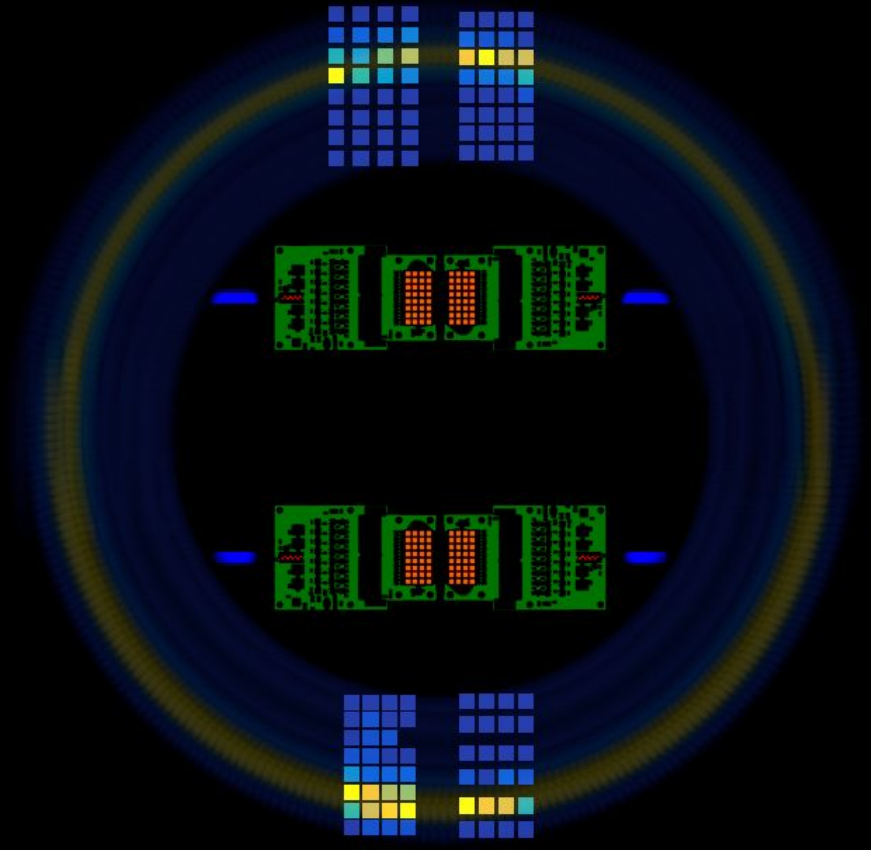
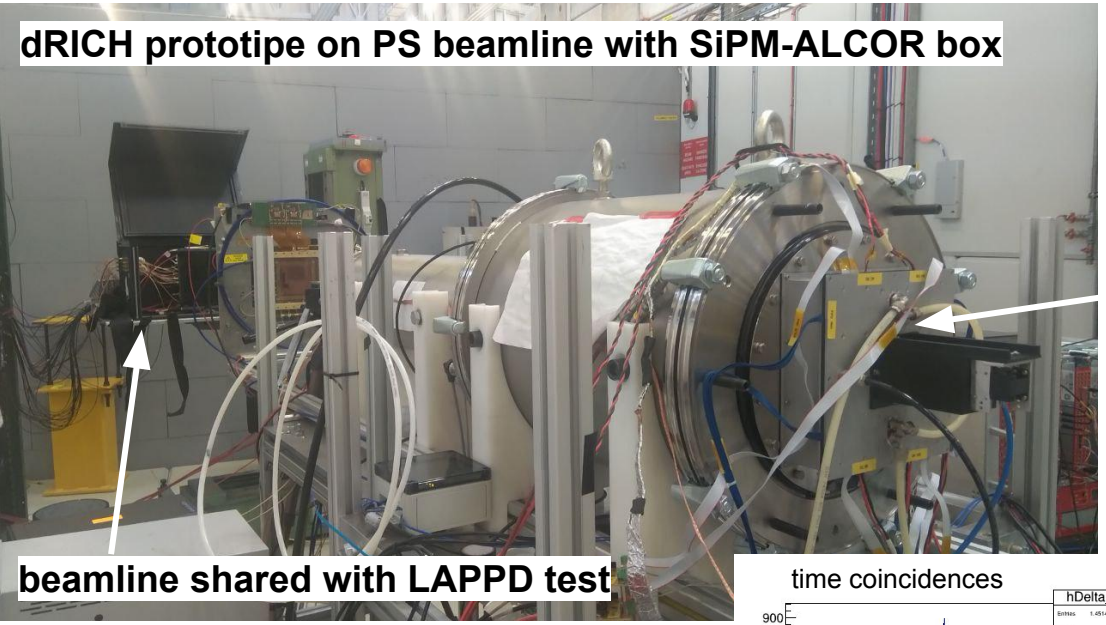
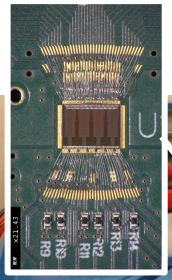
Results on SiPM with ALCOR

ALCOR for EIC meeting

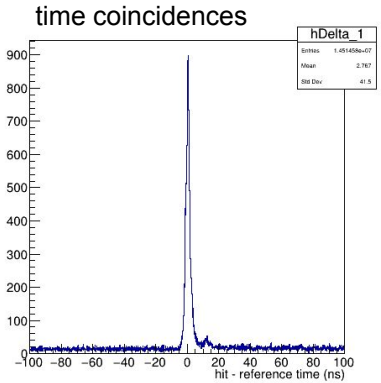


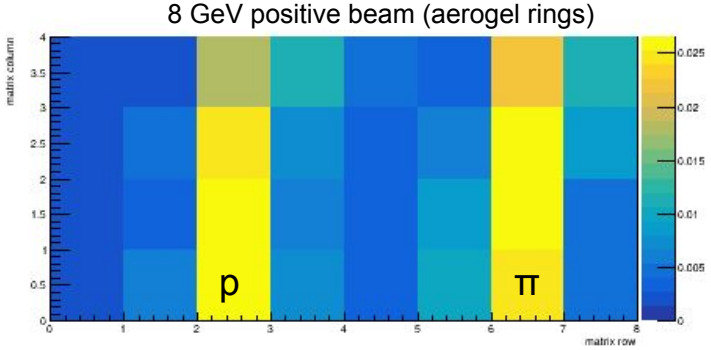
2022 test beam at CERN-PS





successful operation of SiPM
<u>irradiated</u> (with protons up to 10^{10})
and <u>annealed</u> (in oven at 150 C)





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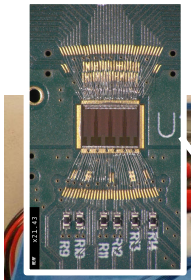


ALCOR inside

dRICH prototipe on PS beamline with SiPM-ALCOR box

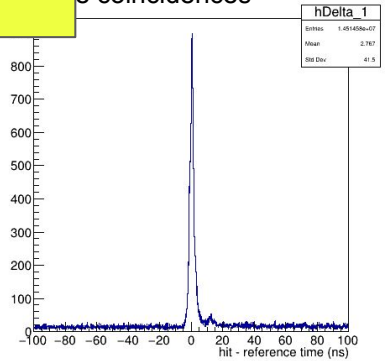
but remember that we had a **test-beam failure in 2021**

ALCOR-v1 chip has some problems with high input rates (cf. SiPM) that prevented us to effectively take data in 2021

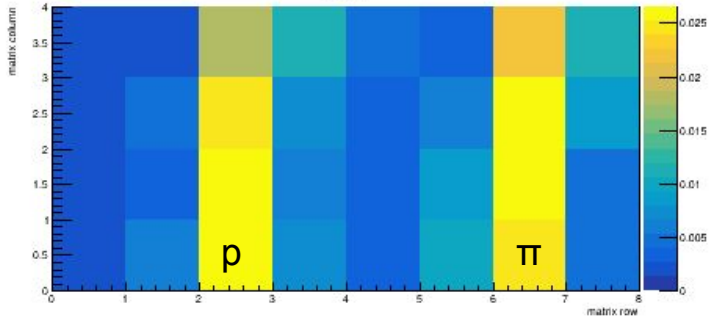
we managed to put in place some bricolage and tricks over one year of lab experience in Bologna and finally take data in 2022 beam test

successful operation of SiPM irradiated (with protons up to 10^{10}) and annealed (in oven at 150 C)

