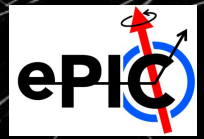
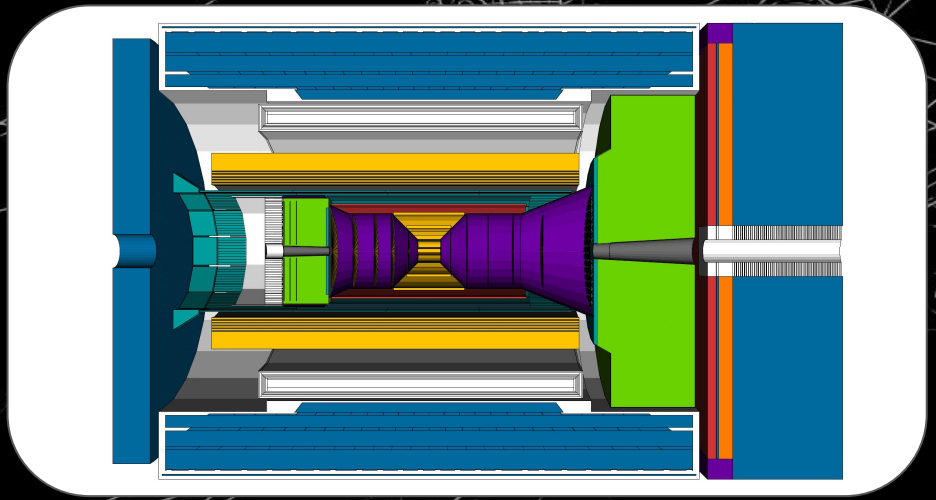
Results of First Test Beam of SiPM-on-Tile Calorimeter Insert

Peter Carney

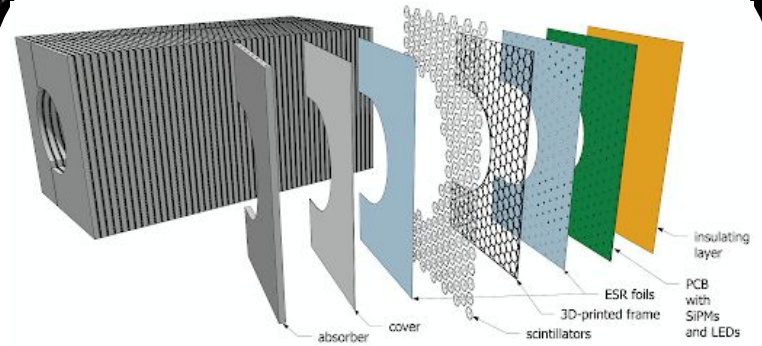


Forward Calorimeter Prototype Design

- Calorimeter insert will be placed near the beampipe: $3.2 < \eta < 4$
- Much higher granularity than rest of Calorimeter



Forward HCal Insert Concept



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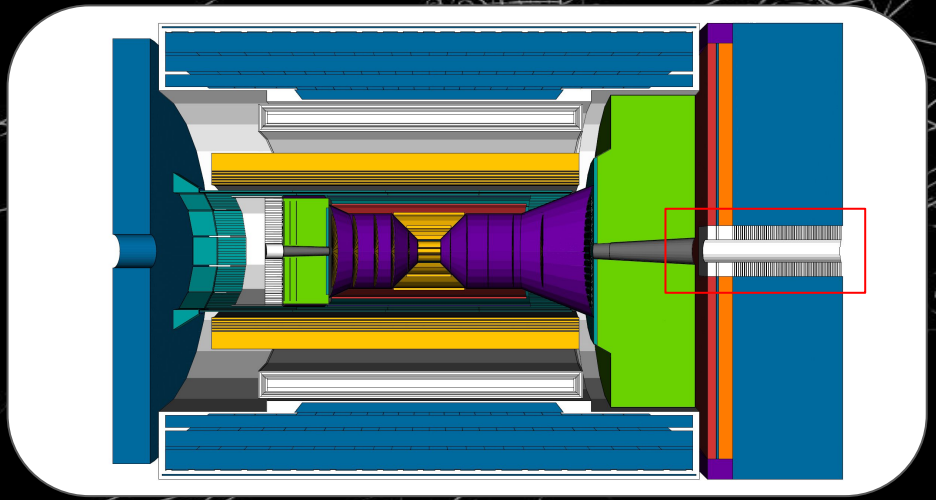

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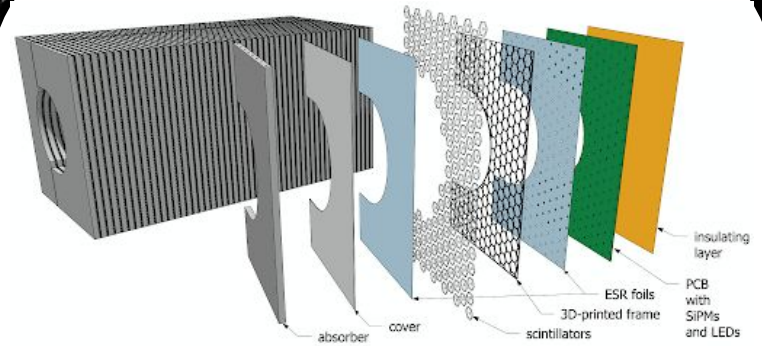
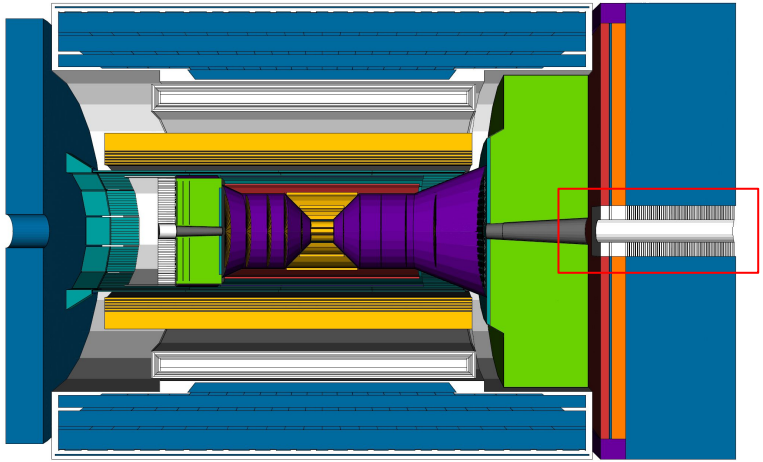
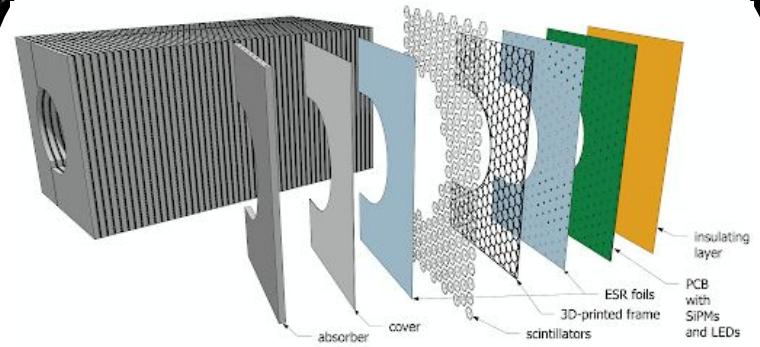


