Exp. Methods in Astroparticle Physics (SS 2020) - Problem sheet 7

Tutorial: Arnulf Barth (arnulf.barth@kip.uni-heidelberg.de)

Deadline for this sheet: Thu, 11.06.2020

Neutrinos: Appearance experiment, CP violation, oscillations

7.1 Neutrino charged current *4 Points*

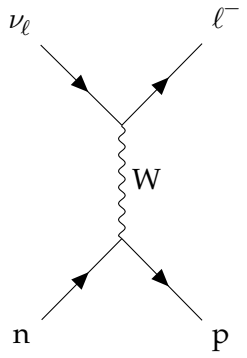
The interaction of neutrinos with neutrons enables a useful method to probe neutrino oscillations. Determine the energy threshold for

a) electron neutrinos

b) muon neutrinos

c) tau neutrinos

for charged current scattering on a neutron in the laboratory frame. Can this charged current interaction be used for appearance experiments aiming to detect muon and tau neutrinos due to the oscillation of solar electron neutrinos?



7.2 CP violation *3 Points*

State whether CP violating effects are possible in a neutrino beam if the mixing is just between two flavor eigenstates (without considering matter effects). Would there be CP violating effects if the neutrino beam were to pass through matter (over a sufficiently large distance)?

7.3 Neutrino oscillations *3 Points*

Let us consider the mixing of the muon and tau neutrinos, using as an approximation the two-flavor neutrino oscillation formula:

$$\mathrm{P}\left(\nu_\mu \to \nu_\tau\right) = \sin^2\left(2\theta_{23}\right) \sin^2\left(\frac{\Delta m^2_{23}}{4E} L\right), \tag{1}$$

where θ_{23} is the mixing angle and Δm^2_{23} the squared mass difference of the 2 and 3 neutrino mass eigenstates, E is the energy of the neutrino, and L is the distance it travels. From the investigation of oscillations of muon neutrinos in Superkamiokande, we know that the mixing angle $\theta_{23} \simeq 41.5$ while the squared mass difference $\Delta m^2_{23} \simeq 2.5 \times 10^{-3}\,\mathrm{eV}^2$. What would be the best distance to place a detector if a muon neutrino beam of $17\,\mathrm{GeV}$ would be used to search for a tau appearance?