Evaluation of Position Resolution for a Prototype Whole-Body PET Detector Based on Suppressing Backgrounds by Compton Scattering

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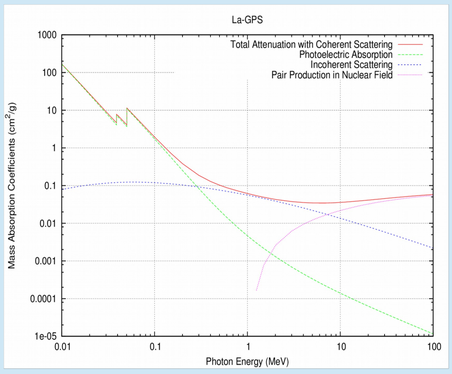
Abstract — The detector with high-growth-rate (HGR) La-GPS and wave-length sifting fiber (WLSF) has sufficient ability for PET in spite of its lower cost. Energy resolution is 31.4%, and position resolution is 1.04 mm. In simulation, our system with parameters from experiment can identify 3 mm cancer.

Introduction

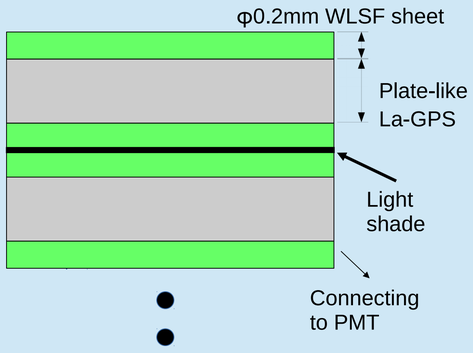


Photon cross section in scintillator[1]

- In scintillator, Compton scattering occur 4 times as much as photoelectric absorption with 0.511 MeV gamma-ray[1]
- Compton scattering makes PET's images unclear.

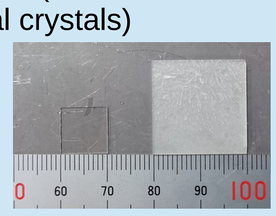
Identifying scattering events is important for PET.

Our detector



Layers of Plate-like HGR La-GPS and WLSF

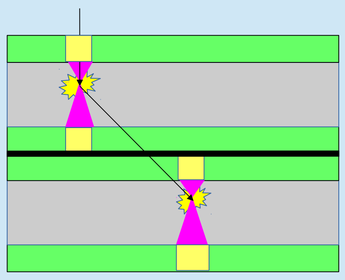
・HGR La-GPS
Lower cost (about one-fifth the cost of normal crystals)



Left : Normal-crystal (1 cm × 1 cm)
Right : HGR crystal (2 cm × 2 cm)

・Layers
Measuring Z-component and identifying scattering event

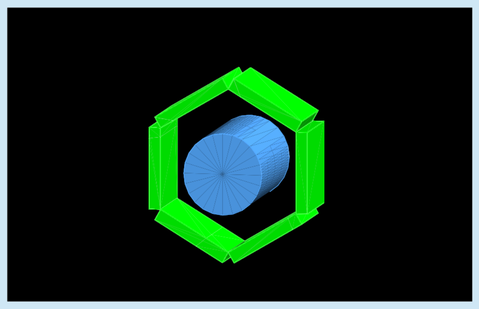
・WLSF
Measuring X- (top surface) , Y- (bottom surface) component and energy deposit



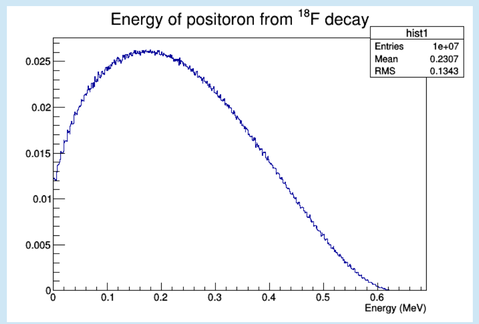
Identifying and analysis method

Signals from plural layers
→Considering as a scattering event
→Regarding the nearest point to the body as the first emission point

Simulation (GEANT4)

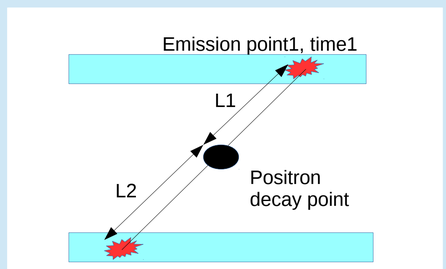


Parameter	Quantity
Radioactivity concentration (normal tissue)	2 Mbq/kg
Radioactivity concentration (cancer)	10 Mbq/kq
Width resolution	1 mm
Depth resolution	1 mm
Energy resolution	31.4% (FWHM)
Time resolution	no error



