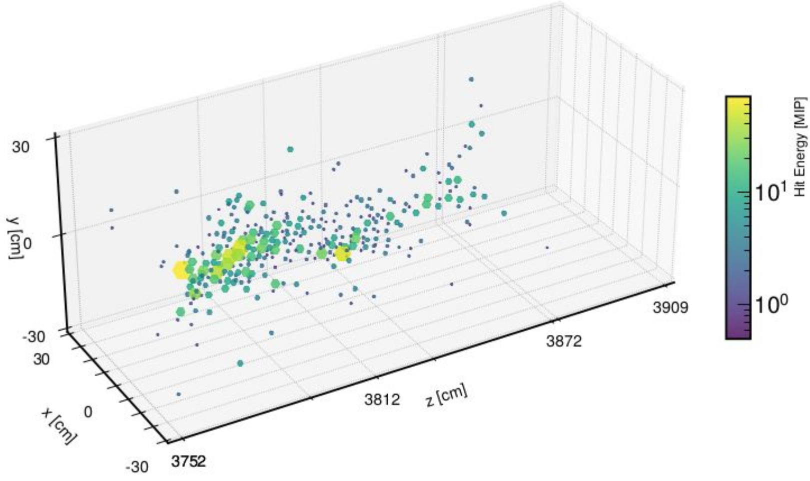
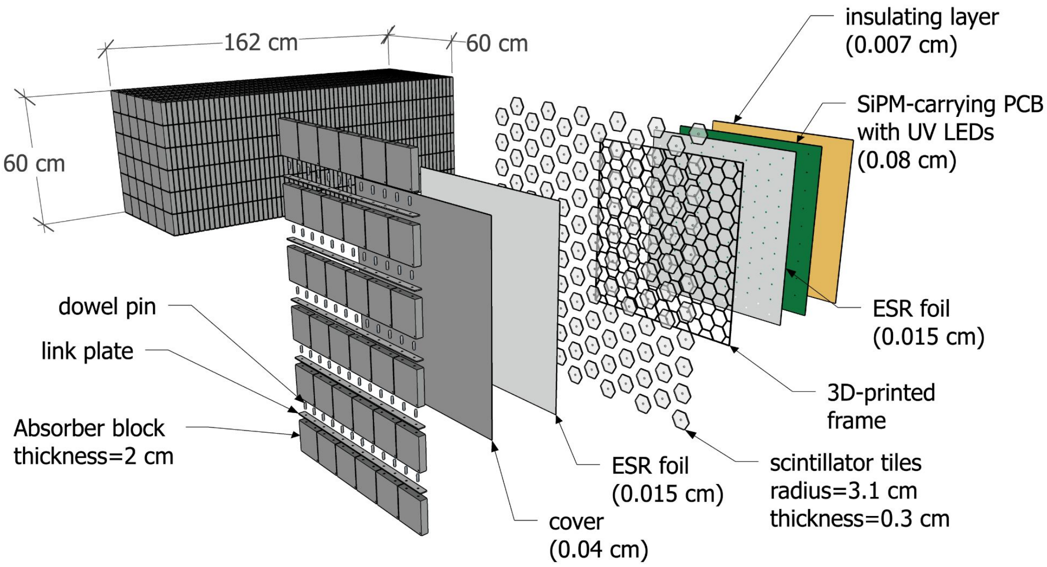
SiPM-on-tile ZDC Reco Status

Sebouh Paul (UC Riverside)

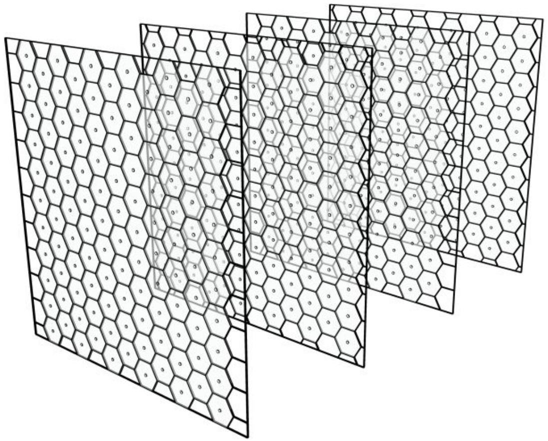


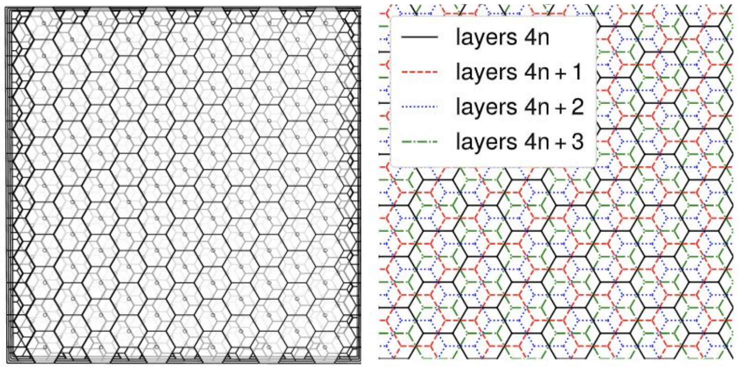
SiPM-on-tile ZDC



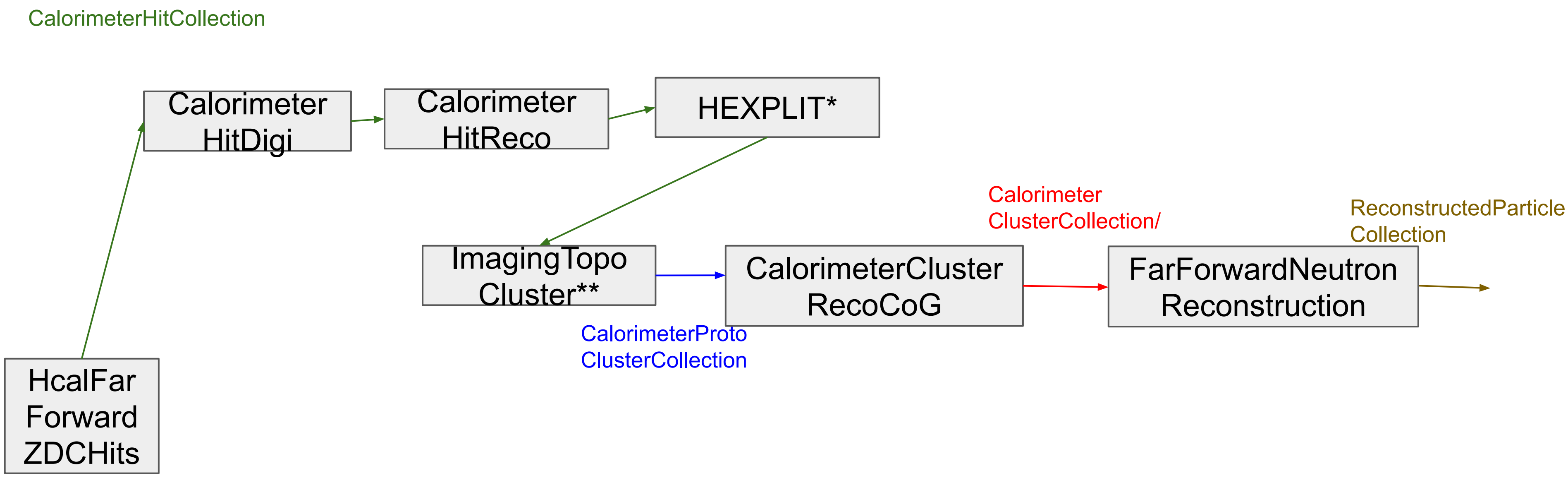
Novel “staggered design”

