Hunting Muon Neutrinos in MicroBooNE with Deep Learning Techniques

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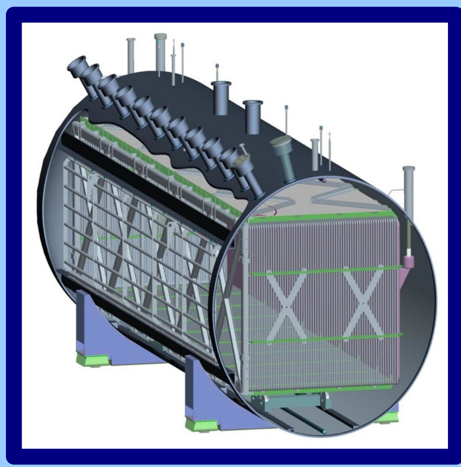
Introduction to MicroBooNE

- Liquid Argon TPC (LArTPC) at Fermi National Lab
  - 85 ton LAr active mass
  - 470 m baseline
  - 3 wire planes
- Major goals
  - investigate MiniBooNE low energy excess in ν_e apperance
  - Measure ν-Ar cross sections
  - R&D for future LArTPC technology (SBN program and DUNE)



The MiniBooNE Excess

- MiniBooNE is an oil Cherenkov detector situated on the same beam at similar baseline
- Observed a 3σ excess in ν_e appearance
- MiniBooNE had limited ability to distinguish e/γ
- MicroBooNE has sufficient spatial resolution to observe the first cm near a vertex, providing superior e/γ separation

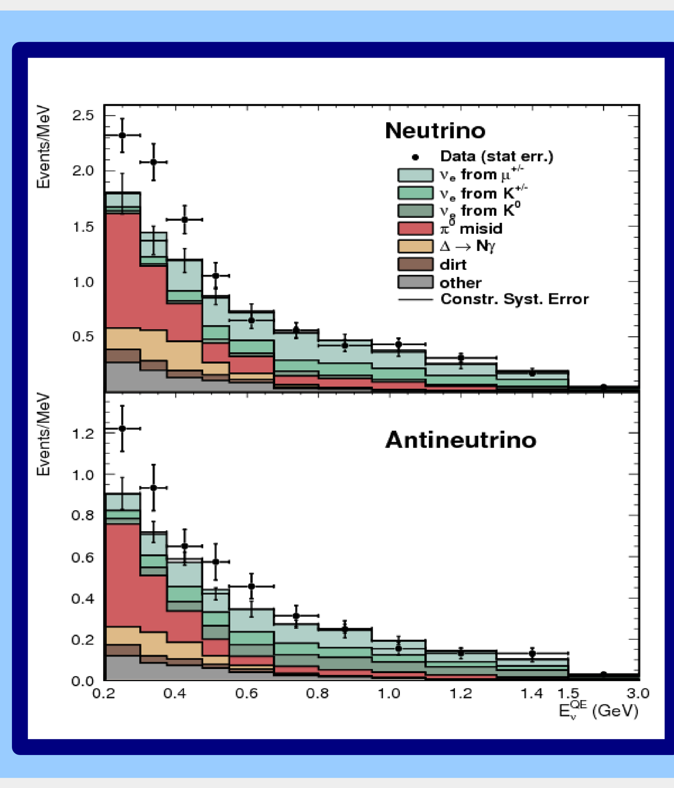


Image Analysis With Deep Learning

- Physics is embedded in the details of the wire readout, essentially images with pixels as fine as our wires are spaced
- We use two types of neural networks to extract information from images

