Clustering algorithms for the CBM calorimeter

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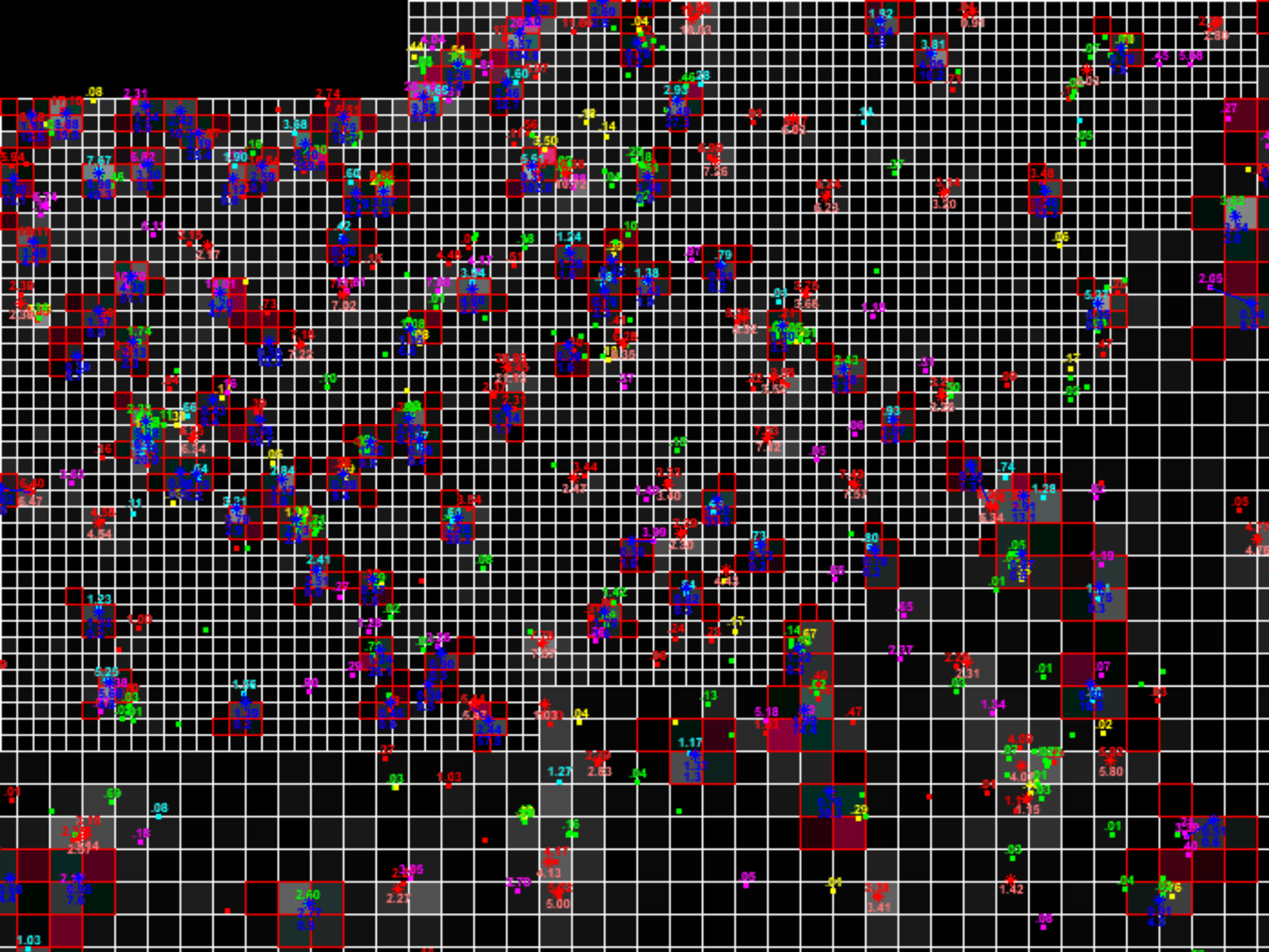
Outline

- Why we need clustering
  - Reconstruction in calorimeter
- CBM calorimeter
  - Electron and muon option
  - “Common” clustering procedure
  - Cluster finding in electron option
  - Cluster finding in muon option

Reconstruction in calorimeter

- Photon reconstruction
  - Energy
  - Position
    - Momentum: all photons from primary vertex
- General case
  - Just single photon reconstruction
- LHC
  - Single photon/pair from π^0 decay?
- Heavy ion experiments
  - Shower overlaps (occupancy)
    - energy deposition from different photons in one cell
    - shower shape and fitting for unfolding



