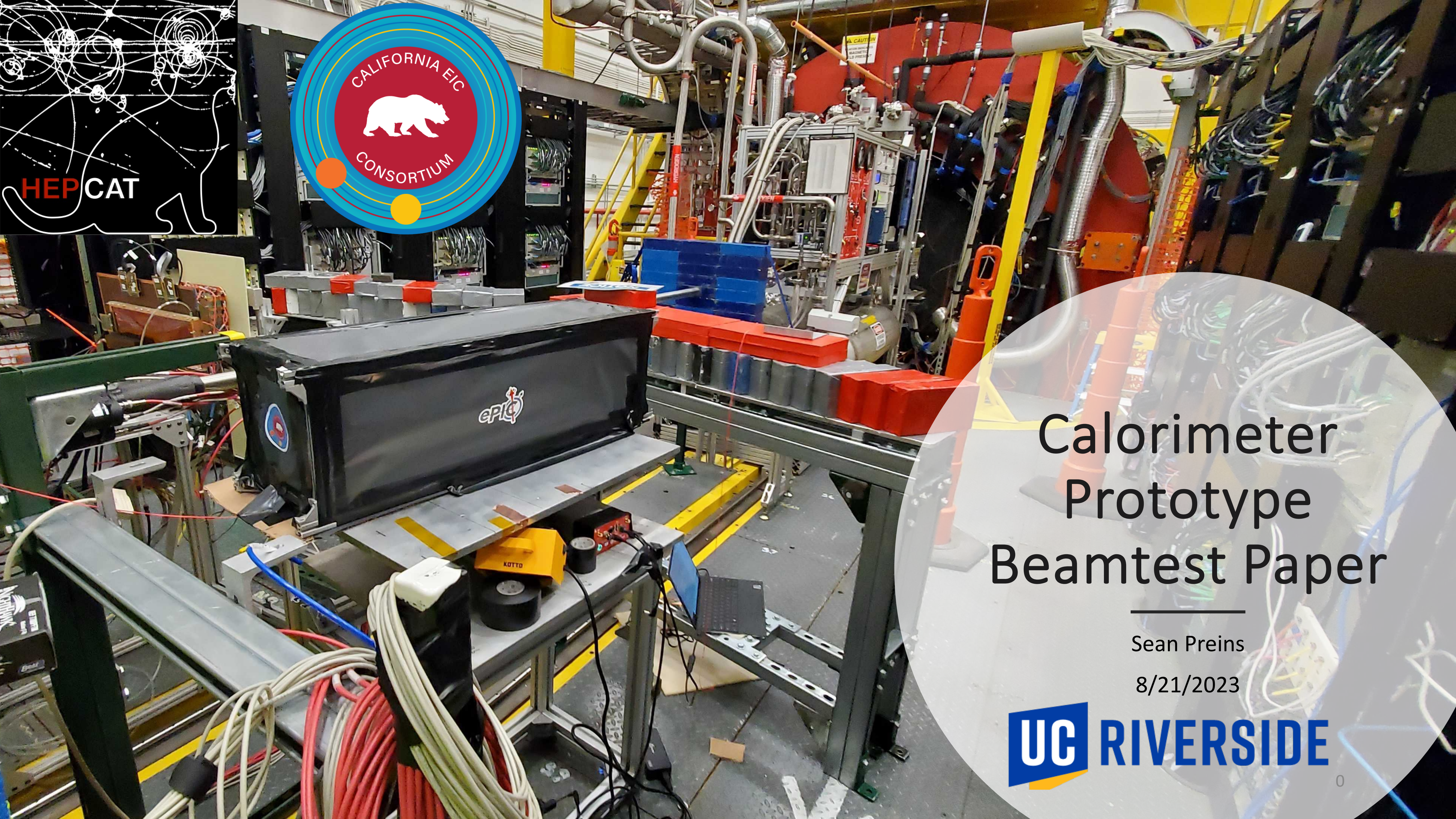
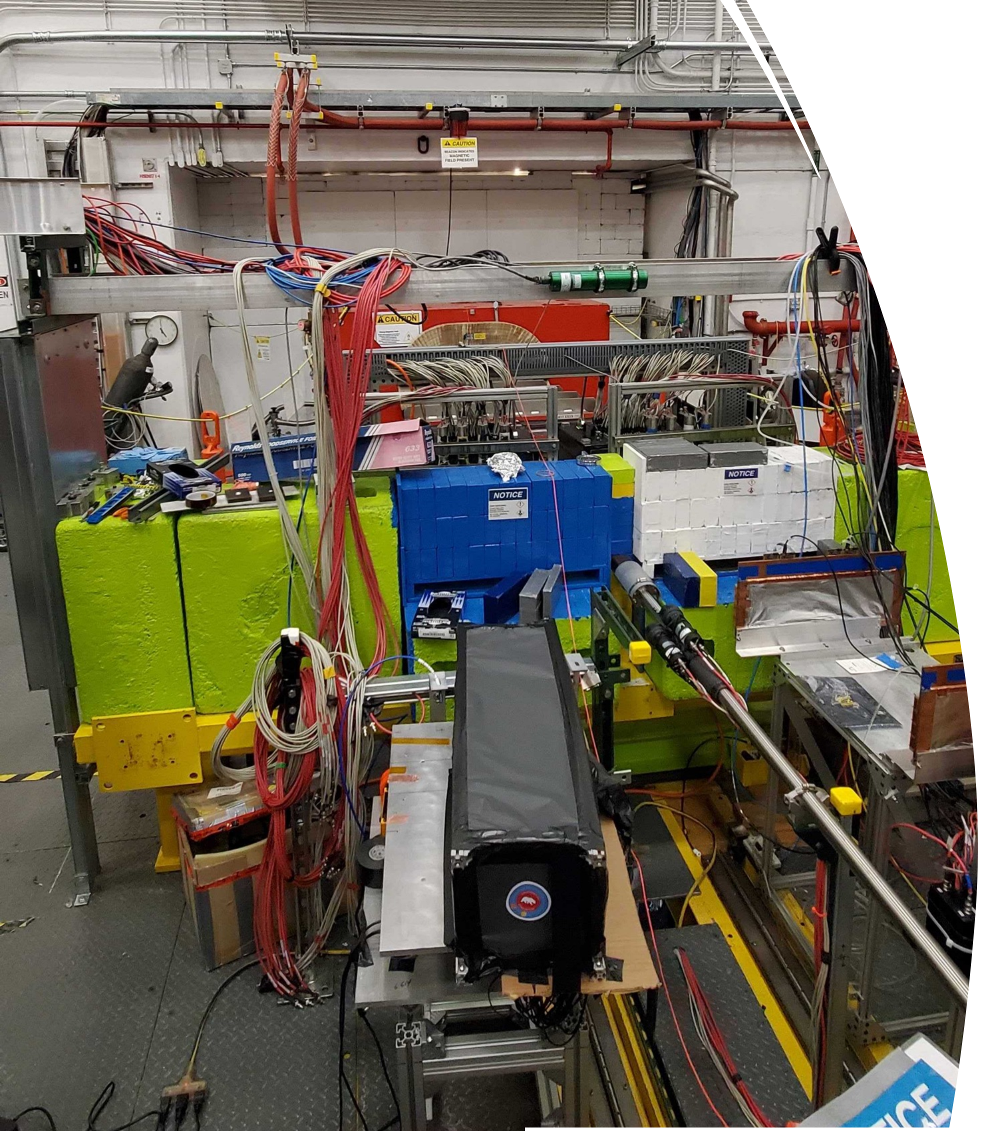


