EIC_NET
National Meeting
2022-03-28

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Highlight: R&D on SiPM
Annealing and characterisation

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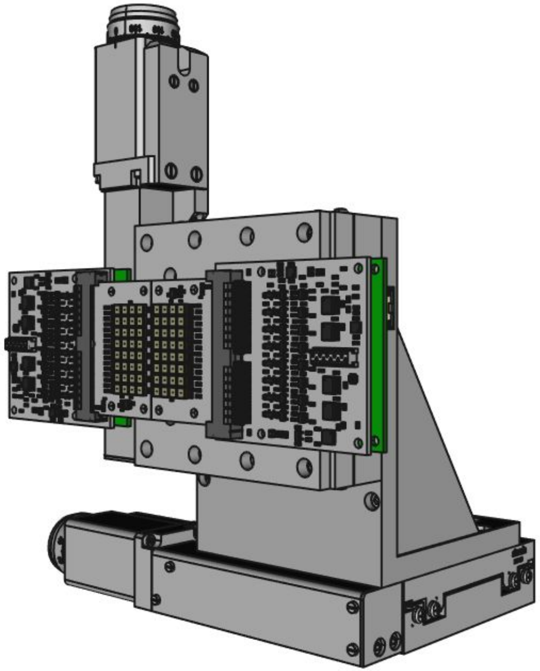
Measuring SiPMs response

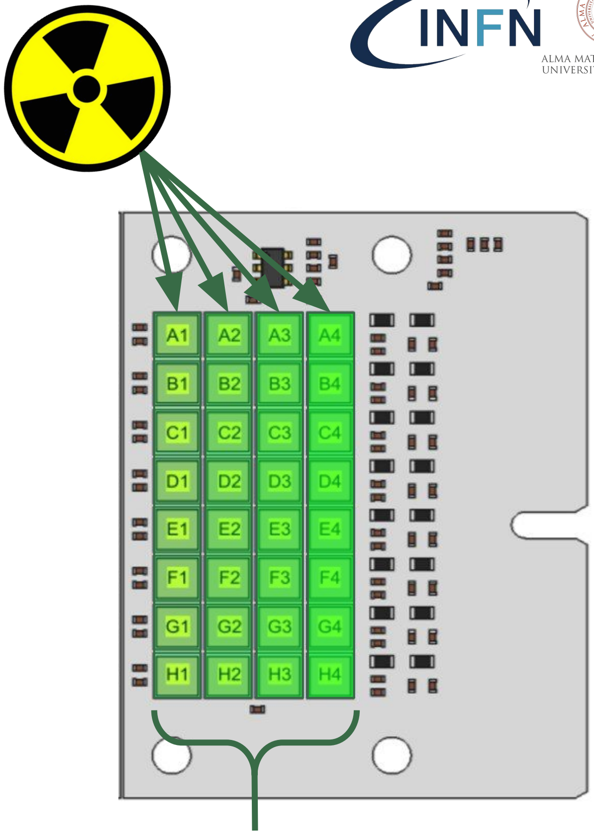
1. Characterise the sensors as brand new devices to have a baseline reference



Measuring SiPMs response

1. Characterise the sensors as brand new devices to have a baseline reference

2. Mimic expected radiation in the experiment to test the sensor response after a given dose



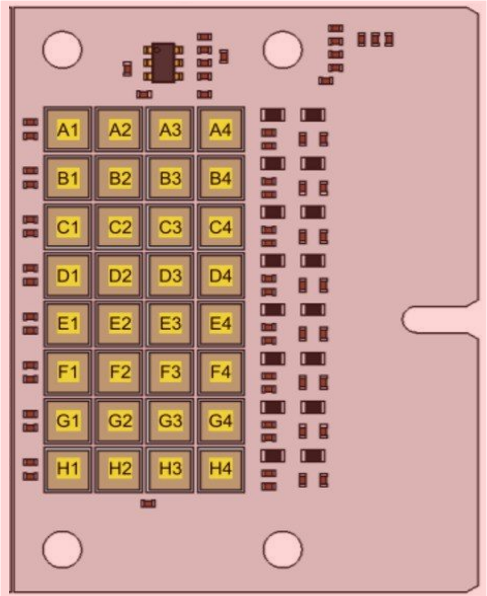
Different levels of dose administered

Measuring SiPMs response

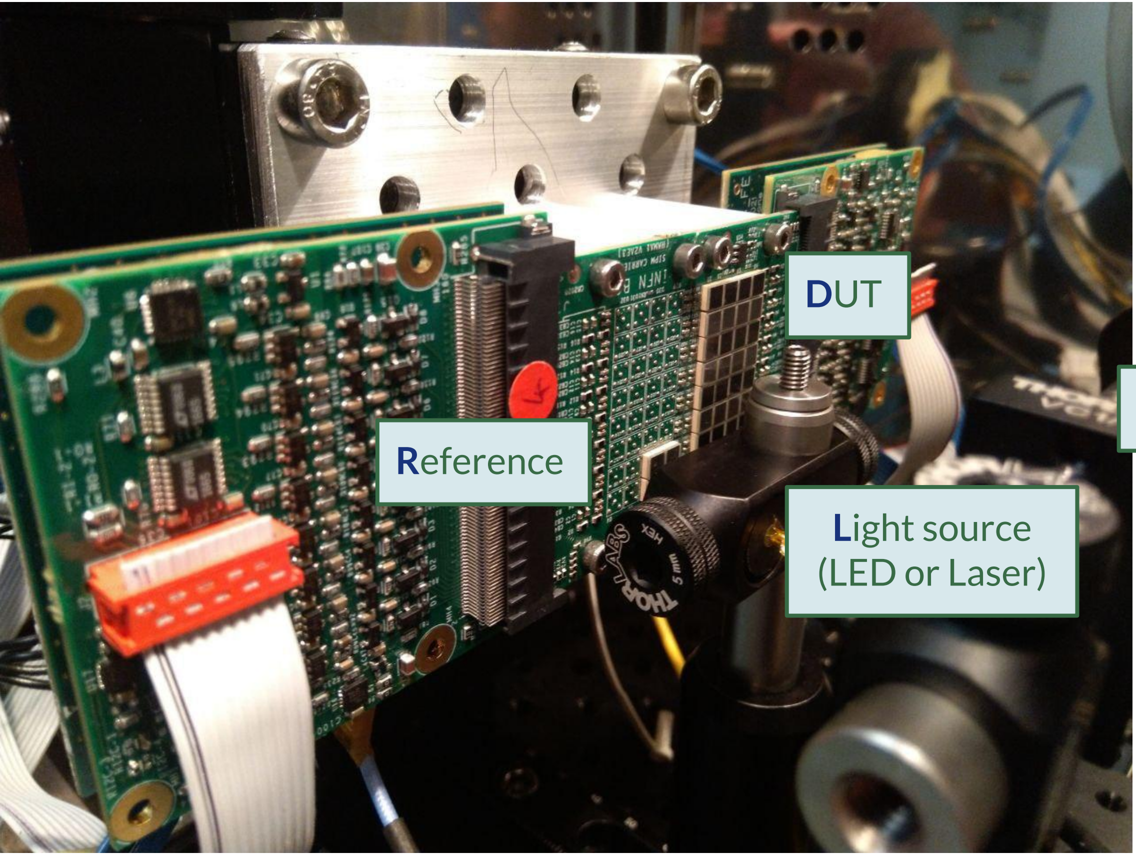
1. Characterise the sensors as brand new devices to have a baseline reference

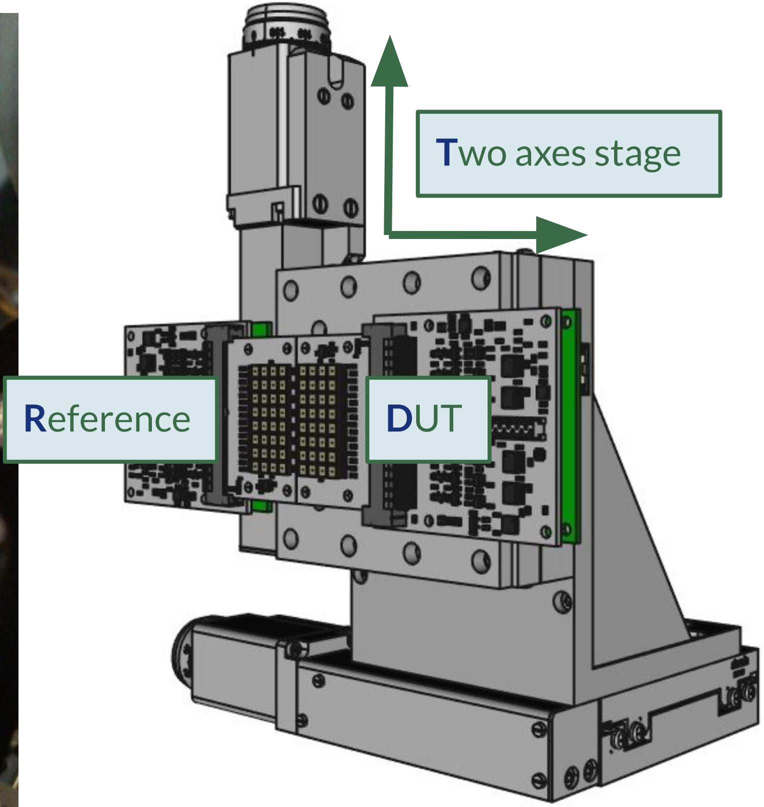
2. Mimic expected radiation in the experiment to test the sensor response after a given dose

3. Test the annealing recovery capabilities to understand the possible life extension for the sensors

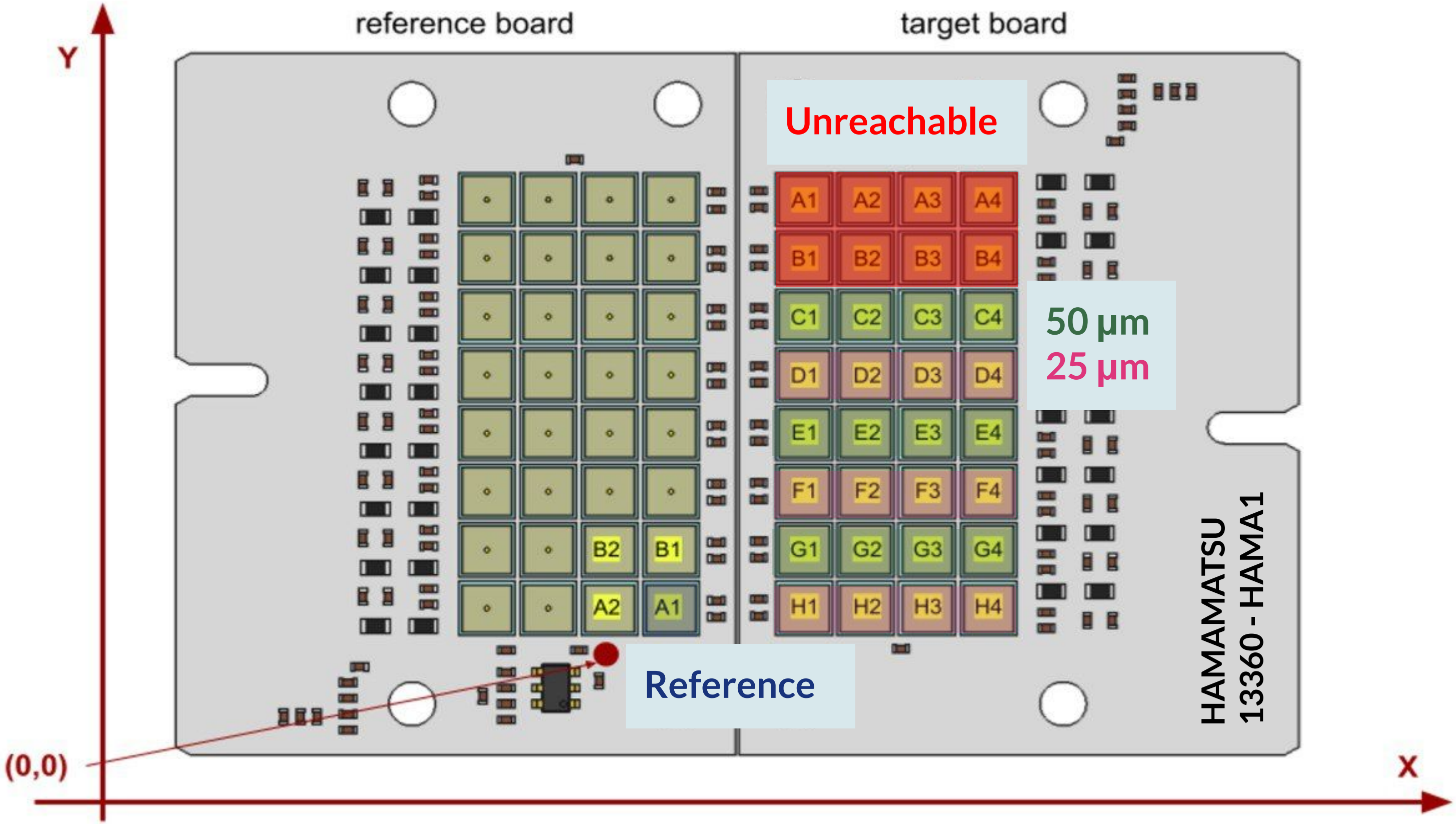


Scan Set-Up


DUT
Reference
Light source
(LED or Laser)

