Modern Experimental Particle Physics (FYST17) - Problems

Chapters 5-7; return by February 15

1) In a fixed target experiment, a π^- beam is used on a proton target and the process $\pi^- + p \to \Delta^0 \to \pi^0 + n$ can occur.

a) Draw a quark diagram for this process and estimate the mean distance travelled by the Δ^0 before it decays, assuming it was produced with $\gamma = E/m \approx 10$.

b) Using four-vectors, compute the π^- beam energy required to produce the above process at the Δ^0 resonance, $m(\Delta^0)$=1230 MeV.

c) Show that, if the π^0 and n are produced with an angle $\theta=\pi/2$ between them, they can only obtain the energies $E(n)E(\pi^0)=E(\pi^-)$ and $E(\pi^0)E(n)=m(p)$, assuming that $m(\pi^-)=m(\pi^0)$ and $m(n)=m(p)$.

2) Resonance Δ^{++} has a barion number B=1, electric charge Q=2, and $S = C = \tilde{B} = T = 0$. Explain why such particle can not exist unless color charge is introduced. Could a baryon with three down quarks exist?

3) The Coulomb potential represents a point charge. When an electrostatic potential is instead represented by a spherically symmetric charge density $\rho(r)$, the differential scattering cross section differs from the Rutherford cross section by a form factor squared, $G^2_E(q^2)$:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_R G_E^2(q^2)$$

where

$$G_E(q^2) = \int \rho(r) e^{i\vec{q}\cdot\vec{x}} d^3\vec{x}$$

Perform the angular integration of the form factor and show that:

- $G^2_E(q^2)$ is a function of q^2 only
- the mean squared radius of $\rho(r)$ equals

$$\overline{r^2} = \int r^2 \rho(r) d^3\vec{x} = -6 \left.\frac{dG_E(q^2)}{dq^2}\right|_{q^2=0}$$

<u>Bonus problem (not mandatory, but you can get an extra point):</u>

Explain the effect on the differential cross section (w.r.t. the scattering angle θ) when a point charge (infinitely narrow distribution) is replaced by a charge density $\rho(r)$, represented by a Gaussian (normal) distribution.

Note that the Fourier transform of a “narrow” Gaussian becomes a “wide” Gaussian distribution (and vice versa). Both charge distributions are normalized to 1.