Calorimeter Prototype Beamtest Paper

Sean Preins

8/21/2023

UC RIVERSIDE



Talk Outline

- I will describe the contents of our paper from data taken in our recent beam test in Jefferson Lab, soon to be uploaded to arXiv
- Abstract
- Energy spectra plots
- Shower distribution plots
- Conclusion

Article

Beam Test of the First Prototype of SiPM-on-Tile Calorimeter Insert for the EIC Using 4 GeV Positrons at Jefferson Laboratory

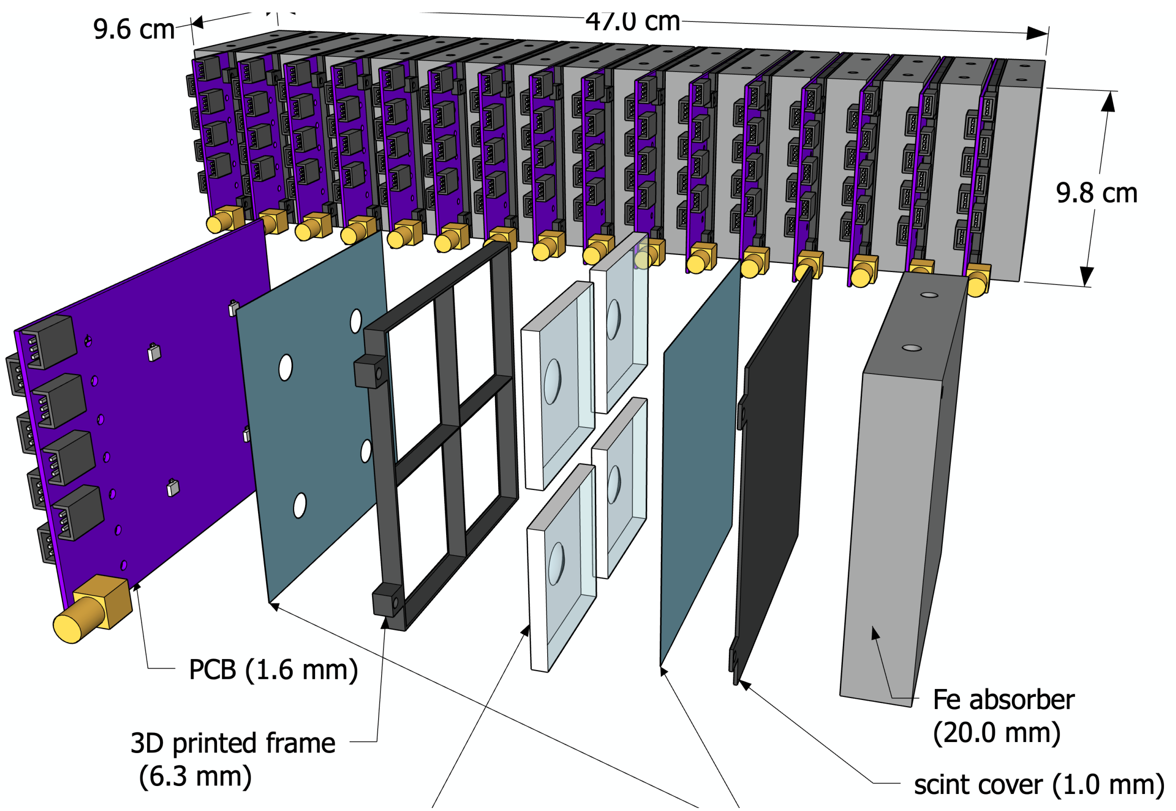
Miguel Arratia [1,2,*], Bruce Bagby[1], Peter Carney[1], Jiajun Huang[1], Ryan Milton[1], Sebouh J. Paul[1], Sean Preins[1], Miguel Rodriguez[1] and Weibin Zhang[1]

Abstract

- Following the proposal to the high-granularity calorimeter insert for the EIC, we present the results of a test beam for a prototype HG CALI at JLab
- The prototype utilizes 3D printed frames to reduce crosstalk, and an ASIC out of SiPM strategy
- Measured energy spectra and shower distributions correspond well with simulations, validating the design
- These results mark the first application of SiPM-on-tile technology for EIC

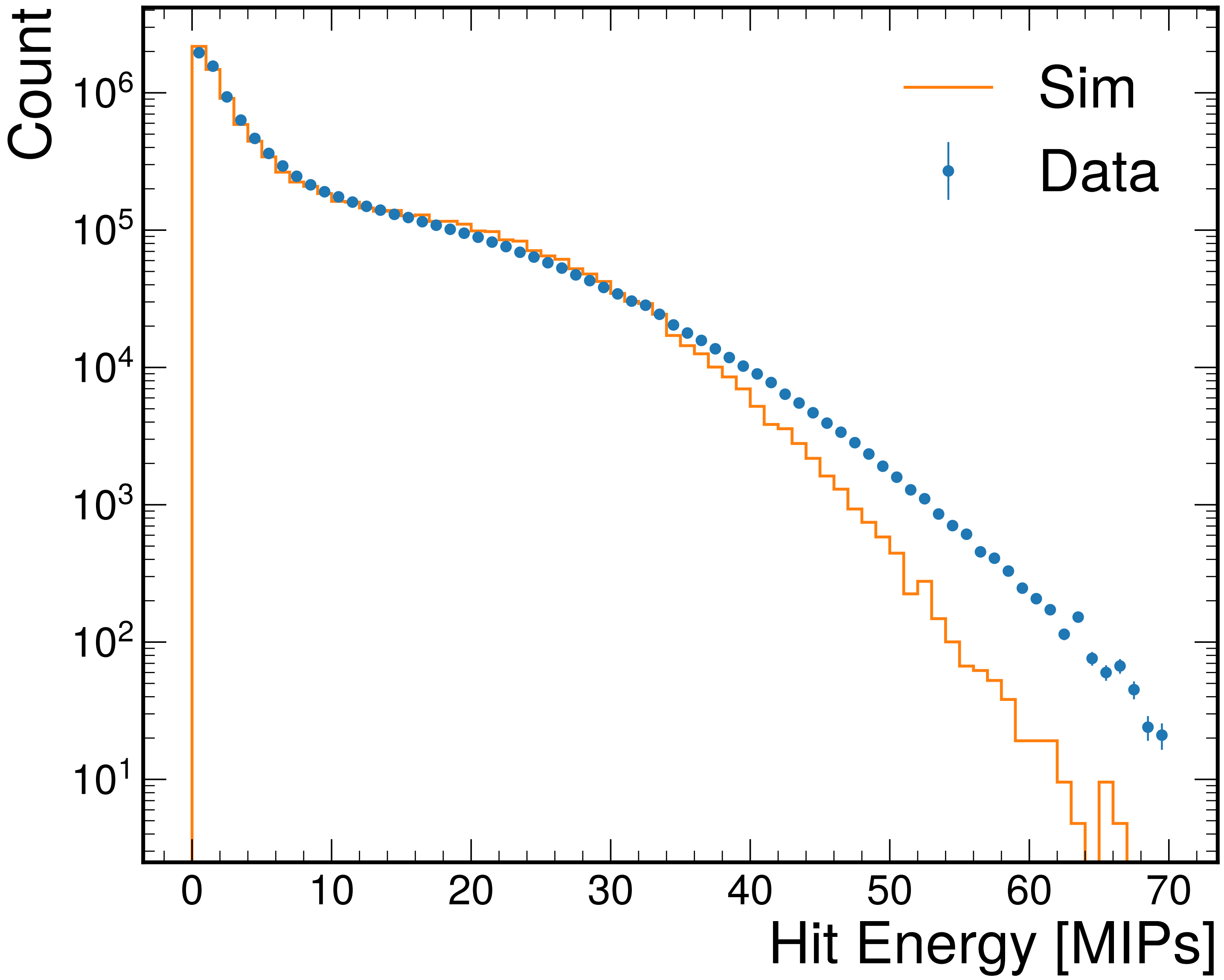
The HG-CALI Prototype, Beam, and Simulation