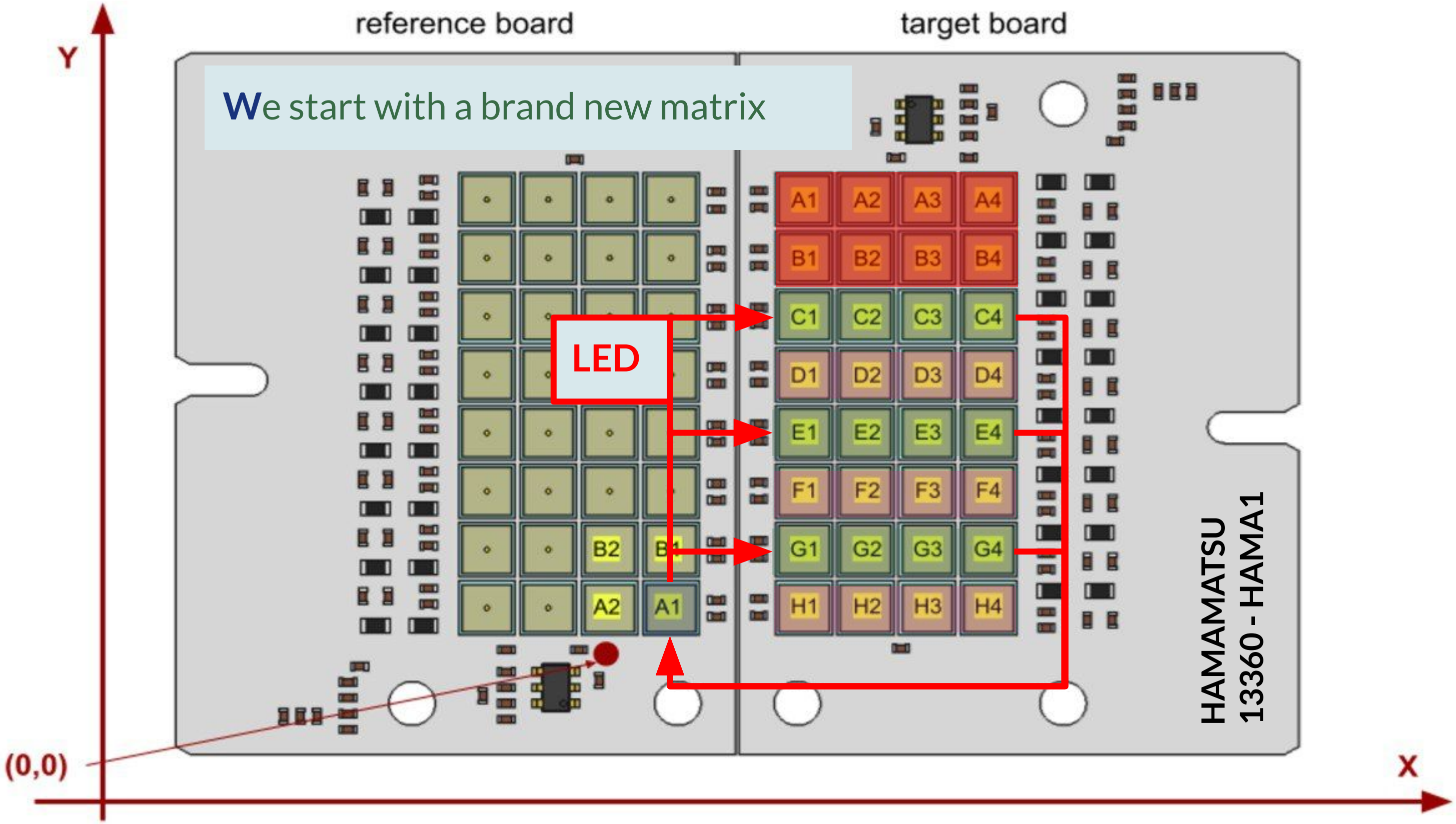

Two axes stage
Reference
DUT

Board coordinates



Board scan procedures

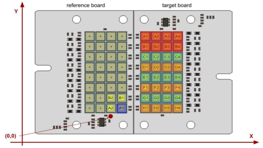
1. Characterise the pulser light on reference A1
2. Scan first row of sensors (C)
3. Return to A1 to check system is still consistent
4. Scan second row of sensors (E)
5. Repeat for all rows

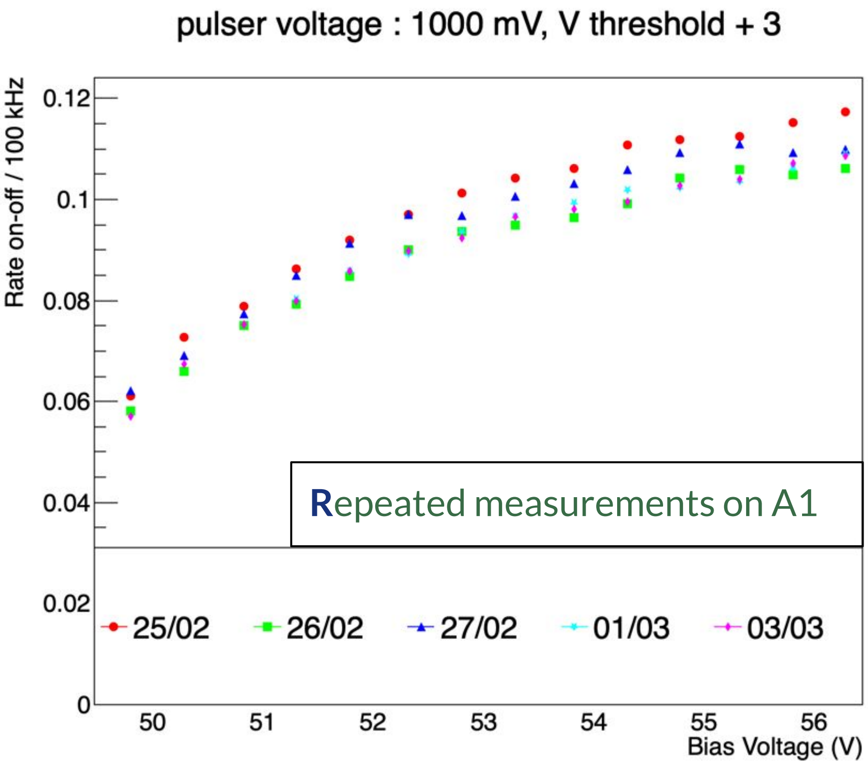


Board scan: check on consistency

HAMAMATSU
13360 - HAMA1
NO IRRAD

-30°C

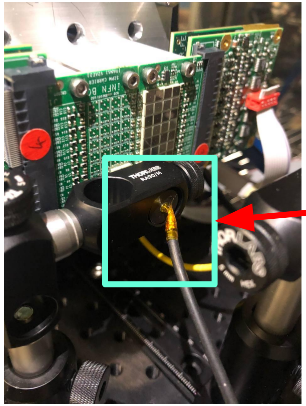




Characterise the pulser light on reference A1

Return to A1 to check system is still consistent

We can evaluate the dispersion of repeated measurements by comparing them with their mean

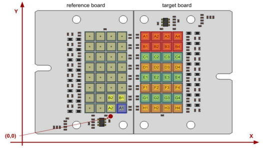


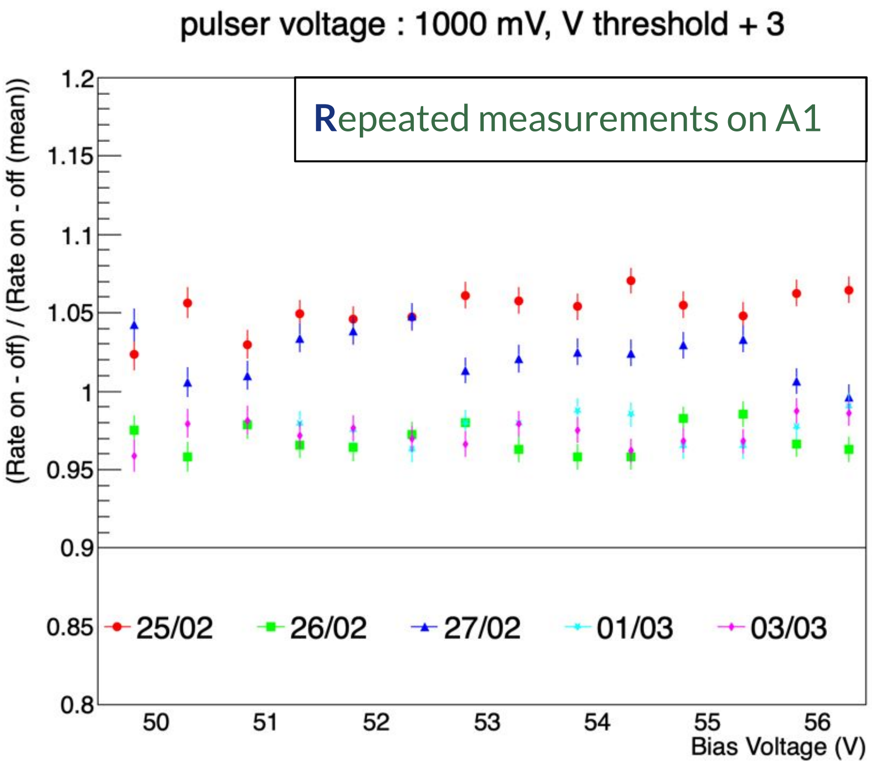
We are currently using the LED as a light source, which is sensitive to Voltage and Temperature changes, so we cross check with the reference sensor to evaluate the repetition stability of the measurement

Board scan: check on consistency

HAMAMATSU
13360 - HAMA1
NO IRRAD

-30°C





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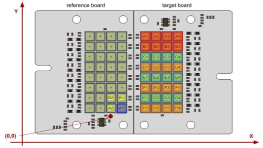

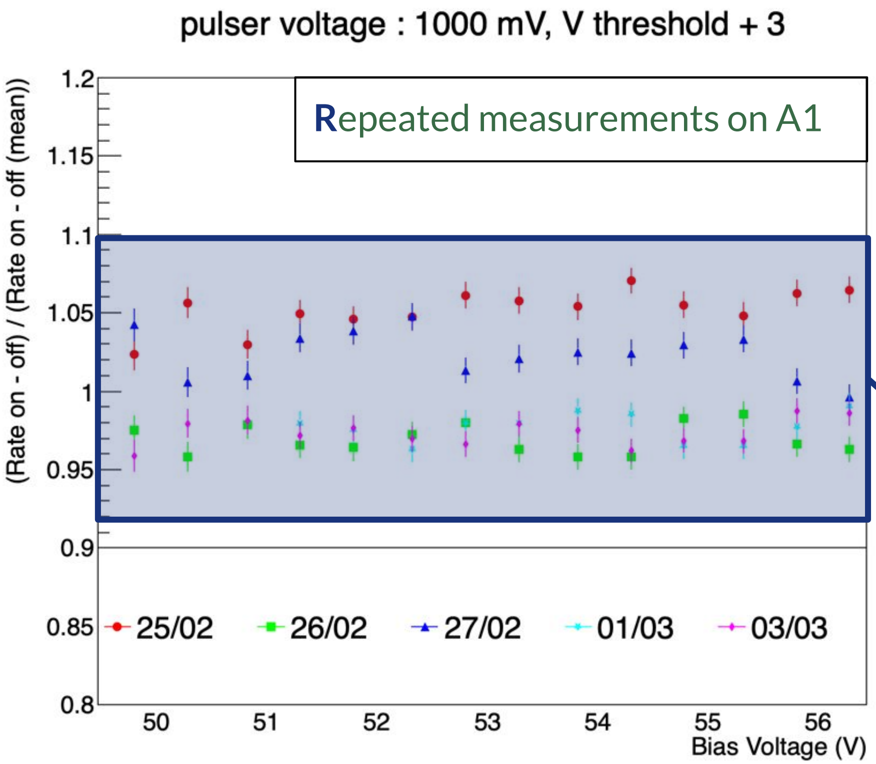

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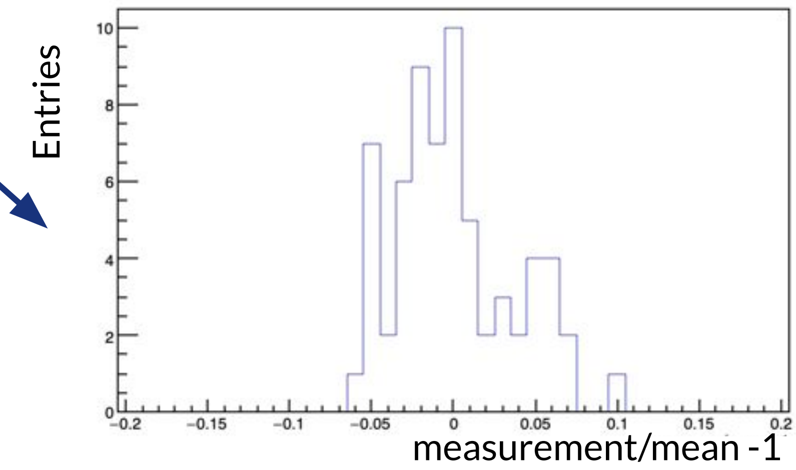

