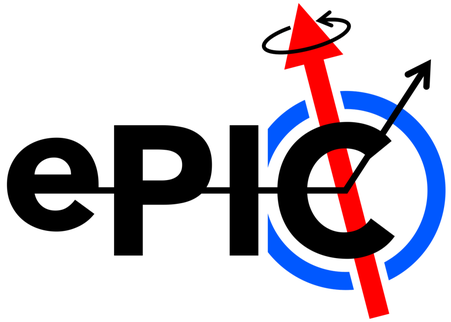
First look (by me) at BIC in simulation — focusing on clustering & response

4 August 2026
BIC Simulation Meeting



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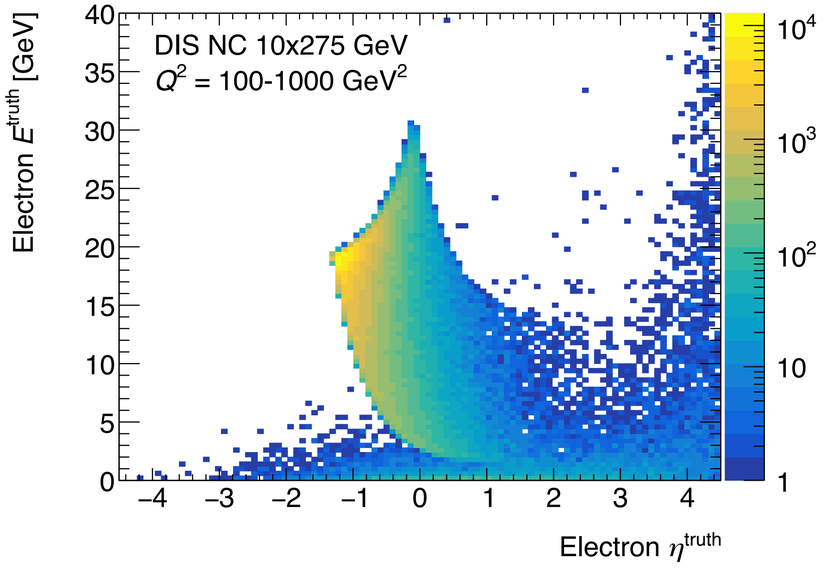
Dataset and collections

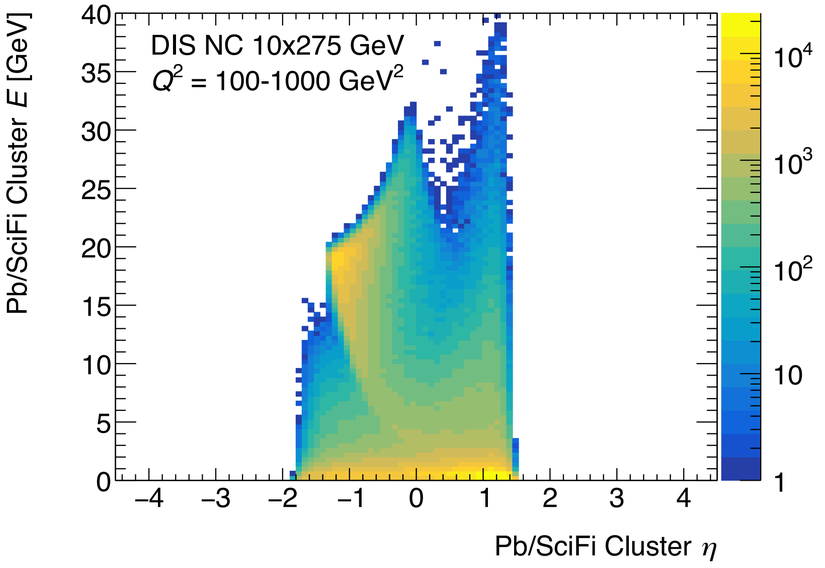
- Analyzing events from **root://epicxrd1.sdcc.bnl.gov:1095//eic/EPIC//RECO/26.06.0/epic_craterlake/DIS/pythia8.316-1.0/NC/noRad/ep/18x275/q2_100to1000/**
  - ➡ 1k files, containing to 427k events
  - ➡ I chose something with a clear high-energy EM shower in the BIC acceptance in every event, just to get started — are there good single particle simulations I should look at?
  - ➡ Not yet looking at ADC/pulse/noise modeling (many thanks Minho Kim for pointers), and not yet at all at AstroPix — just trying to start understanding basic things
- Scattered electron: **MCScatteredElectrons_objIdx.index** → **MCParticles**
- Reco clusters: **EcalBarrelScFiClusters** & **EcalBarrelImagingClusters**
  - ➡ I get the associated RecHits in, e.g., **EcalBarrelScFiRecHits** via **EcalBarrelScFiClusters.hits_begin/end** → **_EcalBarrelScFiClusters_hits.index**

AI acknowledgement: I am using Claude Code to understand the simulation structure/content and for basic plotting

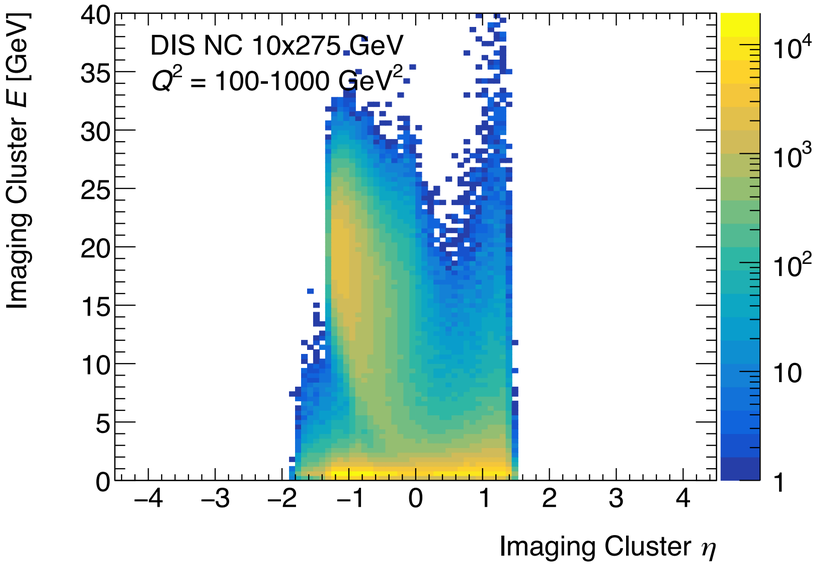
Basic scattered electron / cluster kinematics



η/E of **truth** scattered electrons

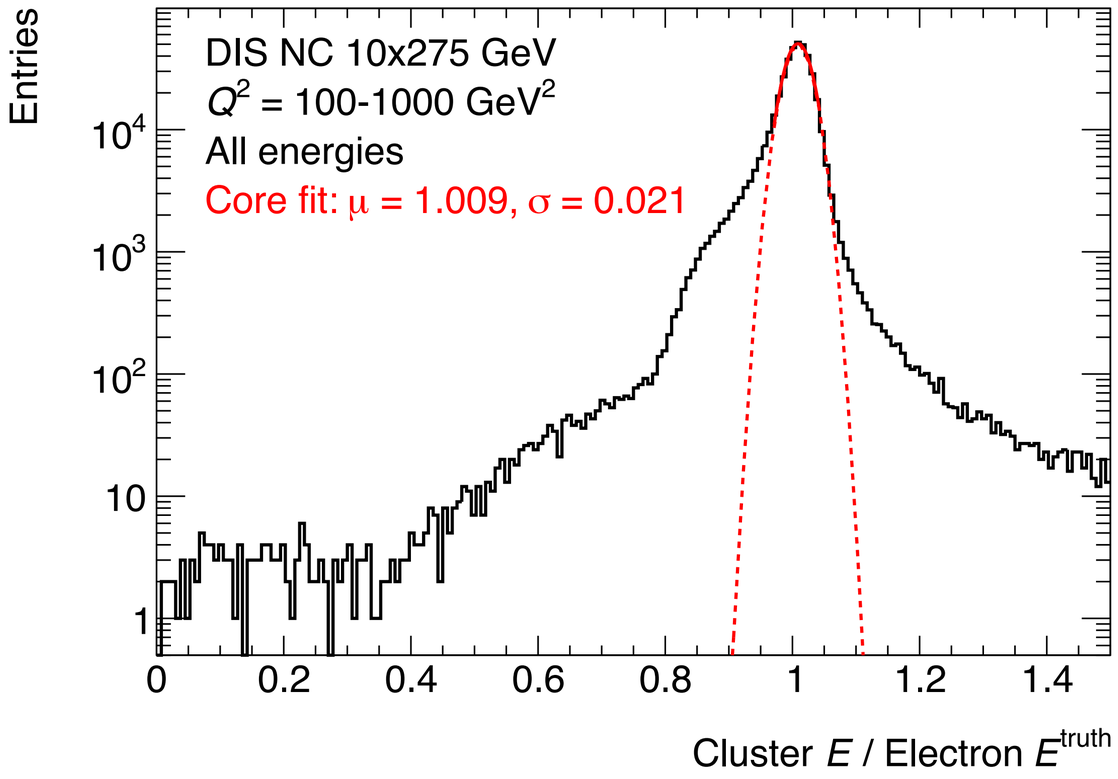


η/E of reco-level **SciFi** clusters (no matching here)

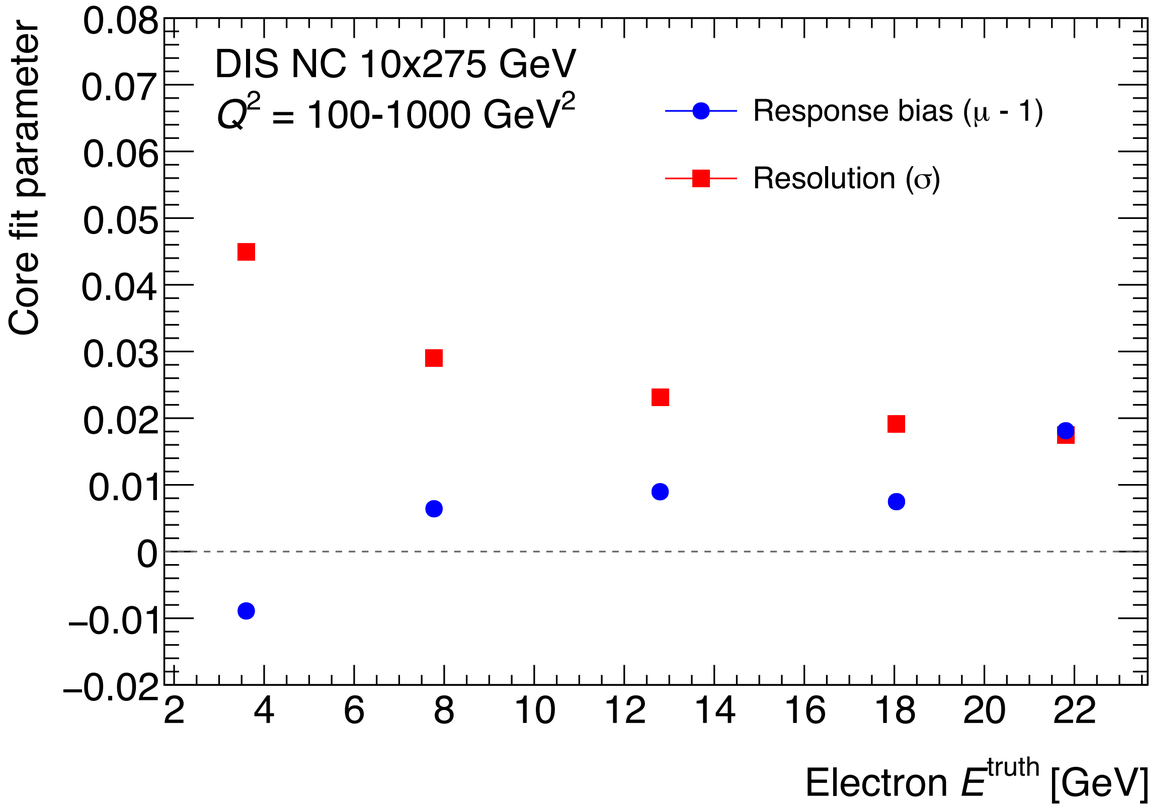


η/E of reco-level **Imaging** clusters (no matching here)

