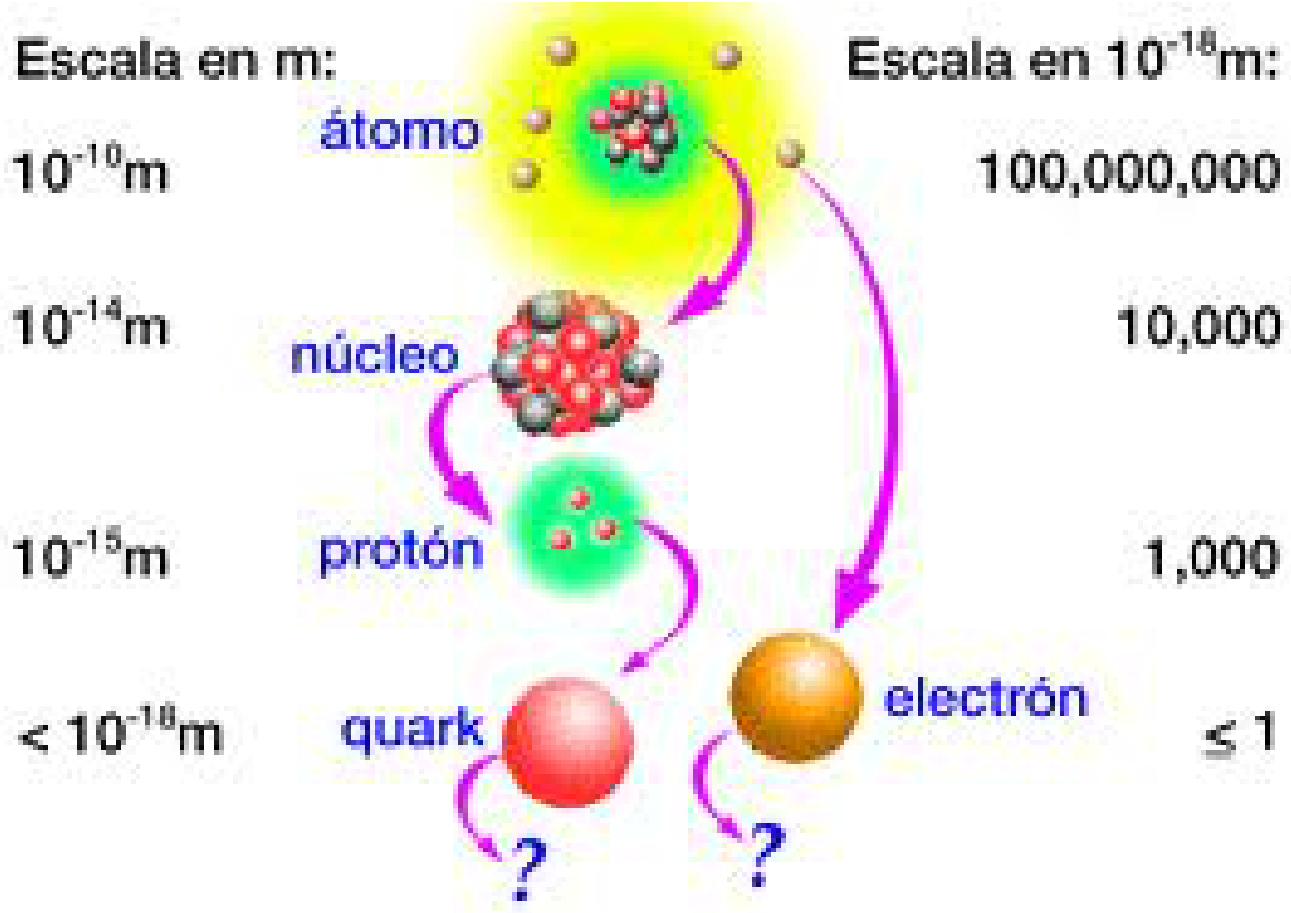
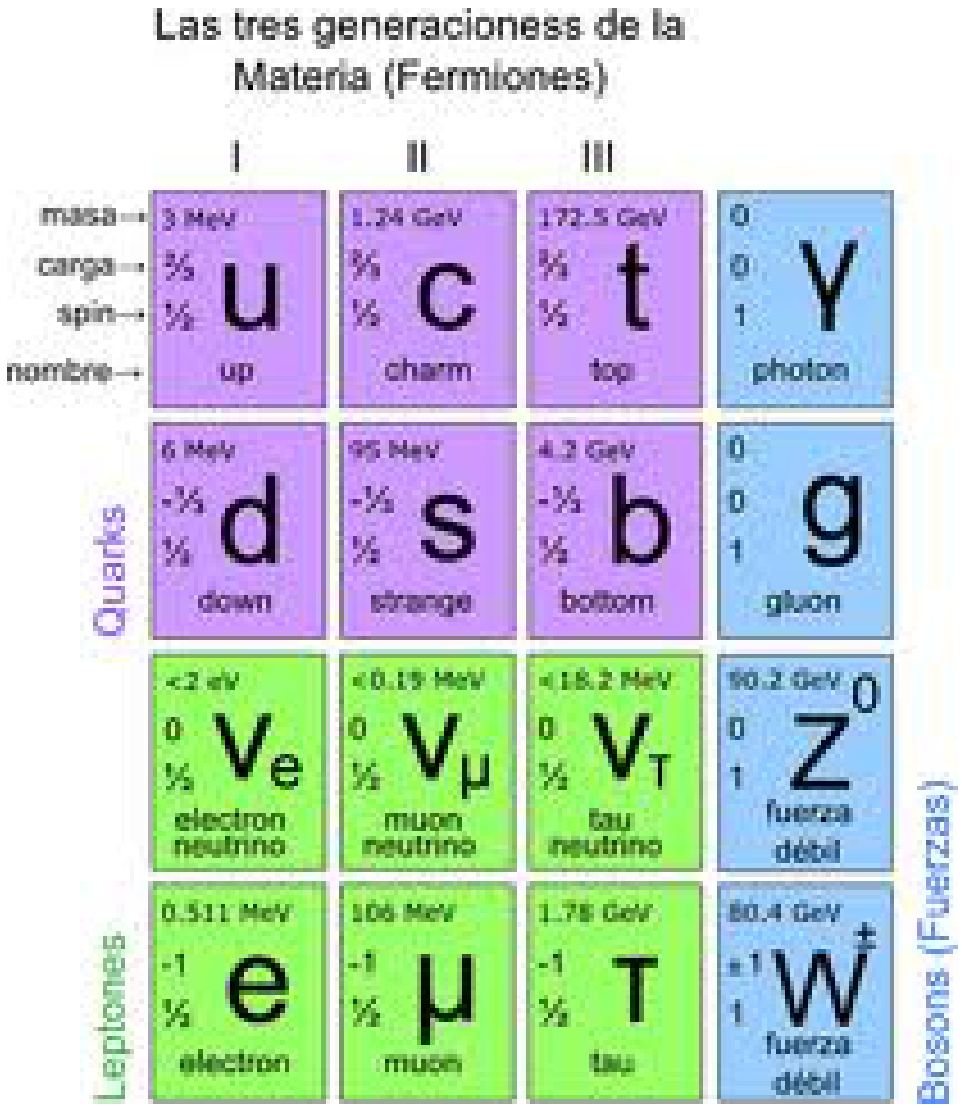
