

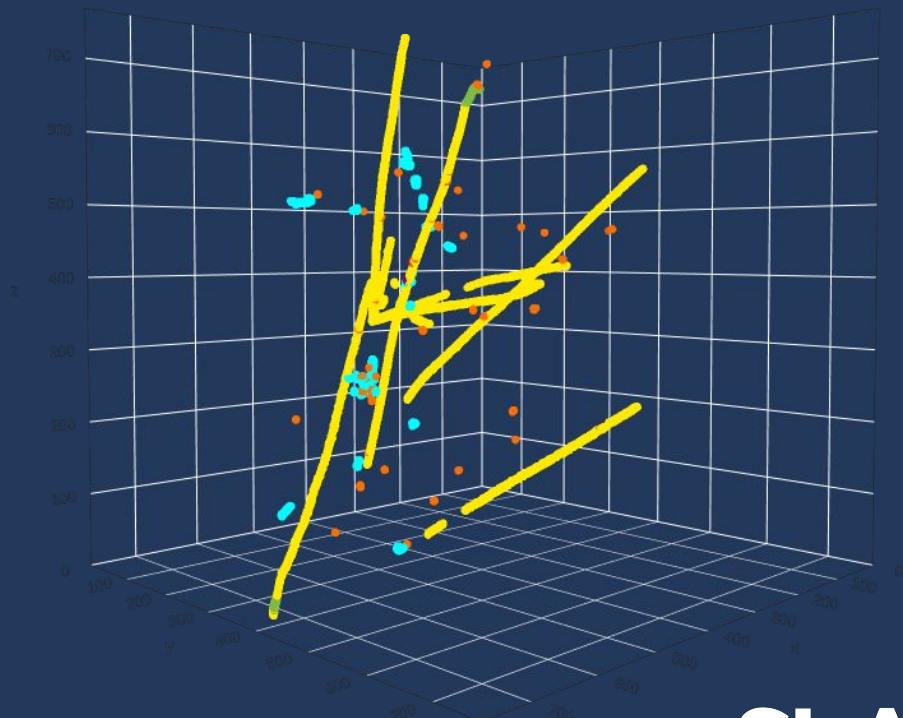
# Reconstructing Michel Electrons

in ICARUS

with Deep Learning

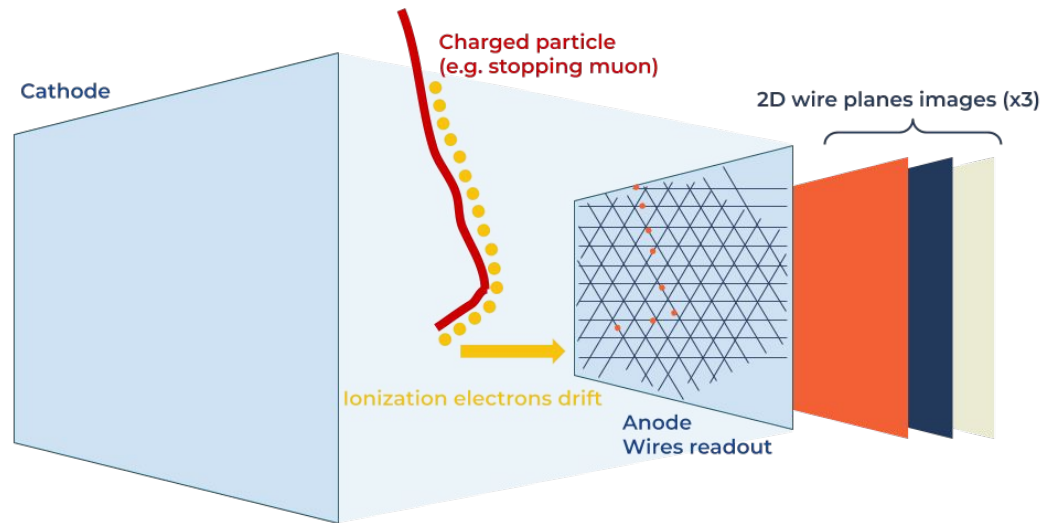
L. Dominé, K. Terao, P. Tsang, T. Usher,  
on behalf of ICARUS collaboration

June 17, 2020



# ICARUS

- ❖ Large-scale (760-ton) LArTPC detector currently at Fermilab
- ❖ Wire LArTPC => **2D images**
- ❖ `cluster3d` algorithm from T. Usher reconstructs 3D points from 2D wire images
- ❖ Following slides use a dataset made with **ICARUS detector simulation**.



