Clustering Cosmic Muon and Neutrino Interactions in MicroBooNE using Mask-RCNN

Joshua Mills and Felix Yu, Representing the MicroBooNE Collaboration

Background (1)

The Liquid Argon Time Projection Chamber in MicroBooNE is subjected to a multitude of cosmic rays. An average event has O(20) cosmic muons within it.

To remove this cosmic background from our data we train a Deep Convolutional Neural Network, Mask-RCNN, to find, label, and cluster both cosmic and neutrino interactions. [2]

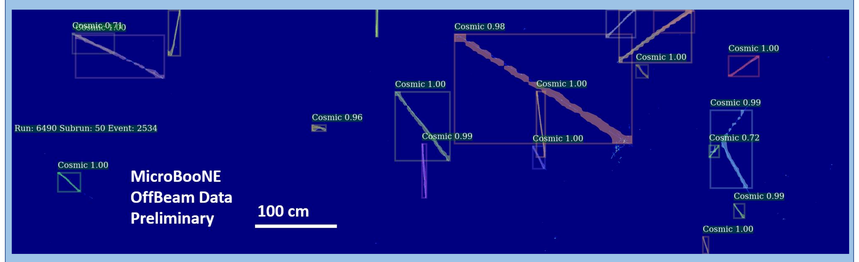

Fig. 1 Mask-RCNN's outputs shown on data taken while the neutrino beam is off. Therefore everything in the event is a cosmic muon.

The Network: Mask-RCNN (2)

Mask-RCNN [3] has three tasks performed by subnetworks:

1. Region Proposal Network: Propose a list of Bounding Boxes around Interaction
2. Classifier: Classify the Interaction as either Cosmic or Neutrino
3. Maskifier: Cluster Charge within the Interaction with a 'Mask'. This is a Fully Convolutional Network (FCN)

These subnetworks rely on features built using a Residual Neural Network (ResNet)

Boxes Proposed (RPN) Boxes Classified Masks (Clustering FCN)

Leaf, Dog Face, Background

Fig. 2 A visual example of Mask-RCNN's outputs

Sparse Convolutions (3)

We modify the original Mask-RCNN's ResNet to use Sparse Convolutions [3]. This allows us to be deployable on CPU clusters such as the FermiGrid.

- Convolutions only occur centered on nonzero pixels, cannot output features where zero pixels are located.
- Reduction of ResNet processing time by 95%
- Reduction of ResNet memory consumption

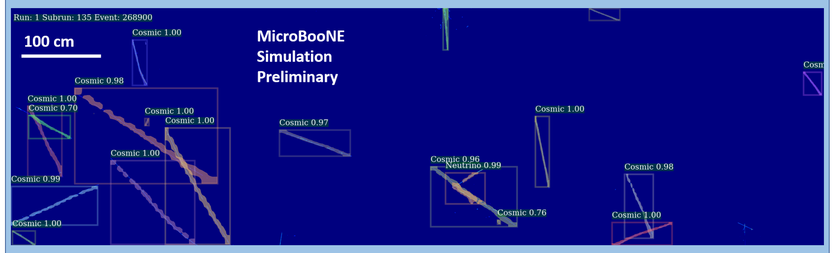

Fig. 3 Mask-RCNN's outputs shown on a simulated electron neutrino event are shown.

Efficiency and Purity (4)

Event Averaged Efficiencies and Purities of interactions:

- Efficiency at pixel level clustering of simulated interactions
- Purity of mapping a proposed cluster to only one simulated interaction

