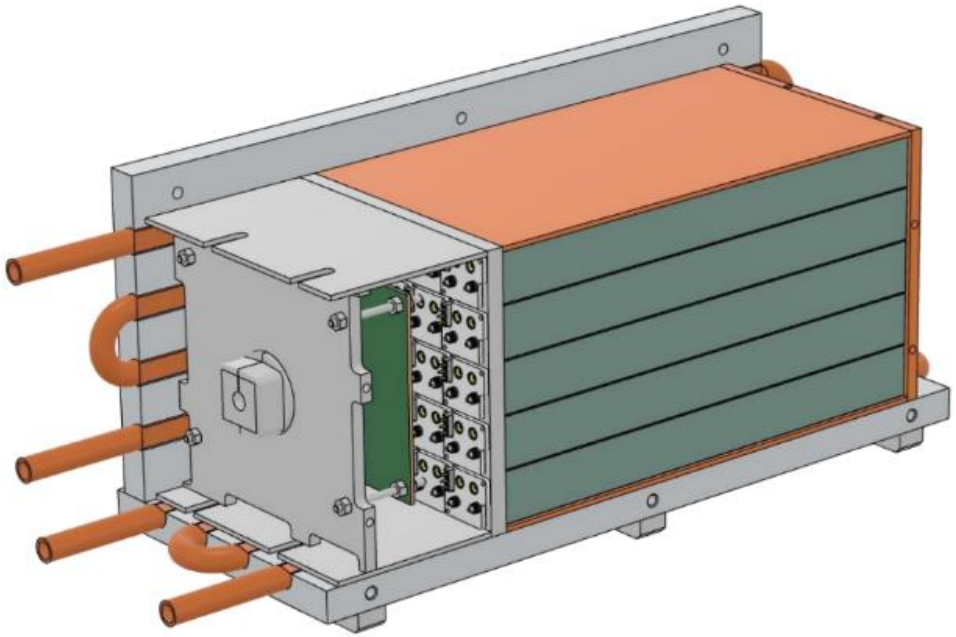


Lead tungsten calorimetry for the Electron-Ion Collider:

first beam test results

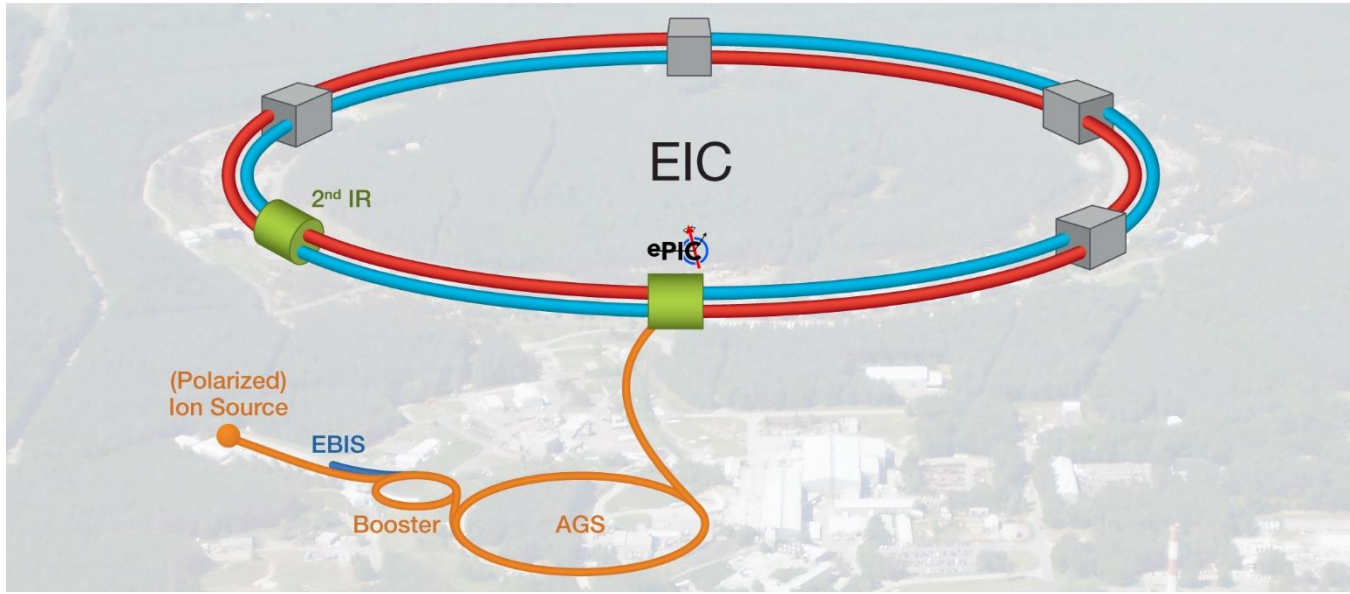
Carlos Muñoz Camacho

IJCLab

AG GDR GI2I, June 19 (2025)

The EIC facility at BNL (NY, U.S.A.)

- Highly polarized electron / Highly polarized proton and light ions /Unpolarized heavy ions
- CME: ~ 20–140 GeV
- Luminosity: ~ $10^{33\text{-}34}$ $cm^{-2}s^{-1}$



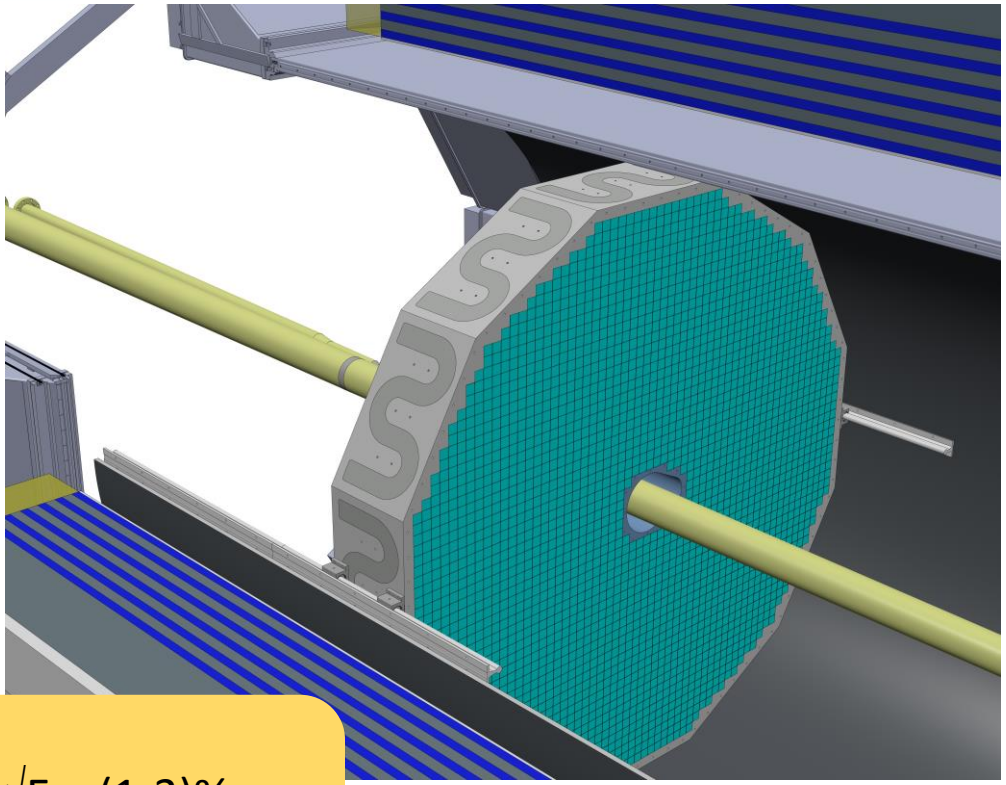
EIC detector milestones

- **Dec 2021:** Detector design
- *Currently:* *Detector R&D*
- End 2025: TDR completed (CD-3), start of construction
- 2030: Detector commissioning
- 2031: Pre-ops
- 2034: Start of physics program (CD-4)

- ❑ Polarized proton beams and ion beams based on existing RHIC facility
- ❑ 2 detector interaction points capability in the design

Backward ECal in ePIC (EIC detector)

