Shower Shape Analysis of Calorimeter Insert First Test Beam Data

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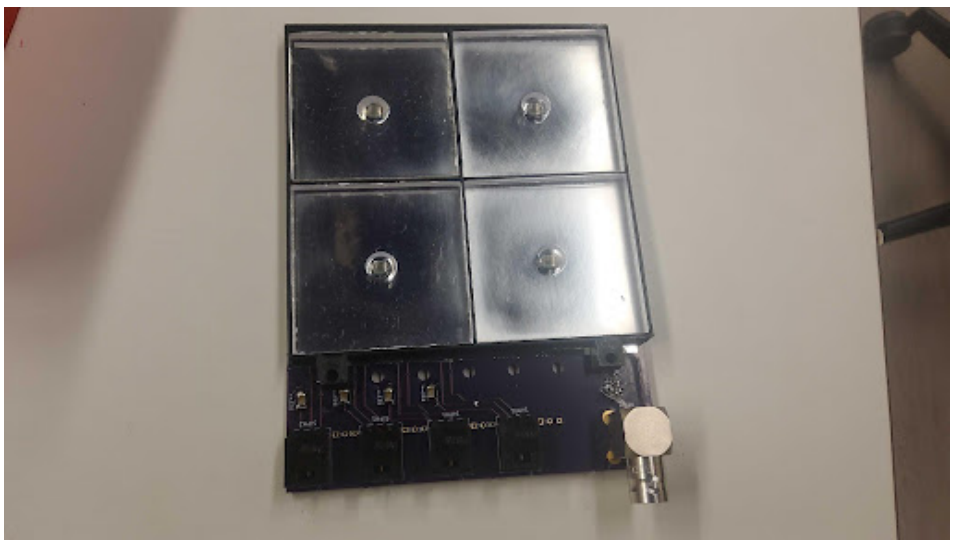
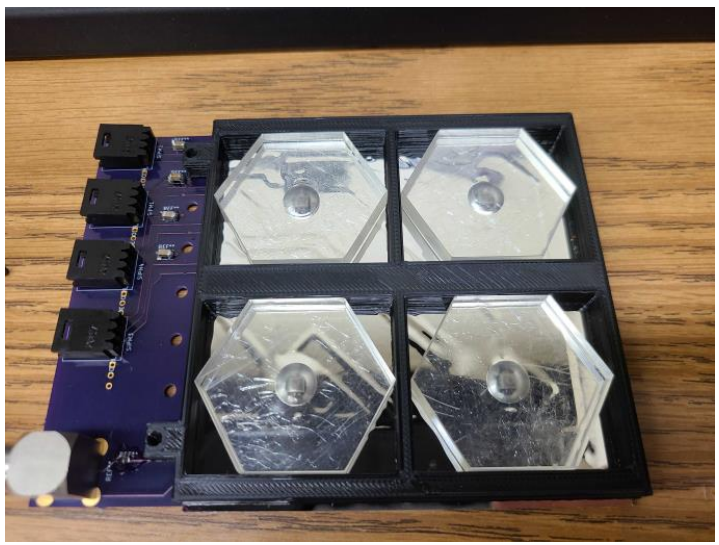
2023-06-07

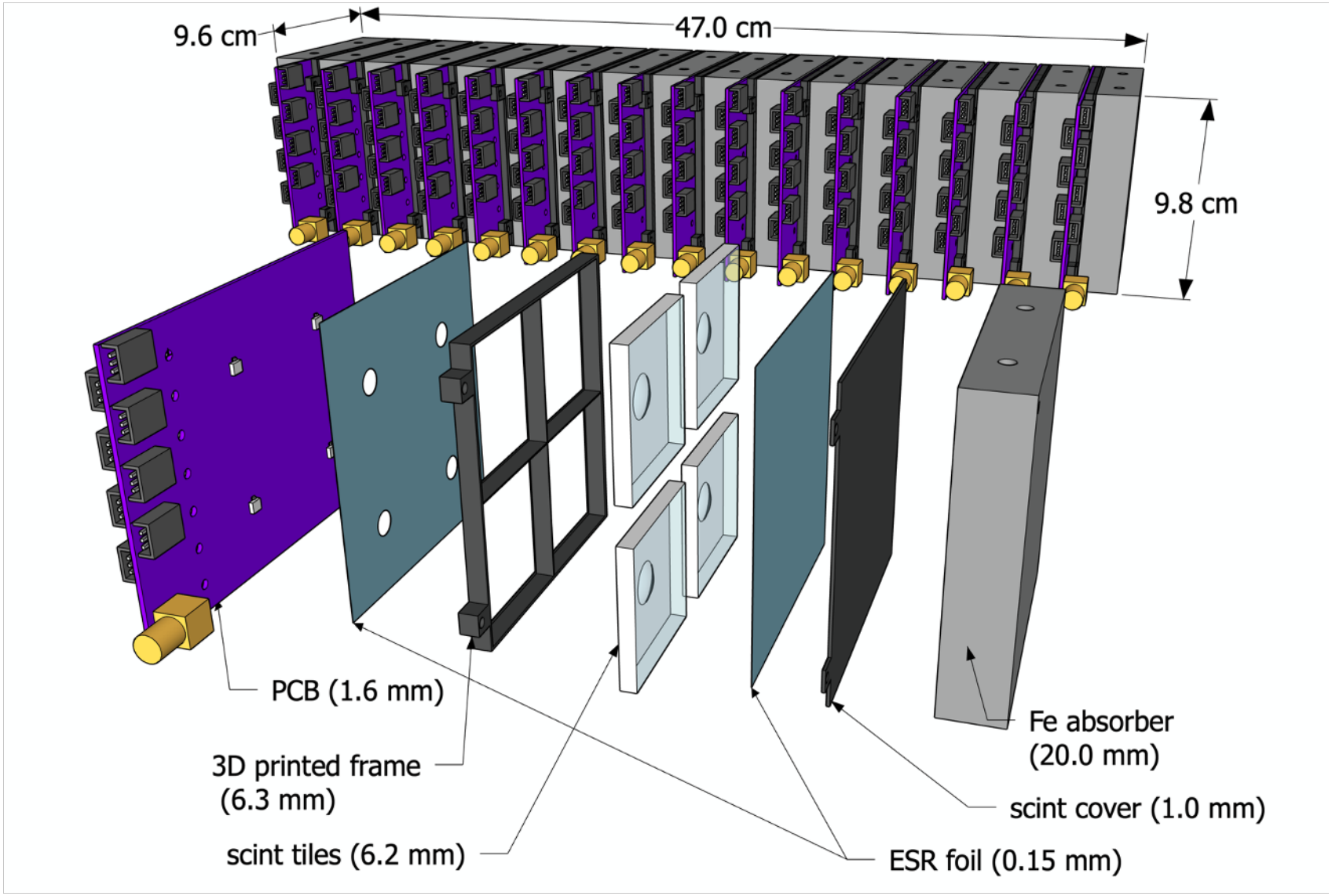
Introduction

- Proof of concept prototype: 10 layers, 4 scintillator tile cells per layer
- Beam test in Hall D at JLab last year
- $\sim$ 4 GeV positrons



