AI Driven Detector Reconstruction Enhancement for Pixelated Detectors for the Electron-Ion Collider

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Jefferson Lab
Thomas Jefferson National Accelerator Facility

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EIC^2 EIC Center at Jefferson Lab

GEANT4 A SIMULATION TOOLKIT

I Electron-Ion Collider

- This study is primarily for pixelated detectors on the EIC.
- The calorimeter on the electron endcap is being utilized for testing our networks.
- Real time and offline analysis.

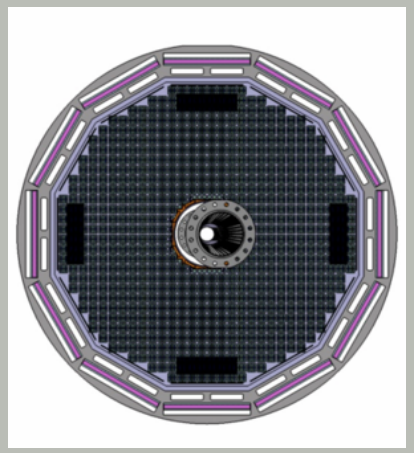


Figure 1: EM Calorimeter schematic on EIC. [1]

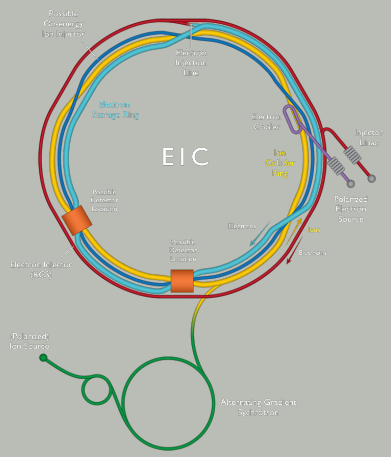


Figure 2: Full EIC detector. [2]

II Pixelated Detectors

- Pixelated detectors give readouts in the form of arrays which are layered in a geometrical pattern.
  - These detectors contain an array of rods that output the readings of many sensors [3]
  - The sensors are close together with no gaps which allows for better performance with convolutional Neural Networks (CNN).
- Pixelated detectors can have a 3D structure as well.

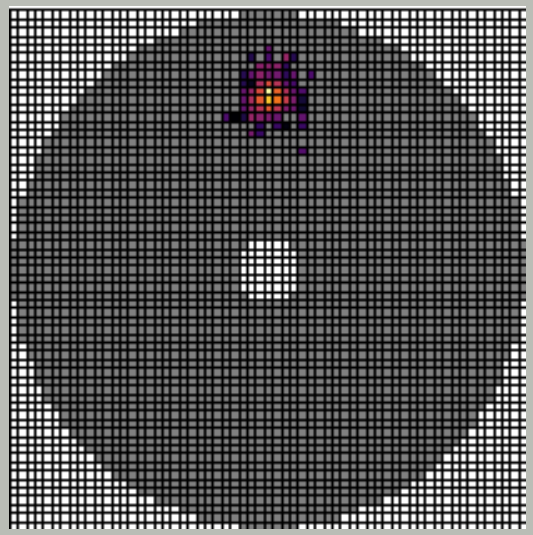


Figure 3: Simulation of calorimeter detector hit.

III Current Algorithm

- Island reconstruction
  - Searches for energy clusters
  - Extracts cluster parameters (energy, incidence, etc.)
  - Is currently the best way to find this data
- Performance degrades when clusters are close together, the detector has background noise, or if a cluster is near an edge.
  - These can be improved by AI.

