SUMMARY OF THE MOST SIGNIFICANT RESULTS REPORTED IN THIS SESSION

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In the following a summary is presented of five parallel sessions on *light quark* hadron spectroscopy. In general all topics which were discussed in the plenary sessions, and for which the proceedings contain separate (invited) papers, will be left out; only occasionally (and for reasons of completeness) will we make a reference to these presentations.

Several other restrictions can be made. Nearly all papers submitted to the (parallel) hadron spectroscopy sessions were experimental[1], the only exceptions being a series of four theoretical papers on the baryonium problem. Furthermore, there was virtually no new information concerning the 'classical' baryons. In particular, no new facts were submitted on the problem of the possible existence of baryon states outside the so-called minimal spectrum, i.e. outside $\{56,L^+_{even}\}$ and $\{70,L^-_{odd}\}$, the existence of the {20}'s, and the existence of (baryon) exotic states. There was one contribution on a 'possible' new Ξ^* [2], and a report on the final measurement of the Σ^+ magnetic moment with the HYBUC bubble chamber[3]. Recent work on πN phase-shift analysis was presented in the plenary sessions[4]. The remaining baryon contributions were on searches for narrow states.

As a result of the situation described above, this summary will to a large extent deal with *meson* spectroscopy only, both with the conventional mesons ($q\bar{q}$ - see Section 1) and with the narrow and broad mesons coupled mainly to $B\bar{B}$ (see Section 2). In (a short) Section 3 we will mention the results of the narrow *baryon* searches. For the $q\bar{q}$ mesons the data obtained will be discussed in the framework of simple SU(6). For the other topics a more 'enumerative' approach will be necessary.

1. THE $q\bar{q}$ MESONS

Figure 1 gives a summary of the different nonets expected. The x-coordinate is a variable proportional to the $(mass)^2$ of the multiplets; the y-coordinate gives the (internal) orbital angular momentum. In general there are four nonets for each L-value (except for L = 0 where there are only two). Each nonet is classified by the usual quantum numbers:

$$J = L + S$$
$$P = (-1)^{L+1}$$
$$C = (-1)^{L+S} ,$$

where S (0 or 1) is the spin of the $q\bar{q}$ system.

The mass-ordering in Fig. 1 is of course potential-dependent. The one shown corresponds to the harmonic oscillator potential, but this assumption will not enter into our discussions; Fig. 1 will only be used as a guide line. In general one would also expect all multiplets to repeat themselves at higher masses as a result of radial excitations. Actually such states have indeed been observed for the low-lying 0^{-+} and 1^{--} multiplets. Again, no new facts concerning the existence of such states were reported to this conference and we leave them out of Fig. 1 for reasons of clarity. This will allow us to discuss the various nonets in terms of their L-grouping only.

1.1 The L = 0 states (0^{-+}, 1^{--})

The L = 0 multiplets present a stationary picture; the only new facts concern singlet-octet mixing angles for the 0^{-+} nonet[5] and new data on rare decays (such as $\omega \to \pi^0\mu^+\mu^-$) [6].

1.2 The L = 1 states (0^{++}, 1^{++}, 1^{+-}, 2^{++})

1.2.1 0^{++} mesons

The scalar meson situation is essentially unchanged. The δ(980) and S*(980) are well established[7] and the ε(800) and κ(1500) are healthy but still in need of further confirmation. The I = 1 δ'(1300) S-wave $K\bar{K}$ resonance reported in $\pi^-p \to K^0K^-p$ [8] and the presumably I = 0 ε'(1300) S-wave structure observed in neutral (ππ) and neutral ($K\bar{K}$) [9] are also still alive, but for the latter Martin et al. have shown that the I = 0 assignment is highly model-dependent, and therefore still in doubt[10]. Whatever the outcome of this isospin assignment problem, however, the fact that additional 0^{++} I = 0/I = 1 states seem to exist around 1300 MeV keeps feeding the speculation of a second 0^{++} nonet due to multiquark ($qq\,\bar{q}\bar{q}$) states[11]. However, as before, a successful allocation of the known 0^{++} states over these two types of nonets is still missing.

