MODELO DE WEINBERG-SALAM

- Isotripleto de correntes fracas J_μ, acopladas aos bosões vectores W_μ:

$$-ig\, J_\mu \cdot W^\mu = -ig\, \overline{\chi}_L \gamma_\mu T \cdot W^\mu \chi_L \quad SU(2)_L$$

- Corrente de hipercarga, acoplada a B^μ:

$$-i\frac{g'}{2} j_\mu^Y B^\mu = -ig' \overline{\psi} \gamma_\mu \frac{Y}{2} \psi B^\mu \quad U(1)_Y$$

- Tranformações $SU(2) \times U(1)$ de ψ:

$$\chi_L \to e^{i\alpha(x)\cdot T + i\beta(x) Y} \chi_L$$

$$\psi_R \to e^{i\beta(x) Y} \psi_R$$

- Números quânticos:

exemplo: $\chi_L = \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L \quad T = 1/2 \ , Y = -1$

$\psi_R = e^-_R \quad T = 0 \ , Y = -2$

$$Q = T^3 + \frac{Y}{2}$$

• "Unificação" da <u>corrente electromagnética</u> e da <u>corrente neutra fraca</u>:

a) $j_\mu^{em} = J_\mu^3 + \frac{1}{2} j_\mu^Y$

b) A_μ e Z_μ são combinações lineares de W_μ^3 e B_μ (ângulo de mistura θ_W)

<u>Resulta</u>:

$$-ig\, J_\mu^3 W^{3\mu} - i\,\frac{g'}{2} j_\mu^Y B^\mu =$$

$$= -i\left[g \operatorname{sen}\theta_W J_\mu^3 + g' \cos\theta_W \frac{j_\mu^Y}{2}\right] A^\mu \quad \gamma$$

$$-i\left[g\cos\theta_W J_\mu^3 - g' \operatorname{sen}\theta_W \frac{j_\mu^Y}{2}\right] Z^\mu \quad Z^0$$

$$= -ie\, j_\mu^{em} A^\mu - \frac{ie}{\operatorname{sen}\theta_W \cos\theta_W}\left[J_\mu^3 - \operatorname{sen}^2\theta_W\, j_\mu^{em}\right] Z^\mu$$

$$e = g \operatorname{sen}\theta_W = g' \cos\theta_W$$

- Lagrangeano electrofraco (par electrão-neutrino)

$$\mathcal{L}_1 = \bar{\chi}_L \gamma^\mu \left[i\partial_\mu - g\frac{1}{2}\tau . W_\mu - \frac{g'}{2} Y B_\mu \right] \chi_L$$

$$+ \bar{e}_R \gamma^\mu \left[i\partial_\mu - \frac{g'}{2} Y B_\mu \right] e_R$$

$$- \frac{1}{4} W_{\mu\nu} \cdot W^{\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu}$$

invariante a transformações locais do grupo $SU(2)_L \times U(1)$

- Massas dos bosões $W^\pm$ e Z^0:

$$\mathcal{L}_2 = \left| \left(i\partial_\mu - g T \cdot W_\mu - g' \frac{Y}{2} B_\mu \right) \phi \right|^2 - V(\phi)$$

$$|\ |^2 \equiv (\ )^\dagger (\ )$$

Campos escalares: $T = 1/2$, $Y = 1$

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \qquad \begin{aligned} \phi^+ &= (\phi_1 + i\phi_2)/\sqrt{2} \\ \phi^0 &= (\phi_3 + i\phi_4)/\sqrt{2} \end{aligned}$$

Valor expectável do vácuo:

$$\phi_0 = \sqrt{\frac{1}{2}} \begin{pmatrix} 0 \\ v \end{pmatrix}$$ neutro, invariante em $U(1)$

Massas dos bosões de gauge:

$$\left|\left(-ig\,\frac{\tau}{2}\cdot W_\mu - i\,\frac{g'}{2}B_\mu\right)\phi\right|^2 =$$

$$= \frac{1}{8}\left|\begin{pmatrix} g W_\mu^3 + g' B_\mu & g(W_\mu^1 - iW_\mu^2) \\ g(W_\mu^1 + iW_\mu^2) & -gW_\mu^3 + g' B_\mu \end{pmatrix}\cdot\begin{pmatrix} 0 \\ v \end{pmatrix}\right|^2$$

$$= \left(\tfrac{1}{2} v g\right)^2 W_\mu^+ W^{-\mu} + \quad \longrightarrow \boxed{M_W = \tfrac{1}{2} v g}$$

$$\underbrace{\tfrac{1}{8} v^2\left[g^2 (W_\mu^3)^2 - 2gg' W_\mu^3 B^\mu + g'^2 B_\mu^2\right]}$$

$$\tfrac{1}{8} v^2 \left[g W_\mu^3 - g' B_\mu\right]^2 \longrightarrow Z_\mu = \frac{g W_\mu^3 - g' B_\mu}{\sqrt{g^2 + g'^2}}$$

$$+\, 0\,\left[g' W_\mu^3 + g B_\mu\right]^2 \longrightarrow A_\mu = \frac{g' W_\mu^3 + g B_\mu}{\sqrt{g^2 + g'^2}}$$

$$\longrightarrow \boxed{M_Z = \tfrac{1}{2} v \sqrt{g^2 + g'^2}}$$

Definição $g'/g = \tan\theta_W$

$$\Rightarrow \boxed{\frac{M_W}{M_Z} = \cos\theta_W}$$

Previsões:

- Intensidade relativa das interacções fracas por corrente neutra e carregada:

$$\rho = \frac{G_N}{G} = \frac{M_W^2}{M_Z^2 \cos^2\theta_W}$$ (definição das correntes)

$$\rho = 1$$ (definição do sector Higgs)

- Massa do W e Z: $\left(G = \frac{10^{-5}}{m_N^2}\right)$

$$\frac{1}{2v^2} = \frac{g^2}{8M_W^2} = \frac{G}{\sqrt{2}} \implies v = 246 \text{ GeV}$$

$$e = g \,\text{sen}\,\theta_W \; ; \; \alpha = \frac{e^2}{4\pi} \; ; \; \alpha = \frac{1}{137}$$

$$\Rightarrow M_W = \frac{37.3}{\text{sen}\,\theta_W} \text{ GeV}$$