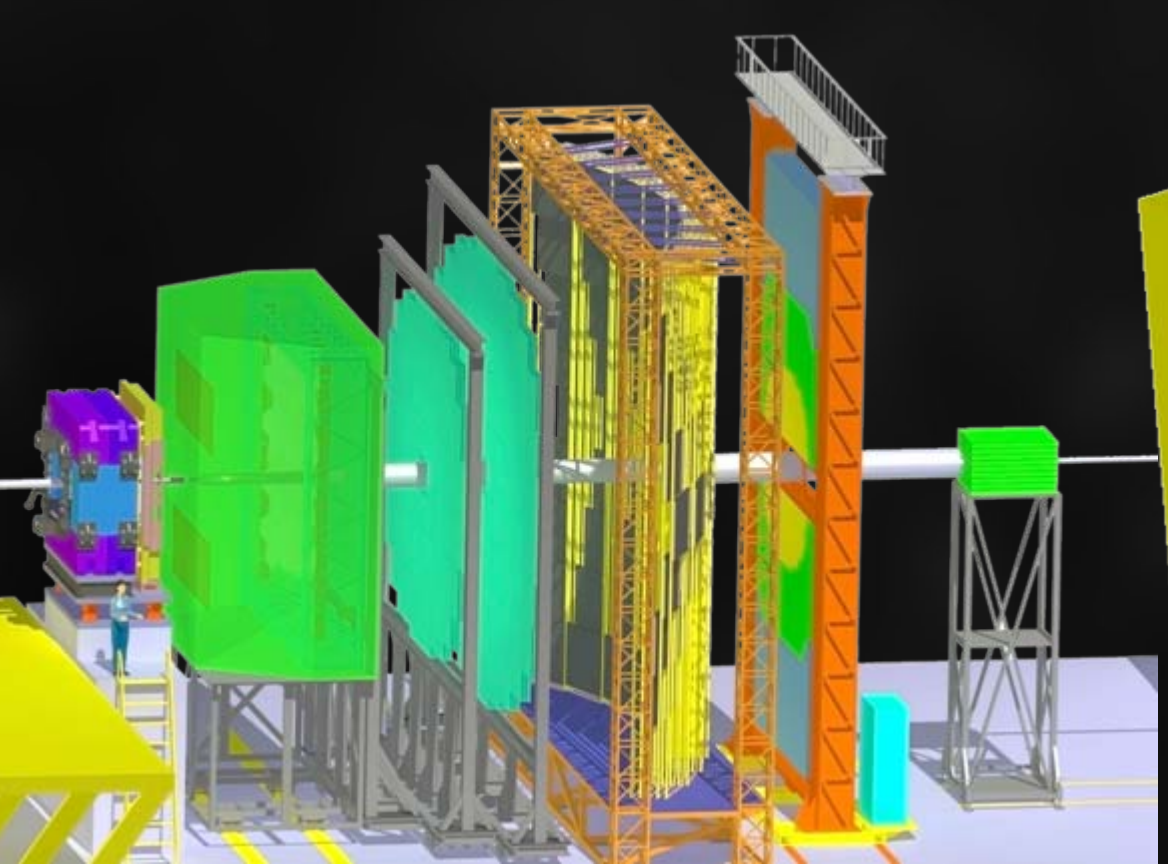
Requrements

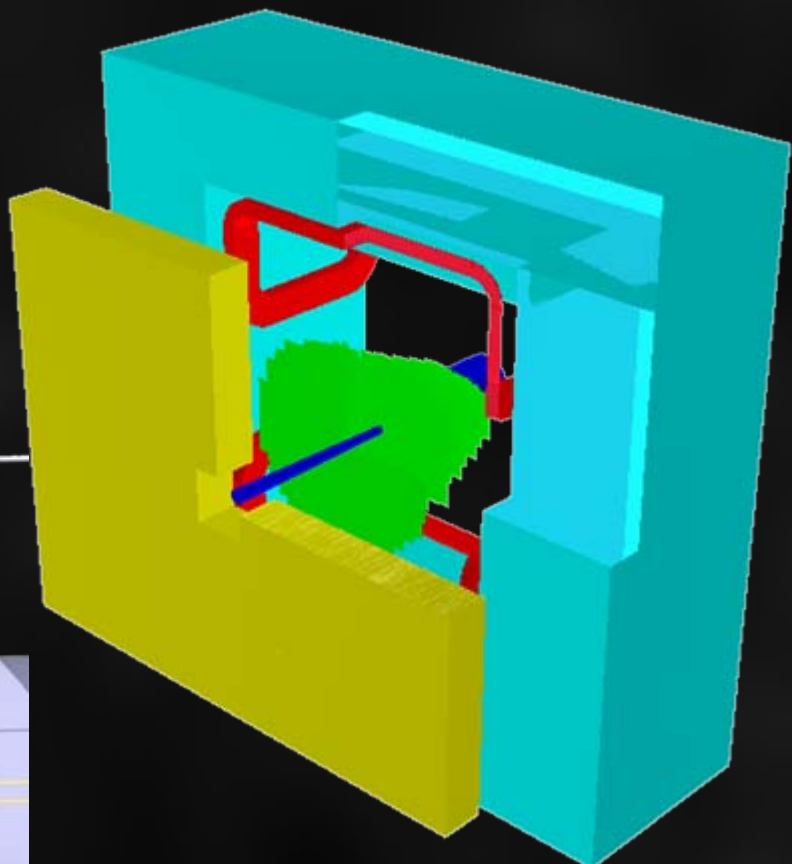
- Cluster should be large
  - information for unfolding procedure
- Cluster should be small
  - fitting of 2 clusters with 2 photons each is much faster than fitting 1 cluster with 4 photons
    - … and results are more accurate
  - minimize contamination of hadrons
  - not less than 3 cells per photon
    - 3 free parameters

