

MINER ν A Neutrino Detector Calibration

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Abstract. MINER ν A is a neutrino scattering experiment that uses Fermilab’s NuMI beamline. Its goal is to measure cross-sections for neutrino scattering from different nuclei. Precise knowledge of these cross-sections is vital for current and future neutrino oscillation experiments. In order to measure these values to a high degree of accuracy, it is essential that the detector be carefully calibrated. Here, we describe in-situ calibration and cross-checks.

Keywords: calibration, neutrino interactions

INTRODUCTION

The MINER ν A detector, which measures neutrino-nucleon cross-sections to high precision, must be carefully calibrated. This document briefly introduces the detector and explains in-situ calibration techniques and cross-checks. Further calibration from Fermilab’s testbeam is discussed separately[1].

THE MINER ν A DETECTOR

The central tracking region of the MINER ν A detector [2] consists of a series of modules, in turn made up of triangular polystyrene scintillator strips. Optical fibers within each strip lead to photomultiplier tubes arrayed around the sides of the detector. Calorimeters situated downstream and outside of the tracker aid energy reconstruction of untracked particles. Upstream of the tracking region, modules consist of scintillator strips interspersed with passive nuclear targets, enabling MINER ν A to measure neutrino cross-sections on several different types of nuclei. Two meters downstream, the MINOS near detector, with its magnetic field, acts as a spectrometer for muons exiting MINER ν A.

PMT GAINS AND PEDESTALS

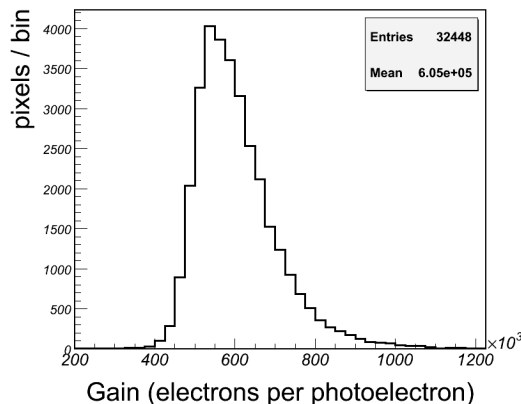


FIGURE 1. Histogram of PMT gains per detector pixel

When the neutrino beam is off, we record data to calibrate the detector’s 507 64-channel instrumented photomultiplier tubes. “Pedestal” runs measure the PMTs’ output with no beam or light input, giving a baseline readout

level per channel. An LED pulser box is used for “light injection” runs, to calculate the gain of each PMT. Gain is defined as the number of electrons generated by a PMT from a single photoelectron. Photoelectrons are produced by the photoelectric effect when light generated by charged particles passing through the associated scintillator strip travels along the optical fiber to the PMT and strikes its photocathode. A histogram of the PMTs’ gain values is shown in Figure 1. This can vary between PMTs, and as a PMT ages. Unexpected gain changes help identify problem hardware. The PMTs’ voltage levels are adjusted based on the gain measurements, to achieve a similar response from each tube.

CALIBRATION WITH ROCK MUONS

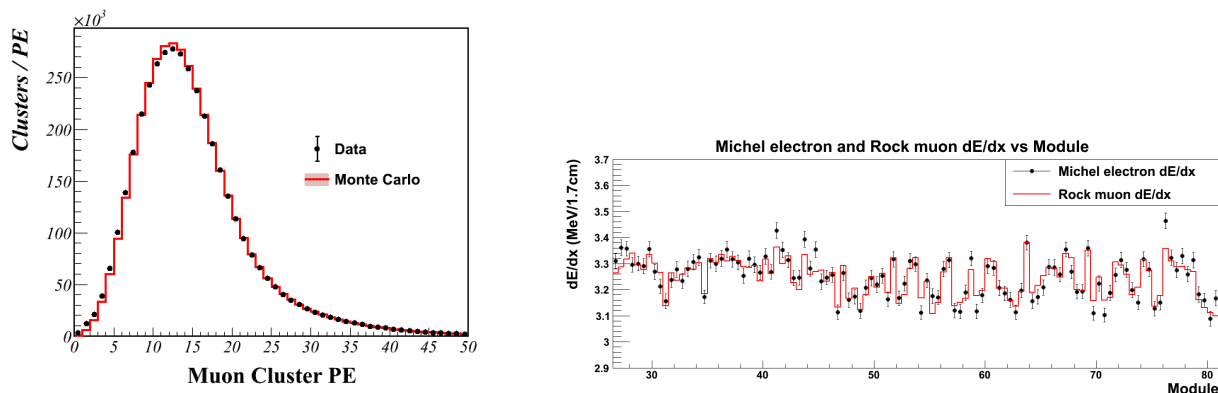


FIGURE 2. Rock muon energy spectrum (left) and $\frac{dE}{dx}$ per module for Michel electrons and rock muons

Upstream of the MINERvA detector, the NuMI muon-neutrino beam passes through rock, where some of its neutrinos interact, producing muons. These so-called “rock muons” enter the front of MINERvA and can travel large distances through the detector, providing a useful tool for calibration. While some lower-energy rock muons stop in the detector, many continue through the entire detector, behaving as minimum-ionizing particles. In this case, the energy they deposit should be consistent in each plane of the tracker. We can calibrate our energy scale by looking at the number of photoelectrons these muons generate per plane (Figure 2, left plot).

