DRAFT
LG 04/02/04

Current Status of the Material Radiation Length Analysis for LBL Pixel Detector

At the current level of the design, we are investigating the material selection and electrical and mechanical constraints that dictate these selections. The current base design is explored and the material properties radiation length given to allow extrapolation to design changes / modifications.

Schematically we have

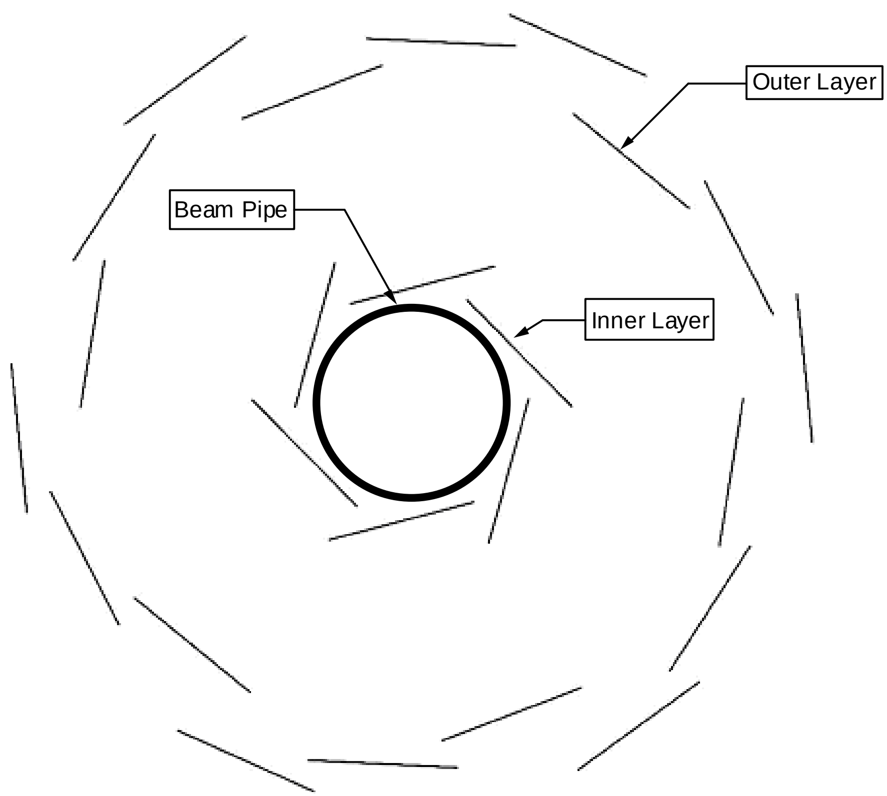

Figure 1

The ladder assemblies are the same construction for the inner and outer layers. We anticipate making the detector assembly as “thin” as reasonably possible. The materials currently under consideration for use in the LBNL Pixel detector that will sit between the interaction and the rest of the detectors are;

1. Beryllium
2. Silicon

3. Kapton (Polyimide Film)
4. Carbon fiber composite
5. Reticulated vitreous carbon foam (RVC)
6. Aluminum
7. Copper
8. Adhesive
9. Teflon

Using Dahl's formula from Review of Particle Physics,

$$X_0 = \frac{716.4(g)(cm)^{-2} A}{Z(Z+1)\ln(287/\sqrt{Z})}$$

and the material density, we can calculate the radiation length for the above materials as a function of thickness for the materials not listed in the Review of Particle Physics. These radiation lengths are shown in the table below[1].

Material	ρ (g/cm^3)	Radiation length (cm)
Beryllium	1.85	35.28
Silicon	2.33	9.36
Kapton (Polyimide Film)	1.42	28.6
Carbon fiber composite	1.713	28
RVC	0.059	728.3
Aluminum	2.7	8.9
Copper	8.96	1.43
Adhesive		35
Teflon	2.20	15.8

We will calculate the radiation length for the material traversed perpendicular to the beam direction and do the correction for the overlap and angle incident later. Further corrections for particle trajectories with axial component will be solved in the geant simulations.
Calculating the radiation length of the materials and assemblies used, we start with the beam pipe.

