

EMC Simulation



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

(a) University of Science & Technology of China, Hefei

(b) Institute of High energy physics, CAS, China

Outline

- ✓ Introduction of Panda
 - Detector
 - Electromagnetic Calorimeters(Target)
- ✓ EMC in PandaRoot
 - EMC simulation
 - EMC reconstruction
- ✓ Summary

Introduction

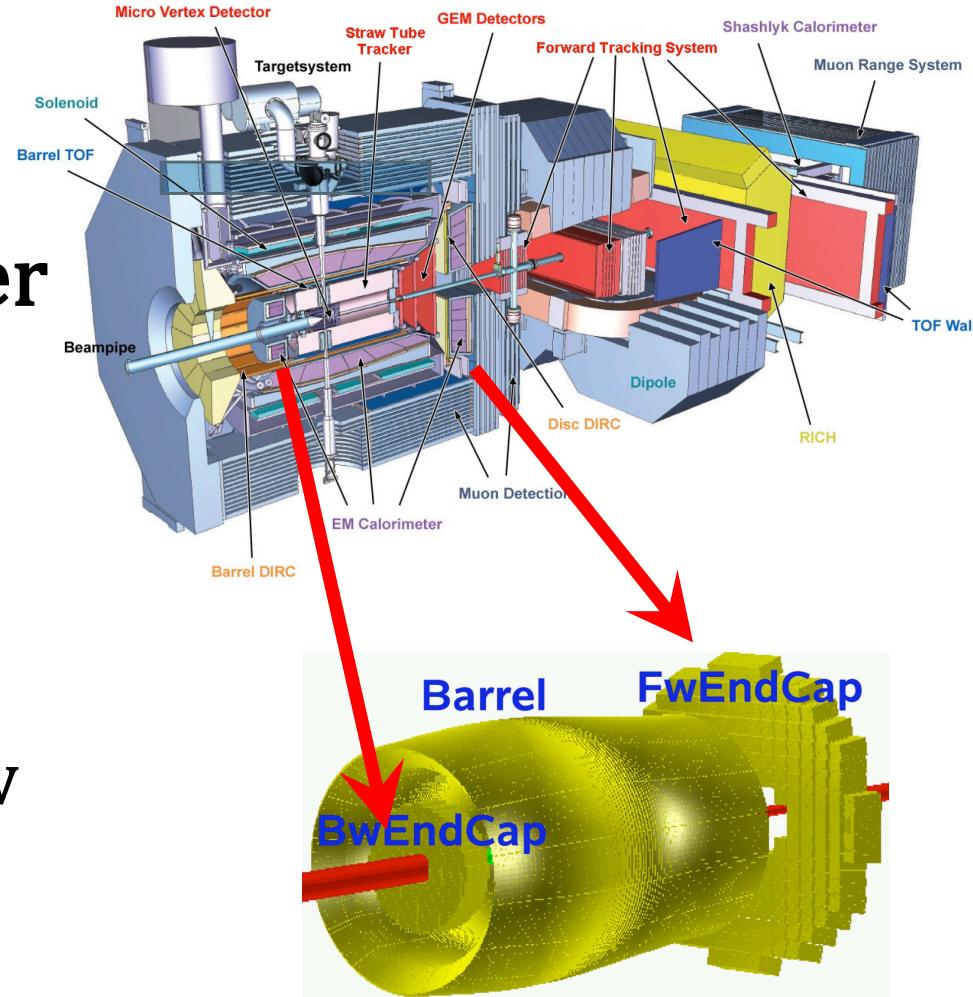
[Detector]

✓ Panda detector

- Target calorimeter
- Shashlyk calorimeter

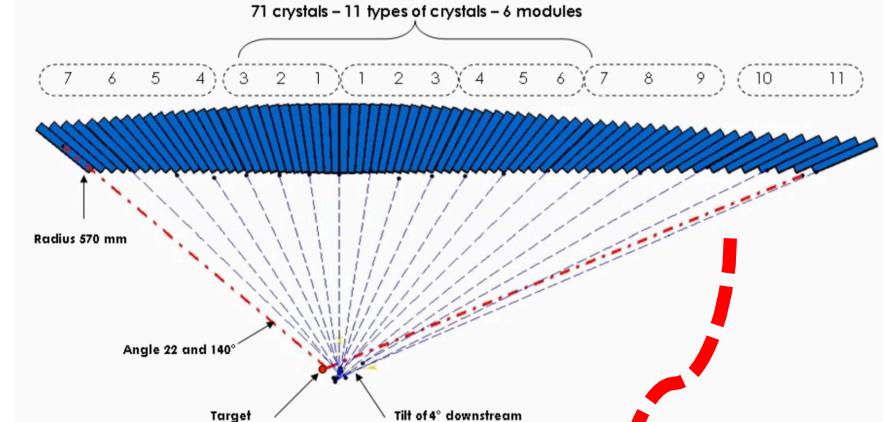
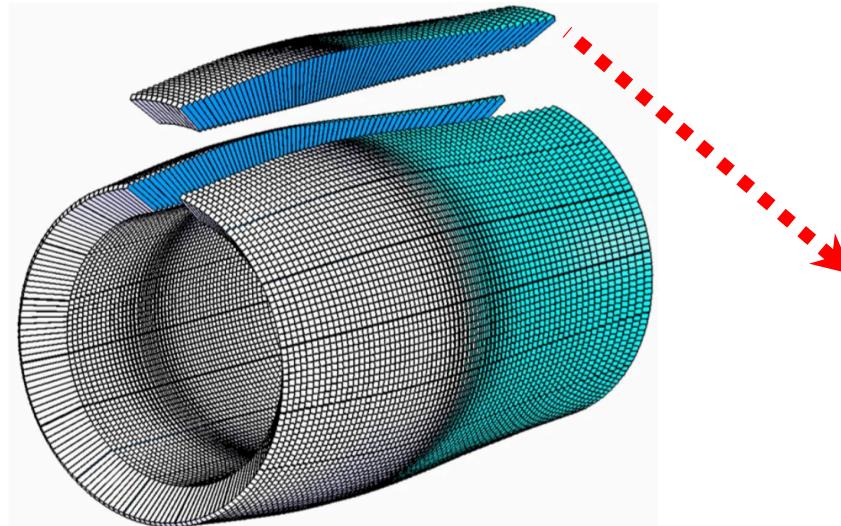
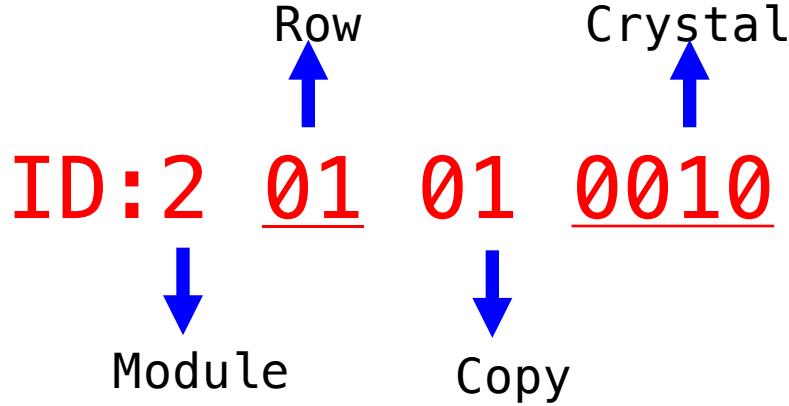
✓ EMC(TDR 2008)

- $\sigma_E/E < 1\%$
- Spatial resolution(barrel)<0.3°
- $E_{threshold}$ (Photon): 10MeV
- $E_{threshold}$ (single crystal): <3MeV
- Angular coverage: 99%



Introduction

[Target EMC]



super modules																			
SM1		SM2				SM3			SM4				SM5			SM6			SM7
L	7me	6me	5me	4me	3me	2me	1me	1pe	2pe	3pe	4pe	5pe	6pe	7pe	8pe	9pe	10pe	11pe	e
R																			
L	7md	6md	5md	4md	3md	2md	1md	1pd	2pd	3pd	4pd	5pd	6pd	7pd	8pd	9pd	10pd	11pd	d
R																			
L	7mc	6mc	5mc	4mc	3mc	2mc	1mc	1pc	2pc	3pc	4pc	5pc	6pc	7pc	8pc	9pc	10pc	11pc	c
R																			
L	7mb	6mb	5mb	4mb	3mb	2mb	1mb	1pb	2pb	3pb	4pb	5pb	6pb	7pb	8pb	9pb	10pb	11pb	b
R																			
L	7ma	6ma	5ma	4ma	3ma	2ma	1ma	1pa	2pa	3pa	4pa	5pa	6pa	7pa	8pa	9pa	10pa	11pa	a
R																			
	7m	6m	5m	4m	3m	2m	1m	1p	2p	3p	4p	5p	6p	7p	8p	9p	10p	11p	

→

\bar{p}

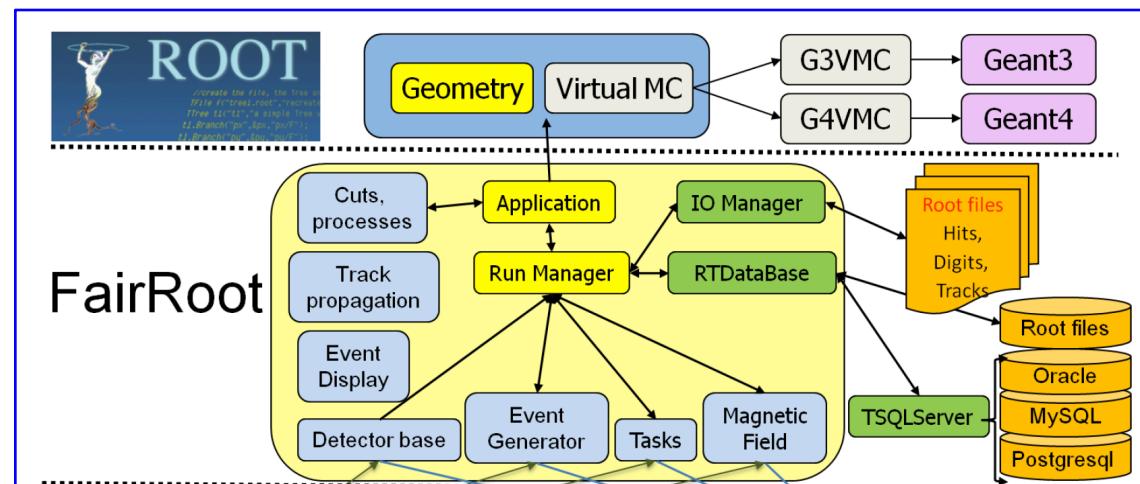
PandaRoot

[EMC Simulation]

