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DATA ON ELEMENTARY PARTICLES AND RESONANT STATES, NOVEMBER 1963

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Abstract: The elementary particle data comprise quantum numbers, mass, magnetic moment, mean life, common decay modes and branching ratios. The resonant state data comprise quantum numbers, mass, width, life time, threshold laboratory momentum for a production process, decay modes, branching ratios and Q values. All data used to obtain the tabulated average values, and some data not used are given in 52 footnotes.

1. Introduction

This is a revised version of previously published tables (Roos, 1963), dated March 1963. In the previous version no distinction was made between generally accepted resonances and not (yet) accepted or dubious resonances.

In this respect the present tables are radically different. First we have omitted all such resonances, which were considered dubious a year ago, and for which no further evidence has been produced since then. This selection rule excludes the resonances named Y^*, Y_0^{**}, Z_3^*, N_{11}^*, Z_1^*, K_3^*, χ_2, κ_3, K^{**}, K_5^*, χ_1, ψ_5, ϕ_3, ρ_2, ρ_1, ψ_4, δ, α, ψ_3, ζ, ψ_2, ϕ_1 and ψ_1 in the previous version. Some of the evidence for the above resonances is still used as possible evidence for particular decay modes of accepted resonances.

Further we have attempted to divide the accepted resonances into two confidence classes. The higher confidence class contains the generally accepted resonances, while the lower class contains dubious resonances or very new resonances for which the data still are meager. The difference in notation between the two classes is very simple: the accepted resonances have symbols, while the lower confidence class is left without symbols. From the previous tables the resonances Y^{**}, Y_2^*, κ_2 and ϕ_2 have been stripped of their symbols and shuffled into the lower class.

Table 1 contains the particles which are customarily called elementary, and their antiparticles.

Table 2 contains the baryonic resonant states, defined as states with baryonic number $B = 1$. The generic symbols Ξ^*, Y^* and N^* are used for states with strangeness -2, -1 and 0, respectively, and they carry two subscripts, corresponding to isospin and spin in the following manner:

$$\Xi^*_{2T,\,2J},\ Y^*_{T,\,2J},\ N^*_{2T,\,2J}\,.$$

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Not known subscripts are left blank. Further degeneracy is resolved by adding more stars to the heavier resonances. Table 3 contains the mesonic resonant states, defined as states with baryonic number $B = 0$.

2. Quantum Numbers

A blank space in any of the quantum-number columns may signify that the quantity in question is not known † or that it cannot be defined (T, T_3, S, and parity for leptons). T is not repeated for isospin multiplets, nor is T, S, or parity repeated for antiparticles. In Tables 2 and 3, J, parity and G parity are not repeated for different charge states.

Different charge states are given separate entries when they have been found.

Parity is defined in relation to N and K; by definition, N has parity + and K has −.

3. Mass and Magnetic Moment

The mass is given in two units, MeV and $m_{\pi^\pm}$; for leptons $m_{\pi^\pm}$ is exchanged for m_e We choose the units

$$\hbar = c = 1,$$
$$m_{\pi^\pm} = 139.58 \text{ MeV} = 2.4881 \times 10^{-25}\text{g},$$
$$m_e = 0.510976 \text{ MeV}.$$

The accurate mass is expressed in MeV for all particles, except the muon and the neutrinos, for which it is expressed in m_e. The mass in the other unit gives only the significant figures.

The magnetic moment is expressed in proton magnetons for baryons, in muon magnetons for the muon, and in electron magnetons for the electron.

The mass and magnetic moments of antiparticles are included when they have been specifically measured; otherwise, a blank space is left. A blank space in the magnetic-moment column may also indicate that the value is not known.

4. Width and Lifetime

In table 1 the mean life is given in two units, accurately in seconds and rounded off in $1/m_{\pi^\pm}$. The relation is

$$1/m_{\pi^\pm} = 4.7153 \times 10^{-24}\text{s},$$

the latter time signifying the time required for light to travel the distance of a Compton wavelength of the $\pi^\pm$-meson. This distance equals

$$1.4136 \times 10^{-13} \text{ cm}.$$

In tables 2 and 3 the full width Γ at half-maximum of the resonance is given in

† "Not known" here and henceforth is short for "not known to the compiler".

MeV, and the lifetime Γ^{-1} in units of $1/m_{\pi^{\pm}}$, to allow comparison with the mean lives in table 1.

A blank space means that the quantity is not known. Widths and lifetimes of antiparticles, and, in tables 2 and 3 charge multiplets, are not included unless they have been specifically measured.

5. Production Properties

In tables 2 and 3 one production reaction is given although others may also have been used. The laboratory momentum of the incident particle has been computed for that production reaction, at the threshold of resonance production.

A blank space in the k_{lab} column signifies that the rest masses in the production reaction have not been computed because no threshold exists or because it is questionable which threshold is of interest.

A blank space in both production columns indicates that detailed information on the production of different charge states is not available.

6. Decay Properties

The commonest decay modes are given if they have been observed. By "commonest" we mean a branching ratio $\geqq 1\%$.

The decay modes of antiparticles are not listed because they are simply the antimodes of the particles, and the branching ratios are the same. A blank space in any of the decay-property columns signifies that the information is lacking.

7. Footnotes and References

All detailed information is collected in the footnotes, where, however, references are given only in the contracted form: first author (year). The full references are collected alphabetically in a separate list. Use has been made of all literature available in Copenhagen by November 1963, and of all results presented in the strong interaction parallel sessions or in the plenary sessions at the Sienna International Conference on Elementary Particles, September 30. - October 5., Sienna, Italy (1963).

The compiler is indebted to countless people for the privilege of being informed about experimental results prior to publication. It is a pleasure to acknowledge the help given by members of the staffs of NORDITA and the Institute for Theoretical Physics at the University of Copenhagen, as well as the financial support of NORDITA.

