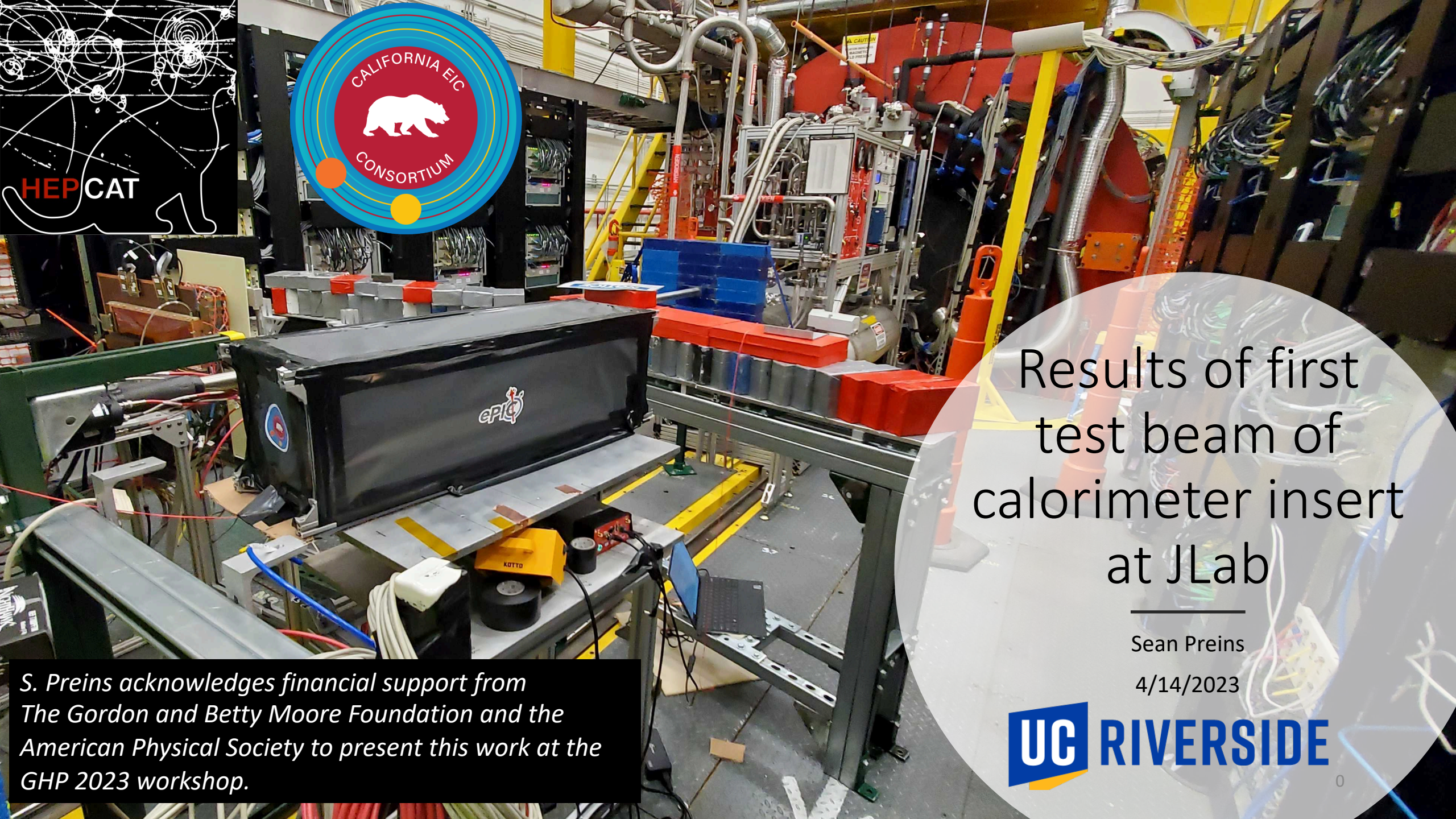


Results of first test beam of calorimeter insert at JLab

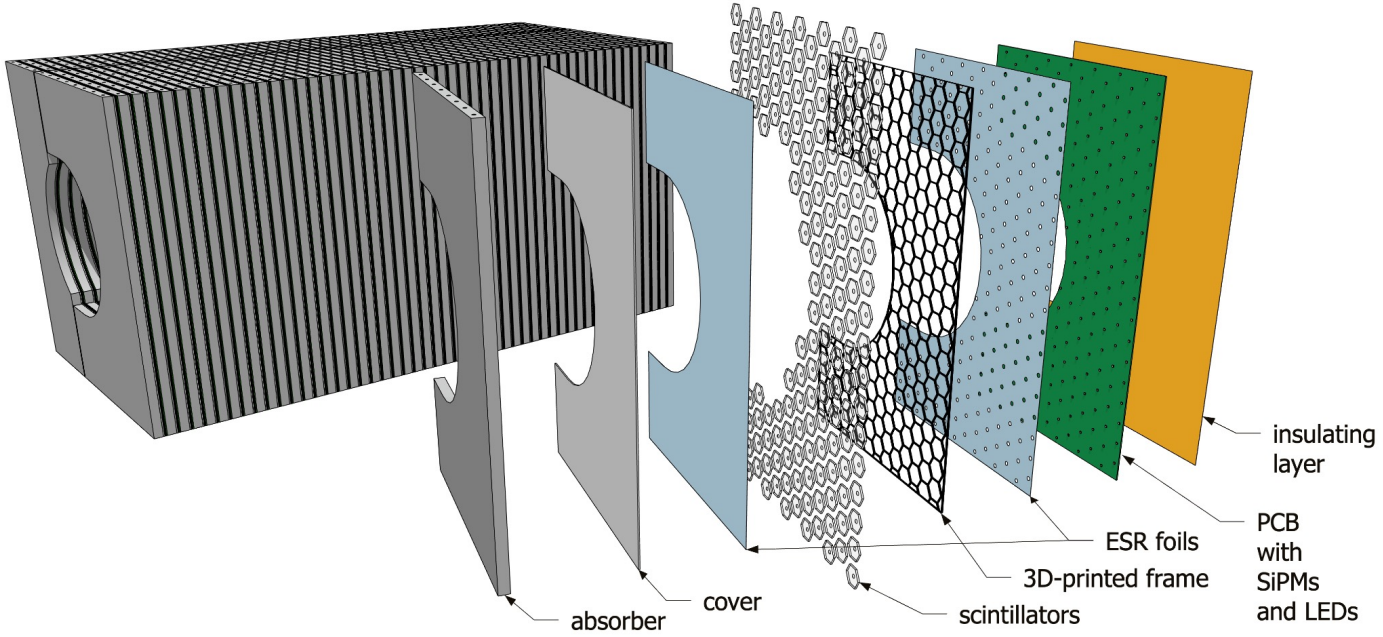
Sean Preins

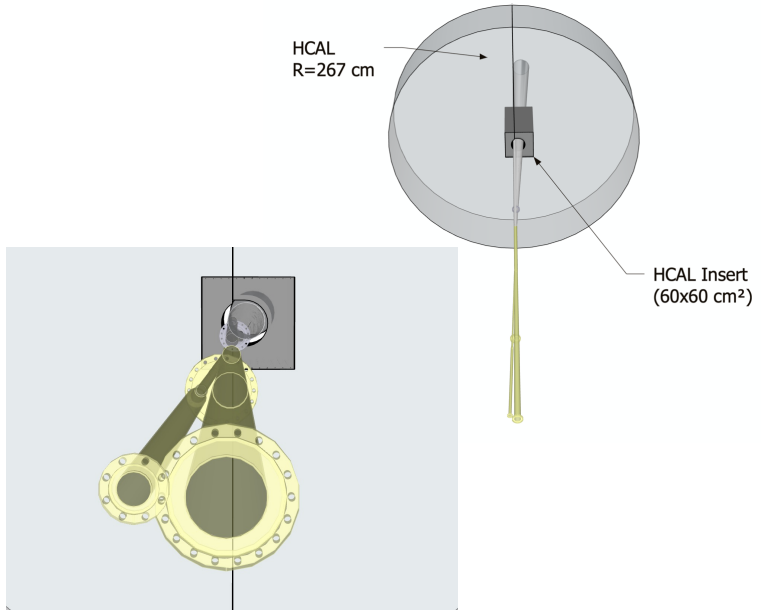
4/14/2023

S. Preins acknowledges financial support from The Gordon and Betty Moore Foundation and the American Physical Society to present this work at the GHP 2023 workshop.

