

Friederike Bock (ORNL)
January 26, 2026

LFHCal TB meeting

Test Beam - November 2025 - setup

Requested time: 1 week

Main purpose: Resolution studies & longitudinal shower development

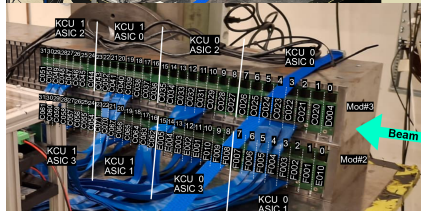
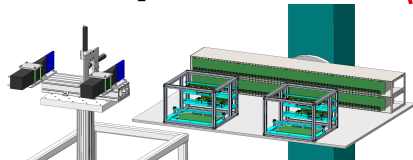
Location: CERN PS (19th Nov.)

Setup:

- Very similar to 2024 setup, with more modules
- 2 full 8M modules (20x20x130cm)
- Readout with H2GCROCs
- 512 channels (8 HGCROCs), 1.3mm SiPMs

Main expected measurements:

- Energy resolution for electrons
- Longitudinal shower development
- Final-Flexible PCB validation



Key differences to last year:

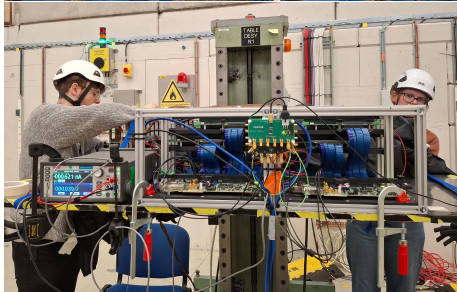
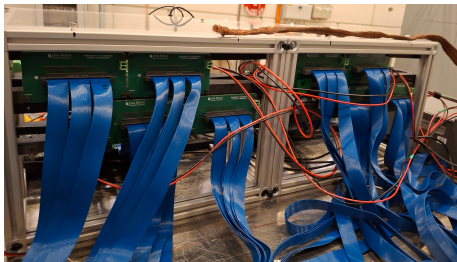
- 2 modules, but same number of RO-channels
- New firmware enabling:
 - ▶ 2 Proto-boards per KCU
 - ▶ 10 GB ethernet transfer KCU to DAQ PC
 - ▶ New UDP data format

Why did we request the new firmware?

- Last year significant problem with synchronization of 4 KCUs and full event building after packet losses over UDP connection
- Significantly rate limited at PS/SPS otherwise
- Data format more efficient and easier to detect packet losses

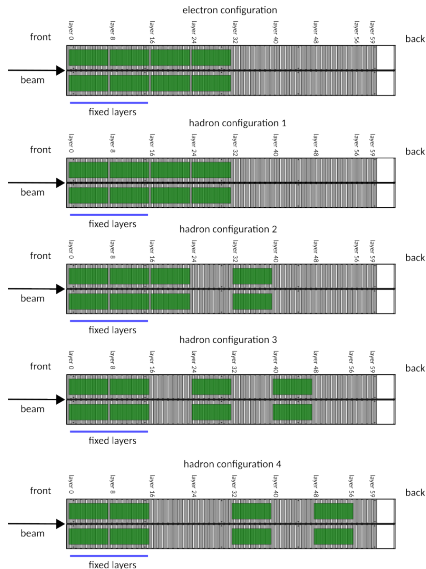
Documentation & How-To

- **How-To starting point**
- Tried to improve documentation in one page (for full TB setup & operation)
- Python based software stack see here: [setup-docu](#)



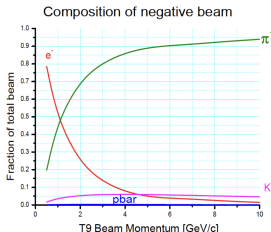
What kind of data did we take?