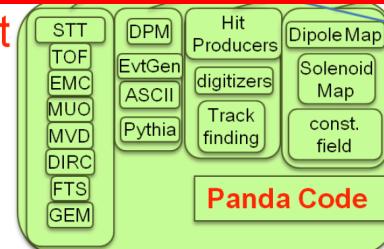
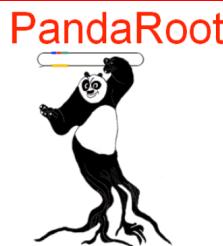
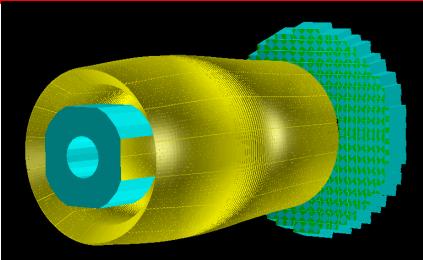
✓ PandaRoot framework

- FairRoot-17.10b
- Root 6.10

<https://github.com/FairRootGroup/FairSoft>



Target calorimeter

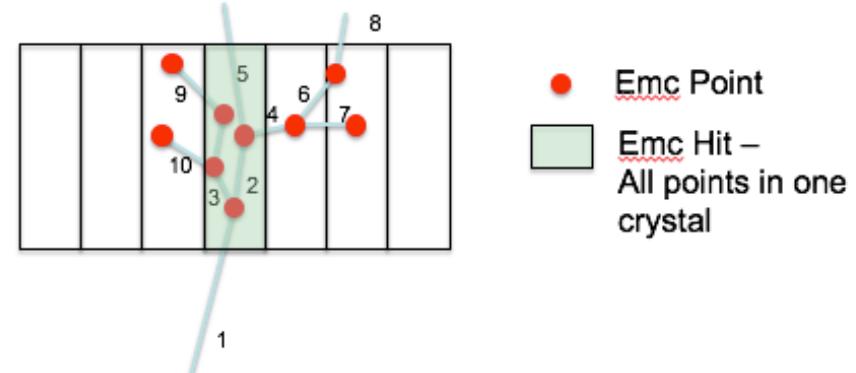
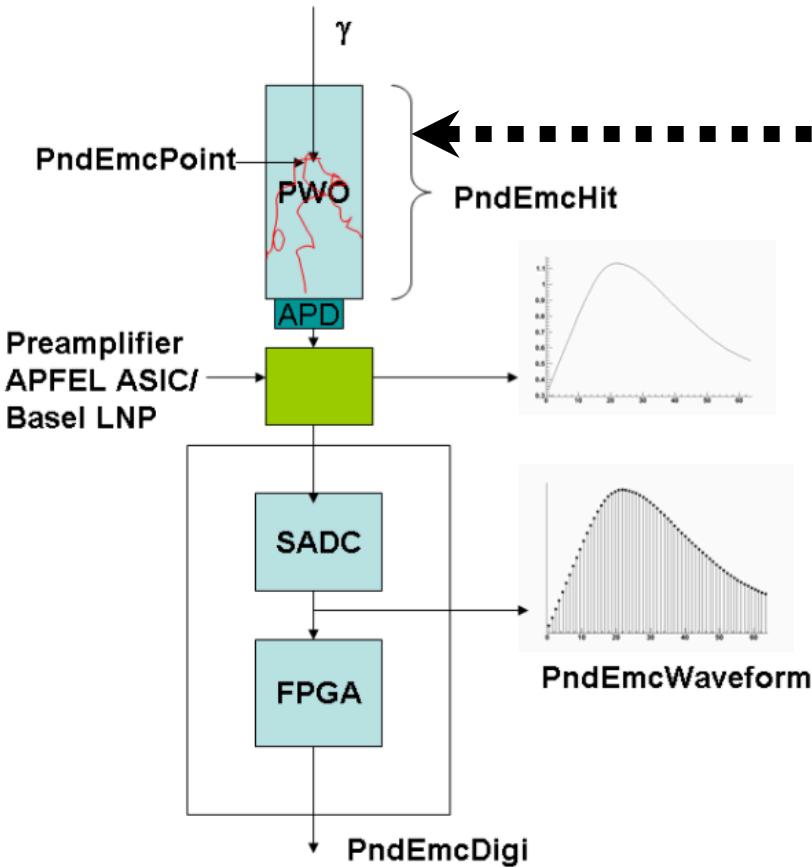


CbmRoot
R3BRoot
MPDRoot (NICA)
ASYEOSRoot
EICRoot

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

EMC Simulation

[Simulation]

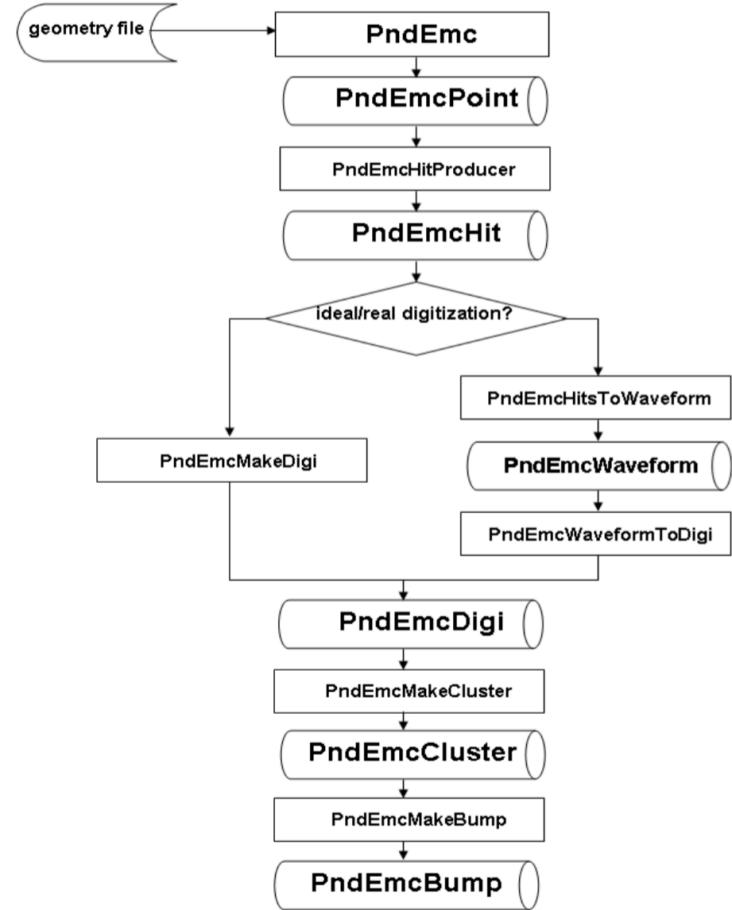
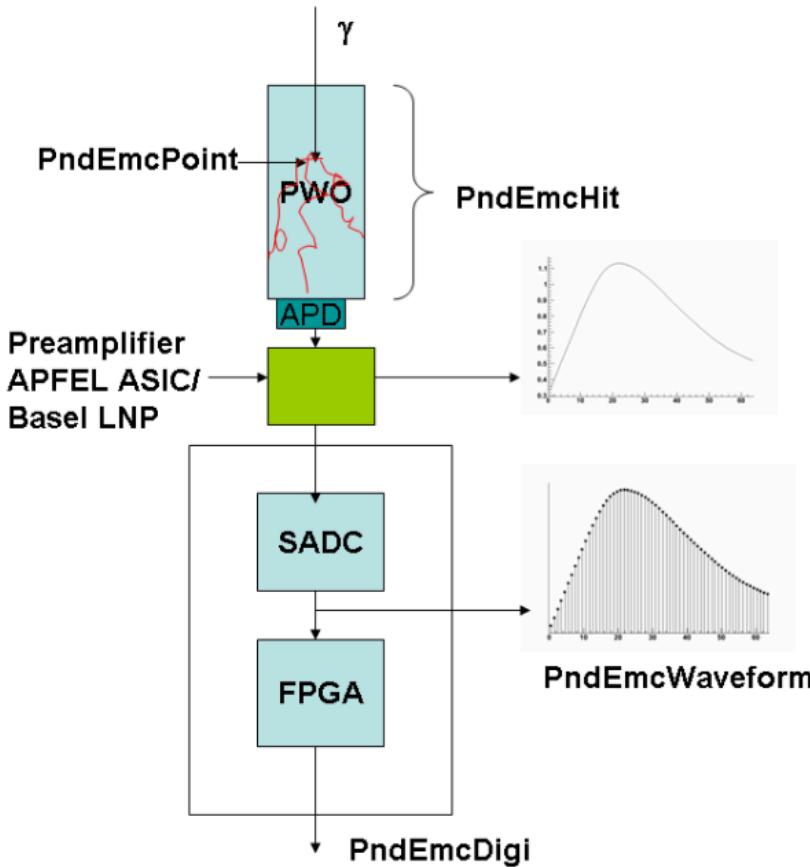


- ✓ Event Generation
 - Box Generator
- ✓ Transport Model
 - Geant3, Geant4
- ✓ Digitization

D. Melnychuk 24.07.2012

Data flow

[Simulation & Reconstruction]



