Exercises for Neutrino Physics: Theory and Experiment

Teresa Marrodán Undagoitia
Werner Rodejohann

Submission Date: Tuesday, 04. May 2021 before 11:00

Tutors:
Janine Hempfling: janine.hempfling@mpi-hd.mpg.de
Oliver Scholer: scholer@mpi-hd.mpg.de

Sheet 3: Experiment

1. **Geoneutrinos [8 Points]**

According to the current geological models, the most dominant and abundant radioactive isotopes in the Earth (^{238}U, ^{232}Th and ^{40}K) are localized mostly in the crust.

(a) Write the decay chains of ^{238}U and ^{232}Th. How many neutrinos are produced in the chains in total?

(b) To estimate the amount of different radioactive isotopes in the Earth the detection of neutrinos from their decay chains can be used. This so-called geoneutrinos were detected for the first time in summer 2005 by KamLAND.
Looking at the expected energy spectrum of the geoneutrinos in Figure 1, discuss if its possible to detect separately neutrinos from ^{238}U, ^{232}Th and ^{40}K.

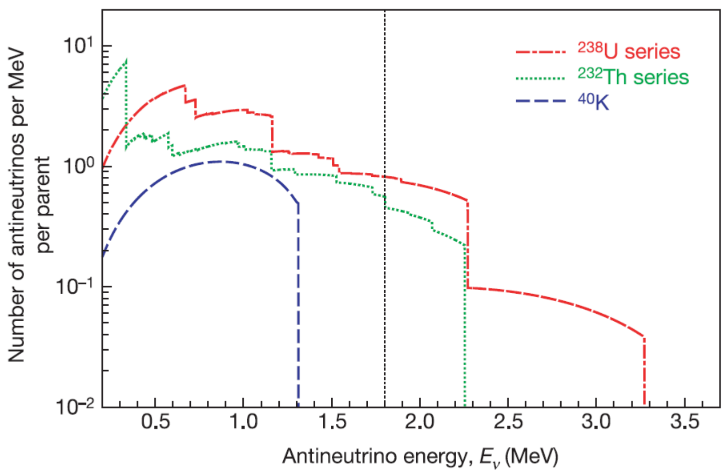

Figure 1: The expected 238U, 232Th and 40K decay chain electron antineutrino energy distributions. The energy threshold of KamLAND is indicated by the dotted black line

(c) In the measured antineutrino spectrum from KamLAND, what are the main sources of background? Which of them could be reduced?

2. **Neutrinos with Superkamiokande [8 Points]**

   To detect neutrinos in the water Cherenkov detector Superkamiokande, the following scattering reaction of neutrinos on electrons can be considered:

$$\nu + \mathrm{e}^- \longrightarrow \nu + \mathrm{e}^- \tag{1}$$

   (a) Give the expression of the angle between the direction of the incident neutrino and the direction of the scattered electron in terms of the electron mass, electron kinetic energy and neutrino energy.

   (b) The minimal kinetic energy of the electron to be detected by Superkamiokande is $5.5\,\mathrm{MeV}$. Calculate the angle for a 8 and a 10 MeV solar neutrino. Why is this angle important for the detection of solar neutrinos?

   (c) In a water Cherenkov detector, how do you distinguish between a π^+ and a π^0?

3. **Neutrino Sources [4 Points]**

   A broad spectrum of natural and artificial neutrino sources exist. However, as neutrinos interact only weakly, they are hard to detect and study. A good way to study neutrino properties is opened by the detection of man-made neutrinos.

   (a) What are the different man-made neutrino sources? Which type of neutrino do they emit, at which flux and in which energy range?

   (b) To which natural neutrino sources are the energies of these man-made neutrinos comparable?