HCal Insert reconstruction in EICrecon

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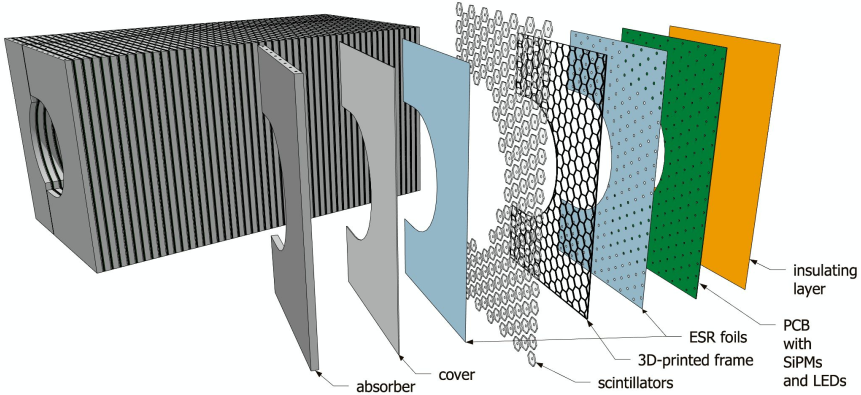
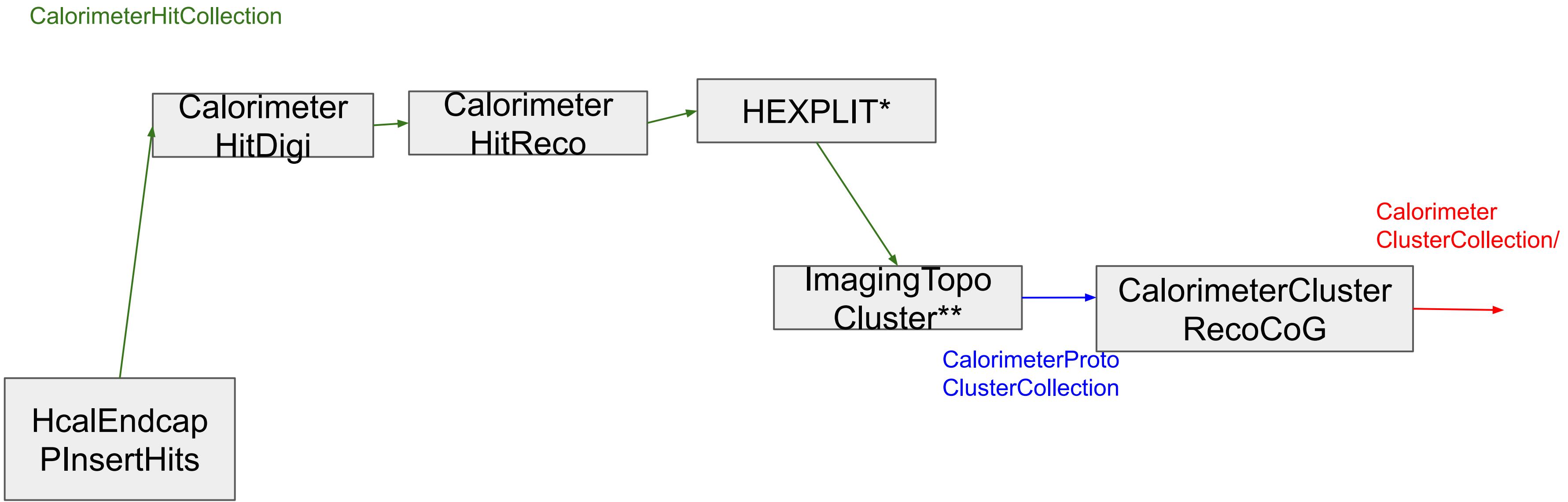


Reconstruction in the Insert in EICrecon***



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

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

***Pull request recently merged:
https://github.com/eic/EICrecon/pull/1474

HEXPLIT algorithm*

- Takes advantage of overlapping cells
- Redistributes energy within a given hit into “subcell hits” in regions defined by overlap between cells.
- Improves position resolution by factor of ~2
- Output is feed to the topological clustering algorithm

