Towards Automated Neutrino Selection at MicroBooNE using Tomographic Event Reconstruction

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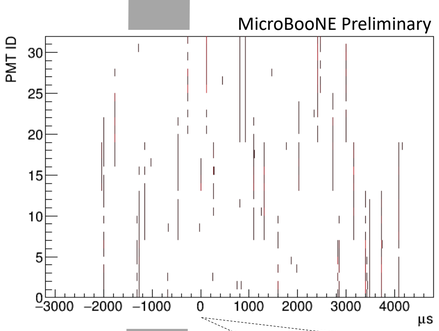
MicroBooNE is a single-phase liquid argon time projection chamber (LArTPC) operating on the surface in the Booster neutrino beam at Fermilab. LArTPC event reconstruction using *tomographic imaging* vastly simplifies downstream reconstruction and neutrino selection. Described are methods and novel techniques to capitalize off of reconstructed 3D charge, which is faithfully consistent with each 2D projective measurement.

Here we describe a ***semi-automated ν_μCC selection*** using tomographic event reconstruction and evaluate the efficacy of newly developed tools.

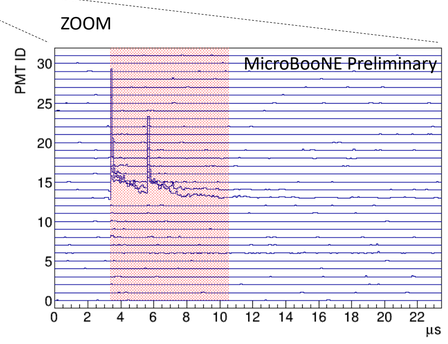
Step 1: Light signal reconstruction

Reconstruct ***flashes*** – time coincident light signals among multiple photomultiplier tubes



Each flash corresponds to particles traversing the LAr detector at a different time.

Tens of flashes are reconstructed for each event spanning 6.4 milliseconds.



Step 2: "PMT Filter"

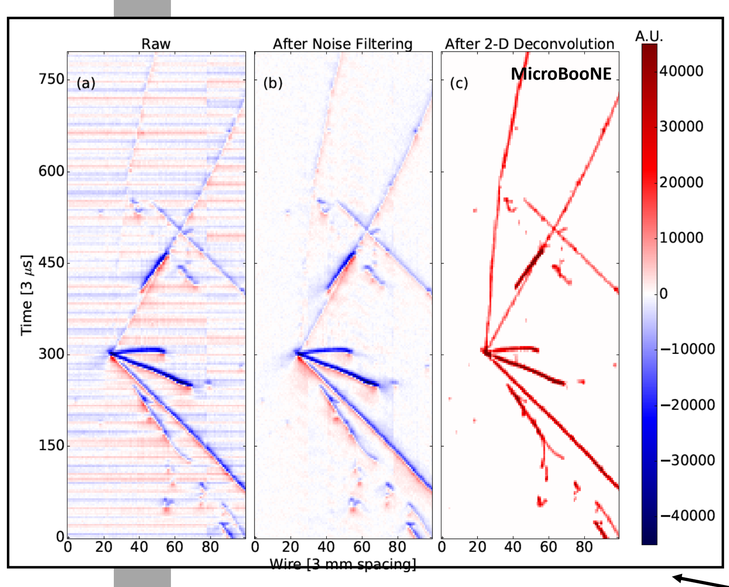
Remove events for which there is no reconstructed flash within the beam activity window spanning 1.6 microseconds

Steps 3: TPC noise filtering [1]

Removal of excess noise from the anode sense wire waveform

Step 4: TPC signal processing [2,3]

