Latest update from Oct. TB and Lab ALICE 3 TOF

ALICE-ePIC meeting

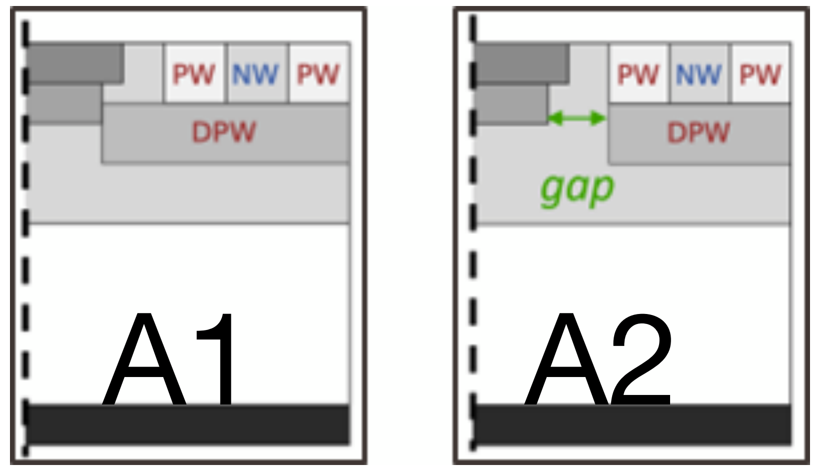
Bianca, 27.11.24

ALICE 3 TOF

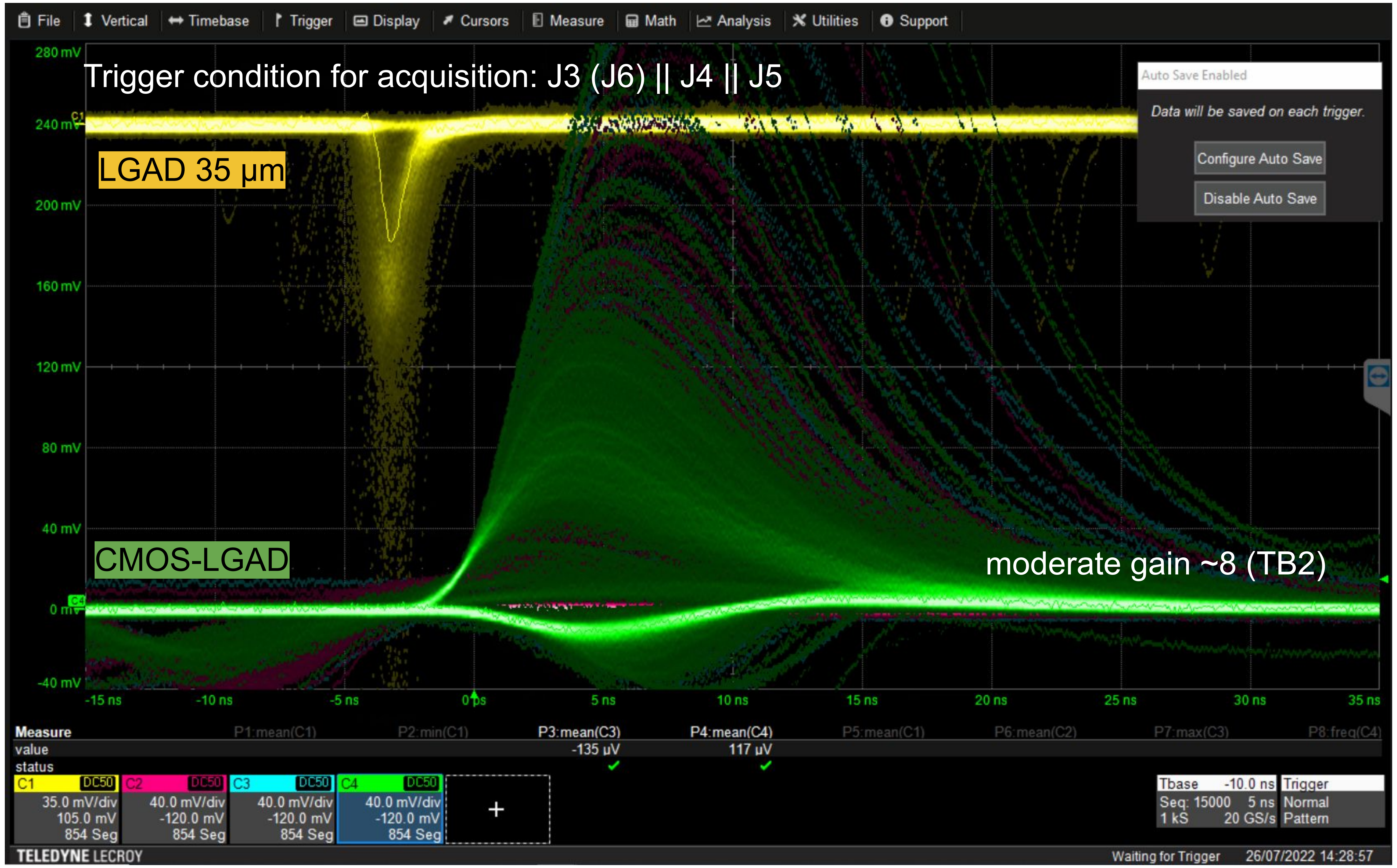
Exploring different technologies as sensors for ALICE 3 (LHC Run 5) timing layers

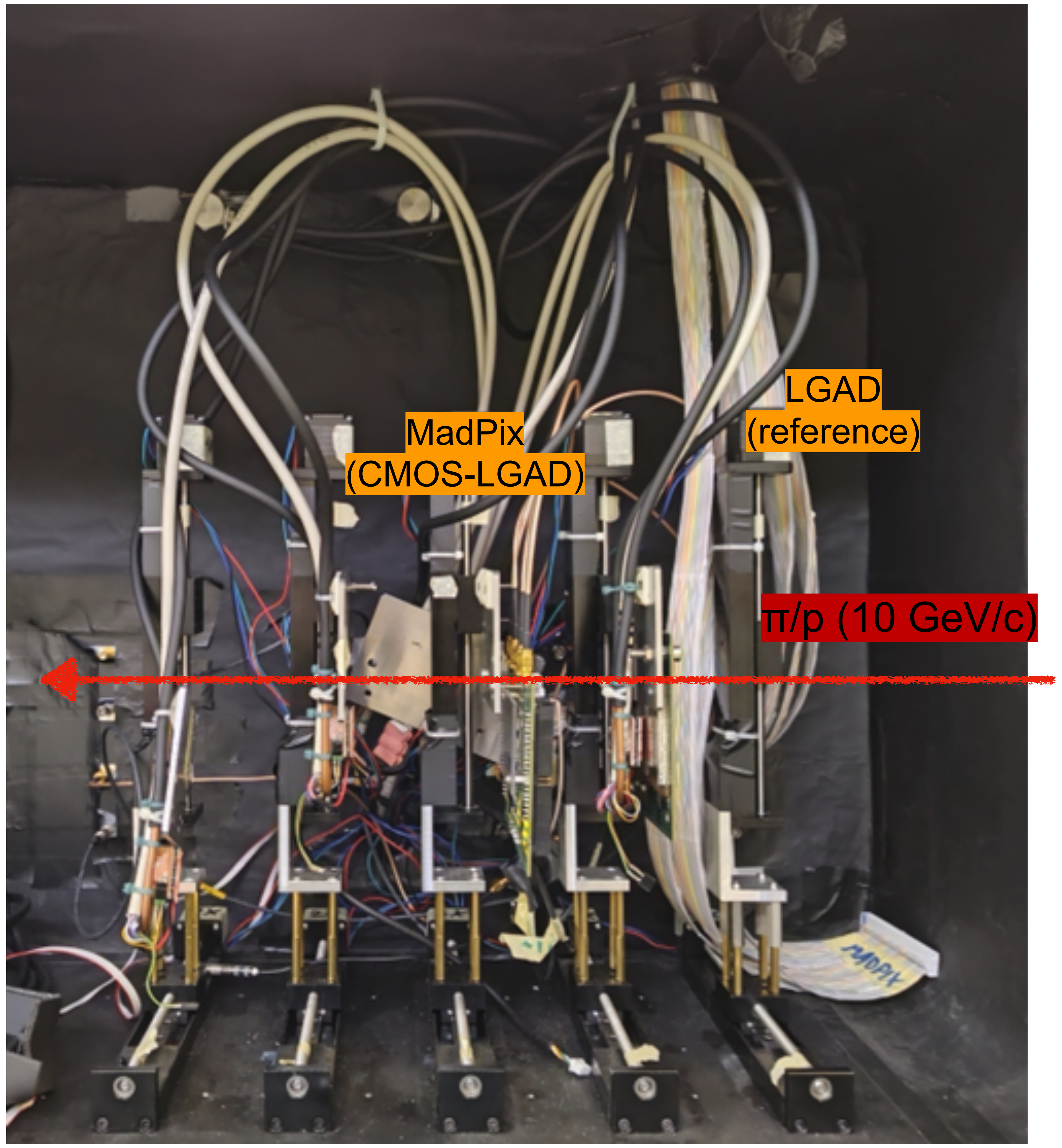
CMOS-LGADs

- See backup for the difference



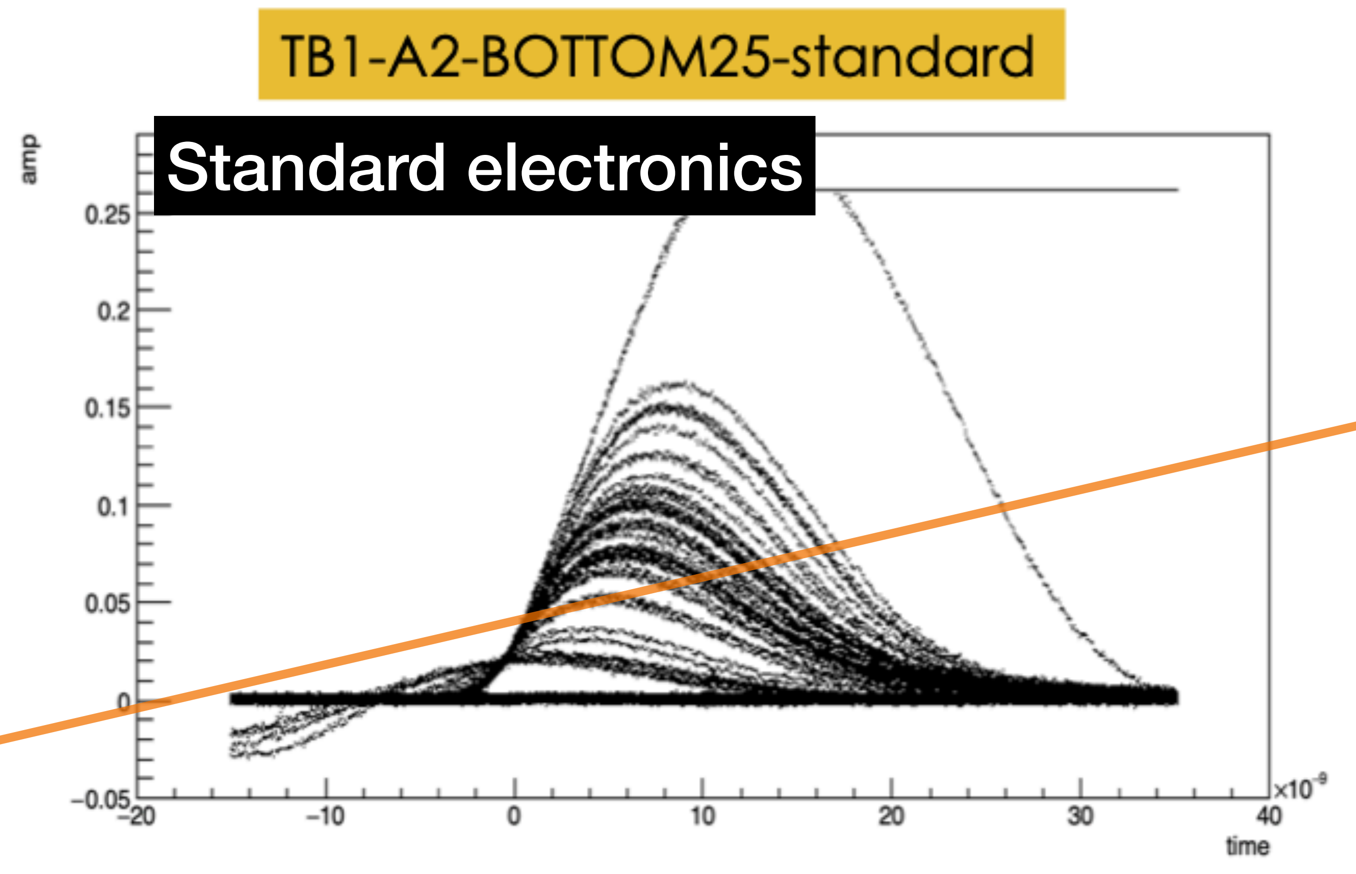
- 4 test boards: TB1 & TB4 w. max gain (~10-12), TB2 moderate gain (~8), TB3 low gain as in July (2-3)
- 2 layouts: A1, A2 (A2 optimized)
- 4 pixels: J4, J5 and J3 or J6

