dRICH photosensors

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on behalf of the sipm4eic-elettronica group
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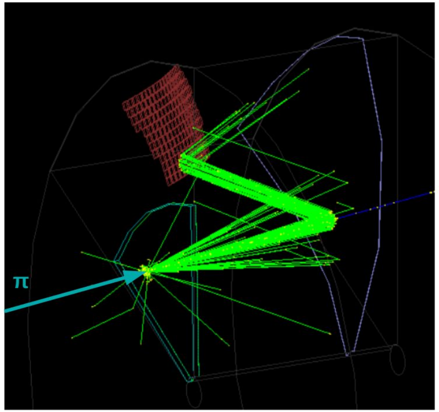
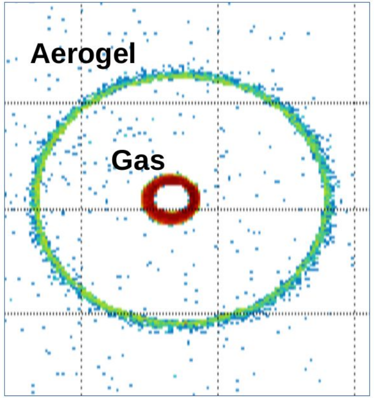
The dual-radiator (dRICH) for forward PID at EIC

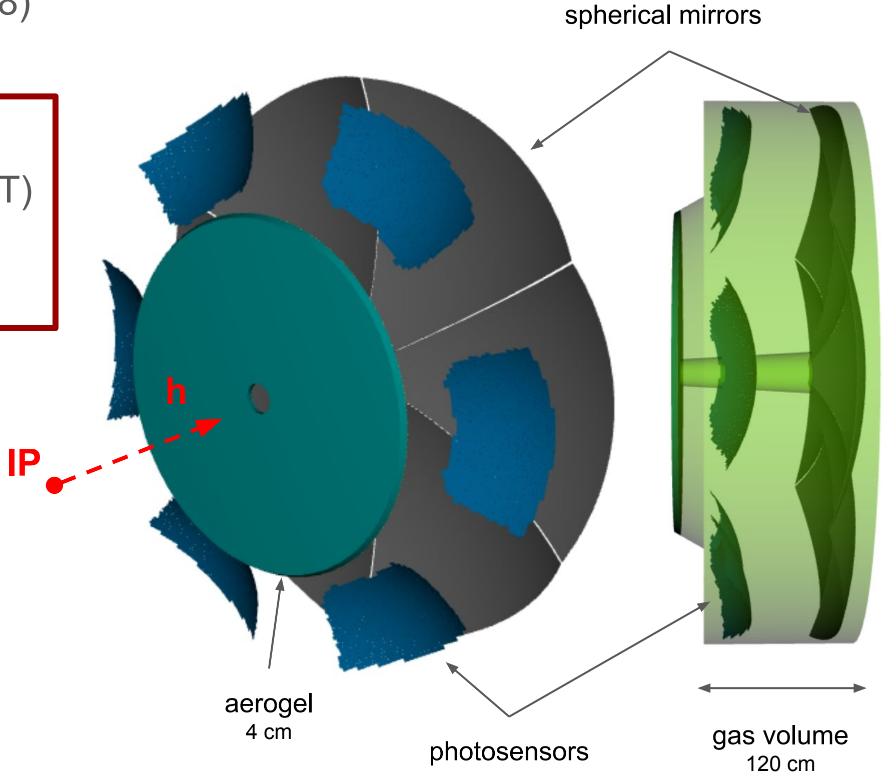
compact and cost-effective solution for broad momentum coverage at forward rapidity

- **radiators:** aerogel (n ~ 1.02) and C_2F_6 (n ~ 1.0008)
- **mirrors:** large outward-reflecting, 6 open sectors
- **sensors:** 3x3 mm^2 pixel, 0.5 m^2 / sector
  - single-photon detection inside high B field (~ 1 T)
  - outside of acceptance, reduced constraints
  - best candidate for SiPM option



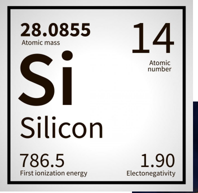


example event (accumulated hits)



SiPM option for RICH optical readout

- **pros**
  - cheap
  - high photon efficiency
  - excellent time resolution
  - insensitive to magnetic field

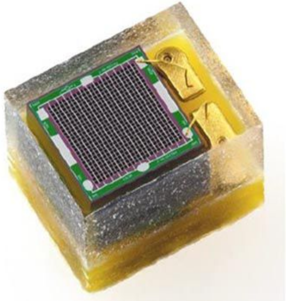


- **cons**

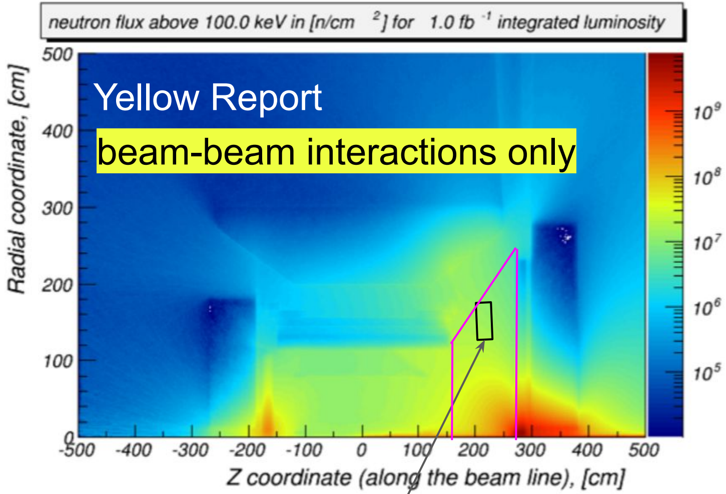
large dark count rates

not radiation tolerant

R&D focus on risk-mitigation strategies
- 🐧 cooling
- 🕓 timing
- 🔥 annealing



Neutron fluxes at the EIC



Most of the key physics topics discussed in the EIC White Paper [2] are achievable with an integrated luminosity of 10 fb^{-1} corresponding to 30 weeks of operations. One notable exception is studying the spatial distributions of quarks and gluons in the proton with polarized beams. These measurements require an integrated luminosity of up to 100 fb^{-1} and would therefore benefit from an increased luminosity of $10^{34}\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$.

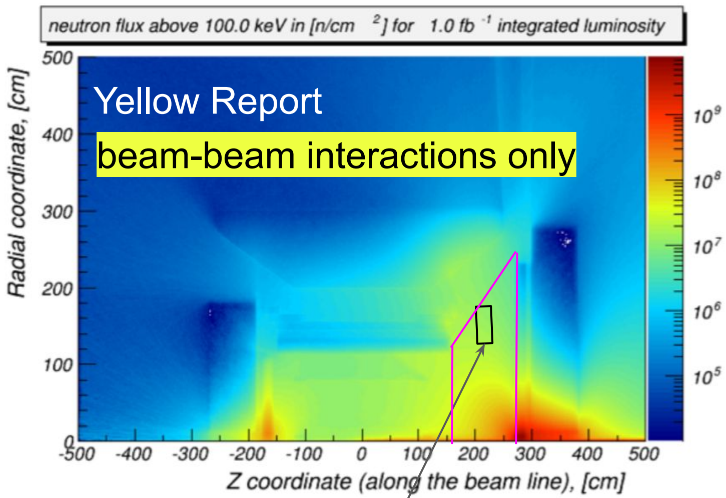
R&D on SiPM as potential photodetector for dRICH, main goal
study SiPM usability for Cherenkov up to 10^{11} 1-MeV n_{eq}/cm^2

location of dRICH photosensors
neutron fluence ~ 1-5 10^7 n / cm^2 / fb^{-1}
(> 100 keV ~ 1 MeV n_{eq})

- radiation level is moderate
- magnetic field is high(ish)

relevant also for space applications
the total dose depends on the specific orbit and the shielding of the instrumentation
but in typical Low Earth Orbits (LEO) or Polar orbit (for few years operations)
the total dose is in the order of 10^{11} particles/cm^2

Neutron fluxes at the EIC



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R&D on SiPM as poten … CH, main goal
study SiPM usability … **1-MeV n_{eq}/cm^2**

R&D on radiation damage and mitigations strategies is also relevant for DRD4

locat …
neut … fb^{-1}
(> 100 …
-
-

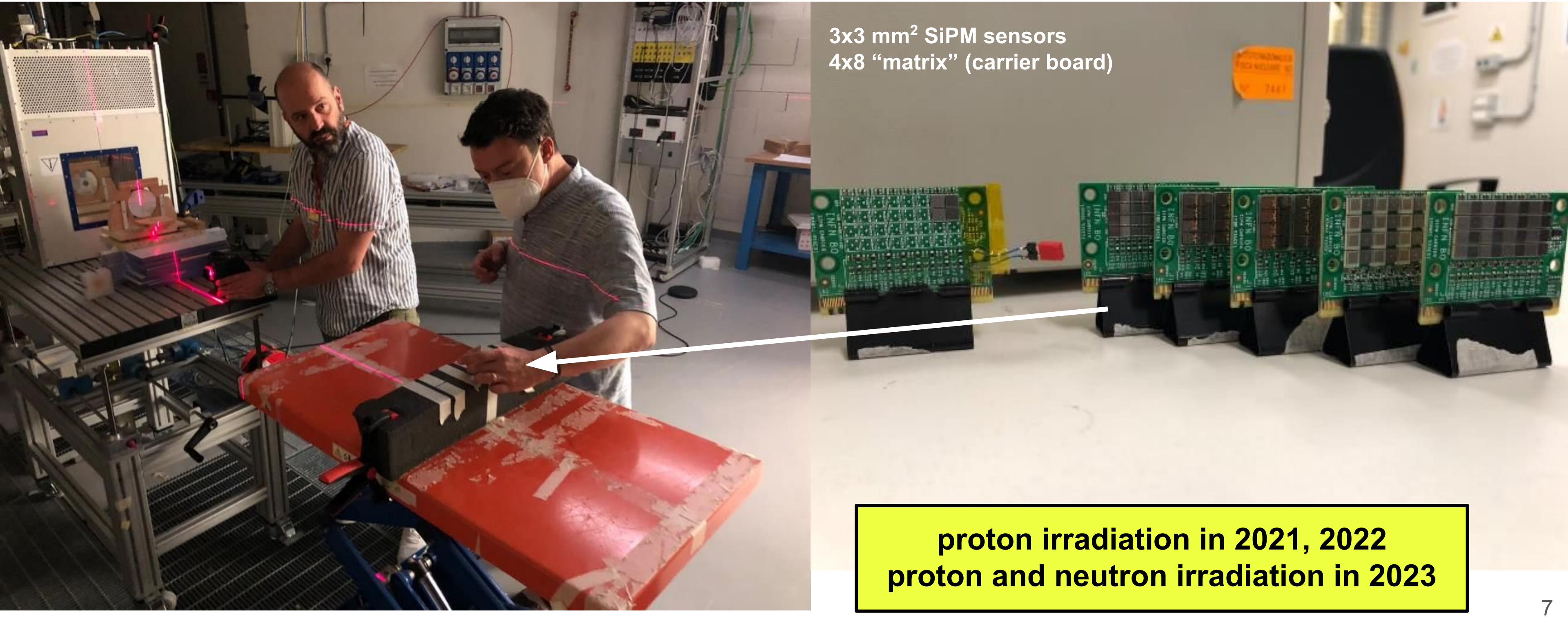
there are updated calculations or radiation expectations in ePIC, the numbers are the same

relevant also for space applications
the total dose depends on the specific orbit and the shielding of the instrumentation
but in typical Low Earth Orbits (LEO) or Polar orbit (for few years operations)
the total dose is in the order of 10^{11} particles/cm^2

SiPM characterisation

Irradiation at Trento Proton-Therapy hall (TIFPA)

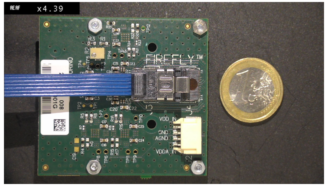
multiple types of SiPM:	commercial **Hamamatsu** (13360 and 14160) and **SENSL** (MicroFJ)
	prototypes from **FBK** (rad.hard and timing optimised)
different SPAD size:	from 15 to 75 μm

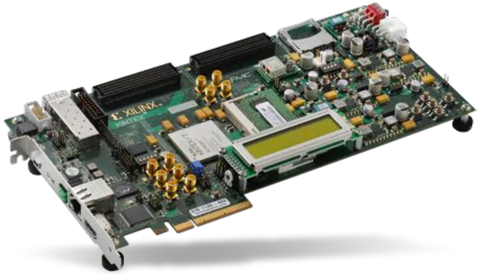


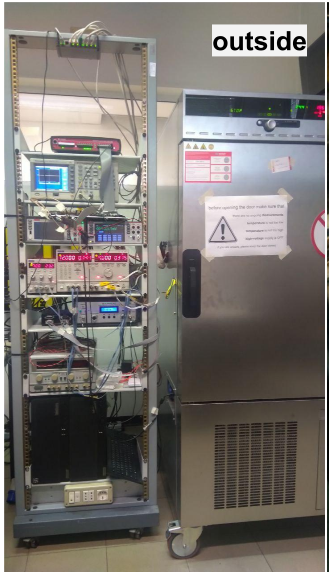
proton irradiation in 2021, 2022
proton and neutron irradiation in 2023

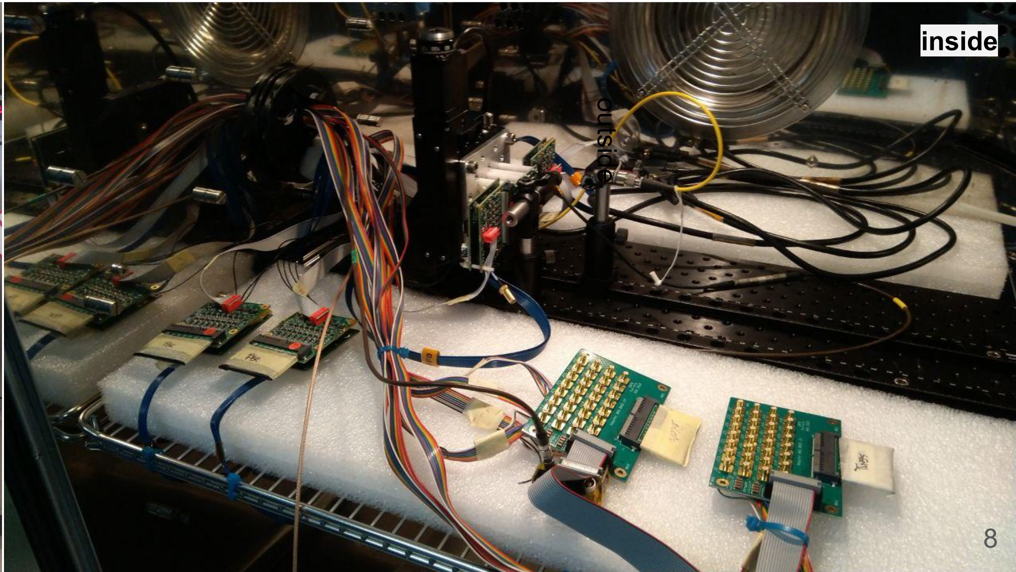
Characterisation setup

- **climatic chamber**
  low-temperature operation (T = -30 C)
- **2x 40-channel multiplexers**
  source meter
- **ALCOR-based front-end chain**
  FPGA (Xilinx) readout
  automatic measurement of 4x SiPM boards (128 channels)

