

Ispin

introdotto da Heisenberg per spiegare inter forte / nucleare
per neutroni e protoni (nucleoni)

Ispin simile ad momento angolare

$$\text{nucleone} = \begin{pmatrix} p \\ n \end{pmatrix} \quad p = \left| \frac{1}{2}, +\frac{1}{2} \right\rangle \quad I_z = \frac{1}{2} \quad I_3 = +\frac{1}{2}$$

$$n = \left| \frac{1}{2}, -\frac{1}{2} \right\rangle$$

Meson: π : π^+ , π^0

$$M_{\pi^+} \approx 140 \text{ MeV} \quad \text{simili}$$

$$M_{\pi^0} \approx 135 \text{ MeV}$$

$$|\pi^+\rangle = |I=1, I_3=+1\rangle \quad |\pi^0\rangle = |1, 0\rangle, \quad (\pi^-) = |1, -1\rangle$$

utilizzare l'isospin

1) classificazione di adroni scoperti (o da scoprire)

2) stimare sezione d'urto di processi fort.

3) provare esistenza di alcuni stati ancora non osservati

Ispin si conserva nelle interazioni fort.

\Rightarrow Trasf. di Flispin è con simm. delle HF.

$$\Delta I = 0 \quad |i\rangle \xrightarrow{\text{HF}} |f\rangle. \quad I_3 \equiv I_2$$

$$I, I_3 \qquad \qquad \qquad f, I_3$$

Deuteron

$$\text{stato legato} \quad np \quad {}^2_H$$

$$n = \left| \frac{1}{2}, -\frac{1}{2} \right\rangle \quad p = \left| \frac{1}{2}, +\frac{1}{2} \right\rangle.$$

$$np \quad I = ? \quad I_3 = ?$$

$$np : I_3 = \frac{1}{2} - \frac{1}{2} = 0 \quad I = 0, 1.$$

tipi di protoni:

$$\left\{ \begin{array}{l} pp := |\frac{1}{2} \frac{1}{2} > | \frac{1}{2} \frac{1}{2} > = |1, +1> \quad I_3 = +1, I = 1. \\ pu := \frac{1}{\sqrt{2}} | \frac{1}{2} \frac{1}{2} > | \frac{1}{2} \frac{-1}{2} > + \frac{1}{\sqrt{2}} | \frac{1}{2} \frac{-1}{2} > | \frac{1}{2} \frac{-1}{2} > \quad I = 1, I_3 = 0. \\ nn := | \frac{1}{2} \frac{-1}{2} > | \frac{1}{2} \frac{-1}{2} > = |1, -1> \quad I = 1. \end{array} \right.$$

pn: $\frac{1}{\sqrt{2}} (| \frac{1}{2} \frac{1}{2} > | \frac{1}{2} \frac{-1}{2} > - | \frac{1}{2} \frac{1}{2} > | \frac{1}{2} \frac{-1}{2} >)$

$I = 0, I_3 = 0.$

singololetti di isotropia.

Se isotropia è una simmetria forte nucleare.

Se np è ($I=1, I_3=0$) \Rightarrow either pp or nn

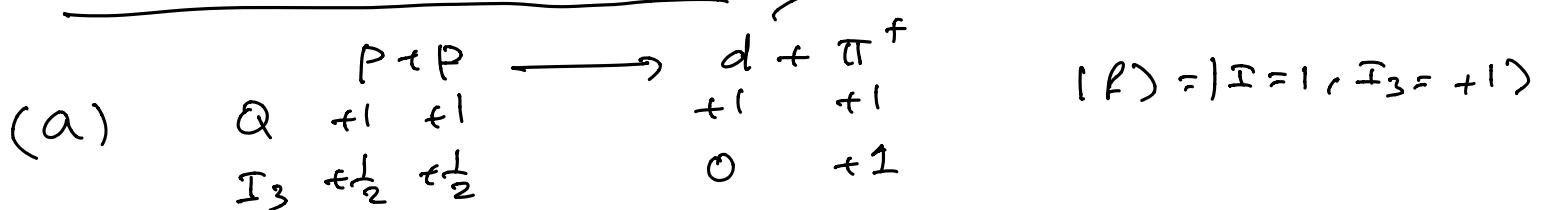
ma spicciatamente non esistono pp, nn.

