Clustering Interactions in MicroBooNE using Mask-RCNN

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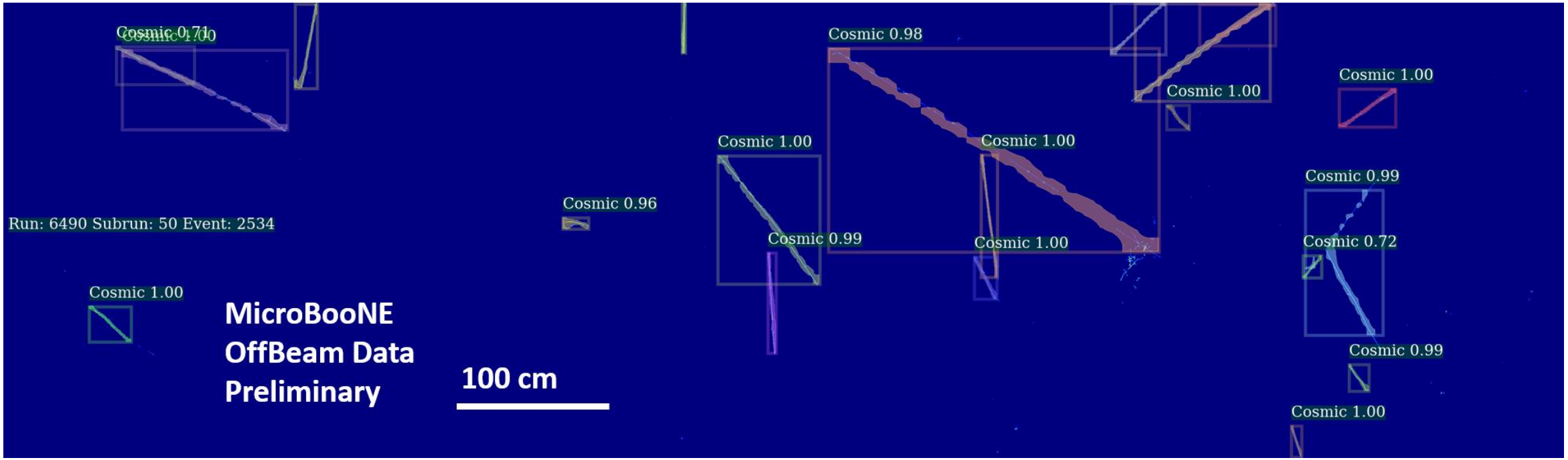
NPML Lightning Talks

June 19th 2020

Cosmic Muon Background

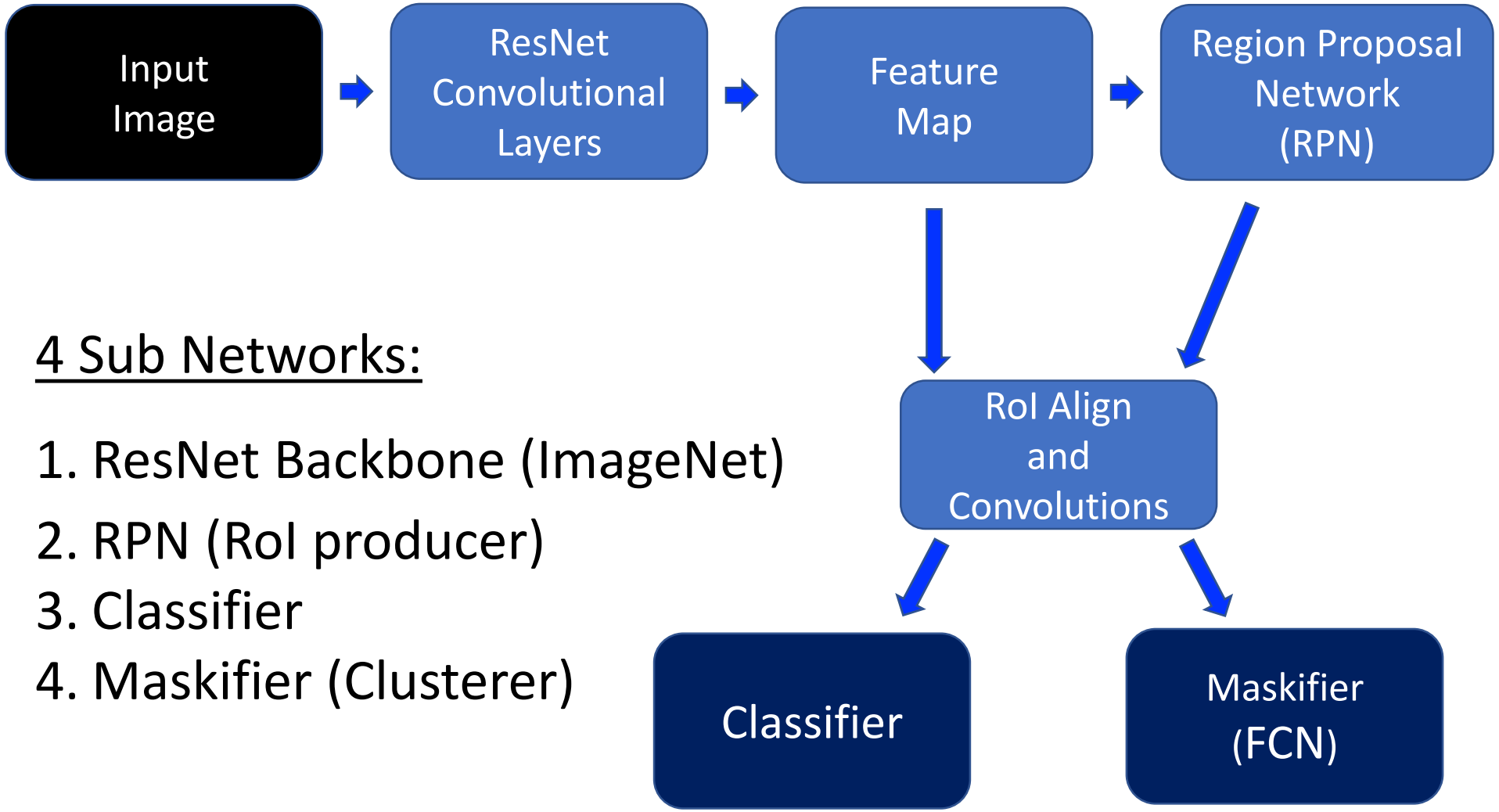
MicroBooNE is a surface level experiment.