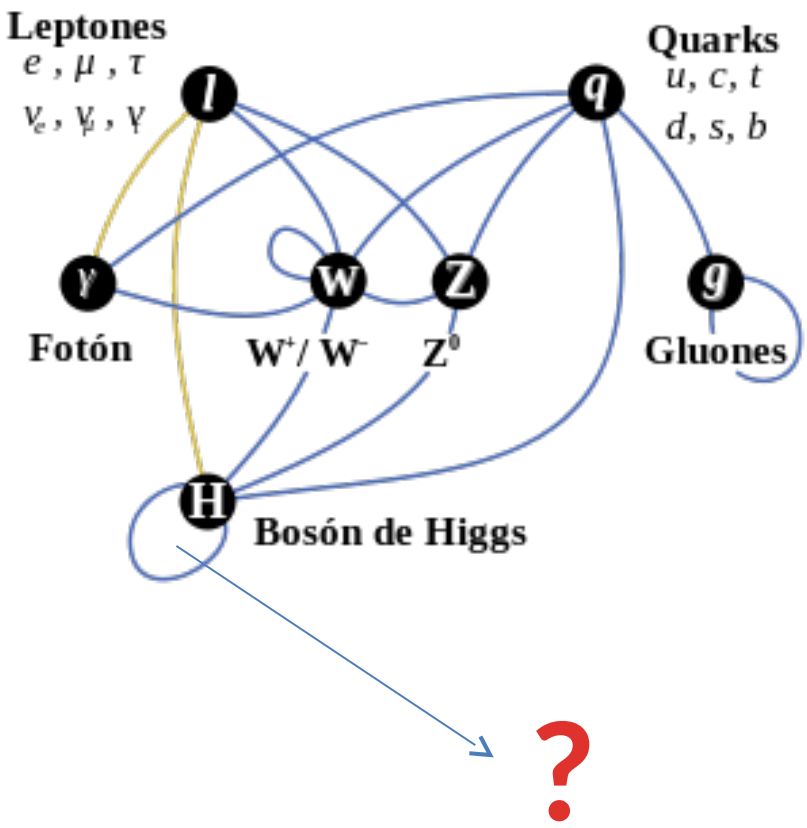
Introducción sobre partículas elementales