Calorimeter in CBM experiment

Electron option

Muon option





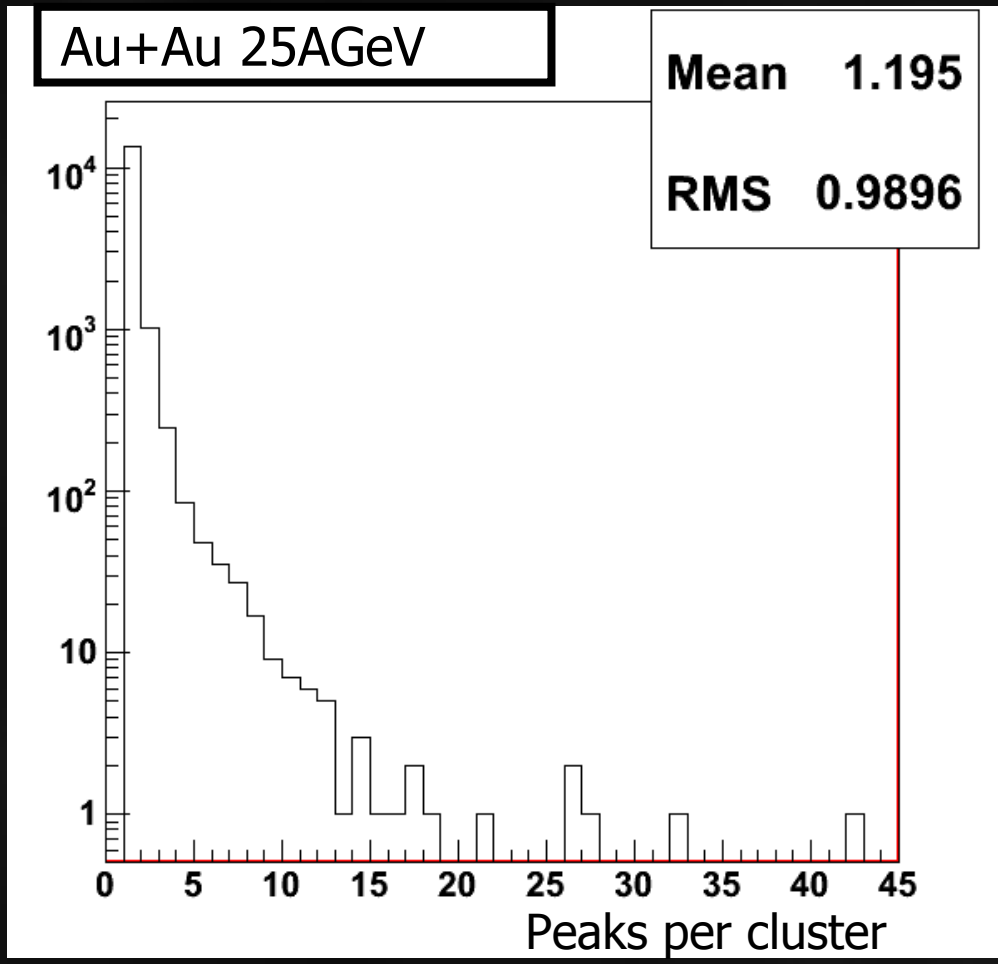
Geometry

- Electron option
  - Distance to target: 12 m
  - Cell size: 3×3, 6×6, 12×12 cm
  - Sampling: 140 layers ($25X_0$)
    - 1.0 mm lead
    - 1.0 mm scintillator
  - Acceptance: 5-25°
  - Energy resolution: 7%/sqrt(E)
  - ~14000 readout channels
- Muon option
  - Distance to target: 1.5 m
  - Cell size: 2.5×2.5 cm
  - Sampling: 70 layers ($20X_0$)
    - 1.0 mm tungsten
    - 1.5 mm scintillator
  - Acceptance: 5-45°
  - Energy resolution 7.6%/sqrt(E)
  - ~8000 readout channels

Calorimeter of muon option could be used as a central calorimeter region in electron option.

Cluster finding. Naive approach

- Cluster definition:
  - connected area of cells with energy deposition above the threshold
  - threshold can be found from MC
- Occupancy differs ~10^2 times
  - partially compensated by segmentation
  - lost clusters in periphery of calorimeter
  - create too large clusters in central region
- No chance to fit cluster with >7 peaks
  - central region is lost!
- Clusters with size <3 cells require additional information



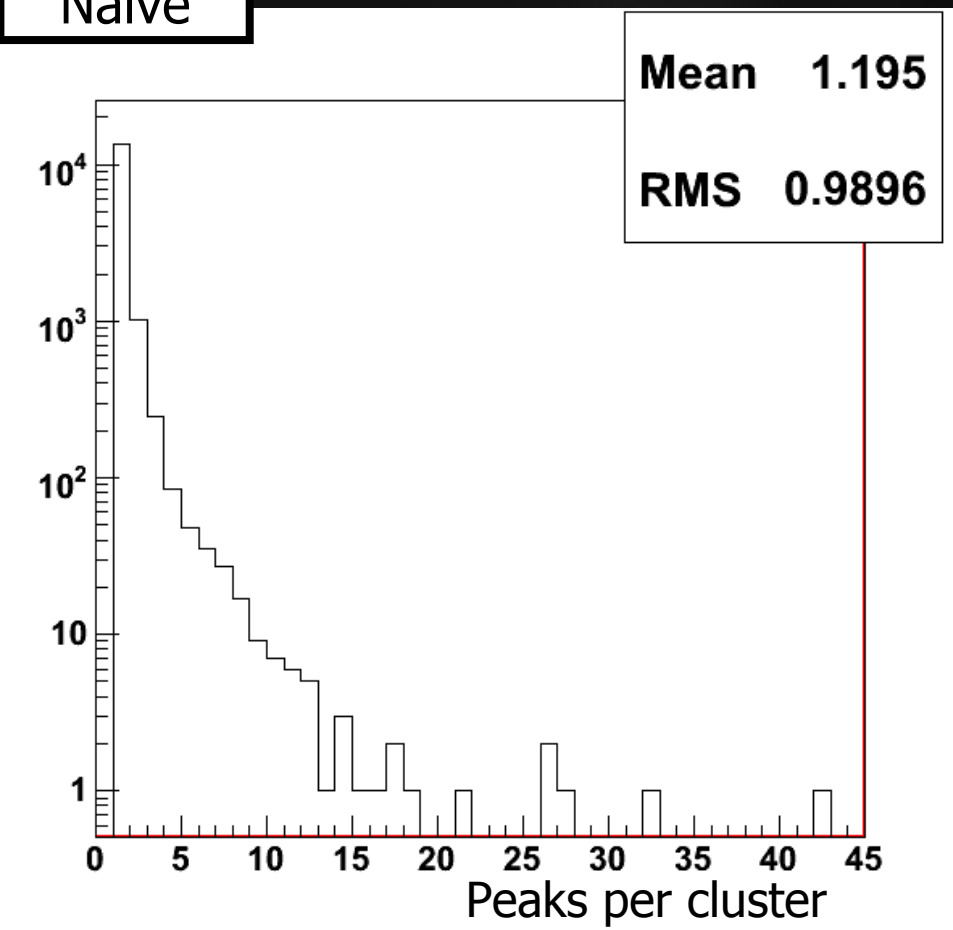
Standard approach

Cluster finding

- Find peak above threshold
  - peaks associated with charged track are removed from the consideration
- Construct a subcluster with certain number of cells around the peak
  - it should contain 2×2 submatrix with maximum energy of 3×3 matrix around peak
  - add a cell from 3×3 matrix with minimum energy deposition
    - adds information for unfolding
- Cluster is a set of preclusters with common cells