ZDC





Single neutron reconstruction in the SiPM-on-tile ZDC In EICrecon

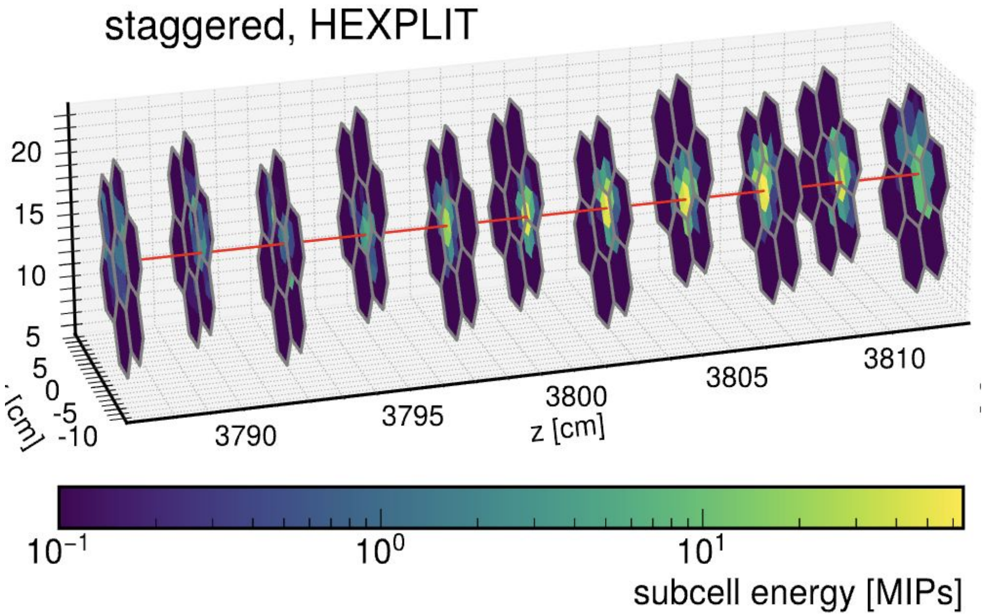


* https://doi.org/10.1016/j.nima.2023.169044

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

Topological clustering

Using pre-existing ImagingTopoClustering algorithm implemented by Chao Peng.

Starts with a definition of a neighbor:

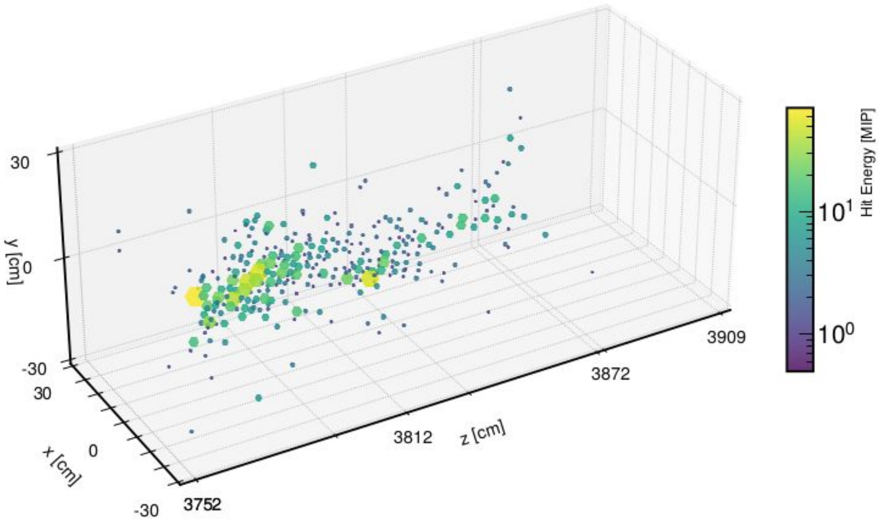
- Same layer: Δx and Δy cut
- Adjacent layers: $\Delta \varphi$ and $\Delta \eta$ cut

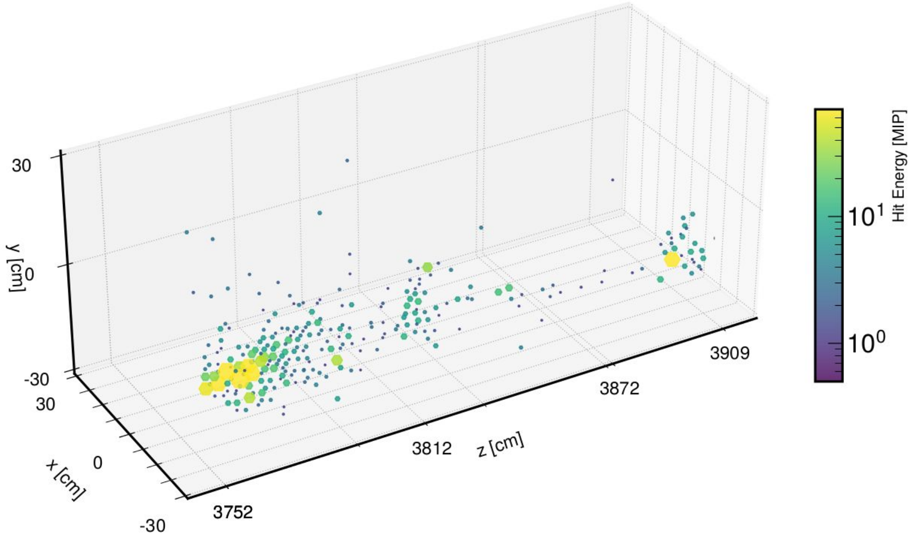
Algorithm:

- 3 thresholds are defined for cell energy: *S* for seeding proto-clusters, *N* for growth of proto-clusters, and *P* for the minimum energy of any hit included
- Define seed hits for proto-clusters as those above threshold *S*, and include their neighboring hits in the protoclusters that are above threshold *P*
- For any hit with energy greater than *N*, include all of that hit's neighbors above *P*. (and merge if it has neighbors in more than one protocluster)

