Shower separation in AHCAL using track-wise clustering algorithm

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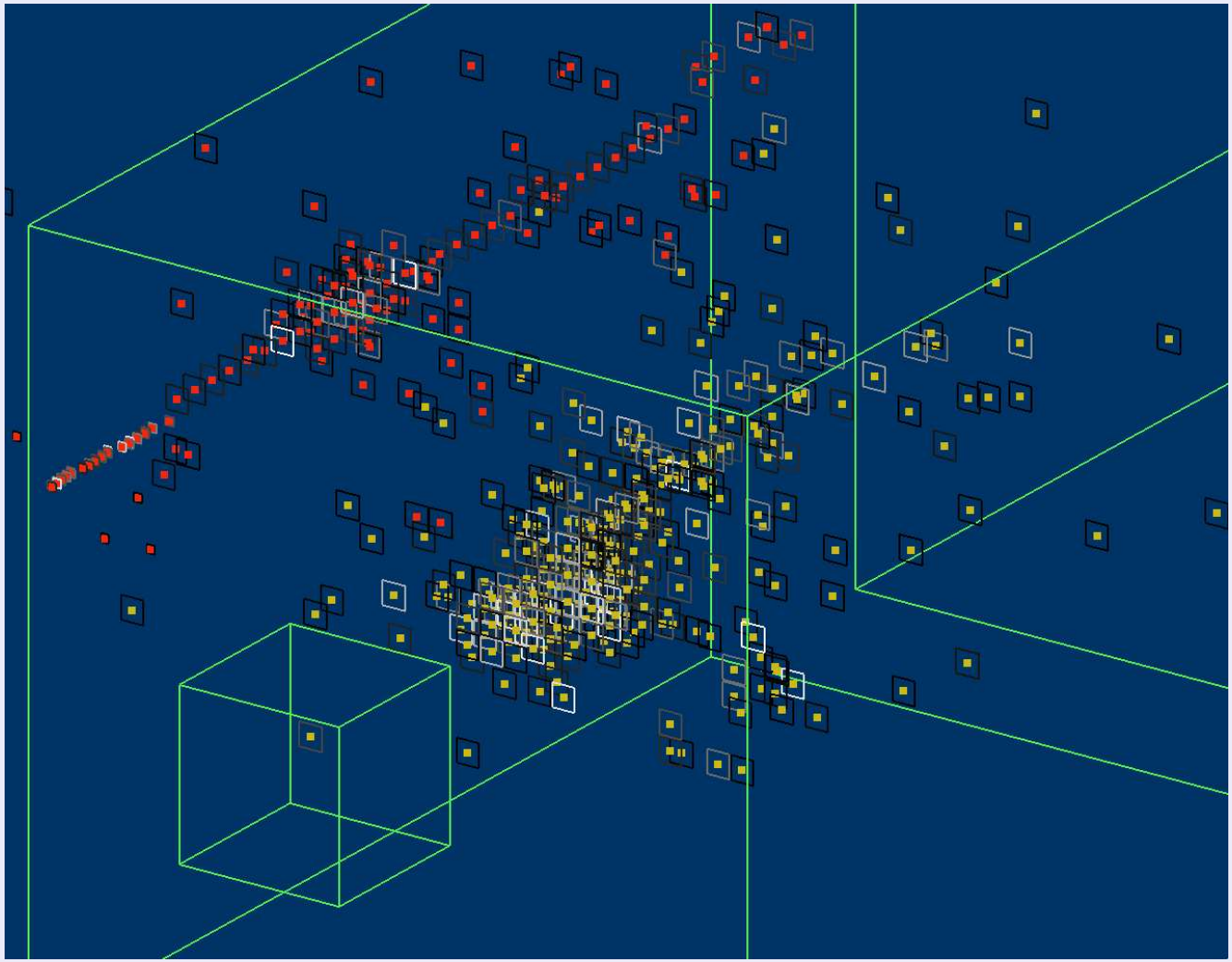
Content

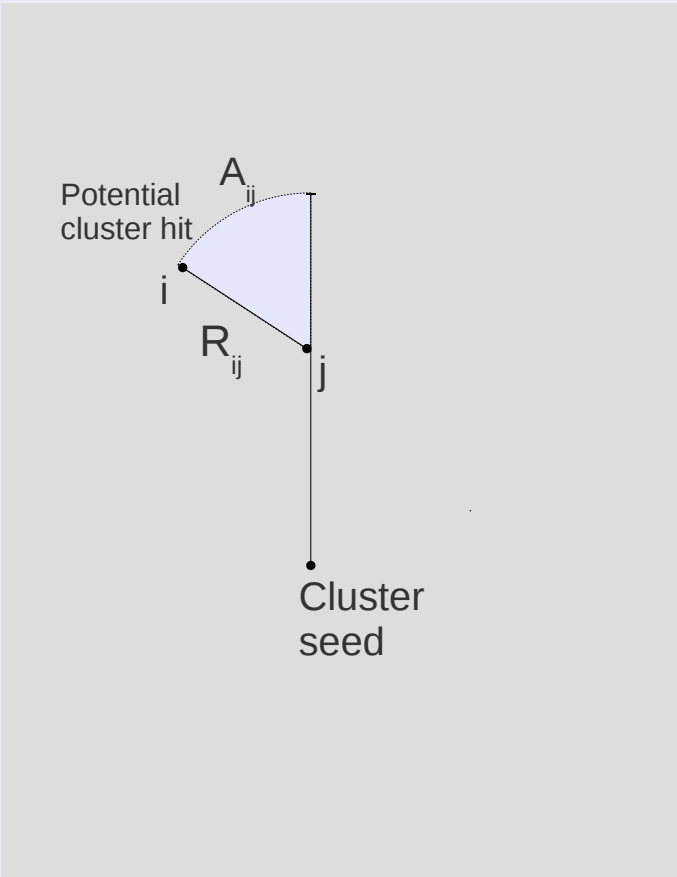
Goal: finding the “neutral hadron” cluster in vicinity of charged cluster

- extension of TWC study of J. Samson (CAN-11)
  - extension of particles distance
  - comparision of neutral-charged particle instead of charged-charged
  - MC study
- validation studies (ahcal geometry)
- comparing results with PandoraPFA study of Oleg Markin (CAN-24)



Trackwise clustering

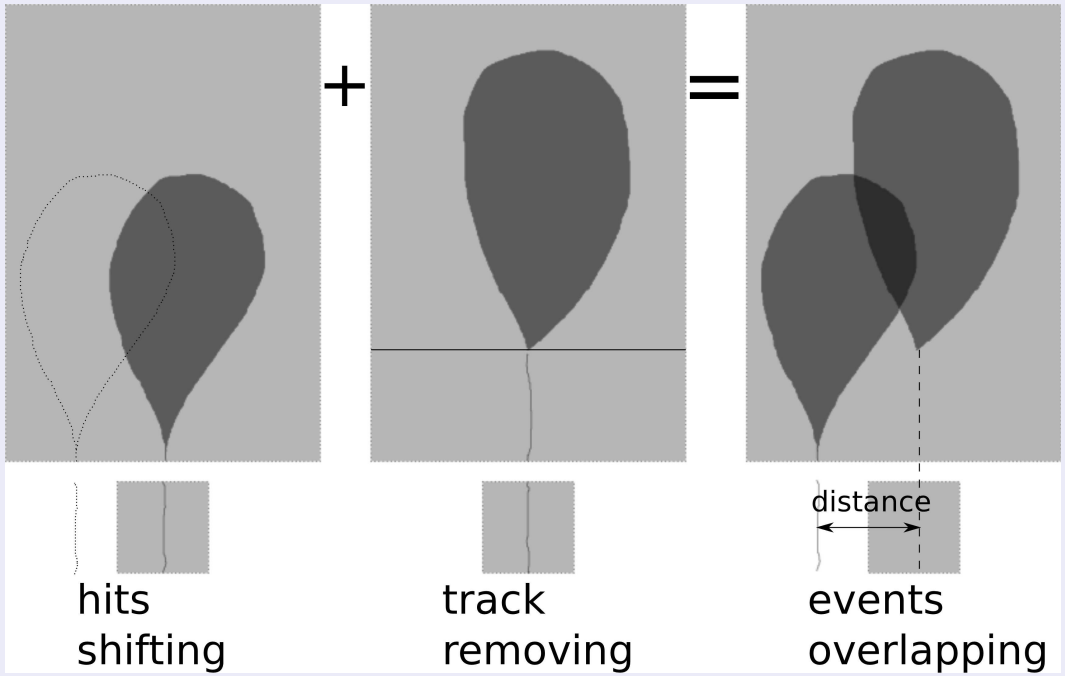
- algorithm for clusters separation
- suited for a Tesla detector concept
- iterative algorithm: having cluster seed and hit(j)
- using them to estimate if potential hit(i) is a cluster hit
- Only the value for cluster hit estimation: $s_{ij} = w \cdot R_{ij} + (1 - w) \cdot A_{ij}$ and also separately R_{ij} and A_{ij}
  - possible as a steering parameter: cut on s_{ij},R_{ij},A_{ij},w
  - study of J. Samson for ahcal (2 charged π^- events): $R_{ij} : 20 \rightarrow 25$ and $A_{ij} : 80 \rightarrow 92$
- no track-cluster matching



- used also an extension of *Trackwise algorithm* - *Wolf algorithm*: implemented possibility of merging clusters using charged particle energy and resolution

Main steps for data preparation

1. selection of proper runs (centered)
2. shifting hits of particles
3. creation of neutral particle
4. creation of double particle events (overlapping events)



Main steps for data preparation

1. selection of proper runs

- CERN-2007 π^- runs with beam position in centre of ahcal$\rightarrow$ minimalizing of 6x6 and 12x12 cm tiles influence

π^- runs

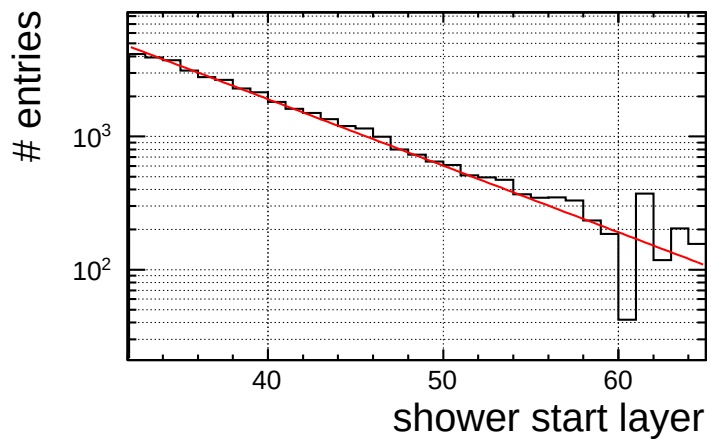
Run	Energy [GeV]	# events [x10^3]
330641	8	227
330643	10	227
330645	12	227
330647	15	250
330648	18	230
330649	20	230
330650	25	229

Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle

neutral particle simulation, finding the position of particle

1. finding the shower start layer
   - creating neutral particle: exclusion of track in ecal and ahcal
   - using only events with shower start layer in first 10 layers
2. finding the track in ecal
   - determination of particle position (next slides)

