PRESENTATIONS ? ⟶ SIGN UP
↳ CLASS SURVEY

→ HW4 B ⟶ print out has typos
→ IT'S LONG HW
→ PROB 5 IS EC.

<u>FLAVOR SUMMARY</u> : supressing all other indices

$$(y_u)^I{}_J \; H Q^J \bar{u}_I + \cdots$$

3x3 matrix that connects I-generation $\bar{u}$ to J-generation Q

$\begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$ contracts w Q DOUBLET w/ ε_{ij}

↳ PROJECTS OUT u_L COMPONENT OF Q.

$$Q^I = \underset{I=1}{\begin{pmatrix} u_L \\ d_L \end{pmatrix}}, \underset{I=2}{\begin{pmatrix} c_L \\ s_L \end{pmatrix}}, \underset{I=3}{\begin{pmatrix} t_L \\ \cancel{b_L} \end{pmatrix}}$$

← $\langle H \rangle$ PICKS UP TOP

$$\bar{u}_I = \bar{u}, \; \bar{c}, \; \bar{t}$$

$$y^{\circ} \cdot H Q \, \bar{u}$$

any Q any $\bar{u}$

9 combinations

$U(3)^5$ flavor symmetry (no force particle)

$$Q \to U_Q Q \quad \leftarrow \text{MIXES UP GENERATIONS}$$

$$\bar{u} \to U_{\bar{u}}^{\dagger} \bar{u} \leftarrow \bar{u}_J (U_{\bar{u}}^{\dagger})^J{}_I$$

$$\bar{d} \to U_{\bar{d}}^{\dagger} \bar{d} \leftarrow \bar{d}_J (U_{\bar{d}}^{\dagger})^J{}_I$$

$$L \to U_L L$$

$$\bar{e} \to U_{\bar{e}}^{\dagger} \bar{e} \leftarrow \bar{e}_J (U_{\bar{e}}^{\dagger})^J{}_I$$

ACTS ON FLAVOR INDEX

there are 5 independent symmetries that the non-Yukawa interactions all respect.

eg $(Q^{\dagger})_I (\underline{W}) Q^I \to (Q U_Q^{\dagger})_I \underline{W} (U_Q Q)^I$

$$= Q^{\dagger}_J (U_Q^{\dagger})^J{}_I \underline{W} U_Q{}^I{}_K Q^K$$

$$= Q^{\dagger} \underbrace{(U_Q^{\dagger} U)}_{\mathbb{1}} \underline{W} Q$$

$U(3)^5$ flavor sym

$$Q^I \to U_Q{}^I{}_J Q^J$$
$$\bar{u}_I \to \bar{u}_J (U^\dagger_{\bar{u}})^J{}_I$$
$$\bar{d}_I \to \bar{d}_J (U^\dagger_{\bar{d}})^J{}_I$$
$$L^I \to U_L{}^I{}_J L^J$$
$$\bar{e}_I \to \bar{e}_J (U^\dagger_{\bar{e}})^J{}_I$$

five independent UNITARY transformations

$U_x^\dagger U_x = \mathbb{1}$

the non-Yukawa interactions respect this sym:

$$Q^\dagger_I \underset{\substack{\uparrow \\ \text{no flavor}}}{\underline{W}} Q^I \to Q^\dagger_J \underbrace{(U_Q^\dagger)^J{}_I \; \underline{W} \; (U_Q)^I{}_K}_{(U_Q^\dagger U)^J{}_K \underline{W} = \delta^J_K \underline{W}} Q^K = Q^\dagger_I \underline{W} Q^I \checkmark$$

only Yukawa interactions break the sym!

$$\underbrace{(y_u)^I{}_J}_{\text{does not transform}} H Q^J \bar{u}_I \to \bar{u}_K \underbrace{(U^\dagger_{\bar{u}})^K{}_I (y_u)^I{}_J (U_Q)^J{}_M}_{(U^\dagger_{\bar{u}} y_u U_Q)^K{}_M} Q^M H$$

just some set of 9 ¢ #

ROTATION ON IJ INDICES.

not trivial. CHANGES $y_u \to y_u'$

CAN CHOOSE $U_u^{\dagger}$ & U_Q to MAKE THIS NICE.

↳ e.g. $\langle H \rangle$ COULD POINT IN ANY DIRECTION,
BUT WE COULD DO SU(2) ROTATION TO MAKE SURE IT IS COMPLETELY IN THE REAL COMPONENT OF BOTTOM ($i=2$)

e.g. FERROMAGNET COULD POINT IN ANY DIRECTION,
BUT WE CAN ROTATE THE MAGNET SO THAT THE SPINS POINT IN z - DIRECTION.

fact: for any N×N ℂ matrix,
can diagonalize w/ BIUNITARY transf.

$$y \to \hat{y} = U^{\dagger} y V$$

N×N ℂ

DIAGONAL

UNITARY ROTS.
(DIFFERENT ON EACH SIDE)

SO WE CAN PICK $U_u^{\dagger} y_u U_Q$ s.t. y_u is DIAGONAL.

then when $H \to \langle H \rangle$, only $u_L u_R$ MASS TERM,
NOT $u_L u_R$, $u_L c_R$, $u_L t_R$, ...

Degrees of freedom

↳ # real functions in an object

eg. $H = \begin{pmatrix} a+ib \\ c+id \end{pmatrix} \leftarrow 4 \text{ DOF} = \begin{pmatrix} g_1 + i g_2 \\ h + i g_0 \end{pmatrix}$

MASSLESS GAUGE BOSON:

$A_\mu = \underbrace{(A_0, A_1, A_2, A_3)}$ ← $\mathbb{R}$

4 COMPONENTS, only 2 POLARIZATIONS ARE PHYSICAL (LH, RH POLARIZATION)

↳ reasons are nuanced.

① massless → no longitudinal deg of freedom

② gauge freedom

MASSIVE GAUGE BOSON: $W^\pm_\mu = (W^\pm_0, W^\pm_1, W^\pm_2, W^\pm_3)$

↳ 3 deg of freedom

(∃ longitudinal polz)

Higgs Mechanism: $\underbrace{\underset{3\times 2 \text{ DOF}}{W^{1,2,3}}, \underset{2 \text{ DOF}}{Y}, \underset{4 \text{ DOF}}{H}}_{12} \rightarrow \underbrace{\underset{2 \text{ DOF}}{A}, \underset{3 \text{ DOF}}{Z}, \underset{1 \text{ DOF}}{h}, \underset{2\times 3 \text{ DOF}}{W^\pm}}_{12}$

the MASSIVE Z, $W^\pm$ "EAT" the $g_1 \pm i g_2$, g_0 Degrees of FREEDOM in the H to become massive.

"GOLDSTONE BOSONS"

provide longitudinal polarization