PARTICLE PROPERTIES : August, 1968

Table S: STABLE PARTICLES. August, 1968.
(Closing date for data: July 1, 1968)

From Review of Particle Properties, UCRL-8030.

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Quantities in italics have changed by more than one (old) standard deviation since January, 1967.

Particle	$I^G(J^P)C$	Mass (MeV)	Mass difference (MeV)	Mean life (sec) $c\tau$(cm)	Mass² (GeV)²	Partial mode	Fraction	Q(MeV)	p or p_{max}[‡] (MeV/c)	Partial Rates (sec^{-1})
γ	$0,1(1^-)^-$	0 ($<2.\times10^{-21}$ MeV)		stable	0	stable				
ν	ν_e J = ½	0(<0.2 keV)		stable	0	stable				
	ν_μ	0(<1.6MeV)								
e	J = ½	0.511006 ±.000002		stable ($>2\times10^{21}$y)	0.000	stable	μ_e = 1.001159557 ±.000000030 $e\hbar/2m_ec$			
μ	J = ½	105.659 ±.002		2.1983×10^{-6} ±.0008 $c\tau = 6.592\times10^4$	0.011	$e\nu\bar\nu$	100	105	53	
						$e\gamma\gamma$	(<1.6)10^{-5}	105	53	
						3e	(<1.3)10^{-7}	104	53	
						$e\gamma$	(<6)10^{-9}	105	53	
	μ_μ = 1.00116645 ±.00000033 $e\hbar/2m_\mu c$		-33.919 ±.013							
$\pi^\pm$	$1(0^-)$	139.578 ±.013		2.604×10^{-8} ±.007, S=2.3* $c\tau$ = 781 $(\tau^+-\tau^-)/\bar\tau$=(.4±.2)% (test of CPT)	0.019	$\mu\nu$	100 %	34	30	
						$e\nu$	(1.24±0.03)10^{-4}	139	70	
						$\mu\nu\gamma$	(1.24±0.25)10^{-4}	34	30	
			4.6041 ±.0037			$\pi^0e\nu$	(1.02±0.07)10^{-8}	4	5	
						$e\nu\gamma$	(3.0 ±0.5)10^{-8}	139	70	
π^0	$1^-(0^-)^+$	134.974 ±.013		c 0.89×10^{-16} ±.18, S=1.6* $c\tau = 2.67\times10^{-6}$	0.018	$\gamma\gamma$	(98.83±0.04)%	135	67	
						γe^+e^-	(1.17±0.04)%	134	67	
						$\gamma\gamma\gamma$	(< 5)10^{-6}	135	67	
						$e^+e^-e^+e^-$	b(3.47)10^{-5}	133	67	
$K^\pm$	$\frac12(0^-)$	493.82 ±0.11		1.234×10^{-8} ±.004 S = 1.8* $c\tau$ = 370 $(\tau^+-\tau^-)/\bar\tau$=(.09±.12)% (test of CPT) S=1.3*	0.244	$\mu\nu$	(63.47±0.29)% S = 1.1*	388	236	(51.42 ±0.29)10^6 S = 1.2*
						$\pi\pi^0$	(20.84±0.28)% S = 1.1*	219	205	(16.89 ±0.24)10^6 S = 1.1*
						$\pi\pi^-\pi^+$	(5.54±0.04)% S = 1.1*	75	126	(4.49 ±0.03)10^6 S = 1.1*
						$\pi\pi^0\pi^0$	(1.69±0.05)%	84	133	(1.37 ±0.04)10^6
						$\mu\pi^0\nu$	(3.43±0.08)%	253	215	(2.78 ±0.06)10^6
						$e\pi^0\nu$	(5.02±0.08)%	358	228	(4.07 ±0.07)10^6
						$\pi\pi^\mp e^\pm\nu$	(3.8 ±0.8)10^{-5}	214	203	
						$\pi\pi^\pm e^\mp\nu$	(<2)10^{-6}	214	203	
			-3.94 ±0.13			$\pi\pi^\mp\mu^\pm\nu$	(<1.4)10^{-5}	109	151	
						$\pi\pi^\pm\mu^\mp\nu$	(<3)10^{-6}	109	151	
						$e\nu$	(1.24±0.40)10^{-5}	493	247	
						$\pi\pi^0\gamma$	(2.2 ±0.7)10^{-4}	219	205	
						$\pi\pi^+\pi^-\gamma$	(10 ±4)10^{-5}	75	126	
						$\pi e\nu\gamma$	(6 ±4)10^{-4}	354	227	
						πe^+e^-	(<1.1)10^{-6}	353	227	
						$\pi\mu^+\mu^-$	(<2.4)10^{-6}	143	172	
						$\pi\gamma\gamma$	(<1.1)10^{-4}	354	227	
K^0	$\frac12(0^-)$	497.76 ±0.16		50% K_{short}, 50% K_{long}						
K^0_S	$\frac12(0^-)$	S = 1.5*		0.862×10^{-10} ±.006 S=1.2* $c\tau$ = 2.59	0.248	$\pi^+\pi^-$	(68.4 ±1.1)%	219	206	(0.794±0.013)10^{10}
			$-0.469\times\frac{1}{\tau_S}$ ±.015			$\pi^0\pi^0$	(31.6)%	228	209	(0.367±0.013)10^{10}
K^0_L	$\frac12(0^-)$			5.29×10^{-8} ±.15 $c\tau$ = 1587 S=1.3*	0.248	$\pi^0\pi^0\pi^0$	(25.5 ±2.4)% S=1.3*	93	139	(4.81 ±0.49)10^6 S=1.1*
						$\pi^+\pi^-\pi^0$	(*12.1 ±0.5*)% S=1.1*	84	133	(2.29 ±0.10)10^6 S=1.2*
						$\pi\mu\nu$	(27.3 ±1.4)% S=1.2*	253	216	(5.15 ±0.30)10^6 S=1.1*
						$\pi e\nu$	(*35.2 ±1.5*)% S=1.2*	358	229	(6.64 ±0.33)10^6 S=1.2*
						$\pi^+\pi^-$	(0.149 ± 0.006)%	219	206	(0.028±0.001)10^6
						c) $\pi^0\pi^0$	still uncertain	228	209	
						$\pi^+\pi^-\gamma$	(< 0.3)%	219	206	
						c) $\gamma\gamma$	still uncertain	498	249	
						$e\mu$	(< 0.6)10^{-5}	392	238	
						$\mu^+\mu^-$	(< 1.5)10^{-6}	286	225	
						e^+e^-	(< 1.7)10^{-5}	497	249	
η	$0^+(0^-)^+$	548.8 ±0.6		Γ=(2.3±0.5)keV		Neutral decays 71.0%: $\gamma\gamma$	(*38.1 ±2.2*)% S=1.3* (c)	549	274	
						$\pi^0\gamma\gamma$	(*3.4 ±2.9*)%	414	258	
						$3\pi^0$	(*29.4 ±2.8*)%	144	179	
						Charged decays 29.0%: $\pi^+\pi^-\pi^0$	(*23.4 ± 1.1*)%	135	174	
						$\pi^+\pi^-\gamma$	(5.5 ±0.5)%	269	236	
						$\pi^0e^+e^-$	(< 0.01)%	413	258	
						$\pi^+\pi^-e^+e^-$	(0.1 ±0.1)%	268	236	
p	$\frac12(\frac12^+)$	938.256 ±0.005		stable ($>2\times10^{28}$ y)	0.880					
n	$\frac12(\frac12^+)$	939.550 ±0.005	-1.2933 ±.0001	*(0.96 ±0.04) 10^3* S=3.2* $c\tau = 2.87\times10^{13}$	0.882	$pe^-\nu$	100 %	1	1	
Λ	$0(\frac12^+)$	1115.57 ±0.07 S=1.4*		2.52×10^{-10} ±.03 S=1.3* $c\tau$ = 7.55	1.245	$p\pi^-$	(65.3 ±1.2)%	38	100	
						$n\pi^0$	(34.7)%	41	104	
						$pe\nu$	(0.88±0.15)10^{-3}	177	163	
						$p\mu\nu$	(1.35±0.60)10^{-4}	72	131	
Σ^+	$1(\frac12^+)$	1189.43 ±0.17 S=2.8*		0.810×10^{-10} ±.013 $c\tau$ = 2.43	1.412	$p\pi^0$	(52.8 ±1.5)%	116	189	
						$n\pi^+$	(47.2)%	110	185	
						$p\gamma$	(1.9 ±0.5)10^{-3}	251	225	
						$n\pi^+\gamma$	(≈1.)10^{-3}	110	185	
			-8.00 ±.18			$\Lambda e^+\nu$	(2.2 ±0.7)10^{-5}	73	72	
				$\frac{\Gamma(\Sigma^+\to\ell^+n\nu)}{\Gamma(\Sigma^-\to\ell^-n\nu)} < .05$		$n\mu^+\nu$	(< 0.7)10^{-4}	144	202	
						$ne^+\nu$	(< 0.2)10^{-4}	249	224	
Σ^0	$1(\frac12^+)$	1192.55 ±0.11 S=1.1*		$<1.0\times10^{-14}$ $c\tau<3\times10^{-4}$	1.422	$\Lambda\gamma$	100 %	77	75	
			-4.87 ±.07			Λe^+e^-	b(5.45)10^{-3}			
Σ^-	$1(\frac12^+)$	1197.42 ±0.09 S=1.1*		1.64×10^{-10} ±.06 S=2.4* $c\tau$ = 4.92	1.434	$n\pi^-$	100 %	118	193	
						$ne^-\nu$	(1.14±0.08)10^{-3}	257	230	
						$n\mu^-\nu$	(0.62±0.12)10^{-3}	152	210	
						$\Lambda e^-\nu$	(0.66±0.11)10^{-4}	81	79	
						$n\pi^-\gamma$	(≈1)10^{-3}	118	193	
Ξ^0	$\frac12(\frac12^+)$?	1314.7 ±0.7		3.03×10^{-10} ±.18 $c\tau$ = 9.10	1.728	$\Lambda\pi^0$	100 %	64	135	
						$p\pi^-$	(< 0.9)10^{-3}	237	299	
						$pe^-\nu$	(< 1.3)10^{-3}	376	323	
						$\Sigma^+e^-\nu$	(< 1.5)10^{-3}	125	119	
			-6.6 ±.7			$\Sigma^-e^+\nu$	(< 1.5)10^{-3}	117	112	
						$\Sigma^+\mu^-\nu$	(< 1.5)10^{-3}	20	64	
						$\Sigma^-\mu^+\nu$	(< 1.5)10^{-3}	12	49	
						$p\mu^-\nu$	(< 1.3)10^{-3}	271	309	
Ξ^-	$\frac12(\frac12^+)$?	1321.25 ±0.18		*1.66×10^{-10} ±.04* S=1.1* $c\tau$ = 4.98	1.746	$\Lambda\pi^-$	100 %	66	139	
						$\Lambda e^-\nu$	(0.9 +0.7 -0.4)10^{-3}	205	190	
						$n\pi^-$	(< 1.1)10^{-3}	242	303	
						$\Lambda\mu^-\nu$	(< 1.3)10^{-3}	100	163	
						$\Sigma^0e^-\nu$	(< 0.5)10^{-3}	128	122	
						$\Sigma^0\mu^-\nu$	(< 0.5)%	23	70	
						$ne^-\nu$	(< 1.0)%	381	327	
Ω^-	$0(\frac32^+)$? ?	1672.4±.6 S=1.1*		$1.3^{+0.4}_{-0.3}\times10^{-10}$ $c\tau$ = 3.9	2.797	$\Xi^0\pi^-$	8 events seen	217	293	
						$\Xi^-\pi^0$	3 events seen	216	289	
						ΛK^-	13 events seen	63	210	