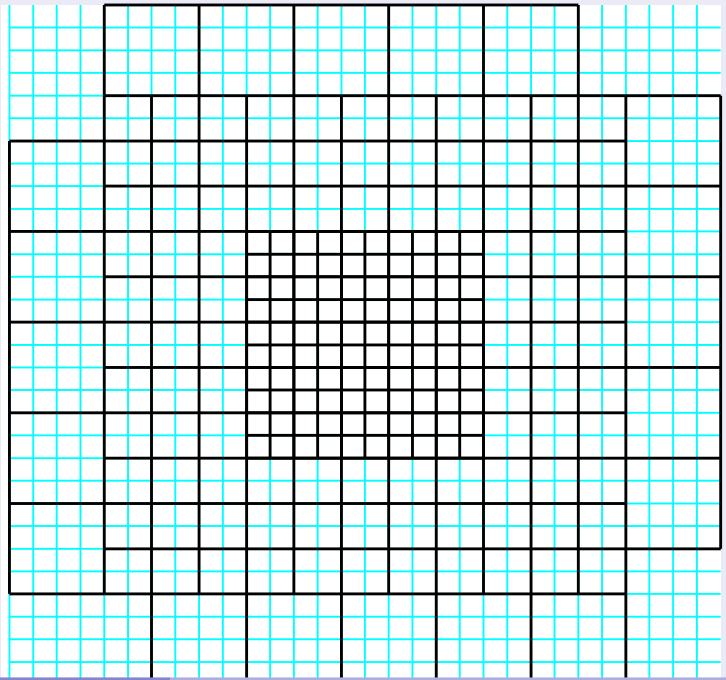


Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle
3. shifting hits of particles onto virtual infinite 3x3 cm grid

Shifting events onto 3x3 cm virtual infinite grid

- shifting by multiply of 3 cm in x and y direction
  - shift: $(0,0) \rightarrow 3 \cdot (n,m);\ n,m \in \mathcal{N}$
- problem of shifting 6x6 (12x12) cm tiles into virtual 3x3 cm tiles
  - $\rightarrow$ random selection of tile vs using all of the tiles (next slides)

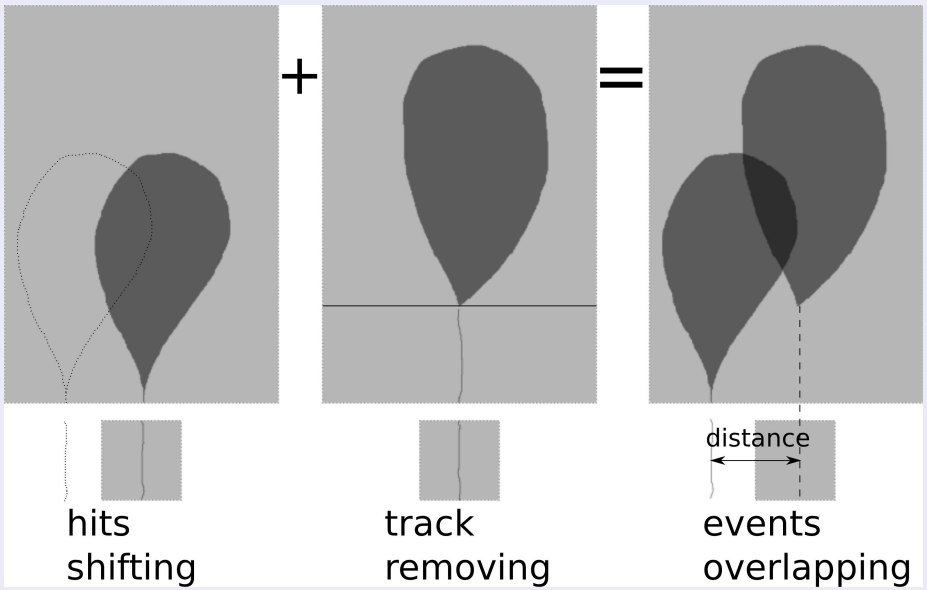


Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle
3. shifting hits of particles onto virtual infinite 3x3 cm grid
4. creating double particle events (overlapping events)

overlapping events

- overlapping with first application of 0.5 MIP cut
- overlapping only consequent events from two runs (e.g. no permutation) due to preservation of energy distribution profiles

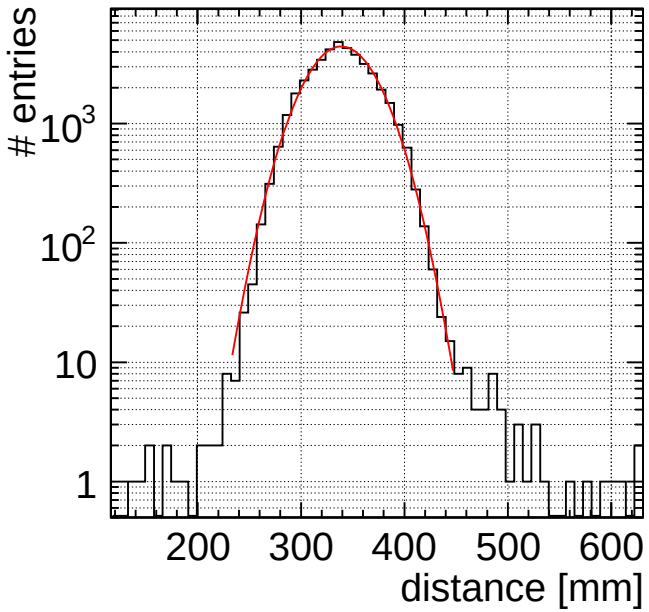


Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle
3. shifting hits of particles onto virtual infinite 3x3 cm grid
4. creating double particle events (overlapping events)
5. definition of distance

Definition of particles distance

1. *Position* of showering particle: defined as the mean of (x,y) track hits positions in ecal
2. **Distance** of charged and neutral particle: distance of their positions
   - using mean of gaus fit (right)

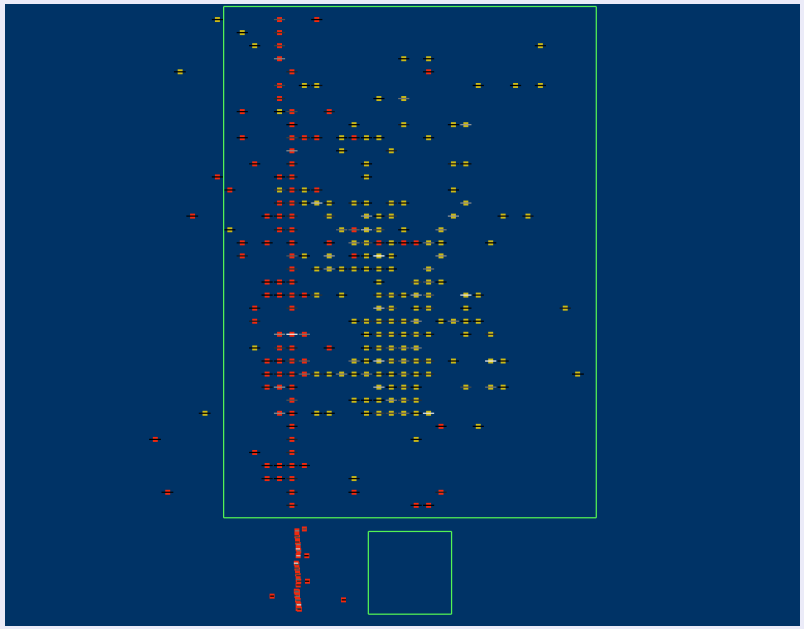


Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle
3. shifting hits of particles onto virtual infinite 3x3 cm grid
4. creating double particle events (overlapping events)
5. definition of distance
6. application of track-wise clustering

matching tracks with clusters

- cluster with the most of track hits is the charged one (right: two found clusters)

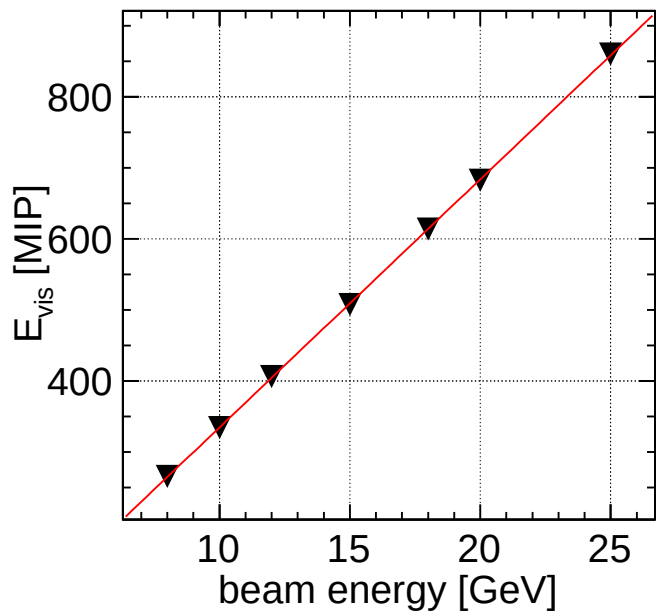


Main steps for data preparation

1. selection of proper runs
2. creation of neutral particle, finding the position of particle
3. shifting hits of particles onto virtual infinite 3x3 cm grid
4. creating double particle events (overlapping events)
5. definition of distance
6. application of track-wise clustering
7. application of Wolf algorithm, energy conversion

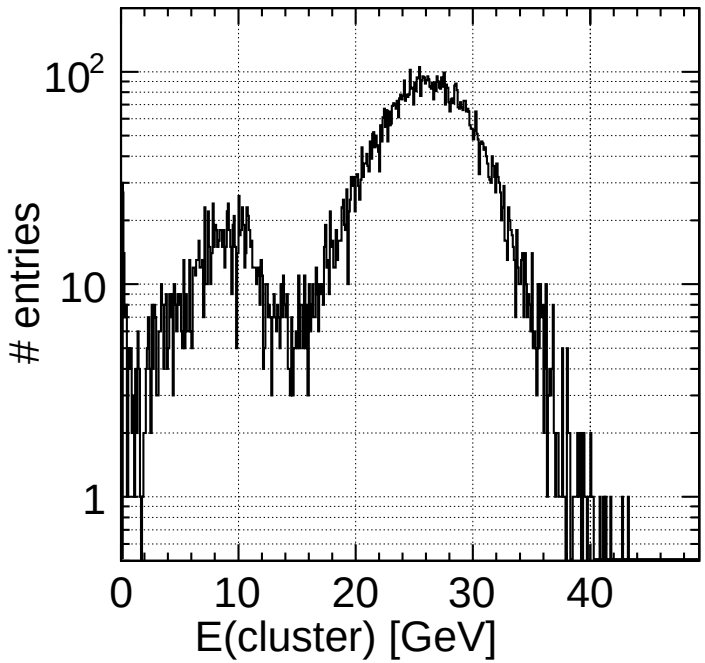
conversion MIP $\rightarrow$ GeV

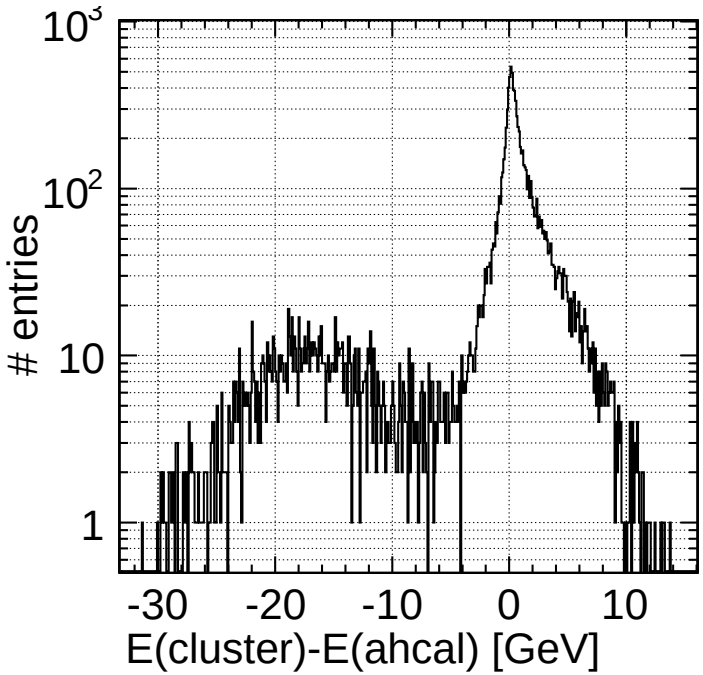
- Wolf algorithm compare an energy of charged particle with reconstructed clusters for merging clusters
- deposited energy of “neutral particles” from gaus fit of deposited energy per run
- energy conversion factor using linear fit $(a + b * x)$
- $b = 34.94 \pm 0.07$ MIP/GeV
- $a = 1 \pm 1$ MIP



