Reconstruction in the forward calorimeter insert and the Ecal

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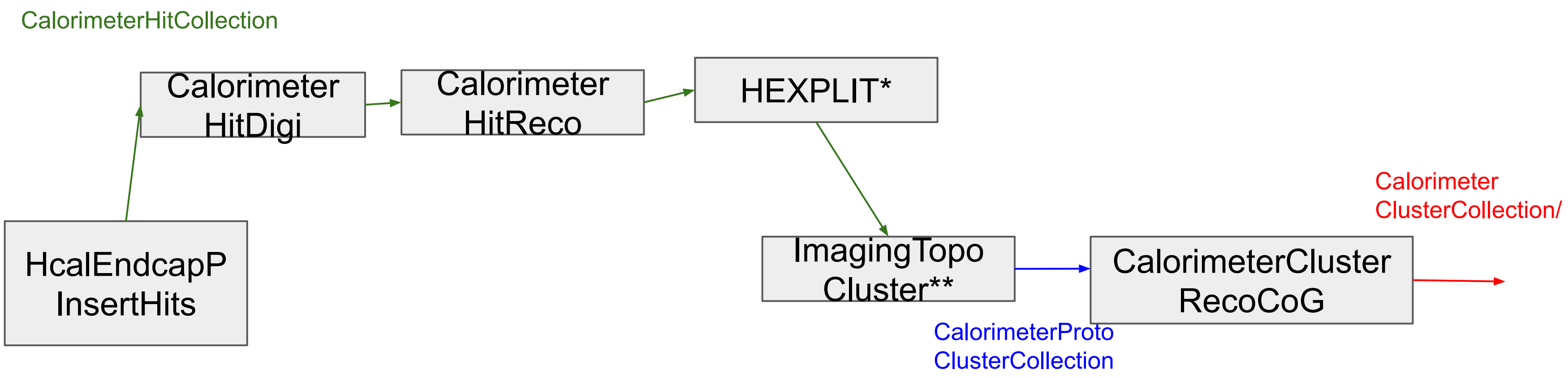
Event reconstruction in the Hcal Insert

https://github.com/eic/EICrecon/blob/main/src/detectors/FHCAL/FHCAL.cc



* https://doi.org/10.1016/j.nima.2023.169044

**https://doi.org/10.1140/epjc/s10052-017-5004-5

HEXPLIT algorithm*

- Takes advantage of overlapping cells**
- Redistributes energy within a given hit into “subcell hits” in regions defined by overlap between cells.
- Feeds into the clustering algorithm

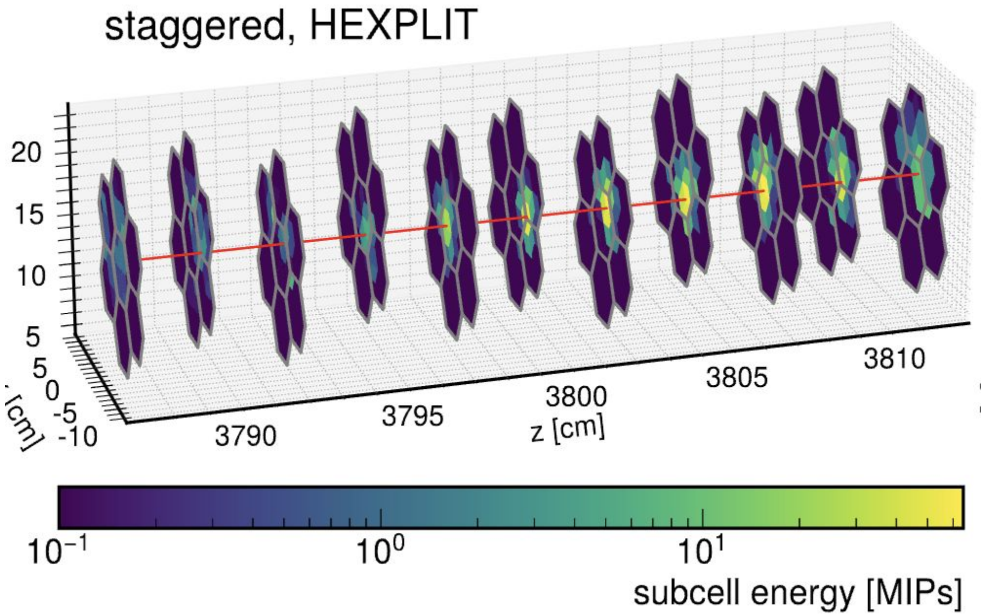
https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/HEXPLIT.cc

https://github.com/AIDASoft/DD4hep/blob/master/DDCore/src/segmentations/HexGrid.cpp

https://doi.org/10.1016/j.nima.2023.169044

Cuts:

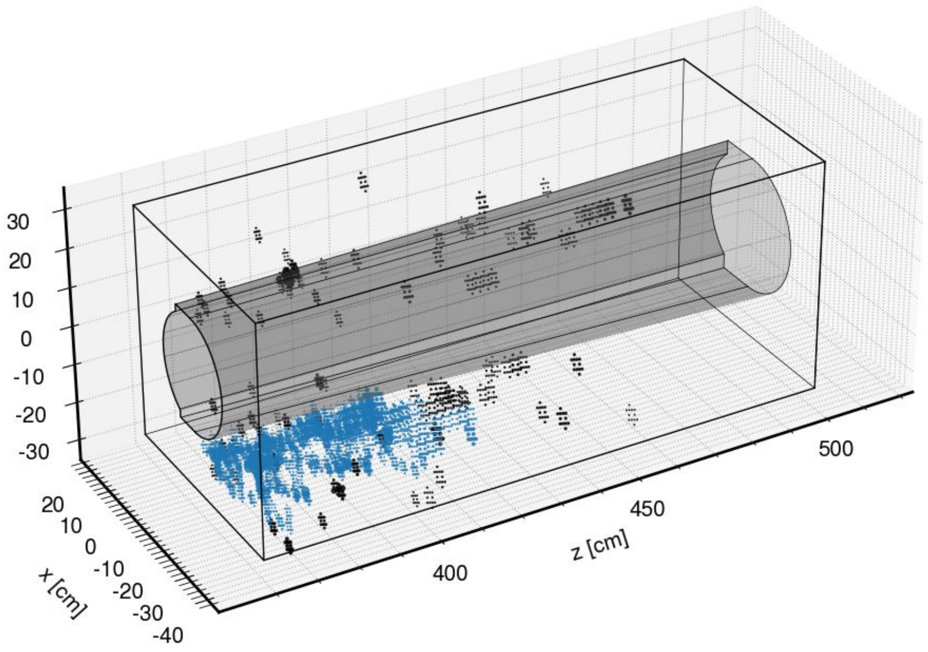
- t<150 ns +(z at front face of ZDC or Insert)/(speed of light)
- E>0.5 MIP



Topo clustering

- Filter low energy hits: E_{hit}>5 keV
- Uses local Δx, Δy and layer number to determine if two (subcell) hits are "neighbors"
    - (15.5 mm, 13.4 mm), if on same layer
    - (7.8 mm, 6.7 mm) if on adjacent layers
- Hits are in the same proto-cluster if there is a series of neighboring hits with energy above 3 MeV connecting them
- Accept a proto-cluster only if it has at least 11 MeV and 100 (subcell) hits

neutron, $E_{truth, total}$ = 50 GeV, η=3.6



Cluster reconstruction

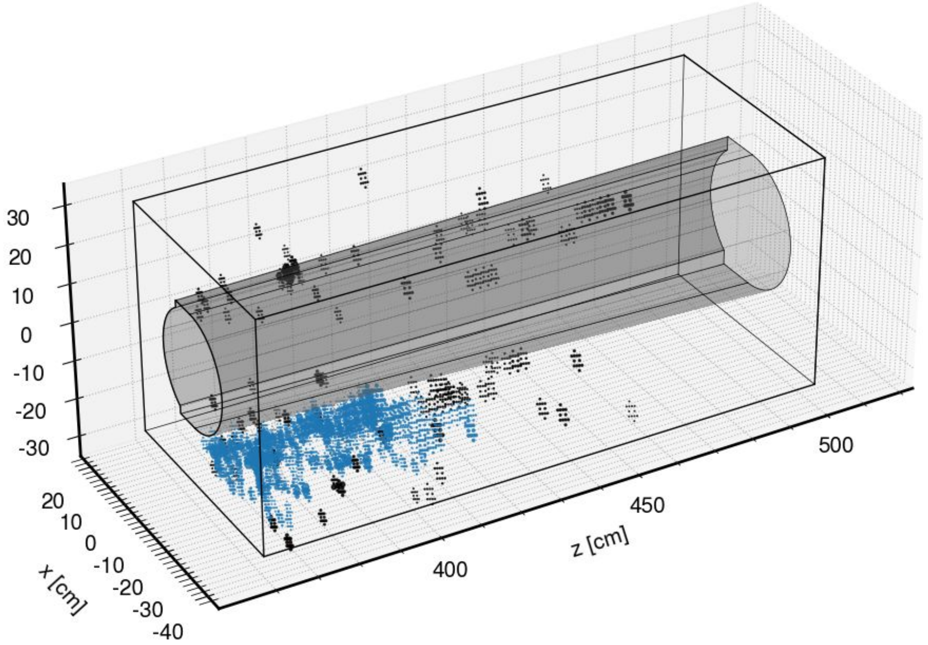
- Transforms proto-clusters into clusters
- Determines position, cluster shape, and energy
  - $E_{clust}=\Sigma\ E_{hit}/sf$ where sf = 2.57%
  - Position determined using log-weighted CoG

$$\vec{x}_{\rm rec} = \frac{\sum_{i\in \rm hits} \vec{x}_i w_i}{\sum_{i\in \rm hits} w_i}$$