- **Electron resolution:** 3 sets (Full set A & B, electron set C) at 3 different $V_{op} = 44, 45, 42.5$ V
- **Gain scan:** 2 muon HV scan (41-46 V)
- **Hadron depth scan:** 4 different layer configurations
- **Calibration sets:** for each set of the above
 - ▶ at least 1 full set of muon runs in 4 beam positions (200k each)
 - ▶ at least 1 pedestal run with same settings (10k)
- Full sets A & B also contained hadron data for comparison with same settings

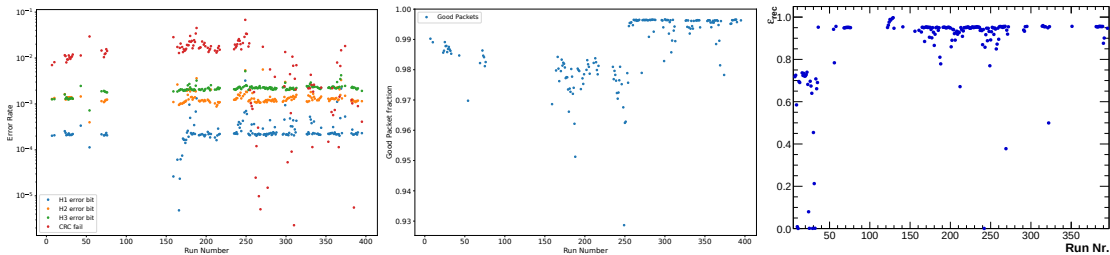


Available species & energy

- μ^+ : 5 GeV
- e^+/e^- : 1, 2, 3, 4, 5 GeV
- h^+/h^- : 3, 5, 8, 10, 12, 15 GeV
- details [TB wiki](#)



What were we able to reconstruct?



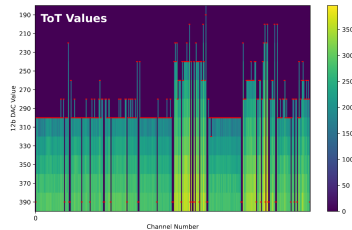
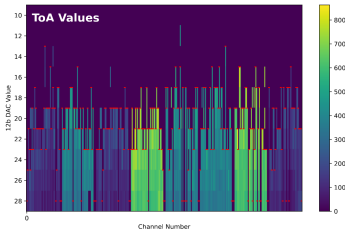
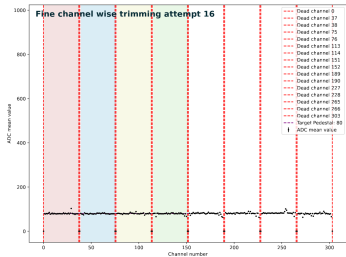
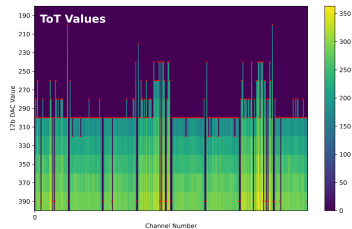
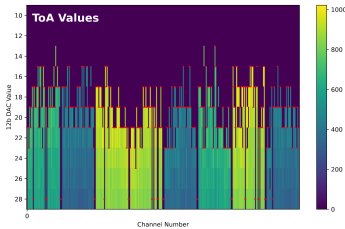
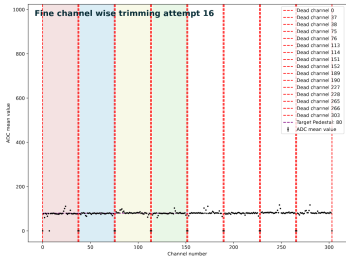
- Several packet level checks during data taking running semi-online:
 - ▶ packet integrity: CRC, hamming codes
 - ▶ packet loss: Do we receive all packets from FPGA (UDP packet ID consecutive?)
 - ▶ Significant losses in beginning due to bug in DAQ for high instantaneous rate → fixed after run 160
- Event building:
 - ▶ a) waveform building (all 11 samples available) per asic & KCU → KCU events
 - ▶ b) both KCUs events reconstructed:
 - ★ based on event ID stored in data-package header
 - ★ possible offset corrected using time difference between first few fully reconstructed events in both KCUs
- Total number of received triggers: 26.8Mio, $\langle \varepsilon_{rec} \rangle = 0.91$ ($>$ run 160)

