



# Functionality check of the EMC simulation and reconstruction in PandaRoot

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PANDA @China 16, Dec, 2018

IHEP, Beijing, China

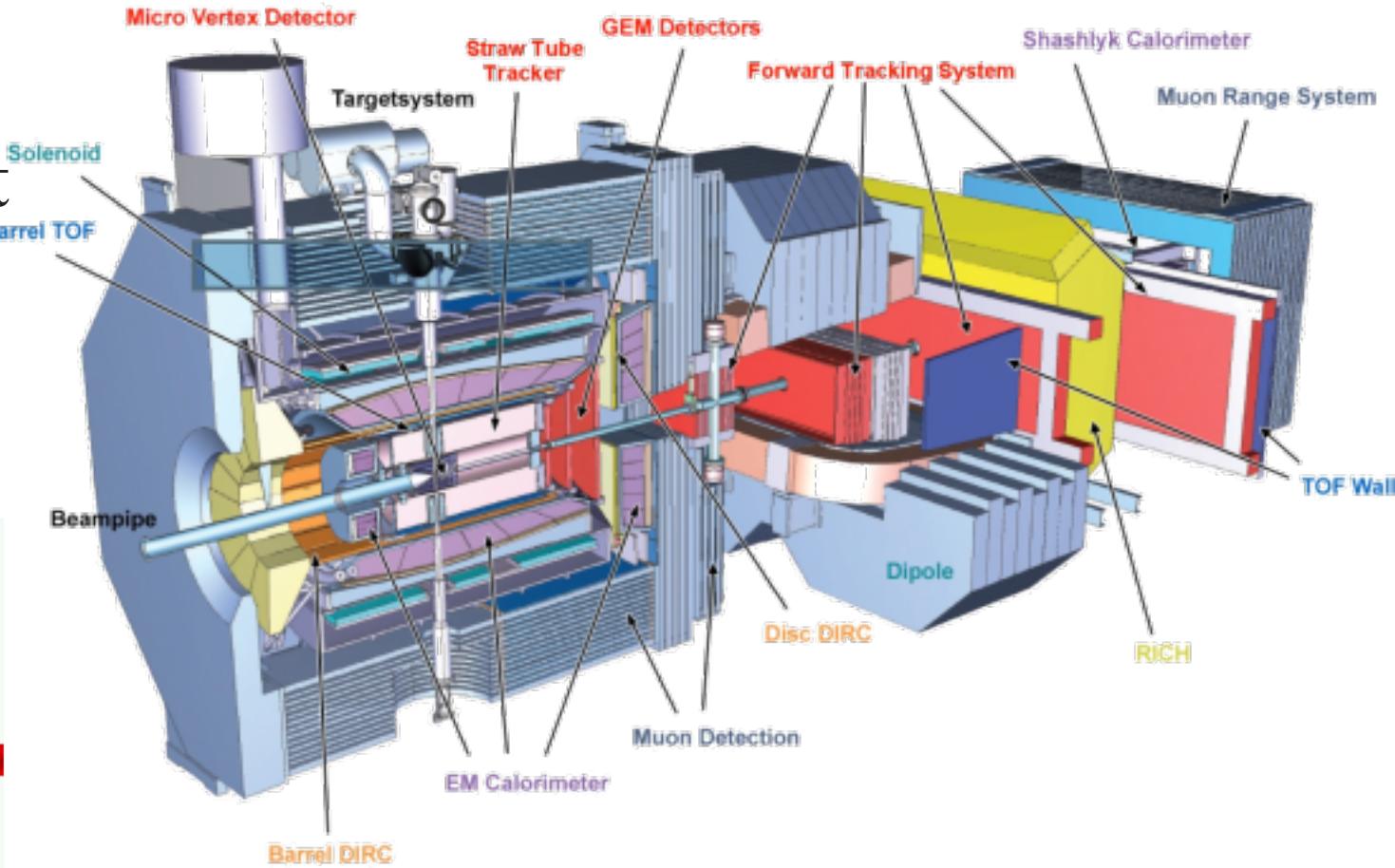
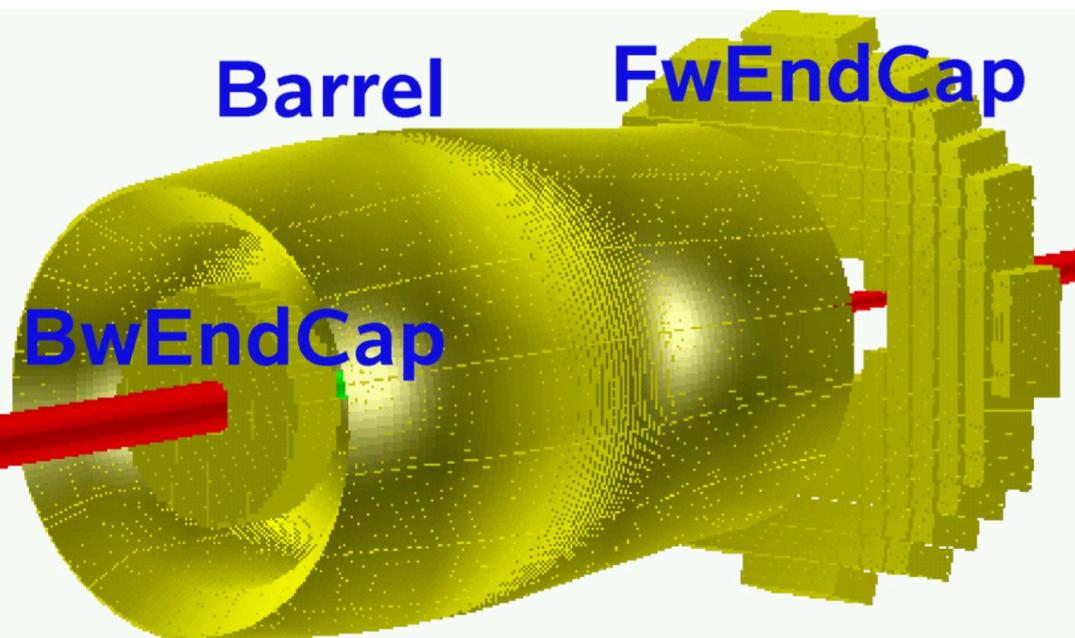
# Outline

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- Introduction
  - Detector
  - Software
- Simulation
  - Detector response
  - Electronic response
- Reconstruction
  - Cluster
  - Bump
- Summary

# Introduction: Detector

- Target EMC
  - energy measurement
  - position
  - PID



FairRoot version: v-17.10b  
PandaRoot version: dev

# Introduction: Software

- EMC Software
  - Simulation
    - geometry description
    - sensitive material
    - physical processes
    - signal collection
    - digitization
  - Reconstruction
    - cluster finding
    - bump splitting
    - track reconstruction

FairRoot version: v-17.10b

PandaRoot version: dev

Emc functionalities refer to  
BABAR experiment, some codes  
are **very old** and **may expired**.  
**Need validation**

Goal: functionality check

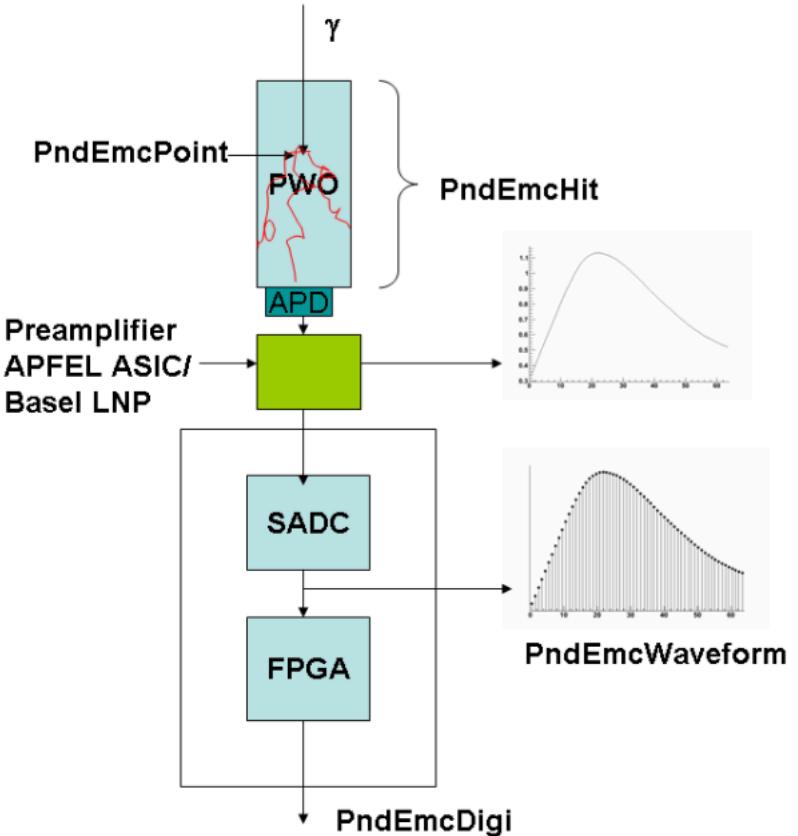
- What kind of data processed?
- Are the results reasonable?

# EMC Simulation

physical events → electronic signals

Simulation processes:

- Response of sensitive material
  - energy deposition
- Electronic process
  - signal collection
  - shaping and amplification
  - sampling
  - filter
  - digitized signal

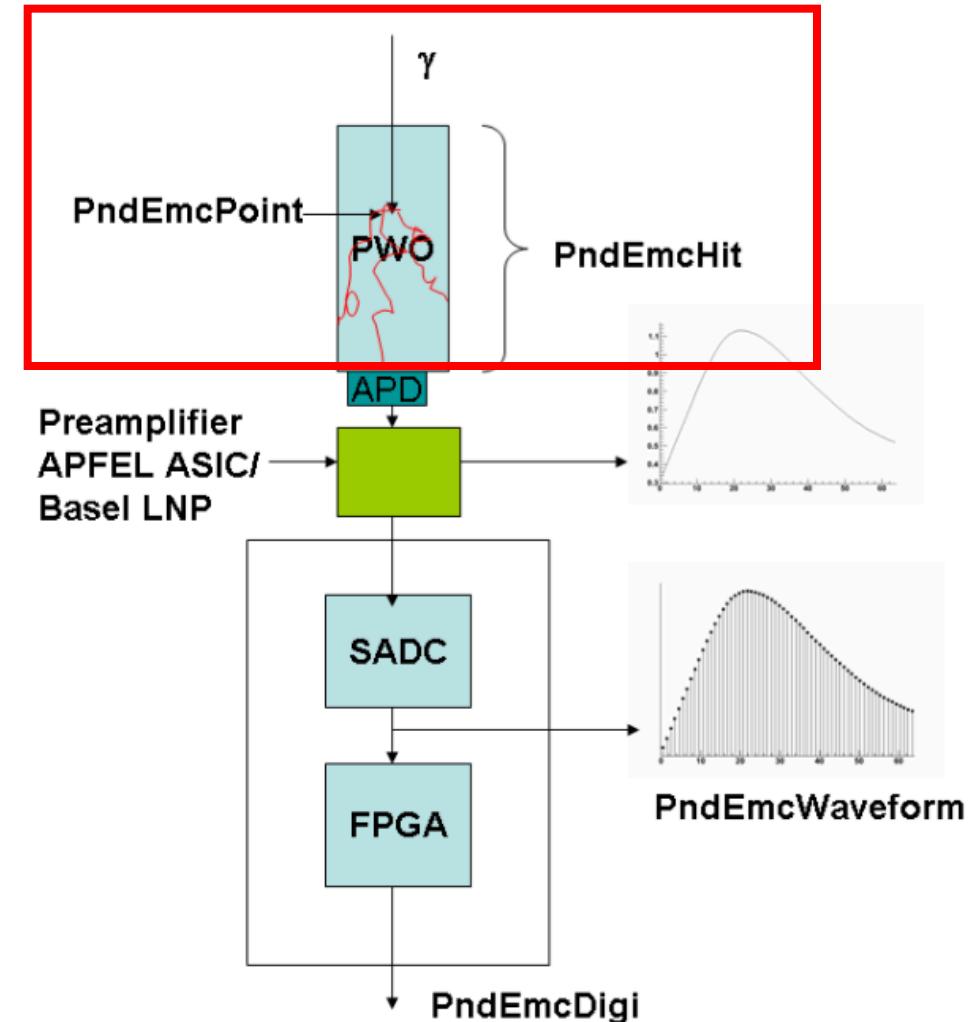


D. Melnychuk 24.07.2012

# EMC Simulation

## Simulation setup:

- Geometry: beam pipe, barrel EMC
- Simulation Engine: Geant4
- Generator: Box
- Setting:
  - particle: 22 (gamma)
  - position: (0, 0, 0)
  - direction: point to a barrel crystal
  - Momentum: from 1 to 15 GeV/c, 1 GeV/c per step



# EMC Simulation: detector response

Process:

- shower
- light collection

Shower at truth level:

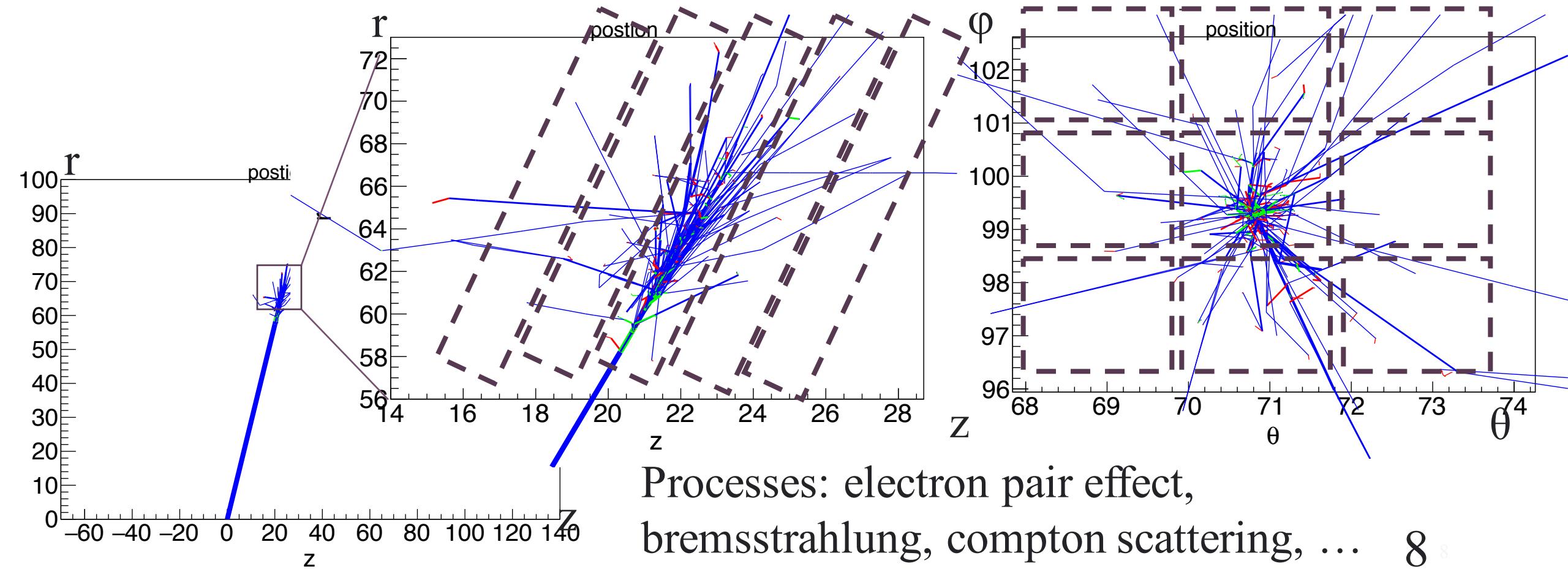
- ✓ Interaction between incident particle and material
- ✓ Tracks and Steps