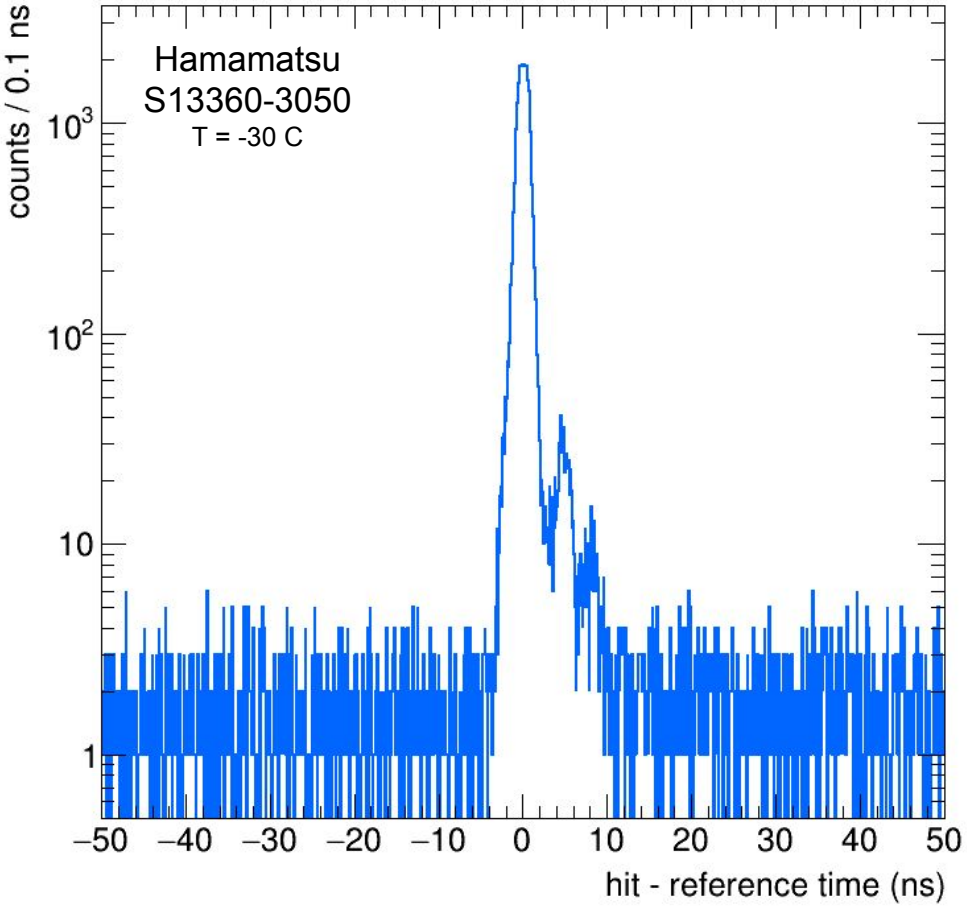
e coincidences

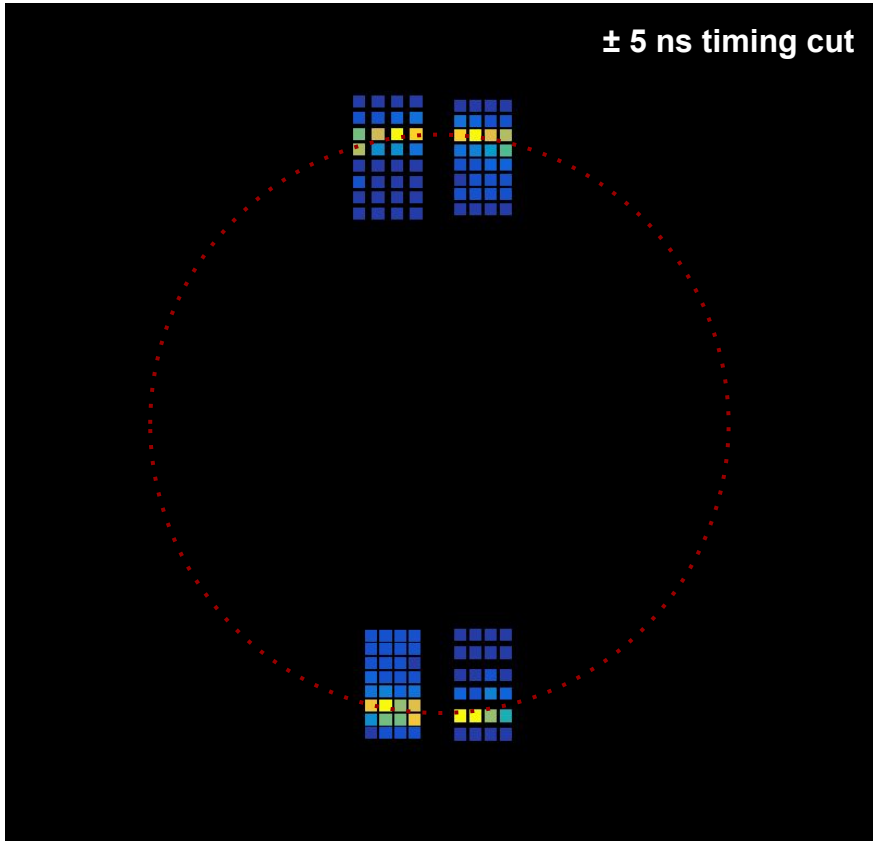


8 GeV positive beam (aerogel rings)



after irradiation with $2 \cdot 10^9$ n_{eq}/cm^2 fluence (protons)
and oven annealing at T = 150 C for 150 hours





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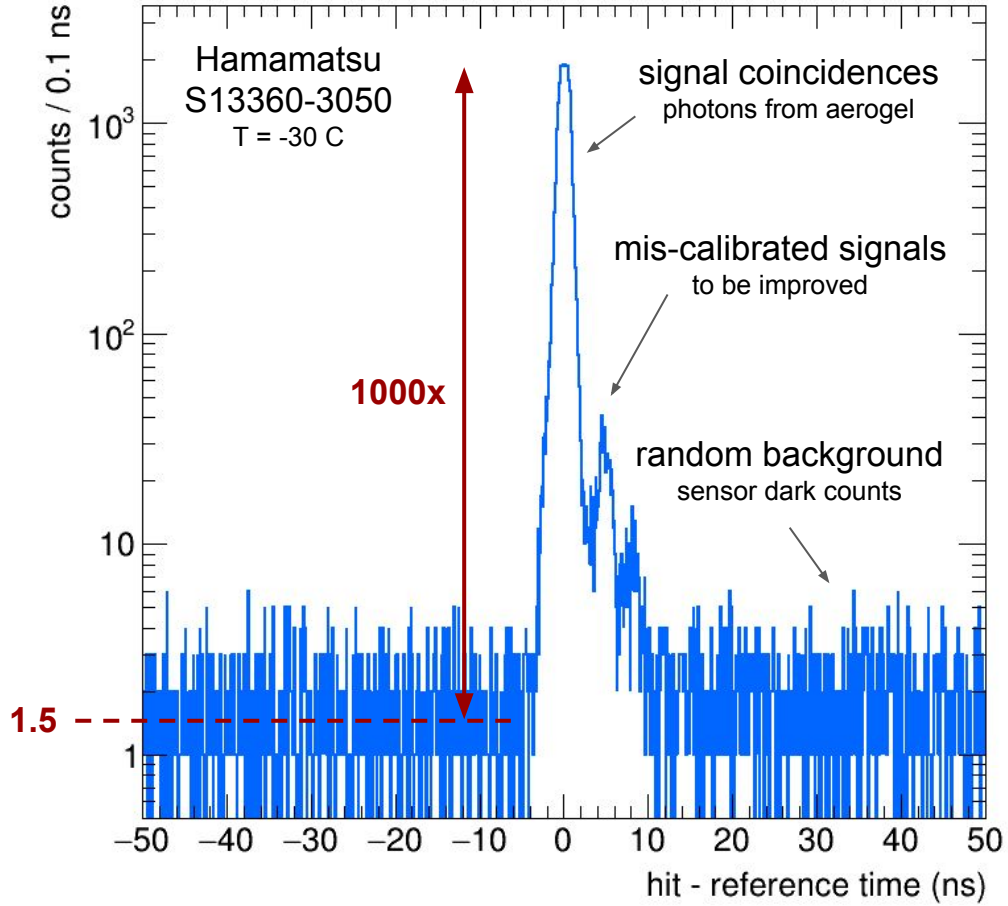
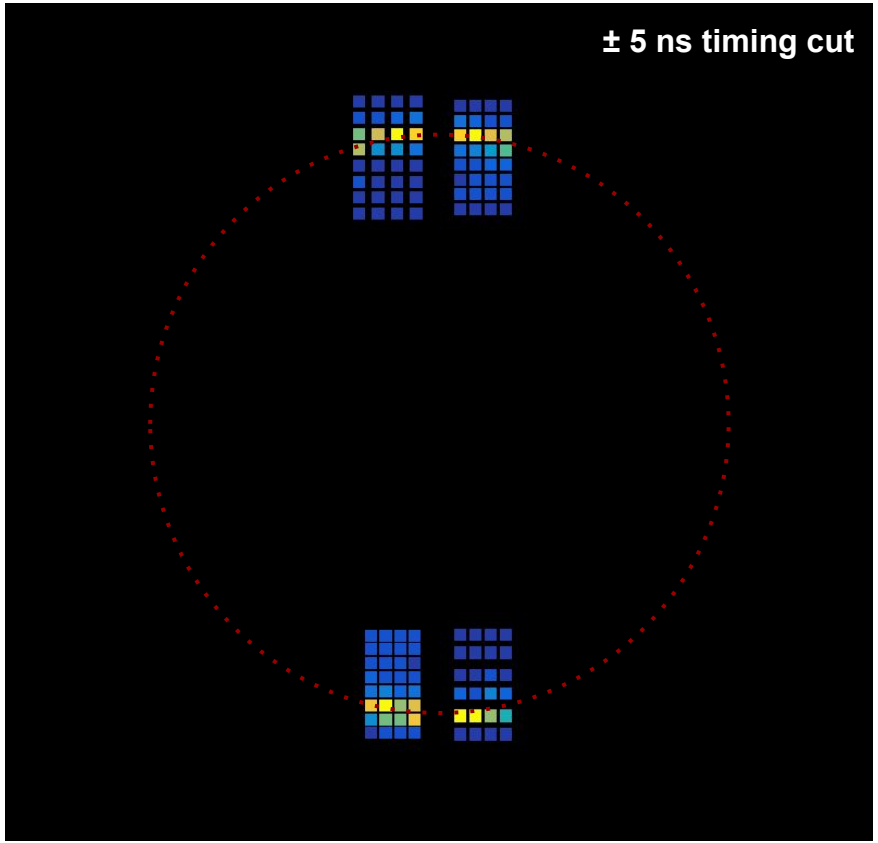
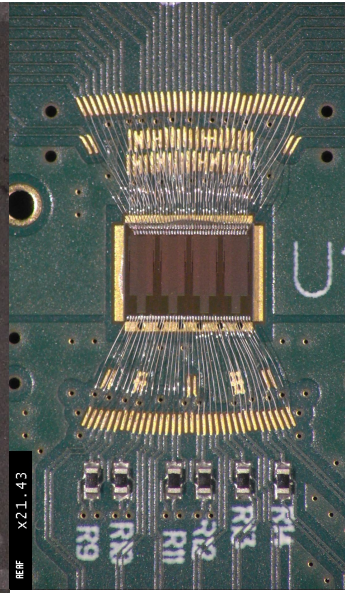
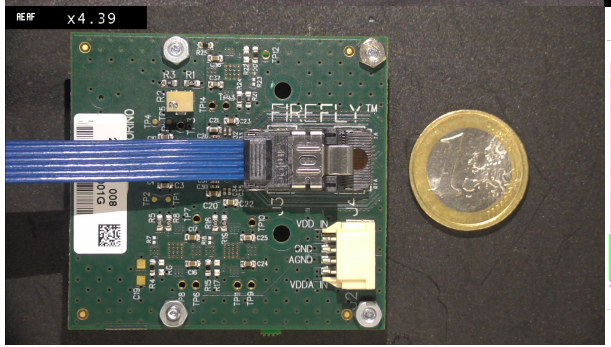


