ePIC LFHCal R&D Efforts at Yale

2024 ePIC Collaboration Meeting — Argonne National Laboratory

Fernando Antonio Flor
Yale University

January 12th, 2024

with

Jack Roche, Joshua Kerner, Mary Zhang,
Ananya Rai, Iris Ponce Pinto,
Friederike Bock, Prakhar Garg and Helen Caines

NSF
U.S. DEPARTMENT OF ENERGY | Office of Science
Wright Laboratory

Longitudinal Forward Hadronic Calorimeter

- When probing the internal structure of proton/ion target, copious hadrons are generated in process
  - Majority are produced in the same direction as the hadron beam
  - Jets of particles expected to reach forward region of the detector
  - Poses challenge at forward rapidity $(\eta > 3)$
    - Worsened tracking momentum and angular resolution
- Position of Longitudinal Forward Hadronic Calorimeter (LFHCal) remedies said detector acceptance losses
  - Requires robust R&D initiative for SiPM and Scintillator characterization
    - LFHCal design calls for 62,424 read-out channels
  - LFHCal Project led by Friederike Bock (ORNL/Yale)
- Yale helping to meet demand for humanpower starting Summer '23
  - Plenty of room for additional involvement from more institutes

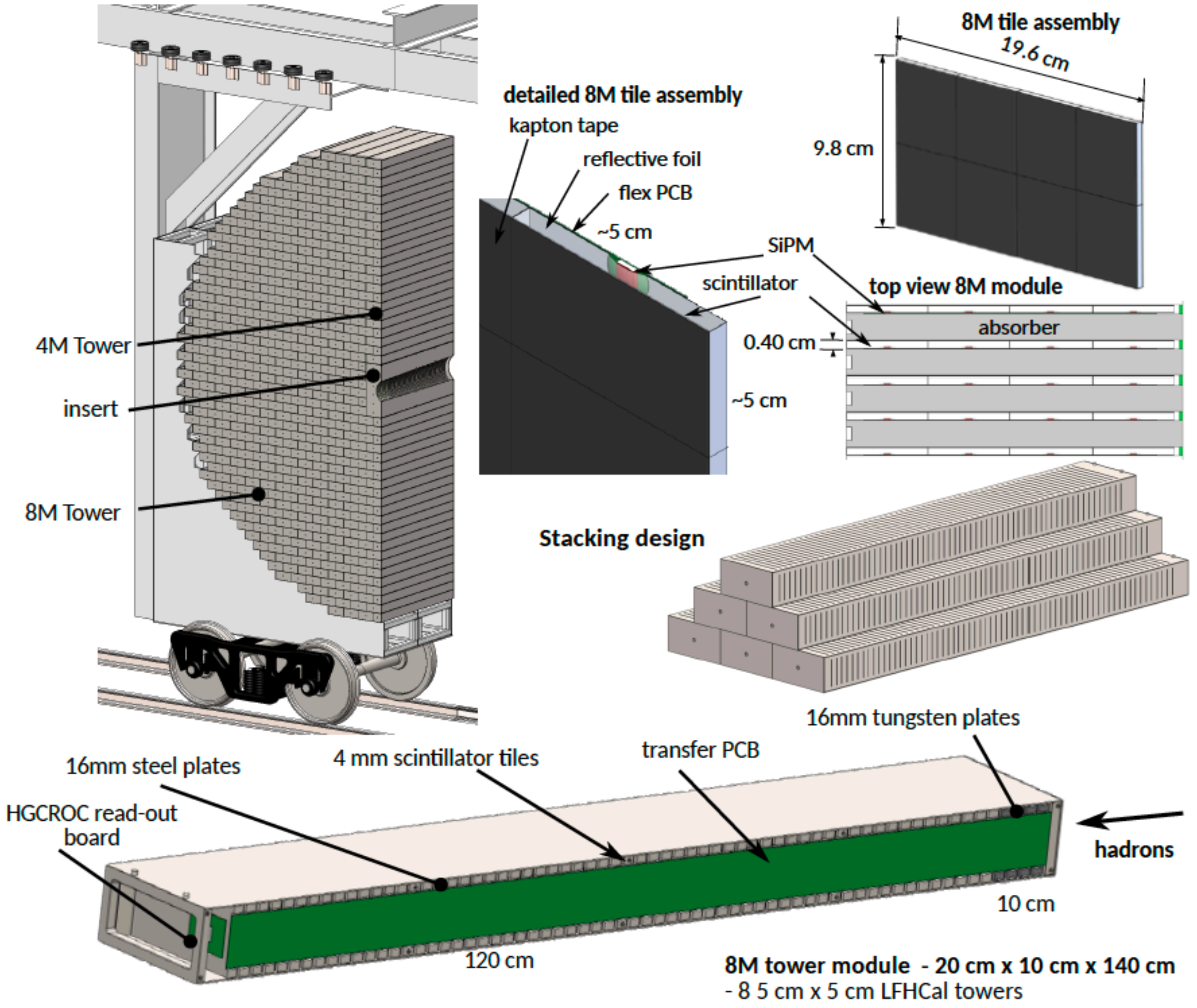


Figure 1: Renderings of the forward calorimeter assembly (top left), tile assembly of 8 scintillator tiles of the LFHCal with the SiPMs sitting in a dimple on each tile, detailed stacking example (middle right) and 8-tower module design (bottom).

Bock, et al. *eRD107* (2023)

Overview: LFHCal R&D Efforts at Yale

Summer 2023 **(Josh Kerner, Mary Zhang, Iris Ponce Pinto)**

- Initial set-up for LFHCal R&D Site at Yale
  - Dark box, DAQ, SiPM & Tile Arrival from ORNL
  - SiPM QA: IV Characterization, Staircase Plot Acquisition, ADC to PE Conversion with LED Pulser
  - Tile QA: Cosmic Coincidence (2 and 3 Tiles)
    - Shown at Quark Matter 2023

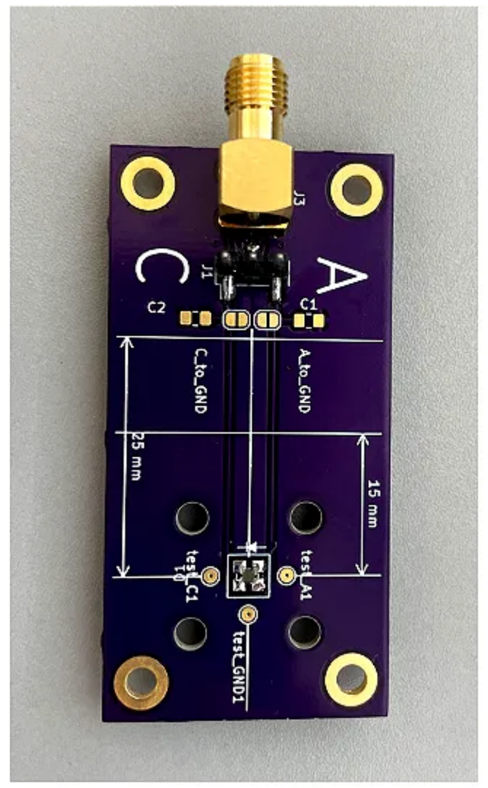
Fall 2023 **(Iris Ponce Pinto, Ananya Rai, Jack Roche)**

- October Test Beam of LFHCal 8M Modules at CERN
  - Electron and pion beams
  - Measuring shower profiles with different absorbers
- Tile QA using Sr-90 Source
  - Hardware designs: Source holder, SiPM/Tile racks and manual translation grid
  - Preliminary tile scans via 2-tile coincidence across grid

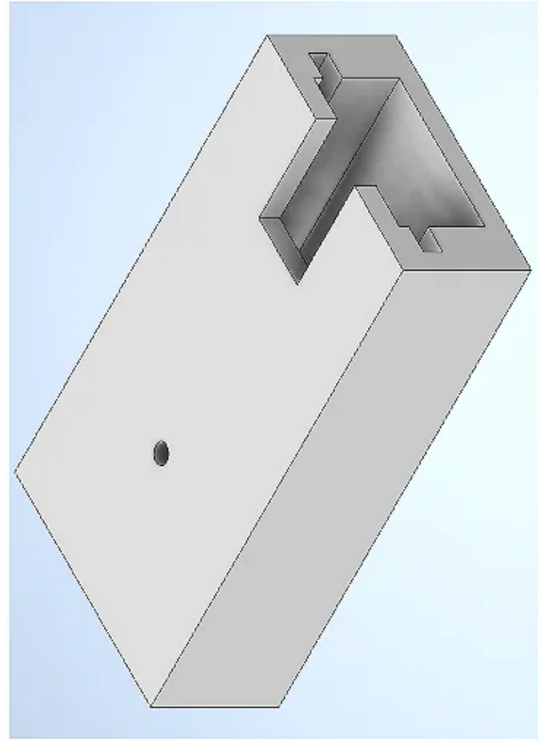
Initial Set Up at Yale

- Design and assembly of light-tight dark box
  - Featuring throughput panel for SMA, SHV, pin headers and banana connectors
  - Door included for ease of access
  - Serves as Faraday cage suitable for SiPM and Tile characterization
- LED Pulser holder design with SiPM PCB slot
  - Utilized for single photon efficiency determination
- First iteration of SiPM/Tile holder and rack stack
  - Utilized for coincidence tests of multiple tiles with variable distances between each stack

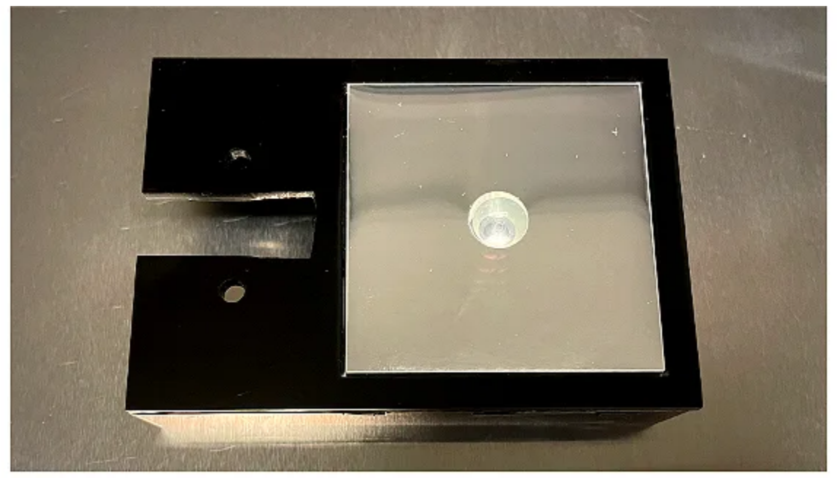
(a) Light-tight Faraday box with connector panel