Forward Calorimeter Prototype Design

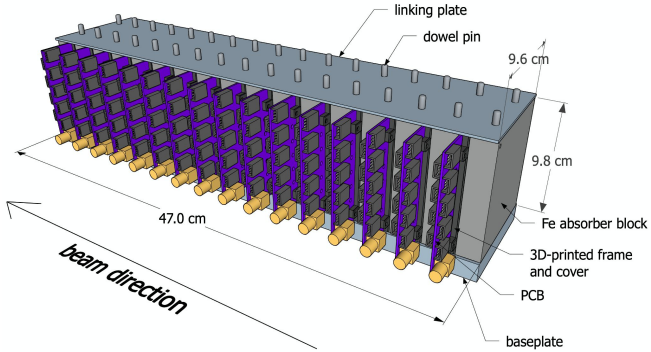
- Calorimeter insert will be placed near the beampipe: $3.2 < \eta < 4$
- Much higher granularity than rest of Calorimeter
- Prototype constructed to resemble a small section of insert.



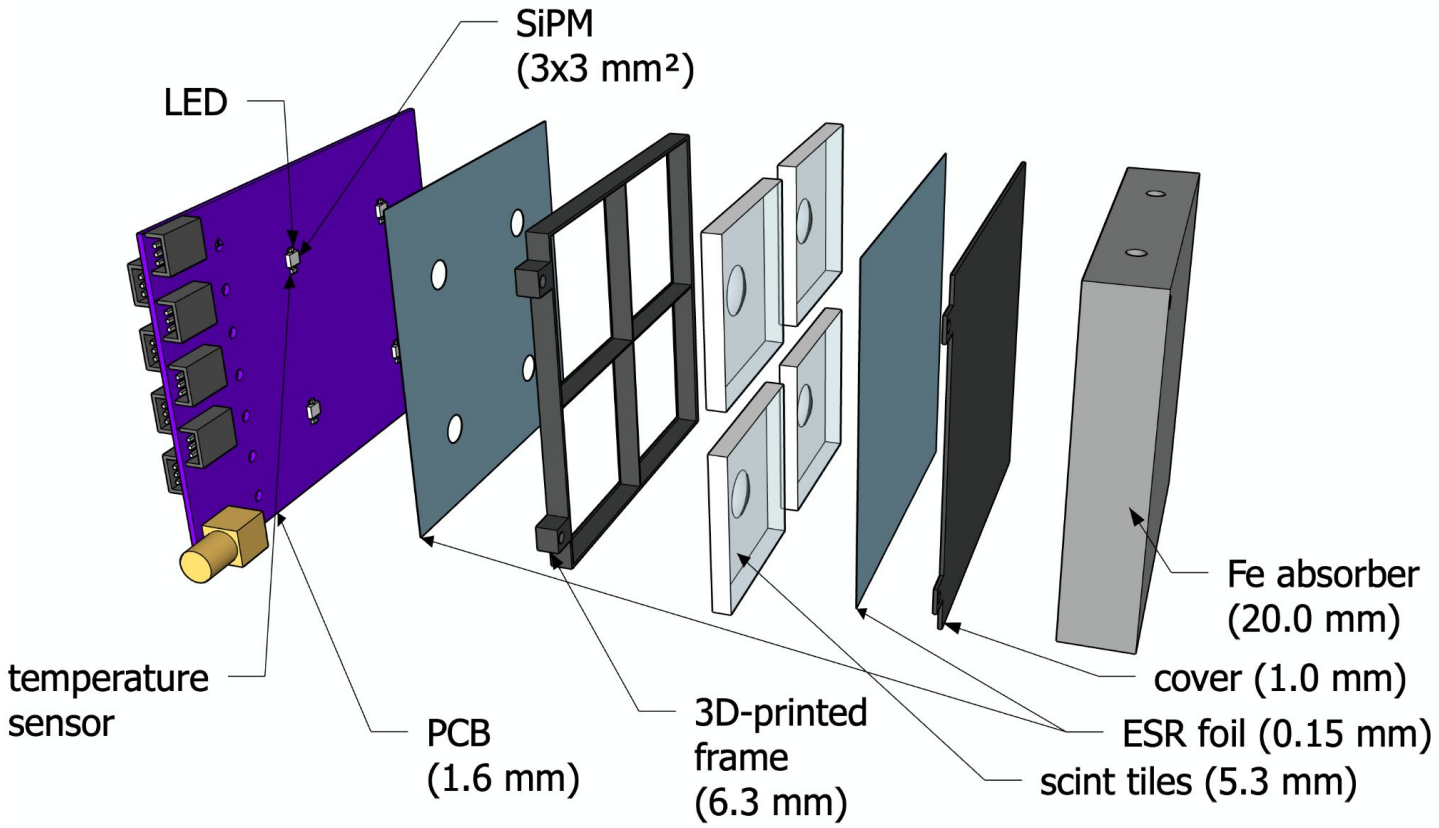
Forward HCal Insert Concept



Prototype Concept

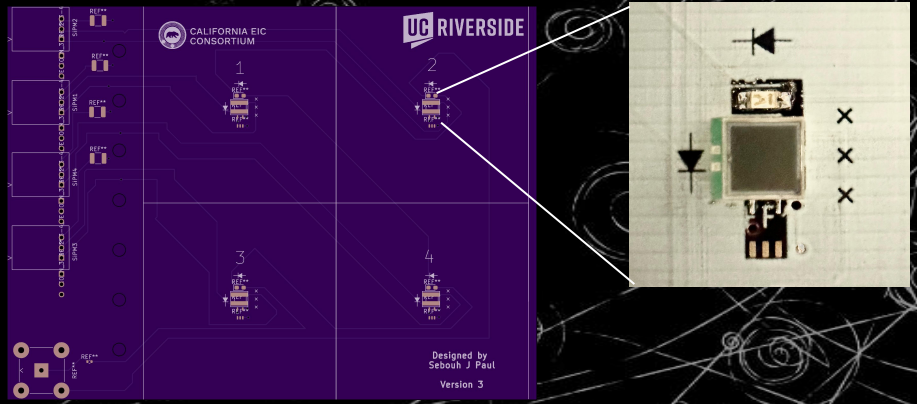


Prototype Layer Design: SiPM-on-Tile

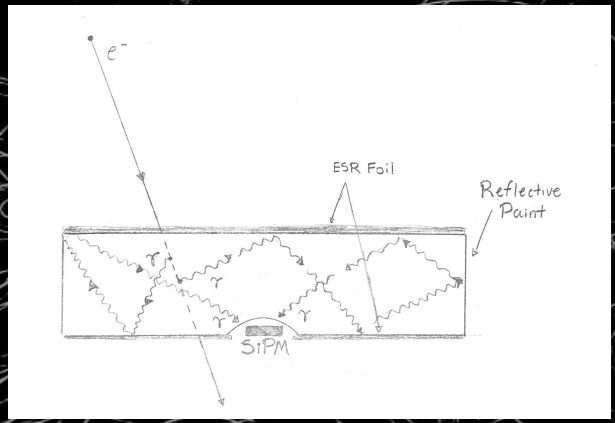


Prototype Layer Design