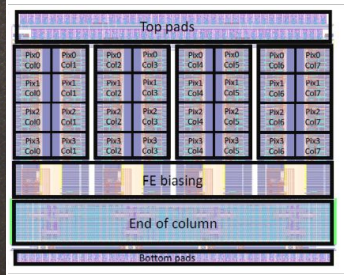


sensor DCR ~ 15 kHz

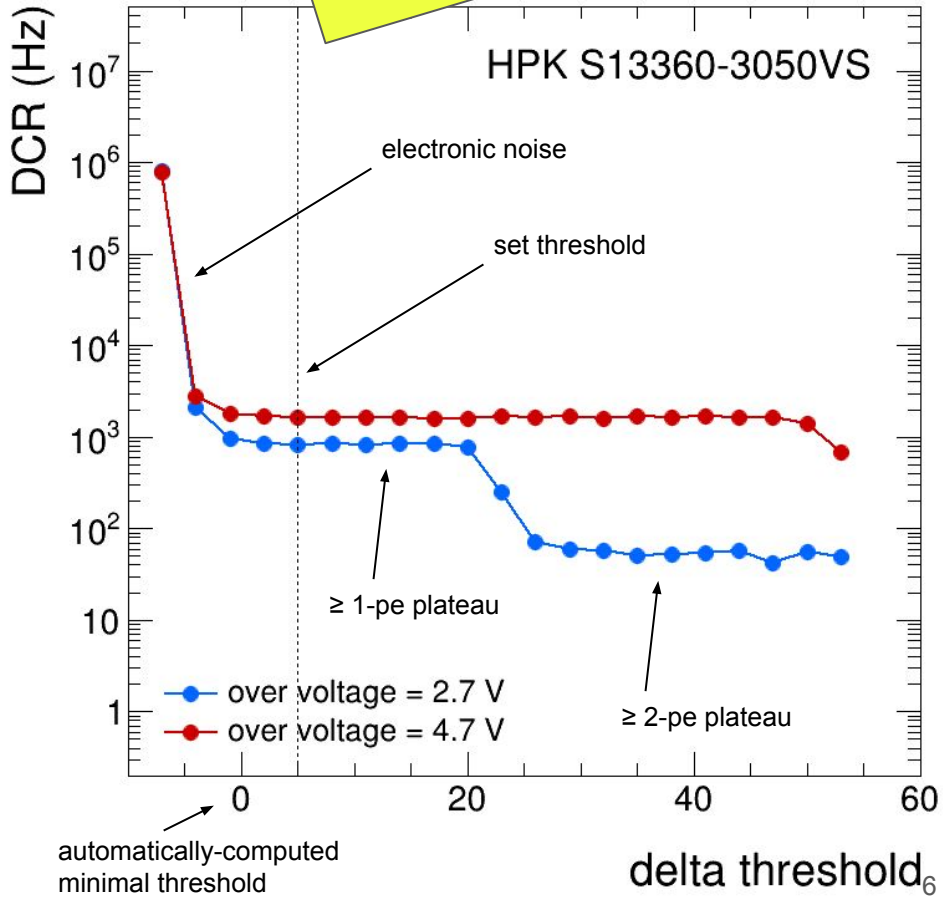
Photon counting with ALCOR



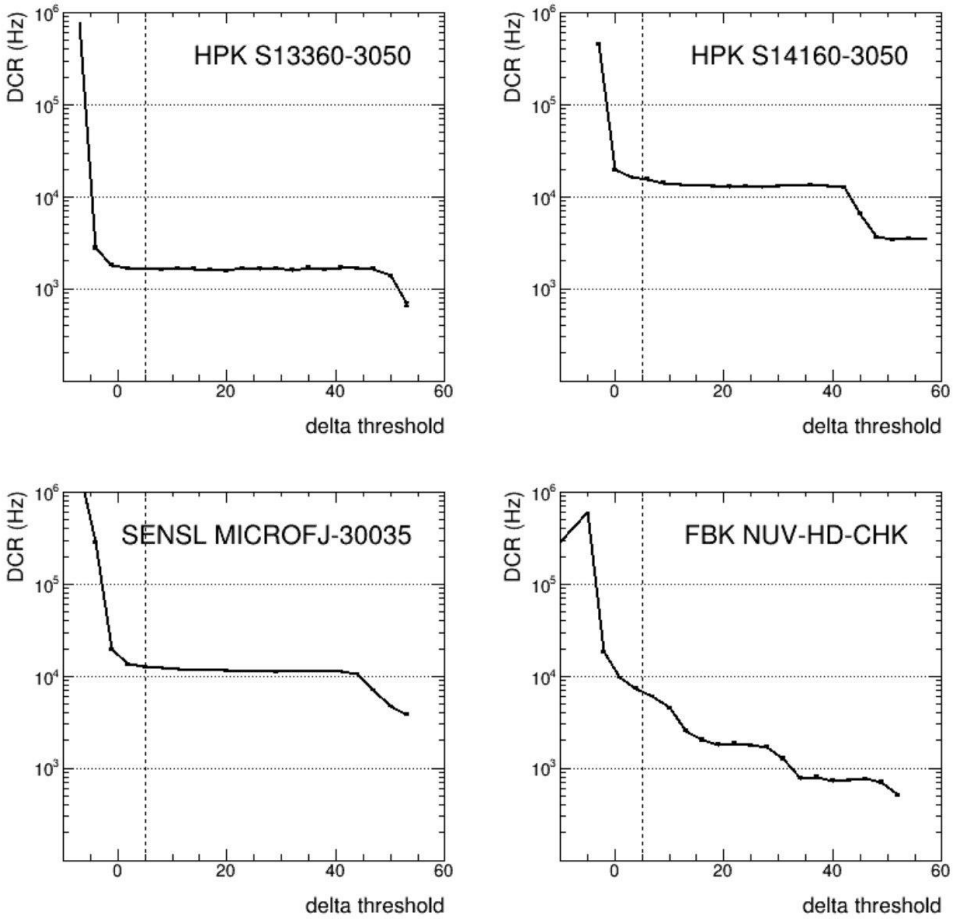




home cooking for automatic setting of optimal discriminator threshold works well



Coupling ALCOR with SiPM (FBK)



