Interaction clustering in Liquid Argon Time Projection Chamber using Graph Neural Network

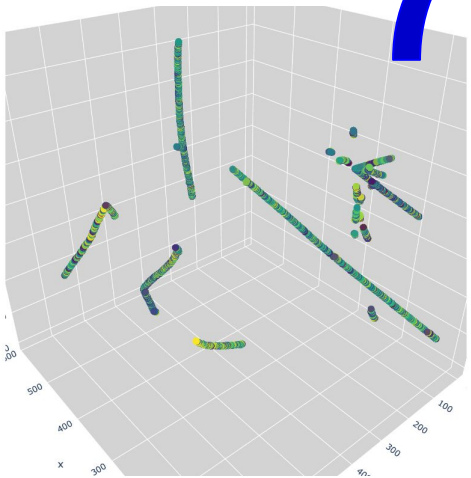
Qing Lin
on behalf of DeepLearnPhysics collaboration
June 19th

U.S. DEPARTMENT OF ENERGY
Office of Science

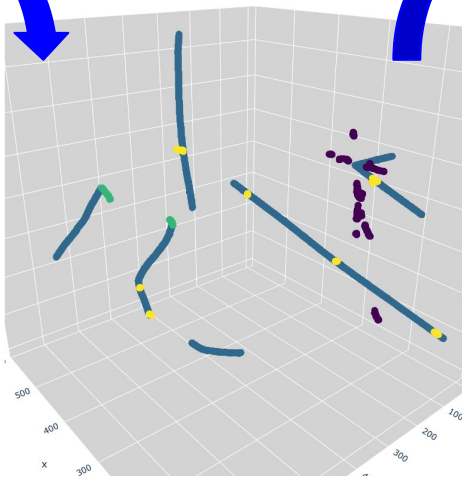
SLAC NATIONAL ACCELERATOR LABORATORY

Recap on Recon. Framework (Simplified)

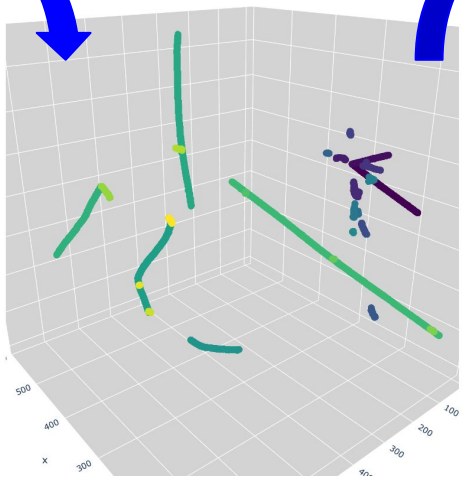
SLAC



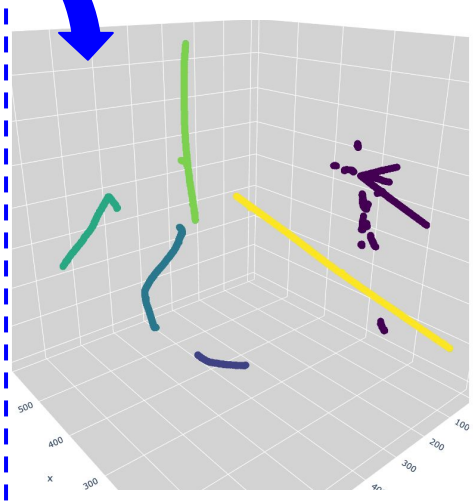
Input:
3D image with depth of 1 (energy dep. or charge)