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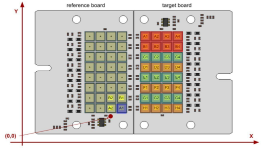

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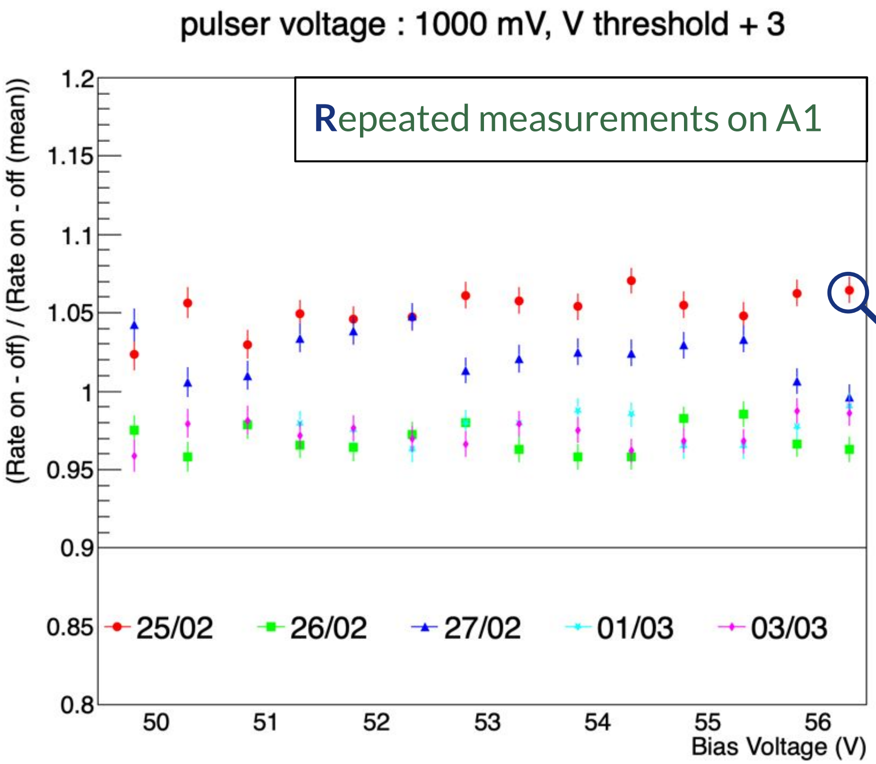

Characterise the pulser light on reference A1

Return to A1 to check system is still consistent

We can evaluate the dispersion of repeated measurements by comparing them with their mean

We evaluate the statistical contribution to the dispersion by averaging the single point statistical errors

Board scan: check on consistency

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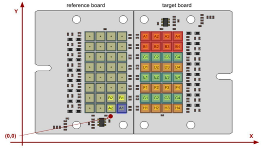
13360 - HAMA1
NO IRRAD

-30°C



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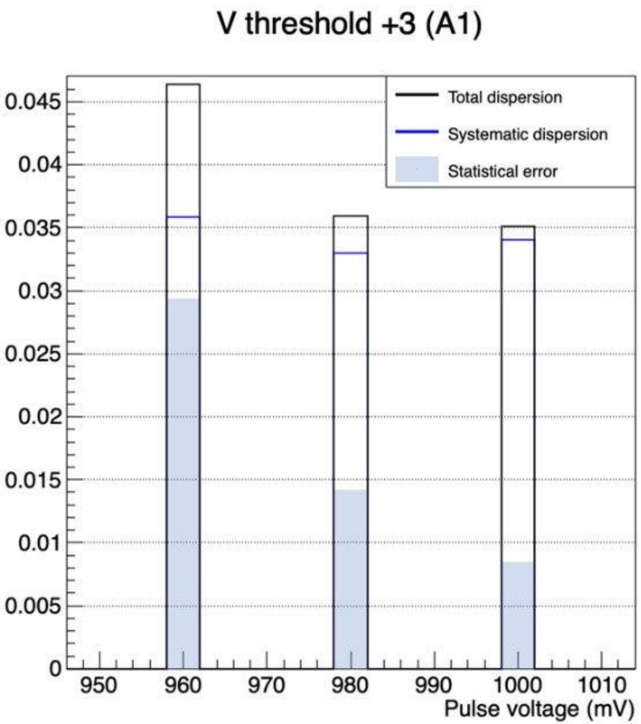

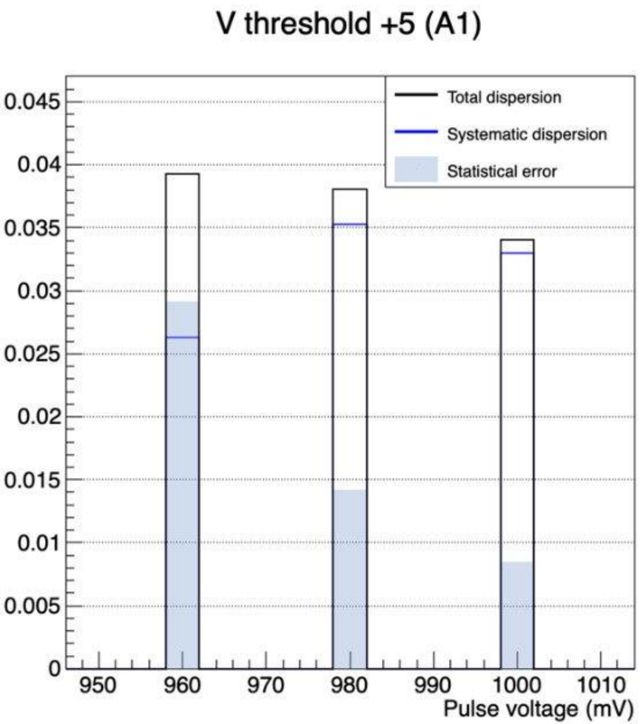

We can now breakdown the dispersion in:

1. Systematic fluctuations due to uncertainty in the measurement reproducibility

2. Statistical contribution due to the measurement uncertainty

Board scan: check on consistency

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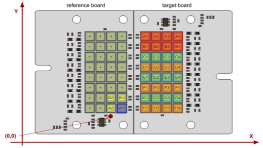

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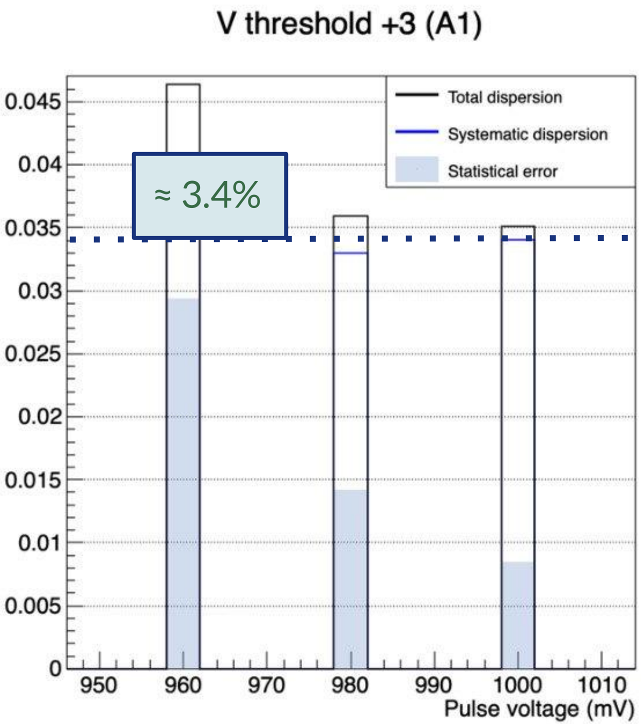

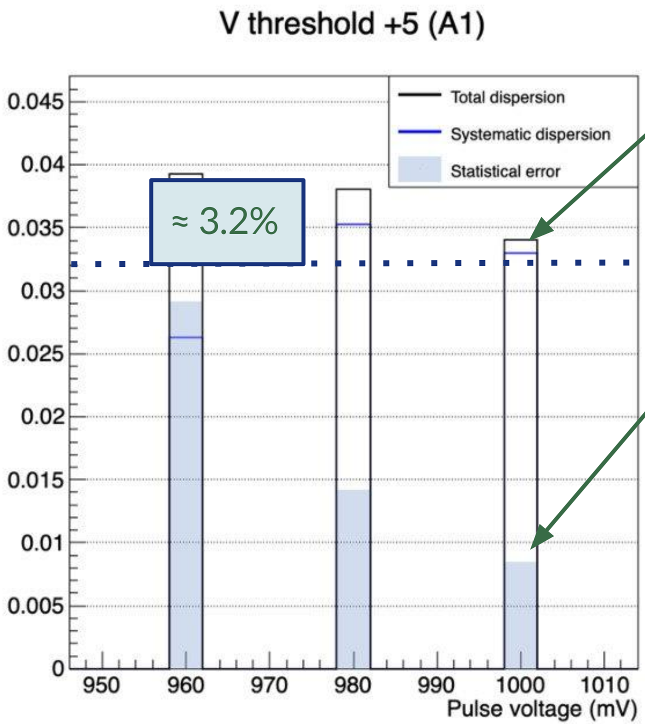

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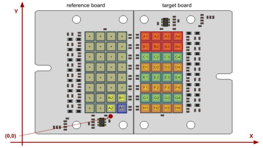
Board scan: sensor homogeneity

HAMAMATSU
13360 - HAMA1
NO IRRAD

-30°C



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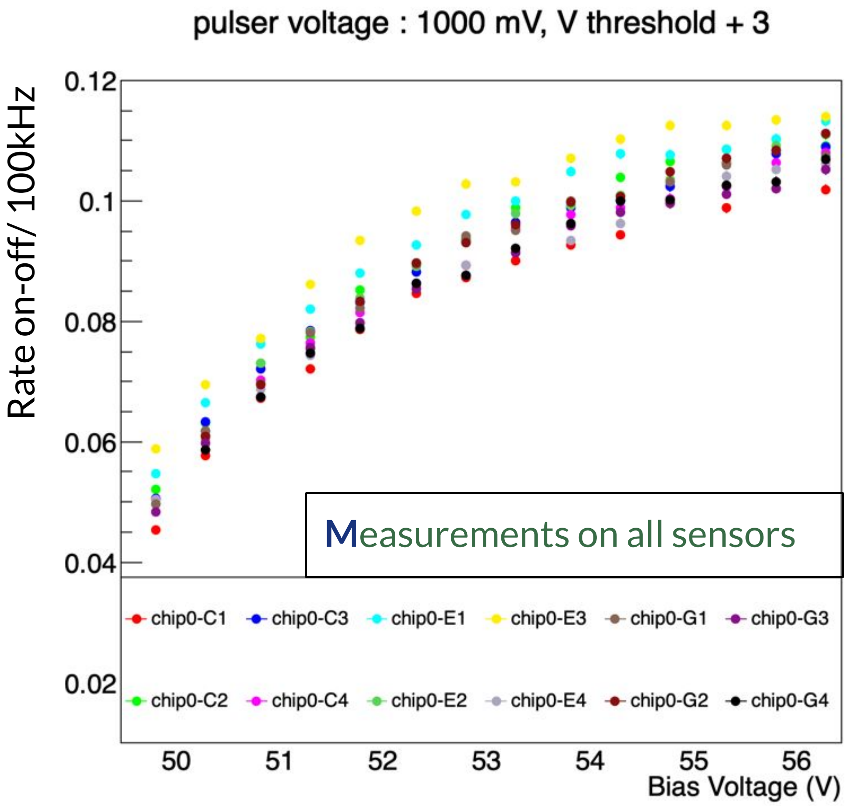