Information in PndMCTrack

- particle type
- start point
- momentum (& direction)
- mother track ID
- generator tag (from it or not)
- number of interaction point

# EMC Simulation: detector response

➤ Tracks at truth level:  
shower generated in EMC, interactions

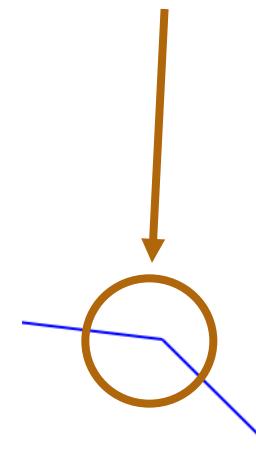
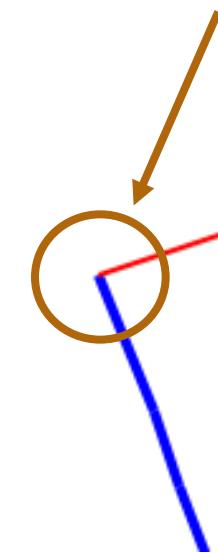
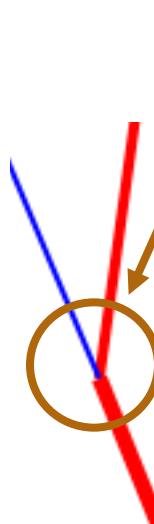
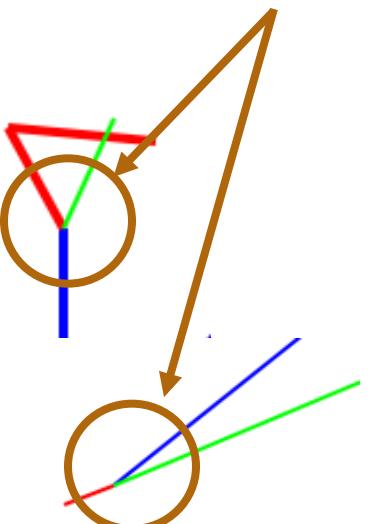


# EMC Simulation: detector response

- **Tracks** at truth level:  
shower generated in EMC, **interactions**

Processes:

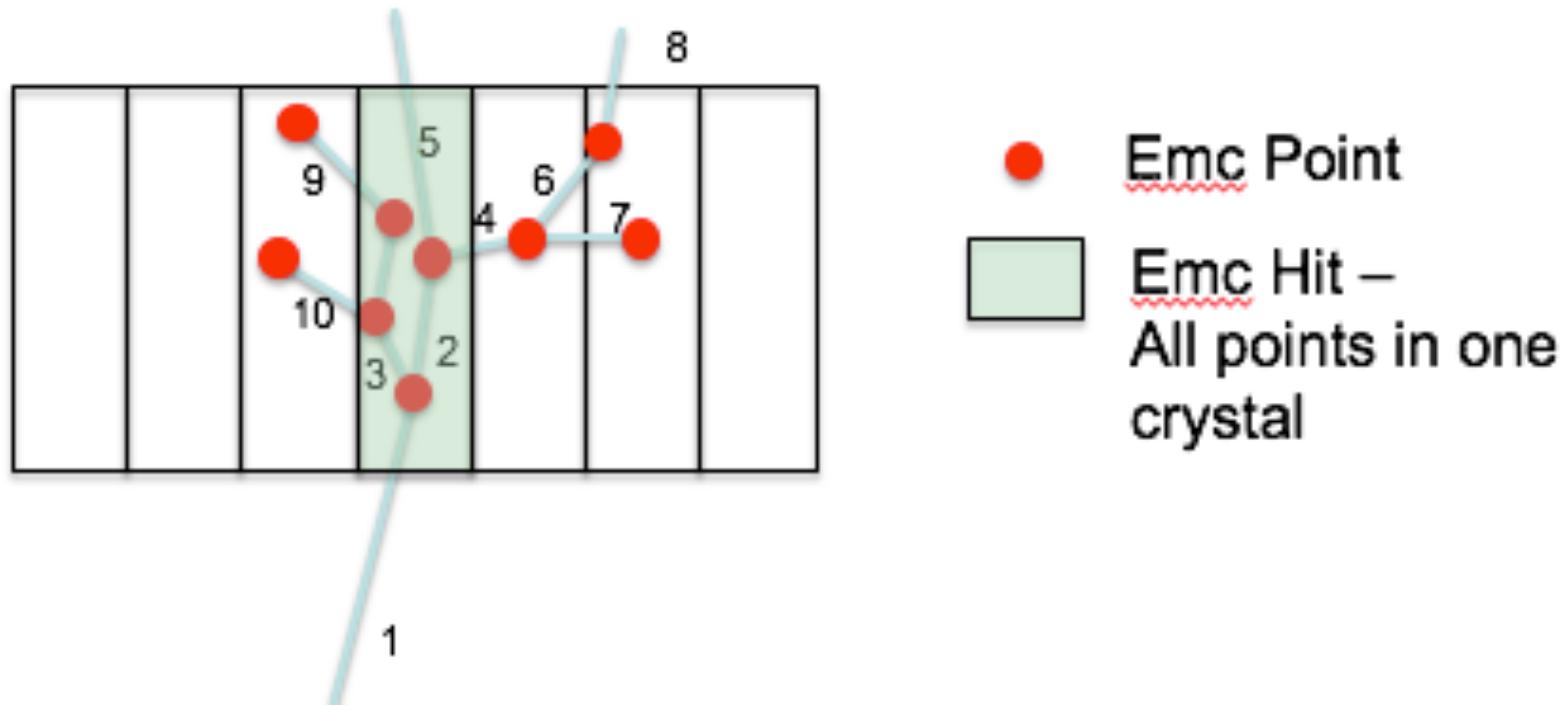
- ✓ electron pair effect, bremsstrahlung, photoelectron, compton scattering, ...



# EMC Simulation: detector response

## ➤ Steps:

In a shower, one track generates a few points, a few points contribute to one hit

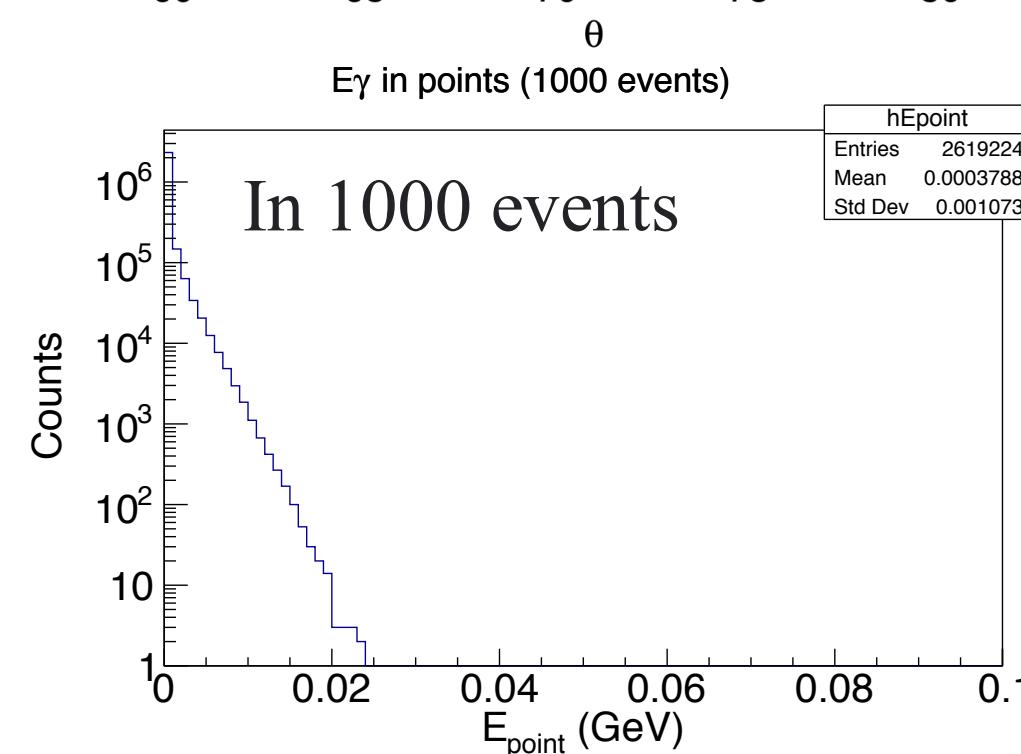
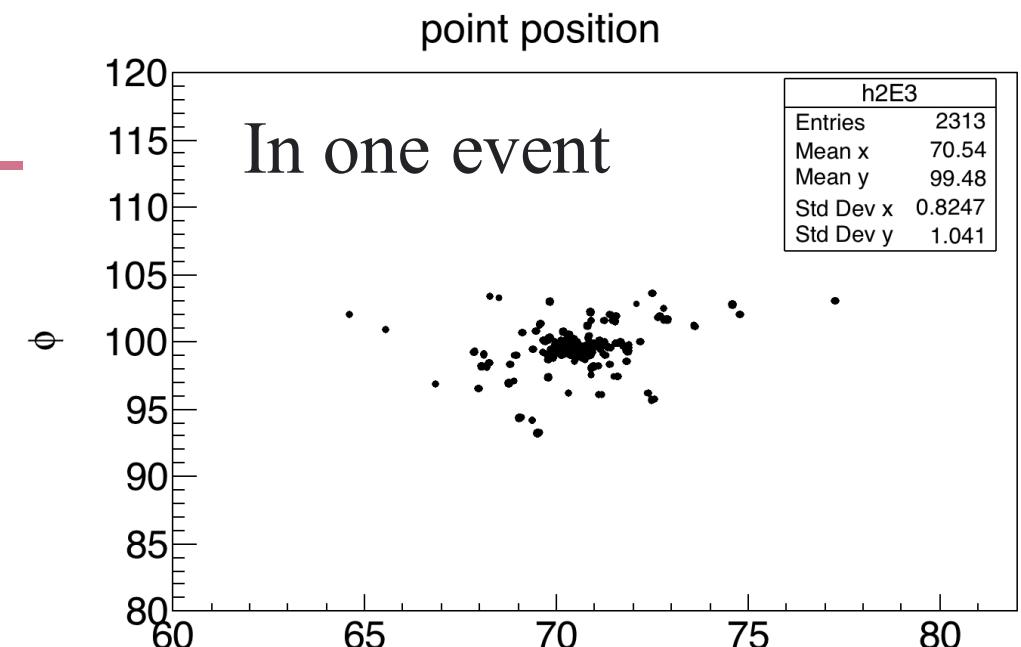


# EMC Simulation: detector response

- Shower:  
**one track generates a few points**

Information in PndEmcPoint:

- momentum after the interaction
- position
- energy deposition
- crystal ID
- track ID
- track length since creation
- time

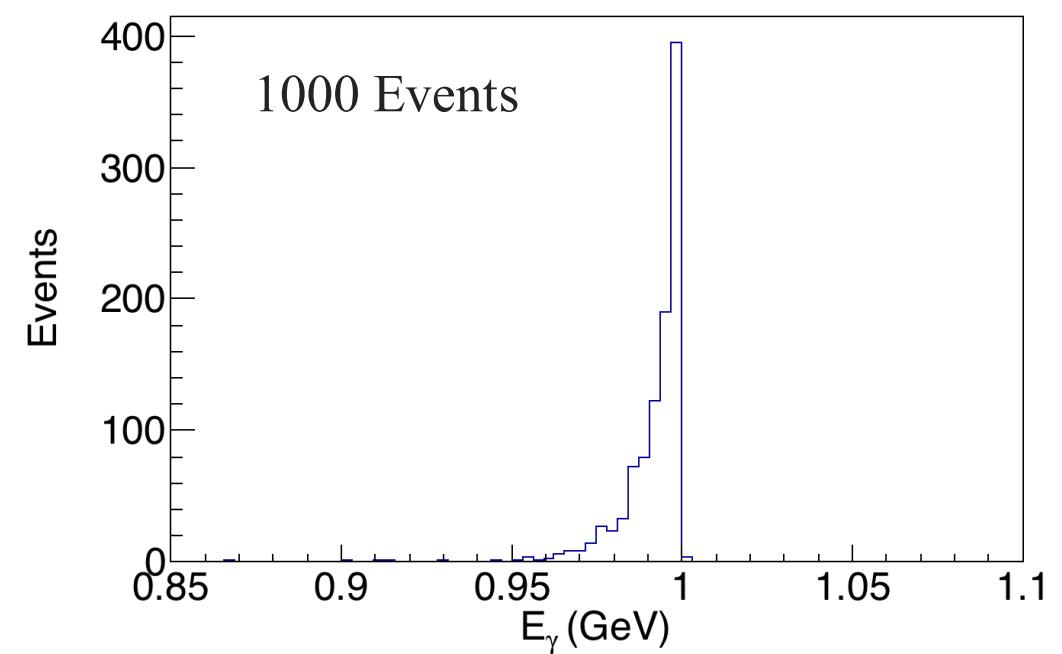
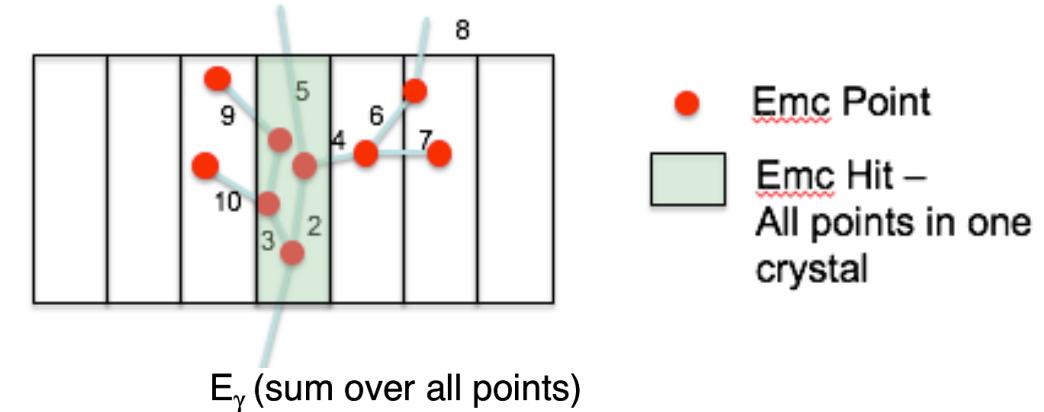


