Development of gamma-detectors for PET with position resolution of 0.5mm

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Introduction In the conventional way of gamma imaging by PET, only photoelectric absorption events are used as the data and Compton scattering events are ignored. If you could completely distinguish photoelectric absorption events from Compton scattering events which occurred in the detectors, you will typically observe 5 events/mm^3 as the background and 10 events/mm^3 as the detection of cancer. It's not sufficient data for making the position resolution smaller than 1mm.

We are developing the gamma-ray detectors for detecting Compton events.

Methods We use plate-like(34mm×34mm× thickness of 3mm) GAGG scintillators of which sheets of wavelength-shifting fibers(Φ0.2mm) are attached on the top and bottom surfaces and 10 SiPM modules (3mm×3mm) are attached on each lateral side(Fig.1). We are evaluating the performance of this detector with the sodium-22 sealed gamma-sources. We also evaluated the performance of this detector using numerical calculation tool Geant4.

Results: 80% of the Compton scattering events in the detector were correctly determined as the Compton events. 50% of those events were determined the first Compton scattering position with the reliability of 95% despite Compton scattering would occur several times in one Compton event.

Discussion: See "Fig.2". This shows the result of our simulation by Geant4.When 10^7 positrons are created by radioactive decay of the ingredient of PET Drugs and the positrons caused the annihilation, how many times can we observe the pair of gamma rays? In "Fig.2", "double_photoele" means the events which two gamma rays caused the photoelectric absorption in the detector. "double_Comp(good)" means the events which two gamma rays caused the Compton scattering, but the first scattering positions are identified with 100% reliability because of the energy deposit. "photoele_and_Comp(good)" means the events which one gamma ray caused the photoelectric absorption and another gamma ray caused Compton scattering and the first scattering position is identified with 100% reliability. Generally, if the energy deposit was more than 340keV(=the Compton edge for 511keV gamma ray),it means that the photoelectric absorption has occurred at that position. Thus, in such case, first scattering position is identified with 100% reliability. So, the graph means that if we use the Compton events, we can observe the positron annihilation events at least 1.6 times as many as the events observed by conventional way of gamma imaging by PET which only uses photoelectric absorption events.

In the Compton events, most of the time the angle of the scattering is shallow. Considering it, the first scattering position is infered with 95% reliability in the events which are five times as many as the photoelectric absorption events.

Conclusion: When this detectors come into use for the PET devices, if energy threshold 426keV, you can observe 5 events/mm^3 as the background and 50 events/mm^3 as the detection of cancer. if energy threshold is 494keV, you can observe 2.5 events/mm^3 as the background and 40 events/mm^3 as the detection of cancer, and sufficient data can be acquired for making the position resolution 0.5mm.

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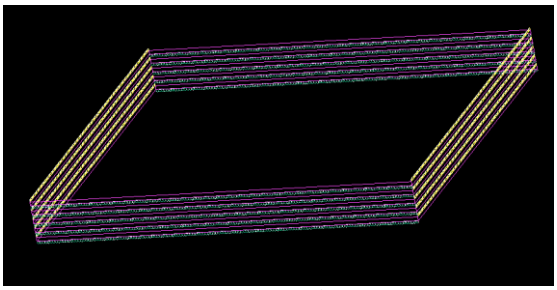

Fig.1 The image of our detectors.
In this illustration, the SiPM modules are not drawn. Five layers of GAGG scintillators and wavelength-shifting fibers are lined up in this illustration, but we may need eight layers or ten layers for getting sufficient data.

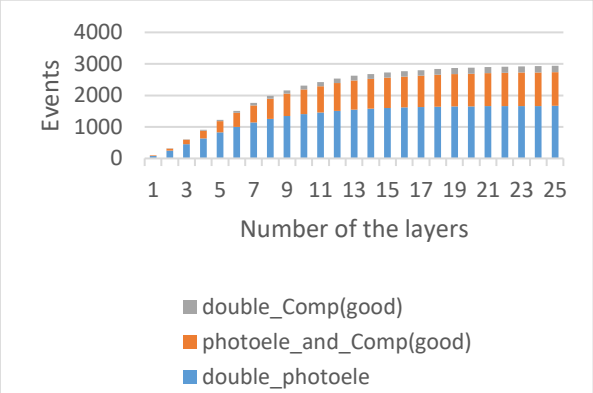

Fig2.Number of Compton events and photoelectron absorption events