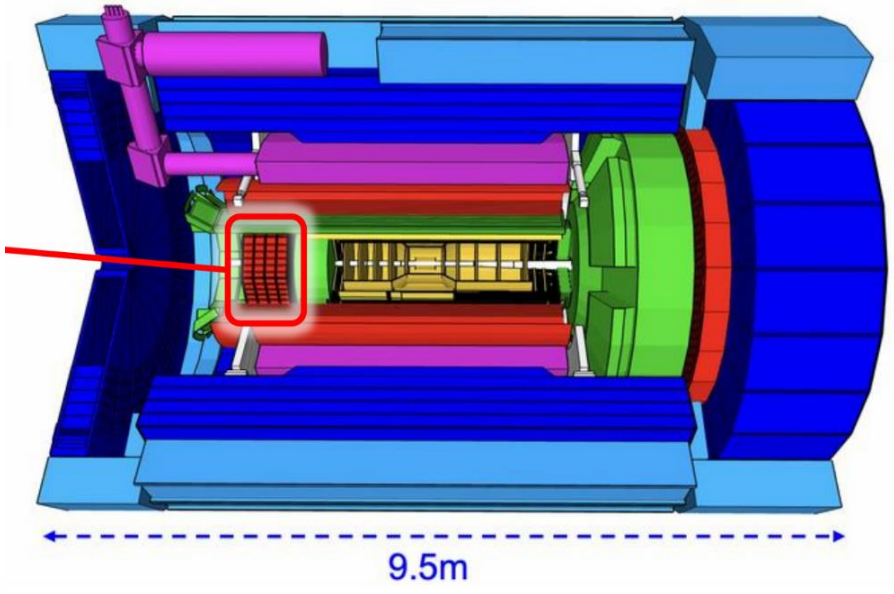
- ~3000 PWO crystals
- SiPM readout
- Cooling
- LED monitoring



High resolution in the forward region (endcap) can only be achieved with homogeneous materials, such as crystals

Requirements:

- Energy resolution: $2\%/\sqrt{E} + (1\text{-}3)\%$
- Pion suppression: $1{:}10^4$
- Minimum detection energy: > 50 MeV

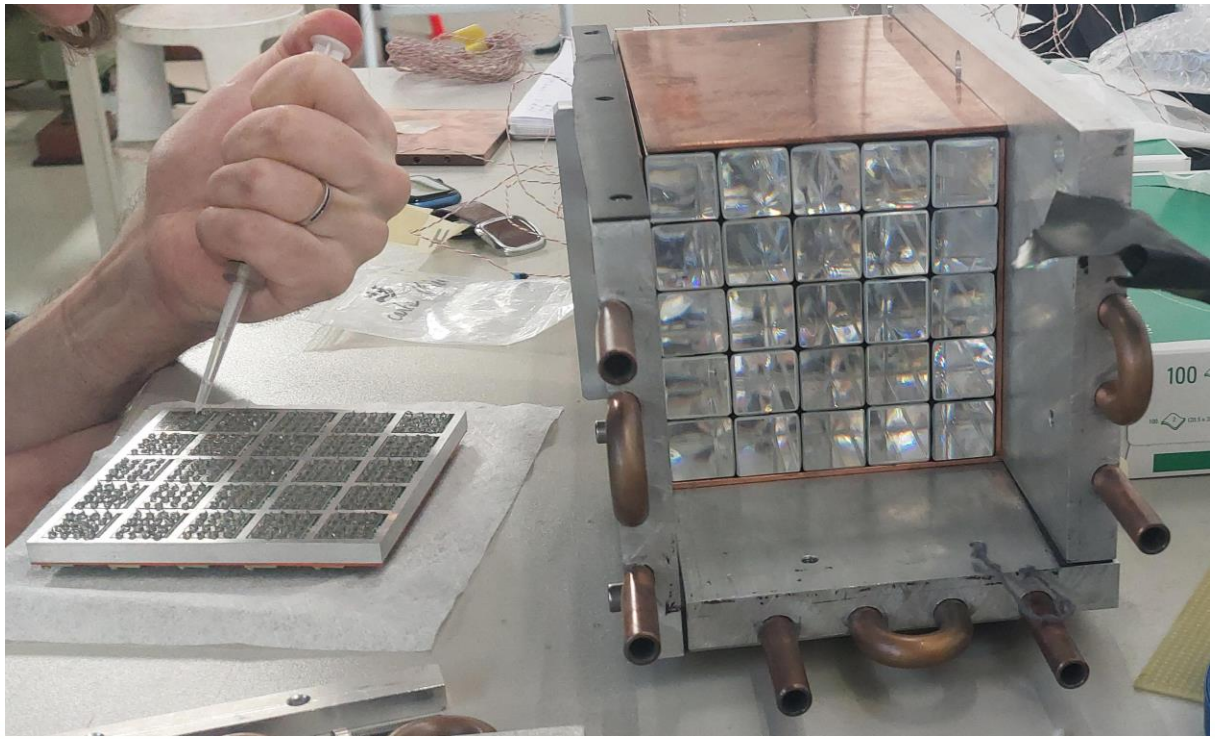


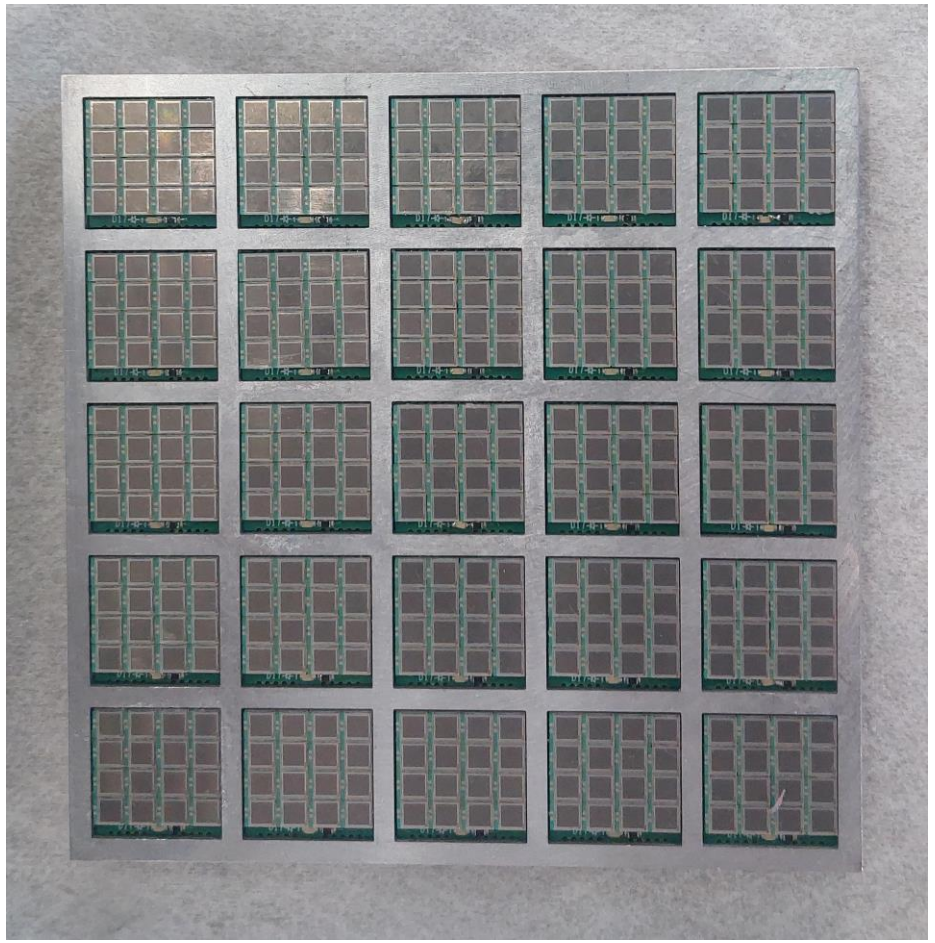
Technology choice: PWO crystals (2x2 cm^2) with high density SiPM (16 3x3 mm^2 or 4 6x6 mm^2 per crystal)

