Comissioning of a Burn-In Setup for PS and 2S Detector Modules for the Upgrade of the CMS Outer Tracker

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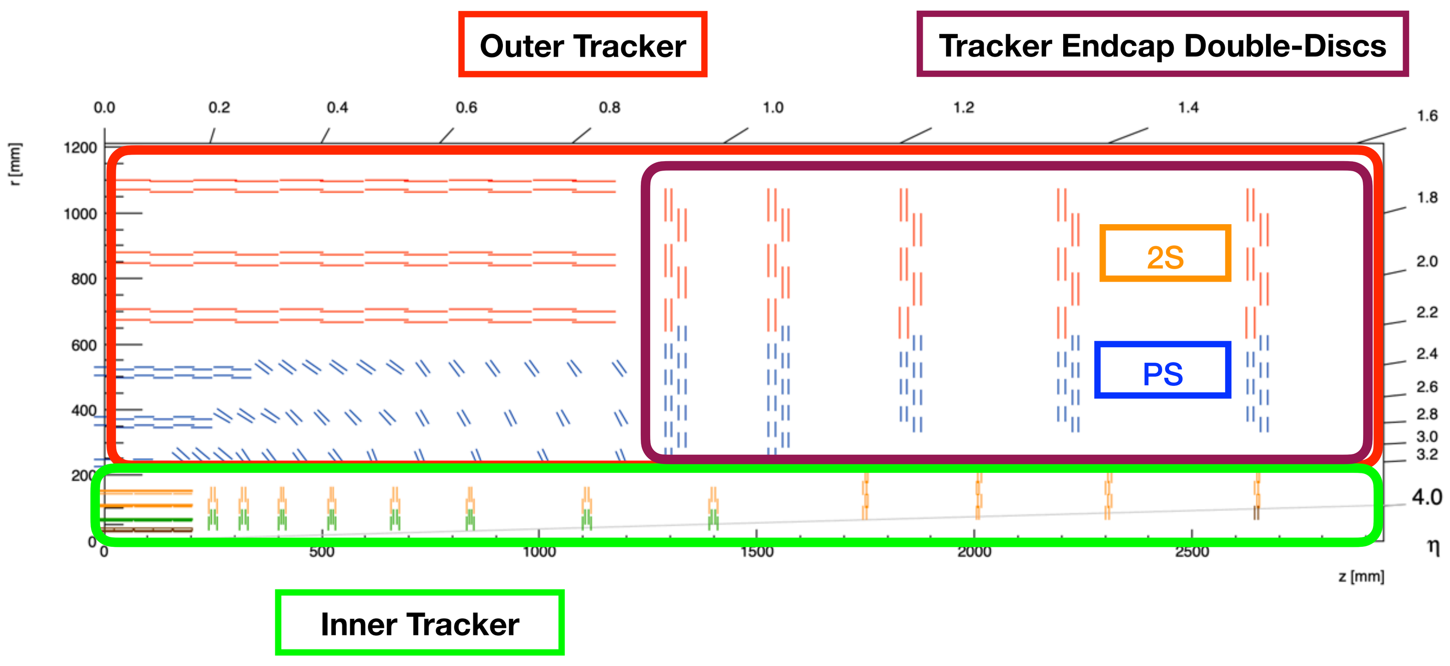
High Luminosity LHC

- Higher radiation levels, up to $1.1 \times 10^{15}\ n_{eq} \times cm^{-2}$ in the Outer Tracker
- Larger pileup, 140 and 200 expected, in comparison with the current 60
- Higher L1 rates, from the current ~110 kHz to 750 kHz

