P630 Nuclear Astrophysics

Problem Set #5 **C. Horowitz**

Due Monday Nov. 4, 2002

1] Testing solar ν osc. at Kamland

If the solar ν problem is explained by $\nu_e \rightarrow \nu_\mu$ oscillations with parameters

$$\delta m^2 = 5 \times 10^{-5} ev^2$$

and

$$\sin \theta_v = 30^\circ$$

a) Plot the $\bar{\nu}_e$ to $\bar{\nu}_e$ survival probability for reactor antineutrinos over distances up to 500 km. Note KAMLAND is a large liquid scint. detector that measures $\bar{\nu}_e$ produced by power reactors at distances of 100 to 1000 km. Assume the $\bar{\nu}_e$ energy is 5 MeV. Ignore matter effects.

b) Calculate the density at which a 1 MeV solar ν will become resonant in the Sun.

c) Calculate the minimum neutrino energy that becomes resonant in the core of the Earth. The density of the Fe in the Earth's core is about 13 g/cm^3. This number governs the size of expected day night effects in the measured solar ν_e flux. Note even if the resonant energy is larger than that for ^8B neutrinos, there can still be very small but nonzero matter effects for ν that don't quite reach resonance.

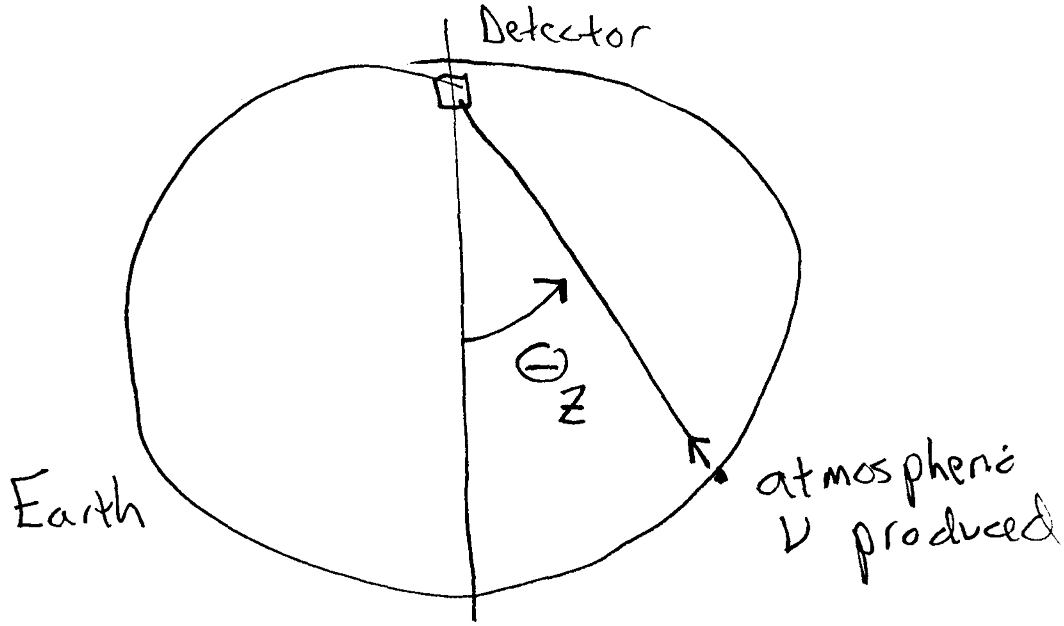
2] Atmospheric Neutrinos

Appear to oscillate $\nu_\mu \rightarrow \nu_\tau$ with parameters

$$\delta m^2 \approx 3 \times 10^{-3} ev^2$$

$$\theta_v \approx 45^\circ$$

Calculate the survival probability $P_{\nu_\mu \to \nu_\mu}$ for a 5 GeV atmospheric neutrino as a function of the zenith angle θ_Z



Let $\cos\theta_Z = 1$ be a neutrino coming straight up.

Plot $P_{\nu_\mu \to \nu_\mu}$ versus $\cos\theta_Z$. Assume the detector is near the surface of the Earth.

3] LSND Neutrinos at MiniBoone.

The LSND experiment at Los Alamos appears to see $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations with parameters that could include

$$\Delta m^2 = 1 eV^2$$

$$\sin^2 2\theta_v = 0.01$$

Calculate the oscillation length for 800 MeV neutrinos produced at the Fermi lab booster. Note the MiniBoone detector is 500 meters away from the beam stop. Discuss this choice of distance.