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Status of the silicon strip detector at CMS

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ABSTRACT

The CMS Tracker is the world's largest silicon detector. It has only recently been moved underground and installed in the 4 T solenoid. Prior to this there has been an intensive testing on the surface, which confirms that the detector system fully meets the design specifications. Irradiation studies with the sensor material shows that the system will survive for at least 10 years in the harsh radiation environment prevailing within the Tracker volume. The planning phase for SLHC as the successor of LHC, with a 10 times higher luminosity at the same energy has already begun. First R&D studies for more robust detector materials and a new Tracker layout have started.

1. Introduction

The CMS Tracker project was inaugurated more than 10 years ago. Only recently the completed Tracker has been inserted underground into the center of the CMS magnet, hence marking the turning point from the construction phase to the actual experiment.

According to the CMS philosophy, the silicon strip Tracker is designed as a compact, hermetically closed system. Each track is recorded with at least 10 high resolution space points in the range $|\eta|<2.4$ [1,2].

The LHC environment, namely the short (25 ns) bunch structure and the high luminosity of $10^{34}\,(\mathrm{s\,cm^2})^{-1}$ led to the chosen high granularity of 10M readout channels and special radiation hard ⟨100⟩-Si sensor material. The Tracker will be operated at a temperature of $-10\,^{\circ}\mathrm{C}$ to reduce the irradiation induced leakage currents and to permit a stable 10 years of operation.

2. Constituents

The Silicon Strip Tracker consists of 15 148 silicon strip detector modules which are grouped in four large substructures: the Tracker Outer Barrel (TOB), the Tracker Inner Barrel (TIB), the Tracker Inner Disk (TID) and the Tracker EndCap (TEC) (see Fig. 1).

2.1. The barrels

In the two barrel substructures the strips of the modules are oriented parallel to the beam and the prevailing 4 T magnetic field. The modules are arranged in four (TIB) respective six (TOB) concentric cylinders "shells" around the beam axis, covering the radial range $25\,\mathrm{cm}<r<108\,\mathrm{cm}$.

Two of these layers in TID as well as in TOB are "stereo layers": here modules are mounted in back-to-back pairs, where one module has an axial strip orientation and the second module oriented at an angle of 100 mrad with respect to the first. The resulting strip crossing leads to an enhancement of the spatial resolution along the strip direction by about two orders of magnitude.

The modules for the TIB subsystem are directly mounted on carbon fiber half shells—two of which combine to a full shell. The four shells of the inner barrel are assembled together and constitute an independent detector unit in the sense of cooling, powering and readout. Fig. 2 shows how the TIB modules are mounted so that they overlap on their shells.

For the outer barrel system the modules are installed on "rods" (Fig. 3), which in turn are used to populate the six layers. A rod is a carbon fiber frame equipped with a cooling tube and a pcb motherboard to enable the operation of six modules (12 modules for stereo layers). The TOB consists of 688 rods mounted in a large carbon fiber support structure.

2.2. The disks

In the TID and TEC substructures (Fig. 1) the modules are oriented perpendicular to the magnetic field. They are arranged in seven rings (three rings for TID) at different overlapping radii around the beam axis. All strips point radially to the beam axis

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[1] On behalf of the CMS Tracker Community.

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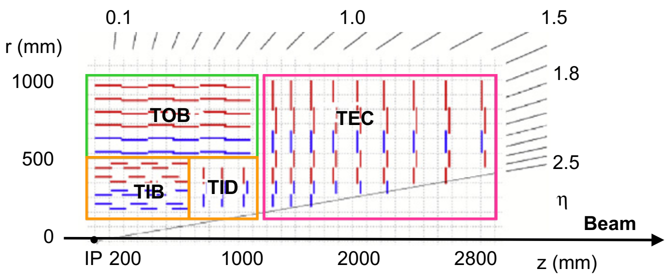

Fig. 1. Schematic view of a sector of the Tracker. Each line represents a detector module. The structure is meant to be rotated around the beam axis and mirrored at the interaction point.

