

# Reconstruction and correction of position for Panda EMC

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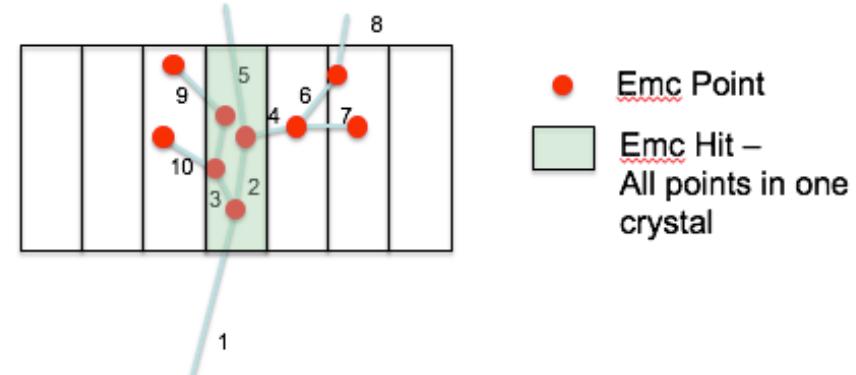
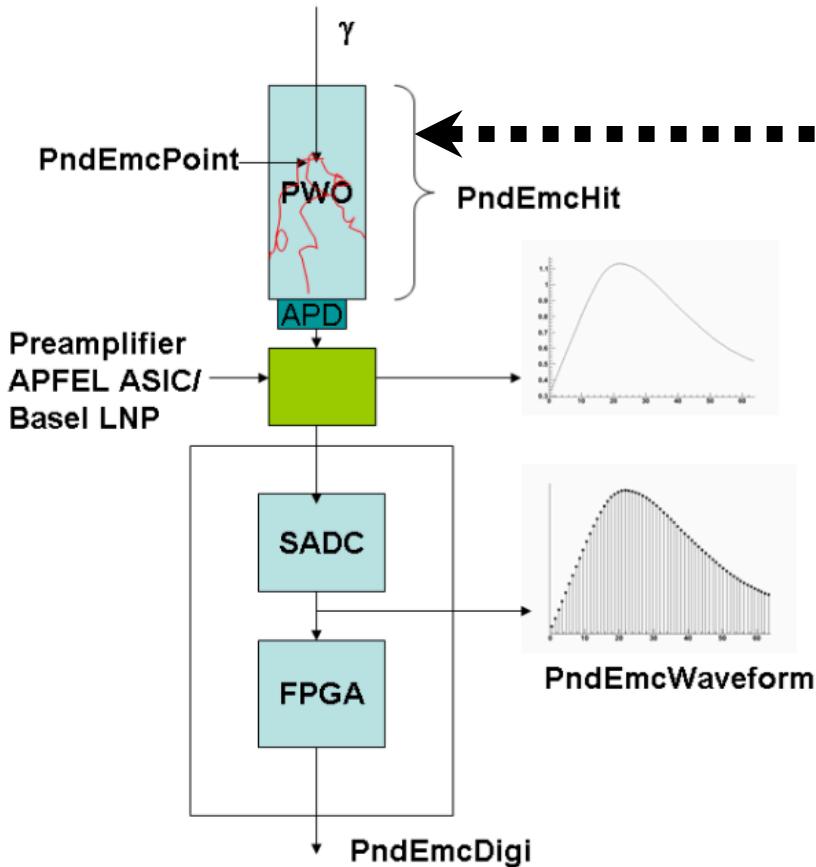


# Outline

- ✓ Simulation of Panda EMC
- ✓ EMC reconstruction
  - Reconstruction of energy
  - Reconstruction and correction of position
    - Basic method
      - Linear and Log-method
      - Correction of S curve
    - Machine learning
      - CNN model
- ✓ Summary

# EMC Simulation

## [Simulation]

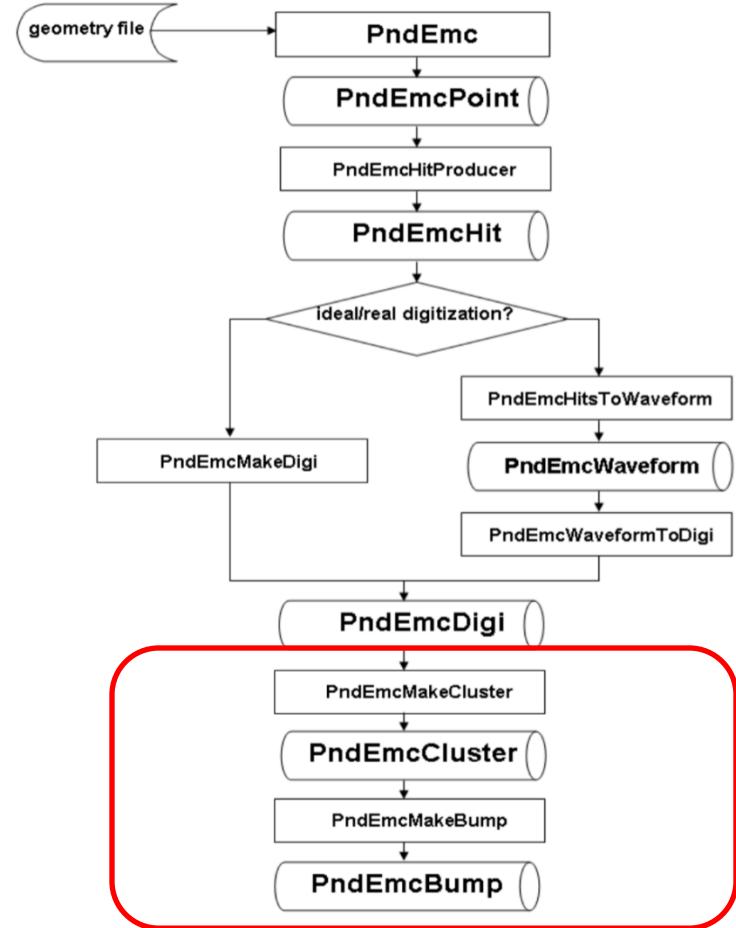
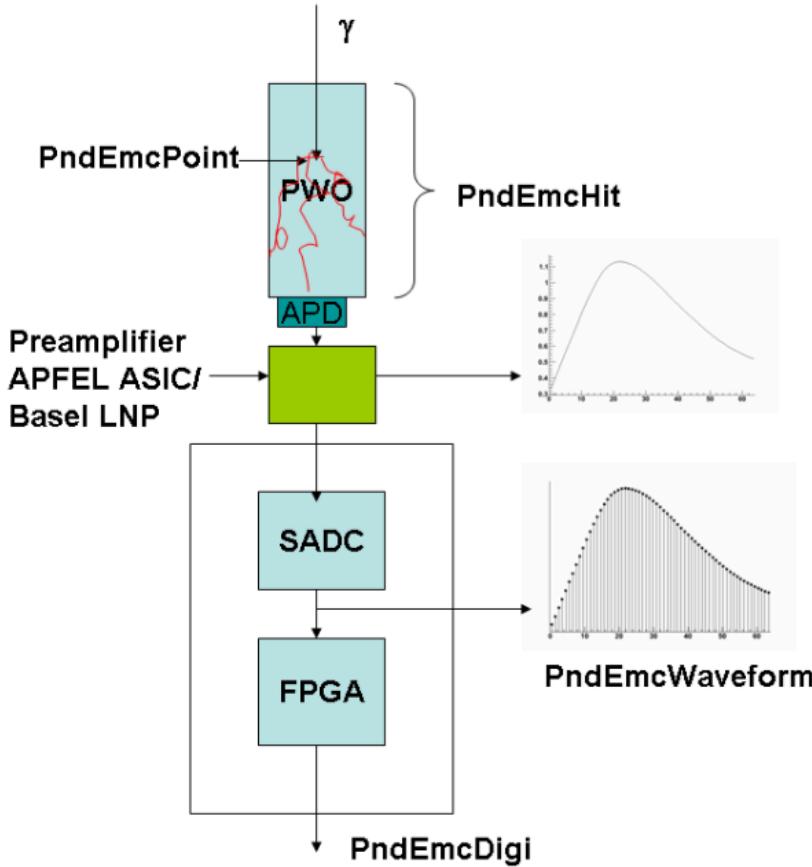


- ✓ Event Generation
  - Box Generator
- ✓ Transport Model
  - Geant4
- ✓ Digitization

D. Melnychuk 24.07.2012

# EMC Simulation

## [Data flow]



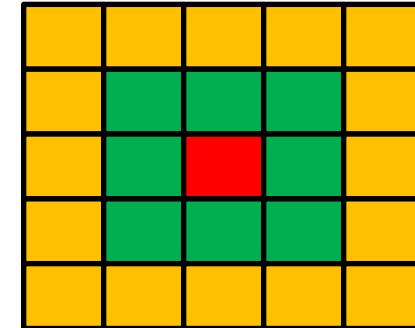
D. Melnychuk 24.07.2012

# EMC Reconstruction

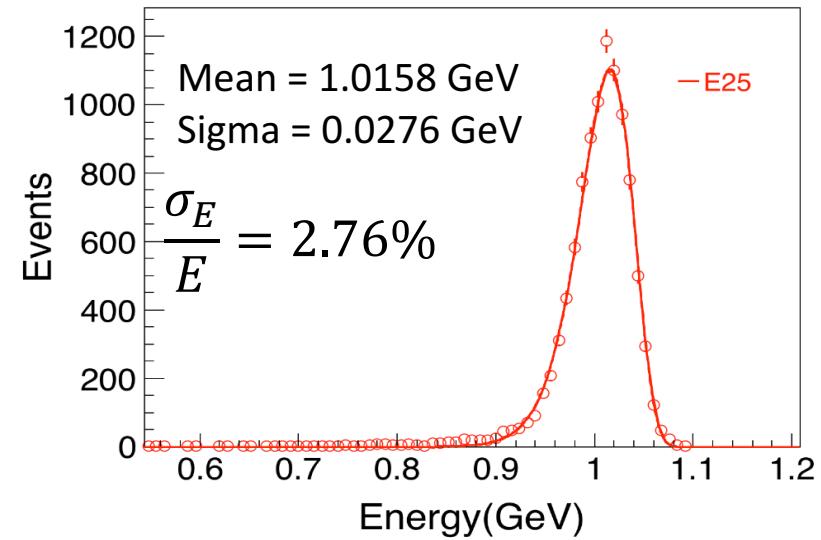
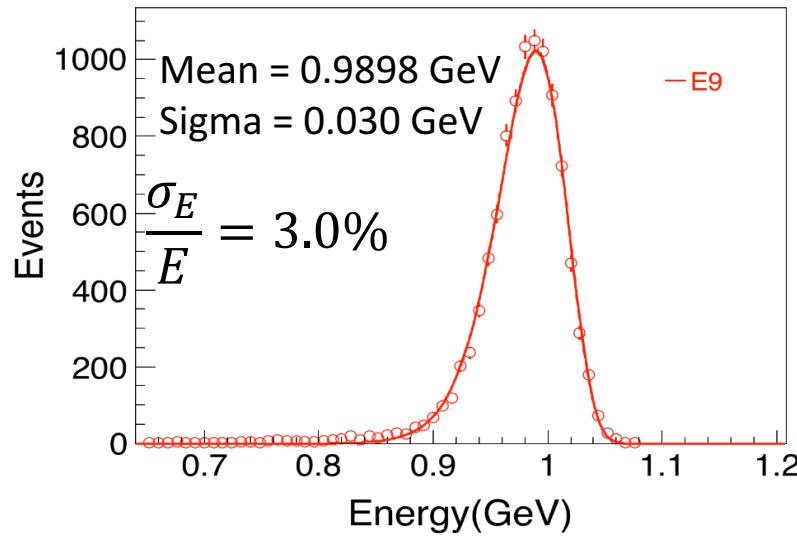
## [Energy]

### ✓ Data sample

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



### ✓ Fit to Matrix(3,3)or Matrix(5, 5)

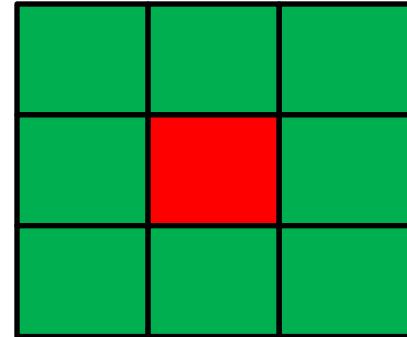


# EMC Reconstruction

## [Position]

### ✓ Data sample

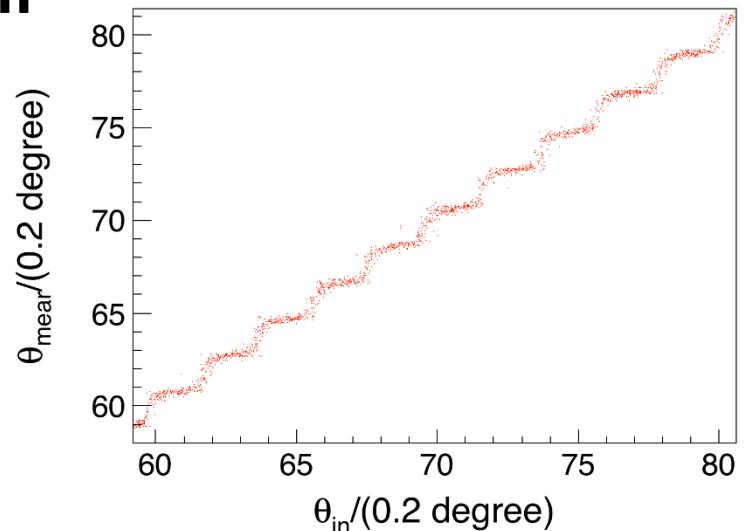
- Gamma (1GeV)
- Events =10000
- Phi(0, 360) & Theta(22, 140)
- 3\*3 Matrix crystals