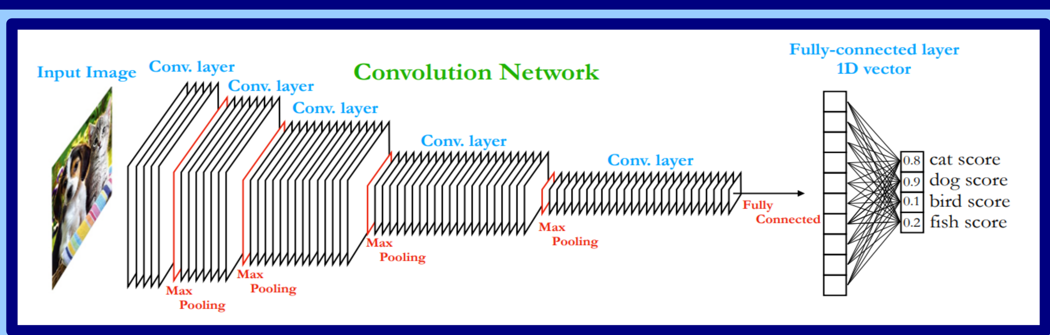
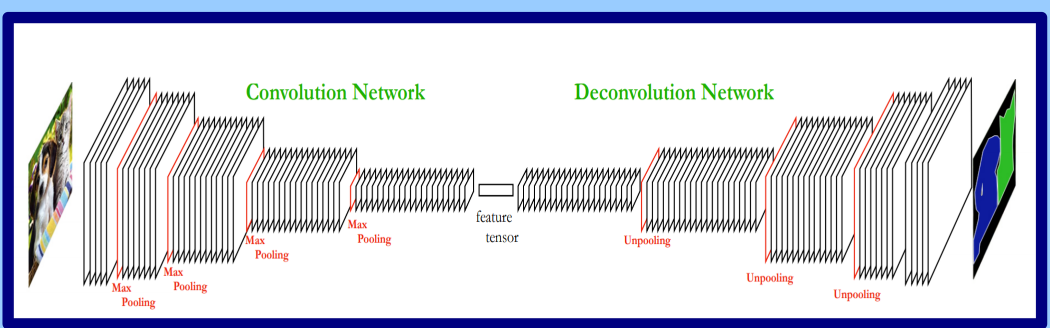
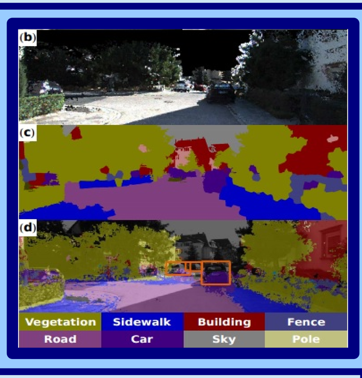


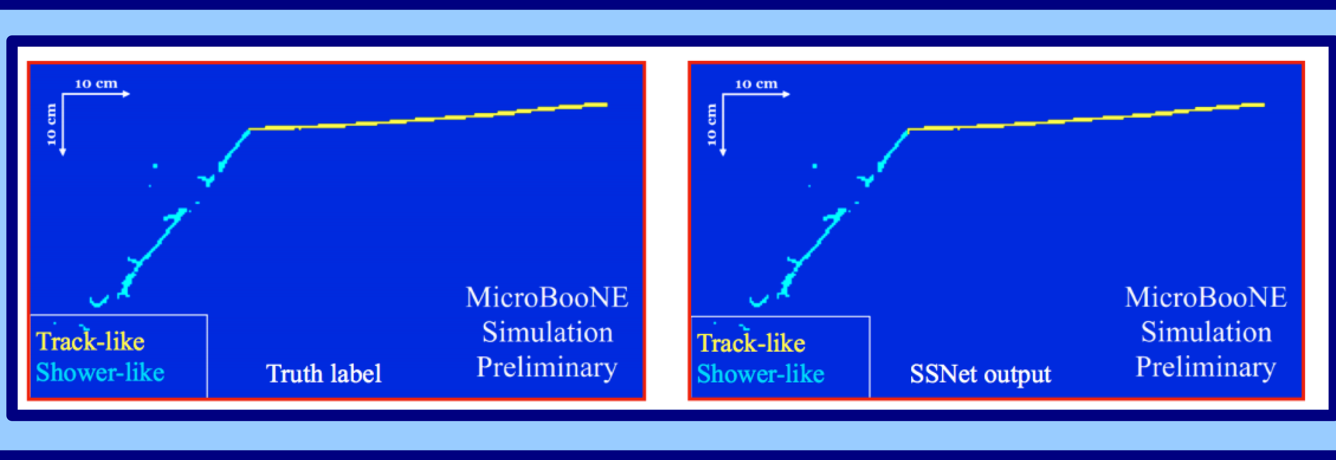
Image labeling networks return a score corresponding to how likely the network thinks it is that the image contains that object.





