OAK RIDGE National Laboratory

LFHCAL (+EEEMC) Test Beam August/September 2024

Oskar Hartbrich

(for the whole testbeam crew and everyone involved)

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

LFHCAL Prototype: The Plan

- First full LFHCAL module: 64 layers
  - 20cm*10cm
  - 512 readout channels
  - +parasitic EEEMC module testing

- Two continuous weeks of beam time at CERN PS.
- **August 28-September 11**
- First week: HGCROC Readout
- Second week: CAEN DT5202+DT5215 Readout

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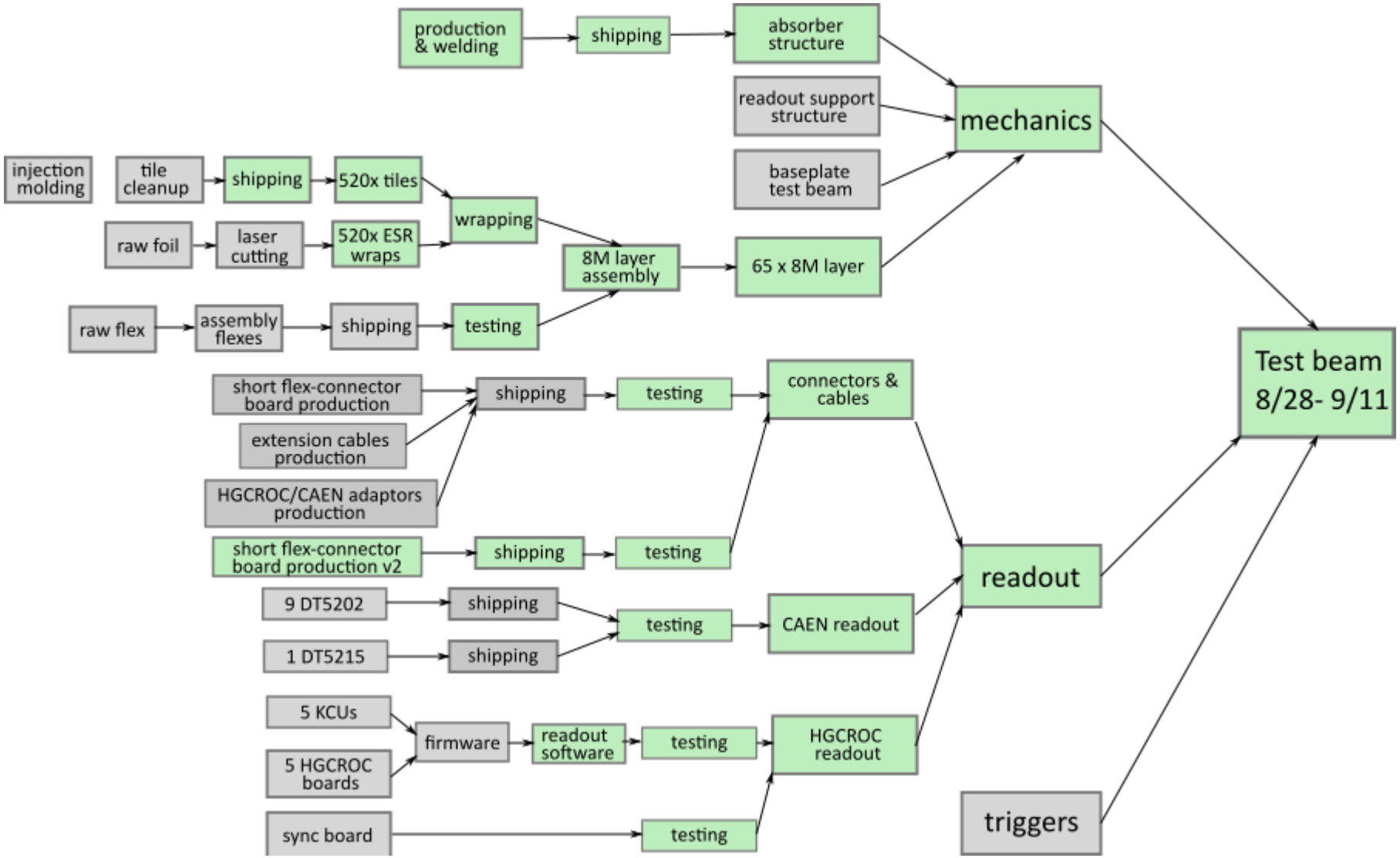
LFHCAL Prototype: Status at LeHigh Meeting



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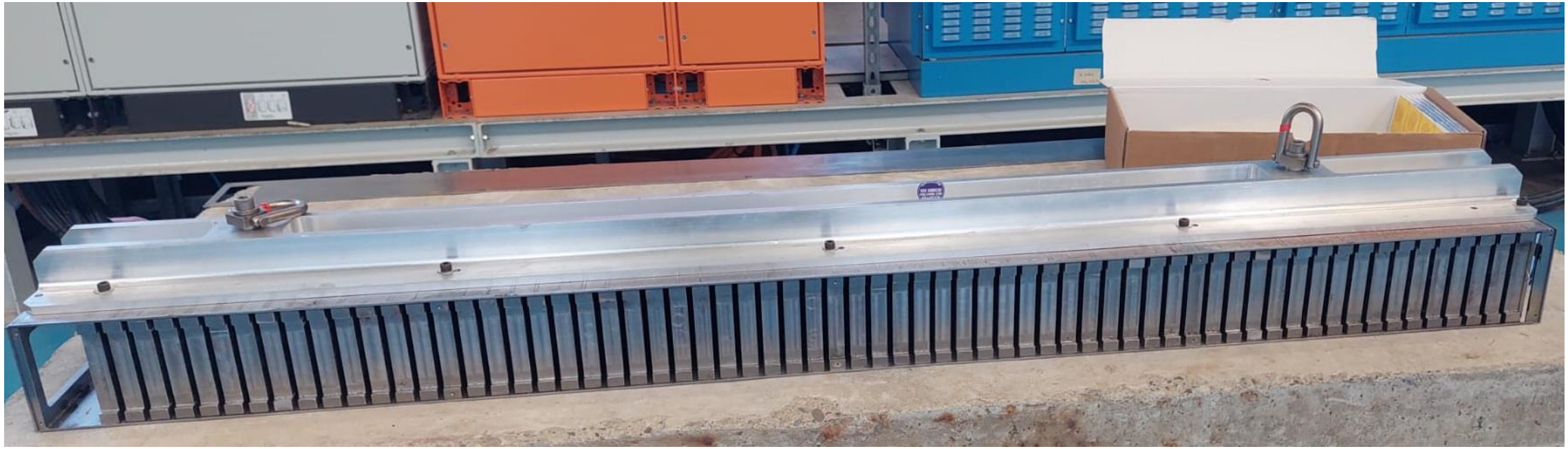
LFHCAL Prototype: Mechanics

- First mechanics module available since August
  - E-beam welded in CA, shipped to ORNL for compliance testing
  - Shipped to CERN few weeks in advance



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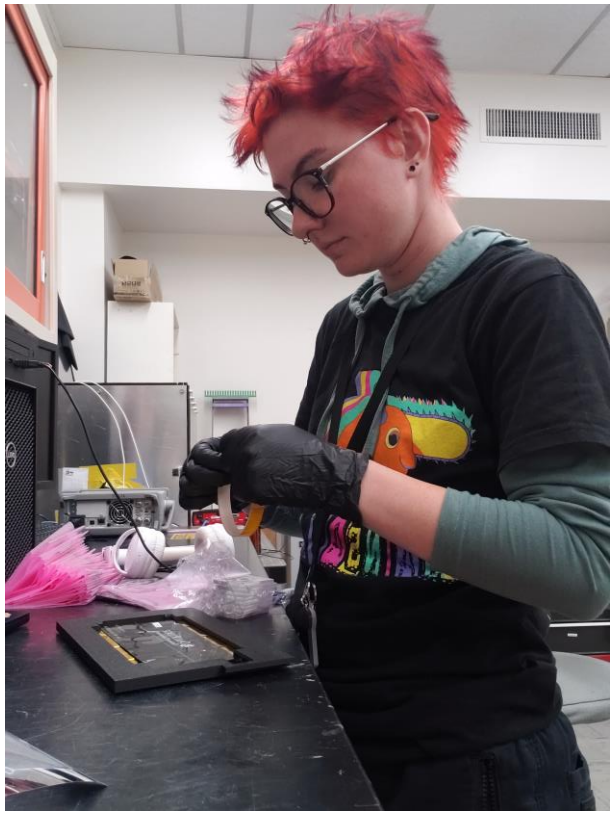
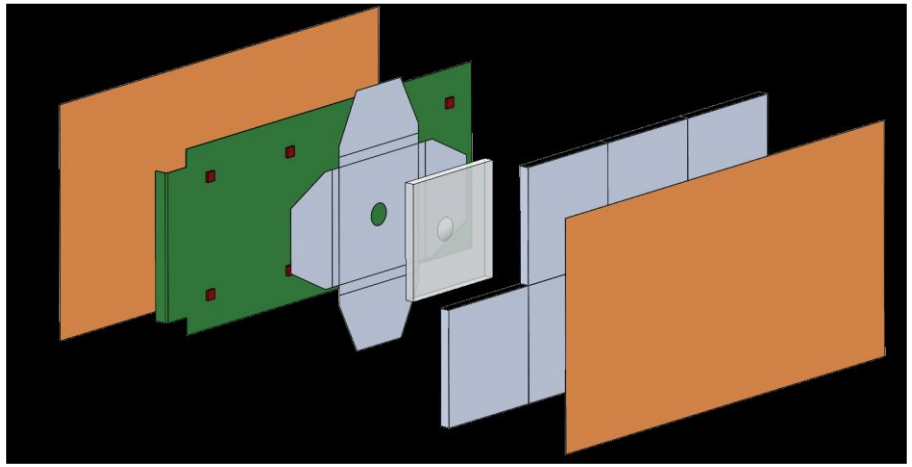
LFHCAL Prototype: Scintillator Layers

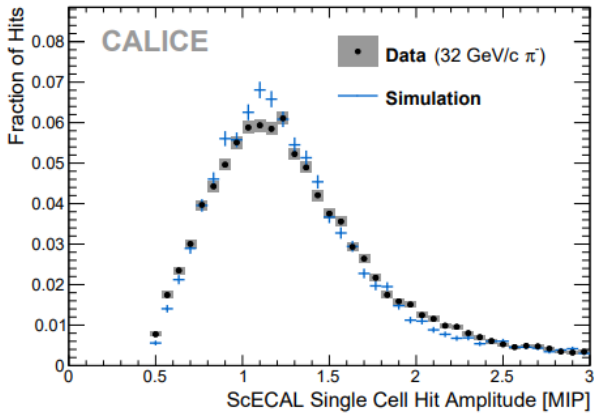
- All tiles available at ORNL (produced by FNAL, cleaned by Valpo)
- ORNL summer interns Droc and Hagen (both UTK) assembled and tested 74 scintillator layers

