Clustering algorithm

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FCC hadron detector meeting
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Status of calorimeter reconstruction

In official repository of FCC Software. Reconstruction documentation

Digitisation:

- Merging energy deposits in cells
- Calibration to the EM scale
- **Noise**

Clustering algorithm:

- **Sliding window algorithm**
  - Electron / photon reconstruction
  - Used in ATLAS [ATLAS note]

Noise in the ECAL

Electronic noise

- Scales with detector capacitance [FCC meeting]

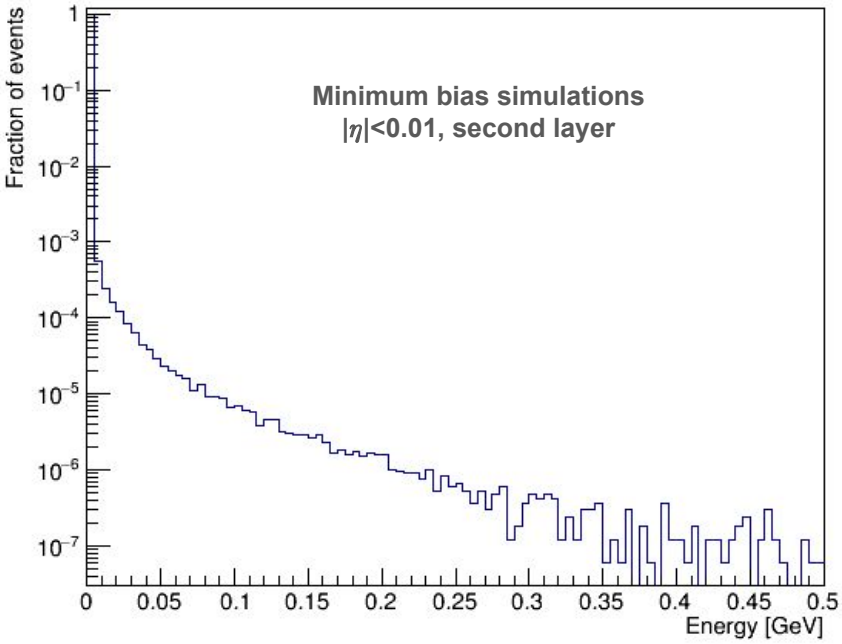
Pile-up

- **In-time pile-up**: a number of minimum bias events in the same bunch crossing
- **Out-of-time pile-up**: contribution from minimum bias events from the previous bunch crossing (drift time)
- Depends on $\Delta\eta$ x $\Delta\phi$, radial layer, material in front of the calorimeter, energy of the minimum bias collisions
  - Difficult to be extrapolated from ATLAS

Pile-up noise

Estimation based on FCC full simulations

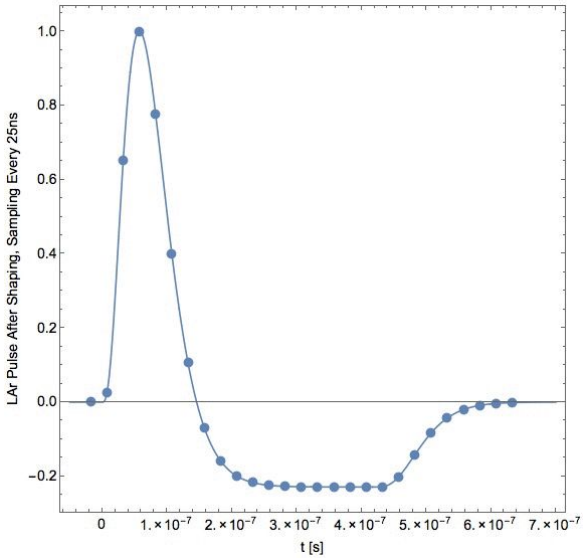
- Simulation of minimum bias (MB) collisions in ECAL (one per bunch crossing)
- Corrections
  - Scaling with avg. number of MB events per bunch crossing ($\sqrt{\mu}$)
  - Out-of-time pile-up



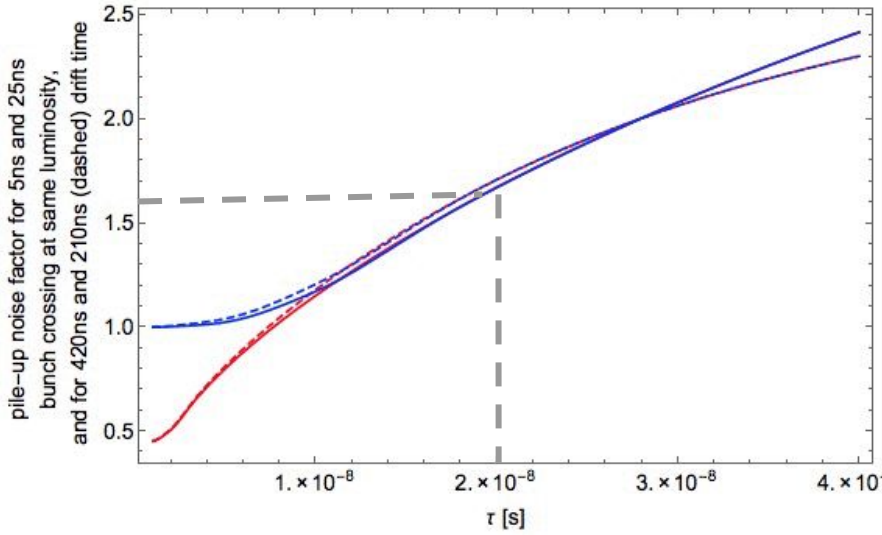
Out-of-time pile-up

Pulse-shape in ATLAS

- Drift time 420 ns
- Pulse is digitized every 25 ns
- Bipolar shaping
  - The sum of in-time pile-up and out-of time pile-up yields zero
  - Fluctuations will be higher than those measured for the in-time pile-up only → correction factor



Correction factor: **1.6**
(shaping time ~20 ns,
for 5 ns and 25 ns bunch crossings)



Pile-up noise

Simulations of min. bias event: RMS_{1MB} per cell

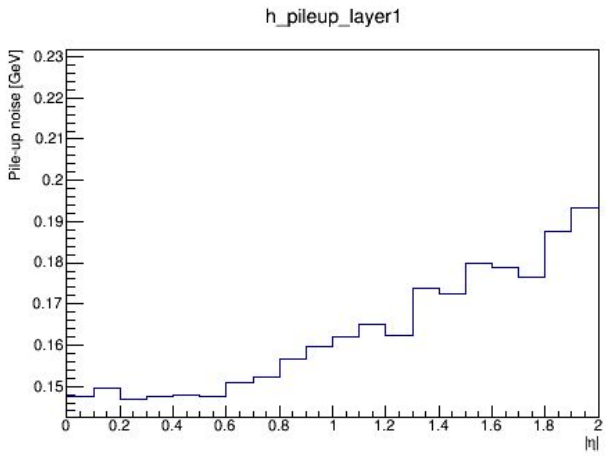
Final pile-up noise: RMS_{1MB}* 1.6 * $\sqrt{\mu}$ (μ = 1000)

