Appendix: Simulating the Silicon Detector

Using the fast and flexible detector simulation package developed by the ALCPG Simulation and Reconstruction group, over fifty different detector designs were modeled during the course of this LOI exercise before selecting the baseline design. A somewhat simplified geometry, called sid02, was used for the large-statistics detector response simulations used for the physics benchmarking analyses. For reference, we include here a fairly complete textual description of the sid02 baseline detector. Full details can be found at **http://confluence.slac.stanford.edu/display/ilc/sid02**.

In addition, another model, called sidloi, was developed to more closely represent the engineering drawings of the individual subdetectors described in the subsystems chapter of the LOI.

0.1 sid02

0.1.1 Beampipe

The beampipe is composed of three sections: a cylindrical central tube and forward and backward conical sections. The central tube has an inner radius of 1.2cm and a z extent of $\pm$ 6.251cm and is made of 0.040cm thick beryllium. The conical sections are 0.875mm thick beryllium and flare from 1.2cm inner radius at 6.25cm to 8.2cm at the edge of the tracking region. The beam pipe has a titanium inner liner 0.0025cm thick for the central barrel section and 0.0075cm thick for the conical sections.

0.1.2 Vertex Detector

The vertex detector is composed of a central barrel system with five layers and forward systems composed of four disks. The barrels are all 12.5cm long and are composed of 0.0113cm silicon, of which the outer 0.002 is sensitive. The inner radii of the layers are:

1.46, 2.26, 3.54, 4.8, 6.04cm.

There are four forward disks on either end, composed of a total of 0.0113cm of silicon, of which the inner 0.002cm is sensitive. All of the disks extend to a maximum radius of 7.1cm. The z positions and inner radii for the four disks are:

z (cm)	inner radius (cm)
7.18	1.4
9.02	1.6
12.16	1.8
17.0	2.0

The entire vertex detector is enclosed within a double walled carbon fiber support tube. The support tube walls are 0.05cm thick carbon fiber with inner radii of 16.87cm and 18.42cm and a $|z|$ extent of $|z|$ <89.48cm. The ends of the support tube are double-walled disks of 0.05cm thick carbon fiber disks.

The mechanical supports for the endcap disks are modeled as carbon fiber rings with a reduced density of 25% to reflect the lightening holes in the real structures. The VXD utility mixture of cooling channels, cables and fibers etc. is represented by layers of G10 and copper at the endplates, extending down to the beampipe and exiting the detector along the beampipe.

0.1.3 Tracker

The tracker is composed of five cylindrical barrels with four disk-shaped endplanes. The z extent of the barrels increases with radius and the endplane for each extends beyond its cylinder in radius to provide overlap. The sensitive medium is silicon, assembled into carbon-fiber/Rohacell/PEEK modules and read out via a bump-bonded chip and Kapton/copper cables. These modules are supported by carbon-fiber/Rohacell/carbon-fiber barrels or disks. Each barrel cylinder is supported from the next barrel out by an annular carbon fiber-ring. Outside each of these support rings in z, G10/copper printed circuit boards are mounted for power and readout distribution to all silicon modules in a layer.

Barrels The radii and z extent of the barrel silicon are:

layer	z (cm)	inner radius (cm)
1	55.8	21.8
2	82.5	46.8
3	108.3	71.8
4	134.7	96.8
5	160.6	121.8

For the barrels, the support tubes are composed of 0.05cm carbon fiber, 0.8cm of Rohacell31 (15% coverage) and 0.05cm carbon fiber. The sensor modules for the barrel are single-sided and have 0.03cm of silicon mounted on carbon fiber/Rohacell31 frames that clip into PEEK (Polyetheretherketone) mounts. The average thickness of the carbon fiber, Rohacell31 (50% coverage) and PEEK in the modules of each barrel layer are 0.016cm, 0.28cm and 0.02cm repectively. The average thicknesses of the readout materials are 0.00048cm of silicon, 0.0064cm of Kapton and 0.00065cm of copper, however, the thickness of the cable material varies by layer.

