Mass and β-decay measurement of neutron-rich nuclei around N=56

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The origin of the elements around Zr (Z=40) is one of the most intriguing questions regarding nucleosynthesis of the heavy elements during the rapid neutron-capture process (r-process). In recent years, the observation of elemental abundances in a growing sample of extremely metal-poor star has shown a remarkably robust pattern of abundances in the heavier elements (beyond Te, at Z=52), in very good agreement with the r-process abundance pattern derived from the Solar System [1)]. This provides evidence that the r-process is a mechanism contributing to the chemical evolution of the Galaxy from its early stages. On the other hand, the scenario for the elements in the Sr to Ag region is more complex[2)]. The abundances do not show such a clear correlation with the solar r-process pattern. For example, some stars present an overabundance of A≈90 isotopes. Additional nucleosynthesis processes, such as a weak r-process acting in neutrino-driven winds of core-collapse supernovae, have been proposed as an explanation[2)].

Astrophysical model calculations consistently show that the uncertainty in the available nuclear physics input contributes in a significant way to the uncertainty of their results. For some models, the region around ^{92}Se studied in our experiment, has been identified as having a high impact[3)]. The region is critical to disentangle the contribution of the strong r-process from other nucleosynthesis processes. Our new data will help to address the question of what, if any, the contribution of the strong r-process to elements lighter than Ag (Z=47) is, or which alternative processes could be responsible for the synthesis of these elements.

The objective of our experiment, performed in June of 2016, is to measure for the first time the mass and β-decay half-lives of a number of neutron-rich isotopes in the Z≈34 region. The experiment combines a β-decay measurement using the Advanced Implantation Detector Array (AIDA) with a simultaneous mass measurement using the time-of-flight (TOF) technique[4)]. A neutron-rich beam in the ^{92}Se region was produced by fragmentation of a 345 MeV/u primary beam of ^{238}U on a Be target. In addition to the separation of the secondary beam ions, BigRIPS was used for the TOF mass measurement. Its optics were tuned to High Resolution Mode, using a TOF flight path from the F3 to the F11 focal plane positions. The beam ions were then implanted in the double-sided silicon strip detectors of AIDA, which was placed at the focal plane of the Zero-Degree Spectrometer and surrounded by the EURICA gamma detector array.

Figure 1 shows a particle-identification plot for the experiment, with a line indicating the limit of known nuclear masses. We expect to measure new decay half-lives of 10 isotopes in the region of Ge to Kr region, and the mass for up to 10 isotopes. The data analysis for the mass and half-live measurement is in progress, as well as that for decay spectroscopy with EURICA.

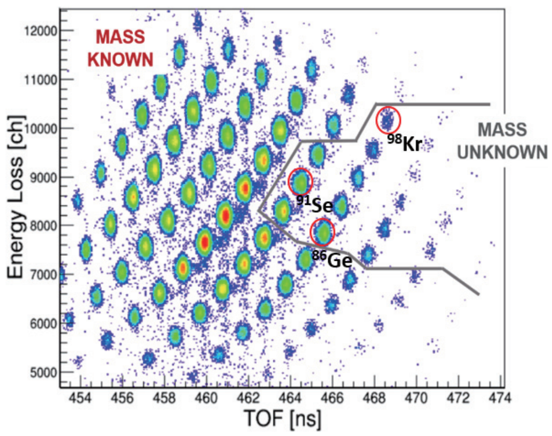

Fig. 1. Particle identification plot for secondary beam ions in the experiment, showing the limit of previously measured masses (with three isotopes labelled as reference).

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References
1) I. U. Roederer et al.: Astrophys. J. Lett. **747**, L8 (2012).
2) C. Hansen et al: Astrophys. J. **797**, 123 (2014).
3) S. Brett et al: Eur. Phys. J. A **48**, 184 (2012).
4) M. Matos et al: Nucl. Instr. Meth. A **696**, 171 (2012).