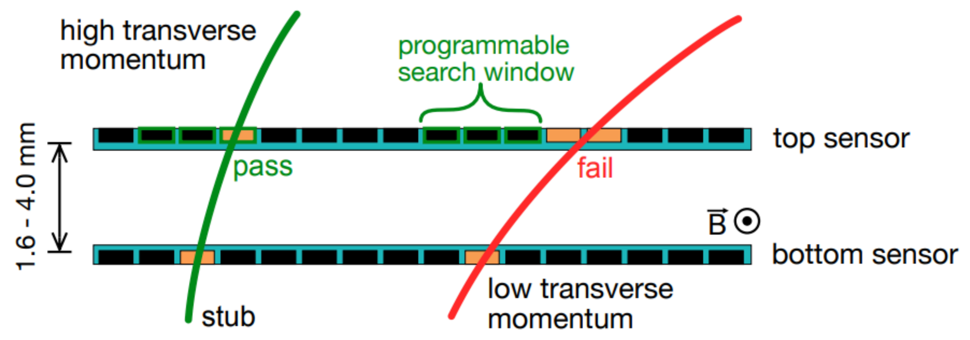
The Phase-2 CMS Tracker [1]

- Radiation tolerant - higher granularity - less material
- Tracks in hardware trigger (L1) making use of Outer Tracker information
- Coverage up to I η I = 4



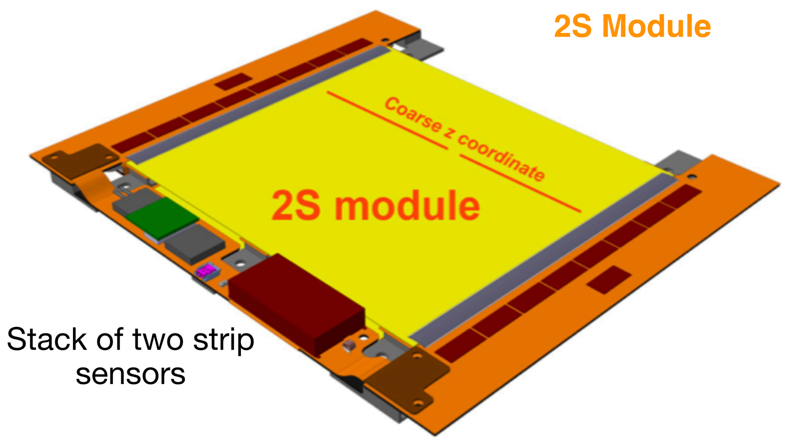
[1]: The Phase-2 Upgrade of the CMS tracker. Technical Design Report. CMS-TDR-14

Transverse Momentum Discrimination



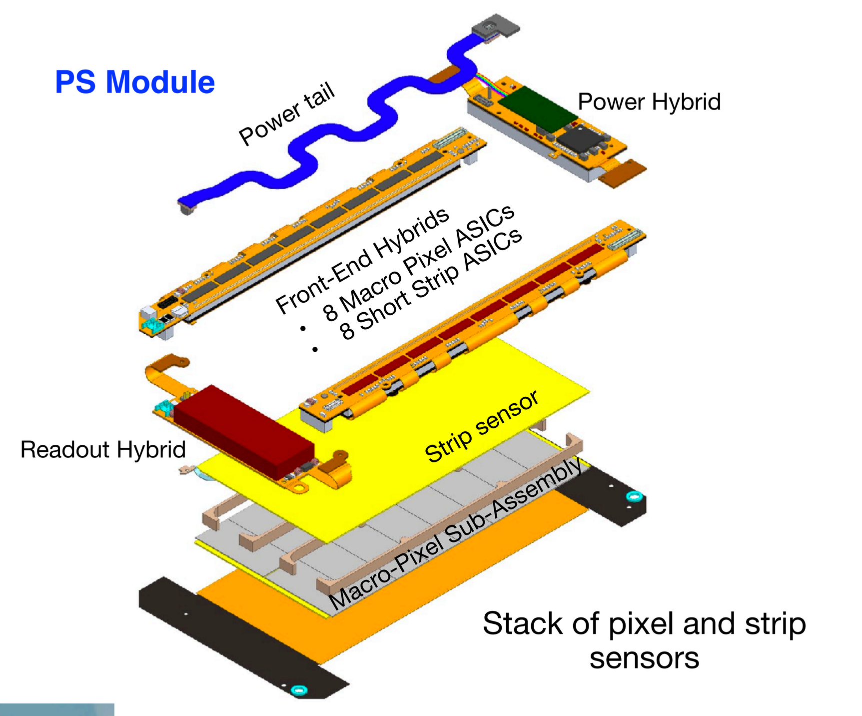
Based on the correlation of the signals within a programmable search window