Cosmic Ray Muons are a significant background to neutrino interactions.



MicroBooNE data event taken while beam is off, all interactions are therefore cosmics.

Mask R-CNN Structure

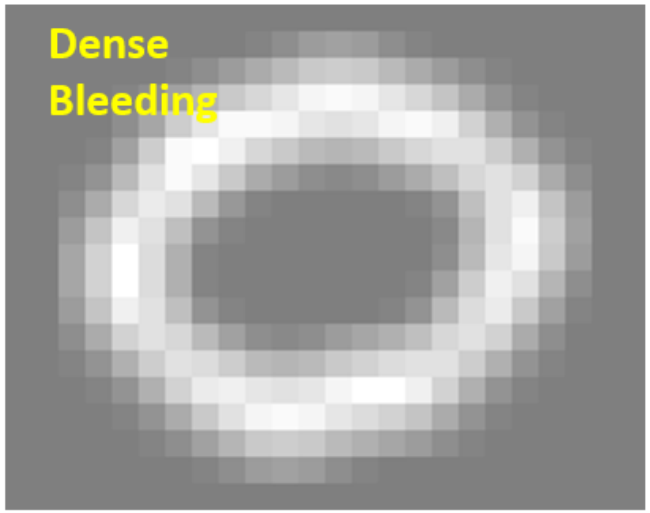


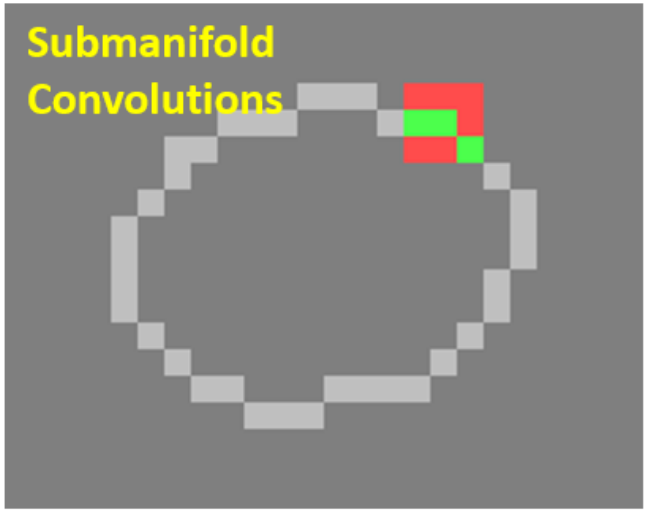
4 Sub Networks:

1. ResNet Backbone (ImageNet)
2. RPN (RoI producer)
3. Classifier
4. Maskifier (Clusterer)

Sparse ResNet, For Speed and Memory

- Replace ResNet Convolutions with Submanifold Convolutions
- Only output features where input is nonzero at center of kernel
- Information won't spread out across empty pixels as you gain depth
- 95% drop in ResNet forward pass time on CPU.