Printed Circuit Board Base

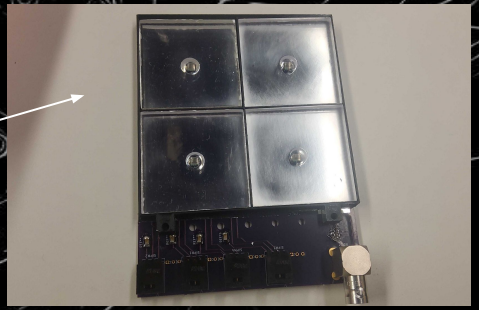


Light Yield Process



Foils + Frames + Scintillating Tiles

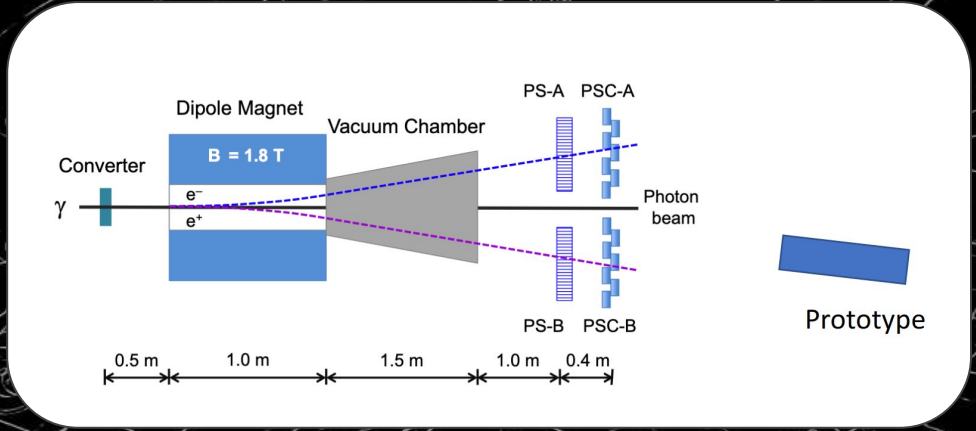
First 4 layers

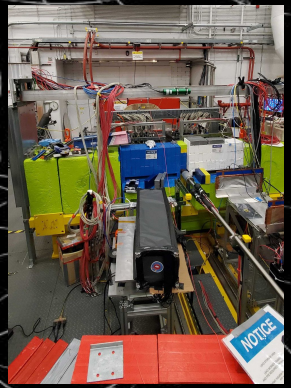


Last 6 layers

Prototype Jefferson Lab Test

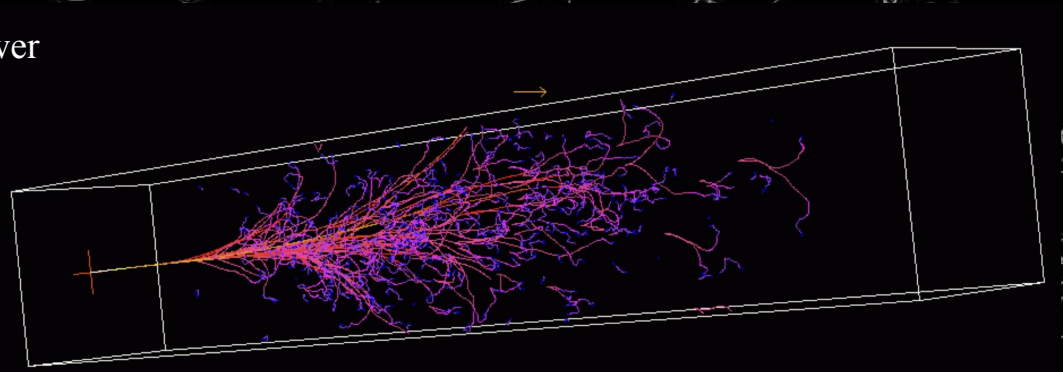
- Prototype consists of 10 layers: 30cm in beam direction.
- 11.7 Effective Radiation Lengths
- Test conducted in Hall D of JLab. January 2023
- Exposed to:
  - ~ 4 GeV positrons
  - ~ 3 kHz bunch rate



