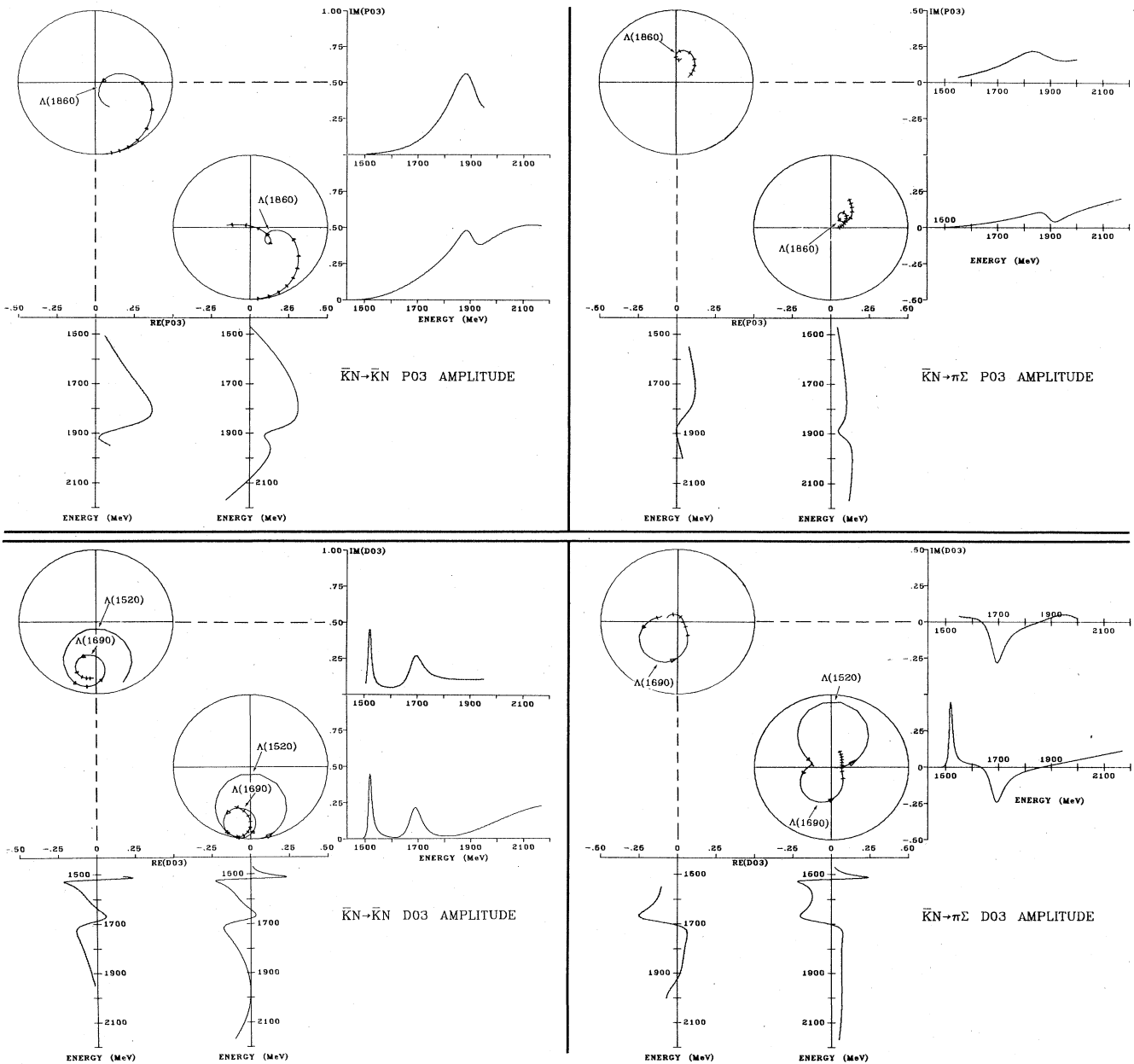


Fig. 9. Amplitudes for $\bar{K}N$ scattering in the P_{03} and D_{03} partial waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the established resonances $\Lambda(1520)$, $\Lambda(1690)$, and $\Lambda(1860)$ are indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the $\pi\Sigma$ channel.

Data Card Listings

For notation, see key at front of Listings.

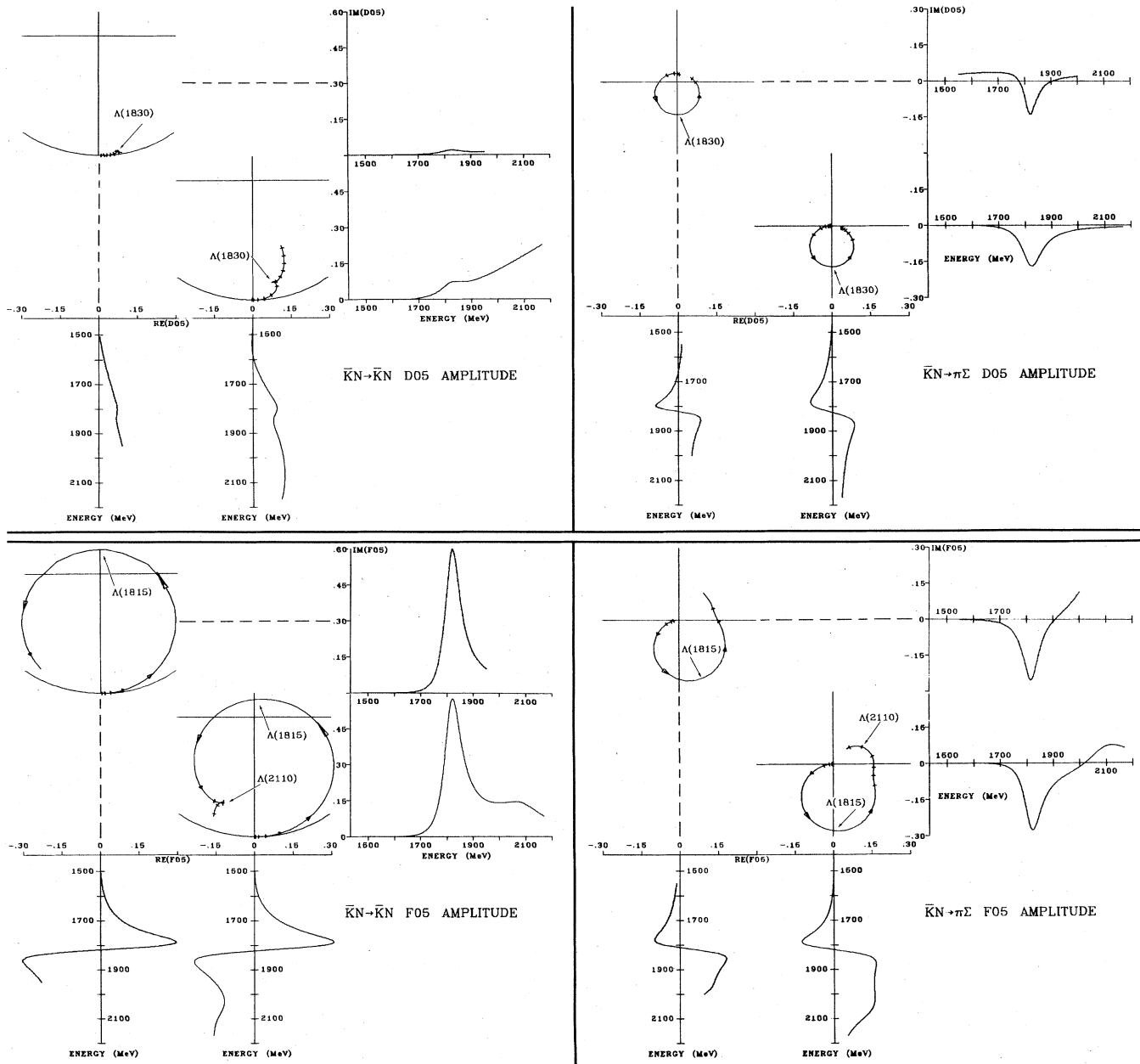
Baryons
 Λ 's and Σ 's

Fig. 10. Amplitudes for $\bar{K}N$ scattering in the D_{05} and F_{05} partial waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the established resonances $\Lambda(1815)$, $\Lambda(1830)$, and $\Lambda(2110)$ are indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the $\pi\Sigma$ channel.

Baryons

Λ 's and Σ 's

Data Card Listings

For notation, see key at front of Listings.

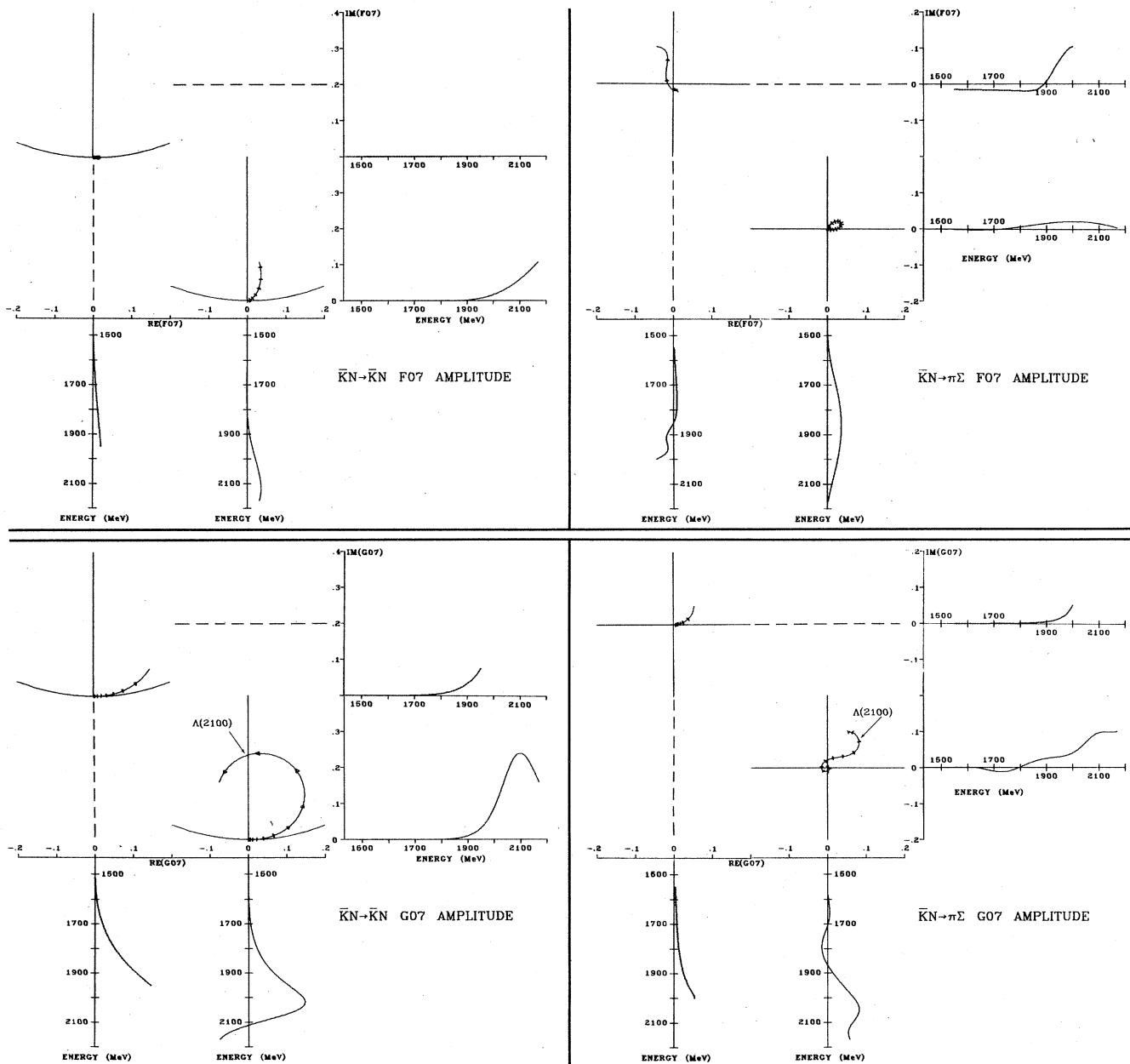


Fig. 11. Amplitudes for $\bar{K}N$ scattering in the F_{07} and G_{07} partial waves. The energy dependence of each amplitude is displayed by plotting its real and imaginary parts versus energy, in alignment with the corresponding Argand plot. In addition, arrows with bases positioned at integral multiples of 50 MeV and a base-to-tip length of 5 MeV are plotted on the Argand plots, and the established resonance $\Lambda(2100)$ is indicated. The results of two different analyses are shown for each channel; the energy axes all run from elastic threshold to 2200 MeV and are aligned for ease of comparison. The lower plot for each channel is from RLIC 77. The upper plot is from ALSTON 78 for the elastic channel and from MARTIN 77 for the $\pi\Sigma$ channel.

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For notation, see key at front of Listings.

Baryons
 Λ 's and Σ 's

effects" are not found and new possible resonances are proposed. The situation in particular for the low partial waves and for low energy is still very confused.

The same group has also published analyses for the main quasi-two-body channels, namely $\Lambda(1520)\pi$, $\Sigma(1385)\pi$, and $\bar{N}\bar{K}^*(892)$ (CAMERON 77, CAMERON 78, and CAMERON2 78). The statistical accuracy of the data here is lower than for the real two-body channels, and only constrained energy-dependent fits have been made, with most of the well-known resonances being included with fixed parameters. Only one new resonant structure, not observed in real two-body analyses, is suggested, and this is seen in the $\bar{N}\bar{K}^*$ channel only. Many new couplings of known resonances to quasi-two-body channels were found.

b) The analysis of B. Martin and M. Pidcock (MARTIN 77) is a multi-channel energy-dependent partial-wave analysis with parametrized K-matrix elements. The mass range covered is 1.54 to ~ 2 GeV. Here the 3 channels $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$ are always considered simultaneously, a fictitious channel being introduced to account for the global effect of the remaining final states. The $\Lambda\eta$ and $\Sigma\eta$ channels have thresholds within the above mass range and they may induce a "cusp effect". In order not to exclude such a possibility, an additional channel, opening up at the right energy, is also included for the S waves. (It is known that the inelasticities in the S waves are largely due to the production of the η meson, and a similar effect is seen in S-wave πN elastic scattering.) These additional channels, for which no data are fitted, have large cross sections, so it is not clear if such a multi-channel analysis really imposes more stringent unitarity constraints than those already contained in single-channel fits. For this analysis also, a careful selection of the available data has been made. The number of data points which have been fitted amounts to about 12,000. Some of the experimental points have been renormalized in order to suppress unphysical discontinuities in the data. The various channels or types of data may have very different numbers of data points; it would be possible to have a good overall χ^2 with some pieces of data being badly fitted. This was prevented by introducing weights

for the various types of data so that each type is reasonably well fitted.

Resonances can appear as poles of the K-matrix, but the K-matrix parameters thus deduced are difficult to compare to those obtained in the more conventional analyses. Two other methods in which the resonance parameters are calculated from the poles of the T-matrix are also given. We list the results of these two methods in the Data Card Listings. It should be noted that no claim for uniqueness of the proposed solution is made; in fact, another solution with almost the same χ^2/N was presented at the Oxford Conference.⁵ This latter solution has not been retained as it was not in agreement with present ideas about the low energy behavior of some waves.

c) The single-channel $\bar{K}N$ analysis of ALSTON 78 is worth mentioning because it includes a large amount of new data¹⁻³ not used by the two analyses mentioned above. It is a conventional energy-dependent analysis, covering the mass range 1.5 to 1.94 GeV, which uses a unitary background parametrization expressed in terms of scattering lengths. The cusp effects observed at the $\Lambda\eta$ and $\Sigma\eta$ thresholds are included by the introduction of a square-root singularity in the energy variation of the S-wave resonance widths. All the confirmed states are observed, but most of the less well established resonances (one and two stars in Table I) are neither observed nor required.

d) Other analyses: Preliminary results of a $\bar{K}N$ single-channel analysis by Hansen *et al.*⁶ have been reported. They incorporate more theoretical ingredients than any of the analyses done so far. We have not yet included these results in the Listings. In this energy-independent analysis, invariant amplitudes at fixed t are used as supplementary constraints in the fit. These fixed- t amplitudes themselves are computed using dispersion relations for which not only experimental data but also a first estimate of the partial waves is needed. The method requires that the process of estimating the fixed- t amplitudes and then the partial-wave amplitudes be iterated a few times until full consistency is obtained. This kind of analysis may eventually provide us with more

Baryons

Λ 's and Σ 's

reliable partial-wave amplitudes which satisfy fixed- t analyticity and crossing.

In the Listings, the resonance parameters obtained in the latest single-channel analyses are given. These usually cover a limited mass range, but include new data not yet incorporated in the multi-channel analyses described above. In particular, the Saclay-Collège de France collaboration has now published three separate energy-dependent analyses for the channels $\bar{K}N$, $\Lambda\pi$, and $\Sigma\pi$ extending up to a mass of 2.5 GeV (BELLEFON 78, 76, and 77, respectively). They indicate that the bumps seen in total cross sections at these higher energies are made up of many resonant states.

For a brief description of the older analyses we refer to the previous editions of this compilation.

Production Experiments

Production experiments are often difficult to analyze for the same reasons as mentioned in the preceding Note on N's and Δ 's. $I=0$ states can only be studied when there is no $I=1$ state at a similar mass. In the Baryon Table we only use results from production experiments for the lower mass states. $\Sigma(1385)$ and $\Lambda(1405)$ lie below the $\bar{K}N$ threshold. Production and formation experiments agree quite well in the case of $\Lambda(1520)$, and thus they have been combined for this state. There is some disagreement between the two types of experiment in the 1600-to-1700 MeV region. See the $\Sigma(1620)$ and $\Sigma(1670)$ mini-reviews for details.

Figures

Argand plots of fifteen $S=-1$ partial waves are shown in Figs. 1 through 11. The analyses shown were picked largely for illustrative purposes rather than on the basis of our judgment of their quality; for the $\bar{K}N$ channel, we chose to show the amplitudes obtained by RLIC 77 and ALSTON 78, and for the $\Lambda\pi$ and $\Sigma\pi$ channels those from RLIC 77 and MARTIN 77.

Errors on Masses and Widths

Often the quoted errors in partial-wave analyses are only statistical, and the values of masses and widths can change by more than these errors when a new parametrization is used. For this reason we report the values of M , Γ , and x_i

Data Card Listings

For notation, see key at front of Listings.

obtained by different authors even if they analyze the same data. The spread of these masses and widths is certainly a better estimate of the uncertainties than the statistical errors. Sometimes the errors quoted are obtained by the inspection of various fits done with different hypotheses (see, for example, BERTHON 70, GALTIERI 70, VANHORN 75, RLIC 76). For three states, $\Lambda(1520)$, $\Lambda(1815)$, and $\Sigma(1765)$, there are enough data available to perform an overall fit of the various x_i of the type discussed in the main text (Sec. VII B). In this case we are forced to use the errors, however small they may be, but we warn the reader that the final errors are not to be taken seriously.

In the Baryon Table we choose not to give errors on masses and total widths determined primarily by partial-wave analyses, but, whenever necessary, to show a range of values. As for the branching ratios, we use the errors when needed to perform an overall fit, but we caution the reader.

Conclusions

Table I is an attempt to evaluate the status of the various Y^* 's. The evaluations are of course partly subjective. A blank indicates that there is no corresponding evidence at all. This may mean either that the relevant couplings are small or that the resonance does not really exist. The Baryon Table includes only the well established resonances. It seems clear, however, that whereas any particular one of the questionable resonances may disappear with the next analysis, there are probably many new resonances underlying those already established.

References

1. M. Alston-Garnjost *et al.*, Phys. Rev. D17, 2216 (1978).
2. M. Alston-Garnjost *et al.*, Phys. Rev. D17, 2226 (1978).
3. R. D. Ehrlich *et al.*, Phys. Lett. 71B, 455 (1977).
4. C. Damerell *et al.*, Nucl. Phys. B129, 397 (1977).
5. B. R. Martin, in Proceedings of the Topical Conference on Baryon Resonances (Oxford, 1976), edited by R. T. Ross and D. H. Saxon, pg.285.
6. P. N. Hansen *et al.*, in Oxford Conference Proceedings (*ibid.*), pg.275.

For other references, see the Data Card Listings.

Data Card Listings

Baryons

For notation, see key at front of Listings.

Λ 's and Σ 's, Λ , $\Lambda(1330)$, $\Lambda(1405)$

TABLE I. STATUS OF Σ^* RESONANCES

THOSE WITH AN OVERALL STATUS OF *** OR **** ARE INCLUDED IN THE MAIN BARYON TABLE. THE OTHERS AWAIT CONFIRMATION.

PARTICLE	LIJ	OVERALL STATUS	STATUS AS SEEN IN --					OTHER CHANNELS
			TOTAL# CR. SEC.	KBAR N	LAM PI	SIG PI		
LAM(1115) P01		****					WEAK TO N PI	
LAM(1330)		DEAD					LAMBDA GAMMA	
LAM(1405) S01		****		****	F	****		
LAM(1520) D03		****	****	****	O	****	LAM2PI, LAM GAM	
LAM(1600) P01		**		****		*		
LAM(1670) S01		****	****	****	B	****	LAM ETA	
LAM(1690) D03		****	****	****	I	****	LAM2PI, SIG2PI	
LAM(1800) S01		****	****	****	D	****	N K*, SIG* PI	
LAM(1800) P01		**		**		*	N K*	
LAM(1800) G09		*		*	E	*		
LAM(1800) PE		*		*	N	*	LAM PI PI	
LAM(1815) F05		****	****	****	F	****	SIG(1385) PI	
LAM(1820) D05		****	****	****	O	****	SIG(1385) PI	
LAM(1860) P03		****	**	****	R	**	N K*, SIG* PI	
LAM(2010)		*		*	B	*	LAM OMEGA, N K*	
LAM(2020) F07		*		*	I	*		
LAM(2100) G07		****	****	****	D	****	LAM OMEGA, N K*	
LAM(2110) F05		****	****	****	E	****	LAM OMEGA	
LAM(2325) D03		*		*		*		
LAM(2350)		****	****	****	N	****		
LAM(2585)		****	****	****		****		
SIG(1193) P11		****		****		****	WEAK TO N PI	
SIG(1385) P13		****		****		****		
SIG(1480) PE		*		*		*		
SIG(1560) PE		**		**		**		
SIG(1580) D13		**	**	**		**		
SIG(1620) S11		**	**	**		**		
SIG(1660) P11		**	**	**		**		
SIG(1670) D13		****	**	****		****	SEVERAL OTHERS	
SIG(1670) PE		**	**	**		**	SEVERAL OTHERS	
SIG(1690) PE		**	*	**		**	LAM 2-PI	
SIG(1750) S11		****	****	****		****	SIG ETA	
SIG(1765) D15		****	****	****		****	SEVERAL OTHERS	
SIG(1770) P11		*	*	*		*		
SIG(1840) P13		*	*	*		*		
SIG(1880) P11		**	**	**		**	N K*	
SIG(1915) F15		****	****	****		****	SIG(1385) PI	
SIG(1940) D13		****	****	****		****	QUASI-2-BODY	
SIG(2000) S11		*	*	*		*	N K*, LAM* PI	
SIG(2030) F17		****	****	****		****	SEVERAL OTHERS	
SIG(2070) F15		*	*	*		*		
SIG(2080) P13		**	**	**		**		
SIG(2100) G17		*	*	*		*		
SIG(2250)		****	****	****		****		
SIG(2455)		****	****	****		****		
SIG(2620)		****	****	****		****		
SIG(3000)		**	**	**		**		
SIG(3170) PE		*	*	*		*	MULTI-BODY	

**** GOOD, CLEAR, AND UNMISTAKABLE.
 *** GOOD, BUT IN NEED OF CLARIFICATION OR NOT ABSOLUTELY CERTAIN.
 ** NEEDS CONFIRMATION.
 * WEAK.

* ATTRIBUTED TO THE STATE CLOSEST TO WHERE THE CROSS SECTION PEAKS.

S=-1 I=0 HYPERON STATES (Λ)

Λ

18 LAMBDA(1115, JP=1/2+) I=0
 SEE STABLE PARTICLE DATA CARD LISTINGS

$\Lambda(1330)$
 BUMPS

A PEAK WAS SEEN NEAR 1330 MEV IN THE LAMBDA GAMMA SPECTRUM IN THREE PI-PROPANE EXPERIMENTS (YUNG-CHANG 64, BUBELEV 67, AND BOZOKI 68). ALL MORE RECENT RESULTS INDICATE THAT THERE IS NO RESONANCE NEAR THIS MASS VALUE.

REFERENCES FOR $\Sigma^*(1330)$ (PROD. EXP.)

Y-CHANG 64 DUBNA CONF I 615	YUNG-CHANG, IN, KLDNITSKAYA, + (DUBNA)
BUBELEV 67 PL 248 246	+CHADRAA, CHUVILO, + (JINR, BUGHAREST, CERN)
DAHL 67 PR 163 1377	DAHL, HARDY, HESS, KIRZ, MILLER (LRL)
BOZOKI 68 PL 288 360	+FENYVES, GEMESY, + (BUDAPEST, DUBNA)
TAN 69 PRL 23 101	T H TAN (SLAC)
MAYEUR 70 PL 338 441	+VAN BINST, WILQUET+++ (BRUX, CERN, TUFT)
COLAS 75 NP B91 253	COLAS, FARWELL, FERRER, SIX (ORSA)

$\Lambda(1405)$

37 $\Sigma^*(1405, JP=1/2-) I=0$
 PRODUCTION EXPERIMENTS

S₀₁

THIS RESONANCE CAN BE IDENTIFIED WITH THE VIRTUAL BOUND STATE IN THE KBAR-N SYSTEM FOUND IN THE ANALYSIS OF LOW ENERGY K-P INTERACTION. WE LIST SUCH EXPERIMENTS SEPARATELY BELOW. WE USE ONLY PRODUCTION EXPERIMENTS FOR AVERAGING OF MASSES AND WIDTHS.

37 $\Sigma^*(1405)$ MASS (MEV) (PROD. EXP.)

M	(1405.0)		ALSTON 61 HBC	K-P 1.15 BEV/C
M	(1410.0)		ALEXANDER 62 HBC	PI-P 2.1 BEV/C
M	(1405.0)		ALSTON 62 HBC	K-P 1.2-1.5 BEV/C
M	(1382.0)	(8.0)	ENGLER 65 HBC	PI-P, PI+D 1.68
M	1400.0	24.0	MUSGRAVE 65 HBC	PBAR P 3-4 BEV/C
M	67 1400.0	5.0	BIRMINGHAM 66 HBC	K-P 3.5
M	120 1405.0	5.0	GALTIERI 68 DBC	K-D 2.1-2.7BEV/C
M	1402.4	3.5	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
M	STUDENT 1402.4	3.9	AVERAGE USING STUDENT 10(H/1.11) -- SEE MAIN TEXT	

37 $\Sigma^*(1405)$ WIDTH (MEV) (PROD. EXP.)

W	(20.0)		ALSTON 61 HBC	7/66
W	35.0	5.0	ALEXANDER 62 HBC	
W	(50.0)		ALSTON 62 HBC	
W	(89.0)	(20.0)	ENGLER 65 HBC	7/66
W	60.0	20.0	MUSGRAVE 65 HBC	7/66
W	67 50.0	10.0	BIRMINGHAM 66 HBC	K-P 3.5
W	120 35.0	8.0	GALTIERI 68 DBC	K-D 2.1-2.7BEV/C
W	38.1	3.9	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
W	STUDENT 37.9	4.3	AVERAGE USING STUDENT 10(H/1.11) -- SEE MAIN TEXT	

37 $\Sigma^*(1405)$ PARTIAL DECAY MODES (PROD. EXP.)

P1 $\Sigma^*(1405)$ INTO SIGMA PI 11974 139

REFERENCES FOR $\Sigma^*(1405)$ (PROD. EXP.)

ALSTON 61 PRL 6 698	+ALVAREZ, EBERHARD, GOOD, GRAZIANO, + (LRL) I
ALEXANDER 62 PRL 9 447	ALEXANDER, KALDFLEISCH, MILLER, SMITH (LRL) I
ALSTON 62 CERN CONF 311	+ALVAREZ, FERRO-LUZZI, ROSENFELD, + (LRL) I
ENGLER 65 PRL 15 224	+FISK, KRAEMER, MELTZER, WESTGARD, + (CARN, BNL) IJ
MUSGRAVE 65 NC 35 735	+PETMEZAS, + (BIRM, CERN, EPOL, LOIC, SACLAY)
BIRMINGHAM 66 PR 152 1148	BIRMINGHAM, GLASGOW, LOIC, OXFORD, RUTHERFORD
GALTIERI 68 PRL 21 573	BARBARO-GALTIERI, CHADWICK + (LRL, SLAC)

1405 MEV REGION: EXTRAPOLATIONS BELOW THRESHOLD

24 $\Sigma^*(1405, JP=1/2-) I=0$ S₀₁
 EXTRAPOLATION BELOW THRESHOLD

SEE NOTE IN $\Sigma^*(1405)$ PRODUCTION EXPERIMENTS. THE DIFFICULTIES IN EXTRAPOLATING FROM THE PHYSICAL REGION TO THE RESONANCE LOCATION ARE DISCUSSED BY DALITZ 67.

THE QUESTION ON WHETHER $\Sigma^*(1405)$ IS A KBAR-N BOUND STATE OR A CDD POLE (DALITZ 70, RAJASEKARAN 72 HAS BEEN INVESTIGATED BY CLINE 71, MARTIN 71, GALTIERI 72, AND DBBSON 72. THE LAST TWO PAPERS CONCLUDE THAT THE DATA CANNOT TELL THE DIFFERENCE.

THE (N KBAR)/(PI SIGMA) COUPLING RATIO IS DISCUSSED BY DADES 77.

24 $\Sigma^*(1405)$ MASS (MEV)

M	1410.7	(1.0)	KIM 65 HBC	0-EFF-RANGE FIT	7/66
M	1409.6	(1.7)	SAKITT 65 HBC	0-EFF-RANGE FIT	7/66
M	1407.5	(1.2)	DATA OF SAKITT ARE USED IN FIT BY KITTEL.		
M	1403.0	(3.0)	KIM 67 HBC	K MATRIX FIT(KP)	8/67
M	1416.0	(4.0)	MARTIN 69 HBC	CONST. K MATRIX	10/69
M	(1421.0)		MARTIN 70 RVUE	CONST. K MATRIX	6/70
M	1 (1406.1)		CHAD 73 DPWA	0-RNG. FIT, SOL B	9/73
M	1		SEE ALSO THE ACCOMPANYING PAPER OF THOMAS 73.		

24 $\Sigma^*(1405)$ WIDTH (MEV)

W	37.0	(3.2)	KIM 65 HBC	7/66
W	28.2	(4.1)	SAKITT 65 HBC	7/66
W	34.1	(4.1)	KITTEL 66 HBC	7/66
W	50.0	(5.0)	KIM 67 HBC	K MATRIX FIT(KP)
W	29.0	(6.0)	MARTIN 69 HBC	CONST. K MATRIX
W	(20.0)		MARTIN 70 RVUE	CONST. K MATRIX
W	1 (95.1)		CHAD 73 DPWA	0-RNG. FIT, SOL B
W	1		ASYMMETRIC RESONANCE SHAPE, W/2=41 MEV BELOW RESONANCE, 14 MEV ABOVE.	

REFERENCES FOR $\Sigma^*(1405)$ (FROM EXTRAPOLATIONS)

KIM 65 PRL 14 29	J K KIM (COLUMBIA) IJP
SAKITT 65 PR 139 8719	+DAY, GLASSER, SEEMAN, FRIEDMAN, + (UMD, LRL) IJP
KITTEL 66 PL 21 349	W KITTEL, G OTTER, I WACEK (VIENNA) IJP
KIM 67 PRL 19 1074	J KIM (YALE) IJP
MARTIN 69 PR 183 1352	B R MARTIN, M SAKITT (LOUJ) IJP
MARTIN 70 NP 816 479	A D MARTIN, G G ROSS (DURHAM) IJP
CHAD 73 NP 856 46	CHAD, KRAEMER, THOMAS, MARTIN (RHEL+CARN+LOUC) IJP
ALSO 73 NP 856 15	THOMAS, ENGLER, FISK, KRAEMER (CARN) IJP

Baryons

$\Lambda(1405), \Lambda(1520)$

Data Card Listings

For notation, see key at front of Listings.

PAPERS NOT REFERRED TO IN DATA CARDS

ABRAMS 65 PR 139 B454 G S ABRAMS, B SECHI-ZORN (UMD)IJP
DONALD 66 PL 22 711 + EDWARDS, GYS, NISAR, MOORE (LIVERPOOL)
KADYK 66 PRL 17 599 +OREN, G+S GOLDBER, TRILLING (LRL)IJP
FIT SOLUTIONS GIVING AN I#0 S1 (2 RESONANCE.)
ABRAMS 65, KADYK 66, AND DONALD 66 SUPPORT THOSE EFFECTIVE-RANGE-

$\Lambda(1520)$

D03

38 Y*0(1520, JP=3/2-) I=0
PRODUCTION AND FORMATION EXPERIMENTS AGREE QUITE WELL WITH EACH OTHER, SO THE RESULTS OF THE TWO KINDS OF EXPERIMENTS ARE LISTED TOGETHER HERE.

THE DECAY MODE LAMBDA P1 P1 IS LARGELY DUE TO Y*(1385) P1. ONLY THE VALUES OF (Y*(1385) P1)/(LAMBDA P1 P1) GIVEN BY MAST 72 AND GORDEN 75 ARE BASED ON REAL 3-BODY PARTIAL WAVE ANALYSES (THE OLDER RESULTS BEING OBTAINED USING CRUDER METHODS). THE DISCREPANCY BETWEEN THE 2 RESULTS IS ESSENTIALLY DUE TO THE DIFFERENT HYPOTHESIS MADE CONCERNING THE SHAPE OF THE EPSILON MESON.

38 Y*0(1520) MASS (MEV)

Table with columns for mass values and associated references (e.g., GALTIERI 63 DBC, WATSON 63 HBC, ALMEIDA 64 HBC).

38 Y*0(1520) WIDTH (MEV)

Table with columns for width values and associated references (e.g., WATSON 63 HBC, BIRMINGHA 66 HBC, DAHL 67 HBC).

38 Y*0(1520) PARTIAL DECAY MODES

Table listing decay modes and masses (e.g., Y*0(1520) INTO KBAR N, Y*0(1520) INTO SIGMA P1).

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i +/- delta P_i, where delta P_i = sqrt(delta P_i delta P_i), while the off-diagonal elements are the normalized correlation coefficients (delta P_i delta P_j) / (delta P_i delta P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Matrix of branching fractions and correlations (e.g., P1 .4503+-0.0056, P2 -.6215 .4199+-0.0064).

38 Y*0(1520) BRANCHING RATIOS

Large table of branching ratios for various decay channels (e.g., Y*0(1520) INTO (SIGMA P1)/(KBAR N), Y*0(1520) INTO (LAMBDA P1 P1)/(KBAR N)).

Baryons

$\Lambda(1670)$, $\Lambda(1690)$, $\Lambda(1800)$

Data Card Listings

For notation, see key at front of Listings.

R4 Y*0(1670) FROM KBAR N TO SIGMA(1385) PI SQRT(P1*P4)
R4 -18 .05 PREVOST 74 DPWA O- K-N TO S(1385)PI 10/74

***** REFERENCES FOR Y*0(1670) *****

BERLEY 65 PRL 15 641 *CONNOLLY, HART, RAUM, STONEHILL, + (BNL)IJP
ARMENT-1 68 NP 88 195 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
ARMENT-2 68 NP 88 223 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
ARMENT-3 69 LUND PAPER 229 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
VALUES ARE QUOTED IN LEVI
SETTI 69
ARMENT-4 69 NP 814 91 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
BERLEY 69 PL 308 430 + HART, RAHM, WILLIS, YAMAMOTO (BNL)IJP
GALTIERI 70 DUKE 173 A. BARBARO GALTIERI (LRL)IJP
CONFORTO 71 NP 834 41 +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM 71 PRL 27 356 J. K. KIM (HARV)IJP
ALSO 70 DUKE 161 J. K. KIM (HARV)IJP
LANGBEIN 72 NP 847 477 *WAGNER (MPI)IJP
BAXTER 73 NP 867 125 BAXTER,BUCKINGHAM,CORBETT,DUNN,+ (OXFORD)IJP
HART 73 PURDUE CONF. 311 +RICE,BAGASTON,FUNG,+ (TENN+UCR+MASA+BUFF)IJP
PREVOST 74 NP 869 246 PREVOST,BARLOUTAUD,+ (SACL+CERN+HEID)
LONDON 75 NP 885 289 LONDON,YU,BOYD,+ (BNL,CERN,EPL,ORSA,TORI)

HEPP2 76 PL 658 487 *BRAUN,GRIMM,STROBELE,THOL+(CERN,HEID,MPIN)IJP
MARTIN 77 NP B127 349 MARTIN,PIDCOCK,MOORHOUSE (LDCU+GLAS)IJP
ALSO 77 NP B126 266 MARTIN,PIDCOCK (LDCU)
ALSO 77 NP B126 285 MARTIN,PIDCOCK (LDCU)IJP
RLIC 77 NP B119 362 GOPAL,ROSS,VAN HORN,MCPHERSON+ (LDCU+RHEL)IJP
ALSTON 78 PR D18 182 *KENNEY,POLLARD,ROSS+ (LBL+MTHO+CERN)IJP
ALSTON-GARNUST,KENNEY (LBL+MTHO+CERN)IJP

PAPERS NOT REFERRED TO IN DATA CARDS

(BIRMINGHAM,GLASGOW,LOIC,OXFORD,RUTHERFORD)
R LEVI SETTI (RAPPORTEUR) (CHICAGO)

***** BIRMINGHAM 66 PR 152 1148
LEVISETT 69 LUND 339 R LEVI SETTI (RAPPORTEUR) (CHICAGO) *****

$\Lambda(1690)$

55 Y*0(1690, JP=3/2-) I=0

D_{03}^0

SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.

THIS RESONANCE IS WELL ESTABLISHED.

55 Y*0(1690) MASS (MEV)

Table with columns for mass (M), width (W), and references. Includes entries for ARMENT-1, ARMENT-3, BARTLEY, BUGG, CONFORTO, KIM, LANGBEIN, BAXTER, HART, CARROLL, HEPP2, MARTIN, CARROLL, HEPP2, ALSTON.

