

# SIPM irradiation and annealing

dRICH Meeting 19/12/2022  
Luigi Rignanese rignanes@bo.infn.it



# Full 2022 irradiation / characterization calendar: 4 irradiation cycles

	May			Jun			Jul			Aug			Sep			Oct			Nov			Dec			Jan			
	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	
1	Sun																											
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3																												
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7	Sat																											
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28	Sat																											
29	Sun																											
30																												
31																												

# Full 2022 irradiation / characterization calendar: 4 irradiation cycles

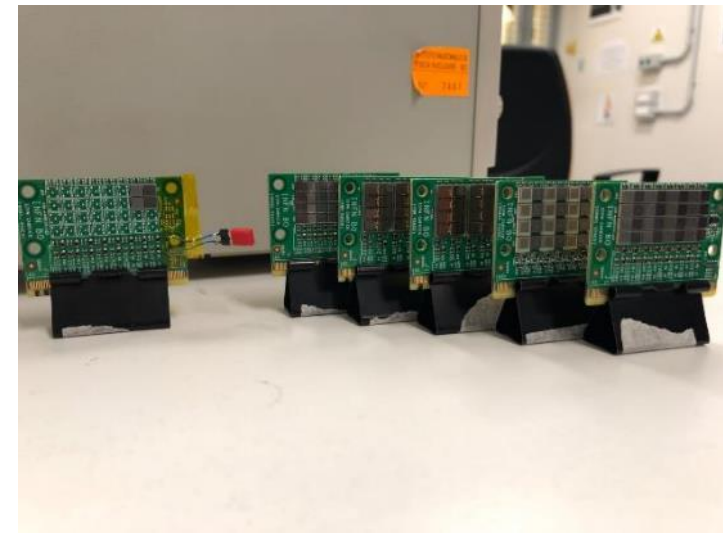
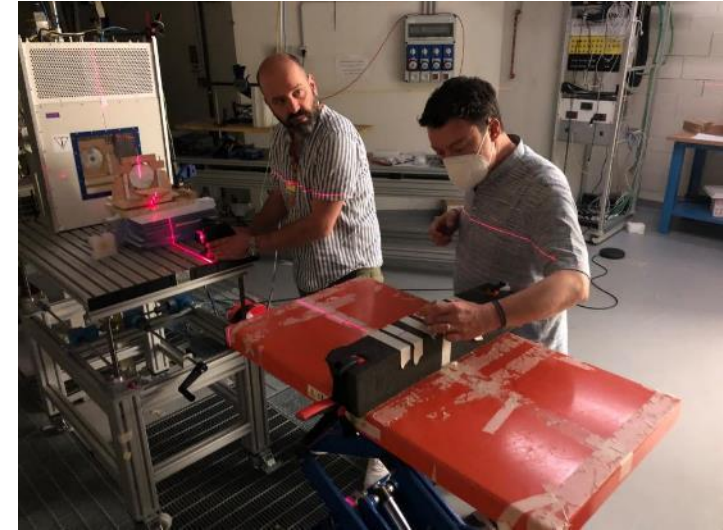
	May			Jun			Jul			Aug			Sep			Oct			Nov			Dec			Jan		
	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE
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28	Sat							LED																			
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**5/11 3rd irradiation**  
cycle **completed**

	Nov			Dec			Jan		
	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE
1							Sun		ANN
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3									ANN
4									ANN
5	Sat		TIFPA				Holy		
6	Sun						Sat		
7							Sun		
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9									
10									IV
11									IV
12	Sat								IV
13	Sun						Sat		
14							Sun		
15		IV							
16		IV							
17		IV							
18			ANN				Sat		
19			ANN				Sun		
20	Sat		ANN						
21	Sun		ANN						
22			ANN				Sat		
23			ANN				Sun		
24			ANN						
25		IV					Sat		
26		IV					Sun		
27	Sat						Holy		
28	Sun								IV
29									IV
30									IV
31		PC1					Sat		ANN

**4/12 4th irradiation** cycle  
**completed**

**Last** cycle of **2022**.  
**HPGe (TIFPA)** detector  
was not working thus  
they **can't release** the  
boards.  
**2 weeks delay**

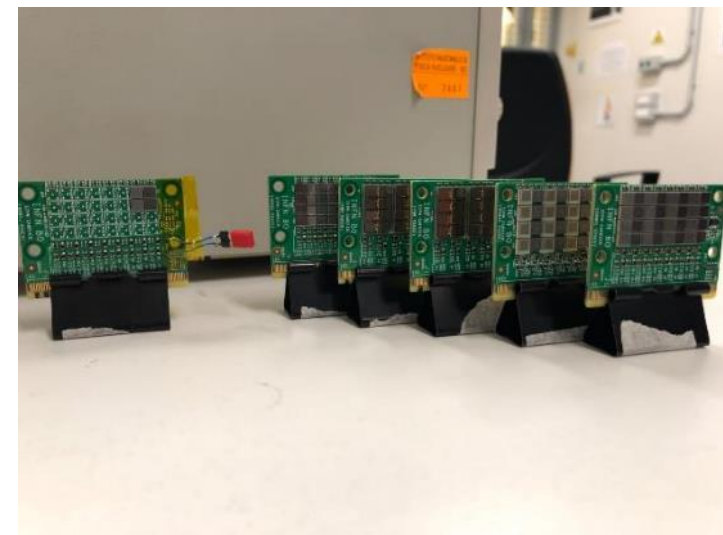
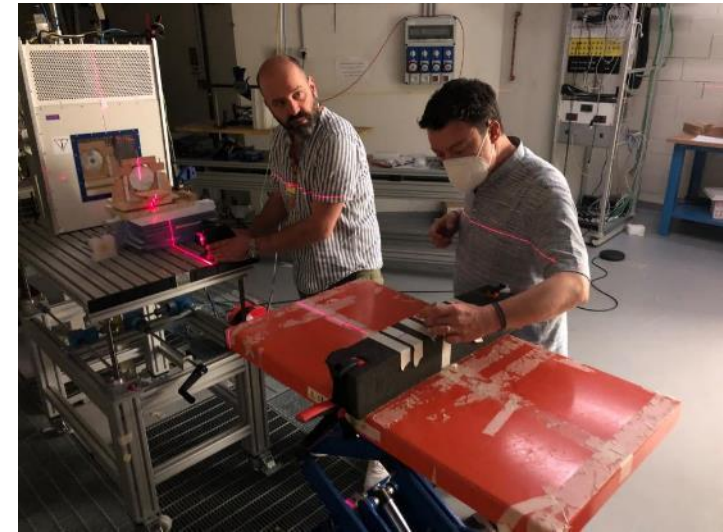