https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/ImagingTopoCluster.h

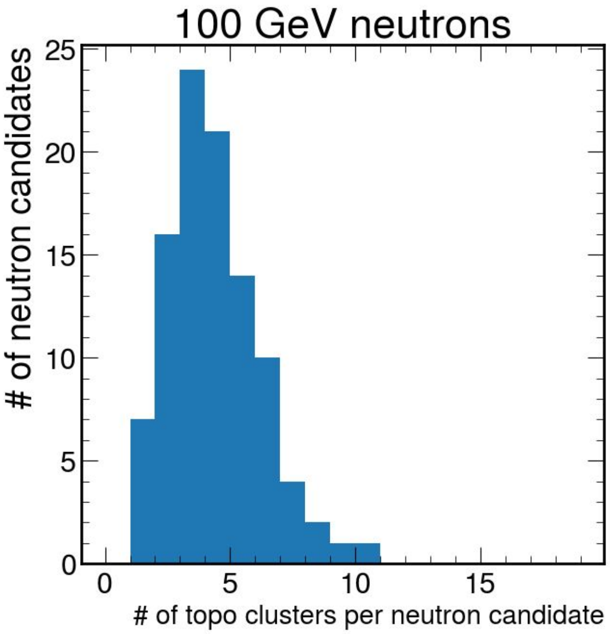
Example 100 GeV neutron showers

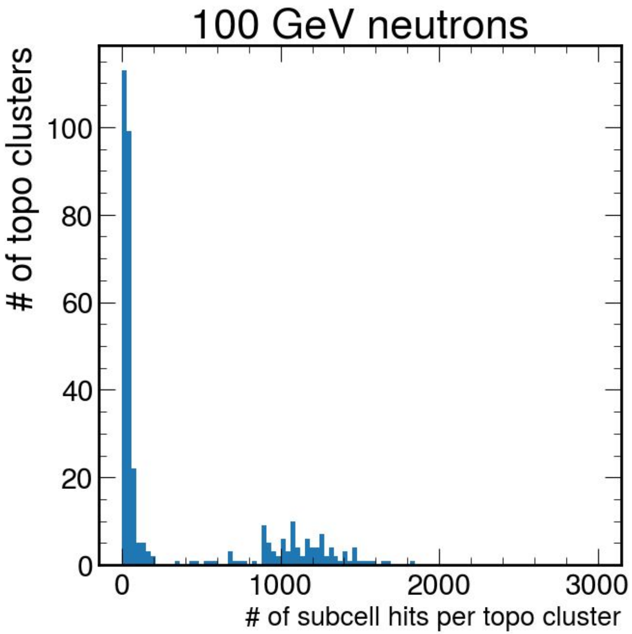


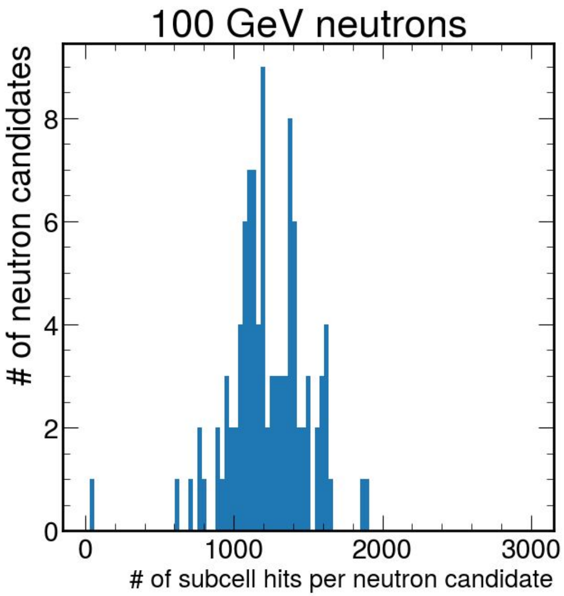


Due to high granularity, we EXPECT the topocluster to often yield more than one "cluster" per particle. This is expected, and seen in H1@HERA / ATLAS@LHC

Topo clustering and merging into "neutron candidates" in EICrecon



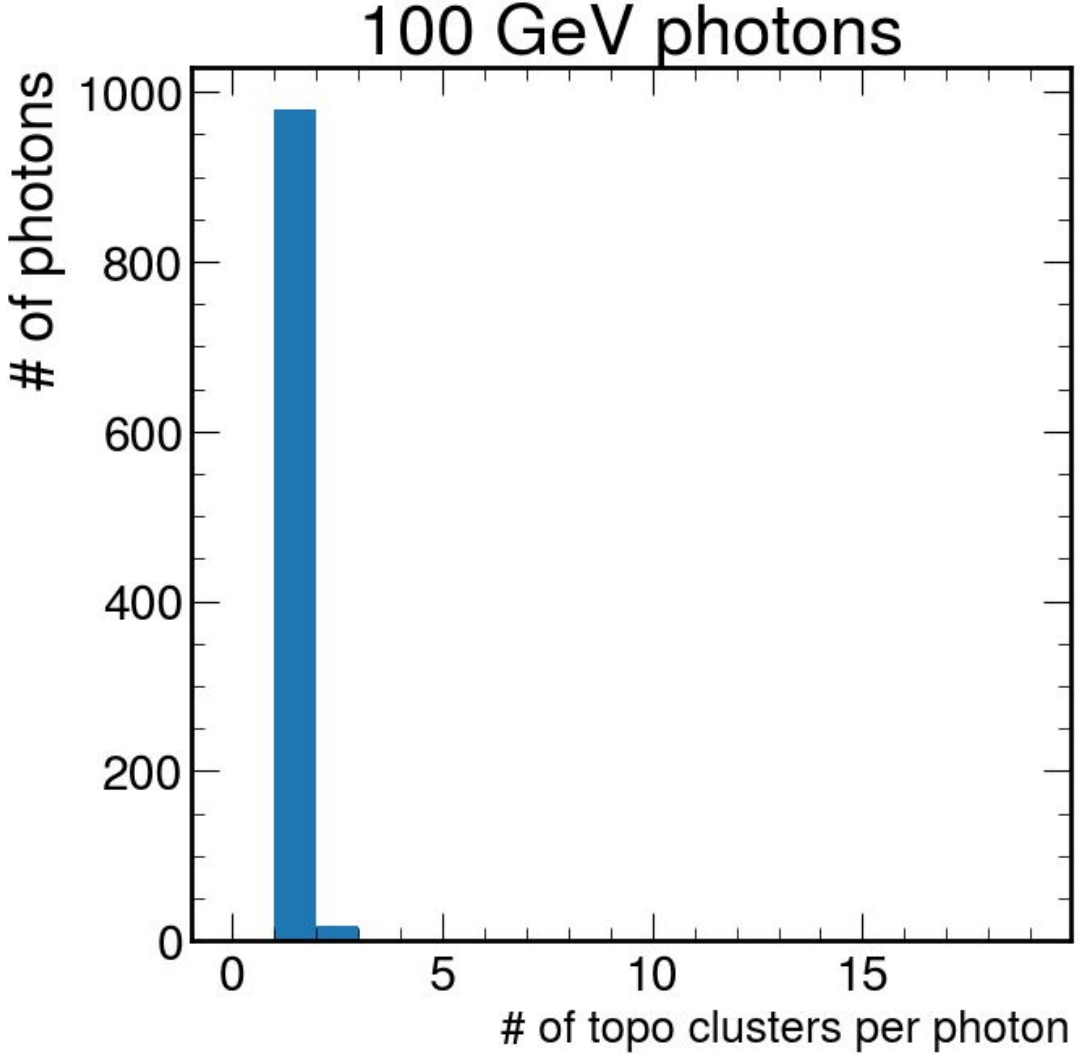




https://github.com/eic/EICrecon/blob/main/src/algorithms/reco/FarForwardNeutronReconstruction.cc

