PH5260 – Particle Physics / 2006-07

Post Graduate Problem Set 1

To be handed in to PTD before the tutorial on November 9, 2006

---

1. The LEP1 collider at CERN collided electrons with positrons, both with energy 45 GeV. What positron beam energy would be required to obtain the same centre-of-mass energy on a stationary electron target? The proposed LHC will collide protons with protons at a beam energy of 7 TeV. What beam energy would be required for the same centre-of-mass energy in a fixed target experiment in this case?

♠

2. The π^0 is a spinless particle of mass 135 MeV which decays electromagnetically to two photons, $\pi^0 \to \gamma\gamma$, with a lifetime of 8.4×10^{-17}s. Show that the laboratory photon energy spectrum from pions is flat and compute its boundaries, $\mathrm{E}_\gamma^{\mathrm{min}}$ and $\mathrm{E}_\gamma^{\mathrm{max}}$. Sketch the spectrum for pions with total lab energy:
a) 135 MeV; **b)** 500 MeV; **c)** 1 GeV.

♣

3a) Use the Fermi Golden Rule to derive an expression for the differential cross-section, $d\sigma/d\Omega$, for two-particle scattering (A+B→C+D; m_{A}=m_{B}) in the centre-of-mass frame, in terms of the matrix element $\mathcal{M}$. **b)** If the particles are pointlike (*i.e.* zero size), how should the cross section vary as a function of energy?

♠

4. The ratio of the total cross-section for $\mathrm{e^+e^-}$ annihilation into hadrons to the $\mathrm{e^+e^-} \to \mu^+\mu^-$ cross-section is called R. **a)** Derive a formula for R between threshold and $E_{CM} > 2\,m_b$, where m_b is the b-quark mass. **b)** List the processes which contribute to the variation of R between threshold and 200 GeV centre-of-mass energy.

♣

5. The η is a spinless particle of mass 547 MeV which (like the π^0, question 2 above) decays electromagnetically to two photons: $\eta \to \gamma\gamma$. **a)** Use the Fermi Golden Rule for decays to estimate the lifetime of the η, using the π^0 as an analogy . **b)** Given that the full width of the η is 1.2 keV and the branching ratio of its decay to two photons is 39%, discuss critically the assumptions made in your estimate.