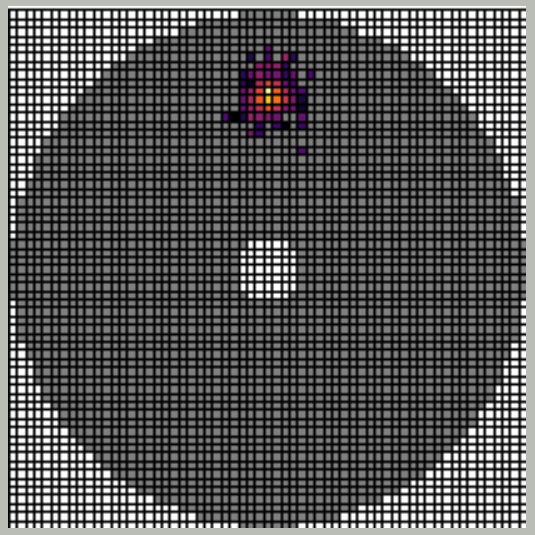


Figure 4: Simulation of calorimeter detector hit.

IV Goal

- Combine the traditional algorithm with ML model to improve reconstruction performance
- Condensing the cluster to a point (Figure 5) is an example of how this can be used

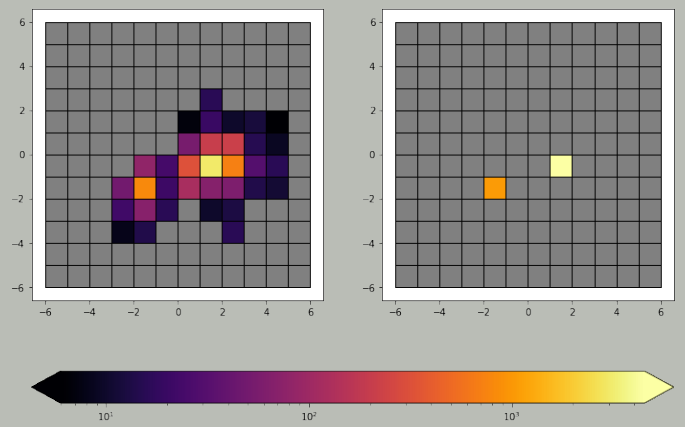
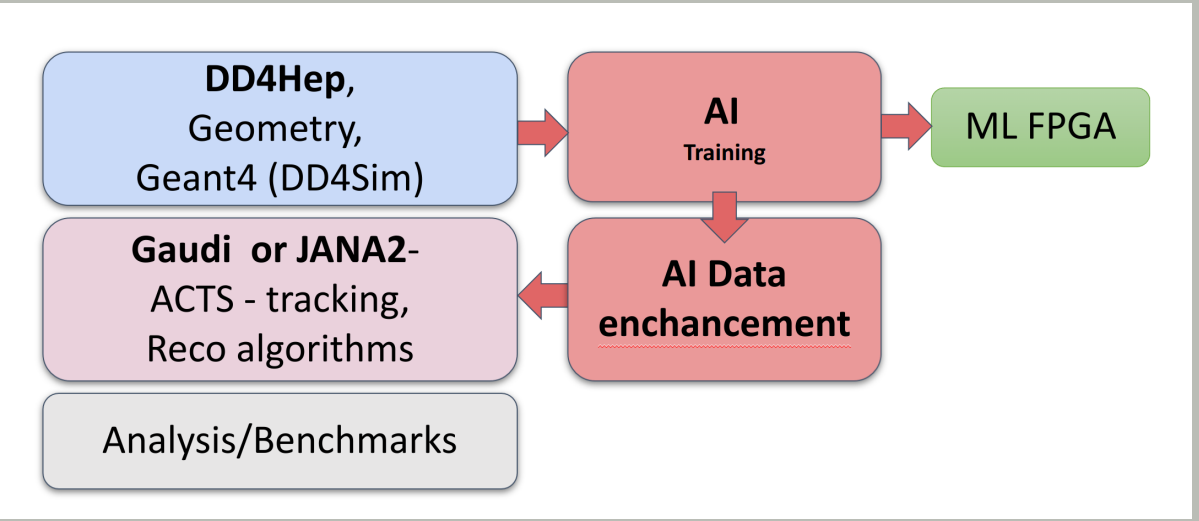


Figure 5: Test of an 11x11 calorimeter with two hits (left). ML output from clusters on the left with each hit condensed to one point (right).

V Process

Toolchain



V Process cont.