1.2.2 1^+ mesons

i) There were several new developments for the 1^+ mesons. The A_1 lived up to its reputation of an on-off problematic state through the results reported by the ACCMOR Collaboration in $\pi^-p \to \pi^-\pi^-\pi^+p$ at 63 and 94 GeV/c [12]. The A_1 is observed, but at a mass of (1280 ± 40) MeV, i.e. approximately 200 MeV higher than has been seen by most of the experiments up to now[12].

More welcome information was that of the J^{PC} determination of the E(1420) meson observed in $\pi^-p \to K^0_S K^\pm \pi^\mp n$ at 4 GeV/c by the CERN-Collège de France-Madrid-Stockholm Collaboration[13]. A Zemach spin parity analysis, sensitive to the sign of the interference between the two possible K*'s in the decay modes*)

$$E \to K^{*+}K^-(K^{*+} \to K^0_S\pi^+)$$

and

$$E \to K^{*0}K^0_S(K^{*0} \to K^\pm\pi^\mp) \; ,$$

favours the C = +1 assumption and a 1^+ J^P value (see Figs. 2a and 2b).

ii) Partial wave analyses of the $(K\pi\pi)^-$ systems in the *Q_1-Q_2 region* of the reactions $K^-p \to (K\pi\pi)^-p$ at 4.2 GeV/c yield results[14] which are essentially in agreement with the ones reported by the SLAC group[15]. In the reaction $\pi^-p \to (K\pi\pi)^0\Lambda$ at 4.0 GeV/c, not only the 1^+S $Q_1(\to K\rho)$ was observed but also a $K^*\pi$ contribution in the mass region of the Q_2 (1.33-1.43 GeV) [16]. The partial wave analysis of this second peak is not yet completed. If it turns out to contain a sizeable 1^+ contribution, this finding would contradict the generally observed absence of the Q_2 in non-diffractive reactions.

iii) For the *1^{+-} mesons* there is still no trace of the I = 0 members; were it not for these states, the L = 1 multiplets would be complete.

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*) And thus also sensitive to C-parity, C = +1 corresponding to a constructive interference and C = -1 to a destructive one.

iv) Irving pointed out that *1^+ meson* spectroscopy can be substantially modified by production mechanisms, and that these modifications can (sometimes) be parametrized in a consistent way[17]. An example in case are the production and decay relations for the Q/C mesons; taking into account such relations it is possible to retrieve uniquely defined SU(3) states from the different types of Q-bumps seen in forward and backward production, diffractive and non-diffractive production, etc.

1.3 The L = 2 states

A substantial amount of confirmatory evidence was presented for the (L = 2) 2^{-+} and 3^{--} nonets.

1.3.1 The 2^{-+} mesons

The ACCMOR Collaboration raised the status of the I = 1 $f^0\pi^-$ enhancement at 1640 MeV (called the A_3 meson and up to now labelled as 'a not well established resonance') to respectability by establishing the resonant nature of the 2^- $S(f^0\pi^-)$ wave, and by showing a coupling of the A_3 mass bump to the $(\rho^0\pi^-)$ and $(\varepsilon^0\pi^-)$ channels[18] [see Figs. 3a, b, c*)].

Recent information concerning the L meson, i.e. the I = 1/2 member of the 2^{-+} nonet, comes from a partial wave analysis of the $(K\pi\pi)^-$ system in the L-region using $K^-p \to (K^-\pi^+\pi^-)p$ data at 10, 14, and 16 GeV/c [19] (not presented to the conference but mentioned during the discussions). No *new* evidence for the resonant nature of the L was found, but the general dominance of an S-wave [$K^*(1420)$ π] 2^{-+} wave was confirmed. However, the authors stress that this contribution does not fully explain the L-enhancement.

1.3.2 The 3^{--} mesons

An amplitude analysis by the Bari-Bonn-CERN-Daresbury-Glasgow-Liverpool-Milano Collaboration[9] of the K^+K^- system produced in the reaction $\pi^-p \to K^+K^-n$ at 10 GeV/c yields clear confirmation of the g(1680)/ω(1670) resonances in the (zero helicity) F-wave. The $d\sigma/dt$ distribution furthermore suggests that this $|F_0|^2$ structure is mainly g^0 production.

