SiPM annealing with a fluid assisted system without thermal camera

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dRICH meeting

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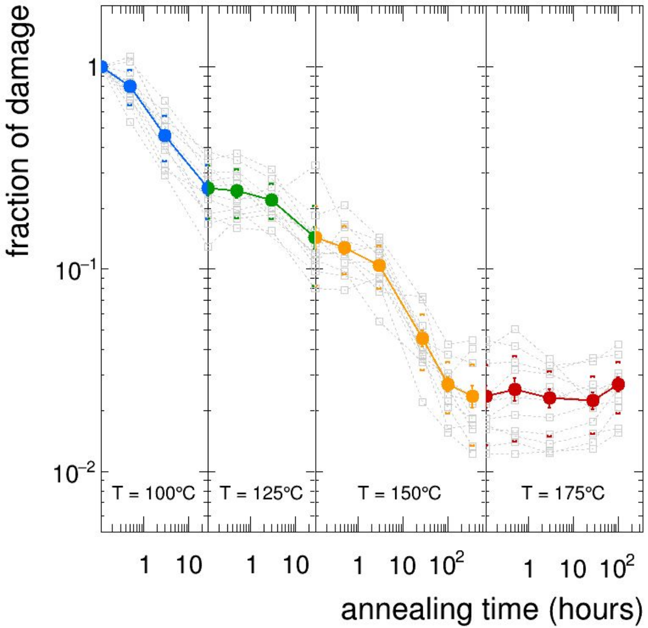
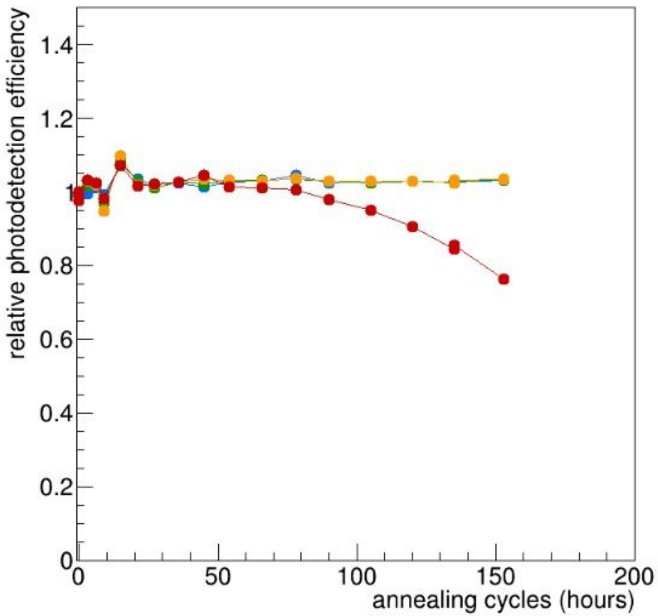
Motivation

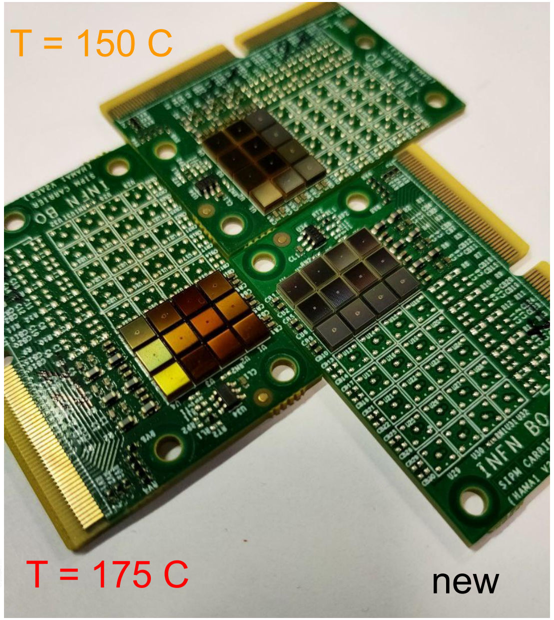
Previous online-insitu forward bias annealing showed promising results with recovery upto 97% in only few hundreds hours of annealing time.