**5/11 3rd irradiation**  
cycle **completed**

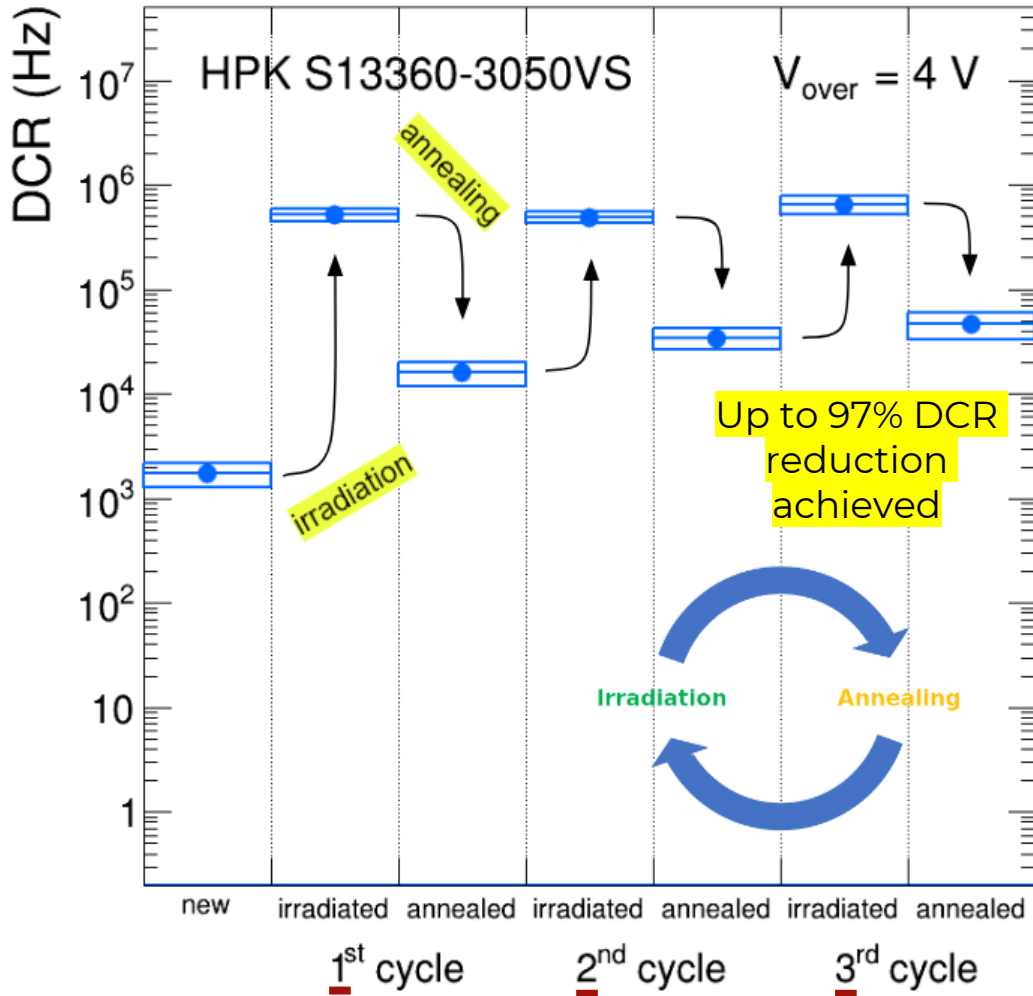
	Nov			Dec			Jan		
	Holy	BO	FE	Holy	BO	FE	Holy	BO	FE
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**4/12 4th irradiation** cycle  
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# Repeated irradiation-annealing cycles



## Main goal of 2022 irradiation campaign

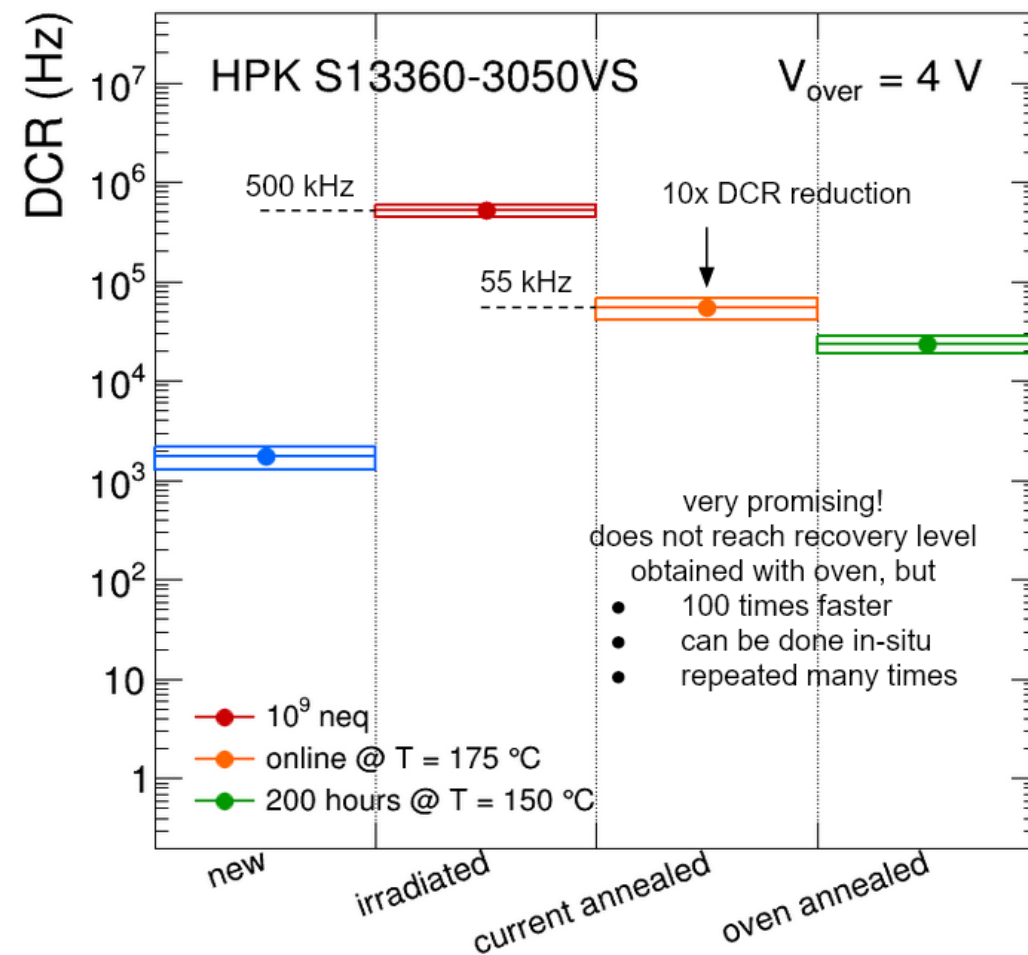
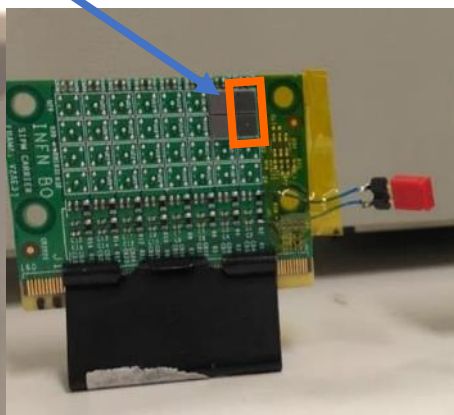
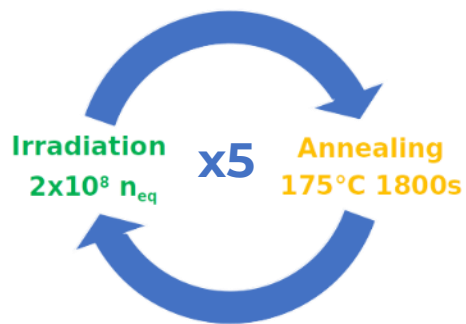
### Test reproducibility of repeated irradiation-annealing cycles

