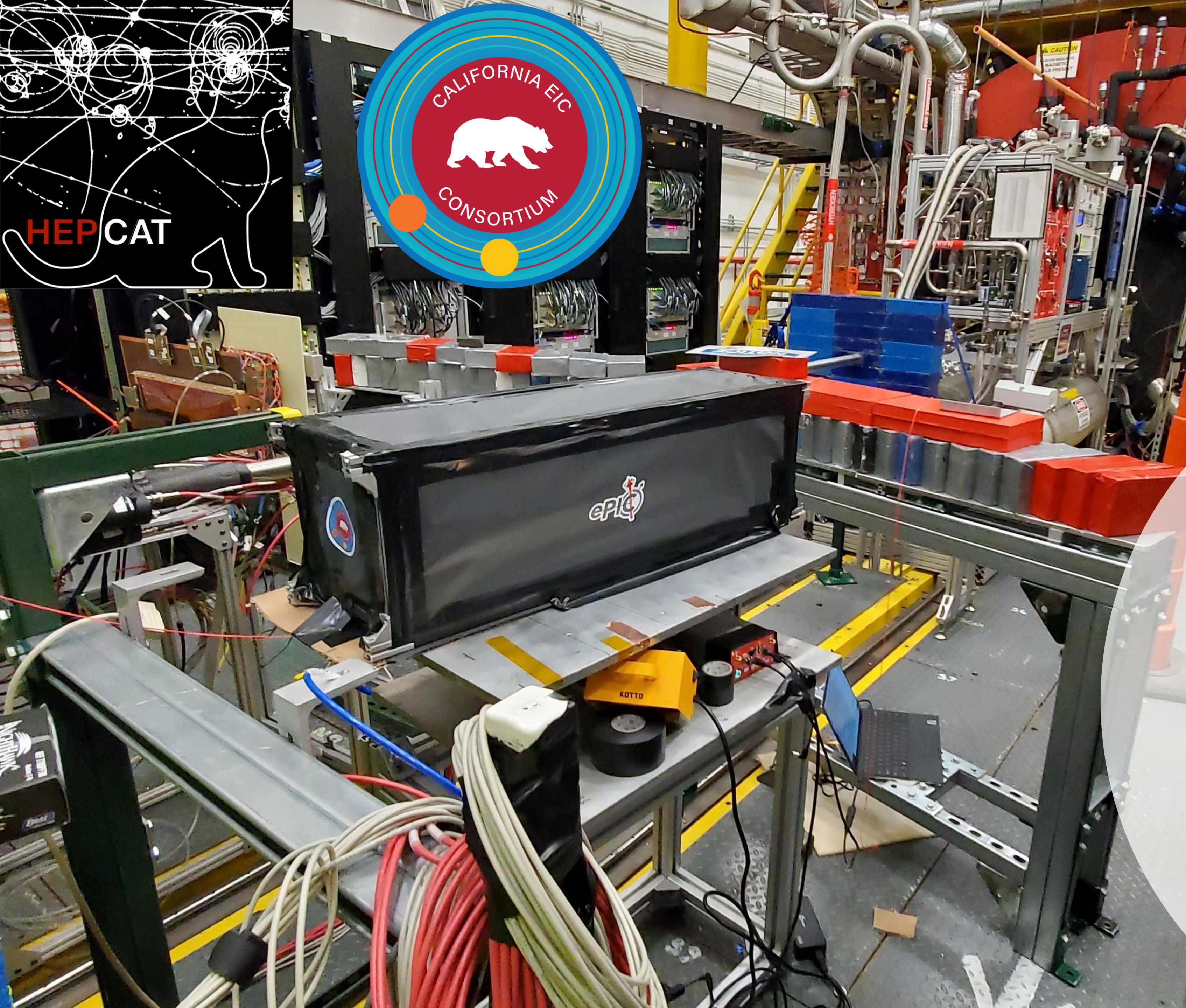


Results of first test beam of calorimeter insert at JLab

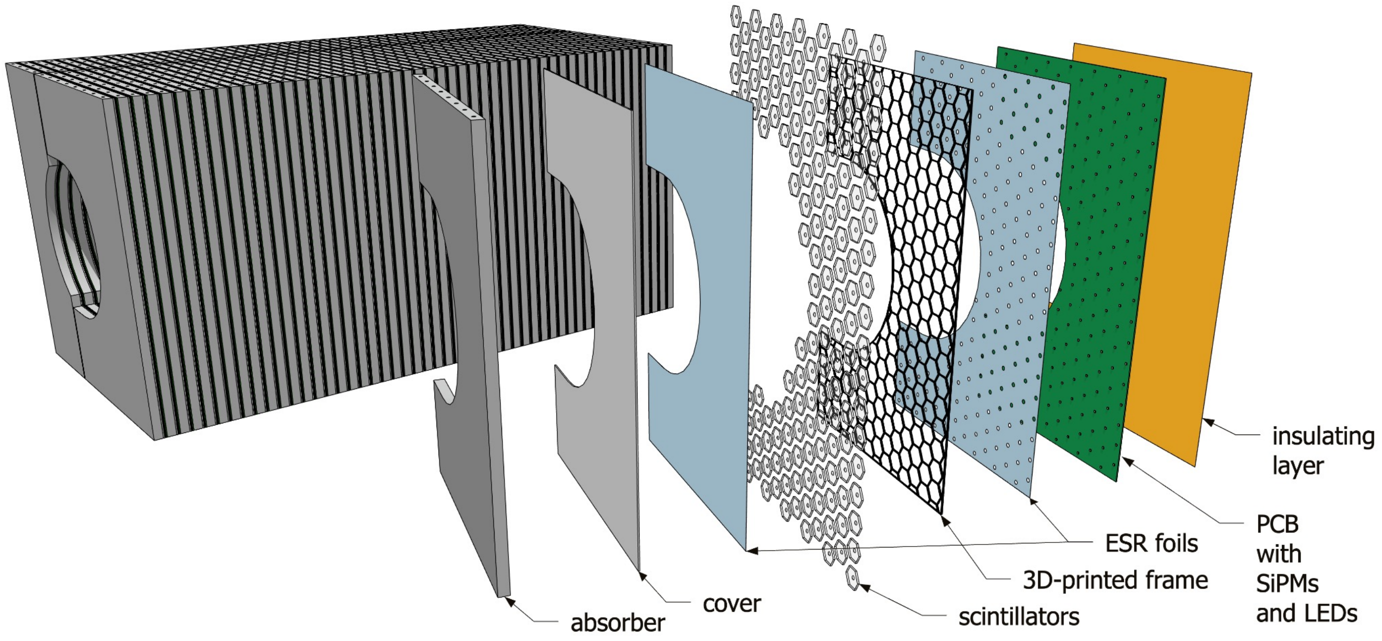
Sean Preins

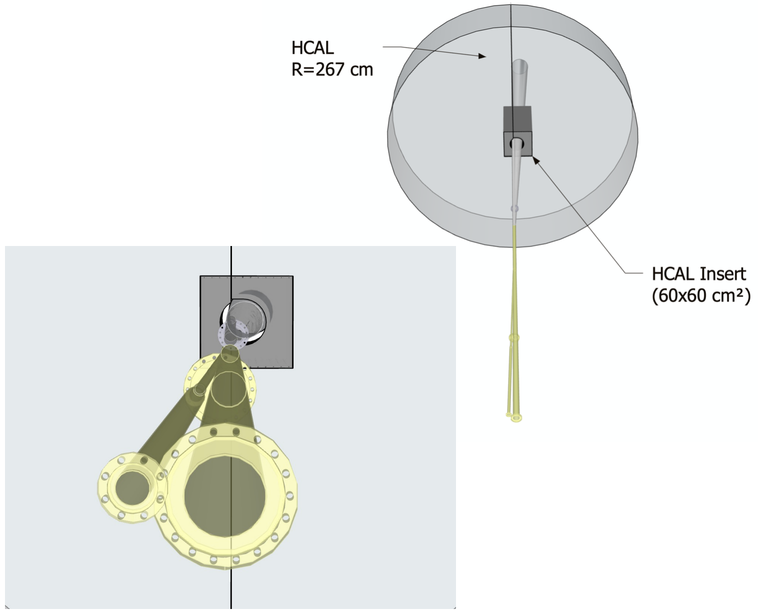
4/19/2023

UC RIVERSIDE

The Calorimeter Insert for ePIC

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

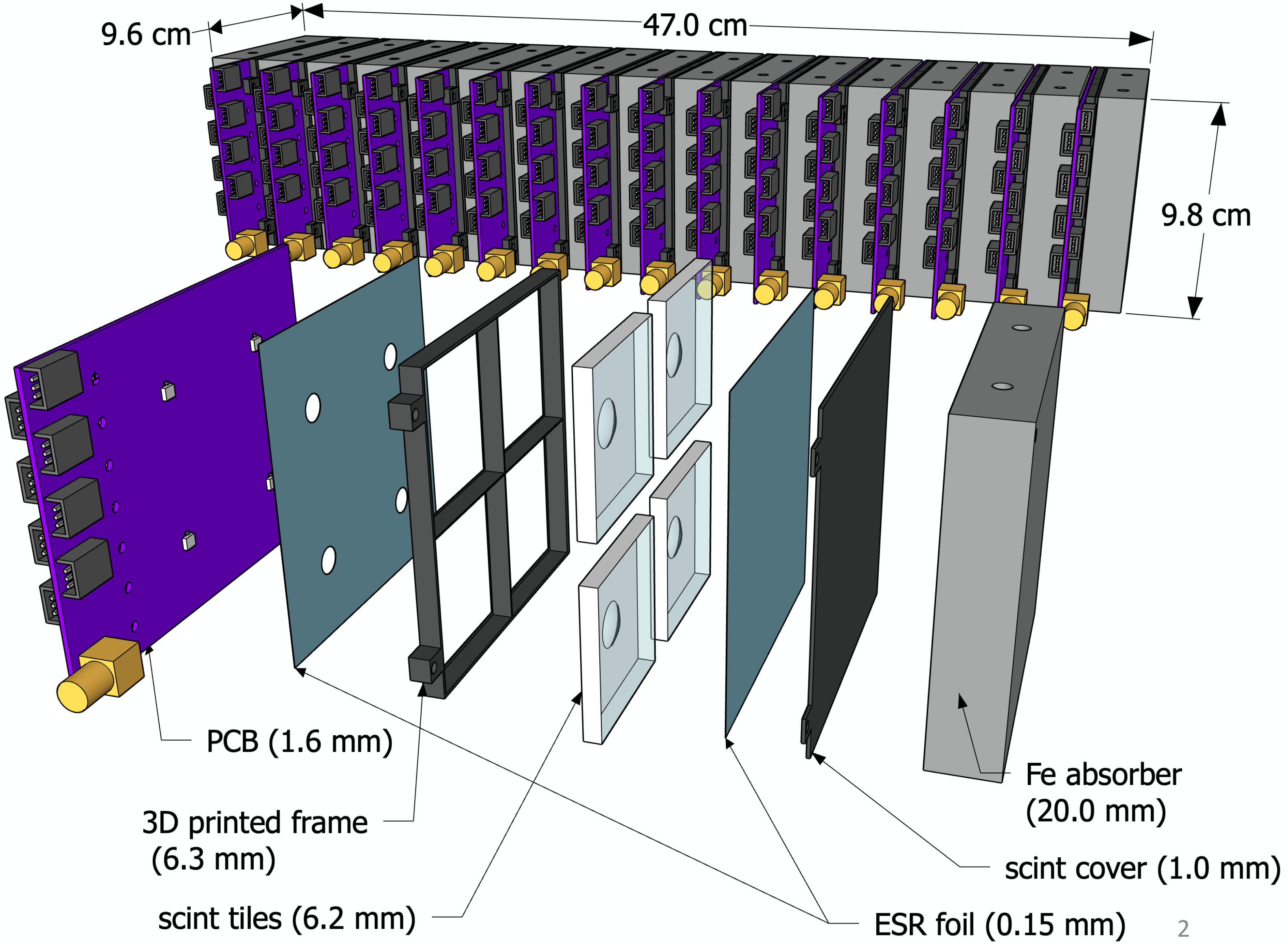




- Optimal acceptance with high-granularity to cover 3<η<4 range (poor tracking)
  - To improve acceptance for jets and inclusive DIS reco via event transverse-momentum
  - Tag beam-induced backgrounds with topology