Online calibrations

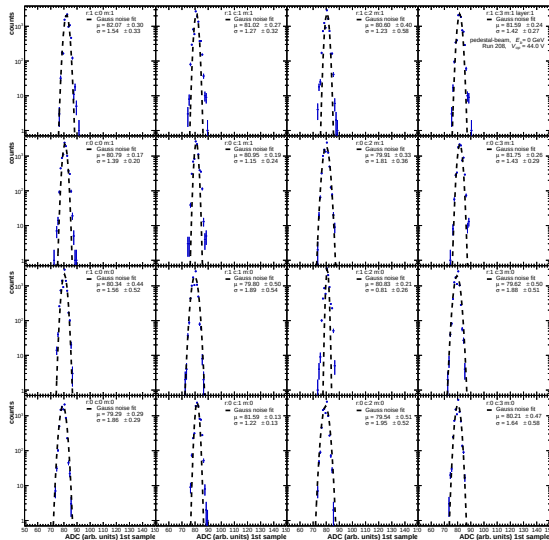
- HGCROC calibrated for only one gain setting ($\text{conv_gain} = 0.3$ (1100)), calibration done with full setup (i.e. SiPMs connected)
- Pedestal target 80 ADC
- ToA threshold set at 20 DAC, ToT threshold set to 300 DAC (this might have been too low)

Offline calibrations

- Pedestal calibration based on random triggers (10k events) for each set ([tutorial](#))
- Max ADC-MIP calibration for every tile/SiPM/channel based on dedicated muon position scans (4 positions, each $\sim 200\text{K}$ events) ([tutorial](#))
- ToA calibration to be implemented
- ToT calibration to be implemented
- Ch-by-Ch calibrations to be applied ([tutorial](#))

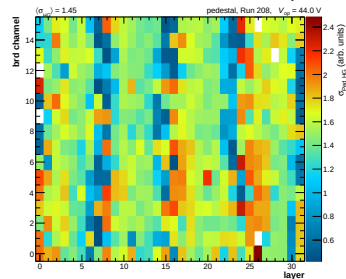
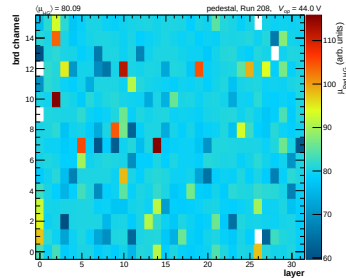


Pedestal Calibration - Full Set A- 2



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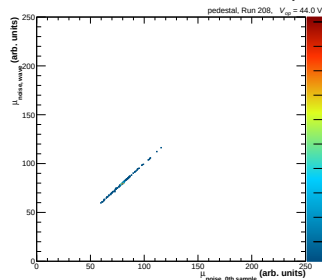
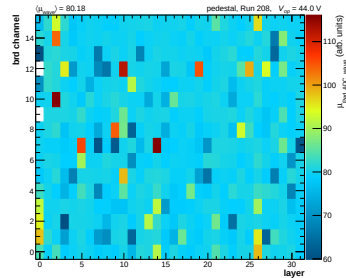
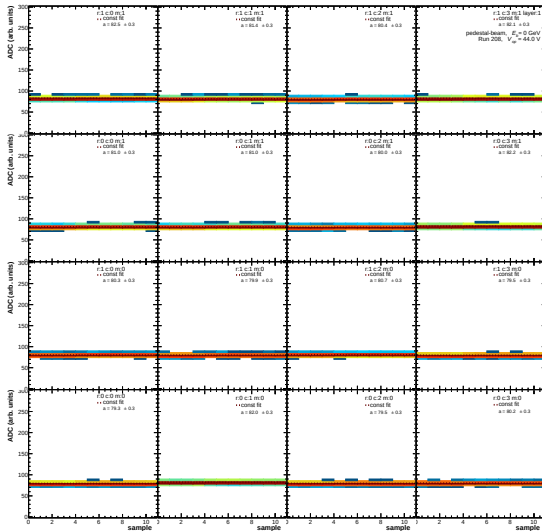
ePIC LFHCaI