- Multiple network structures are being looked at.
  - autoencoder
  - dense
  - inception
  - ResNet
  - GraphNet

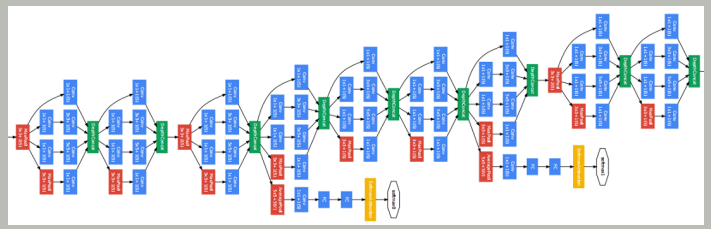


Figure 6: Inception Model Structure

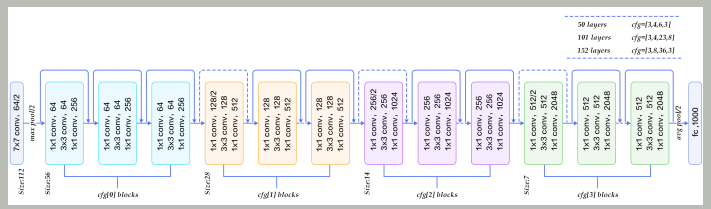
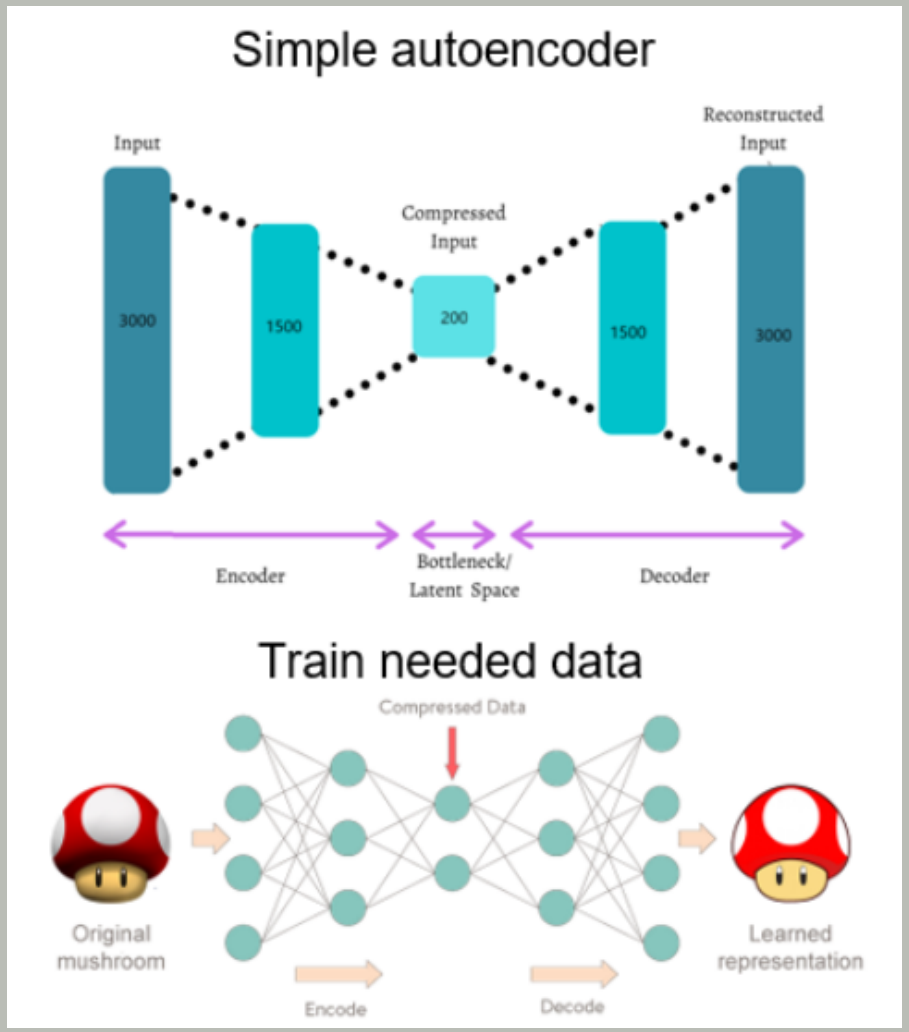
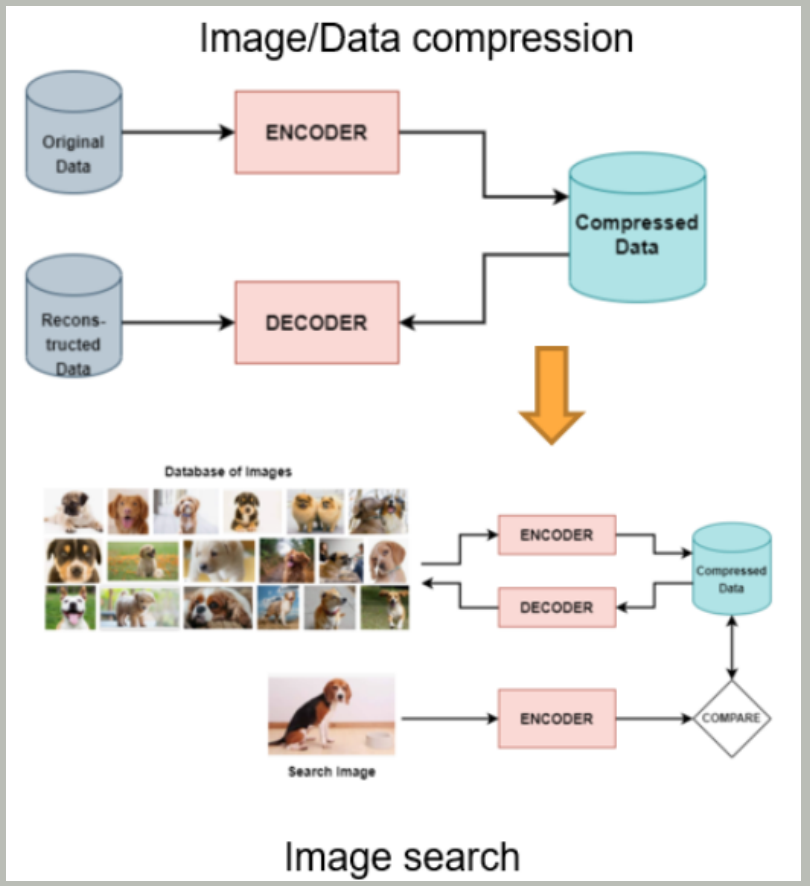