- The prototype consists of 10 layers, 4 SiPM-on-tile channels per layer, using square and hexagonal tiles
- The MIP scale of each channel was calibrated individually from a cosmic ray run
- Tested at the JLab Hall D pair spectrometer, received a horizontal spread of 4 GeV positrons at 3 kHz
- Prototype and test beam conditions were recreated in DD4HEP, calibrated in a similar way



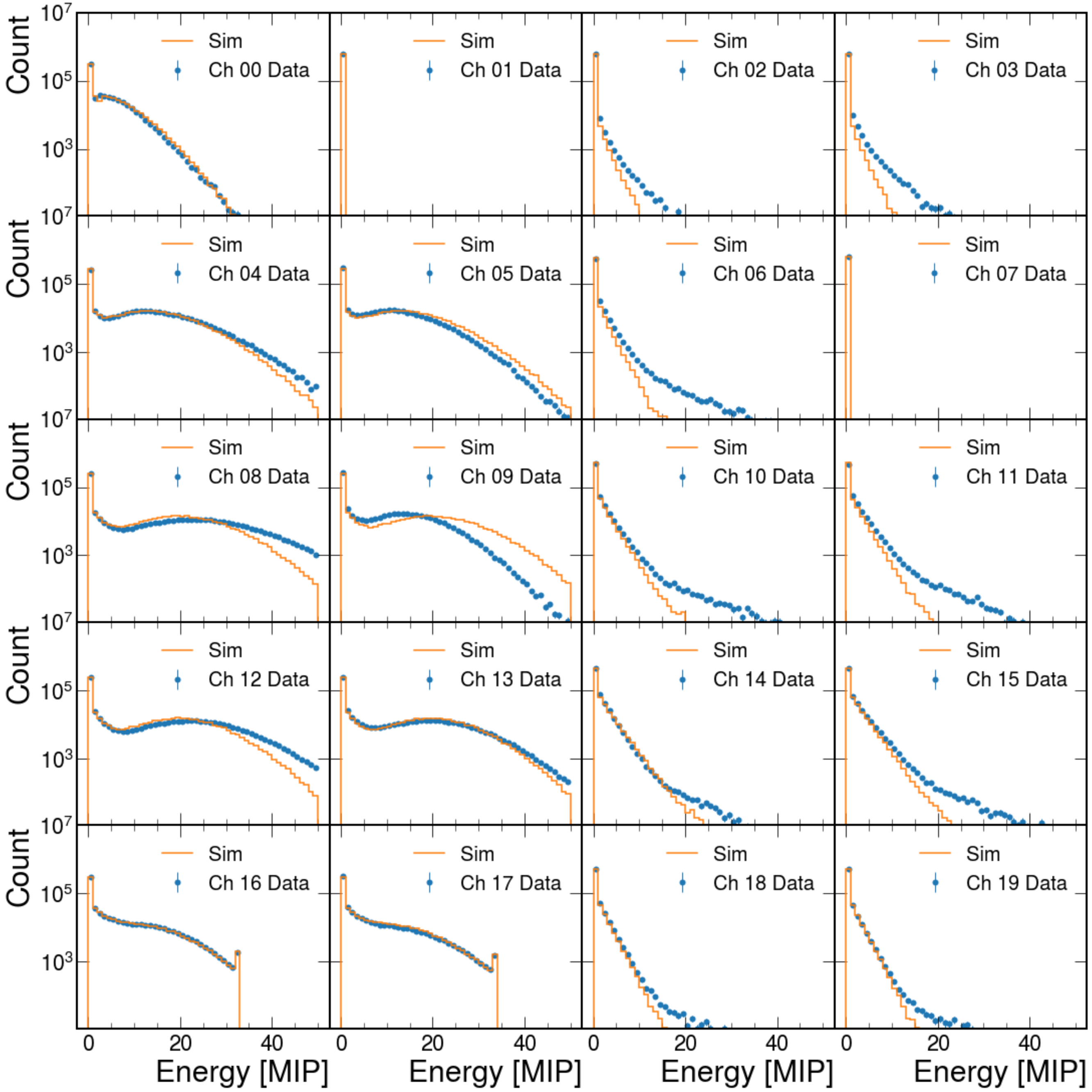
Hit Energy Spectrum

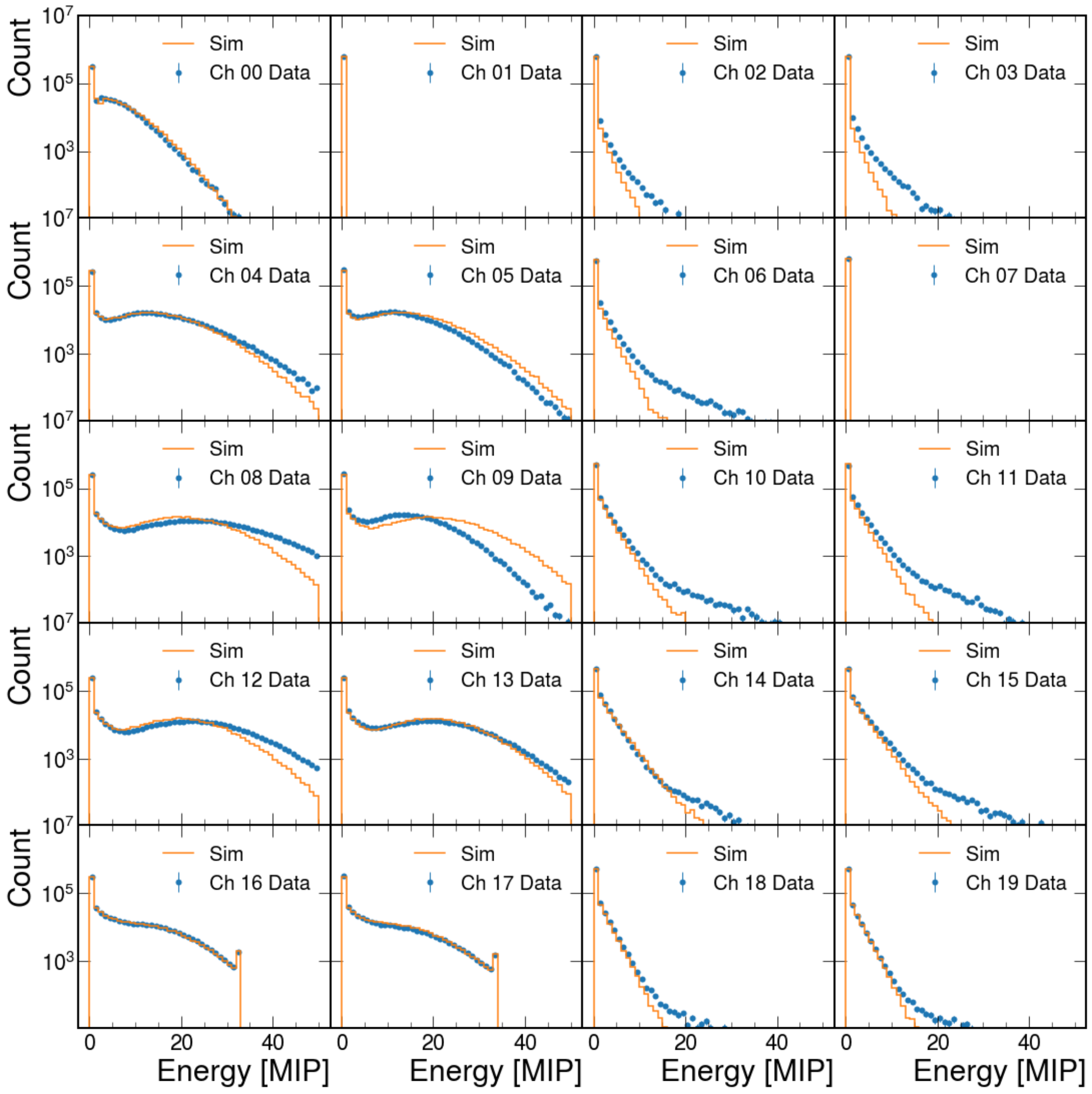
- Single hit energy can reach up to 70 MIPs for both cell types
- Very good agreement between simulation and data in the low energy regime
- Mismatch in the high energy regime may be caused by a mismatch between the true and simulated beam conditions