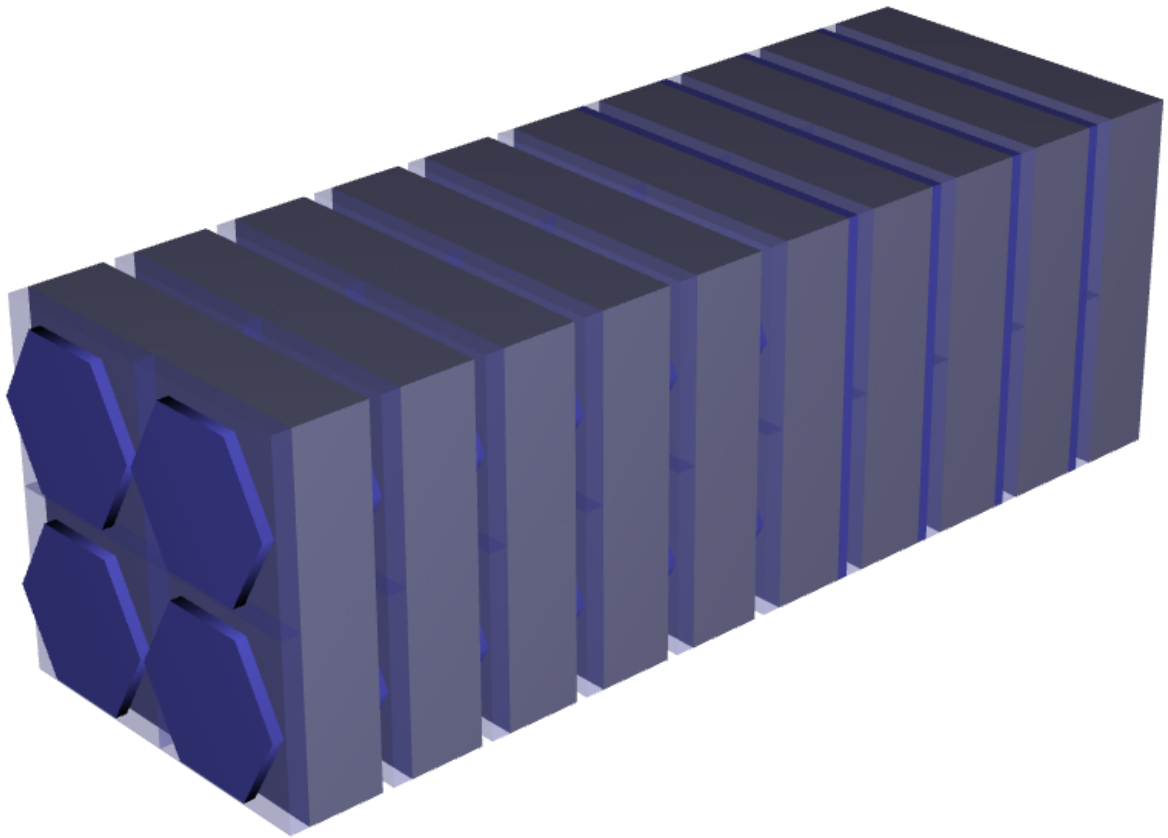


Prototype

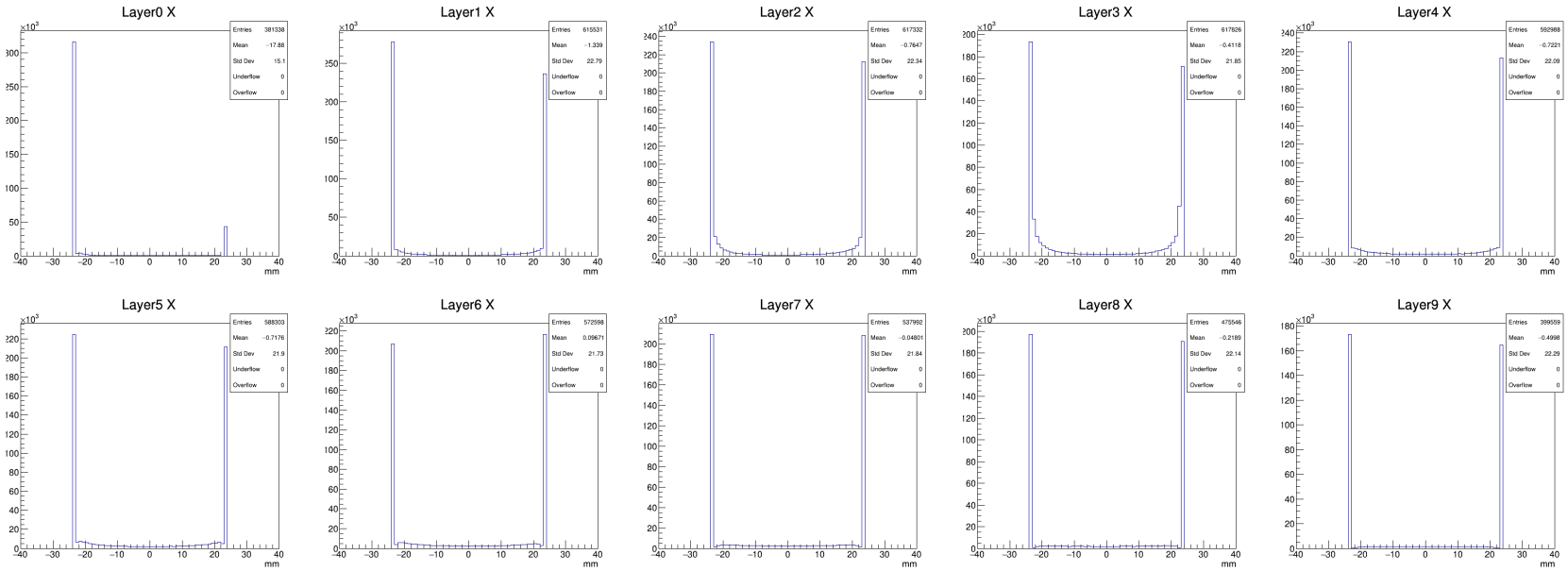

9.6 cm
47.0 cm
9.8 cm
PCB (1.6 mm)
3D printed frame
(6.3 mm)
scint tiles (6.2 mm)
ESR foil (0.15 mm)
Fe absorber
(20.0 mm)
scint cover (1.0 mm)