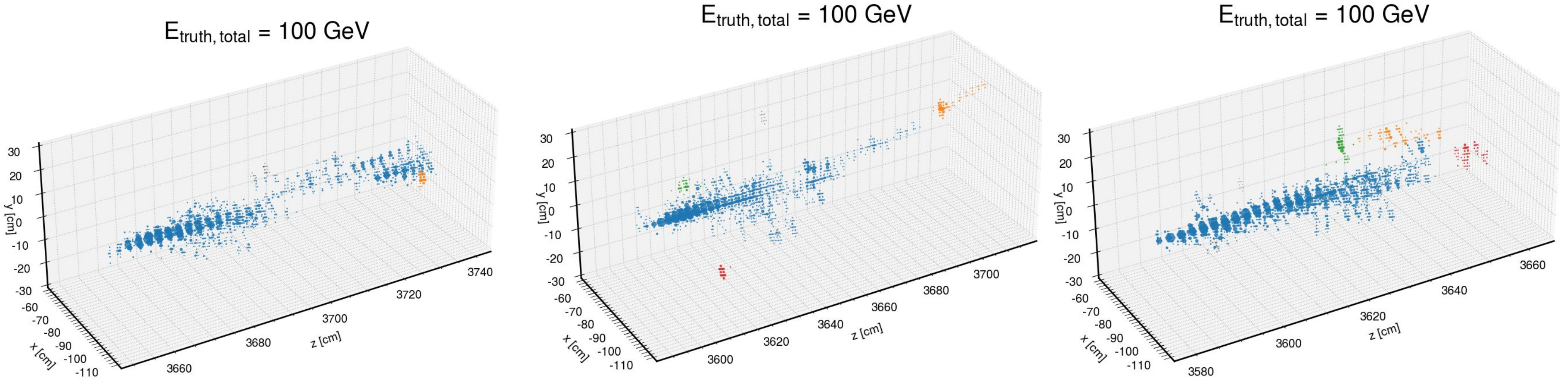
For reference…

Photon showers usually have only one topo-cluster per shower



Results of Clustering algorithm for neutron showers

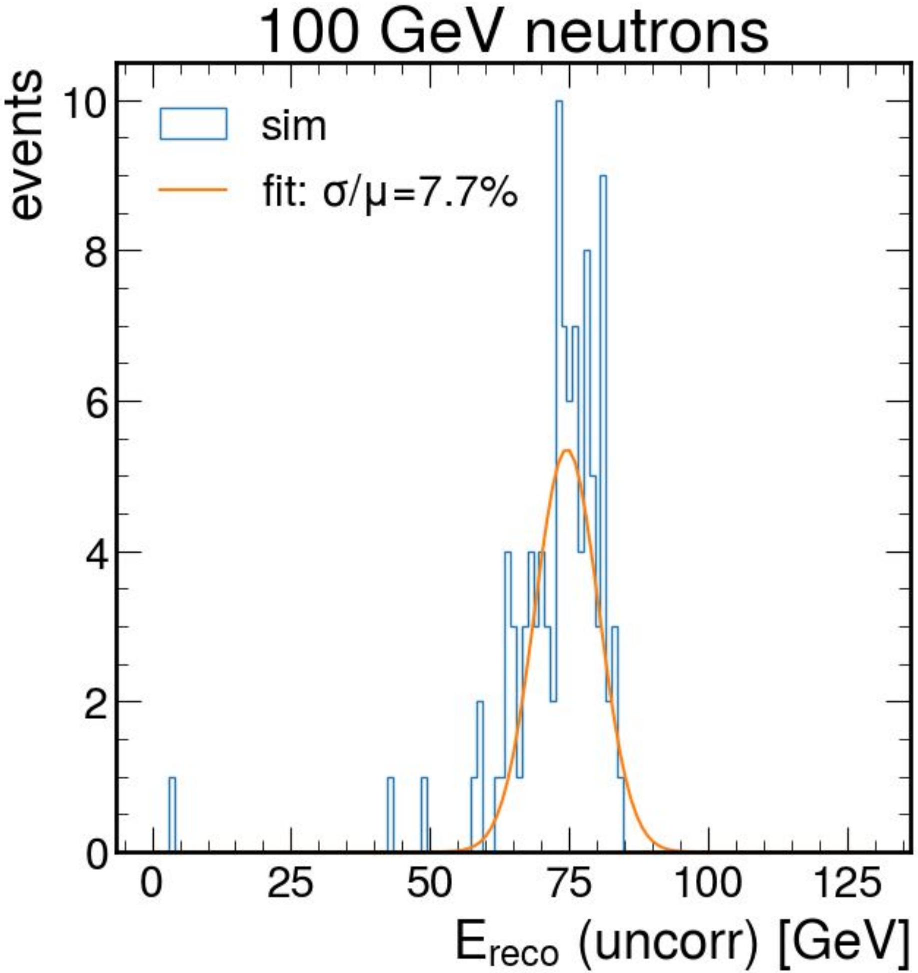
Different colors represent different topoclusters formed by the imaging topoclustering algorithm. Shown are subcell hits (after HEXPLIT)



Energy reconstruction (pre correction)

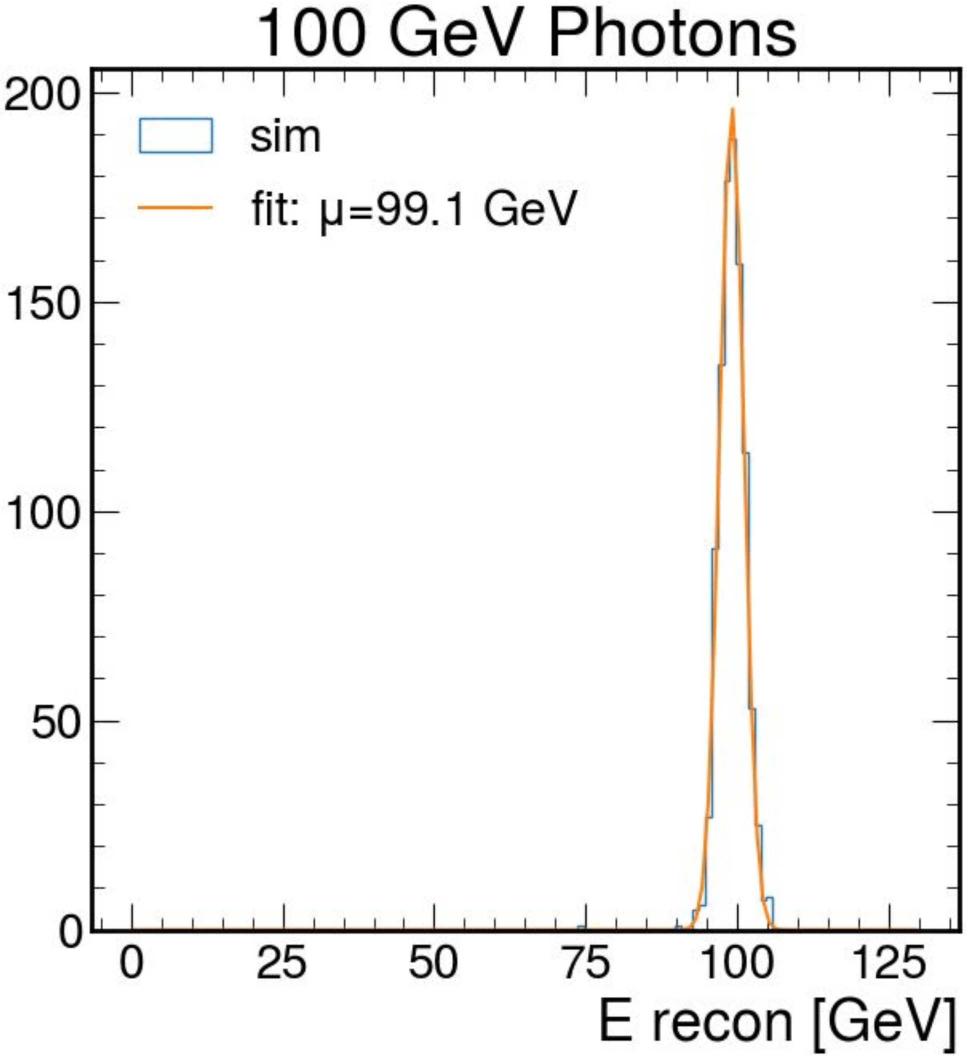
Sampling fraction calibrated with EM showers

About 30% below the truth energy of the neutrons.
This is expected due to non-compesated nature of Fe/Sc calorimeter
(e/h~1.2)



For reference:

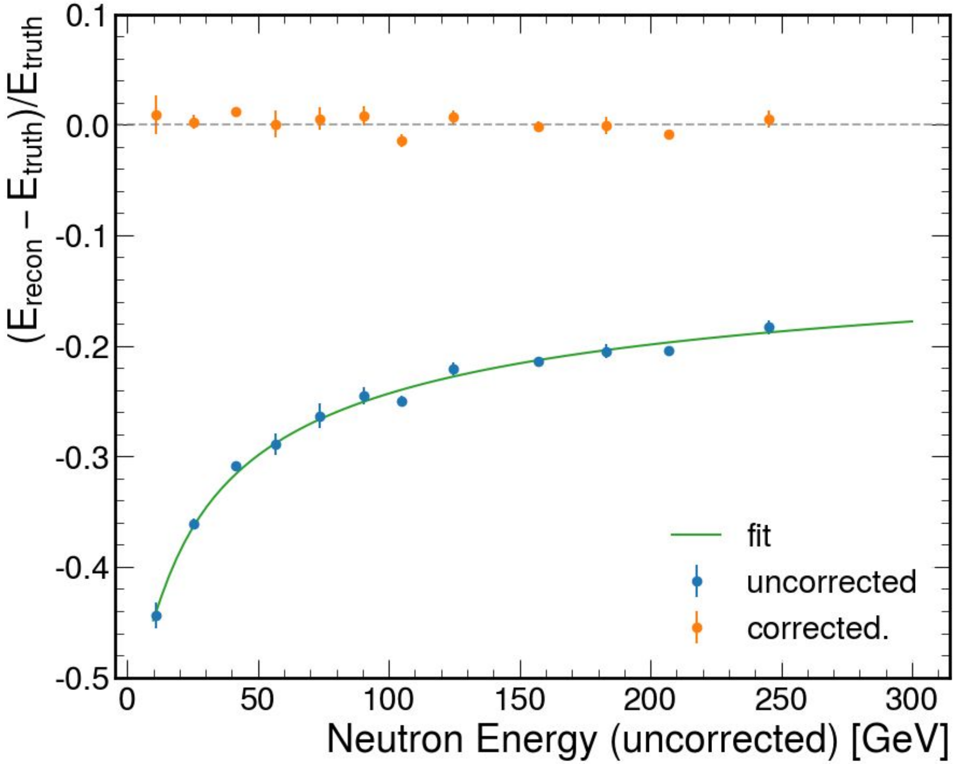
- Repeated procedure with photons
- Almost no difference between mean recon value and truth energy.



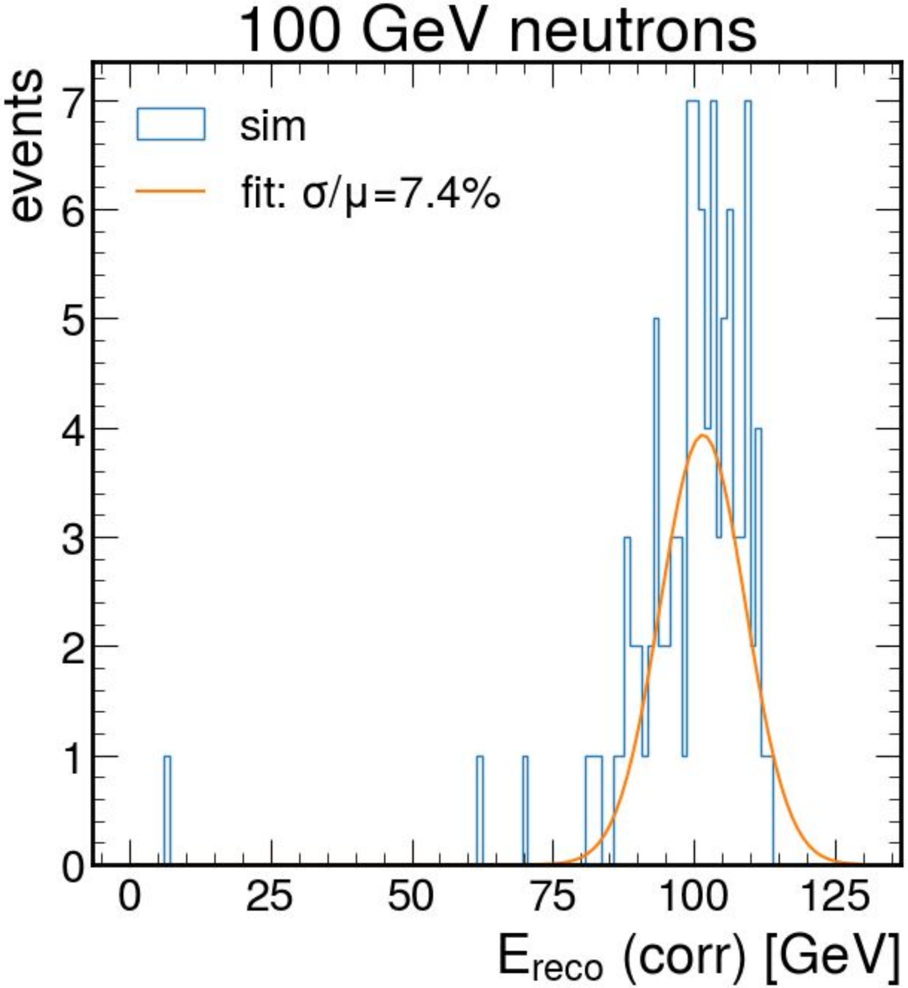
Scale correction for neutron recon

- Uncorrected energy is the total energy of all clusters in ZDC
- Determined a functional form for the correction*:
- Ecorr=E/(1+a+b/sqrt(E)+c/E), where E is the uncorrected energy

*https://github.com/eic/EICrecon/pull/1454, merged into main two days ago.