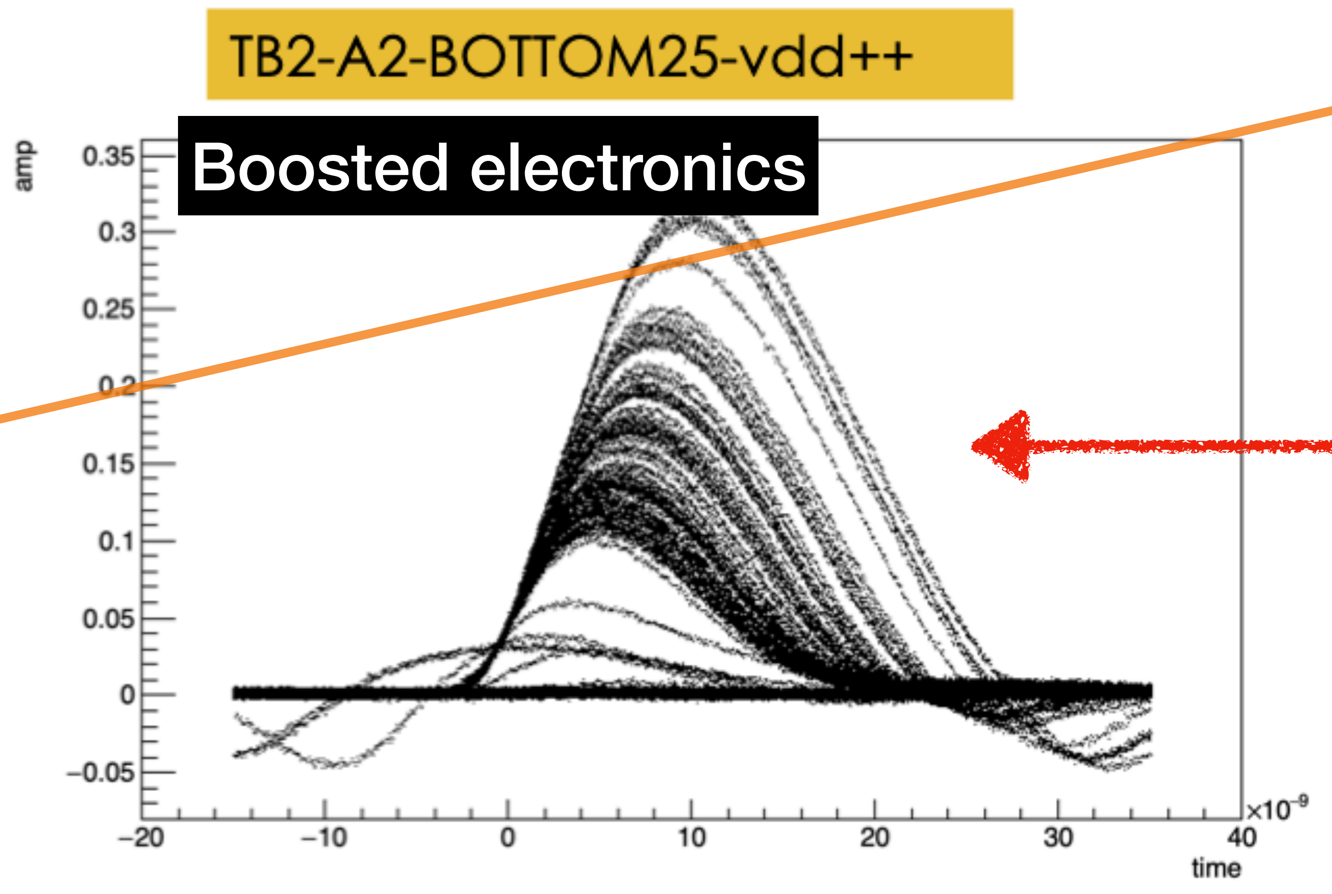




CMOS-LGADs preliminary results

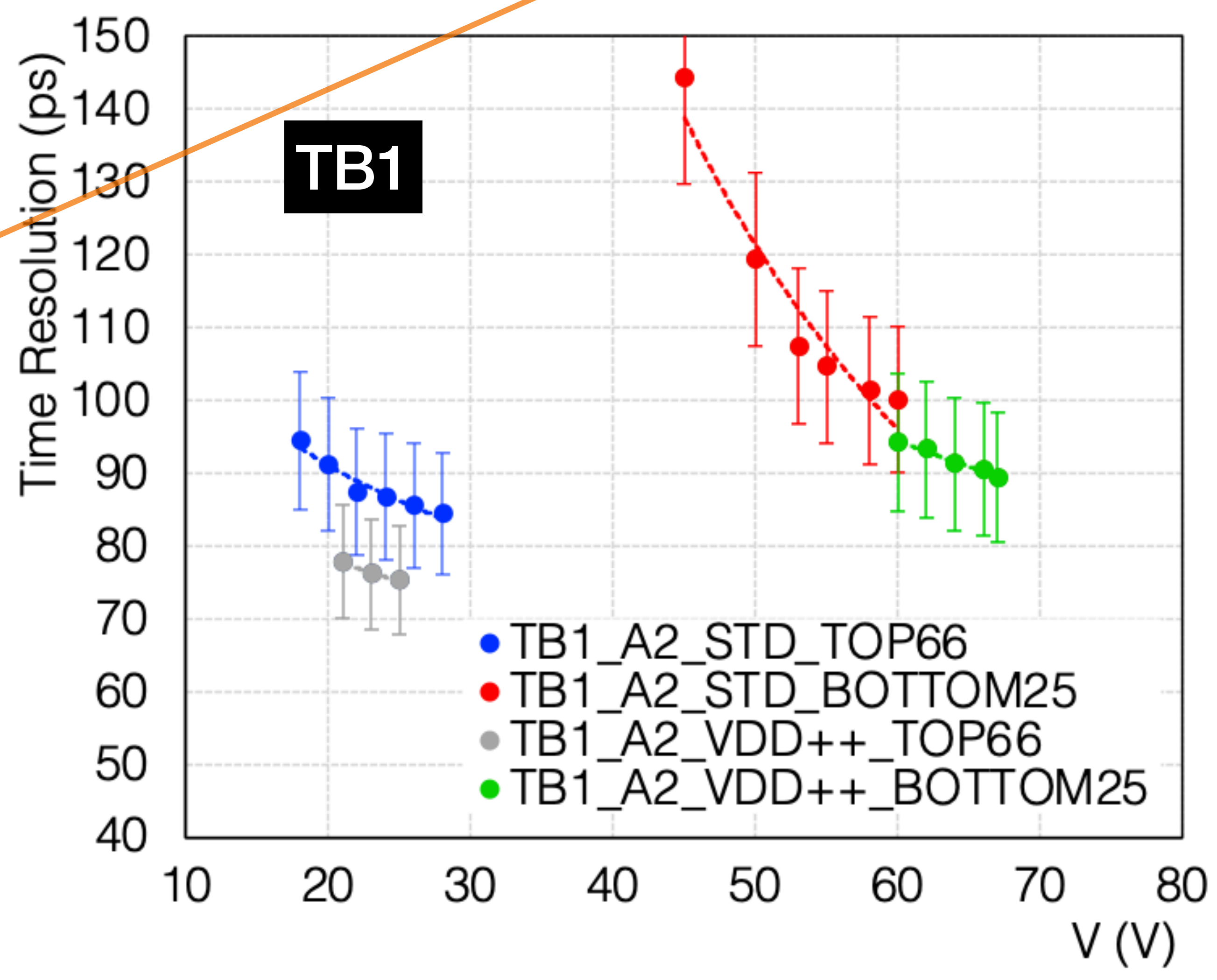
- Jitter contribution ~20 ps
- **Sensor resolution down to ~72 ps** (LGAD ~28 ps) in the “boosted” (“Vdd++”) configuration i.e. higher amplification while reducing as much as possible the slew rate limitation on MadPix side

