PHYSICS 474: Introduction to Particle Physics

Homework 4 **Due: 11.30 Monday 02/10/2020**

1. **Isospin in Nuclear Physics:**

   (a) [5 points] The α particle (used in Rutherford's scattering experiment) is a bound state of two protons and two neutrons, i.e. a ^{4}He nucleus. Given that we do not find either ^{4}H or ^{4}Li in nature, what can you say about the isospin of an α particle?

   (b) [5 points] Based on your result from part (a), explain why the reaction $D + D \to \alpha + \pi^0$ has never been observed. [Here D stands for deuteron (^{2}H).]

   (c) [5 points] Based on isospin arguments, would you expect a four-proton bound state (^{4}Be) to exist? What about a four-neutron bound state?

2. **Isospin in Particle Physics:** [25 points] Using the fact that strong interactions conserve isospin, find the ratio of cross sections for the following reactions:

   (a) $\pi^- + p \to K^0 + \Sigma^0$, (b) $\pi^- + p \to K^+ + \Sigma^-$, (c) $\pi^+ + p \to K^+ + \Sigma^+$.

   You can assume that the center-of-mass energy is such that either the $I = 3/2$ or $I = 1/2$ channel dominates at a given energy. [*Hint:* See the eightfold-way diagrams from class (also on p. 35-36 of Griffiths) if you aren't sure what isospin multiplets K mesons and Σ baryons belong to.]

3. **Dipole Moments:**

   The non-relativistic Hamiltonian in presence of electric and magnetic fields is given by

   $$H = -\frac{1}{|\mathbf{J}|}(\mu\, \mathbf{J}\cdot\mathbf{B} + d\, \mathbf{J}\cdot\mathbf{E}), \tag{1}$$

   where $\mathbf{J}$, $\mathbf{B}$ and $\mathbf{E}$ are the total angular momentum, magnetic and electric field vectors respectively, and μ, d are the magnetic and electric dipole moments respectively.

   (a) [5 points] Find the C, P and T transformation properties of $\mathbf{J}$, $\mathbf{B}$ and $\mathbf{E}$.

   [*Hint:* You may use the fact that Maxwell's equations are invariant under C, P, T.]

   (b) [5 points] What can you tell about the C, P and T properties of the magnetic and electric dipole moments (μ and d) in Eq. (1)?