Thermal Performance Analysis of SiPM Board

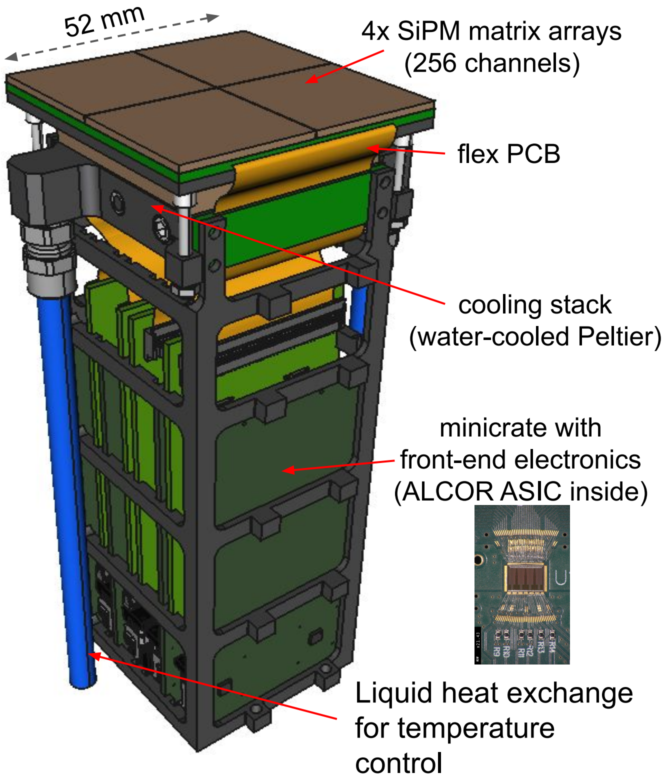
B Rajesh Achari, PhD

University and INFN Bologna

ALICE-ePIC monthly meeting

Date: Oct 30, 2024

Motivation



PhotoDetector Unit (PDU)

- It is very much essential to operate the SiPM at low temperature.
- Peltier module is a great tool to lower the temperature of SiPM.

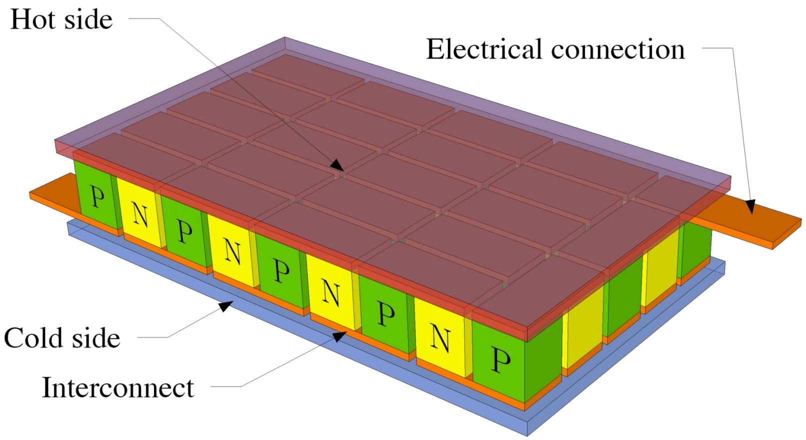
- **Advantage** of peltier module:
  - No moving parts.
  - Compact size.
  - Precise temperature control.
- **Limitations:**
  - Limited temperature differential.
  - Heat dissipation

Introduction to Peltier Module

A **Peltier module**, or **thermoelectric cooler**, is a device that uses the Peltier effect to transfer heat.

- **Peltier Effect**: Named after physicist Jean Peltier, the effect occurs when an electric current flows through two different conductors, causing heat absorption at one junction and heat emission at another.

