Lab Setup:
ALCOR use in dRICH facilities

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on behalf of ePIC dRICH Bologna

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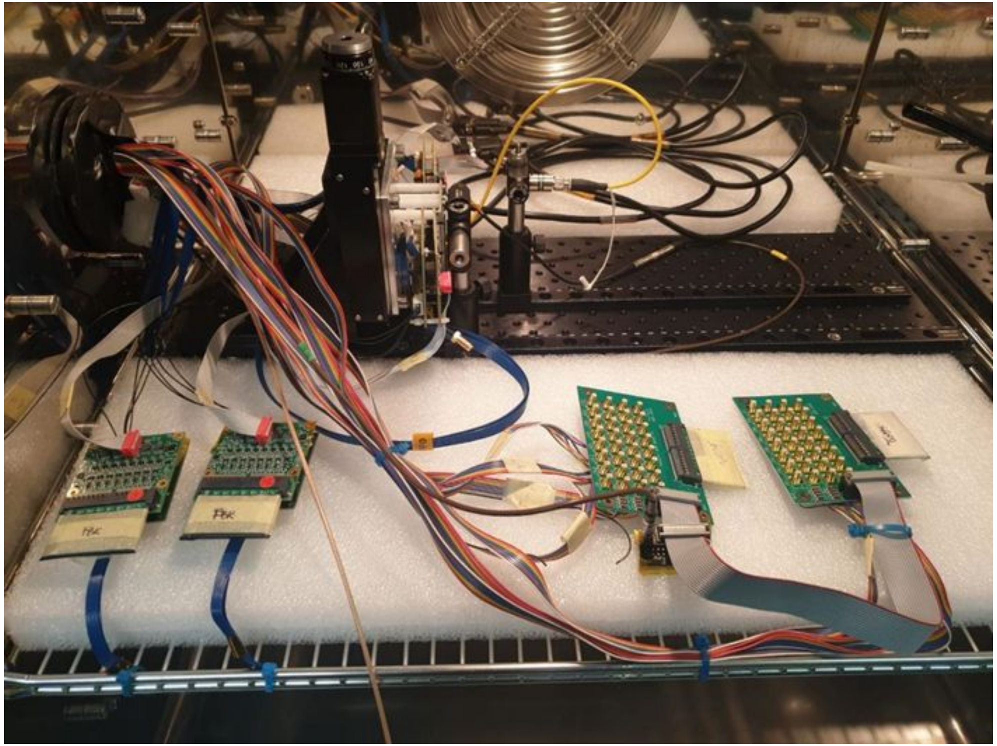
8 February 2023

Outline

- Introduction
- Irradiation and annealing campaign
- Characterization setup
- First campaign results

Extras:

- dRICH prototype
- Portable setup AirBOx



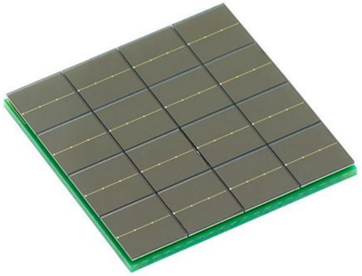
Introduction

SiPMs are a valuable option for the Dual Rich optical readout:

- Cheap
- Low voltage operation
- Excellent time resolution
- Single photon detection
- Insensitive to magnetic field
- High spatial resolution

But:

- High **number** of **channels**
- High **Dark Count Rate**
- Prone to **radiation damage**.



In this first phase of the detector **R&D** we needed to test the capabilities of the **SiPMs** to withstand **radiation damage**:

- Sensor selection (Vendor and Model)
- Irradiation & Annealing campaigns

The test setup must mimic the operative condition in a multichannel configuration.

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Irradiation & Annealing campaign

Several SiPMs sensors (> 120) from **different vendors** were tested. Different irradiation levels with 148 MeV protons @ TIFPA (TN).
2021 campaign 10^9-10^{11} n_{eq}
2022 campaign 4 $\times 10^9$ n_{eq} cycles

board	sensor	uCell (µm)	V_{bd} (V)	PDE (%)	DCR (kHz/mm^2)	window	notes
HAMA1	S13360 3050VS	50	53	40	55	silicone	legacy model Calvi et. al
	S13360 3025VS	25	53	25	44	silicone	legacy model smaller SPAD
HAMA2	S14160 3050HS	50	38	50		silicone	newer model lower V_{bd}
	S14160 3015PS	15	38	32	78	silicone	smaller SPADs radiation hardness
SENSL	MICROFJ 30035	35	24.5	38	50	glass	different producer and lower V_{bd}
	MICROFJ 30020	20	24.5	30	50	glass	the smaller SPAD version
BCOM	AFBR S4N33C013	30	27	43	111	glass	commercially available FBK-NUVHD

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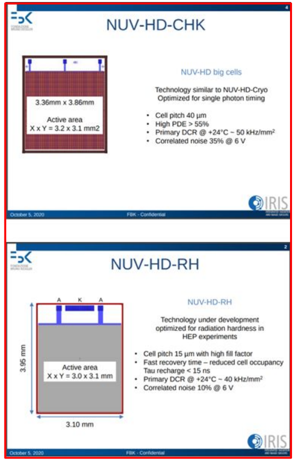

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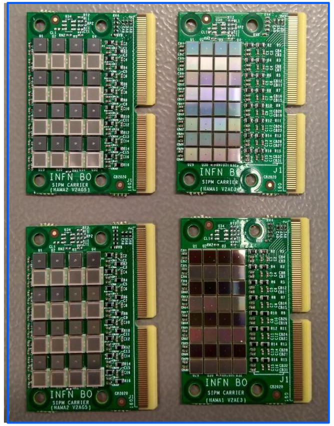
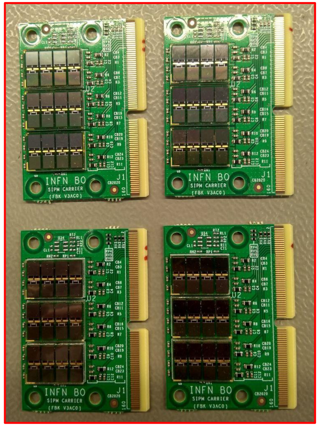


FBK



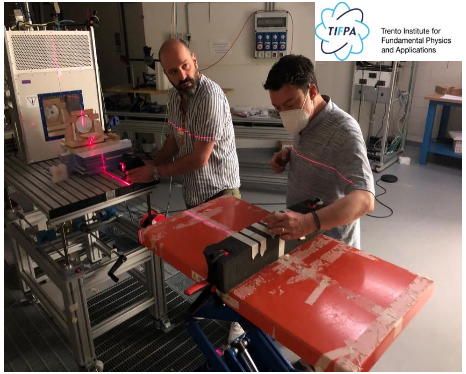
Edge connector (no plastic)

3x3 mm^2 SiPM sensors
4x8 "matrix" (carrier board)

Temperature sensor for operation with Peltier cooling

Irradiation & Annealing campaign 2022

Test reproducibility of repeated irradiation-annealing cycles simulate a realistic experimental situation

