Progress on the measurements of P_n-values and half-lives for understanding the formation of the r-process rare-earth peak

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The Rare Earth Peak (REP) is a small, but clearly distinctive, peak around mass $A \sim 160$ in the elemental solar system abundances created by the rapid neutron-capture process (r-process). In contrast to the r-process abundance peaks associated with neutron shell closures (*e.g.* $A \sim 130$, 195), which are formed during the $(n,\gamma) \leftrightarrow (\gamma,n)$ equilibrium, the REP is formed later after the neutron exhaustion. Thus, the understanding of the REP formation offers a unique probe for the study of the late times environmental conditions in the r-process site. According to theoretical models,[1)] masses, β-decay rates, β-delayed neutron emission probabilities (P_n) and the capture rates play a key role in the formation of the REP. The most influential nuclei to the REP formation have been determined by sensitivity studies to be the neutron-rich region with mass $A \sim 160$ from Cs to Gd.[2)] The physical input for these sensitivity studies is based on current nuclear model calculations. Recently, several of the half-lives in the REP region have been measured by the EURICA collaboration at RIBF in the RIKEN Nishina Center.[3)] More recently, the largest and most efficient β-delayed neutron detector of its kind has been built by the BRIKEN collaboration,[4)] at the RIKEN Nishina Center, for a systematic study of the decay properties of the most exotic neutron-rich nuclei, including the REP nuclei, accessible currently by experimental means. A detailed description of the BRIKEN detector and the scientific program of the BRIKEN project is provided by Tain *et al.*[5)]

The NP1612-RIBF148 experiment make use of BRIKEN for the measurement of β-delayed neutron emission probabilities and half-lives in the REP nuclei region. The experiment has been allocated with 10 days of total beamtime. An exploratory experimental run (2.5 days in total) was carried out in 2017 with a setting centered on ^{167}Sm, the heaviest most exotic accessible REP nuclei. This run has provided data for measurement of some new half-lives in the region from Gd to Pm.[6)] However the statistics for precise measurement of P_n-values was rather poor. In 2018 a new experimental run has been carried using a total of 5.0 days of beamtime. The 2018 run has used a setting centered on ^{165}Pm, providing data for measurement of P_n-values in the region from Ce to Eu. In Fig. 1 is presented the preliminary analysis of partial data for the case of ^{157}Pr. The analysis make use of the approach developed by Tolosa-Delgado *et al.*[7)] for a consistent fit of parameters of the decay chain in implant-β-gated and implant-β-neutron-gated time correlation histograms. The preliminary analysis yielded a half-live of 327 ms, in agreement with the previous EURICA measurement (295 ms +10% −4%), and a new P_n-value of 6.8%.

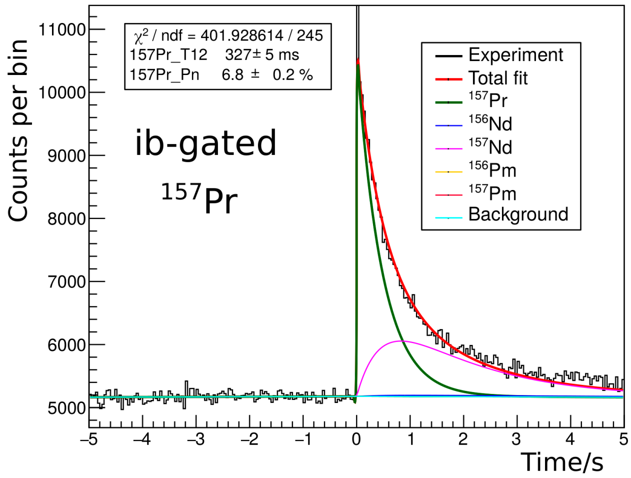

Fig. 1. Preliminary analysis from partial data for the β-decay for ^{157}Pr.

In summary, three quarters of the allocated beamtime for the experiment have been completed. The coverage region of the experimental data from 2017 and 2018 runs, for measurement of the REP P_n-values and half-lives, extends from Ce to Gd nuclei. The detailed data analysis of this region is ongoing.

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