- Rejection of low transverse momentum particles



Stack of two strip sensors

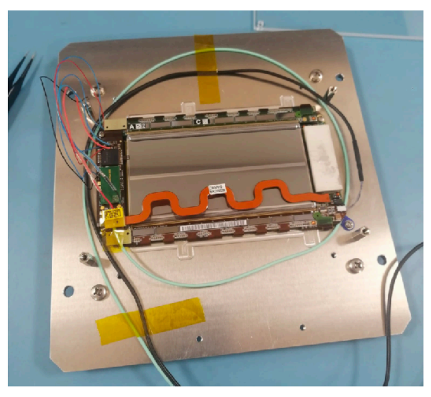
P_T discriminating detector modules



Stack of pixel and strip sensors

At DESY

- Module Production
  - 1120 PS modules at DESY
- Burn-in test
  - DESY PS modules and 800 2S modules from Aachen
- Dee (half disc) integration and 5 Double-Discs assembly
  - 2S modules coming from Aachen and KIT
- Tracker Endcap Double-Discs assembly and integration will be done at CERN



Modules and connectors are delicate. To avoid handling them during the different production and test steps

- Carrier plate

Burn-in test

Final test for module qualification to certify that a module is good for integration

Why:

- Modules quality control needed
  - Ensure operation at operating temperatures (-35 ˚C)
  - Ensure long term operation
  - Ensure correct functionality of module after warmup and cooldown cycles

Specifications:

- 24h test with 5/6 cycles
- 10 modules per setup in parallel
- Running unattended

How:

- Thermal cycles from room temperature to operating temperature
- I-V measurement in warm and in cold
- Noise measurements before the test, after the first cool down and at the end of the test

~2000 modules to be tested

At DESY we will have 2 burn-in setups

Different flavour (2S and PS)

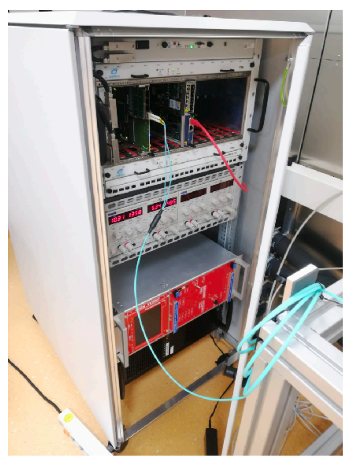
System overview

Chiller

- Unistat Hubber Pilot One

Controller Board

- Interface between the temperature and dew point sensors and the DAQ software

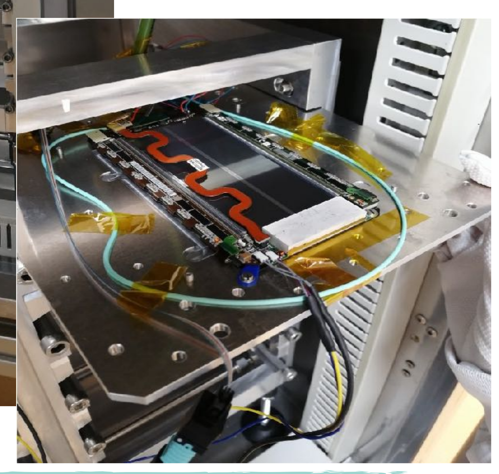


Rack

- Power supplies
- Read-out system
  - FC7: FPGA-based circuit board

Fridge: Passive cooling unit

- Carrier plate support
- Cooling pipes connected to the chiller
- Temperature sensors
- Dew point sensor
- Magnetic interlock
- Dry air supply