Step 1:
Semantic Segmentation & Point Proposal



Step 2:
Cluster fragments into particle groups

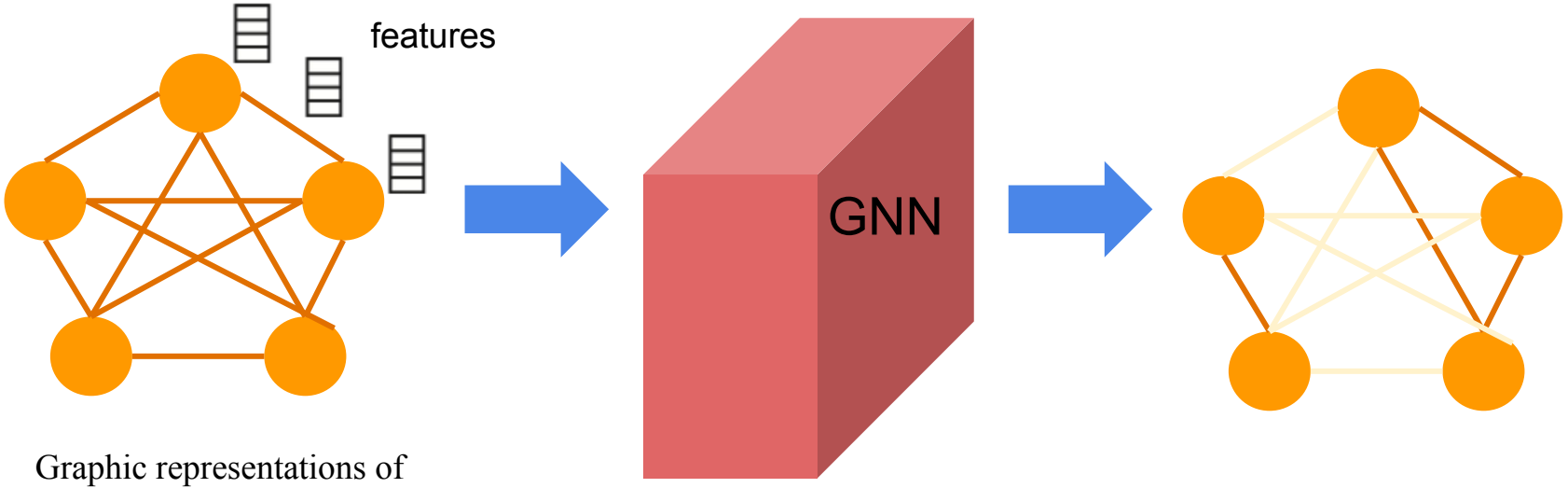


Step 3:
Cluster particle groups into interaction groups (this presentation)

Step 1.5:
Dense clustering

arXiv: 1903.05663
doi.org/10.5281/zenodo.1300713

Interaction clustering



- Graphic representations of particle groups.
- **Node** presents each particle group, and **edge** (connection between two nodes) represents two particle correlation.

- Use Graph Neural Network (GNN) available on market for predicting the edge on/off.
- Currently used GNN is kernel-based convolution operator (torch.geometric.nn.NNConv).
- Based on edge prediction, the interaction clustering can be interpreted.

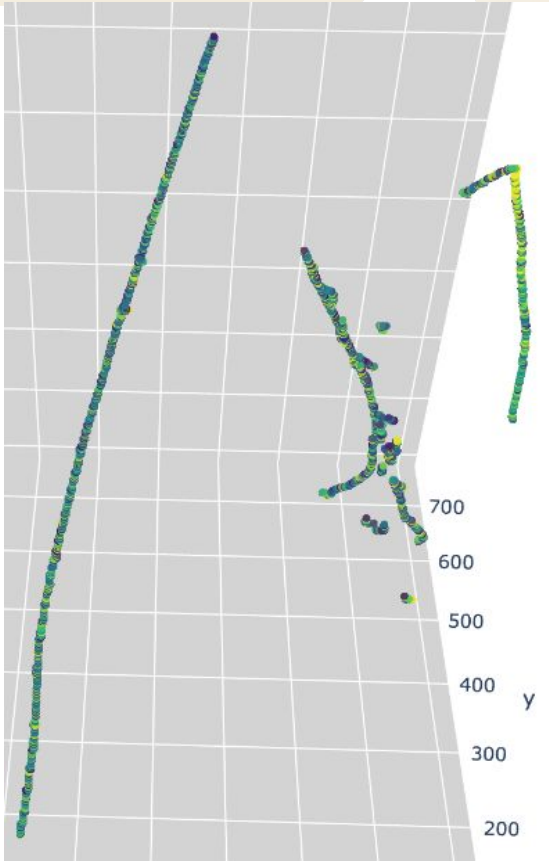
Node & Edge Features (baseline model)