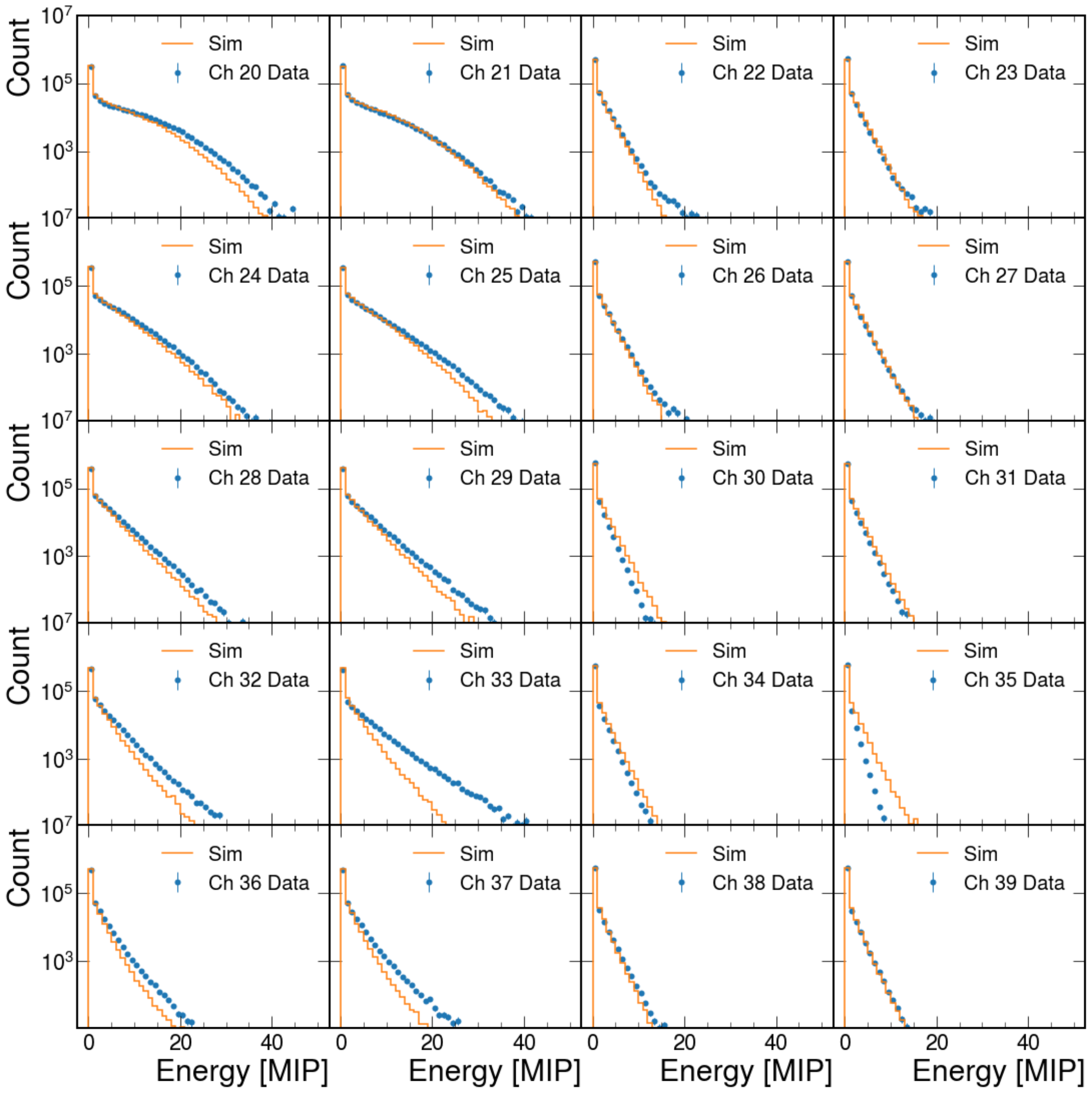


Channel Hit Spectra

- Dead channels (1 and 7) were mimicked in the simulation, in addition to an energy cap
- Many channels are in strong agreement with simulation
- A vertical shift caused the top two rows to receive more energy than the bottom two
- Ch 9 shows the largest discrepancy, likely caused by an incorrect MIP scaling

