Modern Experimental Particle Physics FYST17
Problem set 1, VT2016

Deadline: February 1, 2016, 15:00

Problem 1

Elastic scattering of elementary particles preserves their identities, and proceeds via exchange of neutral gauge bosons. Estimate the maximal range over which such exchange can take place, if the exchanged boson is:

a) a photon
b) a Z boson
c) a Higgs boson

Problem 2

The resonance Δ^{++} has baryon number B=1, electrical charge q=2, and flavor quantum numbers = 0. Explain why such a particle cannot exist unless color charged in introduced. Could a baryon with three down-type quarks exist?

Problem 3

In a fixed targed 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. Assume that it was produced with $\gamma = E/m \approx 10$.

b) Using 4-vectors, compute the π^- beam energy reguired to produce the above processes at the Δ^0 resonance, m(Δ^0) = 1230 MeV.

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

Problem 4

To the lowest order in weak interactions decays proceed via a single W-boson exchange. Explain why the decay $\Sigma^- \to n + e^- + \bar{\nu}_e$ have been observed, while the decay $\Sigma^+ \to n + e^+ + \nu_e$ is never observed. (Σ^- = dds, Σ^+ = uus) Plot the quark diagram for the Σ^- decay.

Problem 5

In February 1987 bursts of neutrino interactions associated with $\bar{\nu}_e$ were observed at both the *Kamioka* and the *IMB* detectors, which were buildt to detect proton decay. A few hours later, astronomers reported visual observation of the supernova SN1987, approximately 1.5×10^5 light years away. Assuming that this event was the source of the registered neutrino bursts, estimate an upper limit of the $\bar{\nu}_e$ mass, knowing that the incident neutrino energies covered the range 10-40 MeV and the interactions were observed to occur over a ~10 second period.