Endcap The z positions and radial extents of the endcap silicon are:

layer	inner radius (cm)	outer radius (cm)	z (cm) for u plane	z (cm) for v plane
1	20.7	49.4	85.5	85.9
2	20.7	74.7	111.4	111.8
3	20.7	99.9	137.8	138.2
4	20.7	125.0	163.6	164.0

where each layer is composed of two sensor modules to measure coordinates in two stereo (u-v) views. The forward disk supports are composed of .05cm carbon fiber, 0.63cm Rohacell31 (15% coverage) and 0.05cm of carbon fiber. There are two sensor modules mounted outside of the disks to provide stereo measurements and have 0.03cm of silicon mounted on either side of carbon fiber/Rohacell31 frames that clip into PEEK (Polyetheretherketone) mounts. The average thickness of the carbon fiber, Rohacell31 and PEEK in the modules of each disk double-layer is assumed to be the same as that for the barrel modules.

0.1.4 Calorimeters

Electromagnetic Calorimeter This element sets the basic size and aspect ratio for the rest of the detector. The inner radius for the barrel is 127cm. The aspect ratio is set to cosine(theta)=0.8, meaning the inner z of the endcap EM calorimeter is at z of 168cm. The EM calorimeter is a sampling calorimeter composed of 20 layers of:

material	thickness (cm)
Tungsten	0.250
Silicon	0.032
Copper	0.005
Kapton	0.030
Air	0.033

This is followed by ten layers of the same readout, but doubled thickness of tungsten. There is a sensitive silicon layer before the first layer of tungsten to provide additional electron/photon discrimination, giving a total of 31 layers of silicon readout. The tungsten alloy being used is TungstenDen24 (93% W, 6.1% Ni, .9% Fe) with a density of 17.8 g/cm^3.

The endcap plug sits inside the barrel cylinder, so the barrel z extent is ± 182cm. The endcap starts at an inner radius of 20cm and extends out to 126.5cm.

Hadron Calorimeter The hadron calorimeter is a sampling calorimeter composed of 40 layers of

material	thickness (cm)
Steel	2.0
PyrexGlass	0.11
RPCGas	0.12
PyrexGlass	0.11
G10	0.3
Air	0.16

It begins immediately outside of the EM calorimeters, with the endcap plug sitting inside the barrel. The barrel inner radius is 141cm with a z extent of $\pm$ 294cm. The endcap extends from an inner radius of 20cm to an outer radius of 140.75cm, inner z of 182cm.

0.1.5 Solenoid

The solenoid is modeled as a cylinder with an inner radius of 255cm. This is larger than the outer radius of the hadron calorimeter since we will not be building a cylindrical detector, but a polygonal one (current thinking is dodecagonal). The barrel composition is as follows:

material	thickness (cm)	z (cm)
Steel	6.0	271.0
Air	8.5	271.0
Aluminum	39.3	262.5
Steel	6.0	262.5
Air	20.0	271.0
Steel	3.0	271.0

This is capped with disk endplates of 6cm steel from r=250cm to 332.8cm. The field is solenoidal, constant 5 Tesla along z up to half the coil thickness and -0.6 outside.

0.1.6 Muon System

The muon system is composed of 11 layers of 20cm thick iron plates interspersed with double RPC readout. The barrel inner radius is 338.8cm with z extent of ± 294cm. The endcap sits outside the barrel at an inner z of 303.3cm and radius from 20.0cm to 608.2cm.

0.1.7 Masks and Far Forward Detectors

The far forward region is designed for the 14mr beam crossing solution so has separate incoming (inner radius 1.0cm) and outgoing (inner radius 1.5cm) beampipes. The far forward plug is designed to fit within a radius of 20cm. It starts with an electromagnetic calorimeter (LumiCal) with the same composition as the endcap calorimeter, extending from 6.0cm out to 19.5cm. The calorimeter is backed up by a conically tapered tungsten mask, inner radius 8.0cm at z of 182cm, tapering to 16cm at z of 313.5cm. The outer radius is constant at 15.5cm. There is a far forward low-Z shield (12.39cm thick Borated polyethylene) at z of 282cm. This is followed by a 50 layer silicon-tungsten calorimeter (BeamCal)at z of 295cm.

