Higgs

$$H \sim \left(\underset{SU(3)_c}{1},\ \underset{SU(2)_L}{2},\ \underset{Y}{\tfrac{1}{2}}\right)$$

$$-\mathcal{L}_{SM}^{flavor} = \lambda^E_{ij}\, \overline{e_R}_i L_j H^* + \lambda^D_{ij}\, \overline{d_R}_i Q_j H^* + \lambda^U_{ij}\, \overline{u_R}_i Q_j \varepsilon H + h.c.$$

$$\mathcal{L}_{SM}^{EWSB} = (D_\mu H)^\dagger (D^\mu H) - V(H^\dagger H) \qquad V = \mu^2 H^\dagger H + \lambda (H^\dagger H)^2$$

$$\lambda > 0 \qquad \mu^2 < 0$$

$$D_\mu H = \partial_\mu H + i g W_\mu^a \frac{\sigma_a}{2} H + i g' B_\mu \frac{1}{2} H$$

$$\mathcal{L}_{SM} = \mathcal{L}_{SM}^{\text{gauge}} + \mathcal{L}_{SM}^{\text{flavour}} + \mathcal{L}_{SM}^{\text{EWSB}} + \mathcal{L}_{g.f.} + \theta\text{-term} \dots$$

$$V = \mu^2 |H|^2 + \lambda |H|^4 \quad \lambda > 0 \quad \mu^2 < 0$$

$$|\langle H \rangle|^2 = v^2 \qquad v^2 = -\frac{\mu^2}{2\lambda} \approx (174\,\text{GeV})^2$$

$$\langle H \rangle = \begin{pmatrix} 0 \\ v \end{pmatrix} \quad \text{up } SU(2)_L \text{ transf.} \quad v > 0$$

$$t = \alpha_A t_A^{(3)} + \beta_a t_a^{(2)} + \gamma y \qquad \alpha_A, \beta_a, \gamma \in \mathbb{R}$$

$$T = \qquad + \beta_a \frac{\sigma_a}{2} + \gamma \frac{\mathbb{1}}{2}$$

$0 = T\langle H\rangle \iff \beta_1=\beta_2=0 \quad \beta_3=\gamma \quad$ any $\alpha_A \quad t_A^{(3)} \quad q = t_3 + y$

$$G_{SM} \to SU(3)_c \times U(1)_{em}$$

$12 - 9 = 3$ broken generators $\longleftrightarrow$ 3 NG bosons

$\longleftrightarrow$ 3 massive vectors $W^\pm Z$

$H : 2\mathbb{C} \sim 4\mathbb{R} - 3 = 1$ physical d.o.f. : Higgs boson

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$S=1$: $\quad G_A^\mu \quad W_a^\mu \quad B^\mu$

from $|D_\mu H|^2 \to |D_\mu \langle H\rangle|^2 = M_W^2 W_\mu^+ W^{\mu -} + \frac{M_Z^2}{2} Z^\mu Z_\mu$

$\uparrow V_A^\mu$

$$M_W^2 = \frac{g^2 v^2}{2} \qquad M_Z^2 = \frac{g^2+g'^2}{2} v^2 \qquad W_\mu^\pm = \frac{W_\mu^1 \mp i W_\mu^2}{\sqrt{2}}$$

$$s_w = \sin\theta_w \leftarrow \text{Weinberg} \qquad = \frac{g'}{\sqrt{g^2+g'^2}}$$

$$Z_\mu = \frac{g W_\mu^3 - g' B_\mu}{\sqrt{g^2+g'^2}} = c_w W_\mu^3 - s_w B_\mu$$