Partículas elementales





Quarkos ligeros

u

$$I(J^P) = \tfrac{1}{2}(\tfrac{1}{2}^+)$$

$m_u = 2.3^{+0.7}_{-0.5}$ MeV Charge $= \frac{2}{3}\ e$ $I_z = +\frac{1}{2}$

$m_u/m_d = 0.38$–0.58

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d

$$I(J^P) = \tfrac{1}{2}(\tfrac{1}{2}^+)$$

$m_d = 4.8^{+0.7}_{-0.3}$ MeV Charge $= -\frac{1}{3}\ e$ $I_z = -\frac{1}{2}$

$m_s/m_d = 17$–22

$\overline{m} = (m_u+m_d)/2 = 3.2$–$4.4$ MeV

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s

$$I(J^P) = 0(\tfrac{1}{2}^+)$$

$m_s = 95 \pm 5$ MeV Charge $= -\frac{1}{3}\ e$ Strangeness $= -1$

$m_s\ /\ ((m_u + m_d)/2) = 27 \pm 1$

Quarkos pesados

c

$I(J^P) = 0(\frac{1}{2}^+)$

$m_c = 1.275 \pm 0.025$ GeV Charge $= \frac{2}{3}\ e$ Charm $= +1$

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b

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= -\frac{1}{3}\ e$ Bottom $= -1$

$m_b(\overline{\text{MS}}) = 4.18 \pm 0.03$ GeV
$m_b(1\text{S}) = 4.65 \pm 0.03$ GeV

