Improvement of the β-ion correlation algorithm in decay spectroscopy

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Decay spectroscopy provides information about the decay properties of unstable nuclei on a nucleosynthesis path. Many experiments were performed under the EURICA collaboration at RIKEN RIBF. The Double-Sided Strip Si Detectors (DSSDs) called WAS3ABi were installed to measure the energy and time of implanted nuclei (ions) and β-rays.[1)] A β-ion correlation to determine the parent nucleus was performed using the position difference between the β-rays and ions. A new algorithm was developed to increase the correlated events and decrease background by selecting the β-ray origin from all detected positions. The outline of the algorithm is as follows:

(1) Categorize the β-ray events using the hit pattern of the DSSDs (see Fig. 1).
(2) For cases (category #=10* in Fig. 1) for which the maximum number of hits in one layer = 1, check whether the upstream/downstream plastic scintillator has detected the β-ray or not.
(2-1) If it has, the emitted β-ray has gone to the plastic scintillator. Therefore, the direction of the β-ray and the emitted position candidate can be determined explicitly.
(2-2) If it has not, if an energy deposition by a penetrated beta ray was also lower than one, it is selected as the emitted position candidate.
(3) If there is detection on only one side, detection of the β ray in the implanted layer is difficult because the passing distance in one DSSD is shorter than the DSSD with the penetrated β ray. When detection occurs on only one side of the DSSD, the position of the other side is estimated by trajectory extrapolation.
(4) For implanted ions, implanted events near the surface of DSSDs can be assigned.[2)] The implanted layer may not detect the emitted β-ray because the energy loss is too small to detect when the beta ray is emitted towards the near surface. Therefore, a layer difference of up to one between the ion and beta ray is accepted only for this surface-implantation case.

To compare the old and new algorithms, isotope ^{112}Nb was chosen (Fig. 2). In the previous algorithm, all β-ray hit positions were candidates for β-ion correlation, and it collected 38.7% of the total β decay by accepting the X(Y) position difference ΔX (ΔY)$\leq$1 strip. The new algorithm, using the same condition ΔX (ΔY)$\leq$1, detects more β-ion correlations, collecting 41.9% of the total β decay (option 1 in Fig. 1). The ratio of the number of detected parent decays to the number of background events in the first 10 ms was also compared. Figure 2 shows the improvement in this ratio obtained by the new algorithm. The new algorithm provides options, as described in the caption of Fig. 2, for different requirements. The improvement was achieved mainly by selecting the position candidates and considering the surface implantation of the ions.

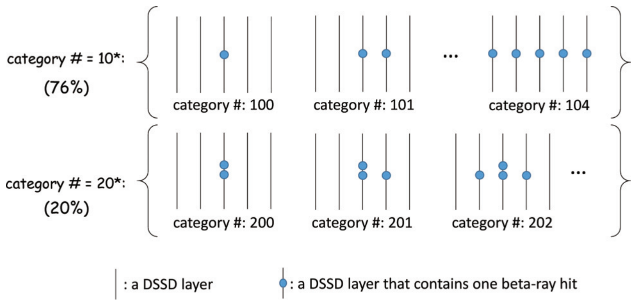

Fig. 1. β-ray events are categorized by category number. Numbers in the 100s indicate that the number of hits in a given layer is one or less. Numbers in the 200s indicate that the number of hits in a given layer is two or less. The total fraction of category 10* (100 to 104) is 76%.

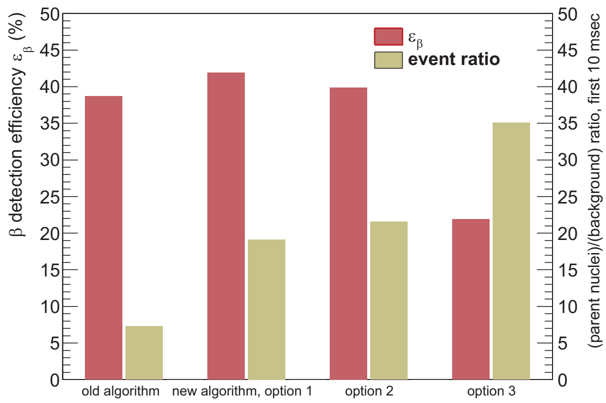

Fig. 2. β detection efficiency ε_β of the old and new algorithms for ^{112}Nb decay. Option 1 uses the position difference condition ΔX (ΔY)$\leq$1. Option 2 uses ΔX (ΔY)=0, and option 3 uses the events for which the β-ray was detected by upstream or downstream plastic scintillators and ΔX (ΔY)=0 to minimize background events.

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References
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