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

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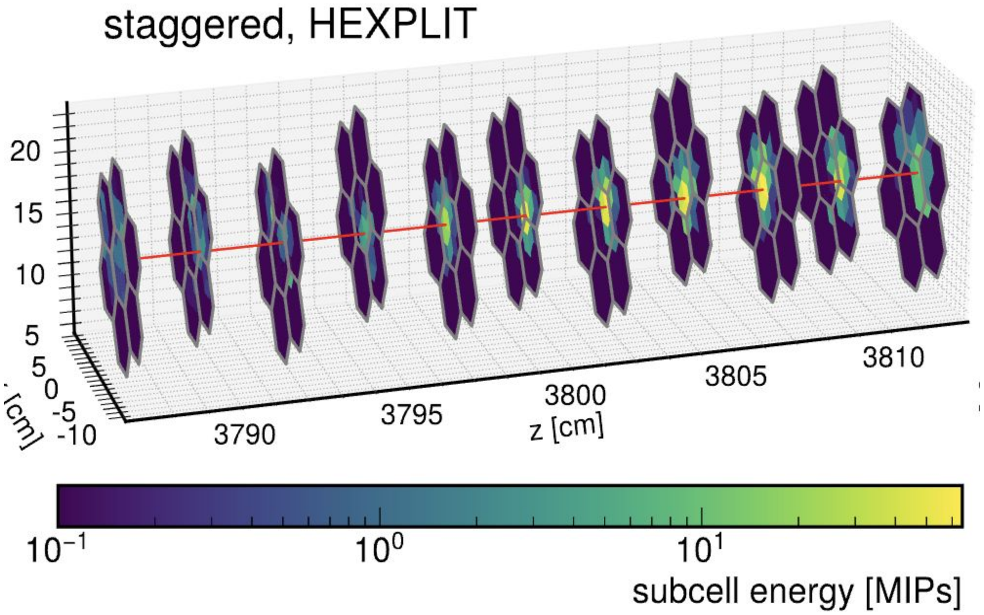
Cuts:

Ehit>0.1 MIP

t<50 ns



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: Δφ and Δη cut

Algorithm:

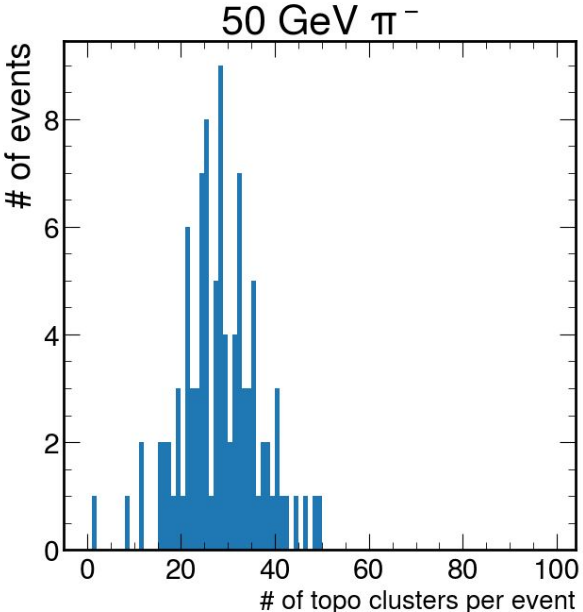
- 3 thresholds are defined for cell energy: *S* for seeding proto-clusters, *N* for growth of proto-clusters, and *P* for the minimum energy of any hit included
- Define seed hits for proto-clusters as those above threshold *S*, and include their neighboring hits in the protoclusters that are above threshold *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)

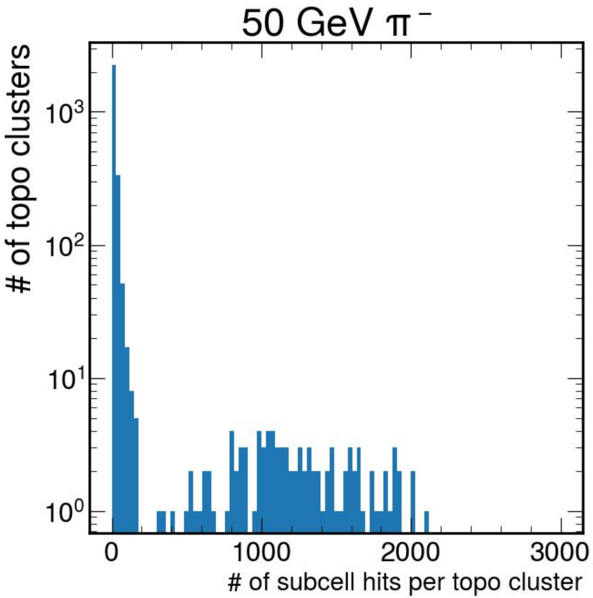
https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/ImagingTopoCluster.h