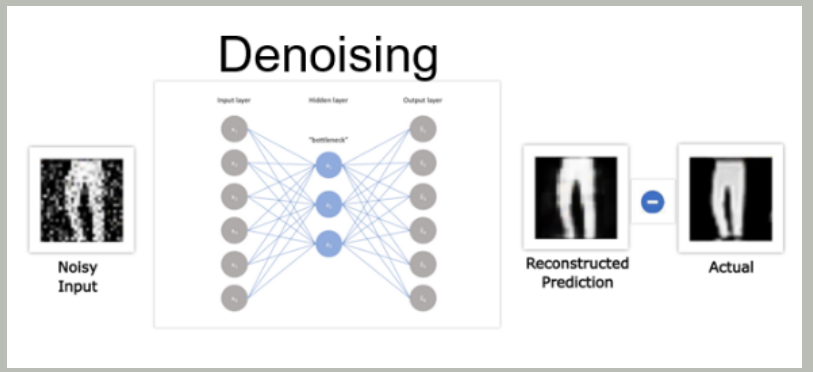
Figure 7: ResNet Model Structure

VI Autoencoder



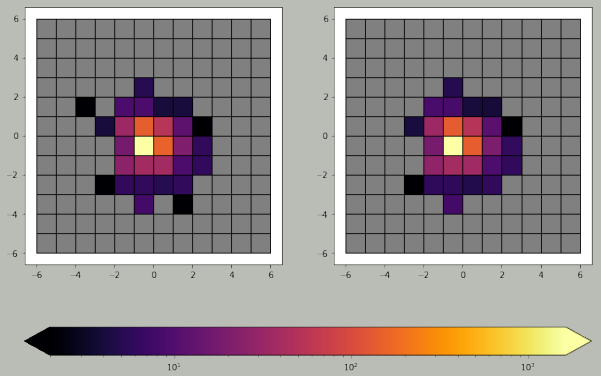
VI Autoencoder cont.

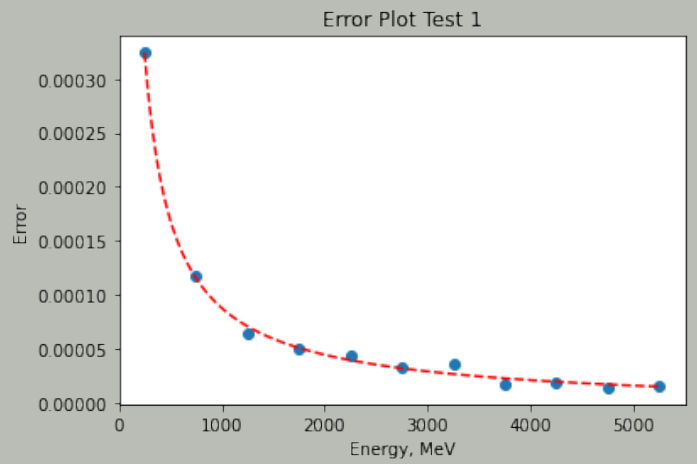




VII Testing

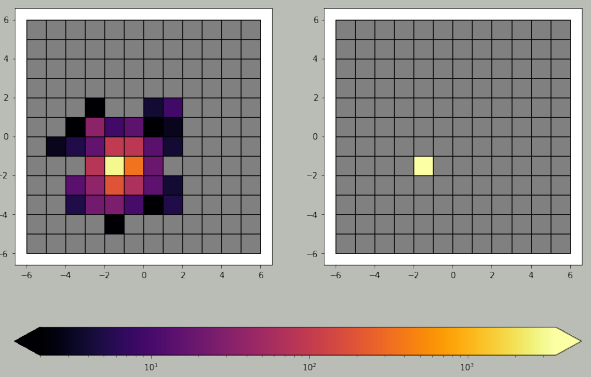
An identity autoencoder was created first, having the model output the exact same data as the input. We needed to know how well the network can encode calorimeter data.

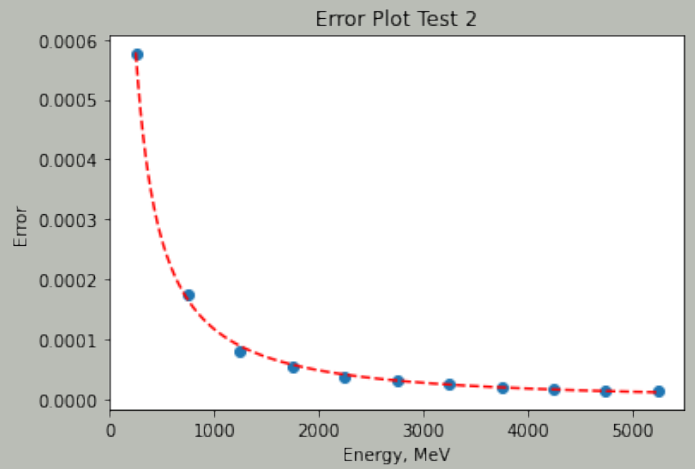




VII Testing cont.

