Segmenting Particle Showers in the ATLAS Detector with PointNet

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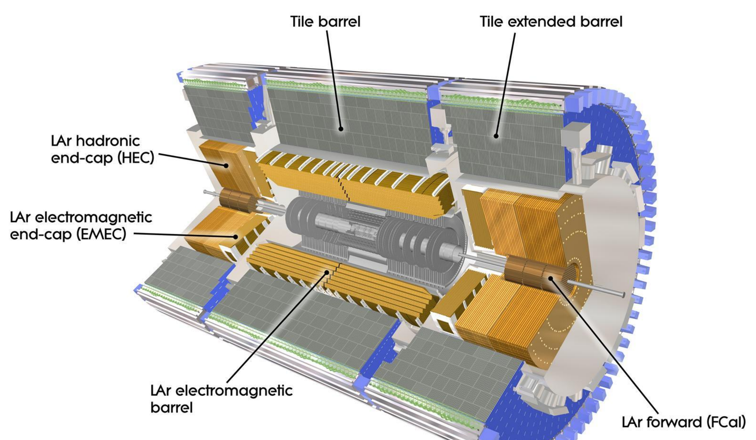
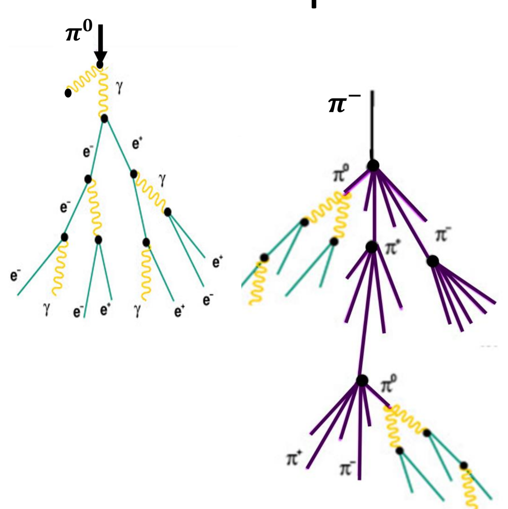
The ATLAS Detector

The detector records a snapshot of the proton-proton collision events occurring at the ATLAS collision point in the LHC. The inner tracking layers of the detector record tracks left by the charged particles produced in the collision. The granular calorimeter layers record the sum of all produced particles' energy deposits into each cell of the calorimeter. This information is used to reconstruct the set of truth particles produced in a collision, as well as the particles' truth energy.



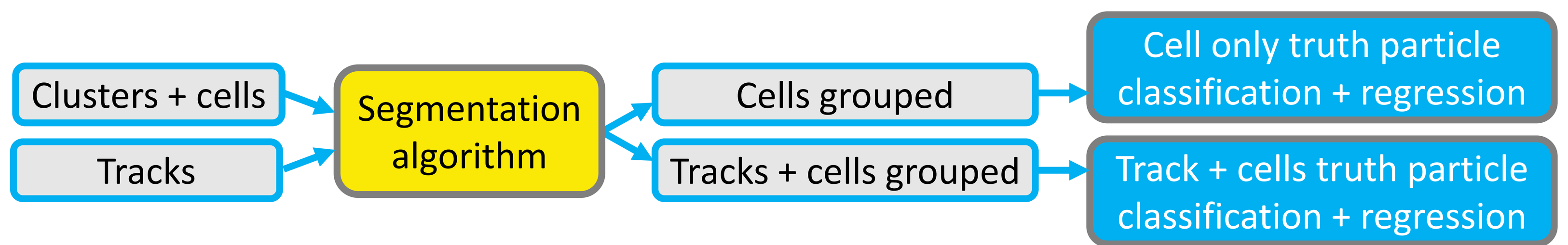
Particle Showers

The truth particles of a collision uniquely shower into other particles as they travel through the layers of the calorimeters. Charged pion showers lose energy to the nuclei of the calorimeters, requiring their energy deposits to be distinguished from the neutral pion showers and further corrected.



