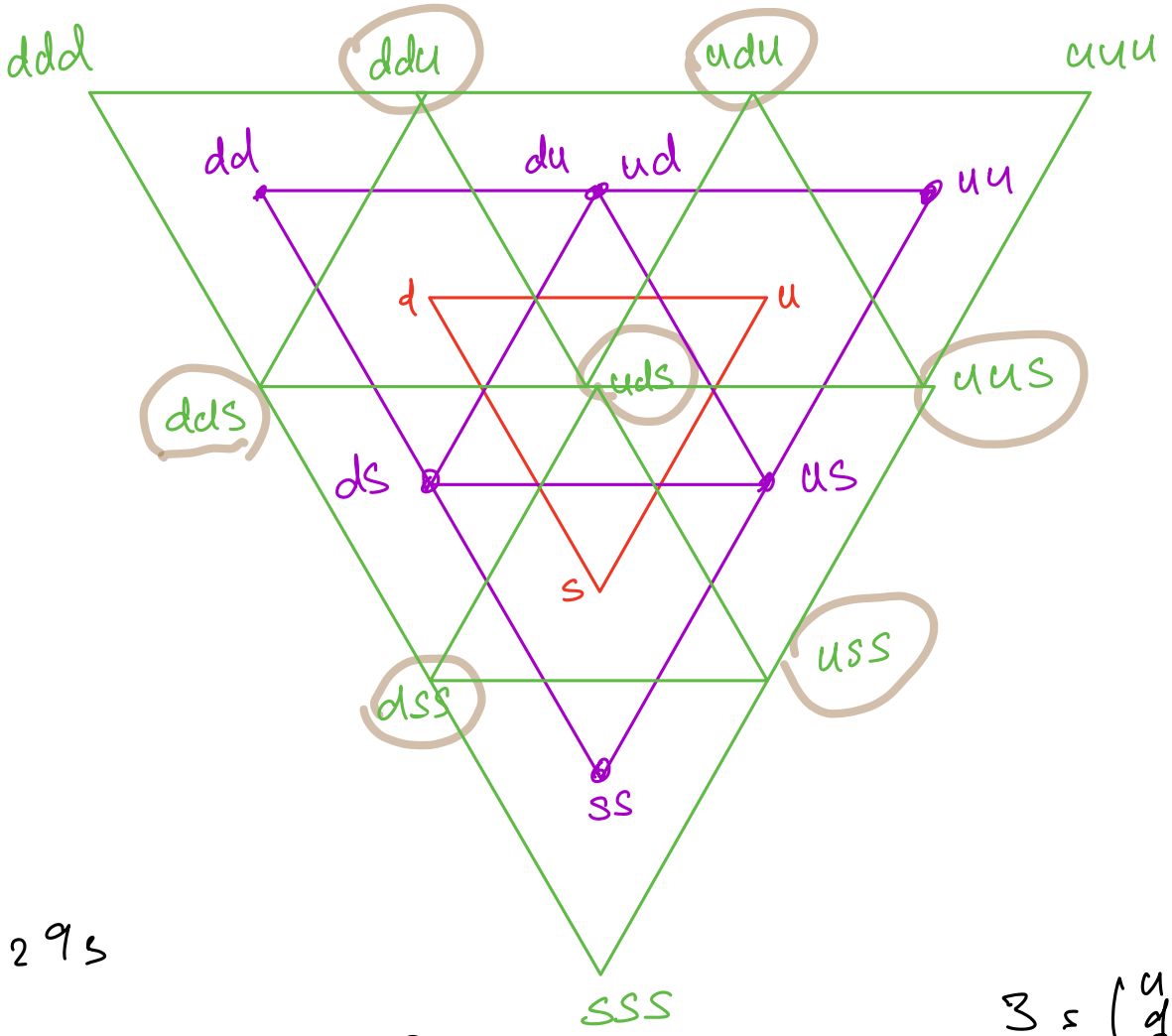


$q_1 q_2 q_3$

$3 \times 3 \times 3 = 1_A \oplus 8_{M_{12}} \oplus 8_{M_{23}} \oplus 10_S$

$3 = \begin{pmatrix} u \\ d \\ s \end{pmatrix}$

SU(3) flavor

possible states: 27

physical states: 18 = 10 + 8

$J = \frac{3}{2}$ $J = \frac{1}{2}$

S: $q_1 q_2 q_3$. symmetric under exchange of any quark

$q_i = u_i d_i s_i$.