1-pe plateau for FBK sensors (large 40 um) SPAD is very short

small amplitude signals seen by ALCOR? why? in principle FBK has similar capacitance / gain as HPK sensors

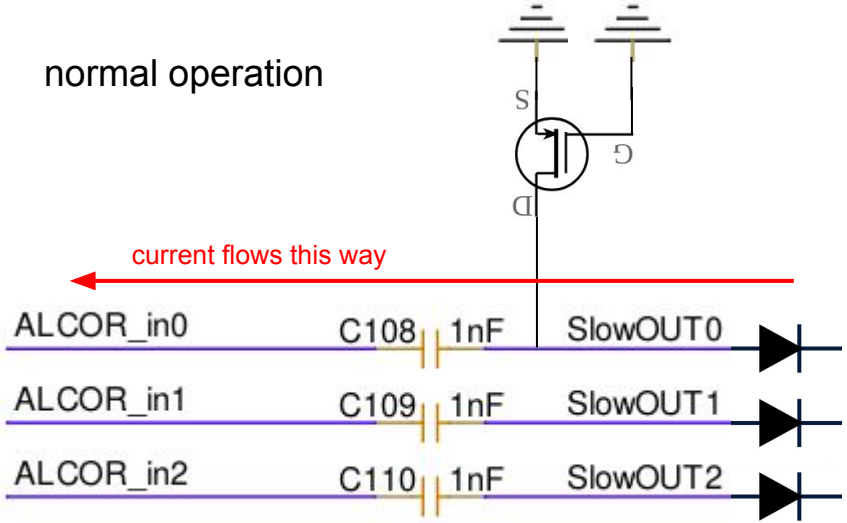
moreover the 1-pe plateau in FBK is not really a plateau

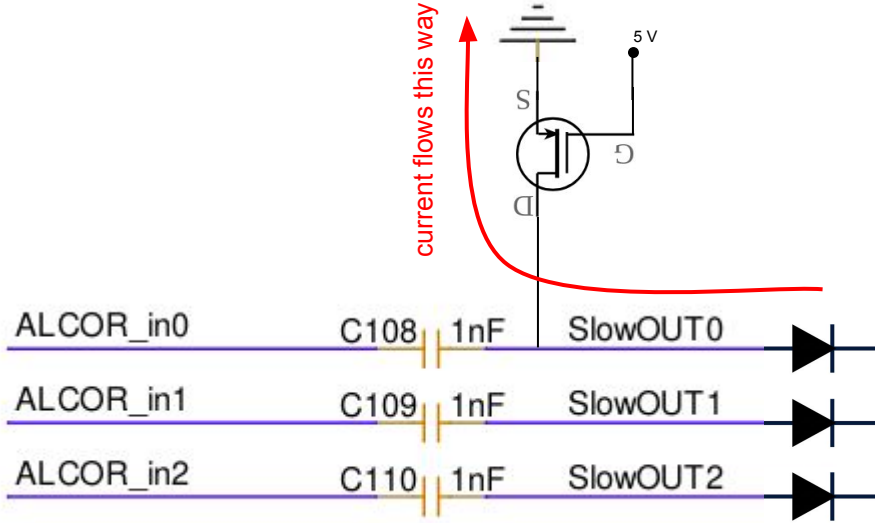
is ALCOR “more noisy” with FBK sensors? “less gainy” with FBK sensors?

need to better study how we couple ALCOR with the SiPM

Testing circuitry effects on signal amplitude (shape)

normal operation

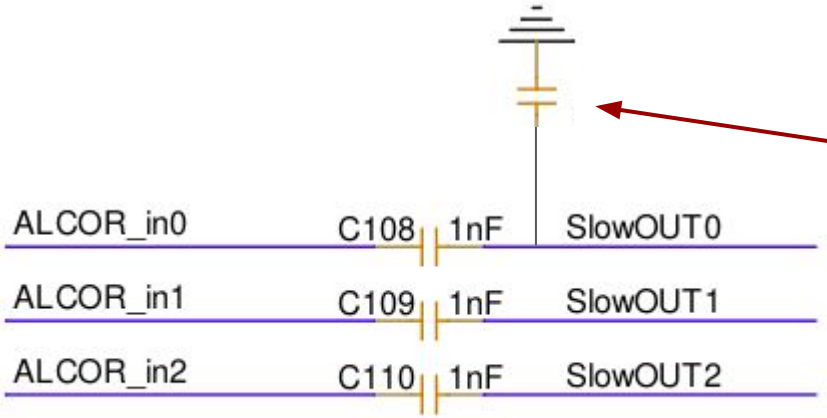


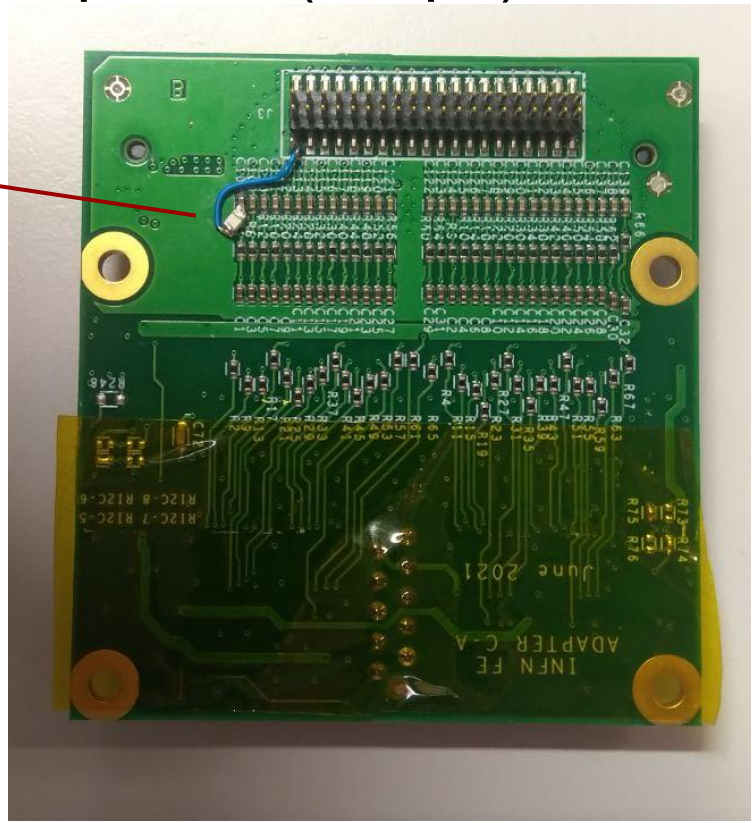


we need specialised circuitry (mosfet) to be able to “disconnect” ALCOR (and other circuitry downstream the SiPM) when performing current annealing

being implemented on new prototype electronics. Mosfet parasitic capacitance will “eat” part of the signal. How much? Which frequencies? Simulation?
in meantime we did measurements

Testing circuitry effects on signal amplitude (shape)





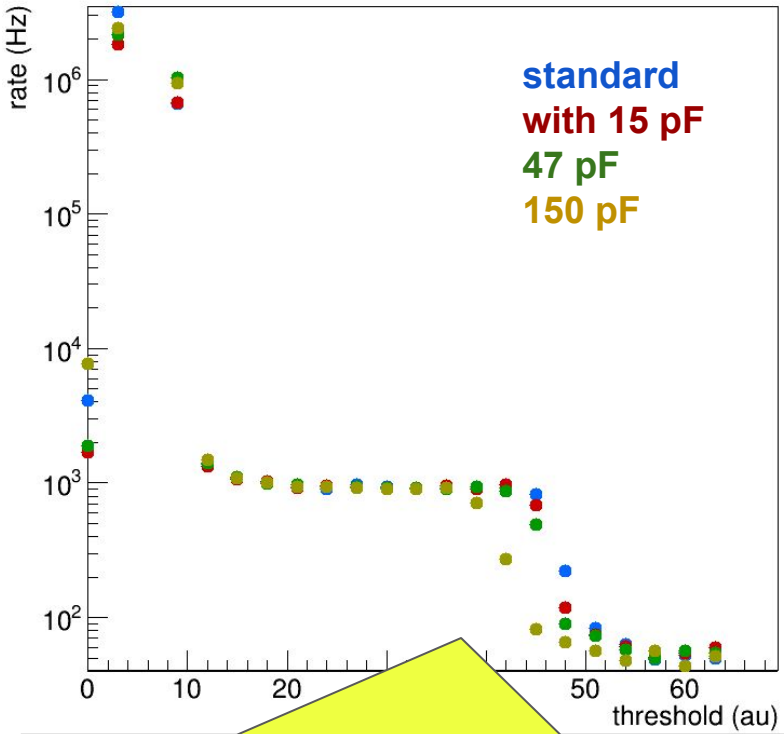
very first tests using discrete capacitor used ALCOR for “the real thing” test of signal change, but how to see it?