Table 1
Elementary particles, November 1963

Class	Symbol Charge	Anti-particle	Quantum numbers: Iso-spin T	T_3	J^P	S	Mass (MeV)	Mass ($m_{\pi\pm}$)	Magnetic moment ($e/2m_p$)	Mean life (10^{-10} sec)	Mean life ($1/m_{\pi\pm}$)	Common decay modes	Branching ratios (%)	Foot-notes
Hyperons	Ξ^-		$\frac{1}{2}$	$-\frac{1}{2}$	$\frac{1}{2}$	-2	1321.2 ± 0.2	9.46		1.75 ± 0.05	3.7×10^{13}	$\Lambda\pi^-$	100	1
		$\bar{\Xi}^+$		$\frac{1}{2}$		2								
	Ξ^0			$\frac{1}{2}$		-2	1315.2 ± 1.0	9.43		2.80 ± 0.26	5.9×10^{13}	$\Lambda\pi^0$	100	2
		$\bar{\Xi}^0$		$-\frac{1}{2}$		2	1329 ± 19	9.52						3
	Σ^-		1	-1	$\frac{1}{2}^+$	-1	1197.6 ± 0.5	8.58		1.59 ± 0.05	3.4×10^{13}	$n\pi^-$	100	4
		$\bar{\Sigma}^+$		1		1								
	Σ^0			0	$\frac{1}{2}^+$	-1	1193.2 ± 0.7	8.55		$0.1 > \tau > 10^{-12}$	$10^{12} > \tau > 10$	$\Lambda\gamma$	100	4, 5
		$\bar{\Sigma}^0$		0		1								
	Σ^+			1	$\frac{1}{2}^+$	-1	1189.35 ± 0.15	8.52		0.78 ± 0.03	1.65×10^{13}	$p\pi^0$	50.7 ± 2.3	4
												$n\pi^+$	49.3 ± 2.3	
		$\bar{\Sigma}^-$		-1		1								
	Λ^0		0	0	$\frac{1}{2}^+$	-1	1115.38 ± 0.10	7.991	-1.5 ± 0.5	2.57 ± 0.30	5.4×10^{13}	$p\pi^-$	66(+4/-3)	6
												$n\pi^0$	34(+3/-4)	
		$\bar{\Lambda}^0$		0		1	1115.44 ± 0.32	7.991		1.9 ± 1.0	4×10^{13}			
Nucleons	n^0		$\frac{1}{2}$	$-\frac{1}{2}$	$\frac{1}{2}^+$	0	939.505 ± 0.01	6.731	-1.913148	(1013 ± 26)	2.15×10^{26}	$pe^-\bar{\nu}_e$	100	7
									±0.000066	$\times 10^{10}$				
		$\bar{n}$		$\frac{1}{2}$		0								
	p^+			$\frac{1}{2}$	$\frac{1}{2}^+$	0	938.211 ± 0.01	6.722	2.792777	∞	∞			7, 8
									±0.000034					
		$\bar{p}$		$-\frac{1}{2}$		0			-1.8 ± 1.2					9

Mesons	K^+		$\frac{1}{2}$	$\frac{1}{2}$	0^-	1	493.7 ± 0.3	3.537	0	122.7 ± 0.8	2.60×10^{15}	$\mu^+\nu_\mu(\mu 2)$	64.2 ± 1.3	10
												$\pi^+\pi^0(\pi 2)$	18.6 ± 0.9	
												$\mu^+\pi^0\nu_\mu(\mu 3)$	4.8 ± 0.6	
												$e^+\pi^0\nu_e(e3)$	5.0 ± 0.5	
												$\pi^+\pi^+\pi^-(\tau+)$	5.7 ± 0.3	
												$\pi^+\pi^0\pi^0(\tau+')$	1.7 ± 0.2	
		K^-		$-\frac{1}{2}$		-1								
	K^0			$-\frac{1}{2}$	0^-	1	497.9 ± 0.6	3.57	<0.04 ($\hbar e/m_K$)	K_1^0: 0.90 ± 0.02	1.9×10^{13}	$\pi^+\pi^-$	66.5 ± 1.4	11
		$\bar{K}^0$		$\frac{1}{2}$		-1						$\pi^0\pi^0$	33.5 ± 1.4	
										K_2^0: $630\ ^{+160}_{-100}$	1.3×10^{16}	$\pi^+\pi^-\pi^0$	8.7 ± 2.3	12
												$3\pi^0$	38 ± 7	
												$\pi^+e^-\bar{\nu}_e$, $\pi^-e^+\nu_e$	28.3 ± 5.9	
												$\pi^+\mu^-\bar{\nu}_\mu$, $\pi^-\mu^+\nu_\mu$	25.0 ± 5.9	
	π^+		1	1	0^-	0	139.58 ± 0.05	1	0	254.7 ± 2.7	5.48×10^{15}	$\mu^+\nu_\mu$	100	13
		π^-		-1		0								
	π^0	π^0		0	0^-	0	134.97 ± 0.05	0.967	0	$(1.05 \pm 0.18) \times 10^{-6}$	2.23×10^{7}	2γ	98.8	14
												γe^+e^-	1.2	
Leptons	μ^-	μ^+			$\frac{1}{2}$		105.65	206.765 ± 0.002 (m_e)	1.001162 ± 0.000005 ($e/2m_\mu$)	22040 ± 70	4.69×10^{17}	$e^-\bar{\nu}_e\nu_\mu$	100	15
	e^-	e^+			$\frac{1}{2}$		0.510976 ± 0.000007	1(m_e)	1.0011609 ± 0.0000024 ($e/2m_e$)	∞	∞			7, 16
	ν_μ^0	$\bar{\nu}_\mu$			$-\frac{1}{2}$, $\frac{1}{2}$		<2.5	< 5(m_e)						17, 19
	ν_e^0	$\bar{\nu}_e$			$-\frac{1}{2}$, $\frac{1}{2}$		<0.00025	$<5\times 10^{-4}$ (m_e)						18, 19
Photon	γ^0				1	0	0	0						19