The Calorimeter Insert for ePIC

More details in:
https://arxiv.org/abs/2208.05472
https://arxiv.org/abs/2302.03646

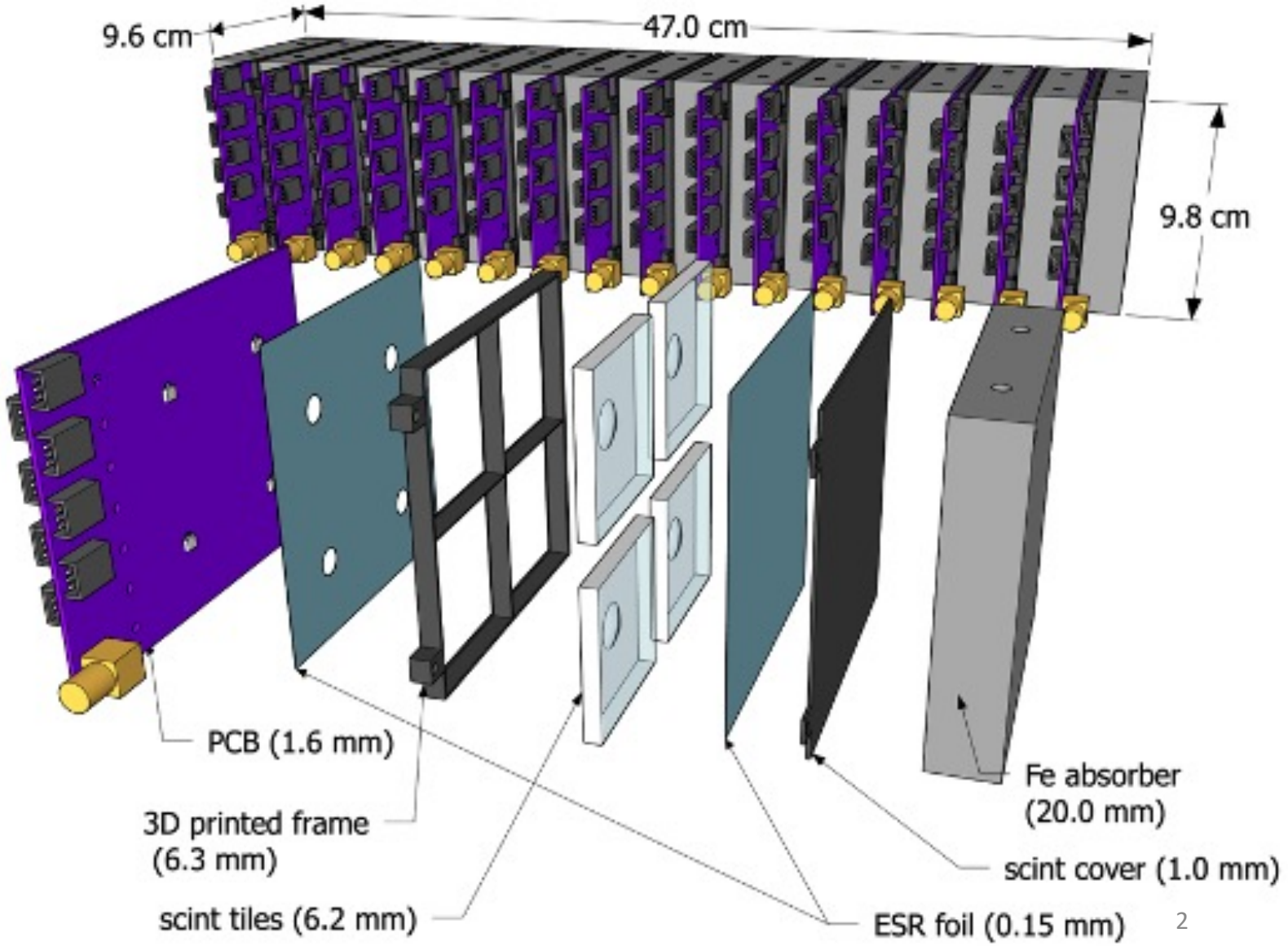




- Optimal acceptance with high-granularity to cover 3<η<4 range (poor tracking)
  - To improve acceptance for jets and inclusive DIS reco via event transverse-momentum
  - Tag beam-induced backgrounds with topology
  - To ensure SiPMs and scintillator remain easily accessible for repair/maintenance & upgrades

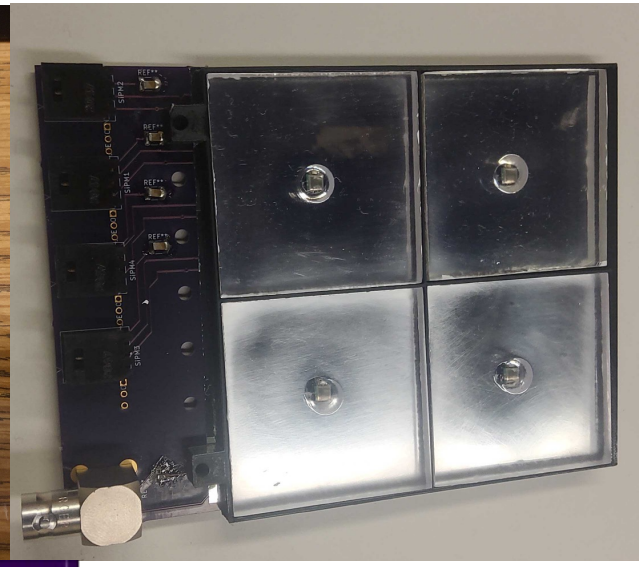
The First Insert Prototype for JLab Test

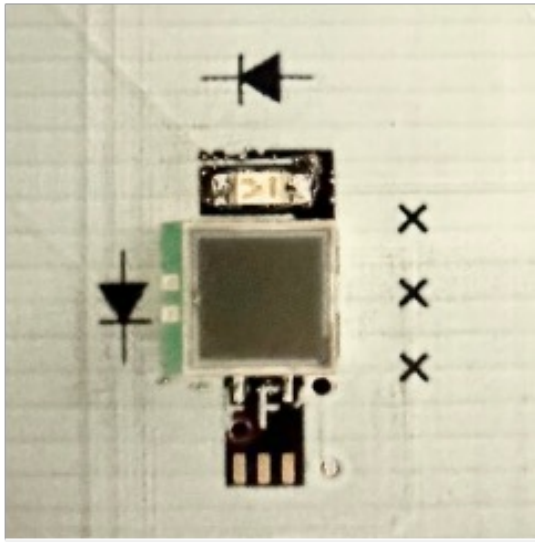
- Characterize components, work as proof of concept
- Consists of 10 layers, each subdivided into four scintillating tile cells (40 channels)
- Effectively 11.4 radiation lengths long
- Cross sectional area of 2x2 Moliere radii



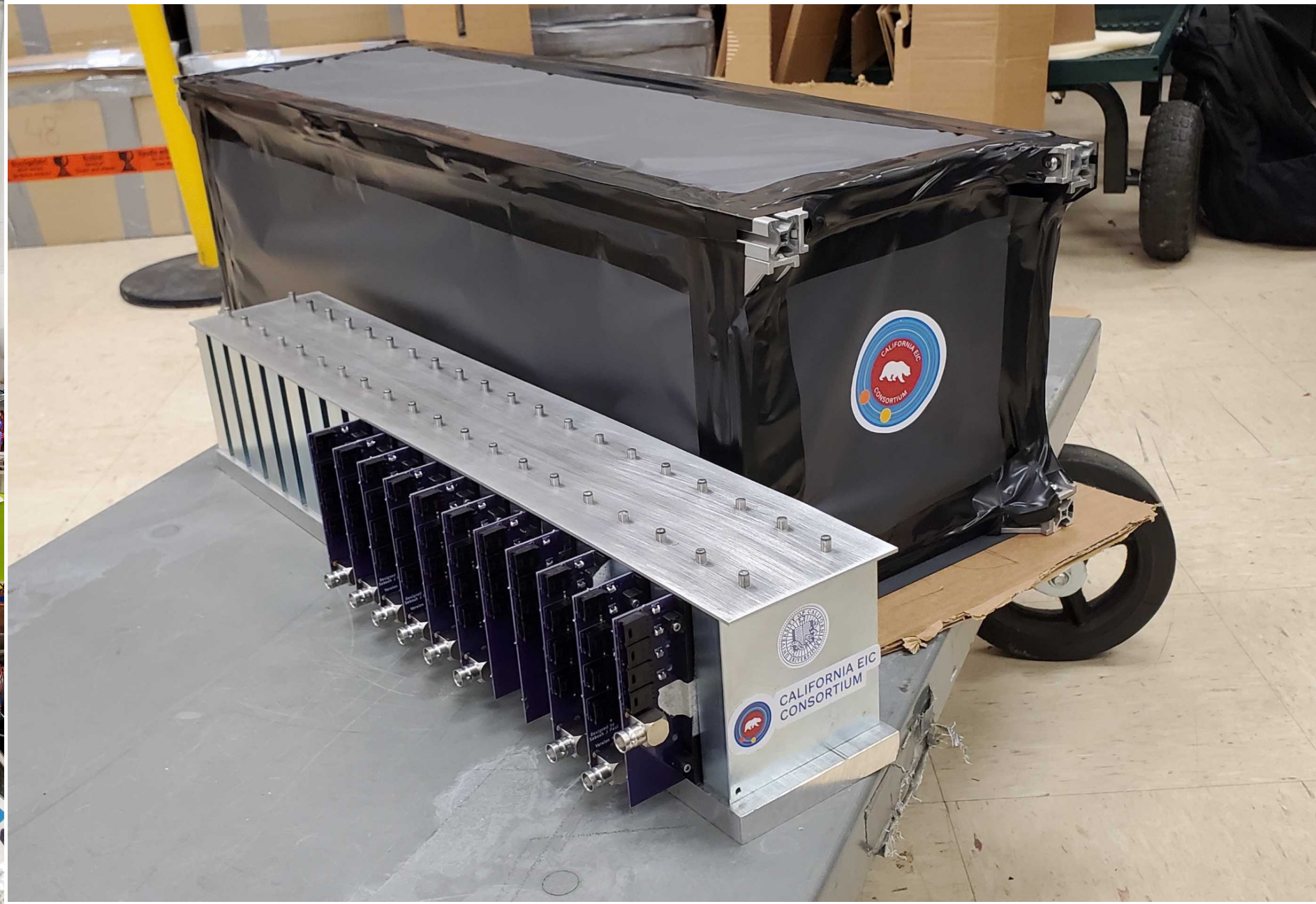
The First Insert Prototype for JLab Test