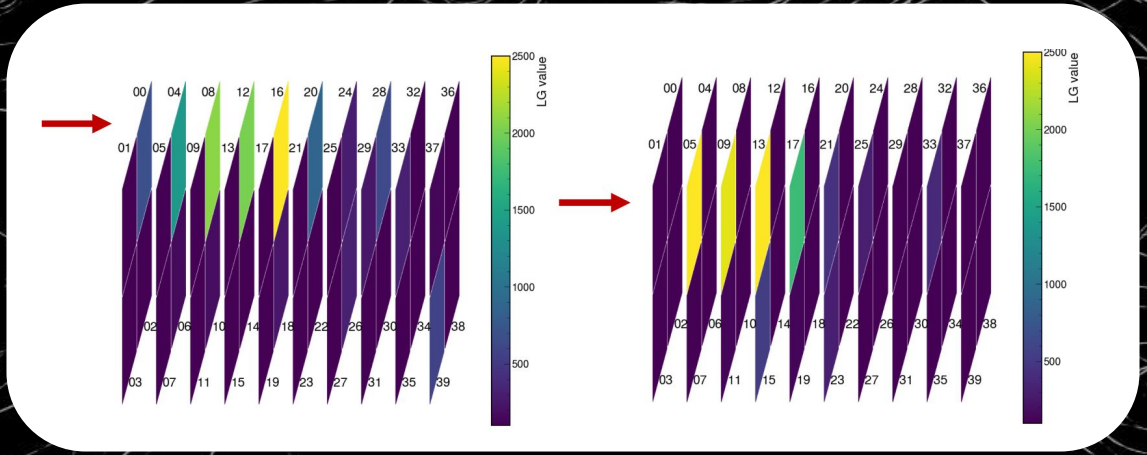


Event Reconstruction

Expected Electron Shower



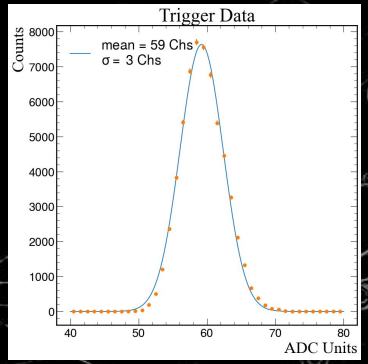
Actual Event Reconstruction



Data Analysis Procedure

Data Analysis Procedure

Take random trigger data to determine noise level → Pedestal



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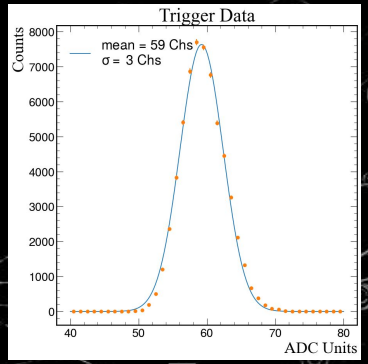
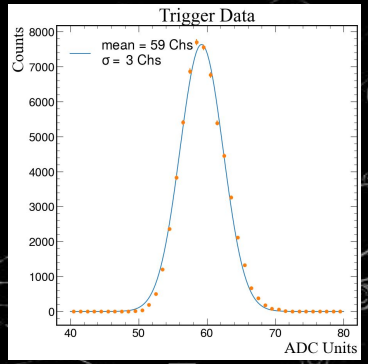


Apply a Pedestal cut for all data going forward

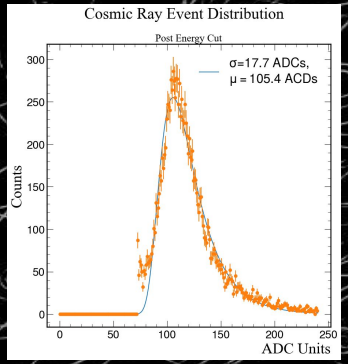
Data Analysis Procedure

Take random trigger data to determine noise level → Pedestal



Apply a Pedestal cut for all data going forward

Take cosmic ray data to determine how many ADC units corresponds to a MIP



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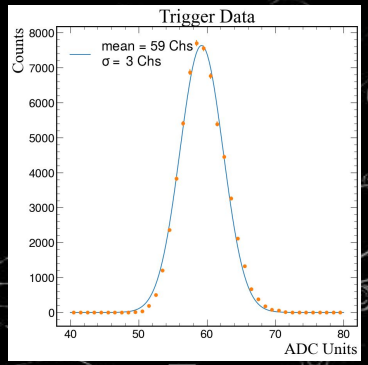

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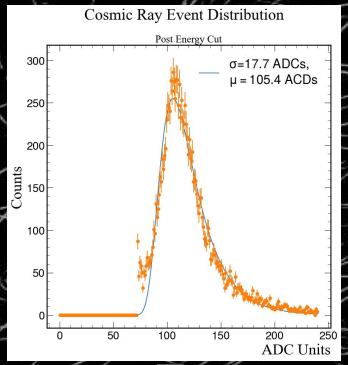

Convert data from ADC Units → MIPs

Data Analysis Procedure

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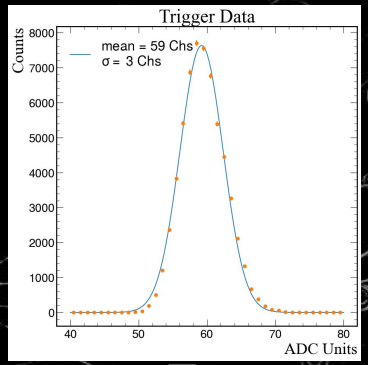

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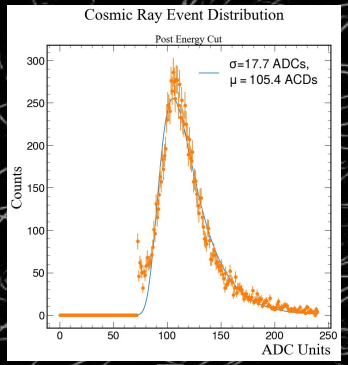

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Collect JLab Beam Data in the form of events

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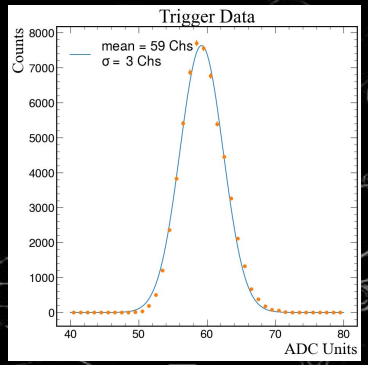

