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

Summary

•Objective:

The primary objective of this research was to provide a reliable method for estimating the lutetium concerntration in Lutetium Yttrium Oxyorthosilicate (LYSO) crystals, crucial for Positron Emission Tomography (PET) detectors. Given the use of LYSO crystals in PET imaging due to their high gamma attenuation, and fast scintillation decay time, the accurate determination of lutetium density is essential. The presence of the natural ^{176}Lu isotope within these crystals contributes to a constant background radiation, influencing the imaging quality and detector performance. Previous efforts, [1-3], have utilized this intrinsic radiation for calibration purposes but lacked a precise methodology for estimating unknown crystal compositions.

•Methodology:

The methodology relied on analyzing the intrinsic radioactivity of LYSO crystals, by focusing on the background (BG) radiation spectrum intensity resultant from the decay of the ^{176}Lu isotope. This approach involves several key steps:

- Initial application of the methodology on a well-characterized LYSO crystal sample to validate the approach against known composition information.
- Extension of the methodology to various undisclosed LYSO crystal samples, with different geometries.
- Use of Monte Carlo (MC) simulations and discrete analytical methods to model the decay spectrum of the 176 Lu isotope. A comparison between simulated results and actual measured spectra validates the accuracy of the simulation model.

The research involved measuring the BG spectrum of LYSO samples using photomultiplier tubes (PMTs) and multichannel analyzers, followed by simulation validation. The simulations employed the GEANT4 library, ensuring a comprehensive analysis of the measurement and their impact of the BG spectrum.

•Results:

The results show high precision in the estimated lutetium composition across different sample with variations kept under 1%.

Key findings include:

- The methodology's efficacy in accurately estimating the lutetium density in LYSO crystal samples, aligning closely with known compositions for validated samples.
- Successful generate of the background radiation spectra observed in various LYSO-based detector geometries through simulation models, validating the method's validity.
- Consistency in the estimated lutetium composition across different LYSO material samples, ensuring less than 1% variation and demonstrate the approach's precision and reliability.

•Significance:

The significance of this research lies in its potential to enhance PET detector applications through the precise estimation of lutetium composition in LYSO crystals. The coincidences from BG radiation contribution is accurately generated in simulation, for 2D arrays prepresenting PET detetector in the previous study, [4].

- Enhanced predictive assessment of PET system behaviors and improved autonomy in configuring LYSO-based detectors.
- 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 the development of more accurate, efficient, and reliable PET imaging systems, with implications for clinical diagnostics and research in nuclear medicine.

Reference

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[2] Alva-S´anchez, H. (2022). Background energy spectra for lso/lyso scintillation crystals of different geometries. Journal of Applied Physics, 131(14).

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[4] Nemallapudi, M. V., Rahman, A., Chen, A. E.-F., Lee, S.-C., Lin, C.-H., Chu, M.-L., and Chou, C.-Y. (2021). Positron emitter depth distribution in pmma irradiated with 130-mev protons measured using tof-pet detectors. IEEE Transactions on Radiation and Plasma Medical Sciences, 6(3):345–354.