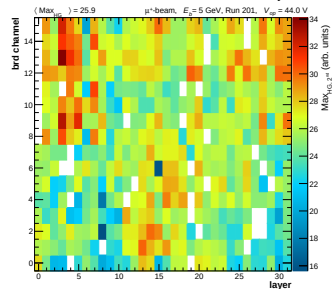
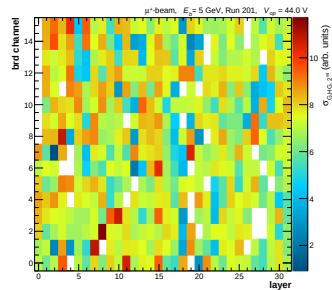
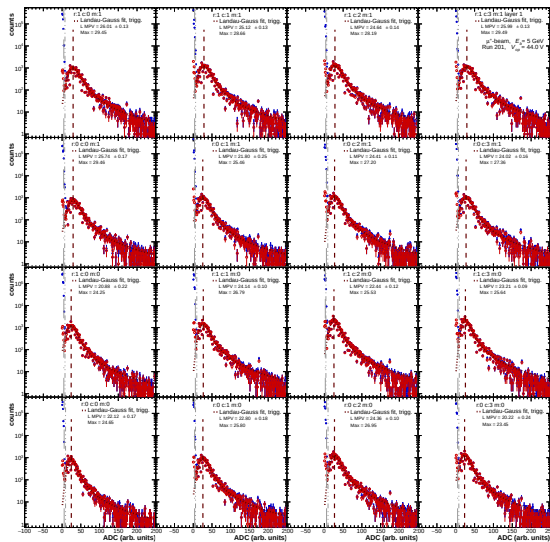


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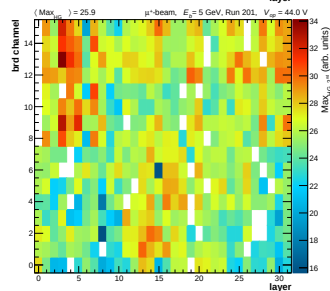
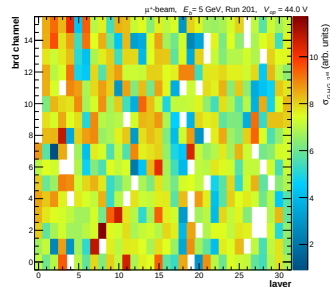
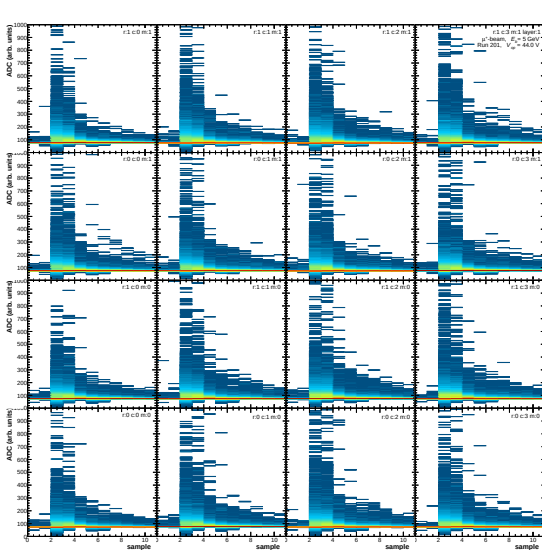
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Pedestal Calibration - Full Set A- 2

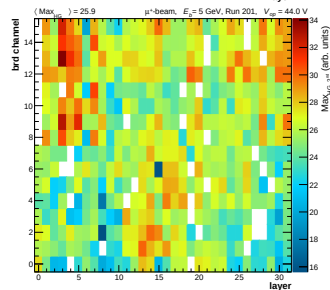
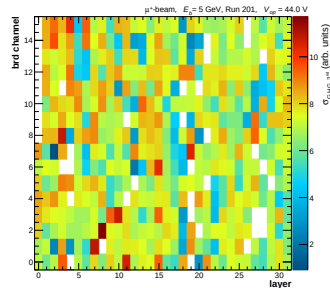
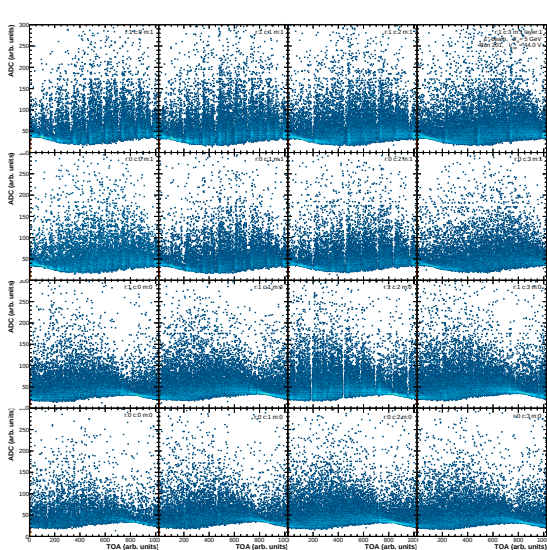