(b) SiPM on a PCB board

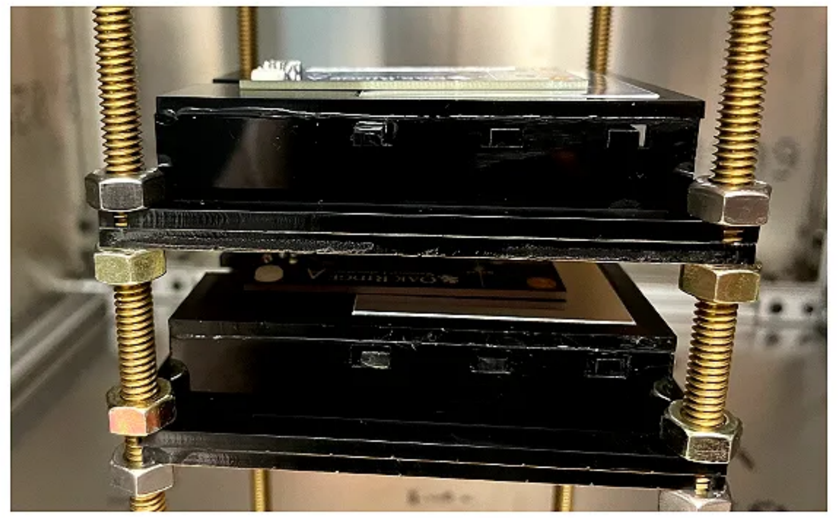


(c) SiPM Holder with hole to shine 400 nm LED photons



(d) Tile-SiPM holder with scintillator tile

(e) Tile-SiPM holder with SiPM board

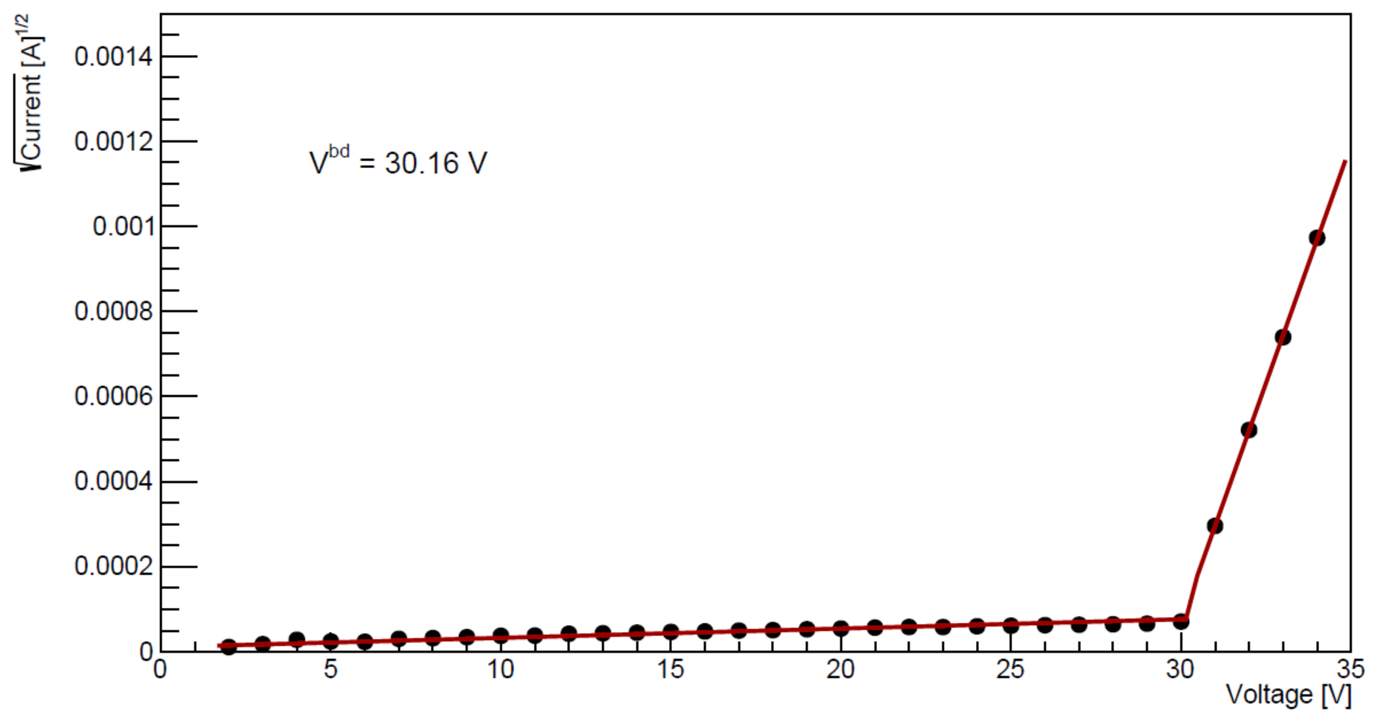


(f) Two Tile-SiPM holders on shelf

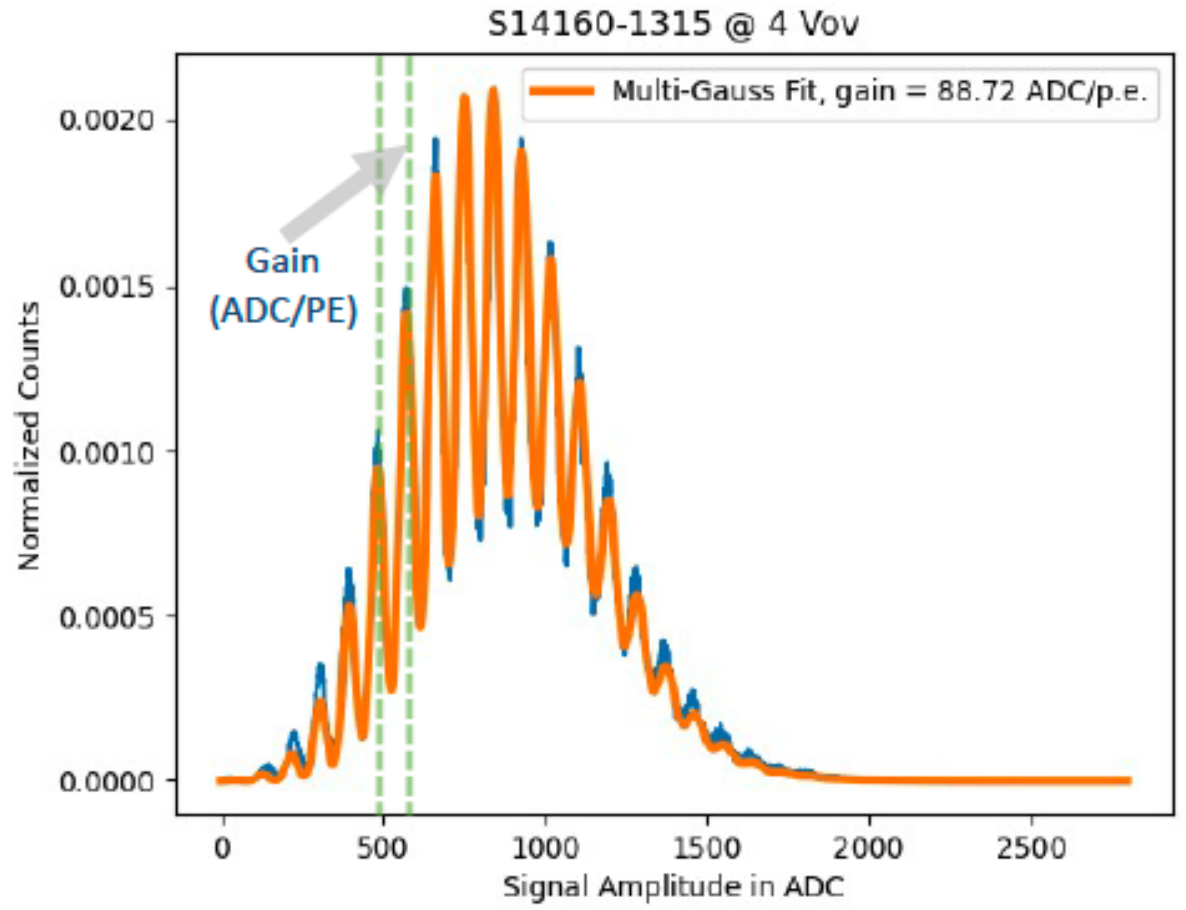
Bock, et al. *eRD107* (2023)