Basic node features (28):

- (1) Size (number of voxels)
- (9) Covariance matrix
- (3) Principle axis
- (3) Particle group centroid
- (2) Energy dep. mean & std
- (1) Largest-fraction semantic type of particle group
- (6) Start & end point
- (3) Direction

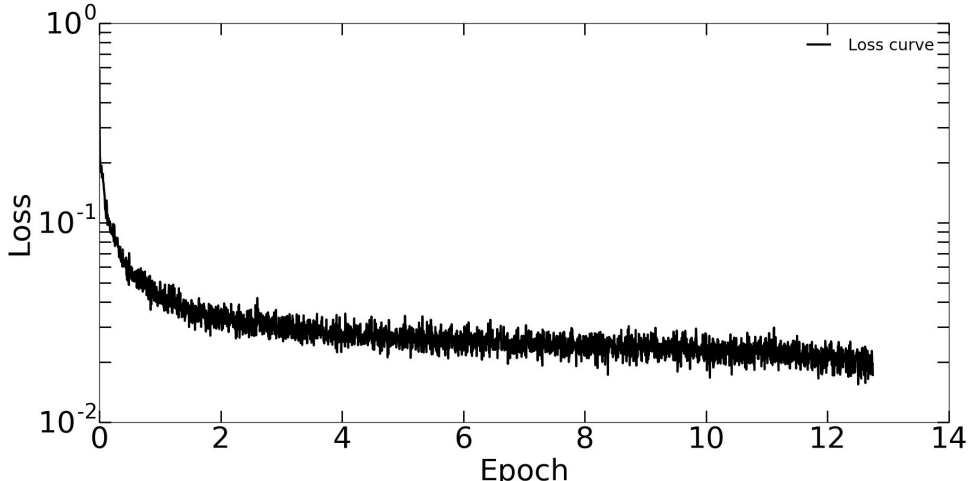
Basic edge features (19):

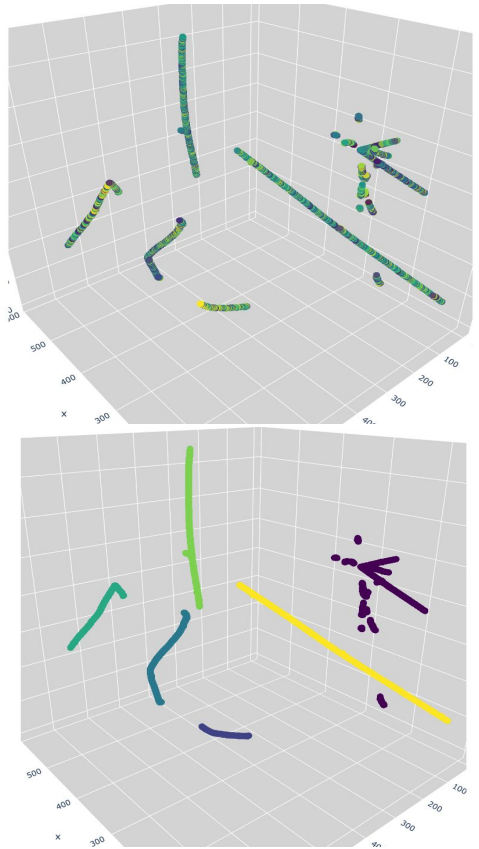
- (3) Closest point in particle 1
- (3) Closest point in particle 2
- (3) Displacement of two closest points
- (1) Length of displacement
- (9) Outer product of displacement