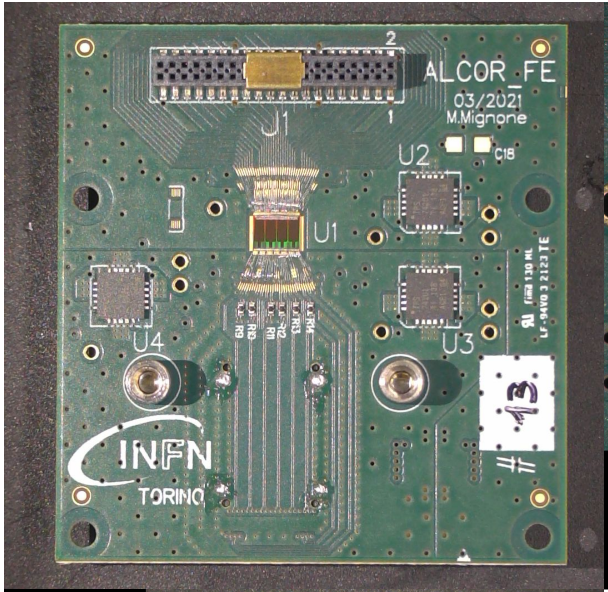


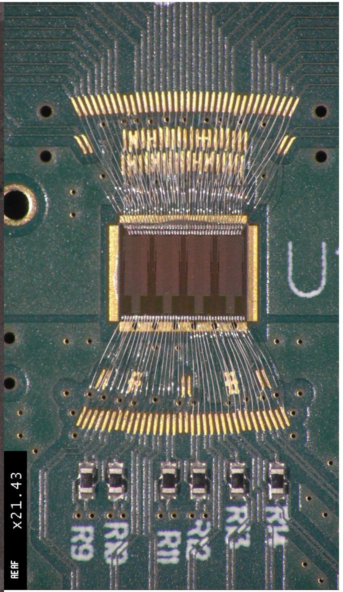


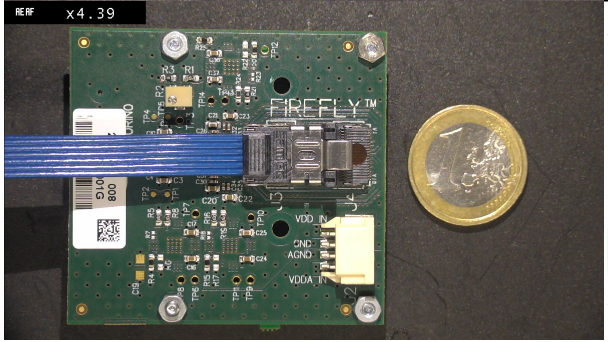


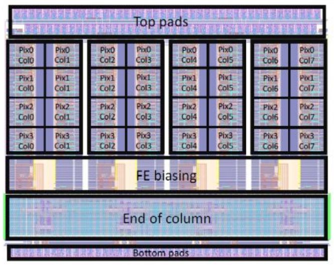


ALCOR: A Low Power Chip for Optical sensor Readout









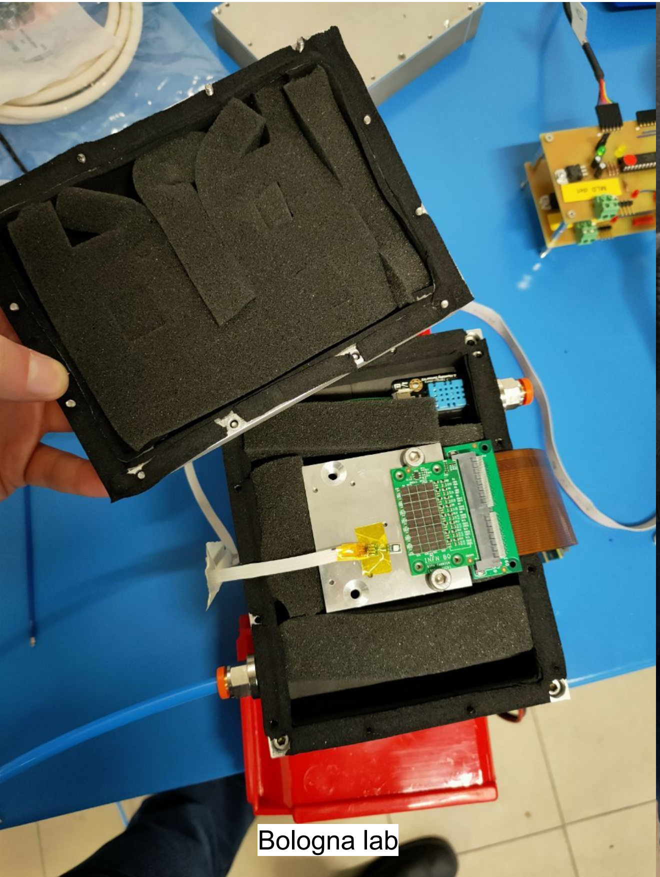
developed by INFN-TO for DarkSide

32-pixel matrix mixed-signal ASIC

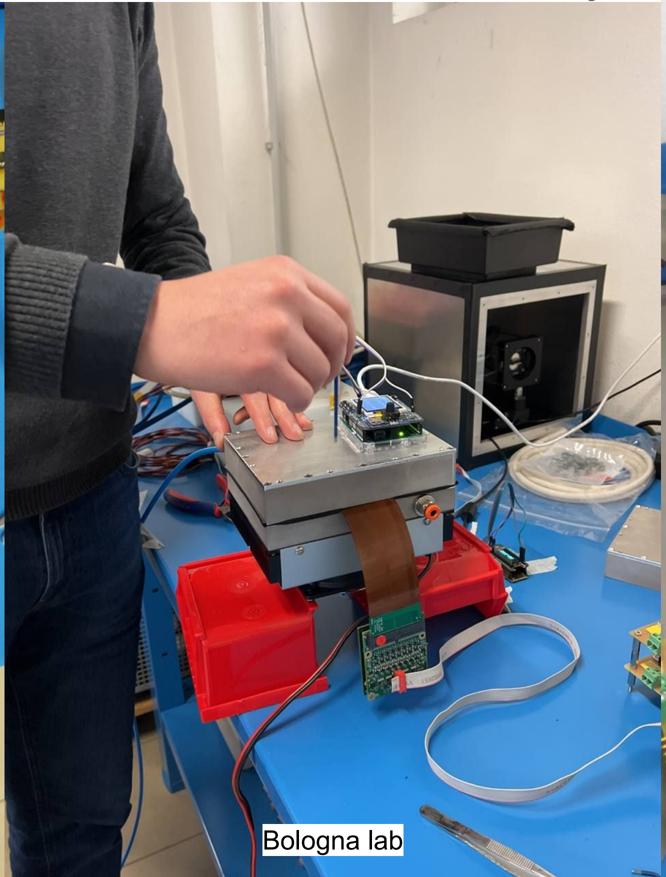
- **the chip performs**
  - signal amplification
  - conditioning and event digitisation
- **each pixel features**
  - dual-polarity front-end amplifier
    - low input impedance
    - 4 programmable gain settings
  - 2 leading-edge discriminators
  - 4 TDCs based on analogue interpolation
    - 25 or 50 ps LSB (@ 320 MHz)
- **single-photon time-tagging mode**
  - continuous readout
  - also with Time-Over-Threshold
- **fully digital output**
  - 4 LVDS TX data links

Air-cooled portable Peltier box

designed and realised by us based on Laird cooler assembly



Bologna lab



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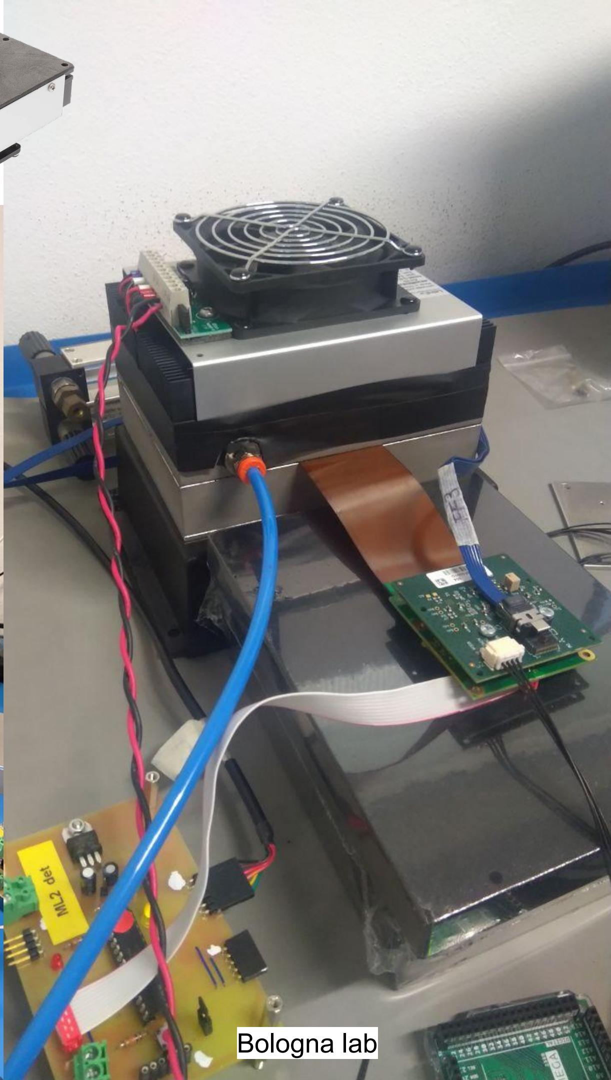
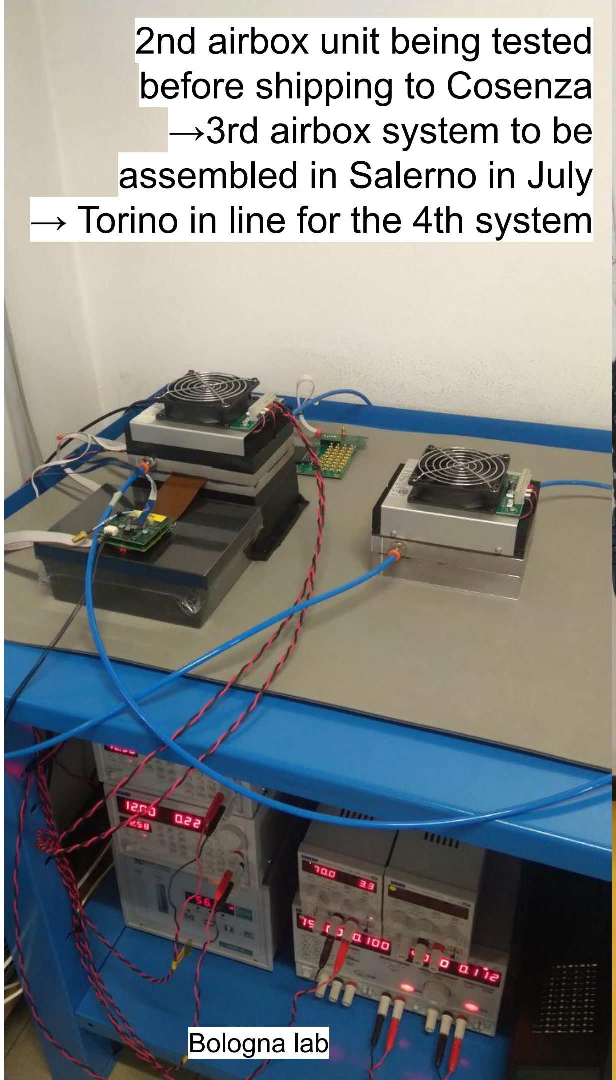


Bologna lab

airbox in Cosenza

- **airbox installed in Cosenza**
  - after tests in Bologna
  - shipped to Cosenza
  - system installed on 13-14 April
  - good teamwork
    - Bologna
    - Cosenza
    - Salerno
- **Cosenza ready to contribute**
  - to SiPM characterisation
  - in charge of proton-energy scan
- **3rd airbox to Salerno**
  - system will be installed in July
  - increase SiPM test capacity
- **Torino in line for 4th system**
  - for tests of ALCOR chip with SiPM at low T



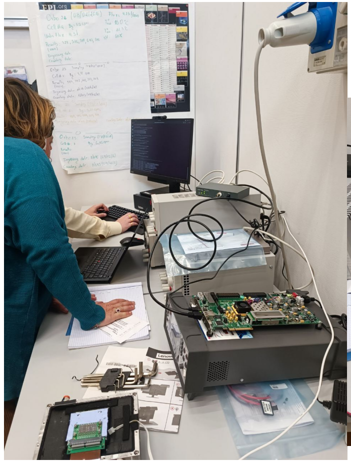
Bologna lab

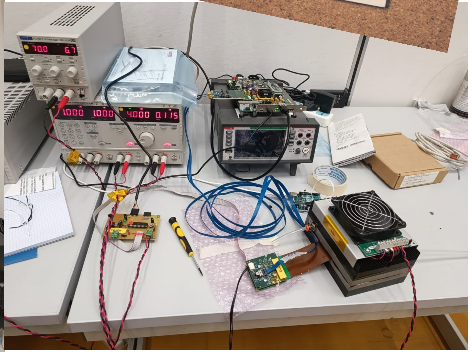
Cosenza lab

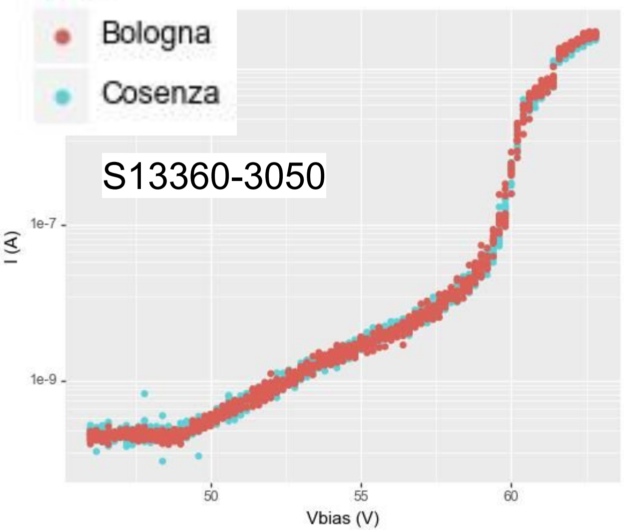
Characterisation setup in Cosenza

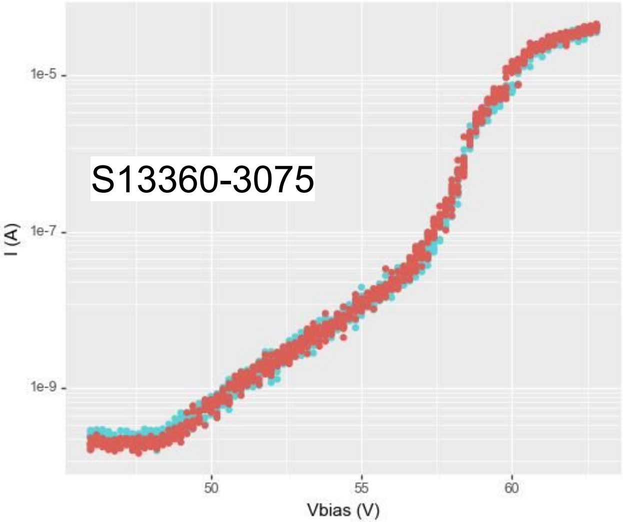
IV characteristics of 3 different SiPM types compared measured both in Bologna and Cosenza setups
- Bologna uses climatic chamber
- Cosenza uses AirBox air-cooled Peltier setup

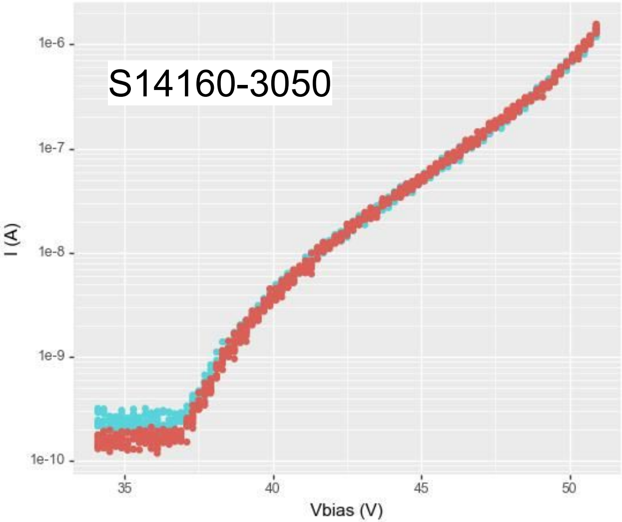
the results are nicely compatible between the two setups
Cosenza setup is up and running to efficiently contribute to SiPM R&D and characterisation



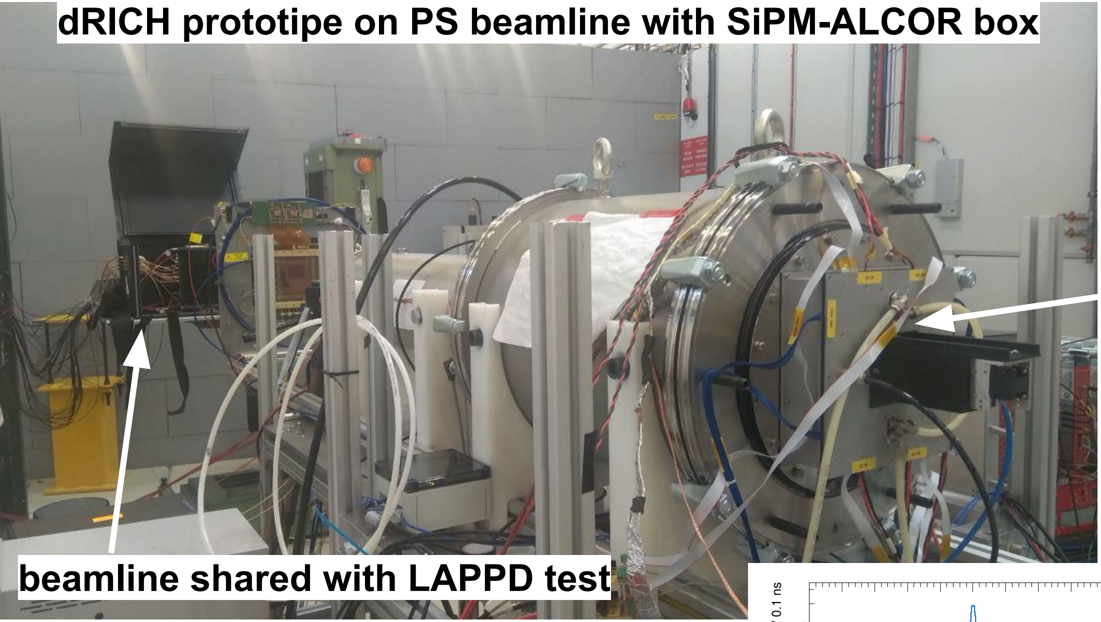


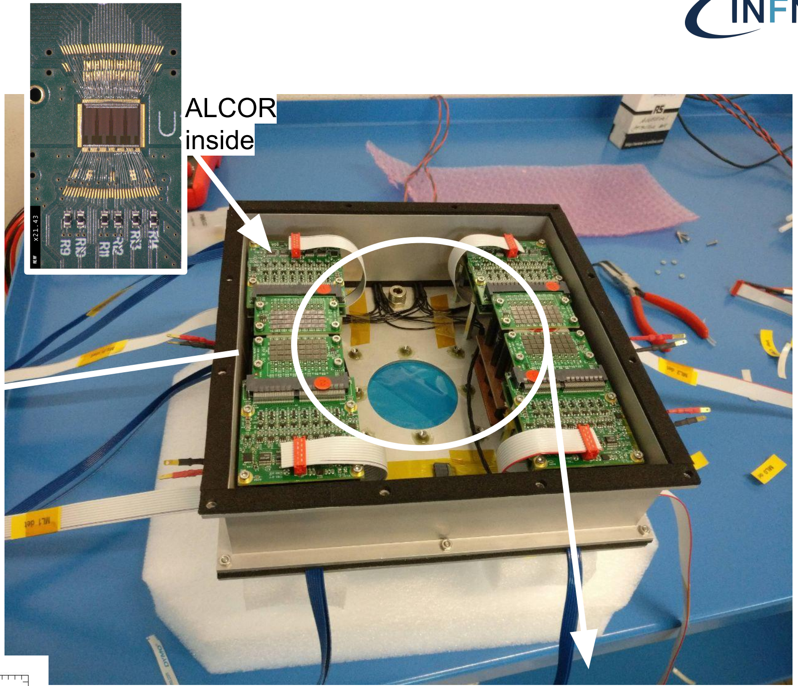




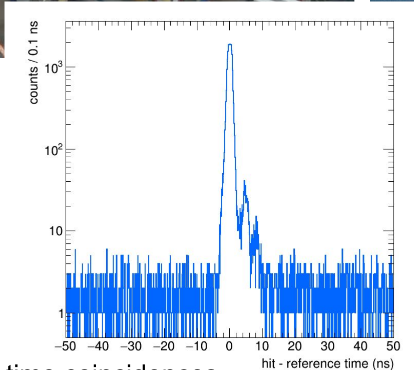


2022 test beam at CERN-PS



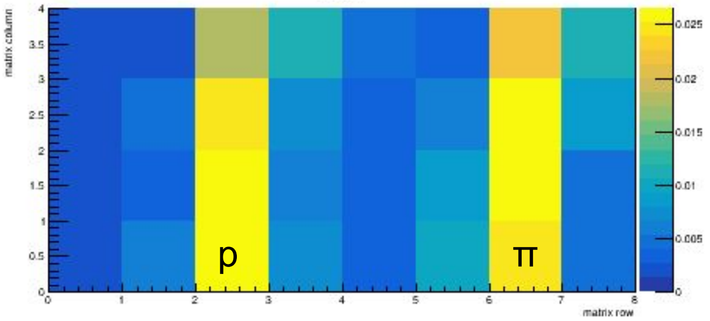


successful operation of SiPM
irradiated (with protons up to 10^{10})
and annealed (in oven at 150 C)



time coincidences

8 GeV positive beam (aerogel rings)



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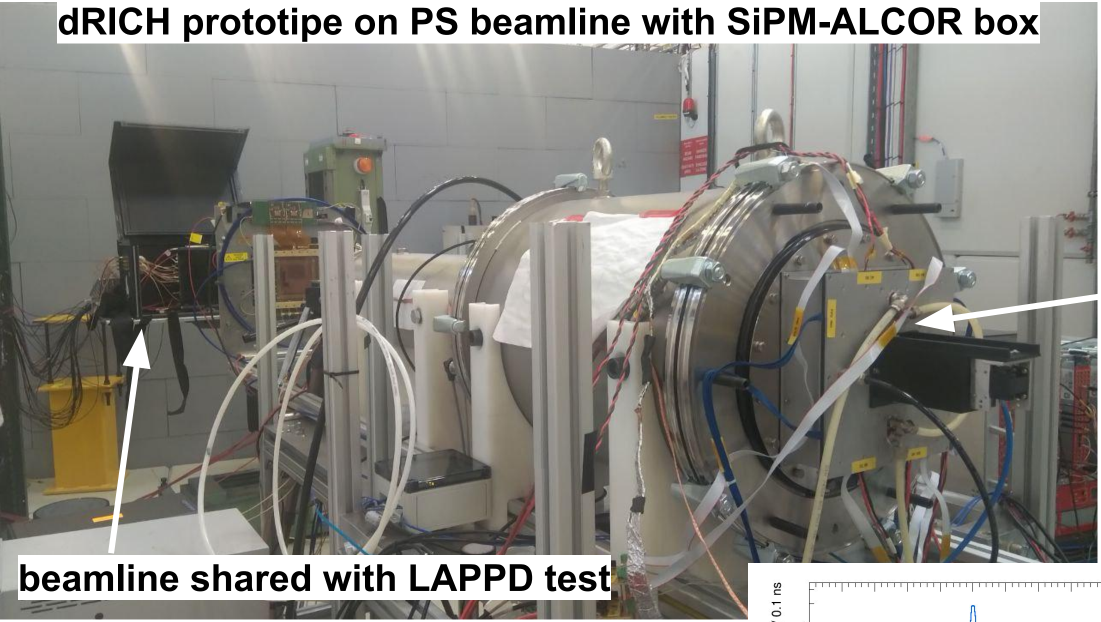