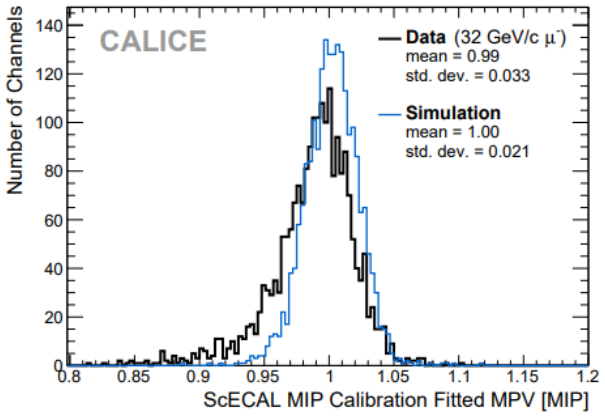


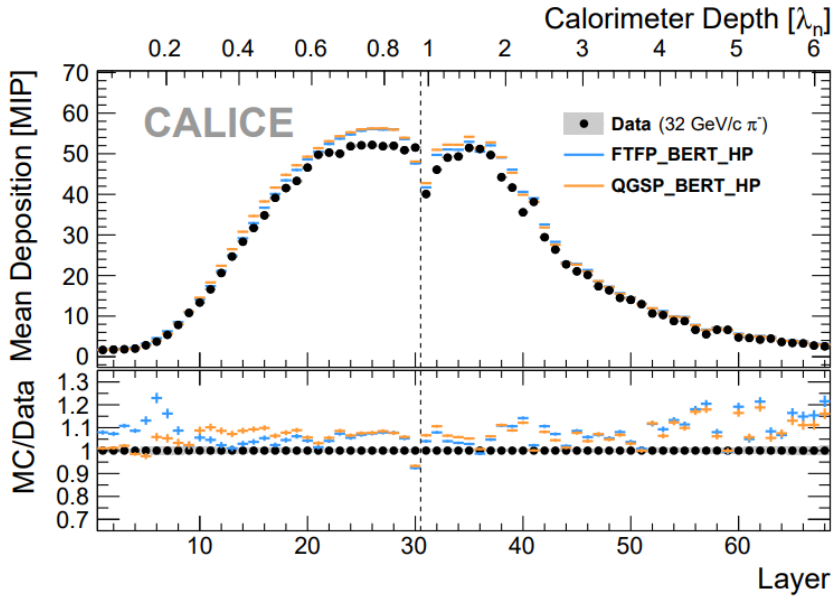


LFHCAL Prototype: Goals

- Expose LFHCAL module to muons, electrons, pions in energy range 1-10GeV
- Muons: Cell-by-cell MIP calibration
- Electrons: Response, resolution
  - Single cell hit spectra, SiPM saturation effects
  - + Geant4 comparison
- Pions: no chance to laterally contain pion showers
  - Longitudinal shower profiles, hit spectra
  - + Geant4 comparisons
- Publish in NIM/JINST:
  - Single paper?: construction, beam analysis?
  - Two papers?: construction, lab tests, 2023 beam + 2024 beam







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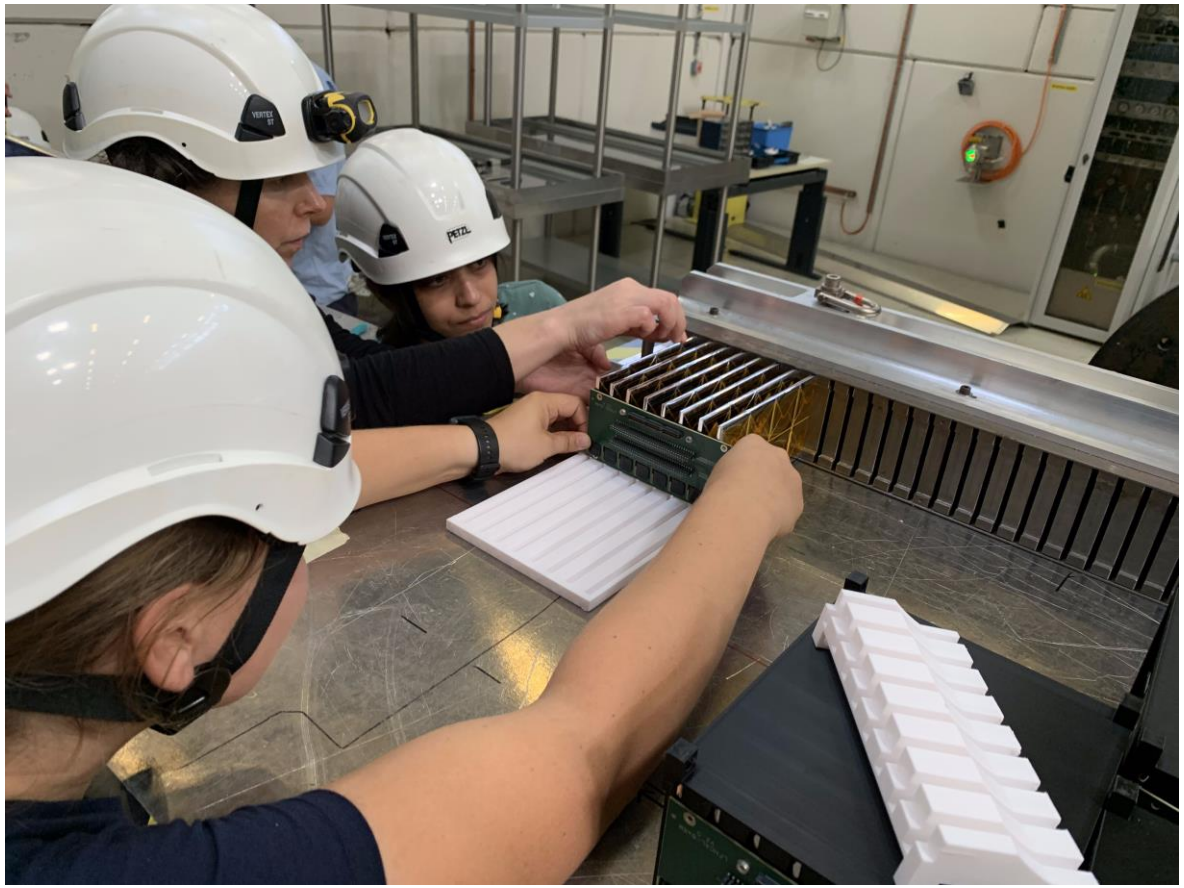
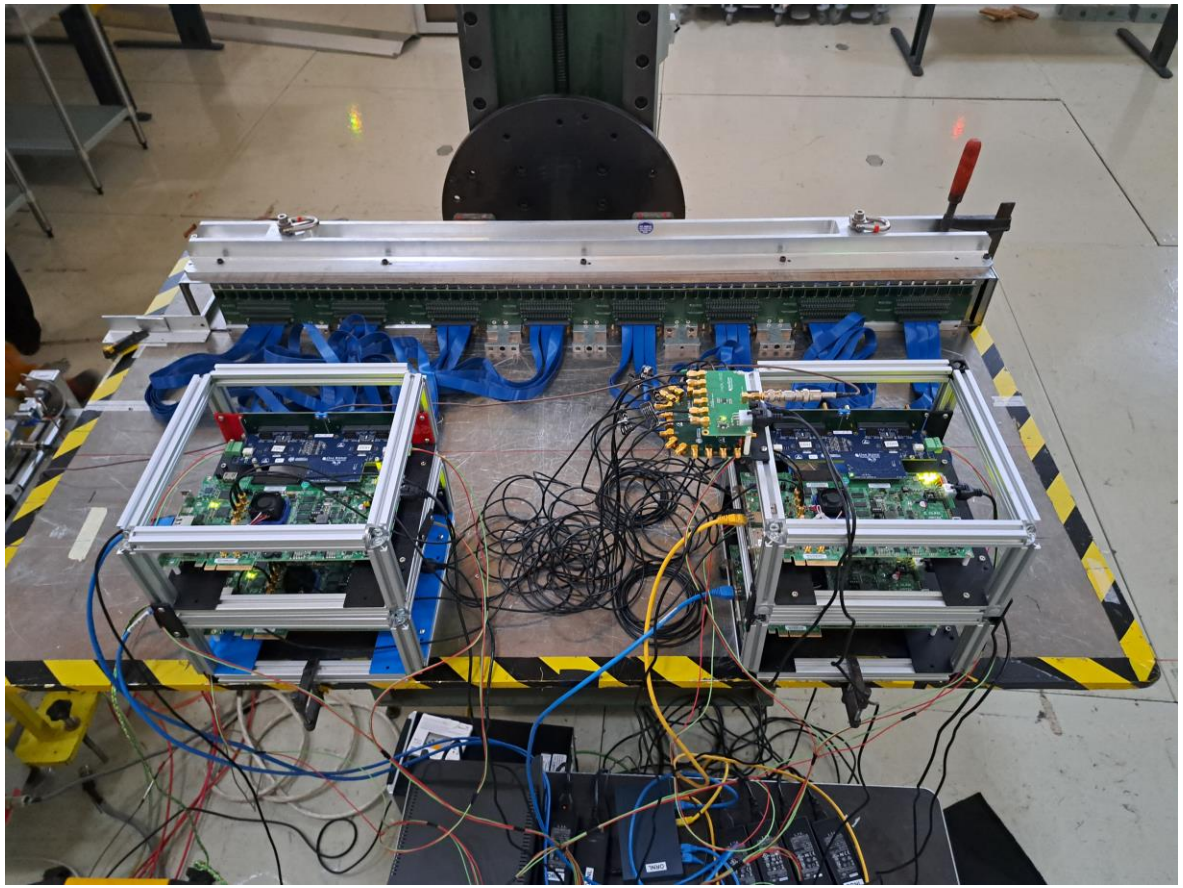
Initial Setup





HGCROC Run Summary

- Setup without major issues
- First useful runs within hours of setup
  - Some calibrations etc. needed of course
- Trigger rates very very low (single digit events per spill)
  - Ultimately traced down to misconfigured FOCAL trigger board
- Still acquired full dataset:
  - Muons, electrons 1GeV-5GeV, hadrons (+-) 3-15GeV
- There will be a dedicated talk on HGCROC experience soon™

