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Development of a novel in-beam spherical PET scanner for small animal proton irradiation

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Introduction

We have developed a unique in-beam PET scanner for a novel small animal proton irradiator under development in our department. This in-beam PET scanner will image positron emitters generated by the proton beam during small animal irradiation. We designed the PET scanner to achieve high sensitivity and have open spaces for beam irradiation, vertical placement of the small animal and additional imaging probes inside. Therefore, the shape of the scanner is spherical. Another design goal of the PET scanner was sub-millimeter and uniform spatial resolution. We demonstrate its imaging performance with point sources in this study.

Materials & Methods

Fig. 1 (a) shows a PET detector composed of a pixelated 3-layer $Lu_{1.8}Y0_{.2}SiO_5$ scintillator block (EPIC, China) and an 8×8 silicon photo-multiplier (SiPM) array (Multi Pixel Photon Counter, Hamamatsu photonics K.K, S14161-3050HS-08, Japan). The scintillator pixel size is 0.9 mm×0.9 mm×6.67 mm to achieve sub-millimeter spatial resolution. The array size of the 1st, 2nd and 3rd layers are 23×20, 23×23 and 24×24, respectively. A light guide with a thickness of 1 mm is inserted between the detector block and the SiPM array. Depth-of-Interaction information can be obtained with the 3-layer structure for uniform image resolution. 64 signals from the SiPM array are processed with a charge division circuit to reduce the 64 signals to 4 signals. Those signals are amplified and fed to a R5560 (CAEN, Italy) digitizer. We use an Anger calculation to determine the interaction position [1]. We configured the spherical PET scanner with 56 PET detectors (Figure 1 (b)). The inner diameter of the PET scanner is 72 mm and the solid angle coverage is 44%. There is an open aperture vertically for the small animal (Y direction) and beam irradiation (Z direction). We placed two Na-22 point sources with a diameter of 1 mm each and with distance inbetween of 1 mm along the Z direction to assess spatial resolution. The distance between the center of two sources was 2 mm. The maximum likelihood estimation maximization algorithm was used to reconstruct the image.

Results

Figure 2 (a) and (b) shows the reconstructed image and line profile, where the 1 mm gap is observed. Distance between two peaks of the reconstructed image was 1.8 mm.

Summary

We have configured a unique spherical in-beam PET scanner and demonstrated high resolution performance with point sources, which we expect to be preserved also for proton beam imaging.

Figure 1

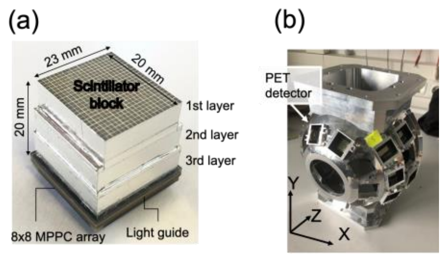

Figure 2

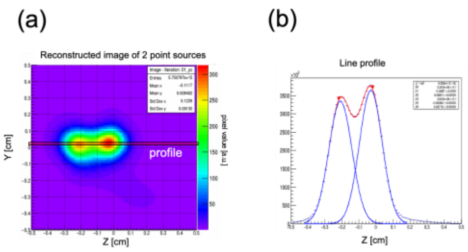

Fig.1: (a) A staggered 3-layer PET detector and (b) the novel small animal in-beam PET scanner. Fig.2: (a) Reconstructed image of two point sources of 1 mm diameter size, separated by a gap of 1 mm and (b) line profile of the image.

References

[1] Han Gyu Kang et al, "A staggered 3-layer DOI PET detector using BaSO4 reflector for enhanced crystal identification and inter-crystal scattering event discrimination capability", 2021 Biomed. Phys. Eng. Express 7 035018

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