- Uses 3x3 mm Hamamatsu 14160 SiPMs
- SiPMs are biased and read out by a CAEN digitizer unit
- Scintillator tiles are made with recycled material and polished by hand



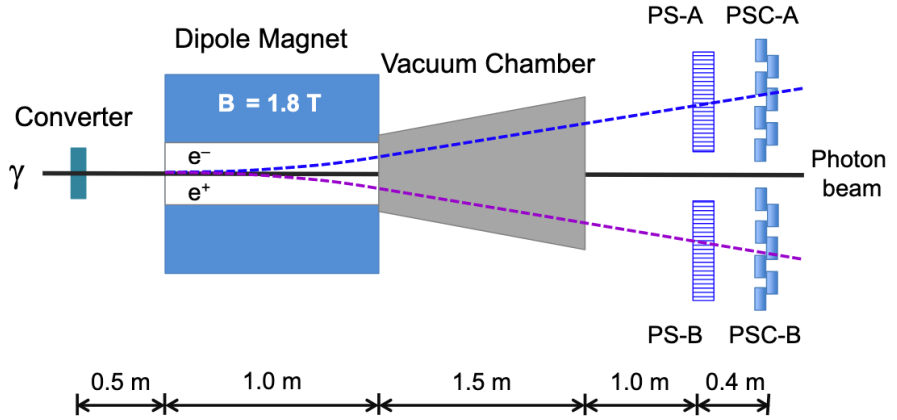



NOTICE


CALIFORNIA EIC CONSORTIUM
CALIFORNIA EIC CONSORTIUM

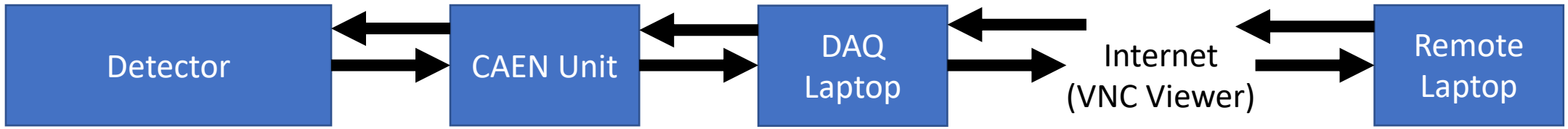
Hall D Beam Characteristics

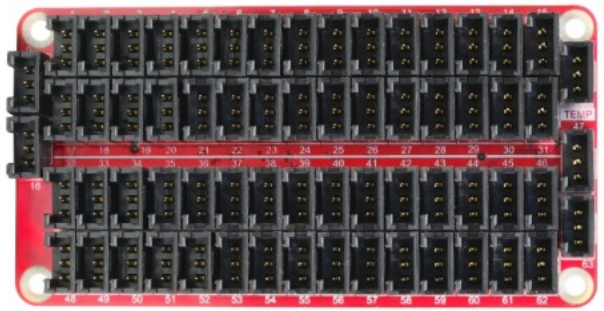
- The prototype was situated in front of the Hall D pair spectrometer, off the beamline
- It received ~4 GeV positrons at a variable luminosity (maximum of ~3 kHz)
- Data collection and bias control was operated remotely from Riverside



Prototype

DAQ Setup





A5253 - 3-pin header adapter for FERS-5200 (optional)

Data Acquisition Procedure

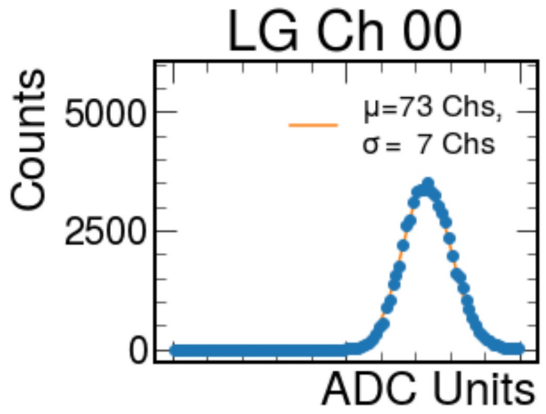
Decide on CAEN settings

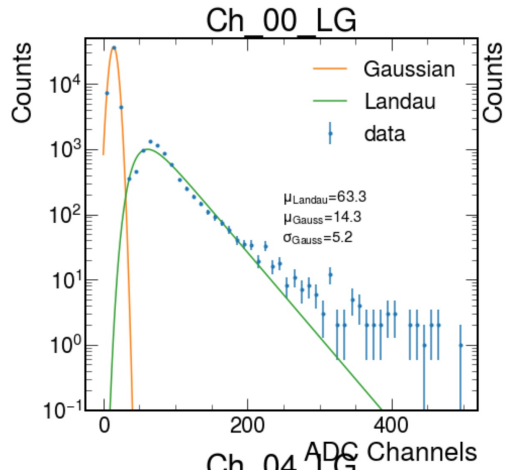
Record noise data from random triggers to determine the pedestal position and width for each channel

Apply pedestal cuts to all data going forward

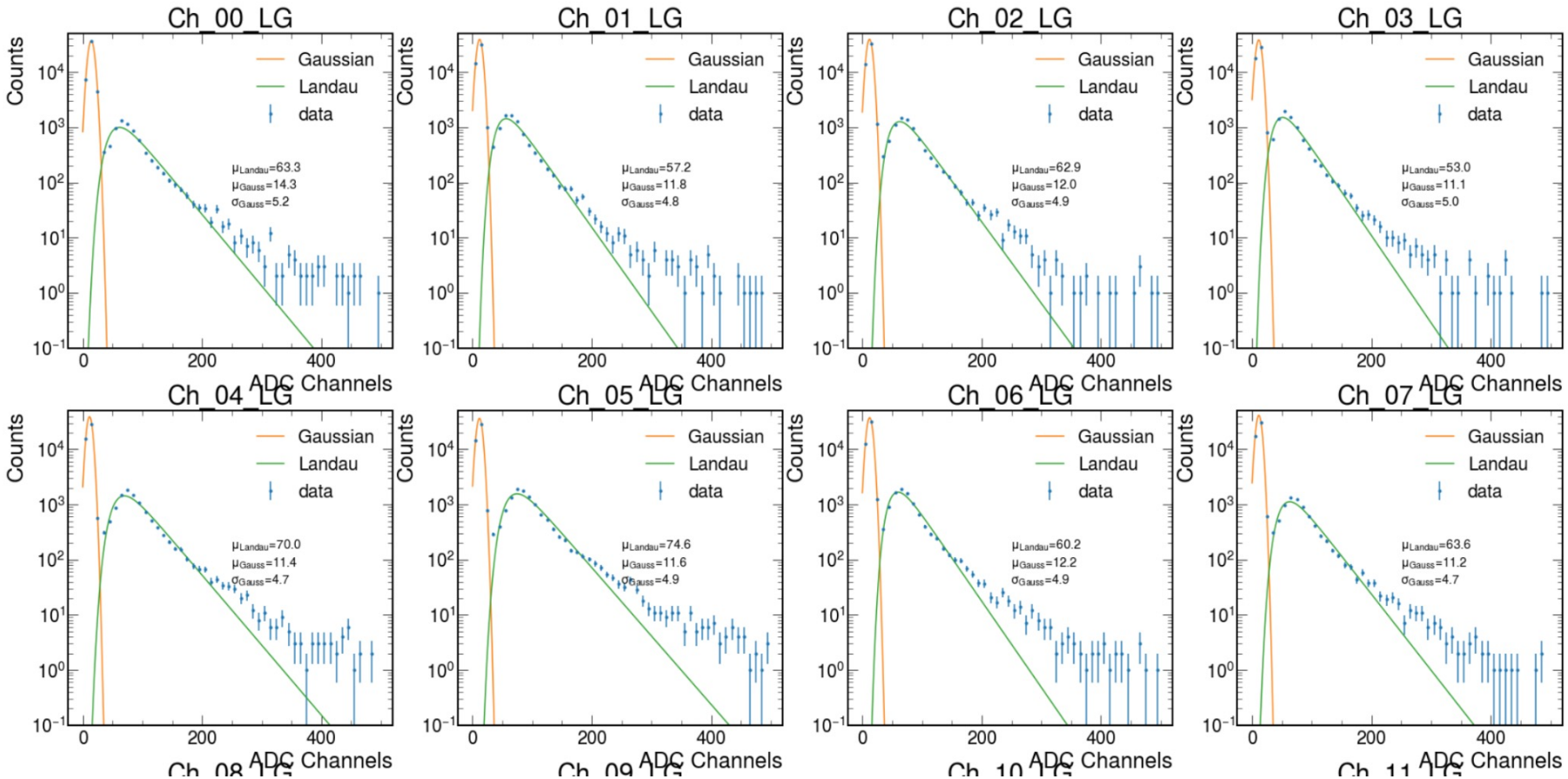
Record cosmic rays to determine how to convert between ADC Channels and MIPs

Record beam data, sum the total energy per event, and the layer-by-layer breakdown





