PHYS4702 Atomic, Nuclear, & Particle Physics Fall 2015 HW #12

Due to the Grader by 5pm on Tuesday 8 Dec 2015

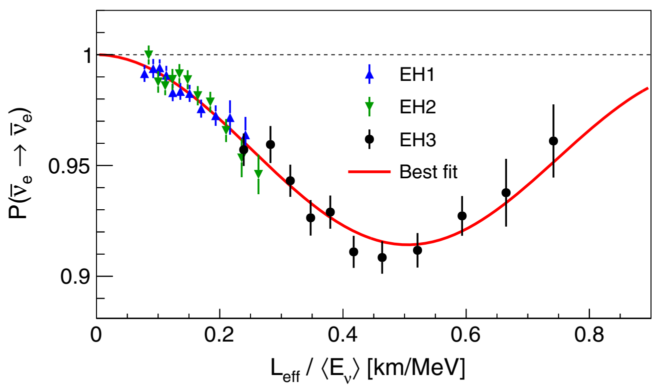
(1) Derive the formula for "two-neutrino disappearance" oscillations, namely

$$P(\nu_a \to \nu_a) = |\langle \nu_a | t \rangle|^2 = \left| \langle \nu_a | e^{-iHt/\hbar} | \nu_a \rangle \right|^2 = 1 - \sin^2 2\theta \sin^2\left(1.27\ \Delta m^2 \frac{L}{E}\right)$$

where ν_a is a flavor eigenstate, θ is the mixing angle between flavor and mass eigenstates, $\Delta m^2 \equiv m_2^2 - m_1^2$ is the difference between the squares of mass eigenvalues in eV/c^2, and L/E is in m/MeV or km/GeV. Here H is the Hamiltonian for a free (relativistic) particle and all neutrino states have definite momentum $p \gg m_{1,2}c$. The mixing between ν_a and ν_b is

$$|\nu_a\rangle = \cos\theta|\nu_1\rangle - \sin\theta|\nu_2\rangle \qquad \text{and} \qquad |\nu_b\rangle = \sin\theta|\nu_1\rangle + \cos\theta|\nu_2\rangle$$

Use the following data to estimate θ and Δm^2 for $\bar{\nu}_e$ disappearance:



The reference is F.P. An, et al., PRL 115(2015)111802 if you'd like to check your answer.

(2) The following pairs of mesons are the lowest mass 0^- & 1^- partners of a u/d quark paired with u/d, s, c, and b quarks:

$$\pi\ \&\ \rho \qquad K\ \&\ K^\star \qquad D\ \&\ D^\star \qquad B\ \&\ B^\star$$

In the quark model, these are ground state "spin flip" pairs of the u/d quark with the other quark, and the mass differences are due to the "color hyperfine" interaction, modeled after the hyperfine interaction in hydrogen, that is

$$\Delta M = k \frac{\mathbf{S}_1 \cdot \mathbf{S}_2}{m_1 m_2}$$

Identify the ground state "quarkonium" vector meson corresponding to each of these pairs. Using constituent quark masses derived from the quarkonium vector mesons, show that there is (more or less) one constant k that explains all four mass splittings. Compare to the result in hydrogen, and explain why it is so much larger.

(3) Find online at pdg.lbl.gov a comparison of measurements of decay modes of the Higgs boson to predictions from the theory. What does this say about the Standard Model? Would you call this "good news" or "bad news" for particle physics?