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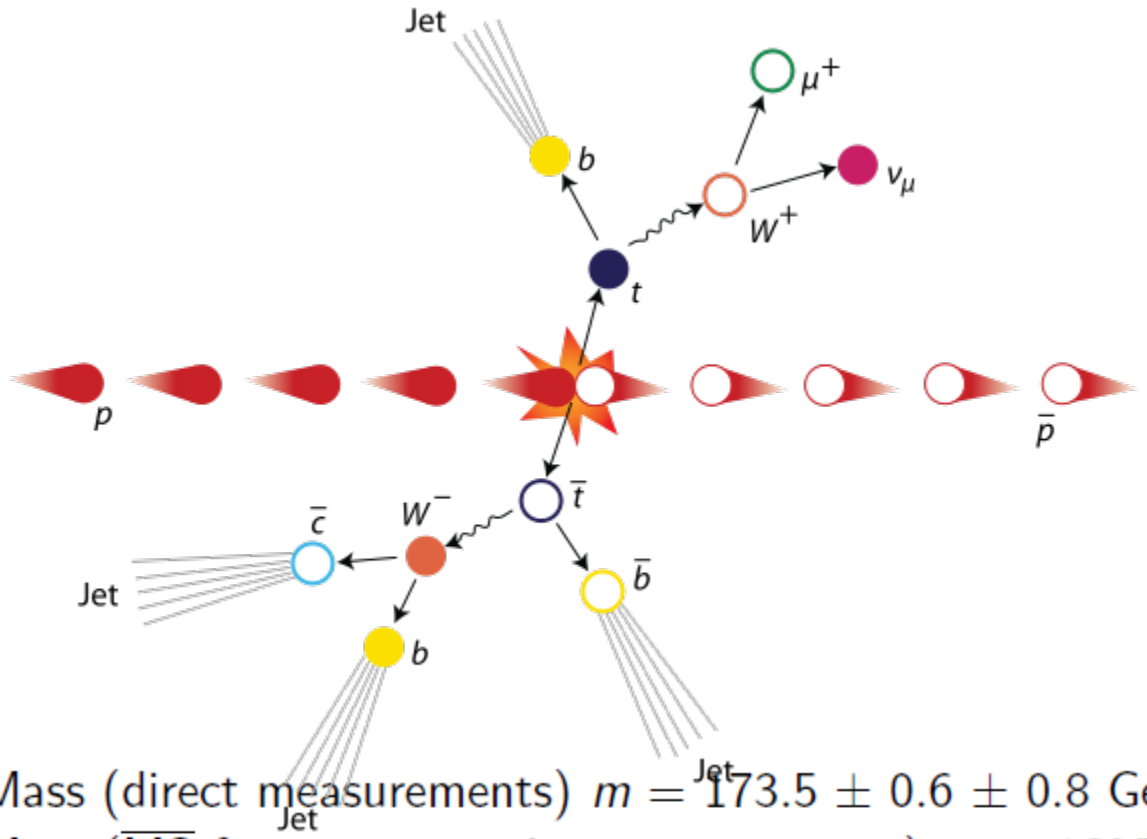
t

$I(J^P) = 0(\frac{1}{2}^+)$

Charge $= \frac{2}{3}\ e$ Top $= +1$

Mass (direct measurements) $m = 173.5 \pm 0.6 \pm 0.8$ GeV [a,b]
Mass ($\overline{\text{MS}}$ from cross-section measurements) $m = 160^{+5}_{-4}$ GeV [a]
$m_t - m_{\overline{t}} = -1.4 \pm 2.0$ GeV (S = 1.6)
Full width $\Gamma = 2.0^{+0.7}_{-0.6}$ GeV
$\Gamma(W\,b)/\Gamma(W\,q(q = b,\ s,\ d)) = 0.91 \pm 0.04$

Top quark



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Leptones electron

e

$$J = \frac{1}{2}$$

Mass $m = (548.57990946 \pm 0.00000022) \times 10^{-6}$ u

Mass $m = 0.510998928 \pm 0.000000011$ MeV

$|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$, CL = 90%

$|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$

Magnetic moment anomaly

$(g-2)/2 = (1159.65218076 \pm 0.00000027) \times 10^{-6}$

$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$

Electric dipole moment $d < 10.5 \times 10^{-28}$ $e$cm, CL = 90%

Mean life $\tau > 4.6 \times 10^{26}$ yr, CL = 90% [a]

Leptones, muon

μ

$$J = \tfrac{1}{2}$$

Mass $m = 0.1134289267 \pm 0.0000000029$ u
Mass $m = 105.6583715 \pm 0.0000035$ MeV
Mean life $\tau = (2.1969811 \pm 0.0000022) \times 10^{-6}$ s
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.6384$ m
Magnetic moment anomaly $(g-2)/2 = (11659209 \pm 6) \times 10^{-10}$
$(g_{\mu^+} - g_{\mu^-}) \,/\, g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$
Electric dipole moment $d = (-0.1 \pm 0.9) \times 10^{-19}\ e\,\text{cm}$

μ^- DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$e^- \overline{\nu}_e \nu_\mu$		$\approx 100\%$		53
$e^- \overline{\nu}_e \nu_\mu \gamma$	[d]	(1.4 ± 0.4) %		53
$e^- \overline{\nu}_e \nu_\mu e^+ e^-$	[e]	$(3.4 \pm 0.4) \times 10^{-5}$		53