SciFi: electron energy measurement

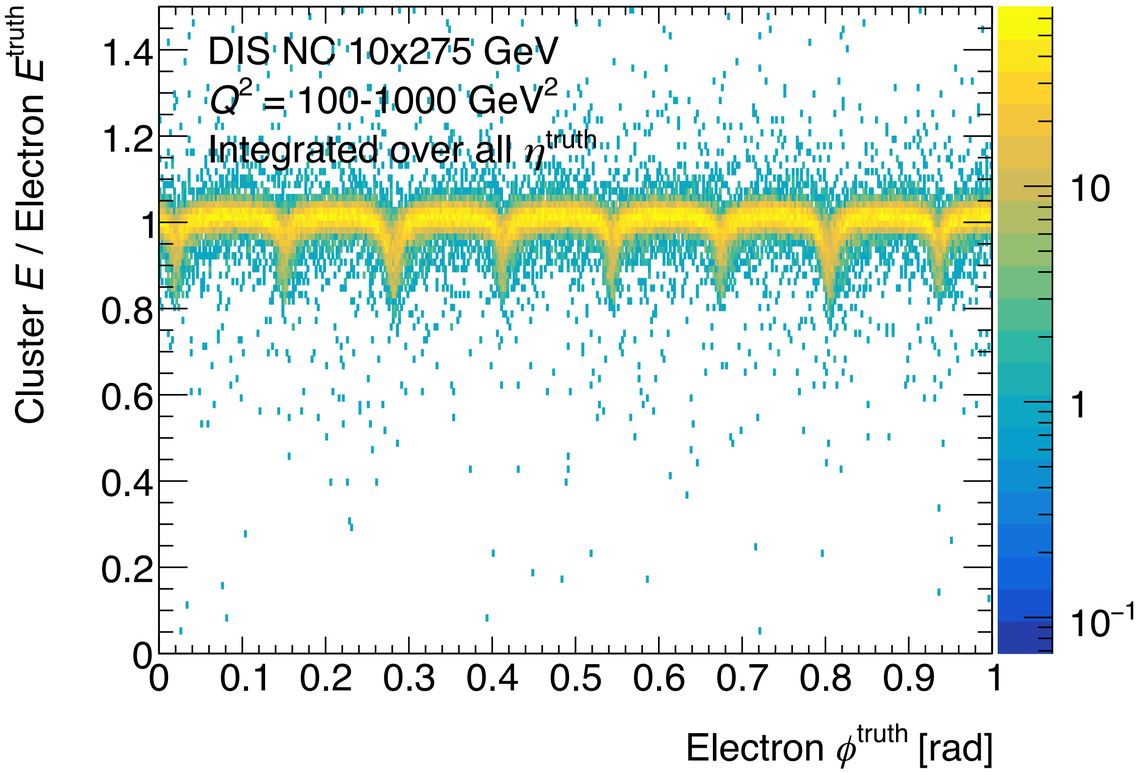


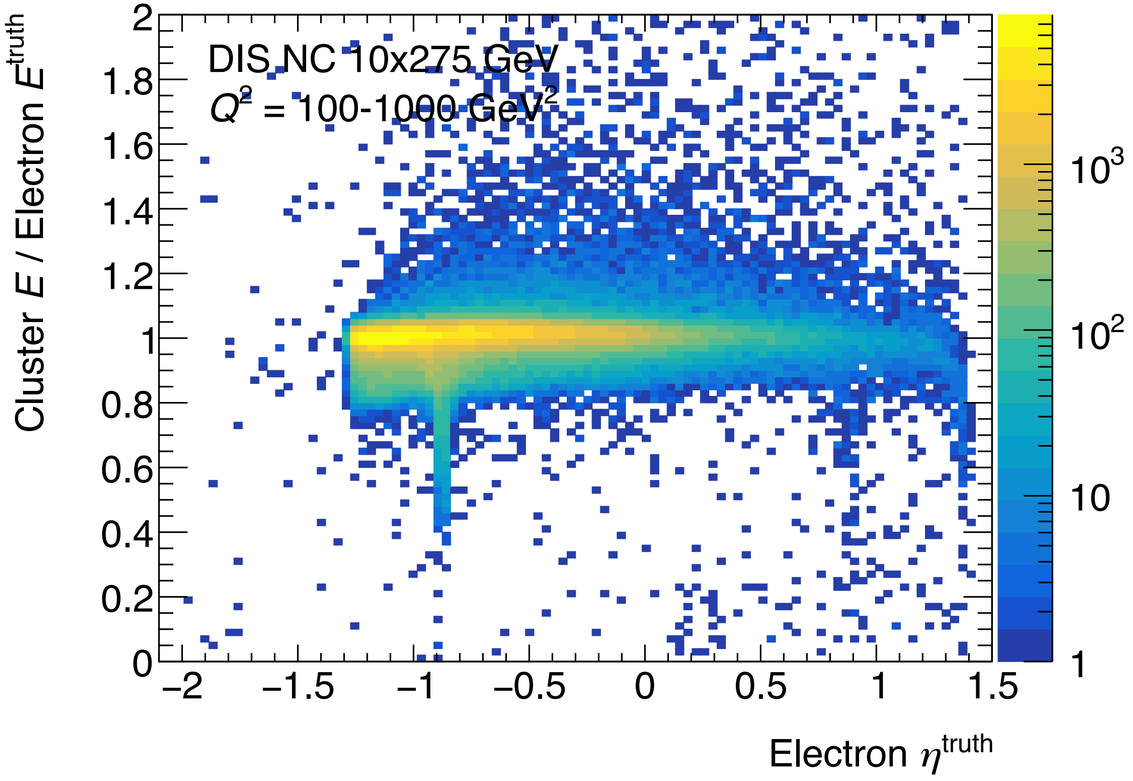
- Response distribution for all energies, with example Gaussian fit to core



- Energy response typically within 1% of unity
- Energy resolution systematically decreases with increasing E, ~2% at ~20 GeV
  - ➡ Seems broadly similar to, e.g., combined SciFi/AstroPix resolution found by Tommy Tsang