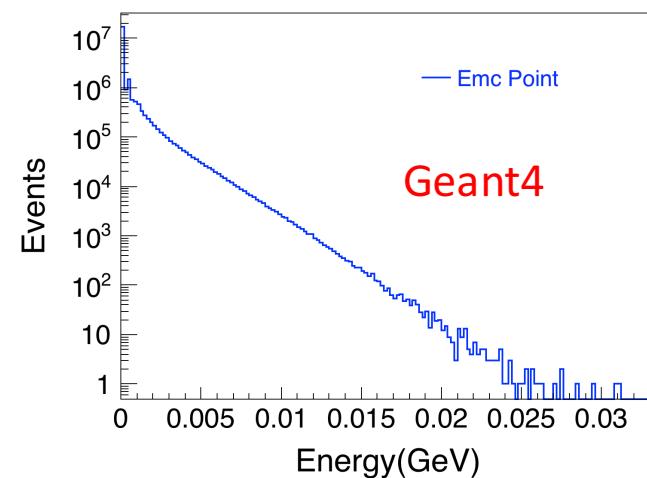
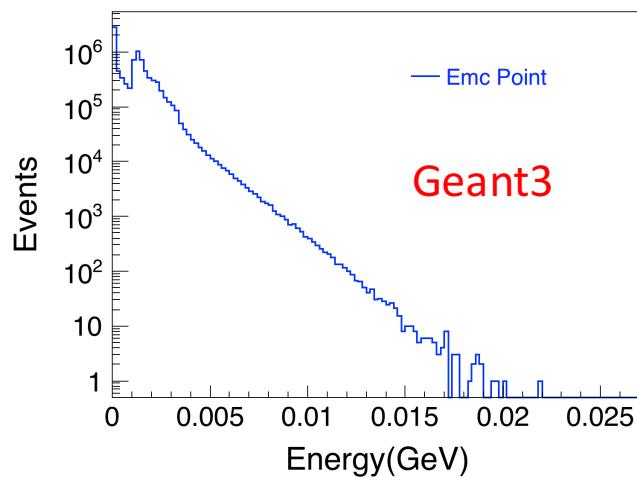
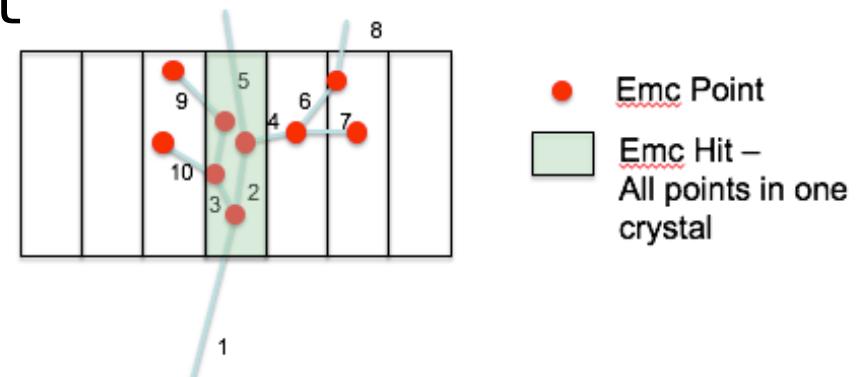
D. Melnychuk 24.07.2012

EMC Simulation

[EmcPoint]

✓ PndEmcPoint->FairMCPoint

- Gamma (1GeV)
- Events=10000
- Phi(0, 360)
- Theta(22, 140)

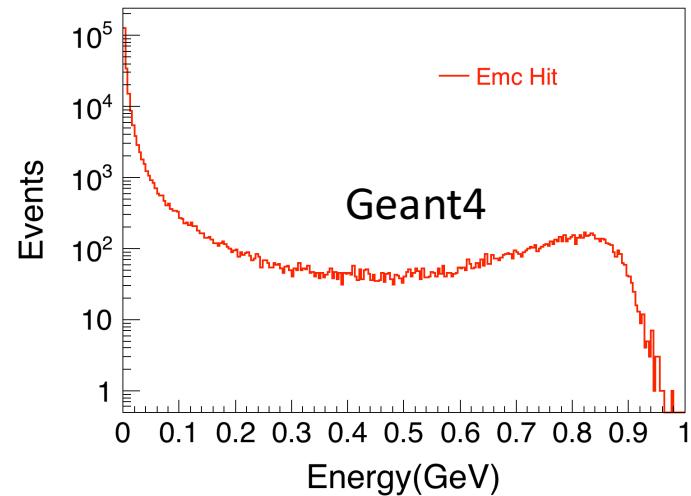
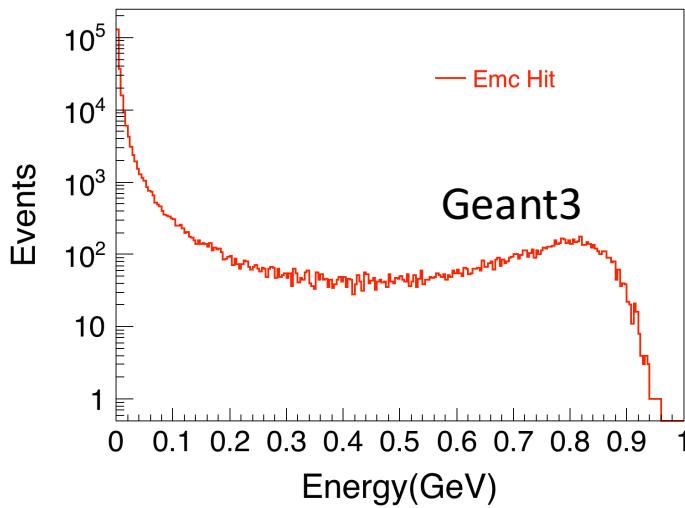
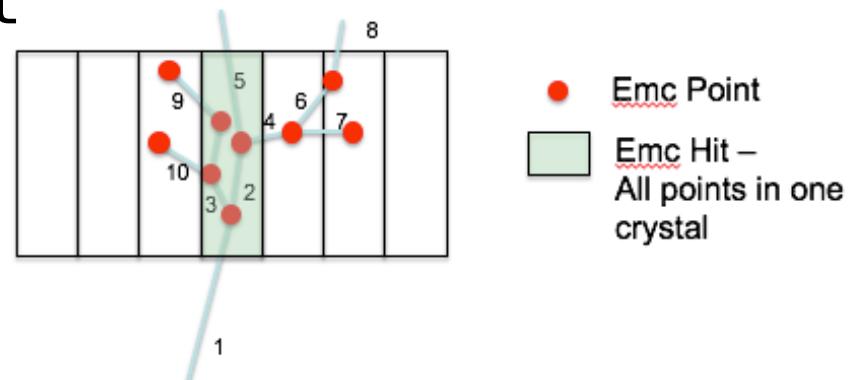


EMC Simulation

[EmcPoint]

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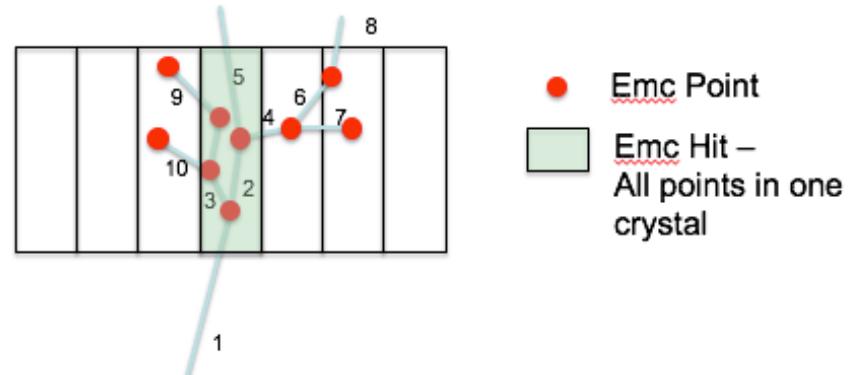


EMC Simulation

[EmcHit]

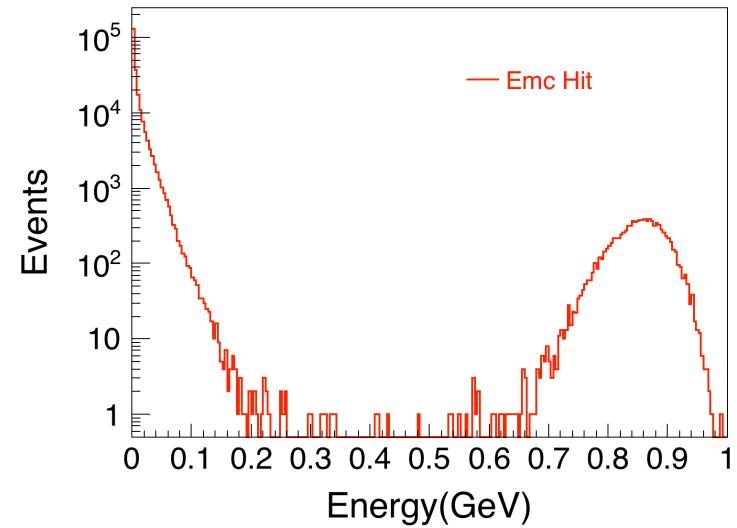
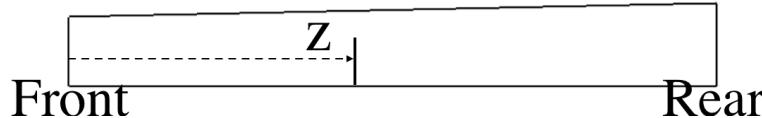
✓ PndEmcHitProducer