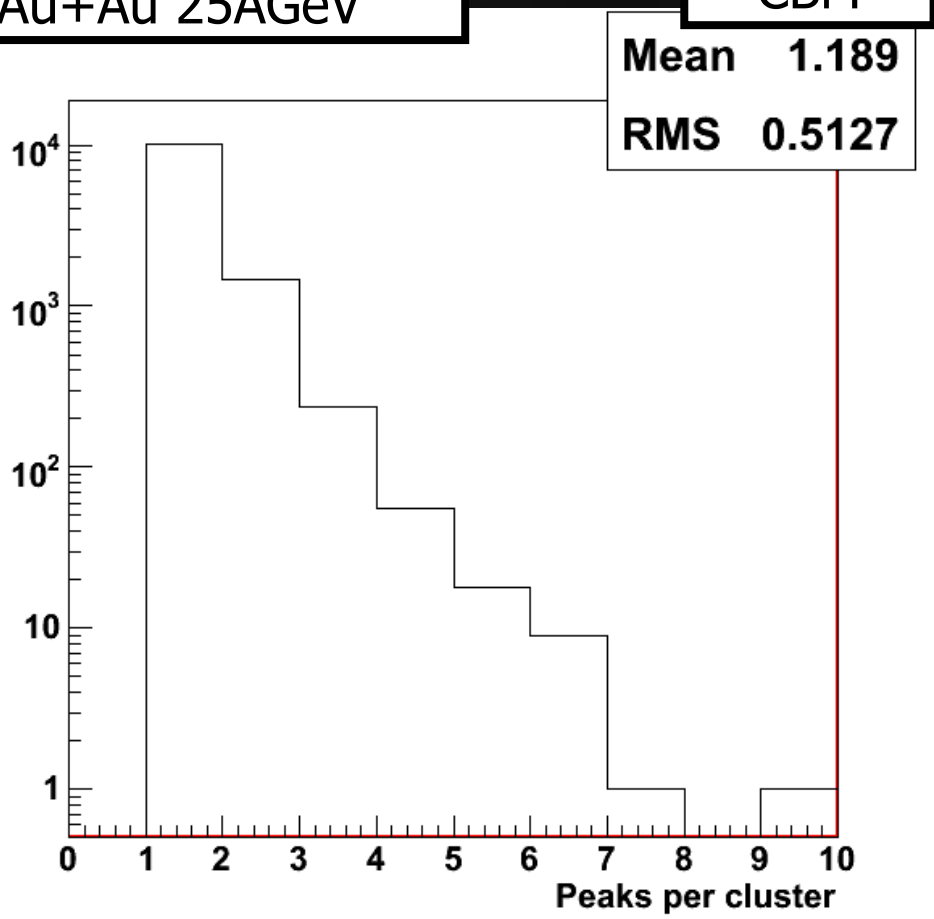
Comparison

Naive



Au+Au 25AGeV

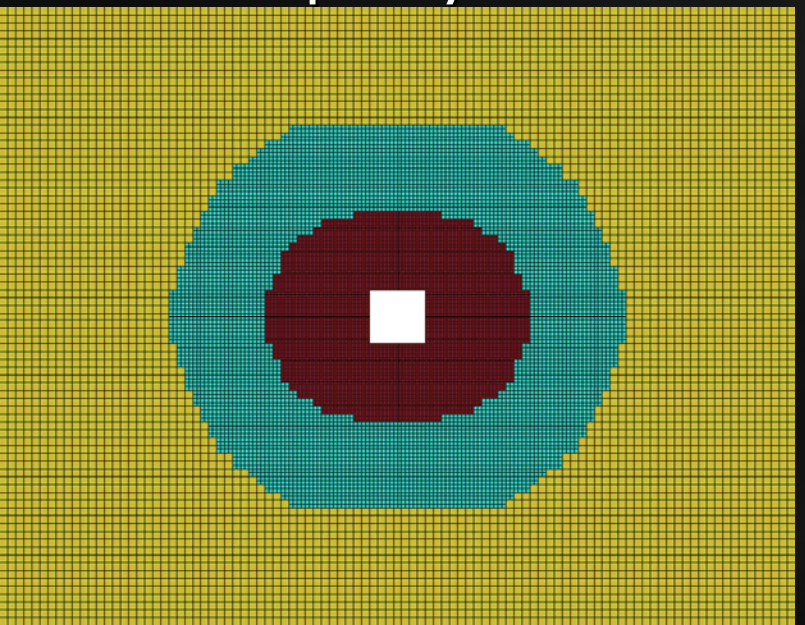
CBM



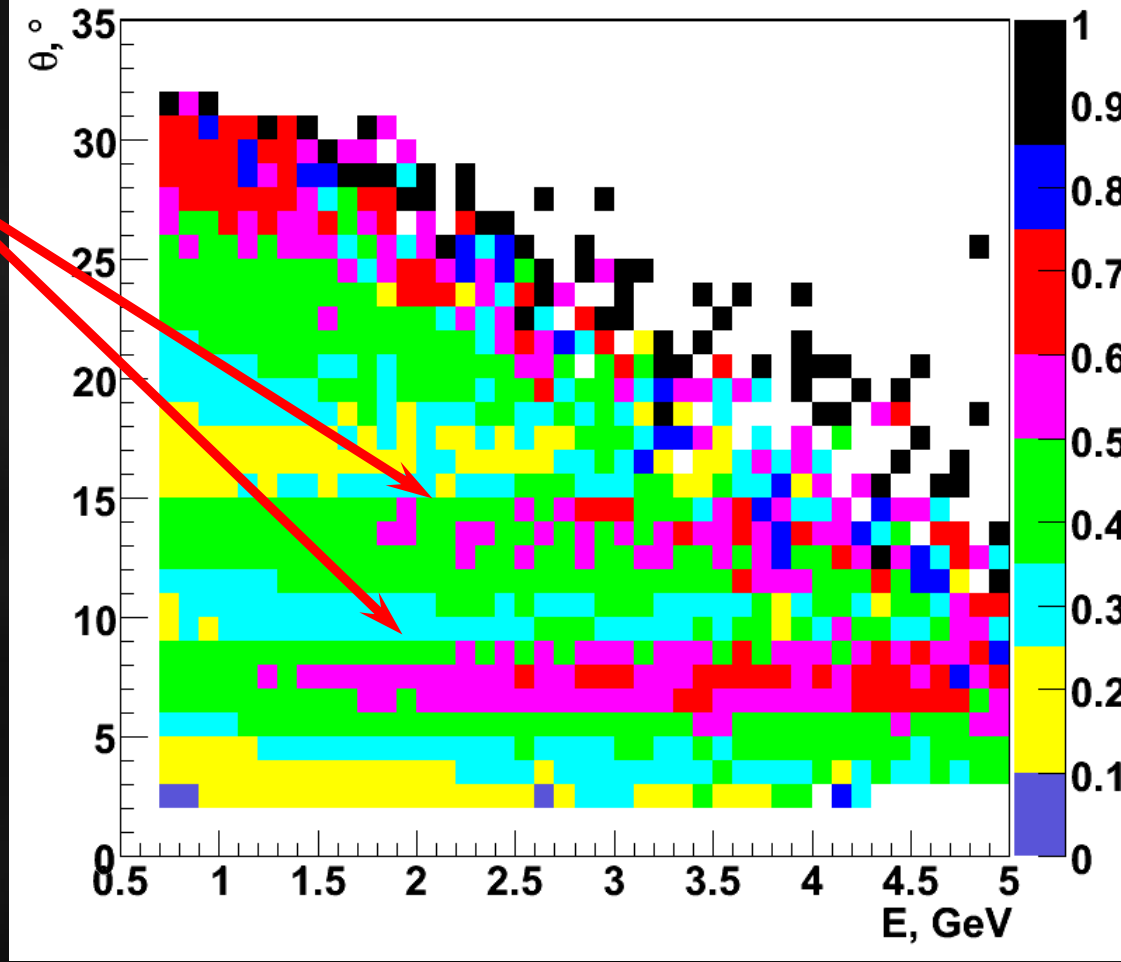
Number of peaks per cluster lower using new approach

AuAu 25 GeV UrQMD events

- 35% reconstruction efficiency
- Boundaries between calorimeter regions
  - occupancy