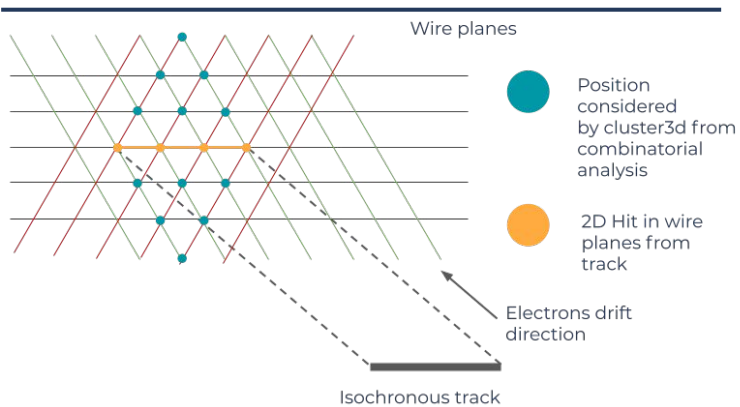
# Reconstructing 3D points



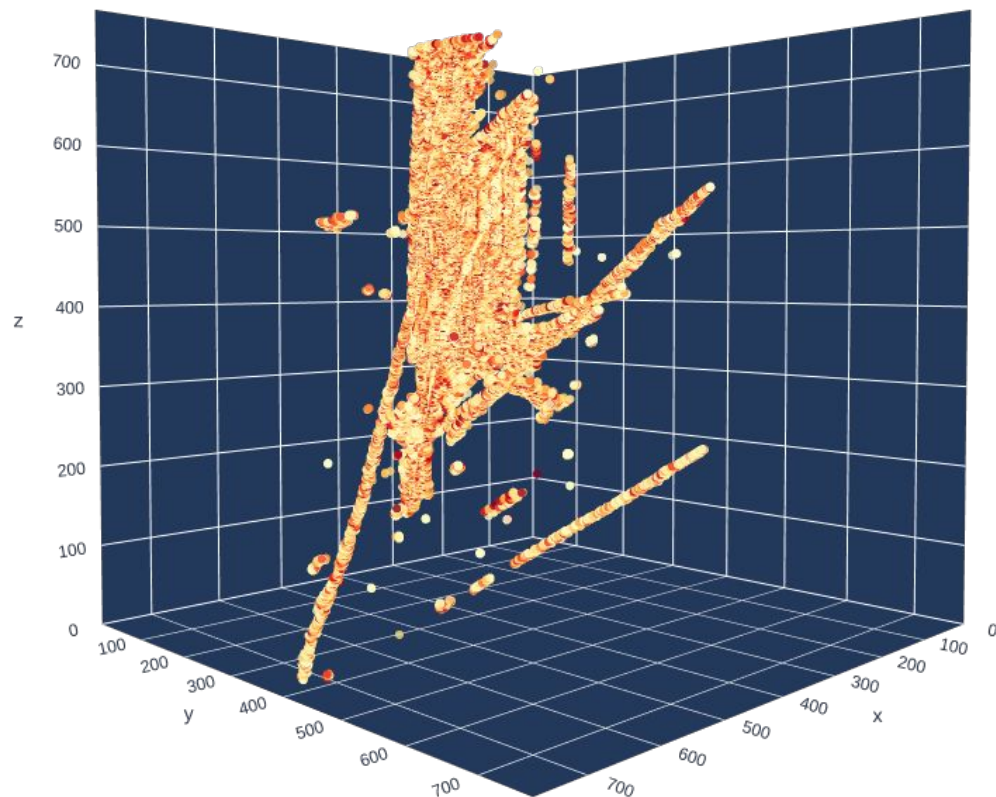
Problem: cluster3d yields a lot of false positives = “ghost points”

First step is to remove ghosts!