- Gamma (1GeV)
- Events=10000
- Energy deposition
- Nonuniform light yield



$$Energy_{hit} = \sum factor \cdot Energy_{point}$$

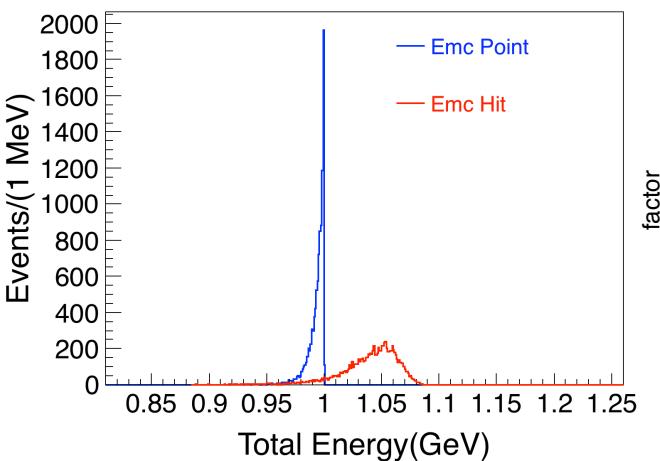
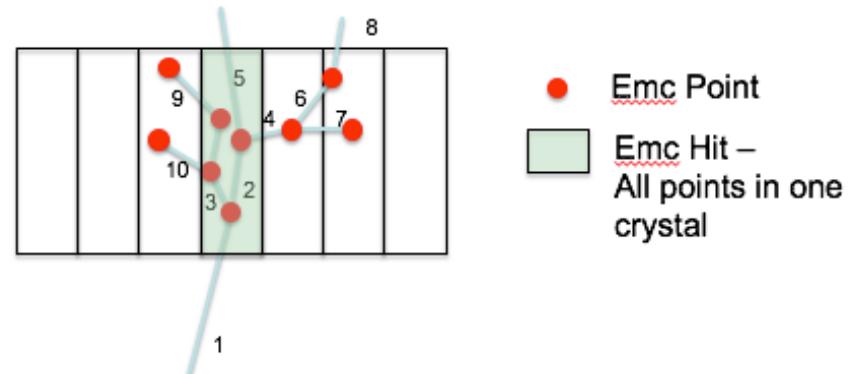
$$factor = c_0 + z(c_1 + z \cdot c_2)$$



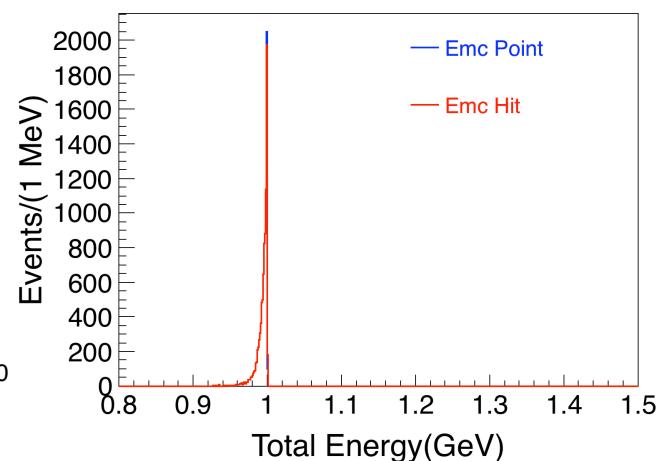
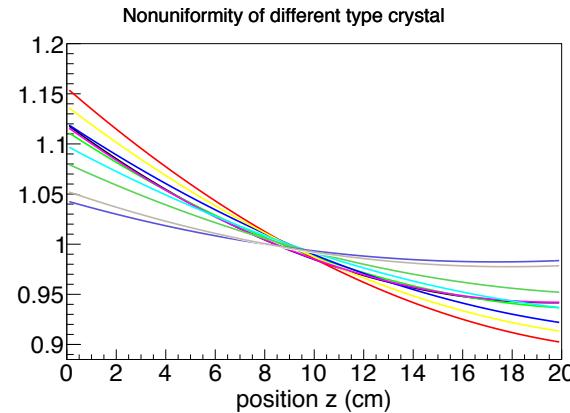
EMC Simulation

[EmcHit]

- ✓ PndEmcHitProducer
 - Gamma (1GeV)
 - Events=10000
 - Total energy deposition
 - Nonuniform light yield



Nonuniformity



No Nonuniformity

EMC Simulation

[Pulseshape]

✓ PndEmcHitsToWaveform

➤ PndEmcAsicPulseshape

- Barrel Emc
- Bwd endcap
- Fwd endcap

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

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

➤ PndEmcCRRCPulseshape

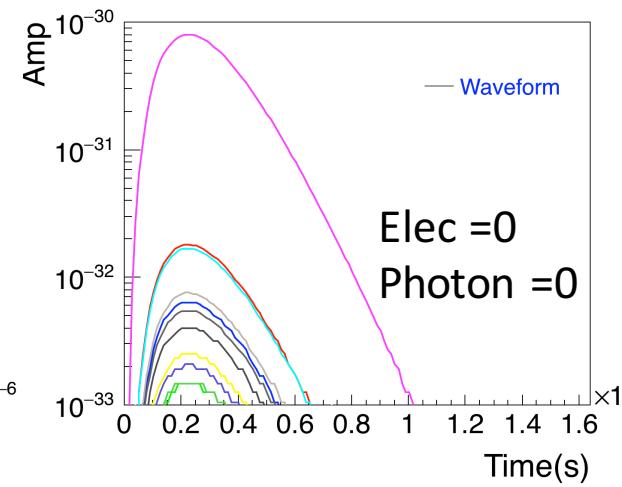
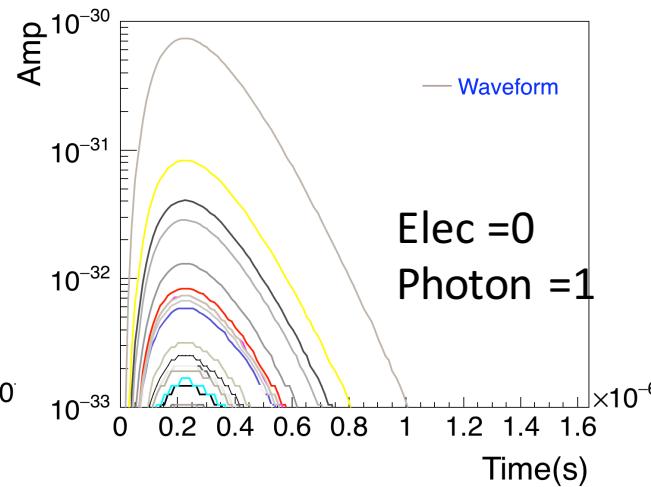
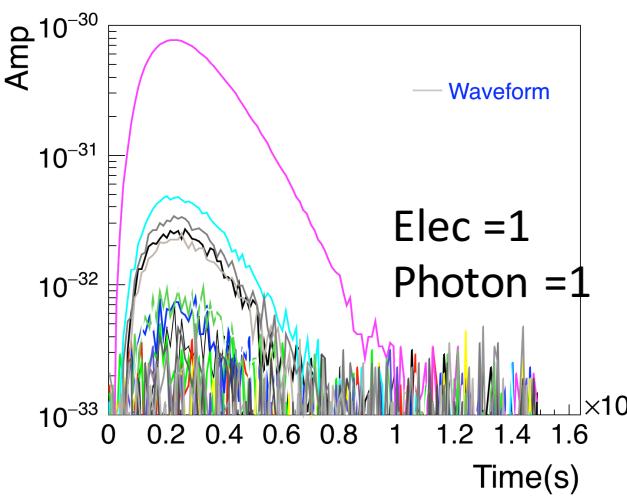
- Shashlyk calorimeter

EMC Simulation

[EmcWaveform]

✓ PndEmcWaveform

- Gamma (1GeV)
- Elec-noise(Y/N)
- Photon statistic (Y/N)

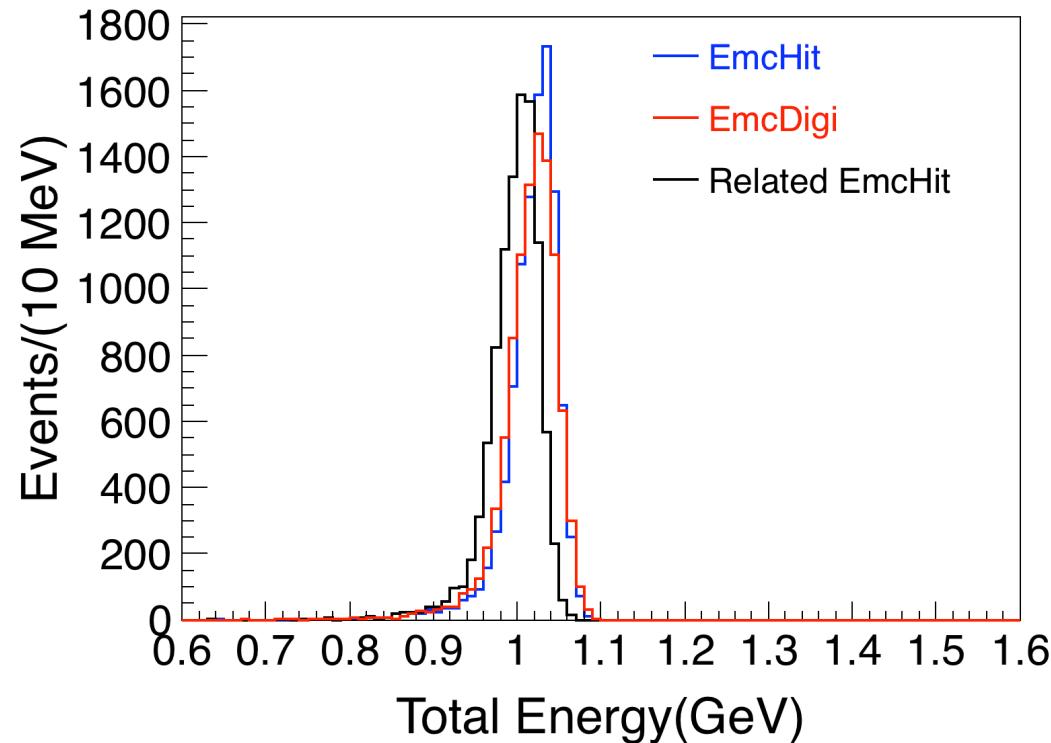


EMC Simulation

[EmcDigi]

✓ PndEmcWaveformToDigi

- Gamma (1GeV)
- Events = 10000
- Phi(0, 360)
- Theta(22, 140)
- Total energy depositon

