P424 Assignment 3

1) Interaction of particles in matter

a) The amount of energy a 1.5 GeV particle loses when traversing material depends on the particle type. Assume the particles e, μ, π, K, and p, each with 1.5 GeV momentum, traverse a medium of thickness 0.01 X_0. Which, on average, loses the most energy (order them from largest to smallest energy loss).

b) The particles from (a) enter a quartz bar with index of refraction n = 1.5. Which particles will emit Cherenkov radiation?

c) Consider an electromagnetic shower initiated by a 1 GeV positron in Lead. If we model the shower process as a series of bremsstrahlung events and subsequent pair production from the photons, estimate (crudely) how many positrons we expect to produce. (Hint: the critical energy in Lead is about 1 MeV.)

2) Particle detectors

Consider the BaBar detector (see http://www.slac.stanford.edu/BFROOT/www/doc/workbook/detector/detector.html). Describe how you would expect the decay $B \rightarrow J/\psi\ \pi^0$ to be recorded in the detector when the π^0 decays to $\gamma\gamma$ and the J/ψ decays to $\mu^+\mu^-$. Note that the decay lifetimes of both the J/ψ and the π^0 are less than 10^{-16} s. You should say where and how each particle is detected, and what properties are measured in each relevant device.

3) An experiment searching for proton decay in the mode $p \rightarrow e^+ + \pi^0$ is carried out using a cubical tank of water as the proton source. Possible decays are to be detected using the Cherenkov light emitted when the electromagnetic showers from the decay products traverse the water. (a) How big should the tank be in order to contain such showers if they start in the centre? (b) Estimate the total track length integral (TLI) of the showers from a decay event and hence the total number of photons emitted in the visible region (λ = 400-700 nm). (c) If the light is detected by means of an array of photomultipliers at the water surface, the effective optical transmission of the water is 50% and the photocathode efficiency is 20%, what fraction of the surface must be covered by photocathode to give an energy resolution of 5%?