Scan first row of sensors (C)

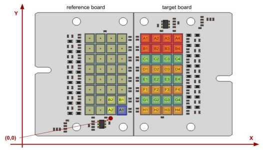
Scan second row of sensors (E) and so on

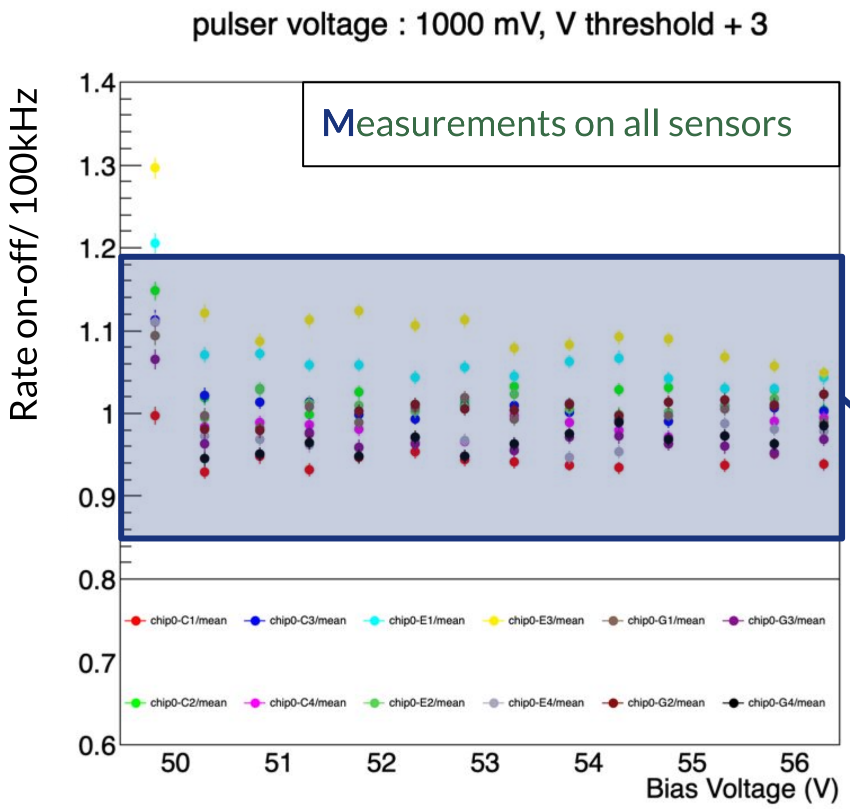
We can evaluate the dispersion for different sensors response by comparing them with their mean

Board scan: sensor homogeneity

HAMAMATSU
13360 - HAMA1
NO IRRAD

-30°C





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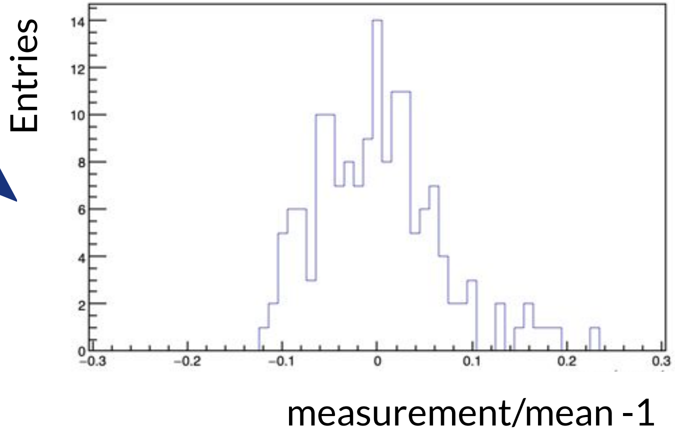
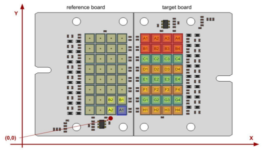
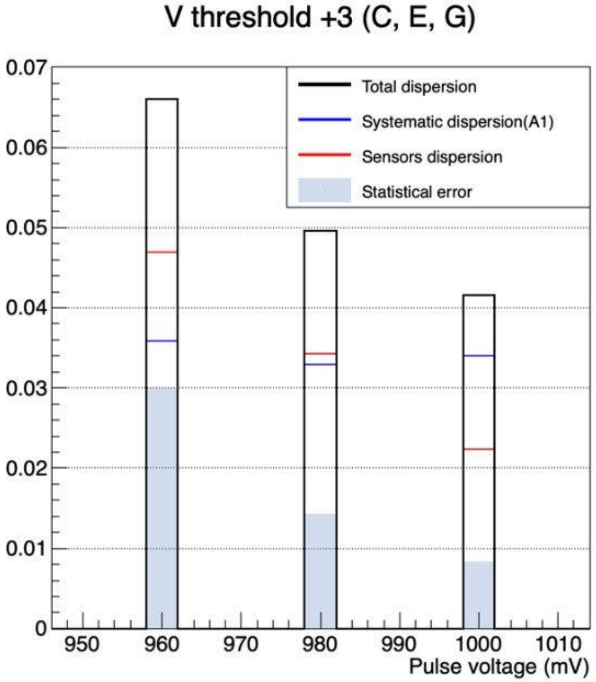
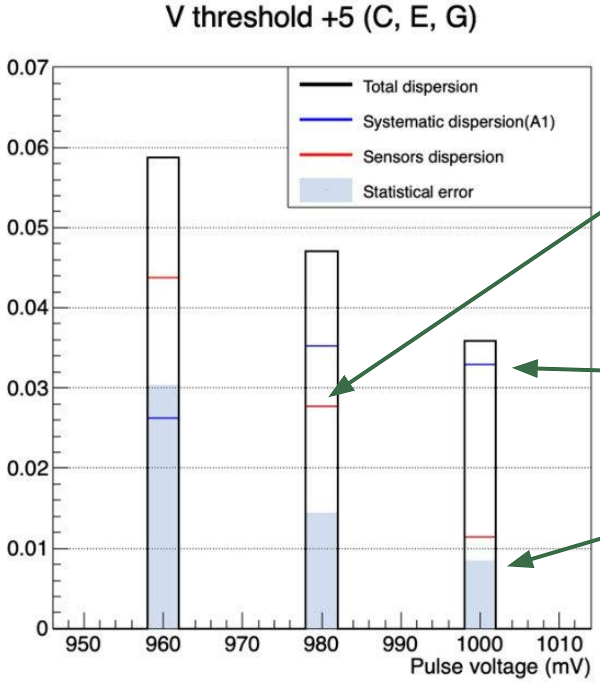


Board scan: sensor homogeneity







We can now breakdown the dispersion in:

1. Systematic contribution from inhomogeneities in sensor-to-sensor behaviour
2. Systematic on reproducibility
3. Statistical

Measuring SiPMs response

1. Characterise the sensors as brand new devices to have a baseline reference ✓

2. Mimic expected radiation in the experiment to test the sensor response after a given dose

Measuring SiPMs response

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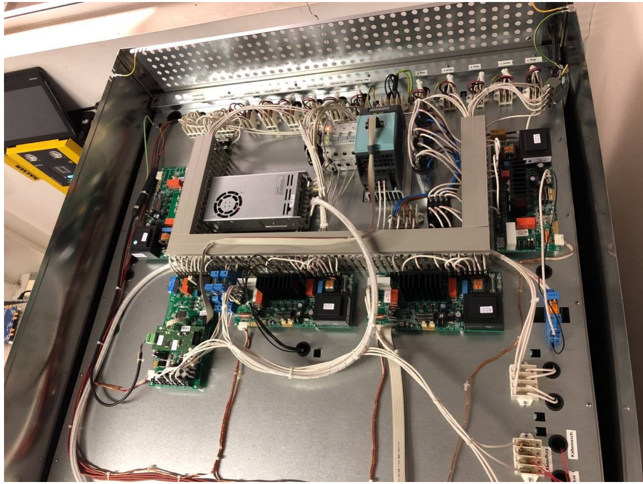

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3. Test the annealing recovery capabilities to understand the possible life extension for the sensors

Can we start working on this?

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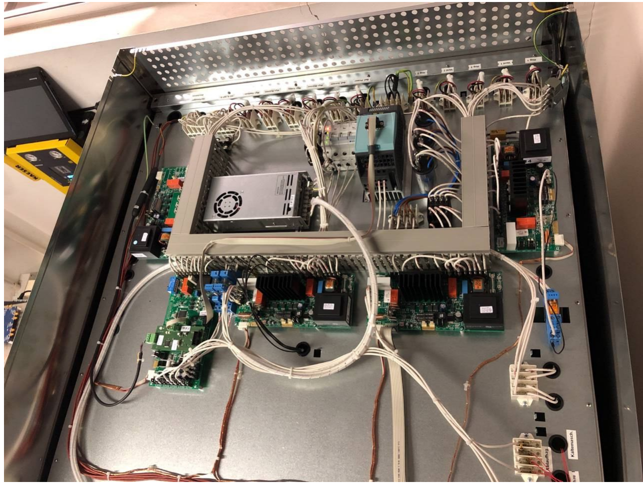
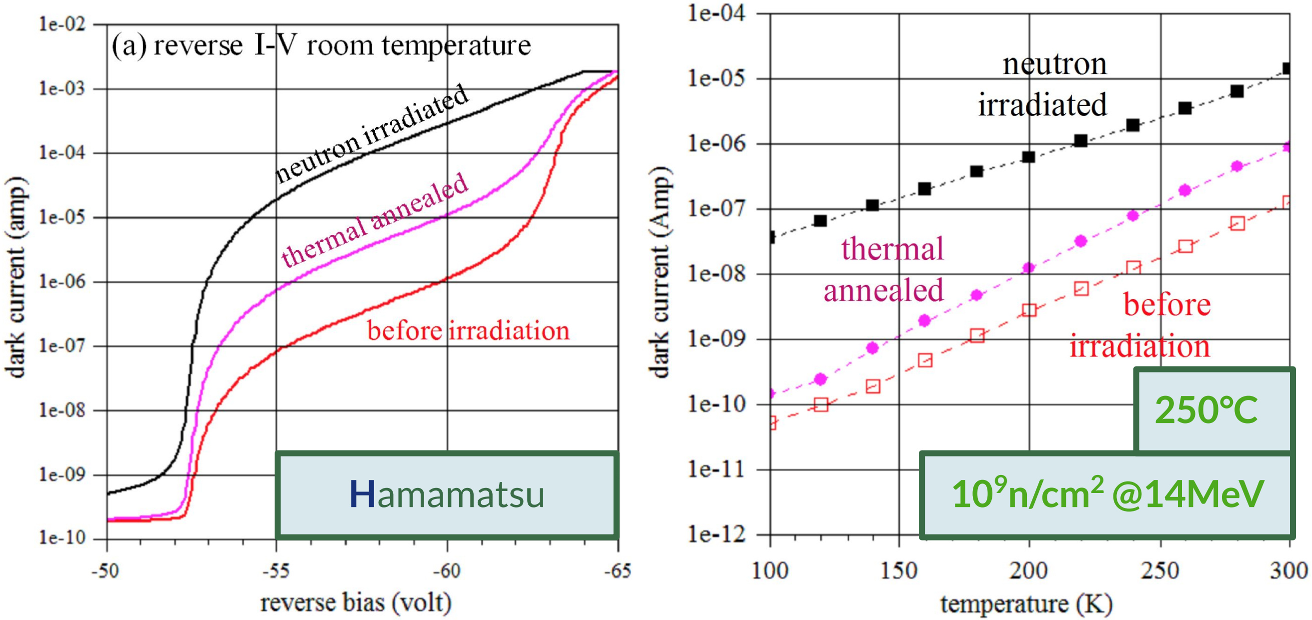


Annealing as a recovery tool for SiPMs

Recent developments in SiPMs suggested that a recovery in performance was possible by the means of annealing the sensors. The recovery was estimated after a radiation damage was induced in the sensors.