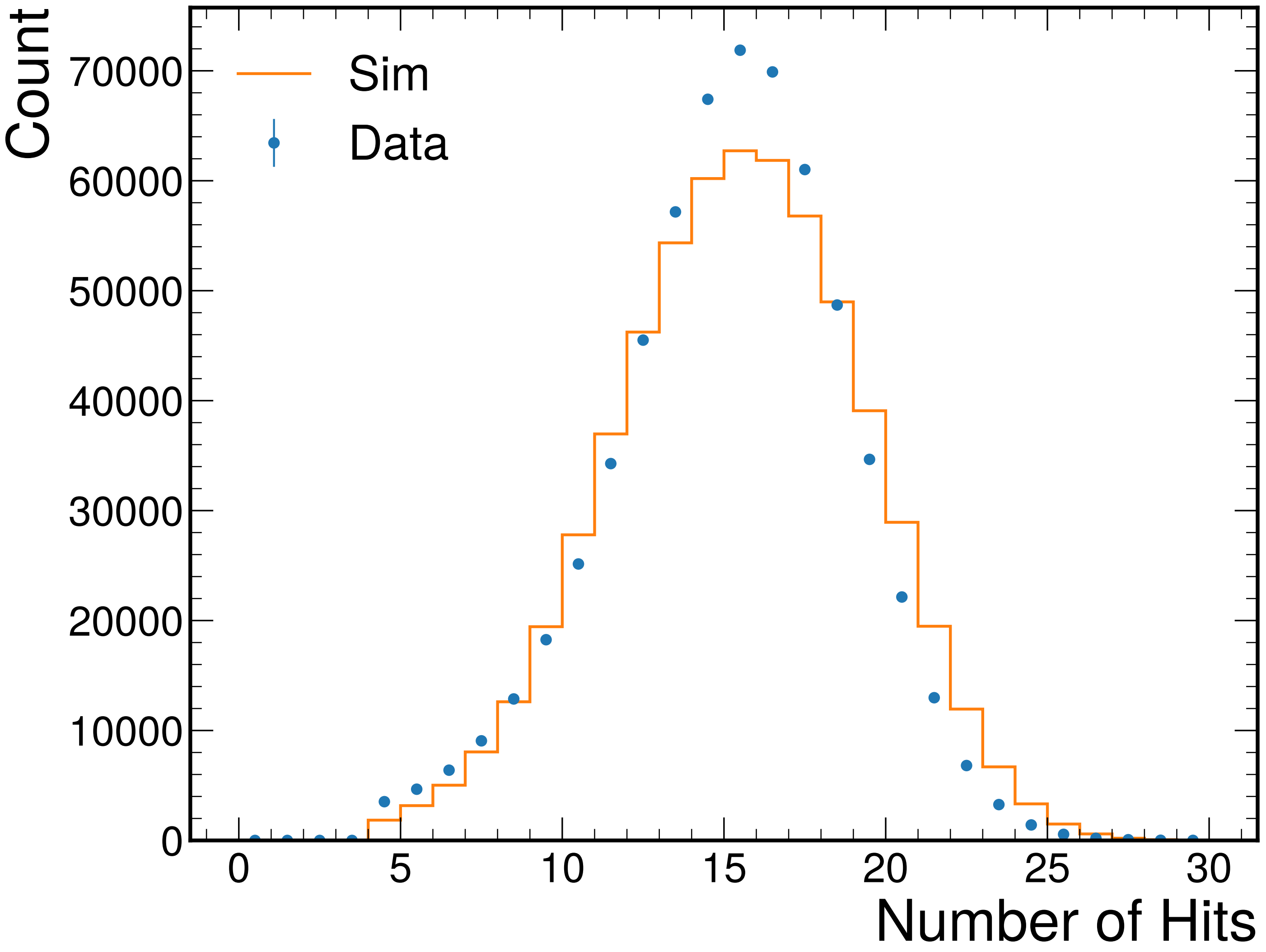



Count
10^7
10^5
10^3
Sim
Ch 00 Data
Ch 01 Data
Ch 02 Data
Ch 03 Data
Ch 04 Data
Ch 05 Data
Ch 06 Data
Ch 07 Data
Ch 08 Data
Ch 09 Data
Ch 10 Data
Ch 11 Data
Ch 12 Data
Ch 13 Data
Ch 14 Data
Ch 15 Data
Ch 16 Data
Ch 17 Data
Ch 18 Data
Ch 19 Data
0
20
40
Energy [MIP]


Count
10^7
10^5
10^3
Sim
Ch 20 Data
Ch 21 Data
Ch 22 Data
Ch 23 Data
Ch 24 Data
Ch 25 Data
Ch 26 Data
Ch 27 Data
Ch 28 Data
Ch 29 Data
Ch 30 Data
Ch 31 Data
Ch 32 Data
Ch 33 Data
Ch 34 Data
Ch 35 Data
Ch 36 Data
Ch 37 Data
Ch 38 Data
Ch 39 Data
0
20
40
Energy [MIP]

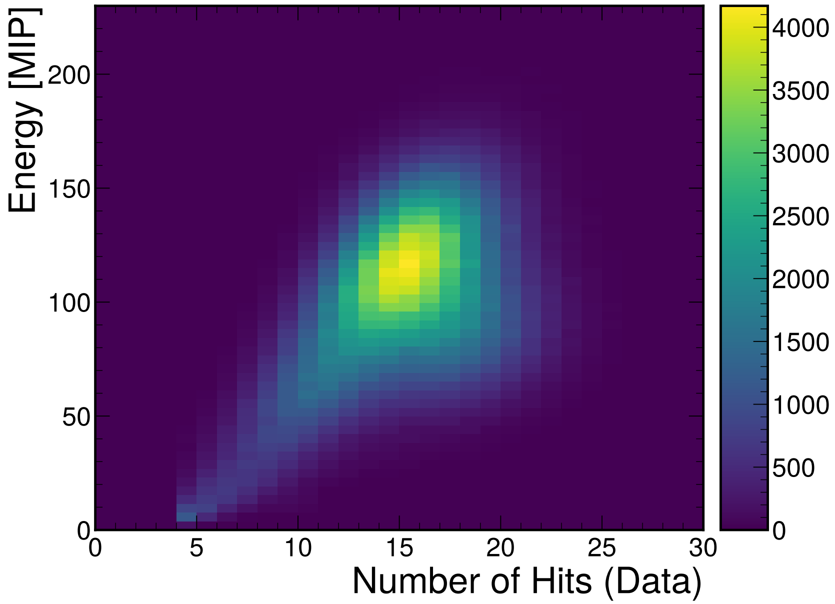
Hit Multiplicity

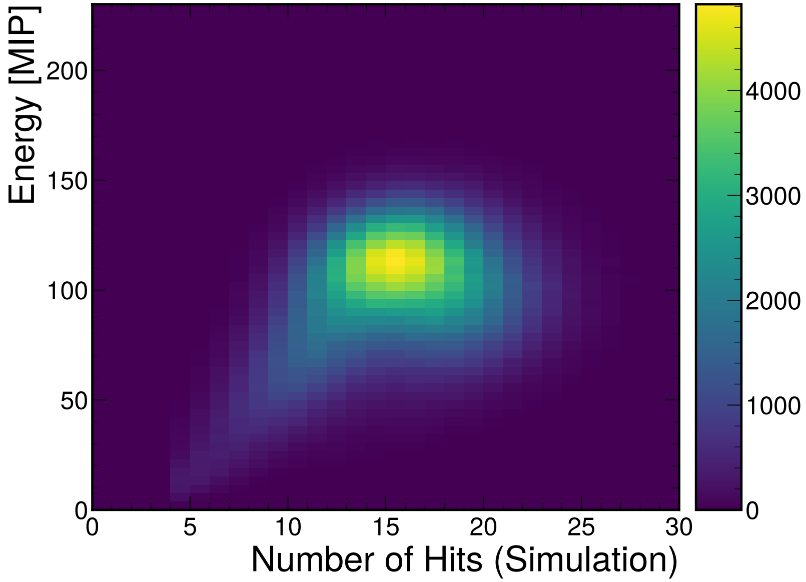
- Hit multiplicity is defined by the number of individual channels that exceeded 0.3 MIPs in a shower
- Most events have a hit multiplicity peak at 15, in both data and simulation
- If the positron is perfectly aligned along z, the shower can be fully contained in one corner
- A small tilt in y can extend the shower into nearby cells, as seen in data