### ✓ Reconstruction of position

- Linear-method

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

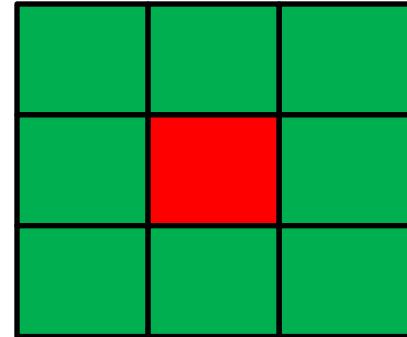


# EMC Reconstruction

## [Position]

### ✓ Data sample

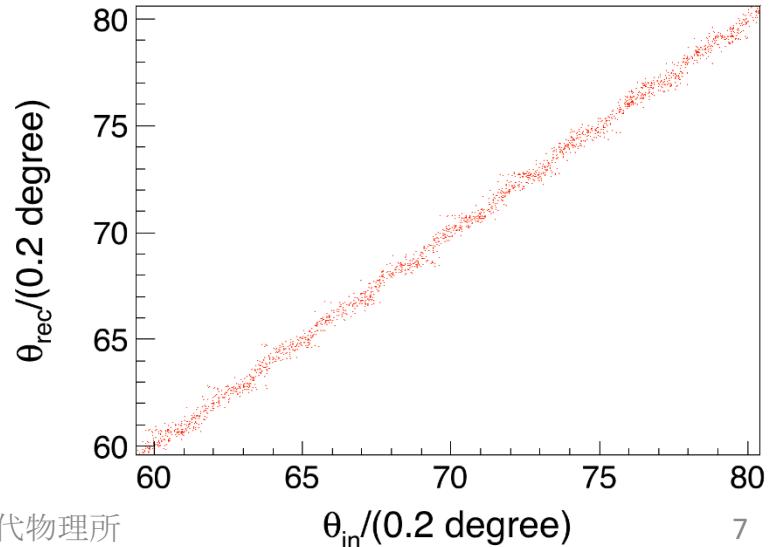
- Gamma (1GeV)
- Events =10000
- Phi(0, 360) & Theta(22, 140)
- 3\*3 Matrix crystals



### ✓ Reconstruction of position

- Log-method

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



# EMC Reconstruction

## [Position]

- ✓ Energy-dependence of A(E)

- **PndEmcClusterProperties**

- Where(TString method, std::vector<Double\_t> params)

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

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

$$parA = 4.071$$

$$parB = 0.678$$

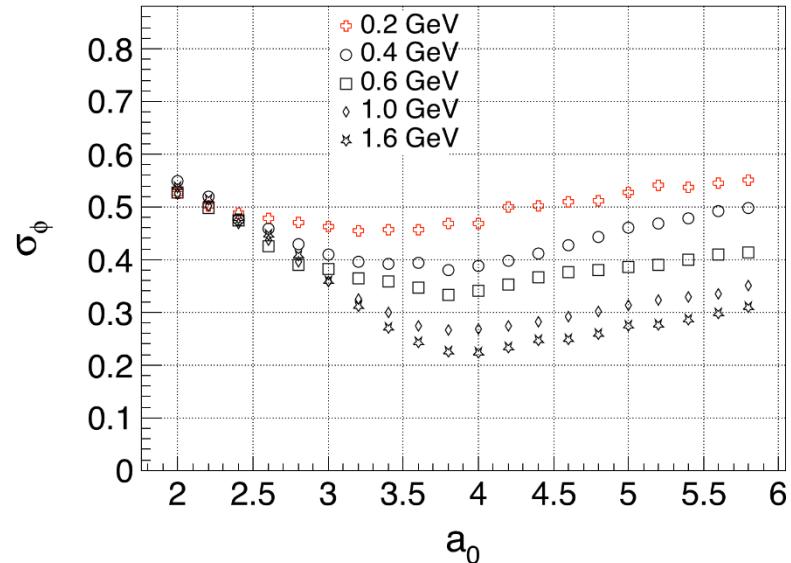
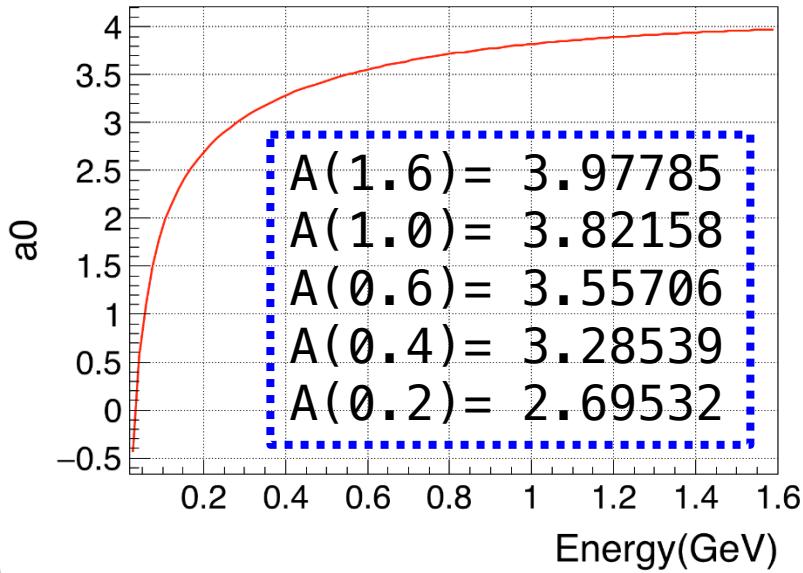
$$parC = 1.0$$

# 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

## [Position]

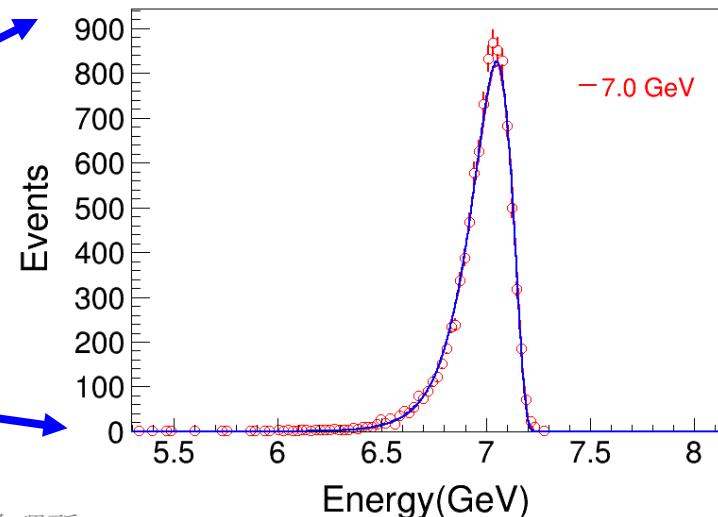
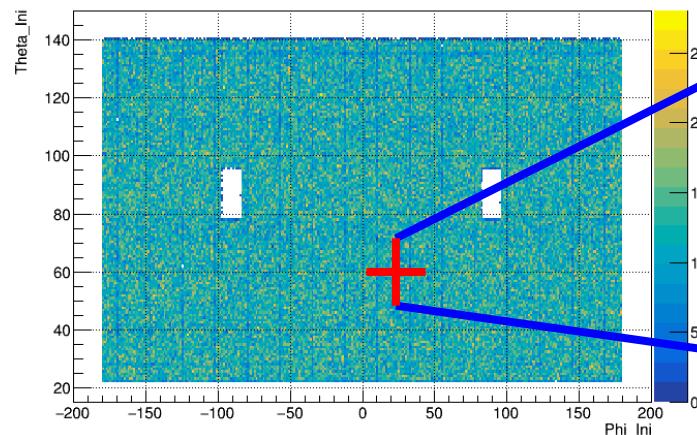
### ✓ Data sample->Gamma

- Energy=(0.1, 7.0) GeV
- Events=10,000
- Theta= 64.35 deg
- Phi=16.94 deg



### ✓ Energy of Cluster

- Total digi-energy



# EMC Reconstruction

## [Energy]

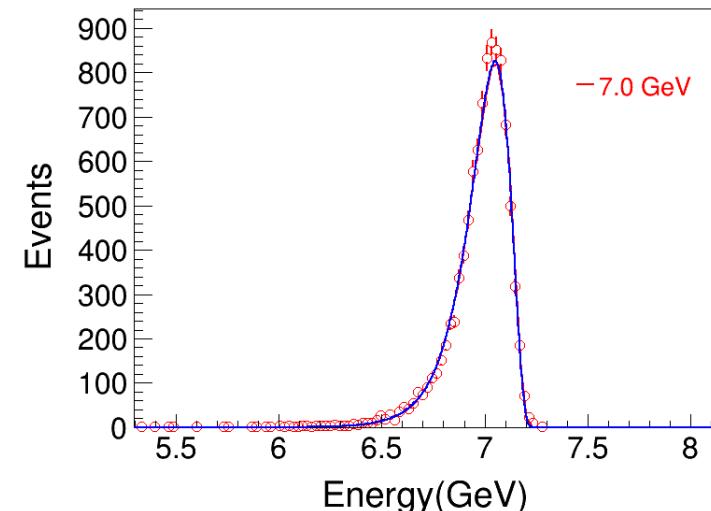
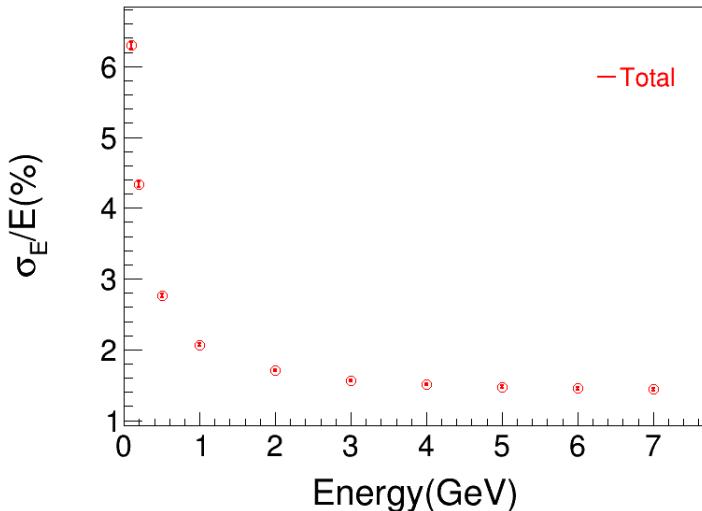
### ✓ Data sample->Gamma

- Energy=(0.1, 7.0)GeV
- Events=10,000
- Theta=64.35 deg
- Phi=16.94 deg

### ✓ Cluster

- M3×3
- M5×5
- Total digi-Energy

### ➤ Resolution-energy as a function of energy



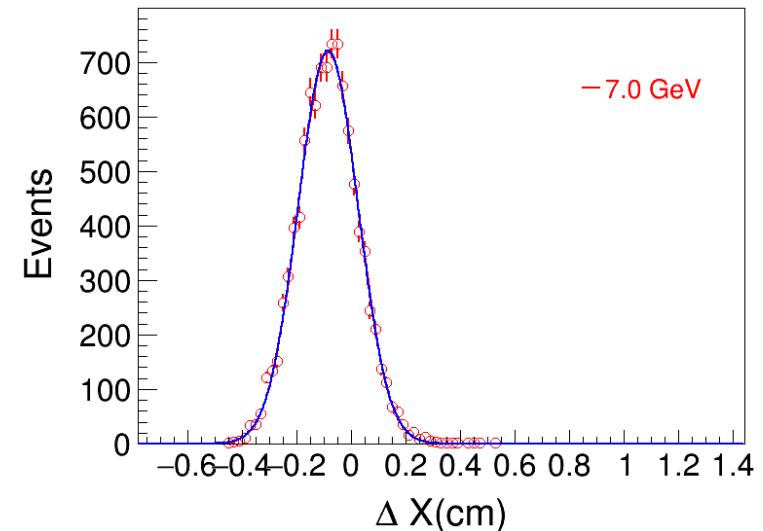
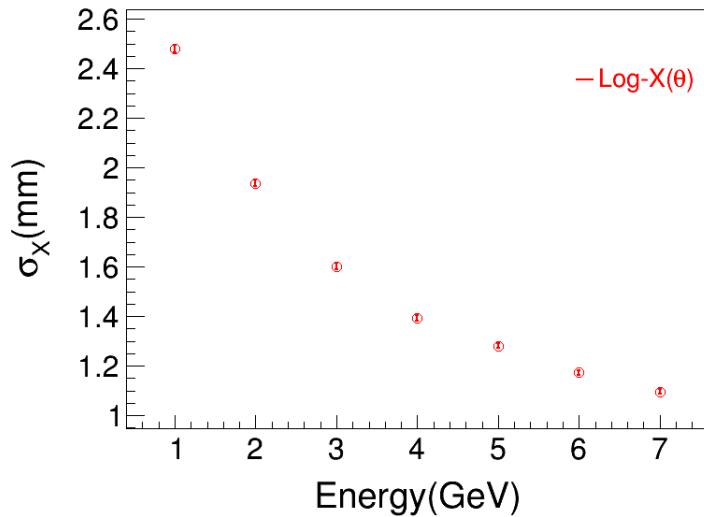
# EMC Reconstruction

[ $\mathbf{x} - \theta$ ]

## ✓ Data sample->Gamma ✓ Cluster

- Energy=(1.0, 7.0)GeV
- Events=10,000
- Theta=64.35 deg
- Phi=16.94 deg
- Log-method
- Fixed Depth of crystal

## ➤ Resolution-X as a function of energy



# EMC Reconstruction

[ $y - \varphi$ ]

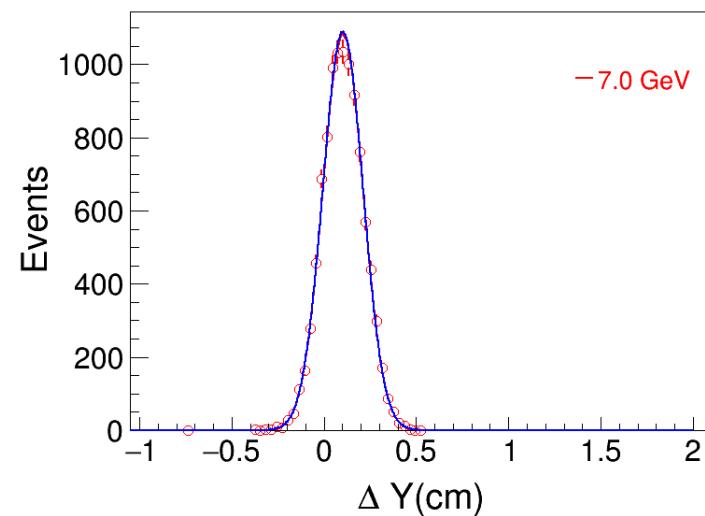
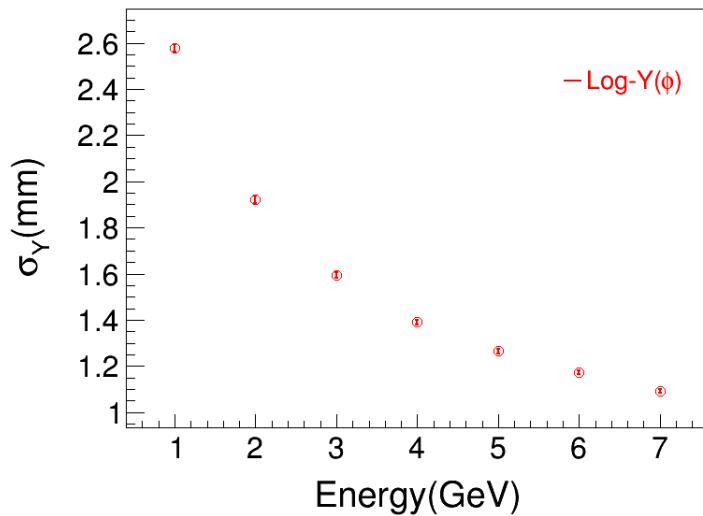
## ✓ Data sample->Gamma