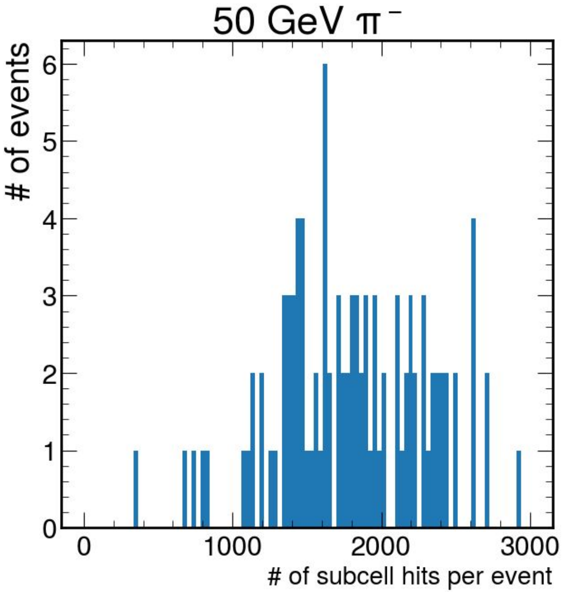
Results of HEXPLIT + topo clustering

A large number of “clusters” with only one or a few real hits

Parameters will need to be better tuned to appropriate values.


50 GeV π^-

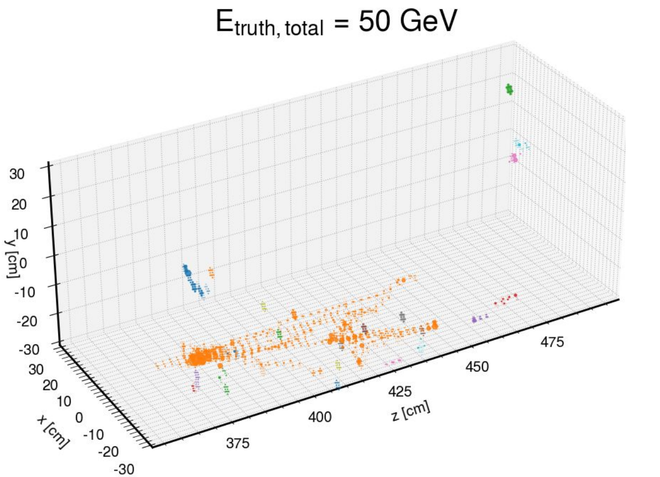

50 GeV π^-


50 GeV π^-

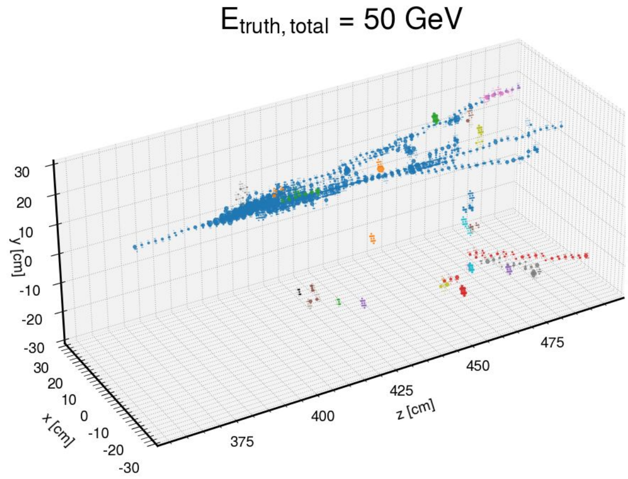
A few events (each color represents a different topocluster)

Clearly a lot of small “clusters” that don’t look like they belong to the shower.

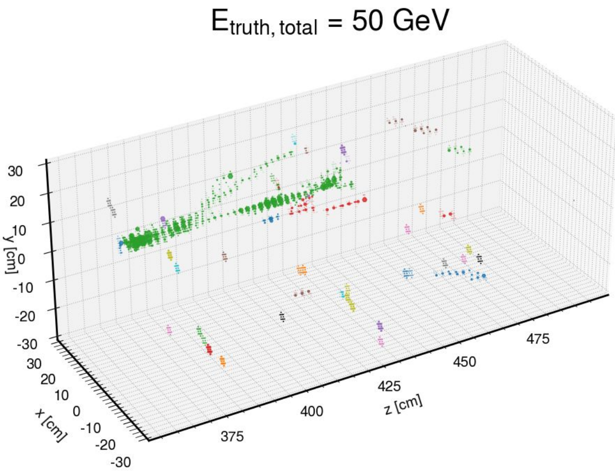
Needs to be cleaned up. (i.e. topocluster parameters tweaking)