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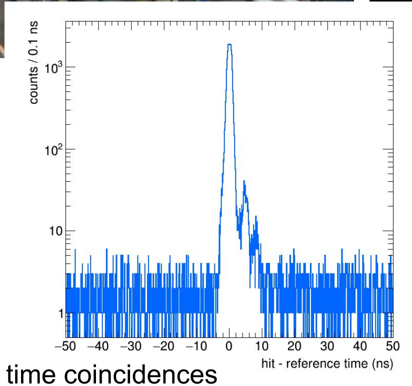
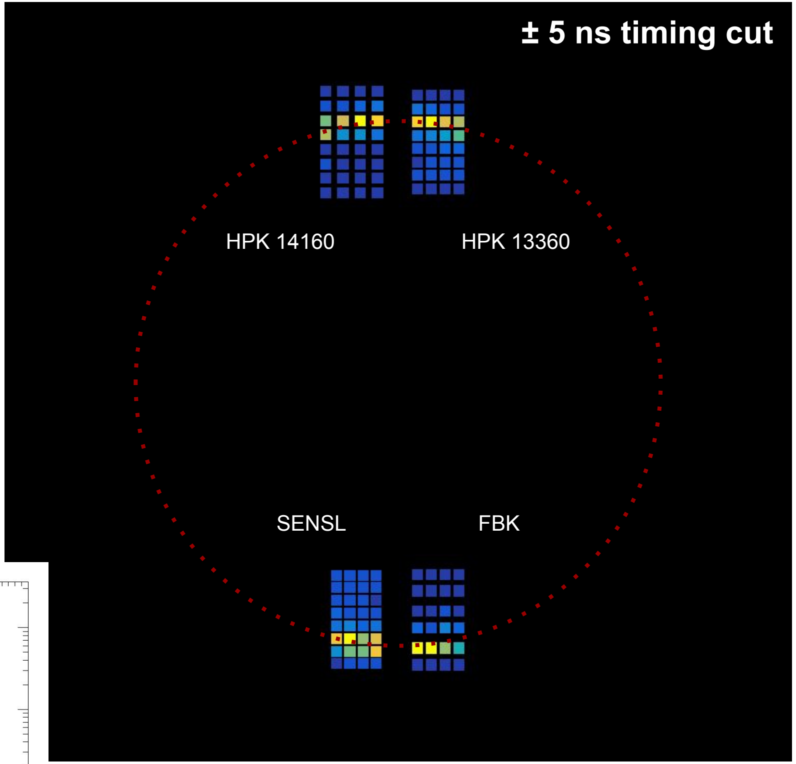


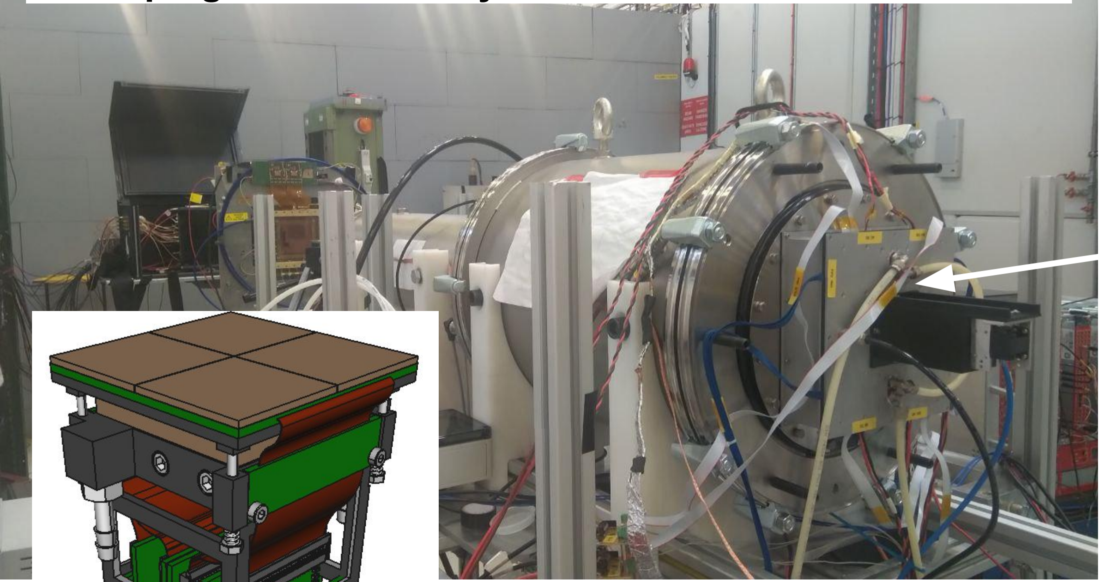
time coincidences

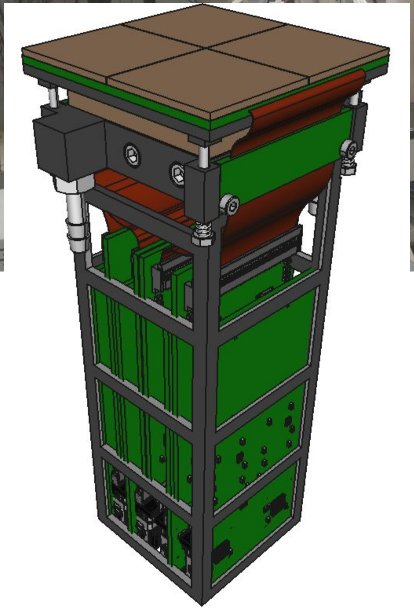


8 GeV negative beam (aerogel rings)

New photosensor plane for 2023 test beam at CERN

developing mechanical layout and new readout electronics

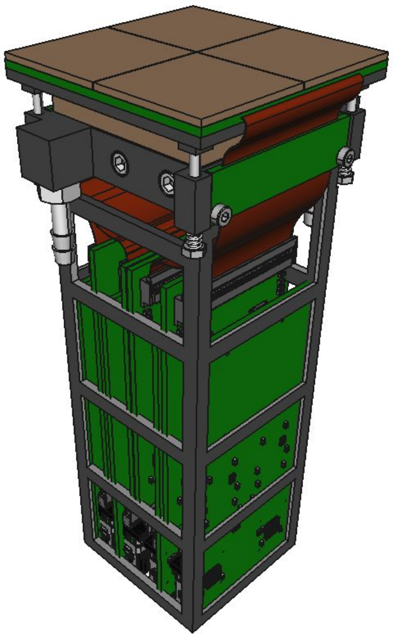




new SiPM readout unit based on
Hamamatsu S13360-3050 arrays
integrated with cooling and
ALCOR front-end electronics

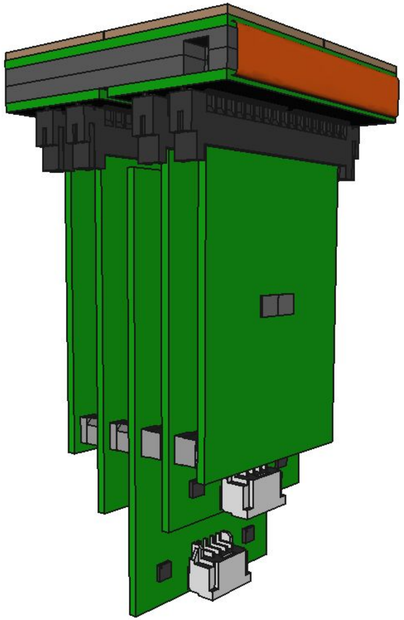
PhotoDetector Unit – PDU

current version (v2)



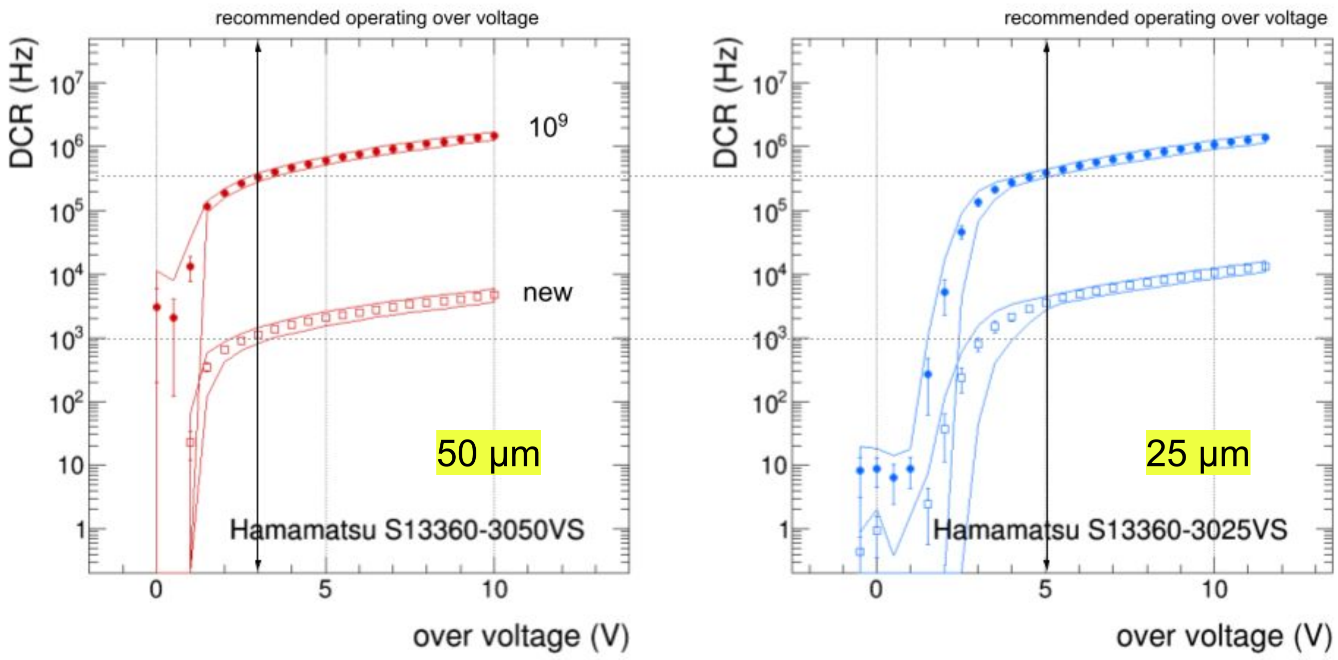
Peltier cooling layout
8x ALCOR-32 asics
4x ALCOR-FE-DUAL boards
4x adapter boards

possible future version (v3)



final cooling layout
4x ALCOR-64 asics
4x FEB boards
1x RDO board

Small vs. large SPAD sensors



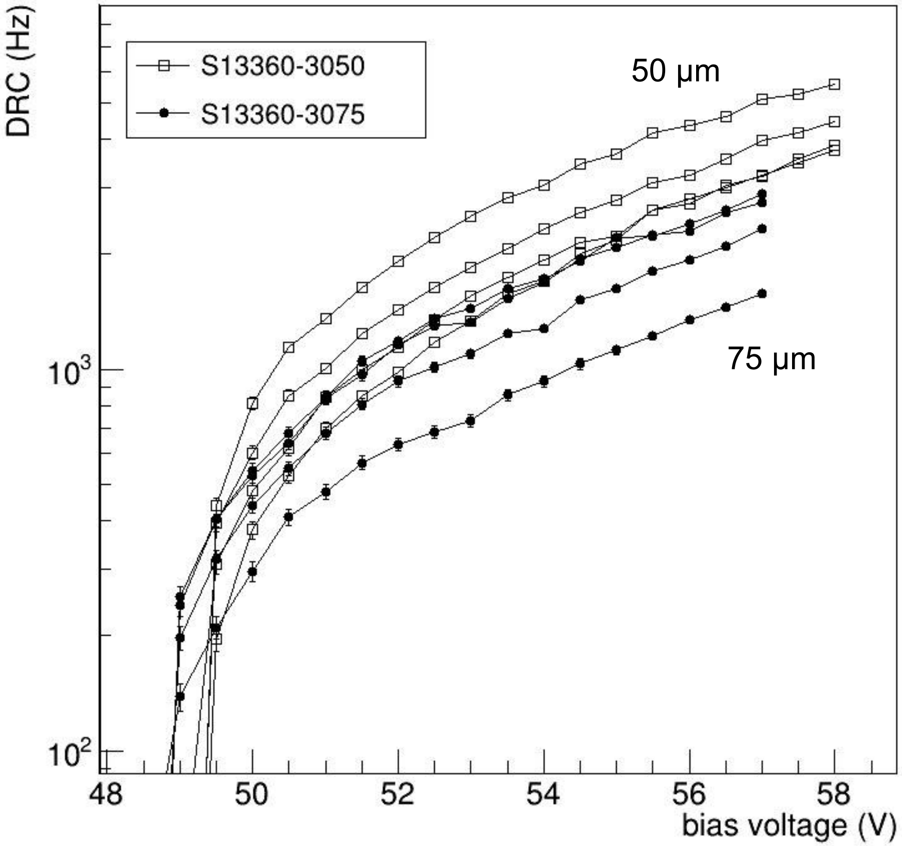
sensors with **small SPADs have lower SNR** also after irradiation

small SPAD sensors are not radiation harder for single-photon applications (RICH)

- **sensors operated at Hamamatsu recommended over-voltage**
  - [datasheet] 50 µm sensors have 40% PDE, 25 µm have 25%
  - [measured] 50 µm sensors have lower DCR than 25 µm when new
  - [measured] both sensors have similar DCR after irradiation

similar results and conclusions obtained with SENSL sensors

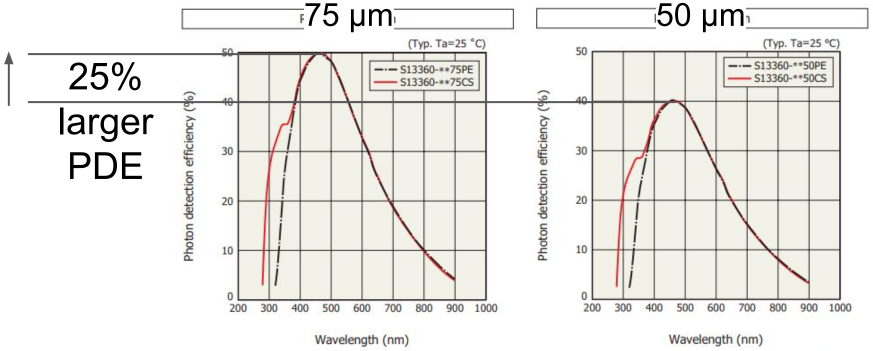
Hamamatsu 75 μm SPAD sensors



first preliminary comparison between NEW sensors
Hamamatsu S13360-3050 (50 μm SPADs)
Hamamatsu S13360-3075 (75 μm SPADs)
identical technology, different SPAD size
we knew already that 50 μm are better that 25 μm for us
preliminary results show that 75 μm are better that 25 μm
averaged over the 4 sensors tested here
75 μm sensors have sensibly lower DCR than 50 μm
and it is known that 75 μm sensors have larger PDE
→ 75 μm SPADs might soon become the baseline

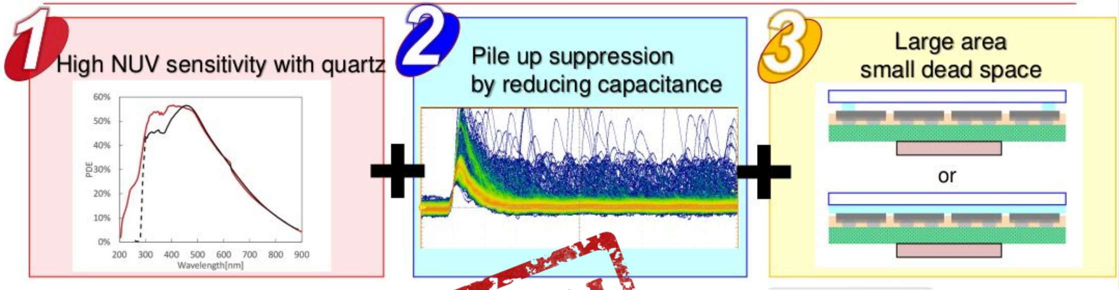
we need of course to characterise and test them deeply
with irradiation, annealing and everything else
this is our plan for 2023, this is R&D

