Charged Current Quasi-elastic Neutrino Analysis at MINERvA

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Abstract. MINERνA (Main INjector Experiment for ν-A) is a neutrino scattering experiment in the NuMI high-intensity neutrino beam at the Fermi National Accelerator Laboratory. MINERvA was designed to make precision measurements of low energy neutrino and antineutrino cross sections on a variety of different materials (plastic scintillator, C, Fe, Pb, He and H2O). We present the current status of the charged current quasi-elastic scattering in plastic scintillator.

Keywords: neutrino interactions, quasi-elastic scattering, cross section, MINERvA

INTRODUCTION

MINERνA is a dedicated neutrino-nucleus scattering experiment in the high-intensity NuMI neutrino beamline at Fermilab [1]. MINERνA will, among other things, measure the cross section of the ν_μ charged current quasi-elastic interaction in a nuclear enviroment. This channel is very important for modern neutrino oscillation experiments [2]. MINERνA's fine-grained detector will allow to perform this measurement using different reconstruction techniques to quantify the effect of the nuclear enviroment [3]. In this document, a ν_μ charged current quasi-elastic (CCQE) event selection, using muon reconstruction and recoil energy, is defined and a preliminary comparison between MINERνA's data and the prediction of a Monte Carlo (MC) simulation is presented. MINERVνA's data correspond to an exposure of 9.43E19 protons on target and the simulation uses GENIE [4] as event generator.

EVENT SELECTION

Signature of ν_μ CCQE events is relative simple: the final state particles are a proton and a muon. The present analysis rely on the reconstruction of the muon and recoil energy only [1]. We use muon kinematics to reconstruct the event's neutrino energy and 4-momentum transfer under a CCQE hypothesis:

$$E_\nu^{QE} = \frac{2(M_n - E_B)E_\mu - \left[(M_n - E_B)^2 + m_\mu^2 - M_p^2\right]}{2\left[(M_n - E_B) - E_\mu + \sqrt{E_\mu^2 - m_\mu^2}cos\theta_\mu\right]} \tag{1}$$

$$Q^2_{QE} = -m_\mu^2 + 2E_\nu^{QE}\left(E_\mu - \sqrt{E_\mu^2 - m_\mu^2}cos\theta_\mu\right) \tag{2}$$

An enriched sample of ν_μ CCQE events is obtained by using the following selection criteria (cuts): One negative muon reconstructed in the MINOS near detector and with its origin inside MINERνA's active tracker region (plastic scintillator); only one track, the muon track; less than three isolated energy depositions in the fiducial volume but unattached to the vertex; and a reconstructed Q2 dependent recoil energy cut. To avoid biasing the analysis by relying in the MC simulation of vertex energy that is not complete, we select QE events by looking at non-vertex energy[2]. In the future, vertex energy will be studied very carefully. Figure 1 shows the distributions where the analysis cuts are applied.

The selection efficiency of the resulting sample is $\sim 25\%$ and the sample purity is $\sim 80\%$. The distribution of selected events ("signal" region in figure 1) as a function of reconstructed E_ν and Q^2 are showed in figure 2.

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[1] One MINERνA's CCQE analysis using proton reconstruction were showed in [3].
[2] Non-vertex energy is defined as the energy outside a 10 cm sphere around the vertex.

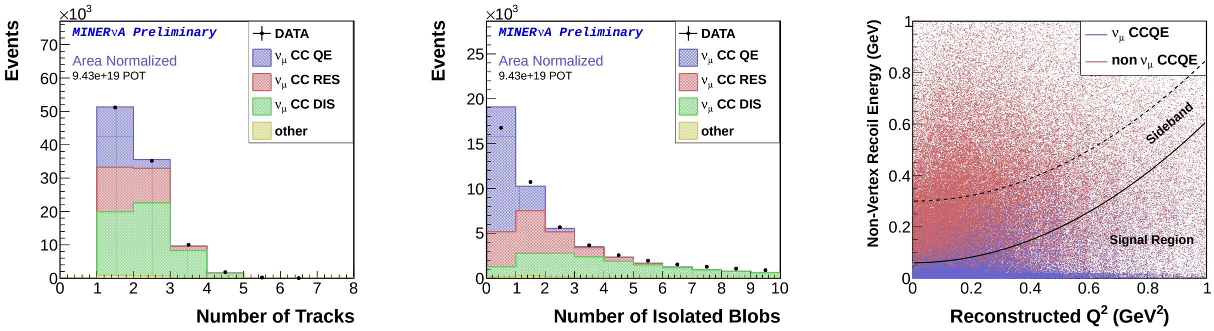

FIGURE 1. The number of reconstructed tracks at the muon vertex, including the muon found in the MINOS-matched muon sample (left). The number of isolated energy depositions found away from the muon track in the one track sample (center). Number of events passing the previous cuts and the reconstructed Q2 dependant recoil energy cut (right).

