Electron-neutrino reconstruction and selection in the μBooNE LArTPC using the Pandora pattern recognition

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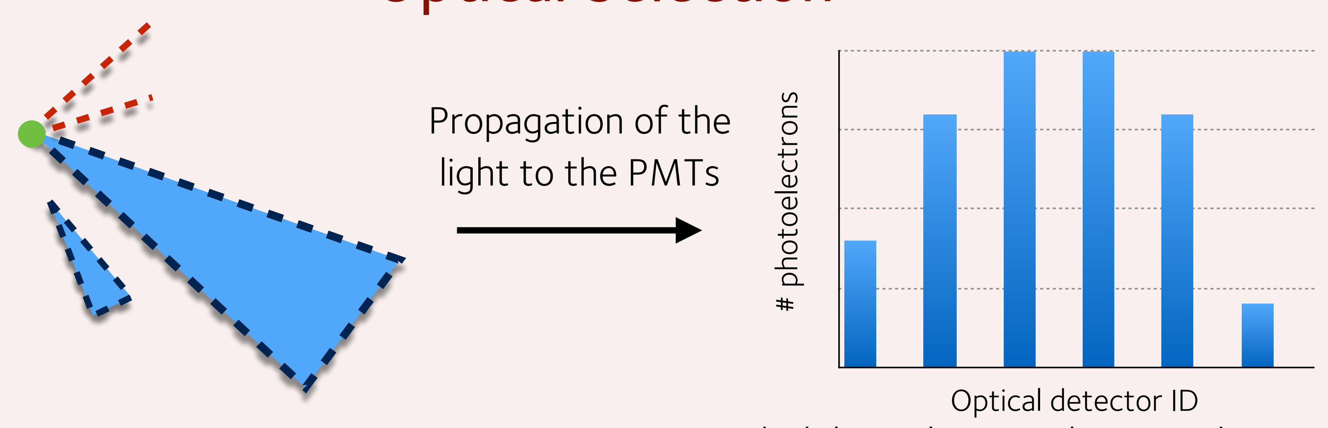
MICROBOONE (the Micro Booster Neutrino Experiment) is a liquid argon time-projection chamber experiment designed for short-baseline neutrino physics [1], currently running at Fermilab. It aims to address the anomalous excess of low-energy events observed by the previous MiniBooNE experiment [2]. **In this poster we present a fully automated event selection algorithm that can identify charged-current electron neutrino event candidates with no pions and at least one proton in the final state (ν_e CC0π-Np events).** We also show some cuts on kinematic and geometric variables which reject background events. These cuts have been validated by analyzing two event samples orthogonal to our signal. The data shown here is an unblinded subsample collected by the detector between February and April 2016. It corresponds to an exposure of 4.4 × 10^{19} POT.

EVENT SELECTION

Optical Selection

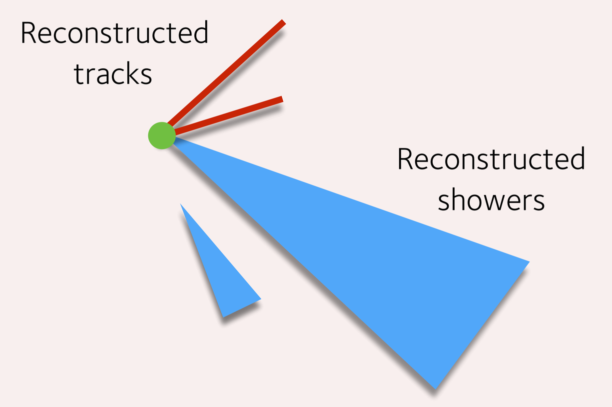


Deposited charge in the TPC

Flash hypothesis in the optical systems (schematic)

- The spatial distribution of the deposited charge is translated into an estimation of the emitted scintillation light. These scintillation photons are then propagated towards the PMTs to construct a flash hypothesis using only time projection chamber information.
- A flash-matching algorithm compares the reconstructed flash object as seen by the PMTs with the hypothetical flash for all possible neutrino candidates and picks the best matching candidate [3].

