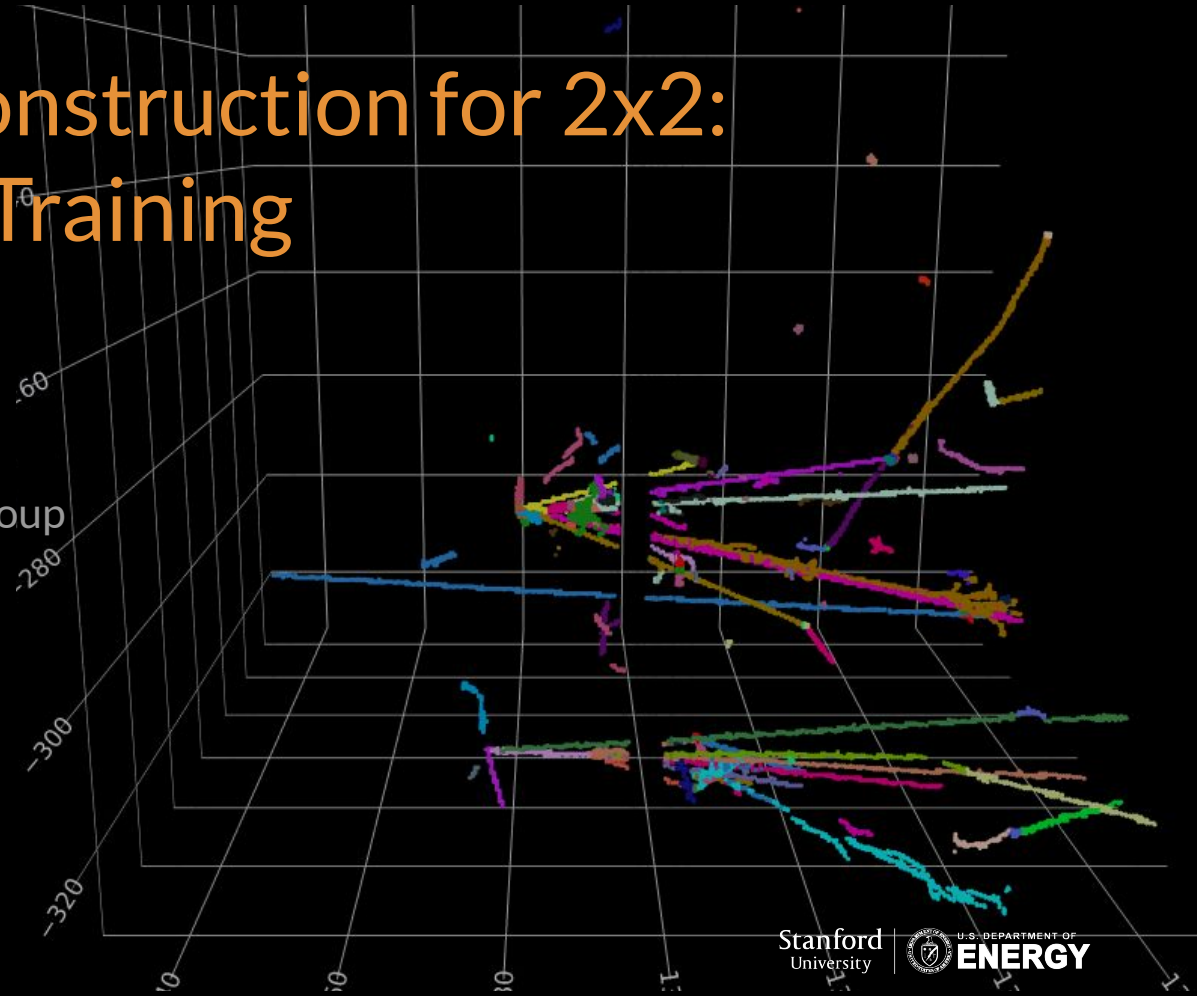
ML-based Reconstruction for 2x2: Status of New Training

2x2 ML Weekly Meeting

François Drielsma (SLAC)

on behalf of the ML working group

July 3rd, 2024



SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

ML Reconstruction Subgroup

ML Reco. Subgroup, convened by *yours truly*. Goal:

- Apply ML-based LArTPC reco. chain to 2x2.
  SLAC: K. Terao, P. Tsang, Y. Chen, D. Douglas, **Tufts**: J. Wolcott, J. Micallef, **LBNL**: M. Kramer, **UCI**: S. Kumaran, **Ulowa**: O. Neogi, **Rochester**: H. Utaegbulam, **ANL**: Z. Djurcic, M. B. Azam
- **Weekly meeting** on **Wed. 2PM CST** (dunend-simreco-technical@slac.stanford.edu)

F. Drielsma

K. Terao
Labeling

J. Wolcott
Labeling, CAF

J. Micallef
Minerva integration

M. Kramer
Prod.

H. Utaegbulam
Dead region inference

Z. Djurcic
Infrastruct.

P. Tsang
Diff. γ simulation

Y. Chen
Simulation

S. Kumaran
Data, sim, CAFs

D. Douglas
Inverse problem solving

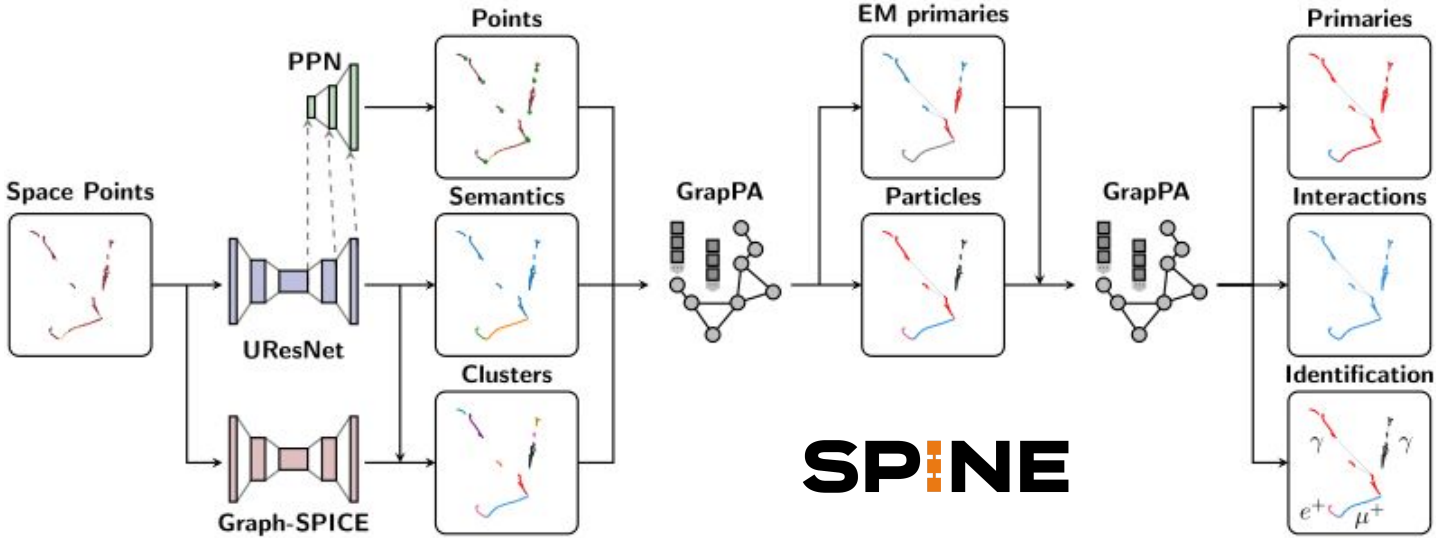
O. Neogi
Training, infrastruct.

M. B. Azam
Track multiplicity study

Scalable Particle Imaging with Neural Embeddings

Reconstruction flow (lartpc_mlreco3d):

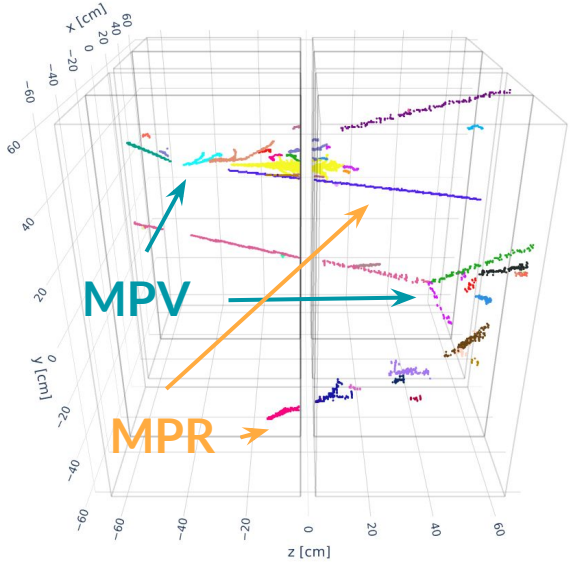
1. Voxel semantic classification, point identification (**CNN**: UResNet+PPN, **L. Dominé**)
2. Dense clustering (Smart DBSCAN, **CNN**: Graph-SPICE, **D.H. Koh**)
3. Particle aggregation, shower primary identification (**GNN**: GrapPA-Track/Shower)
4. Interaction aggregation, particle identification, primary identification (**GNN**: GrapPA-Interaction)

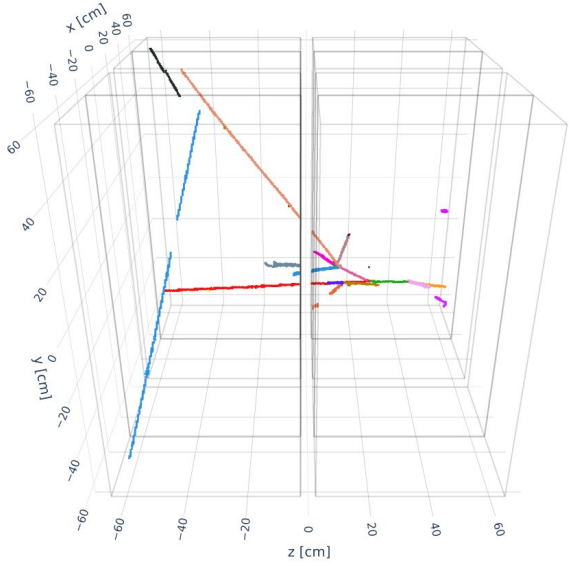


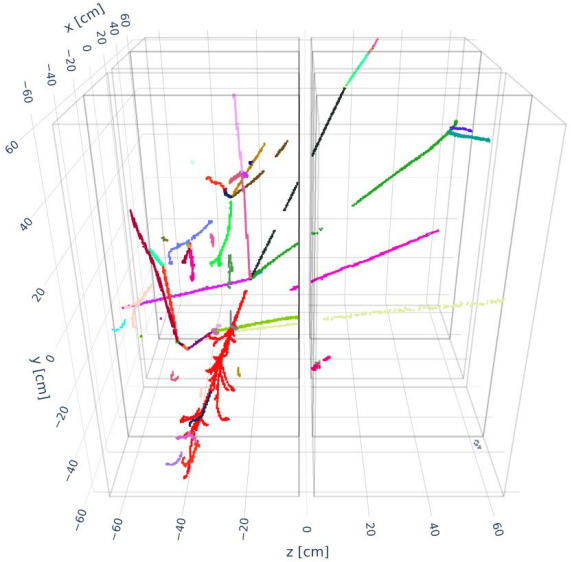
Training/Validation sample

Training sample (0.2 M) generated using the [DeepLearnPhysics generator]