Decay Parameters †

Particle	Magnetic Moment ($e\hbar/2m_pc$)	Measured α	Measured Φ(degree)	Derived γ	Derived Δ(degree)
p	2.792763 ±.000030				
n	-1.913148 ±.000066	g_A/g_V = -1.198 ± .022†			
Λ	-0.73 ±.16 S=1.2*	0.646±0.016	(-6±7)° S=1.2*	0.75	(7±8)°
		0.71 ±0.18			
		0.06 ±0.19	For Λ → peν, g_A/g_V = $-1.14^{+0.23\dagger}_{-0.33}$		
Σ^+	2.4 ±.6	-.955±0.070 S=1.1*			
		+.018±0.039	(180±30)°	-0.99	(0±85)°
Σ^-		-.06 ±0.05 S=1.6*	(-22±30)°	0.90	
		For $\Sigma^-\to ne^-\nu$, $g_A/g_V = 0.05^{+.23\dagger}_{-.32}$			
		For $\Sigma^-\to\Lambda e\nu$, g_V/g_A = 0.3 ± 0.3†			
Ξ^0		-.37 ±0.08	(13± 15)°	0.93	(28 ± 34)°
Ξ^-		-.42 ±.03	(0± 7)° S=1.1*	0.91	(0 ± 15)°

†The definition of these quantities is as follows: [for more details on sign convention, see RMP 39, 1 (1967)]

$$\alpha = \frac{2\,\mathrm{Re}(S^*P)}{|S|^2+|P|^2};\quad \beta = \frac{2\,\mathrm{Im}(S^*P)}{|S|^2+|P|^2};\quad \gamma = \frac{|S|^2-|P|^2}{|S|^2+|P|^2}$$

$\tan\Phi = \beta/\gamma$ $\quad\tan\Delta = -\beta/\alpha$

g_A/g_V defined by $M \propto \langle B_f|\gamma_\lambda(g_V - g_A\gamma_5)|B_i\rangle$

General Atomic and Nuclear Constants [a]

N	= 6.02252×10^{23} mole^{-1} (based on $A_C{}^{12}$=12)
c	= 2.997925×10^{10} cm sec^{-1}
e	= 4.80298×10^{-10} esu = 1.60210×10^{-19} coulomb
1 MeV	= 1.60210×10^{-6} erg
ħ	= 6.5819×10^{-22} MeV sec
	= 1.05449×10^{-27} erg sec
ħc	= 1.9732×10^{-11} MeV cm = 197.32 MeV fermi
k	= 8.6171×10^{-11} MeV deg^{-1} (Boltzmann const.)
α	= $e^2/\hbar c$ = 1/137.0388
m_e	= 0.511006 MeV/c^2 = 1/1836.10 m_p
m_p	= 938.256 MeV/c^2 = 1836.10 m_e = 6.721 $m_{\pi^\pm}$
	= 1.00727663 m_1 (where m_1 = 1 amu = $\frac{1}{12}m_{C^{12}}$ = 931.478 MeV/c^2)
r_e	= e^2/m_ec^2 = 2.81777 fermi (1 fermi = 10^{-13}cm)
$\lambda\!\!\!^-_e$	= $\hbar/m_ec = r_e\alpha^{-1} = 3.86144\times10^{-11}$ cm
a_∞ Bohr	= $\hbar^2/m_ee^2 = r_e\alpha^{-2}$ = 0.529167 A (1 A = 10^{-8} cm)
$\sigma_{Thomson}$	= $\frac{8}{3}\pi r_e^2 = 0.66516\times10^{-24}$ cm^2 = 0.66516 barn
μ_{Bohr}	= $e\hbar/2m_ec = 0.578817\times10^{-14}$ Mev gauss^{-1}
μ_{nucl}	= $e\hbar/2m_pc = 3.1524\times10^{-18}$ Mev gauss^{-1}
$\frac12\omega_{cyclotron}$ (rad sec^{-1}gauss^{-1})	= $e/2m_ec = 8.79404\times10^6$
	= $e/2m_pc = 4.7895\times10^3$

(continued on the other side)

[a] Based mainly on E. R. Cohen and J. W. M. DuMond, Rev. Mod. Phys. 37, 537 (1965). Note that recent fine structure and ac Josephson effect measurements currently indicate that α is ~20 ppm larger than the value given above. The corresponding readjustment of the fundamental constants will increase e by 60 ppm, ħ by 100 ppm, m_e by 60 ppm, and decrease N by 60 ppm. For a preliminary analysis see W. H. Parker, B. N. Taylor, and D. N. Langenberg, Phys. Rev. Lett. 18, 287 (1967).

CP violation parameters

$$\eta_{+-\,(00)} = \frac{A(K_L\to\pi^{+(0)}\pi^{-(0)})}{A(K_S\to\pi^{+(0)}\pi^{-(0)})} = |\eta_{+-\,(00)}|\,e^{i\Phi_{+-\,(00)}}$$

$|\eta_{+-}| = (1.89\pm0.04)\times10^{-3}$

$\Phi_{+-} = (49\pm8)^\circ$

$|\eta_{00}|$ still uncertain, see data listings for published values

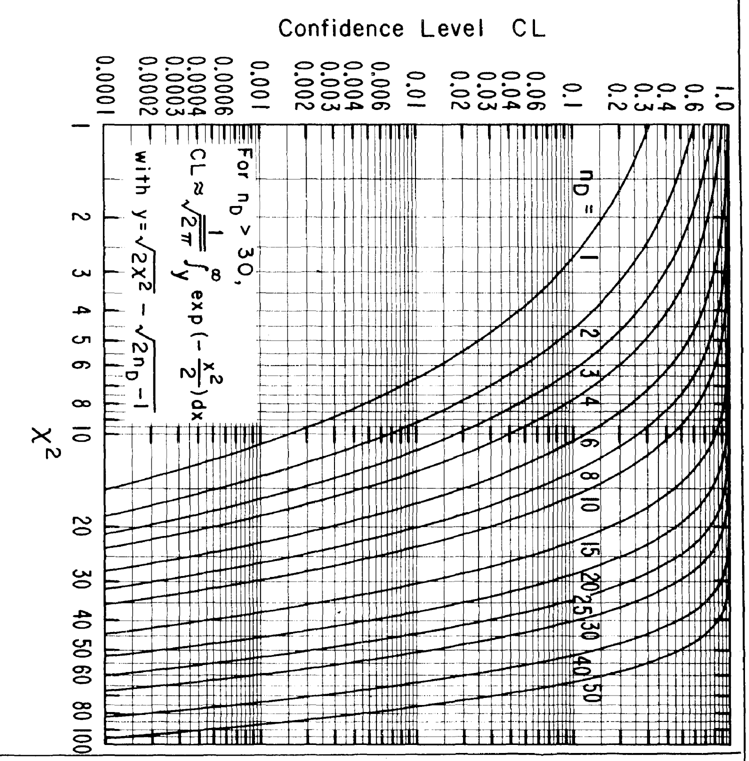
* S = Scale factor = $\sqrt{\chi^2/(N-1)}$ where N ≈ number of experiments. S should be ≈ 1. If S > 1, we have enlarged the error of the mean, δx, i.e., δx→S δx. This new convention is still inadequate, since if S > 1, the real uncertainty is probably even greater than Sδx. See text of January 1967 edition.

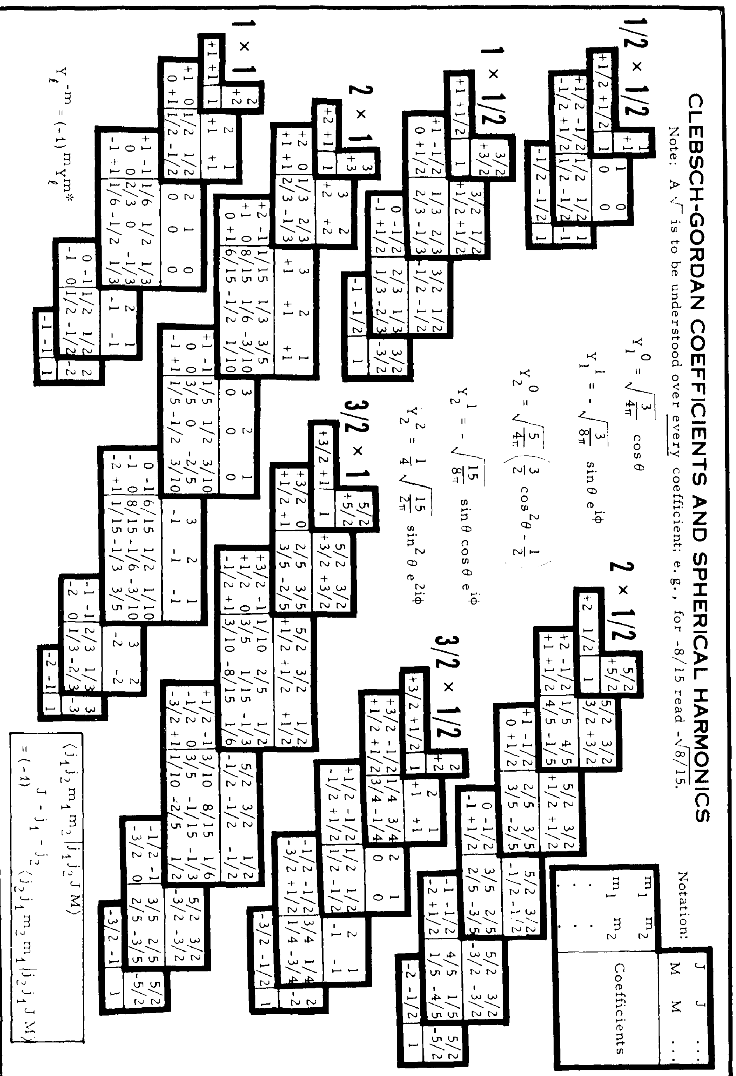
‡ In decays with more than two bodies, p_{max} is the maximum momentum that <u>any</u> particle can have.

b. Theoretical value, see also data card listings.