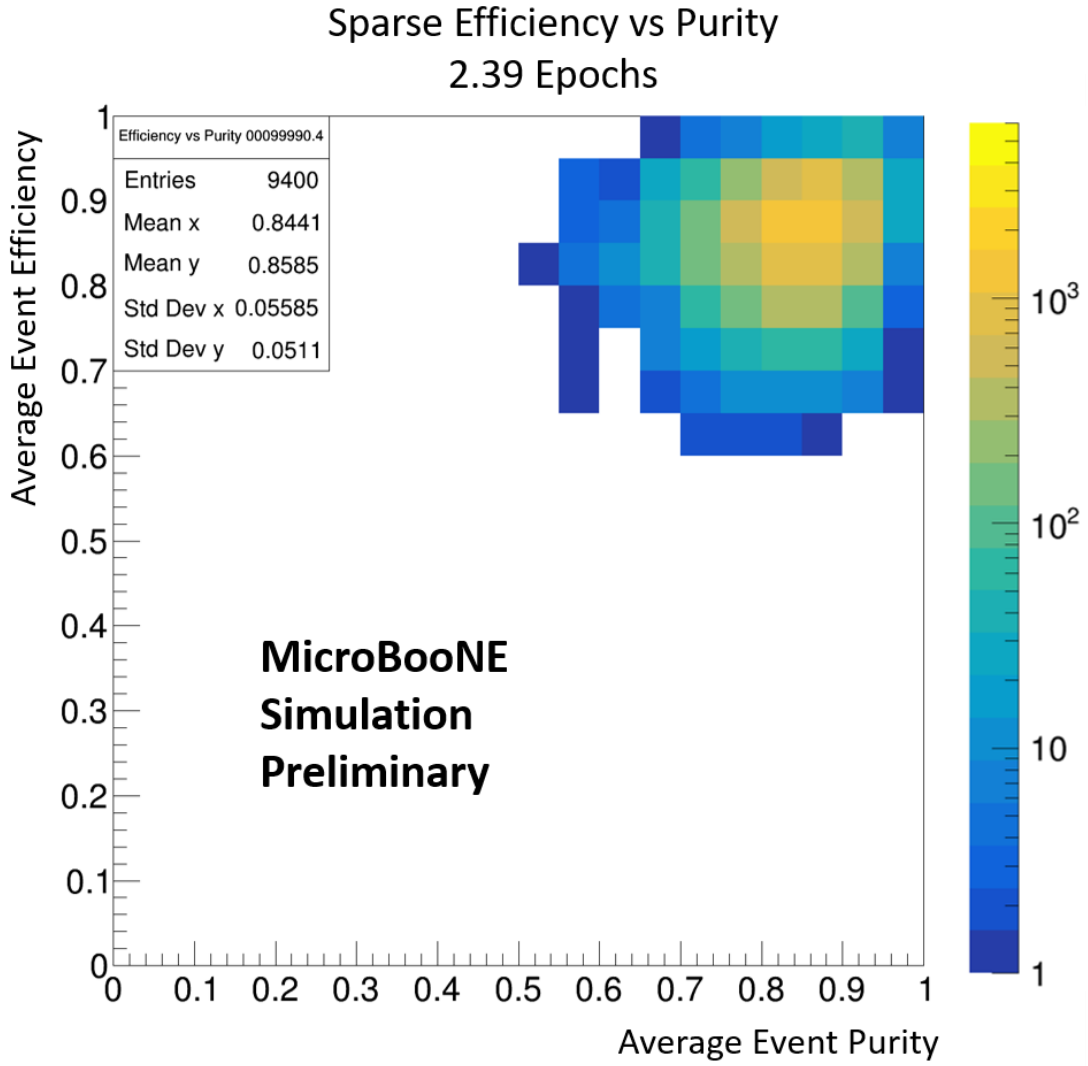




Timing performed using:
Intel(R) Core(TM) i9-9820X CPU @ 3.30GHz

Event Averaged Efficiency and Purity

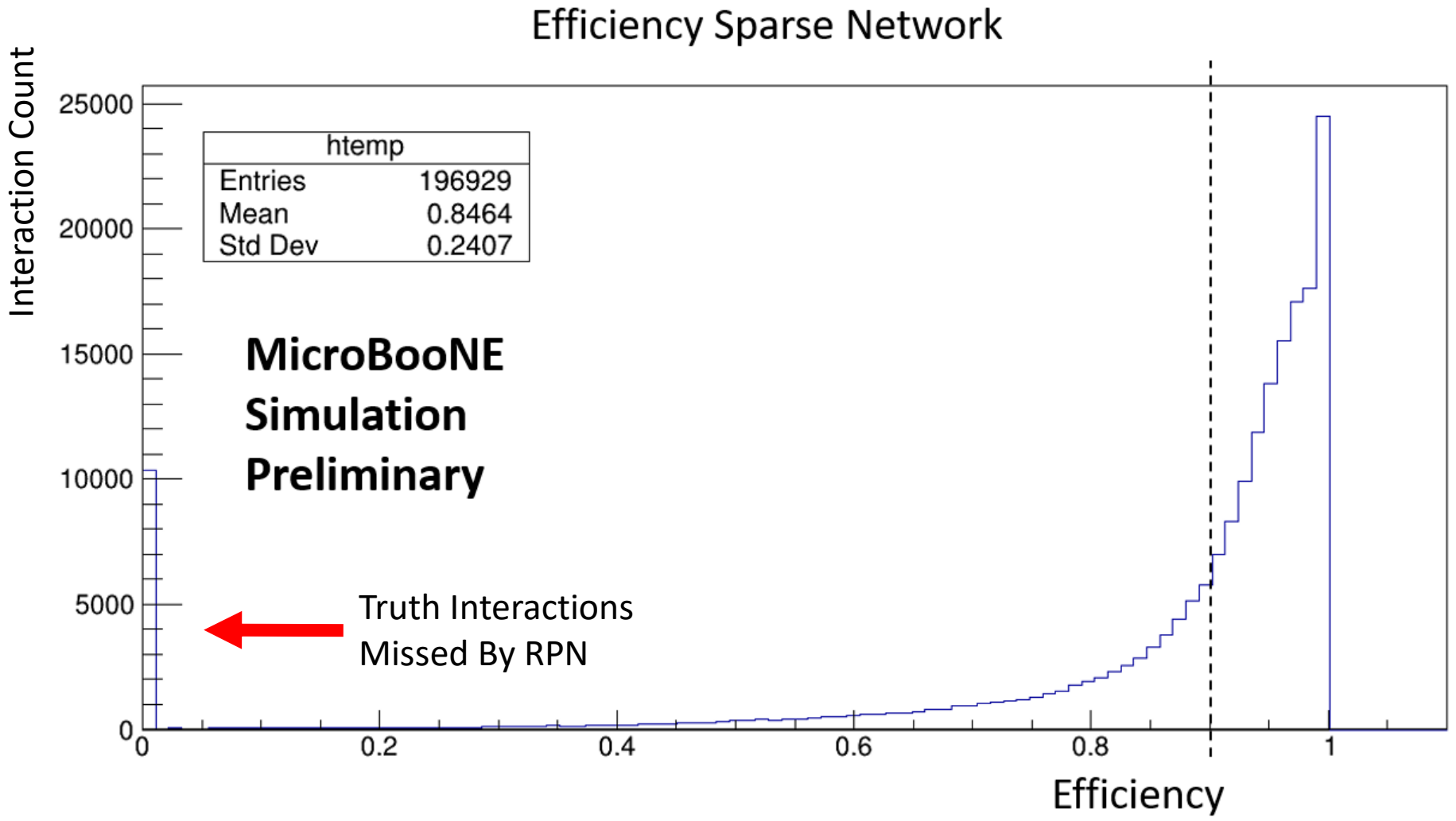
- Pixel Level Efficiency is measured for each truth interaction to see what percentage of pixels are captured by the best proposal
- Pixel Level Purity is a measure for each proposal to see what percentage of that proposal maps to a single truth interaction