$$w_i = \max\left(0,\ w_0 + \log\frac{E_i}{E_{\rm tot}}\right)$$

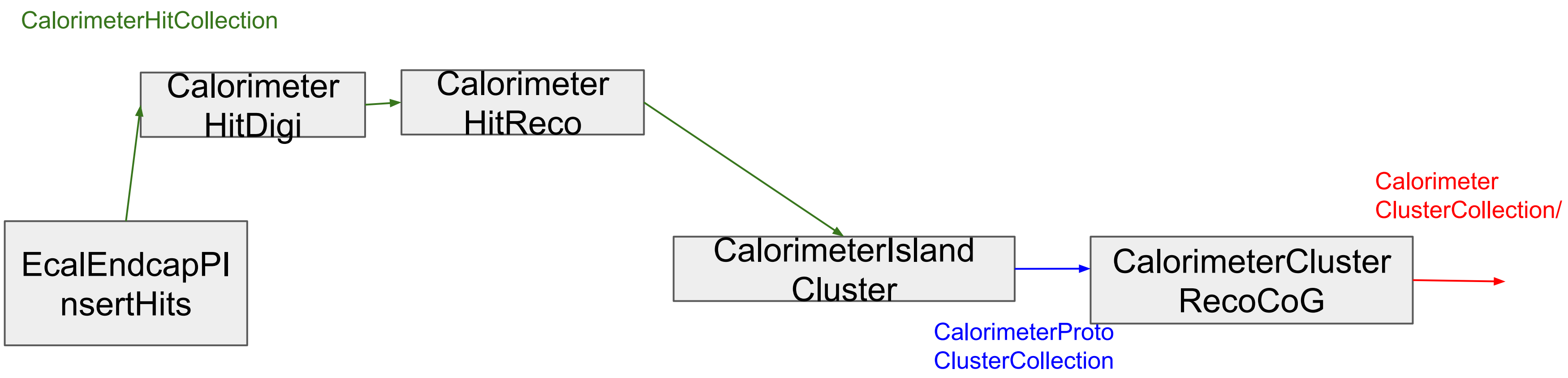
$$w_0 = 6.2$$

neutron, $E_{\rm truth,\,total}$ = 50 GeV, η=3.6



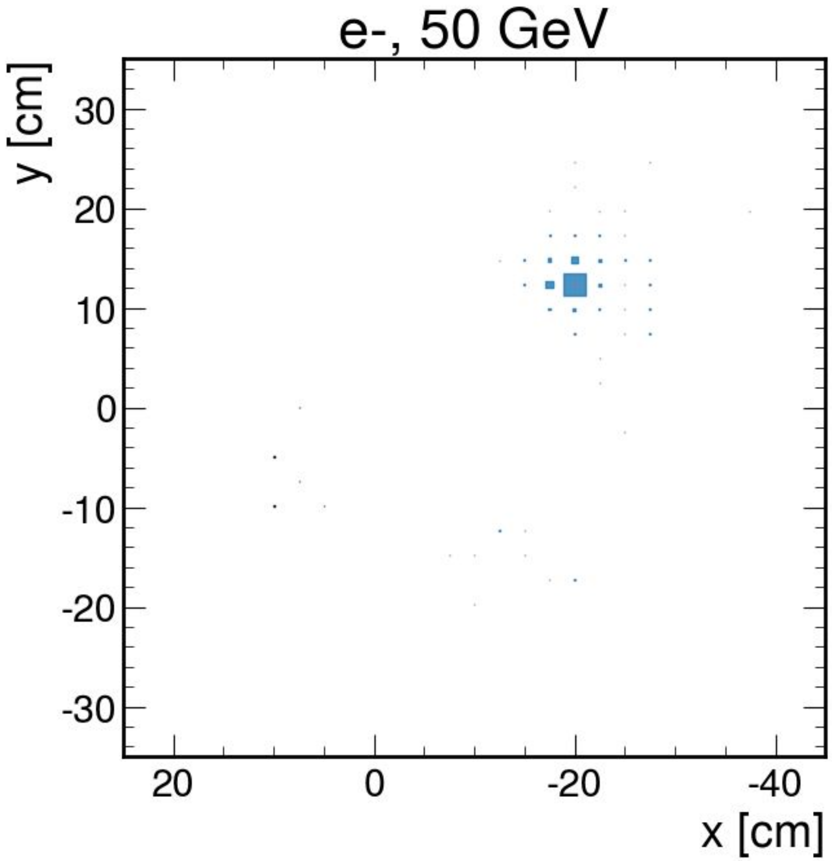
Event reconstruction for the Ecal

https://github.com/eic/EICrecon/blob/main/src/detectors/FEMC/FEMC.cc



Update to Island clustering

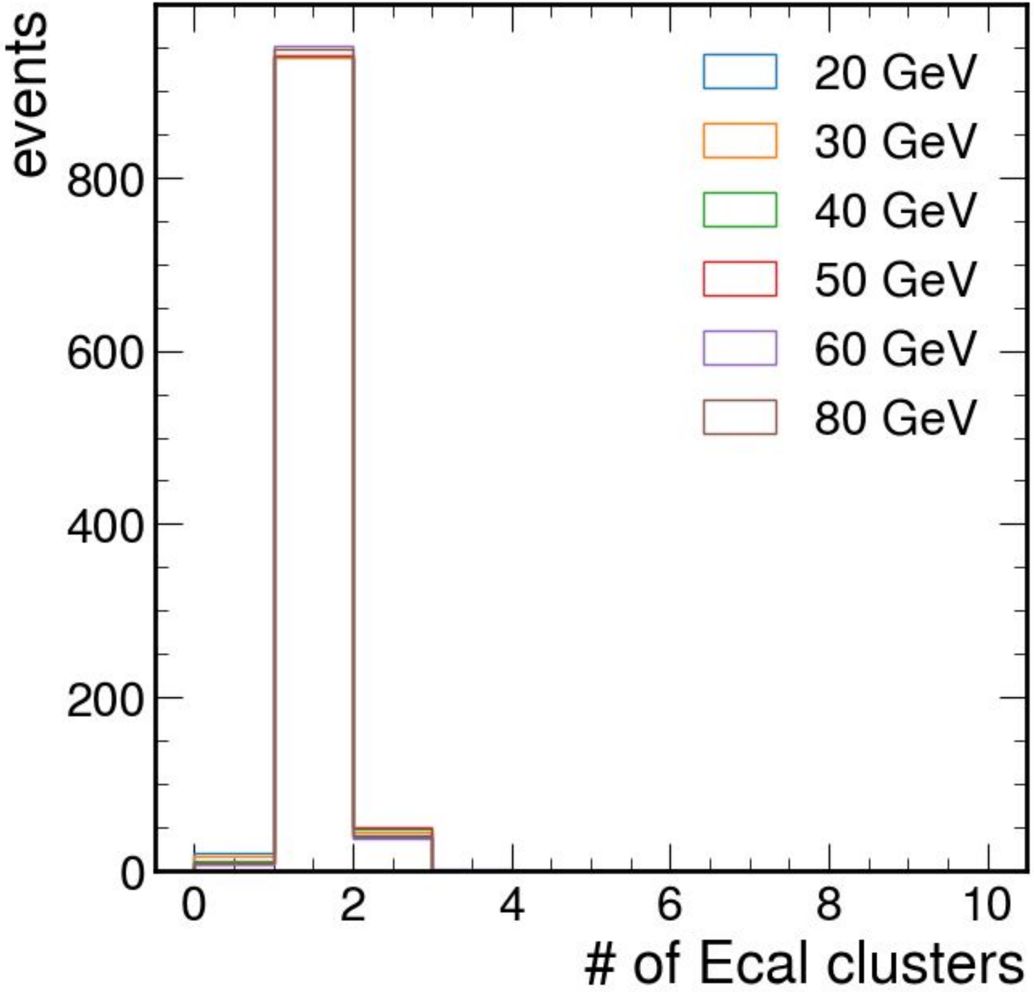
- Changed "neighbor" determination to use local cartesian coordinates
