# MACHINE LEARNING FOR PION IDENTIFICATION AND ENERGY CALIBRATION WITH ATLAS DETECTOR

ATL-PHYS-PUB-2020-018

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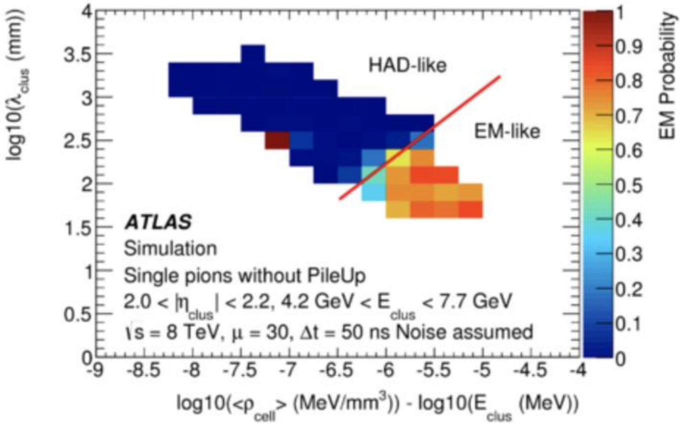
17-08-2021
TRIUMF SCIENCE WEEK 2021

# Overview

## Hadronic Calibration in ATLAS

- **Hadronic showers are mostly composed of pions**
  - $\pi^0$: Captured by the **electromagnetic** calorimeter
  - $\pi^{\pm}$: Require the dense material in the **hadronic** calorimeter to be stopped

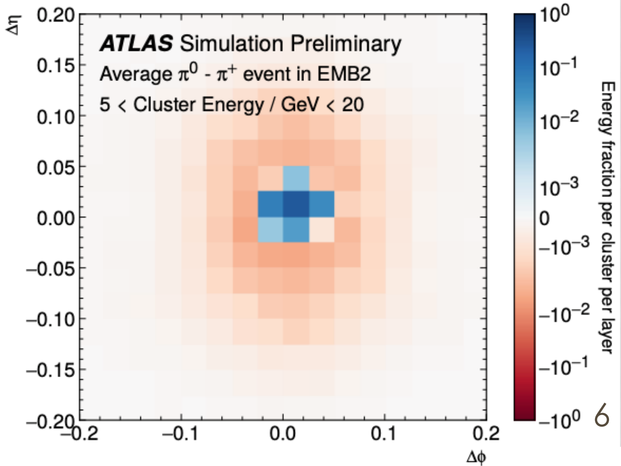



- Baseline hadronic reconstruction in ATLAS uses clusters of calorimeter cells

- Currently, **clusters are calibrated** in two steps:
  1. **Classified** as **electromagnetic** or **hadronic** calculating the EM probability $\mathscr{P}^{EM}_{clus}$;
  2. **Calibration** of its energy

