PARTICLE PROPERTIES: January 1970

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(Closing date for data: November 1, 1969)

STABLE PARTICLES: January 1970

Quantities in italics have changed by more than one (old) standard deviation since January 1969.

	$I^G(J^P)C$	Mass (MeV) / Mass^2 (GeV)^2	Mean life (sec) / $c\tau$(cm)	Decays: Partial mode	Decays: Fraction[a]	p or p_{max} (MeV/c)[b]
γ	$0,1(1^-)^-$	$0(<2.)\times10^{-21}$	stable	stable		
ν	ν_e $J=\frac{1}{2}$	$0(<60$ eV$)$	stable	stable		
	ν_μ	$0(<1.6)$				
e	$J=\frac{1}{2}$	0.511006 ±.000002	stable ($>2\times10^{21}$y)	stable		
μ	$J=\frac{1}{2}$	105.659 ±.002	2.1983×10^{-6} ±.0008	$e\bar{\nu}\nu$	100	53
		$m^2=0.0112$	$c\tau=6.592\times10^4$	$e\gamma\gamma$	(<1.6)10^{-5}	53
	$m_\mu-m_{\pi^\pm}=-33.920$ ±.013			3e	(<1.3)10^{-7}	53
				$e\gamma$	(<2)10^{-8}	53
$\pi^\pm$	$1^-(0^-)$	139.578 ±.013	2.603×10^{-8} ±.006, S=2.0*	$\mu\nu$	100 %	30
		$m^2=0.0195$	$c\tau=781$	$e\nu$	(1.24±0.03)10^{-4}	70
		$(\tau^+-\tau^-)/\overline{\tau}=(0.05\pm0.07)\%$		[c] $\mu\nu\gamma$	(1.24±0.25)10^{-4}	30
		(test of CPT)		$\pi^0e\nu$	(1.02±0.07)10^{-8}	5
				[c] $e\nu\gamma$	(3.0 ±0.5)10^{-8}	70
π^0	$1^-(0^-)^+$	134.975	0.89×10^{-16} ±.18, S=1.6*	$\gamma\gamma$	(98.83±0.04)%	67
		$m^2=0.0177$	$c\tau=2.67\times10^{-6}$	γe^+e^-	(1.17±0.04)%	67
	$m_{\pi^\pm}-m_{\pi^0}=4.6041$ ±.0037			$\gamma\gamma\gamma$	(<5)10^{-6}	67
				[d] $e^+e^-e^+e^-$	(3.47)10^{-5}	67
$K^\pm$	$\frac{1}{2}(0^-)$	493.82 ±0.11	1.235×10^{-8} ±.004 S=1.8*	$\mu\nu$	(63.77±0.29)% S=1.1*	236
		$m^2=0.244$	$c\tau=370$	$\pi\pi^0$	(20.93±0.30)% S=1.2*	205
		$(\tau^+-\tau^-)/\overline{\tau}=(.09\pm.12)\%$		$\pi\pi^-\pi^+$	(5.57±0.04)% S=1.2*	126
		(test of CPT)		$\pi\pi^0\pi^0$	(1.70±0.05)%	133
		S=1.3*		$\mu\pi^0\nu$	(3.18±0.11)% S=2.0*	215
				$e\pi^0\nu$	(4.85±0.07)% S=1.2*	228
	$m_{K^\pm}-m_{K^0}=-3.94$ ± 0.13			$\pi\pi^\mp e^\pm\nu$	(3.3 ±0.3)10^{-5}	203
				$\pi\pi^\mp e^\mp\nu$	(<7)10^{-7}	203
				$\pi\pi^\mp\mu^\pm\nu$	(0.9 ±0.4)10^{-5}	151
				$\pi\pi^\pm\mu^\mp\nu$	(<3)10^{-6}	151
				$e\nu$	(1.2 ±0.3)10^{-5}	247
				[c] $\pi\pi^0\gamma$	(<1.9)10^{-4}	205
				[c] $\pi\pi^+\pi^-\gamma$	(10 ±4)10^{-5}	126
				[c] $\pi e\nu\gamma$	(6 ±4)10^{-4}	227
				πe^+e^-	(<0.4)10^{-6}	227
				$\pi\mu^+\mu^-$	(<2.4)10^{-6}	172
				$\pi\gamma\gamma$	(<1.1)10^{-4}	227

	$I^G(J^P)C$	Mass (MeV) / Mass^2 (GeV)^2	Mean life (sec) / $c\tau$(cm)	Decays: Partial mode	Decays: Fraction[a]	p or p_{max} (MeV/c)[b]
K^0	$\frac{1}{2}(0^-)$	497.76 ±0.16	50% K_{Short}, 50% K_{Long}			
K^0_S	$\frac{1}{2}(0^-)$	S=1.5*	0.862×10^{-10} ±.006 S=1.2*	$\pi^+\pi^-$	(68.7 ±0.6)% S=1.6*	206
		$m^2=0.248$	$c\tau=2.59$	$\pi^0\pi^0$	(31.3)%	209
				$\mu^+\mu^-$	(<3.1)10^{-7}	225
				e^+e^-	(<2.2)10^{-7}	249
				[c] $\pi^+\pi^-\gamma$	(3.3 ±1.2)10^{-3}	206
K^0_L	$\frac{1}{2}(0^-)$		5.38×10^{-8} ±0.19	$\pi^0\pi^0\pi^0$	(21.5 ±0.7)% S=1.2*	139
			$c\tau=1614$ S=1.6*	$\pi^+\pi^-\pi^0$	(12.6 ±0.3)%	133
				$\pi\mu\nu$	(26.8 ±0.7)% S=1.2*	216
				$\pi e\nu$	(38.8 ±0.8)% S=1.2*	229
	$m_{K_S}-m_{K_L}=-0.469\times\frac{1}{\tau_S}$ ± 0.015			$\pi^+\pi^-$	(0.157±.005)%	206
				$\pi^0\pi^0$	(0.121±.029)% S=1.5*	209
				[c] $\pi^+\pi^-\gamma$	(<0.4)10^{-3}	206
	$\frac{\Gamma(K_S\to\pi^+\pi^-\pi^0)}{\Gamma(K_L\to\pi^+\pi^-\pi^0)}<0.45$			$\gamma\gamma$	(5.2 ±0.5)10^{-4} S=1.6*	249
	(test of CP)			$e\mu$	(<0.6)10^{-5}	238
				$\mu^+\mu^-$	(<1.5)10^{-6}	225
				e^+e^-	(<1.7)10^{-5}	249
η	$0^+(0^-)^+$	548.8 ±0.6	$\Gamma=(2.63\pm.64)$keV	$\gamma\gamma$	(38.2 ±2.1)%	274
		$m^2=0.301$	Neutral decays 71.5%	$\pi^0\gamma\gamma$	(2.0 ±2.8)% S=1.4*	258
				[e] $3\pi^0$	(31.4 ±2.7)%	179
			Charged decays 28.5%	$\pi^+\pi^-\pi^0$	(23.0 ±1.1)% S=1.2*	174
				$\pi^+\pi^-\gamma$	(5.4 ±0.5)%	236
				$\pi^0e^+e^-$	(<0.01)%	258
				$\pi^+\pi^-e^+e^-$	(0.1 ±0.1)%	236
p	$\frac{1}{2}(\frac{1}{2}^+)$	938.256 ±0.005	stable ($>2\times10^{28}$y)			
		$m^2=0.880$				
n	$\frac{1}{2}(\frac{1}{2}^+)$	939.550 ±0.005	[e] $(0.932\pm0.014)10^3$ $c\tau=2.80\times10^{13}$	$pe^-\nu$	100 %	1
		$m^2=0.882$				
	$m_p-m_n=-1.2933$ ± 0.0001					