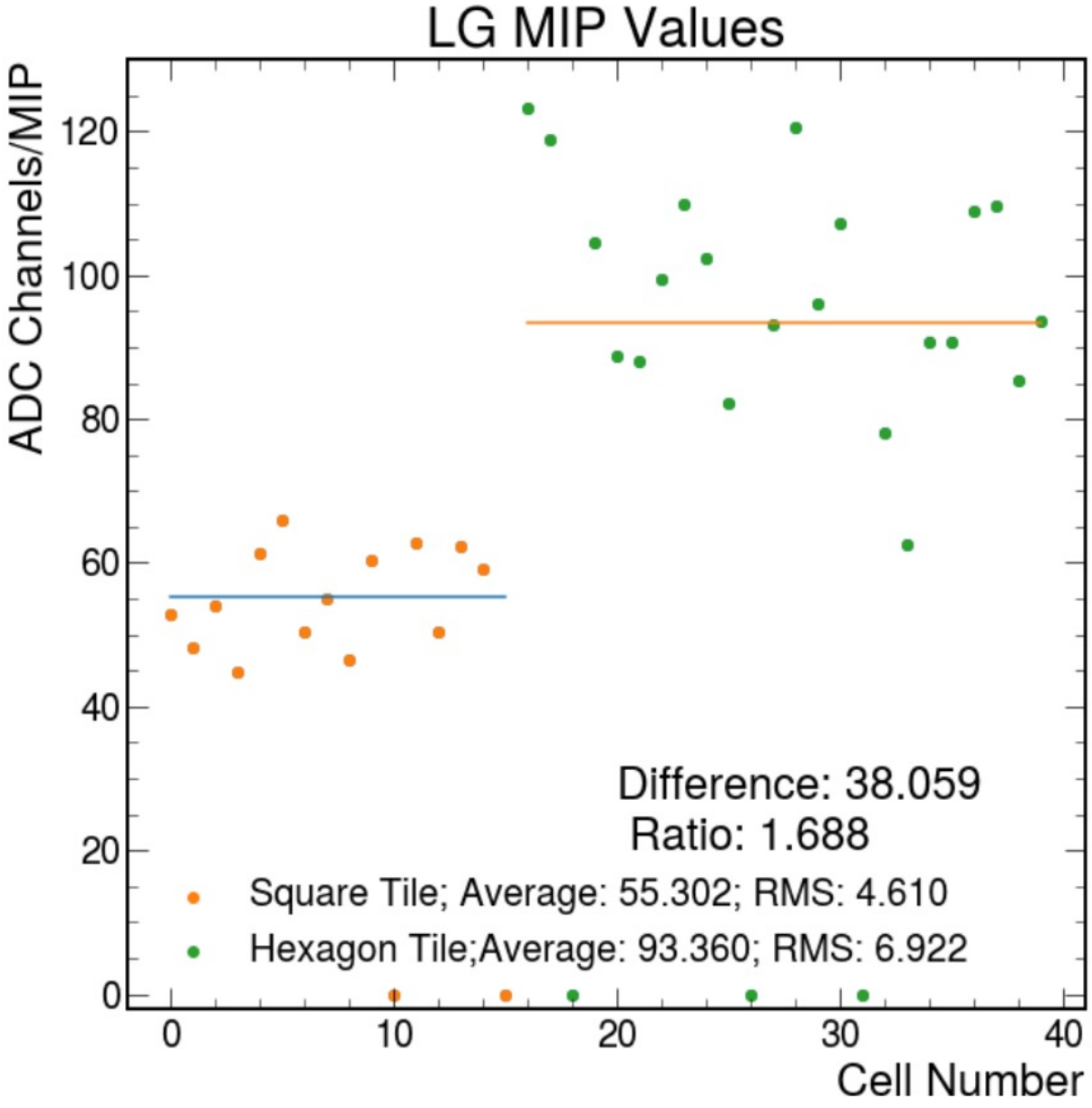
Cosmic Ray Runs



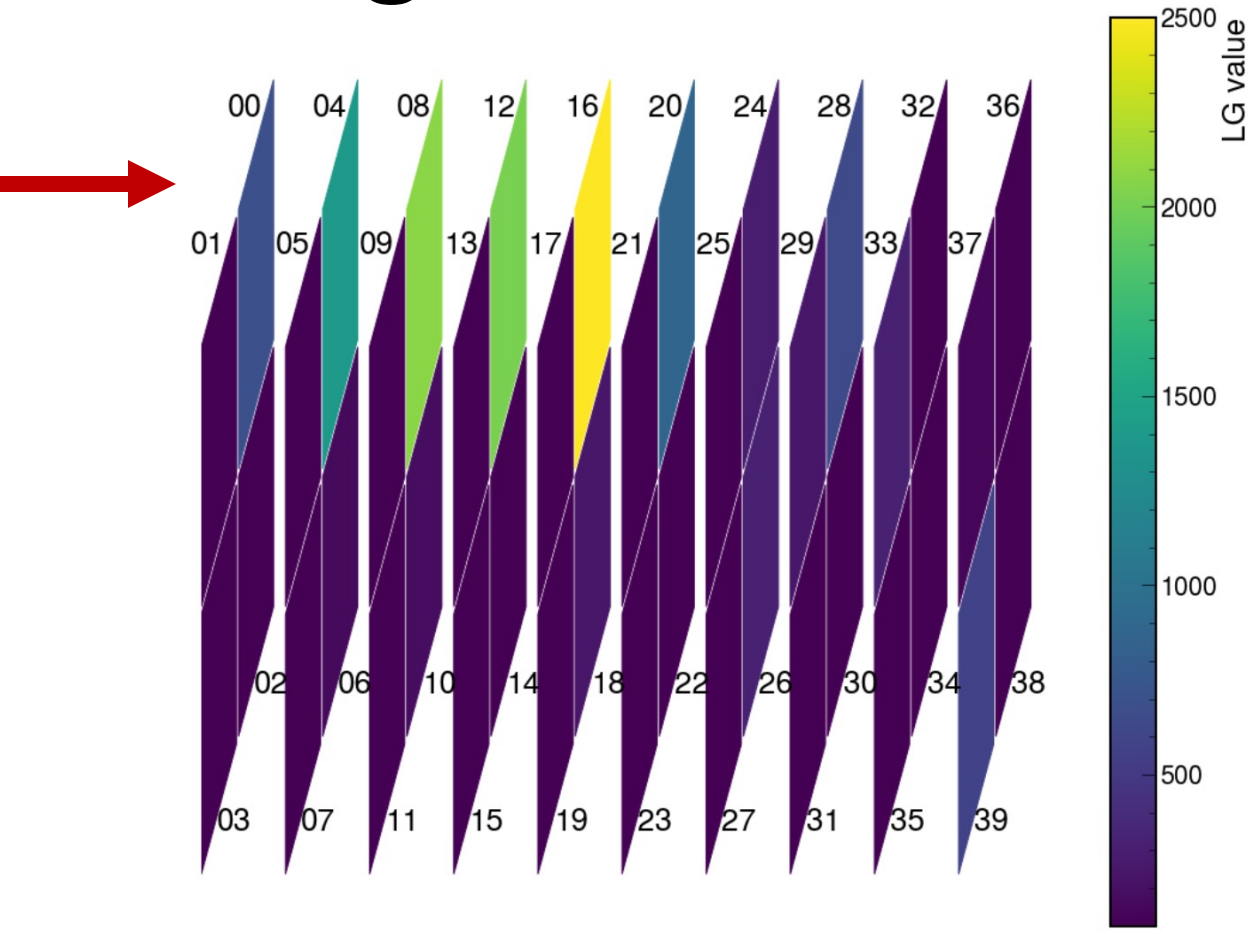
Cosmic runs were performed before it was installed in Hall D

