Development of High Resolution Gamma-Detectors for PET

A. Kobayashi, E. Yusaku, H. Ito, H. Kawai, T. Mizuno, F. Kento, S. Kimura

Abstract—**Recently we are developing a new gamma ray detector for Positron Emission Tomography (PET). It is expected the position resolution and the energy resolution are a few mm and approximately 10%, respectively. In this study, three experiments using 511-keV gamma rays from ^{22}Na source are done to estimate the performance. As a result, the position resolution and the energy resolution are estimated at 1.0 mm and 9.7%, respectively.**

Index Terms—**PET, Wavelength-sifting fibers, plate scintillator**

I. Introduction

RECENTLY we are developing a new gamma ray detector using wavelength-sifting fibers (WLSFs) and scintillator plate for Positron Emission Tomography (PET) [1]. WLSF is an optical fiber that contains wavelength-sifter in its core. This fiber has property that absorbs light, re-emit and propagate light to ends. It works as very fine photo devise by connecting to a photo-detector.

This detector is expected the position resolution and the energy resolution are a few mm [2] and approximately 10% [3], respectively. Mainly the detector has two advantages. First, it can reduce the expense of cutting scintillator into small pieces. Second, it probably achieves the high position resolution by using 0.2 mm phi WLSFs. In this study, the detector performance for 511-keV gamma ray is estimated by an experiment.

II. Concept of Detector

The detector consists of six plate detectors (the effective area is 300 mm × 300 mm) setting up around the human body. The plate detector consists of several layers. The structure of a layer is shown in Fig.1. Each layer consists of 8 times 8 scintillator plates. The size of each scintillator plate is 34 mm × 34 mm × a few mm. 160 wavelength-sifting fibers (WLSFs) cover each 34 mm × 34 mm surface of each plate along each

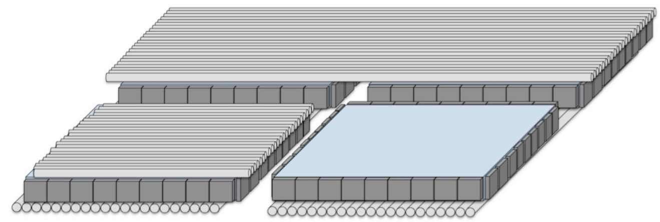

Fig. 1. A schematic of a layer sample which consist of 2 × 2 scintillator plates. WLSFs attached to the surface and SiPMs attached to the side.

axis (x or y). Ends of each fiber are connected to photo-detectors. On each side of plate SiPMs are glued.

Fig.2 shows a method of gamma ray detection.

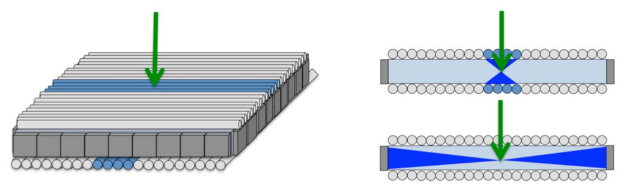

Fig. 2. The method of gamma ray detection.

When a gamma ray incidents to the plate and deposit energy, the light emitted isotopically. The light satisfied total reflection condition detected by glued SiPMs on side. Then deposit energy and incident time of gamma are measured. On the other hands, the light leaked out from the crystal propagates WLSFs, detected by photo-detectors connected end of the fiber and the incident position of gamma is measured.

III. Experiment of Energy Measurement

First we did an experiment of energy measurement. The setup is shown in Fig.3.

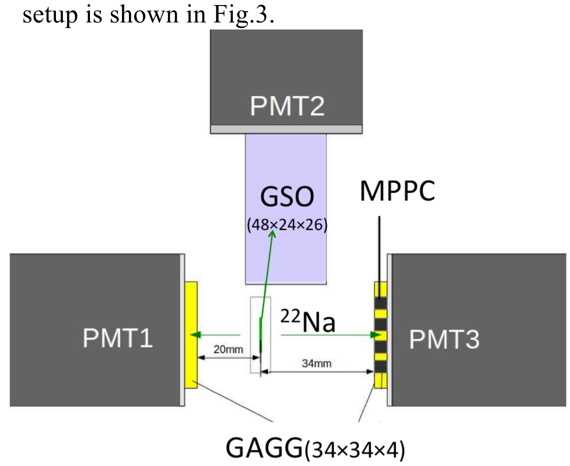

Fig. 3. A schematic of the setup.

This paper is submitted June 1, 2017.

