Study of β-delayed proton emitters in the region from Zn to Kr

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Studies of nuclei far from stability can provide excellent tests of the validity of nuclear structure models. They are also of interest in relation to astrophysical processes such as the *rp*-process (rapid-proton capture) for proton-rich nuclei. They decay via direct proton, β-delayed proton (βp) or γ emission.

The production of very exotic proton-rich nuclei was achieved at RIBF by ^{78}Kr projectile fragmentation on a Be target. This reaction was used for the first time during the ^{78}Kr campaign in 2015, allowing the observation of new isotopes[1)] and 2*p* radioactivity[2)]. After selection and identification by BigRIPS and the ZD spectrometer, the nuclei were implanted in the three WAS3ABi DSSSDs to measure β particles and protons, surrounded by the EURICA γ-ray array[3)].

A DSSSD allows implantation-decay position and time correlations, strongly reducing the background in the spectra. However, a lot of random correlations remain. Background can be removed using two energy spectra: one from implantation-decay correlations in a positive time window and another in a negative one of the same width. Because the background time distribution is uniform, the background is removed when the second spectrum is subtracted from the first one. The proton branching ratios were determined comparing the number of events above 1 MeV with the number of implants happening in the same pixel. β particles have an average energy loss of 400 keV, their contribution can therefore be neglected above 1 MeV. The half-lives were determined from time spectra considering our experimental branching ratios and the β-detection efficiency for the daughter contributions. This efficiency was estimated from known β emitters.

Nucleus	Proton branching ratio (%)	Half-life (ms)
^{57}Zn	81(2)	44.8(4)
^{61}Ge	86(2)	39.1(4)
^{65}Se	88(2)	33.2(6)
^{68}Kr	90(10)	20(4)
^{69}Kr	95^{+5}_{-6}	30(2)

Table 1. Measured proton branching ratios and half-lives.

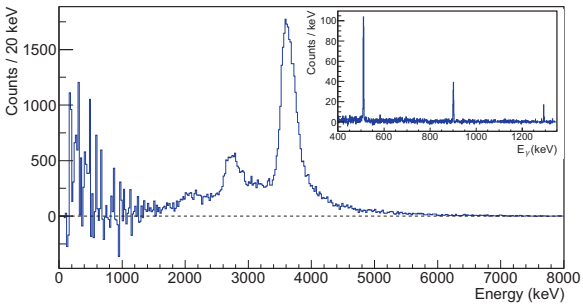

Fig. 1. Charged-particle spectrum for ^{65}Se decay after background subtraction. The inset shows the γ-ray spectrum in coincidence with the 2.6 MeV proton peak. The 901.7-keV peak confirms the feeding of the $2^+ \rightarrow 0^+$ transition in ^{64}Ge and the scheme proposed by ref.[4)].

The high statistics of the experiment gave more accurate values for βp emitters (cf. Table 1) as compared to the literature values. New measurements of ^{65}Se (see Fig. 1) and ^{69}Kr were made, relevant for the *rp*-process because of their proton-unbound β daughters ^{65}As and ^{69}Br[4)]. New values for ^{61}Ge and ^{57}Zn allow a comparison with existing ones[5)]. ^{68}Kr was measured for the first time.

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References

1) B. Blank et al., Phys. Rev. C **93**, 061301(R) (2016).
2) T. Goigoux et al., Phys. Rev. Lett. **117**, 162501 (2016).
3) P.-A. Söderström et al., Nucl. Instrum. Methods Phys. Res. Sect. B **317**, 649 (2013).
4) A. M. Rogers et al., Phys. Rev. C **84**, 051306(R) (2011).
5) B. Blank et al., Eur. Phys. J. A **31**, 267 (2007).