16th Pisa Meeting on Advanced Detectors

Noise and performance tests results of the PS modules for the phase-2 CMS Outer Tracker

I.Margjeka on behalf of the CMS Tracker group
INFN, section of Bari ilirjan.margjeka@cern.ch

Istituto Nazionale di Fisica Nucleare
Sezione di Bari

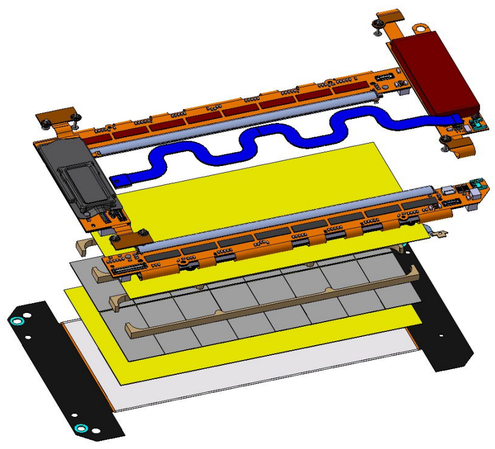


Fig. 1 Exploded view of the PS module

1.INTRODUCTION

The CMS experiment will undergo an upgrade for the HL-LHC project to reach an instantaneous luminosity up to 7.5 × 10^{34} cm^{-2} s^{-1} . The total integrated luminosity is planned to be 4000 fb^{-1} for a lifetime of ten years. The new requirements for the CMS Tracker upgrade for the HL-LHC project are:

- Radiation tolerance: According to simulations with FLUKA, at an integrated luminosity of 3000 fb^{-1} , at 14 TeV center of mass energy, we expect a maximal fluence of 2.3 × 10^{16} n_{eq} / cm^2 in the innermost regions of the Inner Tracker, one order of magnitude higher then the current CMS Tracker
- Increased granularity: The pile-up will increase from ~60-65 in Run III (2023) up to 140 - 200 collisions per bunch crossing
- Improved two-track separation
- Reduced material in the tracking volume
- The L1 trigger rate will increase up to 750 kHz,
- The new latency will be about 12.5μs .
- Contribution to the Level-1 trigger: Solution at hardware level (strip-strip silicon 2S pixel-strip PS modules)

The upgraded CMS Outer Tracker (OT) (Fig. 3) will be composed out of the new pixel-strip (PS) and strip-strip (2S) modules, arranged as shown in Fig. 3. The PS modules will be assembled by **DESY (Germany), INFN Bari and Perugia (Italy), US East (Brown, Princeton and Rutgers University), US Midwest (FNAL)**

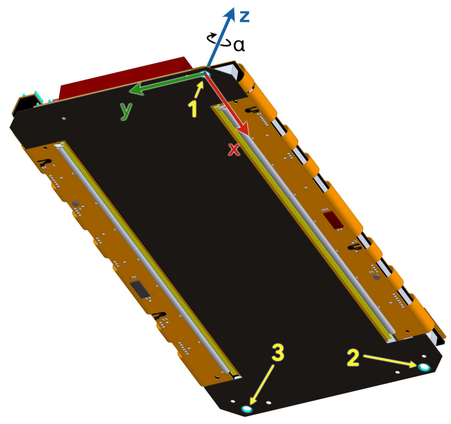
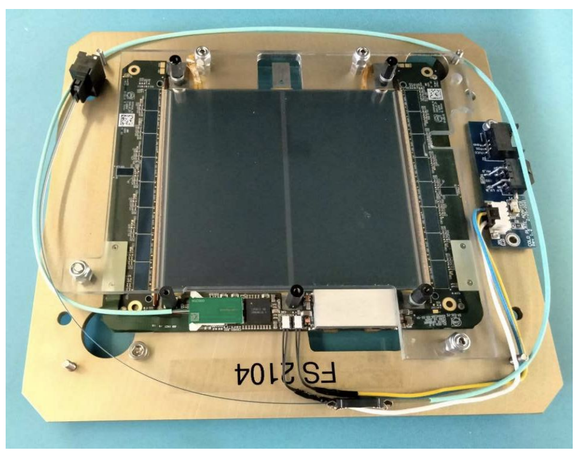
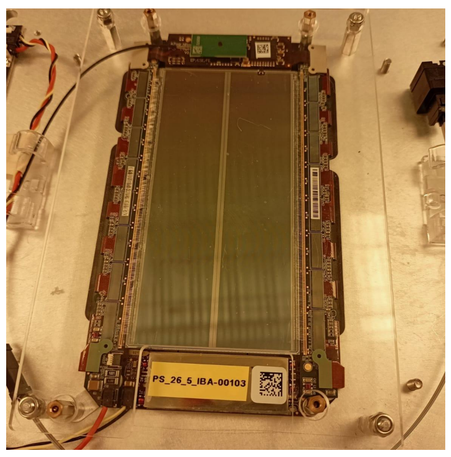
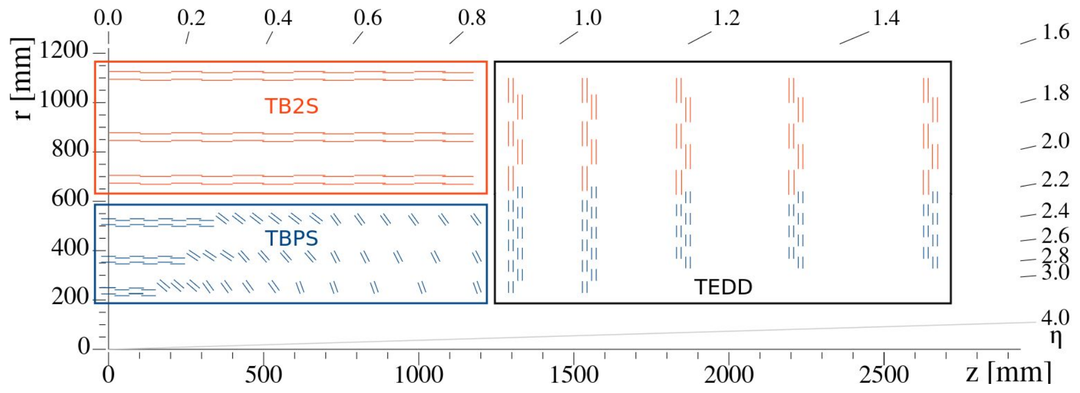


