LHCb-CONF-2009-035

Performance of the LHCb Silicon Tracker with first data *

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*Proceedings of 11^{th} ICATPP Conference, Como 2009

Abstract

The LHCb Silicon Tracker consists of two sub-detectors the Tracker Turicensis and Inner Tracker that are constructed from silicon microstrip technology. Performance studies of both sub-detectors using data taken during the LHC synchronization tests are described.

1 Introduction

LHCb is a dedicated b physics experiment at the LHC [1]. At the LHC the production of b pairs is peaked in the forward region. Therefore, LHCb is designed as a single arm spectrometer covering the polar angle of 15 - 300 mrad. The Silicon Tracker project consists of two sub-detectors, the Tracker Turicensis and the Inner Tracker that make use of silicon micro-strip technology.

The Tracker Turicensis (TT) [1] is located in the fringe field of the magnet and covers the full detector acceptance. It consists of four layers arranged into two half stations separated by 30 cm along the beam axis. The detector is constructed using 500 μm thick p-on-n type sensors of the same design as used in the CMS barrel. The readout pitch is 198 μm. The layout of a layer is illustrated in Figure 1. The areas above and below the beam pipe are each covered by a single seven-sensor long silicon ladder, the areas to the left and to the right of the beam pipe are covered by seven (TTa) or eight (TTb) 14-sensor long ladders. Electronically, each ladder is split into several readout sectors, indicated by the different shadings in the figure.

The Inner Tracker (IT) [1] covers the region of highest particle density closest to the beam-pipe in the three T stations which are located downstream of the LHCb spectrometer magnet. Though it covers only 1.5 % of the surface area 20% of the tracks pass through it. An IT station consists of four independent boxes located around the beam-pipe (Fig 1). Each box contains four layers of silicon in the orientation $0°, 5°, -5°, 0°$. For the ladders located left and right of the beam-pipe 22 cm long ladders with a thickness of 410 μm are used. Above and below the beam-pipe ladders of 11 cm in length and 320 μm thickness are used. The readout pitch is 198 μm. In total there are 336 ladders and 129,000 readout channels.

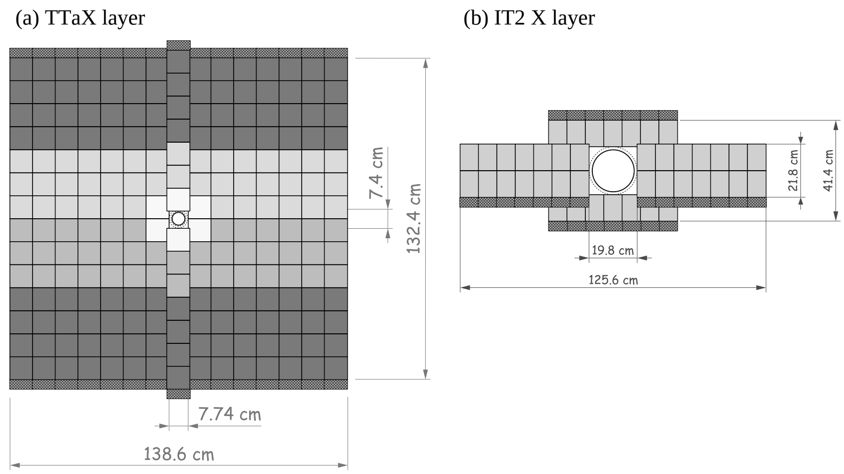

Figure 1: Layout of (a) the x layer in TTa and (b) a x layer in IT station 2.

2 Status

Detector installation was completed by early summer 2008. During the following months both sub-detectors took part in cosmic running and the LHC synchronization tests described in the following section. This running allowed several faults, mainly related to lower power optical links, to be identified and repaired. At the time of writing 99.7 % of the channels in both the IT and TT are functional.

3 Performance Studies

At the end of August 2008 and the beginning of June 2009, during the start-up of the LHC, the machine carried out several synchronization tests. Runs were taken where a beam of 450 GeV protons extracted from the SPS was dumped on to a beam stopper (the 'TED') located 350 m downstream of LHCb. First studies with a full Monte Carlo simulation indicate that the majority of the particles produced in the TED which reach the Silicon Tracker are 10 GeV muons. Using this dataset studies of both IT and TT performance have been made. In these runs the detector occupancies reach up to 8 % creating a challenging environment for track reconstruction. The high occupancy is offset by the fact that during these runs the LHCb spectrometer magnet was switched off simplifying the pattern reconstruction.

The first step during the TED runs was to perform an internal time alignment of the detector. Runs were taken where the delay between the sampling time and the trigger time was varied in 6.5 ns steps around the maximum of the signal, and the most probable value of the signal determined for each set of ladders grouped in one front-end service box. The delay time for the subsequent data taking was the one that maximized the most probable signal amplitude. After this procedure the detector is time aligned with a precision of better than 1 ns.

For the IT a robust stand-alone track reconstruction that is able to cope with the high track densities of the TED run has been developed [2]. This has been used together with the LHCb alignment software described in [3, 4] to internally align the IT. These studies use a sample of 16000 isolated tracks selected from the TED events with the lowest occupancy. The detector boxes were aligned for translations in x,y and rotations about the z axis, the layers for x translations and z rotations and the ladders for x translations. The quality of the alignment has been validated with an independent data sample from the TED run by studying the mean (bias) and σ (resolution) of the unbiased residual distributions per ladder. The σ of the bias distribution (15 μm) is an indication of the size of the misalignments that remain. The quality of the alignment can also be judged from the probability of χ^2 given by the track fit. This is shown in Figure 2. It can be seen that despite the momentum of the tracks being poorly known the quality of this distribution is already good.