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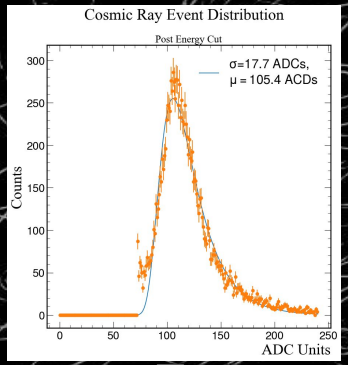


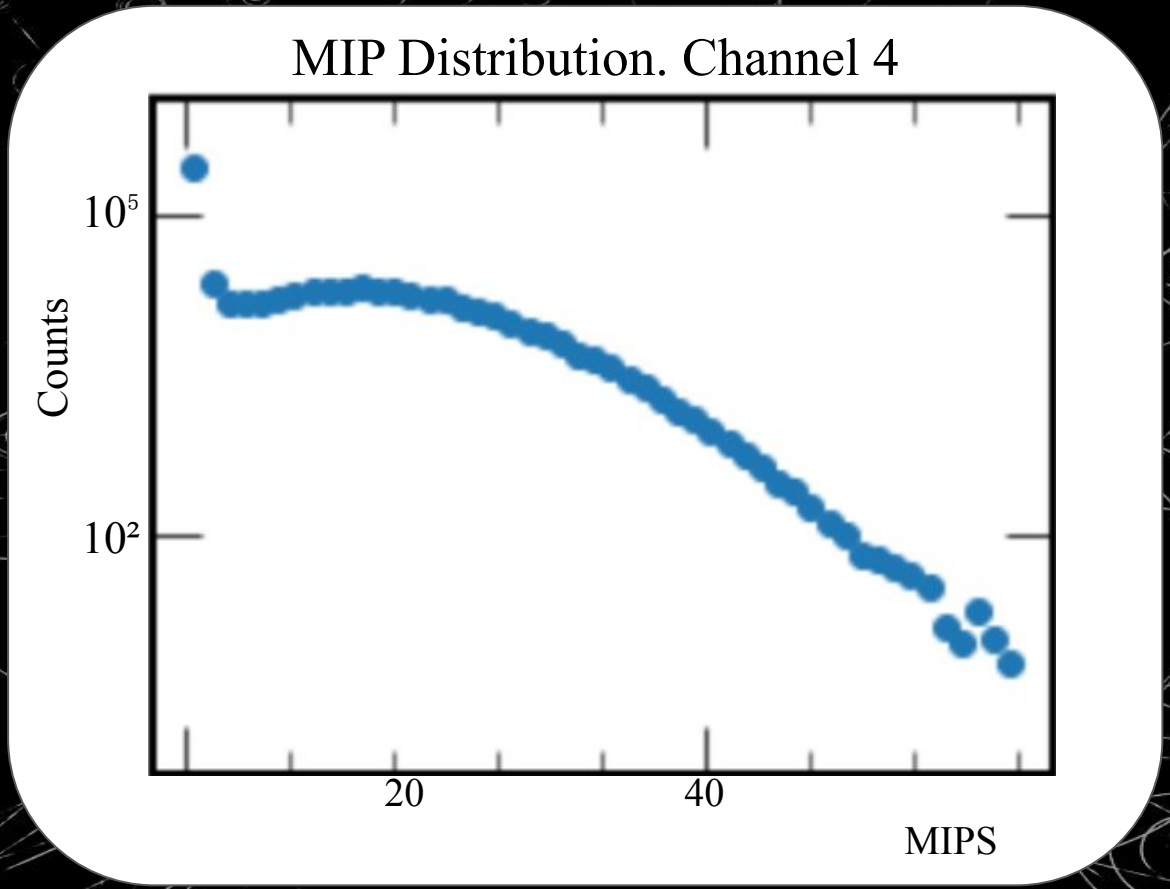
Convert data from ADC Units → MIPs

Collect JLab Beam Data in the form of events

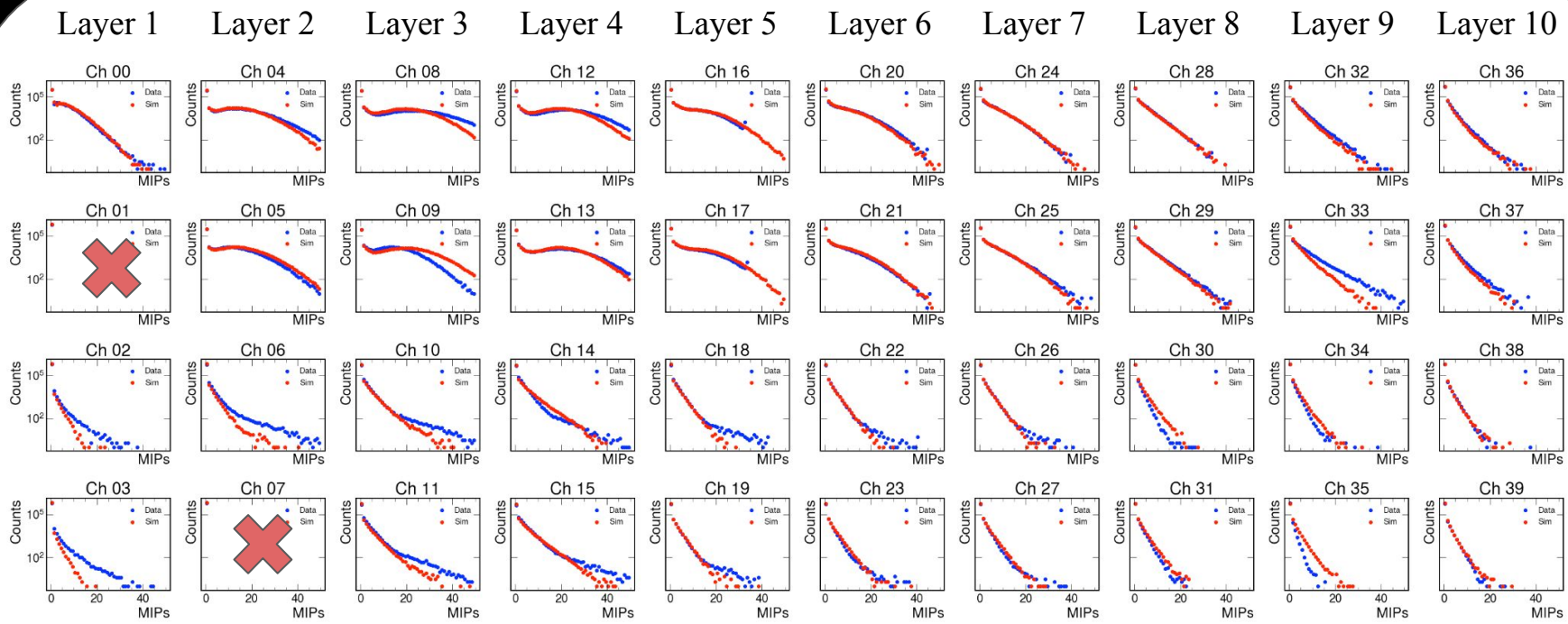
Add up all of the energy deposits for each layer