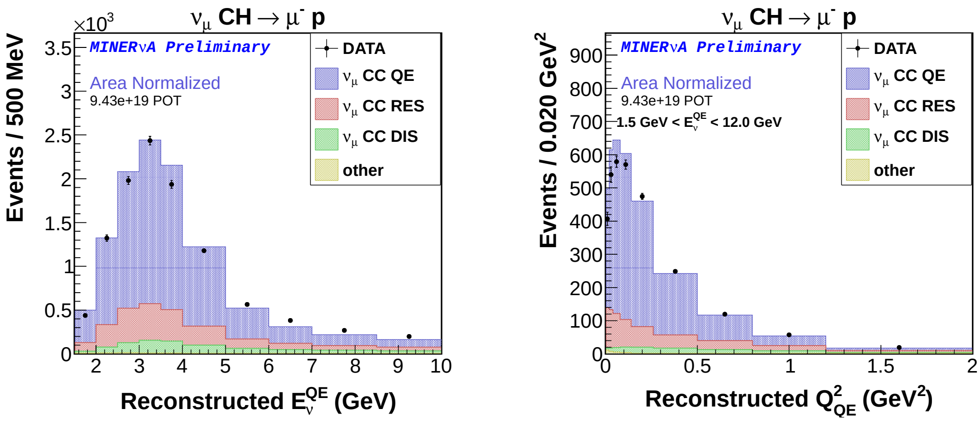

FIGURE 2. Distribution of ν_μ CCQE event candidates as a function of reconstructed E_ν^{QE} and Q^2_{QE} as deined in equations 1 and 2 respectively.

BACKGROUND CONSTRAINT

MINERνA uses its own data to constraint the background found in the ν_μ CCQE event selection. A sample dominated by background (non-QE) events is obtained by considering the "sideband" region showed in figure 1. Figure 3 shows the distribution of these events as a function of reconstructed Q^2. We compute a "background scale" as a function of reconstructed Q^2 from this plot in a way that if applied to background events in the sideband, data and MC agree perfectly. The background scale obtained this way is also showed in figure 3.

TOWARDS A CROSS SECTION MEASUREMENT

In order to obtain a cross section measurement from the selected events, we first procced to substract the predicted background (using the background constraint described in the previous section) from the event candidates distribution. Second, we correct for bin migration effects due to detector resolution using a technique based on Bayes theorem [5] Efficiency corrected distributions and cross-section will be avaliable soon.

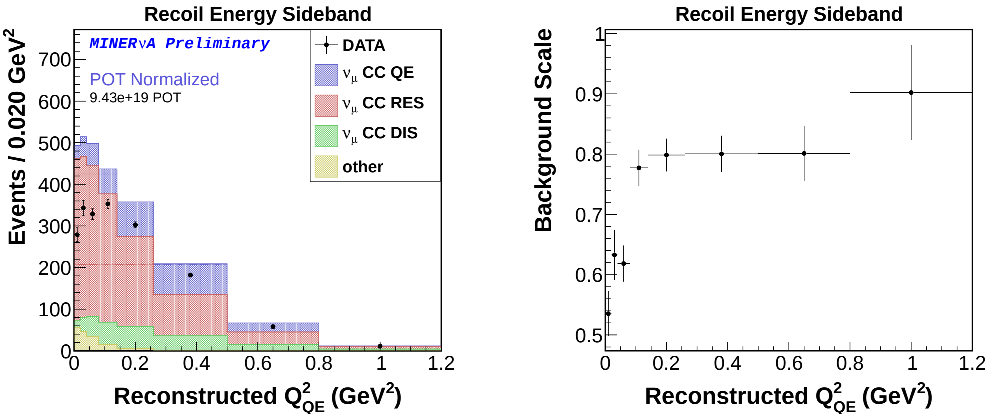

FIGURE 3. Reconstructed Q^2_{QE} distribution of events in the sideband region (left). Background scale defined as the correction factor needed to the background in order to have perfect data-MC agreement in the reconstructed Q^2 distribution of events in the sideband region (right).

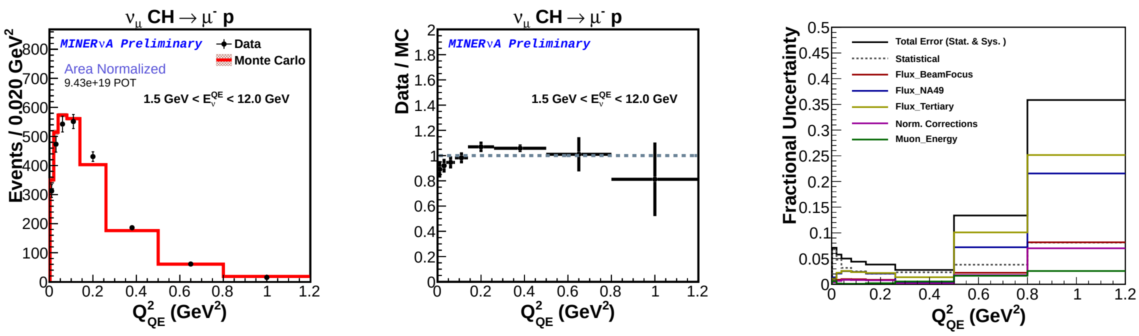

FIGURE 4. Background subtracted and unfolded distribution of events in bins of reconstructed Q^2_{QE} as defined in equation 2 (left). The ratio between data and MC (center). A summary of fractional uncertainties (statistical and systematics) on data (right).

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