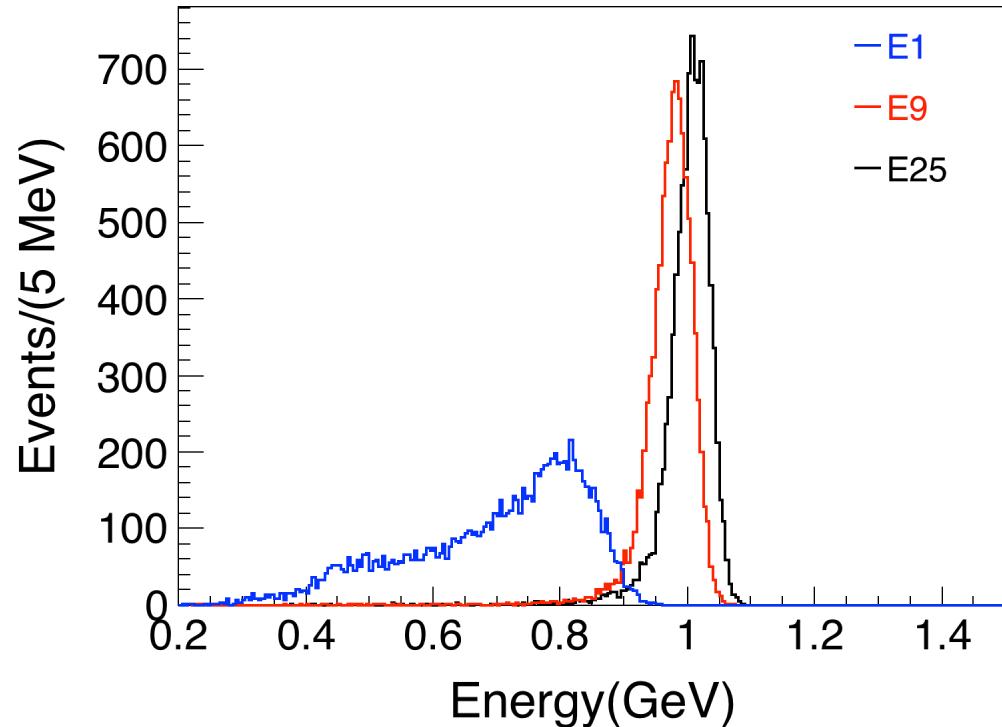


EMC Reconstruction

[EmcCluster]

✓ PndEmcCluster

- Gamma (1GeV)
- Events =10000
- Geant3
- Generator: Box
- Phi(0, 360)
- Theta(22, 140)
- E1:maximum energy
- E9:3x3 matrix crystals
- E25:5x5 matrix crystals

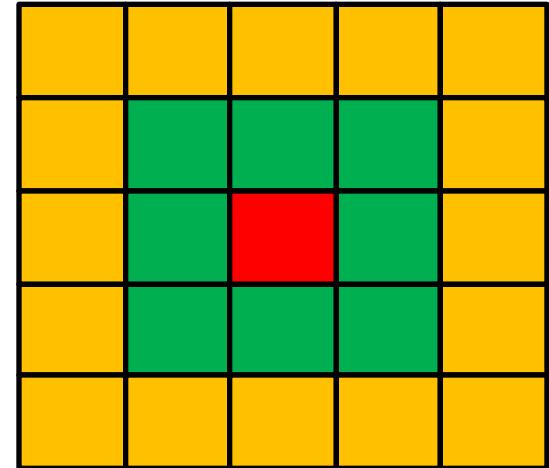


EMC Reconstruction

[Position]

✓ PndEmcCluster

- Total Energy of Cluster
 - energy()
- Where is cluster
 - where();x();y();z();
- Zernike moment
 - Z20()
 - Z53()
- Lateral energy deposition
 - LatMom()



EMC Reconstruction

[Position]

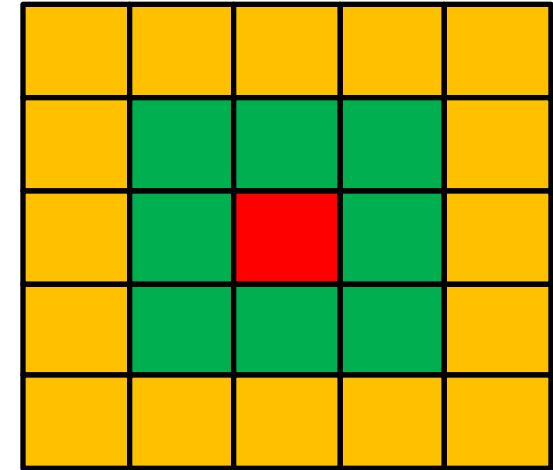
✓ PndEmcClusterEnergySums

- Partial Energy of Cluster

```
virtual Double_t E1() const;  
virtual Double_t E9() const;  
virtual Double_t E25() const;
```

- Energy ratios of Cluster

```
virtual Double_t E1E9() const;  
virtual Double_t E9E25() const;
```



EMC Reconstruction

[Position]

✓ **PndEmcClusterProperties**

- Where(TString method, std::vector<Double_t> params)
- LiloWhere(std::vector<Double_t> params);
- LinearWhere();
- GravWhere();

$$W(E_i) = \text{Max}[0, A(E) + \ln(E_i/E)]$$

$$A(E) = parA - parB * \exp(-parC * E^{1.171}) * E^{-0.534}$$

$$parA = 4.071$$

$$parB = 0.678$$

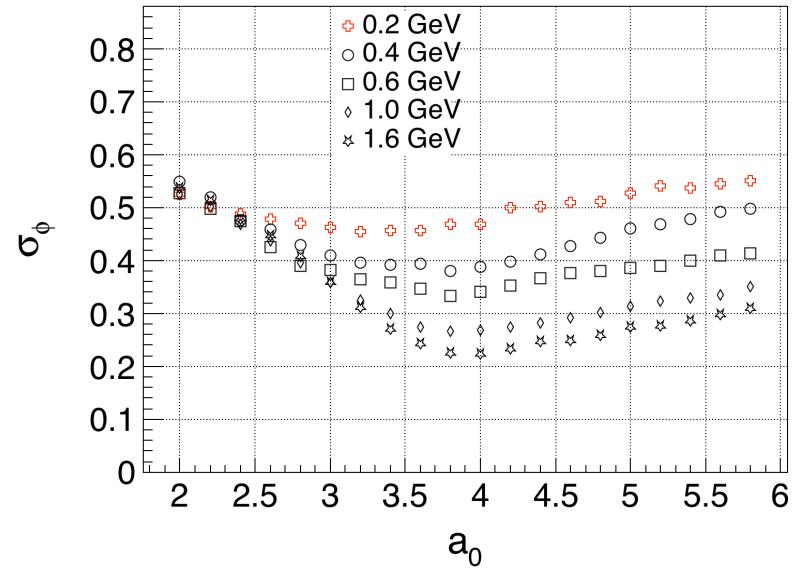
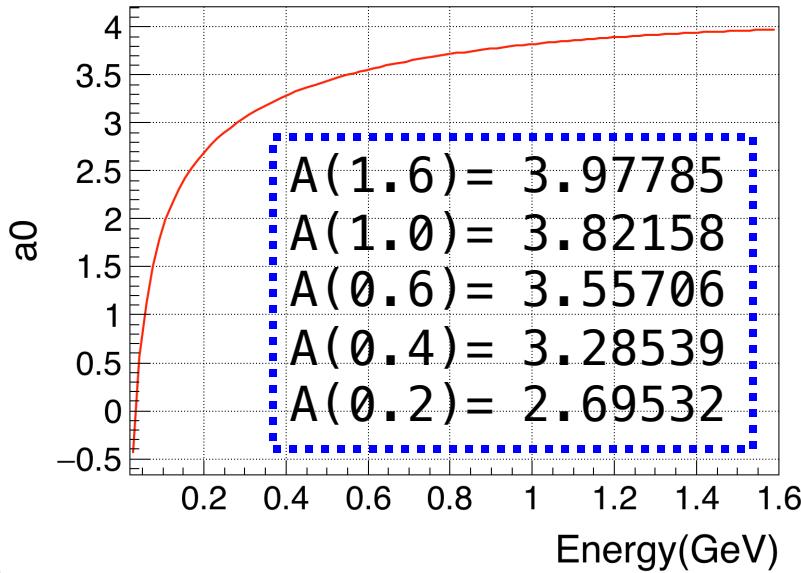
$$parC = 1.0$$

EMC Reconstruction

[Position]

$$W(E_i) = \text{Max}[0, A(E) + \ln(E_i/E)]$$

$$A(E) = \text{parA} - \text{parB} * \exp(-\text{parC} * E^{1.171}) * E^{-0.534}$$



EMC Reconstruction

[Resolution]

✓ Energy resolution

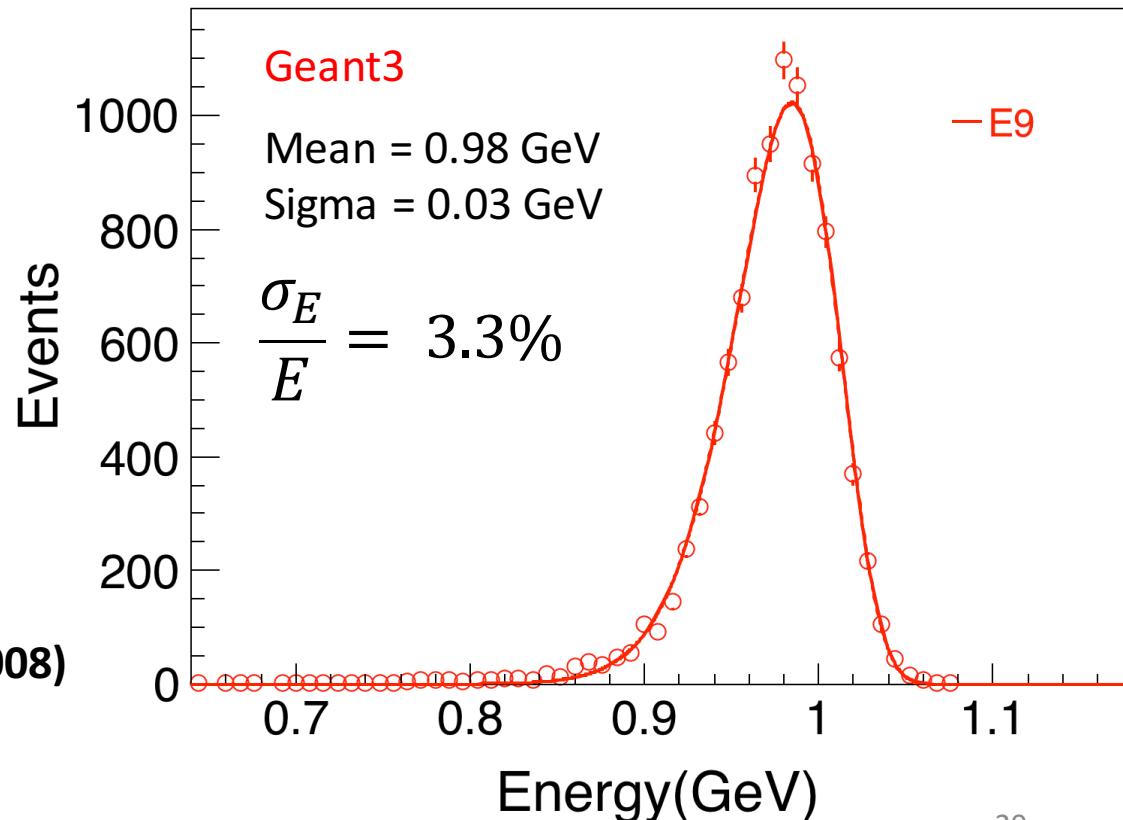
- Gamma (1GeV)
- Events = 10000
- Phi(0, 360)
- Theta(22, 140)
- 3*3 Matrix crystals
- Novosibirsk function

$$f(E) = A_S \exp(-0.5 \ln^2 [1 + \Lambda \tau \cdot (E - E_0)] / \tau^2 + \tau^2)$$

