Fall Quarter 2007
UCSD Physics 214 & UCSB Physics 225
Homework 2

The first question is the promised Q that let's you explore the CMS detector a bit. All the remaining questions revolve around isospin and or the "generalized Pauli principle". I'm guessing that 2,6, and 7 are easier than some of the others. You might want to start with the easier ones.

1. This questions is meant to have you explore the CMS physics TDR volume 1 a bit. I will refer to information in the printed copy. However, there's also an online copy at https://cmsdoc.cern.ch/cms/cpt/tdr/ . You can find the material budget of the tracking system versus η in Figure 6.1 on p.226. The basic parameters of the tracking system are summarized in 1.5.5. Efficiencies are given in Figure 1.12 on p.23. The ECAL performance is summarized in 1.5.3.
   a. Figure 1.5 shows the tracking resolution for muons using the tracker only for two different ranges in η. In class we discussed a simplified model for the tracking resolution. Take that model and plot the corresponding resolution vs momentum. As inputs assume a point resolution of 40 microns for all layers. Plot the resolution for η=0 and η=1.6, and determine the momentum at which intrinsic resolution and multiple scattering are equal. How does this compare with the typical momentum for muons from Z decay?
   b. Given the material budget of the tracker, what fraction of pions undergo hadronic interaction before they reach the ECAL? Calculate this for η=0 and η=1.6 . Compare this with the efficiency for pions given in Figure 1.12.
   c. What's the minimum momentum required to reach the outer most silicon layer at η=0?
   d. For a 50GeV electron, compare the expected loss of energy due to radiation with the intrinsic resolution of the ECAL at that energy. Do so for η=0 and η=1.6. At what energy is the intrinsic resolution roughly equal to the average energy radiated for these two values of η. To be fair, the electron reconstruction algorithm in CMS accounts for this by allowing a much larger shower size in phi than η. A significant fraction of the radiated photon energy is thus measured in the ECAL, and attributed correctly to the electron track.
   e. Electrons from pair production are a significant source of "fake" electron backgrounds. The existing tracking algorithm in CMS requires hits in all three layers of the pixel detector. What percentage of high energy photons at our two favorite η points produce conversion electrons that might fake electrons from the interaction region? (Hint: Assume that 1/3 of the total material in the pixel detector is the relevant material budget for this question.)

2. What are the branching fractions of K^{*0} to K^0pi^0 , K^+pi^-, and K^-pi^+ ?
3. The parity of the charged pion can be deduced from the capture of pi^- in deuterium: pi^- d -> nn. The capture takes place from an S=0 state. Show that this reaction implies that the pion has odd parity. (Hint: Deuterons have spin 1 and even parity.)
4. Consider a pi0pi0 system in a state of angular momentum *l*. This could occur in the decay X -> pi0pi0 if the spin of the decaying particle is $S_X = l$, since the pion is spinless.
    a. What values of Isospin I are allowed for the pi0pi0 system?
    b. The pi0pi0 system can be described by a wave function that is a product of the spin and isospin wave functions. What is the symmetry of the space part of the wavefunction under interchange of the two pions? What can we say about the allowed values of *l* ?
    c. Is the decay rho0 -> pi0pi0 allowed? If so, by what interaction?
5. In which isospin states can (a) pi+pi-pi0 (b) pi0pi0pi0 exist?
6. Some of the most interesting isospin relationships are triangles in the complex plane. Show such a relationship for the amplitudes of the three scattering processes:
    a. Neutron pi0 -> proton pi-
    b. Proton pi- -> proton pi-
    c. Proton pi+ -> proton pi+
7. Consider proton deuteron scattering. The deuteron has I=0 while the proton is of course I=1/2. There are two final states with pions:

    Pi0 + He^3 and pi^+ + H^3

He^3 and H^3 form an Isodoublet, the former being +1/2 the latter -1/2. Predict the ratio of cross sections for the two reactions.