Geometry in Simulation

- 10 layers
- 4 layers of square cells + 6 layers of hexagonal cells
- absorber + scintillator cover + ESR foil + scintillator tile + frame + ESR foil + PCB

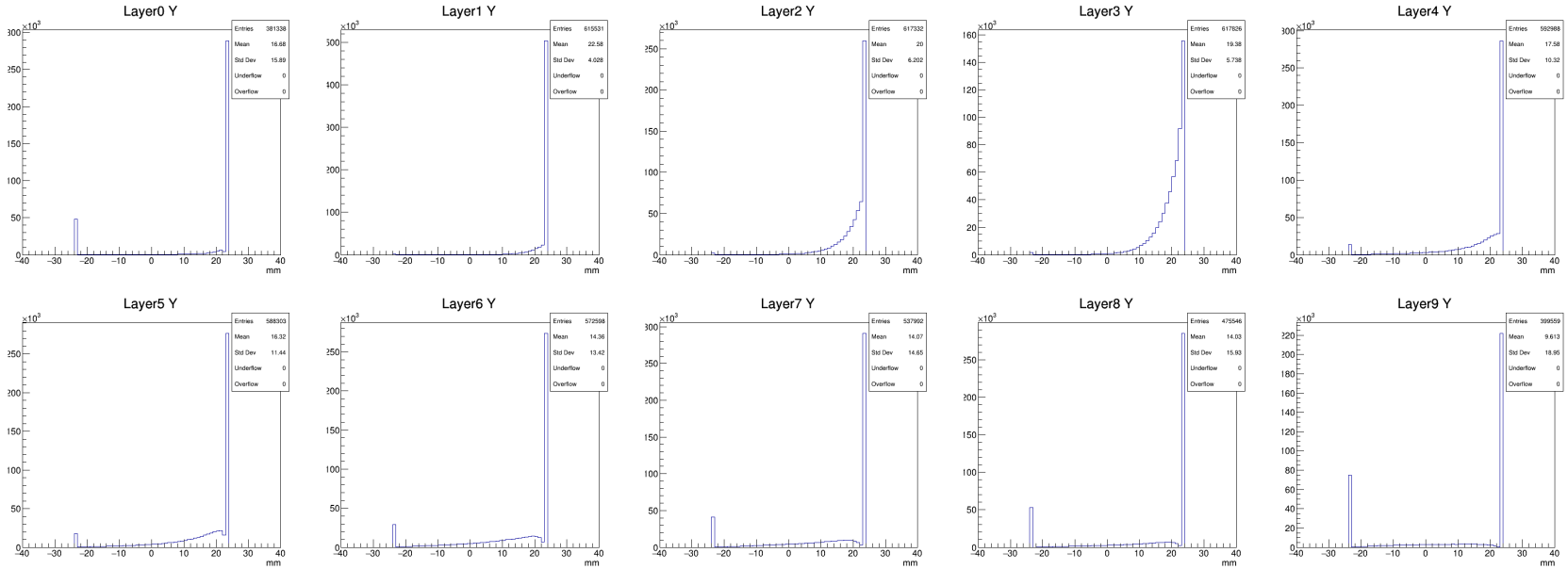


Data Characteristics: Energy Weighted Layer X



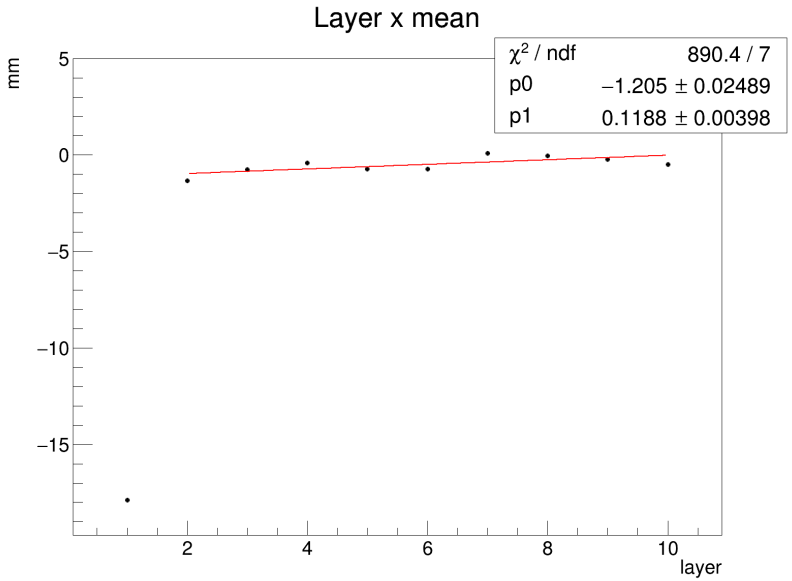
- $x_{\text{layer}} = \frac{\sum_i x_i E_i}{\sum_i E_i}$ where i loops over all hit in a layer
- Cell 1 (layer 0) and cell 7 (layer 1) are blocked
- Almost symmetric distribution $\rightarrow$ beam is centered in the X direction
- Most showers are limited to only 1 cell in each layer

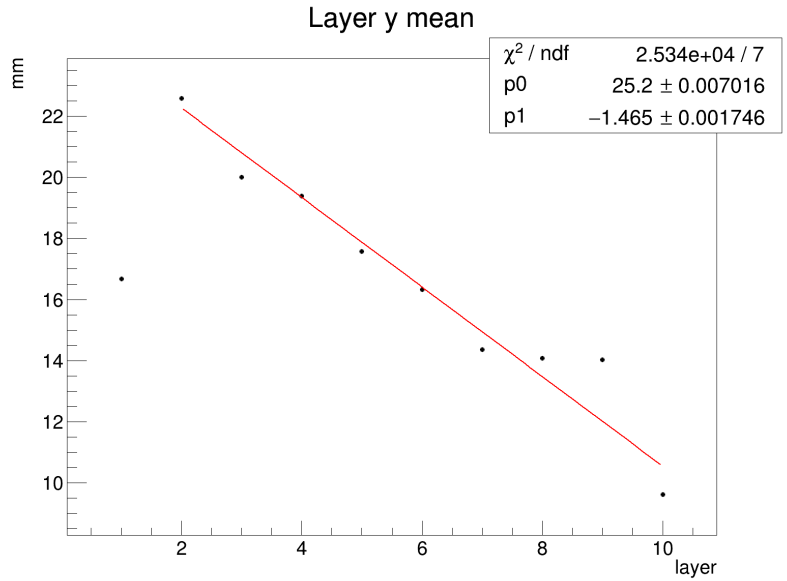
Data Characteristics: Energy Weight Layer Y