	$I^G(J^P)C$	Mass (MeV) / Mass^2 (GeV)^2	Mean life (sec) / $c\tau$(cm)	Decays: Partial mode	Fraction[a]		p or p_{max} (MeV/c)[b]
Λ	$0(\frac{1}{2}^+)$	1115.60 ±0.08 S=1.3*	2.51×10^{-10} ±.03 S=1.3*	$p\pi^-$	(65.3 ±1.3)%		100
		m^2= 1.245	$c\tau$ = 7.54	$n\pi^0$	(34.7)%		104
				$pe\nu$	(0.85±0.07)10^{-3}	S=1.3*	163
				$p\mu\nu$	(1.35±0.60)10^{-4}		131
Σ^+	$1(\frac{1}{2}^+)$	1189.40 ±0.19 S=1.7*	0.802×10^{-10} ±.007	$p\pi^0$	(51.7 ±0.8)%		189
		m^2 = 1.412	$c\tau$ = 2.41	$n\pi^+$	(48.3)%		185
				$p\gamma$	(*1.16±0.17*)10^{-3}	S=1.4*	225
				$n\pi^+\gamma$	(*1.3 ±0.3*)10^{-4}		185
		$m_{\Sigma^+}-m_{\Sigma^-}$ = -7.92 ±.13		$\Lambda e^+\nu$	(2.02±0.47)10^{-5}		72
			$\frac{\Gamma(\Sigma^+\to\ell^+n\nu)}{\Gamma(\Sigma^-\to\ell^-n\nu)}$ =<.03←	$n\mu^+\nu$	(<1.1)10^{-5}		202
				$ne^+\nu$	(<0.7)10^{-5}		224
Σ^0	$1(\frac{1}{2}^+)$	1192.46 ±0.12 S=1.2*	$<1.0\times10^{-14}$ $c\tau<3\times10^{-4}$	$\Lambda\gamma$	100 %		75
		m^2= 1.422		Λe^+e^-	[d](5.45)10^{-3}		
Σ^-	$1(\frac{1}{2}^+)$	1197.32 ±0.11 S=1.3*	[e] *1.49*$\times10^{-10}$ *±.03* S=2.1*	$n\pi^-$	100 %		193
		m^2 = 1.434	$c\tau$ = 4.47	$ne^-\nu$	(1.06±0.05)10^{-3}		230
				$n\mu^-\nu$	(0.45±0.04)10^{-3}		210
				$\Lambda e^-\nu$	(0.60±0.06)10^{-4}		79
		$m_{\Sigma^0}-m_{\Sigma^-}$ = 4.86 ±.07		$n\pi^-\gamma$	[c](1.0 ±0.2)10^{-4}		193
Ξ^0	$\frac{1}{2}(\frac{1}{2}^+)^f$	1314.7 ±0.7	3.03×10^{-10} ±.18	$\Lambda\pi^0$	100 %		135
		m^2= 1.728	$c\tau$ = 9.10	$p\pi^-$	(<0.9)10^{-3}		299
				$pe^-\nu$	(<1.3)10^{-3}		323
		$m_{\Xi^0}-m_{\Xi^-}$ = 6.6 ±.7		$\Sigma^+e^-\nu$	(<1.5)10^{-3}		119
				$\Sigma^-e^+\nu$	(<1.5)10^{-3}		112
				$\Sigma^+\mu^-\nu$	(<1.5)10^{-3}		64
				$\Sigma^-\mu^+\nu$	(<1.5)10^{-3}		49
				$p\mu^-\nu$	(<1.3)10^{-3}		309
Ξ^-	$\frac{1}{2}(\frac{1}{2}^+)^f$	1321.25 ±0.18	1.66×10^{-10} ±.04 S=1.1*	$\Lambda\pi^-$	100 %		139
		m^2= 1.746	$c\tau$ = 4.98	$\Lambda e^-\nu$	[g](0.67±0.23)10^{-3}		190
				$\Sigma^0e^-\nu$	(<0.5)10^{-3}		122
				$\Lambda\mu^-\nu$	(<1.3)10^{-3}		163
				$\Sigma^0\mu^-\nu$	(<0.5)%		70
				$n\pi^-$	(<1.1)10^{-3}		303
				$ne^-\nu$	(<1.0)%		327
Ω^-	$0(\frac{3}{2}^{+\,f})$	1672.5±.5 m^2= 2.797	$1.3^{+0.4}_{-0.3}\times10^{-10}$ $c\tau$ = 3.9	$\Xi^0\pi^-$ or $\Xi^-\pi^0$ or ΛK^-	Total of 28 events seen		293 289 210

*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→Sδx. This convention is still inadequate, since if S >> 1, the experiments are probably inconsistent, and therefore the real uncertainty is probably even greater than Sδx. See text and ideogram in data card listings.

a. Quoted upper limits correspond to a 90% confidence level.
b. In decays with more than two bodies, P_{max} is the maximum momentum that any particle can have.
c. See data card listings for energy limits used in measuring this branching ratio.
d. Theoretical value; see also data card listings.
e. See note in data card listings.
f. Predicted from SU(3).
g. Assumes rate for $\Xi^-\to\Sigma^0e^-\nu$ small compared with $\Xi^-\to\Lambda e^-\nu$.

Addendum to STABLE PARTICLES

Magnetic moment

e: 1.001 159 557 ±.000 000 030 $\frac{e\hbar}{2m_ec}$

μ: 1.001 166 14 ±.000 000 31 $\frac{e\hbar}{2m_\mu c}$

μ Decay parameters [a]

ρ = 0.752±0.003 η = - 0.12 ±0.21
ξ = 0.972±0.013 δ = 0.755±0.009 h = 1.00±0.13
$|g_A/g_V| = 0.86^{+0.33}_{-0.11}$ φ = 180° ±15°

$K^\pm$

Mode	Partial rate (sec^{-1})	
$\mu\nu$	(51.54±0.30)10^6	S=1.3*
$\pi\pi^0$	(16.95±0.25)10^6	S=1.2*
$\pi\pi^+\pi^-$	(4.51±0.03)10^6	S=1.1*
$\pi\pi^0\pi^0$	(1.38±0.04)10^6	
$\mu\pi^-\nu$	(2.58±0.09)10^6	S=2.0*
$e\pi^0\nu$	(3.93±0.06)10^6	S=1.2*

$\Delta I = \frac{1}{2}$ rule: See Appendix I

Form factors: See listings for λ, ξ

K^0_S

$\pi^+\pi^-$	(0.797±.009)10^{10}	S=1.4*
$\pi^0\pi^0$	(0.363±.007)10^{10}	S=1.5*

CP violation parameters

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

$|\eta_{+-}|$=(1.92±0.05)10^{-3}, ϕ_{+-}=(44±5)° S=1.4*

$|\eta_{00}|$=(2.5±0.8)10^{-3}, ϕ_{00} (23±32) S=1.5*

$\Delta S = -\Delta Q$: See listings

Form factors: See listings for λ, ξ

K^0_L

$\pi^0\pi^0\pi^0$	(3.99 ±0.20)10^6	S=1.3*
$\pi^+\pi^-\pi^0$	(2.35 ±0.10)10^6	S=1.4*
$\pi\mu\nu$	(4.98 ±0.22)10^6	S=1.5*
$\pi e\nu$	(7.22 ±0.29)10^6	S=1.5*
$\pi^+\pi^-$	(0.029±.001)10^6	S=1.2*
$\pi^0\pi^0$	(0.023±.006)10^6	S=1.5*

η

Mode	Asymmetry parameter
$\pi^+\pi^-\pi^0$	(1.3±0.6)%
$\pi^+\pi^-\gamma$	(1.9±1.1)%

	Magnetic Moment ($e\hbar/2m_pc$)	Decay parameters [b] Measured α	φ(degree)	Derived γ	Δ(degree)	g_A/g_V [b]	g_V/g_A [b]
p	2.792763 ±.000030						
n	-1.913148 ±.000066	$pe^-\nu$					-1.231±0.010 [δ=(176.1±6.4)°]
Λ	-0.73 ±.16 S=1/2*	$p\pi^-$ 0.645±0.016 $n\pi^0$ 0.71 ±0.18	(-6.3±3.5)°	0.76	(7.5±3.9)°		
		$pe\nu$					-0.83 ±0.18
Σ^+		$p\pi^0$ -0.995±0.022 $n\pi^+$ +0.068±0.016	(167±20)°	-0.97	(-73^{+102}_{-10})°		
Σ^-		$n\pi^-$ -0.078±0.020 $ne^-\nu$ S=1.7* $\Lambda e^-\nu$	(10±15)°	0.98	(246^{+14}_{-108})°	0.25 ±0.11	0.35±0.18
Ξ^0		$\Lambda\pi^0$ -0.35±0.08	(25±21)° S=1.3*	0.85	(229^{+14}_{-38})°		
Ξ^-		$\Lambda\pi^-$ -0.41±0.04	(-3±9)° S=1.3*	0.90	(172±18)°		

*S = scale factor. Quoted error includes scale factor; see footnote to main Stable Particles Table for definition.

a. $|g_A/g_V|$ defined by $g_A^2 = |C_A|^2+|C'_A|^2$, $g_V^2=|C_V|^2+|C'_V|^2$, and $\Sigma\langle\bar{e}|\Gamma_i|\mu\rangle\langle\bar{\nu}|\Gamma_i(C_i+C'_i\gamma_5)|\nu\rangle$;
φ defined by $\cos\phi = -R_e(C^*_AC'_V+C'_AC^*_V)/g_Ag_V$ [for more details, see text].

b. The definition of these quantities is as follows [for more details on sign convention, see text]:

$\alpha = \frac{2|s||p|\cos\Delta}{|s|^2+|p|^2}$; $\beta = \frac{-2|s||p|\sin\Delta}{|s|^2+|p|^2}$.

