Information for DOE Report

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This document summarizes the work I have done in the past year for the DOE report, starting with DUNE and followed by NOνA.

1. DUNE

1.1. Comparison of Photon Detector Designs at CDDF

We compared the performance of the photon detector designs from CSU and LSU. Detectors were put side by side in the Dewar at CDDF. Each detector has 2 SiPM channels. Figure 1 shows the integrated ADC for the four SiPM channels. A threshold scan was done to set the threshold just above the pedestal peak. The detectors were irradiated by an α source and triggered at 0.5 photoelectron for each channel independently.

Figure 2 shows calibrated photoelectron (PE) spectra for the four channels. The calibration was done by assigning the first peak to 1 PE, the second to 2 PE, etc.

Since the data showed a high trigger rate, the light yields were compared by excluding the single PE events. Figure 3 shows the average number of photoelectrons of events with at least 2 PEs. This figure shows the four channels have comparable light yield in this $\geq$ 2 PE measure.

1.2. Monitor Application for Voltage Readback of the SiPM Signal Processor

CSU owns 2 SiPM Signal Processors (SSP). The SSP supplies high voltage to its 12 independent channels, and for each channel a readback register is in place for monitoring voltage in operation. A monitor application is developed to serve this purpose.

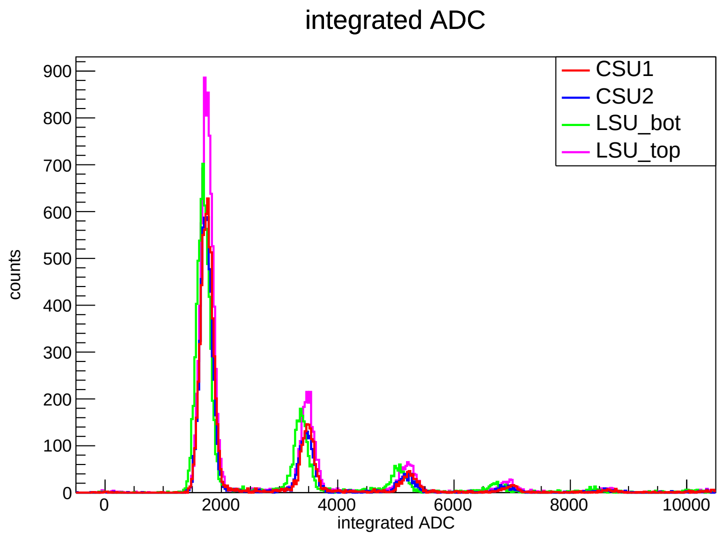

Figure 1. Integrated ADC for the four SiPM channels.

1.3. Control Application for the LBNE Calibration Module

This module is named after the former name of the experiment, LBNE. The LBNE Calibration Module (LCM) outputs calibration signals to 3 different calibration subsystem, namely, the Indiana University (IU) system, the TPC system, and the photon detector (PD) system. Figure 4 shows sample pulses generated by the control application for the LCM. To facilitate the use of the control application, a simple GUI frontend is also provided as shown in Figure 5.

2. NOνA

2.1. Generation of Flat Monte Carlo Neutrino Spectrum

The neutrino flux of the NuMI beam peaks at 2 GeV. The total interaction cross-section of neutrino is roughly $\sim E$, which at high energy is dominated by the deep inelastic scattering. The left plot in Figure 6 shows the total neutrino flux of the NuMI beam (the black histogram) from simulation. The right plot in Figure 6 is the neutrino event

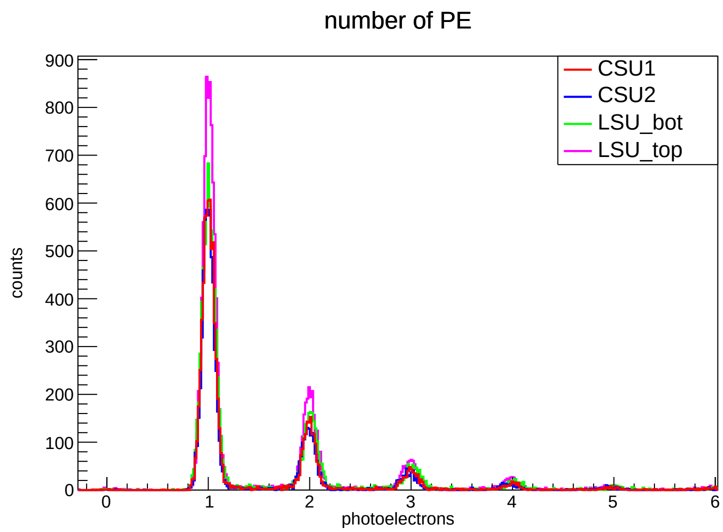

Figure 2. ADC to photoelectron calibration for the four SiPM channels.