- $y_{\text{layer}} = \frac{\sum_i y_i E_i}{\sum_i E_i}$
- Asymmetric distribution $\rightarrow$ beam is shifted in the Y direction

Data Characteristics: Energy Weight Layer X/Y Mean

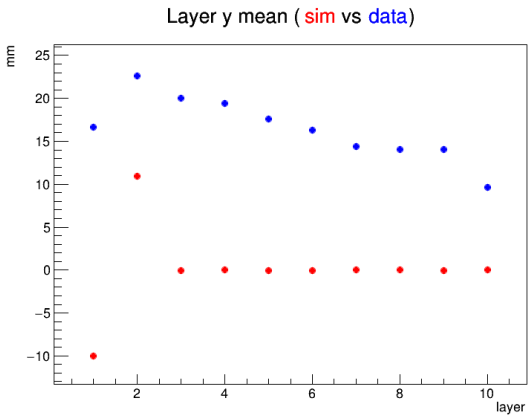




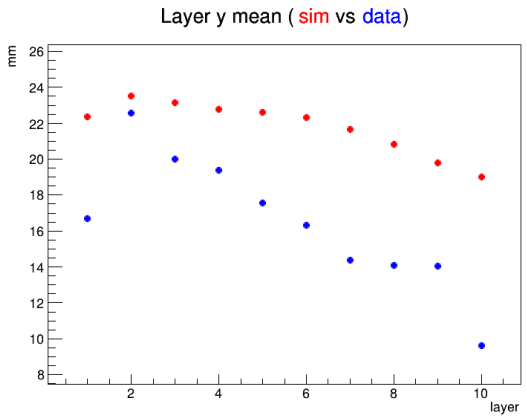
- A slope (-1.465 mm/2.91 cm ~ -0.05) is seen in the Y direction
  - The incoming beam is slightly tilted in the Y direction
  - The large shift in the Y direction results in some showered electrons/photons escape from the top, leading to a slope in the Y direction

Simulation With Large Y Shift

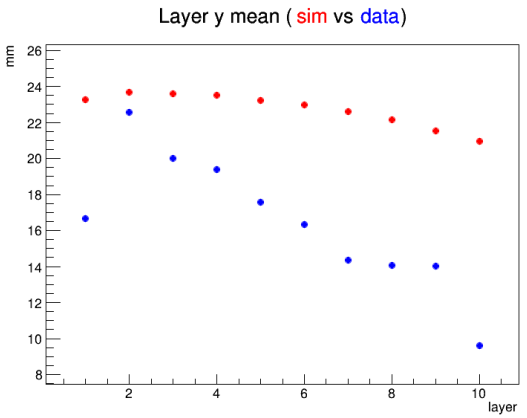
y shift = 0



y shift = 20 mm



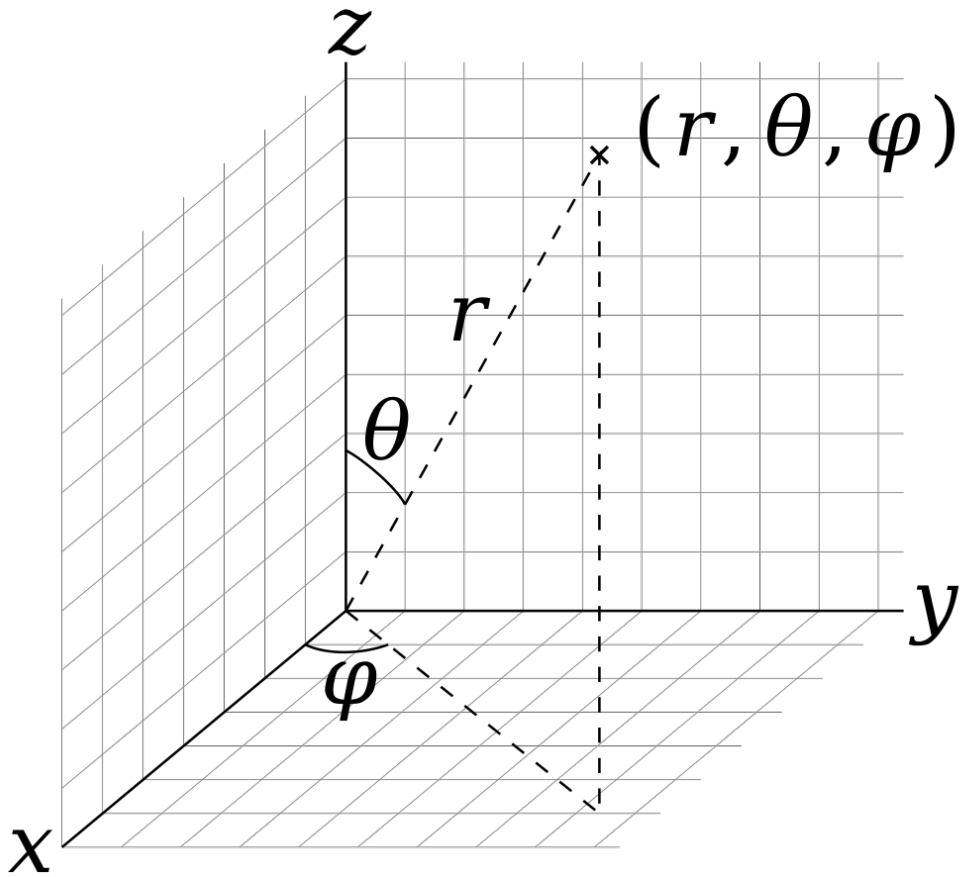
y shift = 40 mm



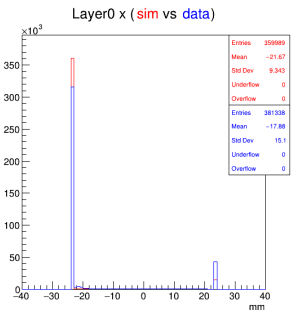
- The y shift does contribute to the y slope
- The slope caused by the y shift is smaller than what is shown in data, which means there are other contributions: the beam is tilted

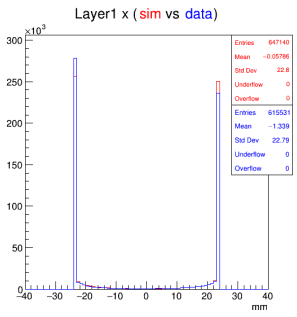
A Good Model: Beam Configuration in the Simulation