- Both these metrics are averaged across the event, then entered into the histogram



Efficiency on Individual Truth Interactions

If MaskRCNN puts a box around it, then it is efficient usually > 80% efficiency

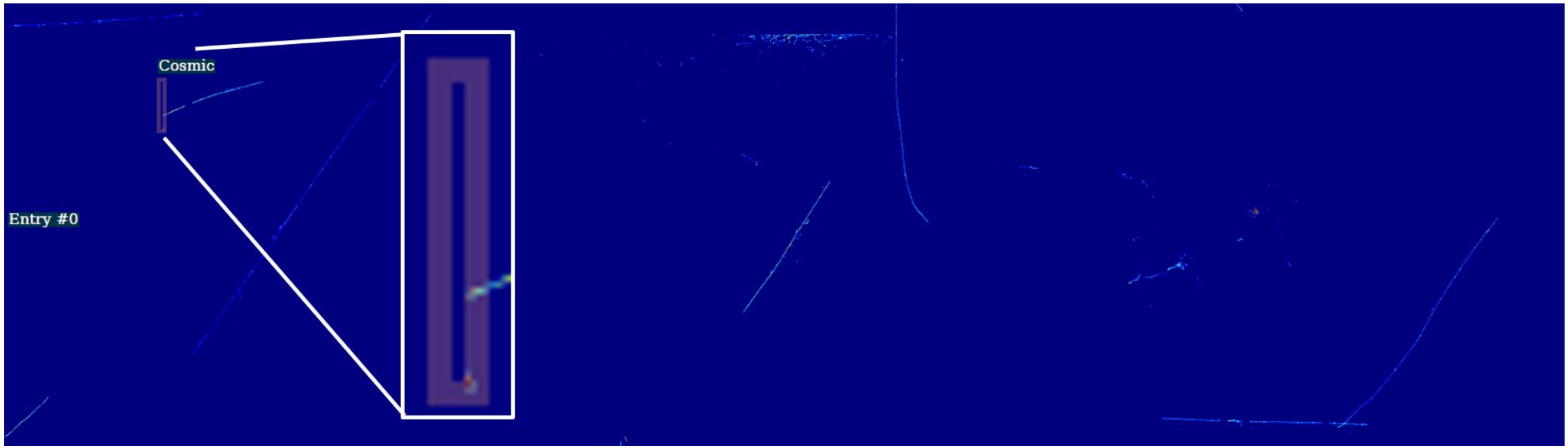
The efficiency is being dragged down by a large fraction of completely missed objects