, with

- $\Lambda = \sinh(\tau \sqrt{\ln 4}) / (\sigma \tau \sqrt{\ln 4})$,
- E_0 = peak position,
- σ = width, and
- τ = tail parameter

TDR of EMC (2008)

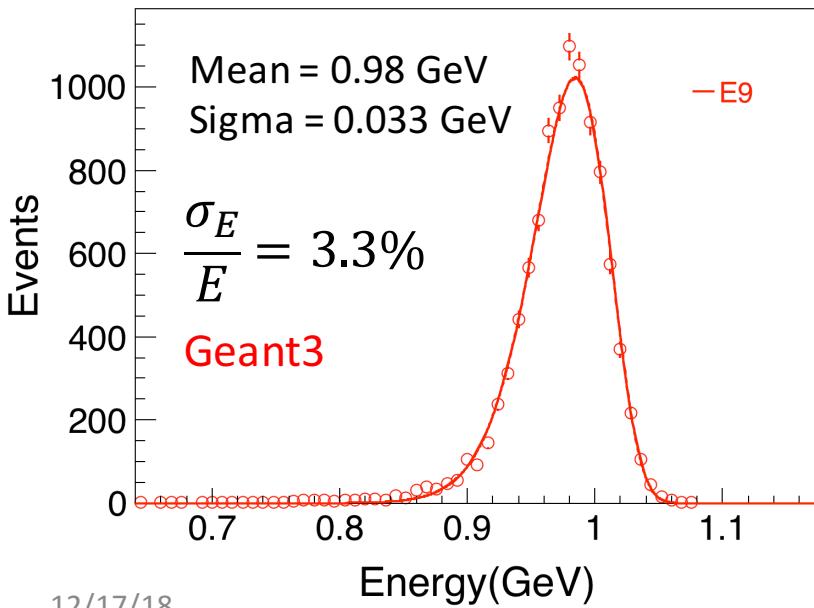


EMC Reconstruction

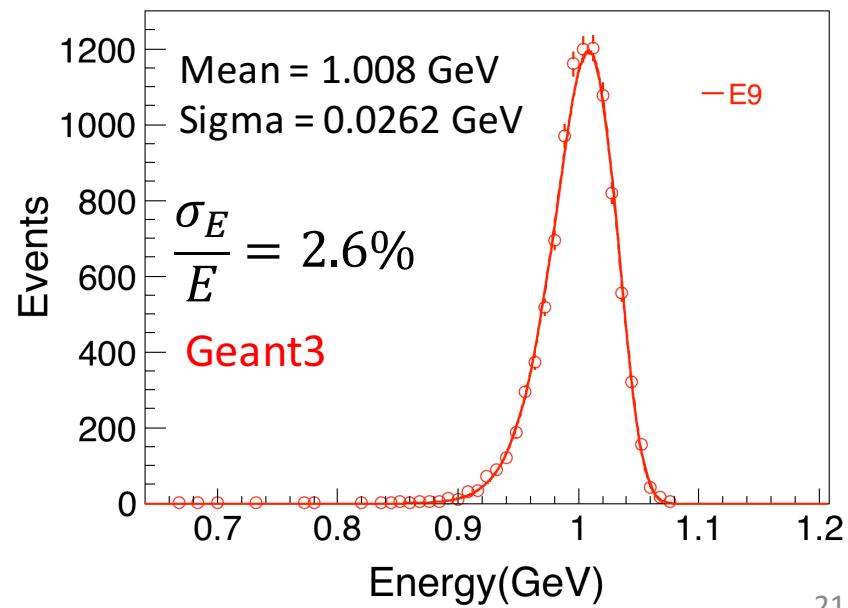
[Resolution]

✓ Energy resolution

- Gamma (1GeV)
- Events =10000
- Phi(0, 360)
- Theta(22, 140)



- Phi(99.3251)
- Theta(70.7429)

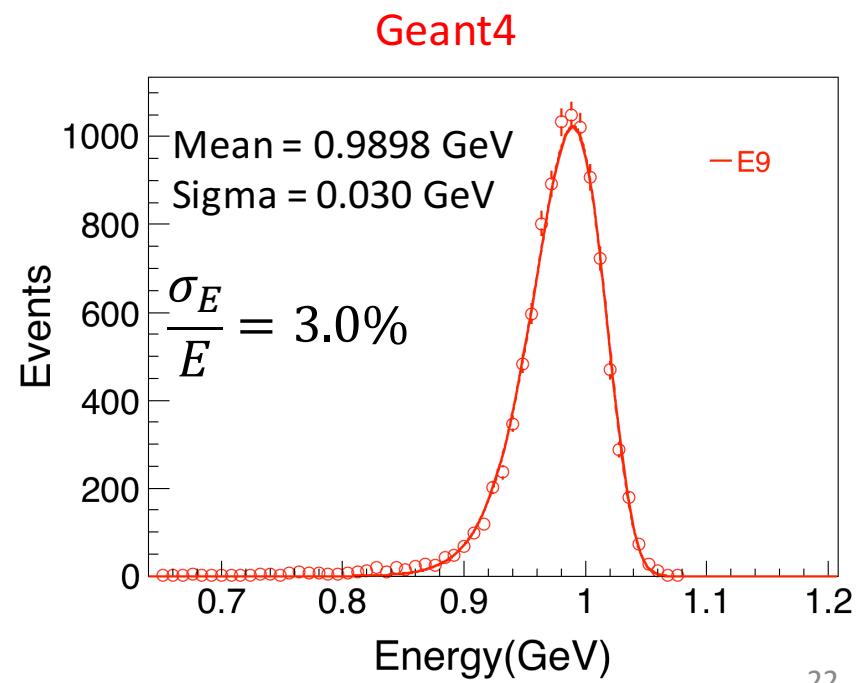
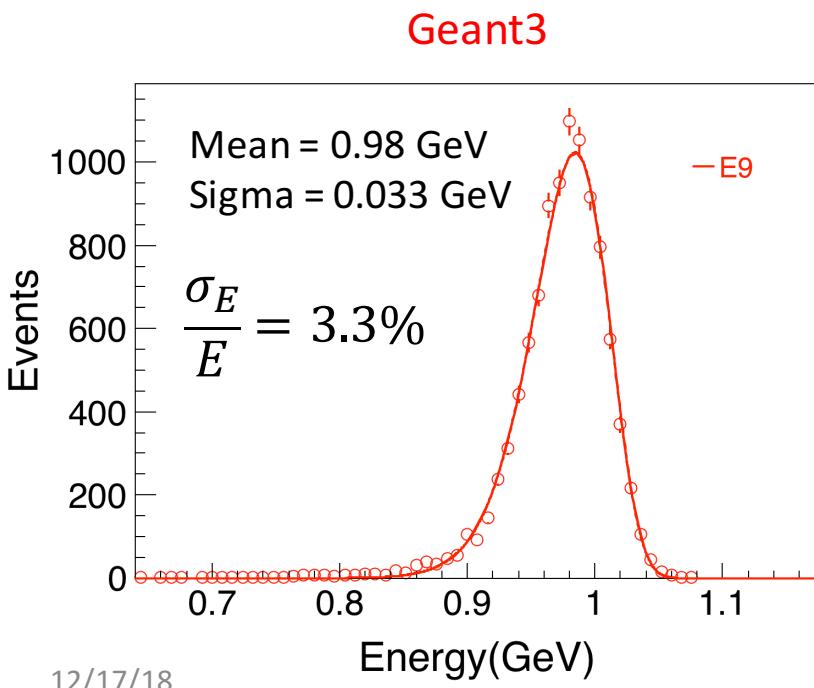


EMC Reconstruction

[Resolution]

✓ Energy resolution

- Gamma (1GeV)
- Events =10000
- Phi(0, 360)&&Theta(22, 140)