<u>Beam Pipe</u> – Be at 500 μm
500 μm/35.28cm = 0.001417 or **0.1417 %** of a radiation length

Next are the ladder assemblies

The layers are based on the same mechanical carrier / Silicon design, 2 initial versions of which are shown schematically below:

[1] Some interaction lengths were obtained from reference materials or other sources rather than calculated.

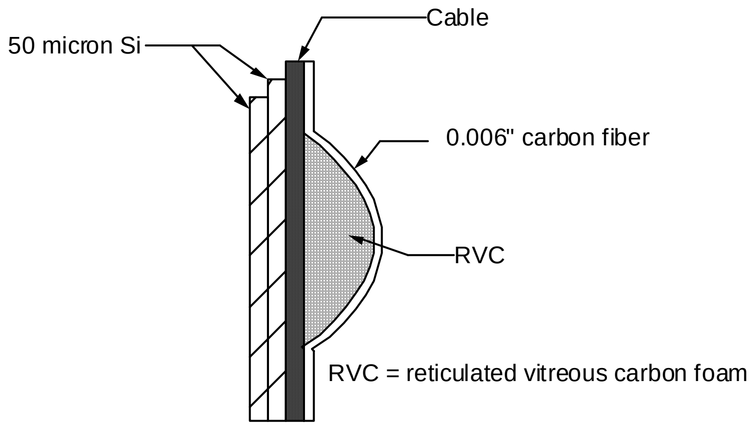

Figure 2

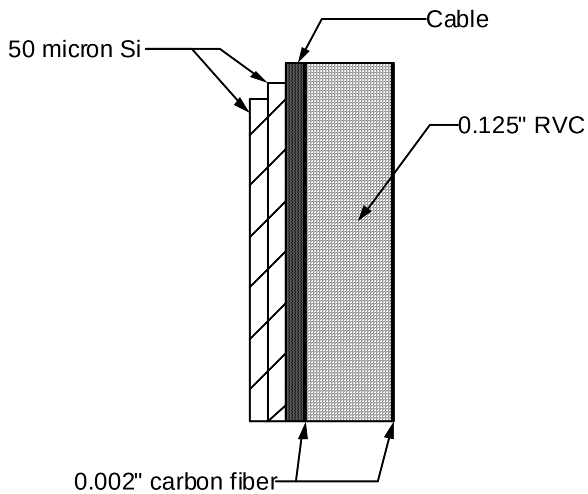

Figure 3

Naturally, the layers all have a layer of adhesive between them, which is not shown but is taken into account when we do the final calculations.

<u>Silicon Detector layer</u> - 50 μm

50 μm / 9.36cm = 0.000534 or **0.0534%** of a radiation length

ADC/RDO chip - 50 μm

As above 0.000534 or **0.0534%** of a radiation length

Cable – The design for the cable is currently in flux. Designs for two types of possible cables are shown below. This area will be the focus of more work in the near future. A simple copper and a simple aluminum design are shown for illustration of the differences in material. We expect to achieve a radiation length less than these examples.

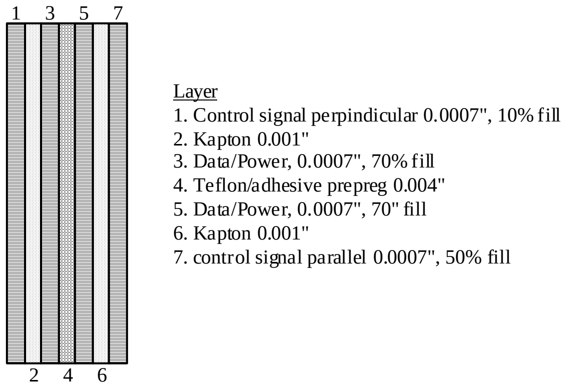

Figure 4

Each signal layer can be copper in this design. The copper traces are chosen to give less than 100mV drop (assuming 100mW / cm^2 of detector) A single sided aluminum on Kapton cable is examined after figure 5.