Add up all energy deposits to find total energy

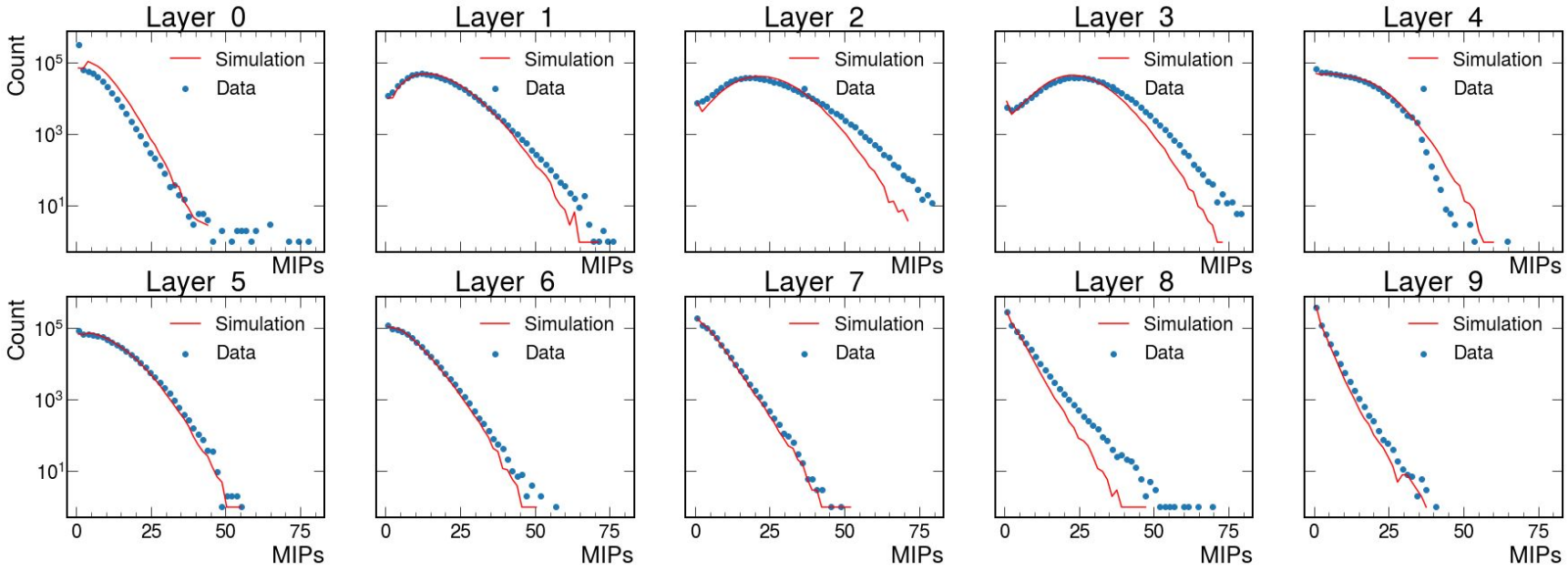
Energy Distribution for a Single Channel