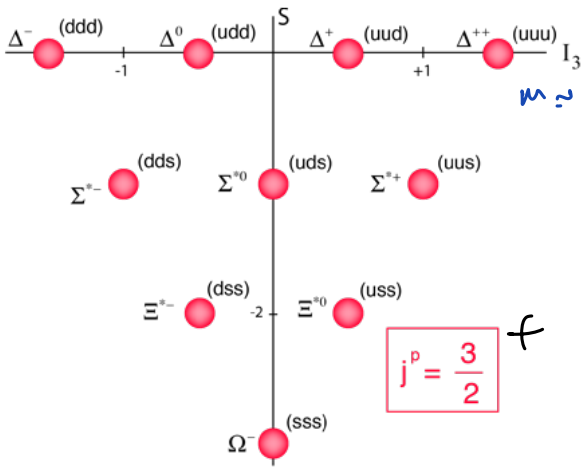
S ψ_{flavor} symm under $1 \leftrightarrow 2$, $2 \leftrightarrow 3$, $1 \leftrightarrow 3$

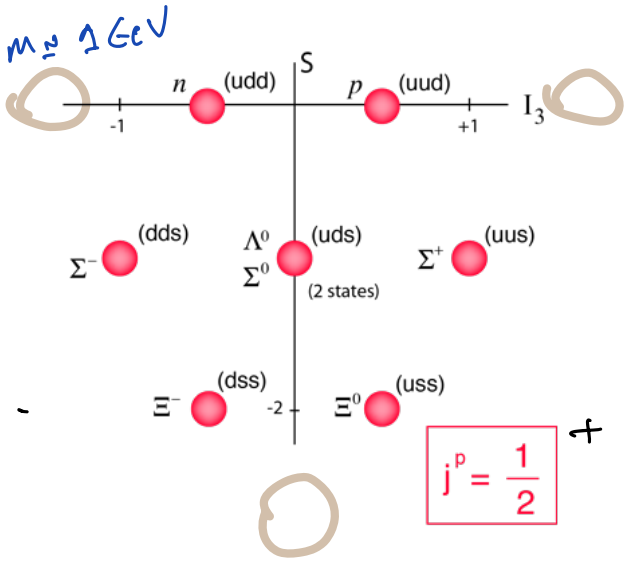
A: anti symm under $1 \leftrightarrow 2$, $2 \leftrightarrow 3$, $1 \leftrightarrow 3$

M_{12}: symm. under $1 \leftrightarrow 2$

M_{13}: symm. under $1 \leftrightarrow 3$

M_{23}: symm. under $2 \leftrightarrow 3$





quarks: $P_{int} = +1$

$P = (-1)^2 = +1$

Baryon: $q_1 q_2 q_3 \xrightarrow{C} \bar{q}_1 \bar{q}_2 \bar{q}_3$

$L = 0$ ground state lowest mass baryons.

Baryons	qqq	J^P	I	I_3	S	$Q^{(1)}$	mass (MeV)
p, n	uud, udd	$1/2^+$	½	½, -½	0	1, 0	~~940~~
Λ	uds	$1/2^+$	0	0	-1	0	1115
$\Sigma^+, \Sigma^0, \Sigma^-$	uus, uds, dds	$1/2^+$	1	1, 0, -1	-1	1, 0, -1	1190
Ξ^0, Ξ^-	uss, dss	$1/2^+$	½	½,-½	-2	1, 0	1320
$\Delta^{++}, \Delta^+, \Delta^0, \Delta^-$	uuu, uud, udd, ddd	$3/2^+$	3/2	$3/2, 1/2, -1/2, -3/2$	0	2, 1, 0, -1	1230
$\Sigma^{*+}, \Sigma^{*0}, \Sigma^{*-}$	uus, uds, dds	$3/2^+$	1	1, 0, -1	-1	1, 0, -1	1385
Ξ^{*0}, Ξ^{*-}	uss, dss	$3/2^+$	½	½,-½	-2	1, 0	1530
Ω^-	sss	$3/2^+$	0	0	-3	-1	1670

$\Delta m \simeq 150$ MeV
$\Delta m \simeq 150$ MeV
$\Delta m \simeq 150$ MeV

1962: No Ω^- seen yet

Some year Ξ^* $m = 1530$ MeV

Expected mass of Ω^-: $1530 + 150 = 1680$ MeV

$B = +\frac{1}{3}$ quarks.

Ω^- should be sss! Isospin $= 0$

$$Q = I_3 + \frac{B+S}{2} = -1$$

suppose we produce Ω^- with $m = 1680$ MeV.
what decay modes?

