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First experience and results with the LHCb Silicon Tracker

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ABSTRACT

The LHCb experiment is designed to perform high-precision measurements of CP violation and rare decays of b hadrons. The construction and installation of the Silicon Tracker (ST) was completed by the summer of 2008. Here, we report on first results obtained using the data taken during injection tests ('TED' run) in August and September 2008.

1. Introduction

LHCb is a single-arm spectrometer optimized for the study of b decays. The Silicon Tracker (ST) is part of the tracking system of the experiment [1]. It consists of two silicon micro-strip detectors that cover an active area of $12\,m^2$ with 272k read-out channels. The first detector, the Tracker Turicensis (TT), is located upstream of the LHCb dipole and has a width of 150 cm and a height of 130 cm. The second is the Inner Tracker (IT) which has a width of 125 cm for a height of 40 cm in a cross shape. It is located in the center of the three tracking stations downstream the LHCb dipole magnet. Each station of the Silicon Tracker consists of four silicon layers. Two of the layers are vertically orientated such that they measure the x coordinate (the bending plane of the spectrometer). The remaining two layers are have a stereo angle $\pm 5^\circ$ from the vertical allowing a full three-dimensional track reconstruction. The same radiation-hard chip and read-out link are used for both detectors.

2. First beam events and tracking algorithm

Installation of the ST was completed by the summer of 2008. By end of August, the TT had 99% working channels and the IT 97%. The remaining problems, mainly due to low power optical transmitters, have been fixed for the coming 2009-2010 run. Data taken during LHC injection tests in August and September 2008 has allowed a first time and spatial alignment of both the Tracker Turicensis and the Inner Tracker. In these runs a beam of 5×10^9 protons, extracted from the SPS, is dumped on to a tungsten beam-stopper (the 'TED') which is located 350 m downstream of LHCb. This gives a spray of muons with a momentum around 10 GeV in the LHCb detector. For this running the spectrometer magnet of the spectrometer was turned off.

Time alignment of both detectors with an accuracy of 1 ns was performed by taking several runs with various trigger delay settings. For each run a fit of the cluster charge distribution to a Landau convolved with a Gaussian was made. An example the fit of the Landau for the TT detector for a timing close to the optimum is shown in Fig. 1. The most probable value corresponds to a signal-to-noise of 13—close to the expectations.

A TED shot has an occupancy 20 times higher than that in b events in normal LHCb running. To deal with this challenging environment a special track finding algorithm has been developed

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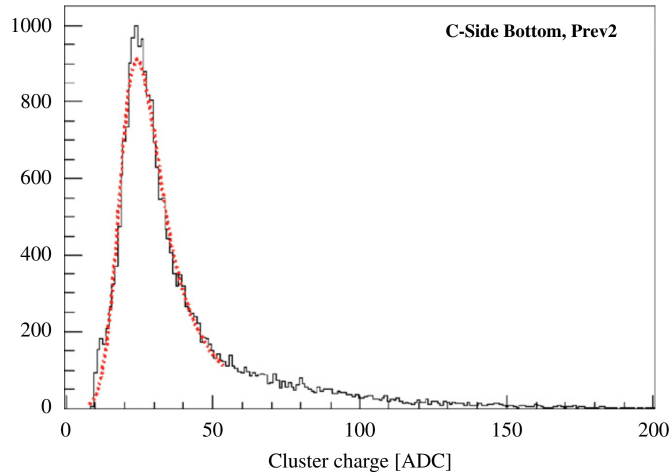

Fig. 1. Charge deposit in the TT.

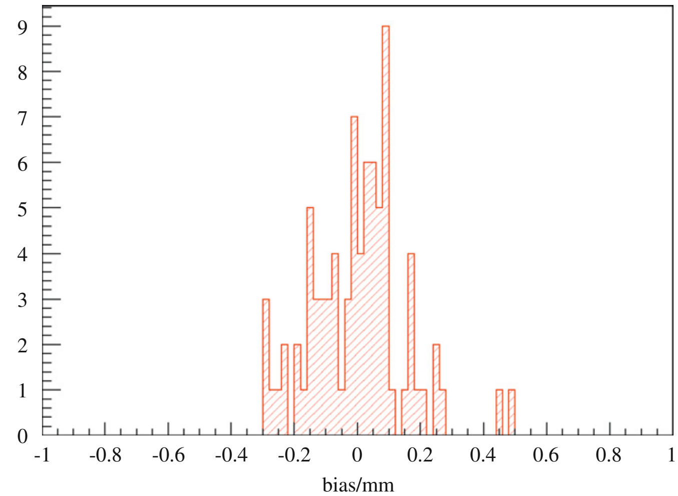

Fig. 2. Biases of the bottom box ladders before alignment.