- 1-3 **particle bombs** (multi-particle vertex, aka MPV)
- 1-5 **single particles** (multi-particle rain, aka MPR)







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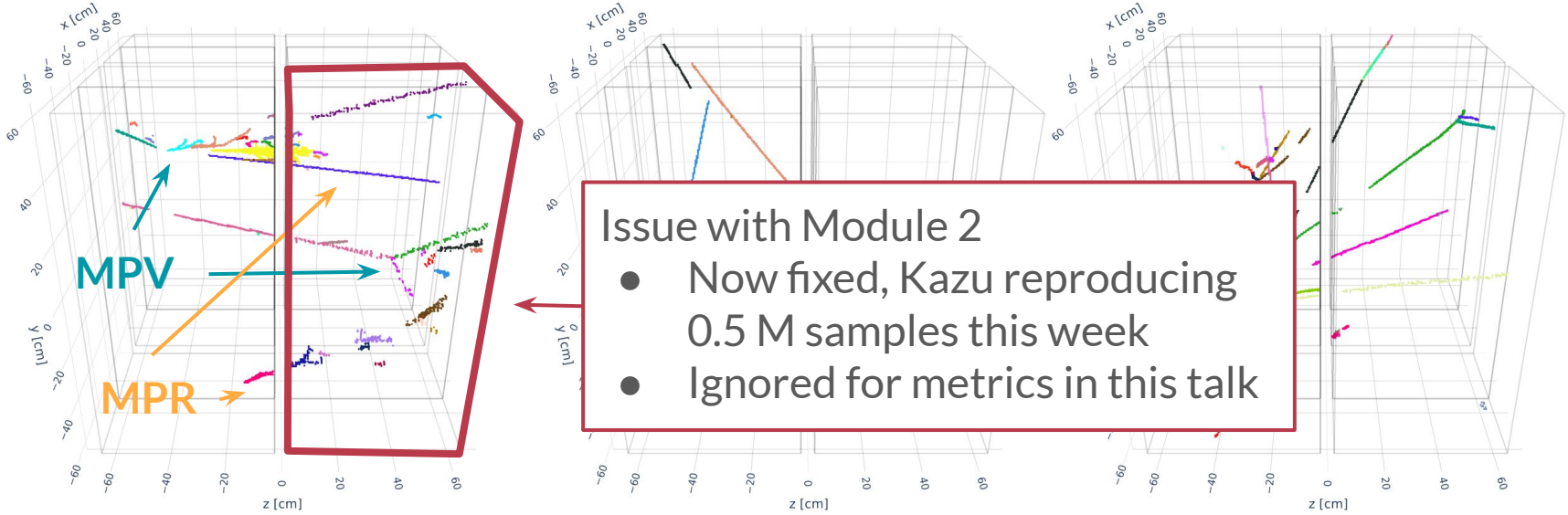


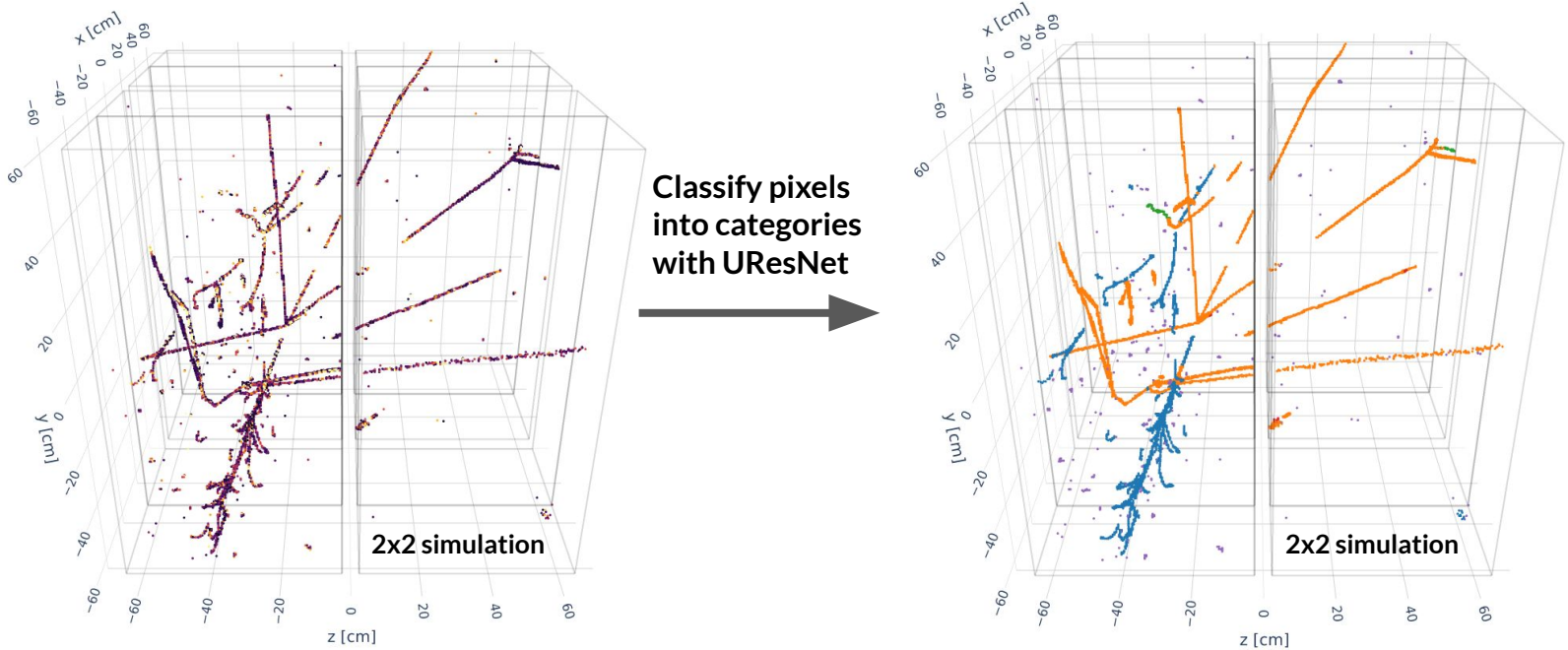
Issue with Module 2

- Now fixed, Kazu reproducing 0.5 M samples this week
- Ignored for metrics in this talk

Semantic Segmentation

Separate **topologically different** types of activity

- Tracks, Showers, delta rays, Michel electrons, low energy blips



Paper: PhysRevD.102.012005

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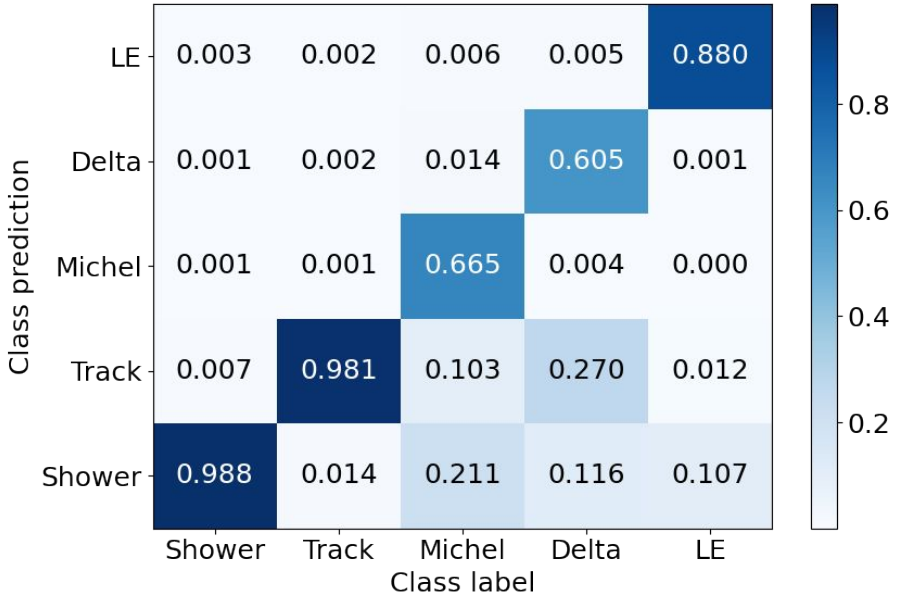