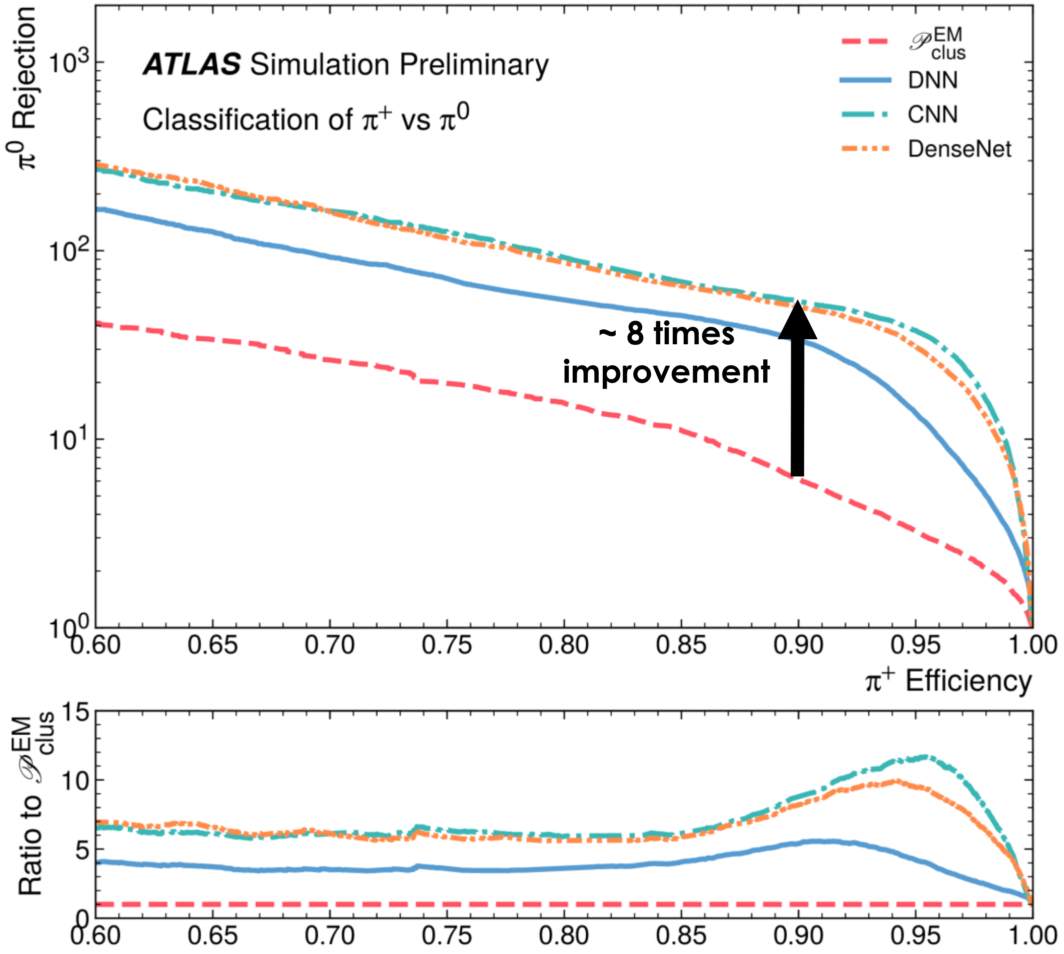
**Can we use deep learning to improve these techniques?**

- **Neural Networks** trained on calorimeter images can classify clusters and predict their energies
  - Studied DNNs, CNNs, and DenseNet



# Cluster identification performance

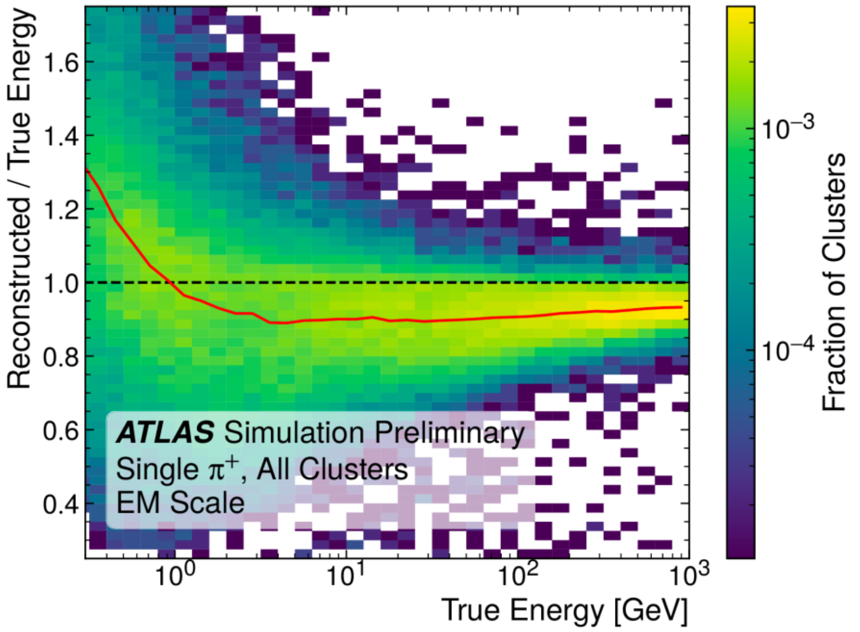
- The ML techniques all do an excellent job of distinguishing $\pi^0$ from $\pi^{\pm}$ showers
  - Dramatic **improvements** compared to the current classification method using $\mathcal{P}^{EM}_{clus}$