- Energy=(1.0, 7.0)GeV
- Events=10,000
- Theta=64.35 deg
- Phi=16.94 deg

## ✓ ClusterPosition

- Log-method
- Depth

## ➤ Resolution-Y as a function of energy



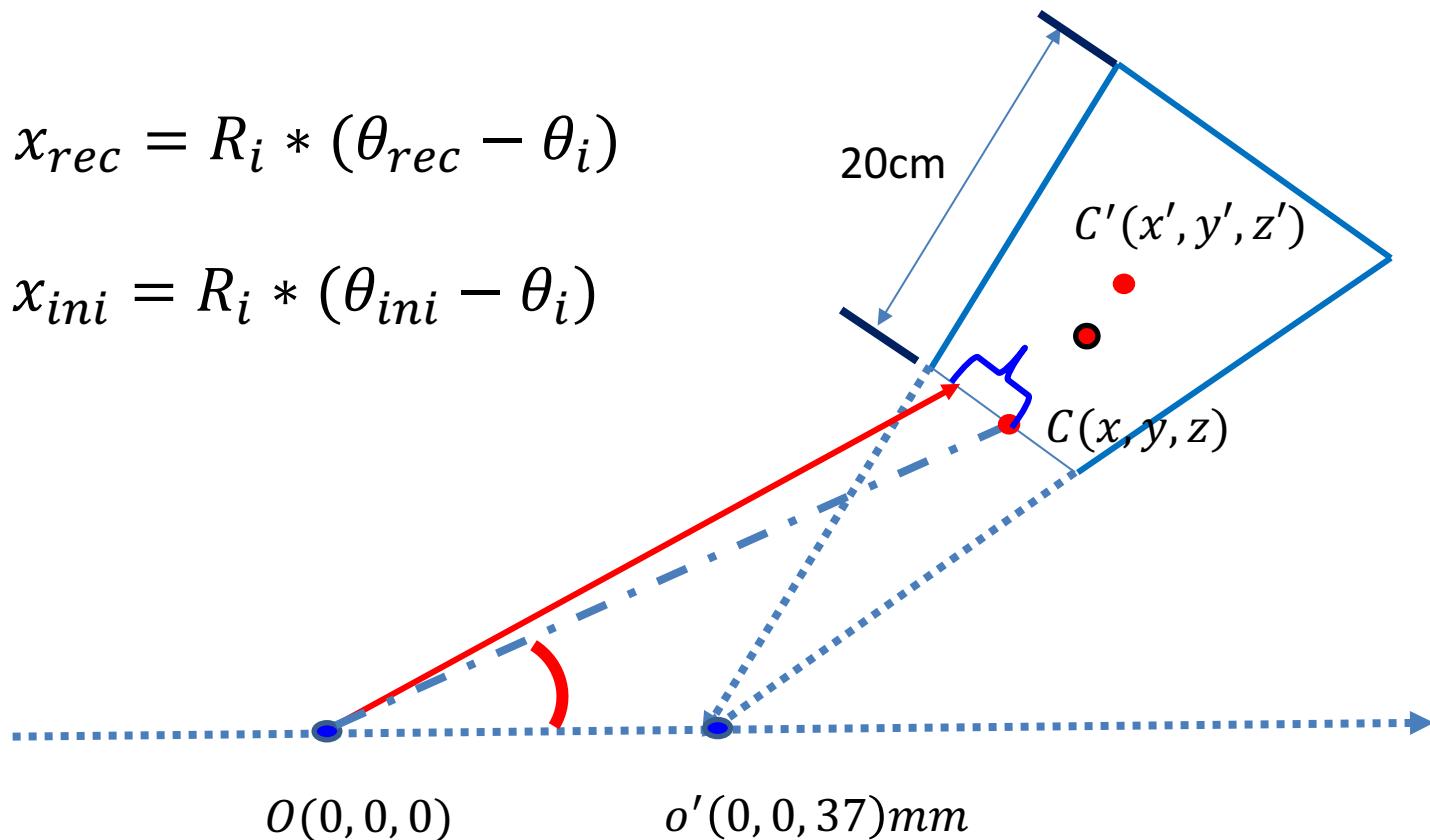
# Position Reconstruction

[Correction]

## ✓ Definition of x-Position

$$x_{rec} = R_i * (\theta_{rec} - \theta_i)$$

$$x_{ini} = R_i * (\theta_{ini} - \theta_i)$$

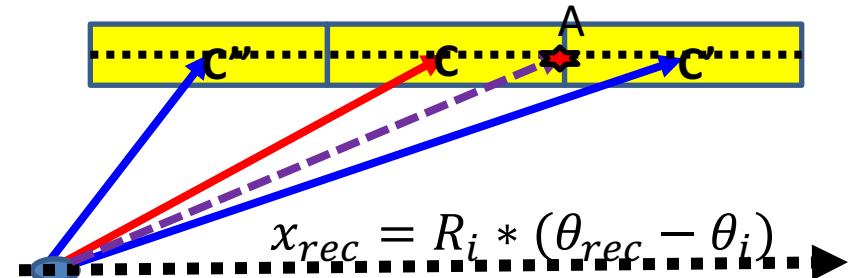


# Position Reconstruction

## [Correction]

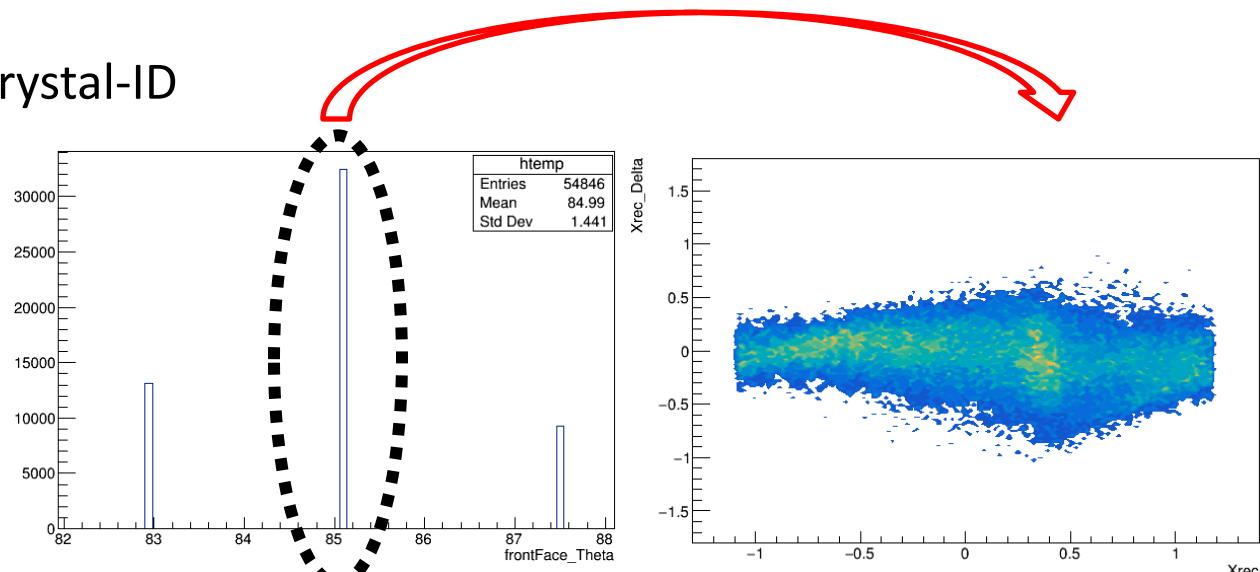
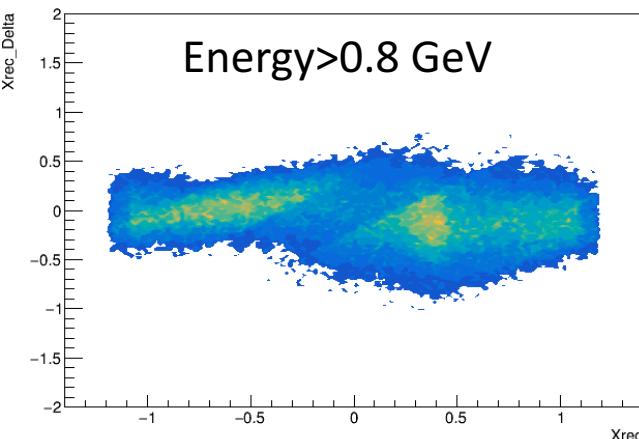
### ✓ Data sample

- Gamma (1.0 GeV)
- Events =60000
- **Phi(0, 360)**
- Theta(85.13 -2.0, 85.13 +2.0 )



### ✓ Position

- Energy Cut && Crystal-ID

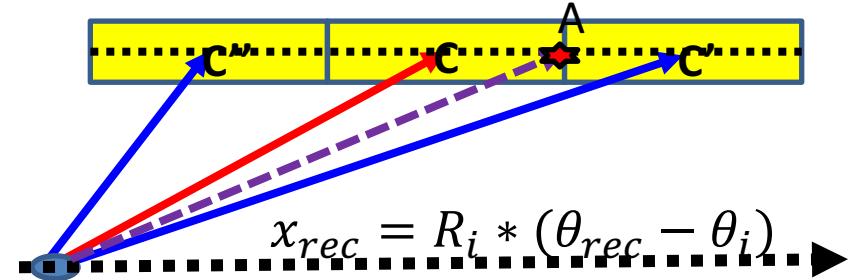


# Position Reconstruction

## [Correction]

### ✓ Position

- Gamma (1.0 GeV)
- Events =60000
- **Phi(0, 360)**
- Theta(85.13 -2.0, 85.13 +2.0 )

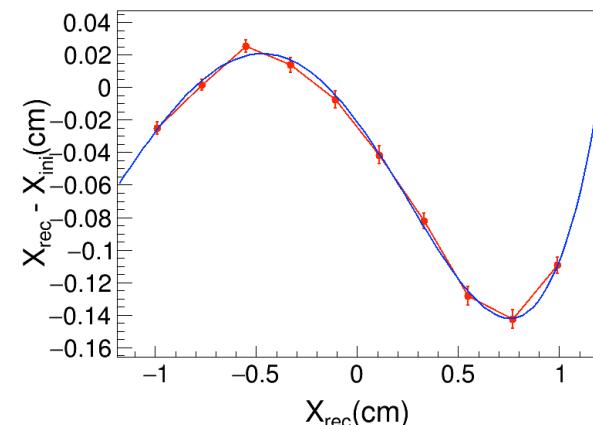
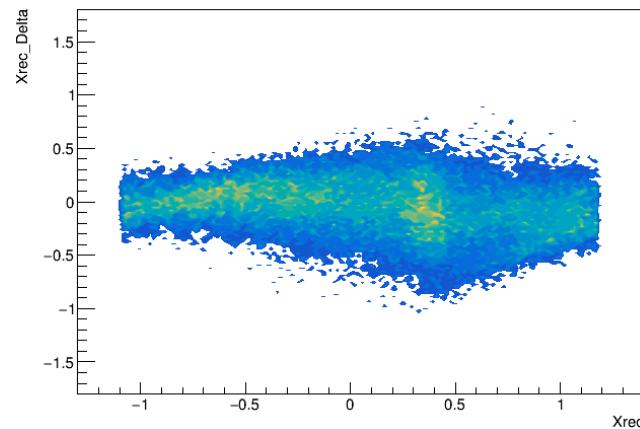
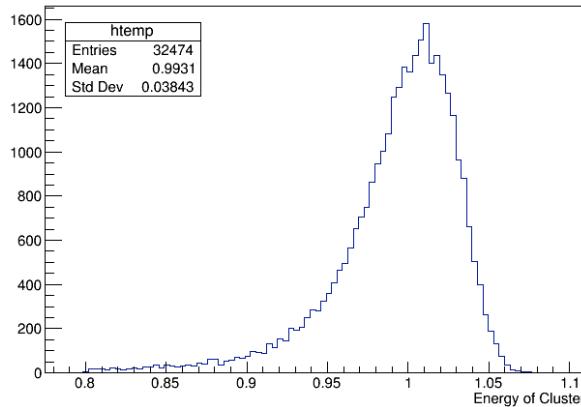


