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The D0 silicon tracker

W.E. Cooper *

Fermi National Accelerator Laboratory, Batavia, IL 60510–5011, USA

For the D0 Collaboration

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ABSTRACT

The D0 silicon micro-strip tracker, which was installed for Run II of the Fermilab Collider, and an inner silicon micro-strip layer 0, which was installed for Run IIb of the Collider, are described.

1. Introduction

The D0 silicon tracker comprises two portions: an original set of barrels and disks built for Run IIa of the Tevatron Collider [1,2] and an additional "Layer 0", built for Run IIb of the Collider. The original portions of the tracker have been in operation since spring 2001. To address concerns regarding possible deterioration of the inner layers of that detector due to radiation damage and to improve the vertex resolution, an inner Layer 0 was added for Run IIb of the Collider. Layer 0 has been in operation since spring 2006.

2. Run IIa silicon

The 792,576-channel, 1248-sensor, Run IIa silicon tracker includes a central portion with six barrels, each with four layers, six "F-disks", one attached to each barrel, and six more F-disks divided evenly between two end disk modules. The general arrangement of Run IIa silicon within the surrounding detector elements is shown in Fig. 1. The central silicon elements are supported from the inner surface of central scintillating fiber tracker (CFT) barrel 1 via two double-walled cylinders made of carbon fiber–epoxy laminate. Barrel sensor centerline radii range from 27.1 to 100.6 mm. F-disks cover a similar radial range. The barrels and F-disks of the central silicon occupy a 1066-mm-long region and are arrayed symmetrically about the center of the interaction diamond. For tracks from the origin and at the least favorable azimuth, the central silicon provides three or more hits to $\eta = \pm 3.54$.

Four "H-disks", with silicon centered at $z = \pm 1004$ and ± 1210 mm, are supported independently from the inner surface of scintillating fiber tracker barrel 3. The H-disks, whose silicon extends from $R = 96$ to 236 mm, complete the tracker and allow more precise momentum measurements of forward tracks.

Central silicon is supported from two half-length, double-walled carbon fiber laminate cylinders with removable access covers. Signals from individual ladders and wedges are brought on hybrid "pigtails" to the outer surface of the support cylinder. There they are connected to low-mass cables that run longitudinally.

All D0 silicon is cooled by a 32% by volume mixture of ethylene glycol in water. Coolant is drawn from an atmospheric pressure reservoir, which ensures that coolant pressure within the detector region is sub-atmospheric. No leaks, blockages, corrosion, or other problems have been observed in the detector region since the silicon was commissioned. Typical coolant temperature is $-8.5\,^{\circ}$C, which leads to a maximum temperature of $+2\,^{\circ}$C at any point within a Run IIa sensor. To ensure that condensation of moisture will not occur, the silicon region is purged with dry air having a dew-point which is typically below $-50\,^{\circ}$C.

2.1. Sensors

Seven varieties of sensors were used in the Run IIa silicon tracker (see Table 1). All sensors are AC coupled and nominally 300-μm thick. All barrel and F-disk sensors were obtained from Micron Semiconductor, Ltd., Eurisys, or CSEM. All H-disk sensors were obtained from ELMA.

2.2. Sensor support, cooling, and readout connections

Sensors of barrels are formed into ladders of nominal length of 120 mm. The 72 ladders of each barrel are supported from a 9.525-mm-thick "cooled" beryllium bulkhead, which connects to

