Performance Evaluation of A Prototype PET Detector with High-Growth-Rate Scintillators and Wavelength-Shifting fibers

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Introduction: Existing PET systems have a problem caused by Compton scattering. In scintillators, scattering occur 4 times as much as photoelectric absorption with 0.511-MeV gamma ray. Even if they have high position resolution, misidentifying plural emissions as a single emission makes reconstructed image unclear. Based on this problem, we are developing a lower cost popular type PET.

Methods: Main components of the system are wavelength-shifting fibers (WLSF) and platelike high-growth-rate (HGR) La-GPS ($[Ce_{0.01}La_{0.24}Gd_{0.75}]_2Si_2O_7$) scintillators.

WLSF is an optical fiber kneaded fluorescent material into. It can transmit light from the side of a fiber.

HGR crystals are produced at lower cost and have low transparency because of microbubbles. This is useful for reducing cost and identifying scattering. In this system, emission positions are measured by WLSFs' sheets on top and bottom of scintillators. If transparency of scintillator is moderately low, scintillation light don't spread in scintillator; nevertheless, sufficient quantity of light is ensured.

The size of detection area is 300 mm by 300 mm. The detector consists of some scintillators. Top and bottom surface of scintillator were covered by dual sheets of WLSF with a diameter of 0.2 mm. Sheets of WLSF on top and bottom of the scintillator make a right angle with each other, and measure X- and Y-components. Z-component is measured by the layer number and difference of the number of WLSFs outputting signal between top and bottom. If plural layers output signals, this counter identifies the event as scattering event. Even if only a layer output signals, the event is identified as a scattering event when the number of WLSFs outputting signals is 1.5 times more than that of a single emission. When the event is identified as scattering event, this system regard nearest emission point to body as the first emission point.

Experiment and simulation: In this study, a preliminary test was performed for developing the PET detector by using a ^{22}Na sources (Fig. 1), where the consistency was demonstrated by using an numerical simulation, Monte Carlo code: GEANT4 (Fig. 2).

In experiment, we measured amount of luminescence from La-GPS (1 mm thickness, top surface of scintillator are covered by sheets of WLSF with a diameter of 0.2 mm) with ^{22}Na gamma-ray source. The number of sheets is from 1 to 6. On each number of sheets, we measured 3 runs and calculated the average (One run includes 10000 events).

In the simulation, six detectors surround human (30 cm in diameter and filled with water) like a hexagon. One detector has 300 mm width and 24 mm thickness. If distance between two reaction point is longer than 1 mm, the event is regarded as a scattering event.

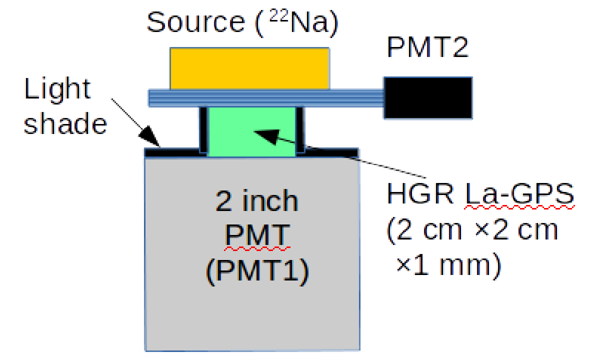

Fig. 1. Setting of experiment

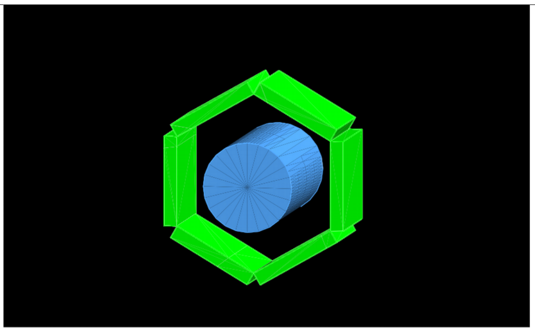

Fig. 2. Overall view of simulation in GEANT4

TABLE I
PARAMATER OF SIMULATION

Parameter	Quantity
Radioactivity concentration (normal tissue)	1 Mbq/kg
Radioactivity concentration (cancer)	5 Mbq/kq
Width resolution	0.2 mm
Depth resolution	1 mm
Energy resolution	15% (σ)
Time resolution	no error

Results: In experiment, detector with HGR La-GPS and WLSF (B-3, Kuraray) measured 22.1 ± 5.96 p.e. in 460-560 keV and 14.1 ± 5.58 p.e. in 290-390 keV from single-face, single-end (Fig. 3-5). By light output from La-GPS and refractive indexes of La-GPS and WLSFs, efficiency of WLSFs is estimated to be about 4.07%. In addition, we estimated 88 photoelectrons and 36% resolution in 511-keV from both-faces, both-ends readout.