## How do ghost points arise?

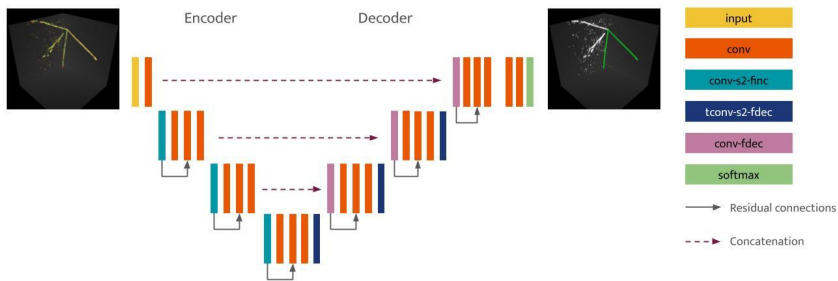


Output of cluster3d = Network input



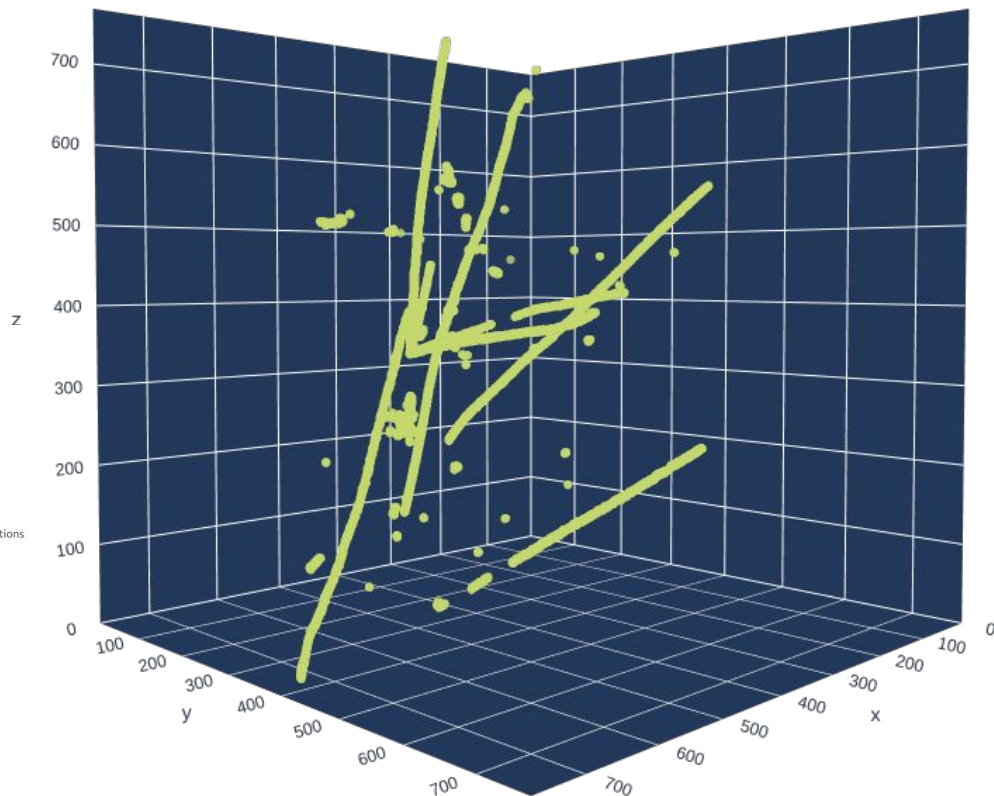
# Reconstructing 3D points

**Sparse UResNet** predicts binary semantic segmentation (ghost vs. non-ghost).



See [arxiv:1903.05663](https://arxiv.org/abs/1903.05663)  
for details on the architecture & sparse convolutions

