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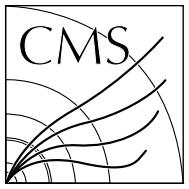
CMS DP -2024/037



The Compact Muon Solenoid Experiment

CMS Performance Note

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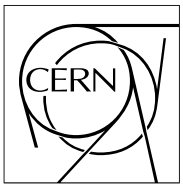

05 June 2024 (v2, 15 June 2024)

Results of the thermal tests performed using the BTL cooling setup at TIF

CMS Collaboration

Abstract

The thermal validation test for the Barrel Timing Layer (BTL) performed with the setup at the Tracker Integration Facility (TIF) are presented in the note.

Results of the thermal tests performed using the BTL cooling setup at TIF

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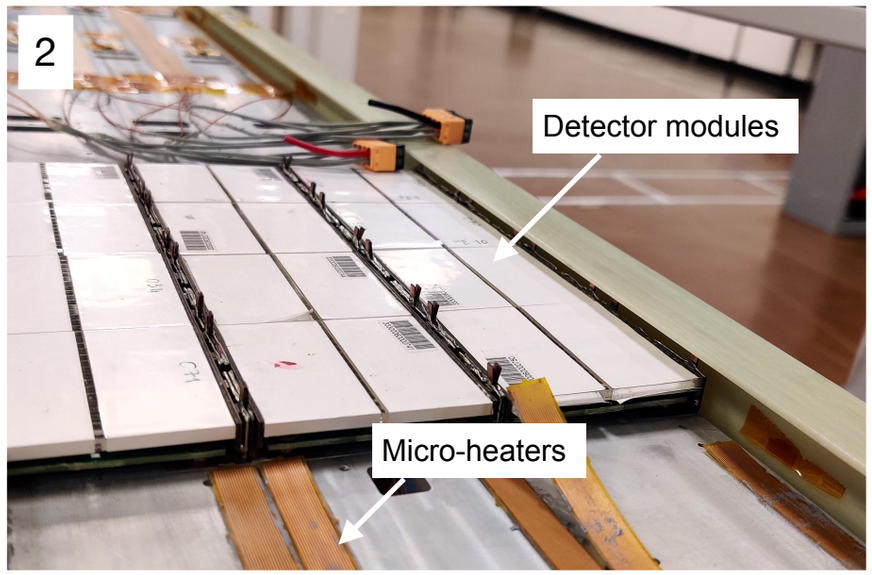
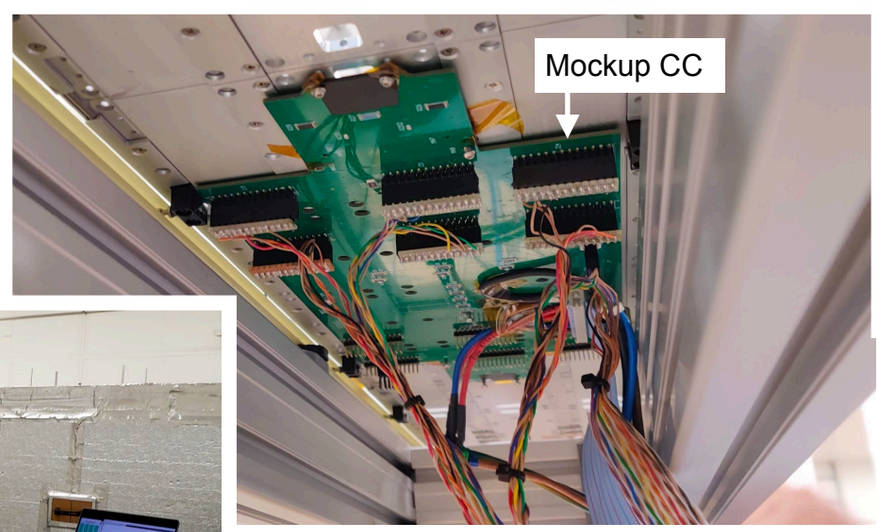
BTL thermal validation test setup at TIF

- BTL thermal validation setup at the CMS Tracker Integration Facility (TIF):
  - A design specification BTL cooling tray fully assembled and equipped with dual-phase CO_2 cooling.
  - 1/2 of a mockup BTL readout unit (RU) — mockup concentrator card (CC) + front-end (FE) board + pre-series SiPMs and LYSO — mounted on one segment of the tray.
  - Remaining segments equipped with resistive strips called “microheaters” which are powered to desired values to emulate the heat dissipation of the BTL RUs
  - Armaflex sheets are attached on the top and bottom of the tray to emulate the real, semi-closed BTL volume in CMS.
  - Top cover made of thermally insulating foam with dry air supply pipes inside for operations at -35°C.
- Read out and monitoring:
  - 72 + 4 (PLC) Pt1000 temperature sensors glued to different positions of interest on the tray and the mockup RU using thermally conducting adhesive, 2 humidity sensors and 2 pressure sensors (1 each for the inlet and outlet).
  - SiPM packages have thermistors close to the centre of an SiPM array to read out the SiPM temperatures.
  - Prototype MTD detector control system (DCS) graphical user interface (GUI) for read out of all sensors.

