

Homework 2 Elementary Particle Physics (PHYSICS 552 UIC)

Be creative, and independent. Not think of this a homework, but fun.

Estimate how many events of deep inelastic scattering ($\nu_\mu N \rightarrow \mu X$) occurs when a beam of 10^{12} muon neutrinos at an energy 500 GeV hitting upon a thick wall of iron-stell, 1 meter long. Use the approximation that the nucleons in Fe are half protons and half neutrons. Roughly use the known fact that the momentum fraction carried by quarks in a nucleon is only about half, with rest carried by gluons.

(Hint: use the density of Fe 7.8 g/cc.)

Solution: Let N_{beam} be the number of the beam particles and N_{target} be the number of the target particles. A is the common overlapping area of the beam and the target. ρ_N is the target particle density, and d is the thickness of the target slab.

$$\frac{n_{\text{event}}}{N_{\text{beam}}} = \frac{\sigma}{A} \times N_{\text{target}} = \frac{\sigma}{A} \rho_N A d = \sigma \rho_N d$$

$$\begin{aligned} n_{\text{event}} &= N_{\text{beam}} \sigma \rho_N d = 10^{12} \sigma \left(7.8 \text{ (g/cm}^3\text{)} \times 1 \text{ (mole/g)} \times 6.022 \times 10^{23} \text{/mole)} \right) \times 100 \text{ cm} \\ &= 4.7 \times 10^{38} \text{ cm}^2 \times \sigma \end{aligned}$$

For an average nucleon,

$$\sigma = (G_F^2 m_N E / \pi) \int_0^1 x [u(x) + d(x)] dx$$

$$\sigma \approx (1.166 \times 10^{-5})^2 \times (0.94 \times 500 / 3.1416) \times 0.5 \text{ GeV}^{-2} = 1.02 \times 10^{-8} \text{ GeV}^{-2}$$

Check the conversion between the natural unit and SI unit, $1 \text{ GeV}^{-2} = 389 \times 10^{-30} \text{ cm}^2$. The expected event count is about 1828.