55 Y*0(1690) WIDTH (MEV)

Table with columns for width (W) and references. Includes entries for ARMENT-1, ARMENT-3, BARTLEY, BUGG, CONFORTO, ARMENT-4, ARMENT-4, BERLEY, GALTIERI, CONFORTO, KIM, LANGBEIN, BAXTER, HART, CARROLL, HEPP2, MARTIN, ALSTON.

55 Y*0(1690) PARTIAL DECAY MODES

Table with columns for decay modes (P1-P6) and decay masses. Includes entries for Y*0(1690) INTO KBAR N, Y*0(1690) INTO SIGMA PI, Y*0(1690) INTO LAMBDA PI PI, Y*0(1690) INTO SIGMA PI PI, Y*0(1690) INTO Y*1(1385) PI S-WAVE, Y*0(1690) INTO LAMBDA ETA.

55 Y*0(1690) BRANCHING RATIOS

THE SUM OF ALL THE QUOTED BRANCHING RATIOS IS MORE THAN 1.0. THE TWO-BODY RATIOS ARE FROM PARTIAL WAVE ANALYSES, AND THUS PROBABLY ARE MORE RELIABLE THAN THE THREE-BODY RATIOS, WHICH ARE DETERMINED FROM BUMPS IN CROSS SECTIONS. OF THE LATTER, THE SIGMA PI PI BUMP LOOKS MORE SIGNIFICANT (THE ERROR GIVEN FOR THE LAMBDA PI PI RATIO LOOKS UNREASONABLY SMALL). HARDLY ANY OF THE SIGMA PI PI DECAY CAN BE VIA Y*1(1385), FOR THEN NINE TIMES AS MUCH LAMBDA PI PI DECAY WOULD BE REQUIRED.

Table with columns for branching ratios (R1-R6) and references. Includes entries for Y*0(1690) INTO (KBAR N)/TOTAL, Y*0(1690) FROM KBAR N TO SIGMA PI, PUBLISHED SIGN CHANGED TO AGREE WITH LUND 1969 CONVENTION, Y*0(1690) FROM KBAR N TO LAMBDA PI PI, Y*0(1690) FROM KBAR N TO SIGMA PI PI, Y*0(1690) FROM KBAR N INTO LAMBDA ETA, Y*0(1690) FROM KBAR N TO Y*1(1385) PI S-WAVE.

***** REFERENCES FOR Y*0(1690) *****

ARMENT-1 68 NP 88 195 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
ARMENT-2 68 NP 88 216 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY) I
ARMENT-3 68 NP 88 223 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
BARTLEY 68 PRL 21 1111 +CHU,DOND,GREENE,+ (TUFTS,FSU,BRANDEIS) I
BUGG 68 PR 168 1466 +GILMORE, KNIGHT,+ (BIRM,CAVE,RHEL) I
ALSO 67 PRL 18 62 DAVIES,DOHLL,+ (BIRM,CAVE,RHEL) I
CONFORTO 68 NP 88 265 +HARMSSEN, LASINSKI, + (CHICAGO,HEIDEL)IJP
ARMENT-4 69 NP 814 91 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP
BERLEY 69 PL 308 430 + HART, RAHM, WILLIS, YAMAMOTO (BNL)IJP
BERTANZA 69 PR 177 2036 +BIGI,CARRARA,CASALI, + (PISA,BNL,YALE)IJP
GALTIERI 70 DUKE 173 A. BARBARO GALTIERI (LRL)IJP
CONFORTO 71 NP 834 41 +LEVI SETTI,LASINSKI..OBERLACK++ (EFI+HEID)IJP
KIM 71 PRL 27 356 J. K. KIM (HARV)IJP
ALSO 70 DUKE 161 J. K. KIM (HARV)IJP
LANGBEIN 72 NP 847 477 *WAGNER (MPI)IJP
BAXTER 73 NP 867 125 BAXTER,BUCKINGHAM,CORBETT,DUNN,+ (OXFORD)IJP
HART 73 PURDUE CONF. 311 +RICE,BAGASTON,FUNG,+ (TENN+UCR+MASA+BUFF)IJP
PREVOST 74 NP 869 246 PREVOST,BARLOUTAUD,+ (SACL+CERN+HEID)
LONDON 75 NP 885 289 LONDON,YU,BOYD,+ (BNL,CERN,EPL,ORSA,TORI)
CARROLL 76 PRL 37 806 +CHIANG,KYC IA,LI,MAZUR,MICHAEL + (BNL)I
HEPP2 76 PL 658 487 *BRAUN,GRIMM,STROBELE,THOL+(CERN,HEID,MPIN)IJP
MARTIN 77 NP B127 349 MARTIN,PIDCOCK,MOORHOUSE (LDCU+GLAS)IJP
ALSO 77 NP B126 266 MARTIN,PIDCOCK (LDCU)
ALSO 77 NP B126 285 MARTIN,PIDCOCK (LDCU)IJP
RLIC 77 NP B119 362 GOPAL,ROSS,VAN HORN,MCPHERSON+ (LDCU+RHEL)IJP
ALSTON 78 PR D18 182 *KENNEY,POLLARD,ROSS+ (LBL+MTHO+CERN)IJP
ALSTON-GARNUST,KENNEY (LBL+MTHO+CERN)IJP

PAPERS NOT REFERRED TO IN DATA CARDS

PREVOST 71 AMSTERDAM CONF + CHS COLLABORATION (CERN+HEID+SACL)

$\Lambda(1800)$

36 Y*0(1800, JP=1/2-) I=0

S_{01}^0

THE S01 AMPLITUDE SHOWS A RATHER CLEAR SECOND RESONANCE BEHAVIOR IN THE 1700-1900 MEV REGION. THERE ARE WIDE DISAGREEMENTS AMONG THE MASS, WIDTH, AND COUPLING DETERMINATIONS.

36 Y*0(1800) MASS (MEV)

Table with columns for mass (M) and references. Includes entries for BRICHAN, KIM, LANGBEIN, MARTIN, CARROLL, HEPP2, ALSTON.

For notation, see key at front of Listings.

Baryons

$\Lambda(1800)$, $\Lambda(1815)$

$\Lambda(1800)$ BUMPS

119 Y*0(1800, JP=) I=7 PRODUCTION EXPERIMENTS

LOCKMAN 78 OBSERVE A 5 STD. DEV. ENHANCEMENT IN THE LAMBDA P1+ P1- MASS SPECTRUM FROM THE REACTION PP -> LAMBDA P1+ P1- + ANYTHING IN A CERN 138 EXPERIMENT AT C.M. ENERGIES OF 43 AND 62 GEV. THE MAIN DECAY MODES APPEAR TO BE Y*1(1385) P1 AND Y*1(1560) P1 (SEE THE ENTRY FOR Y*1(1560)).

THE I-SPIN IS NOT ESTABLISHED, BUT SINCE THE LAMBDA P1 DECAY IS NOT OBSERVED, I=0 IS MARGINALLY PREFERRED.

119 Y*0(1800) MASS (MEV) (PROD. EXP.)

M	60 1802.	3.	LOCKMAN	78 SPEC	0 PP TO L PI PI X	12/79*
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119 Y*0(1800) WIDTH (MEV) (PROD. EXP.)

W C	60 24.	8.	LOCKMAN	78 SPEC	0 PP TO L PI PI X	12/79*
W C	OBSERVED WIDTH CONSISTENT WITH EXPERIMENTAL RESOLUTION.					

119 Y*0(1800) PARTIAL DECAY MODES (PROD. EXP.)

P1	Y*0(1800) INTO LAMBDA P1 P1	DECAY MASSES
P2	Y*0(1815) INTO Y*1(1385) P1	1115+ 139+ 139
P3	Y*0(1800) INTO Y*1(1560) P1	1384+ 139
		1553+ 139

119 Y*0(1800) BRANCHING RATIOS (PROD. EXP.)

R1	Y*0(1800) INTO LAMBDA P1 P1	(P1)	LOCKMAN	78 SPEC	0 PP TO L PI PI X	12/79*
R2 <td>Y*0(1800) INTO Y*1(1385) P1</td> <td>(P2)</td> <td>LOCKMAN</td> <td>78 SPEC</td> <td>0 PP TO L PI PI X</td> <td>12/79*</td>	Y*0(1800) INTO Y*1(1385) P1	(P2)	LOCKMAN	78 SPEC	0 PP TO L PI PI X	12/79*
R3 <td>Y*0(1800) INTO Y*1(1560) P1</td> <td>(P3)</td> <td>LOCKMAN</td> <td>78 SPEC</td> <td>0 PP TO L PI PI X</td> <td>12/79*</td>	Y*0(1800) INTO Y*1(1560) P1	(P3)	LOCKMAN	78 SPEC	0 PP TO L PI PI X	12/79*

REFERENCES FOR Y*0(1800) (PROD. EXP.)

LOCKMAN 78 CEN DPHPE 78-01 +MEYER,RANDER,POSTER,SCHLEIN+ (UCLA+SACL)

$\Lambda(1815)$

39 Y*0(1815, JP=5/2+) I=0

SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

THIS STATE IS WELL ESTABLISHED. MOST OF THE QUOTED ERRORS ARE STATISTICAL ONLY. THE SYSTEMATIC ERRORS DUE TO THE PARTICULAR PARAMETRIZATION USED IN THE P.W.A. ARE NOT INCLUDED. FOR THIS REASON WE DO NOT CALCULATE WEIGHTED AVERAGES FOR MASS AND WIDTH.

39 Y*0(1815) MASS (MEV)

M	N	1813.0 (2.0)	ARMENT-1	67 HBC	0 K-P TO SIGMA PI	8/67
M	N	1816.0 (4.0)	BELL	67 HBC	0 K-N TO SIGMA PI	11/67
M	N	1817.0 (2.0)	ARMENT-3	68 HBC	0 ELASTIC, CH EXCH	11/68
M	N	1819.0 (4.0)	BUGG	68 CNTR	0 K-P, D TOTAL	6/68
M	N	1825.0 (1.0)	BRICMANI	70 CNTR	0 TOTAL AND CH EX	6/70
M	N	1819.0 (1.0)	BRICMANI	70 DPWA	SIGTOT,ELAS,CHEX	1/71
M	N	1830.0 (10.0)	COOL	70 CNTR	K-P, D TOTAL	10/70
M	N	1820.0 (10.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
M	N	1818.0 (2.0)	CONFORTO	71 DPWA	0 ELASTIC, CH EXCH	6/70
M	N	1810.0 (3.0)	KIM	71 DPWA	K-MATRIX ANAL.	3/71
M	N	1823.0 (3.0)	KANE	72 DPWA	0 K-P TO PI SIG	10/71
M	N	1818.0 (3.0)	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
M	N	1830.0 (10.0)	DECLAIS	77 DPWA	KBAR N TO KBAR N	1/78
M	2	1817. OR 1819.	MARTIN	77 DPWA	KBAR N MULTICHNL	11/77
M	2	THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.				
M	N	1822. (2.)	RLIC	77 DPWA	KBAR N MULTICHNL	1/76
M	N	1819. (2.)	ALSTON	78 DPWA	KBAR N ELASTIC	1/78
M	N	ERROR STATIST. ONLY- NO ERROR DUE TO PARTICULAR P.W.A. ANAL. INCLUDED				1/71

39 Y*0(1815) WIDTH (MEV)

W	N	87.0 (15.0)	ARMENT-1	67 HBC	0	8/67
W	N	64.0 (12.0)	BELL	67 HBC	0	11/67
W	N	71.0 (4.0)	ARMENT-3	68 HBC	0 ELASTIC, CH EXCH	11/68
W	N	75.0 (7.0)	BUGG	68 CNTR	0 K-P, D TOTAL	6/68
W	N	80.0 (6.0)	BRICMANI	70 CNTR	0 TOTAL AND CH EX	6/70
W	N	79.0 (3.0)	BRICMANI	70 DPWA	SIGTOT,ELAS,CHEX	1/71
W	N	100.0 (20.0)	COOL	70 CNTR	K-P, D TOTAL	10/70
W	N	90.0 (4.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
W	N	70.0	CONFORTO	71 DPWA	0 ELASTIC, CH EXCH	6/70
W	N	104.0 (16.0)	KIM	71 DPWA	K-MATRIX ANAL.	3/71
W	N	70.0 (5.0)	KANE	72 DPWA	0 K-P TO PI SIG	10/71
W	N	82.1	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
W	2	76. OR 76.	DECLAIS	77 DPWA	KBAR N TO KBAR N	1/78
W	N	81. (5.)	MARTIN	77 DPWA	KBAR N MULTICHNL	11/77
W	N	72. (5.)	ALSTON	78 DPWA	KBAR N ELASTIC	1/78

SEE THE NOTES ACCOMPANYING MASSES QUOTED

39 Y*0(1815) PARTIAL DECAY MODES

P1	Y*0(1815) INTO KBAR N	DECAY MASSES
P2	Y*0(1815) INTO SIGMA N	497+ 939
P3	Y*0(1815) INTO SIGMA P1 P1	1189+ 139
P4	Y*0(1815) INTO ETA LAMBDA	1192+ 139+ 139
P5	Y*0(1815) INTO Y*1(1385) P1 P-WAVE	548+1115
P6	Y*0(1815) INTO Y*1(1385) P1 F-WAVE	139+1384
		139+1384

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i , as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{(\delta P_i \delta P_i)}$, while the off-diagonal elements are the normalized correlation coefficients $(\delta P_i \delta P_j) / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i , see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

P 1	P 2	P 3	P 4	P 5	P 6	
P 1	.6008+- .0193					
P 2	-.4763	.1155+- .0078				
P 3	-.1042	.0496	.1034+- .0287			
P 4	-.3565	-.0111	-.8126	.1579+- .0334		
P 5	-.0579	.0276	.0060	-.2343	.0153+- .0085	
P 6	-.0361	.0172	.0038	-.1750	.0021	.0070+- .0063

39 Y*0(1815) BRANCHING RATIOS

ERRORS QUOTED BY EXPERIMENTERS DO NOT INCLUDE UNCERTAINTY DUE TO PARAMETRIZATION USED IN THE P.W.A. THEY SHOULD BE INCREASED.

R1 Y*0(1815) INTO (KBAR N)/TOTAL (P1)

R1	0.62	0.02	ARMENT-3	68 HBC	0 ELASTIC, CH EXCH	11/68
R1	(0.72)		BUGG	68 CNTR	0 K-P, D TOTAL	6/68
R1	0.58	0.02	BRICMANI	70 CNTR	0 TOTAL AND CH EX	6/70
R1	(0.8)		COOL	70 CNTR	K-P, D TOTAL	10/70
R1	0.63	0.01	CONFORTO	71 DPWA	0 ELASTIC, CH EXCH	6/70
R1	(0.52)		KIM	71 DPWA	K-MATRIX ANAL.	3/71
R1	0.47	0.02	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
R1	(.51)		DECLAIS	77 DPWA	KBAR N TO KBAR N	1/78
R1	2	(.59)OR .58	MARTIN	77 DPWA	KBAR N MULTICHNL	11/77
R1	.65	.02	RLIC	77 DPWA	KBAR N MULTICHNL	1/76
R1	.60	.03	ALSTON	78 DPWA	KBAR N ELASTIC	1/78

R1 AVG .601 0.021 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 3.2)

R1 STUDENT .6128 0.0100 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

R1 FIT .601 0.019 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 3.0)

R2 Y*0(1815) FROM KBAR N INTO SIGMA P1 (P2)

R2	1	0.27	0.01	ARMENT-1	67 DPWA	0 K-P TO SIGMA PI	10/74
R2	1	PUBLISHED SIGN CHANGED TO AGREE WITH LUND 1969 CONVENTION (SEE TEXT)					10/74
R2	1	0.23	0.025	BELL	67 DPWA	0 K-P TO SIGMA PI	11/67
R2	1	-0.26	0.03	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
R2	1	(0.26)		KIM	71 DPWA	K-MATRIX ANAL.	3/71
R2	1	-0.268	0.027	KANE	72 DPWA	0 K P TO PI SIG	10/71
R2	1	0.25	0.03	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
R2	2	(-.25)OR -.25		MARTIN	77 DPWA	KBAR N MULTICHNL	11/77
R2	1	-.28	.03	RLIC	77 DPWA	KBAR N MULTICHNL	1/76

R2 AVG MOD .2645 0.0078 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

R2 STUDENT 0.2650 0.0087 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

R2 FIT 0.2635 0.0078 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R3 Y*0(1815) FROM KBAR N TO ETA LAMBDA (P3)

R3	-0.096	.040	.020	RADER	73 MPWA		9/73
R3	0.096	0.027					9/73

R3 FIT .096 0.027 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R4 Y*0(1815) INTO (Y*1(1385) P1)/TOTAL (P4)

R4	0.20	0.05	BIRGE	65 HBC	0 K-P TO LAM PI PI	7/66
R4	0.103	0.029				

R4 FIT .103 0.029 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)

R5 Y*0(1815) INTO (SIGMA P1 P1)/TOTAL (P5)

R5	P	NO CLEAR SIGNAL	ARMENT-4	68 HBC	0 K-N TO SIG PI PI	11/68
R5	P	THERE IS A SUGGESTION OF A BUMP, ENOUGH TO BE CONSISTENT WITH WHAT IS EXPECTED FROM SIGMA P1 DECAY OF THE Y*1(1385) -- ABOUT 0.02.				

R5 FIT .158 0.033 FROM FIT

R6 Y*0(1815) FROM KBAR N TO Y*1(1385) P1 P-WAVE (P6)

R6	A	(0.31)	(0.05)	ARMENT-2	67 HBC	0 K-P TO LAM P+ P+	
R6	A	+27	.03	PREVOST	74 DPWA	0 K-N TO S(1385)PI	10/74
R6	3	-1.67	.054	CAMERON	78 DPWA	0 K-P TO S(1385)PI	1/78

R6 AVG MOD .2645 0.044 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.7)

R6 STUDENT 0.248 0.031 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT

R6 FIT 0.249 0.034 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.5)

R7 Y*0(1815) FROM KBAR N TO Y*1(1385) P1 F-WAVE (P7)

R7	3	+0.065	.029	CAMERON	78 DPWA	0 K-P TO S(1385)PI	1/78
R7	3	THE SIGN HERE AND IN R6 IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION.					12/79*

R7 FIT .065 0.029 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

REFERENCES FOR Y*0(1815)

BIRGE 65 ATHENS CONF 296 +ELY,KALMUS,KERNAN,LOUIE,SAHOURIA, + (LRL)IJP

ARMENT-1 67 PL 248 198 ARMENTEROS, F LUZZI, + (CERN,HEIDEL,SACLAY)IJP

ARMENT-2 67 ZEIT PHYS 202 486 ARMENTEROS, F LUZZI, + (CERN,HEIDEL,SACLAY)IJP

BELL 67 PRL 19 936 R B BELL (LRL)IJP

ARMENT-3 68 NP 88 195 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP

ARMENT-4 68 NP 88 216 ARMENTEROS, BAILLON, + (CERN,HEIDEL,SACLAY)IJP

BUGG 68 PR 168 1466 +GILMORE, KNIGHT, + (RHEL+BIRM+CAVE) I

BRICMANI 70 PL 318 152 +FERRO LUZZI, PERREAU, + (CERN,CAEN,SACLAY)

BRICMANI 70 PL 338 511 +FERRO-LUZZI,LAGNAUX (CERN)

COOL 70 PR D 1887 +GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL) I

GALTIERI 70 DUKE CONF 173 A BARBARO-GALTIERI (LRL)IJP

CONFORTO 71 NP 834 41 +LEVI SETTI,LASINSKI..OBERLACK+ (EFI+HEIDI)IJP

KIM 71 PRL 27 356 J K KIM (HARV)IJP

ALSO 70 DUKE 161 J. K. KIM (HARV)IJP

KANE 72 PR D5 1583 D F KANE (LBL)IJP

LANGBEIN 72 NP 847 477 +WAGNER (IPM)IJP

RADER 73 NC 164 178 +BARLOUTAUD, + (SACL+HEID+CERN+HEID)CDFE

PREVOST 74 NP 869 246 +BARLOUTAUD, + (SACL+CERN+HEID)

Data Card Listings
For notation, see key at front of Listings.

Baryons
Lambda(1815), Lambda(1830), Lambda(1860)

DECLAIS 77 CERN 77-16
MARTIN 77 NP B127 349
ALSO 77 NP B126 266
ALSO 77 NP B126 285
RLIC 77 NP B119 362
ALSTON 78 PR D18 182
ALSO 77 PRL 38 1007
CAMERON 78 NP B143 189

PAPERS NOT REFERRED TO IN DATA CARDS

THE FOLLOWING PAPERS ARE NOW OF ONLY HISTORICAL INTEREST --

CHAMBERLAIN 62 PR 125 1696
GALTEIERI 63 PL 6 296
SODICKSON 64 PR 133 8757
HOLLEY 65 UCLR-16274 THESIS
BIRMINGHAM 66 PR 152 1148
COOL 66 PRL 16 1228
GELFAND 66 PRL 17 1224
ARMENTERO 67 NP B3 592
CONFORTO 68 NP B8 265
LASINSKI 68 PR 163 1792
PREVOST 71 AMSTERDAM CONF

+DUCHON, LOUVEL, PATRY, SEGUINOT+ (CAEN+ CERN) IJP
MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS) IJP
MARTIN, PIDCOCK (LUCJ)
MARTIN, PIDCOCK (LUCJ) IJP
GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL) IJP
+KENNEY, POLLARD, ROSS+ (LBL+MTHO+ CERN) IJP
ALSTON-GARAJOST, KENNEY (LBL+MTHO+ CERN) IJP
+FRANEK, GOPAL, BACON, BUTTERWORTH+ (RHEL+LOIC) IJP

Lambda(1830)

56 Y*0(1830, JP=5/2-) I=0

D05

SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

THE BEST EVIDENCE FOR THIS RESONANCE COMES FROM THE SIGMA PI CHANNEL. IT IS WELL ESTABLISHED.

56 Y*0(1830) MASS (MEV)

Table with columns M, N, mass, and description. Includes entries for ARMENTERO, BELL, GALTIERI, CONFORTO, KIM, KANE, LANGBEIN, MARTIN, RADER, and PREVOST.

56 Y*0(1830) WIDTH (MEV)

Table with columns W, N, width, and description. Includes entries for ARMENTERO, GALTIERI, CONFORTO, KIM, KANE, LANGBEIN, MARTIN, and RADER.

56 Y*0(1830) PARTIAL DECAY MODES

Table with columns P1, P2, P3, P4, decay mode, and mass. Includes entries for INTO KBAR N, INTO SIGMA PI, INTO Y*(1385) PI D-WAVE, and INTO ETA LAMBDA.

56 Y*0(1830) BRANCHING RATIOS

Table with columns R1, R2, R3, R4, branching ratio, and description. Includes entries for INTO (KBAR N)/TOTAL, FROM KBAR N INTO SIGMA PI, PUBLISHED SIGN CHANGED TO AGREE WITH LUND 1969 CONVENTION, FROM KBAR N TO Y*(1385) PI D-WAVE, and FROM KBAR N TO Y*(1385) PI D-WAVE.

REFERENCES FOR Y*0(1830)

ARMENTERO 67 PL 248 198
BELL 67 PRL 19 936
ARMENTERO 68 NP B8 195
CONFORTO 68 NP B8 265
15 SUPERSEDED BY CCNFORTO
BRICMANI 70 PL 33B 511
GALTIERI 70 DUKE CONF 173
CONFORTO 71 NP B34 41
KIM 71 PRL 27 356
ALSO 70 DUKE 161
KANE 72 PR D5 1583
LANGBEIN 72 NP B47 477
RADER 73 NC 16A 178
PREVOST 74 NP B69 246
MARTIN 77 NP B127 349
ALSO 77 NP B126 286
ALSO 77 NP B126 285
RLIC 77 NP B119 362
ALSTON 78 PR D18 182
ALSO 77 PRL 38 1007
CAMERON 78 NP B143 189

PAPERS NOT REFERRED TO IN DATA CARDS

PREVOST 71 AMSTERDAM CONF + CHS COLLABORATION (CERN+HEID+SACL)

Lambda(1860)

60 Y*0(1860, JP=3/2+) I=0

P03

THE JP=3/2+ ASSIGNMENT IS CONSISTENT WITH ALL AVAILABLE DATA (INCLUDING POLARIZATION) AND RECENT PARTIAL WAVE ANALYSES. THE DOMINANT INELASTIC MODES REMAIN UNKNOWN. SEE ALSO Y*0(2010) MINI-REVIEW.

60 Y*0(1860) MASS (MEV)

Table with columns M, N, mass, and description. Includes entries for ARMENTERO, BUGG, BRICMANI, CONFORTO, KIM, LANGBEIN, LEA, HEMINGWA, NAKKASYA, BACCARI, MARTIN, and ALSTON.

60 Y*0(1860) WIDTH (MEV)

Table with columns W, N, width, and description. Includes entries for ARMENTERO, BUGG, BRICMANI, CONFORTO, KIM, LANGBEIN, LEA, HEMINGWA, NAKKASYA, MARTIN, RLIC, and ALSTON.

60 Y*0(1860) PARTIAL DECAY MODES

Table with columns P1, P2, P3, P4, P5, P6, decay mode, and mass. Includes entries for INTO KBAR N, INTO SIGMA PI, INTO LAMBDA OMEGA, INTO Y*(1385) PI P-WAVE, and INTO N K*(890), PI WAVE.

60 Y*0(1860) BRANCHING RATIOS

Table with columns R1, R2, R3, R4, R5, R6, branching ratio, and description. Includes entries for INTO (KBAR N)/TOTAL, FROM KBAR N INTO SIGMA PI, FROM KBAR N TO Y*(1385) PI P-WAVE, and FROM KBAR N TO Y*(1385) PI P-WAVE.

Baryons

$\Lambda(1860)$, $\Lambda(2010)$, $\Lambda(2020)$, $\Lambda(2100)$

Data Card Listings

For notation, see key at front of Listings.

R2 Y*0(1860) INTO SIGMA PI (P2)
 R2 P PROBABLY SEEN GALTIERI 68 DBC 0 K-N TO SIG PI PI 11/68
 R2 (0.03) OR LESS LANGBEIN 72 IPWA MULTICHANNEL 12/72
 R2 POSSIBLY THIS BUMP SEEN AT 1840+10 MEV WITH A WIDTH OF 35+10 MEV
 R2 IS THE Y*0(1860), WHICH DECAYS STRONGLY TO SIGMA PI. HOWEVER THE
 R2 NARROW WIDTH HERE ARGUES FOR ITS BEING THE Y*0(1860).

R3 Y*0(1860) FROM KBAR N TO SIGMA PI SQRT(P1*P2) 9/73
 R3 2 (+.15) LEA 73 DPWA MULTICHNL K-MTRX 9/73
 R3 4 (+.15)OR +.14 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
 R3 -.09 .03 RLIC 77 DPWA KBAR N MULTICHNL 1/76

R4 Y*0(1860) FROM KBAR N INTO LAMBDA OMEGA SQRT(P1*P3) 1/76
 R4 (.052) NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 1/76

R5 Y*0(1860) FROM KBAR N INTO Y*1(1385) PI P-WAVE SQRT(P1*P4) 1/78
 R5 LESS THAN 0.03 CAMERON2 78 DPWA 0 K-P TO S(1385)PI 1/78

R6 Y*0(1860) FROM KBAR N INTO Y*1(1385) PI F-WAVE SQRT(P1*P5) 1/78
 R6 -.126 .055 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78
 R6 5 SIGN CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION. 12/79*

R7 Y*0(1860) FROM KBAR N INTO N K*(890), P1 WAVE SQRT(P1*P6) 12/79*
 R7 6 -.07 0.03 CAMERON2 78 DPWA K-P TO K*N 12/79*
 R7 6 THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
 R7 6 CONVENTION. UPPER LIMITS ON THE P3 AND F3 WAVES ARE EACH 0.03. 12/79*

REFERENCES FOR Y*0(1860)

ARMENTEROS 68 NP 88 195
 BUGG 68 PR 168 1466
 GALTIERI 68 PRL 21 573

BRICMAN 70 PL 318 152
 BRICMANI 70 PL 338 511
 CONFORTO 71 NP 834 41
 KIM 71 PRL 27 356
 ALSO TO DUKE 161
 LANGBEIN 72 NP 847 477

LEA 73 NP 856 77
 HEMINGWA 75 NP 891 12
 NAKKASYA 75 NP 893 85

MARTIN 77 NP 8127 349
 ALSO 77 NP 8126 266
 ALSO 77 NP 8126 285
 RLIC 77 NP 8119 362
 ALSTON 78 PR 118 182
 ALSO 77 PRL 38 1007
 CAMERON 78 NP 8143 189
 CAMERON2 78 NP 8146 327

+MARTIN, MOORHOUSE+ (RHEL+LOUC+GLAS+AARHUS) IJP
 HEMINGWAY, EADES, HARMSEN+ (CERN, HEID, MPIM) IJP
 A. NAKKASYAN (CERN) IJP

MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS) IJP
 MARTIN, PIDCOCK (LOUC) IJP
 MARTIN, PIDCOCK (LDC) IJP
 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL) IJP
 +KENNEY, POLLARD, ROSS+ (LBL+MTHO+CERN) IJP
 ALSTON-GARNJOST, KENNEY (LBL+MTHO+CERN) IJP
 +FRANEK, GOPAL, BACON, BUTTERWORTH+ (RHEL+LOIC) IJP
 +FRANEK, GOPAL, KALMUS, MCPHERSON+ (RHEL+LOIC) IJP

PAPERS NOT REFERRED TO IN DATA CARDS

ARMENTEROS, F-LUZZI, + (CERN, HEIDEL, SACLAY) IJP
 AND CONFORTO 68.
 +HARMSEN, LASINSKI, + (CHICAGO, HEIDEL) IJP
 R. LEVI SETTI (RAPPORTEUR) (EFI)
 +ANDERSON, BOSNJAKOVIC, DAUN, ERNZ, + (CERN)
 +POULARD, REVEL, TALLINI+ (SACL+CDEF) IJP

$\Lambda(2010)$

89 Y*0(2010,) I=0
 SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
 WE LIST HERE ALL THE AMBIGUOUS RESONANCE POSSIBILITIES
 WITH A MASS AROUND 2 GEV. THE PROPOSED QUANTUM NUMBERS
 ARE D3 (GALTIERI 70 IN SIGMA PI), D3+F5, P3+D5, OR
 P1+03 (BRANDSTETTER 72 IN LAMBDA OMEGA), AND S1
 (CAMERON2 78 IN N K*). THE FIRST TWO OF THE ABOVE ANALYSES SHOULD NOW
 BE CONSIDERED OBSOLETE.

89 Y*0(2010) MASS (MEV)

M	(2010.0)	(30.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
M	1	1935. TO 1971.	BRANDSTE	72 DPWA	0 K-P TO LAM. OMG.	1/74
M	1	1951. TO 2034.	BRANDSTE	72 DPWA	0 K-P TO LAM. OMG.	1/74
M	1	PARAMETERS QUOTED ARE RANGES FROM THREE BEST FITS, THE LOWER				11/75
M	1	(HIGHER) MASS STATE PROBABLY HAS J.L.E.3/2(5/2).				11/75
M		2030.0	30.0	CAMERON2	78 DPWA	K-P TO K*(890) N 12/79*

89 Y*0(2010) WIDTH (MEV)

W	(130.0)	(50.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
W	1	180. TO 240. (LWR. MASS)	BRANDSTE	72 DPWA	0 K-P TO LAM. OMG.	1/74
W	1	73. TO 154. (HGR. MASS)	BRANDSTE	72 DPWA	0 K-P TO LAM. OMG.	1/74
W		125.0	25.0	CAMERON2	78 DPWA	K-P TO K*(890) N 12/79*

SEE THE NOTES ACCOMPANYING MASSES QUOTED

89 Y*0(2010) PARTIAL DECAY MODES

P1	Y*0(2010) INTO KBAR N	DECAY MASSES
P2	Y*0(2010) INTO SIGMA PI	497+ 939
P3	Y*0(2010) INTO LAMBDA OMEGA	1197+ 139
P4	Y*0(2010) INTO N K*(890), S1 WAVE	934+ 892
P5	Y*0(2010) INTO N K*(890), D3 WAVE	934+ 892

89 Y*0(2010) BRANCHING RATIOS

R1	Y*0(2010) FROM KBAR N TO SIGMA PI	SQRT(P1*P2)
R1	(-.02) TO (.04)	GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70
R2	Y*0(2010) FROM KBAR N INTO LAMBDA OMEGA	SQRT(P1*P3)
R2	(.17) TO .25 (LWR.)	BRANDSTE 72 DPWA 0 K-P TO LAM. OMG. 1/74
R2	(.04) TO .15 (HGR.)	BRANDSTE 72 DPWA 0 K-P TO LAM. OMG. 1/74

R3 Y*0(2010) FROM KBAR N INTO N K*(890), S1 WAVE SQRT(P1*P4)
 R3 2 -.012 0.03 CAMERON2 78 DPWA K-P TO K*N 12/79*
 R3 2 THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
 R3 2 CONVENTION. 12/79*

R4 Y*0(2010) FROM KBAR N INTO N K*(890), D3 WAVE SQRT(P1*P5) 12/79*
 R4 +0.09 0.03 CAMERON2 78 DPWA K-P TO K*N 12/79*

REFERENCES FOR Y*0(2010)

GALTIERI 70 DUKE CONF 173 A BARBARO-GALTIERI (LRL) IJP
 BRANDSTE 72 NP 839 13 BRANDSTETTER-BUTTERWORTH+ (RHEL+CDEF+SACL)
 CAMERON2 78 NP 8146 327 +FRANEK, GOPAL, KALMUS, MCPHERSON, + (RHEL+LOIC) IJP

PAPERS NOT REFERRED TO IN DATA CARDS

NAKKASYA 75 NP 893 85 A. NAKKASYAN (CERN) IJP

$\Lambda(2020)$

F07

27 Y*0(2020, JP=7/2+) I=0
 EFFECTS IN THIS PARTIAL WAVE HAVE OBSERVED AT SOMEWHAT
 DIFFERENT ENERGIES IN TWO CHANNELS. HOWEVER, LITCHFIELD
 71 NOTE THAT THE NEED FOR THIS STATE IN THEIR ANALYSIS
 RESTS SOLELY ON A POSSIBLY INCONSISTENT POLARIZATION
 MEASUREMENT AT 1.784 GEV/C. THE STATE WAS NOT REQUIRED
 IN THE KBAR N TO KBAR N ANALYSIS OF HEMINGWAY 75, BUT
 COULD NOT BE CONCLUSIVELY RULED OUT. IT IS NOW
 SEEN IN THE NEW ANALYSIS OF DECLAIS 77 WHICH INCLUDES
 K- NEUTRON ELASTIC DIFFERENTIAL CROSS SECTION DATA,
 AND IS WEAKLY SUPPORTED BY BACCARI 77.

27 Y*0(2020) MASS (MEV)

M	(2020.0)	(20.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
M	(2100.)	(30.)	LITCHFIE	71 DPWA	K-P TO KBAR N	10/71
M	(2140.)	(30.)	BACCARI	77 DPWA	0 K-P TO LAM. OMG.	1/78
M	(2117.)	(30.)	DECLAIS	77 DPWA	KBAR N TO KBAR N	1/78

27 Y*0(2020) WIDTH (MEV)

W	(160.0)	(30.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI	7/70
W	(120.)	(30.)	LITCHFIE	71 DPWA	K-P TO KBAR N	10/71
W	(128.)	(30.)	BACCARI	77 DPWA	0 K-P TO LAM. OMG.	1/78
W	(167.)	(30.)	DECLAIS	77 DPWA	KBAR N TO KBAR N	1/78

27 Y*0(2020) PARTIAL DECAY MODES

P1	Y*0(2020) INTO KBAR N	DECAY MASSES
P2	Y*0(2020) INTO SIGMA PI	497+ 939
P3	Y*0(2020) INTO LAMBDA OMEGA	1197+ 139
		1115+ 782

27 Y*0(2020) BRANCHING RATIOS

R1	Y*0(2020) INTO (KBAR N)/TOTAL	(P1)
R1	(0.05) TO (0.02)	LITCHFIE 71 DPWA K-P TO KBAR N 10/71
R1	(.05)	DECLAIS 77 DPWA KBAR N TO KBAR N 1/78
R2	Y*0(2020) FROM KBAR N TO SIGMA PI	SQRT(P1*P2)
R2	(-.0,15) TO (0.02)	GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70
R3	Y*0(2020) FROM KBAR N TO LAMBDA OMEGA	SQRT(P1*P3)
R3	LESS THAN .05	BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78

REFERENCES FOR Y*0(2020)

GALTIERI 70 DUKE CONF 173 A BARBARO-GALTIERI (LRL) IJP
 LITCHFIE 71 NP 830 125 LITCHFIELD, ...+LESQUOY, ... (RHEL+CDEF+SACL) IJP

BACCARI 77 NC 41A 96 +POULARD, REVEL, TALLINI+ (SACL+CDEF) IJP
 DECLAIS 77 CERN 77-16 +DUCHON, LOUVEL, PATRY, SEGUINOT+ (CAEN+CERN) IJP

PAPERS NOT REFERRED TO IN DATA CARDS

HEMINGWA 75 NP 891 12 HEMINGWAY, EADES, HARMSEN+ (CERN, HEID, MPIM) IJP

$\Lambda(2100)$

G07

41 Y*0(2100, JP=7/2-) I=0
 SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
 THIS ENTRY ONLY INCLUDES RESULTS FROM PARTIAL-WAVE
 ANALYSES. PARAMETERS OF PEAKS SEEN IN CROSS-SECTIONS
 AND INVARIANT-MASS DISTRIBUTIONS AROUND 2100 MEV ARE
 GIVEN IN A SEPARATE ENTRY BELOW.

41 Y*0(2100) MASS (MEV)

M	(2120.0)	(10.0)	WOHL	66 HBC	K-P CH EX	7/66
M	A	(2080.0)	BURGUN	68 DPWA	0 K-P TO XI K	10/69
M	L	(2130.0)	(20.0)	BERTHONI	70 DPWA	0 K-P TO SIGMA PI 10/70
M		2110.0	(20.0)	GALTIERI	70 DPWA	0 K-P TO SIGMA PI 7/70
M		2100.	(15.)	LITCHFIE	71 DPWA	K-P TO KBAR N 10/71
M	L	2110.0	(30.0)	LITCHFIE	71 DPWA	K-P TO SIG PI 10/71
M	1	2113. TO 2154.	BRANDSTE	72 DPWA	0 K-P TO LAM. OMG.	1/74
M		2092.0	(12.0)	KANE	72 DPWA	0 K-P TO PI SIG 10/71

Data Card Listings

For notation, see key at front of Listings.