Table 2
Baryonic resonant states, November 1963

Class	Symbol	Charge	Quantum numbers T	J	P	S	Mass (MeV)	Mass $(m_{\pi\pm})$	Full width Γ (MeV)	Lifetime Γ^{-1} $(1/m_{\pi\pm})$	Production: Process	k_{lab} (MeV)	Decay: Modes	Branching ratio (%)	Q (MeV)	Footnotes
Hyperonic States		$\pm$	≤ 2			-1	2350	16.8			K^-p	2290	$\Sigma^{\pm}\pi^+\pi^-$		880	20
	Y^*_{05}	0	0	$\frac{5}{2}$	+	-1	1815 $\pm$35	13.0	70	2	K^-p	1050	K^-p others		383	21
		0	$\frac{1}{2}$			-2	1770 $\pm$25	12.6	<80	>1.7	K^-N	2090	$\Xi^-\pi^+$ $\Xi^-\pi\pi$		314 175	22
		0	≤ 1	$\frac{5}{2}$	-	-1	1765 $\pm$30	12.6	60	2.8	K^-N	940	K^-p others		333	23
	Y^{**}_{13}	+	1	$\frac{3}{2}$		-1	1660 $\pm$10	11.9	40 $\pm$ 10	3.5	K^-p	715	$\bar{K}^0p$ $(\Sigma\pi)^+$ $\Lambda\pi^+$ $\Lambda\pi^+\pi^0$ $\Sigma^{\mp}\pi^{\pm}\pi^+$	12 $\pm$ 6 25 29 17 17	224 332 405 270 187	24
			1			-1	1550 $\pm$20	11.1	125	1.1	π^-p	1770	$\Sigma\pi$	100	220	25
	Ξ^*_{13}	-	$\frac{1}{2}$	$\frac{3}{2}$	+	-2	1533 $\pm$ 3	10.98	7 $\pm$ 2	20	K^-p	1512	$\Xi^-\pi^0$ $\Xi^0\pi^-$	40 60	78 82	26
	Ξ^*_{13}	0				-2						1521	$\Xi^-\pi^+$ $\Xi^0\pi^0$	72 $\pm$ 8 28 $\pm$ 12	73 83	26
	Y^*_{03}	0	0	$\frac{3}{2}$	-	-1	1518.7 $\pm$ 1.7	10.88	16.4 $\pm$ 2	8.7	K^-p	395	$(\bar{K}N)^0$ $(\Sigma\pi)^0$ $\Lambda\pi^+\pi^-$	30 55 15	82-88 184-193 126	27

Nucleonic States

Y^*_{01}	0	0	$\frac{1}{2}$	-	-1	1404.7 ± 0.4	10.1	50	2.8	K^-p	445	$(\Sigma\pi)^0$		69-78	28
												$\Lambda\pi\pi$		10-20	
Y^*_{13}	±	1	$\frac{3}{2}$	+	-1	1382 ± 2	9.90	39 ± 7	3.6	K^-p	408	$(\Sigma\pi)^-$	1 (± 3)	54	29
												$\Lambda\pi^-$	99 (± 3)	130	
Y^*_{13}	0				-1						395	$(\Sigma\pi)^0$		49-58	29
												$\Lambda\pi^0$		135	
	+++	$\frac{5}{2}$			0	2400 ± 20	17.2	120	1.16	π^+p	2590	$p\pi^+\pi^+$		1180	30
N^*_3		$\frac{3}{2}$			0	2360 ± 25	16.9	200 ± 25	0.7	π^+p	2510	πN		1280	31
												others			
N^*_1		$\frac{1}{2}$			0	2190 ± 20	15.7	200 ± 20	0.7	π^-p	2080	πN		1110	31
												others			
N^*_{37}		$\frac{3}{2}$	$\frac{7}{2}$		0	1920	13.8	200	0.7	π^-p	1450	πN	30	840	32
												$K\Sigma$	<4	235	
												$K\Lambda$		310	
												others			
N^*_{15}		$\frac{1}{2}$	$\frac{5}{2}$		0	1685 ± 5	12.07	100 ± 10	1.4	π^-p	1020	πN	80	605	33
												$K\Lambda$	<2	76	
												others	>18		
N^*_{13}		$\frac{1}{2}$	$\frac{3}{2}$		0	1515 ± 3	10.85	115 ± 25	1.2	π^-p	731	πN		437	34
												others			
	++	$\frac{3}{2}$			0	1400	10	100	1.4	γp	1070	$\pi^-N^{*++}_{33}$		160	35
										pp	1750	πN		320	
N^*_{33}	-	$\frac{3}{2}$	$\frac{3}{2}$	+	0	1237	8.86	94 ± 16	1.49	πN	303	π^-n	100	159	36
N^*_{33}	0				0							π^-p		160	36
												π^0n		164	
N^*_{33}	+				0							π^0p		165	36
												π^+n		159	
N^*_{33}	++				0							π^+p	100	160	36

Table 3
Mesonic resonant states, November 1963

Symbol	Charge	Quantum numbers T	J	P	G	S	Mass (MeV)	Mass $(m_{\pi\pm})$	Full width Γ (MeV)	Lifetime Γ^{-1} $(1/m_{\pi\pm})$	Production: Process	Production: k_{lab} (MeV)	Decay: Modes	Decay: Branching ratio (%)	Decay: Q (MeV)	Footnotes
	0	≤1				0	1410	10.1	50-60	2.5	$\bar{p}p$		$K_1^0K^\pm\pi^\mp$		280	37
f	0	0	2	+	+	0	1256 ±14	9.0	160	0.88	π^-p	2070	$\pi^-\pi^+$	100	970	38
B	-	1			+	0	1215	8.7	170	0.8	π^-p	1990	$\pi^-\omega$		295	39
B	+					0	1220	8.7	100 ± 20	1.4	π^+p	1990	$\pi^+\omega$		300	40
	0	0	even	+	+	0	1040 ±40	7.4			K^-p	1780	$K_1^0K_1^0$		44	41
													$2n\times\pi$			
ϕ	0	0	1	-	-	0	1019.5 ± 0.3	7.30	3.1 ± 0.6	45.0	K^-p	1760	$K_1^0K_2^0$	90 ± 10	24	42
													$(2n+1)\times\pi$			
													$\rho\pi$	10 ± 10	130	
	-	≥1				0	1000 ±10	7.1	120 ± 30	1.2	π^-p	1515	$\pi^-\pi^0\pi^0$		590	43
	0	0				0	922 ±30	6.6	<150	>0.9	π^-p	1360	$\pi^-\pi^+$		643	44
K*	-	$\frac{1}{2}$	1	-		-1	890.4 ± 1.2	6.38	51 ± 2	2.74	K^-p	1074	$\bar{K}^0\pi^-$	60 ± 16	254	45
													$K^-\pi^0$	40 ± 16	263	
$\bar{K}$*	0					-1					K^-p	1078	$K^-\pi^+$		258	
													$\bar{K}^0\pi^0$		259	
K*	+					1					π^-p	1834	$K^0\pi^+$	67	254	
													$K^+\pi^0$	33	263	
K*	0					1					π^-p	1657	$K^+\pi^-$		258	
													$K^0\pi^0$		259	