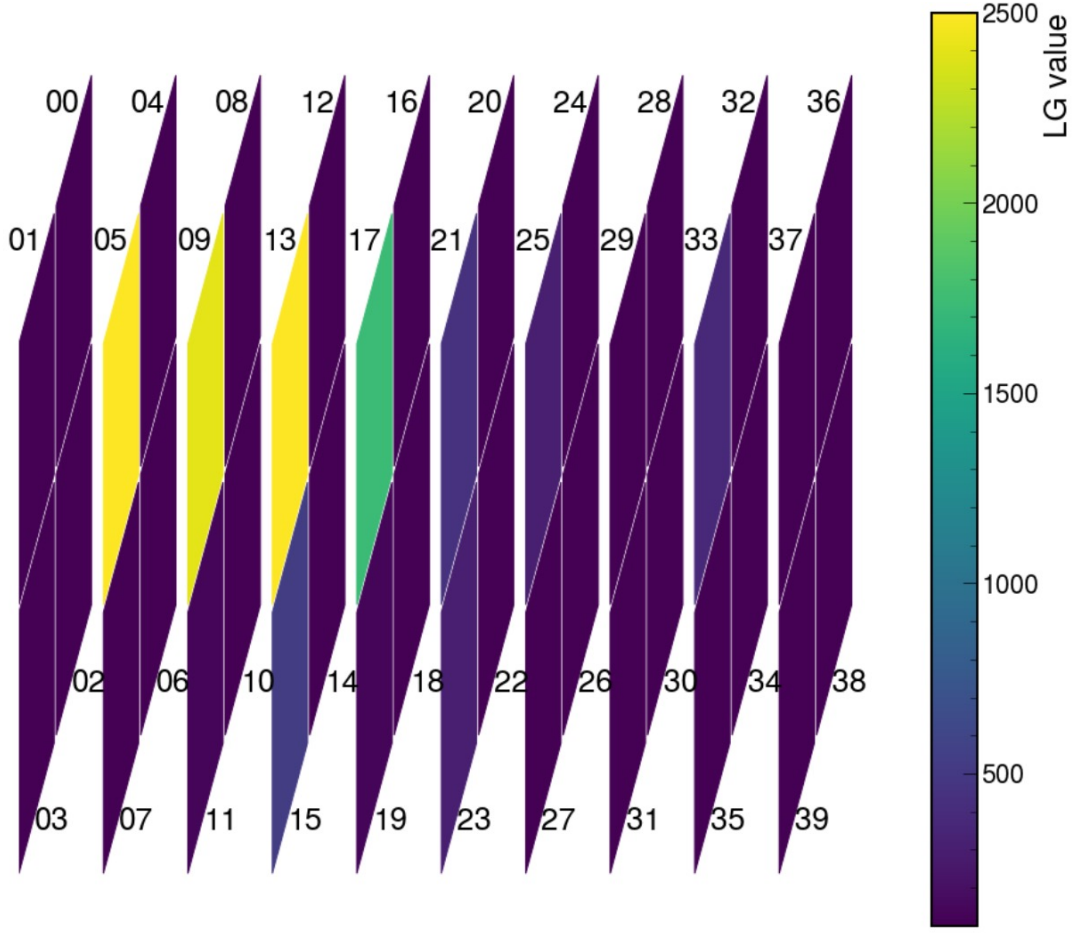
MIP Calibration

- Cosmic rays were used to calibrate each individual channel, which are used to convert arbitrary ADC units to MIPs.
- We observed large cell-to-cell variations, which we seek to improve in later iterations
- Variations are likely due to polishing of old recycled scintillator



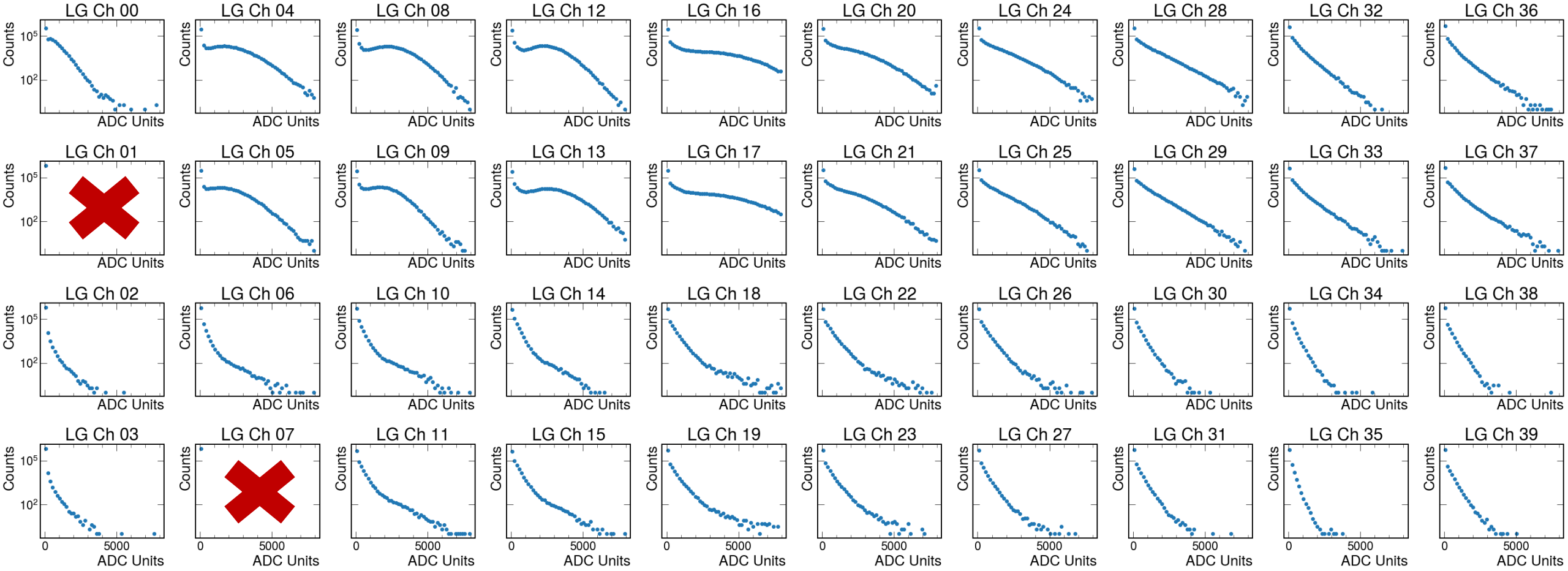
Single Events





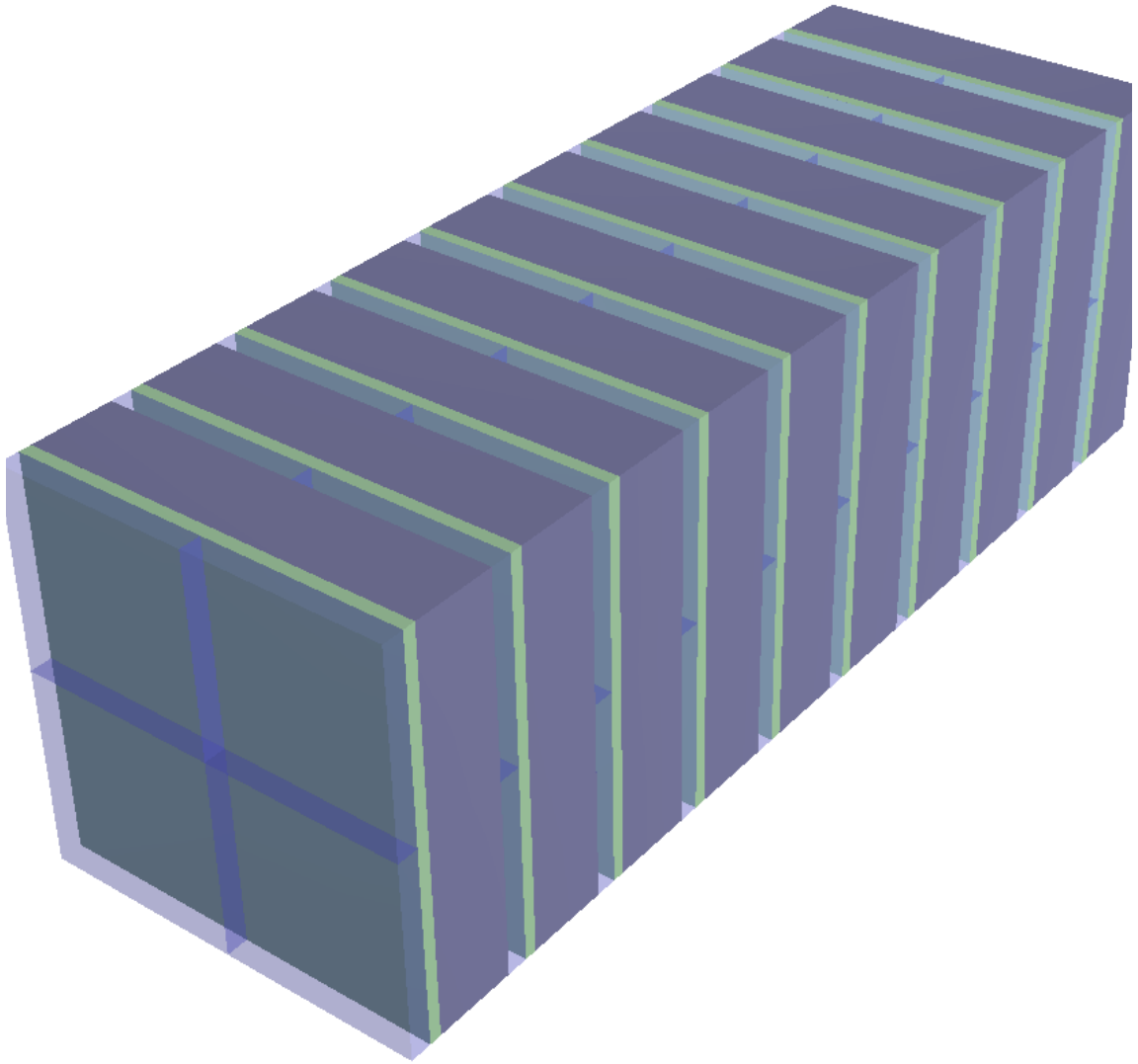
- We generally see only the top two rows show beam-like events
- Our detector was likely positioned slightly low relative to the beamline
- In future iterations we will add hodoscope layers before the first absorber plate