A semantic segmentation network (SSNet) associates each pixel with a particular label. i.e. a labeling network tells you the score for "dog" in this image. An SSNet will label which pixels it thinks are dogs

We use semantic segmentation to separate shower like pixels and track like pixels. Below we show a 1 electron 1 muon event with true labeling vs SSNet

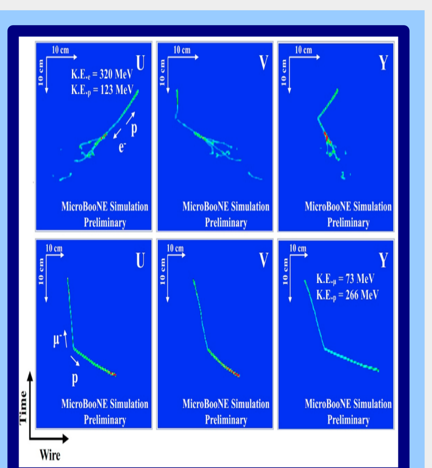


- A multi particle ID network is being developed.
- This is a labeling network that returns a score for a proton, muon, electron, gamma, or pion existing in a given image.

Our Signal : 1 Lepton + 1 Proton Events

Signal Definition:
- 1 lepton with KE >35 MeV
- 1 proton with KE >60 MeV
- Particles remain contained

Motivation:
- V shape makes cosmic rejection easier
- Energy requirements ensure tracks are long enough to be reconstructable
- Topology helps distinguish CCQE from other CC modes which are more difficult to reconstruct



Simulated 1e1p (top) and simulated 1μ1p event. Shown on all 3 wire planes

Analysis Chain

- We have developed a fully automated analysis to selection and reconstruction
- Makes use of a hybrid of CNN and traditional algorithms

PMT PreCuts	Optical cuts to remove only cosmic activity
Cosmic Tagging / ROI Finding	Tags likely cosmic activity and identifies a search region for the nu
SSNet: Track / Shower Labels	SSNet labels each pixel as track or shower
Candidate Vertex Finding	Vertices are found from topological & SSNet info
3D Reconstruction	Vertices and tracks are 3D reconstructed (see Wed Session Poster #73 for more details)
Select 1μ1p / Select 1e1p	A set of cuts and a log likelihood is used to select 1μ1p events from the candidate vertices.

Selection of 1μ1p Vertices

- Significant number of candidate vertices are spurious cosmic vertices, or vertices from non-signal neutrino interactions
- Use the topology and kinematics of 1μ1p events to select events

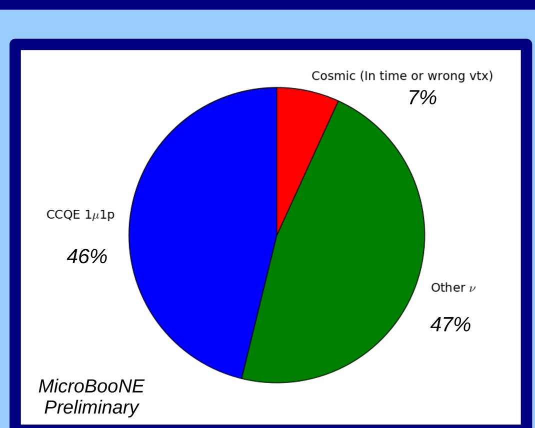
We require:

1) Exactly two reconstructed 3D tracks
2) Vertex must be inside a 10 cm fiducial volume
3) Vertex must pass two likelihoods - one comparing signal to cosmic, one comparing signal to non-signal neutrinos. These are built from the following variables

- Ionization difference between tracks (called η)
- 3D Opening angle between tracks
- How close to exiting is the event
- Angular profile relative to drift direction (φ)
- Angular profile relative to beam direction (θ)

