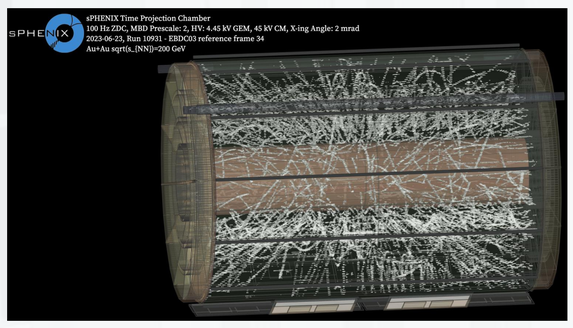
Clustering hits of Time Projection Chamber by using machine learning and neural networks at sPHENIX

Zhongling Ji, UCLA *for the sPHENIX Collaboration*

SEPTEMBER 3-9, 2023 | HOUSTON, TEXAS
Quark Matter 2023
The 30th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions

TPC Event Display

The figure shows TPC hits in Au+Au 200 GeV collisions. Due to the high collision rate at RHIC and thus pile up in the TPC, clustering hits is a difficult task. This motivates using neural networks (NN) to perform clustering in the TPC.



Traditional Clustering (CCA)

- Charged particles will ionize electrons when passing through the TPC. Ionized electrons will drift to the two sides of TPC under the electric field. Their positions are determined by both the readout positions and the drift time.
- The current Connected Component Analysis (CCA) method clusterizes hits if they are connected. Clusters are centered around hits with the highest energies. They are separated if there is a dip between two energy peaks.

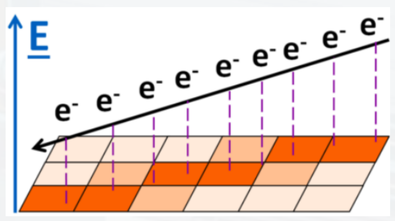
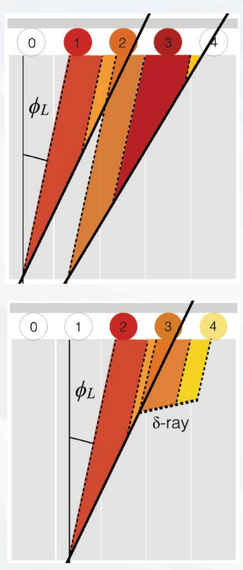


Figure from TexAT TPC

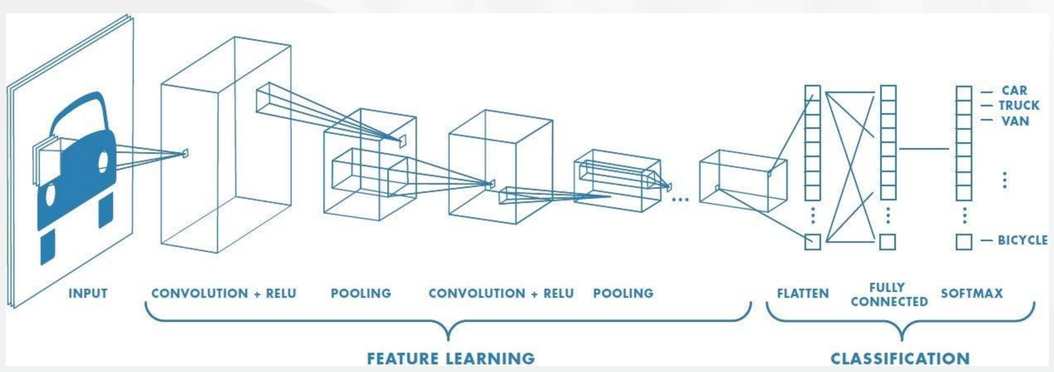
δ-electrons

- Upper figure: Two clusters are separated if there is a dip between two peaks.
- Lower figure: δ-electrons can produce two peaks or large clusters, which can make cluster centroid identification difficult for traditional clustering algorithms.
- This motivates using a NN clusterizer to identify and improve cluster position resolution in these cases.
- Figures from JINST 9, P09009 (2014).



Convolutional Neural Networks

- CNNs are widely used in imaging processing. For each layer of the CNN, the same weights on 3x3 pixels are shared over all pixels.
- Figure from blog by Sumit Saha on Sept. 15, 2018.