### ✓ Position

- Energy Cut && Crystal-ID

### ✓ S-Curve of correction

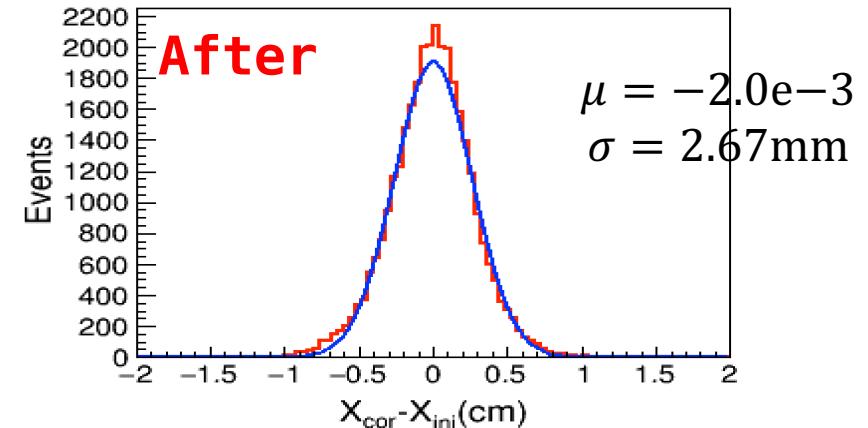
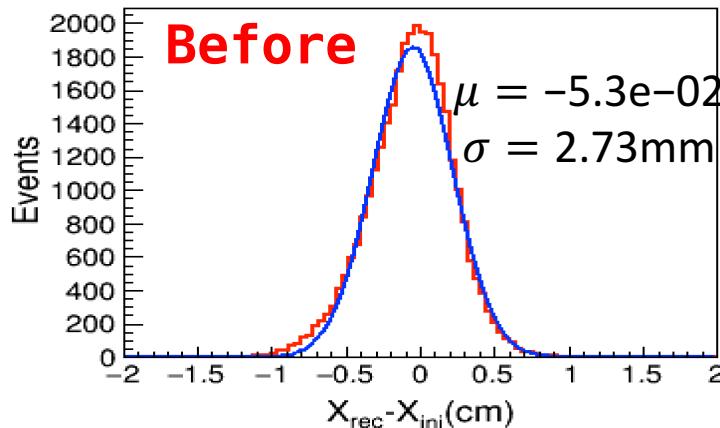
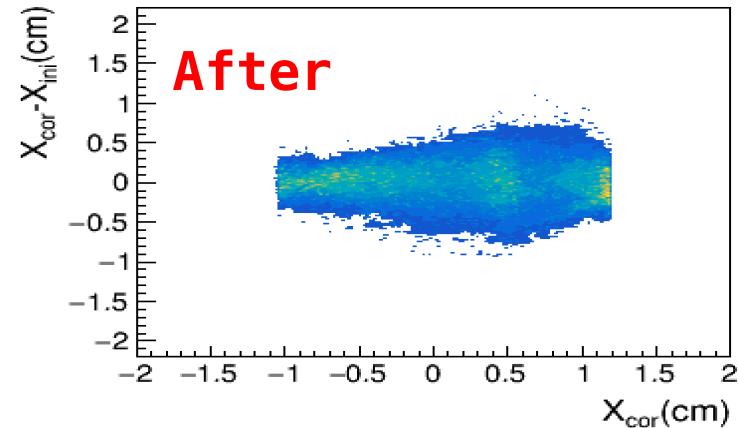
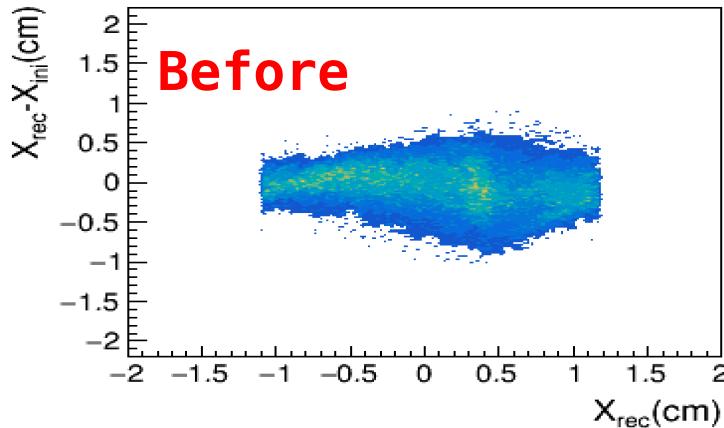
- Polynomial-func



# Position Reconstruction

[Correction]

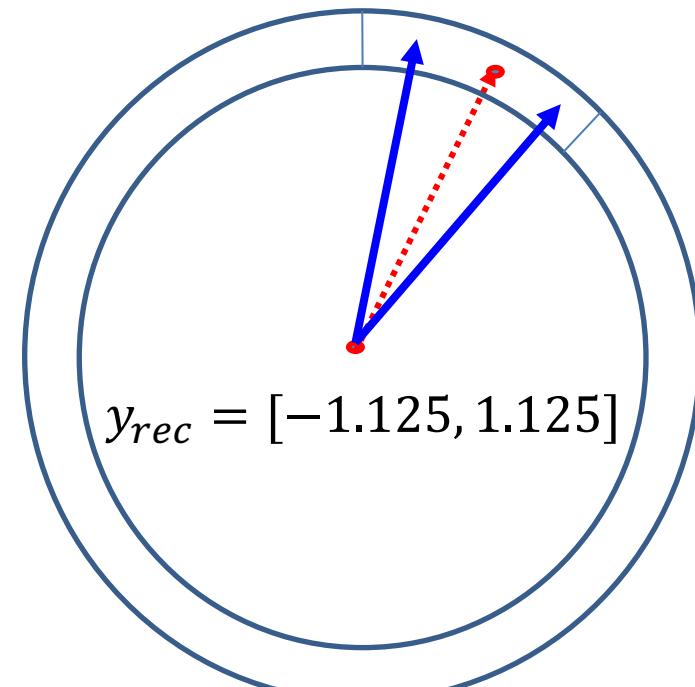
✓ Before and after correction



# Position Reconstruction

## [Resolution]

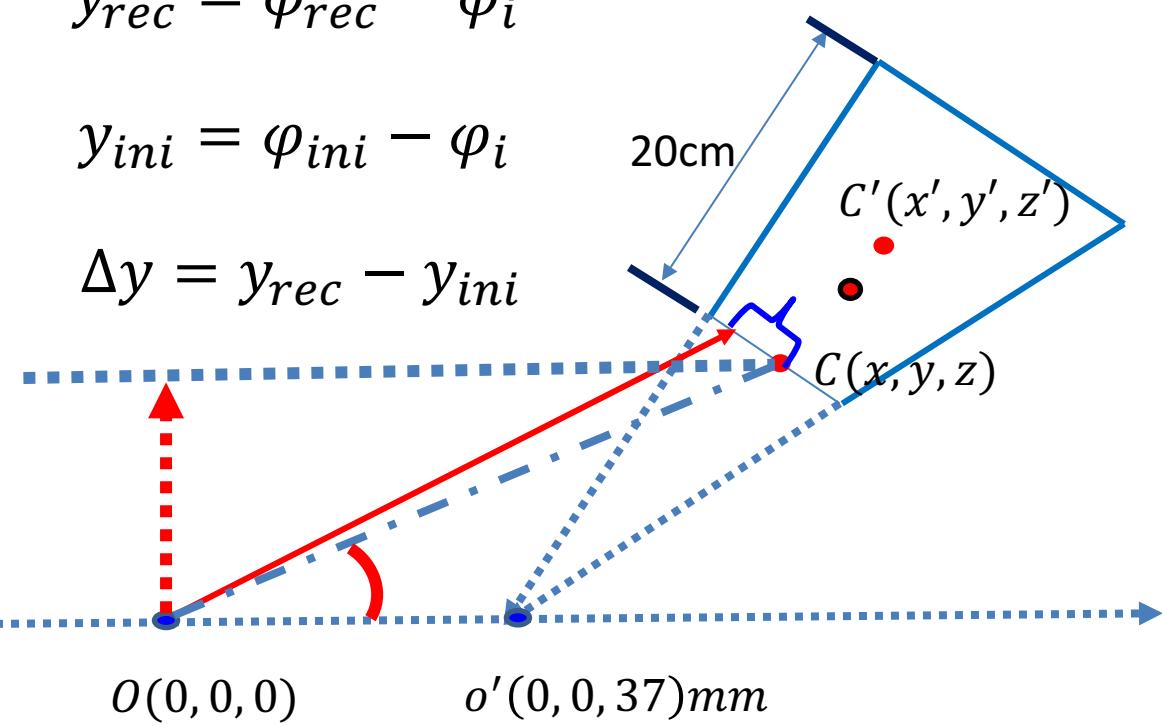
### ✓ Definition of y-Position



$$y_{rec} = \varphi_{rec} - \varphi_i$$

$$y_{ini} = \varphi_{ini} - \varphi_i$$

$$\Delta y = y_{rec} - y_{ini}$$

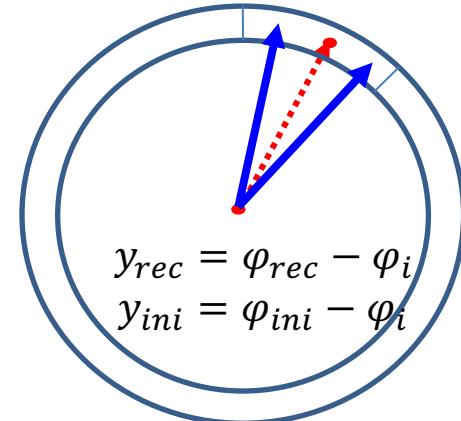


# Position Reconstruction

## [Resolution]

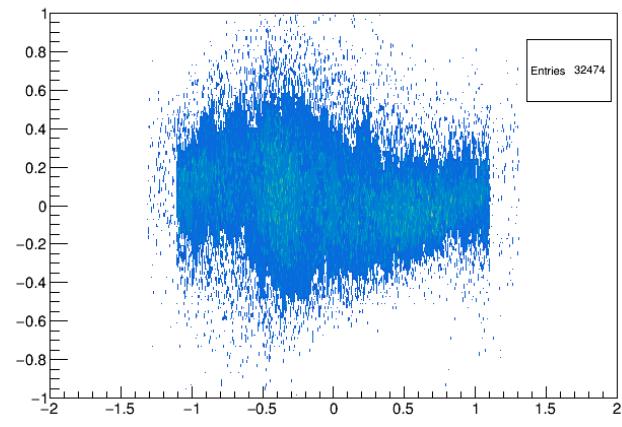
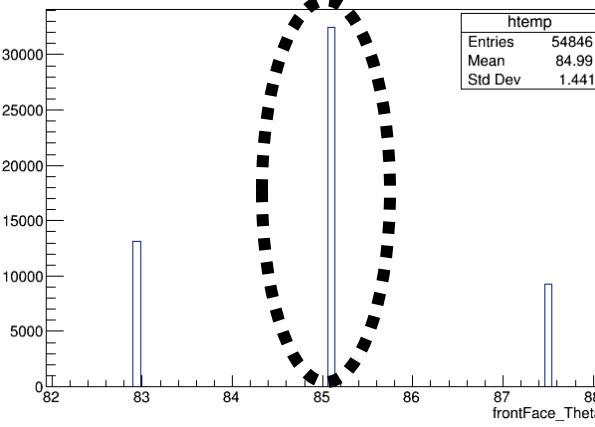
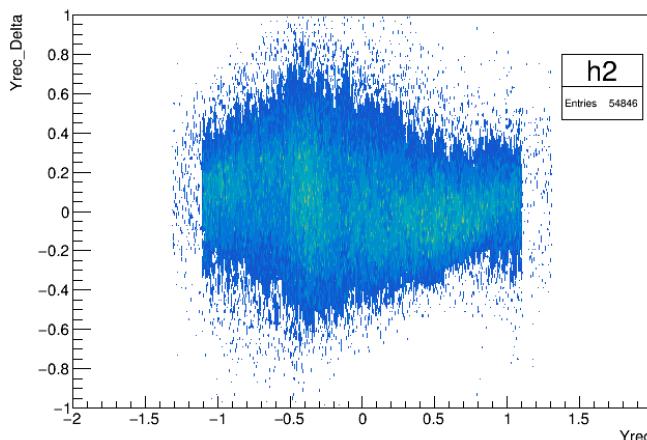
### ✓ Data sample

- Gamma (1.0 GeV)
- Events =60000
- **Phi(0, 360)**
- Theta(85.13 -2.0, 85.13 +2.0 )



### ✓ Position

- Energy Cut && Crystal-ID

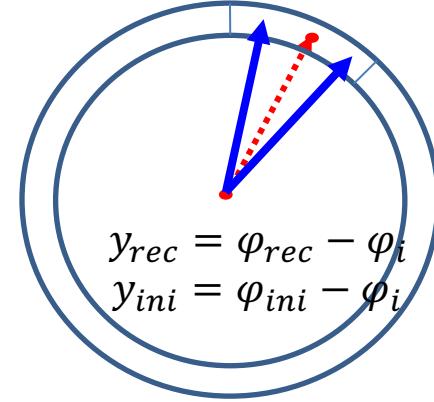


# Position Reconstruction

## [Resolution]

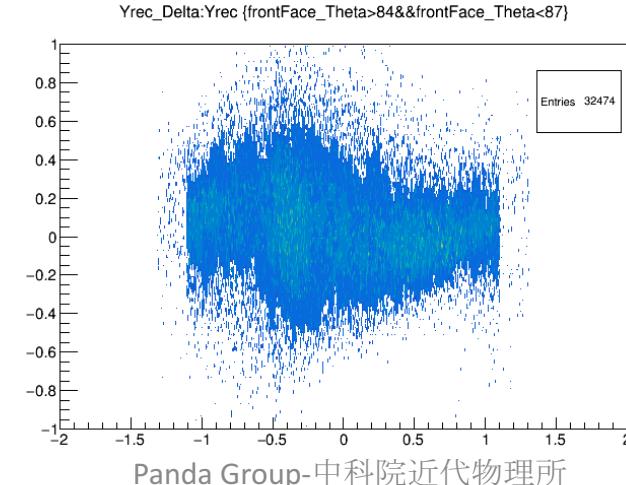
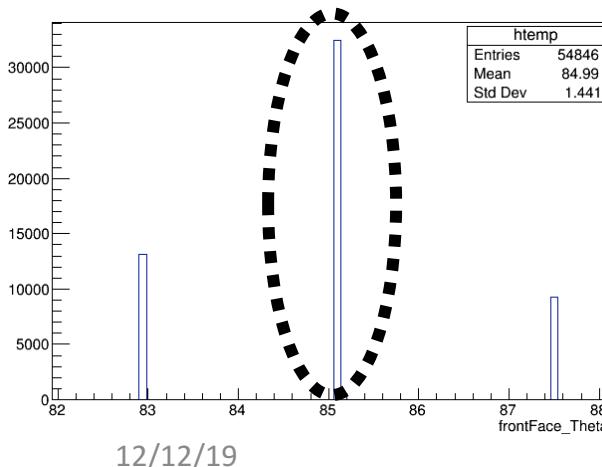
### ✓ Data sample

- Gamma (1.0 GeV)
- Events =60000
- **Phi(0, 360)**
- Theta(85.13 -2.0, 85.13 +2.0 )