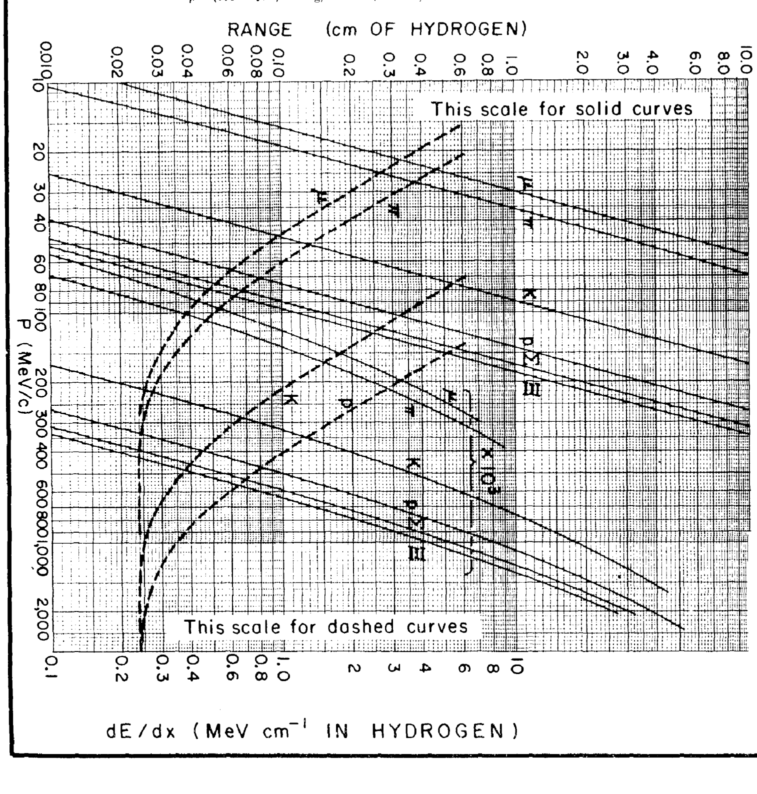
c. See note in data card listings.

CONFIDENCE LEVEL VS. χ^2 FOR n_D DEGREES OF FREEDOM





Ranges in liquid hydrogen bubble chamber, determined by a μ^+ range of $1.103 \pm .003$ cm from the $\pi^+ \to \mu^+\nu$ decay. Liquid hydrogen conditions: $T = 27.6 \pm .1$ °K; $P = 48 \pm 5$ psia; $\rho = (5.86 \pm .06) 10^{-2}$ g/cm^3. (Data by Clark and Diehl.)



Atomic and Nuclear Properties of Materials

Change in Notation. The subscript N stands for "normal spin-parity series" ($J^P=0^+, 1^-, 2^+, \ldots$), A for "abnormal" ($J^P=0^-, 1^+, 2^-, \ldots$).

Quantities in italics have changed by more than one (old) standard deviation since January, 1967.

Particle	Symbol (J^P)	$I^G(J^P)C_n$ (⊢⊣ estab., ? = guess)	Mass M (MeV)	Width Γ (MeV)	$M^2 \pm \Gamma M$[(a)] (GeV^2)	Partial decay modes: Mode	Fraction %	Q (MeV)	p or p_{max}[(b)] (MeV/c)
$\pi^\pm(140)$	$\pi(0^-)$	$1^-(0^-)+$	139.58		0.019	See Table S			
$\pi^0(135)$			134.97		0.018				
$\eta(549)$	$\eta(0^-)$	$0^+(0^-)-$	548.8 ±0.6	2.3 kev ±.5 keV	0.301 ±.000	all neutral	71	See Table S	
						$\pi^+\pi^-\pi^0 + \pi^+\pi^-\gamma$	29		
$\rho^\pm(765)$	$\rho(1^-)$	$1^+(1^-)-$	755-770 (c)	110-150 (c)	0.585 ±.095	$\pi\pi$	≈ 100	491	359
						$\pi^\pm\pi^+\pi^-\pi^0$	< 0.2	212	247
						$\pi^+\pi^-\pi^+\pi^-$	< 0.15	212	247
						$\pi^0\gamma$	< 0.4	630	372
$\rho^0(765)$			764±11	90-150 (c)	0.590 ±.090	$\eta\pi^\pm$	< 0.8	82	146
						e^+e^-	.0056±.0006 (d)	769	385
						$\mu^+\mu^-$	.0066±.0015 (e)	559	370
$\omega(783)$	$\phi'(1^-)$	$0^-(1^-)-$	783.4 ±0.7 S=2.0*	12.2 ±1.3	0.614 ±.009	$\pi^+\pi^-\pi^0$	≈ 90	369	328
						$\pi^+\pi^-$	seen (f)	504	366
						$\pi^0\gamma$	9.3±0.8	648	380
						η+ neutral	< 1.5	234	199
						$\pi^+\pi^-\gamma$	< 5	504	366
						$\pi^0\pi^0\gamma$	< 1	513	368
						e^+e^-	0.02±.012 (g)	782	392
						$\mu^+\mu^-$	< 0.10	572	377
						$\pi^0\mu^+\mu^-$	< 0.2	437	350
$\eta'(958)$ or X^0	$\eta'(0^-)$	$0^+(0^-)+$ ($J^P=1^+, 2^-$ not yet excluded)	958.3 ±0.8	<4	0.918 <.004	$\eta\pi\pi$	67 ± 11	131	232
See note (h), on name η'.						$\pi^+\pi^-\gamma$(incl. $\rho^0\gamma$)	22 ± 3	679	458
						neutrals (excl. $\eta\pi\pi$)	11 ± 9		
						for upper limits see footnote (i)			
$\delta(962)$ Still needs confirmation	?( )	≥1 ( )	962 ±5	<5	0.927 <.005				
$\pi_N(1016) \to K\bar{K}$	$\pi(0^+)$	$1^-(0^+)+$	1016 ← (if → ≈25 ±10 res.) ≈5		1.032 ±.025	$K^\pm K^0$	only mode seen	24	110
						$\eta\pi$	< 80	328	342
Resonance, virtual bound state, or antibound state, still not distinguished.									
$\phi(1019)$	$\phi(1^-)$	$0^-(1^-)-$	*1019.5* *±0.6* S = 1.5*	3.4 ±0.8	1.039 ±.004	K^+K^-	47.3 ± 3.2	32	126
						K_LK_S	38.9 ± 3.1	24	109
						$\pi^+\pi^-\pi^0$ (incl. $\rho\pi$)	13.8 ± 4.3	605	462
						e^+e^-	0.049±.016	1018	510
						$\mu^+\mu^-$	$0.035^{+.035}_{-.018}$	808	499
						for upper limits see footnote (j)			
$\eta_{0+}(1070) \to K_SK_S$	$\eta(0^+)$	$0^+(0^+)+$	1069 ±20§ S=2.3*	~ 80 (?) see note (k)	1.14 ±.09	$\pi\pi$	< 70	793	516
(Some data still favor large scattering length)						$K\bar{K}$	≈30	76	198
A1(1070) Existence still in doubt	$\pi(1^+)$	$1^-(1^+)+$ ($J^P = 2^-$ not yet excluded)	1070 ±20§	80 ±35§	1.12	3π see note (ℓ)	≈ 100	651	488
						$K\bar{K}$	< 0.25, $G=(-1)^{\ell+I}$ forbids this		
B(1220)	$\rho(A)$?	$1^+(1^+)-$	1221 ±16 S=1.2*	123 ±16 S=1.3*	1.46 ±.14	$\omega\pi$	≈ 100	297	339
$J^P = 2^+, 3^-, \ldots$ still poss.						$\pi\pi$	< 30 } suggests	950	600
						$K\bar{K}$	< 2 } J^P=Abnormal	240	360
						for upper limits see footnote (m)			
f(1260)	$\eta'(2^+)$	$0^+(2^+)+$	1264 ±10§	*145* § *±25* S=2.7*	1.57 ±.15	$\pi\pi$	large	984	616
						$2\pi^+2\pi^-$	< 4	705	552
						$K\bar{K}$ indic. seen,	< 2.5	267	388
D(1285)	$\eta'(A)$	$0^+(A)+$ ($J^P = 0^-, 1^+, 2^-$ with 1^+ favored)	1285 ±4	32 ±8	1.65 ±.04	$K\bar{K}\pi$(mainly $\pi_N(1016)\pi$)	only mode seen	154	304
						$K^*\bar{K} + \bar{K}^*K$		-100	
						$\pi\pi\rho$	not seen	256	356
$A2_L(1270)$ see footnote (n)	$\pi(N)$	$1^-(N)+$	1269 ±5	26 ±7	1.61 ±.03	$\rho\pi$ (and π+neutrals)	dominant	364	387
						$\eta\pi$ indication seen → J^P=N		580	504
						$K\bar{K}$, $\omega\pi$ not seen → $G(K\bar{K}) = (-1)^{\ell+I}$ sugg. ℓ odd.			
$A2_H(1315)$ see footnote (n)	$\pi(2^+)$	$1^-(2^+)+$	1315 ±3 S=1.3*	29 ±6 S=1.4*	1.73 ±.04	$\rho\pi$ (and π+neutrals)	dominant	410	420
						$K\bar{K}$	seen	327	434
						$\eta\pi$	indication seen	626	532
E(1420)	$\eta(A)$	$0^+(0^-)+$ ($J^P = 1^+$ not yet excluded)	1424 ±6	71 ±10 S=1.2*	2.03 ±.10	$K^*\bar{K} + \bar{K}^*K$	50 ± 10	38	157
						$\pi_N(1016)\pi$	50 ± 10	268	328
						$\pi\pi\eta$	< 88	596	569
						$\pi\pi\rho$	not seen	384	455
f'(1515)	$\eta(2^+)$	$0^+(2^+)+$	1514 ±5	73 ±23 S=1.8*	2.29 ±.11	$K\bar{K}$	72 ± 12 (o)	518	570
						$K^*\bar{K} + \bar{K}^*K$	10 ± 10 (o)	128	294
						$\pi\pi$	< 14	1235	744
						$\eta\pi\pi$	18 ± 10	686	624
						$\eta\eta$	< 40	417	522
$\pi_A(1640) \to 3\pi$	$\pi(A)$?	$1^-(A)+$?	1633 ±9 S=1.2*	93 ±24	2.73 ±.18	3π	dominant	1245	797
[≟ $R_1(1630)$ see note (p)] Not yet a completely established resonance						†[$\pi^\pm\rho^0$/all $\pi^\pm\pi^+\pi^-$	< 20]	745	637
						†[$\pi^\pm f(\to\pi^+\pi^-)$/all $\pi^\pm\pi^+\pi^-$	35 ± 20]	252	320
						$\pi\eta$	< 9	966	727
						$K\bar{K}$	< 40	654	658
						$\pi^\pm 2\pi^+2\pi^-$	< 10	935	714
$\rho_N(1650)$ $g \to 2\pi$	$\rho(N)$	$1^+(N)-$ ($J^P = 1^-, 3^-, \ldots$ with 3^- favored)	1650 (q) ±20	120 (q) ±30	2.72 ±.20	2π	dominant	1385	820
[≟ $R_1(1630)$ see note (p)]						$K\bar{K}$ indication seen,	< 10	668	667
						(other possible modes see under $\rho(1700)$? below)			
$\rho(1700)$?	$\rho(A)$?	$1^+(A)-$?	1700 (r) ±20	110 (r) ±25	2.89 ±.19	4π	dominant	1141	792
[≟ $R_2(1700)$ see note (p)] Not yet clear whether this is just an alternative mode of the $\rho_N(1650)$, or a different resonance. The branching ratios are therefore only tentative.						†[$\pi^\pm A_2^0(\to\pi^+\pi^-\pi^0)$/all $\pi^\pm\pi^+\pi^-\pi^0$	40±20]	263	333
						†[$\pi^\pm\omega(\to\pi^+\pi^-\pi^0)$/all $\pi^\pm\pi^+\pi^-\pi^0$	25±10]	777	661
						†[$\rho^\pm\rho^0$	seen]	170	371
						$\pi^\pm\phi/\pi^\pm\pi^+\pi^-\pi^0$	< 11	540	532
						$\pi^\pm 2\pi^+2\pi^-\pi^0$	< 15	862	699
						2π (if ≠ $\rho_N(1650)$)	< 10	1420	838