* Tel.: +1 630 840 4093; fax: +1 630 840 8886.
E-mail address: cooper@fnal.gov

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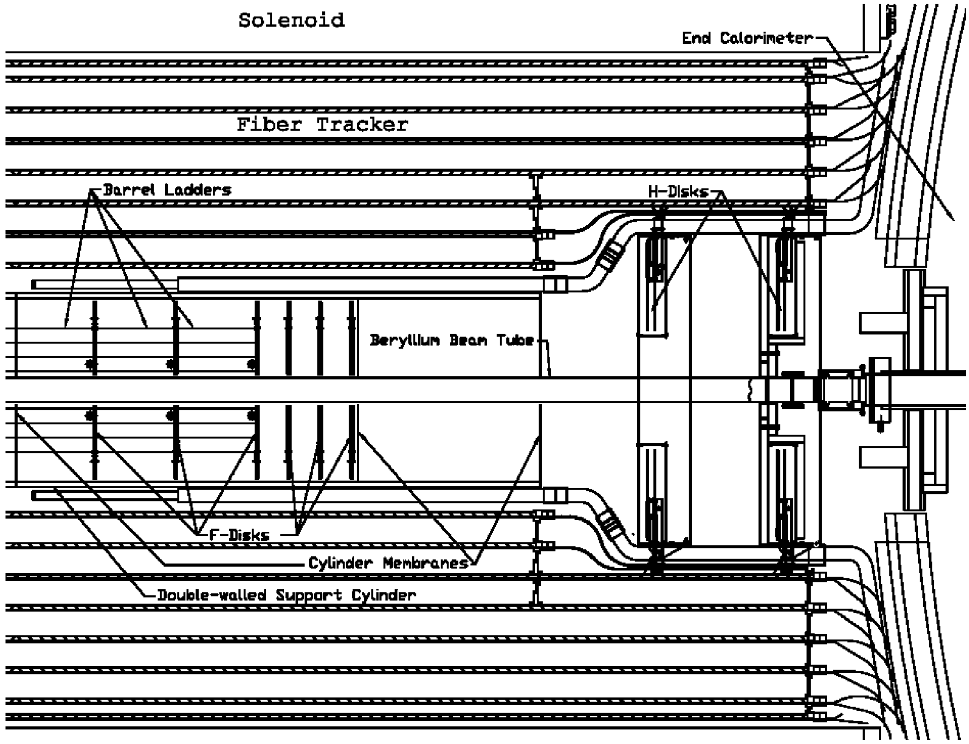

Fig. 1. Plan view of the Run IIa silicon tracker within the surrounding elements of the D0 detector.

Table 1
Sensor types

Location	Type	Pitch (μm)
Central 4 barrels, layers 1 and 3	Double-sided, double-metal, 90° stereo	50, axial surface 153.5, stereo surface
Outer 2 barrels, layers 1 and 3	Single-sided, axial	50
All barrels, layers 2 and 4	Double-sided, 2° stereo	50, axial surface 62.5, stereo surface
F-disks	Double-sided, 30° included stereo angle	50, p-side 62.5, n-side
H-disks	Single-sided, mated back-to-back to provide 15° stereo	40, trace pitch 80, readout pitch

the silicon support cylinder via leaf springs and adjustable mounts at 3, 6, and 9 o'clock. A 0.762-mm-thick "passive" beryllium bulkhead locates the far ends of ladders relative to one another. Coolant flows through two passages of typical flow cross-section 5.842 mm × 7.366 mm within each cooled bulkhead (see Fig. 2).

SVX-2 readout chips on multi-layer "high-density interconnects" (HDI's) are mounted via beryllium substrates to the silicon surface of each ladder. "Pigtail" extensions of the HDI's carry signals to and from the outer periphery of the silicon support cylinder. On the outer periphery, each pigtail is connected to a low-mass cable running longitudinally along the support cylinder. Hirose zero insertion force connectors are used for connecting to low-mass cables.

Sensors of F-disks are attached to beryllium substrates, which carry their readout structures, to form wedges. Each disk comprises 12 wedges mounted alternately on the two surfaces of a planar beryllium cooling channel (Fig. 3). Coolant flow cross-section of the channel is 1 mm × 7.5 mm. Readout is at a larger radius than the cooling channel to aid in isolating heat sources from the sensors; the sensor is at a smaller radius. On the n-side of sensors, which faces the cooling channel, a short copper-on-kapton jumper carries signals from the sensor to the SVX-2 chips. On the p-side, wire bonds connect the sensor to readout chips directly.

Each barrel carries six posts to locate and hold its associated F-disk. Once joined, the barrel and F-disk are handled as a single unit. The three outer F-disks are joined to one another via posts to form an end F-disk module. Adjustable leaf spring mounts support the module from the silicon support cylinder.

H-disks carry 24 wedges mounted alternately on the two surfaces of a planar beryllium cooling channel. A relatively complex structure is used to obtain the desired radial coverage and an effective stereo angle of 15° with single-sided sensors. Two sub-layers, each with one inner- and one outer-radius sensor, are joined back-to-back to form a wedge (Fig. 4). Back-to-back alignment was accomplished on a specially equipped coordinate measuring machine (CMM) with a pair of collinear optical probes.

3. Run IIb silicon

D0 improvements for Run IIb included the addition of Layer 0 silicon (L0), which has 12,288 channels, within the inner radius of Run IIa silicon. A suitable, new beryllium beam pipe had already been obtained in conjunction with an earlier upgrade proposed for Run IIb. Therefore, the transverse space available for L0 was set by the Run IIa silicon structures and the new beam pipe.

Openings at six Z locations in carbon fiber laminate membranes of the Run II a silicon support structure set the outer limit for L0. Measurements to confirm that the transverse alignment of openings was understood correctly were conducted in fall 2004. Based on those measurements and the need for radial clearance during L0 installation, the maximum radius for L0 was selected to be 22.02 mm. That provides a minimum radial installation clearance for L0 of 0.09 mm.