<code>PHYS4702</code> Atomic, Nuclear, & Particle Physics $\,$ Fall 2015 $\,$ HW $\#12$ Due to the Grader by 5pm on Tuesday 8 Dec 2015 LD NOW $\#12$ Ω allowed at the 68.3%, 95.5%, and 99.7% confidence levels by the mic, inuclear, & Particle Physics Fall μ e Crodon by Enm on Tuesday Ω <u>the Grader by 5pm</u> on Tuesday 8 L

 (1) Derive the formula for "two-neutrino disappearance" oscillations, namely \log_{10} $\mathcal{F}_{\mathcal{A}}$ μ a for μ wo-neutrino disappearance oscinations, eej

dependence of Δ on sin2 Δ on sin2 Δ on sin2 Δ

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

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/c², and L/E is in m/\overline{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 \mathbf{r} dependent disappearance of the electron antineutrino inter- μ and μ is a and ν_b to

$$
|\nu_a\rangle = \cos \theta |\nu_1\rangle - \sin \theta |\nu_2\rangle
$$
 and $|\nu_b\rangle = \sin \theta |\nu_1\rangle + \cos \theta |\nu_2\rangle$

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.

pairs of mesons are the lowest mass $0^- \& 1^-$ partners of a u/d quark $\frac{1}{2}$ sin 2 $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ with sin2 $\frac{1}{2}$ with sin2 $\frac{1}{2}$ with sin2 $\frac{1}{2}$ (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:

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

In the quark model, these are ground state "spin flip" pairs of the u/d quark with the other Material at http://link.aps.org/supplemental/10.1103/ Physical articles these are greater scale fight in points of the α_j 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?