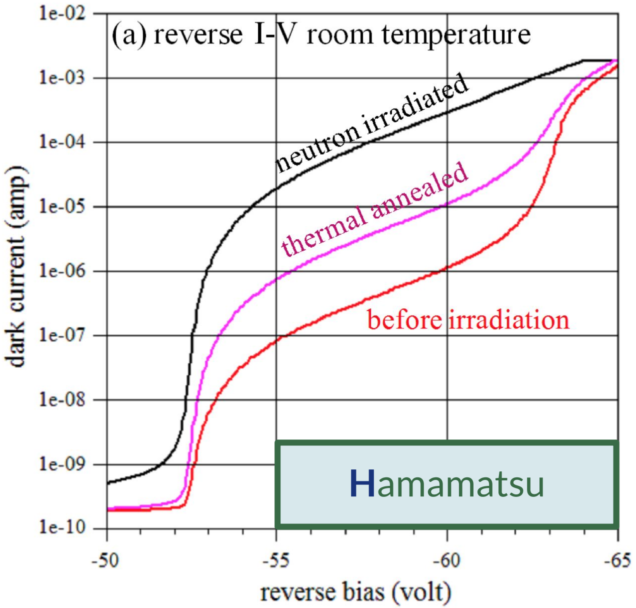
https://iopscience.iop.org/article/10.1088/1748-0221/11/12/P12002/meta

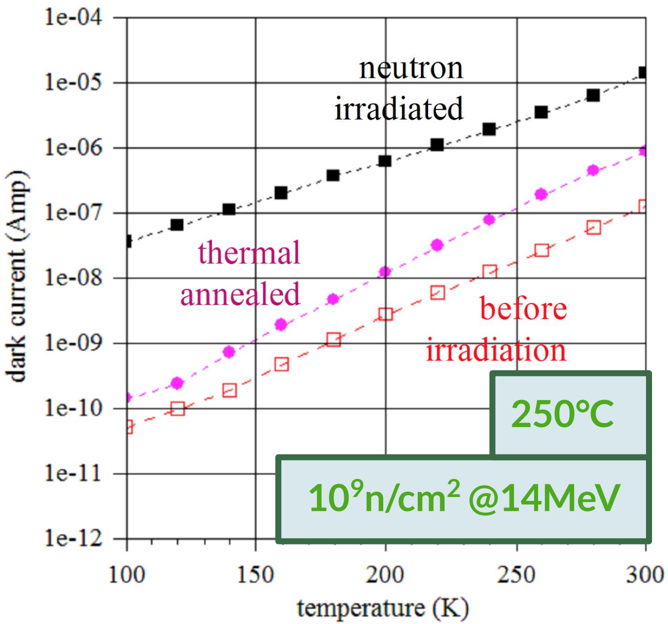
Annealing as a recovery tool for SiPMs

Recent developments in SiPMs suggested that a recovery in performance was possible by the means of annealing the sensors. The recovery was estimated after a radiation damage was induced in the sensors.

Our Lab campaign used the climatic chamber to heat the sensors up to 150°C for up to one week time. This is difficult to reproduce in a detector setting...

Is there another way to this?





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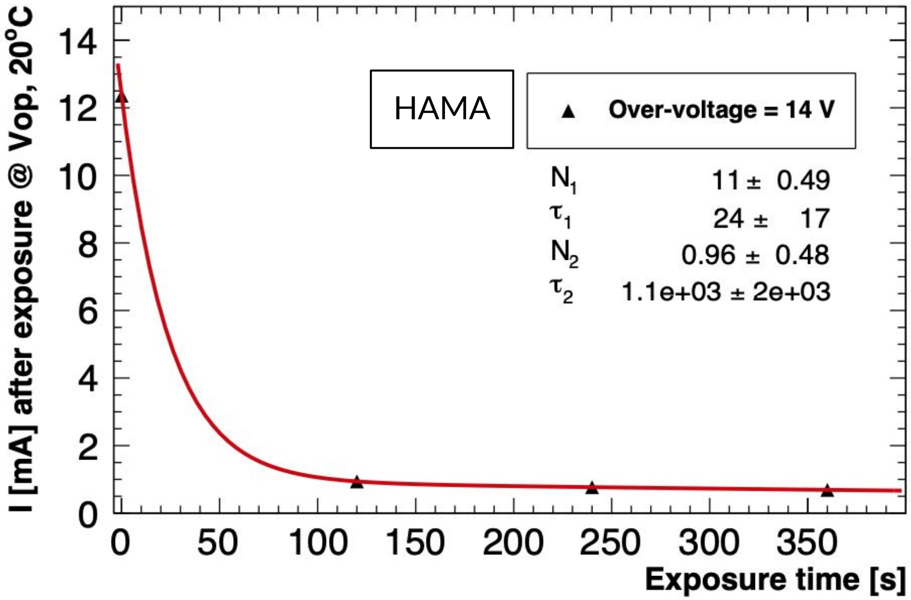
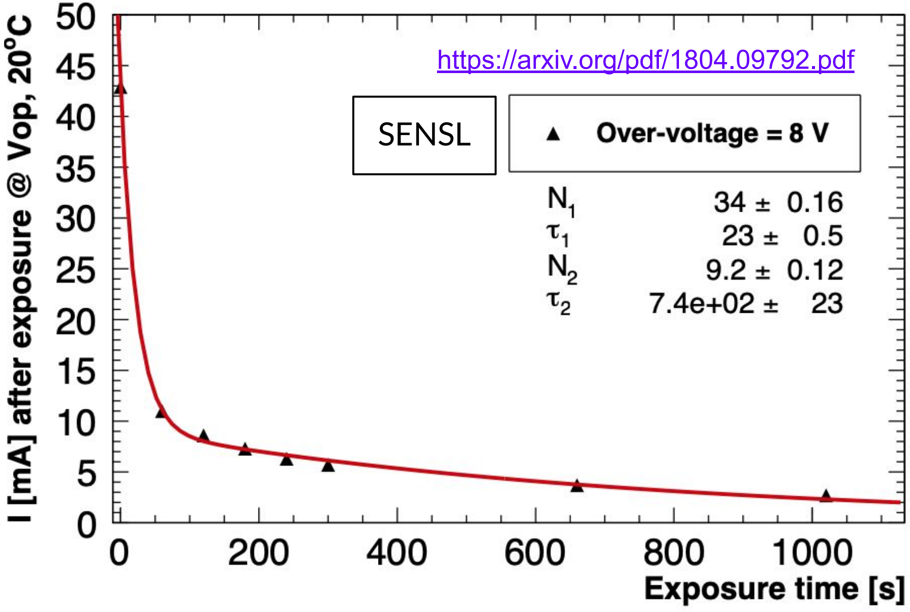
Annealing in-situ for SiPMs: inverse current

$$I_{dark} = N_1 \cdot \exp(-t/\tau_1) + N_2 \cdot \exp(-t/\tau_2)$$

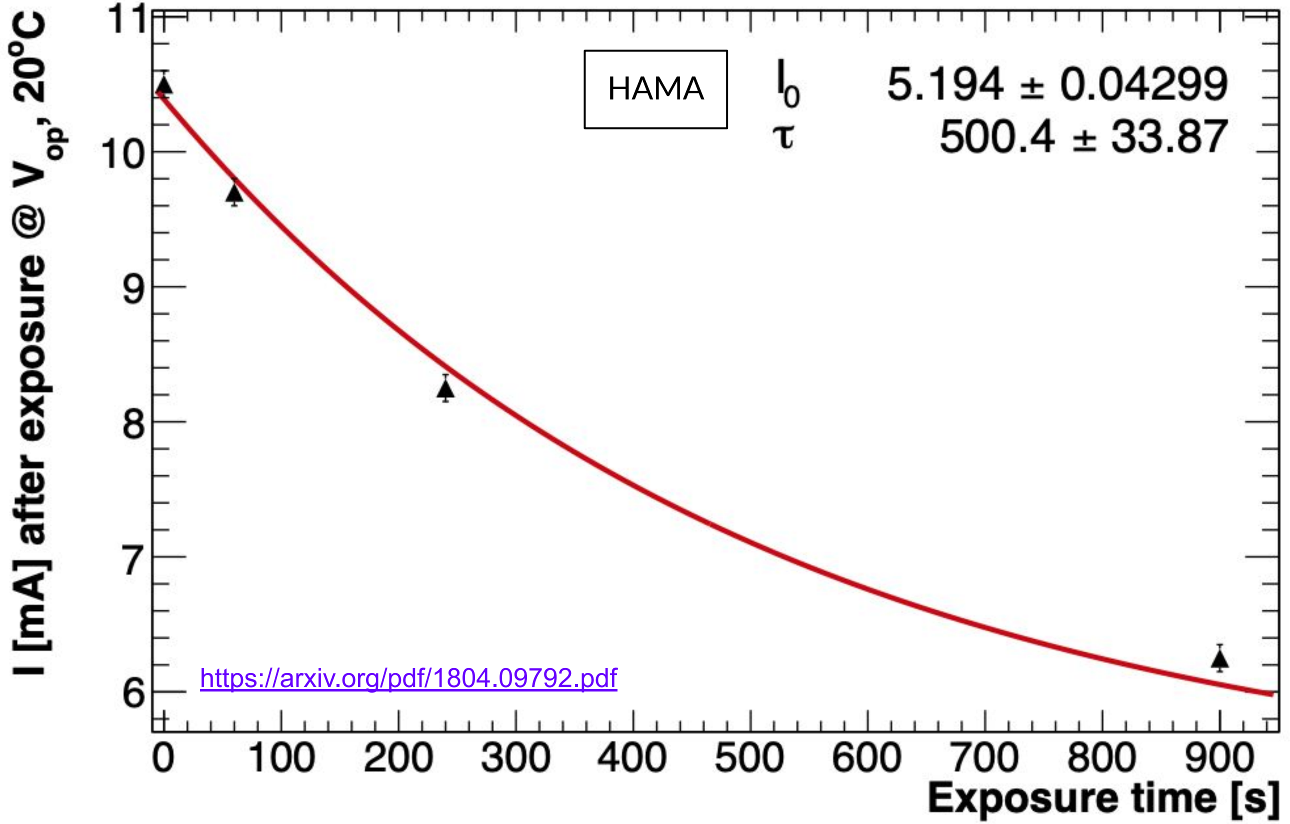




I_{test} the current produced throughout the annealing procedure is about 186 mA that is equivalent of about 12 W for a T of about 150°C

I_{test} the current produced throughout the annealing procedure is about 400 mA that is equivalent of about 13 W for a T of about 150°C

Annealing in-situ for SiPMs: direct current



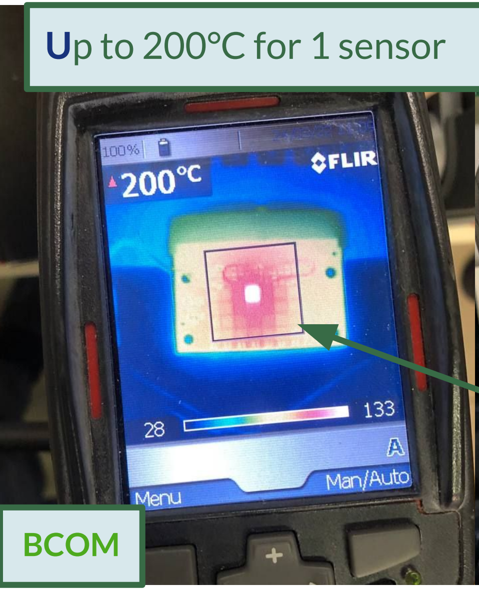
I_{test} the current produced throughout the annealing procedure is about 530mA that is equivalent of about 5 W

$$I_{dark} = I_{0dark} \cdot (1 + \exp(-t/\tau)).$$

Annealing in-situ for SiPMs: direct current

+26°C

Up to 200°C for 1 sensor



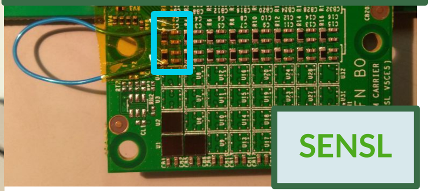
BCOM

The single sensor needs 3W to heat

Up to 200°C for 8 sensors

The octet of sensors needs 1W/sensor to heat

Bypass on R to give full current on sensor



SENSL

Not all sensors are evenly heated

Much of the heat is lost to heat the carrier

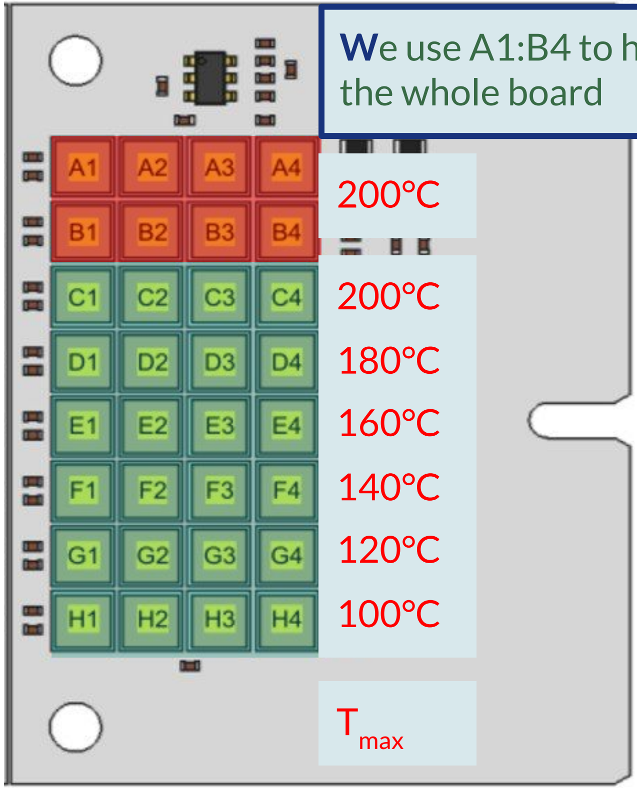
The difference in power suggests the dissipation dynamic of the carrier should be carefully studied to evenly heat all sensors reducing heat waste