Predicted non-ghost voxels

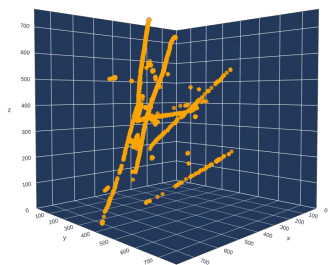


# Reconstructing 3D points

92%

Fraction of ghost voxels correctly predicted

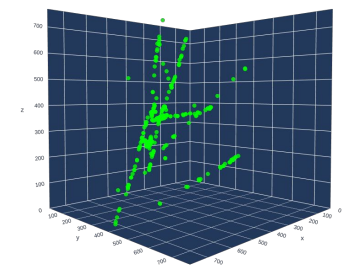
*Remaining mistakes are "reasonable".*



True ghost voxels mistakenly predicted as non-ghost

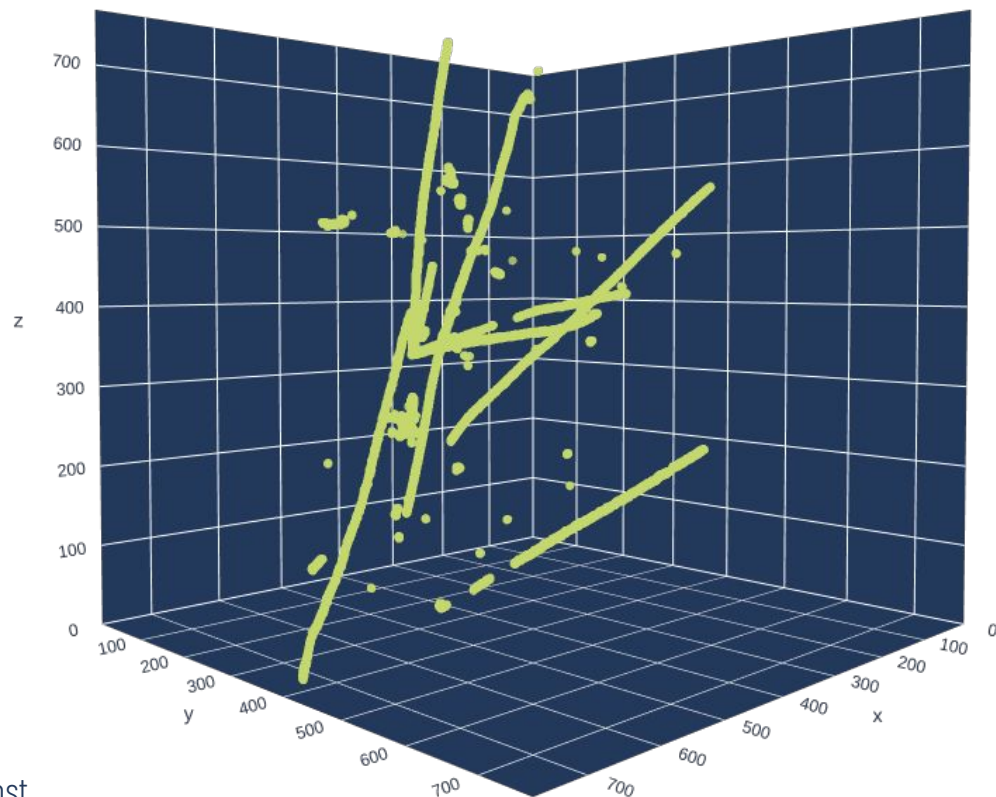
94%

Fraction of non-ghost voxels correctly predicted



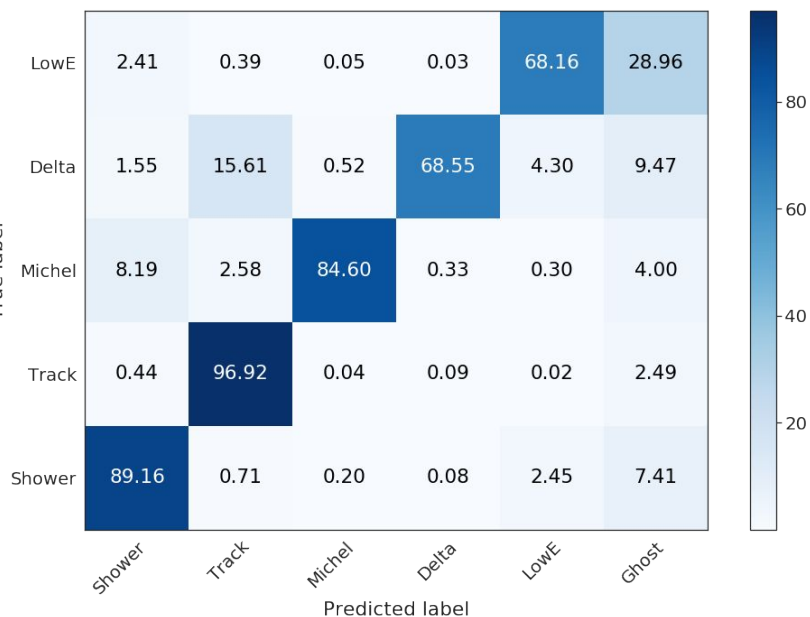
True non-ghost voxels mistakenly predicted as ghost