The degradation of relative PDE and yellowish tint on the resins of the SiPM window is under investigations.

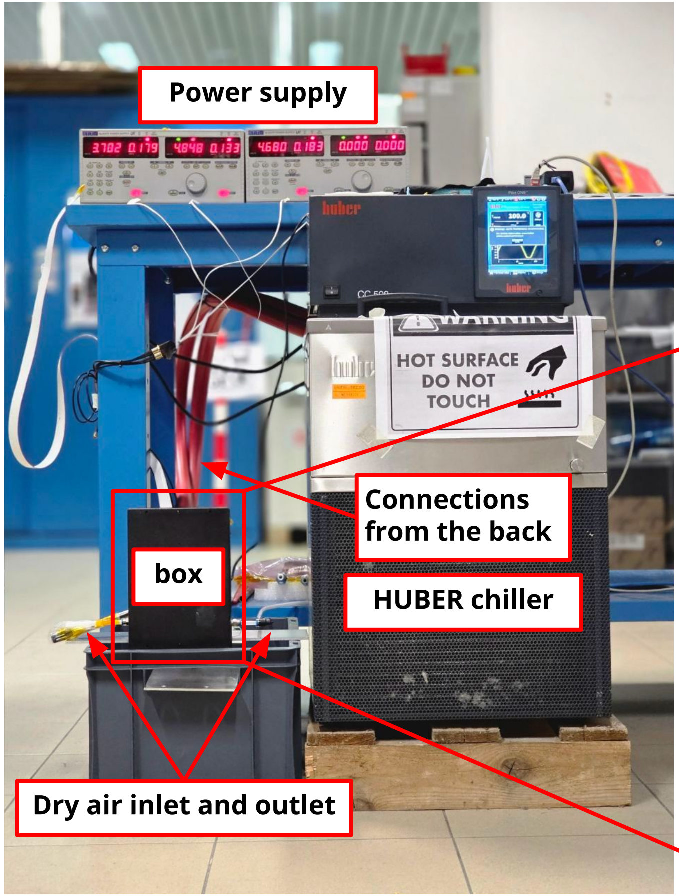
Hypothesis: At elevated temperatures, components of atmospheric air or residual humidity may react with the resin material, leading to discoloration and performance degradation.





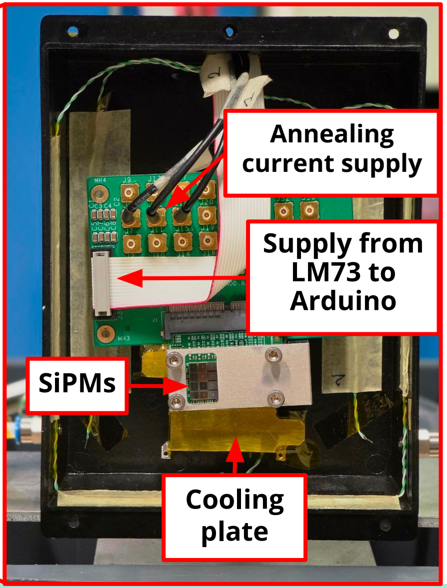


Experimental setup



Different approach for annealing:

1. **Humidity** will always be kept **at 0%** by flushing **dry air** in a closed a box.
2. It uses **both liquid chiller and forward current** to heat up the sensors upto the desired temperatures.
3. The goal now was to **go upto 100 ℃ with huber chiller** and **remaining temperatures with forward bias current**.



The SiPM board is attached on the surface of a cooling plate where liquid from the HUBER flows through it to maintain at 100 ℃.

