New implant-decay correlation method for β-delayed neutron emission measurements with the BRIKEN setup

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With the observation of a binary neutron-star merger accompanied by the spectroscopic identification of r-process nucleosynthesis[1)] taking place in 2017, there have been major developments in identifying a site of the r-process. These new observations will increase the demand for precise nuclear data that is necessary to reach a clearer understanding of the r-process mechanisms thought to be occurring in these environments.

In June 2017, an experiment was performed to study the decay properties of the β-delayed neutron emitters in the mass region $A = 130$ near the doubly magic nucleus ^{132}Sn. The active-stopper array AIDA[2)] was placed at F11 with the nuclei of interest being implanted and detected alongside their subsequent decays in the silicon detector stack. Neutrons emitted from the β-decay of the implanted ions were detected by the BRIKEN neutron counter array[3,4)] surrounding AIDA. The neutron counter array consisted of 140 gas-filled ^{3}He counters, which were held inside a large moderation block made of high-density polyethylene.

In carrying out analysis on the data, a new method of correlating beta events with implanted ions was developed. As the detectors that comprise the AIDA detector stack are double-sided silicon strip detectors (DSSDs), positional information of both high energy implant and low energy decay events is obtained. With β-decay energies of 100 s of keV and a narrow strip pitch of 560 μm, decay events will be spread across multiple strips. This results in a trade-off between detection efficiency and a background from electronic noise for low energy signals, which is sensitive to the detection threshold and the correlation method.

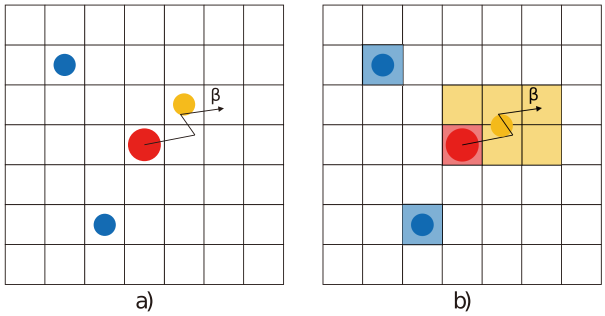

Fig. 1. Comparison between the old correlation method (a) and the new method (b). In both images the red circle indicates an implant particle, the orange circle a beta particle and the blue circles as noise events.

In previous experiments single points have been assigned to the location of the implants and betas with correlation performed based upon the beta points that fall within an area around the implant signal, typically a 7×7 pixel square shown in Fig. 1 a). The new method instead takes into account all of the strips that fire during an event and assigns an area for both implant and decay signals. Correlations can then be performed by searching for an overlap between the areas of the beta and implant events as shown in Fig. 1 b). This new method has been shown to reduce the amount of noise correlated with implants whilst maintaining the beta-detection efficiency of the previous method, as noise events that would otherwise fall within the 7×7 area will now be rejected.

The data analysis for the experiment is ongoing. The data shows the potential of the BRIKEN setup to extend the systematics of β-delayed neutron emission probabilities along the N = 82 and Z = 50 shell closures south and east of ^{132}Sn. The results will improve the reliability of nuclear data for r-process models.

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