Initial SiPM Characterization

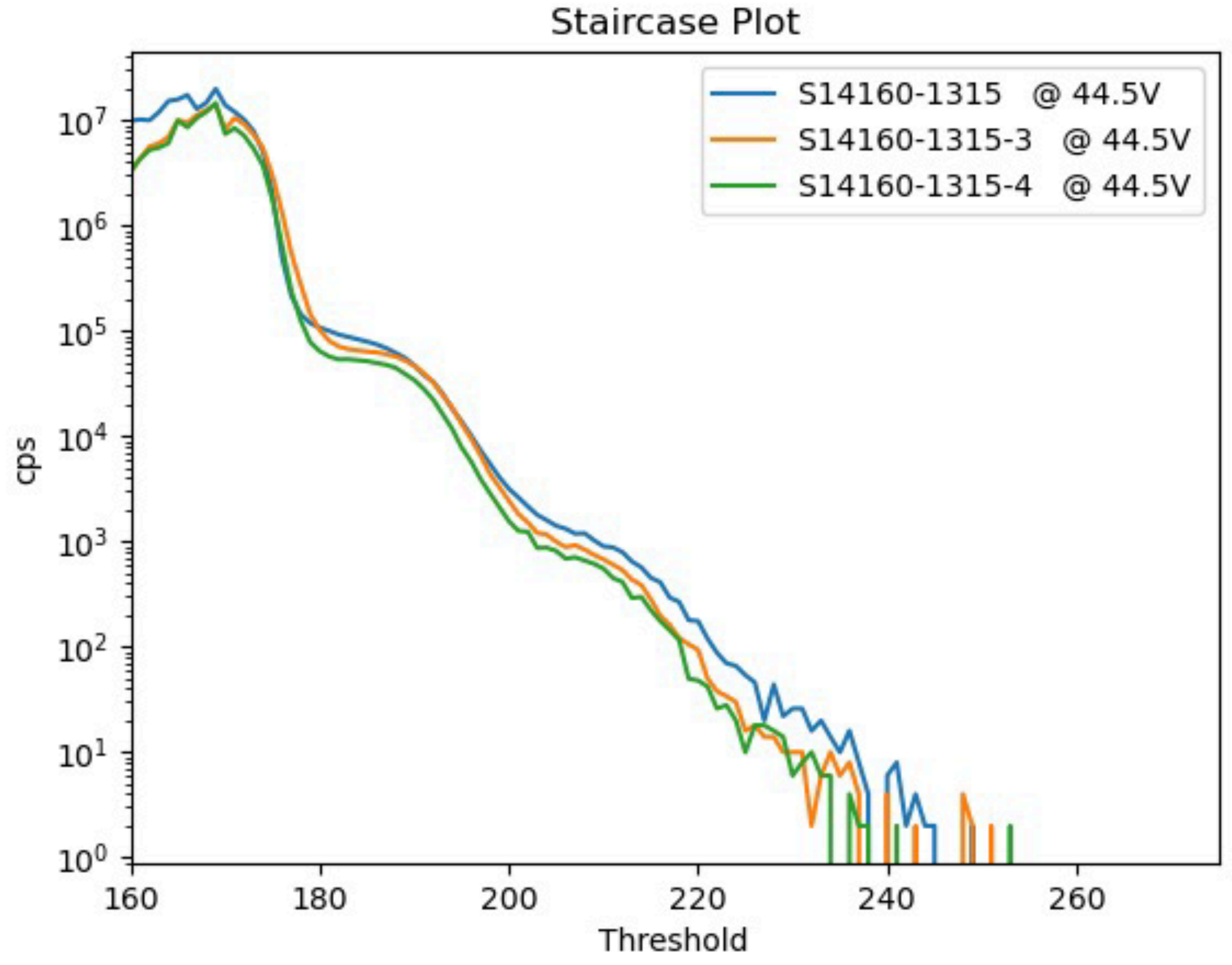
- SiPM Breakdown Voltage determination



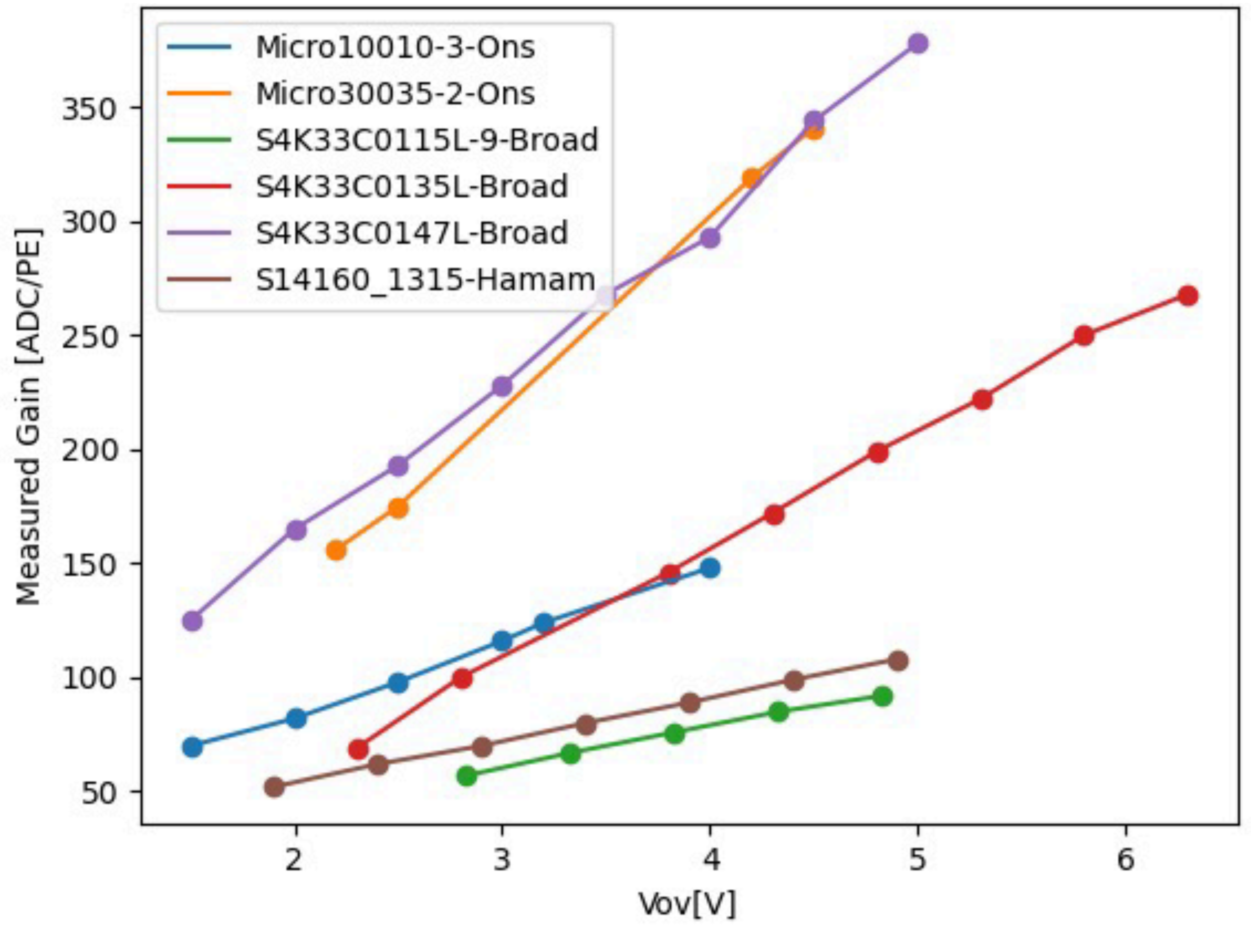
- Single photon spectrum for ADC to photoelectron conversion



- Produced staircase plots to Established thresholds to account for noise from dark current

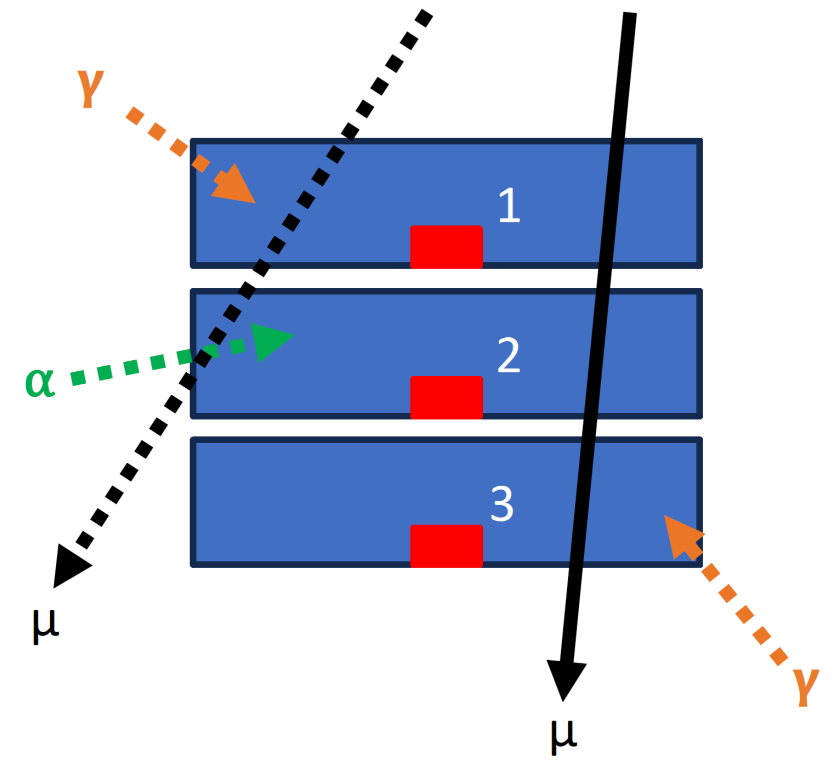


- Comparing gains as a function of over-voltage for various SiPM models

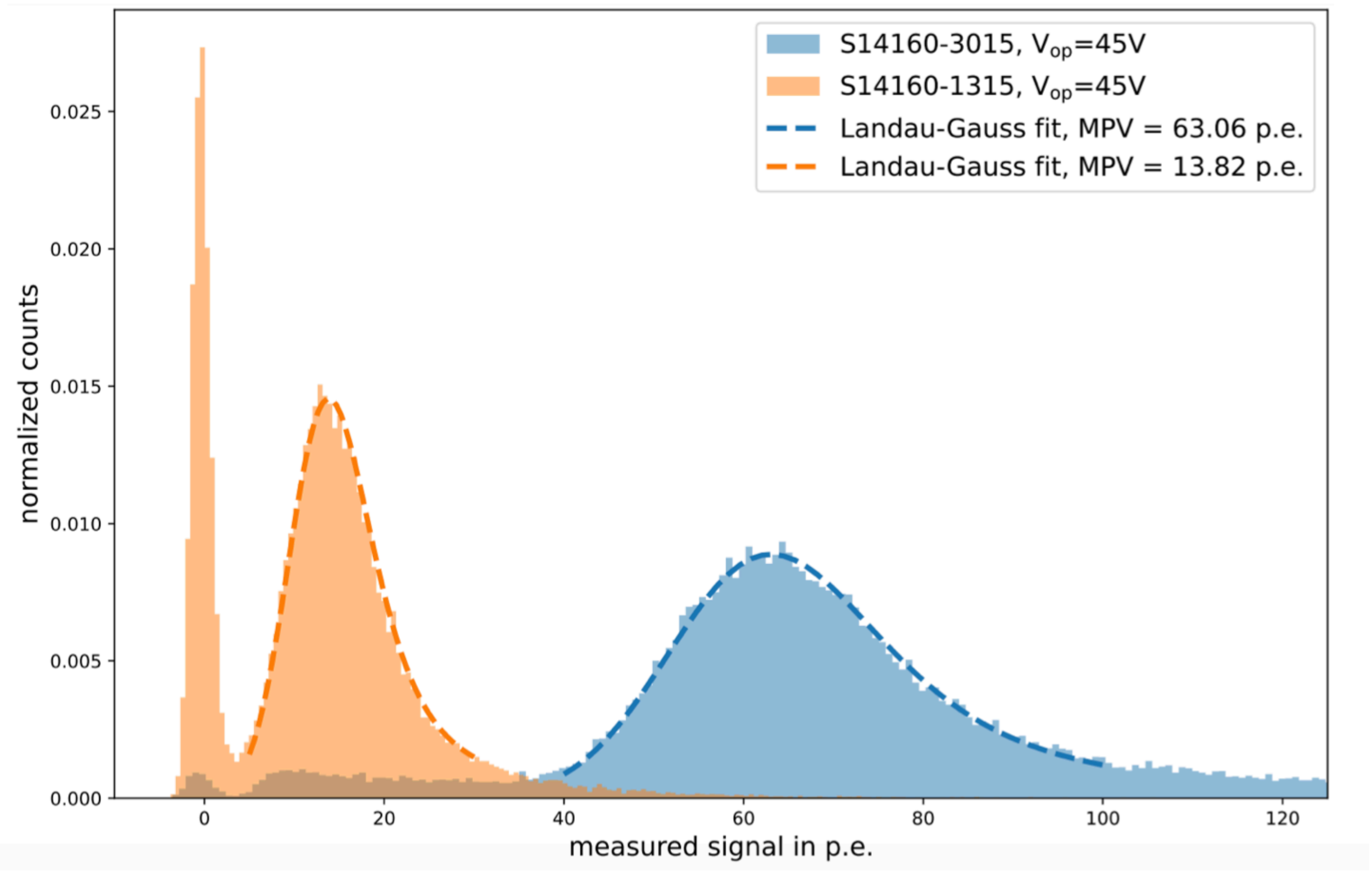


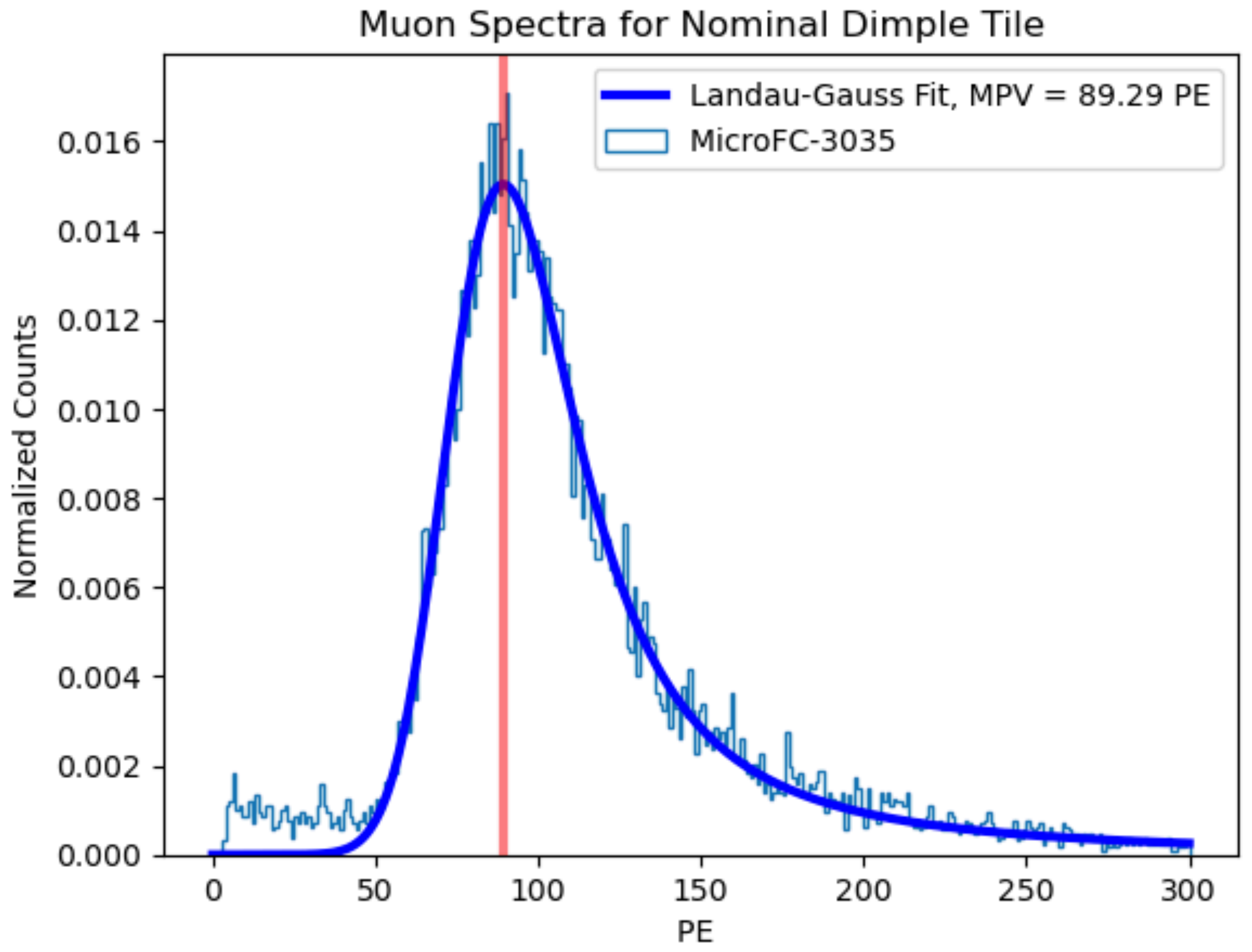
I. Ponce Pinto, M. Zhang, J. Kerner (QM23)

