Particle Physics, Part 2

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Recall from Wednesday

- Deep Inelastic Scattering (DIS): use high-virtuality photons from e to probe proton structure, process $e + p \to e + X$
- Cross section parametrized in terms of structure functions F_1, F_2 related to *parton distribution functions* $f_i(x, Q^2)$
- More QCD phenomenolgoy, e.g. jet production in $p + p$ (read!)
- CP is conserved in weak interactions
- Helicity: projection of the spin in the direction of momentum
- Only left-handed $\vec{p} \uparrow\downarrow s_p$ neutrinos exist
- Chirality: eigenvalue of γ^5 (left and right-chiral components)
- $SU(2) \times U(1)$: left-chiral fermions in doublets $\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L$ and $\begin{pmatrix} u \\ d \end{pmatrix}_L$, $SU(2)_L$ transform
- Right-chiral fermions: 1 component, $U(1)_Y$ transform

Quiz, p. 363

Quiz

Check that the Z-boson-neutrino interaction term reads (starting from Eq. 14.12)

$$\bar{\nu}_{eL} \frac{-ig}{2\cos\theta_W} \not{Z} \nu_{e,L}.$$

Use the definitions of the fields Z_μ and A_μ in terms of the Weinberg angle and the unification conditions (p. 363).

Quiz, p. 363

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$$\bar{\nu}_{eL}\left(\frac{-ig}{2}A^3_\mu + \frac{ig'}{2}B_\mu\right)\gamma^\mu \nu_{eL} = \bar{\nu}_{eL}(ig\cos\theta_W + ig'\sin\theta_W)Z_\mu\gamma^\mu\nu_{eL} = \frac{-ig}{2}\bar{\nu}_{EL}(\cos\theta_W + \frac{g'}{g}\sin\theta_W$$

$$\times \not{Z}\nu_{eL} = -\frac{g}{2}\bar{\nu}_{eL}\left(\frac{\cos^2\theta_W}{\cos\theta_W} + \frac{\sin\theta_W\sin\theta_W}{\cos\theta_W}\right)\not{Z}\nu_{eL} = \bar{\nu}_{eL}\frac{-ig}{2\cos\theta_W}\not{Z}\nu_{eL}$$

Quiz, p. 369

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(Note: this is a toy model, not the Standard Model!)

Quiz, p. 369

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hhh, $hhhh$, $hhAA$, hAA

Recall from Monday

- $SU(2) \times U(1)$: Lefthanded fermions in doublets, $SU(2)$ transforms, gauge fields A^1, A^2, A^3
- Right handed fermions: singlets, $U(1)$ transforms, gauge field B
- Identify $W_\mu^\pm = \frac{1}{\sqrt{2}}(A_\mu^1 \pm A_\mu^2)$ and (θ_W Weinberg angle)

$$\begin{pmatrix} A_\mu^3 \\ B_\mu \end{pmatrix} = \begin{pmatrix} \cos\theta_W & \sin\theta_W \\ -\sin\theta_W & \cos\theta_W \end{pmatrix} \begin{pmatrix} Z_\mu \\ A_\mu \end{pmatrix}$$

- Interactions: eeZ, $ee\gamma$, $\nu\nu Z$, $e\nu W$ (and also for quarks, e.g. udW)
- The Higgs mechanism: start with massless gauge bosons $A_\mu, W_\mu^\pm, Z_\mu$ and fermions. Higgs field has a vacuum expectation value $v/\sqrt{2}$. Choose vacuum = spontaneous symmetry breaking. Spurious d.o.f. (Goldstone bosons) removed by gauge transform.
- Masses to gauge bosons (Higgs part of $\mathcal{L}$ and femions (Yukawa $\mathcal{L}$)

Quiz, p. 375

Quiz

There is no Higgs-photon coupling, as $m_\gamma = 0$. However, the most clean channel to observe the Higgs is $H \to \gamma\gamma$. Draw a likely diagram for this. Why is this a clean process?

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The invariant mass of the photon pari $= m_H^2$. No invisible (undetected) particles. See lecture notes p. 408.

Quiz, p. 396

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Sort the following decays based on their likelihood (decay width). Begin by drawing the Feynman diagram.

1. $D^+(c\bar{d}) \to \overline{K^0}(s\bar{d}) + K^+(u\bar{s})$
2. $D^+(c\bar{d}) \to \overline{K^0}(s\bar{d}) + \pi^+(u\bar{d})$
3. $D^+(c\bar{d}) \to K^+(u\bar{s}) + \rho^0(d\bar{d})$

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2,1,3 (see page 397)