0.2 sidloi

The sidloi detector model is intended to reflect the design of the Silicon Detector, as described in this LOI, as faithfully as possible. All of the tracker elements are therefore modeled as planar silicon wafers with their attendant support structures. The readout geometry is simplified, but reflects the gross amount and general distribution of the materials. The calorimeters are modeled as polygonal staves in the barrel region or planes in the endcaps, with interleaved readouts. The complexity of this detector model does not lend itself to a simple textual description. We therefore present a few figures to give an indication of the detail implemented in this model. A full three-dimensional model built from the Geant geometry is available in PDF at **http://silicondetector.org/download/attachments/46170132/sidloi3D.pdf**

A cross section of the tracking detector is shown in Figure 1. This is to be compared with Figure 2 (Figure 2.5 in the LOI) which shows an engineering elevation view of the tracking system. An orthographic cutaway view of the central tracker as implemented in the sidloi model is shown in Figure 3. An orthographic cutaway view of the complete detector as implemented in the sidloi model is shown in Figure 4. The electromagnetic barrel calorimeter is modeled as a dodecagonal tube with overlapping staves. The main difference between this model and the LOI engineering design is the hadron calorimeter barrel. In this implementation it is built of twelve symmetric staves, as opposed to the model described in Section 2.2.3.1 of the LOI. The effect of projective cracks on the detector performance is still being studied. Finally, the octagonal layout of the magnetic flux return yoke, with its eleven layers of muon detection instrumentation is clearly visible. An X-Y cross section of the sidloi model at z=0 is shown in Figure 5. Finally, a Y-Z quadrant of the sidloi model is shown in Figure 6.

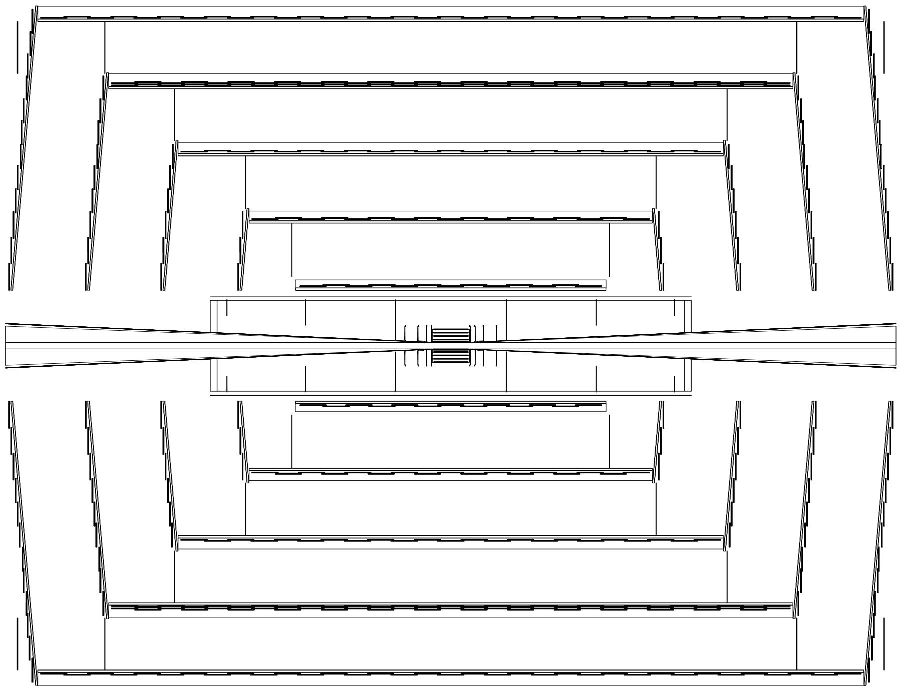

Figure 1: R-z view of the tracking system as implemented in sidloi. Some support and readout structures have been hidden to improve the visibility of sensors.