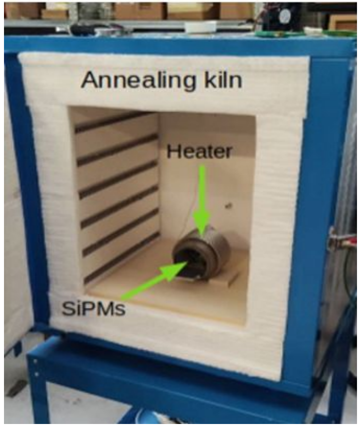


Irradiation fluence/cycle of 10^9 n_{eq}

Characterization Bo → Annealing Fe → Characterization Bo → Irradiation TIFPA-TN → Characterization Bo

4x

Interleaved with full characterisation



150 °C 150 hours annealing

Irradiation & Annealing campaign 2022

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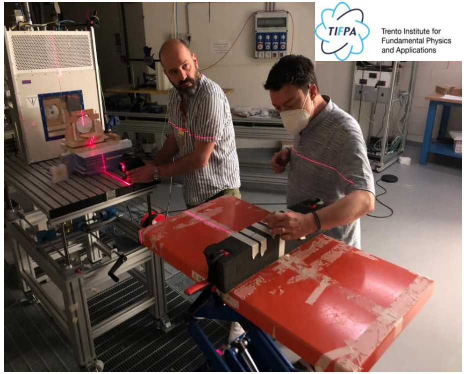

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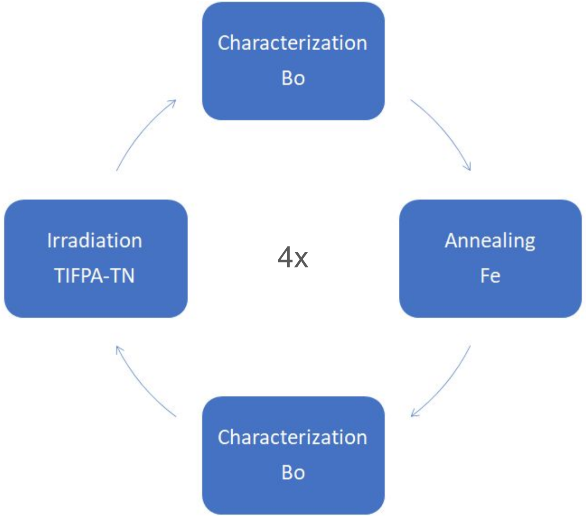
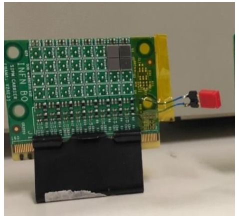
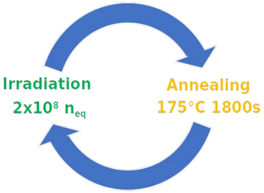


Interleaved with full characterisation



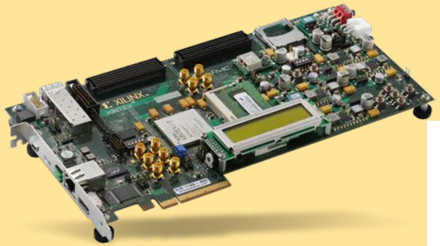


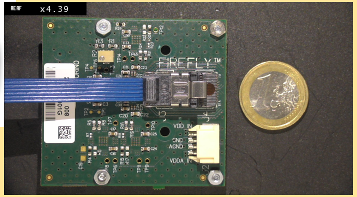
online annealing

Characterization setup

Automatic measurement of 4x SiPM boards (128 channels)

- **climatic chamber**
  low-temperature operation (T = -30 C)
- **multiplexed source meter**
- **ALCOR-based front-end chain**
  FPGA (Xilinx) readout
- **LED pulser**
- **Power supplies**

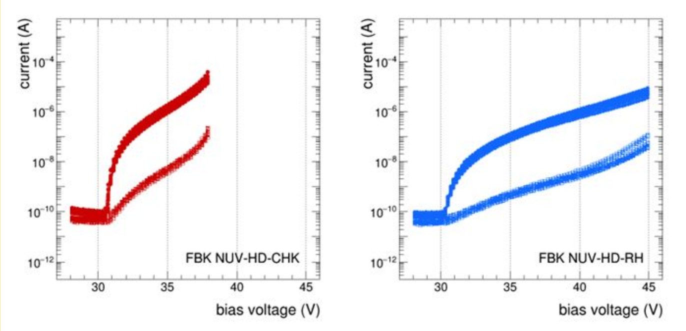


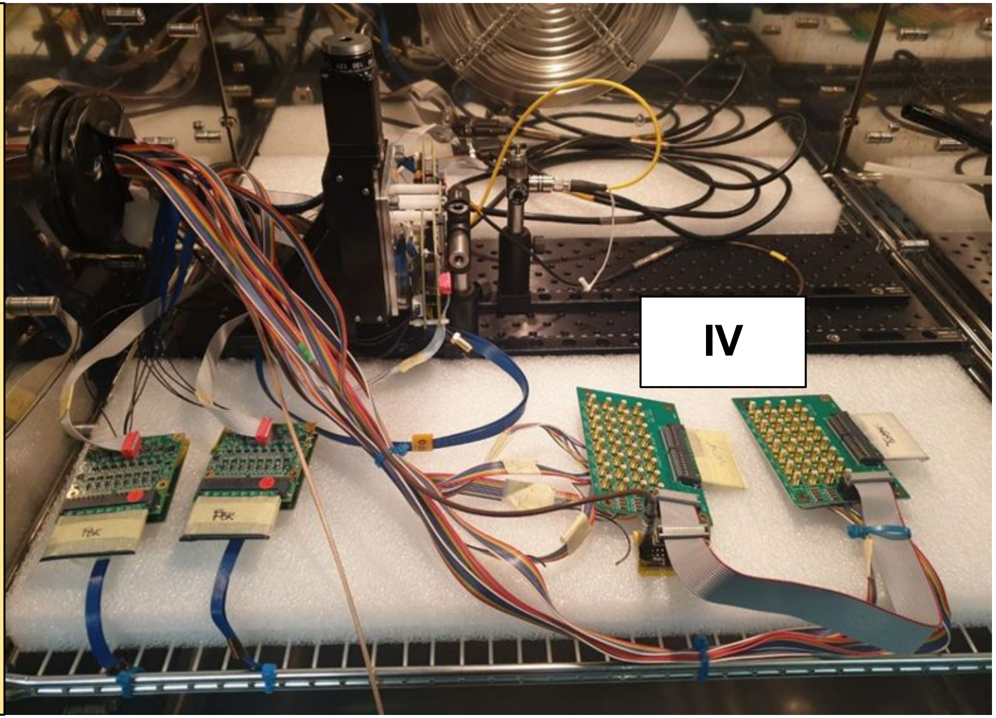


Characterization setup

IV setup: **Dark Current - V_{BD}**

Keithley 2450 SMU (up to 10 fA resolution)
Keithley 7702 40 ch **Mux**
32 channels (2 carrier boards) fully **automated** measurement





