[more quarks]

[About 1965] Leptons ν_e ν_μ
e^- μ^-

Quarks u
d s

Glashow proposed a new "charmed" quark c [wouldn't it be charming?]
w/ a property called charm C

[Nov 1974] New meson discovered w/ $m \sim 3000$ MeV [→ our plot]

called { ψ [SLAC, Richter]
J [BNL, Ting]

↓ [PPB, toward end of mesons, p 116 in 2018 edition]

J/ψ = charmonium = $c\bar{c}$ $m \sim 3100$ MeV

$\Rightarrow m_c \sim 1500$ MeV

Other charmed mesons soon discovered

$D^+ = c\bar{d}$ } $m \sim 1900$ MeV
$D^0 = c\bar{u}$

$D_s^+ = c\bar{s}$ $m \sim 2000$ MeV

Charmed baryons

$\Sigma_c^{++} = ccu$ [analogous to $\Sigma \sim \begin{matrix} suu \\ sud \\ sdd \end{matrix}$]

$\Lambda_c^+, \Sigma_c^+ = cud$
$\Sigma_c^0 = cdd$

$\Xi_{cc}^{++} = ccu$
$\Xi_{cc}^{+} = ccd$ and $\Omega_{ccc}^{++} = ccc$

Nomenclature: Σ - 1 extra
Ξ - 2 extra
Ω - 3 extra

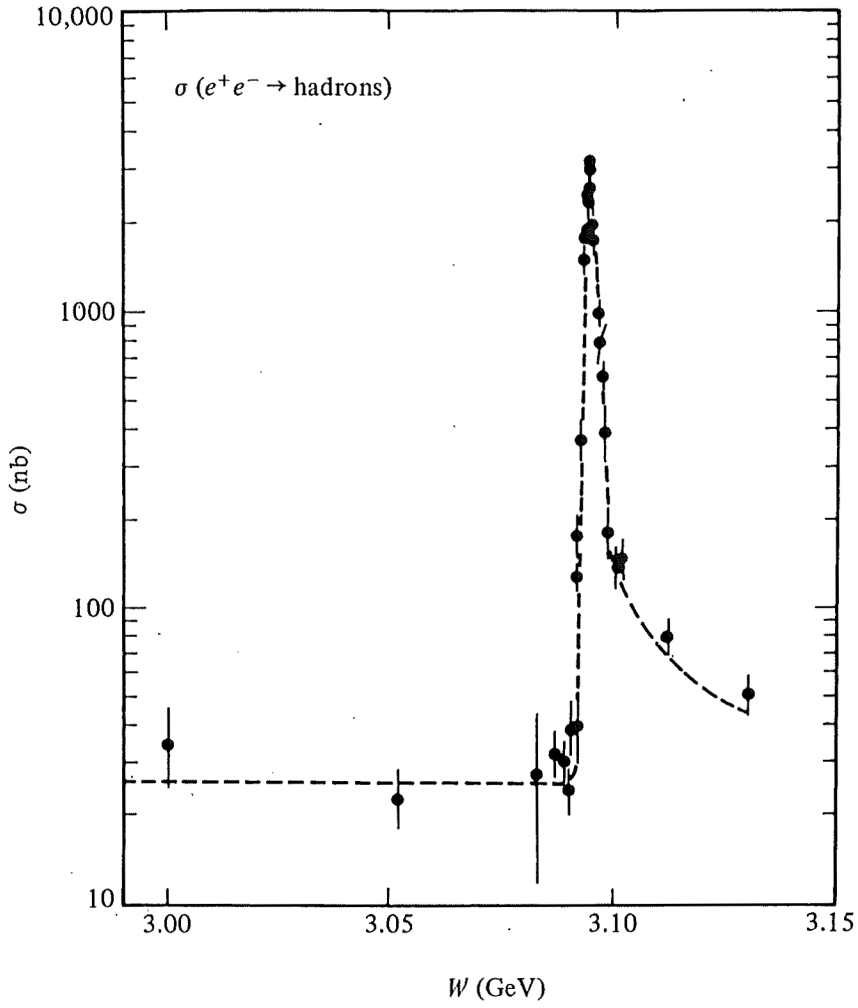
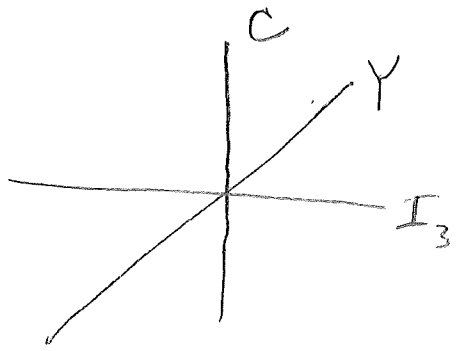


Fig. 10.23. Total hadron production cross section in e^+e^- collisions near 3.1 GeV and the J/ψ peak. [From A. M. Boyarski et al., *Phys. Rev. Lett.* **34,** 1357 (1975).]

[New quantum number ⇒ another dimension to weight diagram]

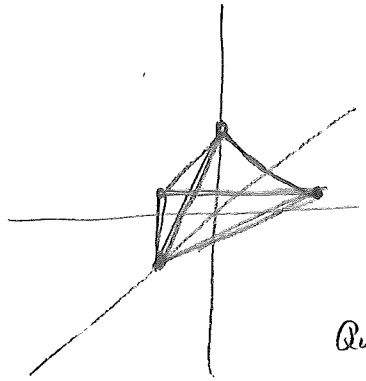


Use hypercharge Y instead of S

$$Y = S + A - \frac{1}{3}C$$

	I_3	A	S	C	Y
u	$\frac{1}{2}$	$\frac{1}{3}$	0	0	$\frac{1}{3}$
d	$-\frac{1}{2}$	$\frac{1}{3}$	0	0	$\frac{1}{3}$
c	0	$\frac{1}{3}$	0	1	0
s	0	$\frac{1}{3}$	−1	0	$-\frac{2}{3}$

[Prob: express Q as ...]