SciFi: non-uniformities in response

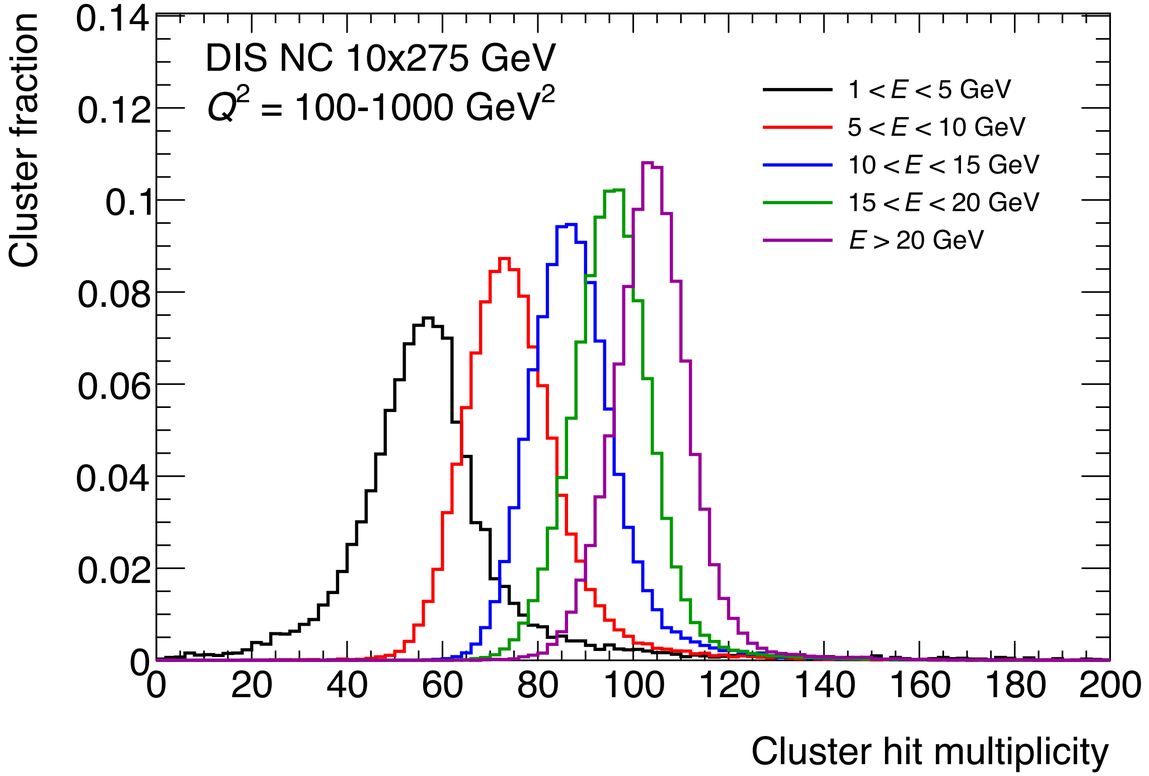


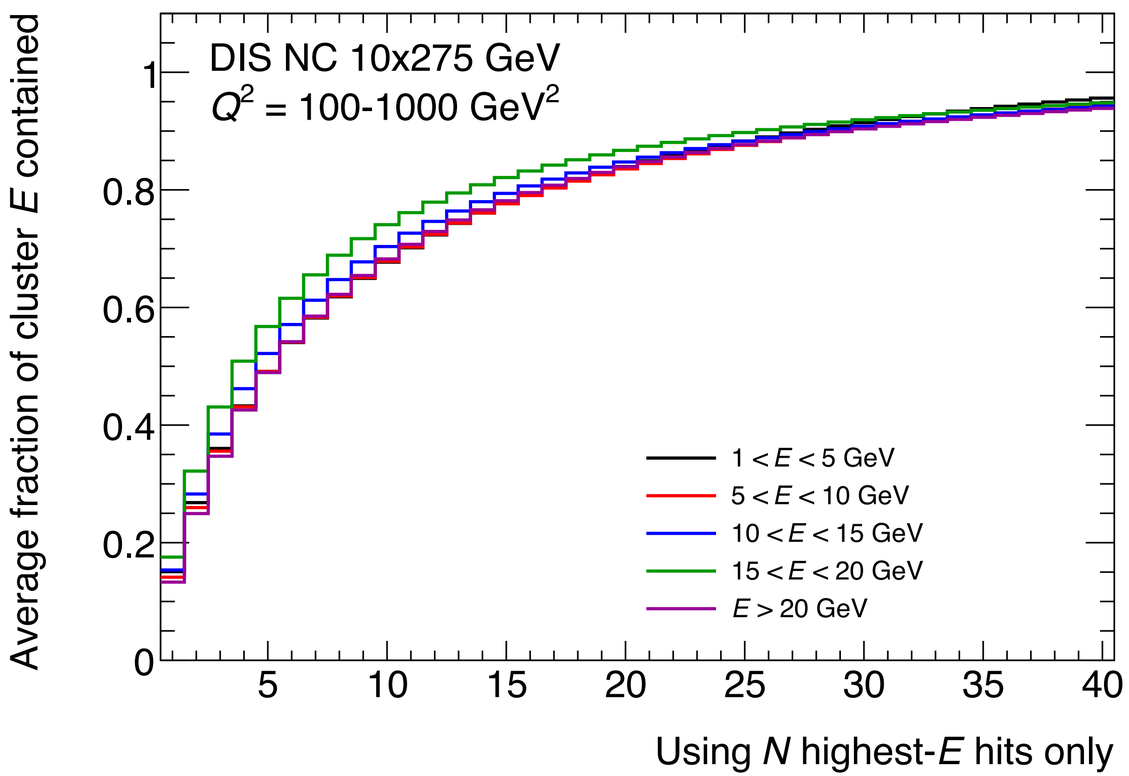


- Zooming in on response vs. ϕ — clear period banding structure from sector size
- **Question**: status of any “position-dependent correction”?

- Noticeable low-response tail right in $-1 < \eta < -0.8$
- **Question:** any ideas?

SciFi: cluster hit multiplicity

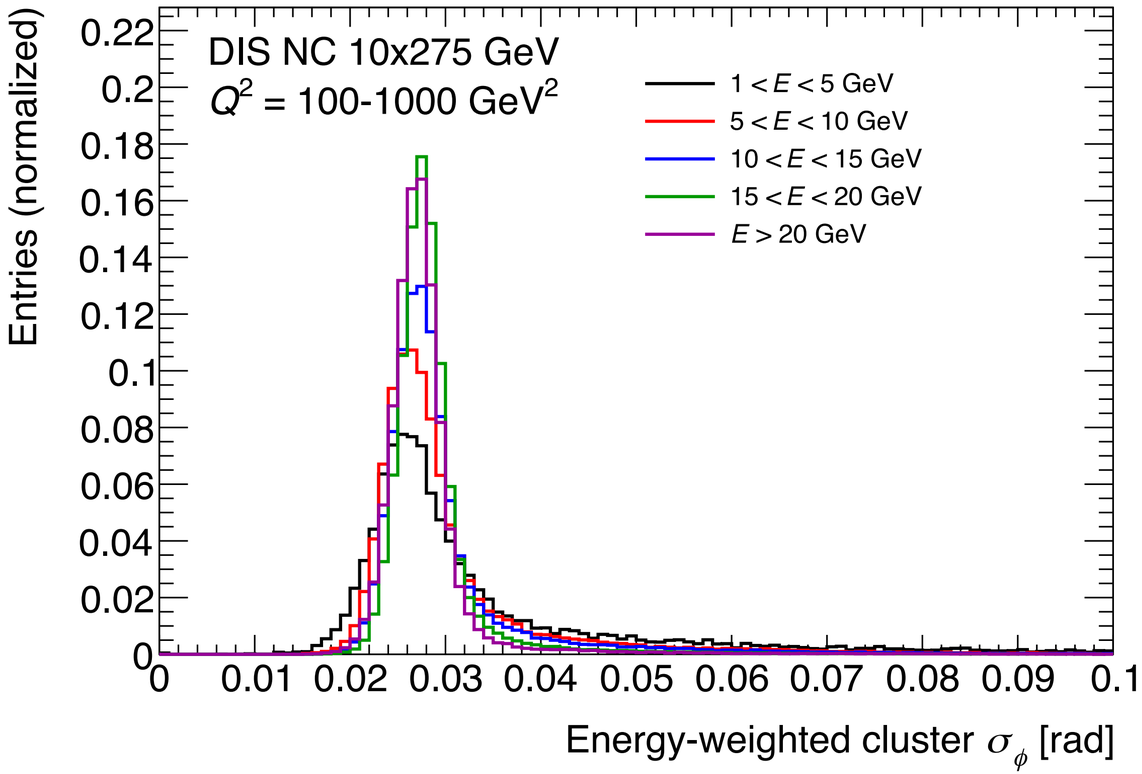




- Number of RecHits grows with energy, although maybe this is “artificial” given the “granularity” in z in simulation (?)
- **Questions** about minimum E threshold for cluster inclusion, noise modeling, etc…

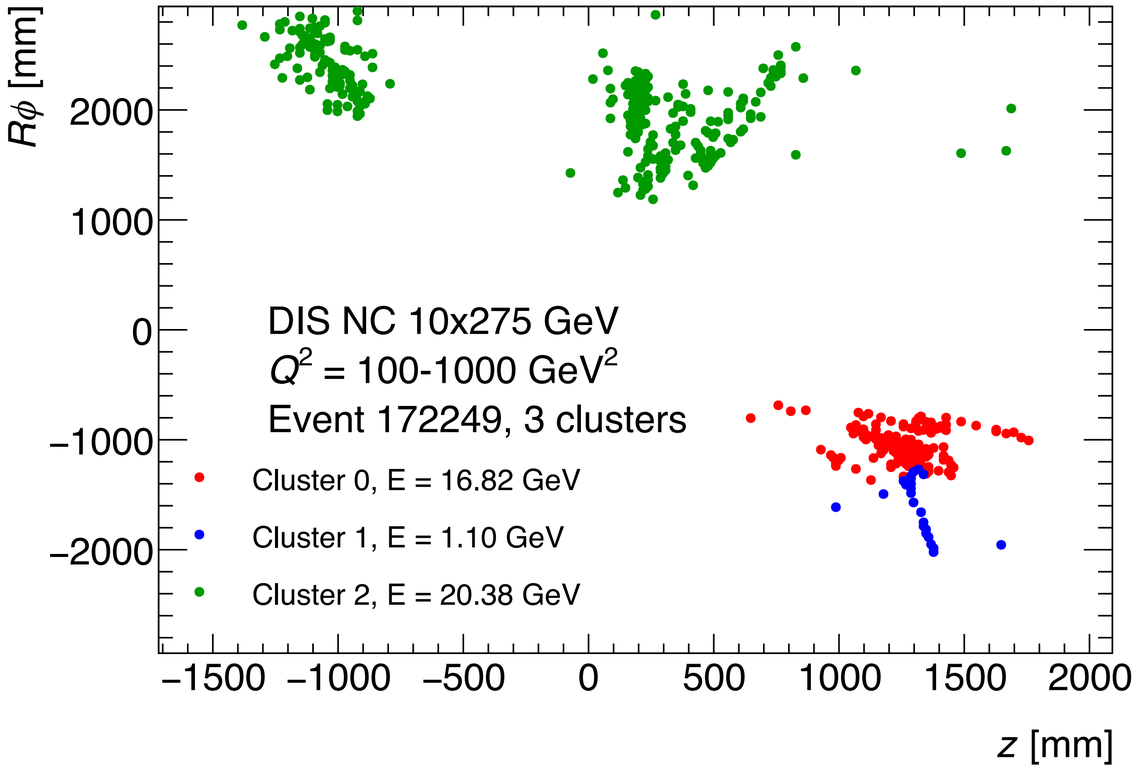
- Fraction of cluster energy carried by highest-N hits
- Much of the “cluster” is from very low-energy deposits far away from the core of the shower…

SciFi: cluster size



- Clusters typically have energy-weighted ϕ width of 0.02-0.03 rad

  ➡ Typical $\sigma(r\phi)$ ~ 20-30mm vs. Moliere radius in Pb ~16mm (?)