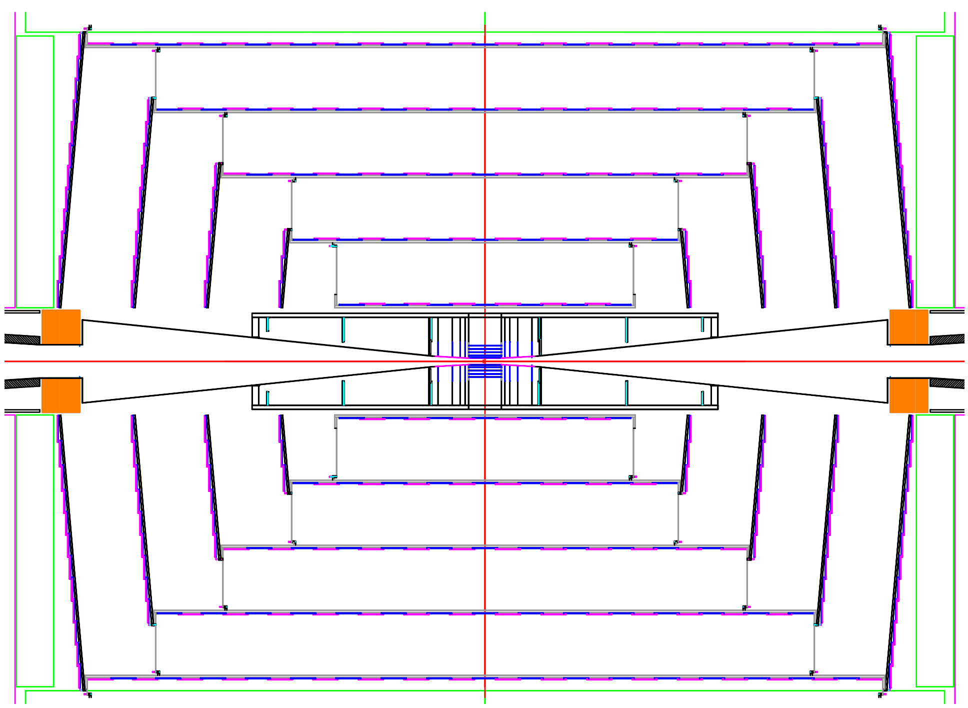

Figure 2: R-z view of the tracking system.

