Progress of double-photon coincidence imaging with ^{28}Mg

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In nuclear medicine, positron emission tomography (PET) and single photon emission computed tomography (SPECT) have been widely used for diagnosis. However, the principles of these imaging technologies constrain the type of radioisotopes that can be used. Clinically available radioisotopes are positron emitters or single photon emitters with low energies (typically up to 400 keV). Recently, Compton imaging[1)] has been studied as a promising gamma-ray imaging technology because it can offer image capture for a wide range of energy (100 keV to a few MeV) without mechanical collimators. Therefore, this capability provides an opportunity for the exploitation of new radionuclides in nuclear medicine.

In conventional Compton imaging, the source position can be estimated only on the surface of a cone with an opening angle θ, which is calculated from the recoil electron and scattered photon energies by following the equation of Compton scattering kinematics. However, this results in low signal-to-background ratio (SBR) in the Compton image. For improvement in the SBR, we have demonstrated the double-photon coincidence imaging technology.[2–5)] Some nuclides emitting two or more successive gamma-rays with an intermediate state can be applied for the double-photon coincidence imaging (*e.g.* ^{60}Co,[3)] ^{43}K,[4)] and ^{111}In[5)]). Thus, one can specify the position at the intersection of two (or more) Compton cones by coincidence detection. In this study, we focused on a radionuclide of ^{28}Mg. ^{28}Mg is a promising radionuclide for bio-imaging owing to its suitable half life of 21 hours. Moreover, because it emits cascade photons with energies of 400.6 keV (Intensity: 35.9%), 941.7 keV (36.3%), and 30.6 keV (89%) via short duration, coincidence imaging can be applied.

We produced ^{28}Mg via the ^{27}Al(α, 3p)^{28}Mg reaction at the RIKEN AVF cyclotron. After chemical separation, 0.5 MBq in 37 μL HCl was dispensed in a 0.5 mL micro tube. Figure 1(a) shows the experimental setup. Eight Compton cameras surrounded the ^{28}Mg source. The distance between the source and camera was approximately 42 mm. A Compton camera consists of a scatterer and an absorber, which are 8 × 8 arrays of $Gd_3(Al, Ga)_5O_{12}(Ce)$ (GAGG) scintillators (C&A Co.) coupled to an 8 × 8 array of silicon photomultipliers (SiPM, Hamamatsu MPPC S13361-3050). The GAGG crystal size is 2.5 mm × 2.5 mm, and the pitch size is 3.2 mm × 3.2 mm. The thicknesses of the scatterer and absorber are 4 mm and 9 mm, respectively.

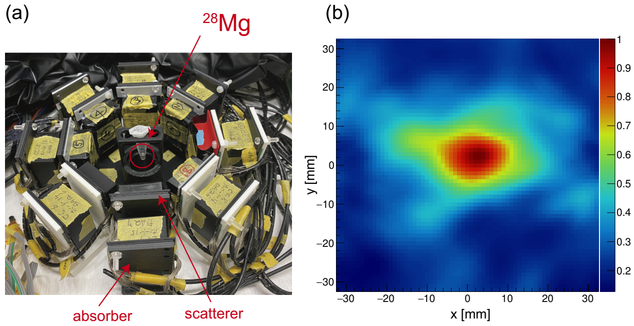

Fig. 1. (a) Photograph of the experimental setup. (b) Double-photon coincidence imaging of ^{28}Mg.

The 64 channel signals from the SiPM array are processed by the dynamic time over threshold method[6)] and are then converted to digital signals of a time width. The 128 channel digital signals from the scatterer and absorber are acquired using 125 ps sampling by a field-programmable gate array-based data acquisition system. The data is recorded as list-mode data. In analysis, coincidence events between the scatterer and absorber were extracted as single-photon Compton events. For double-photon coincidence imaging, coincidence events between two different Compton camera events were selected as double Compton events.

Figure 1(b) shows the preliminary double-photon coincidence imaging of ^{28}Mg. In image reconstruction, double Compton events with energies of 400.6 keV and 941.7 keV were used. Although we succeeded the double-photon coincidence imaging, the detection efficiency is a disadvantage of this method. While the absolute efficiency of the single-photon Compton imaging with our imaging system was 0.029% @ 400.6 keV gamma-ray, and 0.014% @ 941.7 keV gamma-ray, that of the double-photon coincidence imaging was 8.2×10^{-6}%. Unlike the annihilation gamma-rays emitted at opposite directions, cascade gamma-rays are emitted without collinearity. We must improve the imaging system geometry, such that it covers a wider range of solid angles to increase the detection efficiency.

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