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Document Title

Preliminary Radiation Hardness Test of Full-size CsI Crystals

Introduction

We have conducted a preliminary test of the gamma radiation hardness of full-size CsI(Tl) crystals from Amcrys H. The primary purpose of this test was to work out a procedure for a final measurement of the crystal performance after having received a substantial dose of gamma radiation. The final goal is to establish 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.

Test setup

For this test we have used a radiation facility at the Karolinska Institutet in Stockholm containing a strong ^{60}Co source. Available calibration data 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 crystals to be irradiated were placed at 125 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 1.23 krad/h.

Crystal performance was monitored with a ^{22}Na source using the same equipment as for the quality insurance tests and described in the document LAT-SS-00820-02. One difference, though, was the elimination of the Sylgard optical connection between crystal and PM tube. 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 of 4% as compared to when using Sylgard silicon optical connectors. Another difference was the choice of output signal from the amplifier. Normally we use the unipolar output signal. However, since the bipolar signal gives a 14% higher peak value we decided to use this signal instead (ADC is peak sensitive).

The intention with the radiation hardness tests is to irradiate two full-length crystals and a small boule sample crystal simultaneously, and to compare the results for deterioration in light performance. In this way we can establish a correspondence between the observed effect on a boule sample crystal and the expected performance of a full-size crystal read out with PM tubes or diodes. At the present occasion there was however not enough time to achieve conclusive results for a complete comparison. The equipment used for data acquisition with the PIN diodes was similar to the one used for boule sample tests and described in LAT-TD-01213-01.

Measurements

Four different crystals were irradiated, three full-size crystals (size 333×26.7×19.9 mm^3), and one small boule sample crystal (25 mm high, 25 in diameter). Two of the full-size crystals were read out by using PM tubes while the third one was equipped with PIN diodes. The boule sample crystal was also fitted with a diode. Before irradiation reference measurements were made with all crystals. The long crystals were measured at 9 longitudinal positions, viz. at 20, 51, 83, 125, 167, 209, 250, 282, 313 mm from the left end. After irradiation we measured only at 5 positions, viz. at 20, 83, 167, 250, 313 cm 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.

Crystal No.	dose	readout
33K4-7-1	0.6+0.9	PM tubes
33K4-1-2	0.3	PM tubes
33K4-6-1	0.6+0.9	PIN diodes

Test Results

The three test crystals were irradiated simultaneously. Test results were not as conclusive as intended. Nevertheless, they indicate a clear trend. The results are presented below crystal by crystal.

Long Crystal 33K4-7-1

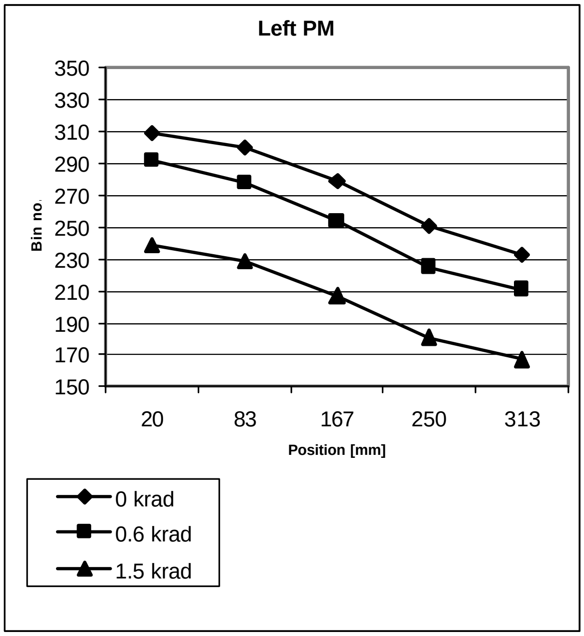
Crystal 33K4-7-1 was given a total dose of 1.5 krad in two steps: 0.6 krad plus 0.9 krad. After the first irradiation the crystal was left to “cool down” for one hour. It turned out, however, that the crystal was still too noisy to be measured. The crystal was left over night. After a total cool-down period of 16.5 hours we obtained a useable spectrum to monitor the light output. The crystal light output was measured by scanning it with the ^{22}Na source at 5 different locations along the crystal (see above). The result is presented in table 1 and fig. 1.