Baryons
Lambda(2100), Lambda(2110)

M 2105. (10.) HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
M 2 2110. OR 2089. NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 11/75
M 3 (2094.) BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
M (2094.) DECLAIS 77 DPWA KBAR N TO KBAR N 1/78
M 2110. (10.) RLIC 77 DPWA KBAR N MULTICHNL 1/76
M 2106. (30.) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
M 2 QUOTED PARAMETERS CORRESPOND TO THE TWO BEST SOLUTIONS FOUND. 11/75
M 2 EACH HAS THE Y*0(2100) AND ONE ADDITIONAL RESONANCE (P3 OR F5). 11/75
M A BURGUN 68 SEE A RESONANCE-LIKE EFFECT IN THIS REGION IN THE REACTION K-P TO XI K. HOWEVER, AS THE POINT OUT, IT IS NOT CLEAR WHETHER IT IS MAINLY THE GOT Y*0(2100) OR INSTEAD A SO FAR OTHERWISE UNOBSERVED RESONANCE WITH A SPIN LESS THAN 7/2.
M L LITCHFIELD 71 IS AN UPDATE OF BERTHONI 70 3/72
M 1 PARAMETERS QUOTED ARE RANGES FROM THREE BEST FITS. 1/74

41 Y*0(2100) WIDTH (MEV)
W (145.0) WDH 66 HBC 7/66
W A (80.0) (10.0) BURGUN 68 DPWA 0 K-P TO XI K 10/69
W 140.0 (15.0) BERTHONI 70 DPWA 0 K-P TO SIGMA PI 10/70
W 60.0 (25.0) GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70
W B (170.) TO 300. LITCHFIE 71 DPWA K-P TO KBAR N 10/71
W B LARGER VALUE CORRESPONDS TO PURE B.W. LOWER VALUE + TG B.W. + BCKGRD
W L 140.0 (50.0) (30.0) LITCHFIE 71 DPWA K-P TO SIG PI 10/71
W 1 208. TO 229. BRANDSTE 72 DPWA 0 K-P TO LAM. OMG. 1/74
W 144.0 (26.0) KANE 72 DPWA 0 K-P TO PI SIG 10/71
W 241. (50.) HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
W 2 244. OR 302. NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 11/75
W 3 (98.) BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
W (250.) DECLAIS 77 DPWA 0 KBAR N TO KBAR N 1/78
W 250. (30.) RLIC 77 DPWA KBAR N MULTICHNL 1/76
W 157. (40.) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
SEE THE NOTES ACCOMPANYING MASSES QUOTED

41 Y*0(2100) PARTIAL DECAY MODES
P1 Y*0(2100) INTO KBAR N 497+ 939
P2 Y*0(2100) INTO SIGMA PI 1197+ 139
P3 Y*0(2100) INTO XI K 1321+ 497
P4 Y*0(2100) INTO LAMBDA OMEGA 1115+ 782
P5 Y*0(2100) INTO ETA LAMBDA 548+115
P6 Y*0(2100) INTO N K*(890), D3 WAVE 939+ 892
P7 Y*0(2100) INTO N K*(890), G1 WAVE 939+ 892

41 Y*0(2100) BRANCHING RATIOS
R1 Y*0(2100) INTO (KBAR N)/TOTAL WDH 66 HBC (P1) 7/66
R1 D (0.33) DAUM 68 CNTR K-P ELA, POL, SIGT 7/70
R1 0.30 (.03) LITCHFIE 71 DPWA K-P TO KBAR N 10/71
R1 .31 (.03) HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
R1 (.29) DECLAIS 77 DPWA KBAR N TO KBAR N 1/78
R1 .30 (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R1 .24 (.06) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
R1 D DAUM 68 ASSUMES (J+1/2)*X VALUE SEEN IN TOTAL CROSS SECTION.
R2 Y*0(2100) FROM KBAR N INTO SIGMA PI SQR(P1*P2)
R2 L (+0.16) (0.02) BERTHONI 70 DPWA 0 K-P TO SIGMA PI 10/70
R2 +0.06 (0.03) GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70
R2 L 0.16 (0.05) LITCHFIE 71 DPWA K-P TO SIG PI 10/71
R2 +0.06 (0.03) KANE 72 DPWA 0 K-P TO PI SIG 10/71
R2 +.12 (.04) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R3 Y*0(2100) FROM KBAR N TO XI K SQR(P1*P3)
R3 (0.05) TRIPP 67 RVUE 0 K-P TO XI K 8/67
R3 B (0.09) (0.01) BURGUN 68 DPWA 0 K-P TO XI K 10/69
R3 (0.003) MULLER 69 DPWA 0 7/70
R3 0.035 0.018 LITCHFIE 71 DPWA K-P TO XI K 3/72
R3 B BURGUN 68 UPDATED BY LITCHFIELD 71, WHO TAKES SOLUTION C OF BURGUN 3/72
R4 Y*0(2100) FROM KBAR N INTO LAMBDA OMEGA SQR(P1*P4)
R4 1 (.05) TO .11 BRANDSTE 72 DPWA 0 K-P TO LAM. OMG. 1/74
R4 2 (.122) OR .154 NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 11/75
R4 3 (-.070) BACCARI 77 DPWA 0 G37-WAVE 1/78
R4 3 (-.011) BACCARI 77 DPWA 0 G617-WAVE 1/78
R4 3 (+.008) BACCARI 77 DPWA 0 G637-WAVE 1/78
R4 3 NOTE THAT THE 3 ENTRIES FOR BACCARI77 ARE FOR 3 DIFFERENT WAVES. 1/78
R5 Y*0(2100) FROM KBAR N TO ETA LAMBDA SQR(P1*P5)
R5 -.050 .020 RADER 73 MPWA 9/73
R6 Y*0(2100) FROM KBAR N INTO N K*(890), D3 WAVE SQR(P1*P6)
R6 +0.21 0.04 CAMERON2 78 DPWA K-P TO K*N 12/79*

41 Y*0(2100) BRANCHING RATIOS (P1)
R1 Y*0(2100) FROM KBAR N TO SIGMA PI SQR(P1*P2)
R1 (+.17) (.03) BERTHONI 70 DPWA 0 K-P TO SIG PI 1/71
R1 A (+0.156) (0.013) KANE 72 DPWA 0 K-P TO PI SIG 10/71
R1 (+.14) (.01) BELLEFON 76 DPWA 0 K-P TO SIG PI 1/76
R1 (+.10) (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R2 Y*0(2100) INTO (KBAR N)/TOTAL (P1)
R2 D05 0.14 0.04 LITCHFIE 71 DPWA K-P TO KBAR N 10/71
R2 (.07) (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R2 2 (.27) (.06) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
R2 2 THE PUBLISHED ERROR OF 0.6 WAS A MISPRINT. 12/79*
R3 Y*0(2100) FROM KBAR N INTO LAMBDA OMEGA SQR(P1*P3)
R3 1 (.112) NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 1/76
R3 LESS THAN .05 BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
R4 Y*0(2100) FROM KBAR N TO Y*1(1385) PI P-WAVE SQR(P1*P4)
R4 2 +.071 .025 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78
R4 2 CAMERON 78 UPPER LIMIT ON F-WAVE DECAY IS 0.03. THE SIGN HERE IS 12/79*
R4 2 CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION. 12/79*
R5 Y*0(2100) FROM KBAR N INTO N K*(890), F1 WAVE SQR(P1*P5)
R5 3 0.17 0.04 CAMERON2 78 DPWA K-P TO K*N 12/79*
R5 3 THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST 12/79*
R5 3 CONVENTION. UPPER LIMITS ON THE P3 AND F3 WAVES ARE EACH 0.03. 12/79*

REFERENCES FOR Y*0(2100)
WDH 66 PRL 17 107 C G WOH, F T SOLMITZ, M L STEVENSON (LBL)IJP
TRIPP 67 NP B3 10 + LEITH, + (LRL, SLAC, CERN, HEIDEL, SAC)LAY
BURGUN 68 NP 88 447 + MEYER, PAULI, + (SACLAY, COLFRANCE, RHEL)
DAUM 68 NP B7 19 + ERNE, LAGNAUX, SENS, STEUER, UDO (CERN)IJP
CONFIRMS THE SPIN-PARITY ASSIGNMENT. (LRL)
MULLER 69 THESIS, UCRL 19372 R A MULLER (LRL)
BERTHONI 70 NP B24 417 +VRANA, BUTTERWORTH, + (CDFE, RHEL, SACLAY)IJP
GALTIERI 70 DUKE CONF 173 A BARBARD-GALTIERI (LRL)IJP
LITCHFIE 71 NP B50 125 LITCHFIELD, ...+LESQUOY, ... (RHEL+CDEF+SACLAY)IJP
BRANDSTE 72 NP B39 13 BRANDSTETTER, ...+TALLINI (RHEL+CDEF, SACL) IJP
KANE 72 PR D5 1583 D F KANE (LBL)IJP
RADER 73 NC 16A 178 +BARLOUTAUD, + (SACL+HEID+CERN+RHEL+CDEF)
HEMINGWA 75 NP B91 12 HEMINGWAY, EADES, HARMSEN+ (CERN, HEID, MP)IJP
NAKKASYA 75 NP B93 85 A. NAKKASYAN (CERN)IJP

BACCARI 77 NC 41A 96 +POULARD, REVEL, TALLINI+ (SACL+CDEF)IJP
DECLAIS 77 CERN 77-16 +DUGNON, LOUVEL, PATRY, SEGUINOT+ (CAEN+CERN)IJP
RLIC 77 NP B119 362 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL)IJP
BELLEFON 78 NC 42A 403 +BERTHON, BILLOIR, BRUNET+ (CDFE+SACL)IJP
CAMERON2 78 NP B146 327 +FRANEK, GOPAL, KALMUS, MCPHERSON, + (RHEL+LOIC)IJP

Lambda(2110) 35 Y*0(2110, JP=5/2+) I=0 F'05

BERTHONI 70 FIND EITHER F05 OR D05 POSSIBLE IN THE SIG PI CHANNEL, WITH F05 SLIGHTLY PREFERRED. IN THE KBAR N CHANNEL, LITCHFIELD 71 (SAME GROUP) FIND ONLY D05. AS USUAL, THE STATISTICS ARE MUCH BETTER IN THE ELASTIC CHANNEL. ALTHOUGH KANE 72 FINDS AN F05 EFFECT, THE UNUSUALLY BROAD WIDTH MAY INVALIDATE A RESONANT INTERPRETATION. HOWEVER RLIC 77, BELLEFON 77, AND BELLEFON 78 ALSO FIND AN F05. THE EVIDENCE FOR F05 FROM THE LAMBDA OMEGA ANALYSES, NAKKASYAN 75 AND BACCARI 77, IS QUITE WEAK, BUT THEY GIVE NO EVIDENCE IN FAVOR OF D05. THE WEIGHT OF THE EVIDENCE IS THUS IN FAVOR OF F05. SEE ALSO THE Y*0(2010) MINI-REVIEW.

35 Y*0(2110) MASS (MEV)
M (2110.) (10.) BERTHONI 70 DPWA - K-P TO SIG PI 1/71
M D05 2140. 40. LITCHFIE 71 DPWA K-P TO KBAR N 10/71
M A (2141.0) (4.0) KANE 72 DPWA 0 K-P TO PI SIG 10/71
M A RESONANCE OUTSIDE RANGE OF DATA.
M 1 (2103.) NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 1/76
M 1 FOUND IN ONE OF TWO BEST SOLUTIONS.
M (2140.) (20.) BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
M (2100.) (50.) RLIC 77 DPWA KBAR N MULTICHNL 1/76
M 2 (2106.) (50.) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
M 2125.0 25.0 CAMERON2 78 DPWA K-P TO K*(890) N 12/79*

35 Y*0(2110) WIDTH (MEV)
W (185.) (30.) BERTHONI 70 DPWA - K-P TO SIG PI 1/71
W D05 120. 40. LITCHFIE 71 DPWA K-P TO KBAR N 10/71
W A (504.0) (10.0) KANE 72 DPWA 0 K-P TO PI SIG 10/71
W 1 (351.) (10.) NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 1/76
W (132.) (10.) BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
W (140.) (20.) BELLEFON 77 DPWA 0 K-P TO SIG PI 1/77
W (200.) (50.) RLIC 77 DPWA KBAR N MULTICHNL 1/76
W 2 (251.) (50.) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
W 160.0 30.0 CAMERON2 78 DPWA K-P TO K*(890) N 12/79*

35 Y*0(2110) PARTIAL DECAY MODES
P1 Y*0(2110) INTO KBAR N 497+ 939
P2 Y*0(2110) INTO SIGMA PI 1197+ 139
P3 Y*0(2110) INTO LAMBDA OMEGA 1115+ 782
P4 Y*0(2110) INTO Y*1(1385) PI P-WAVE 139+1384
P5 Y*0(2110) INTO N K*(890), F1 WAVE 939+ 892

35 Y*0(2110) BRANCHING RATIOS
R1 Y*0(2110) FROM KBAR N TO SIGMA PI SQR(P1*P2)
R1 (+.17) (.03) BERTHONI 70 DPWA 0 K-P TO SIG PI 1/71
R1 A (+0.156) (0.013) KANE 72 DPWA 0 K-P TO PI SIG 10/71
R1 (+.14) (.01) BELLEFON 76 DPWA 0 K-P TO SIG PI 1/76
R1 (+.10) (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R2 Y*0(2110) INTO (KBAR N)/TOTAL (P1)
R2 D05 0.14 0.04 LITCHFIE 71 DPWA K-P TO KBAR N 10/71
R2 (.07) (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R2 2 (.27) (.06) BELLEFON 78 DPWA 0 KBAR N TO KBAR N 1/78
R2 2 THE PUBLISHED ERROR OF 0.6 WAS A MISPRINT. 12/79*
R3 Y*0(2110) FROM KBAR N INTO LAMBDA OMEGA SQR(P1*P3)
R3 1 (.112) NAKKASYA 75 DPWA 0 K-P TO LAM. OMG. 1/76
R3 LESS THAN .05 BACCARI 77 DPWA 0 K-P TO LAM. OMG. 1/78
R4 Y*0(2110) FROM KBAR N TO Y*1(1385) PI P-WAVE SQR(P1*P4)
R4 2 +.071 .025 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78
R4 2 CAMERON 78 UPPER LIMIT ON F-WAVE DECAY IS 0.03. THE SIGN HERE IS 12/79*
R4 2 CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION. 12/79*
R5 Y*0(2110) FROM KBAR N INTO N K*(890), F1 WAVE SQR(P1*P5)
R5 3 0.17 0.04 CAMERON2 78 DPWA K-P TO K*N 12/79*
R5 3 THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST 12/79*
R5 3 CONVENTION. UPPER LIMITS ON THE P3 AND F3 WAVES ARE EACH 0.03. 12/79*

REFERENCES FOR Y*0(2110)
BERTHONI 70 NP B24 417 +VRANA, BUTTERWORTH, + (CDFE, RHEL, SACLAY)IJP
LITCHFIE 71 NP B50 125 LITCHFIELD, ...+LESQUOY, ... (RHEL+CDEF+SACLAY)IJP
KANE 72 PR D5 1583 D F KANE (LBL)IJP
NAKKASYA 75 NP B93 85 A. NAKKASYAN (CERN)IJP
BACCARI 77 NC 41A 96 +POULARD, REVEL, TALLINI+ (SACL+CDEF)IJP
BELLEFON 77 NC 37A 175 DE BELLEFON, BERTHON, BILLOIR+ (CDFE+SACL)IJP
RLIC 77 NP B119 362 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL)IJP
BELLEFON 78 NC 42A 403 +BERTHON, BILLOIR, BRUNET+ (CDFE+SACL)IJP
CAMERON 78 NP B143 199 +FRANEK, GOPAL, SACON, BUTTERWORTH (RHEL+LOIC)IJP
CAMERON2 78 NP B146 327 +FRANEK, GOPAL, KALMUS, MCPHERSON, + (RHEL+LOIC)IJP

Data Card Listings

Baryons

For notation, see key at front of Listings.

$\Lambda(2585)$, Σ^+ , Σ^- , Σ^0 , $\Sigma(1385)$

$\Lambda(2585)$ BUMPS
7 Y*(2585, JP=) I=0 PRODUCTION EXPERIMENTS
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
7 Y*(2585) MASS (MEV) (PROD. EXP.)
M 2585.0 45.0 ABRAMS 70 CNTR K-P, D TOTAL 10/70
M (2530.0) (25.0) 70 CNTR O GAMMA P TO K+ Y* 1/71
7 Y*(2585) WIDTH (MEV) (PROD. EXP.)
W (300.0) ABRAMS 70 CNTR K-P, D TOTAL 10/70
W (150.0) LU 70 CNTR O GAMMA P TO K+ Y* 1/71
7 Y*(2585) PARTIAL DECAY MODES (PROD. EXP.)
PI Y*(2585) INTO KBAR N DECAY MASSES 497+ 939
7 Y*(2585) BRANCHING RATIOS (PROD. EXP.)
R1 Y*(2585) INTO KBAR N/TOTAL
R1 J IS NOT KNOWN. THE FOLLOWING IS (J+1/2)+P1 (P1)
R1 (1.0) ABRAMS 70 CNTR K-P, D TOTAL 10/70
R1 C (0.12) (0.12) BRICMAN 70 CNTR TOTAL AND CH EX 10/70
R1 C RESONANCE AT END OF REGION ANALYZED -- NO CLEAR SIGNAL.
REFERENCES FOR Y*(2585) (PROD. EXP.)
ABRAMS 70 PR 10 1917 +COOL, GIACOMELLI, KYCIA, LEONTIC, + (BNL) I
BRICMAN 70 PL 31B 152 +FERRO LUZZI, PERREAU, + (CERN, CAEN, SACLAY)
LU 70 PR D2 1846 +GREENBERG, HUGHES, MINEHART, MORI, + (YALE)
PAPERS NOT REFERRED TO IN DATA CARDS
COOL 66 PRL 16 1228 +GIACOMELLI, KYCIA, LEONTIC, LUNDBY + (BNL) I

S=-1 I=1 HYPERON STATES (Σ)

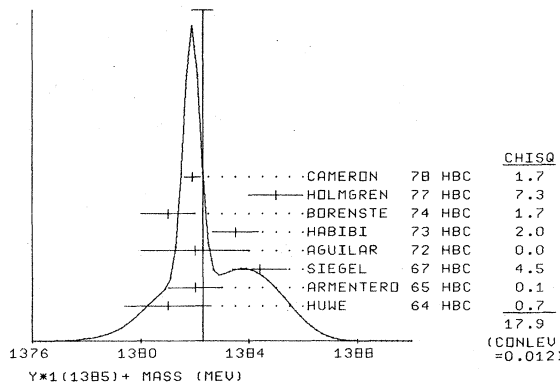
Σ^- 19 SIGMA-(1189, JP=1/2+) I=1
SEE STABLE PARTICLE DATA CARD LISTINGS
 Σ^+ 20 SIGMA+(1198, JP=1/2+) I=1
SEE STABLE PARTICLE DATA CARD LISTINGS
 Σ^0 21 SIGMA0(1193, JP=1/2+) I=1
SEE STABLE PARTICLE DATA CARD LISTINGS

$\Sigma(1385)$ P13
43 Y*(1385, JP=3/2+) I=1
SERIOUS INCOMPATIBILITIES EXIST BETWEEN DIFFERENT MEASUREMENTS OF THE Y*(1385) MASS AND WIDTH. THESE INCOMPATIBILITIES ARE AT LEAST PARTIALLY ACCOUNTED FOR BY SOME EXPERIMENTS QUOTING UNREALISTICALLY SMALL ERRORS. WE CONSISTENTLY INCREASE UNREALISTIC ERRORS BEFORE AVERAGING (SEE THE TYPED NOTE ON K*(892)).
IN THE LISTINGS BELOW WE ATTEMPT TO OBTAIN THE BEST VALUES FOR THE SEPARATE CHARGE STATE MASSES AND WIDTHS. THUS WE DO NOT USE RESULTS QUOTED FOR MIXED CHARGES.
WE NO LONGER USE EVERY PUBLISHED VALUE, BUT AVERAGE ONLY THE MOST SIGNIFICANT DETERMINATIONS. NEITHER DO WE AVERAGE RESULTS FROM INCLUSIVE EXPERIMENTS WITH LARGE BACKGROUNDS OR RESULTS WHICH ARE NOT ACCOMPANIED BY AT LEAST A DISCUSSION ON EXPERIMENTAL RESOLUTION. NEVERTHELESS SYSTEMATIC DIFFERENCES BETWEEN EXPERIMENTS REMAIN (SEE THE IDEOGRAMS INSERTED IN THE DATA CARD LISTINGS BELOW). THESE DIFFERENCES COULD ARISE FROM INTERFERENCE EFFECTS THAT CHANGE WITH PRODUCTION MECHANISM AND/OR BEAM MOMENTUM. THEY CAN ALSO BE ACCOUNTED FOR IN PART BY DIFFERENCES IN THE PARAMETRIZATIONS EMPLOYED (SEE BORENSTEIN 74 FOR A DISCUSSION ON THIS POINT). THUS BORENSTEIN 74 USE A BREIT-WIGNER WITH ENERGY INDEPENDENT WIDTH, SINCE A P-WAVE WAS FOUND TO GIVE UNSATISFACTORY FITS, CAMERON 78 USE THE SAME FORM. ON THE OTHER HAND HOLMGREN 77 OBTAIN A GOOD FIT TO THEIR LAMBDA PI MASS SPECTRUM WITH A P-WAVE BREIT-WIGNER, BUT INCLUDE THE PARTIAL WIDTH FOR THE SIGMA PI DECAY MODE IN THE PARAMETRIZATION.

43 Y*(1385) MASS (MEV)
M 141(1384.0) ALSTON 60 HBC -- K-P 1.15 BEV/C
M (1385.0) 61 HBC -- K-P -- .85 BEV/C
M 38(1384.0) MARTIN 61 HBC +0 K20 P .98 BEV/C
M (1392.0) (7.0) COLLEY 62 HLBC -0 PI- PRP 2. BEV/C
M (1389.0) (3.0) BALTAY 65 HBC +- PBAR P 3.7 BEV/C
M (1392.0) (10.0) MUSGRAVE 65 HBC +-OPBAR P 3+- BEV/C
M 200(1384.8) (2.0) ATHERTON 71 HBC +- LAM PI+ + C.C. 11/77
M 190(1380.) (5.) AMMANN 73 DBC +- K-N 4.5GEV/C 11/77
M 200(1386.) ATHERTDI 73 HBC +-OPBAR P 5.7 GEV/C 1/76
M 242(1396.-) (5.) DIONISI 78 HBC +- K-P TO Y* K KBAR 3/79*
M I 1K(1383.) (1.) BANERJEE 79 HBC +- LAM PI+ + C.C. 1/80*
M I 500(1388.) (2.) BANERJEE 79 HBC +- LAM PI- + C.C. 1/80*
M I FROM FIT TO INCLUSIVE LAMBDA PI + C.C. SPECTRA

NO 106(1381.0) (4.0) CURTIS 63 OSPK 0 PI-P 1.5 BEV/C
MO E 240 1385.1 2.5 THOMAS 73 HBC 0 PI-P TO PIKOLM 11/77
MO E ERROR ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE ON K* MASS.
MO 2 3100 1380. 2. BORENSTE 74 HBC 0 K-P TO(1385)+PIS 11/77
MO 2 FROM FIT TO LAM PIO MASS SPECTRUM (IN LAM PI+ PI- PIO EVENTS) WITH
MO 2 NO FIXED AT 34 MEV.
MO F 500(1389.) (3.) BAUBILLIE 79 HBC 0 K-P AT 8.25 GEV 1/80*
MO
MO AVG 1382.0 2.5 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
MO STUDENT1381.9 1.9 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT
MO F FROM FIT TO INCLUSIVE LAMBDA PIO SPECTRUM WITH WIDTH FIXED AT
MO F 40 MEV.
M+ E 154(1376.0) (3.9) ELY 61 HLBC + K-P 1.11 BEV/C 11/77
M+ 170(1375.0) (3.9) COOPER 64 HBC + K-P 1.45 BEV/C 11/77
M+ 859 1381.0 1.6 HUME 64 HBC + K-P 1.22 BEV/C
M+ 750 1382.0 1.0 ARMENTERO 65 HBC + K-P 9-1.2 BEV/C
M+ E 250(1384.-) (1.9) SMITH 65 HBC + K-P 1.8 BEV/C 11/77
M+ E 250(1382.6) (2.1) SMITH 65 HBC + K-P 1.95 BEV/C 11/77
M+ E 62(1383.0) (8.0) BIRMINGHA 66 HBC + K-P 3.5 GEV/C 11/77
M+ 135(1378.0) (5.0) LONDON 66 HBC + K-P 2.24 GEV/C 11/77
M+ 1260 1384.4 1.0 SIEGEL 67 HBC + K-P AT 2.1 GEV/C 10/69
M+ 46(1390.0) (6.0) AGULLAR 70 HBC + K-P 4 GEV/SIG-PI 11/77
M+ 400 1382.0 2.0 AGULLAR 72 HBC + K-P TO LAM+PIS 10/74
M+ 2300 1383.5 .85 HABIBI 73 HBC + K-P TO 2PI LAM 9/73
M+ R 3740(1382.) (1.) BERTHON 74 HBC + K-P 1263-1843MEV 10/74
M+ R ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
M+ I 22K(1385.) (3.) BORENSTE 74 HBC + K-P TO(1385)+PIS 10/74
M+ I (1380.) (2.) BARBADIN 75 HBC + K-P 14.3 GEV/C 11/77
M+ HI 22K(1385.) (3.) BARREIRO 77 HBC + K-P AT 4.2 GEV 11/77
M+ H INCLUDES DATA OF HOLMGREN 77
M+ 2594 1385. 3. HOLMGREN 77 HBC + K-P AT 4.2 GEV 11/77
M+ 6900 1381.9 0.3 CAMERON 78 HBC + K-P 0.96-1.36GEV 11/77
M+ I 7K(1381.) (2.) BAUBILLIE 79 HBC + K-P AT 8.25 GEV 1/80*
M+ 2K(1391.) (2.) GAUTIS 79 HYBR + PI+K-P 11.5 GEV 1/80*
M+ I 100(1390.) (2.) SUGAHARA 79 HBC + PI-P AT 6 GEV/C 1/80*
M+
M+ I FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM
M+ E ERROR ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE ON K* MASS.
M+ AVG 1382.29 0.39 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
M+ STUDENT1382.20 0.31 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 1382.29 ± 0.39
ERROR SCALED BY 1.6



M- 93(1382.0) (3.0) DAHL 61 DBC - K-D 0.45 BEV/C 11/77
M- E 224(1376.0) (4.4) ELY 61 HLBC - K-P 1.11 BEV/C 11/77
M- E 200(1392.0) (6.2) COOPER 64 HBC - K-P 1.45 BEV/C 11/77
M- E 1086 1385.3 1.9 HUME 64 HBC - K-P 1.15-1.30GEV 11/77
M- 1380 1384.0 1.0 ARMENTERO 65 HBC - K-P 9-1.2 BEV/C
M- E 120(1391.5) (2.6) SMITH 65 HBC - K-P 1.8 BEV/C 11/77
M- E 58(1399.8) (5.2) SMITH 65 HBC - K-P 1.95 BEV/C 11/77
M- 15(1389.0) (9.0) LONDON 66 HBC - K-P AT 2.24 GEV 11/77
M- 370 1390.7 2.0 SIEGEL 67 HBC - K-P AT 2.1 GEV/C 10/69
M- 1900 1390.7 1.2 HABIBI 73 HBC - K-P TO 2PI LAM 9/73
M- E 630 1387.1 1.9 THOMAS 73 HBC - PI-P TO PI+K+L 11/77
M- R 3060(1389.) (1.) BERTHON 74 HBC - K-P 1263-1843MEV 10/74
M- R ERRORS STATISTICAL ONLY. RESOLUTION NOT UNFOLDED.
M- I 2303 1383. 2. BORENSTE 74 HBC - K-P TO(1385)+PIS 10/74
M- I (1383.) (2.) BARBADIN 75 HBC - K-P 14.3 GEV/C 11/77
M- HI 12K(1387.) (3.) BARREIRO 77 HBC - K-P AT 4.2 GEV 11/77
M- H INCLUDES DATA OF HOLMGREN 77
M- 193 1391. 3. HOLMGREN 77 HBC - K-P AT 4.2 GEV 11/77
M- 9720 1387.6 0.3 CAMERON 78 HBC - K-P 0.96-1.36GEV 11/77
M- I 4.5K(1383.) (1.) BAUBILLIE 79 HBC - K-P AT 8.25 GEV 1/80*
M- I 150(1380.) (6.) SUGAHARA 79 HBC - PI-P AT 6 GEV/C 1/80*
M-
M- I FROM FIT TO INCLUSIVE LAMBDA PI SPECTRUM
M- E ERROR ENLARGED BY US TO GAMMA/SQRT(N). SEE TYPED NOTE ON K* MASS.
M- AVG 1387.44 0.58 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 2.2)
M- STUDENT1387.53 0.31 AVERAGE USING STUDENT10(H/1.1) -- SEE MAIN TEXT (SEE IDEOGRAM BELOW)

Baryons
Σ(1385)

Data Card Listings

For notation, see key at front of Listings.

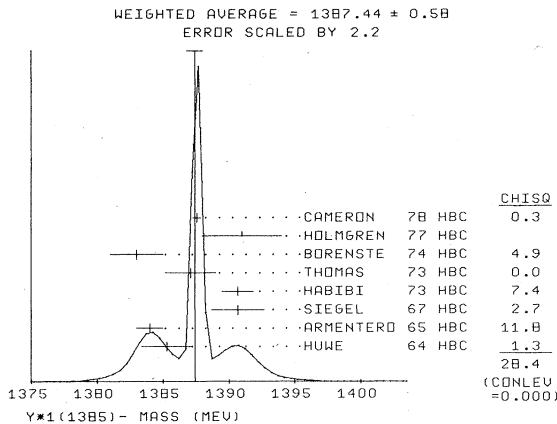


Table listing mass differences for Σ(1385) baryons. Columns include particle codes (D+, D-, etc.), mass values, baryon names (ELY, COOPER, HUWE, etc.), and their masses in BEV/C. A note at the bottom states 'REDUNDANT WITH DATA IN MASS LISTINGS'.

Table listing mass differences for Σ(1385) baryons, similar to the previous table but with different mass values and baryon names.

Table listing mass differences for Σ(1385) baryons, including a note 'REDUNDANT WITH DATA IN MASS LISTINGS'.

Table listing widths for Σ(1385) baryons. Columns include particle codes, width values, baryon names, and their widths in BEV/C. A note at the bottom states 'REDUNDANT WITH DATA IN MASS LISTINGS'.

Table listing branching ratios for Σ(1385) baryons. Columns include particle codes, branching ratio values, baryon names, and their masses in BEV/C. A note at the bottom states 'REDUNDANT WITH DATA IN MASS LISTINGS'.

Table listing mass differences for Σ(1385) baryons, including a note 'REDUNDANT WITH DATA IN MASS LISTINGS'.

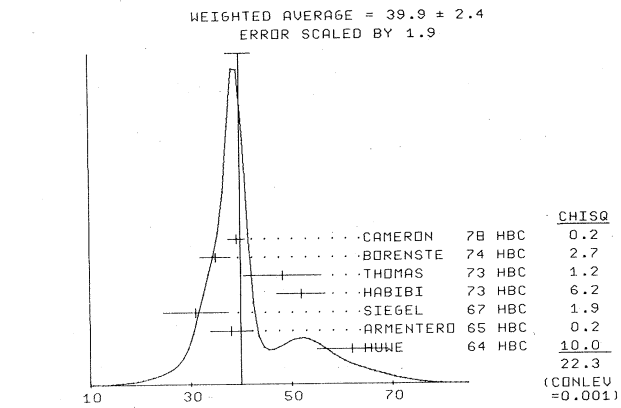


Table listing real parts of pole positions for Σ(1385) baryons. Columns include particle codes, real part values, baryon names, and their widths in BEV/C.

Table listing imaginary parts of pole positions for Σ(1385) baryons. Columns include particle codes, imaginary part values, baryon names, and their widths in BEV/C.

Table listing partial decay modes for Σ(1385) baryons. Columns include particle codes, decay modes, and their widths in BEV/C.

Table listing branching ratios for Σ(1385) baryons, including a note 'REDUNDANT WITH DATA IN MASS LISTINGS'.

Data Card Listings

For notation, see key at front of Listings.

Baryons

Σ(1385), Σ(1480), Σ(1560), Σ(1580)

REFERENCES FOR Y*(1385)
ALSTCN 60 PRL 5 520
BASTIEN 61 PRL 6 702
BERGE 61 PRL 6 557
DAHL 61 PRL 6 142
ELY 61 PRL 7 461
MARTIN 61 PRL 6 283
ALSTON 62 CERN CONF 311
COLLEY 62 PR 128 1930
CURTIS 63 PR 132 1771
COOPER 64 PL 8 365
HUME 64 UGRL-11291 THESIS
ALSO 69 PR 180 1824
ARMENTEROS 65 PL 19 75
BALTAY 65 PR 140 B1027
MUSGRAVE 65 NC 35 735
SMITH 65 THESIS (UCLA)
BIRMINGHAM 66 PR 152 1148
LONDON 66 PR 143 1034
SIEGEL 67 UGRL 18041 THESIS
PAN 69 PRL 23 808
AGUILAR 70 PRL 25 58
ATHERTON 71 NP B29 477
COLLEY 71 NP B31 61
AGUILAR 72 PR D6 29
MEISNER 72 NC 12A 62
AMMANN 73 NP B91 330
MAST 73 PRD 7 3212
ALSO 73 PRD 7 5
HABIBI 73 NEVIS 1991 THESIS
ALSO 73 PURD73, PG. 387
THOMAS 73 NP B56 15
BERTHON 74 NC 21A 146
BORENSTEIN 74 PR D9 3006
DEVENISH 74 NP B81 330
LICHTENB 74 PRD 10 3865
ALSO 74 PRIV. COMM.
ATHERTON 75 NC 25A 1
BARDADIN 75 NP B98 418
COLAS 75 NP B91 253
BARREIRO 77 NP B126 319
HCLMGTREN 77 NP B119 261
ALSTON 78 PR D18 182
CAMERON 78 NP B143 189
DICINSI 78 PL 788 154
BANERJEE 79 ZPHY C3 1
BAUBILLIER 79 NP B148 18
CAUTIS 79 NP B156 507
SUGAHARA 79 NP B156 237
MALAMUD 64 PL 10 145
SHAFFER 64 PR 134 B1372
HUNGERBU 74 PRD 10 2051

Σ(1480) BUMPS

23 Y*(1480, JP=) I=1 PRODUCTION EXPERIMENTS
SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.
PEAKS ARE SEEN IN LAMBDA PI AND SIGMA PI SPECTRA IN THE REACTION PI+P TO K+ PI Y AT 1.7 GEV/C. ALSO THE Y POLARIZATION OSCILLATES IN THE SAME REGION.

SEE MILLER 70 FOR A DISCUSSION OF THIS STATE. HE SUGGESTS A POSSIBLE ALTERNATE EXPLANATION IN TERMS OF A REFLECTION OF N*1/2(1670) DECAY TO LAMBDA K. HOWEVER, SUCH AN EXPLANATION FOR THE K+ SIGMA+ P10 CHANNEL SEEMS UNLIKELY (SEE PAN 73) IN TERMS OF KNOWN N*3/2(1690) DECAY INTO SIGMA K. IN ADDITION SUCH REFLECTIONS WOULD ALSO HAVE TO ACCOUNT FOR THE OSCILLATION OF THE Y POLARIZATION IN THE 1480 MASS REGION.

HANSON 71, WITH FEWER DATA THAN PAN 70, CAN NEITHER CONFIRM NOR DENY THE EXISTENCE OF THIS STATE. MAST 75 SEES NO STRUCTURE IN THIS MASS REGION IN K- P TO LAMBDA P10.

Table with 4 columns: M, L, C, and values. Row 1: M 1479, L 10, C PAN 70 HBC + PI+P TO K PI LAM 3/71. Row 2: M 1465, L 15, C PAN 70 HBC + PI+P TO K PI SIG 3/71. Row 3: M 1485, L 10, C CLINE 73 MPWA K- D TO LM PI- P 9/73. Row 4: M AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Table with 4 columns: W, L, C, and values. Row 1: W 31, L 15, C PAN 70 HBC + PI+P TO K PI LAM 3/71. Row 2: W 30, L 20, C PAN 70 HBC + PI+P TO K PI SIG 3/71. Row 3: W 40, L 20, C CLINE 73 MPWA K- D TO LM PI- P 9/73. Row 4: W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Table with 4 columns: P1, P2, P3, and values. Row 1: P1 Y*(1480) INTO KBAR N 497+ 939. Row 2: P2 Y*(1480) INTO LAMBDA P1 1115+ 139. Row 3: P3 Y*(1480) INTO SIGMA PI 1189+ 139

Table with 4 columns: R1, R2, and values. Row 1: R1 Y*(1480) INTO (SIGMA PI)/(LAMBDA PI) (P3)/(P2) 0.82 0.51 PAN 70 HBC + 3/71. Row 2: R2 Y*(1480) INTO (PROTON KOBAR)/(LAMBDA PI) (P1)/(P2) 0.36 0.25 PAN 70 HBC + 3/71

R3 Y*(1480) INTO KBAR N (P1) 9/73
R3 SMALL CLINE 73 MPWA K- D TO LM PI- P 9/73

REFERENCES FOR Y*(1480) (PROD. EXP.)
PAN 70 PR D2, 49 +FORMAN,KO,HAGOPIAN,SELOVE (PENN)
CLINE 73 LNC 6 205 CLINE,LAUMANN,MAPP (WISCONSIN)JP
PAPERS NOT REFERRED TO IN DATA CARDS
YU-LI PA 69 PRL 23 806 YU-LI PAN, F L FORMAN (PENN) I
YU-LI PA 69 PRL 23 808 YU-LI PAN, F L FORMAN (PENN) I
MILLER 70 DUKE 229 D H MILLER (REVIEW TALK) (PURDUE)
HANSON 71 PR D4 1296 +KALMUS,LOUIE (LBL) I
MAST 75 PRD 11 3078 +ALSTON-GARNJOST, BANGERTER+ (LBL)

Σ(1560) BUMPS
80 Y*(1560, JP=) I=1 PRODUCTION EXPERIMENTS
THIS ENTRY LISTS PEAKS REPORTED IN MASS SPECTRA AROUND 1560 MEV WITHOUT IMPLYING THAT THEY ARE NECESSARILY RELATED.
DIONISI 78 OBSERVE A 6 STD. DEV. ENHANCEMENT AT 1553 MEV IN THE CHARGED (LAMBDA/SIGMA PI) MASS SPECTRA FROM K-P --> LAMBDA/SIGMA PI K BAR AT 4.2 GEV/C. IN A CERN ISR EXPERIMENT, LOCKMAN 78 REPORT A NARROW 6 STD. DEV. ENHANCEMENT AT 1572 MEV IN THE LAMBDA PI+PI- SYSTEMS FROM THE REACTION PP --> LAMBDA PI+ PI- + ANYTHING AT C.M. ENERGIES OF 53 AND 62 GEV. THESE ENHANCEMENTS ARE UNLIKELY TO BE ASSOCIATED WITH THE Y*(1580) (WHICH HAS NOT BEEN CONFIRMED BY SEVERAL RECENT EXPERIMENTS - SEE THE DATA CARD LISTINGS BELOW).
CARROLL 76 OBSERVE A BUMP AT 1550 MEV (AS WELL AS AT 1580 MEV) IN THE K-N I=1 TOTAL CROSS SECTION, BUT UNCERTAINTIES IN CROSS SECTION MEASUREMENTS OUTSIDE THE MASS RANGE OF THE EXPERIMENT PRECLUDE ESTIMATING ITS SIGNIFICANCE. IN NEED OF CONFIRMATION. OMITTED FROM TABLES.