Hit Multiplicity vs Event Energy

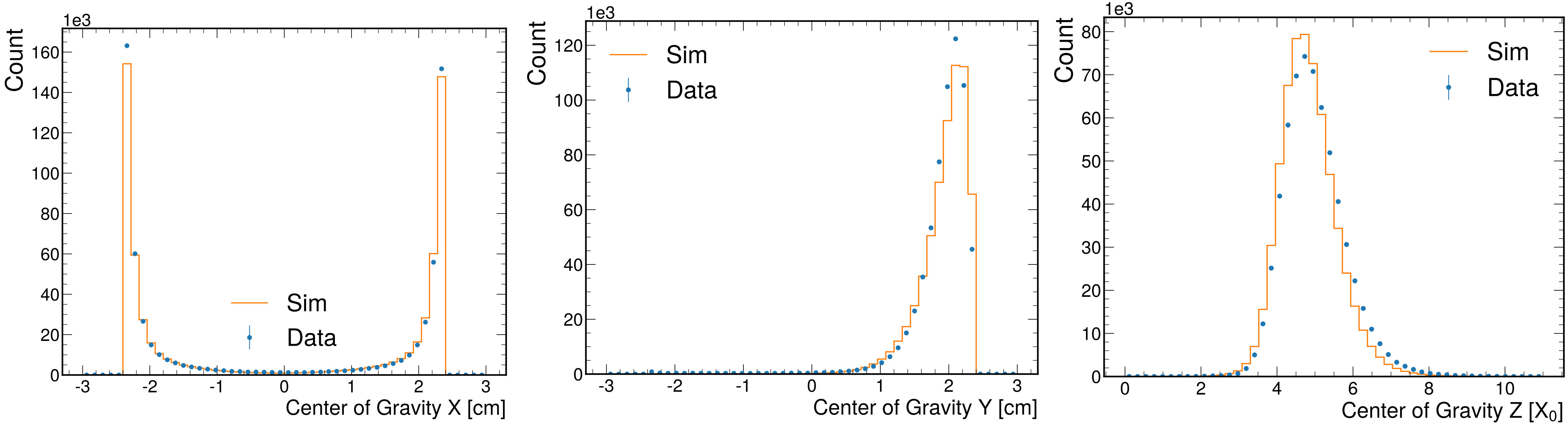
- Good agreement is made between data and simulation in the central region
- The data shows a stronger correlation between hit multiplicity and event energy
- The divergence in the high multiplicity region is likely caused by some highly angular showers partially escaping out the edge, and depositing less energy



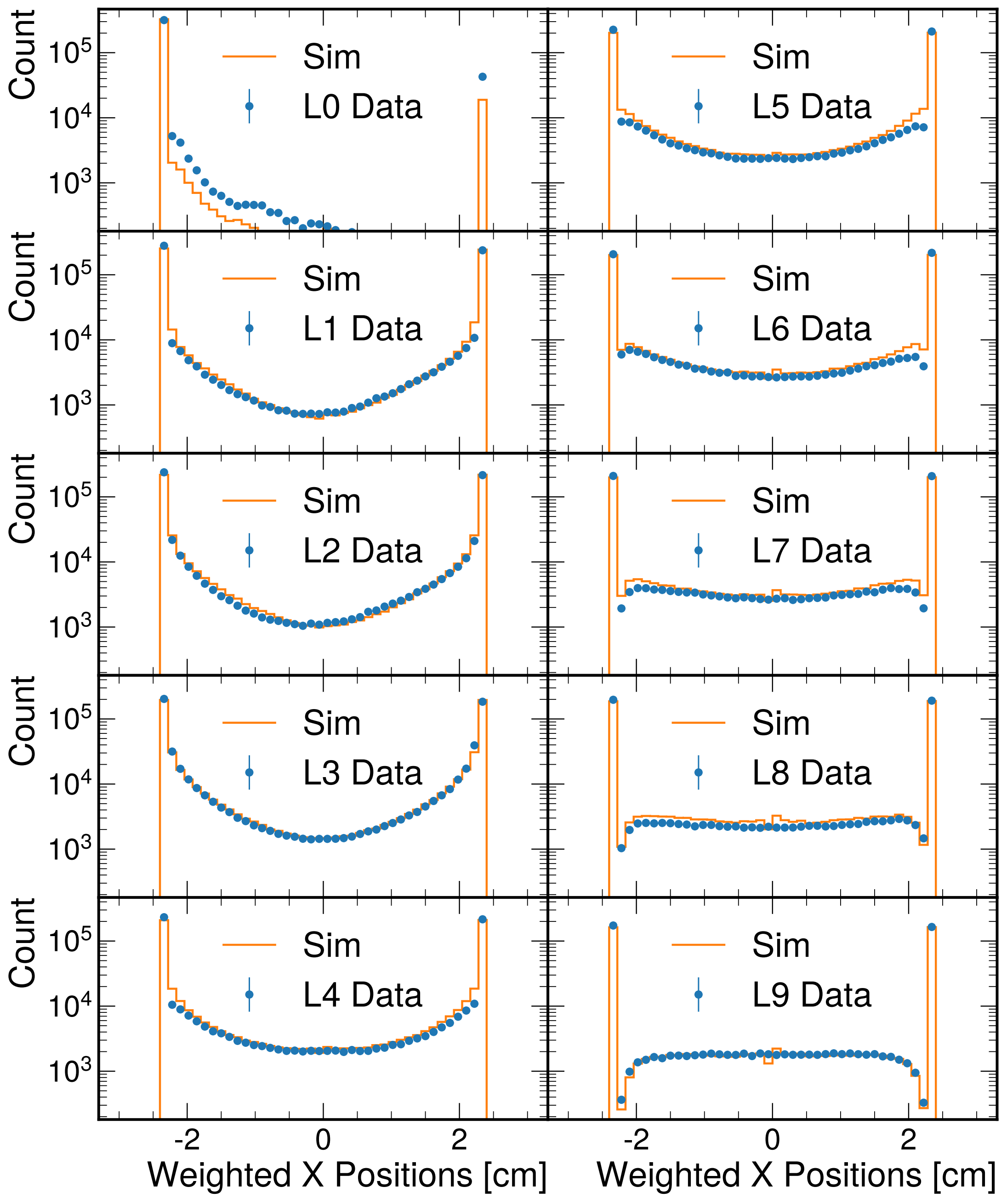


Shower Center of Gravity

$$\mathrm{COG}_{x,y} = \frac{\sum_i E_i \cdot \vec{X}_i}{\sum_i E_i} \qquad \mathrm{COG}_z = \frac{\sum_i E_i \cdot Z_i}{\sum_i E_i},$$