→ There is no well-established Y = 0 meson resonance with M > 1700 MeV. For a list of some possible states
→ see footnote (p).

Particle	Symbol (J^P)	$I(J^P)$	Mass M (MeV)	Width Γ (MeV)	$M^2 \pm \Gamma M$ (GeV^2)	Mode	Fraction %	Q (MeV)	p or p_{max} (MeV/c)
$K^+(494)$	$K(0^-)$	$1/2(0^-)$	493.82		0.244	See Table S			
$K^0(498)$			497.76		0.248				
$K^*(890)$	$K(1^-)$	$1/2(1^-)$	891.4 ±0.6	49.7 ±1.1 ↳ for charged K^*	0.797 ±.044	$K\pi$	≈ 100	259	289
	$m_0 - m_\pm = 6.3 \pm 4.1$					$K\pi\pi$	< 0.2	120	216
$K_A(1230)$ or C	K(A)	$1/2(1^+)$	≈ 1240	≈ 60	1.54 ±.07	Q-Region } $K\pi\pi$ dominant. See footnote (r).			
	Still some doubt. 2^- still poss.								
$K_A(1320)$	K(A)	$1/2(1^+)$	≈ 1330	≈ 70	1.77 ±.09				
	$J^P = 2^-$ not yet completely ruled out.								
$K_N(1420)$	$K(2^+)$	$1/2(2^+)$	*1422* *±4* S=1.2*	89 ±6	2.012 ±.126	$K\pi$	51 ± 4	787	615
						$K^*\pi$	33 ± 4	388	413
						$K\rho$	11 ± 3 } S = 1.4*	156	318
						$K\omega$	3.4 ± 1	143	304
						$K\eta$	2.0 ± 1	378	482
$K_A(1780)$ or L	K(A) ?	$1/2(A)$?	1775 ±12 S=1.3*	72 ±26 S=1.4*	3.17 ±.13	$K\pi$	< 2.3	1167	825
						$K^*\pi$	24 ± 8	772	670
						$K_N(1420)\pi$	16 ± 8	245	317
						$K\rho$	10 ± 6	532	632
						Remaining $K\pi\pi$	45 ± 15	1032	807
						$K\omega$	4.8 ± 2	519	624
						$K\eta$	< 1	754	732

→ The following bumps, excluded above, are listed among the data cards: σ(410); ε(730); H(990); A1.5(1170); ρρ(1410); K_SK_S(1440); η(1600)→4π; R_{1-4}(1630-1830); η or ρ(1830)→4π; φ or π(1830)→ωππ; S(1930); T(2200); $N\bar{N}_{I=0}$(2380), U(2380); κ(725); K_N(1080); $K_{A(I=3/2)}$(1175); $K_{A(I=3/2)}$(1265); $K_{A(I=1/2)}$(1280); $K_{N(I=1/2)}$(1660); K^*(2240) → $\bar{Y}N$

* Quoted error includes scale factor $S = \sqrt{\chi^2/(N-1)}$. See footnote to Table S.

† Square brackets indicate a subreaction of the previous (unbracketed) decay mode.

§ This is only an educated guess; the error given is larger than the error of the average of the published values (see listings for the latter).

(a) ΓM is 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 using the averaged central mass values, without taking into account the widths of the resonances.

(c) Values reported for M(ρ) and Γ(ρ) fluctuate so widely that we cannot give averaged values with meaningful errors. The ranges given in the main table show where we believe the final values are most likely to fall. Contrast the results tabulated in this note.

	M	Γ	
ρ^0	764±11	93±15	from e^+e^- colliding beams
ρ^0	767± 2	151± 4	from ππ phase shift anal.
ρ^-	764± 2	147± 4	from πN → ρN, fits in phys. region
ρ^-	755± 5	110± 9	from πN → ρN, Chew-Low extrap.

(d) The quoted value of the rate $\rho^0 \to e^+e^-$ is the average from two $e^+e^- \to \pi^+\pi^-$ experiments (which alone give an average of (0.0054±0.0007)%) and one photoproduction experiment of high mass resolution. Interference effects with ω decay are hoped to be small.

(e) Warning: The values given in the literature, and in our table, for the rate $\rho^0 \to \mu^+\mu^-$ may be somewhat too high, due to possible interference with ω decay.

(f) Reported values range between 1% and 10%, and depend on assumptions on ρ-ω interference.

(g) If one includes results from experiments that do not resolve ω from ρ and therefore assume a ratio $\Gamma(\omega \to e^+e^-)/\Gamma(\rho \to e^+e^-)$ from SU(3) and ωφ mixing, the average value of the rate $\omega \to e^+e^-$ becomes (0.0069±.0013)% (where the error does not include systematic uncertainties).

(h) This 0^- meson was named η' on discovery, when it looked as if it completed the 0^- nonet. With the recent evidence that the E(1420) is probably also 0^-, it is no longer clear whether η' or E or both are mixed in with the π, η, K octet; so the name η' may be misleading.

(i) Empirical limits on fractions for other decay modes of η'(958): $\pi^+\pi^-$ < 7%, 3π < 7%, 4π < 1%, 6π < 1%, $\pi^+\pi^-e^+e^-$ < 0.6%, $\pi^0e^+e^-$ < 1.3%, ηe^+e^- < 1.1%, $\pi^0\rho^0$ < 4%, $\pi^0\omega$ < 8%.

(j) Empirical limits on fractions for other decay modes of φ(1019): $\pi^+\pi^-$ < 20%, ηγ < 8%, η + neutrals < 13%, $\pi^+\pi^-\gamma$ < 4%, ωγ < 5%, ργ < 2%.

Footnotes continued on back of third page (under SU_3 Isoscalar Factors).