Temperature studies

Studies performed during commissioning for understanding the distribution of cooling through the module

- 7 thermistors attached to different positions
- Check homogeneity through the module, thermal contact and hot spots

S1: on top of the optical link module (VTRx+), located in the Readout Hybrid

S2: on top of the DCDC converter in the Power Hybrid

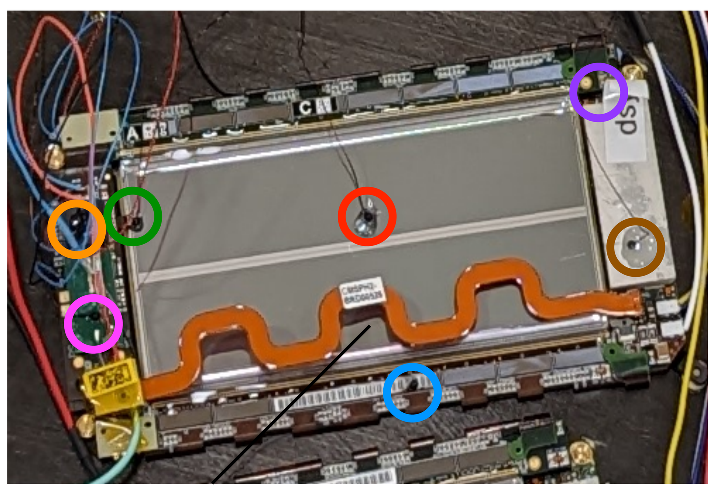
S3: on the low-power Gigabit Transceiver (lpGBT), located in the Readout Hybrid

