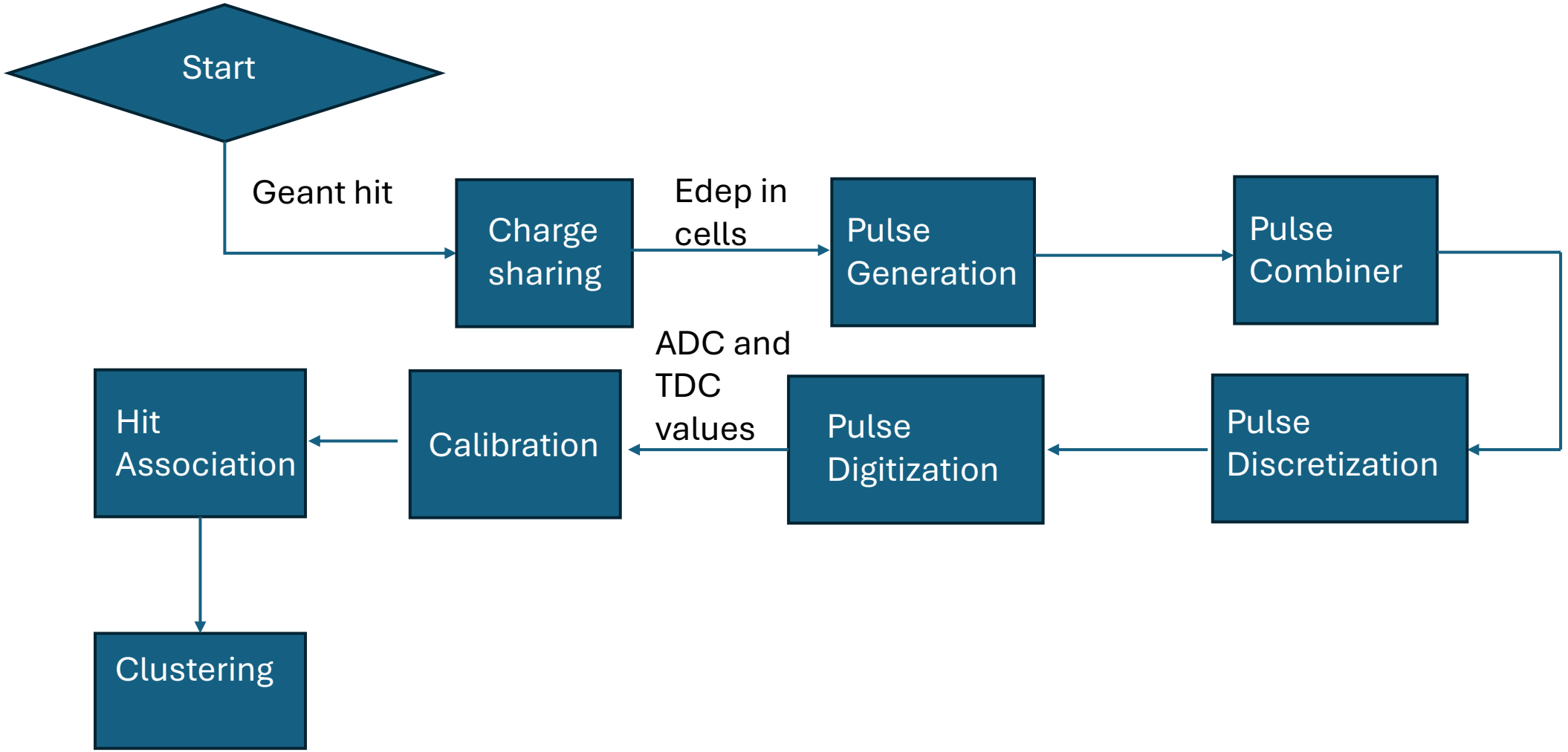
BTOF clusters performance review

Chun Yuen Tsang

7/21/2025

Introduction: Clustering workflow

Digitization work-flow



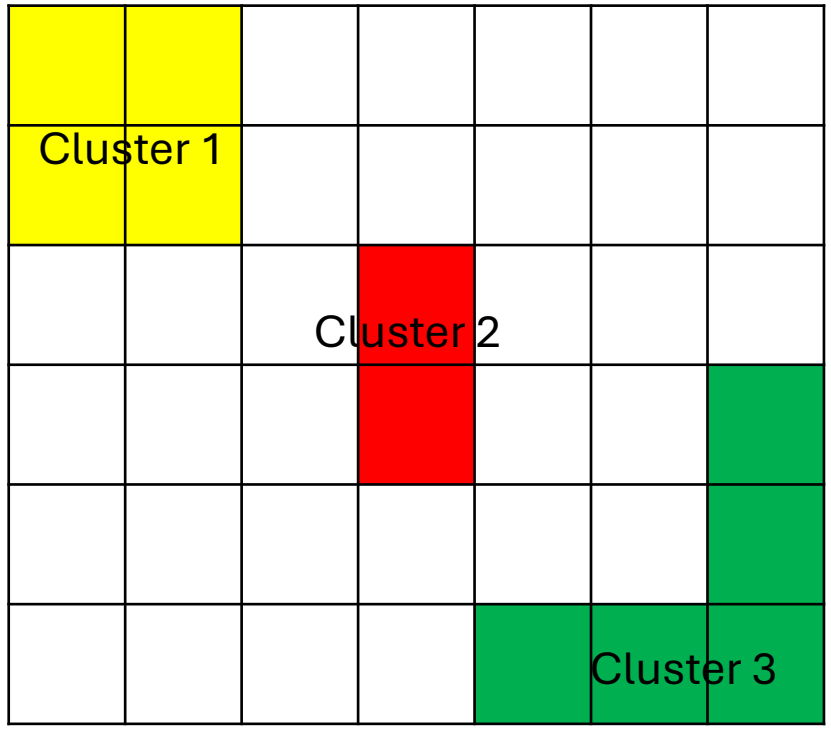
Simulation and Digitization parameters

- N.O. ADC channel = 256.
- N.O. TDC channel (within 25ns EICROC cycle) = 1024.
- Max Edep (i.e. Edep when ADC = 255) = 3e-4 GeV.
- ADC threshold for TDC = 5% Edep = 0.05*3e-4 = 1.5e-5 GeV)
- Charge sharing fix from https://github.com/eic/EICrecon/pull/1945 applied.
- Epic Geometry: main branch of epic on July 10th 2025.
- EICrecon: pr/use-LGAD-clustering on July 10th 2025.
- **No noise in the pulses.**
- Simulated 1000 uniformly distributed pi+ from the particle gun.

Calibration and clustering

- Calibration of TDC to time is just a linear transformation.
  - Same for ADC.
  - **No time walk correction.**
- Clustering is just weighted average of neighbors.
  - Group connected neighbors together.
    - Hits are neighbors if $\Delta t < 1$ns.
  - Weighted by Edep.
  - Time of a cluster = time of the earliest hit.
  - **No Edge correction.**

Time axis not shown



Hit association

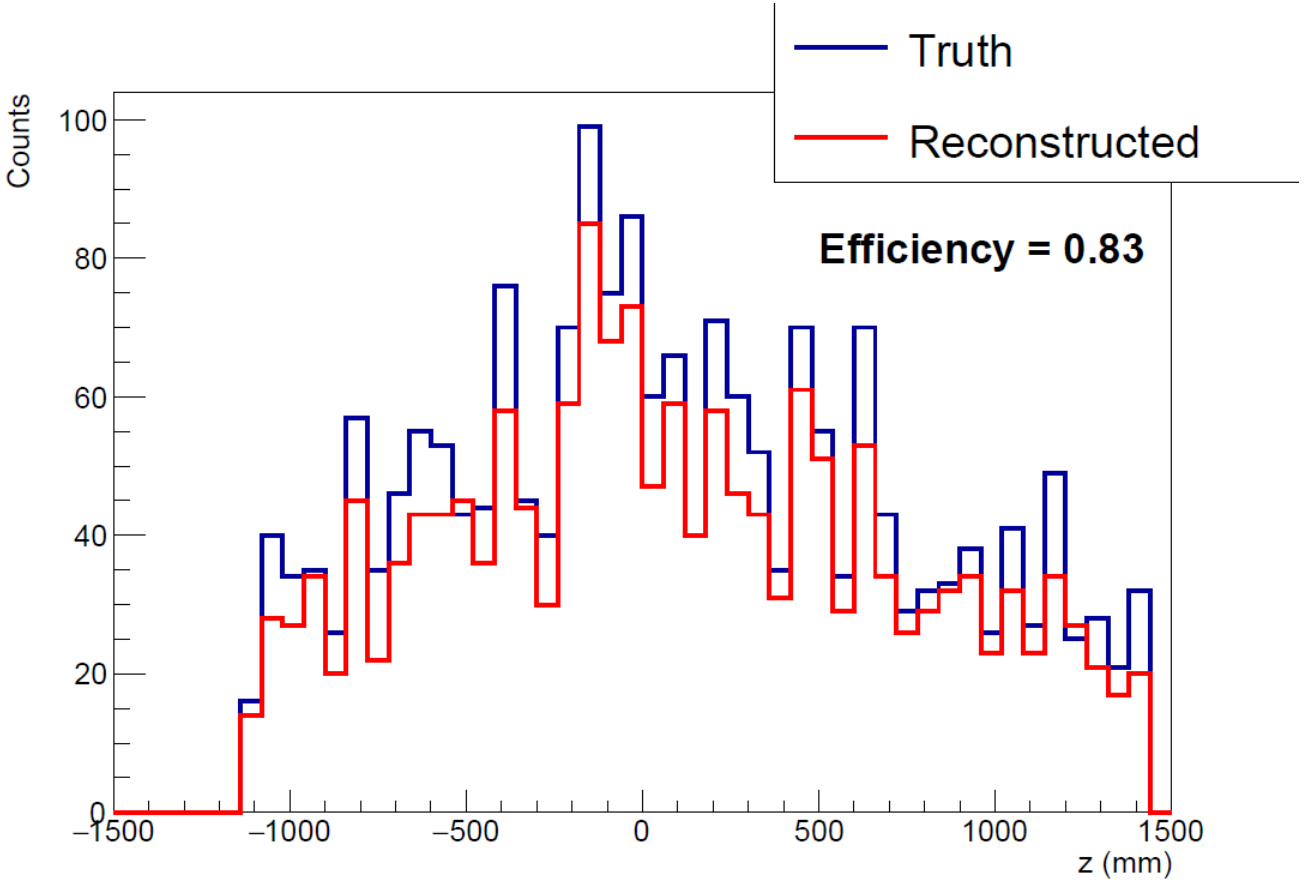
- Associate reconstructed hit with true hits if:
  1. They come from the same sensor.
  2. Time difference between the two hits < 1 ns.
  3. If there are multiple hits within 1 ns, choose the one with the smallest Delta t.