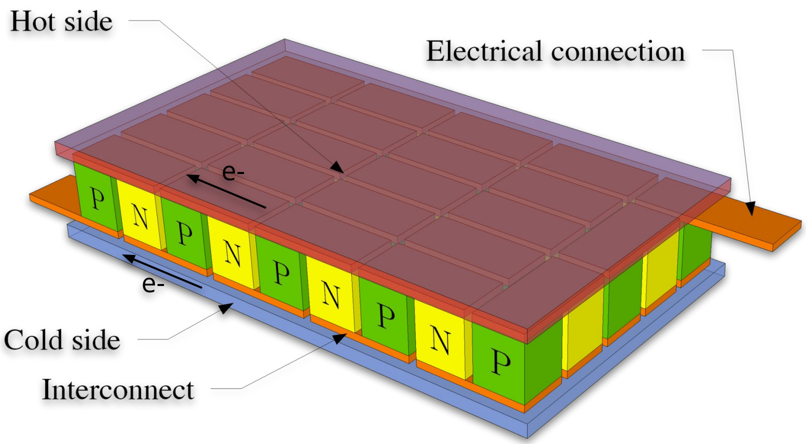
  - Pairs of p and n type semiconductors are placed in between two ceramic plates
  - They are electrically in series and thermally parallel
  - The ceramic plates are electrically insulating and thermally conducting
  - When current passes through the semiconductor, heat is absorbed at the cool side and released on the hot side



Heat Transfer Mechanism

- P-type materials have a higher concentration of "holes" (positive charge carriers) with a relatively lower energy level in the conduction band.
- N-type materials have more free electrons with a higher energy level in the conduction band.
- When electron moves from lower energy state to higher energy state, it absorbs energy from the surrounding

- **Cold Side**: When electrons move from the P-type material to the N-type material, they absorb heat from the surroundings at that junction, creating the cold side.
- **Hot Side**: Conversely, when electrons move from the N-type material to the P-type material, they release heat at that junction, generating the hot side.



Note: Changing the direction of current will result in change in hot and cold side

Sample Peltier Module

Adaptive Peltier Module, 54.6W, 4.4A, 20V, 40 x 40mm

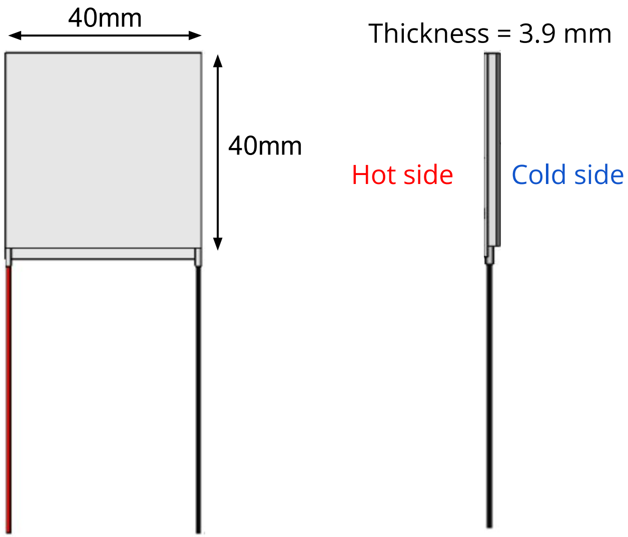
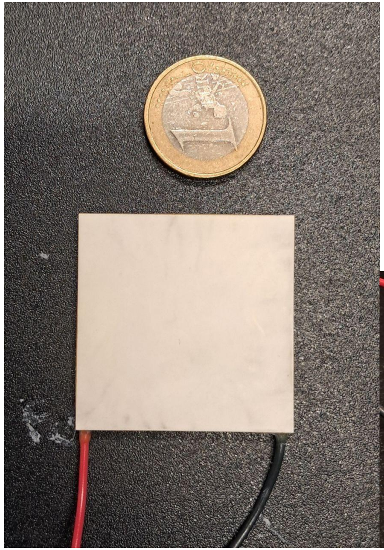
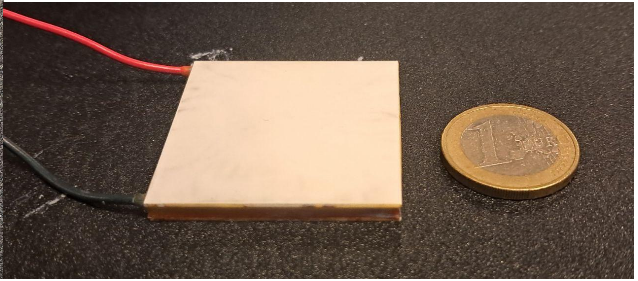