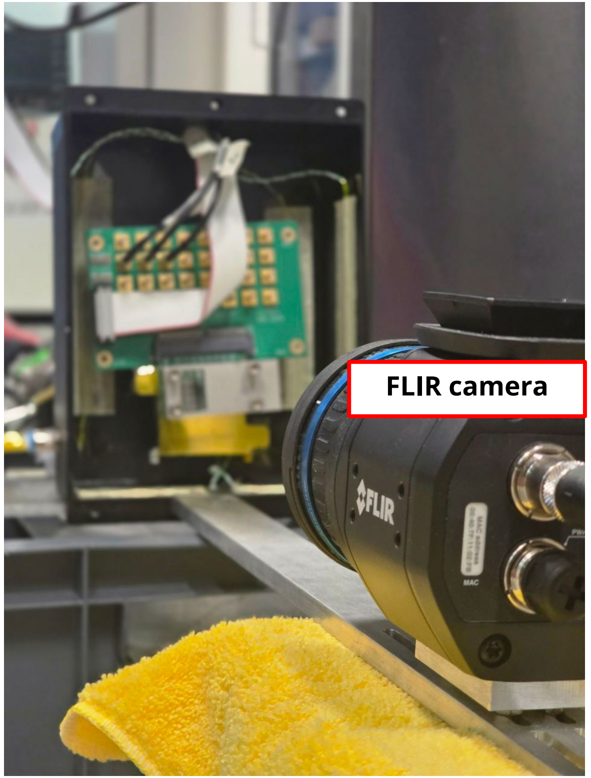
The LM73 sensor measures the ambient temperature near SiPM region.

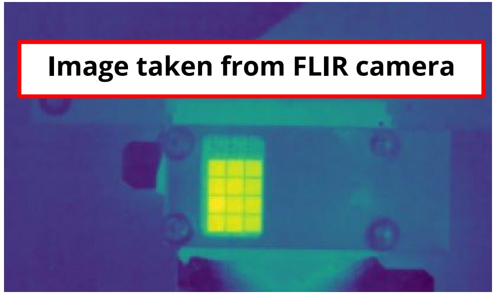
There are two main calibrations needed:

1. Variations of LM73 with chiller temperatures.
2. SiPM temperature with supplied power in forward bias.

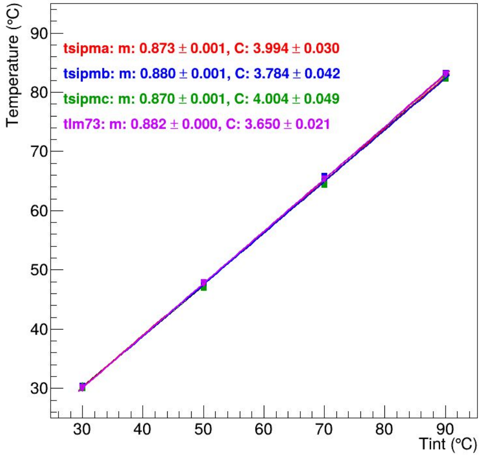
Calibration setup and methods

Before annealing **for the calibration a FLIR thermal camera** was used **to measure the temperature of the SiPMs** and temperature of the **LM73 was measured by using an ARDUINO**





All the temperature and humidity sensors, HUBER chiller, power supplies are controlled automatically by a Linux PC.

