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CMS Silicon Strip alignment and monitoring with the Laser Alignment System

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ABSTRACT

The alignment of the CMS Silicon Strip detector can be monitored using its built-in Laser Alignment System. The 32 Laser beams in endcaps and the eight Laser beams connecting the barrel and the endcap regions make it possible to monitor the alignment changes to a precision better than 10 μm and the measurement of the absolute alignment parameters better than 100 μm.

For this, 434 of the Silicon Strip modules (3%) are illuminated by the Laser beams, assuring a continuous surveillance during the collisions and cosmics data taking. In this contribution the status and the preliminary results of monitoring and alignment parameters during the 2011 data taking period at the Large Hadron Collider (LHC) are presented.

1. Introduction

The Compact Muon Solenoid (CMS) detector has two concentric tracking sub-detectors built out of Silicon. The inner detector uses a pixel structure, while the outer one is made out of strips. The CMS Silicon Strip detector has an inner radius of 20 cm and an outer radius of 116 cm. Its length along the z-axis is 564 cm. It has 9.3 millions silicon strips and covers an active area of 198 m^2 [1].

The components of the CMS Silicon Strip detector are the Tracker Inner Barrel (TIB), Tracker Inner Discs (TID), Tracker Outer Barrel (TOB) and two Tracker Endcaps (TEC+ and TEC−), as presented in Fig. 1. In order to monitor the stability and the alignment of its mechanical structure the Laser Alignment System (LAS) was built-in.

2. Laser Alignment System

The LAS uses 434 Silicon modules (3%) that are also used for track reconstruction. These are illuminated by eight Laser beams that are passing between TIB and TOB, and enter both endcaps. They allow the alignment of the sub-detectors with respect to each other. In addition to this, in each of the endcaps the 9 discs are monitored by 16 Laser beams. They are placed in two concentric rings, as shown in Fig. 2, perpendicular to the strip direction. The rings are called Ring 4 and 6. The Laser beams have a wave length of 1075 ± 4 nm. At this wave length the silicon modules have a transmission of up to 20% for Ring 4 and up to 18% for Ring 6. The reflectivity is less than 6%. More technical details can be found in Refs. [2,3].

The Laser light, generated by Laser diodes, is coupled into optical fibres that enter the Silicon Strip detector volume. At the end of these fibres there are beam splitters that produce pairs of collimated, back-to-back oriented beams. These beams pass several layers of modules in TEC. The silicon sensors have a hole in the back-plane metallization and are covered with an anti-reflective coating. In TIB, outermost layer, and TOB, innermost layer, the light is coupled out by semi-reflecting glass plates.

In order to achieve a good signal on every module used by LAS, the beam intensities and the firing time delays need to be properly adjusted. Like a crossing particle, the Laser light absorbed inside the Silicon sensors generates a signal. The Laser signals are 3–20 strips wide and the Laser pulse intensity is adjusted to be inside the dynamic range of the frontend amplifiers.

In Fig. 3(a) the TEC Laser beam profiles are presented. Due to the fact that each beam has to travel over 4 modules a diffraction pattern is observed. The beam position is given by the main maximum. In TOB, as well as in TIB, the beams illuminate only one module, as illustrated in Fig. 3(b). The number of ADC counts is proportional to the beam intensity. In order to exploit also the signals that are close to the saturation of the frontend amplifiers, the position of the Laser spot is computed with an algorithm which uses the profile slopes.

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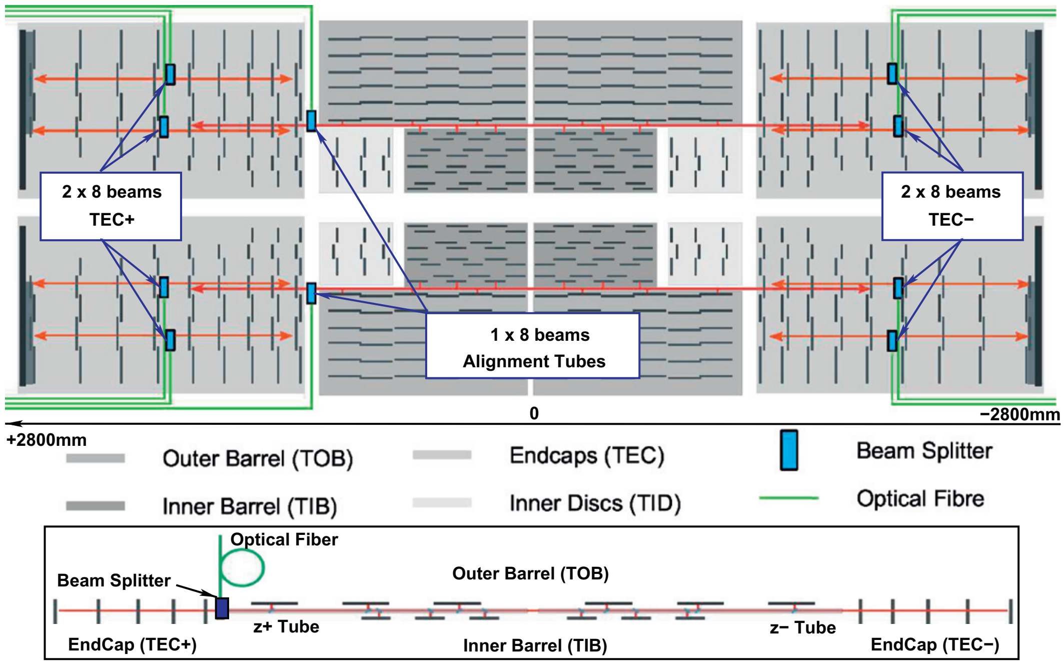