Training

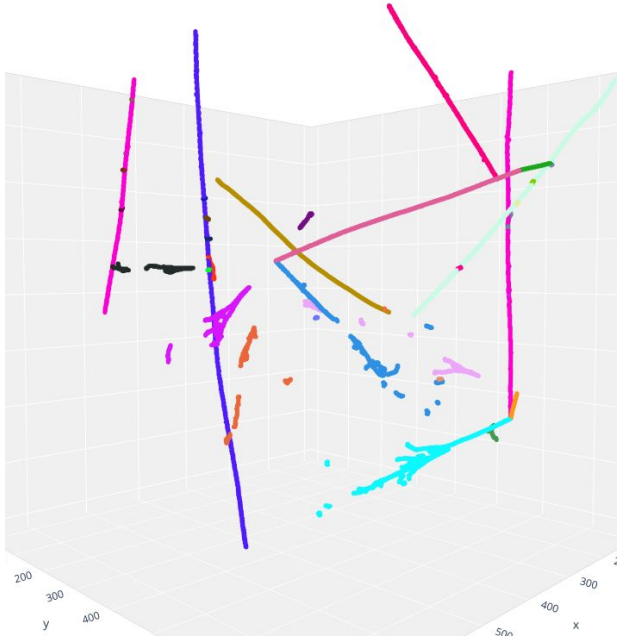
- Image size: 768 px (~2.3 m) on each dimension
- 125k training samples and 22k test samples.
- Sample contain nu-like and cosmic-like
- Cosmic-like includes track and gamma showers
- Angular distributions of “nu daughters” and “cosmics” are isotropical.
- Number of nu-like follows Poissonian with mean of 2



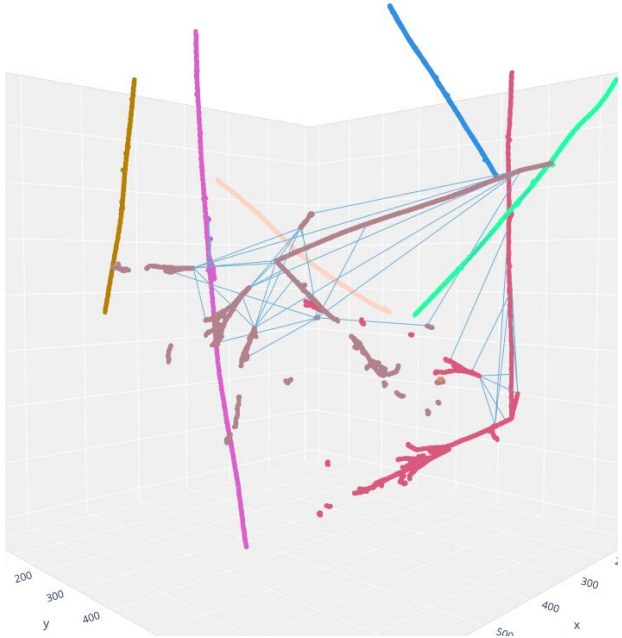


Performance (2 nu)