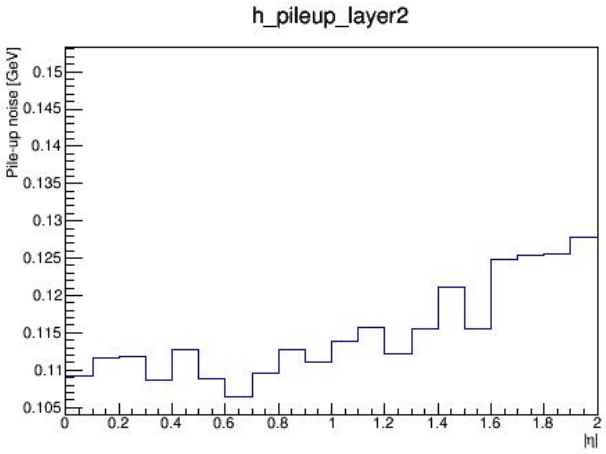
Three radial layers, cell size 0.01 x 0.01 in $\Delta\eta$ x $\Delta\phi$

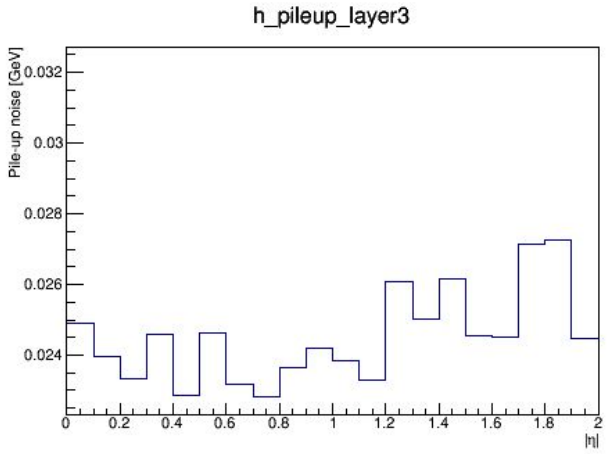
Notes:

- Largest pile-up in the first radial layer
- Pile-up increases with η

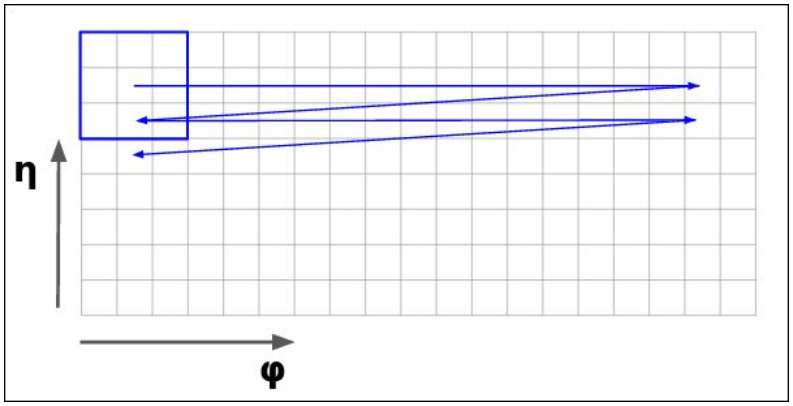
-> As expected







Sliding window algorithm



0. Calorimeter towers with fixed η x φ size

1. Seeding

- Scanning the η x ϕ tower map with a fixed size window for local maxima
- If energy inside window is above threshold → mark as pre-cluster

2. Barycentre position calculation

- Energy-weighted position for each pre-cluster

3. Duplicates removal

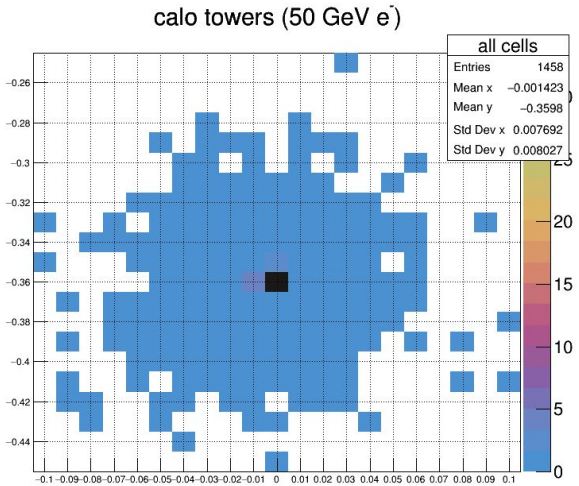
- If two pre-clusters are next to each other, the pre-cluster with lower energy is removed

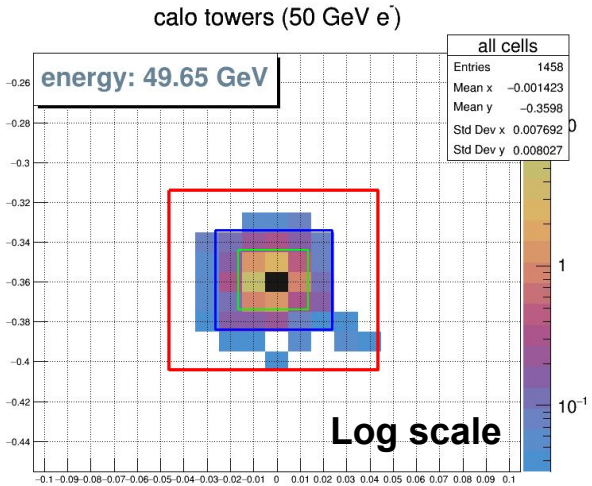
4. Cluster building

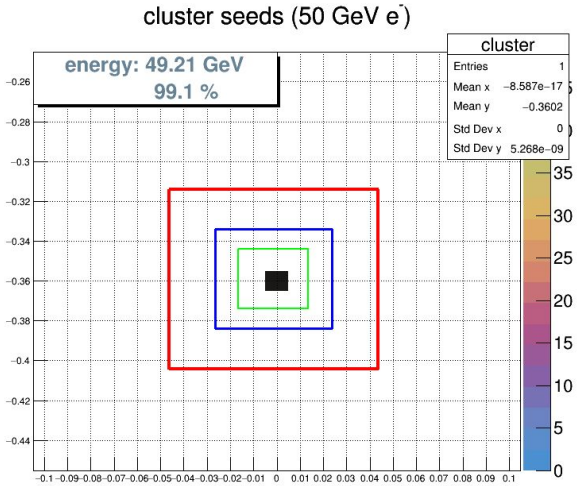
Each step (1-4) can use window of different size (centred around the tower seed)

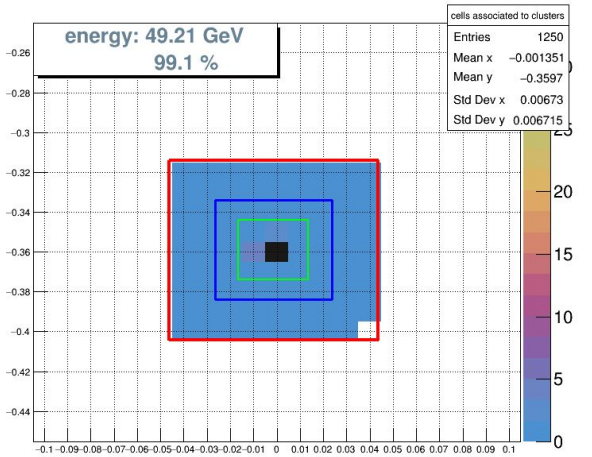
Proof of principle

Sizes of the windows (seeding, position calculation, duplicate removal) and the energy threshold are to be optimised.