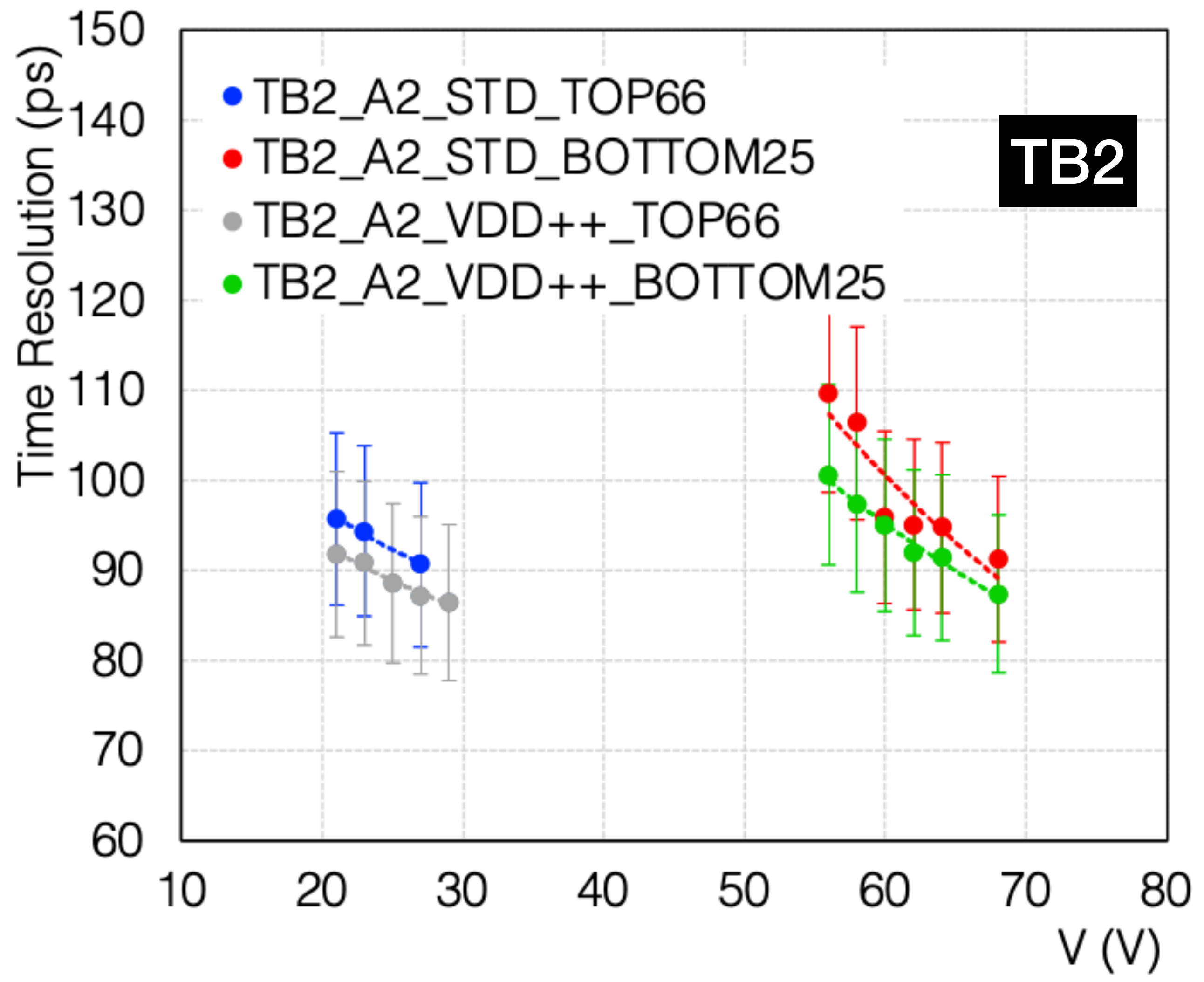




Analysis results being **cross-check among TO and BO teams:**

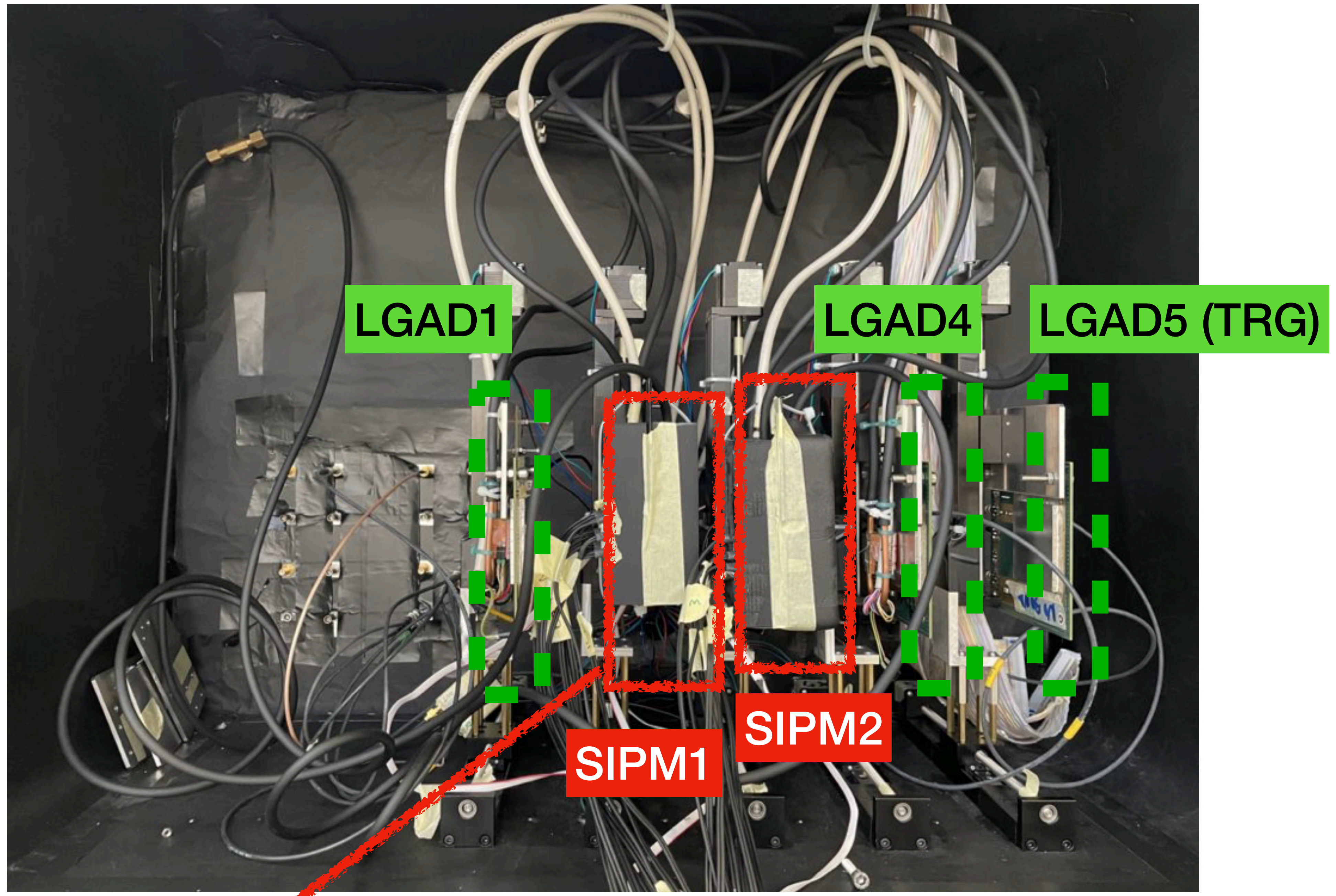
-> high and intermediate gain, TB1 and TB2 respectively, now in agreement with TO analysis