Annealing in-situ for SiPMs: direct current

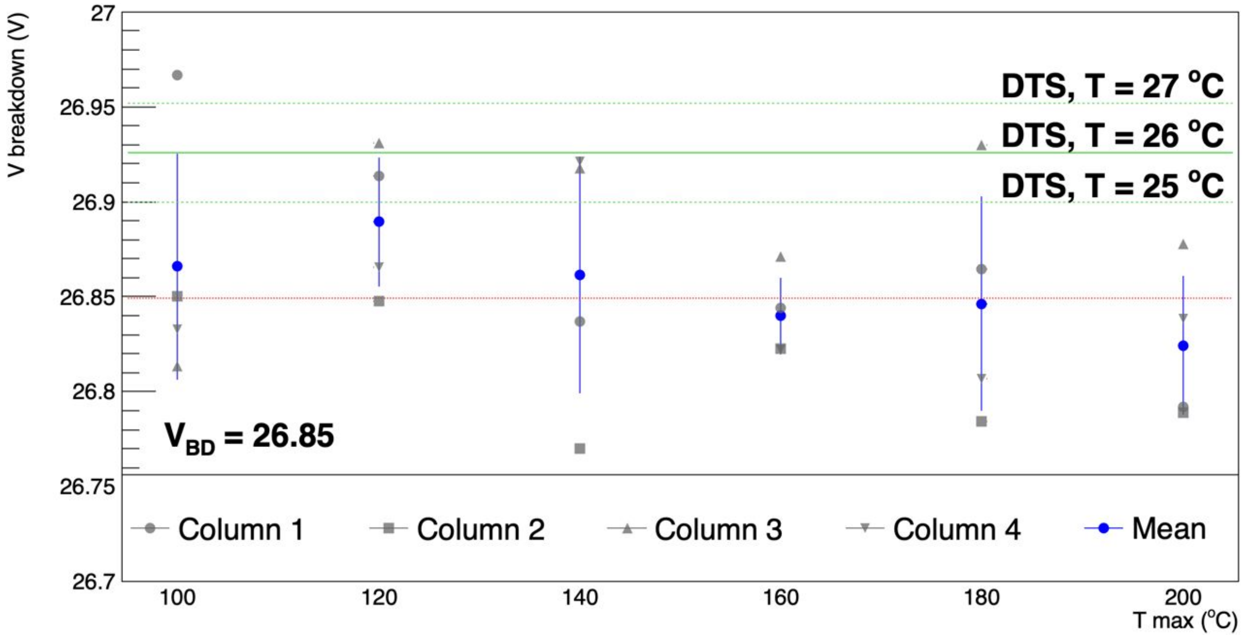
+26°C

Measured with infra-cam

We use A1:B4 to heat the whole board



Measured sensors C1:H4



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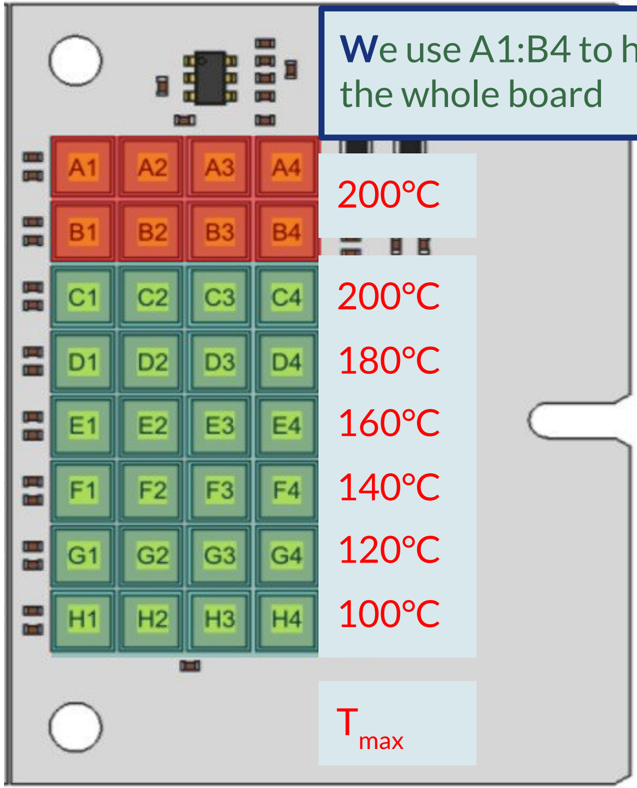

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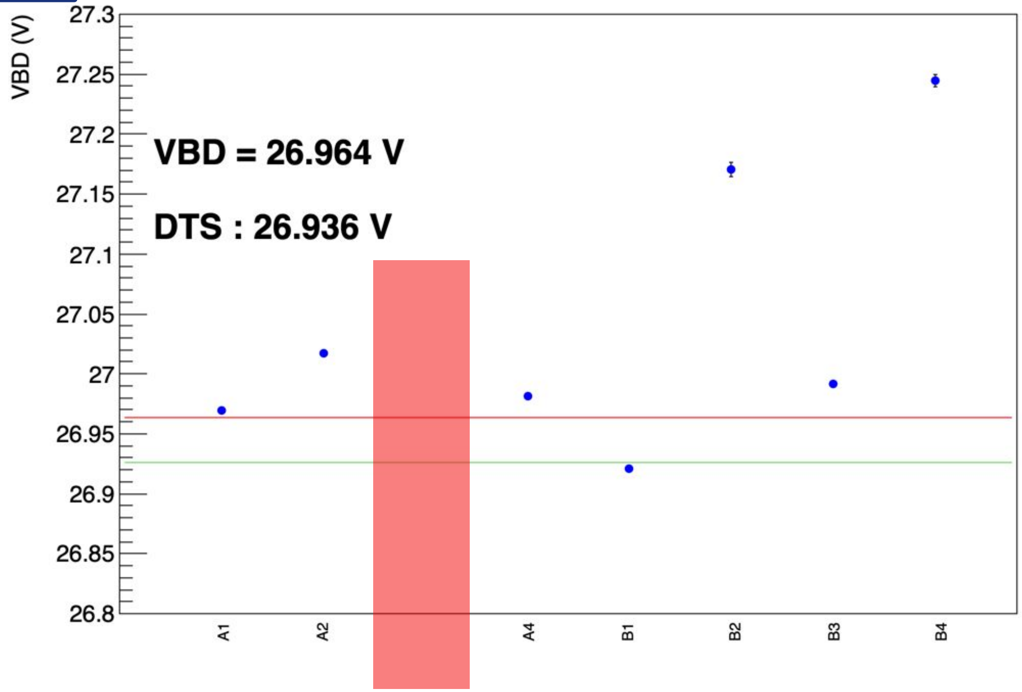