Table with 4 columns: M, L, C, and values. Row 1: M 121 1553, L 7, C DIONISI 78 HBC +- K-P TO Y* K BAR 3/79*. Row 2: M 40 1572, L 4, C LOCKMAN 78 SPEC +- PP TO L PI PI X 12/79*. Row 3: M AVERAGE MEANINGLESS (SCALE FACTOR = 2.4)

Table with 4 columns: W, L, C, and values. Row 1: W 121 79, L 30, C DIONISI 78 HBC +- K-P TO Y* K BAR 3/79*. Row 2: W 40 15, L 6, C LOCKMAN 78 SPEC +- PP TO L PI PI X 12/79*. Row 3: W C OBSERVED WIDTH CONSISTENT WITH EXPERIMENTAL RESOLUTION. Row 4: W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Table with 4 columns: P1, P2, and values. Row 1: P1 Y*(1560) INTO LAMBDA PI 1115+ 139. Row 2: P2 Y*(1560) INTO SIGMA PI 1197+ 139

Table with 4 columns: R1, R2, and values. Row 1: R1 Y*(1560) INTO SIGMA PI/(SIGMA PI + LAMBDA PI) (P2)/(P1+P2) 0.35 0.12 DIONISI 78 HBC +- K-P TO Y* K BAR 3/79*. Row 2: R2 Y*(1560) INTO LAMBDA PI (P1) SEEN LOCKMAN 78 SPEC +- PP TO L PI PI X 12/79*

REFERENCES FOR Y*(1560) (PROD. EXP.)
DIONISI 78 PL 78B 154 +ARMENTEROS,DIAZ+ (CERN+AMST+NIJH+OXF)I
LOCKMAN 78 CEN DPHE 78-01 +MEYER,RANDER,POSTER,SCHLEIN+ (UCLA+SACL)

PAPERS NOT REFERRED TO IN DATA CARDS
CARROLL 76 PRL 37 806 +CHIANG,KYCIA,LI,MAZUR,MICHAEL+ (BNL)I

Σ(1580) D13
00 Y*(1580, JP=3/2-) I=1 4/75
OBSERVED IN K- N I=1 TOTAL CS WITHOUT JP ASSIGNMENT AT BNL(LI 73, CARROLL 73, CARROLL 76) AND IN PWA OF K- P --> LAMBDA PI FOR CM ENERGIES=1560-1600 MEV BY LITCHFIELD 74. LITCHFIELD 74 FINDS JP=3/2-. NOT SEEN B ENGLER 78 OR BY CAMERON 78 (WITH LARGER STATISTICS), IN KLONG P TO PI+ LAMBDA AND PI+ SIGMA0.

Table with 4 columns: M, L, C, and values. Row 1: M L 1582, L 4, C LITCHFIELD 74 DPWA 0 K- P TO LAM PI 4/75. Row 2: M C 1583, L 4, C CARROLL 76 DPWA I=1 TOTAL CS 2/77

Table with 4 columns: W, L, C, and values. Row 1: W L 11, L 4, C LITCHFIELD 74 DPWA 0 K- P TO LAM PI 4/75. Row 2: W C (15.) 4, C CARROLL 76 DPWA I=1 TOTAL CS 2/77

Baryons

$\Sigma(1580)$, $\Sigma(1620)$

For notation, see key at front of Listings.

00 Y*1(1580) PARTIAL DECAY MODES 4/75

P1	Y*1(1580) INTO KBAR N	497+ 939
P2	Y*1(1580) INTO LAMBDA PI	1115+ 139
P3	Y*1(1580) INTO SIGMA PI	1197+ 139

00 Y*1(1580) BRANCHING RATIOS 4/75

R1	Y*1(1580) INTO KBAR N/TOTAL	(P1)	4/75	
R1 L	+0.03	.01	LITCHFIELD 74 DPWA KBAR N MULTICHNL	4/75
R1 L	MAIN EFFECT OBSERVED BY LITCHFIELD 74 IS IN PI LAMBDA FINAL STATE, 4/75			
R1 L	KBAR N AND SIGMA PI COUPLINGS ALSO ESTIMATED FROM MULTICHANNEL FIT 4/75			
R1 L	INCLUDING TOTAL CROSS SECTION DATA (LI 73). 4/75			
R1 C	TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.06 SEEN BY CARROLL 76 2/77			
R2	Y*1(1580) FROM KBAR N TO LAMBDA PI	SQRT(P1*P2)	4/75	
R2 L	+0.10	.02	LITCHFIELD 74 DPWA 0 K- P TO LAM PI	4/75
R2	NOT SEEN	CAMERON 78 HBC + KL P TO P1+ LAM	1/78	
R2	NOT SEEN	ENGLER 78 HBC + KL P TO P1+ LAM	2/77	
R3	Y*1(1580) FROM KBAR N TO SIGMA PI	SQRT(P1*P3)	4/75	
R3 L	+0.03	.04	LITCHFIELD 74 DPWA KBAR N MULTICHNL	4/75
R3	NOT SEEN	CAMERON 78 HBC + KL P TO P1+ SIGMA	1/78	
R3	NOT SEEN	ENGLER 78 HBC + KL P TO P1+ SIGMA	2/77	

REFERENCES FOR Y*1(1580)

LITCHFIELD 74 PL 518 509	LITCHFIELD	(GERNIJJP)
CARROLL 76 PRL 37 806	+CHIANG,KYCIA,LI,MAZUR,MICHAEL+	(BNLII)
ENGLER 76 PL 638 231	+KEYES,KRAEMER,SCHLERETH,TANAKA+	(CARN,ANL)I
CAMERON 78 NP B132 189	+CAPILUPPI+ (BGNA+EDIN+GLAS+PISA+RHEL)I	
ENGLER 78 PR D18 3061	+KEYES,KRAEMER,TANAKA,CHD,+	(CARN,ANL)

PAPERS NOT REFERRED TO IN DATA CARDS

CARROLL 73 APS BRKLY MTG 208	CARROLL,CHIANG,KYCIA,LI,MAZUR,MICHAEL+(BNL)I
LI 73 PURDUE CONF. 283	LI (BNL)I

Note on $\Sigma(1620)$

This state was first suggested by the BNL-CCNY collaboration (CRENNELL 68) who presented evidence for it in the reaction $K^- n \rightarrow \Sigma(1620)^\pm \pi^\mp \pi^-$ with $\Sigma(1620)^\pm$ decaying into $\Lambda\pi^\pm$. Since then there have been conflicting reports about this state (or states).

Total Cross-Section Experiment

A measurement of the $K^- p$ and $K^- d$ total cross sections in the 0.4 to 1.1 GeV/c range has been reported by the BNL group (CARROLL 76). Three narrow (10-15 MeV wide) bumps in the $I=1$ $K^- N$ cross section are seen at 1583, 1608, and 1633 MeV.

Formation Experiments

There is evidence from several partial-wave analyses for one or two fairly narrow states within ~50 MeV of the effect seen in production; see the entries for $\Sigma(1580,3/2^-)$, $\Sigma(1620,1/2^-)$, and $\Sigma(1660,1/2^+)$. Note however that the various analyses do not agree on the widths and branching ratios of these states.

Production Experiments

A good review of the production experiments has been given by MILLER 70. There has been no new evidence from production experiments since 1970. The existing evidence is only in the $\Lambda\pi$ channel. The BNL-CCNY collaboration (CRENNELL 69) claimed

the effect in the $\Lambda\pi$ channel with no evidence seen in $\bar{K}N$ or $\bar{K}N\pi$. SABRE 70 studied the same reaction at 3.0 GeV/c with comparable statistics and did not see any evidence for it in the $\Lambda\pi$ channel; on the contrary, they believed it to be a spurious peak resulting from misidentified Σ^0 from the production of $\Sigma(1670)$ decaying into $\Sigma^0\pi^+$. AMMANN 70 studied the same reaction at 4.5 GeV/c and reported a state at 1640 MeV, again decaying only into $\Lambda\pi$ (no evidence seen in $\Sigma\pi$ or $\bar{K}N$ channels). Upper limits on production cross sections for a 25 GeV/c Σ^- beam are reported by HUNGERBUHLER 74.

In conclusion, for understanding of the $\Sigma(1620)$ we probably have to wait for more data and for a more complete understanding of the entire mass region from 1600 to 1700 MeV. The closeness of the $\Sigma(1620)$ mass to 1670 MeV is suggestive that this effect may be related to what goes on in that region (see the "Note on $\Sigma(1670)$ " below).

$\Sigma(1620)$

S₁₁

32 Y*1(1620, JP=1/2-) I=1

THE S₁₁ STATE AT 1697 MEV REPORTED BY VANHORN 75 IS INTERMEDIATE IN MASS BETWEEN THE SIGMA(1620) AND SIGMA(1750). WE TENTATIVELY LIST IT UNDER SIGMA(1750). CARROLL 76 SEES TWO BUMPS IN THE I=1 TOTAL CROSS SECTIONS NEAR THIS MASS.

32 Y*1(1620) MASS (MEV)

M	(1620.)		KIM	71 DPWA	K-MATRIX ANAL.	3/71	
M	1630.0	(10.0)	LANGBEIN	72 IPWA	MULTICHANNEL	12/72	
M	L 1608.	5.	CARROLL	76 DPWA	I=1 TOTAL CS	2/77	
M	H 1633.	10.	CARROLL	76 DPWA	I=1 TOTAL CS	2/77	
M	1 (1600.0)	(6.0)	MORRIS	78 DPWA -	K- N TO LAM PI-	3/79*	
M	1	AN EQUALLY GOOD FIT IS OBTAINED WITHOUT INCLUDING THIS RESONANCE.					3/79*
M	AVG	1613.0	10.0	AVERAGE [ERROR INCLUDES SCALE FACTOR OF 2.2]			
M	STUDENT	1612.1	5.6	AVERAGE USING STUDENT(10/1,11) -- SEE MAIN TEXT			

32 Y*1(1620) WIDTH (MEV)

W	(40.)		KIM	71 DPWA	K-MATRIX ANAL.	3/71
W	L 65.0	(20.0)	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
W	H (15.)		CARROLL	76 DPWA	I=1 TOTAL CS	2/77
W	1 (10.)		CARROLL	76 DPWA	I=1 TOTAL CS	2/77
W	1 (87.0)	(19.0)	MORRIS	78 DPWA -	K- N TO LAM PI-	3/79*

32 Y*1(1620) PARTIAL DECAY MODES

P1	Y*1(1620) INTO KBAR N	497+ 939
P2	Y*1(1620) INTO SIGMA PI	1197+ 139
P3	Y*1(1620) INTO LAMBDA PI	1115+ 134

32 Y*1(1620) BRANCHING RATIOS

R1	Y*1(1620) INTO KBAR N	(P1)	3/71			
R1	(0.05)	KIM	71 DPWA	K-MATRIX ANAL.	3/71	
R1 A	0.05	OR LESS	WONG	71 DPWA	K-+P--LAM+PI	10/71
R1	0.22	(0.02)	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
R1 L	TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.06 SEEN BY CARROLL 76 2/77					
R1 H	TOTAL CROSS SECTION BUMP WITH (J+1/2)X=.04 SEEN BY CARROLL 76 2/77					
R1 A	K-MATRIX FIT(NEGLECTS 3-BODY CHANNELS) REQUIRES NO RESONANCE 10/71					
R2	Y*1(1620) FROM KBAR N TO SIGMA PI	SQRT(P1*P2)	3/71			
R2	(0.08)	KIM	71 DPWA	K-MATRIX ANAL.	3/71	
R2	0.40	(0.06)	LANGBEIN	72 IPWA	MULTICHANNEL	12/72
R2	NOT SEEN	HEPP2	76 DPWA -0	K- NUC TO SIG PI	2/77	
R3	Y*1(1620) FROM KBAR N TO LAMBDA PI	SQRT(P1*P3)	3/71			
R3	(0.15)	KIM	71 DPWA	K-MATRIX ANAL.	3/71	
R3	NOT SEEN	BAILLON	75 IPWA	KBAR N TO LAM PI	11/75	
R3 1	(0.12)	(0.02)	MORRIS	78 DPWA -	K- N TO LAM PI-	3/79*

Data Card Listings

For notation, see key at front of Listings.

Baryons
Sigma(1620), Sigma(1660)

REFERENCES FOR Y*(1620)

KIM 71 PRL 27 356 J K KIM (HARV)IJP
ALSO 70 DUKE 161 J. K. KIM (HARV)IJP
WONG 71 NC 2A 353 N S WONG (YALE)IJP
LANGBEIN 72 NP B47 477 *WAGNER (MPIM)IJP
BAILLON 75 NP B94 39 P. BAILLON, P. J. LITCHFIELD (CERN,RHEL)IJP
CARROLL 76 PRL 37 806 *CHIANG, KYCIA, LI, MAZUR, MICHAEL (BNL)I
HEPP2 76 PL 658 487 *BRAUN, GRIMM, STROBELE, THOL+ (CERN, HEID, MPIM)IJP
MORRIS 78 PR D17 55 *ALBRIGHT, COLLERAINE, KIMEL, LANNOTTI (FSU)IJP

PAPERS NOT REFERRED TO IN DATA CARDS

VANHORN 75 NP B87 145 A. J. VAN HORN (LBL)IJP
ALSO 75 NP B87 157 A. J. VAN HORN (LBL)IJP

1620 MEV REGION - PRODUCTION EXPERIMENTS

78 Y*(1620, JP=) I=1 PRODUCTION EXPERIMENTS
SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.

THIS RESONANCE NEEDS CONFIRMATION. THE RESULTS OF CRENNELL 69 AT 3.9 GEV/C ARE NOT CONFIRMED BY THE SABRE COLLABORATION AT 3.0 GEV/C (SABRE 70). HOWEVER IN AN EXPERIMENT AT 4.5 GEV/C, AMMANN 70 SEE A PEAK AT 1642 MEV WHICH ON THE BASIS OF BRANCHING RATIOS THEY DO NOT ASSOCIATE WITH THE Y*(1620). SEE MILLER 70 FOR A REVIEW OF THESE CONFLICTS.

78 Y*(1620) MASS (MEV) (PROD. EXP.)

Table with columns M, N, mass values, and references. Includes entries for CRENNELL 68 DBC, BLUMENFEL 69 HBC, and AMMANN 70 DBC.

78 Y*(1620) WIDTH (MEV) (PROD. EXP.)

Table with columns W, N, width values, and references. Includes entries for CRENNELL 68 DBC, BLUMENFEL 69 HBC, and AMMANN 70 DBC.

78 Y*(1620) PARTIAL DECAY MODES (PROD. EXP.)

Table with columns P1, P2, P3, P4, P5, P6 and decay mode descriptions. Includes entries for INTO KBAR N, INTO LAMBDA PI, INTO Y*(1385) PI, INTO LAMBDA PI PI, INTO SIGMA PI, and INTO Y*(1405) PI.

78 Y*(1620) BRANCHING RATIOS (PROD. EXP.)

Table with columns R1, R2, R3, R4, R5, R6 and branching ratio descriptions. Includes entries for INTO (LAMBDA PI)/(LAMBDA PI), INTO (KBAR N)/(LAMBDA PI), INTO LAMBDA PI, INTO Y*(1385) PI, INTO (SIGMA PI)/(LAMBDA PI), and INTO Y*(1405) PI.

REFERENCES FOR Y*(1620) (PROD. EXP.)

CRENNELL 68 PRL 21 648 *DELANEY, FLAMINIO, KARSHON, + (BNL,CUNY) I
BLUMENFEL 69 PL 298 58 *BLUMENFELD, KALBFLEISCH (BNL) I
CRENNELL 69 LUND PAPER 183 *KARSHON, LAI, ONEIL, SCARR, + (BNL,CUNY) I
RESULTS ARE QUOTED IN LEVI SETTI 69.
AMMANN 70 PRL 24 327 *GARFINKEL, CARMONY, GUTAY, + (PURDUE,IND)
ALSO 73 PR D7 1345 AMMANN, CARMONY, GARFINKEL, (PURDUE)IJP
PAPERS NOT REFERRED TO IN DATA CARDS
ARMENTERO 68 NP B8 183 ARMENTEROS, BAILLON + (CERN,HEID+SACL)
LEVISETTI 69 LUND CONF R LEVI SETTI (RAPPORTEUR) EFINS
TRIPP 69 UCRL 19361 R D TRIPP (LRL)
ARMENTERO 70 DUKE 123 ARMENTEROS, BAILLON + (CERN,HEID+SACL)

MILLER 70 DUKE 229 D H MILLER (REVIEW TALK) (PURDUE)
SABRE 70 NP B16 201 SABRE COLLAB. (SACL,AMST,BGNA,REHO,EPL)
HUNGERBU 74 PR D10 2051 HUNGERBUHLER, MAJKA, + (YALE, FNAL, BNL, PITT)

Sigma(1660) 79 Y*(1660, JP=1/2+) I=1 P11
SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.

79 Y*(1660) MASS (MEV)

Table with columns M, N, mass values, and references. Includes entries for ARMENTERO 70 HDBC, KIM 71 DPWA, LEA 73 DPWA, HART 73 DPWA, BAILLON 75 IPWA, VANHORN 75 DPWA, MARTIN 77 DPWA, and ALSTON 78 DPWA.

79 Y*(1660) WIDTH (MEV)

Table with columns W, N, width values, and references. Includes entries for ARMENTERO 70 HDBC, KIM 71 DPWA, LEA 73 DPWA, HART 73 DPWA, BAILLON 75 IPWA, VANHORN 75 DPWA, MARTIN 77 DPWA, and ALSTON 78 DPWA.

79 Y*(1660) PARTIAL DECAY MODES

Table with columns P1, P2, P3 and decay mode descriptions. Includes entries for INTO KBAR N, INTO SIGMA PI, and INTO LAMBDA PI.

79 Y*(1660) BRANCHING RATIOS

Table with columns R1, R2, R3, R4, R5, R6 and branching ratio descriptions. Includes entries for FROM KBAR N TO SIGMA PI, FROM KBAR N TO LAMBDA PI, and FROM KBAR N TO SIGMA PI.

REFERENCES FOR Y*(1660)

ARMENTERO 70 DUKE 123 ARMENTEROS, BAILLON, + (CERN,HEIDEL)IJP
KIM 71 PRL 27 356 J K KIM (HARV)IJP
ALSO 70 DUKE 161 J. K. KIM (HARV)IJP
HART 73 PURDUE CONF. 311 *RICE, BACA STOW, FUNG, + (TENN+UCR+MASA+BUFF)IJP
LEA 73 NP B56 77 *MARTIN, MOORHOUSE+ (RHEL+LOUC+GLAS+ARHUS)IJP
BAILLON 75 NP B94 39 P. BAILLON, P. J. LITCHFIELD (CERN,RHEL)IJP
PCNTE 75 PR D 12 2597 *HERTZBACH, BUTTON-SHAFER+ (MASA+TENN+UCR)IJP
VANHORN 75 NP B87 145 A. J. VAN HORN (LBL)IJP
ALSO 75 NP B87 157 A. J. VAN HORN (LBL)IJP
HEPP2 76 PL 658 487 *BRAUN, GRIMM, STROBELE, THOL+ (CERN,HEID, MPIM)IJP
MARTIN 77 NP B127 349 MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS)IJP
ALSO 77 NP B126 266 MARTIN, PIDCOCK (LOUC)
ALSO 77 NP B126 285 MARTIN, PIDCOCK (LOUC)IJP
RLIC 77 NP B119 362 GOPAL, ROSS-VAN HORN, MCPHERSON+ (LOIC+HHEL)IJP
ALSTON 78 PR D18 182 *KENNEY, POLLARD, ROSS+ (LBL+MTHO+CERN)IJP
ALSO 77 PRL 38 1007 ALSTON-GARNJOST, KENNEY (LBL+MTHO+CERN)IJP

Baryons
Σ(1670)

Data Card Listings

For notation, see key at front of Listings.

Note on Σ(1670)

Production Experiments

The measured Σπ/Σππ branching ratio for produced Σ(1670)'s is strongly dependent on momentum transfer. This was first discovered by EBERHARD 69, who suggested the existence of two Y*1's with the same mass and quantum numbers; one object with a large Σππ [mainly Λ(1405)π] decay mode produced peripherally, and another one with a large Σπ decay mode produced at larger angles. This observation has been confirmed by AGULLAR-BENITEZ 70, ASPPELL 74, ESTES 74, and TIMMERMANS 76. When determined, the most likely quantum numbers are 3/2- [for both Σπ and Λ(1405)π]. There is also the possibility of a third Y*1 state, referred to as Σ(1690) in the Data Card Listings, with a large Λπ/Σπ branching ratio and somewhat larger mass. The large branching ratio is the main justification for this hypothesis and needs confirmation. These problems have been reviewed by EBERHARD 73 and MILLER 70.

Formation Experiments

Two states are also observed near this mass in formation. One of these, the Σ(1670, 3/2-), has the same quantum numbers as those observed in production and a large Σπ/Σππ branching ratio. It may well correspond to the produced Σ(1670) seen at larger angles. (See TIMMERMANS 76 on this point.) The other state, the Σ(1660, 1/2+), has different quantum numbers from those seen in production, and its Σπ/Σππ branching ratio is unknown. Thus its relation to the produced Σ(1670) remains obscure. (See also the "Note on Σ(1620)" above.)

Σ(1670)

44 Y*(1670, JP=3/2-) I=1
SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.
WELL ESTABLISHED RESONANCE. IT HAS BEEN SEEN IN BOTH FORMATION AND PRODUCTION EXPERIMENTS.

D'13

SEE LISTING OF PRODUCTION EXPERIMENTS BELOW

Table with columns for mass (MEV), quantum numbers, and experimental references for Σ(1670) production experiments.

Table with columns for mass (MEV), quantum numbers, and experimental references for Σ(1670) formation experiments.

Table 44 Y*(1670) WIDTH (MEV) listing various decay channels and branching ratios.

Table 44 Y*(1670) PARTIAL DECAY MODES listing decay masses and associated parameters.

Table 44 Y*(1670) BRANCHING RATIOS listing ratios for various decay modes and experimental data.

Table 44 Y*(1670) MASS (MEV) listing masses and quantum numbers for various Σ(1670) states.

Data Card Listings

For notation, see key at front of Listings.

Baryons
Σ(1670)

REFERENCES FOR Y*(1670)

BERLEY 64 DUBNA CONF I 565 +CONNOLLY,HART,RAHM,STONEHILL, + (BNL)JJP
ARMENTER 68 NP 88 195 ARMENTEROS,BAILLON + (CERN+HEID+SACLAY)IJP
ARMENTE1 68 NP 88 182 ARMENTEROS,BAILLON + (CERN+HEID+SACLAY)IJP
ARMENTE2 68 NP 88 223 ARMENTEROS,BAILLON + (CERN+HEID+SACLAY)IJP
ARMENTE3 68 PL 280 521 ARMENTEROS,BAILLON + (CERN+HEID+SACLAY)I
SIMS 68 PRL 21 1413 SIMS,ALBRIGHT,BARTLEY,MEER+ (FSU,TUFT,BRAN)

PAPERS NOT REFERRED TO IN DATA CARDS

BASTIEN1 63 PRL 10 188 P L BASTIEN, J P BERGE (LRL) IJ
REPLACED BY BASTIEN 2, BUT SIMILAR AND MORE READILY AVAILABLE.
BASTIEN2 63 UCRL-16779 THESIS P L BASTIEN (LRL) IJ
T-ZADEH 63 PRL 11 470 TAHER-ZADEH,PROWSE,SCHLEIN,SLATER,+ (UCLA) JP
SEE NOTE FOLLOWING SCHLEIN 66.

Σ(1670) BUMPS

51 Y*(1670, JP=) I=1 PROD. AND CROSS SECT. EXPS.
SEE NOTE PRECEDING Y*(1670)
PROBABLY THERE ARE TWO STATES AT SAME MASS WITH SAME QUANTUM NUMBERS, ONE DECAYING INTO SIGMA PI AND LAMBDA PI, THE OTHER INTO Y*(1405) PI.

51 Y*(1670) MASS (MEV) (PROD. EXP.)

Table with columns for mass (mev), production experiment, and decay mode. Includes entries for Alexander, Alvarez, Bugg, etc.

51 Y*(1670) MASS (MEV) (PROD. EXP.)

Table with columns for mass (mev), production experiment, and decay mode. Includes entries for Alexander, Alvarez, Bugg, etc.

51 Y*(1670) PARTIAL DECAY MODES (PROD. EXP.)

Table with columns for decay mode, production experiment, and decay masses. Includes entries for Y*(1670) into Kbar N, Y*(1670) into Lambda Pi, etc.

51 Y*(1670) BRANCHING RATIOS (PROD. EXP.)

Large table of branching ratios for Y*(1670) decays. Columns include decay mode, production experiment, and branching ratio. Includes entries for Y*(1670) into Kbar N/(Sigma Pi), Y*(1670) into Lambda Pi/(Sigma Pi), etc.

51 Y*(1670) QUANTUM NUMBER DETERMINATION (PROD. EXP.)

Table of quantum number determination for Y*(1670). Columns include decay mode, production experiment, and quantum number determination. Includes entries for JP=3/2-, JP=3/2-, JP=3/2-.

REFERENCES FOR Y*(1670) (PROD. EXP.)

ALEXANDE 62 CERN CONF 320 ALEXANDER,JACOBS,KALBFLEISCH,MILLER,+ (LRL) I
ALVAREZ 63 PRL 10 184 +ALSTON,FERRO-LUZZI,HUWE,+ (LRL) I
SMITH 63 ATHENS CONF 67 G A SMITH (LRL) I
HUWE 64 PR 180 1824(1969) D O HUWE (LRL) I
EBERHARD 65 PRL 14 466 +SHIVELY,ROSS,SIEGAL,PI CENEC,+ (LRL,ILL) I

Baryons

$\Sigma(1690)$, $\Sigma(1750)$

$\Sigma(1690)$
BUMPS

58 Y*(1690, JP=) I=1 PRODUCTION EXPERIMENTS

SEE THE MINI-REVUE AT THE START OF THE Y* LISTINGS.

SEE NOTE PRECEDING Y*(1670) LISTINGS, SEEN IN PRG. EXPERIMENTS ONLY, MAIN DECAY MODE IS LAMBDA PI.

58 Y*(1690) MASS (MEV) (PROD. EXP.)

Table with columns for mass (MEV), production experiments, and decay modes. Includes entries for COLLEY, PRIMER, SIMS, ADERHOLZ, BLUMENFEL, MOTT, and GODDARD.

58 Y*(1690) WIDTH (MEV) (PROD. EXP.)

Table with columns for width (MEV), production experiments, and decay modes. Includes entries for COLLEY, PRIMER, SIMS, ADERHOLZ, BLUMENFEL, MOTT, and GODDARD.

58 Y*(1690) PARTIAL DECAY MODES (PROD. EXP.)

Table listing partial decay modes for Y*(1690) into various baryon and meson states.

58 Y*(1690) BRANCHING RATIOS (PROD. EXP.)

Table listing branching ratios for Y*(1690) decays into various channels.

REFERENCES FOR Y*(1690) (PROD. EXP.)

COLLEY 67 PL 248 499 (BIRM, GLAS, LOIC, MUNICH, OXFORD, RHEL) I
DERRICK 67 PRL 18 266 +FIELDS, LOKEN, AMMAR, (ARGONNE, NORTHWEST) I
REPLACED BY MOTT 69.
PRIMER 68 PRL 20 619 +GOLDBERG, JAEGER, BARNES, + (SYRACUSE, BNL) I
SIMS 68 PRL 21 1413 +ALBRIGHT, + (FSU, TUFTS, BRANDEIS) I
ADERHOLZ 69 NP 811 259 +BARTSCH, SCHULTE* (AACH+BERL+CEERN+CRAC+WARS) I
BLUMENFEL 69 PL 298 58 B J BLUMENFELD, G R KALBFLEISCH (BNL) I
MOTT 69 PR 177 1566 +AMMAR, DAVIS, KROPAC, +(NORTHWEST, ARGONNE) I
GODDARD 79 PR D19 1350 +KEY, LUSTE, PRENTICE, YOON, GORDON+ (TNTC+BNL) I
PAPERS NOT REFERRED TO IN DATA CARDS
AGUILAR 70 PRL 25 58 AGUILAR-BENI TEZ, BARNES, BASSANO+ (BNL+SYRA)
CCOPER 70 NP B23 605 +MANNER, MUSGRAVE, POLLARD, VOYVODIC (ANL) I

$\Sigma(1750)$

57 Y*(1750, JP=1/2-) I=1

S₁₁

THERE IS EVIDENCE FOR THIS STATE IN MANY PARTIAL-WAVE ANALYSES, BUT WITH RATHER WIDE VARIATIONS IN THE MASS, WIDTH AND COUPLINGS. THE LATEST ANALYSES INDICATED SIGNIFICANT COUPLINGS TO KBAR N AND LAMBDA PI, AS WELL AS SIGMA ETA WHOSE THRESHOLD IS NEARBY AT 1746 MEV (JONES 74).

57 Y*(1750) MASS (MEV)

Table with columns for mass (MEV), production experiments, and decay modes. Includes entries for CLINE, MEYER, ARMENBERG, CONFORTO, KIM, LANGBEIN, BAXTER, JONES, DEVENISH, and PREVOST.

Data Card Listings

For notation, see key at front of Listings.

Table listing data card entries for Y*(1690) decays, including production experiments and decay modes.

57 Y*(1750) WIDTH (MEV)

Table listing width (MEV) data for Y*(1750) decays.

57 Y*(1750) PARTIAL DECAY MODES

Table listing partial decay modes for Y*(1750) into various baryon and meson states.

57 Y*(1750) BRANCHING RATIOS

Table listing branching ratios for Y*(1750) decays into various channels.

Table listing data card entries for Y*(1750) decays, including production experiments and decay modes.

REFERENCES FOR Y*(1750)

CLINE 67 PL 258 41 CLINE, OLSSON (WISCONSIN) IJP
MEYER 67 HEIDELBERG C 117 J MEYER (RAPPORTEUR) (SACLAY) IJP
ARMENBERG 70 DUKE 123 ARMENBERG, BAILLON, + (CERN, HEIDEL) IJP
CONFORTO 71 NP 834 41 +LEVI SETTI, LASINSKI, OBERLACK+ (FEI+HEID) IJP
KIM 71 PRL 27 356 J K KIM (HARV) IJP
ALSO 70 DUKE 161 J. K. KIM (MPIM) IJP
LANGBEIN 72 NP 847 477 +WAGNER
BAXTER 73 NP 867 125 BAXTER, BUCKINGHAM, CORBETT, DUNN, + (OXFORD) IJP
CHU 74 NC 20A 35 CHU, BARTLEY, + (SUNY PLATTSBURG+TUFTS+BRAN) IJP
JONES 74 NP 873 141 JONES (U. CHICAGO) IJP
DEVENISH 74 NP 881 330 DEVENISH, FROGGATT, MARTIN (DESY, NORDITA, LUGO)
PREVOST 74 NP 869 246 PREVOST, BARLOUTAUD, + (SACL+CERN+HEID)

Data Card Listings

For notation, see key at front of Listings.

Baryons

Σ(1750), Σ(1765)

BELLEFON 76 NP B109 129
CARROLL 76 PRL 37 806
CAMERON 77 NP B131 399
MARTIN 77 NP B127 349
ALSO 77 NP B126 266
ALSO 77 NP B126 285
RLIC 77 NP B119 362
ALSTON 78 PR D18 182
ALSO 77 PRL 38 1007

FERRO-LU 66 BERKELEY CONF 183 M FERRO LUZZI (RAPPORTEUR) (CERN)
ARMENTER 68 NP B9 183 ARMENTEROS, BAILLON, + (CERN, HEIDEL, SACLAY) IJP
ARMENTER 69 LUND CONF PAPER ARMENTEROS, BAILLON, + (CERN, HEIDEL, SACLAY) IJP
HARRISON 70 FSU-HEP 70 3 1 W.C. HARRISON (THESIS) (FSU)

Σ(1765)

45 Y*(1765, JP=5/2-) I=1
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

D15

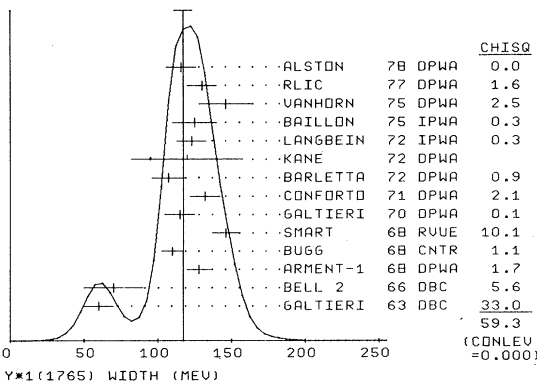
45 Y*(1765) MASS (MEV)

Table with columns for mass (MEV), width (MEV), and various decay channels and branching ratios for Σ(1765).

45 Y*(1765) WIDTH (MEV)

Table with columns for width (MEV), mass (MEV), and various decay channels and branching ratios for Σ(1765).

WEIGHTED AVERAGE = 117.4 ± 6.2
ERROR SCALED BY 2.2



45 Y*(1765) PARTIAL DECAY MODES

Table listing partial decay modes for Σ(1765) and their corresponding decay masses.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± δP_i, where δP_i = sqrt(δP_i δP_i), while the off-diagonal elements are the normalized correlation coefficients (δP_i δP_j) / (δP_i δP_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table showing fitted partial decay mode branching fractions for Σ(1765).

45 Y*(1765) BRANCHING RATIOS

ERRORS QUOTED BY EXPERIMENTERS DO NOT INCLUDE UNCERTAINTY DUE TO PARAMETRIZATION USED IN THE P.W.A. THEY SHOULD BE INCREASED.

Table listing branching ratios for Σ(1765) into various decay channels, including error bars and fit parameters.

WEIGHTED AVERAGE = 0.407 ± 0.016
ERROR SCALED BY 2.6

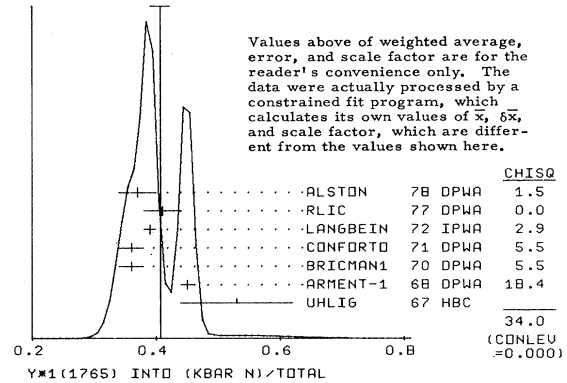


Table listing branching ratios for Σ(1765) from various decay channels, including error bars and fit parameters.

Baryons

$\Sigma(1765)$, $\Sigma(1770)$, $\Sigma(1840)$

Data Card Listings

For notation, see key at front of Listings.

R4 Y*1(1765) FROM KBAR N TO Y*1(1385) PI 0-WAVE SQRT(P1*P4)

R4 A (0.24) (0.03) ARMENT-2 67 HBC 0 K-P TO LAM PI 8/67

R4 S (0.32) (0.06) SIMS 68 DBC - K-N TO LAM PI 11/68

R4 S SIMS 68 USES ONLY CROSS-SECT. DATA. RESULT USED AS UPPER LIMIT ONLY 3/72

R4 +2.0 +.081OR +.02 PREVOST 74 DPWA 0 K-N TO S(1385)PI 10/74

R4 2 -184 +.011 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78

R4 2 CAMERON 78 UPPER LIMIT ON G-WAVE DECAY IS .03 1/78

R4 R4 R4 R4

R4 AVG MOD 0.1877 0.0096 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)

R4 STUDENT 0.188 0.011 AVERAGE USING STUDENT(100/1.11) -- SEE MAIN TEXT

R4 FIT 0.1884 0.0094 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R5 Y*1(1765) FROM KBAR N INTO SIGMA PI SQRT(P1*P5)

R5 +0.07 0.02 ARMENTERO 67 DPWA 0 K-P TO SIGMA PI 10/74

R5 +0.06 0.03 GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70

R5 (0.09) KIM 71 DPWA K-MATRIX ANAL. 3/71

R5 +0.074 0.017 KANE 72 DPWA 0 K-P TO PI SIG 10/71

R5 0.09 OR LESS LANGBEIN 72 IPWA MULTICHANNEL 12/72

R5 (+.081OR +.08 MARTIN 77 DPWA KBAR N MULTICHNL 11/77

R5 +.13 +.02 RLIC 77 DPWA KBAR N MULTICHNL 1/76

R5 R5 R5 R5

R5 AVG 0.086 0.015 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.5)

R5 STUDENT 0.082 0.013 AVERAGE USING STUDENT(100/1.11) -- SEE MAIN TEXT

R5 FIT 0.077 0.012 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.1)

R6 Y*1(1765) INTO (LAMBDA PI)/(KBAR N) (P2)/(P1)

R6 0.33 0.05 UHLIG 67 HBC 0 K-P, .9 GEV/C 9/66

R6 R6 R6 R6

R6 FIT 0.339 0.034 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)

R7 Y*1(1765) INTO (Y*0(1520)PI)/(KBAR N) (P3)/(P1)

R7 0.28 0.05 UHLIG 67 HBC 0 K-P, .9 GEV/C 9/66

R7 R7 R7 R7

R7 FIT 0.467 0.087 FROM FIT (ERROR INCLUDES SCALE FACTOR CF 3.2)

R8 Y*1(1765) INTO (Y*1(1385)PI)/(KBAR N) (P4)/(P1)

R8 0.25 0.09 UHLIG 67 HBC 0 K-P, .9 GEV/C 9/66

R8 R8 R8 R8

R8 FIT 0.208 0.025 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.2)

R9 Y*1(1765) INTO (SIGMA PI PI)/TOTAL (P7)

R9 P (0.12) ARMENT-2 68 HBC -0 K-N TO SIG PI 11/68

R9 P FOR ABOUT 3/4 OF THIS, THE SIGMA PI SYSTEM HAS I=0 AND IS ALMOST

R9 P ENTIRELY Y*0(1520). FOR THE OTHER 1/4, THE SIGMA PI HAS I=1. THIS

R9 P IS ABOUT WHAT IS EXPECTED FROM THE KNOWN RATE Y*1(1765) TO Y*1(1385)

R9 P PI, AS SEEN IN LAMBDA PI.