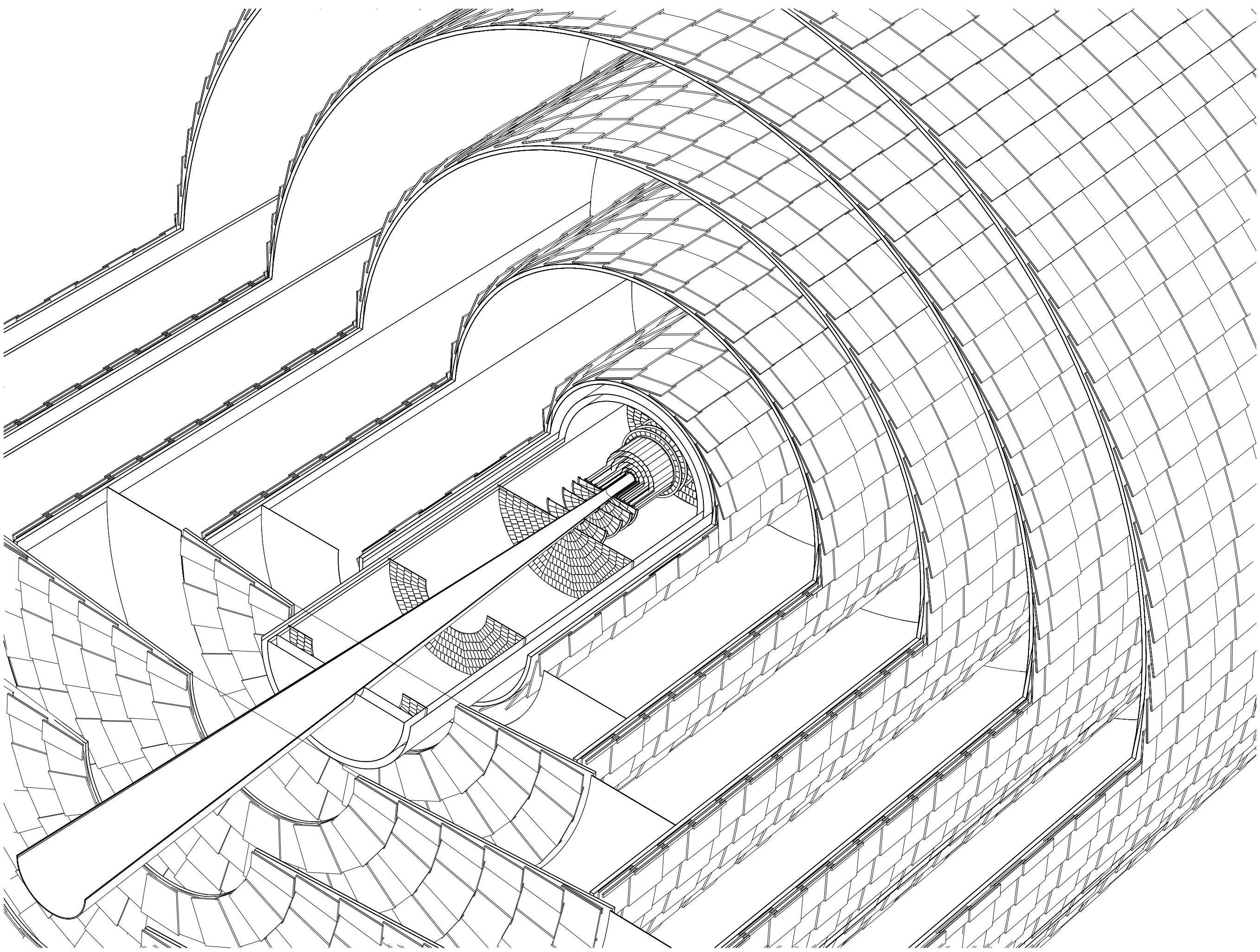

Figure 3: Cutaway view of the tracking system as implemented in sidloi. Some support and readout structures have been hidden to improve the visibility of sensors.

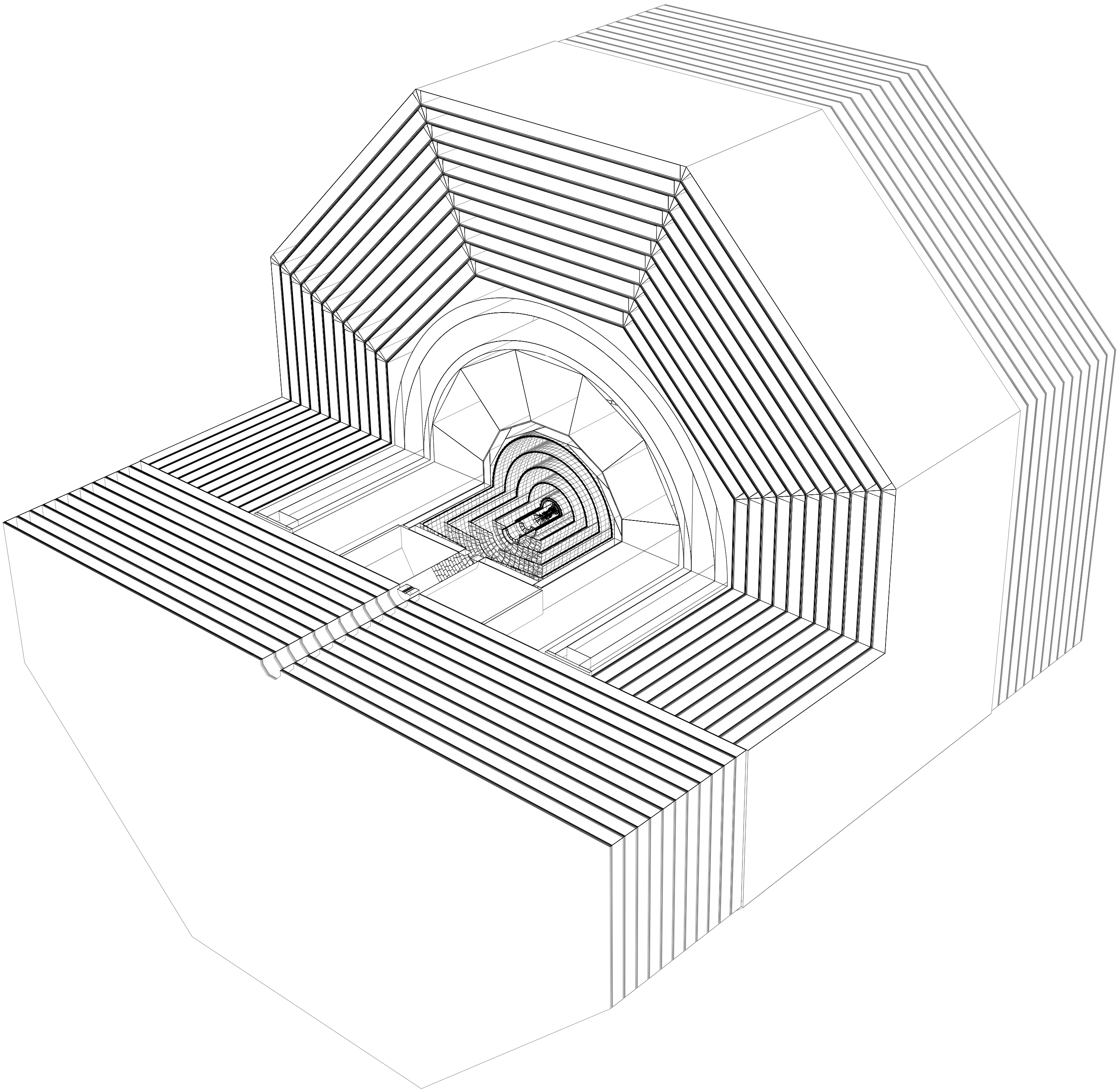

Figure 4: Cutaway view of the Silicon Detector as implemented in sidloi. Some support structures and layering details in the calorimeters have been hidden to improve the visibility of the model.