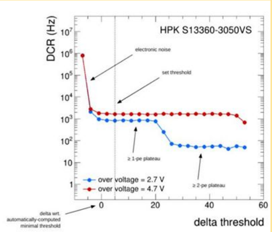
Characterization setup

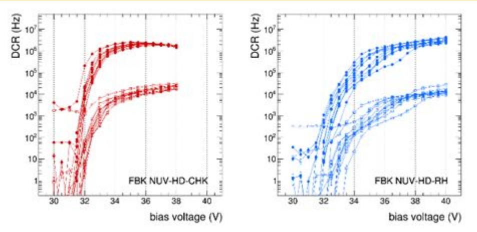
DCR

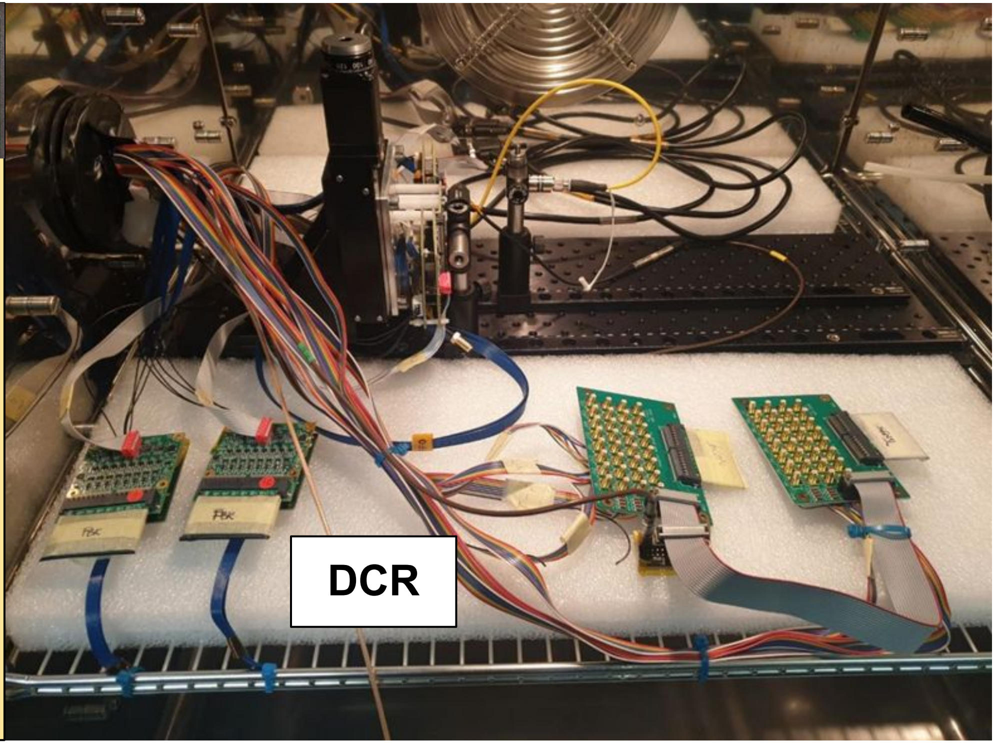
Full dressed redout:

- **ALCOR** v1 with **TDCs** in **LET** mode
- **Bias** distribution to fine **tune** the **HV** through precision DAC (Fe)
- Xilinx **FPGA** connected through high speed links (Samtec FIREFLY cables) for the acquisition

TDC threshold scan computed **automatically** to find the **baseline** and measure the **DCR**





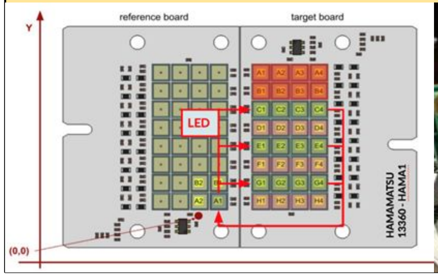


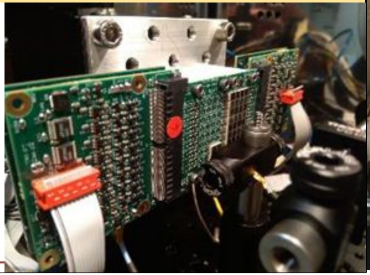
Characterization setup

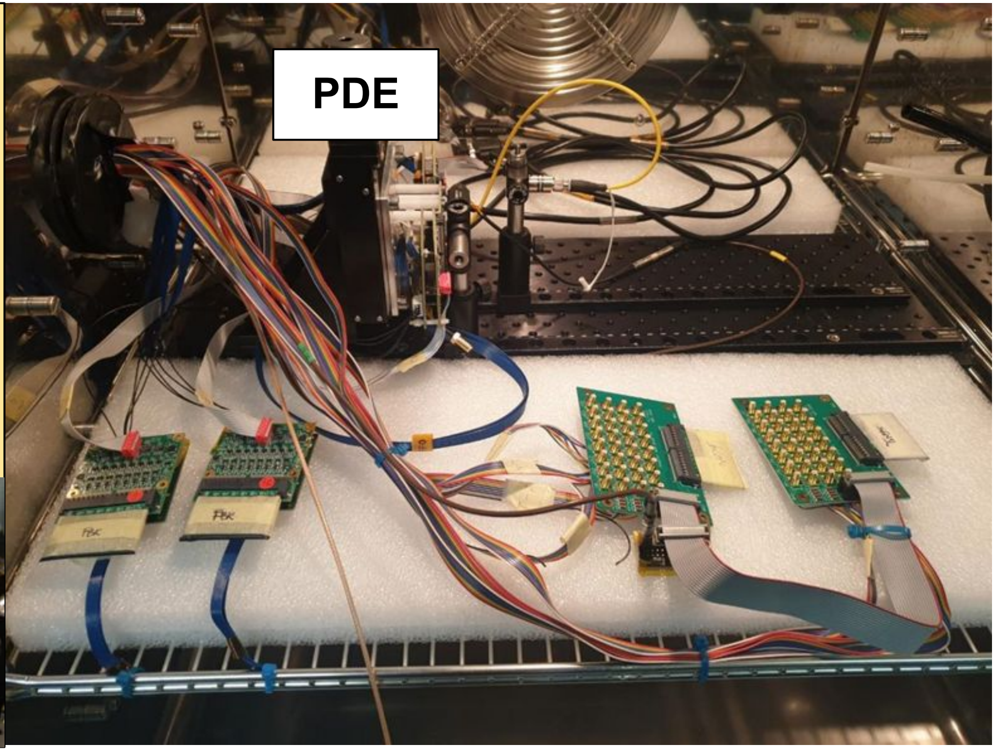
LED optical bench - PDE

- Same Alcor readout as for the DCR measurement
- Linear stage to scan different SiPMs
- LED driven by a fast RF pulser
- Coincidence computed in the FPGA

At the beginning of each line a reference sensor is scanned to ensure the maximum repeatability.