Zero Efficiency Simulated Boxes: Dead Channels

MicroBooNE has dead wires in the detector, which means some vertical lines of pixels will always be empty, even if an interaction was there.

Sometimes network is asked to find interaction entirely in dead region, impossible task, negatively affects efficiency.

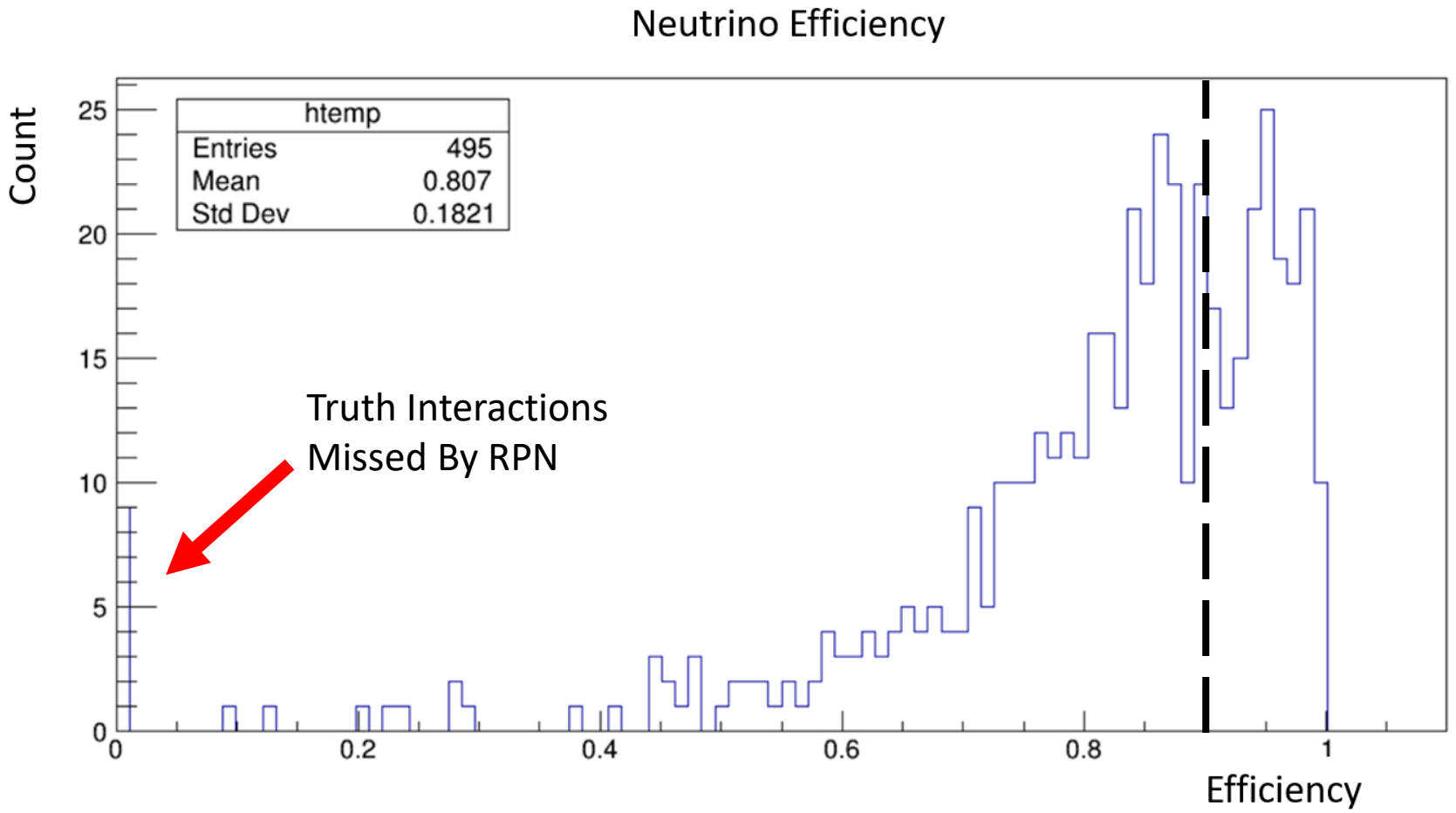


Efficiency of Electron Neutrinos

Efficiency of finding the neutrino class is similar to the efficiency as a whole.