  - To ensure SiPMs and scintillator remain easily accessible for repair/maintenance &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

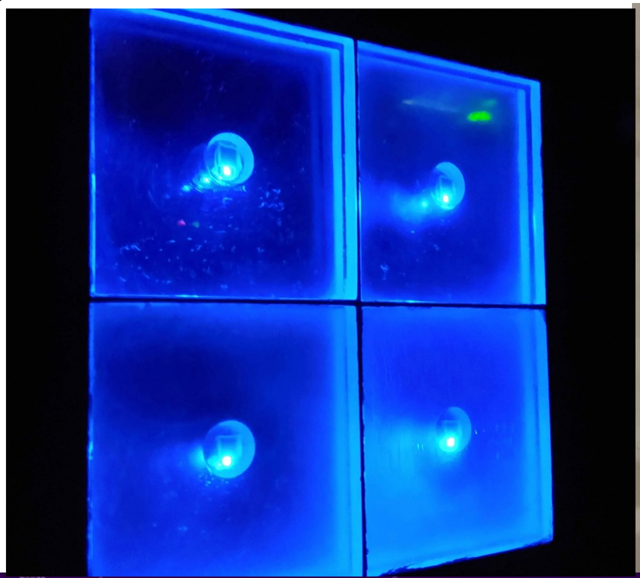
The First Insert Prototype for JLab Test

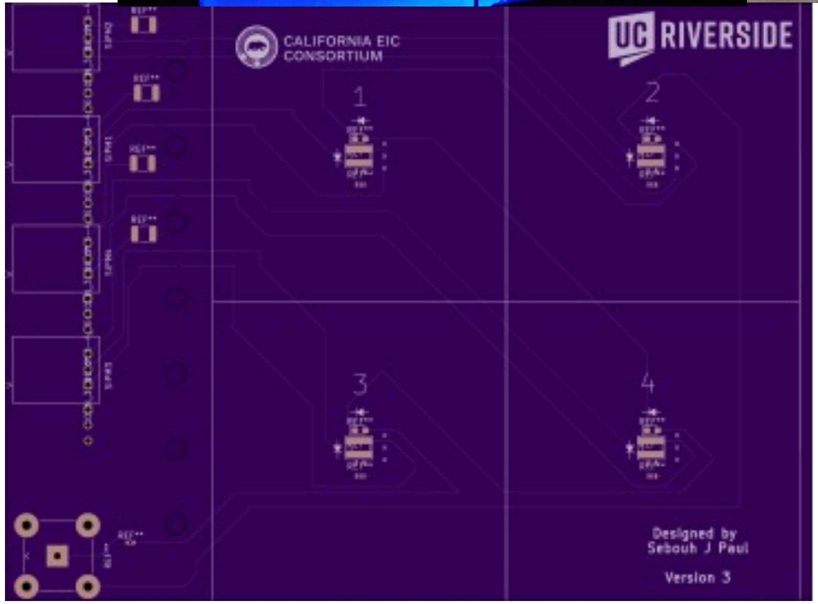
- Characterize components, work as proof of concept
- Consists of 10 layers, each subdivided into four scintillating tile cells (40 channels)
- Effectively 11.4 radiation lengths long
- Cross sectional area of 2x2 Moliere radii

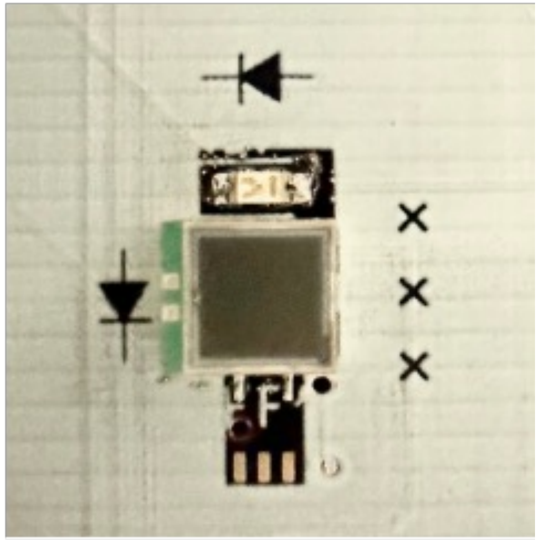


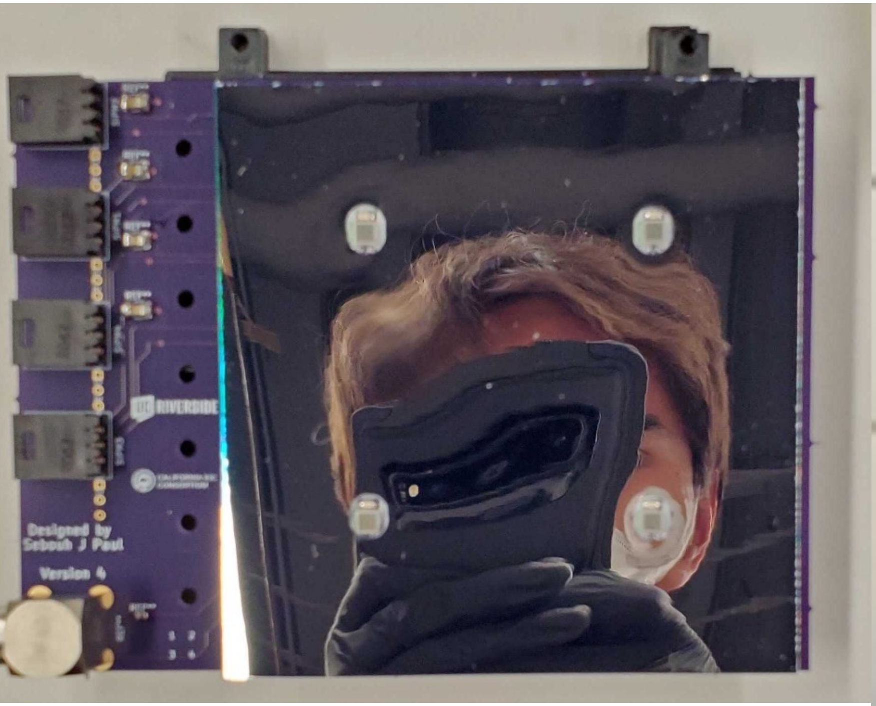
The First Insert Prototype for JLab Test