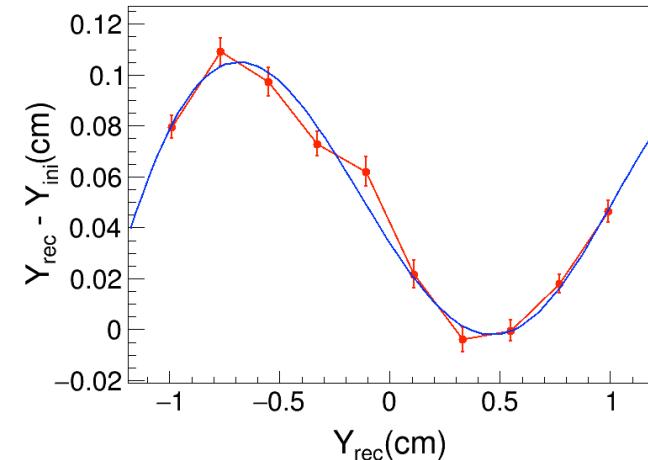
### ✓ Position

- Energy Cut && Crystal-ID



### ✓ S-Curve of correction

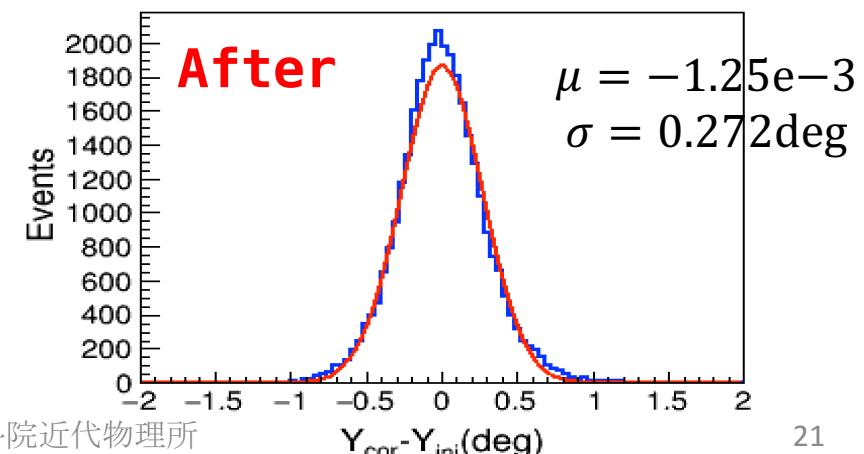
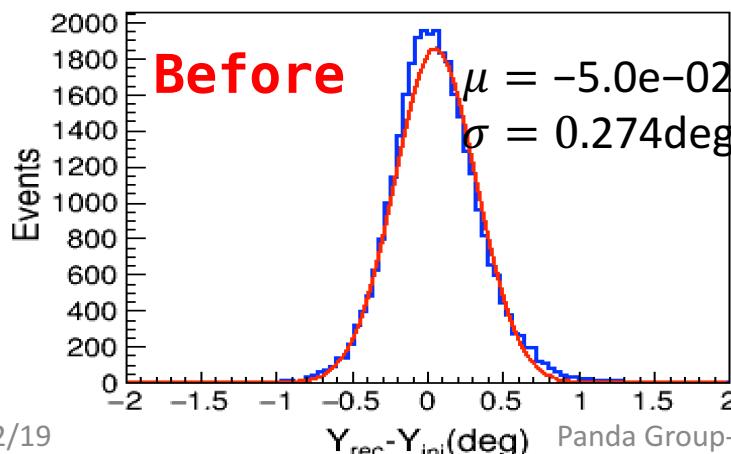
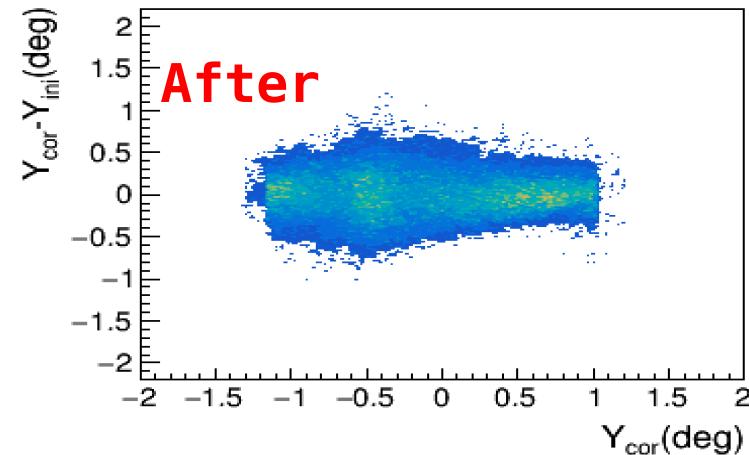
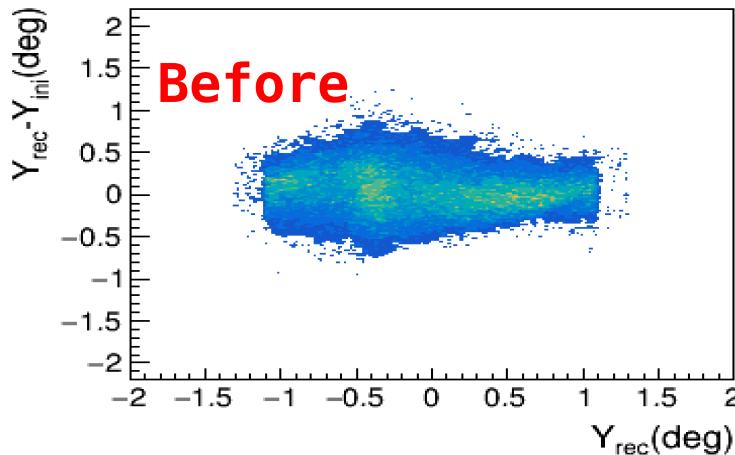
- Polynomial-func



# Position Reconstruction

[Resolution]

✓ Before and after correction

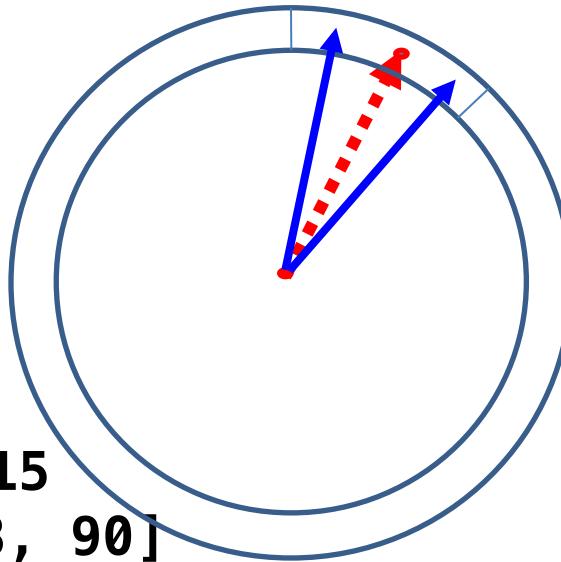


# Position Reconstruction

[ $y - \phi$  correction]

## ✓ ClusterPosition

➤ Depth



$$\Delta\phi = \phi_{rec} - \phi_{ini}$$

## ✓ Gamma

➤ Energy=10GeV

➤ Events=500,000

➤ Samples-1

➤ Theta= 64.353515

➤ Phi=[73.195838, 90]

➤ Samples-2

➤ Theta= [50, 66]

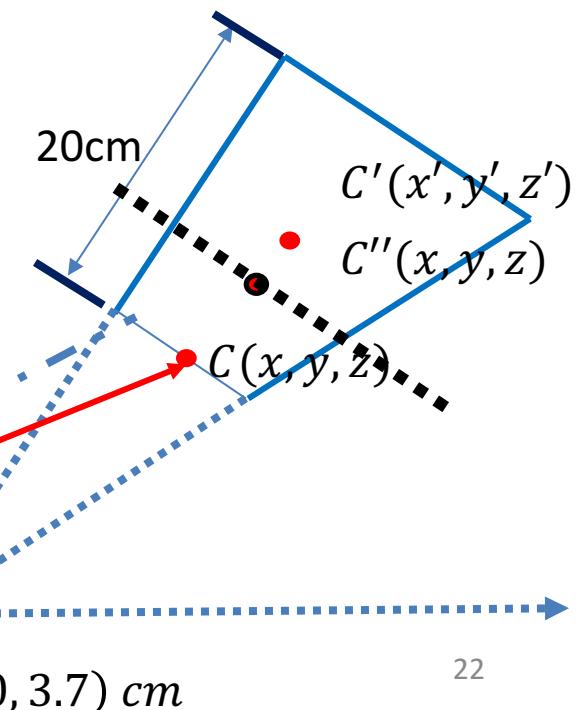
➤ Phi= 75

## ✓ Frontface

➤ OC (red line)

➤ Fixed Position

$$\Delta\theta = \theta_{rec} - \theta_{ini}$$

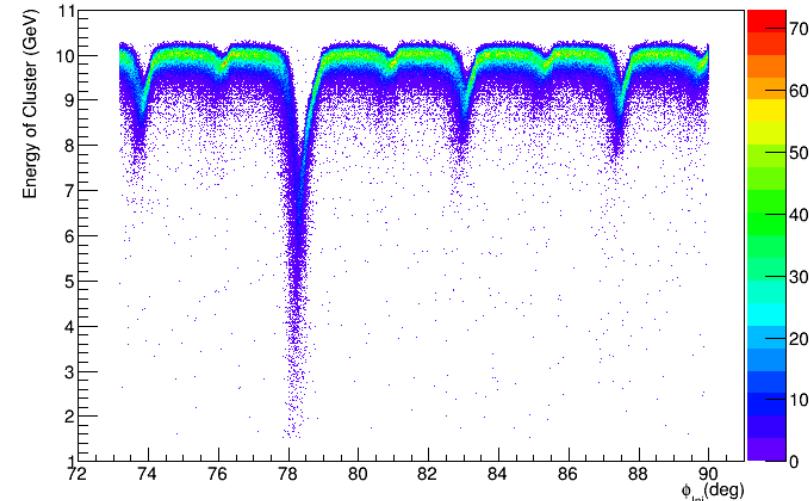


# Position Reconstruction

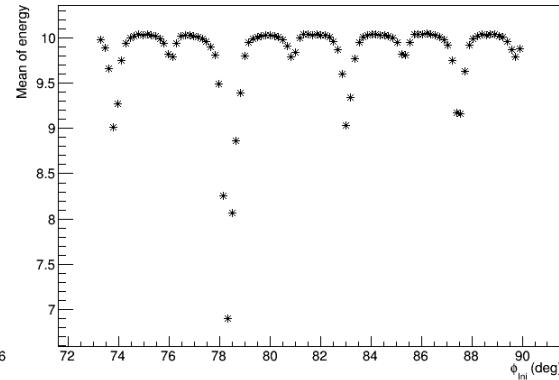
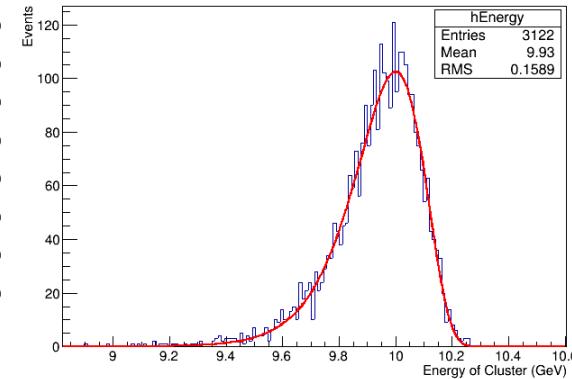
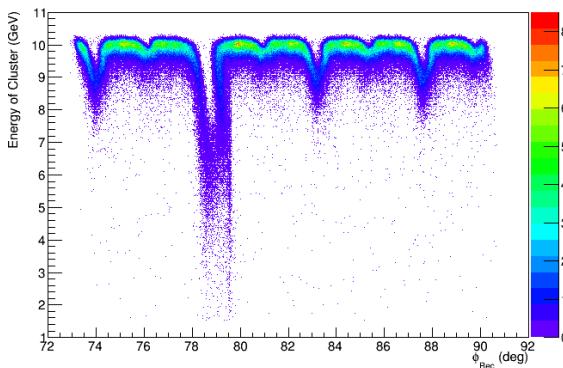
[ $y - \phi$  correction]

## ✓ Data sample->Gamma

- Energy=10GeV
- Events=500,000
- Samples-1
  - 1. Theta= 64.353515
  - 2. Phi=[73.195838, 90]



## ✓ Energy Vs hi-angle

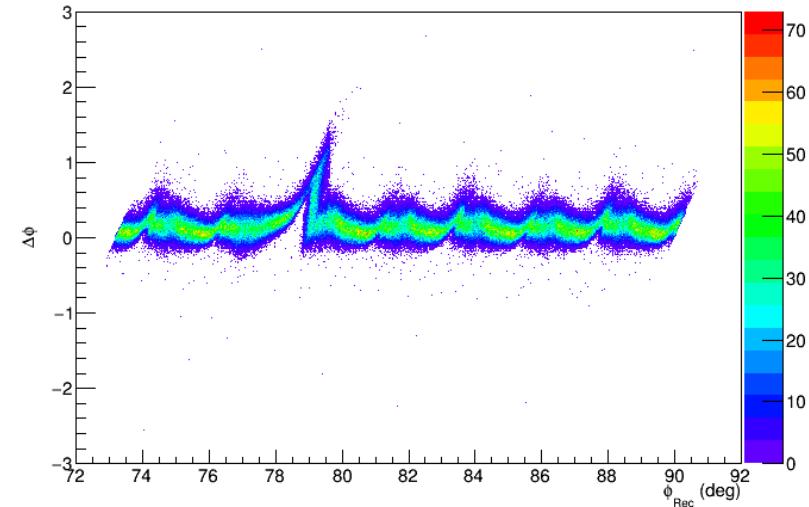


# Position Reconstruction

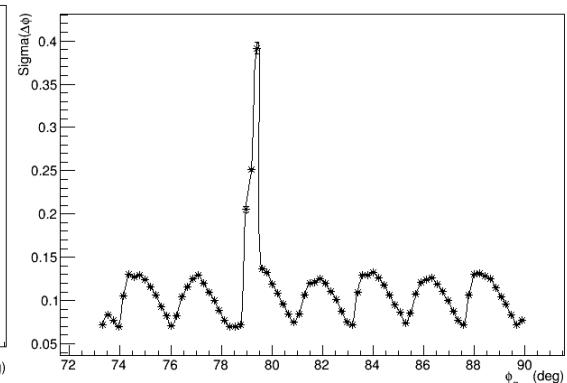
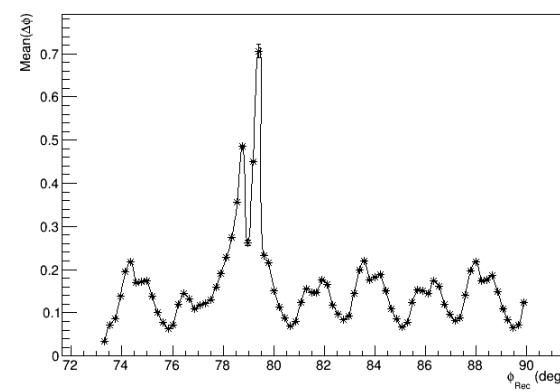
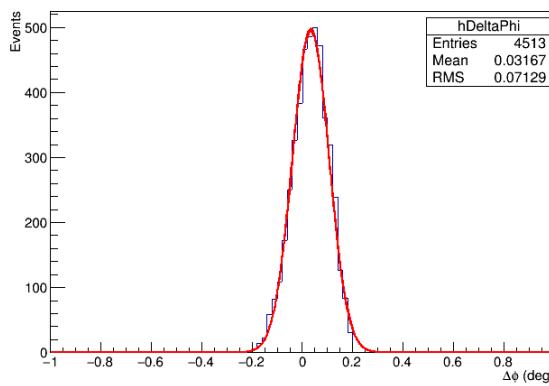
[ $y - \phi$  correction]