\Rightarrow np è $I=0, I_3=0$.

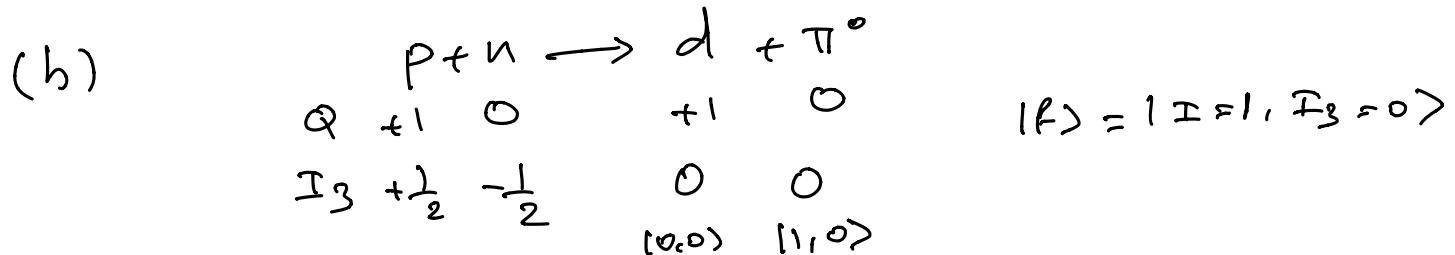
Singololetti di isotropia.

dettone (nucleo del deuterio) $I=0$

Isotropie sezioni d'urto.



$$|i\rangle = |I=1, I_3=+1\rangle$$



$$p_{\text{en}} = \frac{1}{\sqrt{2}} (|1,0\rangle + |0,0\rangle)$$

$$\therefore I_3 = 0. \quad I = 0, 1$$

$$|\psi\rangle = \frac{1}{\sqrt{2}} (|1,0\rangle + |0,0\rangle) \rightarrow |\psi\rangle = |1,0\rangle$$

(c) $n + u \rightarrow d + \pi^-$

I_3	$-\frac{1}{2}$	$-\frac{1}{2}$	0	-1	$(f) = 1, -1\rangle$
Q	0	0	$+1$	-1	

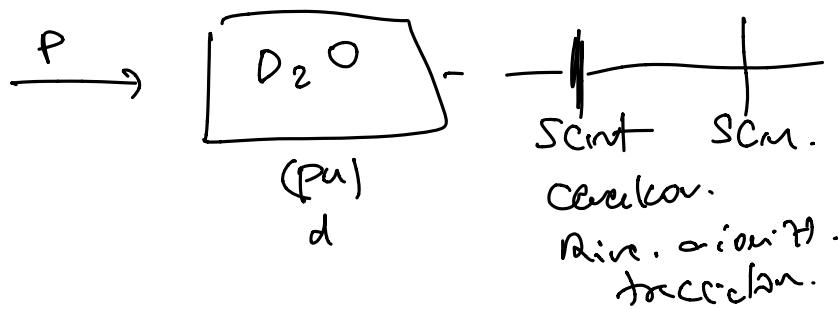
$|1,1\rangle$

$$\mu_a : \mu_b : \mu_c = 1 : \frac{1}{\sqrt{2}} : 1$$

$\propto M_f^2$ (regole di Fermi).

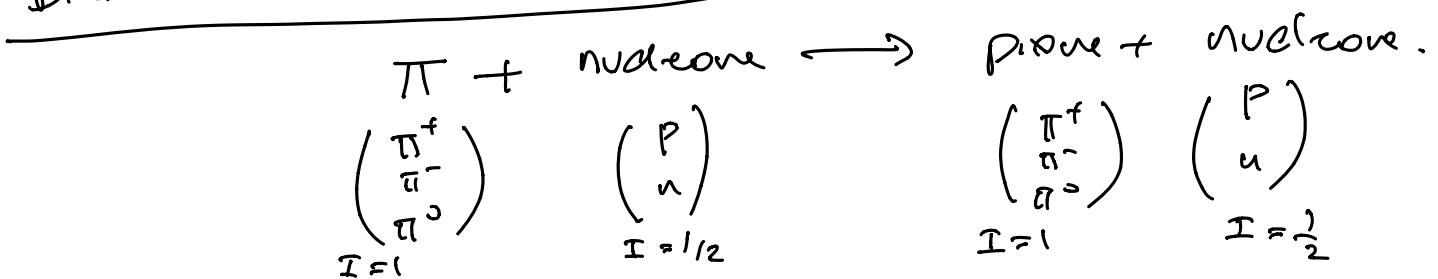
$$\sigma_a : \sigma_b : \sigma_c \doteq 1 : \frac{1}{2} : 1$$