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There are two reference detectors and a main detector. One of reference consists of a small GAGG scintillator ($Gd_3Al_2Ga_3O_{12}$(Ce), 34 mm × 34 mm × 4 mm, C&A Co., Ltd.) and PMT1. The other one consists of GSO (48 mm × 24mm × 26mm, Asahi Kasei Co., Ltd.) and PMT2. A main detector consists of a big GAGG scintillator (34 mm × 34 mm × 4 mm, C&A Co., Ltd.), MPPCs (Hamamatsu Photonics Co., Ltd.) and a PMT3 (Hamamatsu Photonics Co., Ltd.).

^{22}Na shielded source is between GAGG scintillators. When reference using PMT1 and the main detector observe energy more than 341 keV as well as reference using PMT2 observe 700 keV simultaneously, PMT1~3 and MPPCs are read signals. Therefor narrow 511-keV gamma beam (its width is approximately 1mm) enter to the main detector. We did measurements shifting position of the main detector 2 mm apart.

The relative of energy of two references and distribution of PMT3 is shown in Fig.4.

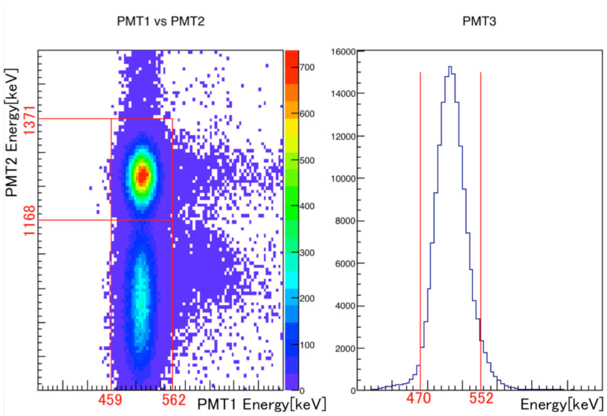

Fig. 4. Distributions of PMTs.

Events that PMT1 and PMT3 observe 511-keV gamma ray and PMT2 observes 1.27 MeV gamma-ray are selected. Ranges of selection are ±2 sigma for each peak. Fig.5 is the distribution of total photoelectron of glued MPPCs.

The peak of distribution is 1410 p.e.. The energy resolution is

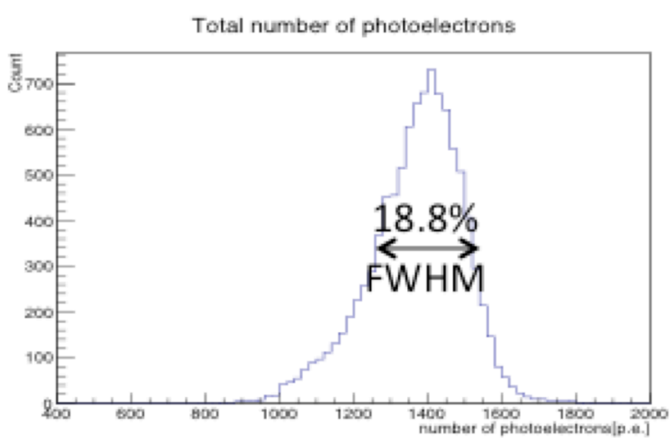

Fig. 5. The distribution of total photoelectron.

also calculated and it is approximately 18.8%(FWHM). In this experiment, the effective areas of MPPCs cover only 26.5% of side surfaces. If MPPCs cover 100% of surface, a number of photoelectrons become 5320 p,e.. The energy resolution is estimated to be 9.7%.

IV. Experiment of Position Measurement

Secondly, we did a preliminary experiment of position measurement. The setup is shown in Fig.6.

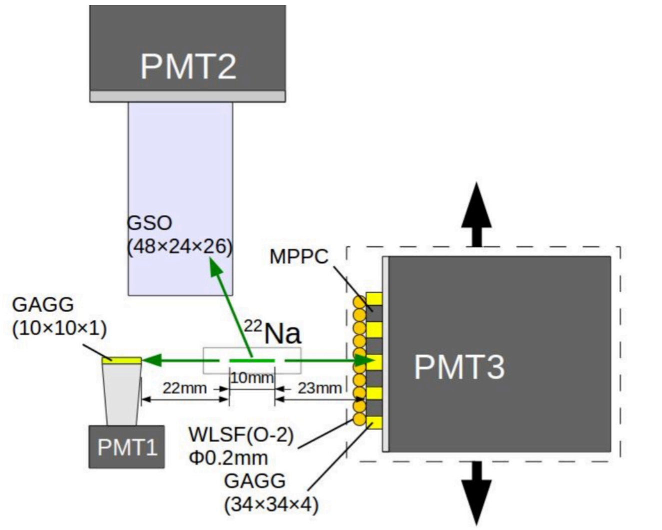

Fig. 6. A schematic of the setup.