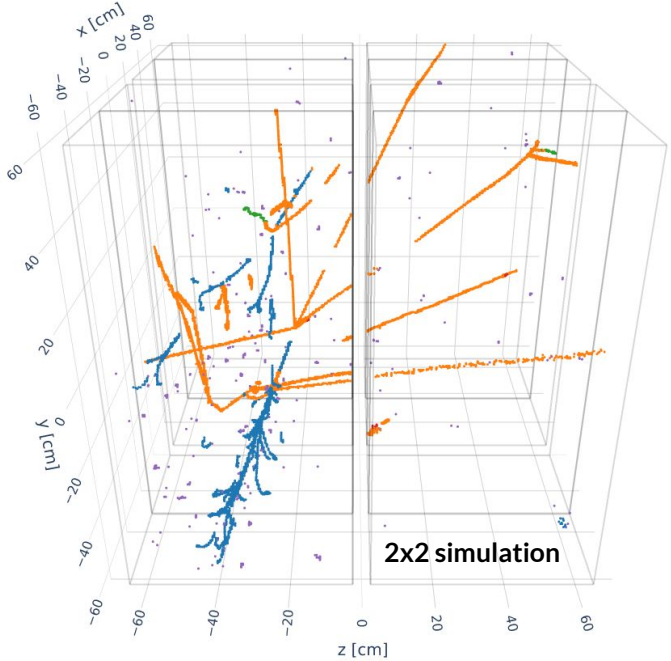

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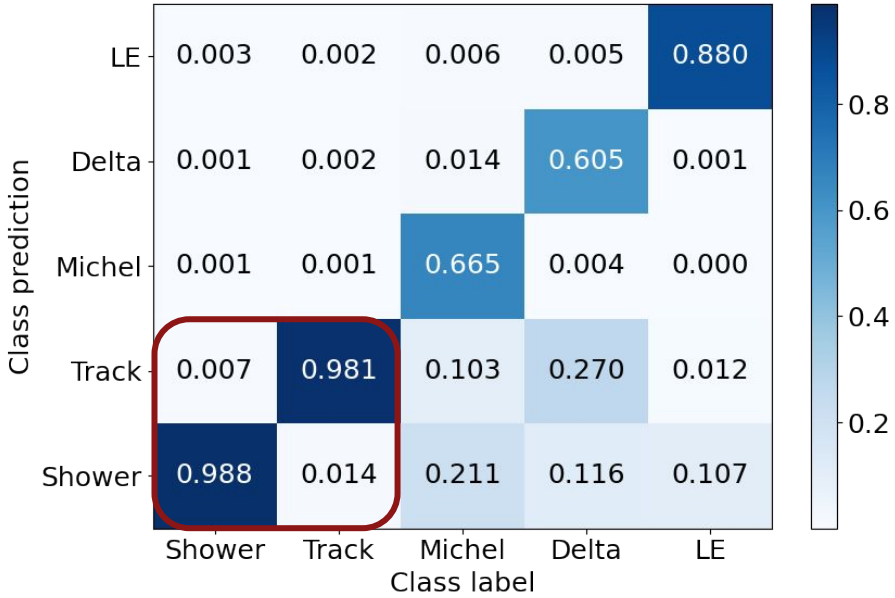
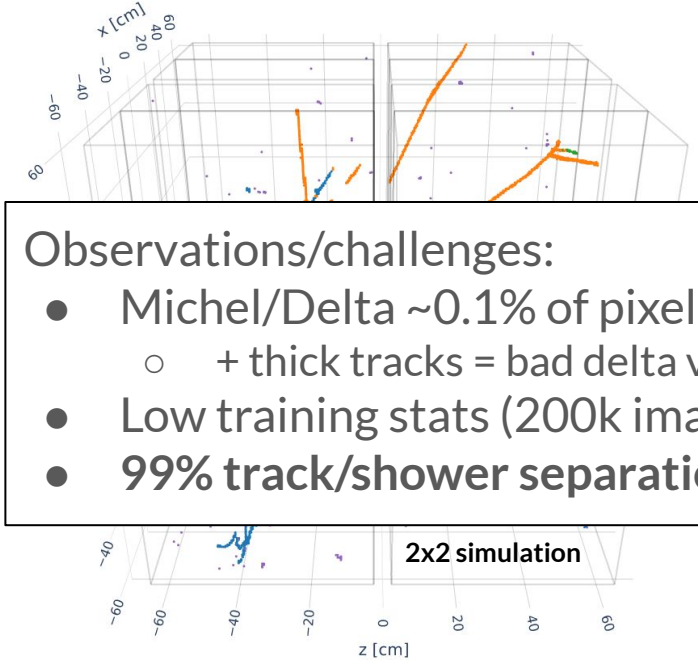




Observations/challenges:

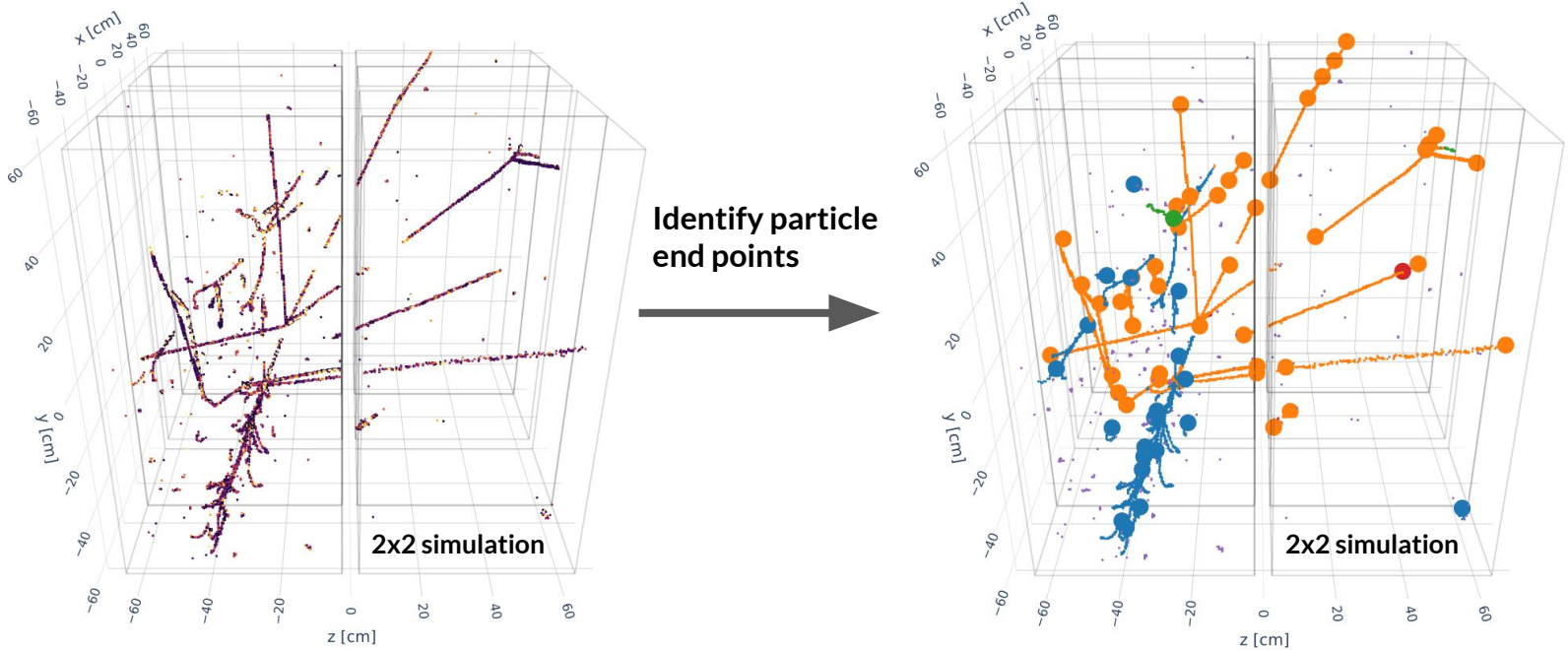
- Michel/Delta ~0.1% of pixels
  - + thick tracks = bad delta visibility
- Low training stats (200k images)
- **99% track/shower separation**

Paper: PhysRevD.102.012005

Points of Interest

Identify start points of showers and end points of tracks

- Tracks, Showers, delta rays, Michel electrons, low energy blips



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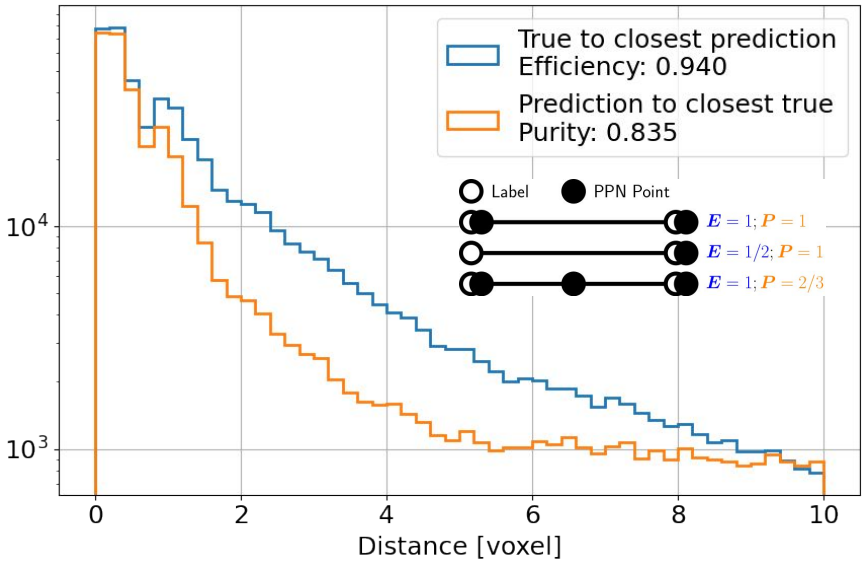

