β-delayed neutron emission probabilities for understanding the formation of the r-process rare-earth peak

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The main signatures of the rapid-neutron capture process (so-called r-process) are the three large abundance maxima in the solar-system composition at masses of A$\sim$80, 130, and 195, which are related to the flow of matter through the three neutron shell closures at N=50, 82, and 126. In contrast to these three characteristic peaks, there is a small—but distinct—peak around A$\sim$160, that corresponds to the region of rare-earth elements. From the astrophysics point of view, the most interesting feature of the rare-earth peak (REP) is that, contrary to the three main maxima that form during (n, γ) $\leftrightarrow$ (γ, n) equilibrium, the REP originates later, after neutron exhaustion, thus representing a unique opportunity to study the late-time environmental conditions.

Although several different production mechanisms were suggested, most models agree on the fact that β-delayed neutron emission plays a crucial role in the REP formation.[1–3] Recently, the largest and most efficient β-delayed neutron detector[4] was built by the BRIKEN collaboration at the RIKEN Nishina Center to study systematically the decay of very neutron-rich nuclei across the nuclear chart. The so-called BRIKEN neutron detector 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 around the AIDA DSSSD array,[5] which contains six layers of highly segmented Si detectors for the detection of implantations and beta electrons.

The NP1612-RIBF148 experiment is focused on the measurement of the β-delayed neutron emitters, which are critical for the formation of the REP in the solar system abundances. In an exploratory run ($\sim$25% total beamtime), performed in June 2017, the β decays of exotic Pr-Gd species were studied at the Radioactive Isotope Beam Factory. A 50-pnA-intensity ^{238}U beam was accelerated up to an energy of 345 MeV/nucleon before it was incident on a 4-mm-thick Be target to produce radioactive secondary beams by in-flight fission. The nuclei of interest were separated and identified in the BigRIPS spectrometer, transported through the ZeroDregree spectrometer and implanted in the AIDA array. Figure 1 (top) shows the particle identification matrix for the statistics accumulated during the first 24 h. The bottom panel of Fig. 1 shows the projection of the PID matrix on the A/Q axis for the Nd isotopes; the A/Q resolution achieved—less than 0.05%—ensures a good separation of fully- stripped and H-like ions. The results of the exploratory run are promising; for the first time ever, key REP progenitors[3] have become accessible and the study of their beta decay properties will be possible thanks to the use of the state-of-the-art detectors BRIKEN and AIDA. Our intention is to continue the experiment as soon as the ^{238}U beam is available again.

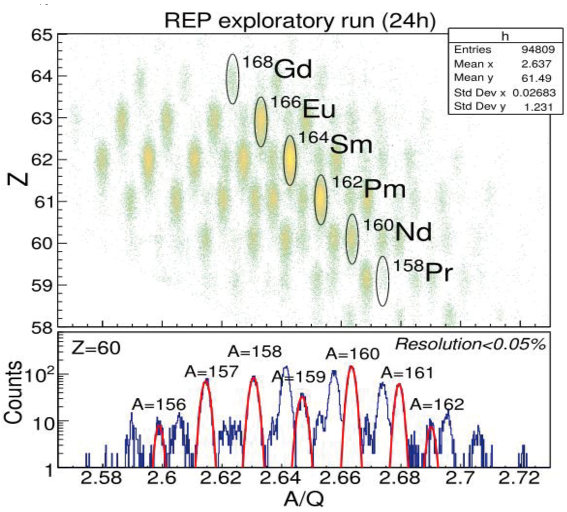

Fig. 1. PID of the exploratory run for the NP1612-RIBF148 experiment.

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