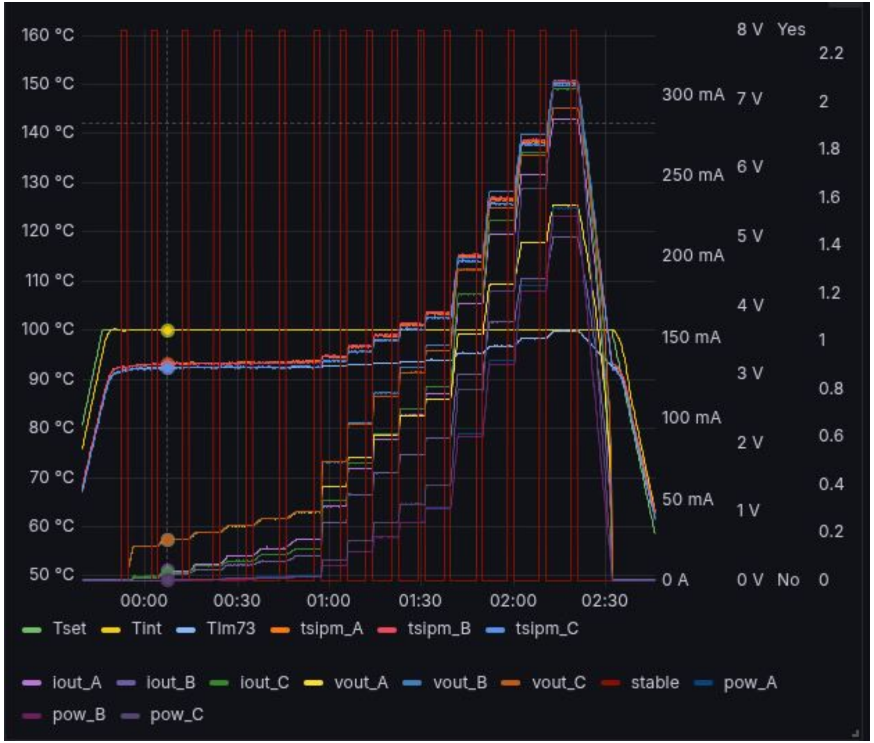


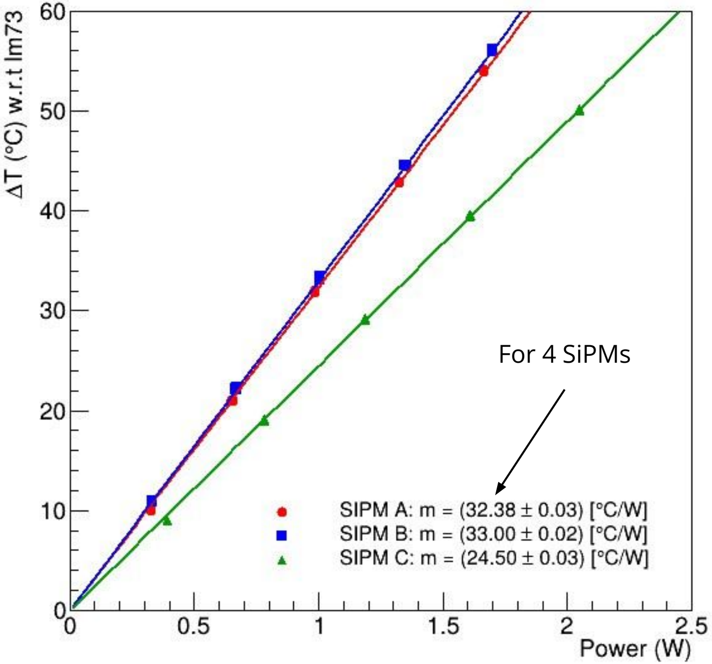
With HUBER control, all the temperatures looks almost same in the temperature range from 30 ℃ to 100 ℃.
There is a heat loss at higher temperature.

Calibration of temperature and power

The LM73 temperature acts a ambient temperature.

ΔT = (temperatures of the sipm recorded on FLIR camera) - (temperature recorded by the LM73 sensor)

