Beam test results for a thin silicon sensor with short strips

Abstract

In order to achieve precise position measurements near the interaction region, the next generation of B-flavour factories will need a tracking device with an innermost layer (Layer0) as close as possible to the Interaction Point (IP). The requirements of the Layer0 will thus be very stringent in terms of granularity, readout speed, material budget and radiation tolerance. Several options have been considered for the SuperB Silicon Vertex Tracker (SVT). In its TDR baseline the Layer0 is based on high resistivity sensors with a thin silicon substrate (200 μm) and short double-sided strips (striplet detector or "Striplets"), at ±45° angle to the detector's edge.

A prototype of this device with 50 μm readout pitch has been successfully realized in 2008 by the SLIM5 collaboration. In September 2011 Striplets were tested in a 120 GeV/c pion beam at the CERN SPS. We report here experimental results on efficiency and spatial resolution achieved as a function of the incidence angle up to 70°.

Keywords:
Striplets, Striplet detector, Charged particle tracking.

1. Introdution

The SuperB Silicon Vertex Tracker (SVT) design [1, 2] is an evolution of the BABAR vertex detector with an extended angular coverage and with the addition of an innermost layer (Layer0) closer to the interaction point (IP). The SuperB SVT is thus designed to be made of 5 layers of double sided silicon strip sensors plus a Layer0 at a radius of about 1.5 cm, very close to the beam pipe.

Several options have been considered for the Layer0: high resistivity sensors with short strips (striplet detector or "striplets" in the following), hybrid pixels, and other thin pixel sensors based on CMOS Monolithic Active Pixel Sensor (MAPS). For the first phase of the experiment the baseline option is a high resistivity double sided silicon detector, with short strips at ±45° angle to the detector's edge.

The thickness of the silicon substrate has been reduced from the standard 300 μm to 200 μm to minimize the amount of material. Moreover, the strips are shorter than in standard designs; this reduces the average occupancy per channel and compensates for the increased strip-to-back capacity.

A prototype of this device with 50 μm readout pitch has been built and successfully tested with 12 GeV/c protons, at the PS-T9 test-beam at CERN in September 2008 by the INFN SLIM5 collaboration [3, 4, 5, 6]. That prototype was readout by the FSSR2 chip, the second release of the Fermilab Silicon Strip Readout chip, originally designed for the silicon strip detectors of the BTeV experiment. The striplet device proved to be very efficient, above 98.6% for track incidence angles up to 45°. The core resolution of the devices tested was also very close to expected values for all incident angles up to 45°. At at larger incidence angles there was loss of efficiency and resolution, due to the relatively high threshold compared to the reduced signal in the 200 μm thin detector.

In the following we present the beam test results on the same striplet device in a 120 GeV/c pion beam at the CERN SPS in September 2011. We report here experimental results on efficiency and spatial resolution achieved as a function of the incidence angle up to 70° angle and with a 25% lower threshold.

2. Experimental Setup

A high-resolution and fast-readout reference telescope was used to trigger good events and to find the impact point of tracks at the detector. It is an upgrade of the one used by the INFN SLIM5 collaboration with the addition of two extra modules. It is composed of six modules 2×2 cm^2, 300 μm thick double-sided silicon strip detectors, with AC-coupling, 25 μm strip pitch on the p-side and 50 μm on the n-side (the readout pitch was 50 μm on bothsides) [4, 6]. One set of three modules was positioned upstream and the other downstream of the devices under test (DUTs). The two sets of telescope detectors were placed 40 cm apart, with a fixed 3.5 cm distance between the sensors inside each sets. The modules (telescope and DUTs) were placed on a customized motorized table with remote control that allow three directions translation for the whole system and a rotation around the vertical axis for the DUT to check the performance at different angles of incidence up to 70°.

Both the telescope strips and the striplets are read out by the FSSR2 Chip [9], completely data-driven. Each chip reads 128 strips with a digital output providing address, time stamp and three bit on pulse height.