In the backward production of ω(1670) in the reactions $K^-p \to \pi^+\pi^-\omega\Lambda$ at 8.25 GeV/c [20], evidence was found for the decay of ω(1670) into $B^\pm\pi^\mp$. A branching ratio for $B^\pm\pi^\mp/\omega\pi^+\pi^-$ = = (1.00 ± 0.25) was obtained, or alternatively $B\pi$/total = (0.56 ± 0.16).

Finally, confirmatory evidence for the production of K*(1780) in $K^-p \to \bar{K}^0\pi^-p$ and $\bar{K}^0\pi\pi N$ at 8.25 GeV/c was presented[21]. The angular distributions of the decay $K^*(1780) \to \bar{K}^0\pi^-$ are consistent with $J^P = 3^-$. An enhancement near 1.8 GeV observed in the $K(3\pi)$ mass spectra of the same experiment (and mainly associated with $K^{*-}\rho^0$) could not be positively identified as being due either to the $K^*(1780)$ or to the L(1770) [22].

1.4 The L ≥ 3 states

Further analysis of the K^+K^- system in the reaction $K^-p \to K^+K^-n$ now also suggests a new 2^{++} state at approx. 1.8 GeV with $\Gamma \sim 200$ MeV [9]. It could either enter into the L = 3 nonet or else be a radial recurrence of the A_2 meson. Further confirmation is needed however. Previously, this same analysis had shown evidence for the h meson at 2 GeV and a new (J ≥ 4) structure at 2.2 GeV [23] (in addition to the g/ω* confirmation mentioned above).

*) Figure 3d shows evidence for a further possibly resonant 2^{-+} structure in the 2^- $D(f^0\pi)^-$ wave at 1850 MeV. In principle this could be a radial excitation of the A_3, but the fact that such a state would lie only about 200 MeV higher than the A_3 would be rather surprising. Actually the authors themselves caution against accepting this structure as a new 2^{-+} resonance before other explanations (e.g. in terms of interferences between resonance production and Deck amplitudes) are more fully explored.

The ACCMOR Collaboration provided the first real evidence for the existence of a spin-5 boson in $\pi^- p \to K^+K^- n$ at 62 GeV/c [24]. The mass and width found are (2300 ± 10) MeV and (272 ± 32) MeV, respectively. These values are not incompatible (within errors) with the state claimed at 2.2 GeV/c by C. Evangelista et al.[23]. It would have to belong to the L = 4 level.

2. THE $B\bar{B}$ MESONS

2.1 The narrow $B\bar{B}$ states (baryonium)

We refer to the plenary reviews of Povh[25] and Chan[26] for a status report on baryonium search and theoretical background.

2.1.1 Theory - Baryonium

In the parallel sessions Fukugita examined various theoretical aspects of baryonia spectroscopy in a mini-report, including four theoretical contributions presented to the Conference[27-30]. A review of the different spectrum models now used for $qq\bar{q}\bar{q}$ (= diquonium) states and of the decay properties of these states, led him to conclude that much more experimental information is needed [especially for key states such as the narrow 2.02 GeV and 2.20 GeV states[31]] in addition to a more unified understanding of meson and baryon spectroscopy, before the baryonium problem can make decisive progress.

2.1.2 The S(1936) meson

Coming back to the experimental baryonium contributions, the highlight was the report from an LBL (Berkeley)-BNL Collaboration[32] on a (low-energy) $p\bar{p}$ formation experiment nearly identical to the one performed by Carroll et al.[33]. The latter experiment is generally regarded as providing the best evidence for the $p\bar{p}$ resonance S(1936). In this new experiment (which in principle should have smaller systematic effects, e.g. as a result of a much reduced target length) no evidence for such a narrow resonance is observed, at least not for one of the magnitude seen by Carroll et al. (An upper limit of 2-4 mb is quoted.) Figure 4 illustrates the discrepancy in the *total* $p\bar{p}$ cross-section; the dashed line shows the peak expected from the Carroll et al. experiment*). The disagreement is also present in the annihilation channel $p\bar{p} \to n\bar{n}$, the total *absorption* cross-section, and the backward elastic pp scattering.

