The CMS Silicon Strip Tracker

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Abstract

The CMS tracker is the first large scale tracker entirely based on silicon strip detectors technology. A few numbers to clarify the dimensions of this project: active silicon area of 198 m^2, 15148 silicon strip modules, 9.316.352 analogue readout channels, -10^{o}C sensor operating temperature, radiation resistance up to 2x10^{14} n/cm^2.

The realization of such a scientific instrument is based on the following points. Availability of excellent performance, low price, radiation tolerant, frontend chips realized in 0.25 μm technology. The silicon sensor design is of P on N type: in such a way they maintain adequate performance after bulk type inversion once operated at high bias voltage; metal over-hang is implemented to obtaining sensors with high breakdown voltage. The <100> orientation of the crystals minimizes the surface damage. Simple design rules are used for guard ring and strip geometries, obtaining sensors that can be produced in large 6” industrial lines, with high yield and affordable price. The assembly of over 15,000 detector modules has been carried out using automatic machines, saving manpower and producing modules with a high precision and reproducibility. The module testing team has characterize each single strip of the whole production set, probing also early failure at realistic final experiment conditions. Module production yield in the range 95-99% and fraction of bad strips less than 0.1% have been achieved.

A few words to describe the CMS Silicon Tracker layout. The innermost region (at radii below 15 cm) hosts the Silicon pixel vertex detector (not covered by this presentation); the Silicon Strip Tracker occupies the radial range, around the LHC interaction point, between 20 and 110 cm. The barrel region (jzj < 110 cm) is split into an Inner Barrel (TIB) made of four detector layers, and an Outer Barrel (TOB) made of six detector layers. The TIB is shorter then the TOB, and is complemented by three Inner Disks per side (TID) each made of three rings. The region 120 < jzj < 280 cm is covered by nine End-Cap (TEC) disks per side, each made of seven rings. The whole tracker region is embedded into a 4 Tesla solenoidal magnetic field.

Detectors of the TIB, TID, and of the four innermost rings of the TEC have strip lengths of approximately 12 cm and pitch between 80 and 120 μm. These detectors are made of a single sensor of 320 μm thickness. In the outer part of the tracker (TOB and three outermost TEC rings) strip length and pitch are increased by about a factor of two with respect to the inner one. In order to compensate for the noise increase due to the higher inter-strip capacitance, a silicon thickness of 500 μm is chosen for these larger detectors.

The signals coming from each silicon strip are processed by frontend readout chips (APV25) mounted on the detector kapton-based hybrid circuit. The APV25 is built in radiation hard 0.25 μm CMOS technology. It is a 128 channel chip which samples at the LHC frequency of 40 MHz and implements a charge-sensitive amplifier with a time constant of 50 ns, a shaper and a pipeline memory. This frontend chip can be also operated in the so called ‘deconvolution mode’ where three consecutive samples are used to eventually compensate for nearby bunch crossing contributions leading to an effective time constant of 25ns which is important for correct bunch crossing identification in the high luminosity running phase of the LHC. The electrical signals are then converted to optical signals in dedicated Analog-Opto Hybrids, and transmitted to the counting room by means of multimode optical fibres, where they are digitized. The entire readout chain is able to sustains a level 1 trigger rate of about 100KHz. Data coming from the Silicon strip tracker will also be used by the CMS High Level Trigger.

The module and other Silicon strip tracker components production is now finished. The integration of module, electronics, mechanics and services all together to finally arrive to the construction of a working scientific instrument has started last year and it is now to a well advanced stage.

This presentation will review the CMS silicon tracker design and construction with particular emphasis on the TIB and TID integration activities and results.

The TIB-TID modules are assembled into large structures each of them containing several hundreds of different components: TIB structures are half-shell shaped, four for each layers, while TID ones are disks.

The integration starts from the carbon fibre based mechanics, which already contains the cooling pipes and precision ledges for modules mounting and cooling. Then the analogue opto-hybrids, with two metres long optical fibres tails attached to them, are mounted onto the structure routing the fibres outside the half shells to a temporary fibre holder. Modules are then mounted on the ledges and tested, together the opto-hybrids, for communication and full functionality (high voltage test at 400V and noise measurements). Finally the control electronics are mounted and cabled on the mechanical structure and everything is fully tested again before sending the structures to the burn-in test to be performed in a cold room. After burn-in the structures are assembled together to form a barrel (TIB) and a series of three disks (TID), with the services (cooling pipes, optical fibres and power and HV cables) packed on a ‘service cylinder’ and connected to a main patch panel. The entire TIB-TID is done by two of this macro structures, called ‘plus’ and ‘minus’ from their location on the two sides of the tracker, which are joined together directly in the tracker support tube. The support tube hosts also the outer barrel (TOB) and the two endcaps (TEC) to complete the CMS Silicon strip tracker.

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