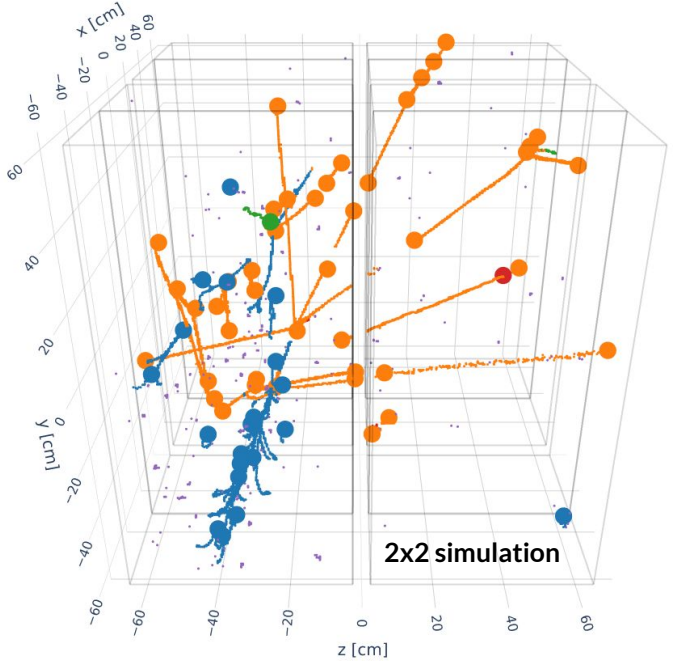

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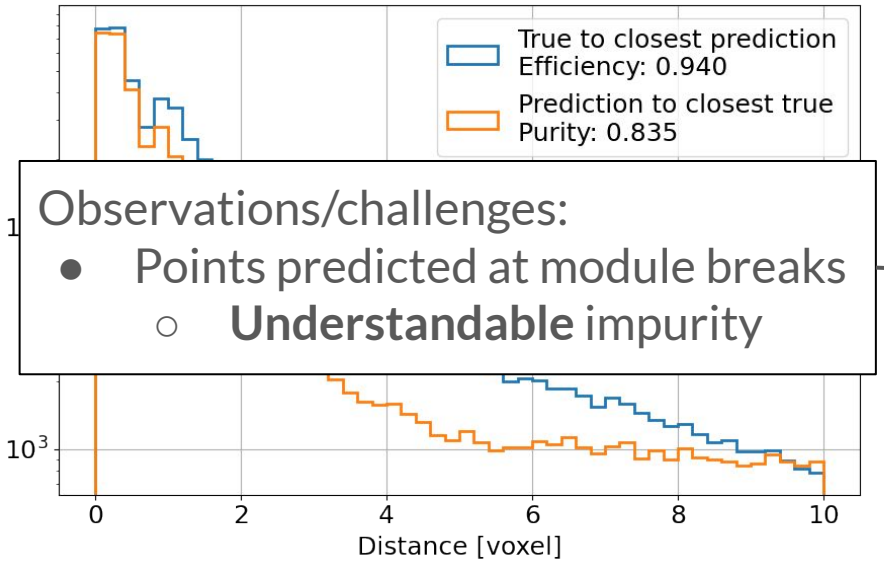
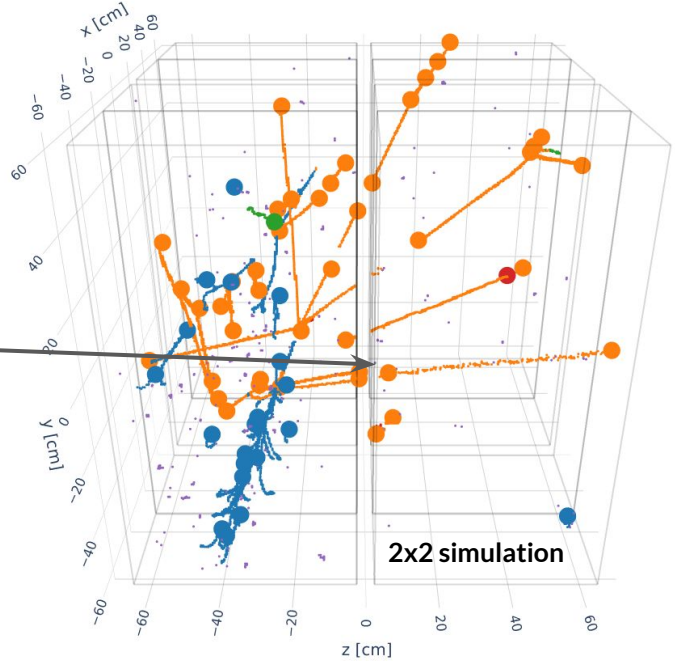


Observations/challenges:

- Points predicted at module breaks
  - **Understandable** impurity



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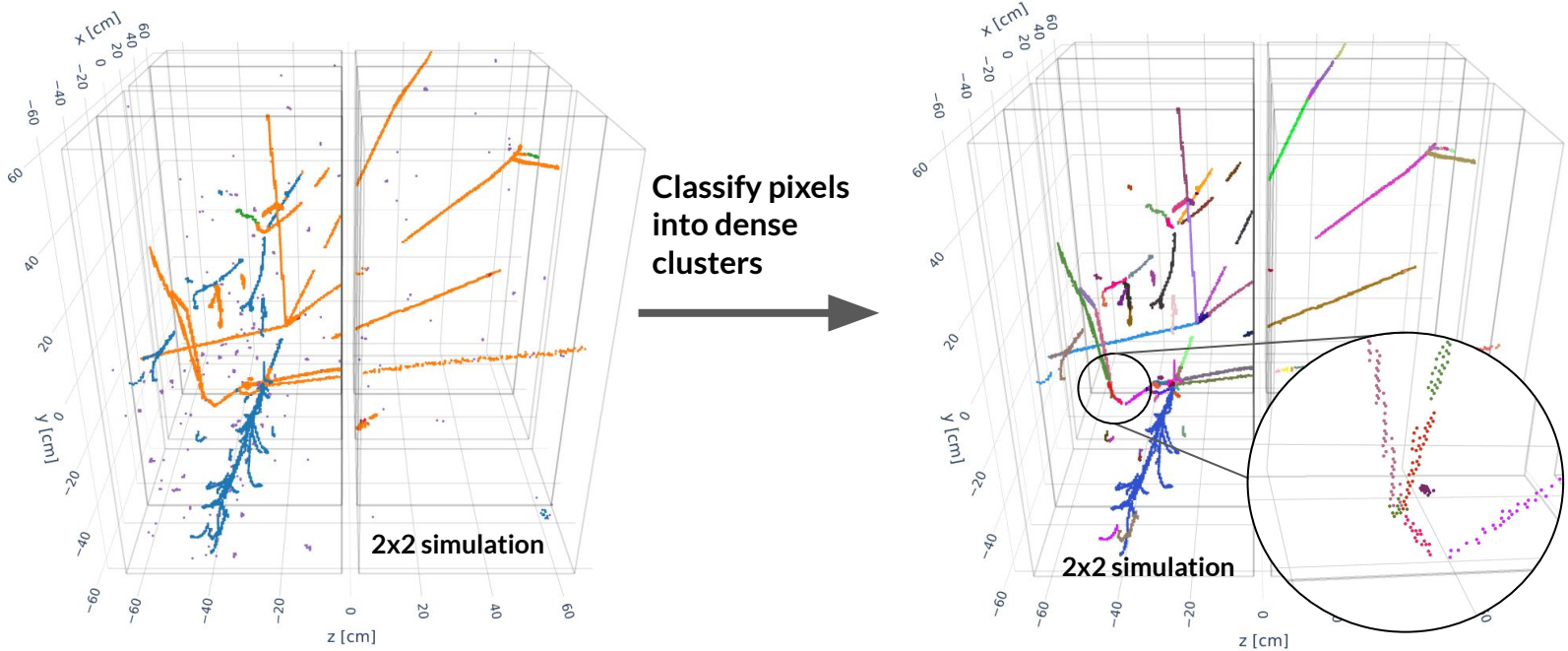
Dense Fragment Formation

Break track/shower fragment instances **where constituent pixels touch**

- Cluster track/shower **fragments** at this stage



Paper: arXiv:2007.03083

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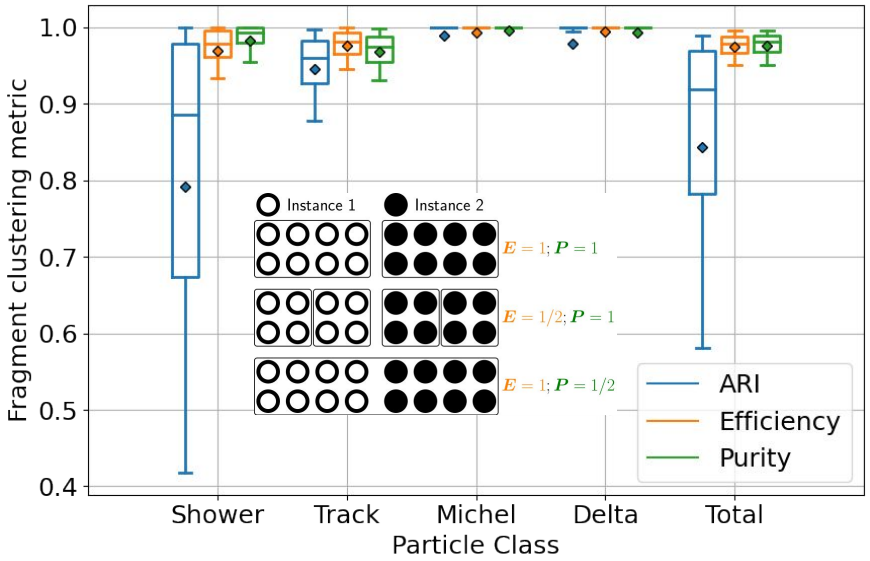