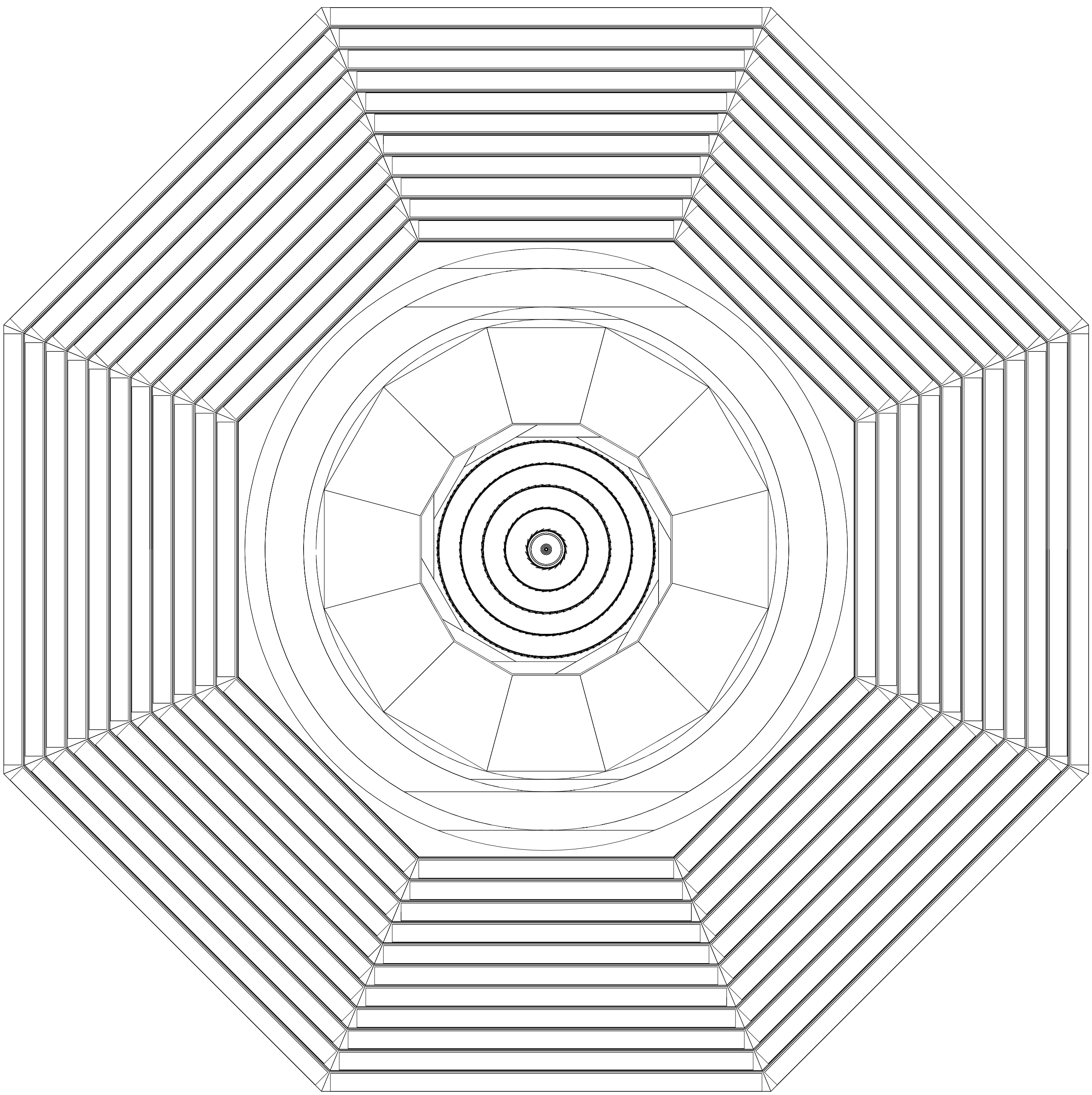

Figure 5: X-Y Cross section view through the center of the Silicon Detector as implemented in sidloi. Some support structures and layering details in the calorimeters have been hidden to improve the visibility of the model.