A re-analysis of old Brookhaven 30" bubble chamber data on total and partial $\bar{p}d$ cross-sections for incident momenta between 260 and 460 MeV/c was presented[34]. A discrepancy with the recent LBL-BNL experiment[32] is present, but no definite conclusion as to the existence or non-existence of the S(1936) could be drawn from this.

Kluyver[35] pointed out that in a model in which the S meson is assumed to be a baryonium state composed of I = 1 diquarks and anti-diquarks only, the S-*formation* cross-section ratios -- as they were known before the results of Ref. 32 -- can be understood as a result of I-spin conservation in the s-channel (combined with quark additivity).

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*) 1936 MeV corresponds to a laboratory momentum of 500 MeV/c. Incidentally, a mass of 2020 MeV corresponds to 805 MeV/c; here, too, no structure is observed.

2.1.3 Search for other narrow $B\bar{B}$ states

A search for narrow $p\bar{p}$ and $p\bar{p}\pi$ states produced diffractively (i.e. *forward*) in the reaction $\pi^+p \to pp\bar{p}\pi^+$ at 150 GeV/c led to a negative result[36]. In the mass ranges 2.2 GeV < $M(p\bar{p})$ < 4.0 GeV and 1.9 < $M(p\bar{p}\pi)$ < 2.7 GeV and at a level of 25 nb, no states were found. The above mass bands cover the 2.02 GeV and 2.20 GeV narrow states observed by the CERN-Collège de France-Ecole Polytechnique-Orsay Collaboration[31]; it should be remembered, however, that the latter states were observed in a baryon exchange process*).

2.2 The broad $B\bar{B}$ states

2.2.1 The T, U, V mesons

An analysis of the differential cross-section data on $p\bar{p} \to \pi^+\pi^-$ in the 1-2 GeV/c laboratory momentum range[37] by Carter et al.[38] had previously led to the conclusion that the three broad resonances at 2.17, 2.33, and 2.48 GeV [known as the T, U, and V mesons since their first detection as bumps in $\sigma(\bar{p}N)$ many years ago] were mesons with $J = 3^{--}$, 4^{++}, and 5^{--}, respectively. However, to reach these conclusions some simplifying assumptions had to be made. A new analysis by Martin et al.[39] using simultaneously the $p\bar{p} \to \pi^+\pi^-$ data and recently published $p\bar{p} \to \pi^0\pi^0$ data[40] confirmed an earlier analysis by Dulude et al.[41] which had shown that the Carter solutions are ruled out by the $\pi^0\pi^0$ data. The new situation is that a J = 5 assignment for the V meson is still tenable, but that the resonant character of the U bump is unclear and that the T bump -- if at all a resonance -- should have a spin parity 1^- or 2^+.

2.2.2 Search for strange $B\bar{B}$ states

In a study of the reactions $K^+p \to (\bar{\Lambda}p)p$ and $K^-p \to (\Lambda\bar{p})p$ at an incident momentum of 50 GeV/c, evidence has been sought for strange counterparts of the broad $p\bar{p}$ mesons[42]. In a mass region extending up to 3 GeV, a moment analysis of the $\bar{\Lambda}p$ and $\Lambda\bar{p}$ c.m. angular distributions provides evidence for a 2^- state at 2.26 GeV and a 4^- state at 2.50 GeV, both with a width of approximately 250 MeV.

3. SEARCH FOR NARROW BARYON RESONANCES

The interest of these searches stems from the fact that they may give information on five-quark ($qqqq\bar{q}$) systems forming (narrow) colour isomers which decay dominantly into multiparticle ($\geq$ 3) final states.

i) A search for narrow high-mass Y* hyperons by the Birmingham-CERN-Glasgow-Michigan State-Paris LPNHE Collaboration[43] in K^-p at 8.25 GeV led to the observation of a significant enhancement ($\gtrsim 5\sigma$) at a value of (3170 ± 5) MeV in the combined mass spectra of various $\Sigma|S| \geq 3$ final states (such as $R^+ = \Lambda K\bar{K}$ + pions, $\Sigma K\bar{K}$ + pions or ΞK + pions recoiling against a π^-) (see Fig. 5). The observed width is $\leq$ 20 MeV. Recently the ACNO Collaboration[44] has claimed the existence of a 5σ enhancement (with $\Gamma \leq 40$ MeV) at 2.58 GeV in the $\Sigma^-K^+K^0_S$ mass spectrum of the reaction $K^-p \to \Sigma^-K^+K^0_S$.