simulate a realistic experimental situation

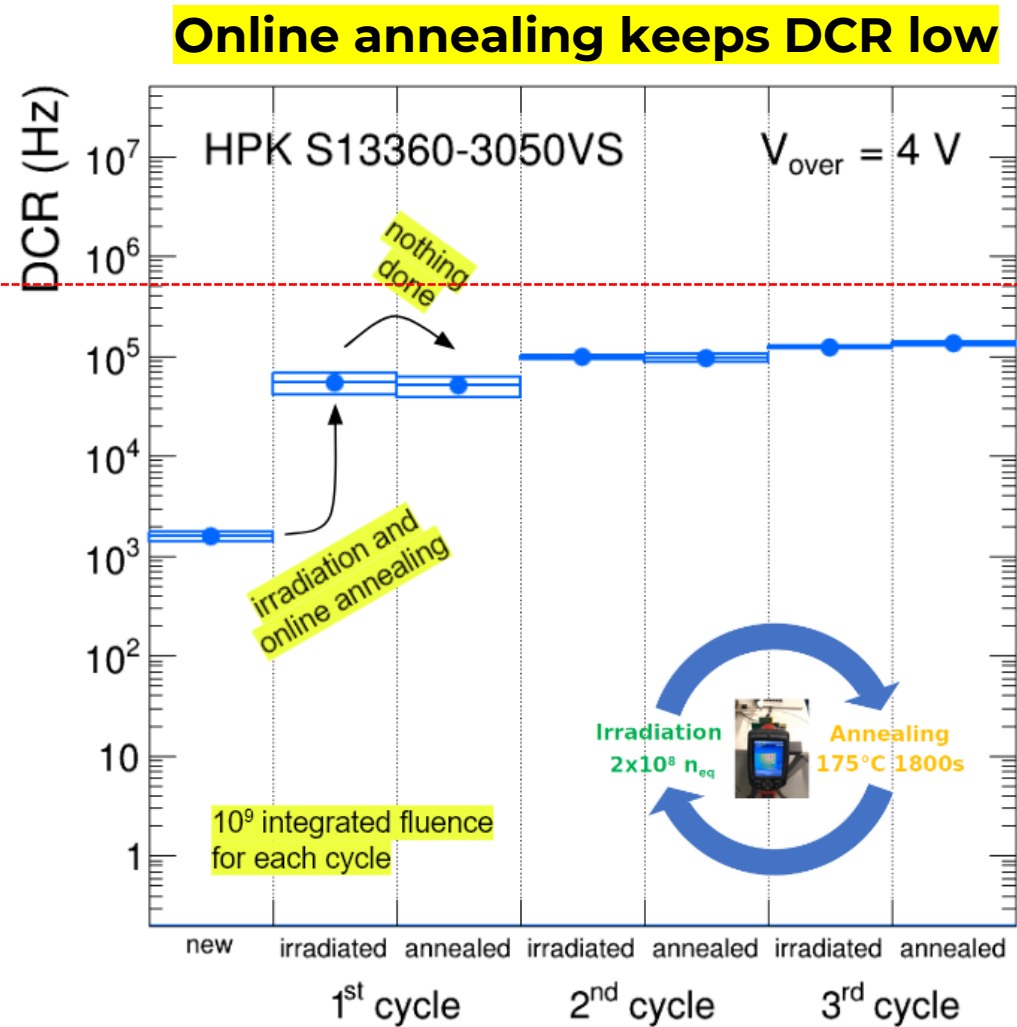
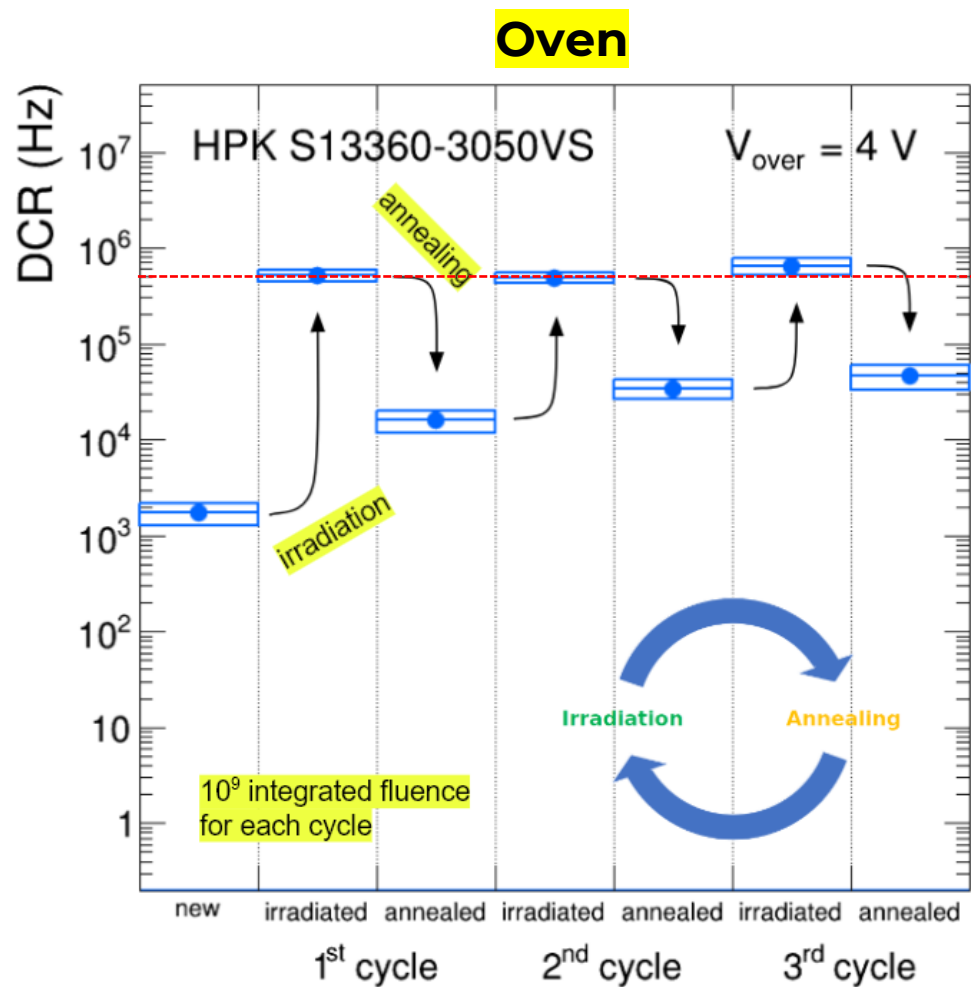
- campaign is almost concluded
  - last (4th) irradiation cycle done on 3/12
  - partial results reported here
- 3 cycles analyzed so far
  - irradiation fluence/cycle of  $10^9 n_{eq}$
  - annealing in oven for 150 hours at 150 °C
- interleaved with full characterization
  - new
  - after each irradiation
  - after each annealing