Channel Energy

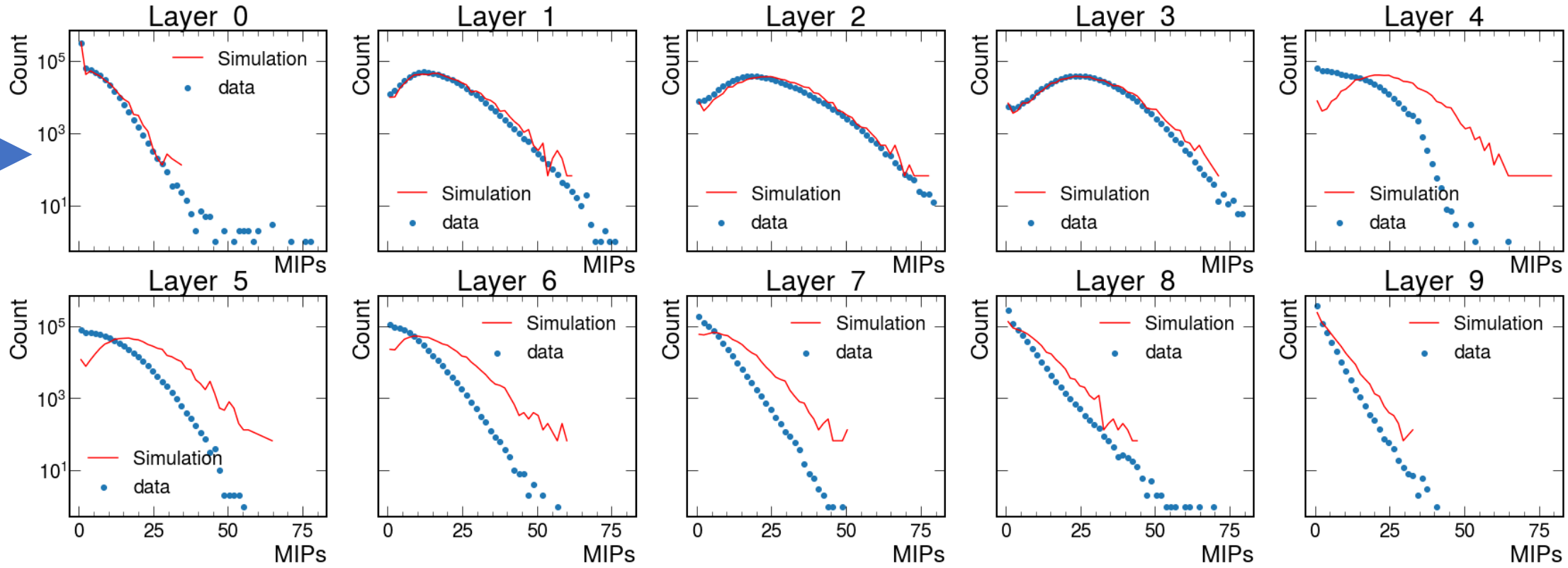


Simulation

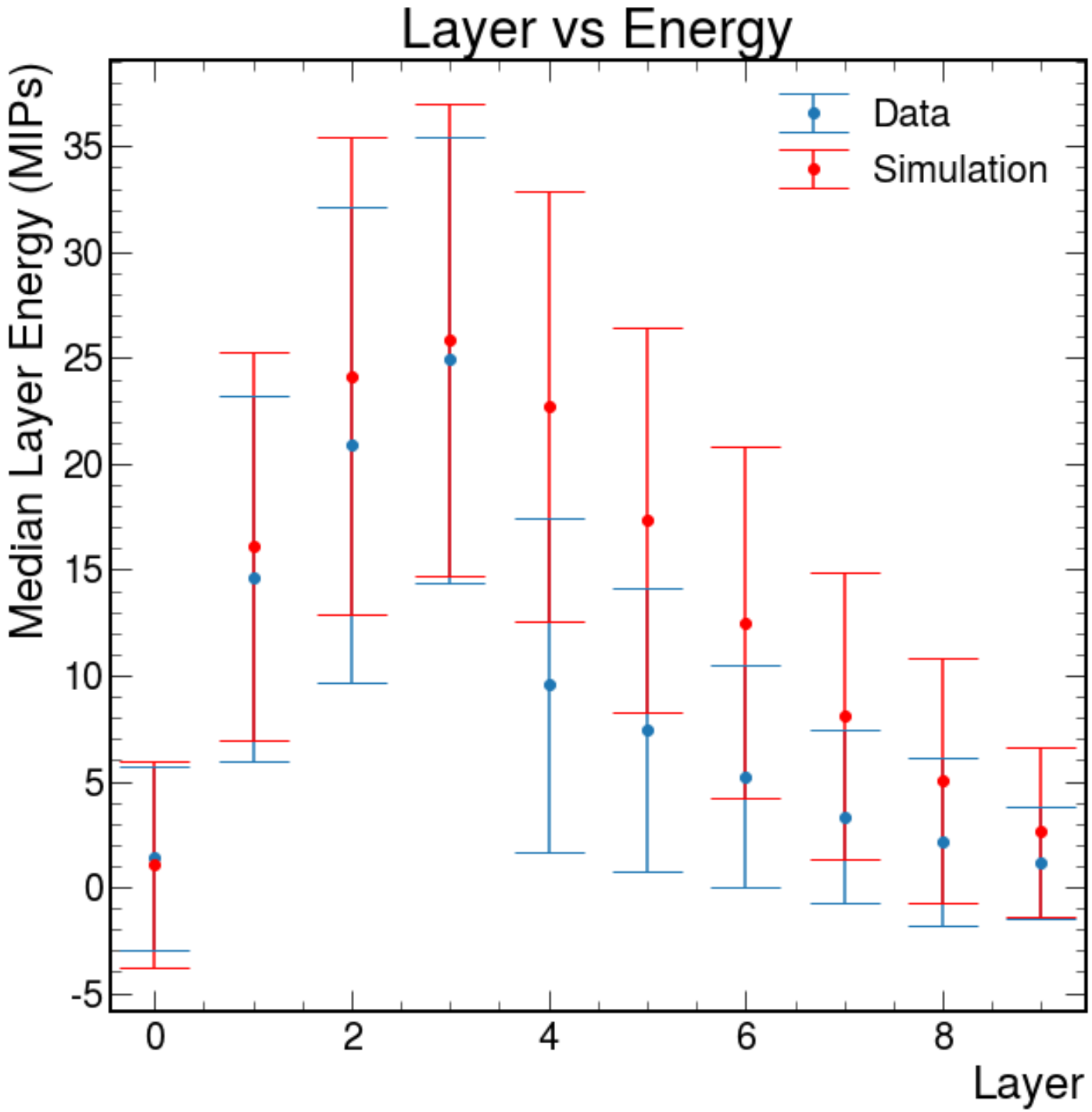
- Using DD4HEP, we simulated the prototype replicating test conditions
- Included:
  - MIP scale from simulated muons
  - Two dead channels
  - Mimicked horizontal beam spread
  - Shifted the detector down 2 cm
  - 0.3 MIP hit energy cut
- Did not yet include:
  - Small hexagonal cells in layers 4-9
  - Nonuniform cell response



Layer Energy



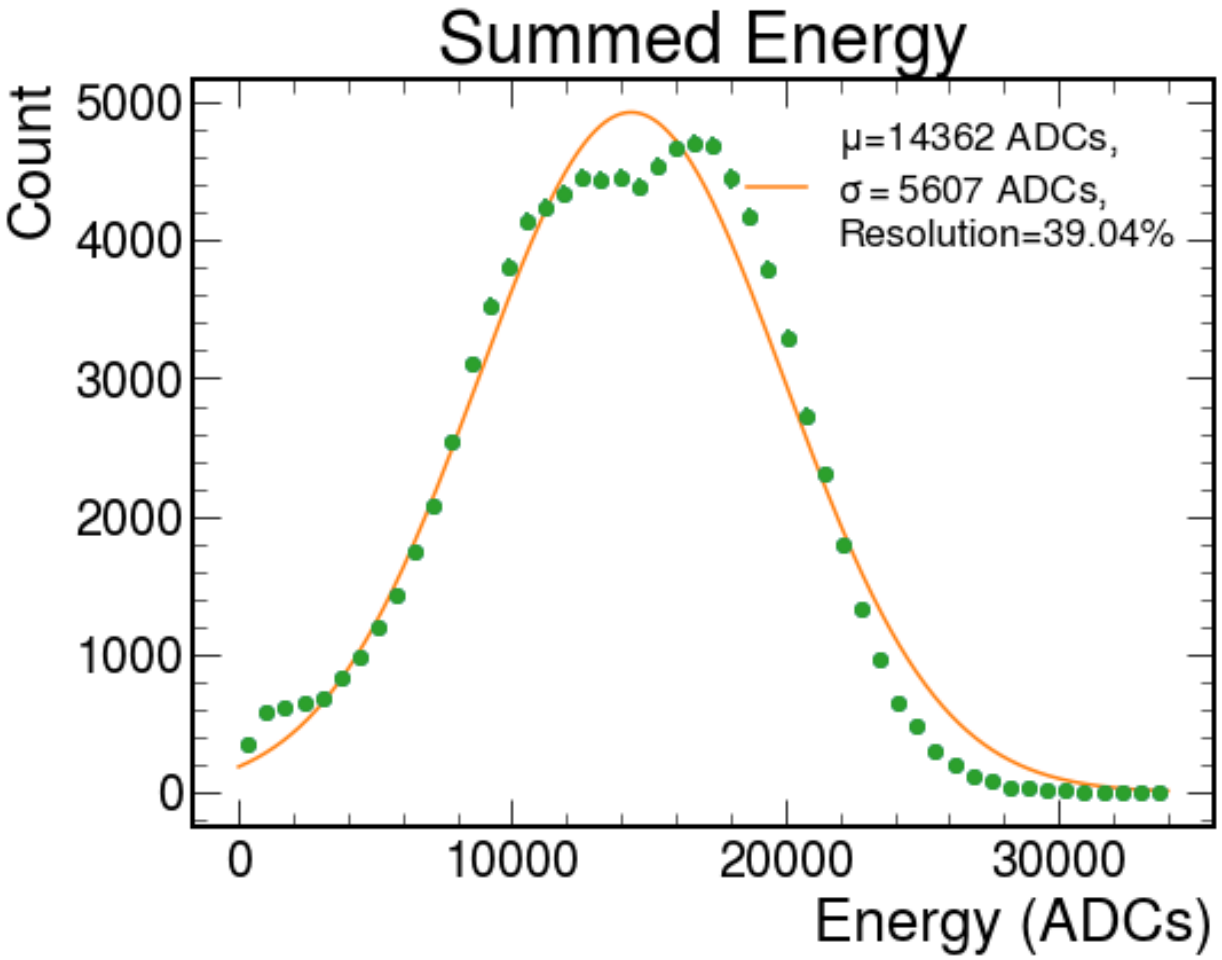
Strong agreement for layers 0-3, where the square cells are accurately modeled



