Particle Physics: Problem Sheet 1

Introduction, Measuring Techniques

1. List all fundamental fermions in the Standard Model.

2. Explain why the decays $\mu^- \to e^- \bar{\nu}_e \nu_\mu$ and
   $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$ are allowed and why $\mu^+ \to e^+ \gamma$ and $\mu^+ \to e^+ e^- e^+$ are forbidden.

3. What is 1 fm in inverse GeV? How many seconds is 1 inverse GeV?

4. What are the Centre-of-Momentum (CoM) energies of the following machines:

   LEP1: e^+e^- collider, both beams 45.6 GeV

   LHC: pp collider, both beams 7 TeV

   HERA: ep collider, $E_\mathrm{e} = 30$ GeV and $E_\mathrm{p} = 820$ GeV (m_p=938.272 MeV/c^2)
   If HERA were a fixed target machine what energy would the electron require to give an equivalent CoM energy?

5. The Δ^{++} particle can be produced as a resonance by aiming a pion beam onto a hydrogen target, $\pi^+ p \to \Delta^{++} \to \pi^+ p$. Using the masses $m_\pi = 139.6$ MeV, $m_p = 938.3$ MeV and $m_\Delta = 1232$ MeV calculate the energy and momentum of the pions in the Δ^{++} centre-of-mass frame.

   From the measured resonance width of 120 MeV calculate the lifetime of the Δ^{++}.

6. The B_d meson has a mass of 5.28 GeV and mean lifetime of 1.54 ps. At the LEP collider operating at a beam energy of 45.6 GeV the B_d mesons are produced with an average energy of 32 GeV. Calculate the mean decay length of a B_d meson. What is the most probable decay length?