$$N(p+p \rightarrow d + \pi^+) : N(p+u \rightarrow d + \pi^0) = 2 : 1$$



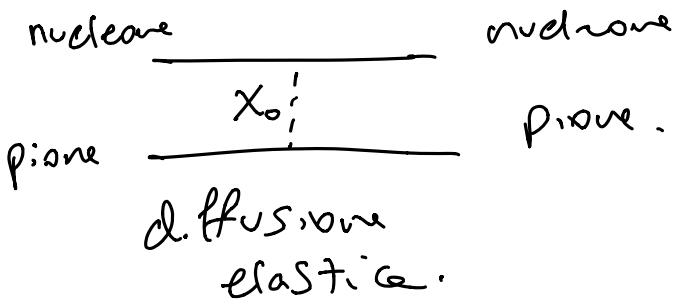
Si è misurato $\frac{\sigma_a}{\sigma_b} \approx 2$

Diffusione pione-nucleone:



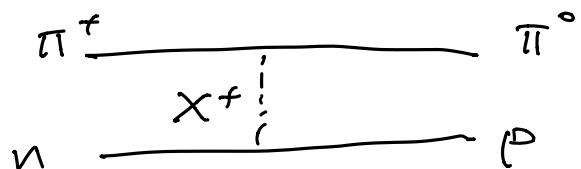


↑
↓
↓



$\rightarrow t$

processi: con scambi di Coul



pione + nucleone

$|I=1, a\rangle + |I=\frac{1}{2}, b\rangle = \alpha |I=\frac{3}{2}, I_3=a+b\rangle +$

$\beta |I=\frac{1}{2}, I_3=a+b\rangle .$

Table 3.3. Clebsch-Gordan coefficients in pion-nucleon scattering

Pion	Nucleon	$I = \frac{3}{2}$				$I = \frac{1}{2}$	
		$I_3 = \frac{3}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{3}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
π^+	p	1					
π^+	n		$\sqrt{\frac{1}{3}}$			$\sqrt{\frac{2}{3}}$	
π^0	p		$\sqrt{\frac{2}{3}}$			$-\sqrt{\frac{1}{3}}$	
π^0	n			$\sqrt{\frac{2}{3}}$			$\sqrt{\frac{1}{3}}$
π^-	p			$\sqrt{\frac{1}{3}}$			$-\sqrt{\frac{2}{3}}$
π^-	n				1		



$$|i\rangle = \alpha |I=3/2\rangle + \beta |I=1/2\rangle \quad |f\rangle = \gamma |I=3/2\rangle + \delta |I=1/2\rangle$$

$$\langle f | H_F | i \rangle = A \langle f, I=3/2 | H_3 | i, I=3/2 \rangle + B \langle f, I=1/2 | H_1 | i, I=1/2 \rangle$$

$$H_F = H_3 + H_1 \quad \begin{matrix} \text{se inter forte} \\ \text{conservate} \pm \text{spin} \end{matrix}$$

$$\Delta I = 0$$

$$I_f = I_i$$

$$\sigma \propto |M_{fi}|^2$$

$$M_{fi} = \langle f | H_F | i \rangle = a M_3 + b M_1$$

$$N(\text{event.}) \propto \sigma \propto |M_{fi}|^2 \propto (a^2 M_3)^2 + (b^2 M_1)^2 + ab M_1 M_3$$

Sperimentalmente 3 reazioni che si osservano.