→ threshold scan as proxy of amplitude measurements

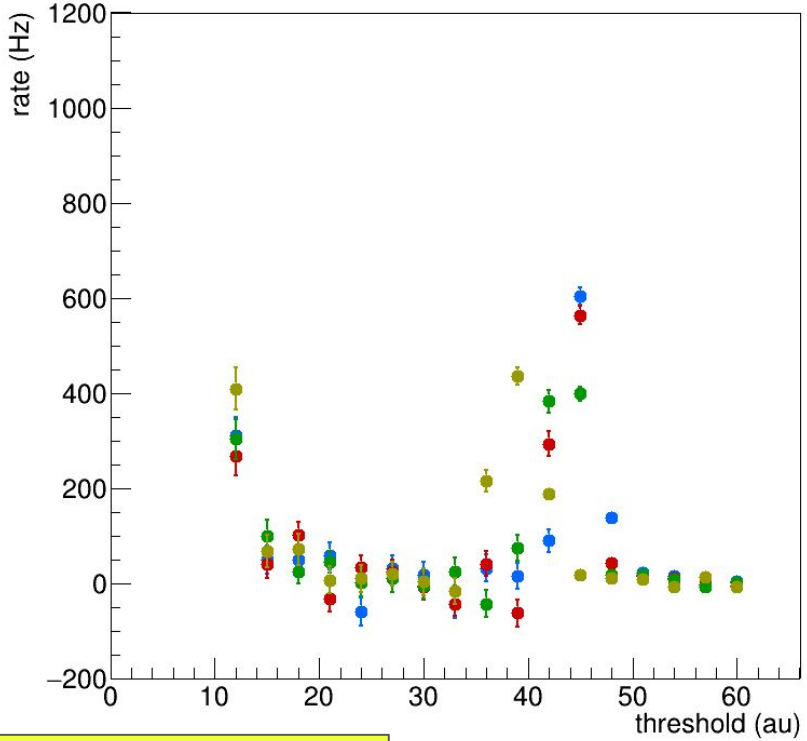
capacitor will “eat” high frequencies
if signal decreases → significant cut of high frequencies → worse timing

Testing circuitry effects on signal amplitude (shape)

threshold scan

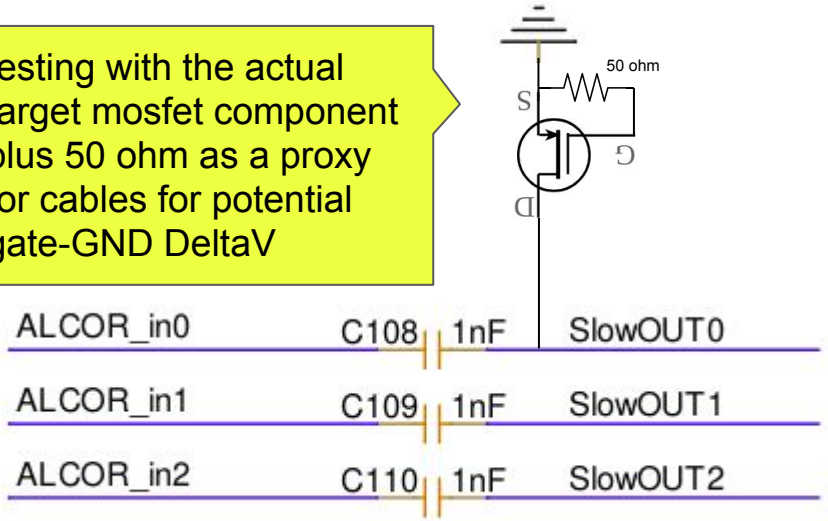


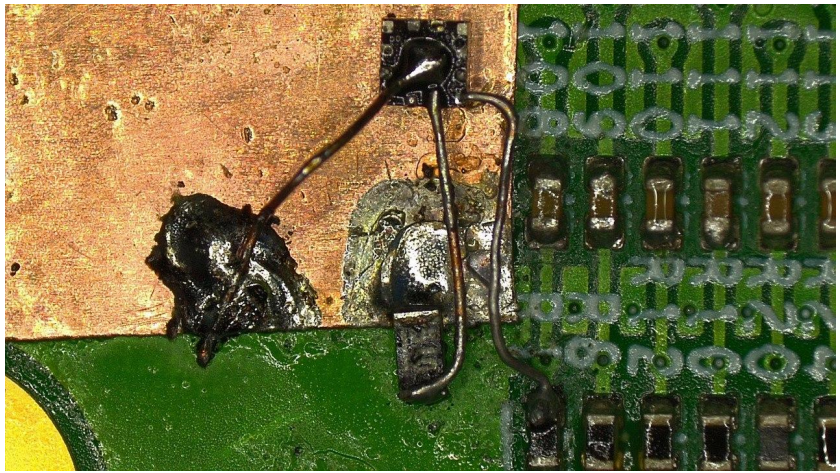
derivative, which is the amplitude spectrum

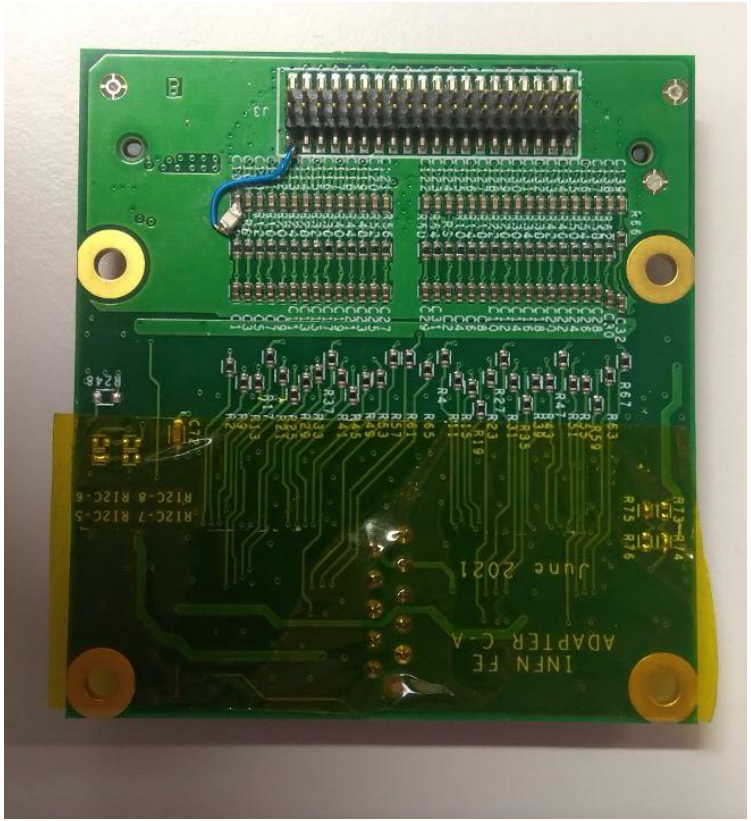


barely an effect for < 47 nF capacitance
visible at 150 pF
makes sense since SiPM capacitance is of similar order of magnitude

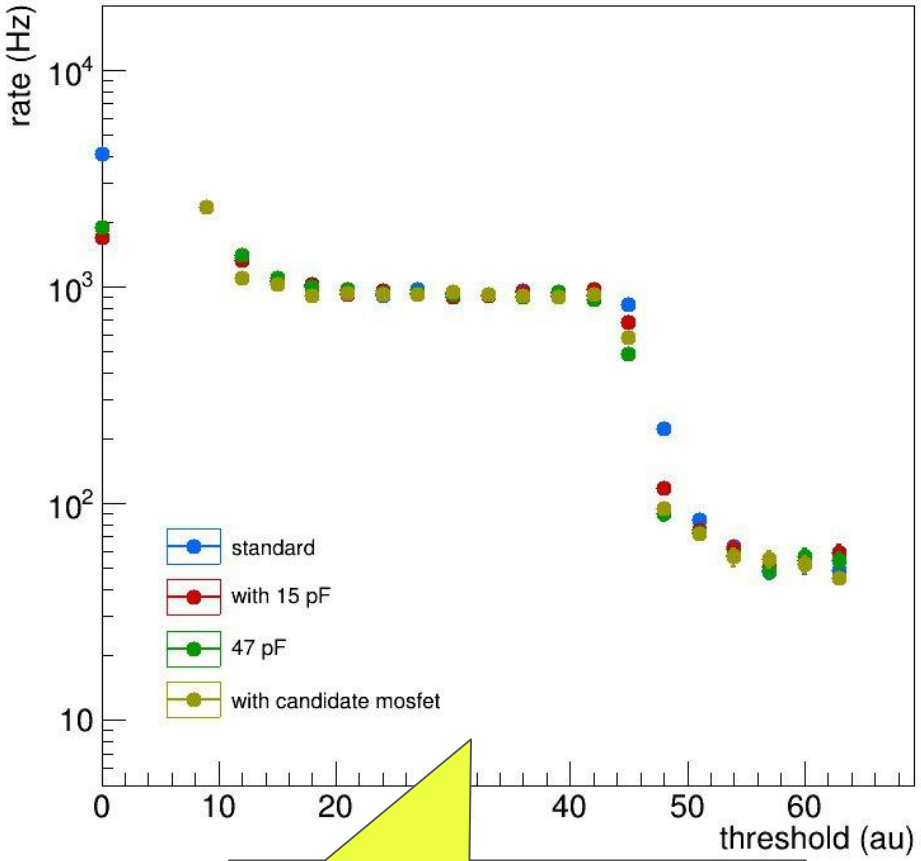
testing with the actual target mosfet component plus 50 ohm as a proxy for cables for potential gate-GND DeltaV