Predicted non-ghost voxels



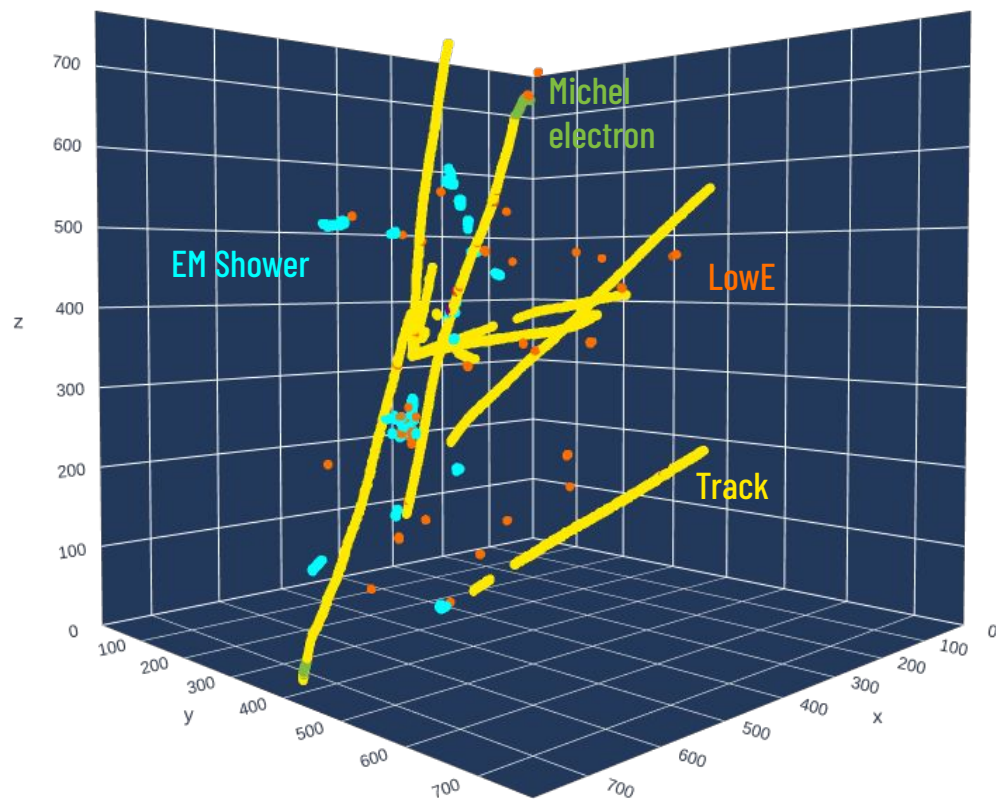
# Particle type

5-classes semantic segmentation on predicted non-ghost voxels



Confusion matrix (rows sum up to 1)

