Evolution of the Design of a Silicon Tracker for the Linear Collider

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A design for the silicon tracker for SiD was proposed at the Victoria Linear Collider Workshop [1]. This paper describes development of that design by the SiD group into a baseline model for simulation studies. The design has been modified to take into account detector fabrication and servicing requirements, features specific to the vertex chamber, and detector elements in the region surrounding the silicon tracker.

1. THE VICTORIA DESIGN

Prior to the 2004 Victoria Linear Collider workshop, concepts for an all-silicon tracker had been proposed by M. Breidenbach and other members of the SiD group [2]. At the Victoria workshop, a more detailed mechanical design, based upon an array of five barrels with single-sided silicon at radii ranging from 22 cm to 124 cm, was suggested [1]. Barrel active lengths increased approximately uniformly with radius in order to provide barrel coverage over the range cos(θ) = ±0.8; active lengths of innermost and outermost barrels were 30 cm and 331 cm, respectively. Carbon fiber – epoxy rings join one barrel to the next. Ten disks, one closing each end of a barrel, extended cone angle coverage to cos(θ) = ±0.99. Each disk was assumed to have overlapping layers of silicon arranged in such a way that two transverse coordinates would be measured. Sensor positions and dimensions for both barrels and disks were chosen to provide at least 0.1 cm overlap of edges of adjacent sensors. A region 20 cm in radius x 55 cm long was provided for the vertex chamber. The basic geometrical arrangement of the tracker is shown in Figure 1.

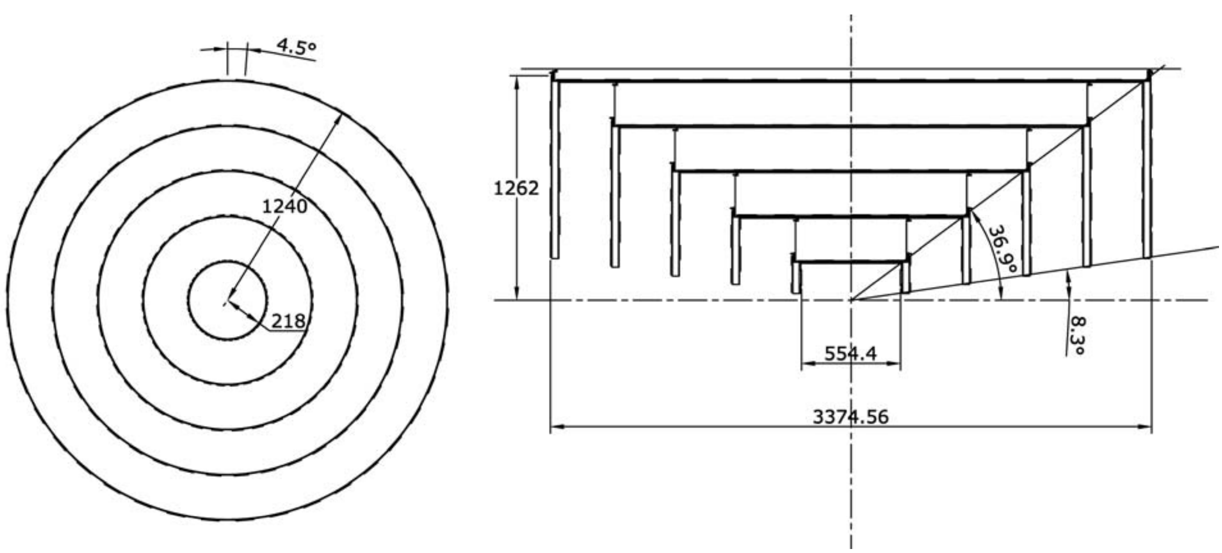

Figure 1: End and elevation views of the Victoria design.