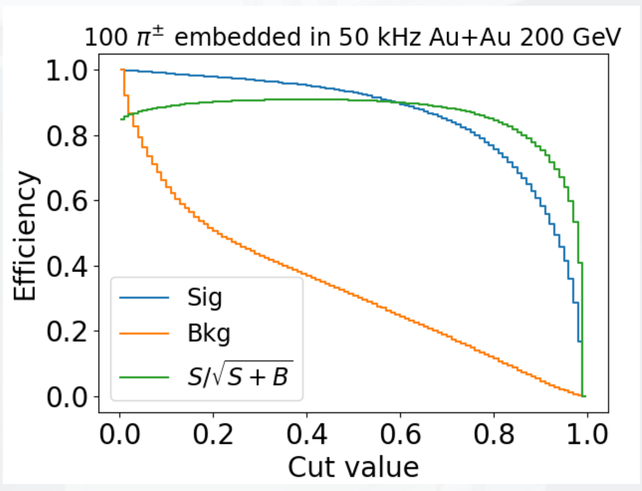


NN Structures for Clustering

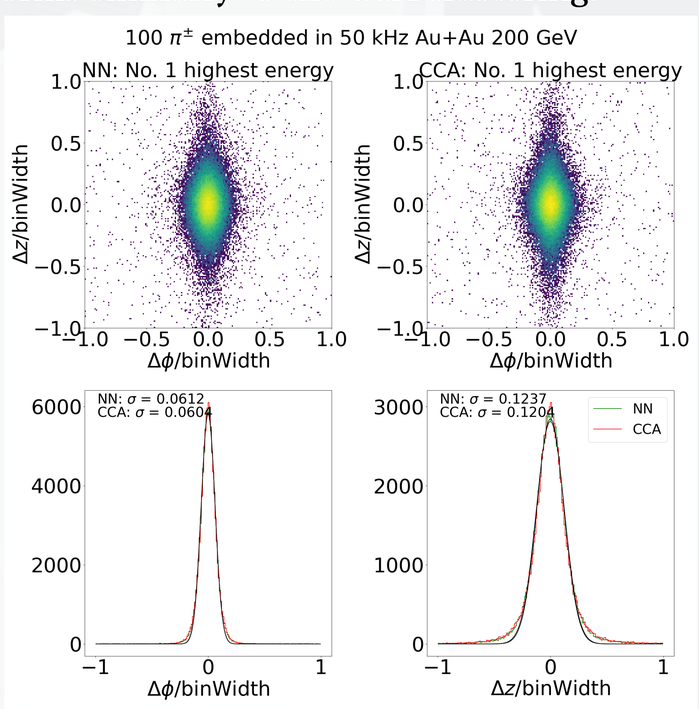
- The TPC readout consists of 48 layers. Each hit has an ADC value that is proportional to the energy deposited and a ϕ-z (drift time) coordinate. The hits can be taken as an "image" and their ADC values are the "colors" of the "image". Use two CNNs.
- Input of NNs: ADC, hit layer, and global z position of 11x11 hits.
- Output of NN1: Whether a true cluster was present.
- Output of NN2: The reconstructed cluster ϕ and z positions.

NN Clustering Performance

The output of NN1 gives a single value. Applying different cuts on this value gives different rates of signal (true clusters) to background (background clusters). Decreasing this value increases the signal efficiency but also includes more background. The best cut value is chosen when $S/\sqrt{S+B}$ is maximized.



- The NN2 outputs are the reconstructed cluster ϕ and z positions.
- We calculate the difference between reconstructed and true ϕ and z positions both for NN and CCA.
- The NN clustering performs similarly to the CCA clustering.
- Upper left: Δz *vs* $\Delta\phi$ between NN reco and true positions.
- Upper right: Δz *vs* $\Delta\phi$ between CCA reco and true positions.
- Lower left: σ of $\Delta\phi$ from NN and CCA reconstructions.
- Lower right: σ of Δz from NN and CCA reconstructions.



Conclusions and Outlook

- The framework of NN clustering at sPHENIX is constructed.
- The NN clustering performs similarly to the CCA clustering.
- We aim to improve the performance of the NN clustering with better truth-reconstructed cluster associations..

U.S. DEPARTMENT OF ENERGY | Office of Science
UCLA
Brookhaven National Laboratory