Performance with no charge sharing.

Sanity check.

Efficiency without bug fix in https://github.com/eic/EICrecon/pull/1945 applied

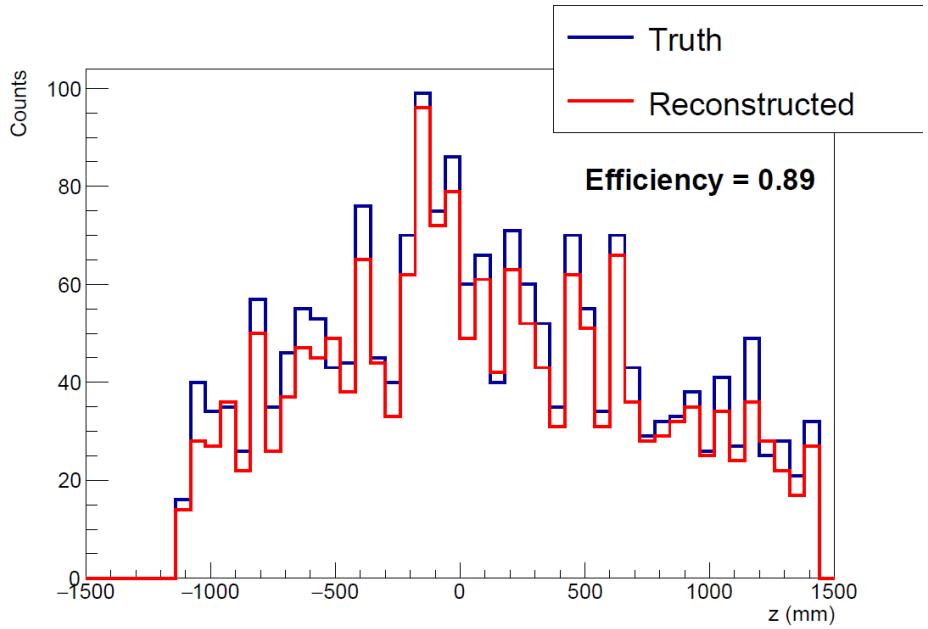
83% efficiency is a bit low.

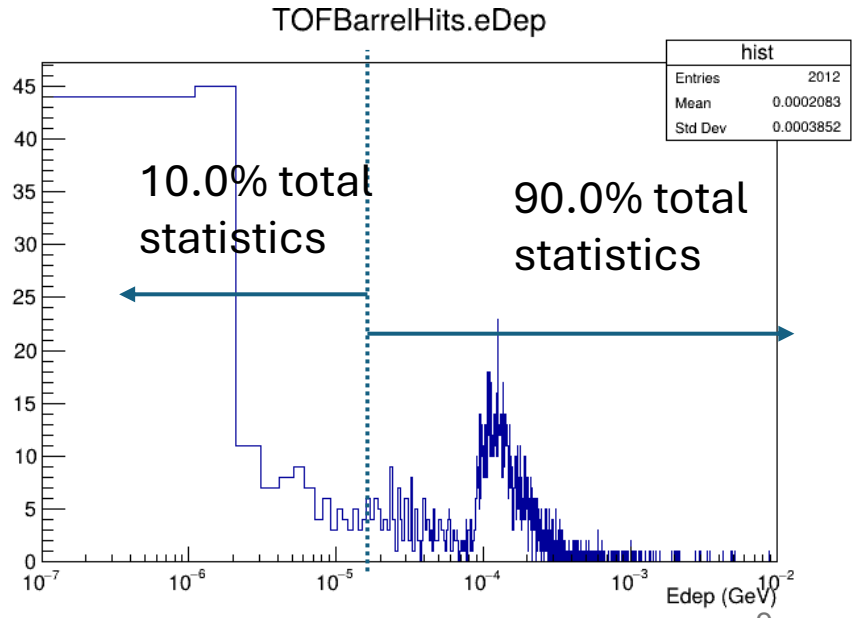


Efficiency with bug fix

- 83% -> 89% Efficiency seems low, but remember:
  - ADC threshold = 1.5e-5 GeV !!!

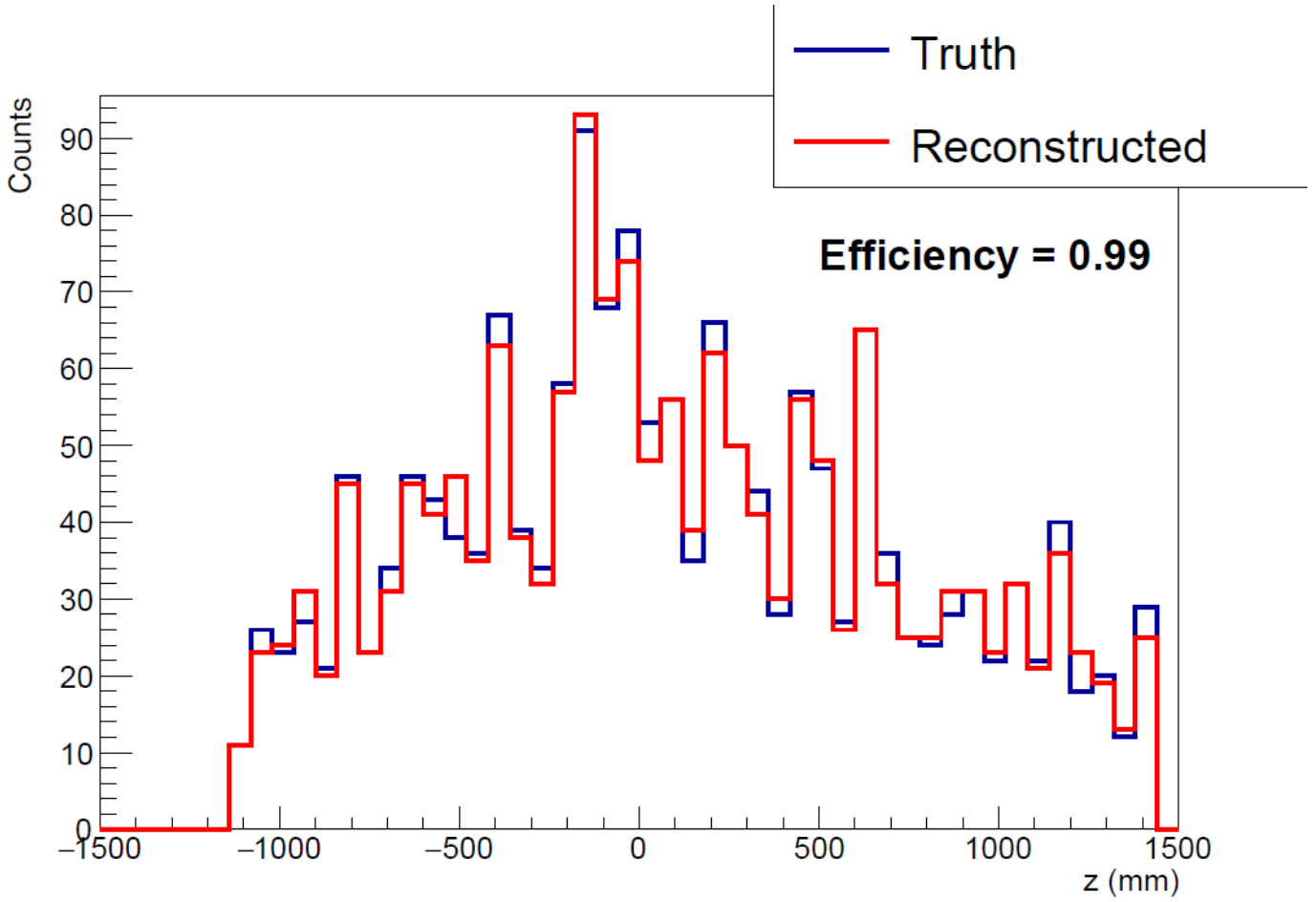
- We lost 10% efficiency due to that alone.



