A preliminary investigation into determining CC0π cross-section sensitivities in SBND

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1$^{\text{st}}$ year PhD report

Abstract

Random stuff

1. Introduction

Neutrino physics is at the core of current high energy research. One of the profound discoveries made in recent years was the observation of neutrino flavour oscillations by the Super-Kamiokande experiment, which was the first confiramtion that physics existed beyond the standard model of particle physics. In brief, neutrinos described by the standard model would be massless particles, but since the flavours are made up of superpositions of mass states, the oscillation of the flavour states implies that the mass states are different, and therefore non-zero [1].

Future, long-baseline, neutrino experiments such as the Deep Underground Neutrino Experiment (DUNE) and Hyper-Kamiokande (Hyper-K) are hoping to investigate some of the most fundamental questions we are still asking: Why does the universe constist of matter, and not anti-matter? What is the neutrino mass heirarchy?

Neutrino research is an extremely active field. Optimising the current and future detectors to maximise the accuracy of all interaction anaylses is a crucial step towards obtaining concrete answers to these questions.

1.1. Neutrino interactions

Due to the elusive nature of the neutrino, directly observing one in a detector isn't possible. It is therefore necessary to infer their existence from particles produced when they interact. Since this process relies upon the reconstruction capability of the experiment, purpose-built detectors will attempt to maximise the efficiency of this.

Another property of the neutrino which poses a significant difficulty within detectors is their interaction probability, or cross-section. A typical neutrino cross-section is on the order of 10^{-44} cm^2 which translates to $\sim$1 interaction every 10 light years in steel, for neutrinos with only a few MeV energy [1]. This fact introduces the need for the interacting neutrinos to have high energies in these dedicated experiments, if we are to sufficiently reduce their mean free path.

More detail on this topic will be discussed in section 2.

1.2. GENIE

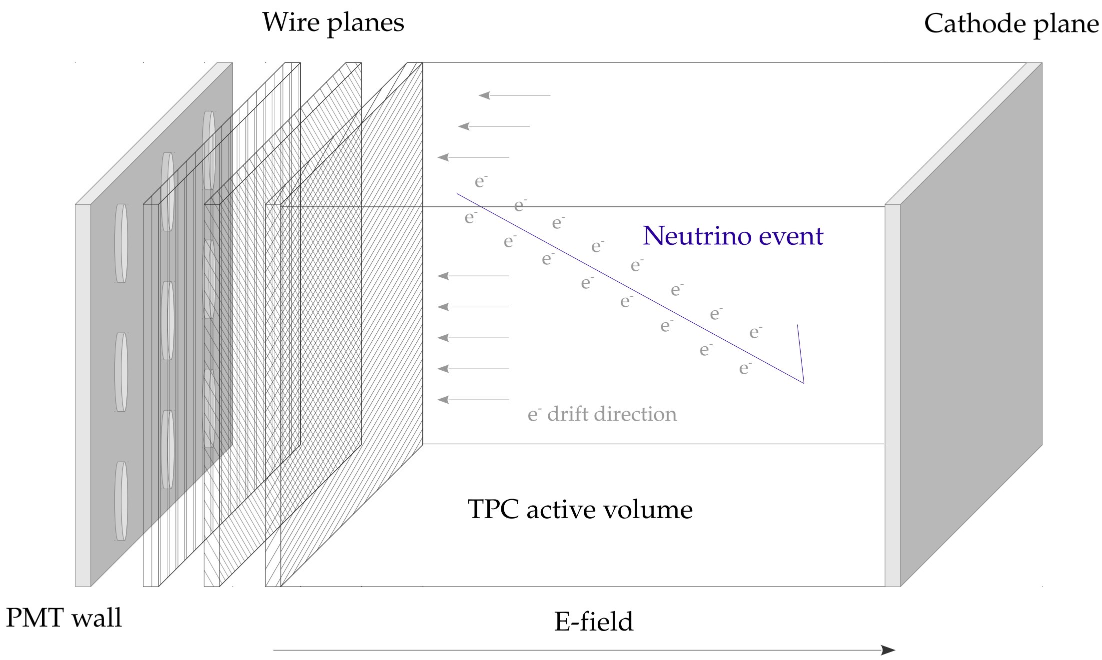
GENIE is the world leading neutrino interaction generator.

1.3. Cross-sections

- Why?
  - Simulation
  - GENIE
- Historical

- Current knowledge
- Needs for future
  - LArTPCs
  - Statistics

Process		No. Events
	ν_μ Events	
CC 0 π	$\nu_\mu N \rightarrow \mu + Np$	3,551,830
CC 1 $\pi^\pm$	$\nu_\mu N \rightarrow \mu + nucleons + 1\pi^\pm$	1,161,610
CC $\geq 2\pi^\pm$	$\nu_\mu N \rightarrow \mu + nucleons + \geq 2\pi^\pm$	97,929
CC $\geq 1\pi^0$	$\nu_\mu N \rightarrow \mu + nucleons + \geq 1\pi^0$	497,963
NC 0 π	$\nu_\mu N \rightarrow nucleons$	1,371,070
NC 1 $\pi^\pm$	$\nu_\mu N \rightarrow nucleons + 1\pi^\pm$	260,924
NC $\geq 2\pi^\pm$	$\nu_\mu N \rightarrow nucleons + \geq 2\pi^\pm$	31,940
NC $\geq 1\pi^0$	$\nu_\mu N \rightarrow nucleons + \geq 1\pi^0$	358,443
Total ν_μ & ν_e events		7,251,948



1.4. SBND

- LArTPC general functionality

- LArTPC resolution benefits
- Comparison with other detector materials
  - Example event display?
- SBND specifics
  - Dimensions
  - Beamline
  - Flux
  - Statistics
- Cross-section precision capabilites

1.5. GENIE-Professor global fits

2. Neutrino Interaction Phenomenology in the few-GeV Energy Range

2.1. Dominant topologies

2.2. Golden channel

2.3. Signal

2.4. Potential backgrounds

2.5. Maybe some results here?

3. Theory and Recent Measurements of CC0π Cross-Section

3.1. Cross-sections

Inc. equations

3.2. Method

3.3. Unfolding

3.4. Results

Plots and cross-section values

4. A Global Fit of CC0π Data

4.1. Experiments involved

4.2. Process

4.3. Results

5. Prospects for a CC0π Measurement at SBND and Sensitivity Esimates

5.1. SBND sensitivity

5.2. Future

6. Discussion

References

[1] Y. Fukuda et al. Evidence for oscillation of atmospheric neutrinos. Phys. Rev. Lett., 81:1562–1567, 1998.