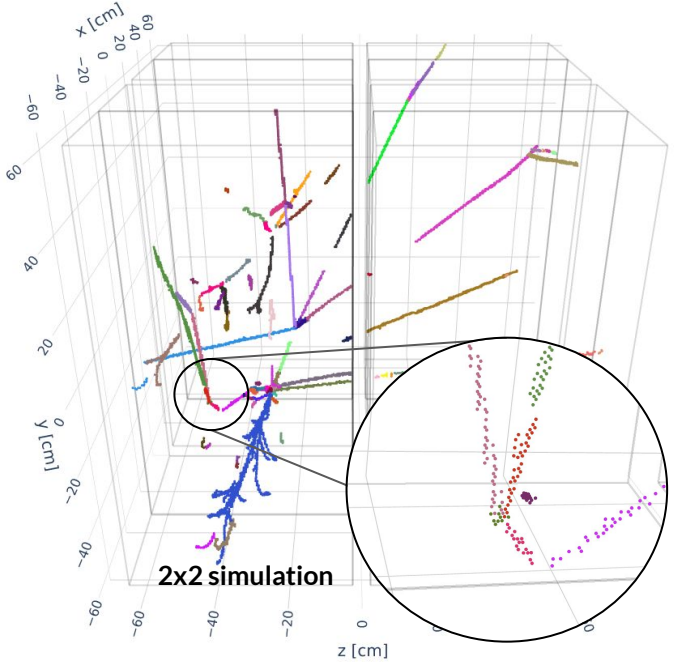

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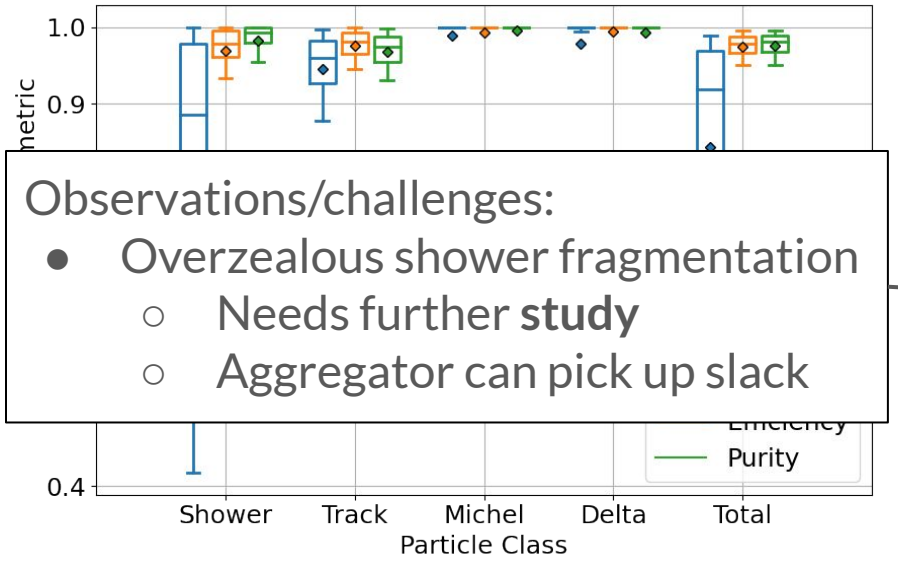
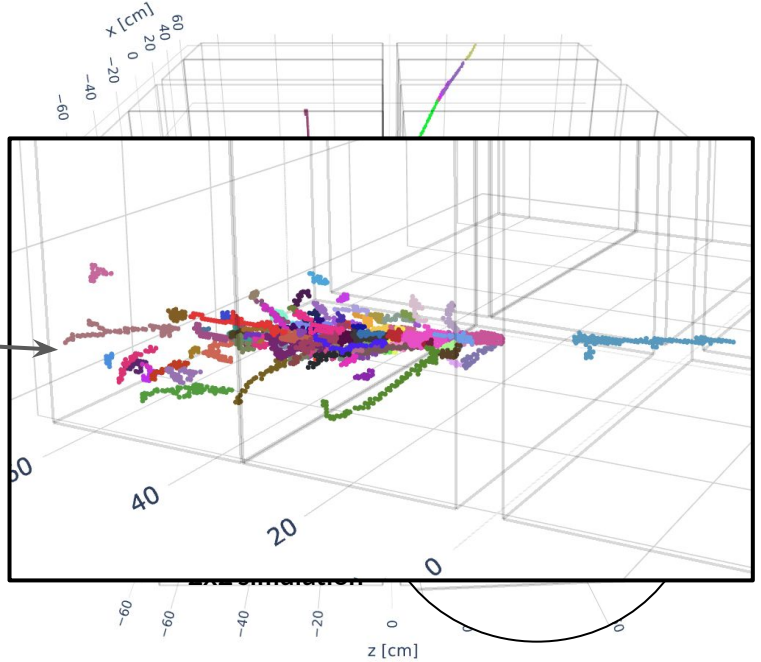


Observations/challenges:

- Overzealous shower fragmentation
  - Needs further **study**
  - Aggregator can pick up slack



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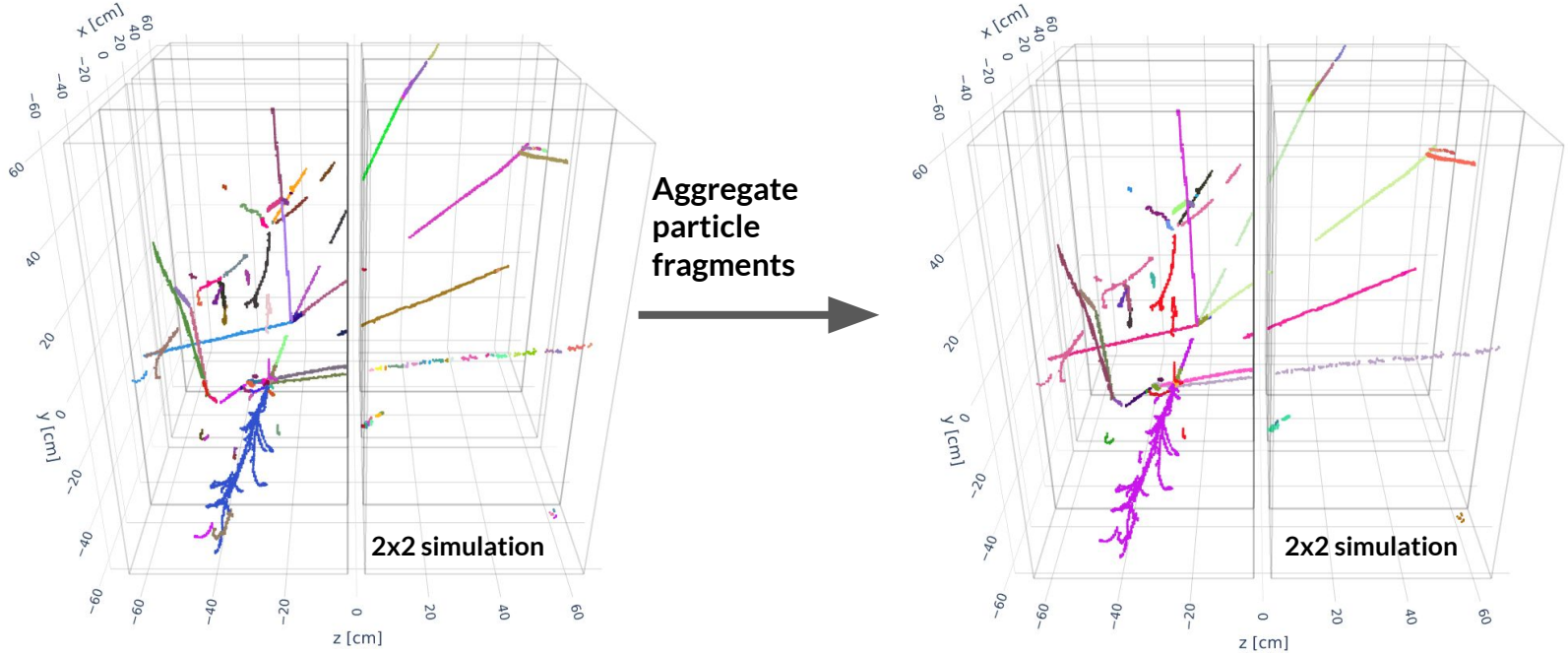
Particle Aggregation

Aggregate track/shower fragment instances into **particles**

- Find edges that connect **fragments that belong together**



Paper: PhysRevD.104.072004

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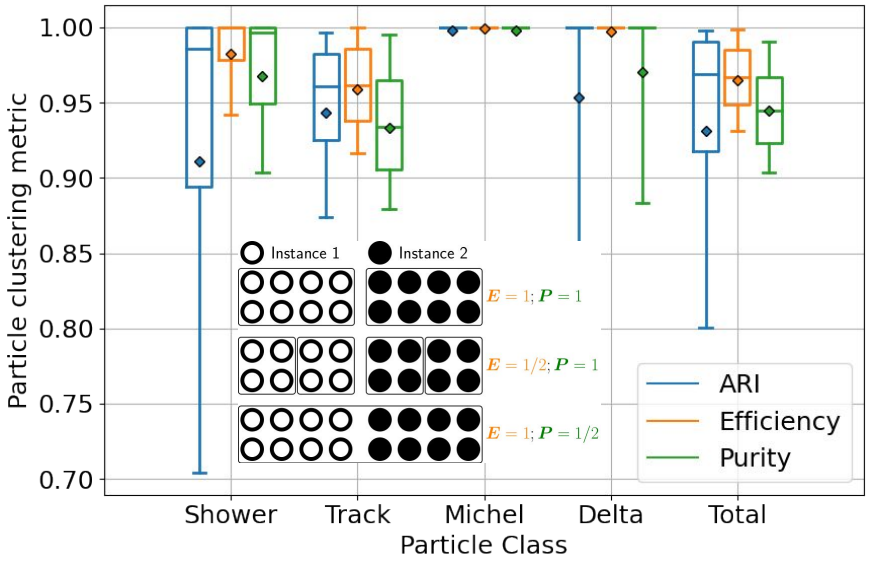

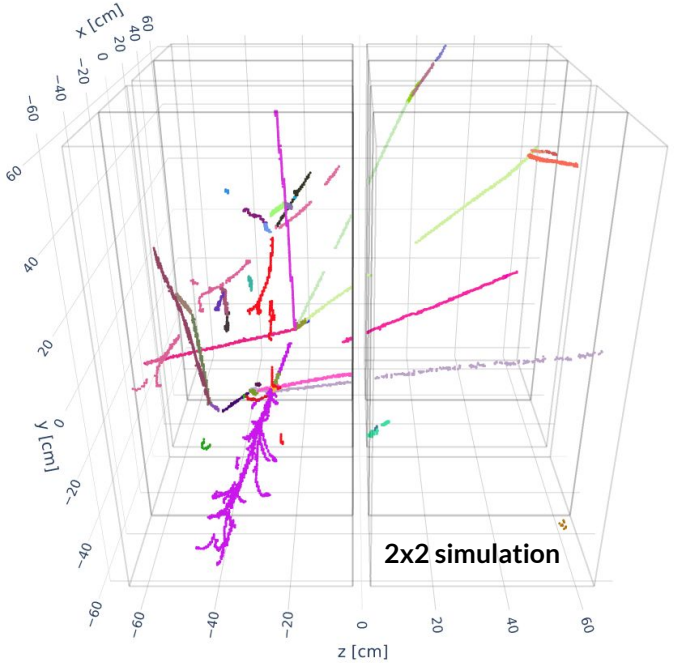

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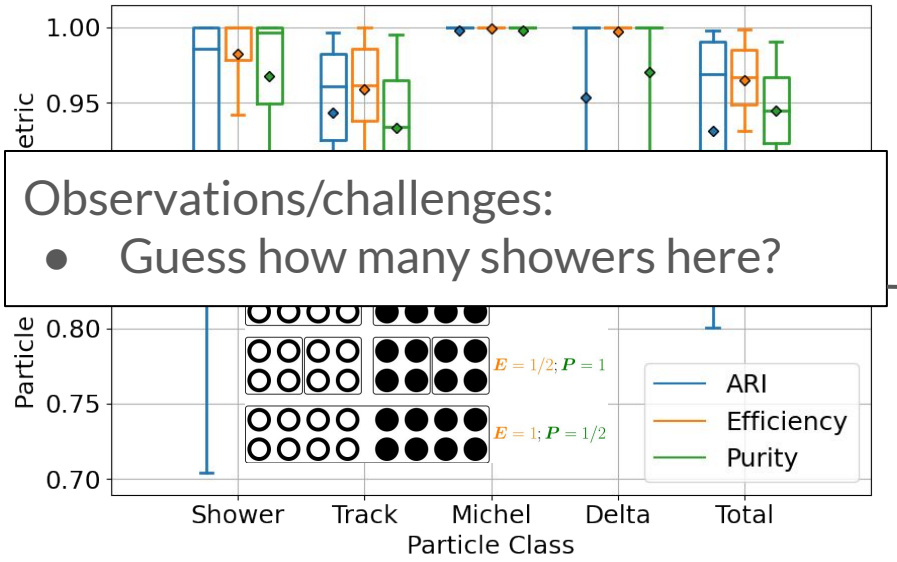
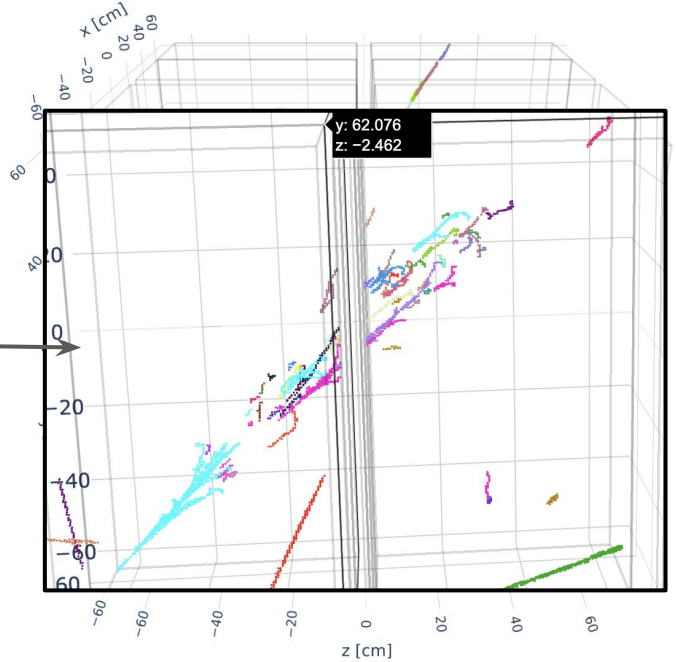


Observations/challenges:

- Guess how many showers here?



