Decay studies in the region of ^{54}Zn

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In April 2019, we performed an experiment at the RIBF facility to study the two-proton ($2p$) radioactivity of ^{54}Zn. The main goal was to measure correlations between momenta of emitted protons in order to investigate whether they can provide insight into the structure of this exotic, extremely neutron-deficient nucleus. In particular, the comparison of the measured $p-p$ correlations for ^{54}Zn with the previously established correlations for ^{45}Fe[1)] could reveal the expected influence of the proton $Z = 28$ shell closure on these proton drip-line nuclei.

The nuclei of interest were produced using a ^{78}Kr primary beam at 345 MeV/nucleon impinging on a 10 mm-thick beryllium target and separated with the help of the BigRIPS separator and ZeroDegree spectrometer.[2)] The separated ions, identified in-flight, were implanted into the Warsaw Optical Time Projection Chamber (OTPC)[3)] mounted in the final focal plane of the ZeroDegree spectrometer (F11). In order to increase the stopping efficiency in the relatively thin gas of the OTPC, a monoenergetic degrader was installed at the F10 focal plane.

The OTPC is a gaseous detector working in the TPC mode, in which the signals are read out by means of optical methods instead of electronic ones. It can record images of tracks of charged particles, allowing their identification and the reconstruction of the decay events in three dimensions. The reconstruction is performed by combining the two-dimensional image recorded using a CCD camera with the signal from a photomultiplier recording the total light intensity as a function of time, which is related to the position in the direction perpendicular to the image via the constant drift velocity. The OTPC was filled with a gas mixture consisting of 69% Ar, 29% He, and 2% CF_4 at atmospheric pressure.

During the measurement, it was found that the production cross section for ^{54}Zn was smaller than the value predicted by the EPAX 3.1 empirical formula[4)] by a factor much larger than anticipated before the experiment. Nevertheless, decays of several ions of ^{54}Zn were recorded, showing clear images of ($2p$) emission. An example of such a decay is shown in Fig. 1(a). The detailed analysis of the recorded ($2p$) events is currently in progress. In addition, the collected data will be used to determine the production cross section for ^{54}Zn, which was previously unknown for the reaction used in this experiment. The cross-section systematics for neutron-deficient zinc isotopes may shed light on the puzzle of the lower-than-expected production of ^{54}Zn. Understanding the fragmentation cross sections for nuclei at the proton drip-line is of great importance for the upcoming next-generation radioactive beam facilities.

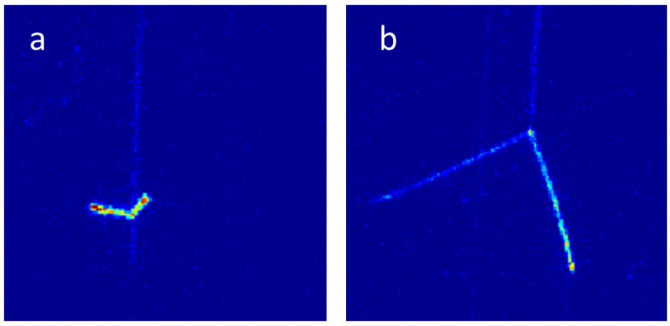

Fig. 1. Examples of CCD images showing decay events of ions stopped in the OTPC detector: (a) two-proton radioactivity of ^{54}Zn and (b) β-delayed two-proton emission from ^{55}Zn, illustrating the first observation of this channel for this nucleus.

Before the final setting on ^{54}Zn was tuned, other settings of BigRIPS were optimized and calibrated. This allowed us to collect decay data for a few less-exotic nuclei in this region. According to a preliminary scan of the recorded events, approximately 50 decays of ^{55}Cu, 380 decays of ^{56}Zn, and 300 decays of ^{55}Zn were observed. Among them, the latter case is the least known: spectroscopic data for this nucleus are scarce.[5)] Among the decay events of this nucleus, we observed several clear images of the β-delayed two-proton emission, a channel that has not been observed previously for this nucleus. An example of such an event is shown in Fig. 1(b). Careful analysis of all recorded decay events is in progress.

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