8.701

Introduction to Nuclear and Particle Physics

Markus Klute - MIT

6. Weak Interaction

6.2 Electroweak Unification

Chiral Fermion States

Aim to combine weak and electromagnetic interaction

Issues

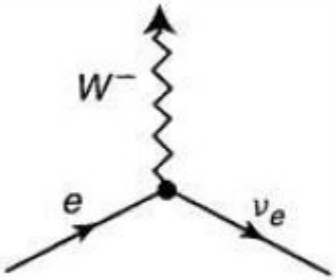
a) Strength of interaction
b) Structure of coupling - vector versus vector-axial

Absorb into particle spinor

$$u_L(p) \equiv \frac{(1-\gamma^5)}{2}u(p) \quad v_L(p) \equiv \frac{(1+\gamma^5)}{2}v(p)$$

$$u_R(p) = \frac{(1+\gamma^5)}{2}u(p), \quad v_R(p) \equiv \frac{(1-\gamma^5)}{2}v(p)$$

Currents



$$j_\mu^- = \bar{\nu}\gamma_\mu\left(\frac{1-\gamma^5}{2}\right)e$$

$$j_\mu^- = \bar{\nu}_L\gamma_\mu e_L$$

$$j_\mu^{em} = -\bar{e}\gamma_\mu e = -(\bar{e}_L + \bar{e}_R)\gamma_\mu(e_L + e_R) = -\bar{e}_L\gamma_\mu e_L - \bar{e}_R\gamma_\mu e_R$$

Weak Isospin and Hypercharge

$$\chi_L = \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L$$

$$j_\mu^\pm = \overline{\chi}_L \gamma_\mu \tau^\pm \chi_L$$

$$\tau^+ \equiv \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix}, \qquad \tau^- \equiv \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix}$$

$$\tau^\pm = \tfrac{1}{2}(\tau^1 \pm i\tau^2)$$

$$j_\mu^3 = \overline{\chi}_L \gamma_\mu \tfrac{1}{2}\tau^3 \chi_L = \tfrac{1}{2}\overline{\nu}_L \gamma_\mu \nu_L - \tfrac{1}{2}\bar{e}_L \gamma_\mu e_L$$

$$\tfrac{1}{2}\tau^3 = \tfrac{1}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

$$Q = I^3 + \tfrac{1}{2}Y$$

$$j_\mu^Y = 2j_\mu^{em} - 2j_\mu^3 = -2\bar{e}_R \gamma_\mu e_R - \bar{e}_L \gamma_\mu e_L - \overline{\nu}_L \gamma_\mu \nu_L$$

Isospin, hypercharge, and EM currents

$$\chi_L \to \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L, \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L, \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L, \begin{pmatrix} u \\ d' \end{pmatrix}_L, \begin{pmatrix} c \\ s' \end{pmatrix}_L, \begin{pmatrix} t \\ b' \end{pmatrix}_L$$

$$\mathbf{j}_\mu = \tfrac{1}{2}\overline{\chi}_L \gamma_\mu \boldsymbol{\tau} \chi_L$$

$$j_\mu^{em} = \sum_{i=1}^{2} Q_i(\overline{u}_{iL}\gamma_\mu u_{iL} + \overline{u}_{iR}\gamma_\mu u_{iR})$$

$$j_\mu^Y = 2j_\mu^{em} - 2j_\mu^3$$

Electroweak Mixing

$$-i\left[g_w \mathbf{j}_\mu \cdot \mathbf{W}^\mu + \frac{g'}{2} j_\mu^Y B^\mu\right]$$

$$W_\mu^\pm \equiv (1/\sqrt{2})(W_\mu^1 \mp i W_\mu^2)$$

$$A_\mu = B_\mu \cos\theta_w + W_\mu^3 \sin\theta_w$$

$$Z_\mu = -B_\mu \sin\theta_w + W_\mu^3 \cos\theta_w$$

$$g_w \sin\theta_w = g' \cos\theta_w = g_e$$

$$g_z = \frac{g_e}{\sin\theta_w \cos\theta_w}$$