— tetrahedron

Quarks belong to $\underset{\sim}{4}$ of SU(4)

Mesons belong to $\underset{\sim}{4} \otimes \underset{\sim}{\bar{4}} = \underset{\sim}{15} \oplus \underset{\sim}{1}$

↑ cuboctahedron

Baryons belong to $\underset{\sim}{4} \otimes \underset{\sim}{4} \otimes \underset{\sim}{4} = \underset{\sim}{2^0} \oplus \underset{\sim}{2^0_S} \oplus \underset{\sim}{2^0} \oplus \underset{\sim}{\bar{4}}$

↑ pyramid; ↑ truncated pyramids; ↑ inverted tetrahedron

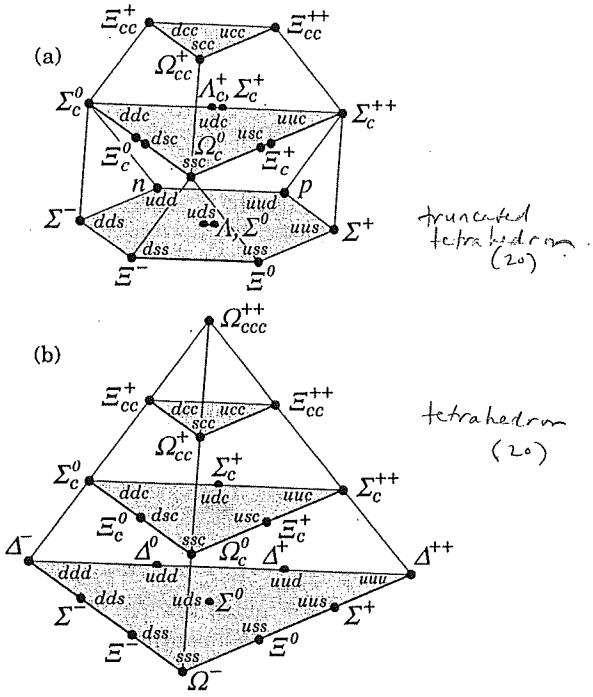


Figure 14.4: SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet. (b) The 20-plet with an SU(3) decuplet.

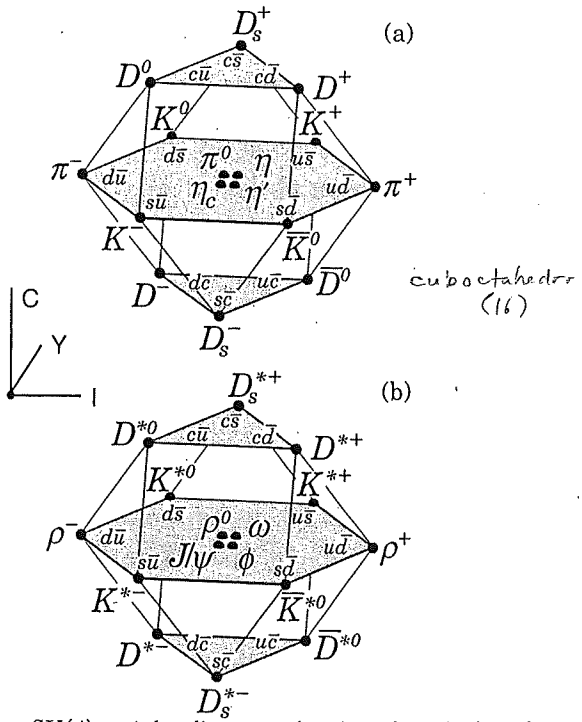


Figure 14.1: SU(4) weight diagram showing the 16-plets for the pseudoscalar (a) and vector mesons (b) made of the u, d, s and c quarks as a function of isospin I, charm C and hypercharge $Y = S + B - \frac{C}{3}$. The nonets of light mesons occupy the central planes to which the $c\bar{c}$ states have been added.

Σ_c^+, Λ_c^+ udc u d

Σ_c^{++} ucuu

Σ_c^0 cdd

Ξ_{cc}^{++} ccu

Ξ_{cc}^{+} ccd

Ω_{ccc}^{++} ccc

D^0 $c\bar{u}$

D^+ $c\bar{d}$ (1976)

D_s^+ $c\bar{s}$

Third generation

ν_e	ν_μ	ν_τ	(discv 1999)	
e^-	μ^-	τ^-	(disc 1975)	top/bottom
u	c	t	(disc 1994)	truth / beauty
d	s	b	(disc 1977)	

(1977) Υ = upsilon : bottomium $b\bar{b}$ $\quad m \sim 10$ GeV $\Rightarrow m_b \sim 5$ GeV

(1983) B-mesons : contain one b or $\bar{b}$ [analogous to K's, D's]

$B^+ = u\bar{b}$

$B^0 = d\bar{b}$

$B_s^0 = s\bar{b}$

$B_c^+ = c\bar{b}$ etc.

Beautiful baryon

(1981) $\Lambda_b = udb$

Top quark, long anticipated, not disc. until 1994 at Fermilab

Decays so quickly that no mesons are formed

$\Gamma \sim 1.4$ GeV $\Rightarrow 5 \times 10^{-25}$ s $\ll 10^{-23}$ s

Why such a wide range of quark masses?

Why 3 generations?