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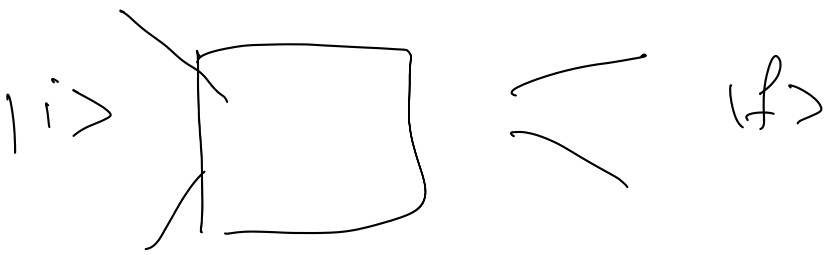
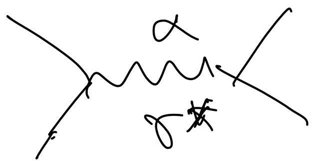
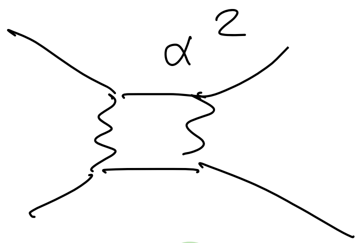
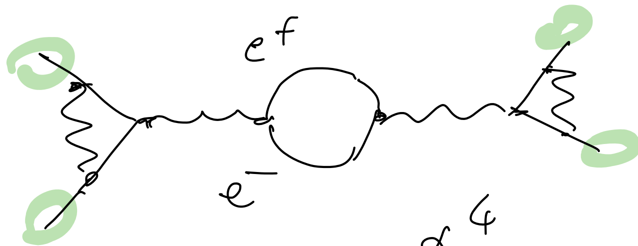








α^4

$$\mathcal{M} = \mathcal{M}_0 + \alpha \mathcal{M}_1 + \alpha^2 \mathcal{M}_2 + \cdots + \alpha^n \mathcal{M}_n$$

			antibarioni
Barioni	$(q_1 q_2 q_3)$	$B = 1$	$B = -1$
mesoni	$(q_1 \bar{q}_2)$	$B = 0$	$B = 0$

$B = \frac{1}{3}(n_q - n_{\bar{q}})$ num. barionico.

$\begin{pmatrix} e^- \\ \nu_e \end{pmatrix}$ $\begin{pmatrix} \mu^- \\ \nu_\mu \end{pmatrix}$ $\begin{pmatrix} \tau^- \\ \nu_\tau \end{pmatrix}$ $\begin{pmatrix} \bar{\nu}_e \\ e^+ \end{pmatrix}$ $L_e = -1$

$L_e = 1$ $L_\mu = 1$ $L_\tau = 1$ num. leptonici

Tutte le reazioni $\Delta B = 0$ / $\Delta L_i = \emptyset$

si conservano

nn

pp

$m_p = 938.3$ $m_n = 939.6$ MeV.

$m_{\pi^\pm} = 140$ MeV $m_{\pi^0} = 135$ MeV

$p + p \to p + p$

$p + n \to p + n$

Int. forte non distingue fra n, p

Heisenberg: ipotesi: esiste una nuova simm. delle int. forti.

Ipotesi isospin, segue la stessa algebra dello spin.

num. quantico nuovo.
grado libertà nuovo.

$|p\rangle = |I = \frac{1}{2}, I_3 = +\frac{1}{2}\rangle$

$|\uparrow\rangle$

$|n\rangle = |I = \frac{1}{2}, I_3 = -\frac{1}{2}\rangle$

$|\downarrow\rangle$

int. forti $\Delta I = 0$

non esiste

pp $= |\tfrac{1}{2},\tfrac{1}{2}\rangle |\tfrac{1}{2},\tfrac{1}{2}\rangle = |1,1\rangle$

pn $\frac{1}{\sqrt{2}}\left(|\tfrac{1}{2},\tfrac{1}{2}\rangle |\tfrac{1}{2},\tfrac{1}{2}\rangle + |\tfrac{1}{2},\tfrac{1}{2}\rangle |\tfrac{1}{2},-\tfrac{1}{2}\rangle \right)$

nn $|\tfrac{1}{2},-\tfrac{1}{2}\rangle |\tfrac{1}{2},-\tfrac{1}{2}\rangle = |1,-1\rangle$

pn singoletto $\frac{1}{\sqrt{2}}(- - \quad - \quad - \quad -)$

deutone pn legato nucleo del deuterio

$\Rightarrow$ pn è singoletto di isospin.

$|I=0, I_3=0\rangle$ deutone.