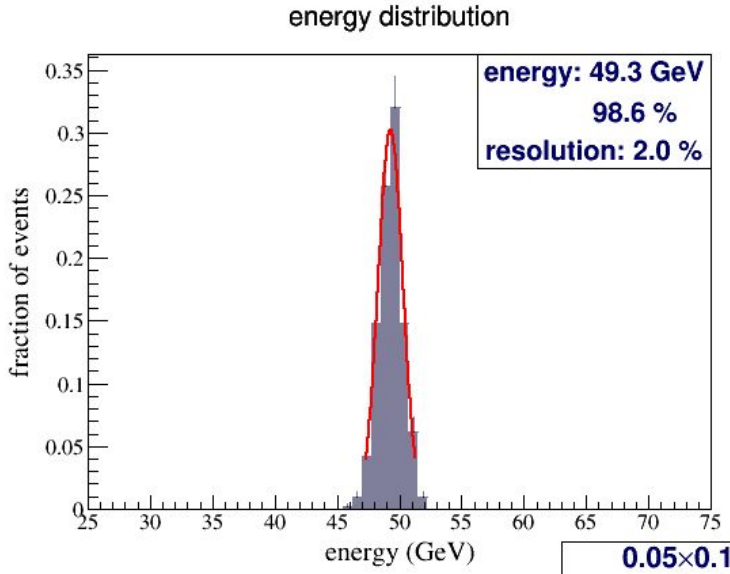


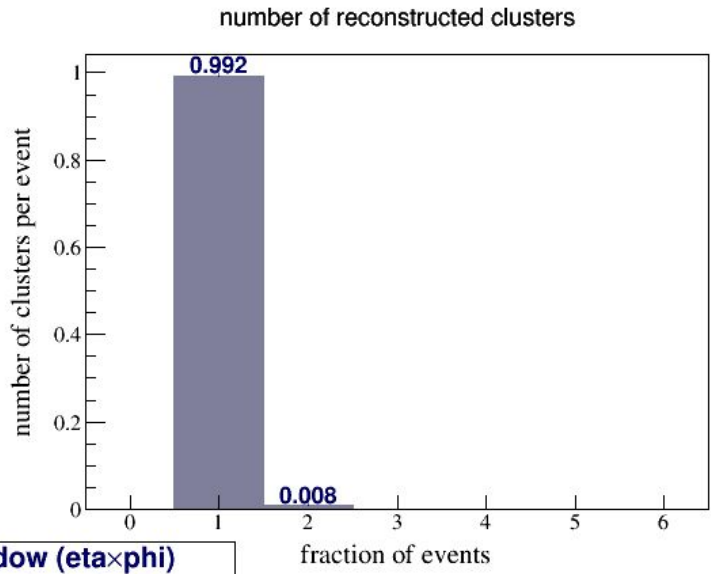




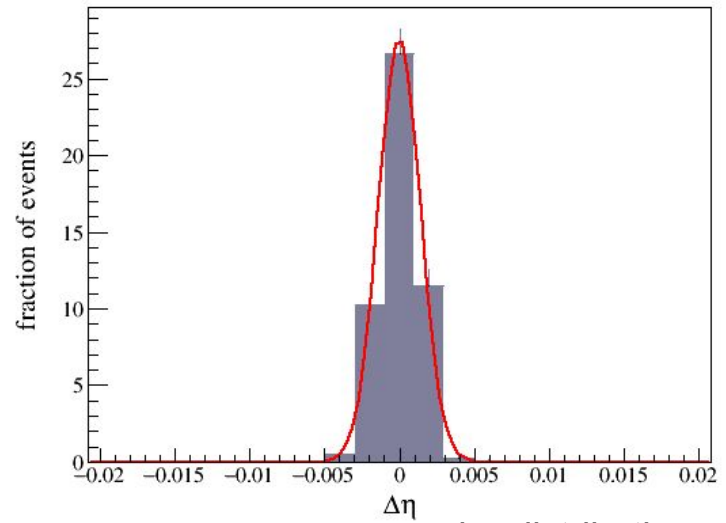
Simple noise

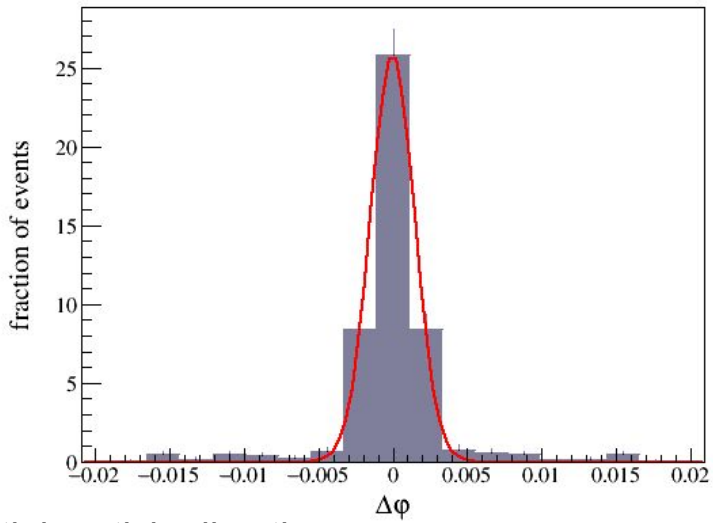
500 single electron events (50 GeV)
B = 0
no tracker, no cryostat
Gaussian noise (all cells: σ = 10 MeV)