5x5 PWO prototype with 16 SiPMs per crystal

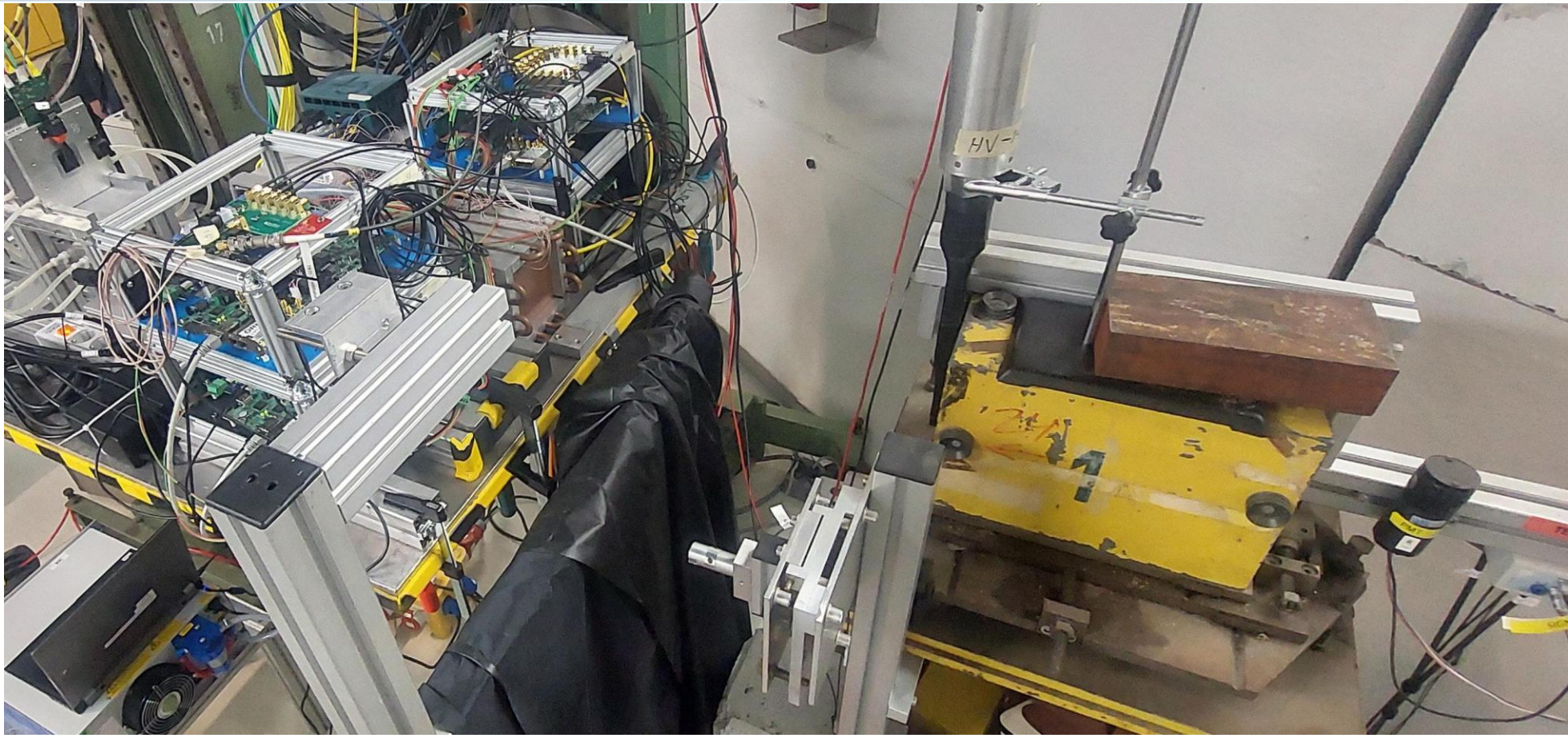
SiPMs: Hamamatsu S14160-3015PS
(3x3 mm^2; 15μm pixel size)

- 25 PWO crystals from CRYTUR
- SiPM readout
- Cooling and temp control



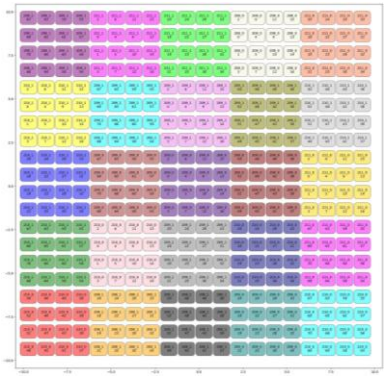


Setup at T24 in DESY test beam facility



- 1 – 5 GeV electron beam through a 2x2 mm^2 collimator
- Triggered by 2 scintillators
- Typical DAQ rates: ~50-100 Hz
- Prototype on a X-Y table with 0.1 mm position accuracy

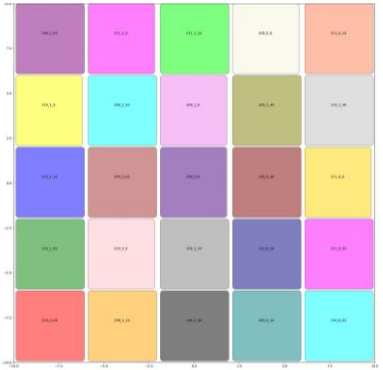
Readout options tested



- Each SiPM individually
- 400 channels
- 530 pF per channel

- SiPMs grouped by 4 in a crystal
- 100 channels
- 2120 pF per channel

- All 16 SiPM in a crystal read in parallel
- 25 channels
- 8480 pF per channel



- All 16 SiPM in a crystal read in parallel
- 25 channels
- 8480 pF per channel

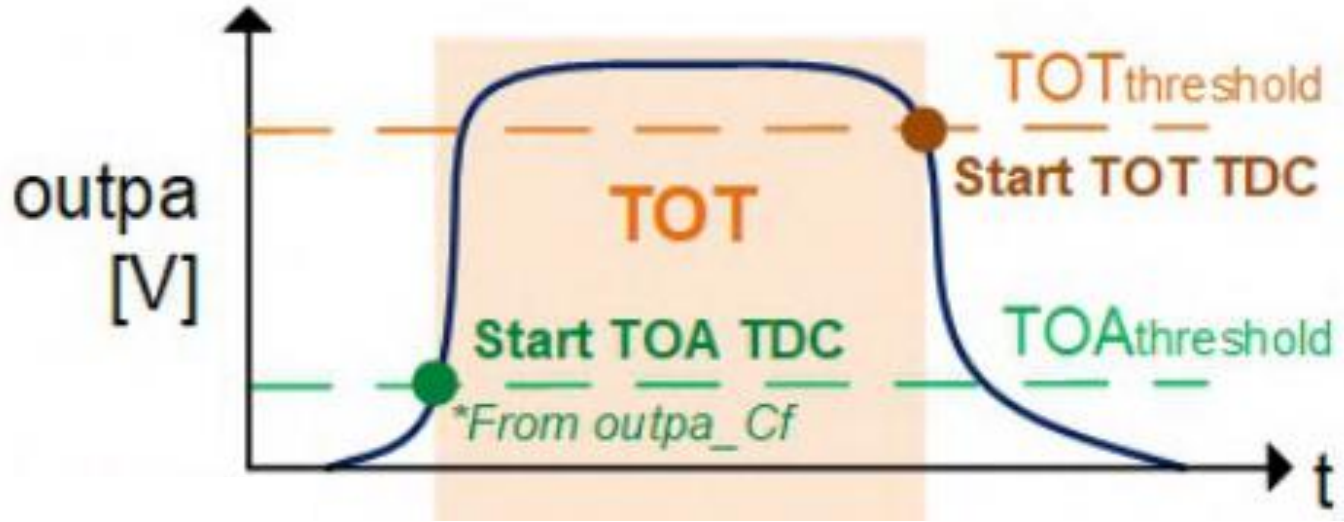
+ Readout with H2GCROC3b chip

+ preamp board &
CAEN V1725S 14-bit 250MS/s digitizers

ADC vs TOT

Energy measurement by a combination of a:

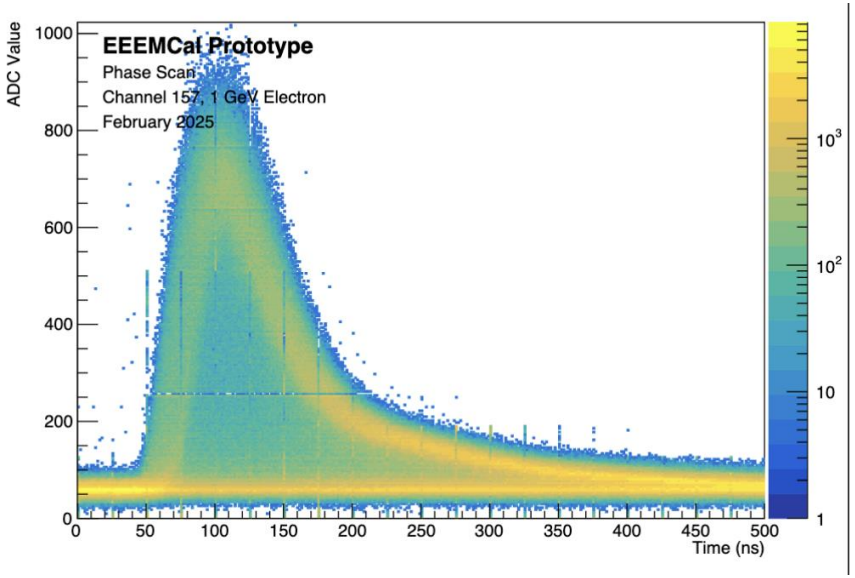
- 10-bit ADC (for small signals) and a
- 12-bit TDC (for large signals)