Topology Requirement

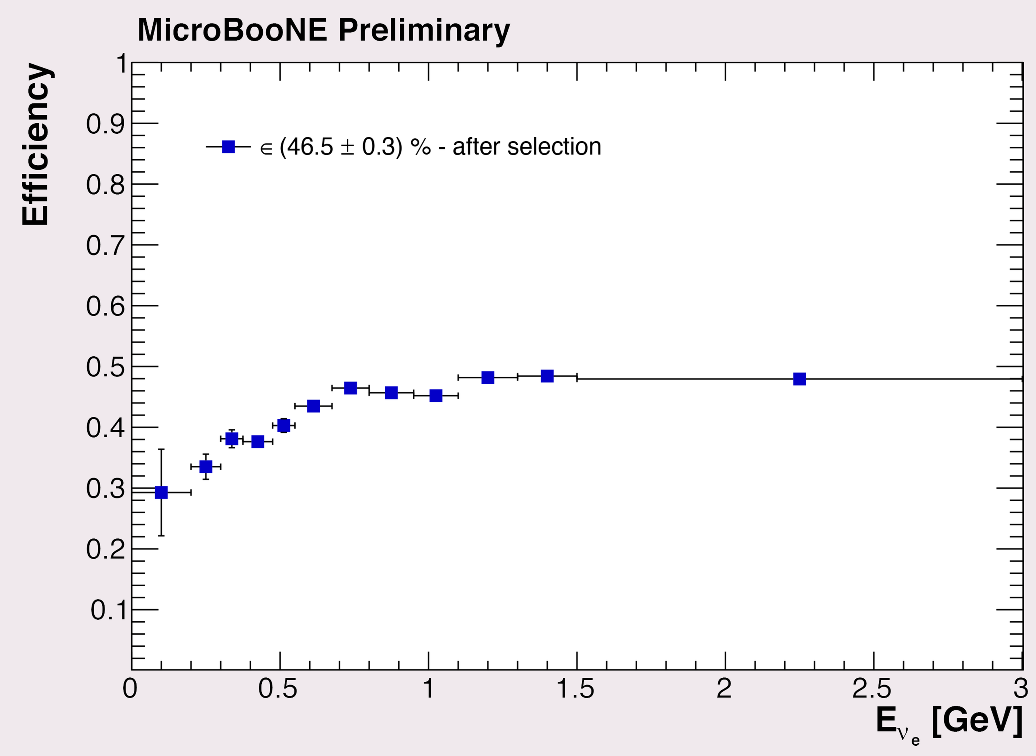


Reconstructed objects in the TPC

- Select events with particle topologies consistent with 1+ proton(s) and 1 electron in the final state (ν_e CC0π-Np event).
- The objects reconstruction is performed by the Pandora multi-algorithm pattern recognition software [4]. Each object is classified as track-like or shower-like.

SELECTION EFFICIENCY

$$\epsilon = \frac{\text{N. of selected } \nu_e \text{ CC}0\pi\text{-Np events}}{\text{N. of generated } \nu_e \text{ CC}0\pi\text{-Np events}}$$