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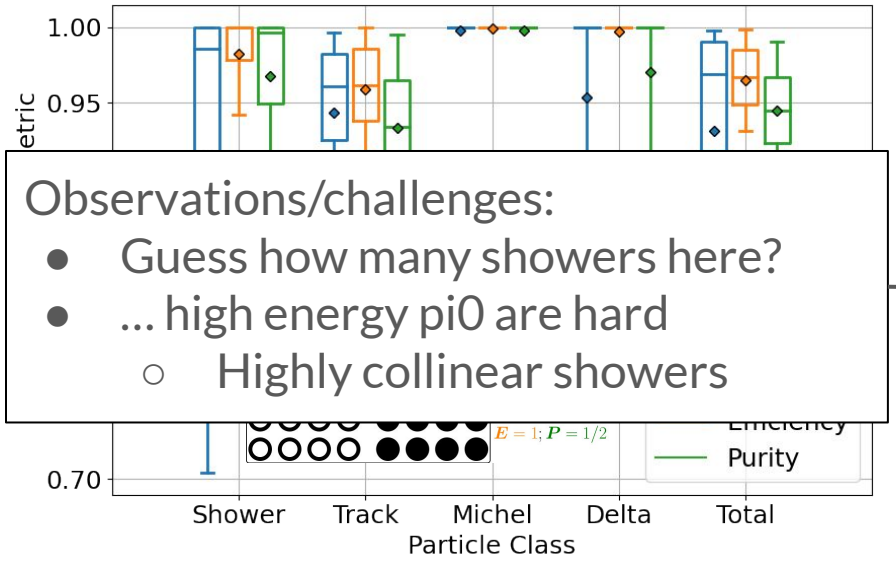
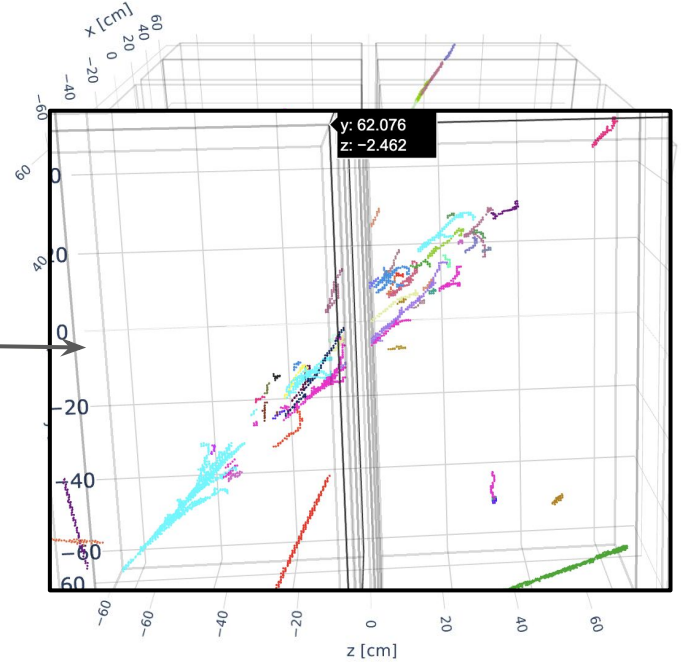


Observations/challenges:

- Guess how many showers here?
- … high energy pi0 are hard
  - Highly collinear showers

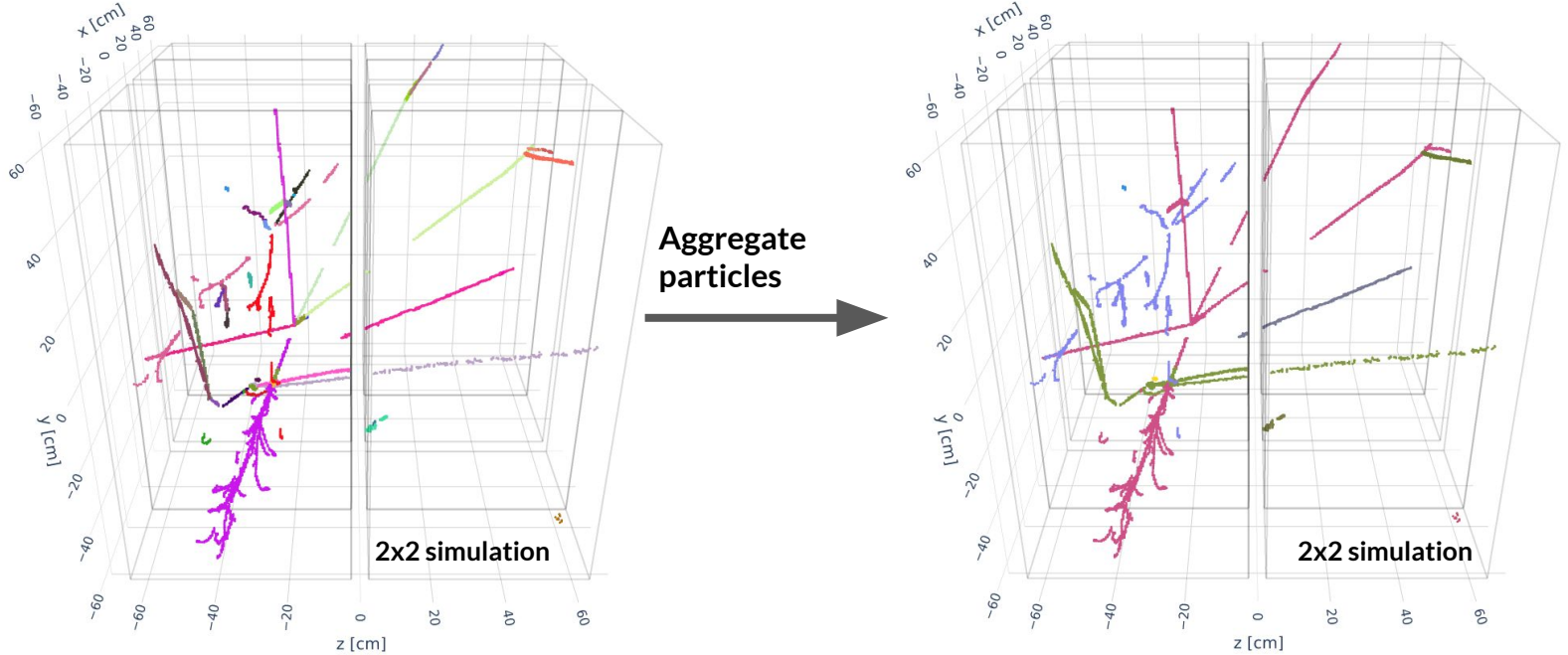


Paper: [PhysRevD.104.072004]

Interaction Aggregation

Aggregate track/shower instances into **interactions**

- Find edges that connect **particles that belong together**



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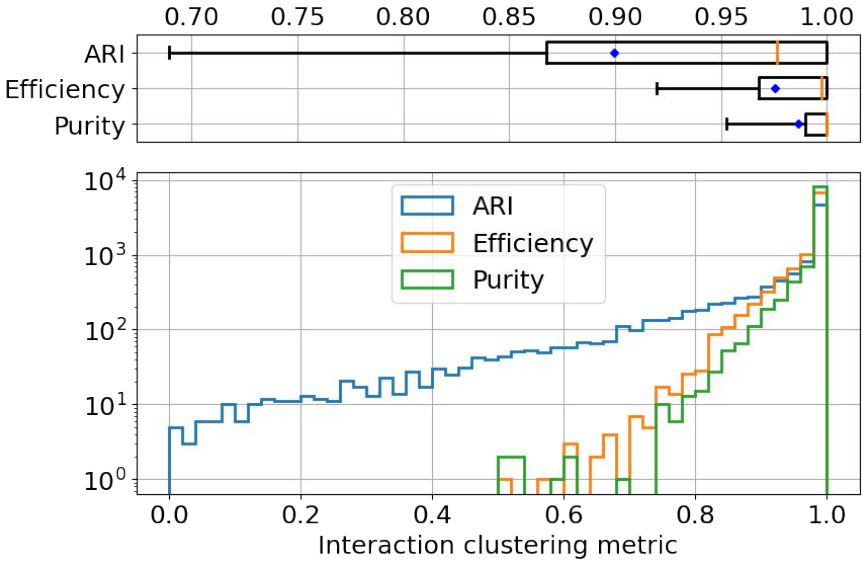

