
# Determination of lutetium density in LYSO crystals: methodology and PET detector applications

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## Introduction

Lutetium yttrium oxyorthosilicate (LYSO) scintillation crystals are favored in positron emission tomography (PET) imaging for their high gamma-ray attenuation, and rapid scintillation decay rates. The natural $^{176}Lu$ isotope, with a half-life of 37.9 billion years, contributes a steady background radiation (BG) profile influenced by the crystals' geometry and composition. In this study, by exploring the one-to-one relationship between BG spectrum intensity and intrinsic radioactivity, we can accurately estimate the Lutetium concentration within LYSO crystal samples. Initially tested on a well-documented LYSO sample, our method closely matched the sample's known composition. This estimation technique was applied to various unidentified LYSO samples, including both individual crystals and arrays, finding a high consistency in Lutetium content across samples of the same material, with discrepancies of about 1%. Additionally, the background spectrum for LYSO-based arrays representing a PET detector are generated simulations using the Geant4 library. Our approach, combined with simulation, effectively predicts the background radiation spectra for different LYSO detector designs. This research has provided implications for enhancing the predictive capabilities and autonomous adjustment of system settings in LYSO-based PET detectors.

## 1 Methodology

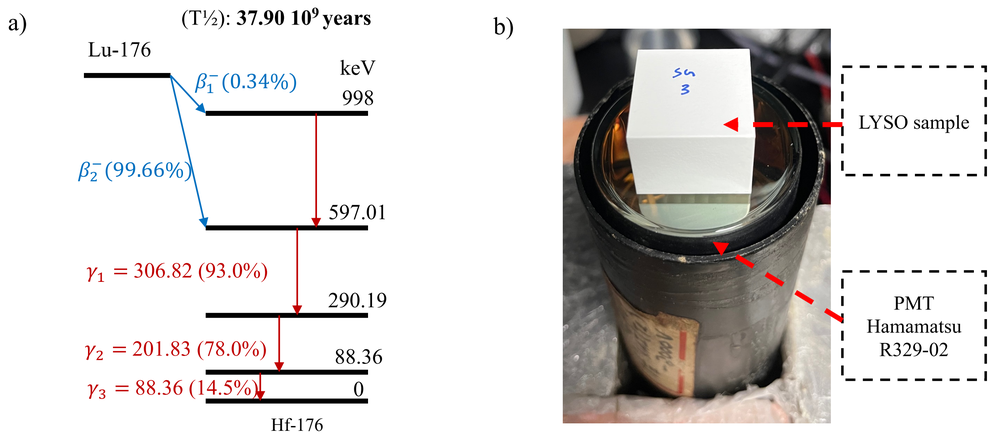


**Figure 1:** a) Schematic diagram of $^{176}$Lu decay. b) Measurement of BG spectrum of a LYSO crystal sample using a PMT.

The methodology hinged on analyzing the intrinsic radioactivity of LYSO crystals, particularly focusing on the background (BG) radiation spectrum intensity resulting from the decay of the 176 Lu isotope. The composition "x" value is accurately obtained by measuring the BG spectrum of LYSO samples using a PMT, followed by simulation validation (GEANT4 library).

## 2 Result

**Table 1:** Estimated composition "x" values from the investigated unknown LYSO sample

| LYSO samples | Sample sizes | Estimated "x" |
|---|---|---|
| LYSO-S1 | 11.52 $cm^3$ | 0.901 (±0.2%) |
| LYSO-S2 | 5.76 $cm^3$ | 0.923 (±0.7%) |
| LYSO-S3 | 0.18 $cm^3$ | 0.975 (±1.3%) |

The results demonstrated high precision in the estimated lutetium composition across different samples, with variations kept under 1%, highlighting the methodology's robustness.