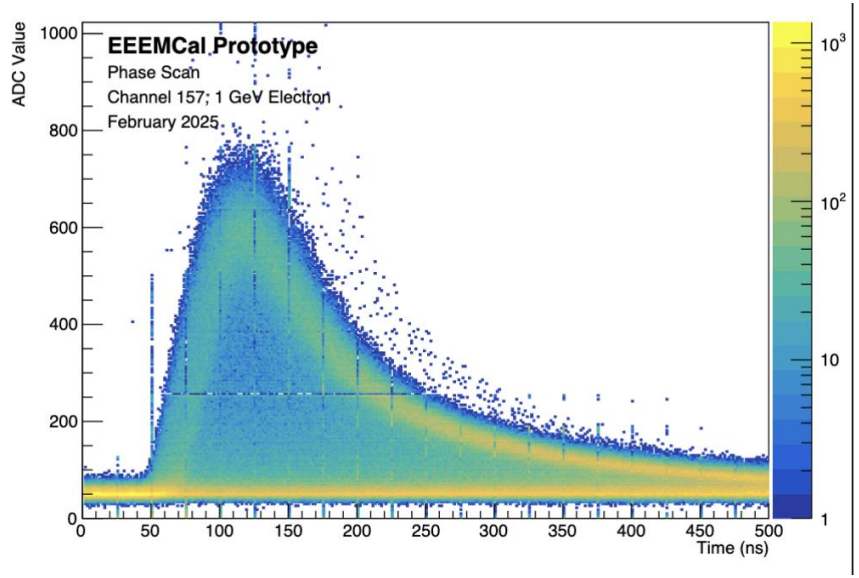
SiPM signal shapes

- HGCROC can sample the signal at 40 MHz (every 25 ns)
- We can scan the phase between the trigger and the sampling clock for finer time resolution

16-independent readout



4x4 readout



16-parallel readout

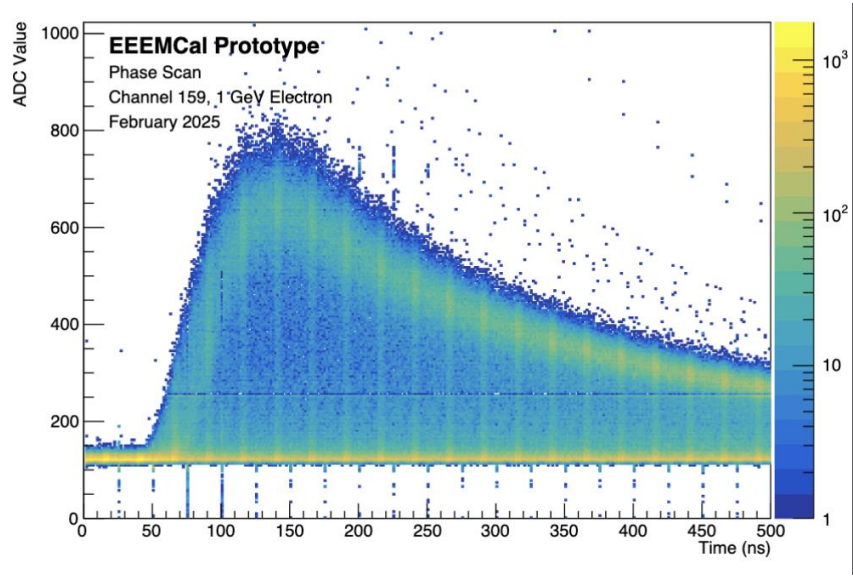
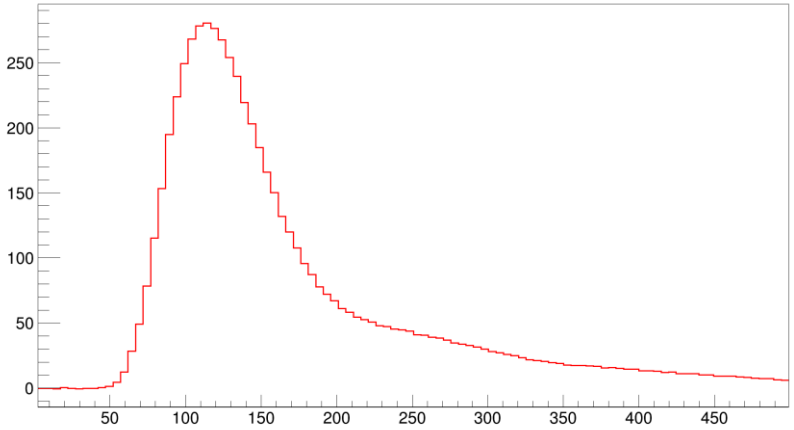
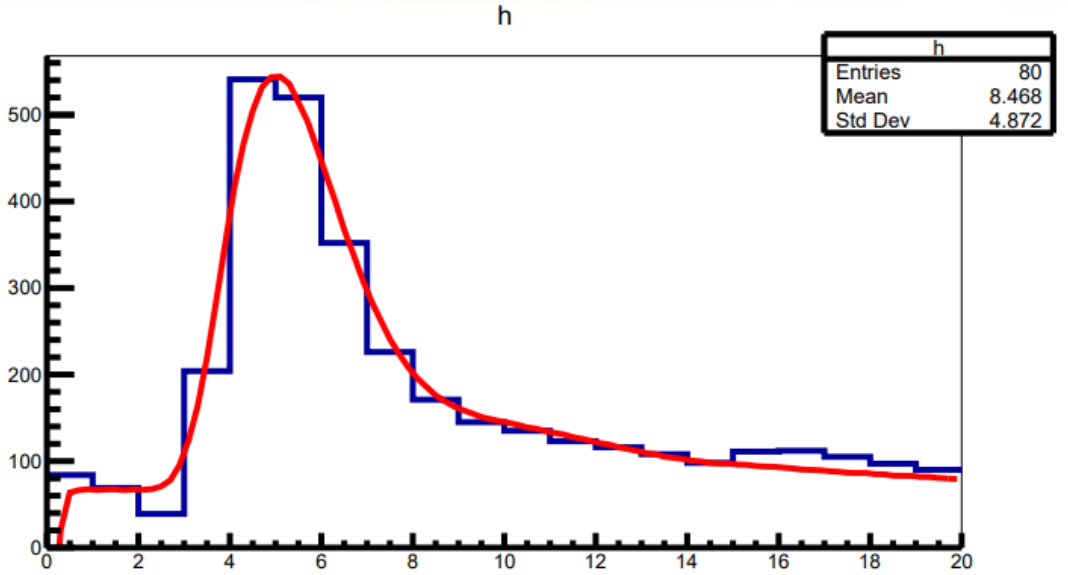


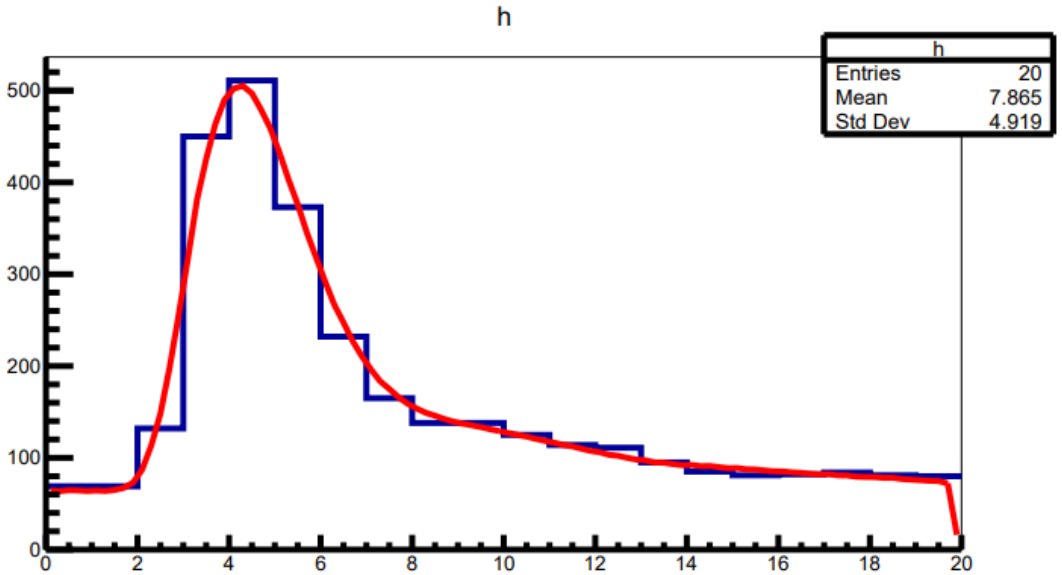
Figure 22: Waveform measured in a phase scan for each of the different daughther boards: all independent (left), 4×4 (center) and all parallel (right). The value of Rf is 1100 (6.7 KOhm). The current conveyor gain is 0.3 (left), 0.1 (center) and 0.05 (right).