In simulation, background level is 10.2 (σ = 3.2) and cancer level is 6.8 . Cancer level is more than 2σ, therefore cancer is visible (Fig. 6) .

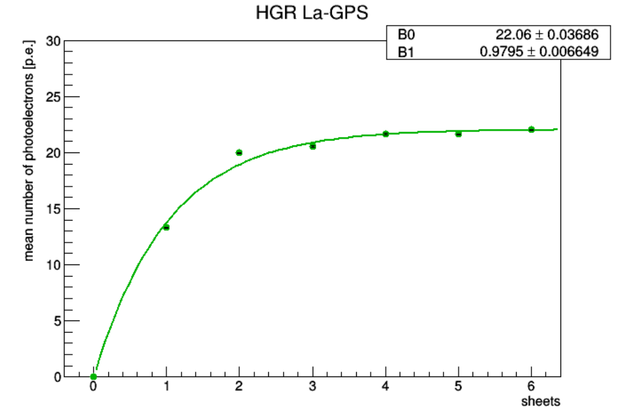

Fig. 3. The number of p.e. in 511-keV gamma rays

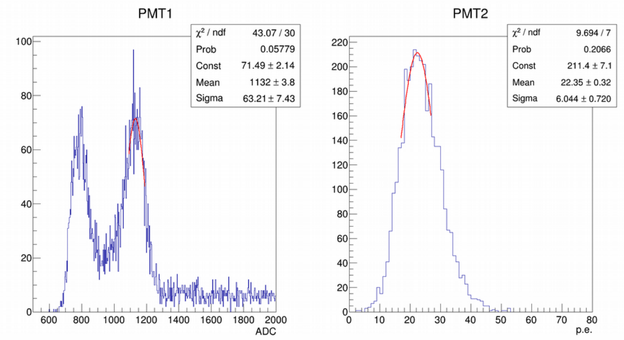

Fig. 4. The number of p.e. in 511-keV gamma rays

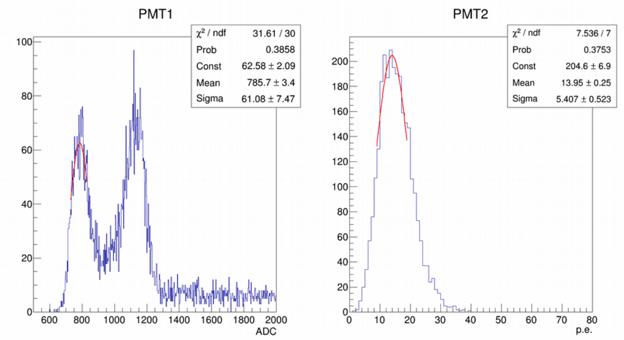

Fig. 5. The number of p.e. in 341-keV gamma rays

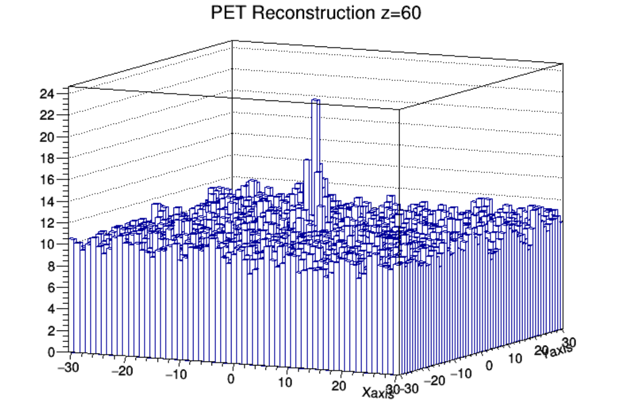

Fig. 6. Reconstruct image of the simulation

Discussion: In terms of intensity, HGR scintillator has sufficient ability. Linearity is confirmed; Therefore, the number of p.e. with WLSFs in *460-560* keV is about 1.5 times as it in *290-390* keV. Value of *mean – HWHM in 460-560 keV* is 74.1 and value of *mean + HWHM in 290-390 keV* is 69.5 . This means that the system is feasible and can reduce the cost by HGR scintillators. However, correlation between growth late of HGR La-GPS and transparency is an important subject. We considered that this is closely related to optimal thickness of scintillators, definitive cost and position resolution.

Conclusion: PET's problem about resolution arise from Compton scattering. Therefore identifying them makes PET systems much better. According to experiment and simulation, this detector is sufficient for our plan.

Reference:

[1]Berger M J; Hubbell J H; Seltzer S M; Chang J; Coursey J S; Sukumar R; Zucker D S; Olsen K: NIST XCOM: Photon Cross Section Database

http://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html (retrieved on the 8th of May 2017)

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