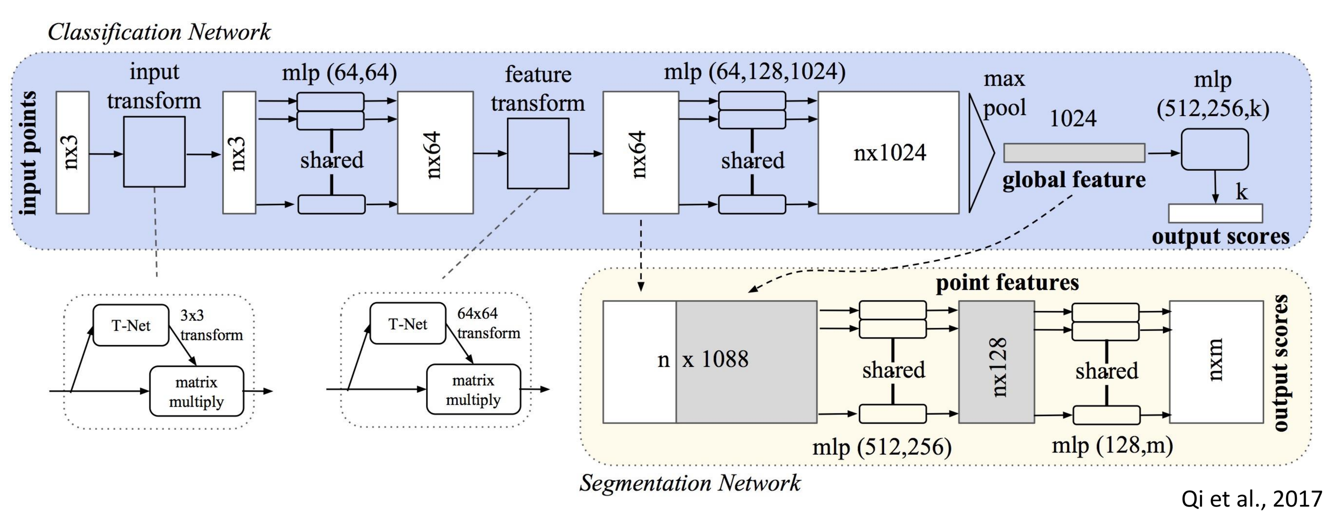
Particle Flow Algorithm

Currently classical approaches are used to correct energy deposits and reconstruct the set of truth particles and their associated energies. ML4Pions team has applied deep learning to significantly improve these processes. A stage of this modalized machine learned process that is not yet developed is a segmentation algorithm to learn which cell deposits are associated with which track deposits.



PointNet

PointNet is a deep learning segmentation network applied to geometric point cloud data in order to learn per point info.

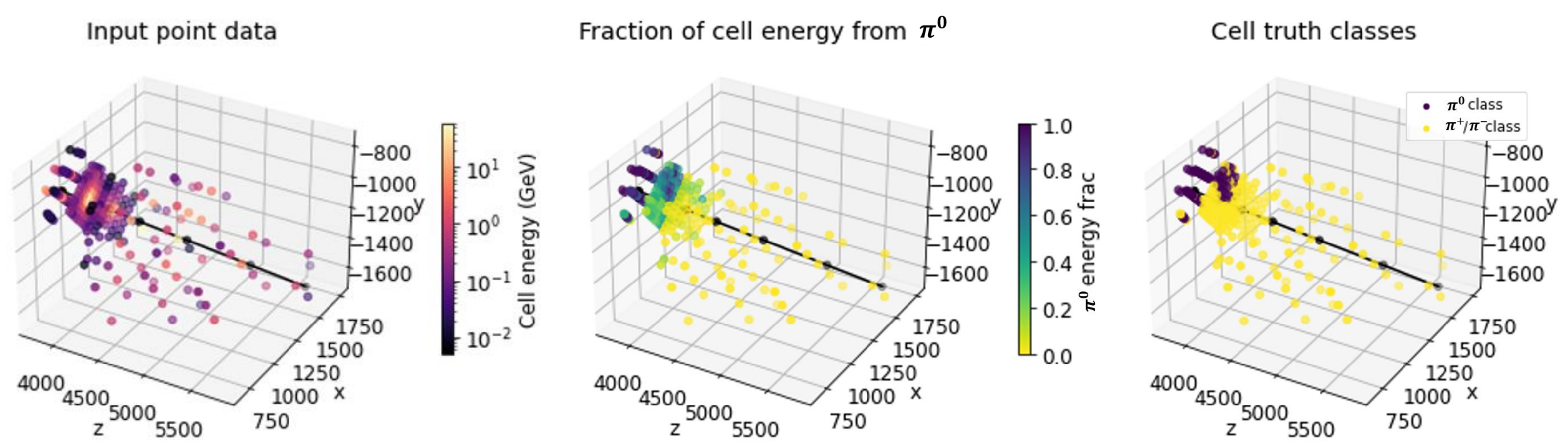


Training Data

PointNet is applied to collision event data to classify the calorimeter cell energy deposits as primarily a certain particles energy deposit.
The Dataset trained on is of simulated single rho particles which decay to a charged and a neutral pion.