The network has not sacrificed neutrino finding in order to find the much more common cosmic muons

Low Stats: 500 Events

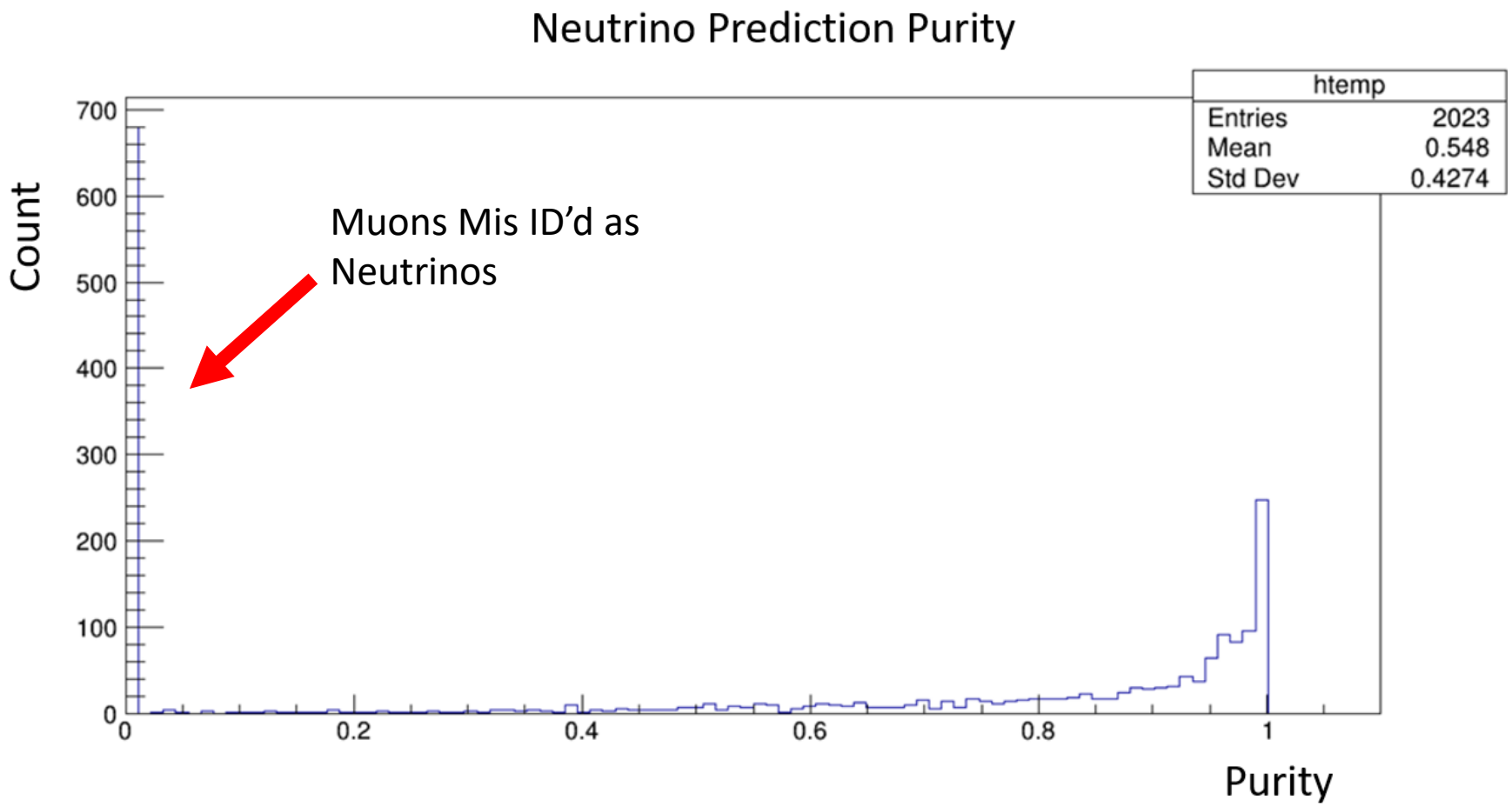


Purity on Electron Neutrinos

Often the network mislabels a muon as a neutrino because Neutrinos are that much more important

If used as an early stage cosmic tagger this MisID would pass the cosmics along to the rest of the chain to be reco'd.