$$(a) \pi^+ + p \rightarrow \pi^+ + p \quad M_a = M_3$$

$$\sigma_a \propto (M_3)^2$$

$$(f) \pi^- + n \rightarrow \pi^- + n \quad M_f = M_3$$

$$\sigma_f \propto (M_3)^2$$

$$\mu_i \propto \text{aspetto} \quad N(\pi^+ + p \rightarrow \pi^+ + p) = N(\pi^- + n \rightarrow \pi^- + n)$$

$$(c) \pi^- + p \rightarrow \bar{\pi}^- + p \quad M_c = \frac{1}{3} M_3 + \frac{2}{3} M_1$$

$$(j) \pi^- + p \rightarrow \pi^0 + n \quad M_j = \frac{\sqrt{2}}{3} (M_3 - M_1)$$

$$(a) \pi^+ + p \rightarrow \pi^+ + p \quad N_a \propto \sigma_a \propto |M_3|^2$$

$$(c) \pi^- + p \rightarrow \pi^- + p \quad N_c \propto \sigma_c \propto \left(\frac{1}{3} M_3 + \frac{2}{3} M_1 \right)^2 \\ = \frac{1}{9} (M_3 + 2M_1)^2$$

$$(j) \pi^- + p \rightarrow \pi^0 + n \quad N_j \propto \sigma_j \propto \frac{2}{9} |M_3 - M_1|^2$$

2 Scenari:

$$M_1 \gg M_3$$

$$\sigma_a \approx 0$$

$$\sigma_c \approx \frac{4}{9} |M_1|^2$$

$$\sigma_j \approx \frac{2}{9} |M_1|^2$$

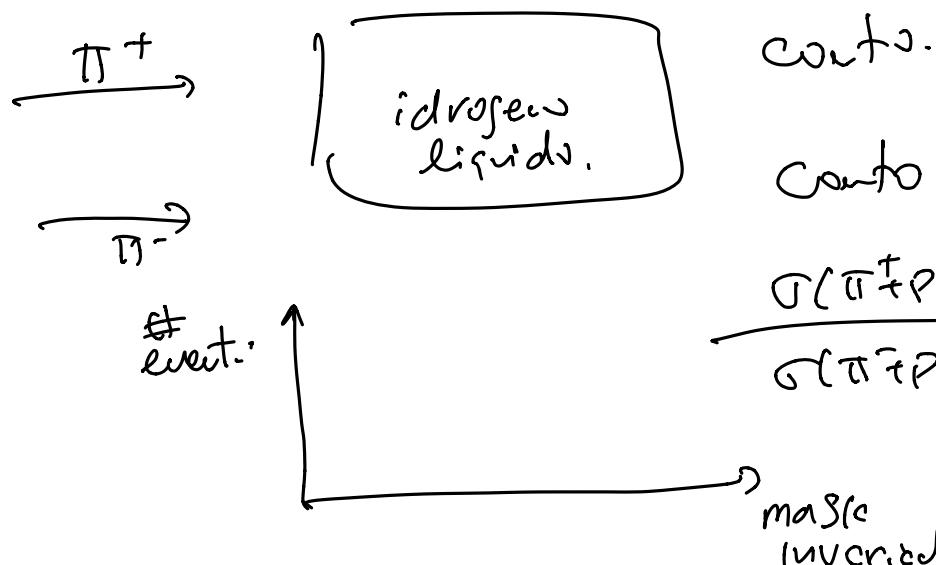
N eventi: 0 : 2 : 1

$$M_3 \gg M_1 \quad (a) \quad \sigma_a \approx |M_3|^2 \quad \pi^+ + p \rightarrow \pi^+ + p.$$

$$(c) \quad \sigma_c \approx \frac{1}{9} |M_3|^2 \quad \pi^- + p \rightarrow \pi^- + p.$$

$$(j) \quad \sigma_j \approx \frac{2}{9} |M_3|^2 \quad \pi^- + p \rightarrow \pi^0 + n$$

$$\frac{N(\pi^+ + p)}{N(\pi^- + p)} = \frac{\sigma_a}{\sigma_j + \sigma_c} = \frac{\frac{1}{9}}{\frac{2}{9} + \frac{1}{9}} = \frac{1}{3} = 3$$



$$\frac{\sigma(\pi^+ + p)}{\sigma(\pi^- + p)} = \frac{N(\pi^+ + p)}{N(\pi^- + p)}$$