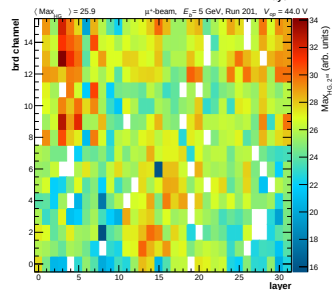
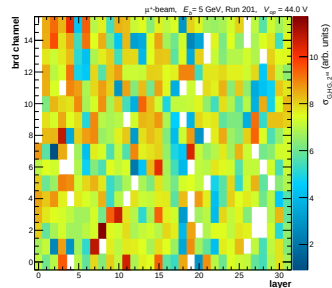
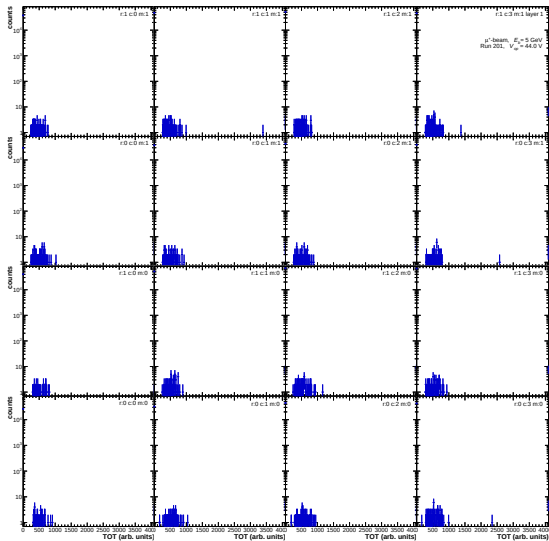
MIP Calibration - Full Set A- 2



MIP Calibration - Full Set A- 2

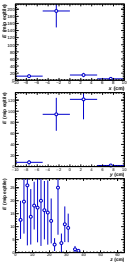
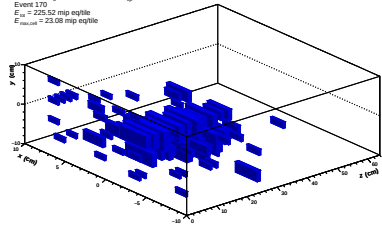


MIP Calibration - Full Set A- 2

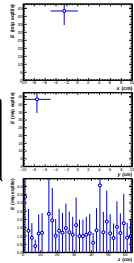
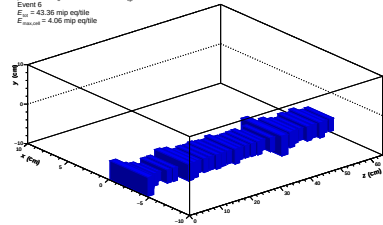


First Calibrated Event Displays

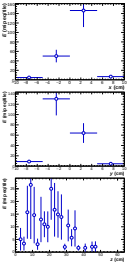
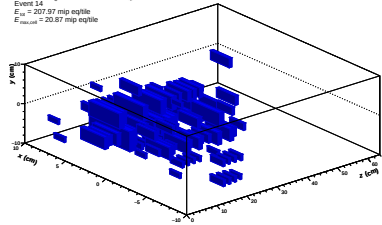
LFHCal TB: CERN-PS -T09, 11-2025, HGCROC read-out
 e^- -beam, $E_b = 5$ GeV, Run 170, $V_{dr} = 44.0$ V
 Event 170
 $E_{tot} = 225.52$ mip eq/tile
 $E_{miss,0.05} = 23.08$ mip eq/tile



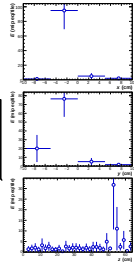
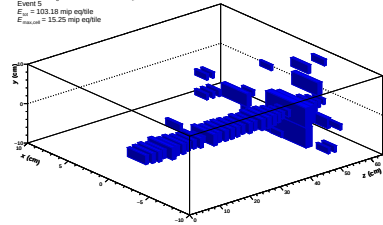
LFHCal TB: CERN-PS -T09, 11-2025, HGCROC read-out
 μ^+ -beam, $E_b = 5$ GeV, Run 69, $V_{dr} = 44.0$ V
 Event 6
 $E_{tot} = 43.36$ mip eq/tile
 $E_{miss,0.05} = 4.06$ mip eq/tile