ω	0	0	1 - -	0	783 ± 2	5.6	9.5 ± 2.1	14.7	$\bar{p}p$		$\pi^+\pi^-\pi^0$	86	368	46
											$\pi^0\gamma$	9.6 ± 1.2	647	
											$\pi^+\pi^-$	3.9 ± 1.4	503	
											e^+e^-	0.4 ± 0.26	782	
											$\pi^+\pi^-\gamma$		503	
ρ	-	1	1 - +	0	757 ± 5	5.4	120 ± 10	1.2	π^-p	1029	$\pi^-\pi^0$	>86	475	47
											$\pi^-\pi^0\pi^0$	< 3	340	
											$\pi^-\pi^0\pi^0\pi^0$	⩽ 4	205	
											$\pi^-\pi^+\pi^-\pi^0$	< 2	196	
											$\pi\gamma$	< 5	617	
ρ	0			0	754 ± 5	5.4	110 ± 10	1.3	πN	1029	$\pi^-\pi^+$	94(+6/-40)	470	48
											neutrals	6(+40/-6)		
											$\pi^+\pi^-\pi^+\pi^-$	< 2	191	
ρ	+			0					π^+p	1066	$\pi^+\pi^0$		495	
κ	0	½	⩾1	1	725 ± 2	5.2	<12	>12	π^-p	1485	$K^+\pi^-$		96	49
											$K^0\pi^0$		97	
κ	+			1							$(K\pi)^+$		92-101	
η	0	0	0 - +	0	548.5 ± 0.6	3.93	⩽7	⩾20	π^-p	685	$\pi^+\pi^-\pi^0$	25 ± 8	135	50
											$\pi^+\pi^-\gamma$	7 ± 2	270	
											$3\pi^0$	21 ± 9; 16 ± 16; 31 ± 17 (68 ± 9 combined)	144	
											$\pi^0\gamma\gamma$		414	
											2γ		549	
	0	0		0	520 ± 20	3.7	70 ± 30	2.0	π^-p	639	$\pi^+\pi^-$		240	51
ω_{ABC}	0	0	0 + +	0	317 ± 6	2.3	⩽ 16	⩾ 9	pd		$\pi^+\pi^-$		38	52

FOOTNOTES

1. $m(\Xi^-)$ is a weighted average of
   1321.1 ± 0.65 Schneider (1963)
   1321.4 ± 0.4 Jauneau *et al.* (1963a)
   1311.1 ± 0.2 Connolly *et al.* (1963c).
   $\tau(\Xi^-)$ is a weighted average of the following measurements in 10^{-10} s:
   1.86 (+0.15/−0.14) Jauneau *et al.* (1963a)
   1.55 ± 0.31 Schneider (1963)
   1.74 (+0.18/−0.15) Connolly *et al.* (1963c)
   1.75 ± 0.07 L. Alvarez, J. Berge, J. Hubbard, R. Kalbfleisch, J. Shafer, F. Solmitz, M. Stevenson and S. Wojcicki, unpublished work quoted by Ticho (1963)
   1.77 ± 0.12 D. Carmony, G. Pjerrou, P. Schlein, W. Slater, D. Stork, H. Ticho, unpublished work quoted by Ticho (1963).
   $J = \frac{1}{2}$ is compatible with the data of Bertanza *et al.*

2. $m(\Xi^0)$ is obtained from $m(\Xi^-)$ and the weighted average 6.0 ± 1.0 of the following measurements of the mass difference $m(\Xi^-) - m(\Xi^0)$
   3.6 ± 2.4 Connolly *et al.* (1963c)
   6.8 ± 1.5 Jauneau *et al.* (1963b)
   6.1 ± 1.6 D. Carmony, G. Pjerrou, P. Schlein, W. Slater, D. Stork, H. Ticho, unpublished work quoted by Ticho (1963).
   $\tau(\Xi^0)$ is the weighted average given by Ticho (1963).

3. $m(\bar{\Xi}^0)$ is reported by Baltay *et al.* (1963b).

4. The Σ masses are from Barkas *et al.* (1963).
   $\tau(\Sigma^+)$ and $\tau(\Sigma^-)$ are weighted averages of the following results in 10^{-10} s:
   $\left.\begin{array}{l}\tau(\Sigma^+) = 0.81(+0.06/-0.05)\\ \tau(\Sigma^-) = 1.61(+0.10/-0.09)\end{array}\right\}$ Barkas *et al.* (1960)
   $\left.\begin{array}{l}\tau(\Sigma^+) = 0.765 \pm 0.04\\ \tau(\Sigma^-) = 1.58 \pm 0.06\end{array}\right\}$ Humphrey *et al.* (1962).
   The Σ^+ branching ratio is a weighted average of
   51.0 ± 2.4 Humphrey *et al.* (1962)
   48 ± 7 Granet (1962).
   The Σ parity is + from Tripp *et al.* (1962), who report $P(\Sigma \mathrm{pK}) = -1$.

5. The upper limit of $\tau(\Sigma^0)$ is from Alvarez *et al.* (1957); the lower limit from Dreitlein *et al.* (1961), who also give a theoretical estimate
   $\tau(\Sigma^0) = 1.1 \times 10^{-19}$ s.

6. $m(\Lambda)$ is a weighted average of
   1115.36 ± 0.14 Barkas *et al.* (1960)
   1115.46 ± 0.15 Bhowmik *et al.* (1961)

1115.25$\pm$0.36 Armenteros *et al.* (1962b)
1115.04$\pm$0.41 Baltay *et al.* (1962).