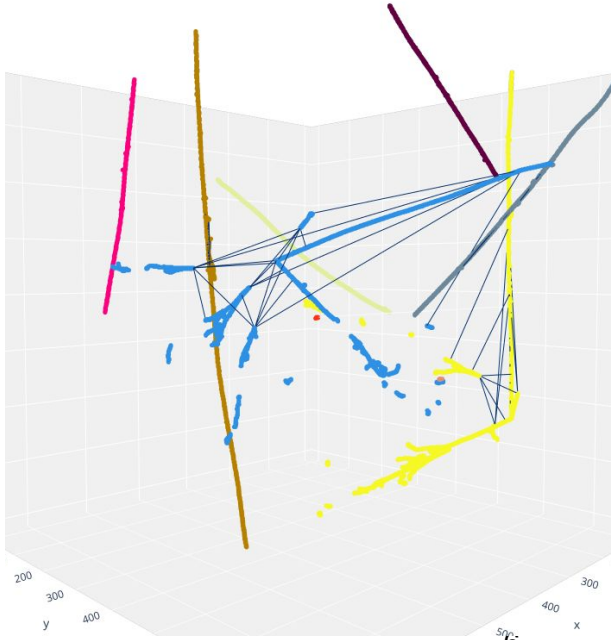
Particle groups



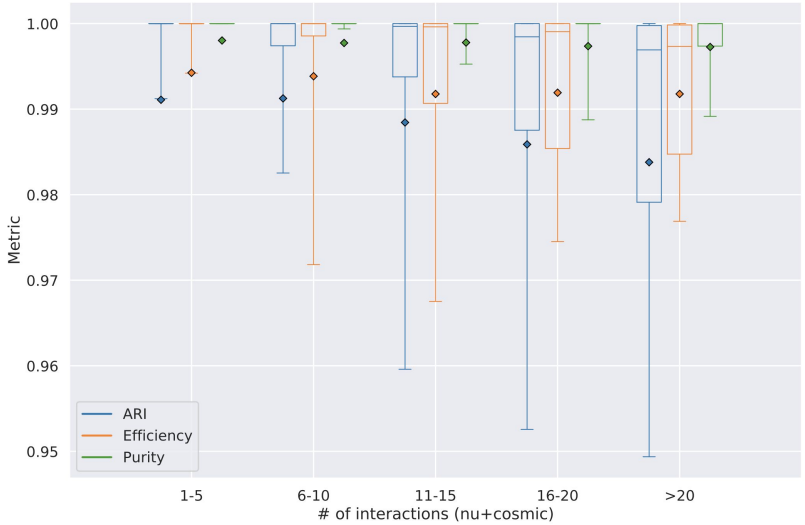
Interaction
ground truth

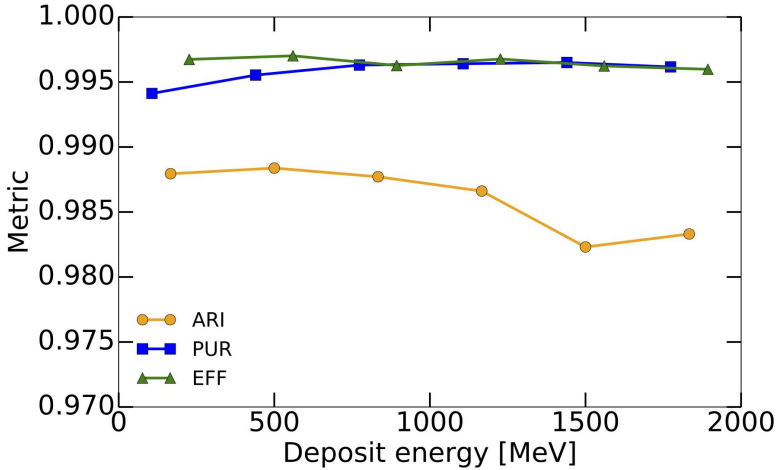


Prediction; ARI = 1.0



Performance:



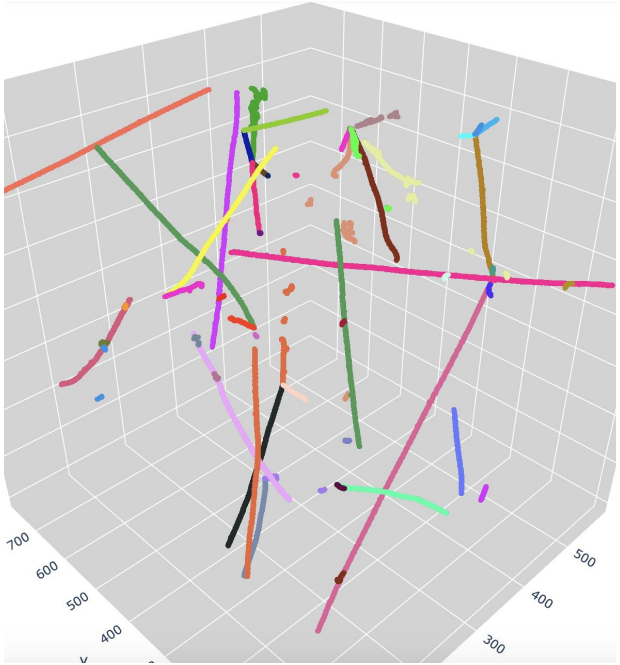


Nv	ARI	PUR	EFF
1	0.986	0.996	0.997
2	0.987	0.996	0.994
4	0.980	0.996	0.989

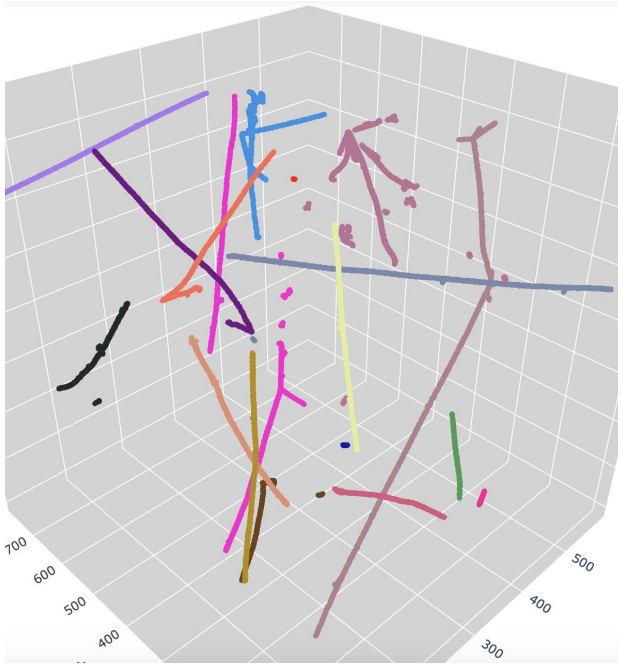
- ARI (adjusted rand index) is used for measuring goodness of clustering.
- Purity and efficiency for checking over- and under-clustering

Performance (4 nu)

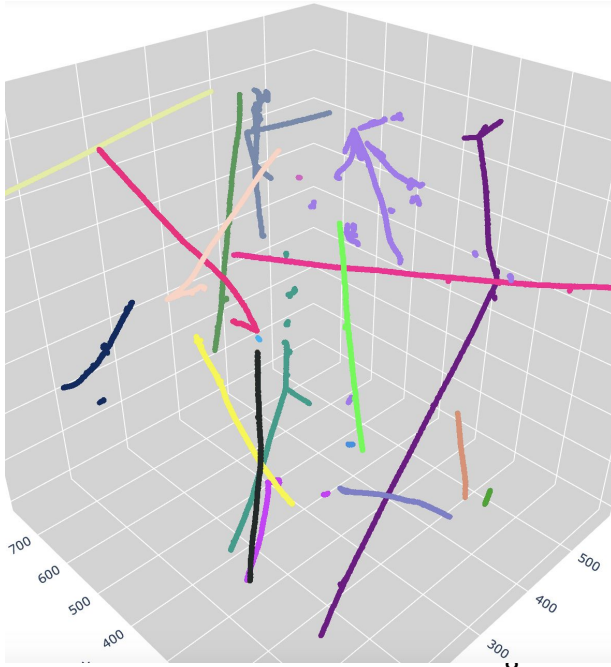
Particle groups



Interaction
ground truth



Prediction; ARI = 1.0



Summary

- **Baseline model of particle clustering in recon. chain is more or less finished. Input with human-supervised features, GNN is able to achieve ARI of >0.98 @ 4-nu per image**

- **We are also exploring ways to improve performance of particle clustering, such as feeding CNN encoder extracted features into GNN.**

ML for LArTPCs | SLAC Group

SLAC NATIONAL ACCELERATOR LABORATORY

At SLAC, research supported by DoE ML grants (**K. Terao**):

- **Deep-learning-based data reconstruction chain for liquid argon time-projection chambers**
- μBOONE, pDUNE, ICARUS, ArgonCube 2x2, DUNE

Group consists of three **scientists**, three **postdocs**, three **grad students**

T. Usher
ICARUS

F. Drielsma
ICARUS

Q. Lin
ICARUS

L. Domine
ICARUS

P. Tsang
pDUNE

R. Itay
μBOONE

D.H. Koh
ICARUS

P. Cotes de Soux