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Measuring the β-decay properties of Na-Al species located at the neutron drip line

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The β-delayed neutron emission is a process that can occur when the neutron separation energy in the daughter nucleus (S_n) is smaller than the energy window for the β-decay (Q_β). The delayed neutron emission is characterized by the emission probability (P_n) which that yields information on both the β-strength distribution and the level structure of the daughter nucleus.[1)]

The existing nuclear structure models approach the delayed neutron emission from different directions, depending on their underlying theoretical bases.[2–5)] The difficulties in describing the neutron emission probabilities arise from the need to describe in detail the beta strength of the nucleus, implying an intimate knowledge of its single particle structure.

Of particular importance are the data on multiple neutron emission, as they provide valuable insight into the competition between γ-, one- and multi-neutron emission in highly exotic nuclei. Current models typically assume no competition between the various de-excitation channels, and emit as many neutrons as energetically possible. To improve the predictive powers of macroscopic models and our understanding of nuclear structure in general, more data are required.

The latest atomic mass evaluation lists 2451 isotopes, from which 300/138/58 are energetically allowed delayed 2/3/4 neutron emitters. So far only 23 P_{2n}, 4 P_{3n}, and only 1 P_{4n} values were measured.[6)] The beta delayed neutron emission measurements at RIKEN (BRIKEN) project offers a unique opportunity to study this rare decay mode. The BRIKEN[7)] setup consists of 140 ^{3}He gas-filled proportional counters embedded in a high-density polyethylene moderator. The neutron detector and two CLARION-type clover HPGe detectors are placed surrounding the AIDA DSSSD array,[8)] which contains six layers of highly segmented Si detectors for the detection of implantations and beta electrons.

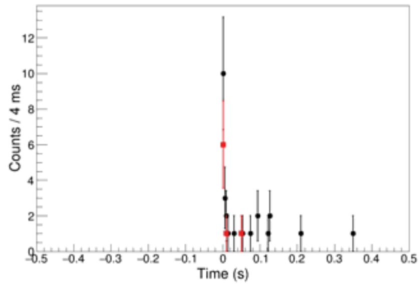

Fig. 1. Time distribution of the β particles emitted after the decay of ^{37}Na. Red and black circles show the data with and without neutron signals in coincidence at the BRIKEN detector, respectively.

In April 2017, the first measurement addressing the multiple neutron emission was conducted in parasitic mode, together with a new isotope search experiment,[9)] targeting the very neutron-rich species in the Na-Al region. The secondary beams, produced using a 345-MeV/nucleon energy ^{48}Ca primary beam impinging on a 20-mm thick Be target, were identified and purified using the BigRIPS spectrometer. They were then transported through the ZD spectrometer to reach the decay station located at the F11 focal plane.

The position and time correlations between the implantation and subsequent decay events were used to derive the half-lives of eight (^{35,37}Na, ^{38,40}Mg, ^{40,41,42}Al, and ^{43}Si) isotopes for the first time. Figure 1 shows the time distributions of β and β-n decays ^{37}Na isotope.

A more detailed analysis is in progress. The new data will constrain the theoretical models, and although in some cases the statistics is poor it will be used to optimize the recently accepted NP1712-RIBF159 experiment.

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