Particle physics - written test n. 2

14th January 2020

Solve the following three problems (including the extra questions only if desired). The test is passed with a score of at least 15 points.

Problem 1 (5 points)

A photon collides with a proton of mass M at rest in the lab frame. What is the necessary minimal energy for the photon such that in the final states we will have a neutral pion of mass M_0 in addition to the original proton?

(Extra question, +2 points)

What is the necessary minimal energy for the photon such that in the final state there are n neutral pions in addition to the original proton?

Problem 2 (10 points)

Consider the flavour SU(3) baryon decuplet.

(a) Draw the decuplet in the (I_3, Y) plane, indicating the name of the particles and their quark content **(5 points)**.

(b) For each particle calculate $I(I+1) - Y^2/4$, where I is the total isospin, show that it is a linear function of Y, $I(I+1) - Y^2/4 = \alpha Y + \beta$, and find the coefficients α, β **(5 points)**.

Problem 3 (10 points)

Let $\phi(x)$ be a real scalar field and $\psi(x)$ a Dirac spinor field in the usual 3+1 dimensions, and assume that their interaction is described by the Lagrangian density

$$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{1}{2}m^2\phi^2 + \bar{\psi}(i\gamma^\mu\partial_\mu - M)\psi + g\phi\bar{\psi}\psi\,.$$

(The last term is often called *Yukawa interaction.*) Determine the following:

(a) mass dimension of m, M and g **(4 points)**;

(b) the expression for the vertex in Feynman diagrams, including

i) its graphic representation **(3 points)**;

ii) the associated factor **(3 points)**.

(Extra question, +4 points)

Determine the mass dimension of g in general D (time+space) dimensions.