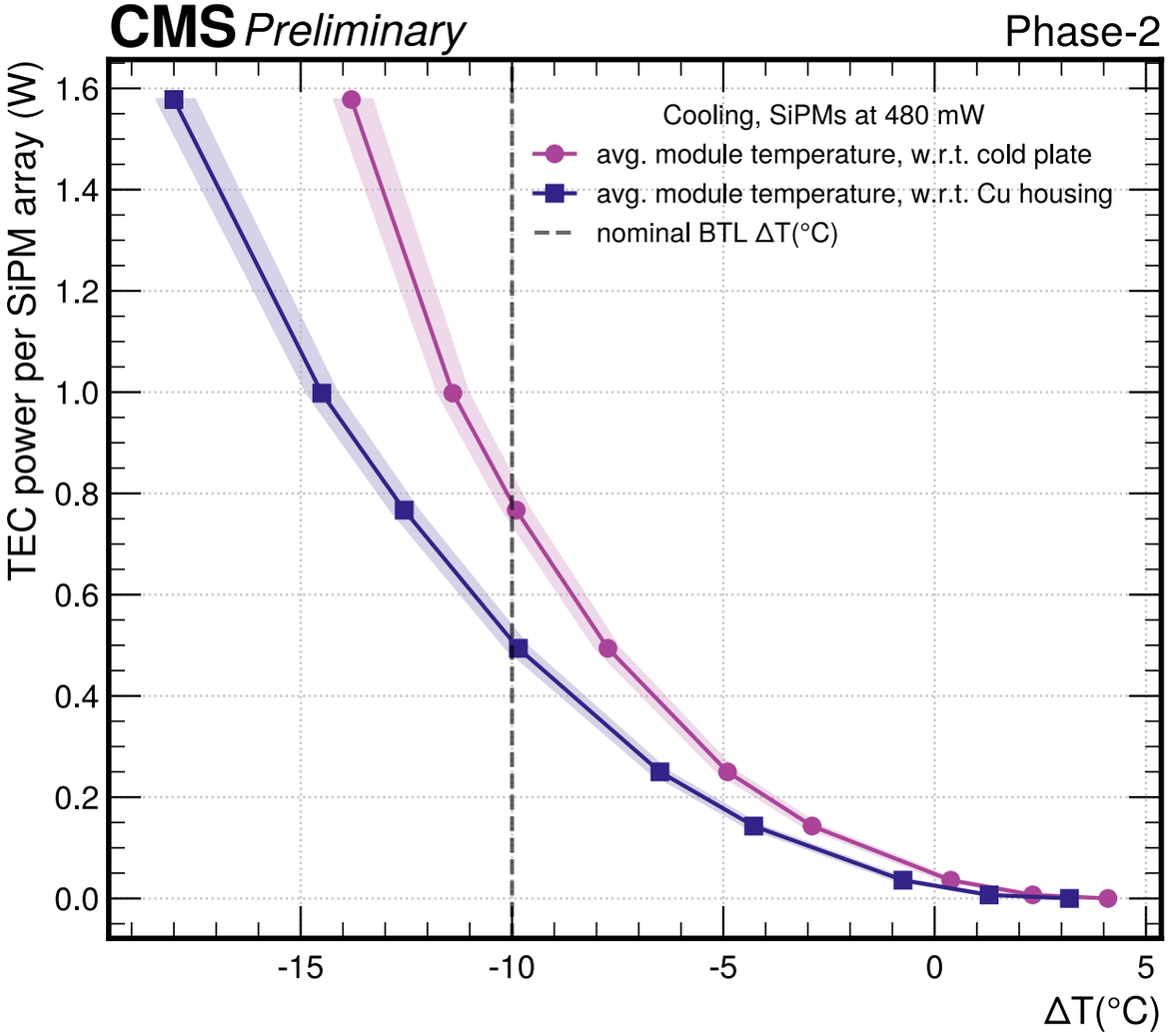
BTL thermal validation test setup at TIF