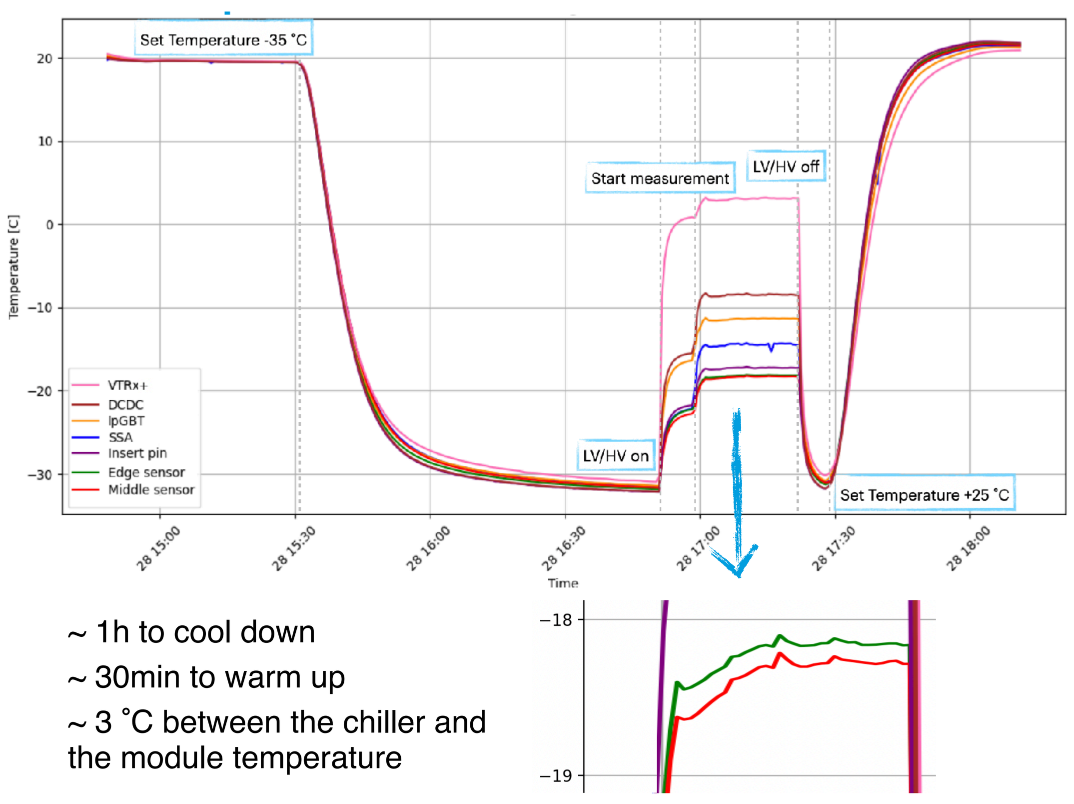
S4: on one of the Front-End Hybrids

S5: next to one of the insert pins

S6: in the edge of the the Strip sensor, next to temperature sensor in the hybrid

S7: in the middle of the Strip sensor





~ 1h to cool down

~ 30min to warm up

~ 3 ˚C between the chiller and the module temperature

Observations

Highest temperature at S1 (VTRx) when module is powered. High temperature in S2 and S3 when powered and configured

- Non-optimal thermal contact with the carrier plate

S4 big increase when starting a measurement

- Localized power dissipation during configuration and readout

S5 expected to be the coolest (proximity to module's thermal contact)

S6 and S7 almost same temperature

- Good homogeneity in the Strip sensor

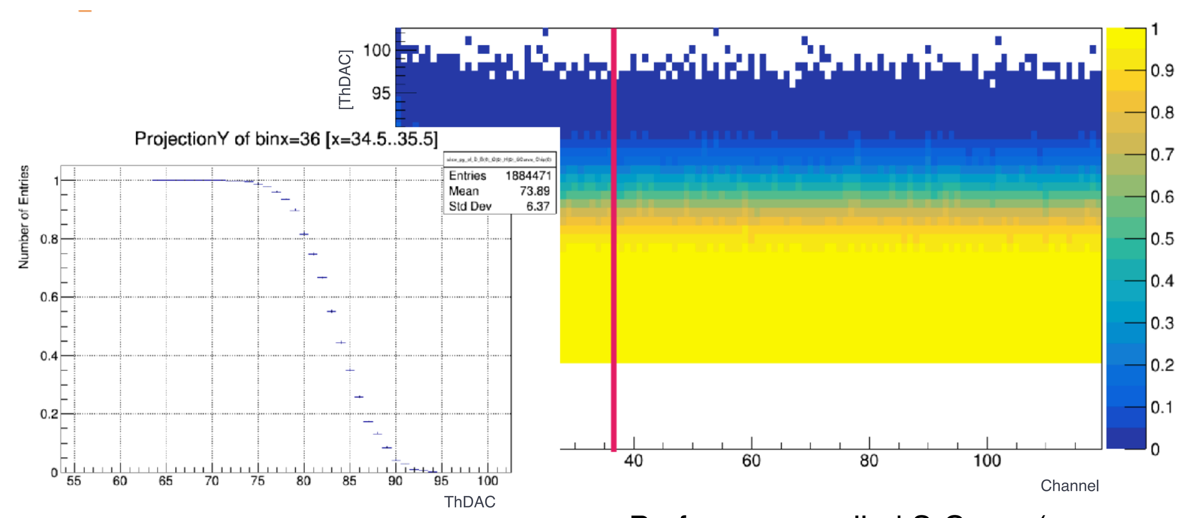
Noise studies

Noise is a key measure of the quality and performance of each individual Front-End channel