0.05×0.15 window (eta×phi)
7 GeV energy threshold

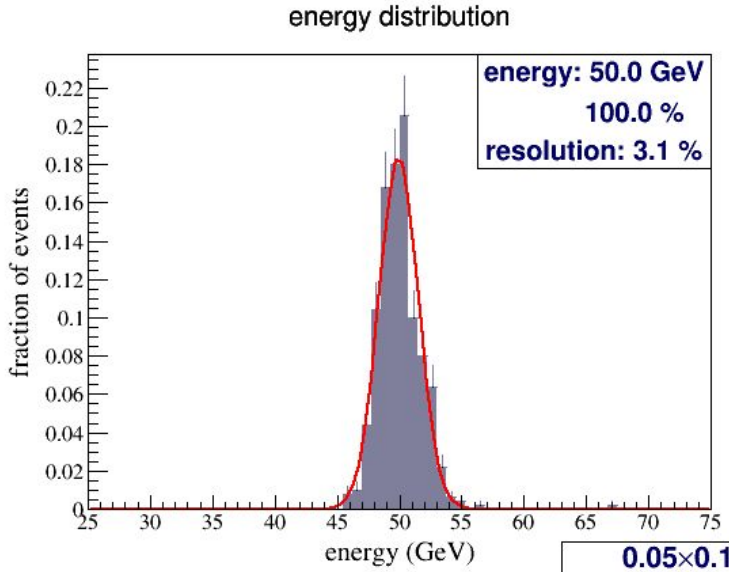


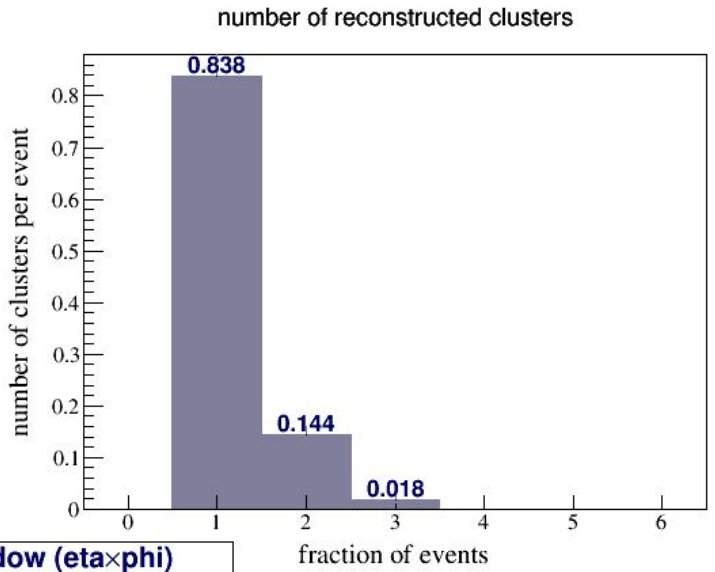


η and φ distributions wrt initial particle direction

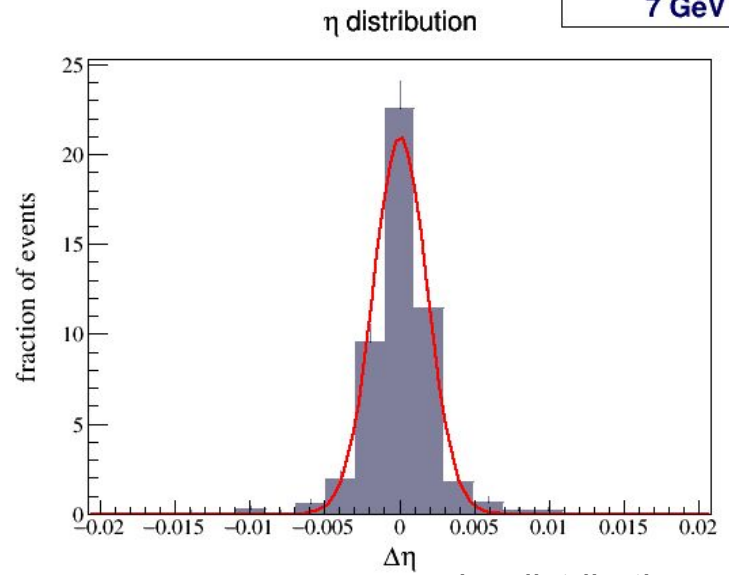
More realistic noise

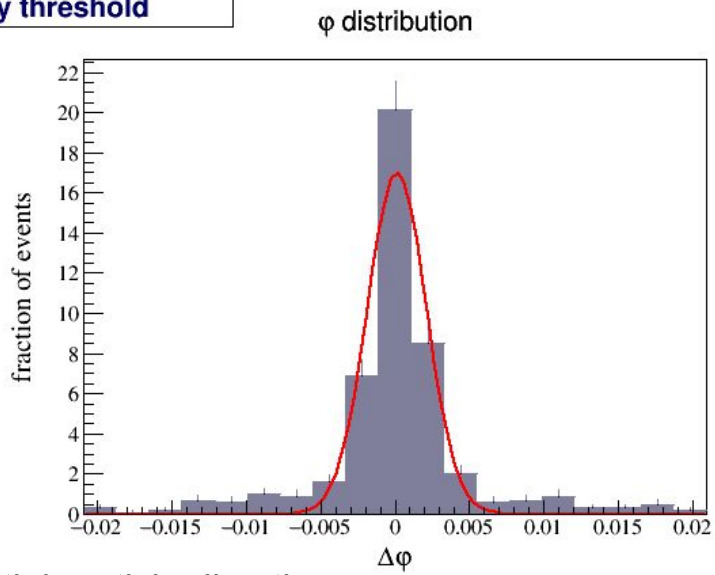
500 single electron events (50 GeV)
B = 0
no tracker, no cryostat
electronic + pileup noise





0.05×0.15 window (eta×phi)
7 GeV energy threshold



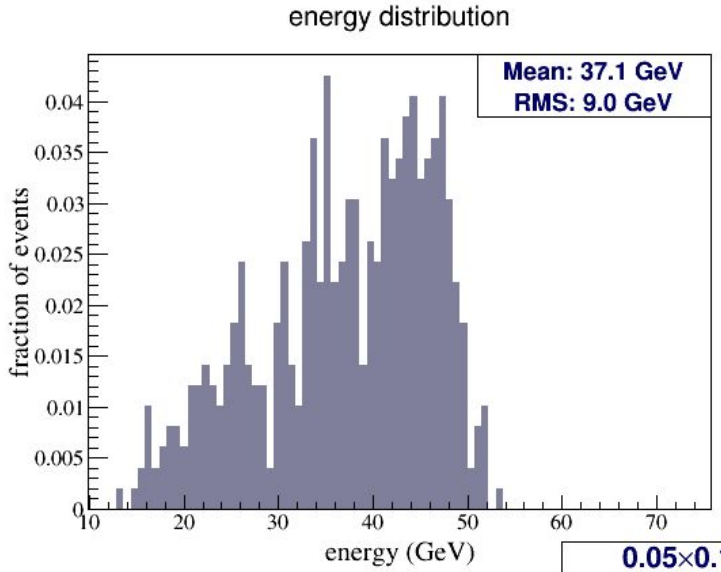


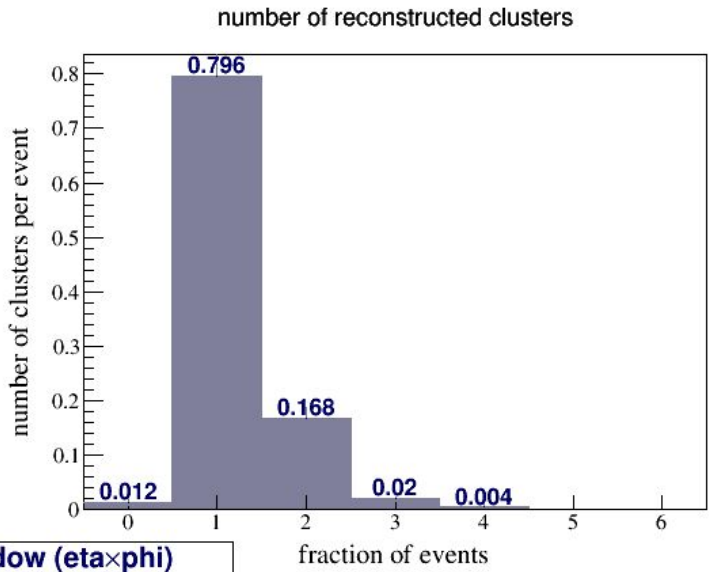
η and φ distributions wrt initial particle direction