Figure not to scale

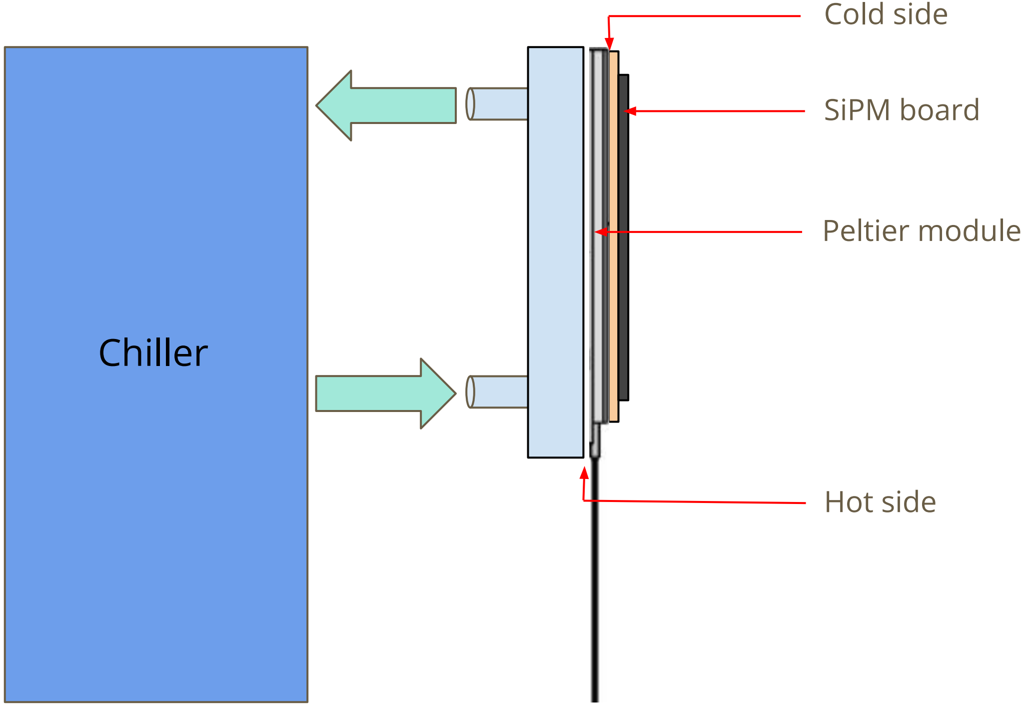


Data sheet

- Epoxy sealed
- Max hot side temperature = 90℃
- Max ΔT = 74℃
- Maximum mounting pressure = 1.5MPa