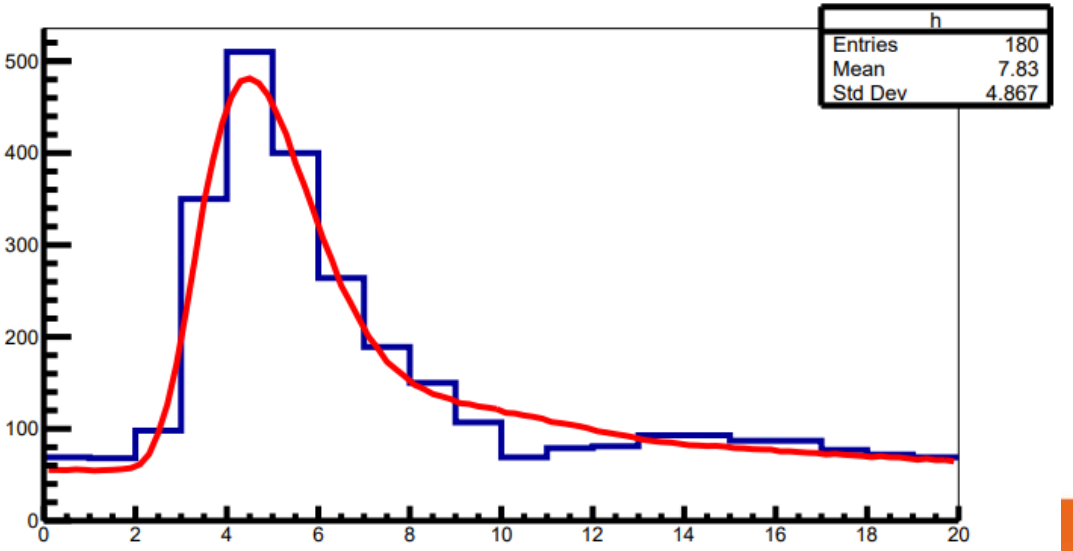
Waveform fits

Reference shape for the fits



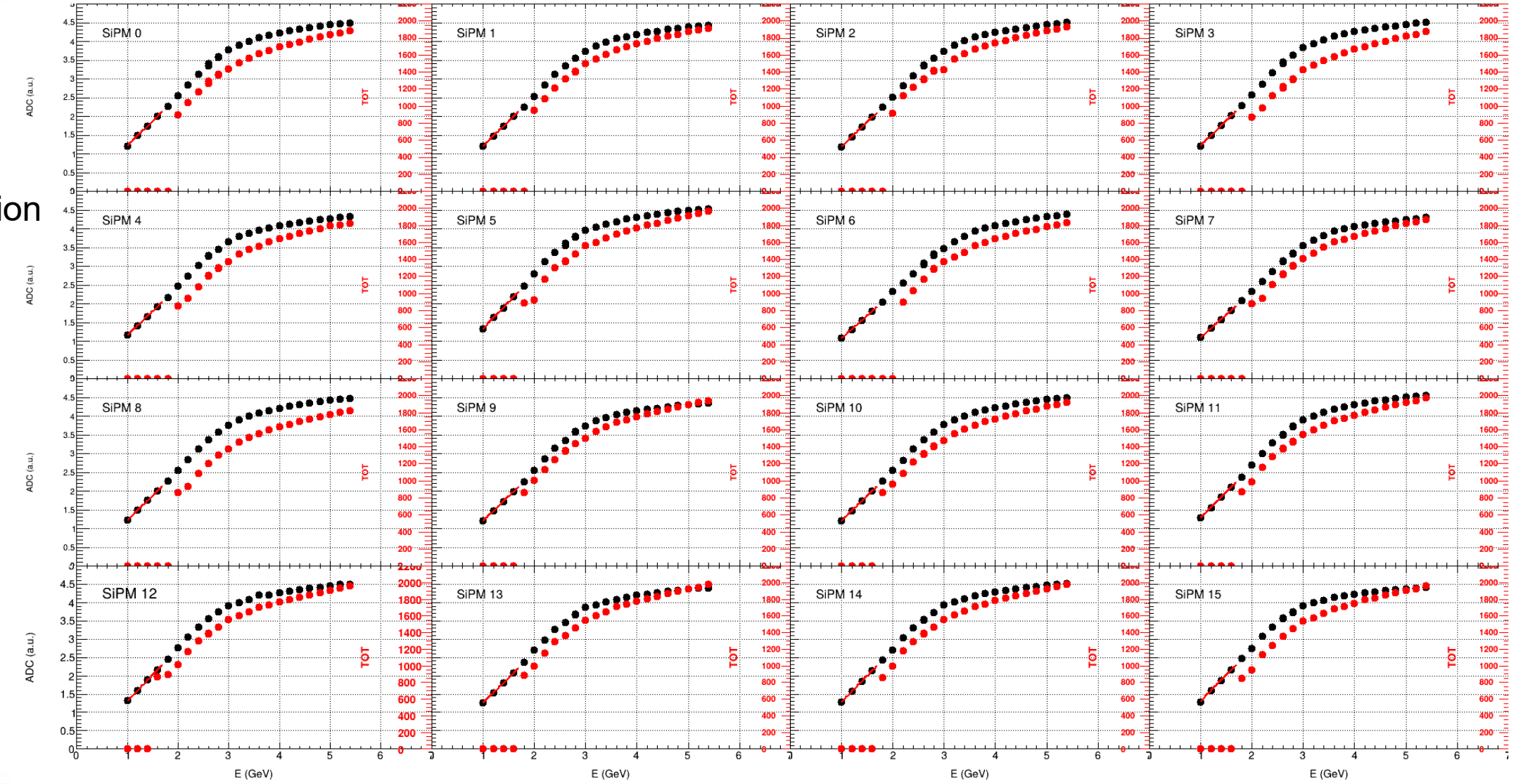




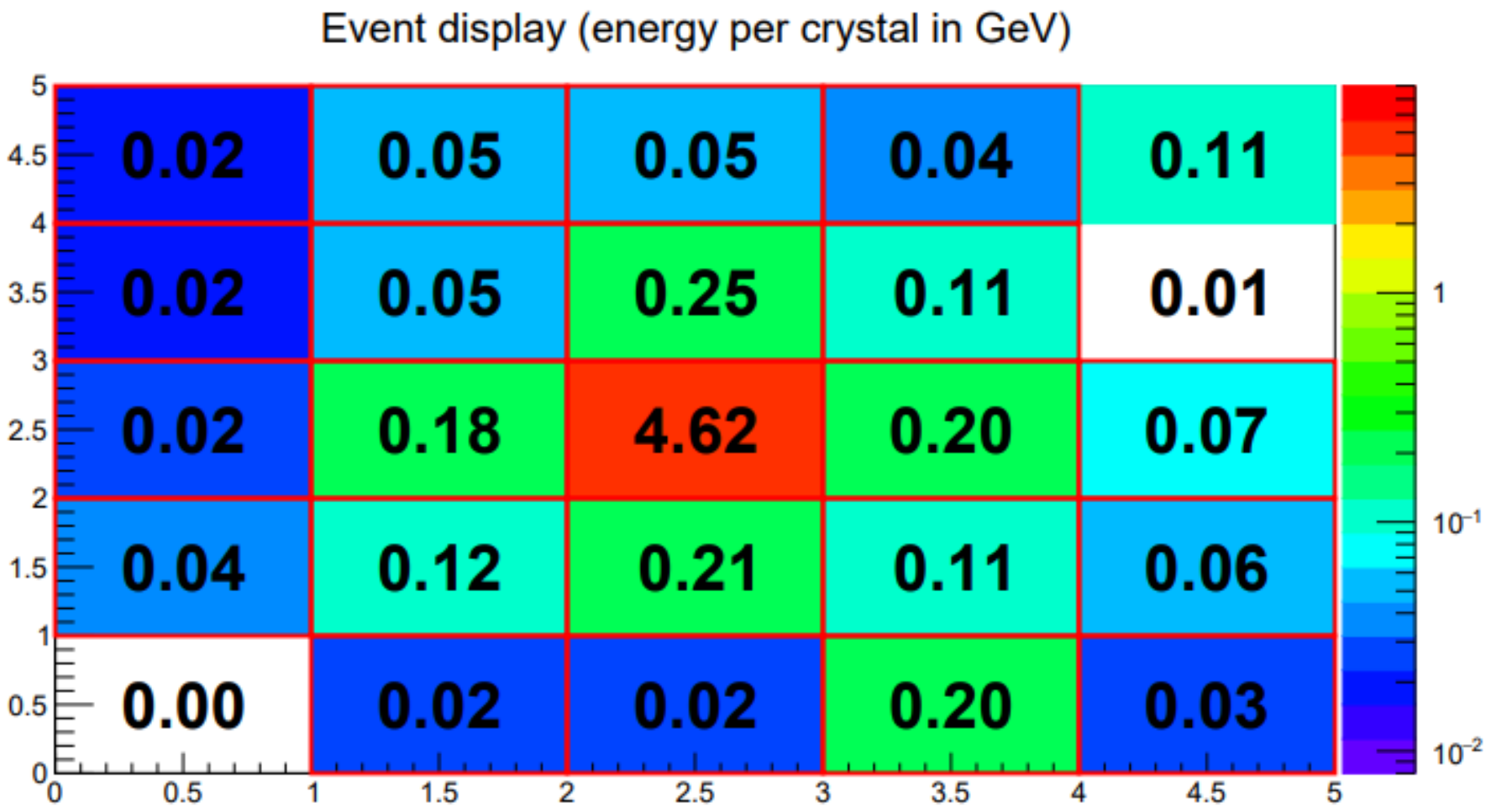