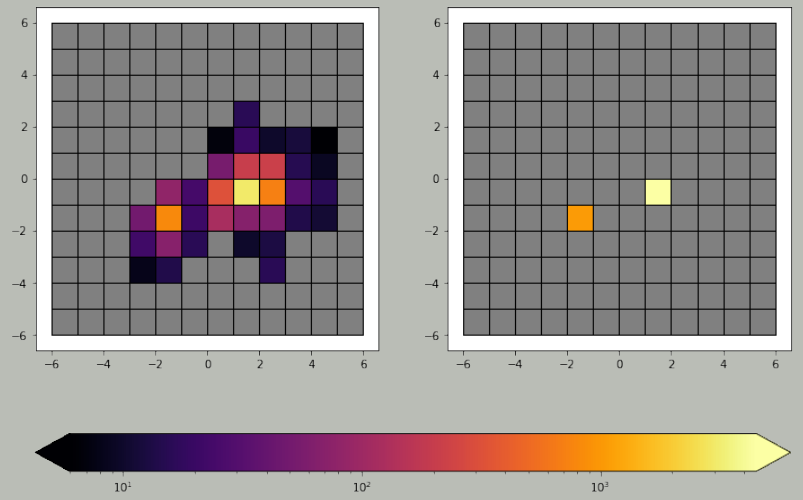
Next, using a variational autoencoder, a single cluster was condensed to one point to validate the total energy and position for one cluster was correct.





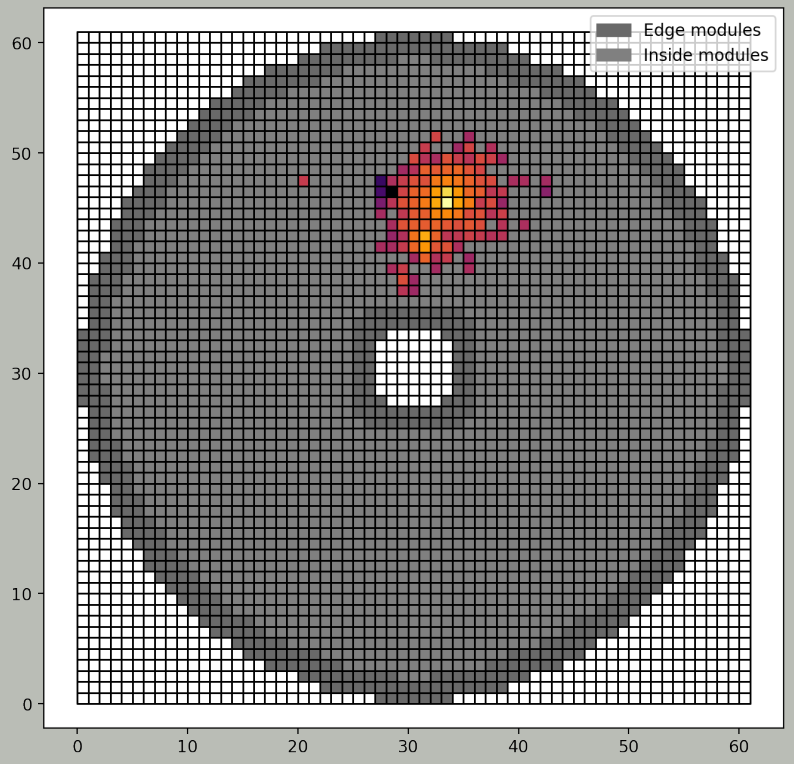
VII Testing cont.

