Interaction of particles with matter

Examination 10/02/2017 - 1 h 30'

Lecture slides, your lecture notes and pocket calculators are authorized. All questions can be answered using the formulas, the tables or the plots given in the lecture slides.

1 - Interactions of pions and electrons with matter

a) Compute the Lorentz factor, γ, the speed, β, and the momentum of charged pions ($\pi^{\pm}$) of kinetic energy $E_k = 100$ MeV. Give β with three significant digits. Take the mass of the pion, m ($\pi^{\pm}$) = 139.6 MeV/c^2.

b) Calculate the stopping power of these pions in iron (^{56}Fe) neglecting the shell and density corrections and compare it with the value extracted from the figure given in the slides of the course. Discuss if it is a reasonable assumption to neglect the shell and density correction.

c) Assume that the stopping power doesn't vary as function of $\beta\gamma$ of the pion. Will these pions emerge after having traversed a layer of iron of 1.5 cm of thickness ? Justify quantitatively the answer.

d) The range of $\pi^{\pm}$ with momentum p = 0.5 GeV/c in iron (^{56}Fe) is 250 g cm^{-2}. Evaluate the range in *cm* of pions with p = 0.5 GeV/c in tungsten (^{184}W). The mean free path of high energy pions (p $\geq$ 0.5 GeV/c) in ^{56}Fe and in ^{184}W is $\lambda = 132.1$ g cm^{-2} and $\lambda = 191.9$ g cm^{-2}, respectively. If you want to stop $\pi^{\pm}$ with momentum p = 0.5 GeV/c, with a minimum amount of matter will you use iron or tungsten ? Explain the answer.

2 - Cherenkov radiation

A proton with a momentum of 1.0 GeV/c passes through a gas at high pressure. The index of refraction of the gas can be changed by changing the pressure. Take the mass of the proton, m$_p \approx 1$ GeV/c^2.

a) What is the minimum index of refraction at which the proton will emit Cherenkov radiation ?

b) Consider a beam of particles with momentum p = 1 GeV composed of protons and muons. Is it possible to distinguish between these two kinds of particles using the Cherenkov effect ? (The mass of the muon is m$_\mu = 105.6$ MeV/c^2, m$_p \approx 1$ GeV/c^2). Explain the answer.

3 - Interactions of neutral particle on matter

a) Demonstrate the expression of the threshold energy of a photon for pair production in the field of a nucleus neglecting the participation of the nucleus to the process.

b) The mean free path of fast neutrons in lead is about 5 cm. Compute the total neutron cross section in lead in barn.