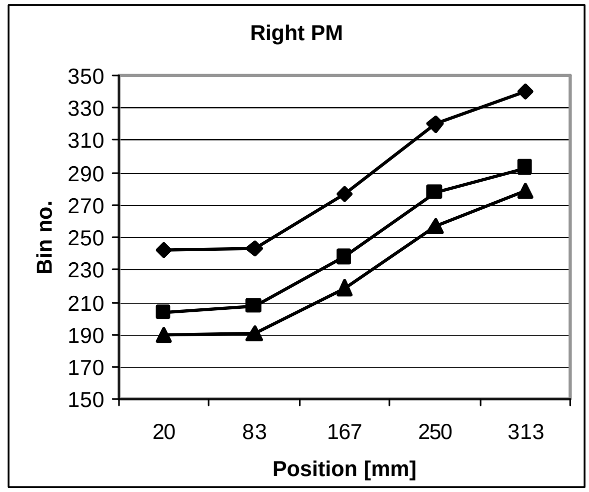
***Table 1**: Relative light output from crystal 33K4-7-1 after 0.6 krad of radiation from ^{60}Co. The third column lists the peak shift expressed in bin numbers. The fourth column gives the relative peak shift in percent; statistical error is 3 %-units. The last row is he sum of left and right PMT averaged over all five positions.*

PMT	Position [mm]	Peak shift [bin No.]	Relative peak shift [%]
Left	20	309 → 292	5.5
Left	167	279 → 254	9.0
Left	313	233 → 211	9.4
Right	20	242 → 204	15.7
Right	167	277 → 238	14.1
Right	313	340 → 293	13.8
Average	all	279 → 249	11

After the second step of irradiation the cool-down of the crystal was monitored. After 2.5 hours the 511 keV annihilation peak from ^{22}Na could barely be identified. After 4.5 hours the peak could be fitted with a gaussian in both PM spectra with the ^{22}Na source positioned at the middle of the crystal. Resulting fitting parameters were not very accurate though. There also seemed to be a light pile-up effect. The crystal was not further irradiated.

48 hours after the last irradiation stopped the light output from the crystal was measured again at the same 5 positions along the crystal. The result is presented in a table 2 and fig. 1.





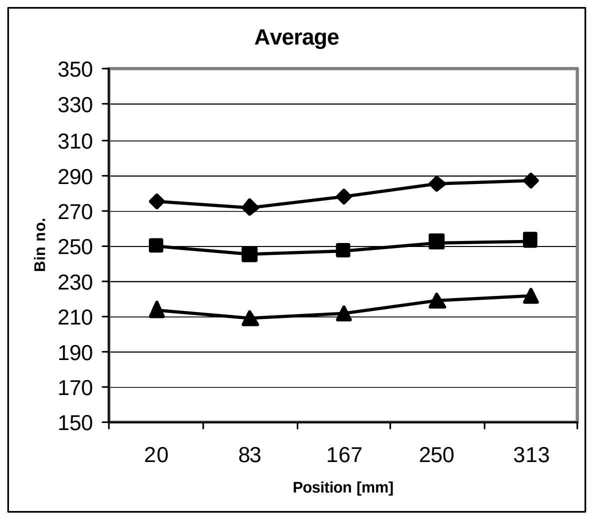


Fig. 1: Light output from a long CsI crystal as a function of the longitudinal position of the ^{22}Na source. The plot to the right shows the average signal of left and right PM for the 5 longitudinal positions respectively.

Table 2: Relative light output from crystal 33K4-7-1 after 1.5 krad of radiation from ^{60}Co. The third column lists the peak shift expressed in bin numbers. The fourth column gives the relative peak shift in percent; statistical error is 3 %-units. The last row is he sum of left and right PMT averaged over all five positions.

PMT	Position [mm]	Peak shift [bin No.]	Relative peak shift [%]
Left	20	309 → 239	22.7
Left	167	279 → 207	25.8
Left	313	233 → 167	28.3
Right	20	242 → 190	21.5
Right	167	277 → 219	20.9
Right	313	340 → 279	17.9
Average	all	279 → 215	23

Long Crystal 33K4-1-2

This crystal was only given a radiation dose of 0.3 krad. It was used to check afterglow. This crystal performed very similar to crystal 33K4-7-1 (cf. above). Light output was measured after 48 hours of cool-down period. The result is presented in table 3.

Table 3: Relative light output from crystal 33K4-1-2 after 0.3 krad of radiation from ^{60}Co. The third column lists the peak shift expressed in bin numbers. The fourth column gives the relative peak shift in percent; statistical error is 3 %-units. The last row is he sum of left and right PMT averaged over all five positions.

PMT	Position [mm]	Peak shift [bin No.]	Relative peak shift [%]
Left	20	279 → 273	2
Left	167	203 → 195	3.9
Left	313	162 → 153	6
Right	20	174 → 174	0
Right	167	219 → 220	0
Right	313	277 → 285	0
Average	all	218 → 214	2

Long Crystal 33K4-6-1

This crystal was read out with PIN diodes instead of PM tubes. The crystal was given a dose of 0.6 krad. The light output was monitored 7 days after irradiation with the same system as used for the radiation hardness testing of small boule sample crystals and described in the document LAT-TD-01213-01. A ^{22}Na source was used as a standard light source and positioned 20 mm from the crystal end being read out. The light output from the crystal was found to have decreased by 10% after 0.6 krad of gamma radiation from ^{60}Co. This agrees well with the result found with PM tubes.