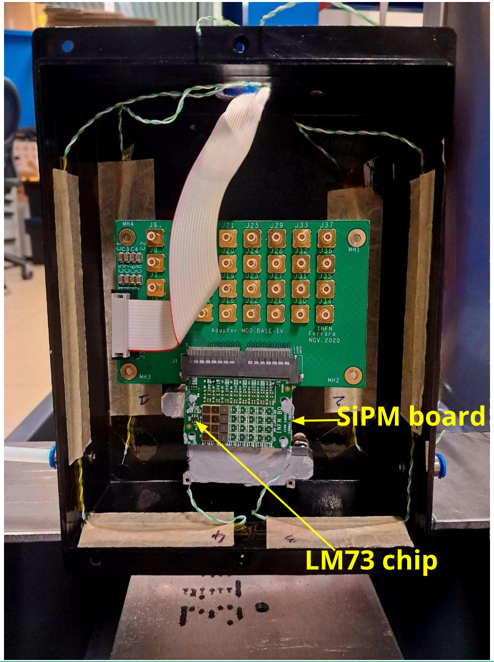
Experimental Setup



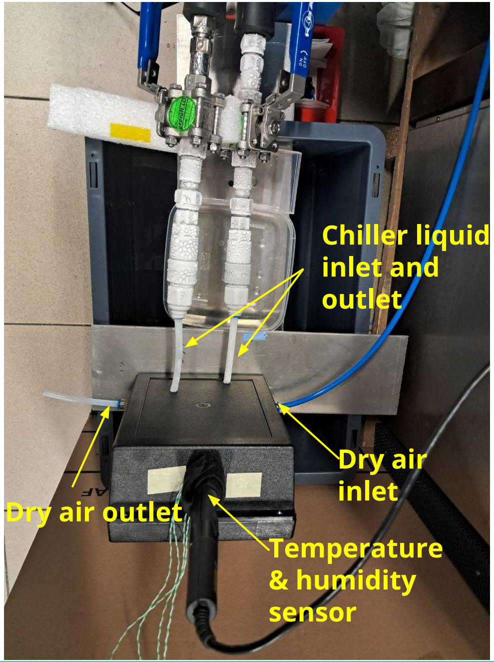
- The cold side is attached to the SiPM board
- The hot side is attached to a heat exchanger where Si oil is flowing with the help of a chiller (heat sink)
- Chiller act as a heat sink (such that we can maintain the temperature of hot side)
- Chiller temperature range: -30 to 105℃
- The cold side can go below -30℃

Experimental Setup

Electrical connection with thermal probe

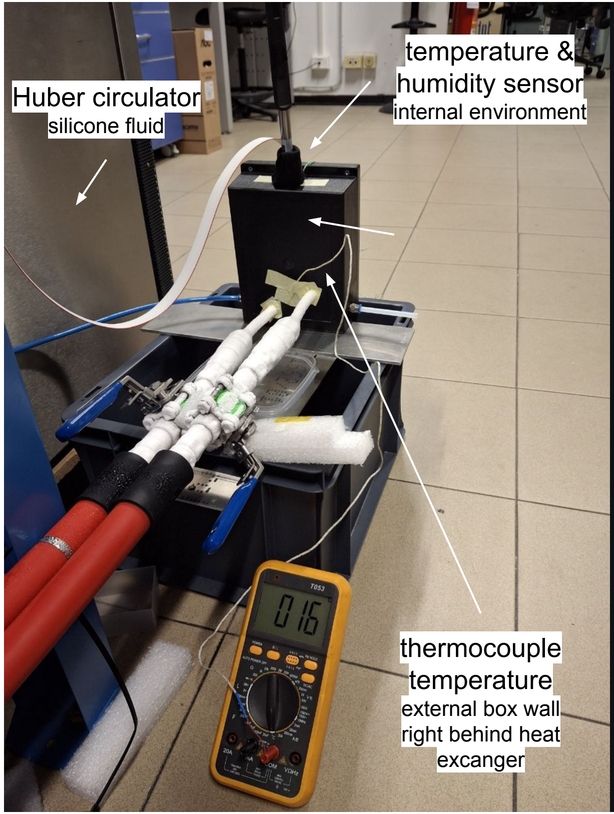


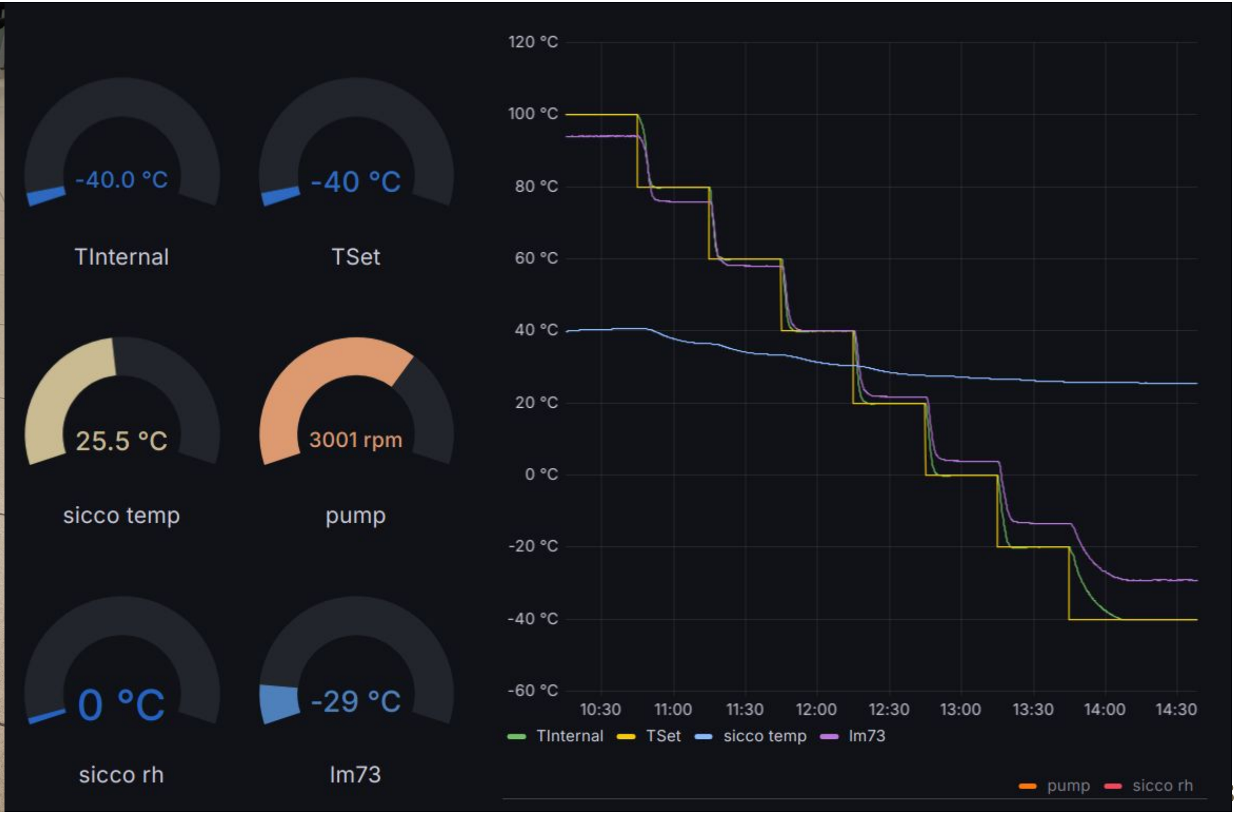
Black box was used to make a closed system and dry air was continuously circulating through the box to maintain the humidity low (almost zero)