Particle or resonance	I(J^P) —— = estab.	Beam π, K (BeV) (BeV/c)	Mass (MeV)	Γ (MeV)	M²±ΓM (BeV²)	Partial decay modes: Mode	Fraction (%)	p or p_{max}[‡] (MeV/c)	$4\pi\lambda^2$ (mb)
N									
p n	1/2($1/2^+$)		938.3 939.6		0.880 0.883	See Table S			
N′(1470)	1/2($1/2^+$) P_{11}	T=0.53πp p=0.66	1470	210	2.16 ±0.31	Nπ Nππ [Nσ][a]	65 35 [domin]	420 368 283	27.8
N(1518) (See footnote c.)	1/2($3/2^-$) D_{13}	T=0.62 p=0.75	1525	115	2.33 ±0.18	Nπ Nππ [Δ(1236)π][a] Nη	55 45 [domin] ~0.5	460 414 229 161	23.2
N(1550)	1/2($1/2^-$) S_{11}	T=0.66 p=0.79	1550	130	2.40 ±0.20	Nπ Nη Nππ	30 70 small	477 210 434	21.5
N(1680)	1/2($5/2^-$) D_{15}	T=0.88 p=1.02	1680	170	2.82 ±0.29	Nπ Nππ [Δ(1236)π][a] ΛK Nη	40 dom. inel. [?] <1.6 <2.5	567 533 365 218 379	15.2
N(1688)	1/2($5/2^+$) F_{15}	T=0.90 p=1.03	1690	130	2.86 ±0.22	Nπ Nππ [Δ(1236)π][a] ΛK Nη	65 dom. inel. [?] < .13 < 1.5	574 540 374 234 390	14.9
N′(1710)	1/2($1/2^-$) S_{11}	T=0.94 p=1.07	1710	300	2.92 ±0.51	Nπ	80	587	14.2
N(2190)	1/2($7/2^-$) G_{17}	T=1.96 p=2.10	2200	250	4.84 ±0.55	Nπ	30	894	6.13
N(2650)	1/2($?^-$)	T=3.12 p=3.26	2650	360	7.02 ±0.95	Nπ	(J+1/2)x=0.45[b]	1154	3.67
N(3030) ‡	1/2(?)	T=4.26 p=4.40	3030	400	9.18 ±1.21	Nπ	(J+1/2)x=0.05[b]	1377	2.62
Δ									
Δ(1236) (See footnote c.)	3/2($3/2^+$) P_{33}	T=0.195 p=0.304 $m_0 - m_{++}$ = 0.45±0.85	(++) 1236.0 ±0.6 $m_- - m_{++}$ = 7.9±6.8	120 ±2	1.53 ±0.15	Nπ $N\pi^+\pi^-$ Nγ	100 0 ~0.6	231 89 262	91.9
Δ(1640)	3/2($1/2^-$) S_{31}	T=0.81 p=0.94	1640	180	2.69 ±0.30	Nπ Nππ	30 dom. inel.	540	16.8
Δ(1950)	3/2($7/2^+$) F_{37}	T=1.41 p=1.54	1950	220	3.80 ±0.43	Nπ ΣK Σ(1385)K Δ(1236)π Δ(1236)ρ	40 2.4 1.2 >30 seen	741 453 232 571	8.91
Δ(2420)	3/2($11/2^+$)	T=2.50 p=2.64	2420	310	5.86 ±0.75	Nπ Nππ	11 > 20	1024 1007	4.67
Δ(2850)	3/2($?^+$)	T=3.71 p=3.85	2850	400	8.12 ±1.14	Nπ	(J+1/2)x=0.25[b]	1266	3.05
Δ(3230)	3/2(?)	T=4.94 p=5.08	3230	440	10.4 ±1.4	Nπ	(J+1/2)x=0.05[b]	1475	2.24
Z									
Z_0(1865) →	0(?)	p=1.15 K^+p	1865	180	3.47 ±0.34	NK NK*	(J+1/2)x=0.35[b]	579 179	14.6
	— Resonance interpretation not established.								
Λ									
Λ	0($1/2^+$)		1115.6		1.24	See Table S			
Λ(1405)	0($1/2^-$) S_{01}	p<0 K^-p	1405 ±5[§]	40 ±10[§]	1.97 ±0.06	Σπ	100	140	
Λ(1520)	0($3/2^-$) D_{03}	p=0.392	1518.8 ±1.5	16 ±2	2.31 ±0.02	NK̄ Σπ Λππ	45±4 }S=1.8* 45±4 10±1	235 258 251	83.6
Λ′(1670)	0($1/2^-$) S_{01}	p=0.74	1670	18	2.79 ±0.03	NK̄ Λη	$K^-p \to \Lambda\eta$ seen	410 66	28.5
Λ′(1690)	0($3/2^-$) D_{03}	p=0.79	1695	40	2.88 ±0.07	NK̄ Σπ	20 58	434 407	25.6
Λ(1815)	0($5/2^+$) F_{05}	p=1.05	1815 ±5[§]	75 ±10[§]	3.30 ±0.14	NK̄ Σπ Σ(1385)π Λη	70 10 8 ~ 1	538 500 359 346	16.7
Λ(1830) →	0($5/2^-$) D_{05}	p=1.08	1830	80	3.35 ±0.15	NK̄ Σπ	8 42	550 510	16.0
Λ(2100)	0($7/2^-$) G_{07}	p=1.68	2100	140	4.41 ±0.29	NK̄ Σπ Λη ΞK Λω	30 4 < 3 ~ 1 <10	748 699 617 483 443	8.68
Λ(2350)	0(?)	p=2.29	2350	210	5.52 ±0.49	NK̄	(J+1/2)x=0.6[b]	913	5.85
	— Seen in total c. s.								
Σ									
Σ	1($1/2^+$)		(+)1189.4 (0)1192.6 (-)1197.4		1.41 1.42 1.43	See Table S			
Σ(1385)	1($3/2^+$) P_{13}	p<0 K^-p	(+)1382.2±0.8 S=1.4* S=4.8*! ←→(-) 1388.0±3.0	(+)36±3 S=2.1* (-)38±8, S=3.7*!	1.92 ±0.05	Λπ Σπ	91±3 9±3 S=1.4*	208 117	
Σ(1660)	1($3/2^-$) D_{13}	p=0.72	1660	50	2.76 ±0.08	Λ(1405)π NK̄	large small for both	197 400	29.9
	Decay modes of these two states not separated yet.								
Σ(1700)	1 (? ?)	p=0.80	1700	110	2.89 ±0.19	Λπ Σπ	large not disentangled	470 411	25.1
Σ(1770)	1($5/2^-$) D_{15}	p=0.95	1765 ±5[§]	100 ±15[§]	3.13 ±0.18	NK̄ Λπ Λ(1520)π Σ(1385)π Ση Σπ	45 15 15 15 ~1 ~1	497 519 190 317 140 463	19.4
‡ Σ(1910)	1($5/2^+$) F_{15}	p=1.25	1910	60	3.65 ±0.11	NK̄ Λπ	8 8	612 619	12.9
	A small effect. Not established beyond all question.								
Σ(2030)	1($7/2^+$) F_{17}	p=1.52	2030	120	4.12 ±0.24	NK̄ Λπ Σπ ΞK	10 35 10 < 2	700 700 652 412	9.92
Σ(2250)	1(?)	p=2.04	2250	200	5.06 ±0.45	NK̄	(J+1/2)x=0.4[b]	849	6.76
	— Seen in total c. s.								
Σ(2455)	1(?)	p=2.57	2455	120	6.03 ±0.29	NK̄	(J+1/2)x=0.3[b]	979	5.08
	— Seen in total c.s.								
Σ(2595) →	1(?)	p=2.95	2595	~ 140	6.73 ±0.36	NK̄	(J+1/2)x=0.25[b]	1064	4.30
	— Seen in total c.s.								
Ξ									
Ξ	1/2($1/2^+$)		(0)1314.7 (-)1321.3		1.73 1.75	See Table S			
Ξ(1530)	1/2($3/2^+$) p-wave		(0)1528.9±1.1 (-)1533.8±1.9	7.3 ±1.7	2.34 ±0.01	Ξπ	100	145	
† Ξ(1815)	1/2(?)		1815 ±3	16 ±8 S=2.2*	3.29 ±0.03	ΛK̄ Ξπ Ξππ [Ξ(1530)π][a] ΣK̄	~65 ~ 10 ~ 25 [~20] <2	391 409 351 220 299	
	Branching ratios poorly known.								
Ξ(1930)	1/2(?)		1915	120	3.58 ±0.23	Ξπ ΛK̄	seen	487 488	
	— Needs confirmation.								
Ω									
Ω^-	0($3/2^+$)		1672.4		2.80	See Table S			

§ This is only an educated guess; the error given is larger than the error of the average of the published values (see listings for the latter).

→ at left of Table indicates a candidate that has been omitted because the evidence for the existence of the effect and/or for its interpretation as a resonance is open to considerable question. See listings for information on the following: $N_?$(3245), N(3690), N(3755), Z_1^*(1900), Λ(1860) F_{07}, Σ(1780), Σ(1880), Σ(3000), and Ξ(1705).

* Quoted error includes an S(scale) factor. See footnote to Table S.

‡ 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 using the averaged central mass values, without taking into account the widths of the resonances.

a. Square brackets indicate a sub-reaction of the previous unbracketed decay mode.

b. J is not known; x is Γ_{el}/Γ.

c. Several new resonances have been reported by the CERN group (Donnachie et al.) as a result of their phase-shift analysis up to M = 2100 MeV. The other two groups working on phase-shift analysis (Berkeley, Saclay) have not claimed these states at this time; therefore we have to take them with some caution. For the time being, we classify the nine new CERN resonances as follows (the numbers in parentheses are M, Γ, Γ_{el}/Γ, slightly rounded): i) Strong candidates, D_{33}(1690, 270, 0.14), F_{35}(1910, 350, 0.16); ii) less certain, P_{31}(1930, 340, 0.30), P_{33}(1690, 280, 0.10), P_{11}(1750, 330, 0.32), F_{17}(1980, 220, 0.13); iii) require some imagination, D_{35}(1950, 310, 0.15), P_{13}(1860, 300, 0.21), D_{13}(2060, 290, 0.26).

Special Relativity

Notation. 4-vector in c.m. $p = (w, \vec{p})$; in lab $P = (W, \vec{P})$, $T = W - m$.
Solid-angle element $d\omega = 2\pi d\cos\theta$; $d\Omega = 2\pi d\cos\Theta$.
$p^2 = w^2 - \vec{p}^2 = m^2$ is an invariant. Cross section σ is invariant.

Lorentz Transformation

$$\begin{pmatrix} w \\ p_x \\ p_y \\ p_z \end{pmatrix} = \begin{pmatrix} \bar{\gamma} & -\bar{\eta} & 0 & 0 \\ -\bar{\eta} & \bar{\gamma} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} W \\ P_x \\ P_y \\ P_z \end{pmatrix}$$

If θ and Θ are measured with respect to the transformation axis x,

$$\frac{P_\perp}{P_x} = \tan\theta = \frac{P\sin\Theta}{-\bar{\eta}W + \bar{\gamma}P\cos\Theta}. \qquad (1)$$

If particle 1 is beam, 2 is target, $(W_2, \vec{P}_2) = (m_2, \vec{0})$ and

$$\bar{\gamma} = (W_1 + m_2)/\sqrt{s}, \quad \bar{\eta} = \bar{\gamma}\bar{\beta} = |\vec{P}_1| / \sqrt{s}, \quad |\vec{p}_1| = |\vec{p}_2| = \bar{\eta}m_2 = |\vec{P}_1| m_2/\sqrt{s}. \qquad (2)$$

For $m_1 = m_2$, $\bar{\gamma}^2 = 1 + T_1/2m_1$.

General Lorentz Transformation (characterized by $\vec{\beta}$, with $\bar{\gamma} = (1-\vec{\beta}^2)^{-1/2}$, $\vec{\eta} = \bar{\gamma}\vec{\beta}$):
$w = \bar{\gamma}W - \vec{\eta}\cdot\vec{P}$; $\vec{p} = \vec{P} - \vec{\eta}\,\frac{W + w}{\bar{\gamma} + 1}$

Invariants. Notation: $1 + 2 \to 1' + 2'$.

$$s = (p_1 + p_2)^2 = m_1^2 + m_2^2 + 2(w_1 w_2 - \vec{p}_1\cdot\vec{p}_2) \qquad (3)$$

$$t = (p'_i - p_i)^2 = m_i^2 + m_i'^2 - 2(w_i w'_i - \vec{p}_i \cdot \vec{p}'_i) \quad (i = 1, 2) \qquad (4)$$

$$u = (p'_1 - p_2)^2 = (p'_2 - p_1)^2 \qquad (5)$$

General relation: $s + t + u = m_1^2 + m_1'^2 + m_2^2 + m_2'^2$. (6)

In lab system $P_2 = (m_2, \vec{0})$, and writing $W = m + T$

$$s = m_1^2 + m_2^2 + 2W_1 m_2 = (m_1 + m_2)^2 + 2T_1 m_2 \qquad (3, lab)$$

$$t = m_2^2 + m_2'^2 - 2W'_2 m_2 = (m_2 - m'_2)^2 - 2T'_2 m_2 \qquad (4, lab)$$

In c.m. system $.\ dt = +2|\vec{p}_i|\,|\vec{p}'_i|\, d\cos\theta$ (4, cm)

For elastic scattering $(m_1 = m'_1,\ m_2 = m'_2)$, (4) in c.m. simplifies to

$$t = -2\vec{p}^2(1 - \cos\theta) = -4\vec{p}^2\sin^2\theta/2 \qquad (4, el)$$

$$u = (m_1^2 - m_2^2)^2/s - 2\vec{p}^2(1 + \cos\theta) = (m_1^2 - m_2^2)^2/s - 4\vec{p}^2\cos^2\theta/2$$

For elastic scattering, using (4, lab), (4, el), and (2),

$$T'_2 = \frac{2\vec{P}_1^2 m_2}{s}\sin^2\left(\frac{\theta}{2}\right) \quad \text{(useful for calculating } \delta\text{-ray energies).} \qquad (7)$$

Two-Body States. Energies and momenta in c.m.

$$w_1 = \frac{s + m_1^2 - m_2^2}{2\sqrt{s}}, \qquad \vec{p}_1^2 = \vec{p}_2^2 = \frac{1}{4s}\left[s - (m_1 + m_2)^2\right]\left[s - (m_1 - m_2)^2\right]. \qquad (8)$$

3- and 4-Body States. Let $m_{ij}^2 = (p_i + p_j)^2$, etc., then

$$\sum_{i<j} m_{ij}^2 = \Sigma m_i^2 + m_{123}^2 = \text{const.} \quad (i, j = 1, 2, 3) \text{ (follows from (6)).} \qquad (9)$$

$$= 2\Sigma m_i^2 + m_{1234}^2 = \text{const.}$$

$$\sum_{i<j<k} m_{ijk}^2 = \Sigma m_i^2 + 2m_{1234}^2 = \text{const.} \quad (i, j, k = 1, 2, 3, 4.) \qquad (10)$$

R_n, Invariant Volume in n-Body Momentum Space

A useful invariant is $d^4p\,\delta(p^2 - m^2) = \frac{d^3\vec{p}}{2w} = \frac{\vec{p}^2 d|\vec{p}| d\omega}{2w} = \frac{1}{2}|\vec{p}|\, dw\, d\omega$.