spectrum. The event spectrum is highly peaked around 2 GeV, leading to lack of statistics for particle identification (PID) training with neural network algorithms outside the peak range. There is need to warp the input neutrino flux to have a flat neutrino event spectrum for the PID training of the off-peak events. The idea is to make the input flux $\sim 1/E$. Figure 7 shows the $1/E$ warped flux. Figure 8 is a sample output of the neutrino event spectrum gone through GENIE simulation with a $1/E$ input flux, which has an evenly distributed number of events in the interested energy range.

2.2. ν_μ on e event topology

$\nu_\mu - e$ scattering is one of the simplest processes whose cross-section can be calculated very accurately. Therefore these events can be used for constraining the NuMI flux. The characteristic feature of the $\nu_\mu - e$ events leaving in the detector is a 1-prong electromagnetic shower in the very forward direction. We used the near detector MC data to check how well our current reconstruction algorithms work for $\nu_\mu - e$ scattering events. A sample event where the current reconstruction algorithms reconstruct successfully as

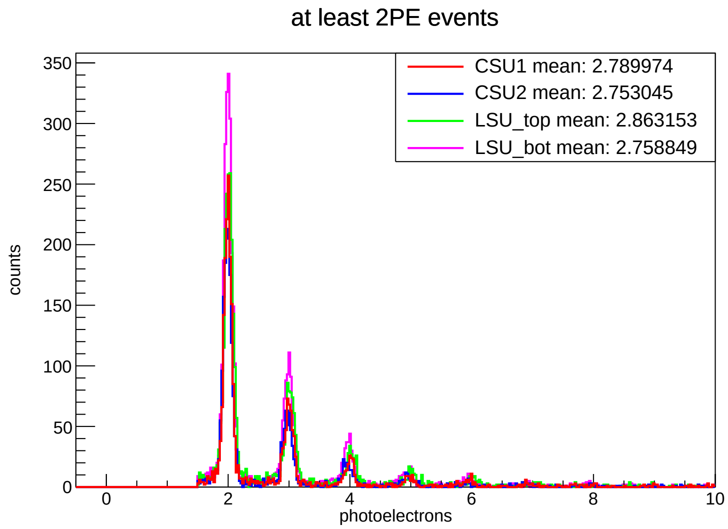

Figure 3. Average light yield for at least 2 PEs for the four channels.

Figure 4. Sample pulses generated by the control application for the LCM.

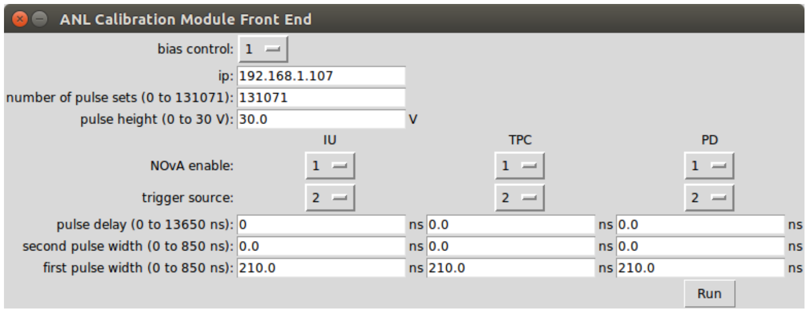

Figure 5. A GUI frontend for the control application for the LCM.

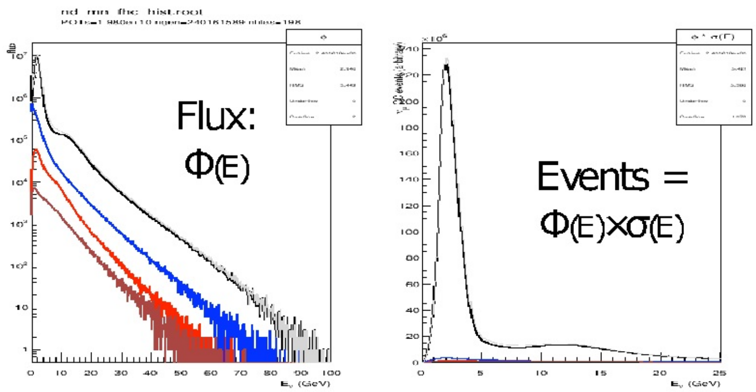

Figure 6. Left: The total neutrino flux of NuMI beam (black) and the fluxes of various components. Right: The neutrino event spectra for the corresponding fluxes.