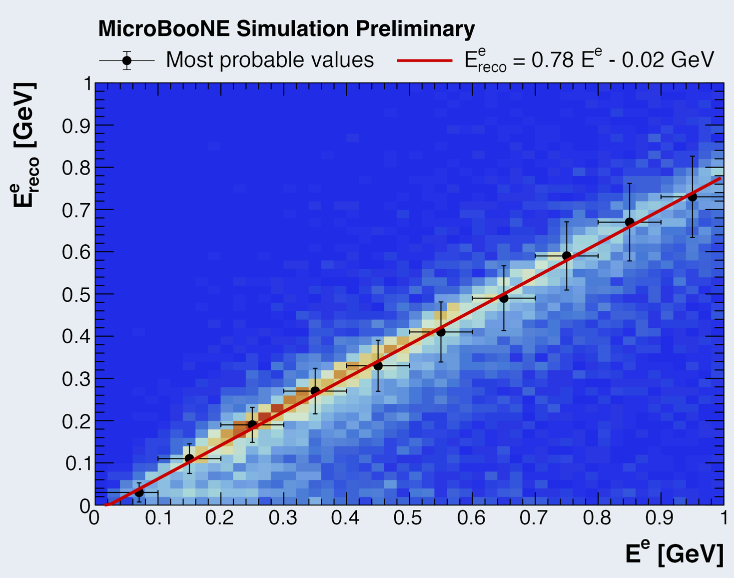


The selection efficiency of the algorithm is obtained by calculating the fraction of events selected in a Monte Carlo sample. The true neutrino vertex must lie within a fiducial volume.

ENERGY RECONSTRUCTION

Electron energy

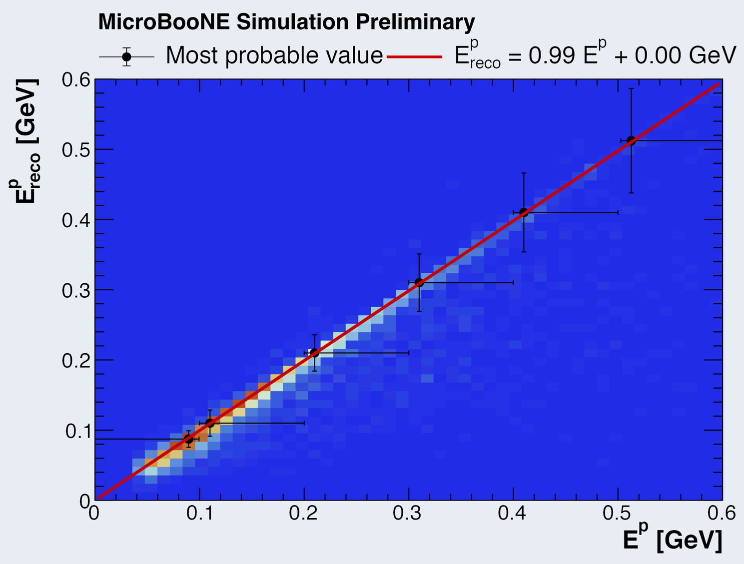
The calibration slope is measured using a Monte Carlo simulation. We compare the reconstructed energy, obtained converting the collected charge into deposited energy [5], with the true electron energy.



Proton energy

The calibration slope is measured using a Monte Carlo simulation. We convert the track length into energy using the stopping power in liquid argon.

The reconstructed energy is compared with the true proton energy.



Total deposited energy

The total deposited energy $E_{deposited}$ is defined as the sum of the reconstructed track energy, corrected by the proton calibration slope, and the reconstructed electron energy, corrected by the electron calibration slope:

$$E_{deposited} = \sum^{N_p} E^p_{deposited} + \sum^{N_e} E^e_{deposited},$$

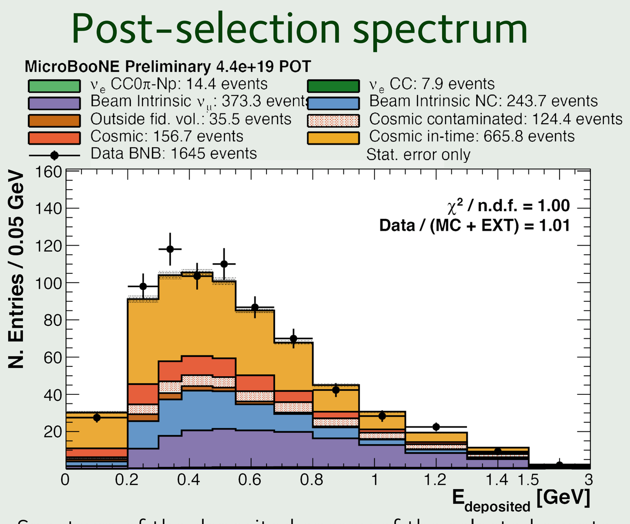
where N_p is the number of reconstructed tracks and N_e is the number of reconstructed showers.

