Energy correction for PANDA EMC

Dong Liu[a], Yankun Sun[a], Guang Zhao[b],
Chunxiu Liu[b], Shengsen Sun[b], Guangshun Huang[a]

[a]University of Science and Technology of China, Hefei, China
[b]Institute of High Energy Physics, CAS, Beijing, China

GSI/FAIR, PANDA CM 2/19, June 25, 2019

Outline

1. Electromagnetic calorimeter
2. EMC in PandaRoot
3. Energy normalization
4. Energy correction
5. Summary

PANDA EMC

- Components: Target + Forward
- Goal
- Requirement
  - Coverage
    - ◇ Energy threshold (*10(20) MeV*)
    - ◇ Geometry coverage (*99%x4π in c.m.s*)
    - ◇ Energy range (*up to 0.7 GeV BW, 7.3 GeV B, 14.6 GeV FW*)
  - Resolution
    - ◇ Single crystal threshold ($\sigma_{E,noise} = 1MeV, E_{xtl} = 3MeV$)
    - ◇ Energy Resolution ($1\% \oplus 2\%/\sqrt{E}$)
    - ◇ Spatial Resolution (0.5^o *BW*, 0.3^o *B*, 0.1^o *FW*)

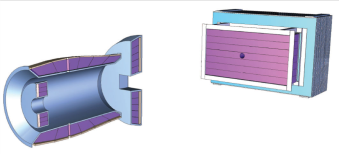


Figure: PANDA EMC

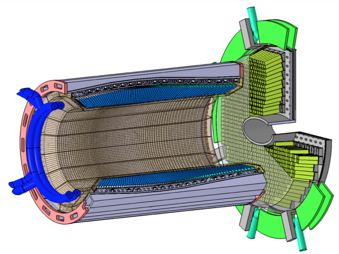
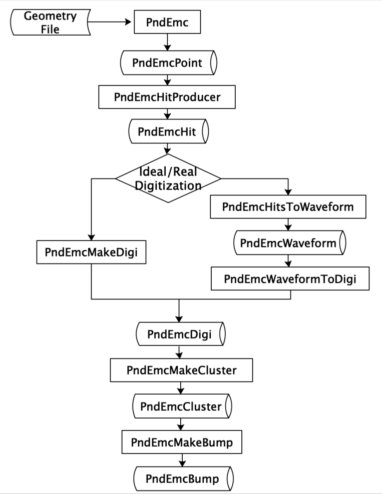


Figure: Target EMC

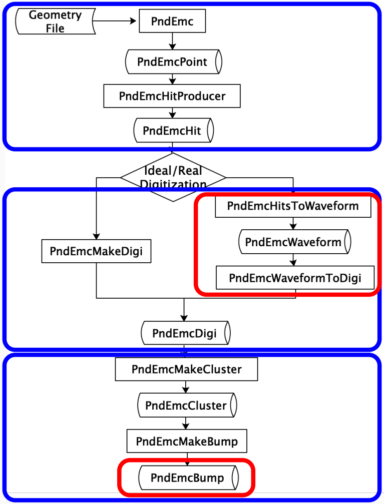
EMC in PandaRoot

- Functionalities
  - Simulation
  - Digitization
  - Calibration
  - Reconstruction
    - ◇ Cluster finding
    - ◇ Bump splitting
    - ◇ Correction
- Current status



EMC in PandaRoot

- Functionalities
  - Simulation
  - Digitization
  - Calibration
  - Reconstruction
    - ◇ Cluster finding
    - ◇ Bump splitting
    - ◇ Correction
- Current status
  - Functionalities are checked
  - Need Optimization



Procedure

Procedure

- Calibration
- Crystal type normalization
  - crystal type related
  - energy related
- Bump correction
  - Leakage correction
  - Preshower correction

Why should we do energy normalization?

- Energy

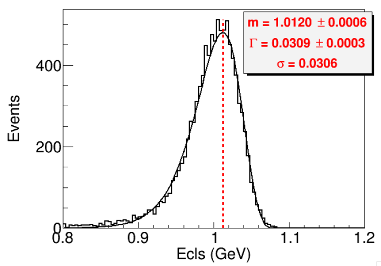
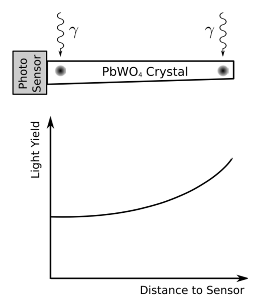


Figure: Example with 1 GeV γ.
Resolution is 3.06%, worse than TDR;
Events with Energy Higher than 1 GeV

- Reasons
  - Nonuniformity: The amount of light collected at sensor depends on the position of the energy deposition.