These form our selected and reconstructed 1μ1p sample

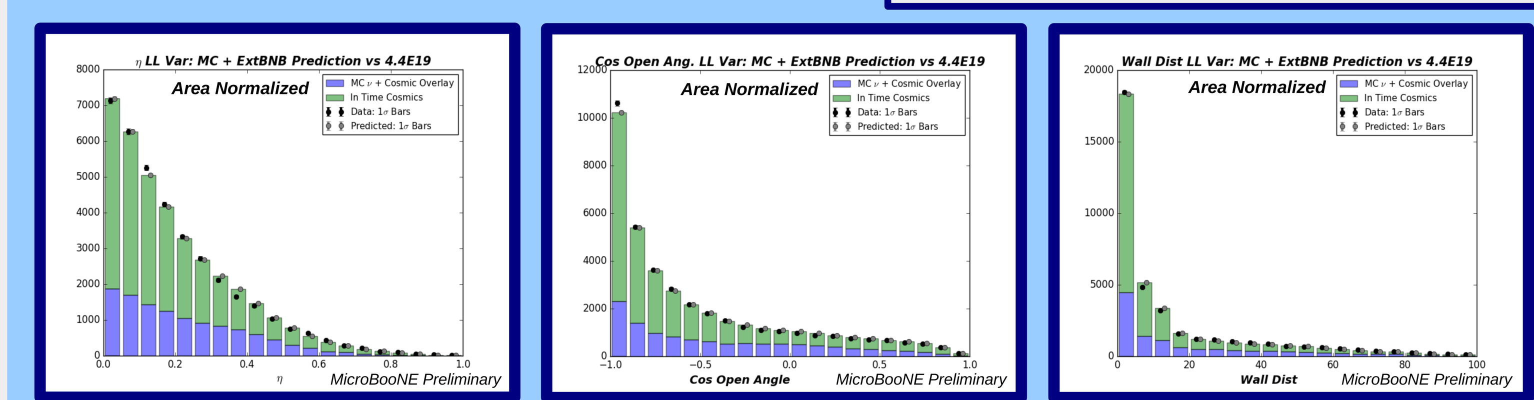
Our residual background is dominated by neutrinos, >99.9% cosmic elimination

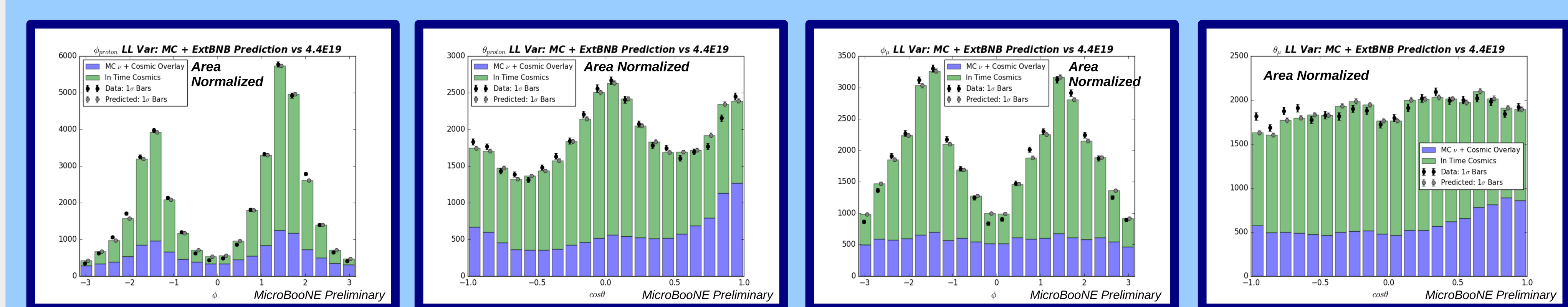


Efficiency = 18%
Purity = ~47%

Data-MC Comparisons

Comparisons of the 7 variables used to build the likelihood for selecting 1μ1p events .





Post Selection

Comparing the reconstructed vertex position

Reconstructed Candidate Proton Length