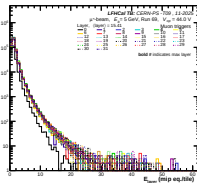
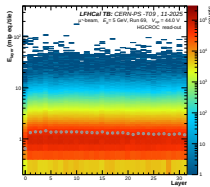
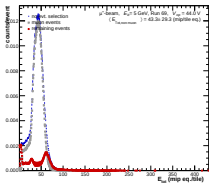
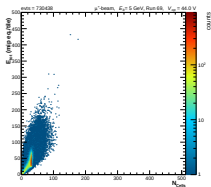
LFHCal TB: CERN-PS -T09, 11-2025, HGCROC read-out
 e^- -beam, $E_b = 5$ GeV, Run 175, $V_{dr} = 44.0$ V
 Event 14
 $E_{tot} = 207.97$ mip eq/tile
 $E_{miss,0.05} = 20.87$ mip eq/tile



LFHCal TB: CERN-PS -T09, 11-2025, HGCROC read-out
 e^- -beam, $E_b = 5$ GeV, Run 177, $V_{dr} = 44.0$ V
 Event 5
 $E_{tot} = 103.18$ mip eq/tile
 $E_{miss,0.05} = 15.25$ mip eq/tile

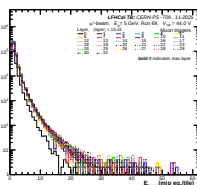
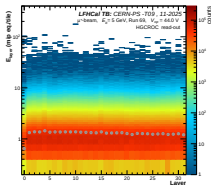
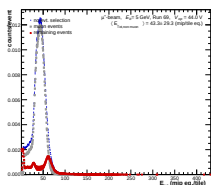
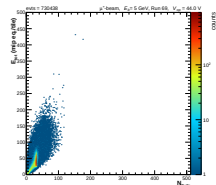


First Look at MIP calibrated data

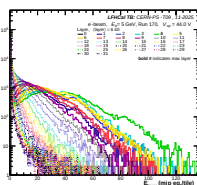
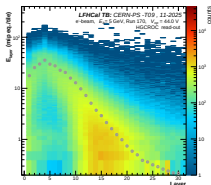
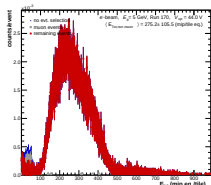
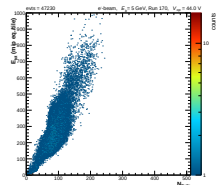


μ beam 5 GeV

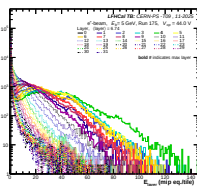
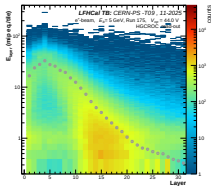
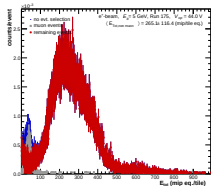
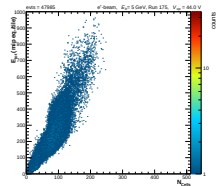
First Look at MIP calibrated data



μ beam 5 GeV

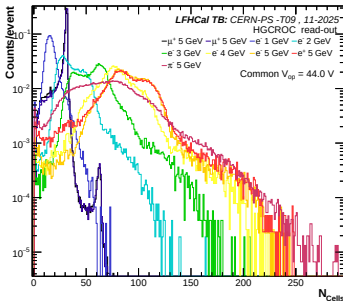
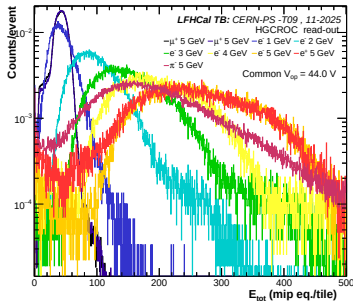


