Introdução à Física das Partículas Elementares

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(buscar: física das partículas elementares)

Fernando S Navarra

navarra@if.usp.br

Guilherme Germano

guilherme.germano@usp.br

Plano do Curso

14/03	Cap. 1
16/03	Cap. 1
21/03	Cap. 2
23/03	Cap. 2
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30/03	Cap. 3
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09/05	Cap. 7
11/05	Cap. 7
16/05	Cap. 8
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01/06	Cap. 9
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08/06	
13/06	Cap. 10
15/06	Cap. 10
20/06	Cap. 11 (Daniel)
22/06	Cap. 11
27/06	Cap. 11 (Lucas, Fran)
29/06	P3
04/07	Sub

Monitoria
27/06 18:00
Sala 2003

3ª Prova

Capítulo 09 : exercícios 9.1 e 9.5

Capítulo 10 : exercícios 10.1 , 10.2 , 10.5 e ler a seção 10.9 para fazer o exercício 10.6

Capítulo 11 : exercícios 11.1 e 11.3

Reproduzir as passagens dos slides !

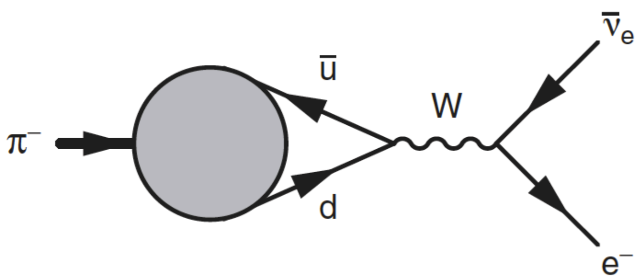
Aula 25

Capítulo 11

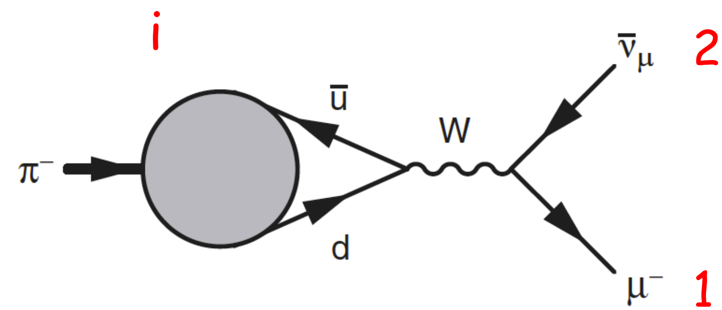
Interações Fracas

Decaimento fraco de pions carregados

$\pi^- \rightarrow e^- \overline{\nu}_e$



$\pi^- \rightarrow \mu^- \overline{\nu}_\mu$



$$\Gamma = \frac{p^*}{32\pi^2 m_a^2} \int |\mathcal{M}_{fi}|^2 d\Omega,$$

$$p^* = \frac{1}{2m_i}\sqrt{\left[(m_i^2 - (m_1 + m_2)^2\right]\left[m_i^2 - (m_1 - m_2)^2\right]}$$

0 0

$$p^* = \frac{m_i^2 - m_1^2}{2m_i}$$

$$m_1 = \begin{cases} m_\mu = 100\ MeV \\ m_e = 0.5\ MeV \end{cases}$$

$$p_e^* >> p_\mu^*$$

$$\Gamma_e >> \Gamma_\mu$$

mas:

$$\frac{\Gamma(\pi^- \rightarrow e^- \overline{\nu}_e)}{\Gamma(\pi^- \rightarrow \mu^- \overline{\nu}_\mu)} = 1.230(4) \times 10^{-4}$$

Uma explicação qualitativa

Vamos lembrar :

Espinor de helicidade: $$u_\uparrow(\mathrm{p},\theta,\phi) = N\begin{pmatrix} c \\ se^{i\phi} \\ \kappa c \\ \kappa s e^{i\phi} \end{pmatrix} \qquad \kappa = \frac{\mathrm{p}}{E+m} \qquad N = \sqrt{E+m}.$$

Espinor mão direita pode ser projetado em componentes quirais:

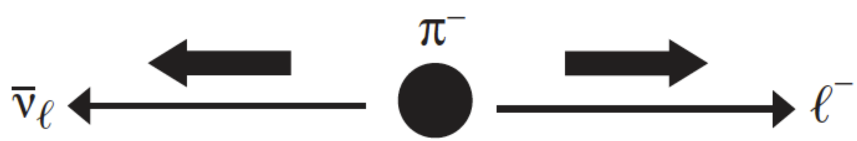
$$P_R u_\uparrow = \tfrac{1}{2}(1+\kappa)\,N\begin{pmatrix} c \\ se^{i\phi} \\ c \\ se^{i\phi} \end{pmatrix} \qquad P_L u_\uparrow = \tfrac{1}{2}(1-\kappa)\,N\begin{pmatrix} c \\ se^{i\phi} \\ -c \\ -se^{i\phi} \end{pmatrix}.$$

