Point Cloud Deep Learning Methods for Pion Reconstruction in the ATLAS Detector

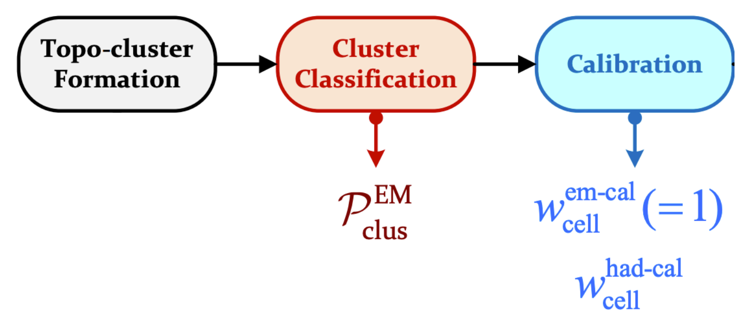
Dilia María Portillo (TRIUMF) on behalf of the ATLAS collaboration

Separating charged and neutral pions as well as calibrating the pion energy response is a core component of reconstruction in the ATLAS calorimeter.

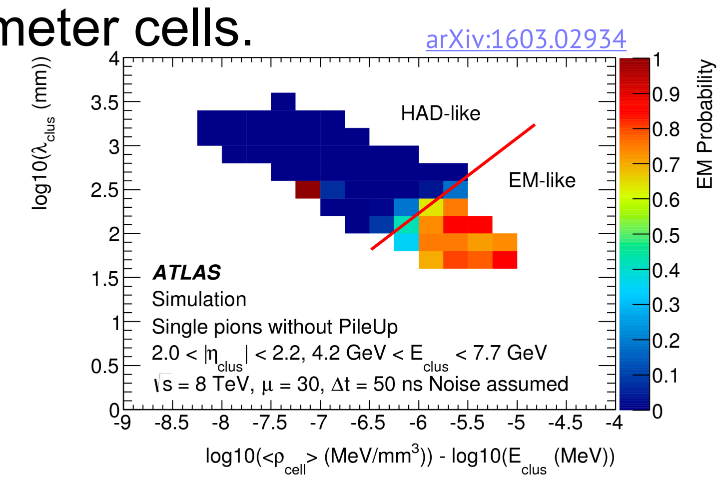
Hadronic Calibration in ATLAS

- Hadronic showers are mostly composed of pions
  - π^0: Captured by the electromagnetic calorimeter
  - $\pi^{\pm}$: Require the dense material in the hadronic calorimeter to be stopped
- Different detector response for π^0 vs. $\pi^{\pm}$ showers

- **Topo-clusters:** Baseline hadronic reconstruction in ATLAS, uses clusters of noise-suppressed calorimeter cells.
- **Topo-cluster calibration:**