Chiller was used to regulate the temperature by continuous flowing of liquid

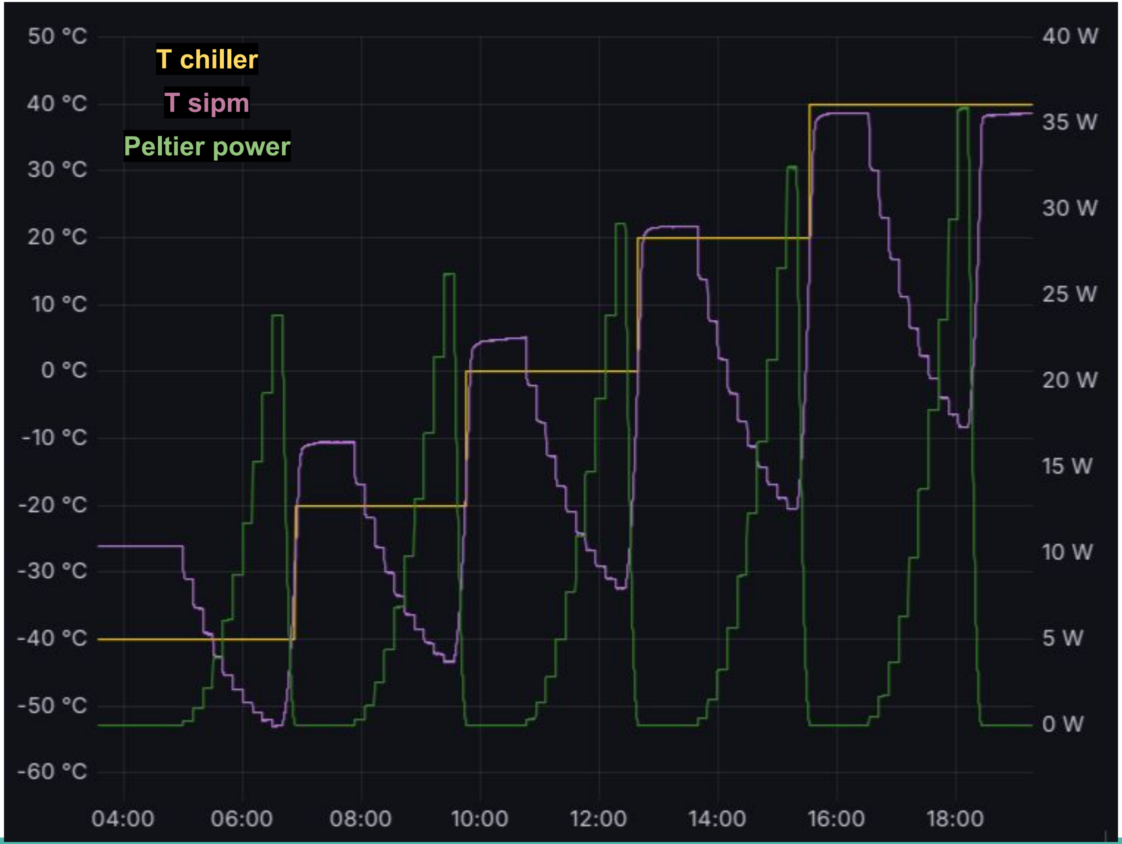
Temperature Regulation of SiPM with the Chiller