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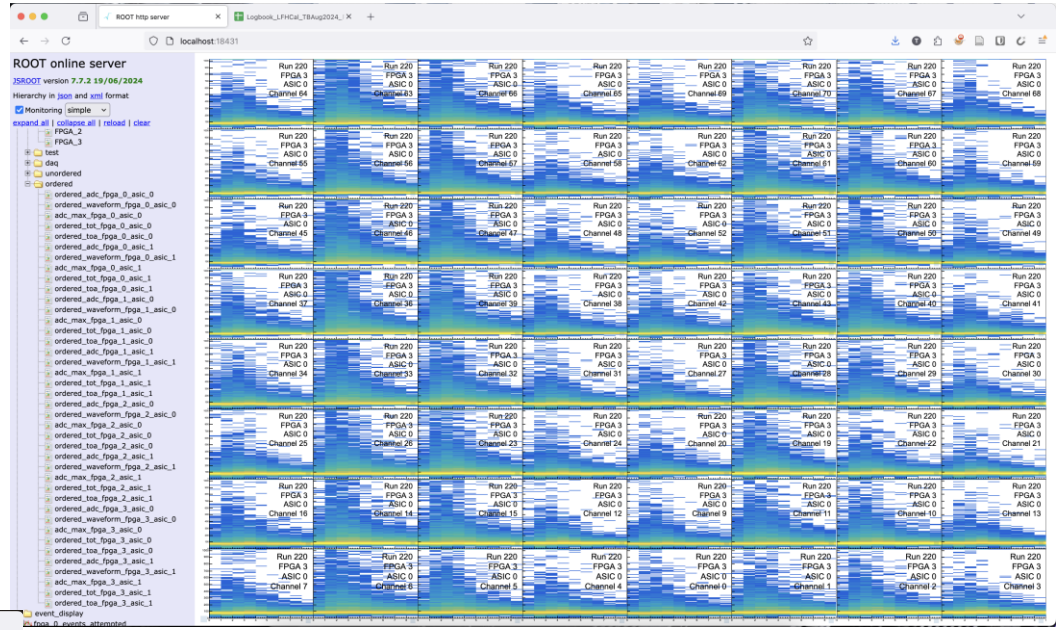
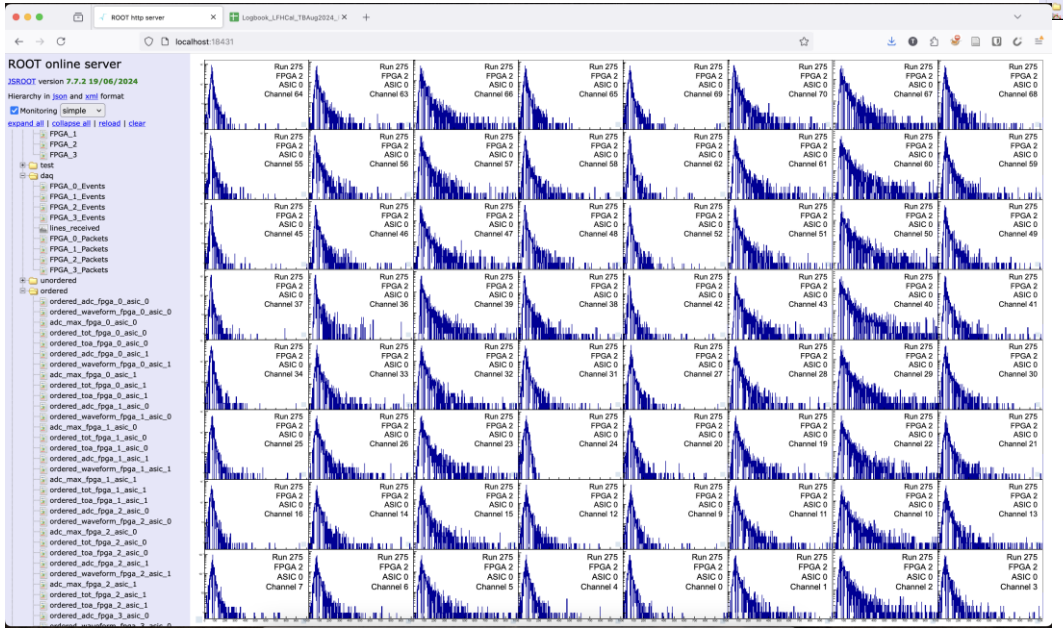
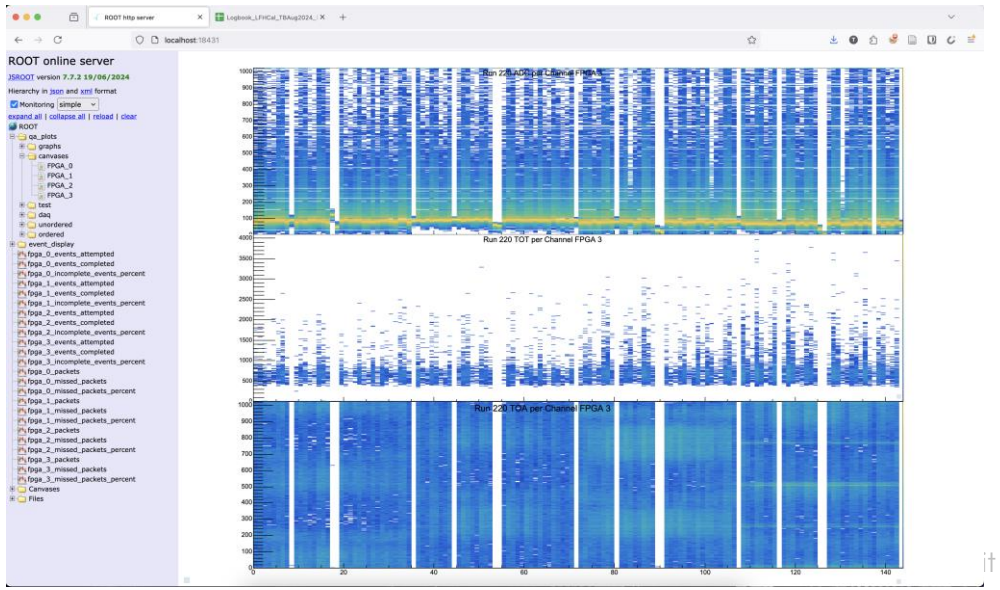
Live Data Monitoring

- Tristan Protzmann (LeHigh) developed live data monitor for HGCROC (+CAEN) data
  - Available to everyone interested







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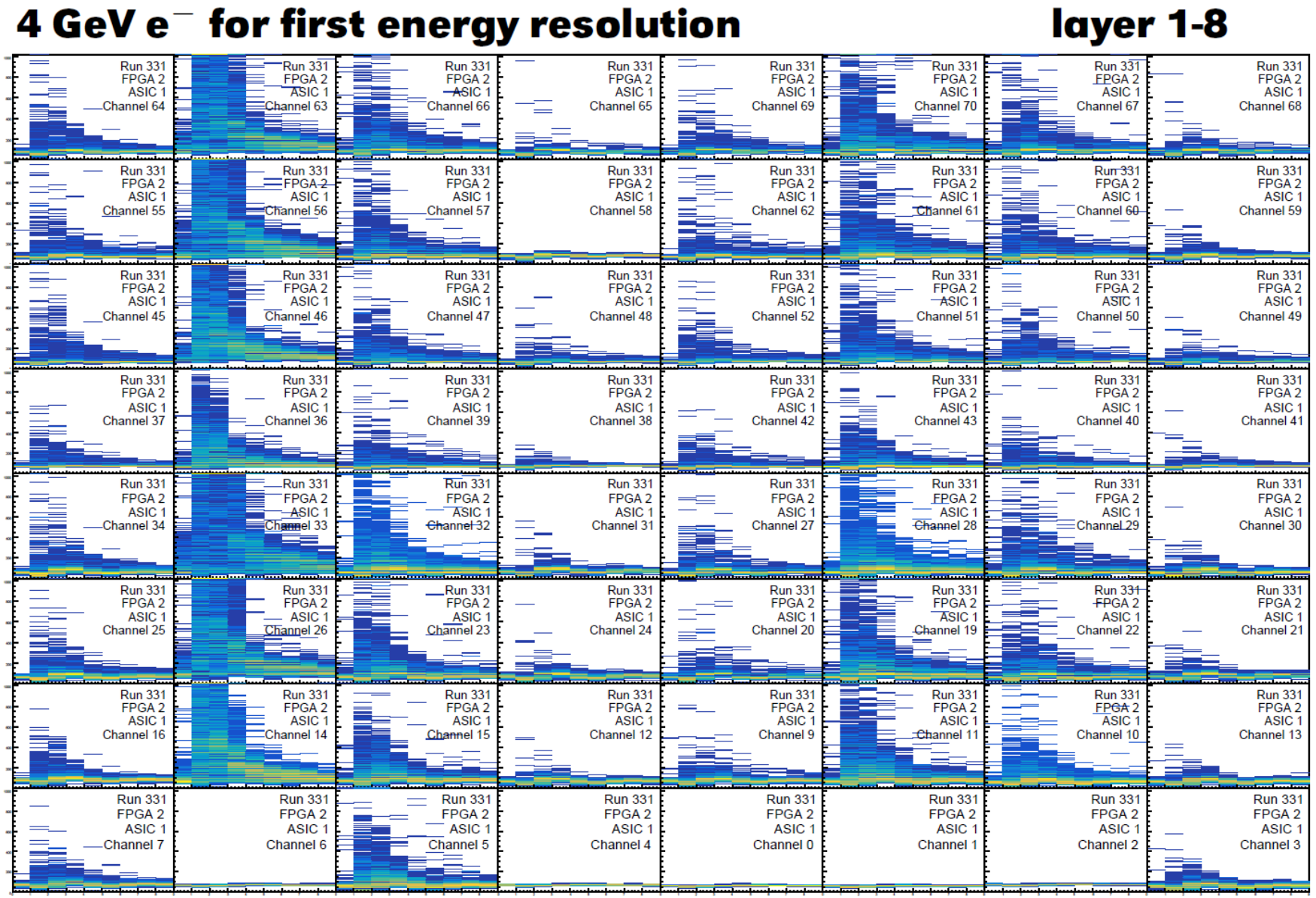
4 GeV e⁻ in HGCROC LFHCAL: Layer 1-8



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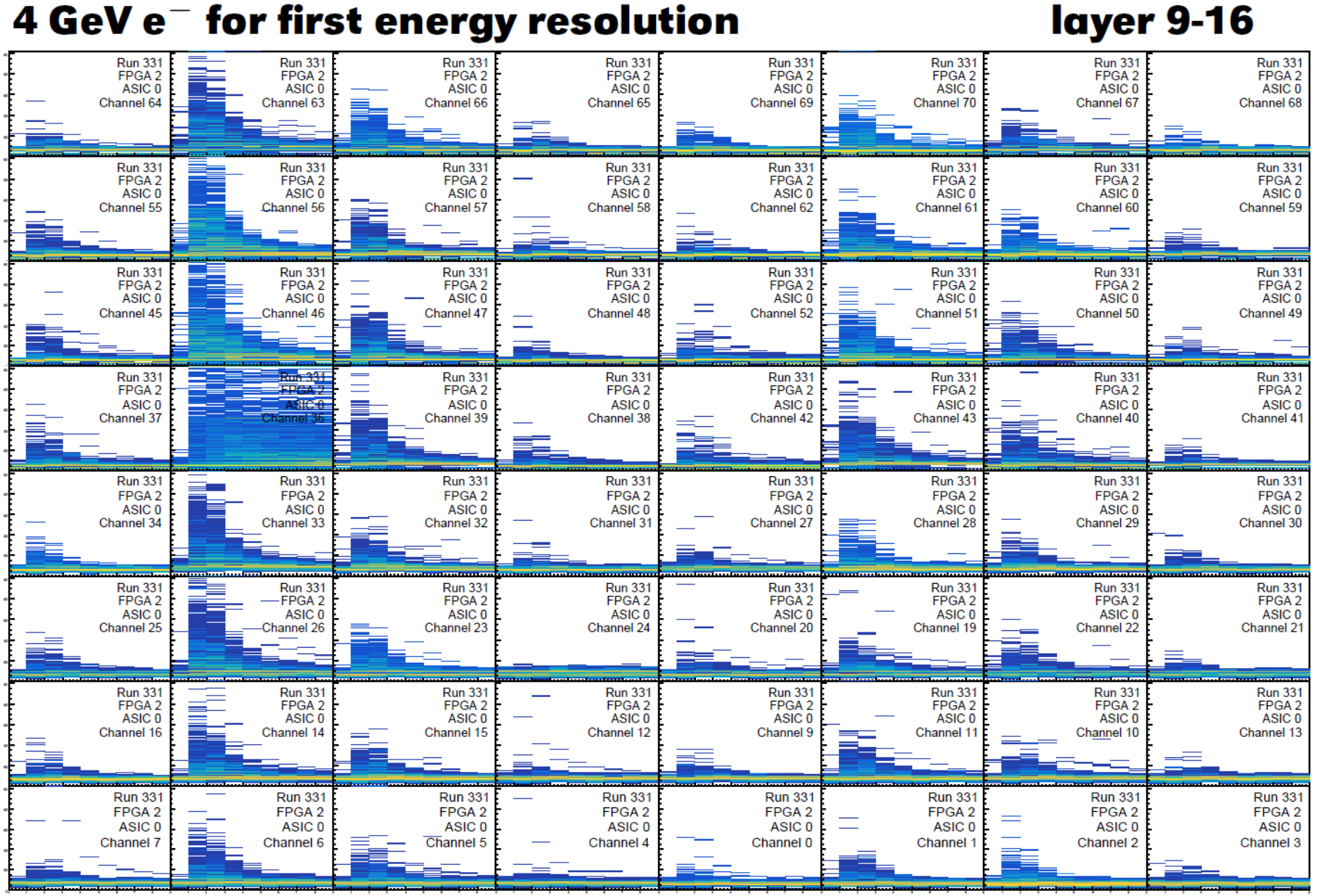
4 GeV e⁻ in HGCROC LFHCAL: Layer 9-16



