Integration Test with CMS 2S Module Prototypes on a CO_2 Cooled Ladder

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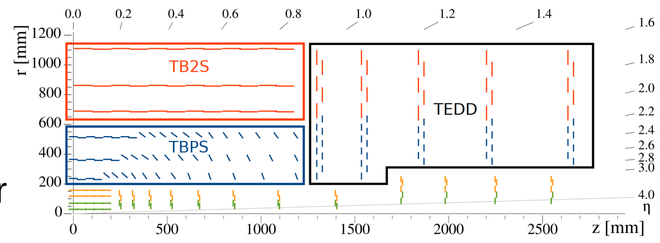
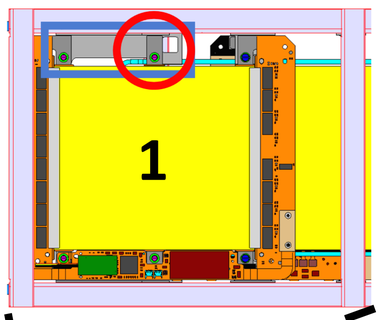
Jeremy Andrea, Giorgio Baldinelli, Francesco Bianchi, Alexander Dierlamm, Saskia Falke, Thomas French, Clement Haas, Ulrich Husemann, Stefan Maier, **Lea Stockmeier**, Cristiano Turrioni

Karlsruhe Institute of Technology · Institut Pluridisciplinaire Hubert Curien Strasbourg · Institute of Experimental Particle Physics

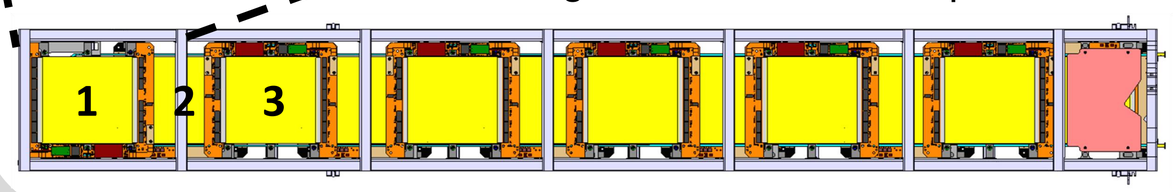
Phase-2 Upgrade of the CMS Tracker

- New silicon outer tracker (OT) for HL-LHC
- OT consists of 13,000 p_T-modules
  - 2S: strip/strip sensor
  - PS: pixel/strip sensor



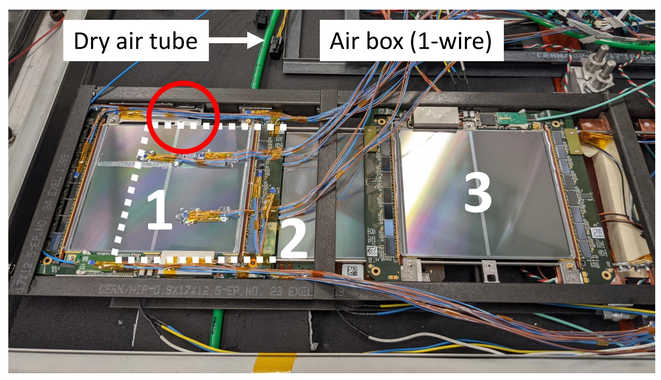


- Tracker Barrel (TB2S) formed by ladders equipped with twelve 2S modules each
- Additional 6th cooling point of module 1 at long cooling insert to improve cooling at this most critical position



