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Operation and Performance of the Silicon Vertex Detector (SVX') at CDF

Prem P. Singh
The CDF Collaboration
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

Department of Physics and Astronomy, University of Pittsburgh,
Pittsburgh, PA 15260

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OPERATION AND PERFORMANCE OF THE SILICON VERTEX DETECTOR (SVX') AT CDF.

PREM P SINGH*

Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260. USA

ABSTRACT

We describe the operation and performance of the Silicon Vertex Detector (SVX'), which replaced the CDF SVX detector for run 1b of the Fermilab Tevatron Collider. The new features of the SVX' include AC coupled readout, Field OXide Field Effect Transistor (FOXFET) biasing and radiation hard front end electronics. We expect the detector to survive beyond the 100 pb^{-1} of data taking anticipated for the present CDF physics run. Preliminary results from the collider data show that the detector has a resolution of about 12 μm. This provides a powerful tool to do top and bottom physics.

1. Introduction

The Collider Detector at Fermilab (CDF) [1] uses a silicon vertex detector in its central tracking system. For the present collider run (run 1b) the original silicon vertex detector (SVX) [2,3] was replaced by an upgraded detector SVX'. SVX was the first such detector to be built for a hadron collider. During the past collider run (run 1a) it received about 15 Krad of radiation and would not have lasted for a long time in run 1b, hence it was replaced to ensure good operation throughout this run.

The overall geometric design of SVX' is the same as that of SVX. Compared to DC coupled silicon strip detectors and radiation soft read out chips in SVX, SVX' has AC-coupled, FOXFET biased silicon strip detectors [4] and radiation hard read out chips. These differences make SVX' a significant improvement over SVX.

2. Detector Description

2.1. *Geometry*

SVX' consists of two independent cylindrical modules of equal length (see Fig. 1) These modules are aligned along the beam line (z-axis of the CDF) and are placed on both sides of the center of the CDF detector (z=0) with a gap of about 2.15 cm at z=0. The active length of SVX' is 51 cm which results in an acceptance of $\sim$ 60% of the $p\bar{p}$ collision vertices.

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*Representing the CDF collaboration.

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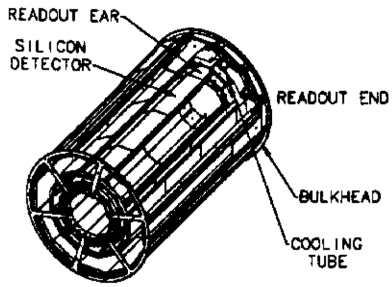

Fig. 1. Schematic drawing of one of the SVX' barrel

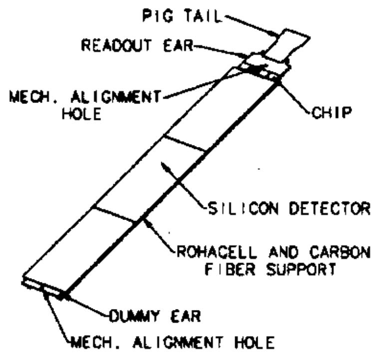

Fig. 2. Schematic drawing of a SVX' ladder.

Each module (also referred to as barrel) consists of four concentric layers, numbered from 0 to 3 in increasing radius. The basic building block of the layers is a ladder, shown in Fig. 2. A ladder has three AC coupled, single sided silicon strip detectors micro-bonded to one another. The readout end of the ladder is microbonded to the front end chips. The inner and the outer radii of the barrel are 2.8612 and 7.8658 cm respectively. The inner radius of SVX' is less than that of SVX by $\sim$ .14 cm and the ladders in layer 0 of SVX' have an additional 1^o rotation along their longitudinal axis. This was done to improve the ϕ coverage of layer 0. There is a 0.17^o (0.24 strip) overlap between the adjacent layer 0 ladders in SVX' compared to a 1.26 degree gap in SVX.

2.2. Readout Electronics

The readout chip of SVX' (SVXH3 chip) was fabricated in 1.2 μm radiation hard CMOS technology. It is expected to tolerate more than 1 MRad of radiation. This chip has 20% less noise and 30% more gain than the chip used for SVX (SVXD chip). The typical charge gain for this chip is 24mV/fC.

