High-resolution spectroscopy and lifetime measurements in neutron-rich Zr and Mo isotopes

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One of the most interesting cases of shape evolution in nuclei is encountered along the semi-magic ($Z = 40$) Zr isotopes. While ^{90}Zr, at neutron number $N = 50$, shows properties of a doubly-magic nucleus, neutron-deficient Zr isotopes become well-deformed towards ^{80}Zr. On the neutron-rich side, a sudden onset of deformation is also indicated by the dramatic lowering of the first excited 2^+ state from ^{98}Zr to ^{100}Zr.

When going towards even more neutron-rich isotopes the question about the further shape evolution arises since the theoretical predictions diverge. Many theoretical calculations have been performed for ^{110}Zr since it combines the magic numbers $Z = 40$ and $N = 70$ of the harmonic oscillator potential and could be another quasi doubly-magic nucleus. This question was answered in a previous SEASTAR experiment at the RIBF,[1] which measured the first excited states of ^{110}Zr and showed that this isotope is rather well deformed. However, several questions remain open, such as the possibility of shape coexistence or triaxial deformation at $Z = 40$, $N = 70$ as predicted by different theoretical models.[3–5]

We performed high-resolution spectroscopy of nuclei around ^{110}Zr in an experiment with the HiCARI array[2] in order to measure lifetimes of their (first) excited states . The high-resolution γ-ray detectors from HiCARI will allow to resolve level schemes by measuring γ rays from ∼100 keV, and to measure lifetimes of excited states between ∼20 ps and 1 ns. The results will also allow to confirm the level scheme of ^{110}Zr and to measure decay branching ratios of states beyond the 2_1^+ for the first time.

The nuclei of interest were populated by proton-removal reactions from projectiles around ^{112}Mo, produced from a primary ^{238}U beam, impinging on a secondary Be target. Particle identification of the radioactive beams for selecting the proper reaction channel was performed with the BigRIPS and the ZeroDegree spectrometers. Examples of the particle identification plots are shown in Fig. 1. Average intensities and purities of the projectiles of interest amounted to 81 and 3000 pps and 0.8% and 34% for ^{111}Nb and ^{113}Tc, respectively. Additionally, ^{112}Mo was transmitted at a high rate as well. ^{110}Zr was populated through proton removal reactions from ^{111}Nb and ^{112}Mo. The high intensity of ^{113}Tc allowed to obtain significantly more statistics for ^{112}Mo than in the previous experiment.[1] Additionally, the neighbouring even-even nuclei, ^{108}Zr and ^{110}Mo, have been populated strongly to allow for a detailed lifetime analysis.

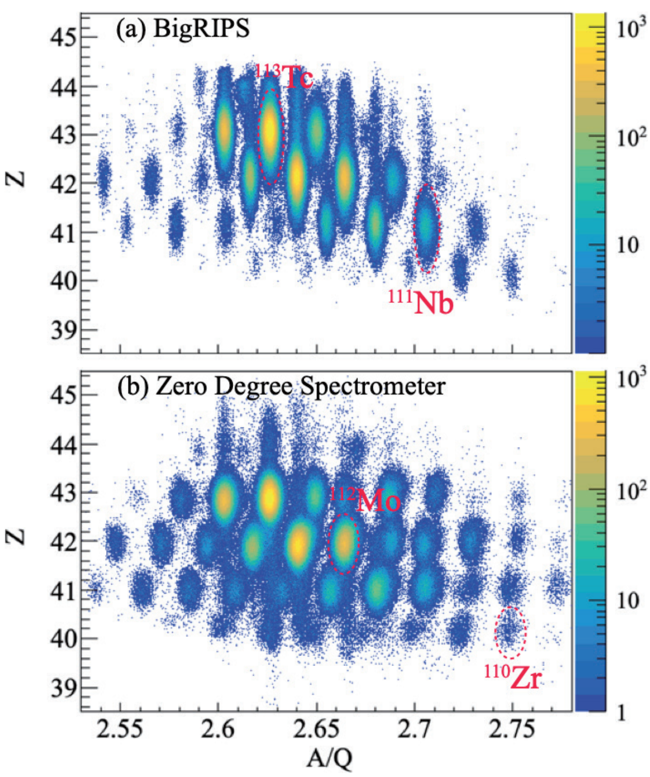

Fig. 1. Preliminary particle Identification (PID) for BigRIPS (top) and ZeroDegree (ZD) spectrometer (bottom).

In order to optimize the experiment for the long lifetimes of the 2^+ states, expected to be several hundred ps, the Be target was positioned 10 cm upstream of the center of HiCARI. Lifetimes will be extracted using the line-shape method[6] and will give access to the collective properties. The experiment will allow to distinguish between predictions of different nuclear models concerning the shape of ^{110}Zr, the key isotope for the evolution of collective properties along the $N = 70$ isotones.

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