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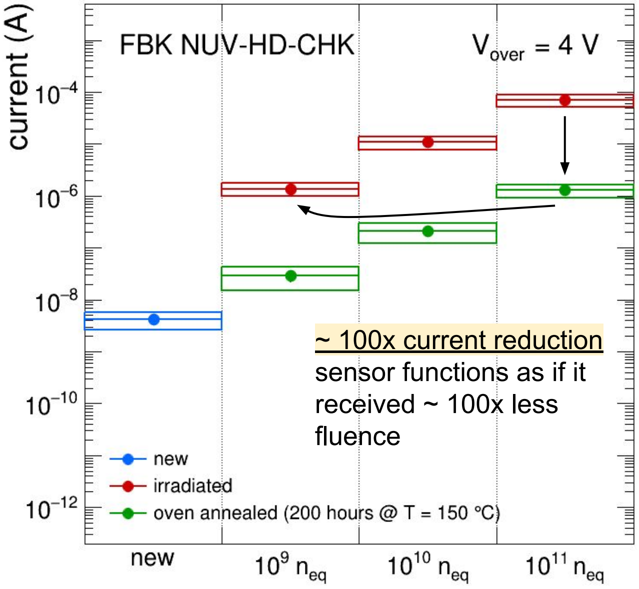
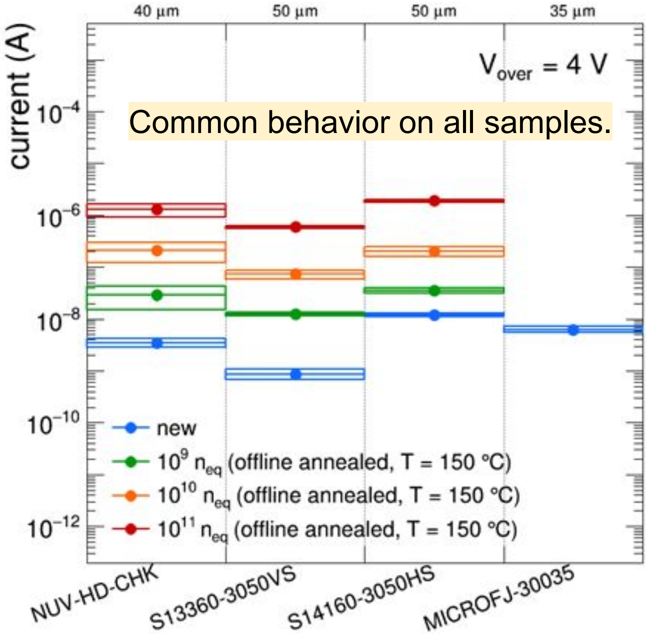
First campaign results 2021





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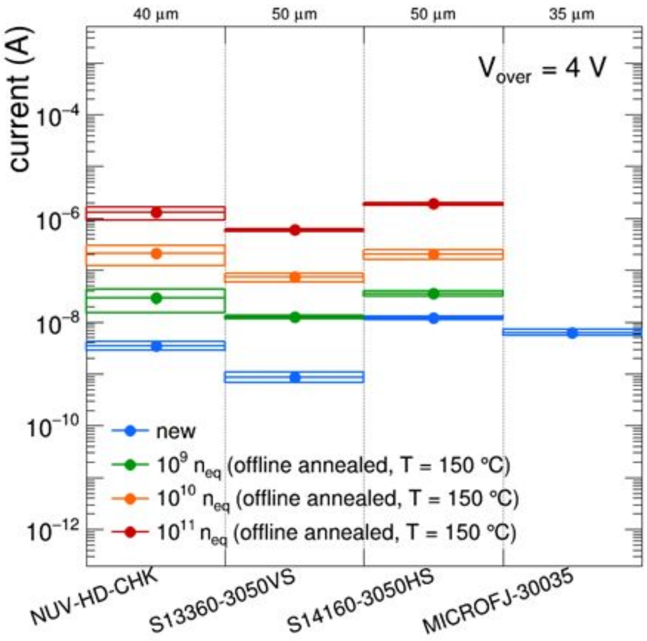
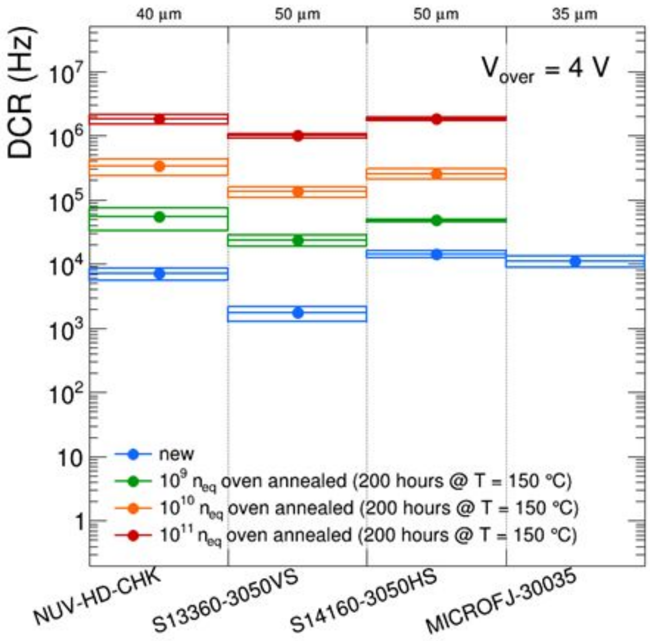


Dark current and DCR are essentially the same measurement



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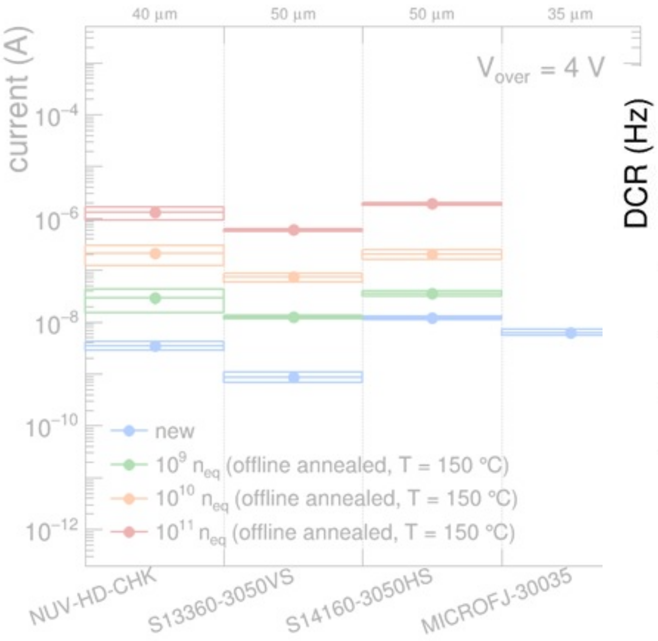