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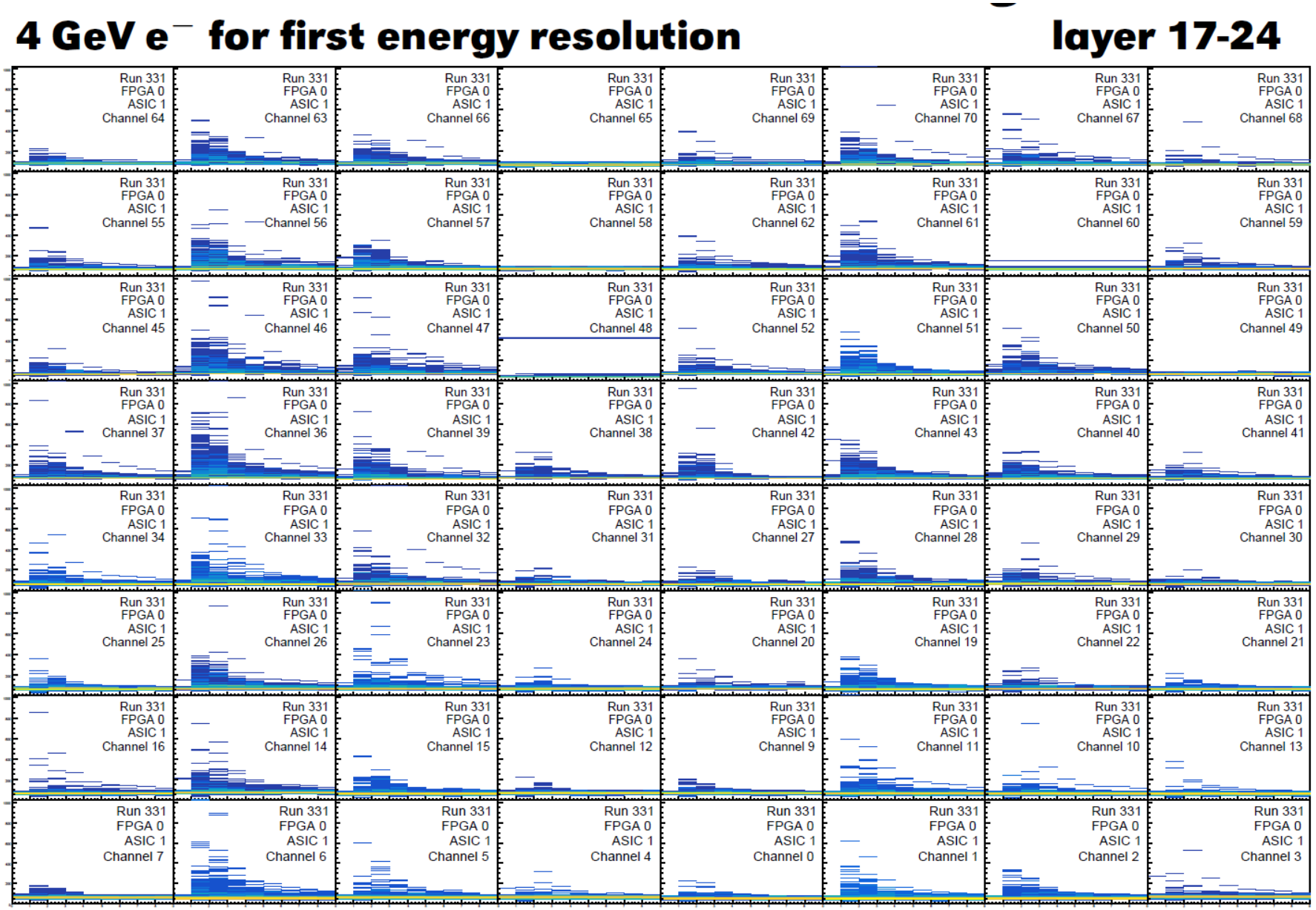
4 GeV e⁻ in HGCROC LFHCAL: Layer 17-24



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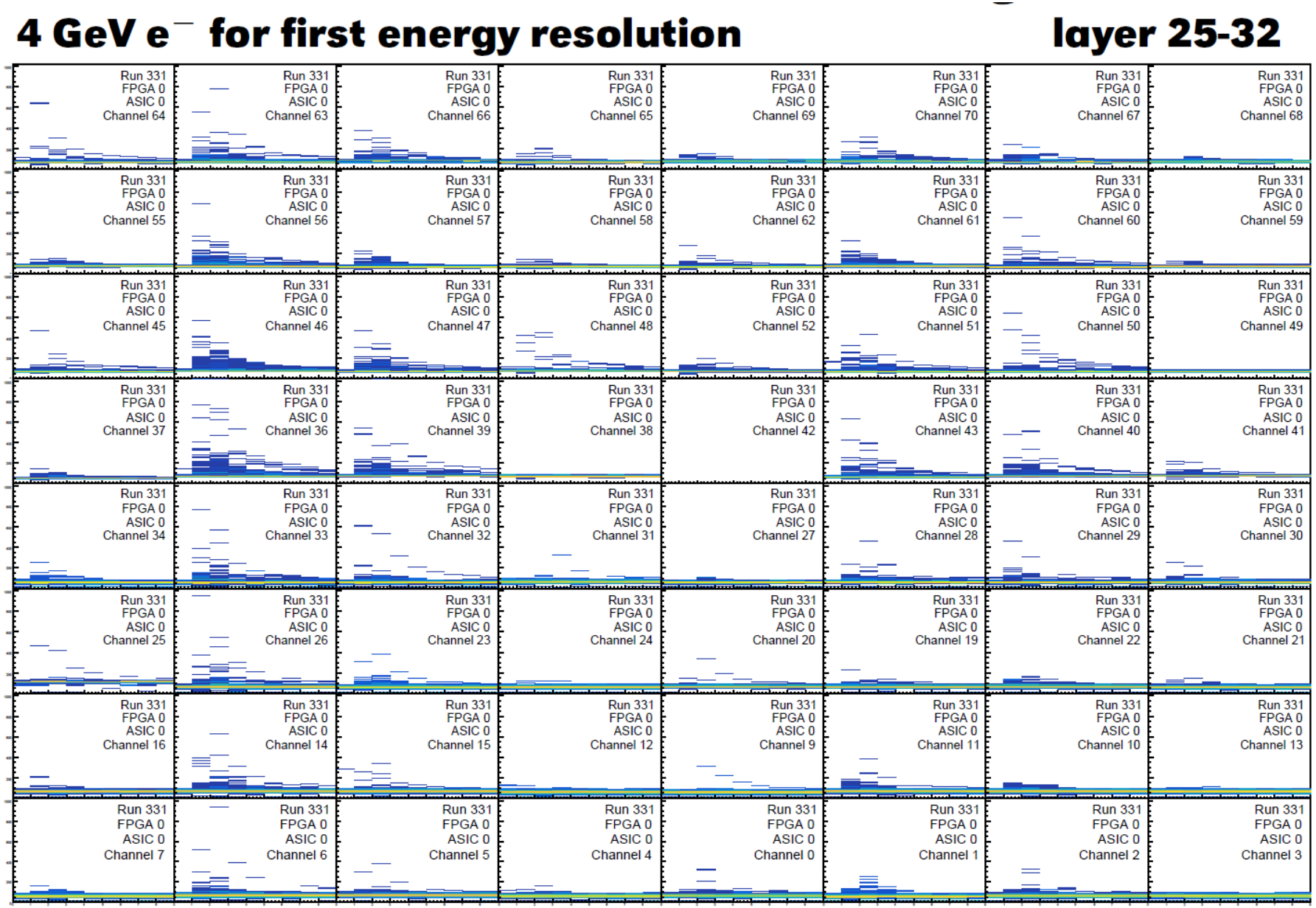
4 GeV e⁻ in HGCROC LFHCAL: Layer 25-32



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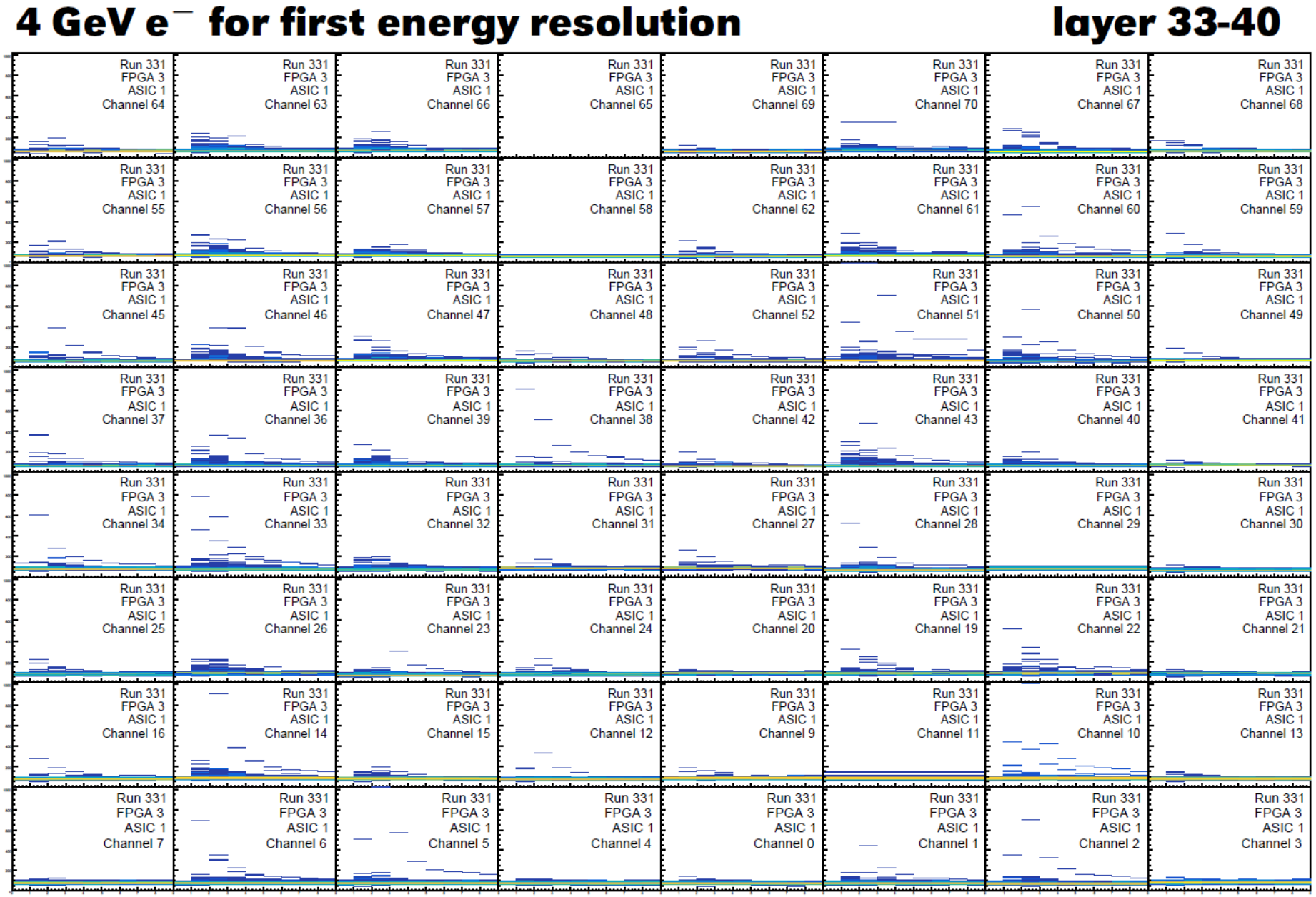
4 GeV e⁻ in HGCROC LFHCAL: Layer 33-40