Reconstruction efficiency vs. θ and energy



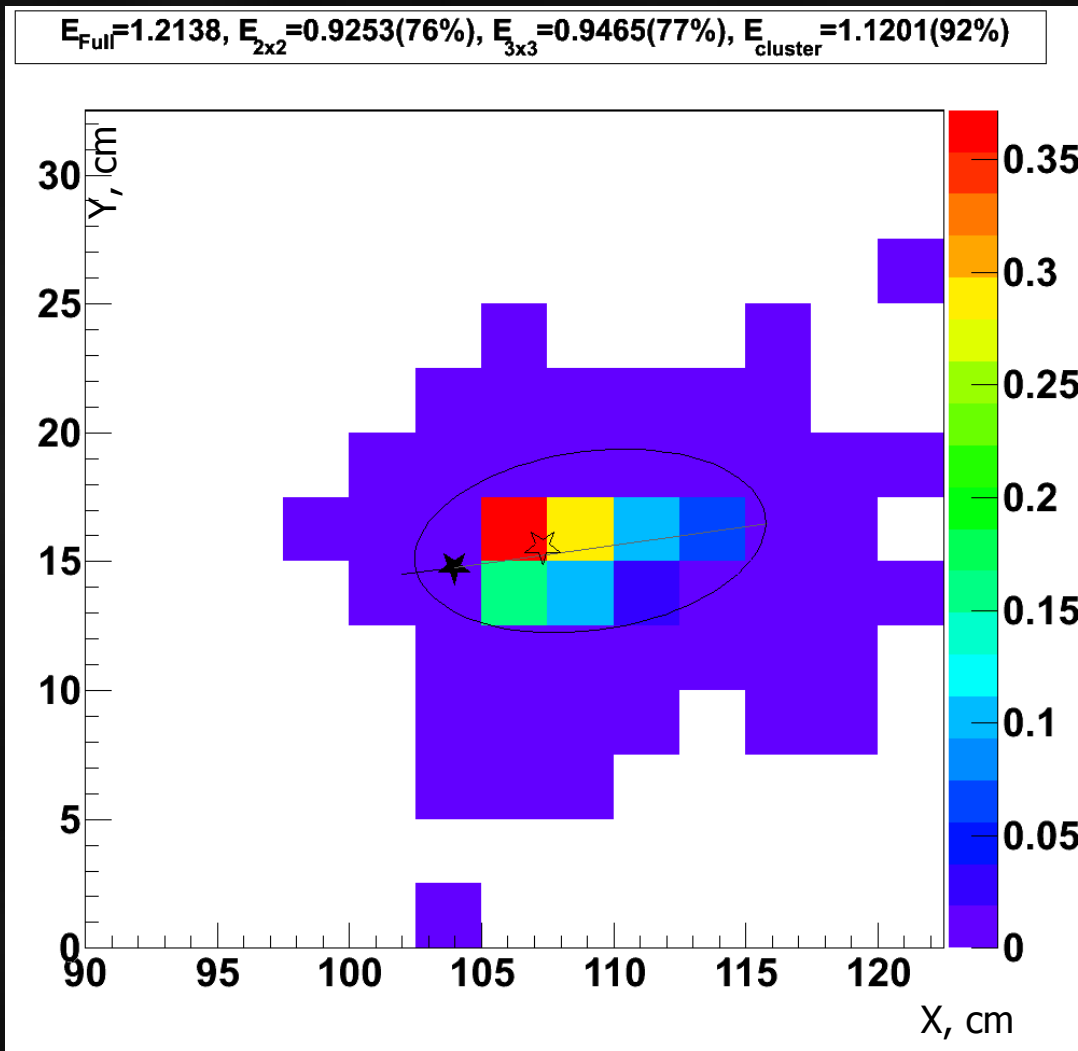
Cluster finding in muon option

- Main difference with electron option:
  - small (2.5×2.5 cm) cell size and large (up to 45°) impact angle
- Keep general procedure
  - maximum location
  - precluster formation
  - cluster is a set of preclusters with common cells
  - … but use a shower shape for precluster formation
    - shower is “more long than wide”
  - precluster size as a parameter
    - small clusters in inner regions and large in outer

Precluster formation

- Procedure
  - local maximum
  - 2x2 maximum matrix
  - center of gravity of 2x2 maximum matrix (☆)
  - ellipse
    - center of ellipse located on line from center of calorimeter to found center of gravity
  - sort all cells on area intersect with ellipse
  - precluster
    n cells with maximum intersection area

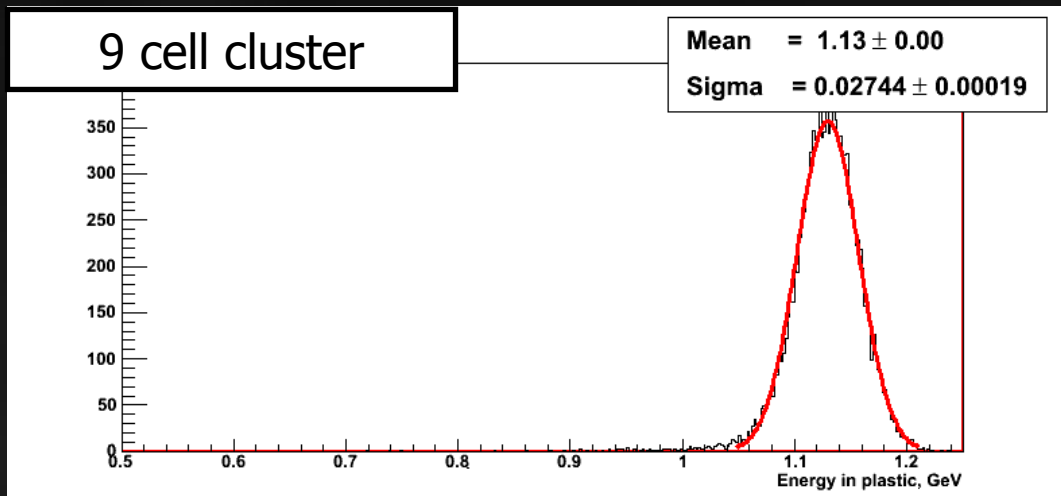
E_{photon}=16 GeV, Angle=35°

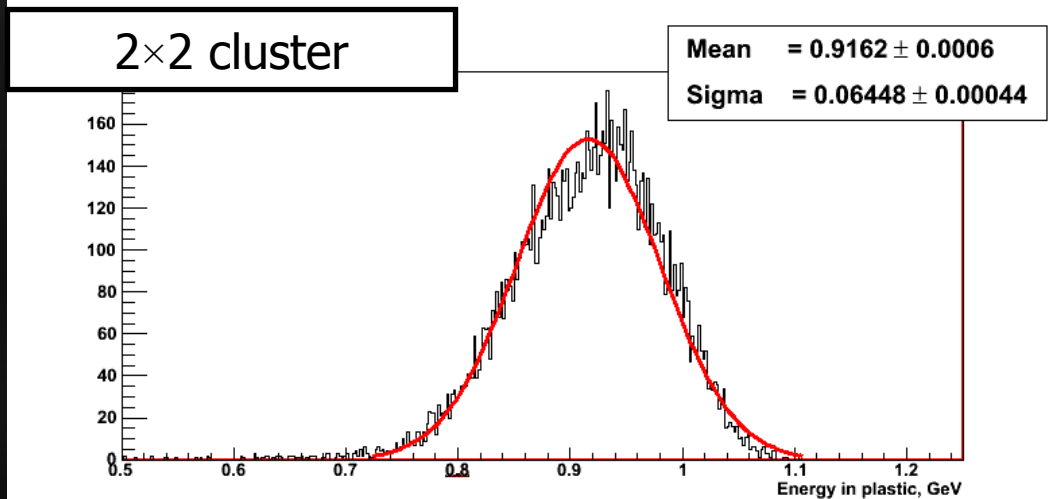


Precluster formation

- Parameters
  - cluster size
    - keep as low as possible
  - semiaxes of ellipse
  - distance from center of mass to ellipse center