Reconstructed neutral particle energy, definition of “confusion”

- example: charged particle (10 GeV), neutral particle (25 GeV), mean distance 34 cm
- **only events with just 2 found clusters**



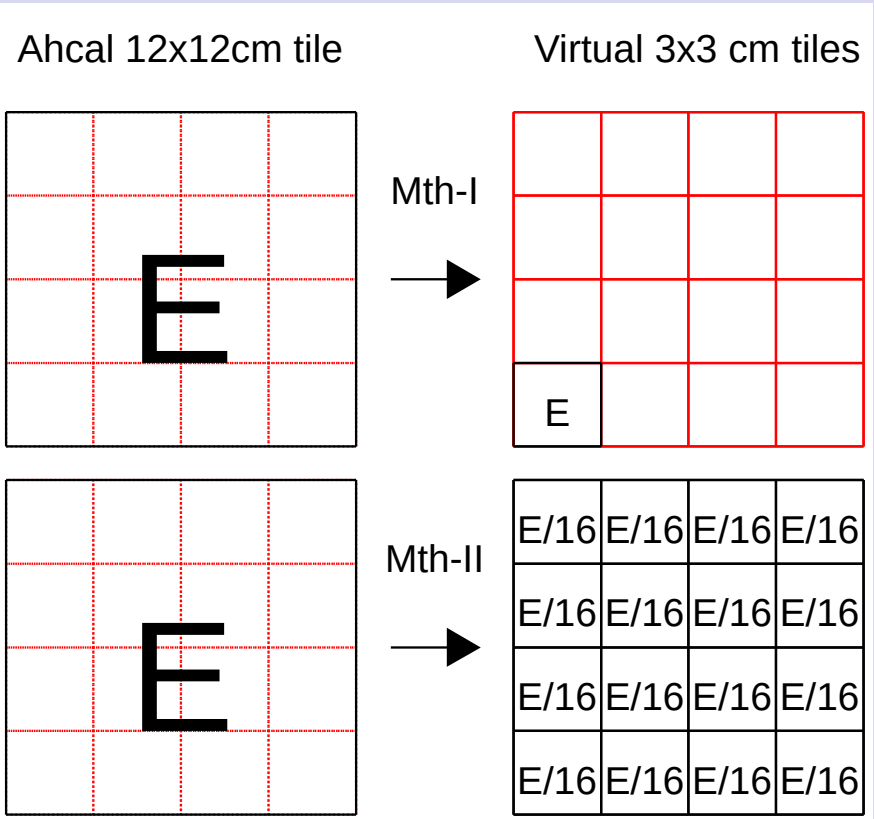


- neutral cluster distribution
- second peak on energy of charged particle

- **Definition of confusion**: energy of rec. neutral cluster - energy measured in ahcal (from the shower start layer)

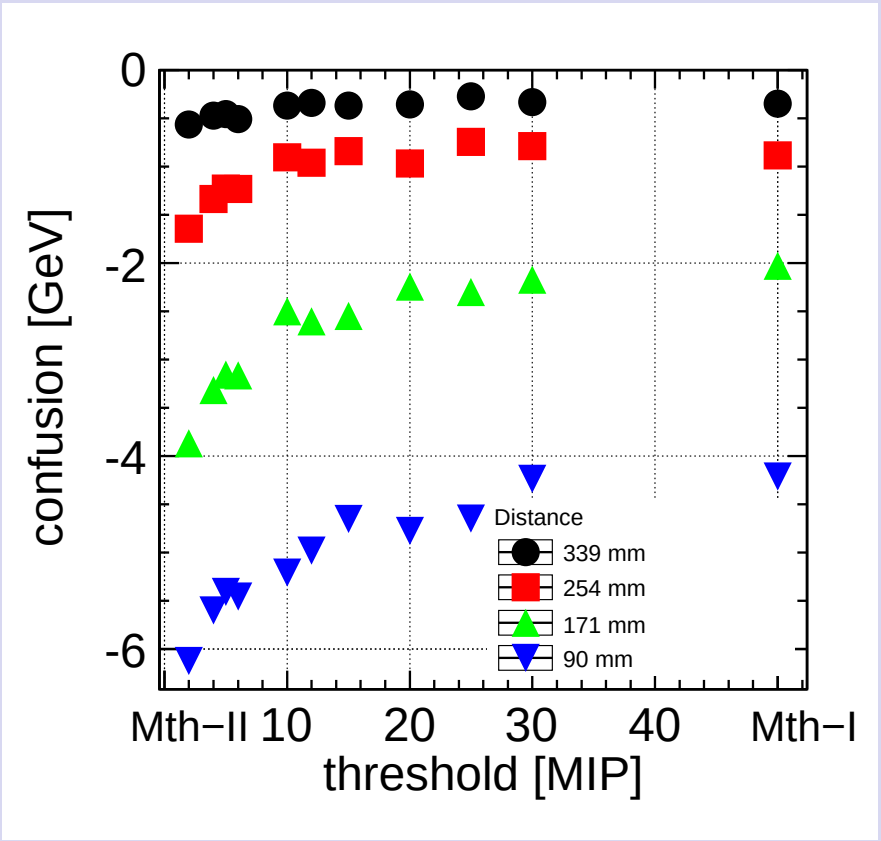
Shifting events study (How to shift the 6x6 and 12x12 tiles onto 3x3 cm grid

Shifting methods (Mth-I(II))



- Mth-I: using random tile
- Mth-II: all tiles, equally distr. energy

Shifting methods (Mth-III)



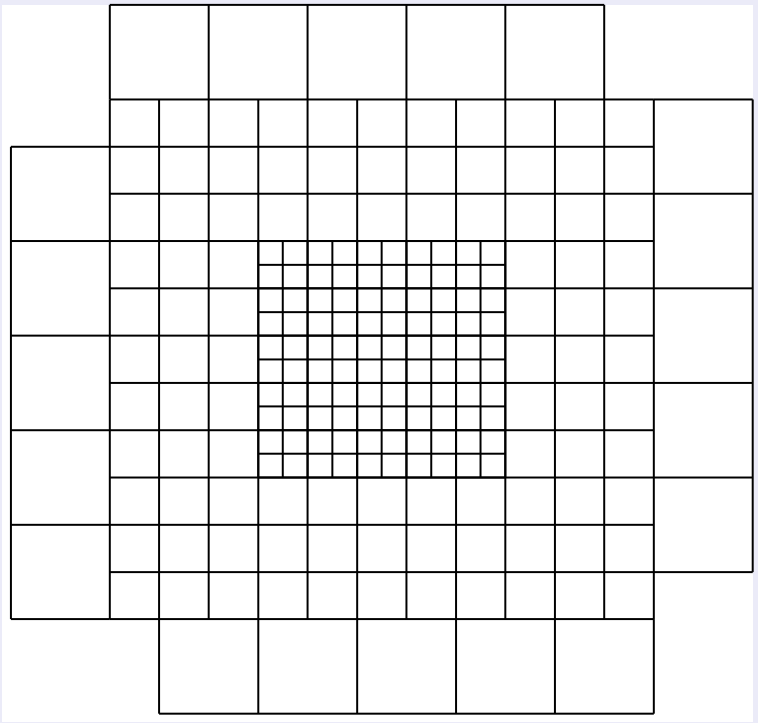
- Mth-III: if energy of cell $<$ threshold, use Mth-I, else use Mth-II

- smallest confusion using Mth-I (used in next studies)

Influence of 6x6 cm and 12x12cm ahcal tiles (Ganging study)

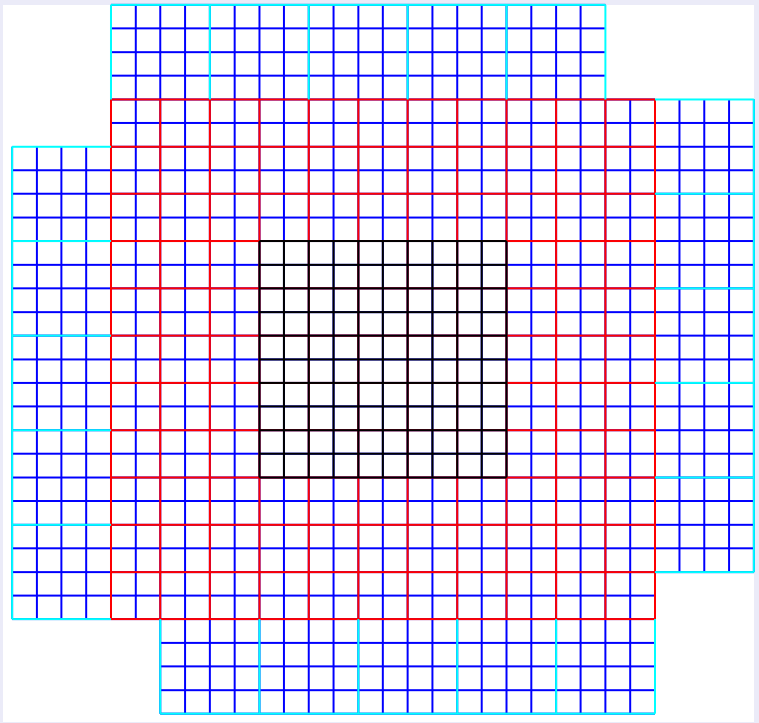
Problem

What would be the difference using only 3x3 cm tiles instead of 6x6 and 12x12 cm tiles



Ahcal fine module

- hadronic showers cover also 6x6 and 12x12 cm ahcal tiles (ILD only 3x3 cm)
  - How they influence results of TWC?