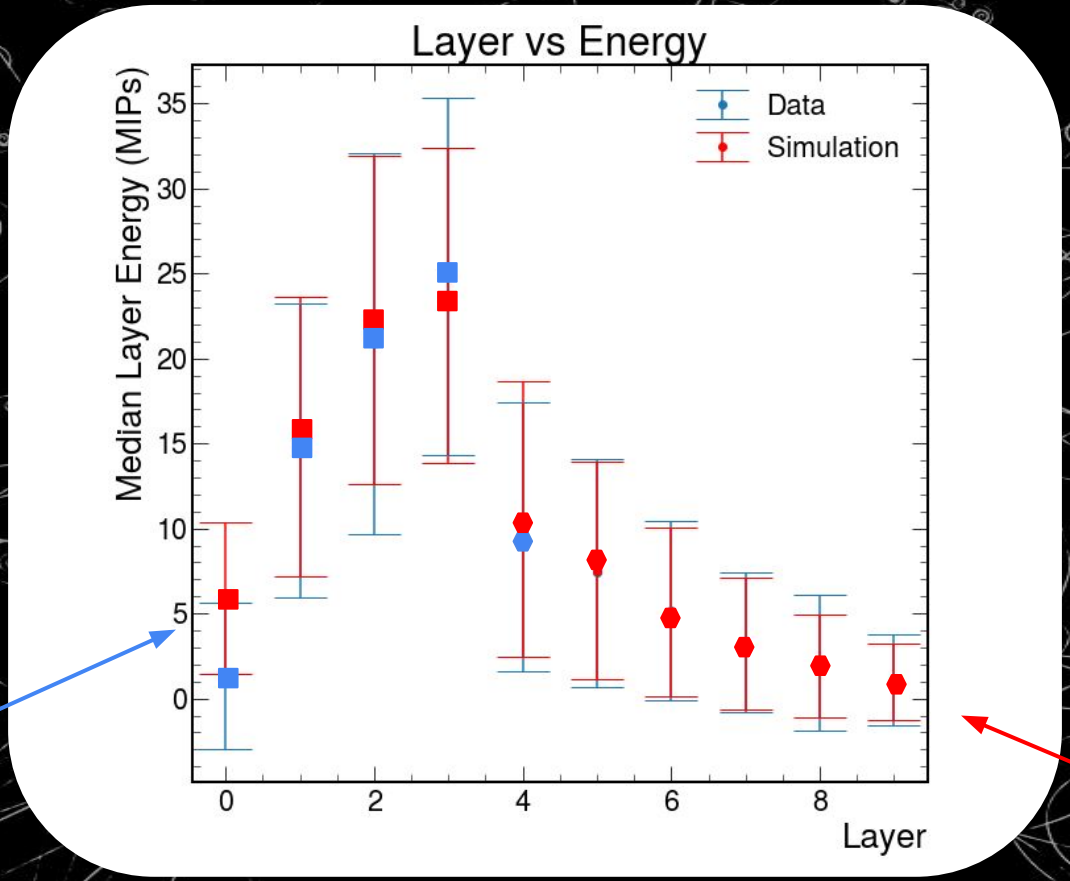
Energy Distribution for all Channels



Energy Distribution for Each Layer



Average Energy Deposited in Each Layer

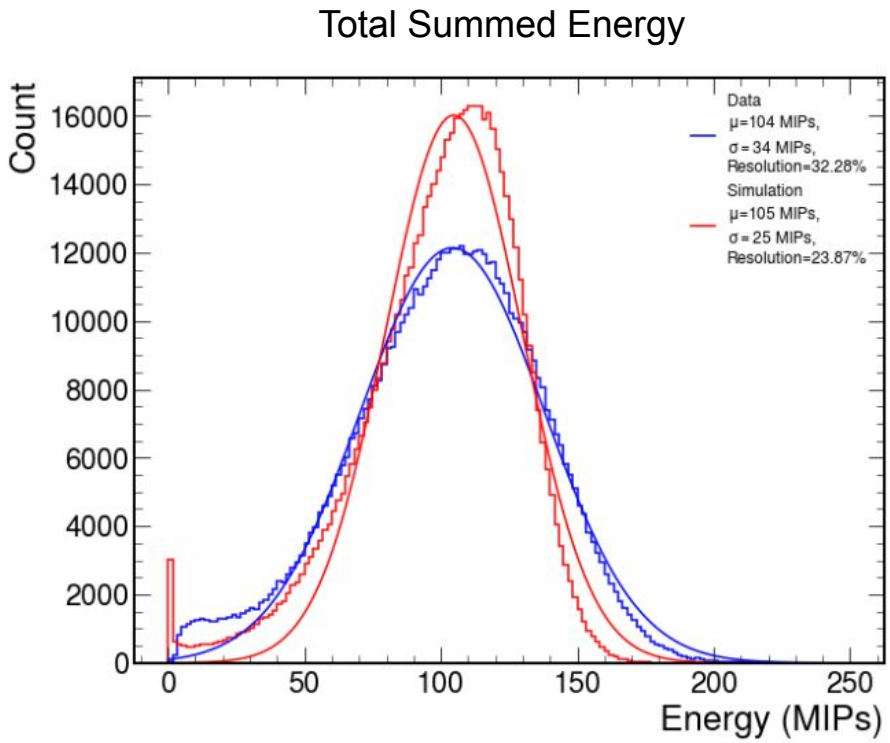


First 4 Layers used Square Scintillating Tiles

Last 6 Layers used Hexagonal Scintillating Tiles

*These are standard deviations. Not error bars

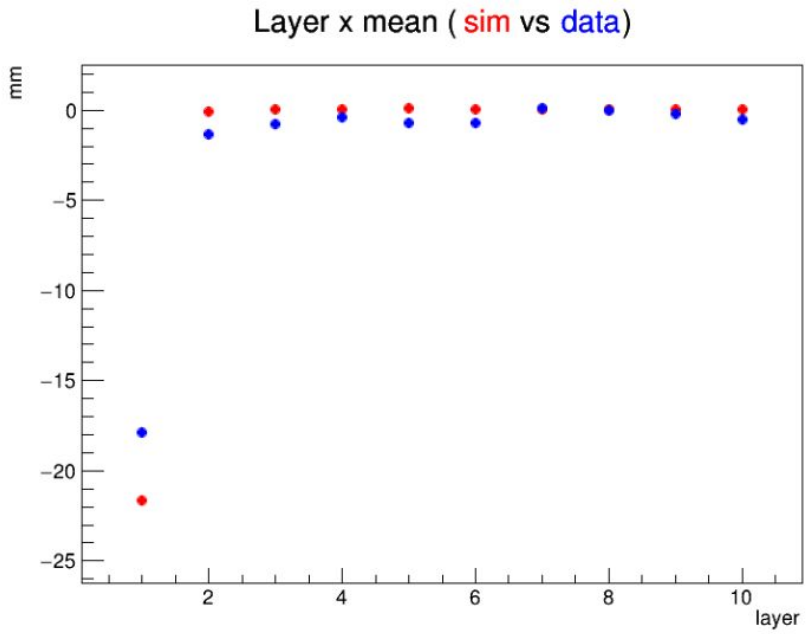
The Total Energy

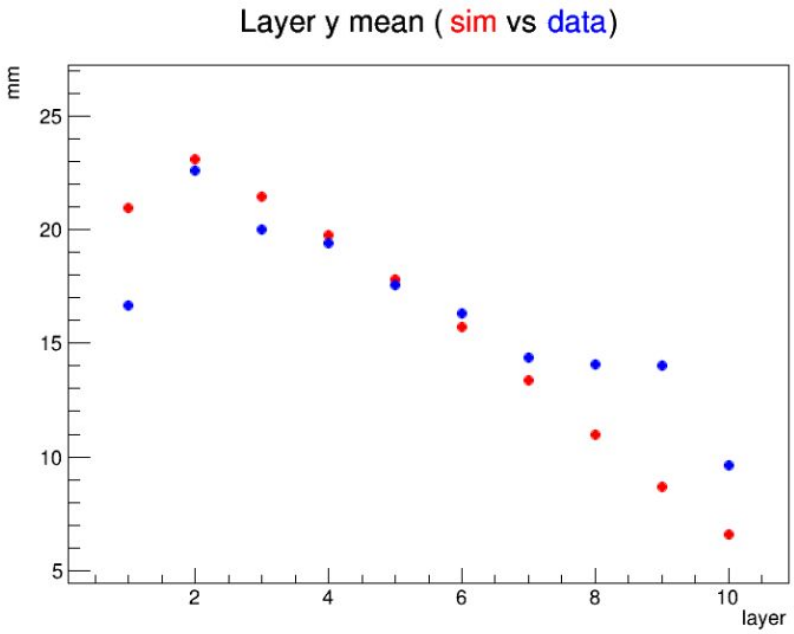


Reasons for uncertainty:

- Large dead space in hexagonal cells
- MIP values may have needed more calibration
- Scintillating Tiles are recycled → optical loss
- Prototype aligned slightly below positron beam → some events don't traverse full prototype

