Reconstructing Michel Electrons in ICARUS with Deep Neural Networks

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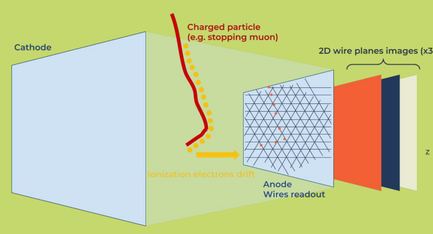
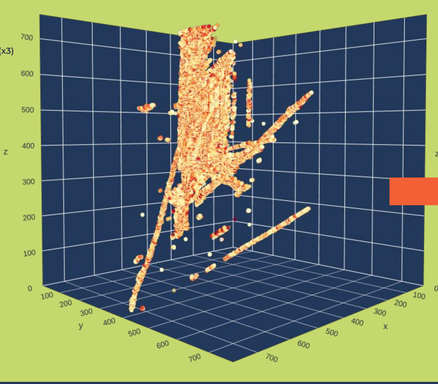
The ICARUS experiment

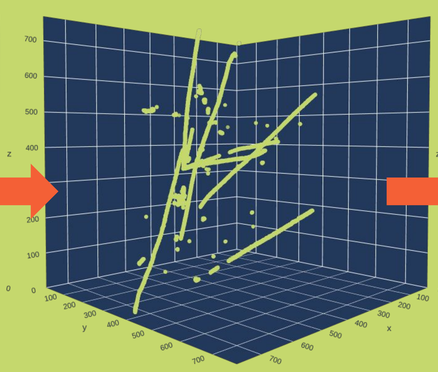


Large scale (760 ton) wire LArTPC at Fermilab

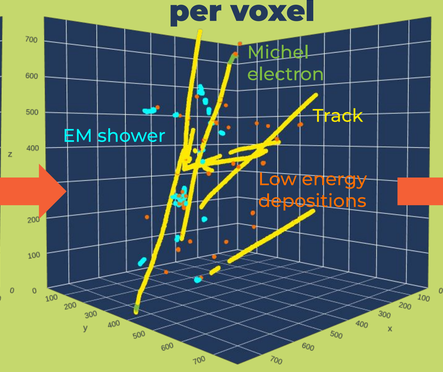
Network input



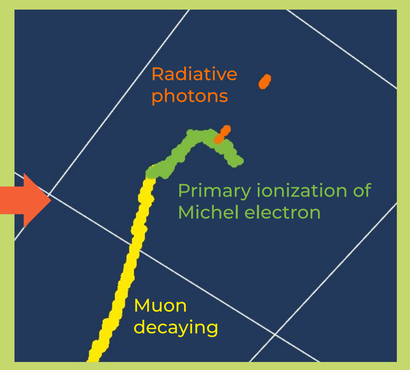
Predicted non-ghost voxels



Predicted particle type per voxel



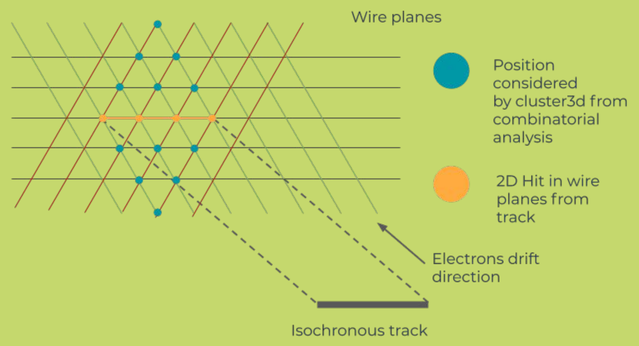
Candidate Michel electron cluster



- Density-based clustering (DBSCAN) on predicted Michel and Track voxels
- Select Michel clusters attached to the edge of a Track cluster
- Event display online

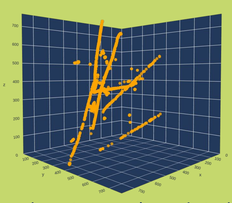
From 2D wire images to 3D images: removing ghost points

- Detector using wire readouts = 2D images
- 3D point reconstruction algorithm yields a lot of false positives ("ghost points").
- UResNet trained to predict ghost vs non-ghost points classification



92%

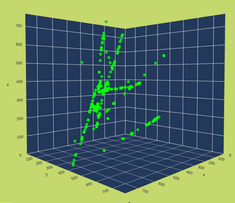
Fraction of ghost voxels correctly predicted