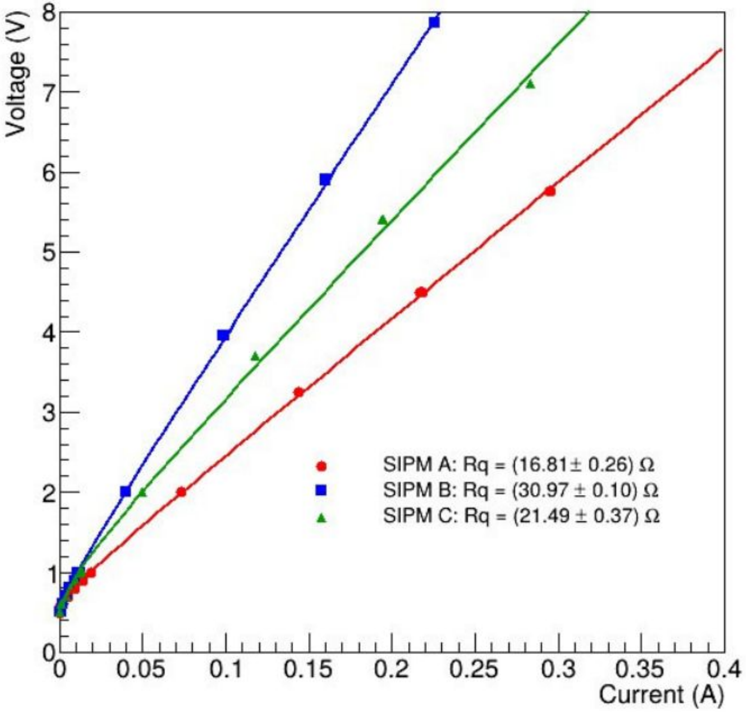




Approximately 2W of power is required to reach upto 150 ℃ for 4 SiPMs.

Calibration of voltage and current

To control the power delivery to the SiPM, IV characterisation is required, as we regulate the voltage and current of a power supply.



The IV data is fitted with the following diode equation:

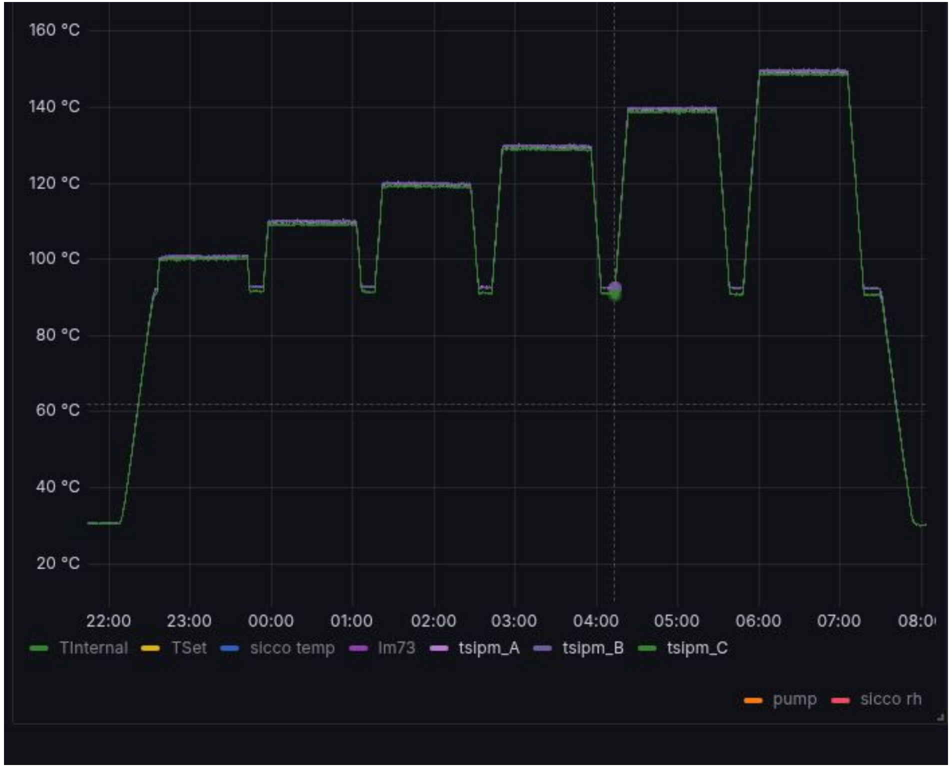
$$V = R_q I + V_T \ln\left(1 + \frac{I}{I_s}\right)$$