With tracker and B field

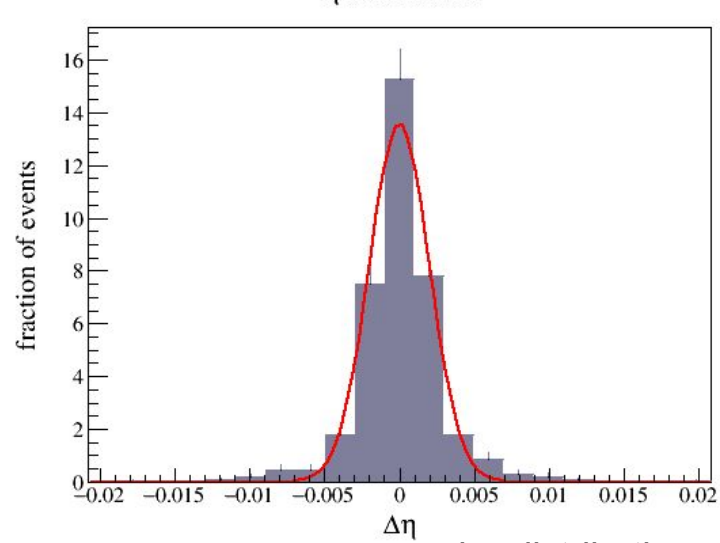
500 single electron events (50 GeV)
B = 4 T
with tracker + cryostat
electronic + pileup noise

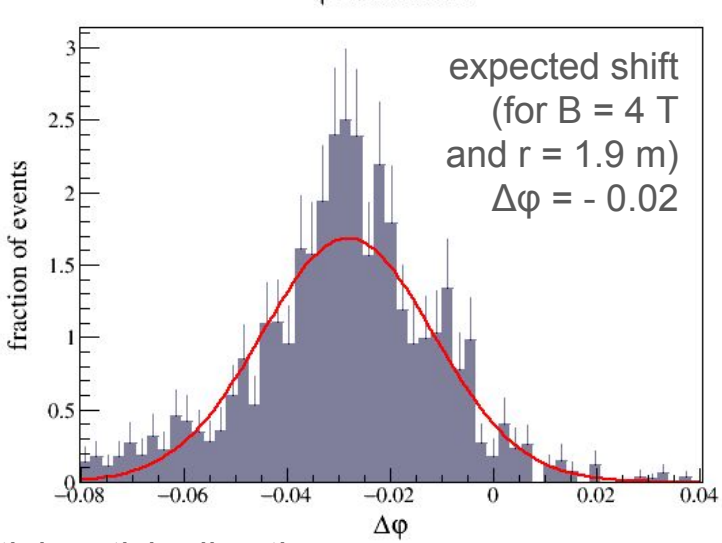
Work in progress





0.05×0.15 window (eta×phi)
7 GeV energy threshold



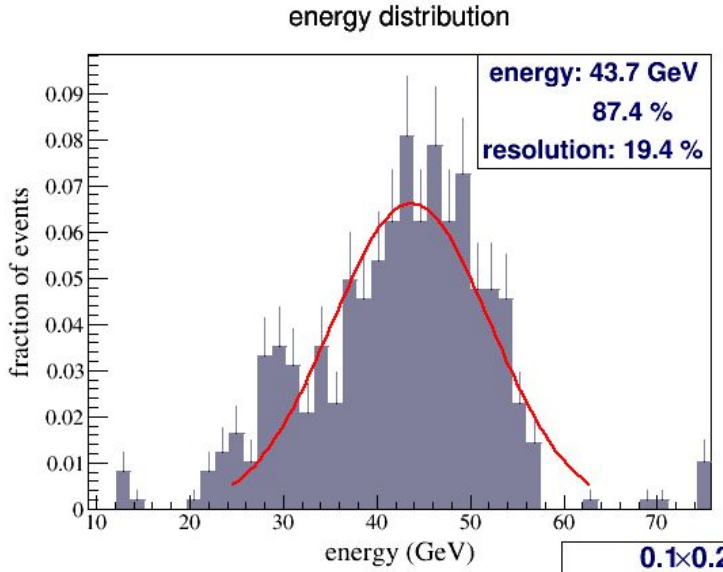


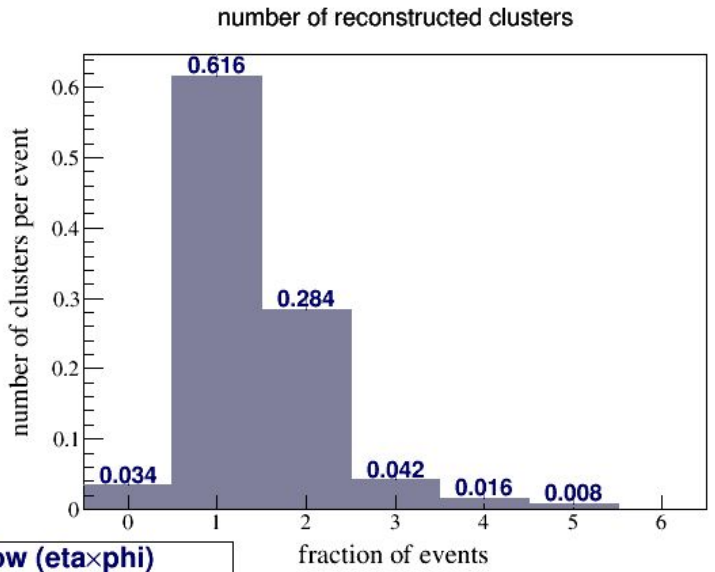
η and φ distributions wrt initial particle direction

Larger window

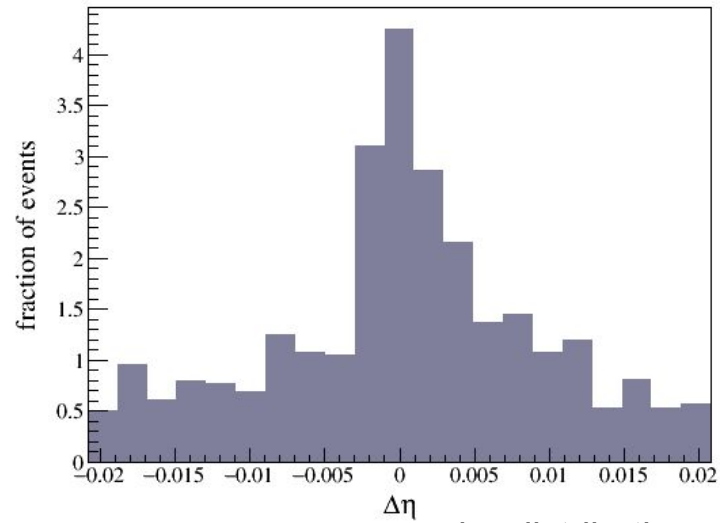
500 single electron events (50 GeV)
B = 4 T
with tracker + cryostat
electronic + pileup noise

