PHYSICS 474: Introduction to Particle Physics

Midterm March 5, 2018

1. [5 points] Following is a list of conservation laws (or symmetries) for interactions between particles. For each indicate by S, E, W those classes of interactions – strong, electromagnetic, weak – which respect that symmetry.

   (a) Isospin (I) conservation

   (b) I_3 (but not I) conservation

   (c) Strangeness (S) conservation

   (d) CP conservation

   (e) CPT conservation

   Bonus 1 (2 points): If any interaction violates any of these symmetries, give an example decay process in each case to support your claim.

2. (a) [10 points] Suppose a particle X decays *at rest* to two other particles Y and Z. Specify the kinematic constraint under which this decay is allowed. Find the energies and momenta of the outgoing particles.

   (b) [5 points] A typical example of 2-body decay is $\pi^+ \to \mu^+ + \nu_\mu$ (or $\pi^- \to \mu^- + \bar{\nu}_\mu$). Assuming the neutrino to be massless, find the energy and momentum of the muon in MeV units. [*Hint:* $m_\pi = 139.6$ MeV/c^2 and $m_\mu = 105.6$ MeV/c^2.]

3. [10 points] The electrically neutral baryon Σ^0 (of mass 1915 MeV/c^2) has isospin $I = 1$, $I_3 = 0$. Find the ratio of the rates for the *strong* decays $\Sigma^0 \to K^- p$ and $\Sigma^0 \to \bar{K}^0 n$. [*Hint*: (p, n) and $(\bar{K}^0, K^-)$ both form isospin doublets.]

   Bonus 2 (2 points): There also exists a *weak* decay mode: $\Sigma^0 \to \pi^- p$. What should be the rate of this decay as compared to that of $\Sigma^0 \to K^- p$?

   Bonus 3 (1 point): What about the decay $\Sigma^0 \to \pi^+ \pi^-$?