The observation of gamma rays after neutral current interactions at Super-Kamiokande by using the T2K neutrino beam

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Abstract

We report the first measurement of the neutral current quasi-elastic (NCQE) cross section on oxygen by observing nuclear de-excitation gamma rays with the T2K neutrino beam. The interaction from atmospheric neutrino is one of the main background in supernova relic neutrino search. The de-excitation gamma rays can be observed in the Super-Kamiokande (Super-K) water Cherenkov detector. We selected candidate events by using the T2K beam timing, dramatically reducing the background of natural radioactivity. We observed 43 events in the 4-30 MeV reconstructed energy region. We measured the NCQE cross section of \( 1.35 \times 10^{-38} \text{cm}^2 \).

Motivation

- No previous measurements of NCQE scattering on oxygen at hundreds of MeV with de-excitation gamma rays.
- Gamma rays produced by atmospheric neutrinos are one kind of the main backgrounds in supernova relic neutrino searches.
- NC samples can be used to search for sterile neutrino oscillations.
- Can use similar low-energy samples to look for low-mass dark matter.

T2K neutrino beam @Super-K

- Off-axis 2.5 degree
- Energy peak is at 630 MeV.
- NCQE interactions are the largest NC samples in T2K-SK data.

NCQE physics process

- Goal: De-excitation gamma rays of NCQE interaction.
- Backgrounds
  - \( v \) beam-related: NC-other interactions, CC interactions
  - \( v \) beam-unrelated: gamma rays from radioactive impurities of Super-K wall and PMTs, decay \( e \) from cosmic muon.

MC production

- Neutrino flux-- simulated with FLUKA & Geant3, constrained by monitoring and external experiments.
- NEUT--Use Ankowski model for NCQE scattering and photon production.
- Detector simulation-- Geant3, CALOR to simulate Cherenkov photons and neutrinos which produce secondary gammas.

No previous experimental data about secondary gamma production. We compared different MC models to get these systematic error values.

Systematic Errors and \( \sigma_{\text{NCQE}} \) measurement result

- T2K has already reached 6.57x10^{20} neutrons on target (POT) now, and we have analyzed about half accumulated data to search for NCQE event candidates.
- After data reduction, 43 event samples are selected as \( \gamma \) ray candidates, which is lower than MC simulation prediction (55.7).
- There are discrepancies between MC and data in the Cherenkov angle distribution. Analysis is now in progress.
- Observed NCQE cross section: \(< \sigma_{\text{obs},\text{NCQE}} > = 1.35 \times 10^{-38} \text{cm}^2 \) with a 68% confidence interval of (1.06, 1.94) \( \times 10^{-38} \text{cm}^2 \).

Summary

- \( < \sigma_{\text{obs},\text{NCQE}} > = 1.35 \times 10^{-38} \text{cm}^2 \) with a 68% confidence interval of (1.06, 1.94) \( \times 10^{-38} \text{cm}^2 \).