# EMC Simulation: detector response

- Shower:  
one track generates a few points

Total Energy in `PndEmcPoint`

- ❑ Energy leakage
  - trace via FairLink

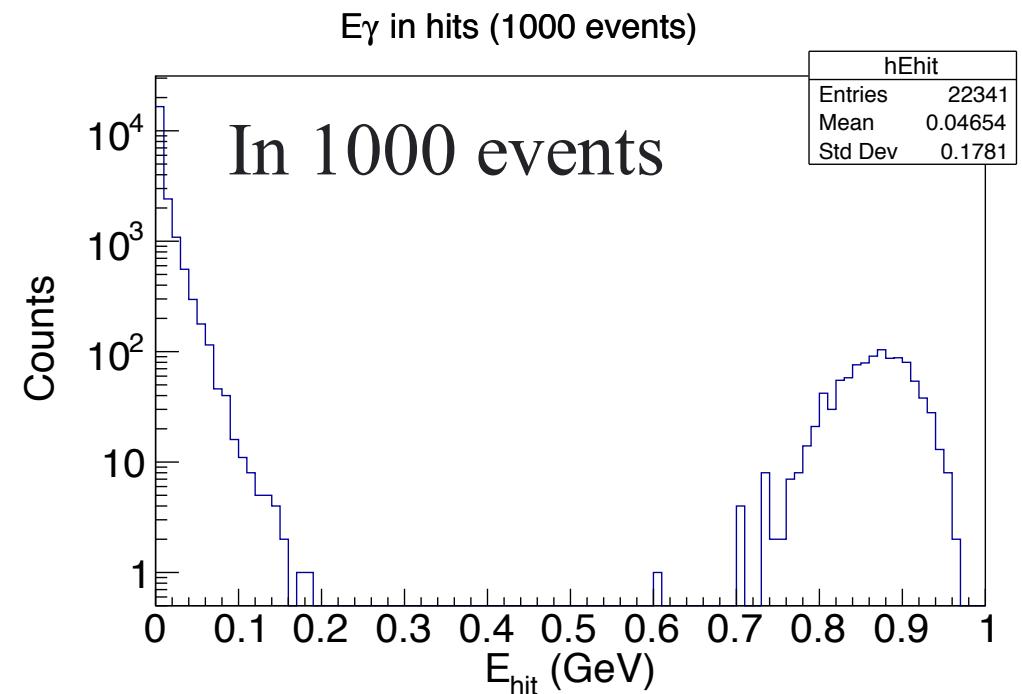
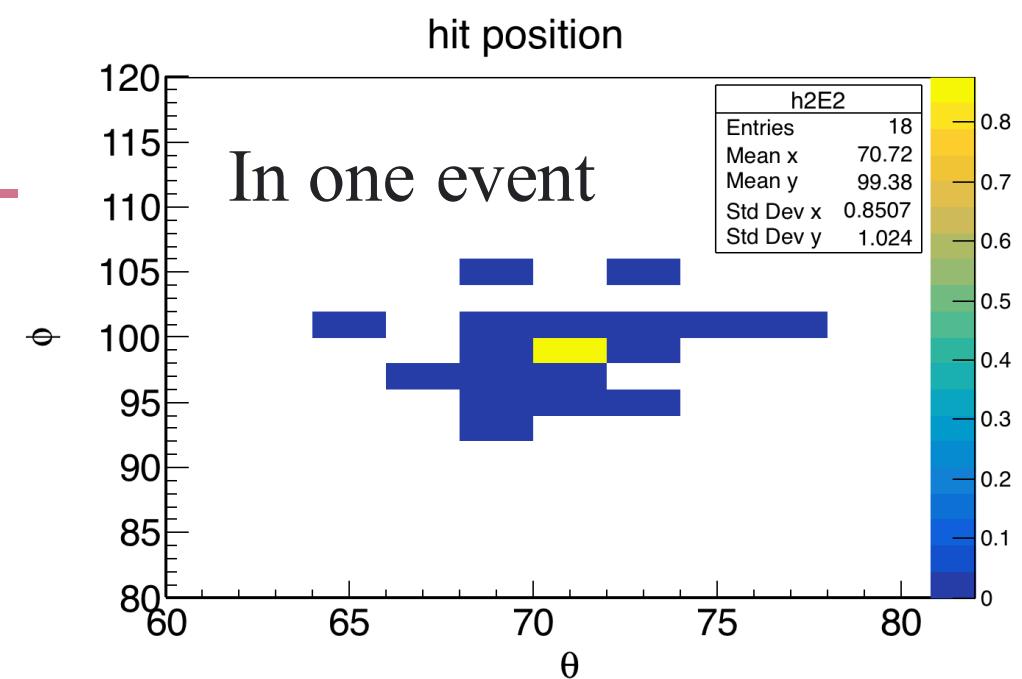


# EMC Simulation: detector response

- Light collection:  
a few points contribute to one hit

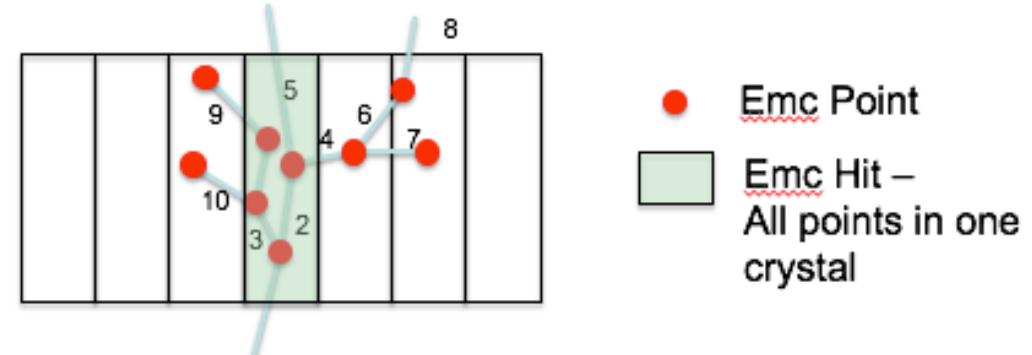
Information in PndEmcHit:

- hit amplitude
- position
- crystal ID
- point list
- time



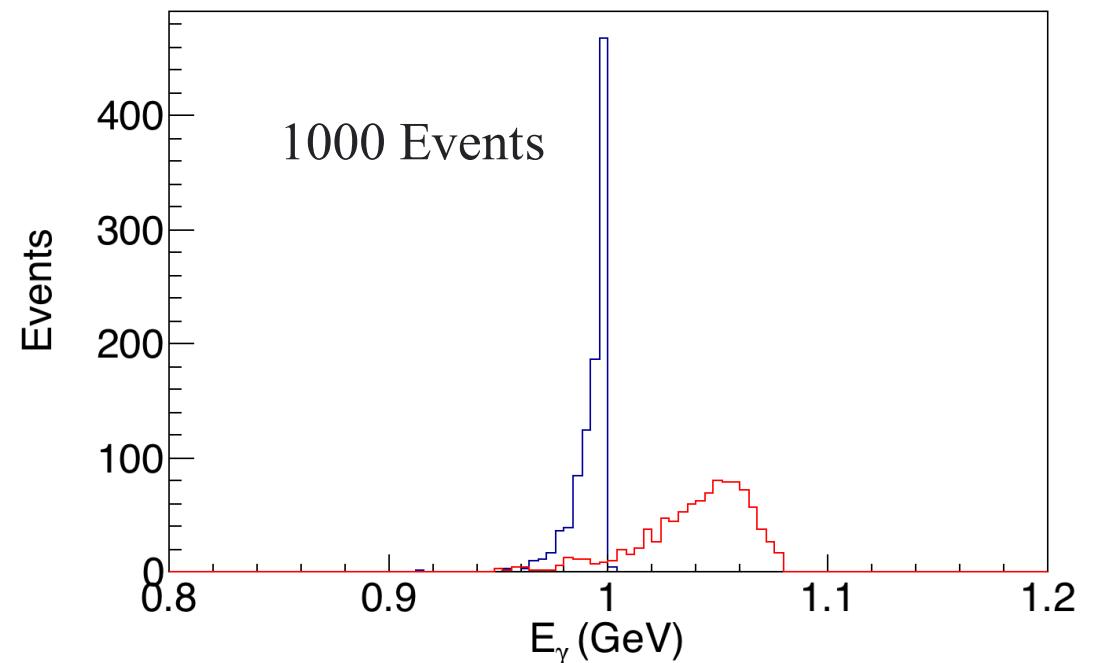
# EMC Simulation: detector response

- Light collection:  
a few points contribute to one hit



Total Energy in `PndEmcPoint`  
Total Energy in `PndEmcHit`

- Difference in hits and points



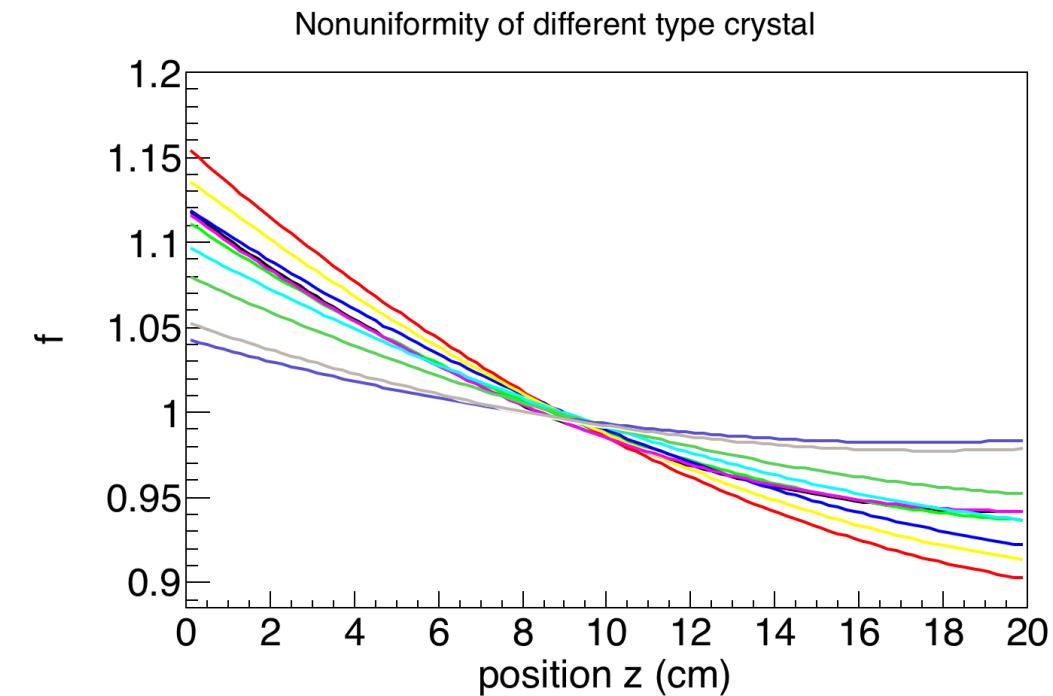
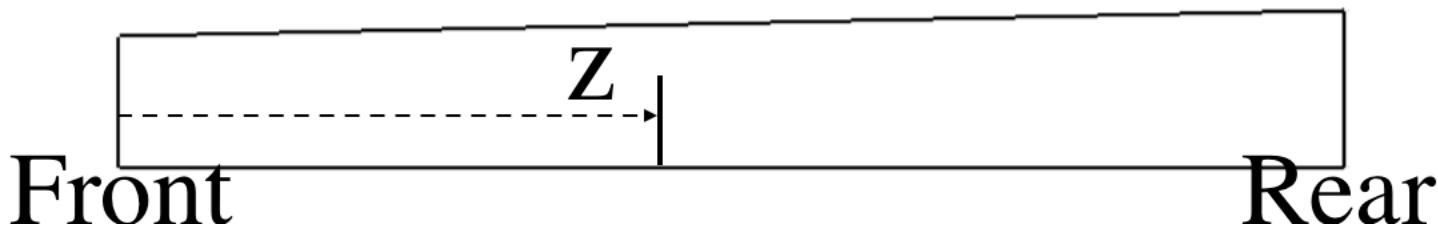
# EMC Simulation: detector response

- Light collection:  
a few points contribute to one hit

Difference between EmcHit and EmcPoint  
HitProducer: nonuniform light yield

$$E_{\text{hit}} = \sum f \cdot E_{\text{point}}$$

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



$f$  of different crystals

# EMC Simulation: detector response

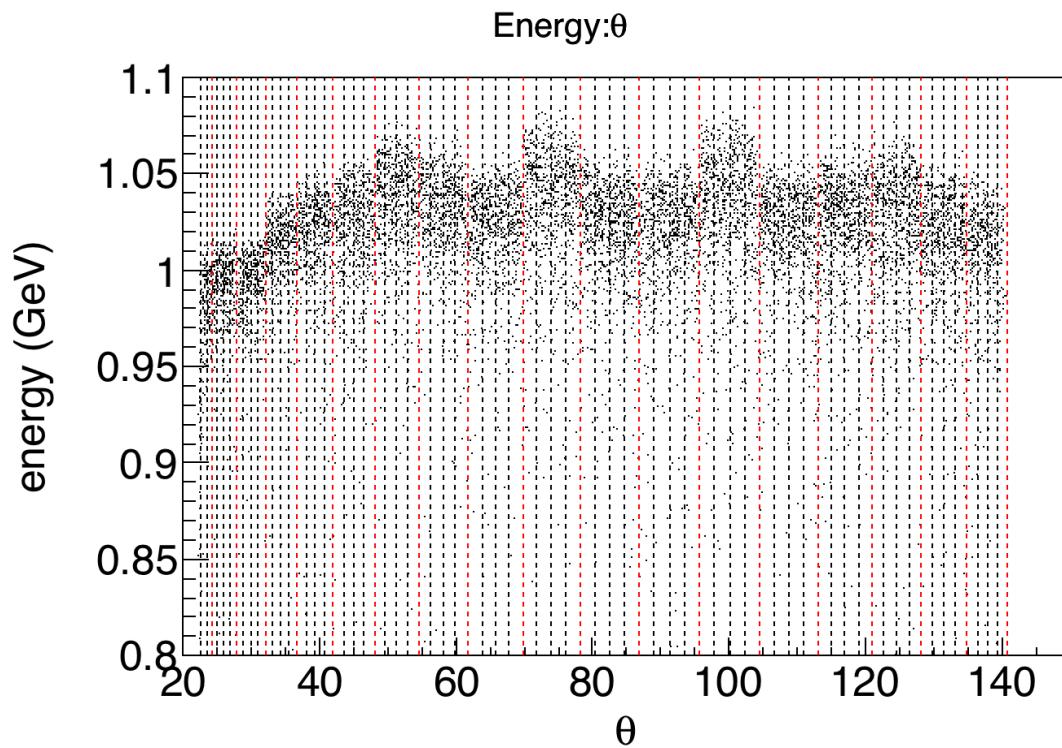
- Light collection:  
a few points contribute to one hit