REFERENCES FOR Y*1(1765)

GALTIERI 63 PL 6 296 A BARBARO-GALTIERI, A HUSSAIN, RD TRIPP (LBL) J

ARMENTEROS 65 P 238 ARMENTEROS, + (CERN, HEIDELBERG, SACLAY) IJP

BELL 1 66 PRL 16 203 R B BELL, R W BERGE, Y-L PAN, R T PU (LBL) IJP

BELL 2 66 UCRL-16936 THESIS R B BELL (LBL) IJP

ARMENTER 67 PL 248 198 ARMENTEROS, FERRO-LUZZI+ (CERN, HEID, SACLAY) I

ARMENT-2 67 ZEIT. PHYS. 202 486 ARMENTEROS, FERRO-LUZZI+ (CERN, HEID, SACLAY)

UHLIG 67 PR 155 1448 +CHARLTON, CONDON, GLASSER, YODH+ (UMD, NRL)

ARMENT-1 68 NP 88 195 ARMENTEROS, BAILLON, + (CERN, HEIDEL, SACLAY) IJP

ARMENT-2 68 NP 88 216 ARMENTEROS, BAILLON, + (CERN, HEIDEL, SACLAY) I

BUGG 68 PR 168 1466 +GILMORE, KNIGHT, DAVIES+ (BIRM, CAVE, RHEL) I

SIMS 68 PRL 21 1413 SIMS, ALBRIGHT, BARTLEY, MEER+ (FSU, TUFT, BRAN)

SMART 68 PR 169 1330 W M SMART (LBL) IJP

BRICMAN 70 PL 338 511 +FERRO-LUZZI, LAGNAUX (CERN)

COOL 70 PR D1 1887 +GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL) I

GALTIERI 70 DUKE CCNF 173 A BARBARO-GALTIERI (LBL) IJP

CCNFCTO 71 NP 834 41 +LEVI SETTI, LASINSKI..OBERLACK++ (EFI+HEID) IJP

KIM 71 PRL 27 356 J K KIM (HARV) IJP

ALSO 70 DUKE 161 J. K. KIM (HARV) IJP

BARLETTA 72 NP 840 45 W.A. BARLETTA (EFI) IJP

KANE 72 PR 05 1583 D F KANE (LBL) IJP

BUGG 72 NP 847 477 +WAGNER (MPI) IJP

DEVENISH 74 NP 881 230 DEVENISH, FROGGATT, MARTIN (DESY, NORDITA, LEUC)

PREVOST 74 NP 869 246 PREVOST, BARLOTTAUD, + (SACL+CERN+HEID)

BAILLON 75 NP 894 39 P. BAILLON, P. J. LITCHFIELD (CERN, RHEL) IJP

VANHORN 75 NP 887 145 A. J. VAN HORN (LBL) IJP

ALSO 75 NP 887 157 A. J. VAN HORN (LBL) IJP

BELLEFON 76 NP 8109 129 DE BELLEFON, BERTHON (CDF) IJP

CAMERON 77 NP 8131 399 +FRANEK, GOPAL, KALMUS, MCPHERSON+ (RHEL+LOIC) IJP

MARTIN 77 NP 8127 349 MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS) IJP

ALSO 77 NP 8126 266 MARTIN, PIDCOCK (LOUC)

RLIC 77 NP 8119 362 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL) IJP

ALSTON 78 PR D18 182 +KENNEY, POLLARD, ROSS+ (LBL+MTHO+CERN) IJP

ALSO 77 PRL 38 1007 ALSTON-GARNUST, KENNEY (LBL+MTHO+CERN) IJP

CAMERON 78 NP 8143 189 +FRANEK, GOPAL, BACON, BUTTERWORTH+ (RHEL+LOIC) IJP

PAPERS NOT REFERRED TO IN DATA CARDS

FENSTER 66 PRL 17 841 +GELFAND, HARMSEN, L-SETTI, + (CHIC, ANL(CERN)) IJP

-- FENSTER 66 IS SUPERSEDED BY BARLETTA 72

CONFORTO 68 NP 88 265 +HARMSEN, LASINSKI, + (CHICAGO, HEIDEL) IJP

SUPERSEDED BY CONFORTO 71.

HARRISON 70 FSU-HEP 70 3 1 W.C. HARRISON (THISIS) (FSU)

PREVOST 71 AMSTERDAM CONF + CHS COLLABORATION (CERN+HEID+SACL)

$\Sigma(1770)$

100 Y*1(1770, JP=1/2+) I=1

P₁₁

100 Y*1(1770) MASS (MEV)

M (1772.0) KANE 72 DPWA K-P TO SIGMA PI 11/77

M 1 1770. 20. BAILLON 75 IPWA KBAR N TO PI LAM 11/75

M 1 FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2. 1/76

M 1738. 10. RLIC 77 DPWA KBAR N MULTICHNL 1/76

M M

M AVERAGE MEANINGLESS (SCALE FACTOR = 1.4)

100 Y*1(1770) WIDTH (MEV)

W (80.) KANE 72 DPWA K-P TO SIGMA PI 11/77

W 1 80. 30. BAILLON 75 IPWA KBAR N TO PI LAM 11/75

W 72. 10. RLIC 77 DPWA KBAR N MULTICHNL 1/76

W W

W AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

100 Y*1(1770) PARTIAL DECAY MODES

P1 Y*1(1770) INTO KBAR N 497+ 939

P2 Y*1(1770) INTO LAMBDA PI 115+ 139

P3 Y*1(1770) INTO SIGMA PI 1197+ 139

100 Y*1(1770) BRANCHING RATIOS

R1 Y*1(1770) FROM KBAR N INTO LAMBDA PI SQRT(P1*P2)

R1 1 -.08 .02 BAILLEN 75 IPWA KBAR N TO PI LAM 11/75

R1 LESS THAN .04 RLIC 77 DPWA KBAR N MULTICHNL 1/76

R2 Y*1(1770) INTO (KBAR N)/TOTAL (P1) 1/76

R2 -.14 .04 RLIC 77 DPWA KBAR N MULTICHNL 1/76

R3 Y*1(1770) FROM KBAR N INTO SIGMA PI SQRT(P1*P3)

R3 (-108) KANE 72 DPWA K-P TO SIGMA PI 11/77

R3 LESS THAN .04 RLIC 77 DPWA KBAR N MULTICHNL 1/76

REFERENCES FOR Y*1(1770)

KANE 72 PR 05 1583 D F KANE (LBL)

BAILLON 75 NP 894 39 P. BAILLON, P. J. LITCHFIELD (CERN, RHEL) IJP

RLIC 77 NP 8119 362 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL) IJP

$\Sigma(1840)$

01 Y*1(1840, JP=3/2+) I=1

P₁₃

SEE THE MINI-REVIEWS PRECEDING THE Y*0'S.

FOR THE TIME BEING, WE LIST ALL RESONANCE CLAIMS IN THE P13 WAVE IN THE 1700-1900 MEV MASS REGION TOGETHER UNDER THIS HEADING.

01 Y*1(1840) MASS (MEV)

M 1840.0 (10.0) LANGBEIN 72 IPWA MULTICHANNEL 12/72

M 1 (1720.) (30.) BAILLON 75 IPWA KBAR N TO LAM PI 11/75

M 1 FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2. 1/76

M 1925. (200.) VANHORN 75 DPWA 0 K-P TO LAM P10 11/75

M 2 1758. OR 1802. MARTIN 77 DPWA KBAR N MULTICHNL 11/77

M 2 THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE

M 2 PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.

01 Y*1(1840) WIDTH (MEV)

W 120.0 (10.0) LANGBEIN 72 IPWA MULTICHANNEL 12/72

W 1 (120.) (30.) BAILLON 75 IPWA KBAR N TO LAM PI 11/75

W 65. (50.) (20.) VANHORN 75 DPWA 0 K-P TO LAM P10 11/75

W 2 93. OR 93. MARTIN 77 DPWA KBAR N MULTICHNL 11/77

01 Y*1(1840) PARTIAL DECAY MODES

P1 Y*1(1840) INTO KBAR N 497+ 939

P2 Y*1(1840) INTO SIGMA PI 1197+ 139

P3 Y*1(1840) INTO LAMBDA PI 115+ 134

01 Y*1(1840) BRANCHING RATIOS

R1 Y*1(1840) INTO (KBAR N)/TOTAL (P1) 12/72

R1 0.37 (0.13) LANGBEIN 72 IPWA MULTICHANNEL 12/72

R1 (0.0)DR(0.0) MARTIN 77 DPWA KBAR N MULTICHNL 11/77

R2 Y*1(1840) FROM KBAR N INTO SIGMA PI SQRT(P1*P2)

R2 0.15 (0.04) LANGBEIN 72 IPWA MULTICHANNEL 12/72

R2 (-0.4)DR -0.4 MARTIN 77 DPWA KBAR N MULTICHNL 11/77

R3 Y*1(1840) FROM KBAR N INTO LAMBDA PI SQRT(P1*P3)

R3 0.20 (0.04) LANGBEIN 72 IPWA MULTICHANNEL 12/72

R3 +.122 -.078 DEVENISH 74 0 FIXED T DISP REL 4/75

R3 1 (+.11) (.02) BAILLON 75 IPWA KBAR N TO LAM P10 11/75

R3 +.06 (.04) VANHORN 75 DPWA 0 K-P TO LAM P10 11/75

R3 2 (+.03)DR +.03 MARTIN 77 DPWA KBAR N MULTICHNL 11/77

REFERENCES FOR Y*1(1840)

LANGBEIN 72 NP 847 477 +WAGNER (MPI) IJP

DEVENISH 74 NP 881 330 DEVENISH, FRGGGATT, MARTIN (DESY, NORDITA, LOUC)

BAILLON 75 NP 894 39 P. BAILLON, P. J. LITCHFIELD (CERN, RHEL) IJP

VANHORN 75 NP 887 145 A. J. VAN HORN (LBL) IJP

ALSO 75 NP 887 157 A. J. VAN HORN (LBL) IJP

MARTIN 77 NP 8127 349 MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS) IJP

ALSO 77 NP 8126 266 MARTIN, PIDCOCK (LOUC)

ALSO 77 NP 8126 285 MARTIN, PIDCOCK (LOUC) IJP

Data Card Listings

For notation, see key at front of Listings.

Baryons
Sigma(1880), Sigma(1915)

Sigma(1880)

67 Y*1(1880, JP=1/2+) I=1
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

P11

A RESONANCE IS SUGGESTED BY SEVERAL PARTIAL-WAVE ANALYSES ACROSS THIS REGION, BUT WITH WIDE VARIATIONS IN THE MASS AND OTHER PARAMETERS. WE LIST HERE ALL CLAIMS WHICH LIE WELL ABOVE THE Y*1(1770).

67 Y*1(1880) MASS (MEV)
M 1882.0 40.0 SMART 68 DPWA -0 K-N TO LAM PI 7/68
M (1850.0) BAILEY 69 DPWA 0 ELASTIC, CH EXCH 10/70
M ABOUT 1850.0 ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH 6/70
M 1550.0 50.0 GALTIERI 70 DPWA -0 K-N TO LAM PI 7/70
M 1920.0 30.0 LITCHFIE 70 DPWA -0 K-N TO LAM PI 6/70
M 2 (1990.0) LEA 73 DPWA MULTICHNL K-MTRX 9/73
M 2 ONLY UNCONSTRAINED STATES FROM TABLE 1 OF LEA73 ARE IN LISTINGS. 9/73
M 1 (1960.) (30.) BAILLON 75 IPWA KBAR N TO LAM PI 11/75
M 1 FROM SOLUTION 1 OF BAILLON 75, NOT PRESENT IN SOLUTION 2. 1/76
M 3 1847. OR 1863. MARTIN 77 DPWA KBAR N MULTICHNL 11/77
M 3 THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M 3 PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M 1870.0 10.0 CAMERON2 78 DPWA K-P TO K*(890) N 12/79*
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.5)

67 Y*1(1880) WIDTH (MEV)
W 222.0 150.0 SMART 68 DPWA -0 K-N TO LAM PI 7/68
W (200.0) BAILEY 69 DPWA 0 ELASTIC, CH EXCH 10/70
W ABOUT 30.0 ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH 6/70
W 200.0 50.0 GALTIERI 70 DPWA -0 K-N TO LAM PI 7/70
W 170.0 40.0 LITCHFIE 70 DPWA -0 K-N TO LAM PI 6/70
W 2 (222.2) (40.) LEA 73 DPWA MULTICHNL K-MTRX 9/73
W 1 (260.) (40.) BAILLON 75 IPWA KBAR N TO LAM PI 11/75
W 3 222.0 140.0 VANHORN 75 DPWA 0 K-P TO LAM PIO 11/75
W 216. OR 220. MARTIN 77 DPWA KBAR N MULTICHNL 11/77
W 80.0 10.0 CAMERON2 78 DPWA K-P TO K*(890) N 12/79*
W AVERAGE MEANINGLESS (SCALE FACTOR = 2.2)

67 Y*1(1880) PARTIAL DECAY MODES
DECAY MASSES
P1 Y*1(1880) INTO KBAR N 497+ 939
P2 Y*1(1880) INTO LAMBDA PI 1115+ 134
P3 Y*1(1880) INTO SIGMA PI 1197+ 139
P4 Y*1(1880) INTO N K*(890), P1 WAVE 939+ 892
P5 Y*1(1880) INTO N K*(890), P3 WAVE 939+ 892

67 Y*1(1880) BRANCHING RATIOS
R1 Y*1(1880) INTO (KBAR NI)/TOTAL (P1)
R1 (0.22) BAILEY 69 DPWA 0 ELASTIC, CH EXCH 10/70
R1 (0.20) ARMENTERO 70 IPWA -0 ELASTIC, CH EXCH 6/70
R1 2 (0.31) LEA 73 DPWA MULTICHNL K-MTRX 9/73
R1 3 (.27) OR .27 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R2 Y*1(1880) FROM KBAR N INTO LAMBDA PI SQRT(P1*P2)
R2 -0.11 0.03 SMART 68 DPWA -0 K-N TO LAM PI 7/68
R2 -0.09 0.04 GALTIERI 70 DPWA 0 ELASTIC, CH EXCH 10/70
R2 -0.14 0.03 LITCHFIE 70 DPWA -0 K-N TO LAM PI 6/70
R2 2 (-.30) LEA 73 DPWA MULTICHNL K-MTRX 9/73
R2 -0.169 .119 DEVENISH 74 0 FIXED T DISP REL 4/75
R2 1 (-.12) (.02) BAILLON 75 IPWA KBAR N TO LAM PI 11/75
R2 +.05 .07 VANHORN 75 DPWA 0 K-P TO LAM PIO 11/75
R2 3 (-.24) OR -.24 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R2 AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

R3 Y*1(1880) FROM KBAR N INTO SIGMA PI SQRT(P1*P3) 9/73
R3 2 NOT SEEN LEA 73 DPWA MULTICHNL K-MTRX 9/73
R3 3 (+.30) OR +.29 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R4 Y*1(1880) FROM KBAR N INTO N K*(890), P1 WAVE SQRT(P1*P4)
R4 -0.05 0.03 CAMERON2 78 DPWA K-P TO K*N 12/79*
R4 4 THE SIGN HERE IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST CONVENTION. 12/79*

R5 Y*1(1880) FROM KBAR N INTO N K*(890), P3 WAVE SQRT(P1*P5) 12/79*
R5 +0.11 0.03 CAMERON2 78 DPWA K-P TO K*N

REFERENCES FOR Y*1(1880)
SMART 68 PR 169 1330 W M SMART (LRL)IJP
BAILEY 69 THESIS UCLR-50617 DAVID SAAL BAILEY (LRL LIVERMORE)IJP
ARMENTERO 70 DUKE CONF 123 ARMENTEROS, BAILLON, + (CERN, HEIDEL)IJP
GALTIERI 70 DUKE CCNF 173 A BARBARO-GALTIERI (LRL)IJP
LITCHFIE 70 NP B22 269 P J LITCHFIE (RUTHERFORD)IJP
LEA 73 NP B56 77 +MARTIN, MOORHOUSE+ (RHEL+LOUC+GLAS+AARHUS)IJP
DEVENISH 74 NP B81 330 DEVENISH, FROGGATT, MARTINIDESY, NORDITA, LUCI
BAILLON 75 NP B94 39 P. BAILLON, P. J. LITCHFIE (CERN, RHEL)IJP
VANHORN 75 NP B87 145 A. J. VAN HORN (LBL)IJP
ALSO 75 NP B87 157 A. J. VAN HORN (LBL)IJP
MARTIN 77 NP B127 349 MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS)IJP
ALSO 77 NP B126 266 MARTIN, PIDCOCK (LOUC)
ALSO 77 NP B126 285 MARTIN, PIDCOCK (LOUC)IJP
CAMERON2 78 NP B146 327 +FRANEK, GOPAL, KALMUS, MCPHERSON,+ (RHEL+LCLIC)IJP

R3 AVG MOD 0.1660 0.0089 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R3 STUDENT 0.1661 0.0099 AVERAGE USING STUDENT(10/H(1.11)) -- SEE MAIN TEXT

Sigma(1915)

46 Y*1(1915, JP=5/2+) I=1
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

F15

THIS RESONANCE WAS FIRST SEEN IN THE TOTAL-CROSS-SECTION MEASUREMENTS OF COOL 66. IN THIS ENTRY, HOWEVER, WE LIST ONLY THE RESULTS FROM PARTIAL-WAVE ANALYSES. SEE THE NEXT ENTRY FOR THE PARAMETERS OF PEAKS SEEN AROUND 1900-1950 MEV IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS. WE MAKE THIS SEPARATION BECAUSE ONLY THE PARTIAL-WAVE ANALYSES EXTRACT THE F15 WAVE. SEE ALSO THE NOTE TO THE NEXT ENTRY.

46 Y*1(1915) MASS (MEV)
M 1902.0 11.0 SMART 68 DPWA -0 K-N TO LAMBDA PI 7/68
M 1910.0 20.0 BERTHON 70 DPWA 0 K-P TO LAMBDA PI 7/70
M 1900.0 15.0 BERTHON1 70 DPWA 0 K-P TO SIGMA PI 10/70
M N 1936.0 (3.0) BRICMANI 70 DPWA SIGTOT, ELAS, CHEX 1/71
M 1903.0 10.0 COX 70 DPWA - K-N TO LAMBDA PI 6/70
M 1905.0 30.0 GALTIERI 70 DPWA 0 K-P TO LAMBDA PI 7/70
M 1895.0 10.0 LITCHFIE 70 DPWA -0 K-N TO LAMBDA PI 6/70
M 1910. 15. LITCHFIE 71 DPWA K-P TO KBAR N .10/71
M 1925.0 8.0 KANE 72 DPWA 0 K-P TO PI SIG 10/71
M 1920. 30. BAILLON 75 IPWA KBAR N TO LAM PI 11/75
M 1914. 10. HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
M 1920. 15. 20. VANHORN 75 DPWA 0 K-P TO LAM PIO 11/75
M (1915.) BELLEFON 76 IPWA 0 K-P TO LAM PI 2/77
M 3 1900. 4. CORDEN 76 DPWA - K-N TO PI- LAM 2/77
M 3 PREFERRED SOLUTION 3, SEE CORDEN 76 FOR OTHER POSSIBILITIES. 2/77
M 3 CORDEN 76 INCLUDES THE DATA OF COX TO AS A SUBSAMPLE
M 1 1894. 5. CORDEN1 77 - K-N TO PI SIG 11/77
M 2 1909. 5. CORDEN1 77 - K-N TO PI SIG 11/77
M 1 THE 2 ENTRIES FOR CORDEN177 ARE FROM 2 DIFFERENT ACCEPTABLE SLTNS. 11/77
M NOT SEEN DECLAIS 77 DPWA KBAR N TO KBAR N 1/78
M 4 1925. OR 1933. MARTIN 77 DPWA KBAR N MULTICHNL 11/77
M 4 THE TWO ENTRIES FOR MARTIN 77 CORRESPOND TO EXTRACTION OF RESONANCE
M 4 PARAMETERS FROM THE T-MATRIX POLE AND FROM A B-W FIT, RESPECTIVELY.
M 1920. 10. RLIC 77 DPWA KBAR N MULTICHNL 1/76
M 1937. 20. ALSTON 78 DPWA KBAR N ELASTIC 1/78
M N ERROR STATIST. ONLY- NO ERROR DUE TO PARTICULAR P.W. ANAL. INCLUDED 1/71
M AVERAGE MEANINGLESS (SCALE FACTOR = 1.3)

46 Y*1(1915) WIDTH (MEV)
W A (50.0) (20.0) ARMENTER1 67 DPWA 0 ELASTIC, CH EXCH 11/67
W 52.0 25.0 SMART 68 DPWA -0 K-N TO LAMBDA PI 7/68
W 60.0 20.0 BERTHON 70 DPWA 0 K-P TO LAMBDA PI 7/70
W 75.0 20.0 BERTHON1 70 DPWA 0 K-P TO SIGMA PI 10/70
W 135.0 12.0 BRICMANI 70 DPWA SIGTOT, ELAS, CHEX 1/71
W 77.0 27.0 COX 70 DPWA - K-N TO LAMBDA PI 6/70
W 70.0 20.0 GALTIERI 70 DPWA 0 K-P TO LAMBDA PI 7/70
W 70.0 15.0 LITCHFIE 70 DPWA -0 K-N TO LAMBDA PI 6/70
W 70. 15. LITCHFIE 71 DPWA K-P TO KBAR N 10/71
W 146.0 22.0 KANE 72 DPWA 0 K-P TO PI SIG 10/71
W 70. 20. BAILLON 75 IPWA KBAR N TO LAM PI 11/75
W 85. 15. HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
W 102. 18. VANHORN 75 DPWA 0 K-P TO LAM PIO 11/75
W (60.) BELLEFON 76 IPWA 0 K-P TO LAM PI 2/77
W 3 75. 14. CORDEN 76 DPWA - K-N TO PI- LAM 2/77
W 1 107. 14. CORDEN1 77 - K-N TO PI SIG 11/77
W 2 107. 13. CORDEN1 77 - K-N TO PI SIG 11/77
W 4 171 OR 173. MARTIN 77 DPWA KBAR N MULTICHNL 1/77
W 130. 10. RLIC 77 DPWA KBAR N MULTICHNL 1/76
W 161. 20. ALSTON 78 DPWA KBAR N ELASTIC 1/78
W A LACK OF DATA PREVENTS FROM DETERMINING UNAMB. THIS AMPLITUDE 11/67
W AVERAGE MEANINGLESS (SCALE FACTOR = 1.9)

46 Y*1(1915) PARTIAL DECAY MODES
DECAY MASSES
P1 Y*1(1915) INTO KBAR N 497+ 939
P2 Y*1(1915) INTO LAMBDA PI 1115+ 139
P3 Y*1(1915) INTO SIGMA PI 1197+ 139
P4 Y*1(1915) INTO Y*1(1385) PI P-WAVE 139+1384
P5 Y*1(1915) INTO Y*1(1385) PI F-WAVE 139+1384

46 Y*1(1915) BRANCHING RATIOS
R1 Y*1(1915) INTO (KBAR NI)/TOTAL (P1)
R1 A (0.12) (.01) ARMENTER1 67 DPWA 0 ELASTIC, CH EXCH 11/67
R1 0.18 (0.02) BRICMANI 70 DPWA SIGTOT, ELAS, CHEX 1/71
R1 0.11 (0.03) CONFORTO 71 DPWA 0 ELASTIC, CH EXCH 6/70
R1 0.15 (0.04) MARTIN 77 DPWA KBAR N ELASTIC 1/77
R1 .11 (.04) HEMINGWA 75 DPWA 0 K-P TO KBAR N 11/75
R1 4 (.08) OR .08 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R1 .05 (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R1 .14 (.05) ALSTON 78 DPWA KBAR N ELASTIC 1/78
R2 Y*1(1915) FROM KBAR N INTO LAMBDA PI SQRT(P1*P2)
R2 -0.08 (0.02) SMART 68 DPWA -0 K-N TO LAMBDA PI 7/68
R2 -0.1 (0.02) BERTHON 70 DPWA 0 K-P TO LAMBDA PI 7/70
R2 -0.09 (0.02) COX 70 DPWA - K-N TO LAMBDA PI 6/70
R2 -0.11 (0.03) GALTIERI 70 DPWA 0 K-P TO LAMBDA PI 7/70
R2 -0.07 (0.015) LITCHFIE 70 DPWA -0 K-N TO LAMBDA PI 6/70
R2 -0.87 (.056) DEVENISH 74 0 FIXED T DISP REL 4/75
R2 -0.09 (0.02) BAILLON 75 IPWA KBAR N TO LAM PI 11/75
R2 -0.09 (.02) VANHORN 75 DPWA 0 K-P TO LAM PIO 11/75
R2 (-.10) BELLEFON 76 IPWA 0 K-P TO LAM PI 2/77
R2 3 -0.10 .01 CORDEN 76 DPWA - K-N TO PI- LAM 2/77
R2 4 (-.09) OR -.09 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R2 -0.09 (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76

R3 Y*1(1915) FROM KBAR N INTO SIGMA PI SQRT(P1*P3)
R3 A (0.00) (0.01) ARMENTERO 67 DPWA 0 K-P TO SIGMA PI 11/67
R3 -0.13 (0.03) BERTHON1 70 DPWA 0 K-P TO SIGMA PI 10/70
R3 -0.06 (0.03) GALTIERI 70 DPWA 0 K-P TO SIGMA PI 7/70
R3 -0.137 (0.015) KANE 72 DPWA 0 K-P TO PI SIG 10/71
R3 1 -0.17 .01 CORDEN1 77 - K-N TO PI SIG 11/77
R3 2 -0.15 .02 CORDEN1 77 - K-N TO PI SIG 11/77
R3 4 (-.05) OR -.05 MARTIN 77 DPWA KBAR N MULTICHNL 11/77
R3 -0.19 (.03) RLIC 77 DPWA KBAR N MULTICHNL 1/76
R3 AVG MOD 0.1660 0.0089 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R3 STUDENT 0.1661 0.0099 AVERAGE USING STUDENT(10/H(1.11)) -- SEE MAIN TEXT

Baryons

$\Sigma(1915)$, $\Sigma(1940)$

R4 Y*1(1915) FROM KBAR N INTO Y*1(1385) PI P-WAVE SQR(T(P1*P4)
R4 LESS THAN .01 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78
R5 Y*1(1915) FROM KBAR N INTO Y*1(1385) PI F-WAVE SQR(T(P1*P5)
R5 .039 .009 CAMERON 78 DPWA 0 K-P TO S(1385)PI 1/78
R5 5 THE SIGN IS CHANGED TO BE IN ACCORD WITH THE BARYON-FIRST
R5 5 CONVENTION. 12/79*

REFERENCES FOR Y*1(1915)

ARMENTERO 67 PL 248 158 ARMENTEROS, FERRO-LUZZI* (CERN, HEID, SACLAY)
ARMENTERE 67 NP 83 592 ARMENTEROS, FERRO-LUZZI* (CERN, HEID, SACLAY)
SMART 68 PR 169 1350 W M SMART (LRL)IJP
BERTHON 70 NP 820 476 +RANGAN, VRANA, +(COL FRANCE, RHEL, SACLAY)IJP
BERTHON1 70 NP 824 417 +VRANA, BUTTERWORTH, + (CDEF, RHEL, SACLAY)IJP
BRICHMAN 70 PL 358 511 +FERRO-LUZZI, LAGNAUX (CERN)
CDX 70 NP 819 61 +ISLAM, COLLEY, + (BIRM, EDIN, GLAS+LOIC)IJP
GALTIERI 70 DUKE CONF 173 A BARBARO-GALTIERI (LRL)IJP
LITCHFIELD 70 NP 822 269 P J LITCHFIELD (RUTHERFORD)IJP
CONFORTO 71 NP 834 41 +LEVI SETTI, LASINSKI, OBERLACK+ (EFI+HEID)IJP
LITCHFIELD 71 NP 830 125 LITCHFIELD, ...+LESQGY, ... (RHEL+CDEF+SACL)IJP
KANE 72 PR 05 1583 D F KANE (LRL)IJP
DEVENISH 74 NP 881 330 DEVENISH, FROGGATT, MARTIN(DESY, NORDITA, LUC)
BAILLON 75 NP 894 39 P. BAILLON, P. J. LITCHFIELD (CERN, RHEL)IJP
HEMINGWAY 75 NP 891 12 HEMINGWAY, EADES, HARMSSEN+ (CERN, HEID, MPI)IJP
VANHORN 75 NP 887 145 A. J. VAN HORN (LRL)IJP
ALSO 75 NP 887 157 A. J. VAN HORN (LRL)IJP
BELLEFON 76 NP B105 129 DE BELLEFON, BERTHON (CDEF)IJP
CORDEN 76 NP B104 382 +COX, DARTNELL, KENYON, ONEALE, SUMOROK+ (BIRM)IJP
CORDEN 77 NP B125 61 +COX, KENYON, ONEALE, STUBBS, SUMOROK+ (BIRM)IJP
DECLAIS 77 CERN 77-16 +DUCHON, LOUVEL, PATRY, SEGUINOT+ (CAEN+CERN)IJP
MARTIN 77 NP B127 349 MARTIN, PIDCOCK, MOORHOUSE (LOUC+GLAS)IJP
ALSO 77 NP B126 266 MARTIN, PIDCOCK (LOUC)IJP
ALSO 77 NP B126 285 MARTIN, PIDCOCK (LOUC)IJP
RLIC 77 NP B119 362 GOPAL, ROSS, VAN HORN, MCPHERSON+ (LOIC+RHEL)IJP
ALSTON 78 PR D18 182 +KENNEY, POLLARD, ROSS+ (LBL+MTHO+CERN)IJP
ALSTON 77 PRL 38 1007 ALSTON-GARAJOST, KENNEY (LBL+MTHO+CERN)IJP
CAMERON 78 NP B143 189 +FRANEK, GOPAL, BACON, BUTTERWORTH+ (RHEL+LOIC)IJP
PAPERS NOT REFERRED TO IN DATA CARDS
SMART 66 PRL 37 556 W M SMART, A KERNAN, G E KALMUS, R P ELY (LRL)IJP
SUPERSEDED BY SMART 68.
CONFORTO 68 NP B8 265 +HARMSSEN, LASINSKI, + (CHICAGO, HEIDEL)
SUPERSEDED BY CONFORTO 71.

1915 MEV REGION - PRODUCTION AND σ_{TOTAL} EXP'TS

29 Y*1(1915, JP=) I=1 PRODUCTION EXPERIMENTS
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
SEE THE NOTES TO THE Y*1(1915) AND Y*1(1940), WHICH IMMEDIATELY PRECEDE AND FOLLOW THIS ENTRY. HERE WE LIST ONLY PARAMETERS OF PEAKS SEEN IN CROSS SECTIONS AND INVARIANT-MASS DISTRIBUTIONS. THE CROSS-SECTION PEAKS ARE ALMOST CERTAINLY ASSOCIATED WITH THE F15 Y*1(1915) SEEN IN PARTIAL-WAVE ANALYSES. THE INVARIANT-MASS PEAKS SEEM MORE LIKELY TO BE ASSOCIATED WITH THE D13 Y*1(1940).

Table with columns: M, CROSS-SECTION PEAKS, INVARIANT-MASS-DISTRIBUTION PEAKS, ELASTIC DCS, AVERAGE MEANINGLESS (SCALE FACTOR = 2.7)

Table with columns: W, CROSS-SECTION PEAKS, INVARIANT-MASS-DISTRIBUTION PEAKS, ELASTIC DCS, AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

Table with columns: P1, P2, P3, P4, Y*1(1915) PARTIAL DECAY MODES (PROD. EXP.), DECAY MASSES

Data Card Listings
For notation, see key at front of Listings.

29 Y*1(1915) BRANCHING RATIOS (PROD. EXP.)
R1 Y*1(1915) INTO (KBAR N)/TOTAL (P1)
R1 THESE VALUES OF ELASTICITIES ASSUME J=5/2 --
R1 0.06 BUGG 68 CNTR ASSUMING J=5/2 6/68
R1 0.07 BRICHMAN 70 CNTR 0 TOTAL AND CH EX 6/70
R1 0.07 COOL 70 CNTR K-P, D TOTAL 10/70
R1 1 THIS ELASTICITY ASSUMES J=7/2
R1 .62 .08 DADO 72 HBC 0 K-P ELSTC DCS 2/73
R1 .10 .13 AVERAGE (ERROR INCLUDES SCALE FACTOR OF 6.7)
R1 STUDENT 0.077 0.022 AVERAGE USING STUDENT'S T -- SEE MAIN TEXT

REFERENCES FOR Y*1(1915) (PROD. EXP.)
BOCK 65 PL 17 166 +COOPER, FRENCH, KINSON, + (CERN, SACLAY) I
COOL 66 PRL 16 1228 +GIACOMELLI, KYCIA, LEONTIC, LI, LUNDBY, + (BNL) I
SUPERSEDED BY COOL 70.
BUGG 68 PR 168 1466 +GILMORE, KNIGHT, DAVIES+ (BIRM, CAVE, RHEL) I
BARNES 69 PRL 22 479 +FLAMINIO, MONTANET, SAMIOS + (BNL+SYRA)
AGUILAR 70 PRL 25 58 AGUILAR-BENITEZ, BARNES, + (BNL+SYRA)
BRICHMAN 70 PL 318 152 +FERRO LUZZI, PERREAU, + (CERN, CAEN, SACLAY)
COOL 70 PR D1 1887 +GIACOMELLI, KYCIA, LEONTIC, LI, + (BNL) I
DADO 72 PRL 29 1695 +BIRMAN, GOLDBERG, WEISS (HAIF)JP
BRIEFEL 77 PR D 16 2706 +GUREVITCH, CHANG+ (BRAN+UMD+SYRA+TUFT)
PAPERS NOT REFERRED TO IN DATA CARDS

PRIMER 68 PRL 20 610 +GOLDBERG, JAEGER, BARNES, DORNAN + (SYRA, BNL)
SUPERSEDED BY BARNES 69 AND AGUILAR-BENITEZ 70.

Σ(1940) 98 Y*1(1940, JP=3/2-) I=1 D13
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
SUCH A RESONANCE IS SUGGESTED BY SOME BUT NOT ALL PARTIAL-WAVE ANALYSES IN THIS REGION. THIS EFFECT IS PERHAPS ASSOCIATED WITH THE BUMPS SEEN IN PRODUCTION EXPERIMENTS NEAR THIS MASS. SEE THE PRECEDING ENTRY.

Table with columns: M, 98 Y*1(1940) MASS (MEV), GALTIERI 70 DPWA, LITCHFIELD 74 DPWA, KANE 72 DPWA, LEA 73 DPWA, BAILLON 75 DPWA, VANHORN 75 DPWA, BELLEFON 76 DPWA, MARTIN 77 DPWA, RLIC 77 DPWA

Table with columns: W, 98 Y*1(1940) WIDTH (MEV), GALTIERI 70 DPWA, LITCHFIELD 70 DPWA, KANE 72 DPWA, LEA 73 DPWA, LITCHFIELD 74 DPWA, BAILLON 74 DPWA, VANHORN 75 DPWA, MARTIN 77 DPWA, RLIC 77 DPWA, CAMERON2 78 DPWA

Table with columns: P1, P2, P3, P4, P5, P6, P7, P8, P9, 98 Y*1(1940) PARTIAL DECAY MODES, DECAY MASSES

Data Card Listings

For notation, see key at front of Listings.

Baryons
Sigma(1940), Sigma(2000), Sigma(2030)

98 Y*1(1940) BRANCHING RATIOS

Table with columns for particle name, mass, width, and branching ratios for various decay modes. Includes entries for Y*1(1940) and Y*1(1940) into Kbar N into Lambda PI.

REFERENCES FOR Y*1(1940)

Table listing references for Y*1(1940) from various sources like Galtieri, Kane, Devenish, etc.

PAPERS NOT REFERRED TO IN DATA CARDS

Table listing papers not referred to in data cards, such as Hemingway, Eades, Harmsen.

Sigma(2000)

02 Y*1(2000, JP=1/2-) I=1

S11

WE LIST HERE ALL REPORTED S11 STATES LYING ABOVE THE Y*1(1750)

02 Y*1(2000) MASS (MEV)

Table showing mass values for Y*1(2000) from different experiments like VanHorn, Martin, etc.

02 Y*1(2000) WIDTH (MEV)

Table showing width values for Y*1(2000) from different experiments like VanHorn, Martin, etc.

02 Y*1(2000) PARTIAL DECAY MODES

Table showing partial decay modes for Y*1(2000) into various particles like Kbar N, Lambda PI, Sigma PI, etc.

02 Y*1(2000) BRANCHING RATIOS

Table showing branching ratios for Y*1(2000) into various decay channels.

REFERENCES FOR Y*1(2000)

Table listing references for Y*1(2000) from sources like Baillon, VanHorn, Cameron, etc.

Sigma(2030)

47 Y*1(2030, JP=7/2+) I=1

F17

SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

THIS ENTRY ONLY INCLUDES RESULTS FROM PARTIAL-WAVE ANALYSES. PARAMETERS OF PEAKS SEEN IN CROSS-SECTIONS AND INVARIANT-MASS DISTRIBUTIONS AROUND 2030 MEV ARE GIVEN IN THE NEXT ENTRY. EVENTUALLY THE PARTIAL-WAVE ANALYSES SHOULD GIVE THE BEST RESULTS, AS THEY ISOLATE THE F17 WAVE. THIS SUPERIORITY IS, HOWEVER, PROBABLY NOT YET ATTAINED, AND WE RELY ON BOTH ENTRIES FOR PARAMETERS GIVEN IN THE MAIN BARYON TABLE.

47 Y*1(2030) MASS (MEV)

Table showing mass values for Y*1(2030) from various experiments like Wohl, Berton, etc.

47 Y*1(2030) WIDTH (MEV)

Table showing width values for Y*1(2030) from various experiments like Wohl, Smart, etc.

Baryons
Σ(2030)

Data Card Listings

For notation, see key at front of Listings.

Table with columns W, N, M, and text describing particle properties and decay modes for Σ(2030).