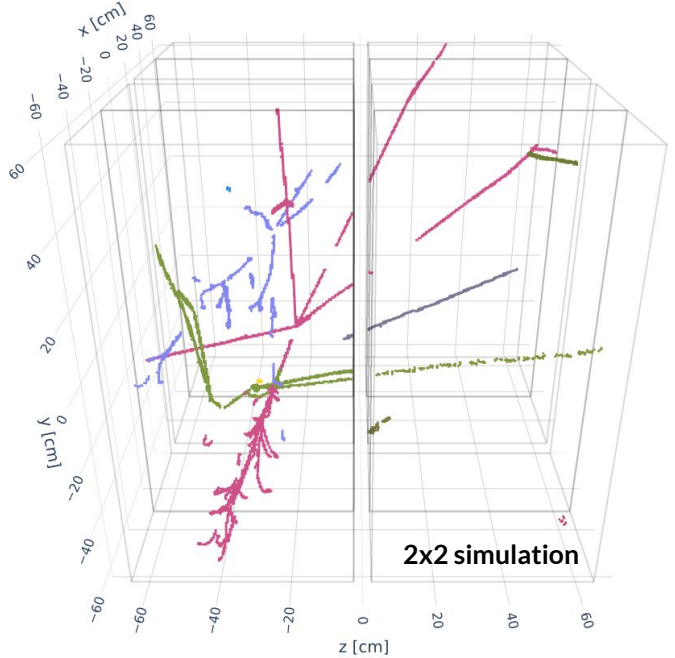

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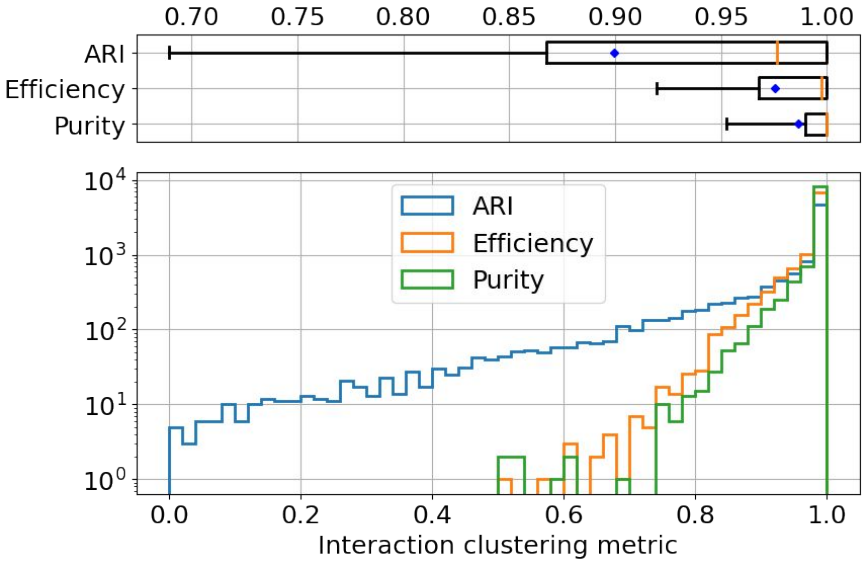

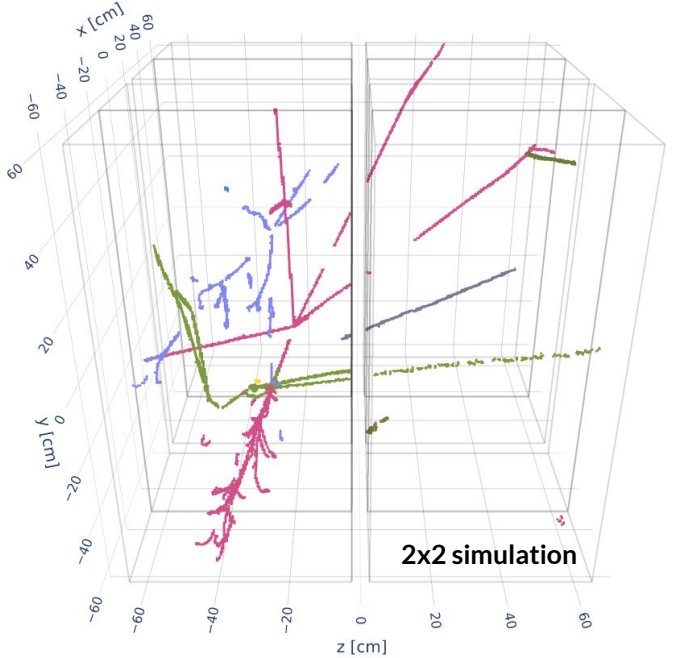

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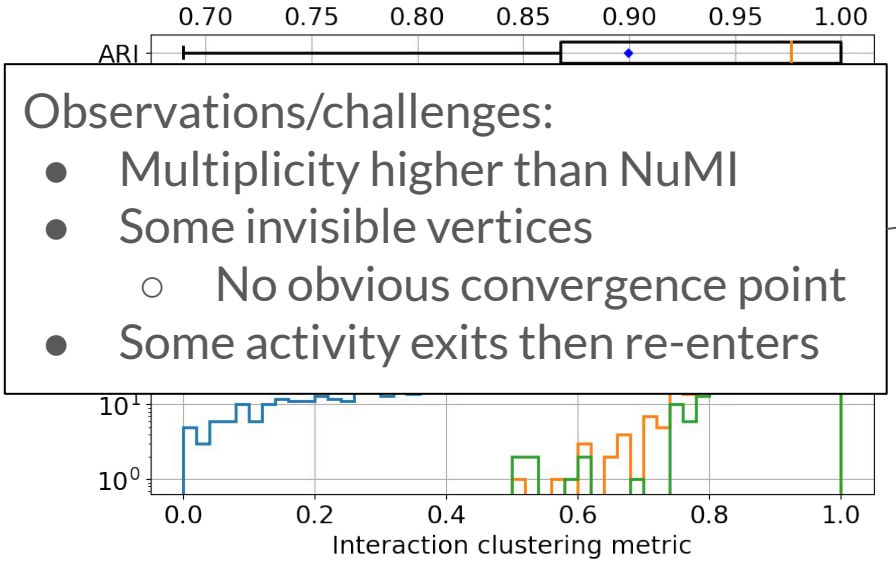
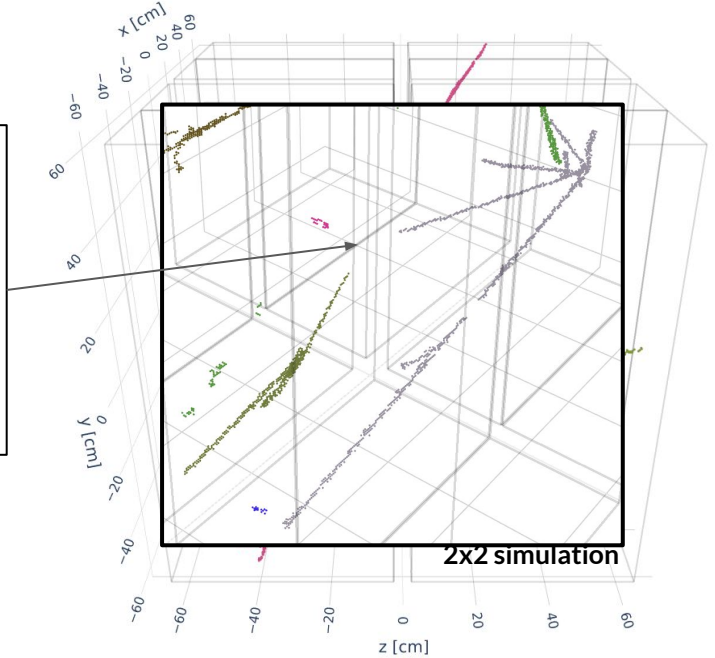


Observations/challenges:

- Multiplicity higher than NuMI
- Some invisible vertices
  - No obvious convergence point
- Some activity exits then re-enters



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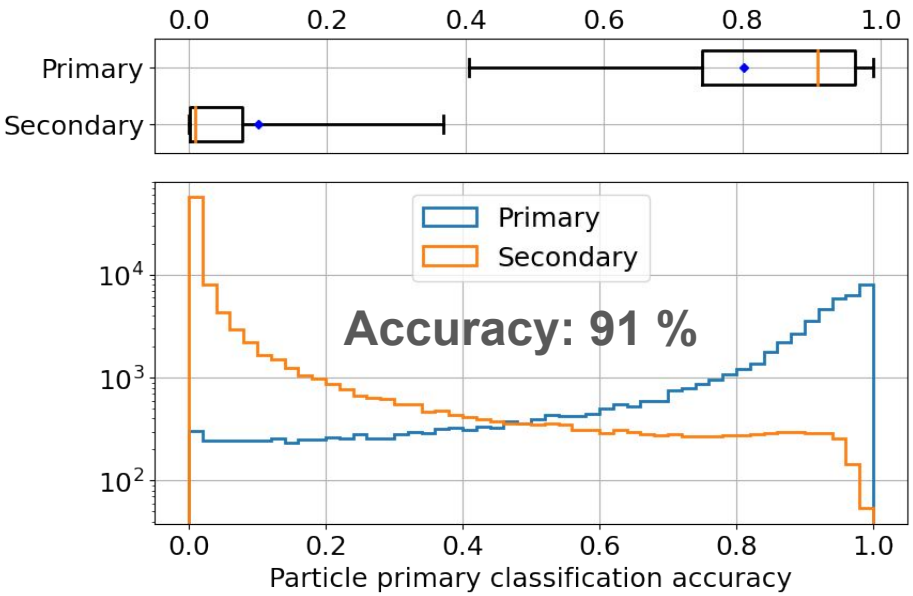
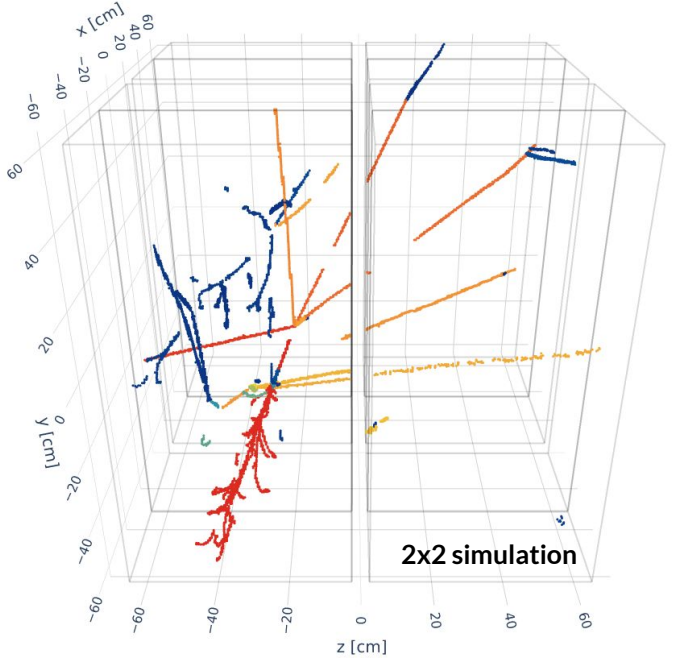
Primary Identification

