Experimental Particle Physics

ESIPAP 2020

Homework 1: Exercises

1 Order of magnitudes

Estimate the order of magnitude of the momentum p of the probe needed to explore the structure of each of the following objects:

Object	size [m]	p [GeV/c]
Atom	10^{-10}	
Nucleus	10^{-14}	
Nucleon	10^{-15}	
Quark	10^{-18}	

Assume that the typical size of the explored structure is comparable with the De Broglie wavelength of the probe:

$$\lambda = \frac{h}{p} \tag{1}$$

Hint: remember that $\hbar c = 197$ MeV fm, and work in natural units.

2 Reaction threshold

Compute the energy a pion beam impacting a metal target (assume the target is made of protons) should have for this reaction to happen:

$$\pi^- + p \to \pi^- + \pi^+ + \pi^- + p \tag{2}$$

Hint: remember that for a reaction to happen $\sqrt{s} \geq \sum_i m_i c^2$. Work in natural units to make calculation simpler.

3 Fixed target vs. collider experiments

How much energy E_{fix} should a fixed target experiment have to equal the center of mass energy E_{col} of two colliding beams? Prove that:

$$E_{\text{fix}} = 2\frac{E_{\text{coll}}^2}{m} - m \tag{3}$$

assuming both the beam(s) and the target are composed by particles of mass $m = m_1 = m_2$.
Hint: define the center of mass energy in both cases, then equal them.

4 Accelerating electrons

How much energy did electrons and positrons of $E = 50$ GeV and 100 GeV loose in one round at LEP ($L = 27$ km)? Remember that:

$$\Delta E = \frac{4\pi}{3}\frac{1}{4\pi\varepsilon_0}\left(\frac{e^2\beta^3\gamma^4}{R}\right) \tag{4}$$

Hint: remember that $\frac{e^2}{4\pi\varepsilon_0\hbar c} = \alpha$.