*) In this respect it might be relevant to point out that the narrow resonance reported at 2.95 GeV in the *forward* direction by another Omega spectrometer collaboration [C. Evangelista et al., Phys. Lett. 72B, 139 (1977)] was recently retracted on the basis of an experiment by essentially the same collaboration but with twelve times the original statistics [T. Armstrong et al., Phys. Lett. 85B, 304 (1979)].

ii) A (preliminary) negative result was reported[45] of a search for narrow baryon resonances coupled to the π^-p channel. With a sensitivity for resonance detection in terms of width of $\sim$ 200 keV and in terms of elastic branching ratio of $\sim$ 5%, no evidence was found in a mass region extending from 3.5 to 5 GeV.

4. CONCLUSIONS

- There is no progress in experimental baryon spectroscopy.
- In $q\bar{q}$ meson spectroscopy there is healthy progress, especially for the L = 1 nonets, albeit that the 0^{++} situation is still unclear.
- The 'ancestor' of the narrow $B\bar{B}$ meson resonances -- the S(1936) -- is 'experimentally' in trouble. New experiments (also covering the 2.02 and 2.20 GeV narrow states) are necessary.
- The J^P assignments of the broad U, T, V states are again an open question. In the meanwhile, new (broad, but) strange states are ready to join the group of meson states coupling predominantly to $B\bar{B}$.
- Another high-mass Y* decaying into $\geq$ 3-body final states (with $\Sigma|S| \geq 3$) has been observed.

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3) The final result obtained is $\mu_{\Sigma^+} = (2.30 \pm 0.14)\mu_N$, to be compared with a world average (prior to the HYBUC measurement) of $\mu_{\Sigma^+} = (2.62 \pm 0.41)\mu_N$. The new result has consequences for mass-splitting hypotheses inside quark models. S. Reucroft et al., MPI-Vanderbilt Collab., Paper 166.