E_{photon}=16 GeV, Angle=35°

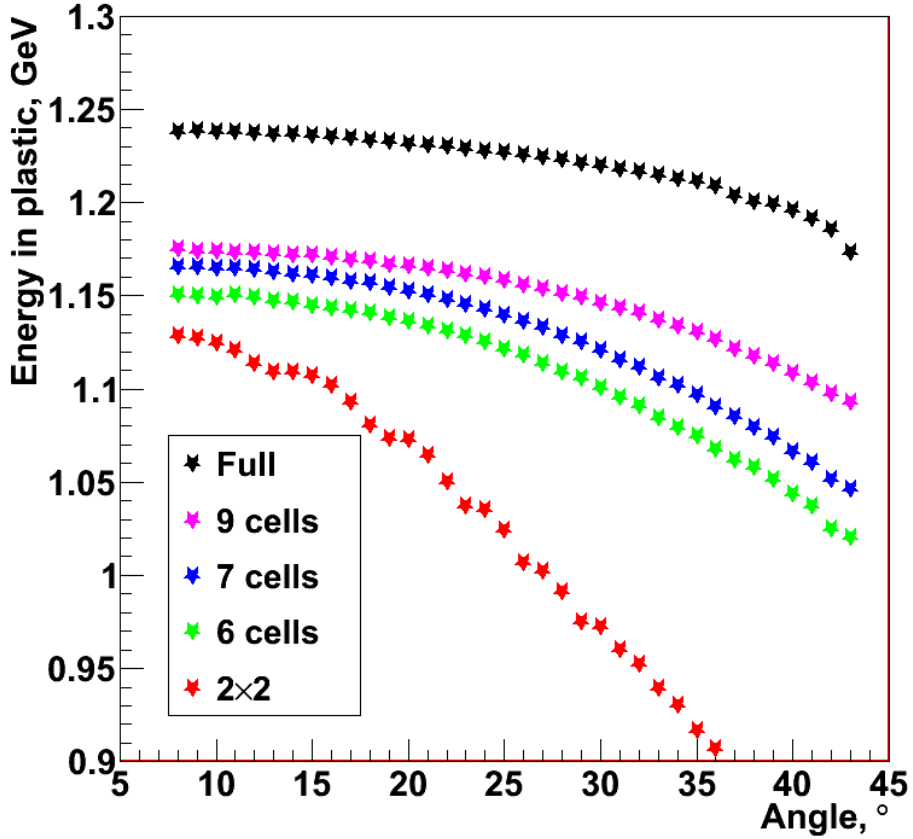




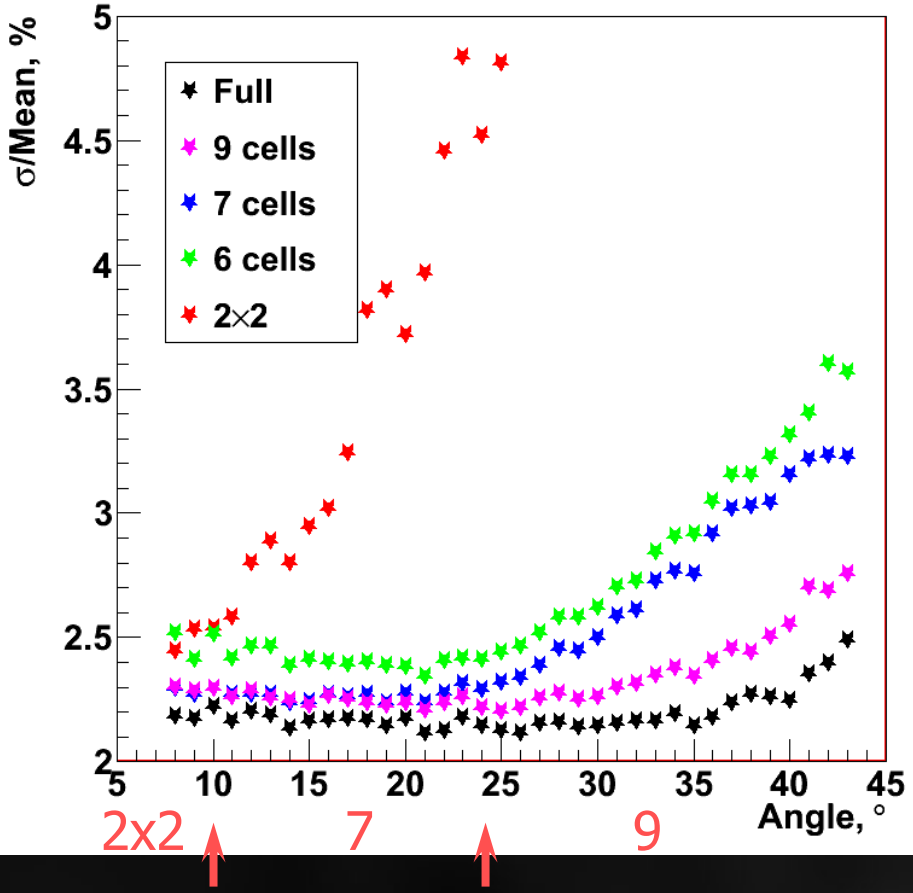
Cluster size

16 GeV photons

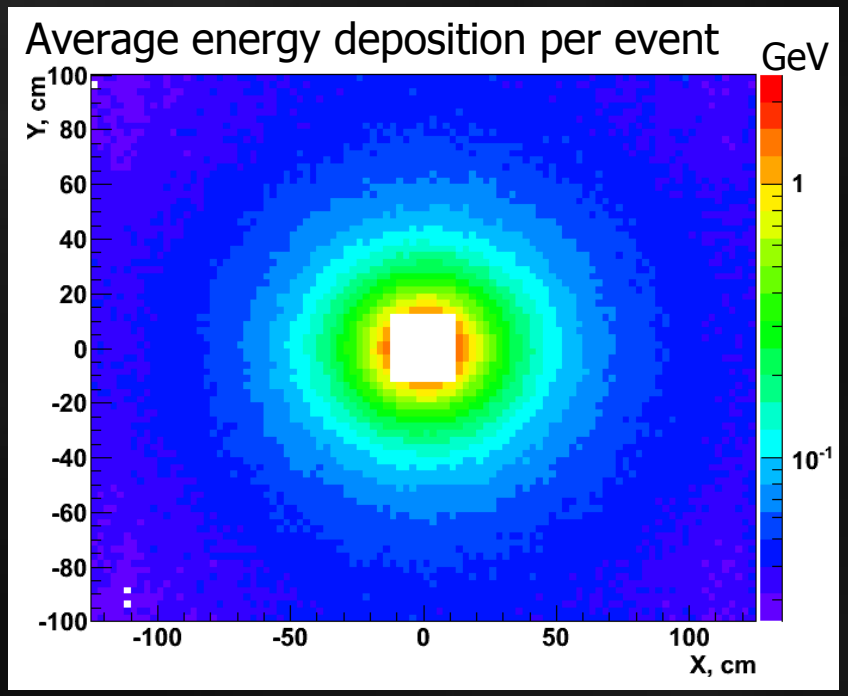
Different cluster finders

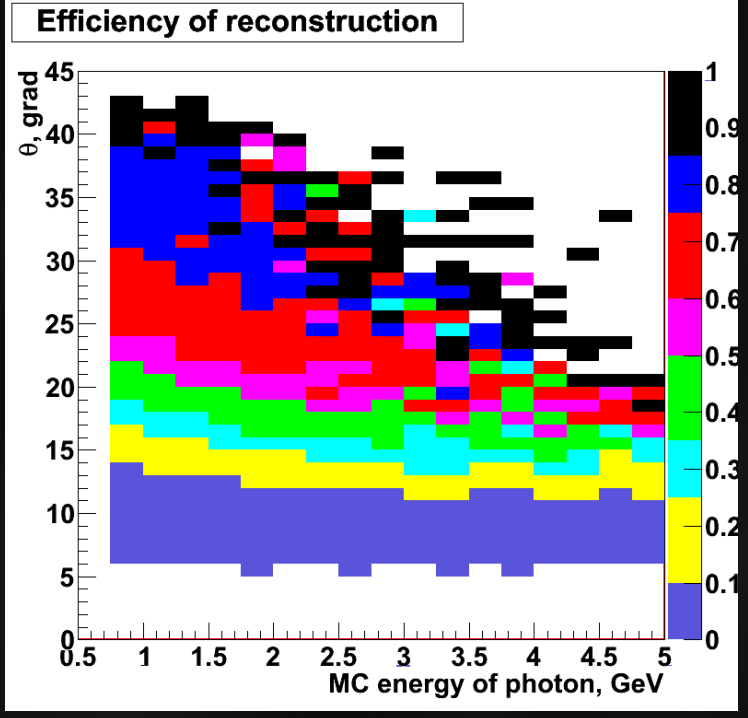


Relative σ for different cluster finders

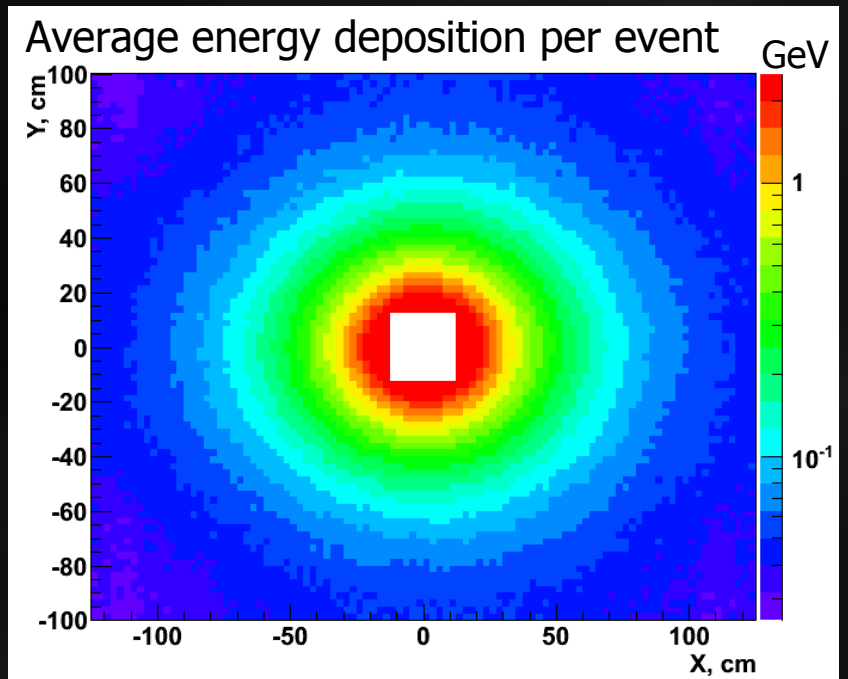