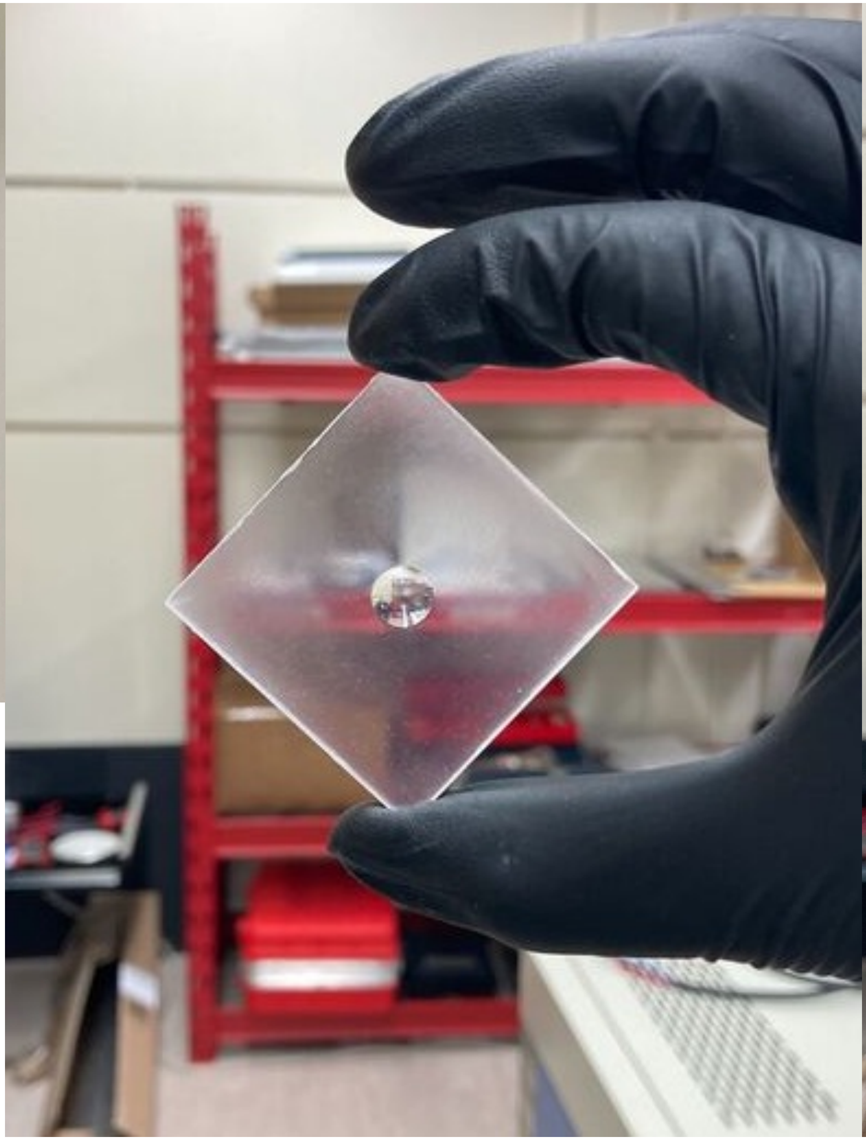
- Uses 3x3 mm Hamamatsu 14160 SiPMs
- SiPMs are biased and read out by a CAEN digitizer unit
- Tried different shapes along the length

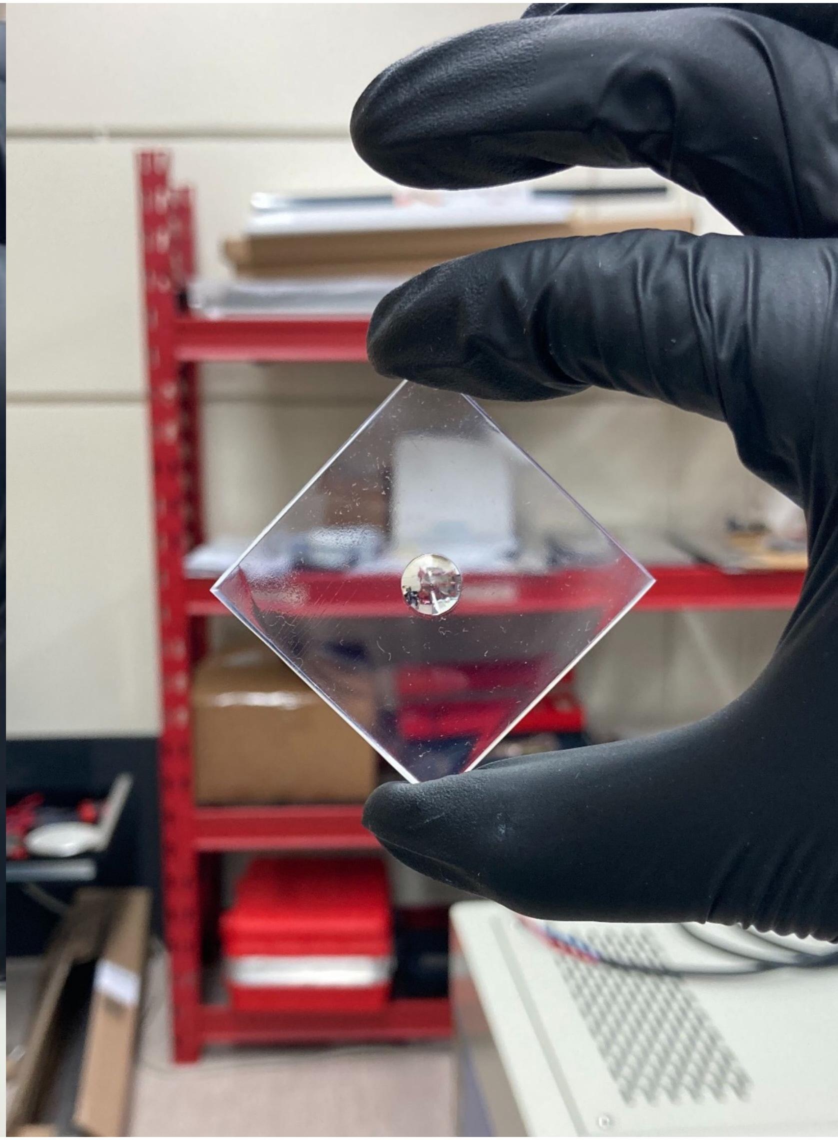






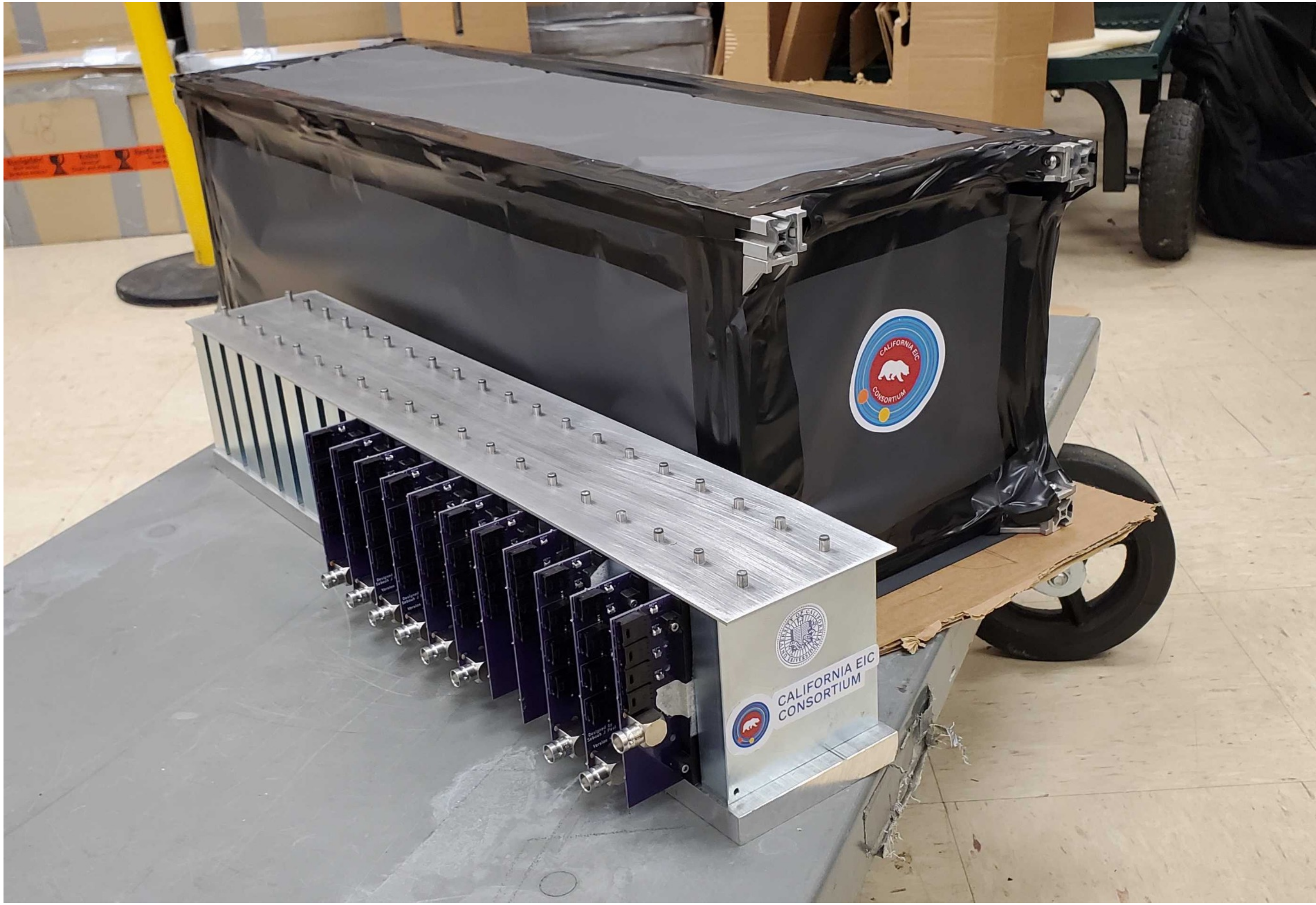






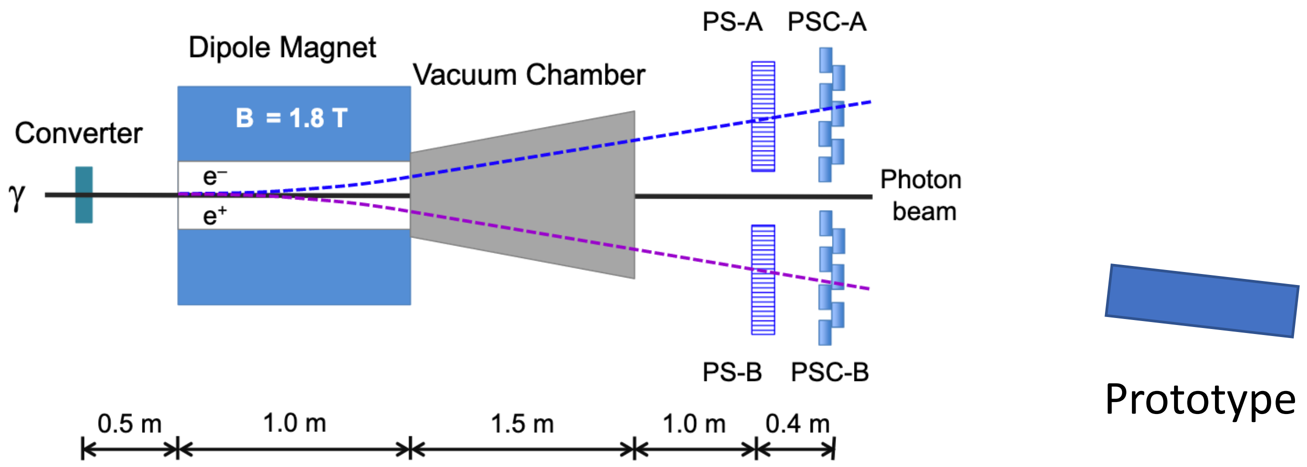
- Scintillator tiles are made with recycled old, scrap material and polished by hand


