PROCEEDINGS OF SCIENCE

Measurement of the ν_μ CCQE Cross Section with the ND280 Detector at T2K

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The first measurement of the ν_μ Charged Current Quasi-Elastic (CCQE) cross section on Carbon by the T2K experiment is presented. The cross section is extracted in bins in E_ν from a binned template fit of the NEUT MC model to the observed $p_\mu - \cos(\theta_\mu)$ distribution in the off-axis near detector. A fit for the effective quasi-elastic axial mass is also shown.

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T2K is an accelerator based long baseline neutrino oscillation experiment [1]. The Charged-Current Quasi-Elastic (CCQE) interaction, $\nu + n \to l^- + p$, is the main signal in the neutrino oscillation measurement. Oscillation probability depends on the neutrino energy. This two-body interaction is important because the initial neutrino energy can be inferred from the final state lepton kinematics. Recent CCQE measurements [2] have shown disagreement between low/high energy experiments and nuclear/deuterium targets. Understanding the CCQE interaction in the few GeV energy range is essential for current and future long baseline neutrino oscillation experiments.

The T2K off-axis near detector, shown in fig. 1, is divided into a tracker and π^0 detector region. This analysis used events reconstructed in the tracker region. The Fine Grained Detector (FGD1) consists of layers of plastic scintillator bars, 10×10 mm in cross section, readout with wavelength shifting fibers into Multi-Pixel Photon Counters (MPPCs). It provided target mass and track reconstruction near the interaction vertex. The Time Projection Chambers (TPCs) provided PID based on dE/dx in the Argon based gas and momentum measurement from track curvature in the magnetic field. The analysis shown here is based on 2.7×10^{20} POT. The predicted flux at the ND280 is shown in fig. 2.

CCQE-like interactions containing a muon with no pions in the final state were selected. A good-quality track starting within the FGD fiducial volume with a muon-like TPC PID was required. Events with additional tracks in the TPC were vetoed as most protons from CCQE interactions stop in the FGD. To further reduce the π background, events with Michel electrons reconstructed within the FGD were vetoed. This event selection achieved an efficiency of 40% and purity 72% for true CCQE events. The reconstructed muon kinematics are shown in fig. 3.

The CCQE cross section was extracted by fitting the NEUT MC model [3] to the reconstructed $p_\mu - \cos(\theta_\mu)$ distribution. The NEUT CCQE model uses the Smith-Moniz implementation of the Fermi Gas Model and a cascade model for FSI. No additional contribution from multi-nucleon effects were included.

Simulated template histograms were fit to the observed $p_\mu - \cos(\theta_\mu)$ distribution. The

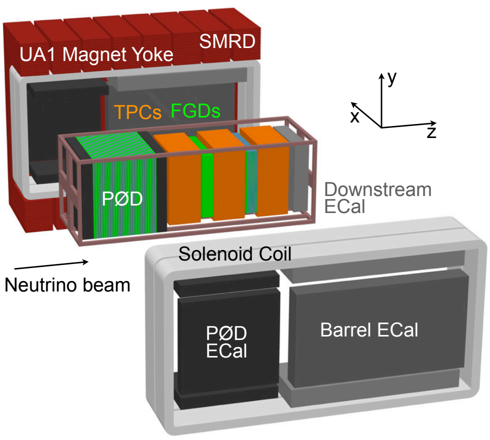


Figure 1: The ND280 off axis near detector.

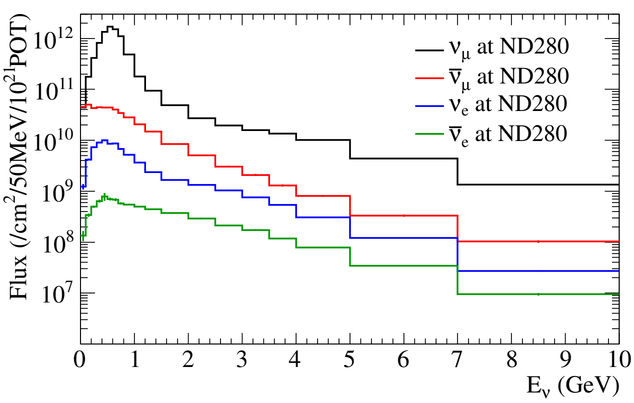
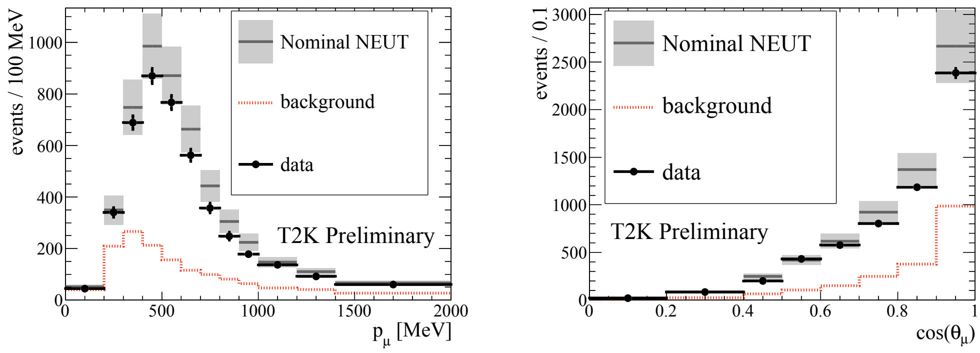


Figure 2: Predicted neutrino flux at the ND280.



(a) p_μ (b) $\cos(\theta_\mu)$

Figure 3: Reconstructed muon kinematics.

CCQE cross section was extracted by weighting 5 template histograms in bins of E_ν. Systematic uncertainties were accounted for by varying bin contents with nuisance parameters. A maximum likelihood fit was used to find the best fit parameters.

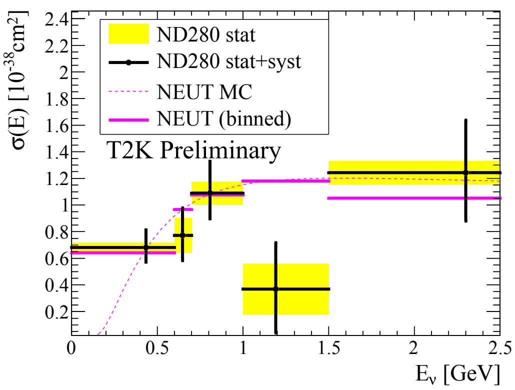


Figure 4: Energy dependent CCQE cross section extracted from the fit to ND280.

Figure 4 shows the best fit CCQE cross section. A χ^2 test comparing the fitted result with the nominal NEUT model gives p-value of 17% indicating agreement between the data and the cross section model. The best-fit to the ND280 data preferred a lower overall cross section than the NEUT prediction. However, the fit results were still consistent with the NEUT prediction within error.

An alternative approach to fitting the cross-section normalisation, is to directly fit the CCQE model parameters. The axial mass parameter M_A^{QE} was varied to obtain the best fit to the observed data. The best-fit using shape and normalisation information was M_A^{QE}-norm $= 1.14^{+0.27}_{-0.20}$ GeV. The best-fit using only shape information was M_A^{QE}-shape $= 1.38^{+0.39}_{-0.27}$ GeV. Large effective M_A^{QE} is believed to be due to unaccounted for nuclear effects. Note that the meaning of this effective parameter depends on the details of the QE model; comparison with results from other experiments should be done with care.

References

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[3] Y. Hayato, Acta Phys. Polon. B **40**, 2477 (2009).