# Online annealing **explorative study during irradiation campaign**

Direct current annealing

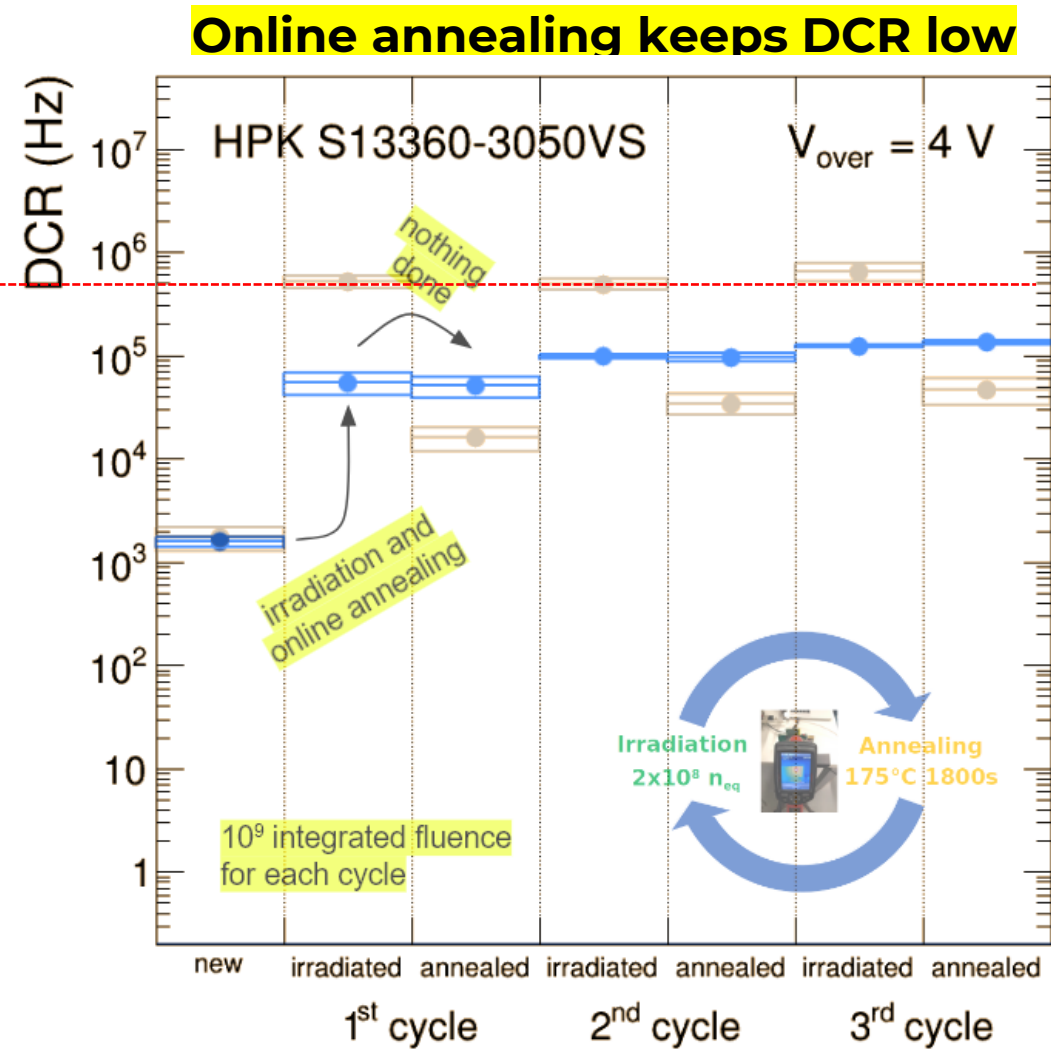
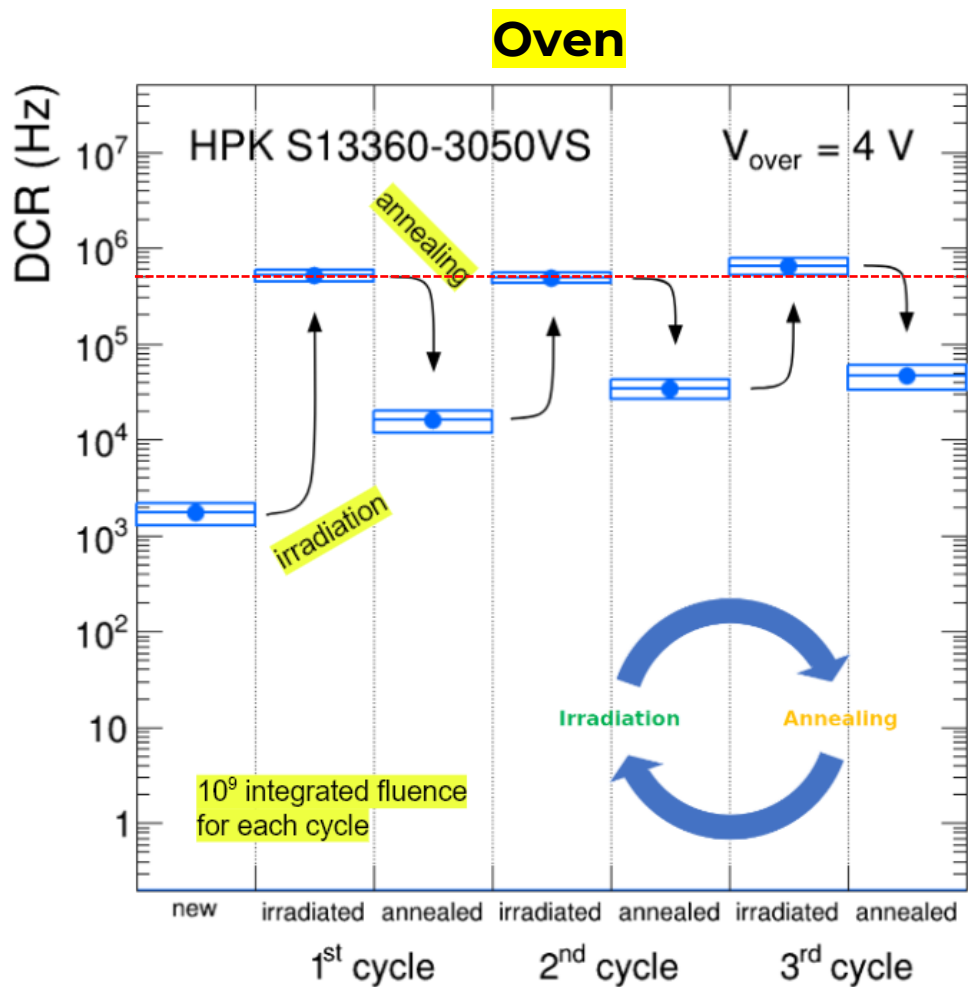


