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Inclusive measurements with MINER nu A

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of a target and collimator, two pairs of wire chambers upstream and downstream of a pair of dipole magnets and a time of flight system. In addition to low energy hadrons, the detector was exposed to a broad spectrum, unmeasured muon beam and cosmics. The project ran during the Summer of 2010; calibrations and analysis are in progress. The spectrum of beamline particles is shown in Figures 1 & 2.

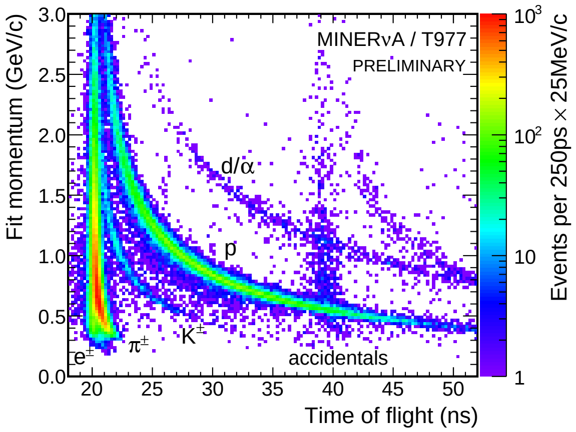

Figure 1. Spectrum of particles observed in the test beam beamline. Accidental triggers from particles in adjacent accelerator buckets produce a shadow at +19 ns.

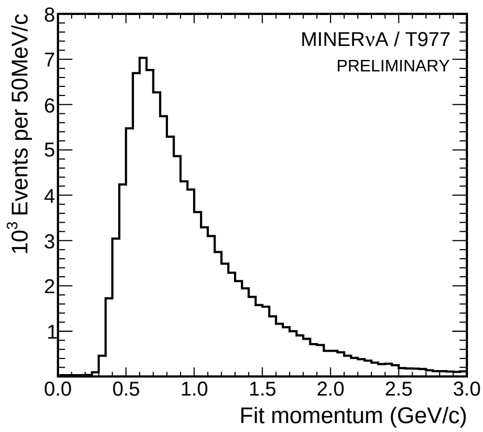

Figure 2. Projection of Figure 1 onto the vertical (momentum) axis. Data is 107×10^3 events from the Summer 2010 run.

4. Calorimetric energy resolution

The calorimetric energy resolution of the detector is determined by a monte-carlo study of neutral current events with a vertex in the upstream, fully active tracker region. Events are generated with Genie 2.6 [2] and simulated in Geant4 [3] with the QGSP BERT model. Visible energy is summed in the tracker and downstream electromagnetic and hadronic calorimeters. The energy in the calorimeters is weighted to account for the additional passive material. An overall energy correction is then applied. The true recoil energy is defined as $E_{recoil} \equiv E_\nu^{in} - E_\nu^{out}$. Using this simple calorimetry, the energy resolution is $\sigma/E = 0.12 \oplus 0.27/\sqrt{E\,(\mathrm{GeV})}$ (see Figure 3). The energy resolution will improve with shower reconstruction algorithms and EM/hadronic compensation.

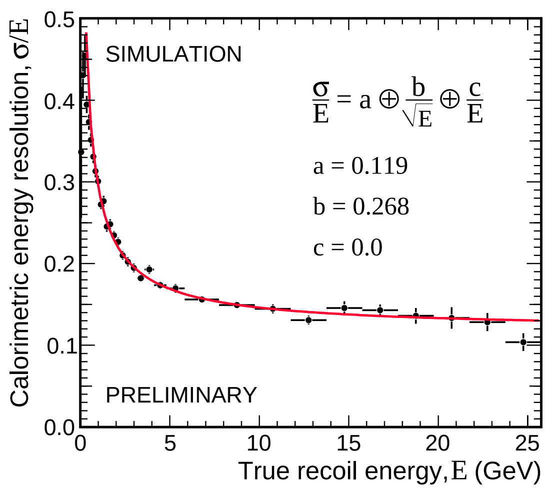

Figure 3. Calorimetric energy resolution for neutral current monte-carlo events. True recoil energy is defined as $E_{recoil} \equiv E_\nu^{in} - E_\nu^{out}$.

5. Towards charged current inclusive cross-sections

MINERνA is actively working towards producing charged current inclusive cross-sections on plastic scintillator and the iron, lead and carbon targets. To that end, we present the following two preliminary analyses.

5.1. Charged current neutrino energy spectra

The NuMI beamline is reconfigurable; the positions of the target and horns and the horn current can be varied to select the neutrino energy spectra. Figures 4 & 5 show the observed spectra of neutrinos producing a charged current interaction in the MINERνA detector in three beamline configurations: low energy (LE), pseudo medium energy (pME) and pseudo high energy (pHE). Events are restricted to a primary vertex in the upstream, fully active tracker region with a muon track analyzed in the MINOS spectrometer. Tracks identified in the final state products are fit to a dE/dx profile for particle identification. The remaining energy is summed calorimetrically as described in Section 4.

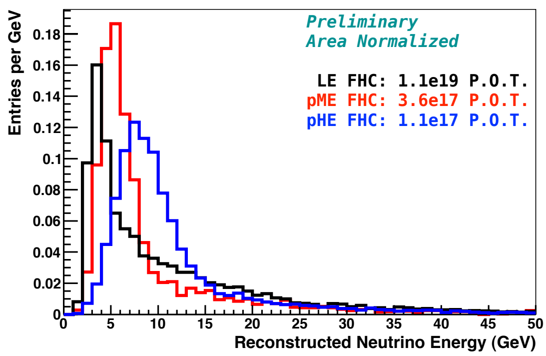

Figure 4. Spectra of neutrinos producing a charged current interaction in the low energy (LE), pseudo medium energy (pME) and pseudo high energy (pHE) beamline configurations in forward horn current (FHC, neutrino-focusing) mode.