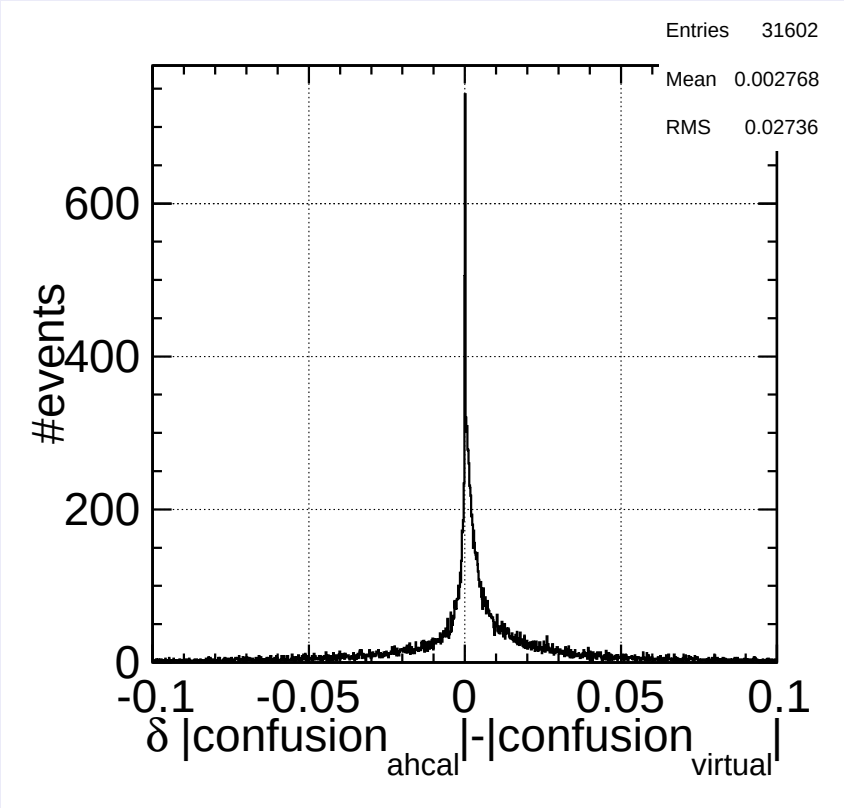


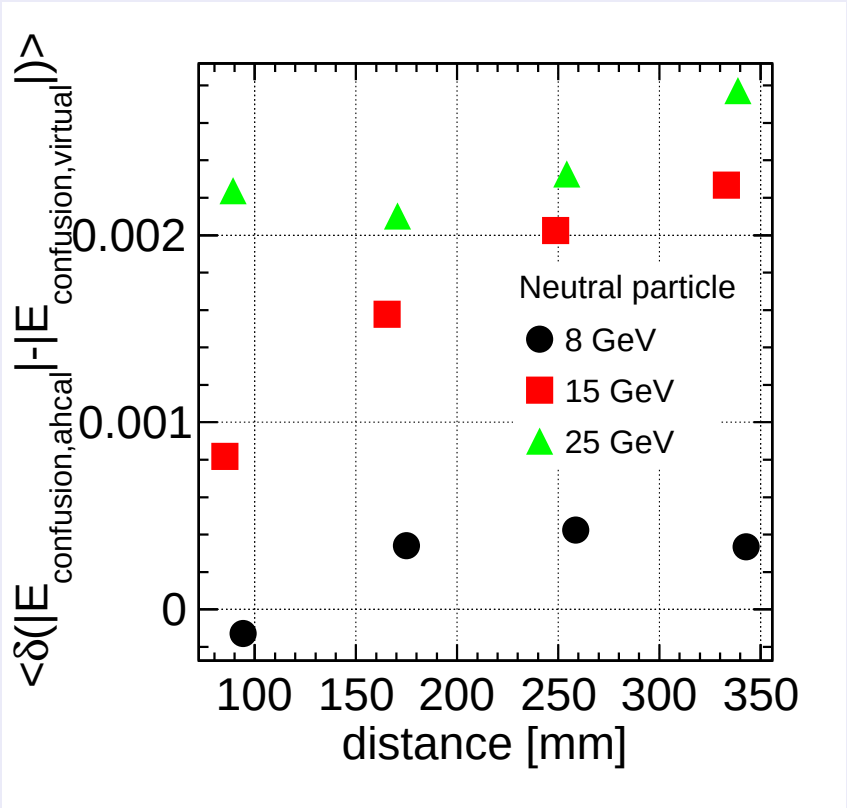
Virtual module

- Pure Mokka events 1x1 cm tiles $\rightarrow$ 3x3 cm tiles
- using the frame of ahcal
- no digitization both ahcal and ecal

ganging study event by event

- every event in the same condition (shower start, track position) before shifting, overlapping and TWC.



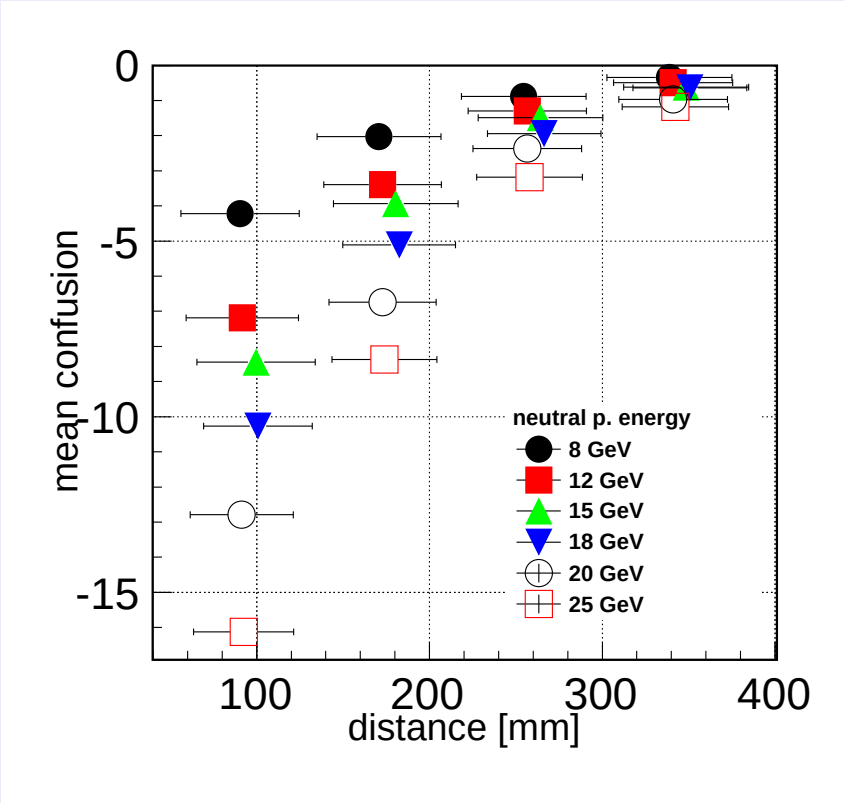


Relative difference between $|<\text{confusion}>|$ of ahcal and 3x3 ganging for 10 GeV charged and 25 GeV neutral particle

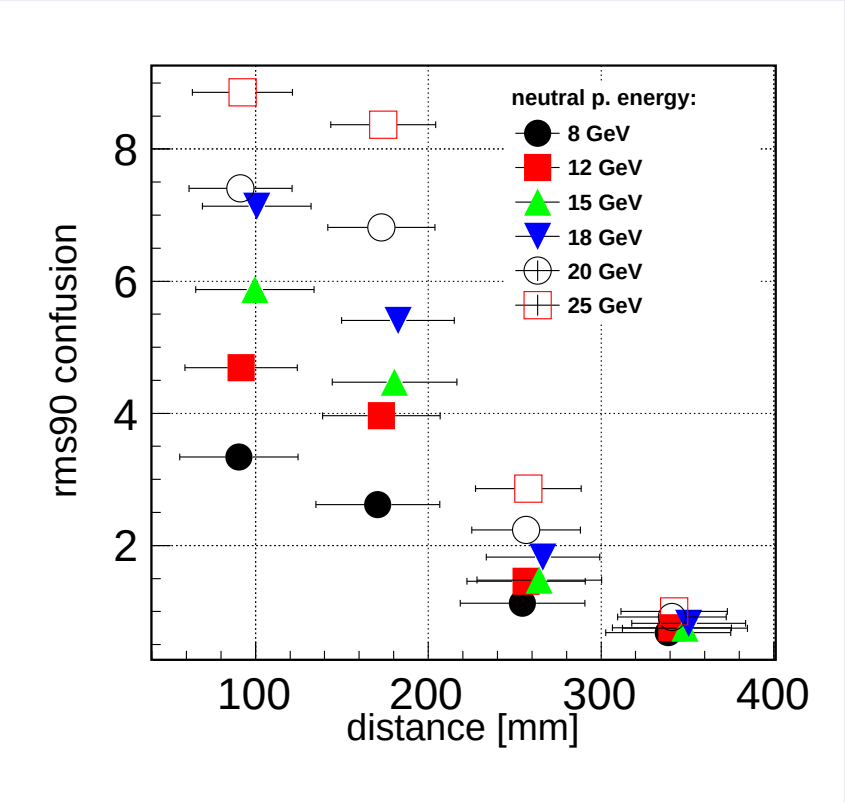
Relative difference between $|<\text{confusion}>|$ of ahcal and 3x3 ganging as a function of distance

- relative difference of confusion module in order of ‰
- bigger modul of confusion for ahcal as expected

Results of Trackwise Clustering, confusion term



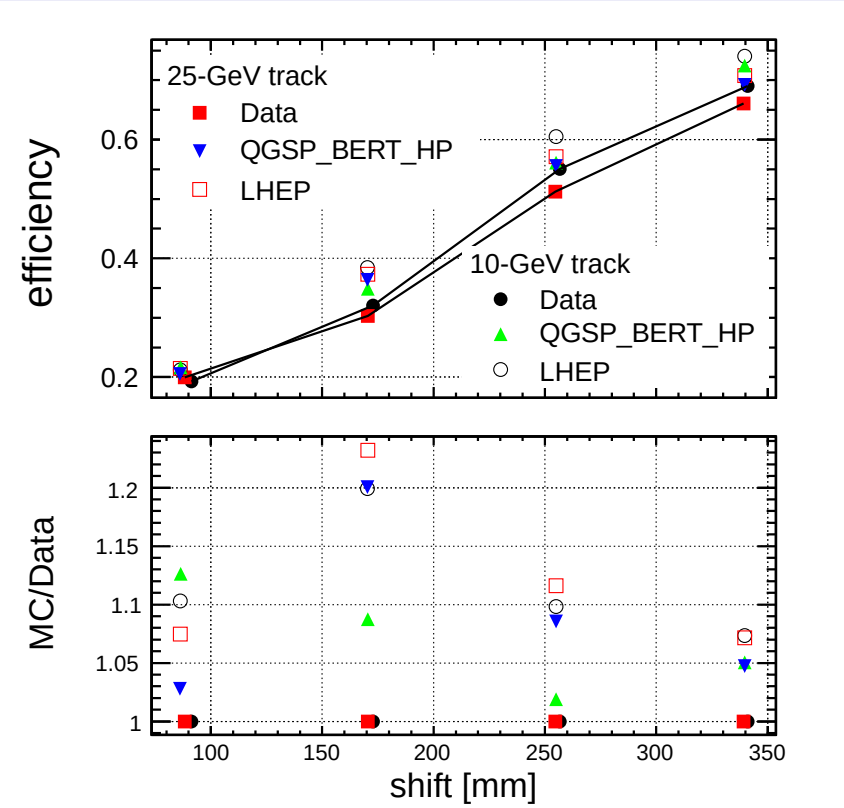
Mean of confusion



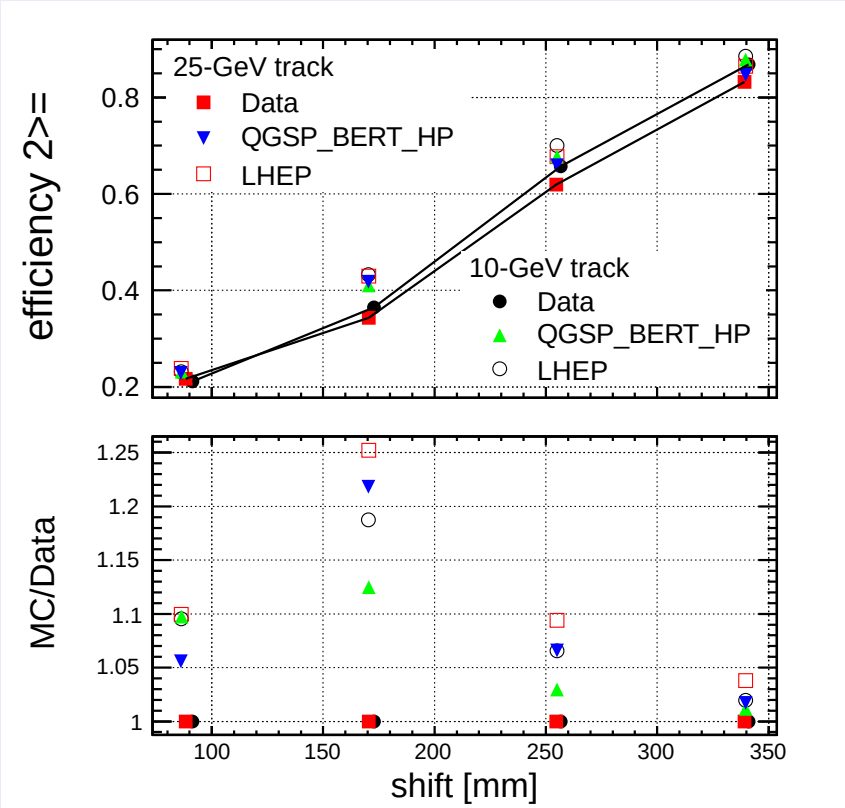
RMS90 of confusion

- charged particle 10 GeV, using only first 10 ahcal layers for shower start
- strong dependence of confusion term on energy of neutral particle
- 3 times bigger modul of confusion for 25 GeV neutral particle (not expected knowing lateral shapes)

