Simultaneous imaging of Na^+/K^+ by semiconductor Compton camera GREI

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We have been studying the simultaneous imaging of sodium (Na) and potassium (K) ions that are dynamically controlled in a living body. Na^+ and K^+ are very common cations in body fluids; however, interestingly, they are controlled very differently by some biomolecules. Owing to the different behavior and distribution of Na^+ and K^+, membrane potential can be formed in neurons, and Na^+ can be reabsorbed in the kidneys. Therefore, the imaging of Na^+/K^+ dynamics may be beneficial in inspecting the function of biomolecules.

As summarized in a previous report, we were able to simultaneously take the images of ^{24}NaCl and ^{43}KCl solutions using our imaging apparatus GREI.[1,2] However, we determined some challenges to be addressed in the imaging of ^{24}Na, in addition to the low detection efficiency for the 1369-keV gamma ray. In the gamma-ray energy spectrum of ^{24}Na + ^{43}K (Fig. 1), there is a gamma-ray peak at 1732 keV that corresponds to the double escape peak for the 2754-keV gamma ray of ^{24}Na. This originates from the escape of two 511-keV gamma rays created by the annihilation of the positron that was created by the pair-creation interaction of gamma rays in the gamma-ray detectors. In addition, the $E1+E2 = 1732$ keV events were observed in the $E1$-$E2$ histogram (Fig. 2), where $E1$ and $E2$ represent the detected energies by the front and rear detectors, respectively. Furthermore, the $E1 + E2 =$ 2754 keV events were also observed, although the measurable energy range for each detector was less than 2000 keV in the current GREI system. We inferred that these 1732- and 2754-keV gamma events doubled the dead time of the GREI system. Hence, to realize efficient imaging experiment, we need to further develop a proper method to process the gamma events.

To circumvent the current problem of ^{24}Na, we decided to use ^{22}Na for now. Although ^{22}Na is not suitable for clinical use, owing to its long half-life of 2.6 years, we can use it for preliminary or preclinical experiments. ^{22}Na is a positron emitter and emits two 511-keV gamma-rays and one 1275-keV intrinsic gamma ray.

We performed GREI imaging experiment of ^{22}Na and ^{43}K simultaneously injected in a live mouse. We can use a 511-keV gamma-ray peak to identify ^{22}Na, which is in the optimal imaging efficiency region for GREI (Fig. 3). The $E1$-$E2$ histogram for ^{22}Na + ^{43}K is shown in Fig. 4. Clear lines can be observed for each gamma ray that were all covered by the energy range of GREI. This study is still ongoing, and the results are being prepared to be considered for publication.

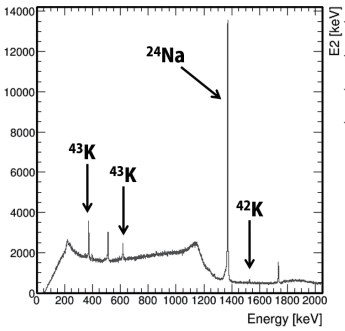

Fig. 1. Gamma-ray energy spectrum of ^{24}Na and ^{43}K measured by GREI.

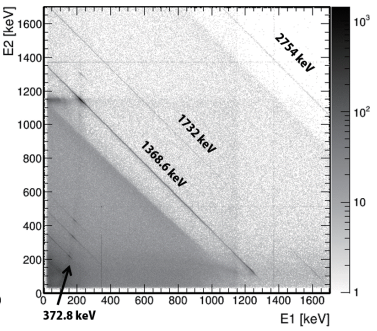

Fig. 2. $E1$-$E2$ histogram of ^{24}Na and ^{43}K.

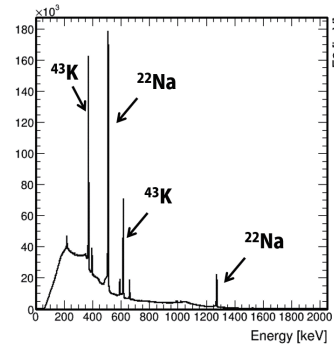

Fig. 3. Gamma-ray energy spectrum of ^{22}Na and ^{43}K measured by GREI.

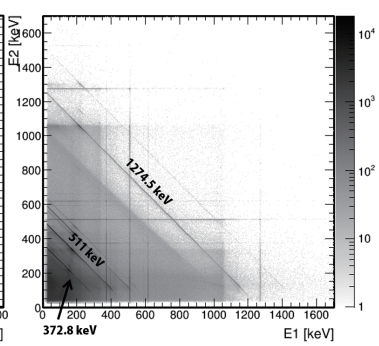

Fig. 4. $E1$-$E2$ histogram of ^{22}Na and ^{43}K.

References

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2) T. Ida *et al.*, Jpn. J. Appl. Phys. **58**, 016002 (2019).

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