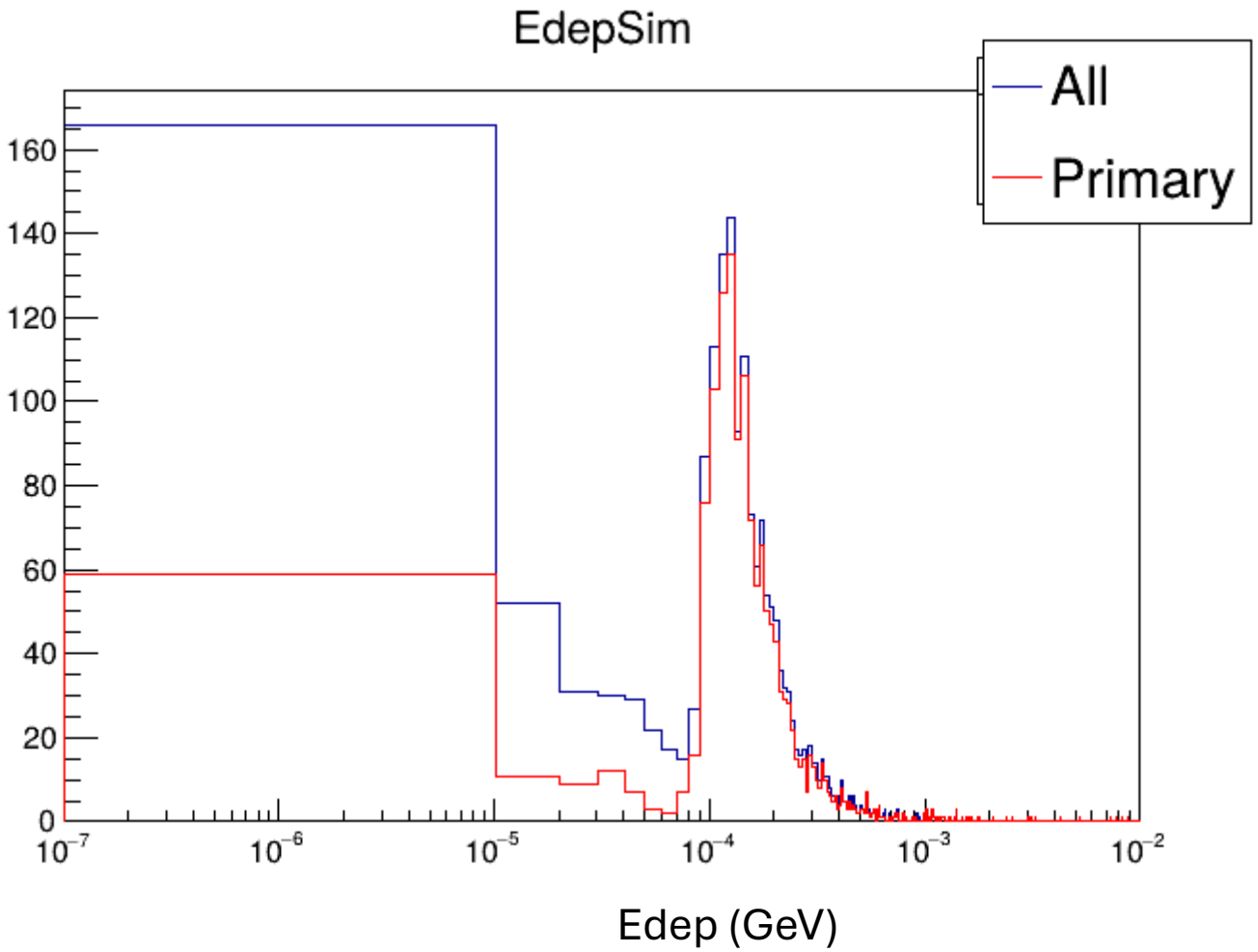


Efficiency with Edep > 5e-5 GeV

- Efficiency = 99%

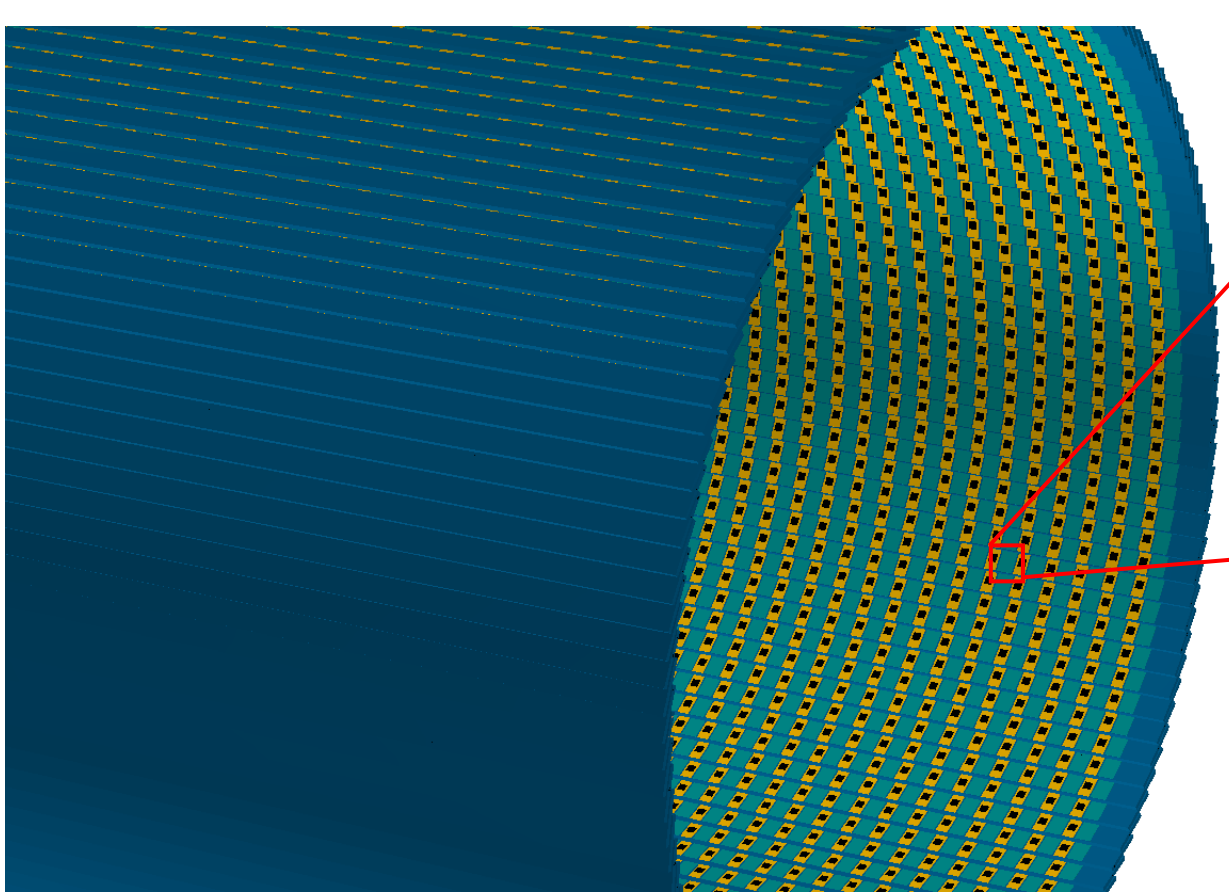


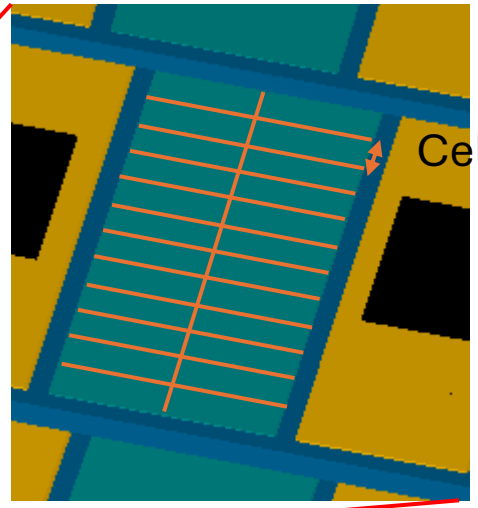
7.7% of Primary hits have Edep < 5e-5 GeV.