$R_2 = \pi|\vec{p}_1|/\sqrt{s}$, $\quad R_3 = \pi^2\int dw_1 dw_2 = (\pi^2/4s)\int dm_{12}^2\, dm_{23}^2$ (using c.m. quantities)

Recurrence Relation for Factoring R_n (see e.g., Hagedorn, p. 93[a])

Write $N \to 1, 2, \cdots k, k+1, \cdots n$ $\quad (R_n)$, then

as $N \to K, k+1, \cdots n$ $\quad (R_{n-k+1})$; $\quad R_n = \int d(m_K^2) R_k R_{n-k+1}$

$\quad\quad \hookrightarrow 1, 2, \cdots k$ $\quad (R_k)$

Cross Section (or Decay Rate)

For $1 + 2 \to n$ particles (or $1 \to n$ particles)

$\sigma F = |M|^2 R_n$ $\quad$ (or $\Gamma w_1 = |M|^2 R_n$)

where M is an invariant matrix element.

F is (Møller's) invariant flux factor, $F^2 = (p_1 p_2)^2 - m_1^2 m_2^2$.

In every system where $\vec{p}_1$ and $\vec{p}_2$ are collinear, $F = w_1 w_2 |\vec{v}_1 - \vec{v}_2|$ $\quad (\vec{v} = \vec{p}/w)$.

If particle 1 is beam, 2 is target ($\vec{P}_2 = 0$), $F = |\vec{P}_1| m_2 = |\vec{p}_1|\sqrt{s}$ [cf. (2)].

The rate (= number per unit 4-dimensional volume $d^4r = dt\, d^3\vec{r}$) is
$d^4N/d^4r = \sigma\,\rho_1\rho_2\,|\vec{v}_1 - \vec{v}_2|$, $\quad \rho_i$ = volume density of particles (i = 1, 2).

a. R. Hagedorn, Relativistic Kinematics, (W. A. Benjamin, New York, 1964).

C. M. Energy (μ) and Momentum (P_{CMS}) vs. Beam Momentum (P) of e, π, K, or p on p

$$\mu d\mu = m_p dE = m_p v_{beam,\,lab}\, dP \approx m_p dP$$

P(LAB) (MEV/C)	INVARIANT MASS (MEV) ep	πp	Kp	pp	P(CMS) (MEV/C) ep	πp	Kp	pp
0	939	1078	1432	1877	0	0	0	0
20	958	1079	1432	1877	20	17	13	10
40	977	1083	1433	1877	38	35	26	20
60	996	1089	1434	1877	56	52	39	30
80	1015	1096	1436	1878	74	68	52	40
T(PI) = PLAB - 59 MEV								
100	1033	1105	1439	1879	91	85	65	50
120	1051	1116	1441	1880	107	101	78	60
140	1069	1127	1445	1882	123	117	91	70
160	1087	1139	1449	1883	138	132	104	80
180	1104	1152	1453	1885	153	147	116	90
T(PI) = PLAB - 92 MEV								
200	1121	1165	1457	1887	167	161	129	99
220	1137	1178	1462	1889	182	175	141	109
240	1154	1192	1468	1892	195	189	153	119
260	1170	1206	1474	1894	209	202	166	129
280	1186	1219	1480	1897	222	215	178	138
T(PI) = PLAB - 107 MEV								
300	1201	1233	1486	1900	234	228	189	148
320	1217	1247	1493	1903	247	241	201	158
340	1232	1261	1500	1906	259	253	213	167
360	1247	1274	1507	1910	271	265	224	177
380	1262	1288	1514	1913	282	277	235	186
T(PI) = PLAB - 115 MEV								
400	1277	1302	1522	1917	294	288	247	196
420	1292	1315	1530	1921	305	300	258	205
440	1306	1329	1538	1925	316	311	268	214
460	1320	1342	1546	1929	327	322	279	224
480	1335	1356	1554	1933	337	332	290	233
T(PI) = PLAB - 120 MEV								
500	1349	1369	1563	1938	348	343	300	242
520	1362	1382	1572	1943	358	353	310	251
540	1376	1395	1580	1947	368	363	321	260
560	1390	1408	1589	1952	378	373	331	269
580	1403	1421	1598	1957	388	383	341	278
T(PI) = PLAB - 123 MEV								
600	1416	1434	1607	1962	397	393	350	287
620	1430	1446	1616	1967	407	402	360	296
640	1443	1459	1625	1973	416	412	370	304
660	1456	1472	1634	1978	425	421	379	313
680	1468	1484	1644	1984	434	430	388	322
T(PI) = PLAB - 125 MEV								
700	1481	1496	1653	1989	443	439	397	330
720	1494	1509	1662	1995	452	448	406	339
740	1506	1521	1671	2001	461	457	415	347
760	1519	1533	1681	2007	470	465	424	355
780	1531	1545	1690	2013	478	474	433	364
T(PI) = PLAB - 127 MEV								
800	1543	1557	1699	2019	486	482	442	372
820	1555	1569	1709	2025	495	490	450	380
840	1567	1580	1718	2031	503	499	459	388
860	1579	1592	1728	2037	511	507	467	396
880	1591	1604	1737	2043	519	515	475	404
T(PI) = PLAB - 129 MEV								
900	1603	1615	1747	2049	527	523	483	412
920	1615	1627	1756	2056	535	531	492	420
940	1626	1638	1765	2062	542	538	500	428
960	1638	1649	1775	2069	550	546	508	435
980	1649	1661	1784	2075	558	554	515	443
T(PI) = PLAB - 130 MEV								
1000	1660	1672	1794	2082	565	561	523	451
1020	1672	1683	1803	2088	573	569	531	458
1040	1683	1694	1812	2095	580	576	538	466
1060	1694	1705	1822	2102	587	583	546	473
1080	1705	1716	1831	2108	594	591	553	481
T(PI) = PLAB - 131 MEV								
1100	1716	1726	1840	2115	601	598	561	488
1120	1727	1737	1850	2122	609	605	568	495
1140	1738	1748	1859	2129	616	612	575	502
1160	1748	1758	1868	2135	622	619	583	510
1180	1759	1769	1877	2142	629	626	590	517
T(PI) = PLAB - 131 MEV								
1200	1770	1780	1887	2149	636	633	597	524
1220	1780	1790	1896	2156	643	639	604	531
1240	1791	1800	1905	2163	650	646	611	538
1260	1801	1811	1914	2170	656	653	618	545
1280	1812	1821	1923	2177	663	660	624	552
T(PI) = PLAB - 132 MEV								
1300	1822	1831	1932	2184	669	665	631	559
1320	1832	1841	1941	2191	676	673	638	565
1340	1843	1851	1950	2198	682	679	645	572
1360	1853	1862	1959	2205	689	685	651	579
1380	1863	1872	1968	2212	695	692	658	585
T(PI) = PLAB - 133 MEV								

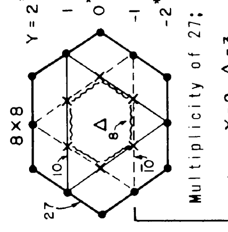
P(LAB) (MEV/C)	INVARIANT MASS (MEV) ep	πp	Kp	pp	P(CMS) (MEV/C) ep	πp	Kp	pp
1400	1873	1881	1977	2219	701	698	664	592
1420	1883	1891	1986	2226	708	704	671	599
1440	1893	1901	1995	2233	714	711	677	605
1460	1903	1911	2004	2240	720	717	684	612
1480	1912	1921	2013	2247	726	723	690	618
T(PI) = PLAB - 133 MEV								
1500	1922	1930	2022	2254	732	729	696	624
1520	1932	1940	2031	2261	738	735	702	631
1540	1942	1950	2039	2268	744	741	709	637
1560	1951	1959	2048	2275	750	747	715	643
1580	1961	1969	2057	2282	756	753	721	650
T(PI) = PLAB - 133 MEV								
1600	1970	1978	2065	2289	762	759	727	656
1620	1980	1988	2074	2296	768	765	733	662
1640	1989	1997	2083	2304	773	770	739	668
1660	1999	2006	2091	2311	779	776	745	674
1680	2008	2016	2100	2318	785	782	751	680
T(PI) = PLAB - 134 MEV								
1700	2018	2025	2109	2325	791	788	756	686
1720	2027	2034	2117	2332	796	793	762	692
1740	2036	2043	2126	2339	802	799	768	698
1760	2045	2053	2134	2346	807	805	774	704
1780	2054	2062	2143	2353	813	810	779	710
T(PI) = PLAB - 134 MEV								
1800	2064	2071	2151	2360	818	816	785	716
1820	2073	2080	2159	2367	824	821	791	721
1840	2082	2089	2168	2374	829	827	796	727
1860	2091	2098	2176	2381	835	832	802	733
1880	2100	2107	2184	2388	840	837	808	739
T(PI) = PLAB - 134 MEV								
1900	2108	2115	2193	2395	845	843	813	744
1920	2117	2124	2201	2402	851	848	818	750
1940	2126	2133	2209	2409	856	853	824	756
1960	2135	2142	2217	2416	861	859	829	761
1980	2144	2150	2226	2423	867	864	835	767
T(PI) = PLAB - 135 MEV								
2000	2153	2159	2234	2430	872	869	840	772
2020	2161	2168	2242	2437	877	874	845	778
2040	2170	2176	2250	2444	882	879	851	783
2060	2179	2185	2258	2451	887	885	856	789
2080	2187	2194	2266	2458	892	890	861	794
T(PI) = PLAB - 135 MEV								
2100	2196	2202	2274	2465	897	895	866	799
2120	2204	2211	2282	2472	902	900	872	805
2140	2213	2219	2290	2479	907	905	877	810
2160	2221	2227	2298	2486	912	910	882	815
2180	2230	2236	2306	2493	917	915	887	821
T(PI) = PLAB - 135 MEV								
2200	2238	2244	2314	2500	922	920	892	826
2220	2246	2253	2322	2507	927	925	897	831
2240	2255	2261	2330	2514	932	930	902	836
2260	2263	2269	2338	2520	937	934	907	841
2280	2271	2277	2346	2527	942	939	912	846
T(PI) = PLAB - 135 MEV								
2300	2280	2286	2353	2534	947	944	917	852
2320	2288	2294	2361	2541	951	949	922	857
2340	2296	2302	2369	2548	956	954	927	862
2360	2304	2310	2377	2555	961	959	932	867
2380	2312	2318	2384	2561	966	963	937	872
T(PI) = PLAB - 135 MEV								
2400	2320	2326	2392	2568	970	968	941	877
2420	2328	2334	2400	2575	975	973	946	882
2440	2336	2342	2407	2582	980	977	951	887
2460	2344	2350	2415	2589	984	982	956	892
2480	2352	2358	2423	2595	989	987	960	897
T(PI) = PLAB - 136 MEV								
2500	2360	2366	2430	2602	994	991	965	901
2520	2368	2374	2438	2609	998	996	970	906
2540	2376	2382	2445	2616	1003	1001	975	911
2560	2384	2390	2453	2622	1007	1005	979	916
2580	2392	2398	2460	2629	1012	1010	984	921
T(PI) = PLAB - 136 MEV								
2600	2400	2405	2468	2636	1017	1014	988	926
2620	2408	2413	2475	2643	1021	1019	993	930
2640	2415	2421	2483	2649	1025	1023	998	935
2660	2423	2429	2490	2656	1030	1028	1002	940
2680	2431	2436	2498	2663	1034	1032	1007	944
T(PI) = PLAB - 136 MEV								
2700	2439	2444	2505	2669	1039	1037	1011	949
2720	2446	2452	2512	2676	1043	1041	1016	954
2740	2454	2459	2520	2682	1048	1045	1020	959
2760	2462	2467	2527	2689	1052	1050	1025	963
2780	2469	2474	2534	2696	1056	1054	1029	968
T(PI) = PLAB - 136 MEV								

