Benefits of MeV-Scale Reconstruction in Large Liquid Argon TPCs

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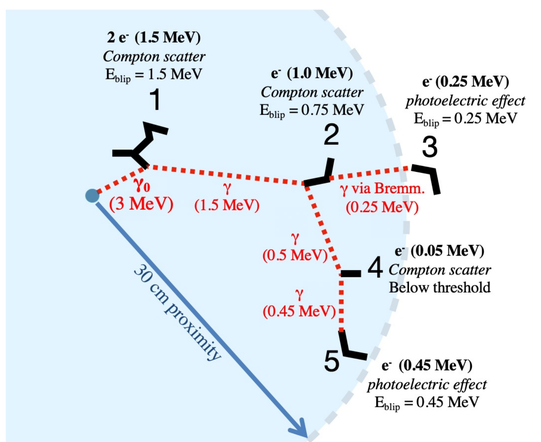
Introduction

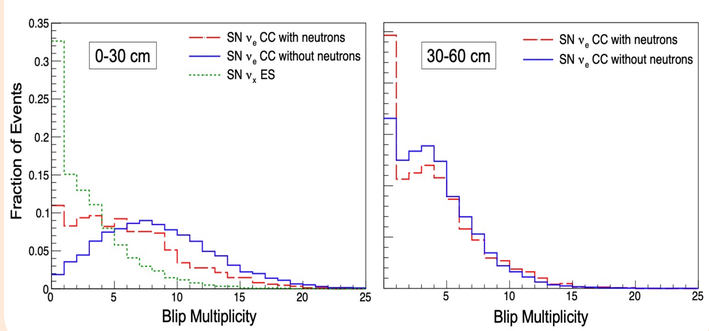
- LArTPCs ideally suited for observing neutrino interactions, though existing reconstruction techniques focus on event topologies in the 100 MeV to ~few GeV range
- LAr ionization threshold of ~24 eV → sensitivity to low-energy depositions
- MeV-scale gammas (γ), produced in nuclear processes and electromagnetic (EM) showers, will deposit energy in spatially isolated "blips"
- Monte Carlo (MC) simulations used to explore benefits to ν physics and Beyond Standard Model searches (BSM)
  - Truth-level information from Geant4 MC used to form quasi-reconstructed blips
  - Proximity requirement & energy threshold
  - Paper: Phys. Rev. D 102, 092010 (2020)



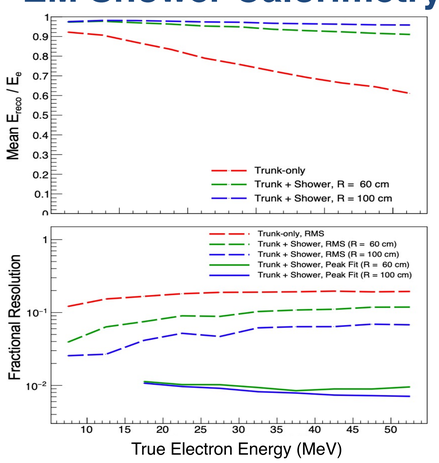
Representation of spatially-isolated energy depositions from a 3 MeV γ-ray in LAr. This event would produce 4 identified "blips" using our algorithm for MC truth-level information with a 75 keV threshold. After a proximity requirement of 30cm, summed blip energy is 2.7 MeV.

Final-State Neutron Identification

- Energy lost to neutrons in many ν-CC interactions
- Thermalization over long time scales, producing numerous γ's in 0-3 MeV range
- ➢ Supernova ν benefits: blip activity and vertex distance suggestive of neutron production
- ➢ Accelerator ν benefits: inclusion of blips can can provide 25% improvement in E-resolution



EM Shower Calorimetry

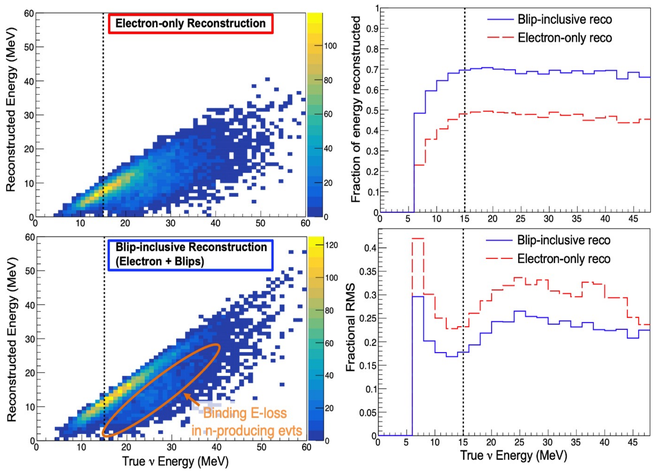


- Electron shower completeness and resolution improved by including blips
- Directly ties to measurement of SN, atmospheric, and beam ν_e-CC neutrino energy resolution