47 Y*(2030) PARTIAL DECAY MODES

Table listing decay modes for Y*(2030) with columns for mode, branching ratio, and decay masses.

47 Y*(2030) BRANCHING RATIOS

Table listing branching ratios for Y*(2030) with columns for mode, ratio, and decay masses.

Table listing branching ratios for Y*(2030) with columns for mode, ratio, and decay masses.

Table listing branching ratios for Y*(2030) with columns for mode, ratio, and decay masses.

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Table listing branching ratios for Y*(2030) with columns for mode, ratio, and decay masses.

Table listing branching ratios for Y*(2030) with columns for mode, ratio, and decay masses.

Table listing particle properties and decay modes for R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22.

Table listing particle properties and decay modes for R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22.

REFERENCES FOR Y*(2030)

Table listing references for Y*(2030) with columns for author, journal, volume, page, and year.

Table listing references for Y*(2030) with columns for author, journal, volume, page, and year.

2030 MEV REGION - PRODUCTION AND σTOTAL EXPTS

Table listing production and total cross-section experiments for the 2030 MeV region.

Table listing production and total cross-section experiments for the 2030 MeV region.

Table listing production and total cross-section experiments for the 2030 MeV region.

Table listing production and total cross-section experiments for the 2030 MeV region.

Table listing production and total cross-section experiments for the 2030 MeV region.

Baryons

$\Sigma(2250)$, $\Sigma(2455)$, $\Sigma(2620)$

Data Card Listings

For notation, see key at front of Listings.

48 Y*1(2250) WIDTH (MEV) (PROD. EXP.)
Table with columns for mass, width, and experimental details for various production experiments.

AVERAGE MEANINGLESS (SCALE FACTOR = 2.7)
SEE THE NOTES ACCOMPANYING THE MASSES QUOTED

48 Y*1(2250) PARTIAL DECAY MODES (PROD. EXP.)
Table listing decay modes and branching ratios for the Sigma(2250) baryon.

48 Y*1(2250) BRANCHING RATIOS (PROD. EXP.)
Table showing branching ratios for various decay channels of Sigma(2250).

48 Y*1(2250) FROM KBAR N TO LAMBDA PI
Table detailing production cross-sections and branching ratios for Sigma(2250) from K-bar N to Lambda pi.

48 Y*1(2250) FROM KBAR N TO SIGMA PI
Table detailing production cross-sections and branching ratios for Sigma(2250) from K-bar N to Sigma pi.

48 Y*1(2250) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and Sigma pi.

48 Y*1(2250) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into Lambda pi and Sigma pi.

48 Y*1(2250) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2250) from K- p to Xi*1/2(1530) KO.

48 Y*1(2250) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and total.

48 Y*1(2250) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and Sigma pi.

48 Y*1(2250) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into Lambda pi and Sigma pi.

48 Y*1(2250) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2250) from K- p to Xi*1/2(1530) KO.

48 Y*1(2250) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and total.

48 Y*1(2250) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and Sigma pi.

48 Y*1(2250) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into Lambda pi and Sigma pi.

48 Y*1(2250) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2250) from K- p to Xi*1/2(1530) KO.

48 Y*1(2250) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and total.

48 Y*1(2250) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into K-bar N and Sigma pi.

48 Y*1(2250) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2250) into Lambda pi and Sigma pi.

Sigma(2455) BUMPS
53 Y*1(2455, JP=) I=1
PRODUCT ION EXPERIMENTS
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

53 Y*1(2455) MASS (MEV) (PROD. EXP.)
Table with columns for mass, width, and experimental details for Sigma(2455).

53 Y*1(2455) WIDTH (MEV) (PROD. EXP.)
Table with columns for mass, width, and experimental details for Sigma(2455).

53 Y*1(2455) PARTIAL DECAY MODES (PROD. EXP.)
Table listing decay modes and branching ratios for the Sigma(2455) baryon.

53 Y*1(2455) BRANCHING RATIOS (PROD. EXP.)
Table showing branching ratios for various decay channels of Sigma(2455).

53 Y*1(2455) FROM KBAR N TO LAMBDA PI
Table detailing production cross-sections and branching ratios for Sigma(2455) from K-bar N to Lambda pi.

53 Y*1(2455) FROM KBAR N TO SIGMA PI
Table detailing production cross-sections and branching ratios for Sigma(2455) from K-bar N to Sigma pi.

53 Y*1(2455) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and Sigma pi.

53 Y*1(2455) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into Lambda pi and Sigma pi.

53 Y*1(2455) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2455) from K- p to Xi*1/2(1530) KO.

53 Y*1(2455) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and total.

53 Y*1(2455) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and Sigma pi.

53 Y*1(2455) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into Lambda pi and Sigma pi.

53 Y*1(2455) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2455) from K- p to Xi*1/2(1530) KO.

53 Y*1(2455) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and total.

53 Y*1(2455) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and Sigma pi.

53 Y*1(2455) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2455) into Lambda pi and Sigma pi.

53 Y*1(2455) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2455) from K- p to Xi*1/2(1530) KO.

53 Y*1(2455) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2455) into K-bar N and total.

Sigma(2620) BUMPS
54 Y*1(2620, JP=) I=1
PRODUCT ION EXPERIMENTS
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.

54 Y*1(2620) MASS (MEV) (PROD. EXP.)
Table with columns for mass, width, and experimental details for Sigma(2620).

54 Y*1(2620) WIDTH (MEV) (PROD. EXP.)
Table with columns for mass, width, and experimental details for Sigma(2620).

54 Y*1(2620) PARTIAL DECAY MODES (PROD. EXP.)
Table listing decay modes and branching ratios for the Sigma(2620) baryon.

54 Y*1(2620) BRANCHING RATIOS (PROD. EXP.)
Table showing branching ratios for various decay channels of Sigma(2620).

54 Y*1(2620) FROM KBAR N TO LAMBDA PI
Table detailing production cross-sections and branching ratios for Sigma(2620) from K-bar N to Lambda pi.

54 Y*1(2620) FROM KBAR N TO SIGMA PI
Table detailing production cross-sections and branching ratios for Sigma(2620) from K-bar N to Sigma pi.

54 Y*1(2620) INTO (KBAR N)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2620) into K-bar N and Sigma pi.

54 Y*1(2620) INTO (LAMBDA PI)/(SIGMA PI)
Table showing ratios of production cross-sections for Sigma(2620) into Lambda pi and Sigma pi.

54 Y*1(2620) FROM K- P TO XI*1/2(1530) KO
Table detailing production cross-sections and branching ratios for Sigma(2620) from K- p to Xi*1/2(1530) KO.

54 Y*1(2620) INTO (KBAR N)/TOTAL
Table showing ratios of production cross-sections for Sigma(2620) into K-bar N and total.

Data Card Listings

Baryons

For notation, see key at front of Listings.

$\Sigma(3000)$, $\Sigma(3170)$, EXOTIC HYPERONS, Ξ 's

$\Sigma(3000)$
BUMPS

59 Y*1(3000, JP=) I=1 PRODUCTION EXPERIMENTS
SEE THE MINI-REVIEW AT THE START OF THE Y* LISTINGS.
ENHANCEMENT IN LAMBDA PI AND KBAR N INVARIANT MASS SPECTRA AND IN MISSING MASS OF NEUTRALS RECOILING AGAINST K0. EVIDENCE NOT CONCLUSIVE. OMITTED FROM TABLE.

M (3000.0) EHRlich 66 HBC 0 PI-P 7.91 BEV/C 9/66

59 Y*1(3000) PARTIAL DECAY MODES (PROD. EXP.)

P1 Y*1(3000) INTO KBAR N 497+ 939
P2 Y*1(3000) INTO LAMBDA PI 1115+ 139

REFERENCES FOR Y*1(3000) (PROD. EXP.)

EHRlich 66 PR 152 1194 R EHRlich, W SELOVE, H YUTA (PENN(BNL)) I

$\Sigma(3170)$
BUMPS

118 Y*1(3170, JP=) I=1 PRODUCTION EXPERIMENTS
SEEN BY AMIRZADEHI 79 AS A NARROW 6.5 STD. DEV. ENHANCEMENT IN THE REACTION K-P -> Y* PI- USING DATA FROM TWO INDEPENDENT HIGH STATISTICS BUBBLE CHAMBER EXPERIMENTS AT 8.25 AND 6.5 GEV/C. THE DOMINANT DECAY MODES ARE INTO MULTI-BODY, MULTI-STRANGE FINAL STATES AND THE PRODUCTION IS VIA I=3/2 BARYON EXCHANGE. I=1 IS FAVORED.
IN NEED OF CONFIRMATION. OMITTED FROM TABLES.

M 35 3170. 5. AMIRZAD1 79 HBC + K-P TO Y* PI- 12/79*

118 Y*1(3170) WIDTH (MEV) (PROD. EXP.)

W C 35 (20.1) OR LESS AMIRZAD1 79 HBC + K-P TO Y* PI- 12/79*
W C OBSERVED WIDTH CONSISTENT WITH EXPERIMENTAL RESOLUTION.

118 Y*1(3170) PARTIAL DECAY MODES (PROD. EXP.)

P1 Y*1(3170) INTO LAMBDA K KBAR + PIONS
P2 Y*1(3170) INTO SIGMA K KBAR + PIONS
P3 Y*1(3170) INTO XI K + PIONS

118 Y*1(3170) BRANCHING RATIOS (PROD. EXP.)

R1 Y*1(3170) INTO LAMBDA K KBAR + PIONS (P1) 12/79*
R1 SEEN AMIRZAD1 79 HBC + K-P TO Y* PI-
R2 Y*1(3170) INTO SIGMA K KBAR + PIONS (P2) 12/79*
R2 SEEN AMIRZAD1 79 HBC + K-P TO Y* PI-
R3 Y*1(3170) INTO XI K + PIONS (P3) 12/79*
R3 SEEN AMIRZAD1 79 HBC + K-P TO Y* PI-

REFERENCES FOR Y*1(3170) (PROD. EXP.)

AMIRZAD1 79 PL 898 125 AMIRZADEH+ (BIRN+CERN+GLAS+MSU+LNP+CAVE+II)

EXOTIC HYPERON CROSS SECTION LIMITS

31 EXOTIC HYPERON CROSS SECTION LIMITS

THIS IS NOT A COMPLETE LIST. WE TABULATE ONLY FROM 1970 ON.

CS UNITS MICROBARNS
CS G (20.1) OR LESS GALTIERI 68 DBC -- K-N TO SG-PI-PI0 7/70
CS G ABOVE LIMIT FOR MASS < 2.15 GEV AND WIDTH < 60 MEV- (2.1 GEV/C K-) 7/70
CS A (40.) OR LESS GALTIERI 68 DBC -- K-N TO SG-PI-PI0 7/70
CS A ABOVE LIMIT FOR MASS < 2.3 GEV AND WIDTH < 120 MEV- (2.7 GEV/C K-) 7/70
CS X (4.7) OR LESS CL=90 BRIEFEL 75 DBC -- K-D 2.87 GEV/C 3/79*
CS X WIDTH < 60 MEV. K-N -> (XI- PI-1) K+ PI0
CS Y (1.4) OR LESS CL=90 BRIEFEL 75 DBC -- K-D 2.87 GEV/C 3/79*
CS Y WIDTH < 40 MEV. K-N -> (XI- PI- P10) K+
CS Z (5.4) OR LESS CL=90 BRIEFEL 75 DBC -- K-D 2.87 GEV/C 3/79*
CS Z WIDTH < 60 MEV. K-N -> (XI- PI-1) K+ PI0
CS B (8.6) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS B WIDTH < 60 MEV. K-N -> (SIGMA- PI-) P1+
CS C (13.3) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS C WIDTH < 120 MEV. K-N -> (SIGMA- PI-) P1+
CS D (6.9) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS D MASS > 2 GEV. WIDTH < 60 MEV. K-N -> (SIGMA- PI-) P1+
CS E (7.7) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS E MASS > 2 GEV. WIDTH < 120 MEV. K-N -> (SIGMA- PI-) P1+
CS F (17.1) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS F WIDTH < 60 MEV. K-N -> (SIGMA- PI- P10) P1+
CS H (23.) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS H WIDTH < 120 MEV. K-N -> (SIGMA- PI- P10) P1+
CS I (28.1) OR LESS CL=90 KATSOUFI 78 DBC -- K-D 2.87 GEV/C 3/79*
CS I WIDTH < 80 MEV. K-N -> (SIGMA- PI-) P1- P10

REFERENCES FOR EXOTIC HYPERONS

GALTIERI 68 PRL 21 573 A. BARBARO-GALTIERI, CHADWICK + (LRL+SLAC)
BRIEFEL 75 PRD 12 1859 +GUREVITCH, KIRSCH+ (BRAN+UMD+SYRA+TUFT) I
KATSOUFI 78 PRD 18 16 KATSOUFIS, CANTER, MANN, SCHNEPS+ (TUFT+BRAN) I

Note on Ξ Resonances

The Ξ resonance situation has long been unsettled. This is mainly because: (1) Ξ^* 's can only be produced as part of a final state, $K^- p \rightarrow \Xi^* +$ others, where the analysis is more complicated than if direct formation were possible; (2) they are so-produced with small cross sections (typically a few μb); and (3) the final states are in general topologically complicated and difficult to study with purely electronic techniques. Thus over the years our knowledge of Ξ^* spectroscopy has come wholly from bubble chamber experiments, where the number of events available are small.

Until fairly recently only the $\Xi(1530)$ could be considered as really well established. However, the 1978 edition of this review¹ saw a significant improvement in our understanding of the Ξ^* spectrum with the data of GAY 76 and HEMINGWAY 77. The $\Xi(1820)$ and $\Xi(2030)$ were definitely established as narrow states (with widths ~ 20 MeV), and the spin of the $\Xi(1820)$ was determined to be $3/2$ (TEODORO 77).

As far as the other Ξ^* states are concerned, the situation continues much as before, although there is some evidence for a new $\Xi(2370)$ (AMIRZADEH2 79). There is probably at least one other state in the 1850-2000 MeV region and there are indications of several others above 2000 MeV. Indeed, numerous states are predicted to exist below 2500 MeV and the broad $\Xi(1940)$ could well be a mixture of several.² Thus for the time being, we are still forced to group together rather disparate observations and await more new results. The disagreement among various experiments is indicated by means of ideograms in the Data Card Listings.

More new results may shortly be forthcoming from two large bubble chamber experiments currently in progress (MORRIS 75, AMIRZADEH2 79). In addition, future experiments with the MPS at BNL and with hyperon beams at both FNAL and CERN³ may further clarify the situation.

The table following this note gives our evaluation of the status of the Ξ resonances, based on data available at this time.

Baryons

Ξ 's, Ξ^- , Ξ^0 , $\Xi(1530)$

Data Card Listings

For notation, see key at front of Listings.

References

1. Particle Data Group, Phys. Lett. 75B, 1 (1978).
 2. R.J.Hemingway, Proc. of the Topical Conference on Baryon Resonances, Oxford, 1976, edited by R.T.Ross and D.H.Saxon (Science Research Council, Chilton).
 3. M. Bourquin et al., Nucl. Phys. B153, 13 (1979).
- For other references see the Data Card Listings.

STATUS OF XI* RESONANCES
 THOSE WITH AN OVERALL STATUS OF *** OR **** ARE INCLUDED IN THE MAIN BARYON TABLE. THE OTHERS AWAIT CONFIRMATION.
 IN THE PAST WE HAVE LOWERED OUR STANDARDS FOR XI* RESONANCES AND TABULATED STATES EVEN THOUGH THEY HAD ONLY BEEN SEEN AT LOW LEVELS OF STATISTICAL SIGNIFICANCE. NOW THAT NEW HIGH STATISTICS DATA IS BECOMING AVAILABLE, WE PROPOSE TO ADOPT SOMEWHAT STRICTER CRITERIA.

STATUS AS SEEN IN --							
PARTICLE	LIJ	OVERALL STATUS	XI PI	LAM K	SIG K	XI* PI	OTHER CHANNELS
XI(1317) P11		****					WEAK TO LAM PI
XI(1530) P13		****	****				
XI(1630)		**	**				
XI(1680)		**	**		**		
XI(1820) 13		***	*	***	**	***	
XI(1940)		**	**			**	
XI(2030) 1		***		**	***		
XI(2120)		*		*			2-BODY DECAYS
XI(2250)		*					3-BODY DECAYS
XI(2370) 1		**					3-BODY DECAYS
XI(2500)		**		**	**		3-BODY DECAYS

**** GOOD, CLEAR, AND UNMISTAKABLE.
 *** GOOD, BUT IN NEED OF CLARIFICATION OR NOT ABSOLUTELY CERTAIN.
 ** NEEDS CONFIRMATION.
 * WEAK.

S=-2 I=1/2 HYPERON STATES (Ξ)

Ξ^- 22 XI*(1321, JP=1/2) I=1/2
 SEE STABLE PARTICLE DATA CARD LISTINGS

Ξ^0 23 XI0(1314, JP=1/2) I=1/2
 SEE STABLE PARTICLE DATA CARD LISTINGS

$\Xi(1530)$ 49 XI*1/2(1530, JP=3/2+) I=1/2 P_{13}
 THIS IS THE ONLY WELL-ESTABLISHED XI* WHOSE PROPERTIES ARE ALL AT LEAST REASONABLY WELL-KNOWN. SPIN-PARITY 3/2+ IS FAVOURED BY THE DATA.
 WE DO NOT USE DETERMINATIONS OF THE MASS AND THE WIDTH OF THIS STATE UNLESS THEY ARE ACCOMPANIED BY SOME DISCUSSION OF SYSTEMATICS AND RESOLUTION.

49 XI*1/2(1530) MASS (MEV)

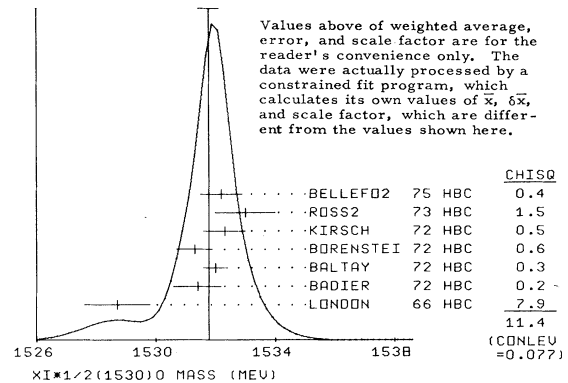
M	MIXED CHARGES				
M	20(1535.)				
M	55(1529.0)	(5.0)	BERTANZA	62 HBC	-0 K-P 2.3 GEV/C
M	(1532.0)	(2.0)	PJERROU	62 HBC	-0 K-P 1.8 GEV/C
M			BADIER	64 HBC	-0 K-P 3 GEV/C
M-	NEGATIVE CHARGE ONLY				
M-	38 1535.7	3.2	LONDON	66 HBC	- K-P 2.24 GEV/C 7/66
M-	334(1534.7)	(1.1)	BALTAY	72 HBC	- K-P 1.75 GEV 1/73
M-	185 1536.2	1.6	KIRSCH	72 HBC	- K-P 2.87GEV/C 2/72
M-	1535.3	2.0	ROSS2	73 HBC	- XI KBAR PI (PI) 2/74
M-	48(1540.)	(3.)	BERTHON	74 HBC	- QUASI 2 BODY CS 10/74
M-	1534.5	1.2	BELLEFO2	75 HBC	- K-P TO XI- K PI 11/75
M-					
M-	AVG	1535.18	0.84	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
M-	STUDENT	1535.18	0.92	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT	
M-	FIT	1534.97	0.63	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)	

NEUTRAL CHARGE ONLY

MO	76 1528.7	1.1	LONDON	66 HBC	0 K-P 2.24 GEV/C	7/66
MO	59 1531.4	0.8	BADIER	72 HBC	0 K-P AT 3.95GEV/C	10/71
MO	1262 1532.0	0.4	BALTAY	72 HBC	0 K-P 1.75 GEV	1/73
MO	324 1531.3	0.6	BORENSTEI	72 HBC	0 K-P 2.2GEV/C	2/72
MO	286 1532.3	0.7	KIRSCH	72 HBC	0 K-P 2.87GEV/C	2/72
MO	1533.0	1.0	ROSS2	73 HBC	XI KBAR PI (PI)	2/74
MO	97(1533.6)	(1.4)	BERTHON	74 HBC	0 QUASI 2 BODY CS	10/74
MO	1532.2	.7	BELLEFO2	75 HBC	0 K-P TO XI- K PI	11/75
MO	80(1527.)	(6.)	SIXEL	79 HBC	0 INCL. K-P 10 GEV	1/80*
MO	100(1535.)	(4.)	SIXEL	79 HBC	0 INCL. K-P 16 GEV	1/80*
MO	.....	.....		
MO	AVG	1531.78	0.34	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.4)		
MO	STUDENT	1531.84	0.28	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
MO	FIT	1531.80	0.31	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.3)		

(SEE IDEOGRAM BELOW)

WEIGHTED AVERAGE = 1531.78 ± 0.34
 ERROR SCALED BY 1.4



49 (XI*) - (XI*) MASS DIFFERENCE (MEV)

D	5.7	3.0	PJERROU	65 HBC	-0 1.8-1.95 GEV/C	7/66
D R	(7.0)	(4.0)	LONDON	66 HBC	-0 2.24 GEV/C	7/66
D	2.0	3.2	MERRILL	66 HBC	-0 1.7-2.7 GEV/C	7/66
D	2.7	1.0	BALTAY	72 HBC	-0 K-P 1.75 GEV	1/73
D R	(3.9)	(1.8)	KIRSCH	72 HBC	-0 K-P 2.87 GEV/C	2/72
D R	REDUNDANT WITH DATA IN MASS LISTING.					
D	.....	.....		
D	AVG	2.92	0.91	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
D	STUDENT	2.90	0.99	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
D	FIT	3.17	0.64	FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)		

49 XI*1/2(1530) WIDTH (MEV)

W	MIXED CHARGES	OR LESS			
W	20 (35.1)		BERTANZA	62 HBC	-0 K-P 2.3 GEV/C
W-	NEGATIVE CHARGE ONLY				
W-	7.8	3.5	7.8	BALTAY	72 HBC - K-P 1.75 GEV 1/73
W-	16.2	4.6		KIRSCH	72 HBC - XI- PI0, XI0 PI- 2/72
W-	8.3	3.6		ROSS2	73 HBC - XI KBAR PI (PI) 2/74
W-	9.6	2.8		BELLEFO2	75 HBC - K-P TO XI- K PI 11/75
W-	.....	.....	
W-	AVG	10.1	1.9	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)	
W-	STUDENT	10.0	2.1	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT	

NEUTRAL CHARGE ONLY

WO	7.0	2.0	SCHLEIN	63 HBC	0 1.8, 1.95 GEV/C	7/66
WO	7.0	7.0	BERGE	66 HBC	0 1.5-1.7 GEV/C	7/66
WO	8.5	3.5	LONDON	66 HBC	0 2.24 GEV/C	7/66
WO	11.0	2.0	BADIER	72 HBC	0 K-P AT 3.95GEV/C	10/71
WO	9.0	0.7	BALTAY	72 HBC	0 K-P 1.75 GEV	1/73
WO	8.4	1.4	BORENSTEI	72 HBC	0 XI- PI+ MODE	2/72
WO	11.0	1.8	KIRSCH	72 HBC	0 XI- PI+	2/74
WO	9.1	2.4	ROSS2	73 HBC	0 XI KBAR PI (PI)	2/74
WO	9.5	1.2	BELLEFO2	75 HBC	0 K-P TO XI- K PI	11/75
WO R	80 (19.)	(6.)	SIXEL	79 HBC	0 INCL. K-P 10 GEV	1/80*
WO R	100 (14.)	(5.)	SIXEL	79 HBC	0 INCL. K-P 16 GEV	1/80*
WO	.....	.....		
WO	AVG	9.14	0.48	AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)		
WO	STUDENT	9.13	0.53	AVERAGE USING STUDENT10(H/1.11) -- SEE MAIN TEXT		
ZO	R	EXPERIMENTAL RESOLUTION OF 15 MEV NOT UNFOLDED.				

49 XI*1/2(1530) REAL PART OF POLE POSITION

REO	1531.6	0.4	LICHTENB	74	0 EXTRAP HABIBI73	4/75
RE-	1534.4	1.1	LICHTENB	74	- EXTRAP HABIBI73	4/75

49 XI*1/2(1530) IMAGINARY PART OF POLE POSITION

IMO	4.45	0.35	LICHTENB	74	0 EXTRAP HABIBI73	4/75
IM-	3.9	1.75	LICHTENB	74	- EXTRAP HABIBI73	4/75

49 XI*1/2(1530) PARTIAL DECAY MODES

P1	XI*1/2(1530) INTO XI PI	DECAY MASSES
		132+ 139
P2	OTHER STRONG DECAYS ARE FORBIDDEN BY ENERGY CONSERVATION.	
	XI*1/2(1530) INTO XI GAMMA	132+ 0

Data Card Listings

Baryons

For notation, see key at front of Listings.

E(1530), E(1630), E(1680), E(1820)

49 XI*1/2(1530) BRANCHING RATIOS (MEV)
R1 XI*1/2(1530) INTO (XI GAMMA)/TOTAL (P2) 1/76
R1 (0.04) OR LESS CL=90 KALBFLEI 75 HBC - K-P AT 2.18 GEV 1/76

REFERENCES FOR XI*1/2(1530)
+BRINSON,CONNOLLY,GOLDBERG,GRAY,+ (BNL,SYRA) IJ
+PROWSE,SCHLEIN,SLATER,STORK,TICHO (UCLA) I

BERGANZA 62 PRL 9 180
PJREROU 62 PRL 9 116
SCHLEIN 63 PRL 11 167
BADIER 64 DUBNA I 593
PJREROU 65 PRL 14 275
BERGE 66 PR 147 945
LONDON 66 PR 143 1034
MERRILL 66 UCLR-16455 THESIS D W MERRILL (LRL) JP

PAPERS NOT REFERRED TO IN DATA CARDS
SHAFER 66 PR 142 883
A SPIN-PARITY DETERMINATION.
HABIBI 73 NEVIS 199(THESIS) HABIBI (COLU)

E(1630)

21 XI*1/2(1630, JP=) I=1/2

THIS EFFECT NEEDS CONFIRMATION.
BARTSCH 69 SEE A SMALL, BROAD ENHANCEMENT NEAR
1650 MEV - IT IS NOT CLEAR THAT IT IS THE SAME
PHENOMENON AS BRIEFEL 77, WHO FIND CS=2.6+-0.9
MICROBARN AT 2.87 GEV/C INCIDENT K- MOMENTUM.

21 XI*1/2(1630) MASS (MEV)
M 29 14.06. 6. ROSS 72 HBC 0 K-P AT 3.1-3.7 3/72
M 34 16.33. 12. BELLEF02 75 HBC 0 K-P TO XI- K PI 11/75
M 31 16.24. 3. BRIEFEL 77 HBC 0 K-P 2.87 GEV/C 1/78

21 XI*1/2(1630) WIDTH (MEV)
W 29 21. 7. ROSS 72 HBC 0 XI-PI+ K*0(890) 3/72
W 34 40. 15. BELLEF02 75 HBC 0 K-P TO XI- K PI 11/75
W F 31 (22.5) BRIEFEL 77 HBC 0 K-P 2.87 GEV/C 1/78

21 XI*1/2(1630) PARTIAL DECAY MODES
PI XI*1/2(1630) INTO XI PI 1321+ 139
SEEN IN K- P TO XI- PI+ KO AND XI- P10 K+.

REFERENCES FOR XI*1/2(1630)
+BURAN,LLOYD,MULVEY,RADJICIC (OXF) I
BELLEF02 75 NC 28A 289
BRIEFEL 77 PRD 16 2706

PAPERS NOT REFERRED TO IN DATA CARDS
APSELL 69 PRL 23 884
SUPERSEDED BY BMST 70.
BARTSCH 69 PL 288 439
KALBFLEI 70 DUKE CONF 331

E(1680)

S11

5 XI*1/2(1680, JP=1/2-) I=1/2
SEEN BY DIONISI 78 AS A THRESHOLD ENHANCEMENT IN BOTH
THE NEUTRAL AND NEGATIVELY CHARGED SIGMA KBAR MASS
SPECTRA FROM THE REACTIONS K-P -> (SIGMA KBAR) K PI
AT 4.2 GEV/C. THE DATA FROM THE SIGMA KBAR CHANNELS
ALONE CANNOT DISTINGUISH BETWEEN A RESONANCE
INTERPRETATION AND A LARGE SCATTERING LENGTH.

5 XI*1/2(1680) MASS (MEV)
M0 NEUTRAL CHARGE (5.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*
M0 F 175(1699.) (5.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*
M0 C 183(1684.) (5.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*

5 XI*1/2(1680) WIDTH (MEV)
W0 NEUTRAL CHARGE (23.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*
W0 F 175 (44.) (23.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*
W0 C 183 (20.) (4.) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*

5 XI*1/2(1680) PARTIAL DECAY MODES
P1 XI*1/2(1680) INTO SIGMA KBAR 1192+ 497
P2 XI*1/2(1680) INTO LAMBDA KBAR 1115+ 497
P3 XI*1/2(1680) INTO XI PI 1314+ 134
P4 XI*1/2(1680) INTO XI*1/2(1530) PI 1533+ 134
P5 XI*1/2(1680) INTO XI PI PI (INCLUDING P4) 1314+ 134+ 134

5 XI*1/2(1680) BRANCHING RATIOS
R1 XI*1/2(1680) INTO (SIGMA KBAR)/(LAMBDA KBAR) (P1)/(P2)
R1 Z (2.7) (0.9) DIONISI 78 HBC 0 K-P AT 4.2 GEV/C 3/79*
R1 N (3.1) (1.4) DIONISI 78 HBC - K-P AT 4.2 GEV/C 3/79*

REFERENCES FOR XI*1/2(1680)
DIGNISI 78 PL 80B 145 +DIAZ,ARMENTEROS+ (CERN+AMST+NIJH+OXF) I,JP

E(1820)

50 XI*1/2(1820, JP=3/2-) I=1/2
WE LIST HERE EVERYTHING REPORTED IN THE MASS RANGE
1750-1875 MEV.
THE CLEARER EVIDENCE FOR THIS STATE IS THAT OF
GAY 76, WHO SEE AN 8 STD. DEV. ENHANCEMENT IN
LAMBDA K-, AS WELL AS ENHANCEMENTS IN XI*1(1680) PI,
AND SIGMA KBAR. THE ENHANCEMENT OBSERVED BY GAY 76
IS NARROW (WIDTH 21 +- 7 MEV), IN CONTRAST TO RESULTS FROM EARLIER LESS
SIGNIFICANT DATA WHERE WIDTHS OF UP TO 100 MEV HAVE BEEN REPORTED (SEE
THE DATA CARD LISTINGS BELOW). GAY 76 OBSERVE NO SIGNAL IN THE XI PI
CHANNEL. IT IS POSSIBLE THAT THE XI PI ENHANCEMENTS SEEN IN THIS MASS
REGION BY SOME EXPERIMENTS AT LOWER MOMENTUM ARE AT LEAST PARTIALLY DUE
TO THE XI*(1940), WITH A SHAPE DISTORTED BY THE MORE LIMITED AVAILABLE
PHASE SPACE (SMITH 65). THE SITUATION IS FURTHER CONFUSED BY SOME
EXPERIMENTS BEING FORGED TO ADD SEVERAL DIFFERENT CHANNELS TO OVERCOME
POOR STATISTICS (CRENNELL 70, BADIER 71).

50 XI*1/2(1820) MASS (MEV)
M (1770.0) HALSTEINS 63 FBC -0 K-FR 3.5 GEV/C
M 30 1814.0 4.0 BADIER 65 HBC 0 LAMBDA KOBAR
M 29 1817.0 7.0 SMITH 1 65 HBC -0 LAMBDA KBAR
M C 40 1830.0 10.0 ALITTI 69 HBC - LAM, SIG KBAR 9/69
M C 25 1830.0 10.0 CRENNELL 70 DBC -0 3.6, 3.9 GEV/C 10/70
M C FROM FIT TO INCLUSIVE XI PI, XI PI PI AND LAMBDA K- SPECTRA
M O (1826.0) (12.0) CRENNELL 70 DBC -0 3.6, 3.9 GEV/C 11/77
M C FROM FIT TO INCLUSIVE XI PI AND XI PI SPECTRA ONLY
M B 28 1762.0 8.0 BADIER 72 HBC -0 XI PI,XI2PI,K Y 10/71
M B 38 1838.0 5.0 BADIER 72 HBC -OXI PI,XI2PI,K Y 10/71
M B BADIER 72 ADDS ALL CHANNELS AND DIVIDES PEAK IN LOWER AND HIGHER
M B MASS REGIONS. THE DATA CAN ALSO BE FITTED WITH A SINGLE BREIT-
M B WIGNER OF MASS 1800 AND WIDTH 150 MEV.

Baryons

$\Xi(1820)$

Table with columns for mass, width, and branching ratios for various decay modes of Xi*1/2(1820). Includes entries for Lambda K-bar, Sigma K-bar, and Xi Pi Pi decays.

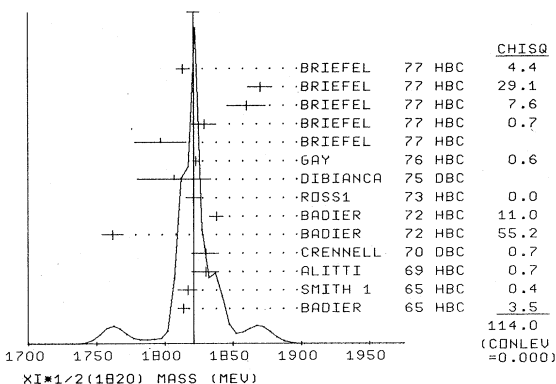


Table titled '50 XI*1/2(1820) WIDTH (MEV)' listing widths and branching ratios for various decay channels. Includes a section for 'AVERAGE MEANINGLESS (SCALE FACTOR = 2.2)'.

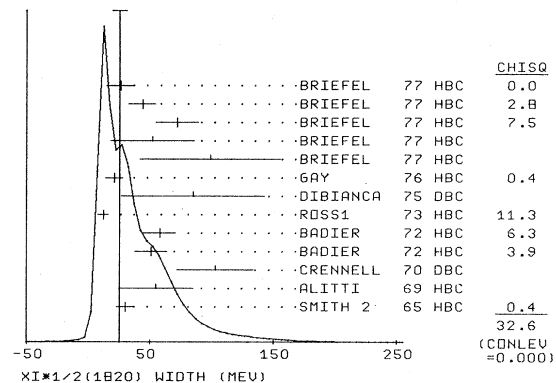


Table titled '50 XI*1/2(1820) PARTIAL DECAY MODES' listing decay modes and their corresponding masses. Includes a section for 'AVERAGE MEANINGLESS (SCALE FACTOR = 2.2)'.

FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are P_i ± 6P_i, where 6P_i = sqrt(6P_i^2 + 6P_i^2), while the off-diagonal elements are the normalized correlation coefficients (6P_i 6P_j) / (6P_i 6P_j). For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

Table showing fitted partial decay mode branching fractions P1, P2, P3, and P4 with their values and error bars.

Table titled '50 XI*1/2(1820) BRANCHING RATIOS' listing branching ratios for various decay modes (R1-R53) and their corresponding experimental references.

REFERENCES FOR XI*1/2(1820) listing various experimental sources and their contributions to the data, including references to specific papers and conferences.

Data Card Listings

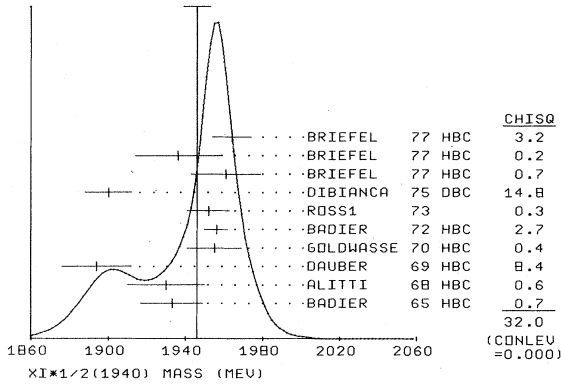
For notation, see key at front of Listings.

Baryons
Xi(1940), Xi(2030)

Xi(1940)

52 Xi*1/2(1940, JP=) I=1/2
WE LIST UNDER Xi(1940) EVERYTHING REPORTED IN THE MASS RANGE 1875-2000 MEV.

Table with 4 columns: Particle Name, Mass (MEV), and other properties. Includes entries for BADIER, ALITTI, DAUBER, GOLDWASSE, ROSSI, DIBIANCA, BRIEFEL, and DAUBER.



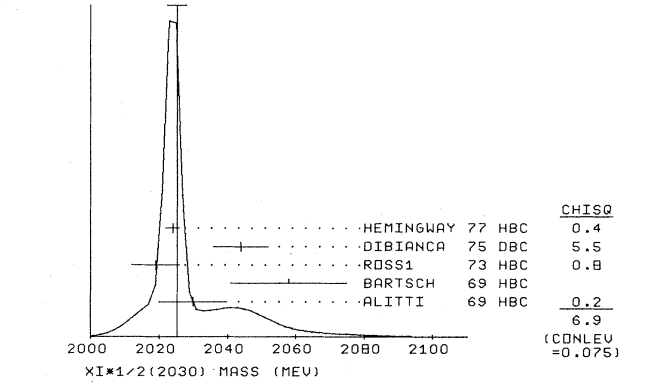
52 Xi*1/2(1940) BRANCHING RATIOS
Table listing branching ratios for various decay channels like Xi*1/2(1940) INTO Xi PI, Xi*1/2(1940) INTO Xi PI PI, etc.