Fig. 1. The geometry of CMS Silicon Strip detector and the Laser Alignment System.

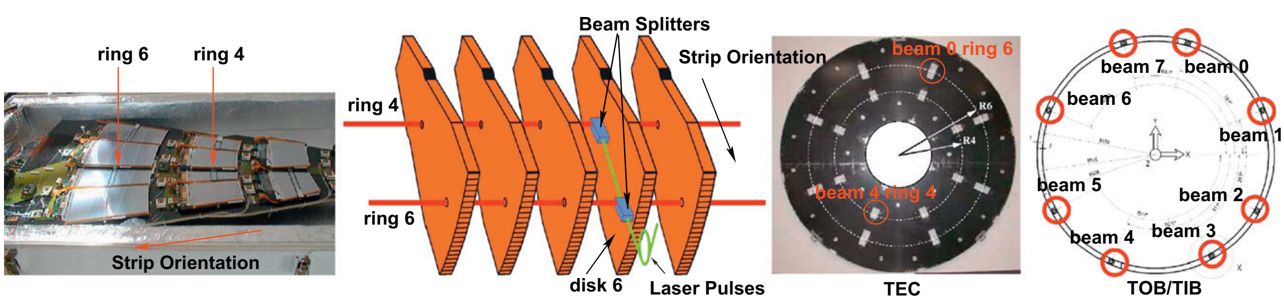

Fig. 2. The LAS Rings and Beam geometry in TEC and TOB/TIB.

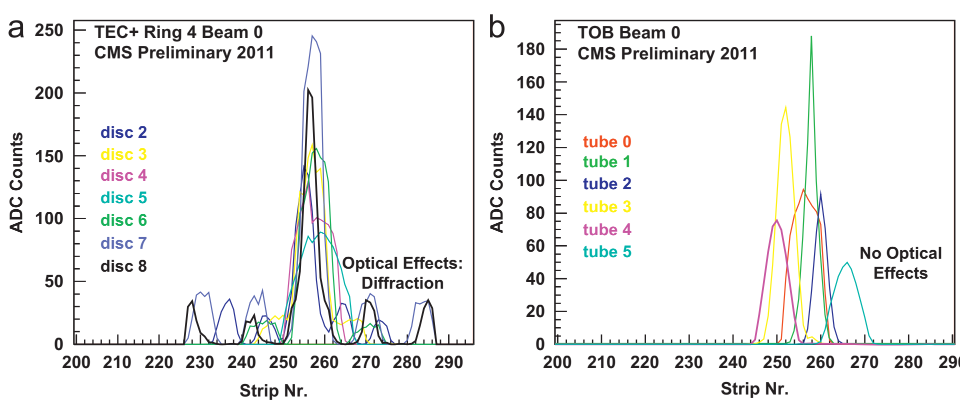

Fig. 3. The Laser beam profiles in (a) TEC+ for Ring 4 Beam 0 of various discs and (b) TOB for Beam 0 corresponding to the alignment tubes.

The same acquisition system as for physics data is used to collect alignment data during *pp* collisions and cosmic runs, using the calibration triggers. The Lasers fire 2000 pulses at 100 Hz every 5 min. The pulses are synchronized with the LHC clock and fall into the orbit gap to avoid interference with physics events produced in *pp* collisions.

The relative movements of the sub-detectors with respect to each other are monitored with these beams to a precision better than 10 μm. Another goal is to measure the absolute alignment parameters with a precision better than 100 μm, which can be used as input for the tracking alignment. The movements and the deformations of the CMS Silicon Strip detector structure are described in the alignment algorithm by a linear model. The parametrization allows the Laser beams to change orientation and offset, but they are constrained to straight lines. The algorithm uses the χ^2 fit minimization. In this model are aligned the internal parameters, Δx_k, as well as the global parameters, Δx_0, of the TEC structure, as illustrated in Fig. 4(a). For TEC internal discs, three