

Modern Experimental Particle Physics (FYST17) - Problems 2015

Chapters 5-7; return by February 10

1) In a fixed target experiment, a π^- beam is used on a proton target and the process

$\pi^- + p \rightarrow \Delta^0 \rightarrow \pi^0 + n$ 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 baryon 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, $G_E^2(q^2)$:

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

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:

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

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

Bonus problem (not mandatory, but you can get an extra point):

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.