Results of Trackwise Clustering, efficiency; 20-GeV neutral cluster



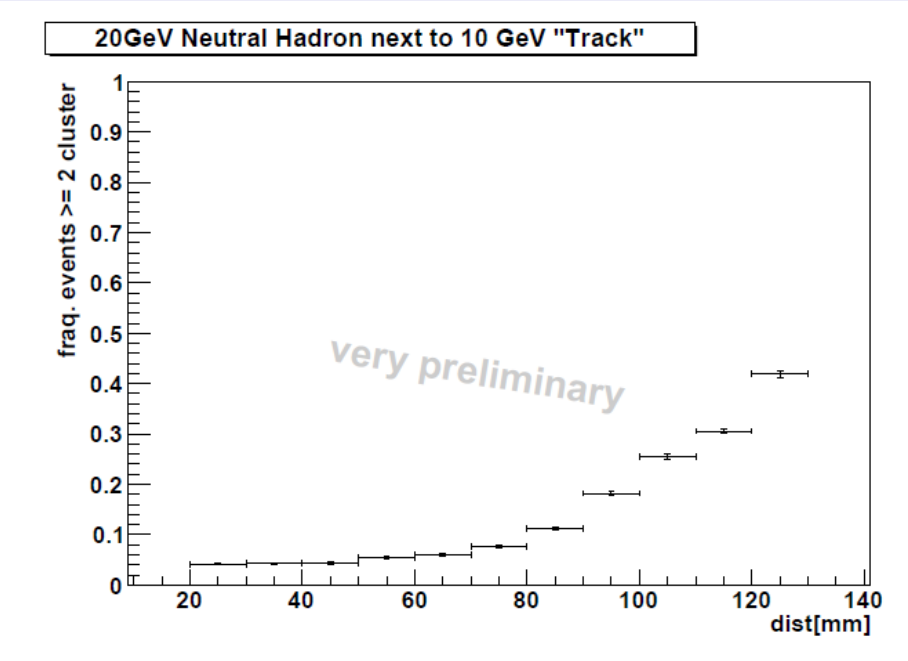
Efficiency of finding 2 clusters



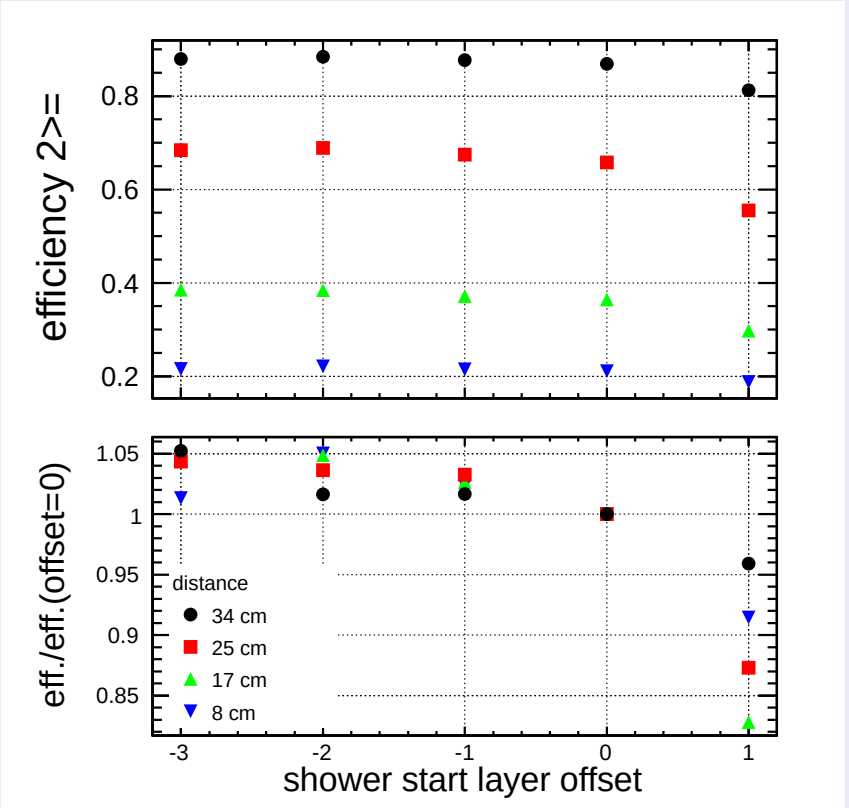
Efficiency of finding 2 and more clusters

- small efficiency: reason for using charged-charged clusters in J. Samson TWC study

Results of Trackwise Clustering, efficiency dependence on shower start layer



Preliminary results of efficiency of finding 2 and more clusters from J. Samson talk; with removing track

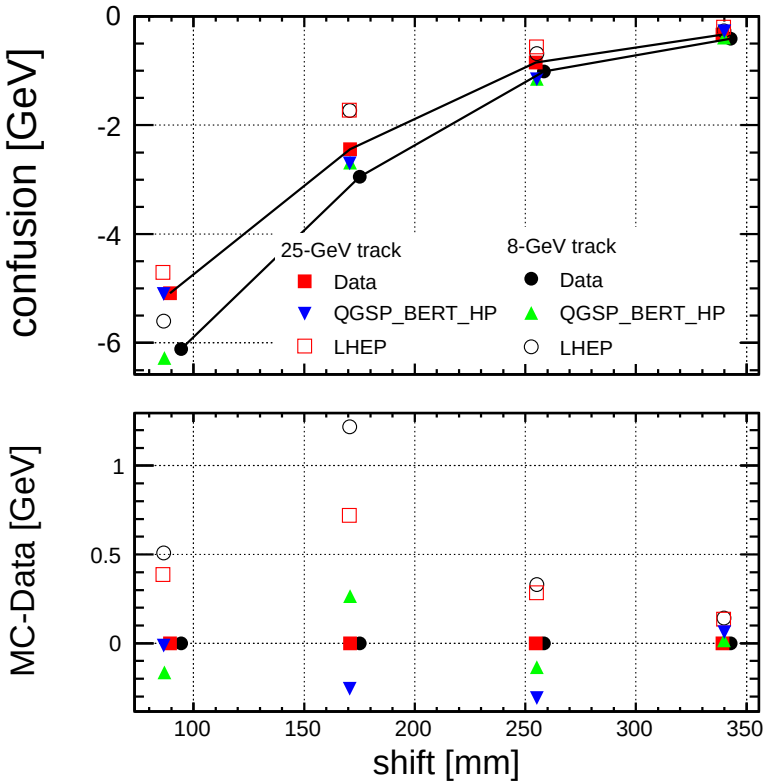


Efficiency for different shower starts

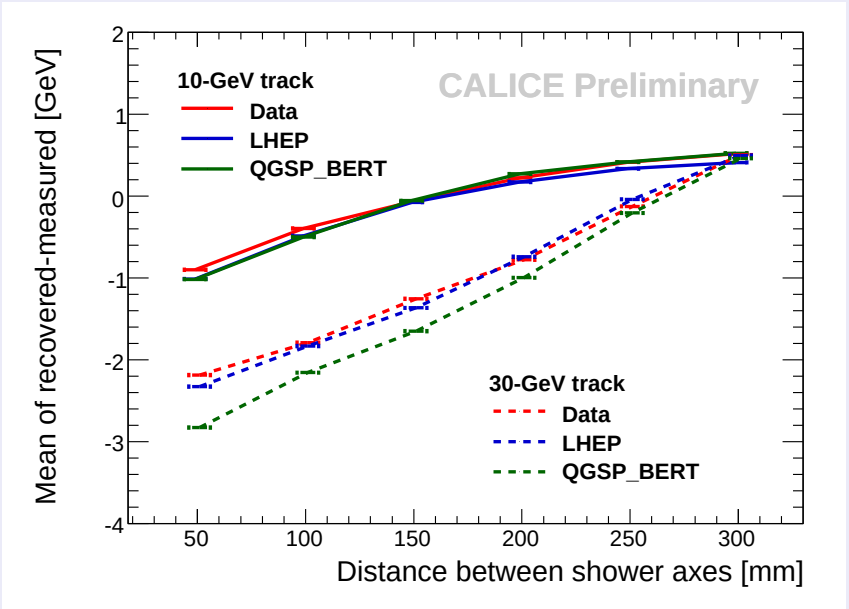
- having charged cluster instead of neutral improved efficiency $\rightarrow$ what is an influence of shower start layer definition on efficiency?

Comparision with results of Oleg Markin's PandoraPFA study, mean confusion

- The same initial conditions:
  - using 0.5 MIP cut before overlapping
  - while shifting using random cell assignment



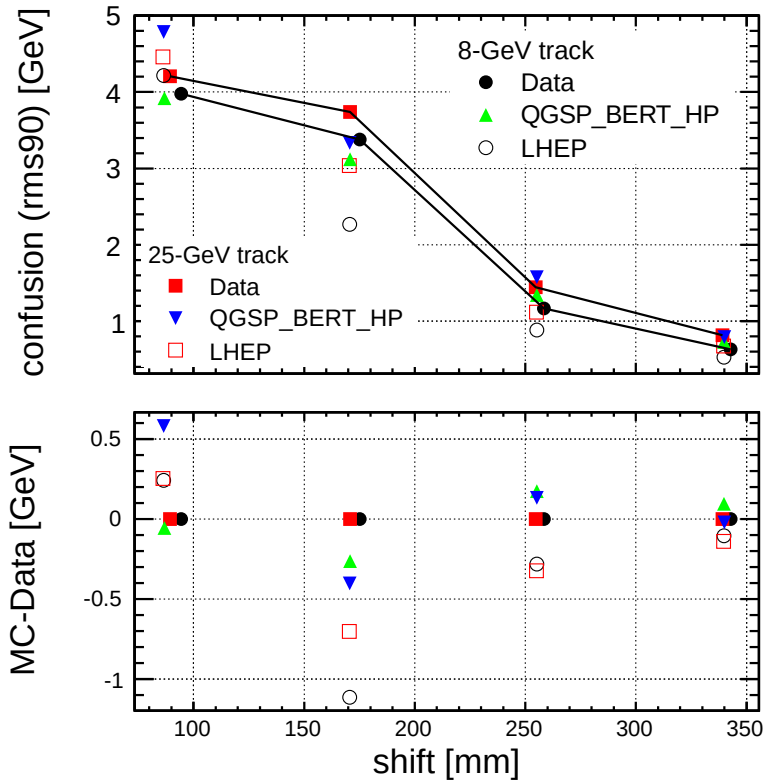
mean confusion, 10 GeV neutral particle



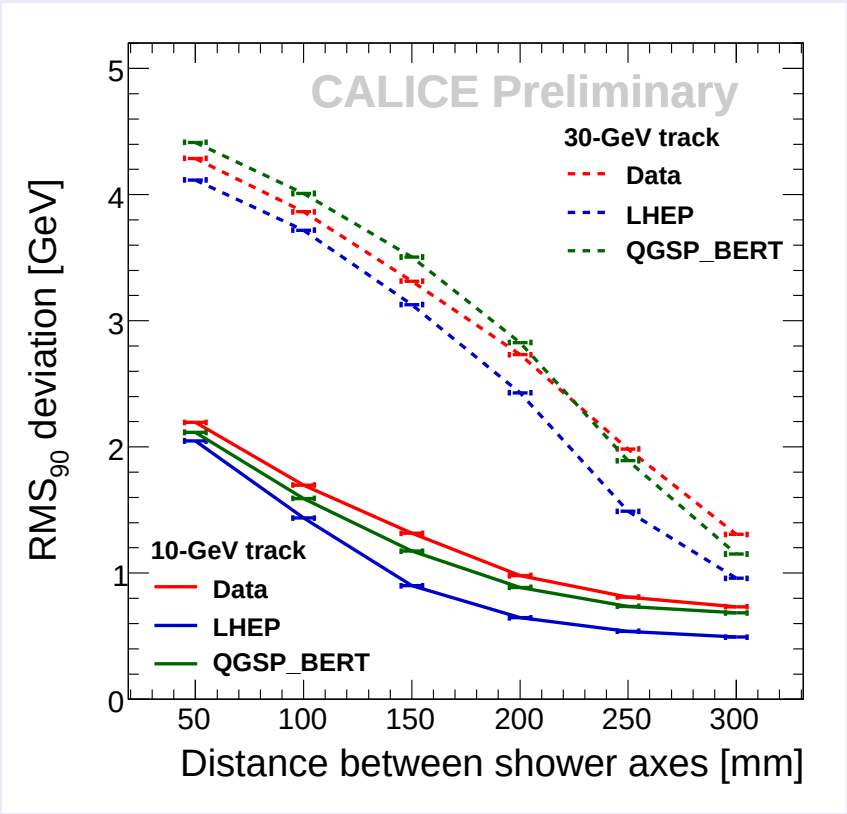
mean confusion from O. Markin study, 10 GeV neutral particle

