Progress on double-photon coincidence imaging with ¹⁶⁹Yb

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In the field of nuclear medical imaging, positron emission tomography and single photon emission computed tomography are widely used imaging techniques that have remained largely unchanged since decades in terms of their fundamental imaging principles. However, our research has introduced a novel imaging method known as double photon emission coincidence imaging (DPECI), which leverages the emission of two consecutive gamma-rays from cascade nuclides.¹⁾ By detecting the coincidental emission of these two gamma-rays, the radioisotope can be located precisely with a single event. Previous studies have demonstrated the improvement in signal-to-noise ratio and reduction of interference between different nuclides by employing timing-based selection techniques with clinically used radioisotopes such as $^{111}\mathrm{In}\ \mathrm{and}\ ^{177}\mathrm{Lu}$ for diagnostic and therapeutic purposes.^{2,3)} Furthermore, aside from the traditional accumulation imaging of radioisotopes, we have explored the potential of utilizing the hyperfine interaction of intermediate states in cascade nuclides with external fields to gather chemical information through successive gamma-ray photons, as demonstrated in previous research findings.^{4,5)} In addition to exploring the capability of collecting chemical information, we have also utilized the quantitative impact of an external field on intermediate states to deduce the localization of nuclide aggregation.⁶⁾

In this study, we investigated the potential use of 169 Yb in a collimator-based imaging system for DPECI and calculated the angular correlation.

¹⁶⁹Yb were produced in ¹⁶⁹Tm(d, 2n)¹⁶⁹Yb reactions at the RIKEN AVF cyclotron, and dissolved in 0.1 molar hydrochloric acid.

The angular correlation ratio function is known below, where A_{22} represents the anisotropy coefficient, and $N(\alpha, t)$ represents the quantity emitted at an angle of $\alpha = 90/180$ degree at time t.

$$R(t) = -2\frac{N(180^{\circ}, t) - N(90^{\circ}, t)}{N(180^{\circ}, t) + 2N(90^{\circ}, t)} \cong -A_{22}G_{22}Q_2$$
(1)

The pulse high spectrum was generated by the histogram of the time-over-threshold (ToT) width. By establishing a linear relationship between the ToT duration and energy, a corresponding calibration is performed. In this calibration process, specific energy peaks are selected as reference points. In our case, the selected energy peaks are 63 keV and 198 keV, and the time constant is approximately 660 ns. The selection of this energy-peak pair has an additional reason related to the anisotropy coefficient ($A_{22} = -0.37$).

We extracted only the events with the desired energy, sorted them using their timestamp information, and created a time difference spectrum for $\gamma 1$ and $\gamma 2$. Furthermore, we set a time window and considered the event pairs of $\gamma 1$ and $\gamma 2$ within this range as coincidence events. The range specified here is 100 ns to 1600 ns, and we observed the time constant of 660 ns successfully.



Fig. 1. Detector setup and angular correlation between 63 keV and 198 keV.

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Fig. 2. Energy spectrum and time difference spectrum.



Fig. 3. Angular correlation ratio with propagation error.

In addition, we processed the data using an angle correlation ratio function and calculated the propagation errors. It can be observed from the graph that due to the insufficient energy resolution of the detection system; the error is relatively large. Thus, the development of a pixelated semiconductor detector system with higher energy resolution is required.

References

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