e escrito como: $$u_\uparrow(\mathrm{p},\theta,\phi) = \tfrac{1}{2}(1+\kappa)\,N\begin{pmatrix} c \\ se^{i\phi} \\ c \\ se^{i\phi} \end{pmatrix} + \tfrac{1}{2}(1-\kappa)\,N\begin{pmatrix} c \\ se^{i\phi} \\ -c \\ -se^{i\phi} \end{pmatrix}$$

$$\propto \tfrac{1}{2}(1+\kappa)\,u_R + \tfrac{1}{2}(1-\kappa)\,u_L,$$

Lembrar: $\gamma^5 u_R = +u_R \qquad \gamma^5 u_L = -u_L$

Pion tem spin zero $\longrightarrow$ lepton e neutrino formam um singleto de spin



duas partículas "mão direita"

$$u_\uparrow \equiv \tfrac{1}{2}\left(1 + \frac{p}{E+m}\right)u_R + \tfrac{1}{2}\left(1 - \frac{p}{E+m}\right)u_L$$

componente favorecida pela interação fraca

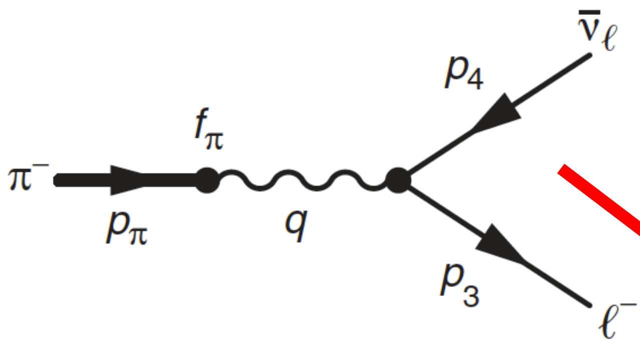
$$\mathcal{M} \sim \frac{1}{2}\left(1 - \frac{p_\ell}{E_\ell + m_\ell}\right)$$

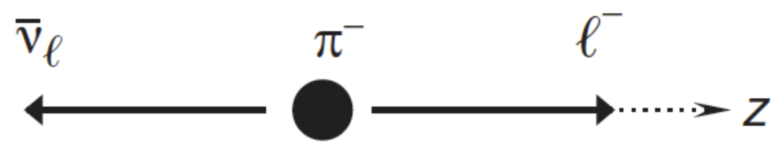
$$\left\{\begin{aligned} E_\ell &= \frac{m_\pi^2 + m_\ell^2}{2m_\pi} \\ p_\ell &= \frac{m_\pi^2 - m_\ell^2}{2m_\pi} \end{aligned}\right. \longrightarrow \frac{p_\ell}{E_\ell + m_\ell} = \frac{m_\pi - m_\ell}{m_\pi + m_\ell} \longrightarrow \mathcal{M} \sim \frac{m_\ell}{m_\pi + m_\ell}$$

O lepton de massa menor tem uma amplitude menor !

A explicação da teoria V-A

Decaimento fraco de pions carregados





$$p_\pi = (m_\pi, 0, 0, 0)$$

$$p_\ell = p_3 = (E_\ell, 0, 0, \mathrm{p})$$

$$p_{\bar{\nu}} = p_4 = (\mathrm{p}, 0, 0, -\mathrm{p})$$

$$j_\ell^\nu = \frac{g_W}{\sqrt{2}}\overline{u}(p_3)\tfrac{1}{2}\gamma^\nu(1-\gamma^5)v(p_4)$$

Os quarks dentro do pion não estão livres. Corrente do pion : $f_\pi p_\pi^\mu$

$$\mathcal{M}_{fi} = \left[\frac{g_W}{\sqrt{2}}\tfrac{1}{2}f_\pi p_\pi^\mu\right]\times\left[\frac{g_{\mu\nu}}{m_W^2}\right]\times\left[\frac{g_W}{\sqrt{2}}\overline{u}(p_3)\gamma^\nu\tfrac{1}{2}(1-\gamma^5)v(p_4)\right]$$

$$= \frac{g_W^2}{4m_W^2}g_{\mu\nu}f_\pi p_\pi^\mu\overline{u}(p_3)\gamma^\nu\tfrac{1}{2}(1-\gamma^5)v(p_4)$$

$$g_{\mu\nu}\, p_\pi^\mu = p_{\pi\,\nu}$$

No sistema do centro de massa o pion está em repouso $p_\pi^0 = m_\pi$

$$\mathcal{M}_{fi} = \frac{g_W^2}{4m_W^2} f_\pi m_\pi \overline{u}(p_3)\gamma^0 \tfrac{1}{2}(1-\gamma^5)v(p_4)$$