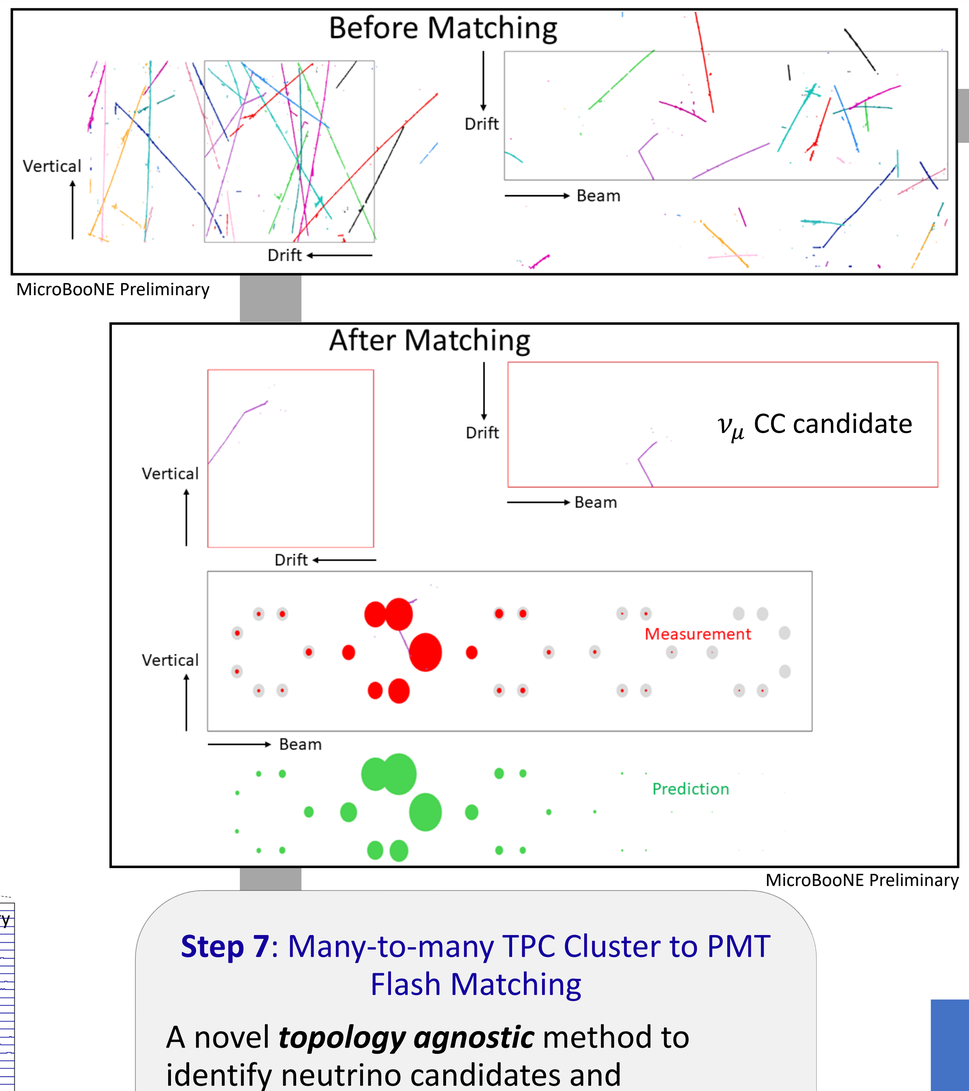
Robust recovery of the number of ionization electrons from both induction and collection wire planes



Step 5 Tomographic imaging

Step 6: Clustering 3D charge to form TPC objects

For more details on ***imaging*** and ***clustering*** see poster "Recent Progress on Wire-Cell Tomographic Event Reconstruction for LArTPCs" by Dr. Hanyu Wei.



Step 7: Many-to-many TPC Cluster to PMT Flash Matching

A novel ***topology agnostic*** method to identify neutrino candidates and ***disambiguate*** neutrino candidate activity from cosmic activity by pairing the O(10) clusters to the O(10) flashes in an event

- Simplifies cosmic ray background rejection
- Enables high performance neutrino selection

Matching procedure:

Step 7A: Hypothesis on matched flash-cluster pair

Step 7B: Iterative examination of matches

Step 7C: Iterative chi-square fits using L1 compressed sensing technique

$$\chi^2 = \sum_i \sum_j \chi^2_{ij} + \chi^2_{p1} + \chi^2_{p2} + \chi^2_{p3}$$

(Terms in green are removed in second iterative fit)

$$\chi^2_{ij} = \frac{(M_{ij} - \sum_k a_{ik} \cdot P_{ikj})^2 - b_{ij} \cdot M_{ij}}{\delta M^2_{ij}}$$

$$\chi^2_{p1} = \frac{(\sum_k a_{ik} - 1)^2}{{c_1}^2}$$

Each cluster can be associated to at most one flash

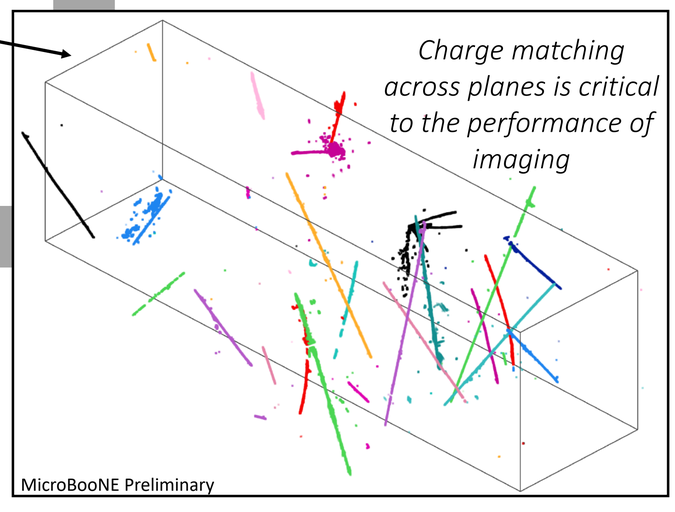
$$\chi^2_{p2} = \frac{b^2_{ij}}{{c_2}^2}$$