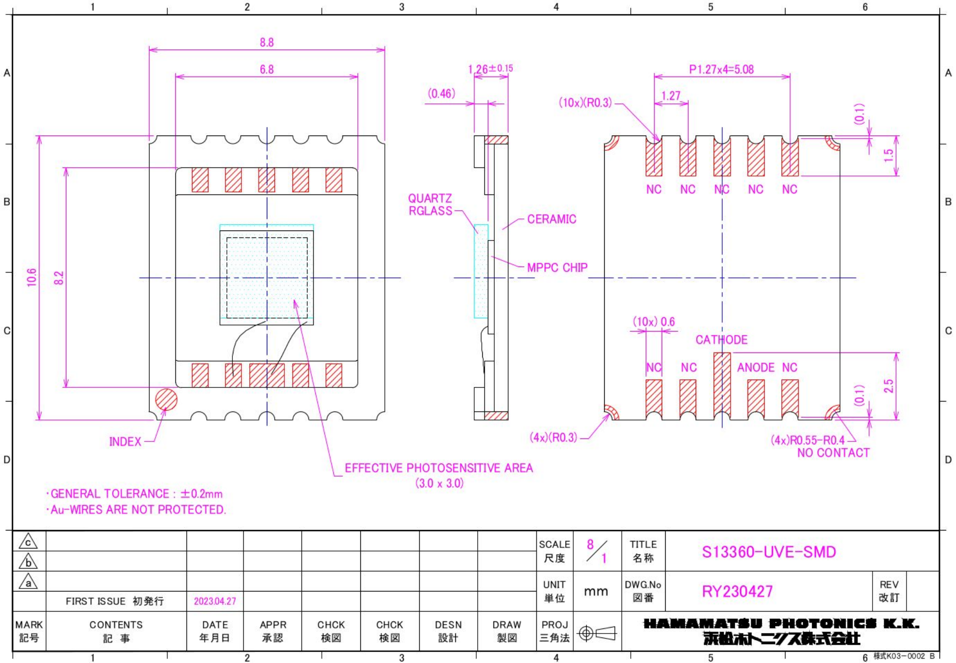
for 2024 we need to buy 75 μm arrays to equip the dRICH
prototype and confirm they might be the best choice
(but keep in mind FBK)



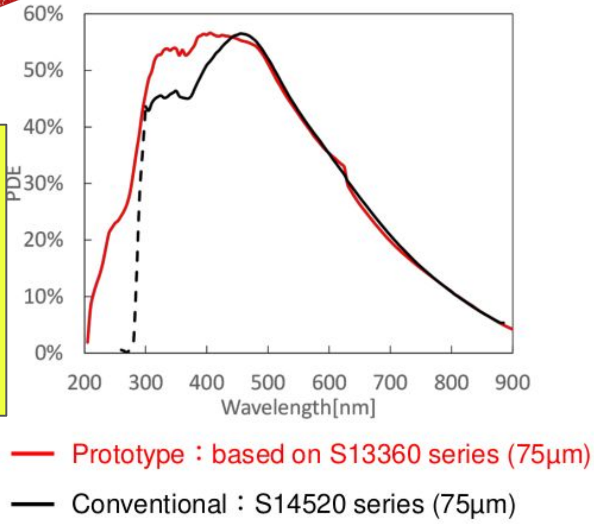
New Hamamatsu prototype samples

samples of newly-developed Hamamatsu SiPM
samples based on S13360 series
on paper they look VERY promising
being shipped to Bologna (arriving soon)
we will characterise and test them in full irradiation, annealing, laser, whatever…



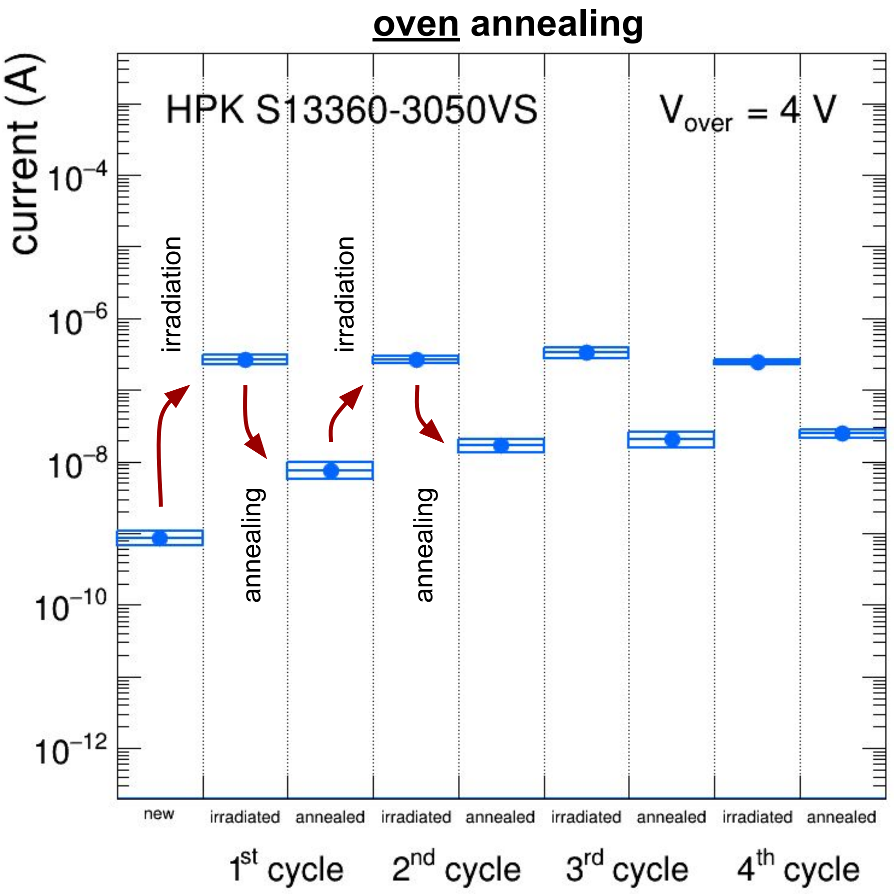


we will receive next week samples of these prototype SiPMs with 50 μm and 75m μ SPADs



annealing

Repeated irradiation-annealing cycles

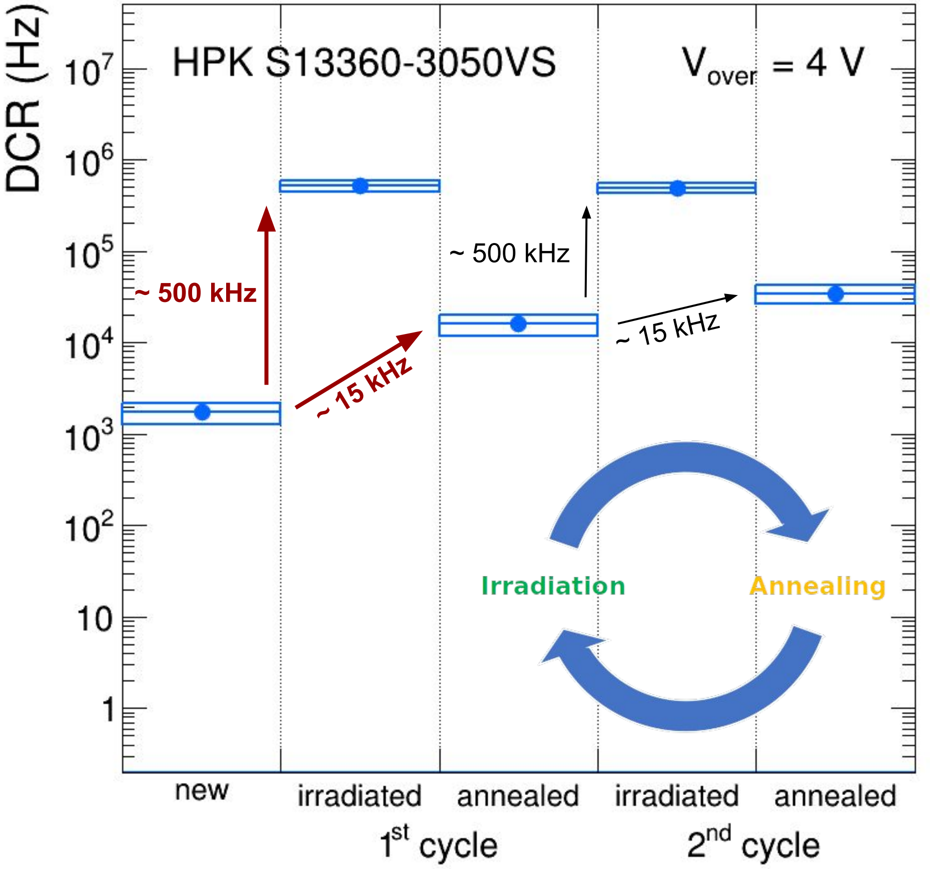


test reproducibility of repeated irradiation-annealing cycles

simulate a realistic experimental situation

- campaign is concluded
  - partial results reported here
  - all measurements in following slides
- 4 cycles performed in 2022
  - irradiation fluence/cycle of 10^9 n_{eq}
  - annealing in oven for 150 hours at 150 °C
- interleaved with full characterisation
  - new
  - after each irradiation
  - after each annealing

Repeated irradiation-annealing cycles



test reproducibility of repeated irradiation-annealing cycles

simulate a realistic experimental situation

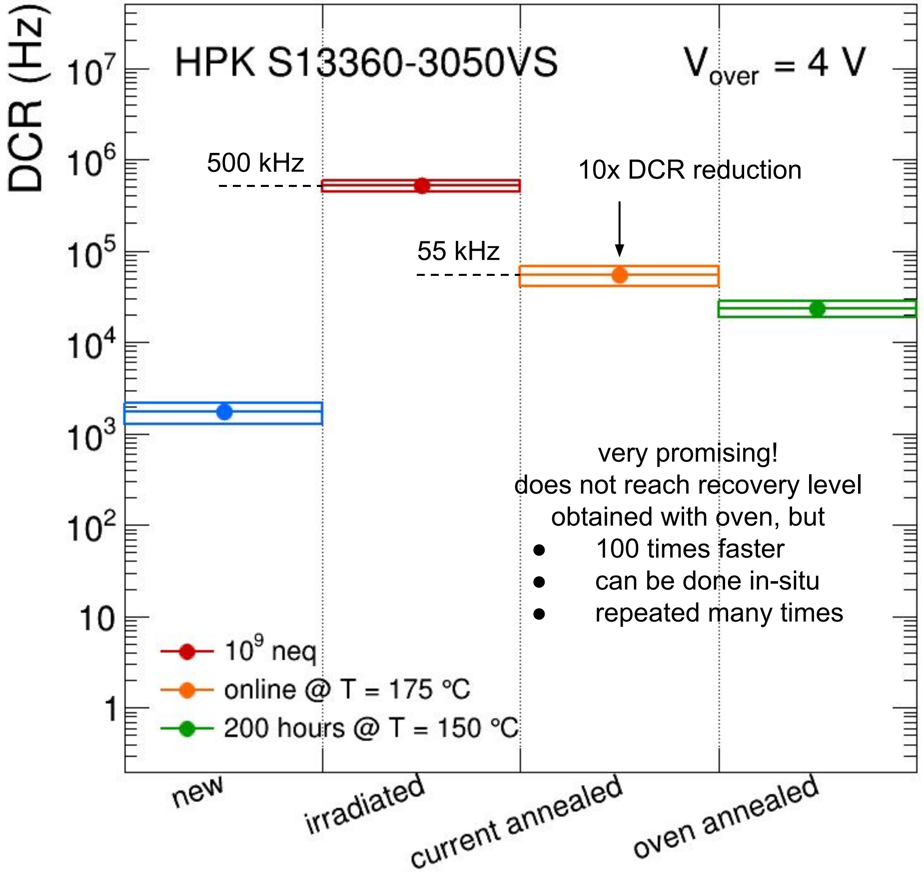
- consistent irradiation damage
  - DCR increases by ~ 500 kHz (@ Vover = 4)
  - after each shot of 10^9 n_{eq}
- consistent residual damage
  - ~ 15 kHz (@ Vover = 4) of residual DCR
  - builds up after each irradiation-annealing