Energy scan: ADC and TOT

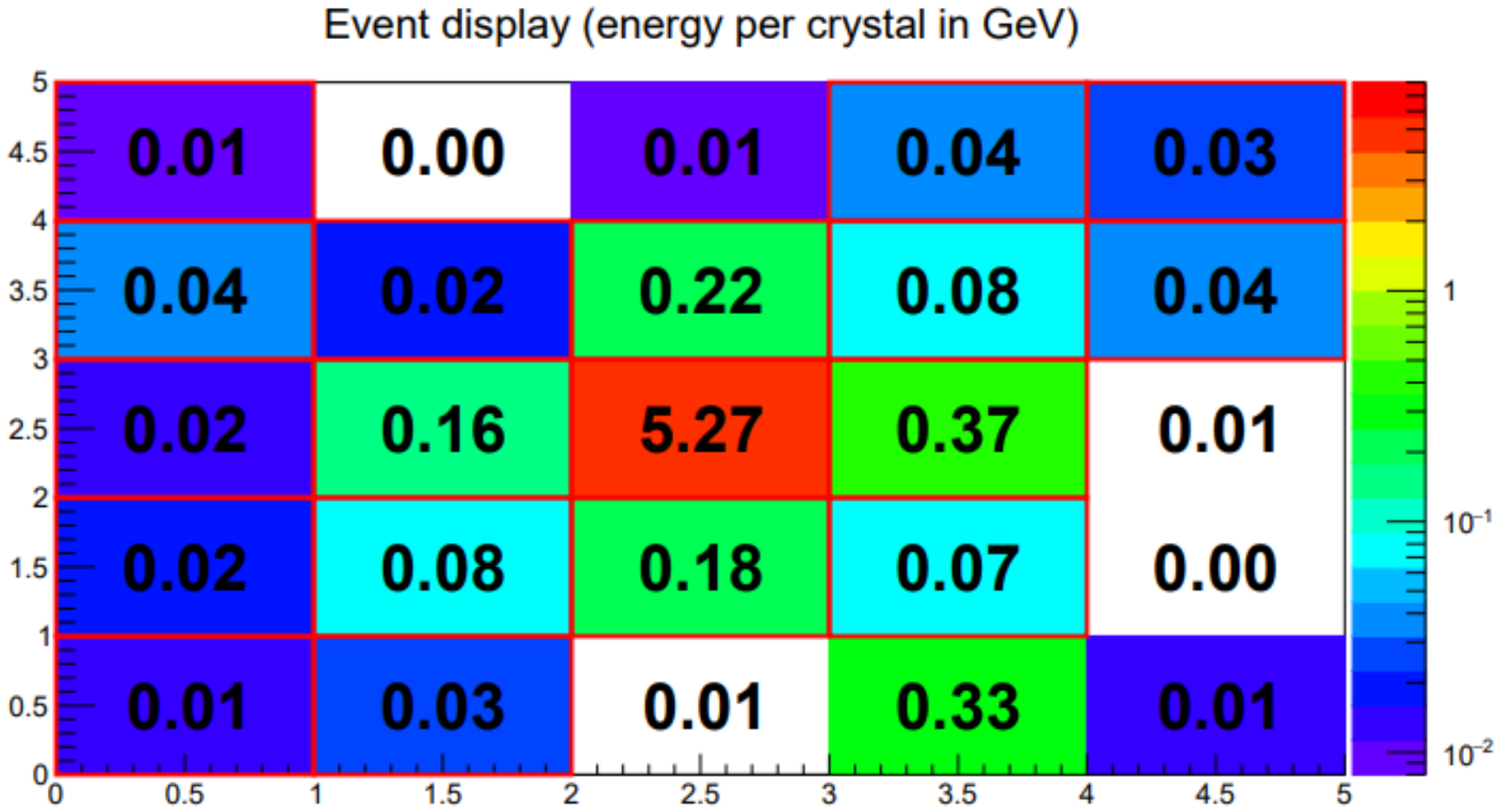
- **ADC** is linear before saturation
- **TOT** needs correction for non-linearity