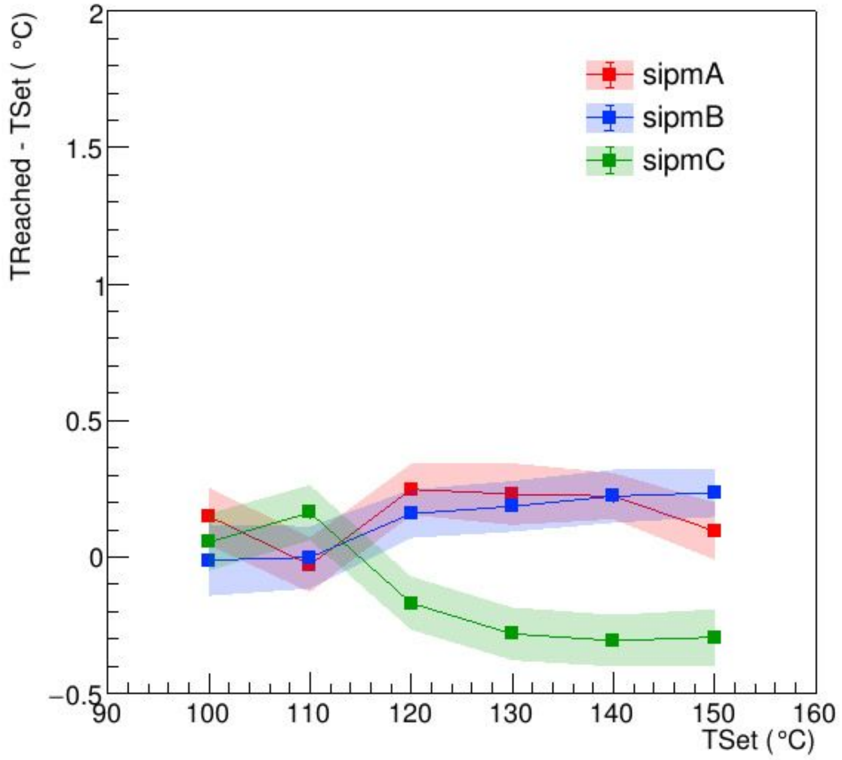
Where R_q is quenching resistor of the SiPM, V_T is the thermal voltage, and I_s is the reverse saturation current of diode.

After calibration, those parameters were used to calculate the voltage and deliver it to the SiPM to achieve a desired temperature.

Validation of calibration parameters

After calibrations the SiPMs were set to various temperature (TSet) from 100 ℃ to 150 ℃ and the results are promising with maximum variations of only ~0.5 ℃ from the set temperature. The Temperature are automatically controlled by taking feedback from the LM73.





Annealing workflow and performance checks

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We plan to perform three types of annealing:

1. **Soft annealing**: T = **125 ℃** for **8** hours per cycle
2. **Fast annealing**: T = **150 ℃** for **2** hours per cycle
3. **Full annealing**: T = **150 ℃** for **25** hours per cycle

We are working with two irradiated boards (Board 23 and 25), which were exposed **at Legnaro** to a fluence of upto **10^9 n_{eq}/cm^2**.

