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Performance of the CDF Silicon Vertex Detector

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PERFORMANCE OF THE CDF SILICON VERTEX DETECTOR

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ABSTRACT

The current status of the online and offline performance of the CDF Silicon VerteX detector is presented. So far, at low radiation dose, the device delivers good quality data. After the latest alignment using collision data, a spatial resolution of 13 μm is achieved in the transverse plane, demonstrating that CDF has a powerful tool to detect b decay vertices.

1. Introduction

During the summer of 1992, the Collider Detector at Fermilab (CDF) has resumed data taking at the Tevatron collider ($\sqrt{s} = 1.8$ TeV) with an upgraded apparatus that now includes a Silicon VerteX detector, the SVX. This device, whose purpose is to identify secondary vertices from the decay of particles containing the b quark, is the first of its kind to be used for physics at a $p\bar{p}$ collider; it is expected to bring a signification contribution to heavy flavor physics[1].

2. Summary of the design

Due to the Tevatron's large luminous region ($\sigma \cong 30$ cm along the beam line), the SVX detector[2] has been designed as two long barrels around the beam pipe, each of active length 25.5 cm. This implies a geometrical track acceptance of the order of 60%.

Each barrel has 4 concentric layers of single sided DC coupled silicon detectors; they are arranged in a 12-sided geometry and are read out by SVX chips[3]. The 30 degree azimuthal sectors are called "wedges". The 46080 strips of the SVX, each as long as a barrel (three 8.5 cm silicon wafers wirebonded together), are running parallel to the beam line at radii ranging from 3 to 8 cm. The strip pitch is 60 μm (55 μm on outermost layer). This design provides enough granularity and redundancy for tracking in dense $p\bar{p}$ events, and is aimed at an average impact parameter resolution in the transverse plane of the order of 10 μm for high p_T tracks.

A water cooling system maintains the beryllium support structure at a uniform temperature of 22°C; the front-end electronics operates near 40°C and the silicon detectors are kept in the range 25–28°C. The whole SVX system, including cables, cooling pipes and electromagnetic shields, is very light and corresponds to 3% of a radiation length for a radial track passing through the middle of a barrel.

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3. Online performance

The 24 wedges are read out in parallel. Hardware thresholds can be injected in the SVX chips; during data taking, only the analog pulse heights of channels above threshold and their neighbors are read out to decrease the size of the raw data (digital channel addresses are also read out). After optimizing the 48 different thresholds (2 per wedge), an efficient readout is obtained with an average occupancy below 10%; this occupancy is dominated by non-uniformities in the chip-to-chip response to injected thresholds. But still, the total readout time is well below 2 ms.

The characteristics of each channel are monitored during calibration runs taken between Tevatron stores. The fraction of non working or unusable channels is approximately 1.5%, including all 128 channels of a chip that had a fatal spontaneous failure. All other channels show a consistent behavior under stable running conditions. No big coherent variations in the analog output levels are observed from event to event. The individual channel offsets (pedestals), which are subtracted during the offline processing of the data, are stable over weeks. Gains are uniform at the 5% level. Minor chip control problems and a few corrupted channel addresses can be recovered offline most of the time.

The signal to noise ratio, as determined from the most probable charge deposited by a MIP in 300 μm of silicon, was measured to be 9/1 at the beginning of this data-taking period[4]. This ratio is expected to decrease in the course of this run because of radiation damage. After 3 pb^{-1} of delivered luminosity ($\sim$ 10% of the goal for this run), no significant degradation of the performance is observed.

4. Offline performance

The SXV offline reconstruction relies on tracks found by the CDF Central Tracking Chamber (CTC) which surrounds the SVX. A pattern recognition algorithm adds SVX hits to each CTC track; the method is iterative and searches for hits in one silicon layer at the time, starting from the outermost layer. At each step (layer), the track is refitted with its corresponding SVX hits and a multiple scattering term is added to the error matrix of the track.

By comparing the number of tracks with 4 hits in the SVX, with the number of tracks with only 3 hits in the SVX (where a fourth hit is expected in a good region of the detector) a layer efficiency of $\sim$ 97% is derived. However, the overall SVX track efficiency is still lower than the 99% expectation, and work is in progress to improve the offline reconstruction and the hardware threshold settings.

Although the assembly of the device was carefully surveyed[5], the alignment of the SVX needs to be refined using reconstructed tracks. The alignment procedure is broken up in two steps, which are iterated to ensure and verify the stability of the solution. First, the barrels, treated as independent rigid bodies, are aligned to the CTC. This is done by requiring that each barrel measures (for a given store) a beam line consistent with the one measured using CTC information only, and by optimizing the match in azimuth between the CTC tracks and their associated hits in the SVX. After this alignment, we perform two independent fits to the beam line using separately tracks fully contained in each barrel. The two fits agree within 5–10 μm for any given Tevatron store.

Then, the subdetectors inside a barrel have to be aligned to each other. Currently, we only align the layers of silicon within each wedge, using good quality tracks with 4 SVX hits in the same wedge. These tracks are constrained to have the momentum measured in the CTC and to pass through the beam spot and the hit on the outermost layer. The 3 inner layers are allowed to float while the residuals are minimized, taking into account magnetic field corrections (Hall effect). In addition to the translation perpendicular to the strips and the rotation in the silicon plane[4], these 3 layers are now given a third degree of freedom: a radial translation. As shown in Fig. 1, the width of the residual distribution is decreased from 17.6 μm down to 10.6 μm.

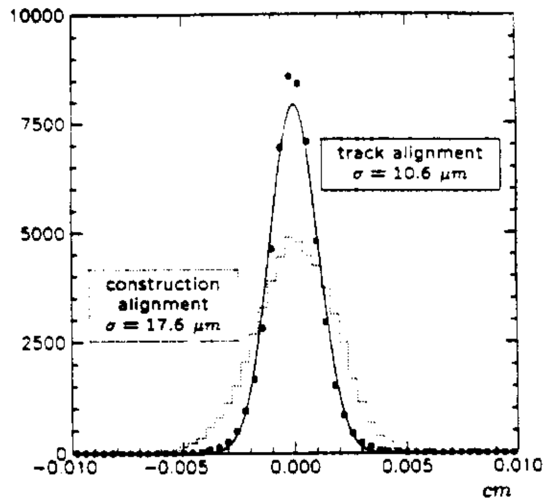

Fig. 1: SVX residual distribution before (dotted histogram in 4 μm bins) and after (points and gaussian fit) alignment using reconstructed tracks.

This result implies an average spatial resolution at the silicon of 13 μm. The corresponding asymptotic impact parameter resolution for high p_T tracks is close to 13 μm, which is approximately 25 times smaller than the resolution provided by the CTC alone in past runs.

5. Conclusion

The SVX is successfully operating at CDF and already performs close to its specifications. Work is still in progress to improve the performance and understand the systematics of the data and alignment. The current performance already indicates that the SVX will be a powerful tool to separate the primary interaction vertex from bottom decay vertices, giving CDF a good opportunity for B physics and top search.

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