$\beta = \sqrt{1-\alpha^2}\sin\phi$; $\gamma = \sqrt{1-\alpha^2}\cos\phi$.

g_A/g_V defined by $\langle B_f|\gamma_\lambda(g_V-g_A\gamma_5)|B_i\rangle$;
δ defined by $g_A/g_V = |g_A/g_V|e^{i\delta}$.

Quantities in italics have changed by more than one (old) standard deviation since January, 1969

Name	$I^G(J^P)C_n$ ⊢ estab. ? = guess	Mass M (MeV)	Width Γ (MeV)	$\pm\Gamma$ $M^2_{(a)}$ $(GeV)^2$	Partial decay modes: Mode	Fraction %	p or p_{max}(b) (MeV/c)
$\pi^{\pm}(140)$	$1^-(0^-)+$	139.58	0.0	0.019483	See Stable Particles Table		
$\pi^0(135)$		134.97	7.2 eV ±1.2 eV	0.018217			
→							
$\eta(549)$	$0^+(0^-)+$	548.8 ±0.6	2.63 keV ±.64 keV	0.301 ±.000	All neutral $\pi^+\pi^-\pi^0 + \pi^+\pi^-\gamma$	71 } See Stable 29 } Particles Table	
$\eta_0{}^+(700)$ "ϵ" → $\pi\pi$	$0^+(0^+)+$	≈700	≫100	≈0.5	$\pi\pi$	100	≈320
	δ_{00} seems to stay near 90° from 650 to 900 MeV; see note in listings						
$\rho(765)$	$1^+(1^-)-$	765 ±10(c)	125 ±20(c)	0.585 ±.095	$\pi\pi$ $\pi^{\pm}\pi^+\pi^-\pi^0$ $\pi^+\pi^-\pi^+\pi^-$ $\pi^{\pm}\gamma$ $\eta\pi^{\pm}$ e^+e^- $\mu^+\mu^-$	≈100 < 0.2 < 0.15 < 0.2 < 0.8 .0060±.0006 (d) .0062±.0011 (e)	356 243 243 370 141 382 368
$\omega(784)$	$0^-(1^-)-$	783.7 ±0.4 S = 1.8*	12.7 ±1.2	0.614 ±.010	$\pi^+\pi^-\pi^0$ $\pi^+\pi^-$ $\pi^0\gamma$ e^+e^- For upper limits, see footnote (f)	87 ± 4 > 0.3 (95% confidence) 9.4 ± 1.7 0.0066±.0017 S = 1.4*	328 366 380 392
$\eta'(958)$ or X^0	$0^+(0^-)\pm$	957.7 ±0.8	< 4	0.917 <.004	$\eta\pi\pi$ $\rho^0\gamma$ $\gamma\gamma$ [note (g)] For upper limits see footnote (i)	*66 ± 4 S = 1.1** *30 ± 3 S = 1.2** 4.7 ± 2.9	231 173 479
	$J^P = 2^-$ not excluded; see note in listings						
See note (h), on name η'							
$\delta(962)$	≥1 ( )	962 ±5	< 5	0.927 <.005	$\eta\pi$ possibly seen		305
→	These two could be related, see listings						
$\pi_N(1016)$ → $K\overline{K}$	$1^-(0^+)+$	1016 ±10	≈25 } if res.	1.032 ±.025	$K^{\pm}K^0$ $\eta\pi$	Only mode seen < 80	111 342
Resonance, virtual bound state, or antibound state, still not distinguished							
$\phi(1019)$	$0^-(1^-)-$	1019.5 ±0.6 S = 1.5*	3.9 ±0.4	1.039 ±.004	K^+K^- K_LK_S $\pi^+\pi^-\pi^0$ (incl. $\rho\pi$) e^+e^- $\mu^+\mu^-$ For upper limits see footnote (j)	*45.5 ± 3.3 S = 1.1** *36.4 ± 3.4 S = 1.3** 18.1 ± 4.9 S = 1.5* 0.036±.003 $0.035^{+.035}_{-.018}$	126 110 462 510 499
$\eta_0{}^+(1060)$ "S^*" → K_SK_S	$0^+(1^+)+$ if res.	1062 ±20§	≈80(?) see note (k)	1.13 ±.09	$\pi\pi$ $K\overline{K}$	< 65 > 35	513 190
Resonance and scattering length both possible							
$A1(1070)$	$1^-(1^+)+$	1070§ ±20§	95§ ±35§	1.14 ±.10	3π see note (ℓ) $K\overline{K}$	≈100 < 0.25	488 201
Interpretation still slightly in doubt; $J^P = 2^-$ not excluded [$G = (-1)^{\ell+1}$ forbids $K\overline{K}$]							
→							

Name	$I^G(J^P)C_n$ ⊢ estab. ? = guess	Mass M (MeV)	Width Γ (MeV)	$\pm\Gamma$ $M^2_{(a)}$ $(GeV)^2$	Partial decay modes: Mode	Fraction %	p or p_{max}(b) (MeV/c)
$B(1235)$	$1^+(1^+)-$	1235 ±15§	*102* ±20§	1.53 ±.13	$\omega\pi$ $\pi\pi$ $K\overline{K}$ For other upper limits see footnote (m)	≈100 < 30 } Absence sug- < 2 } gests J^P = Abn.	350 602 371
$f(1260)$	$0^+(2^+)+$	1264 ±10§	151 ±25§	1.60 ±.19	$\pi\pi$ $2\pi^+2\pi^-$ $K\overline{K}$ indic. seen	≈100 < 4 ≈ 3	616 553 389
$D(1285)$	$0^+(A)+$	1288 ±7 S = 2.3*	33 ±5 S = 1.1*	1.66 ±.04	$K\overline{K}\pi$ [mainly $\pi_N(1016)\pi$] $\pi\pi\eta$ $\pi\pi\rho$	Seen Possibly Large Not seen	307 485 354
	$J^P = 0^-$, 1^+, 2^-, with 1^+ favored						
$A2_L(1280)$	$1^-(2^+)+$	*1280* ±4 S = 1.7*	22 ±4	1.64 ±.028	$\rho\pi$ (and π + neutrals) $K\overline{K}$ $\eta\pi$	Dominant Seen Indication seen	395 405 511
$A2_H(1320)$	$1^-(2^+)+$	*1320* ±5 S = 2.1*	21 ±4	1.74 ±.028	$\rho\pi$ (and π + neutrals) $K\overline{K}$ $\eta\pi$	Dominant Seen Indication seen	423 436 535
						See note (n)	
→							
$E(1422)$	$0^+(0^-)\pm$	1422 ±4	69 ±8	2.02 ±.10	$K^*\overline{K}+\overline{K}^*K$ $\pi_N(1016)\pi$ $\pi\pi\eta$ $\pi\pi\rho$	50 ± 10 } (so 100% 50 ± 10 } $K\overline{K}\pi$) < 60 Not seen	153 326 568 457
	$J^P = 1^+$ not excluded See note in listings						
→							
$f'(1514)$	$0^+(2^+)+$	1514 ±5	73 ±23 S = 1.8*	2.29 ±.11	$K\overline{K}$ $K^*\overline{K}+\overline{K}^*K$ $\pi\pi$ $\eta\pi\pi$ $\eta\eta$	72 ± 12 10 ± 10 < 14 18 ± 10 < 40	570 294 744 624 521
						See note (o)	
$\pi/\rho(1540)$ "F_1" → $K^*\overline{K}$	$1(A)$?	1540 ±5	40 ±15	2.37 ±.06	$K^*\overline{K}+\overline{K}^*K$	Only mode seen	321
	Seen in only one experiment.						
$\pi_A(1640)$ →3π	$1^-(A)+$	1633 ±9 S = 1.2*	93 ±24	2.67 ±.15	3π † [$\pi^{\pm}\rho^0$/all$\pi^{\pm}\pi^+\pi^-$ † [$\pi^{\pm}f(\to\pi^+\pi^-)$/all$\pi^{\pm}\pi^+\pi^-$ $\omega\pi\pi$ $\omega\rho$ $\pi\eta$ $K\overline{K}$ $\pi^{\pm}2\pi^+2\pi^-$	Dominant < 40 $35\pm^{25}_{20}$ Possibly observed Possibly observed < 9 Not seen < 10	788 629 304 592 259 717 647 710
	$J^P = 2^-$ preferred Low signal/background; may be partly Deck effect and (or) several resonances						
→	[R1(1630) is included in both the $\pi_A(1640)$ and $\rho_N(1660)$ listings]						