# Repeated online irradiation-annealing cycles





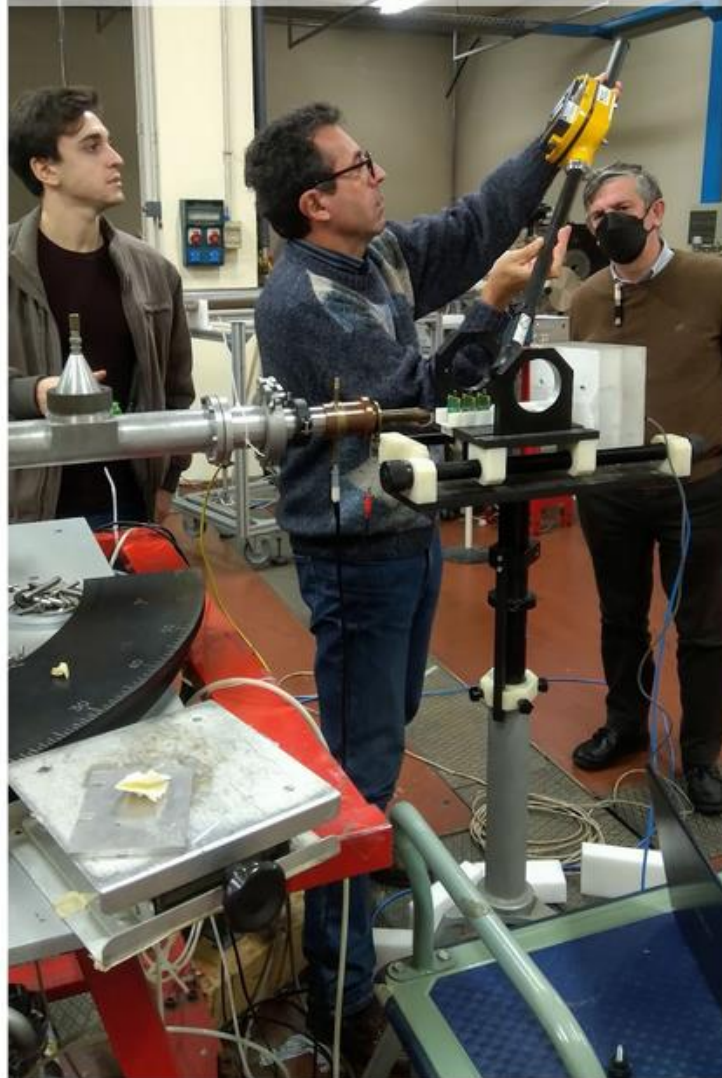
# Repeated online irradiation-annealing cycles



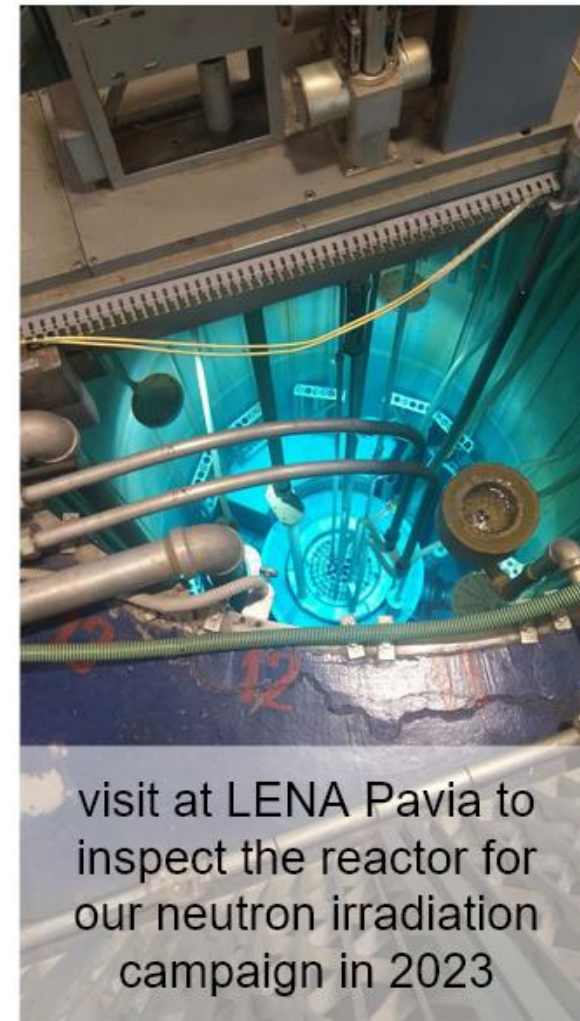
several Peltier modules have been irradiated up to  $10^{11}$  neq in collaboration with INFN-GE (LHCb)



visit at Legnaro to inspect a neutron irradiation campaign at the CN accelerator (Belle 2)