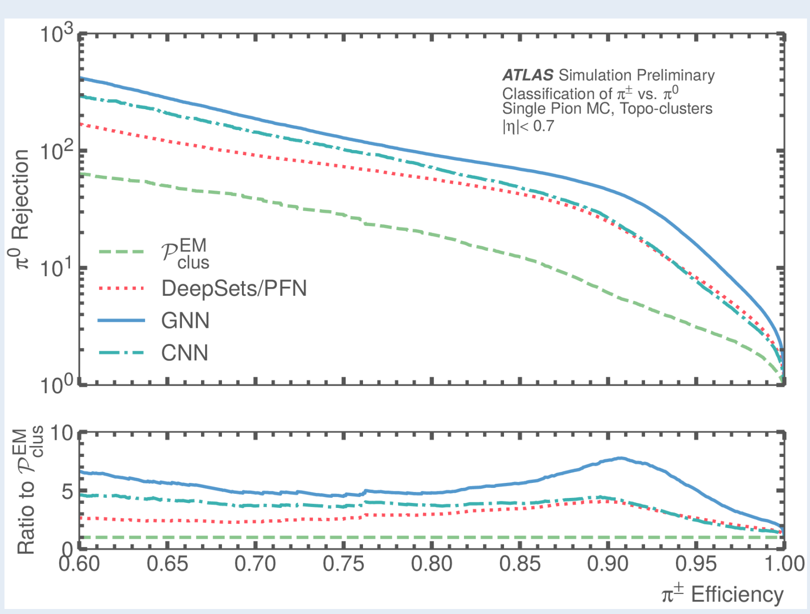
arXiv:1603.02934



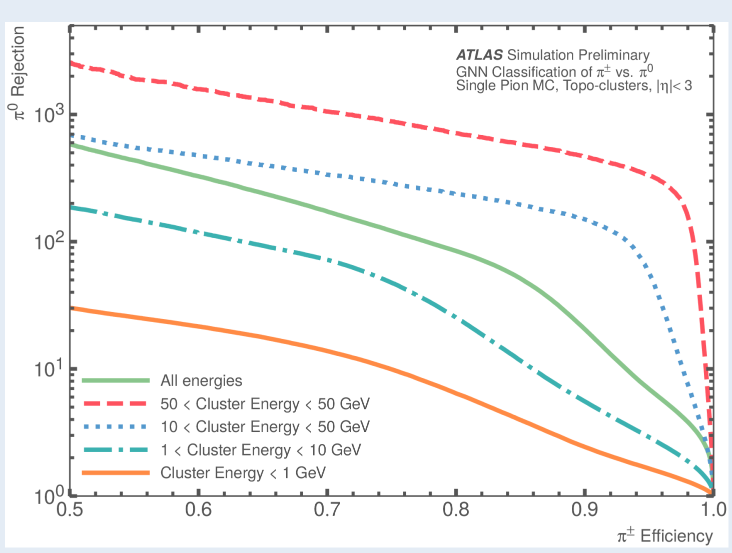
1. Clusters are classified as electromagnetic or hadronic by P^{EM}_{clus}
2. Cluster energy is calibrated by weighting the calorimeter cells energy (LCW calibration)

Pion Classification

- Deep Learning techniques all do an excellent job of distinguishing $\pi^{\pm}$ from π^0 showers
- Graph Neural Network (GNN) & Particle Flow Network (PFN) far outperform the baseline P^{EM}_{clus}: over 5x the background rejection at 90% efficiency.

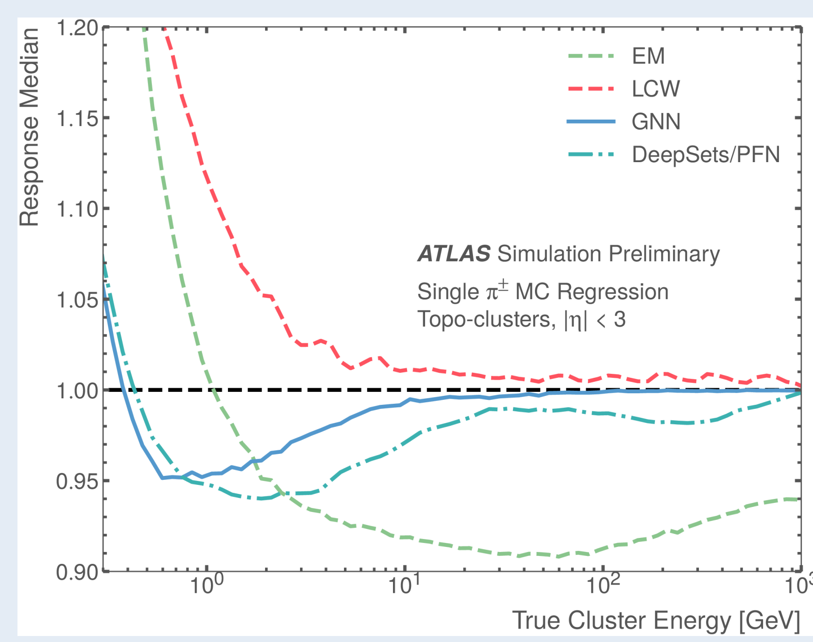


- Classification performance increases with cluster energy

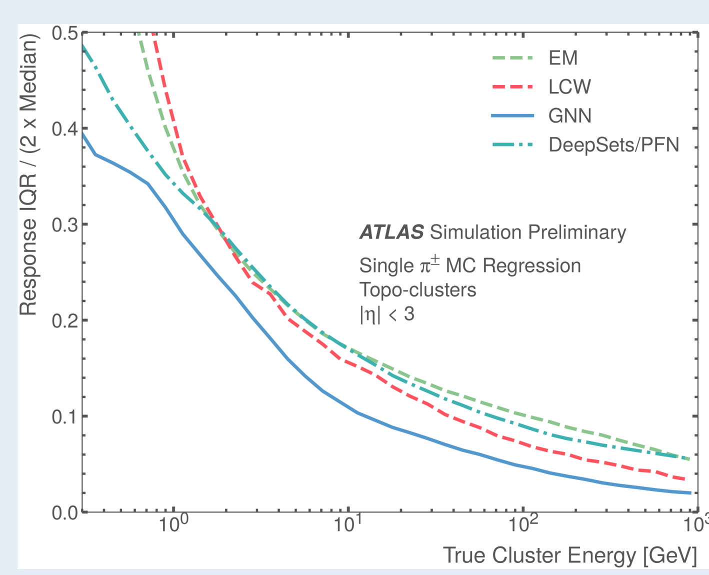


Pion Energy Regression

- Goal: Predict the true energy deposited in the calorimeter shower
  - Energy Response $= E^{measured}/E^{true} \sim 1$
- GNN & PFN are closer to one than the EM scale (raw cluster energy) or LCW (baseline) calibration



- Energy Resolution:



- Deep learning approaches outperform the classification applied in the baseline local hadronic calibration (LCW) and are able to improve the energy resolution for a wide range in particle momenta
- Deep-learning-based low-level hadronic calibrations shows to significantly improve the quality of particle reconstruction in the ATLAS calorimeter.

Public plots:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/JETM-2022-002/

TRIUMF ATLAS EXPERIMENT