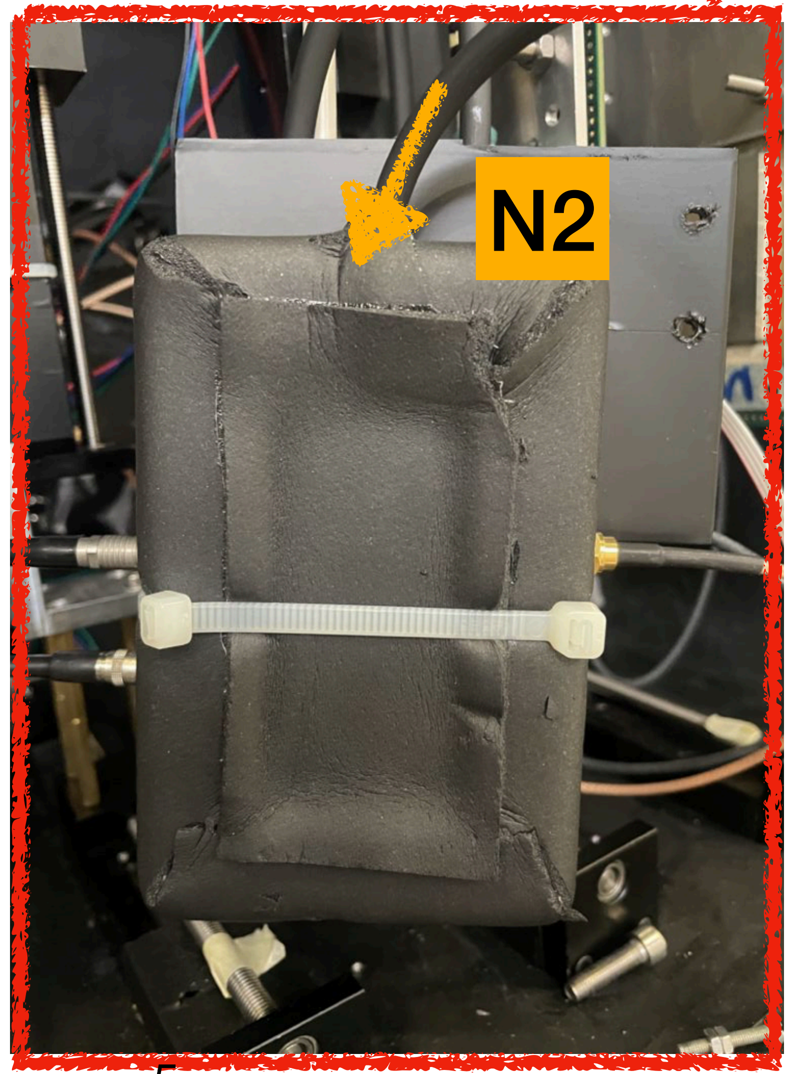


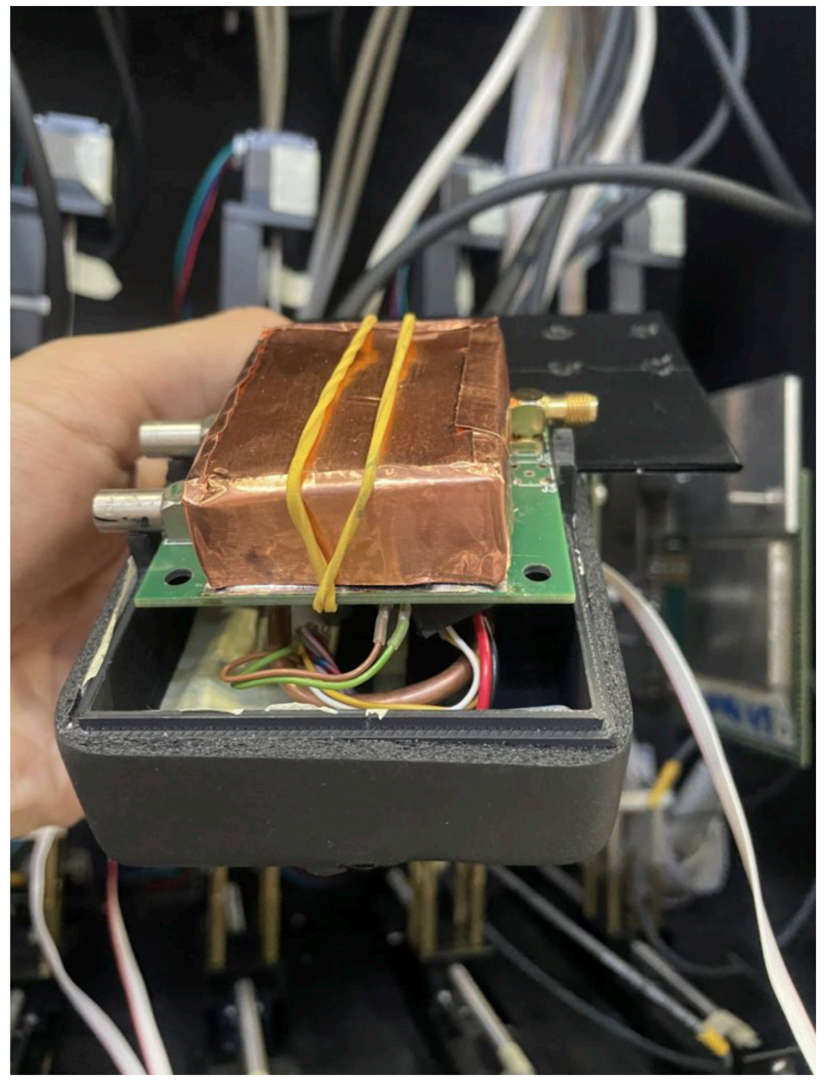


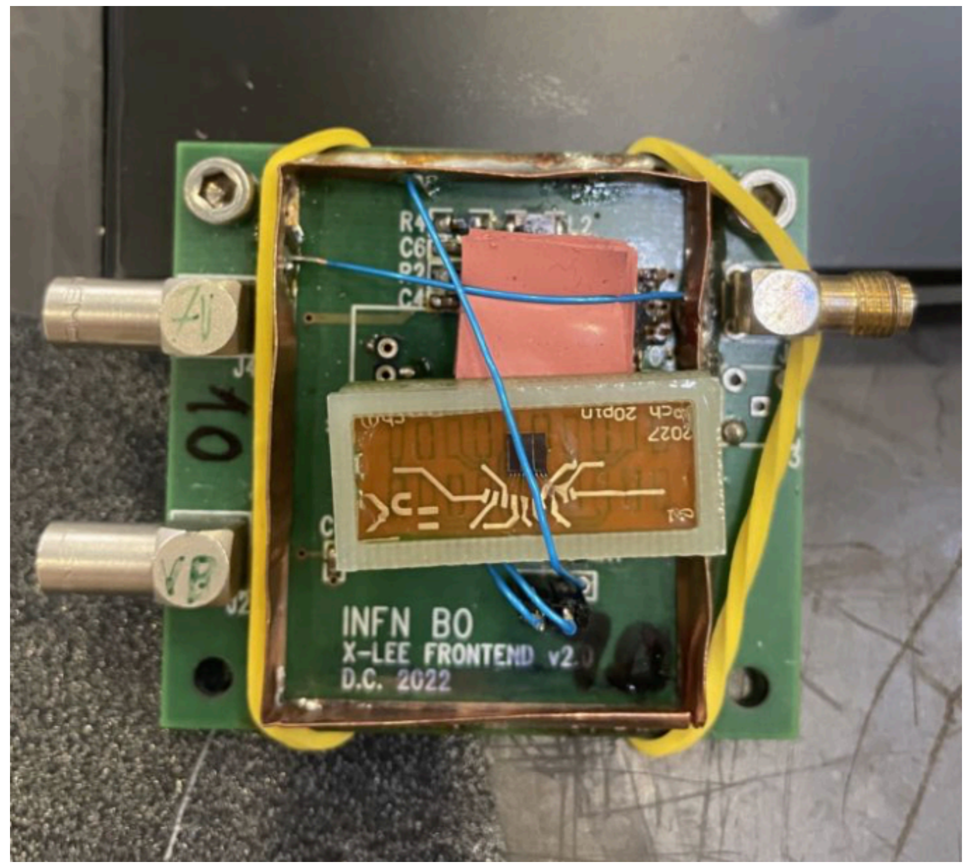
SiPMs: experimental setup

- On the last 2 days of BT, DCR (Dark Count Rate) measured with scope (via digital output reading from LIROC) and picoTDC board (around 20 MHz as with std scope DCR
- Before SiPMs, telescope configuration with **<u>3 LGADs</u>** to measure and cross-check time resolution of LGAD4 being used for reference (also for CMOS!)
- From Sunday 27th, **N2 gas cooling** (100 L/h) for 2 SiPM matrices (3x3 SiPMs) with 3 mm of silicone protection layer:
  - **Min. Temp. Reached ~8°C** after ~30 mins (starting at 24°C)
  - Humidity at ~5-6% wrt ~40% without N2, dew point below -10°C



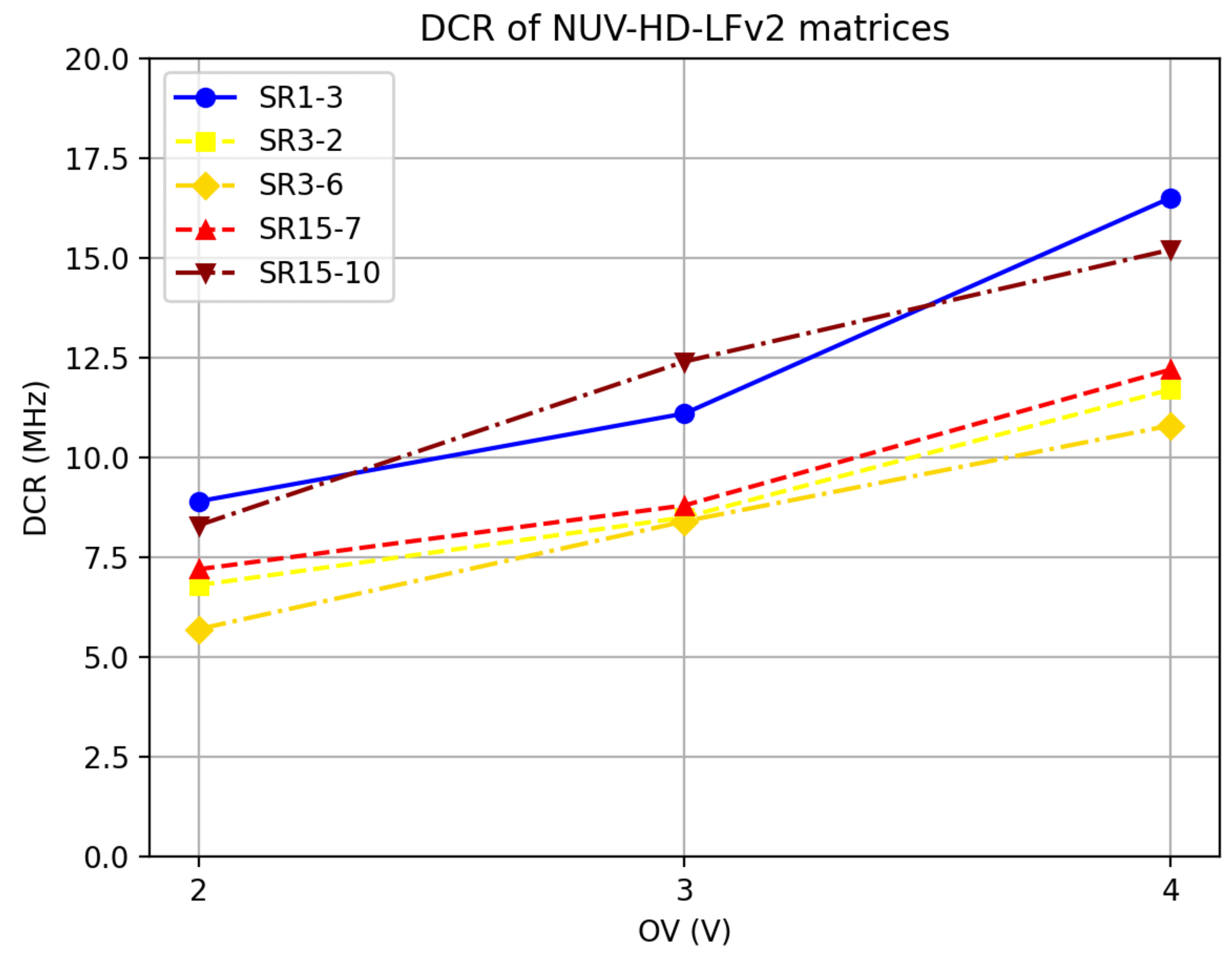






Focus on run list on pTDC

- DCR with scope at BLDG29



- DCR at different temperatures (also with discriminated output from LIROC)
- 2 LIROCs,10K triggers:
  - LGAD thresholds scan
  - Aligning always central SiPMs of matrices, runs at 2 V OV
  - threshold scan

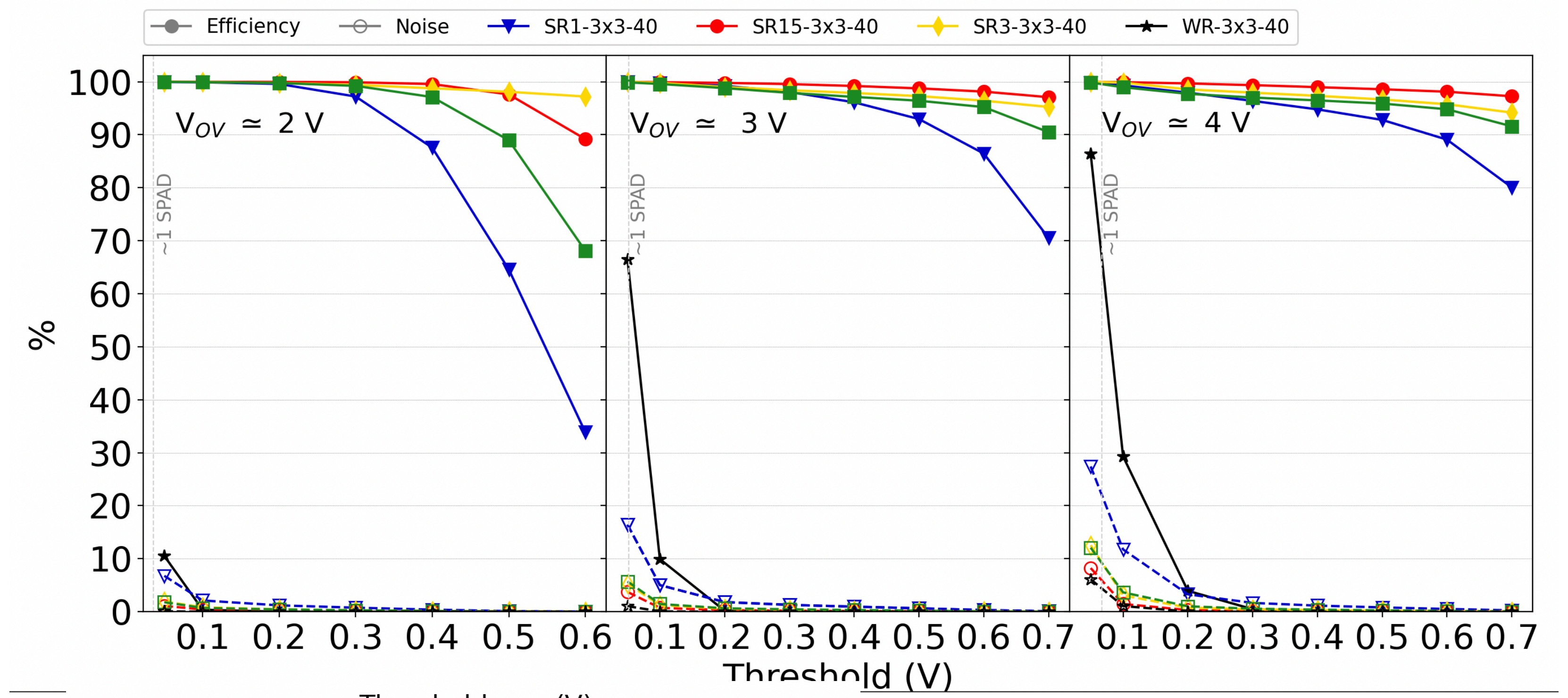
A. **1 LIROC**, 2.5K triggers:
  - Scan in threshold (few steps)

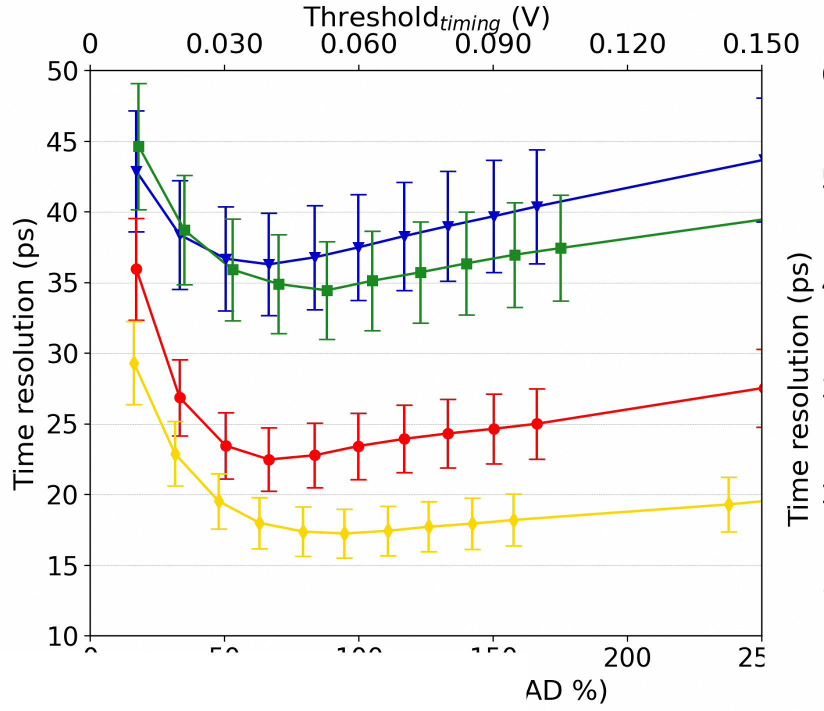
B. **2 LIROCs** at play, LGAD5 2K triggers:
  - Scan in threshold
  - DCR after radiation (also with discriminated output from LIROC)

