higher hadron physics Exercise 2 Julian Bergmann

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 momentumtransfer the and parityviolation of neutrinos weak interaction ther is an additional partial form factor component, adding up to 3 in total for neutrino-DIP in contrast to elektron-DIP.

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No 4

a) $q_{el} = \left(25\,\frac{GeV}{c}, 0, 0, -25\,\frac{GeV}{c} + 511\,\frac{keV}{c}\right)$

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

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

$= 81451\,GeV^2$

b) same reaction $\Leftrightarrow$ same CM-energy

$s = (q_{el}+q_p)^2 c^2 = (E_{el}+E_p)^2 - (\underbrace{(E_{el}-m_{el})+(E_p-m_p)}_{=0\ \text{(fixed targ.)}})^2$

$= E_{el}^2 + E_p^2 + 2E_{el}E_p - (E_{el}^2 - 2E_{el}m_{el} + m_{el}^2)$

$= E_p^2 + 2E_{el}E_p + 2E_{el}m_{el} - m_{el}^2$

$\Rightarrow E_{el} = \frac{E_p^2 - m_{el}^2 + s}{2(E_p + m_{el})}$ fixed proton target : $E_p = m_p$

$\Rightarrow E_{el} = \frac{81451\,GeV^2 - (511\,keV)^2 + (938\,MeV)^2}{2\cdot(938\,MeV + 511\,keV)} = 43395\,GeV = 43{,}4\,TeV$

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

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

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

~~(for two beams)~~

~~$\Delta x = \frac{\hbar c}{\sqrt{s}}$~~

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

In this case that means : $Q^2_{max} = 81451\,\frac{GeV}{c^2}$

e) The Lorentzinvariant 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 highenergy scattering.

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

This leads to the relation that form faktors with the same bjorken-x are independant of Q^2!

The observation of this lead to the pointlike substruct of the proton (quarks)