Thin GAGG scintillator is used for reference. A main detector consists of a big GAGG scintillator, WLSF[O-2] (Kuraray Co., Ltd.), MPPCs (Hamamatsu Photonics Co., Ltd.) and a PMT3. 160 WLSFs are used in the main detector and each 20 fibers are tied and connected to MPPCs.

A method of taking data and a selection of events is same as the experiment of energy measurement. The incident position is reconstructed by the center of gravity calculation of fiber's position and number of photoelectron of MPPC.

The incident position is reconstructed by the center of gravity calculation of fiber's position and number of photoelectron of connected MPPC. Fig.7 is distribution of reconstructed positions.

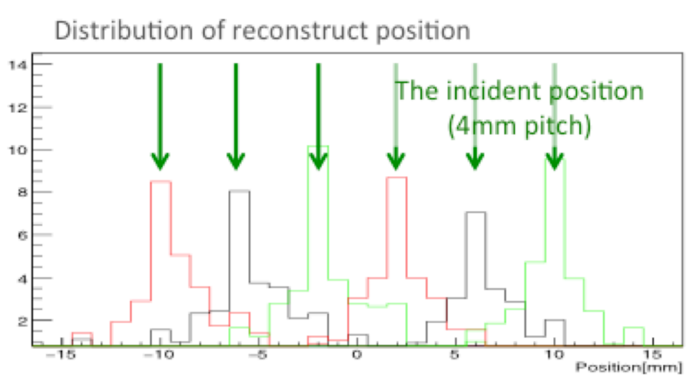

Fig. 7. A Figure of Reconstruct position.

The reconstruct positions are corresponding to the incident position obviously.

V. Additional Experiment of Position Measurement

Finally, we did an experiment of the portion resolution. The setup is shown in Fig.8. A La-GPS[10 mm×10 mm×1 mm, (La,Gd)2Si2O7(Ce)] scintillator, WLSF[B-3] (Kuraray Co., Ltd.), MPPCs (Hamamatsu Photonics Co., Ltd.) and a PMT3 are used for main detector. 48 WLSFs cover surface of

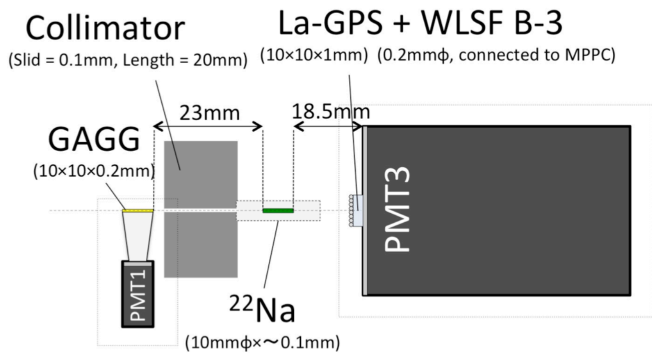

Fig. 8. A schematic of the setup.

La-GPS and each fiber is connected to MPPCs.

To make a narrow gamma ray beam, a lead collimator is used.

A method of taking data, a selection of events and the position reconstruction is same as the experiment of position measurement.

Fig.9 is distribution of reconstructed positions.

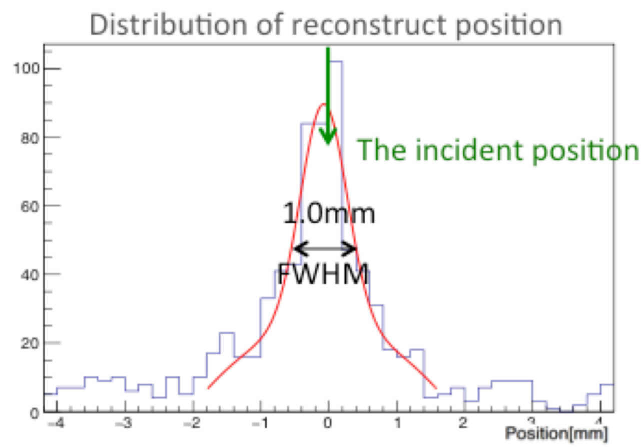

Fig. 9. A Figure of Reconstruct position.

The distribution of reconstructed position has sharp peak, and the position resolution is 1.0 mm (FWHM).

VI. CONCLUSION

We are developing a new PET detector with WLSFs . In this study three experiments are done to estimate the performance. As a result, the position resolution and the energy resolution are estimated at 1.0 mm and 9.7%, respectively.

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