NOTICE

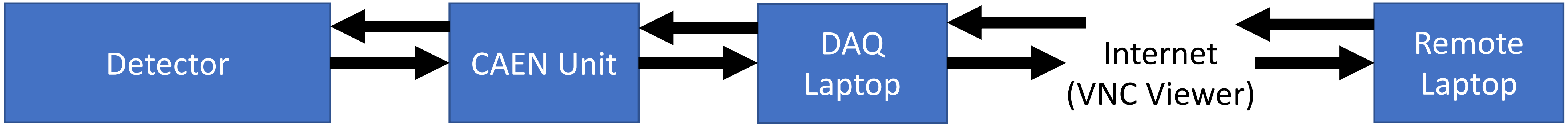

CALIFORNIA EIC CONSORTIUM
CALIFORNIA EIC
CONSORTIUM

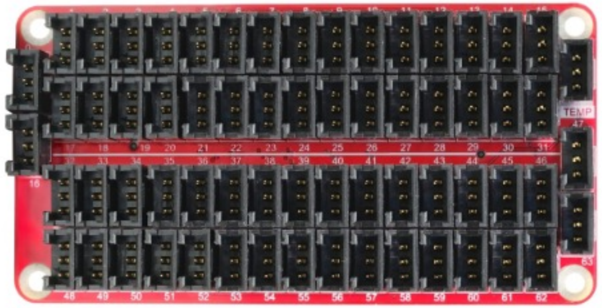
Hall D Beam Characteristics

- 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
- No hodoscope was used, will be implemented in the next iteration



DAQ Setup



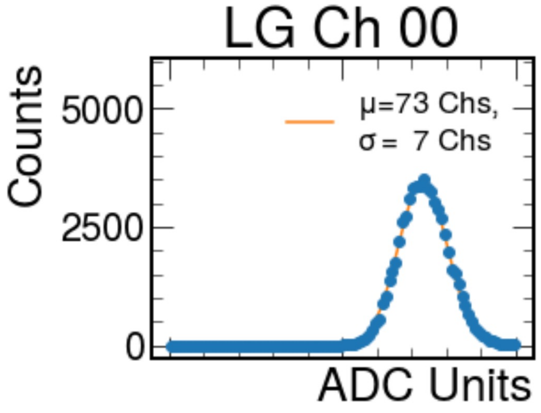


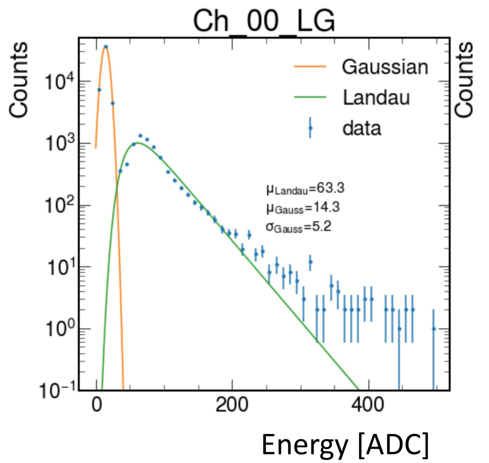
A5253 - 3-pin header adapter for FERS-5200 (optional)

Data Acquisition Procedure

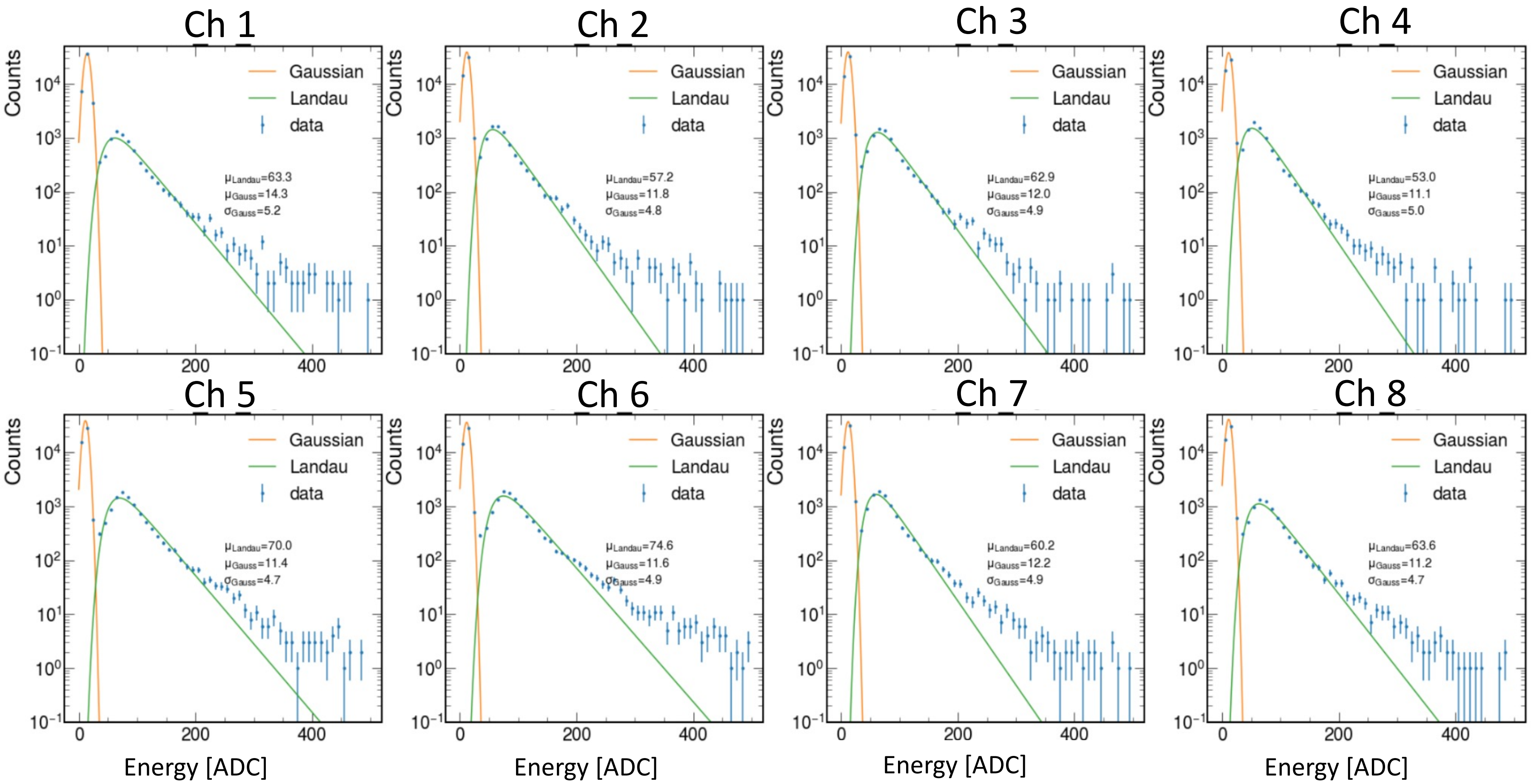
Decide on CAEN settings → Record noise data from random triggers to determine the pedestal position and width for each channel → Apply pedestal cuts to all data going forward → Record cosmic rays to determine how to convert between ADC Channels and MIPs → Record beam data, sum the total energy per event, and the layer-by-layer breakdown

- We've learned about the operation and calibration of a SiPM-on-tile calorimeter