Fig. 2 View from the back side of the PS module

Fig. 3 2S and PS modules of the CMS OT; Schematic view of one quarter of the Phase-2 CMS OT tracking system in r-z view, where in blue are the PS modules, in red the 2S modules





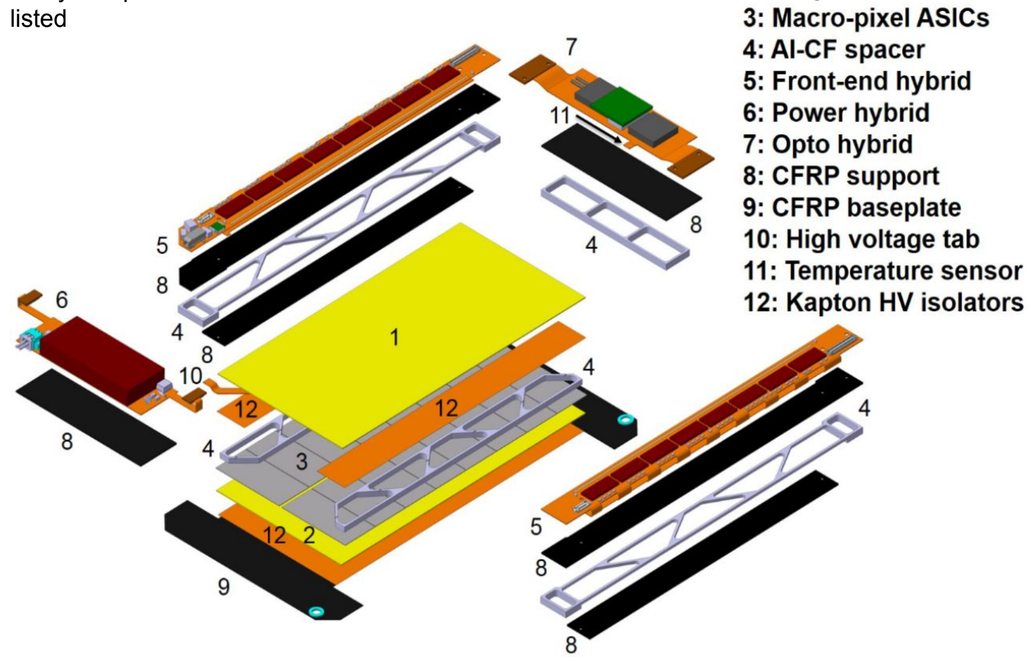


2. The Pixel-Strip (PS) modules

The silicon pixel-strip (PS) modules for the upgrade of the CMS Outer Tracker are made of:

1) Macro Pixel sensor, connected to 16 Macro Pixel ASIC (MPA) chips with 16x120 pixels each (~ 1.5mm × 100μm)
2) Strip sensor, read-out by 16 silicon Short Strip ASIC (SSA) chips, 120 strips each (~ 2.4cm × 100μm).
3) The two sensors are glued to each other separated by ceramic spacers of 1.6, 2.6 or 4.0 mm thickness.
4) The pixel-strip sandwich lies over a thermal conductive kapton sheet, which covers the carbon fiber baseplate.
5) The PS Power Hybrid (PS-POH) delivers the power to the PS module.
6) The pixel and strip sensors are wire-bonded to two Front-End Hybrids (FEH, left and right) interconnected with the PS-POH on one side and with an optical Readout Hybrid (ROH) on the opposite side.
7) Data is carried out from each FE chip and the Concentrator Integrated Circuit (CIC) through 6 differential lines @320MHz and from the CIC to the lpBGT via 6/7 differential lines @320/640Mbps
8) The Versatile Link Plus Transceiver (VTRx+) provides a multi-gigabit optical physical data transmission layer for the readout and control of the PS module at 5 or 10 Gb/s, very important for the High Luminosity LHC (HL-LHC) project.