$\pi^+, \pi^0 \quad I = 1$

$|\pi^+\rangle = |1,1\rangle$

$|\pi^0\rangle\ |1,0\rangle$

$|\pi^-\rangle = |1,-1\rangle$

p, n, deutone, Pioni

$p + p \longrightarrow d + \pi^+$

$Q = +1 \ +1 \qquad +1 \quad 1$

$\qquad\qquad\qquad 2 \qquad 0$

$B = 1 \quad 1$

$I_3 \quad +\tfrac{1}{2} \ +\tfrac{1}{2} \qquad 0 \qquad +1$

$I \quad |1,1\rangle \qquad 0 \qquad 1 \qquad |1,1\rangle$

$M_{fi} = \langle f | H_I | i\rangle = \langle 1,1 | H_I | 1,1\rangle$

a)

$p + p$ $\qquad I_3 = 1$ $\qquad I \neq 0$

$I = 1$

$d + \pi^+$ $\qquad I_3 = 0 + 1$ $\qquad |1,1\rangle$

$I = \cancel{0}, 1$

b)

	p	$+ n$	$\longrightarrow$	d	$+ \pi^0$
Q	1	0		1	0
B	1	1		2	0
I_3	$+\frac{1}{2}$	$-\frac{1}{2}$		0	0
I	$\frac{1}{2}$	$\frac{1}{2}$		0	1

$|i\rangle \quad I_3 = 0.$ $\qquad |i\rangle = \frac{1}{\sqrt{2}}\left(|1,0\rangle + |0,0\rangle\right)$

$I = 0, 1$

$|f\rangle = |1,0\rangle$

$\frac{1}{\sqrt{2}}\left(\langle 0,1| + \langle 0,0|\right) H_I \, |1,0\rangle$

$\langle 0,0| \, H_I \, |1,0\rangle \equiv \emptyset$

se H_I conserve l'isospin.

$[H, I] = \emptyset$

$\frac{1}{\sqrt{2}} \quad \langle \overset{I_3}{0}, \overset{I}{1}| \, H_I \, |\overset{I}{1}, \overset{I_3}{0}\rangle$

c) $n + n \longrightarrow d + \pi^-$ Eroglie?

Q

B

I_3

I

$\pi^0 \longrightarrow \gamma\gamma$

$p + p \longrightarrow p + p$

\# eventi

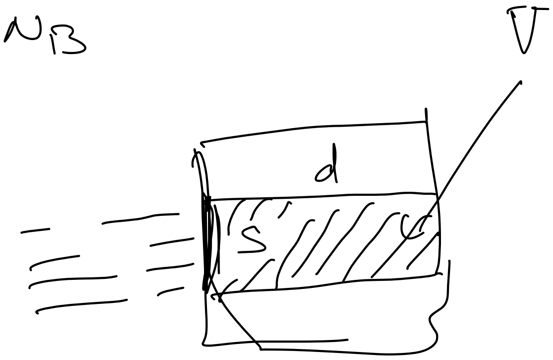
a) $p + p \longrightarrow d + \pi^+$

b) $p + n \longrightarrow d + \pi^0$

\# eventi?

$$\frac{dN_r}{dt} = \sigma \cdot n_b \cdot d = \sigma \cdot \Phi_p \cdot N_B = \sigma \cdot n_p v_p N_B$$

$$= \sigma \frac{N_p}{V} v_p \cdot N_B$$



$$\frac{1}{N_B}\frac{1}{N_p}\frac{dN_r}{dt} = \sigma \cdot \frac{v_p}{V}$$

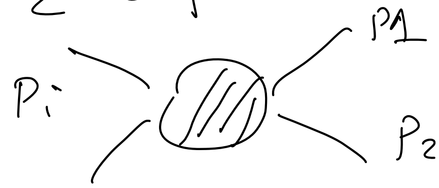
$$\Gamma(i \to f) = 2\pi |M_{fi}|^2 \rho(E)$$

$$\sigma = V \frac{1}{v_p} 2\pi |M_{fi}|^2 \rho(E)$$

$\propto$ # eventi

v_p: velocità dei proiettili

reazione a 2 corpi $\Rightarrow$ $\vec{p}_1 + \vec{p}_2 = 0$ nel c.d.m



$|p_1| = |p_2| = |p|$

$$\rho(E) = \frac{V}{(2\pi)^3} 4\pi \, p^2 dp \cdot \delta(E_f - E_i)$$

$$\frac{\sigma_a}{\sigma_b} \simeq \frac{|M_a|^2}{|M_b|^2} \frac{\rho_a}{\rho_b} \longrightarrow \simeq 1$$

$$\Rightarrow \frac{\#\text{ eventi } a}{\#\text{ eventi } b} \simeq \frac{|M_a|^2}{|M_b|^2}$$

$$M_a \simeq \langle \overset{I_3}{1}, \overset{I}{1} | H_I | \overset{I}{1}, \overset{I_3}{1} \rangle$$

$$M_b \simeq \frac{1}{\sqrt{2}} \langle 0, 1 | H_I | 1, 0 \rangle$$

H_I : Ham. int. forte

$$\frac{M_a}{M_b} = \frac{1}{\frac{1}{\sqrt{2}}} = \sqrt{2} \Rightarrow \frac{\#\text{ eventi } a}{\#\text{ eventi } b} \simeq (\sqrt{2})^2 = 2$$