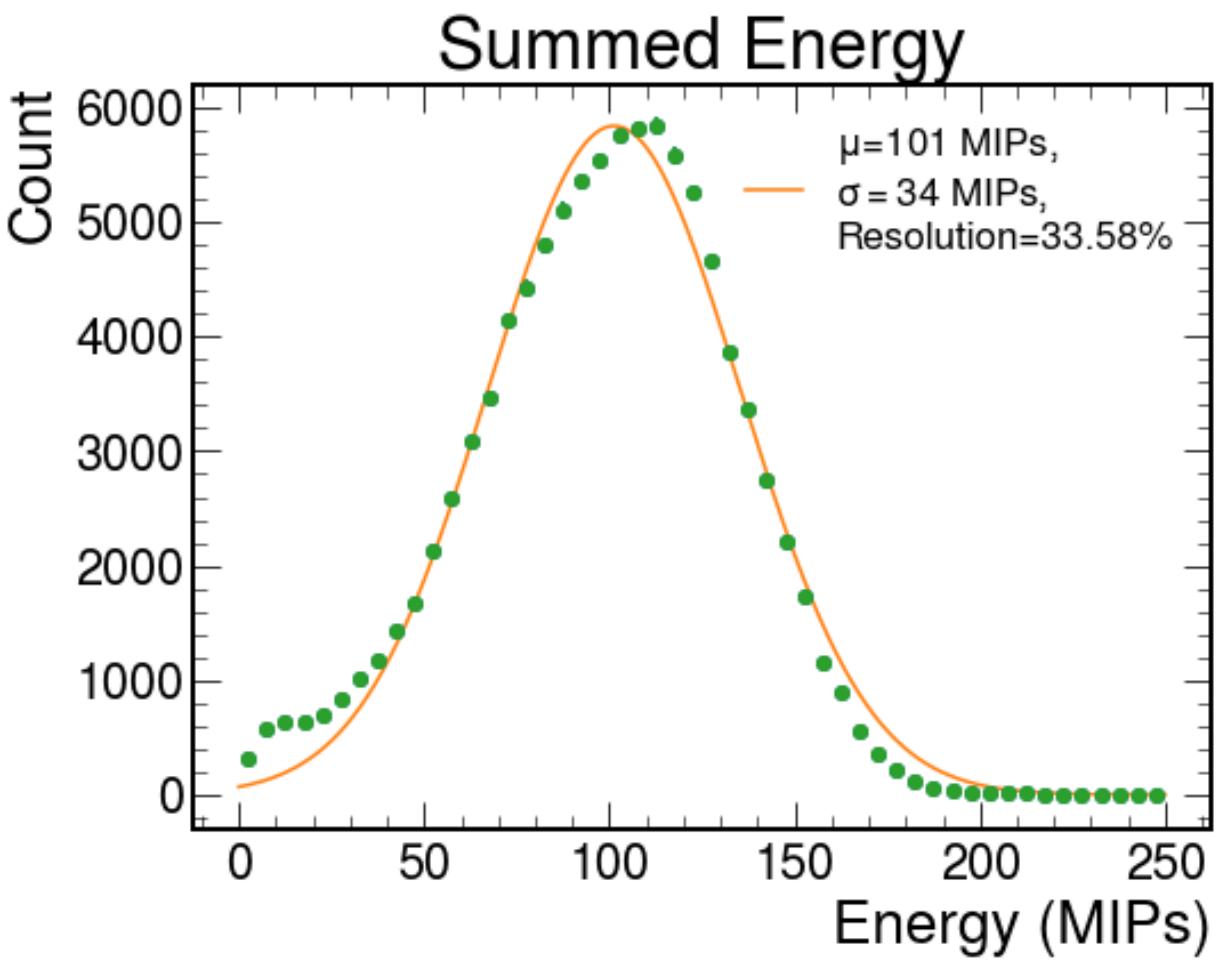
- Error bars represent standard deviation
- Hex cells record consistently lower energy than simulations
- The hex cells have an area 0.59 times that of a square cell, so will inconsistently miss energy from showers

