Cosmic Ray Background Rejection with Wire-Cell LArTPC Event Reconstruction in MicroBooNE

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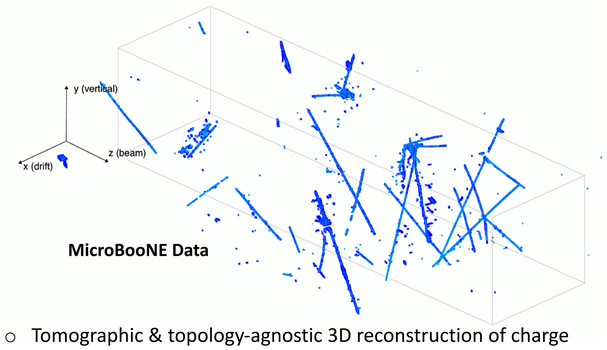
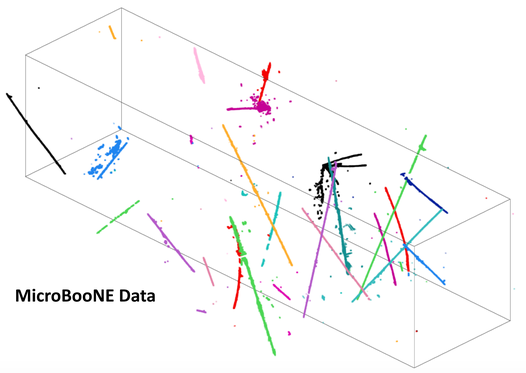
Introduction

For a surface Liquid Argon Time Projection Chamber (LArTPC) to detect neutrino interactions, the rejection of the cosmic background is challenging and critical. We introduce a superior cosmic background rejection procedure applied in MicroBooNE based on the Wire-Cell 3D event reconstruction techniques. The foundational reconstruction techniques include the 3D imaging and clustering of the TPC activity, the many-to-many matching of the TPC clusters and PMT flashes, and a 3D trajectory fitting and dQ/dx determination. This method is able to select 3D images of largely intact high-purity neutrino activity with high-efficiency. These techniques mark an important milestone towards realizing the full scientific capability of single-phase LArTPCs to reconstruct neutrino interactions.

3D imaging and clustering



- Tomographic & topology-agnostic 3D reconstruction of charge
- Mitigation of impact from wire readout ambiguity and nonfunctional wires

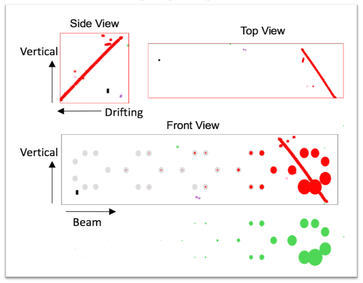


- Proper clusters represent complete TPC objects
- Challenges: ghost tracks, artificial gaps, coincidental overlap, and separate clusters from neutrino interactions

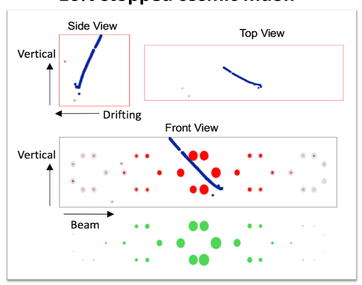
Cosmic rejection/Neutrino selection

After 3D imaging, clustering, and charge-light matching, in-beam neutrino candidate are still cosmic muon dominated:

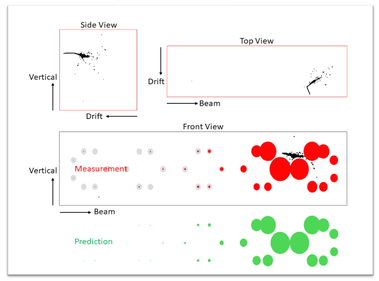
70% through-going cosmic muon



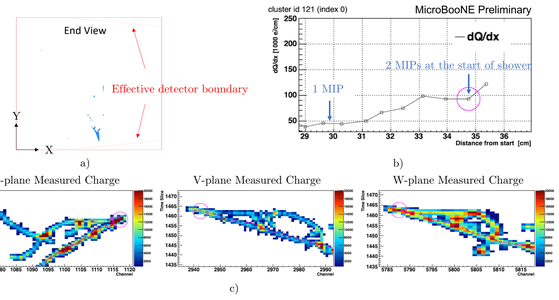
10% stopped cosmic muon



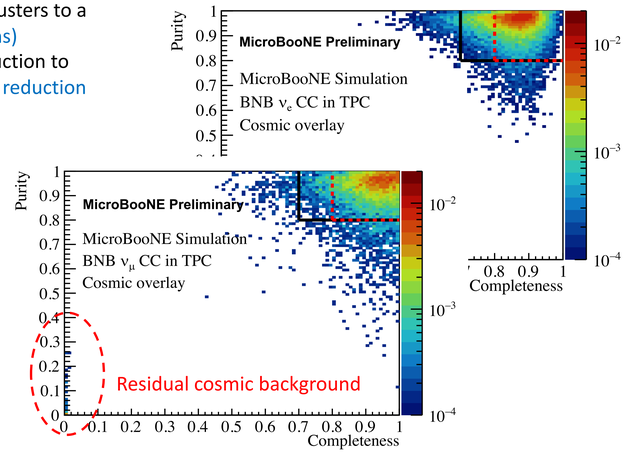
17% neutrino



- Many-to-many charge-light matching [multiple TPC clusters to a single PMT flash] (a 30-fold reduction of cosmic muons)
- Geometrical, topological, and calorimetrical reconstruction to reject in-beam matched cosmic-ray muons (a 40-fold reduction of cosmic muons)