- smaller confusion with higher energy of charged particle (track)
- no significant difference in TWC results while changing the energy of charged particle

Comparision with results of Oleg Markin's PandoraPFA study, rms90 confusion



rms90 confusion, 10 GeV neutral particle



rms90 confusion from O. Markin study, 10 GeV neutral particle

Summary

Results of generic clustering studies

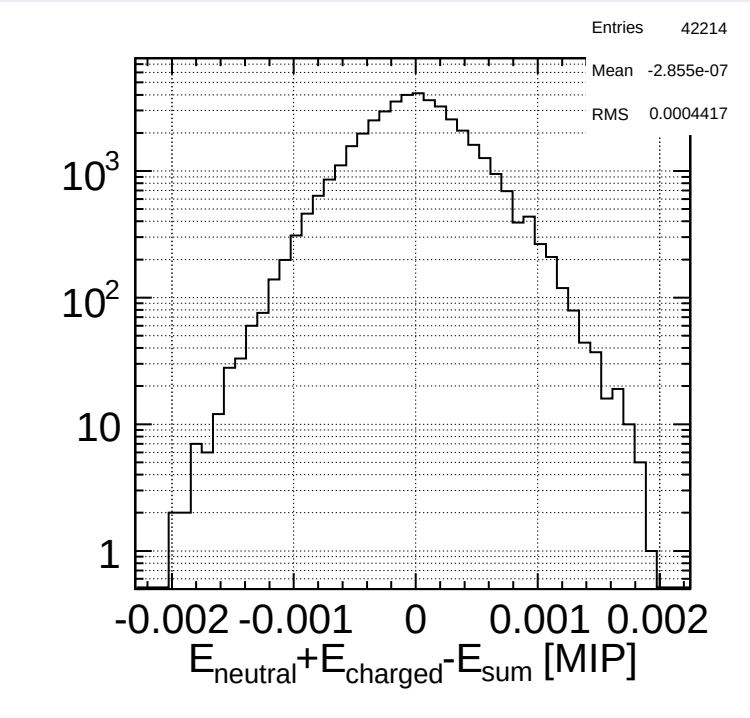
- Shifting study shows as the best choise using random tile assignment
  - already used in PandoraPFA study of Oleg Markin
- Ganging study shows no degradation of clustering results using ahcal geometry

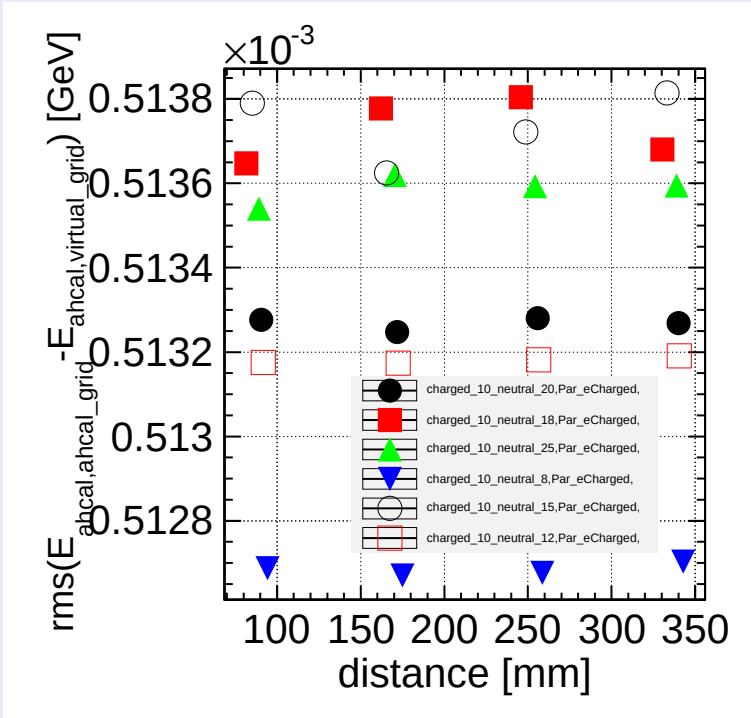
Results of track-wise clustering

- extended study of J. Samson
  - extension of distance range of clusters using shifting procedure
  - data analysis comparision with MC
- comparision of TWA applied on Data and MC shows small differences (mainly small influence of shower shapes differences between Data and MC)

Backup

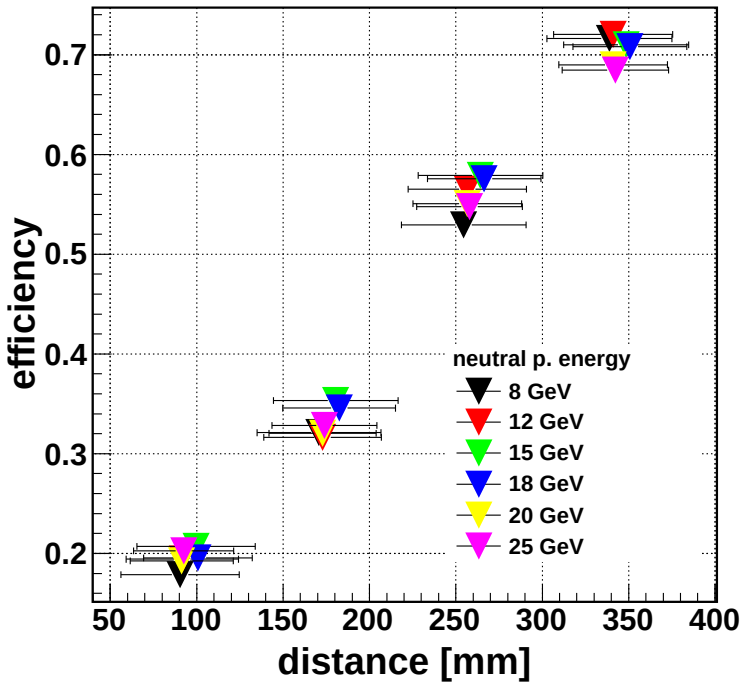
Overlapping and ganging check (debugging)

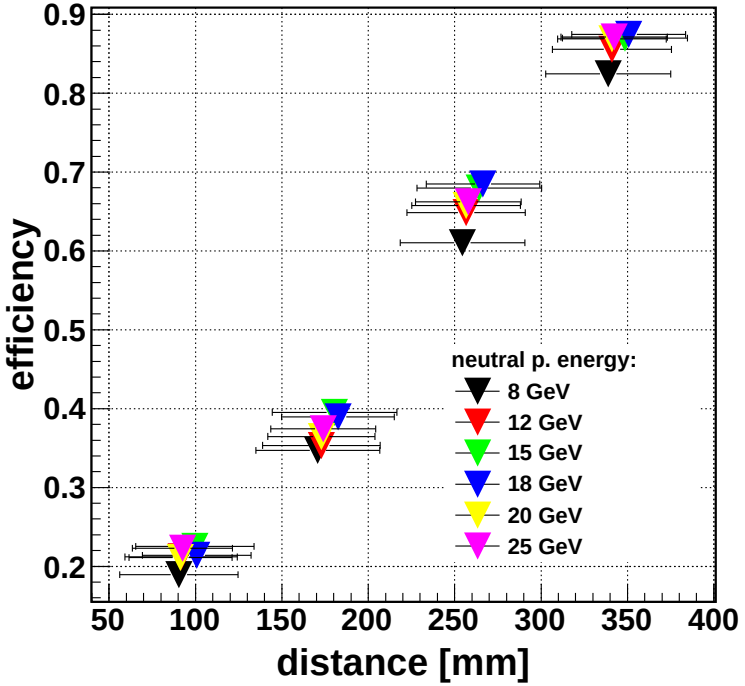




- Overlapping of neutral and charged particle has to give me collection of hits with energy as sum of collections where they originate from. (left).
- ganging of hcal hits can't affect the energy sum (right-differences of ahcal energy sum with(out) ahcal ganging
  - range of float number $\approx$ 7 digits, # hits 10^3