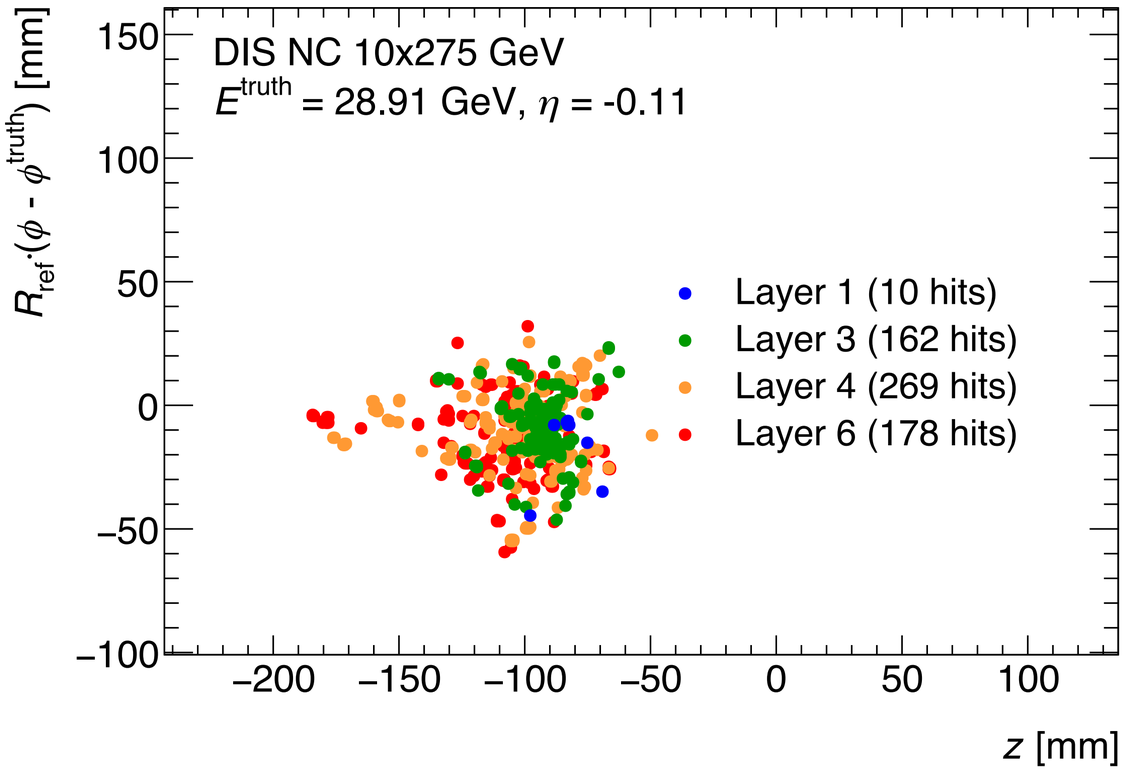


- Example event display in $(z, r\phi)$ — showing three different clusters

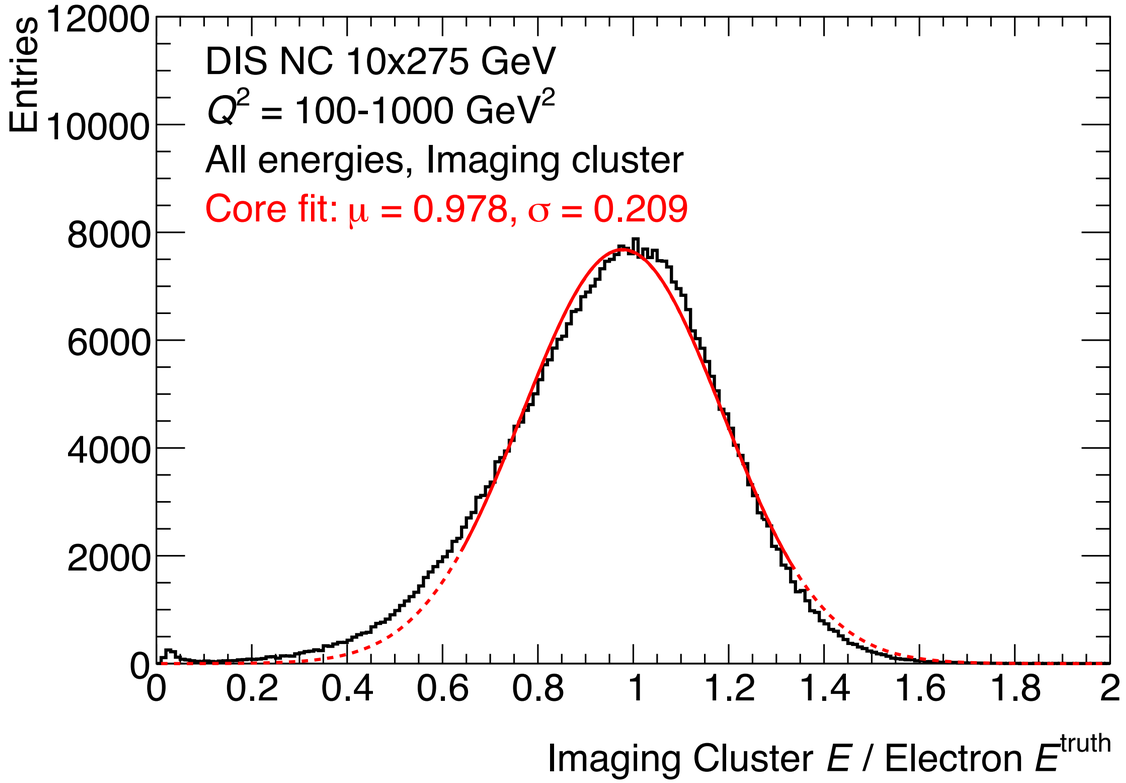
  ➡ For clustering performed only in in x & y, this results in tails in cluster size, matching, response, etc. …

  ➡ **TODO**: check after updates?

Imaging: basic looks

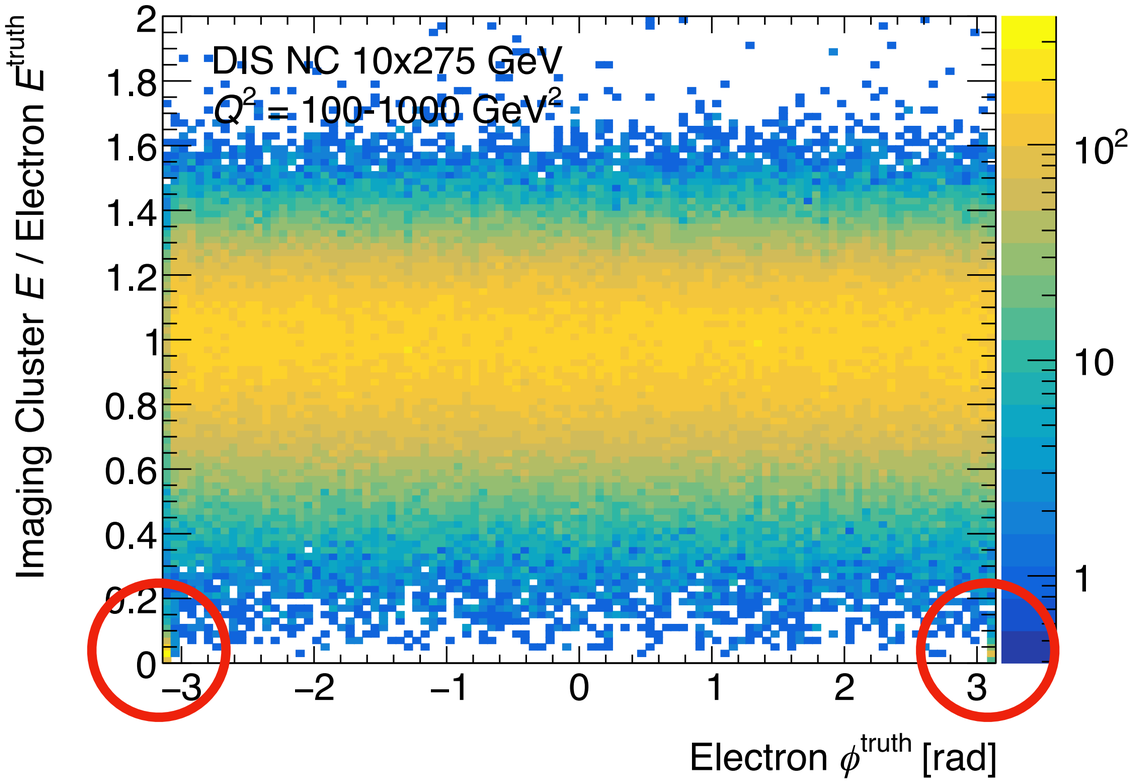


- Example event display showing the hit positions in each of the four layers, to demonstrate the lateral shower spread with increasing depth



- Poorer energy measurement in Imaging standalone (as expected)

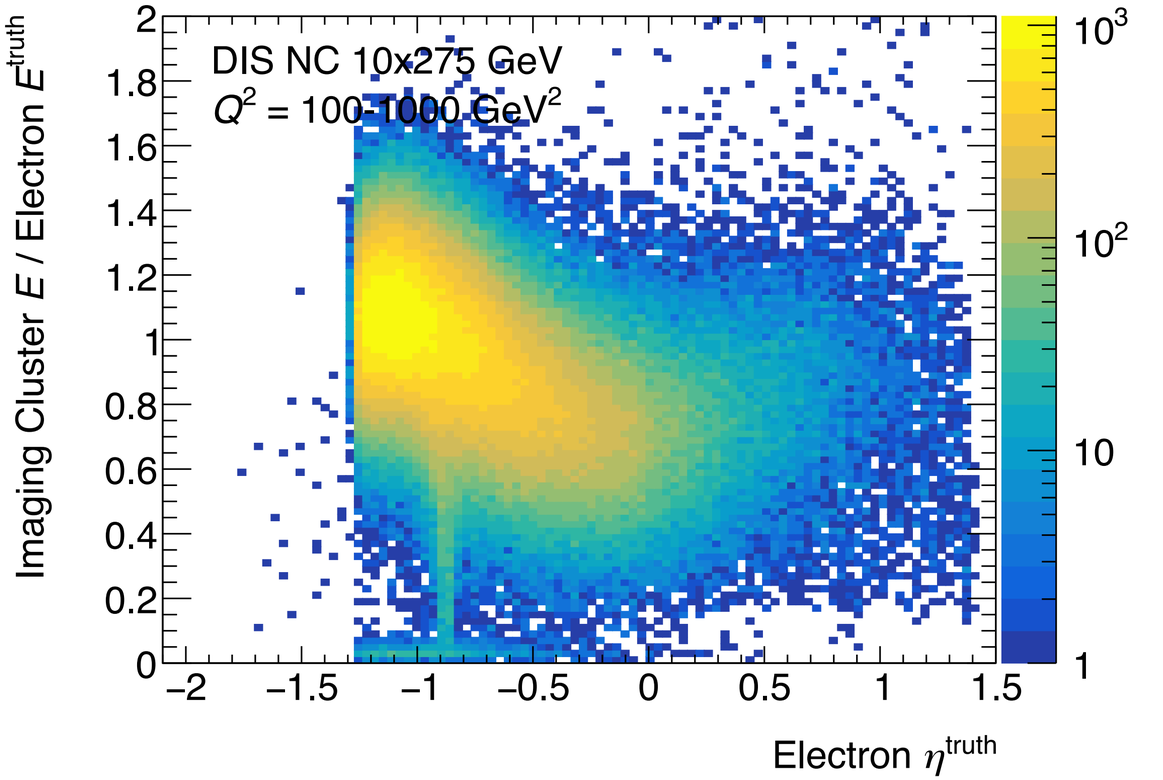
Imaging cluster response - bug find

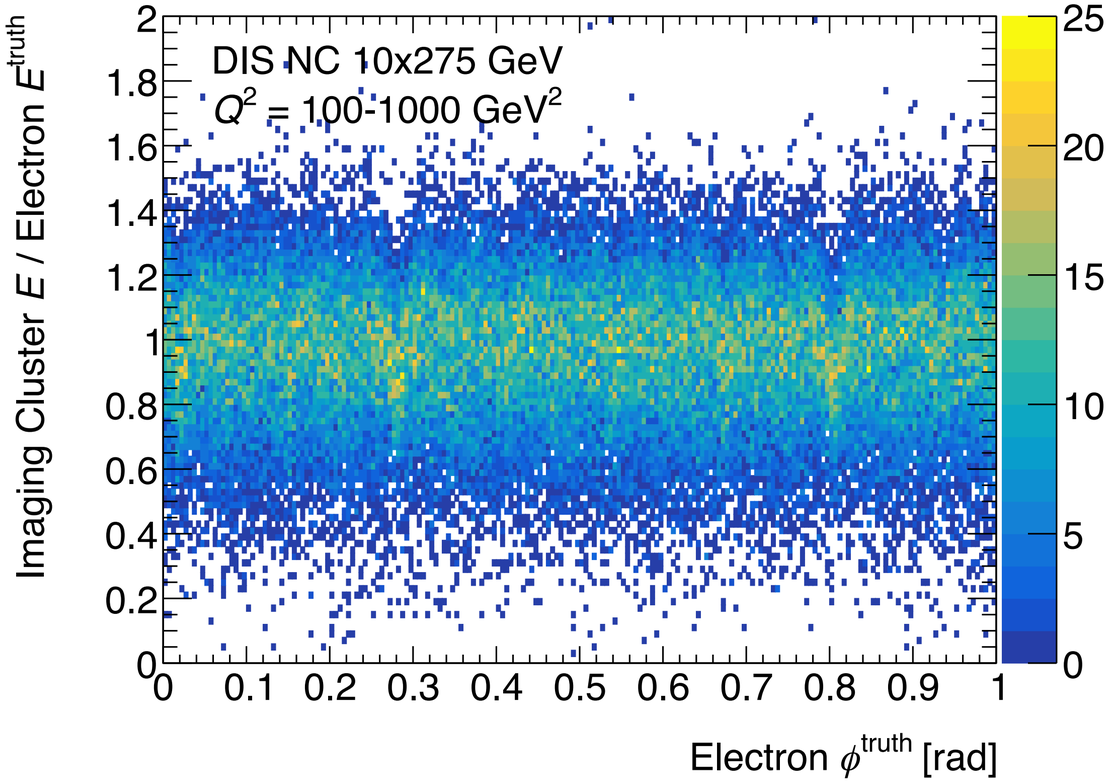


- Abnormally low response right near $\phi = +\pi$ and $-\pi \rightarrow$ smells like a wraparound bug