Difference between EmcHit and EmcPoint  
HitProducer: nonuniform light yield

$$E_{\text{hit}} = \sum f \cdot E_{\text{point}}$$

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

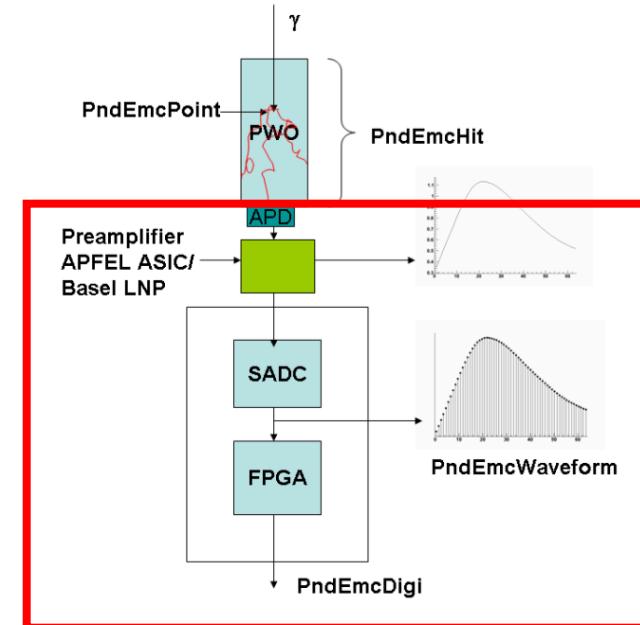
Fluctuation in  $\theta$  direction



# EMC Simulation: electronic response

## Process

- Hit to Waveform
  - APD response: photon statistics, quantum efficiency, ...
  - ADC: pulse shape, sampling, ...
  - Electronic noise: white noise, one bit resolution, ...
  
- Digitization
  - Threshold
  - Filter
  - Peak finding
  - ...

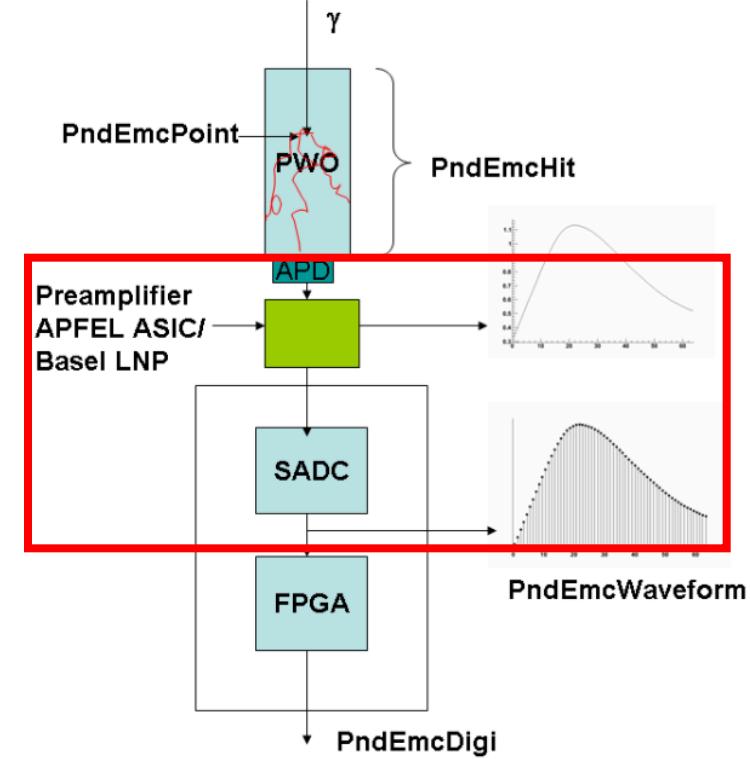


# EMC Simulation: electronic response

## ➤ Hit to Waveform: PndEmcWaveform

### Information in PndEmcWaveform

- a set of sampled amplitudes
- errors of amplitudes
- sample length & rate
- baseline
- crystal ID
- track ID
- hit ID



# EMC Simulation: electronic response

- Hit to Waveform: PndEmcWaveform  
generated via task “PndEmcHitsToWaveform”

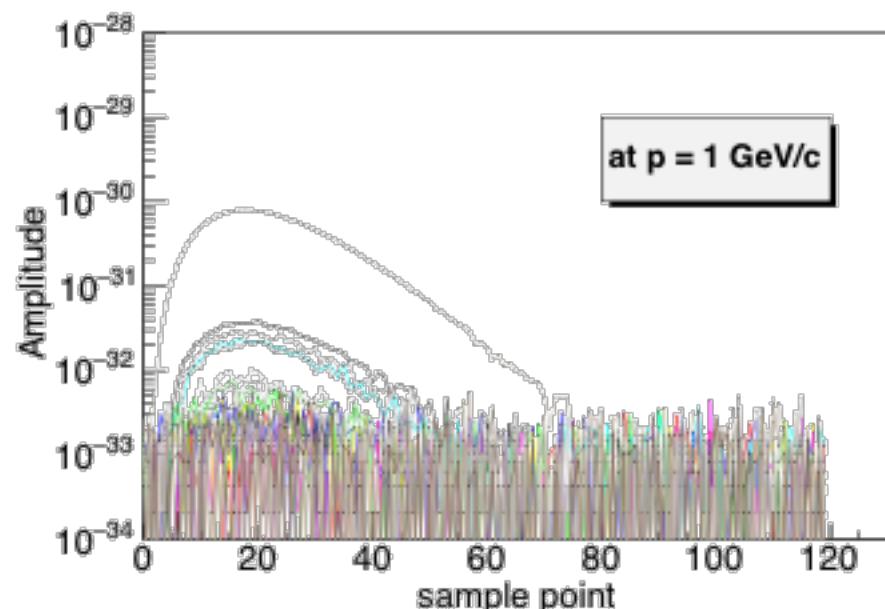
Pulse shape:

$$A \left( \frac{e^{-\Delta t \cdot l_{int}} \cdot \Delta t^3}{6(l_{sig} - l_{int})} - \frac{e^{-\Delta t \cdot l_{int}} \cdot \Delta t^2}{2(l_{sig} - l_{int})^2} + \frac{e^{-\Delta t \cdot l_{int}} \cdot \Delta t}{(l_{sig} - l_{int})^3} - \frac{e^{-\Delta t \cdot l_{int}}}{(l_{sig} - l_{int})^4} + \frac{e^{-\Delta t \cdot l_{sig}}}{(l_{sig} - l_{int})^4} \right)$$

$\Delta t = t - t_0$ ;  $l_{int} = 1/t_{int}$ ;  $l_{sig} = 1/t_{sig}$ ;  
 $t_{int}$ : ASIC sampling int time, 70 ns  
 $t_{sig}$ : crystal sampling time, 12 ns

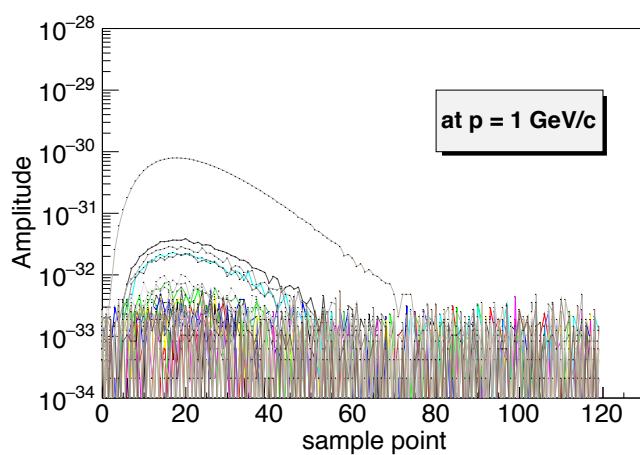
example in one event

- 28 hits, 28 waves

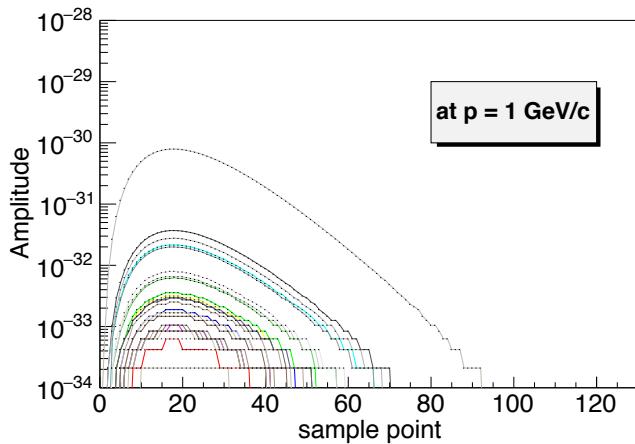


# EMC Simulation: electronic response

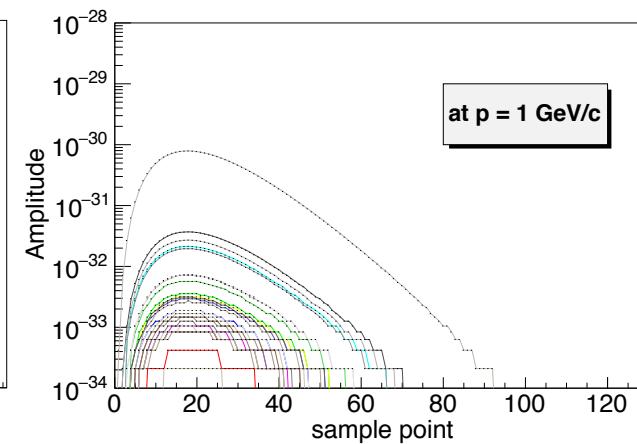
- Hit to Waveform: PndEmcWaveform  
noise effect



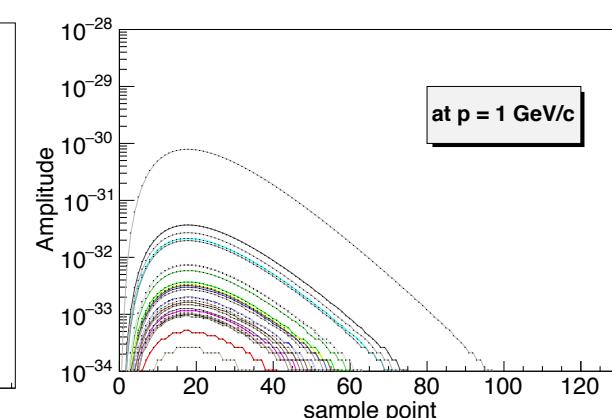
noise  
elec noise:  $1.5 \times 10^{-3}$   
pho stat:  $\frac{1}{\sqrt{E \times 500 \times \frac{200}{745} \times 0.7}}$