Sample event at 5 GeV



Another event at 5 GeV

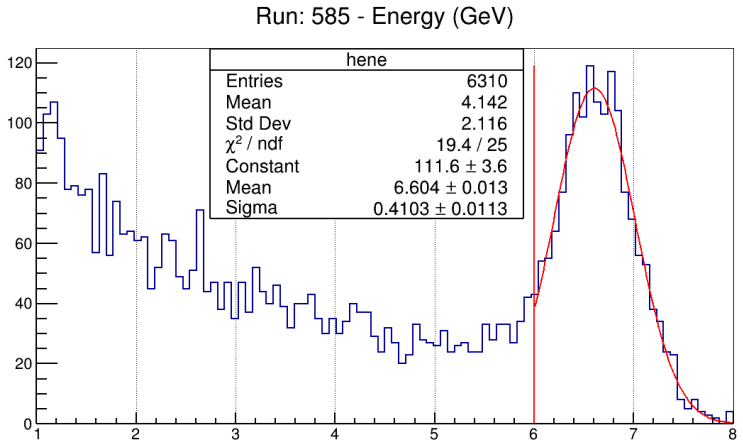


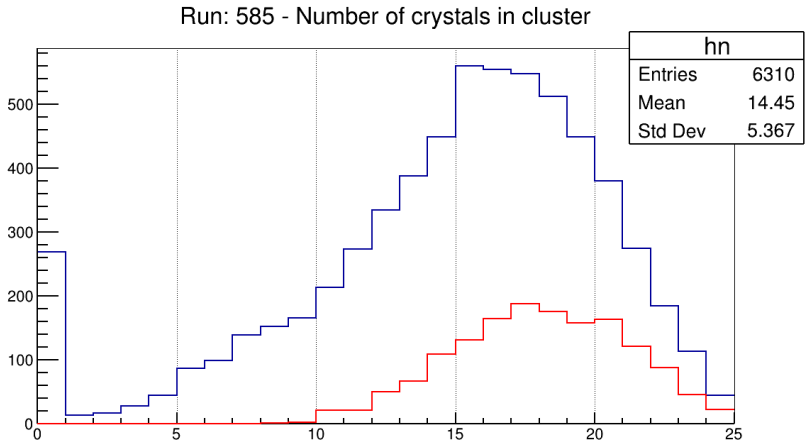
5 GeV run

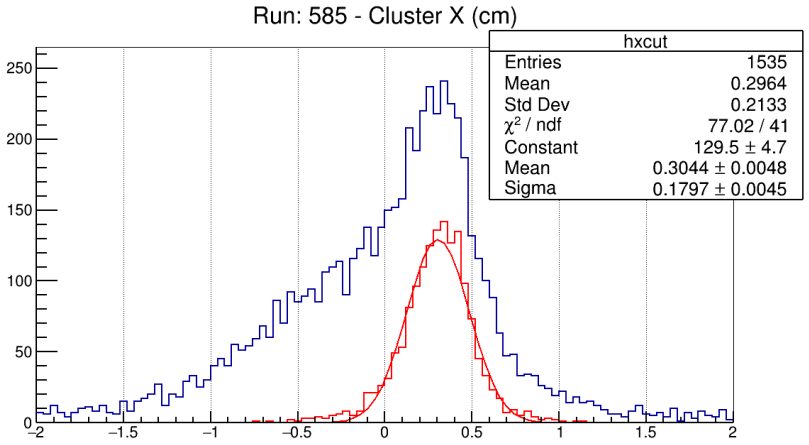
6.2% energy resolution

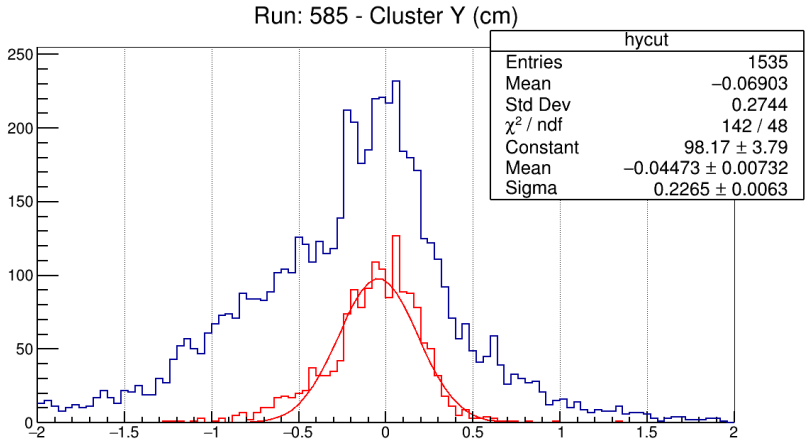
Still far from goal: ~2%

Large low energy background observed

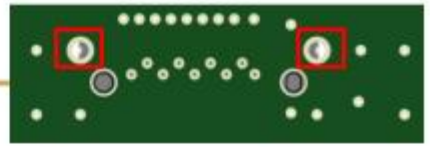






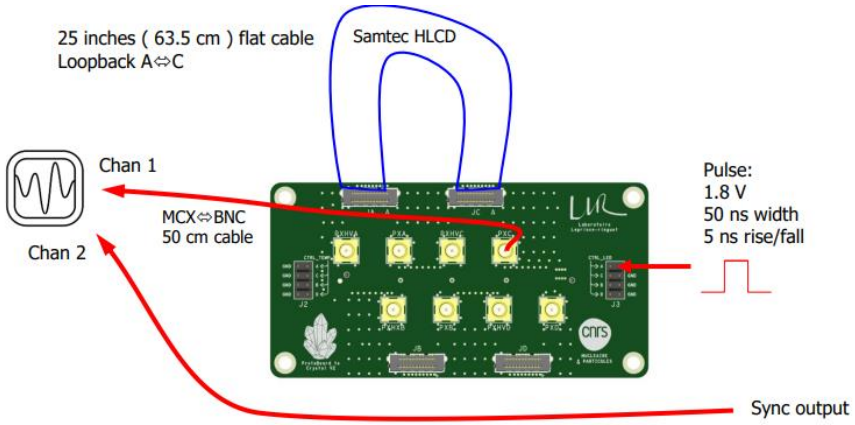


Initial Scheme (cf p.5)



No GND connection of the flat cable connectors pins (floating shields)

=> The amplitude of the spikes significantly varies when moving the cable. Here, "best" case (~33mV pp)

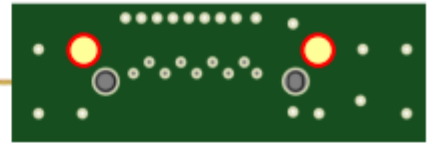


Signal Trigger

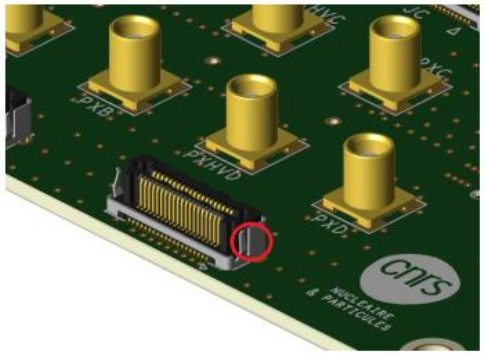
O. Le Dortz / LLR

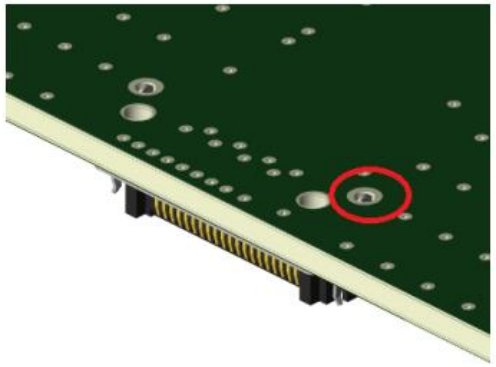
25 April 2025

After shield pins soldering

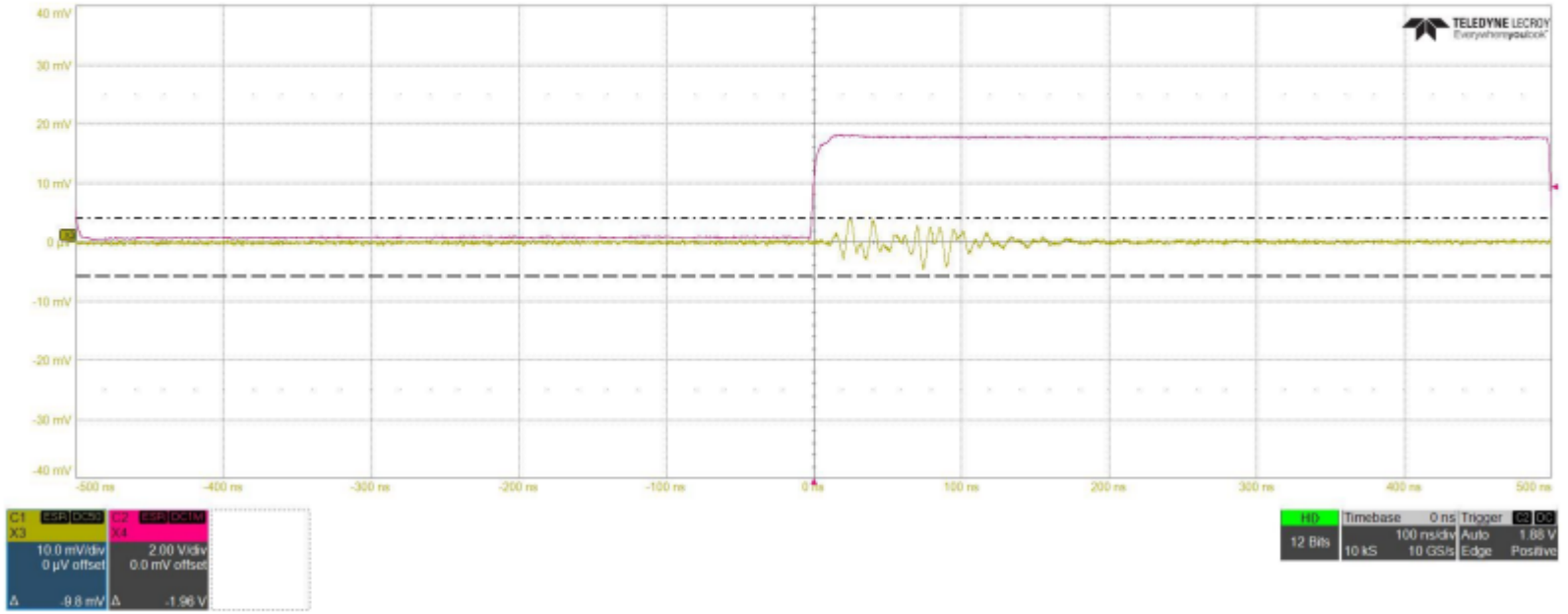


Noticeable reduction of the spikes amplitude (~10mV pp)





Conclusion: soldering the 2 GND pins on each connector **recommended** (if not already done)!