Total Energy

Uncalibrated



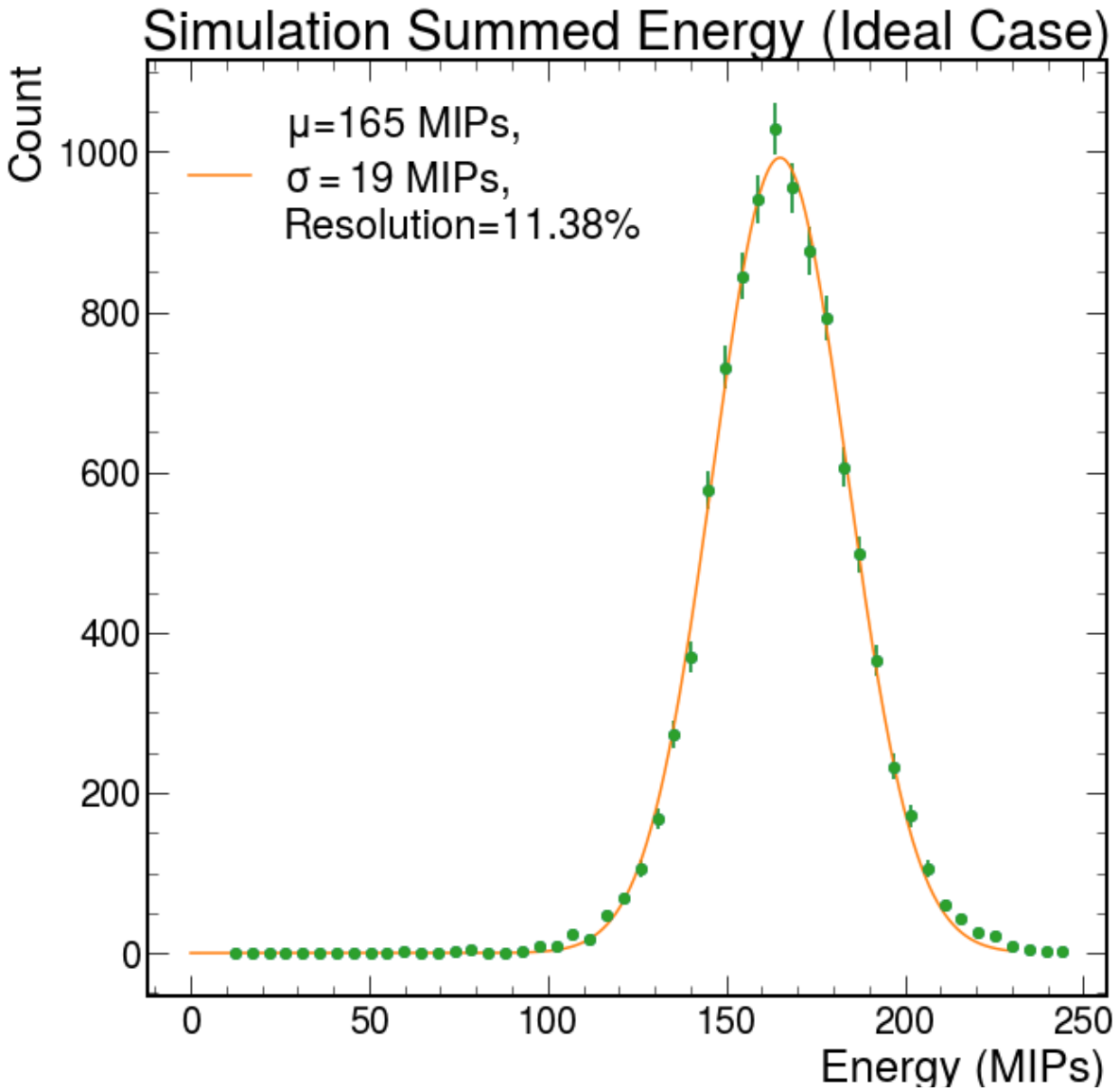
Calibrated



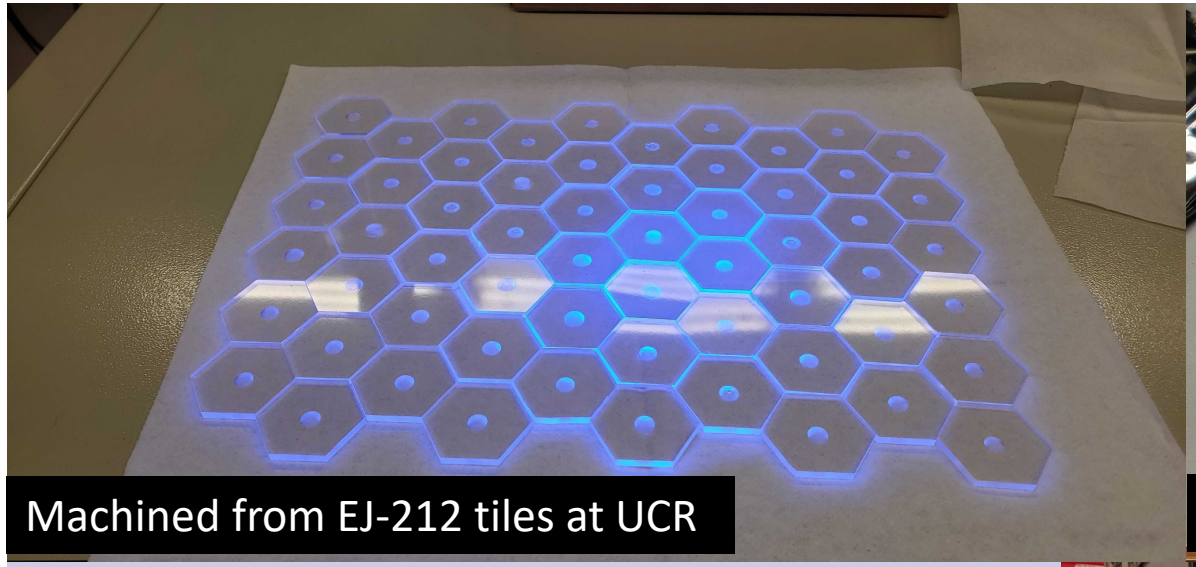
Calibrating each channel cell by cell using their MIP values improves the energy resolution a significant amount, but there is room for improvement...

Ideal Detector Simulation

- Simulated an ideal version of the detector, and measured how it would perform with 4 GeV electrons
- Electrons were sent directly down the center of the detector
- No dead channels

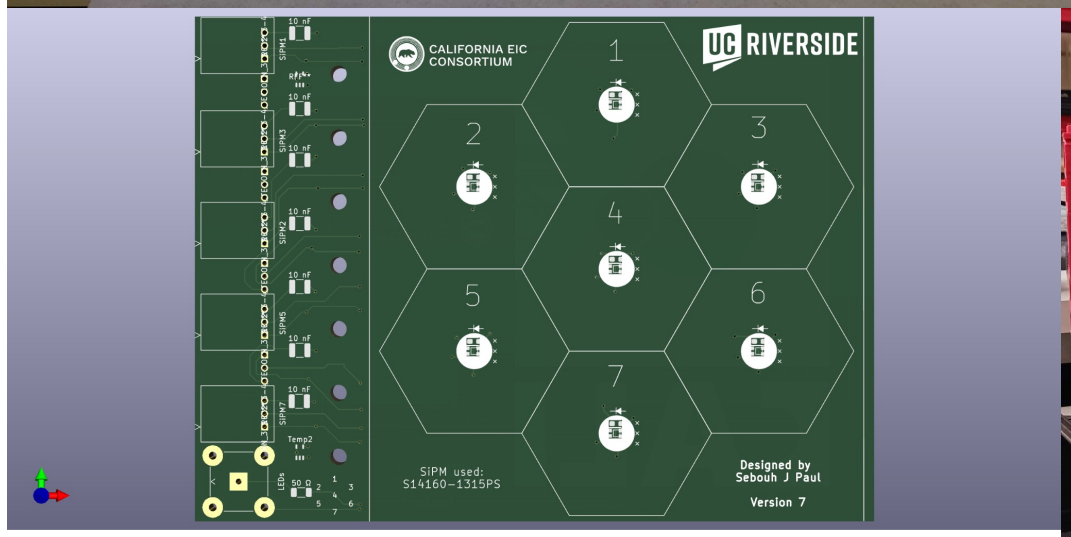


The Next Iteration



Machined from EJ-212 tiles at UCR

FNAL injection molded tiles



Future Tests

This first test beam for the HCAL Insert prototype gave our group good experience, confidence in our simulation framework, and insight into improvements for future test beams

Jefferson Lab

- We plan to return to JLab later this year with a larger 128 channel prototype, with a hodoscope attached

BERKELEY LAB

- We will perform SiPM irradiation tests at the 88” cyclotron this year

Fermilab

- We will test alongside UCLA’s W/SciFi ECAL this year

Brookhaven National Laboratory

- Will run a prototype with several hundred channels parasitically on the East side of STAR close to the beampipe during the 200 GeV pp run in 2024

Summary

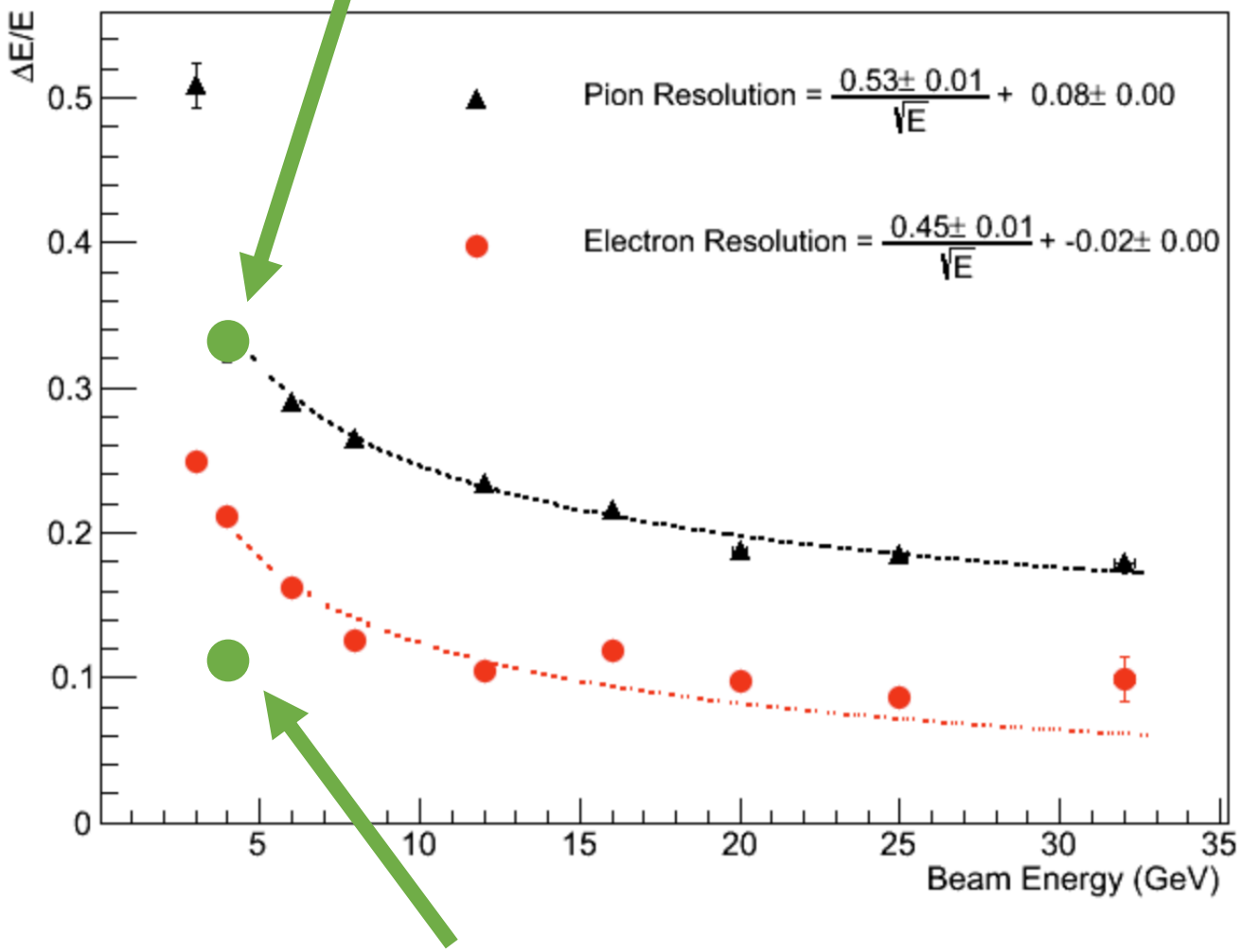
- First calorimeter insert test beam was successfully finished in Jan 2023
- Insights into design, construction, and operation of SiPM-on-tile calorimeter for ePIC
- Paving the way for future tests at JLab, LBNL, FNAL and BNL

Backup Slides

- Relatively poor measured electron resolution when compared with a recent UCLA Pb/Sc calorimeter test beam
- Very good potential for energy resolution when including expected improvements
- The main discrepancy seems to originate from dead space between cells

Measured

Plot from recent UCLA test beam



Ideal Simulation

- Summed energy distribution for the non-ideal simulation – what we likely would have observed if we had no dead space between hex cells.
- Removing dead space will likely be the largest contributor to a better energy resolution