## ✓ Data sample->Gamma

- Energy=10GeV
- Events=500,000
- Samples-1
  - 1. Theta= 64.353515
  - 2. Phi=[73.195838, 90]



## ✓ Phi\_rec Vs Delta-phi



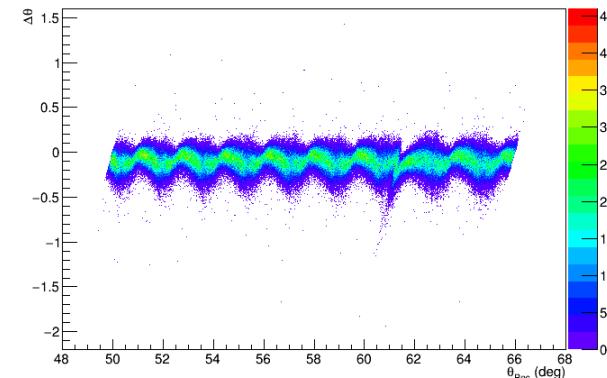
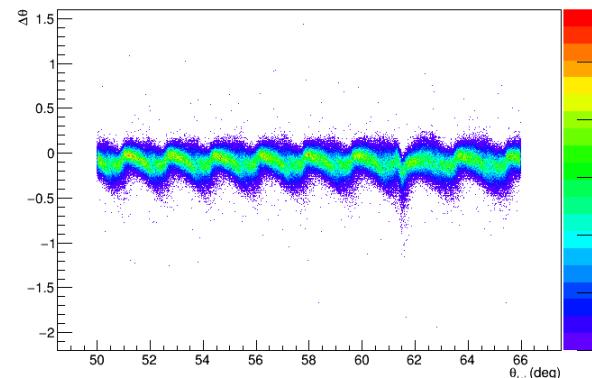
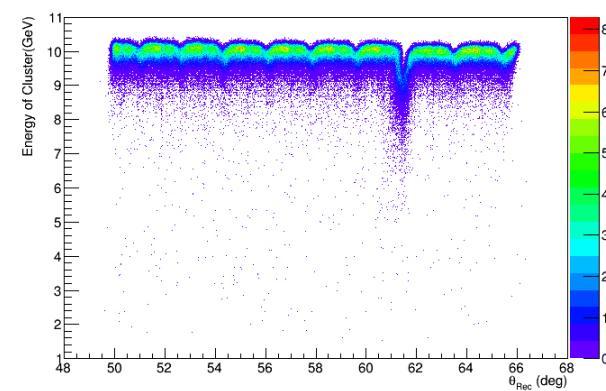
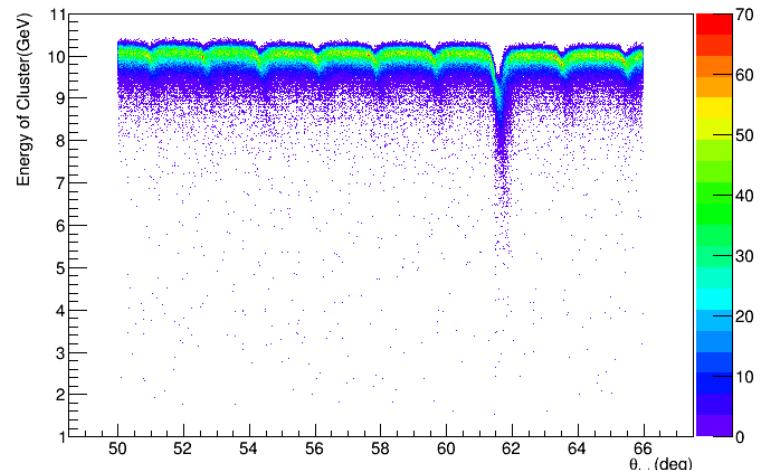
# Position Reconstruction

[ $x - \theta$  correction]

## ✓ Data-sample->Gamma

- Energy=10GeV
- Events=500,000
- Samples-2
  - Theta= [50, 66]deg
  - Phi= 75 deg

## ✓ Energy Vs Theta

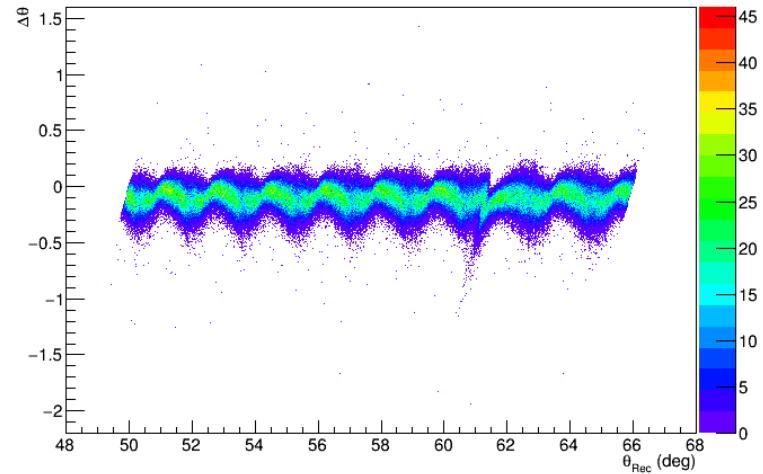


# Position Reconstruction

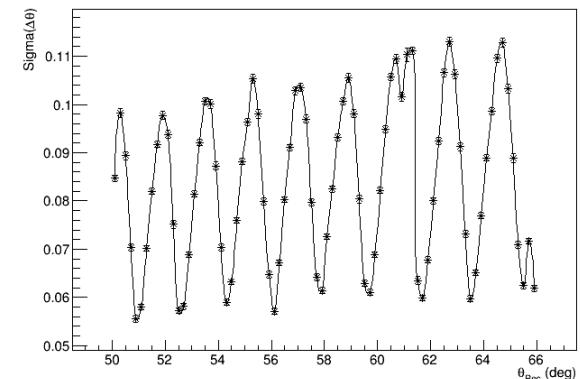
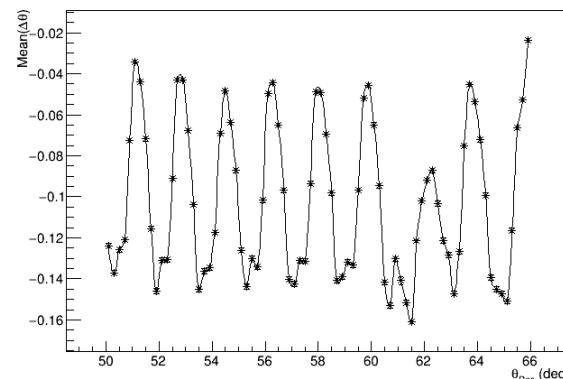
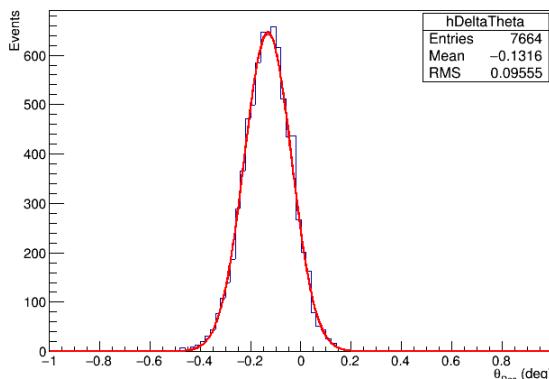
[ $x - \theta$  correction]

## ✓ Data-sample->Gamma

- Energy=10GeV
- Events=500,000
- Samples-2
  - Theta= [50, 66]deg
  - Phi= 75 deg