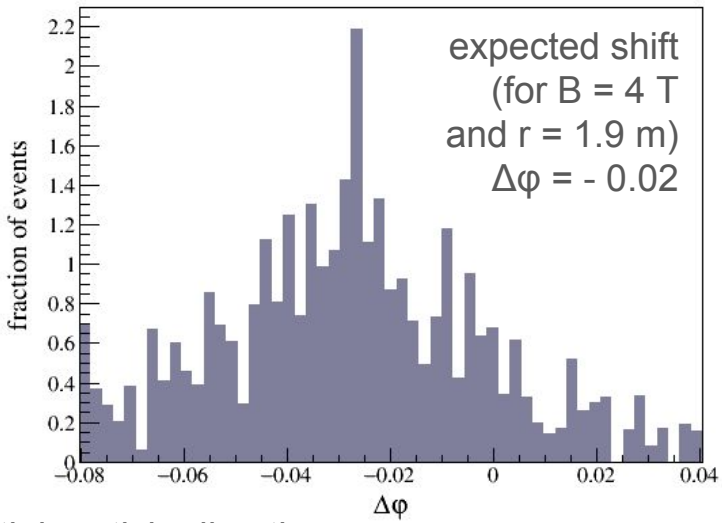
Work in progress





0.1×0.2 window (eta×phi)
12 GeV energy threshold





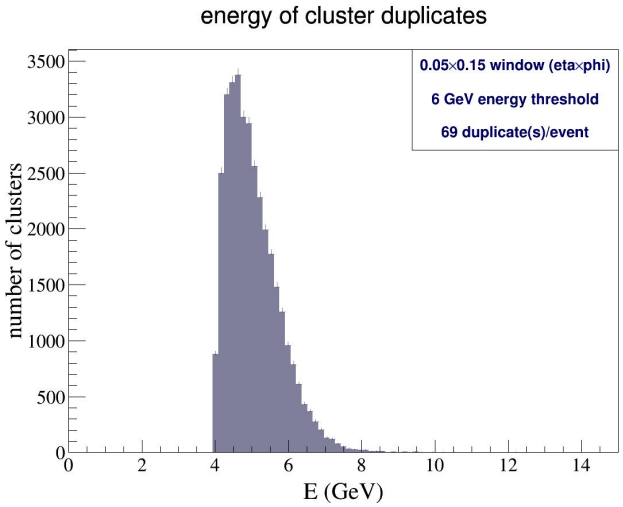
η and φ distributions wrt initial particle direction

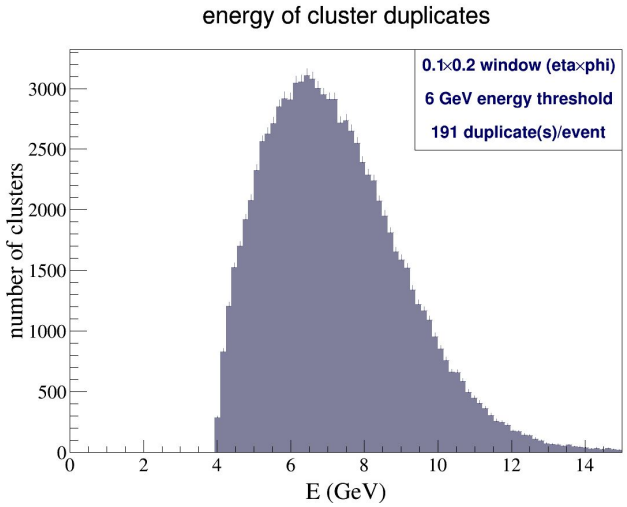
Parameter optimisation (just started)

window 0.05 x 0.15

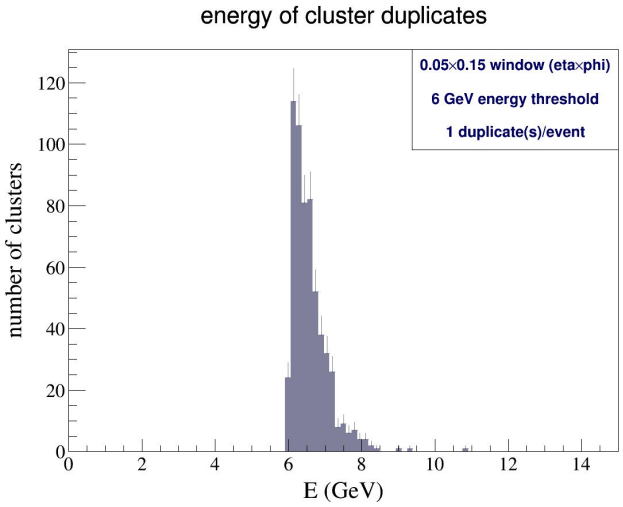
window 0.1 x 0.2

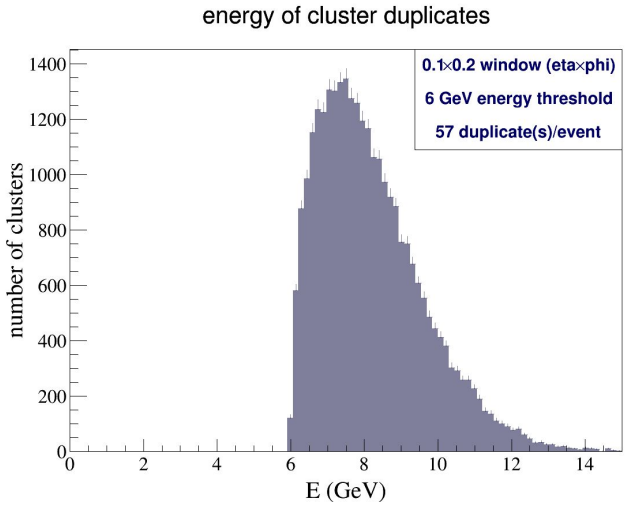
energy threshold 4 GeV





energy threshold 6 GeV





Same trend for all energies -> contribution from noise

Reconstruction parameters may depend on each other
Starting with seeding window size and energy threshold

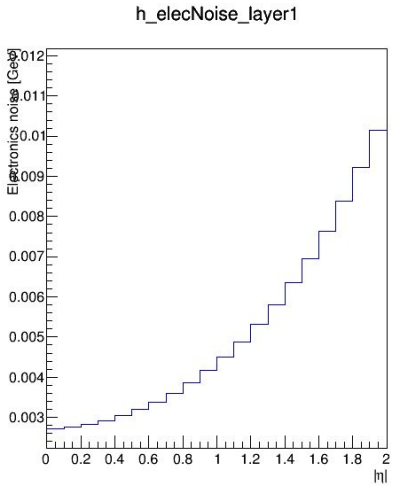
Summary

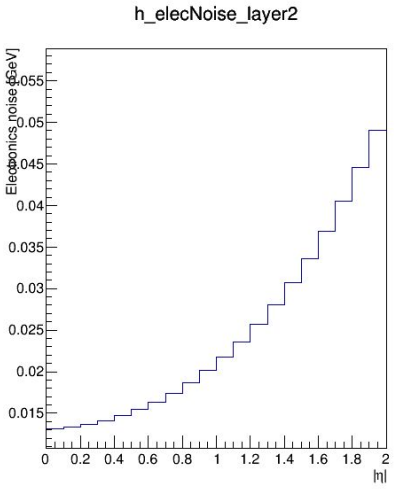
- Pile-up noise estimation in ECAL updated
- Sliding window algorithm implemented
  - Validation done without any material in front of the detector
- Ongoing work: Optimisation of sliding window parameters
  - Reconstruction efficiency and fake clusters rejection
  - Aim to reconstruct as low energetic particles as possible