Fig. 4 Exploded view of the PS module with every component listed



3.The principle of PS modules tracking

The OT modules provide the high-p_T information (particles with a p_T ≥ 2 GeV threshold) to L1 tracking at 40 MHz. The PS modules are designed to reconstruct high p_T particle tracks.

Correlated hit pairs (“stubs”) compatible with particles above a p_T threshold of ≥2 GeV, will be sent to the back-end electronics at 40 MHz to build L1 track primitives .

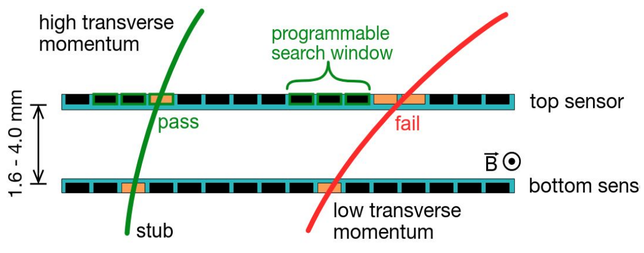
In this way, the coordinates of the hit on the pixel sensor and the momentum with the bending angle in the r − φ plane of the particle track, will define position of the stub.

The Stub Finding algorithm discriminates the particle tracks based on the bending value. The principle of p_T -discrimination is shown in both pictures (below)

4. Noise studies of PS modules

According to simulations (CMS Tracker TDR[1]), the analogue front-end stage features a 17 (24) ns for the SSA (MPA) peaking time (with return to baseline in less than 50 ns) and a 700 (200) electron RMS equivalent noise contribution for the PS-s (PS-p) sensor’s strip capacitance of 4–5 pF (260–280 fF pixel capacitance plus 220 fF of internal capacitance), to be compared with an expected seed signal of 8000 electrons after 1.5 times the nominal fluence. Tests are performed at room temperature (20ºC) and up to −35ºC , using the burn-in system at FNAL, DESY and INFN of Pisa.

Preliminary results at room temperature (20ºC) done with the kick-off batch PS modules show noise values ~4 ThDAC units for the SSA, and ~2.5 ThDAC units for the MPA, comparable with the expected value at RTH. (where 1 ThDAC = 94 electrons for the MPA, 1 ThDAC=250 electrons for the SSA).



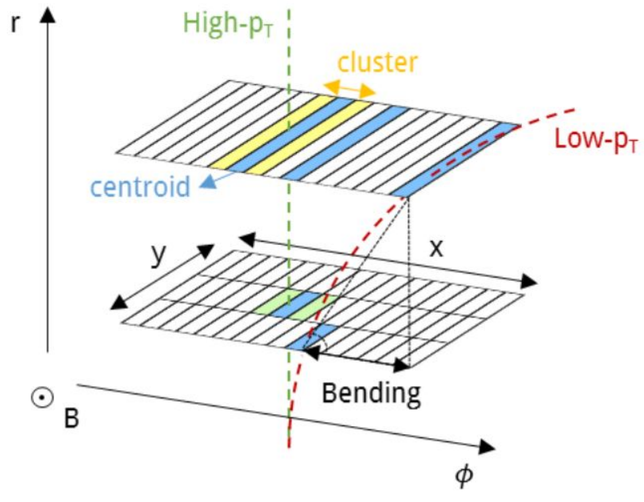


Fig. 5 Two views of the principle of *pT* discrimination in the OT modules

5. CONCLUSIONS

- The assembly procedure of the PS modules is well defined.
- Pre-production of the final PS modules is planned for summer 2024 and full production will start by early 2025.
- A lot of tests with almost the final version of the hybrids have been done (from lab tests up to beam tests at DESY, FNAL and at CERN), in order to access their performance and evaluate the noise values of the pixel and strip sensors.
- Already at room temperature, preliminary results show that we are close to the nominal expected values of the noise (~ 3.6 ThDAC for the strips and ~ 2.5 ThDAC for the pixels).
- The general behaviour looks very promising: more tests down to −35ºC will be done to simulate the cooling temperature for the modules at the CMS Outer Tracker.

REFERENCE(S)
[1] The Phase-2 Upgrade of the CMS Tracker CERN-LHCC-2017-009 ; CMS-TDR-014 10.17181/CERN.QZ28.FLHW