  - |Δx|, |Δy|< 1.5 times the cell size
  - Doesn't make sense to use (Δη, Δφ) for clustering at large η, since the rings of constant η are closer together
- Changed the minimum energy of a cluster's center hit in the island clustering
  - Reduces the number of unwanted low-energy clusters
  - 10 MeV → 40 MeV



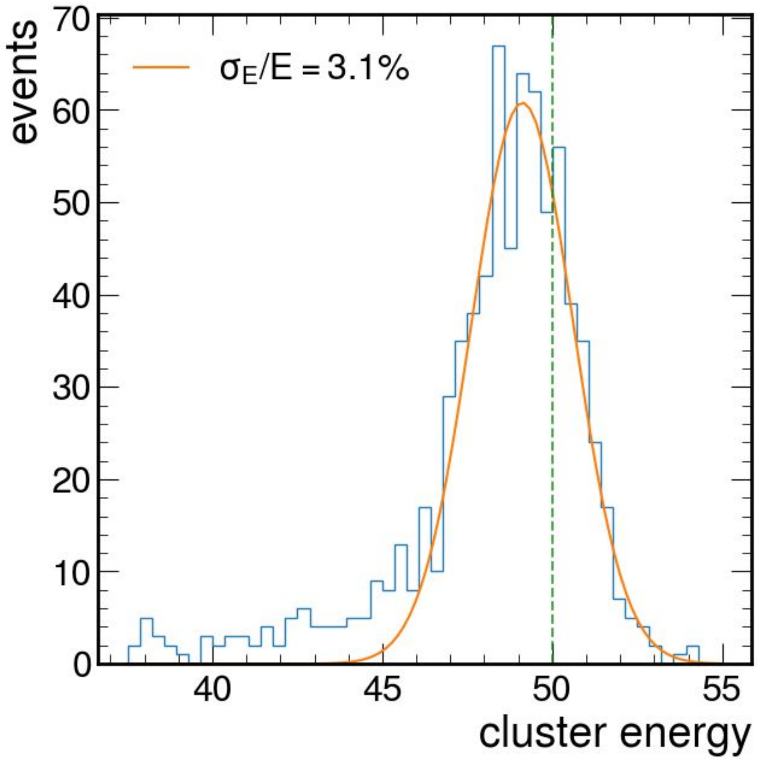
https://github.com/eic/EICrecon/pull/1613

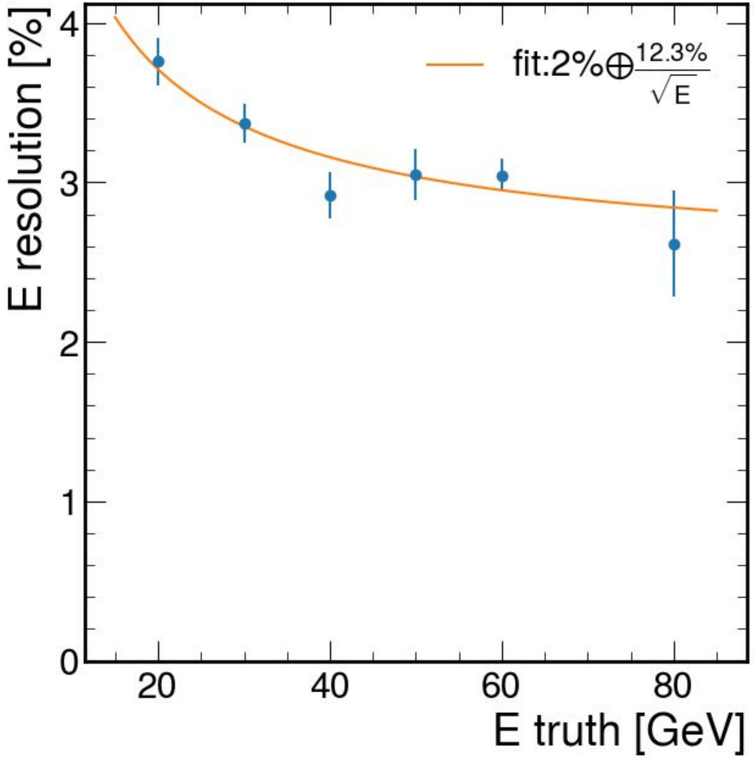
Cluster count

Tuned to make there be ~1 cluster.