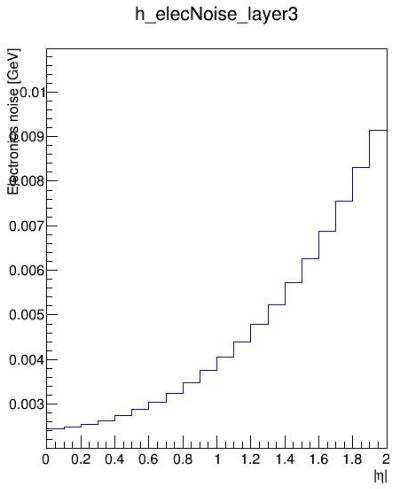
BACKUP

Minimum bias energy distribution

Electronic noise

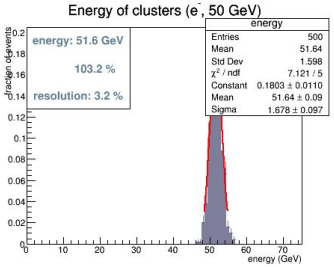


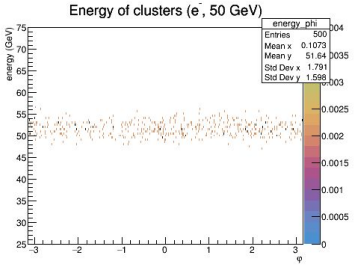


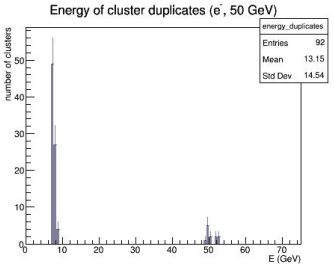


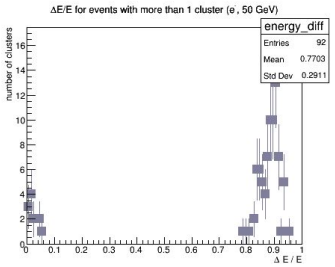
50 GeV

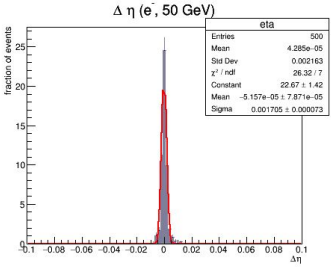
500 single electron events (50 GeV)
B = 0
no tracker, no cryostat
electronic + pileup noise

