Neutrino interaction studies in the near detector of the T2K Experiment

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Outline

Brief history of neutrinos

1914: Chadwick's observation of continuous decay spectrum.

1930: Pauli's proposal for a new particle to explain decay spectrum.

1933: Fermi's neutrino and decay theory.

1956: Reines and Cowan observed the first neutrino interaction.

1962: discovery at BNL, USA.

1975: lepton discovered at SLAC... proposed.

1986: Solar Neutrino Problem.

1989: LEPC's measurement of Z^0 properties... Exactly three light neutrinos.

1998: Atmospheric neutrino oscillations.

2000: DONUT discovered .

2001: Solar neutrino deficit explained by SNO

2013: First observation of high-energy astrophysical neutrinos by IceCube

The T2K Experiment

Long baseline neutrino oscillation experiment in Japan since 2010. The experiment sends a beam of muon neutrinos from Tokai to Kamioka at a distance of 295 km.

https://t2k-experiment.org/t2k/

World's rst o -axis neutrino experiment!

DOI: 10.1088/1367-2630/16/7/075015

Why O -Axis?

The average energy of the neutrino decreases with the deviation from the beam axis.

2:5 chosen to maximize the probability of oscillation at the far detector.

DOI:10.21468/SciPostPhysProc.1.029

Near Detector and Components

ND280 Detector

- 3 vertical Time Projection Chambers
- active material: plastic scintillator
- passive materials: water, iron, lead
- beam content before oscillations
- neutrino interaction studies

Fine Grain Detector-1

- plastic scintillator bars
- target for neutrino interactions

Time Projection Chamber

- Filled with Argon-based gas mixture
- Used for momentum and $\frac{dE}{dx}$ measurements

ECal

- plastic and lead bars
- surrounds the inner part of ND280

Figure: ND280

Charged Current Neutrino-Nuclei interactions

CC interactions

mediated by $W^{+=}$ bosons

NC interactions

mediated by Z^0 boson

Figure: CCQE

Figure: RES

Figure: DIS

Figure: non-RES

Aim of the project and Event Selection

- The following analysis was done using sample of events containing pre-selected candidate starting in FGD1 Fiducial Volume.
- To select tracks having at least 18 hits and starting inside the FGD1 Fiducial Volume.
- To identify particles based on $\frac{dE}{dx}$ and other information.
- To select CC-1 $^{+}$ interactions by choosing events with 1 $^{+}$ and 1 or 0 proton candidates based on pull variables.
- To calculate kinematical properties related to selected neutrino interactions.
- To calculate purity and e ciency of the selection.

Products of CC-1 $^{+}$ signal interaction

, $^{+}$, and 0 or 1 proton

Pull Variable

$$P_a = \frac{\left(\frac{dE}{dx}\right)_{teora} \quad \left(\frac{dE}{dx}\right)_{exp}}{exp}$$

Choosing Candidates

The Chosen Candidates

(T2K)-Not always possible to distinguish particles based on $\frac{dE}{dx}$

Reactions and Topologies

Reaction: Primary neutrino nucleon interaction type

Topology: Reaction type based on the particles leaving the nucleus

Purity and E ciency

The estimation of the quality of event selection is done by observing the following quantities.

Purity

$$\frac{\text{Number of selected signal events}}{\text{Number of all selected events}}$$

E ciency

$$\frac{\text{Number of selected signal events}}{\text{Number of all signal events}}$$

True v/s Reconstructed Energies

The green line shows ideal reconstruction.

Kinematical Properties from Reconstruction

Fermi Momentum of a nucleon
is 250MeV/c

Summary

- We studied nucleon-neutrino interactions in the T2K near detector.
- We analyzed the characteristics of CC1 $^{+}$ interaction with 0 and 1 proton samples.
- We also reconstructed kinematic properties for the CC1 $^{+}$ interaction.
- A similar analysis for CC0 interactions (mainly CCQE reactions) was made for comparison, but not added in this presentation.

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Thank You!

Backup Slides

Pontecorvo{Maki{Nakagawa{Sakata matrix

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{\ i} \\ 0 & 1 & 0 \\ s_{13}e^{i} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

where $c_{ij} = \cos\ _{ij}$; $s_{ij} = \sin\ _{ij}$; $= \ _{CP}$

black : $_e$ blue: red:

Super-Kamiokande Detector

- Located 1000m underground.
- Contains 50,220 tonnes of ultrapure water.
- A water-Cherenkov detector.
- No magnetic eld to distinguish particles from anti-particles.
- particle identi cation based of light ring shape

Nature