Name	$I^G(J^P)C_n$ ⊢ estab. ?- guess	Mass M (MeV)	Width Γ (MeV)	M^2 $\pm\Gamma M$ (a) $(GeV)^2$	Partial decay modes: Mode	Fraction %	p or p_{max} (b) (MeV/c)
$\rho_N(1660)$ "g" → 2π	$1^+(\ )-$ ⊢ ⊢	$1663^{(p)}$ ±20§	111 ±30§	2.77 ±.18	2π	Dominant	820
	$(J^P = 1^-, 3^-, \ldots$ with 3^- favored)				$K\bar{K}$	8^{+8}_{-3}	666
					(Other modes under ρ(1710))		
ρ(1710)? → 4π	$1^+(\ )-$ ⊢ ⊢	1714 ±20§	110 ±25§	2.94 ±.08	4π	Dominant	799
					†[$\pi^\pm A_2^0(\to\pi^+\pi^-\pi^0)$/all$\pi^\pm\pi^+\pi^-\pi^0$	40 ± 20]	342
					†[$\pi^\pm\omega(\to\pi^+\pi^-\pi^0)$/all$\pi^\pm\pi^+\pi^-\pi^0$	25 ± 10]	669
	Not yet clear whether this is just an alternative mode of the $\rho_N(1660)$, or a different resonance; the branching ratios are therefore only tentative				†[$\bar{p}\pm\rho^0$	Seen]	386
					$\pi^\pm\phi/\pi^\pm\pi^+\pi^-\pi^0$	< 11	542
					$\pi^\pm 2\pi^+2\pi^-\pi^0$	< 15	705
					2π (if $\neq \rho_N(1660)$)	< 10	846
→ See Note (q) for bumps grouped as R(1750), S(1930), ρ(2100), T(2200), ρ(2275), and $N\bar{N}$(2345).							
U(2375)	$1^+(\ )-$	2371 ±8	30 ±20§	5.62 ±.07	Seen in $\pi^- p \to pU^-$ and $p\bar{p} \to K_1^0 K_1^0\omega$, $K_1 K_2(n\pi^0)$		
→ See Note (q) for 5 bumps, $N\bar{N}$(2380), X^-(2500), X^-(2620), X^-(2800), X^-(2880).							
$K^+(494)$ $K^0(498)$	1/2(0⁻)	493.82 497.76		0.244 0.248	See Stable Particles Table		
→							
$K^*(892)$	1/2(1⁻)	(±)892.1 ← Charged K^* ±0.4 ($m_0 - m_\pm$ = 7 ±3)	50.1 ±0.8	0.796 ±.045	Kπ	≈ 100	288
					Kππ	0.2	216
→							
$K_A(1240)$ or C	1/2(1⁺)	1243 ±6	90 ±40§	1.54 ±.11	Q region See note (r).		
→					Kππ	Only mode seen	478
					†[$K^*\pi$	Large]	276
K_A(1280 to 1360) ?	1/2(1⁺) 1280 to 1360				†[Kρ	Seen]	0
	$J^P = 2^-$ not completely ruled out						
$K_N(1420)$	1/2(2⁺)	(±)1409 ±4* S = 1.3*	96 ±7* S = 1.3*	1.985 ±.135	Kπ	49.2 ± 3.4 S=1.5*	609
	See note (s).				$K^*\pi$	36.3 ± 3.1 S=1.5*	406
	$J^P = 3^-$ still possible				Kρ	8.0 ± 3.5 S=1.6*	311
					Kω	4.2 ± 1.3 S=1.1*	291
					Kη	2.2 ± 1.6 S=1.4*	474
→							
$K_A(1775)$ or L	1/2(A)	1775		3.15	Kππ	Only mode seen	794
					†[$K^*(1420)\pi$	Large]	305
Interpretation in doubt; see note (t) $J^P = 1^+, 2^-$ favored							
→							

→ The following bumps, excluded above, are listed among the data cards: σ(410); H(990); η_Y(1080); A1.5(1170); $A2_2$(1320) ; ρρ(1410); K_SK_S(1440); φ(1650); R(1750); η or ρ(1830) → 4π; φ or π(1830) → ωππ; S(1930); ρ(2100); T(2200); ρ(2275); $N\bar{N}_{I=0}$(2380); $\bar{X}$(2500); X^-(2620); X^-(2800); X^-(2880); κ(725); K_N(1080-1260); $K_{A(I=3/2)}$(1175); $K_{A(I=3/2)}$(1265); K_N(1660); $K^*(2240) \to \bar{Y}N$. (See note (q).)

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

† 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 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) The values given for M(ρ) and Γ(ρ) and their errors are not average values from various experiments, but rather are intended to give the range where we believe the actual values are most likely to fall. Contrast the results tabulated in this note (references in the listings):

	M(MeV)	Γ(MeV)	
ρ^0	774±5	111±5	From $e^+e^- \to \pi^+\pi^-$, fitted to Gounaris-
ρ^0	768±10	140±14	Sakurai formula.
ρ^0		105±15	From $\pi N \to \pi\pi N$, ππ phase shift
ρ^-	755±5	110± 9	analysis with Chew-Low extrapolation, and energy-independent width.
ρ^0	768±2	132±13	Similar to above, but energy-dependent width and off-shell corrections.
ρ^-	764±2	147±4	From $\pi N \to \pi\pi N$, fits in physical region, energy-dependent width.

Energy-independent width is a narrow-resonance approximation which tends to give lower mass and width.

(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 also give an average of (0.0060±0.0006)%) and one photoproduction experiment of high mass resolution. Interference effects with ω decay are therefore believed to be small.

(e) Warning: The value for the rate $\rho^0 \to \mu^+\mu^-$ may be somewhat too high, due to possible interference with ω decay; the error is, however, chosen large enough to take account of this possibility (see notes in listings).

(f) Empirical limits on fractions for other decay modes of ω(784) are $\pi^+\pi^-\gamma < 5\%$, $\pi^0\pi^0\gamma < 1\%$, η+neutrals < 1.5%, $\mu^+\mu^- < 0.02\%$, $\pi^0\mu^+\mu^- < 0.2\%$.

(g) This $\eta' \to \gamma\gamma$ value is from a constrained fit under the assumption that $\eta'\pi\pi$, $\rho^0\gamma$, and $\gamma\gamma$ are the only existing decay modes. Note that direct measurement of the $\eta' \to \gamma\gamma$ branching fraction gave the slightly different result of $(5.5^{+3.6}_{-3.0})\%$.

(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): $\pi^+\pi^- < 2\%$, $\pi^+\pi^-\pi^0 < 5\%$, $\pi^+\pi^+\pi^-\pi^- < 1\%$, $\pi^+\pi^+\pi^-\pi^-\pi^0 < 1\%$, $6\pi < 1\%$, $\pi^+\pi^-e^+e^- < 0.6\%$, $\pi^0e^+e^- < 1.3\%$, $\eta e^+e^- < 1.1\%$, $\pi^0\rho^0 < 4\%$, $\pi^0\omega < 8\%$.

(j) Empirical limits on fractions for other decay modes of φ(1019) are $\pi^+\pi^- < 5\%$, $\eta\gamma < 8\%$, η+neutrals < 13%, $\pi^+\pi^-\gamma < 4\%$, $\omega\gamma < 5\%$, $\rho\gamma < 2\%$, $\pi^0\gamma < 0.35\%$.

(k) Width of $\eta_{0^+}(1060) \to K_SK_S$: Average value from three bubble chamber experiments is Γ = 63±11 MeV, whereas two spark chamber experiments give Γ > 100 MeV. The latter also allow a scattering-length fit.

(ℓ) ρπ 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(1235): ππ < 30%, $K\bar{K}$ < 2%, 4π < 50%, φπ < 1.5%, ηπ < 25%, $(KK)^\pm\pi^0$ < 8%, $K_SK_S\pi^\pm$ < 2%, $K_SK_L\pi^\pm$ < 6%.

(n) Branching ratios can presently be given only for the overall A2 (splitting unresolved): $\rho\pi$ 85±4% (S=1.9*), $K\bar{K}$ 2.4±0.5%, $\eta\pi$ 12±4% (S=1.9*), $\eta'\pi$ 0.6±0.4%, $\pi^+\pi^-\pi^0$ ($\neq\rho\pi$) < 20%.

(o) There is only a weak indication for a $K^*\bar{K} + \bar{K}^*K$ mode of the f' (1514). 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), and $\eta\pi\pi$ as 20±13%.

(p) See B. French's compilation (Proc. 14th International Conf. High Energy Physics, Vienna, 1968, p. 91) for possible mass difference of charged and neutral $\rho_N(1660)$: M = 1640±20 MeV, Γ = 120±30 MeV for $\rho_N^{\pm}$, M = 1680±15 MeV, Γ = 200±50 MeV for ρ_N^0.

(q) We tabulate here Y = 0 bumps with M ≥ 1700 MeV, for which no satisfactory grouping into particles is yet possible. See listings.

