Interaction of particles with matter

IPM Tutorial1

1 - Exercise 1

Give all results with three significant digit.

a) Which is the most probable interaction mechanism of 100 KeV photons in lead (Z=82) ?

b) Compute the maximal kinetic energy that a photon with energy $E_\gamma = 950$ KeV can transfer to an electron of the matter in a Compton process. Which is the minimal energy of the final photon ?

c) Compute the maximum energy that a photon with energy $E_\gamma = 950$ KeV can transfer to the final photon and the minimal energy of the scattered electron.

d) If the scattering angle of the final photon is 30 degrees, compute the $\beta\gamma$ of the scattered electron.

2 - Exercise 2

1. Give the formula of the maximal kinetic energy that can be transferred to an atomic electron by an incoming particle in the regime where $\beta\gamma$ reduced to β, expressing, in this approximation, the energy in the center of mass of the incoming particle and the atomic electron.

2. Write the Bethe and Bloch formula in this regime neglecting the atomic shell and density corrections.

3. Explain how charged low-energy heavy particles of same velocity and different mass could be separated by measuring the energy loss in a thin detector.

4. For particles (Pa) of electric charge z (in unit of e) show that if the detector is thin enough the average energy loss is given by $\Delta E_{Pa} = z^2 \Delta E_{proton}$ for protons with the same velocity of Pa.

5. Express $\beta\gamma$ as function of the kinetic enegy, T, and the mass m.

6. Compute $\beta\gamma$ of α particles with T=0.4 GeV (take m_α = 4 GeV).

7. Compute the energy loss in hydrogen for protons of T=0.1 GeV (take m_p =1 GeV).

8. Compute the energy loss in hydrogen for α particles with T=0.4 GeV (take m_α = 4 GeV).

9. How could these results be used to identify heavy-charge particles ?

3 - Exercise 3

An accelerator produces 100 MeV protons and deuterons

1. Show that both particles satisfy the low-energy condition $2\gamma\frac{m_e}{m_0} \ll 1$.

2. Compute the time of flight of both particles over a 10 m distance.

4. Compute the average specific energy loss in a plastic scintillator made of CH_x (specific mass = 1.03 g cm^{-3}) for both particles, where x = 1.1 is the equivalent molecular H/C ratio. We will neglect the density and atomic shell corrections.

5. Compute for both particles the average energy loss ΔE in a 1-cm thick detector D1 made of CH_x.

6. What should be the approximate thickness of a second detector D2 located downstream of D1, if one wants to stop both protons and deuterons inside and measure their energies ?

7. If D1 is separate from D2 by 10 m what should be the signal time difference between D1 and D2 for protons and deuterons ?

8. Could you use that to separate protons from deuterons ?

4 - Exercise 4

1. What is the maximum kinetic energy of delta rays produced by 10 GeV/c K^- mesons in liquid nitrogen (at boiling point) ?

2. How many delta rays with kinetic energy greater than 100 MeV are produced in 2 m ? The specific mass of liquid nitrogen at boiling point is 1.3954 g/cm^3.

3. Can the K^- mesons of point 1. produce Cherenkov radiation in liquid nitrogen (the refractive index of liquid nitrogen is 1.205) ?