The Silicon Tracker of the LHCb Experiment

(Summary - Design & Test Results)

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1 Introduction

LHCb is a dedicated B-physics experiment at LHC. CP-violation and other precision measurements with B-mesons provide important tests of the Standard Model and may hint towards new physics. Taking advantage of the particular angular distribution of the $b\overline{b}$-pairs the detector was designed as a forward spectrometer.

The Silicon Tracker (ST) consists of two sub-detector systems: The TT-station (Trigger Tracker) before the magnet and the Inner Tracker consisting of three cross-shaped tracking stations T1-T3 behind the magnet. It covers a total area of 12.5 m^2 with 310k channels readout. Both sub-systems are built out of single-sided AC coupled p-on-n silicon strip sensors read out via the custom-developed Beetle front-end readout chip.

Each station of the Inner Tracker (IT) consists of 4 boxes located around the beam pipe. The boxes themselves contain 4 layers of silicon orientated as $0°$, $5°$, $-5°$ and $0°$with respect to the vertical axis. The ladders are mounted on two cooling rods and are operated at $5°$ C to reduce leakage current after irradiation. Silicon ladders are either one (11cm) and two sensors (22cm) long and have 384 readout strips with a strip pitch of approximately 200 μm. Besides being modular and simple, the design is well adapted to the distribution of particle tracks in the experiment.

The TT-station consists of two half stations TTa and TTb, separated by 30cm along the beam axis, and a total of 4 layers of silicon. Both stations are enclosed in a single box providing thermal and electrical shielding. Similar to the Inner Tracker the second and third layer have a stereo angle of $\pm 5°$. The detection layers are arranged in readout sectors of two sensors in the middle and four sensors outside. The readout hybrids are located outside the acceptance at the edge of the box. The inner sectors are conncected via a kapton cable to the hybrids.

2 Prototype test results

In order to determine the optimal thickness of the silicon sensors three prototype ladders have been built out of 500 μm-thick CMS-OB2, 410 μm-thick GLAST2000 and 320 μm-thick LHCb multi geometry sensors. Their properties are given in the table below.

Ladder	length/cm	thickness/μm	Pitch/μm	C_{Strip}/pF
LHCb3	32.4	320	198	50.6
GLAST2000	26.3	410	228	41.3
CMS-OB2	28.9	500	183	37.6

Their performance has been tested using a 120 GeV pion beam at CERN. Spatially resolved measurements investigating the charge loss in between two readout strips for 200 μm readout pitch have been performed as well as pulse-shape measurements.

The shaping time of the Beetle front-end amplifier has been varied in order to adjust the remaining signal 25ns after the maximum (i.e. one LHC bunch crossing later) to the required 30% and 50% for the Inner Tracker and the TT-station, respectively. The width

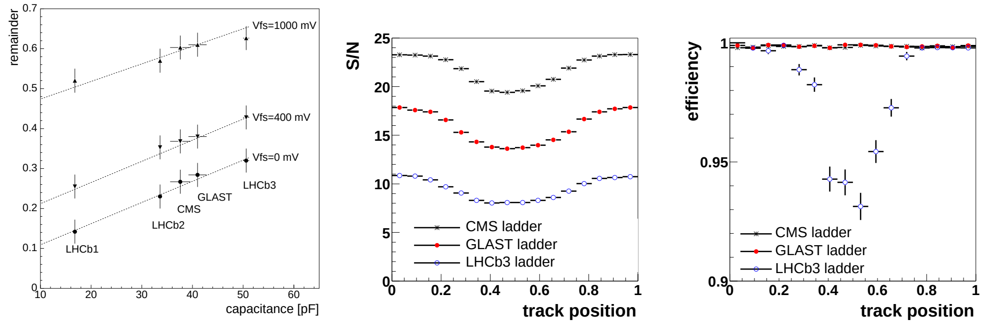

Figure 1: Signal remainder after 25 ns,the S/N ratio and efficiency depending on the position of the incident particle.

of the pulse-shape, and thus the remaining signal after 25 ns, increases with increasing load capacitance.

For signal shaping times compatible with LHCb requirements, the test beam measurements gave average most-probable signal to noise (S/N) ratios of 8.9 for the LHCb3, 14.6 for the GLAST2000 and 20.0 for the CMS-OB2 ladders. These values were measured for bias voltages of approximately 130 V above the full depletion voltage of the respective sensors and were found to be independent of the position of the tracks along the readout strips. However a significant drop in the S/N ratio was observed for all prototype ladders in the central region between two readout strips. For the GLAST2000 and CMS-OB2 ladder this has no effect on the detection efficiencies whereas for the thinner module out of the LHCb multi geometry sensor the efficiency decreases to 88% for the region between two strips, which is unacceptable for operation in LHCb.

An analysis of the detector behaviour as a function of the depletion voltage is given. It could be shown that the observed charge loss in between the two readout strips is not due to a ballistic deficit.

The performance of the ladders was also studied by applying various clustering algorithms. We report here about a study of clustering algorithms using a Likelihood approach combining different discriminating variables to optimise the hit finding efficiency with respect to the noise rate. Comparisons of the cluster characteristics for in time signal events with ghost events from a previous bunch crossing are used to discriminate ghost clusters to reduce combinatorics for offline track reconstruction.

In July 2004 another testbeam experiment will be performed and the performance of Silicon Tracker modules after 10 years expected irradiation dose will be investigated. In addition an LHCb Silicon Module with the long Kapton interconnect cable will be tested for the first time under testbeam conditions. Interesting results from this experiment will be included in the presentation.