Supernova and Solar Neutrinos

Calorimetry

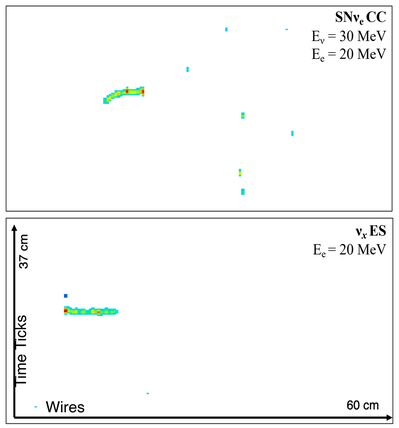
- Higher E_{reco}/E_{true} and better RMS resolution
- Neutron ID allows for account of binding energy losses



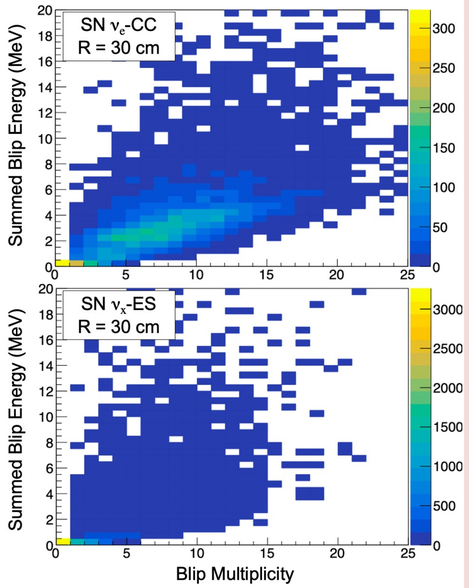
Left: True ν_e energy and reconstructed energy when excluding (top) or including (bottom) isolated blips surrounding the main electron track. Right: Fraction of reconstructed energy (top) and RMS resolution (bottom).

CC/ES Channel Identification

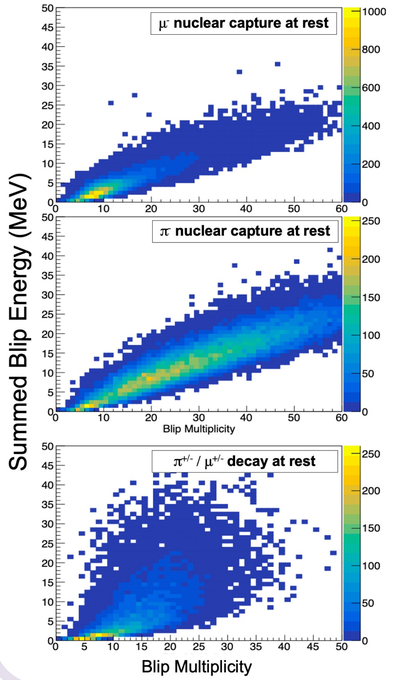
- ν_e-CC produce more blips compared to elastic scattering (ES)
- 2D cuts on blip multiplicity and energy can enhance sample separation



Left: Example event displays showing differences in blip activity between CC and ES. Right: Blip metrics that can be used to enhance sample purity.



Particle Discrimination and BSM Searches



- Blip activity near track endpoint indicative of nuclear activity (i.e., capture)
  - Can aid in discrimination of μ- and π- capture-at-rest (CAR), μ decay
  - Charge-sign discrimination
- BSM signatures that include di-lepton pairs ($\ell^+ \ell^-$) may benefit from BG reduction via blip-based π/μ and charge discrimination

Radius	N_{blip}	E_{blip}	E_{vert}	μ CAR	μ Decay	π CAR
30 cm	> 7	–	–	52%	65%	85%
30 cm	–	⩾ 4 MeV	–	33%	47%	77%
30 cm	> 7	⩾ 4 MeV	–	30%	42%	75%
60 cm	> 14	–	–	34%	46%	85%
60 cm	–	⩾ 8 MeV	–	22%	44%	78%
60 cm	> 14	⩾ 8 MeV	–	21%	33%	77%
60 cm	–	–	> 5 MeV	18%	0%	74%
60 cm	> 14	⩾ 8 MeV	> 5 MeV	6.3%	0%	53%

TABLE IV. Selection efficiency for various blip activity and vertex activity cuts for μ^- captures at rest (CAR), decaying μ^-, and π^- CAR. The vertex region is defined by a 5 mm radius sphere centered at the particle's decay or capture point; only blips found outside of this region are considered.

Acknowledgements: This work was supported by DOE Office of Science, under award No. DE-SC0008347, as well as by the IIT College of Science and Rutgers University–New Brunswick School of Arts and Sciences. We thank Russell Betts, Avinay Bhat, Erin Conley, Ryan Dorrill, Roni Harnik, Zhen Liu, and Pedro Machado for insightful discussions that helped motivate this study, and especially thank David Caratelli, Steven Gardiner, Shirley Li, Ornella Palamara, and Tingjun Yang for their insights on portions of the presented analysis. We also acknowledge the ArgoNeuT Collaboration for the use of its LArTPC event display and LArSoft implementations, which were primarily used for this analysis.

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