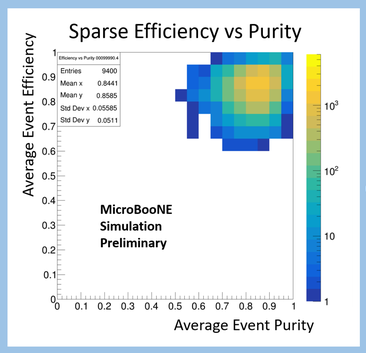

Fig. 4 Event Averaged Efficiency and Purity

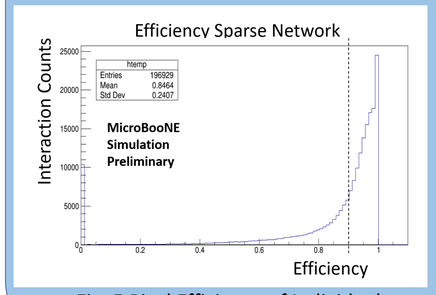

Fig. 5 Pixel Efficiency of Individual simulated interactions

Interaction level Efficiencies

- Strong peak at 1,, indicated completely clustered interaction
- The peak at exactly 0 features interactions simulated in dead regions, impossible to find.

Interaction Coverage (5)

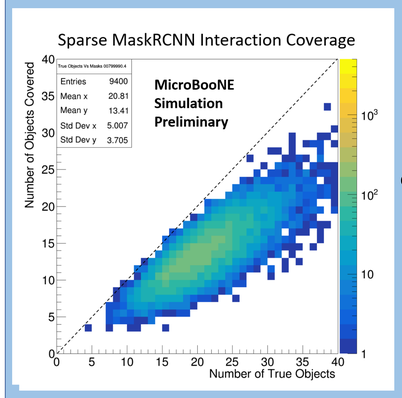

Fig 6. Interactions Covered vs Interactions Simulated

- Covers 65% of interactions

- Events very rarely have less than half of interactions 'covered'

Covered = Pixel level clustering efficiency > 90%

- This is a strict standard, given the tail of our efficiency
- The average event has 20.81 simulated interactions, 13.41 covered

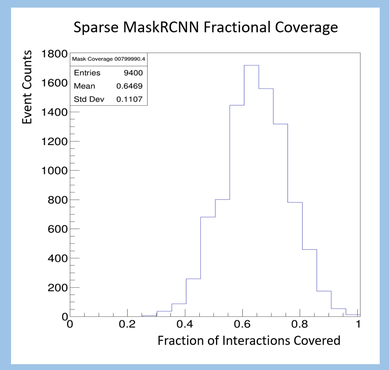

Fig. 7 Fraction of Interactions Covered

Neutrino Finding (6)

The interaction level efficiency for just neutrinos.

- Network not sacrificing ability to cluster neutrinos
- Peak not quite at 1, network often misses clustering shower fringes

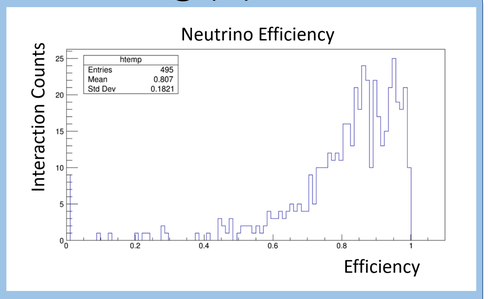

Fig. 8 Neutrino Only Efficiency

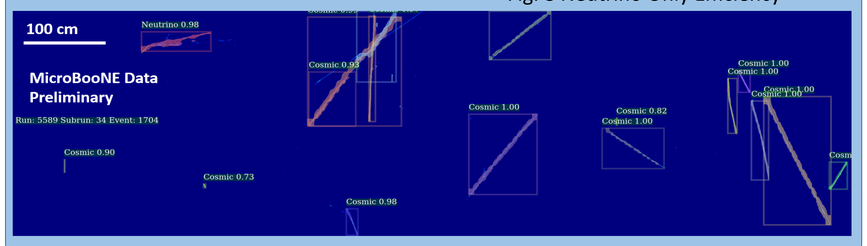

Fig. 9 A data event. The network successfully labels the neutrino interaction in the top left.

References and Acknowledgements

[1] Design and construction of the MicroBooNE detector, [2] 3 MICROBOONE-NOTE-1081-PUB , [3] *Mask-RCNN*,

This work is supported by the United States Department of Energy under Grant No. DE-SC0007866.