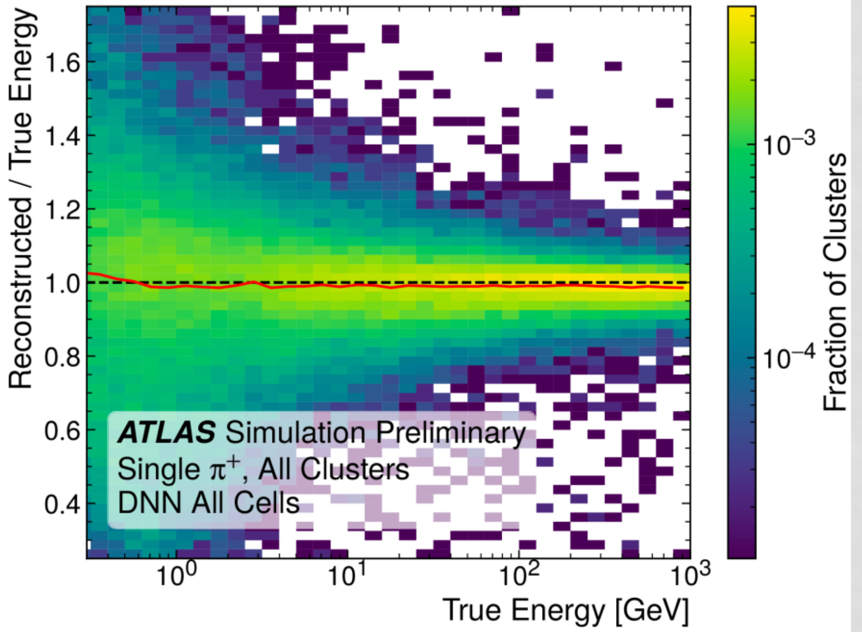
# Pion Energy Calibration

- After classifying a cluster, need to calibrate its energy
- **Energy regression goal**: Correctly **predict the true energy** deposited in the cluster.
  - Quantified by measuring the cluster **energy response**: $R = \frac{E^{\text{reco}}}{E^{\text{truth}}}$ that should be $\sim 1$

## Regression performance for charged pions




**Before Calibration**



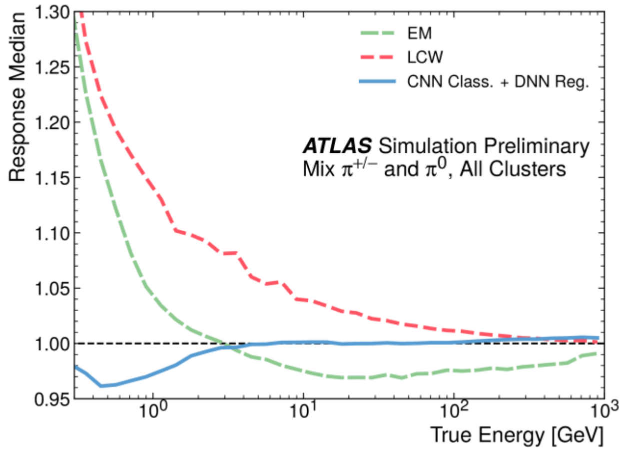

**After calibration**

# Outlook

- Promising results for pion classification and energy calibration with deep-learning!

**Looking forward studying more complex scenarios:**

- First look at the **performance with jets**
  - $\pi^+, \pi^-$ and $\pi^0$ mixed in a 1:1:1 ratio
  - Roughly correspond to the expected distribution in jets




- Another handy way to represent energy deposits is as a **point-cloud**
  - Points contains cell info & cluster-level info.
  - Allows for combining signals from the inner detector (tracks) and from calorimeter (clusters)