$\mu(\Lambda)$ is the value of Cool *et al.* (1962), which disagrees with the value 0.0$\pm$0.6 nm, reported by Kernan *et al.* (1963).

$\tau(\Lambda)$ is a central value from the ideogram of Crawford (1962). The new values which have appeared since 1962 do not resolve the so called East-West effect.

$m(\bar{\Lambda})$ is a weighted average of
1115.40$\pm$0.39 Baltay *et al.* (1962)
1115.52$\pm$0.55 Armenteros *et al.* (1962b).

$\tau(\bar{\Lambda})$ is from Baltay *et al.* (1962).

The $\Lambda \to p\pi^-$ branching ratio is a central value of
64.3$\pm$1.6 Humphrey *et al.* (1962)
64.5$\pm$2.2 Crawford (1962), weighted average based on earlier measurements;
68.5$\pm$1.7 J. Anderson, F. and B. Crawford, R. Golden, L. Lloyd, G. Meisner and L. Price (unpublished), quoted by Crawford (1962)
70.9$\pm$3.4 Chrétien *et al.* (1963).

The Λ parity is + from Cronin *et al.* (1962), who give support for $P(K\Lambda) = -1$.

7. The nucleon and electron masses are from R. Cohen *et al.* (1957).
μ(n) is from V. Cohen *et al.* (1956).
The neutron mean life is based on the value 11.7$\pm$0.3 min for the half life, by Sosnovskij *et al.* (1959).

8. μ(p) is a weighted average of the following data in nuclear magnetons:
2.79277 $\pm$0.00005 Sanders *et al.* (1963a)
2.792765$\pm$0.000060 Sommer *et al.* (1951)
2.792810$\pm$0.000076 average value computed using the electron and proton masses and the following values of μ(p) in Bohr magnetons:
657.442 $\pm$0.003 Liebes *et al.* (1959)
657.4436$\pm$0.0025 Sanders *et al.* (1963b).

9. Button *et al.* (1962b).

10. $m(K^+)$ is from Barkas *et al.* (1963).
$\tau(K^+)$ is a weighted average of the following results in 10^{-8} s:
1.224$\pm$0.013 Barkas *et al.* (1960)
1.231$\pm$0.011 Boyarski *et al.* (1962).
The K^+ branching ratios are from Roe *et al.* (1961) and Giacomelli *et al.* (1963). Note that these branching ratios (except for τ) disagree with the weighted averages obtained from emulsion experiments, as quoted by Crawford (1962):

$$\mu 2 = 57.4\pm 2.0$$
$$\pi 2 = 25.6\pm 1.5$$
$$\mu 3+e3+\tau = 11.0\pm 1.0$$
$$\tau = 5.7\pm 0.2$$

11. $m(K^0)$ is from Rosenfeld *et al.* (1959). $\mu(K^0)$ is from Okonov (1962).

$\tau(K_1^0)$ is a weighted average, based on the following recent results only (in 10^{-10}s), all quoted by Crawford (1962):

0.94 ± 0.05 Crawford *et al.* (1962)

0.90 ± 0.05 A. F. Garfinkel, Report Nevis 104 (1962) (Thesis, Columbia University Physics Department),

0.885 ± 0.025 R. L. Golden, G. Alexander, J. A. Anderson, F. S. and B. B. Crawford, L. J. Lloyd, G. W. Meisner, and L. Price (to be published).

The $K_1^0 \to \pi^0\pi^0$ branching ratio is from Brown *et al.* (1963). The values 28.5 ± 3.6 by Crawford *et al.* (1959), 28.8 ± 2.1 by Chrétien *et al.* (1963), 26.0 ± 2.4 by Anderson *et al.* (cf. reference 6), and 29 ± 3, weighted average of earlier results, reported at the 1960 Rochester Conference, are less accurate and do not agree with theory.

12. $\tau(K_2^0)$ is a weighted average of the following results in 10^{-8} s:

$6.8(+2.6/-1.5)$ Crawford (1962)

$8.1(+3.3/-2.4)$ Bardon *et al.* (1958)

$5.1(+2.4/-1.3)$ Darmon *et al.* (1962).

The branching ratios have been obtained from the following results:

$$R_1 = \frac{K_2^0 \to 3\pi^0}{K_2^0 \to \text{all charged}} = 0.38 \pm 0.07 \text{ Anikina } et\ al. \text{ (1962)}$$

$$R_2 = \frac{K_2^0 \to \pi^+\pi^-\pi^0}{K_2^0 \to \text{all charged}} = 0.127 \pm 0.020 \text{ Luers } et\ al. \text{ (1961)}$$

$R_2 = 0.134 \pm 0.018$, Anikina *et al.* (1962)

$$R_3 = \frac{K_2^0 \to \pi e \nu_e}{K_2^0 \to \text{all charged}} = 0.458 \pm 0.048, \text{ Luers } et\ al. \text{ (1961)}$$

$R_3 = 0.415 \pm 0.120$, Astier *et al.* (1961).

A value on $R_3 = 0.185(+0.038/-0.034)$ by Astier *et al.* has not been used.

13. $m(\pi^\pm)$ is from Shapiro *et al.* (1962).

$\tau(\pi^\pm)$ is from Merrison (1962).

14. $\tau(\pi^0)$ is from von Dardel *et al.* (1963).

The π^0 mass has been obtained from the π^+ mass and the measurement by Czirr (1963) of the mass difference

$m(\pi^-) - m(\pi^0) = (4.6056 \pm 0.0055)$ MeV.

The relative frequency for γe^+e^--decay is from J. Tietge *et al.* (1962).

15. $\mu(\mu^+)$ is from Charpak *et al.* (1962).

$m(\mu^+)$ is a combined value of the latest measurements as given by G. Bingham (1963).

$\tau(\mu^+)$ is a central value including all measurements quoted by Lundy (1962) and the values

$\tau(\mu^+) = (2.197 \pm 0.002)\mu s$ } Meyer *et al.* (1963)
$\tau(\mu^-) = (2.198 \pm 0.002)\mu s$ }
$\tau(\mu^+) = (2.202 \pm 0.004)\mu s$ Eckhause *et al.* (1963).

