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Demonstrating MeV-Scale Physics Capabilities of Large Neutrino LArTPCs with Ambient Blip Activity in MicroBooNE

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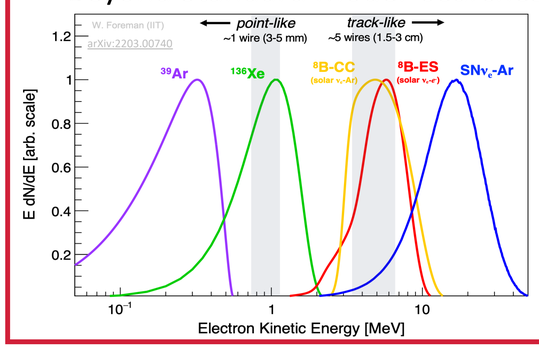
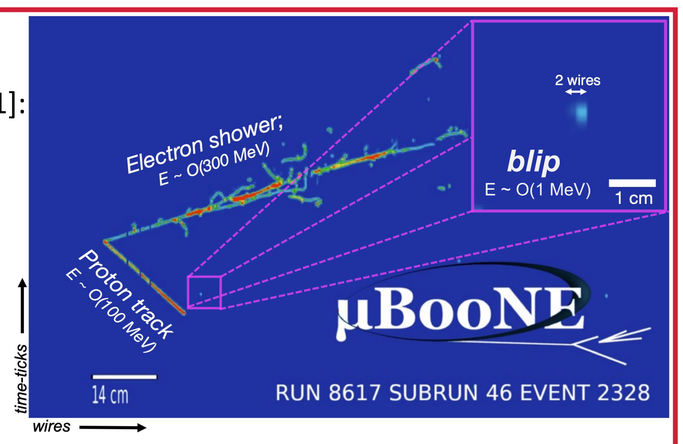
μBooNE

Energy Scales in LArTPCs

Benefits to MeV-scale blip reconstruction[1]:

- Tagging neutrons & γ-rays from ν-Ar hadronic final-states for calorimetry
- PID for μ/π capture-at-rest
- Supernovae & solar ν detection
- 'Beyond Standard Model' searches





Produced by:

- γ-rays
- Neutrons
- Radiological contaminants (^{39}Ar, Rn, etc.)

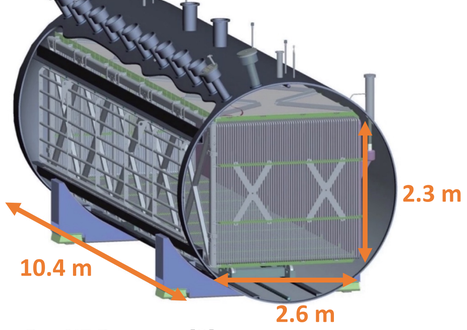
MeV Scale regime in LArTPCs

- MeV-scale energy depositions visible in LArTPCs as small, topologically isolated blips of ionization of mm- or cm in size.
- Analysis goal: Distinguish between *p*-blips from $e^{\pm}$-blips.

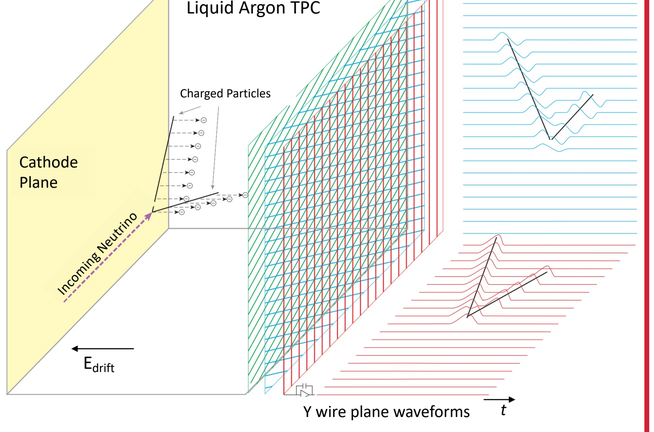
MeV scale - PID capability useful for:

- ❑ Displaced proton tagging (Neutrons)
- ❑ Low hadronic energy final state identification (Coherent Interactions)
- ❑ Low-momentum-transfer (NC interactions)
- ❑ Identification of low-energy features near gLEE-like event topology

The MicroBooNE LArTPC



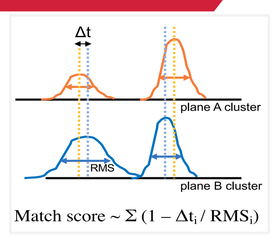
MicroBooNE Detector [2]