For copper;

17.78 μm / 1.43cm = 0.001243 or **0.1243% radiation length * % fill / layer**

For Kapton;

25.4 μm / 28.6cm = 0.0000888 or **0.00888% radiation length / layer**

For Teflon/adhesive (50% each)

101.6 μm / ((35cm + 15.8cm)/2) = 0.00040 or **0.04% radiation length / layer**

<u>Total for the copper based cable is</u>

0.1243 * 2 + 0.00888 * 2 + 0.04 * 1 = **0.3063% radiation length**

A possible single sided aluminum based cable design is shown below. In this case and the Copper case, the adhesive between the Kapton and the bonded copper or aluminum layer is neglected. We will investigate using vacuum deposited aluminum layers on the Kapton.

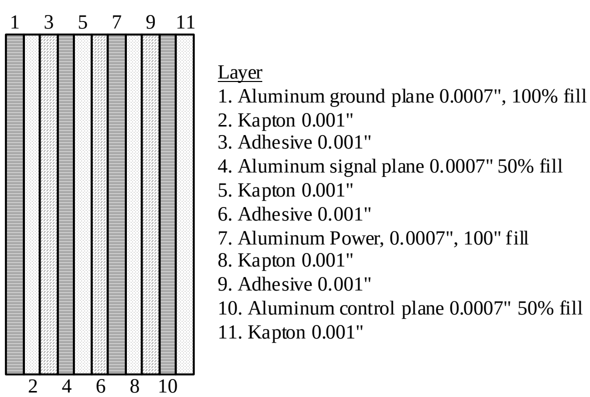

Figure 5

Each signal layer is aluminum in this design.
For Aluminum;
17.78 μ m / 8.9cm = 0.000200 or **0.020% radiation length * %fill / layer**
For Kapton;
25.4 μ m / 28.6cm = 0.0000888 or **0.00888% radiation length / layer**
For Adhesive
25.4 μ m / 35cm = 0.0000726 or **0.00726% radiation length / layer**
<u>Total for the Aluminum based cable is</u>
0.020 * (1+1+0.5 + 0.5) + 0.00888 * 4 + 0.00726 * 3 = **0.117% radiation length**

In figure 2, we have one layer of 0.006" carbon fiber composite and an equivalent of 0.090" of RVC. In addition we have 2 layers of 0.001" adhesive and 2 layers of 0.002" adhesive. The geometry of the carbon fiber composite layer gives an additional multiplicative factor for the carbon fiber of 1.145.
For the design shown in figure 1,
1.145 * 152.4 μ m / 28cm + 2286 μ m / 728.3cm + 152.4 μ m / 35cm = 0.001373 or **0.1373% radiation length** + Si + cable
<u>Total for design in Figure 2 with Cu cable</u>
0.1373 + 0.0534 * 2 + 0.3063 = **0.550% radiation length**
<u>Total for design in Figure 2 with Al cable</u>
0.1373+ 0.0534 * 2 + 0.117 = **0.361% radiation length**

In figure 3 we have 2 layers of 0.002" carbon fiber composite and 1 layer of 0.125" RVC. In addition we have 3 layers of 0.001" adhesive and 2 layers of 0.002" adhesive.
For the design shown in figure 2,
50.8 μ m / 28cm * 2 + 3175 μ m / 728.3cm + 177.8 μ m / 35cm = 0.001307 or **0.1307%** radiation length + Si + cable
<u>Total for design in Figure 3 with Cu cable</u>
0.1307 + 0.0534 * 2 + 0.3063 = **0.544% radiation length**
<u>Total for design in Figure 3 with Al cable</u>
0.307 + 0.0534 * 2 + 0.117 = **0.354% radiation length**

<u>Corrections</u>
In addition, due to the angle of the detectors with respect to the beam pipe, all numbers derived from summing the above ladder quantities for the inner ladder should be increased by ~23% (the correction for the outer ladder will be lower). Furthermore, overlapping detector edges will add another 13% (for the case shown in figure 3. In the figure 2 case the RVC does not overlap, but the contribution of the RVC to the total radiation length is small.