Physics 492 Homework X, due Fri Mar 28

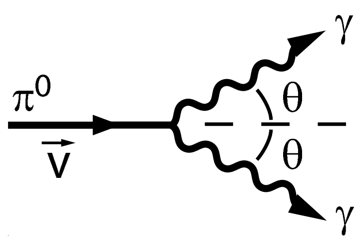
Reading: Chapters 9 and 10.1-7

Problems:

1. Consider the common neutral pion decay

$$\pi^0 \to \gamma + \gamma\,.$$

In the π^0 rest frame the photons have equal energies, equal to $m_\pi\, c^2/2$. Consider a Lorentz frame in which the π^0 energy is ϵ_π and in which the photons are emitted symmetrically as shown:



(a) Determine the angle between the photon directions as a function of ϵ_π. (Hint: In the pion rest frame, the photon momenta are equal in magnitude and opposite, perpendicular to the direction of $\vec{v}$. Apply a Lorentz transformation.)

(b) Calculate 2θ for $\epsilon_\pi = 1$ GeV and 10 GeV.

2. A typical strange particle production reaction is

$$\pi^- + p \to K^0 + \Lambda\,.$$

(a) Determine the Q value. (Particle masses: Williams, Tables 10.3, 10.4, and 10.5)

(b) Determine the π^- threshold energy in the p rest frame.

(c) Draw a Feynman diagram with quarks and gluons for this reaction. What is the basic quark process?

3. At the LEP collider at CERN, head-on electron-positron collisions take place, with E_e = electron energy = positron energy.

(a) Determine E_e for the production of a Z^0 boson in the reaction

$$e^+ + e^- \to Z^0\,.$$

The Z^0 mass is 92 GeV/c^2, and the total momentum is 0.

(b) Suppose that instead a fixed target experiment is carried out, with the electron at rest and the positron energy E'_e. Determine E'_e for the production of a Z^0.

(c) Explain in words why colliding beams can produce higher mass particles than a single beam hitting a fixed target.

4. Look up the masses of the spin-$\frac{3}{2}$ baryons of the baryon decuplet (Williams, Table 10.5).

(a) Plot the masses vs strangeness.

(b) Estimate the mass of the strange quark from the baryon masses.

5. Experiments in high-energy physics observe collisions between elementary particles which have been accelerated in a charged-particle accelerator to relativistic speeds. The products of the collisions are observed and measured in particle detectors.

Read about particle detectors in Perkins, *Introduction to High Energy Physics*, or Frauenfelder and Henley, *Subatomic Physics*, and write a one-page explanation of one kind of particle detector. Your explanation should include how the detector is constructed, how it is used, and the physical principles of how it works. (The books are on reserve in Physics Library.)

Reminder: The first draft of your term paper is due on Friday, April 4.