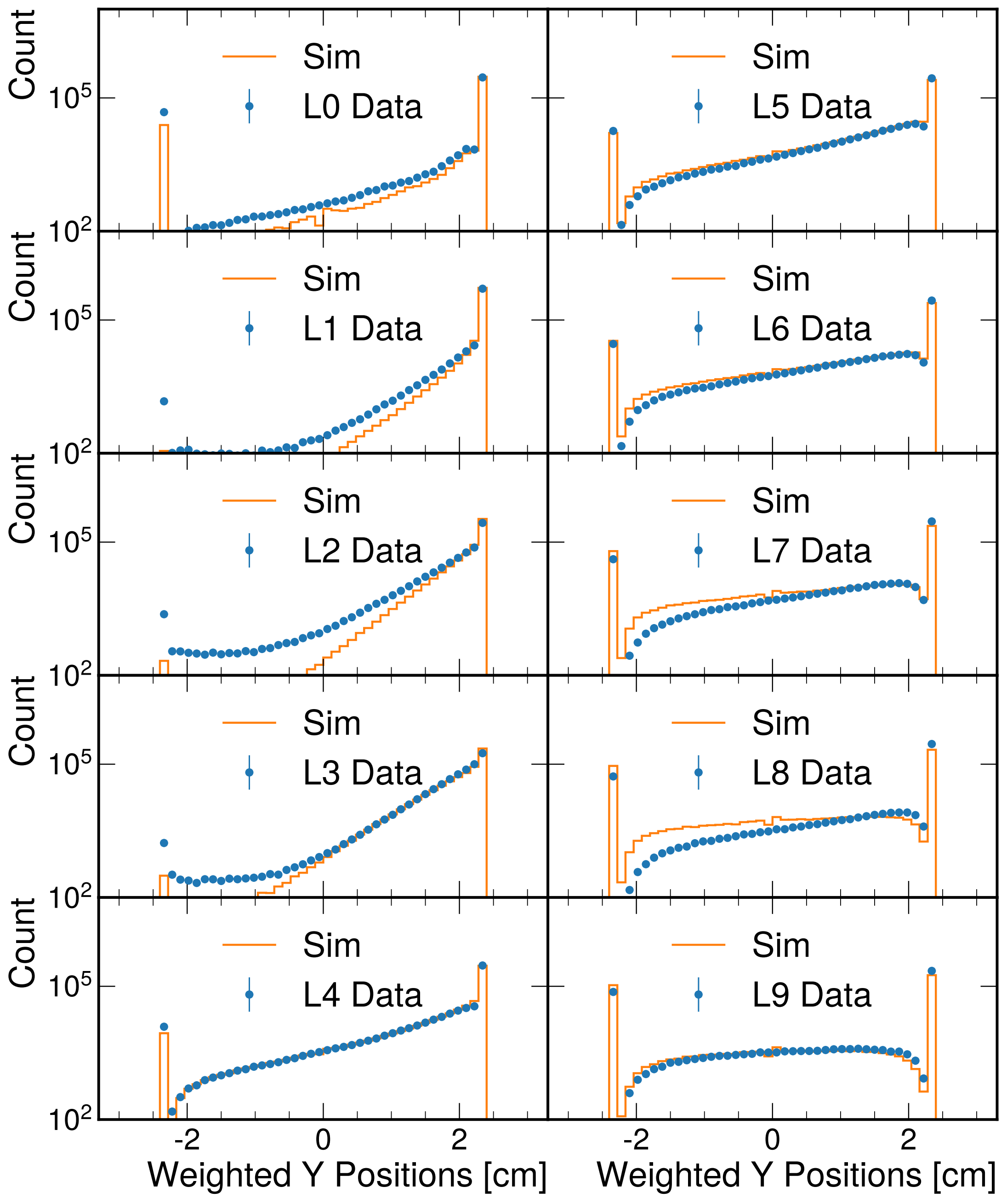


- From CoG_Z, we see the shower maximizes around the fourth layer
- The near symmetric distribution in CoG_X indicated the beam was uniformly spread in X
- The peak in CoG_Y is determined by a vertical shift, and the tail is determined by a vertical tilt



Layer Energy Weighted X Positions

- The symmetrical distribution in nearly all layers supports that the beam was uniformly spread in X
- The asymmetric distribution in layer 0 is due to a dead cell
- Large optical crosstalk would likely result in a flatter distribution in X
- The simulation modeled no optical crosstalk, and the data is in excellent agreement for all layers

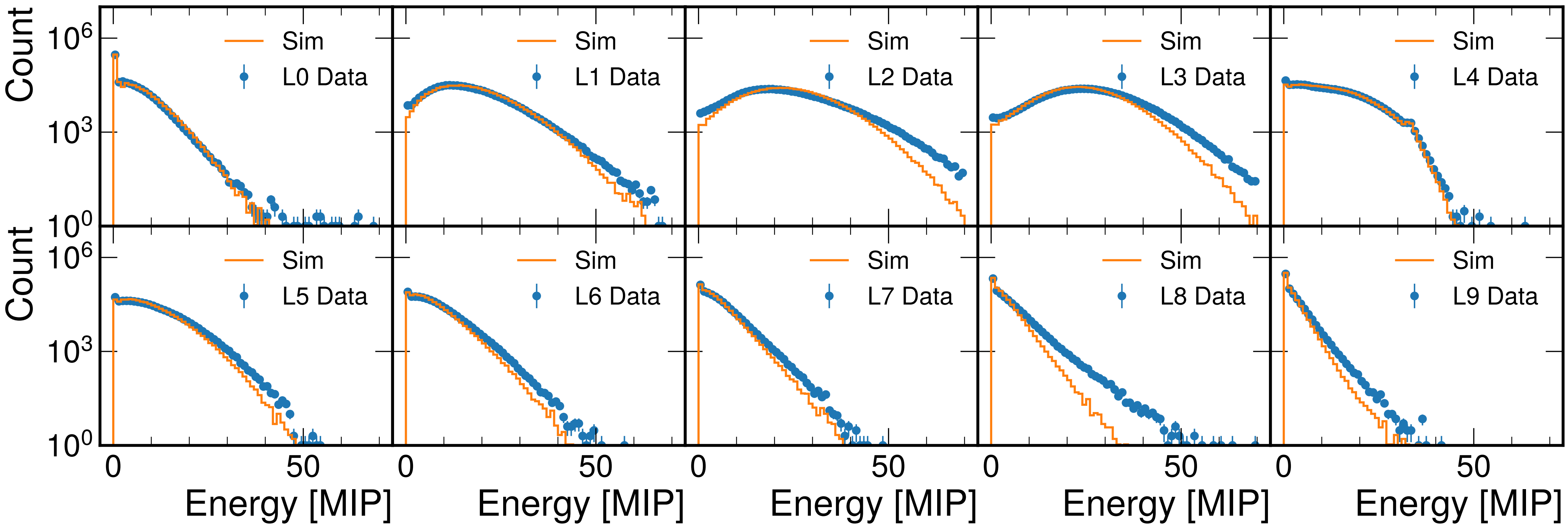


Layer Energy Weighted Y Positions

- The large asymmetry in the first layer was used as a starting point to find the vertical displacement of the prototype
- The central region flattens out in deeper layers as a result of showering
- Strong sensitivity to the misalignment in Y demonstrates the potential to track particles