- Used to optimize the design and operation of the module

Noise level targeted

- Around 4 ThDAC for Strips
- Between 2 and 3 ThDAC for Pixels

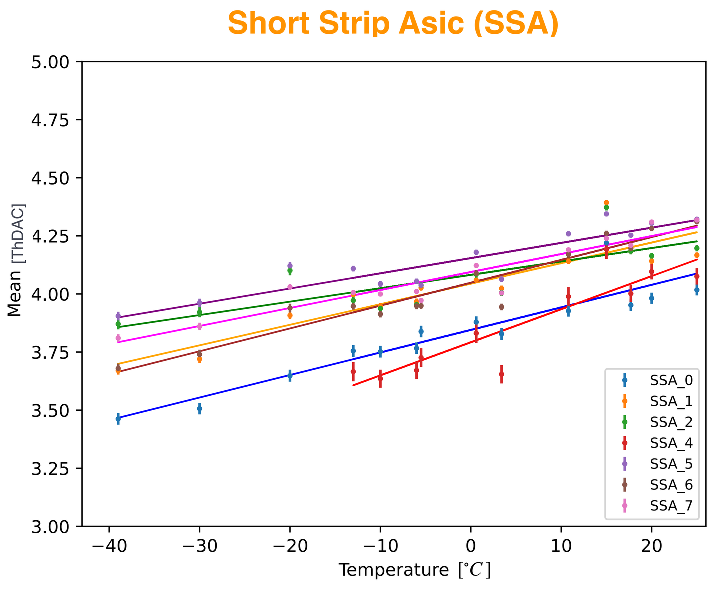


Perform a so-called S-Curve (occupancy as a function of threshold measurement) and fit it for each channel with an error function

$$f(x) = \frac{1}{2} erf(\frac{x-\mu}{\sqrt{2}\sigma})$$

Extraction of the pedestal (μ) and the front-end channel noise (σ)

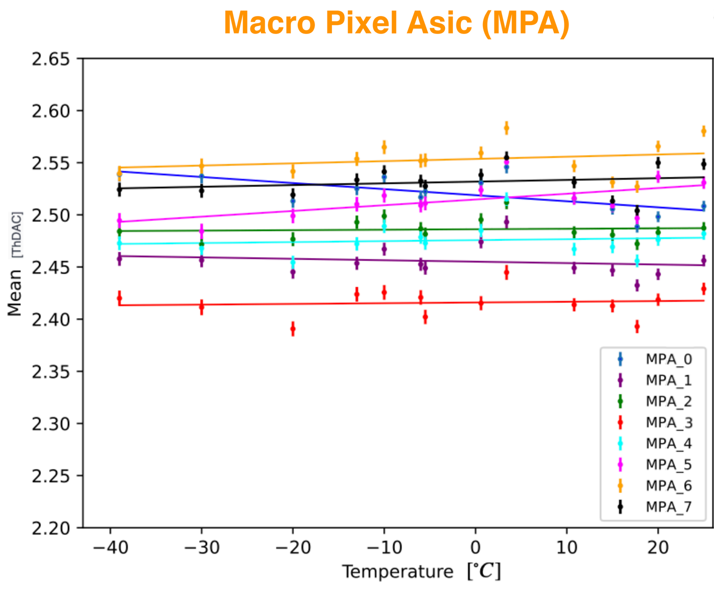
Short Strip Asic (SSA)



The noise decreases in the SSA while the temperature decreases as expected

1 ThDAC = 0.040 fC = 250 electrons

Macro Pixel Asic (MPA)



For the MPA, the noise is constant with respect to the temperature as expected

1 ThDAC = 0.015 fC = 94 electrons

HV Bias -300V

Dew point between -54˚C to -58˚C

Temperatures from 25˚C to -40˚C in the carrier plate

Conclusions

- The Burn-in setup is usable for the first modules but not yet fully automated
- Temperature studies were performed showing good homogeneity with the power off and the expected behaviour when turning on and performing a measurement
- Noise measurements showed expected behaviour

Next steps

- Extreme cold test of the module
- Optimization of the time needed to reach stablehand lower temperatures
- Automated temperature cycles measurement
- A full burn-in test (24h temperature cycle with noise measurements) of a functional module

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