$E_{\text{truth, total}} = 50$ GeV



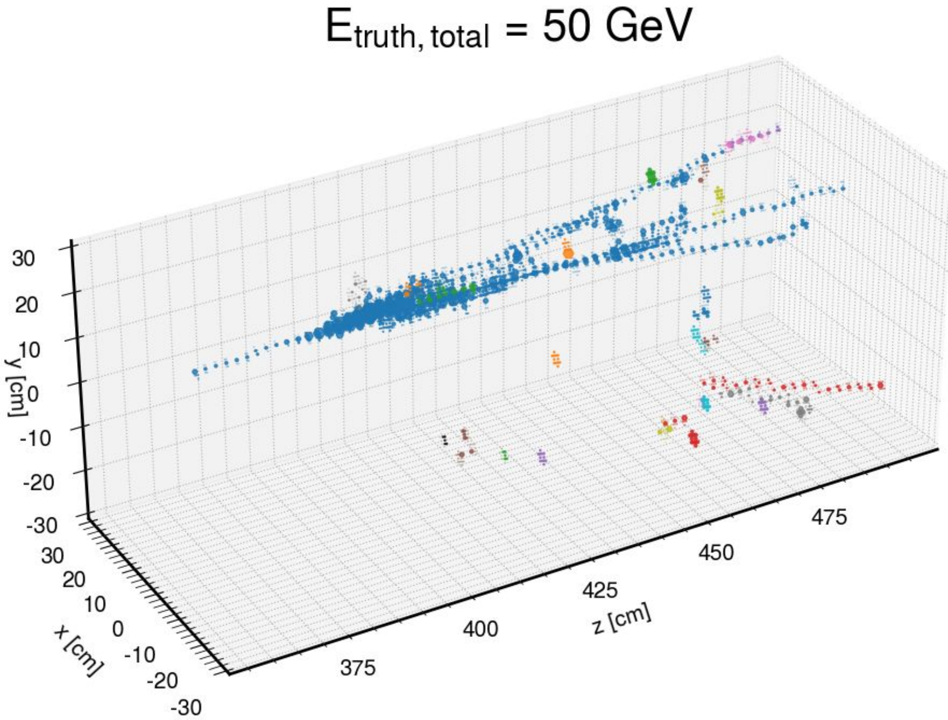
$E_{\text{truth, total}} = 50$ GeV



$E_{\text{truth, total}} = 50$ GeV

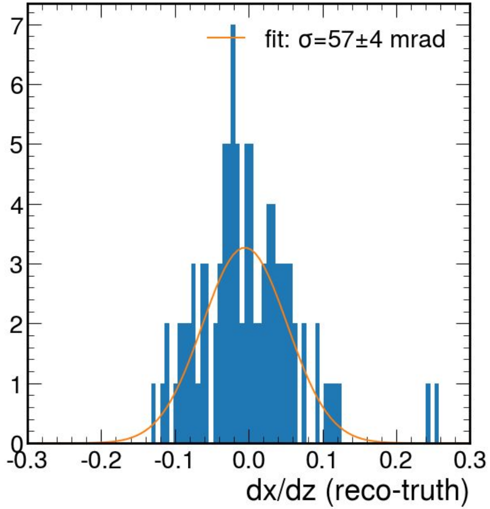
Single-hit or few-hit clusters

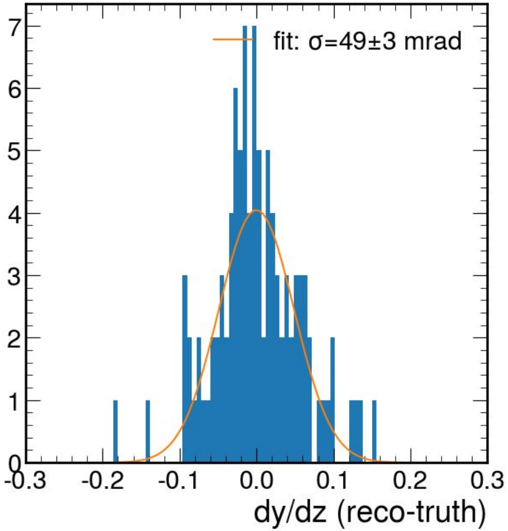
- One possible solution:
  - switch order of HEXPLIT and topo clustering
  - Have HEXPLIT optionally run on hits from each cluster separately, rather than on all hits in the event
  - Adjust parameters of the topo clustering so that they are appropriate for cell-level hits instead of subcell hits
- Another solution:
  - Keep the current order of algorithms, but increase the minimum number of hits per cluster (currently 10, should be increased to O(100) subcell hits)



