

# Modern Experimental Particle Physics (FYST17) - Problems

## Chapters 5-7; return by February 27

1) In a fixed target experiment, a  $\pi^-$  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  $\Delta^0$  before it decays, assuming it was produced with  $\gamma = E/m \approx 10$ .

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

c) Show that, if the  $\pi^0$  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  $\Delta^{++}$  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  $\theta$ ) 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.