Identify particle originating from the **primary vertex**

- **Secondaries — Primaries**





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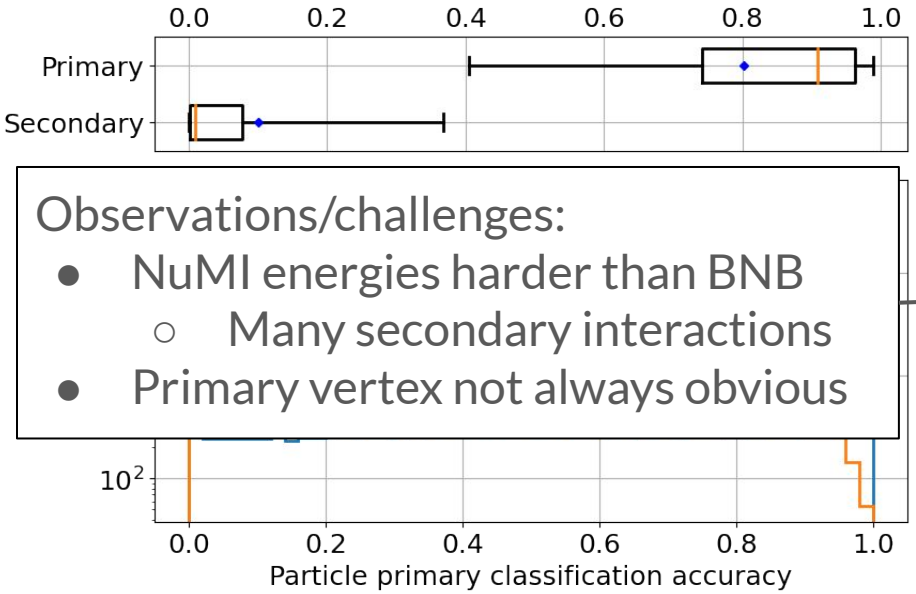
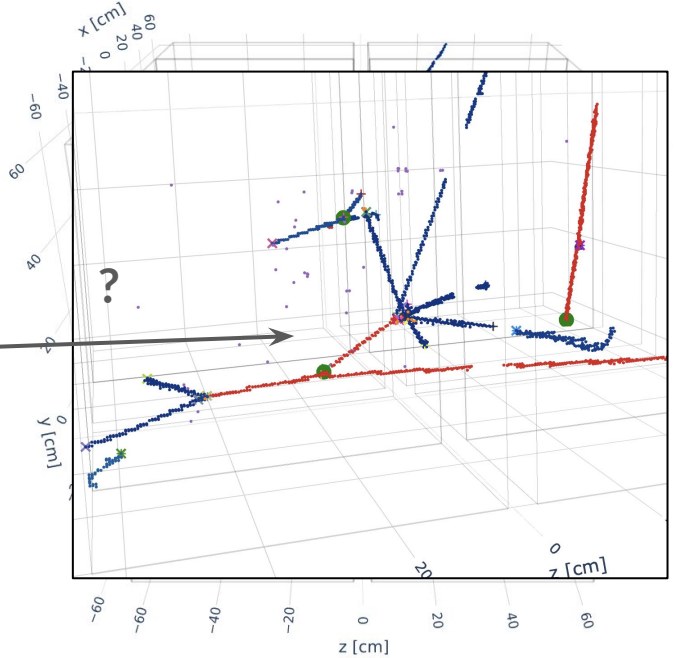


Observations/challenges:

- NuMI energies harder than BNB
  - Many secondary interactions
- Primary vertex not always obvious



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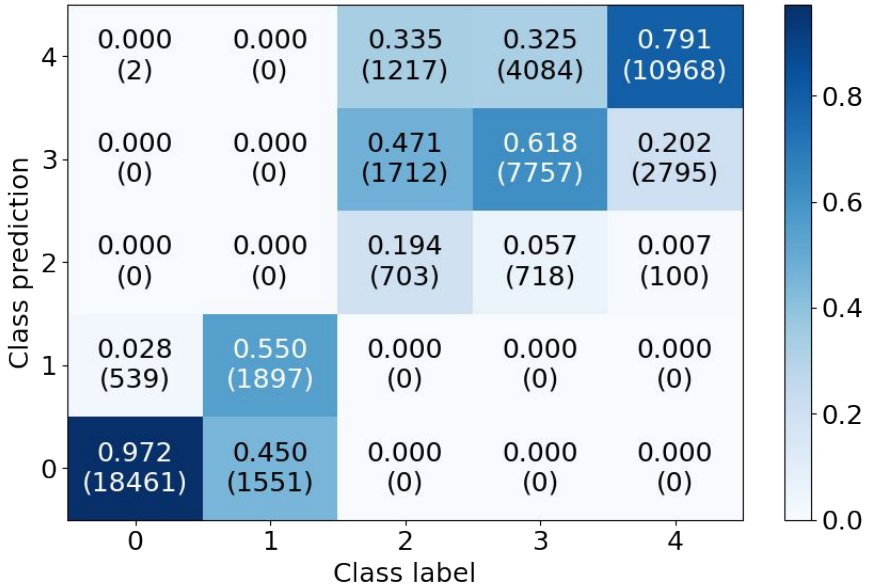
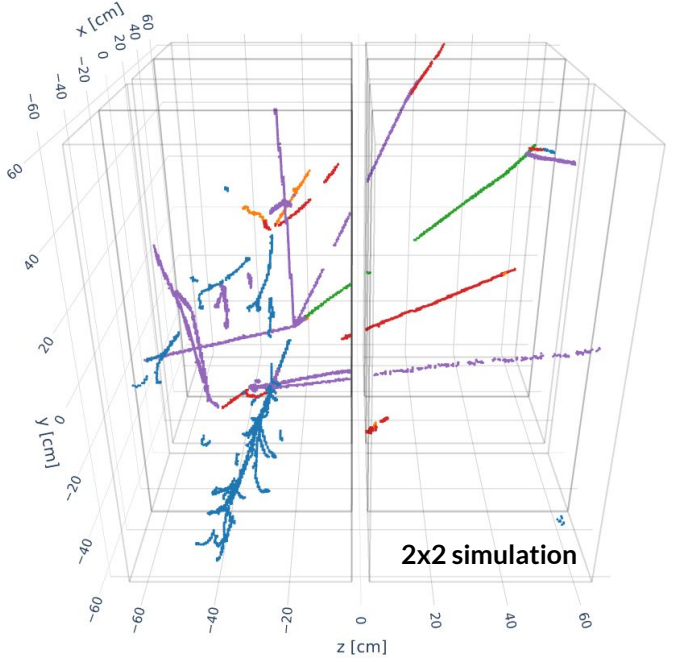
Particle Identification

Classify **particles** within interactions into different species

- Photons (0), Electron (1), Muons (2), Pions (3), Protons (4)





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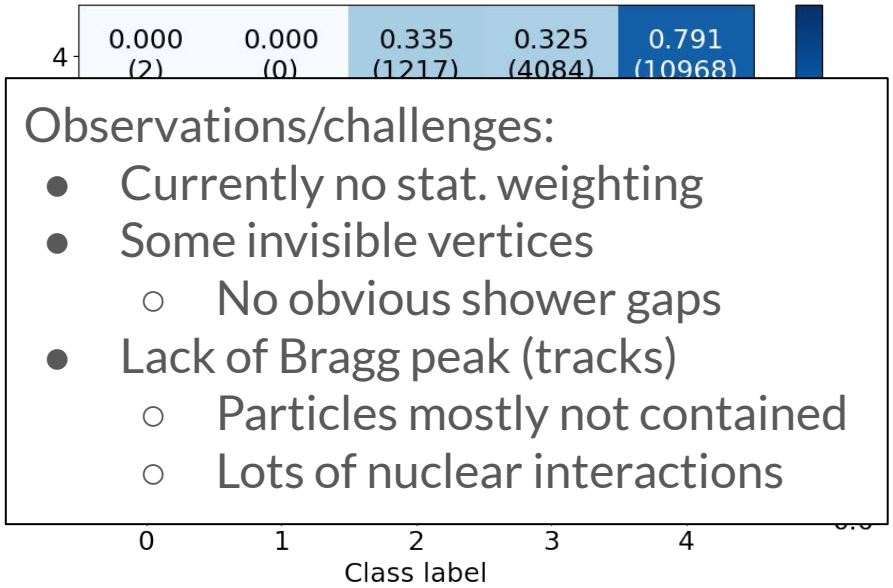
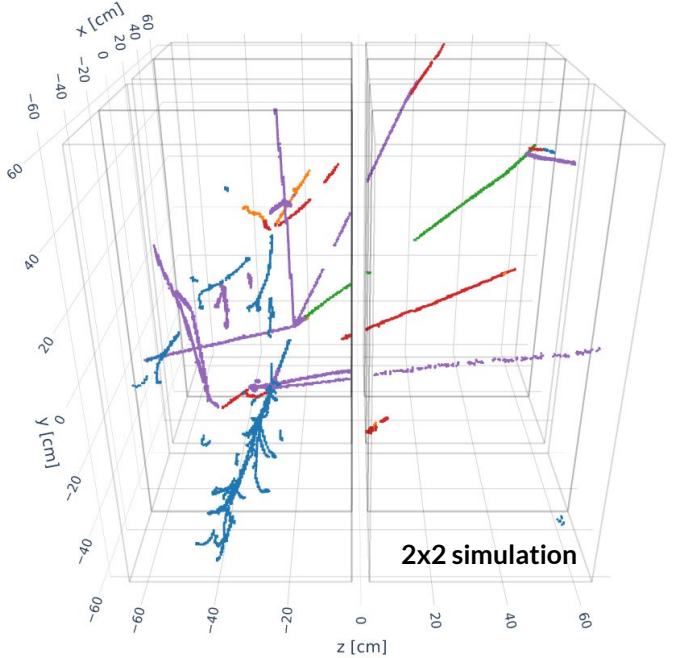


Observations/challenges:

- Currently no stat. weighting
- Some invisible vertices
  - No obvious shower gaps
- Lack of Bragg peak (tracks)
  - Particles mostly not contained
  - Lots of nuclear interactions



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SBN-2x2 Joint ML Workshop

Goal: Familiarize analyzers with the inner workings of the ML-based reco. chain

Where: Tufts University, Boston, MA

When: 22-26 July, join us!!! https://indico.slac.stanford.edu/event/8926/

Conclusions

Current Status:

- New training sample tested!
  - Looking good, addressed most issues
  - Module 2 bug fixed, new sample underway
- Transfer train with fix this week
- MR5 beta 3 (?) imminent
  - Should process up to LArCV to validate ASAP, then push through mlreco next week

Check out this brand new **2x2** [interactive reconstructed event]