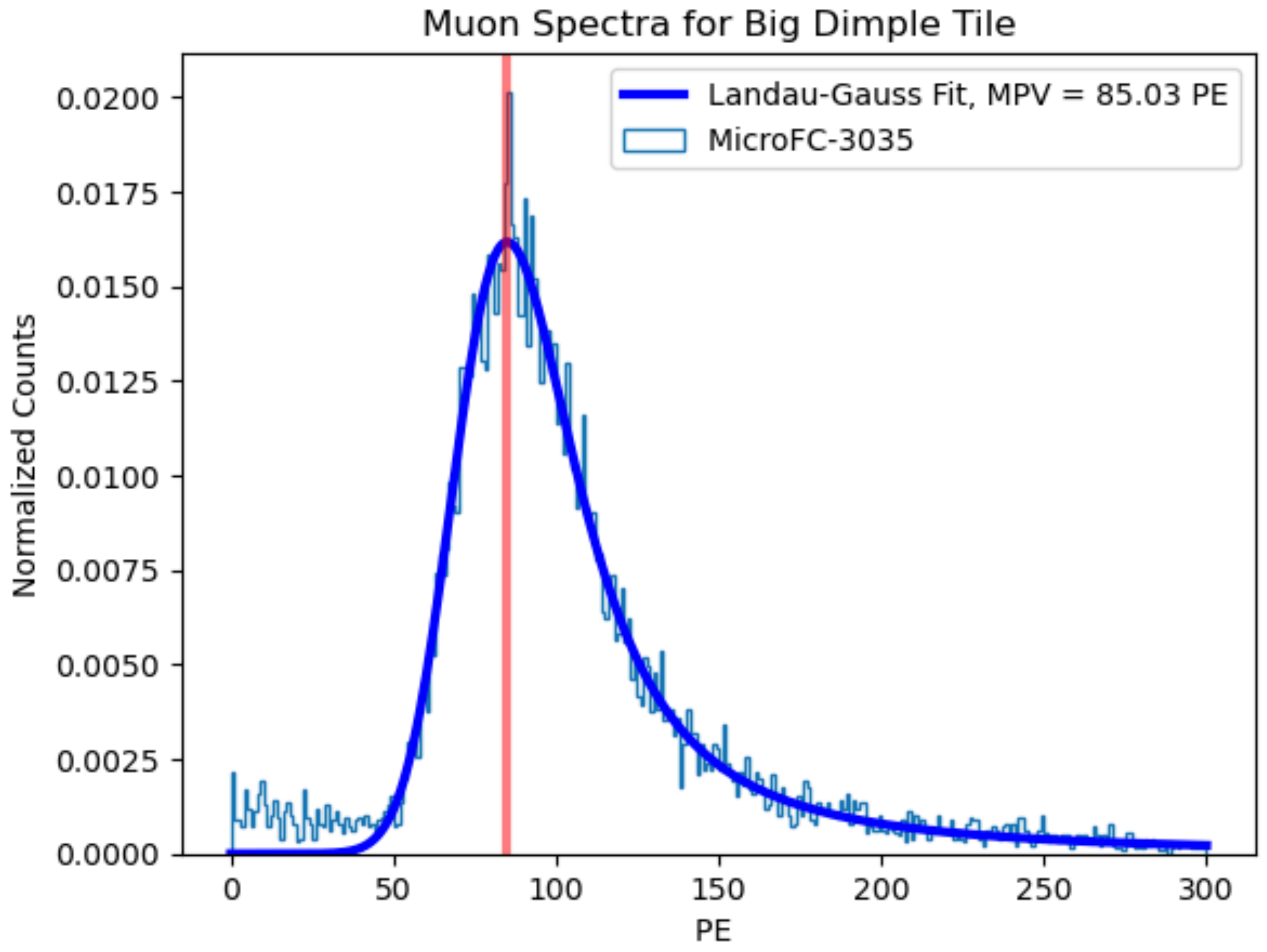
Initial Tile Characterization



- 3-Tile Cosmic Coincidence runs were performed in order to test the light yield for each tile
  - Measured signals were then fit with Landau+Gauss to determine MPV
- Performed comparison of muon spectra acquired from tiles of different dimple sizes
  - In order to account for different geometries of the actual SiPMs





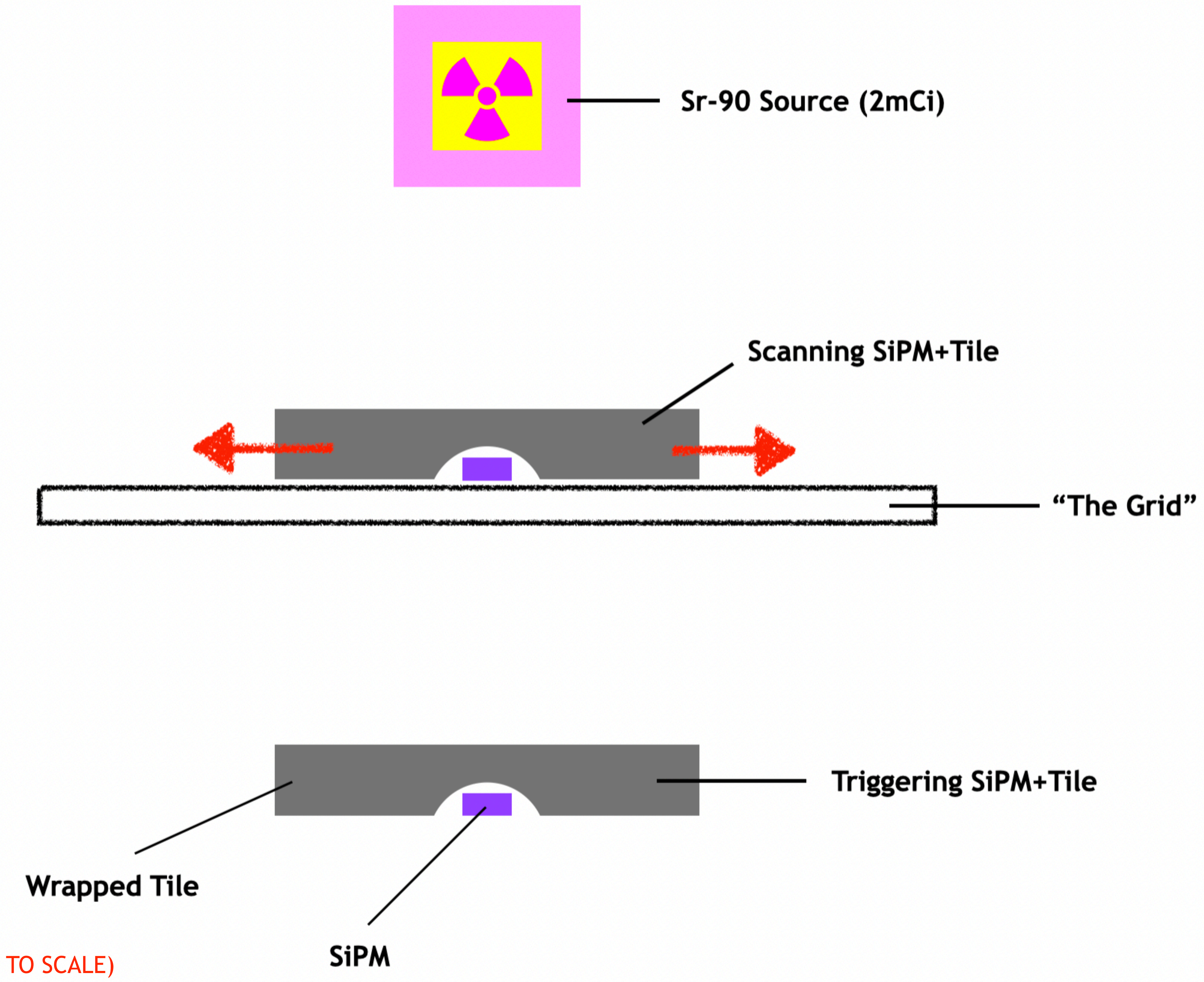


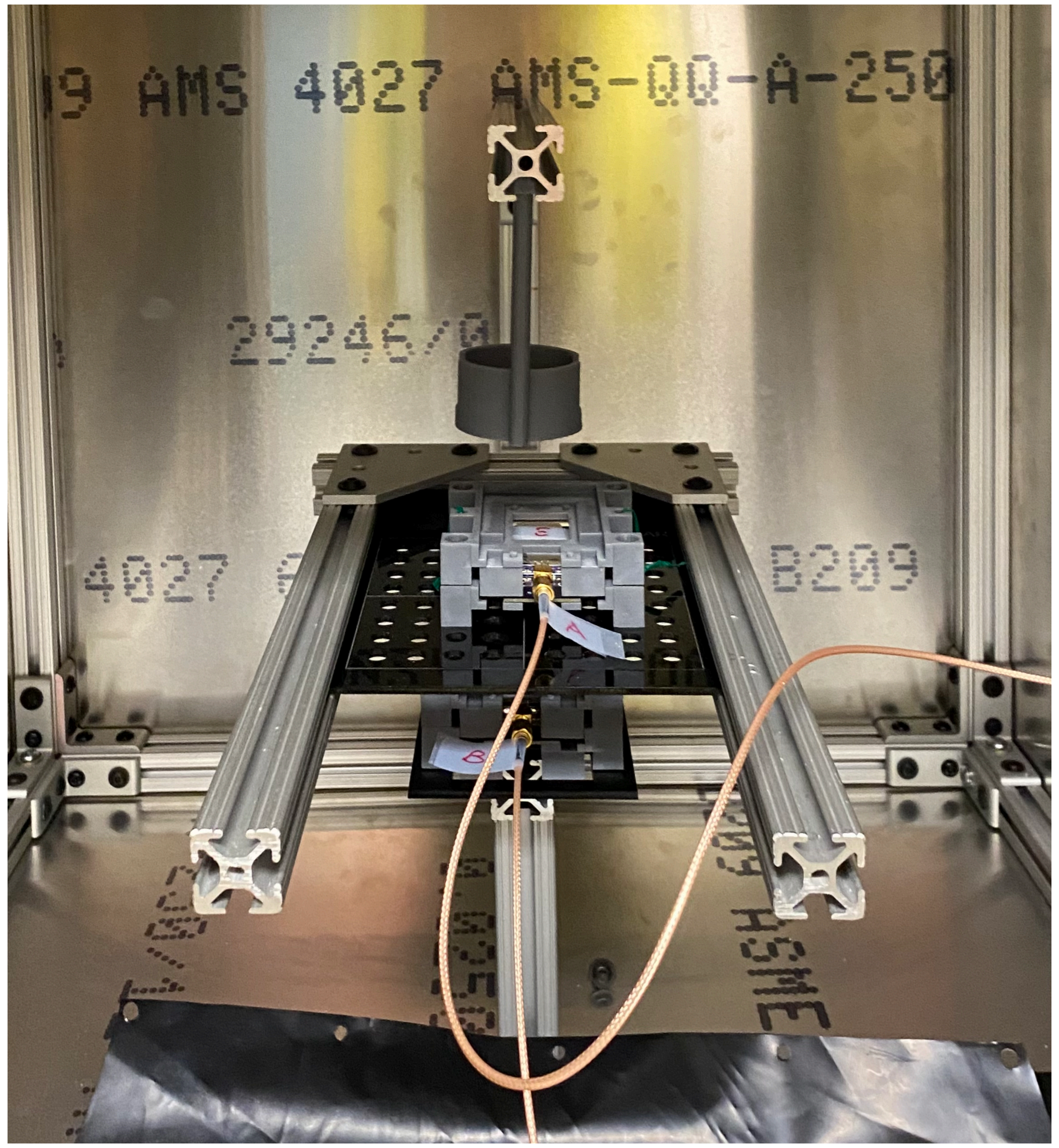
- 1.3 x 1.3 mm ≈ 12 - 14 P.E. for machined tiles and 3 x 3 mm ≈ 60 - 76 P.E. for machined tiles
- Evaluation of machining effects underway as well as different material (EJ-200, BC-408 and Fermilab injection mold)