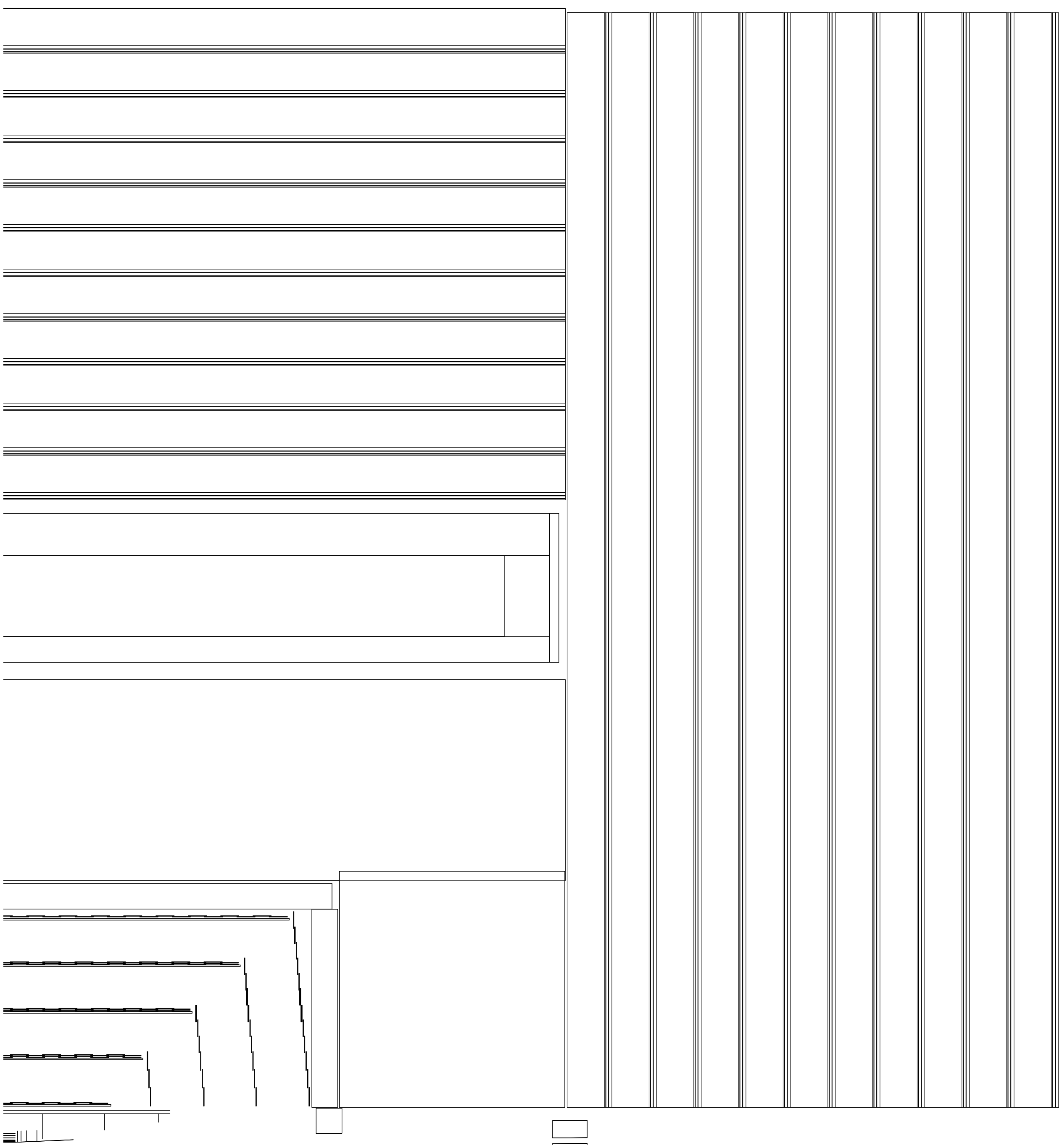

Figure 6: Y-Z Quadrant view of the Silicon Detector as implemented in sidloi. Some support structures and layering details in the calorimeters have been hidden to improve the visibility of the model.