POST-SELECTION CUTS

Several kinematic and calorimetric variables can be used to select the ν_e CC0π-Np events.

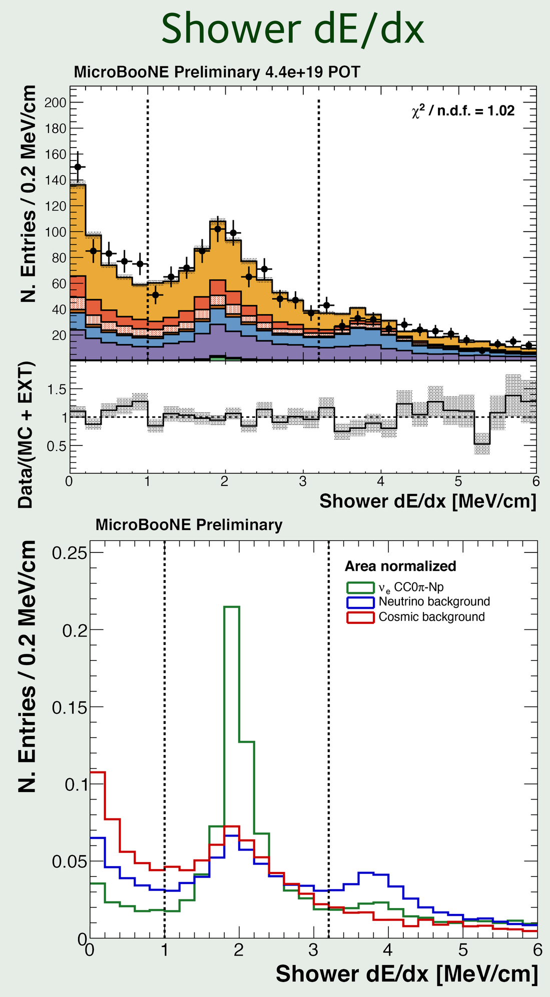
The cuts can be used to reduce both the neutrino and the cosmogenic background, and ensure that the selected events are well reconstructed.

Post-selection spectrum



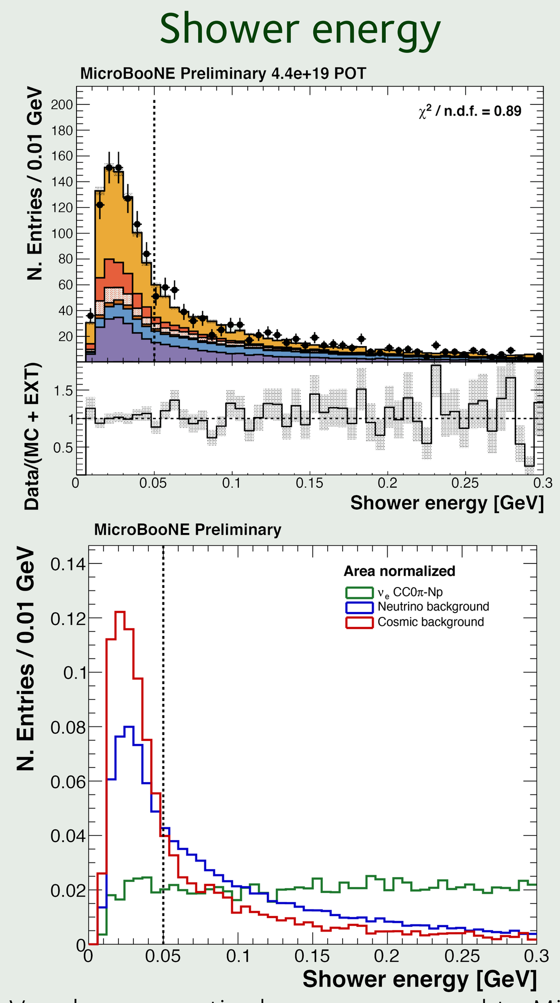
Spectrum of the deposited energy of the selected events.