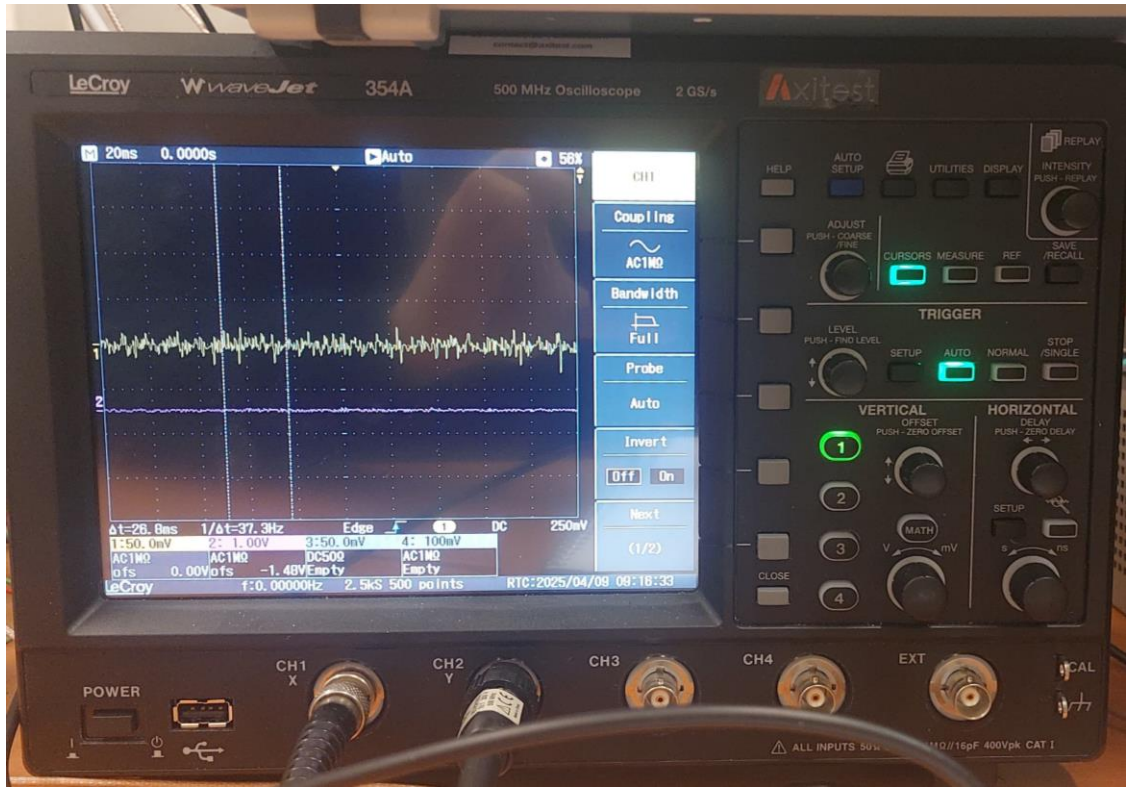
Signal Trigger

O. Le Dortz / LLR

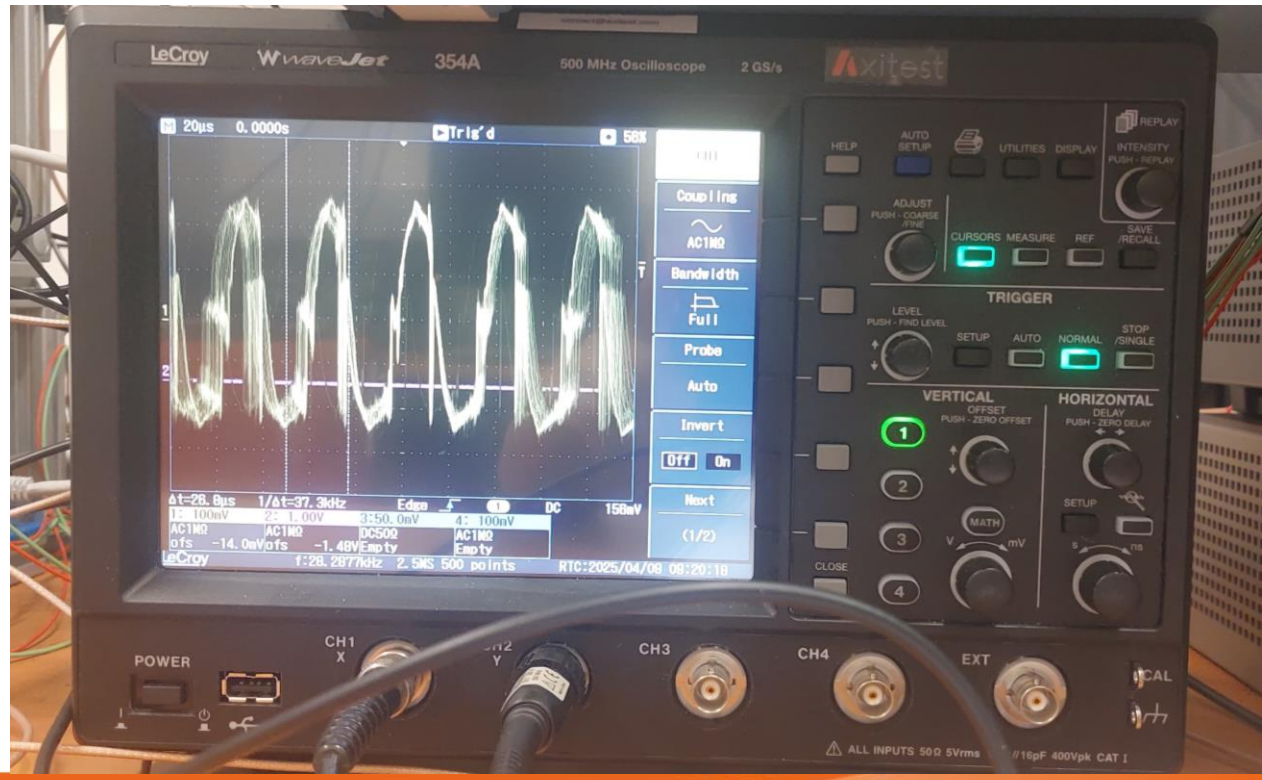
25 April 2025

Stability of the bias voltage supply

- A large oscillation in the power supply is observed when SiPMs are connected
  (400 mV peak-to-peak, ~37kHz)
- This affects all SiPMs, as the power supply is common



With a different power supply with a ‘High Capacitance Mode’



Summary and outlook

- Analysis still ongoing
  - Channel-by-channel ref shapes
  - Better calibration of individual channels
  - Mask (and correct for) bad/dead channels

- Investigation on different sources of background and fluctuations

(Power supply, HGCROC boards, light leaks…)

- Upcoming 2nd campaign at DESY this improved setup with improved setup

(better PS, better grounding, improved trigger)

The team

J. Bettane[1], E. Cline[8,9], J. Crafts[10], V. Chaumat[1], M. Czeller[4], C. Delafosse[1], P. Dinaucourt[6], C. Domingues Goncalves[1], F. Dulucq[6], P. Dumas Ziehlmann[6], R.H. Fatemi[14], J. Frantz[13], B. Geoffroy[1], A. Hoghmrtsyan[15], C. de La Taille[6], O. Le Dortz[5], N. Gabor[4], D.K. Hasell[8], T. Horn[10,16], M. Imre[1], L.D. Isenhower[12], S. Jia[7], B. Mathon[1], H. Mkrtchyan[15], A. Migayron[1], R.G. Milner[8], C. Muñoz Camacho[1], M. Nguyen[5], T. Nguyen Trung[1], N. Novitzky[3], S. Obraztsov[5], S. Olmo[1], T. Protzman[2], R. Reed[2], A. Shatat[5], D. Thienpont[6], G. Visser[11]