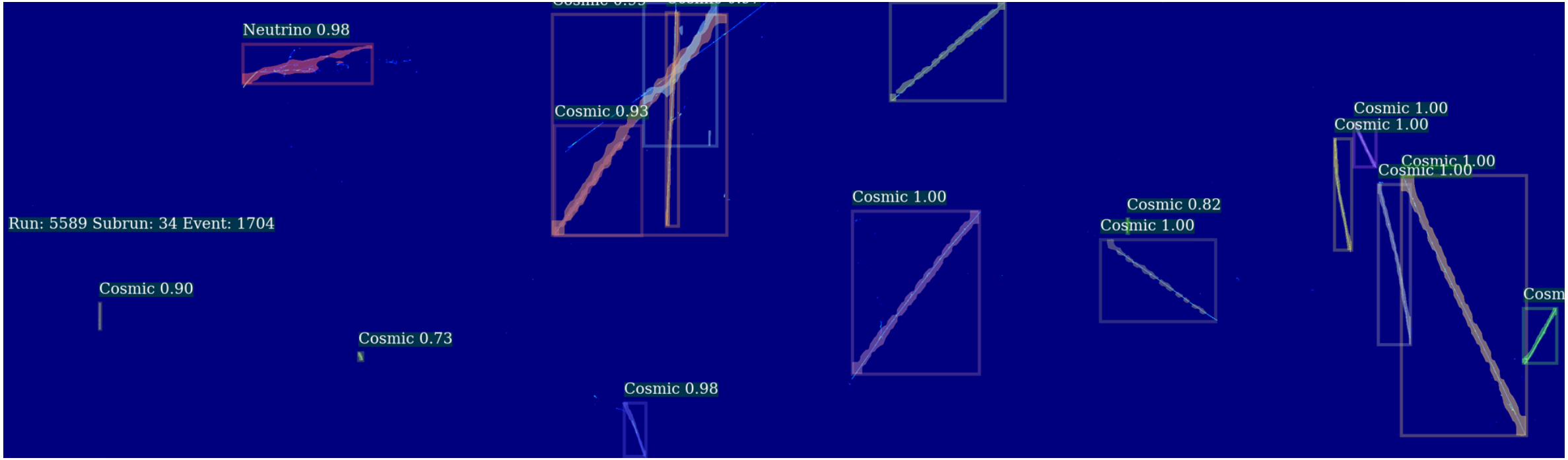
Low Stats: 500 Events



Mask-RCNN on Data, Neutrino Event!

A data event containing a neutrino interaction in the top left.

Sparse Mask-RCNN successfully finds, classifies and masks the neutrino while capturing most of the cosmics in the rest of the image.



Conclusions

Sparse submanifold convolutions substituted into ResNet can increase the image process speed of the netw ork.

Sparse Mask-RCNN is able to locate, distinguish, and cluster 2D interactions in the MicroBooNE wire signal images.

Despite the abundance of Cosmic Muon interactions, the network still maintains the ability to find Neutrino interactions, though it sometimes mislabels cosmics as neutrinos.

Future Work

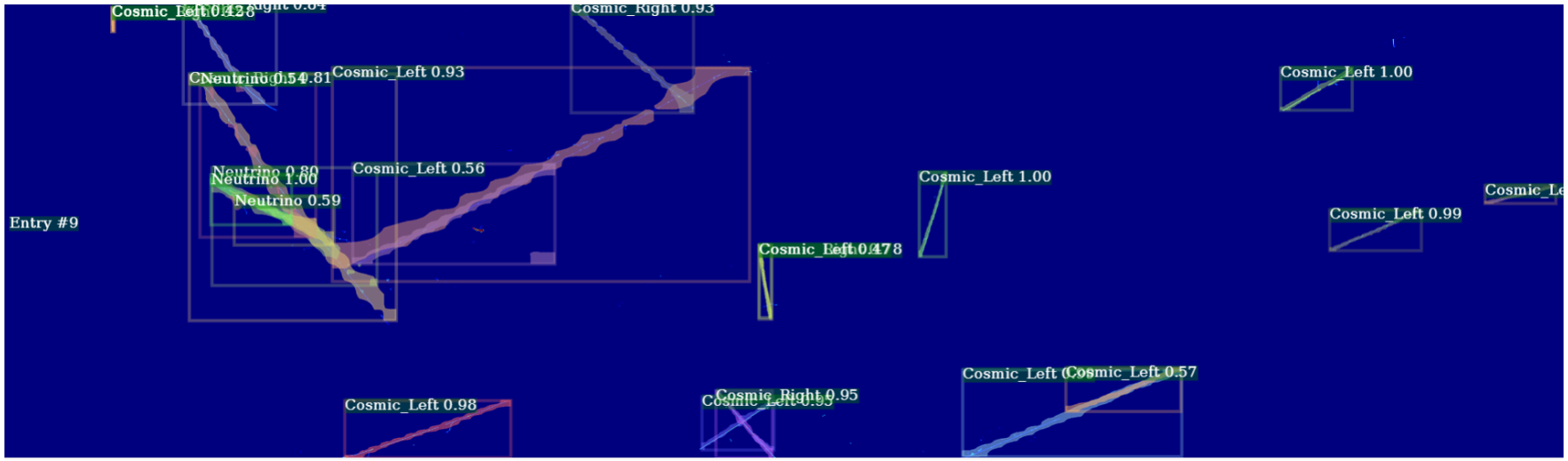
- Train with Multiple versions of cosmic class (diagonal right & diagonal left) to distinguish overlapping cosmics

