First Demonstration of LArTPC MeV-Scale Physics

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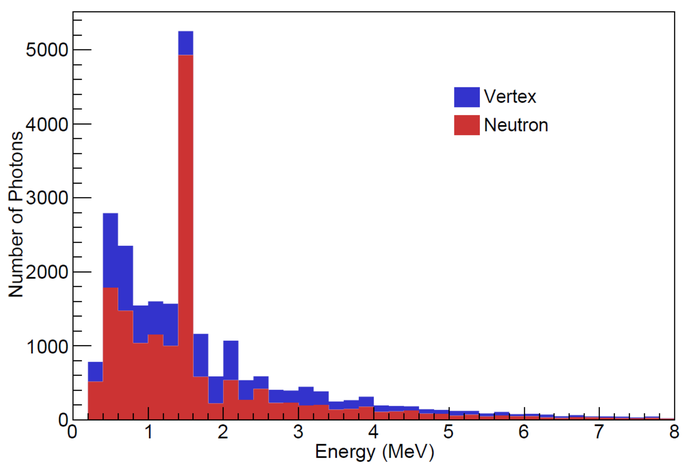
Low-Energy Photons

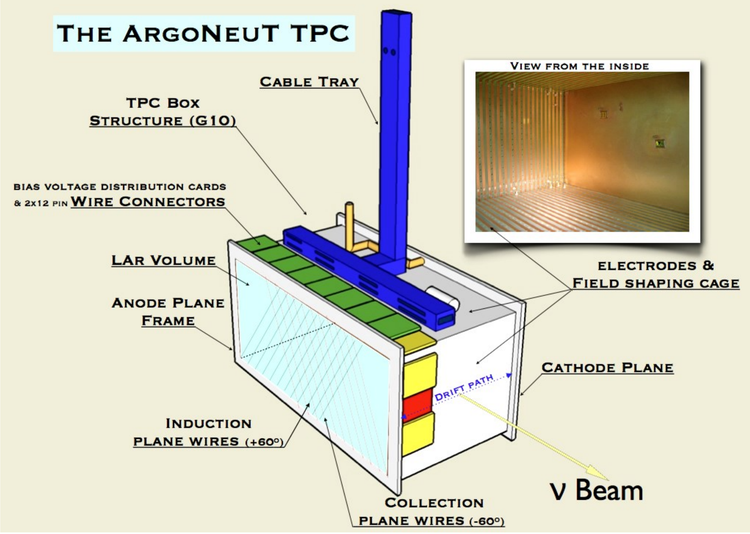
- Focus: photons from neutrino-produced nuclear de-excitation and inelastic neutron scattering
  - Energies: 0.1 – 10 MeV
- Detect electrons produced primarily by Compton scattering
- Multiple small and topologically isolated energy depositions

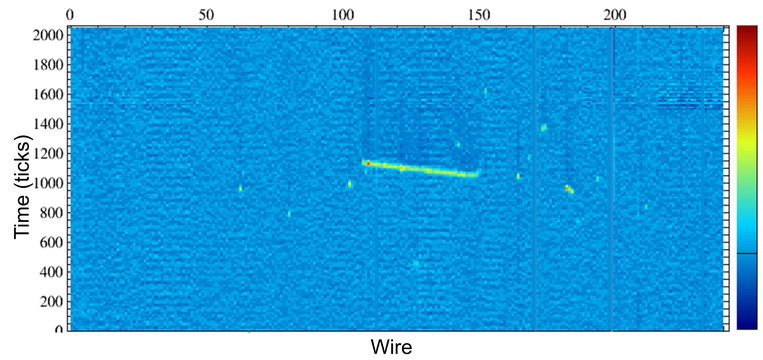


Energies of photons detected in ArgoNeuT as determined by a FLUKA simulation. Color indicates source of photon: red describes photons produced by the de-excitation of the final state nucleus. Blue describes photons produced by inelastic neutron scattering. The peak at 1.46 MeV is due to the first excited state of ^{40}Ar.

ArgoNeuT

- LArTPC placed in NuMI beam at Fermilab [1]
- 47 (*w*) × 40 (*h*) × 90 (*l*) = 0.24 tons
- Readout: two planes of 240 wires each
  - 4 mm pitch, ± 60° to the beam
- NuMI Beam: GeV neutrinos
  - Antineutrino mode