Average x and y position of events

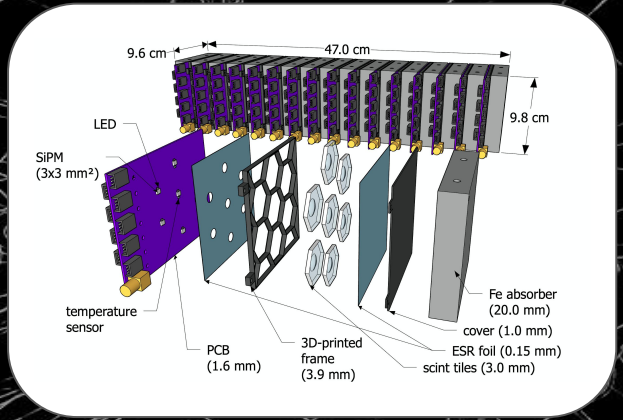


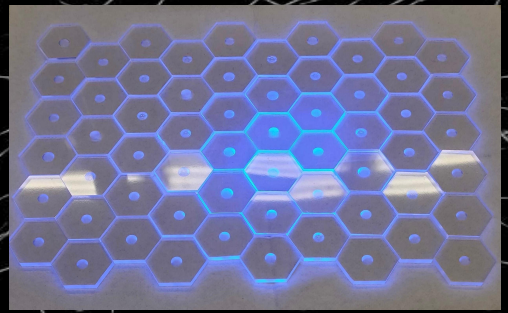


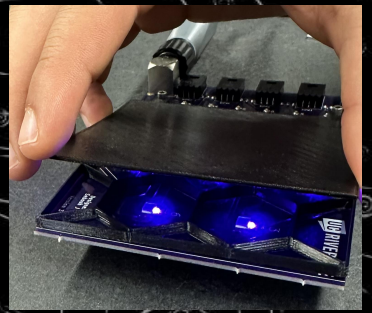
We're Not Done!

Upgrades for next beam test

- 10 layers → 16 layers
- 4 cell square tiles → 7 cell Hexagonal tiles
- Recycled scintillating tiles → Fermilab tiles
- UV Light SiPM calibration

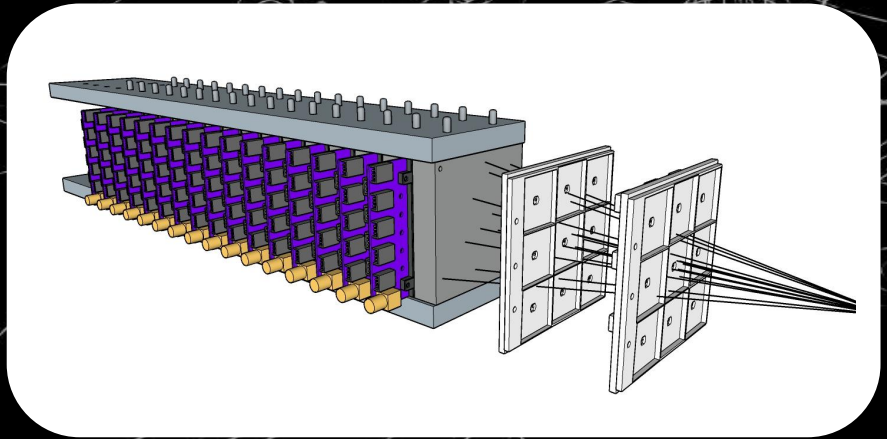






Addition of the Hodoscope

- Tracking system implemented before prototype → Hodoscope
- Localizes beam / determines trajectory before it enters calorimeter



Where do we go from here?

- Finish prototype construction
  - Test/Calibrate SiPM
  - Refine Scintillator polishing process

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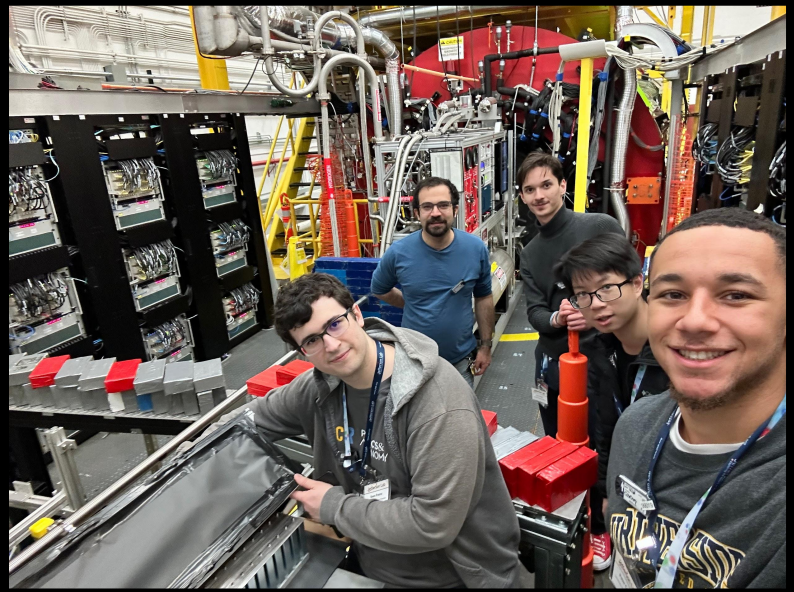
  - Test/Calibrate SiPM
  - Refine Scintillator polishing process
- Finish Hodoscope
  - Add extra layer
  - Determine timing resolution
- Determine testing site/conditions
  - JLab or Fermilab early 2024
- Implement Simulation
  - Simulate expected data using pre-known factors
  - Use simulation to optimize construction / train data analysis

Thank you / Dziękuję !



Sources

- Studies of time resolution, light yield, and crosstalk using SiPM-on-tile calorimetry for the future Electron-Ion Collider. Miguel Arratia et. al. https://iopscience.iop.org/article/10.1088/1748-0221/18/05/P05045
- A high-granularity calorimeter insert based on SiPM-on-tile technology at the future Electron-Ion Collider. Miguel Arratia et. al. https://www.sciencedirect.com/science/article/abs/pii/S0168900222011585
- New paradigms for the CMS Phase-2 Upgrades https://cms.cern/news/new-paradigms-cms-phase-2-upgrades
- Detectors. Summer Student Lecture Programme 2023.Werner Riegler.