Phi resolution expectation

$$\Delta\phi = \phi_{true} - \phi_{reco}$$



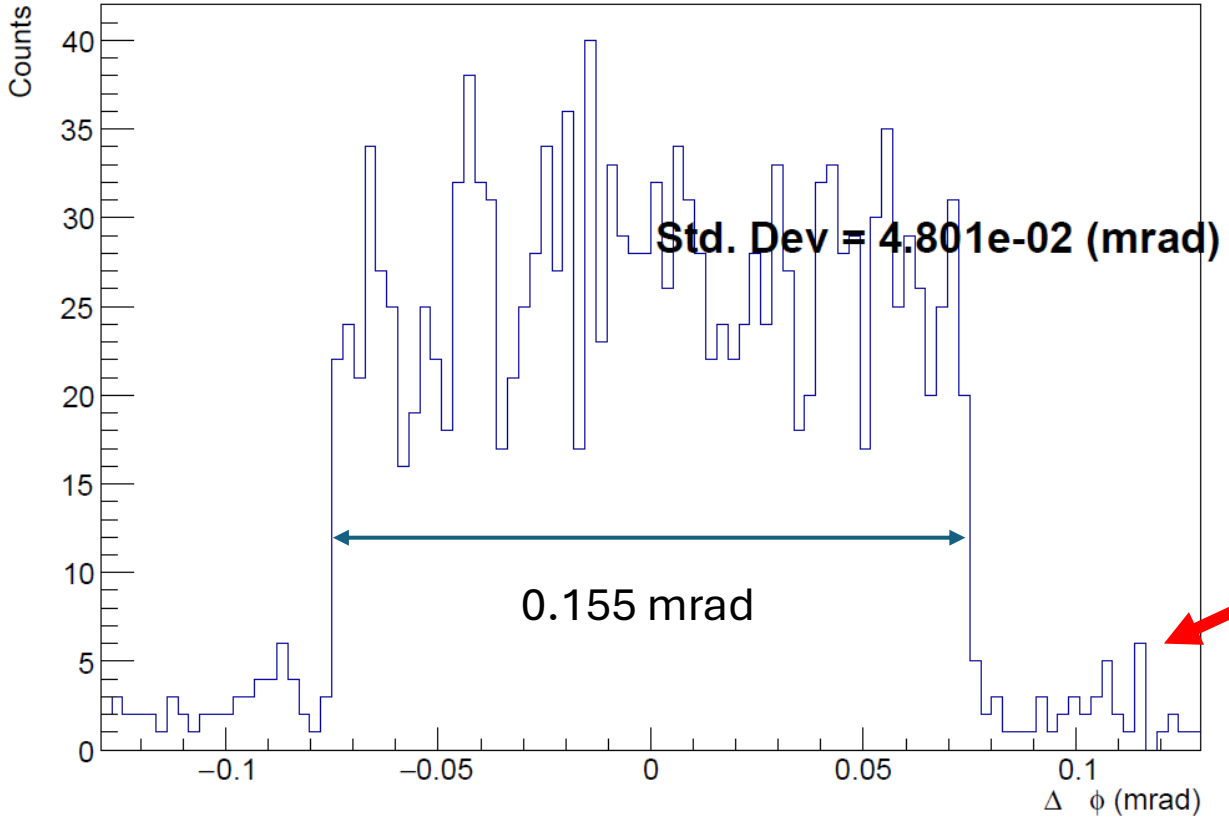


- BTOF barrel radius = 64.4 cm
- Expected ϕ range = 0.1 mm/64.4 cm = 0.155 mrad
- **Expected res. = 0.155/sqrt(12) = 0.045 mrad**

Phi resolution

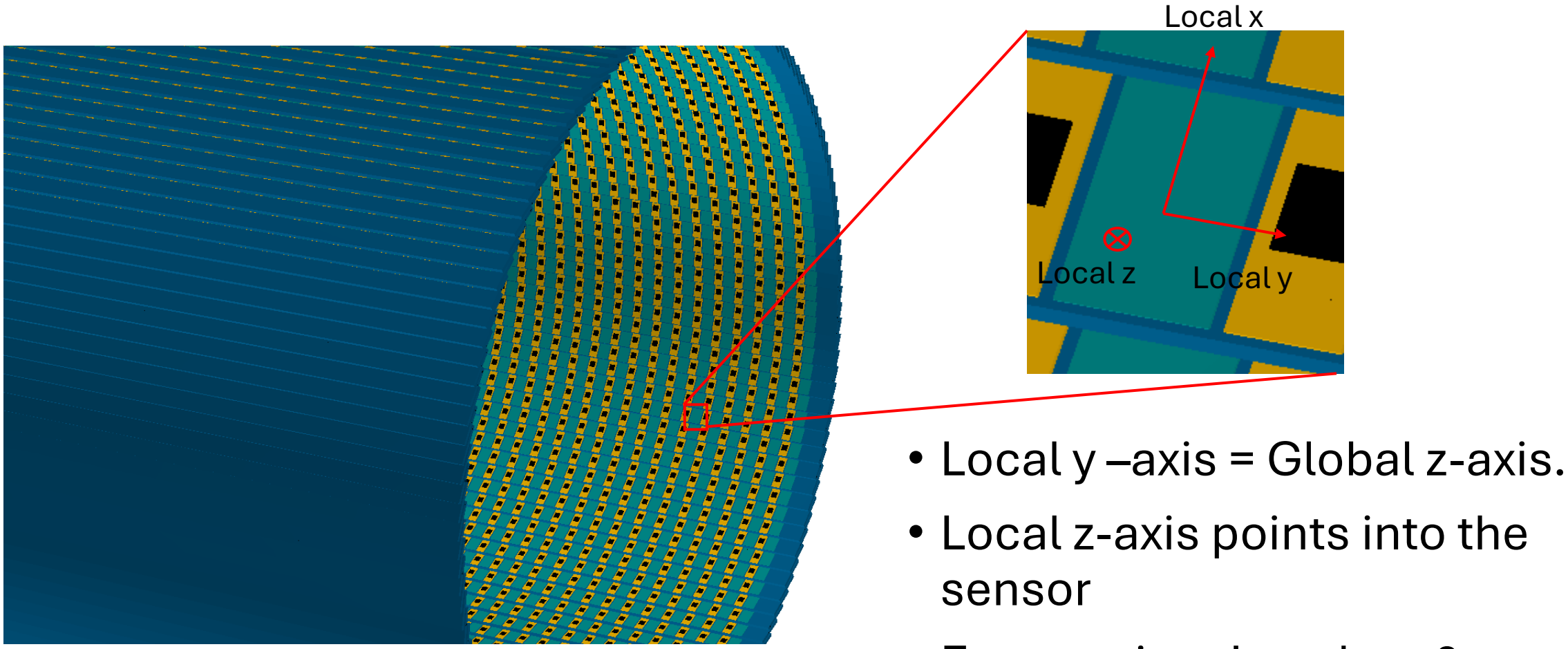
$$\Delta\phi = \phi_{true} - \phi_{reco}$$

- Expected ϕ range = 0.155 mrad
- Expected ϕ resolution = **0.045 mrad**



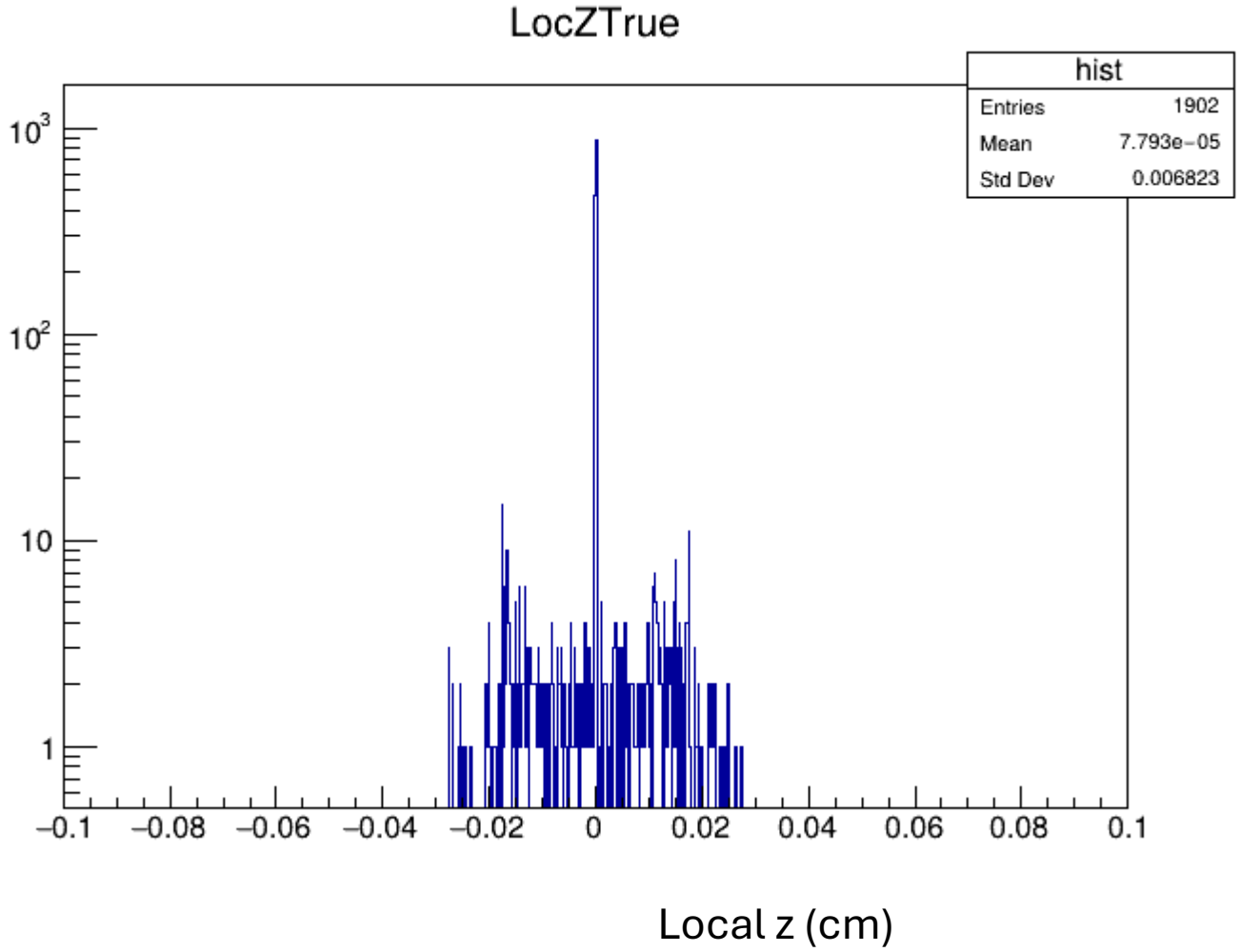
What are these tails?