- Tracked down by Claude Code as bug in the Imaging cluster phi determination in ImagingClusterReco.cc
  - ➡ Cluster ϕ was being determined using energy-weighted average of RecHit ϕ values, all restricted to $(-\pi, +\pi)$
  - ➡ This (obviously) does the wrong thing — imagine a cluster right at π with hits at $\pi - \epsilon$ and $-\pi + \epsilon$ — the energy-weighted average could come out to $\phi \approx 0$ (or any number!)
- GitHut issue with example, PR #2809 with simple fix, now merged into EICrecon
  - ➡ **Question**: is it useful to take a fresh look at cluster η determination as well?

Imaging cluster response — differential

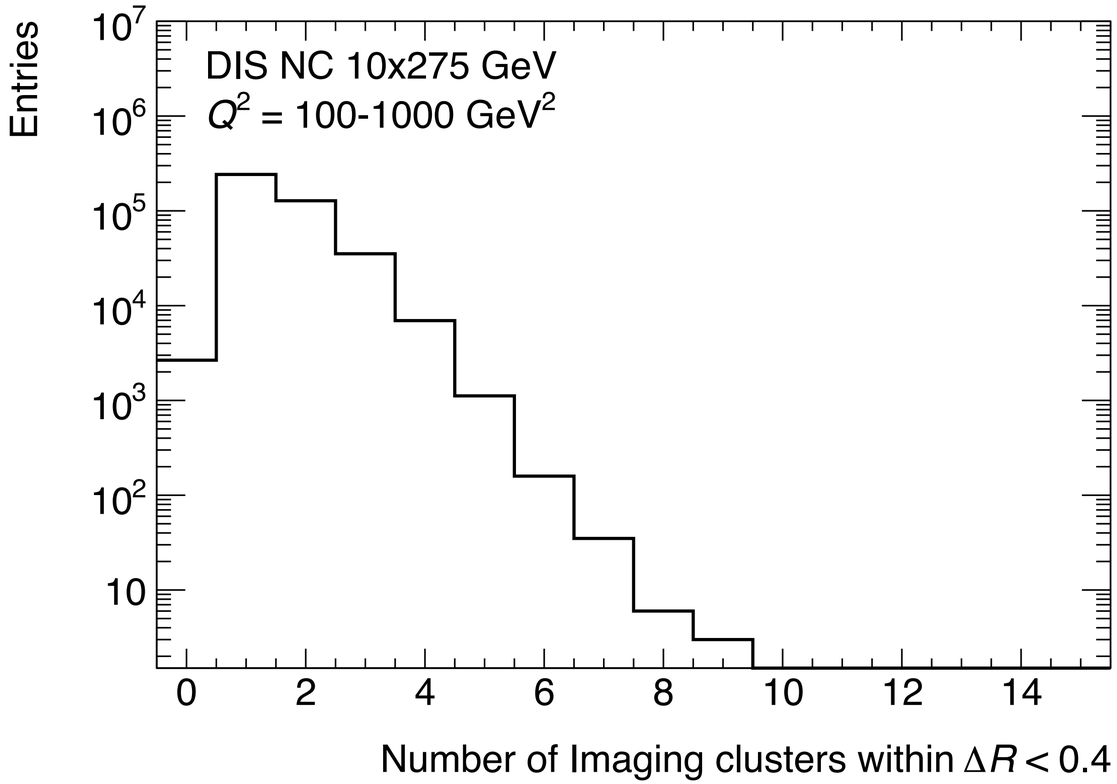


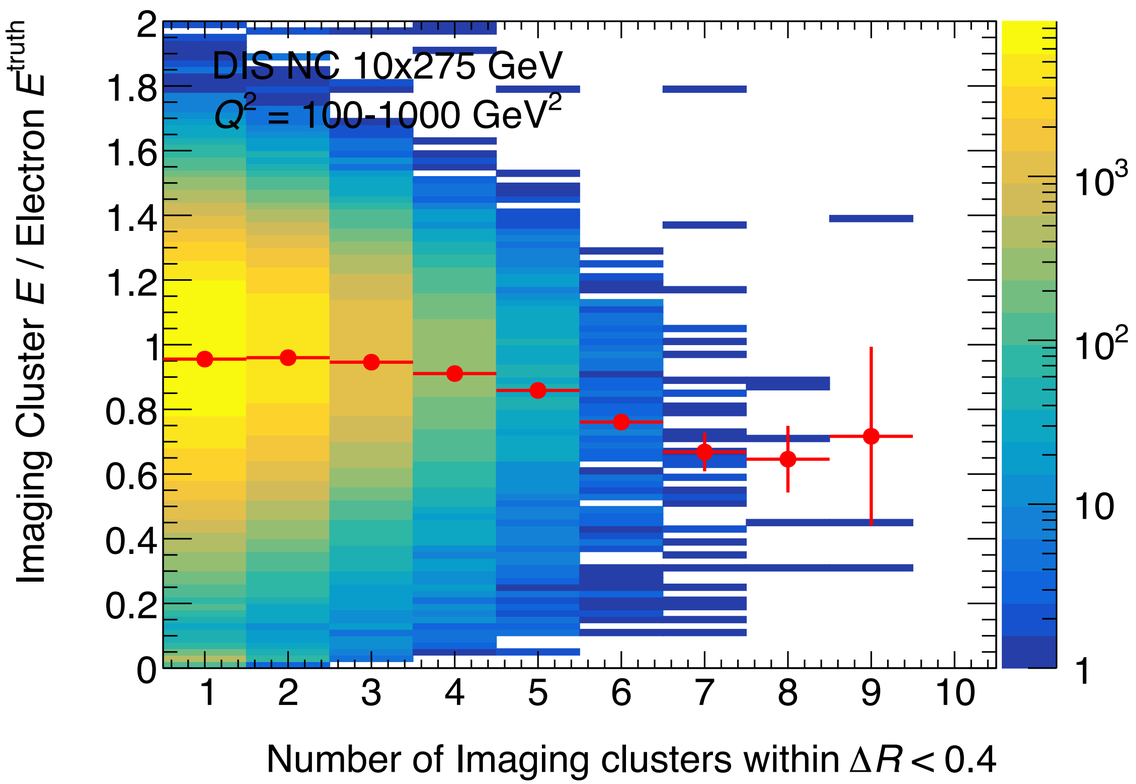


- Strange response near $\eta \approx$ -0.9 — similar to what is seen for SciFi clusters
- **Question**: any ideas from BIC/ simulations experts? I can dig further …

- Modest ϕ dependence from sector boundaries — significantly weaker than observed for SciFi