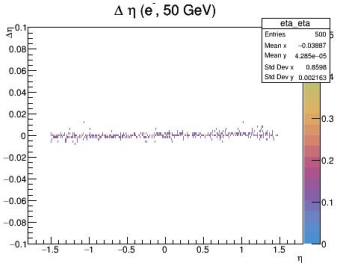


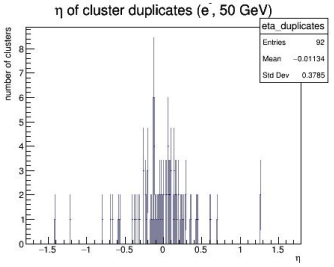


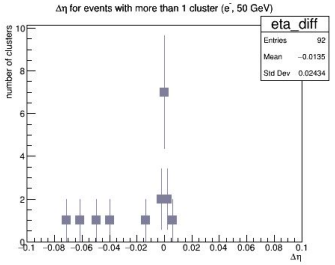


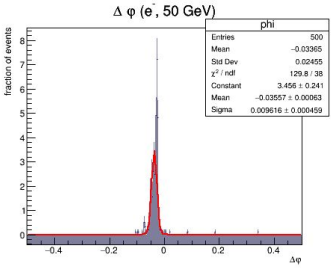


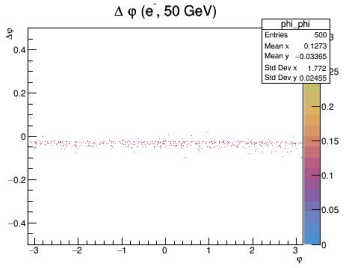


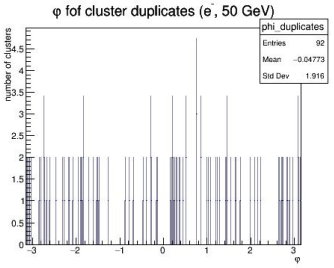


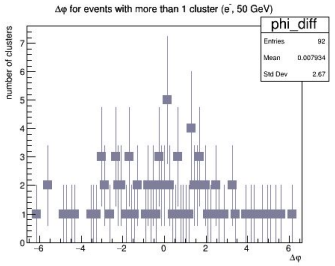


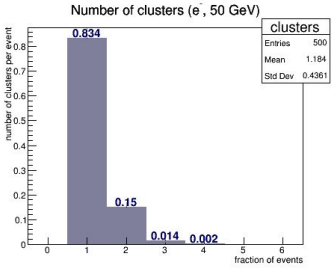


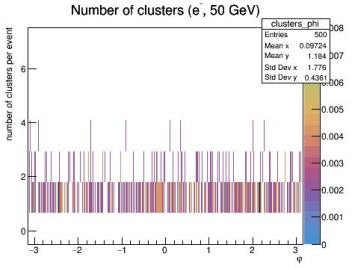


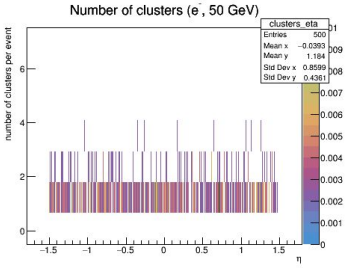


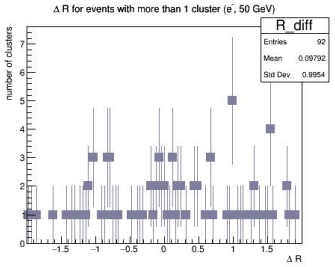






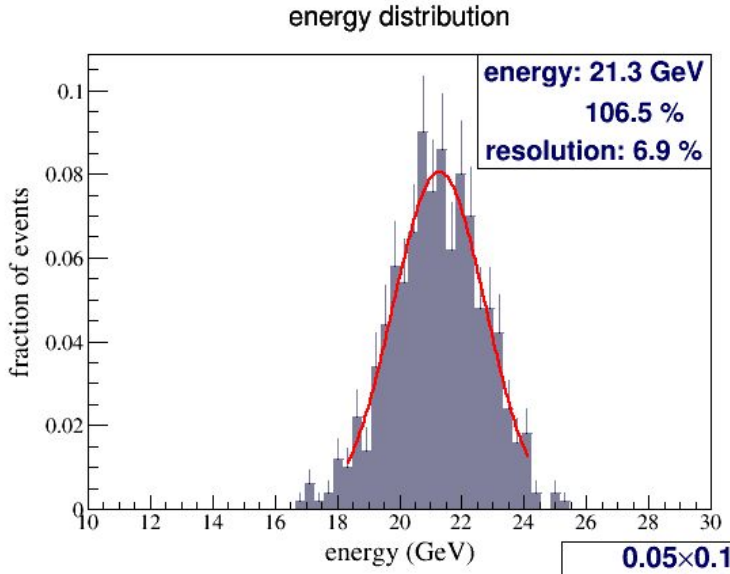


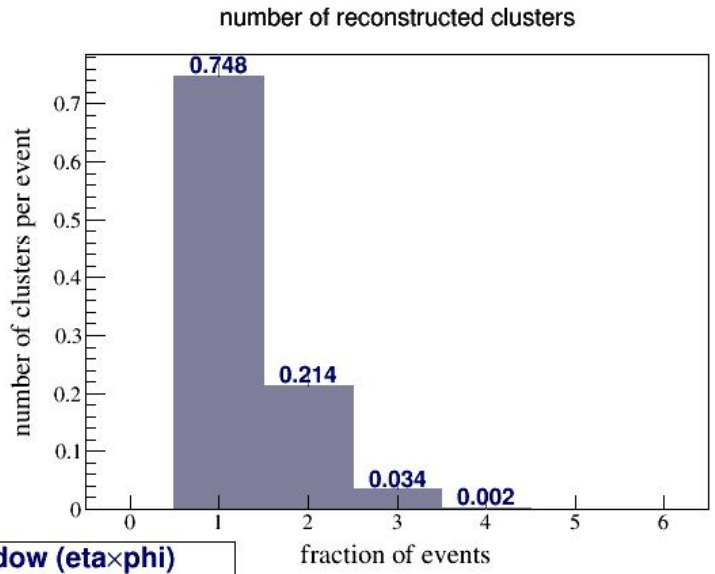




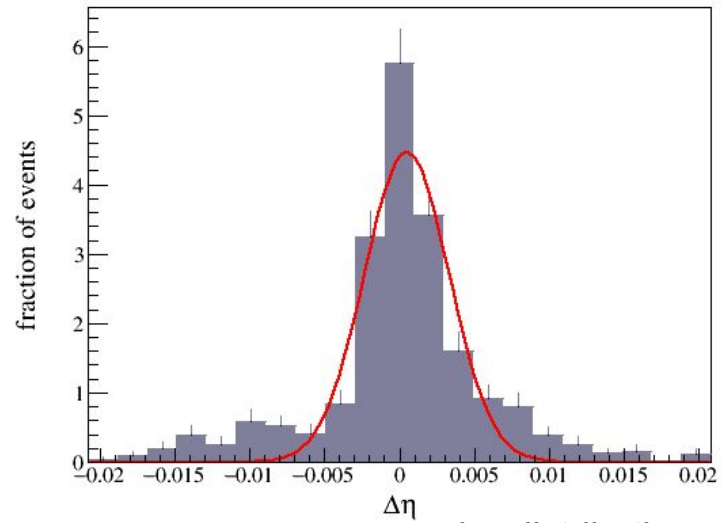
20 GeV

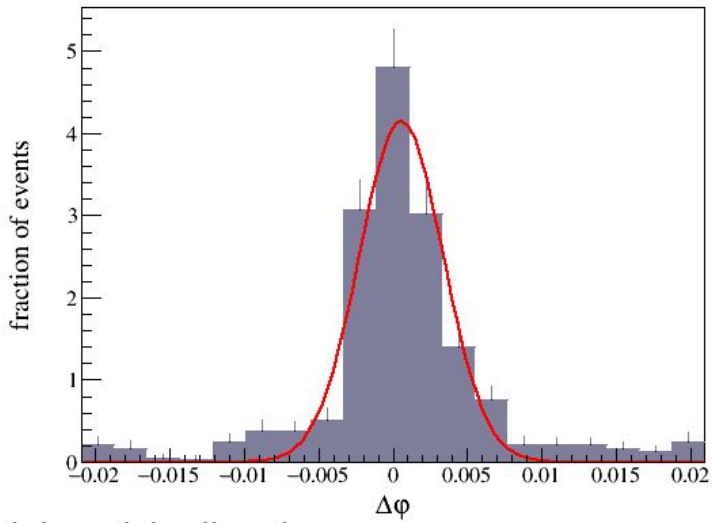
500 single electron events (20 GeV)
B = 0
no tracker, no cryostat
electronic + pileup noise





0.05×0.15 window (eta×phi)
7 GeV energy threshold

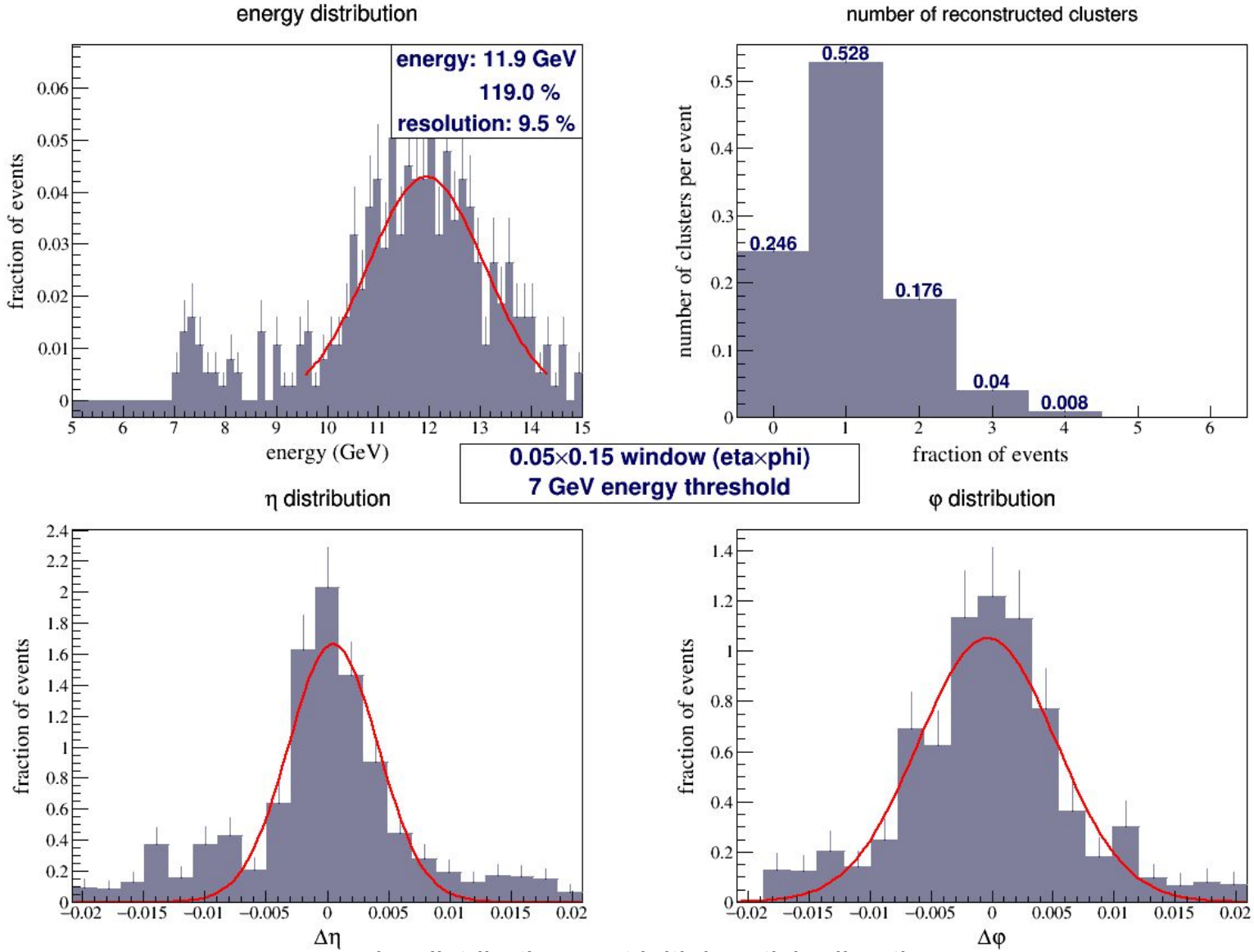




η and φ distributions wrt initial particle direction

10 GeV

500 single electron events (10 GeV)
B = 0
no tracker, no cryostat
electronic + pileup noise



η and φ distributions wrt initial particle direction