Setting

・Positron energy : ^{18}F decay energy
・Detector : 1 mm thickness La-GPS × 24 layers × 6 detectors
・Cancer area : 3 mm × 3 mm × 3 mm cube, center of human
・Energy threshold : 430 – 590 keV

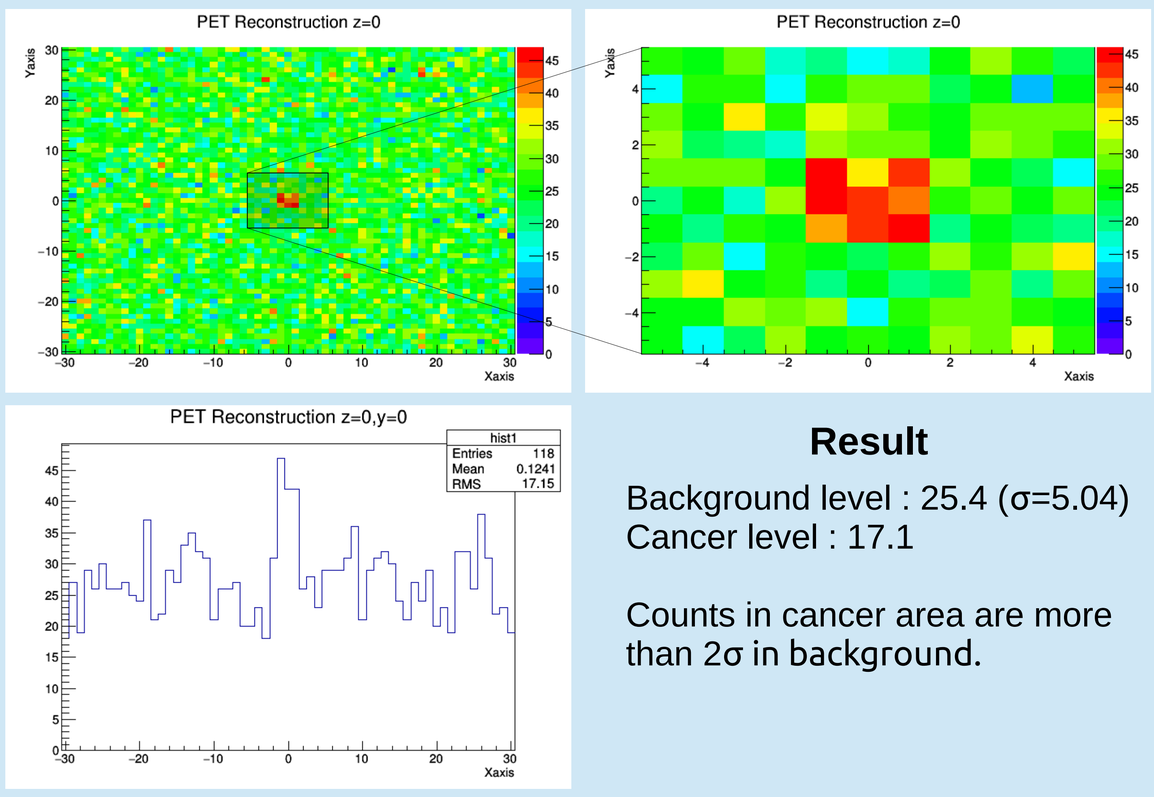


Reconstructing method

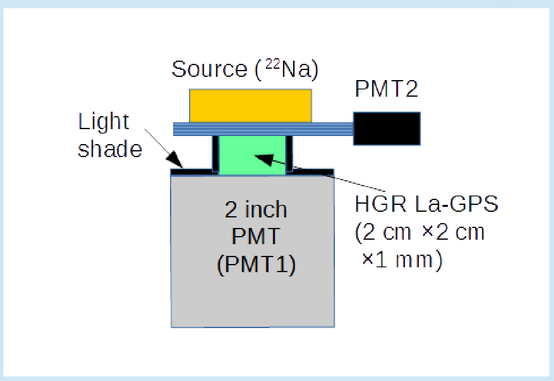
①Measuring 430 - 590 keV in 2 detectors
②Analyzing first emission points (scattering event : adopting nearest point to the body)
③Calculating positron decay point by the method in left figure