Annealing in-situ for SiPMs: direct current

+26°C

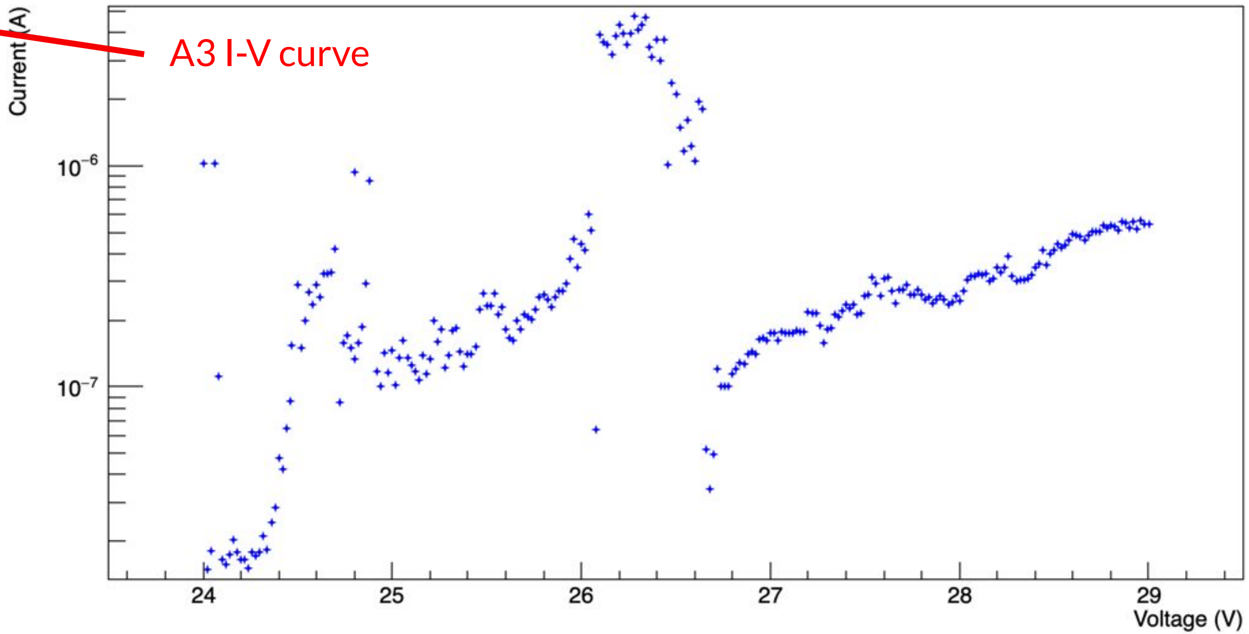
Measured with infra-cam

We use A1:B4 to heat the whole board

Rows	T_{max}
A–B	200°C
C	200°C
D	180°C
E	160°C
F	140°C
G	120°C
H	100°C

We had some jumps over this 200°C during our tests

A3 I-V curve



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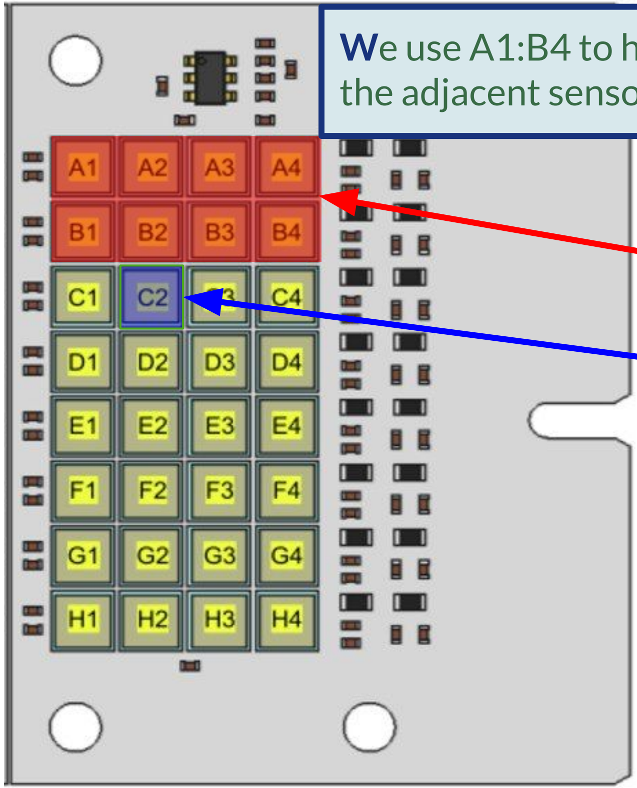
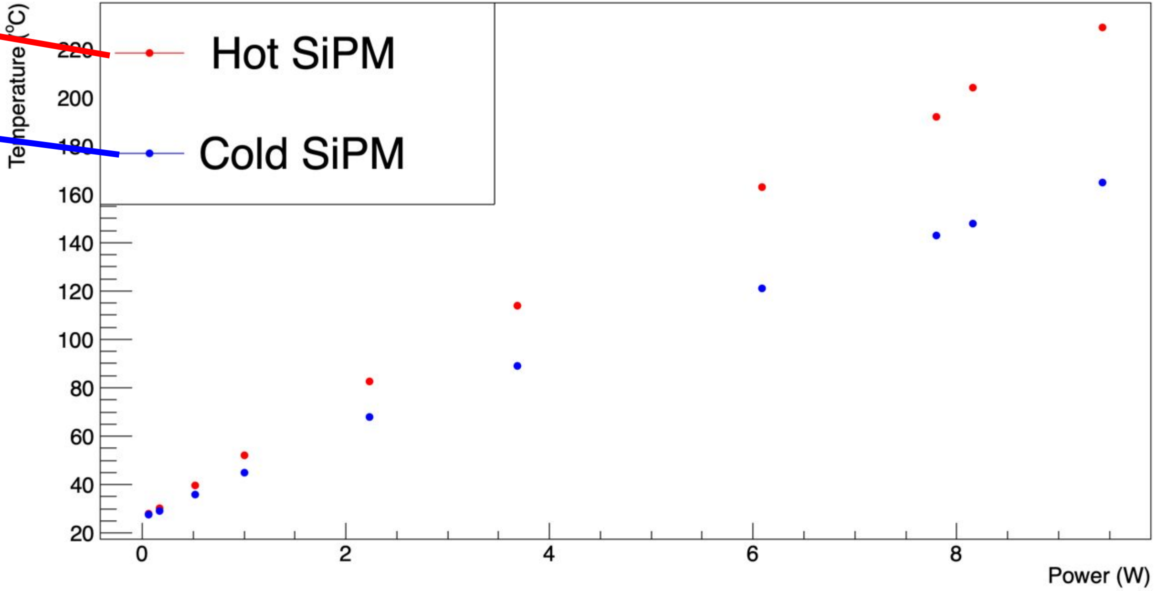


We use A1:B4 to heat the adjacent sensor

We can test the sensor response at different temperatures



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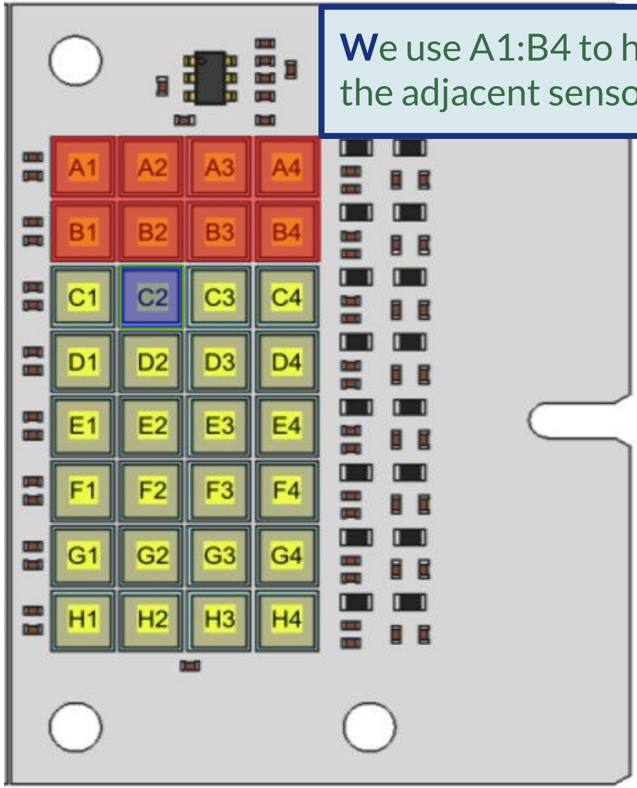

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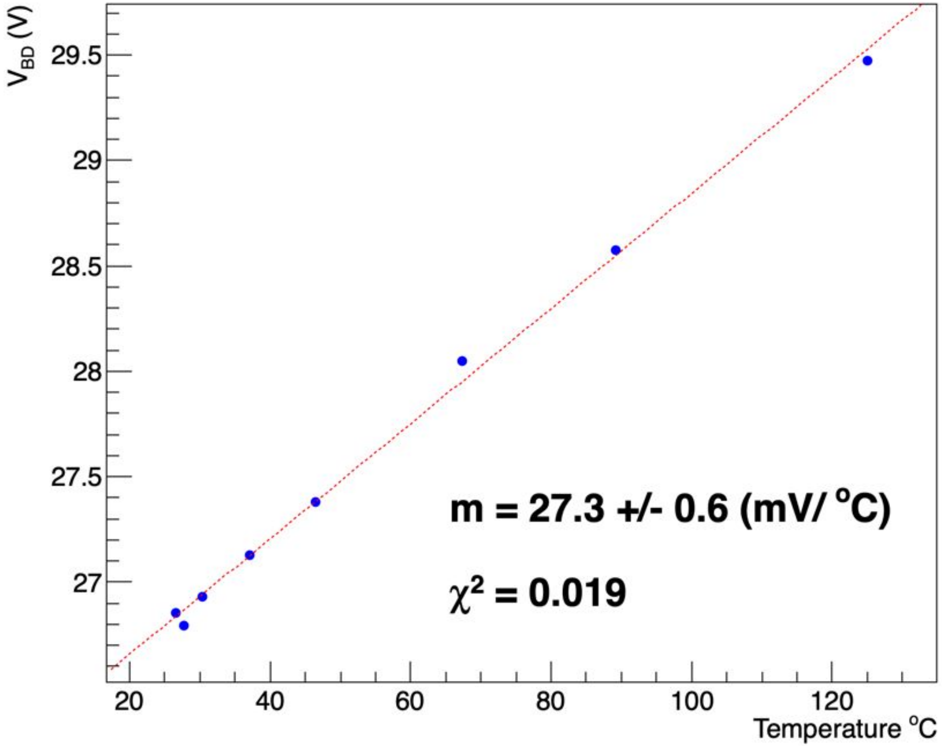

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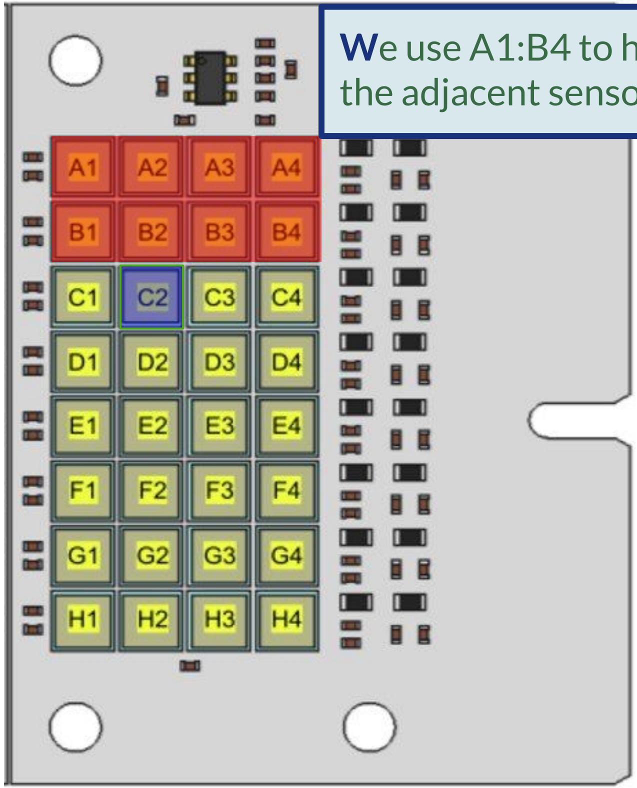

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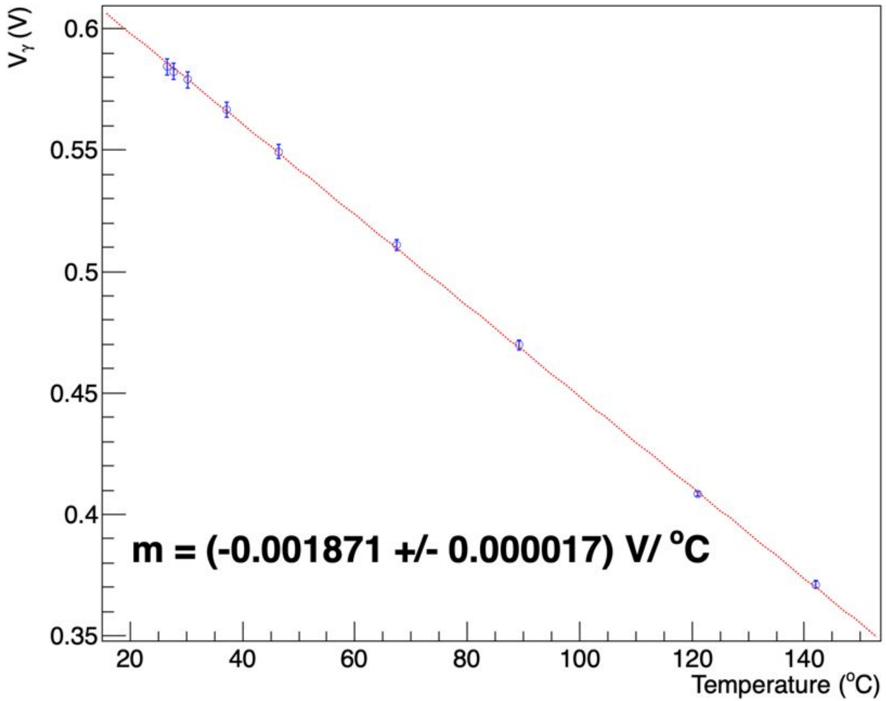

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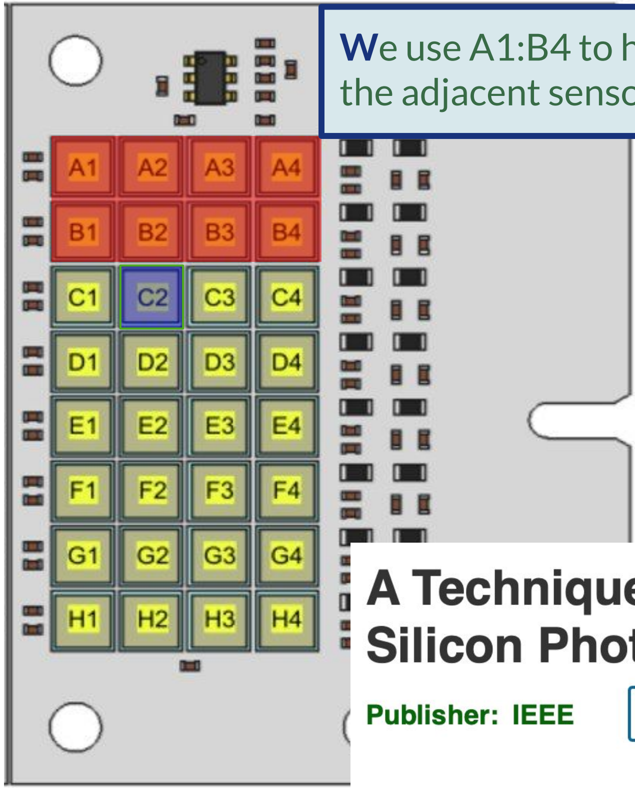

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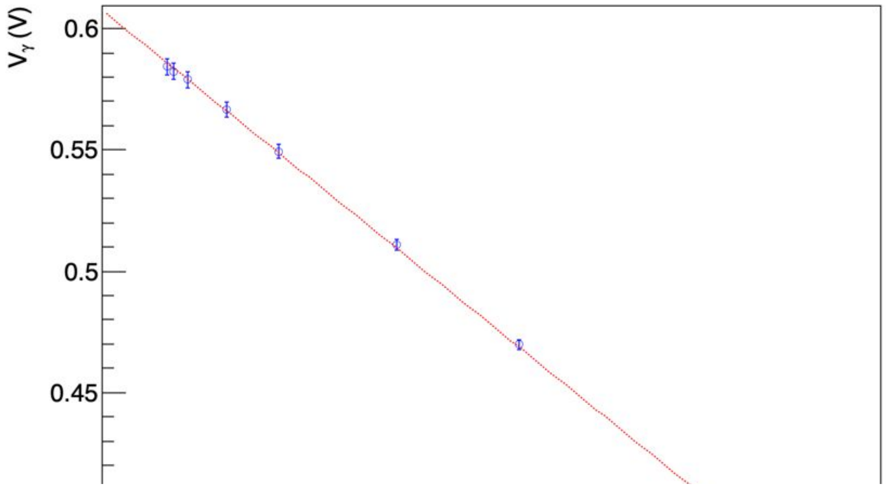


