



Improving High-Energy Particle Detectors with Machine Learning

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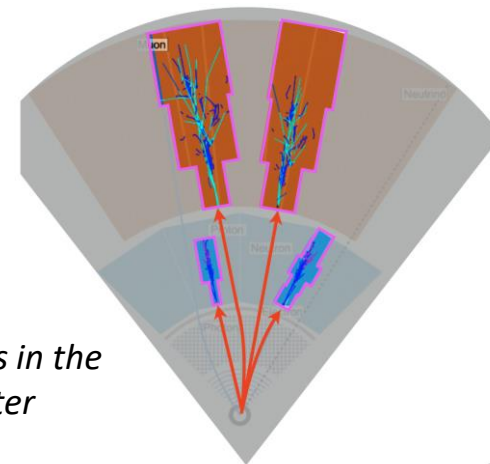
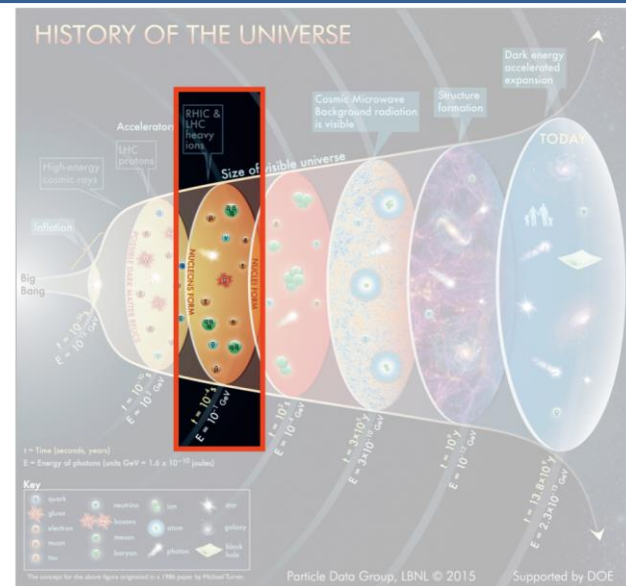
Aaron Angerami, Piyush Karande, and Ron Soltz



Motivations and Objectives



- What did the universe look like after the Big Bang?
 - Quark-gluon plasma (QGP) microseconds after the Big Bang
- Use heavy ion collisions at the LHC to recreate QGP and study its properties
 - QGP produces thousands of particles, and we record energy deposition of these particles in the calorimeter system
- Want to reconstruct particles from the energy deposition
 - 1. classify the particles correctly
 - 2. recalibrate deposited energy to the true energy
- Objective: Use techniques from machine learning to improve reconstruction of particles
 - Treat energy deposition like a 3D image