- Compare performance to current MicroBooNE cosmic tagging methods.

- Connect 2D clusters together across planes with LArMatch* or plane connection algorithms.

* See Ralitsa Sharankova's NPML talk and Poster

Cosmic Class Split, Occlusion Solution



Cosmic Class split into two versions:

- Diagonal Right
- Diagonal Left

To solve problem of instances being on top of one another.

Special Thanks to Felix Yu

Questions?

Backup

Cosmic Tagging with MaskRCNN

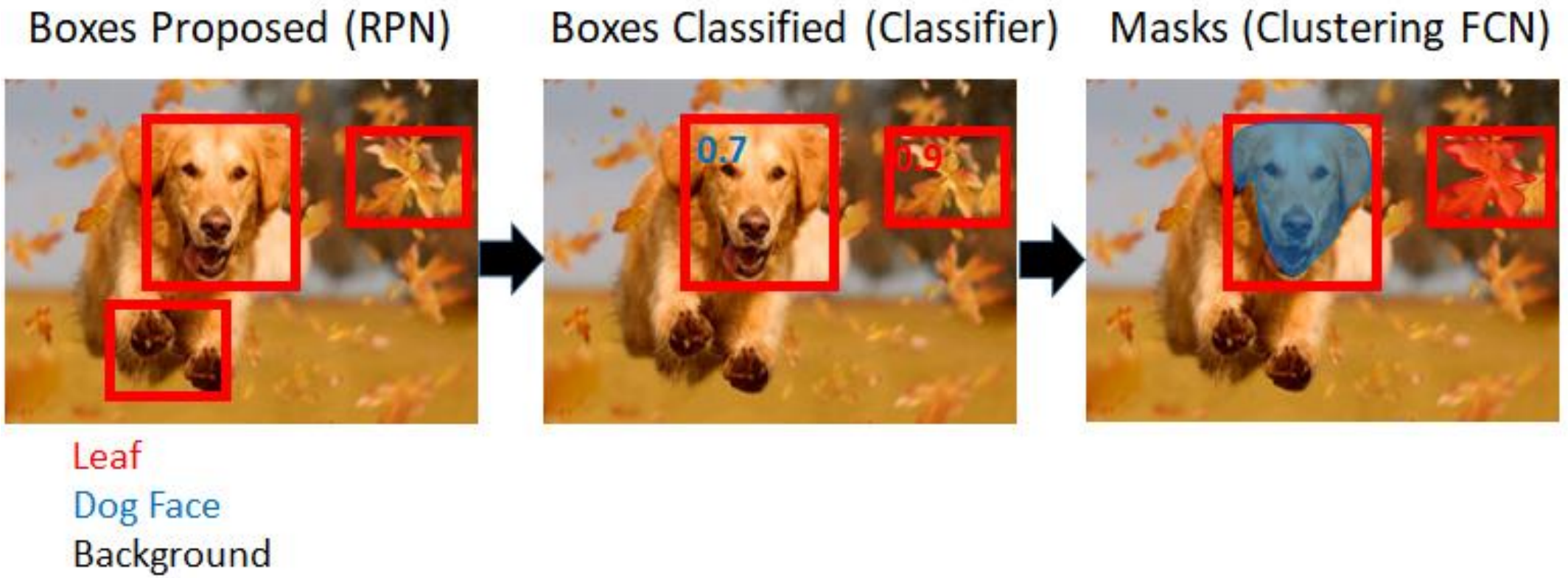
MaskRCNN was originally a network from Facebook designed to cluster different instances of set categories in images, dogs, cats, cars etc.

We decided to take this same framework and use it to try to tag charge deposited in our wire signal images based on ancestor particle.

This means all charge deposited from all daughters from a neutrino interaction would be clustered and classified as: “Neutrino” and all charge from a cosmic muon with potential michel decay will be clustered labeled: “Cosmic”

This clustering would happen in 2D and serve as a Cosmic Tagger.

RPN, Classifier, and Maskifier



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