Autumn 2012

FYSH300 Particle Physics

Return by 09:00 on **Monday** 17.12.

Exercise 12 Discussed in **FYS5** on 17.12. at 12.15

1. On page 355 in the lecture notes we defined the helicity operator $\hat{\lambda}$ in its matrix form for a spin-$\frac{1}{2}$-particle.
   (a) Show that for a spin-$\frac{1}{2}$-particle the possible values of helicity are $\pm\frac{1}{2}$.
   (b) Using the Dirac-Pauli-representation results for the spinors $u^{(s)}$ on page 259 (let's take $E = E_p > 0$), show that at the ultrarelativistic limit $|\bar{p}| \gg m$ the chirality operator corresponds to the helicity operator i.e. that $\gamma^5 u^{(s)} \cong \hat{\lambda} u^{(s)}$.

2. On page 359 in the lecture notes we defined the projection operators P_L and P_R. Using the properties of γ^5 show that
   (a) $P_L^2 = P_L$
   (b) $P_R^2 = P_R$
   (c) $P_R P_L = P_L P_R = 0$
   (d) $\overline{\psi}_{L,R}\gamma^\mu\psi_{L,R} = \frac{1}{2}\overline{\psi}\gamma^\mu(1 \mp \gamma^5)\psi$

3. Verify equation 13.34 on page 369 in the lecture notes and convince yourself that the gauge field gets a mass ev and the Higgs field a mass $\sqrt{2\lambda v^2}$.

4. Consider pion decays to the channels $\pi^- \to \mu^-\bar{\nu}_\mu$ and $\pi^- \to e^-\bar{\nu}_e$.
   (a) Given that
   $$\Gamma(\pi^- \to l\bar{\nu}_l) = \frac{G^2}{8\pi} f_\pi^2 m_\pi m_l^2 \left(1 - \frac{m_l^2}{m_\pi^2}\right)^2$$
   estimate the ratio
   $$\frac{\Gamma(\pi^- \to e^-\bar{\nu}_e)}{\Gamma(\pi^- \to \mu^-\bar{\nu}_\mu)}.$$
   Compare your result with PDG.
   (b) The physical explanation for this small ratio is that at the extreme ultrarelativistic limit only lefthanded spin-$\frac{1}{2}$-fermions couple to the weak current. Draw the (first order) Feynman diagrams for such decays and figure out the helicities of the final state particles. Show that e^- is now ultrarelativistic and righthanded.

5. As suggested on page 373 in the lecture notes, compute the estimates for the gauge boson masses M_Z and M_W.

6. Drawing the Feynman diagrams figure out which of the following D^+-decays are Cabibbo-allowed or Cabibbo-suppressed and which of them are higher order in the weak interaction (and thus suppressed).
   a) $D^+ \to K^- + \pi^+ + e^+ + \nu_e$
   b) $D^+ \to K^+ + \pi^- + e^+ + \nu_e$
   c) $D^+ \to \pi^+ + \pi^+ + e^- + \bar{\nu}_e$
   d) $D^+ \to \pi^+ + \pi^- + e^+ + \nu_e$