16. μ(e) is from Schupp *et al.* (1961).

17. Bahcall *et al.* (1961).

18. Langer *et al.* (1952).

19. ν_μ and ν_e are left-handed screw states, $\bar{\nu}_\mu$ and $\bar{\nu}_e$ right-handed, γ has two spin states: right- and left-handed. We define a left-(right)-handed screw state as a state with negative (positive) spin.

20. This possible resonance was found in the $\Sigma^\pm\pi^+\pi^-$ channels but not in the $\Sigma^\pm\pi^\pm\pi^\pm$ or $\Sigma^\mp\pi^\pm\pi^\pm$ channels, using 3.5 GeV/c K^--mesons, by the Glasgow, Imperial College, Oxford and Rutherford Laboratory (1963).

21. Quantum numbers, mass and width values are taken from Barbaro-Galtieri *et al.* (1963b). Further evidence has been given by Kerth (1961), Chamberlain *et al.* (1962), Kuznetsov *et al.* (1962a) and Beall *et al.* (1962, 1963).

22. Belliere *et al.* (1963), Halsteinslid *et al.* (1963).

23. Barbaro-Galtieri *et al.* (1963b). Some previous indications have been given by Belyakov *et al.* (1962b) and Grashin *et al.* (1963).

24. The $\bar{K}N$ branching ratio is from Smith (1963b): An indication for positive parity has been given by Taher-Zadeh *et al.* (1963), all other data are from Alvarez *et al.* (1963). For further evidence, cf. reference list in Roos (1963).

25. Indications by March *et al.* (1962), Koch *et al.* (1962) and Baltay *et al.* (1963a). Evidence against has been given by Kalbfleisch *et al.* (1963).

26. $m(\Xi^*_{13})$ is a weighted average of the following results in MeV:
1529±5 Pjerrou *et al.* (1962)
1535±3 Bertanza *et al.* (1962b).
The spin and parity assignments, the width and the Ξ^{*0}_{13} branching ratios are from Schlein *et al.* (1963). Note that this width is in disagreement with the value $\Gamma = 16 \pm 3$ MeV, given by Connolly *et al.* (1963b).

27. $m(Y^*_{03})$ is a weighted average of
1519.4±2 Watson *et al.* (1963)
1517.2±3 Barbaro-Galtieri *et al.* (1963b).
The width and branching ratios are from Watson *et al.* (1963).

28. $m(Y^*_0)$ is from Frisk *et al.* (1962).
This mass value is confirmed by Samman *et al.* (1963) who give (1405.1±0.9) MeV. The width claimed by Frisk *et al.* (1962) has, however, not been confirmed in similar experiments by Barbaro-Galtieri *et al.* (1963a) nor by Lokanathan

et al. (1963). The width of Samman *et al.* (1963) is 10.3 MeV, or intermediate to that of Frisk *et al.* (1962) and the commonly accepted bubble chamber value, which we have listed.

Determinations of the spin and the parity are consistent with $J^P = \frac{1}{2}^-$, but this assignment is not finally settled, cf. Dalitz (1963).

29. $m(Y^*_{13})$ is a weighted average of
 1382 ± 3 Dahl *et al.* (1961)
 1385 ± 5 Alston *et al.* (1961a)
 1380 ± 3 Bertanza *et al.* (1963)
 1383.5 ± 4 Cooper *et al.* (1963), Y^{*+}_{13} mass
 1381 ± 4 Curtis *et al.* (1963).

 The value 1389 ± 3 of Baltay *et al.* (1963c) has not been used.

 The spin and parity assignments are from Shafer *et al.* (1963) and Bertanza *et al.* (1963). $\Gamma(Y^*_{13})$ is a weighted average of
 50 ± 10 Bertanza *et al.* (1963)
 30 ± 9 Curtis *et al.* (1963).

 The value 26 ± 5 of Baltay *et al.* (1963c) has not been used. The branching ratios are from Alston *et al.* (1961a).

30. Lander *et al.* (1963).
 Some indications at 2.6 GeV have been reported by the Aachen-Berlin-Birmingham-Bonn-Hamburg-London (I.C.)-München collaboration (1963).

31. Diddens *et al.* (1962). An indication for $J(N^*_1) = \frac{9}{2}$ is reported by Alexander *et al.* (1963).

32. Klepikov *et al.* (1960), Falk-Vairant *et al.* (1961), Moyer (1961), Devlin *et al.* (1962), Helland *et al.* (1963), Salin (1963). The KΣ-decay mode has been reported by March *et al.* (1962) and W. Walker (1962b), and the KΛ-decay mode by Erwin *et al.* (1962a), Kuznetsov *et al.* (1962b) and W. Walker *et al.* (1963b). The branching ratios are from Rosenfeld (1963).

33. The mass value is obtained from the weighted average of
 $T_\pi = (890 \pm 9)$MeV Falk-Vairant *et al.* (1961)
 $T_\pi = (900 \pm 15)$ MeV Devlin *et al.* (1962).

 The width is given by Omnès *et al.* (1961). The branching ratios are from A. H. Rosenfeld (1963). Further possible evidence for KΛ decay has been reported by Kuznetsov *et al.* (1962b), Baz *et al.* (1962) and Bertanza *et al.* (1962a).

 For further details, cf. Klepikov *et al.* (1960), Moyer *et al.* (1961), Feld *et al.* (1962), Helland *et al.* (1963), Salin (1963), R. Walker (1963) and Cocconi *et al.* (1963).

34. The mass value is obtained from the weighted average of
 $T_\pi = (605 \pm 5)$ MeV Falk-Vairant *et al.* (1961)

T_π = (600 ± 15)MeV Devlin *et al.* (1962)
E_γ = (740 ± 10)MeV Deutsch *et al.* (1961)
E_γ = (750 ± 15)MeV Bellettini *et al.* (1963),
where $T_\pi = E_\gamma - 140$ MeV.

$\Gamma(N^*_{13})$ is a central value, which includes the values of Omnès *et al.* (1961), Devlin *et al.* (1962), Feld *et al.* (1962), Salin (1963) and Cocconi *et al.* (1963), but does not agree with the value < 60 MeV given by Deutsch *et al.* (1961). See also Klepikov *et al.* (1960).