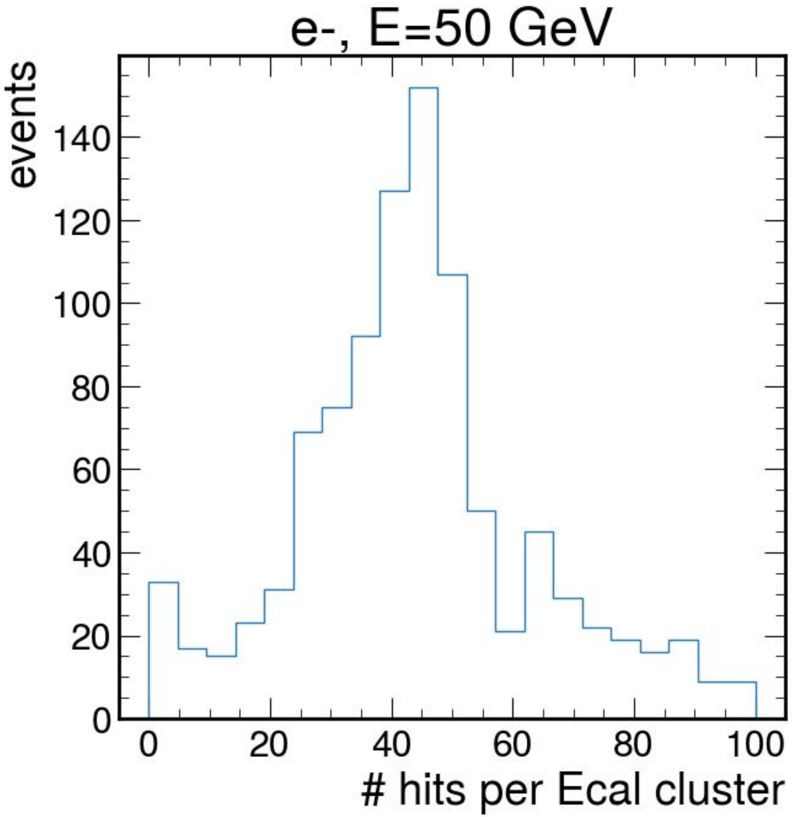
Results of this update*

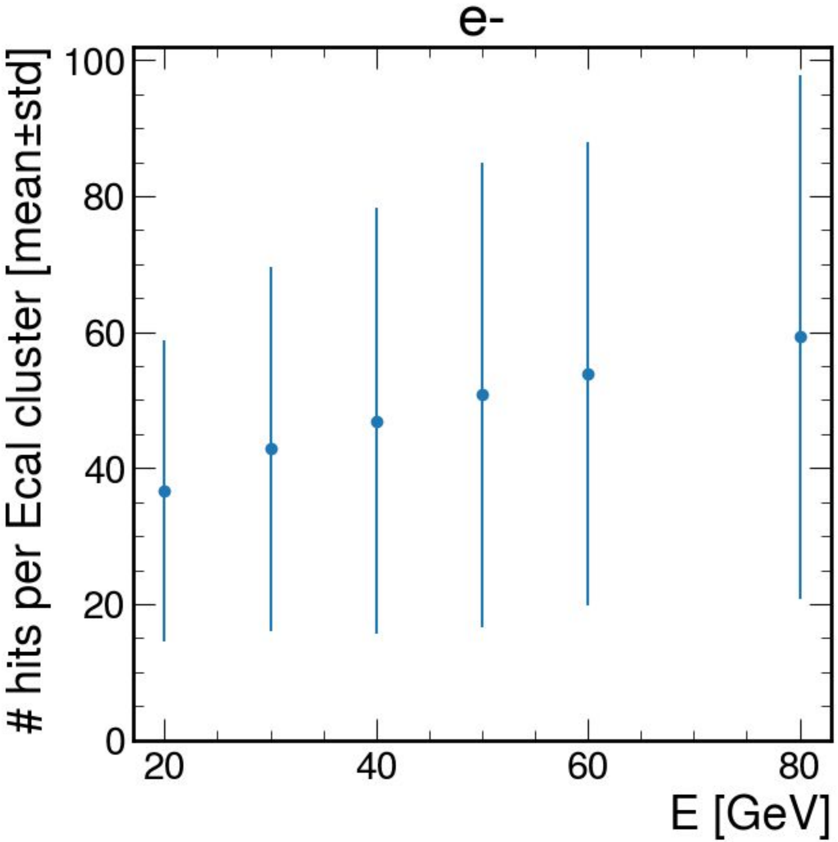




Drafting pull request :https://github.com/eic/physics_benchmarks/pull/35

Number of hits per cluster

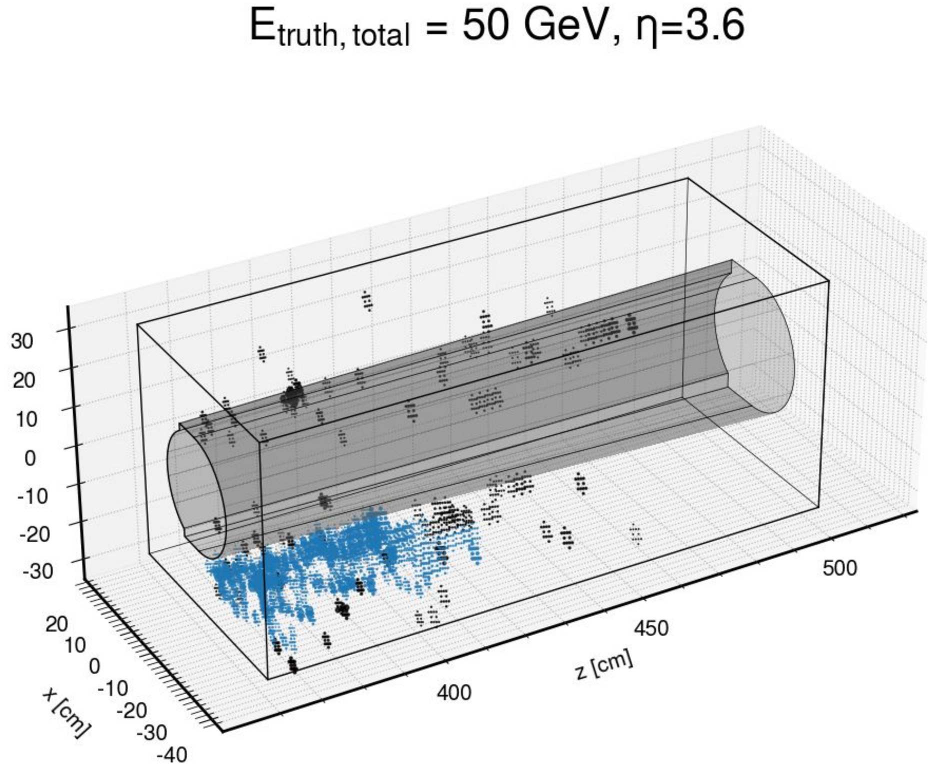




Neutron in Insert benchmark

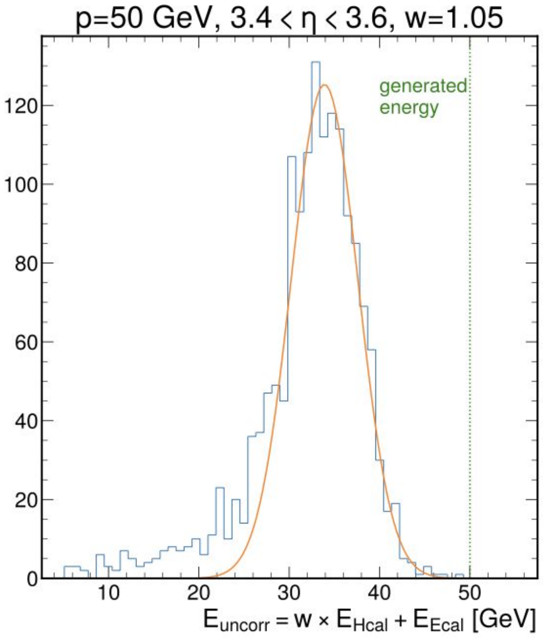
- Generates neutrons at 20-80 GeV, 3.0<η<4.0, full φ range
- Simulates them in the craterlake configuration FTFP_BERT physics
- Reconstructs clusters in Hcal insert and insert part of Ecal
- Reconstruct neutron kinematics:
  - Energy with strawman algorithm