$$\overline{u}\gamma^0 = u^\dagger\gamma^0\gamma^0 = u^\dagger$$

$$\mathcal{M}_{fi} = \frac{g_W^2}{4m_W^2} f_\pi m_\pi u^\dagger(p_3) \tfrac{1}{2}(1-\gamma^5)v(p_4)$$

$$\tfrac{1}{2}(1-\gamma^5)v = v_R$$

$$\tfrac{1}{2}(1-\gamma^5)v(p_4) = v_\uparrow(p_4)$$

$$\mathcal{M}_{fi} = \frac{g_W^2}{4m_W^2} f_\pi m_\pi u^\dagger(p_3) v_\uparrow(p_4)$$

$$u_\uparrow(p_3) = \sqrt{E_\ell + m_\ell}\begin{pmatrix} 1 \\ 0 \\ \frac{p}{E_\ell+m_\ell} \\ 0 \end{pmatrix} \qquad u_\downarrow(p_3) = \sqrt{E_\ell + m_\ell}\begin{pmatrix} 0 \\ 1 \\ 0 \\ -\frac{p}{E_\ell+m_\ell} \end{pmatrix} \qquad v_\uparrow(p_4) = \sqrt{p}\begin{pmatrix} 1 \\ 0 \\ -1 \\ 0 \end{pmatrix}$$

$$\mathcal{M}_{fi} = \frac{g_W^2}{4m_W^2} f_\pi m_\pi \sqrt{E_\ell + m_\ell}\,\sqrt{p}\left(1 - \frac{p}{E_\ell + m_\ell}\right)$$

$$u_\downarrow^\dagger(p_3)v_\uparrow(p_4) = 0$$

$$\mathcal{M}_{fi} = \frac{g_W^2}{4m_W^2} f_\pi m_\pi \cdot \frac{m_\pi + m_\ell}{\sqrt{2m_\pi}} \cdot \left(\frac{m_\pi^2 - m_\ell^2}{2m_\pi}\right)^{\frac{1}{2}} \cdot \frac{2m_\ell}{m_\pi + m_\ell} \qquad = \left(\frac{g_W}{2m_W}\right)^2 f_\pi m_\ell (m_\pi^2 - m_\ell^2)^{\frac{1}{2}}$$

$$E_\ell = \frac{m_\pi^2 + m_\ell^2}{2m_\pi}$$

$$\langle|\mathcal{M}_{fi}|^2\rangle \equiv |\mathcal{M}_{fi}|^2 = 2G_F^2 f_\pi^2 m_\ell^2 (m_\pi^2 - m_\ell^2)$$

$$p_\ell = \frac{m_\pi^2 - m_\ell^2}{2m_\pi}$$

$$\Gamma = \frac{p^*}{32\pi^2 m_a^2} \int |\mathcal{M}_{fi}|^2 d\Omega,$$

$$\frac{G_F}{\sqrt{2}} = \frac{g_W^2}{8m_W^2}$$

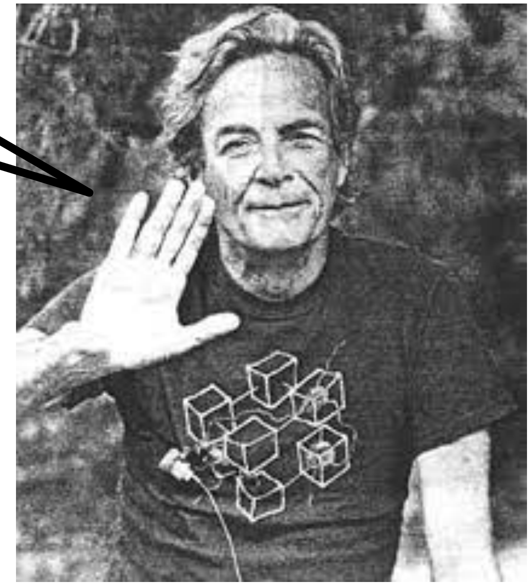
$$\Gamma = \frac{4\pi}{32\pi^2 m_\pi^2} p \langle|\mathcal{M}_{fi}|^2\rangle \quad = \frac{G_F^2}{8\pi m_\pi^3} f_\pi^2 \left[m_\ell (m_\pi^2 - m_\ell^2)\right]^2$$

$$\frac{\Gamma(\pi^- \to e^- \overline{\nu}_e)}{\Gamma(\pi^- \to \mu^- \overline{\nu}_\mu)} = \left[\frac{m_e(m_\pi^2 - m_e^2)}{m_\mu(m_\pi^2 - m_\mu^2)}\right]^2 = 1.26 \times 10^{-4} \qquad = 1.230(4) \times 10^{-4}$$

Valor experimental !

E assim acabamos o capítulo 11...   e o curso...

Tchau pessoal ...
Desculpem os excessos
Foi um prazer !



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