

Mass of GLAST BTEM Tray Electronics Assemblies

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HDI Board

Total mass of the board alone: 15.35 g.

Total thickness of the board: 0.889 mm.

Total surface area of the board: 67.80 cm².

Estimates of the coverage by copper of the eight layers:

Layer	Percent coverage	Material
1	25	Cu + Au
2	10	Cu
3	100	Cu
4	100	Cu
5	100	Cu
6	95	Cu
7	95	Cu
8	90	Cu + Au

This is roughly equivalent to 6 layers of copper.

Each copper layer is ½ oz per square foot, or 0.0153 g/cm². Using a density of 8.96 g/cm³ gives a copper thickness of 17 μm. Eight layers of this amounts to 0.136 mm, leaving 0.787 mm of G10 type material (plus adhesive). From this, we estimate the masses:

Copper, 6 full layers, each 17 μm thick:	6.20 g
0.787 mm of G10 (1.7 g/cm ³):	9.07 g
10 microinches of gold:	0.04 g
TOTAL:	15.3 g

The total agrees very well with the measured mass of the board, lending some confidence to the estimates.

When the board is loaded with all components except for the IC chips, its mass is 17.05 g, including 0.74 g for the connector sockets and 0.12 g for the tantalum capacitors. The total mass of the 27 IC chips is 0.82 g. That leads to the following estimates for the total material in a readout section, not including the insulator backing that should go between the board and the tray closeout. The connectors are assumed to be plastic, and the balance of material in the parts is assumed to be some sort of ceramic. This

accounting for the parts is crude, but their contribution is relatively small. Note that the radiation lengths are calculated assuming a uniform distribution of the material over the surface of the board, which is a significantly smaller area than the surface of the side of the tray.

Material	Mass (grams)	X_0 (gr/cm ²)	Radiation Lengths (%)
Copper	6.20	12.86	0.714
Gold	0.04	6.4	0.009
G10	9.07	33.0	0.406
Silicon	0.82	21.82	0.055
Tantalum	0.12	6.8	0.026
Plastic	0.74	40	0.027
Ceramic	0.88	12	0.108
TOTAL	17.87		1.35

Kapton Detector Interconnect

Total mass: 30.0 g

Thickness: 150 μ m

Area: 1050 cm²

This circuit has 2 copper layers and 3 polyamide layers. The lower copper layer is a ground plane, which is hatched such that 45% of the copper is removed. The top layer is made of traces and pads with roughly 15% coverage overall. Therefore, there is an equivalent of about 0.7 solid layers of 1/2 oz copper in the circuit, for a total mass of 11.2 g, or 0.011 g/cm². The rest we assume to be polyamide (0.018 g/cm²) and assume a radiation length of 40 g/cm² (mylar). That results in an estimate of 0.083% radiation lengths for the copper and 0.045% for the plastic.

Kapton Flex Cables

There are 4 types of cables, which are similar to each other and have 4 layers of copper traces and planes (the planes being hatched). The mass of each cable that reads out a tray bottom (arms extending downward) is 15.3 g. Those cables extend from the top of the tracker just to the bottom, so the mass does not include any extensions below the tracker. Each of the eight cables in a tower has eight 25-pin plugs and one 37-pin plug, for a total mass of about 3.5 g. That leads to a mass of 18.8 g per cable assembly with connectors included.