Sensor local coordinates and global coordinates



- Local y –axis = Global z-axis.
- Local z-axis points into the sensor
- Expectation: Local z = 0

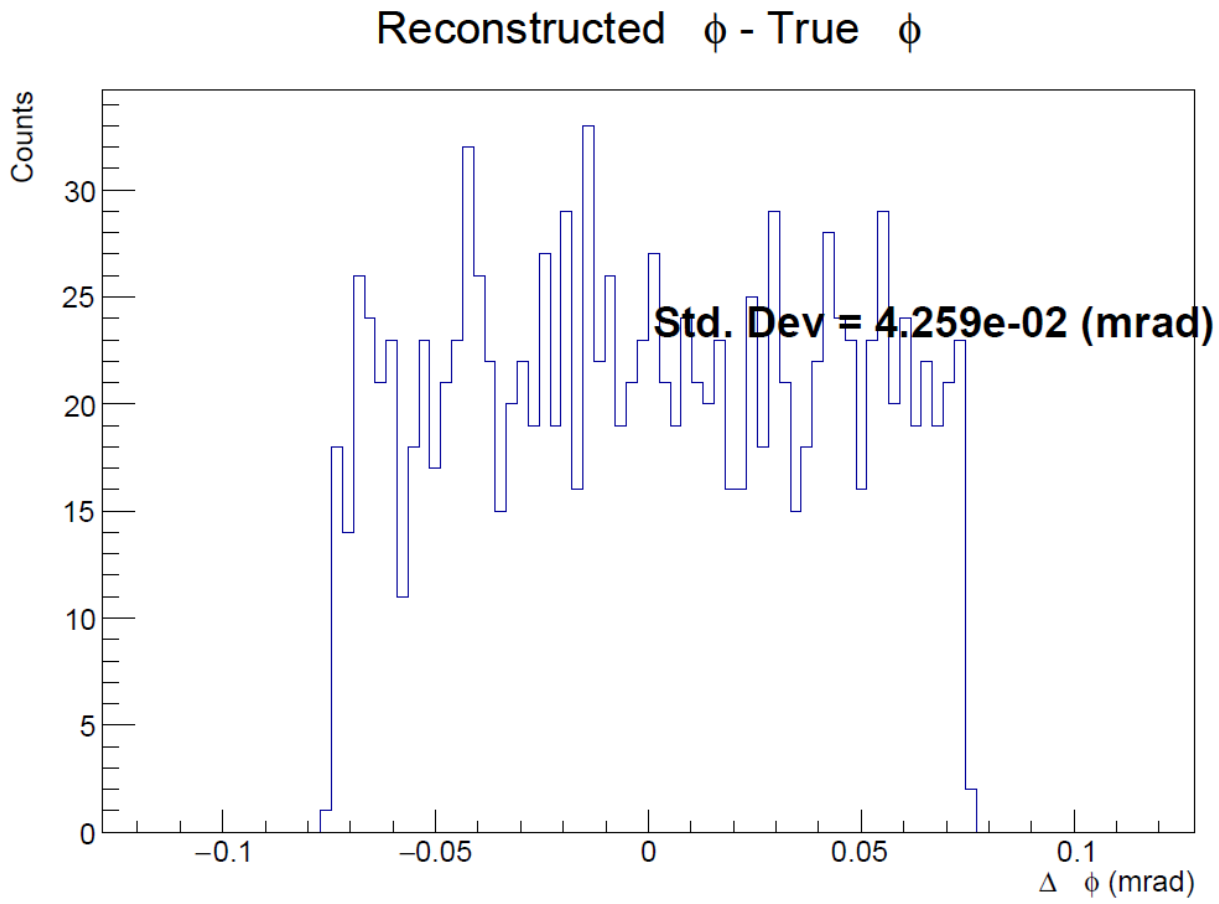
Local z distribution



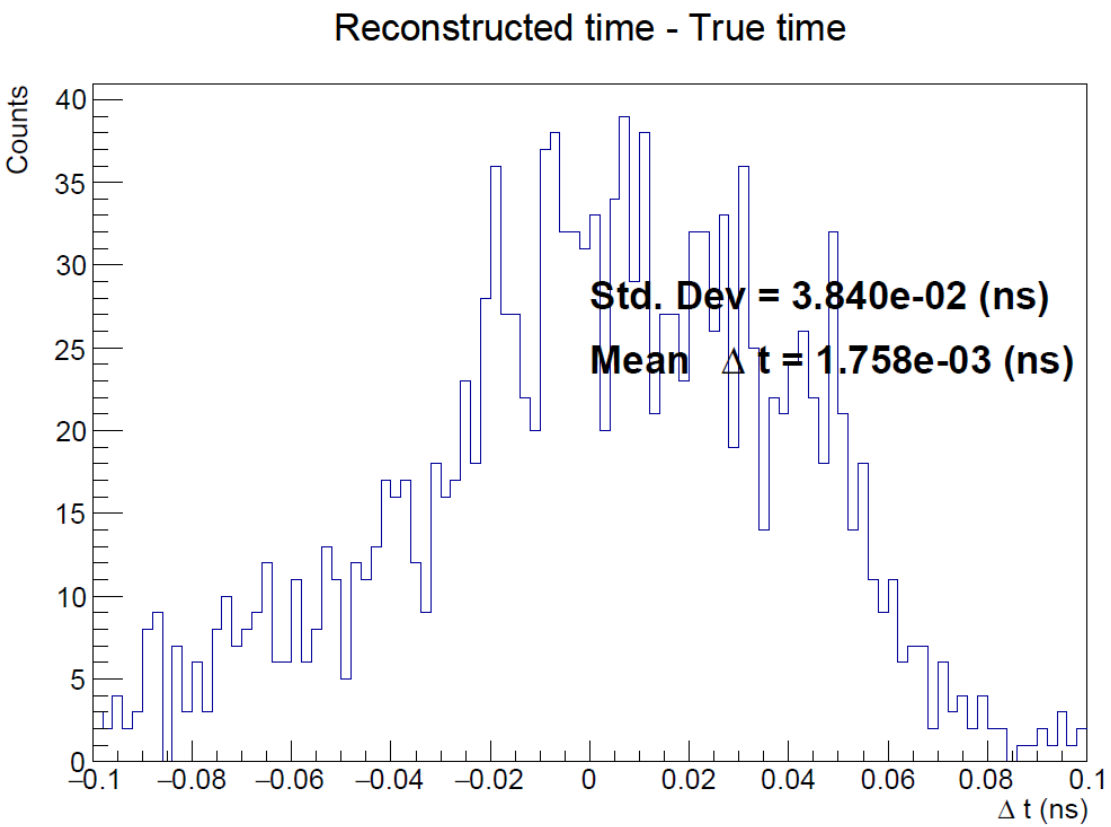
Not all hits lies on the surface of the sensor.

When hit point has large angle of incidence, the extrapolated points deviates from its hit point on surface by more than one cel width.