no elec noise



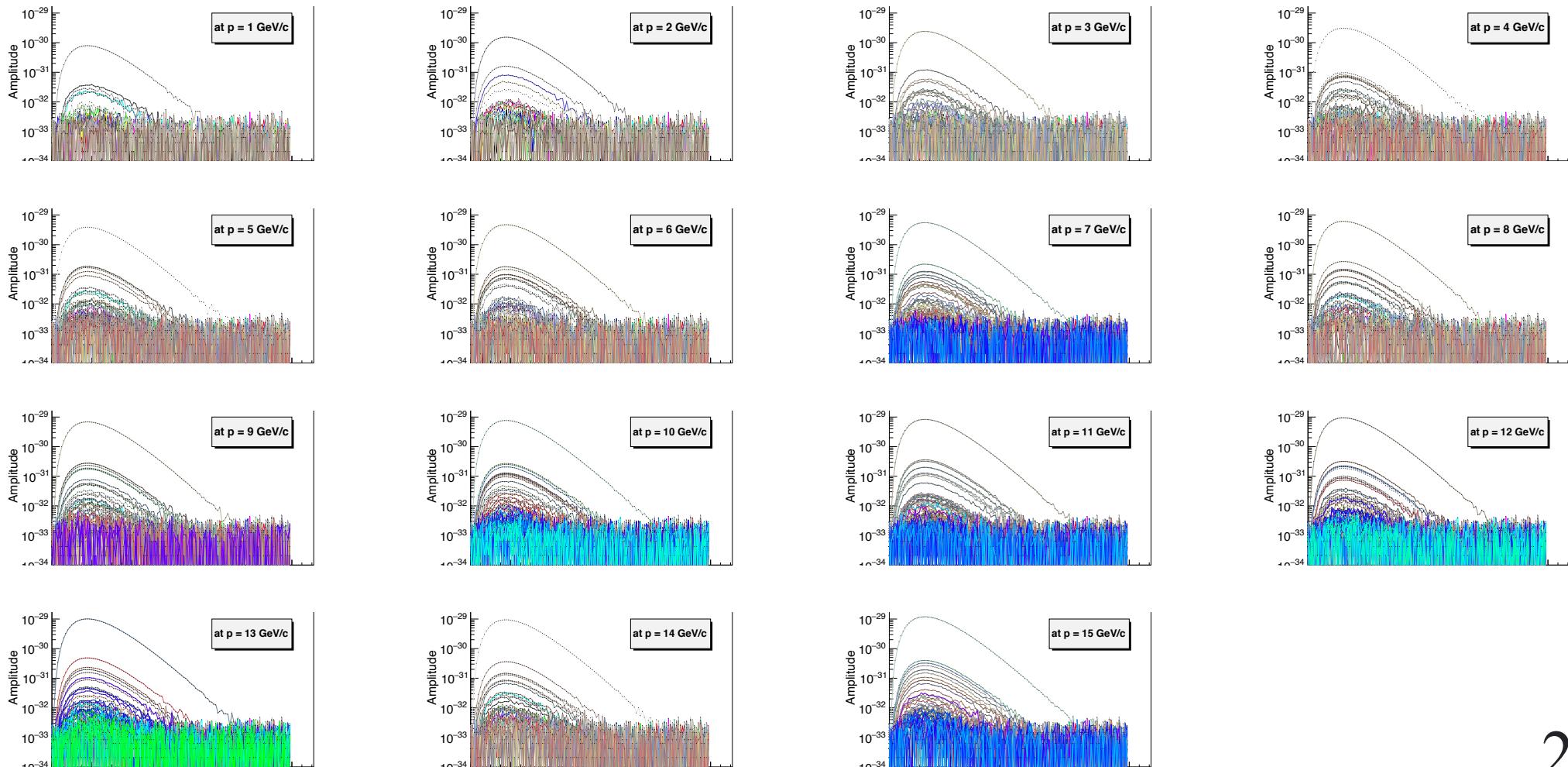
no elec noise  
no pho stat



no elec noise  
no pho stat,  
Nbits=16 → 18  
20<sup>20</sup>

# EMC Simulation: electronic response

➤ Hit to Waveform: PndEmcWaveform, energy relation

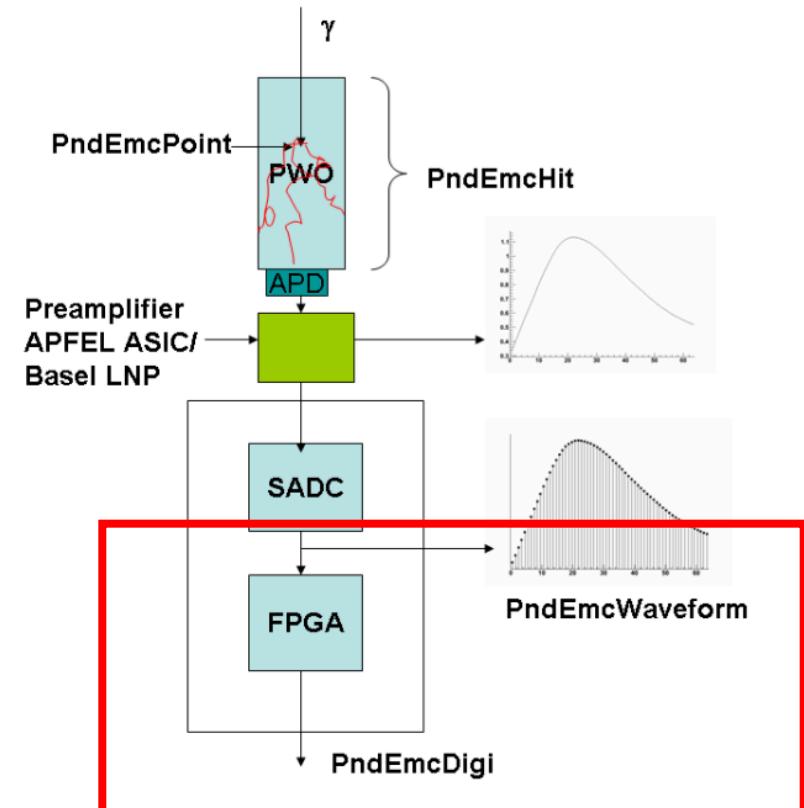


# EMC Simulation: electronic response

- Digitization: PndEmcDigi generated via task “PndEmcWaveformToDigi”

## Information in PndEmcDigi

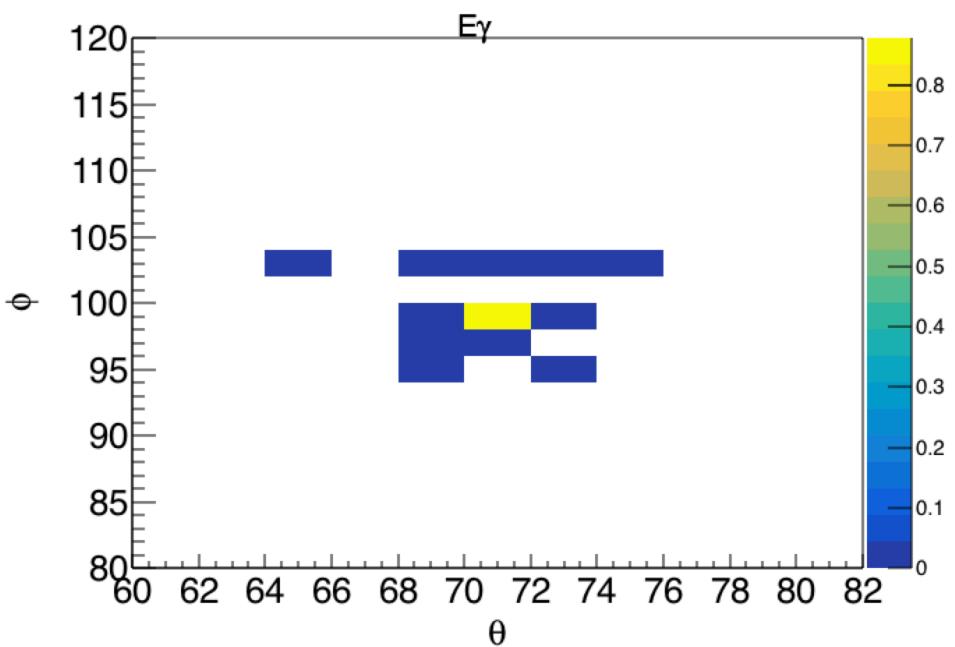
- digi amplitude
- position
- crystal ID
- track ID
- hit ID
- event ID



# EMC Simulation: electronic response

## ➤ Digitization: PndEmcDigi

- Threshold
- Filter
- Peak finding
- ...



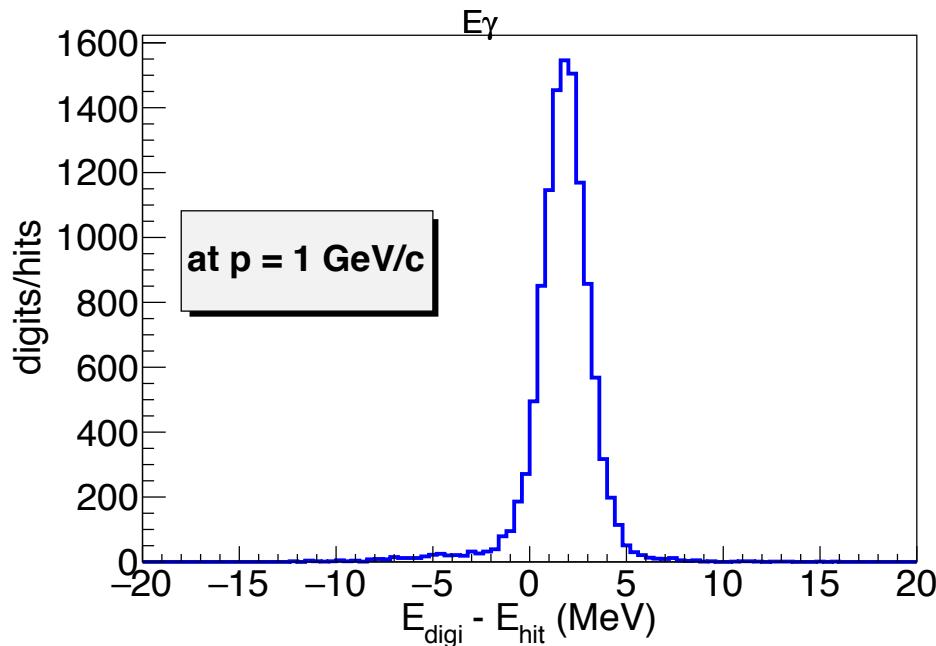
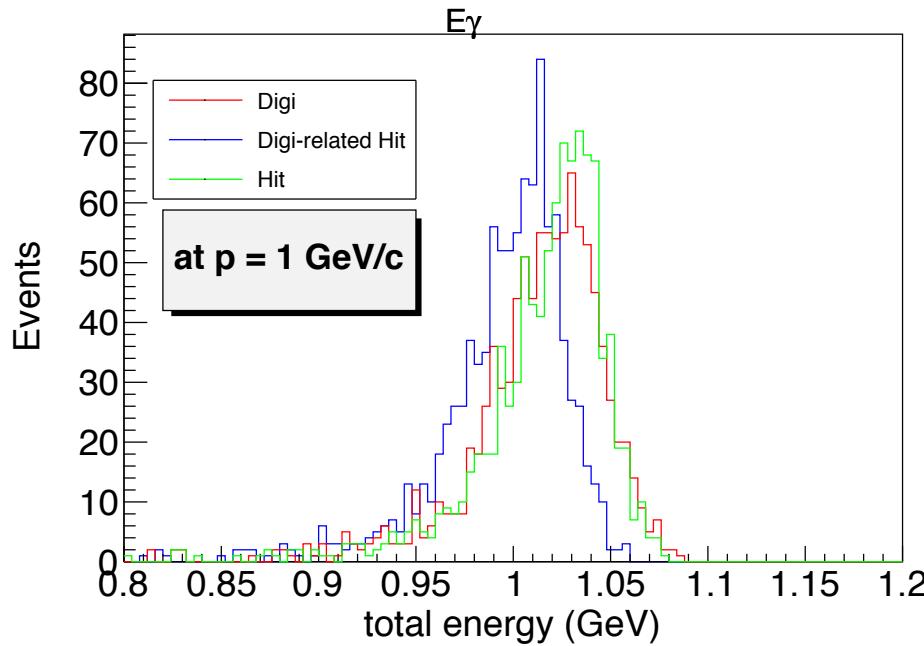
The FPGAs perform the following tasks:

- time adjustment and distribution of the global clock signal;
- noise calibration;
- common mode noise suppression;
- pedestal subtraction;
- autonomous hit detection;
- **conversion of ADC data and linearization of the full data range;**
- transporting the hit information together with the time stamp to the data multiplexer;
- slow control.

*From EMC TDR 2008*

# EMC Simulation: electronic response

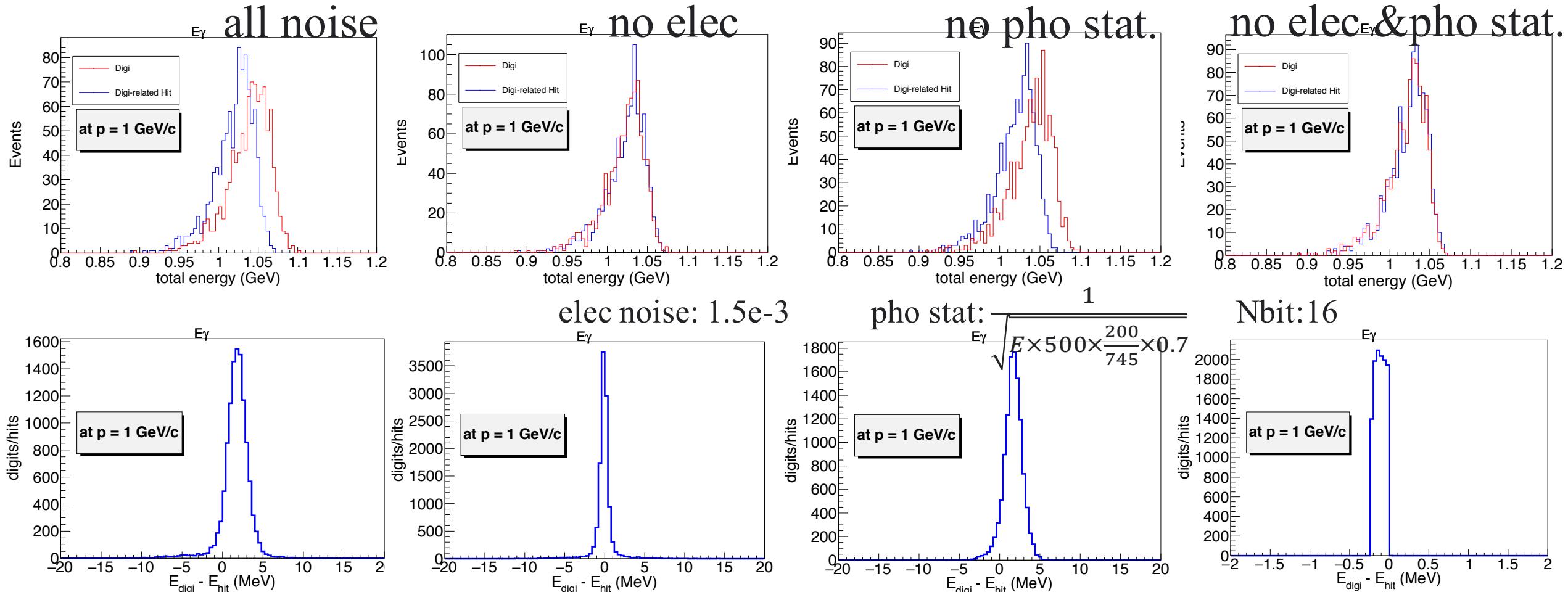
- Digitization: PndEmcDigi
  - Digitized energy and compared to Hits