By means of the telescope information a horizontal and vertical widths of the beam spot at DUT of about 8 and 4 mm respectively are measured.

3. DataAnalysis

The analysis of the striplet detectors is ... Known malfunctioning strips have been removed for this analysis. For the

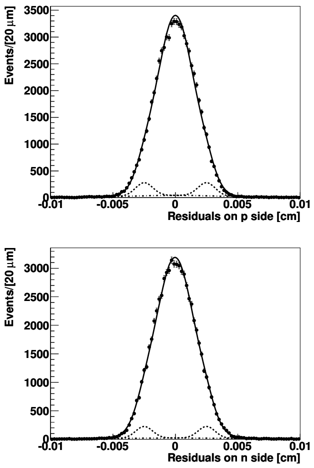

Figure 1: Residual fit for the striplets as a DUT for (a) p-side and (b) n-side

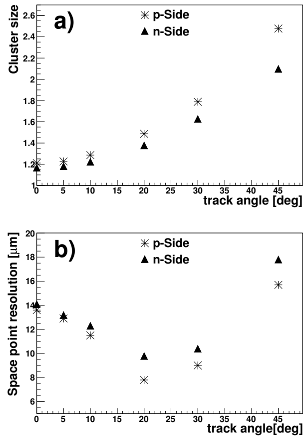

Figure 2: a) Average cluster size for the striplets as a function of track angle. b) Resolutions for the striplets as a function of track angle.

striplets more than 99.X% of the tracks have a space point within 80 μm from the intersection point of the track, while the contamination of spurious space points is less than 0.5%.

For a track with normal incidence, signal clusters are comprised of one strip in 82.5% of the cases or two adjacent strips in 16.1% of the cases for the U-coordinate. In the V-coordinate, the one- and two-strip cluster frequencies are 85.6% and 13.3%, respectively. After alignment, the residual distribution, shown in Figure 1, looks similar, but broader than the one of the telescope and has been fitted with the same function. The contribution of the two symmetrical Gaussians with mean ±25 μm is greater here than for the telescope detectors, accounting for about 7% of the signal. The broad "outlier" component is found to be negligible after removing bad strips.

The increase in the importance of the pair of displaced Gaussians is due to the lower charge deposition in the striplets, relative to the telescope modules (because the striplet modules are thinner). Since the same threshold was used for telescope and striplets, the probability of losing a strip under threshold is increased for the striplets. Dedicated runs with lower thresholds both for striplets and telescope modules confirm this effect. In fact, in these runs the average cluster size associated to the tracks increases as well as the number of isolated random hits.

The intrinsic resolution was obtained using Eq. **??**, where $\sigma_{residual}$ is taken as the width of the narrow Gaussian of the fit function. We find an intrinsic resolution of 13.6 μm for the U-coordinate and 14.1 μm for the V-coordinate, slightly better than the digital resolution for a 50 μm readout pitch and in agreement with the expected values for such S/N strip detector [10]. Compared with telescope detectors the resolutions are here similar for the two coordinates mainly because there are no floating strips on the p-side. The overall resolutions are anyway slightly worse compared to the telescope detectors due to the lower average cluster multiplicity, dominated by the single strip occurrence, due to the 33% reduction in the signal and the same FSSR2 operation thresholds. Resolutions and efficiencies were also studied as a function of the incidence angle; while the efficiencies are stable above 97%, the average cluster size increases and therefore the resolutions improve considerably as a function of the incidence angle up to 30° as shown in Figure 2. At 45° the resolution is 20% worse than the resolution at normal incidence. Also the angular behaviour is in agreement with expectations [10]. At very large angles (60 – 70°) one track crosses a volume corresponding to several strips in both coordinates since both sides strips are tilted by ±45°. The expected charge collected per strip starts to be comparable to the threshold set, especially for the n-side. The efficiency of finding a cluster in the expected area is anyway above 98%, although one or more intermediate strips within the cluster may get lost.

4. Conclusions

Striplets are orthogonal in the two sides, but tilted by 45° with respect to the detector edge.

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