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The DØ Upgrade Silicon Tracker

A.P. Heinson
for the DØ Collaboration

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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A.P. HEINSON, for the DØ Collaboration
Department of Physics, University of California,
Riverside, CA 92521-0413, USA

ABSTRACT

A large silicon strip tracking detector is planned for the upgrade of the DØ experiment at Fermilab. This detector is designed to tag secondary vertices, to measure the momenta of charged particles and to operate in the high rate environment of the upgraded Tevatron. Details of the detector design are presented here.

1. Introduction

The DØ detector at Fermilab will need its tracking capability improved to keep pace with upgrades in the luminosity of the Tevatron and to replace the existing wire chambers. These will be unable to operate due to radiation damage and a much shorter time between beam crossings. For Run II, scheduled for November 1995, the beam crossing time will go from $3500ns$ to $396ns$. Later, the time is expected to be reduced to $132ns$. The new inner detector will be a silicon strip tracker, capable of operating at this high interaction rate, and surviving at least $1Mrad$ of charged particle dose. The Silicon Tracker will be built in two phases. Step 1 will be ready for Run II, to replace the inner layer of the present Vertex Detector. It will have ~250,000 channels. Step 2, the full upgrade, will have ~1,000,000 channels and measure momentum out to η=3.3 in a $2T$ solenoidal field.

2. The Detector Design

The Step 1 design of the DØ tracking is shown in figure 1. The Step 1 Silicon Tracker consists of three single-sided barrels and six double-sided forward disks. The ~$50cm$ z coverage of the barrels is necessary because the Tevatron interaction region has $\sigma(z)=\pm 30cm$. Figure 2 shows the Step 2 design. There are large single-sided disks at distant z, for coverage of low angle tracks. Using a smeared vertex z, the mean number of hits on a track from the silicon in Step 1 is 1.7 at $\eta=0$ and 4.5 at $\eta=2.8$. When hits from the Fiber Tracker, and the Central and Forward Drift Chambers are included, these values rise to 13.7 and 8.8. For Step 2, the number of hits from the silicon is 2.3 at $\eta=0$ and 14.5 at $\eta=2.8$. With the fiber hits, these become 10.3 and 14.5. The momentum resolution for Step 2 with $|\eta|\leq 1.5$ is $\sigma(p_T)/p_T \approx 0.01\sqrt{4+0.25p_T^2}$. By $|\eta|=3$ it rises to $\approx 0.01\sqrt{16+4p_T^2}$. Secondary vertex resolution is $20\mu m$ in x and $64\mu m$ in z. Using a smeared vertex z, Step 1 radiation lengths for the silicon wafers vary from 0.6% at $\eta=0$ to 2.5% at $\eta=2.8$. For Step 2 they vary from 1.0% to 3.0%. The full tracker has 3× as much material.

3. The Silicon Detectors

The barrels are made of ladders, each containing 4 silicon wafers, 3.405×6.000 cm, 640 ac-coupled channels, $50\mu m$ pitch readout. Wafers are wire-bonded in pairs to give $11.8cm$ strips. Wafer pairs are read out at each end of a ladder. For Step 1 there are 78 ladders and for Step 2 there are 234. Figure 3 shows cross-sections through the Step 1 and Step 2 barrels. The 6 Step 1 disks each contain 12 wedge-shaped wafers, which are $75mm$ high, with 1024 ac-coupled strips on each side, at $50\mu m$ readout pitch, and $\pm 15°$ stereo angle between the p- and n-sides. The strip length varies from 74.643 to $0.500mm$. There is a total overlap of the active region between neighboring wedges of $707\mu m$, for good tracking efficiency and ease of alignment. In Step 2, there are 10 of these disks and a further 10 similar disks, with a larger inner radius. At large z, there are several large single-sided disks. All Step 1 ladders and disks will be reused in Step 2.

4. Readout Electronics and Cooling

The strips will be read out with radiation hard CMOS chips, 128 channels each, mounted on high density interface circuits epoxied directly on the wafers to minimize material. Each channel contains a preamplifier, an analog pipeline with 16 signal storage cells, and a 7-bit $53MHz$ analog-to-digital converter. The sparsified digital signals are sent with channel and chip addresses to a VME data acquisition system. The readout may be done in parallel using microstrip cables or in series using optical fibers. The power supply cables will probably be aluminum on kapton strips, for low radiation length. Since the chips generate about $2mW$ per channel, the Step 2 detector will generate over $2kW$ of heat. Turbulant water cooling will be used with $10°C$ inlet temperature to keep the maximum chip temperature below $20°C$. The cooling pipes may be $\sim 1.5mm$ diameter, operating at subatmospheric pressure. Dry nitrogen will be flowed through the whole detector to control humidity.

