GLAST LAT TECHNICAL NOTE	Document # LAT-TD-01531-01	Date 6 Feb 2003
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Document Title First Radiation Hardness Test of CDE CsI(Tl) Crystals		

1. Introduction

We have conducted a first test of the gamma radiation hardness of full-size CsI(Tl) crystals from Amcrys H to be used for GLAST CDEs. The primary purpose of this test was to get a first measurement of the decrease in light output from a long full-size crystal after having received a substantial dose of gamma radiation. The purpose of the test was further to establish a procedure in order to eventually obtain a correspondence between the performance of the full-size crystal and a small boule sample crystal after having been exposed to the same amount of gamma radiation. All boules that will be used for crystal manufacturing will be tested for radiation hardness by using a small sample crystal cut from the boule. By using the result from the correspondence test we thus get an estimate of the expected performance of the full-size crystals from that boule.

2. Test Setup

For this test we have used the same radiation facility at the Karolinska Institutet in Stockholm containing a strong ^{60}Co source as was used for the preliminary test described in a previous report. Available calibration data at the facility lists the dose rate for each calendar week. The listed numbers give the dose rate in a water sample 80 cm from the source, and at 5 mm depth in the water where the dose is maximum. The crystal to be irradiated was placed at 97 cm from the source (virtually a point source). Using the difference in gamma absorption coefficients, we have calculated the maximum dose rate obtained by the full-size CsI(Tl) crystal to be 2.00 krad/h. The crystal was regularly turned up side down so that deposited gamma energy would be as uniformly distributed as possible throughout the crystal volume.

Crystal performance was monitored with a 200 µCi ^{56}Co source collimated to a 2 mm slice beam, and using the same equipment as for the quality insurance tests described in the document LAT-SS-00820-02. As for the preliminary test the Sylgard optical connection between crystal and PM tube was removed. Instead we used an air gap of 2 mm, the reason being that the amount of attenuation introduced by the optical connection was more reliably reproduced with an air gap. In this context we considered it being an advantage as compared to the relatively small additional loss of light when not using Sylgard silicon optical connectors.

The isotope ^{56}Co gives several gamma energies, of which 0.511, 0.846, 1.238, 2.034, 2.597 and 3.251 MeV are enough frequent to be useful for fitting. In most cases the line at 846 keV is optimal to fit.

3. Measurements

The irradiated crystal has the Amcrys ID-number 33K4-7-2 and the dimensions 326×26.7×19.9 mm^3, which are the final dimensions for CDEs. It was read out by PM tubes via a 2 mm air gap. Before irradiation a reference measurement was made. The crystal was measured at 7 longitudinal positions, viz. at 20, 56, 92, 163, 234, 270 and 306 mm from the left end. The absolute accuracy in position relative to the left end of the crystal is about 2 mm. However, the correlation between different positions is strong. Irradiation was done in steps so that the accumulated dose became 2, 5, 15, and 18 krad, respectively. (20 krad was the goal but beam time ended before it was reached.) The crystal performance was measured after each irradiation period and after a few hours of cool-down. However, after 6 h light pile-up due to afterglow was still substantial. In order not to lose too much of allocated beam time the crystal performance was measured anyway. The decay of afterglow was measured after the last irradiation period, and the previous measurements were corrected for this effect. After 6 h the afterglow still gives a 20–30% larger pulse at 0.846 MeV. After 16 h some afterglow was still present. After 70 h, though, the asymptotic value had clearly been reached.

4. Test Result

The table shows the decrease in relative light output from the crystal in response to a gamma line from ^{56}Co. The second column shows the average of left and right PM with the source positioned close to the PM, the third column with the source positioned at the far end of the crystal. The forth column shows the average of columns two and three. No significant difference could be seen between left and right PM with the source at the same relative position.

dose [krad]	close PM	far PM	average
0	100%	100%	100%
2	99%	82%	90%
5	86%	71%	78%
15	82%	66%	74%
18	82%	70%	76%

We estimate the rms errors in the first (0 krad) and last (18 krad) rows to be less than 0.05 times the listed percentage. In the three middle rows the errors are larger due to the correction of afterglow. These numbers could possibly also contain a systematic error introduced by finite precision in the correction method. Last row's numbers are the directly measured asymptotic values after 70 h of cool-down, which remained stable up to more than 140 h after irradiation had stopped.

5. Conclusions

We find that the average light output from a 326 mm long crystal decreases (24±4)% after 18 krad of gamma radiation, and as seen with Hamamatsu R669 PM tubes. Average signal is here average of left and right PM signals and averaged over source positions along the crystal. From the differences between columns two and three in the table we also conclude that there are two components contributing to the radiation damage. When the source is placed far from the PM, and the light has to travel throughout the crystal, the decrease in light output is significantly larger than when the source is placed close to the PM. This effect was similar for left and right PM. Thus, we conclude that both light production as well as light attenuation in the crystal material becomes worse after irradiation.

No small sample crystal from the same boule 33K4 was irradiated at this time but had been irradiated at an earlier occasion. The result from that test was presented in document LAT-TD-01213-01 and showed a decrease in light production of 19% after 8.6 krad and 15% after 9.2 krad, respectively, for two different sample crystals, one from the top of the boule, the other from the bottom. This agrees well with the number (17±4)% found in the present test when the source was placed close to the PM.