Data Acquisition for Hybrid Cooling

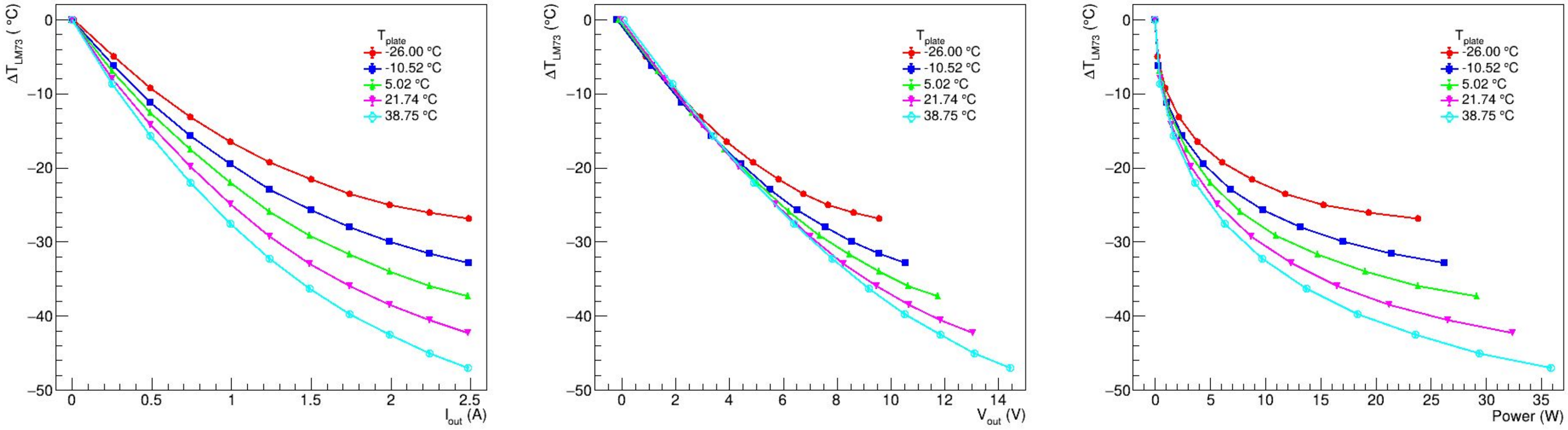
- **T chiller:** Temperature of the chiller liquid
- **T sipm:** Temperature measured at the SIPM board with a LM73 chip
- **Peltier power:** power delivered to the peltier module
- Humidity was kept constant and almost zero through the experimental period



Results

Temperature of the SiPM board were recorded with the help of LM73 chip by an Arduino.

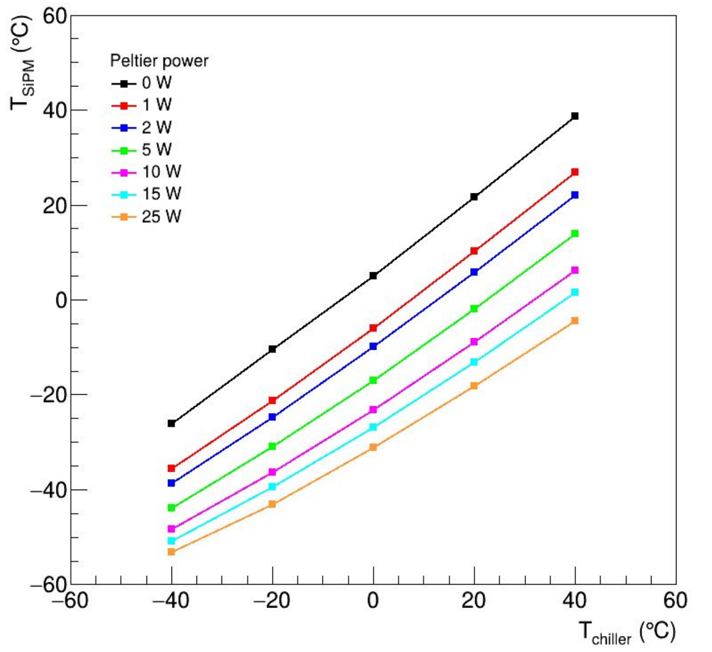
ΔT_{LM73}= T (I, V, P) - T (I(0), V(0), P(0))