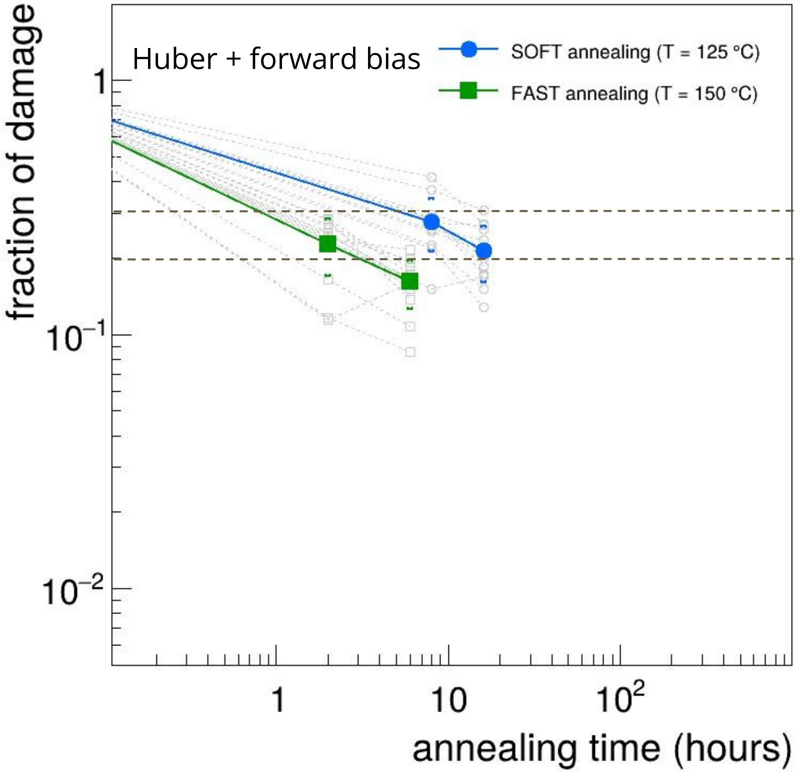
Board 23	Irradiated	SOFT 1 cycle	SOFT 2 cycles	SOFT 4 cycles	SOFT 8 cycles	FULL 1 cycles	FULL 2 cycles	FULL 4 cycles	FULL 8 cycles	495 h
Board 25	Irradiated	FAST 1 cycle	FAST 2 cycles	FAST 4 cycles	FAST 8 cycles	FULL 1 cycles	FULL 2 cycles	FULL 4 cycles	FULL 8 cycles	455 h

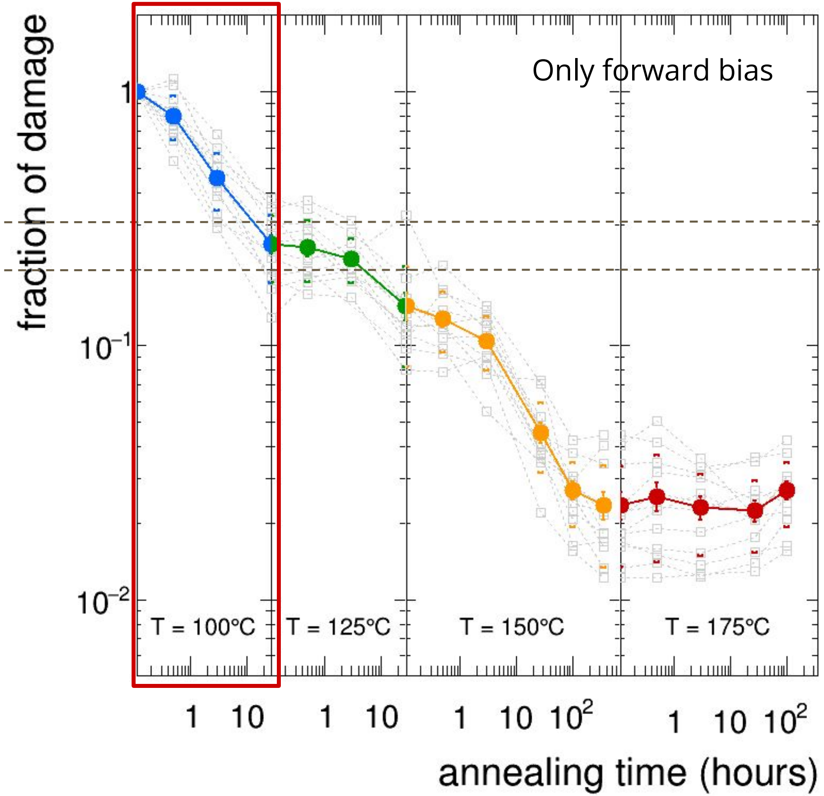
We have completed these many measurements and the remaining all measurements are expected to be completed by the **end of July**.

After each annealing step, we measure the IV to assess the recovery from the radiation damage. The **coloured blocks** indicate the PDE measurements after that step.

