94 β-decay half-lives of neutron-rich nuclei from $_{55}$Cs to $_{67}$Ho[†]

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The two most prominent features of the r-process abundances in the solar system are the large abundance of $_{52}$Te, $_{54}$Xe (mass number $A\sim130$) and $_{78}$Pt, $_{79}$Au ($A\sim195$), which are understood in terms of the enhanced stability of nuclei with filled major neutron shells (of neutron number N=82 and N=126). However, the production mechanism of the peak of rare-earth elements (REE) ($A\sim165$) is still a controversial topic.[1)]

To address this problem, two β-decay spectroscopy experiments optimized for the transmission of ^{158}Nd and ^{170}Dy were performed at the Radioactive Isotope Beam Factory (RIBF) by using the in-flight fission of a 345 MeV/A ^{238}U primary beam with an average intensity of 7 and 12 pnA, respectively. The secondary beam selected and identified by BigRIPS separator was implanted to the beta-counting system of the Wide range Active Silicon-Strip Stopper Array for Beta and ion detection (WAS3ABi), which is surrounded by the high purity germanium cluster detectors of the Euroball RIken Cluster Array (EURICA). The β-decay half-life of an isotope of interest was extracted from the fit of the time distribution of electrons detected after the implantation of an ion and correlated to them in position and time[2)].

In this measurement, 57 β-decay half-lives of neutron-rich nuclei from $_{55}$Cs to $_{67}$Ho were measured for the first time with 94 half-lives measured in total. The impact of newly measured β-decay half-lives on the shape of the REE peak is illustrated in Fig. 1. The figure shows the theoretical uncertainty estimated for each model, determined by varying theoretical half-lives within a factor of two. The study indicates that the new measurements remove a significant uncertainty in the calculations associated with theoretical half-lives.

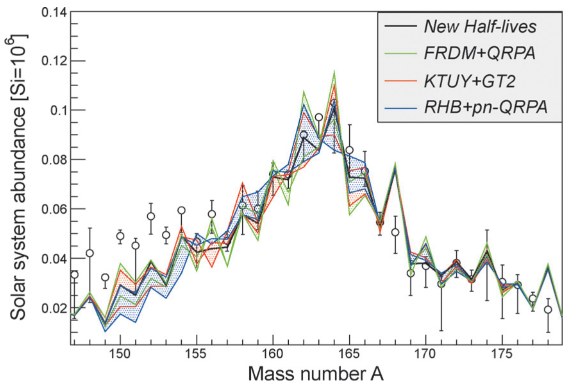

Fig. 1. (color online). The r-process abundance pattern observed in the solar system (open circles)[3)] and calculated using the experimental and theoretical half-lives. KTUY05[4)] mass and the ReaclibV1.0[5)] Database of nuclear reaction rates were employed for the baseline calculation. Experimental data and three theoretical predictions replaced the half-lives of nuclei whose values were measured for the first time.

In summary, the newly measured half-lives have a direct impact in r-process abundance calculations affecting almost all mass numbers in the range A=150−170. This is an important step towards the long-term goal of removing nuclear-physics uncertainties so that the REE peak can be used as a unique probe of the r-process freeze-out conditions and eventually reveal the currently unknown r-process site.

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