I. Ponce Pinto, M. Zhang, J. Kerner (QM23)

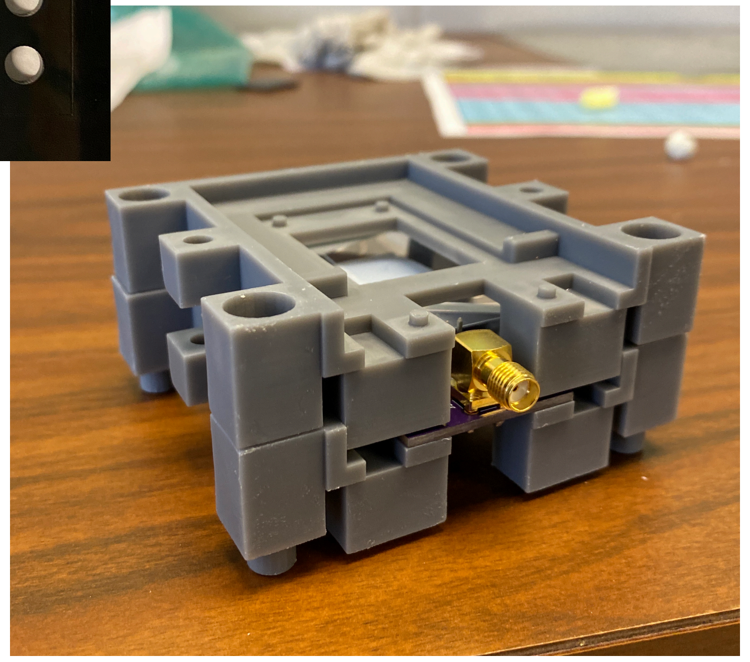
Preliminary Tile Uniformity Scans

- Fixed Sr-90 source placed above two SiPM+Tile couples to perform uniformity scan of top tile in translatable fashion
  - Top SiPM+Tile (scanning) was manually moved along all coordinates on a 4 x 4 grid for 30-minute time intervals
  - Bottom SiPM+Tile (trigger) was fixed to the same position for all 16 scans





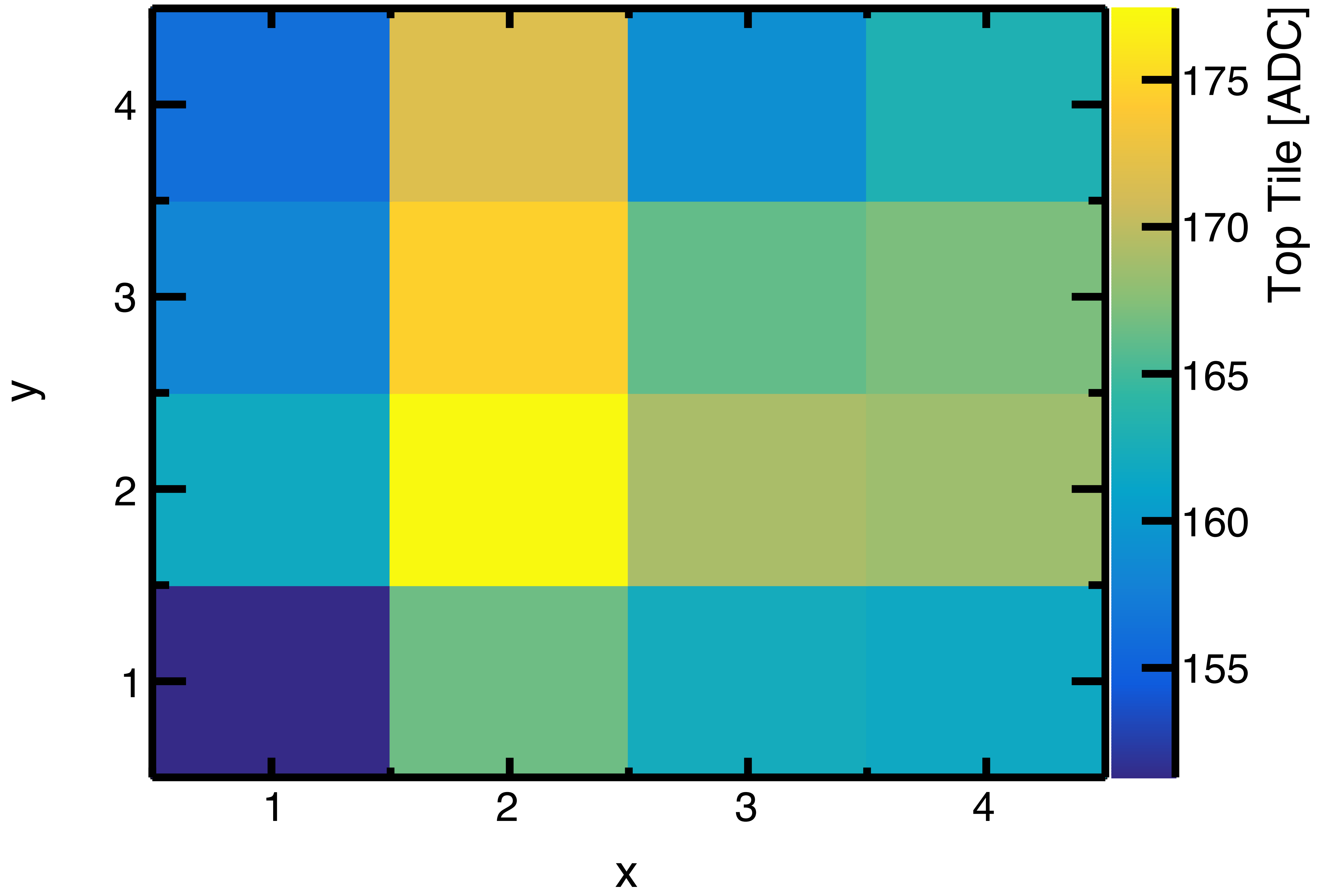
"The Grid"



SiPM+Tile Holder(s)

J. Roche

Preliminary Tile Uniformity Scans



- For S14160-1315 Model: MPV of Landau+Gauss(in ADC) for trigger tile across different grid positions
  - Within < 20% of each other
  - Independent cosmic runs show > 90% efficiency

Note: Mind Orientation of Grid Coordinates

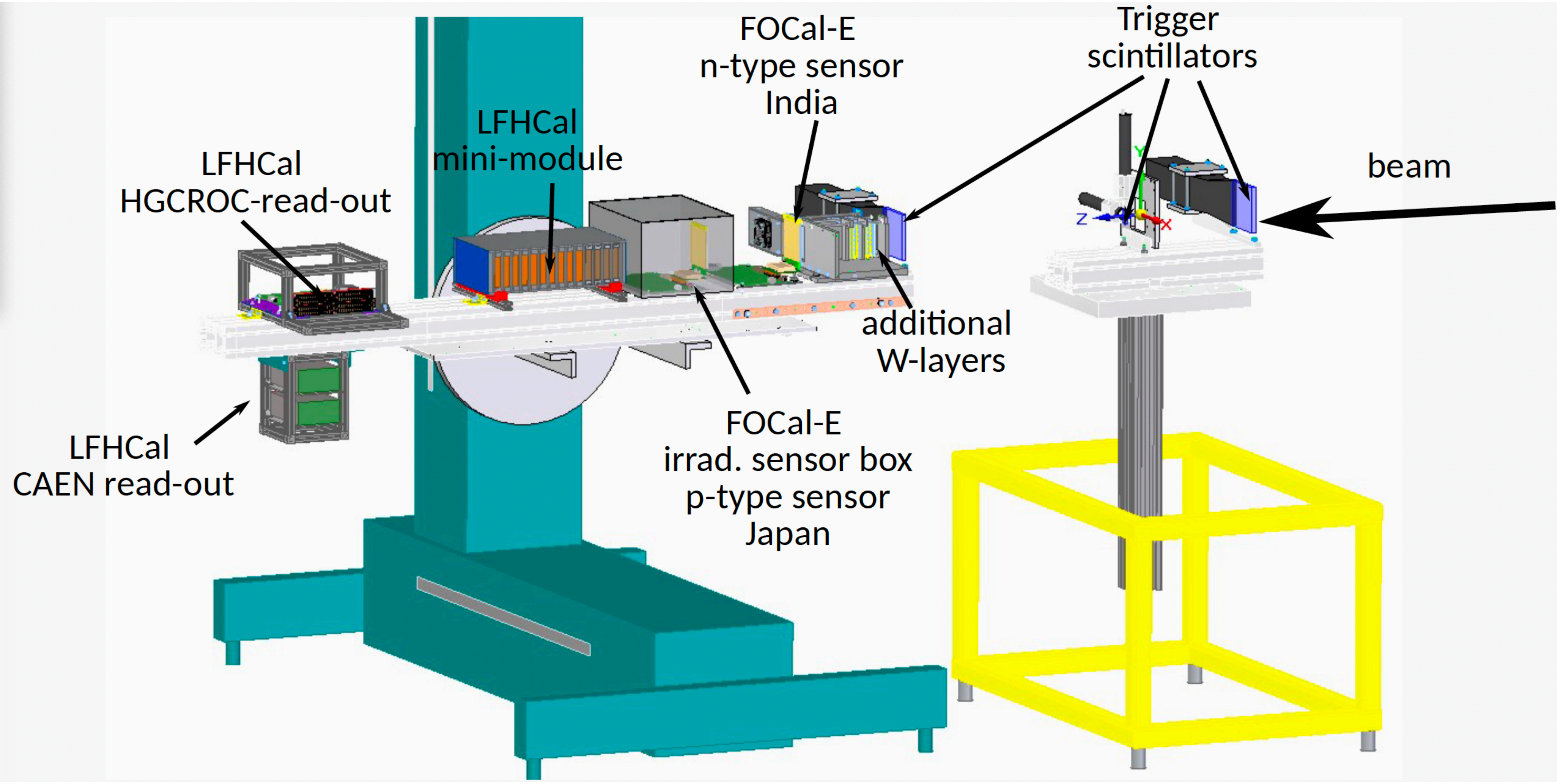
- As a proof-of-principle, the use of a two-tile coincidence setup with Sr-90 source proves to be a viable way to perform tile uniformity scans
  - Useful for comparison of tiles with dimple sizes as well as for tiles from different fabrication methods
- Considerations as we move forward:
  - Automation with translation stage
    - Facilitates finer scans and removes possibility of user error between runs
  - Source collimator geometry
  - Coupling current setup with additional SiPM+tile(s) for efficiency determination
  - Performing scans with purposefully irregular tiles to establish baseline criteria for poor tile quality (and rejection)

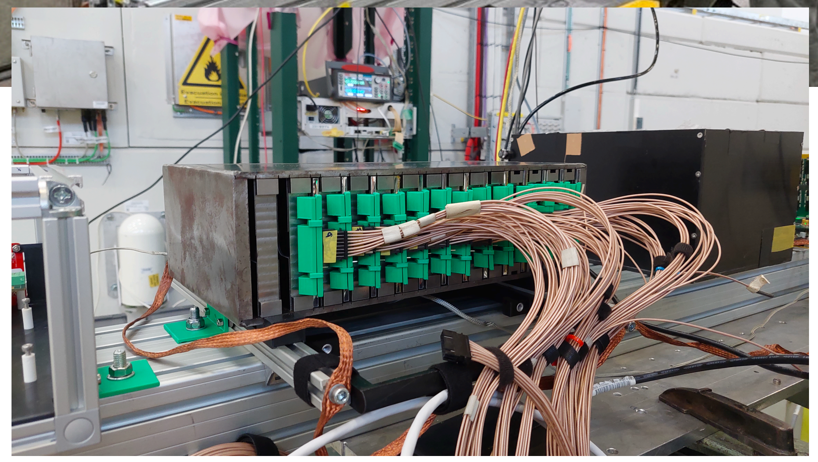
J. Roche

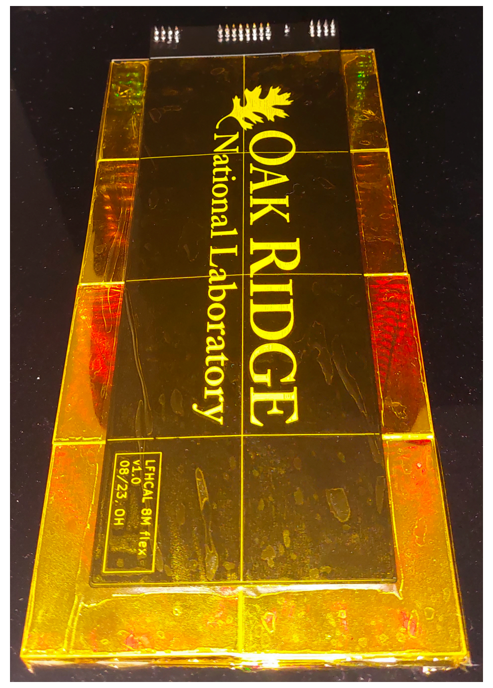
LFHCal Test Beams at CERN

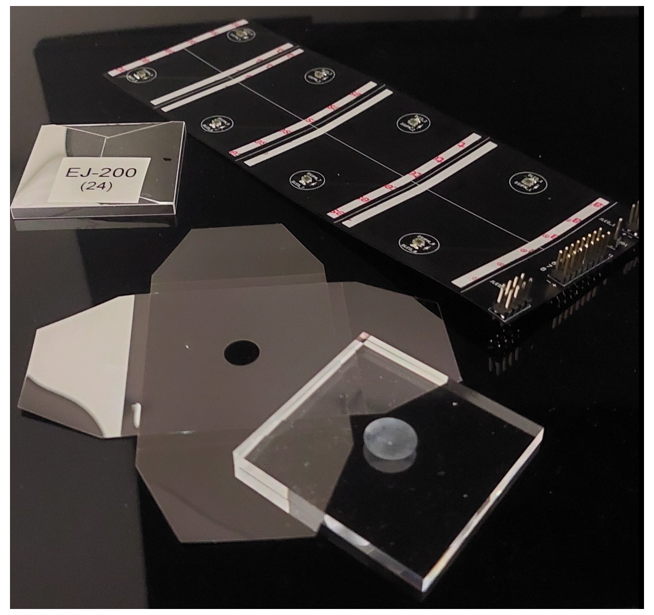
- **SPS: September 6th - 13th, 2023**
- **PS: October 11th - 18th, 2023**
  - Parasitic to FoCal-H/FoCal- E
  - Maximum 14 layers of 8M tile assembly
    - September: without absorber layers
    - October: with absorber layers
      - 4 tungsten, 10 steel
- Read-out: CAEN DT5202 64 channel CITIROC or H2GCROC