Imaging cluster splitting

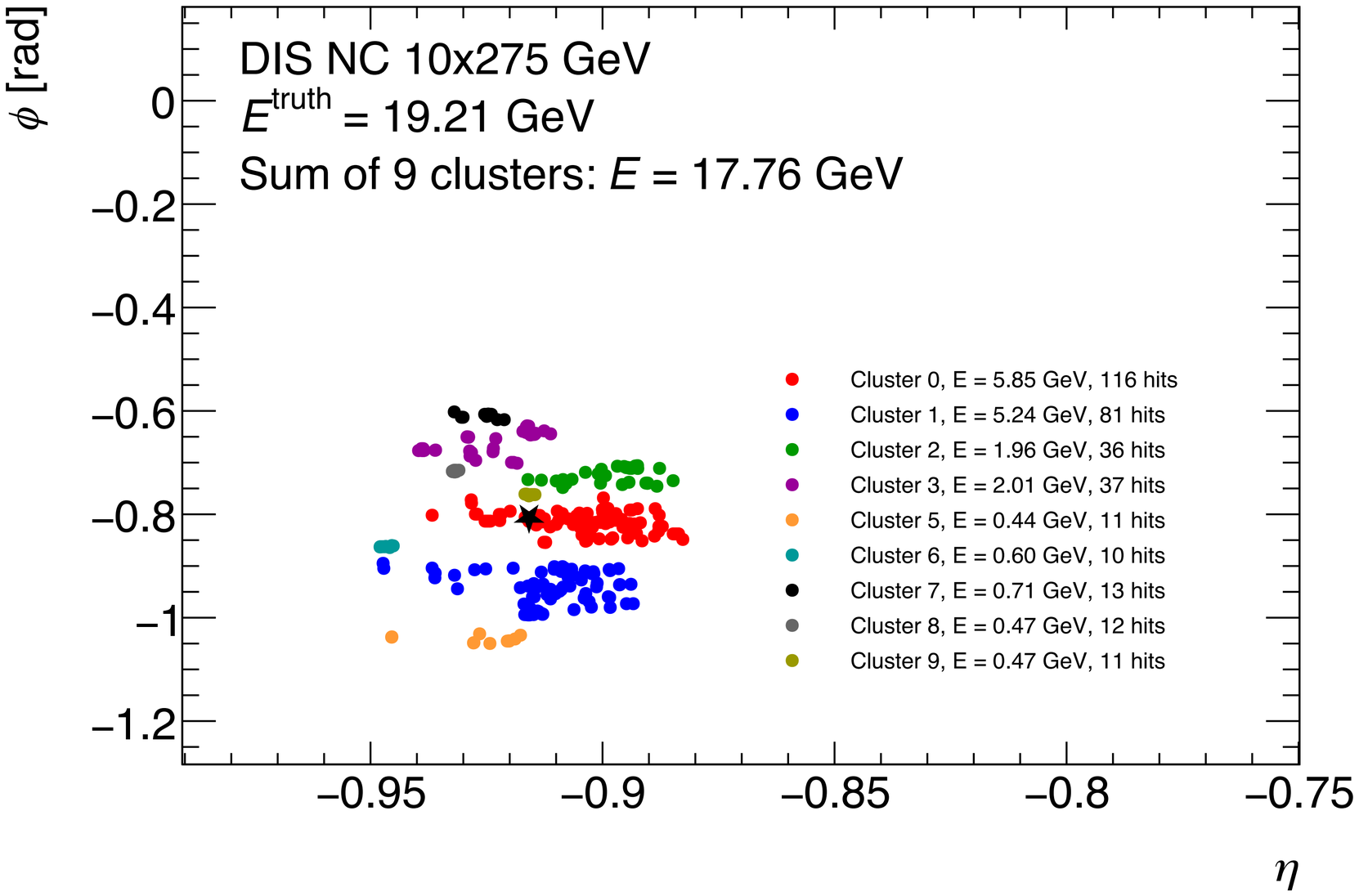




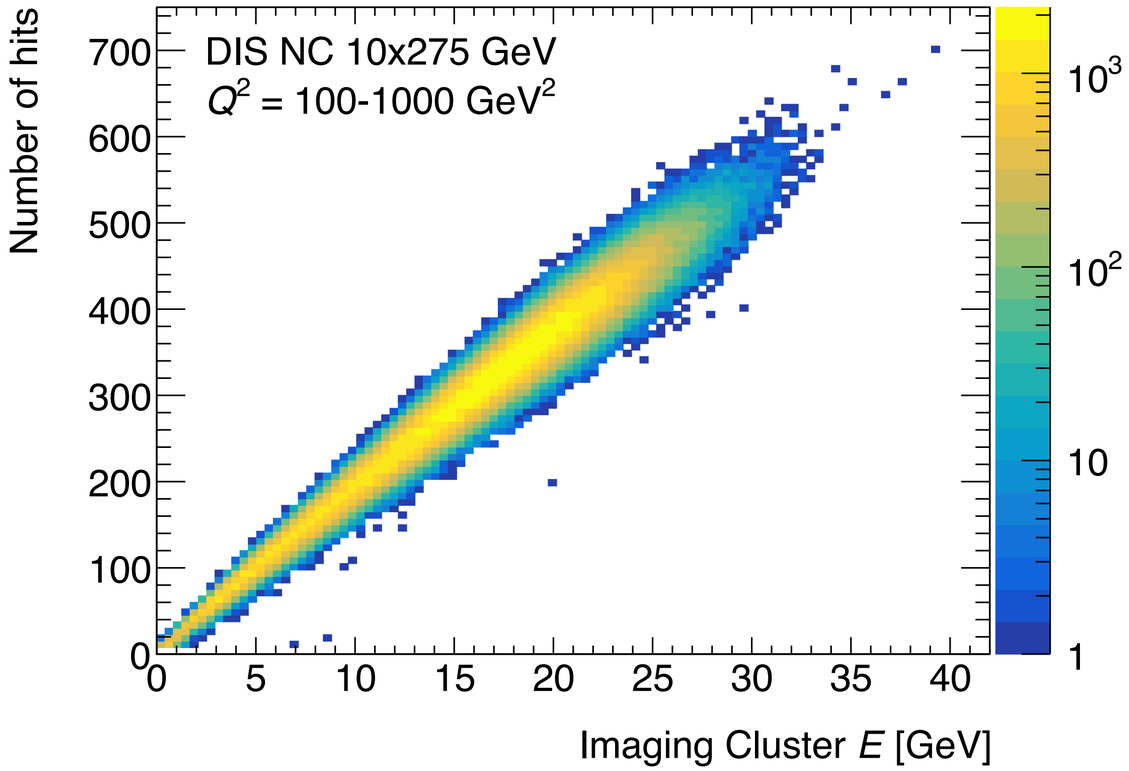
- The modal number of Imaging clusters around a truth electron is 1, but (e.g.) 2 is quite common, with a long tail to many clusters…
- The “response” (= energy measured in the highest-*E* cluster) deteriorates in the large # cluster cases … energy being sheared off into split clusters

Imaging cluster splitting — example

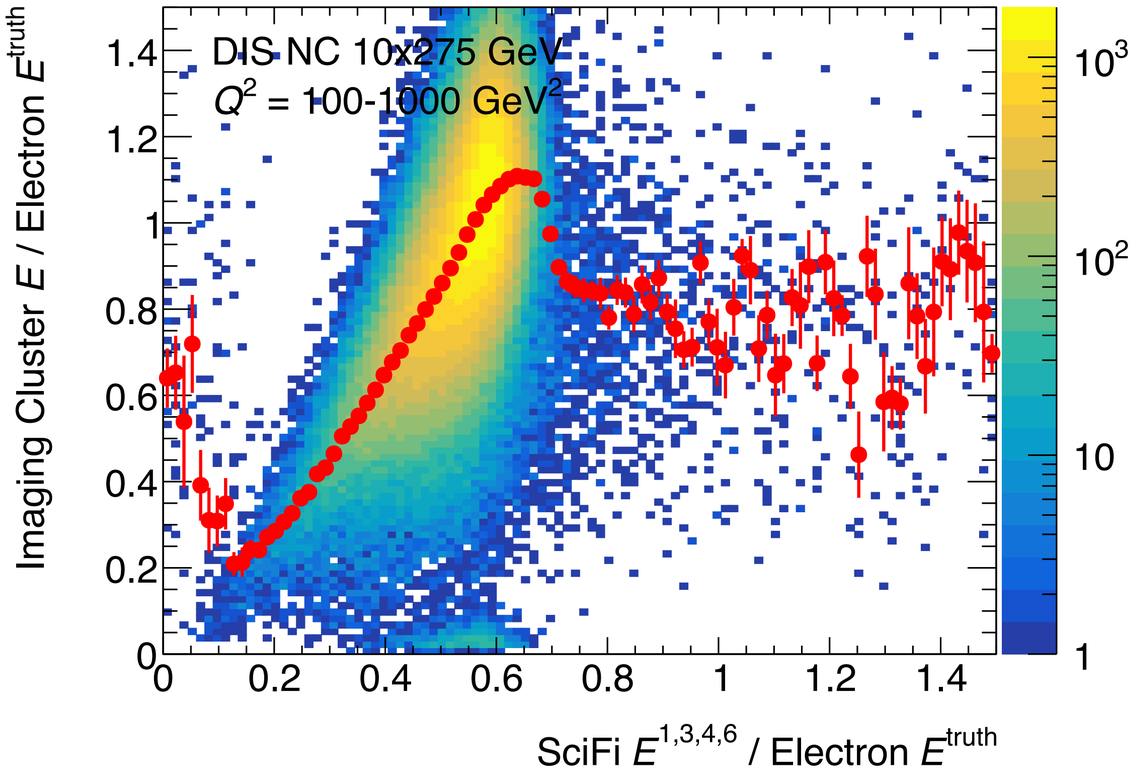
- Fairly extreme example — scattered electron energy shared among 10 clusters (!) — which form “strips” in *z*
- **Question**: is it useful to (re-?)optimize the various TZ / Eta-Phi thresholds used in the clustering?
- **TODO** (for DVP): understand the various “same layer”, “different layer”, etc., behavior in the algorithm …



Imaging: sanity checks



- Does # of hits correlate with measured energy? Yes.



- Is the response in the Imaging detector similar to that in the SciFi **if one uses the same set layers** (=1,3,4,6)? i.e. **do the two detectors see the same shower**? Yes.

Outlook

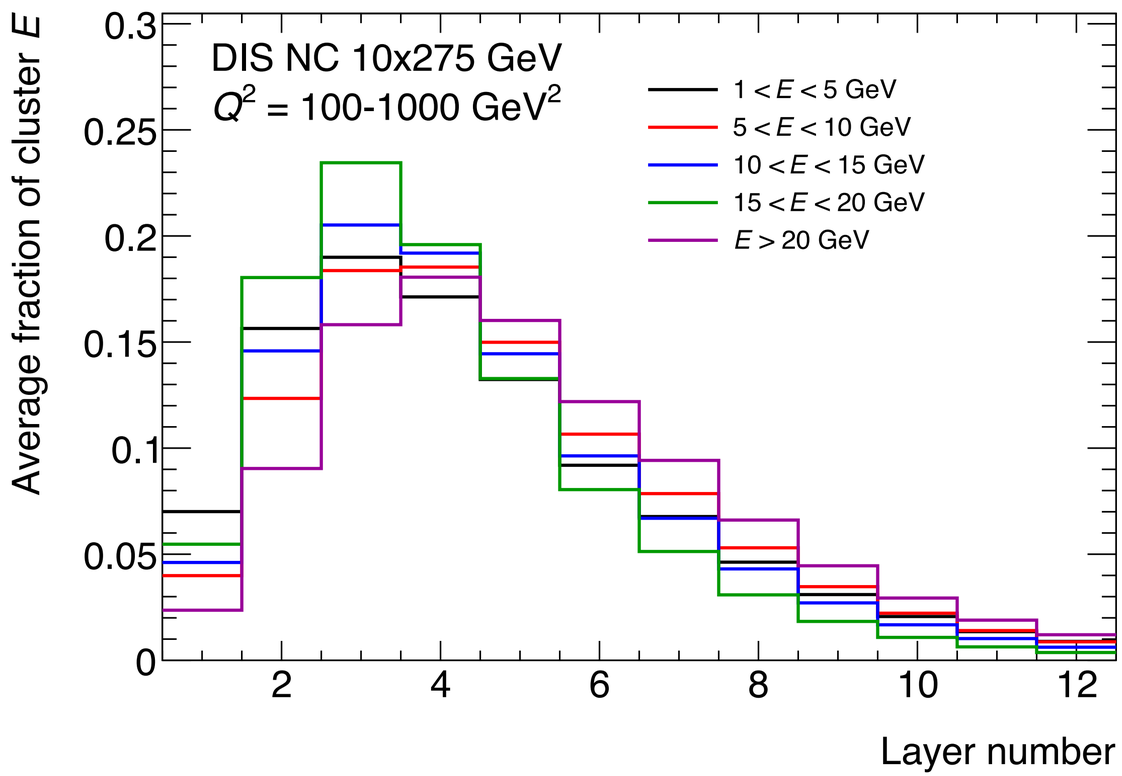
- Many thanks to Maria, Tommy, Minho, and also Derek Anderson for pointers
- First look (by me) at basic aspects of SciFi and Imaging clustering and response