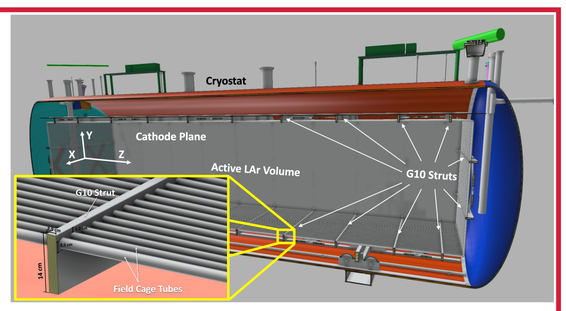
- 85 metric tonnes LArTPC
- Exposed to Fermilab NuMI and BNB beamlines
- Data collection from 2015 to 2021
- 3 wire planes (Charge) & PMT's (Light)
- 3 mm wire spacing
- Electric field 2.74 V/cm
- 2.3 ms charge drift time
- 3.2 ms per triggered readout event

Ambient blips in MicroBooNE

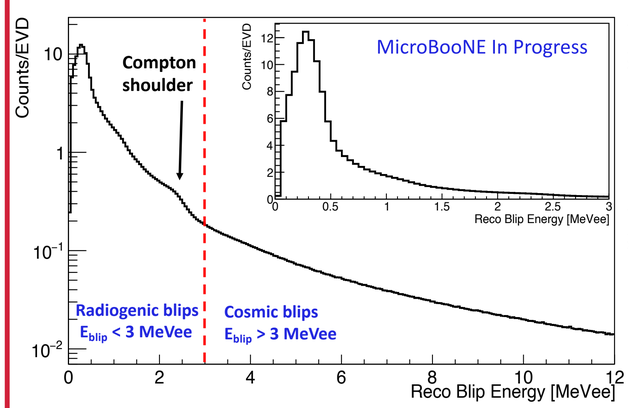
`BlipReco` described in [3].



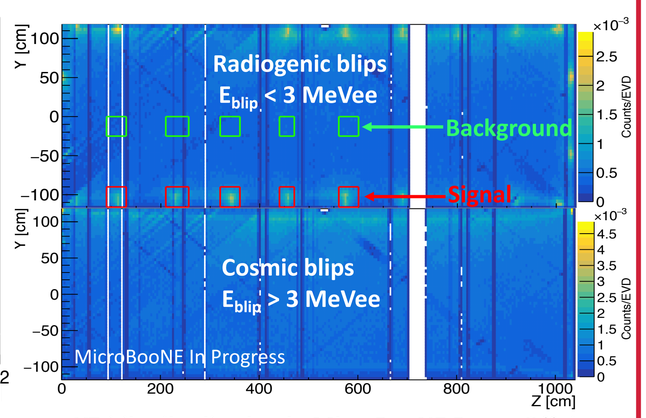
1. Veto hits in or near tracks.
2. Cluster hits.
3. For each collection plane cluster, calculate a match-score for clusters on other planes.
4. Best-matched clusters grouped into 3D blips using wire intersections to get Y/Z coordinates.



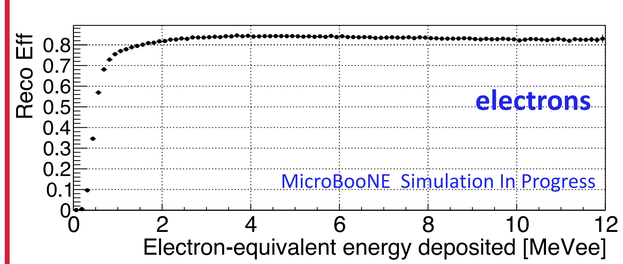
Model of MicroBooNE cryostat and TPC interior