Shower dE/dx



Electron showers can be selected with a cut on the dE/dx.

Shower energy



Very low-energetic showers correspond to Michel electrons from stopping muons.

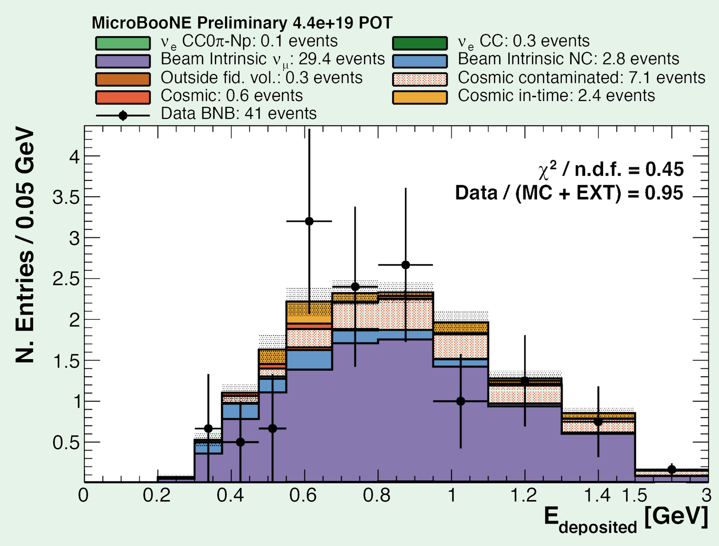
SIDEBANDS DISTRIBUTIONS

Some cuts useful to select ν_e CC0π-Np events can be inverted or modified to explore orthogonal regions of the phase-space.

ν_μ-enhanced spectrum

Here, we restrict ourselves to the events selected by an independent CC ν_μ analysis. We also require at least a reconstructed track longer than 20 cm and we relaxed the requirement on the proton identification score.

We obtain a sample with 69% ν_μ purity.

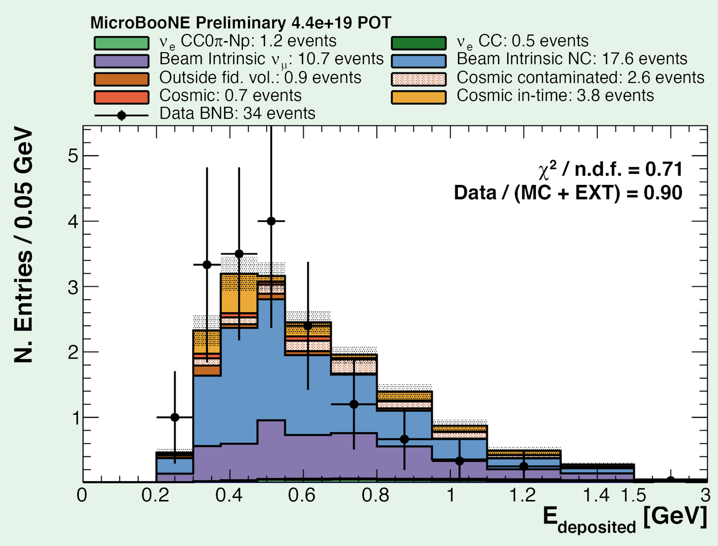


Reconstructed deposited energy of a ν_μ-enhanced sample.