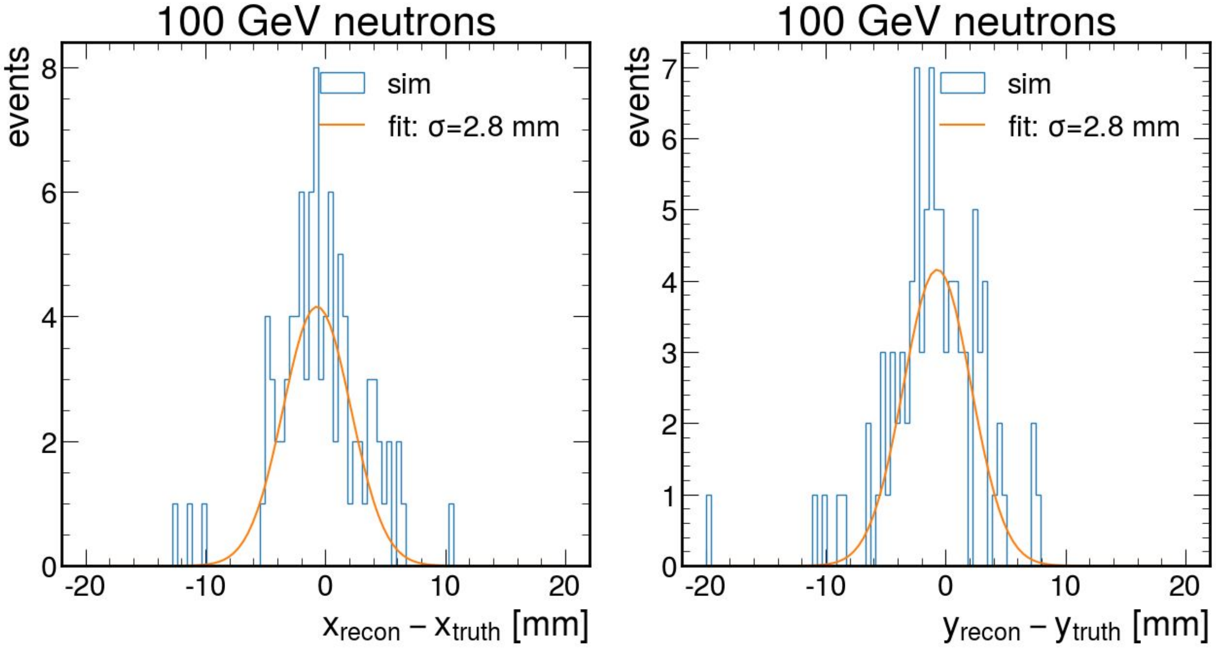


Reconstructed neutron energy after corrections



Position reconstruction neutron showers in EICRECON

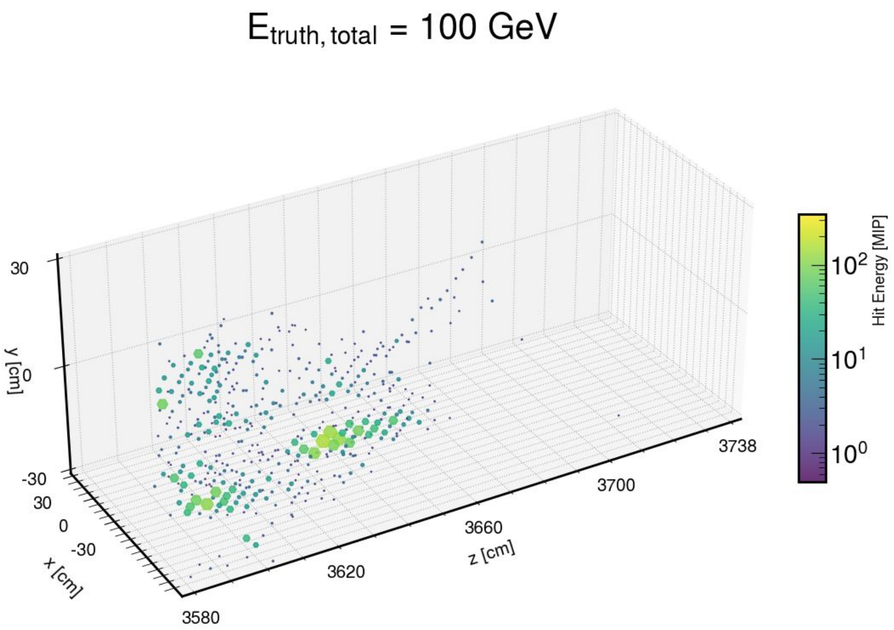
Determined using most energetic cluster in shower



Lambda reconstruction in the ZDC

Require at least three clusters:

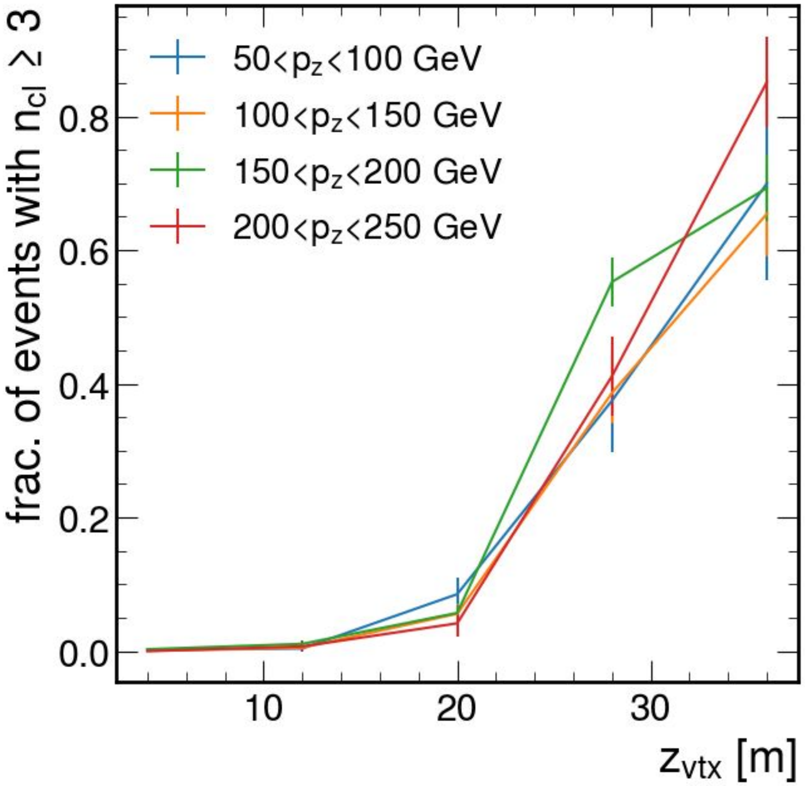
- Neutron + 2 gammas from π0
- Some events will fail this cut:
  - if one or more particles misses the ZDC
  - if the decay takes place downstream of the ZDC
  - If the showers from one particle are merged with those of another



Acceptance*Efficiency

Fraction of events which have at least 3 topo clusters in the final state

If the Λ decays too early, then one of the particles is likely to miss the detector.



Calculating theta

First calculate 3d momentum:

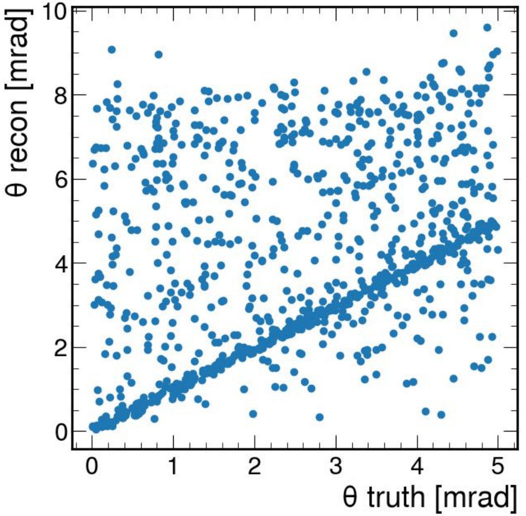
$$\vec{p}_\Lambda = \sum_{i \in \text{clusters}} E_i \frac{\vec{x}_i}{|\vec{x}_i|}$$

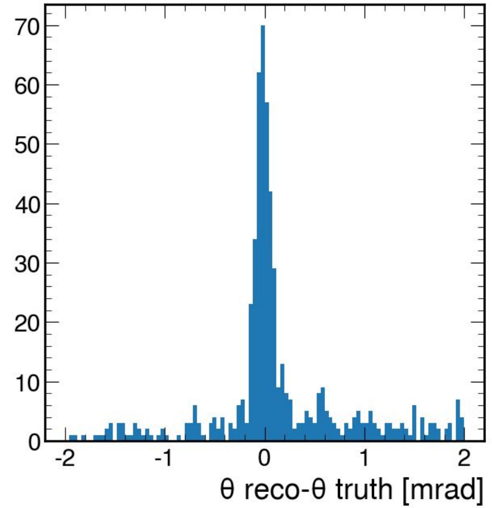
- Positions given by HEXPLIT/log-weight CoG
- Particles are assumed to come from the origin
- No energy correction

Large tails in θ residual distribution

- Could be improved by better identification of Λ candidates through AI

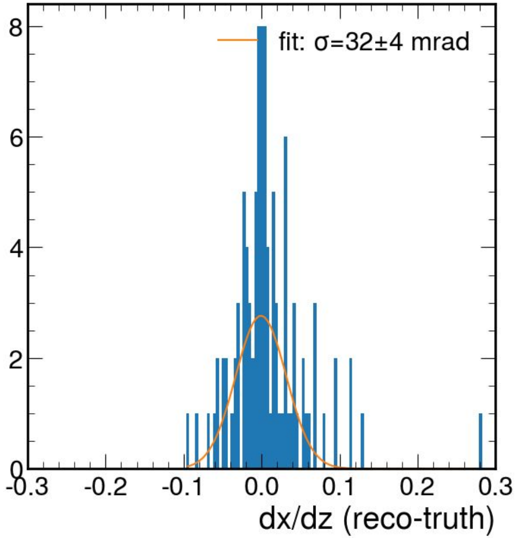
Peak width is ~0.08 mrad, comparable to earlier studies for a single neutron at ~100 GeV with HEXPLIT + log-weight CoG.