annealing cures same fraction of newly-produced damage

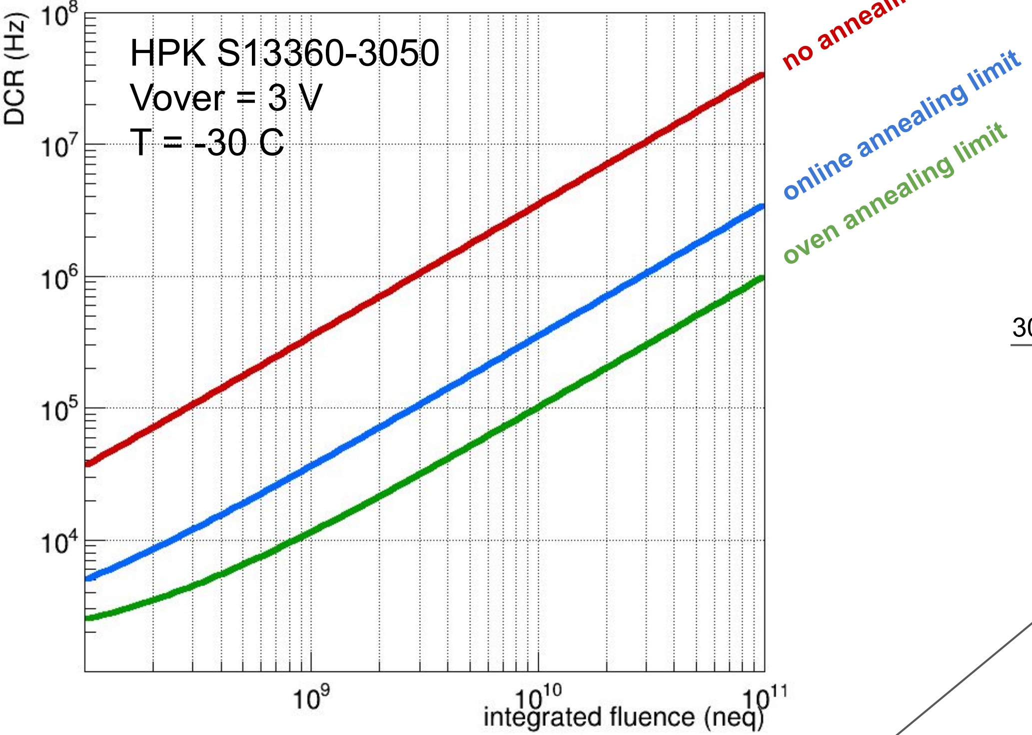
~ 97% for HPK S13360-3050 sensors

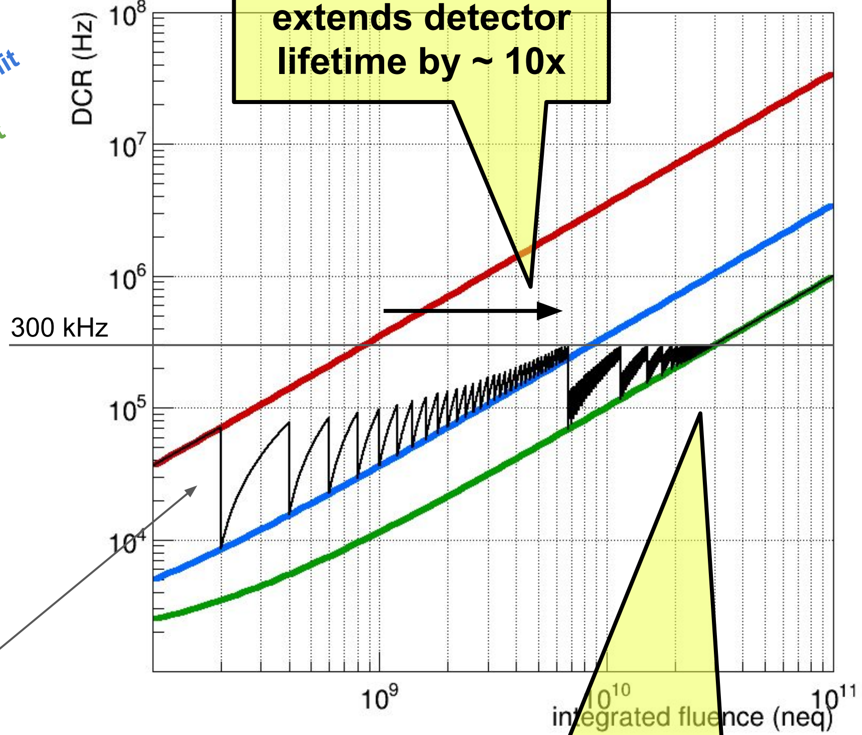
Online annealing

explore solutions for in-situ annealing



Radiation damage model



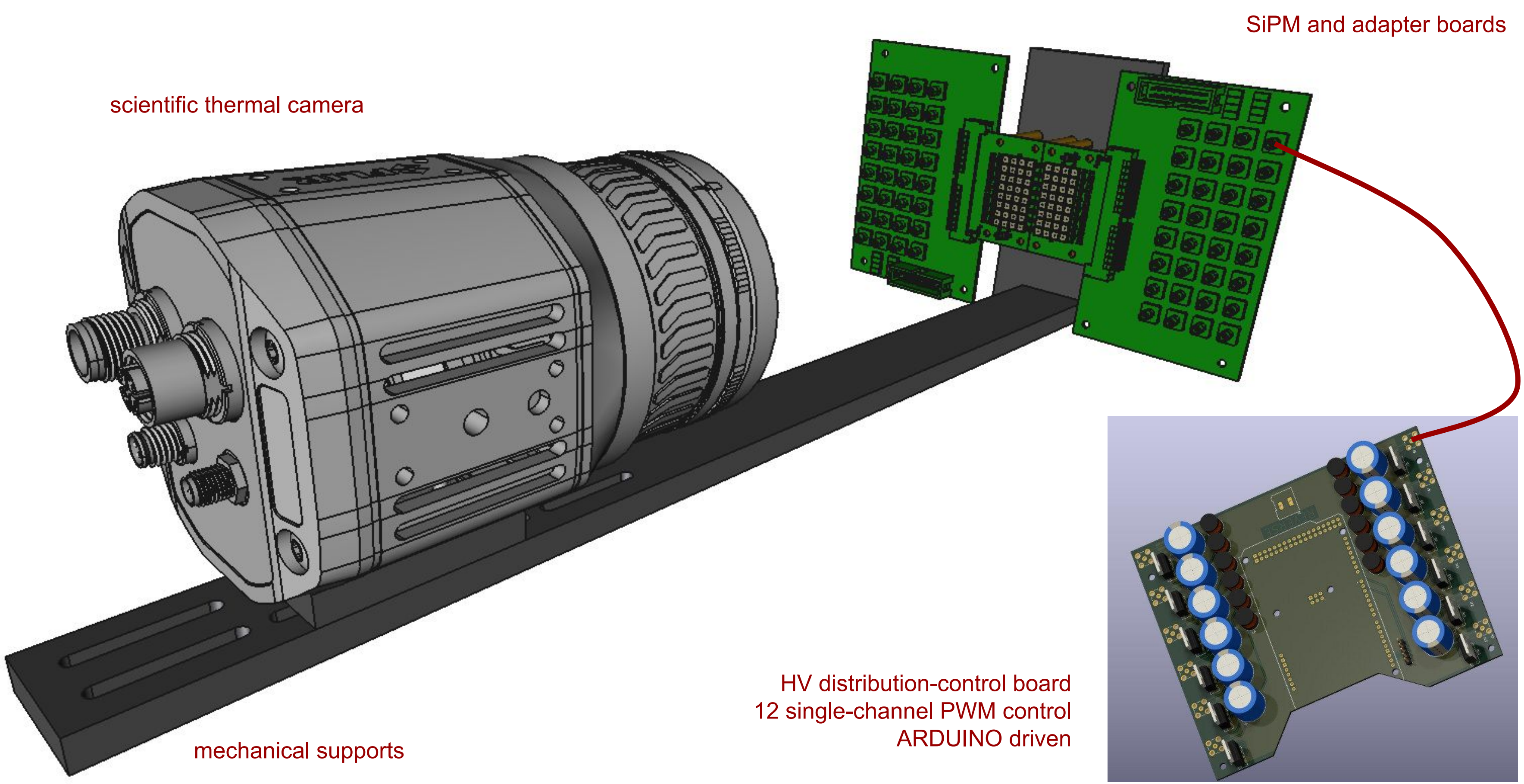


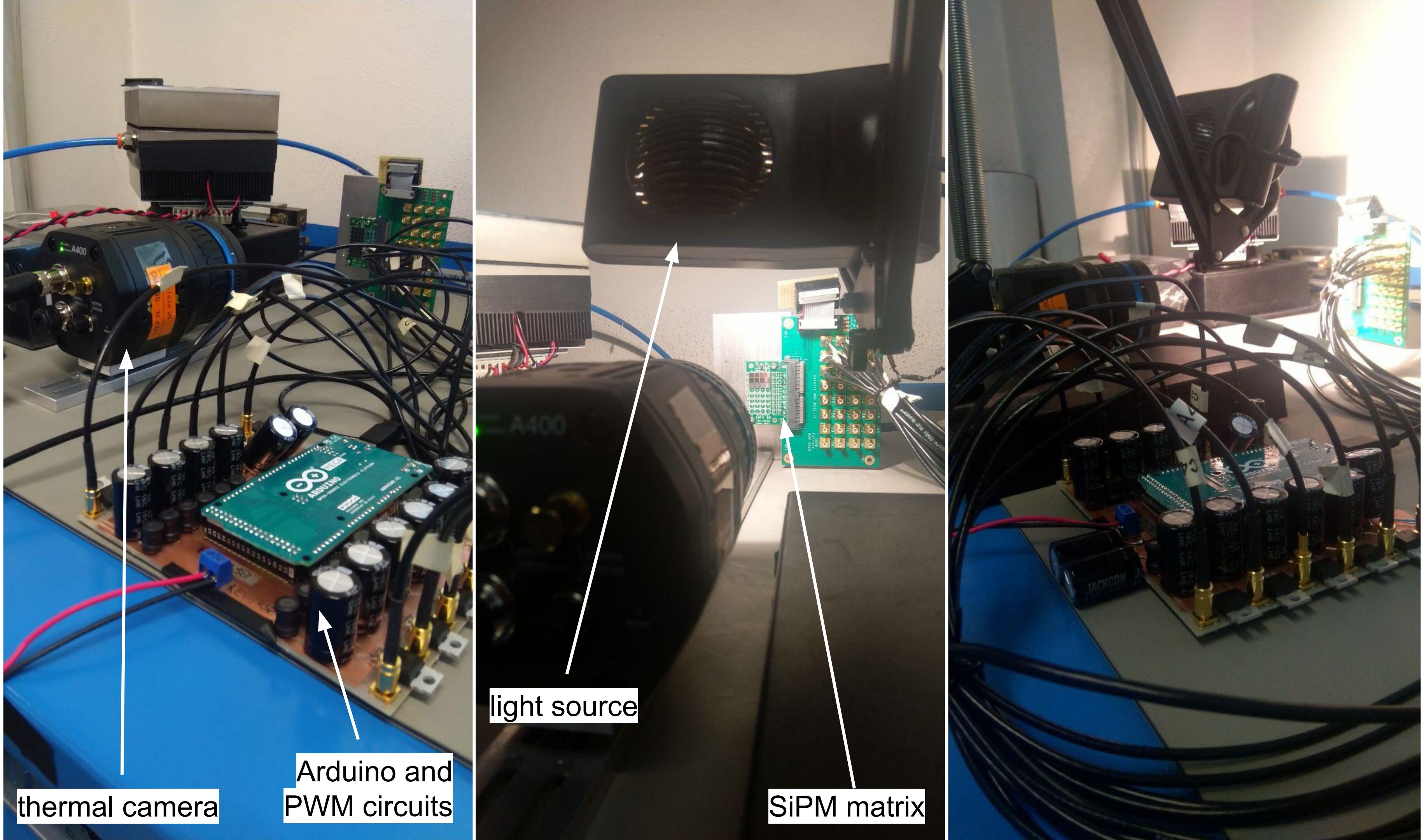
online annealing extends detector lifetime by ~ 10x

after several years one might need/want to replace the SiPMs with new rad. harder technology

online annealing every 2 10^8 neq (many times)
oven annealing when DCR > 300 kHz (few times)
note: 300 kHz limit assumed based on potential bandwidth limitations

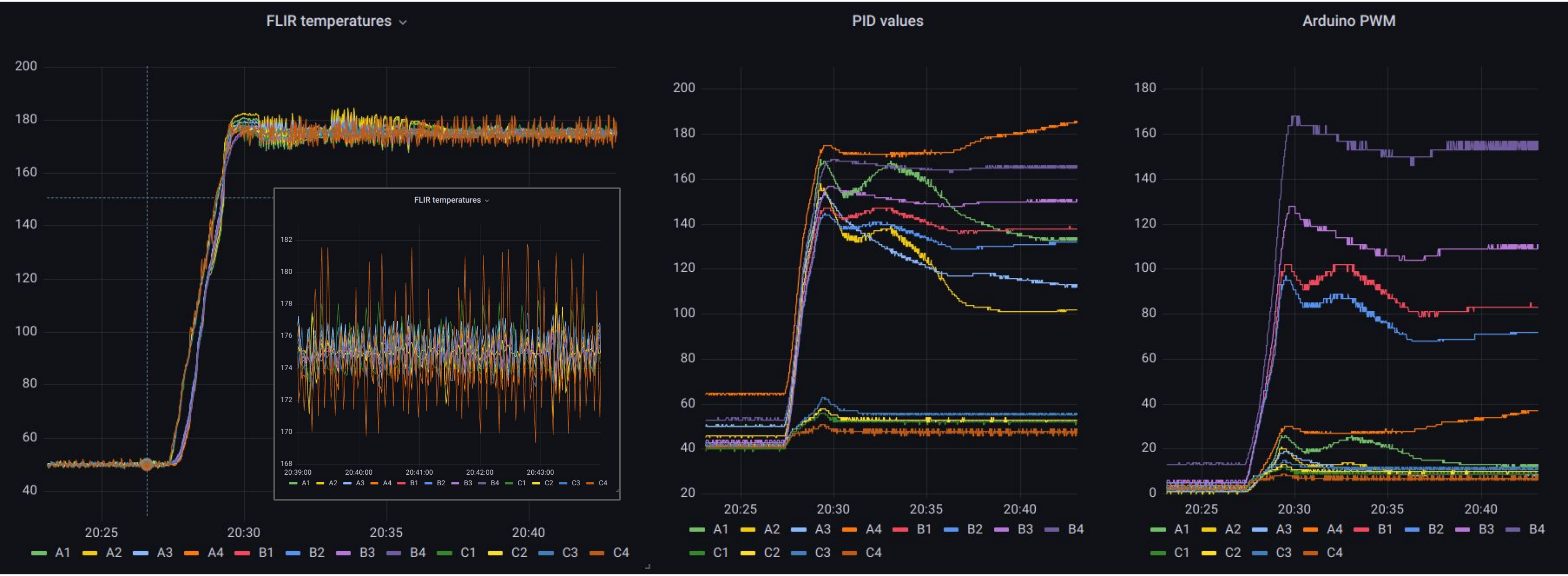
Automated multiple SiPM online annealing




thermal camera
Arduino and
PWM circuits
light source
SiPM matrix

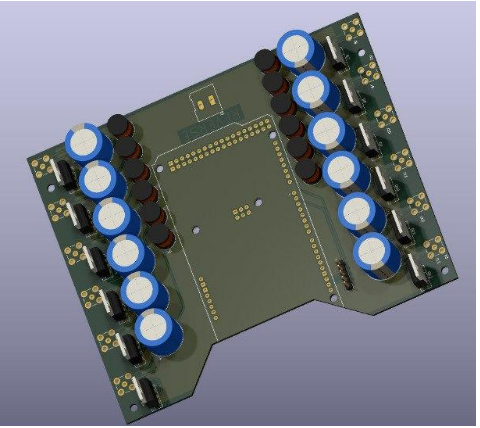
Automated multiple SiPM online annealing

online temperature monitor and control of each SiPM (selected ROIs on thermal image + individual PWM)



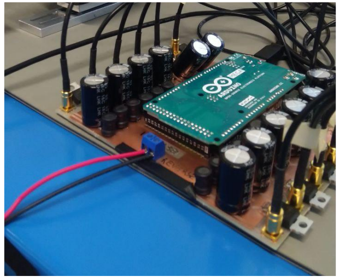
commissioning of the system looks promising for 2023 irradiation/annealing campaign studies

Automated multiple SiPM online annealing → towards experiment



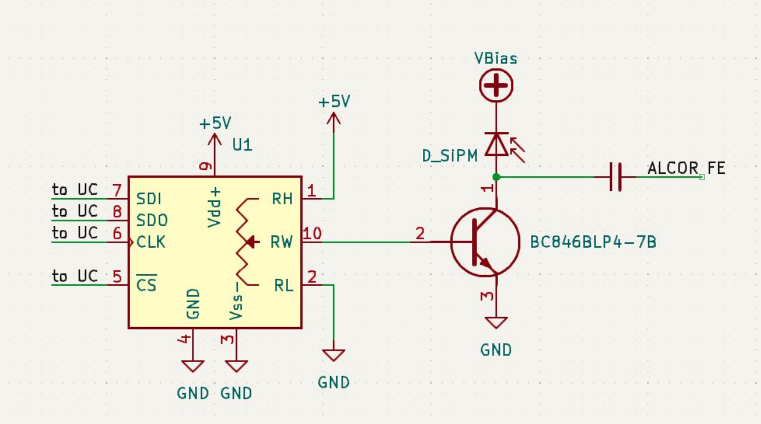
current system developed to fulfill requirements for 2023 irradiation/annealing tests in the laboratories

- 👍 allows to control each single SiPM
- 👎 large discrete components
- PWM modulated gate of MOSFET
- Arduino controlled

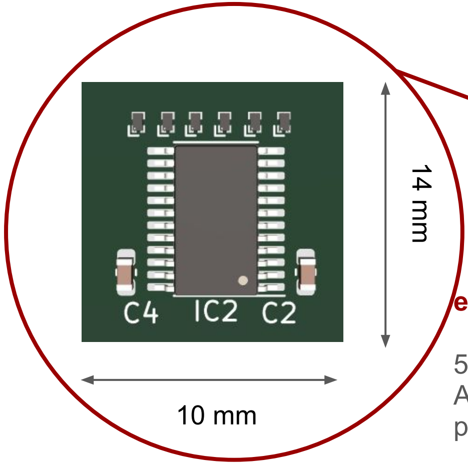


possibly better implementation for the experiment using linear control instead of PWM is being studied

- simple BJT scheme with few components per channel (2)
- current flowing through the SiPM is controlled by a digital potentiometer
- smallest footprint transistor
- impact on the performance of the detector to be estimate
  - increase input capacitance (negligible)
  - increase in current noise



Automated multiple SiPM online annealing → towards experiment



example

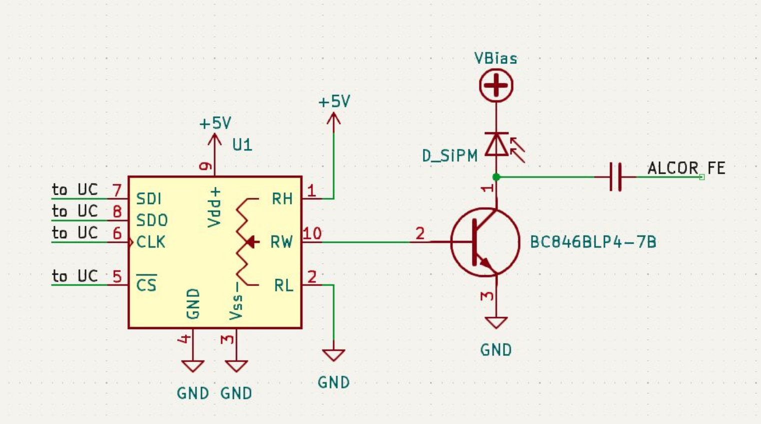
50 kOhm
AD5206BRUZ50 6 ch
potentiometer with SPI

assume similar space for 8-ch
needs 8 for each FEB (64-ch)
can be arranged in a 4x2 matrix
needs 40 x 30 mm of FEB space
→ not negligible, but not bad !
put transistors on the SiPM carrier?

this is still brainstorming, ideas are there

possibly better implementation for the experiment using linear control instead of PWM is being studied

- simple BJT scheme with few components per channel (2)
- current flowing through the SiPM is controlled by a digital potentiometer
- smallest footprint transistor
- impact on the performance of the detector to be estimate
  - increase input capacitance (negligible)
  - increase in current noise



Online annealing in the experiment

- **forward-bias current annealing**
  - 👍 intrinsically more safe than reverse bias annealing
    - makes use of quenching resistor for current
  - 👎 requires inverted bias polarity wrt. the one used for photodetection
    - likely needs a dedicated power-supply system
    - need to look at circuitry to do that
  - 👎 annealing currents are ~ 10x larger than reverse bias annealing
    - bigger components to withstand the currents
  - 👍 likely does not need to control at single SiPM level the bias voltage
  - need to monitor single SiPM for safe operation
- **reverse-bias current annealing**
  - 👎 less safe that forward bias annealing
    - it depends on sensors gain and DCR
    - which might be slightly different from sensor to sensor
  - 👎 requires illumination of sensors
    - to approximately equalise current response of SPADs and SiPMs
  - 👍 does not need different voltage polarity wrt. the one used for photodetection
    - use same HV power-supply system
  - 👍 annealing currents are lower
    - but still larger that normal operation
    - require higher power in HV PS
    - or study how to perform distributed annealing
  - 👎 needs to control at single SiPM level the bias voltage
  - needs to monitor single SiPM for safe operation

both have pros and cons
likely the cons of forward-bias annealing are stronger that the cons of reverse-bias annealing

Online annealing in the experiment

- **fluid-based annealing**
  - use the SiPM cooling circuit to bring hot fluid
    - cooling plant must be heating as well, but this is commercial stuff
    - likely the safest approach for the sensors
    - maybe not for the electronics?
  - does not need monitor at single SiPM level
    - global monitor of the PDU should be sufficient
  - does not need control at single SiPM level
    - in principle not even at dRICH sector level
  - it has to be tested if it is an effective way to anneal the sensors
    - we will give it a try this year
    - but this program was not funded
  - it needs time to switch the SiPM cooling from cold to hot operation
    - unlikely this can be done with same frequency as current-based annealing
- **other ideas to test**
  - use a mix of current-based and fluid-based
  - have infrared lamps that can be positioned by moving them in front of the sensors

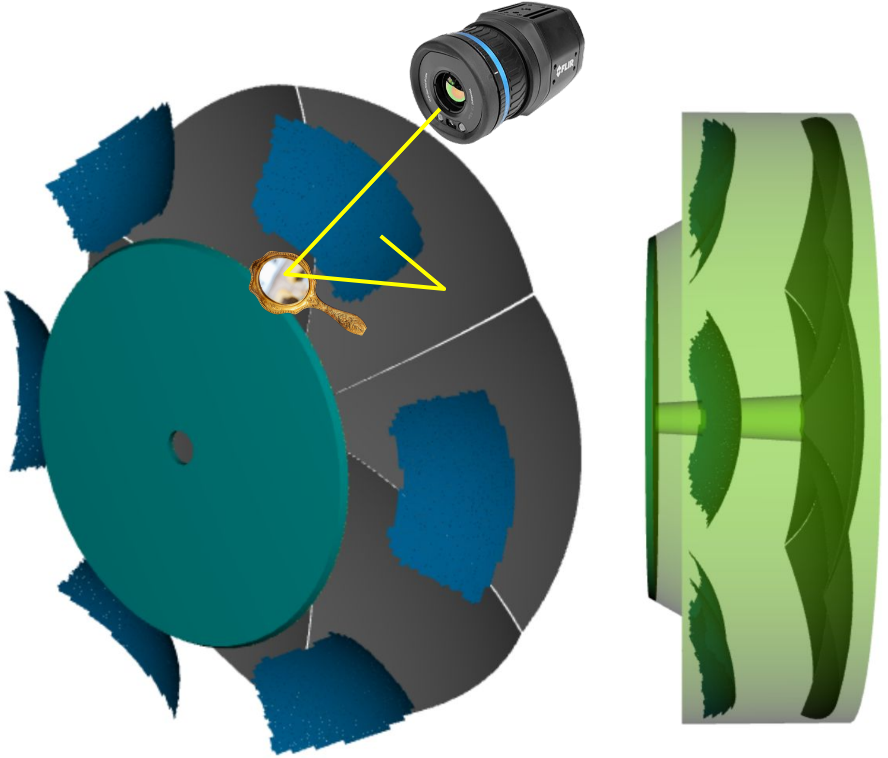
Can we put a thermal camera in the experiment?

explore the possibility of having one thermal camera for each dRICH sector at a fixed position with a mirror that can be oriented to focus onto the sensors, perhaps exploiting the optics of the imaging mirrors

this could allow for scanning of multiple sensors with a single thermal camera

questions:

- can this be really done
- space allocation
- calculation for optics
- radiation damage to camera
    - we have IR devices in space



Thermal scanner in front of sensors?