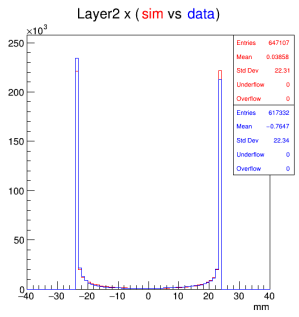
- Beam is along Z
- -1 mm shift in x
- $\theta \in [0.04, 0.044]$
- 225 mm shift in y (the beam source is 5 m away from the prototype)
- $\phi \in [-110°, -70°]$

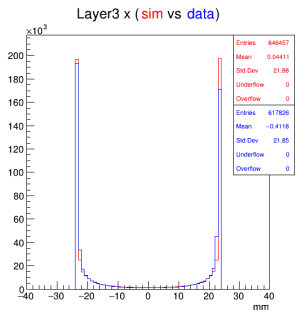


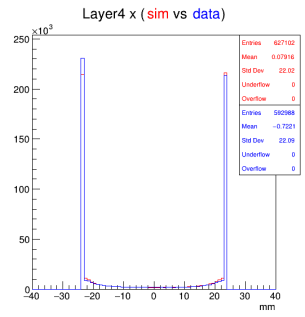
Comparison: Energy Weighted Layer X

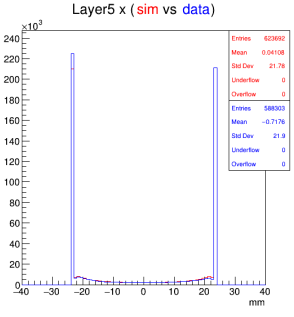


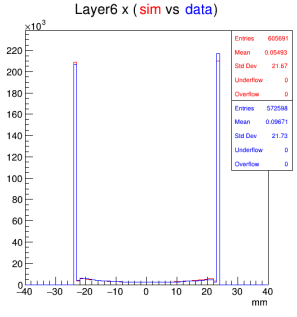


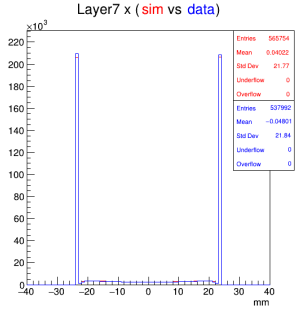


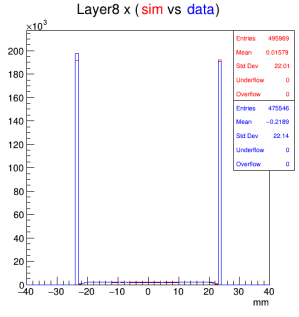


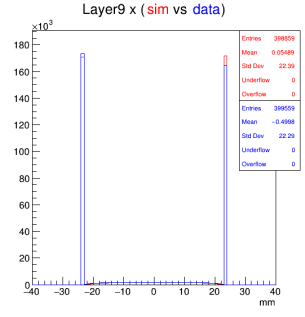




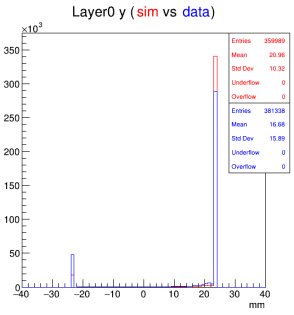


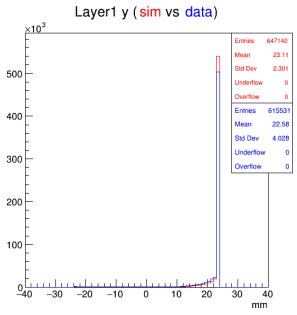


