Name: PHY625 (Fall 2012), 11/07/12

Homework Assignment #5

(*Due Date*: Friday, November 16, 01:50 pm, in class)

5.1 *Kinematics in Hadron Scattering* *(1+2 pts.)*

The 2 sub-problems below are essentially independent of each other.

(a) Fully ionized ^{16}O nuclei are directed toward a ^{197}Au target. What is the minimal kinetic energy (in [MeV]) for an oxygen nucleus to "touch" a gold nucleus in a central collision (use the nuclear radius formula $R_A = 1.2\, A^{1/3}$ fm in this estimate)?

(b) High-energy protons are directed toward a hydrogen target. What is the minimal (total) bombarding energy (in [GeV]) to being able to create antiprotons? (*hint: watch out for baryon number conservation*)

5.2 *Isospin Invariance of* π-N *Interactions* *(2+2 pts.)*

A simple π-N-N interaction Lagrangian may be written as

$$\mathcal{L}_{\pi NN} = g_{\pi NN}\ \bar{\psi}_N\, i\gamma_5\, \vec{\pi}\cdot\vec{\tau}\,\psi_N\ , \tag{1}$$

where the arrows indicate vectors in isospin space (recall that the nucleon spinors are doublets in this space).

(a) Show that the above Lagrangian is invariant under rotations in isospin space by applying an infinitesimal rotation to all field operators about an angle $\epsilon \ll 1$,
$\psi_N \to (1 - \vec{\epsilon}\cdot\vec{\tau}/2)\psi_N\ ,\quad \pi \to (1 + \vec{\epsilon}\,\times)\ \vec{\pi}\ \ ,$
and verifying the invariance to leading order in ϵ.

(b) Show that the above Lagrangian predicts relations between the physical couplings as

$$g_{pp\pi^0} = -g_{nn\pi^0} = \frac{1}{\sqrt{2}} g_{pn\pi^+} = \frac{1}{\sqrt{2}} g_{pn\pi^-} \tag{2}$$

where the physical (charged and neutral) pion fields are related to the cartesian ones, $\vec{\pi} = (\pi_1, \pi_2, \pi_3)$, as $\pi^\pm = (\pi_1 \pm i\pi_2)/\sqrt{2}$ and $\pi^0 = \pi_3$.

5.3 *Hadron Quantum Numbers* *(2+1 pts.)*

Consider the constituent-quark model for hadron structure.

(a) In the meson sector ($\bar{q}q$ states), $SU(3)$ flavor multiplets are characterized by different parity (P) and particle-antiparticle conjugation (C) eigenvalues. Explain how these emerge (for neutral mesons) from the total quark spin, S, and relative angular momentum, L.

(b) Give two empirical evidences that suggested an additional intrinsic quark quantum number (beyond spin and flavor).