[1]. This starts from a pair of hits in two different layers to define a line. Cuts are applied to reject candidates incompatible with originating in the TED. If the candidate passes these cuts, then additional *x*-hits are searched in a window around the line in the other layers. If several compatible hits are found, then the candidate is split. Tracks with too few hits are discarded and optimal estimates of the *x*–*z* track parameters are obtained using a least squares fit to the hits. All stereo hits consistent with the *x*–*z* track are then collected and converted into a *y*-position. They are checked to be compatible with the physical boundaries of the hit channel. The *y*–*z* tracks are built in a similar manner to the *x*–*z* tracks. Next, a full three-dimensional track fit is performed. Finally, a track competition which ranks tracks according to their number of hits and χ^2 is used to select an optimal subset of track candidates.

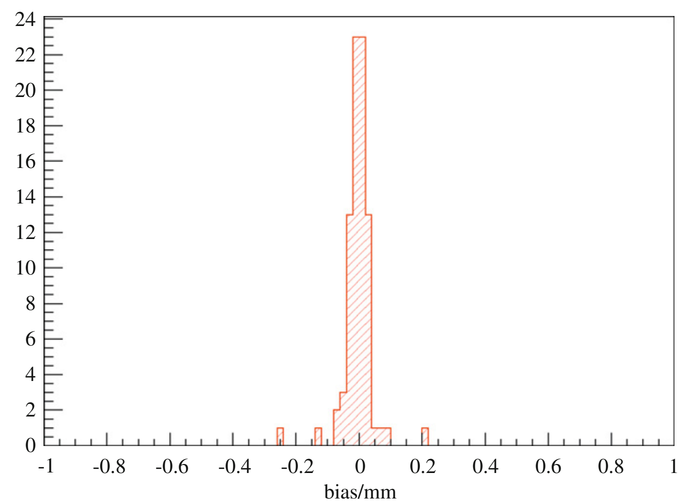

Fig. 3. Biases of the bottom box ladders after alignment.

3. Inner tracker spatial alignment

The starting point of the alignment is a detector survey which has 500 μm precision for the boxes and 50 μm for layers and ladders [2]. This is complemented with a pre-alignment in *x* of the boxes and layers based on the histogramming of residuals [3]. In the TED runs used for this alignment study, the occupancy for the top and bottom boxes is around 1.7% and 4% in the side boxes. Using a Monte-Carlo simulation it is possible to estimate the efficiencies and the ghost rates for the different boxes of the Inner Tracker. For the top and bottom boxes an efficiency of 98% with a ghost rate of 0.8% is expected, while for the side boxes the efficiency is 81% with a ghost rate of 6.2%.

Alignment of the boxes, layers and ladders has been performed using the procedure described in Ref. [4]. To validate the results, unbiased residuals distributions before and after alignment have been studied. For each of the elements of the Inner Tracker the bias (mean) and the resolution (σ) are extracted from the Gaussian fits to the these distributions. As examples of the quality of the results, Figs. 2 and 3 show the biases on the ladders in the bottom boxes before and after alignment. The alignment improves the knowledge of the ladder position from to 200 to 30 μm.

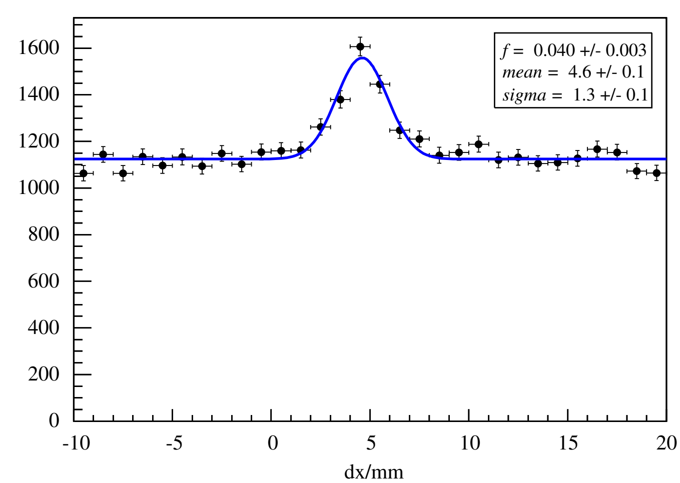

Fig. 4. Residuals in TT of extended IT tracks.

4. Track confirmation by the TT

The Tracker Turicensis is used to confirm the reconstructed IT tracks. The reconstructed IT tracks are extended to TT and distributions of the unbiased residuals made. Fig. 4 shows the distribution of residuals for the case of tracks in the top boxes of the IT. A clear peak can be seen. The width of this distribution (1 mm) is consistent with the particles produced on the TED having a momentum of ~ 10 GeV.

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