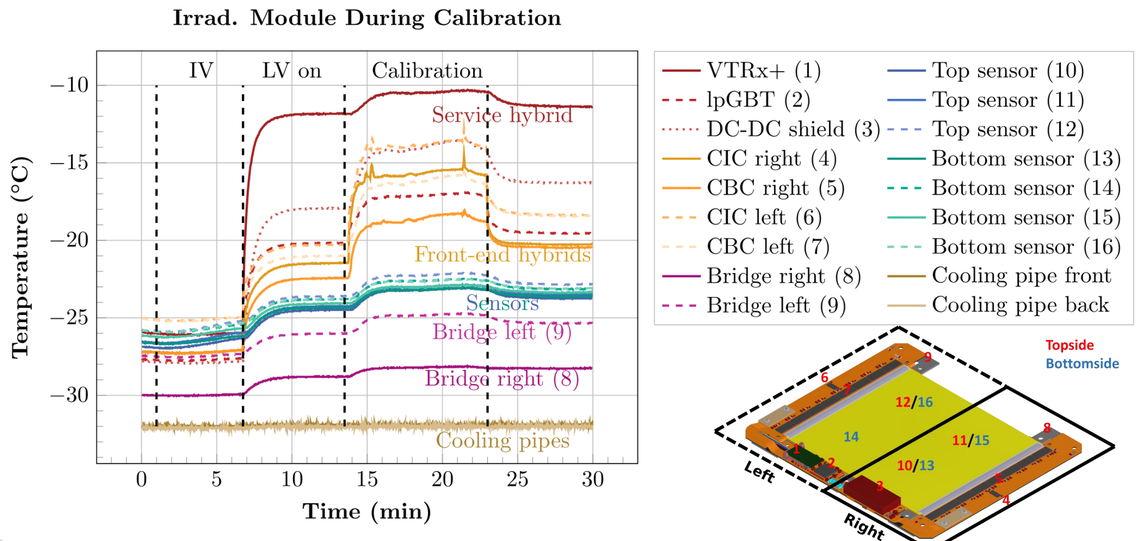
Experimental Setup

- Ladder in aluminum testbox in cold room at CERN
  - Ladder cooled with CO_2
  - Testbox flushed with dry air
- Three functional prototype modules mounted on ladder
  - Position 1: Irradiated module
    - Foreseen 6th cooling point missing
    - Early bridge prototype with less material
    - } Worsens thermal module performance
    - 16 temperature probes for detailed measurements
  - Position 2 and 3: Unirradiated modules
- Heating resistors at other cooling inserts
- ➡ Power consumption of ≈ 70 W across full ladder



Temperatures on Irradiated Module

- Temperature spread from left (dashed) to right (solid) module side due to long cooling insert

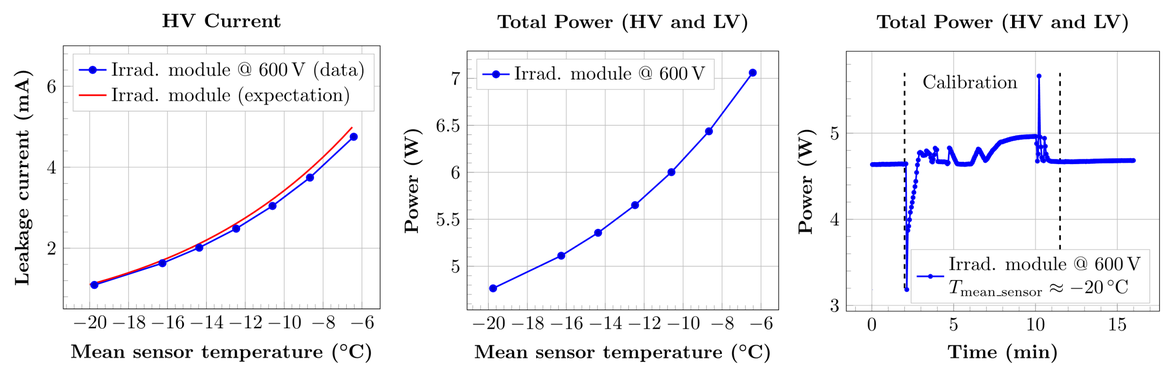


Irradiated Module

- Module components irradiated with 23 MeV protons at KIT before module assembly

Sensor	Top	Bottom
Fluence F (10^{14} $n_{eq}cm^{-2}$)	5.2	3.8
Annealing t_{ann} (days@RT)	154	154
% max. fluence@4000 fb^{-1}	140	101

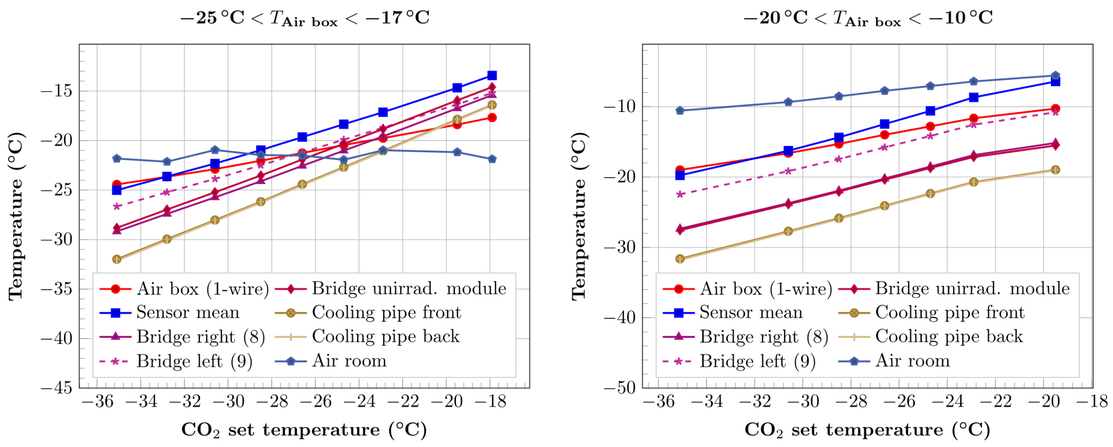
- Leakage current fits expected $I(T_{sensor}, F, t_{ann})$ from [1, 2]
- Power consumption of irradiated module below 5W at –20°C sensor temperature
  - Peak while calibrating the module about 1W higher



[1] A. Chilingarov, Temperature Dependence of the Current Generated in Si Bulk. JINST 8, P10003 (2013)
[2] M. Moll, Radiation Damage in Silicon Particle Detectors, DESY-THESIS-1999-040, University of Hamburg (1999)

Thermal Performance

- Changing CO_2 set temperature by adjusting pressure
- Convective cooling by cold dry air flux assists conductive cooling via pipes



Summary and Outlook

- Measurements show successful operation of an irradiated CMS 2S module on a ladder at various CO_2 temperatures
- No thermal runaway observed during measurements up to –19°C CO_2 set temperature
- Comparison with thermal simulation and single module measurements ongoing
  - Challenges are discussed on poster 35 by Christiano Turrioni