$$pos_{decay} = \frac{time_1\, pos_2 + time_2\, pos_1}{time_1 + time_2}$$

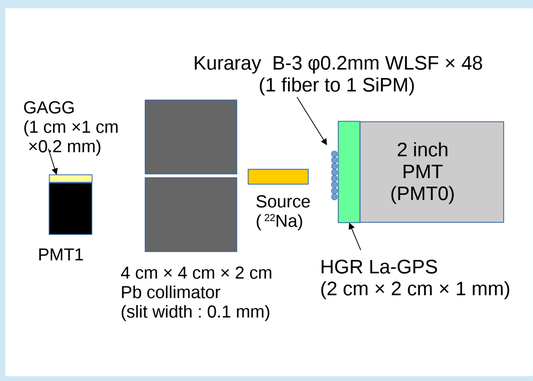
④Filling decay point in histogram (bin-size : 1 mm)



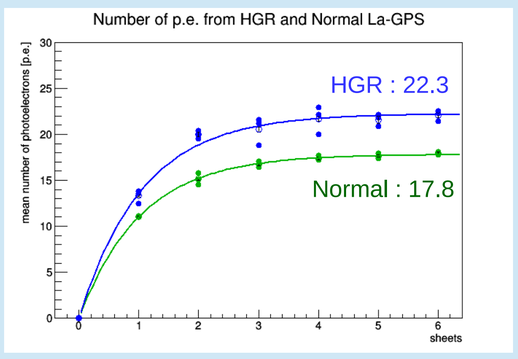
Experiment

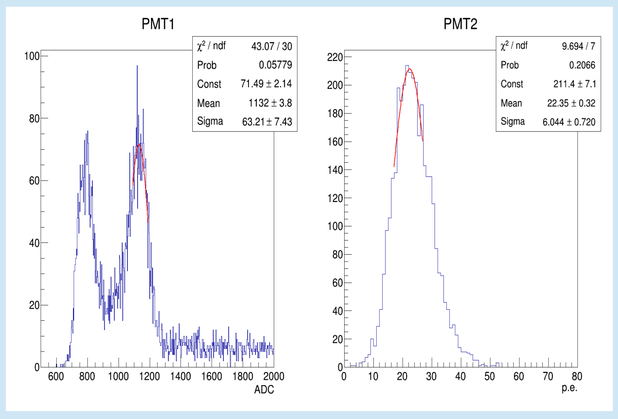


Exp. 1. Measurement of energy resolution



Exp. 2. Measurement of position resolution





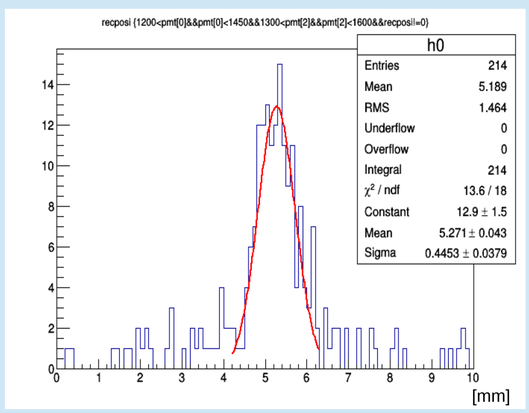
Exp. 1. result
p.e. in 511-keV : 22.3 ± 5.96 (σ)
(HGR,single-face, single-end)
↓
89.2 ± 11.9 (σ)
(double-faces, double-ends)
Energy resolution : 31.4% (FWHM)
cf. p.e. in 511-keV with normal crystal : 17.8

Exp. 2.
Analysis method
Centroid method with all SiPMs' output
Reconstructing formula :

$$pos_{rec} = \frac{\sum_i n_{p.e.,i} \times \left(\frac{10.0}{48} \times (i + 0.5)\right)}{\sum_i n_{p.e.,i}} [mm]$$

(i : SiPM's number)

result
Position resolution : 1.04 mm (FWHM)



Result

Background level : 25.4 (σ=5.04)
Cancer level : 17.1

Counts in cancer area are more than 2σ in background.

Discussion and conclusion

・Our prototype detector, including plate-like HGR La-GPS and WLSF sheets, has 31.4% energy resolution and 1.04 mm position resolution. In GEANT4 simulation, it is confirmed that these parameters are sufficient for identifying 3 mm cancer.

・Setup of exp. 2. has a problem about the width of 511-keV gamma rays from ^{22}Na source. Positrons from ^{22}Na is spread out in acrylic part of source. This is an critical issue.

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)

Acknowledgement

We would like to thank C&A corp. for providing La-GPS scintillators.