EM, strong decay: $\Delta S = 0$

$$\Omega^- \longrightarrow X + Y$$

S	-3	-2	-1
		-1	-2

EM: $\Omega^- \longrightarrow X^{S=-3} + \gamma + \gamma$

strong: $\Omega^- \longrightarrow \Xi^{*-} + \bar{K}^0$

S	-3	-2	-1	
mass	1680	1530	500 MeV	$Q < 0$
Q	-1	-1	$\emptyset$	
B	1	1	$\emptyset$	

Strangeness-conserving strong decay has no phase space

Possible decay: $\Omega^- \longrightarrow \Xi^0 + \pi^-$

$\Xi^- + \pi^0$

S	-3	-2	$\emptyset$	$\Delta S = 1 \Rightarrow$ weak decay.
mass	1680	1320	140	$Q > 0$ $Q = 220$ MeV

$\Lambda^0 + K^-$ $\Delta S = 1$

S	-1	-1	$= 1615$
	1115	500	

$Q = 85$ MeV

$\Gamma \propto |M|^2 \rho(E_f)$.

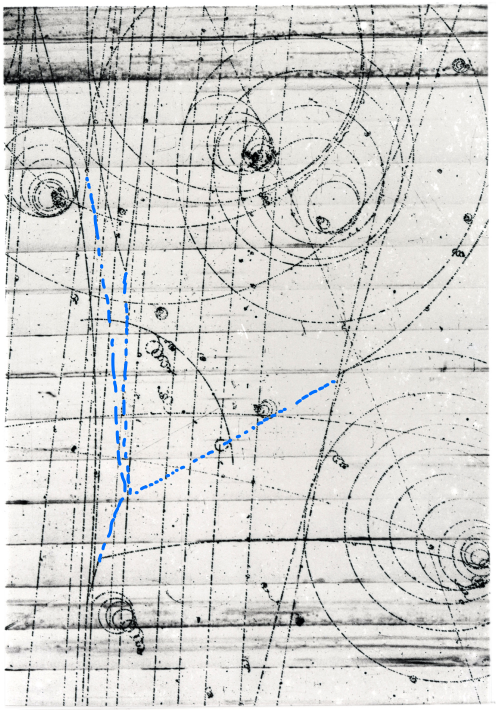
$M_1 = \langle \Lambda^0 K^- | H_I | \Omega^- \rangle$ $\quad \rho_1 : \Omega^- \to \Lambda^0 K^-$

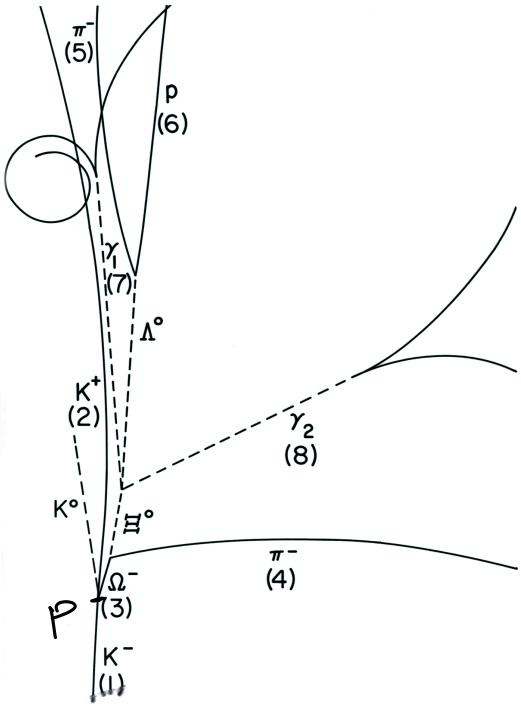
$M_2 \quad \langle \Xi \pi | H_I | \Omega^- \rangle$ $\quad \rho_2 : \Omega^- \to \Xi \pi$

$$\frac{|M_1|}{|M_2|} \sim O(1)$$

$$\rho(\Omega^- \to \Xi \pi) > \rho(\Omega^- \to \Lambda^0 K^-)$$

1964: Experimental evidence @ Brookhaven Nat. Lab.
Nick Samios using bubble chambers





$K^- + p \to \Omega^- + K^+ + K^0$

0 1 1 0 0 B

-1 0 -3 1 +1 S

$\Omega^- \to \Xi^0 + \pi^0$ S

-3 -2 0

$\Delta S = 1$

weak decay.

strong int. $\tau \sim 10^{-23}$ s.

weak $\tau \simeq 10^{-10} - 10^{-8}$ s

$\Xi^0 \to \Lambda^0 + \pi^0$

S -2 -1 0

$\hookrightarrow \gamma\gamma \hookrightarrow e^+e^- \; e^+e^-$ } γ conversion pair production.

$\hookrightarrow p + \pi^-$

S 0 0

SU(3)$_F$ with u, d, s.

Extension to more quarks

Isospin SU(2) symm. between n, p

strangeness SU(3) symm. between baryons, mesons.
Quark Model

SU(N)
N^2-1 generators.
$N-1$ diagonal generators $\longrightarrow$ physical observ.