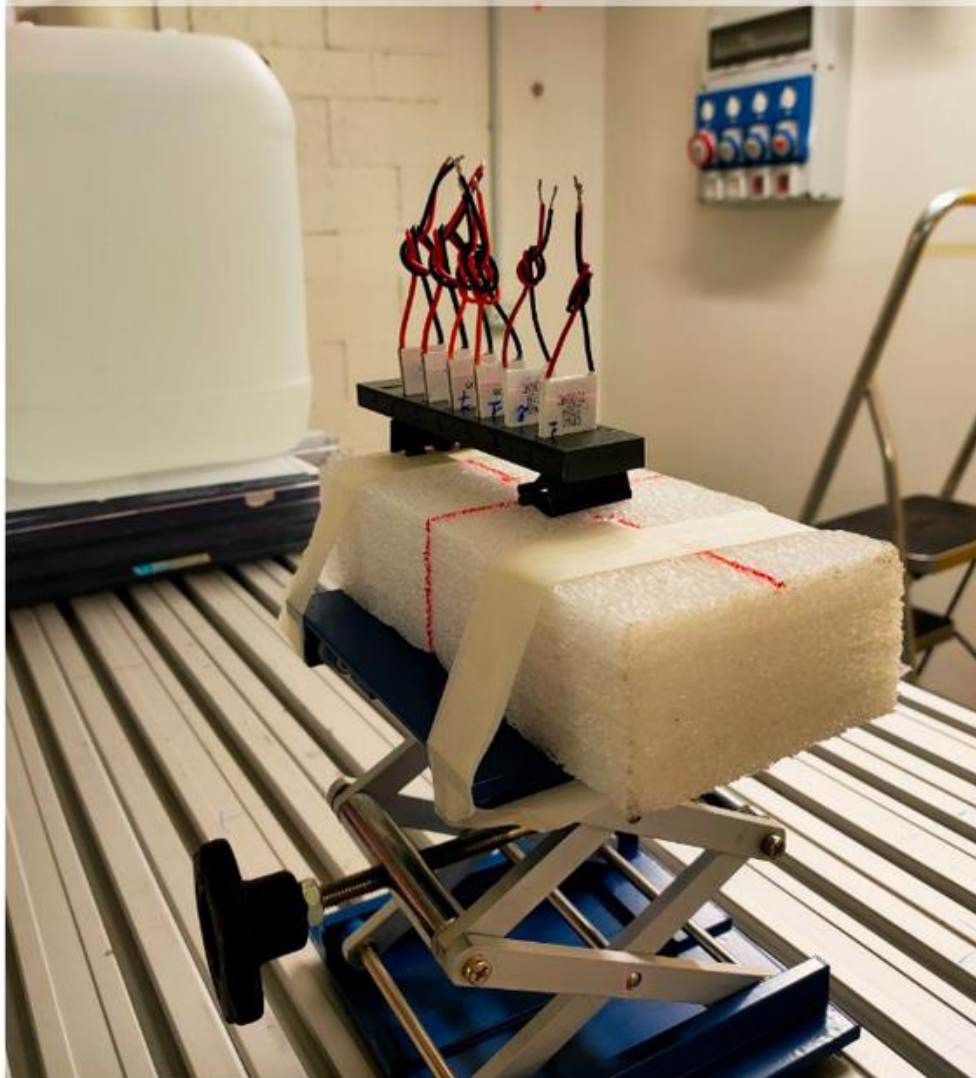


Collaboration with other groups in preparation for 2023



visit at LENA Pavia to inspect the reactor for our neutron irradiation campaign in 2023

several Peltier modules have been irradiated up to  $10^{11}$  neq in collaboration with INFN-GE (LHCb)

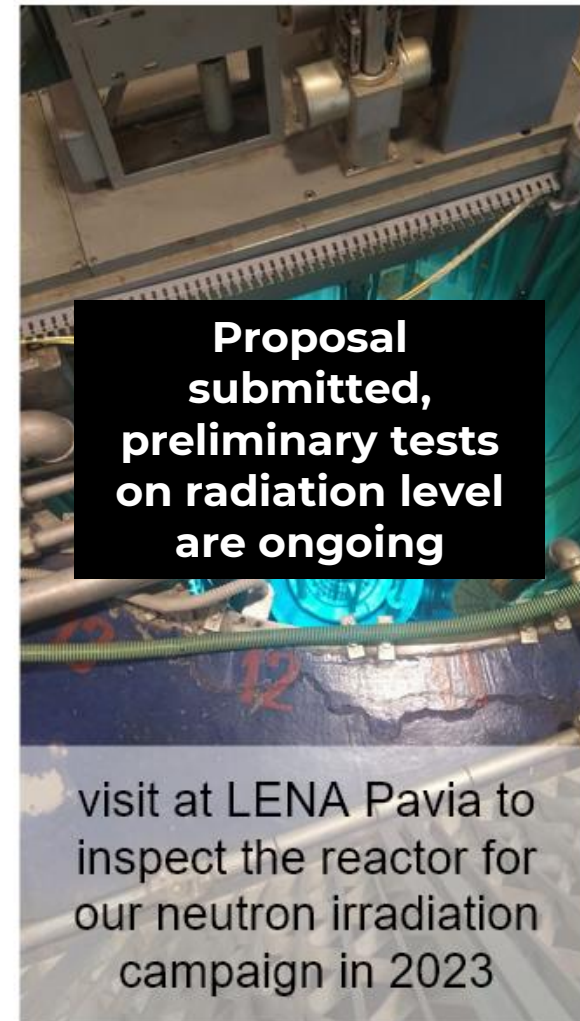


visit at Legnaro to inspect a neutron irradiation campaign at the CN accelerator (Belle 2)



**Proposal submitted and approved for 3 irradiation days in early 2023**

Collaboration with other groups in preparation for 2023

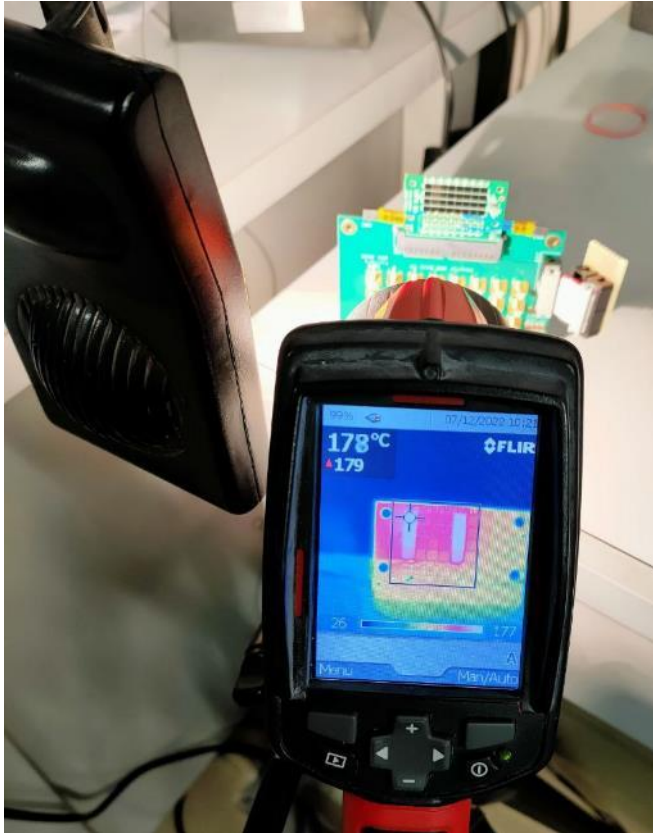


**Proposal submitted, preliminary tests on radiation level are ongoing**

visit at LENA Pavia to inspect the reactor for our neutron irradiation campaign in 2023

## Direct and inverse current annealing

Bachelor student thesis on the difference between **direct** and **inverse** current annealing. We used a **BCOM AFBR** 30 um board irradiated at  $10^9 n_{eq}$  in June.



