Current status of double differential cross section measurement for antineutrino DIS vs A at MINERvA

S. Akhter[1*]
(The MINERνA Collaboration)
[1] *Department of Physics, Aligarh Muslim University, Aligarh-202002,INDIA*

1. Introduction

MINERvA (Main Injector Neutrino ExpeRiment to study ν-A interactions) is a dedicated neutrino-nucleus experiment in the few GeV energy region located at the Fermi National Accelerator Laboratory. One of the goals of this experiment is to understand the hadron dynamics in the nuclear medium using $\nu_\mu(\bar{\nu}_\mu)$ from the NuMI (Neutrino at Main Injector) beamline. Several nuclear targets (carbon, helium, iron, lead and water) have been used to understand the nuclear medium effects in a wide range of Bjorken x and four momentum transferred square Q^2. The detector consists mainly of four parts. The upstream part is the nuclear target region followed by active tracker region, electromagnetic and hadronic calorimeters. The tracker region is made up of scintillator planes. Two meters downstream from the MINERvA detector, the MINOS near detector is used as a muon spectrometer. MINERvA has taken data in the low (peaks around 3GeV) as well as in the intermediate (peaks around 6GeV) energy modes. Fig.1 shows the schematic diagram of MINERvA setup [1].

We are doing 2 dimensional deep inelastic scattering (DIS) analysis of $\bar{\nu}_\mu$-nucleus scattering in the intermediate energy mode. In this paper, the results for the event distribution and migration are discussed in brief. The detailed results will be presented in the conference. Deep inelastic scattering of neutrino with nucleus is important because it helps to probe inside the nucleons. The important variables involved in the DIS kinematics are Q^2, Bjorken x and the hadronic invariant mass W and these are written as

$$W^2 = M_N^2 + 2M_N E_{had} - Q^2 \quad (1)$$

$$Q^2 = 4E_\nu E_\mu sin^2(\frac{\theta_\mu}{2}) \quad (2)$$

$$x = \frac{Q^2}{2M_N E_{had}} \quad (3)$$

where M_N is the mass of struck nucleon, E_{had} is the hadronic energy of the final state and θ_μ is muon scattering angle with respect to the beam. In MINERvA, DIS region is constrained by defining kinematical cuts on $Q^2 \geq 1GeV^2$ and $W \geq 2GeV$.

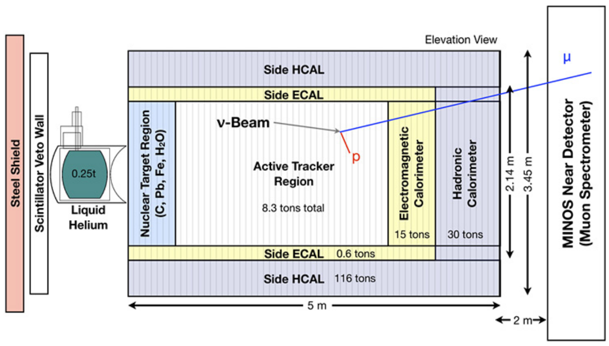

FIG. 1: Schematic diagram of the MINERvA detector with their masses labeled.

2. Analysis procedure

The expression for the double differential cross section is given by

$$\frac{d^2\sigma}{dxdy} = \frac{\sum_{ij} U_{ij\alpha\beta}(N_{data,ij} - N_{ij}^{bkgd})}{A_{\alpha\beta}(\Phi T)(\Delta x \Delta y)} \quad (4)$$

This expression contains all steps beginning from the event selection ($N_{data,ij}$), background events (N_{ij}^{bkgd}), Unfolding $U_{ij\alpha\beta}$ and efficiency correction $A_{\alpha\beta}$. ΦT is the product

*Electronic address: `akhtersayeed65@gmail.com`

of the flux and the number of targets, and $\Delta x \Delta y$ is the bin width normalization. The event selection is the very first and important step in the analysis. For the DIS events, we apply a selection of cuts to get the signal for our analysis. In this analysis, we select our signal as all the charged current antineutrino DIS events that are in the given target material with muon angle $\theta_\mu \leq 17^0$ and muon energy $2 \leq E_\mu \leq 50$ GeV. The events that are not in the signal are the background events.

Since it is not possible to measure (or reconstruct) quantities with 100 % accuracy, some events are reconstructed in the wrong bin. To rectify this, we must know the probability that an event observed in bin ij is actually from bin $\alpha\beta$. We can obtain this with the help of the migration matrix. A diagonalized migration matrix ($M_{ij\alpha\beta}$) infers that most of the events are reconstructed in the correct bin. To get the unfolding matrix ($U_{ij\alpha\beta}$), we just invert the migration matrix [2].

Similarly, some fraction of the signal can not be reconstructed because of the detector limitations and also due to the fact that identification of the neutrino event signature is very difficult. Therefore, efficiency corrections are required in the cross section calculation. Efficiency is defined as the number of signal events reconstructed in bin $\alpha\beta$ divided by the total number of signal events in bin $\alpha\beta$.

$$A_{\alpha\beta} = \frac{N_{\alpha\beta(reconstructed\ signal)}}{N_{\alpha\beta(total\ signal)}} \tag{5}$$

After the efficiency correction, we just integrate over the flux and do the bin width normalization to get the cross section [2].

3. Results and discussion

The results for the event distribution (Fig.2: top panel) and migration matrix (Fig.2: bottom panel) in the nuclear target region (iron) are presented. In event distribution, X axis is the Bjorken x and different bins are Q^2 bins. Here, black dots represent the data points with statistical error and the red and green lines are respectively the total Monte Carlo (MC) and signal . It may be observed that in the nuclear target region, the signal is around 53% of the total MC. Thus the total background in this case is around 47%. In the migration matrix, events on the diagonal are the ones that were reconstructed in the correct bins. Each bigger box is a Q^2 bin and the smaller boxes inside the bigger ones are the x bins. This migration matrix is around 50% diagonalized.

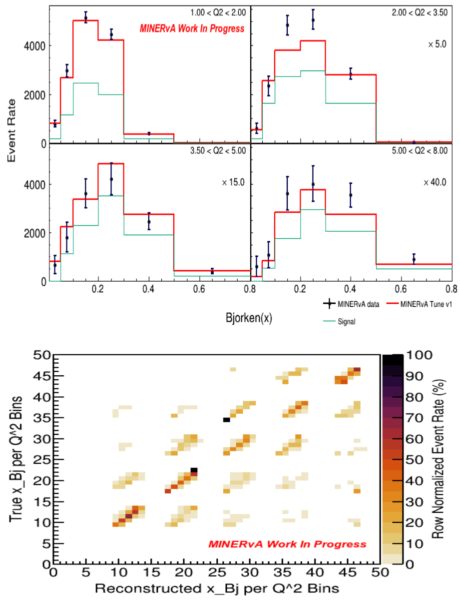

FIG. 2: Event distribution (Top) and migration matrix(Bottom) for iron of all targets.

Presently, we are trying to add the kinematical dependent background subtraction technique so that we can finally extract the cross section and these cross section results will not only help us to understand the nuclear medium effects in the DIS region but also this study will be useful in reducing the systematics in determination of neutrino oscillation parameters.

Acknowledgments

Author acknowledges the support from DST/INSPIRE (Fellowship/IF180685), under the Government of India.

References

[1] https://minerva.fnal.gov/how-it-works/
[2] C. Patrick, doi:10.1007/978-3-319-69087-2