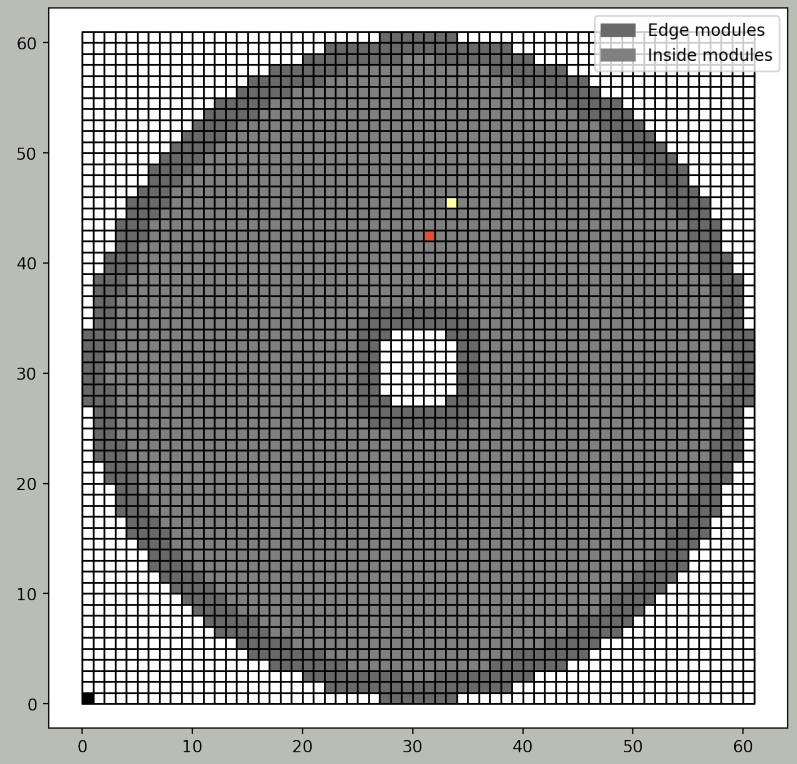
Lastly, two clusters were examined and each condensed to a single point.



VIII Results

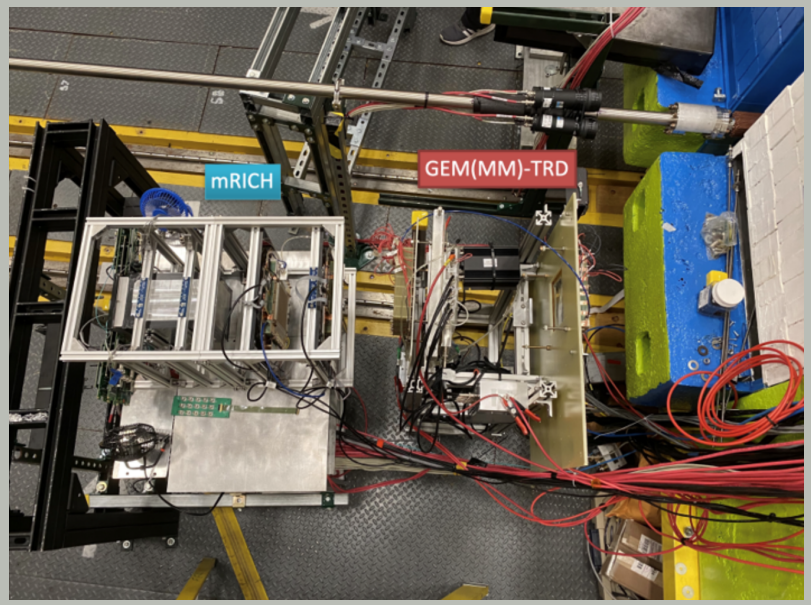
The small scale results were successful. Moving to the full scale 61x61 calorimeter we find similar success.





IX Using this Data

- Offline reconstruction
- ML in FPGA (online quick reconstruction)
- Surrogate model project (AI replacing slow algorithms)
- EIC AI user group (AI projects in EIC)
- Work is easily applicable to other detectors



X Summary and Next Steps

- Improve reconstruction performance for pixelated detectors on the EIC
- AI is sufficient to improve reconstruction for merged clusters
- Will continue working with different network types
- Will work on events with background and near the edge

XI Acknowledgements

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XII Bibliography

[1] Electron-Ion Collider Detectors: Eeemcal. Electron-Ion Collider Detectors: EEEMCal - Cuawiki, https://wiki.jlab.org/cuawiki/index.php/Electron-Ion_Collider_Detectors:_EEEMCal.

[2] The Electron-Ion Collider, Brookhaven National Laboratory. www.bnl.gov/eic/.

[3] Calorimeter, ATLAS Experiment, CERN. https://atlas.cern/Discover/Detector/Calorimeter.