Name	I^G	(J^P)	M(MeV)	Γ (MeV)	Decay modes observed	Tentative grouping
R2(1700)	1, 2		1700±15	≤30	$(MM)^- \to 1/3/>3$ charg. part. ≈ 43/56/1	ρ(1710)
$K\bar{K}$(1740)	1		1740	≈120	$K^0K^{\pm}$	R(1750)
R3(1750)	1, 2		1748±15	≤38	$(MM)^- \to 1/3/>3$ charg. part. > 14/< 80/15	R(1750)
ρ(1900)	$1^+, 2^+$		1900±40	216±105	$\pi^+\pi^0$	S region
$N\bar{N}$(1925)	0, 1		1925	≈10	Structure in $\bar{p}p$ backward el. scattering	S region
S(1929)	1, 2		1929±14	≤35	$(MM)^- \to 3$ charged particles ≈ 92%	Seems to require>1 resonance
$N\bar{N}$(1945)	0, 1		1945	≈22	Structure in $\bar{p}p$ backward el. scattering	Seems to require>1 resonance
ρππ(1985)	$1^+, 2^+, 3^+$		1985	≈100	$\rho^-\pi^+\pi^-$	Seems to require>1 resonance
X^-(2086)	1, 2		2086±38	≈150	$(MM)^-$ backward	ρ(2100)
ρ(2120)	1^+	$3^-(?)$	2120	<249	$\pi^+\pi^-$, $\bar{p}p$	ρ(2100)
$N\bar{N}$(2190)	1^-		2190	20–80	$\rho^0\rho^0\pi^0$, $\bar{p}p$	T region
	1		2190±10	≈85	Structure in $N\bar{N}$ total σ	T region
T(2195)	1, 2		2195±15	≤13	$(MM)^- \to 3$ charged particles ≈ 94%	Seems to require>1 resonance
3π(2207)	$\leq 3^-$		2207±13	62±52	$\pi^+\pi^-\pi^0$	Seems to require>1 resonance
4π(2200)	$1^+, 2^+, 3^+$		2200	≈130	$\rho^-\pi^+\pi^-$	Seems to require>1 resonance
KKω(2176)	$0^-, 1^+$		2176± 5	20^{+16}_{-12}	$K_1^0K_1^0\omega$	Seems to require>1 resonance
X^-(2260)	1, 2		2260±18	≤25	$(MM)^-$ backward	ρ(2275)
ρ(2290)	1^+	$5^-(?)$	2290	<165	$\pi^+\pi^-$, $\bar{p}p$	ρ(2275)
$N\bar{N}$(2380)	0		2380±10	≈140	Structure in $N\bar{N}$ total σ	
$N\bar{N}$(2345)	1		2345±10	≈140	Structure in $N\bar{N}$ total σ	
U(2375)	1^-	Included on the main Meson Table, and summarized in listings				
X^-(2500)	1, 2		2500±32	≈87	$(MM)^-$ backward	
X^-(2620)	1, 2		2620±20	85±30	$(MM)^-$	
X^-(2800)	1, 2		2800±20	46±10	$(MM)^-$	
X^-(2880)	1, 2		2880±20	≤15	$(MM)^-$	

(r) See note in listings. Some investigators see a broad enhancement in mass (Kππ) from 1200–1350 MeV (the Q region), and others see structure. Only the $K_A^*(1240)$ or C seems well established, whereas the structures from 1280 to 1360 MeV cannot be disentangled. For the whole Q region the decay rate into $K^*(892)\pi$ is large, and a Kρ decay is seen. The Kη, Kω, and Kπ rates are less than a few percent.

(s) The average mass of the neutral K_N^* is 1423±4, or 14 MeV higher than that of the charged K_N^*. But these differences are very unreliable; see typed note under $K^*(892)$ mass.

(t) No width and branching ratios can be quoted since presence of kinematic $K_N(1420)\pi$ enhancement makes background subtraction difficult.

Mixing Angles from Quadratic SU(3) Mass Formula:

$J^P = 0^-$ Possible Nonet [π, K, η; η']	θ = 10.4±0.2°	Of the two iso-singlets, the "mainly-octet" one is written first, followed by a semicolon.
$= 0^-$ Alternative Nonet [π, K, η; E]	θ = 6.2±0.1°	
$= 1^-$ [ρ(765±15), K*, φ; ω]	θ = 39.9±1.1°	
$= 2^+$ [A_{2H}, $K_N(1420)$, f'; f]	θ = 29.9±2.2°	

GENERAL ATOMIC AND NUCLEAR CONSTANTS*

N	=	$6.022169(40)\times10^{23}$ mole^{-1} (based on $A_{C12} = 12$)
c	=	$2.997925(10)\times10^{10}$ cm sec^{-1}
e	=	$4.803250(21)\times10^{-10}$ esu = $1.6021917(70)\times10^{-19}$ coulomb
1 MeV	=	$1.6021917(70)\times10^{-6}$ erg
ħ	=	$6.582183(22)\times10^{-22}$ MeV sec
	=	$1.0545919(80)\times10^{-27}$ erg sec
ħc	=	$1.9732891(66)\times10^{-11}$ MeV cm = 197.32891(66) MeV fermi
α	=	$e^2/\hbar c = 1/137.03602(21)$
$k_{Boltzmann}$	=	$1.380622(59)\times10^{-16}$ erg K^{-1}
	=	$8.61708(37)\times10^{-11}$ MeV K^{-1} = 1 eV/11604.85(49)K
m_e	=	0.5110041(16) MeV = $9.109558(54)\times10^{-31}$ kg
m_p	=	938.2592(52) MeV = 1836.109(11) m_e = 6.72211(63)$m_{\pi^{\pm}}$
	=	1.00727661(8)m_1 (where m_1 = 1 amu = $\frac{1}{12}m_{C12}$ = 931.4812(52) MeV)
r_e	=	e^2/m_ec^2 = 2.817939(13) fermi (1 fermi = 10^{-13} cm)
$\lambda\!\!\!^{-}_e$	=	$\hbar/m_ec = r_e\alpha^{-1} = 3.861592(12)\times10^{-11}$ cm
a_∞ Bohr	=	$\hbar^2/m_ee^2 = r_e\alpha^{-2} = 0.52917715(81)$A (1A = 10^{-8} cm)
σ Thomson	=	$\frac{8}{3}\pi r_e^2 = 0.6652453(61)\times10^{-24}$ cm^2 = 0.6652453(61) barns
μ_{Bohr}	=	$e\hbar/2m_ec = 0.5788381(18)\times10^{-14}$ MeV gauss^{-1}
$\mu_{nucleon}$	=	$e\hbar/2m_pc = 3.152526(21)\times10^{-18}$ MeV gauss^{-1}
$\frac{1}{2}\omega^e_{cyclotron}$	=	$e/2m_ec = 8.794014(27)\times10^6$ rad sec^{-1} gauss^{-1}
$\frac{1}{2}\omega^p_{cyclotron}$	=	$e/2m_pc = 4.789484(27)\times10^3$ rad sec^{-1} gauss^{-1}

Hydrogen-like atom (nonrelativistic, μ = reduced mass):

$$\frac{v}{c})_{rms} = \frac{ze^2}{n\hbar c};\ E_n = \frac{\mu}{2}v^2 = \frac{\mu z^2e^4}{2(n\hbar)^2};\ a_n = \frac{n^2\hbar^2}{\mu ze^2}$$

$R_\infty = m_ee^4/2\hbar^2 = m_ec^2\alpha^2/2 = 13.605826(45)$ eV (Rydberg)

pc = 0.3 Hρ(MeV, kilogauss, cm); 0.3 (which is 10^{-11}c) enters because there are ≈ 300 "volts"/esu volt.

1 year (sidereal)	=	3.1557×10^7 sec (≈ $\pi\times10^7$ sec) = 365.256 days
density of dry air	=	1.205 mg cm^{-3} (at 20°C, 760 mm)
acceleration by gravity	=	980.62 cm sec^{-2} (sea level, 45°)
gravitational constant	=	$6.6732(31)\times10^{-8}$ cm^3 g^{-1} sec^{-2}
1 calorie (thermochemical)	=	4.184 joules
1 atmosphere	=	1033.2275 g cm^{-2}
1 eV per particle	=	11604.85(49)°K (from E = kT)

NUMERICAL CONSTANTS

π = 3.1415927	1 rad = 57.2957795 deg		
e = 2.7182818	1/e = 0.3678794		
ln 2 = 0.6931472	ln 10 = 2.3025851		
$\log_{10}2$ = 0.3010300	$\log_{10}e$ = 0.4342945		

*Compiled by Stanley J. Brodsky, based mainly on the adjustment of the fundamental physical constants by B. N. Taylor, W. H. Parker, and D. N. Langenberg, Rev. Mod. Phys. 41, 375 (1969). The figures in parentheses correspond to the 1 standard deviation uncertainty in the last digits of the main number.