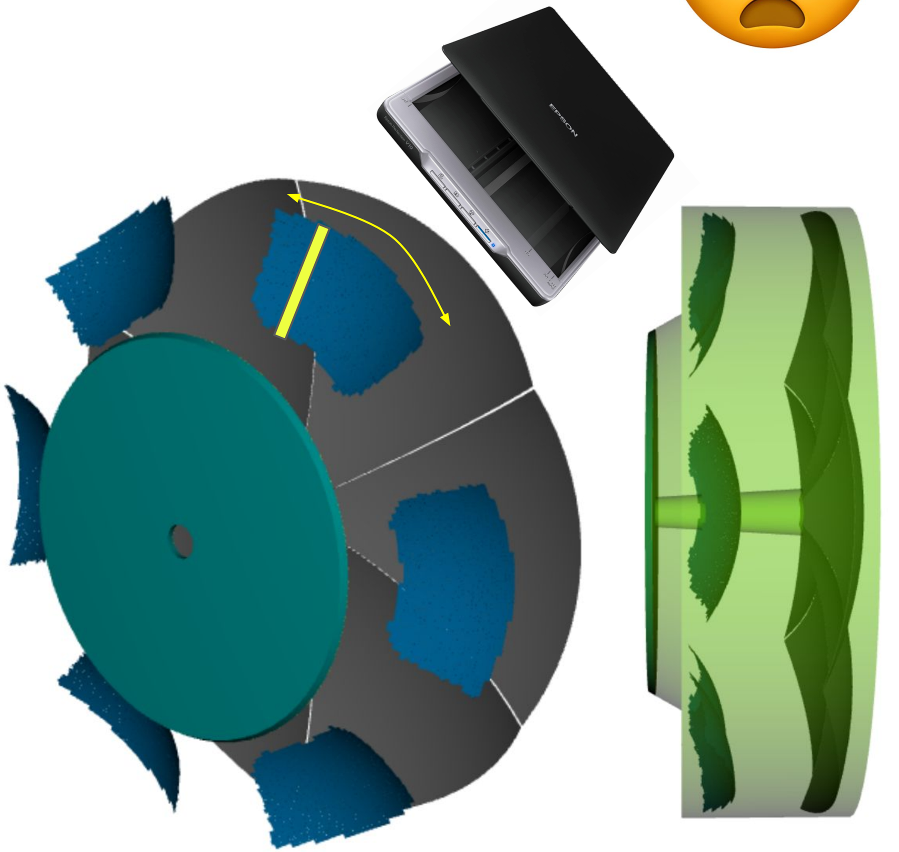
another possible, but not obviously realisable, idea could be to have a sort of scanner running over a structure in front of the sensors.

during normal operation, the scanner head is in HOME position without obstructing the sensor view

during annealing the scanner head starts scanning the sensor surface moving in one direction (think about the Xerox/scanning machines)

scanner head can also be the light source for reverse-bias annealing

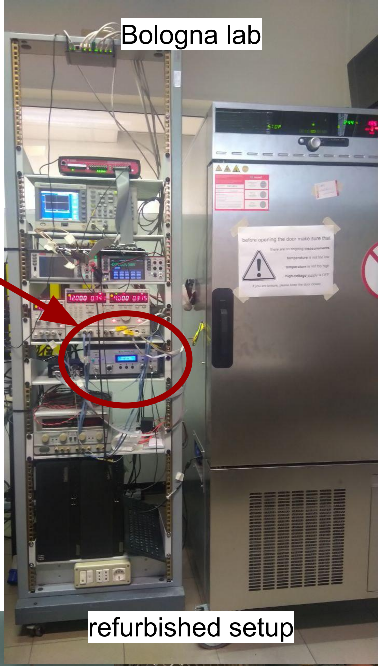
crazy idea? maybe, but operation would be simple and annealing safe

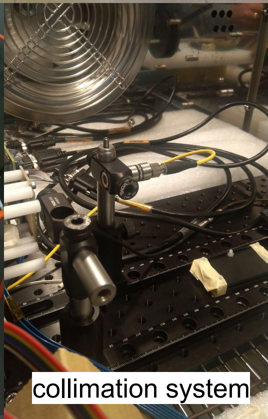


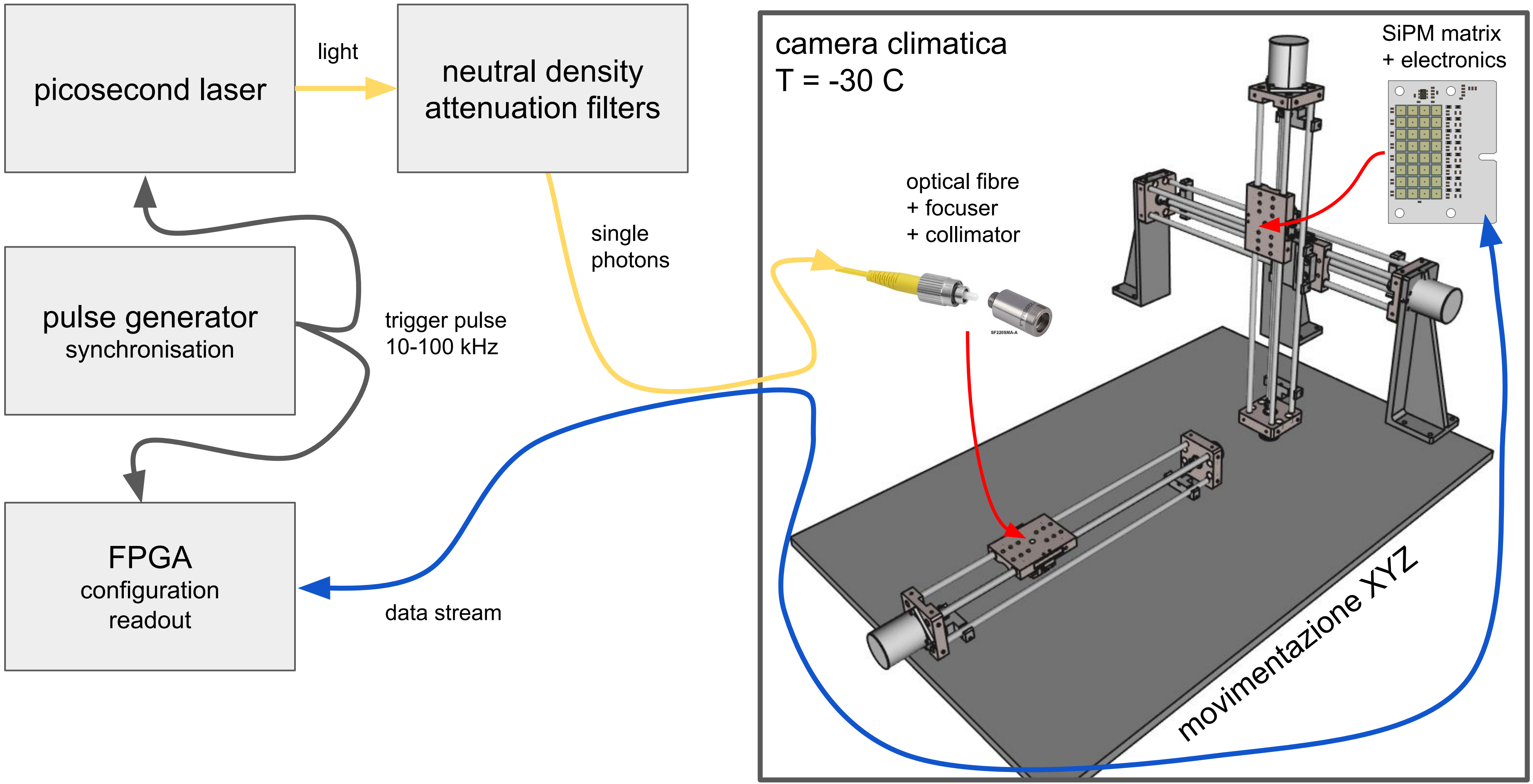
timing performance

We recently received the new laser

- **goal is to measure time resolution of the complete chain**
  - before and after SiPM irradiation and annealing
- **will be able to measure relative variation of PDE**
  - plans also to measure relative variation of PDE vs. incident photon angle
  - we have a calibrated diode to try absolute PDE determination on single photon
    - not trivial need to measure absorption of absorbers
- **characteristics of the laser**
  - picosecond pulsed laser
  - 401.4 nm
  - 25 ps FWHM pulse width
  - < 4 ps synchronisation jitter
  - up to 20 MHz repetition rate
  - > 2 W peak power
- **system is being commissioned with climatic chamber**
  - optical components
    - absorption (<< 1 photon/pulse)
    - transport
    - collimation of light
  - synchronisation with ALCOR readout system
  - precision measurement of reference time

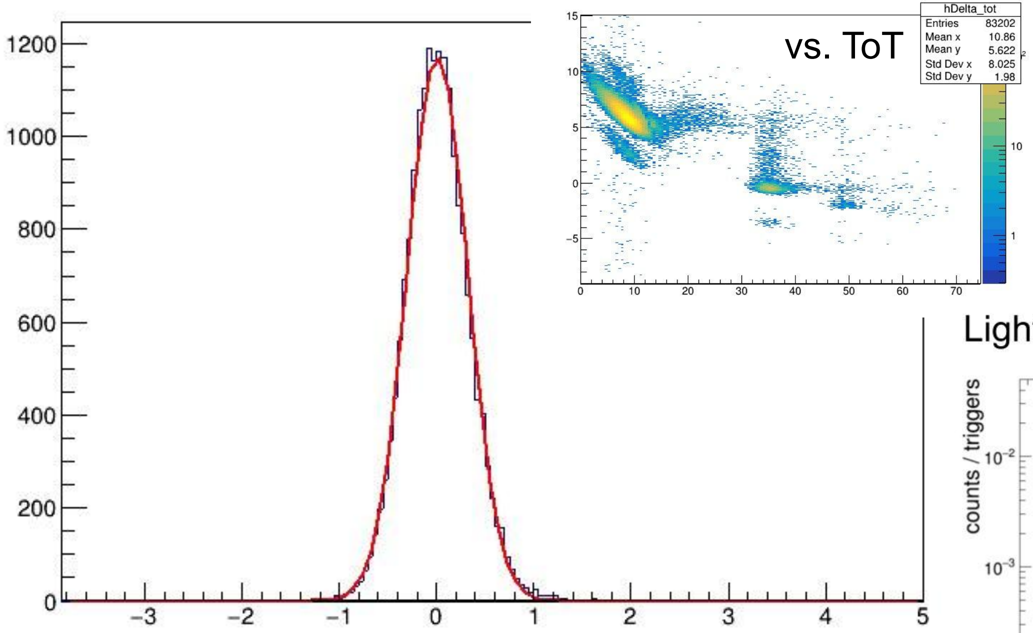





picosecond laser
light
neutral density
attenuation filters
single
photons
pulse generator
synchronisation
trigger pulse
10-100 kHz
FPGA
configuration
readout
data stream
camera climatica
T = -30 C
optical fibre
+ focuser
+ collimator
SiPM matrix
+ electronics
movimentazione XYZ

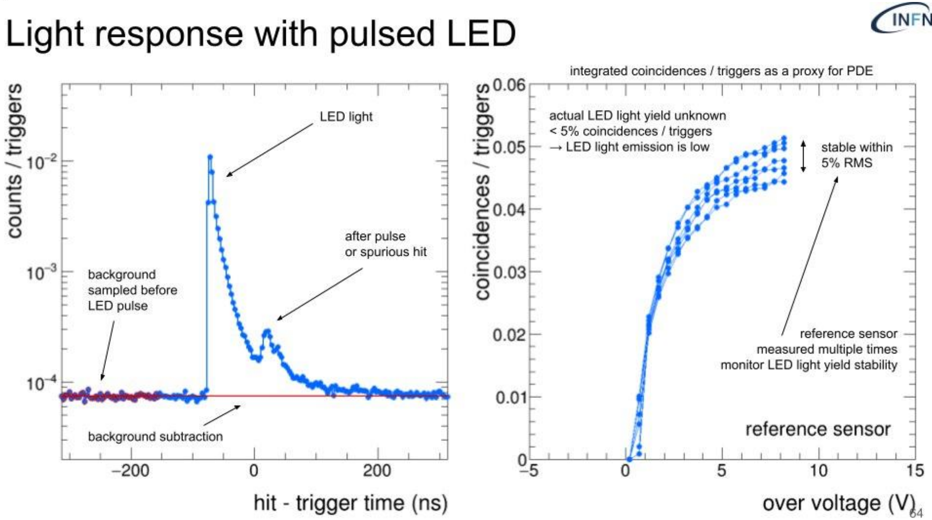
We recently received the new laser

much nicer pulse response wrt. old LED-based system, need to work on sychronisation and calibration

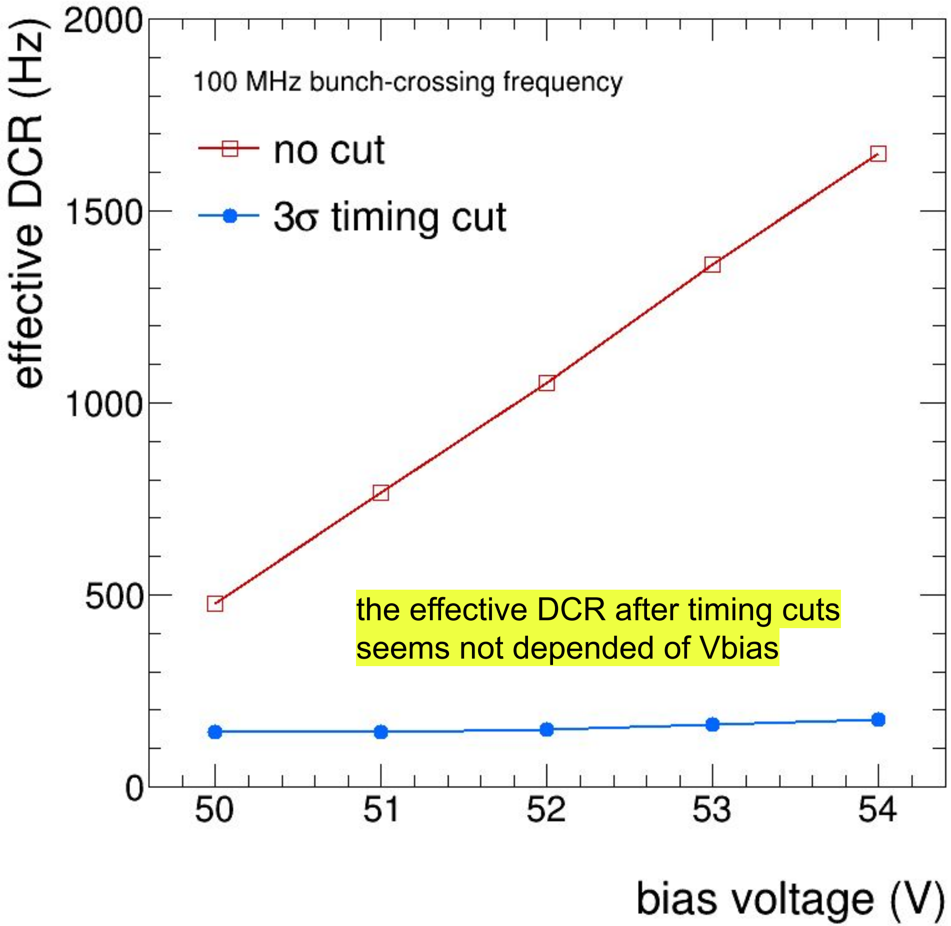


vs. ToT

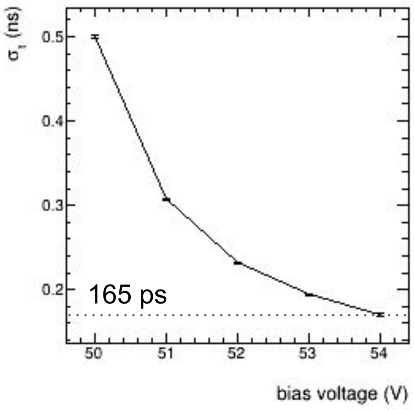
hit- trigger time (ns)



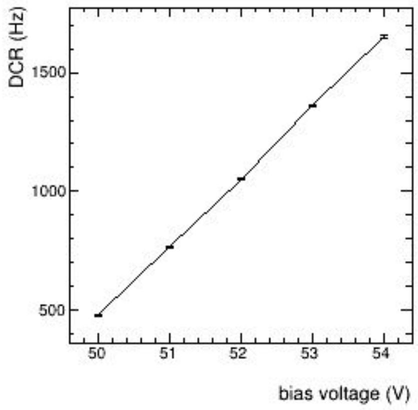
Preliminary first results with timing laser

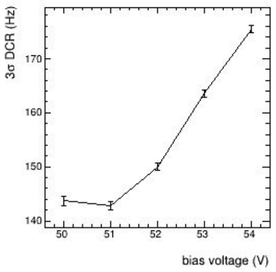


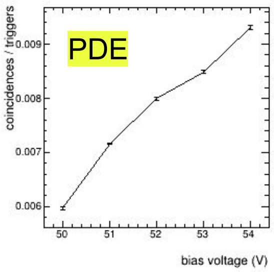
σ$_t$ decreases with Vbias

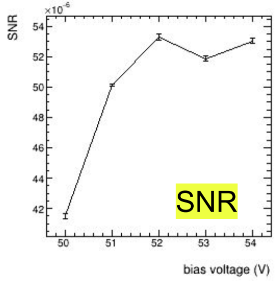


DCR increases with Vbias





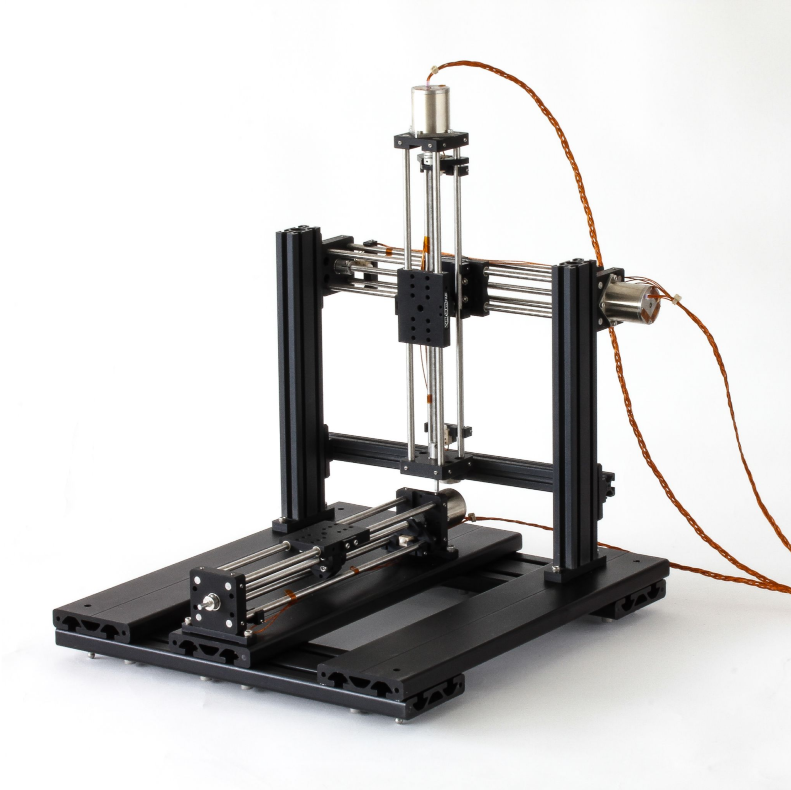




measured PDE increases with Vbias
eventually the SNR also increases with Vbias
→ low Vbias seems NOT the best working point
important to evaluate FBK sensors, because they are know to have higher PDE and better time resolution