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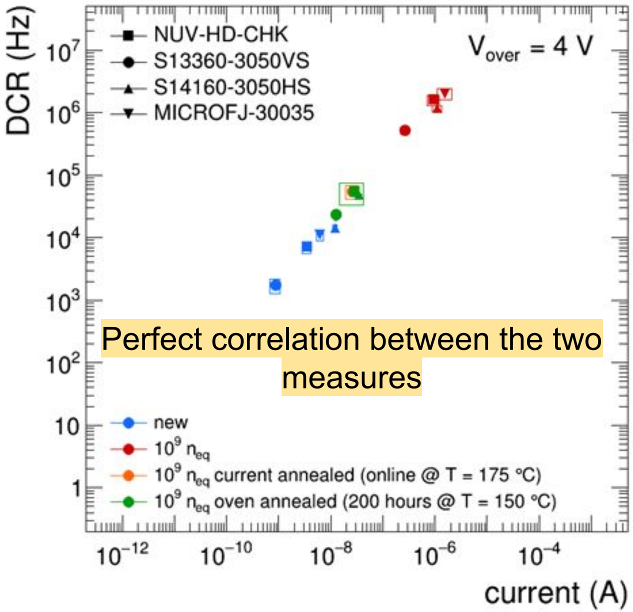
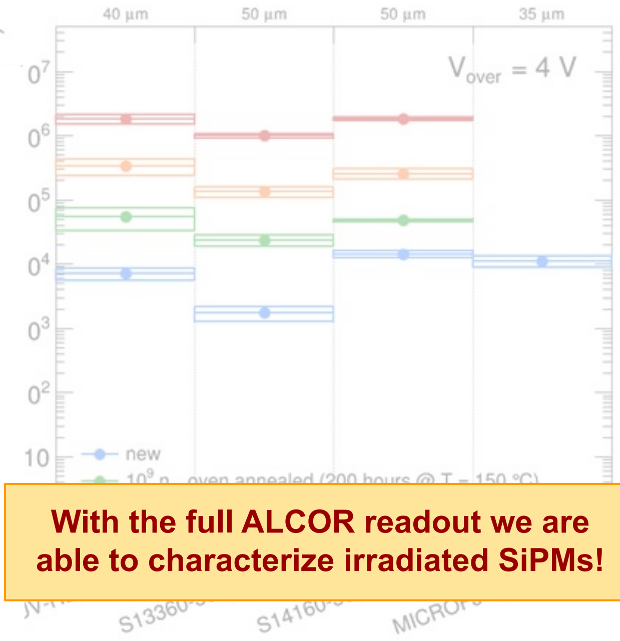
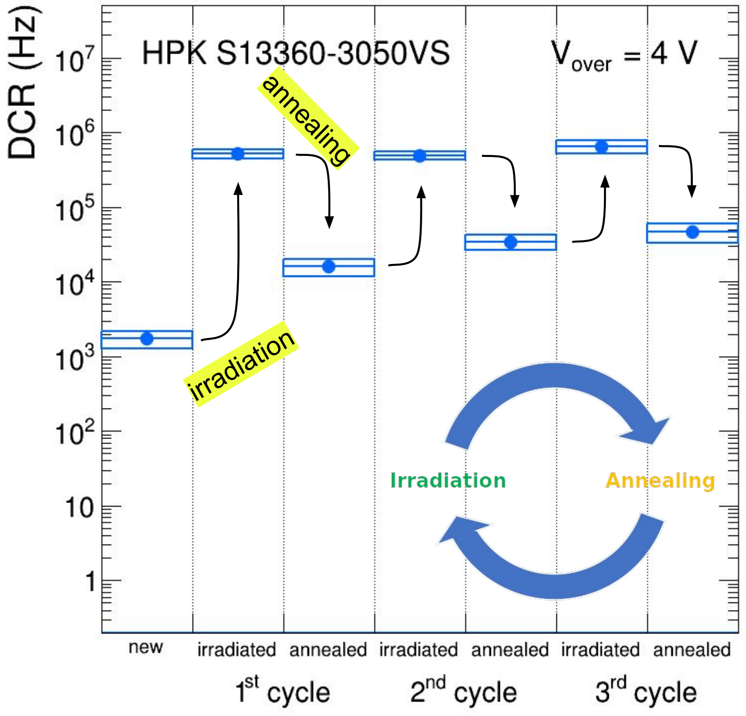


Perfect correlation between the two measures



With the full ALCOR readout we are able to characterize irradiated SiPMs!

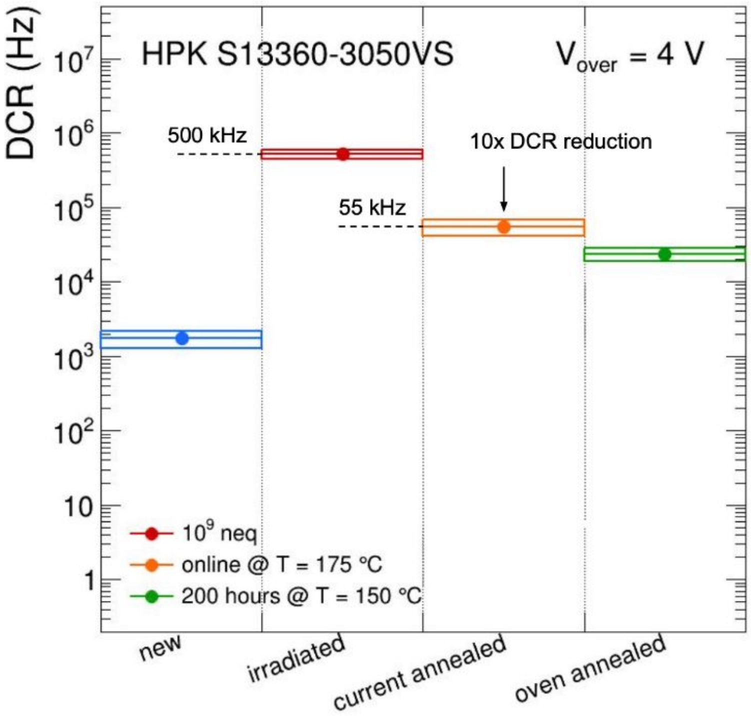
First campaign results 2022



Every **10^9 n_{eq}** of dose, we measure an increment of **500 kHz** in **DCR**
Annealing helps to recover up to **97%** of DCR and after each annealing roughly an **additional 15 kHz** of **DCR** is preset wrt new sensors.
Radiation damage remain **additive** even in this cycle configuration.

