Beta-delayed proton emission of ^{73}Sr and effective lifetime of the rp-process waiting point ^{72}Kr in X-ray bursts environment

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The nuclide ^{72}Kr is a potential waiting point of the astrophysical rp-process. However, its lifetime under conditions of X-ray bursts may significantly be reduced by the two-proton capture reaction ^{72}Kr(p,γ)^{73}Rb(p,γ)^{74}Sr. The rate of this reaction is highly sensitive to the characteristics of the low-energy states of the intermediate nucleus ^{73}Rb and, in particular, to the proton-separation energy, S_p, of ^{73}Rb. No constraints from direct measurements exist, resulting in significant uncertainties in calculations of astrophysical interest.

Nuclear structure in the 70–80 mass-number region is particularly interesting. Rapid shape changes, shape coexistence, and *np*-pairing effects are all expected. This is a challenging region from a theoretical perspective and little experimental data exists for nuclei beyond the $N=Z$ line. This experiment affords an opportunity to access nuclei both at and beyond the $N=Z$ line in this mass-number region.

The nuclei of interest were produced by fragmentation of a 345 MeV/u ^{124}Xe primary beam colliding with a ^{9}Be target. The beam intensity ranged from 30–35 pnA. The secondary beam purification and identification was performed using the BigRIPS fragment separator. The fragments of interest were unambiguously identified, and their subsequent decays were recorded using the WAS3ABi silicon stopper in conjunction with EURICA[1]. Implantations were correlated with their subsequent β-decays on the basis of position and time, enabling measurement of half-lives and β-delayed γ rays.

Two experimental settings were used to access proton-rich isotopes around ^{73}Sr (as shown in the particle-identification (PID) plot in Fig. 1 with ^{73}Sr highlighted). As a first setting, BigRIPS was set for maximum transmission of ^{73}Sr, the number of implanted nuclei predicted by LISE^{++} was 2500 and the requested beam time was 2.5 days. A second setting was optimized for the transmission of ^{74}Sr, and the number of implanted nuclei predicted was 8000 for 0.5 days. The actual total beam time was 45 h for ^{73}Sr and 9 h for ^{74}Sr. The number of implanted ^{73}Sr and ^{74}Sr were 186 and 590, respectively. The discrepancies observed between the expected counts and actual counts is due to the actual production cross-section being lower than that predicted by LISE^{++} calculations.

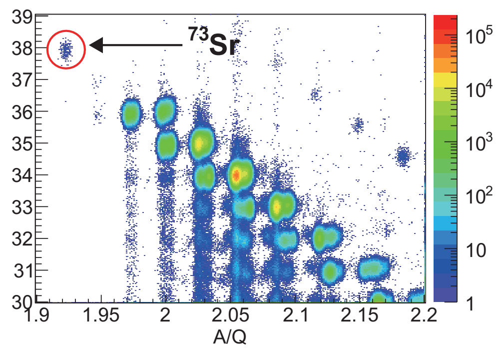

Fig. 1. PID plot of nuclei transmitted through the fragment separator BigRIPS from the ^{73}Sr setting.

Upon the experiment's completion, an energy calibration of WAS3ABi was carried out using 482 and 972 keV conversion electrons emitted from a ^{207}Bi source.

The β^+-decay half-lives of nuclei ^{73}Sr, ^{74}Sr and ^{76}Y have been measured. The accuracy of these measurements were verified by extracting the half-lives of previously studied nuclei and comparing with the literature values.

The isotopes ^{69}Br, ^{72}Rb and ^{73}Rb were observed in BigRIPS, for which there is evidence of implantation and decay events in WAS3ABi. Future analyses will focus on these events, as well as the low-lying structure populated through β^+-decay of exotic nuclei produced around ^{73}Sr. A search for new isomeric states, such as the one found in ^{70}Se, is also being carried out.

This large set of data will provide new half-lives, direct input for rp-process calculations, and new insights into the structure of nuclei in this region.

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References

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