Active area and chip counts (assuming 128 channels per chip) are given in Table 1. To control cost and ensure that the design would be consistent with present technologies, single-sided, 300 μm thick silicon microstrip sensors were assumed to be used in all barrels and disks. Readout pitch was assumed to be 50 µm; trace pitch was assumed to be 25 µm. In the barrels, sensors were arranged to form 80 phi towers. In the disks, the number of phi bins was varied from 80 at the largest radius to 20 at the smallest radius.

Table 1: Barrel and disk parameters

Barrels (Layer)	**Sensors**	**Active Area (m^2)**	**Chips**	**Disks (Sum of two ends)**	**Sensors**	**Active Area (m^2)**	**Chips**
1	640	1.72	1920	1Phi + 1R	100	0.70	1140
2	960	4.11	5760	2Phi +2R	280	2.93	4240
3	1440	9.15	12960	3Phi + 3R	640	6.75	9600
4	1920	16.26	23040	4Phi + 4R	960	12.17	16160
5	1920	19.50	28800	5Phi + 5R	1440	19.16	23840
Sum	6880	50.73	72480	**Sum**	3420	41.71	54960
Barrels + both sets of end disks					**10300**	**92.44**	**127460**

The design assumes that cooling of readout elements on or near silicon will be provided through forced convection of dry gas at approximately room temperature. For a reasonable total flow rate of dry air (0.048 m^3/s), a reasonable rise in temperature of the air between supply and return (5^oC), and optimal heat transfer into the air, 292 watts would be carried away by the air flow. SVX-4 chips dissipate approximately 0.18 watt per chip, or 22940 watts for 127460 chips. That suggests average power dissipation should be reduced by a factor of roughly 79 below that dissipated by SVX-4 chips. To obtain that reduction factor, the baseline SiD design assumes that chip power will be cycled or limited between beam bunches; improvements in readout chip design could also contribute.

2. MODIFICATIONS TO THE DESIGN

Modifications to include vertex chamber details, to allow servicing the vertex chamber, to control the concentration of material at barrel and disk overlap regions, and to simplify assembly have been considered. These are described in subsequent subsections.

2.1. General Layout and Provisions for Servicing

The design has been augmented to include details of one suggested vertex chamber geometry. Access to service the vertex chamber and portions of the outer tracker is achieved by rolling the outer tracker longitudinally in either direction while maintaining the vertex chamber and beam pipe fixed. To allow that motion, the disks of the outer tracker were separated into two radial portions, as shown in Figure 2. The outer portion remains part of the outer silicon tracker; its support structures are shown extending inward to a radius of ~18.8 cm (the optimal radius remains to be determined). Disks of the inner portion are supported from the beam pipe. Longitudinal positions of those disks have been shifted towards the interaction point in order to maintain hermeticity in disk angular coverage with the tracker closed. A gap of 0.4 cm has been shown between support structures which move with the outer tracker and structures which remain stationary during servicing.

