Development of new analysis methods for EURICA data: γ-ray efficiency and γ-γ angular correlation

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The evolution of the nuclear shape as a function of N and Z numbers is one of the most important subjects in nuclear physics to date. In some regions, in particular for the neutron-rich Xe isotopes, not only the shape evolution but also the shape coexistence are expected to appear at low excitation energy region. To study these phenomena for nuclei in this neutron-rich mass region, an experiment was performed as a part of EURICA campaign[1]. The neutron-rich Xe nuclei were produced by the in-flight fission reaction of a ^{238}U beam and were implanted in five double-sided Si-strip detectors (WAS3ABi) with particle identification information. After the implantation, β-rays and γ-rays were detected by WAS3ABi and EURICA consisting of twelve cluster-type Ge detectors, respectively. As the beam spot size is large in WAS3ABi, it is difficult to exactly deduce the γ-ray efficiency and extract the γ-γ angular correlation for Ge detectors with large solid angles. To solve these problems, we developed the following new analysis methods.

The γ-ray efficiencies for all Ge detectors in EURICA were deduced from the data of γ-ray standard sources ^{152}Eu and ^{133}Ba, placed upstream and downstream of WAS3ABi as well as in-beam data to correct the positions of the γ-ray emission from widely distributed isotopes. In the latter case, if two consecutive γ-rays of γ_1 (with intensity of I_1 for 100 decays of the parent nuclei) and γ_2 (I_2) in a cascade are detected by two Ge detectors, the full-energy peak efficiency of γ_1 can be given by $\epsilon_{\gamma 1} = \frac{N_{\gamma 1 \gamma 2} I_{\gamma 2}}{N_{\gamma 2} I_{\gamma 1}}$, where $N_{\gamma 1}$ and $N_{\gamma 2}$ are counts in the full-energy peaks in the singles spectrum and $N_{\gamma 1 \gamma 2}$ is the full-energy peak count in a γ_1-γ_2 coincidence event. The absolute γ-ray efficiency of EURICA (closed circles with error bars) with efficiency curve obtained by source data (solid line) is shown in Fig. 1. In the low-energy region, absolute efficiency is smaller than source data, which may be caused by the spread of isotope distribution and decrease of the γ-ray intensity in WAS3ABi.

Next, we try to deduce the γ-γ angular correlation to obtain multiplicities of γ-ray transitions (ΔI between levels) and extract the spin of newly identified levels. Because of the large solid angle of each cluster-type Ge detector and widely implanted isotopes in WAS3ABi, correction of the γ-ray efficiency for each Ge detector and angle have to be performed. To correct γ-ray efficiency, the γ-γ angular correlation can be deduced by $\mathrm{W}_{\gamma 1 \gamma 2}(\theta) = \frac{N_{\gamma 1 \gamma 2}(\theta)}{N_{\gamma 1} N_{\gamma 2}}$ for a γ_1-γ_2 coincidence event[2], because of this $\mathrm{W}_{\gamma 1 \gamma 2}(\theta) \propto \frac{N_{\gamma 1 \gamma 2}(\theta)}{\epsilon_{tot\gamma 1} \epsilon_{tot\gamma 2}}$, where $\epsilon_{tot\gamma 1}$ and $\epsilon_{tot\gamma 2}$ are the efficiency of the total Ge detectors for γ_1 and γ_2, respectively. For the angle in two Ge detectors and an implanted isotope position in WAS3ABi, the angular spread is also obtained by event-by-event analysis. As an example, in Fig. 2, we show the γ-γ angular distribution between 403 ($4^+ \to 2^+$) and 287 ($2^+ \to 0^+$) keV γ rays in ^{142}Xe for angles of 28°, 54°, and 85°. These data points are found to be in agreement with the calculated values[3] (solid line in Fig. 2) for the case of $4^+ \to 2^+ \to 0^+$. The presented method allows a more effective analysis of the γ-γ angular distribution.

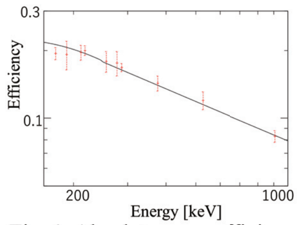

Fig. 1. Absolute γ-ray efficiency of EURICA.

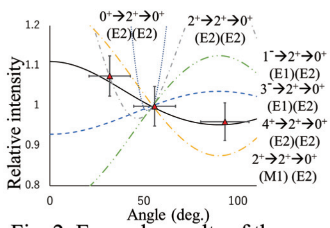

Fig. 2. Example results of the γ-γ angular correlation.

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