  - Polar angle with HEXPLIT and log-scaled CoG

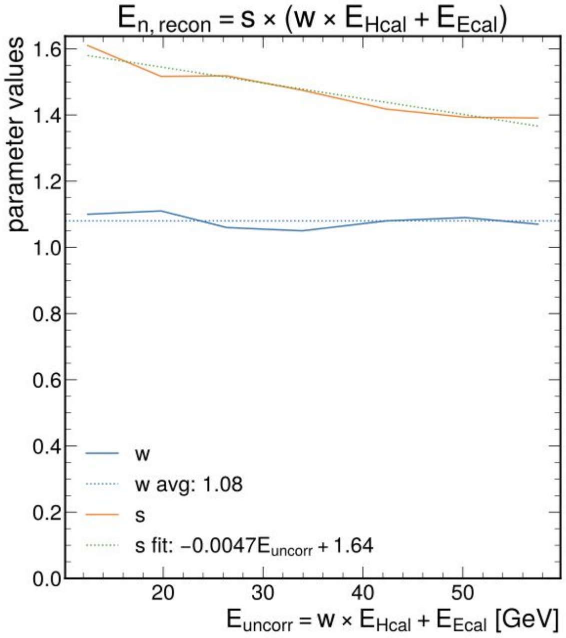
https://github.com/eic/physics_benchmarks/tree/master/benchmarks/neutron



Strawman Energy reconstruction

- Hcal sampling fraction determined at EM scale
- To correct for e/h effects:
    - w parameter: relative energy scale of Ecal vs. Hcal
        - Determined by minimizing σ/μ ratio for gaussian fits to E_{uncorr}=w E_{Hcal}+ E_{Ecal} distribution
    - s parameter: Energy dependent overall scale of e/h. Determined as 1/μ of E_{uncorr}/E_{truth} distribution