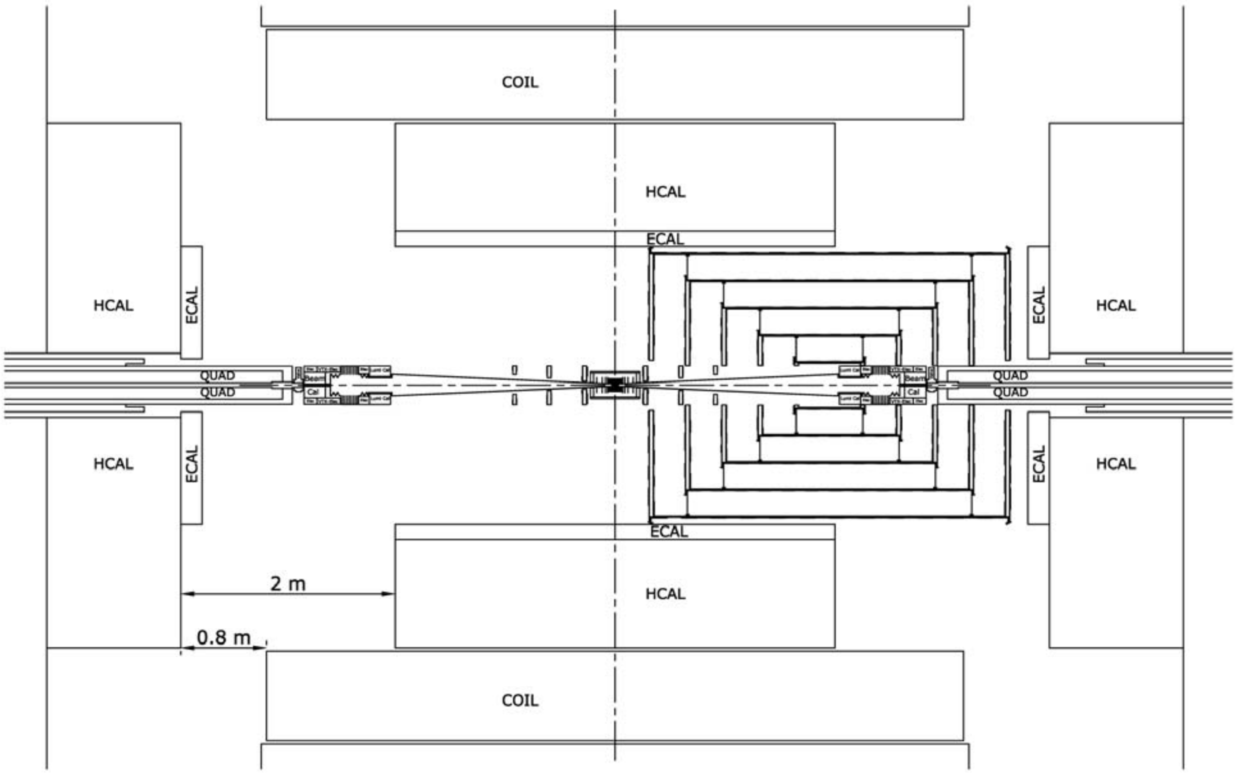

Figure 2: Arrangement of detector elements with the detector “open” for vertex chamber and tracker servicing

While the inner disk portions are drawn with support structures similar to those of the outer disk portions, a different sensor technology, such as one based upon pixels, might be appropriate for the inner portions. That could impact the support of the inner disk potions.

2.2. Modifications to Control Projective Geometry

An estimate of the number of radiation lengths in the tracker as a function of cos(θ) is shown in Figure 3 [3]. Near cos(θ) = 0, the result of about 4.5% of a radiation length for five layers compares reasonably with what was achieved in BaBar [4], approximately 0.8% of a radiation length per layer.