$$\frac{N(\pi^+ p)}{N(\pi^- p)} \approx 3$$

Counterme
di isospin

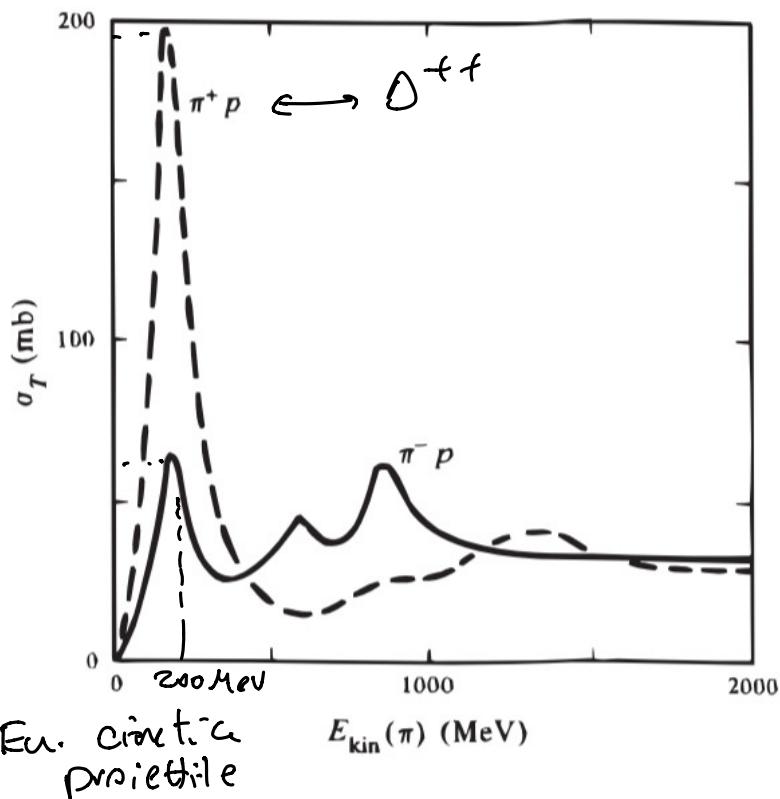


Figure 5.35: Total cross section as a function of pion kinetic energy for the scattering of positive and negative pions from protons. ($1 \text{ mb} = 1 \text{ millibarn} = 10^{-27} \text{ cm}^2$.)

Relazione fra il isospin e la Carga

Nucleo $A = Z + N$.

l'isospin del nucleo $I_3 = Z \times \frac{1}{2} + N \left(-\frac{1}{2}\right)$

$$= \frac{Z}{2} - (A - Z) \frac{1}{2}$$

$$\Rightarrow Z = I_3 + \frac{A}{2}$$

Z : Carga in unità di e.

A : # boriani:

Gell-Mann - Nishijima hanno proposto.

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

B: numero beniano.

p: $Q = \frac{1}{2} + \frac{1}{2} = 1$.

n: $-\frac{1}{2} + \frac{1}{2} = 0$.

funzione anche per i mesoni: $\pi : I = 1, I_3 \in (-1, 0, +1)$.

$$\pi^f: Q = +1 + \frac{0}{2} = +1.$$

Formule rotte dalle scoperte delle particelle strane:

$$(K^+): +1 = Q.$$

$$Q = I_3 + \frac{B}{2} = +\frac{1}{2} + \frac{0}{2} = +\frac{1}{2}. \quad 0.$$

Modifica delle formule:

$$I_{\text{per carica}}: Y = B + S \xrightarrow{\text{stranezza}}$$

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

1974 scoperte del charm. (quark).

1977 beauty / bottom.

1995 top.

$$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} + \\ b \end{pmatrix}$$
$$\hookrightarrow I = \frac{1}{2} \quad u = \left| \frac{1}{2}, +\frac{1}{2} \right\rangle$$
$$d = \left| \frac{1}{2}, -\frac{1}{2} \right\rangle$$

isospin:
 $|C\rangle = |S\rangle = |t\rangle = |b\rangle$
 $= |0,0\rangle.$

nuovi num.夸克: S_f : stranezza.

c: charm.

