Final Design Description of Barrel Modules and Sextants

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I Design Requirements for Inner Three Layers

The primary function of the inner barrel modules is to provide a precise measurement of a charged particle's position and angle. This measurement should be made as close as possible to the beam pipe in order to minimize the effect of multiple scattering in the beam pipe on the resolution. The modules themselves should contain as little mass as possible in order to reduce the effect of multiple scattering on track measurements at larger radius. They must still maintain very good dimensional stability, however.

Additionally, the barrel modules must provide as much coverage of the laboratory polar angle region from 20° to 150° as technically feasible. This must be done in a region of extremely limited space, in both the forward and backward regions. Coverage of the entire azimuth is also required.

Cost and practicality also dictate certain design restrictions. For example, the number of different silicon wafers used in the design should be kept to a minimum, and there are limitations on the size of individual silicon wafers.

II Mechanical Description of Inner Three Layers

This section will give a desription of the design chosen to satisfy the above requirements. Each of the inner three layers is composed of six modules arranged in a hexagonal array around the beam pipe as shown in Figure 1. The minimum radius and length of each layer

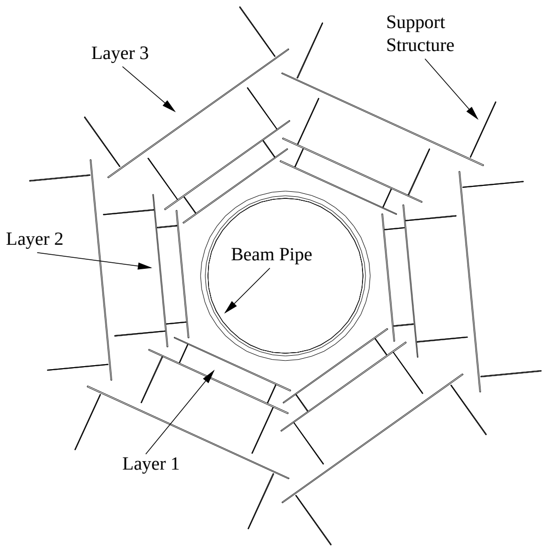

Figure 1: XY cross section of barrel modules

are shown in Table 1.

Layer	Radius	Length
1	33.0mm	169.8mm
2	40.0mm	181.8mm
3	59.0mm	263.8mm

Table 1: Radius and length of silicon in the barrel layer modules.

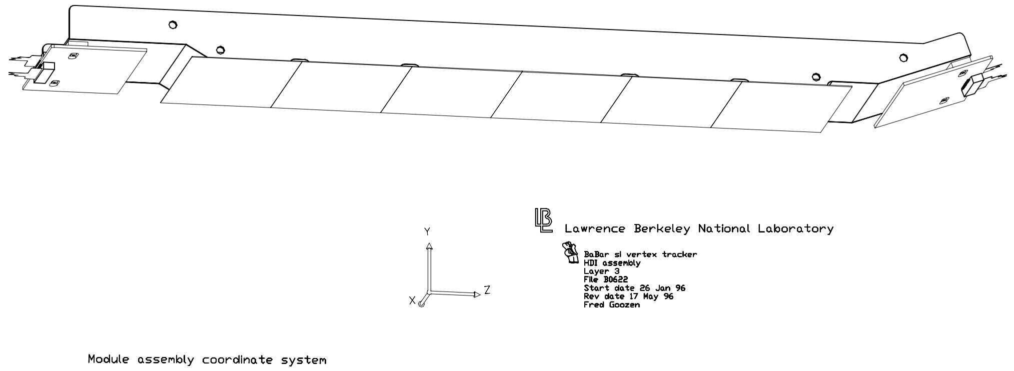

Figure 2: Single module from Layer 3

A single module from Layer 3 is shown in Figure 2. Modules from Layers 1 and 2 are similar. For layers 1 and 2, the modules are joined together to form a sextant, as shown in Figure 3.

