The γ-γ coincidence setup using GAGG(Ce) based position sensitive scintillators for γ-ray imaging applications

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Introduction

Nuclear medical imaging, which relies on the detection of γ rays emitted by unstable radioisotopes, plays a pivotal role in both clinical research and applications within nuclear medicine[1]. The essential task in nuclear imaging is to reconstruct a source distribution i.e. to obtain an accurate image of the radioactivity distribution. The dual-head gamma imaging is one of the cost-effective and time-effective techniques which allows the determination of gamma-emitting sources with good spatial resolution. In anticipation of the increasingly widespread use of detector panels, we are therefore motivated to consider the development of a small device /imaging setup designed to make-based dual head gamma imager. In this study, the objective is to reconstruct the 2D image of the source positioned within the detector's field of view by measuring the two gamma rays emitted in opposite directions from the source in coincidence.

Experimental Details

The imaging setup consists of two Ce-doped GAGG (Gadolinium Aluminum Gallium Garnet: $Gd_3Al_2Ga_3O_{12}$) scintillator crystals, each with dimensions of 5.08 cm $\times$ 5.08 cm $\times$ 0.6 cm, mounted in parallel and facing each other as shown in Fig.1. Each crystal is directly coupled to a multi-anode position-sensitive photomultiplier tube (PSPMT) (Hamamatsu-8500C) using silicone-based optical grease which has a refractive index matching the crystals [2]. To minimize the electronic signals, an external resistive network is used which reduces the 64 PSPMT readouts to four signals, making the design more compact. The spatial origin is set at the midpoint of the line joining the centers of the two detectors. A ^{22}Na radioactive source which emits two 511 keV gamma rays through the positron-electron annihilation process, is used. This source has a diameter $\sim$ 2 mm enclosed in a disc-shaped plastic cover having diameter of 2.5 cm and a thickness of 5 mm. The four anode signals and a dynode (for E_γ) from each detector are recorded on an event-by-event basis. The arrival time difference between the two detectors is also recorded using dynode signal information.

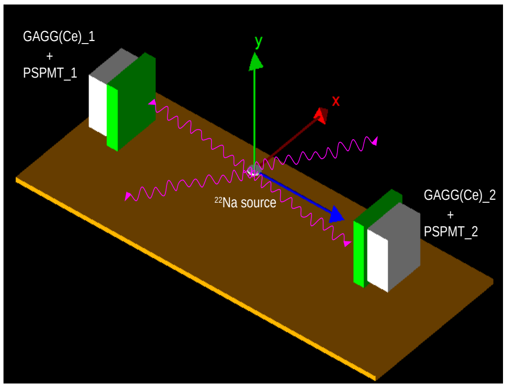

FIG. 1: The schematic of experimental setup

Data Analysis

The position coordinates x and y of the 511 keV γ-ray interactions in each crystal are re-

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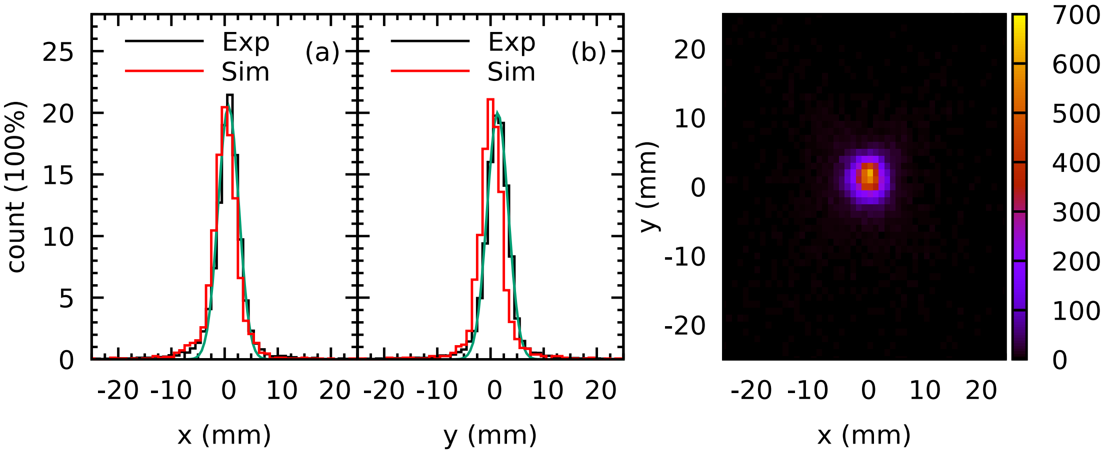

FIG. 2: (a) and (b) Comparison between the 1D reconstructed experimental source distributions along the x and y axes and those obtained from GEANT4 simulations when source is placed at origin. The counts are normalized to 100% for consistency. (c) The 2D source distribution image from experiment.

constructed using the following equations

$$x = \frac{a_2 B + a_4 D}{a_1 A + a_2 D + a_3 C + a_4 D} + b1\,,$$
$$y = \frac{a_3 C + a_4 D}{a_1 A + a_2 D + a_3 C + a_4 D} + b2, \tag{1}$$

Where A, B, C and D are the amplifier amplitudes with a_1,a_2,a_3, and a_4 are corresponding amplifier gains. b_1 and b_2 are the constants added for calibration purposes. The z_1 and z_2 coordinates are derived based on the scintillator crystal thickness and its distance from the origin. The line of response, representing the line connecting the interaction points $(x_1, y_1, z_1$ and $x_2, y_2, z_2)$ in both detectors, is determined for each event under consideration. Subsequently, the shortest distance method in 3D is applied to reconstruct the source image.

Results and Discussion

The reconstructed source distributions in x and y axes when it is mounted at the origin are shown in Fig. 2 (a) and (b), respectively. A reasonably good spatial resolution (FWHM $\sim$ 4.7 mm) is achieved for the x and y positions of the source image. These experimental results are further supported by GEANT4 simulations, which account for all relevant physical processes. The 2d reconstructed image of the source is shown in Fig. 2 (c). This setup can be potentially employed/integrated in devices such as small animal PET scanners, molecular breast imaging devices, etc. The proposed gamma-gamma imaging device could be of prime interest for PET scanning and other nuclear medicine and therapy-related applications. Detailed experimental measurements and simulation results will be discussed at the conference.

Acknowledgments

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References

[1] Zaidi, H., Hasegawa, B.H. (2006). Overview of Nuclear Medical Imaging: Physics and Instrumentation. Quantitative Analysis in Nuclear Medicine Imaging. Springer, Boston, MA.

[2] Biswajit Das, A. Kundu, R. Palit, V. Malik, P. Dey, D. Negi, S.K. Jadhav, A.T. Vazhappilly, B.S. Naidu, NIM A, 1048, 167928 (2023).