True ghost voxels mistakenly predicted as non-ghost

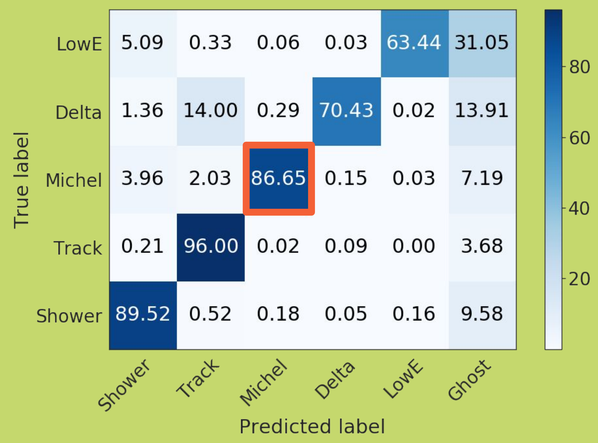
94%

Fraction of non-ghost voxels correctly predicted



True non-ghost voxels mistakenly predicted as ghost

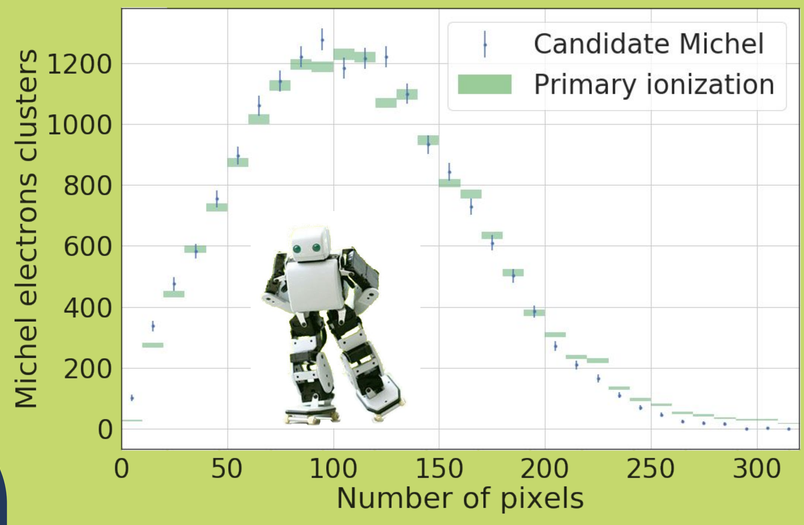
Classifying 3D voxels by particle type

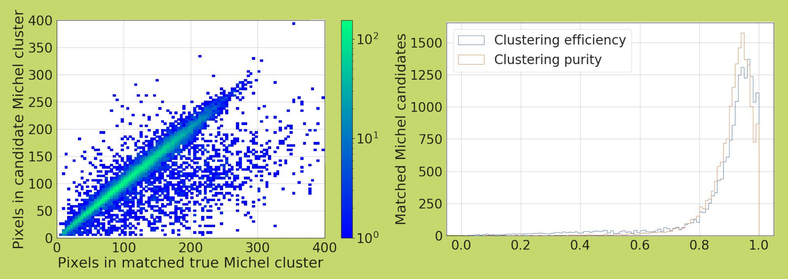


Confusion matrix: fraction of voxels of true type Y identified as type X

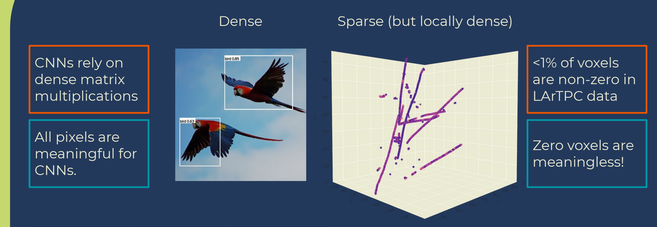
Michel electron reconstruction performance

	Efficiency	Purity
Identification	93%	98%
Clustering	88%	91%





Using Sparse Convolutions



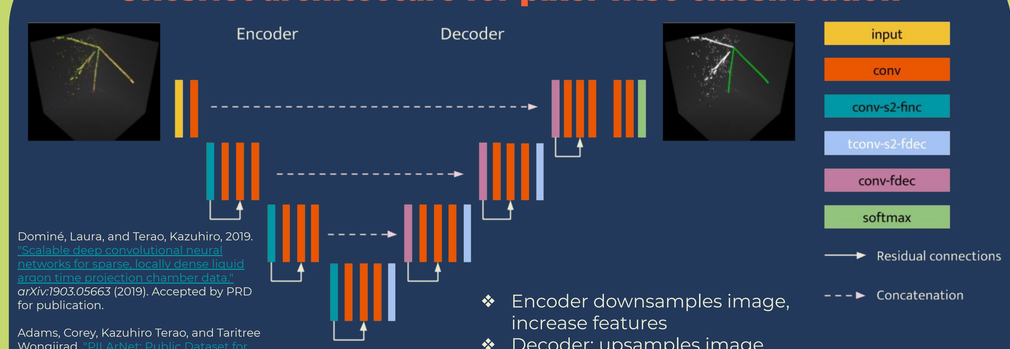
Submanifold sparse convolutions solve...

1. Resources waste: dense convolutions on sparse data

2. Dilation problem: keeping the same level of sparsity

"3d semantic segmentation with submanifold sparse convolutional networks," https://github.com/facebookresearch/SparseConvNet

UResNet architecture for pixel-wise classification



Dominé, Laura, and Terao, Kazuhiro, 2019. "Scalable deep convolutional neural networks for sparse, locally dense liquid argon time projection chamber data." *arXiv:1903.05663* (2019). Accepted by PRD for publication.

Adams, Corey, Kazuhiro Terao, and Taritree Wongjirad. "PILArNet: Public Dataset for Particle Imaging Liquid Argon Detectors in High Energy Physics." *arXiv preprint arXiv:2006.01993* (2020).

Our code lartpc_mlreco3d: https://github.com/DeepLearnPhysics/lartpc_mlreco3d

- Encoder downsamples image, increase features
- Decoder: upsamples image, decrease features
- Residual connections: help to learn
- Concatenation: helps to restore the original resolution

Stanford

SLAC