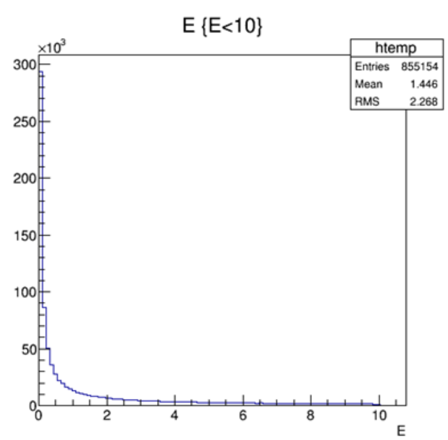

Figure 7. The warped $1/E$ flux.

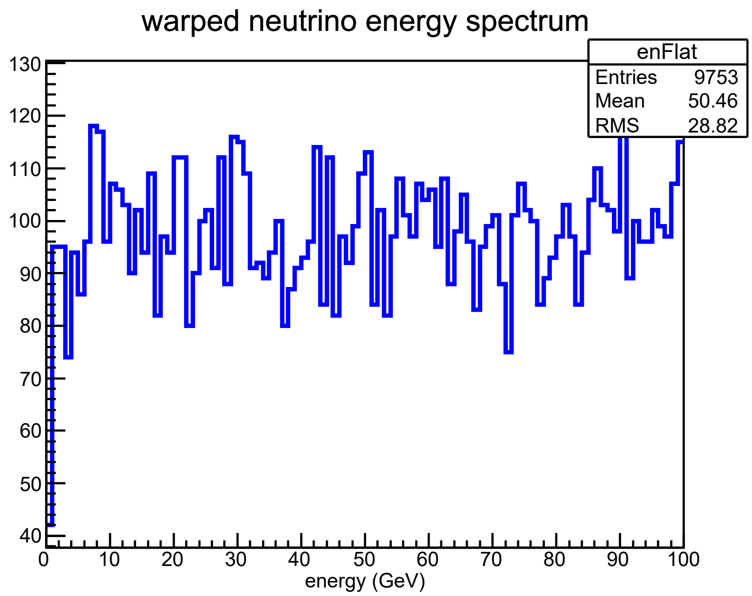

Figure 8. The neutrino event spectrum with a $1/E$ input flux.

a 1-prong event is given in Figure 9. However there are also events in which the number of the reconstructed prongs is more than one, such as that shown in Figure 10. This is because current algorithms pull the vertex downstream into the shower, leaving 2 back-to-back prongs. The proportion of events for which current algorithms perform well is about 70%, while the proportion of the incorrectly reconstructed events is about 30%, leaving room for improvements.