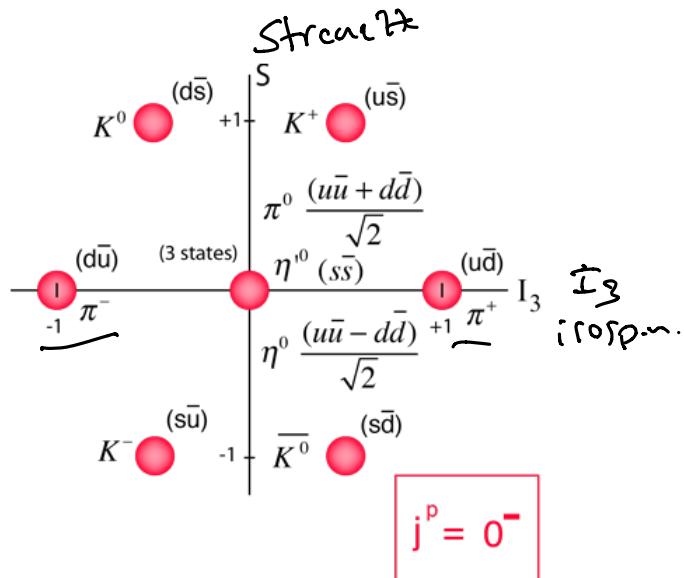
b: beauty.

t: top. $\xrightarrow{* \text{夸克}}$

$$Q = I_3 + \frac{B+S+C+b+t}{2} \xrightarrow{Y} I_{\text{per carica}}$$

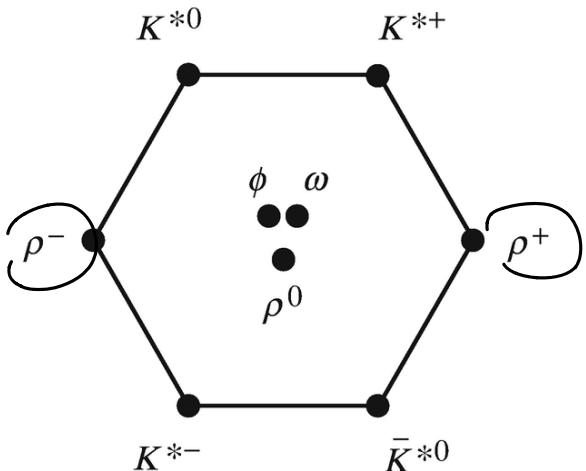
quarks.	num. quarks/c.	
\bar{s}	strange = +1.	s
\bar{b}	beauty = +1	b
\bar{c}	$c = +1$	\bar{c}
\bar{t}	$t = +1$	$t = -1$
		Chem. # quarks.

Meson: PseudoScalar:



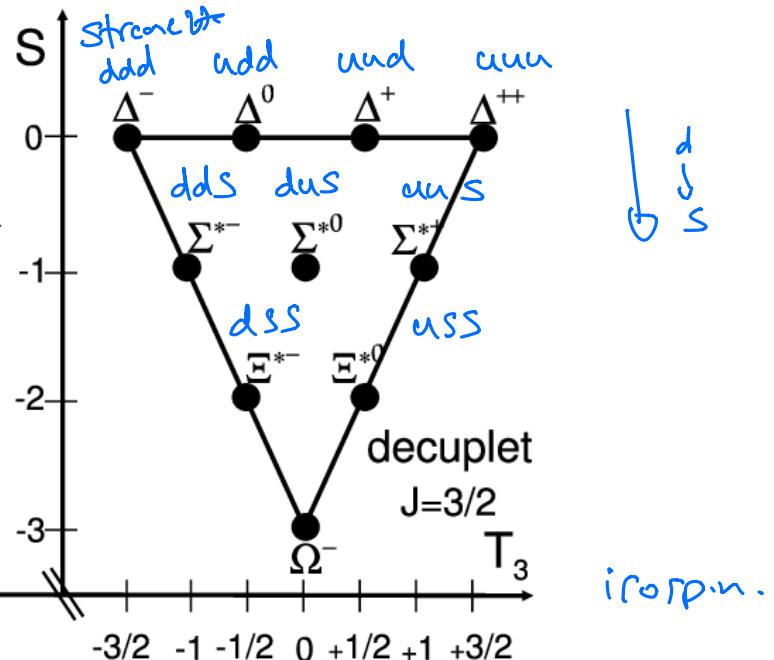
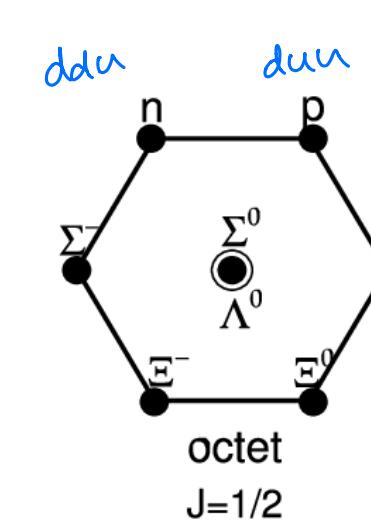
$8 + 1$