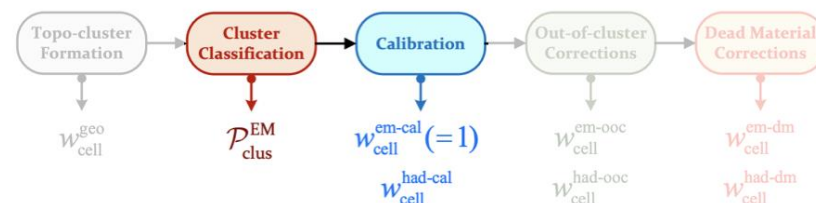


Particle showers in the ATLAS calorimeter

Methods

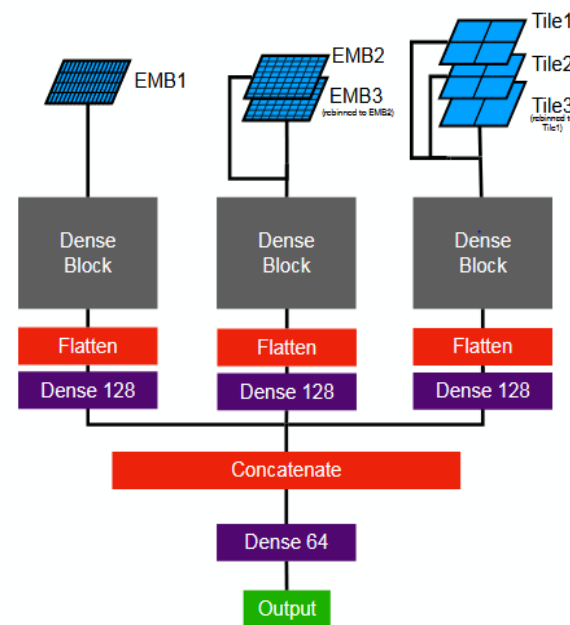


- Form “topoclusters” from cells (pixels) in the calorimeter
 - Find the cluster energy
- Classify** whether the cluster comes from an electromagnetic or hadronic shower
- Calibrate** cluster energy (**regression**)
- Current method: uses hand-picked properties of clusters for **classification** and **calibration**
 - Uses “local cell weighting” (LCW) for **calibration**
- New method: use DenseNet neural network for **classification** and **regression**
 - Treat energy deposition as 3D image
- Goal: Apply **classification** and **regression** in succession to correctly calibrate the energy of particles produced by a nuclear collision



Sequence of calibration steps.

Ref: Eur. Phys. J. C 77 (2017) 490



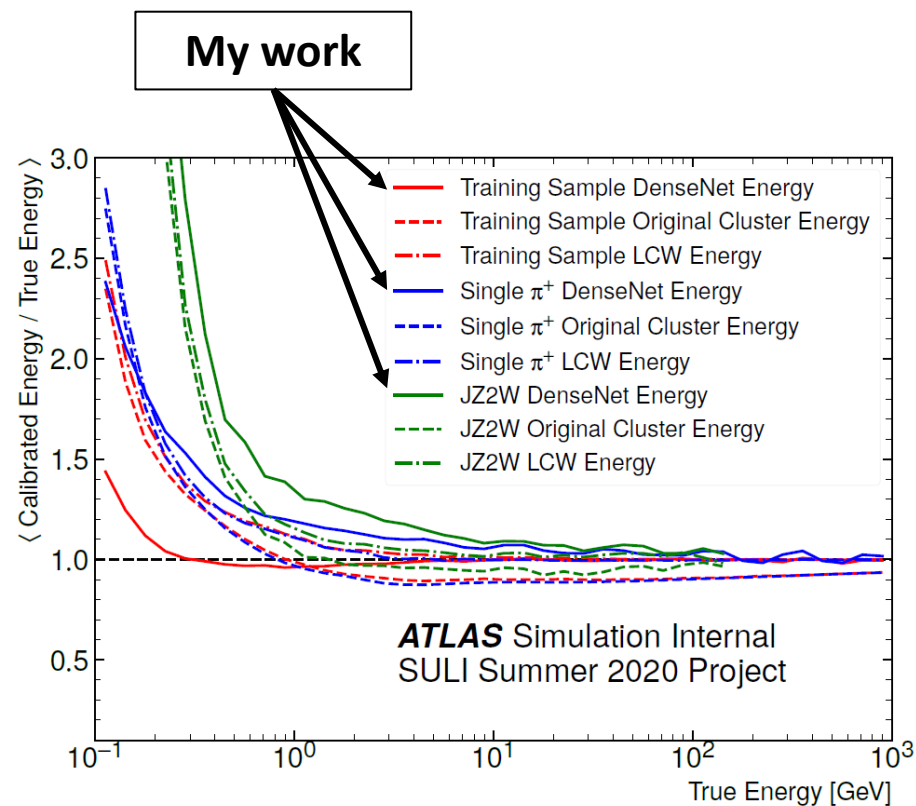
Sketch of DenseNet neural network.

Ref: ATL-PHYS-PUB-2020-018, <https://cds.cern.ch/record/2724632>

Results and Conclusions



- Trained** classification and regression with 5-fold validation
 - Large improvement in calibrated energy compared to LCW
- Used trained calibration models to predict calibrated energies for new data sets
 - The **training sample** is idealized, whereas the **single π^+** and **JZ2W** samples are affected differently by noise
 - Also, the **JZ2W** sample contains multiple types of particles
- Conclusion:** The model still predicts relatively well even though the training sample doesn't include complex effects
- Next step:** try to properly account for these effects



The ratio between the calibrated and true energy, as a function of true energy.



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