## ✓ Theta\_rec Vs Delta-theta

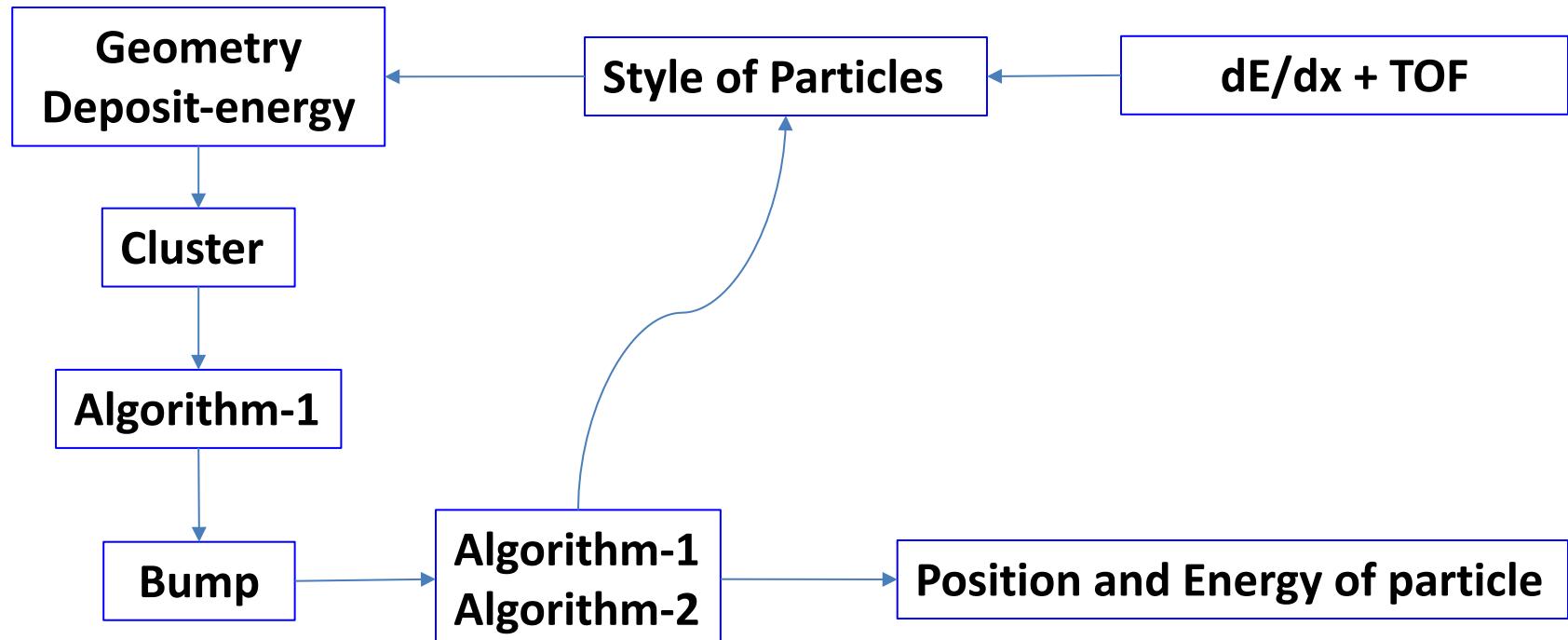


# Position Reconstruction

## [Machine Learning]

✓ Reconstruction of Position

➤ Logic block diagram

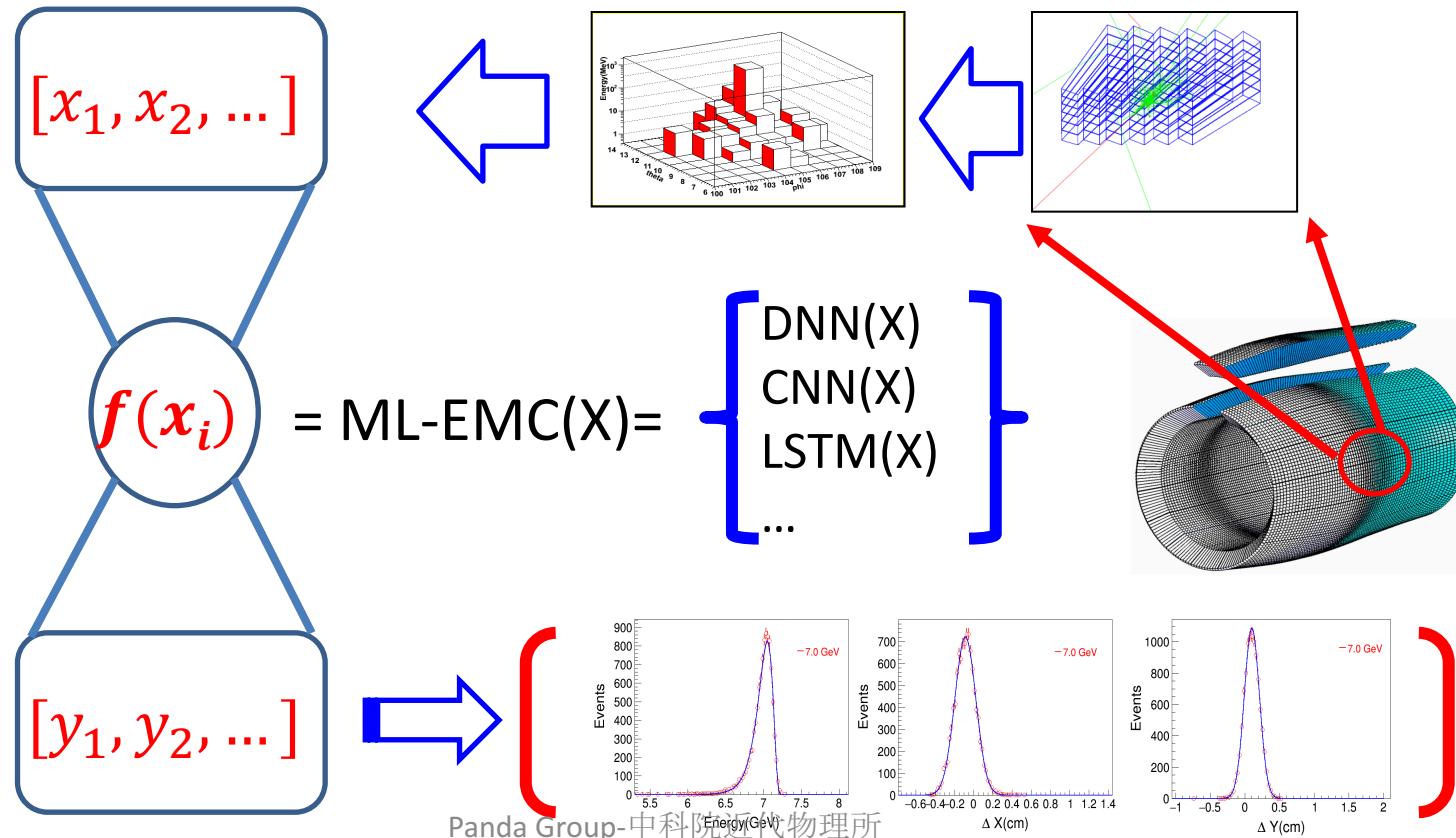


# Position Reconstruction

## [Machine Learning]

### ✓ Data flow

- Data samples ---> Function( $x$ ) ---> Results



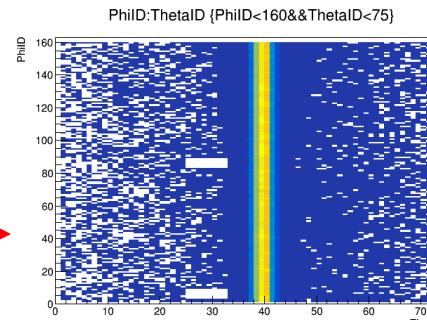
# Position Reconstruction

## [Machine Learning]

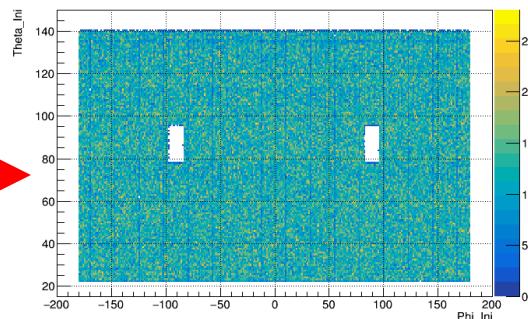
✓ Supervised training

➤ CNN model

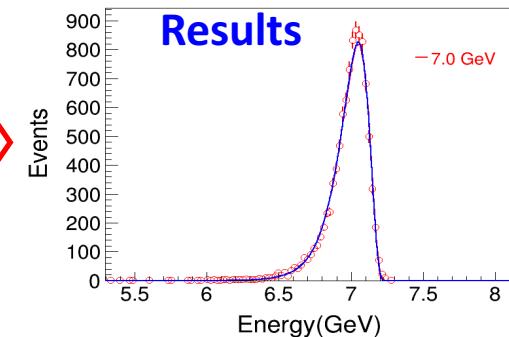
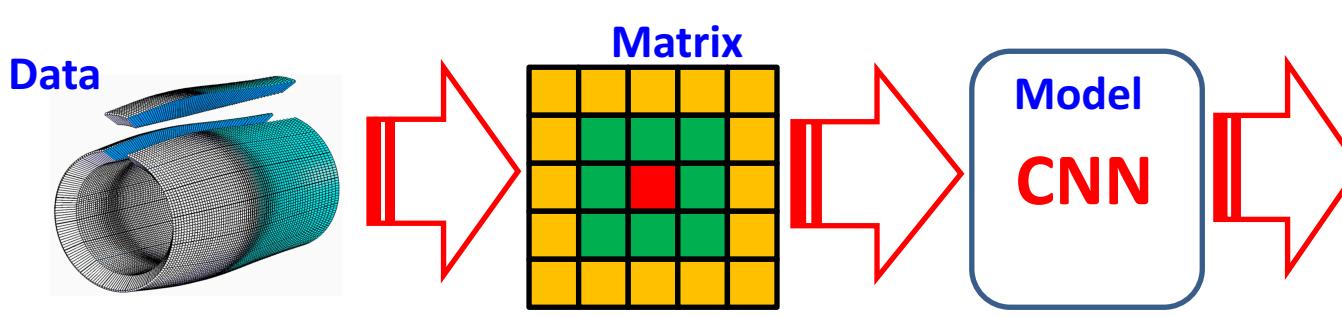
1. Input →



2. Labels →



✓ Data flow

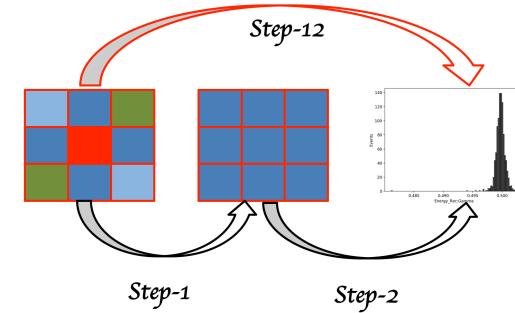
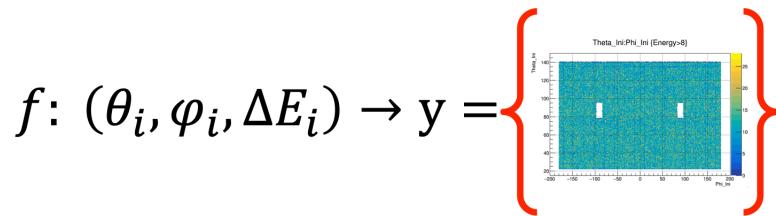


# Position Reconstruction

## [Machine Learning]

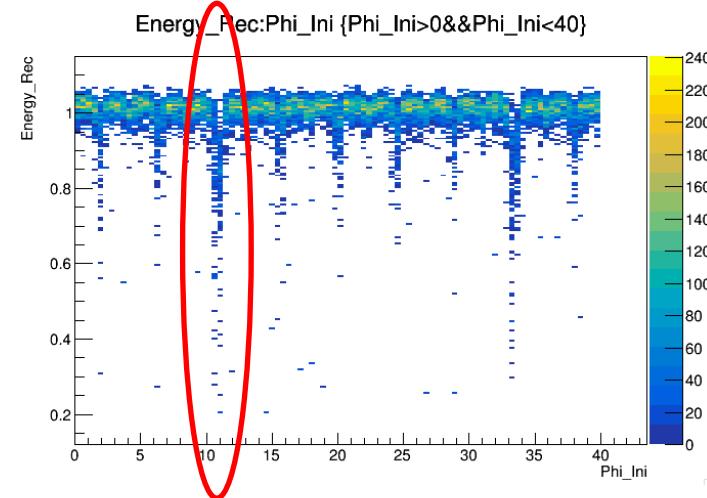
✓ Position reconstruction:

- It is a relationship between Input and Output .



✓ Data samples

- Gamma
- Fixed position
  - Theta = 64.35 deg
  - Phi = 11 deg
  - Energy = (1.0, 7.3) GeV

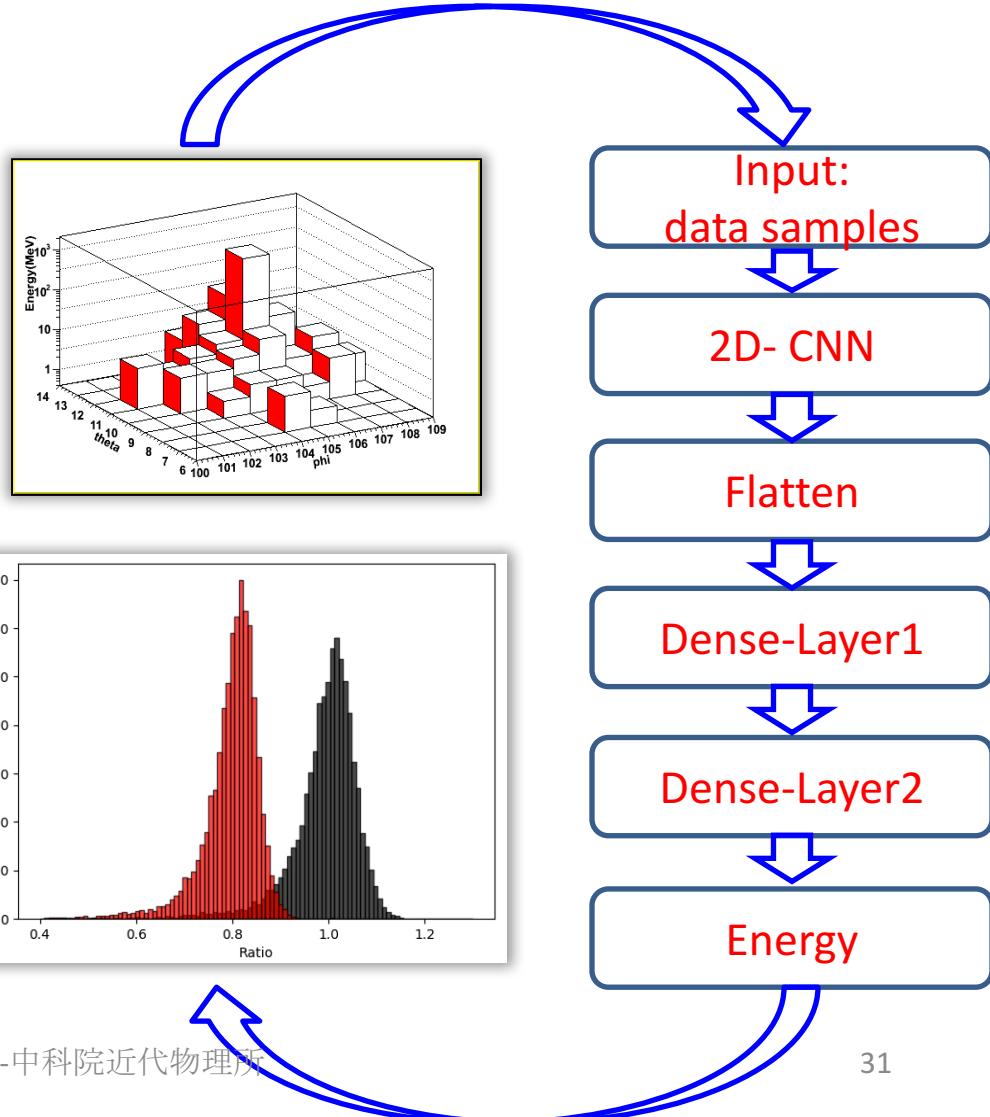


# Position Reconstruction

## [Machine Learning]

### ✓ Data sample->Gamma

- Energy= **(1.0, 7.0)** GeV
- Phi = **11** deg
- Theta= **64.35** deg
- Event = 50000



### ✓ Input -> Matrix(5, 5)

- Normalization
  - 1. Energy/7.0

### ✓ Training-Model(CNN)

### ✓ Training result

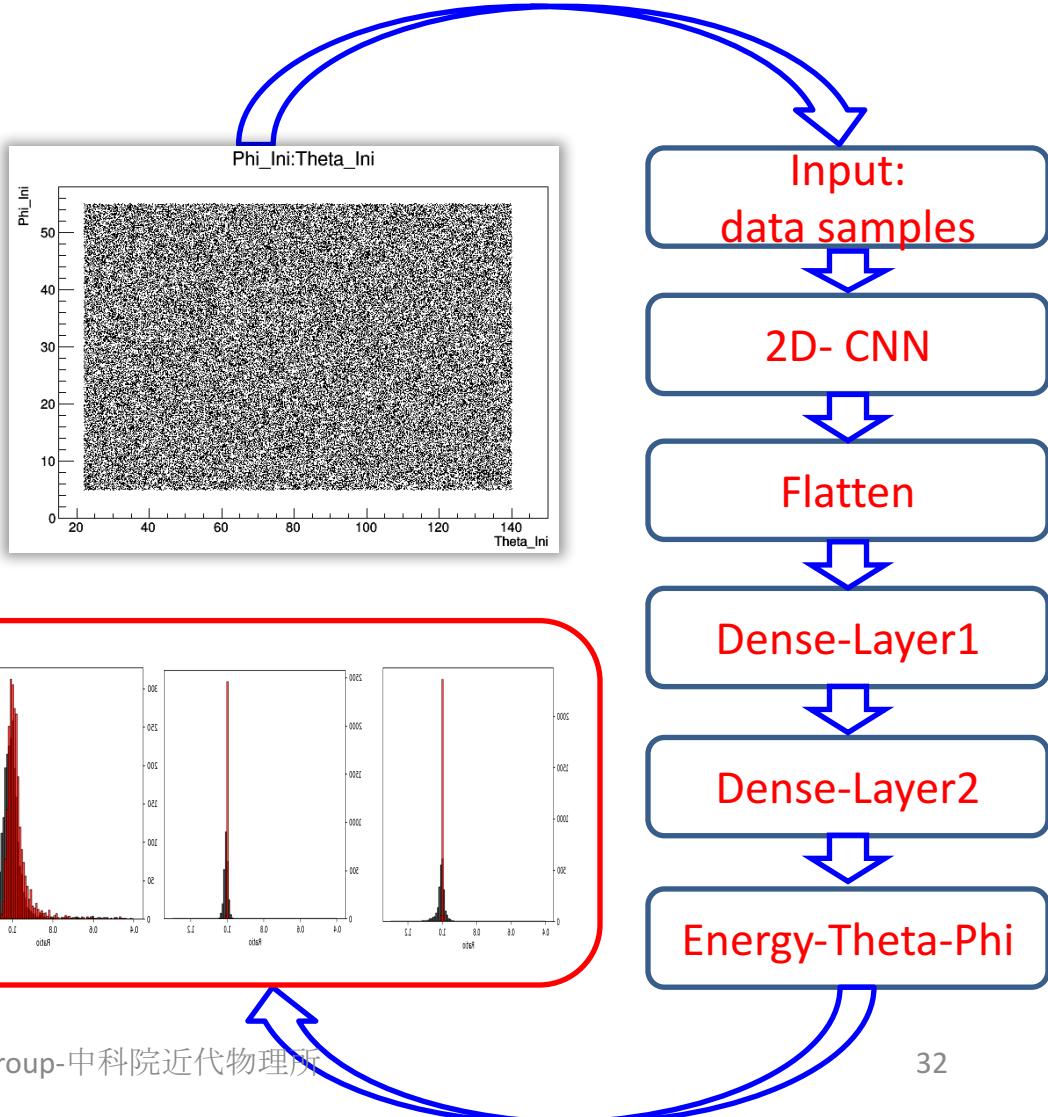
- Ratio=Rec/Truth

# Position Reconstruction

## [Machine Learning]

### ✓ Data sample->Gamma

- Energy= **(1.0, 7.0)** GeV
- Phi = **(5, 55)** deg
- Theta= **(22, 140)** deg
- Event = 50000



