Progress on double photon coincidence imaging with ^{67}Cu and ^{169}Yb

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In nuclear medical imaging, positron emission tomography (PET) and single photon emission computed tomography (SPECT) are two important imaging modalities; however, the imaging principles of these modalities have remained the same for more than 50 years. We have proposed and investigated a novel imaging method referred to as double photon emission coincidence imaging (DPECI) utilizing two successive gamma-rays emitted from cascade nuclides.[1,2] The coincidence detection of two gamma-rays enables the localization of radioisotope with a single event. Previous studies have shown the increase in signal to noise ratio (SNR) and reduction of cross-talks between nuclides through the application of selection with timing information using ^{111}In and ^{177}Lu, which are clinically used radioisotopes for diagnosis and therapy.[3,4] Furthermore, in addition to the conventional accumulation imaging of radioisotope, the hyperfine interaction of intermediate state in cascade nuclides with the external field can be used to detect the chemical information using the successive gamma-ray photons as reported in previous studies.[5,6]

Here we investigate the possible use of ^{67}Cu and ^{169}Yb for DPECI with collimator-based imaging system. ^{67}Cu and ^{169}Yb were produced in the ^{70}Zn$(d, \alpha n)^{67}$Cu and ^{169}Tm$(d, 2n)^{169}$Yb reactions at the RIKEN AVF cyclotron. ^{67}Cu emits two gamma-rays with energies of 91.3 and 93.3 keV with the time constant of 9.1 μs in a cascade decay. ^{169}Yb also emits two gamma-rays with the combination of 63.1–177 keV, 63.1–198 keV, and 63.1–307.7 keV in cascade decays and the time constant is approximately 659.9 ns. The relatively long intermediate time constant could be useful to detect the hyperfine interaction through the gamma-ray distribution. In this study, we demonstrate DPECI method using the combination of slit and parallel-hole collimators achieving higher sensitivity than parallel-hole only collimators using ^{67}Cu.[7]

Figure 1 shows the experimental setup of DPECI to visualize ^{67}Cu radioisotope using the coincidence detection of two gamma-rays. ^{67}Cu with the activity of 2.12 MBq was enclosed in the U-shape phantom and measured for 16 hours. The time window was set to 10 μs. The shape of U is successfully visualized by considering the intersection of a plane determined by slit collimators and a line by parallel-hole collimators. The slit width of collimator was 1.6 mm with thickness of 15 mm. The gamma-rays were detected by 2.5 mm × 2.5 mm × 4 mm (D) HR-GAGG scintillation crystals arrays coupled to SiPM arrays.

For evaluating the feasibility of coincidence detection of two successive gamma-rays from ^{169}Yb, ring-shape GAGG-SiPM detector arrays including 512 channels were used. The left panel in Fig. 2 shows the time difference between two gamma-rays and the decay time constant of 659.9 ns is successfully observed. The right panel shows the energy spectrum obtained from the time-over-threshold (ToT) measurement, which indicates that the gamma ray energy is correctly identified.

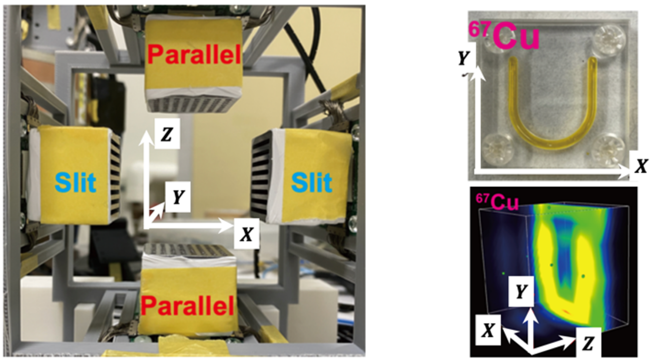

Fig. 1. Geometry of DPECI for visualizing ^{67}Cu radioisotope enclosed in U shape phantom and its image.

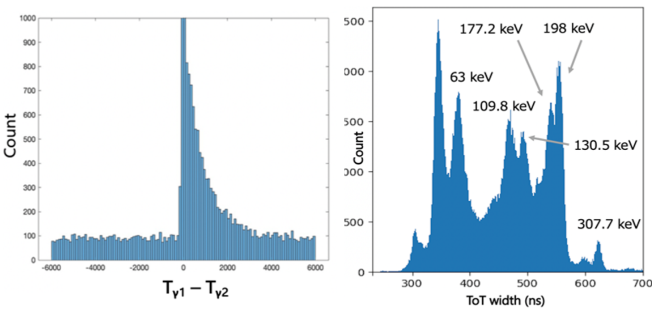

Fig. 2. Coincidence time histogram of two gamma-rays from ^{169}Yb and the measured energy spectra with GAGG-SiPM arrays.

In summary, we have proposed a new method (DPECI) using double photon emitting nuclides and the imaging capability and coincidence detection was demonstrated with ^{67}Cu and ^{169}Yb fabricated at RIKEN AVF cyclotron.

References
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