Partice Physics: Problem Sheet 2

More on QED, Accelerators & Detectors, Quark & Leptons

1. Please make sure you have done questions 9 and 10 on last week's question sheet.

2. Draw the lowest and second order Feynman diagrams for electron-muon scattering $e^-\mu^- \to e^-\mu^-$. Discuss the corresponding Matrix element, $\mathcal{M}$, and cross section for the lowest order. Estimate the contribution of the second order diagrams to the cross section.

3. In a synchrotron accelerator, why do charged particles loose energy? The energy loss per turn is:

$$\Delta E = \frac{q^2\beta^3\gamma^4}{3\epsilon_0\rho}$$

   The LEP and LHC synchrotrons are built in the same tunnel ($\rho_{\text{LEP}} = \rho_{\text{LHC}} = 4300$ m). At LEP the energy of the electrons was $E_e = 45.2$ GeV; at LHC the energy of the protons will be $E_p = 7000$ GeV. What is the ratio of the energy loss at LEP and LHC?

4. Describe (briefly) how an electron, a charged pion and a muon appear in a typical collider detector.

5. Cosmic ray muons are produced at the top of the atmosphere. As they travel through matter, muons loose energy to ionisation. The energy loss for muons can be described by $dE/dx \approx 2.0\ \text{MeVg}^{-1}\text{cm}^2$.

   How much energy does a muon with three-momentum, $p_\pi = 5$ GeV/c lose by ionisation before reaching sea level?

   The mass thickness of the atmosphere, x, in g/cm^2, can be inferred from the pressure at sea level, $P = 1$ atm $= 10^5\ \text{kgm}^{-1}\text{s}^{-2}$, by assuming the density to be constant.

6. What quantum numbers are associated with leptons? Are they conserved in strong, weak and electromagnetic interactions?

7. What quantum numbers are associated with quarks? Are they conserved in strong, weak and electromagnetic interactions?

8. What are the charge, isospin, strangeness and baryon quantum numbers for the $\bar{\text{u}}$, $\bar{\text{d}}$ and $\bar{\text{s}}$ quarks? What are the quantum numbers of the lambda anti-baryon, $\bar{\Lambda}^0$, and of the antiproton, $\bar{p}$? Make sure you understand these in terms of quark content!

9. The four delta baryons: $\Delta^{++}, \Delta^+, \Delta^0, \Delta^-$ are formed only of up and down quarks, and form part of a isospin quadruplet. What is the quark content and isospin, I and I_Z, for these baryons?