REFERENCES FOR Xi*1/2(1940)
BADIER 65 PL 16 171 +DEMOULIN, GOLDBERG, + (EPOL, SACLAY, AMST) I
ALITTI 68 PRL 21 1119 +FLAMINIO, METZGER, RADOJICIC, + (BNL, SYRACUSE) I
DAUBER 69 PR 179 1262 +BERGE, HUBBARD, MERRILL, MULLER (LRL) I
APSELL 70 PRL 24 777 + (BRANDEIS, MARYLAND, SYRACUSE, TUFTS) I
GOLDWASSER 70 PR 10 1960 E L GOLDWASSER, P F SCHULTZ (ILLINOIS)
BADIER 72 NP 837, 429 +BARRELET, CHARLTON, VIDEAU (EPOL)
ROSSI 73 PURDUE CONF. 345 ROSS, LLOYD, RADOJICIC (OXFORD)

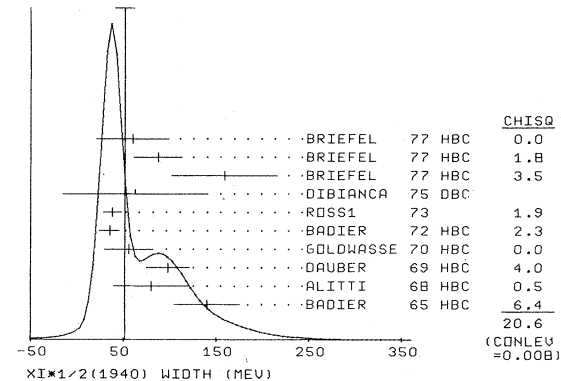
Xi(2030)
68 Xi*1/2(2030, JP=5/2 OR GREATER) I=1/2

THE EVIDENCE FOR THIS STATE HAS BEEN MUCH IMPROVED BY HEMINGWAY 77, WHO SEE AN 8 STD. DEV. ENHANCEMENT IN SIGMA KBAR AND A WEAKER COUPLING TO LAMBDA KBAR. ALITTI 68 AND HEMINGWAY 77 OBSERVE NO SIGNALS IN THE Xi PI PI (OR Xi*(1530) PI) CHANNEL, IN CONTRAST TO DIBIANCA 75. THE DECAY INTO LAMBDA SIGMA KBAR PI REPORTED BY BARTSCH 69 IS ALSO NOT CONFIRMED BY HEMINGWAY 77.

68 Xi*1/2(2030) MASS (MEV)
Table with 4 columns: Particle Name, Mass (MEV), and other properties. Includes entries for ALITTI, BARTSCH, ROSSI, DIBIANCA, and HEMINGWAY.



52 Xi*1/2(1940) WIDTH (MEV)
Table with 4 columns: Particle Name, Width (MEV), and other properties. Includes entries for BADIER, ALITTI, DAUBER, GOLDWASSE, ROSSI, DIBIANCA, BRIEFEL, and DAUBER.



68 Xi*1/2(2030) WIDTH (MEV)
Table with 4 columns: Particle Name, Width (MEV), and other properties. Includes entries for ALITTI, BARTSCH, ROSSI, DIBIANCA, and HEMINGWAY.

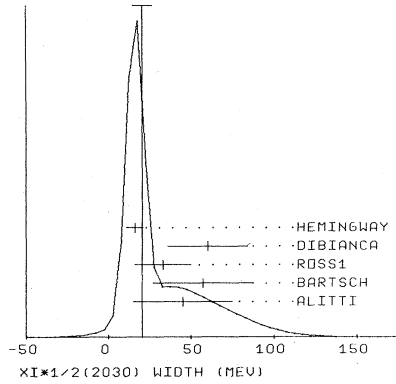
52 Xi*1/2(1940) PARTIAL DECAY MODES
Table with 4 columns: Decay Mode, Particle Name, and other properties. Includes entries for Xi*1/2(1940) INTO Xi PI, Xi*1/2(1940) INTO Xi*(1530) PI, etc.

Baryons

$\Xi(2030)$, $\Xi(2120)$, $\Xi(2250)$, $\Xi(2370)$

Data Card Listings

For notation, see key at front of Listings.



68 $\Xi^*1/2(2030)$ PARTIAL DECAY MODES

P1	Decay Mode	Decay Masses
P1	$\Xi^*1/2(2030)$ INTO Ξ PI	1321+ 139
P2	$\Xi^*1/2(2030)$ INTO LAMBDA KBAR	1115+ 497
P3	$\Xi^*1/2(2030)$ INTO SIGMA KBAR	1197+ 497
P4	$\Xi^*1/2(2030)$ INTO $\Xi^*1/2(1530)$ PI	1533+ 139
P5	$\Xi^*1/2(2030)$ INTO Ξ PI (EXCLUDING P4)	1321+ 139+ 139
P6	$\Xi^*1/2(2030)$ INTO LAMBDA KBAR PI	1115+ 497+ 139
P7	$\Xi^*1/2(2030)$ INTO SIGMA KBAR PI	1189+ 497+ 139

68 $\Xi^*1/2(2030)$ BRANCHING RATIOS

R1	Decay Mode	Branching Ratio
R1	$\Xi^*1/2(2030)$ INTO (Ξ PI)/(MODES P1 TO P4)	(P1)/(P1+P2+P3+P4) - 1 STD DEV LIMIT 9/69
R11	$\Xi^*1/2(2030)$ INTO (Ξ PI)/(SIGMA KBAR)	(P1)/(P3) - K-P AT 4.2 GEV 11/77
R2	$\Xi^*1/2(2030)$ INTO (LAMBDA KBAR)/(MODES P1 TO P4)	(P2)/(P1+P2+P3+P4) - K-P 3.9-5 BEV/C 9/69
R21	$\Xi^*1/2(2030)$ INTO (LAMBDA KBAR)/(SIGMA KBAR)	(P2)/(P3) - K-P AT 4.2 GEV 11/77
R3	$\Xi^*1/2(2030)$ INTO (SIGMA KBAR)/(MODES P1 TO P4)	(P3)/(P1+P2+P3+P4) - K-P 3.9-5 BEV/C 9/69
R4	$\Xi^*1/2(2030)$ INTO (Ξ^* PI)/(MODES P1 TO P4)	(P4)/(P1+P2+P3+P4) - 1 STD DEV LIMIT 9/69
R41	$\Xi^*1/2(2030)$ INTO (Ξ PI PI INCLUDING Ξ^* PI)/(SIGMA KBAR)	(P4+P5)/(P3) - K-P AT 4.2 GEV 11/77
R41 C	FOR THE DECAY MODE (Ξ - PI+ PI-) ONLY	
R6	$\Xi^*1/2(2030)$ INTO LAMBDA KBAR PI	(P6) - K-P AT 10 GEV 11/77
R61	$\Xi^*1/2(2030)$ INTO (LAMBDA KBAR PI)/(SIGMA KBAR)	(P6)/(P3) - K-P AT 4.2 GEV 11/77
R7	$\Xi^*1/2(2030)$ INTO SIGMA KBAR PI	(P7) - K-P AT 10 GEV 11/77
R71	$\Xi^*1/2(2030)$ INTO (SIGMA KBAR PI)/(SIGMA KBAR)	(P7)/(P3) - K-P AT 4.2 GEV 11/77
R71 C	FOR THE DECAY MODE (SIGMA+ - K- PI-) ONLY	

REFERENCES FOR $\Xi^*1/2(2030)$

ALITTI 69 PRL 22 79 +BARNES,FLAMINIO,METZGER, + (BNL,SYRACUSE) I
 BARTSCH 69 PL 288 439 + (AACHEN, BERLIN, CERN, LOIC, VIENNA)
 ROSSI 73 PURDUE CONF. 345 ROSS,LLOYD,RADJICIC (OXFORD)

DIBIANCA 75 NP 898 137 DIBIANCA,ENDORF (CERN)
 HEMINGWAY 77 PL 688 197 HEMINGWAY,ARMENTEROS+ (AMST+CERN+NIJM+CXF) J
 ALSO 76 PL 628 477 GAY,ARMENTEROS,BERGE+ (AMST+CERN+NIJM)

$\Xi(2120)$

103 $\Xi^*1/2(2120)$, JP= $1/2^-$

THIS EFFECT IS REPORTED IN GAY 76 AS A FOUR STANDARD DEVIATION ENHANCEMENT IN LAMBDA K-. AN ANALYSIS OF THE SAME DATA BY HEMINGWAY 77, BUT WITH ADDITIONAL STATISTICS, POINTS OUT THAT THE SIGNIFICANCE OF THE ENHANCEMENT IS GREATLY REDUCED IF A RESTRICTIVE FOUR-MOMENTUM CUT (U-CUT) IS MADE. THIS SUGGESTS AN ANCILLARY PRODUCTION MECHANISM IF THE STATE IS GENUINE. CHLIAPNIKOV 79 REPORT A BUMP OF 18 EVENTS AT 2137 MEV IN AN INCLUSIVE ANTI-LAMBDA K+ SPECTRUM FROM K+P INTERACTIONS AT 32 GEV/C. THE K+ ARE NOT UNIQUELY IDENTIFIED. BUMPS WITH LOWER NUMBERS OF EVENTS ARE ALSO REPORTED AT 2240, 2830, AND 2540 MEV. IN NEED OF CONFIRMATION, OMITTED FROM TABLES.

103 $\Xi^*1/2(2120)$ MASS (MEV)

M	Mass (MeV)	Source
M	2123.0	GAY 76 HBC - K-P AT 4.2 GEV 2/77
M	18(2137.)	CHLIAPNIK 79 HBC + ANTI-LAMBDA K+ 1/80*

103 $\Xi^*1/2(2120)$ WIDTH (MEV)

W	Width (MeV)	Source
W	25.0	GAY 76 HBC - K-P AT 4.2 GEV 2/77
W	18 (20.)	OR LESS CHLIAPNIK 79 HBC + ANTI-LAMBDA K+ 1/80*

103 $\Xi^*1/2(2120)$ PARTIAL DECAY MODES

P1	Decay Mode	Decay Masses
P1	$\Xi^*1/2(2120)$ INTO LAMBDA KBAR	1115+ 497

103 $\Xi^*1/2(2120)$ BRANCHING RATIOS

R1	Decay Mode	Branching Ratio
R1	$\Xi^*1/2(2120)$ INTO LAMBDA KBAR	(P1) - K-P AT 4.2 GEV 2/77

REFERENCES FOR $\Xi^*1/2(2120)$

GAY 76 PL 628 477 +ARMENTEROS,BERGE,GAVILLET+(AMST+CERN+NIJM) I
 HEMINGWAY 77 PL 688 197 HEMINGWAY,ARMENTEROS+ (AMST+CERN+NIJM+CXF)
 CHLIAPNI 79 NP B158 253 CHLIAPNIKOV,GERDYUKOV+ (SERP+BELG+MONS)

$\Xi(2250)$

22 $\Xi^*1/2(2250)$, JP= 1^-

THE EVIDENCE FOR THIS STATE IS WEAK. BARTSCH 69 SEE A BUMP OF NOT MUCH STATISTICAL SIGNIFICANCE IN LAMBDA KBAR-PI, SIGMA-KBAR-PI, AND XI-PI-PI MASS SPECTRA. GOLDWASSER TO SEE A NARROWER BUMP IN XI-PI-PI AT A HIGHER MASS. PERHAPS THEY ARE THE SAME STATE, PERHAPS THEY ARE NOT, BUT SEE ALSO MORRIS 75.

22 $\Xi^*1/2(2250)$ MASS (MEV)

M	Mass (MeV)	Source
M	35 2244.0	52.0 BARTSCH 69 HBC - K-P 10 GEV/C 9/69
M	18 2295.0	15.0 GOLDWASSE 70 HBC - K-P 5.5 GEV/C 10/70

AVERAGE MEANINGLESS (SCALE FACTOR = 1.0)

22 $\Xi^*1/2(2250)$ WIDTH (MEV)

W	Width (MeV)	Source
W	130.0	80.0 BARTSCH 69 HBC - K-P 10 GEV/C 9/69
W	LESS THAN 30.0	GOLDWASSE 70 HBC - K-P 5.5 GEV/C 10/70

22 $\Xi^*1/2(2250)$ PARTIAL DECAY MODES

P1	Decay Mode	Decay Masses
P1	$\Xi^*1/2(2250)$ INTO Ξ PI PI	1321+ 139+ 139
P2	$\Xi^*1/2(2250)$ INTO LAMBDA KBAR PI	1115+ 497+ 139
P3	$\Xi^*1/2(2250)$ INTO SIGMA KBAR PI	1197+ 497+ 139

REFERENCES FOR $\Xi^*1/2(2250)$

BARTSCH 69 PL 288 439 + (AACHEN, BERLIN, CERN, LOIC, VIENNA)
 GOLDWASSER 70 PR 10 1960 E L GOLDWASSER, P F SCHULTZ (ILLINOIS)

PAPERS NOT REFERRED TO IN DATA CARDS

MORRIS 75 ANL-HEP-CP-75-58 MORRIS,OH,PARKER,SMITH,WHITMORE (MSU)

$\Xi(2370)$

131 $\Xi^*1/2(2370)$, JP= 1^- I=1/2

SEEN BY AMIRZADEH 79 IN THE CHARGED AND NEUTRAL LAMBDA/SIGMA KBAR PI MASS SPECTRA FROM THE REACTIONS K-P --> XI* K AND XI* K PI AT 8.25 GEV/C. A SMALL EFFECT AT THE SAME MASS IS ALSO OBSERVED IN THE OMEGA- K MASS SPECTRUM. IN NEED OF CONFIRMATION, OMITTED FROM TABLES.

131 $\Xi^*1/2(2370)$ MASS (MEV)

M	Mass (MeV)	Source
M	94 2373.	8. AMIRZAD2 79 HBC -0 K-P AT 8.25 GEV 1/80*

131 $\Xi^*1/2(2370)$ WIDTH (MEV)

W	Width (MeV)	Source
W	94 80.	25. AMIRZAD2 79 HBC -0 K-P AT 8.25 GEV 1/80*

131 $\Xi^*1/2(2370)$ PARTIAL DECAY MODES

P1	Decay Mode	Decay Masses
P1	$\Xi^*1/2(2370)$ INTO LAMBDA KBAR PI	1115+ 497+ 139
P2	$\Xi^*1/2(2370)$ INTO SIGMA KBAR PI	1197+ 497+ 139
P3	$\Xi^*1/2(2370)$ INTO OMEGA- K	1672+ 497

131 $\Xi^*1/2(2370)$ BRANCHING RATIOS

R1	Decay Mode	Branching Ratio
R1	$\Xi^*1/2(2370)$ INTO LAMBDA KBAR PI	(P1) -0 K-P AT 8.25 GEV 1/80*
R2	$\Xi^*1/2(2370)$ INTO SIGMA KBAR PI	(P2) -0 K-P AT 8.25 GEV 1/80*
R3	$\Xi^*1/2(2370)$ INTO OMEGA- K	(P3) - K-P AT 8.25 GEV 1/80*

Data Card Listings

Baryons

For notation, see key at front of Listings.

$\Xi(2500)$, Ω^- , Λ_c^+ , $\Sigma_c(2430)$, DIBARYONS

REFERENCES FOR $\Xi(2500)$

AMIRZAD2 79 CERN/EP 79-130 AMIRZADEH+ (BIRM+CERN+GLAS+MSU+LPNP) I

$\Xi(2500)$

99 $\Xi(2500)$, JP=) I=1/2

IT IS QUITE POSSIBLE THAT THE REASON THE EXPERIMENTS DISAGREE ABOUT THE MASS AND WIDTH IS THAT THEY ARE SEEING DIFFERENT Ξ 'S. FOR NOW, HOWEVER, WE GROUP THEM TOGETHER.

99 $\Xi(2500)$ MASS (MEV)

M	30	2430.0	20.0	ALITTI	69	HBC	-	K-P 4,6-5	GEV/C	9/69
M	45	2500.0	10.0	BARTSCH	69	HBC	-0	K-P 10	GEV/C	9/69
M		2392.	27.	DIBIANCA	75	DBC		XI 2P1		1/76
M	AVERAGE MEANINGLESS (SCALE FACTOR = 3.2)									

99 $\Xi(2500)$ WIDTH (MEV)

W	150.0	60.0	40.0	ALITTI	69	HBC	-			9/69
W	59.0	27.0		BARTSCH	69	HBC	-0			9/69
W	75.	69.		DIBIANCA	75	DBC		XI 2P1		1/76
W	AVERAGE MEANINGLESS (SCALE FACTOR = 1.1)									

99 $\Xi(2500)$ PARTIAL DECAY MODES

P1	$\Xi(2500)$	INTO	Ξ P1	1321+ 139	DECAY MASSES
P2	$\Xi(2500)$	INTO	LAMBDA KBAR	1115+ 497	
P3	$\Xi(2500)$	INTO	SIGMA KBAR	1197+ 497	
P4	$\Xi(2500)$	INTO	$\Xi(1530)$ P1	1533+ 139	
P5	$\Xi(2500)$	INTO	LAMBDA (OR SIGMA) KBAR P1	1115+ 497+ 139	
P6	$\Xi(2500)$	INTO	Ξ P1 P1	1321+ 139+ 139	

99 $\Xi(2500)$ BRANCHING RATIOS

R1	$\Xi(2500)$	INTO	Ξ P1	(P1)/(P1+P2+P3+P4)	9/69
R1	(0.5)	OR LESS	ALITTI	69 HBC	1 STD DEV LIMIT
R2	$\Xi(2500)$	INTO	LAMBDA KBAR	(P2)/(P1+P2+P3+P4)	9/69
R2	0.5	0.2	ALITTI	69 HBC	-
R3	$\Xi(2500)$	INTO	SIGMA KBAR	(P3)/(P1+P2+P3+P4)	9/69
R3	0.5	0.2	ALITTI	69 HBC	-
R4	$\Xi(2500)$	INTO	Ξ P1	(P4)/(P1+P2+P3+P4)	9/69
R4	(0.2)	OR LESS	ALITTI	69 HBC	1 STD DEV LIMIT
R5	$\Xi(2500)$	INTO	LAMBDA (OR SIGMA) KBAR P1	(P5)	9/69
R5	SEEN		BARTSCH	69 HBC	-0
R6	$\Xi(2500)$	INTO	Ξ P1 P1	(P6)	9/69
R6	SEEN		BARTSCH	69 HBC	-0

REFERENCES FOR $\Xi(2500)$

ALITTI 69 PRL 22 79 +BARNES, FLAMINIO, METZGER, + (BNL, SYRACUSE) I
 BARTSCH 69 PRL 28B 439 + (AACHEN, BERLIN, CERN, COIC, VIENNA)
 DIBIANCA 75 NP B98 137 DIBIANCA, ENDORF (CERN)

S=-3 I=0 HYPERON STATE (Ω)

Ω^-

24 OMEGA-(1675, JP=3/2+) I=0

SEE STABLE PARTICLE DATA CARD LISTINGS

CHARMED BARYONS

Λ_c^+

33 LAMBDA/C+(2260, JP=)

SEE STABLE PARTICLE DATA CARD LISTINGS

$\Sigma_c(2430)$

104 SIGMA/C(2430, JP=)

104 SIGMA/C MASS

M	1	2426.	12.	CAZZOLI	75	HBC	++	LAMBDA/C+ PI+	3/77
M	K	9(2500.)		KNAPP	76	SPEC 0		ANTILAMBDA/C-PI+	3/77
M		1(2439.)	OR MORE	BARISH	77	DBC	++	LAMBDA/C+ PI+	3/77
M	K	KNAPP 76	MAY NOT BE THE SAME STATE AS CAZZOLI 75.	DERUJULA	75				3/77
M	K	PREDICT TWO SIGMA/C STATES AROUND 2.4-2.5 GEV. THIS COULD BE BOTH.							3/77

104 (SIGMA/C)-(LAMBDA/C+) MASS DIFFERENCE (MEV)

D	1	6.5	168.	3.	BALTAY	79	HLBC	++	LAMBDA/C+ PI+	12/79*
D	1	8 EVENTS WITH A BACKGROUND OF 1.5 IDENTIFIED AS								12/79*
D	1	NU+NE-->(MU-)+(SIGMA/C++)X; (SIGMA/C++)-->(LAMBDA/C+)+(PI+);								12/79*
D	1	(LAMBDA/C+)-->LAMBDA+(PI+)								12/79*

104 SIGMA/C(2430) PARTIAL DECAY MODES

P1	SIGMA/C(2430)	INTO	LAMBDA/C+ PI	2273+ 139	DECAY MASSES
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REFERENCES FOR SIGMA/C(2430)

CAZZOLI 75 PRL 34 1125 +CNOOPS, CONNOLLY, LOUITT, MURTAGH+ (BNL)
 KNAPP 76 PRL 37 882 +LEE, LEUNG, SMITH + (COLU+HAWA+ILL+FNAL)
 BARISH 77 PR D15 1 +DERRICK, DOMBECK, MUSGRAVE + (ANL+PURD)
 BALTAY 79 PRL 26 1721 +CAROUMBALIS, FRENCH, HIBBS, HYLTON+(COLU+BNL) I
 THEORY AND REVIEW
 DERUJULA 75 PR D12 147 +GEORGI, GLASHOW (HARV)
 LEE 77 PR D15 157 +QUIGG, ROSNER (FNAL)

Dibaryon States

Dibaryon resonances have been predicted theoretically¹⁻⁴ and claimed experimentally, but although considerable evidence for them has been published, their existence remains controversial. Problems with the pp data have been pointed out by Bugg.⁵ Either the $\Delta(\sigma_L)$ data and elastic data at 1 and 1.1 GeV/c are inconsistent, or accepted ideas about the mechanism of the inelastic channels are wrong. Most significant evidence is included in the Listings, but there may be omissions, especially in earlier work. We have not included evidence on nuclear properties, hypernuclei, d^* 's, or Δ 's bound within the deuteron - though these may be related to effects observed in the search for dibaryon resonances. We have also omitted most data on low energy $\pi^+d \rightarrow pp$. There is a large amount of literature on this reaction which we did not have time to review adequately. Most of these experiments are addressed to the question of whether there is a resonance associated with the $N\Delta$ threshold.

The Listings are grouped by strangeness.

References

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Baryons
DIBARYONS

- 3. R. L. Jaffe, Phys. Rev. Lett. 38, 195 (1977).
4. J. J. de Swart, Nijmegen preprint THEF-NYM-79-16.
5. D. V. Bugg, J. Phys. G5, 1349 (1979).

DIBARYONS

S=0

106 BARYON NUMBER 2, STRANGENESS 0 STATES

EXPERIMENTS USING THE POLARIZED PROTON BEAM AND TARGET AT ARGONNE HAVE SHOWN BROAD STRUCTURES IN THE DIPTON SYSTEM. THE DATA SHOW A SIGNIFICANT DIP IN THE PP TOTAL CROSS SECTION DIFFERENCE BETWEEN ANTI-PARALLEL AND PARALLEL LONGITUDINALLY POLARIZED STATES...

MINAMI 78 HAS PRESENTED CRITICISM OF THE ANALYSIS OF BOTH HIDAKA 77 AND HOSHIZAKI 77, AND SUGGESTS THE OBSERVED EFFECTS ARE CONSISTENT WITH THE ABSENCE OF A RESONANCE.

UEDA 78 SUGGESTS THE 3F3 STATE IS A (PI N N) SYSTEM WITH THE PI N SYSTEMS IN THE DELTA33 RESONANCE.

BUGG 79 POINTS OUT AN INCONSISTENCY BETWEEN THE LONGITUDINALLY POLARIZED CROSS SECTION DATA AND THE REAL PART OF THE CORRESPONDING FORWARD AMPLITUDE BELOW THE REGION OF THE RESONANCES CLAIMED BY THE ARGONNE GROUP.

THE GENEVA GROUP HAS RECENTLY MADE ACCURATE MEASUREMENTS, BUT THEY ARE NOT YET READY TO PUBLISH THEIR RESULTS. PRELIMINARY RESULTS PRESENTED AT THE 1979 CONFERENCE ON HIGH ENERGY PHYSICS AND NUCLEAR STRUCTURE (VANCOUVER) MAY DISAGREE WITH THE (CL,L:0,0) MEASUREMENTS FROM ARGONNE.

106 B=2, S=0 STATES - CROSS SECTION

Table with columns for author, energy, state, and cross-section values. Includes entries for DEBOER, AUER, HIDAKA, BIEGERT, BRYAN, HOSHIZAKI, IKEDA, and MACGREGOR.

Data Card Listings
For notation, see key at front of Listings.

Table listing particle data for 106 B=2, S=0 STATES - MASS (MEV). Columns include author, energy, state, and mass values.

Table listing particle data for 106 B=2, S=0 STATES - WIDTH (MEV). Columns include author, energy, state, and width values.

REFERENCES FOR B=2, S=0 STATES

Table of references for B=2, S=0 states, listing authors and their respective publications.

PAPERS NOT REFERRED TO IN DATA CARDS

Table of references not included in data cards, listing authors and their publications.

S=-1

107 BARYON NUMBER 2, STRANGENESS -1 STATES

THE POSITIVE EVIDENCE FOR A LAMBDA P RESONANCE COMES FROM EXPERIMENTS USING NUCLEAR TARGETS, USUALLY DEUTERIUM. THIS EVIDENCE IS COMPLICATED BY NUCLEAR EFFECTS, BUT EVEN MORE SERIOUS AMBIGUITIES ARISE FROM THE FACT THAT THE MOST LIKELY LAMBDA P RESONANCE, AT 2130 MEV, LIES PRECISELY AT SIGMA NUCLEON THRESHOLD.

Data Card Listings

For notation, see key at front of Listings.

Baryons
DIBARYONS

EXPERIMENTS USING FREE HYPERON BEAMS MAY LACK THE STATISTICAL SENSITIVITY TO OBSERVE THE 2130 MEV EFFECT SEEN IN THE NUCLEAR TARGET DATA.

Table with columns for experiment codes (CS, CS Z, CS R, CS D, CS Z, CS R, CS R, CS R, CS D, CS D) and descriptions of the 107 LAMBDA P(2130) PEAK - CROSS SECTION (MICROBARN) and MASS (MEV).

Table with columns for experiment codes (M, M J, M F, M E, M I, M S, M, M D, M G, M P, M Z, M N, M O, M J, M F, M I, M S, M D, M D, M N, M D) and descriptions of the 107 LAMBDA P(2130) PEAK - MASS (MEV) and WIDTH (MEV).

Table with columns for experiment codes (W, W J, W F, W E, W I, W S, W Z, W N, W D) and descriptions of the 107 LAMBDA P(2130) PEAK - WIDTH (MEV).

Table with columns for experiment codes (CS Z) and descriptions of the 107 OTHER LAMBDA P PEAKS - CROSS SECTION (MICROBARN).

Table with columns for experiment codes (M, M S, M H, M M) and descriptions of the 107 OTHER LAMBDA P PEAKS - MASS (MEV).

Table with columns for experiment codes (W, W S, W H) and descriptions of the 107 OTHER LAMBDA P PEAKS - WIDTH (MEV).

Table with columns for experiment codes (COHN, ALEXANDE, CLINE, ALEXANDE, JAIN, TAN, BUNNEL, EASTWOOD, KADYK, SIMS, SHAHBAZI, HAUPTMAN, SODHI, BRAUN) and descriptions of REFERENCES FOR B=2, S=-1 STATES.

Table with columns for experiment codes (DOSCH, GOYAL, NISHIMUR, SHAHBAZI, SHAHBAZ, NAGELS, ROOSEN, DOSCH, DAHL, PIROUE, GOYAL) and descriptions of BARYON NUMBER 2, STRANGENESS -2 STATES.

S=-2

108 BARYON NUMBER 2, STRANGENESS -2 STATES

EXPERIMENTAL EVIDENCE FOR RESONANCES IN THE STRANGENESS = -2 DIBARYON SYSTEMS IS NOT VERY STRONG, THOUGH RESONANCES ARE PREDICTED (JAFFE 77).

Table with columns for experiment codes (CS, CS W, CS A, CS S, CS W, CS W, CS A, CS S) and descriptions of 108 B=2, S=-2 STATES - CROSS SECTION (MICROBARN/NUCL.).

Table with columns for experiment codes (M, M, M) and descriptions of 108 B=2, S=-2 STATES - MASS (MEV).

Table with columns for experiment codes (W) and descriptions of 108 B=2, S=-2 STATES - WIDTH (MEV).

Table with columns for experiment codes (BEILLIER, SHAHBAZI, WILQUET, GUY, SHAHBAZ, GOYAL) and descriptions of REFERENCES FOR B=2, S=-2 STATES.

Table with columns for experiment codes (JAFFE) and descriptions of REFERENCES FOR B=2, S=-2 STATES.

115 BARYON NUMBER >=2, STRANGENESS -2 STATES

Table with columns for experiment codes (CS S, CS S, CS C, CS C) and descriptions of 115 B>=2, S=-2 STATES - CROSS SECTION (MICROBARN).

Table with columns for experiment codes (M S) and descriptions of 115 B>=2, S=-2 STATES - MASS (MEV).

Table with columns for experiment codes (W S) and descriptions of 115 B>=2, S=-2 STATES - WIDTH (MEV).

Table with columns for experiment codes (CARROLL, SHAHBAZ) and descriptions of REFERENCES FOR B>=2, S=-2 STATES.

Appendix I

TEST OF $\Delta I=1/2$ RULE FOR K DECAYS

The quantities of interest for making tests of theoretical predictions regarding the $\Delta I=1/2$ rule for K decay are usually partial decay rates for single channels or special sums of channels. It is not possible to compute the errors on sums, differences, and ratios of partial decay rates from the information given in the Table of Stable Particles because of the presence of off-diagonal terms in the error matrix. For this reason we give some of these quantities in Table I. Throughout this Appendix, italics are used to indicate that a quantity has changed by more than one (old) standard deviation since our previous edition, and S gives the scale factor included in the quoted error because of inconsistencies in the data (see footnote at end of Stable Particle Table for definition of S).

Table I. (000) and (+-0) refer to the sign of the pions into which the K_L decays.

$\Gamma_{K_{l3}^+} = \Gamma_{K_{e3}^+} + \Gamma_{K_{\mu 3}^+}$	$= (6.484 \pm 0.089) 10^6 \text{ sec}^{-1}$	
$\Gamma_{K_{\mu 3}^+} / \Gamma_{K_{e3}^+}$	$= 0.663 \pm 0.018$	$S=1.7^*$
$\Gamma_{K_7^+} / \Gamma_{K_7^+}$	$= 3.226 \pm 0.082$	
$\Gamma_{K_{l3}^0} = \Gamma_{K_{e3}^0} + \Gamma_{K_{\mu 3}^0}$	$= (12.70 \pm 0.15) 10^6 \text{ sec}^{-1}$	$S=1.1^*$
$\Gamma_{K_{\mu 3}^0} / \Gamma_{K_{e3}^0}$	$= 0.695 \pm 0.017$	
$\Gamma_{K^0(000)} / \Gamma_{K^0(+ - 0)}$	$= 1.733 \pm 0.076$	$S=1.3^*$

1. Leptonic decay rates

The $\Gamma_{K_{l3}}$ rates are useful in testing the leptonic $\Delta I=1/2$ rule in the way suggested by Trilling.¹ The predictions are

$$\Gamma_{K_{l3}^0} / 2\Gamma_{K_{l3}^+} = 1.012, \text{ a phase-space factor,}^2$$

and

$$\Gamma_{K_{\mu 3}^0} / \Gamma_{K_{e3}^0} = \Gamma_{K_{\mu 3}^+} / \Gamma_{K_{e3}^+}.$$

From Table 1,

$$\Gamma_{K_{l3}^0} / 2\Gamma_{K_{l3}^+} = 0.979 \pm 0.018$$

and

$$\frac{\Gamma_{K_{\mu 3}^0}}{\Gamma_{K_{e3}^0}} \left[\frac{\Gamma_{K_{\mu 3}^+}}{\Gamma_{K_{e3}^+}} \right]^{-1} = 1.048 \pm 0.038.$$

These results seem to show a less than 2σ disagreement with the predictions, but the errors should be regarded with caution in view of the internal disagreements in the data. (Note the ideograms in the Data Listings for the charged K meson.)

2. Three-pion decays

We follow here the tests done by Mast et al.,³ based on the general analysis of K decays suggested by Zemach.⁴ Both decay rates (Γ) and slopes (g, the energy dependence of the Dalitz plot distributions) are used. The $\Delta I=1/2$ rule predicts that the following test quantities are all equal to zero:

$$\text{Test 1} = \frac{2}{3} \frac{\Gamma_{K^0(000)}}{\phi_1} \left[\frac{\Gamma_{K^0(+ - 0)}}{\phi_2} \right]^{-1} - 1,$$

$$\text{Test 2} = \frac{1}{4} \frac{\Gamma_{K_7^+}}{\phi_3} \left[\frac{\Gamma_{K_7^+}}{\phi_4} \right]^{-1} - 1,$$

$$\text{Test 3} = \frac{1}{2} \frac{\Gamma_{K_7^+}}{\phi_3} \left[\frac{\Gamma_{K^0(+ - 0)}}{\phi_2} \right]^{-1} - 1,$$

$$\text{Test 4} = \frac{1}{2} g_{K_7^+} + g_{K_7^+},$$

$$\text{Test 5} = g_{K^0(+ - 0)} + g_{K_7^+} - \frac{1}{2} g_{K_7^+}.$$

The ϕ_i are phase-space factors which have been calculated as described in Mast et al.³ by use of a relativistic formulation and the masses and slopes from this edition. The factors labeled UDP are the relative areas of the Dalitz plots, assuming a uniform distribution. The NU DP include the observed slopes (see below). The CNU DP have been calculated by including the final-state Coulomb interaction.

The values are:

	Method		
	UDP	NU DP	CNU DP
$\phi_1(000) =$	1.490	1.490	1.444
$\phi_2(+ - 0) =$	1.221	1.303	1.287
$\phi_3(+ + -) =$	1.000	1.000	1.000
$\phi_4(+ 0 0) =$	1.247	1.173	1.137

For convenience, we repeat the slope parameters tabulated in the Stable Particle Table. They are as follows:

$g_{K_7^+}$	$= -0.215 \pm 0.004$	$S=1.4^*$
$g_{K_7^-}$	$= -0.217 \pm 0.007$	$S=2.5^*$
$\bar{g}_{K_7^+}$	$= -0.215 \pm 0.003$	
$g_{K_7^+}$	$= 0.607 \pm 0.030$	$S=1.3^*$
$g_{K^0(+ - 0)}$	$= 0.670 \pm 0.014$	$S=1.6^*$

A difference in the τ^+ and τ^- slopes would be an indication of CP violation in this decay. Since no difference is observed at this time, we average the two and use this value in Test 4 and Test 5.

We use the CNUDP factors and the rates and slopes reported in this edition to compute the five test quantities which the $\Delta I=1/2$ rule predicts to be zero. The results are:

- Test 1 = 0.030 ± 0.045
- Test 2 = -0.083 ± 0.023
- Test 3 = 0.216 ± 0.020
- Test 4 = 0.088 ± 0.016
- Test 5 = 0.152 ± 0.021

The three-pion final state can be in isospin states $I = 1, 2, 3$. Tests 1 and 2 test the existence of isospin $I = 3$ in the final state. Since the rate tests (Tests 1, 2, and 3) could differ from zero by as much as 0.1 owing to the mass differences and the occurrence of big slopes⁵, no evidence for $I=3$ is found. Test 4 is related to the $I=2$ amplitude in the final state and indicates the presence of $I=2$. Tests 3 and 5 give information on the $\Delta I=3/2$ part of the $I=1$ amplitude relative to the $\Delta I=1/2$ part. Both tests indicate the presence of $\Delta I=3/2$.

References

1. G. Trilling, K-Meson Decays, UCRL-16473, (updated from Argonne Conference Proceedings, 1965, p. 115).
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4. C. Zemach, Phys. Rev. **133**, B1201 (1964).
5. C. Bouchiat and M. Veltman, Topical Conference on Weak Interactions, CERN 69-7 (1969), p. 225.

Appendix II

TEST OF $\Delta I=1/2$ RULE FOR HYPERON DECAYS

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1. Nonleptonic decay Amplitudes

In this edition we again use the new convention for the amplitudes A and B adopted in 1973. Some theorists have suggested that dimensionless amplitudes are more useful to them than the ones appearing in the literature. Berge¹ used a convention with A and B in units of $\text{sec}^{-1/2}$. Samios² used a convention which gave A and B in units of $(\text{MeV}\cdot\text{sec})^{-1/2}$. Following is the convention suggested by Jackson³, which gives dimensionless A and B.

The effective Lagrangian density for nonleptonic hyperon decays ($B_1 \rightarrow B_2 + \pi$) can be written

$$L_{\text{eff}} = G\mu_c^2 [\bar{\psi}_2(A+B\gamma_5)\psi_1]\phi_\pi,$$

where $G=10^{-5}m_p^{-2}$ is a coupling constant characteristic of first-order weak decays, μ_c is the charged pion mass, and A and B are dimensionless complex numbers giving the relative amplitudes of the parity-violating and parity-conserving decays, respectively. The matrix γ_5 is to be taken in the Pauli form, $\gamma_5 = \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}$. The invariant amplitude for the decay is

$$M = G\mu_c^2 [\bar{u}(p)(A+B\gamma_5)u(P)],$$

where P is the 4-momentum of the decaying hyperon of mass M, and p is the 4-momentum of the baryon decay product of mass m. With the normalization convention, $\bar{u}_i u_i = 2m_i$, the Pauli form of the matrix element in the rest frame of the decaying hyperon is

$$M = G\mu_c^2 (\chi_2 | \sqrt{2M(E+m)}A + \sqrt{2M(E-m)}B\hat{\sigma}\cdot\hat{q} | \chi_1),$$

where E is the total energy of the final baryon and \hat{q} is a unit vector in the direction of motion of the final baryon. Comparison with Sec. VI D of the text shows that the amplitudes s and p defined there are proportional to A and B:

$$\frac{p}{s} = \left(\frac{E-m}{E+m} \right)^{1/2} \frac{B}{A} = \left[\frac{(M-m)^2 - \mu^2}{(M+m)^2 - \mu^2} \right]^{1/2} \frac{B}{A}.$$

Here μ is the mass of the pion entering the decay. The parameters α , β , and γ can therefore be expressed in terms of A and B, rather than s and p, if desired.

The decay rate for $B_1 \rightarrow B_2 + \pi$ is

$$\Gamma = \frac{G^2 \mu_c^4}{8\pi} q \left\{ \left[\frac{(M+m)^2 - \mu^2}{M^2} \right] |A|^2 + \left[\frac{(M-m)^2 - \mu^2}{M^2} \right] |B|^2 \right\},$$

where q is the c.m. momentum of the decay products. For reference, the dimensionless constant in this expression has the value $(G^2 \mu_c^4 / 8\pi) = 1.9488 \times 10^{-15}$.

Table I summarizes the amplitudes A and B for the nonleptonic decays of the Λ , Σ , and Ξ hyperons. These amplitudes have been calculated by using the experimental data for mean lives, branching ratios, and the decay asymmetry α given in the Stable Particle Table of this Review. Time-reversal invariance is assumed and final-state interactions are neglected, so A and B are taken to be relatively real. The subscript on the hyperon refers to the sign of the decaying pion. The statistical correlation coefficient

$$C_{AB} = \frac{\langle \Delta A \Delta B \rangle}{\sqrt{\langle \Delta A^2 \rangle \langle \Delta B^2 \rangle}}$$

is also given. The absolute signs of A and B have been assigned, using the following convention. Taking $A(\Lambda_0^0)$ as positive, the other S -wave decay amplitudes are chosen to give an approximate fit to the triangular relationships

$$\sqrt{2}A(\Sigma_0^+) + A(\Sigma_0^+) = A(\Sigma^-) \text{ and } \sqrt{3}A(\Sigma_0^+) + A(\Lambda_0^0) = 2A(\Xi^-).$$

The signs of the B amplitudes relative to those of the corresponding A amplitudes are determined by the sign of the appropriate α decay parameter.