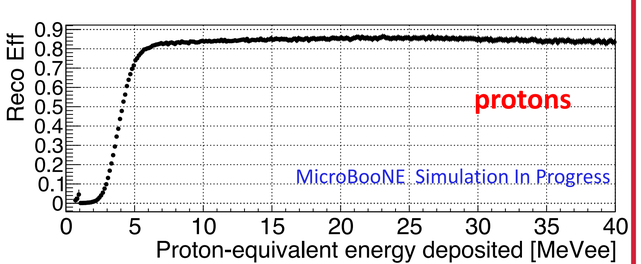


Blip energy spectrum in MicroBooNE Beam-Off data



YZ-blip distribution in MicroBooNE Beam-Off data





Blip Reconstruction efficiency for electrons and protons

MeV Scale Calibration

Procedure

I. Compton edge in data background- subtracted energy spectrum taken as benchmark for radiogenic blips.

II. Simulation of 2.614 MeV gammas to mimic ^{208}Tl radioactivity.

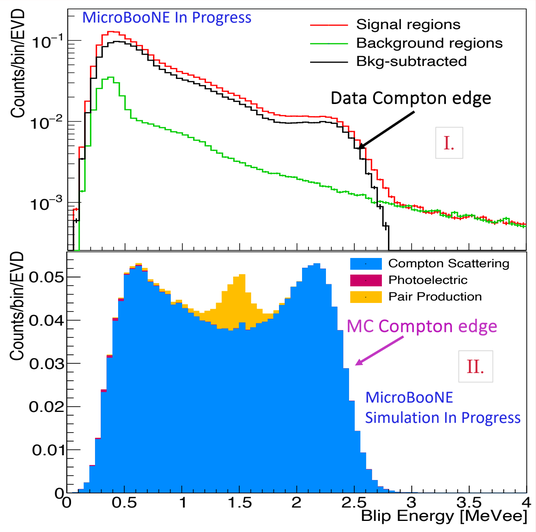
- *Tl-208 Branching Ratio* to 2.614 MeV-γ is 99.75 %

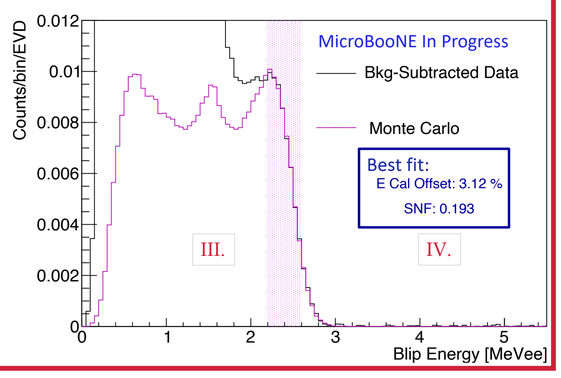
III. Match both Data and MC Compton edges within 2.2-2.6 MeVee range.

IV. Get best fit Energy Calorimetry Offset and Normalization Factor parameters.

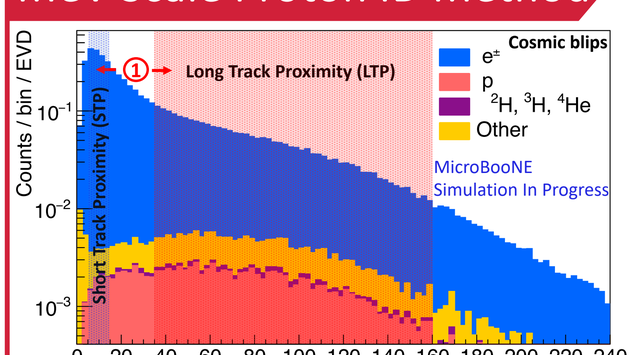
Energy Calorimetry Offset
3.12% ± 0.55% (stat) ± 0.99% (sys)

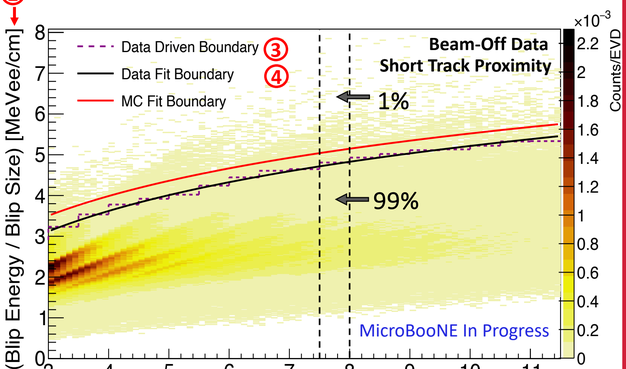
Specific activity of Tl-208 in fiberglass G10-struts
11.7 ± 0.18 (stat) ± 2.9 (sys) Bq/kg