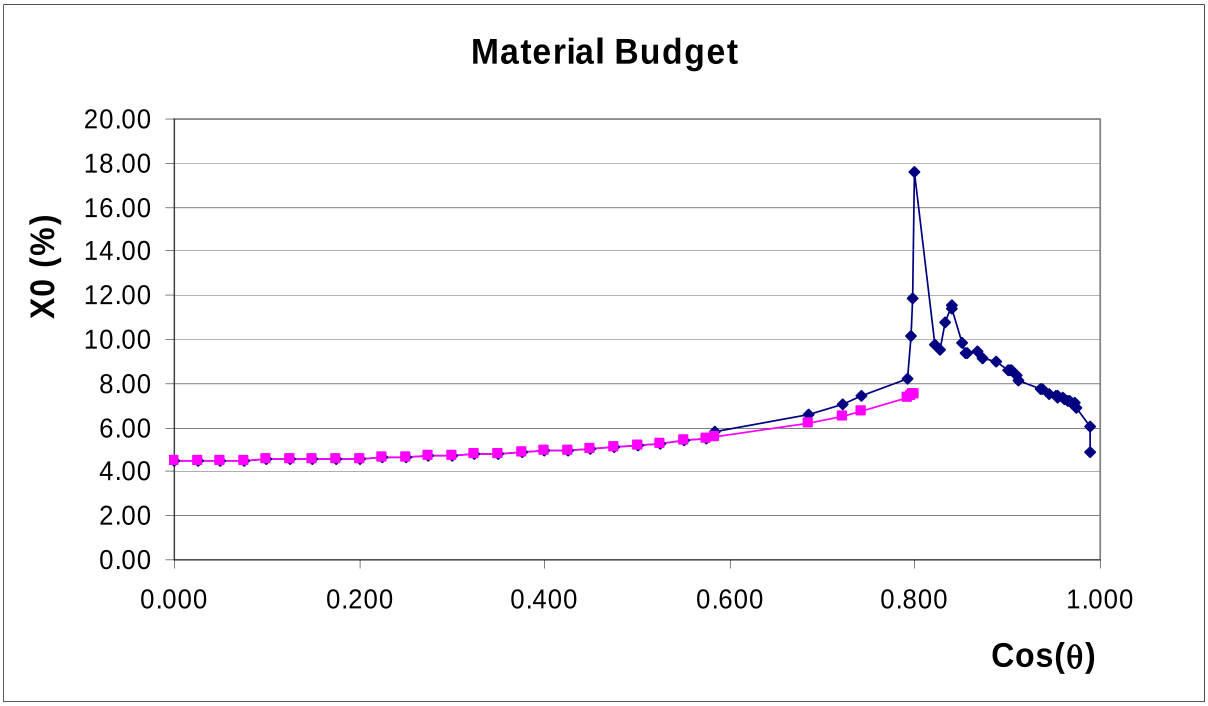

Figure 3: Number of radiations lengths represented by the silicon tracker versus cos(θ)

The lower curve of Figure 3 shows contributions from the barrels only. The upper curve includes contributions from layer-to-layer connecting rings, ring mounts, and disks. Layer-to-layer connecting rings begin at approximately cos(θ) = 0.58. The spike slightly above cos(θ) = 0.8 is associated with overlap of barrels and disks to achieve hermeticity. The amplitude of the spike, but not the total amount of material from which it originates, can be reduced by varying the lengths of barrels, as shown in Figure 4.

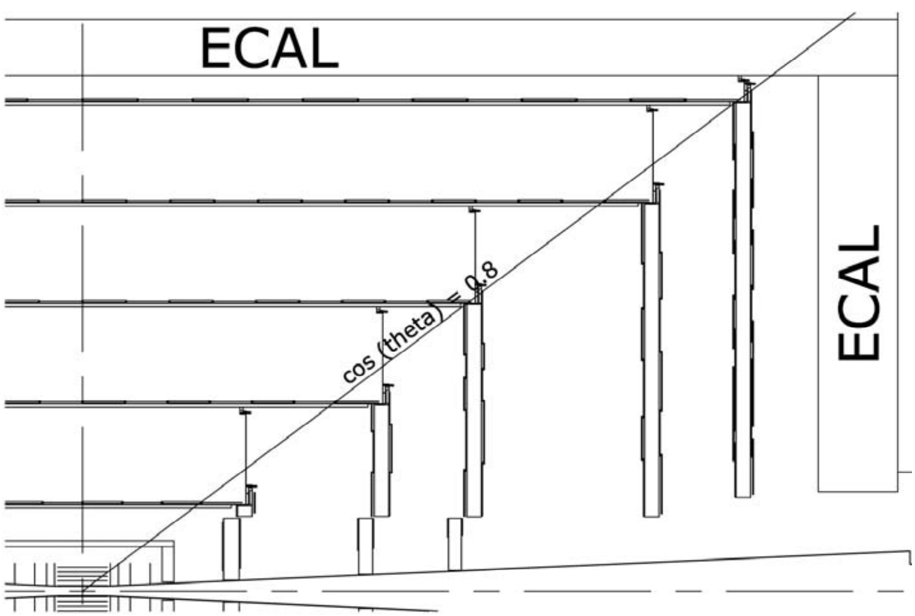

Figure 4: Variation of lengths of barrels to reduce the alignment of pointing material

2.3. Sensor Mounting

Two approaches were considered:

1. The use of three point support of each sensor using posts with ball and socket mounts [5]
2. The use of carbon fiber window frames which would support each sensor, guide cabling from the sensor, and would be accurately placed into a receptacle on the outer surface of a support structure [6][7].