NC-enhanced spectrum

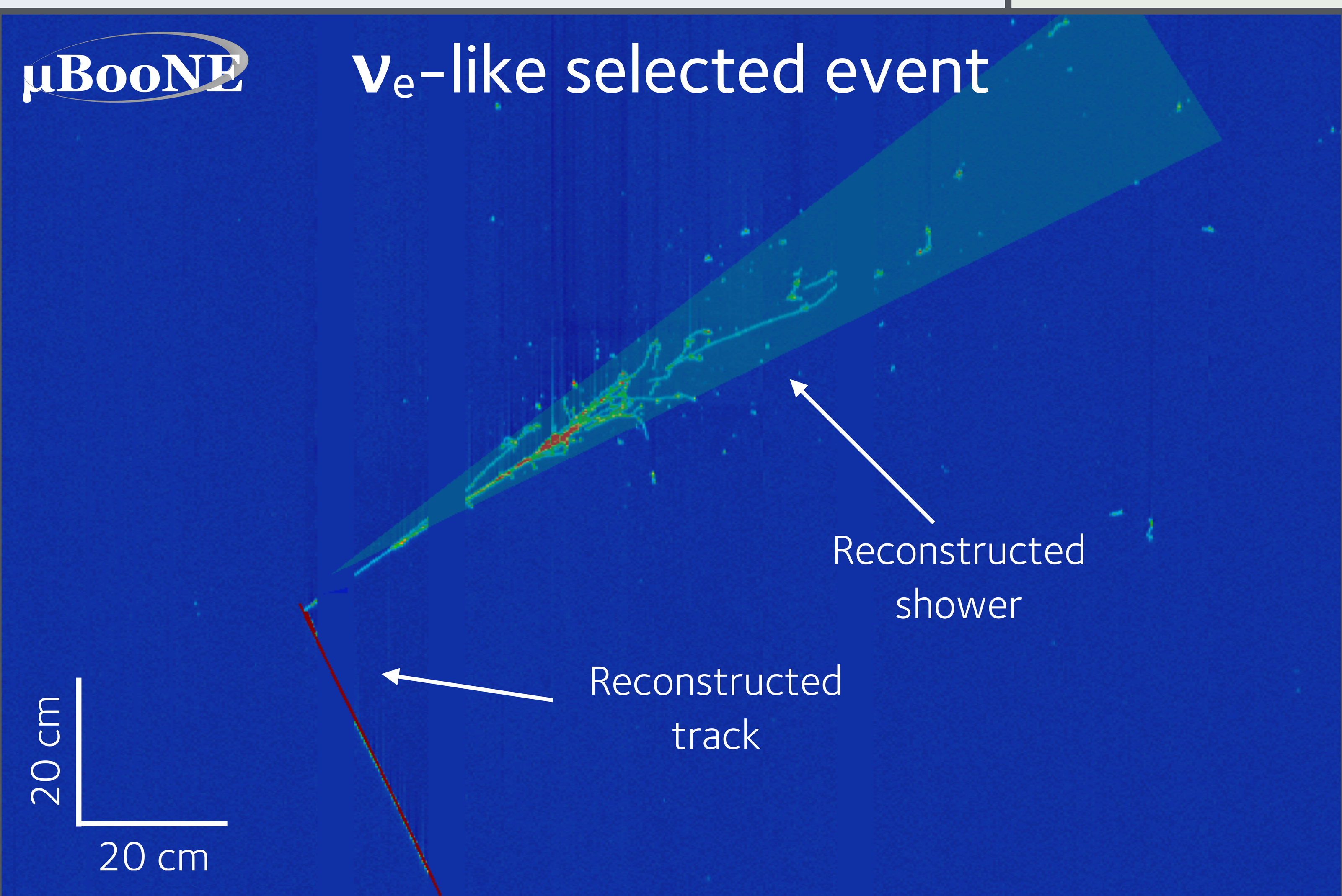
In order to isolate NC events, we require the leading shower to have its dE/dx between 3.2 MeV/cm and 5 MeV/cm. We do not have any requirement on the distance between the leading shower and reconstructed neutrino vertex.

We obtain a sample with 47% NC purity.