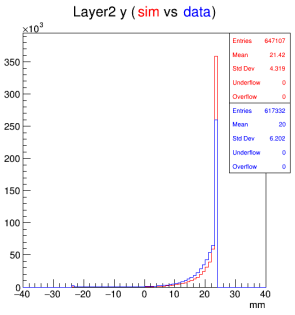


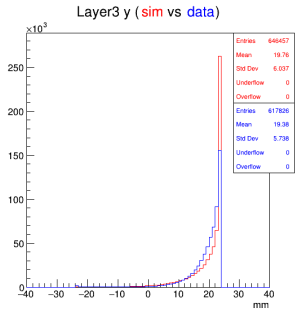


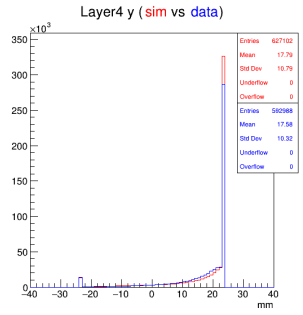
Comparison: Energy Weighted Layer Y

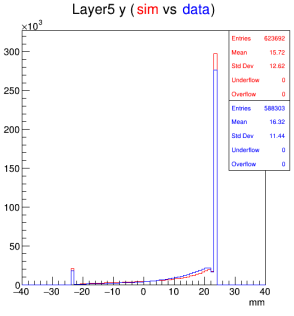


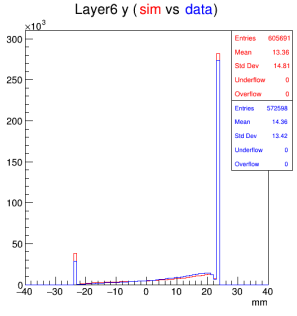


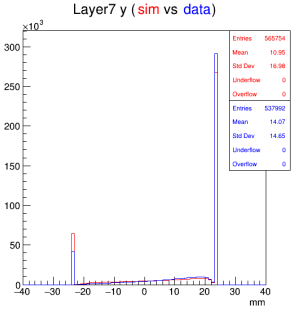


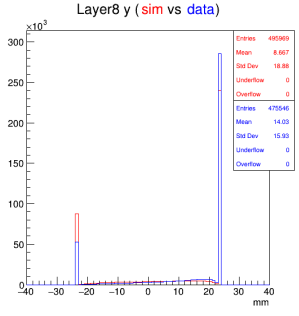


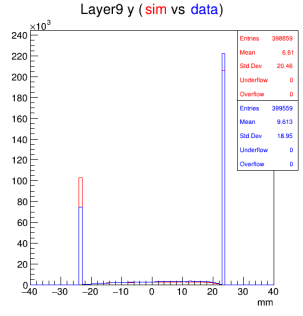




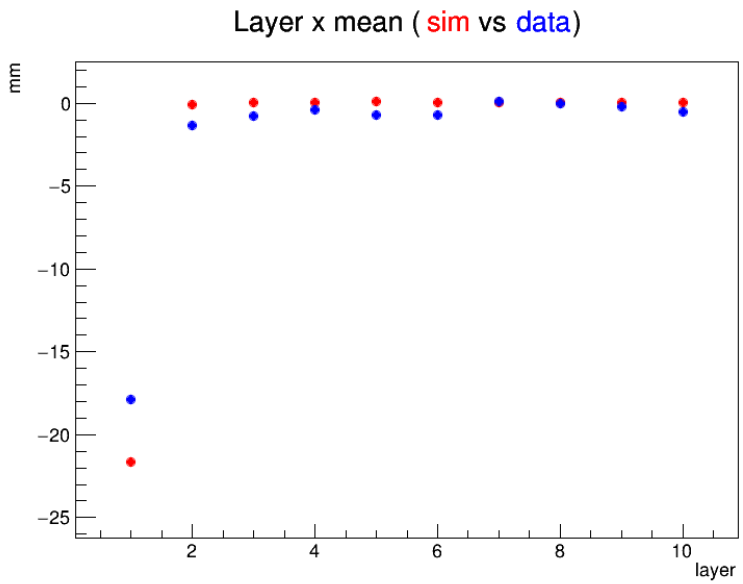


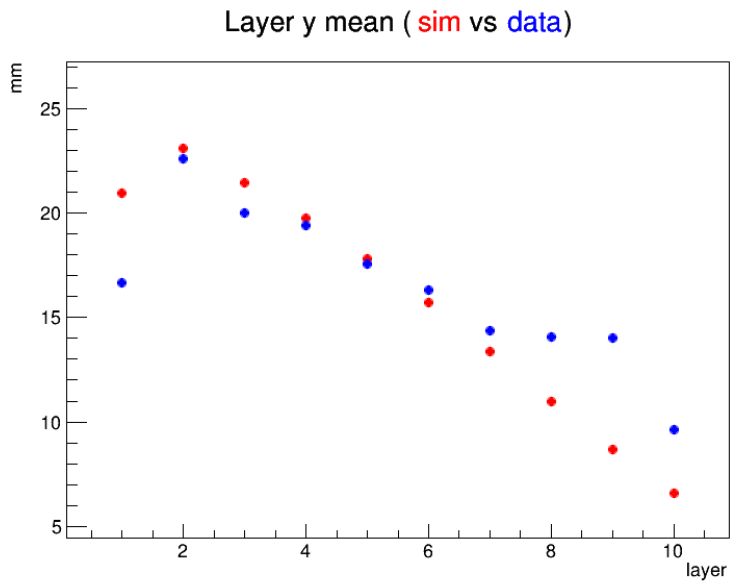




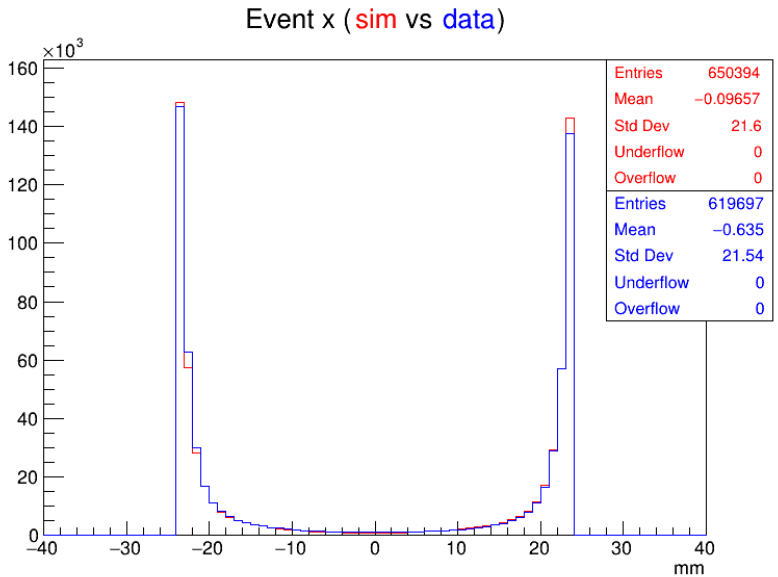


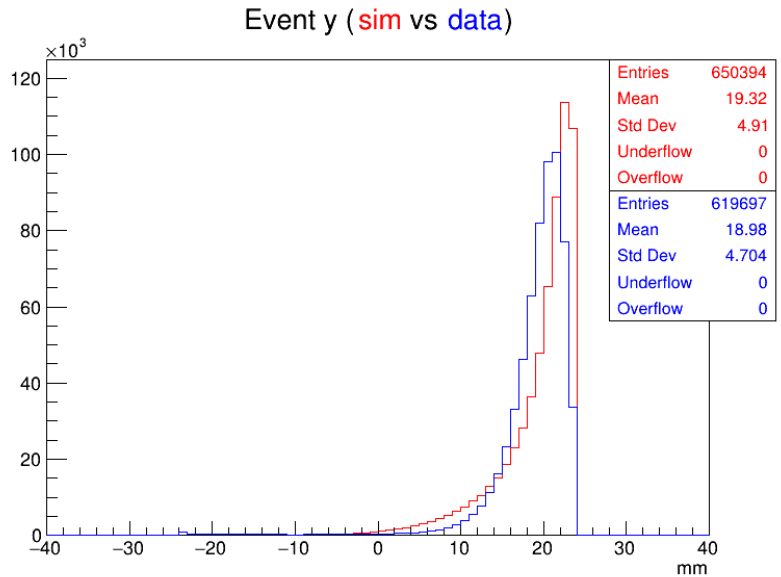
Comparison: Energy Weighted Layer X/Y Mean