Predicted particle type for each voxel

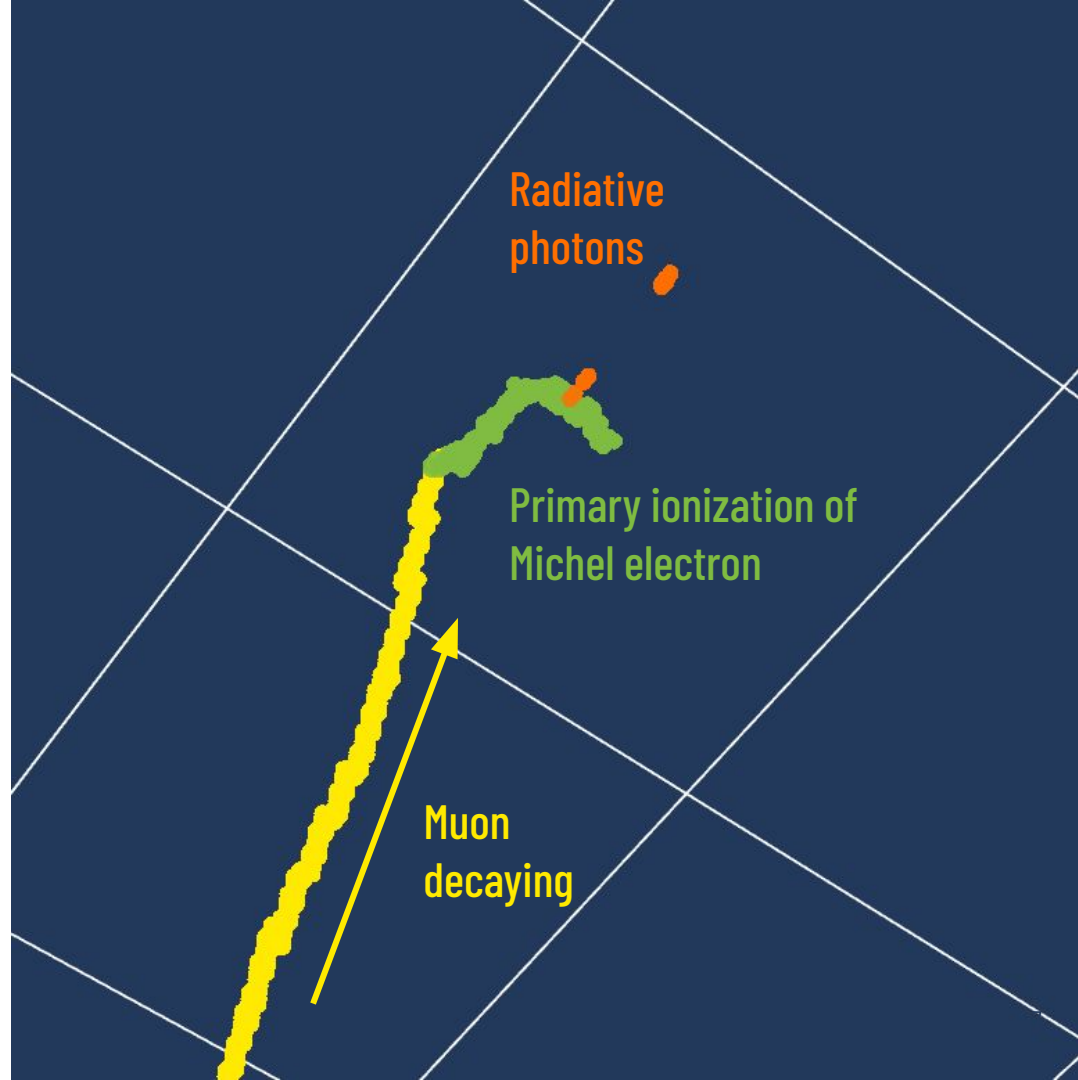


[Look at the 3D event display online!](#)



## Finding Michel electrons

- ❖ Density-based clustering (DBSCAN) on predicted Michel & Track voxels
- ❖ Select Michel clusters attached at the edge of a Track cluster = **candidate Michel clusters**
- ❖ Match candidate Michel clusters with true Michel clusters using maximal voxel overlap count



# Finding Michel electrons

How many candidate Michel clusters can be matched to a true cluster?

.....

