

Nr 3

Neutrinos do much less (no) weak ~~and~~ or electromagnetic interaction than electrons.

Also the average way of flight without collisions is (also due to the first point) much longer.

Regarding deep inelastic scattering, electrons can interact with every quark with electromagnetic interaction while neutrinos are using weak interaction (W^+ transfer) so they are only responsive to d -, \bar{u} -, s -, \bar{c} -quarks (or counterparts regarding anti-neutrinos).

Because of transversal momentum transfer the and parity violation of neutrinos weak interaction there is an additional partial form factor component, adding up to 3 in total for neutrino-DIP in contrast to electron-DIP.

Nr 4

a) $q_{el} = (25 \frac{\text{GeV}}{c}, 0, 0, -25 \frac{\text{GeV}}{c} + 511 \frac{\text{MeV}}{c})$

$$q_p = (800 \frac{\text{GeV}}{c}, 0, 0, 800 \frac{\text{GeV}}{c} - 938 \frac{\text{MeV}}{c})$$

$$s = (q_{el} + q_p)^2 c^2 = (825 \frac{\text{GeV}}{c})^2 - (774, 063 \frac{\text{GeV}}{c})^2 \\ = 81451 \text{ GeV}^2$$

b) same reaction (\Rightarrow same $M + \text{energy}$ \Rightarrow fixed target)

$$s = (q_{el} + q_p)^2 c^2 = (E_{el} + E_p)^2 - (E_{el} - m_{el})^2 - (E_p - m_p)^2 \\ = E_{el}^2 + E_p^2 + 2E_{el}E_p - (E_{el}^2 - 2m_{el}E_{el} + m_{el}^2) - (E_p^2 - 2m_pE_p + m_p^2) \\ = 2E_{el}E_p + E_p^2 + 2m_pE_p - 2m_{el}E_{el} = E_p^2 + 2E_{el}E_p + 2E_{el}m_{el} - m_{el}^2$$

$$\Rightarrow E_{el} = \frac{E_p^2 + m_p^2 + 2m_pE_p}{2E_p + 2m_p} \quad \text{fixed proton target : } E_p = m_p$$

$$\Rightarrow E_{el} = \frac{81451 \text{ GeV}^2 - (511 \text{ MeV})^2 + (938 \text{ MeV})^2}{2 \cdot (938 \text{ MeV} + 511 \text{ MeV})} = 43395 \text{ GeV} = 43.47 \text{ TeV}$$

c) $\Delta x \propto \frac{t}{Q^2}$, $Q^2 = 2E_{el}E_p(1 - \cos(\vartheta)) / c^2$

In case of highest Q^2 , elastic scattering with $\vartheta = 180^\circ$ with full energy-transfer, the equation $Q^2 = \frac{s}{c^2}$ is valid.

$$\Rightarrow \Delta x = \frac{t^2 c^2}{Q^2} = 2,306 \cdot 10^{-27} \text{ s} \cdot c = 6,914 \cdot 10^{-19} \text{ m} = 6,914 \cdot 10^{-4} \text{ fm}$$

(for the beam)

$$\Delta x = \frac{t^2 c^2}{Q^2}$$

d) If the electron is scattered back at $\vartheta = 180^\circ$ elastically and got the full energy of the proton, Q^2 can be calculated with $Q_{\max}^2 = \frac{s}{c^2}$.

In this case that means: $Q_{\max}^2 = 81451 \frac{\text{GeV}^2}{c^2}$

e) The Lorentz-invariant Bjorken x is an indicator in deep inelastic scattering how inelastic the total process of scattering is. For an elastic process x is exactly 1 while otherwise it is between 0 and 1. ($0 < x \leq 1$) It also indicates that hadrons behave like a collection of point-like particles at high energy scattering.

f) Bjorken scaling refers to the model where strong interacting particles are behaving like collections of point-like particles in high energy scattering.

This leads to the relation that form factors with the same Bjorken- x are independent of Q^2 !

The observation of this lead to the point-like substantiation of the proton (model).