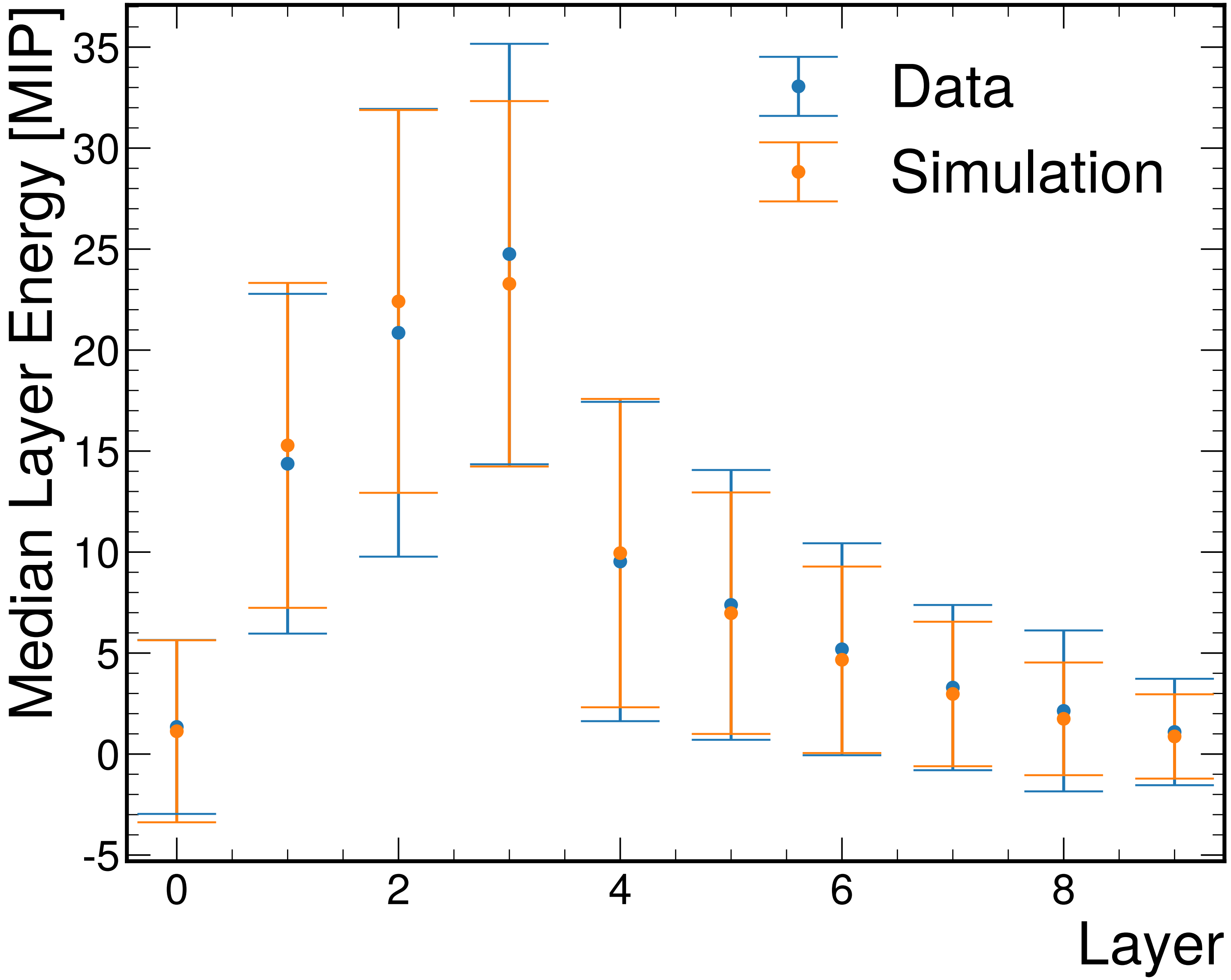
Summed Signals in Each Layer

- The summed energy for each layer in each event is in good agreement with simulation
- The data shows more high energy events in rear layers, potentially from a larger spread in Y
- The small plateau in layer 4 is caused by the cap cut in channels 16 and 17



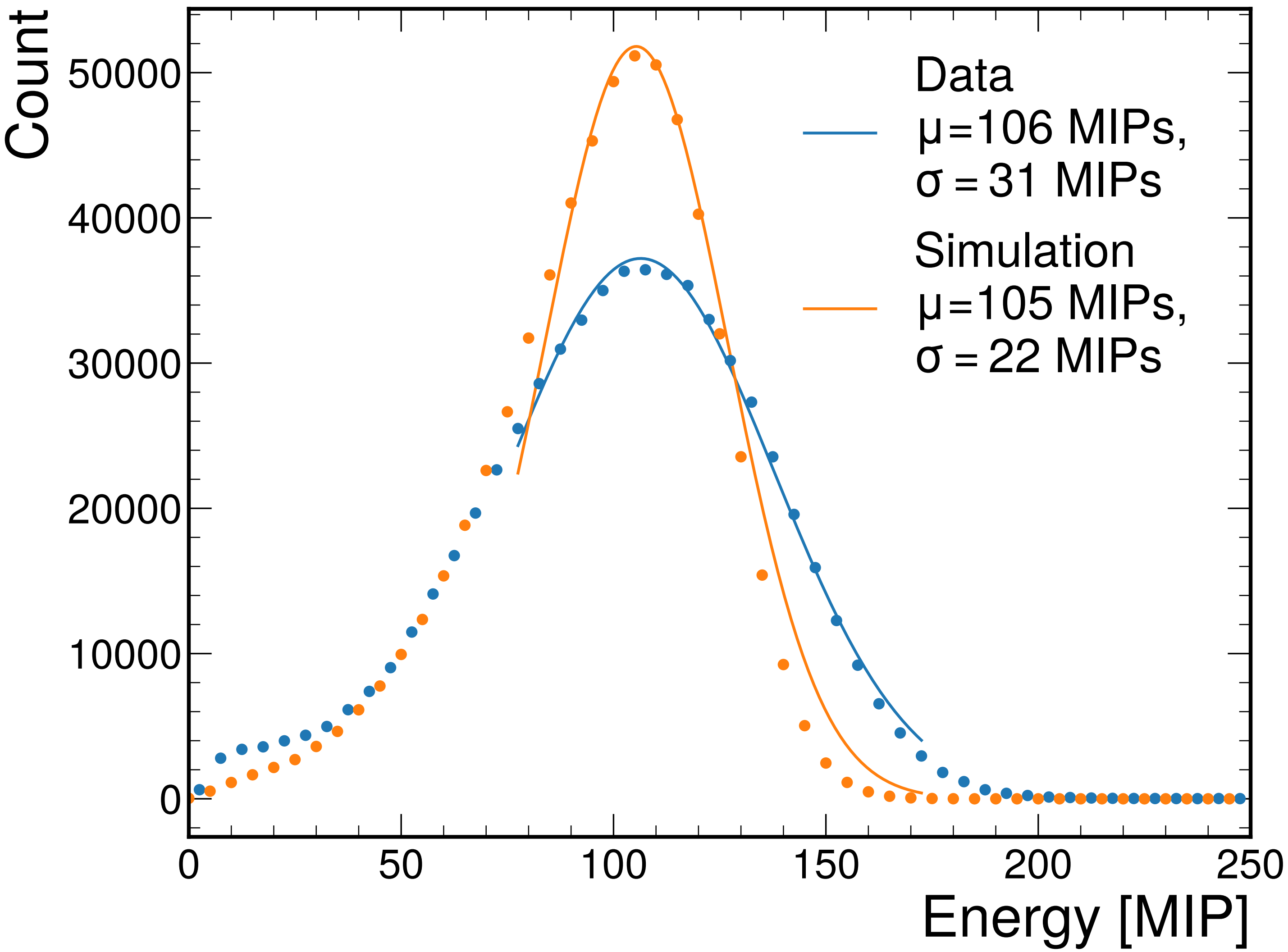
Median Layer Energies

- The median energy in each layer and their corresponding RMS widths match well
- The discontinuity between layers 3 and 4 are partially caused by the change in cell shape
- The slightly smaller widths in the simulation are likely attributed to systematic noise not yet included in the simulation



Total Shower Energy

- The mean recorded energy in the data and simulation are nearly identical
- The imperfect gaussian shapes result from an excess in low energy events caused by events with a large tilt angle
- The wider distribution in data is likely due to the test beam having a spread in energy, or other systematics not yet implemented in the simulation



Conclusion

- Comparison between data and simulation show that separating the readout chips from the SiPMs only partially degrade the energy resolution, at worst
- 3D printed frames greatly suppresses optical crosstalk between neighboring scintillating tiles
- Further improvements to the simulation will likely bring the simulated data further in alignment with the beam test data
- These studies successfully validate the HG-CALI design, and provided great insight into the construction and simulation of this in preparation for scaling up HG-CALI