150 °C 150 hours oven annealing

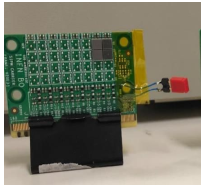
First campaign results 2022

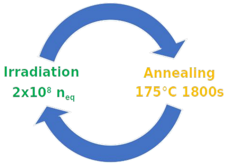


Direct current annealing allows to reduce the DCR by a factor 10. Not as good as the oven but:

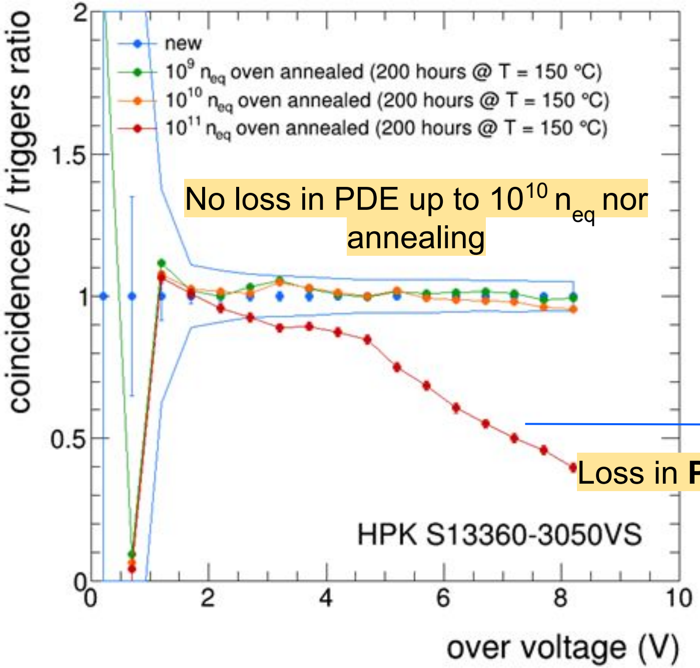
- 100 times faster
- can be done in-situ
- can be done more frequently

Needs a clever electronic design to bypass power supply filter and protect the front end

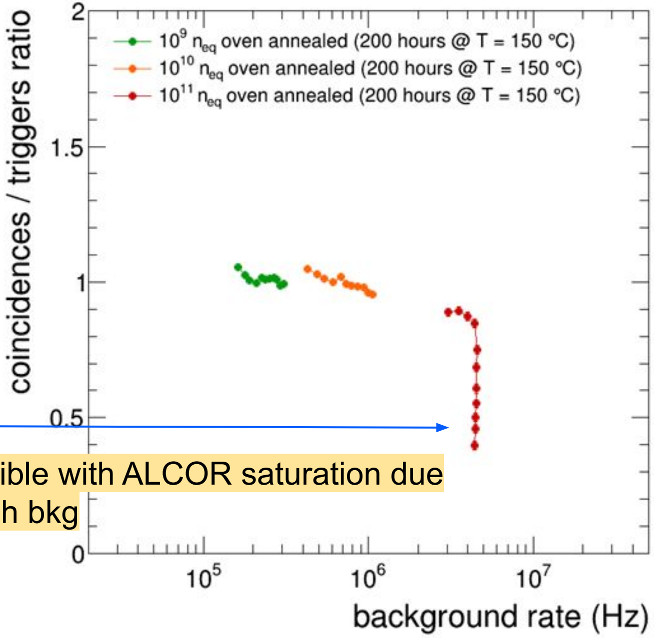




First campaign results PDE

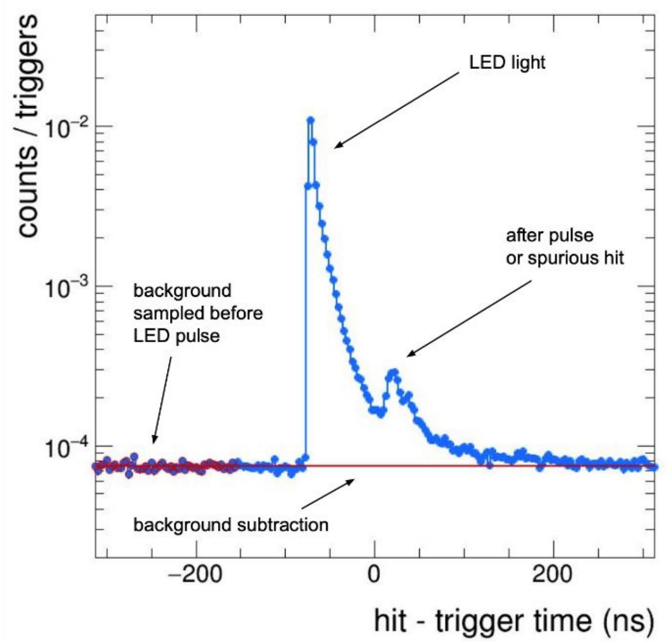


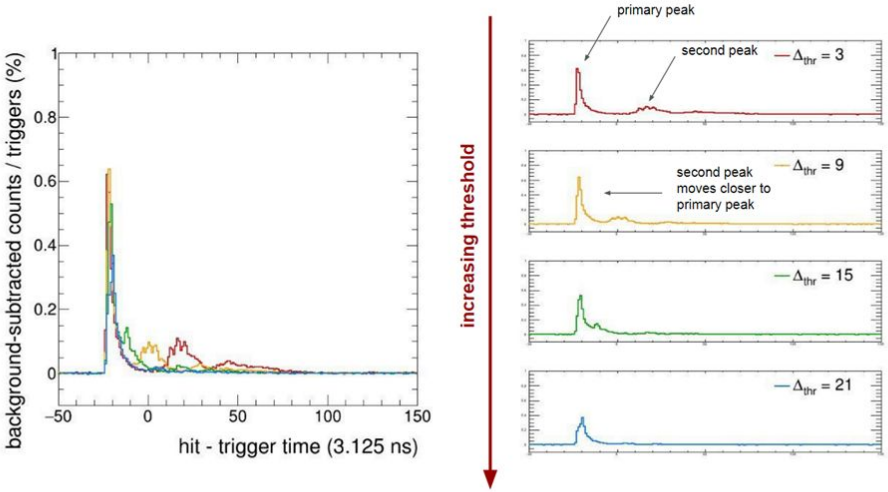
No loss in PDE up to 10^{10} n_{eq} nor annealing



Loss in **PDE** at 10^{11} n_{eq} compatible with ALCOR saturation due to high bkg ePIC

First campaign results PDE





Multi-peak structure (detector dependent) moving with the threshold level due to **oscillations** after the signal peak. Probably due to **peaking** related to the coupling of the **RGC** and the **SiPM capacitance**.