[See notes on N's and Δ's, on possible Z*'s, and on Y*'s at the beginning of those sections in the data listings; also see notes on individual resonances in the listings.]

Particle or resonance[a]	I (J^P)	π or K Beam T(GeV) p(GeV/c) σ = 4π☆2 (mb)	Mass[b] (MeV)	Γ[b] (MeV)	M²±ΓM[c] (GeV²)	Decay Modes: Partial Mode	Decay Modes: Fraction %	p or p_max[d] (MeV/c)
N								
p	1/2(1/2+)		938.3		0.880	See Stable Particles		
n			939.6		0.883			
N'(1470)	1/2(1/2+) P'11	T=0.53πp p=0.66 σ=27.8	1435 to 1505	200 to 400	2.16 ±0.36	Nπ Nππ	60 40	420 368
N'(1520)	1/2(3/2−) D'13	T=0.61 p=0.74 σ=23.5	1510 to 1540	105 to 150	2.31 ±0.18	Nπ Nππ Nη	50 50 ~0.5	456 410 150
N'(1535)	1/2(1/2−) S'11	T=0.64 p=0.76 σ=22.5	1500 to 1600	50 to 160	2.36 ±0.18	Nπ Nη Nππ	34 66 small	467 182 422
N(1670)	1/2(5/2−) D15	T=0.87 p=1.00 σ=15.6	1655 to 1680	105 to 175	2.79 ±0.24	Nπ Nππ ΛK Nη	42 58 <.1 <.3	560 525 200 368
N(1688)	1/2(5/2+) F15	T=0.90 p=1.03 σ=14.9	1680 to 1692	105 to 180	2.85 ±0.21	Nπ Nππ ΛK Nη	60 40 <.1 <.2	572 538 231 388
N''(1700)	1/2(1/2−) S''11	T=0.92 p=1.05 σ=14.3	1665 to 1765	100 to 400	2.89 ±0.44	Nπ ΛK Nη	70 5 ~3	580 250 340
N''(1780)	1/2(1/2+) P''11	T=1.07 p=1.20 σ=12.2	1750 to 1860	270 to 450	3.17 ±0.62	Nπ ΛK Nη	34 ~1 ~10	633 353 476
N(1860)	1/2(3/2+) P13	T=1.22 p=1.36 σ=10.4	1840 to 1900	310 to 450	3.46 ±0.62	Nπ Nππ ΛK Nη	27 <16 ~4	685 657 437 545
N(1990)	1/2(7/2+) F17	T=1.49 p=1.63 σ=8.34	1980 to 2000	220 to 250	3.96 ±0.47	Nπ Nππ	11	766 743
N'''(2040)	1/2(3/2−) D'''13	T=1.60 p=1.73 σ=7.70	2030 to 2060	240 to 290	4.16 ±0.56	Nπ Nππ	17	797 775
N(2190)	1/2(7/2−) G17	T=1.94 p=2.07 σ=6.21	2000 to 2260	300	4.80 ±0.65	Nπ Nππ	35	888 868
N(2650)	1/2(?−)	T=3.12 p=3.26 σ=3.67	2650	360	7.02 ±0.95	Nπ Nππ	(J+1/2)x =0.45[f]	1154 1140
N(3030)	1/2(?)	T=4.27 p=4.41 σ=2.62	3030	400	9.18 ±1.21	Nπ Nππ	(J+1/2)x =0.05[f]	1366 1354
Δ								
Δ(1236)	3/2(3/2+) P'33	T=0.195 p=0.304 σ=91.8 m_0-m_{++}=.45±.85 m_-m_{++}=7.9±6.8	(++)1236.0 ±0.6	120 ±2	1.53 ±0.15	Nπ Nπ+π− Nγ	99.4 0 ~0.6	231 89 262
Δ(1650)	3/2(1/2−) S31	T=0.83 p=0.96 σ=16.4	1620 to 1695	130 to 250	2.72 ±0.25	Nπ Nππ	27 73	547 511
Δ(1670)	3/2(3/2−) D33	T=0.87 p=1.00 σ=15.6	1650 to 1690	175 to 300	2.79 ±0.40	Nπ Nππ	13	560 525
Δ(1890)	3/2(5/2+) F35	T=1.28 p=1.42 σ=9.88	1840 to 1910	135 to 380	3.57 ±0.52	Nπ Nππ	17	704 677
Δ(1910)	3/2(1/2+) P31	T=1.33 p=1.46 σ=9.54	1835 to 1935	230 to 420	3.65 ±0.62	Nπ Nππ	25	716 691
Δ(1950)	3/2(7/2+) F37	T=1.41 p=1.54 σ=8.90	1935 to 1980	140 to 220	3.80 ±0.39	Nπ Δ(1236)π ΣK Σ(1385)K Δ(1236)ρ	45 ≈50 2.4 1.4 seen	741 571 460 232
Δ(2420)	3/2(11/2+) — —	T=2.50 p=2.64 σ=4.68	2420	310	5.86 ±0.75	Nπ Nππ	11 >20	1023 1006
Δ(2850)	3/2(?+)	T=3.71 p=3.85 σ=3.05	2850	400	8.12 ±1.14	Nπ Nππ	(J+1/2)x =0.25[f]	1266 1254
Δ(3230)	3/2(?)	T=4.94 p=5.08 σ=2.25	3230	440	10.4 ±1.4	Nπ Nππ	(J+1/2)x =0.05[f]	1475 1464
Λ								
Λ	0(1/2+)		1115.6		1.24	See Stable Particles		
Λ(1405)	0(1/2−) S01	p<0 K⁻p	1405 ±5[g]	40 ±10[g]	1.97 ±0.06	Σπ	100	142
Λ'(1520)	0(3/2−) D'03	p=0.389 σ=84.5	1518 ±2[g]	16 ±2[g]	2.30 ±0.02	NK̄ Σπ Λππ Λγ Σππ	46±1 41±1 9.6±.6 .8±.2 1.0±.2	237 260 252 351 144
Λ'(1670)	0(1/2−) S'01	p=0.74 σ=28.5	1670	30	2.79 ±0.05	NK̄ Λη Σπ	15 35 50	410 66 393
Λ''(1690)	0(3/2−) D''03	p=0.78 σ=26.1	1690	27 to 85	2.86 ±0.07	NK̄ Σπ Λππ Σππ	20 55 ≈15 ≈10	429 409 415 352
Λ(1815)	0(5/2+) F05	p=1.05 σ=16.7	1815 ±5[g]	75 ±10[g]	3.30 ±0.13	NK̄ Σπ Σ(1385)π	65±1 11±1 17±3	537 504 358
Λ(1830)	0(5/2−) D05	p=1.09 σ=15.8	1835	66 to 145	3.37 ±0.18	NK̄ Σπ	10 30	550 515
Λ(2100)	0(7/2−) G07	p=1.68 σ=8.68	2100	40 to 145	4.41 ±0.21	NK̄ Σπ Λη ΞK Λω	25 ~1 <3 ~.5 <10	748 699 617 483 443
Λ(2350)	0(?)	p=2.29 σ=5.85	2350	150	5.52 ±0.35	NK̄	(J+1/2)x =0.6[f]	913

