

Homework 1

Due Tuesday, Sep. 8 (see Prof. Avery or me for help or hints on any problem)

1. Do the following calculations.
 - a. (5 pts) The decay width of the η meson is $\Gamma_\eta = 1.30$ keV. What is its lifetime in sec?
 - b. (5 pts) The cross section for $e^+ + e^- \rightarrow \mu^+ + \mu^-$ is $\sigma = 4\pi\alpha^2 / 3E^2$, where E is the center of mass energy. Rewrite σ in dimensionally correct form by inserting appropriate factors of c and \hbar . What is σ in nb for $E = 30$ GeV? $1 \text{ nb} = 10^{-33} \text{ cm}^2$.
2. A D^+ meson has a momentum of 2.0 GeV. Use the PDG tables to find its properties.
 - a. (2 pts) What are its mass in GeV and lifetime in sec?
 - b. (3 pts) What is the total energy E in GeV? What is the kinetic energy in GeV?
 - c. (2 pts) What are β and γ ?
 - d. (3 pts) What is its average decay length in meters?
3. (10 pts) A beam of monoenergetic muons traveling at high velocity loses 25% of them over a distance of 1000 m. What is the momentum (GeV) and velocity (units of c) of each muon?
4. (10 pts) Cosmic rays are composed of energetic particles, mainly protons and heavier nuclei. Could long-lived unstable particles such as neutrons be cosmic ray components? One way of finding out is to determine whether neutrons could survive over (at least) interstellar distances of ~ 5 light years. What is the minimum energy (in GeV) needed by a neutron to allow a “reasonable” chance of survival after traveling a typical interstellar distance? How does this energy compare to that of most cosmic rays and what does this say about the likelihood of neutrons making up a significant cosmic ray component?
5. A nucleus of mass M at rest decays into a nucleus of mass $M - \Delta$ plus a photon.
 - a. (5 pts) What is the energy of the photon in terms of M and Δ ? Use 4-vectors to solve this exactly.
 - b. (5 pts) What the energy of the photon using Newtonian physics with conservation of momentum and energy (kinetic energies add up to Δ in natural units)? Assume that $E = p$ for a photon (natural units). Expand as necessary to find the fractional difference from (a) when Δ is small. What is the fractional difference when $\Delta = 0.01M$?