

arXiv:1909.10329

Quantifying multinucleon effect in the Ar-target using High Pressure gas TPC DUNE Near Detector

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Introduction

In this work, we present a simulation based analysis to quantify the multi-nucleon contribution arising in neutrino-nucleon interactions on Argon and Carbon targets for the QE interaction process. To achieve the quantification of uncertainties in the Argon and Carbon targets, the ratio of kinematic variable, Q^2 is calculated with the model once considering the Random Phase Approximation(RPA) effect and then without considering the RPA effect. The uncertainty in the models with and without RPA effect for the Carbon target was recently published by the MINERVA collaboration[1], the study suggests a requirement of modification in the models. At the same time, we have analysed the same interaction sample by adding the 2p2h contribution with the RPA sample following a similar approach as performed in[1]. The motivation behind this combination is an improvement in the description of the MiniBooNE data[2]. The RPA effect is prominent when the four momentum transferred to the nucleus is small, because as the energy transferred to the nucleus increases the RPA effect diminishes. Detailed study of the effect of these interactions have been explored in ref[3].

DUNE ND- HPgTPC Design

The reference design of the DUNE-ND[4] consists of three main components: (1) A 50t LArTPC with pixelated readout (2) A multi-purpose tracker, the HPgTPC, kept in a 0.5T magnetic field and surrounded by ECAL (3) A 8t 3-Dimensional Scintillator Tracker

Spectrometer(3-DST).The working principle of LArTPC to observe neutrino-argon interactions will be similar to that of the far detector while the 3-DST will look for neutrino-CH interactions and is designed to have a powerful detection capability for neutrons.

Simulation Details

In our work we have simulated CCQE neutrino interactions on Argon(Z=18) and Carbon(Z=6) nuclei using two different models- (i) the default GENIE-model and (ii) Nieves *et al* [5], which takes RPA effect into consideration. The final state particles are generated via neutrino-nucleon interactions using GENIE. The particles are visualized in two ways- (i) When no detector cuts are imposed i.e. 'Calculated or Cal'(First set) (ii) When real time detector cuts are imposed i.e. 'Visible or Vis' (Second set). The variation in ν_μ -Ar integrated cross section with energy is shown in Figure 1.

Result and Discussion

In an attempt to quantify the systematic uncertainties introduced due to nuclear effects we have checked the ratio of Q^2 distribution for two different targets: Argon and Carbon. This analysis will help us to understand whether the systematic uncertainty in different targets follows some symmetry or not. This distribution ratio for Ar/C is shown in Figure 2 and the analysis is repeated with both the models i.e. the default and the model with RPA effect for both sets of data (i.e. for Cal and Vis). Further to check the systematic uncertainty in the models for each target separately, we have estimated the ratio of event distributions as a function of Q^2 with RPA effect ON(RPA ON) and with RPA effect OFF

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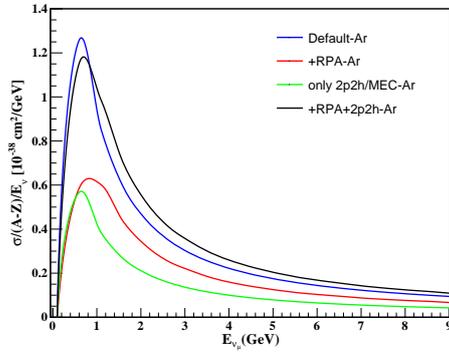


FIG. 1: The integrated cross-section for Argon from GENIE 2.12.6 version for default model(blue line), the same with RPA suppression(red line), with only 2p2h model(green line) and for a RPA combined with 2p2h component(black line).

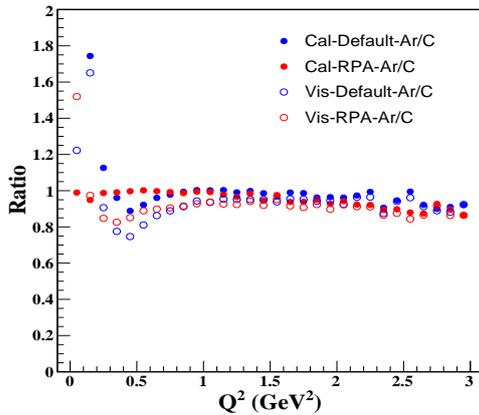


FIG. 2: This figure shows the ratio of Q^2 distribution for Ar/C achieved using the Default model and model with RPA effect.

(RPA OFF) as shown in Figure 3.

Acknowledgments

This work is supported by the Department of Physics, Lucknow University. Financially

it is supported by the Government of India, DST Project no-SR/MF/PS02/2013, Department of Physics, University of Lucknow.

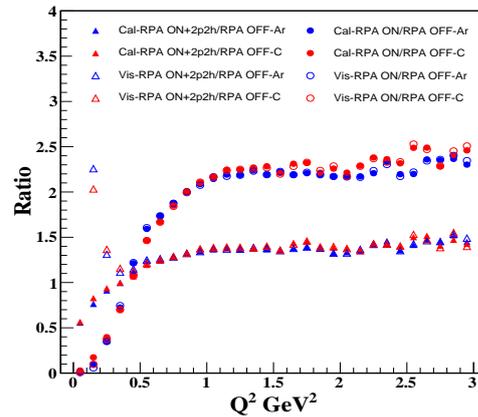


FIG. 3: This figure shows the distribution of Q^2 ratio for Ar/Ar and C/C with RPA effect ON and RPA effect OFF represented by circles and the triangles shows the Q^2 distribution ratio for RPA ON+2p2h and RPA OFF.

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