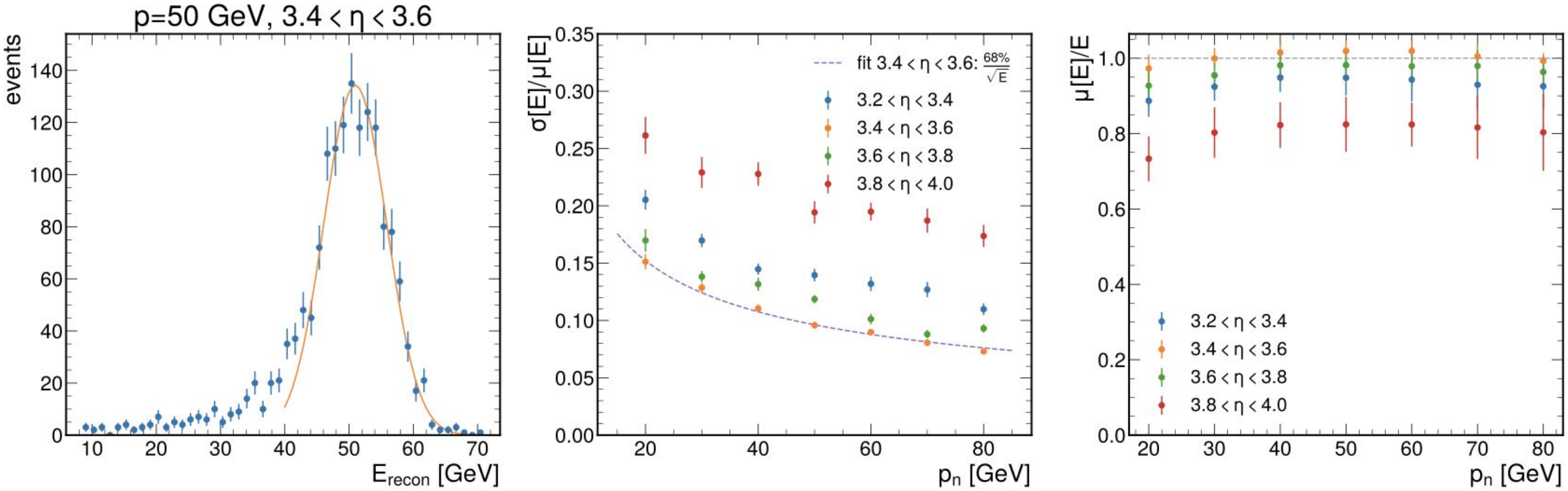




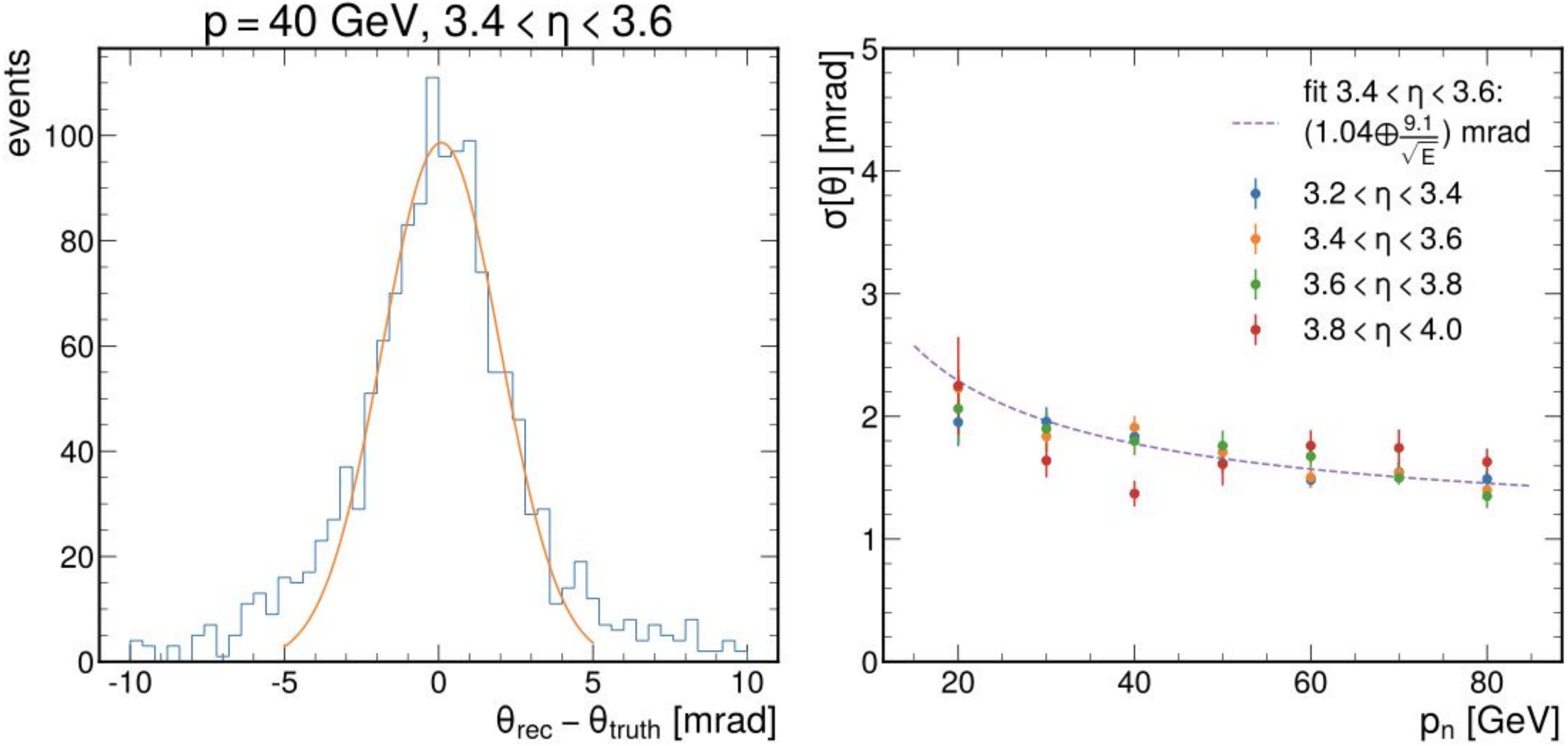
Strawman Reconstruction Energy resolution and scale