e^- beam 5 GeV



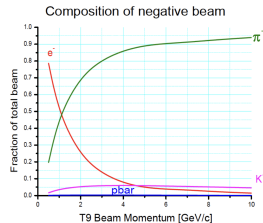
e^+ beam 5 GeV

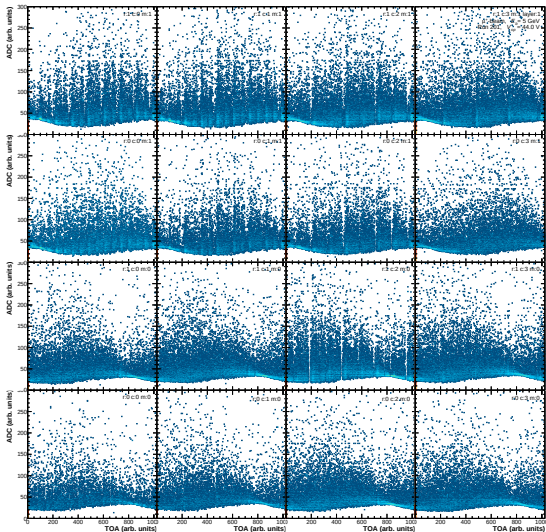
First Look at MIP calibrated data - Full Set A



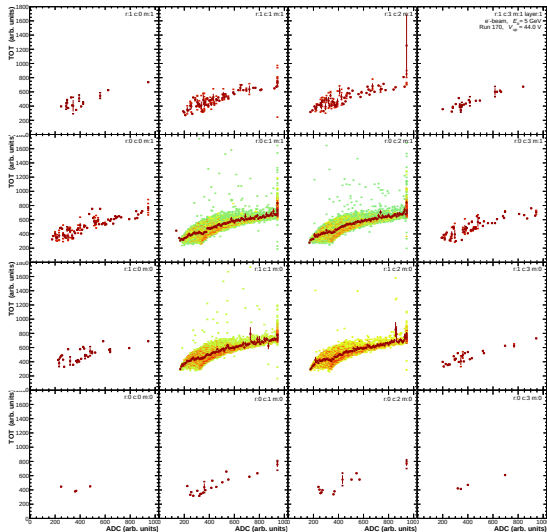
- E_{tot} estimated purely based of max ADC in 1 sample (same as for MIP calibration)
- No specific event selection done (except attempt at muon rejection)
- Significant contamination in all beam types $\rightarrow$ need to disentangle particle types, beam hit positions...

QA looks encouraging, but long way to go!

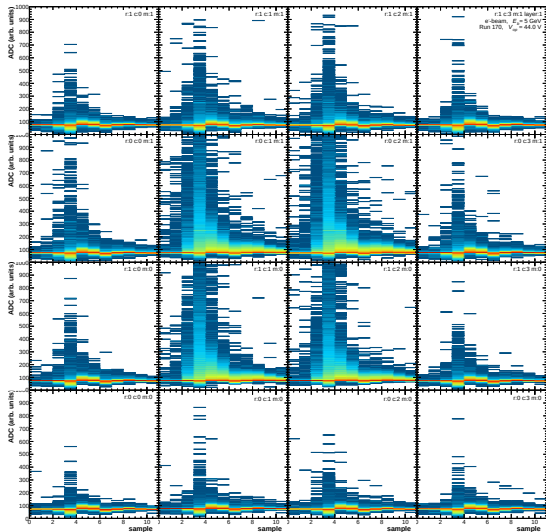




- ToA and ToT online calibration thresholds not optimally chosen
 - ▶ ToA calib at 20 DAC did not succeed for all channels, ToA phase not aligned, not all mips trigger ToA
 - ▶ ToT calib at 300 DAC too low, very large overlap with ADC range & possible saturation for highest signals even in ToT
- Observe crosstalk in fraction of data, need to disentangle possible sources
 - ▶ SiPM flex board
 - ▶ Connector boards (flex end & proto board end) & high density cable
 - ▶ Proto board
 - ▶ HGCROC

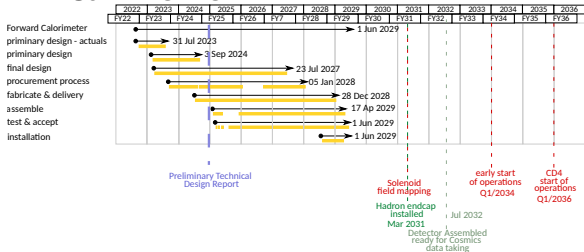


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LFHCaI timeline



Lots of data to analyse!

Next beam time is coming fast!