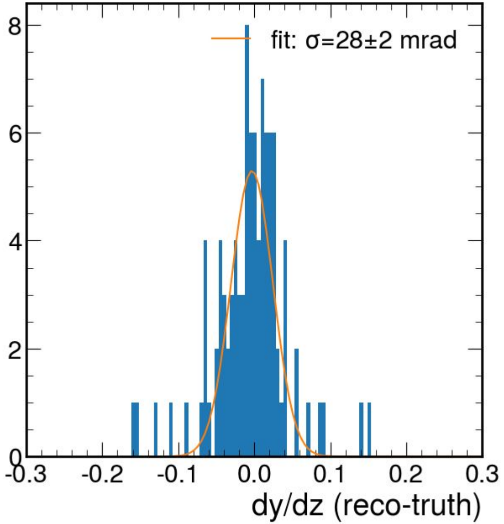




Cluster shape parameters

- Determined the direction of the axis of the cluster as the eigenvector of the moment matrix (log-weighted CoG) corresponding to the largest eigenvalue
    - About 30 mrad of resolution
- Added this to the existing shape parameters

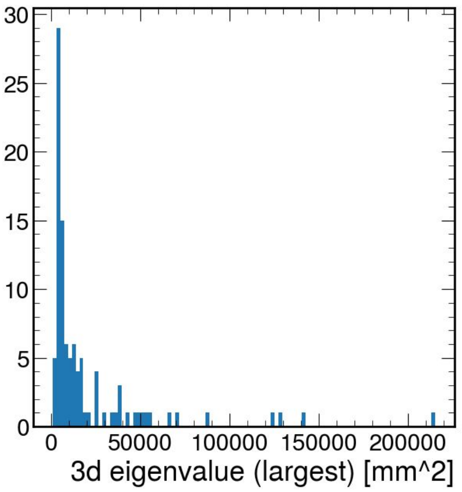


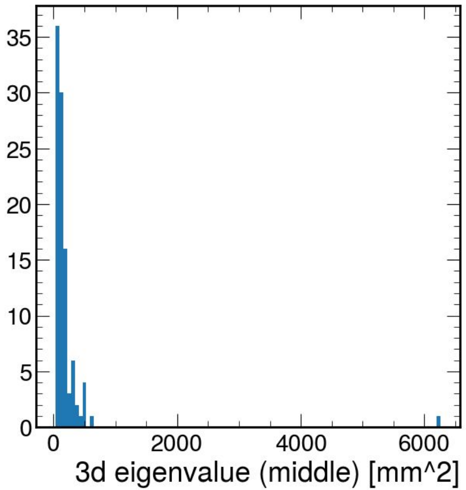


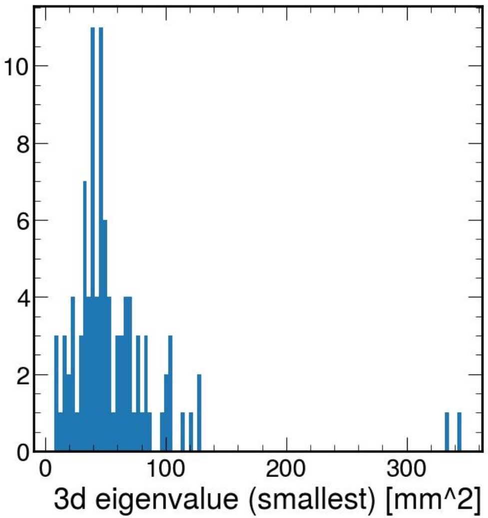
Draft pull request
https://github.com/eic/EICrecon/pull/1391

Other shape parameters

- Existing shape parameters
  - 3D radius (weighted and unweighted)
  - 2D eigenvalues of weighted moment matrix in θ φ space
  - 3D eigenvalues of weighted moment matrix in x, y, z space
- Could be used for distinguishing between π0, single photons and neutrons