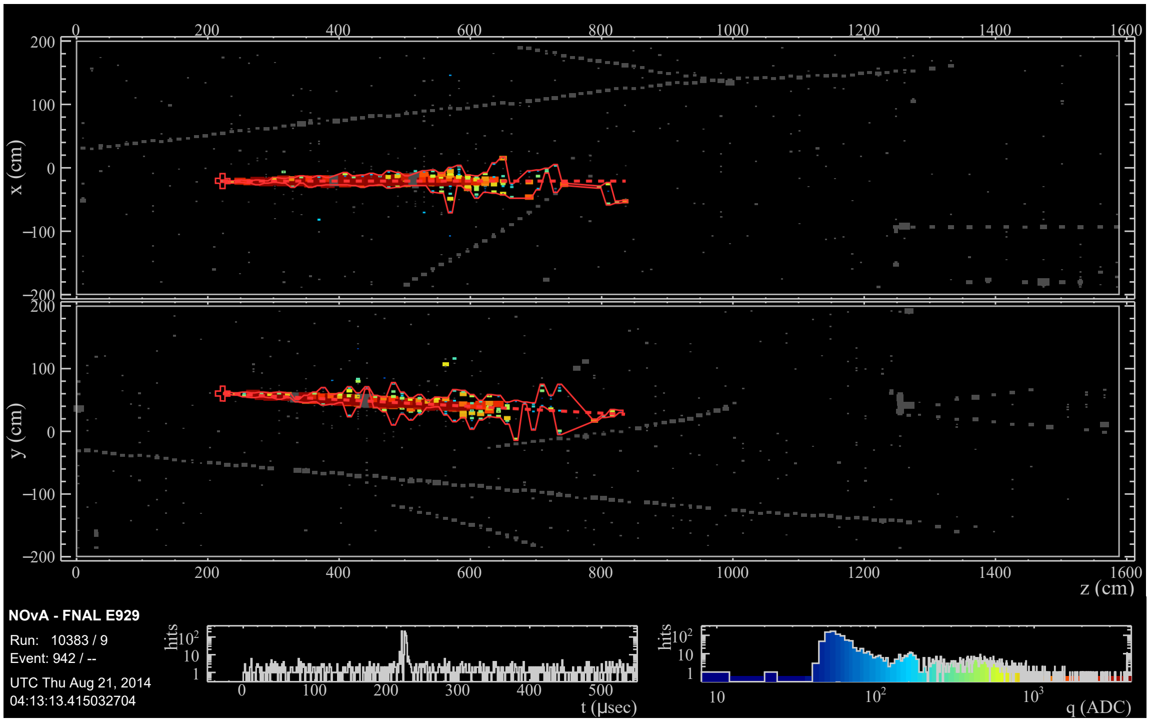

Figure 9. A ν_μ on e event where the current reconstruction algorithms reconstruct successfully as a 1-prong event. The upper plot is the top view of the NOνA near detector, while the bottom is the side view of it.

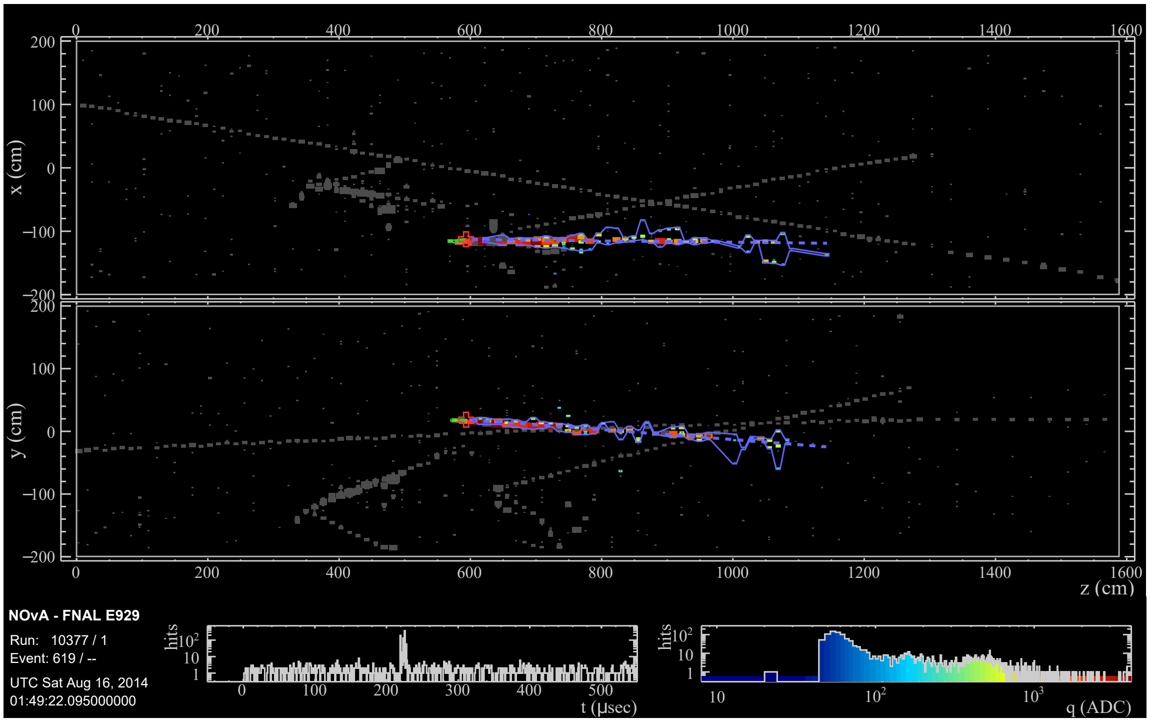

Figure 10. A ν_μ on e event where the current reconstruction algorithms reconstruct incorrectly as a multi-prong event. The hollow cross indicates the reconstructed vertex where the interaction happens. Current algorithms pull the vertex downstream into the shower, leaving 2 back-to-back prongs.