- **Expected Measurements**
  - Per tile light yields
  - Shower profile measurements with different absorber
  - Tile cross-talk estimates
  - Testing SiPM-H2GCROC setup
  - Leakage measurements (when placed behind FoCal-H)





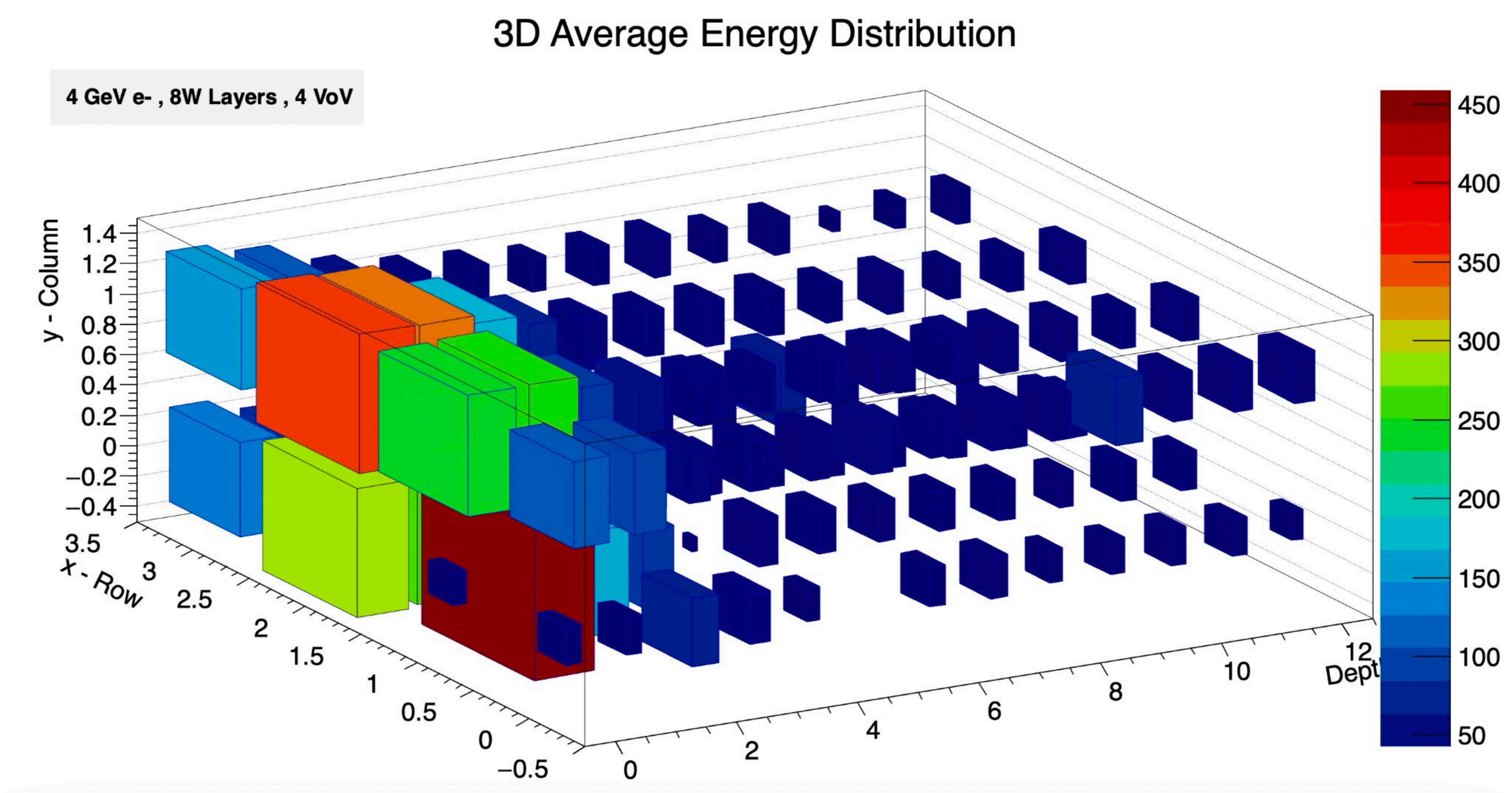


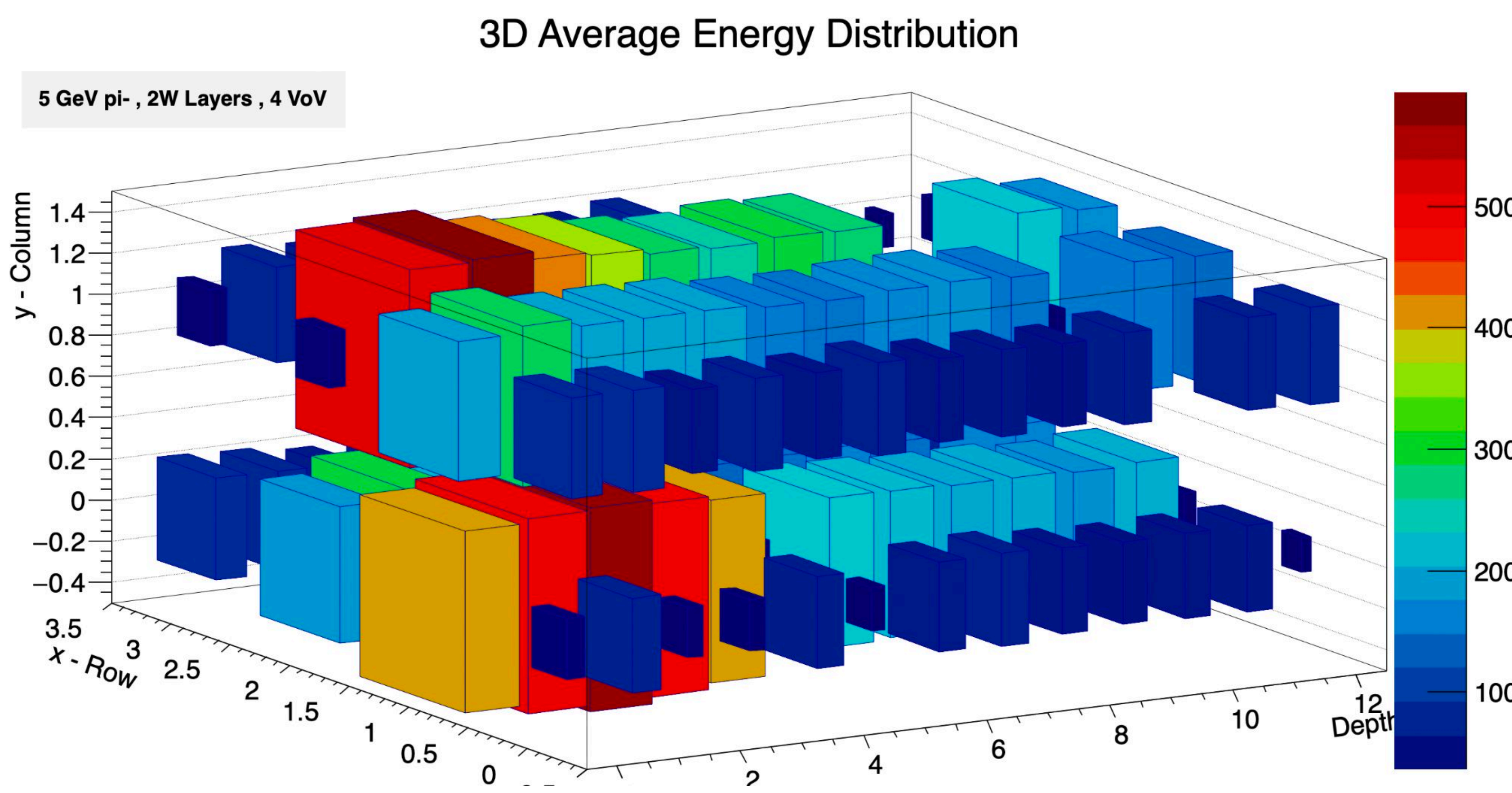


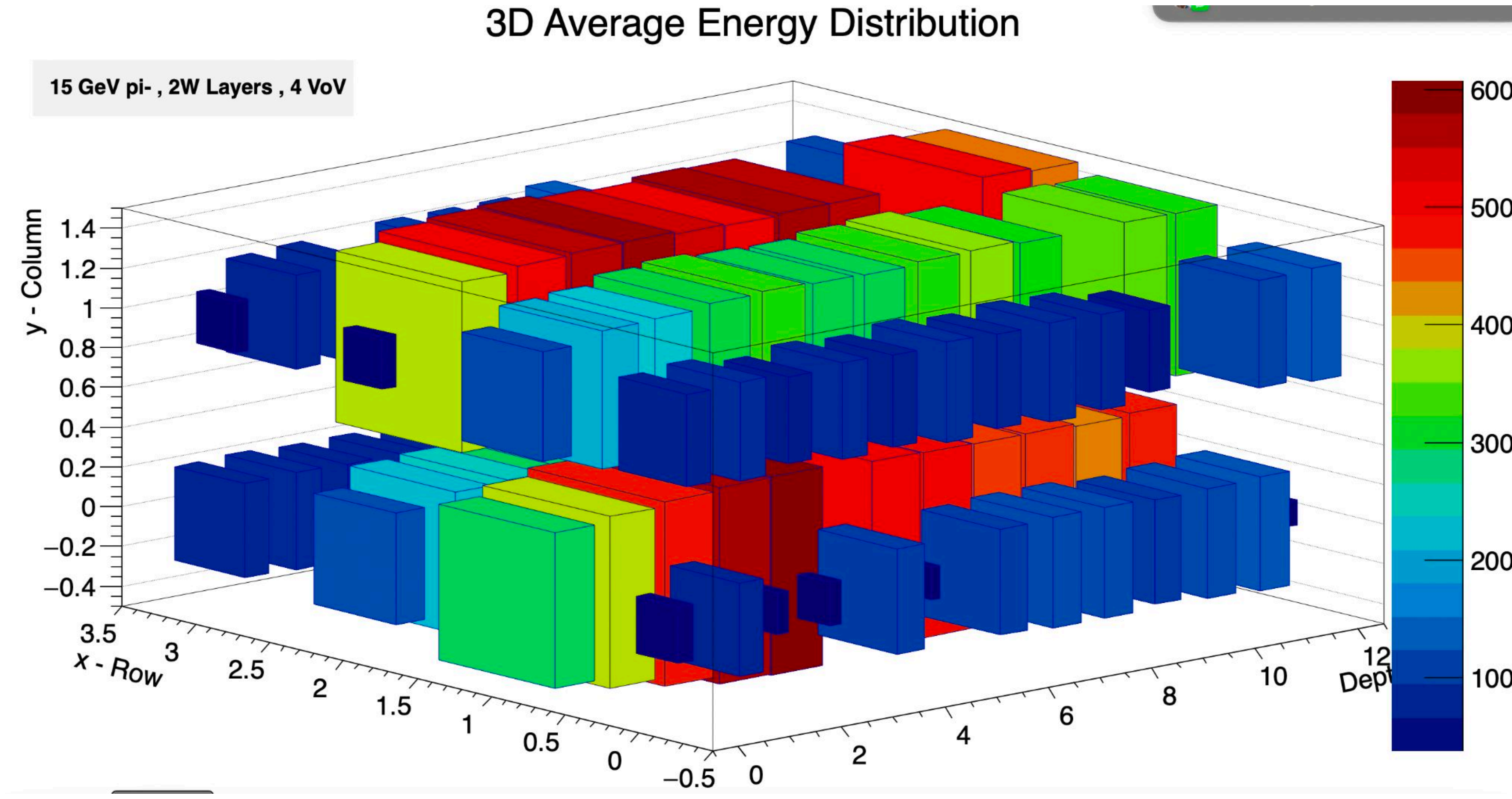
I. Ponce Pinto, Ananya Rai, F. Bock

LFHCal Test Beams at CERN

- **October:**