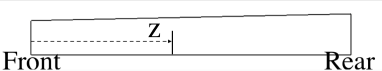


Energy normalization

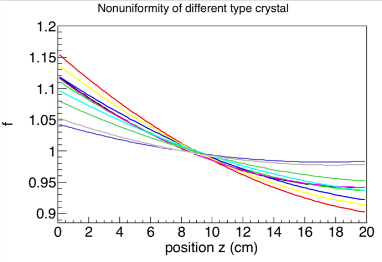
Implementation of nonuniformity in PandaRoot

- light yield in a crystal

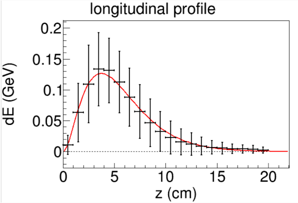
$$ly = c_0 + z(c_1 + z \cdot c_2)$$



- light yield of different type of crystals



- Advantage
  - More sensitive to low energy γ/e
- Disadvantage
  - Resolution Deterioration
  - Type difference of crystals
  - Light yield is not linear to incident energy (longitude depth varies with incident energy)

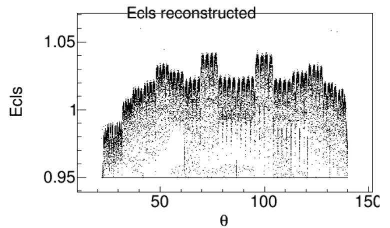


Longitude dE distribution

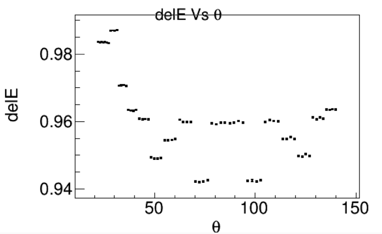
Normalization for different types of crystals

- Phenomena
  - Cluster energy varies with θ
  - One module consists of 4 crystals in θ direction
  - Different behaviours in modules

- Normalization: based on MC
  - Simulation setup: 1 GeV γ to front center of each row
  - Normalization: Scale the energy in each crystal to truth energy



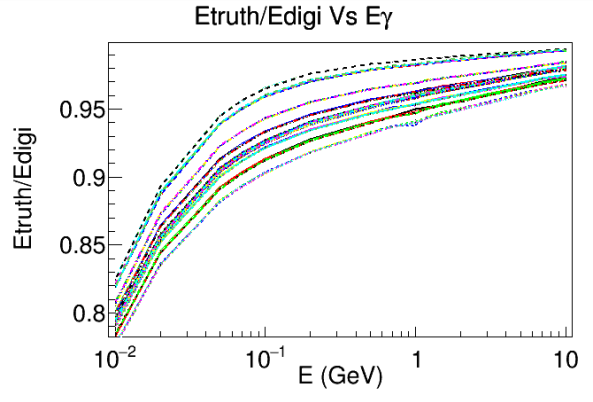
Cluster energy Vs θ



Crystal energy Vs θ

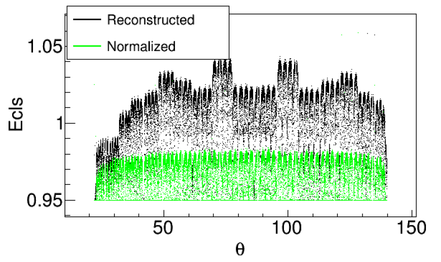
$delE = E_{truth}/E_{digi}$

Normalization for different types of crystals, energy relation

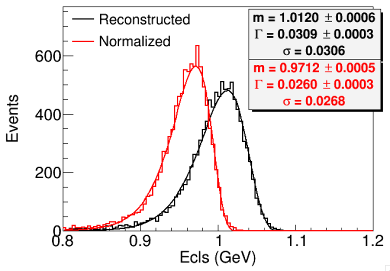


Normalization factor Vs E_{γ}, different colors for different crystal types.

Results of the normalization



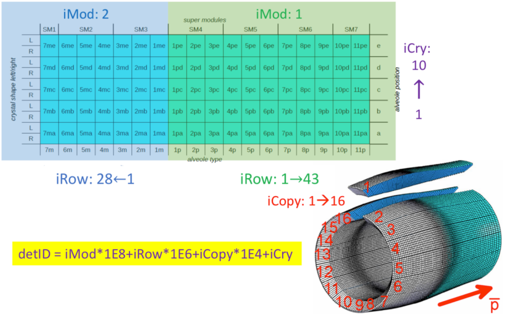
Cluster Energy Vs θ before and after normalization for crystal types.