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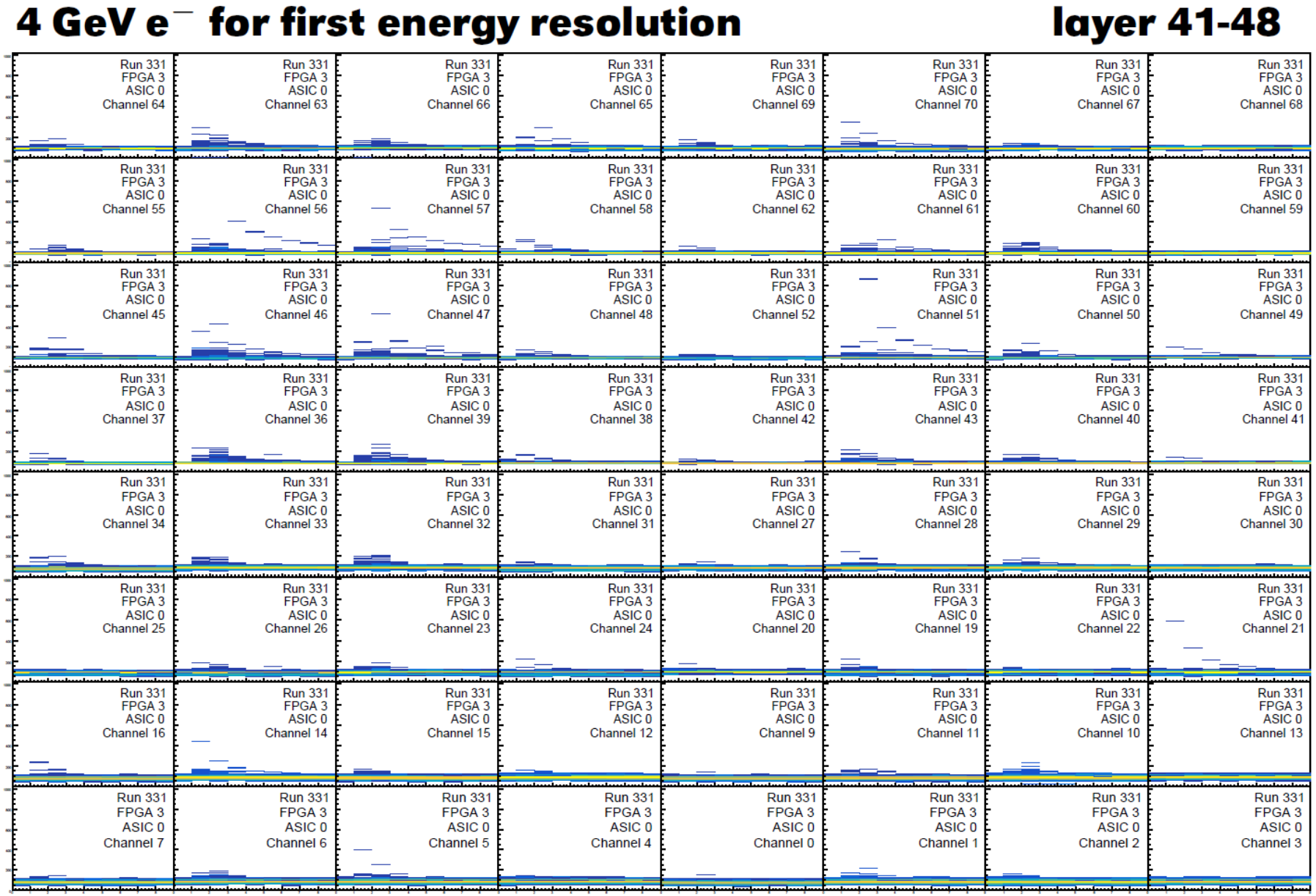
4 GeV e⁻ in HGCROC LFHCAL: Layer 41-48



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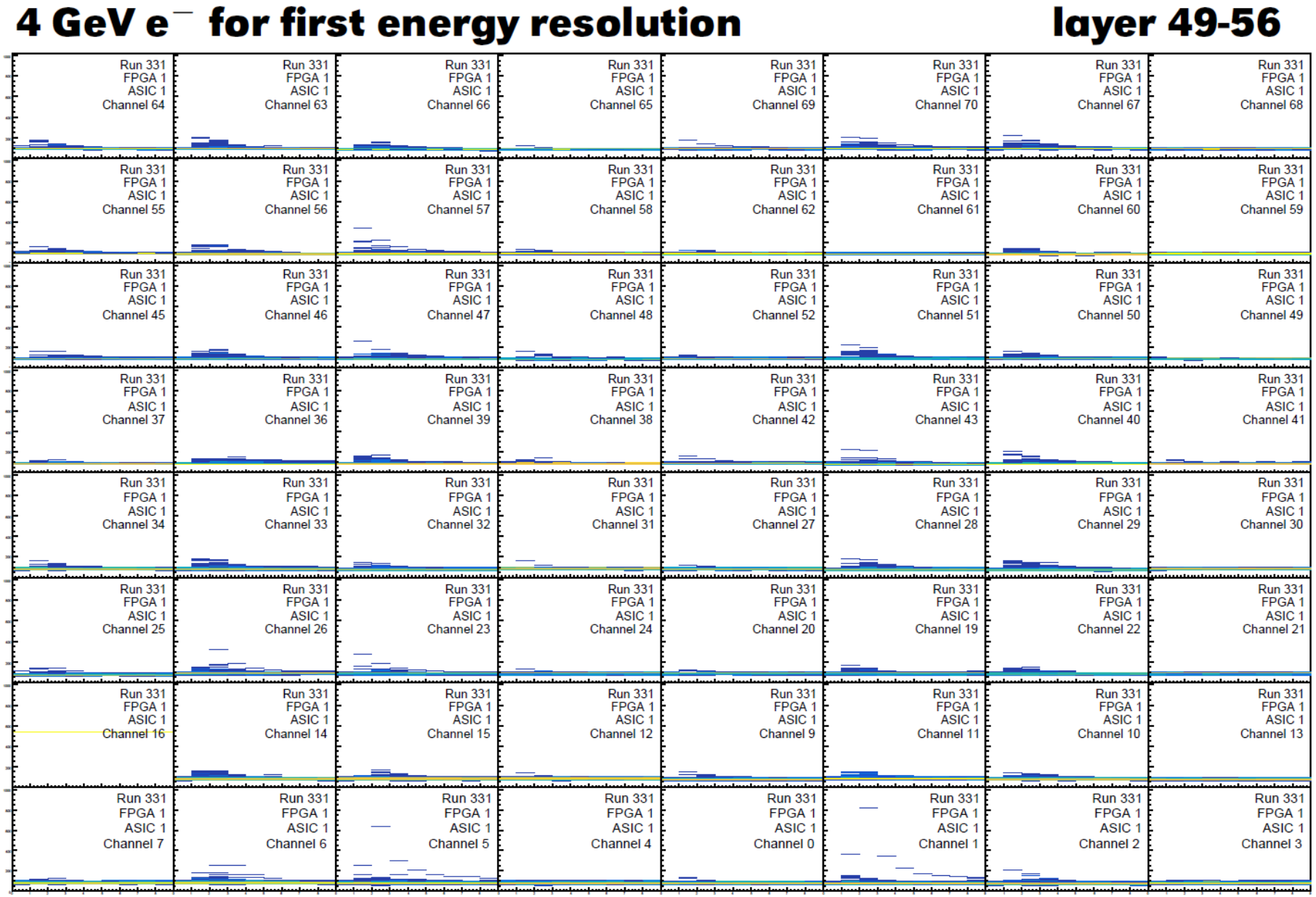
4 GeV e^- in HGCROC LFHCAL: Layer 49-56



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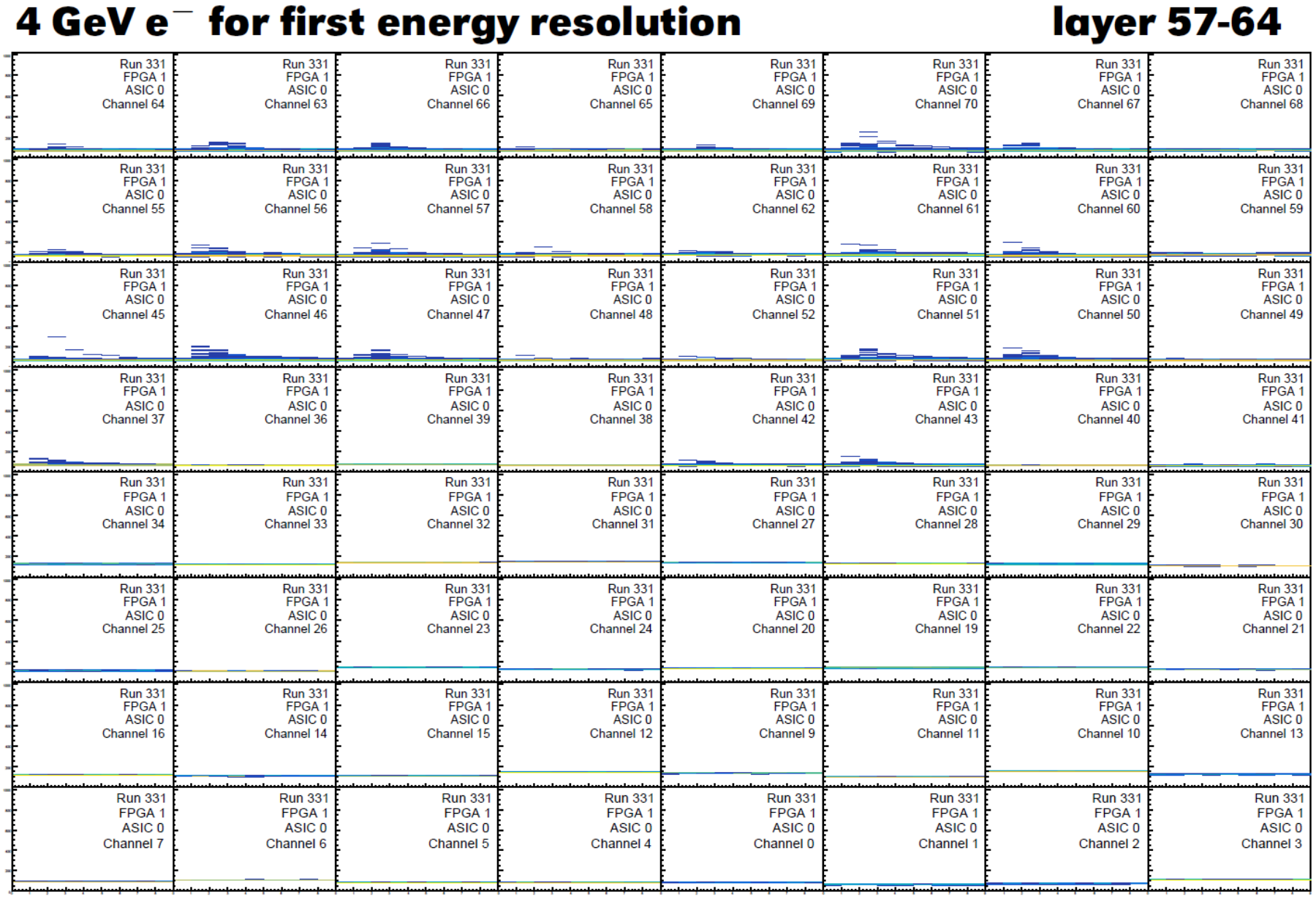
4 GeV e^- in HGCROC LFHCAL: Layer 57-64



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The CAEN Saga pt1

- 8 DT5202 readout units + 1 DT5215 data concentrator
  - Using several loaned DT5202s from all over the world
  - Readout PC <-> single ethernet <-> DT5215 <-> “TDLink” fibers to DT5202
- Cabled up everything: pedestals good
  - No grounding issues, no ground lift to flex boards necessary (PS testbeam is cleaner environment than ORNL lab)
- However: no signal whatsoever.