Leptones, tau

τ

$$J = \frac{1}{2}$$

Mass $m = 1776.82 \pm 0.16$ MeV

$(m_{\tau^+} - m_{\tau^-})/m_{\text{average}} < 2.8 \times 10^{-4}$, CL = 90%

Mean life $\tau = (290.6 \pm 1.0) \times 10^{-15}$ s

$c\tau = 87.11\ \mu$m

Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%

$\text{Re}(d_\tau) = -0.220$ to $0.45 \times 10^{-16}\ e$cm, CL = 95%

$\text{Im}(d_\tau) = -0.250$ to $0.0080 \times 10^{-16}\ e$cm, CL = 95%

Neutrinos

Fermion	Symbol	Mass
Generation 1		
Electron neutrino	ν_e	< 2.2 eV
Electron antineutrino	$\bar{\nu}_e$	< 2.2 eV
Generation 2		
Muon neutrino	ν_μ	< 170 keV
Muon antineutrino	$\bar{\nu}_\mu$	< 170 keV
Generation 3		
Tau neutrino	ν_τ	< 15.5 MeV
Tau antineutrino	$\bar{\nu}_\tau$	< 15.5 MeV

Particulas complejos:hadrones

p

$p,\ N^+ = uud;\qquad I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1.00727646681 \pm 0.00000000009$ u
Mass $m = 938.272046 \pm 0.000021$ MeV [a]
$|m_p - m_{\overline{p}}|/m_p < 2 \times 10^{-9}$, CL = 90% [b]
$|\frac{q_{\overline{p}}}{m_{\overline{p}}}|/(\frac{q_p}{m_p}) = 0.99999999991 \pm 0.00000000009$
$|q_p + q_{\overline{p}}|/e < 2 \times 10^{-9}$, CL = 90% [b]
$|q_p + q_e|/e < 1 \times 10^{-21}$ [c]
Magnetic moment $\mu = 2.792847356 \pm 0.000000023\ \mu_N$
$(\mu_p + \mu_{\overline{p}}) / \mu_p = (-0.1 \pm 2.1) \times 10^{-3}$
Electric dipole moment $d < 0.54 \times 10^{-23}\ e\,\text{cm}$
Electric polarizability $\alpha = (12.0 \pm 0.6) \times 10^{-4}$ fm^3
Magnetic polarizability $\beta = (1.9 \pm 0.5) \times 10^{-4}$ fm^3
Charge radius = 0.877 ± 0.005 fm
Magnetic radius = 0.777 ± 0.016 fm
Mean life $\tau > 2.1 \times 10^{29}$ years, CL = 90% [d] ($p \rightarrow$ invisible mode)
Mean life $\tau > 10^{31}$ to 10^{33} years [d] (mode dependent)

Particulas complejos:hadrones

n $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 1.0086649160 \pm 0.0000000004$ u
Mass $m = 939.565379 \pm 0.000021$ MeV [a]
$(m_n - m_{\overline{n}})/\ m_n = (9 \pm 6) \times 10^{-5}$
$m_n - m_p = 1.2933322 \pm 0.0000004$ MeV
$= 0.00138844920(46)$ u
Mean life $\tau = 880.1 \pm 1.1$ s (S = 1.8)
$c\tau = 2.6383 \times 10^8$ km
Magnetic moment $\mu = -1.9130427 \pm 0.0000005\ \mu_N$

n DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$pe^-\overline{\nu}_e$	100 %		1
$pe^-\overline{\nu}_e\gamma$	[j] $(3.09 \pm 0.32) \times 10^{-3}$		1
Charge conservation (Q) violating mode			
$p\nu_e\overline{\nu}_e$	$Q < 8 \times 10^{-27}$	68%	1

Particulas complejos:hadrones

$N(1440)\ 1/2^+$ $\qquad I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Breit-Wigner mass = 1420 to 1470 ($\approx$ 1440) MeV
Breit-Wigner full width = 200 to 450 ($\approx$ 300) MeV
$p_{\text{beam}} = 0.61$ GeV/c $\qquad 4\pi\lambda\!\!\!^{-2} = 31.0$ mb
Re(pole position) = 1350 to 1380 ($\approx$ 1365) MeV
-2Im(pole position) = 160 to 220 ($\approx$ 190) MeV