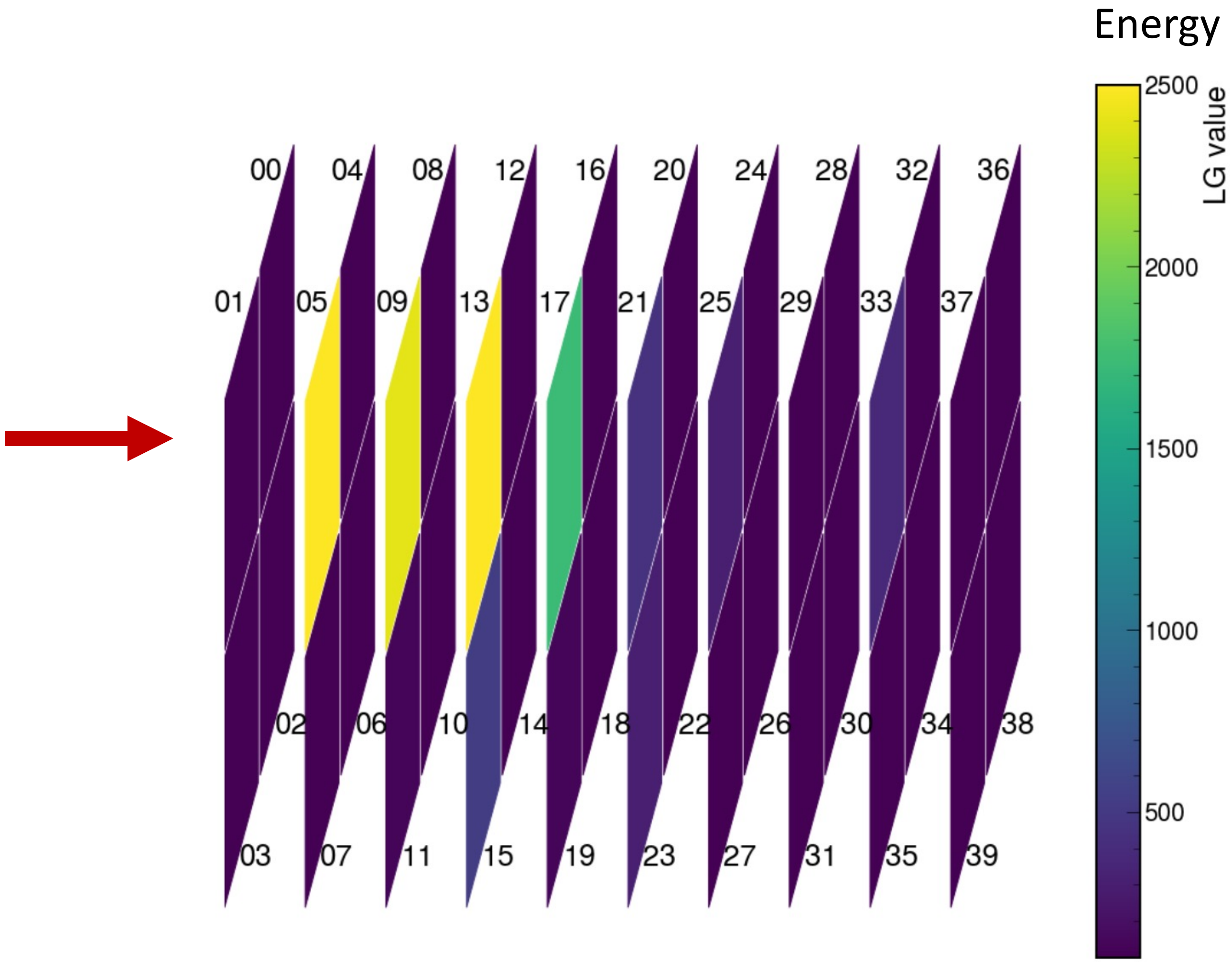


Cosmic Ray Runs



- Cosmic runs were performed before it was installed in Hall D
- Each tile is calibrated independently this way

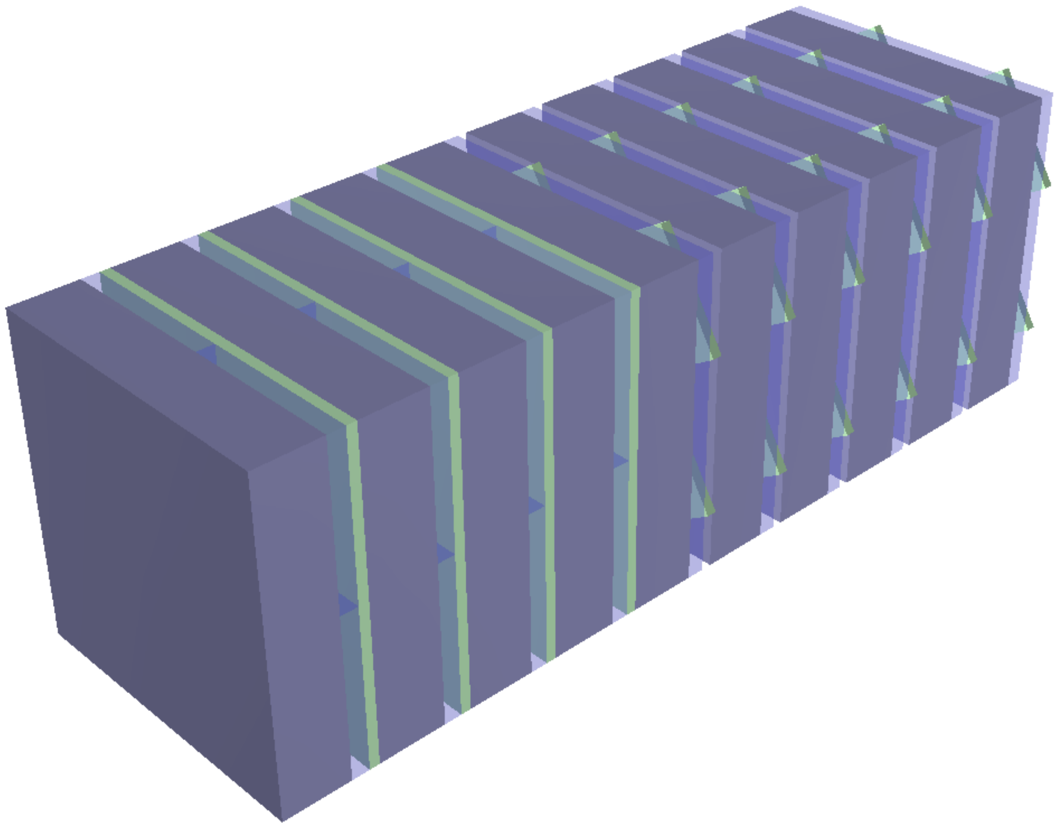
Single Events



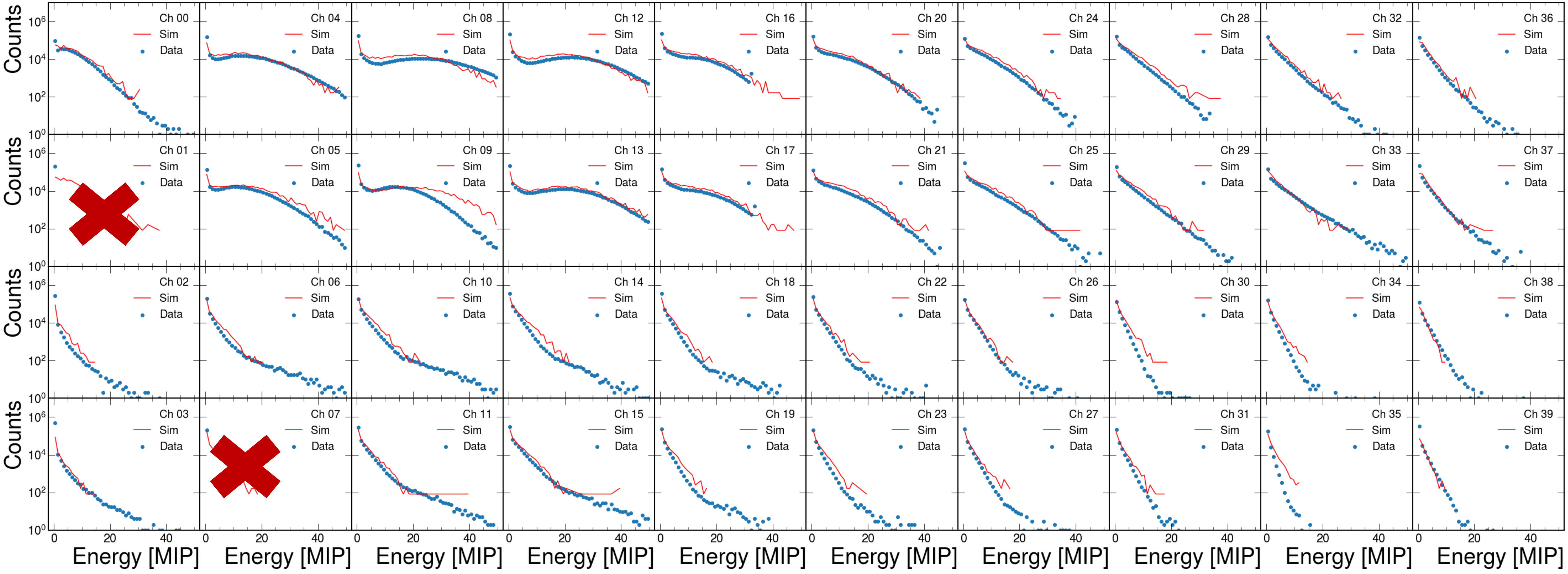
- We generally see only the top two rows show beam-like events
- Our detector was likely positioned slightly low relative to the beamline
- In future iterations we will add hodoscope layers before the first absorber plate

Simulation

- Using DD4HEP, we simulated the prototype replicating test conditions
- Included:
  - MIP scale from simulated muons
  - Two dead channels
  - Mimicked horizontal beam spread
  - Small cells have same area as the hex cells, rotated 45° to mimic intersection with beam plane
  - Shifted the detector down 1 cm
  - 0.3 MIP hit energy cut and max energy cap
- Did not yet include:
  - Hexagon shapes
  - PCB, plastic, or foil material
  - Nonuniform cell response