Michel electrons from muons decaying in the tracker are known to have 53MeV maximum energy. This provides a useful cross-check on the energy scale calculated using rock muons. Figure 2 (right plot) shows the energy deposition per module throughout the tracker region, as calculated using both rock muons and Michels.

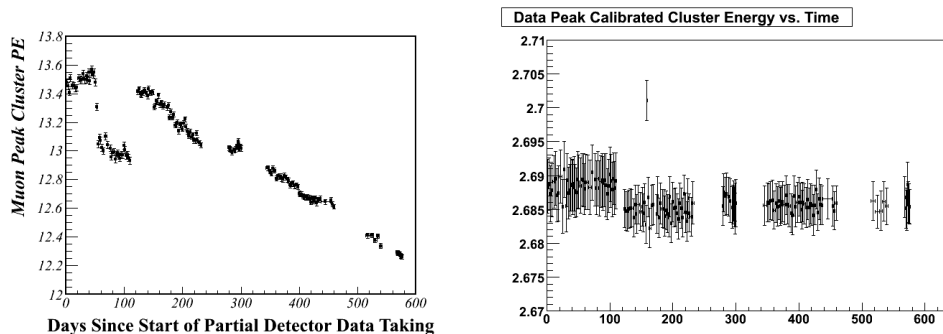


FIGURE 3. Muon cluster PE vs time (left) and time-dependent corrected muon energy vs time

Time-dependent calibration corrects for scintillator aging. Scintillator’s light response diminishes with time (Figure 3, left plot). By monitoring the number of photoelectrons produced by rock muons, we can correct for this aging effect, enabling us to correctly monitor energy deposition as time passes (Figure 3, right plot). It should be noted that this scintillator degradation is temperature dependent, and its effect has now been lessened due to the installation of improved cooling in the detector hall.

Rock muon data can be used to apply corrective multipliers to each channel as tracks traverse the triangular scintillator strips in each plane. We can also use this “strip-to-strip” information to detect dead channels and confirm that the mapping from detector to output electronics is correct.

TRACKING CALIBRATION WITH MINOS

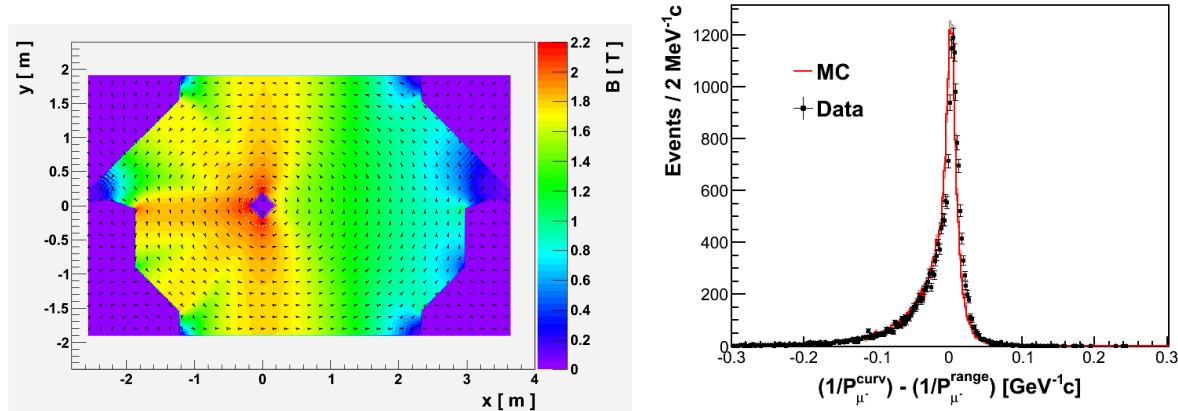


FIGURE 4. MINOS field map (left) and residual of muon momentum calculated using track curvature and range

The MINOS near detector, which has a magnetic field, is located just downstream of MINERvA. Induction coils measure the field map, which has a complex form, as shown in Figure 4 (left plot) [3]. This field allows us to construct muon momenta via two methods: track curvature, and range of muons that stop in MINOS. The right-hand plot in Figure 4 compares the two methods.

CONCLUSION

The precision of MINERvA’s measurements is ensured by multiple calibration techniques and cross-checks. Rock muons and Michel electrons, with their well-understood properties, allow us to determine the detector’s energy scale. By measuring the output of the detector with no beam, we can correct for our electronics’ pedestal values, while the gain of the PMTs can be calibrated using light injection. The MINOS near detector allows us to calibrate our tracking by using its magnetic field to measure the momentum of outgoing muons.

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