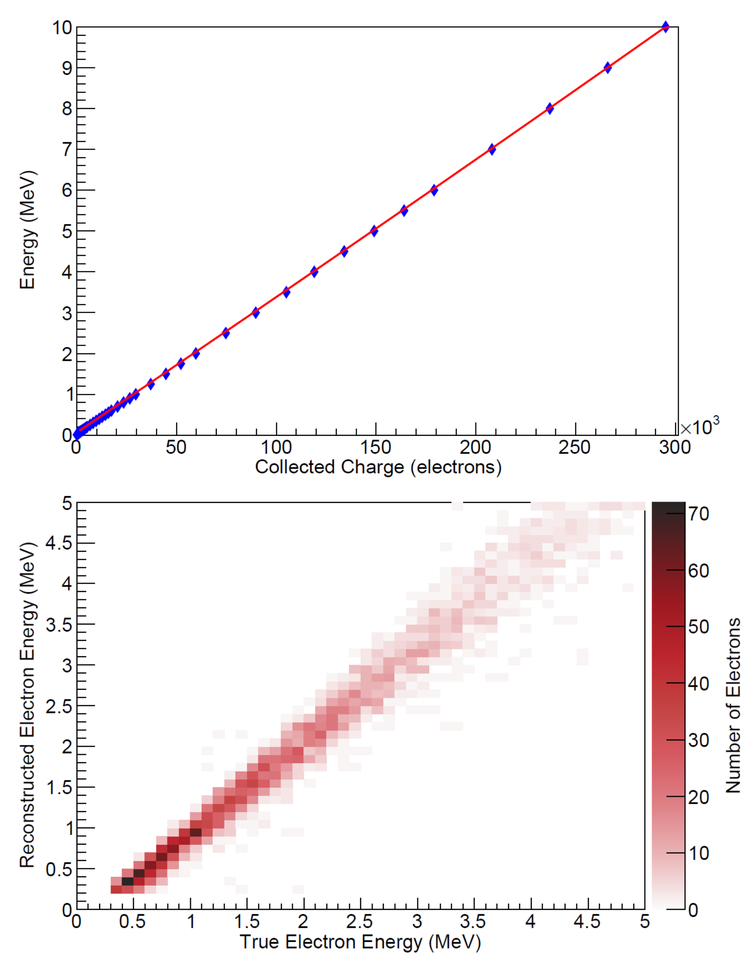




Raw data event with one track reconstructed as a muon and with possible gamma activity (isolated blips). Only the collection plane is shown. Wire number is indicated on the x-axis. The y-axis indicates time in ticks. Color indicates amount of charge deposited.

Reconstruction

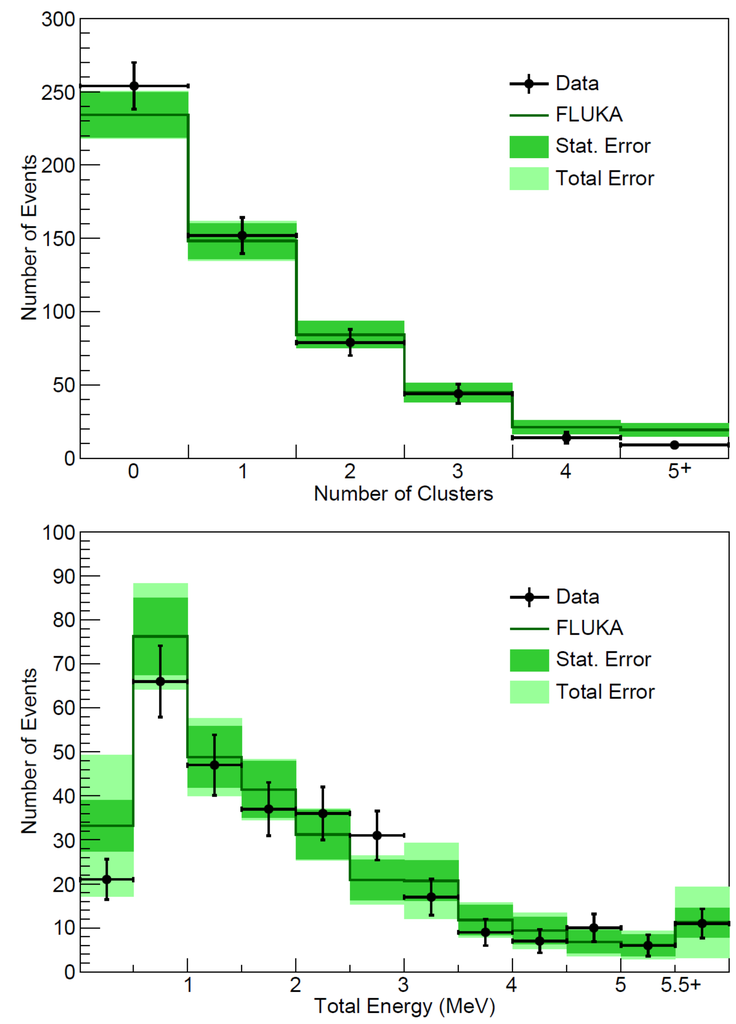
- We first apply the standard LArTPC reconstruction.
- Then, a low-energy specific reconstruction
  - Apply cuts to hits to remove those due to high-energy particles and noise
  - Apply plane matching
  - Remaining hits are isolated energy depositions.
  - Use NIST table of electron energies and ranges (ESTAR) [2] to convert collected charge to energy taking into account recombination in LAr.



Top: Energy vs collected charge using method described above. Bottom: Reconstructed energy vs true electron energy for a sample of simulated electrons with energies between 0 and 5 MeV.

Results

- We use CC0π 1μ + 0,1p events.
- We find good agreement between data and a FLUKA simulation, which models both de-excitation of the final-state nucleus and neutron propagation and interaction in liquid argon.
- Both components (de-excitation and neutron produced photons) are necessary for data-MC agreement.



Distribution of cluster multiplicity (top) and total reconstructed energy (bottom) of MeV-scale energy depositions in an event for neutrino data and FLUKA events. Data points include statistical error. MC is normalized to the number of neutrino data events. Simulation includes de-excitation gammas, neutron-produced gammas and data-driven background.

Conclusions

- We have successfully identified and reconstructed MeV-scale energy depositions left by neutrino interaction products in a LArTPC.
  - Good agreement with FLUKA
- Reconstruction of low-energy activity in LArTPCs is possible.
- We have created techniques for performing MeV-scale physics reconstruction in LArTPCs.

[1] JINST **7**, P10019 (2012)

[2] Berger, M.J., Coursey, J.S., Zucker, M.A., and Chang, J. (2005), ESTAR, PSTAR, and ASTAR: Computer Programs for Calculating Stopping-Power and Range Tables for Electrons, Protons, and Helium Ions (version 1.2.3). http://physics.nist.gov/Star National Institute of Standards and Technology, Gaithersburg, MD.

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