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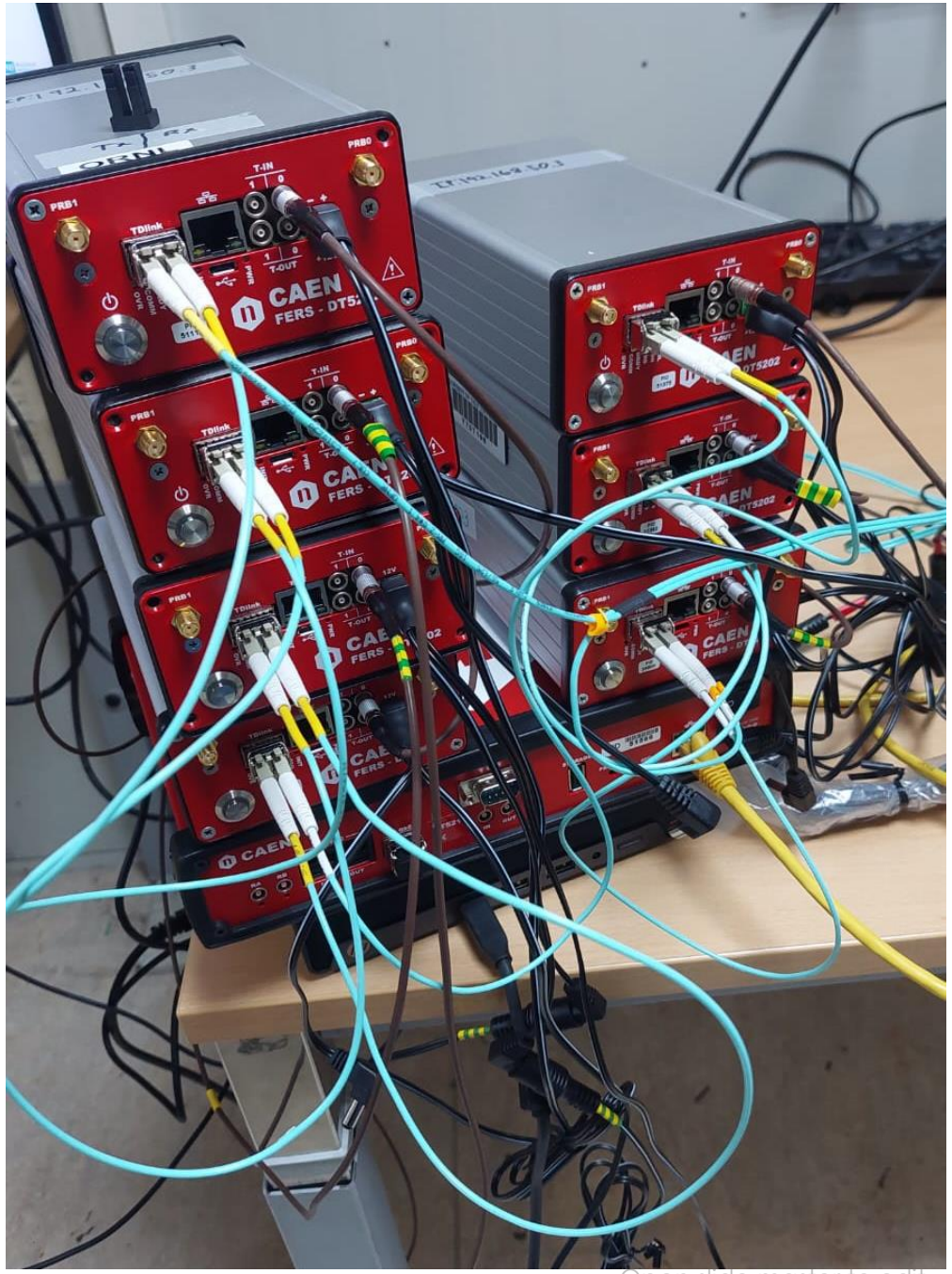
The CAEN Saga pt1



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The CAEN Saga pt2: Fighting for Nanoseconds

- Trigger signal propagation delay too long.
- Did everything to reduce latency.
  - Smallest number of devices in chain, shortest cables, optimized geometry.
  - DT5215 integrated trigger fanout has 20ns delay by itself (CAEN confirmed this…)
- Increased shaping time of DT5202 to maximum
  - 87.5ns up from 25ns
  - Will need conversion factor between 25ns lab LED+cosmics and 87.5ns beam data…
- Finally saw some MIPs

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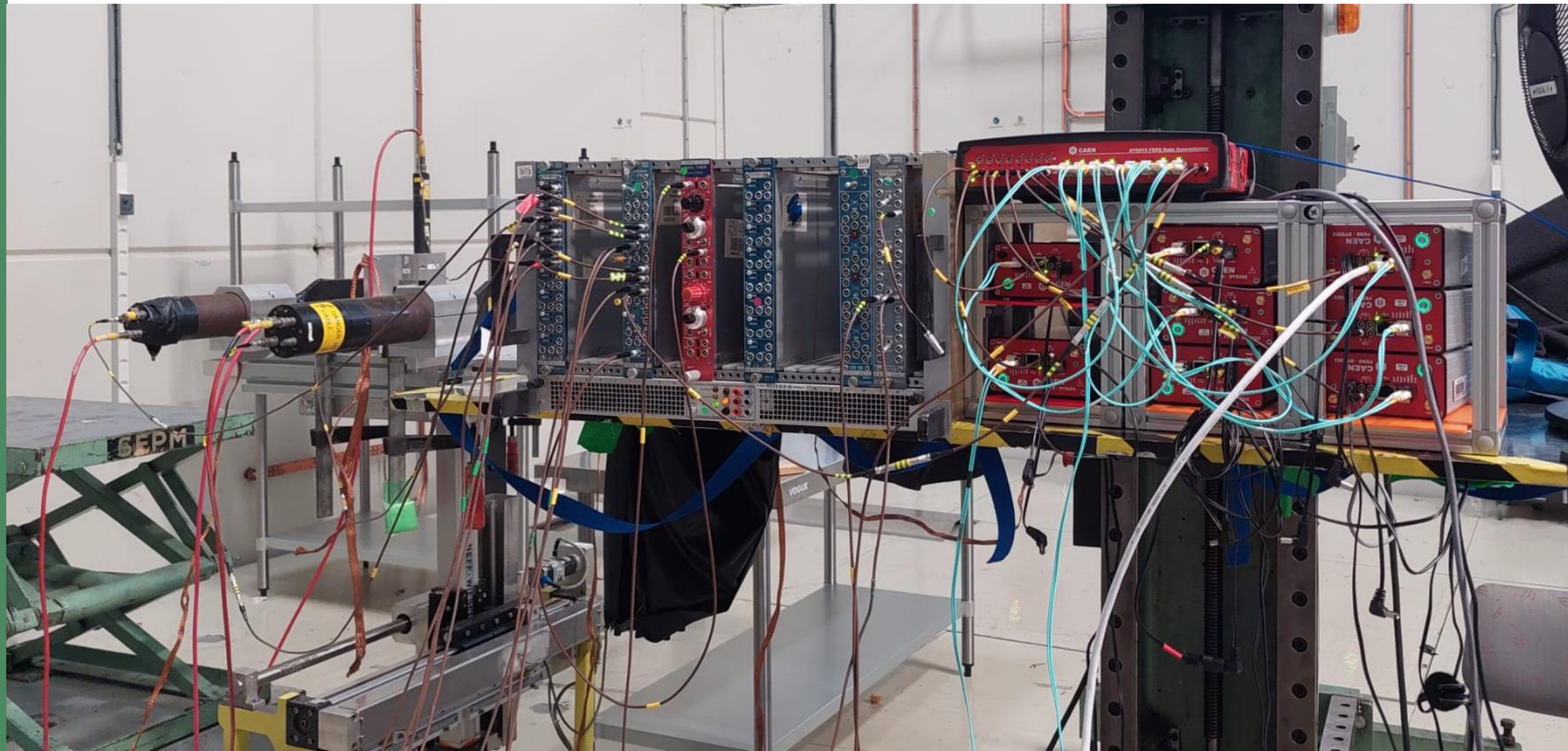
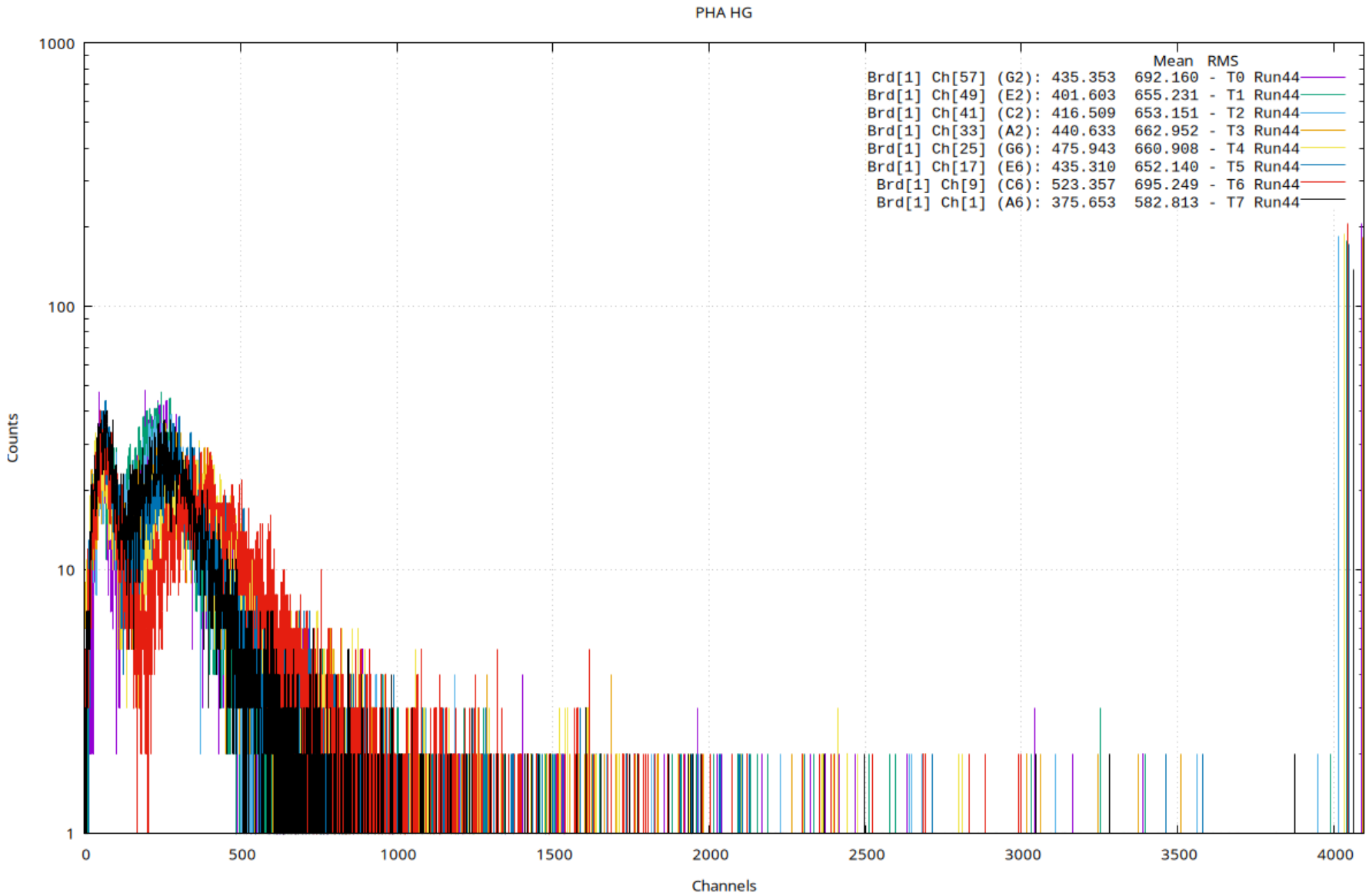

6 EPM
CAEN



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The CAEN Saga pt3: Fighting TDLinks

- Found the signal, but readout very unstable
  - Crashing every 0-5 minutes
  - Most likely due to instabilities in “TDLink” between units
- Suspected temperature issues
  - Stripped all CAEN units of their casing and forced air through everything
- Contacted CAEN, had Zoom meeting with their engineers Friday afternoon: no result
  - New firmwares available with CRC checks, but made things way worse
- The mood got considerably worse at this point.