Cluster axis direction

- Cluster axis is the eigenvector of the log-weighted moment matrix with the largest eigenvalue
- Merged in pull request https://github.com/eic/EICrecon/pull/1391
    - Modified file is https://github.com/eic/EICrecon/blob/main/src/algorithms/calorimetry/CalorimeterClusterRecoCoG.cc
- Resolution is ~50 mrad, as determined from the cluster axis of the highest-energy cluster





Ongoing work: total four momentum

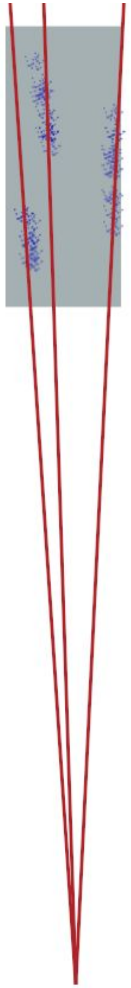
Currently writing an algorithm to add the four momenta of all clusters in event assuming all particles are from the origin

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

Useful for determining the total hadronic transverse momentum of an event.

A large portion of total pT and total energy falls into Insert

https://github.com/eic/EICrecon/issues/1496

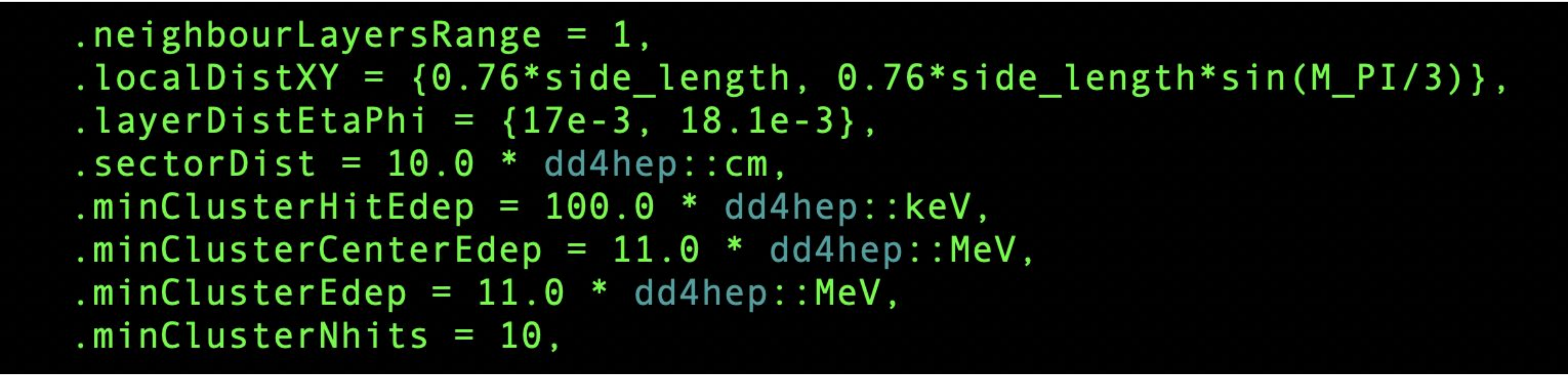


Conclusions/To Do

- HEXPLIT and topo clustering are now used for sub-cell splitting of hits for the insert
- Cluster axis determined from eigenvector with largest eigenvalue of moment matrix
- TODO:
  - Fix issue with single-hit clusters
  - Total four-momentum in the calorimeter insert

Backup slides

Topo clustering parameters currently used



```
.neighbourLayersRange = 1,
.localDistXY = {0.76*side_length, 0.76*side_length*sin(M_PI/3)},
.layerDistEtaPhi = {17e-3, 18.1e-3},
.sectorDist = 10.0 * dd4hep::cm,
.minClusterHitEdep = 100.0 * dd4hep::keV,
.minClusterCenterEdep = 11.0 * dd4hep::MeV,
.minClusterEdep = 11.0 * dd4hep::MeV,
.minClusterNhits = 10,
```