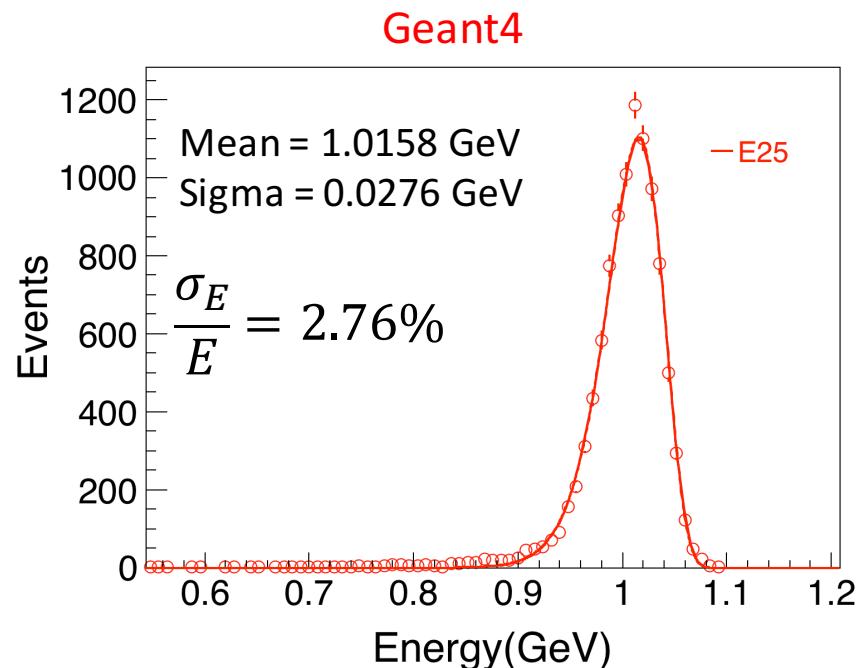
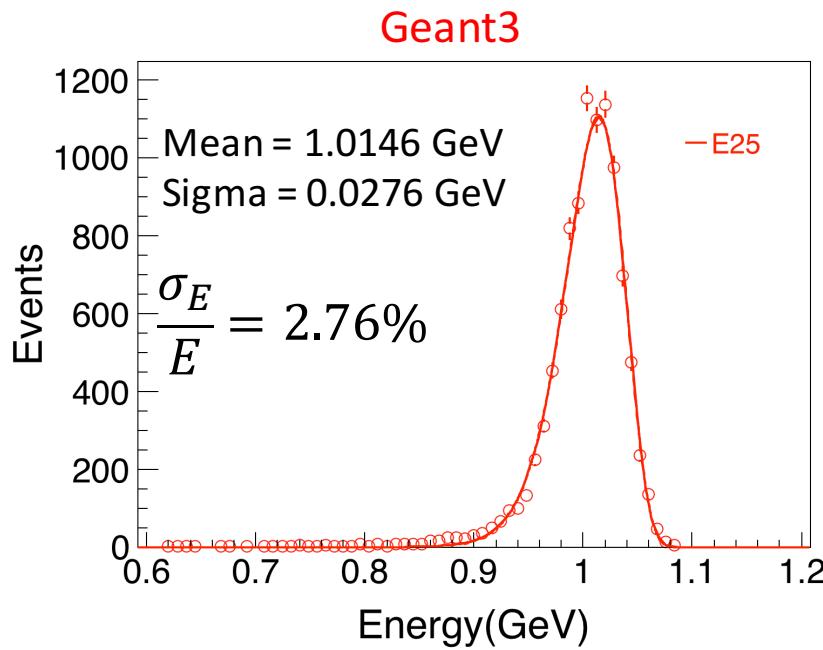


EMC Reconstruction

[Resolution]

✓ Energy resolution

- Gamma (1GeV)
- Events =10000
- Phi(0, 360)&&Theta(22, 140)



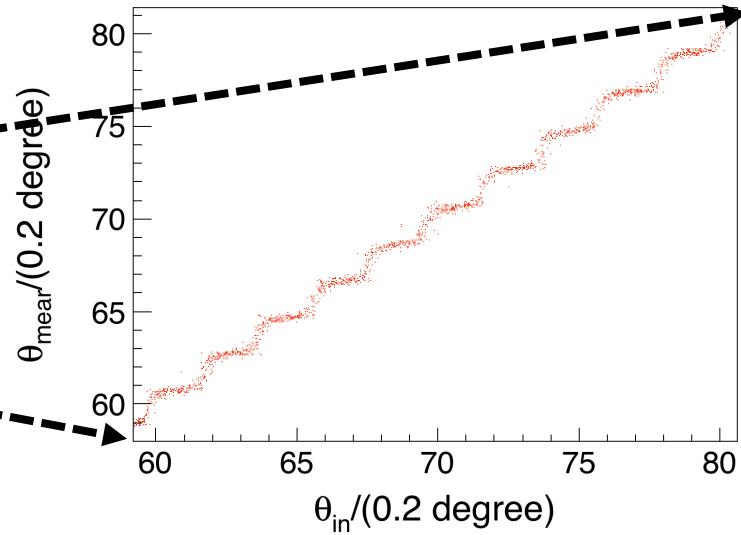
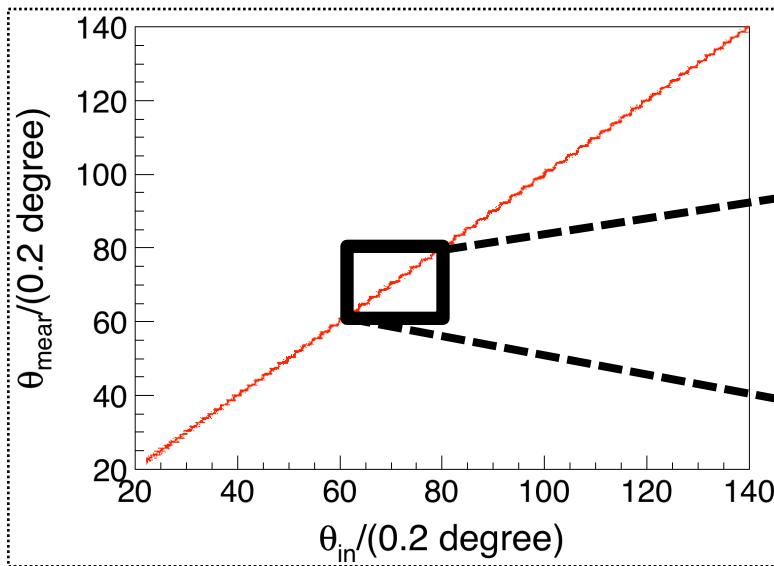
EMC Reconstruction

[Position]

✓ Position resolution

- Gamma (1GeV)
- Events =10000
- Phi(0, 360) & Theta(22, 140)
- 3*3 Matrix crystals

$$X_{mea} = \sum_{i=1}^n E_i * x_i / \sum_{i=1}^n E_i$$



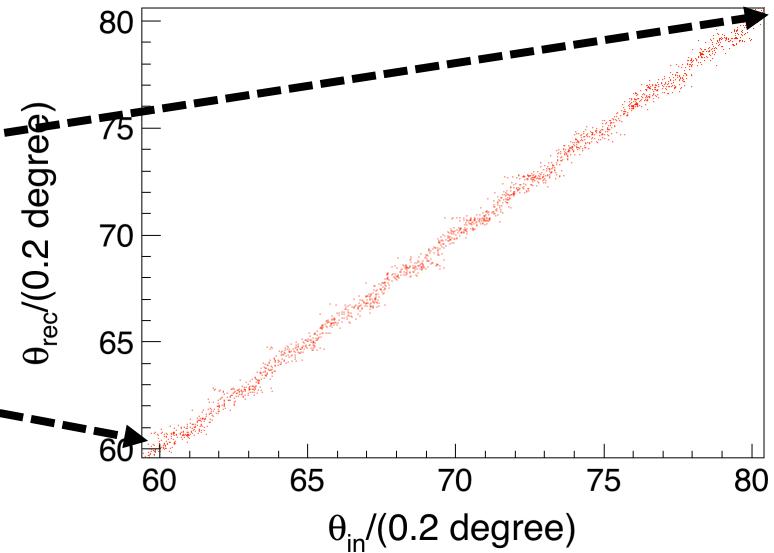
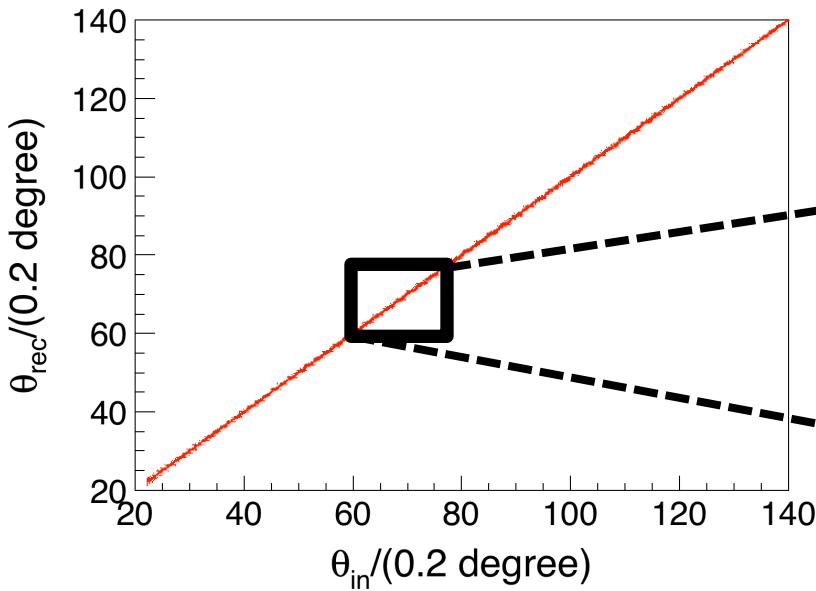
EMC Reconstruction

[Position]

✓ Position resolution

- Gamma (1GeV)
- Events = 10000
- Phi(0, 360) & Theta(22, 140)
- 3*3 Matrix crystals

$$X_{cor} = \sum_{i=1}^n W(E_i) * x_i / \sum_{i=1}^n W(E_i)$$
$$W(E_i) = \text{Max}[0, 3.8 + \ln(E_i / \sum_{i=1}^n E_i)]$$



EMC Reconstruction

[Position]