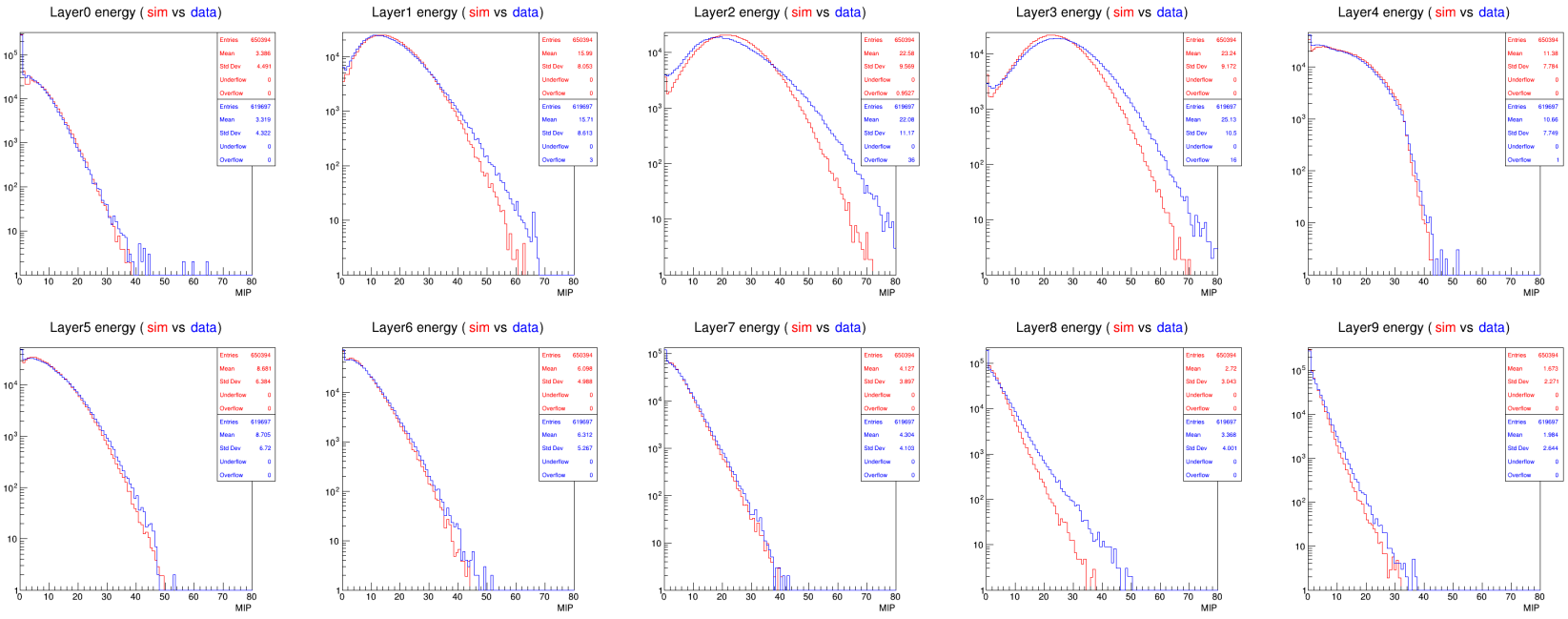
Comparison: Energy Weighted Event X/Y





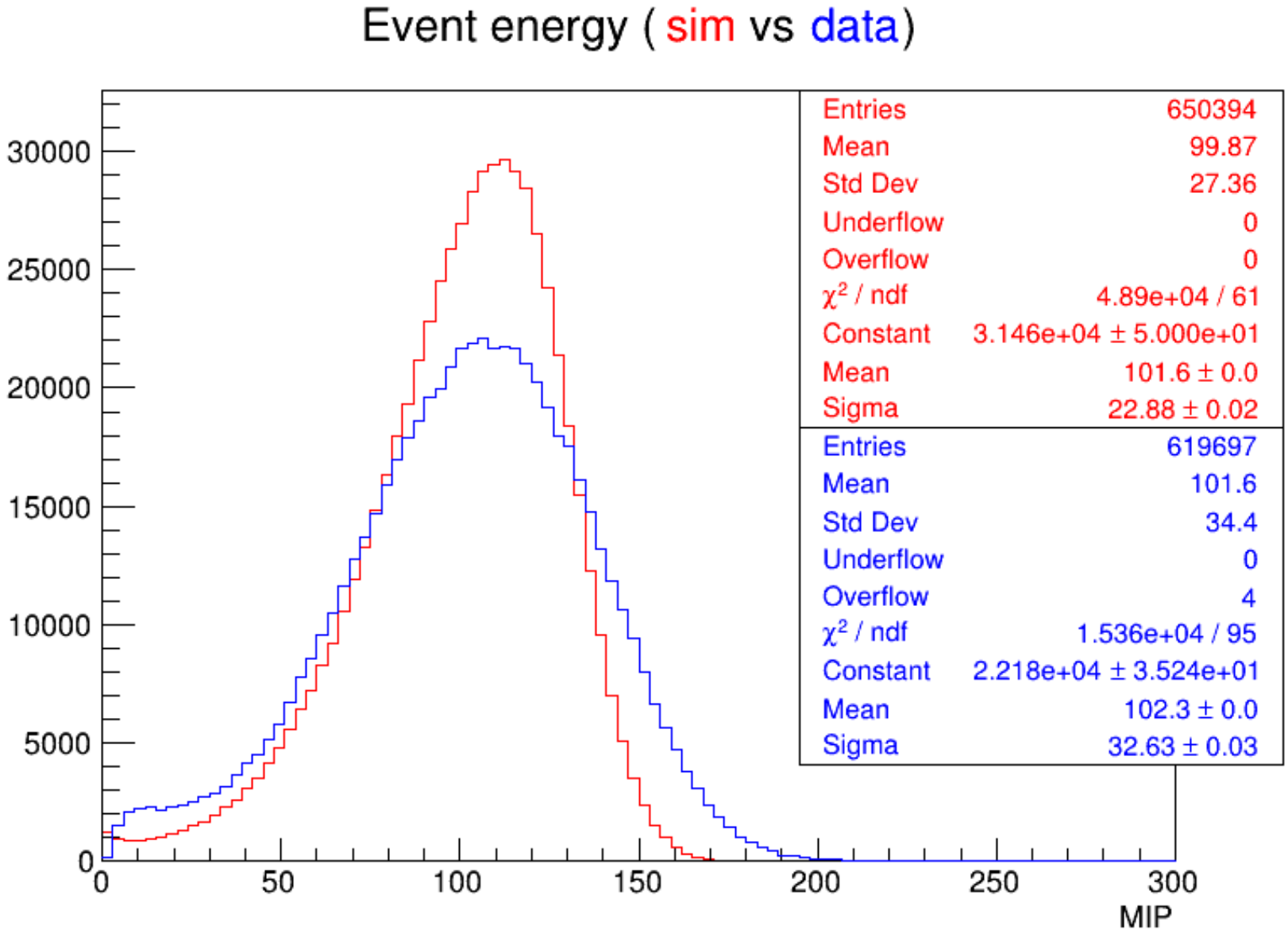
- $x_{\text{event}} = \frac{\sum_i x_i E_i}{\sum_i E_i}$ where i loops over all hits in a event; same definition for y_{event}

