Isomer-decay spectroscopy of ^{67}Fe and reaction-channel dependency of isomeric ratios from interactions in the MINOS proton target

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In this report, we discuss the properties of the isomeric state in ^{67}Fe. While the existence of this isomer is already well established, its nature is still unknown.

The data were obtained using the EURICA[1,2] setup during the SEASTAR campaign in 2014[3] by fissioning a 345 MeV/u ^{238}U beam on a 3 mm-thick beryllium target. Knockout reactions occured in the liquid hydrogen target of MINOS,[4] installed at the F8 focal plane. At the final focal plane the EURICA array was used for measuring the energy and time between implantation and detection of the γ rays. In this experiment only six EURICA clusters were active. A total of $\sim 3\times10^7$ ^{67}Fe nuclei were implanted in a stopper in the center of EURICA. Approximately 96% of these implantation were from unreacted ^{67}Fe secondary beam, the rest were reaction products in MINOS.

Using the BigRIPS and ZeroDegree information the implanted nuclei could be separated into the main reaction channels: ^{68}Co(p, 2p)^{67}Fe, ^{238}U fission, and ^{68}Fe(p, pn)^{67}Fe with isomeric ratios of 56%, 36%, and 28%, respectively. Thus, the isomeric ratio is highest in the proton knock-out channel, but also significant in the other channels. In the Fig. 1, the γ-ray spectra are shown, normalized to the number of incoming ions.

One possible interpretation of the different isomeric ratios is found in the difference in the states of the ternary beam. For ^{68}Co there are two long-lived states that can serve as effective ground state configurations of 1^- and 7^- based on $\pi f_{7/2} \otimes \nu g_{9/2}$. Knocking out a $f_{7/2}$ proton could then leave a $g_{9/2}$ neutron in an excited state, that in turn decays to the isomeric state. With ^{68}Fe in a 0^+ ground state, and no other known long lived configurations, the still relatively high isomeric ratio from neutron knockout can be explained by the breaking of a $\nu g^2_{9/2}$ neutron-pair. In summary, such a picture would be consistent with a $\nu g_{9/2}$-based isomer over a $\nu p_{1/2}$ ground-state.

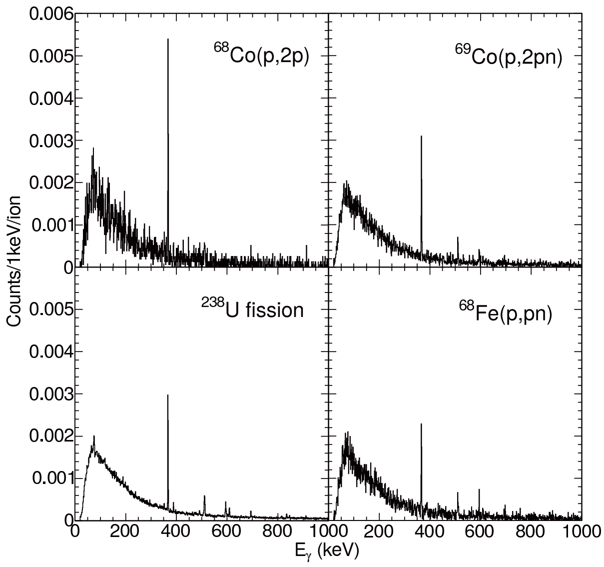

Fig. 1. Spectra of γ rays following isomeric decay separated into the main reaction channels normalised to the respective number of incoming ions.

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References

1) S. Nishimura, Prog. Theor. Exp. Phys. **2012**, 03C006 (2012).
2) P.-A. Söderström *et al.*, Nucl. Instrum. Methods B **317**, 649 (2013).
3) P. Doornenbal *et al.*, RIKEN Accel. Prog. Rep. **48** 5 (2015).
4) A. Obertelli *et al.*, Eur. Phys. J. A **50**, 8 (2014).