***N*(1440) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–75 %	398
$N\eta$	(0.0±1.0) %	†
$N\pi\pi$	30–40 %	347
$\Delta\pi$	20–30 %	147
$\Delta(1232)\pi$, P-wave	15–30 %	147
$N\rho$	<8 %	†
$N\rho$, S=1/2, P-wave	(0.0±1.0) %	†
$N(\pi\pi)^{I=0}_{S\text{-wave}}$	10–20 %	–
$p\gamma$	0.035–0.048 %	414
$p\gamma$, helicity=1/2	0.035–0.048 %	414
$n\gamma$	0.02–0.04 %	413
$n\gamma$, helicity=1/2	0.02–0.04 %	413

Particulas complejos:hadrones

Δ BARYONS
$(S = 0, I = 3/2)$

$\Delta^{++} = uuu, \quad \Delta^{+} = uud, \quad \Delta^{0} = udd, \quad \Delta^{-} = ddd$

$\Delta(1232)\ 3/2^{+}$ $\qquad I(J^P) = \frac{3}{2}(\frac{3}{2}^{+})$

Breit-Wigner mass (mixed charges) = 1230 to 1234 ($\approx$ 1232) MeV

Breit-Wigner full width (mixed charges) = 114 to 120 ($\approx$ 117) MeV

$p_{\text{beam}} = 0.30$ GeV/c $\qquad 4\pi\lambda\!\!\!^{-2} = 94.8$ mb

Re(pole position) = 1209 to 1211 ($\approx$ 1210) MeV

-2Im(pole position) = 98 to 102 ($\approx$ 100) MeV

$\Delta(1232)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	100 %	229
$N\gamma$	0.55–0.65 %	259

Particulas complejos:hadrones

Λ BARYONS
$(S = -1, I = 0)$

$\Lambda^0 = uds$

Λ

$I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 1115.683 \pm 0.006$ MeV
$(m_\Lambda - m_{\overline{\Lambda}}) \,/\, m_\Lambda = (-0.1 \pm 1.1) \times 10^{-5}$ (S = 1.6)
Mean life $\tau = (2.632 \pm 0.020) \times 10^{-10}$ s (S = 1.6)

Λ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$p\pi^-$	(63.9 ±0.5) %	101
$n\pi^0$	(35.8 ±0.5) %	104
$n\gamma$	(1.75±0.15) $\times 10^{-3}$	162
$p\pi^-\gamma$	[l] (8.4 ±1.4) $\times 10^{-4}$	101
$pe^-\overline{\nu}_e$	(8.32±0.14) $\times 10^{-4}$	163
$p\mu^-\overline{\nu}_\mu$	(1.57±0.35) $\times 10^{-4}$	131

Particulas complejos:hadrones

CHARMED BARYONS
$(C = +1)$

$\Lambda_c^+ = udc, \quad \Sigma_c^{++} = uuc, \quad \Sigma_c^+ = udc, \quad \Sigma_c^0 = ddc,$
$\Xi_c^+ = usc, \quad \Xi_c^0 = dsc, \quad \Omega_c^0 = ssc$

Λ_c^+

$I(J^P) = 0(\frac{1}{2}^+)$

J is not well measured; $\frac{1}{2}$ is the quark-model prediction.

Mass $m = 2286.46 \pm 0.14$ MeV
Mean life $\tau = (200 \pm 6) \times 10^{-15}$ s (S = 1.6)

BOTTOM BARYONS
$(B = -1)$

$\Lambda_b^0 = udb, \Xi_b^0 = usb, \Xi_b^- = dsb, \Omega_b^- = ssb$

Λ_b^0

$I(J^P) = 0(\frac{1}{2}^+)$

$I(J^P)$ not yet measured; $0(\frac{1}{2}^+)$ is the quark model prediction.