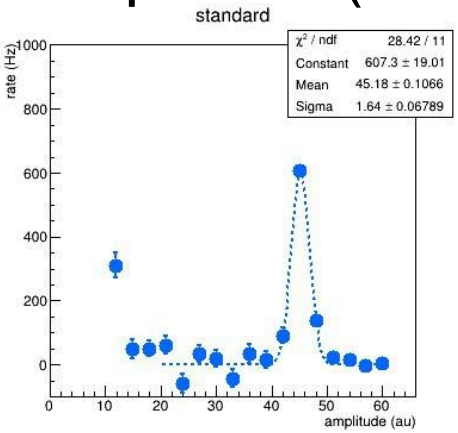


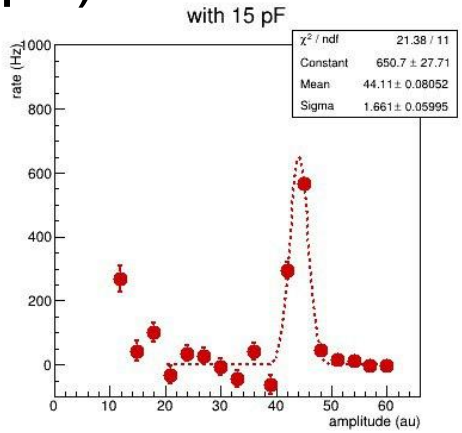


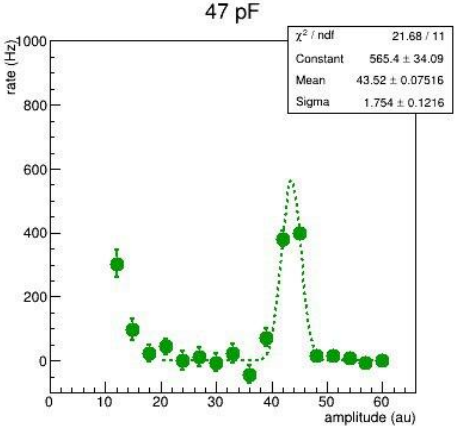
Testing circuitry effects on signal amplitude (shape)