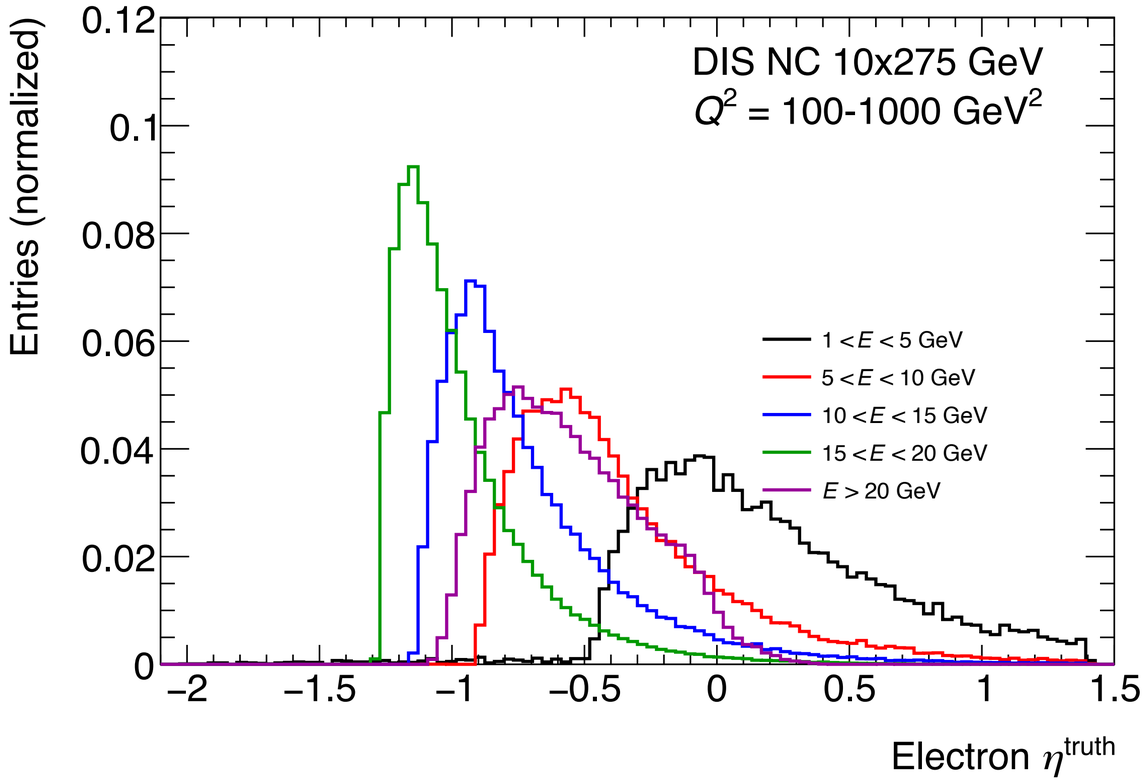
  ➡ Some questions about reconstruction & modeling

- What studies would be most useful to support BIC effort?

Backup

SciFi: longitudinal energy deposition

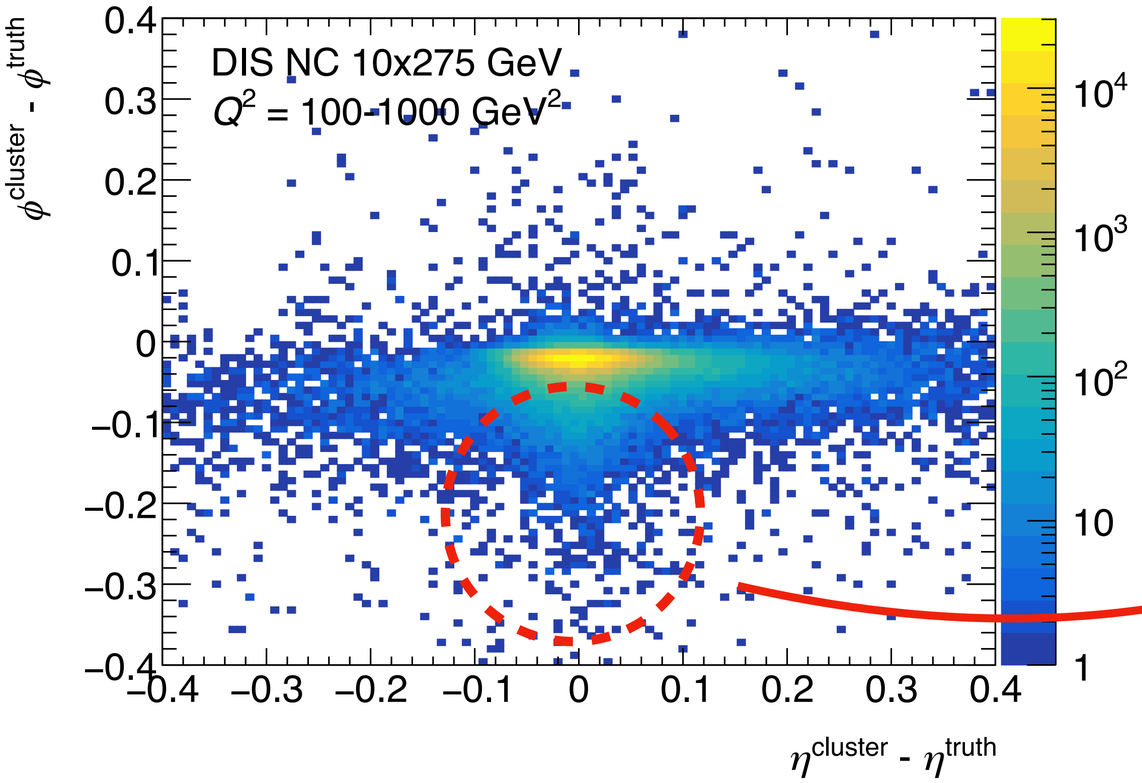


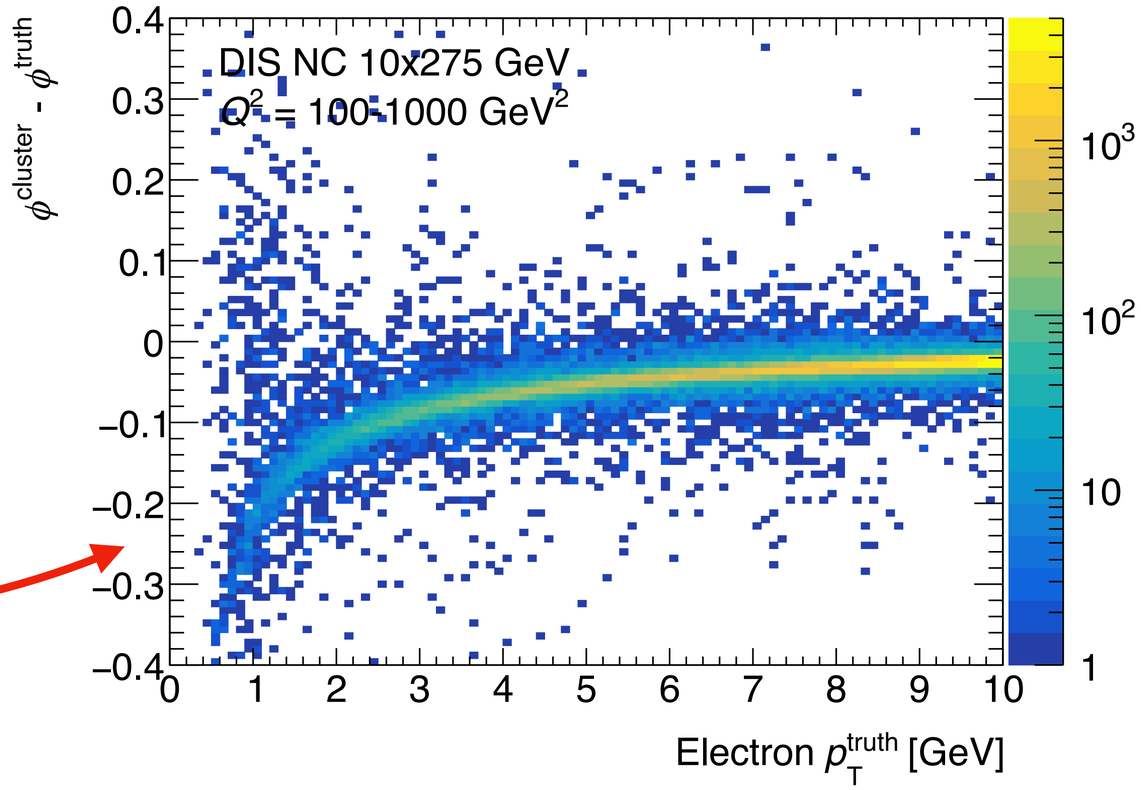


- How is reconstructed cluster energy distributed over layer?
- Max layer is ~3, but the mean of the distribution vs. E is confounded by the changing η distribution (non-projective)

- Note that this particular Q^2 range gives a "non-monotonic" evolution of electron η with increasing E selection
  - ➡ Need a single particle sample (or combine many Q^2 bins?) to do a more fair E scan…