Phi resolution
AFTER |local –z| < 1e-4 cm



Time resolution

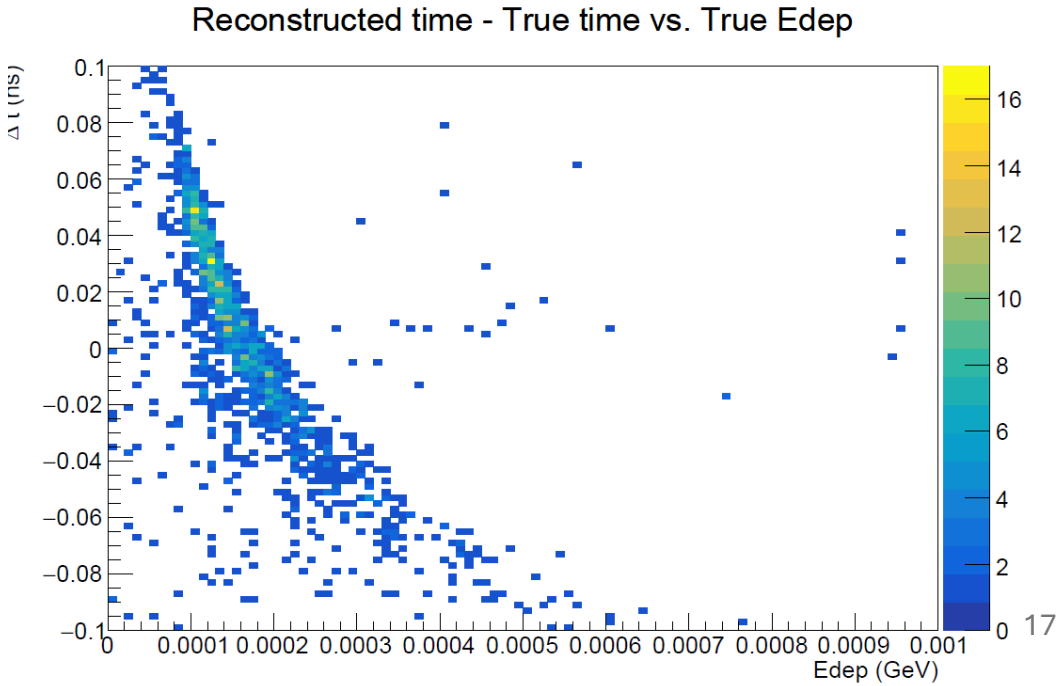


Reco time = slope*TDC + intercept

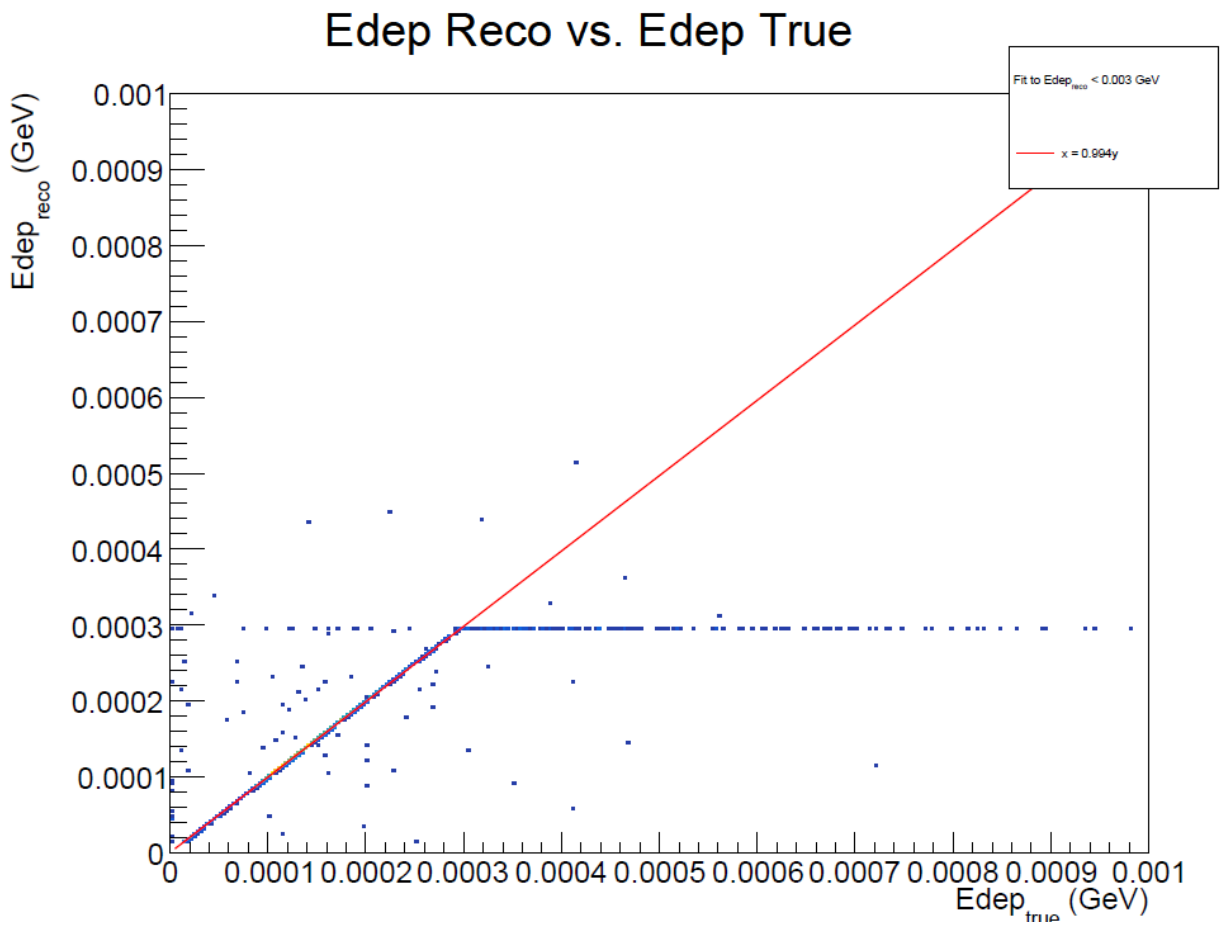
Uncertainty in time = time range in a TDC bin /sqrt(12).

Expected resolution = 0.024414/sqrt(12) = 7.05e-3 ns

Simulated resolution = 3.8e-2 ns



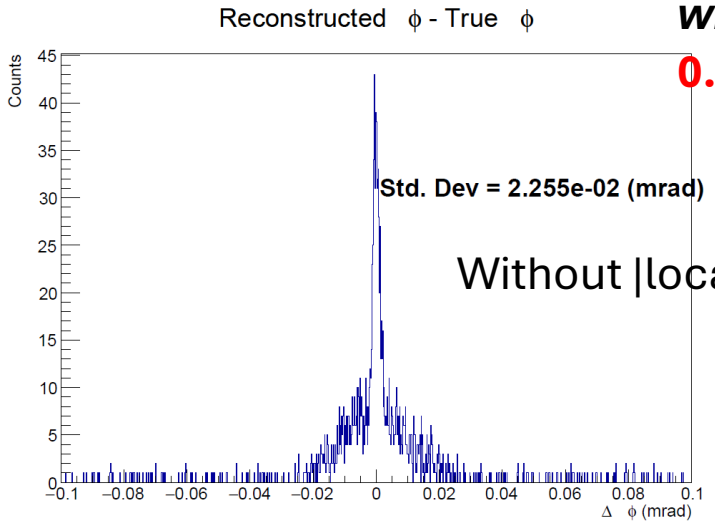
Edep


Edep Reco vs. Edep True
Fit to Edep_reco < 0.003 GeV
x = 0.994y
Edep_reco (GeV)
Edep_true (GeV)
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.001