The hexagonal design was chosen based on several criteria. First, the final SVT assembly involves building the detector in halves and then mounting the two halves around the beampipe. This favors a design with an even number of modules per layer. Second, having a smaller number of modules per layer makes it possible to avoid ganging in the inner three layers. For the barrel layers with 6 modules per layer, the length-width ratio for a half-module is about $2:1$. Since the readout pitch of these layers is also about $2:1$, there is a good match between the number of ϕ and z electronics channels, and no ganging is necessary. Third, each of the first three layers was chosen to have the same number of modules per layer to minimize any potential space conflicts and to ease assembly.

Within each layer, the modules overlap their neighbors in azimuth by about ??? strips. This overlap region is important for doing detector alignment with tracks.

II-A Modules

Each module is made of two half-modules that are electrically independent from each other, but mechanically joined together by a Kevlar support structure. Each half-module is made from one detector-fanout assembly (DFA) and one hybrid assembly (HDI). The fanouts from the DFA are glued to the HDI, and then the traces from the fanout are connected to the ICs on the HDI by μ-bonds. The silicon strips are connected to the fanout by μ-bonds on the

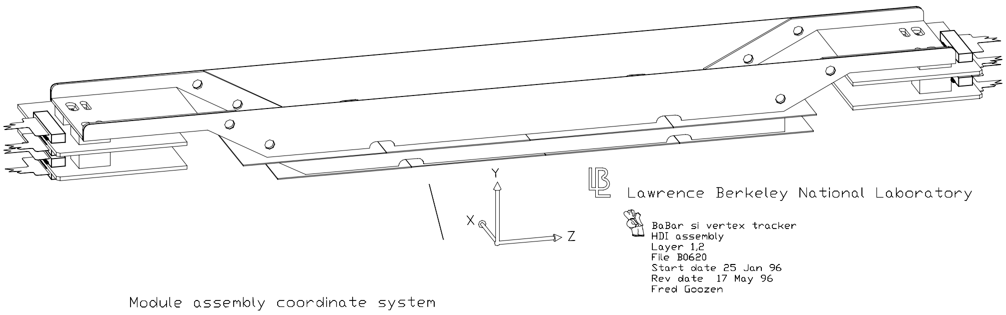

Figure 3: Sextant from Layer 1 and 2

Layer	Readout Pitch (μm)		Number of Strips	
	ϕ Side	z Side	ϕ Side	z Side
1	50	100	799	822
2	55	100	874	882
3	55	100	1275	1278

Table 2: Readout pitch and number of strips in half-modules.

DFA.

The DFAs used in the Layers 1 and 2 half-modules contain two silicon wafers glued head-to-head, and the ones for the Layer 3 half-modules contain three silicon wafers. Table 2 summarizes the readout pitch and number of strips in a half-module for each of the three layers. Detailed desrcriptions of the DFAs and silicon wafers can be found ???.

II-B Sextants

For the inner two layers, each Layer 1 module is glued to a Layer 2 module via the Layer 1 Kevlar support structure to form a sextant (ref Figure 3). The sextant structure enhances the mechanical stability while at the same time solving the problem of how to support Layer 1 in the extremely limited amount of available space. The HDIs from Layers 1 and 2 are also glued together, again due largely to space constraints. The sextant design also makes the final assembly on to the support cones much easier.

III Wirebonds

The connection of the silicon strips to the fanouts, and then the fanouts to the HDIs, is done by wirebonding. On the ϕ side, wirebonds are used to connect strips between adjacent silicon wafers that are glued together head-to-head and to connect strips on the end wafer to the short fanout. On the z side, the strips on every wafer are bonded directly to the long

Layer	# Strips	Wirebonding			Total	
	per 1/2-Mod	Head-to-Head	Si-to-Fan	Fan-to-HDI	per 1/2-Mod	All Modules
1	799	799	799	799	2397	28,764
2	874	874	874	874	2622	31,464
3	1275	1275	2550	1275	5100	61,200
Total						121,428

Table 3: Summary of wirebonds on ϕ side in the barrel modules.