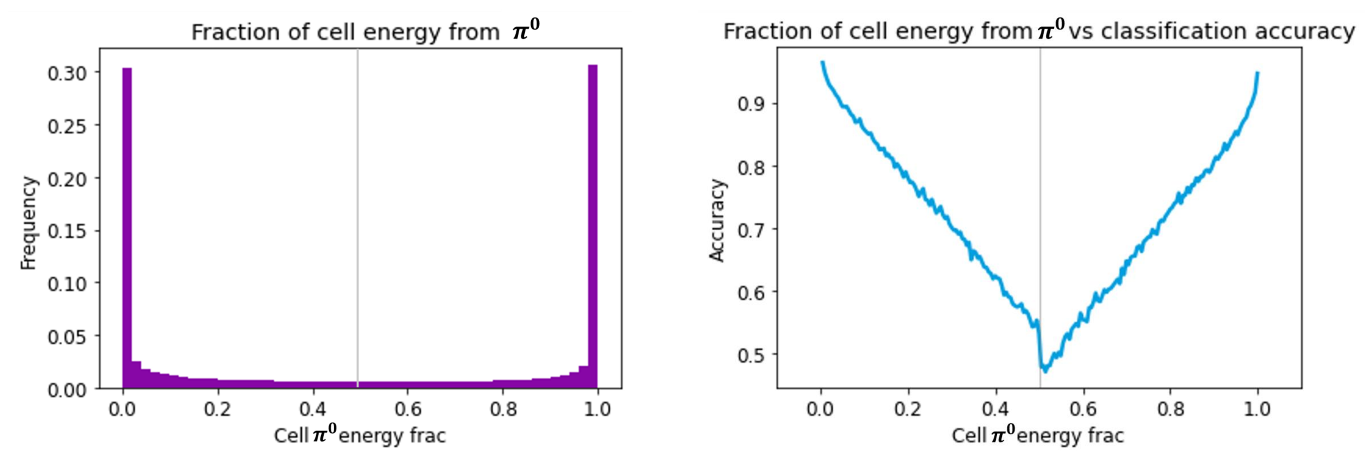
Per point input data: x, y, z, energy of calorimeter cell or momentum of the track, minimum distance to track point, and track Boolean

Per point labels (only for calorimeter cell points): π^0class (1) if majority of the cell's energy is deposited by the neutral pion shower or π^+/π^- class (0) if the majority of the energy is deposited by the charged pion



Results

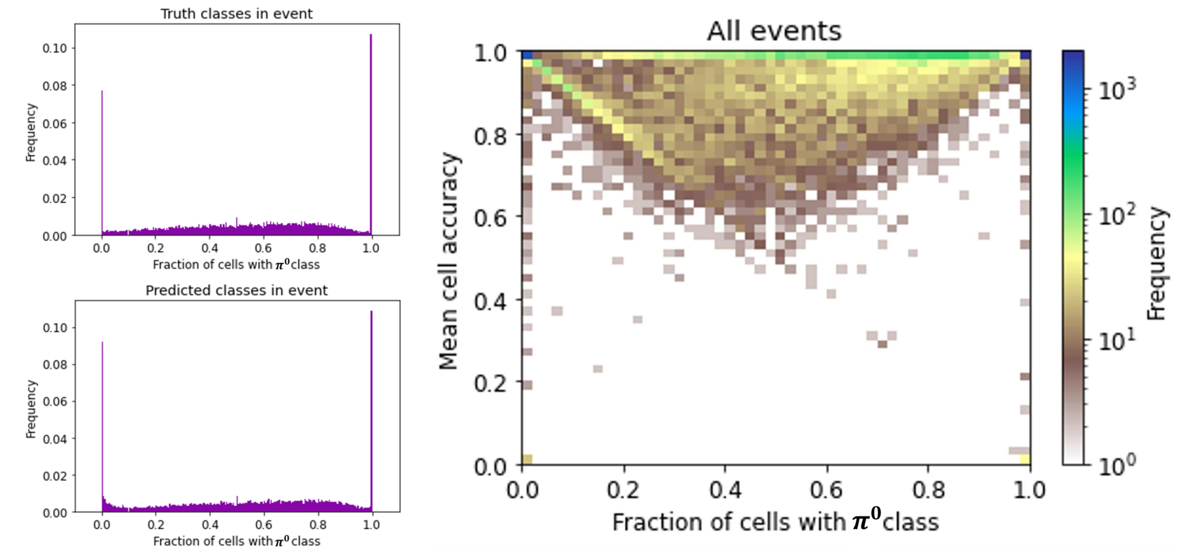
After training until convergence, the model is able to classify the particle depositing the majority of energy into the cell with **87% accuracy.**