Meson: vector:



$8 + 1$

Baryon:

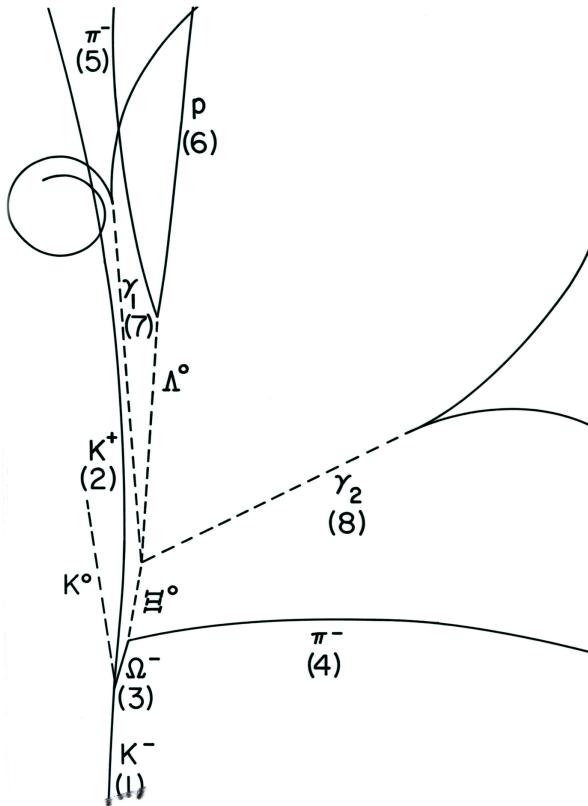
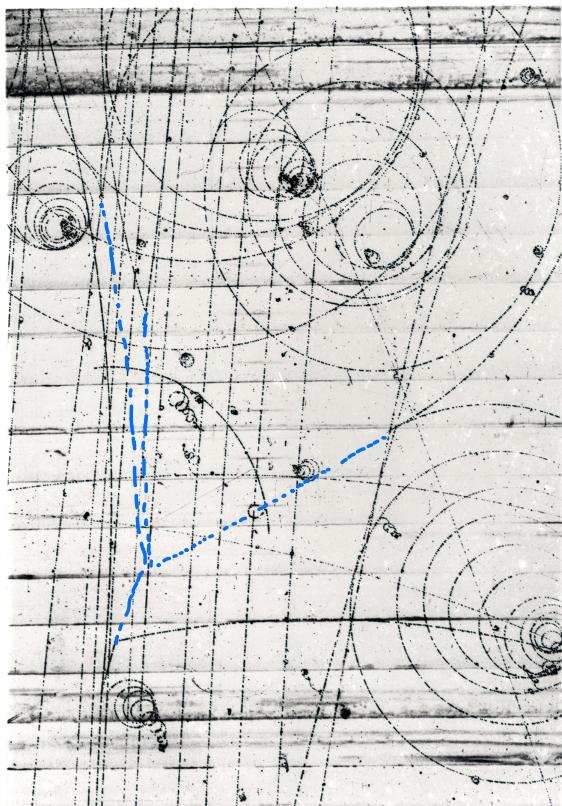


$$\Omega^- : \quad SSS \quad S = -3 \quad \text{bcnione} \quad \text{predive
cnice.}$$

$$Q = I_S + \frac{B+S}{2} = 0 + \frac{1-3}{2} = -1$$

Gell-Mann he calcolato $m_{\Omega} = 1680 \text{ MeV}$ (1961)

1966 Camere a bolle. $m_{\Omega}^{\text{misurata}} = 1672 \text{ MeV}$



$$S \quad -1 \quad 0 \quad -3 \quad +1 \quad +1$$

$$B \quad 0 \quad +1 \quad 1 \quad 0 \quad 0$$

$$Q \quad -1 \quad +1 \quad -1 \quad +1 \quad 0$$

Curvature
traccia