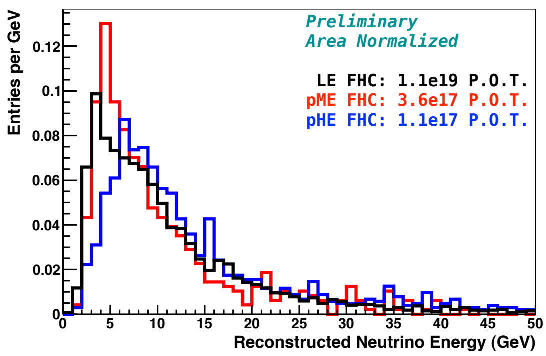

Figure 5. Spectra of anti-neutrinos producing a charged current interaction (from the $\sim$6% $\bar{\nu}$ content of the ν beam).

5.2. Iron/lead charged current event rates

MINERνA is developing analysis techniques for events originating in the passive nuclear targets by studying the most downstream target of iron and lead. Passive target planes are located between active scintillator planes; by requiring muon activity in the first plane downstream of a target, with no activity upstream, a charged current interaction vertex can be localized to the target. The transverse position is determined by projecting the muon track to the center of the target plane. This study requires that the muon is tracked in the MINOS spectrometer.

Backgrounds are introduced from events originating in the scintillator planes upstream and downstream of the target (see Figure 6). Backgrounds and acceptance effects can be studied in data with a scintillator reference target. Eight active planes are declared as a passive target, event selection cuts are applied, then selection purity can be quantified by analyzing the data from within the reference target. The reference target is divided into two regions in the same manner as the passive iron/lead target. A ratio of events originating in these two regions is shown in Figure 7. A data to monte-carlo comparison of events reconstructed in the most downstream target of iron and lead is provided in Figures 8 & 9.

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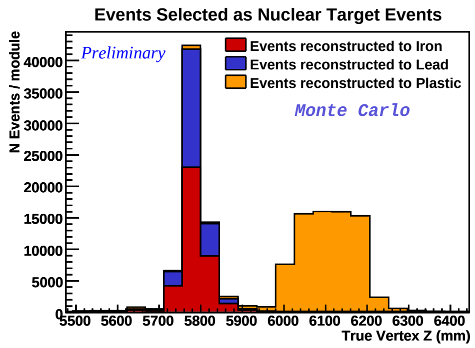

Figure 6. True vertex distribution of charged current interactions reconstructed in the passive and reference targets. Passive target is located at 5760–5800 mm, reference target is 6020–6200 mm.

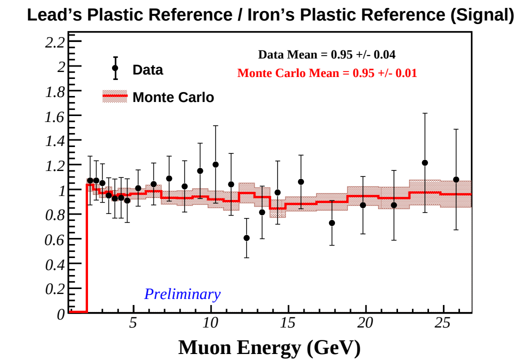

Figure 7. Mass-corrected ratio of events reconstructed in the lead region of the reference target to those in the iron region. Deviations from unity result from acceptance effects.[1]

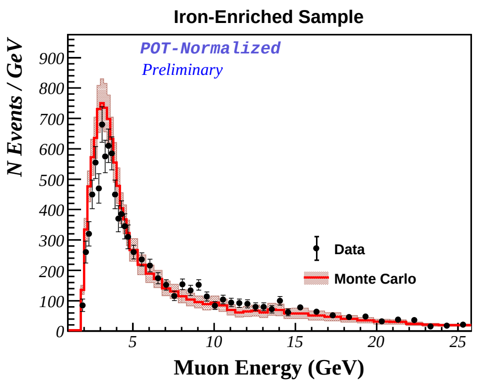

Figure 8. Data/monte-carlo comparison of events reconstructed in the iron region of the most downstream passive target.[1]

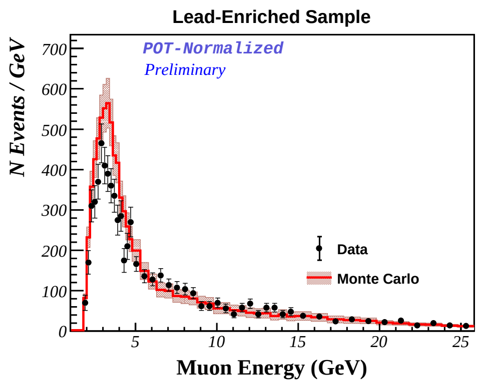

Figure 9. Data/monte-carlo comparison of events reconstructed in the lead region of the most downstream passive target.[1]

6. Conclusion

MINERνA will measure neutrino cross-sections, final states and nuclear effects on a variety of targets in the few-GeV region to reduce systematic uncertainties in oscillation experiments and provide new understanding of the nucleus.

References

[1] http://minerva.fnal.gov
[2] http://www.genie-mc.org
[3] http://geant4.cern.ch

[1] Discrepancies between data and monte-carlo result from incorrect flux modeling. Flux is Fluka08, prior to tuning, with the Genie 2.6 [2] event generator.