Using the clusters on reconstructed tracks the S/N has been studied. For each ladder a fit of a Landau convolved with a Gaussian is made and the Most Probable Value of the Gaussian extracted. Figure 3 shows the S/N per ladder obtained. For the long (short) ladders a S/N of 14.5 (15.5) is obtained. There is a second peak for the short ladders around S/N $\sim$ 20. These are short ladders for which 410 μm thick sensors rather than 320 μm were used. The S/N obtained is consistent with expectations from testbeam measurements [5]. Finally, the ladder efficiency has been measured to be 98 %. Most of the ladders with low efficiency are located close to the edge of the detector. Therefore, this number will improve once the detector alignment and global positioning is better understood.

Since the TT station contains only four layers standalone tracking is not possible and performance studies depend on track seeds either from the Vertex Locator (VELO) or the IT. Hence, studies of the TT performance are less advanced. Extrapolating tracks from the VELO [6] and IT to the TT and calculating the residual to hits in TT clear correlations are seen. These dis-

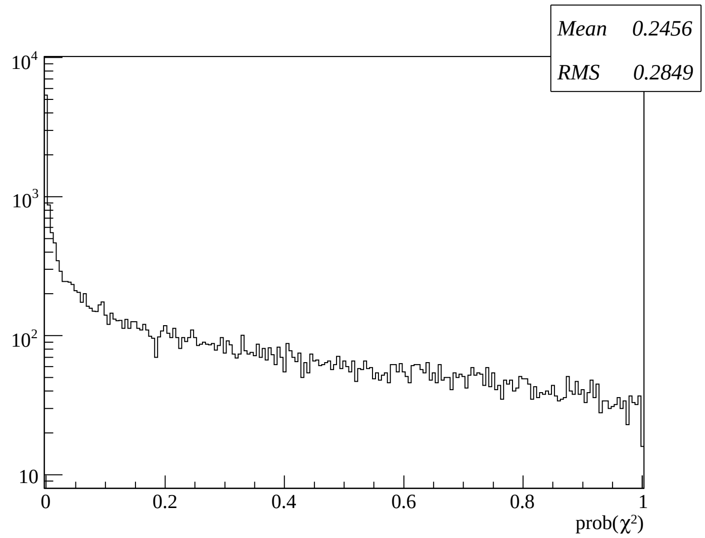

Figure 2: Probability of χ^2 for reconstructed tracks.

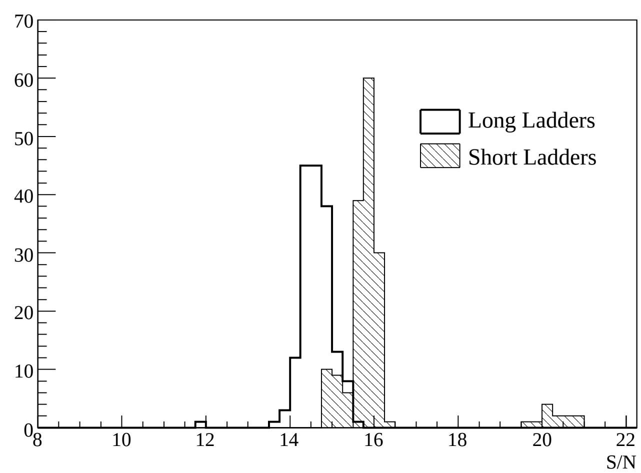

Figure 3: Measured S/N of the Inner Tracker ladders.

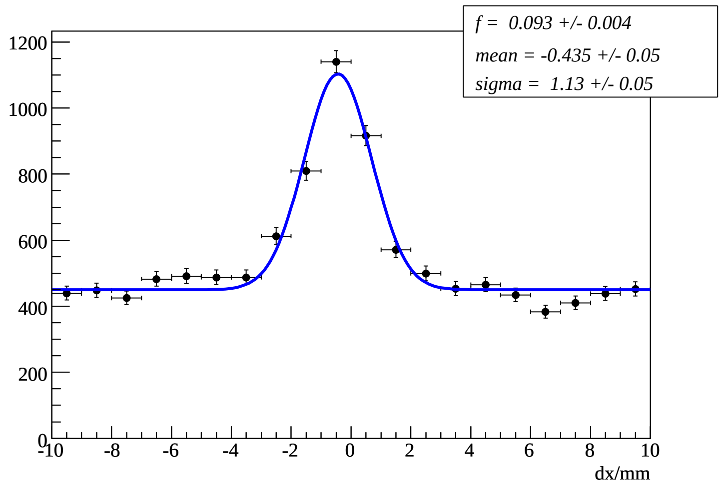

Figure 4: Residual of clusters in TTbX to IT Bottom tracks. The result of a fit to a Gaussian signal combined with a flat background is superimposed.

tributions have allowed to verify the quality of the survey that was performed during the detector installation. As an example Figure 4 shows the residual between clusters in the TTb x-layer and tracks in the IT Bottom boxes. The width of this distribution (1.1 mm) is consistent with the tracks having a momentum of 10 GeV.

4 Summary

Data collected during the LHCb synchronization tests has allowed first studies of the performance of the Silicon Tracker to be made. A first alignment with tracks has been performed and the efficiency of the detector verified. The results of these studies will provide a good starting point for understanding the detector with first colliding beams at the end of 2009.

References

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