Layer	# Strips	Wirebonding		Total	
	per 1/2-Mod	Si-to-Fan	Fan-to-HDI	per 1/2-Mod	All Modules
1	822	822	822	1644	19,728
2	882	882	882	1764	21,168
3	1278	1278	1278	2556	30,672
Total					71,568

Table 4: Summary of wirebonds on z side in the barrel modules.

fanout. Finally, every trace on the fanout is wirebonded to an electronics channel on the HDI. Tables 3 and 4 show a summary of the wirebonding load of the barrel modules. The connection of the silicon bias line is also done with wirebonds.

IV Stiffening Structure

The half-modules for each layer are mechanically joined together by gluing them to a Kevlar support structure. The Kevlar provides good mechanical stiffness while being very low in mass. It also has very low electrical conductivity. Experience from CLEO SVX R&D showed that using a conductive material, such as carbon fiber, can increase the noise seen on strips near the support structure.

The support structure will also have to be mechanically stable. The particular Kevlar/epoxy composite used has been tuned to have a very low coefficient of thermal expansion, around ????. Since the Kevlar's dimensions change somewhat if it absorbs moisture, it will be kept in a dry environment from construction through assembly. This should closely approximate the environment the Kevlar will face during operation of the experiment.

IV-A Ribs

The support for each layer consists of 2 ribs glued perpendicular to the silicon, forming a U-shaped beam. The location of the ribs can be seen in Figure 1. Drawings of the ribs for Layers 1, 2, and 3 are shown in Figures 4, 5 and 6, respectively.

Figure 4: Rib for Layer 1

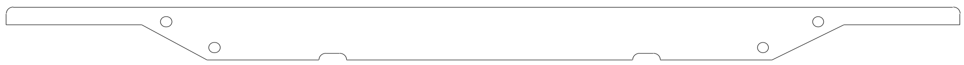

Figure 5: Rib for Layer 2

Each rib is made of a laminate consisting of four layers of Kevlar cloth embedded in a heat resistant epoxy. The laminate will be cured under pressure, and the final thickness will be about 0.41mm. The final part is then cut out of the laminate by laser cutting.

The ribs on the Layer 1 modules are glued to the Layer 2 modules during sextant assembly. For Layers 2 and 3, the ribs are attached to molded Kevlar endpieces before being glued to the silicon, which are described in the next section.

IV-B Endpieces

Drawings of the forward endpieces for Layers 2 and 3 are shown in Figures 7 and 8. The Kevlar-epoxy laminate is the same as used in making the ribs, and the final part is cut with a laser cutter. There are holes in the endpieces for alignment and for attaching the endpiece to the HDI. In addition, some material is removed from the active area of the detector (lightening holes).

V Connection to Support Cones

The connection of the modules to the support cones provides both mechanical support of the module and cooling for the HDI. The modules are screwed to the cooling rings through the brass bushings on the HDIs. This fixes the HDI to the rings and makes a good thermal contact between the HDI substrate and the rings. Once the silicon is properly positioned with respect to the support cones, the Kevlar endpieces are epoxied to the top of the brass