Analysis of thermal bowing and gravitational deflections suggested that the first approach, shown in Figure 5, could be used to fabricate multi-sensor modules of an overall length up to approximately 80 cm. Sensors would be supported by a sandwich structure of carbon fiber – Rohacell – carbon fiber; Rohacell thickness for that length of module would be ~1.2 cm. The material represented by the module structure could be reduced by providing openings in both the carbon fiber and the Rohacell.

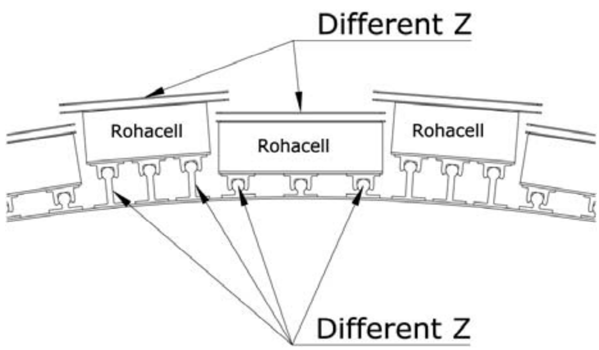

Figure 5: The first approach for modules and their support

The second approach, shown in Figure 6, in principle, also allows the fabrication of multi-sensor modules, but its development was specific to single-sensor modules. Longitudinal bus cables would allow multiplexed readout from multiple modules at a given R-phi; short, low mass flex-circuits would be used to join the readout of each sensor to a connector on the bus cable. To accommodate Lorentz drift, the modules would be arrayed at an appropriate angle on the barrel or disk support structure.

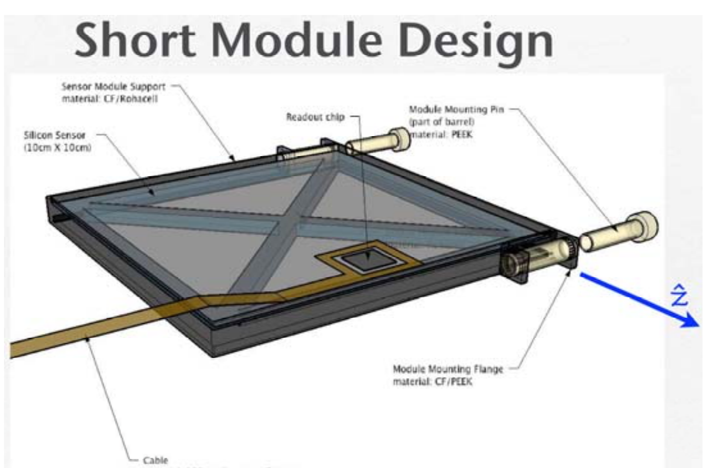

Figure 6: The second approach for modules and their support

The second approach is more consistent with the readout scheme envisioned, and was adopted in the baseline for simulation studies.

2.4. Barrel and Disk Structures and Support

The basic barrel and disk structures consist of two layers of carbon fiber – epoxy laminate separated by Rohacell. Initial hand estimates suggested that a thickness of 0.025 cm would be appropriate for each of the carbon fiber layers and a thickness of 1.3 cm would be appropriate for the Rohacell spacer. Finite element analysis of the outermost barrel [8] predicted a maximum deflection of 14 µm with that construction. Most of the deflection was local and was associated with load transfer of the combined weights of other barrels and disks. Adding reinforcement at the load transfer locations reduced the maximum deflection to 7 µm.

3. AREAS FOR FURTHER STUDY

Simulation studies are planned which would guide designs on the number of barrel and disk layers needed, barrel lengths, the possible need for stereo layers in the barrels and additional stereo layers in the disks, and the disposition of those layers.

Acknowledgments

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References

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