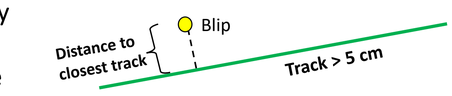


MeV Scale Proton ID Method

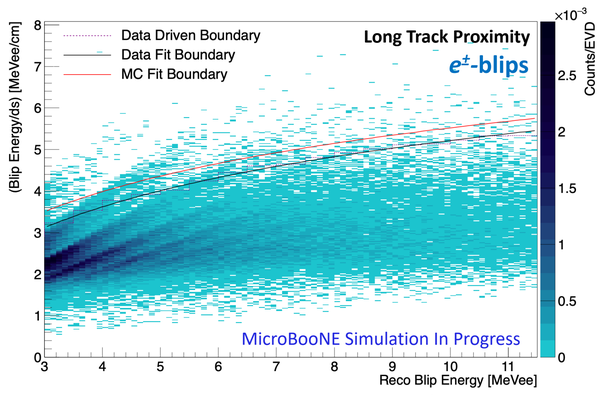


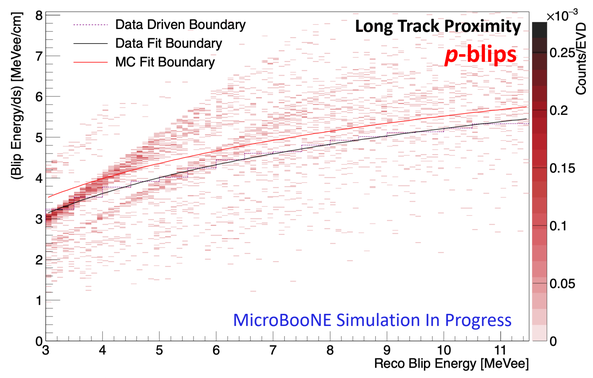


① Samples: Short (5-15 cm) and Long (35-160 cm) Track Proximity
② PID Metric: blip energy[MeVee] / Blip Size [cm]
③ Determine data driven boundary in *metric vs Blip energy* space
④ PID cut fit function based on Short Track Proximity (STP) sample
⑤ Apply PID cut function on the Long Track Proximity sample (LTP)



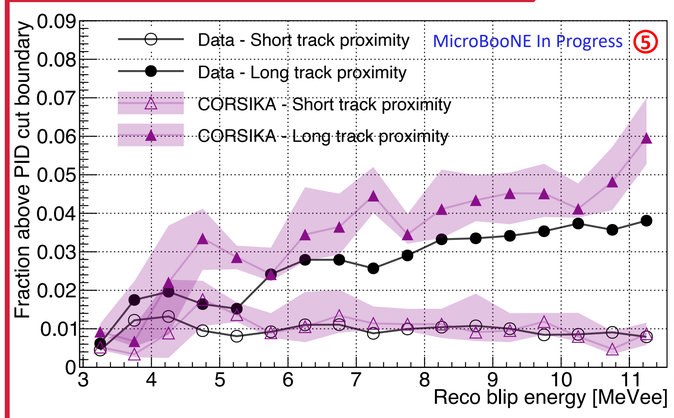
- STP sample: Electron-blip dominated
- LTP sample: Richer in proton content



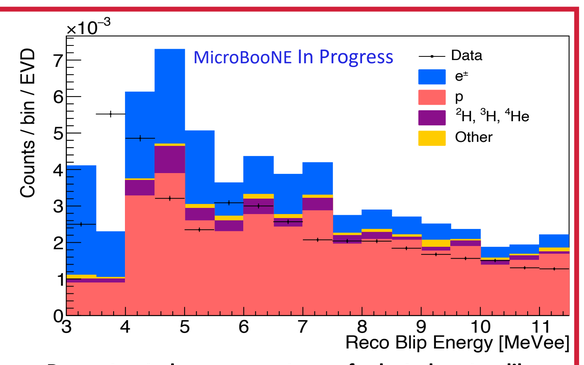


Average energy deposition density, dE/ds, for reconstructed blips of various energies in CORSIKA MC

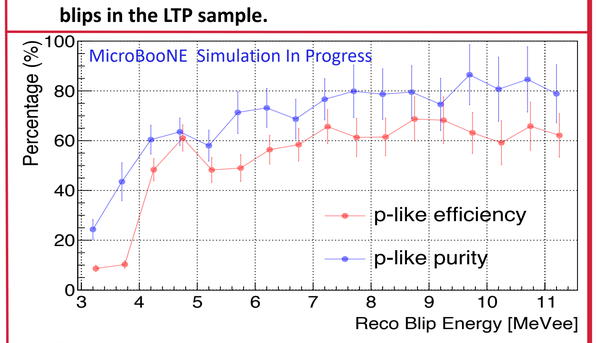
Selected Proton sample



- Roughly 1% of blips above PID cut boundary in the Short Track Proximity sample.
- Higher fraction of blips above PID cut boundary in the Long Track Proximity sample due to p-like blips candidates.
- CORSIKA and Data exhibit similar trend.



Reconstructed energy spectrum of selected proton-like blips in the LTP sample.



Efficiency and purity for selecting reconstructed blips produced by true hadronic parents with the PID cut.

Conclusions

- ❑ Demonstration of new energy calibration and particle discrimination capabilities at the MeV scale in large neutrino LArTPCs using ambient radiogenic and cosmogenic activity in the MicroBooNE detector.
- ❑ Selection of a purified sample of topologically isolated low-energy protons generated by inelastic scatters of cosmic neutrons.
- ❑ Indication of incorrect modelling of incident cosmic fluxes or particle transport modelling issues in GEANT4.
- ❑ Activity of Tl-208 in the DUNE far detector may represent a potential challenge to triggering and reconstructing solar and supernova neutrinos.

References

[1] D. Caratelli et al., Snowmass 2021, arXiv:2203.00740

[2] R. Acciarri *et al* (MicroBooNE))2017 *JINST* **12** P02017

[3] P. Abratenko et al. (MicroBooNE), Phys. Rev. D 109, 052007 (2024)

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