

# Homework Set $\nu$ s

**Due Date:** Friday April 29th

## 1) Neutrino Oscillations

(5 points)

In the two flavour approximation, work out the probability for a  $\nu_e$  to be detected as a  $\nu_\mu$  as a function of mixing angle, mass difference, distance traveled and Energy.

Sketch the probability as a function of  $L/E$ .

## 2) Cosmic Rays

(5 points)

What ratio of  $\nu_e$  and  $\nu_\mu$  do you expect in cosmic rays at low energies ?

*(Treat cosmic rays as protons which produce pions.)*

What can cause this ratio to change at higher energies ?

## 3) SNO

(5 points)

SNO measured the  $\nu$  flux in three different ways. Draw the corresponding Feynman diagrams and indicate if you would expect a difference in cross section between the different  $\nu$  flavours.

## 4) $\nu$ beams

(5 points)

- How could you make a beam of  $\nu$ s ?
- What  $\nu$  flavours would be produced ?
- Would you expect this to make more  $\nu$  or anti- $\nu$  ?
- How could you enhance the  $\nu$  fraction ?
- How about the anti- $\nu$  fraction ?