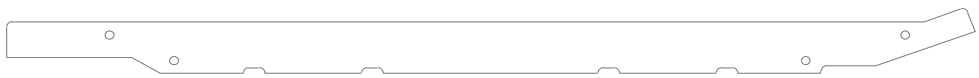

Figure 6: Rib for Layer 3

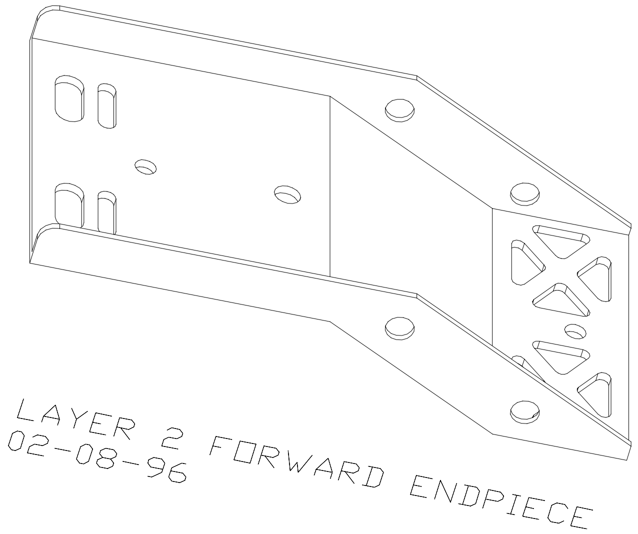

Figure 7: Forward endpiece for Layer 2

bushing on the HDI, permenently fixing the position of the silicon. The details of this assembly sequence will be described elswhere (???).

VI Thermal and Mechanical FEA

Finite element analyses (FEA) of the barrel modules have been done to study both thermal and mechanical properties. For the thermal FEA, it was important to verify that the silicon wafers would not be operating at too high a temperature as a result of being close to the HDIs, which are a heat source. The bulk leakage current in the silicon is a function of the temperature, and the noise increases with the leakage current. The thermal FEA showed that in all three layers, the silicon temperature stayed at the temperature of the surounding air to within XX° C. This presents no difficulty in the silicon operation. There are plans to verify this result with a mechanical model.

The mechanical FEA was done to verify that the chosen design was sufficient for holding the silicon in place. In addition, a modal analysis was done to determine the natural frequencies of the modules. For the Layer 1 and 2 sextant, the FEA found that the maximum deflection of the silicon under the influence of gravity was X.XX μm. For a Layer 3 module, the maximum displacement was X.XX μm. The modal analysis for a sextant found the first natural frequency to be a torsional mode at about 510 Hz, and the second natural frequency to be a flectional mode at about 515 Hz. For a Layer 3 module, the first natural frequency was a flectional mode at about 280 Hz, and the second a flectional mode at about 327 Hz. These are all at a high enough frequency to be no cause for concern.

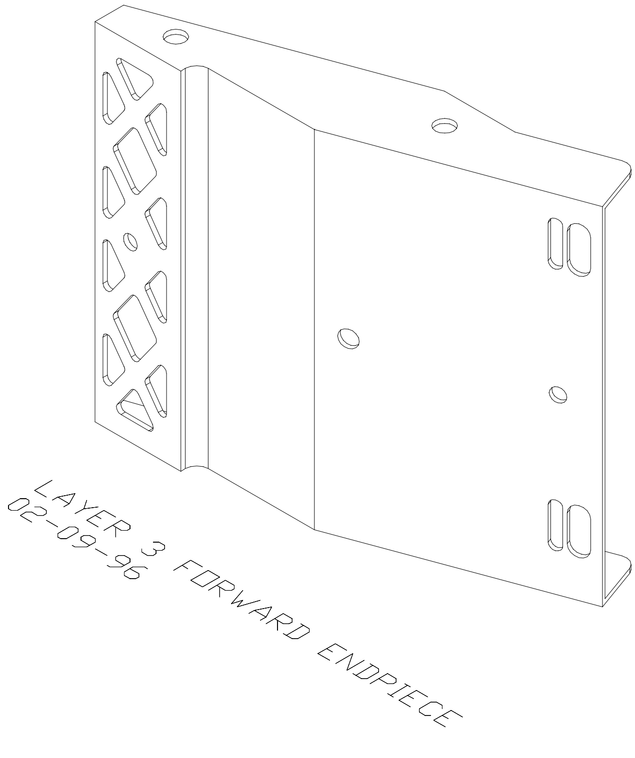

Figure 8: Forward endpiece for Layer 3