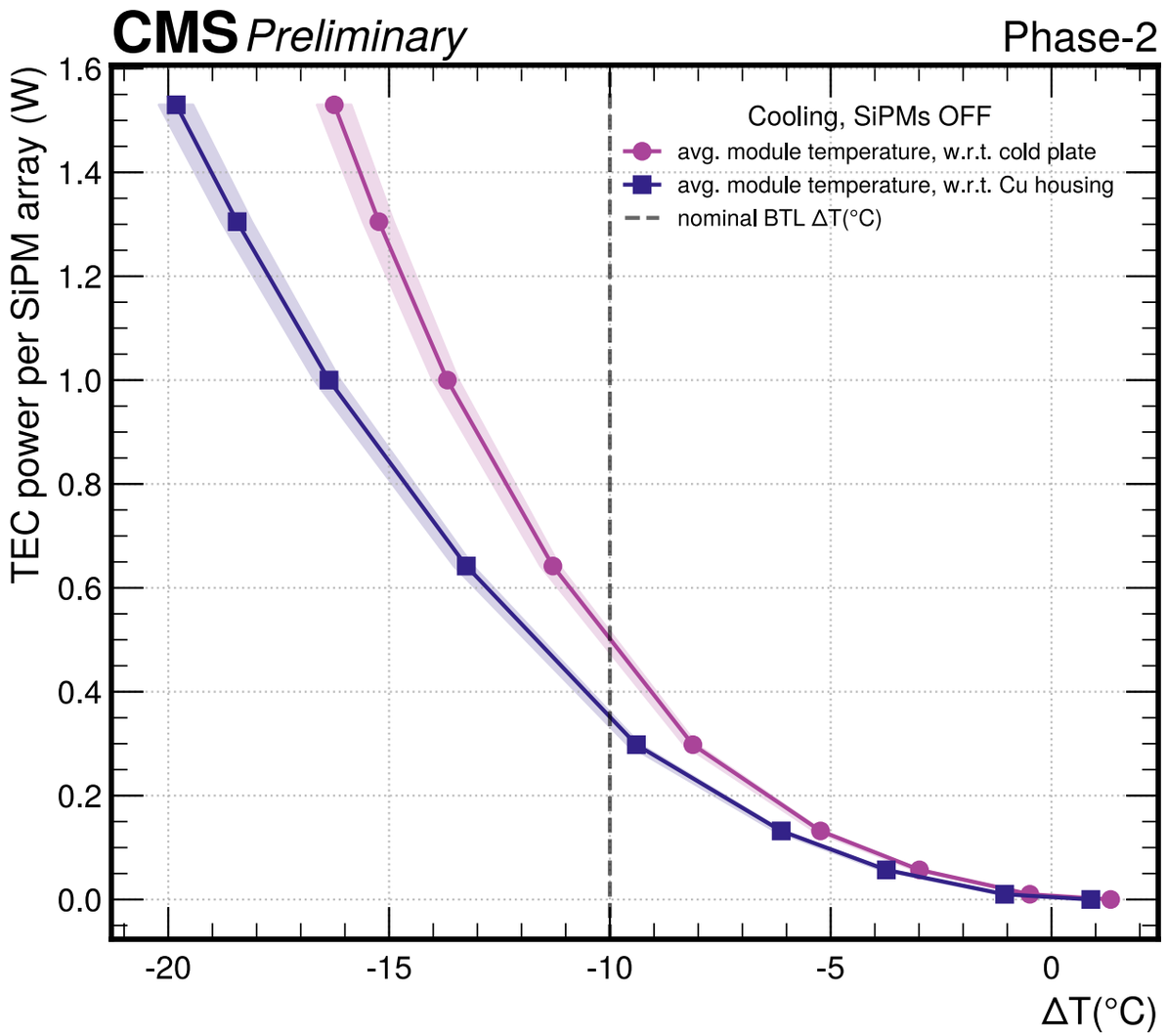




1. **BTL cooling tray assembly at TIF.**
2. **Cooling tray equipped with half of a mockup RU and micro-heaters.**
3. **Cooling tray covered with Armaflex.**
4. **Complete BTL thermal test setup at TIF.**