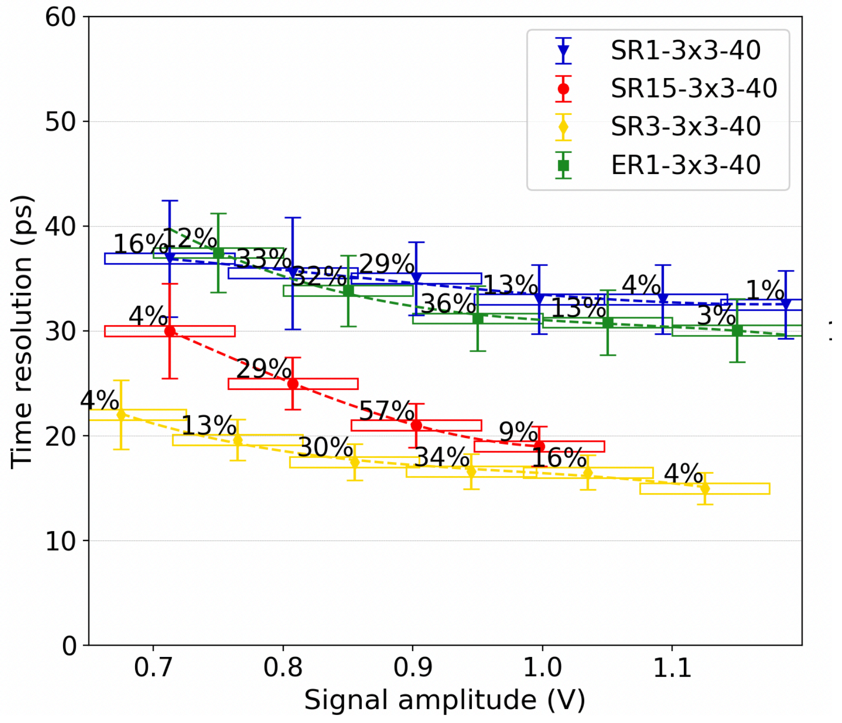
pTDC software: mismatch of the event between the LIROC happened often: option A) using only 1 liroc, option B) decreasing the TRG rate

Summary

- Threshold: at one point, we saw discriminated signal always high from -20 mV(we wanted to go <-15 mV with cooling): need to understand if it is a problem of radiation or other…
- Now finalizing old scope results for the SiPM paper, but then ***efficiency and timing*** from acquired data



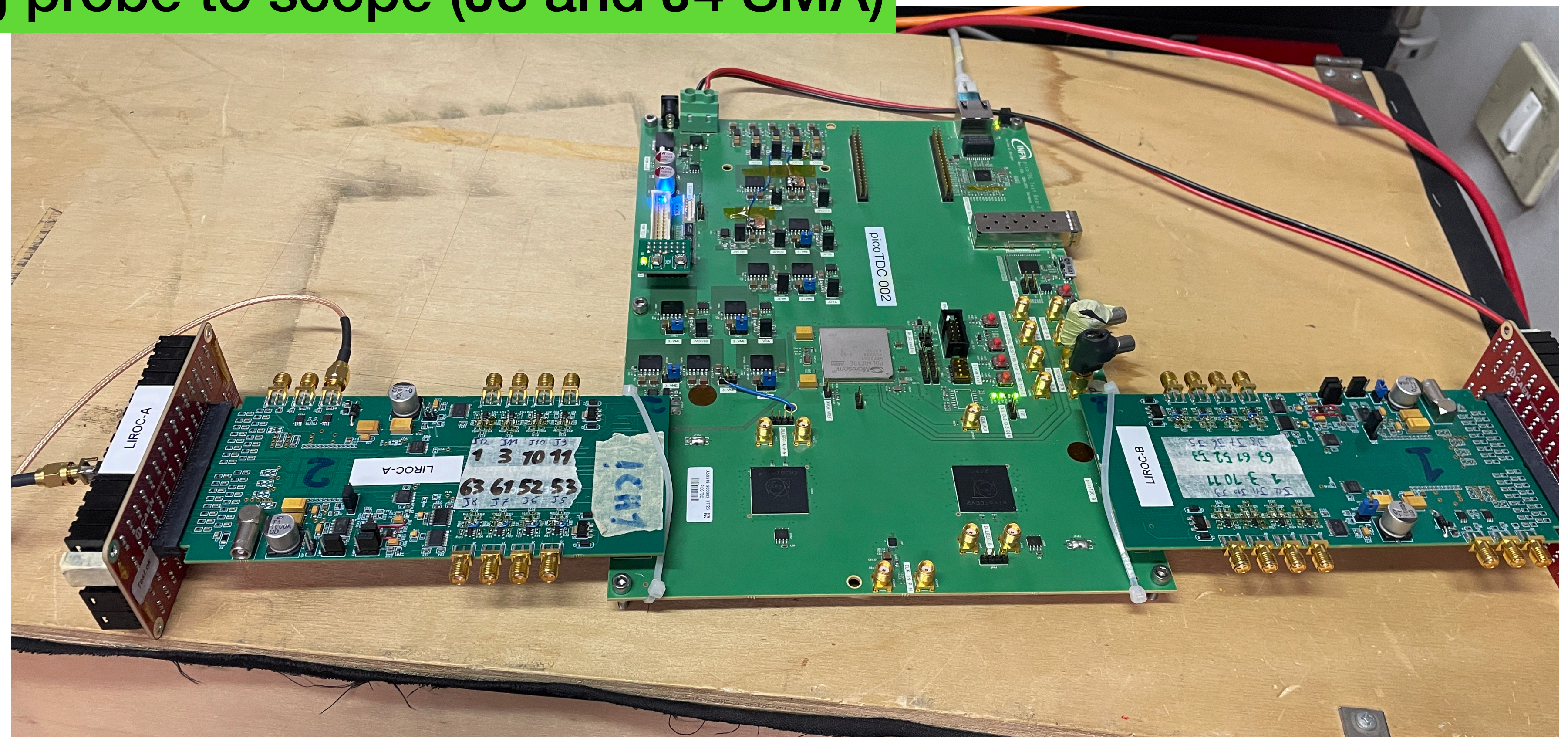


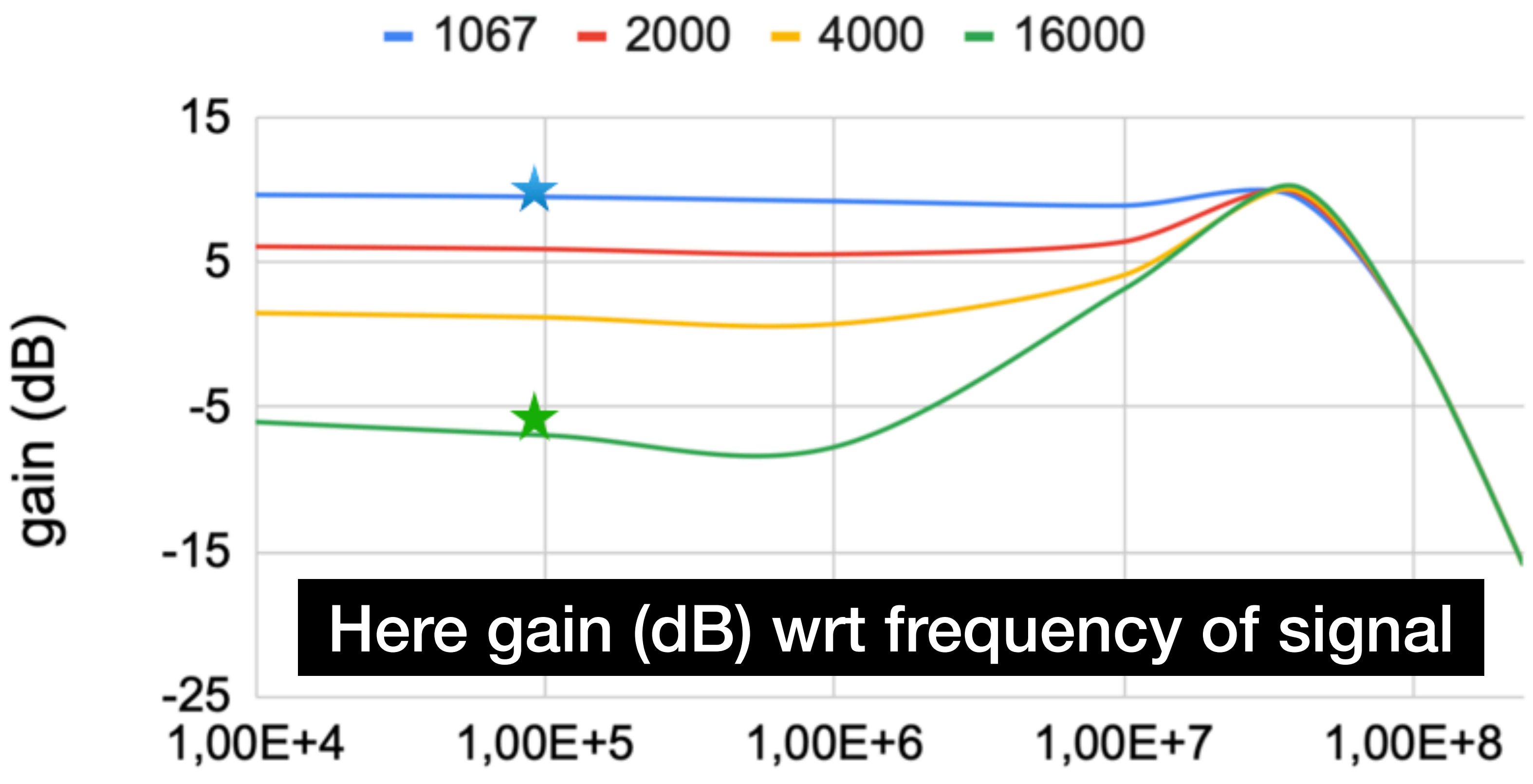


Next plans for SiPMs

- **Many measurements** in the lab (see hint in next slides)
  - Laser setup in place (with no cooling), DCR, LIROC and picoTDC in place for deeper

Analog probe to scope (J3 and J4 SMA)