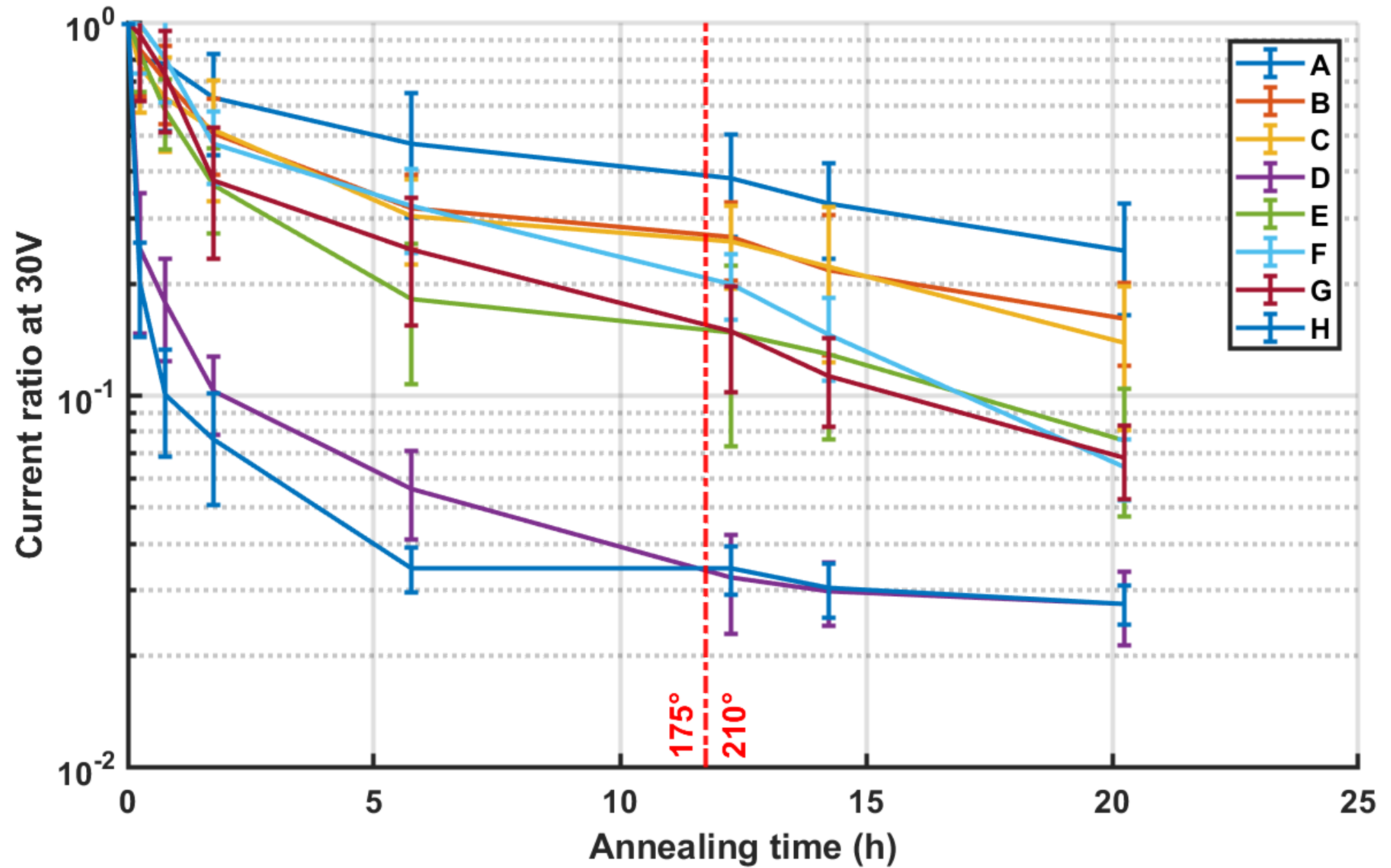
- **4 sensors (H row)** direct current.
- **4 sensors (D row)** inverse current. SiPMs are polarized  $\approx 6$  V above the breakdown voltage in presence of a strong light source
- **9** annealing-characterization cycles (**PC#**) with different annealing durations (15 m to 6 h) and **2** increasing temperatures **175° C** at first and **210° C** at last
- **IV** measured
- The **ration** between the **dark current @30 V after** the procedure and for the **irradiated** sensor used as **figure of merit**
- 5.5 W per row, 4 W when both powered (175° C) and 7 W/5 W (210° C)
- 50-ohm bias filter resistors bypassed