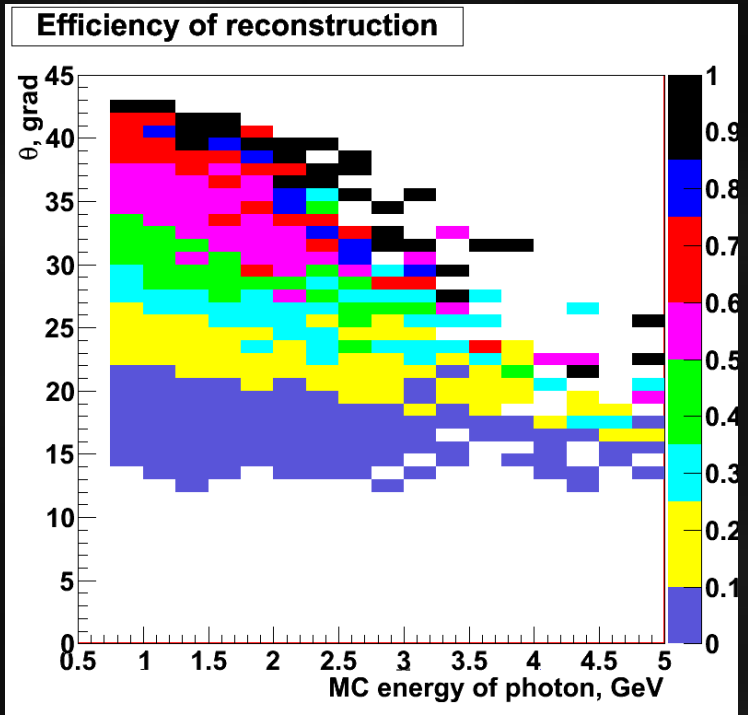
Cu+Cu 25 GeV





Au+Au 25 GeV





Conclusions

- 3 algorithms of clustering was presented
  - “common” one does not work
    - occupancy variations
  - …clusters constructed near maximums of energy deposition
  - ..use of shower shape for large impact angles and small cell size