# EMC Simulation: electronic response

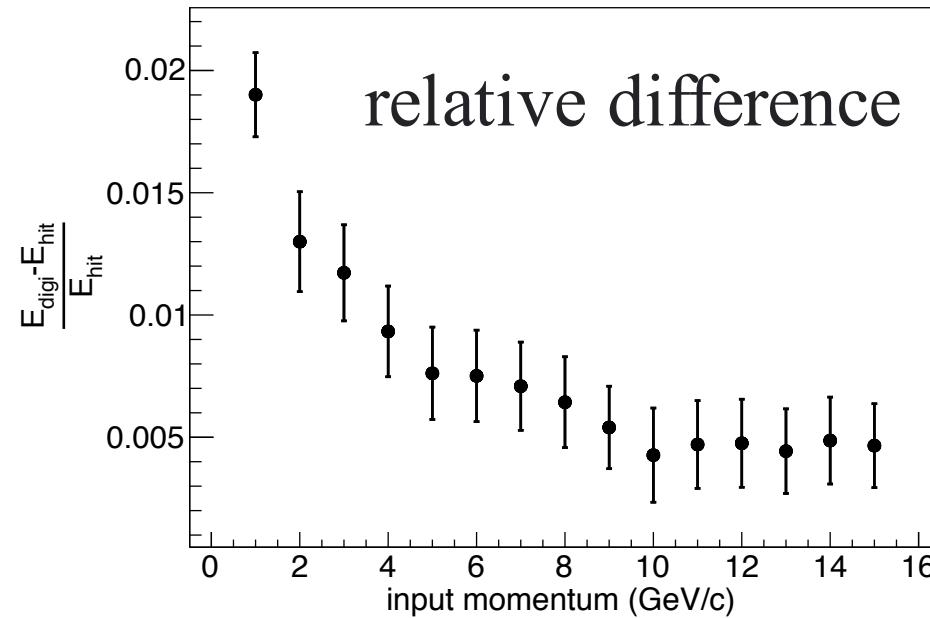
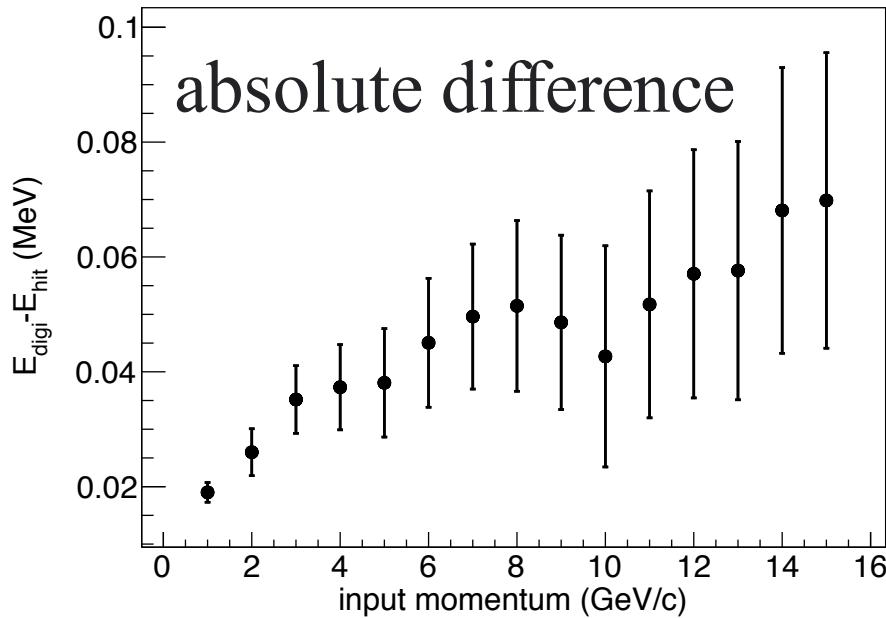
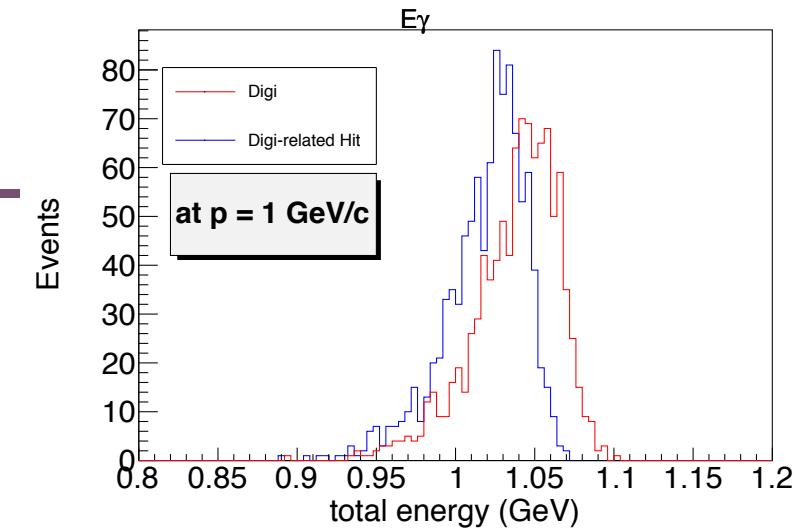
## ➤ Digitization: PndEmcDigi

- $E_{\text{digi}}$  Vs  $E_{\text{hit}}$  (top plots: event energy; bottom plots: crystal energy)



# EMC Simulation: electronic response

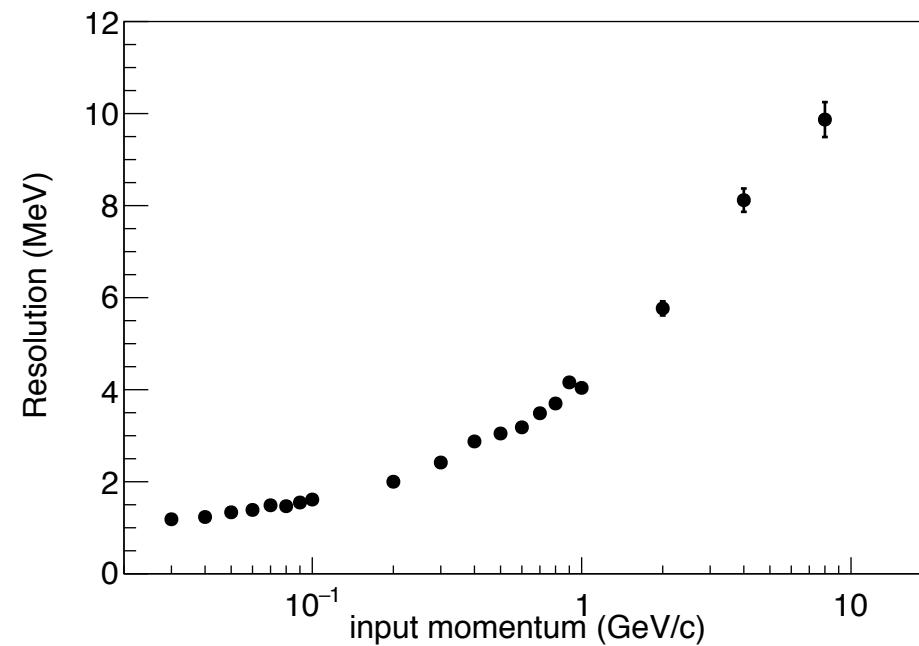
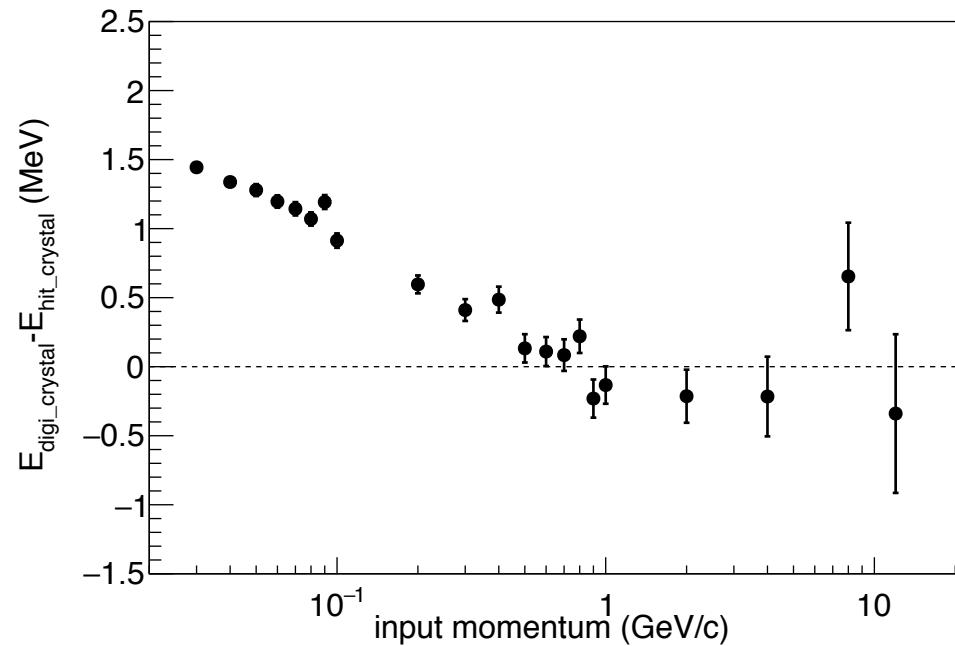
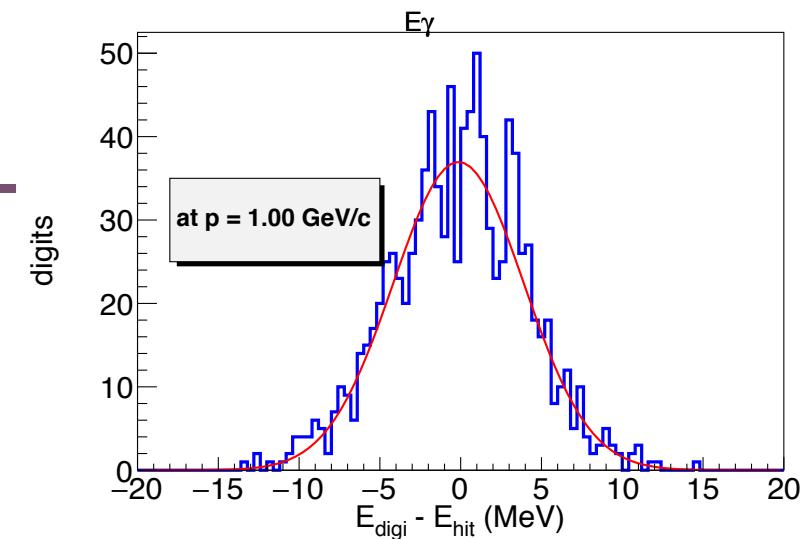
- Digitization: PndEmcDigi
  - Event energy  $E_{\text{digi}}$  Vs  $E_{\text{hit}}$



Relative difference get smaller at high energies

# EMC Simulation: electronic response

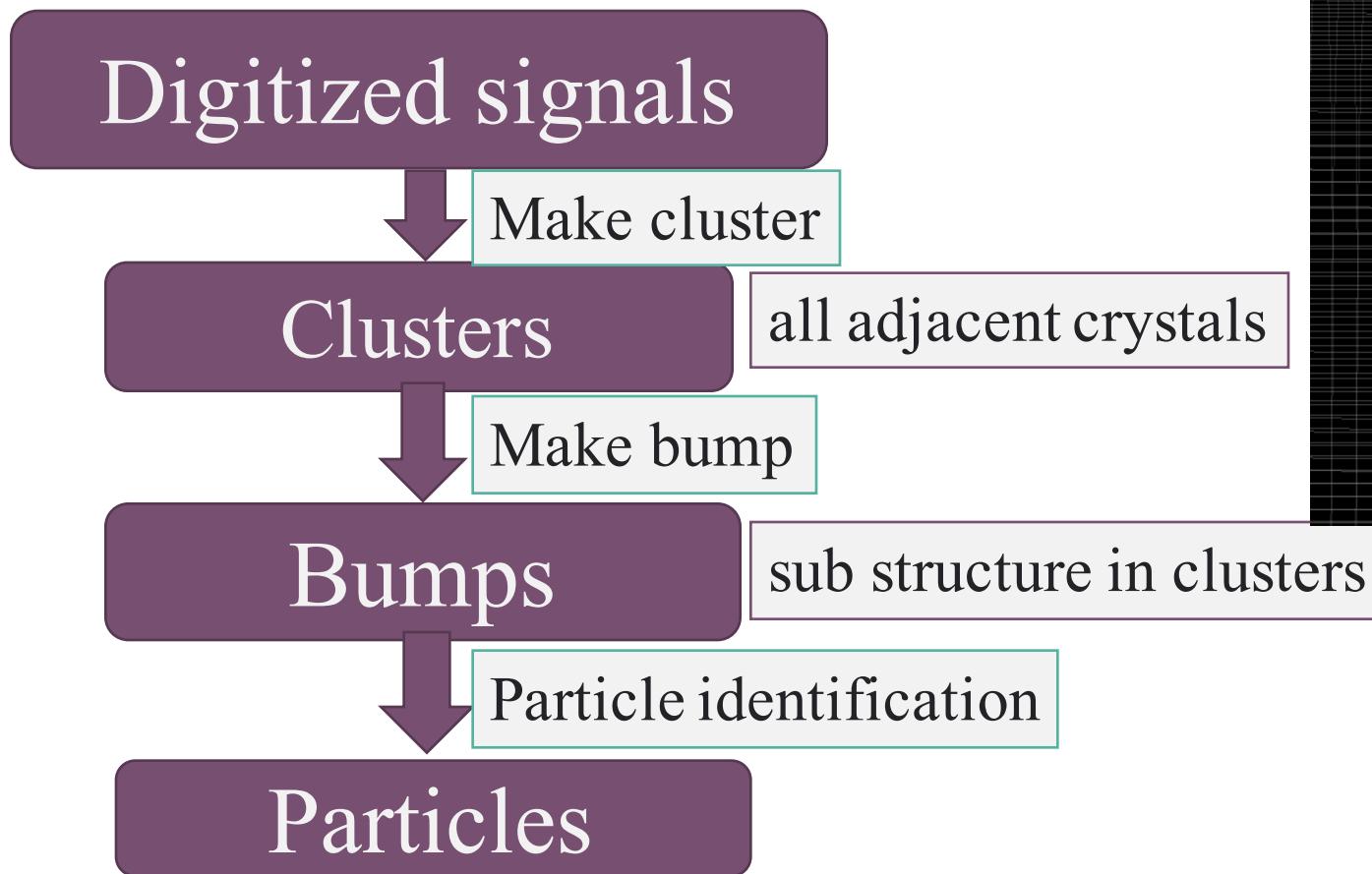
- Digitization: PndEmcDigi
  - Crystal energy  $E_{\text{digi}}$  Vs  $E_{\text{hit}}$  in the bar with maximum deposition