M	$\rightarrow m + \mu$	A	B	C_{AB}
Λ_0^0	$\rightarrow p + \pi^-$	1.47 ± 0.01	9.98 ± 0.24	-0.289
Λ_0^0	$\rightarrow n + \pi^0$	-1.07 ± 0.01	-7.14 ± 0.56	-0.741
Σ_0^+	$\rightarrow n + \pi^+$	0.06 ± 0.01	19.07 ± 0.07	-0.038
Σ_0^+	$\rightarrow p + \pi^0$	1.48 ± 0.05	-12.04 ± 0.58	0.982
Σ_0^-	$\rightarrow n + \pi^-$	1.93 ± 0.01	-0.65 ± 0.07	0.003
Ξ_0^0	$\rightarrow \Lambda + \pi^0$	1.54 ± 0.03	-6.43 ± 0.66	0.188
Ξ_0^-	$\rightarrow \Lambda + \pi^-$	2.04 ± 0.01	-6.93 ± 0.31	0.268

2. Tests of the $\Delta I=1/2$ Rule

(a) Λ Decay

For Λ decay the $\Delta I=1/2$ rule predicts that $\Gamma_0/\Gamma_- = 0.50$ and $\alpha_0 = \alpha_-$. In order to determine the magnitude of possible $\Delta I=3/2$ amplitudes present we write the linear expressions⁴ for the $\Delta I=3/2$ A- and B-wave amplitudes in terms of $\Delta\alpha$, where $\Delta\alpha$ is the measured value of α_0/α_- minus the predicted value, and in terms of $\Delta\Gamma$ similarly defined. Evaluating these we find

$$\begin{aligned} \Delta\alpha &= -1.54 (A_3/A_1) + 1.61 (B_3/B_1), \\ \Delta\Gamma &= 1.84 (A_3/A_1) + 0.25 (B_3/B_1). \end{aligned}$$

Here the $\Delta I=3/2$ amplitudes are expressed relative to the $\Delta I=1/2$ amplitudes. The numerical values of the coefficients depend on the ratio B/A . The uncertainties in the coefficients are small compared to the uncertainties in $\Delta\alpha$ and $\Delta\Gamma$. Final-state πN interactions have been included in these relations but have a very small effect. From the Stable Particle Table,

$$\Delta\alpha = 0.006 \pm 0.066, \quad \Delta\Gamma = 0.058 \pm 0.012,$$

and hence

$$(A_3/A_1) = 0.027 \pm 0.008$$

and

$$(B_3/B_1) = 0.030 \pm 0.037.$$

The possible 3% $\Delta I=3/2$ A-wave amplitude is due to the disagreement of decay rates with prediction. At this level the results are sensitive to electromagnetic corrections. However, in Λ decay the phase space correction and the other radiative corrections appear to be about equal in magnitude and have opposite signs,^{5,6} and hence cancel each other in the correction to the decay rates.

(b) Ξ Decay

The analysis for Ξ decay is very similar to that for Λ decay. If the $\Delta I=1/2$ rule is valid, $\Gamma_0(\Xi^0)/\Gamma_-(\Xi^-) = 0.50$ and $\alpha_0 = \alpha_-$. For this case the expressions linear in $\Delta I=3/2$ A- and B-wave amplitudes are⁴

$$\begin{aligned} \Delta\alpha &= 1.37 (A_3/A_1) - 1.37 (B_3/B_1), \\ \Delta\Gamma &= -1.44 (A_3/A_1) - 0.06 (B_3/B_1). \end{aligned}$$

From the Stable Particle Table,

$$\Delta\alpha = 0.18 \pm 0.12, \quad \Delta\Gamma = 0.066 \pm 0.020,$$

and we find

$$(A_3/A_1) = -0.038 \pm 0.014$$

and

$$(B_3/B_1) = -0.17 \pm 0.09.$$

(c) Σ Decay

The traditional test of the $\Delta I=1/2$ rule in Σ decay is that the amplitudes satisfy the relationship

$$\sqrt{2} \Sigma_0^+ + \Sigma_0^+ - \Sigma_0^- = 0.$$

Graphically this is equivalent to closing the Σ triangle when the amplitudes are plotted on A, B axes. Including $\Delta I \geq 3/2$ amplitudes in Σ decay analysis, the " Σ triangle" relationship becomes

$$\sqrt{2} A_0 + A_+ - A_- = -3\sqrt{2/5} A_3 + \frac{2}{\sqrt{15}} A_5.$$

where A_3 and A_5 are $\Delta I=3/2$ and $\Delta I=5/2$ amplitudes, respectively. There is a similar equation for the B amplitudes. From Table I,

$$\sqrt{2}A_0 + A_+ - A_- = 0.22 \pm 0.09$$

and

$$\sqrt{2}B_0 + B_+ - B_- = 2.7 \pm 1.0$$

If we neglect the $\Delta I=5/2$ amplitudes and assume all amplitudes to be real we can solve for possible $\Delta I=3/2$ amplitudes. The result is

$$\frac{A_3}{A_-} = -0.061 \pm 0.024$$

and

$$\frac{B_3}{B_+} = -0.074 \pm 0.027$$

Thus for hyperon decay, present experimental data limit $\Delta I=3/2$ amplitudes to less than about 5%.

3. The Lee-Sugawara Relation

From Table I the Lee-Sugawara relation,^{7,8} $\sqrt{3}\Sigma_0^+ + \Lambda_0^0 - 2\Sigma_- = 0$, is satisfied to -0.07 ± 0.11 for the A amplitudes, and to 3.0 ± 1.9 for the B amplitudes.

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$$\frac{\Gamma_0}{\Gamma_-} \approx \frac{1}{2} \left\{ 1 + 3\sqrt{2} \times \left[\frac{S_{11}S_{33}\cos(\delta_1 - \delta_3) + P_{11}P_{33}\cos(\delta_{11} - \delta_{31})}{S_{11}^2 + P_{11}^2} \right] \right\}$$

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Appendix III

A. SU(3) CLASSIFICATION OF BARYON RESONANCES

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It is established that a symmetry higher than SU(3) is necessary to classify the known baryon resonances. However, many higher-symmetry schemes have been proposed, and even for SU(6) various versions exist (for a review see Dalitz¹). Since it is not clear which one of these schemes best fits the data, we do not review them here, but we report once again fits of baryon states into SU(3) multiplets.

For the reader's convenience, we collect here the relevant formulae.

Exact SU(3) symmetry predicts that all the members of a multiplet should have the same mass and the same couplings for decays into other multiplets. It has been found, however, that the members of the octet of stable baryons lie within 20% of their mean mass; therefore a symmetry-breaking interaction has been introduced by Gell-Mann and Okubo independently.² In addition, for the isospin-0 vector mesons (ω and ϕ), an additional symmetry-breaking interaction has been introduced by Sakurai³ to take care of octet-singlet mixing. The relevant formulae for masses and decay rates are given below.

Mass Formulae

Broken SU(3) gives:

$$\begin{aligned} \text{Decuplet} \quad \Delta - \Sigma &= \Sigma - \Xi = \Xi - \Omega & \text{GMO} & (1) \\ \text{Octet} \quad 2(N + \Xi) &= 3\Lambda + \Sigma & \text{GMO} & (2) \end{aligned}$$

$$\begin{aligned} \left. \begin{array}{l} \text{Octet-} \\ \text{Singlet} \\ \text{mixing} \end{array} \right\} \quad \sin^2\theta &= \frac{\Lambda - M_B}{\Lambda - \Lambda'} & \text{Mixing} & \\ & & \text{angle} & (3) \\ M_B &= \frac{2(N + \Xi) - \Sigma}{3} & \text{GMO} & (4) \end{aligned}$$

Here GMO stands for the Gell-Mann-Okubo formula; the particle symbol indicates its mass. The formulae would be the same if squared masses were used. For the nonet case, Λ is the "mostly-octet" particle, Λ' is the "mostly-singlet" particle.

Decay Rates

In terms of a relativistically invariant matrix element T, the decay rate for two-body decay of a resonance of mass M_R is

$$\Gamma \propto \frac{|T|^2 R_2}{M_R} \quad (5)$$

where $R_2 = k/M_R$ is the two-body phase space factor. Since the numerator is an invariant, and since Γ must transform as $1/E$, we introduce the denominator M_R .⁵

For meson decays (see below) the rates are calculated according to Eq. (5); for baryon resonance decays into $1/2^+$ baryons and 0^- mesons, one next takes into account the fact that spin sums in $|T|^2$ introduce another factor M_R , cancelling the $1/M_R$. We are then left with

$$\begin{aligned}\Gamma &= \frac{|T|^2 k}{M_R} M_N, \text{ for baryons} & (5') \\ &= \frac{|T|^2 k}{M_R^2} M_N^2, \text{ for mesons.} & (5'')\end{aligned}$$

The powers of the nucleon mass M_N or M_N^2 have been introduced so that we can treat $|T|$ as dimensionless.

$|T|^2$ contains centrifugal barrier factors, which we call B_l . We then have

$$\left. \begin{array}{l} \text{Decuplet} \\ \text{Singlet} \end{array} \right\} \Gamma = (c_g)^2 B_l(k) \frac{M_N}{M_R} k \quad (6)$$

$$\text{Octet} \quad \Gamma = (c_D g_D + c_F g_F)^2 B_l(k) \frac{M_N}{M_R} k \quad (7)$$

$$\left. \begin{array}{l} \text{Octet-} \\ \text{Singlet} \\ \text{mixing} \end{array} \right\} \begin{aligned} \Lambda &= G_B \cos\theta + G_1 \sin\theta \\ \Lambda' &= -G_B \sin\theta + G_1 \cos\theta \end{aligned} \quad (8)$$

$$\text{with} \quad \begin{aligned} G_B &= c_D g_D + c_F g_F \\ G_1 &= c_1 g_1. \end{aligned} \quad (9)$$

Here c_i are the SU(3) coefficients with the sign convention adopted in this article [see note in the Table of SU(3) Isoscalar Factors and Fig. 2 in the text]. M_N is the nucleon mass, M_R is the resonance mass for which Γ is calculated, k is the center-of-mass momentum for the channel being considered, and g_i are the relevant couplings. For the case of singlet-octet mixing, formula (8) has to be used in conjunction with (6) and (7). G_B and G_1 represent the couplings for the multiplet, and Λ and Λ' represent the couplings for the physical states.

The relation between g_D , g_F , and the parameter α is

$$\alpha = \left[1 + \frac{\sqrt{5}}{3} \frac{g_F}{g_D} \right]^{-1}. \quad (10)$$

Exact SU(3) predicts that the couplings g_i for all the members of a multiplet are the same; however, since the symmetry is broken for the masses, it is probably broken for the widths. In the case of the $3/2^+$ decuplet, for broken SU(3) sum rules have been derived by Becchi,⁶ Gupta,⁷ and Konuma⁸ independently. The form derived by Gupta relates the g_i for the members of the decuplet by the relation

$$2(\Delta + \Xi) = 3\Sigma^*(\Lambda\pi) + \Sigma^*(\Sigma\pi), \quad (11)$$

where $\Sigma^*(\Lambda\pi)$ is the coupling for the $\Sigma(1385) \rightarrow \Lambda\pi$ decay and $\Sigma^*(\Sigma\pi)$ is the coupling for the decay $\Sigma(1385) \rightarrow \Sigma\pi$.

As mentioned in the text (Sec. IV B) the determination of the relative signs of resonant amplitudes can be useful in making an SU(3) assignment of resonances. In fact the resonant amplitude $T \propto \sqrt{x_e x_i} \propto G_e G_i$, where the subscript e refers to the elastic channel and the G_e, G_i are the couplings of Eqs. (6) through (9). Assuming that all g_i are positive, the sign of the G_i are dependent upon the sign of the Clebsch-Gordan coefficients c_i . Once a sign convention is adopted (we use the Levi-Setti⁹ convention, see Fig. 2 in the text) and the signs for a Σ state ($I=1$) and a Λ state ($I=0$) of known SU(3) assignment have been chosen for reference, the signs of all the other amplitudes can be useful in determining multiplet assignments. For exact SU(3) all the decays of members of a decuplet have the same sign. For octets the relative sign depends upon the value of g_D/g_F and the mixing angle, as seen from Eqs. (7) through (9).

Fits to the Data

Fits of baryon decay rates within SU(3) can be found in, among others, papers by Tripp,^{10,11} Levi-Setti,⁹ Samios,¹² and Plane.¹³ The most recent fits were made by Barbaro-Galtieri¹⁴ and Samios.¹⁵ A fit of the decay rates within SU(6)_w can be found in Litchfield et al.¹⁶ Analysis of the baryon mass spectrum using the quark shell model has been done by Jones et al.¹⁷ An analysis of baryon couplings in a quark model with chromodynamics has been done recently by Koniuk and Isgur.¹⁸

For our SU(3) analysis in fitting the data a choice for B_l has to be made. Plane¹³ tried two forms for B_l :

(a) The form $B_l = (kr)^{2l} D_l(kr)$, r being the radius of interaction and D_l the polynomials in kr given by Blatt and Weisskopf.¹⁹ Usually r is taken to be 1 fermi.¹⁰

(b) The form $B_l = k^{2l}$.

However, for final results form (b) was chosen. A discussion of the differences among these two forms has been given by Barbaro-Galtieri.²⁰ As shown in Ref. 20, not only the values of the couplings, g_i , depend upon the form used for B_l , but also the value obtained for the mixing angle. For the $3/2^-$ singlet, $\Lambda(1520)$, and the isospin-0 member of the octet, $\Lambda(1690)$, the mixing angles obtained in the two cases were

$$\theta_a = (-16.1_{-1.3}^{+1.4})^\circ, \quad \theta_b = (-27.5_{-3.4}^{+3.6})^\circ,$$

in disagreement by a few standard deviations. However, if a

radius of interaction of $r = 0.15$ fermi was used for form (a), the two values of θ agreed. This value of r does not fit resonance shapes when used in the Breit-Wigner resonant form.

Samios¹⁵ used form (b) for B_L .

Table I is a summary of the fits made by us (update of Barbaro-Galtieri¹⁴) using the barrier factor form (a) and exact SU(3). The values of the masses, widths, and amplitudes used in the fits are taken from this edition's Tables and Listings.

1/2⁻ Nonet (Baryon-Eta Resonances)

For this nonet Eq. (7) was multiplied by the factor

$$\left[\frac{M_R - M_B}{M_R - \bar{M}_B} \right]^2$$

where M_B is the decay baryon and $\bar{M}_R - \bar{M}_B = 564$ MeV is the difference of the mean 1/2⁻ and 1/2⁺ baryon octet masses. This kinematic factor comes from PCAC arguments (i.e., the assumption that the axial vector current remains an octet in the presence of symmetry breaking) and it was advocated by Graham.²¹ For the 1/2⁻ nonet it was used in this form first by Gell-Mann.²²

3/2⁺ Decuplet

The agreement among the coupling constants obtained for the four rates in this decuplet is very bad. The fit made using form (a) for B_L has $\chi^2=58$ for 3 degrees of freedom; the one made with form (b) for B_L has $\chi^2/DF=13/3$. The broken SU(3) relation (11), however, is very well satisfied.

B. SU(3) CLASSIFICATION OF MESON RESONANCES

All of the discussion above applies, except that for bosons the GMO formula is usually applied to the square of the masses, as opposed to the first power for fermions. Thus for example, Eq. (2) becomes

$$4\hat{K} = 3\hat{\eta} + \hat{\pi} \tag{2'}$$

The symbol \hat{K} was introduced by Glashow and Socolow⁴ for the square of the K mass, etc.

Because of the difference between Eqs. (5') and (5''), there is also an extra factor of (M_N/M_R) in Eqs. (6) and (7). The three established nonets (0⁻, 1⁻, 2⁺) and their mixing angles are listed at the bottom of the Meson Table.

Table I. SU(3) baryon multiplets with two or more known members. Values of θ and α [defined by Eqs. (8) and (10)] are the result of fits made to all the measured two-body decay rates of each multiplet.

J ^P	Octet members ^a			Singlet	$\theta(\text{deg})^b$	α
1/2 ⁻	N(1535)	$\Lambda(1670)$	$\Sigma(1750)$	$\Lambda(1405)$	$\left\{ \begin{array}{l} -2 \pm 6 \\ -32 \pm 6 \end{array} \right.$	$\left\{ \begin{array}{l} 0.94 \pm .14 \\ 0.38 \pm .08 \end{array} \right.$
			$\left\{ \begin{array}{l} [\Xi(1850)] \\ [\Xi(1737)] \end{array} \right.$			
3/2 ⁻	N(1520)	$\Lambda(1690)$	$\Sigma(1670)$	$\Lambda(1520)$	-21 ± 3	0.32 ± .04
5/2 ⁻	N(1670)	$\Lambda(1830)$	$\Sigma(1765)$			1.21 ± .04
5/2 ⁺	N(1688)	$\Lambda(1815)$	$\Sigma(1915)$	$\Lambda(2110)$	24 ± 4	0.72 ± .02
Decuplet members ^d				Ξ_{10}		
3/2 ⁺	$\Delta(1232)$	$\Sigma(1385)$	$\Xi(1530)$	Ω^-	1.0-1.5	$\chi^2/DF=58/3$
7/2 ⁺	$\Delta(1950)$	$\Sigma(2030)$				

^aMasses in parentheses are the nominal masses used in the Baryon Table. The Ξ members have masses as calculated by using formulae (1) and (2) with the mixing angle θ derived from the decay widths.

^bSee text for a discussion of the 1/2⁻ mixing angle.

^cThe first values of θ and α are obtained by using a plus sign for the amplitudes of both $N(1535) \rightarrow N\eta$ and $\Lambda(1670) \rightarrow \Lambda\eta$. The second values use a minus sign for the second amplitude. Both fits, however, have a bad χ^2 , mostly due to the two baryon- η amplitudes.

^dCoupling constants updated from Ref. 14, using new $\Xi(1530)$ data.

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Appendix IV

GROWTH OF INFORMATION

From time to time we have presented figures demonstrating the amount of experimental work which has gone into spectroscopy, and the amount of new information available as a result. The 1980 versions of these figures are shown as Figs. 1 and 2.

Figure 1 is a simple count of the number of meson resonances listed in the Tables, categorized as those "understood" -- i.e., all quantum numbers are believed known -- and those simply "listed". The rapid recent increase in both of these categories occurred because of the discovery of the J/ψ and related particles.

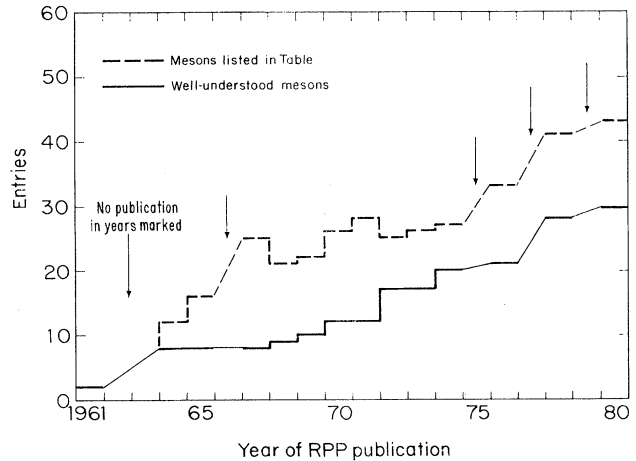


Fig. 1. Number of meson resonances listed in the Tables (dashed line) and those for which all quantum numbers are known (solid line), as a function of year of publication of the Review of Particle Properties.

In Figure 2 we present similar information for the baryon resonances, but concentrate here on the "growth of understanding". That is, the number of known baryons (we include for this figure only those with known J^P) has grown only very slowly with time (dashed line); the real progress has been in the measurement of the properties of those baryons. Therefore we show as the solid line a count of the number of baryonic properties -- mass, width, and branching ratios. Most of these results are from partial-wave analyses.

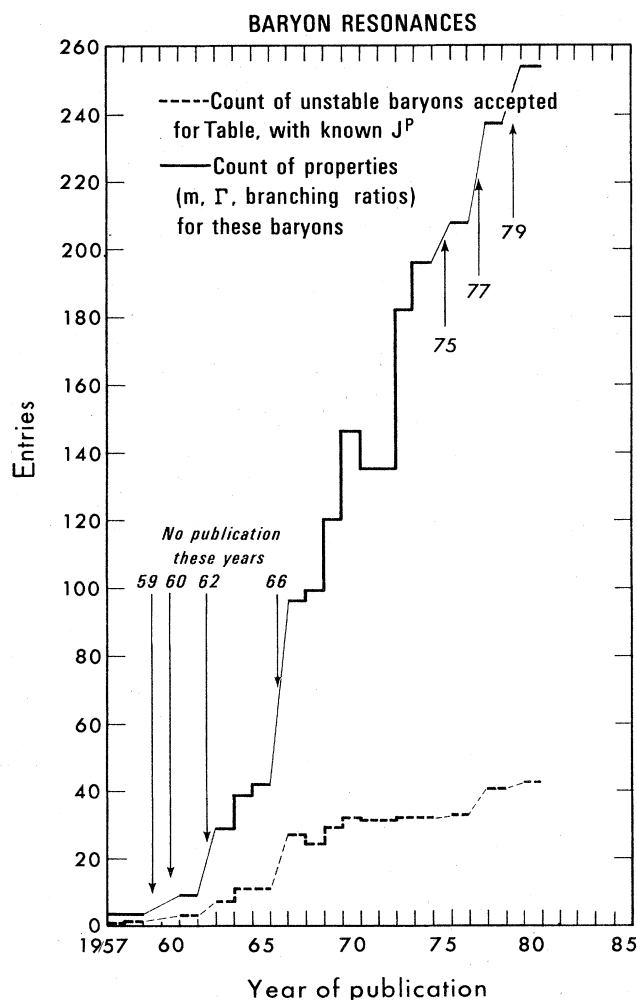


Fig. 2. Total amount of information (mass + width + branching ratios) on baryon resonances listed in the Tables, restricted to those with well-established J^P (solid line). Dashed line shows numbers of such resonances listed. Abscissa shows year of publication of Review of Particle Properties.

A history of the values of some of the constants in the Review of Particle Properties is presented in Figs. 3-7. It may be said that one can estimate the age of a high energy physicist by asking him or her the mass of the Λ . If the answer is 1115.44 MeV, he probably was deep into his graduate training in 1965.

A history of this sort has more than whimsical value. We may use it as a guide to develop a "feel" for the reliability of current values. In Fig. 3 we show how the generally accepted values for the speed of light and a couple of other constants have changed with time. The "generally accepted value" is

usually an average over several experiments, performed by a compiler (in Fig. 3, the compiler is other than the Particle Data Group in all cases, although we do quote the compiled results). The abscissa on all these figures is the date of publication of the value shown. Clearly there is a general progression toward better understanding -- at least as measured by the size of the error bars. However, the size of the error bars does not tell the full story, as we can see by the frequency with which the "best" value has changed by more than one standard deviation. Changes in these values can come from several sources: a new experimental measurement, re-evaluation of an old measurement (which can come about if a previously unrecognized source of bias is discovered and corrected, or if a new value for one of the input constants, e.g. the electric charge, is available), or a change in the averaging procedure.

In Fig. 4 we show the history of some masses (including the Λ , for radioactive Λ dating of your colleagues), based on averages which we ourselves performed. These are adapted from those originally presented by Rosenfeld¹ in 1975. The publication date refers to the publication of the Review of Particle Properties.

In Fig. 5 we show the best estimates for the lifetimes of some of the particles stable against strong decay. These and subsequent figures have been compiled since publication of the Rosenfeld article.¹ In Fig. 6 we show the widths of some of the resonances, and in Fig. 7, the values of some of the branching fractions. All values are taken from the Tables. Before 1964, very few branching fractions were listed in the Tables. In all cases, a representative sample is chosen, usually from those with a lot of activity (a limited number of special requests for a more complete set of such figures may be honored, for those seriously interested in the history of the "best" values of physical constants). In each figure, the heavy inner error bar represents the statistical error computed in the averaging procedure, and the thin outer error bars, when present, indicate the increase in the error due to the "scale factor". The scale factor is described in the introductory text, Sec. VII. It represents an attempt to quantify the increase in the uncertainty which is present in the case of experiments which disagree by more than a certain amount. In the case where the error represents an "educated guess," rather than a calculation, the inner error bar is absent.

On the whole, the number of times the values have changed by more than one standard deviation over the years is remarkably few. Even those branching fractions which involve rare decays and which are therefore presumably difficult to measure (Fig. 7) are, for the most part, within one or two standard deviations in 1978 of their value in any year since 1960. This is in spite of the vast amount of new experimental input, and indicates the general reliability of the results.

Of course, the data points for a given quantity are hardly independent of each other, but those differing by several years frequently have quite different experimental input. The relative lack of change is a comment both on the experiments and on the averaging procedures. We, of course, are responsible only for the averages (except Fig. 3). These averages entail considerable exercise of judgment: there are conflicting experiments, experiments with impossibly small errors, "preliminary" results, and so forth. Statistical procedures will tell us that two experiments do not agree; they do not give a clue as to which (if either) is a good representation of the truth.

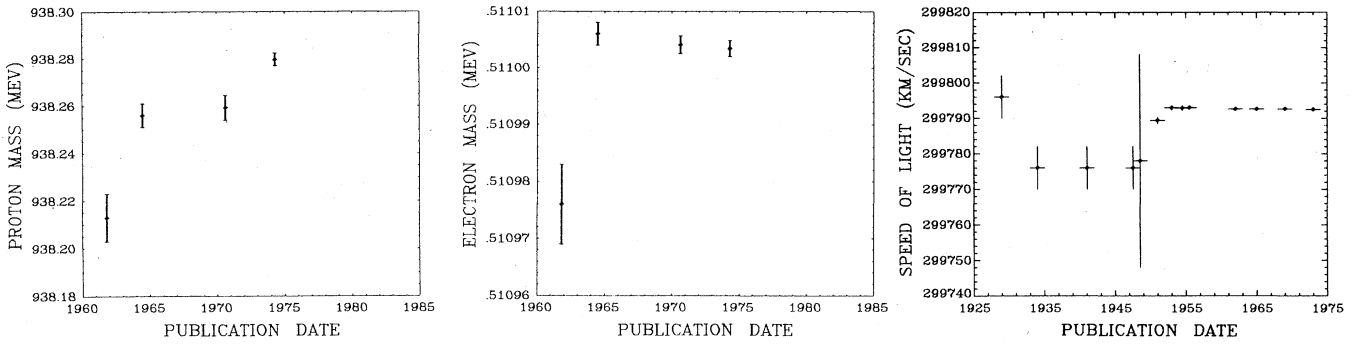


Fig. 3. The "generally accepted values" of the proton mass, the electron mass, and the speed of light, as a function of the publication date of the compilation used (not done by the Particle Data Group). Data for the speed of light plot courtesy of E. R. Cohen, Rockwell International Science Center. See the Stable Particle Data Card Listings for references on proton and electron masses.

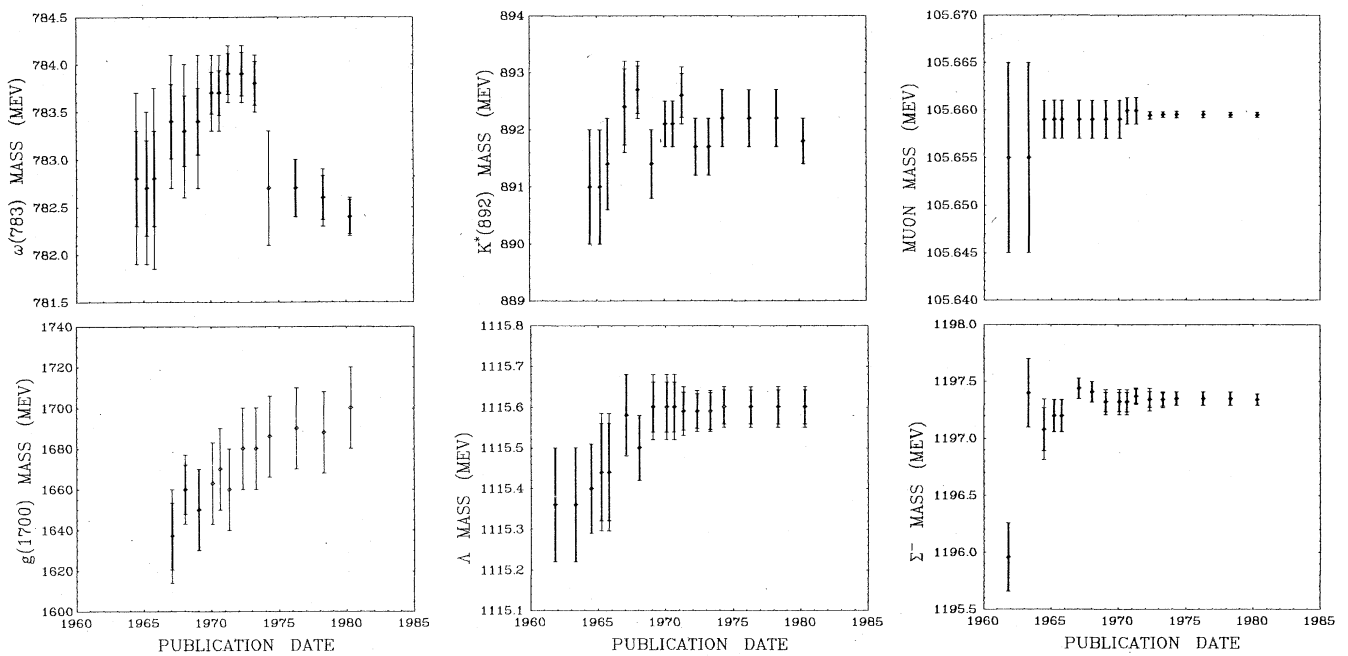


Fig. 4. Particle Data Group averages of the masses of various particles, as a function of date of publication of Review of Particle Properties (Adapted, with permission, from *Annual Review of Nuclear Science*, Volume 25. Copyright 1975 by Annual Reviews, Inc. All rights reserved). Full error bar indicates quoted error; thick-lined portion indicates quoted K error with "scale factor" removed (see Sec. VII of introductory text).

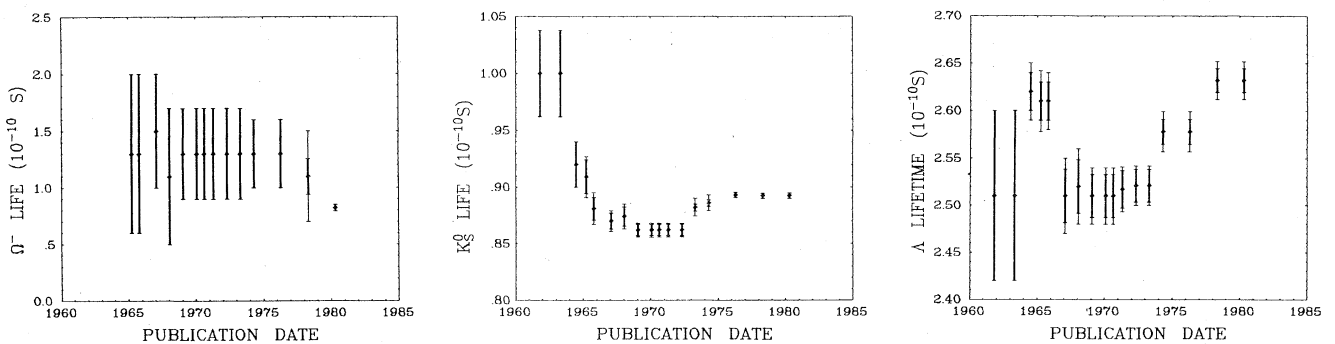


Fig. 5. Particle Data Group averages of the lifetimes of various particles, as a function of publication date of RPP.

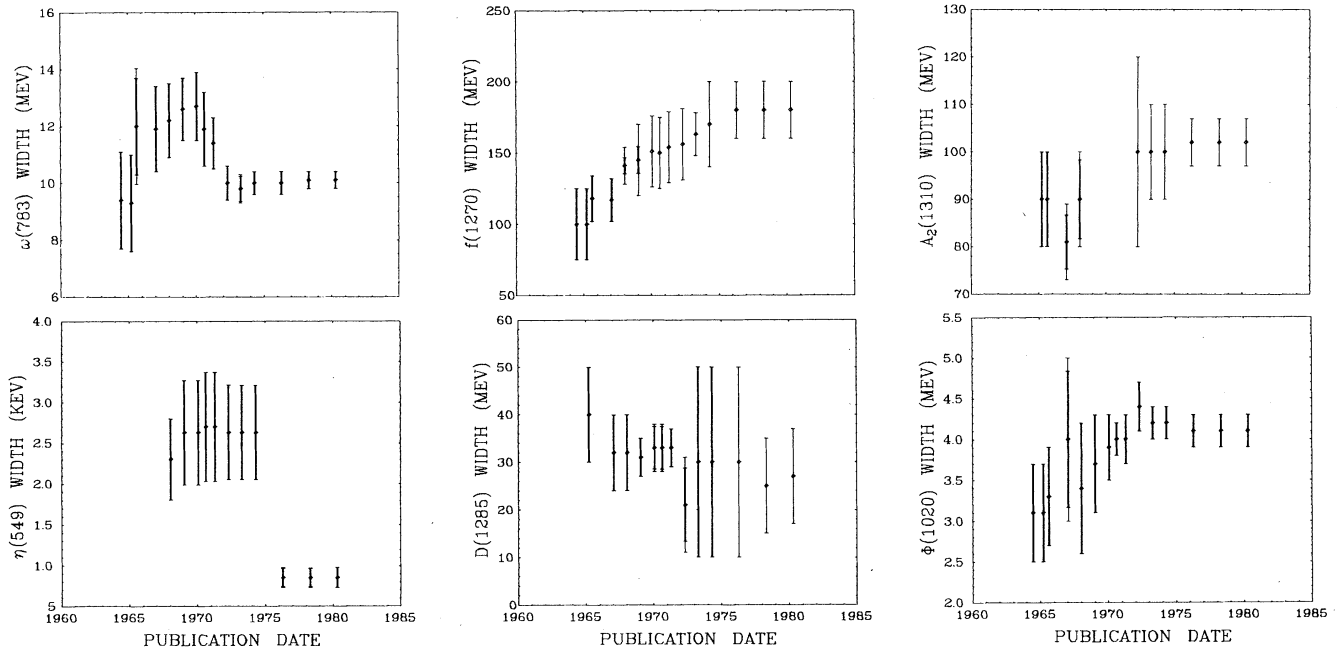


Fig. 6. Particle Data Group averages of the widths of various resonances, as a function of date of publication of RPP. The gap in the A_2 data indicates the years when the A_2 was thought to be split.

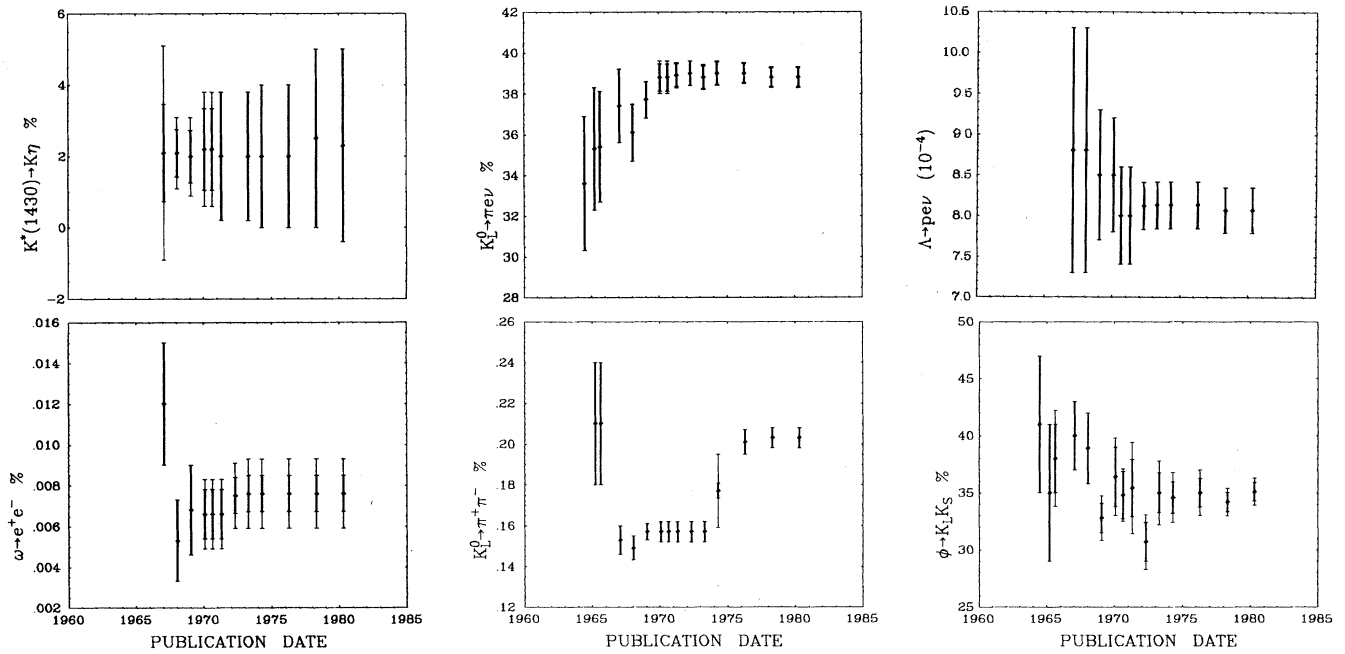


Fig. 7. Particle Data Group averages of various branching fractions, as a function of date of publication of RPP.

Major decisions, and their motivations, are usually discussed on a case-by-case basis in the Data Card Listings; general comments may be found in Sec. II of the text and in Rosenfeld¹. Note that, occasionally, the error bars increase from one publication to the next. This is usually the result of decision making by the compiler, e.g., to cease using a particular result, or because of new results in poor agreement with the old results.

We show these figures not only to demonstrate that there is not much change in these averages in the usual case, but also to show that there exist cases with relatively large changes. There is a psychological danger in preparing tables of "right" answers.

The old joke about the experimenter who fights the systematics until he or she gets the "right" answer (read "agrees with previous experiments"), and then publishes, contains a germ of truth (presumably, those who compile and average experimental results are also not immune to this disease). A result can disagree with the average of all previous experiments by five standard deviations, and still be right! Hence, perhaps it is of value to show that large changes can (and do) sometimes occur.

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