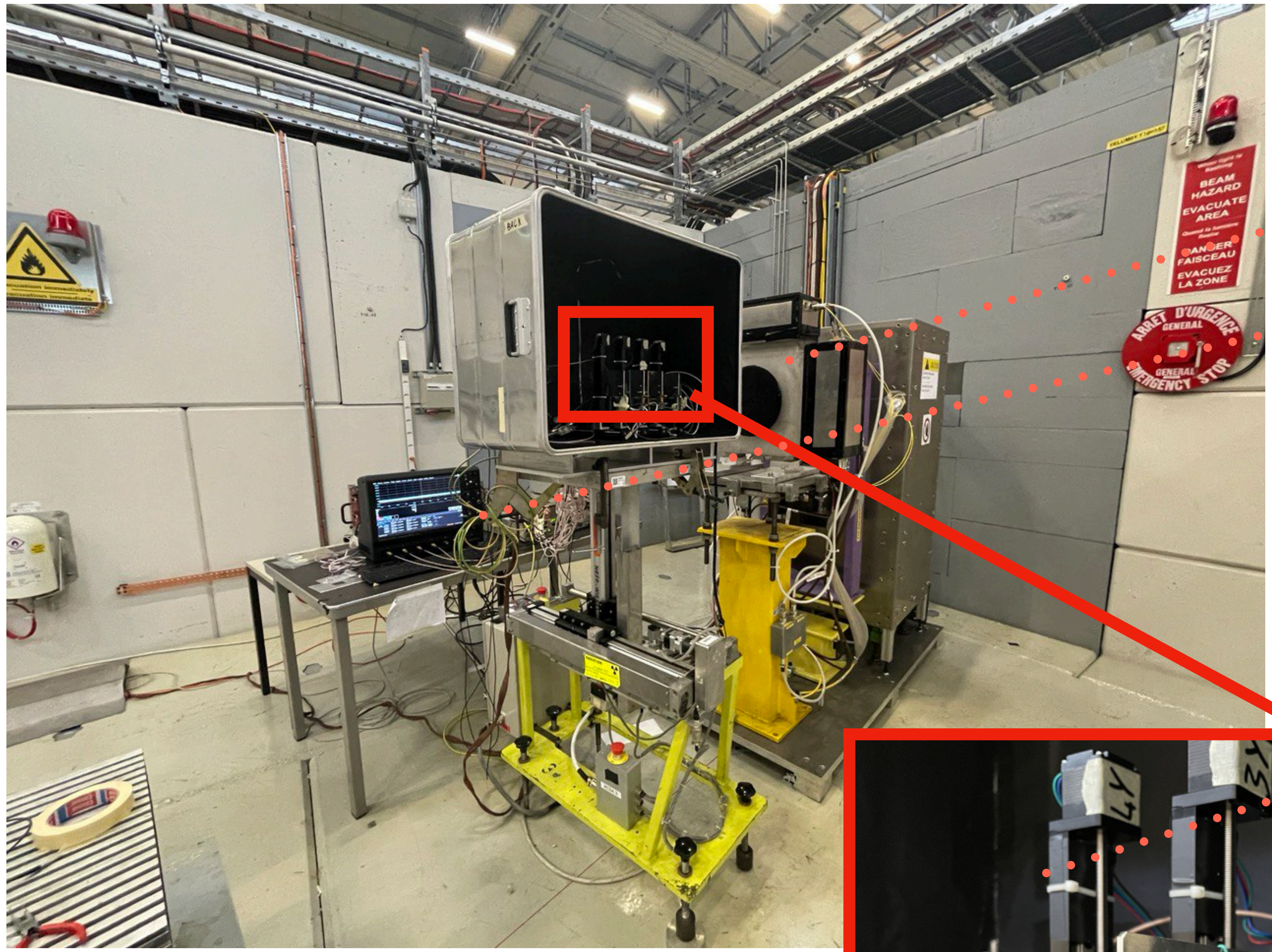


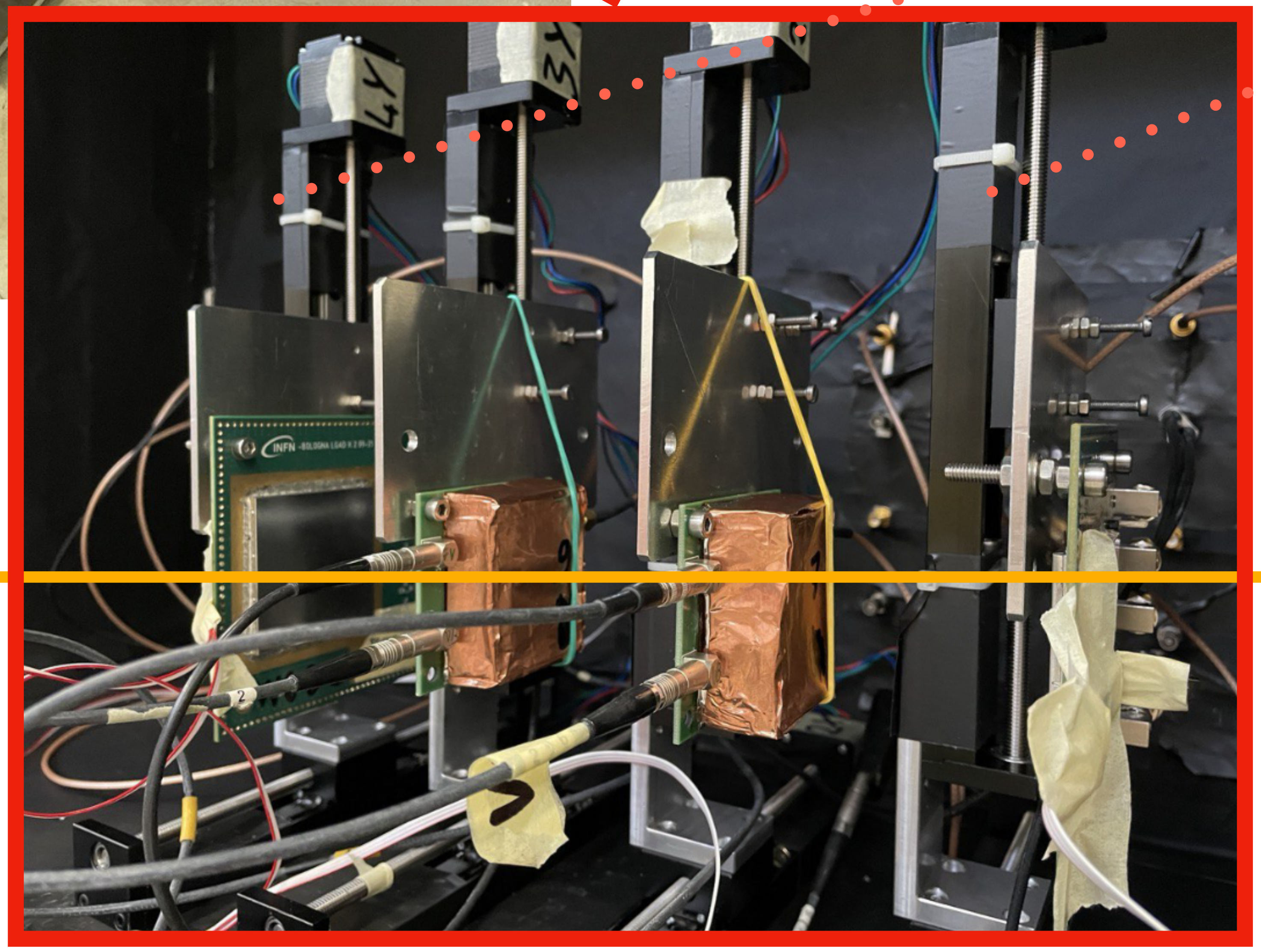
Next plans for CMOS

Next for CMOS next year: sensors to be tested after irradiation, thinner sensors in the 2nd part of 2025, closer in time: data readout with picotdc to setup.

Backup

Experimental setup
CERN PS T10 beamline





beam

protons of 10 GeV/c

DAQ: Lecroy wave runner 94904M-MS
digital oscilloscope 4 GHz bandwidth

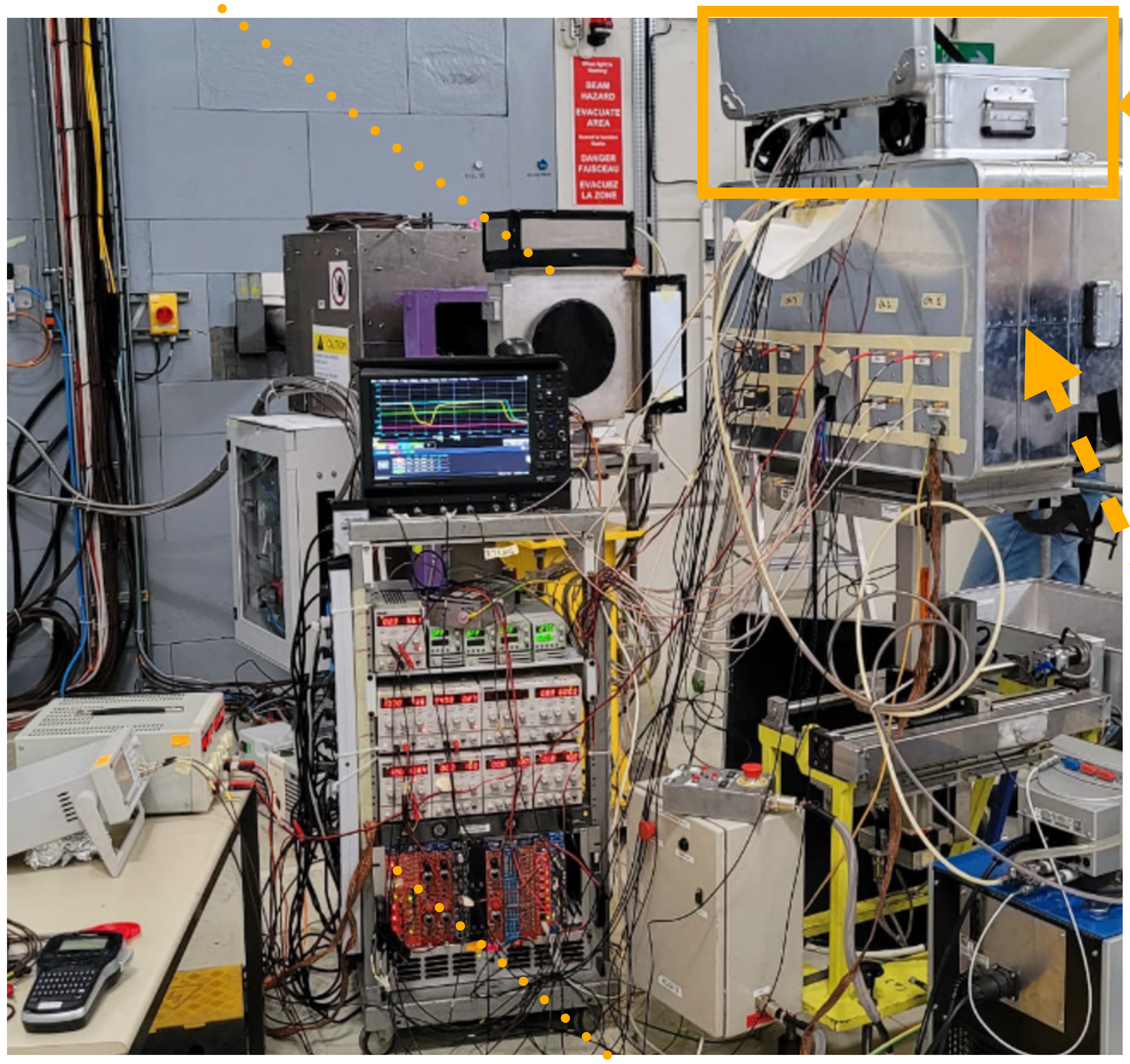
Trigger and timing reference: 25 um and 35 um thick FBK LGAD prototypes of 1 x 1 mm^2 (*Eur. Phys. J. Plus 138, 99 (2023)*)

4 independent micropositioners (10 um precision)

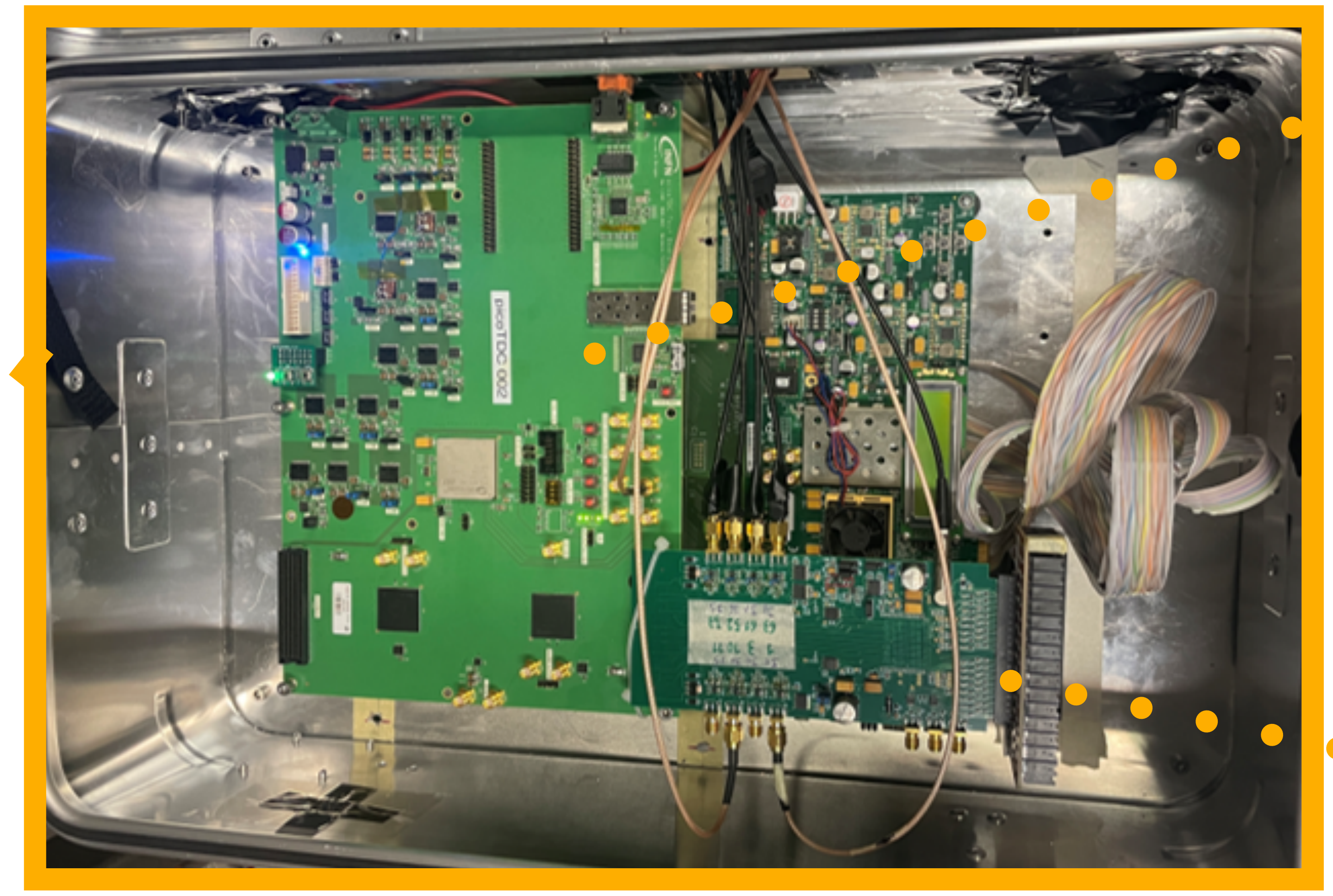
Recent development with full front end and readout electronics