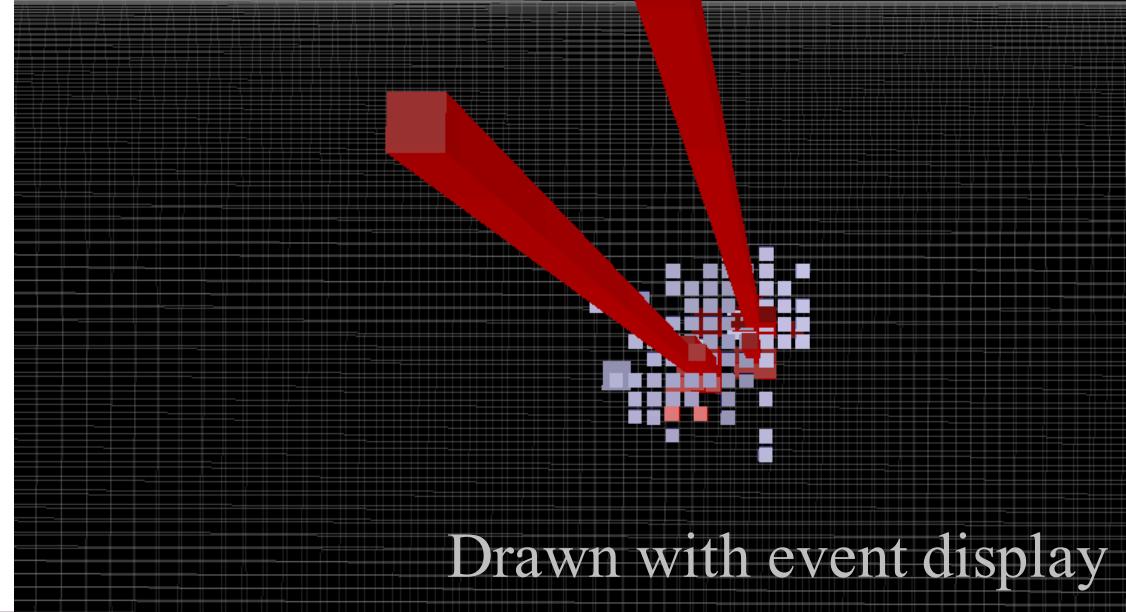
At higher input energy, smaller bias

# Reconstruction

## □ Reconstruction process



## Energy in crystals



# Reconstruction

## ➤ Clusters Reconstruction :

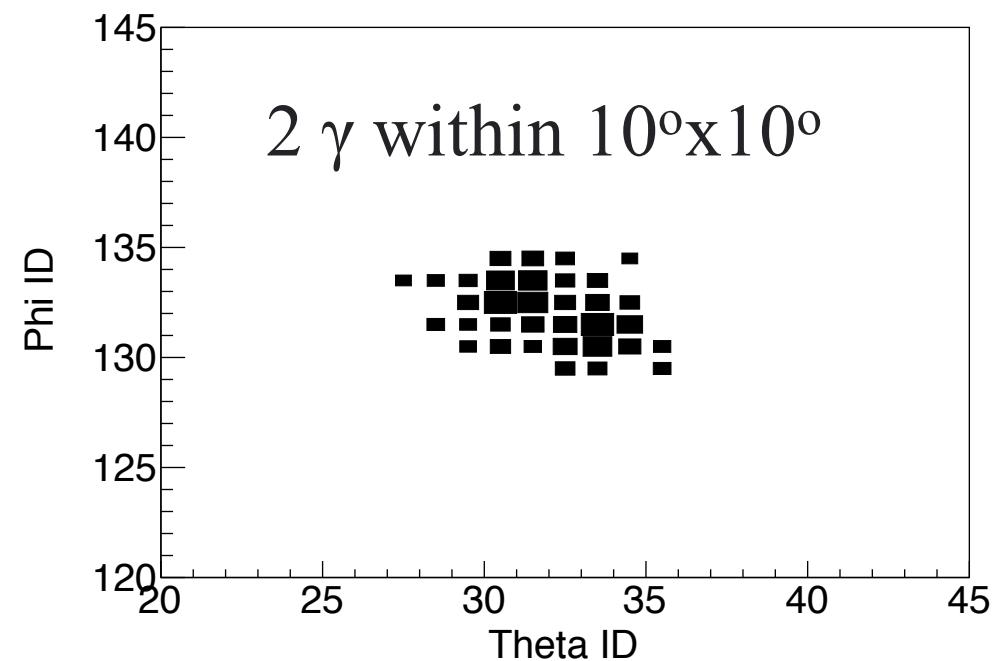
Currently, all adjacent digis are thought to belong to a cluster

### ◆ Algorithm to make clusters:

- loop over digis, judge if a digi is a neighbor of an existing cluster, add it to the cluster.
- if not, create a new cluster
- if a digit close to more than one cluster, then merge them

### Info in PndEmcCluster

- digi index list
- position
- energy
- local maxima



➤ Bumps Reconstruction :

◆ Algorithm to make Bumps:

- PndEmc2DLocMaxFinder;
- PndEmcExpClusterSplitter;
- PndEmcPhiBumpSplitter;

Info in PndEmcBump

- inherit from Cluster
- shared digi with weight

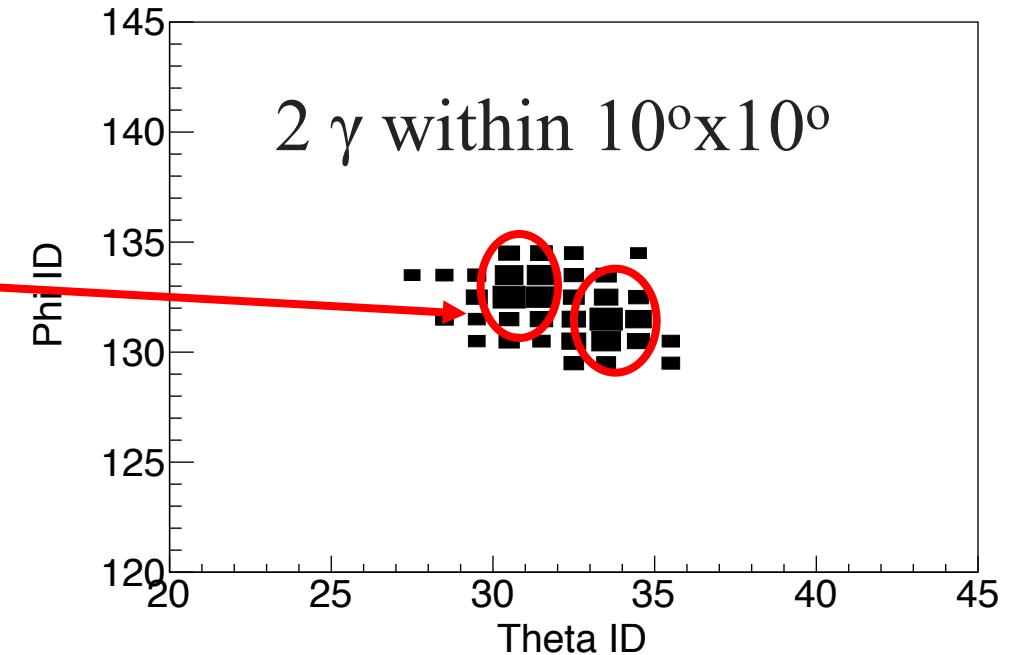
# Reconstruction

➤ Bumps Reconstruction :

◆ Algorithm to make Bumps:

- PndEmc2DLocMaxFinder;
  - Emax\_digi > Eneighbors
  - Emax\_digi > Ecut
  - Emax\_digi/Emax\_neighbor > Rcut

- PndEmcExpClusterSplitter;
- PndEmcPhiBumpSplitter;



No new data, update info in cluster

# Reconstruction

➤ Bumps Reconstruction :

◆ Algorithm to make Bumps:

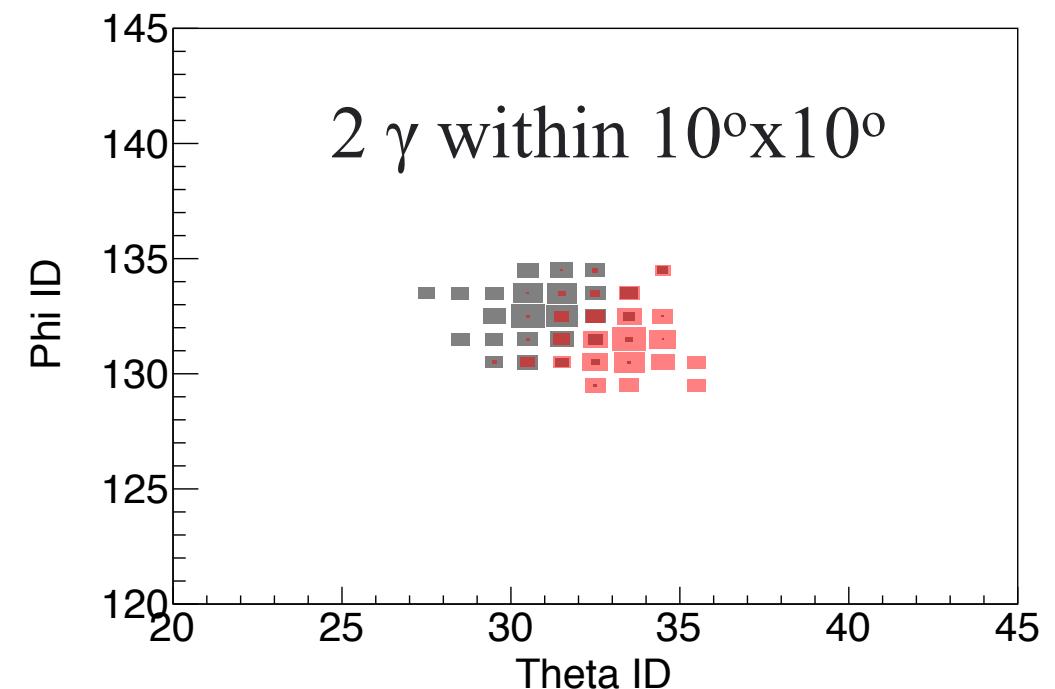
- PndEmc2DLocMaxFinder;
- PndEmcExpClusterSplitter;
  - loop digi, assign weight
  - calculate bump center
  - new weight
  - iteration
- PndEmcPhiBumpSplitter;

New data, use shared digi

B. Aubert et al. NIM A 479 (2002) 1–116

$$w_{i,d} = \frac{E_d \cdot e^{-2.5 \cdot r_{i,d} / R_m}}{\sum_j E_d \cdot e^{-2.5 \cdot r_{j,d} / R_m}}$$

i, j: bump index  
d: digi index

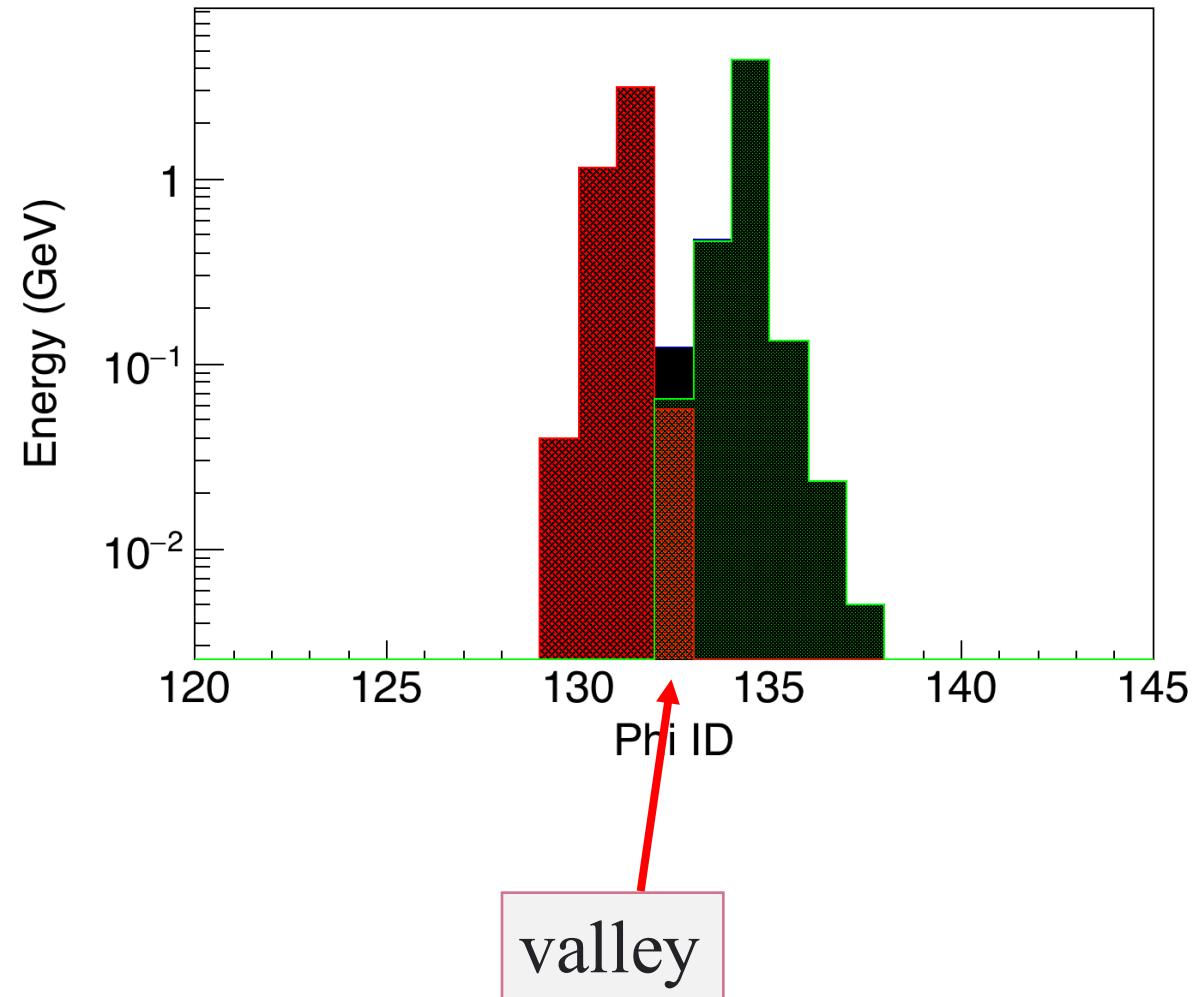


# Reconstruction

➤ Bumps Reconstruction :

◆ Algorithm to make Bumps:

- ◻ PndEmc2DLocMaxFinder;
- ◻ PndEmcExpClusterSplitter;
- ◻ PndEmcPhiBumpSplitter;
  - Project to phi direction
  - split peaks
  - valley split according to areas of left and right sides



Work has been done:

- Simulation and reconstruction has been checked from particle incidence to signal digitization
- Results in MCTrack, EmcPoint, EmcHit, EmcWave, EmcDigi, EmcCluster, EmcBump seem reasonable.