Cluster Energy of a test sample before and after normalization for crystal types..

Energy Leakage (including energy deposition in dead area)

- Gap types between crystals
  - θ direction
    - ◇ in a module
    - ◇ between modules
    - ◇ between supermodules
  - ϕ direction
    - ◇ in a pair
    - ◇ between pairs
    - ◇ between slices



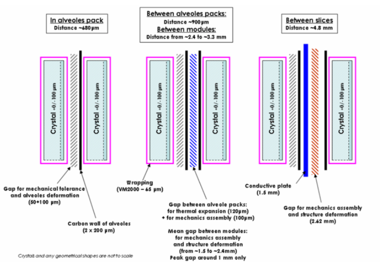
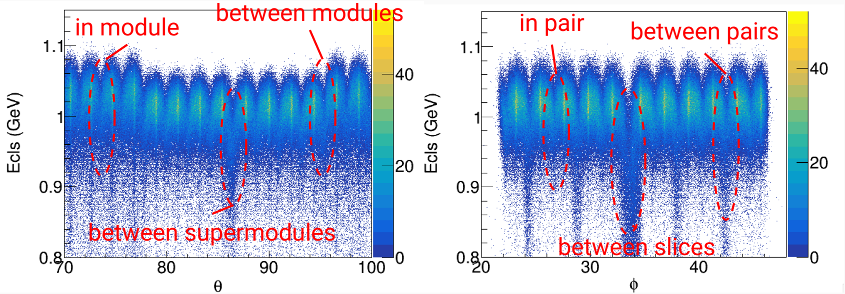


Figure 7.8: Summary of the expected dead space between calorimeter elements.

Energy Leakage (including energy deposition in dead area)

- Gap types between crystals
  - θ direction
  - ϕ direction



Energy Leakage (including energy deposition in dead area)

- Method description [*2007 JINST 2 P04004*]

– variable definition (both in θ and ϕ direction)

  - find seed crystal
  - compare energy in left and right crystals
  - define E1 and E2

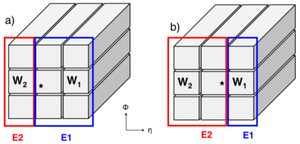


Figure 8. Definition of E1 and E2 when a) W1 < W2 and b) W1 > W2 (see text). The star represents the electron's incident position.

– Relation between $E_{cluster}$ and $ln(E2/E1)$

  - Relation in θ and ϕ direction

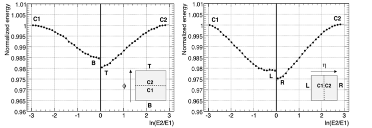


Figure 10. Normalized mean energy measured in the 3×3 array around crystal 204 versus ln(E2/E1) in the Φ (left) and η (right) directions. The curves are 3rd order polynomial functions fitted to the measured distributions, independently for positive and negative values of ln(E2/E1). The square panels represent the central crystal with various regions indicated: T (top), B (bottom), L (left), R (right) and C1 and C2 (just off centre on each side). The labels on the distributions indicate in which region the electrons were incident.

Energy Leakage (including energy deposition in dead area)

- Apply on PANDA

– θ direction (ϕ fixed to 30.1^o)

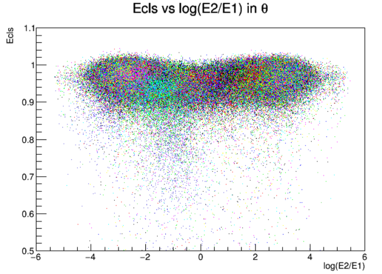
◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in θ direction

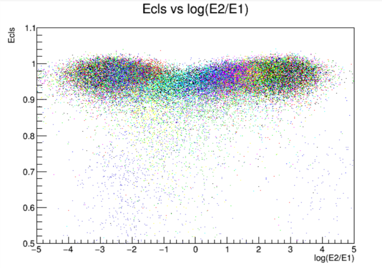
◇ Each color corresponds to γ of a specific direction

– ϕ direction (θ fixed to 49.9^o)

◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in ϕ direction

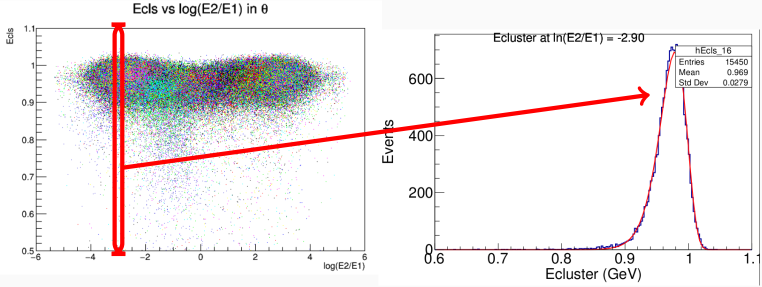
◇ Each color corresponds to γ of a specific direction





Energy Leakage (including energy deposition in dead area)

- Apply on PANDA, extract the relation
  split to slices $\rightarrow$ project to $E_{cluster}$ $\rightarrow$ fit the histogram $\rightarrow$ Extract relation of $E_{cluster}$ Vs $ln(E2/E1)$

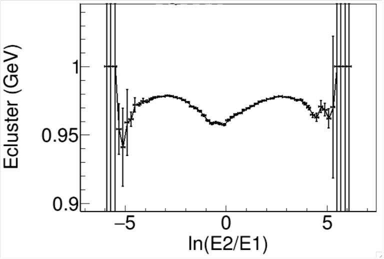


Energy Leakage (including energy deposition in dead area)

- Apply on PANDA, extract the relation

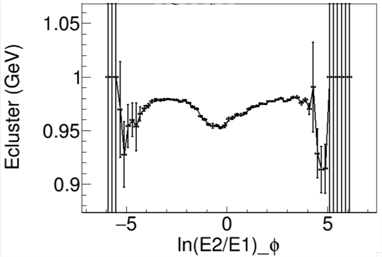
– θ direction (ϕ fixed to 30.1^o)

◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in θ direction



– ϕ direction (θ fixed to 49.9^o)

◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in ϕ direction

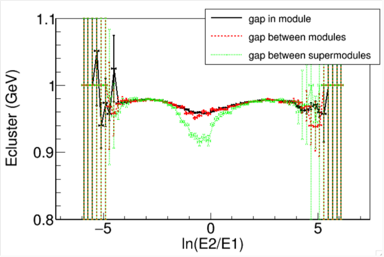


Energy Leakage (including energy deposition in dead area)

- Apply on PANDA, extract the relation, separate different gaps

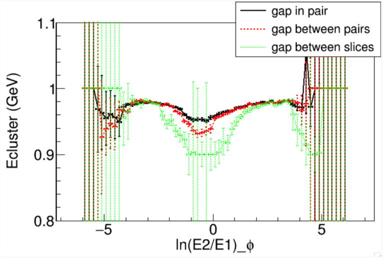
– θ direction (ϕ fixed to 30.1^o)

◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in θ direction

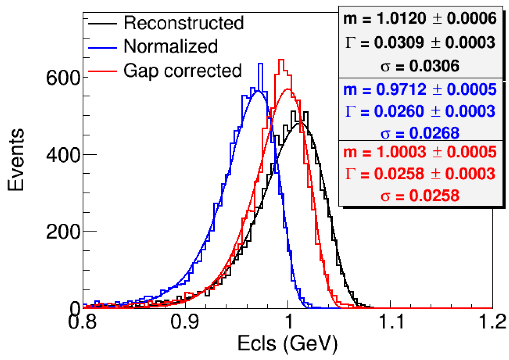


– ϕ direction (θ fixed to 49.9^o)

◇ $E_{cluster}$ Vs $ln(E2/E1)$, where $E2, E1$ defined in ϕ direction



- Result
  - Cluster energy corrected with crystal type has a better resolution than the one without correction. The improvement is about 10%
  - Cluster energy corrected for the gap is slight better than crystal type corrected



Summary

- Functionality check
  - Functionalities of EMC part in PandaRoot has been checked from Simulation to Reconstruction
  - Digitization algorithm is updating
  - Energy and position correction are under studying
  - Calibration algorithm is in consideration
- Energy correction
  - Normalization for each crystal type has been studied, which can provide a better energy resolution
  - Energy leakage has been corrected with $ln(E2/E1)$

Appendix Energy relation of normalization factor

- $\frac{E_{truth}}{E_{digi}} = \frac{E_{truth}}{E_{hit}} \cdot \frac{E_{hit}}{E_{digi}}$