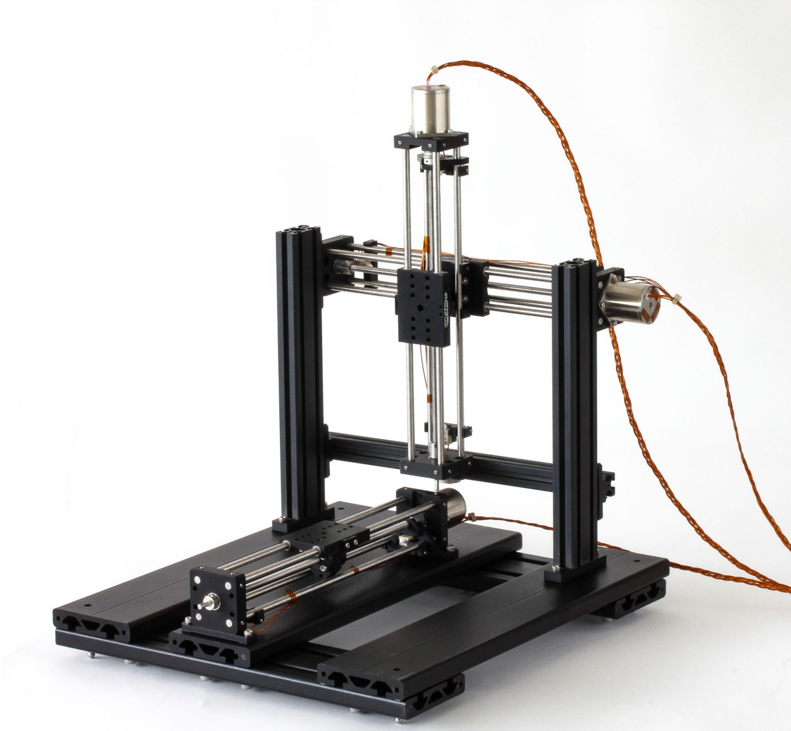
XYZ linear translation stage also arrived, not installed yet

- **brand new linear translation stage**
  - 200 mm stroke on all axes
  - to be installed inside the climatic chamber
  - translate SiPM prototype matrices wrt. laser
    - or viceversa if more conveniente
- **compatible with low-temperature operation**
  - vacuum technology
  - designed to operate down to -40 C
- **automatic scan multiple SiPM performance**
  - time resolution of multiple SiPM
  - as a function of the position on the SiPM
    - can use focused light
  - relative single-photon PDE



Characterisation plans with laser

- **measure time resolution**
  - before and after irradiation
  - before and after annealing cycles
  - as a function of bias voltage
  - for different ALCOR configurations
  - of different SiPM types and SPADs
  - … basically everything that comes into mind
- **measure relative (perhaps absolute) PDE**
  - as above
  - also as a function of photon incidence angle



SiPM irradiation in 2023

SiPM plans for FY 2023

we have not been originally funded and eventually only partially, but we'll keep the milestones alive as much as possible

Milestones FY 2023

critical results for pre-TDR

- Timing measurement of irradiated (and annealed) sensors (6/2023)
- Comparison of the results achieved with proton and neutron irradiation sources (8/2023)
- Study of annealing in-situ technique with a proposed model selected as baseline for the pre-TDR (9/2023)

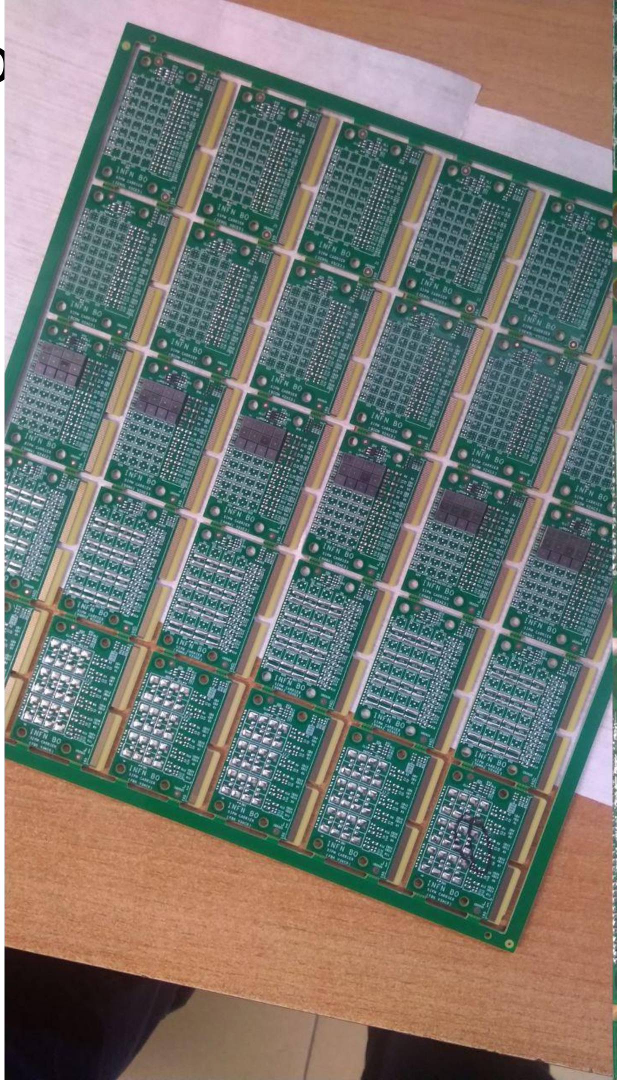
- **single-photon time resolution**
  - of full SiPM-ALCOR readout chain
    - no capacity to measure it so far
  - critical to set performance simulation
- **alternative annealing solutions**
  - so far done with industrial oven (days)
  - address ideas for faster / in-situ recovery
    - exploration started, promising
    - critical to become structured R&D
- **irradiation campaigns**
  - so far only with 150 MeV protons
  - critical to collect data on neutron damage
    - might be topologically different
    - effectiveness of annealing
    - test NIEL damage hypothesis
  - irradiation needed to test new annealings
- **operation at low temperature**
  - so far characterisation in climatic chamber
    - compare results with TEC (Peltier) cooling
  - explore alternative solution to TEC
    - liquid, hybrid (liquid + TEC) approaches
- **development of new sensors**
  - within INFN-FBK collaboration agreement
    - critical for procurement risk mitigation
  - reduction of DCR
    - field / thickness optimisation
    - exploration of advanced microlensing
  - development of "monolithic" SiPM sensor array
    - wire bonded, cost reduction

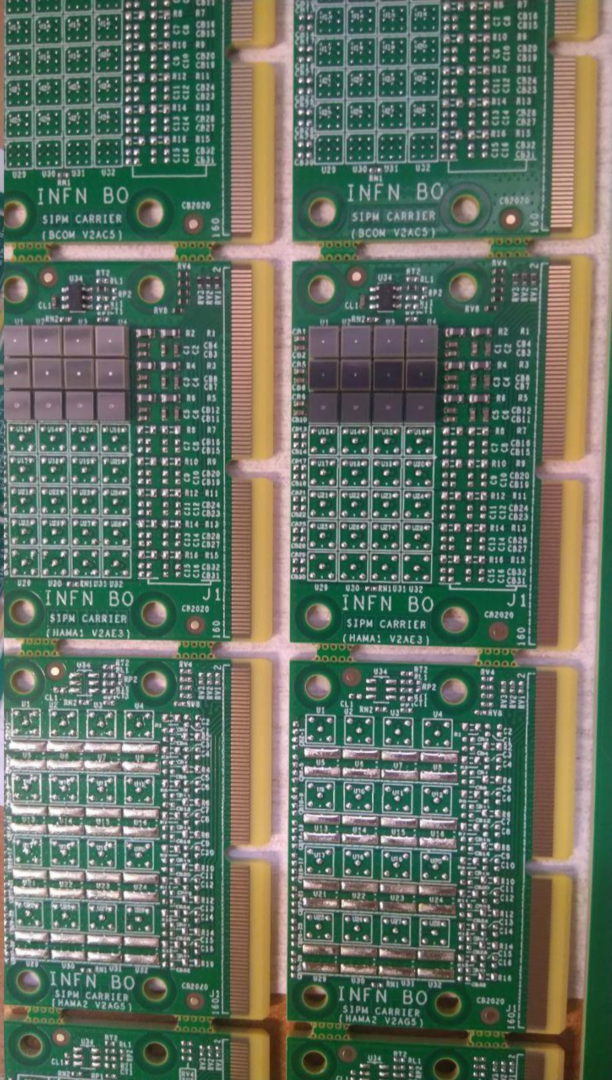
SiPM custom boards for ongoing R&D

35 new boards have been produced

- **new SiPM carriers**
  - keep same boards designed in 2020
  - populate 3 rows
    - 4 sensors / row
  - sensors from Hamamatsu
    - 4x S13360-3050
    - 4x S14160-3050
    - 4x S13360-3075
- **perform different type of irradiation/annealing studies**
  - one carrier board for each study
- **keep a minimal statistical sample for each study**
  - 4 sensors / type

SiPM custom boards fo





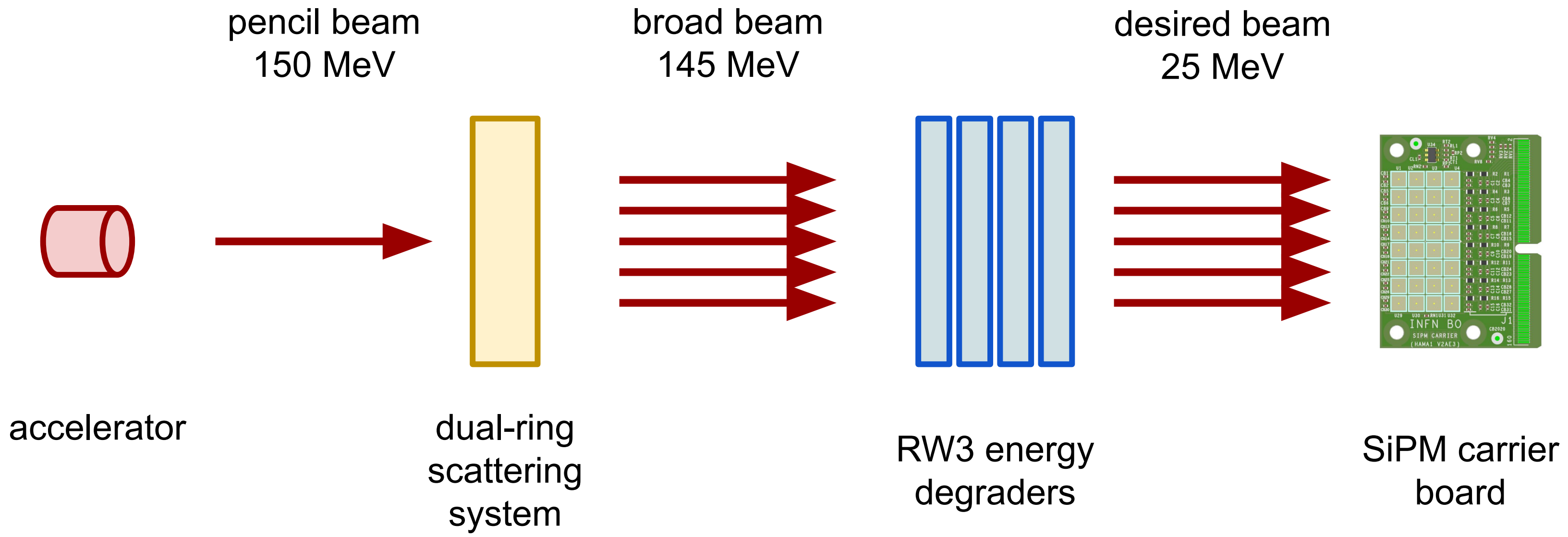
Boards to irradiate at TIFPA in June 2023

- **proton energy scan [5 boards]**
  - proton energy: 145, 75, 45, 25, 18 MeV
    - will scan 5 values of the hardness factor K
    - K = 1.1, 1.5, 2.0, 2.5, 3.0
  - fluence to be defined
    - fixed proton fluence → damage scales with K
- **online annealing [2 boards]**
  - 145 MeV standard energy
  - split 10^9 n_{eq} fluence in 10x repeated irradiation-annealing cycles
    - 10^8 shots
    - 30-minutes long online annealing
  - forward and reverse current bias
- **offline annealing [7 boards]**
  - 145 MeV standard energy
  - 10^9 neutron equivalent fluence
  - study annealing in the laboratory
    - standard oven (150 h - 150 C)
    - forward current
    - reverse current
    - infrared lamp annealing
    - else
  - study impact of preventive-annealing
    - standard oven (150 h - 150 C)
    - multiple standard cycles (4x cycles)

will do 10^9 fluence in June
10^{10} fluence later this year
delivered on the same boards

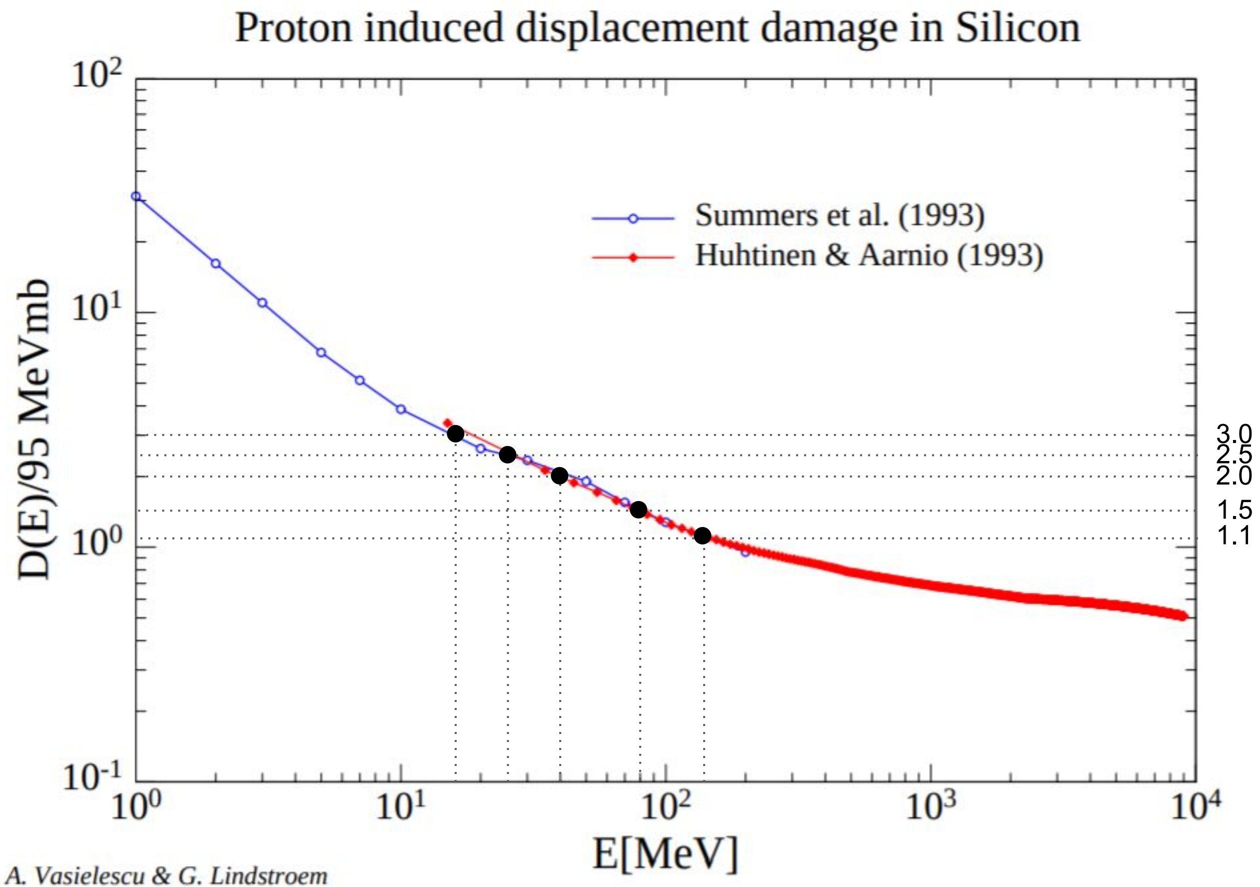
slot on 9-10 June

Proton Energy Scan



change the number of energy degrader to achieve the desired beam
need to study material / thickness and pieces available at TIFPA

Proton Energy Scan

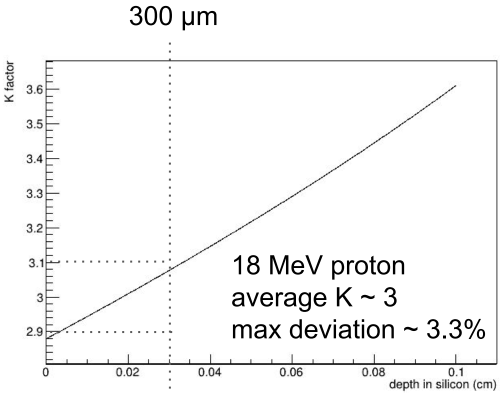


A. Vasielescu & G. Lindstroem

measure 5 points on the hardness factor (K) curve

K < 1.1 cannot be achieved
max 150 MeV with broad beam

energy loss in silicon too large at low proton energy
→ will cause variation of K while crossing the sensor