3. Detector Performance

Each SVX' barrel is divided into 12 wedges of 30° in ϕ and the wedges are read out independently. To reduce the size of the raw data the detector is read out in sparse mode. Two sparse thresholds can be set per wedge. The DC coupling of the SVX to its readout required that the device be operated in a quadruple sample and hold mode. In this mode the charge is integrated twice (once "on beam" and once "off beam") and the difference of these integrations gives the signal. This is done to get rid of the baseline shift due to the varying strip - to - strip leakage current which would also be integrated during the sampling time. However since SVX' is AC coupled the leakage current will not be seen by the readout electronics, hence SVX' operates in a double sample and hold mode, where only one integration is done ("on beam"). This results in the reduction of SVX' noise by $1/\sqrt{2}$ compared to that of SVX. The typical noise for SVX' is 1300 electrons (10.8 ADC counts) compared to 2200 electrons for SVX. Figure 3 shows the plot of charge deposited in a layer of SVX' by a minimum ionizing particle passing through it. The curve peaks around 160 ADC counts; using the value of noise as 10 ADC counts, we get the signal to noise (S/N) for SVX' as 15, compared to 9.5 for SVX.

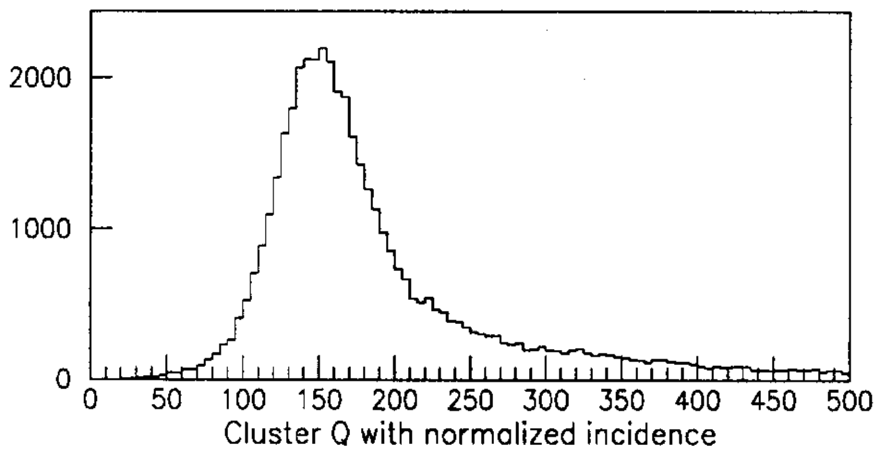

Fig. 3. The charge deposited in ADC counts by a minimum ionizing particle in a SVX' layer. The arrow with SVX points to the place where a similar curve for SVX would have peaked and the arrow with Noise points to the value of the Noise.

The characteristics of each channel of SVX' is monitored by taking calibration runs between the Tevatron stores when there is no beam activity. Calibration studies include measuring the pedestal, gain and the threshold of each channel of the device. Of the total 46080 channels of SVX', about 1.7% channels have a shorted coupling capacitor. These channels are not bonded to the readout chip, instead they are grounded through a capacitor on the dummy (non readout) end.

Radiation will cause an increase in the leakage current of the detector. This increase will not saturate the front end of SVX' because of the AC coupling but it will show up as shot noise. SVX' is expected to take about 100 pb^{-1} of data, during which period it would have received about 60 KRad of radiation. Extrapolating the change in the leakage current from SVX' (change of 30nA per strip for 15 KRad in layer 0) for a 60 KRad dose the leakage current will increase by approximately 120 nA per strip. Calculations [5] show that due to this increase in the leakage current, the total noise of layer 0 in SVX' will increase from an initial 1300 electrons to 1700 electrons by the end of this run, this corresponds to a change in the S/N from 15 to 12.2.

4. Offline Performance

The first step in the offline reconstruction of tracks in SVX' is the conversion of the charge on individual strips to clusters followed by matching of these clusters to tracks found by the Central Tracking Chamber(CTC). The conversion from the charge levels on individual strip starts with the offline subtraction of the pedestals. The pedestal subtraction is carried out on a strip by strip basis and the pedestal values are taken from a pedestal calibration run. After the pedestal subtraction the strips are clustered using a clustering algorithm that requires that there be a group of contiguous strips which have a charge greater than 'M' times the noise, where 'M' is 4, 2.5, and 2 for 1 strip, 2 strip and ≥ 3 strip clusters, respectively. The values of 'M' were optimized for good hit efficiency and noise rejection using cosmic ray and collision data. Cluster positions are calculated as the charge weighted centroid using individual strip charges and strip positions.