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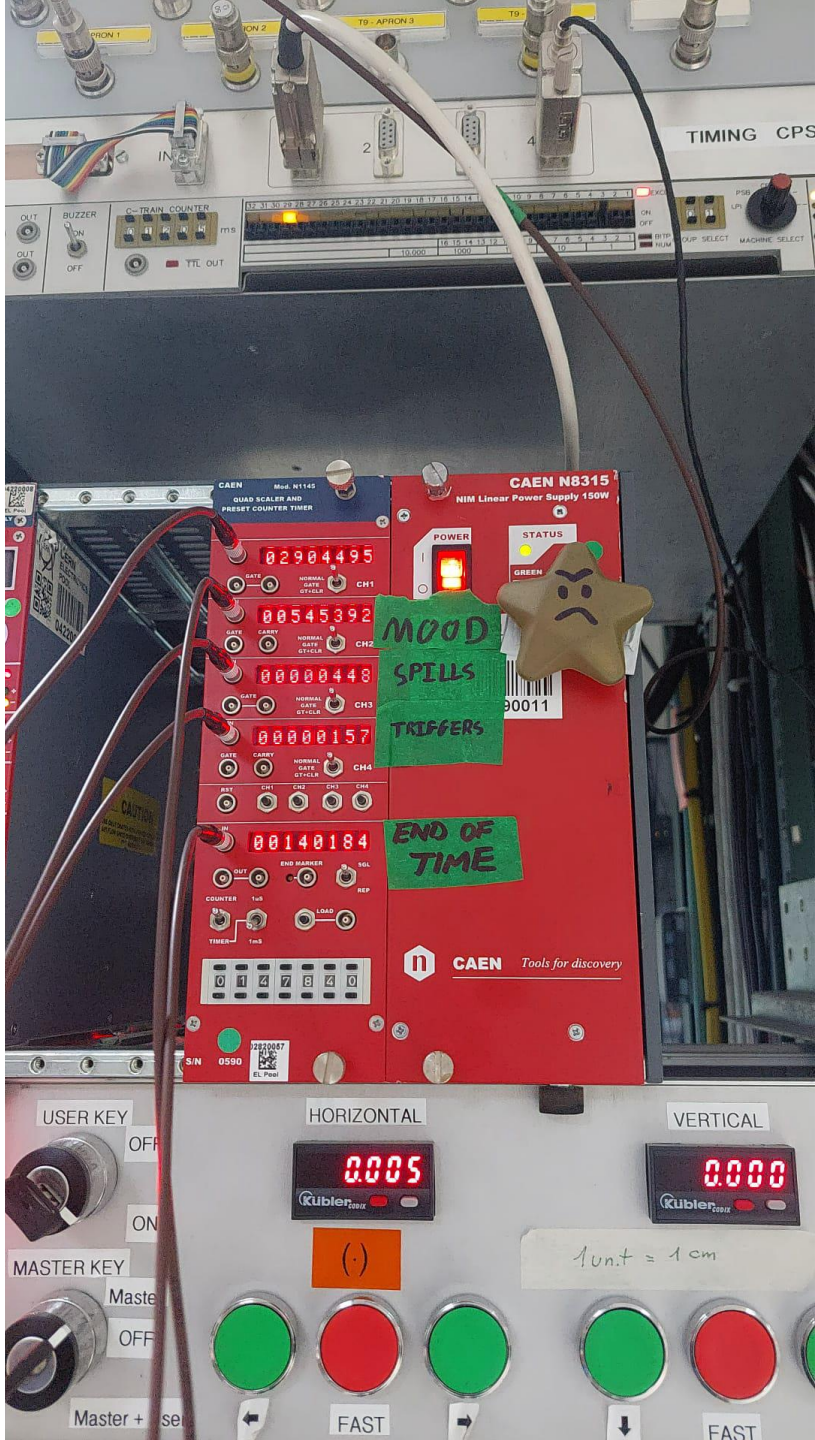
pt4: Happily Ever After

- Run without data concentrator?
  - DT5202 can be run individually in “parallel” via ethernet.
  - Asynchronous, but we distribute synchronous external triggers…
- That actually worked…
  - Needed some minor adjustments in trigger holdoff (maximum 600ish triggers per spill)
  - Shifter needs to make **really** sure all runs are started in between spills.
  - Otherwise no more major issues.



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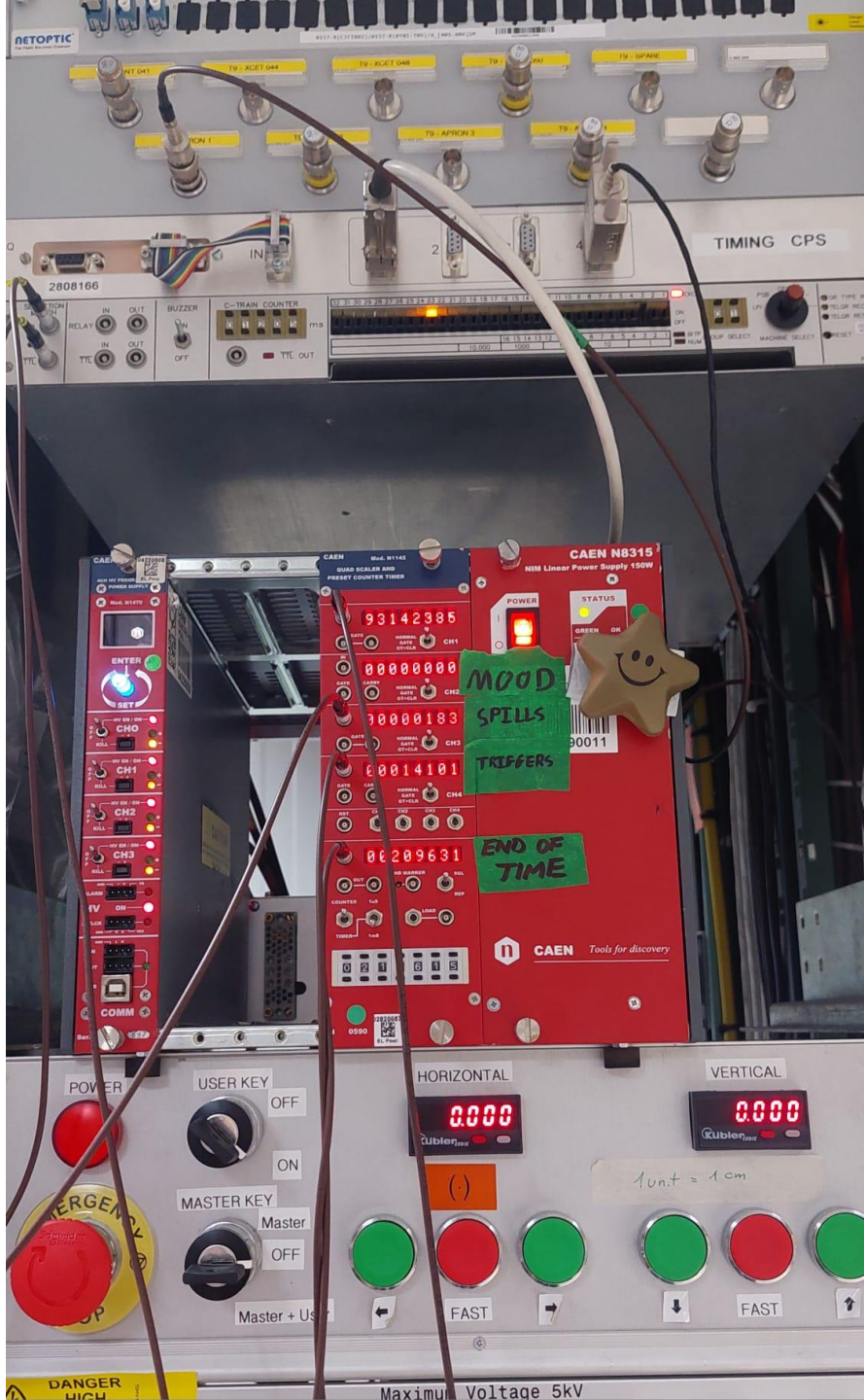
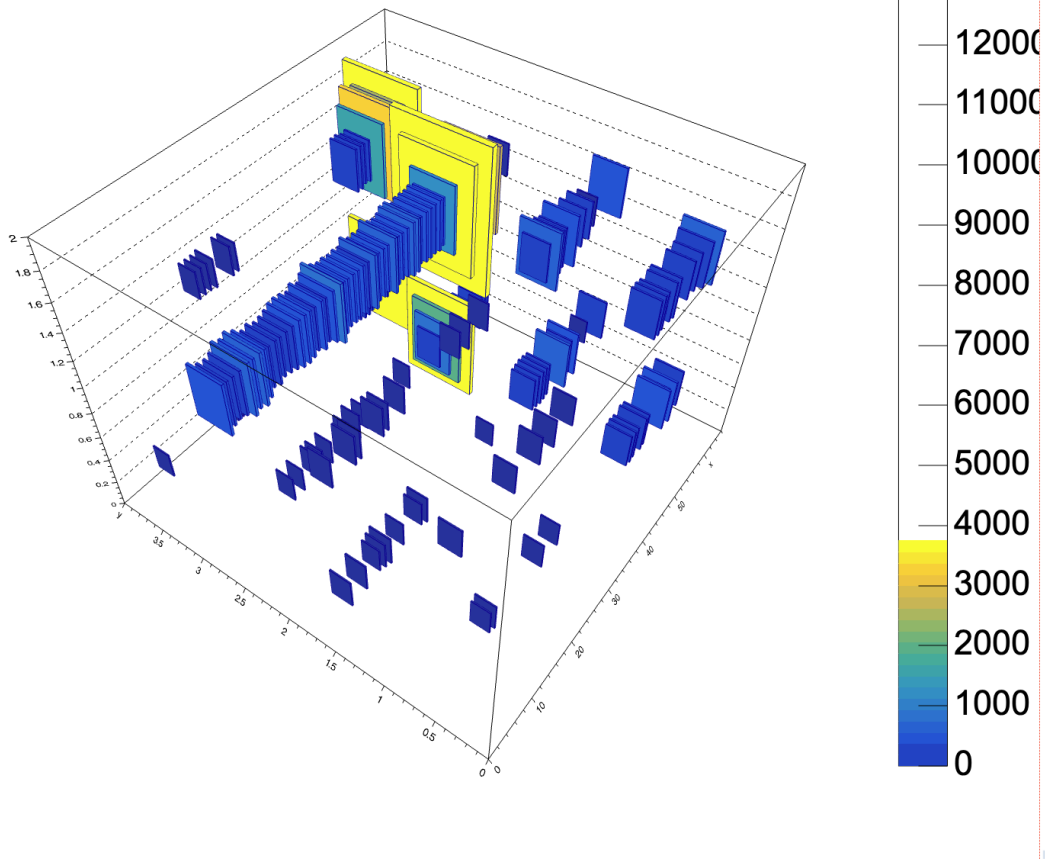
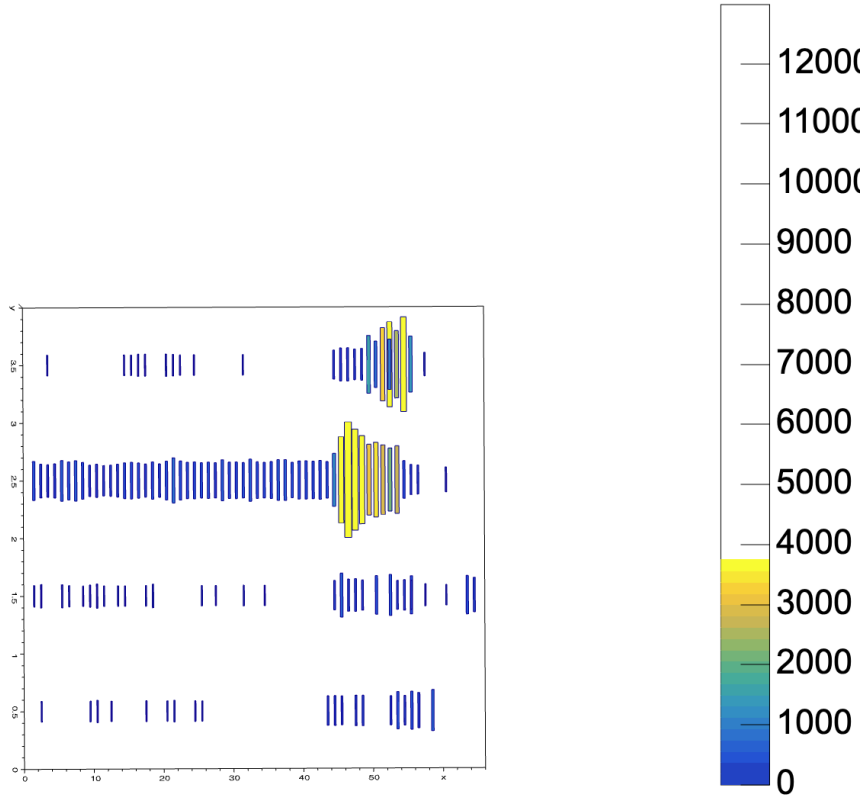


Event Display



Event Display



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CAEN Run Summary

- 4.5days of full-time data.
- Full muons, electrons, hadrons at 3 SiPM bias voltages
  - Full rerun of 45V bias point at the end for validation
- Muon scan with various shaper settings
  - To intercalibrate beam vs. lab measurements
- Full electron energy scan at 6 SiPM bias points total
  - Including dedicated muon calibrations before and after each electron scan
- All QA'd by Tristan's live data monitor (modified for CAEN)