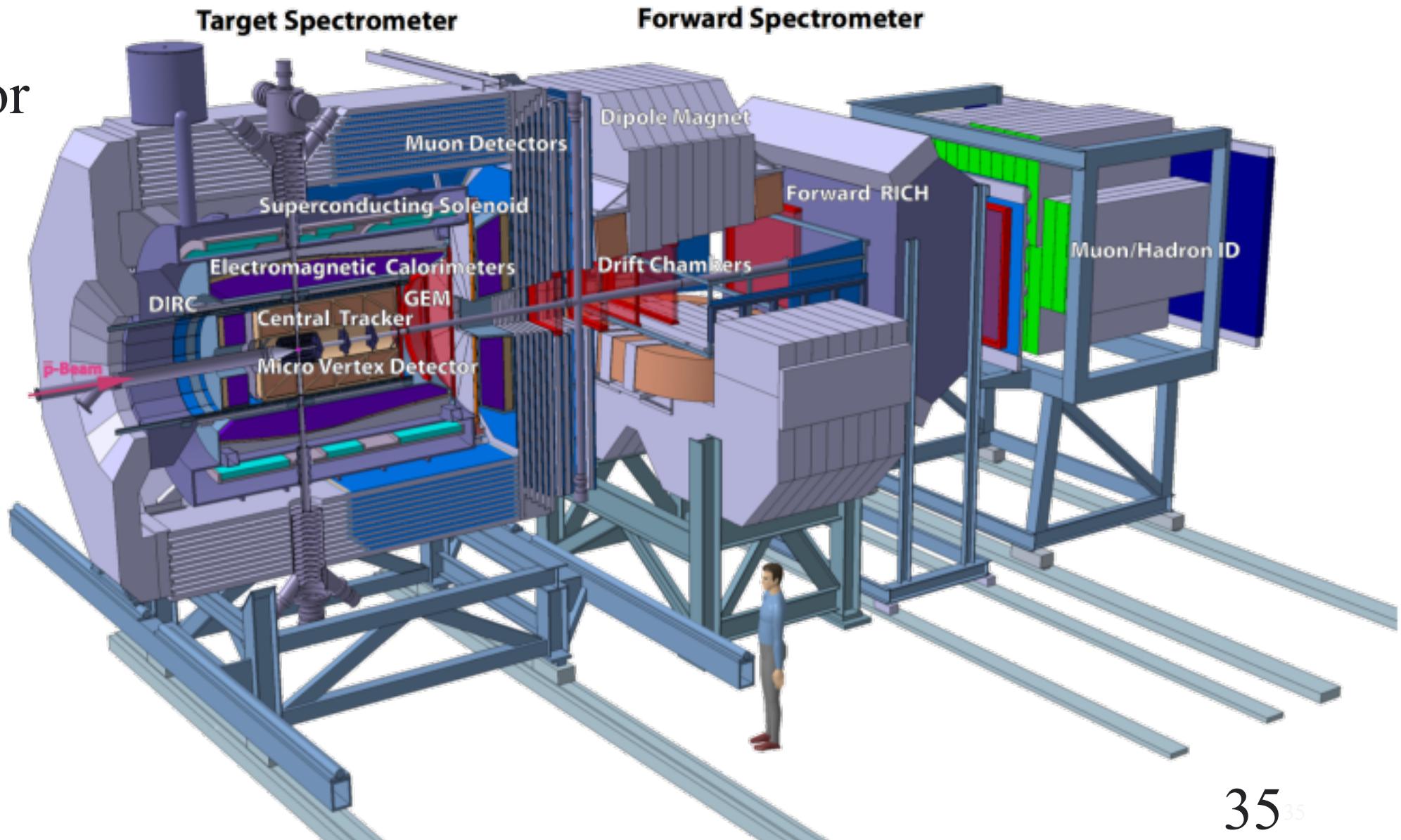
Work to do:

- more careful check: position, PID, efficiency, ...
- contact with hardware exports for validation of the software: detector and electronics
- compare with prototype test or other experimental result

Thank you for your attention!

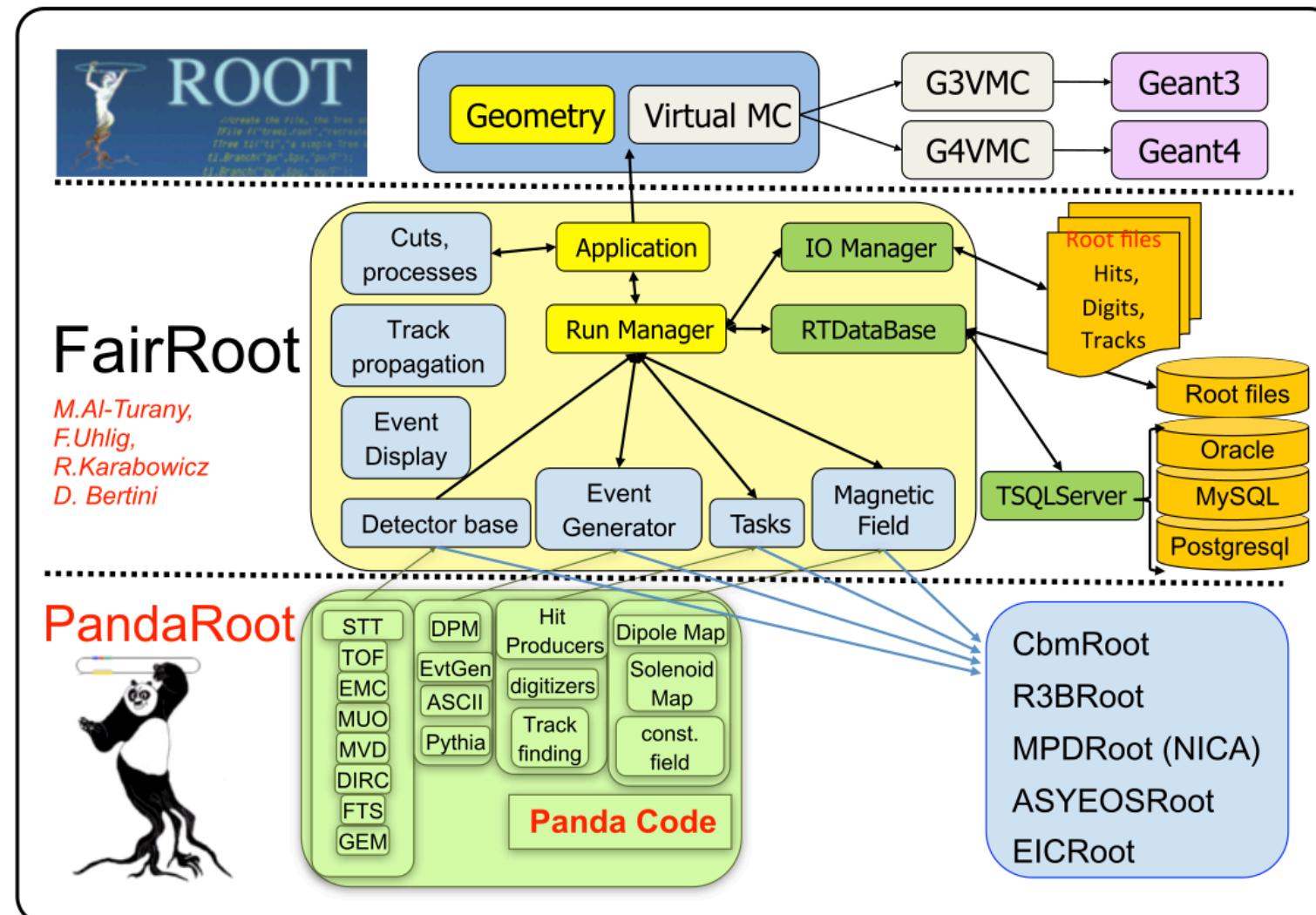
# Introduction: Detector

- Detector



# Introduction: Software

- Software

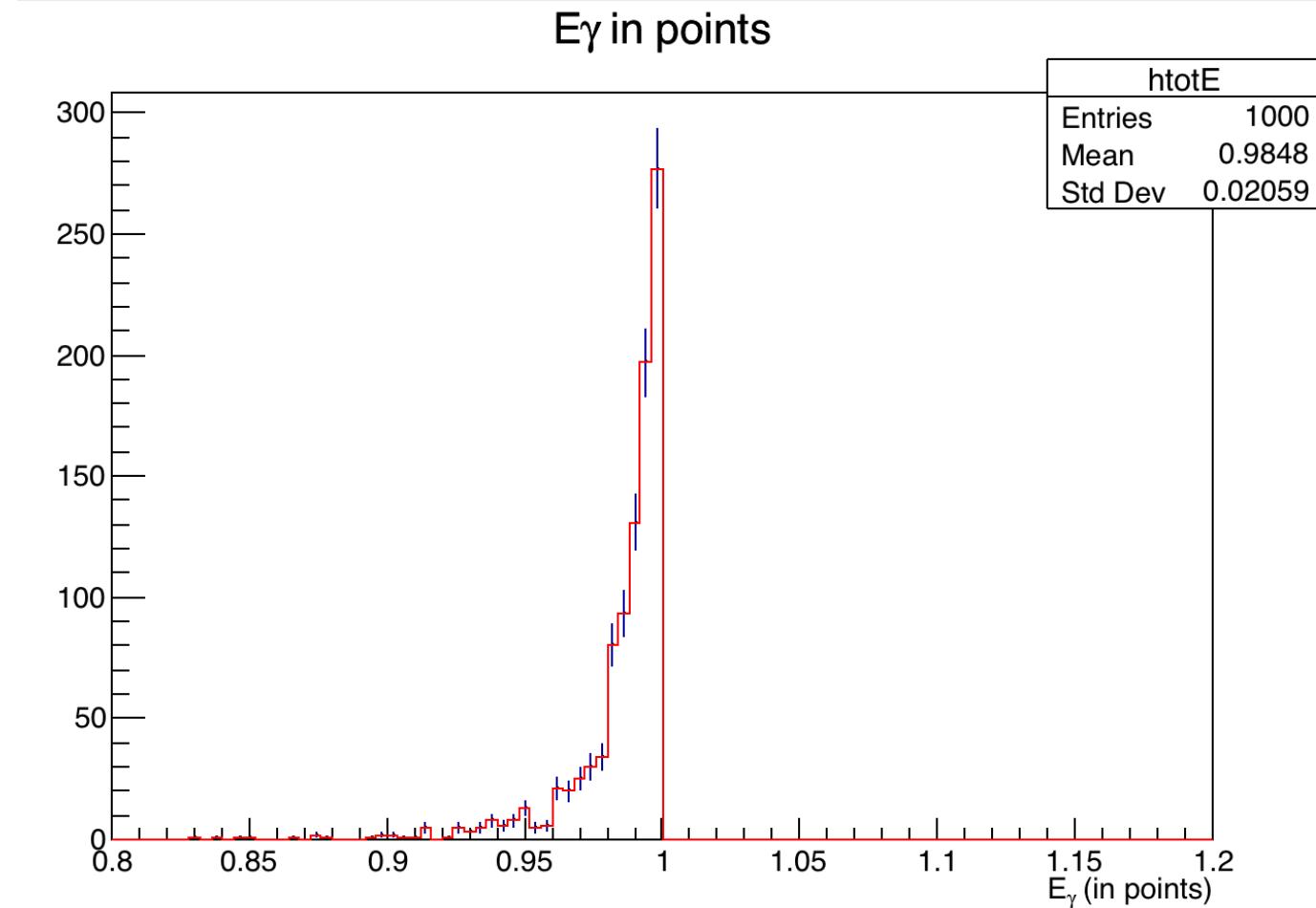


M Al-Turany et al 2012 J. Phys.: Conf. Ser. 396 022001

# Simulation, example at 1 GeV/c

Total Energy in `PndEmcPoints`  
Total Energy in `PndEmcHit`

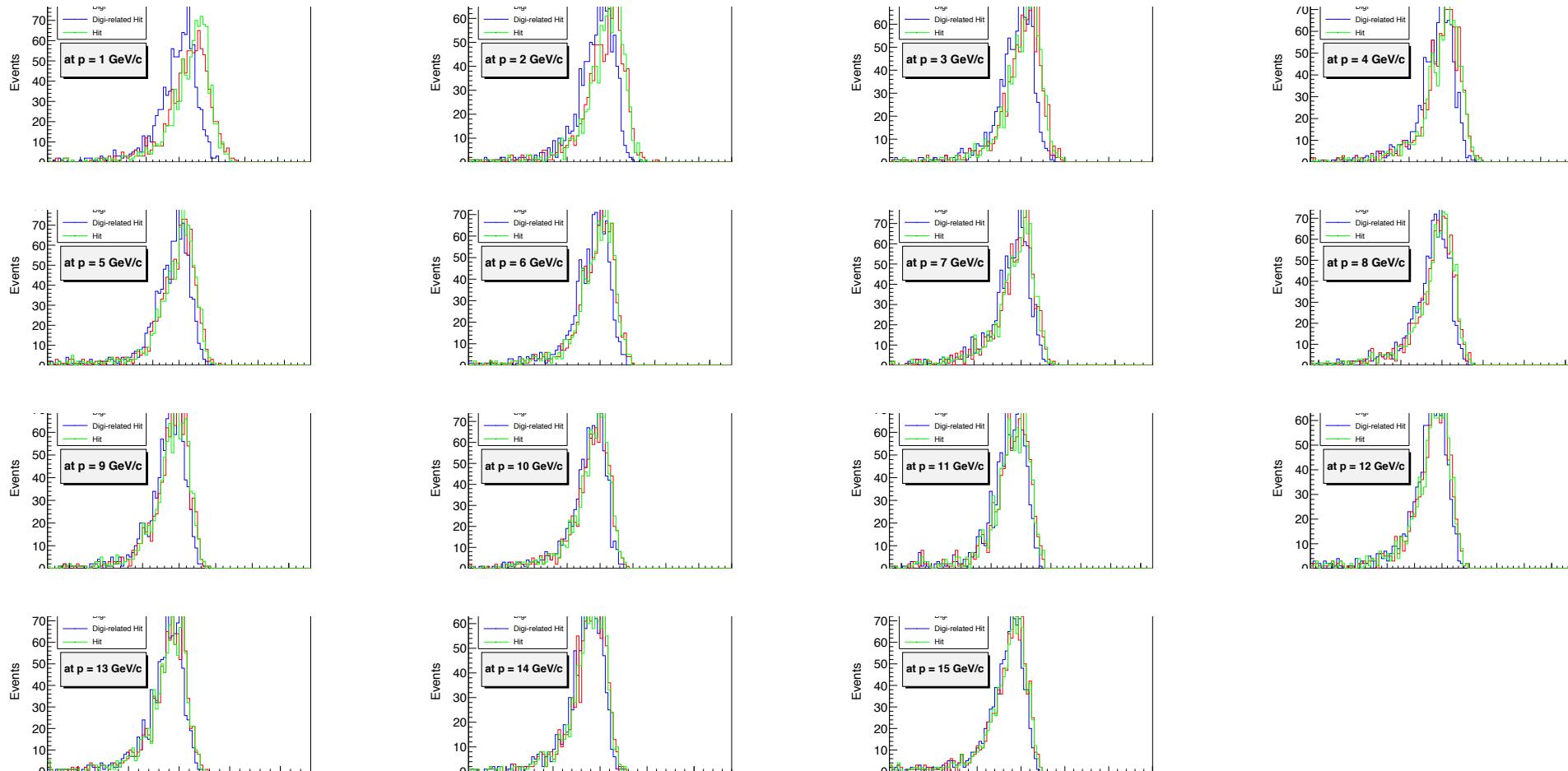
If no nonuniformity, energy in points and hits are the same.



# EMC Simulation: electronic response

## ➤ Digitization: PndEmcDigi

- total energy  $E_{\text{digi}}$  Vs  $E_{\text{Hit}}$ , difference get smaller at high energys



# EMC Simulation: electronic response

## ➤ Digitization: PndEmcDigi

- crystal energy  $E_{\text{digi}}$  Vs  $E_{\text{Hit}}$ , **differences are similar at different  $E_{\gamma}$**