dRich prototype box

Made in Ferrara

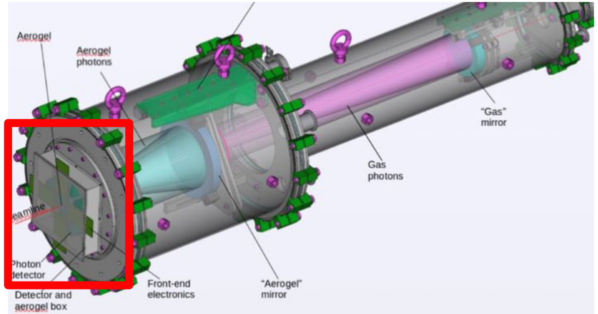
Working temperature -30°C

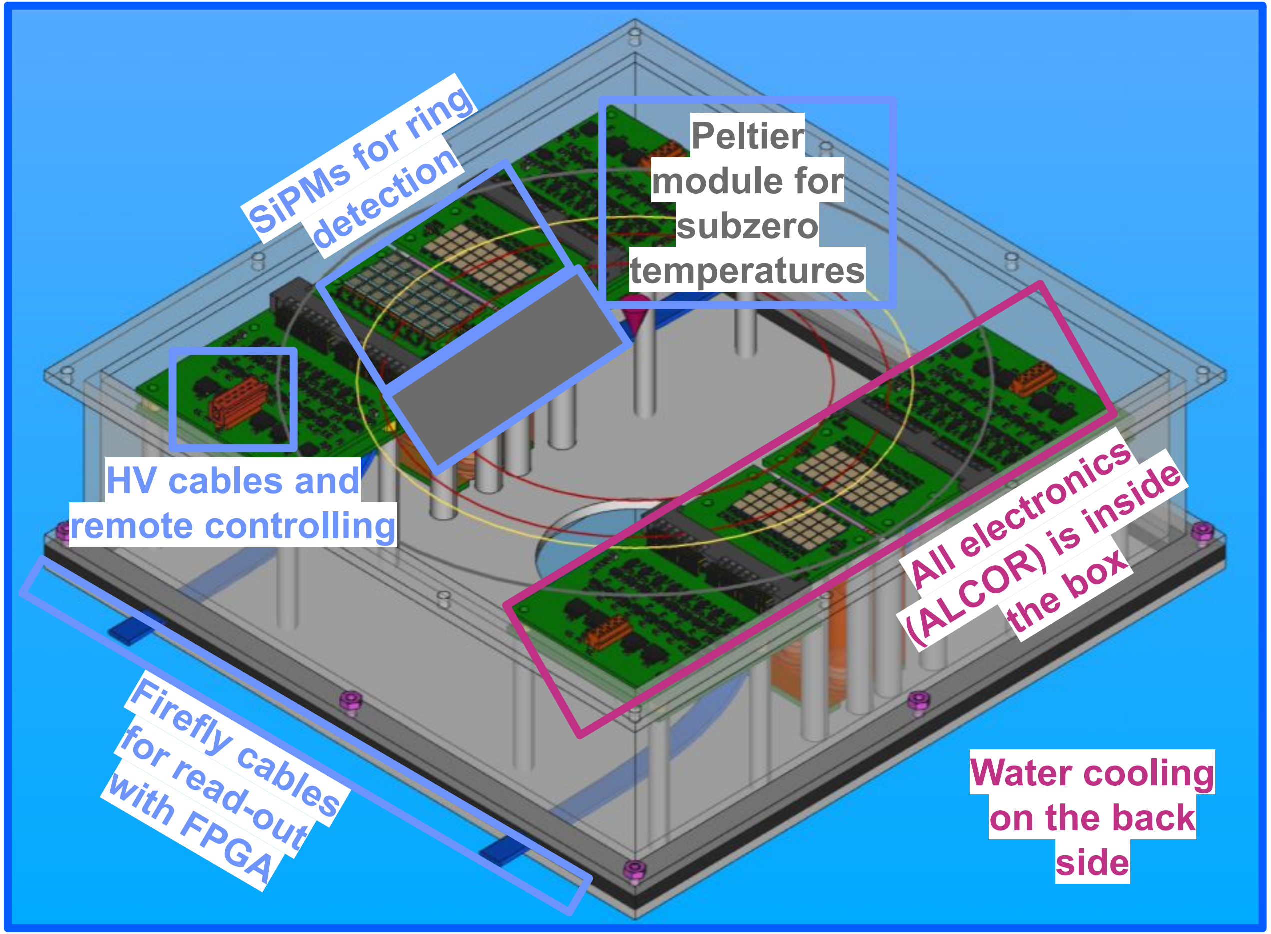
Peltier cooling for subzero temperatures

Water cooled

All-included electronics (HOT)

Used for dRICH prototype in Test Beam 2021 and 2022





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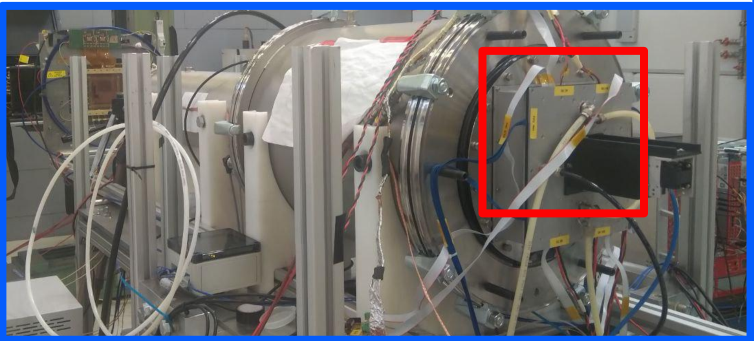
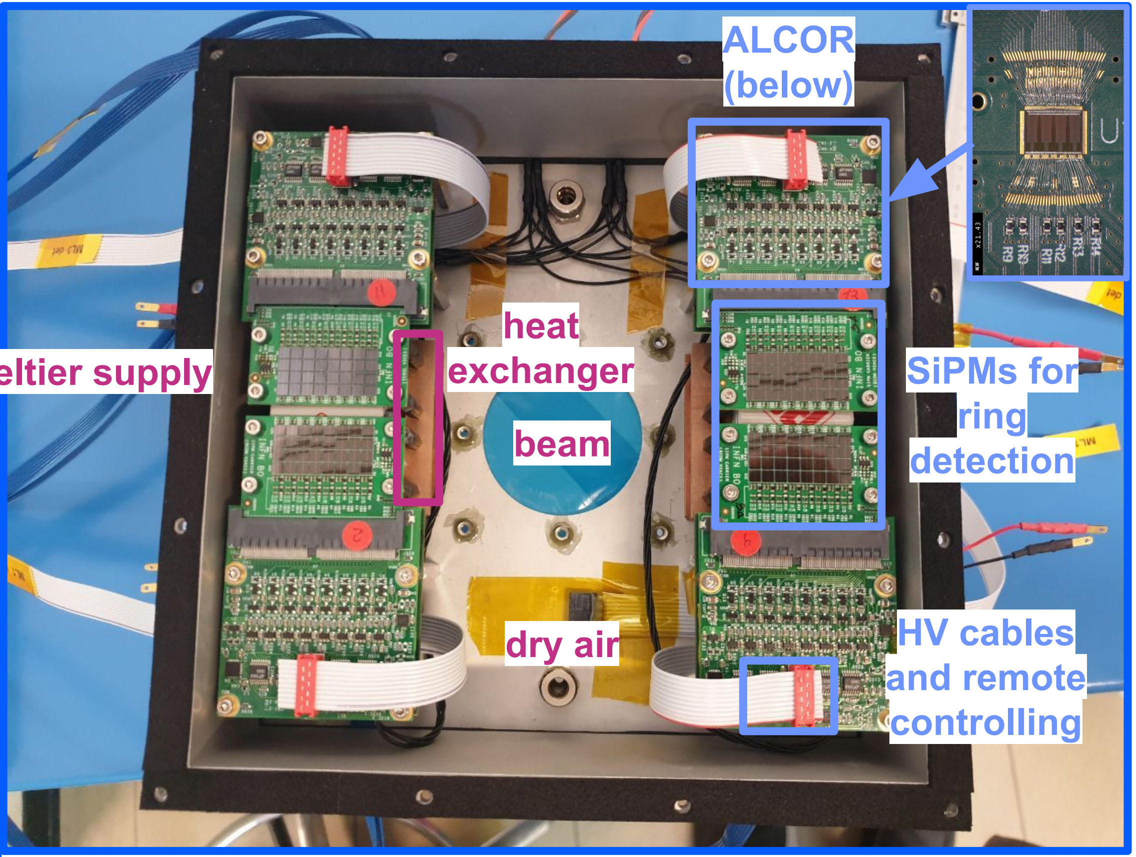