Mass $m = 5619.4 \pm 0.7$ MeV
$m_{\Lambda_b^0} - m_{B^0} = 339.2 \pm 1.4$ MeV
$m_{\Lambda_b^0} - m_{B^+} = 339.7 \pm 0.7$ MeV
Mean life $\tau = (1.425 \pm 0.032) \times 10^{-12}$ s

Particulas complejos:hadrones

Σ BARYONS
$(S=-1, I=1)$

$\Sigma^+ = uus, \quad \Sigma^0 = uds, \quad \Sigma^- = dds$

Σ^+

$I(J^P) = 1(\frac{1}{2}^+)$

Mass $m = 1189.37 \pm 0.07$ MeV (S = 2.2)
Mean life $\tau = (0.8018 \pm 0.0026) \times 10^{-10}$ s

Σ^+ DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$p\pi^0$		(51.57±0.30) %		189
$n\pi^+$		(48.31±0.30) %		185
$p\gamma$		(1.23±0.05) $\times 10^{-3}$		225
$n\pi^+\gamma$	[I]	(4.5 ±0.5) $\times 10^{-4}$		185
$\Lambda e^+\nu_e$		(2.0 ±0.5) $\times 10^{-5}$		71

Particulas complejos:hadrones

Ω BARYONS
$(S = -3, I = 0)$

$\Omega^- = sss$

Ω^-

$I(J^P) = 0(\frac{3}{2}^+)$

$J^P = \frac{3}{2}^+$ is the quark-model prediction; and $J = 3/2$ is fairly well established.

Mass $m = 1672.45 \pm 0.29$ MeV
$(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\Omega^-} = (-1 \pm 8) \times 10^{-5}$
Mean life $\tau = (0.821 \pm 0.011) \times 10^{-10}$ s

Ω^- DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
ΛK^-		(67.8±0.7) %		211
$\Xi^0\pi^-$		(23.6±0.7) %		294
$\Xi^-\pi^0$		(8.6±0.4) %		289
$\Xi^-\pi^+\pi^-$		$(3.7^{+0.7}_{-0.6}) \times 10^{-4}$		189
$\Xi(1530)^0\pi^-$		$< 7 \times 10^{-5}$	90%	17
$\Xi^0 e^- \overline{\nu}_e$		$(5.6\pm2.8) \times 10^{-3}$		319
$\Xi^-\gamma$		$< 4.6 \times 10^{-4}$	90%	314
$\Delta S = 2$ forbidden ($S2$) modes				
$\Lambda\pi^-$	$S2$	$< 2.9 \times 10^{-6}$	90%	449

Particulas complejos:bariones

Ω_c^0

$$I(J^P) = 0(\tfrac{1}{2}^+)$$

J^P has not been measured; $\frac{1}{2}^+$ is the quark-model prediction.

Mass $m = 2695.2 \pm 1.7$ MeV (S = 1.3)
Mean life $\tau = (69 \pm 12) \times 10^{-15}$ s
$c\tau = 21\ \mu$m

No absolute branching fractions have been measured.

Ω_c^0 DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma^+ K^- K^- \pi^+$	seen	689
$\Xi^0 K^- \pi^+$	seen	901
$\Xi^- K^- \pi^+ \pi^+$	seen	830
$\Omega^- e^+ \nu_e$	seen	829
$\Omega^- \pi^+$	seen	821
$\Omega^- \pi^+ \pi^0$	seen	797
$\Omega^- \pi^- \pi^+ \pi^+$	seen	753

Particulas complejos:mesones

LIGHT UNFLAVORED MESONS ($S = C = B = 0$)

For $I = 1$ (π, b, ρ, a): $u\overline{d}$, $(u\overline{u}-d\overline{d})/\sqrt{2}$, $d\overline{u}$;
for $I = 0$ (η, η', h, h', ω, ϕ, f, f'): $c_1(u\overline{u} + d\overline{d}) + c_2(s\overline{s})$

$\pi^{\pm}$

$I^G(J^P) = 1^-(0^-)$

Mass $m = 139.57018 \pm 0.00035$ MeV (S = 1.2)
Mean life $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$ s (S = 1.2)