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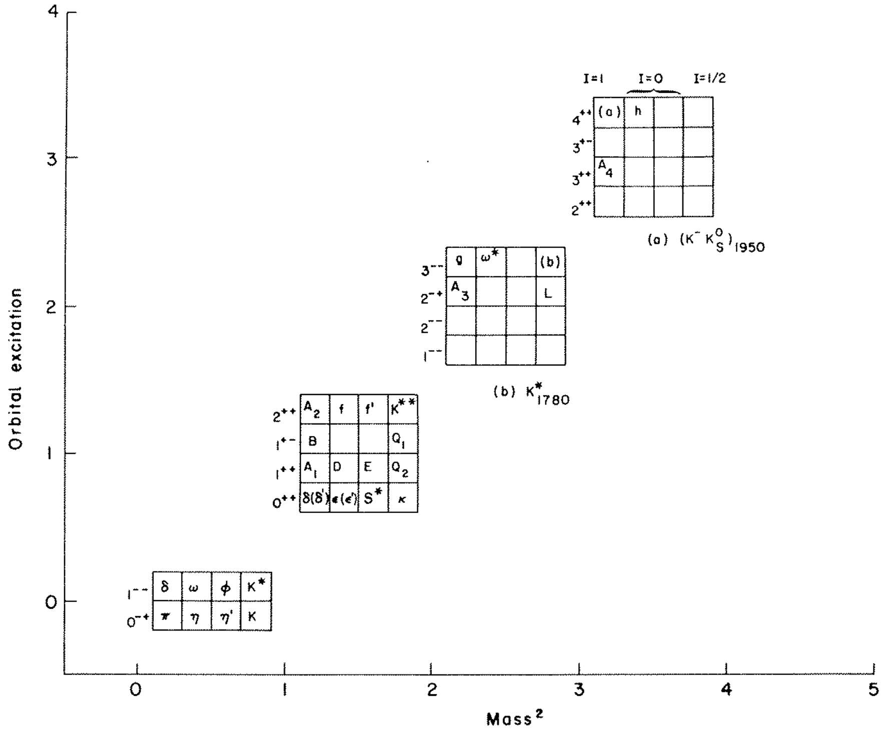
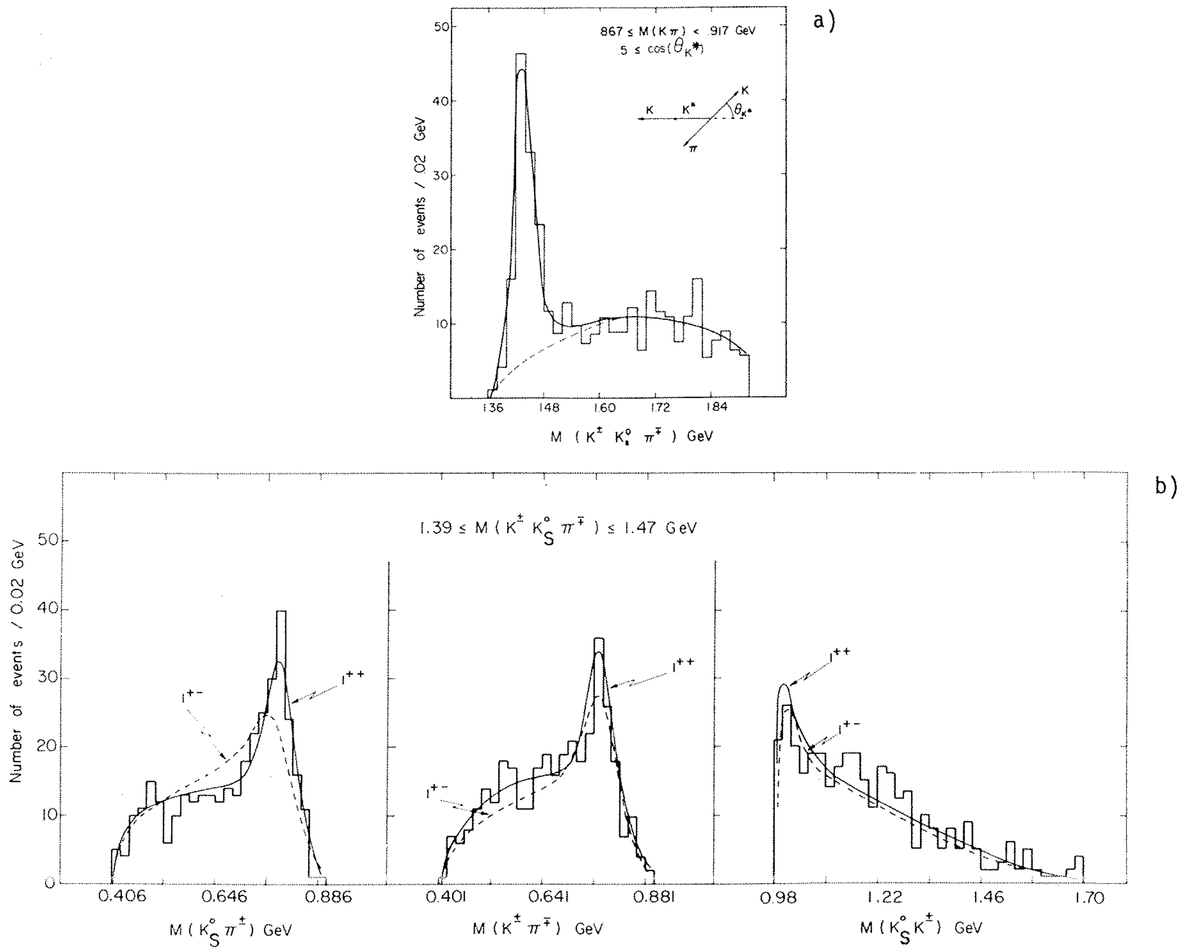

Orbital excitation
Mass²
I=1
I=0
I=1/2
(a) (K⁻ K⁰S)1950
(b) K*1780

Fig. 1


a)
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.5 ≤ cos(θK*)
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M (K± K°s π∓) GeV
b)
1.39 ≤ M (K± K°S π∓) ≤ 1.47 GeV
Number of events / 0.02 GeV
M (K°S π±) GeV
M (K± π∓) GeV
M (K°S K±) GeV