P(LAB) (GEV/C)	INVARIANT MASS (GEV) πp/ep	Kp	pp	P(CMS) (GEV/C) πp/ep	Kp	pp
3.0	2.56	2.61	2.77	1.10	1.08	1.02
3.2	2.63	2.68	2.83	1.14	1.12	1.06
3.4	2.70	2.75	2.89	1.18	1.16	1.10
3.6	2.77	2.82	2.96	1.22	1.20	1.14
3.8	2.83	2.88	3.02	1.26	1.24	1.18
T(PI) = PLAB - .137 GEV						
4.0	2.90	2.95	3.08	1.29	1.27	1.22
4.2	2.96	3.01	3.14	1.33	1.31	1.26
4.4	3.03	3.07	3.19	1.36	1.34	1.29
4.6	3.09	3.13	3.25	1.40	1.38	1.33
4.8	3.15	3.19	3.31	1.43	1.41	1.36
T(PI) = PLAB - .138 GEV						
5.0	3.21	3.25	3.36	1.46	1.44	1.40
5.2	3.27	3.31	3.42	1.49	1.48	1.43
5.4	3.32	3.36	3.47	1.53	1.51	1.46
5.6	3.38	3.42	3.52	1.56	1.54	1.49
5.8	3.43	3.47	3.58	1.59	1.57	1.52
T(PI) = PLAB - .138 GEV						
6.0	3.49	3.52	3.63	1.61	1.60	1.55
6.2	3.54	3.58	3.68	1.64	1.63	1.58
6.4	3.59	3.63	3.73	1.67	1.65	1.61
6.6	3.65	3.68	3.78	1.70	1.68	1.64
6.8	3.70	3.73	3.83	1.73	1.71	1.67
T(PI) = PLAB - .138 GEV						
7.0	3.75	3.78	3.87	1.75	1.74	1.70
7.2	3.80	3.83	3.92	1.78	1.76	1.72
7.4	3.85	3.88	3.97	1.81	1.79	1.75
7.6	3.89	3.93	4.02	1.83	1.82	1.78
7.8	3.94	3.97	4.06	1.86	1.84	1.80
T(PI) = PLAB - .138 GEV						
8.0	3.99	4.02	4.11	1.88	1.87	1.83
8.2	4.04	4.07	4.15	1.91	1.89	1.85
8.4	4.08	4.11	4.20	1.93	1.92	1.88
8.6	4.13	4.16	4.24	1.95	1.94	1.90
8.8	4.17	4.20	4.29	1.98	1.96	1.93
T(PI) = PLAB - .138 GEV						
9.0	4.22	4.25	4.33	2.00	1.99	1.95
9.2	4.26	4.29	4.37	2.03	2.01	1.97
9.4	4.31	4.33	4.41	2.05	2.03	2.00
9.6	4.35	4.38	4.46	2.07	2.06	2.02
9.8	4.39	4.42	4.50	2.09	2.08	2.04
T(PI) = PLAB - .139 GEV						
10.0	4.43	4.46	4.54	2.12	2.10	2.07
10.5	4.54	4.57	4.64	2.17	2.16	2.12
11.0	4.64	4.67	4.74	2.22	2.21	2.18
11.5	4.74	4.77	4.84	2.28	2.26	2.23
12.0	4.84	4.86	4.93	2.33	2.31	2.28
T(PI) = PLAB - .139 GEV						
12.5	4.94	4.96	5.03	2.38	2.36	2.33
13.0	5.03	5.05	5.12	2.43	2.41	2.38
13.5	5.12	5.15	5.21	2.47	2.46	2.43
14.0	5.21	5.24	5.30	2.52	2.51	2.48
14.5	5.30	5.32	5.39	2.57	2.56	2.53
T(PI) = PLAB - .139 GEV						
15.0	5.39	5.41	5.47	2.61	2.60	2.57
15.5	5.48	5.50	5.56	2.66	2.65	2.62
16.0	5.56	5.58	5.64	2.70	2.69	2.66
16.5	5.64	5.67	5.72	2.74	2.73	2.70
17.0	5.73	5.75	5.81	2.78	2.77	2.75
T(PI) = PLAB - .139 GEV						
17.5	5.81	5.83	5.89	2.83	2.82	2.79
18.0	5.89	5.91	5.97	2.87	2.86	2.83
18.5	5.97	5.99	6.04	2.91	2.90	2.87
19.0	6.05	6.07	6.12	2.95	2.94	2.91
19.5	6.12	6.14	6.20	2.99	2.98	2.95
T(PI) = PLAB - .139 GEV						
20.0	6.20	6.22	6.27	3.03	3.02	2.99
21.0	6.35	6.37	6.42	3.10	3.09	3.07
22.0	6.49	6.51	6.56	3.18	3.17	3.14
23.0	6.64	6.66	6.70	3.25	3.24	3.22
24.0	6.78	6.79	6.84	3.32	3.31	3.29
T(PI) = PLAB - .139 GEV						
25.0	6.91	6.93	6.98	3.39	3.38	3.36
26.0	7.05	7.07	7.11	3.46	3.45	3.43
27.0	7.18	7.20	7.24	3.53	3.52	3.50
28.0	7.31	7.33	7.37	3.59	3.59	3.56
29.0	7.44	7.45	7.50	3.66	3.65	3.63
T(PI) = PLAB - .139 GEV						
30.0	7.56	7.58	7.62	3.72	3.71	3.69
35.0	8.16	8.17	8.21	4.02	4.02	4.00
40.0	8.72	8.73	8.77	4.31	4.30	4.28
45.0	9.24	9.25	9.29	4.57	4.56	4.55
50.0	9.73	9.74	9.78	4.82	4.81	4.80
T(PI) = PLAB - .139 GEV						

SU(3) ISOSCALAR FACTORS, adapted from J.J. de Swart, Rev. Mod. Phys. 35, 916 (1963).

$\{8\} \otimes \{8\} = \{27\} \oplus \{10\} \oplus \{10^*\} \oplus \{8\}_1 \oplus \{8\}_2 \oplus \{1\}$.

* Five single-coefficient tables are omitted. The one involving a $\{10^*\}$ has a negative coefficient, i.e. $(N\bar{K}|10^*) = -1$. The others, involving $\{27\}$ and $\{10\}$, are all +1.



Multiplicity of 27;

● = 1, × = 2, Δ = 3

$Y = 1 \quad I = \frac{1}{2}$ N

ξ_1	27 (+)	8_s (+)	8_a (−)	10^* (−)
$K\Sigma$	$\sqrt{5}/10$	$3\sqrt{5}/10$	1/2	−1/2
πN	$-\sqrt{5}/10$	$-3\sqrt{5}/10$	1/2	−1/2
$K\Lambda$	$3\sqrt{5}/10$	$-\sqrt{5}/10$	1/2	1/2
ηN	$3\sqrt{5}/10$	$-\sqrt{5}/10$	−1/2	−1/2

$Y = 1 \quad I = \frac{3}{2}$ Δ

ξ_1	27 (+)	10 (−)
$K\Sigma$	$\sqrt{2}/2$	$-\sqrt{2}/2$
πN	$\sqrt{2}/2$	$\sqrt{2}/2$

$Y = 0 \quad I = 0$ Λ

ξ_1	27 (+)	8_s (+)	1 (+)	8_a (−)
$K\Xi$	$\sqrt{15}/10$	$\sqrt{10}/10$	1/2	$\sqrt{2}/2$
$\bar{K}N$	$-\sqrt{15}/10$	$-\sqrt{10}/10$	−1/2	$\sqrt{2}/2$
$\pi\Sigma$	$-\sqrt{10}/20$	$-\sqrt{15}/5$	$\sqrt{6}/4$	0
$\eta\Lambda$	$3\sqrt{30}/20$	$-\sqrt{5}/5$	$-\sqrt{2}/4$	0

$Y = 0 \quad I = 1$ Σ

ξ_1	27 (+)	8_s (+)	8_a (−)	10 (−)	10^* (−)
$K\Xi$	$\sqrt{5}/5$	$-\sqrt{30}/10$	$\sqrt{6}/6$	$-\sqrt{6}/6$	$\sqrt{6}/6$
$\bar{K}N$	$\sqrt{5}/5$	$-\sqrt{30}/10$	$-\sqrt{6}/6$	$\sqrt{6}/6$	$-\sqrt{6}/6$
$\pi\Sigma$	0	0	$\sqrt{6}/3$	$\sqrt{6}/6$	$-\sqrt{6}/6$
$\pi\Lambda$	$\sqrt{30}/10$	$\sqrt{5}/5$	0	1/2	1/2
$\eta\Sigma$	$\sqrt{30}/10$	$\sqrt{5}/5$	0	−1/2	−1/2