CERN PS T10 beamline

protons of 10 GeV/c



CAEN modules to manipolate signal trigger from LGAD sensor (from NIM to LVTTL)



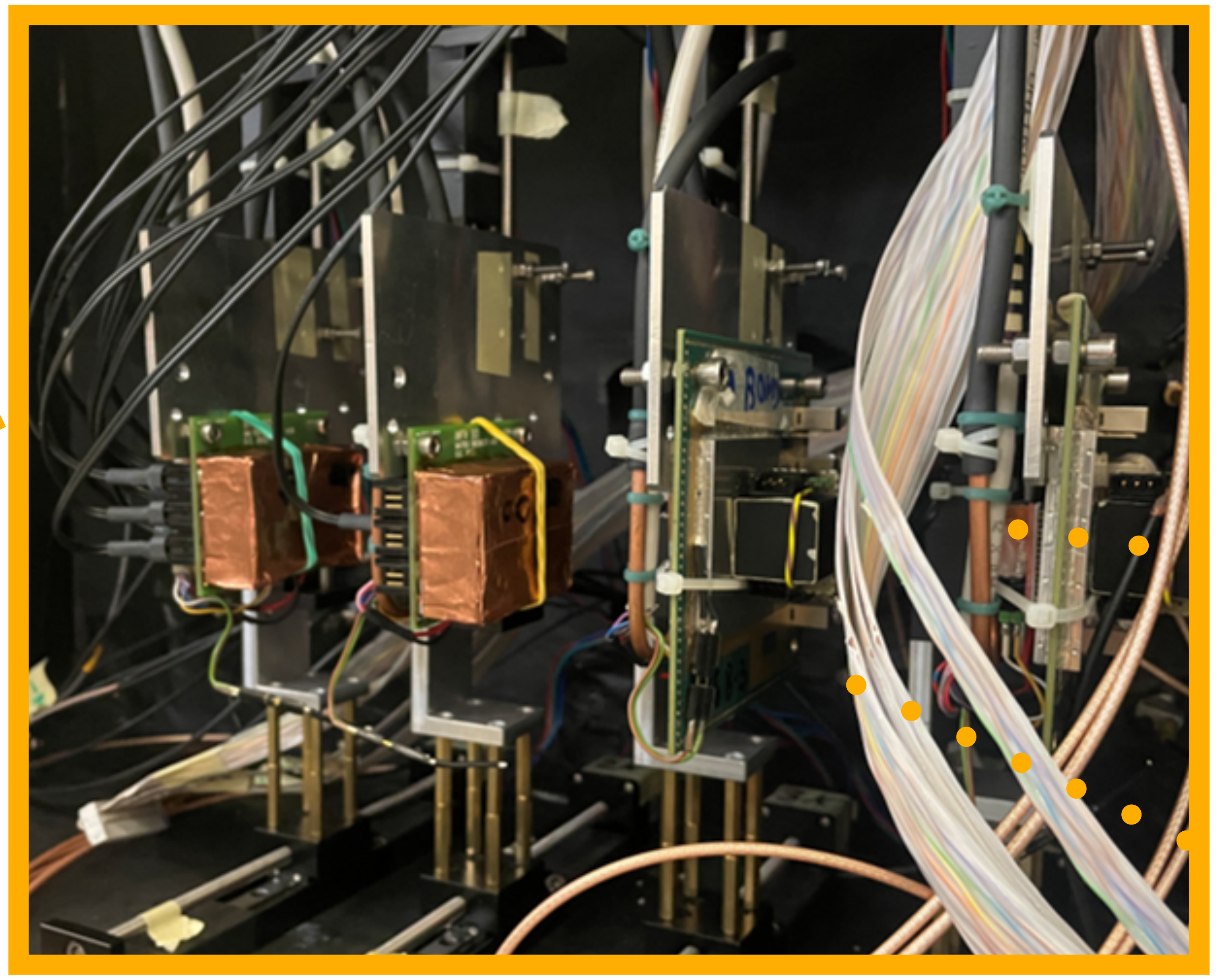
Readout: **pTDC** (Time-to-Digital Converter) **FEB**

- 40 MHz clock, 64 channels, bin size 3.05 ps in fine resolution
- High data bandwidth towards PC with std interfaces (Ethernet and USB),
- First spill trigger from T10 line, second trigger from LGAD prototype

FEE: LIROC amplifier+shape+discriminator

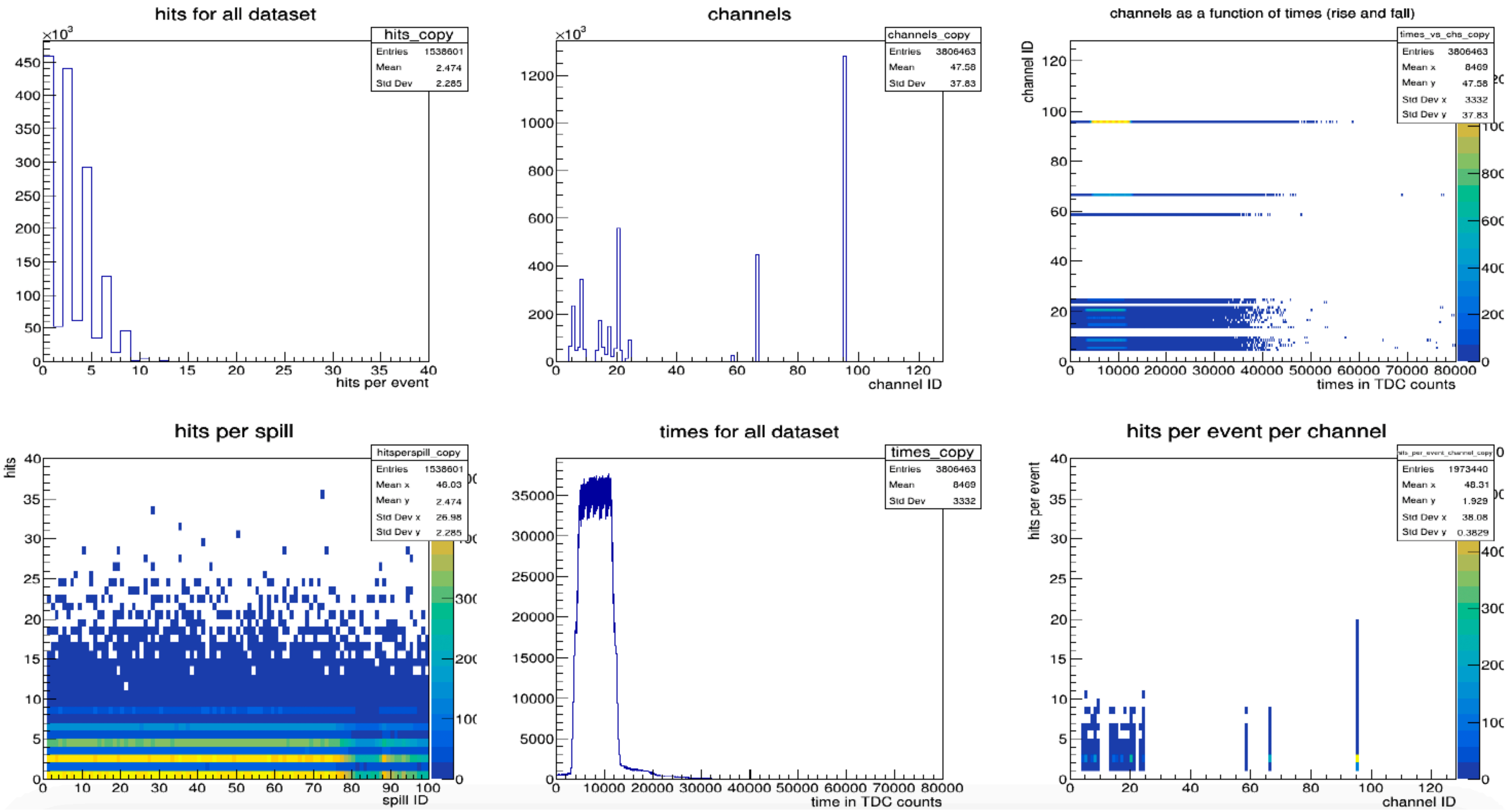
- Weeroc 64 channel front end ASIC (designed for LIDAR applications)
- CAEN Adapter Board

TDK Lambda Z100 power supply for SiPM (into LEMO of LIROC, then common to all SiPMs, single and of a matrix)



Peltier cells in order to keep Temperature as constant as possible

Different configurations (with just 1 LGAD of reference, with 2 LGADs to evaluate efficiency, with CMOS-LGADs prototypes, with LGADs only, with different SiPMs…)


hits for all dataset
hits_copy
Entries 1538601
Mean 2.474
Std Dev 2.285
×10^3
hits per event
channels
channels_copy
Entries 3806463
Mean 47.58
Std Dev 37.83
×10^3
channel ID
channels as a function of times (rise and fall)
times_vs_chs_copy
Entries 3806463
Mean x 8469
Mean y 47.58
Std Dev x 3332
Std Dev y 37.83
channel ID
times in TDC counts
hits per spill
hitsperspill_copy
Entries 1538601
Mean x 46.03
Mean y 2.474
Std Dev x 26.98
Std Dev y 2.285
hits
spill ID
times for all dataset
times_copy
Entries 3806463
Mean 8469
Std Dev 3332
time in TDC counts
hits per event per channel
Entries 1973440
Mean x 48.31
Mean y 1.929
Std Dev x 38.08
Std Dev y 0.3829
hits per event
channel ID