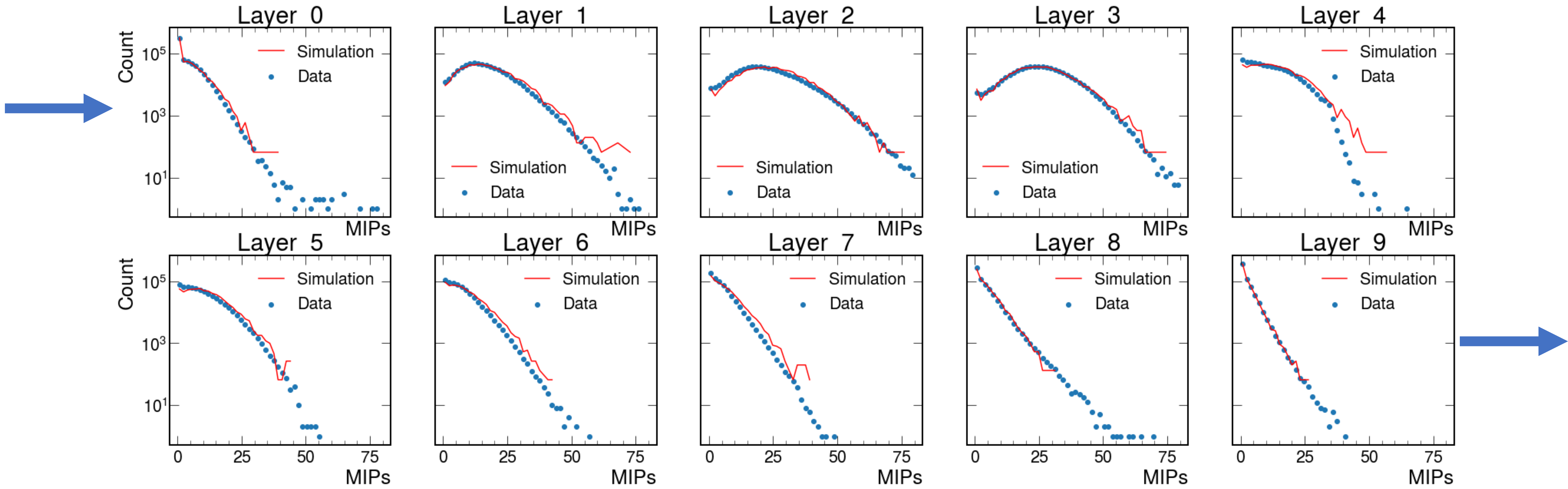
Hit Energy Spectra



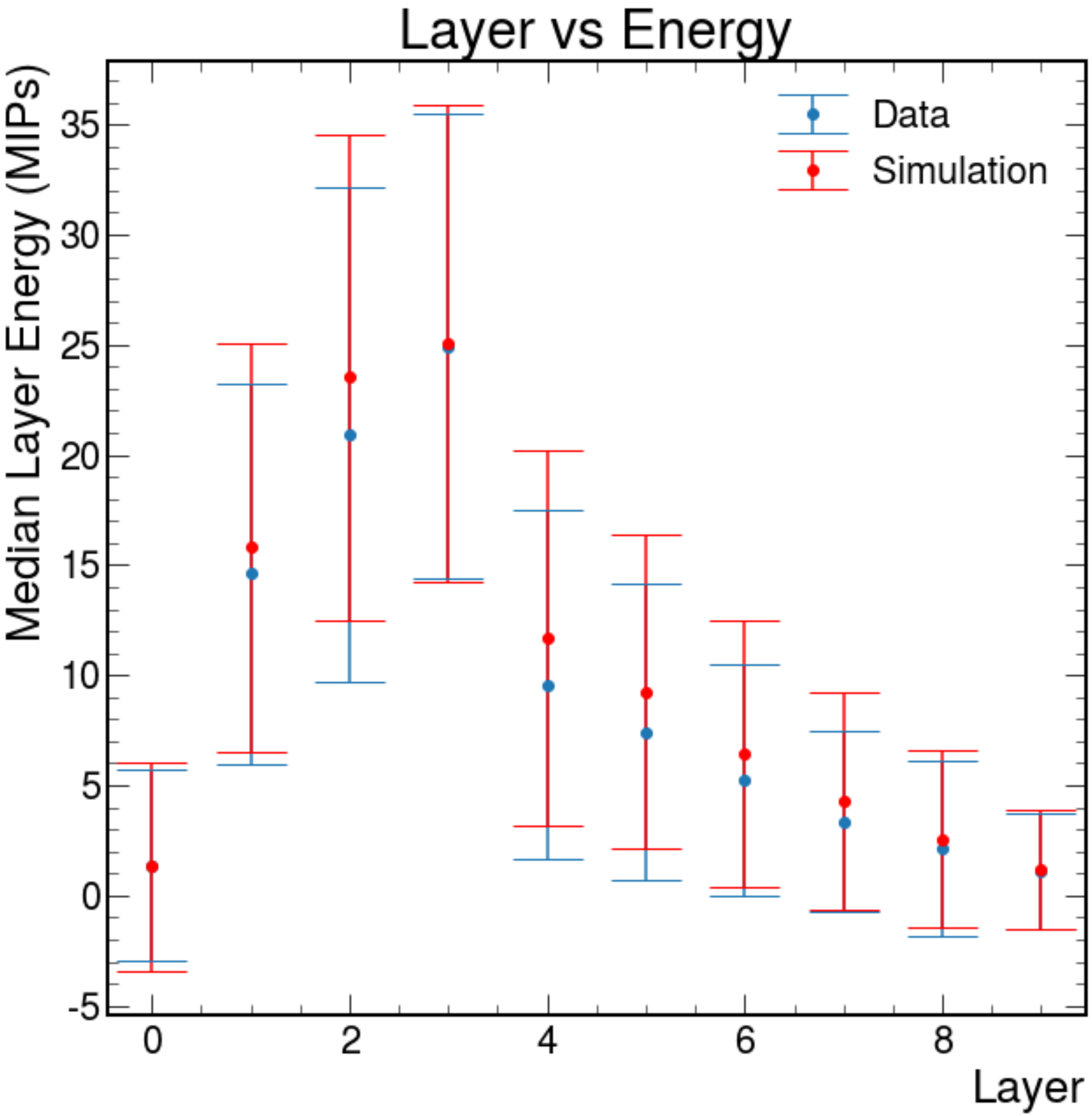
Beam

- Data and simulation calibrated independently in the same way, cell-by-cell with MIPS
- Number of events (showers) in simulation scaled to number of events in data

Layer Energy



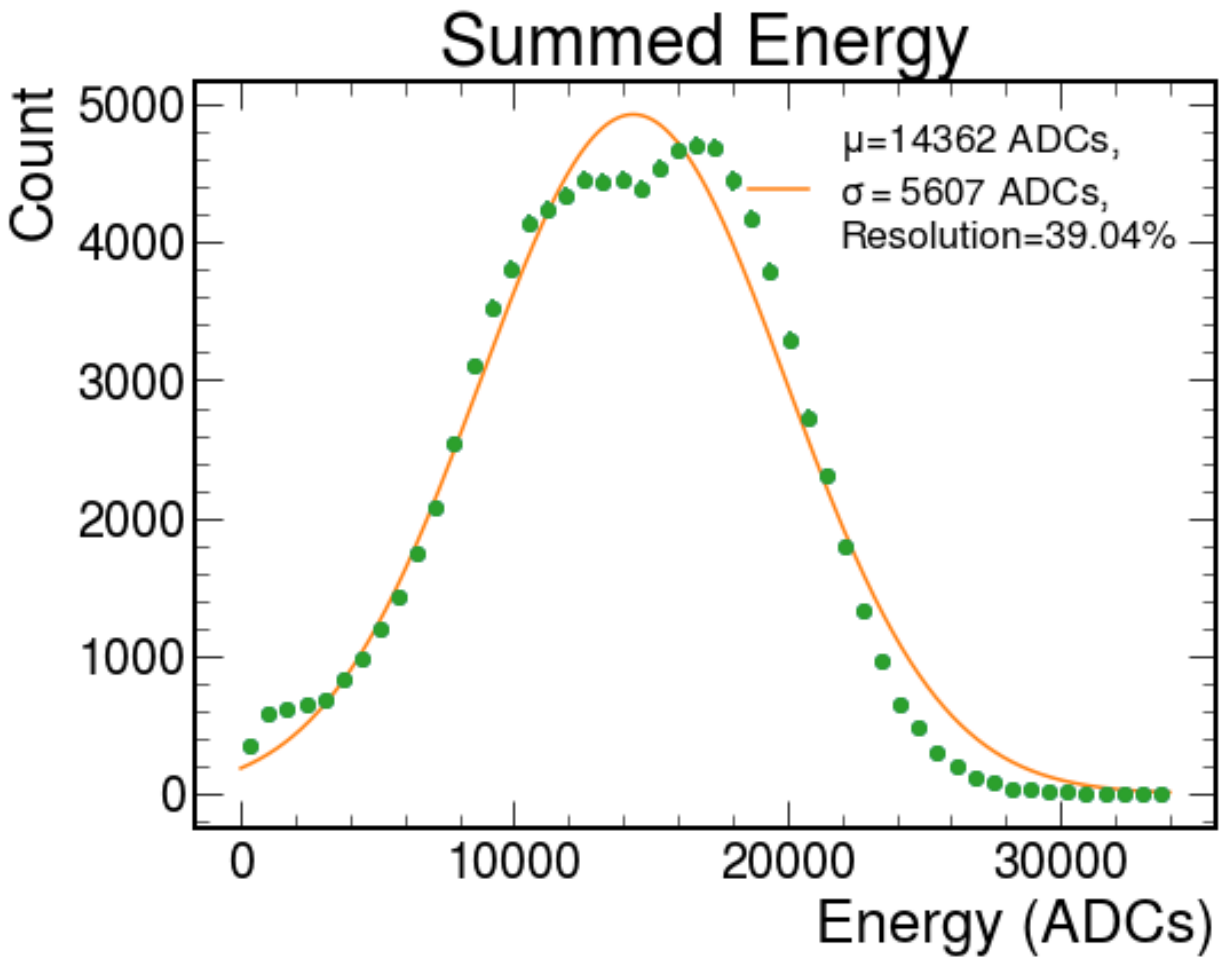
- Decent agreement between data and simulation, but need more statistics