Boards to irradiate at LNL in August 2023

- **online annealing [2 boards]**
  - we have 3 days, we can do many rounds
  - split 10^9 n_{eq} fluence in 10x repeated irradiation-annealing cycles
    - 10^8 shots
    - 30-minutes long online annealing
  - forward and reverse current bias
- **offline annealing [9 boards]**
  - we have only one access in 2023
  - increasing neutron equivalent fluence with standard oven [3 boards]
    - fluence 10^9 10^{10} 10^{11}
    - standard oven (150 h - 150 C)
  - study annealing in the laboratory [4 boards]
    - fluence 10^9
    - forward current
    - reverse current
    - infrared lamp annealing
    - else
  - study impact of preventive-annealing [2 boards]
    - fluence 10^9
    - standard oven (150 h - 150 C)
    - multiple standard cycles (4x cycles)

slot on 2-3-4 August

SiPM run with FBK

SiPM run with FBK

sipm4eic project

funded and approved within INFN-FBK Collaboration agreement

start of run October 2023

1) Sintesi del progetto di ricerca

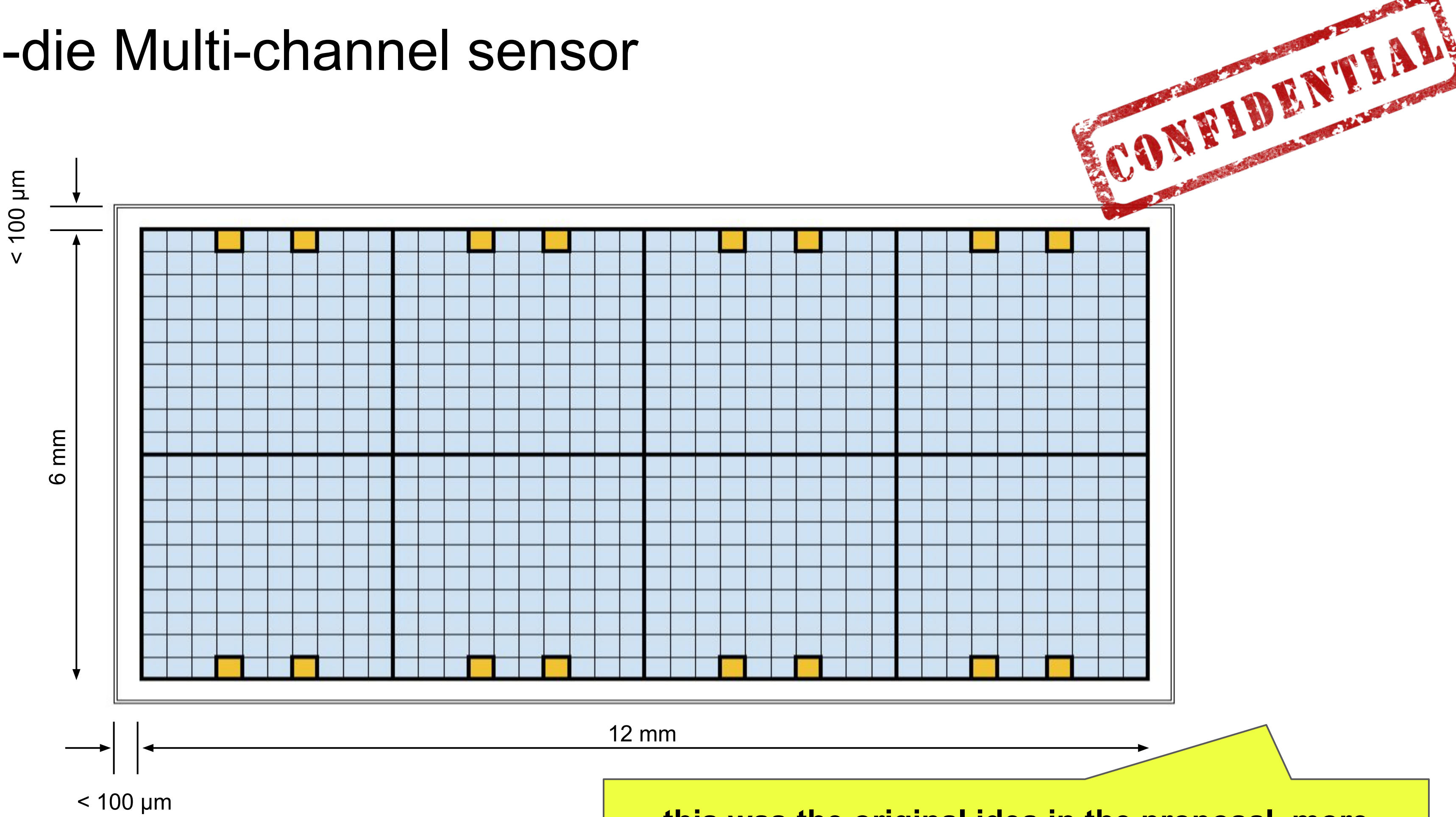
Ring Imaging Cherenkov applications at the EIC require sensors with single-photon detection capabilities with high efficiency and excellent time resolution. High dark count rates (DCR) in SiPM can be counteracted with low-temperature operation and radiation damage can be partially cured with high-temperature annealing. Even small improvements towards reduction of DCR are helpful for a better exploitation of the detectors and to provide a strong alternative to commercially-available sensors. One of the goals of the R&D is to exploit the already-mature FBK NUV-HD technology to improve radiation tolerance and meet the needs for EIC. Increasing the fraction of the sensor active area over the total area while retaining a low-cost process (wire-bonding vs. TSV) is another important step to make FBK technology an even more attractive solution for EIC. These research goals are in line with the timeline for the initial operation of EIC and are targeted to the Technical Design Reports.

in line with initial operation of EIC

Another line of research aims to significantly reduce DCR and radiation vulnerability in SiPM by reducing their active area while maintaining photodetection efficiency. Such a study is exploratory and more ambitious, but has a high return potential. This part of the R&D is not targeted for the EIC initial operation phase, but might yield a new class of SiPM photosensors for the EIC RICH detector upgrades, for the ALICE3 RICH detector as well as future LHCb RICH upgrades.

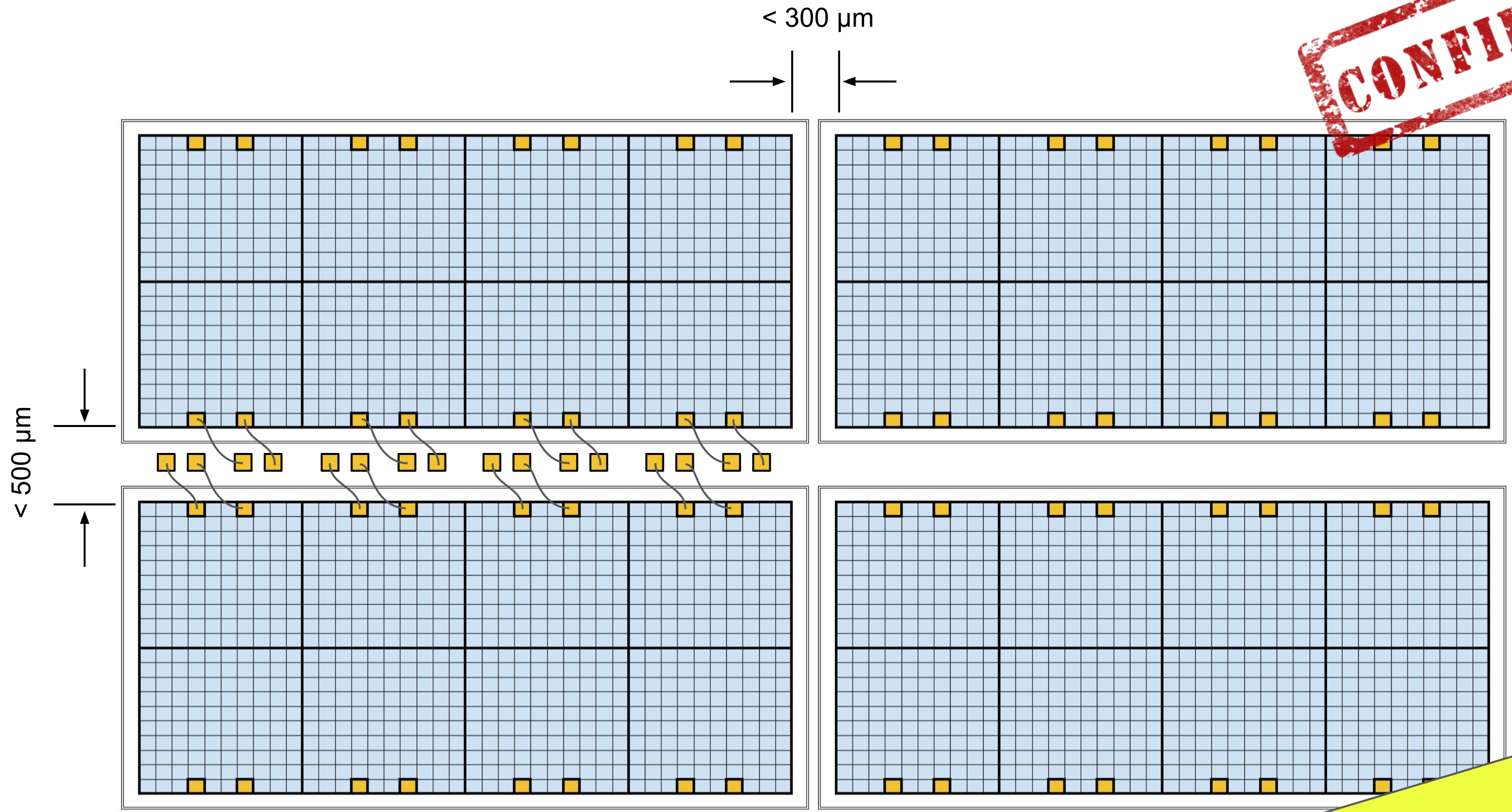
might yield sensors for EIC RICH upgrades and for ALICE3 RICH

Single-die Multi-channel sensor



this was the original idea in the proposal, more ideas are on the table for discussion with FBK

PCB mounting



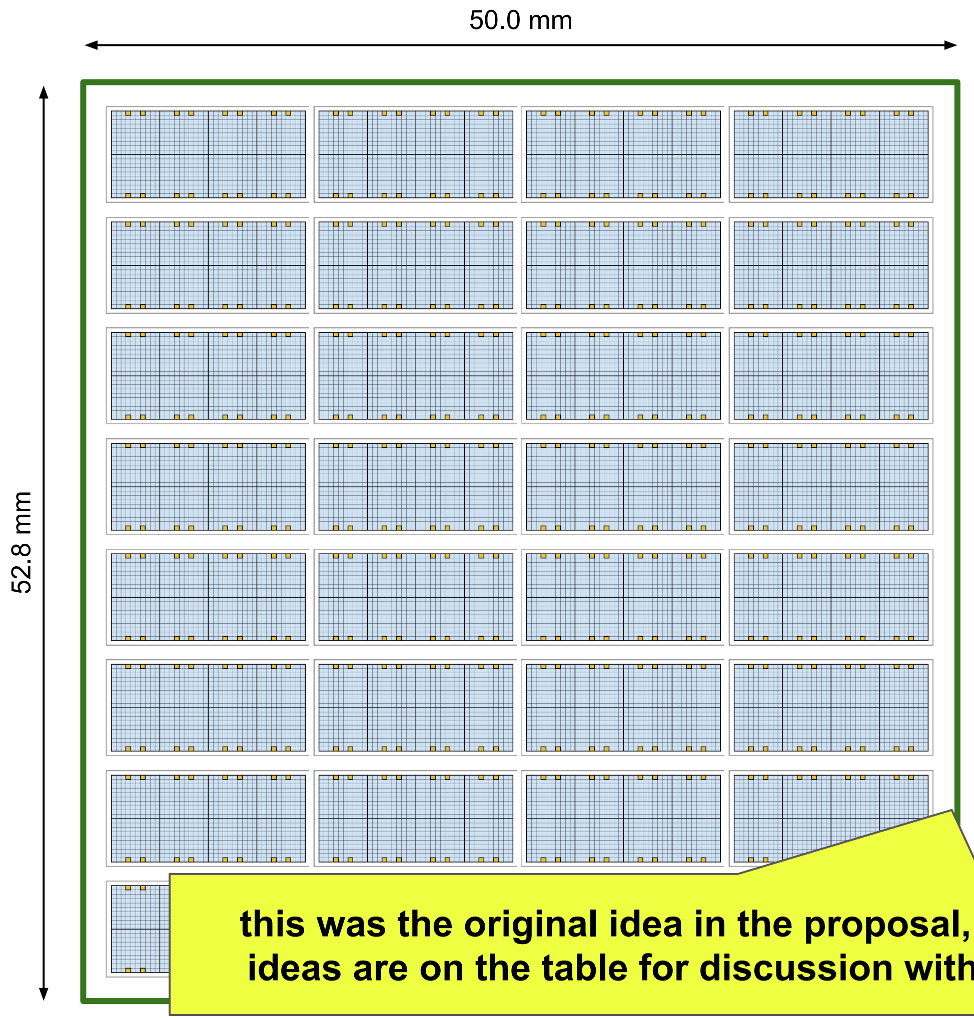
this was the original idea in the proposal, more ideas are on the table for discussion with FBK

EIC readout unit

total area
50.0 x 52.8 mm²
active area
48 x 48 mm²
87.3 % coverage

very similar coverage
compared to
Hamamatsu-based solution

CONFIDENTIAL

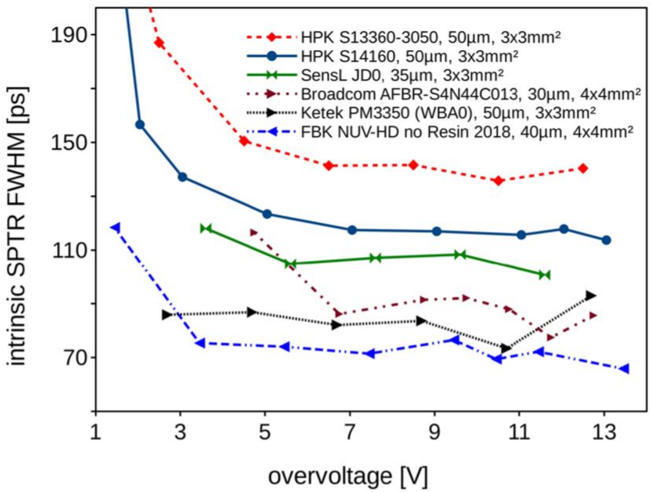


this was the original idea in the proposal, more ideas are on the table for discussion with FBK

SiPM sensor selection

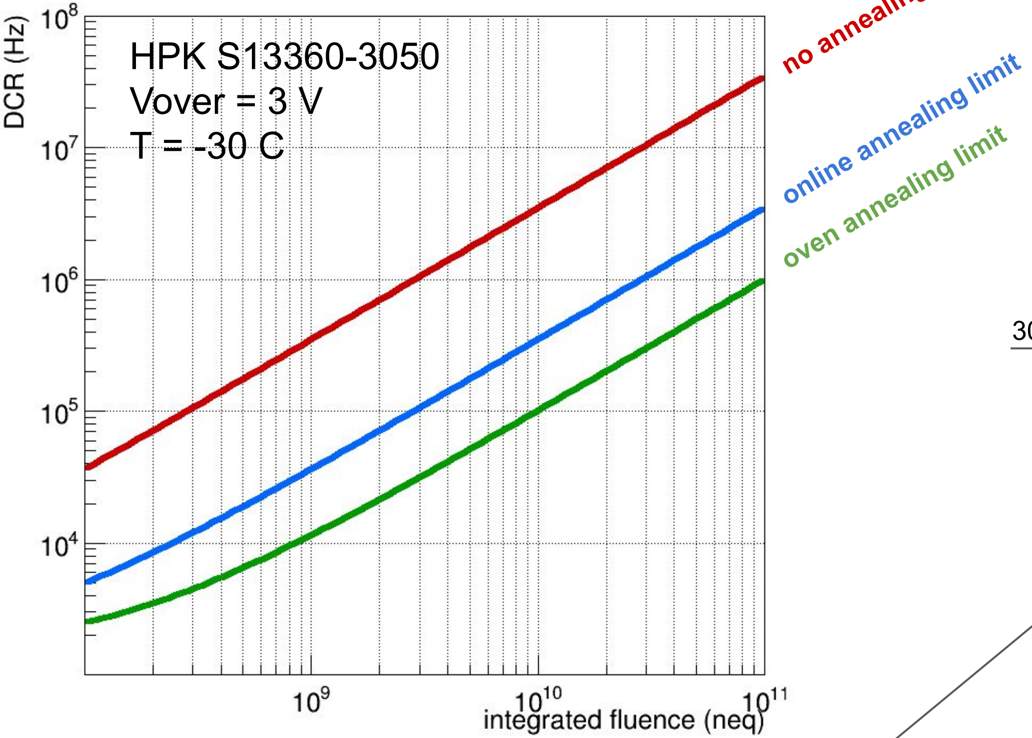
SiPM sensor selection: end of 2024 / beginning 2025

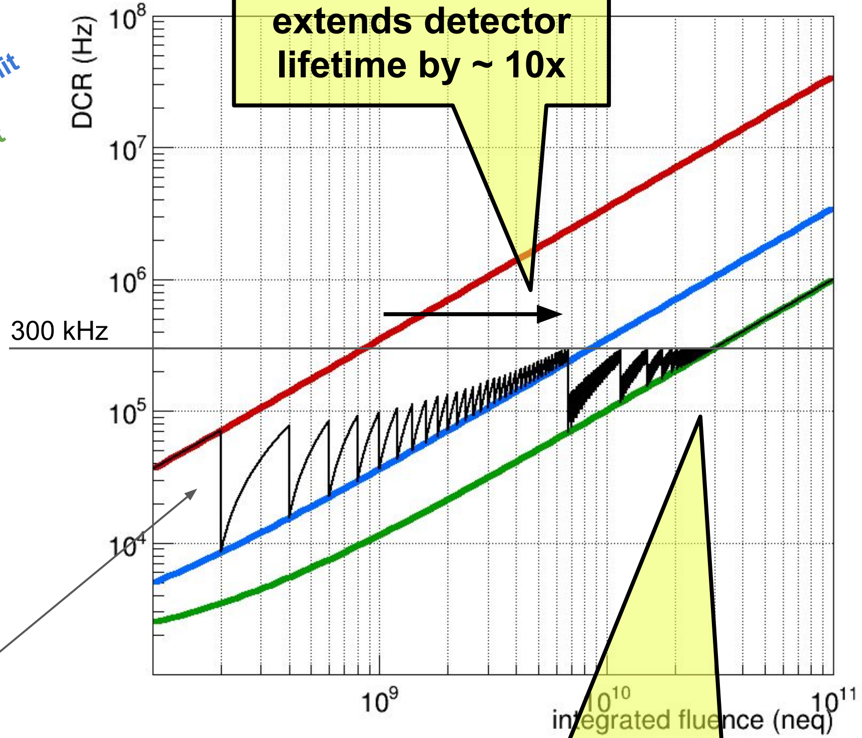
- **we already have a baseline sensor**
  - Hamamatsu S13360-3050
- **but we know that it might not be the best choice**
  - see the 50 vs. 25 μm and the 75 vs. 50 μm SPAD story
  - we already have hints 75 μm
    - let's fully test them this year
    - we do not have 75 μm for beam test of prototype
    - we need to test 75 μm on the beamline with prototype next year (likely Autumn)
- **we have an R&D with FBK to improve their technology**
  - DCR of FBK sensors already close to Hamamatsu
    - we know how to improve that → very-low field implantation
  - FBK sensors have in principle better time resolution
    - see publications, factor of two smaller than S13360
  - wait until FBK run for EIC is completed
    - we will fully test the sensors in 2024
    - characterisation
    - irradiation
    - annealing
    - and so on….
  - we will install them on the dRICH prototype for beam test
    - also this goes in Autumn 2024



perspectives for the future

Radiation damage model





online annealing extends detector lifetime by ~ 10x

online annealing every 2 10^8 neq (many times)
oven annealing when DCR > 300 kHz (few times)
note: 300 kHz limit assumed based on potential bandwidth limitations

after several years one might need/want to replace the SiPMs with new rad. harder technology

FONDAZIONE BRUNO KESSLER
FUTURE BUILT ON KNOWLEDGE

Detector Seminar

Silicon Photomultiplier technologies developed at FBK: roadmap towards 3D integrated devices

by Dr Alberto Gola (Fondazione Bruno Kessler (IT))

Friday Apr 21, 2023, 11:00 AM → 12:15 PM Europe/Zurich

40/S2-D01 - Salle Dirac (CERN)

Status and perspectives of SiPMs at FBK

Alberto Gola
Chief Scientist

Acerbi, A. Ficorella, S. Merzi, L.P. Monreal, E .Moretti, G. Paternoster, M. Penna, M. Ruzzarin, N. Zorzi

a range of possibilities for R&D to have improved SiPM sensors

- backside illuminated
- 3D integration
- microlensing / nanophotonics
- charge-focusing

gola@fbk.eu