For 3.4<η<3.8:

- Energy resolution ~ 68%/sqrt E
- Energy scale ~ 100%

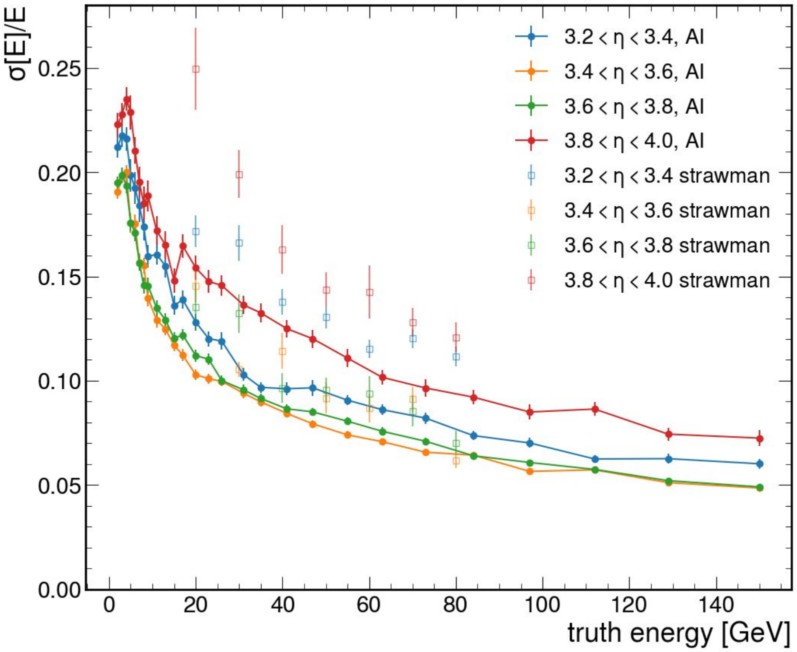


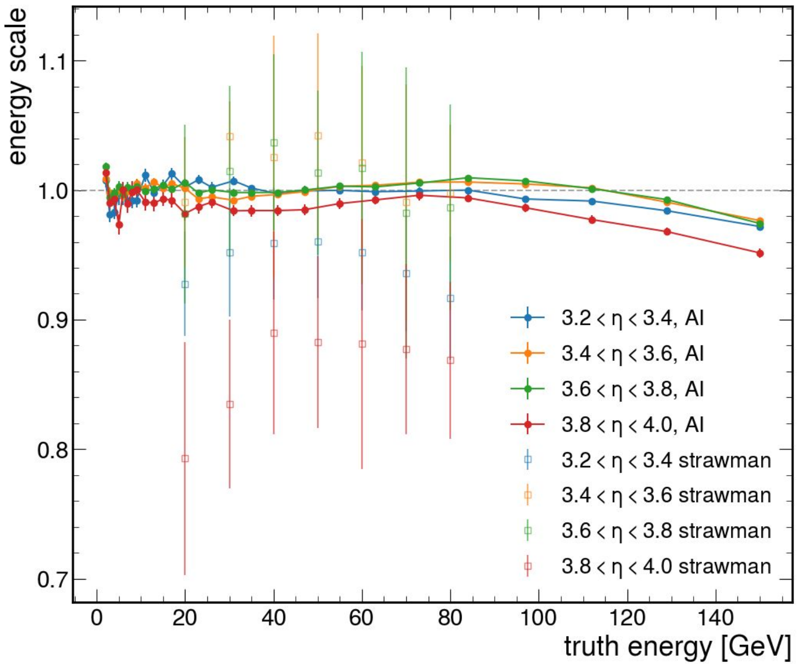
Polar-angle resolution



Improved energy reconstruction with machine learning

- Sebastián Morán independently ran an AI algorithm for reconstructing the energy of neutrons
- Gets even better results than my “strawman” reconstruction





Summary

- EICrecon uses a chain of algorithms with fine-tuned parameters for producing clusters from hits in the Hcal insert and the Ecal
    - Imaging topo clustering for Hcal insert
    - Island clustering for ECal
- Ecal clustering has been updated to reduce excessive numbers of clusters for single-electron events
- Neutron benchmark using strawman energy recon with ECAL and HCAL provides reasonable resolutions:
    - Energy: 68%/sqrt(E)
    - Theta: 1.0\oplus 9.1/sqrt(E) mrad
- AI/ML provides an even further improvement on the energy reconstruction, both in resolution and in scale.
- Planned future benchmarks:
    - Muons (for acceptance)
    - Jet reconstruction