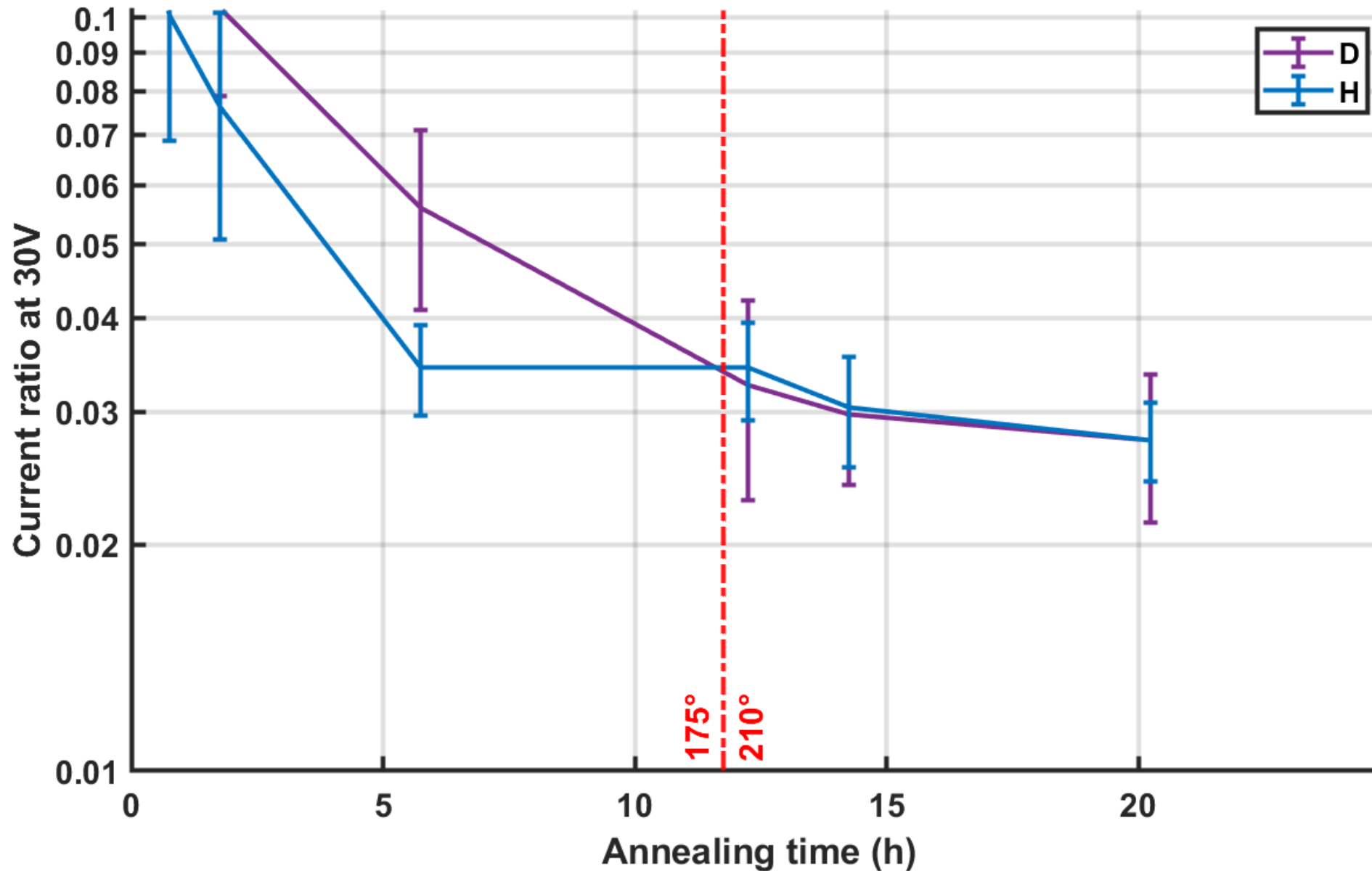
All the **results** are **preliminary** but show some interesting facts.

PCI reference  
(irradiated device)

D inverse current

H direct current



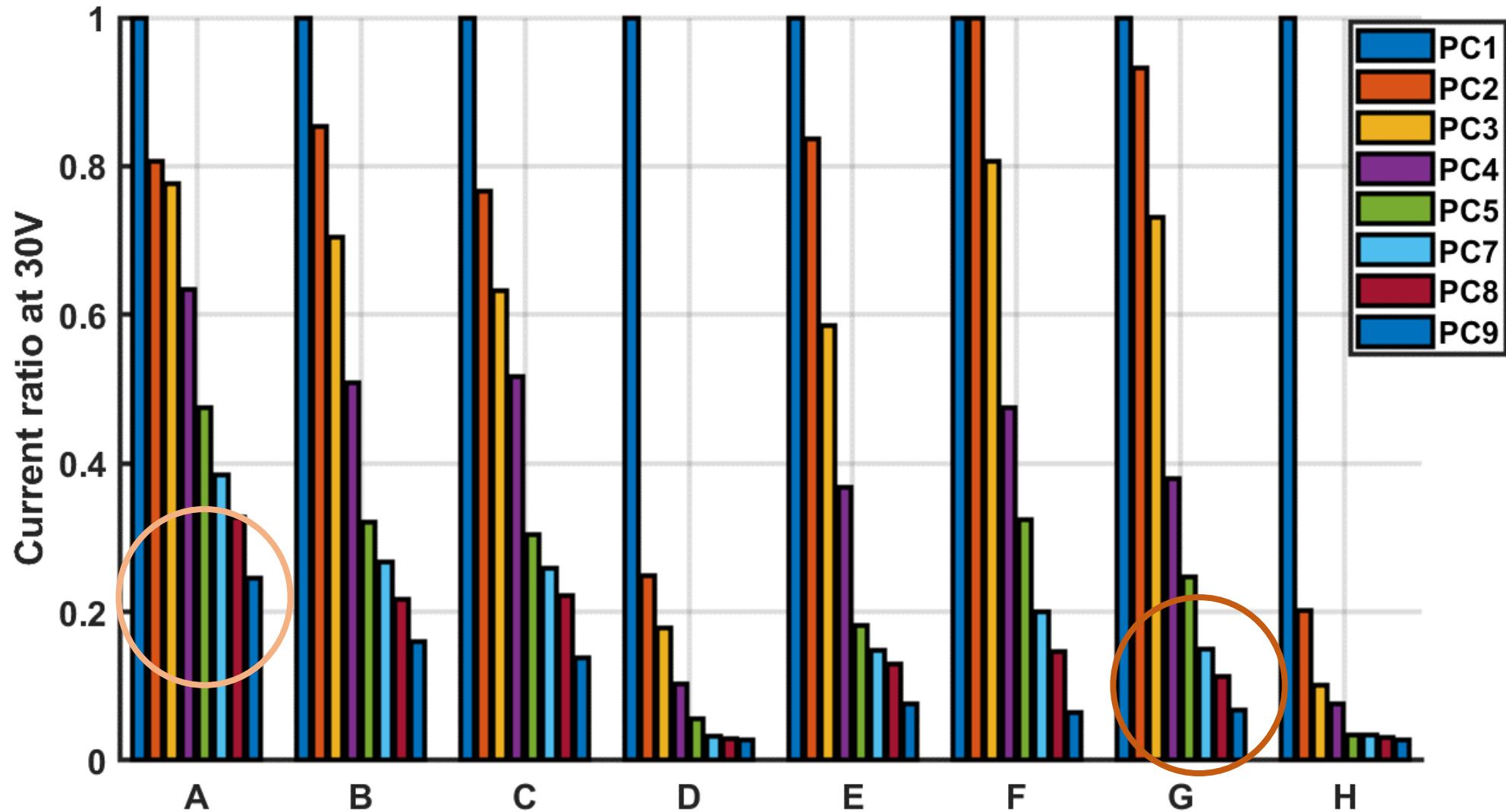


With both methods we reach a **97% reduction** in the dark current after **20 h** of annealing.

**This agrees with the 150° C 150 h oven annealing**

At **175° C**, the **direct current** annealing seems to be **faster** but in the **long run** (and at high temperature) the **two methods** lead to the **same results**

Due to the **heat** dissipated by the annealed sensors, we observed a reduction in the dark current in the neighbors' ones. This is proportional to their **distances** to the **D** and **H** rows



H4 shows a weird behavior after the fifth cycle (still 175° C). An increase in the leakage current could be due to some failure in the soldering of the SiPM or close components.

**The results plot are made excluding H4 after PC5**