π^+ DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$\mu^+\nu_\mu$	[b]	(99.98770±0.00004) %		30
$\mu^+\nu_\mu\gamma$	[c]	(2.00 ±0.25) $\times 10^{-4}$		30
$e^+\nu_e$	[b]	(1.230 ±0.004) $\times 10^{-4}$		70
$e^+\nu_e\gamma$	[c]	(7.39 ±0.05) $\times 10^{-7}$		70
$e^+\nu_e\pi^0$		(1.036 ±0.006) $\times 10^{-8}$		4
$e^+\nu_e e^+e^-$		(3.2 ±0.5) $\times 10^{-9}$		70
$e^+\nu_e\nu\overline{\nu}$		< 5 $\times 10^{-6}$	90%	70

Particulas complejos:mesones

π^0

$$I^G(J^{PC}) = 1^-(0^{-+})$$

Mass $m = 134.9766 \pm 0.0006$ MeV (S = 1.1)
$m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$ MeV
Mean life $\tau = (8.52 \pm 0.18) \times 10^{-17}$ s (S = 1.2)

π^0 DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
2γ	(98.823±0.034) %	S=1.5	67
$e^+ e^- \gamma$	(1.174±0.035) %	S=1.5	67

Particulas complejos:mesones

η

$I^G(J^{PC}) = 0^+(0^{-+})$

Mass $m = 547.853 \pm 0.024$ MeV
Full width $\Gamma = 1.30 \pm 0.07$ keV

neutral modes	(71.91±0.34) %
charged modes	(28.10±0.34) %

$\rho(770)$ [h]

$I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 775.49 \pm 0.34$ MeV
Full width $\Gamma = 149.1 \pm 0.8$ MeV

$\pi\pi$	$\sim$ 100	%

$\omega(782)$

$I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 782.65 \pm 0.12$ MeV (S = 1.9)
Full width $\Gamma = 8.49 \pm 0.08$ MeV

$\pi^+\pi^-\pi^0$	(89.2 ±0.7) %
$\pi^0\gamma$	(8.28±0.28) %
$\pi^+\pi^-$	($1.53^{+0.11}_{-0.13}$) %

Particulas complejos:mesones

STRANGE MESONS
($S = \pm 1, C = B = 0$)

$K^+ = u\bar{s}$, $K^0 = d\bar{s}$, $\overline{K}^0 = \bar{d}s$, $K^- = \bar{u}s$, similarly for K^*'s

$K^\pm$

$I(J^P) = \frac{1}{2}(0^-)$

Mass $m = 493.677 \pm 0.016$ MeV [t] (S = 2.8)
Mean life $\tau = (1.2380 \pm 0.0021) \times 10^{-8}$ s (S = 1.9)

$\mu^+ \nu_\mu$	(63.55 ±0.11) %
$\pi^0 e^+ \nu_e$	(5.07 ±0.04) %
$\pi^0 \mu^+ \nu_\mu$	(3.353±0.034) %
$\pi^+ \pi^0$	(20.66 ±0.08) %
$\pi^+ \pi^0 \pi^0$	(1.761±0.022) %
$\pi^+ \pi^+ \pi^-$	(5.59 ±0.04) %

Particulas complejos:mesones

K^0_S

$$I(J^P) = \tfrac{1}{2}(0^-)$$

Mean life $\tau = (0.8954 \pm 0.0004) \times 10^{-10}$ s (S = 1.1) Assuming *CPT*

Mean life $\tau = (0.89564 \pm 0.00033) \times 10^{-10}$ s Not assuming *CPT*

K^0_L

$$I(J^P) = \tfrac{1}{2}(0^-)$$

$m_{K_L} - m_{K_S}$

$= (0.5293 \pm 0.0009) \times 10^{10}\ \hbar\ \text{s}^{-1}$ (S = 1.3) Assuming *CPT*

$= (3.484 \pm 0.006) \times 10^{-12}$ MeV Assuming *CPT*

$= (0.5289 \pm 0.0010) \times 10^{10}\ \hbar\ \text{s}^{-1}$ Not assuming *CPT*

Mean life $\tau = (5.116 \pm 0.021) \times 10^{-8}$ s (S = 1.1)