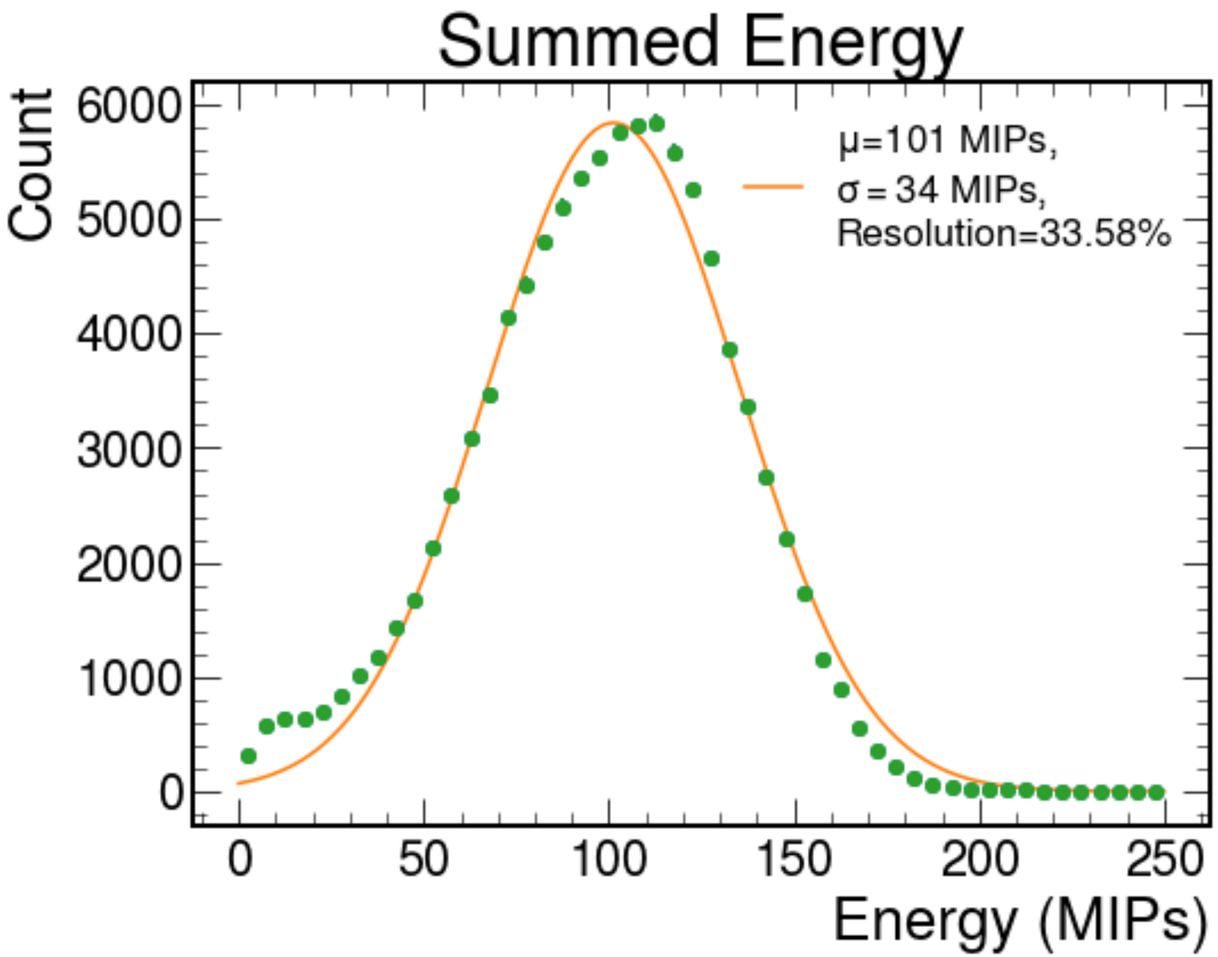
- Error bars represent standard deviation
- Data is in close agreement with simulation, and the median energy per layer is only ~10% lower than simulations
- The standard deviation is also well described by the simulation

Total Energy

Uncalibrated



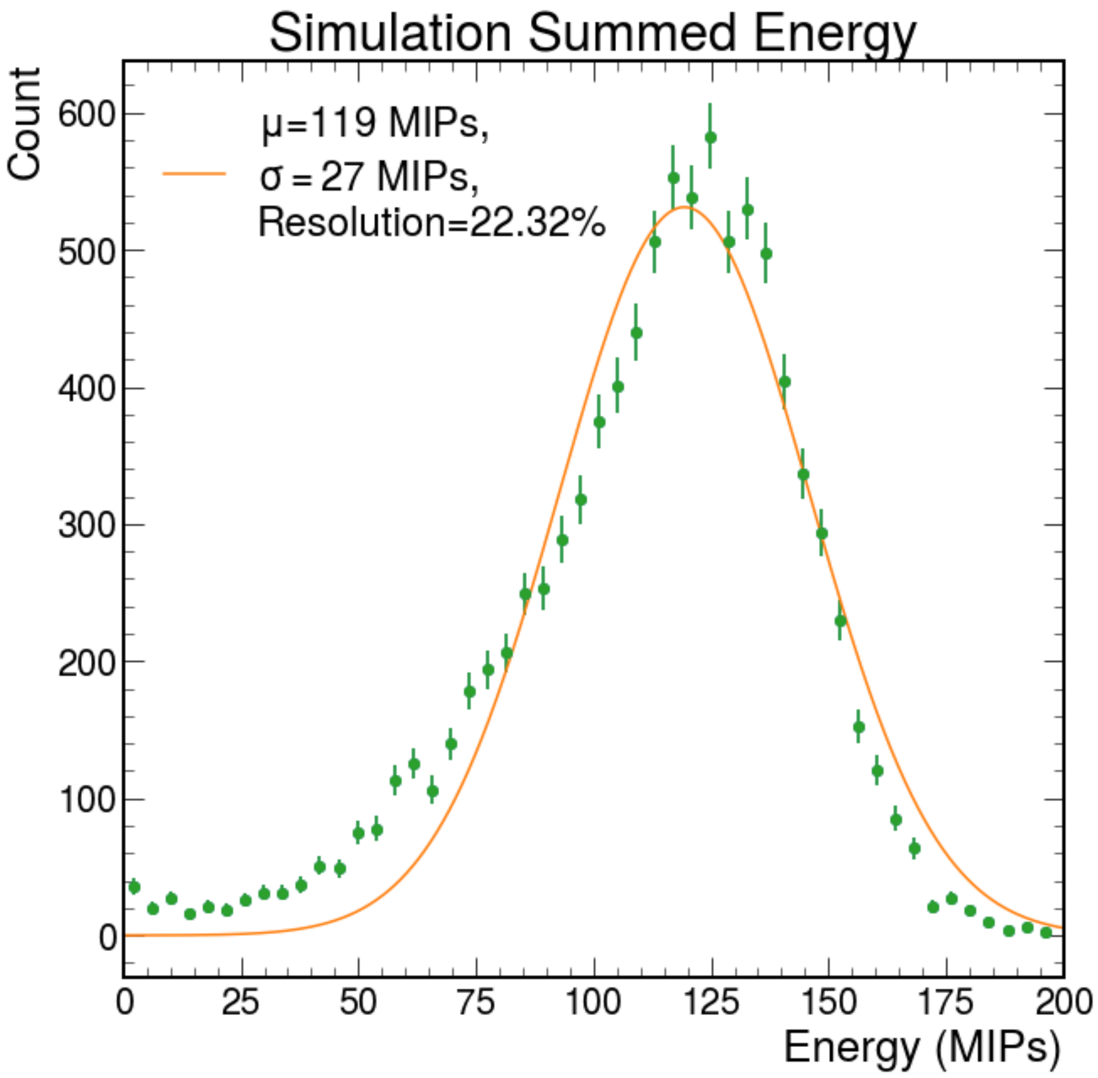
Calibrated



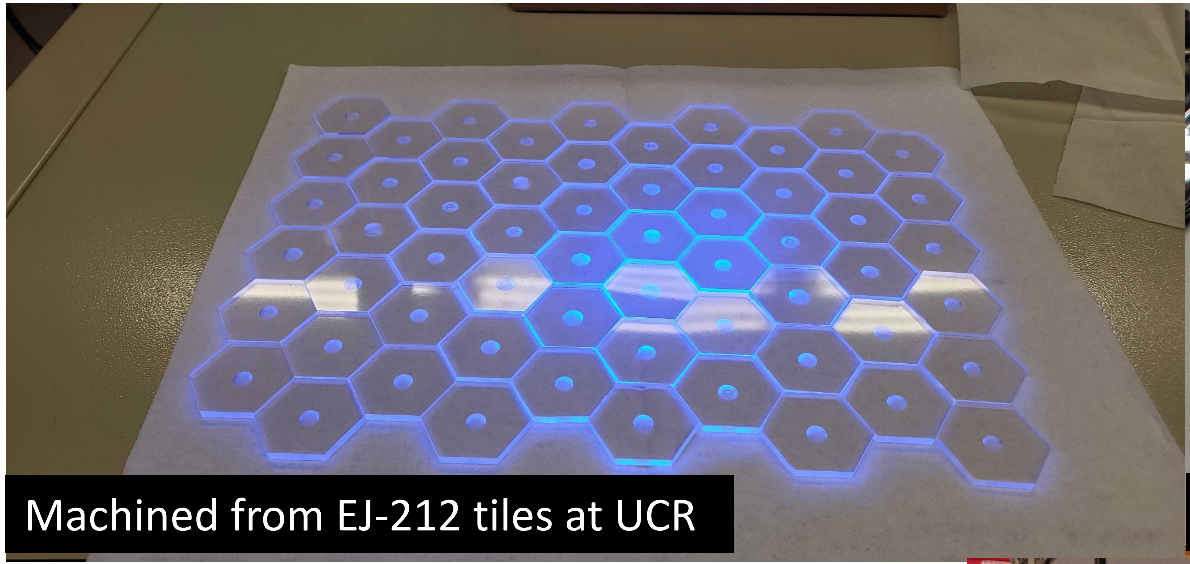
Calibrating each channel cell by cell using their MIP values improves the energy resolution a significant amount, but there is room for improvement...