$p + p \longrightarrow$ stati finali f_1

f_2

f_3

$\vdots$

f_N

σ_{tot}: $p + p \rightarrow$ qualsiasi cosa $= \sum_i \sigma_i$

$$\pi^+ + \begin{pmatrix} p \\ n \end{pmatrix} \longrightarrow$$

proiettili

$\pi^+ + p \rightarrow \pi^+ + p$

$\pi^0 + p \rightarrow \pi^0 + p$

$\pi^- + p \rightarrow \pi^- + p$

$\pi^+ + n \rightarrow \pi^+ + n$

$\pi^0 + n \rightarrow \pi^0 + n$

$\pi^- + n \rightarrow \pi^- + n$

$\pi^+ + n \rightarrow \pi^0 + p$

$\pi^0 + p \rightarrow \pi^+ + n$

$\pi^0 + n \rightarrow \pi^- + p$

$\pi^- + p \rightarrow \pi^0 + n$

$\xrightarrow{\text{proiettile}} \boxed{H_2}$

Difficile accelerare fasci di π^0

$$\frac{\sigma(\pi^+ + p \rightarrow X)}{\sigma(\pi^- + p \rightarrow X)}$$

Più facile misurare usando π^+ e π^- come proiettili sullo stesso bersaglio di p.

$$\pi^+ + p \longrightarrow n + X^{++}$$

$$\pi^0 + B^{++}$$

$\pi^+ + p$

$|\frac{1}{2}, \frac{1}{2}\rangle + |1, 1\rangle \longrightarrow$

$I_3 = 3/2$

$I = \frac{1}{2}, 3/2.$

$$|3/2, 3/2\rangle \longrightarrow |3/2, 3/2\rangle.$$

$$M_{fi} = \langle 3/2\ 3/2 | H_I | 3/2, 3/2 \rangle$$

$\pi^- + p \longrightarrow \pi^- + p.$

$I_3 \; -1 \quad +\frac{1}{2}$

$I \quad 1, \; 1/2.$

$|i\rangle \quad I_3 = -1/2$

$I = 1/2, \; 3/2.$

$\pi^- + p$

$$|i\rangle = \alpha \, \overset{I \quad I_3}{|1/2, -1/2\rangle} + \beta \, \overset{I \;\; I_3}{|3/2, -1/2\rangle}$$

C.G.

$\pi^- + p \longrightarrow n + \pi^0 \qquad |\tfrac{1}{2}, -1/2\rangle \qquad |3/2, -3/2\rangle$

$|1, -1\rangle$

$$\overset{I_3 \;\; I}{\left(-\tfrac{1}{2}, \tfrac{3}{2}\right)} \longrightarrow |3/2, -3/2\rangle$$

Table 3.3. *Clebsch–Gordan coefficients in pion–nucleon scattering*

		$I = \frac{3}{2}$				$I = \frac{1}{2}$	
Pion	Nucleon	$I_3 = \frac{3}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{3}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
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		

a)

$\pi^+ + p \to \pi^+ + p$

$\times 3$

$\pi^- + p \to \pi^- + p$

$\pi^0 + n$

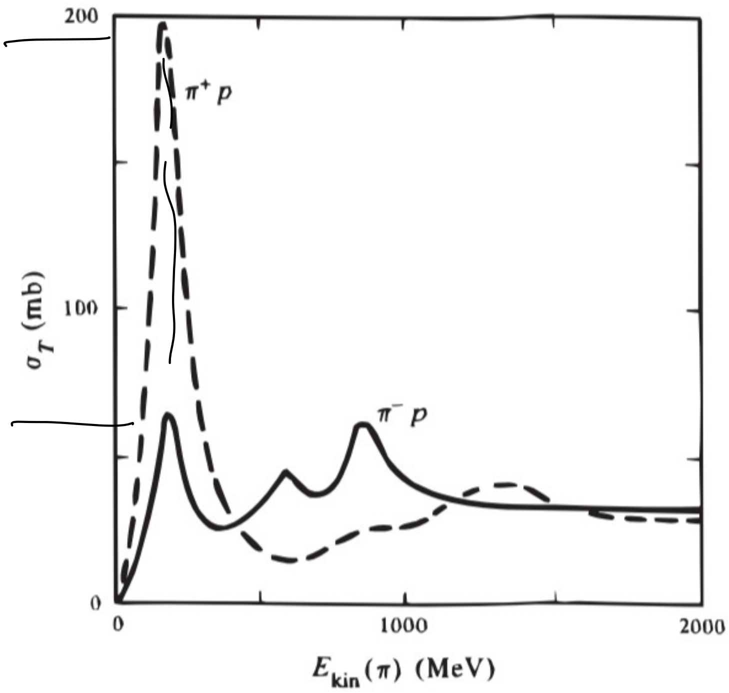


Figure 5.35: Total cross section as a function of pion kinetic energy for the scattering of positive and negative pions from protons. (1 mb = 1 millibarn = 10^{-27} cm^2.)

Table 3.4. *Conservation rules*

	Interaction		
Conserved quantity	strong	electromagnetic	weak
energy–momentum, charge, baryon number, lepton number	yes	yes	yes
CPT	yes	yes	yes
P (parity)	yes	yes	no
C (charge conjugation parity)	yes	yes	no
CP (or *T*)	yes	yes	10^{-3} violation
I (isospin)	yes	no	no