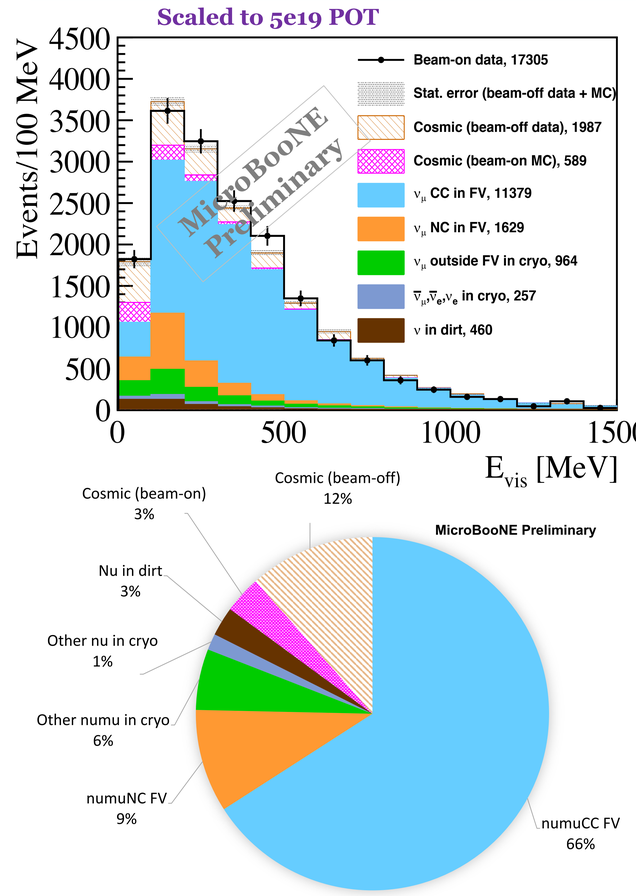


- The most powerful tool is 3D trajectory & dQ/dx fitting
- Bragg peak for stopped muon (incoming particle) removal
- Foundation of subsequent Wire-Cell pattern recognition and particle identification (see below)



- A high-performance selection of neutrino interactions
- A high-quality 3D image: the select neutrino activity is largely intact and clean.

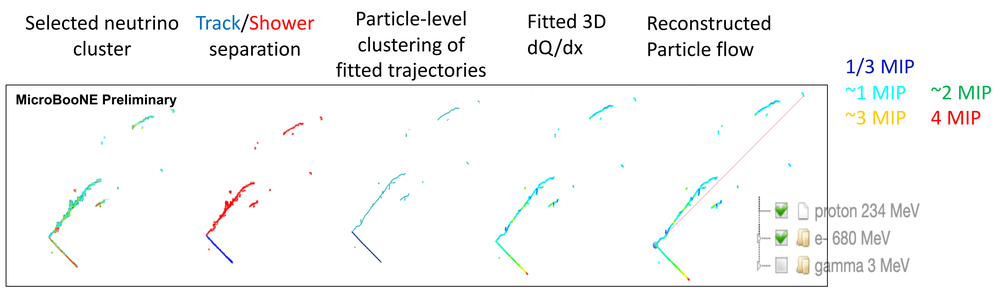
Selection Results



- 14.9% (9.7%) cosmic contamination for visible energy >0 (200) MeV
- 80.4% (88.4%) selection efficiency of charged current ν_μ for visible energy >0 (200) MeV (fiducial volume: 94.2% of TPC active)

Ongoing effort and future plan

- 3D pattern recognition on the largely intact 3D image of neutrino activity.
- Specific neutrino selection, e.g. ν_μ CC and ν_e CC, based on the foundational Wire-Cell event reconstruction.



References

[1] "Neutrino event selection in the MicroBooNE liquid argon time projection chamber using Wire-Cell 3D Imaging, clustering and Charge-light matching", MicroBooNE collaboration, MIcroBoone public note 1083
[2] "Cosmic ray background rejection with Wire-Cell LArTPC event reconstruction in MicroBooNE", MicroBooNE collaboration, MicroBooNE public note 1084
[3] "Wire-Cell pi0 clustering and matching", MicroBooNE public note 1089
[4] More technical details can be found in Neutrino 2020 posters from Xiangpan Ji, Kaicheng Li, and London Cooper-Troendle.