Elementary Particle Physics: Assignment # 1

Due THURSDAY 02/08 10:00 am in class

1. A π^- decays most of the time as $\pi^- \to \mu^- \bar{\nu}_\mu$. What is the minimum energy of the π^- for which both the muon and the antineutrino are produced in the same direction as the π^- irrespective of their emission angle in the π^- rest frame? (Assume the neutrino have a mass of 1 eV, you can find the other masses in the particle data group page).

2. Repeat for a π^0 which decays as $\pi^0 \to \gamma\,\gamma$.

3. Belle II is an experiment working at KeK in Japan. It collides a beam of electrons and a beam of positrons with different beam energies to produce a particle called $\Upsilon(4S)$, a bound state of a bottom-quark and antibottom-quark with mass 10.58 GeV. No other particle is produced with the $\Upsilon(4S)$

   3.1 The electron has 8.0 GeV. What is the energy of the positron?

   3.2 What is the energy, momentum, β and γ of the $\Upsilon(4S)$ in the lab?

   3.3 A theorist has predicted that once in 10^6 times the $\Upsilon(4S)$ should decay into a pair of "exotic" identical neutral particles with mass $M = 4.5$ GeV which should then decay into observable charged particles. The experiment has produced 200 millions of $\Upsilon(4S)$ and did not find any unusual event. What can they tell to the theorist about the lifetime of this exotic particle?
   hint 1: the event of a $\Upsilon(4S)$ decaying so rarely into these exotic particles can only be "seen" if they decay inside the detector. Assume that the maximum distance from the interaction point to the edge of the detector is 8 m.
   hint 2: neglect that the $\Upsilon(4S)$ is decaying in flight