**93%**

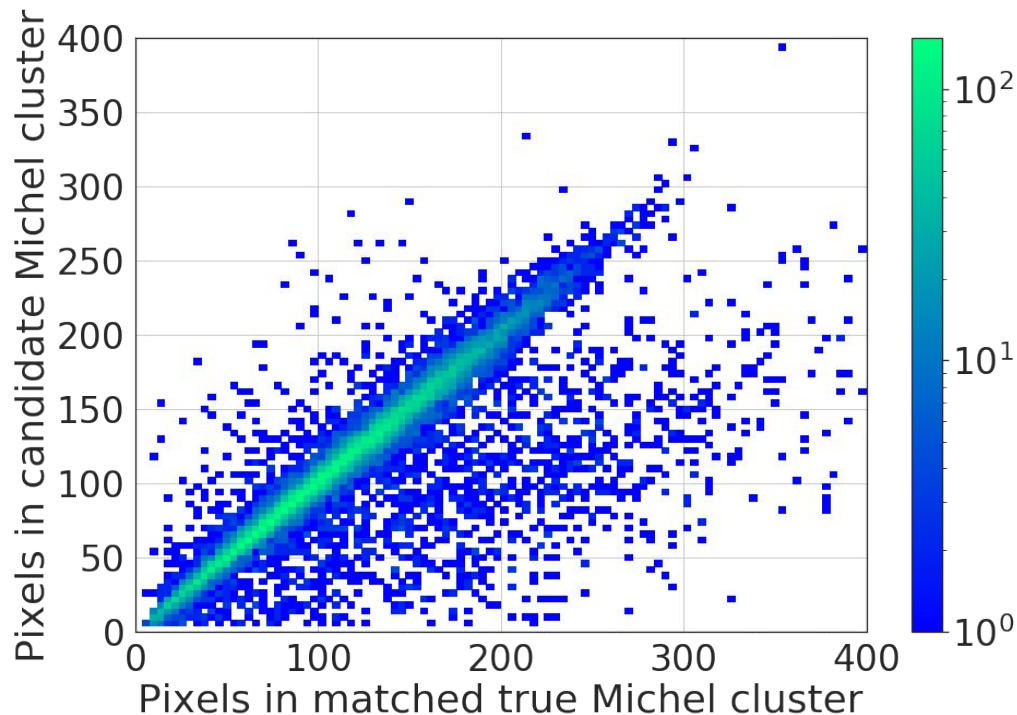
Identification efficiency

How many true Michel clusters are matched to a candidate cluster?

.....

**98%**

Identification purity





# Finding Michel electrons

How many voxels in a matched candidate Michel cluster overlap with true?

⋮

**88%**

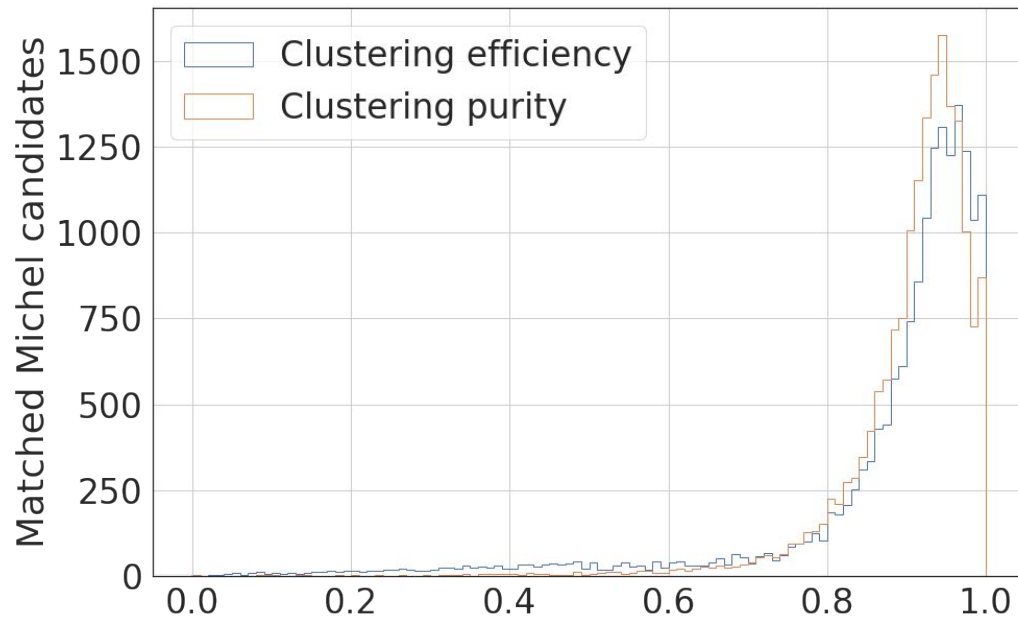
Clustering efficiency

How many voxels in a matched true Michel cluster overlap with the candidate?