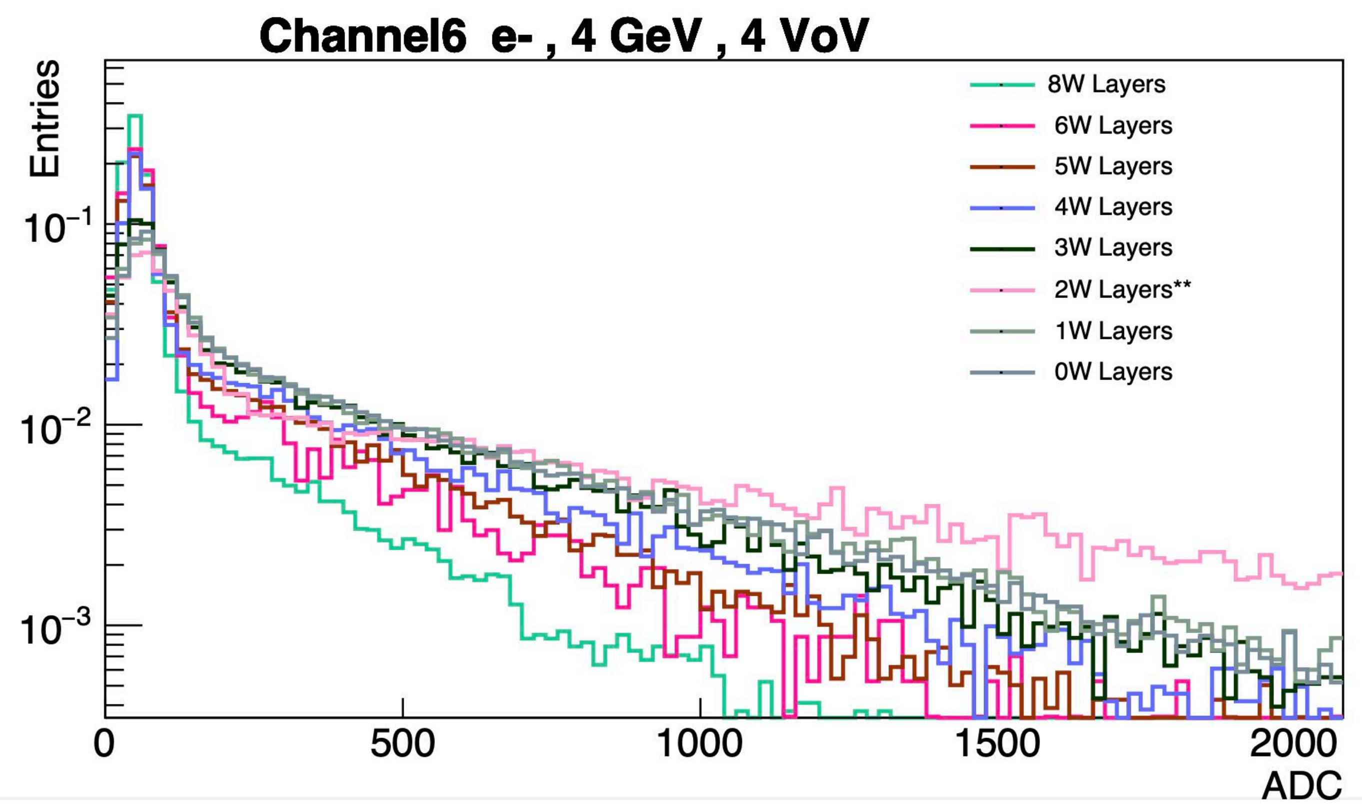
- **September Campaign:**
  - ☐ Full V_{ov} scan
  - ☐ Gain scan
  - ☐ Position scan
  - ☐ FoCal-H Leakage measurement

- **October Campaign:**
  - ☐ Full V_{ov} scan (e^-/π^-)
  - ☐ Gain scan
  - ☐ Scan with additional tungsten plates in front (e^-)
  - ☐ e^- shower (1 - 5 GeV)
  - ☐ π^- shower (5, 10, and 15 GeV)

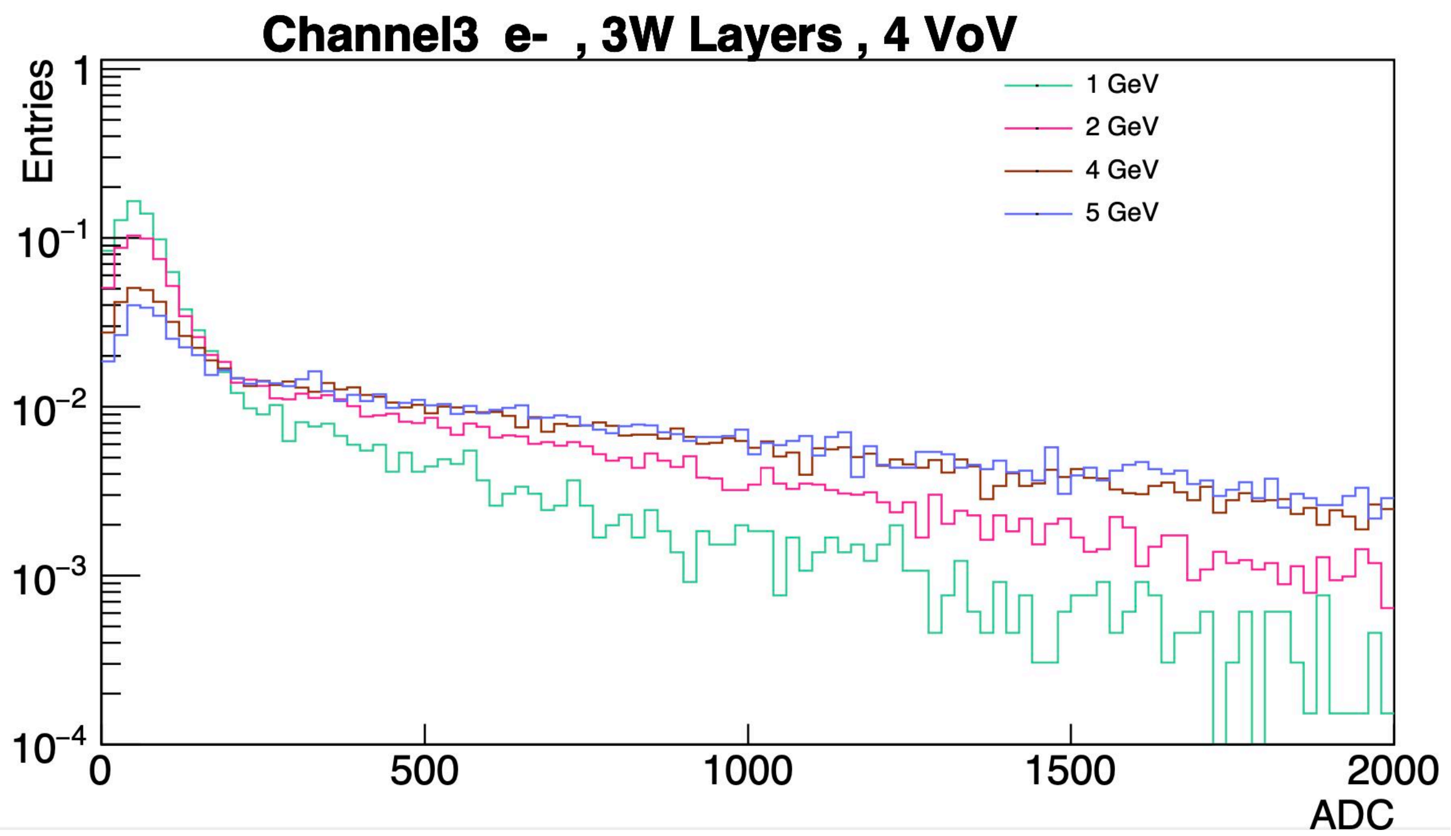
I. Ponce Pinto, Ananya Rai, F. Bock

LFHCal Test Beams at CERN (CAEN Readout)