Fig. 2

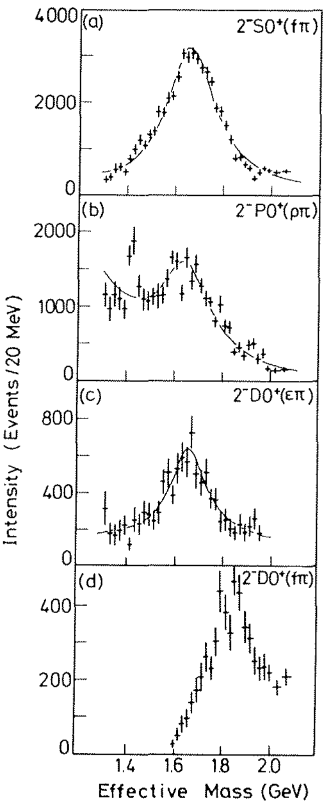

Fig. 3

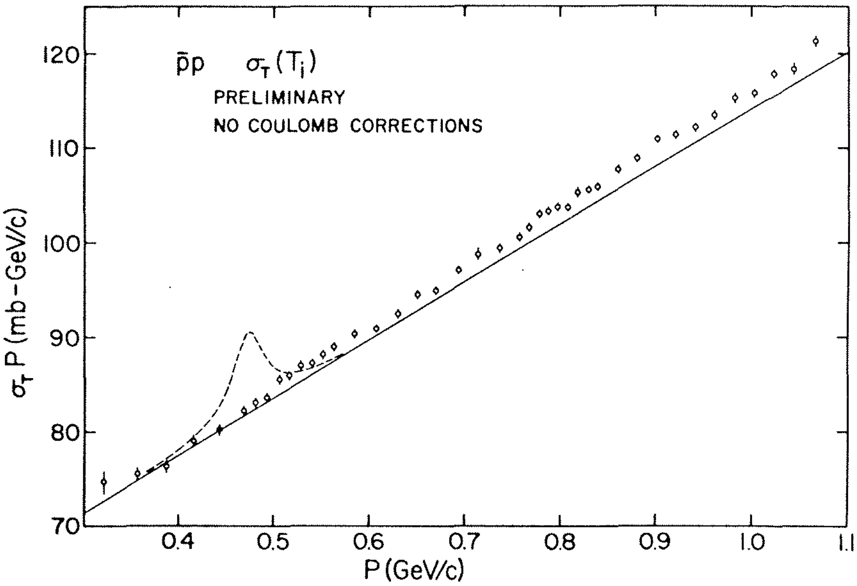

Fig. 4

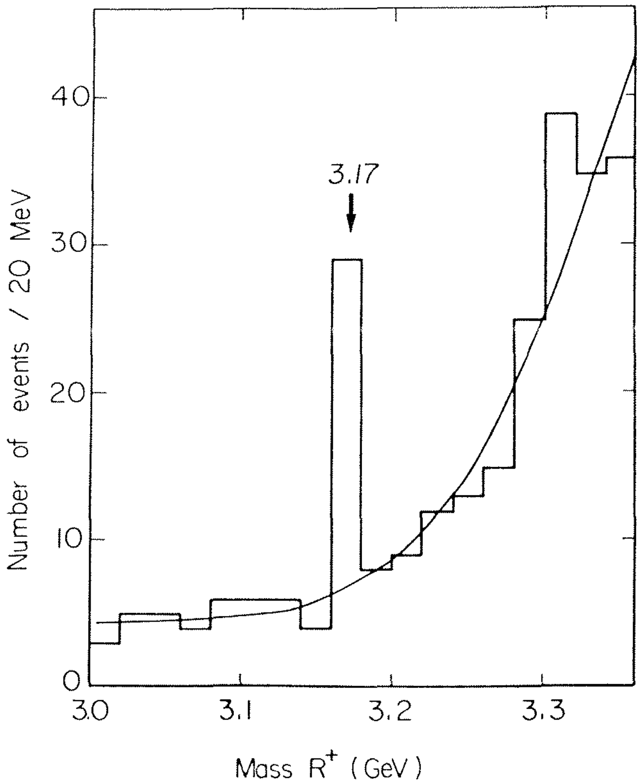

Fig. 5