Simulated Energy Resolution

- Discrepancy may come from materials not yet simulated (plastic, ESR foil, PCBs), and/or tile nonuniformities
- Not optimized for electron resolution – built for high granularity measurements of hadronic showers



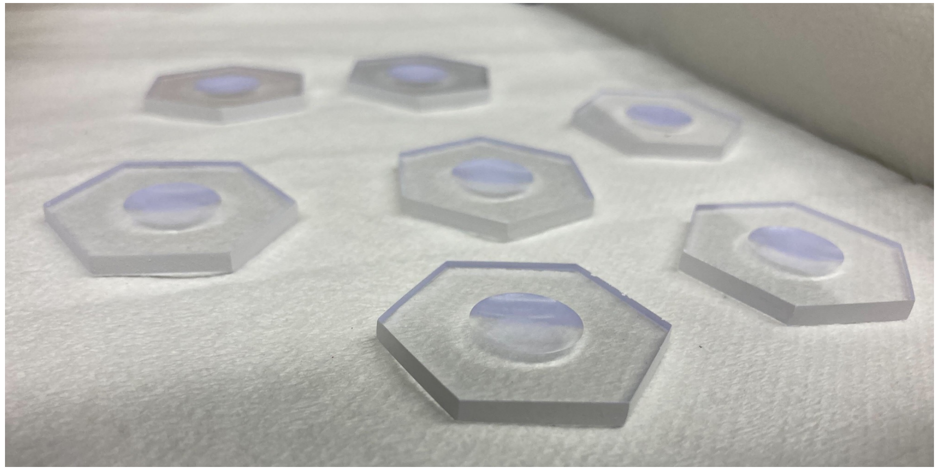
The Next Iteration

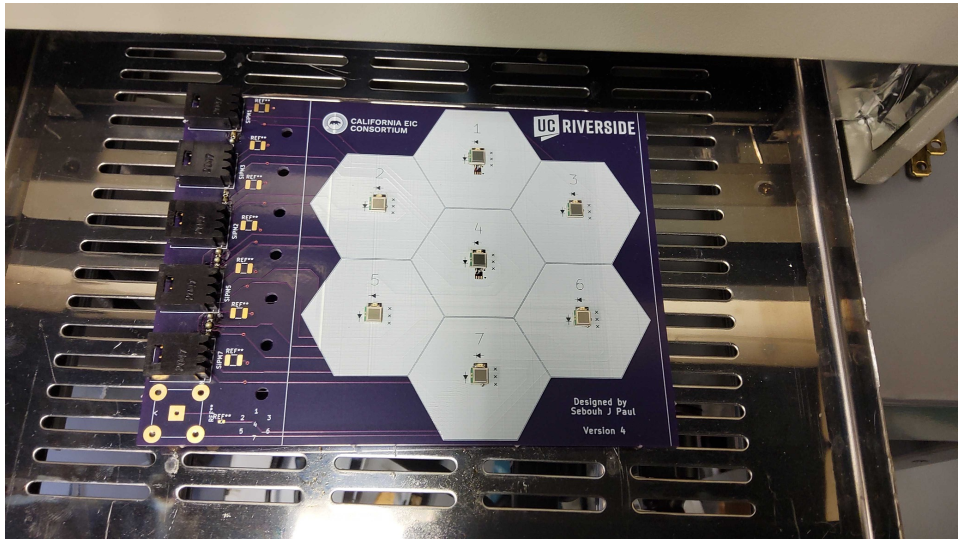

Machined from EJ-212 tiles at UCR

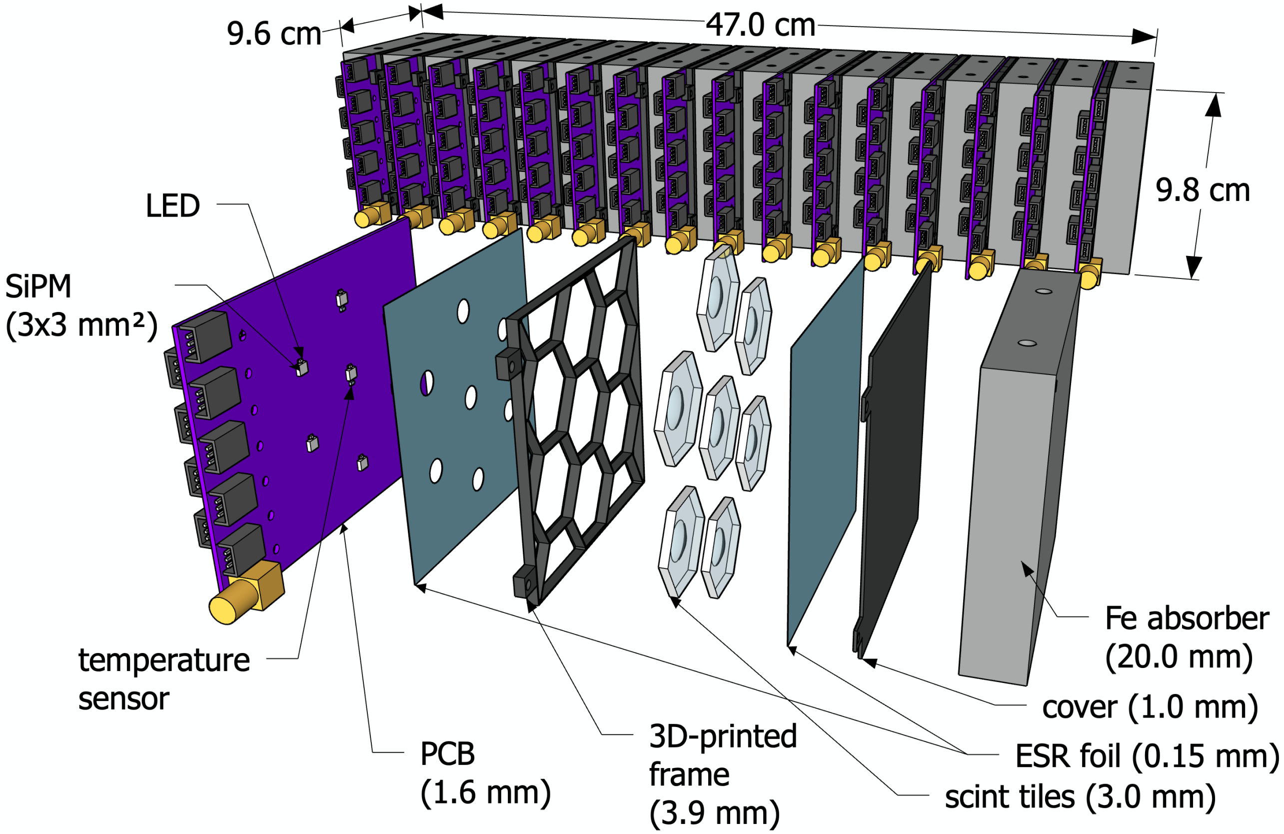

FNAL injection molded tiles

- We will use high-quality scintillator (machined EJ-212 or FNAL injected molded cells). This will improve cell-to-cell uniformity. We will also use 1.3 mm SiPMs

The Next Iteration







- We've learned about the construction methods that we plan to use for for the insert
- Next goal: refine the construction methods that we plan to use in the calorimeter insert

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

- We plan to return to JLab later this year with a larger 128 channel prototype, with a hodoscope attached
- We will perform SiPM irradiation tests at the 88” cyclotron June of this year
- We will test alongside UCLA’s W/SciFi ECAL this year
- 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

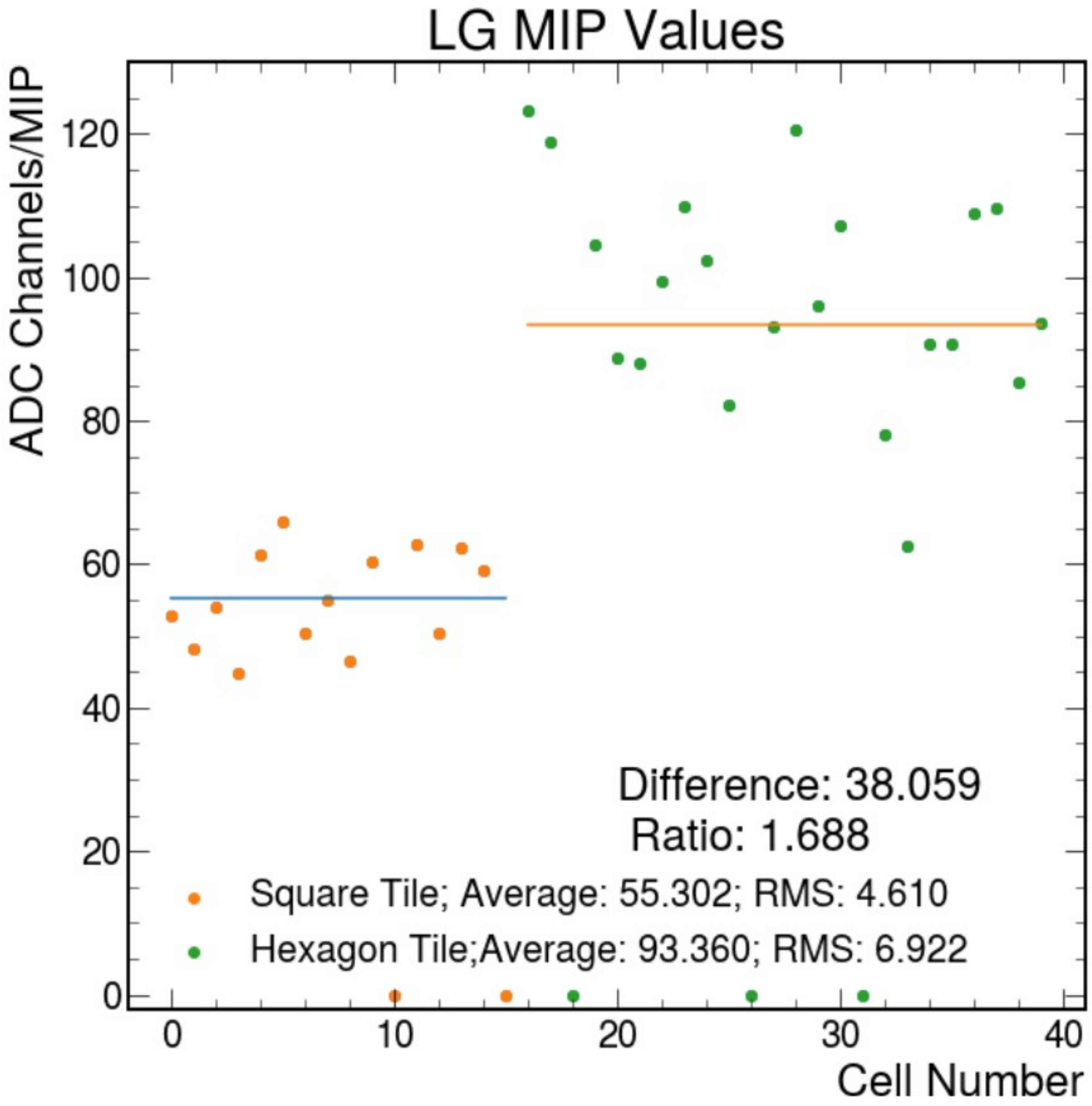
Summary

- 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
- Thank you to Tanja Horn for helping us contact Hall D, and Sasha Somov for technical help and guidance

Backup Slides

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



- 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

Plot from recent UCLA test beam