Evaluation of DOI performance of the sub-mm 8 × 8 SiPM

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Abstract: At present, the resolution of positron emission tomography (PET) is sub-millimeter. Pixel size and parallax error are considered as two of the factors that limit spatial resolution. We plan to apply 500-μm-pitch silicon photomultiplier (SiPM) arrays, which have a recovery time of 8 ns and a gain of 1×10^6, in dual-sided readout to improve the performance of PET system.

Keywords: positron emission tomography, silicon photomultiplier, radiation detector

1. Introduction

Positron emission tomography (PET) is a nuclear imaging technique that can be used to visualize metabolic processes in the body by measuring the concentration of molecular probes labelled with positron-emitting radionuclides.

The most of recent PET detectors are scintillator-based. In a scintillator-based gamma ray detector, gamma rays first interact with the scintillator, and are converted to visible lights, and finally detected by the photo sensor. Recently, SiPMs are widely used in nuclear imaging due to its high gain ($>10^5$), fast responding (several nanoseconds), low bias voltage, insensitivity to magnetic field, large area device availability at low fabrication costs, etc.

Dual-sided readout detectors is a common approach for depth of interaction (DOI) measurement. The DOI information of a dual-sided readout detector is a function of the ratio of energy deposition in one SiPM array (E_1) and the total energy deposition in both of the SiPM arrays (E_{total}).

To obtain smaller spatial resolution in pre-clinical small animal PET, we plan to apply 500um-pitch SiPMs as well as DOI measurement method. The spatial resolution can be improved to ~0.7mm according to theoretical calculation.

2. Materials and methods

GEANT4 was used to simulate DOI estimation. In the simulation, the scintillator was 0.4mm ×0.4mm×20mm $Gd_3Al_2Ga_3O_{12}$ (GAGG) and was polished, wrapped in $BaSO_4$ reflector. The SiPMs were placed at the both side of the GAGG. The result of the simulation can provide an instruction to the real experiment.

In the experiment, 500um-pitch SiPM arrays and Ce:GAGG scintillators are used to build the detector.

3. Result

The result of simulation shows that the relationship between DOI and E_1/E_{total} is a linear function. By fitting the distribution of E_1/E_{total} with gaussian function, and calculating the full width at half maximum (FWHM), the DOI resolution at the center of the crystal (at 10mm) is ~0.76mm.

In the hardware experiment, the energy resolution of 511keV is about 22.25% according to the spectra. The main reason of such a bad energy resolution may be misalignment of the crystal and the pixel.

References

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