35. The γp evidence has been communicated privately from the Stoppini-group at Frascati by R. Gomez. The pp indication has been reported by Cocconi *et al.* (1963). Some further indications of a resonance at 1480 MeV, which may be a mixture of N^*_{13} and the 1400 MeV resonance, has been reported by Pauli *et al.* (1963).

36. The mass value is from Klepikov *et al.* (1960) and corresponds to the position where the phase shift passes through 90° with increasing energy, cf. also Dalitz (1963). The position of the maximum seems to be located at about (1220 ± 10) MeV, cf. Klepikov *et al.* (1960), Hart *et al.* (1962), Samios *et al.* (1962), Duboc *et al.* (1963), Chadwick *et al.* (1963b) and R. Walker (1963).
The width is a weighted average of
90 ± 20 Samios *et al.* (1962)
100 ± 25 Chadwick *et al.* (1963b),
in good agreement with Klepikov *et al.* (1960), Detoeuf (1961) and R. Walker (1963).
For further details, cf. Falk-Vairant *et al.* (1961), Moyer (1961), Feld *et al.* (1962) and Salin (1963).

37. Armenteros *et al.* (1963).

38. $m(f^0)$ is a weighted average of
1260 ± 35 Veillet *et al.* (1963)
1250 ± 25 Selove *et al.* (1962)
1250 ± 50 Guiragossian (1963)
1260 ± 20 Bondar *et al.* (1963a).
$\Gamma(f^0)$ is from Bondar *et al.* (1963a).

39. Chung *et al.* (1963). An indication has been reported by Bondar *et al.* (1963b).

40. Abolins *et al.* (1963).

41. Alexander *et al.* (1962a), Erwin *et al.* (1962b), H. Bingham *et al.* (1962), Bigi *et al.* (1962), A. H. Rosenfeld (1963), Armenteros *et al.* (1963). Possible 4π-decays have been reported by Xuong *et al.* (1962a, b), Chadwick *et al.* (1962), Foelsche *et al.* (1962a) and Lynch (1962).

42. $m(\phi)$ is a weighted average of
1018.6±0.5 Gelfand *et al.* (1963b)
1020.5±0.5 Connolly *et al.* (1963a)
1019 ±1.6 Glasgow, Imperial College, Oxford and Rutherford Laboratory (1963).
$\Gamma(\phi)$ is a weighted average of
3.1±1.0 Gelfand *et al.* (1963b)
3.1±0.8 Connolly *et al.* (1963a).
The $\rho\pi$ branching ratio is from Connolly *et al.* (1963a) who also put an upper limit of 8% to the $\pi\pi/K\bar{K}$ branching ratio.

43. Trebukhovsky *et al.* (1963). Some earlier indications have been reported by Ainutdinov *et al.* (1962) in the $T = 2$ channels ($\pi^{\pm}\pi^{\pm}$) and by Guiragossian *et al.* (1962) in the ($\pi^{+}\pi^{-}$)-channel.

44. Hulubei *et al.* (1963). Erwin *et al.* (1963) give $T = 0$, $m = 940$ MeV and $\Gamma \sim 20$ MeV.

45. $m(K^*)$ and $\Gamma(K^*)$ are weighted averages of the following results in MeV:

$m(K^*)$	$\Gamma(K^*)$	
890.4(±2)	47(±5)	Alston *et al.* (1962)
885 (±5)	60 ±5	Alexander *et al.* (1962b)
897 ±10	60 ±10	Colley et *al.* (1962)
885 ±5	55 ±5	Armenteros *et al.* (1962c)
885 (±10)	50(±10)	Smith *et al.* (1963a)
898 ±5	46 ±8	Chadwick *et al.* (1963b)
892 ±2	50 ±5	Kraemer *et al.* (1963)
888 ±3	45 ±5	Gelsema *et al.* (1963)
	35 ±15	March *et al.* (1962).

The spin and parity assignments are from Chinowsky *et al.* (1962).
The K_1^{*-} branching ratios are weighted averages of the following results:
$R = \Gamma(\bar{K}^0\pi^-)/\Gamma(K^-\pi^0) = 1.4\pm0.4$ Alston *et al.* (1961b)
$1/R = 0.5\pm0.2$ Graziano *et al.* (1962).
The π^- momentum for K_1^{*0} production is here tabulated as 1657 MeV/c which corresponds to associated production with Λ. Associated production with Σ^0 gives 1826 MeV/c.

46. $m(\omega^0)$ is a central value of
779.4±1.4 Armenteros *et al.* (1962a)
784.0±0.9 Gelfand *et al.* (1963a).
$\Gamma(\omega)$ is from Gelfand *et al.* (1963a).
The ($\omega \to$ neutrals)/($\omega \to 3\pi$) branching ratio is a weighted average of
0.135±0.035 Steinberger *et al.* (1963)
0.11 ±0.03 Murray *et al.* (1963)

0.11 ±0.02 Buschbeck-Czapp *et al.* (1963)
0.09 ±0.04 Fields *et al.* (1963).

The branching ratio $(\omega \to 2\pi)/(\omega \to 3\pi)$ is from Murray *et al.* (1963), in agreement with other measurements: W. Walker (1963a), Fickinger (1963) and the value 5% at 2.75 GeV communicated privately by Puppi, and in only mild disagreement with Steinberger *et al.* (1963).

The branching ratio $(\omega \to e^+e^-)/(\omega \to \text{neutrals}) = (0.5 \pm 0.3)\%$ has been quoted by Berthelot (1963). According to Barmin *et al.* (1963) all the neutral decays consist of $\pi^0\gamma$.

The $\pi^+\pi^-\gamma$ decay has been seen by Belyakov *et al.* (1962a), cf. also Nguyen Dinh Tu (1962).