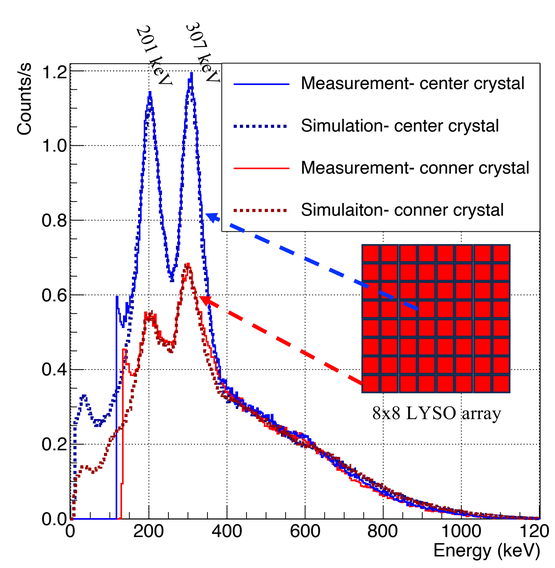


**Figure 2:** BG energy spectra from the simulation, adopting information for the obtained lutetium concentration, are compared with the measurement spectra for different positions of the crystal array.

The methodology's efficacy in accurately estimating the lutetium density in LYSO crystal samples, aligning closely with known compositions for validated samples. Successful replication of the background radiation spectra observed in various LYSO-based detector geometries through simulation models, affirming the method's validity.

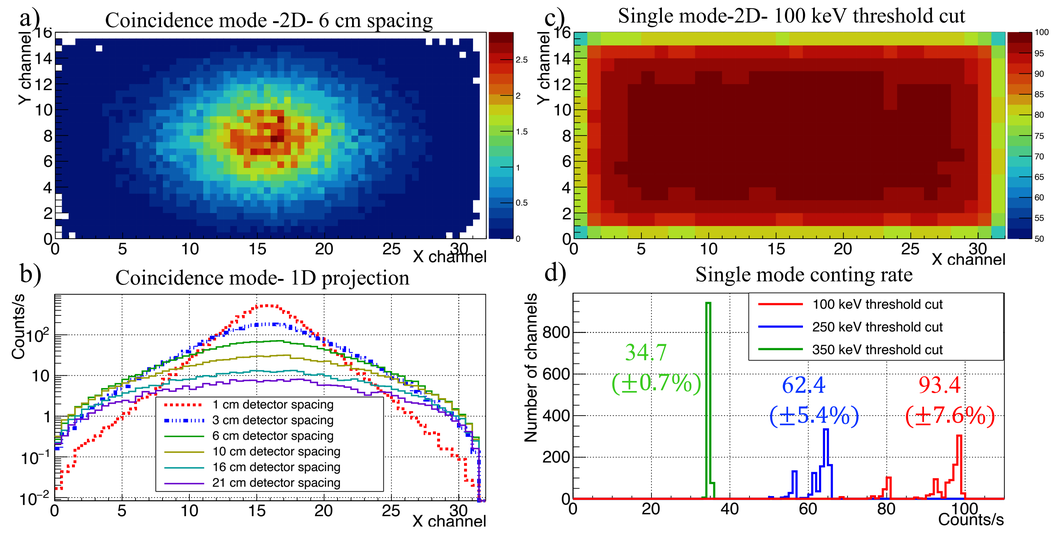


**Figure 3:** a) 2D coincidence BG image generated for a dual PET system using simulation. b) 1D projections of the coincidence image for different detector spacing configurations. c) 2D count rate map from 1 board the LYSO-based 16x32 array PET detector in single mode operation of BG simulation. d) 1D count rate distribution for all channels under different energy threshold cuts.

## 3 Conclusions || Discussion

This research aims to enhance the predictive assessment of PET system behaviors and improve autonomy in configuring LYSO-based detectors [1]. The possibility of refining PET imaging quality by accurately modeling the background radiation spectra, thereby facilitating better image correction methods and detector performance monitoring. Contributions towards developing more accurate, efficient, and reliable PET imaging systems, with wide-reaching implications for clinical diagnostics and research in nuclear medicine.

## References

[1] Tran Cong Thien and Mythra Varun Nemallapudi. Determination of lutetium density in lyso crystals: methodology and pet detector applications. *Physics in Medicine and Biology*, 2024.

## Acknowledgements

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