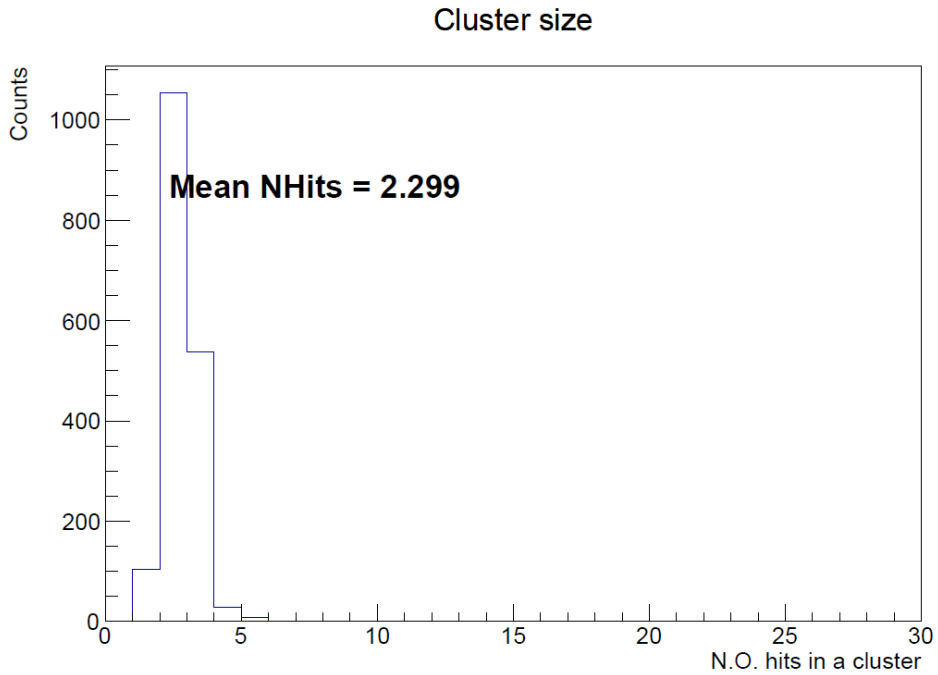
Performance with charge sharing enabled

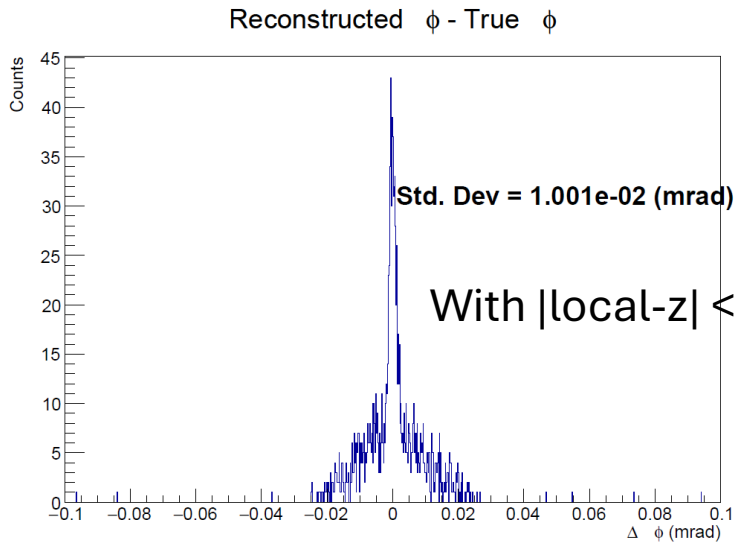
When sigma_x = 0.01 cm = cell pitch

Reminder:
Expected ϕ resolution ***without*** charge sharing = **0.045 mrad**



Without |local-z| < 1e-4 cm

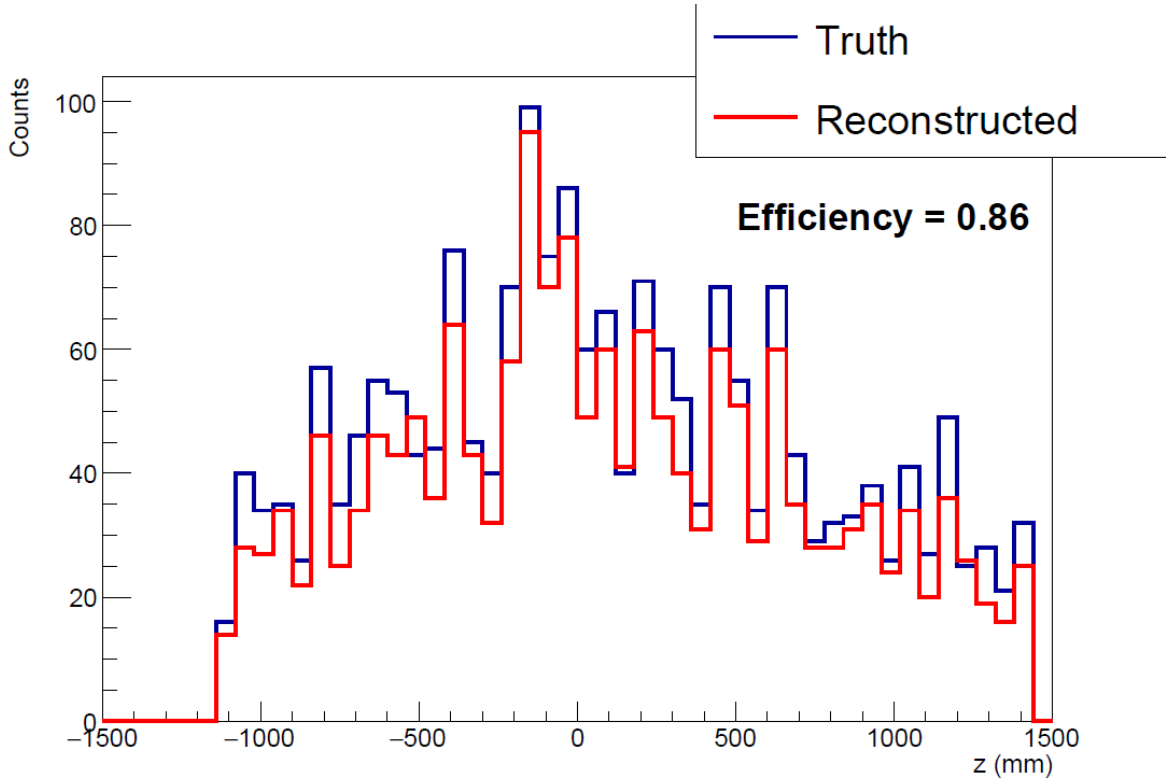




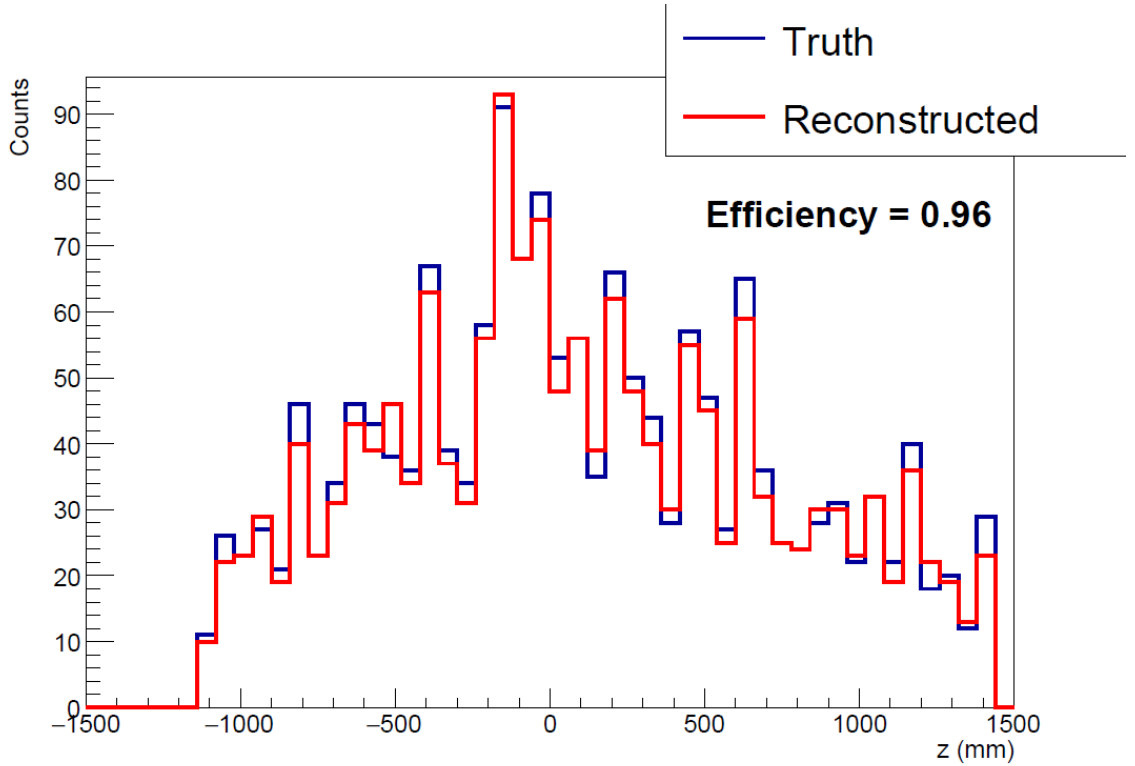
With |local-z| < 1e-4 cm

Efficiency at sigma X = 0.01 cm

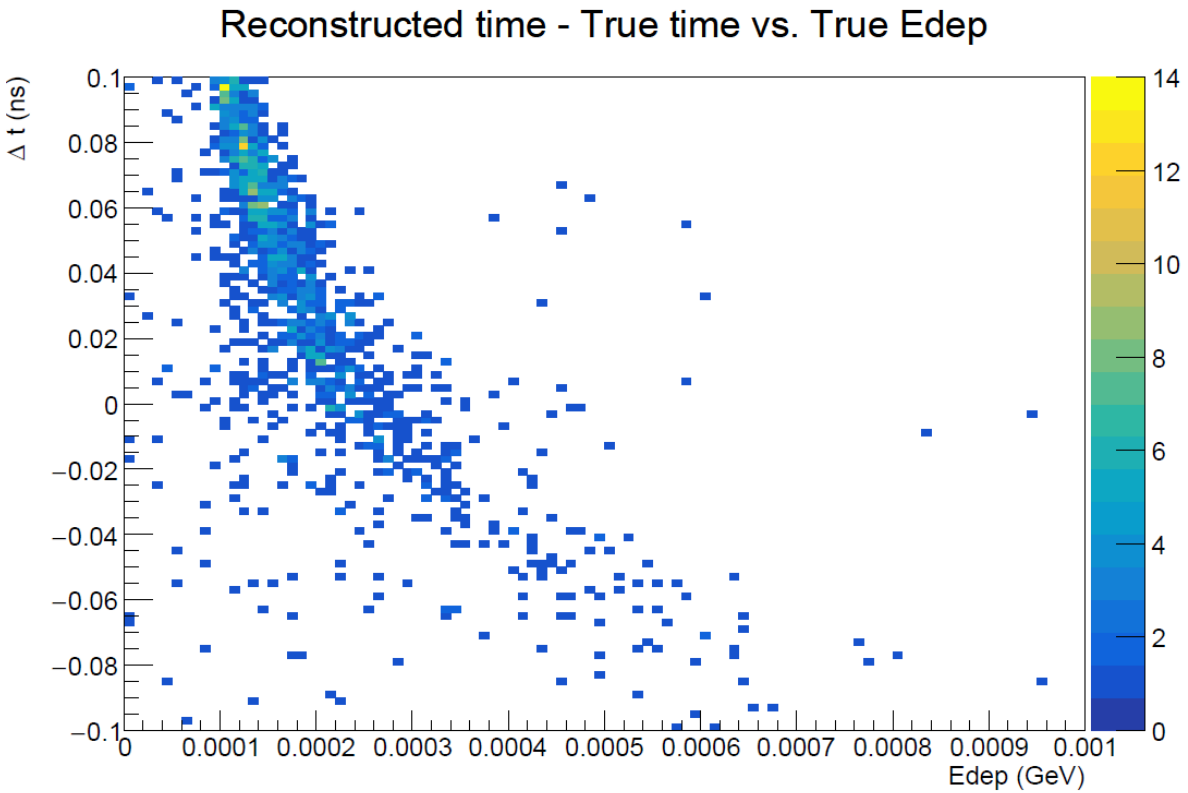
No Edep threshold

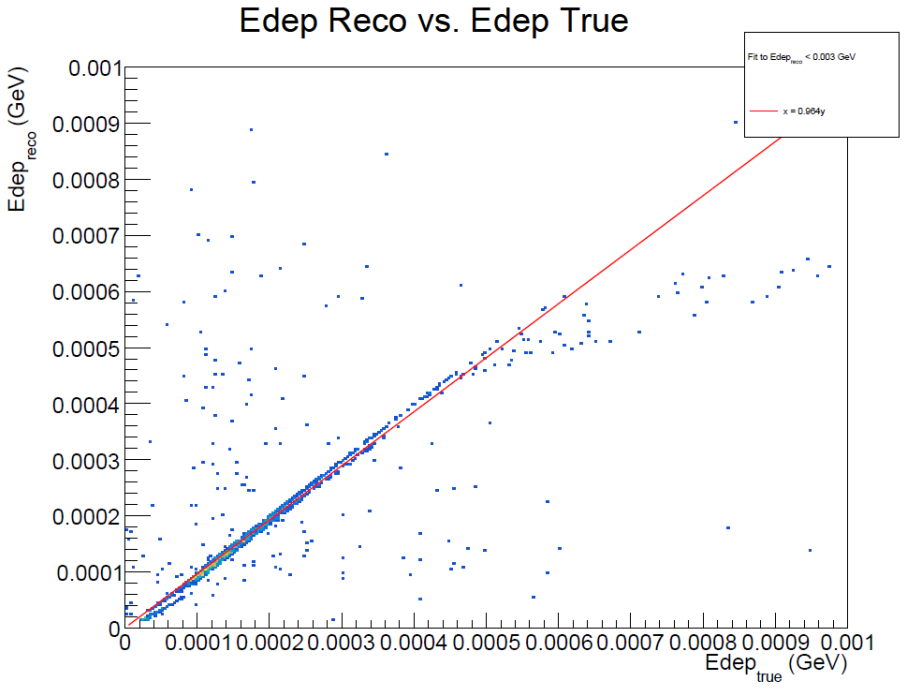


Edep threshold > 5e-5 GeV

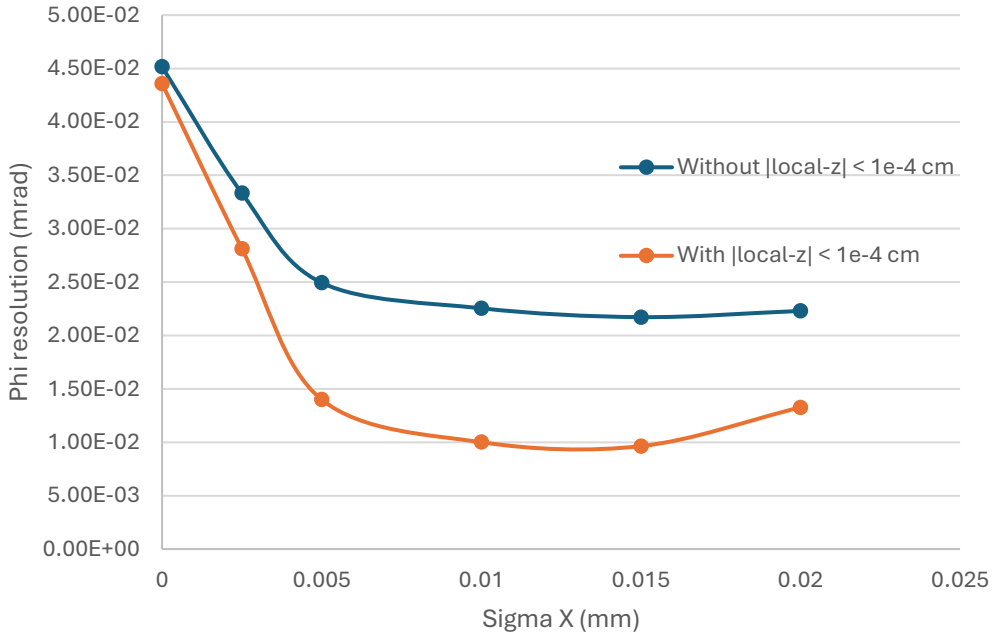


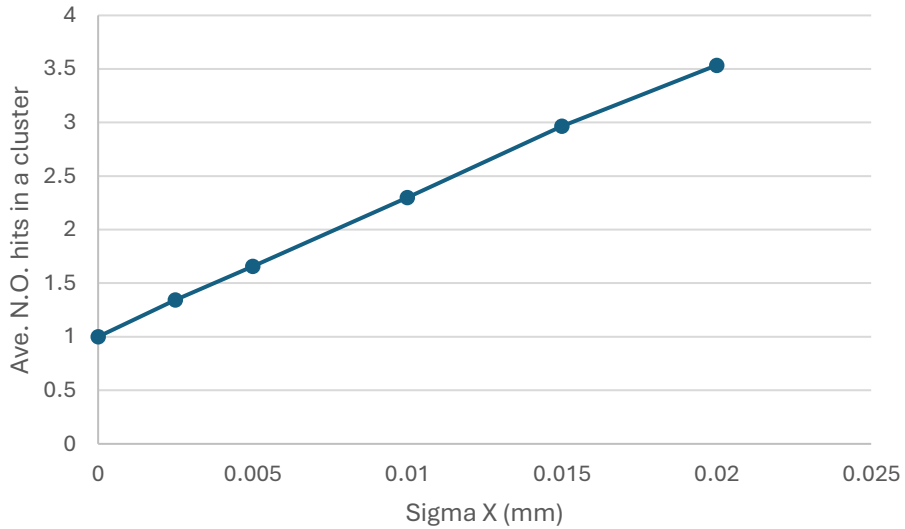
Time and Edep with sigma X = 0.01 cm





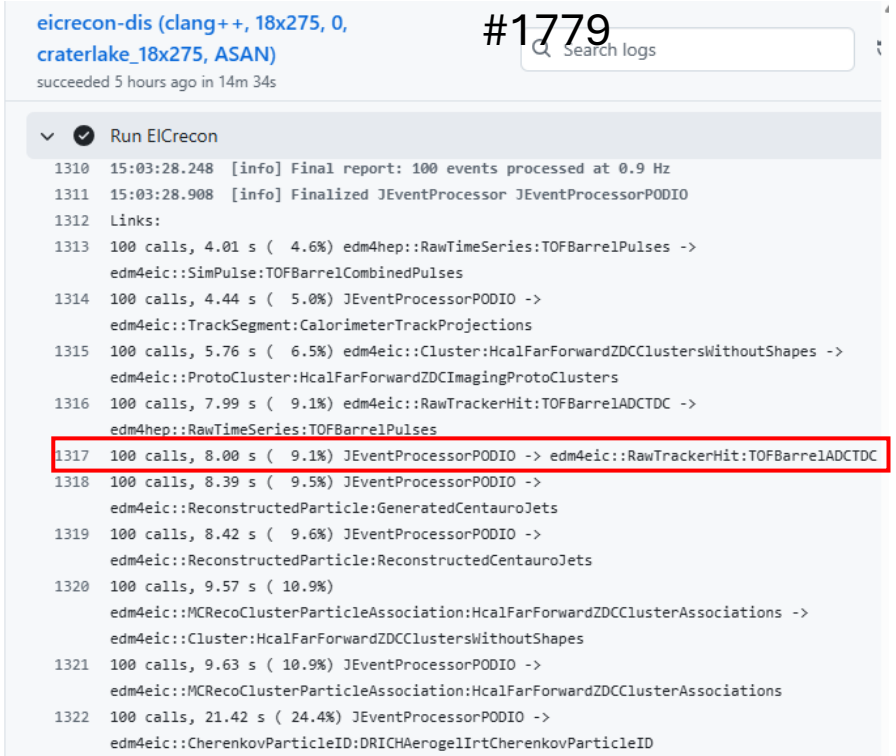
Min Phi resolution = 9.6e-3 mrad at sigmaX = 0.015 cm





Reduce charge sharing spread

- Default sigma_x = 0.1 cm
- https://github.com/eic/EICrecon/pull/1779 switch to 0.01cm.
- Speed improvement:



Conclusion

- ✓Good efficiency.
- ✓ Good position resolution.
- ✓ Good Edep resolution.
- ✓ Time walk as expected.
- Issue to work on:
  - Time walk/edge correction.
  - Use CFD instead of EICROC for BTOF.

Outstand pull request

- Add clustering algorithm (output NOT linked to tracking):
  - https://github.com/eic/EICrecon/pull/1779
- Reduce charge sharing magnitude (Not needed if #1779 is approved):
  - https://github.com/eic/EICrecon/pull/1973
- Fix Charge Sharing
  - https://github.com/eic/EICrecon/pull/1945
- Use CFD for BTOF
  - https://github.com/eic/EICrecon/pull/1974
- Pipe output of digitization to tracking in a future pull request.