47. $m(\rho^-)$ and $\Gamma(\rho^-)$ are weighted averages of the following results, tabulated as functions of the lab kinetic energy T_π:

$m(\rho\pm)$ (MeV)	$\Gamma(\rho\pm)$ (MeV)	T_π (GeV)	References
713 ±81	31 ±143	0.91	Foelsche *et al.* (1962a)
748 ±16		1.1	Kenney *et al.* (1962a, b)
755 ±10	61 ± 24	1.26	Foelsche *et al.* (1962a)
752 ±13		1.45	Saclay-Orsay-Bari-Bologna-collaboration (1961, 1963)
740(±13)	120(±15)	1.72-1.93	W. Walker *et al.* (1962a)
755 ±10		1.89-2.1	W. Walker *et al.* (1963b)
770 ±10	130 ±10	2.19-2.73	Alff *et al.* (1962)
775(±25)	125(±25)	3.3	Guiragossian (1963)
780(±25)		7.0	Grashin *et al.* (1962)
755(±15)	110(±15)	$\bar{p}p$ at rest	Chadwick *et al.* (1963a).

The above mass values are all consistent with 757±5, and no evidence for an energy dependence can be seen. In fact, the only such evidence has been presented by Foelsche *et al.*, who give $m(\rho^+) = 726 \pm 10$ and $\Gamma(\rho^+) = 57 \pm 27$ at $T_\pi = 1.09$ GeV. This value has not been used by us.

The upper limits of the branching ratios into $\pi^-\pi^0\pi^0$ and $\pi^-\pi^+\pi^-\pi^0$ have been given by Lynch (1962), into $\pi^-\pi^0\pi^0\pi^0$ by Alitti *et al.* (1962) and into $\pi\gamma$ by Berthelot (1963).

48. $m(\rho^0)$ and $\Gamma(\rho^0)$ are weighted averages of the following results, tabulated as functions of the lab kinetic energy T_π:

$m(\rho^0)$ (MeV)	$\Gamma(\rho^0)$ (MeV)	T_π (GeV)	References
752 ±27		1.45	Saclay-Orsay-Bari-Bologna collaboration (1963)
760(±15)		1.72	W. Walker *et al.* (1962a)
750 ±10	100 ±10	2.19-2.73	Alff *et al.* (1962)
742(±15)		2.64	Grashin *et al.* (1962)
775(±25)	175(±25)	3.3	Guiragossian (1963)
760 ±10	90 ±10	3.43-3.54	Abolins *et al.* (1963)
747 ±17	156 ±17	4.55	Samios *et al.* (1962)
750(±15)		7.0	Grote *et al.* (1962)
755(±15)	110(±15)	$\bar{p}p$ at rest	Kenney *et al.* (1962a, b)

There is no evidence for an energy dependence.

The branching ratios are from Meer *et al.* (1962).

The upper limit on the $\pi^+\pi^-\pi^+\pi^-$ branching ratio has been given by Lynch (1962).

49. $m(\kappa)$ is a weighted average of
726 ± 3 Miller *et al.* (1963)
723 ± 3 Wojcicki *et al.* (1963).
$\Gamma(\kappa)$ is from Wojcicki *et al.* (1963), in agreement with Miller *et al.* (1963), who give $\Gamma \leqq 20$ MeV. Further support by Connolly *et al.* (1963b).

50. $m(\eta^0)$ is a weighted average of
548 ± 1 Alff *et al.* (1962)
548 ± 1 Foelsche *et al.* (1962a) at 1090 MeV/c
551 ± 2 Foelsche *et al.*, at 1260 MeV/c
546 ± 4 Pickup *et al.* (1962)
550 ± 1.5, 548 ± 2 } Bastien *et al.* (1962) from different decay modes.
$\Gamma(\eta^0)$ is from Bastien *et al.*, Alff *et al.* and Foelsche *et al.* give $\Gamma < 10$ MeV.
The isospin assignment is from Carmony *et al.* (1962) and the spin and parities from Chrétien *et al.* (1962).
The branching ratios have been computed from the following measurements:
$R_1 = \pi^+\pi^-\gamma/\pi^+\pi^-\pi^0 = 0.26 \pm 0.08$ Fowler *et al.* (1963)
$R_2 = \text{neutrals}/\pi^+\pi^-\pi^0 = 2.5 \pm 0.5$, Alff *et al.* (1962)
$R_2 = 2.5 \pm 1.0$, Pickup *et al.* (1962)
$1/R_2 = 0.31 \pm 0.11$, Bastien *et al.* (1962)
$R_2 = 3.0 \pm 0.7$, Fields *et al.* (1963)
$R_2/(1+R_1) = 2.7 \pm 0.8$, Button-Shafer *et al.* (1962c)
$R_2/(1+R_1) = 2.6 \pm 0.9$ Buschbeck-Czapp *et al.* (1963)
$R_3 = 2\gamma/(3\pi^0+\pi^0\gamma\gamma) = 0.8 \pm 0.25$, Bacci *et al.* (1963)
$R_3 = 1.1 \pm 0.5$, Muller *et al.* (1963),
$\gamma\gamma/(\pi^+\pi^-\pi^0+\pi^+\pi^-\gamma) = 0.99 \pm 0.48$, Crawford *et al.* (1963)
$3\pi^0/(\pi^+\pi^-\pi^0+\pi^+\pi^-\gamma) = 0.66 \pm 0.25$, Crawford *et al.* (1963).

51. Samios *et al.* (1962), Vittitoe *et al.* (1963), Kenney *et al.* (1963).

52. $m(\omega_{ABC})$ is a weighted average of
310 ± 10 A. Abashian *et al.* (1960, 1961a, b)
322 ± 8 B. Richter (1962).
Further evidence has been given by Button *et al.* (1962a) and Homer *et al.* (1963). The spin and parity assignments are from Abashian *et al.* (1963).

References

The following shortenings have been used below:

Aix = Proceedings of the Aix-en-Provence International Conference on Elementary Particles in 1961 (C.E.N. Saclay, Seine et Oise, France, 1962);

Athens = Proceedings of the Athens Topical Conference on Recently Discovered Resonant Particles (Ohio University, Athens, Ohio, 1963);

CERN = Proceedings of the 1962 International Conference on High-Energy Physics at CERN (CERN, Geneva, 1962);

Sienna = Proceedings of the Sienna International Conference on Elementary Particles (Frascati National Laboratories, Frascati, Italy, 1963)

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