✓ Position resolution

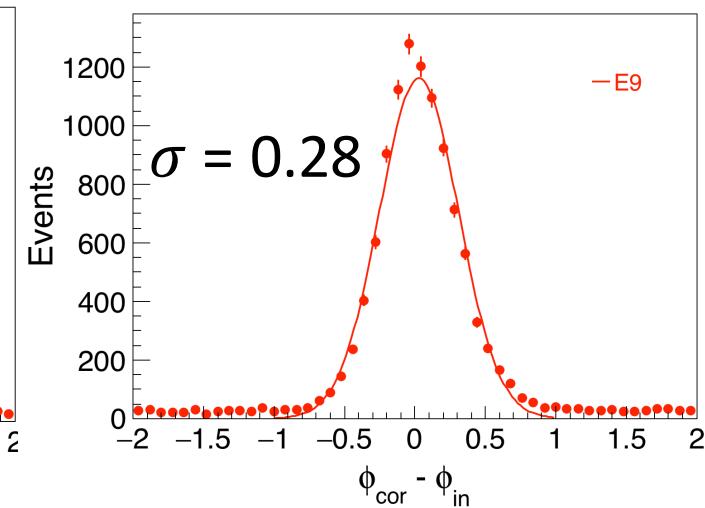
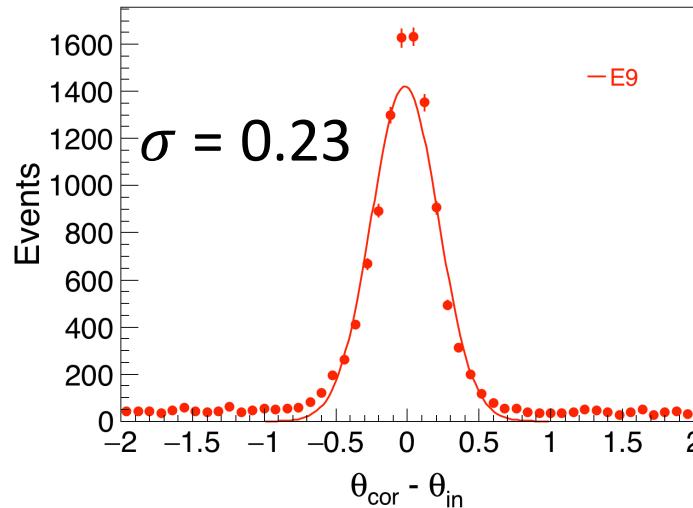
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- Phi(0, 360)&Theta(22, 140)
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$$W(E_i) = \text{Max}[0, 3.8 + \ln(E_i / \sum_{i=1}^n E_i)]$$

✓ Fit function:

- Gaussian



Summary

✓ **Simulation and reconstruction of EMC**

- Distributions of features about EMC

✓ **Next to do:**

- Position Correction
- Energy Correction

Back Up

EMC

[Main requirement]

	Required performance value		
Common properties			
energy resolution σ_E/E	$\leq 1\% \oplus \frac{\leq 2\%}{\sqrt{E/\text{GeV}}}$		
energy threshold (photons) E_{thres}	10 MeV (20 MeV tolerable)		
energy threshold (single crystal) E_{xtl}	3 MeV		
rms noise (energy equiv.) $\sigma_{E,noise}$	1 MeV		
angular coverage $\% 4\pi$	99 %		
mean-time-between-failures t_{mtbf} (for individual channel)	2000 y		
Subdetector specific properties	backward $(\geq 140^\circ)$	barrel $(\geq 22^\circ)$	forward $(\geq 5^\circ)$
energy range from E_{thres} to angular equivalent of crystal size θ	0.7 GeV 4°	7.3 GeV 0.3°	14.6 GeV 1°
spatial resolution σ_θ	0.5°	0.3°	0.1°
maximum signal load f_γ ($E_\gamma > E_{xtl}$) ($p\bar{p}$ -events) maximum signal load f_γ ($E_\gamma > E_{xtl}$) (all events) shaping time t_s	60 kHz 100 kHz 400 ns	500 kHz 500 kHz 100 ns	
radiation hardness (maximum annual dose $p\bar{p}$ -events) radiation hardness (maximum annual dose from all events)	0.15 Gy 10 Gy	7 Gy	125 Gy 125 Gy

EMC Reconstruction

[Resolution]

✓ Energy resolution

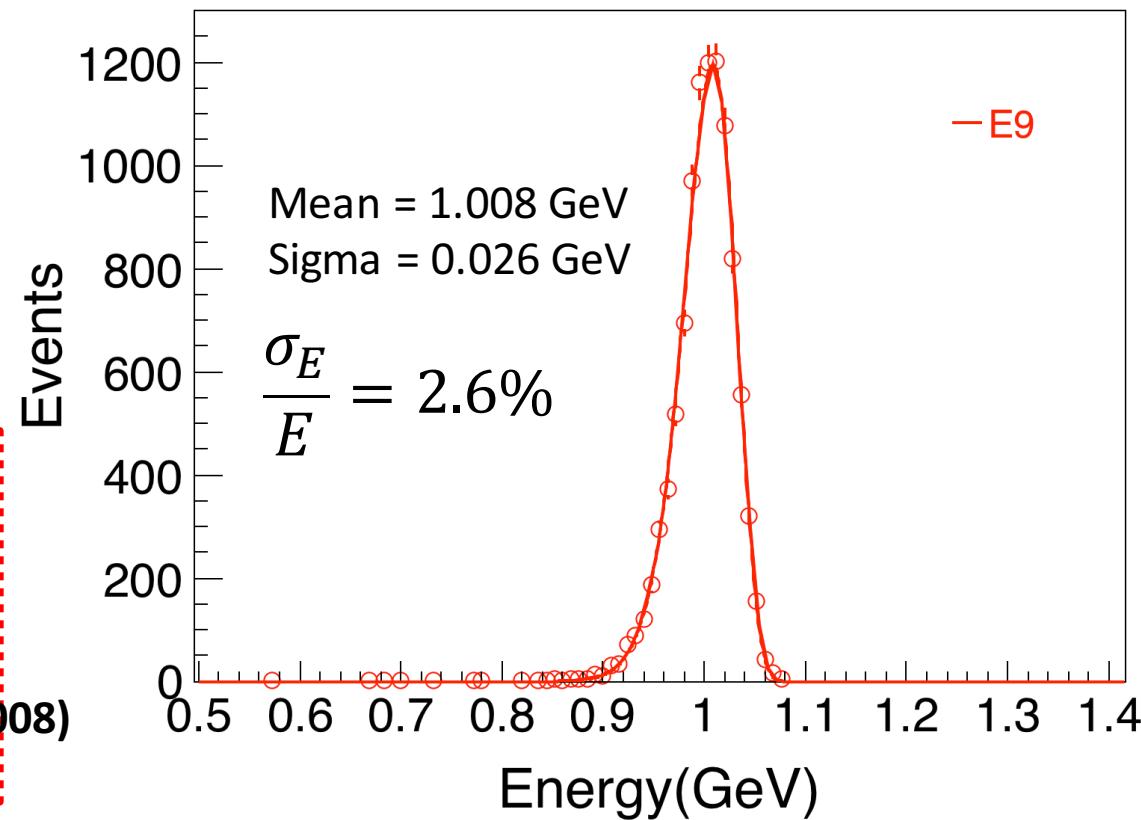
- Gamma (1GeV)
- Events = 10000
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- Theta(70.7429)
- 3*3 Matrix crystals
- Novosibirsk function

$$f(E) = A_S \exp(-0.5 \ln^2 [1 + \Lambda \tau \cdot (E - E_0)] / \tau^2 + \tau^2)$$

, with

- $\Lambda = \sinh(\tau \sqrt{\ln 4}) / (\sigma \tau \sqrt{\ln 4})$,
- E_0 = peak position,
- σ = width, and
- τ = tail parameter

TDR of EMC (2008)



EMC Reconstruction

[Resolution]

✓ Energy resolution

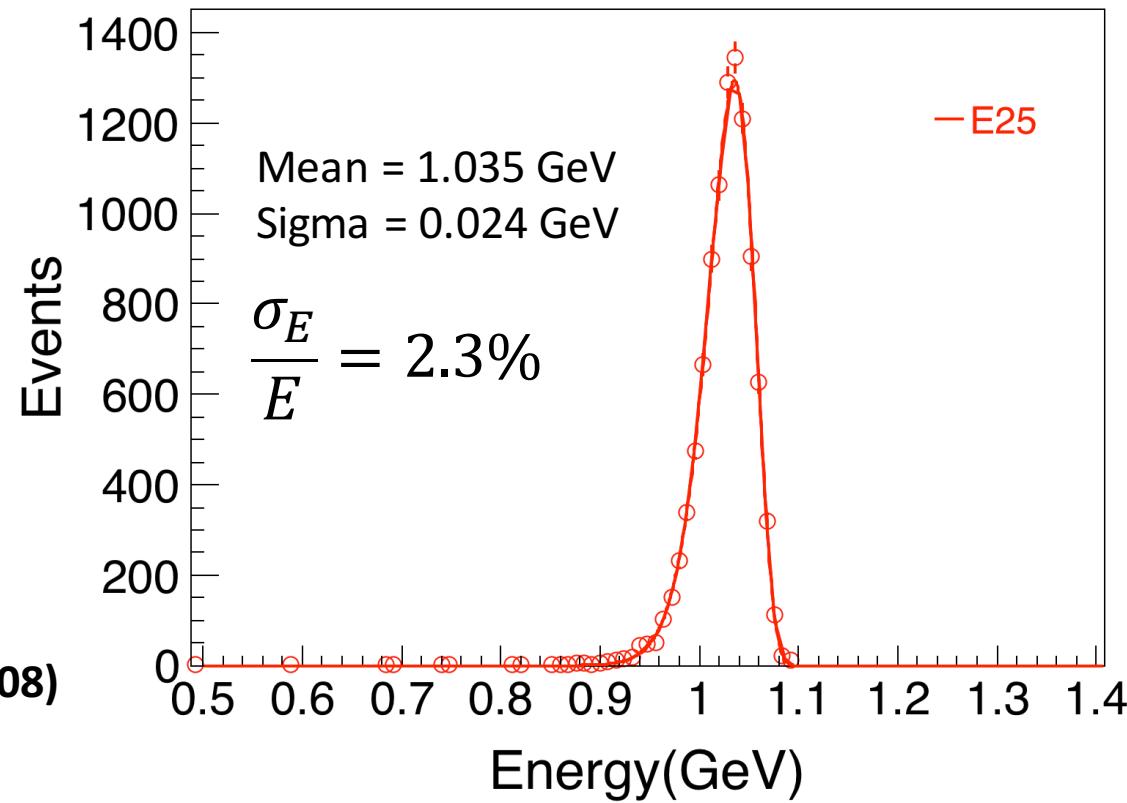
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TDR of EMC (2008)



Data Flow

[Simulation & reconstruction]