$$M_W \simeq 80\,\text{GeV}$$

$$M_Z \simeq 91\,\text{GeV}$$

$$s_w^2 \simeq 0.23$$

$$\frac{G_F}{\sqrt{2}} = \frac{g^2}{8 M_W^2} = \frac{1}{4 v^2}$$

$$A_\mu = \frac{g' W_\mu^3 + g B_\mu}{\sqrt{}}$$

$$\rho = \frac{M_W^2}{c_w^2 M_Z^2} = 1$$

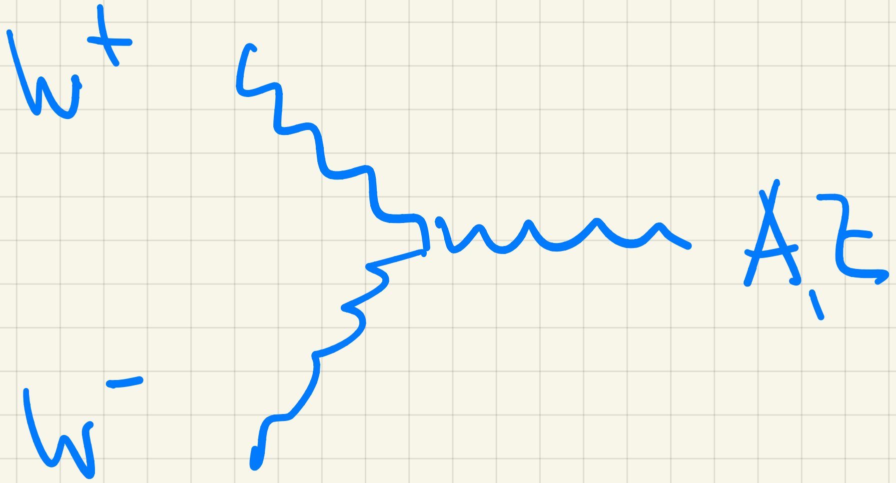
tree level

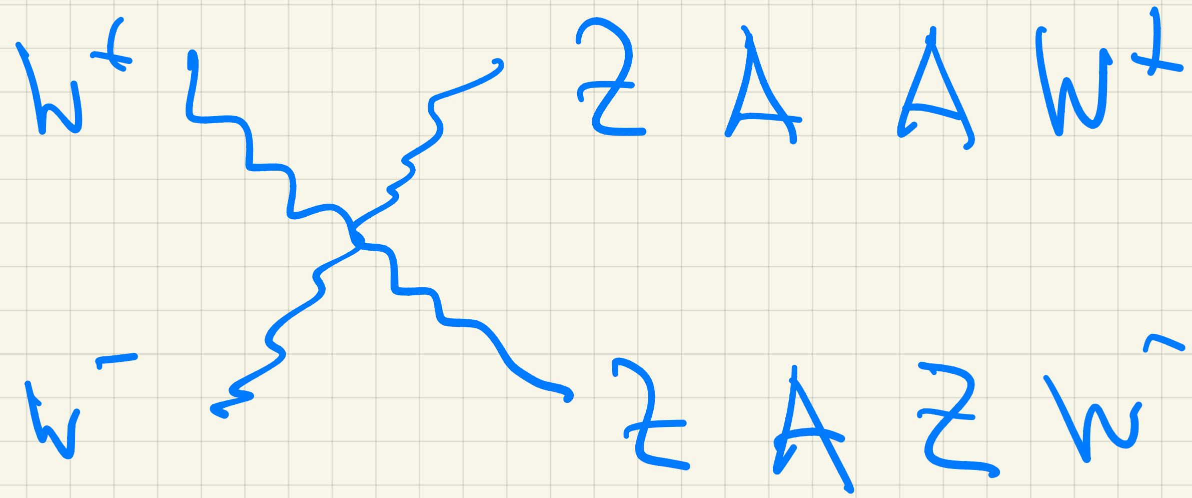
$$\rho_{exp} \simeq 1 + O\left(\frac{1}{200}\right)$$

$$e = \frac{g g'}{\sqrt{g^2+g'^2}} = g\cos\theta_w = g'\sin\theta_w$$

$$D_\mu = \partial_\mu + i g_s G_\mu^A T_A^{(3)} + i\frac{g}{\sqrt{2}}\left(W_\mu^+ T_+ + W_\mu^- T_-\right) + ieQA_\mu + i\frac{g}{c_w}\left(T_3 - s_w^2 Q\right) Z_\mu$$

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





$S=0$: H

linearise

$$e^{\frac{\sqrt{2}\, i G_a T_a^{(2)}}{v}} \langle H \rangle \approx \begin{pmatrix} i G^+ \\ v + \frac{\varphi - i G^0}{\sqrt{2}} \end{pmatrix} = H$$

$$G^\pm = \frac{G_1 \mp i G_2}{\sqrt{2}}$$

$$G^0 \equiv G_3$$

unitary gauge $G = 0$

$$H = \begin{pmatrix} 0 \\ v + \frac{\varphi}{\sqrt{2}} \end{pmatrix}$$

$$V = \text{const} + \frac{m_H^2}{2} \varphi^2 + \sqrt{2}\, v \varphi^3 + \frac{\lambda}{4} \varphi^4$$

$$m_H^2 = 4 \lambda v^2$$

$$\lambda \approx 0.125$$