5. Mechanical Support and Alignment

The ladders will be mounted on beryllium barrel support rings with an $800\mu m$ overlap. The wedges will be mounted on beryllium dodecagons, which will contain the cooling pipes and support the readout and power cables. There will be a lightweight SiC foam central support to protect the inner radius of the wafers. The barrels and disks will be kinematically supported from a spaceframe using small tefzel-coated balls in slots, designed not to overconstrain the system motion. The spaceframe is made of toroidal aluminum tubes, epoxied to hollow non-axial support struts, with 12 struts per z section. The Step 1 spaceframe weighs only $\sim 200g$, and will support over three times its own weight, with a central deflection of only $150\mu m$, for precision alignment. It will disassemble into 6 sections in z, for installation or removal of the detector.

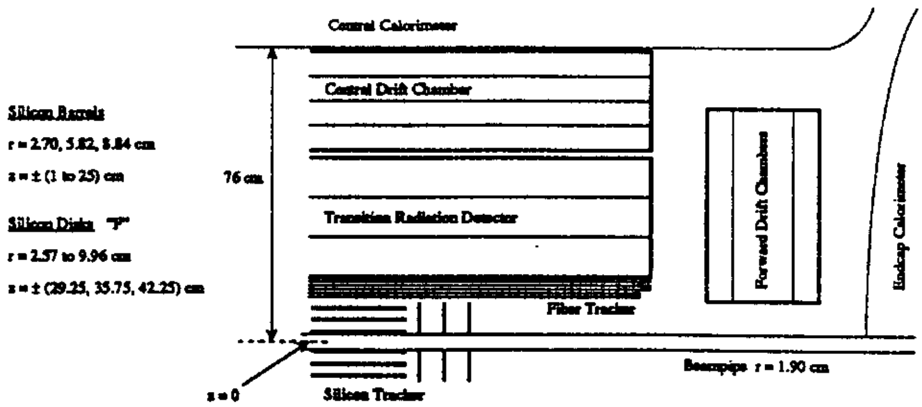

Figure 1: One quarter of the DØ Step 1 upgrade tracking system.

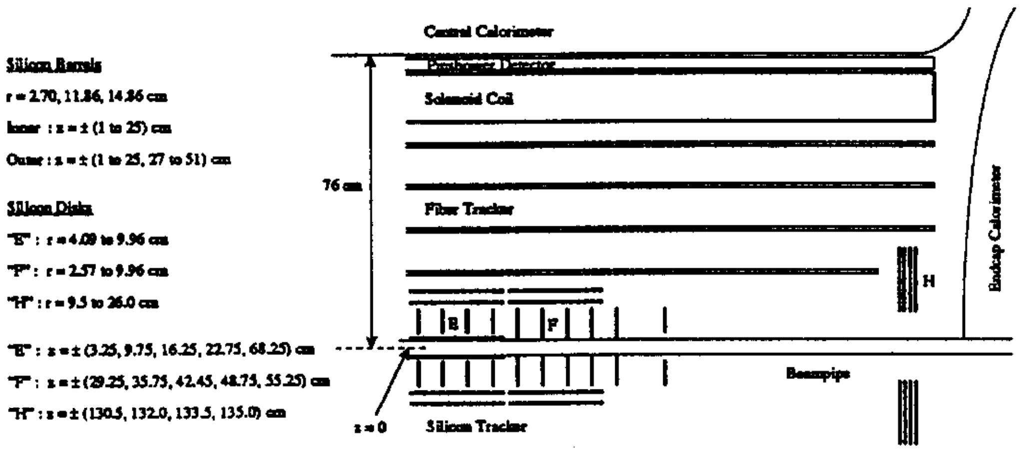

Figure 2: One quarter of the DO Step 2 upgrade tracking system.

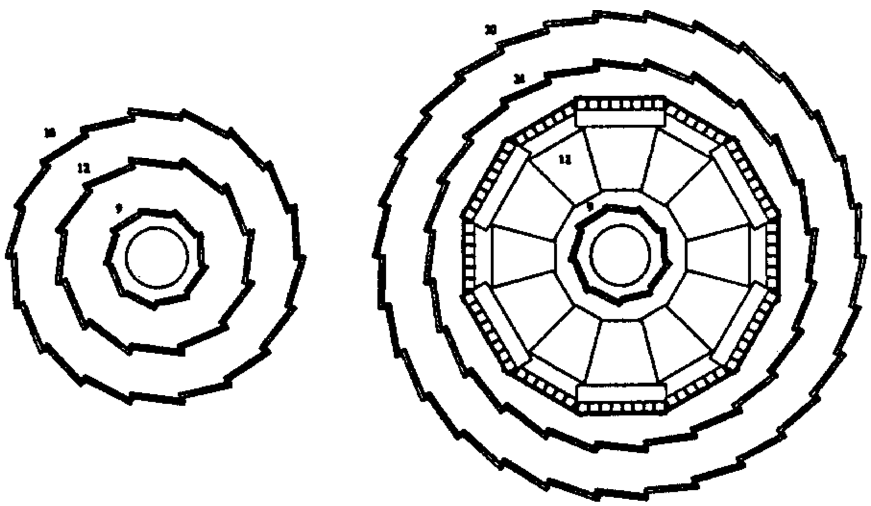

Figure 3: Cross-sections through the Step 1 barrels and Step 2 E-disk and barrels.