TEC cooling test results





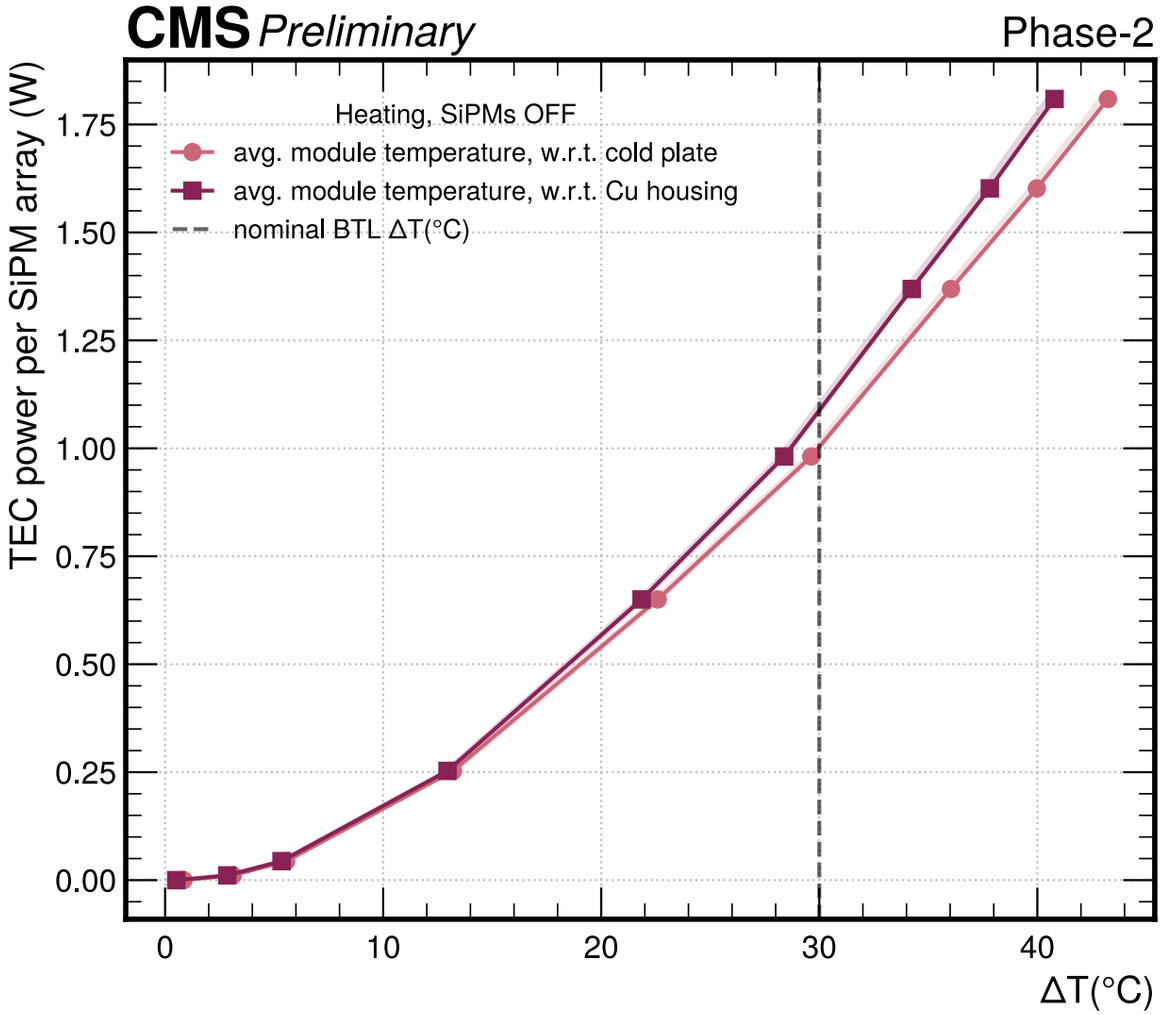
Caption

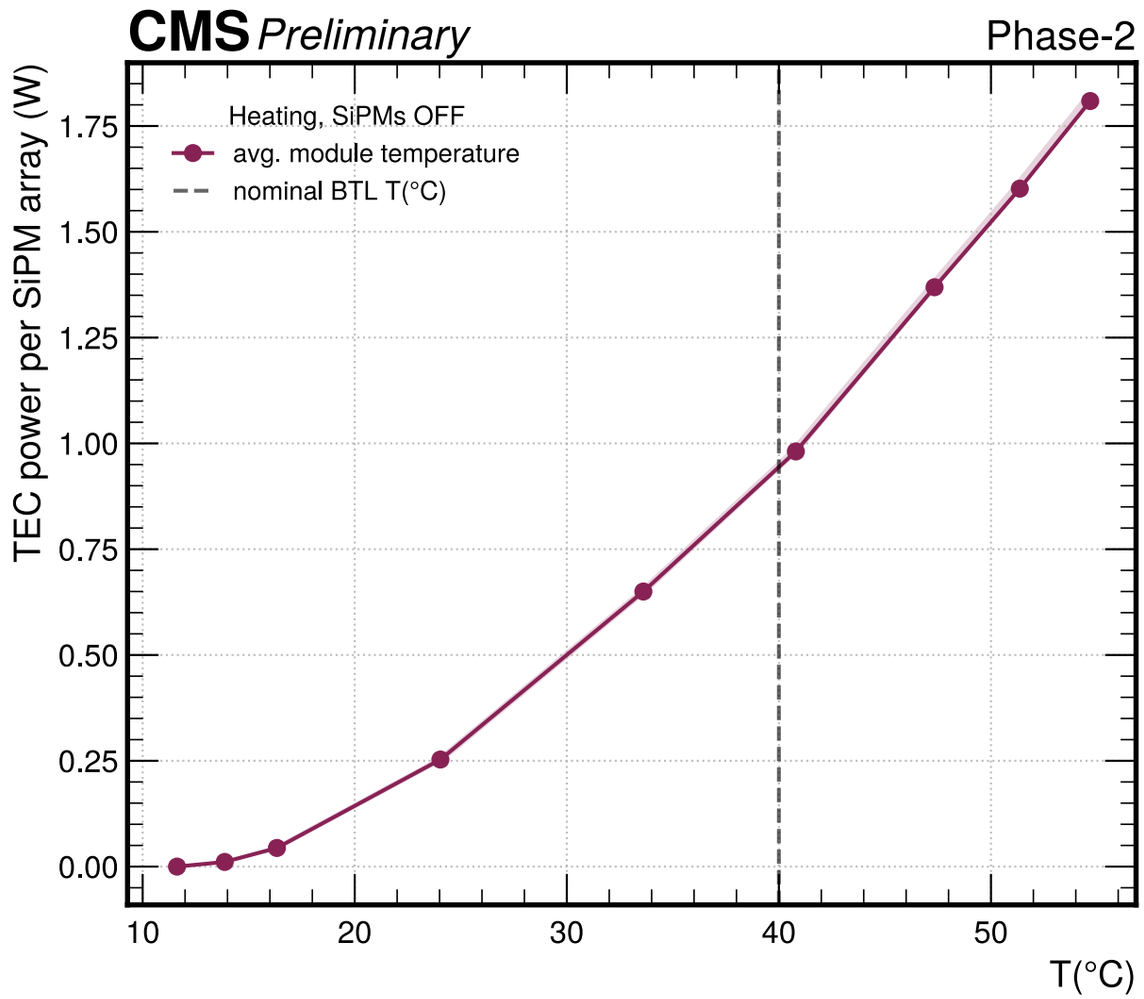
Power consumption of the thermoelectric coolers (TECs) attached to the SiPM arrays as a function of the average SiPM temperature gradient achieved for 3 different modules, relative to the copper housing (square markers) and the cold plate (circular markers) during TEC cooling operation. The left and right figures show the power consumption when there is a SiPM load of 480 mW and when there is no SiPM load, respectively. The shaded region represents the variability in the temperature readings across different modules. The dashed line at -10°C represents the nominal operating point of the TECs.

Factoring in variations in the test setup and environmental conditions, the results shown in the previous slide are comparable to the ones presented in [1]. During the tests, the cold plate was maintained at an average temperature of about -31.5°C. In the right plot, the SiPM temperature gradient relative to the cold plate remains above 0°C even when the SiPMs are turned OFF. This is attributed to the module's exposure to warm ambient air (heat dissipation from the microheaters and electronics warm up the ambient air) and the imperfect thermal coupling between the front-end electronics and the copper housing, as well as between the copper housing and the cold plate.

[1] A. Bornheim, et al., Integration of thermo-electric coolers into the CMS MTD SiPM arrays for operation under high neutron fluence, arXiv:2306.00818

TEC heating test results





Caption

The left figure shows the power consumption of the thermoelectric coolers (TECs) attached to the SiPM arrays as a function of the average SiPM temperature gradient achieved for 3 different modules, relative to the copper housing (square markers) and the cold plate (circular markers) during TEC heating configuration with no SiPM load. The right figure shows the power consumption as a function of the average absolute temperatures achieved. The shaded region represents the variability in the temperature readings across different modules, which is smaller compared to the cooling configuration and is only in one direction in the case of annealing. The dashed lines represent the nominal operating point of the TECs.

The results shown in the previous slide are in very close agreement to the ones presented in [1]. During the tests, the cold plate was maintained at an average temperature of about 11°C. The nominal BTL SiPM annealing temperatures of 40°C is achieved at a TEC input power of around 1W per SiPM array.

[1] A. Bornheim, et al., Integration of thermo-electric coolers into the CMS MTD SiPM arrays for operation under high neutron fluence, arXiv:2306.00818