Matching truth electrons → SciFi clusters

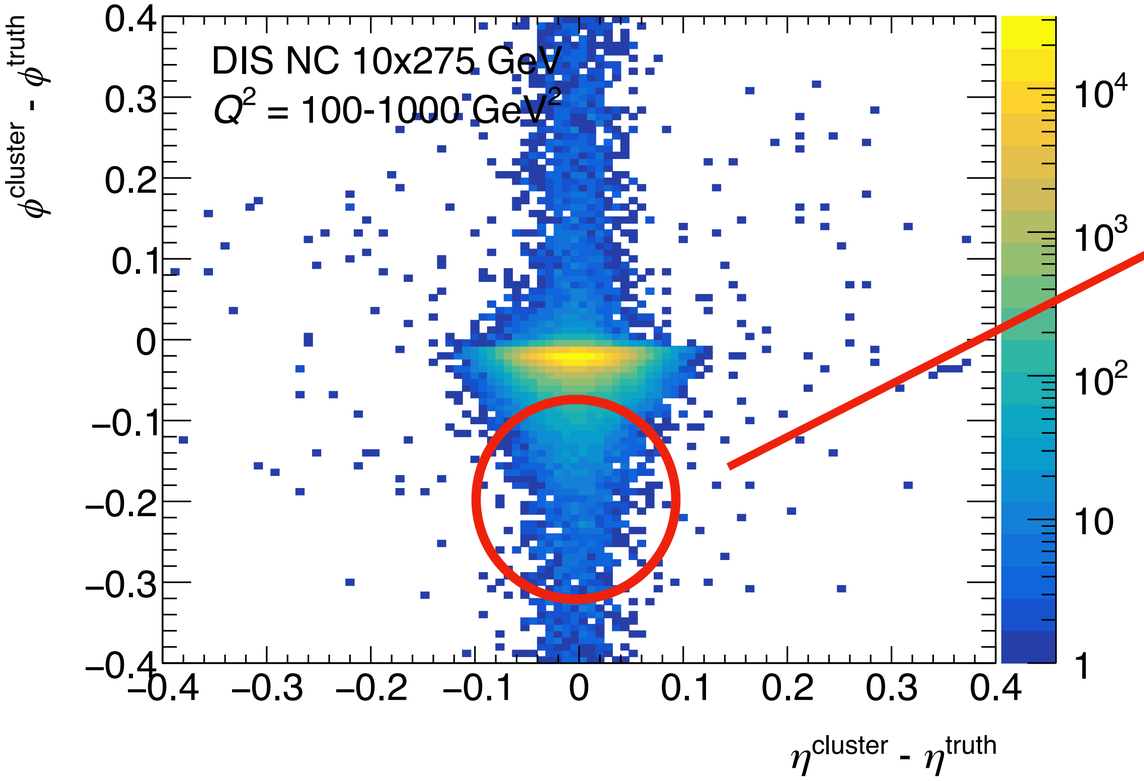


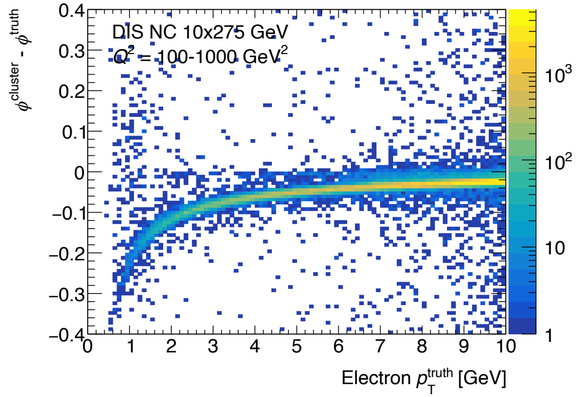


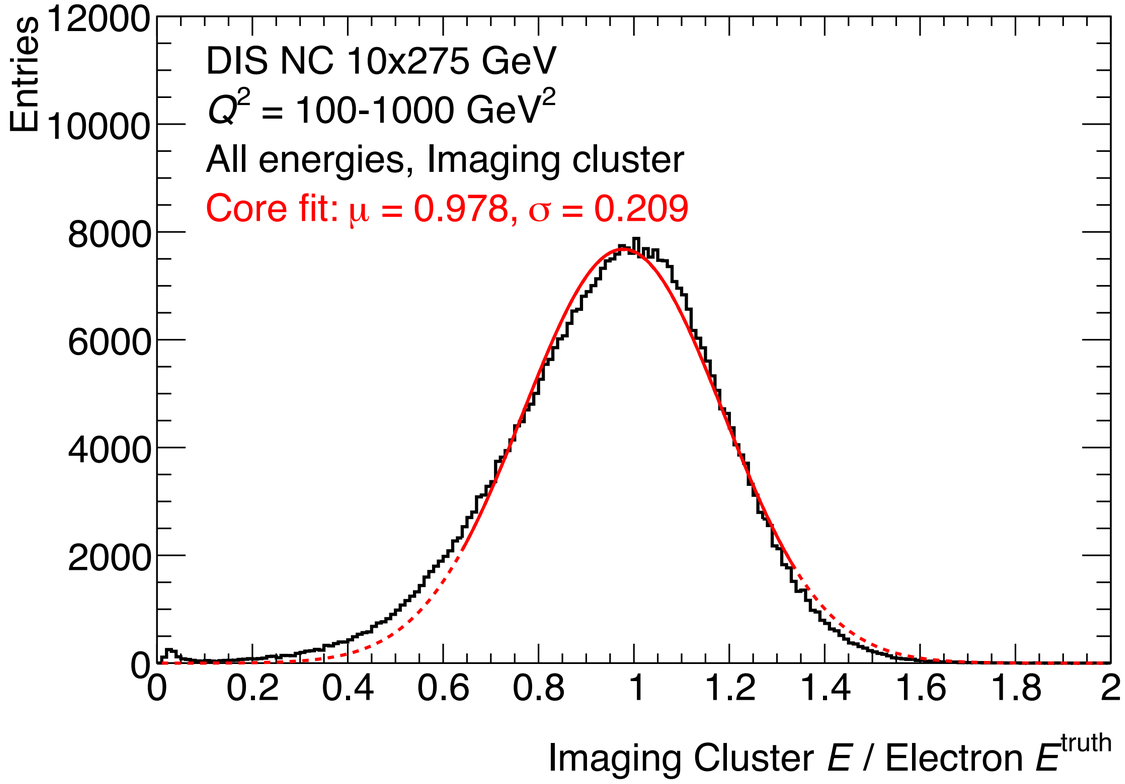
- Take truth scattered electrons with $-2 < \eta < +1.4$ and $E > 1$ GeV, find the closest cluster w.r.t. $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
  - ➡ **TODO**: deep truth matching

- Poor matches in $\Delta\phi$ mostly from bending of electron in magnetic field (expected)
- Note also cases with poor matching in $\Delta\eta$ … more on this later …

Imaging: matching and response

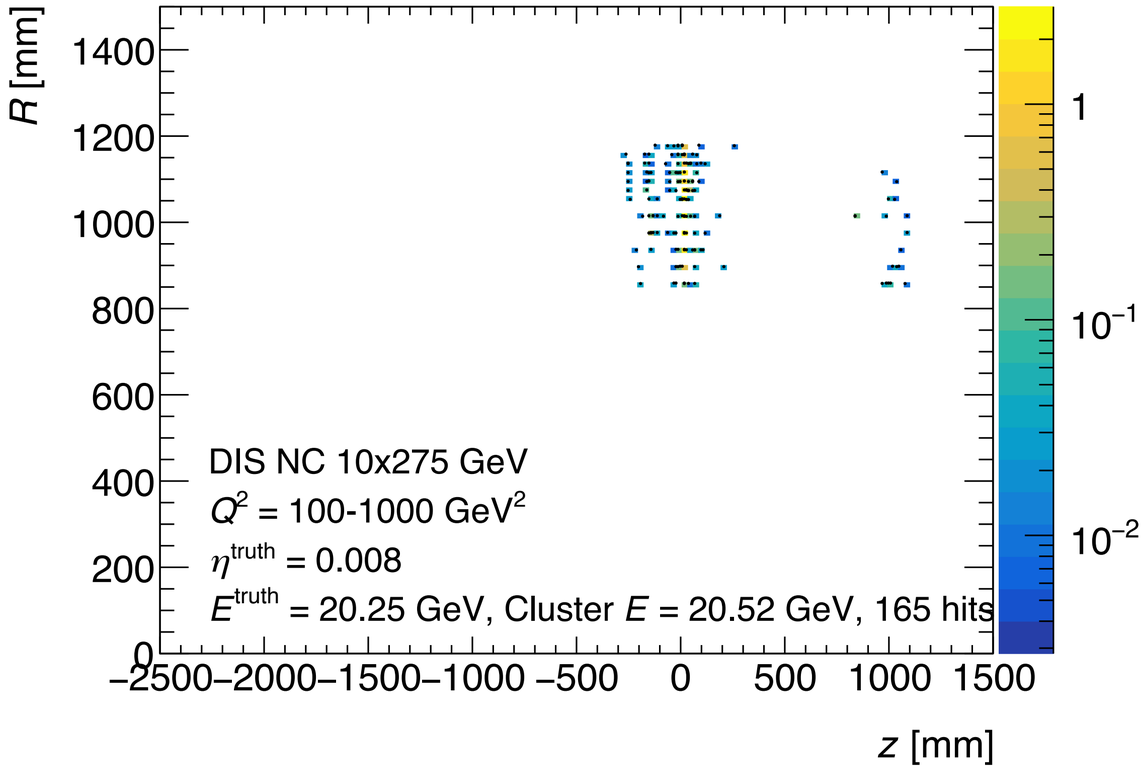


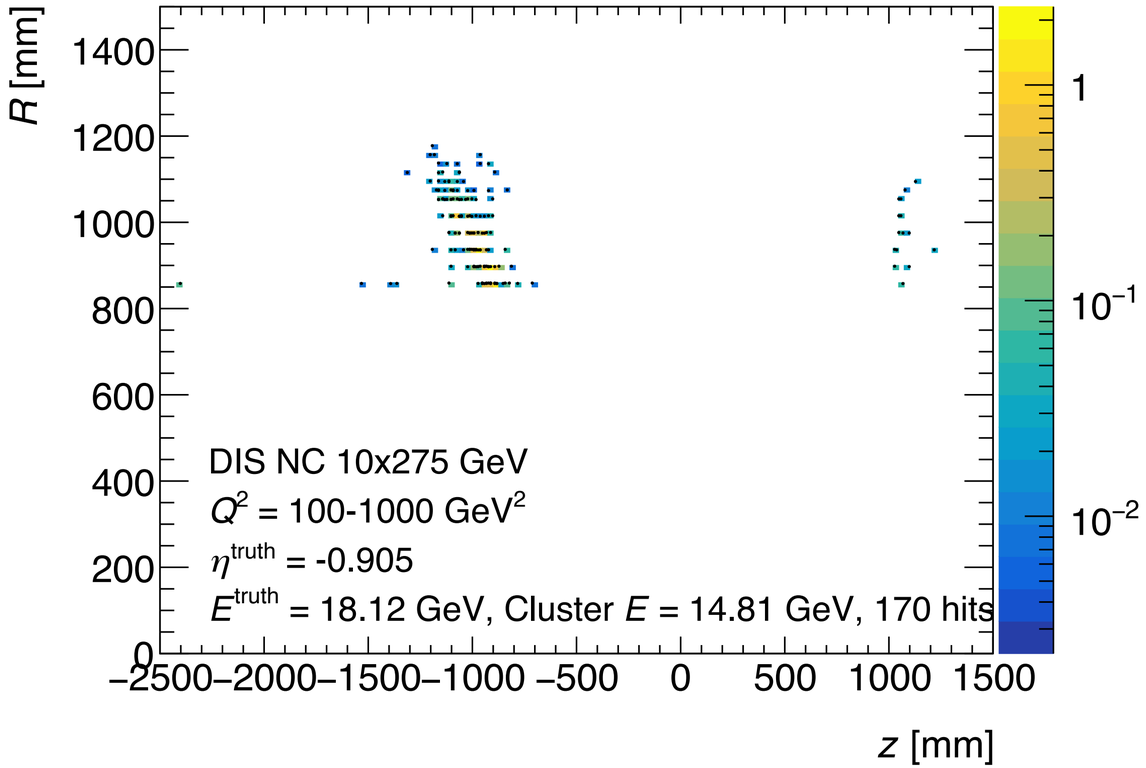




- Usually there is an “obvious”, unambiguous match to the reconstructed Imaging cluster
  - ➡ $\Delta\phi$ difference mostly from low-p_T electrons curving in B field
- Poorer energy measurement in Imaging standalone (as expected)

SciFi event displays





- Two example clusters from high-E electrons, shown here in (z, r) — not $(z, r\phi)$.
- One at $\eta \approx 0$ (left) and $\eta \approx -1$ (right) just to see the projectivity in the calorimeter
  - Note also extra blob at $z \approx 1000$ mm included in the cluster from the (x, y)-only clustering …