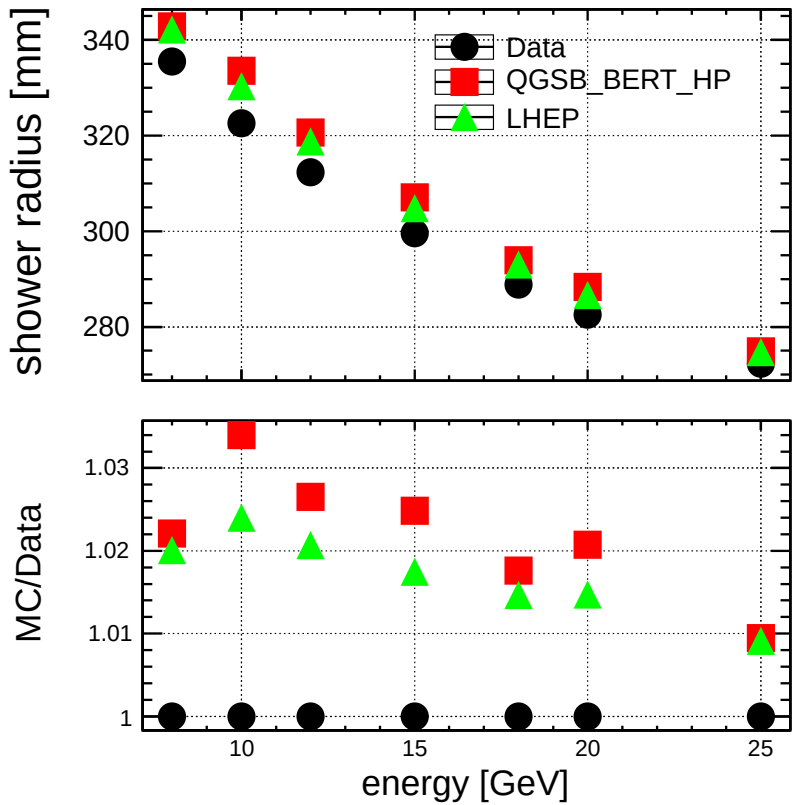
Efficiency of finding two clusters



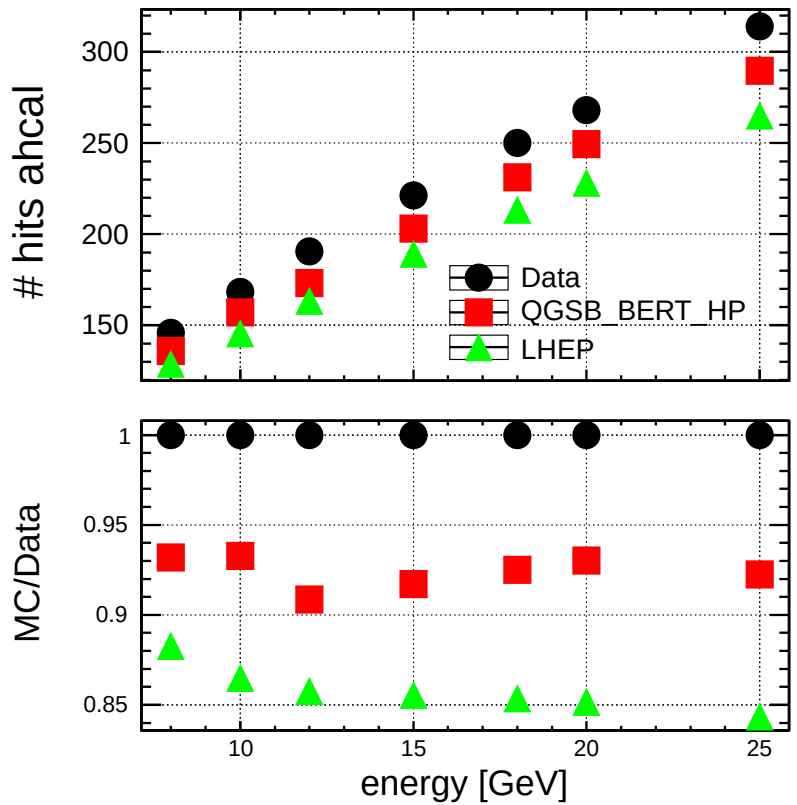


- charged: 10 GeV, neutral 8 GeV
- Data in agreement with MC

shower radius



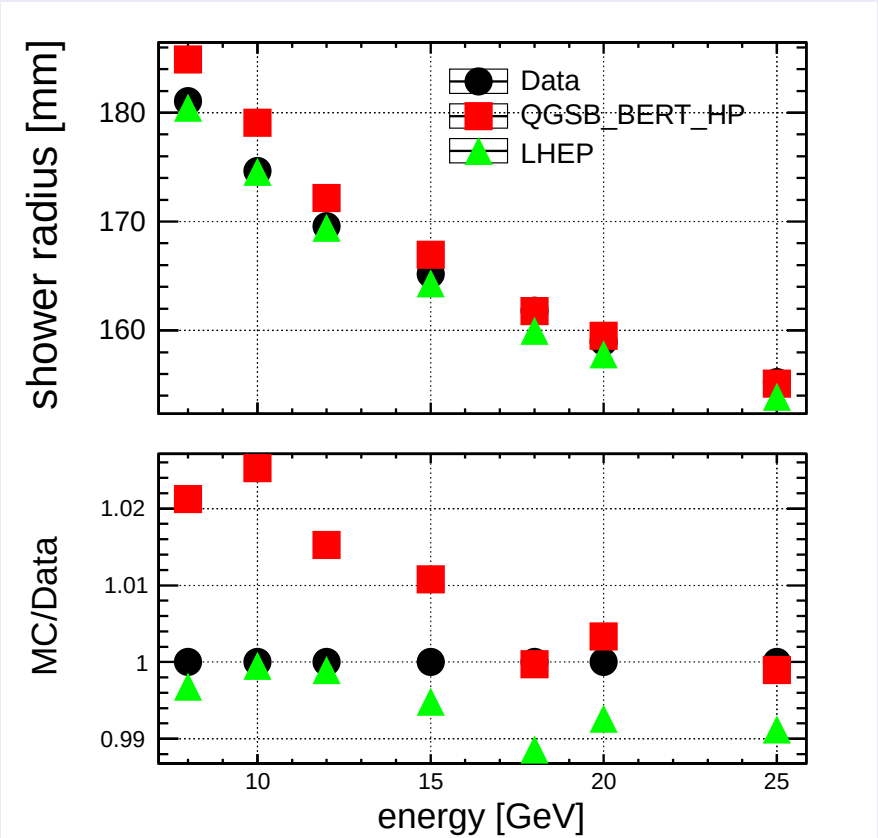
radius of 90 % containment



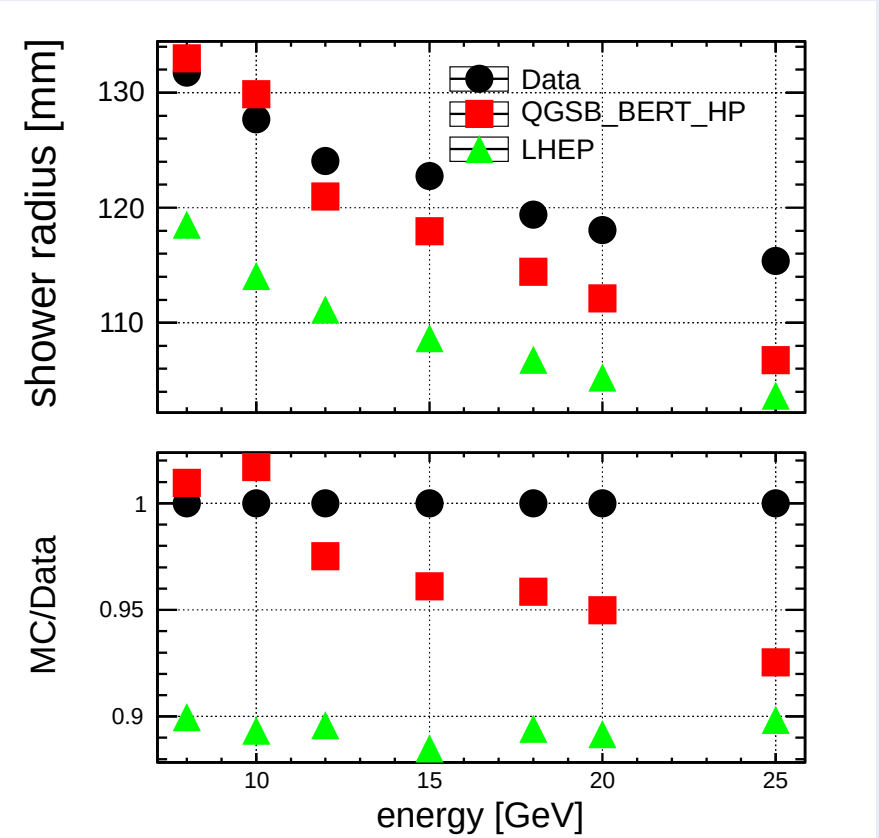
hits in Ahcal

- bigger shower radius for smaller energy
- spread of radius $\approx$ 6 cm
- on the other side bigger # hits for bigger energy

Second Central Moment



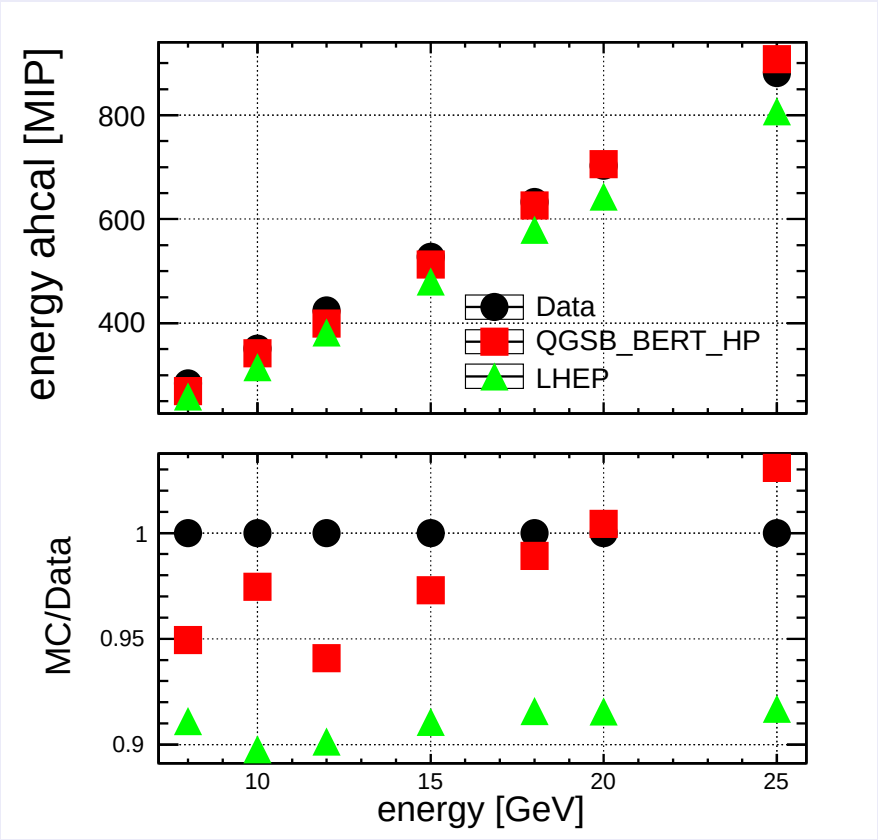
root of second central moment



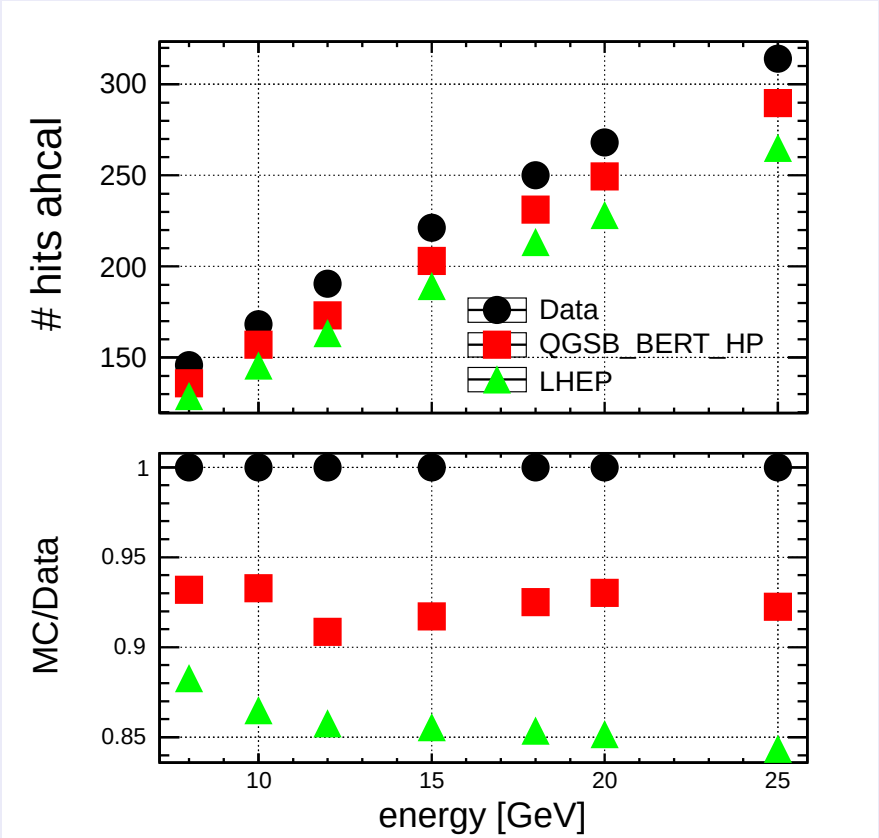
root of energy weighted second central moment

- Second Central Moment without energy weight closer to MC
- Problem of energy or # hits distribution