### ✓ Input -> Matrix(160, 71)

- Normalization

1. Energy/7.0
2. Theta/180.0
3. Phi/360.0

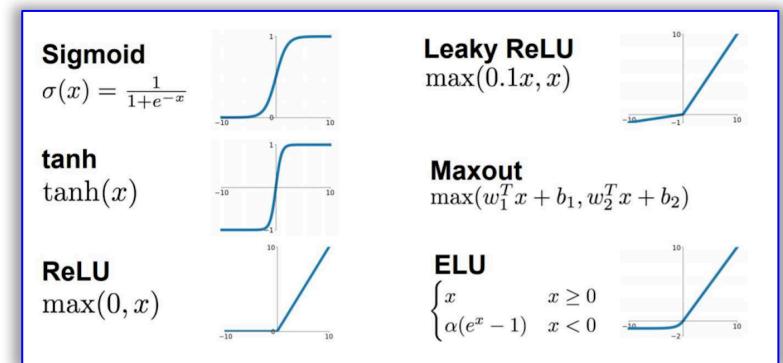
### ✓ Training-Model(CNN)

# Position Reconstruction

## [Machine Learning]

### ✓ Challenge for Training

- Size of samples
- Data format
  1. Matrix(160, 71)
  2. Matrix(5, 5)
- Normalization of data
- Model selection
  1. Activation function
  2. Optimizer
  3. Loss function
- **Regression -> weakness**
- **Classification->Strength**

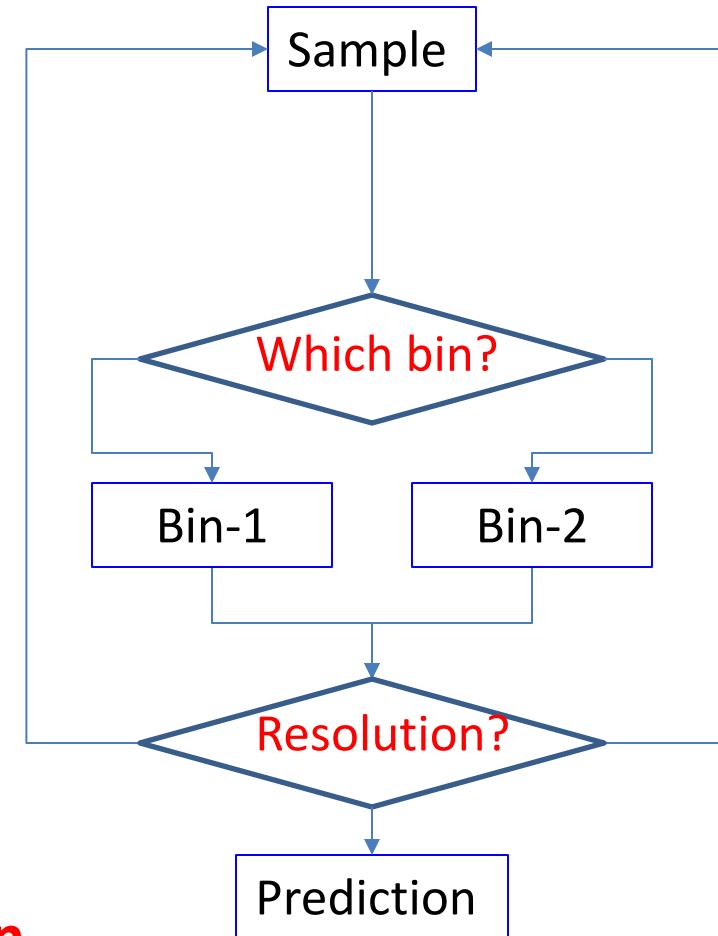


# Position Reconstruction

## [Machine Learning]

### ✓ Challenge for Training

- Size of samples
- Data format
  1. Matrix(160, 71)
  2. Matrix(5, 5)
- Normalization of data
- Model selection
  1. Activation function
  2. Optimizer
  3. Loss function



### ✓ Transfer regression to classification

# Summary

## ✓ Reconstruction and correction of position

- Basic method
  - Log-weighting method

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

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

## ✓ New methods to try

- Machine learning

## ✓ Need to solve the problem

- Gaps between slices
  - A big effect on the calibration of position and energy about EMC.

# Back-Up

# Position Method

[ $y - \phi$  correction]

## ✓ ClusterPosition

➤ Depth

## ✓ Gamma

➤ Energy=10.0 GeV

➤ Phi=(73.195838, 77.195838)

➤ Theta=(64.353515)

➤ Events=201000

➤ Surface Method

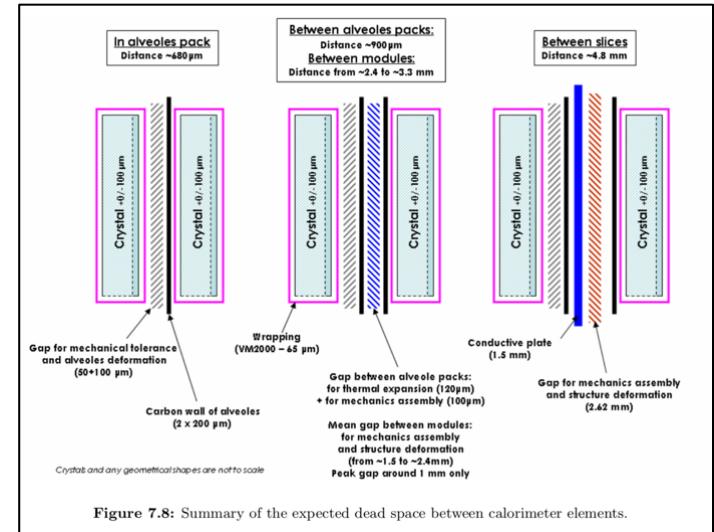
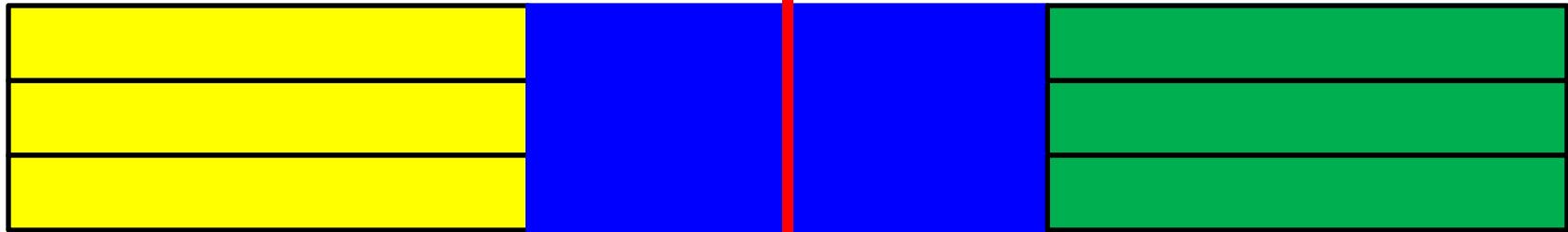


Figure 7.8: Summary of the expected dead space between calorimeter elements.



# Position Method

[ $y - \phi$  correction]

✓ ClusterPosition

➤ Depth

✓ Frontface

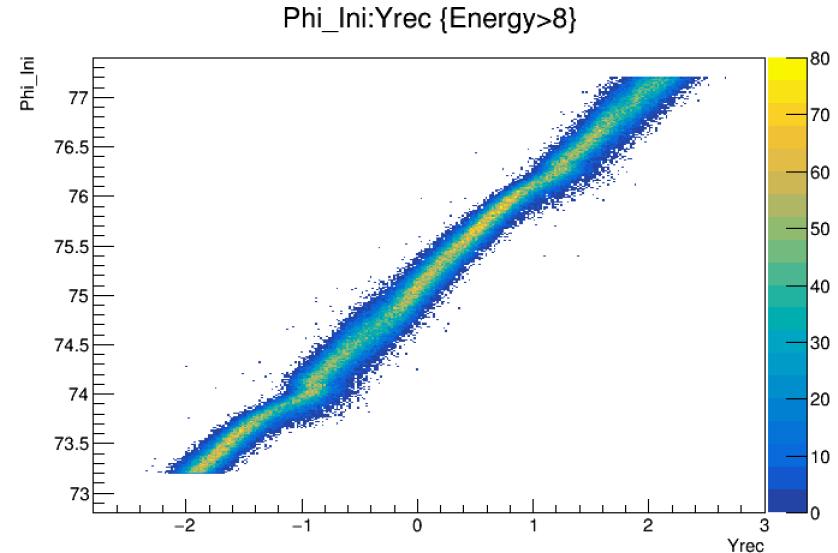
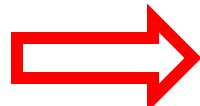
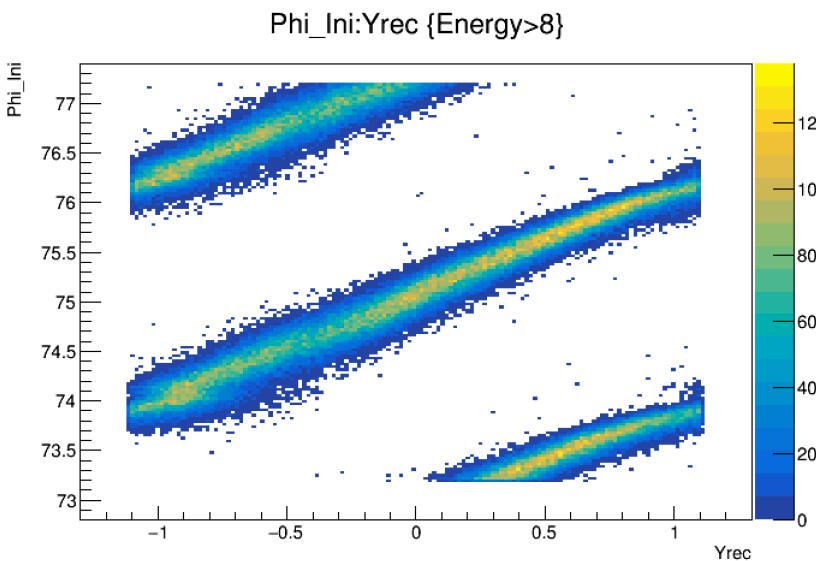
➤ Cluster position

✓ ClusterPosition

➤ Depth

✓ Frontface

➤ Fixed position



MCData/root/root\_V3/Energy-10.0-0/New\_RootFiles

# Position Method

[ $y - \phi$  correction]

✓ ClusterPosition

➤ Depth

✓ Frontface

➤ Cluster position

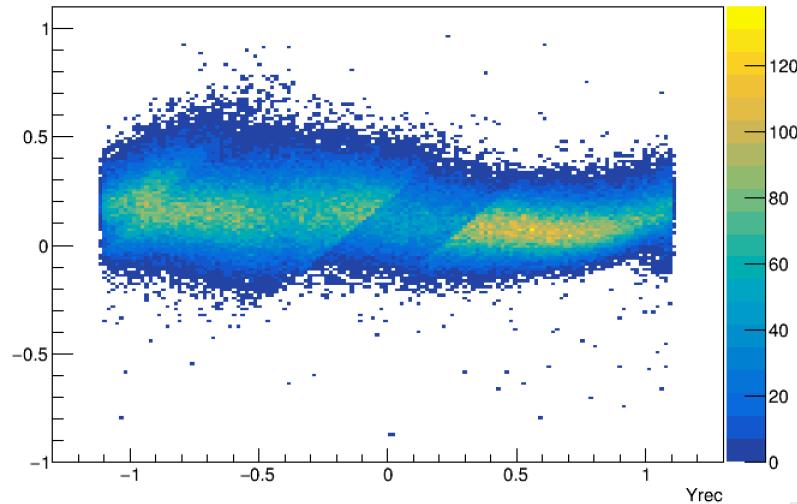
✓ ClusterPosition

➤ Depth

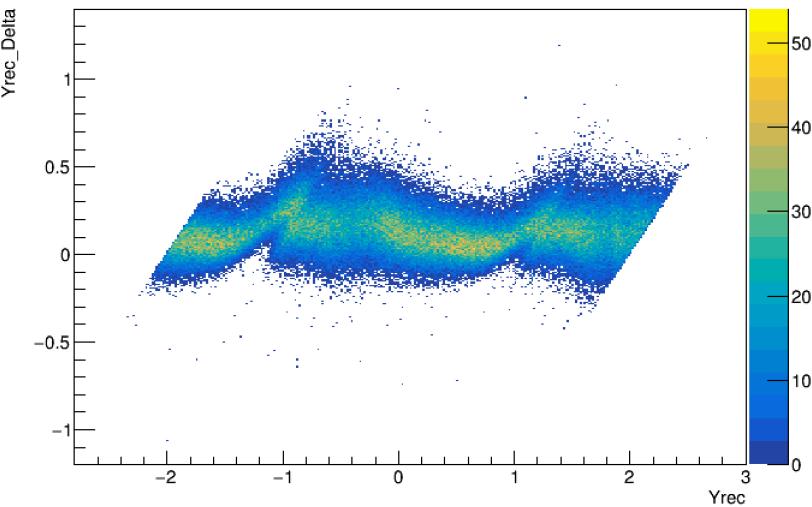
✓ Frontface

➤ Fixed position

Yrec\_Delta:Yrec {Energy>8}



Yrec\_Delta:Yrec {Energy>8}



MCData/root/root\_V3/Energy-10.0-0/New\_RootFiles