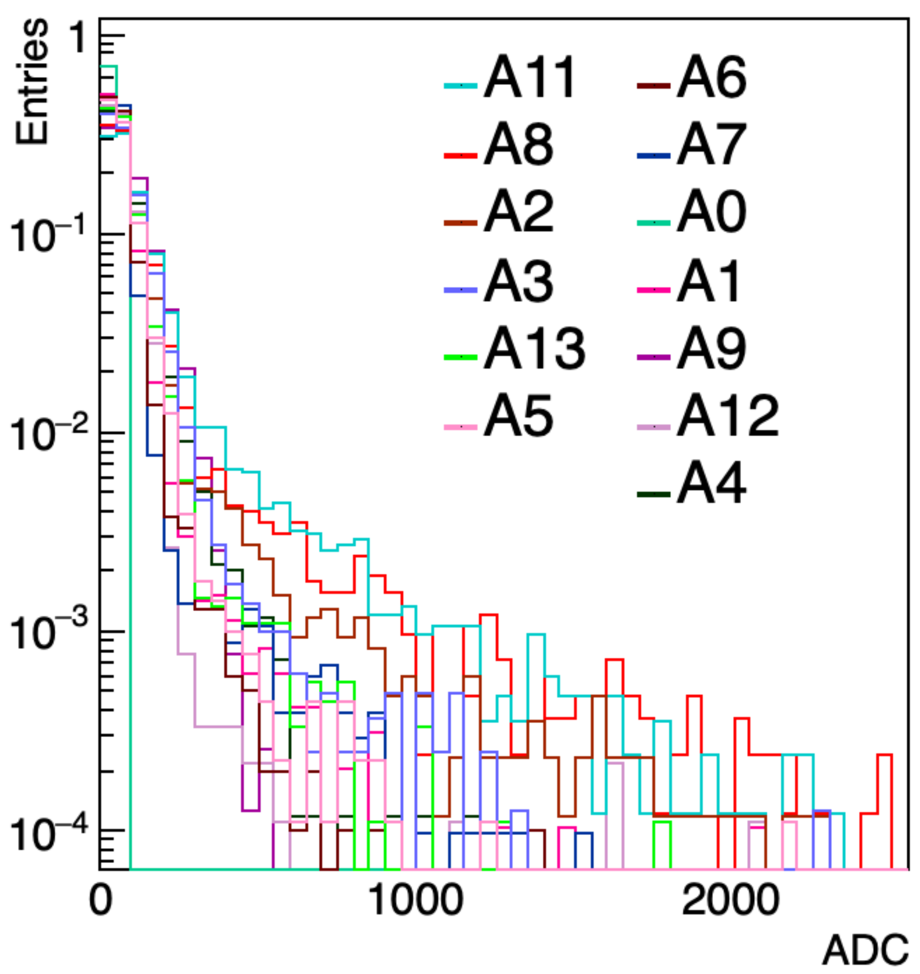
Tungsten layer scan



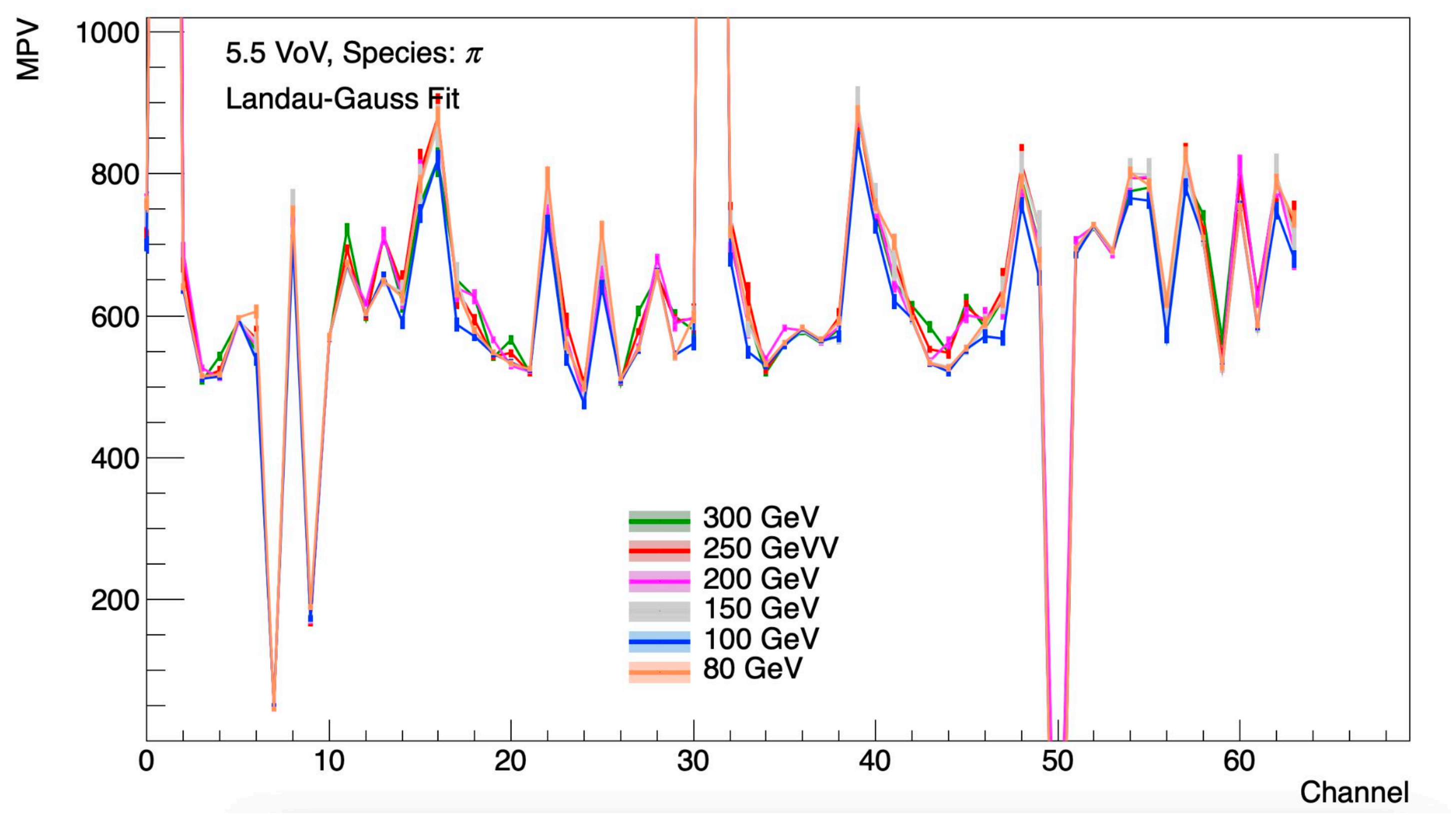
e^- energy scan



e^- shower development



Scintillator MIP response



I. Ponce Pinto, Ananya Rai, F. Bock

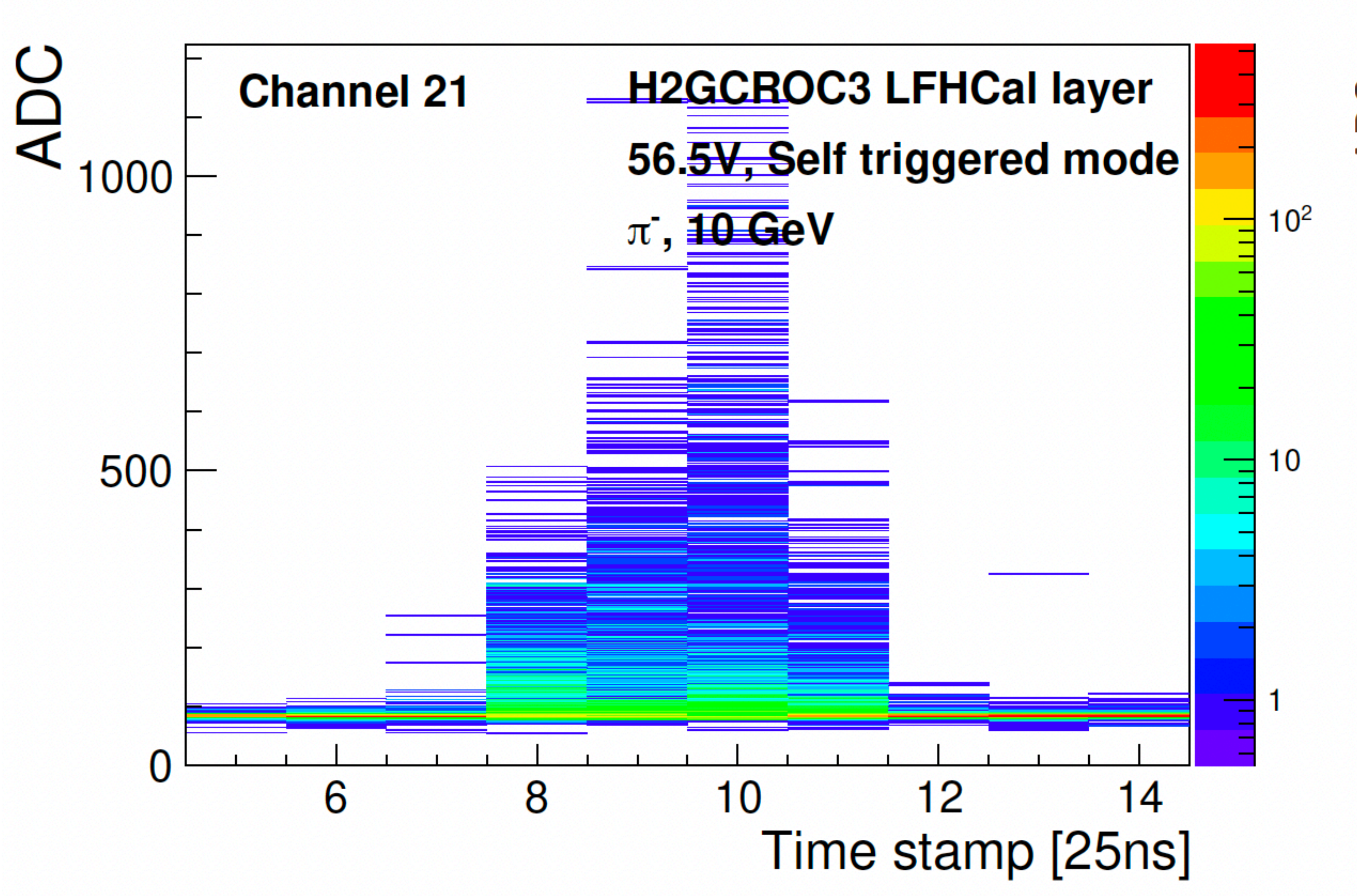
Concluding Remarks

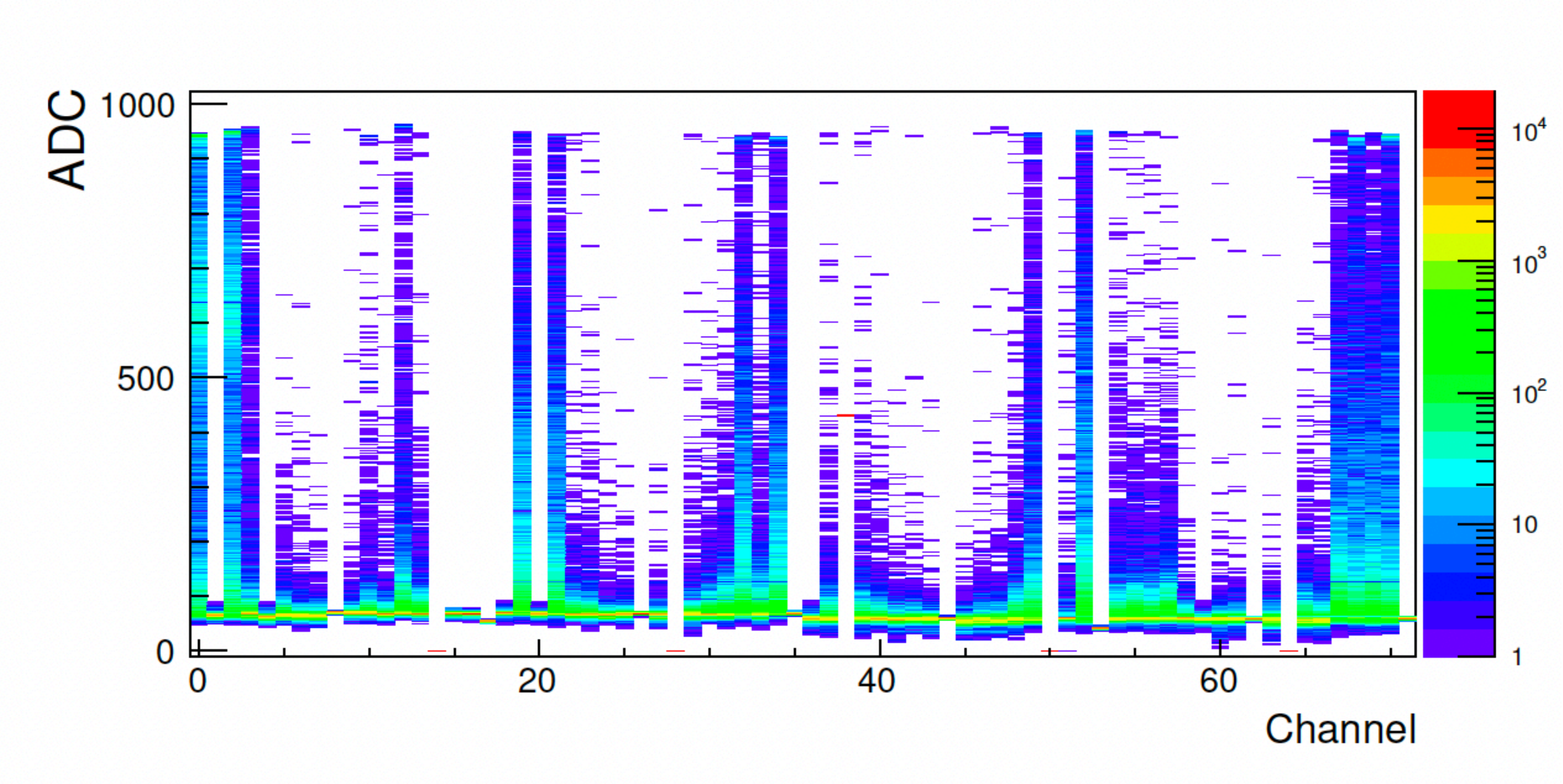
- Yale LFHCal R&D Efforts are well underway
  - Help meet demand for humanpower and instrumentation required for scalability in and out of campus
    - SiPM & Tile QA facility at Yale in full form
    - Aim to sustain and maintain workforce as ePIC unfurls
      - Database development in the works
    - Prepping for expansion beyond LFHCal…
  - Plenty of room for additional institutional collaboration within LFHCal DSC
  - WRT Test Beam, more runs are currently being analyzed
    - Need to account for dead channels present during runs
    - Noise subtraction for Event Displays still pending
    - Investigate whether or not a time dependence is present within the individual test beam runs as well as relative to previous (and future) test beams

THANK YOU!

CAVALRY

LFHCal Test Beam: H2GCROv3a First Results





- H2GCROC read-out ready by last 1.5 days of October campaign
- Self-triggered data was acquired
- PS beam stop during last evening kept externally triggered setup from operating