Development of High Resolution Gamma-Detectors for PET

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In the conventional gamma imaging by PET (positron emission tomography), only photoelectric absorption events are used as the data and Compton scattering events are ignored. When thinking of the La-GPS scintillators detailed below, for example, as 511 keV gamma rays enter crystals, approximately 20% of the gamma rays are absorbed by the photoelectric effect and about 80% of gamma rays cause Compton scattering. Compton scattering events cannot be used for PET analysis unless the first scattering positions are uniquely discriminated. A resolution of tomography image, limited by the statistical constraint, is typically worse than 1 mm. To improve the resolution without raising the radiation exposure level, the Compton scattering events should be used for PET analysis. We are developing a new gamma-ray detectors which can measure the positions and energies of all scattering points and decide the original incident point. The detector consists of layered plate-like (34 mm × 34 mm × thickness of 3 mm) La-GPS scintillators of which sheets of wavelength-shifting fibers (0.2 mm in diameters) are attached on the top and bottom surfaces and 10 SiPM modules (3 mm × 3 mm) are attached on each lateral side. The detector performance was evaluated using the sodium-22 sealed gamma-sources, in comparison with numerical calculation by the simulation code of GEANT4. In the Monte Carlo simulation, 1,000,000 positrons are created by radioactive decay of the ingredient of PET Drug and the positrons cause the annihilation. In about 40,000 events (4%) of the whole 1,000,000 events, the pairs of gamma rays are observed without the gamma rays being scattered before reaching to the detector. In about 1700 events (4.25%) of those 40,000 events, two gamma rays cause the photoelectric absorption in the detector. In the Compton scattering events, which is approximately 96% of the 40,000 events, 98% of them were correctly determined as the Compton events. In those Compton events, the positions are inferred as the first scattering points using the energy deposit data. In the 70% of those events, correct positions are identified. If the Compton scattering occurred in the scintillator and photoelectrons were created at two points, these points can be distinguishable in the case that the points are more than 0.5 mm distant from each other. In the PET inspection, 15,000 positrons are typically created per 1 mm^3 at the cancer cells. Thus, if 490 keV is set as the energy threshold for cutting off the effect of Compton scattering in a patient, only 20 events/mm^3 can be observed as the detection of cancer in the case that only photoelectric absorption events are used for PET analysis. However, when this detectors come into use for the PET devices, 400 events/mm^3 can be observed as the detection of cancer. As a result, the position resolution will be greatly improved.