Energy and Hits distribution



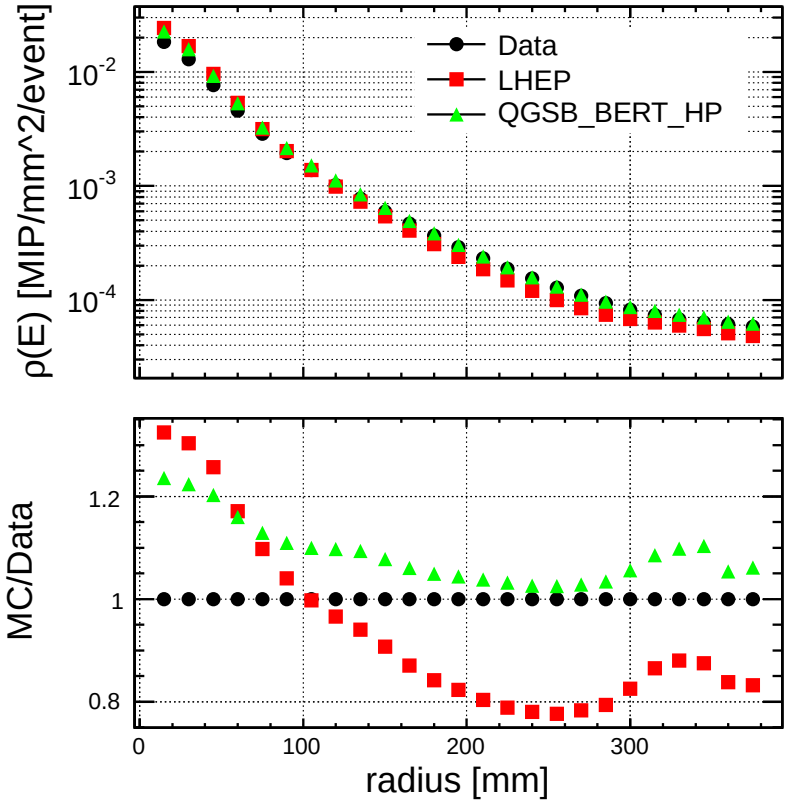
energy of ahcal

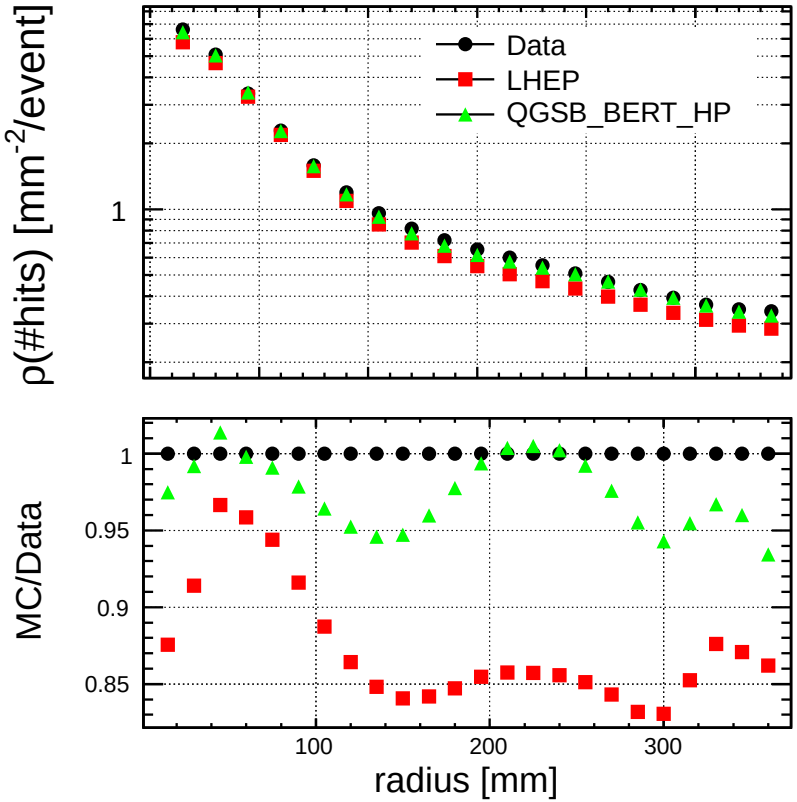


hits of ahcal

- no bias of ahcal energy deposition in comparision with MC
- more # hits for Data.
  - need for lateral energy and hits distribution for answer on weighted SCM discrepancy (SCM is a function only of distance from the mean position)
- using gaus fit peaks
- shower start in first 10 layers

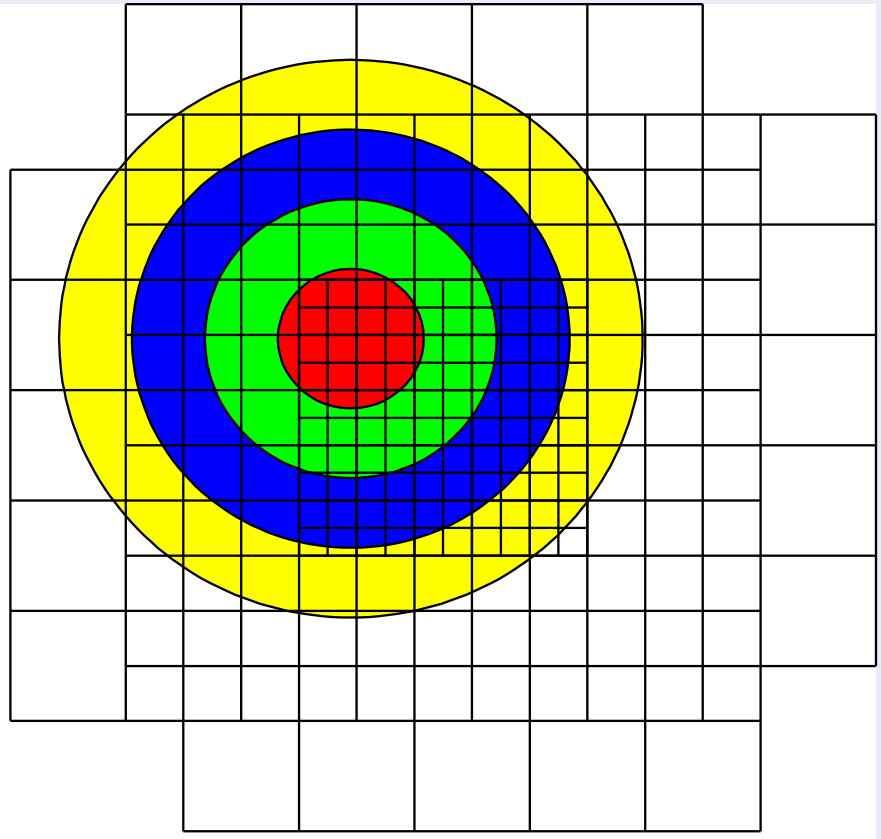
Energy and Hits radial distribution





- Plots:
  - energy of ahcal (left), no bias in comparision with MC
  - hits of ahcal (right), more # hits for Data.
    - need for lateral energy and hits distribution for answer on weighted SCM (if e.g. the energy radial distribution has bigger tale and same for hits distr.)
- not mean but gaus peak comparision
- shower start in first 10 layers

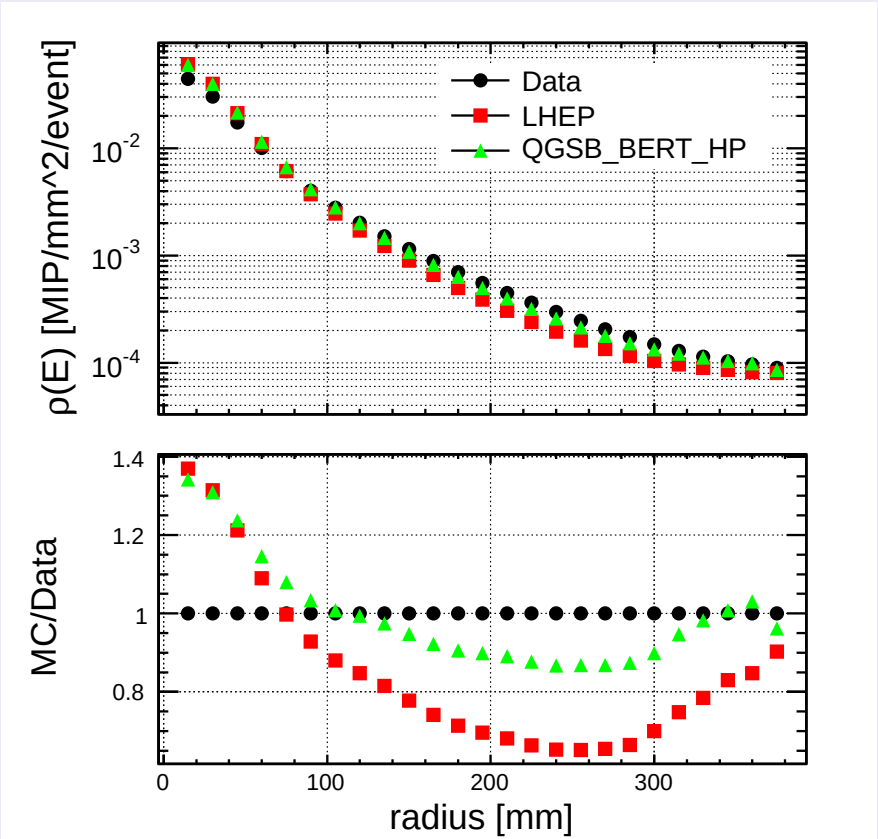
radial distribution definition



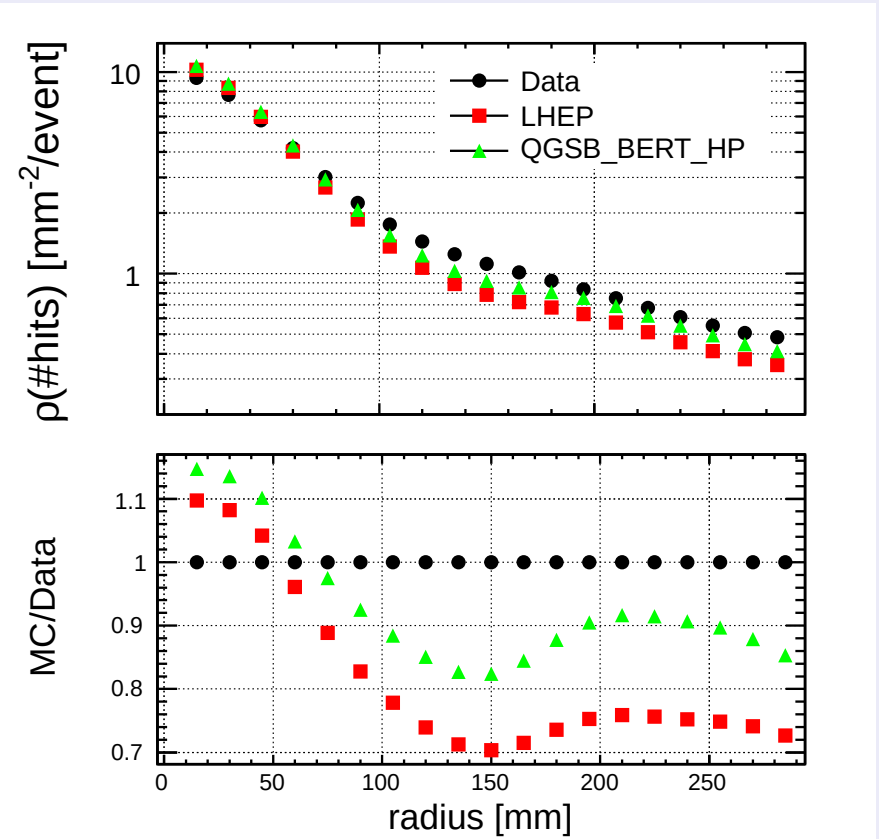
rings-tiles intersections for energy and #hits radial distribution

- for particular event using only rings fully inside ahcal
- Energy in ring: $E = \sum_i E_i * \text{intersection}(\text{tile}_i, \text{ring})/\text{tile}$
- intersections are computed analyticaly

Energy and Hits radial distribution (example of 15 GeV pion)



energy radial density distribution



hits radial density distribution

- underestimated energy density of data for core (saturation)
- overestimated energy density of data for bigger radial distance
  - → bias of SCM to higher value for data