Exp. Methods in Astroparticle Physics (SS 2020) - Problem sheet 10

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

Deadline for this sheet: Thu, 02.07.2020

Neutrino Beams

10.1 Neutrino beam production *4 Points*

Let us consider that after an energetic proton beam hits onto a carbon target, a $10\,\mathrm{GeV}$ beam consisting of positive pions and kaons is created. This beam is then brought into a $500\,\mathrm{m}$ long decay pipe.

a) What is the fraction of pions and kaons (respectively) decaying in the tube? *Note: Look up the meson masses and lifetimes.*

b) Determine the maximum energy of the generated neutrino beam from pion and kaon decay.

c) Demonstrate that the minimum neutrino energy is vanishing in good approximation.

10.2 Energy profile of neutrino beams *4 Points*

A neutrino beam of energy $\langle E_\nu \rangle = 20\,\mathrm{GeV}$ is produced from the decay of charged pions.

a) Write down all decay channels leading to neutrinos.

Estimate:

b) the energy of the pion beam that has generated the neutrino beam (assuming monochromaticity)

c) the divergence of the neutrino beam at the far detector located at a distance of $100\,\mathrm{km}$ downstream of the beam pipe

d) the order of magnitude of the neutrino-nucleus cross section. Take into account the different contributions showcased in Figure 1

e) the mean free path of those neutrinos in water.

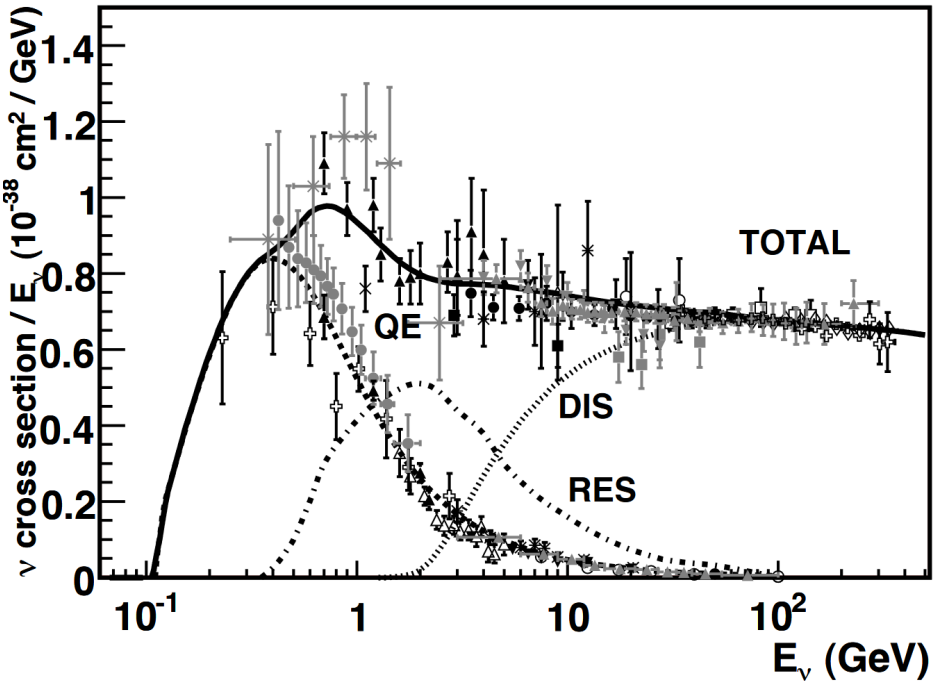

Figure 1: Total neutrino and antineutrino per nucleon CC cross sections (for an isoscalar target) divided by neutrino energy and plotted as a function of energy. Also shown are the various contributions from quasi-elastic (QE), resonance production (RES), and deep-inelastic scattering (DIS). *From: Formaggio, Zeller Rev. Mod. Phys. 84, 1307 (2012)*

10.3 Measuring δ_{CP} *2 Points*

Neutrino beams offer a very good tool to determine the value of δ_{CP}. Which parameter should be derived in order to determine this value? Briefly describe the strategy used by the two upcoming experiments T2HK and DUNE.