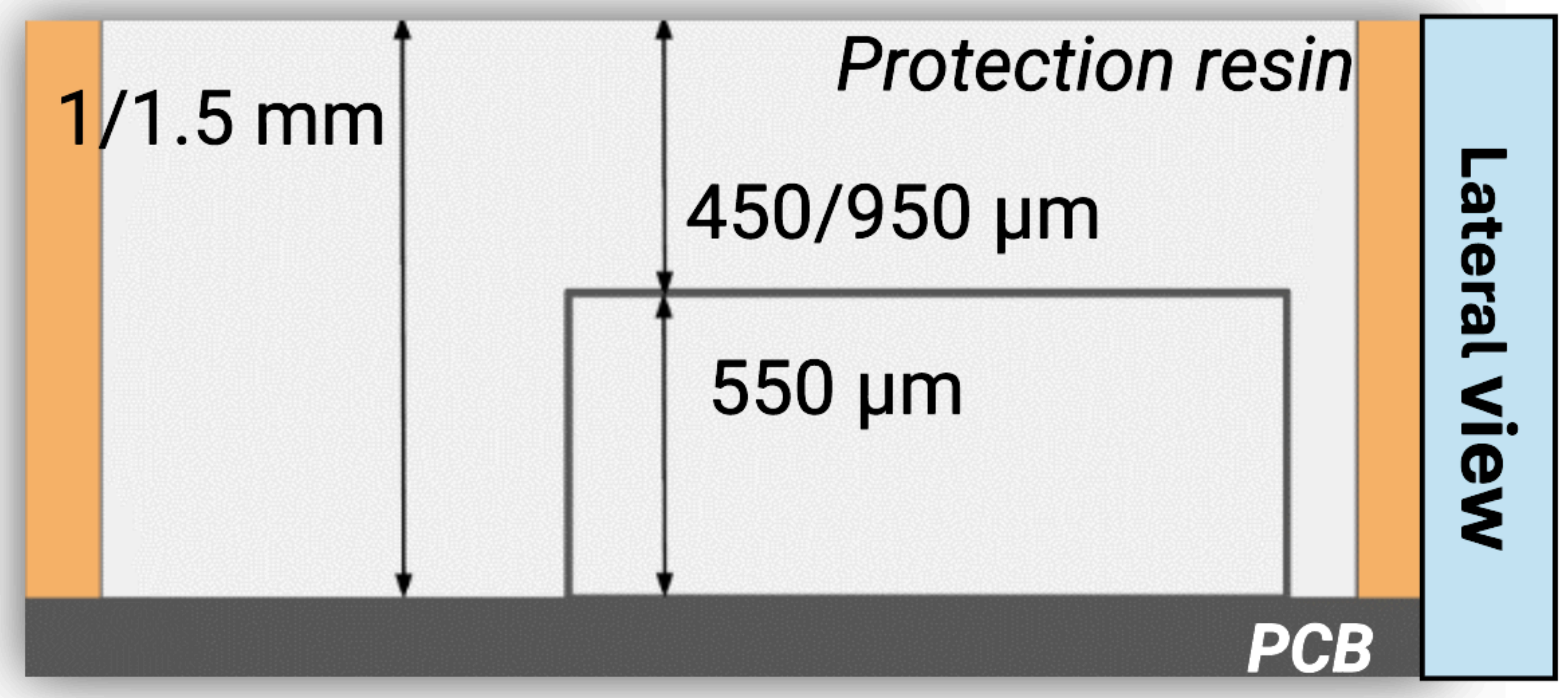
SiPM of larger area under study (paper in preparation)

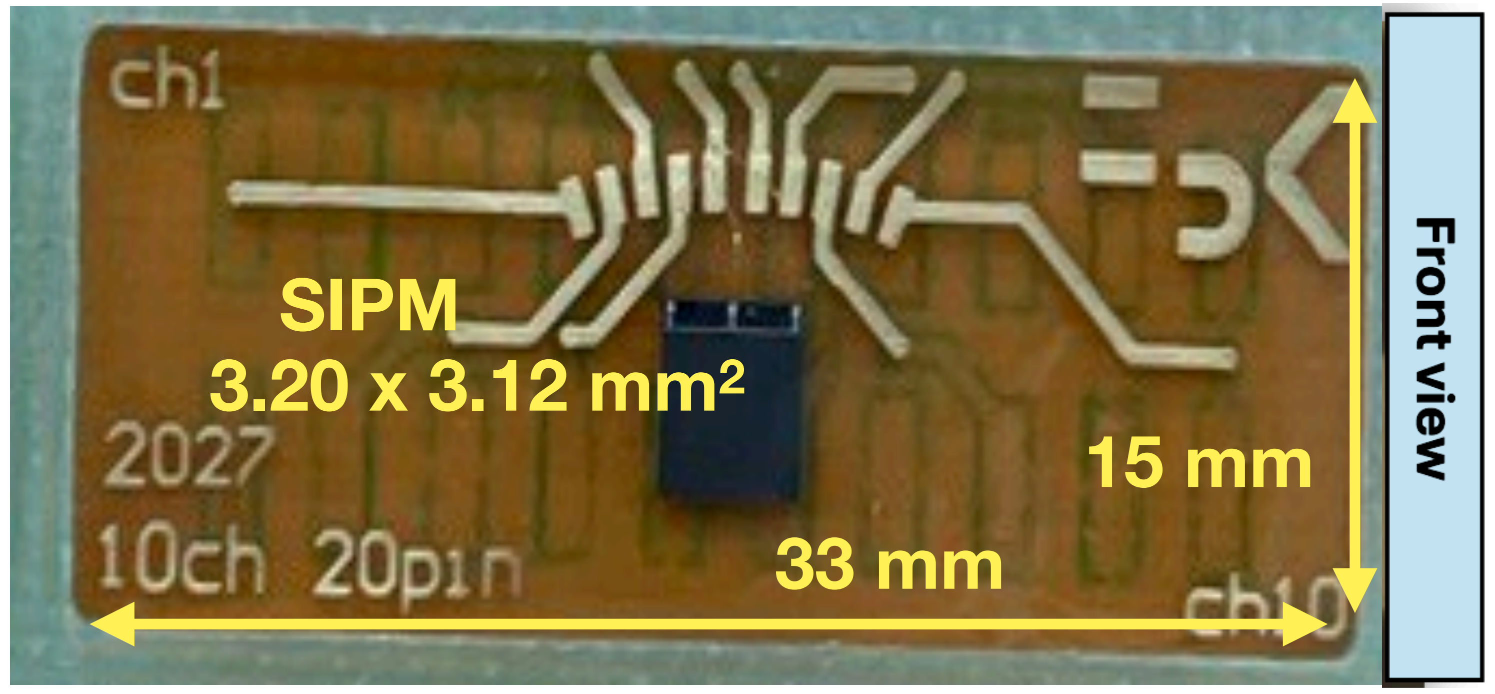
SiPM of FBK **NUV-HD-LFv2** technology with **larger area of 3x3 mm² available both in single and in matrix of SiPMs**:

- every SiPM under test on its own PCB with protection layer all over the PCB
- Different protection layers: 1, 1.5 and 3 mm Silicone resin, 1 mm Epoxy resin and a control sample without any protection layer
- Matrices are of 9 SiPMs of 1x1mm² area

NUV-HD-LFv2-3x3

Active area	Pixel pitch	#SPADs	Fill Factor	V_{bd}
3.20 × 3.12 mm²	40 µm	6200	83%	32.2±0.1 V



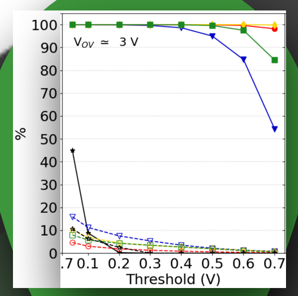


SiPMs in direct detection of charged particles: a roadmap

stay tuned…

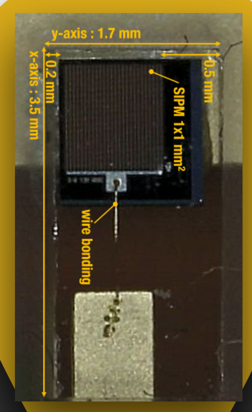
recent developments

SiPMs with a ***complete front-end*** and ***readout electronics***: LIROC discriminator and pTDC, preliminary efficiency and time resolutions results are briefly introduced.



paper in preparation

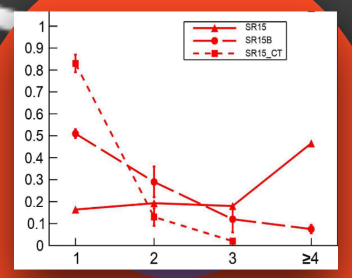
efficiency studied in detail thanks to 3x3 mm^2 area SiPMs to cover all the area subtended by the Cherenkov cone. Preliminary results indicate very high efficiencies with just 5 photoelectrons firing.



Eur. Phys. J. Plus 138, 788 (2023)

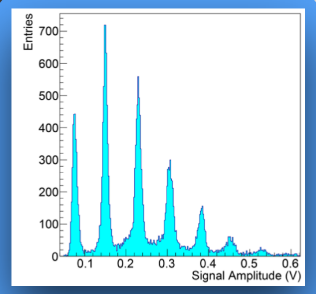
protection layers with known dimensions above single SIPMs of 1x1 mm^2: Cherenkov effect could be studied with a ***position scan***.

Signals and time resolution wrt number of fired SPADs (up to 8-9 SPADs) evaluated in the centre of the position scan. Resolution approaching 20 ps when >5 SPADs are firing were observed, where more than 80% of the total events lie.



Eur. Phys. J. Plus 138 337 *(2023)*

the increased response of SIPM at the passage of a MIP is due to ***Cherenkov light emission*** in the (standard) protection layer, usually placed above the sensor. A benefit in terms of time resolution as the number of fired SPADs increase was observed, going to about 40 ps when more than 4 SPADs are hit.



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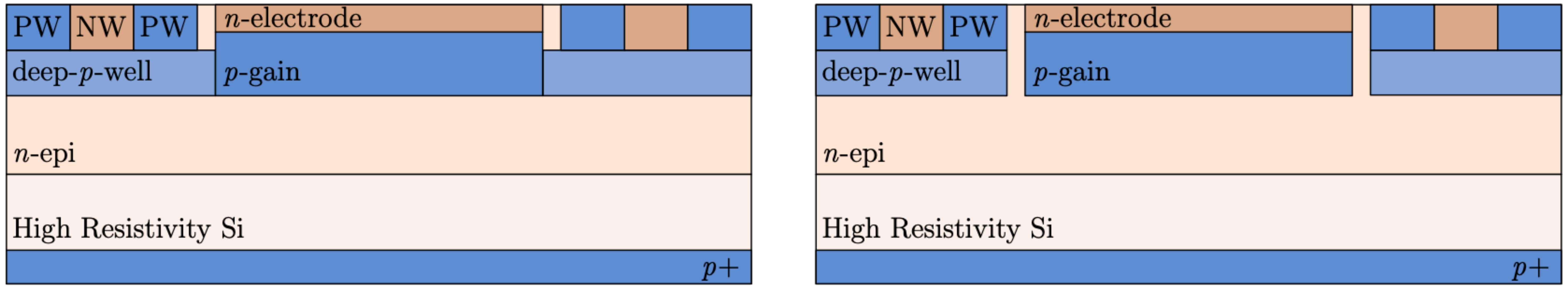
even if a particle should turn on only 1 SPAD per event, several SPADs are fired indicating a higher crosstalk (40-70%) with respect to intrinsic noise (10-15%) (at 6 V OV).

Cherenkov/scintillation effect in the protection layer or process inside the bulk?



(a) Layout A1

(b) Layout A2

Two different pixel layouts, differing by the termination at the pixel periphery, have been designed (see figure 1). In the first one, called A1 (figure 1(a)), the deep-*p*-wells are in contact with the gain layer, determining an increased multiplication volume. With this particular design, also primary charges generated via impact ionization under the *p*-well are multiplied, after being drifted towards the gain layer and then collected by the frontside electrode. However, these charges reach the n^+ implant with a certain delay with respect to the ones produced within the active area, due to the field curvature experienced at pixel borders. In the second layout, called A2 (figure 1(b)), a small gap is provided between the two implants. This means that some charges produced at border may follow drift lines that go through this gap and reach directly the n^+ electrode without crossing the gain layer. As a result, layout A2 allows the discrimination of signals generated in the region with gain, that are induced by charges whose drift lines are straightly directed to the collection electrode, from the peripheral ones, which are not multiplied.