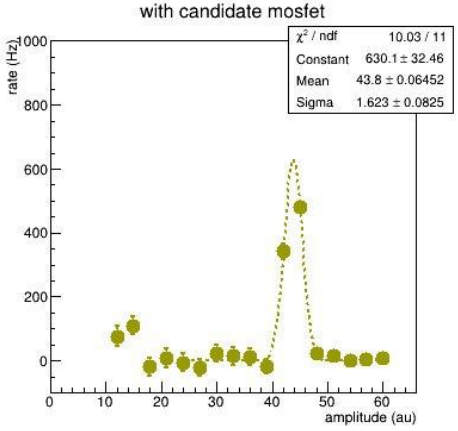


we see an effect, but it is small

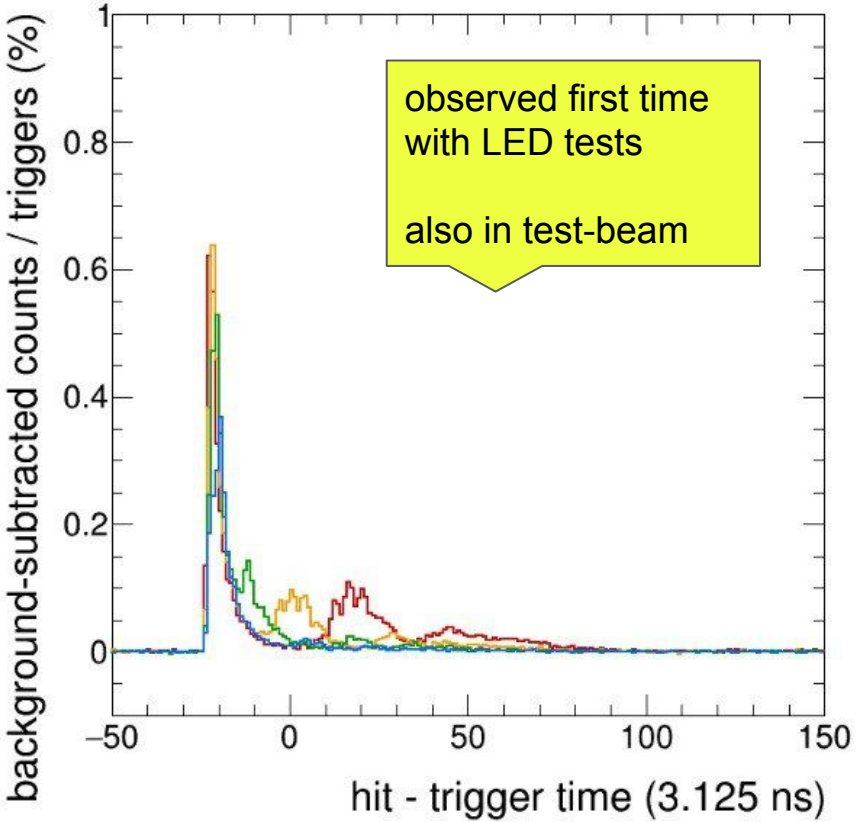


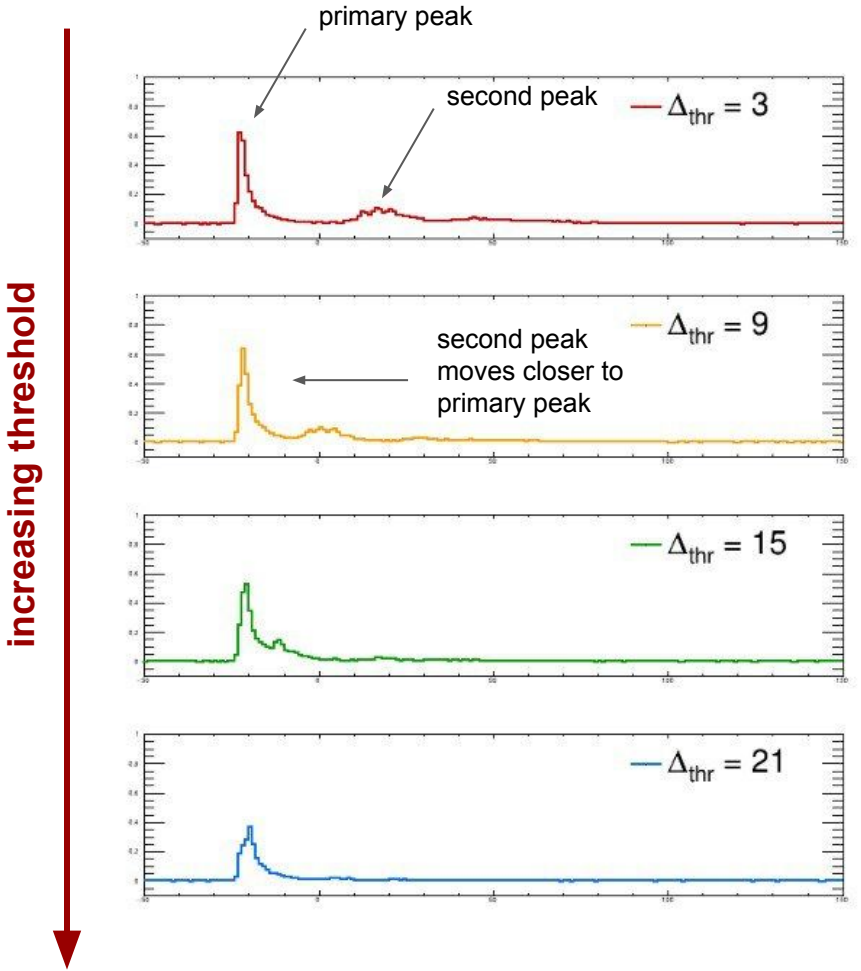






ALCOR afterpulses in lab

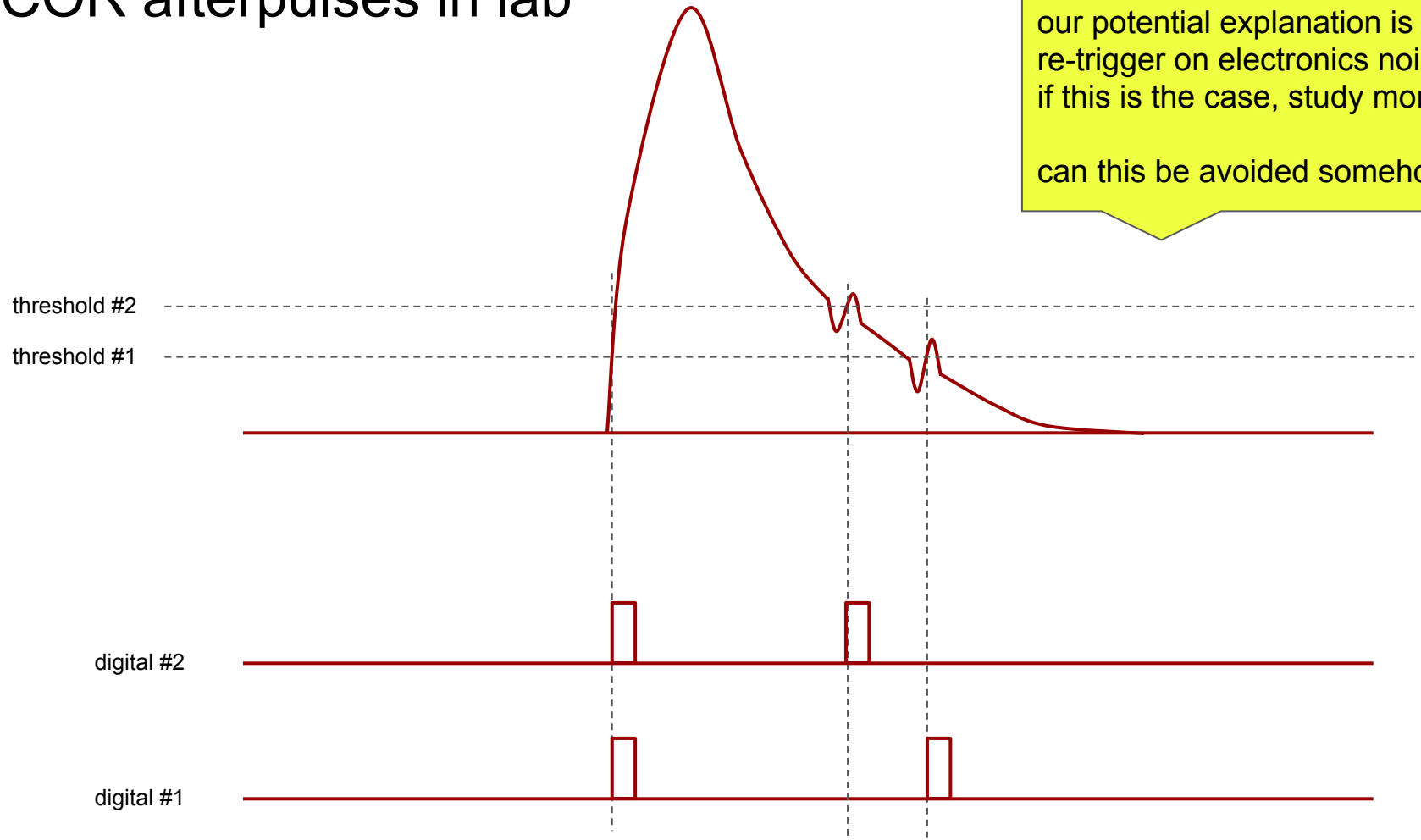




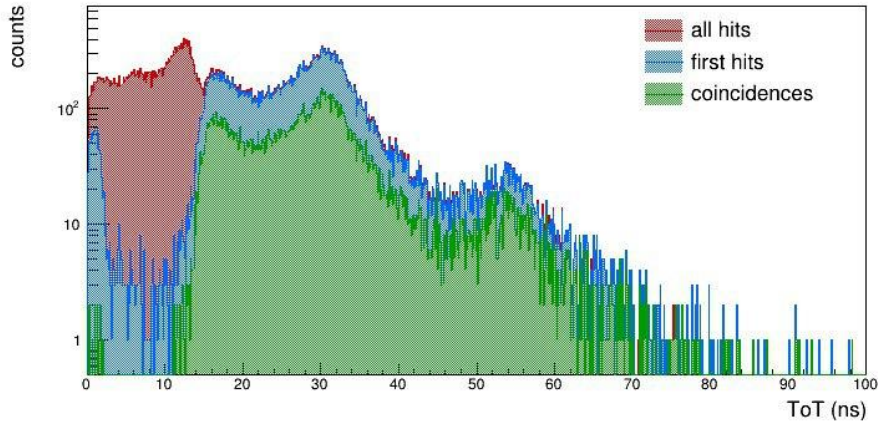
ALCOR afterpulses in lab

our potential explanation is
re-trigger on electronics noise
if this is the case, study more

can this be avoided somehow?



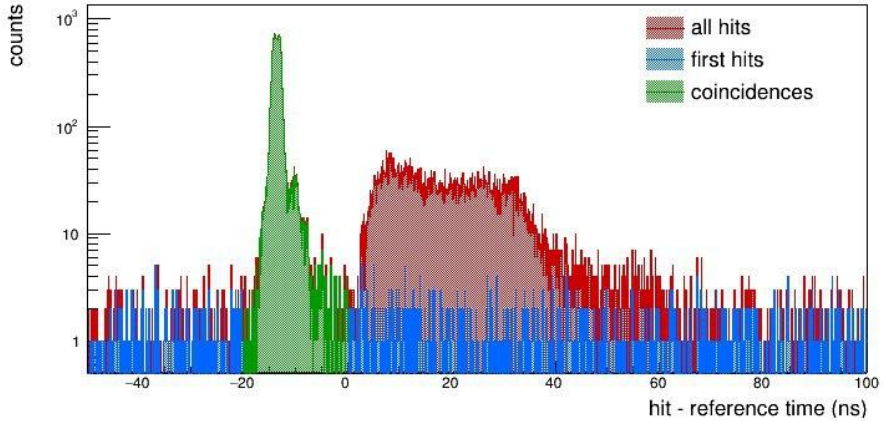
ALCOR afterpulses in test beam

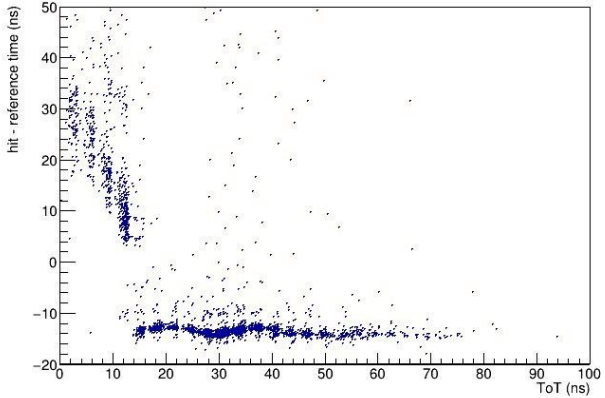


we do see afterpulses also in test beam
ToT feature of ALCOR used for the first time by us in 2022 beam test

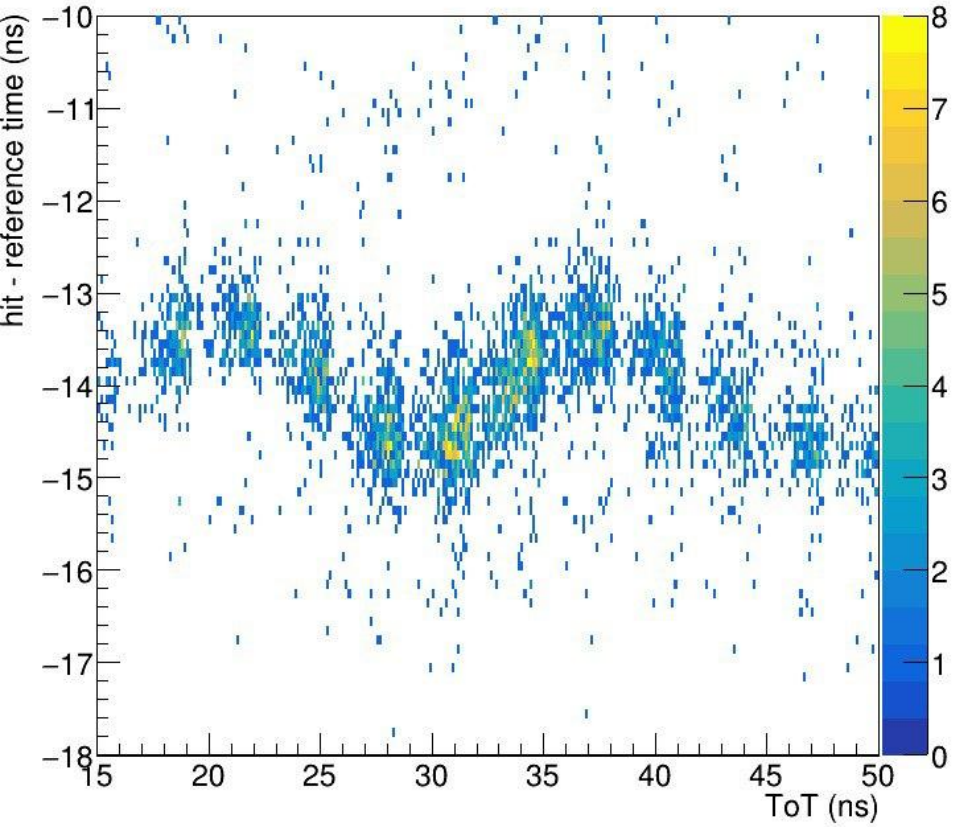
we can nicely correlate after-pulses with low ToT signals (noise ripple?0

→ importance of having a ToT measurement to reject afterpulses (and for time resolution)





ALCOR ToT



ToT feature of ALCOR used for the first time by us in 2022 beam test

not simple to combine leading-trailing hits from TDCs, apparently not appearing in order (leading first, trailing after) in the serial data stream? several (10%) orphans?

