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

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The abundance distribution of the rapid-neutron capture (so-called r-) process is characterized by two large maxima at masses of $A \sim 130$ and $A \sim 195$, which are related to the flow of matter through the neutron shell closures at $N = 82$ and $N = 126$. However, there is an additional, relatively small—but distinct—peak around $A \sim 160$, which corresponds to the region of the rare-earth elements. In contrast to the main abundance maxima that form during the $(n, \gamma) \leftrightarrow (\gamma, n)$ equilibrium, the rare-earth abundance peak (REP) originates later, after neutron exhaustion, thus representing a unique opportunity to study the late-time environmental conditions of the r-process.[1–3] Several different peak-production mechanisms were suggested, but experimental data—masses, β-decay parameters, and neutron capture rates—are clearly needed to evaluate the different astrophysical scenarios. The most influential nuclei to the REP formation, located in the $A \sim 160$, $55 \leq Z \leq 64$ neutron-rich region, have been identified by sensitivity studies.[3]

The aim of the NP1612-RIBF148 experimental program is to measure the β-decay parameters, half-lives, and delayed-neutron-emission probabilities (P_n values) of these species using the BRIKEN array, which is the largest and most efficient β-delayed neutron detector built.[4,5] It consists of 140 ^{3}He gas-filled proportional counters embedded in a high-density polyethylene moderator. The neutron detector and two CLARION-type clover high purity germanium detectors are placed around the AIDA DSSSD array[6] which contains six layers of highly segmented Si detectors for the detection of implantations and β electrons.

The study was conducted at the Radioactive Isotope Beam Factory. A 60-pnA intensity ^{238}U beam was accelerated up to an energy of 345 MeV/nucleon before incidence 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 shows the results of the preliminary half-life analysis of the ^{163}Pm isotope. Although some half-lives in this region have been already measured[7] our experiment will not only provide a large number of new P_n values[8] and half-lives but also considerably improve the precision of the available data.

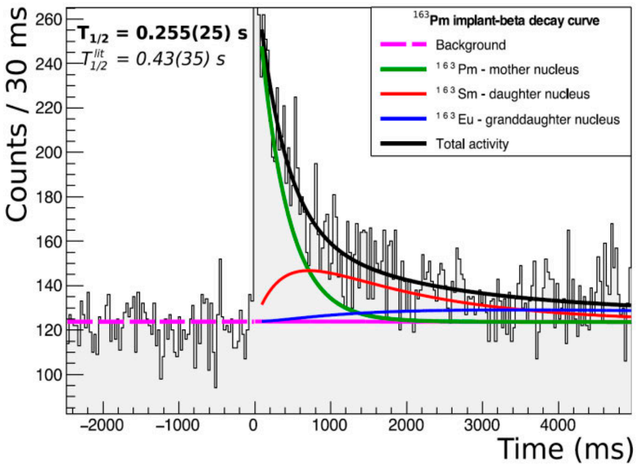

Fig. 1. Preliminary half-life analysis for ^{163}Pm isotopes, showing the contributions to the total fit from the parent, daughter, and granddaughter isotopes. Our $T_{1/2}$ result is compared to the existing data[7] (bold and slanted characters, respectively).

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References

1) R. Surman *et al.*, Phys. Rev. Lett. **79**, 1809 (1997).
2) A. Arcones, G. Martinez Pinedo, Phys. Rev. C **83**, 045809 (2011).
3) R. M. Mumpower *et al.*, Prog. Part. Nucl. Phys. **86**, 86 (2016).
4) A. Tarifeno-Saldivia *et al.*, J. Instrum. **12**, P04006 (2016).
5) A. Tolosa-Delgado *et al.*, Nucl. Instrum. Methods Phys. Res. **925**, 133 (2019).
6) C. Griffin *et al.*, Proc. Sci. **NIC-XIII**, 097 (2014).
7) J. Wu *et al.*, Phys. Rev. Lett. **118**, 072701 (2017).
8) A. Tarifeño-Saldivia *et al.*, RIKEN Accel. Prog. Rep. **52**, 39 (2019).