$Y = -1 \quad I = \frac{1}{2}$ Ξ

ξ_1	27 (+)	8_s (+)	8_a (−)	10 (−)
$\bar{K}\Sigma$	$-\sqrt{5}/10$	$-3\sqrt{5}/10$	1/2	1/2
$\pi\Xi$	$\sqrt{5}/10$	$3\sqrt{5}/10$	1/2	1/2
$\bar{K}\Lambda$	$3\sqrt{5}/10$	$-\sqrt{5}/10$	−1/2	1/2
$\eta\Xi$	$3\sqrt{5}/10$	$-\sqrt{5}/10$	1/2	−1/2

$Y = -1 \quad I = \frac{3}{2}$

ξ_1	27 (+)	10^* (−)
$\bar{K}\Sigma$	$\sqrt{2}/2$	$-\sqrt{2}/2$
$\pi\Xi$	$\sqrt{2}/2$	$\sqrt{2}/2$

The phase factor $\xi_1 = \pm 1$, from de Swart's Table I, enters into his symmetry formula (14.3):

$$\langle \mu_1 \mu_2 | \mu \rangle = \xi_1 (-1)^{I_1 + I_2 - I} \langle \mu_2 \mu_1 | \mu \rangle$$

This factor is irrelevant if you are doing your own self-consistent calculations; it enters when you try to check someone else who chose $\mu_2 \otimes \mu_1$ instead of $\mu_1 \otimes \mu_2$.

$\{8\} \otimes \{10\} = \{35\} \oplus \{27\} \oplus \{10\} \oplus \{8\}$.

* Four single coefficient tables are omitted; only the $\{27\}$ is −1; the three with $\{35\}$ are +1.

$Y = 1 \quad I = \frac{1}{2}$ N

ξ_1	27 (−)	8 (+)
$\pi\Delta$	$\sqrt{5}/5$	$-2\sqrt{5}/5$
$K\Sigma$	$-2\sqrt{5}/5$	$-\sqrt{5}/5$

$Y = 1 \quad I = \frac{3}{2}$ Δ

ξ_1	35 (+)	27 (−)	10 (−)
$\pi\Delta$	−1/4	$-\sqrt{5}/4$	$\sqrt{10}/4$
$\eta\Delta$	$\sqrt{5}/4$	−3/4	$-\sqrt{2}/4$
$K\Sigma$	$\sqrt{10}/4$	$\sqrt{2}/4$	1/2

$Y = 0 \quad I = 0$ Λ

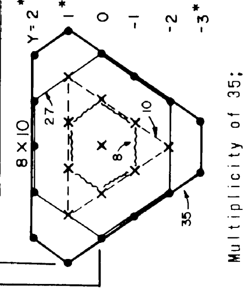
ξ_1	27 (−)	8 (+)
$\pi\Sigma$	$\sqrt{10}/5$	$-\sqrt{15}/5$
$K\Xi$	$-\sqrt{15}/5$	$-\sqrt{10}/5$

$Y = 0 \quad I = 1$ Σ

ξ_1	35 (+)	27 (−)	10 (−)	8 (+)
$\pi\Sigma$	$-\sqrt{3}/6$	$-3\sqrt{5}/10$	$\sqrt{3}/3$	$\sqrt{30}/15$
$\eta\Sigma$	$\sqrt{2}/2$	$-\sqrt{30}/10$	0	$-\sqrt{5}/5$
$K\Xi$	$\sqrt{3}/3$	$\sqrt{5}/5$	$\sqrt{3}/3$	$\sqrt{30}/15$
$\bar{K}\Delta$	$-\sqrt{3}/6$	$\sqrt{5}/10$	$\sqrt{3}/3$	$-2\sqrt{30}/15$

$Y = 0 \quad I = 2$

ξ_1	35 (+)	27 (−)
$\pi\Sigma$	$\sqrt{3}/2$	1/2
$\bar{K}\Delta$	1/2	$-\sqrt{3}/2$



Multiplicity of 35;

● = 1, × = 2

$Y = -1 \quad I = \frac{1}{2}$ Ξ

ξ_1	35 (+)	27 (−)	10 (−)	8 (+)
$\pi\Xi$	−1/4	$-7\sqrt{5}/20$	$\sqrt{2}/4$	$\sqrt{5}/5$
$\eta\Xi$	3/4	$-3\sqrt{5}/20$	$\sqrt{2}/4$	$-\sqrt{5}/5$
$K\Omega$	$\sqrt{2}/4$	$3\sqrt{10}/20$	1/2	$\sqrt{10}/5$
$\bar{K}\Sigma$	−1/2	$\sqrt{5}/10$	$\sqrt{2}/2$	$-\sqrt{5}/5$

$Y = -1 \quad I = \frac{3}{2}$

ξ_1	35 (+)	27 (−)
$\pi\Xi$	$\sqrt{2}/2$	$\sqrt{2}/2$
$\bar{K}\Sigma$	$\sqrt{2}/2$	$-\sqrt{2}/2$

$Y = -2 \quad I = 0$ Ω^-

ξ_1	35 (+)	10 (−)
$\eta\Omega$	$\sqrt{2}/2$	$\sqrt{2}/2$
$\bar{K}\Xi$	$-\sqrt{2}/2$	$\sqrt{2}/2$

$Y = -2 \quad I = 1$

ξ_1	35 (+)	27 (−)
$\pi\Omega$	1/2	$\sqrt{3}/2$
$\bar{K}\Xi$	$\sqrt{3}/2$	−1/2

Footnotes to Meson Table (continued)

(k) Width of $\eta_{0^+}(1070) \to K_S K_S$: Average value from two bubble chamber experiments is $\Gamma = (72 \pm 13)$MeV; whereas two spark chamber experiments on $K_S K_S$ give $\Gamma \gtrsim 100$ MeV and another spark chamber experiment (observing what might be a $\pi^+\pi^-$ mode) yields $\Gamma < 25$ MeV. (For references, see data listings.)

(ℓ) $\rho\pi$ fraction of 3π mode difficult to distinguish because ρ bands cover most of the Dalitz plot.

(m) Empirical limits on fractions for decay modes of B(1220): $\pi\pi < 30\%$, $K\bar{K} < 2\%$, $4\pi < 50\%$, $\phi\pi < 1.5\%$, $\eta\pi < 25\%$, $(K\bar{K})^{\pm}\pi^0 < 8\%$, $K_S K_S \pi^{\pm} < 2\%$, $K_S K_L \pi^{\pm} < 6\%$.

(n) Although the splitting of the A2 needs further confirmation, we give the results from the two experiments that have observed a split A2; for M and Γ of $A2_H$ we have also used the values for the $K\bar{K}$ mode from other experiments. Since most experiments have only seen one rather wide, A2 enhancement, we here list its ("combined") properties: $I^G(J^P)C_n = 1^-(2^+)+$; M = 1297 ± 10 MeV (S=1.9*) (§), Γ = 91 ± 10 MeV (S=1.1*) (§); partial decay modes: $\rho\pi$ 85 ±3%, $K\bar{K}$ 2.5±0.5%, $\eta\pi$ 12 ±4%, $\eta'\pi$ 0.5 ± 0.4% (S=1.9*).

(o) There is only a weak indication for a $K^*\bar{K} + \bar{K}^*K$ mode of the f'(1515). If this mode does not exist, the $K\bar{K}$ branching fraction will have to be reported as (80 ± 13)% (rather than (72 ± 12)% as given in the table).

(p) See the listings for many statistically weak Y = 0 bumps with M ≥ 1700 MeV, seen in bubble chambers. We tabulate here 9 statistically strong bumps seen with a missing mass spectrometer ($\pi^- p \to p(MM)^-$) or seen in counter experiments on the $\bar{p}N$ total cross section.

	Name	I	M (MeV)	Γ(MeV)	Decay Modes Observed	
	R1(1630)	≥1	1630 ± 15	≤21	1/3/>3 charg. part. ≈.37/.59/.04	(MMS)⁻
	R2(1700)	≥1	1700 ± 15	≤30	1/3/>3 charg. part. ≈.43/.56/.01	(MMS)⁻
	R3(1750)	≥1	1748 ± 15	< 38	1/3/>3 charg. part. >.14/<.80/.15	(MMS)⁻
	S(1930)	≥1	1929 ± 14	< 35	1/3/>3 charg. part. ≈ 0/.92/ 0	(MMS)⁻
?	$N\bar{N}$(2190)	1	2190 ± 10	≈85	structure in $N\bar{N}$ total cross section	
?	T(2200)	≥1	2195 ± 15	≤13	$(MM)^- \to 3$ charged particl. ≈94%	
?	$N\bar{N}$(2345)	1	2345 ± 10	≈140	structure in $N\bar{N}$ total cross section	
?	U(2380)	≥1	2382 ± 24	≤30	$(MM)^- \to 1/3/>3$ chrgd part. ≈30/45/25	
	$N\bar{N}$(2380)	0	2380 ± 10	≈140	structure in $N\bar{N}$ total cross section	

There is no evidence on the G, J, or P quantum numbers of these bumps, nor is there satisfactory agreement between them and the bubble chamber claims. Further, the $N\bar{N}$ bumps are broader than the $(MM)^-$ bumps, and there is no evidence for or against their interpretation as resonances.

(q) Taken from compilation by T. Ferbel, Proc. 1968 Philadelphia Conf. See the data listings for averages of the values given in the literature.

(r) See note in listings. Some investigators see a broad enhancement in mass ($K\pi\pi$) from 1200 - 1350 MeV, and others see structure. A further bump at 1280 MeV, Γ = 80 MeV, has been suggested. In light of this confusion, the masses, widths, quantum numbers, and branching ratios are at best tentative. For the mass region 1200 - 1350 MeV, the decay rate into $K^*(890)\pi$ is large, and a $K\rho$ decay is seen. The $K\eta$, $K\omega$ and $K\pi$ rates are less than a few percent (although for $K\pi$, there is some disagreement among experimenters).

Mixing angles from Quadratic SU(3) Mass Formula: 0^- nonet (π, K, η, η') $\theta = 10.4° \pm 0.2°$; 0^- nonet (π, K, η, E) $\theta = 6.2° \pm 0.1°$; 1^- nonet (ρ(m = 765±15 MeV), K^*, ϕ, ω) $\theta = 39.9 \pm 1.1°$; 2^+ nonet (A2, K_V(1420), f', f) $\theta = 29.9° \pm 2.2°$.