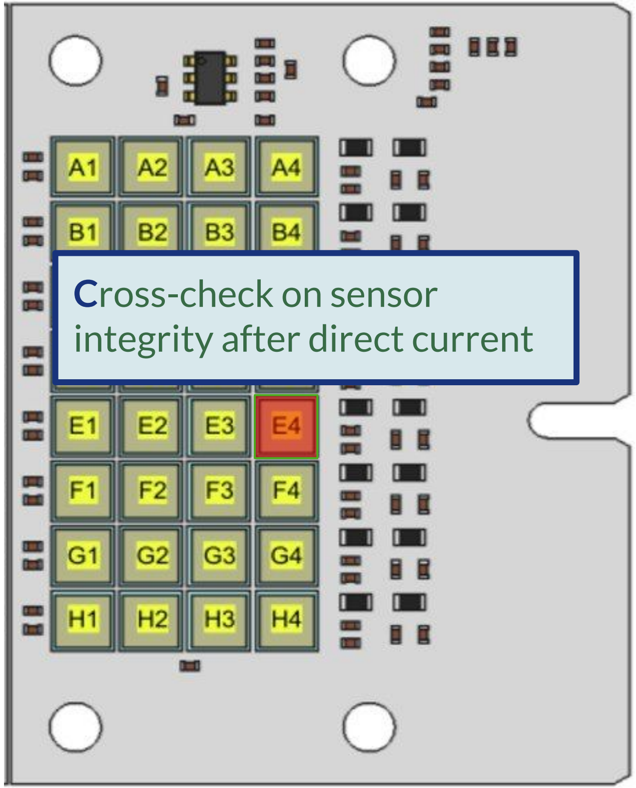
A Technique of In-situ Annealing and Temperature Monitoring for Silicon Photomultipliers

Publisher: IEEE   Cite This   PDF

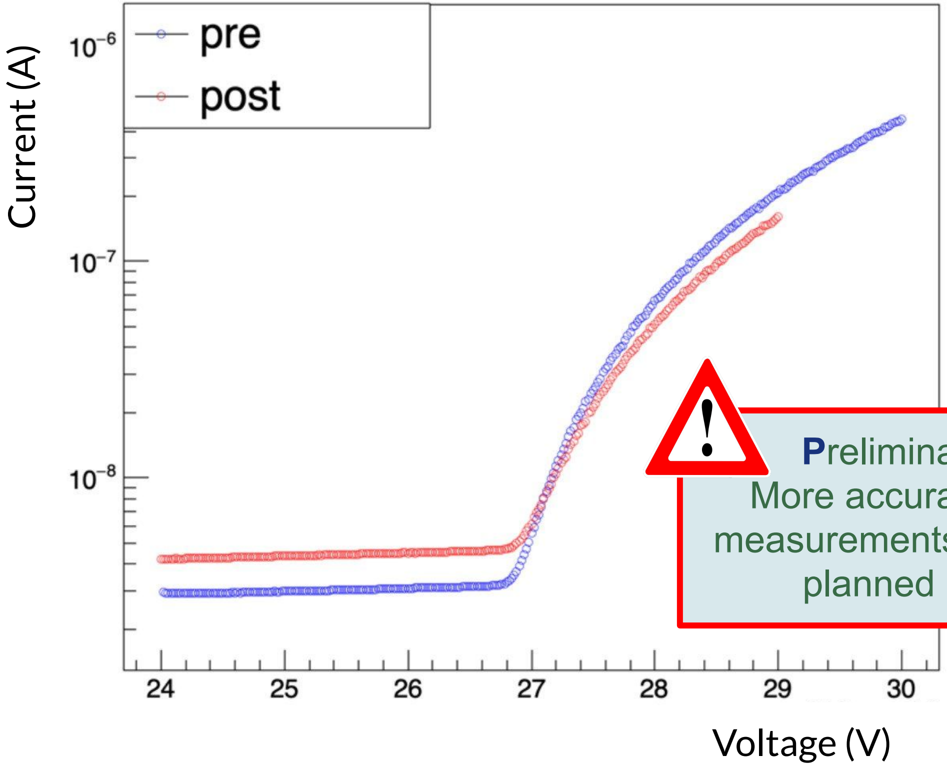
Hongmin Liu ; Yu Peng ; Jinyan Long ; Wenxing Lv ; Kun Liang ; Ru Yang ; Dejun Han   All Authors

Annealing in-situ for SiPMs: direct current

+26°C



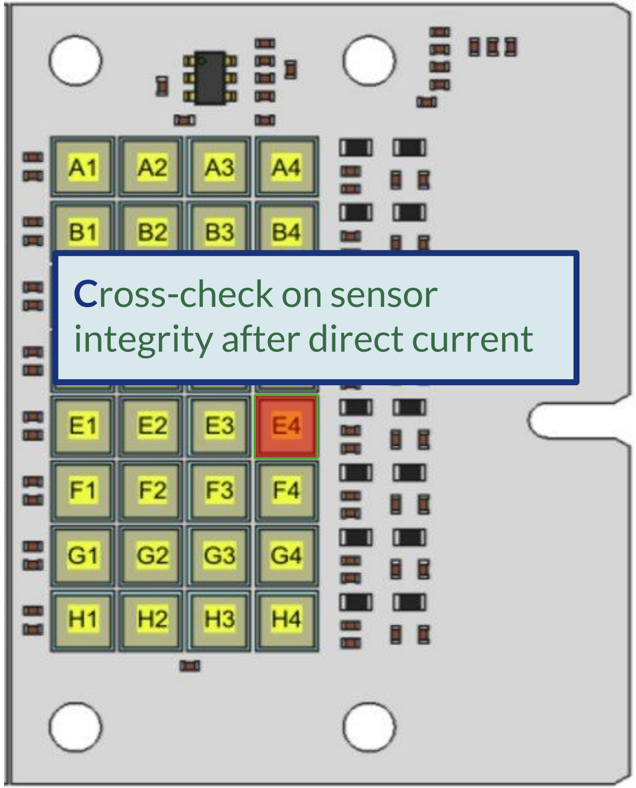
Cross-check on sensor integrity after direct current



Preliminary!
More accurate measurements are planned

Annealing in-situ for SiPMs: direct current

+26°C



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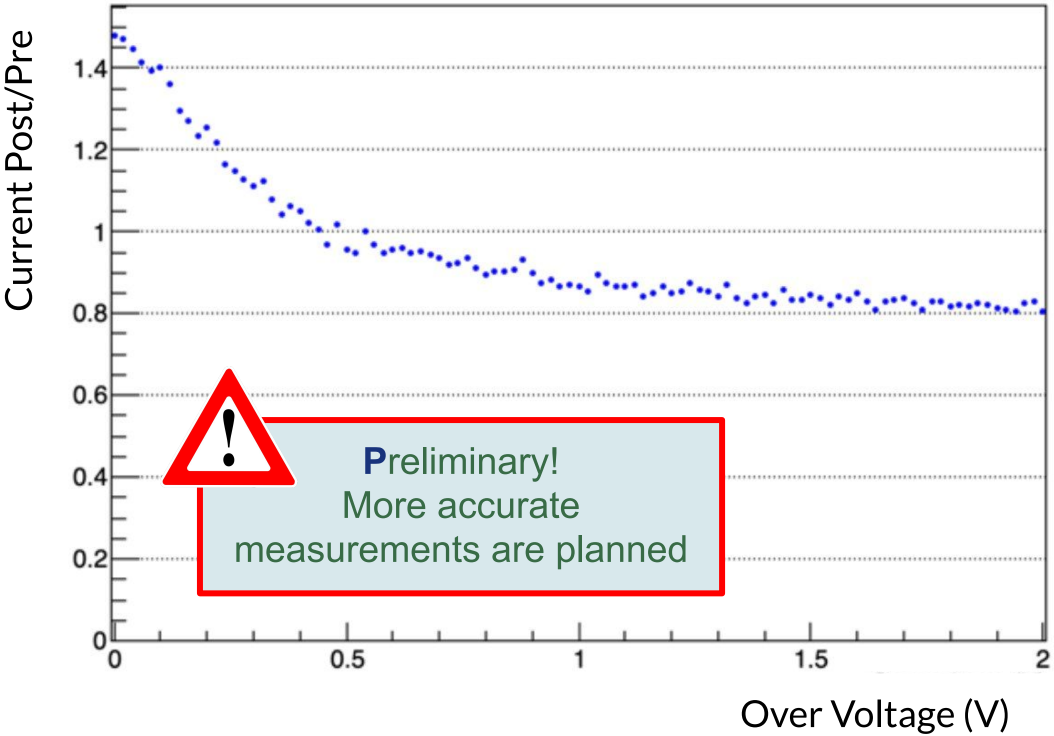

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Summary & prospects

Summary

1. A ≈3% consistency in consecutive measurements
2. There is a strange behaviour in evaluating sensor homogeneity systematics
3. Characterising behaviour of SiPMs at different temperatures, heating them with adjacent sensors with direct current.
4. 3W is a consistent heating power needed to bring a single cell up to 200°C

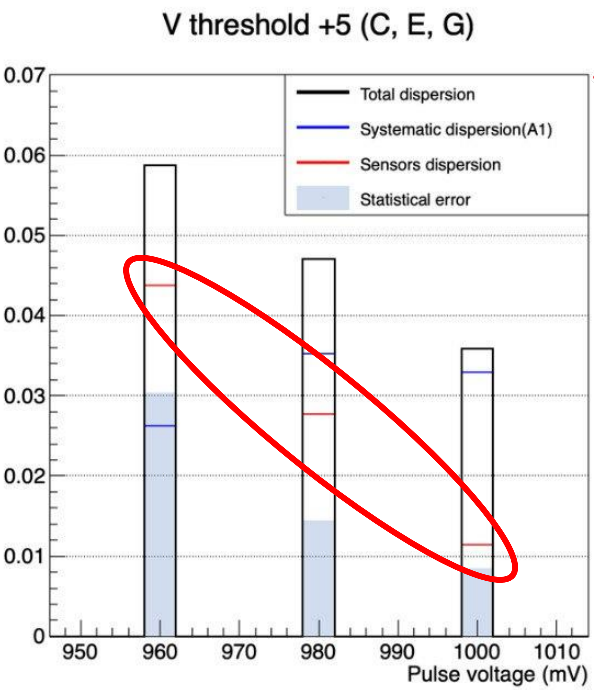
Prospects

1. Cross-check the results starting with a brand-new sensor matrix, characterising the sensors before and after annealing cycles.
2. Test different types of sensors.
3. If procedure is deemed safe, move to irradiated sensors to evaluate recovery possibilities.

Thank you for your attention!
Any questions?

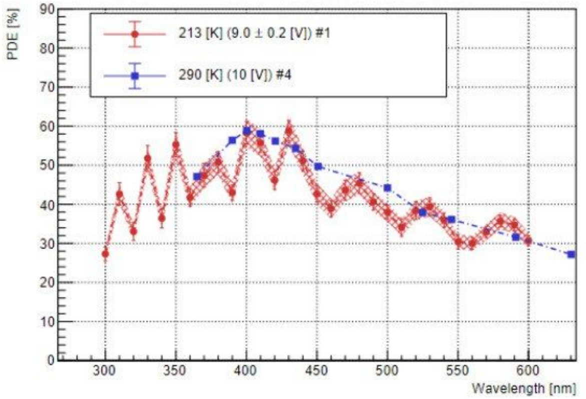
BACK-UP

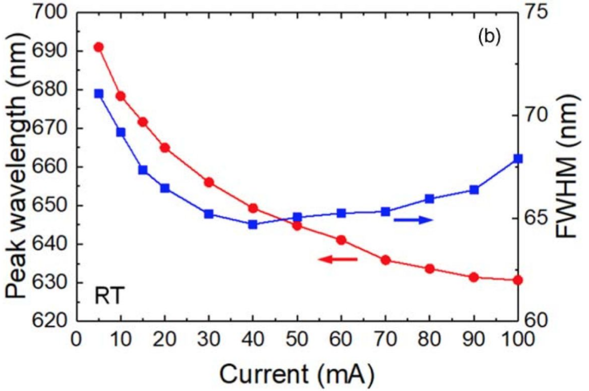
Board scan: sensor homogeneity



We are measuring an unexpected dependence on pulser voltage for systematic dispersion on sensor-to-sensor inhomogeneities

Possible sources for this behaviour is the LED light has different wavelength for different Voltage, thus the sensors might have a different efficiency in detection





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