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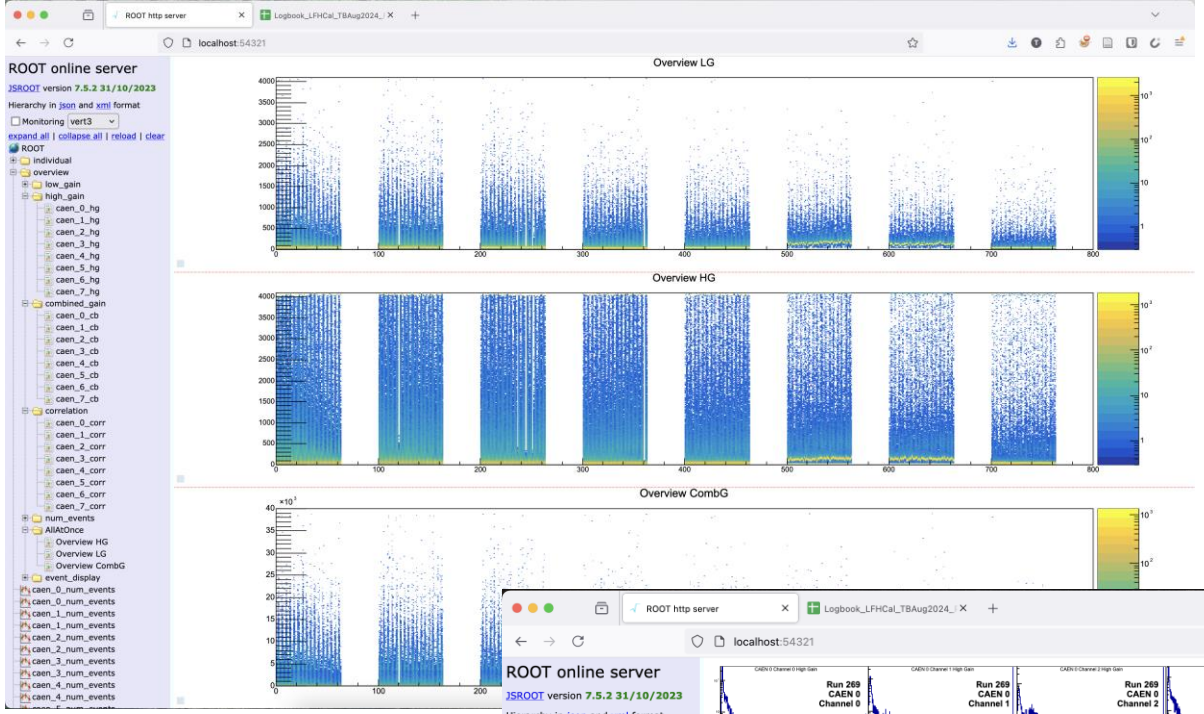

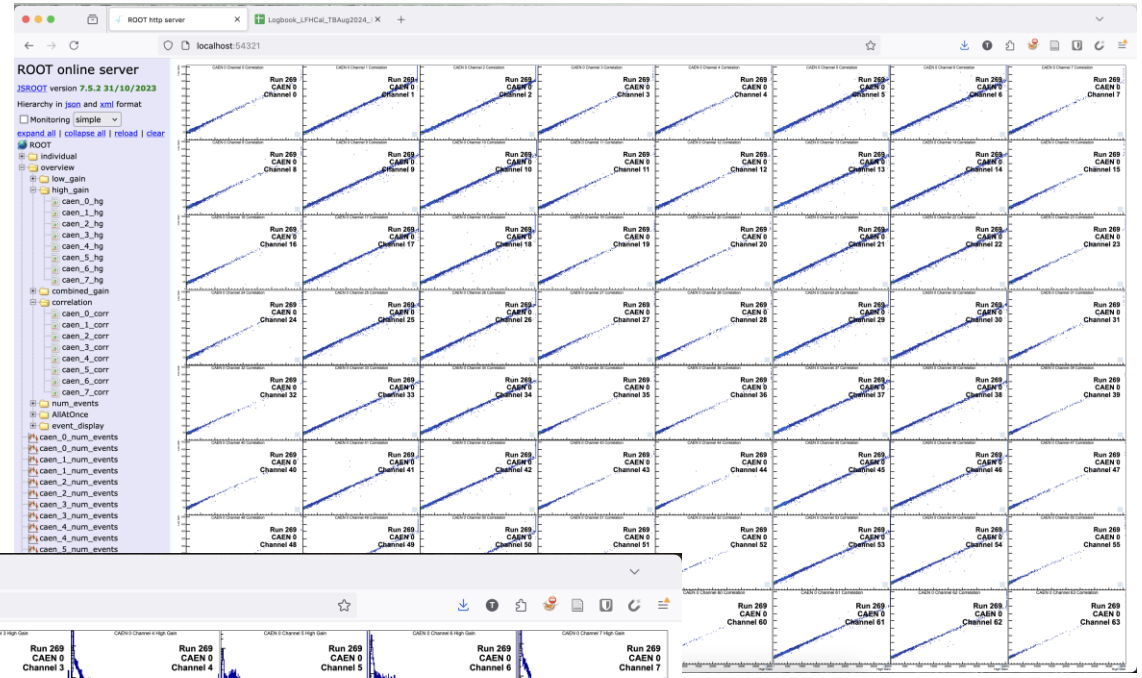

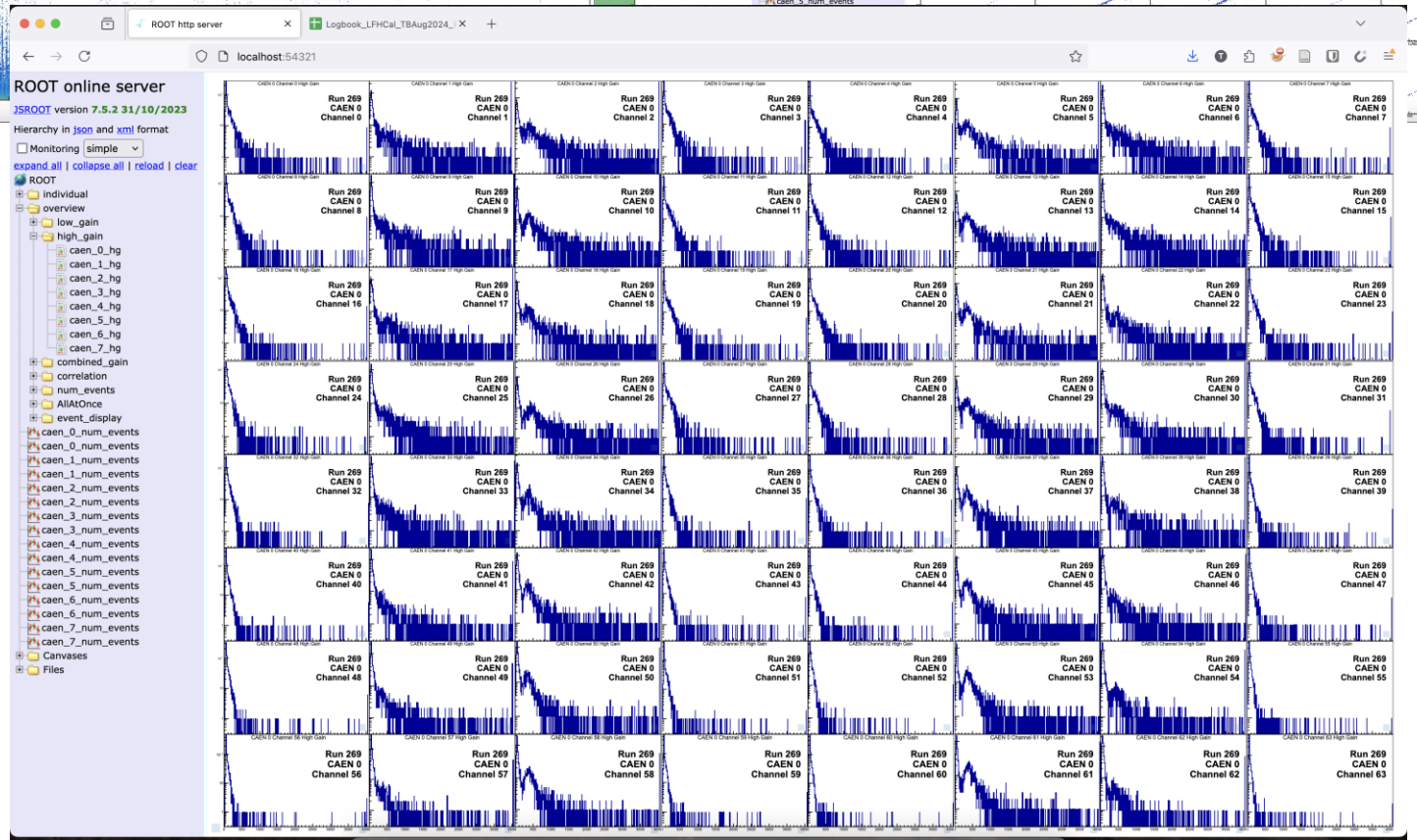

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Shifters Summary

- Strong participation of various ePIC member institutes
  - Thanks to Fredi's tireless advertisement and "encouragement" to join
- Special thanks for support from ALICE FOCAL experts

Name			Friederike Bock	Norbert Novitzky	Fernando Flor	Thibor Bernardon	Tristan Protzman	Stepan Obraztsov	Clément Delafosse	Matt Nguyen	Olivier Le Dortz	Carlos Munoz	Shihai Jia	Bobae Kim	Archita Dash	Miklos Czeller	Charlotte van Hulsen	Peter Steinberg	Oskar Hartbrich	Vincent Andrieux	Wenliang (Bill) Li	Ton van de Brink	Tommaso Isidori	Nicola Minafra
Institute			ORNL	ORNL	Yale	UTK	Lehigh	LLR/CERN	IJCLab	LLR	LLR	IJCLab	Copenh.	ANL	Muenster	Debrezen	UAH	BNL	ORNL	UIUC	MSU	Nikhef (engineer)	KU	KU
Mon	26.8.																					setup		
Tue	27.8.																					setup		
Wed	28.8.																					setup		
Thu	29.8.																					no shifts		
Fri	30.8.																					no shifts		
Sat	31.8.																					no shifts		
Sun	1.9.	HGCROC readout + EEMC prototype																				no shifts		
Mon	2.9.																					no shifts		
Tue	3.9.																					no shifts		
Wed	4.9.																					no shifts		
Thu	5.9.			FoCal TB																		no shifts		
Fri	6.9.			FoCal TB																		no shifts		
Sat	7.9.			FoCal TB																		no shifts		
Sun	8.9.			FoCal TB																		no shifts		
Mon	9.9.	CAEN readout + EEMC prototype if need be		FoCal TB																		no shifts		
Tue	10.9.			FoCal TB																		no shifts		
Wed	11.9.			FoCal TB																		dismount?		
Thu	12.9.																							
Fri	13.9.																							

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Summary

- Testbeams never work as planned.
  - Always stressful, but ultimately always quite fun
- Nevertheless very successful campaign
  - Thanks to **incredible** support from many groups and people!
- All data backed up locally and on grid courtesy of Bill Li.
- Testbeams are bad for your diet.
- Additional resources

The 2025 Testbeam

- May (?) 2025: 8 fully equipped LFHCAL modules
  - 40cmx40cm, almost enough to contain hadron showers…
  - Full readout scheme test: HGCROC, summing boards
- 8x more of everything
  - Challenge in construction, setup, QA…
  - … and then we need to do two more order of magnitude steps up towards full ePIC LFHCAL
- Software and simulation efforts from 2024 beam will enable 2025 analysis…
  - Moving towards implementing test beam analysis in eicsoft/eicrecon

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CPAD 2024

- CPAD 2024 in Knoxville, TN!
  - November 19-22
  - Co-hosted by UTK and ORNL
- Extended abstract submission deadline 10/04 (this Friday!)