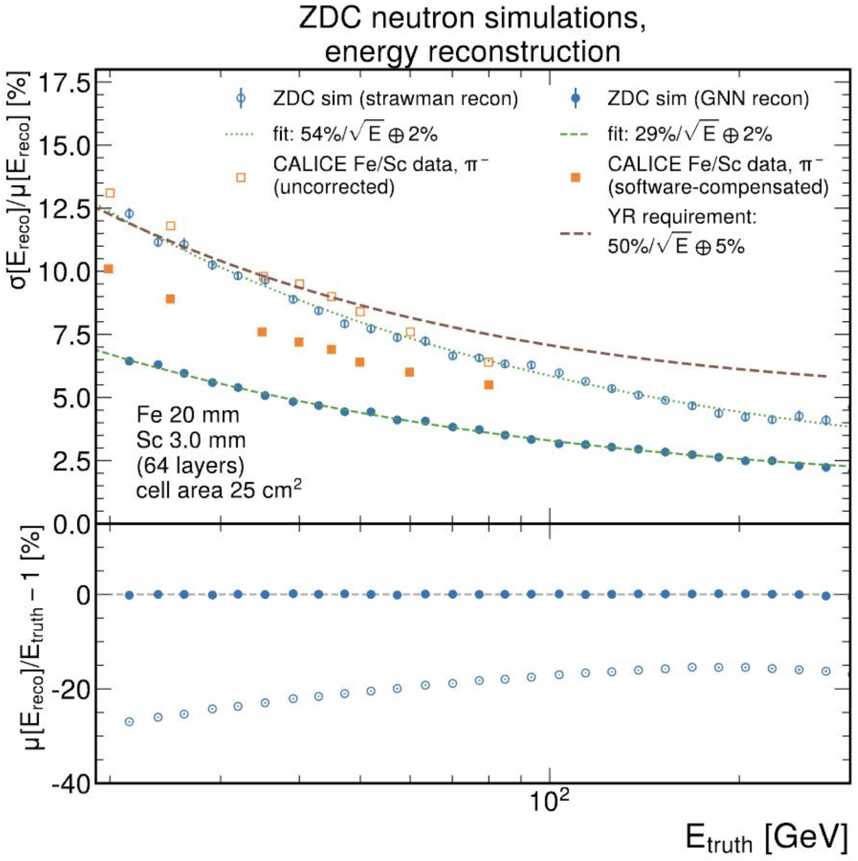






Graph Neural network approach to ZDC recon

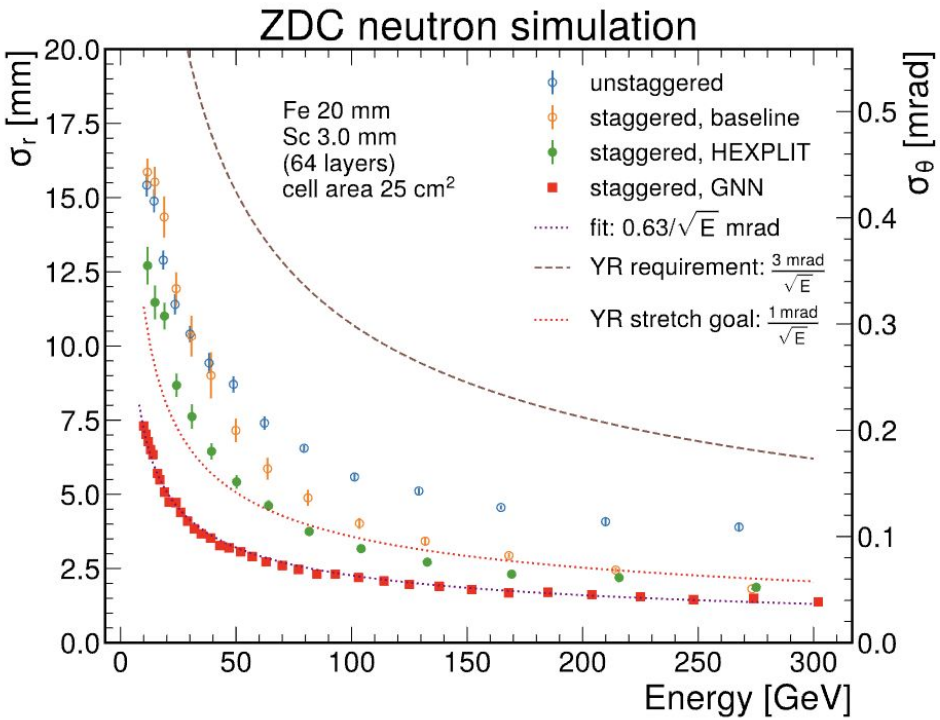
- Alternative to “conventional” method of recon
- GNN to be added to EICrecon soon.
- Much better energy resolution than conventional recon
- Submitted to arXiv, should be up soon.
- Currently being added to the EICrecon



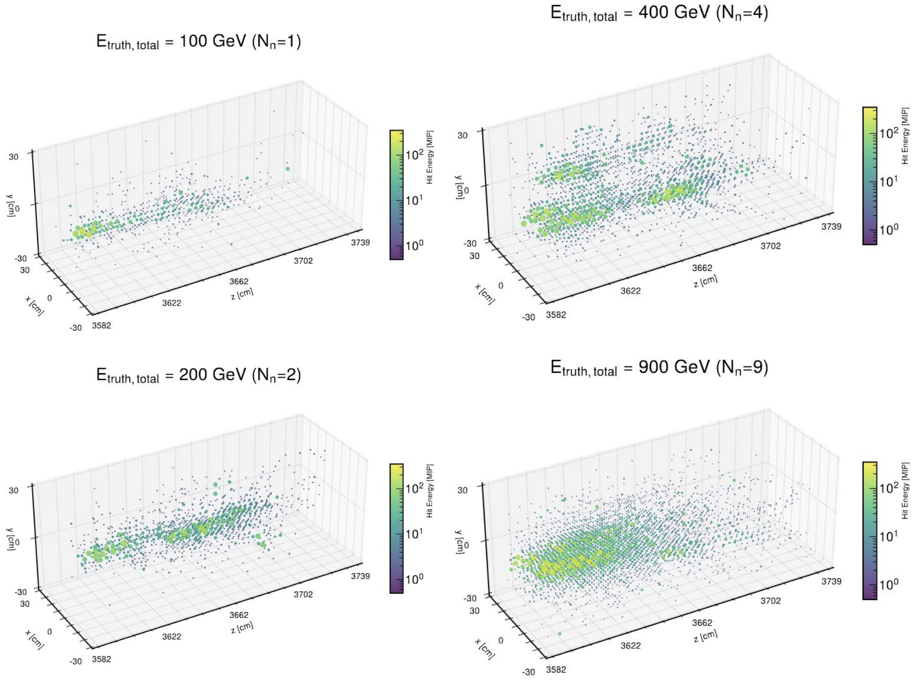
Position resolution from GNN

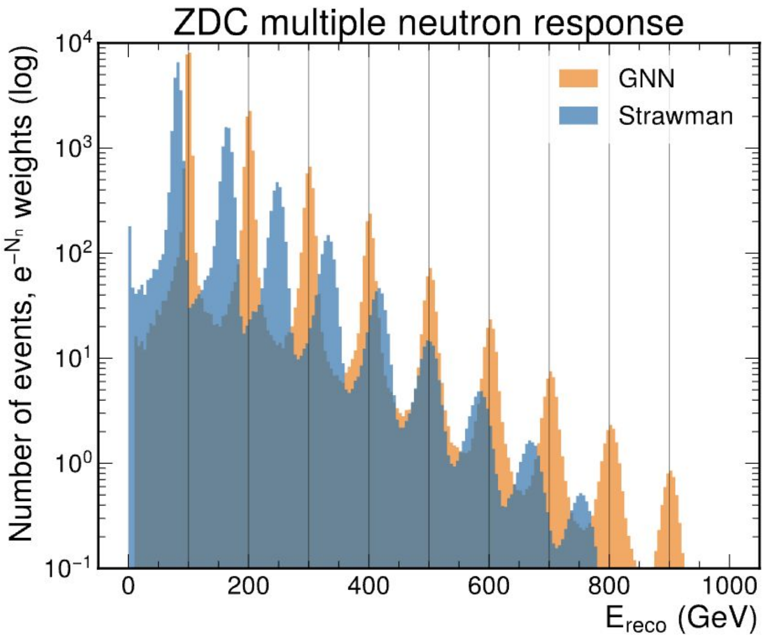
Outperforms conventional (HEXPLIT+log-weighted CoG) method especially at low energies.

Currently GNN being added to EICRECON



Multi-neutron events in the GNN



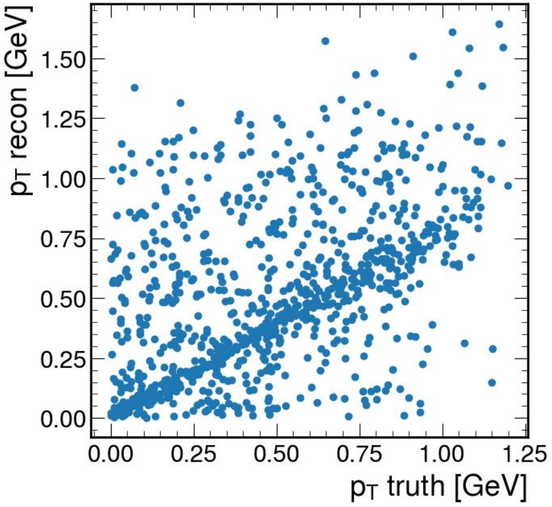


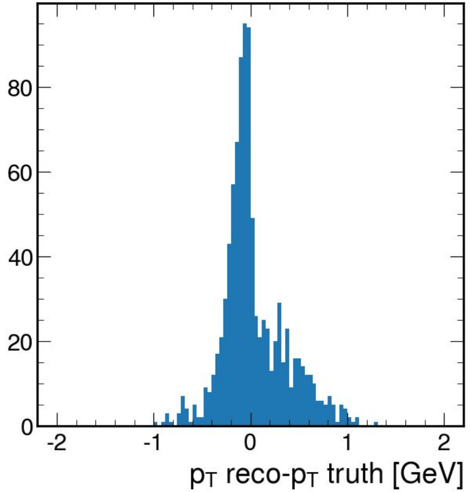
Conclusions

- Single-neutron recon:
  - Can be reconstructed using topological clusters, which are then merged to form a single neutron candidate
  - Energy correction is applied as a function of the total energy
  - Merged into EICrecon with pull request #1454
- Lambda reconstruction
  - Theta resolution is comparable to that of the neutron recon
  - More work should be done to identify “good” lambda events
- GNN recon:
  - Alternative to conventional methods.
  - Better resolution for both neutron energy and angle than the conventional methods
  - Can also reconstruct multi-neutron showers

pT reconstruction

- Limitations of this approach:
  - Neutron energy will be biased due to non-compensated response
  - This biases the overall response for the lambda momentum
  - AI could improve this by identifying neutron and removing energy bias.





Backup slide on the geometry of the detector