AirBOx™

Made in Bologna

Working temperature -30°C

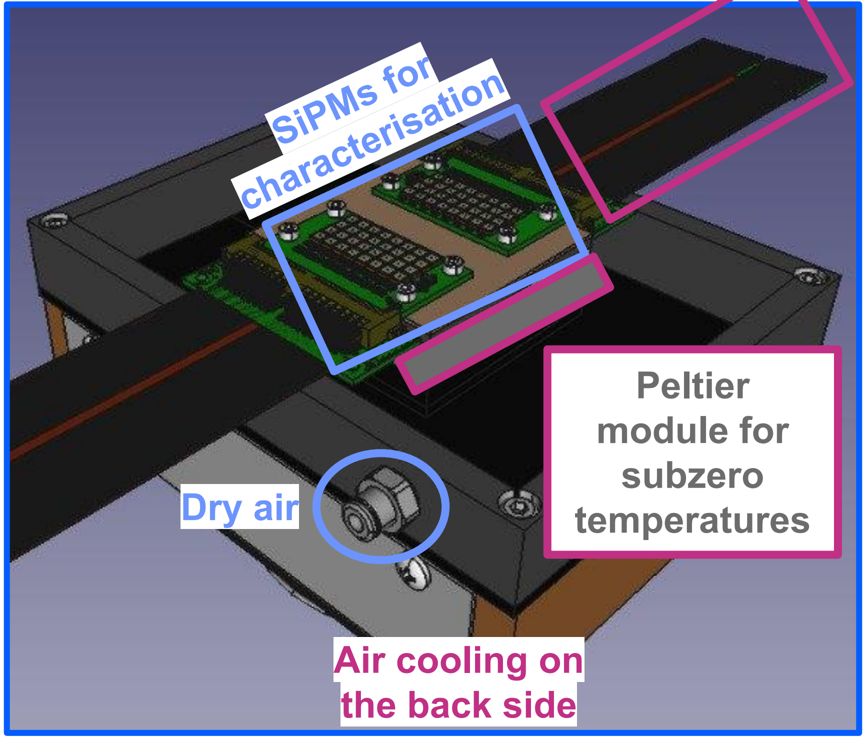
Peltier cooling for subzero temperatures

Air cooled

Outside electronics (HOT) as in the experiment

Used for portable sensors or electronics characterisation

All electronics (ALCOR) is outside the box via this flex cable



AirBOx™

Made in Bologna

Working temperature -30°C

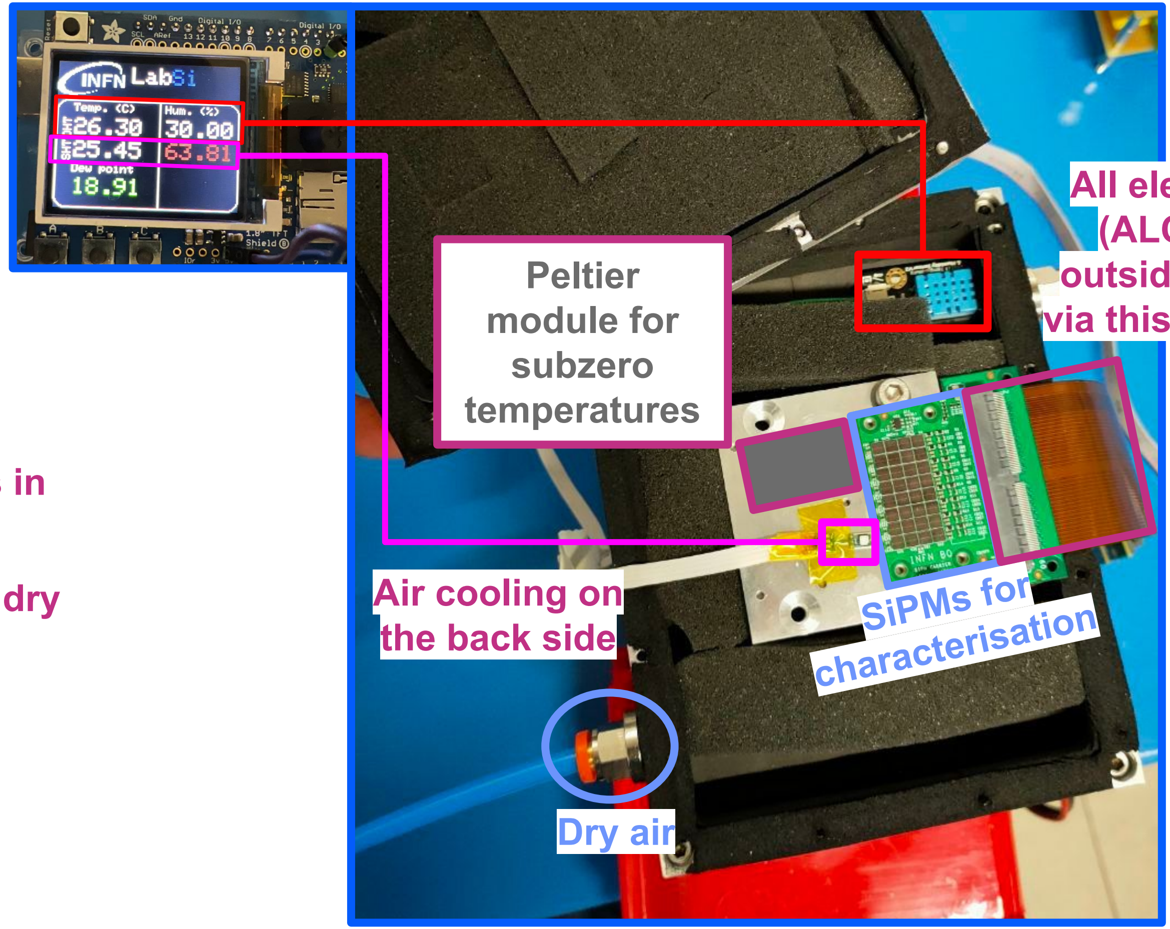
Peltier cooling for subzero temperatures

Air cooled

Outside electronics (HOT) as in the experiment

Used for portable (providing dry air) sensors or electronics characterisation

Later in the lab...



Thank you!