Particle or resonance[a]	I (J^P)	π or K Beam T(GeV) p(GeV/c) σ = 4πƛ^2 (mb)	Mass[b] (MeV)	Γ[b] (MeV)	$M^2 \pm \Gamma M$[c] (GeV^2)	Decay Modes: Partial Mode	Fraction %	p or p_{max}[d] (MeV/c)
Σ	1(1/2$^+$)		(+)1189.4 (0)1192.5 (-)1197.3		1.41 1.42 1.43	See Stable Particles		
Σ(1385)	1(3/2$^+$) P_{13}	p<0 K^-p	(+)1383±1 S=1.3* (-)1386±2 S=2.2*	(+)36±3 S=1.9* (-)36±6 S=3.5*!	1.92 ±0.05	Λπ Σπ	90±3 10±3 S=1.4*	208 117
Σ(1670)	1(3/2$^-$) D_{13}	p=0.74 σ=28.5	1670	50	2.79 ±0.08	NK̄ Σπ Λπ Σππ [Λ(1405)π][e] Λππ	8 50 32 <14 [< 6] <11	410 387 447 326 207 397
The branching ratios as reported here are from formation experiments. Production experiments still confused. See note in listings.								
Σ(1750)	1(1/2$^-$) S_{11}	p=0.91 σ=20.7	1750	80	3.06 ±0.14	NK̄ Λπ Ση	~15 ~20 seen	483 507 55
Σ(1765)	1(5/2$^-$) D_{15}	p=0.94 σ=19.6	1765 ±5[g]	60 to 146	3.12 ±0.21	NK̄ Λπ Λ(1520)π Σ(1385)π Σπ	45±1 15±2 15±2 13±2 ~ 1	496 518 187 315 461
Σ(1915)	1(5/2$^+$) F_{15}	p=1.25 σ=13.0	1910	50	3.65 ±0.10	NK̄ Λπ Σπ	10 5 .4	616 622 571
Formation and production experiments do not agree.[h]								
Σ(2030)	1(7/2$^+$) F_{17}	p=1.52 σ=9.93	2030	80 to 170	4.12 ±0.24	NK̄ Λπ Σπ ΞK	10 35 5 < 2	700 700 652 412
Σ(2250)	1(?)	p=2.04 σ=6.76	2250	200	5.06 ±0.45	NK̄	(J+1/2)x =0.4[f]	849
Σ(2455)	1(?)	p=2.57 σ=5.09	2455	100	6.03 ±0.25	NK̄	(J+1/2)x =0.3[f]	979
Σ(2595)	1(?)	p=2.95 σ=4.30	2595	~140	6.73 ±0.36	NK̄	(J+1/2)x =0.25[f]	1064
Ξ	1/2(1/2$^+$)		(0)1314.7 (-)1321.3		1.73 1.75	See Stable Particles		
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	144
Ξ(1820)	1/2(?)		1820	≈30	3.31 ±0.05	ΛK̄ Ξπ Ξ(1530)π ΣK̄	30 10 30 30	396 413 234 306
Ξ(1930)	1/2(?)		1930	110	3.72 ±0.21	Ξπ ΛK̄	large small	499 502
Ξ(2030)	1/2(?)		2030	50	4.12 ±0.11	Ξπ ΛK̄ ΣK̄ Ξ(1530)π	small ~20 ~70 small	573 587 524 421
Ξ(2250)	1/2(?)		2250	130	5.06 0.29	ΛK̄π ΣK̄π Ξππ	seen seen seen	689 631 701
Ξ(2500)	1/2(?)		2500	60	6.25 0.15	Ξππ ΛK̄π	seen seen	839 839
Ω$^-$	0(3/2$^+$)		1672.4		2.80	See Stable Particles		

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

→ An arrow at the left of the 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(1700) D_{13}, N(3245), N(3690), N(3755), Δ(1690) P_{33}, Δ(1960) D_{35}, Δ(2160) P_{33}, Z_0(1865), Z_1(1900), Λ(1330), Λ(1680) P_{01}, Λ(1800) P_{01}, Λ(1860) F_{07}, Λ(2015) F_{07}, Σ(1440), Σ(1480), Σ(1560) P_{11}, Σ(1620), Σ(1690), Σ(1880) P_{11}, Σ(2130) G_{17}, Σ(3000), Ξ(1630), Ξ(1700).

a. For the baryon states, the name [such as N(1470)] contains the mass, which shifts by 5 or 10 MeV with each new analysis. The value chosen is the rounded average from Table II of the note on N's and Δ's in the baryon listings. The convention for using primes in the names is as follows: when there is more than one resonance on a given Argand diagram, the first has been designated with a prime, the second with a double prime, etc. The name (col. 1) is the same as can be found in large print in the listings.

b. See note on N's and Δ's in baryon listings. For M and Γ we report here an interval instead of an average. Averages are appropriate if each result is based on independent measurements, but inappropriate here where the spread in parameters arises because different models or procedures have been applied to a common set of data.

c. For this column M is the rounded average which also appears in the name column and Γ is the average quoted on Table II of the N's and Δ's note in the baryon listings.

d. 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.

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

f. This state has been seen only in total cross sections. J is not known; x is Γ_{el}/Γ.

g. 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).

h. Branching ratios quoted here are from formation experiments which require a small D_{15} resonant amplitude in this region. Production experiments report a state at this mass of unknown J^P, decaying mainly into Σπ.

Caption for SU(3) Isoscalar Coefficient Tables (next page)

Starting Jan. 1970 we have relabeled the 8×8 table (and changed the 8×10 table) to conform with the convention that the first particle shall be a baryon, the second a meson. This convention is advocated by R. Levi Setti in his report to the 1969 Lund Conference, and our coefficients now agree with Levi Setti's Table II.

The changes that have been made, and their motivation, are as follows: The deSwart table of 8×8 is merely labeled with symbols like (I_1 = 1/2, Y_1 = 1, I_2 = 1, Y_2 = 0), which can be read either as (Nπ) or (KΣ). Since there are no decuplet mesons, his 8×10 table is unambiguous; it must be read with the meson first. Accordingly, before 1970 we labeled the meson first on both tables.

We now realize that this old convention violates the other convention that the N, Nπ coupling shall be D + F (as opposed to -D + F). To get D + F we must use the first line of the "N" table, which reads $\cdots\ 3\sqrt{5/10}\,|8_D\rangle + 1/2\,|8_F\rangle$ as opposed to $\cdots\ -3\sqrt{5/10}\,|8_D\rangle + 1/2\,|8_F\rangle$. The first line must then be labeled Nπ rather than KΣ, i.e., with the baryon first.

Levi Setti further advocates the convention of writing the baryon first for SU(2) as well as SU(3). For example, the sign of the amplitudes as plotted on his and our Argand plots comes from using our SU(2) Clebsch-Gordan coefficients (Condon Shortley notation) and writing the baryon first. To make it easier to abide by this universal convention we have changed deSwart's 8×10 SU(3) table to 10×8, with the help of his Eq. (14.3):

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

CLEBSCH-GORDAN COEFFICIENTS AND SPHERICAL HARMONICS

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

Notation:

m_1 m_2 \ J M	J M	J M	...
m_1 m_2	Coefficients		
. .			

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

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

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

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

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

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

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

1/2 × 1/2

m_1 m_2	J=1, M=+1
+1/2 +1/2	1

m_1 m_2	1, 0	0, 0
+1/2 -1/2	1/2	1/2
-1/2 +1/2	1/2	-1/2

m_1 m_2	1, -1
-1/2 -1/2	1

1 × 1/2

m_1 m_2	3/2, +3/2
+1 +1/2	1

m_1 m_2	3/2, +1/2	1/2, +1/2
+1 -1/2	1/3	2/3
0 +1/2	2/3	-1/3

m_1 m_2	3/2, -1/2	1/2, -1/2
0 -1/2	2/3	1/3
-1 +1/2	1/3	-2/3

m_1 m_2	3/2, -3/2
-1 -1/2	1

2 × 1

m_1 m_2	3, +3
+2 +1	1

m_1 m_2	3, +2	2, +2
+2 0	1/3	2/3
+1 +1	2/3	-1/3

m_1 m_2	3, +1	2, +1	1, +1
+2 -1	1/15	1/3	3/5
+1 0	8/15	1/6	-3/10
0 +1	6/15	-1/2	1/10

m_1 m_2	3, 0	2, 0	1, 0
+1 -1	1/5	1/2	3/10
0 0	3/5	0	-2/5
-1 +1	1/5	-1/2	3/10

m_1 m_2	3, -1	2, -1	1, -1
0 -1	6/15	1/2	1/10
-1 0	8/15	-1/6	-3/10
-2 +1	1/15	-1/3	3/5

m_1 m_2	3, -2	2, -2
-1 -1	2/3	1/3
-2 0	1/3	-2/3

m_1 m_2	3, -3
-2 -1	1

1 × 1

m_1 m_2	2, +2
+1 +1	1

m_1 m_2	2, +1	1, +1
+1 0	1/2	1/2
0 +1	1/2	-1/2

m_1 m_2	2, 0	1, 0	0, 0
+1 -1	1/6	1/2	1/3
0 0	2/3	0	-1/3
-1 +1	1/6	-1/2	1/3

m_1 m_2	2, -1	1, -1
0 -1	1/2	1/2
-1 0	1/2	-1/2

m_1 m_2	2, -2
-1 -1	1

3/2 × 1

m_1 m_2	5/2, +5/2
+3/2 +1	1

m_1 m_2	5/2, +3/2	3/2, +3/2
+3/2 0	2/5	3/5
+1/2 +1	3/5	-2/5

m_1 m_2	5/2, +1/2	3/2, +1/2	1/2, +1/2
+3/2 -1	1/10	2/5	1/2
+1/2 0	3/5	1/15	-1/3
-1/2 +1	3/10	-8/15	1/6

m_1 m_2	5/2, -1/2	3/2, -1/2	1/2, -1/2
+1/2 -1	3/10	8/15	1/6
-1/2 0	3/5	-1/15	-1/3
-3/2 +1	1/10	-2/5	1/2

