Exercises Series 1

1. Consider the conversion of one photon in one electron-positron pair. Determine the minimal energy that the photon has to have in order that this conversion would be possible if the photon is in presence of:

a) one proton

b) one electron

c) no charged particle is around

2. Consider the decay of a π^0 into $\gamma\gamma$ ($P_\pi = 100$ GeV/c). Determine

a) The minimal and the maximal angles that the two photons may have in the Laboratory frame ($P_{\pi^0} = 100$ GeV/c).

b) The probability of having one of the photons with an energy less than E_0, ($E_\pi/2 - P_\pi/2 < E_0 < E_\pi/2$) in the Laboratory frame.

c) Same as a) but considering now that the decay of the π_0 is into e^+e^-.

d) The maximum momentum that the π^0 may have in order that the maximal angle in its decay into $\gamma\gamma$ and in e^+e^- would be the same.

3. Consider a fixed target experiment with a monochromatic proton beam with a energy of 20 GeV and a 2 m length liquid hydrogen (H_2) target ($\rho = 60\,\mathrm{kg\,m^{-3}}$). In the detector, placed just behind the target, were measured beam fluxes of 7×10^6 protons/s and 10^7 protons/s with the target full and empty, respectively. Determine the proton-proton total cross-section at this energy and its statistical error:

a) Without taking into account the attenuation of the beam inside the target.

b) Taking into account the attenuation of the beam inside the target.

4. The LHC running parameters in 2012 were: Number of bunches = 1400; Time between bunches = 50 ns; Number of protons per bunch = 1.1×10^{11}; Beam width (σ) at the crossing point = $16\,\mu$m.

a) Determine the maximum instantaneous luminosity of the LHC in 2012.

b) Determine the number of interactions per collision ($\sigma_{pp} \sim 100$ mb).

c) Determine the maximum number of Higgs bosons decaying into 2 photons ($\sigma_H \sim 21$ pb; $BR_{H\gamma\gamma} = 2.28 \times 10^{-3}$) which could have been produced in 2012 in the LHC. Compare this number to the real number of detected Higgs in this particular decay mode reported by the LHC collaborations (~ 400). Discuss the difference knowing that the integrated luminosity of the LHC (luminosity integrated over the time) during 2012 was around $20\,\text{fb}^{-1}$.

5. In Natural Units (NU) and in SI the expression of the muon life time is given respectively by

$$\tau_\mu = \frac{192\pi^3}{G_F^2 m_\mu^5} \qquad \tau_\mu = \frac{192\pi^3\hbar^7}{G_F^2 m_\mu^5 c^4} \tag{1}$$

where G_F is the Fermi constant.

a) Is the Fermi constant dimensionless? If not, compute its dimension in NU and in SI.

b) Obtain the conversion factor for transforming G_F from SI to NU.