4.1. Hit Efficiency

The hit efficiency for SVX' is affected by S/N, pedestals, clustering, pattern recognition, dead strips and geometrical acceptance. Since the detector has some ϕ gaps and dead strips the hit efficiency can never be 100%. This efficiency is studied by counting tracks in the CTC which extrapolate into the SVX' four layer tracking volume and have missing hits on the various layers. Our studies show a hit efficiency of about 97% for each layer. The bulk of the inefficiencies are due to micro-bonding gaps (1.7%), and the dead strips (1.7%).

4.2. Alignment and Detector Resolution

The final alignment of SVX' was done using reconstructed tracks. The position resolution of a layer is determined by taking a track that also has a hit on each of the other three layers. The three hits from the other layers are fitted to a track. The distance between the intersection of the track with the layer being studied and the cluster centroid of the hit on that layer is plotted and fitted to a gaussian. The width of the gaussian is related to the position resolution by the relation $\sigma^2_{residuals} = \sigma^2_{position} + \sigma^2_{fit}$, where σ_{fit} is the error from the fitted track parameters. The position resolutions for one and two strip clusters in SVX' are 13 and 11 μm, respectively. Figure 4. shows the biased residual distribution for SVX'. Biased residuals are found by taking a track that has 4 hits and fitting all the four hits to a track. The residuals of each layer in this case are known as biased residuals. The σ for the biased residual distribution is 8.73 μm.

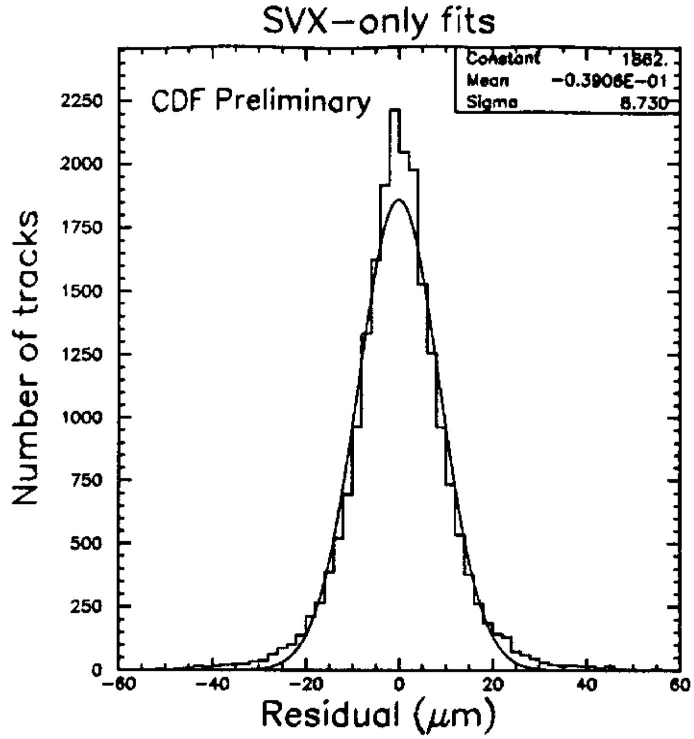

Fig. 4. The biased residual distribution for SVX'

5. Conclusions

SVX' has taken about 15 pb^{-1} of data and is functioning within its specifications. Global and internal alignments are complete and work is in progress to do the wedge to wedge alignment. The S/N for this detector is 16. It has a 1 and 2 strip cluster resolution of 13 and 11 μm respectively. With its marked improvements over SVX, we expect that SVX' will increase our efficiency in doing top and bottom physics during the present Tevatron run.

References

1. F. Abe et al., *NIM* **271** (1990) , p. 387
2. D. Amidei et al., *NIM* **A289** (1990),p. 388-389.
3. D. Amidei et al. *FERMILAB-PUB-94/024-E* Submitted to **NIM**
4. M. Laakso et al. *NIM* **A327** (1993) p. 517-522
5. Private communication with C. Haber.