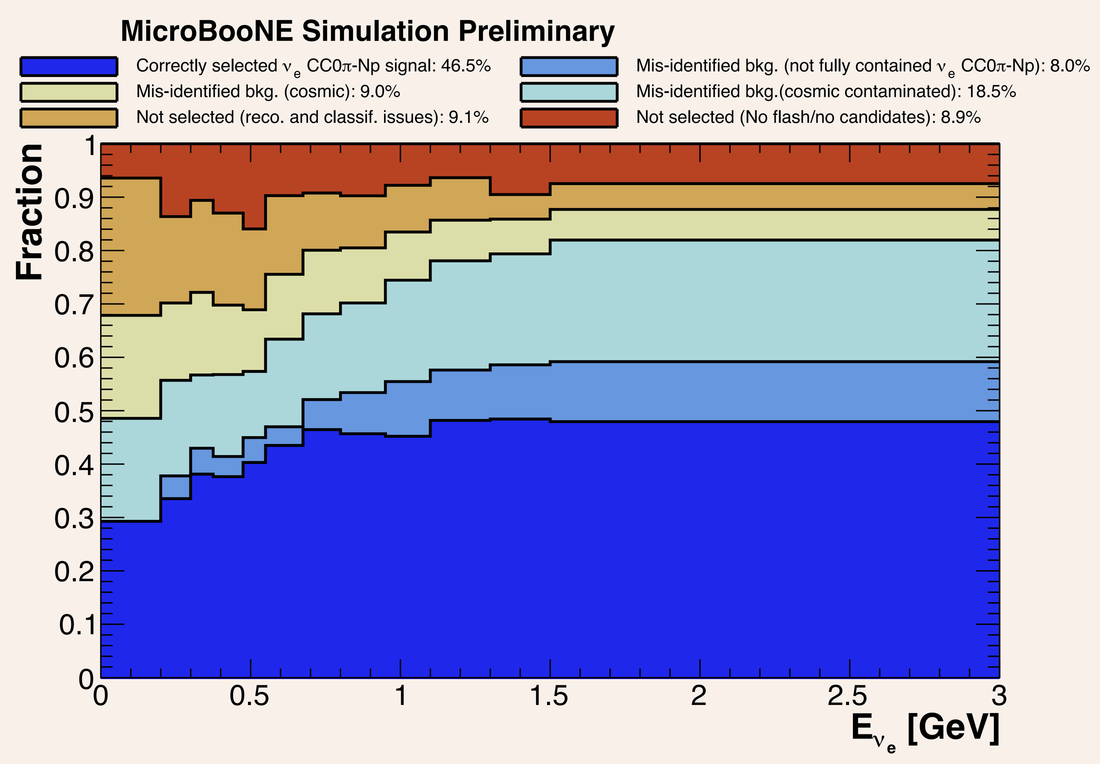


Reconstructed deposited energy of a NC-enhanced sample.

ν_e-like selected event



FUTURE IMPROVEMENTS



Stacked histogram of generated events as a function of the true neutrino energy, categorized into correctly identified signal events and different reconstruction or classification failure modes.

- **Improve Efficiency**: Improvements in the pattern recognition and classification software will allow to recover the events where the topology requirement was not met (9.1% of the total) or in which we did not have any reconstructed neutrino candidate (8.9%).
- **Improve Purity**: The Cosmic-ray Tagger (CRT) [6] will improve cosmic event rejection. This is very important, especially at low energies, where the largest component of events is represented by cosmic interactions wrongly selected as neutrino candidate (9.0%) or with a neutrino candidate contaminated by cosmic activity (18.5%).
- **Lower Energy Threshold**: A new set of cosmic-ray rejection algorithms has been developed and will be implemented in the near future, increasing the capability, especially in the low-energy region.

[1] MicroBooNE Collaboration, JINST 12, no. 02, P02017 (2017)
[2] MiniBooNE Collaboration, Phys.Rev.Lett. 102, 101802 (2009)
[3] W. Van De Pontseele, arXiv:1805.04629
[4] MicroBooNE Collaboration, Eur.Phys.J. C78 no.1, 82
[5] MicroBooNE Collaboration, JINST 12, no. 09, P09014
[6] M. Auger et al., Instruments 1 (2017) no.1, 2

NEUTRINO 2018 Heidelberg 4–9 June