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THE DØ SILICON MICROSTRIP TRACKER: CONSTRUCTION AND TESTING

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The DØ collaboration is nearing completion of the DØ Silicon Microvertex Detector, a 793,000 channel silicon strip tracking system for the DØ Upgrade. The production of this detector, which is one of the two largest detectors to date, included burn-in of electronics, testing with an IR laser, mechanical assembly under coordinate measuring machines, and a test of a significant portion of the readout system. We have observed various failure modes of the silicon sensors, and a particular failure mode involving microdischarges at the coupling capacitor edge will be described.

Fermilab's Tevatron is slated to begin a new run of high energy $p\bar{p}$ collisions, the so called Run II, in March 2001. During this run the center of mass energy will be 2 TeV and the expected luminosity for the first two years will be 2-4 fb^{-1}, i.e. 20 to 40 times more than Run I. Most of the processes of interest (top quark physics, Higgs boson searches, SUSY searches) have b quarks in the final state, and tagging of b quarks through a displaced vertex is a required feature of a detector optimized for such physics. The DØ Upgrade has as a major component a silicon strip vertex detector[1] , the SMT (Silicon Microvertex Tracker), to identify tracks with non-zero impact parameters for $|\eta| < 3$. A silicon track trigger that reconstructs online displaced vertices is also being built [2].

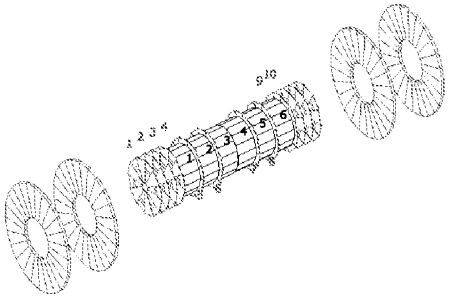

Figure 1. Overall layout of the DØ SMT. The separation between disk 1 and disk 12 is 1.1 m .

The SMT,shown in figure 1, consists of six cylindrical barrels of four layers of silicon sensors as shown in figure 2. The sensors for the four barrels near the z=0 position have double sided detectors with axial and 2^o stereo strips for the second and fourth layers, and for the first and third layers they have sensors with axial and 90^o large angle strips using double-metal readout. For the two outermost barrels single sided axial strip sensors are used instead of the 90^o variety. The innermost(outermost) radius of the barrels is 2.7 cm(10.3 cm). Interspersed between the barrels, and also at the two ends, are twelve disks formed of double sided wedge sensors with 30^o stereo strips which run at $\pm 15^o$ of the radial direction. Two larger disks at each end, built of single sided wedges glued back-to-back that provide a $\pm 7.5^o$ stereo readout, complete the SMT.

The 768 sensor assemblies that comprise the SMT have a silicon area of 3.0 m^2, of which half is double sided, and have $792,576$ AC-coupled readout channels. The size of this detector is of intermediate size between the largest silicon vertex detectors built to date (LEP, CDF Run I, CLEO) and the ones envisioned for LHC (CMS,ATLAS).

Extensive testing is required to assure adequate performance of such a large system. Each sensor module with its on-board

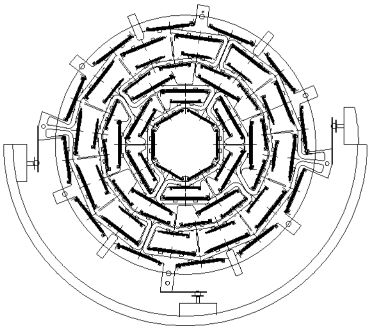

Figure 2. Cross section through the cylindrical portion of the SMT.

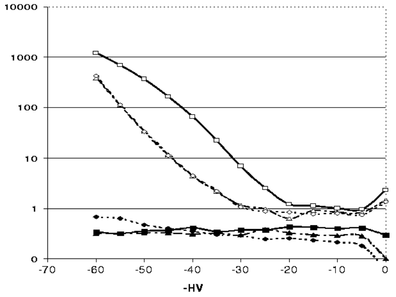

Figure 3. Strip current (nA) for p-side biased unirradiated detector, with p-side AC coupling capacitor floating (open points), or grounded (solid points).

mounted front electronics is tested for at least 72 hours and strips with excessive current/noise, or with shorted coupling capacitors are disconnected. Finally the light beam from an IR laser (λ=1064 nm) is used to scan across each sensor.

Early tests raised concerns about the noise performance of the detector and readout systems. Such issues have been studied with a rather large test setup of a barrel and disk assembly using the same electronics that will be used in the DØ detector. In this setup, which has proven invaluable in debugging the readout, 83,328 channels were run error free (error rate <1 per 3×10^{13} bits).

Final assembly of the detector is proceeding and half of it has been fully assembled. Alignment tolerances of less than 10μm, dictated by the requirements of the trigger processor, have been met.

We saw a variety of silicon sensor failures. In particular, for double sided double metal detectors, defects of the p-stop isolation used on the n-side were a concern. Another failure were microdischarges similar those observed by a KEK group [3]. Figure 3 illustrates the excessive currents seen with double sided detectors when a negative potential is applied on the p-side, if the AC coupling capacitor on the p-side is grounded. This behaviour is correlated with mask misalignments indicating a microdischarge due to high fields in the isolating layer of SiO_2. This phenomenon moves to the n-side following irradiation and type inversion. This is clearly shown in figure 4 where large noise increases are observed for n-side strips with grounded AC coupling capacitors in a detector irradiated by 10^{14}neutrons/cm^2; one sees that the noise clearly depends on the n-side bias (total HV - neg HV), i.e the discharge happens at the n-side that is now the junction side.

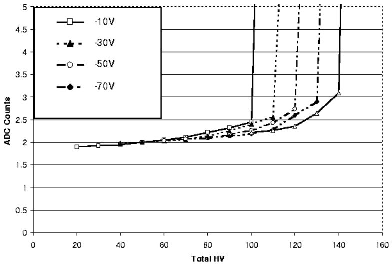

Figure 4. Noise of n-side strips for an irradiated double sided detector with bias on both the p- and n-sides; the four lines correspond to different p-side bias voltages.

References

1. For details see F. Lehner, *Nucl. Instrum. Meth.* A **447**, 9, (2000).
2. M. Narain, *Nucl. Instrum. Meth.* A **447**, 223, (2000).
3. T. Ohsugi *et al., Nucl. Instrum. Meth.* A **342**, 22, (1994), and **383**, 116, (1996).