Annealing results

Clearly demonstrates that fraction of damages decreases as we increase the annealing temperature.





PDE results yet to come to demonstrate if we have any degradation after longer annealing period with the current method!

Conclusion and outlook

- A new annealing method was successfully implemented using **both fluid-assisted heating and a forward current applied to the SiPMs**.
- Continuous dry air flushing inside the box keeps the humidity at 0% and prevents contamination from the atmospheric air.
- With only **~0.5W** of additional power, the SiPMs can reach a temperature **upto 150 ℃**.
- The calibration method is reliable with temperature deviation of only +/- 0.5 ℃ from the set temperature.
- Preliminary results indicate that fast annealing at 150 °C provides better recovery from radiation damage, though long-term validation is still required.
- PDE measurements are planned after extended annealing period.

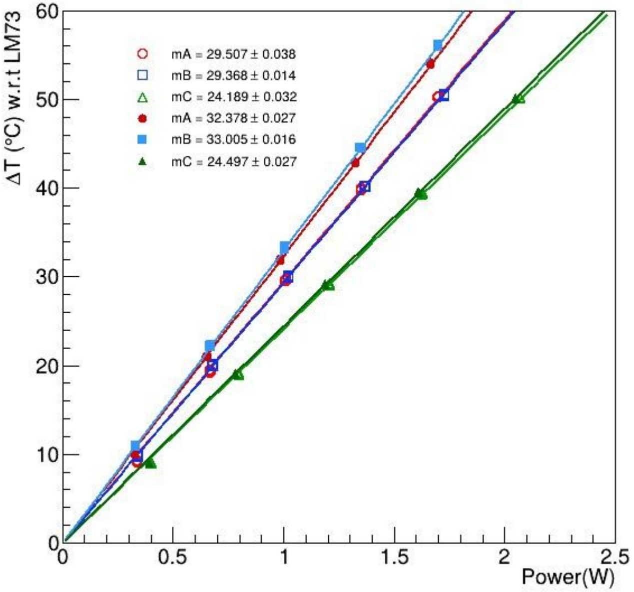
Thank you!

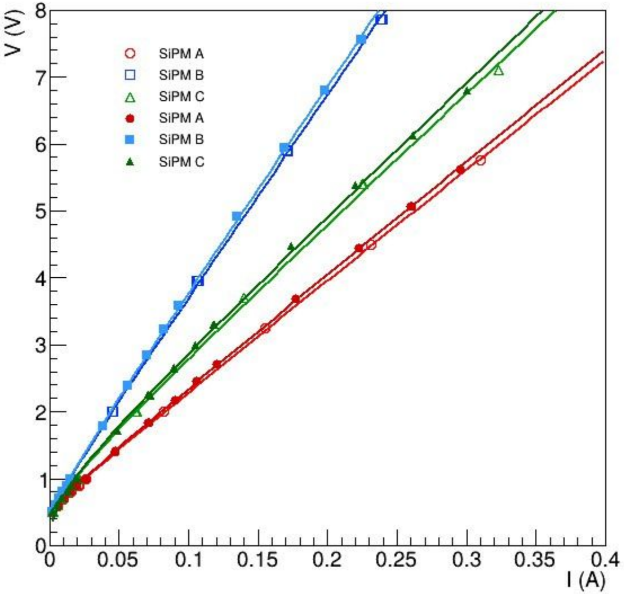
Backup slides

Variations in parameters when switching only one SiPM channel to when switching on all SiPMs

The neighbouring sensors heat up each other, which in results the power requirement is also less when all sipms are switched ON compared to when only one SiPM channel is ON.

The IV curve almost remains same in both the cases.





Variations in parameters with open and closed box

1. As in the case of closed box, the humidity is kept 0% throughout the duration of the experiment.
2. The heat dissipation to the surrounding is also less, which clearly demonstrate a increase in the temperatures of the LM73 sensor.
3. The power requirement is also less compared to the open box case to reach a desired temperature.