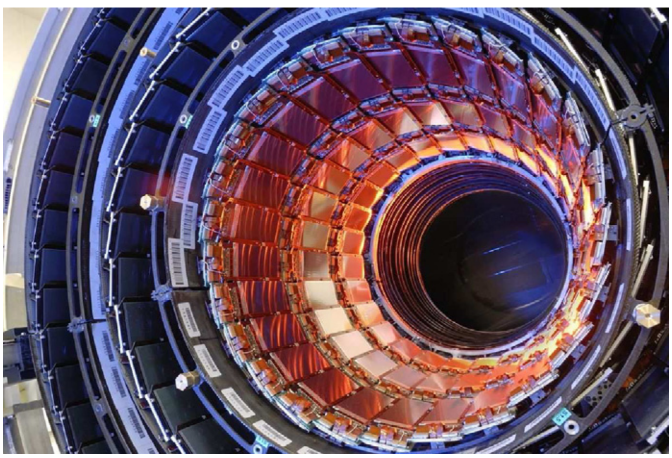

Fig. 2. Tracker inner barrel.

Fig. 3. Carbon fiber support structures for TOB and TEC: (left) a rod in three different phases of construction; (right) a fully assembled petal.

except for the stereo modules in three rings (numbers #1, #2 and #5). In these cases the strips of one module are rotated by an angle of 100 mrad with respect to its back-to-back partner. The radial pointing is achieved through a wedge-shaped sensor design. Keeping the *width*/*pitch* ratio for all strips constant, the signal-to-noise value for particle hits remains independent from the position along the strip. Each ring requires its own sensor design, which led to a large number of different sensors and modules (Fig. 4).

On the three TID disks, the modules are mounted in full rings on carbon fiber support structures, three rings per disk.

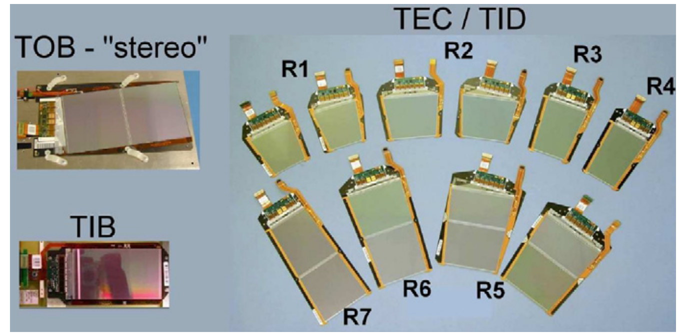

Fig. 4. Many different module geometries are needed in the different substructures of the Tracker.

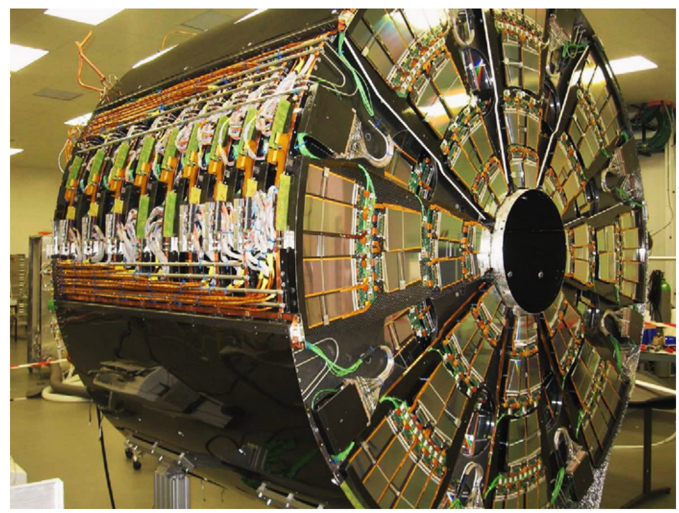

Fig. 5. One Tracker EndCap fully equipped with petals.

A Tracker EndCap (Fig. 5) consists of nine large disks. Modules are not directly mounted to these disks, but to intermediate structures called "petals"—wedge-shaped portions of the disk. The production of these structures allowed a reasonable distribution of assembly tasks among the TEC community (Fig. 3). Sixteen petals are required for one disk. Eight different types of petals are needed with different numbers of modules, depending on the distance from the interaction point; e.g. the farthest disk need not be equipped with the three inner rings to cover the region $|\eta|<2.4$ (Fig. 1).

After completion and individual testing of these four Tracker substructures, the Tracker was assembled within an aluminum support tube which provides thermal insulation in addition to mechanical stability. Equipped with an insulating foam with cooling pipes on the inner side and an electrical heating outside it acts as a thermal shield against the neighboring electromagnetic calorimeter, which requires a temperature of 18 °C, whereas the silicon sensors of the Tracker are cooled down to −10 °C.

3. Performance

During all steps of construction every individual part has been carefully tested. Every detector module as well as the larger structures—rods, petals, half shells and TID disks—have been operated and thermally cycled to ensure reliability when used in the collision hall.

Moreover, a large effort has been made with prototypes from both barrel substructures and the EndCap to study the system