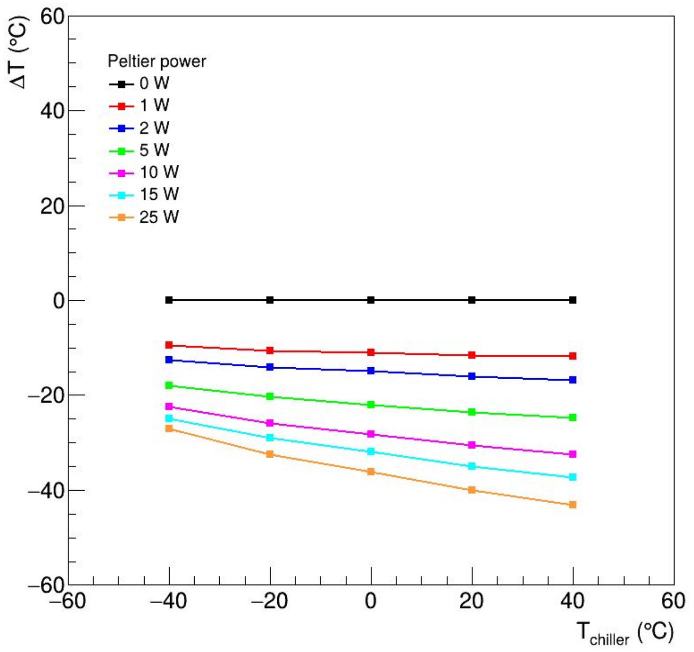
At lower current, $\Delta T \propto I$ but then at higher temperature difference, thermal conduction happens between the junction.

Results

Variation of the temperature of the SIPM board for different input power to the peltier module at different temperature of the chiller



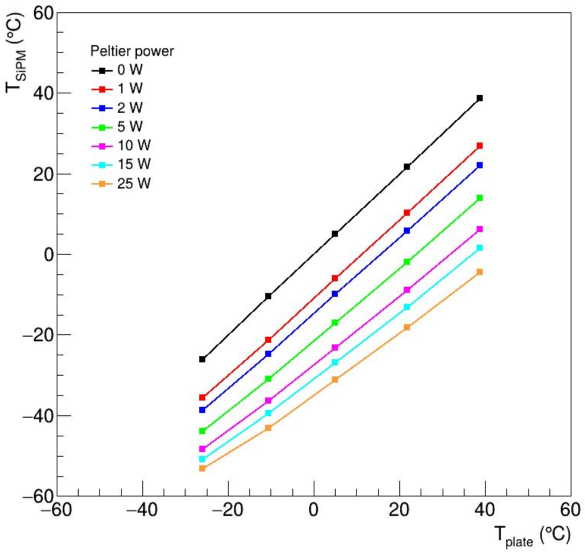
The **temperature difference achieved between in the cold side and hot side** for different input power and different operating temperature of the chiller



Conclusion and outlook

- Peltier module is a great tool to cool down further a PDU to achieve temperature upto -60℃.
- With just little as 2W of power we can reach -40℃.
- The module is less efficient for as we achieve a higher temperature difference.
- The module is also less efficient in lower temperature.
- The peltier module can also be used for in-situ annealing, we just had a quick test and we found that it is very much power efficient than the previous current annealing techniques we have.

Thank you!



T_{SiPM} (°C)
Peltier power
0 W
1 W
2 W
5 W
10 W
15 W
25 W
60
40
20
0
−20
−40
−60
−60
−40
−20
0
20
40
60
T_{plate} (°C)