SU(2) $\longrightarrow$ I_3 $\quad m_p \simeq m_n$

SU(3) $\longrightarrow$ I_3, S $\quad m_u \simeq m_d \neq m_s$

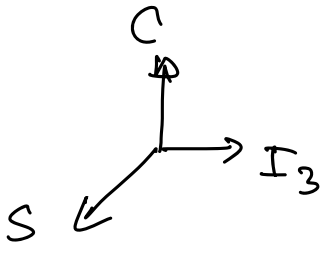
a fourth quark: charm c

SU(4)$_F$

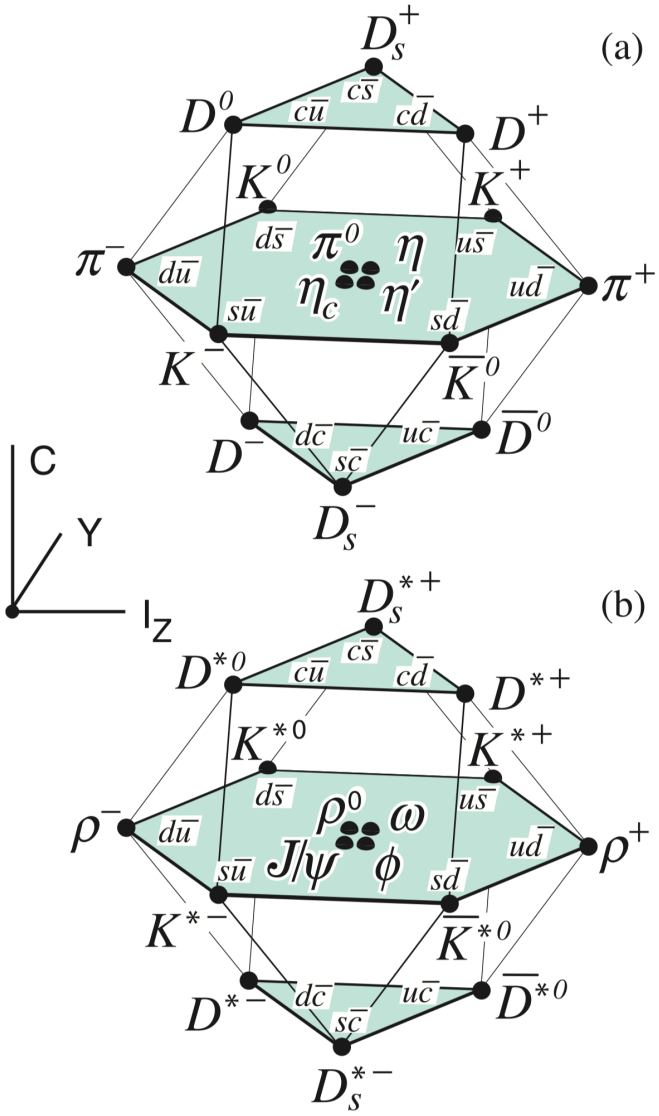
$N-1 = 3$ generators $\quad I_3, S, C$

$$Q = I_3 + \frac{B+S+C}{2}$$

$$\begin{pmatrix} u \\ d \\ s \\ c \end{pmatrix} \equiv 4$$



Meson: $4 \otimes \bar{4} = 1 \oplus 15$



$c\bar{u}$ $c\bar{d}$ $c\bar{s}$

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix}$

D^0 D^+ D_s^+

$D^0 \simeq 1860$ MeV.

$D^* \simeq 2010$ MeV

$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$

B mesons: $b\bar{u}$ B^- $m_B \simeq 5279$ MeV

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

$\rho^0 \to \pi^+\pi^-$

770 2x140

$B^0 \to D^+ \pi^-$

Symmetry Problem

small but relevant

Δ^{++} baryon. uuu ⇑ ⇑ ⇑

$L = 0$.
$S = \frac{3}{2} \Rightarrow J = 3/2$

$P = (-1)^L = +1$.

$\psi_{\Delta^{++}} = \psi_{space}\ \psi_{spin}\ \psi_{flavor}$.

u⇑ u⇑ u⇑
1 2 3

ψ_{space} symm. ψ_{spin} symm ψ_{flavor} symm.

Δ^{++} fermion $\Rightarrow$ $\psi_{\Delta^{++}}$ must be antisymm.

$\psi_{\Delta^{++}} = \psi_{space}\ \psi_{spin}\ \psi_{flavor}\ \psi_{color}$

ψ_{color} antisymm

$u_B^{\uparrow}\ u_B^{\uparrow}\ u_R^{\uparrow}$ 2 colors B, R

⟷ does not work.

$u_B^{\uparrow}\ u_R^{\uparrow}\ u_G^{\uparrow}$ 3 colors B, R, G.

$$\psi_{color} = \left(|RBG\rangle + |BGR\rangle + |GRB\rangle + |BRG\rangle - |RGB\rangle - |GBR\rangle \right) \frac{1}{\sqrt{6}}$$