

# Spectroscopic performance of a LaBr<sub>3</sub>:Ce detector with liquid light-guide configurations up to 10 m

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## 1. Introduction

Remote gamma-ray spectroscopy is required when photomultipliers and electronics must be separated from high-radiation or spatially constrained measurement points. Previous work demonstrated a flexible LaBr<sub>3</sub>:Ce-LLG sensor using 1 and 3 m guides [1]. Because optical loss reduces pulse height and degrades energy resolution [2, 3], this study evaluated direct coupling and LLG configurations up to 10 m to assess their practical spectroscopic performance.

## 2. Materials and Methods

The system comprised a 10 mm-diameter × 10 mm-long LaBr<sub>3</sub>:Ce scintillator (Epic Crystal), an R6231-100 PMT (Hamamatsu), a CR-113 charge-sensitive preamplifier (Cremat), and a DT5725 digitizer operated with MC<sup>2</sup>Analyzer (CAEN). EJ-550 optical grease (Eljen Technology) was applied at every optical interface. Direct coupling was compared with Ø8 mm LLGs of 1 and 3 m and Ø5 mm LLGs of 5 m and 10 m. Because the LLG diameter decreased from 8 mm for the 1-3 m configurations to 5 mm for the 5-10 m configurations, the measured trend reflects the combined effects of length and diameter.

The PMT was operated 925 V. Except for the dedicated 10 m gain tests, spectra were acquired for 600 s live time using a 2.0 Vpp input range and consistent MC<sup>2</sup>Analyzer settings. Photopeak centroids and FWHMs were obtained using Gaussian-based fits that accounted for Poisson count statistics and the surrounding continuum, and the <sup>60</sup>Co doublet was evaluated jointly. Energy resolution was  $R = FWHM/E_{peak} \times 100\%$ . Reported resolution uncertainties include fitting and ROI-dependent variation. Pulse-height retention is the mean of the 122, 511, and 662 keV centroid ratios relative to direct coupling.

## 3. Results and Discussion

The 122, 511, and 662 keV photopeaks remained identifiable with the 10 m LLG (Table I). Mean centroid retention decreased from  $16.34 \pm 0.27\%$  at 1 m to  $2.82 \pm 0.06\%$  at 10 m. The 662 keV energy resolution degraded monotonically from  $2.90 \pm 0.07\%$  for direct coupling to  $7.47 \pm 0.33\%$ ,  $9.27 \pm 0.25\%$ ,  $17.90 \pm 1.09\%$ , and  $23.55 \pm 2.61\%$  for the 1, 3, 5, and

10 m configurations, respectively. Standard-source dead time remained 0.28-1.11%, suggesting that pile-up was not the dominant cause of the degradation.

Table I. Mean centroid retention, 662 keV energy resolution, and <sup>60</sup>Co doublet assessment.

| Coupling | Centroid retention (%) | R <sub>662</sub> (%) | <sup>60</sup> Co doublet |
|----------|------------------------|----------------------|--------------------------|
| Direct   | 100.00                 | 2.90±0.07            | Clear                    |
| 1 m, Ø8  | 16.34±0.27             | 7.47±0.33            | Partial                  |
| 3 m, Ø8  | 12.36±0.21             | 9.27±0.25            | Weak                     |
| 5 m, Ø5  | 4.40±0.05              | 17.90±1.09           | Not resolved             |
| 10 m, Ø5 | 2.82±0.06              | 23.55±2.61           | Not resolved             |

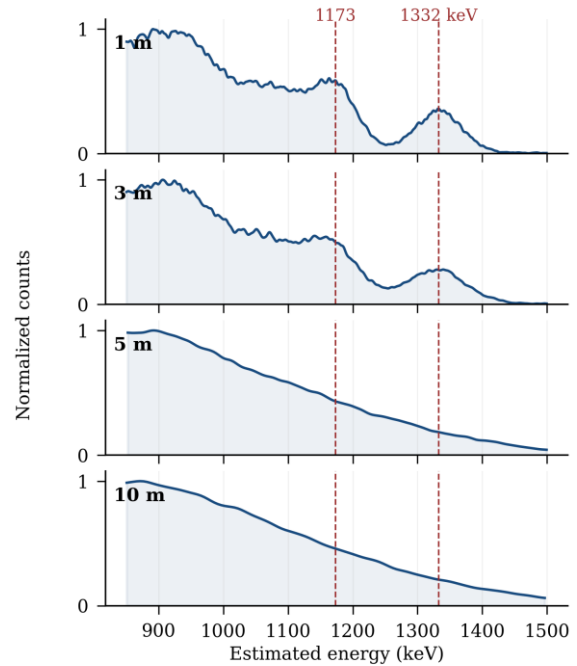


Fig. 1. Normalized <sup>60</sup>Co spectra for the LLG configurations. Dashed lines mark 1173 and 1332 keV; the 5 and 10 m energy axes are extrapolated from the 122-662 keV calibration.

At 1 m, the <sup>60</sup>Co doublet remained partially resolved, with 1173/1332 keV resolutions of  $5.61 \pm 0.29\%/6.04 \pm 0.17\%$ . At 3 m, the corresponding peaks were only

weakly identifiable, with resolutions of  $6.25 \pm 0.48\%$ / $7.03 \pm 0.57\%$ . At 5 and 10 m, broad continua dominated and the doublet could not be reliably identified (Fig. 1). The 5 and 10 m energy axes were extrapolated from the 122-662 keV calibration for visualization only.

At 10 m, reducing the input range to 0.5 Vpp and increasing the PMT voltage to 1000 V increased the apparent pulse-height scale by a factor of 6.04 relative to the 925 V/2.0 Vpp condition. Nevertheless, the  $^{60}\text{Co}$  doublet was not recovered, while dead time increased to 6.08%. The gain adjustment improved channel utilization but did not recover spectral separability.

#### **4. Conclusions**

Photopeaks at 122-662 keV remained measurable with the 10 m LLG despite the accompanying reduction in core diameter, although centroid retention decreased to 2.82% and the 662 keV resolution degraded to 23.55%. The  $^{60}\text{Co}$  doublet was partially resolved at 1 m and weakly identifiable 3 m, but was not resolved at 5-10 m. The gain tests showed that increasing signal amplitude alone could not compensate for LLG-induced optical loss. Further measurements at a fixed LLG diameter are required to isolate the effect of length.

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