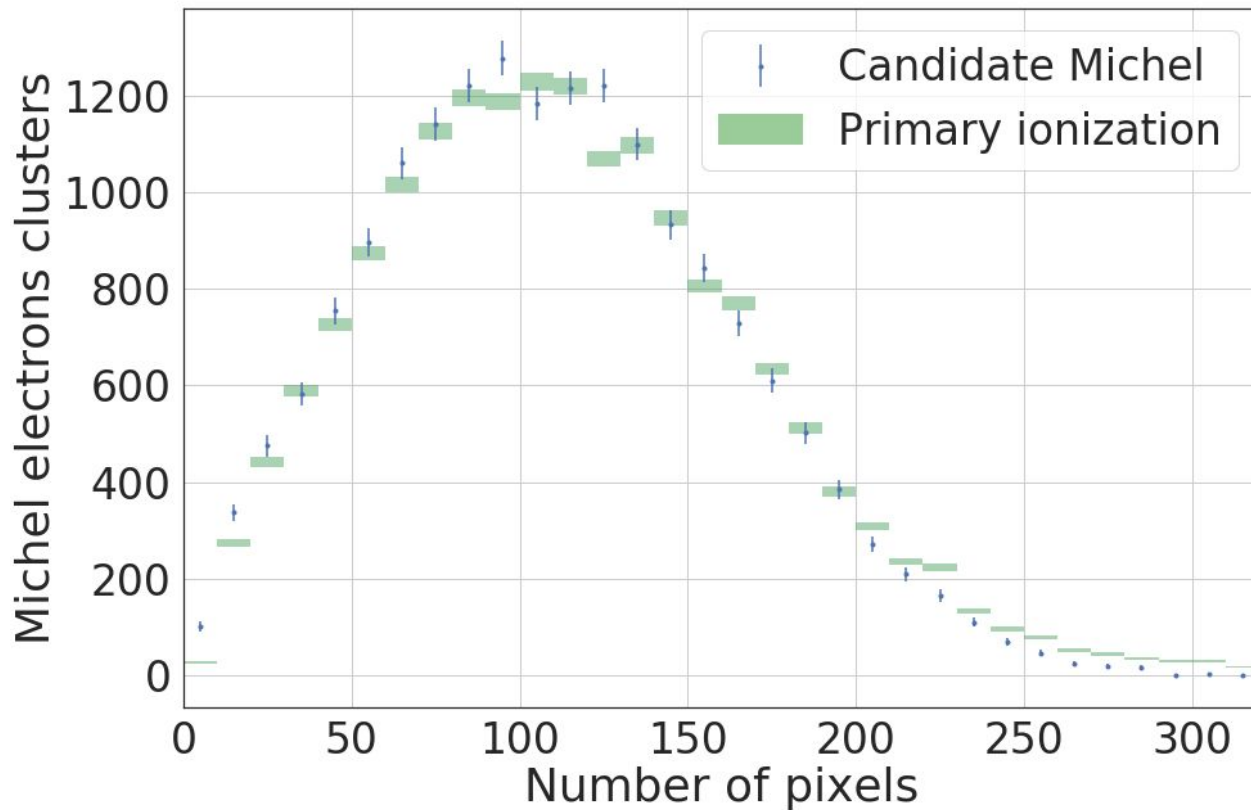
⋮

**91%**

Clustering purity



# Finding Michel electrons



# Next steps



- ❖ Demonstrates a simple way to reconstruct Michel electrons in ICARUS using Deep Learning with **high efficiency/purity**
- ❖ First physics output of our ML-based LArTPC data reconstruction chain **without using any truth information!**
- ❖ **Future work** includes: clustering radiative photons, using predicted points of interest, analyzing mistakes...