m_1 m_2	5/2, -3/2	3/2, -3/2
-1/2 -1	3/5	2/5
-3/2 0	2/5	-3/5

m_1 m_2	5/2, -5/2
-3/2 -1	1

2 × 1/2

m_1 m_2	5/2, +5/2
+2 1/2	1

m_1 m_2	5/2, +3/2	3/2, +3/2
+2 -1/2	1/5	4/5
+1 +1/2	4/5	-1/5

m_1 m_2	5/2, +1/2	3/2, +1/2
+1 -1/2	2/5	3/5
0 +1/2	3/5	-2/5

m_1 m_2	5/2, -1/2	3/2, -1/2
0 -1/2	3/5	2/5
-1 +1/2	2/5	-3/5

m_1 m_2	5/2, -3/2	3/2, -3/2
-1 -1/2	4/5	1/5
-2 +1/2	1/5	-4/5

m_1 m_2	5/2, -5/2
-2 -1/2	1

3/2 × 1/2

m_1 m_2	2, +2
+3/2 +1/2	1

m_1 m_2	2, +1	1, +1
+3/2 -1/2	1/4	3/4
+1/2 +1/2	3/4	-1/4

m_1 m_2	2, 0	1, 0
+1/2 -1/2	1/2	1/2
-1/2 +1/2	1/2	-1/2

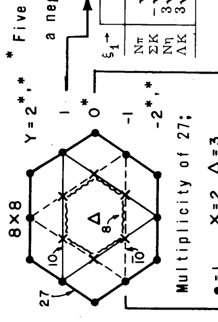
m_1 m_2	2, -1	1, -1
-1/2 -1/2	3/4	1/4
-3/2 +1/2	1/4	-3/4

m_1 m_2	2, -2
-3/2 -1/2	1

Changed to Baryon-First convention, Jan 1970. See caption on previous page.

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

{8} ⊗ {8} = {27} ⊕ {10} ⊕ {10*} ⊕ {8}₁ ⊕ {8}₂ ⊕ {1}.



Multiplicity of 27; ● = 1, × = 2, Δ = 3

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

Y = 1 I = 1/2 N

ξ_1 →	27 (+)	8D (+)	8F (−)	10* (−)
Nπ	$\sqrt{5}/10$	$3\sqrt{5}/10$	1/2	−1/2
ΣK	$-\sqrt{5}/10$	$-3\sqrt{5}/10$	1/2	−1/2
Nη	$3\sqrt{5}/10$	$-\sqrt{5}/10$	1/2	1/2
ΛK	$3\sqrt{5}/10$	$-\sqrt{5}/10$	−1/2	−1/2

Y = 1 I = 3/2 Δ

ξ_1 →	27 (+)	10 (−)
Nπ	$\sqrt{2}/2$	$-\sqrt{2}/2$
ΣK	$\sqrt{2}/2$	$\sqrt{2}/2$

Y = 0 I = 0 Λ

ξ_1 →	27 (+)	8D (+)	1 (+)	8F (−)
N$\bar{K}$	$\sqrt{15}/10$	$\sqrt{10}/10$	1/2	$\sqrt{2}/2$
ΞK	$-\sqrt{15}/10$	$-\sqrt{10}/10$	−1/2	$\sqrt{2}/2$
Σπ	$-\sqrt{10}/20$	$-\sqrt{15}/5$	$\sqrt{6}/4$	0
Λη	$3\sqrt{30}/20$	$-\sqrt{5}/5$	$-\sqrt{2}/4$	0

Y = 0 I = 1 Σ

ξ_1 →	27 (+)	8D (+)	8F (−)	10 (−)	10* (−)
N$\bar{K}$	$\sqrt{5}/5$	$-\sqrt{30}/10$	$\sqrt{6}/6$	$-\sqrt{6}/6$	$\sqrt{6}/6$
ΞK	$\sqrt{5}/5$	$-\sqrt{30}/10$	$-\sqrt{6}/6$	$\sqrt{6}/6$	$-\sqrt{6}/6$
Σπ	0	0	$\sqrt{6}/3$	$\sqrt{6}/6$	$-\sqrt{6}/6$
Ση	$\sqrt{30}/10$	$\sqrt{5}/5$	0	1/2	1/2
Λπ	$\sqrt{30}/10$	$\sqrt{5}/5$	0	−1/2	−1/2

Y = −1 I = 1/2 Ξ

ξ_1 →	27 (+)	8D (+)	8F (−)	10 (−)
Ξπ	$-\sqrt{5}/10$	$-3\sqrt{5}/10$	1/2	1/2
Σ$\bar{K}$	$\sqrt{5}/10$	$3\sqrt{5}/10$	1/2	1/2
Ξη	$3\sqrt{5}/10$	$-\sqrt{5}/10$	−1/2	1/2
Λ$\bar{K}$	$3\sqrt{5}/10$	$-\sqrt{5}/10$	1/2	−1/2

Y = −1 I = 3/2

ξ_1 →	27 (+)	10* (−)
Ξπ	$\sqrt{2}/2$	$-\sqrt{2}/2$
Σ$\bar{K}$	$\sqrt{2}/2$	$\sqrt{2}/2$

The Phase Factor $\xi_1 = \pm 1$, from de Swart's Table I, enters in 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 $\mu_1 \otimes \mu_2$.

{10} ⊗ {8} = {35} ⊕ {27} ⊕ {10} ⊕ {8}.

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

Y = 1 I = 1/2 N

ξ_1 →	27 (−)	8 (+)
Δπ	$-\sqrt{5}/5$	$-2\sqrt{5}/5$
ΣK	$-2\sqrt{5}/5$	$\sqrt{5}/5$

Y = 1 I = 3/2 Δ

ξ_1 →	35 (+)	27 (−)	10 (−)
Δπ	1/4	$-\sqrt{5}/4$	$\sqrt{10}/4$
Δη	$\sqrt{5}/4$	3/4	$\sqrt{2}/4$
ΣK	$\sqrt{10}/4$	$-\sqrt{2}/4$	− 1/2

Y = 0 I = 0 Λ

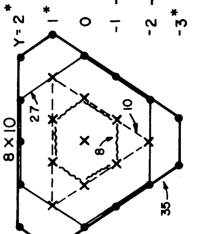
ξ_1 →	27 (−)	8 (+)
Σπ	$-\sqrt{10}/5$	$-\sqrt{15}/5$
ΞK	$-\sqrt{15}/5$	$\sqrt{10}/5$

Y = 0 I = 1 Σ

ξ_1 →	35 (+)	27 (−)	10 (−)	8 (+)
Σπ	$\sqrt{3}/6$	$-3\sqrt{5}/10$	$\sqrt{3}/3$	$-\sqrt{30}/15$
Ση	$\sqrt{2}/2$	$\sqrt{30}/10$	0	$-\sqrt{5}/5$
ΞK	$\sqrt{3}/3$	$-\sqrt{5}/5$	$-\sqrt{3}/3$	$\sqrt{30}/15$
Δ$\bar{K}$	$\sqrt{3}/6$	$\sqrt{5}/10$	$\sqrt{3}/3$	$2\sqrt{30}/15$

Y = 0 I = 2

ξ_1 →	35 (+)	27 (−)
Σπ	$\sqrt{3}/2$	−1/2
Δ$\bar{K}$	1/2	$\sqrt{3}/2$



Multiplicity of 35; ● = 1, × = 2

Y = −1 I = 1/2 Ξ

ξ_1 →	35 (+)	27 (−)	10 (−)	8 (+)
Ξπ	1/4	$-7\sqrt{5}/20$	$\sqrt{2}/4$	$-\sqrt{5}/5$
Ξη	3/4	$3\sqrt{5}/20$	$-\sqrt{2}/4$	$-\sqrt{5}/5$
ΩK	$\sqrt{2}/4$	$-3\sqrt{10}/20$	− 1/2	$\sqrt{10}/5$
Σ$\bar{K}$	1/2	$\sqrt{5}/10$	$\sqrt{2}/2$	$\sqrt{5}/5$

Y = −1 I = 3/2

ξ_1 →	35 (+)	27 (−)
Ξπ	$\sqrt{2}/2$	$-\sqrt{2}/2$
Σ$\bar{K}$	$\sqrt{2}/2$	$\sqrt{2}/2$

Y = −2 I = 0 Ω⁻

ξ_1 →	35 (+)	10 (−)
Ωη	$\sqrt{2}/2$	$-\sqrt{2}/2$
Ξ$\bar{K}$	$\sqrt{2}/2$	$\sqrt{2}/2$

Y = −2 I = 1

ξ_1 →	35 (+)	27 (−)
Ωπ	1/2	$-\sqrt{3}/2$
Ξ$\bar{K}$	$\sqrt{3}/2$	1/2