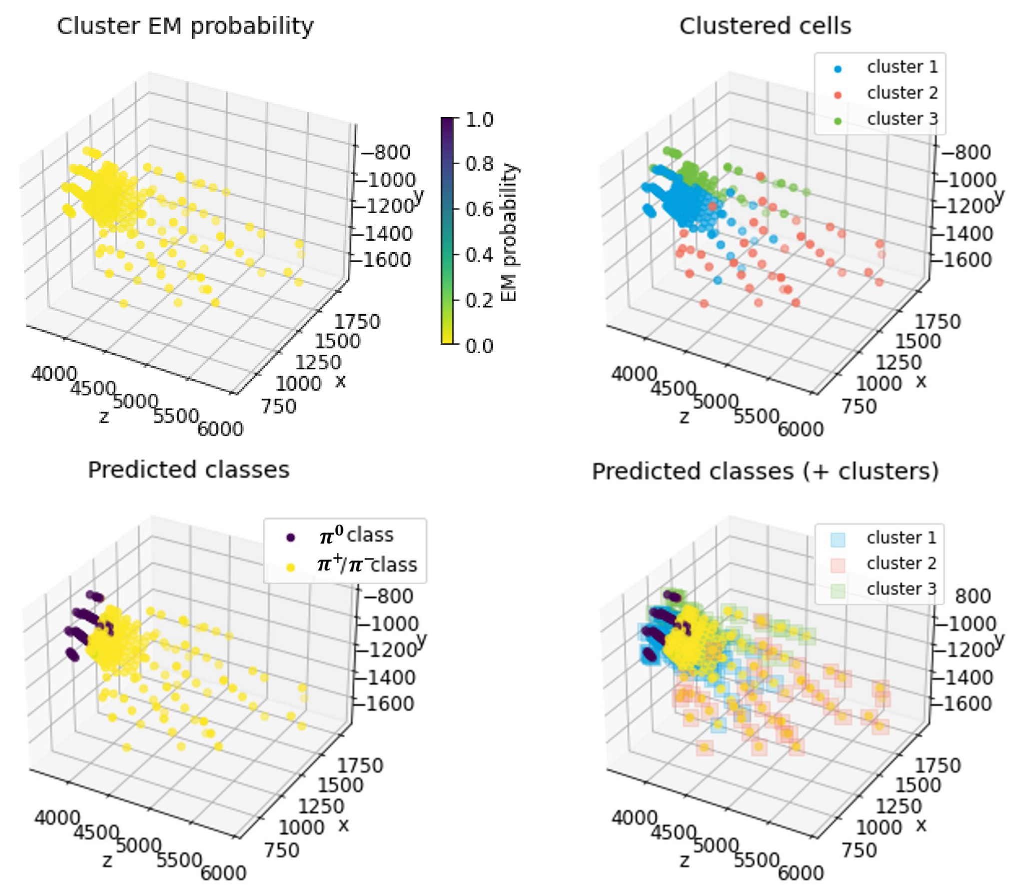
In this dataset 47% of cells have only one particle depositing energy, and these cells are classified with an accuracy of 95%.

Most of the inaccuracies occur when the cell has mixed deposits from both particles, especially around the classification threshold.

Accuracy is also evaluated against the fraction of cells with π^0 class in an event, to determine if events with cells of mixed classifications are learned properly.



Comparing this model's classification accuracy to previous clusterwise EM probability labeling gives a 17% increase in classification accuracy.



Discussion

PointNet could be used in a segmentation algorithm to contribute to a machine learned particle flow energy reconstruction.

Other approaches are mainly focused on per cluster information learning, but these results suggest that per cell learning could improve performance.

A next step with this model is to apply it to particle showers with more tracks and more truth particles in order to pair various tracks with their associated calorimeter cell energy deposits.

Acknowledgements

Much appreciation to Max, Wojtek, and Russell for very helpful input, guidance, and contribution to this project.