Comparison: Layer Energy



- $E_{\text{layer}} = \sum_i E_i$ where i loops over all hits in a layer

Comparison: Event Energy



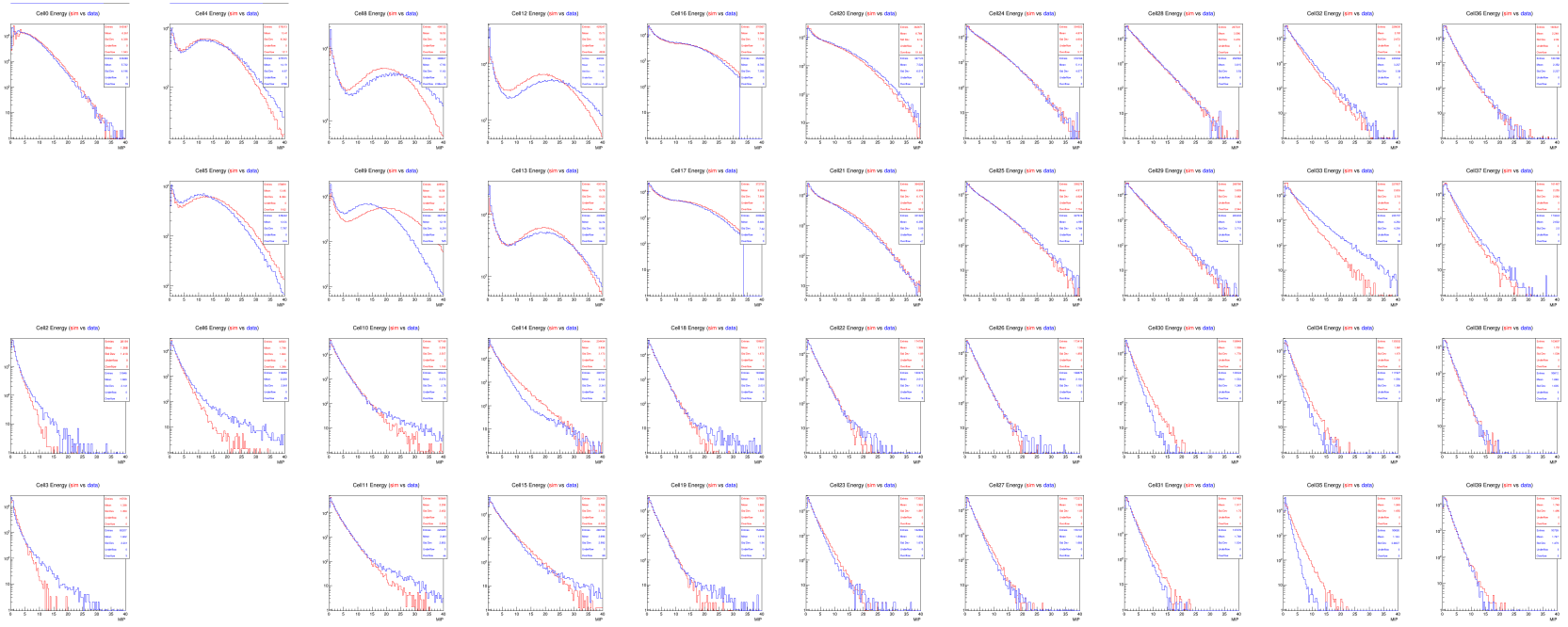
- $E_{\text{layer}} = \sum_i E_i$ where i loops over all hits in a event

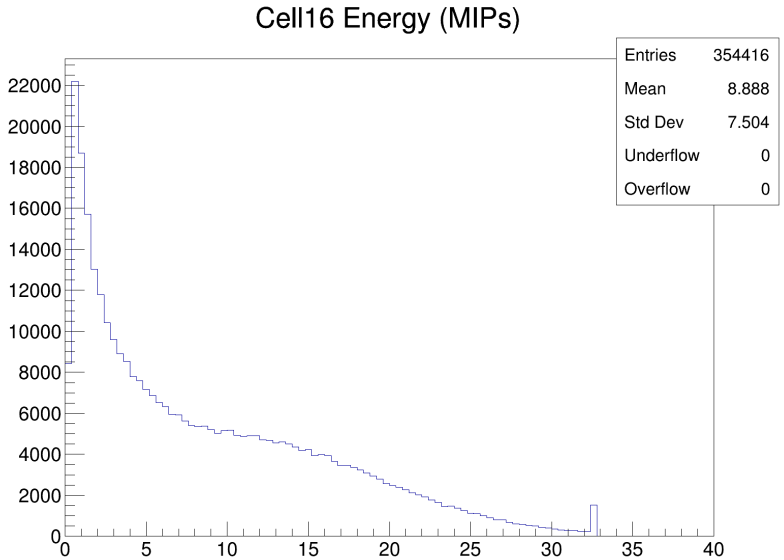
Summary

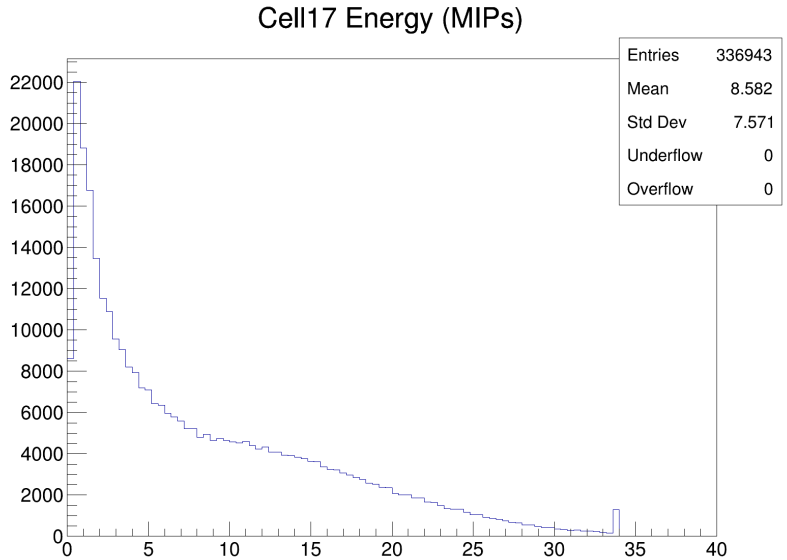
- Successfully simulate the prototype and the beam conditions, achieving good agreement between data and simulation
- The Calorimeter Insert is able to provide the angle information of the incoming beams

Backup

Comparison: Cell Energy




Cell16 Energy (MIPs)
Entries 354416
Mean 8.888
Std Dev 7.504
Underflow 0
Overflow 0
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 5 10 15 20 25 30 35 40


Cell17 Energy (MIPs)
Entries 336943
Mean 8.582
Std Dev 7.571
Underflow 0
Overflow 0
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 5 10 15 20 25 30 35 40