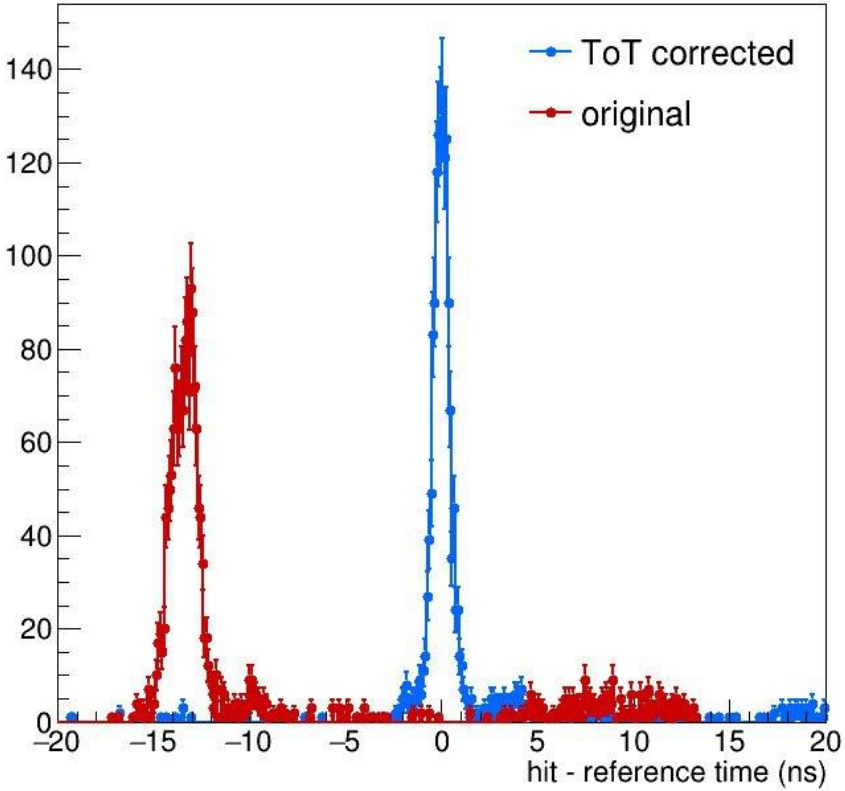
needs work to study and understand how to exploit it at best, but it is needed

very weird time-amplitude (ToT) correlation in HPK 13360 sensors

sinusoidal? fits well with 8.5 ns period… what is this? and why?

whatever it is, needs to be studied and understood

ALCOR ToT



ToT feature of ALCOR used for the first time by us in 2022 beam test

ToT is important for improving time resolution we are far from a measurement of it from the beam test, but we have a best result

which is ~ 350 ps for HPK 13360 sensors
larger than what I hoped
at lowish overvoltage (3 V)

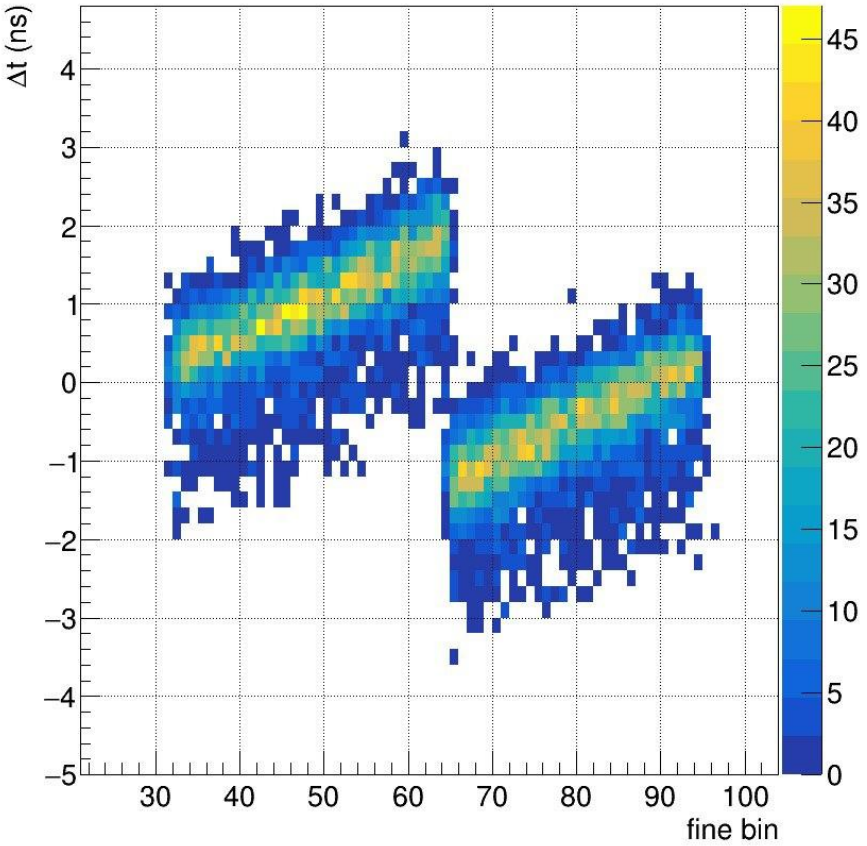
is this close to the limit we can achieve with ALCOR coupled with these SiPM sensors?

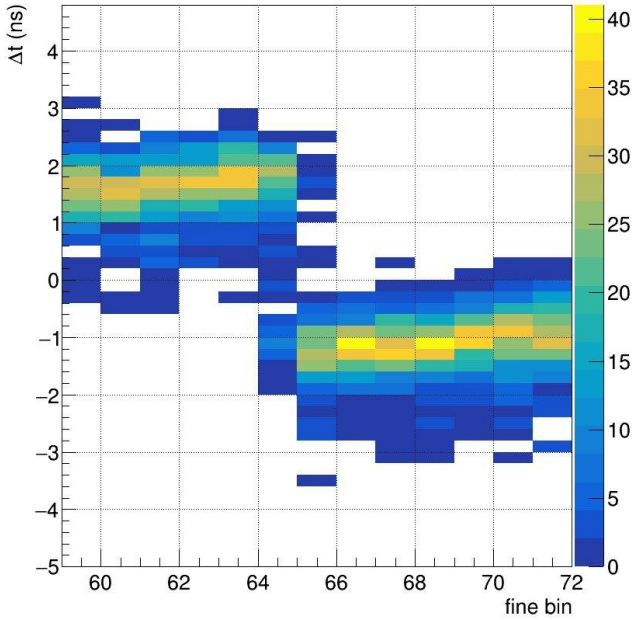
if not, we need to understand where in the electronics chain we need to improve for better timing

ALCOR fine TDC measurement

observed ambiguity in ALCOR fine TDC measurement for same TDC bin (two peak structures)

there are worse cases than this, need to look into this together and replicated in lab





Very brief summary

- **we extensively used ALCOR in the last 1.5 year**
  - far to say that we have thoroughly tested it for EIC SiPM use
  - it took time till we managed to make use of it “bypassing” the limitations (v1 bug)
  - needs IMO more testing with joint efforts between users (ie. BO) and gurus (TO)

  must create a strong user-guru “task force” with regular (monthly) meetings?
  RP planned to organise a kickstart meeting (let’s meet in TO in a month?)

- **various observations point towards test and optimisation needs**
  - afterpulses (and noise that I did not show)
  - proper coupling with SiPM capacitance and signal shaping
  - is the measures time resolution close to what we expect we can have?
  - strange features in ToT correlation, way of ToT data stream to be discussed
  - TDC interpolation seems to introduce ambiguities at clock boundary
- **IMO need to get our hand on v2 soon and iron out remaining wrinkles**
  - v1 bug prevented us to really see ALCOR working at high-rate
  - we use tricks to reach MHz measurements and cope with test-beam (learnt pulse-inhibit by chance)
- **possible further requirements / requests**
  - we are AC-decoupling with discrete components, what is best to be done ? do it in ALCOR ?
  - in electronic boards we put (expensive) DACs to fine-tune HV, put it in ALCOR (as weeroc) ?
  - implement “the annealing mosfet” inside ALCOR ? will it sustain current (20-30 mA/channel) ?