A flash is not necessarily associated with visible TPC activity

$$\chi^2_{p3} = \lambda \cdot \sum_i \sum_k |a_{ik}|$$

ℓ_1-regularization

M_{ij} are the measured photoelectrons in flash *I* for PMT *j*
P_{ikj} are the predicted photoelectrons from TPC cluster *k* on PMT *j* for flash *i*
a_{ik} are the unknowns to be solved for in the fit
b_{ij} coefficient for flash I for PMT j to be associated to visible TPC activity
c_1, c_2 empirical constants



Step 8: Hand scan

Classification of ***singular TPC objects***

- first 3D hand scan tool
- web-based for accessibility
- one key to automatically remove cosmics

TPC boundary – topology examined to infer if it pierced any face of the TPC active volume (black & red rectangles), taking into account the space charge effect which distorts the boundary

Light – check qualitative agreement between predicted (green circles) and measured (red circles) on PMT photoelectron map

Muon track – one or more tracks with one categorized as a muon are expected for ν_μCC

Directionality – if partially contained in the TPC, check for delta rays and evidence of multiple Coulomb scattering

Results

Semi-Automated Selection MicroBooNE Preliminary

	ν_μCC	Light Mismatch	Through going μ	Stopping μ	Other	Total
Beam off	0	187	415	95	40	737
Beam on	113	356	560	171	54	1254

- *The overall passing rate (ratio of selected ν_μCC candidates over initial software triggers) is **2.85%***
- *14 out of 113 ν_μCC candidates were determined to be backgrounds by a second round examination using calorimetry, likely "dirt" or ν NC interactions*

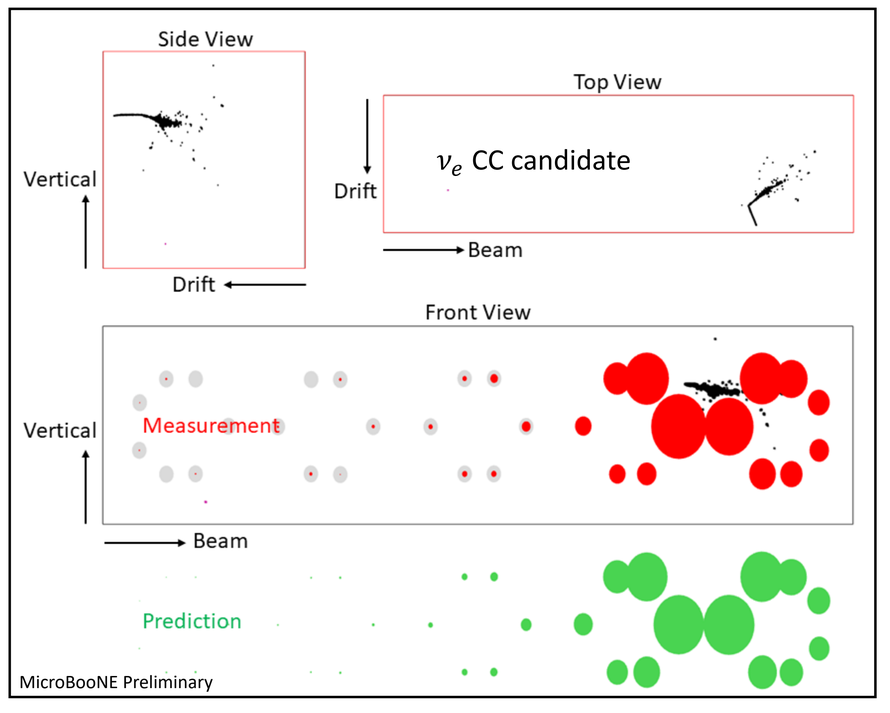
Cosmic Rejection Power MicroBooNE Preliminary

Procedure	Absolute (Relative)
Hardware Trigger	1
Software Trigger	0.041
PMT Filter	9.6×10^{-3} (0.238)
Many-to-Many Matching	3.7×10^{-4} (0.038)
Hand Scan	$<3.7\times10^{-6}$ (<0.01)

Cosmic contamination is significantly reduced by many-to-many matching

Conclusions

- With clean cosmic rejection, we show a step towards high performance neutrino selection for a surface single-phase LArTPC
- Automated tools are being developed to mitigate identified backgrounds for ν_μCC
- We're also pivoting to fully-automated selection of ν_eCC for ν_e appearance search



References: [1] JINST 12 P08003 (2017) [2] arXiv:1802.08709 [3] arXiv:1804.02583 [4] arXiv:1803.04850

Supporting documentation: MICROBOONE-NOTE-1040-PUB http://microboone.fnal.gov/public-notes/

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