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Triaxial deformation in neutron-rich Zr and Mo isotopes explored by high-resolution in-beam gamma-ray spectroscopy

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Since the nuclear collective model was first proposed by Rainwater, and later refined by Bohr and Mottelson, the axially symmetric deformation with rotational motion has successfully described many nuclei. However, certain exotic nuclei require additional degrees of freedom to explain their rotational motion, particularly in relation to the γ-band structure. To address such cases, triaxial deformation was introduced, characterized by the gamma degree of freedom spanning from 0° (prolate) to 60° (oblate).

To describe this triaxial motion, Davydov and Filippov developed a rigid triaxial rotor model, which predicts that the second 2^+ state lies below the first 4^+ state at maximum triaxiality. In contrast, Wilets and Jean proposed the gamma-unstable rotor model, which assumes no strict γ confinement in the potential energy surface. More recently, a novel perspective on nuclear deformation was proposed using ^{166}Er, suggesting that this nucleus does not exhibit axial symmetry but instead possesses triaxial deformation in its ground state. Furthermore, the γ-vibrational band was interpreted as rotational motion along an asymmetric axis. However, there is no definitive conclusion regarding axial versus triaxial deformation in deformed nuclei based on either experimental or theoretical results.

Neutron-rich Zr and Mo nuclides are promising candidates for investigating triaxiality due to their moderately deformed ground states. Recent measurements revealed that ^{110}Zr, which lies at the $Z = 40$ and $N = 70$ shell closures of the harmonic oscillator potential, exhibits a well-deformed nature. Nonetheless, unresolved questions remain, such as the possibility of shape coexistence or triaxial deformation in this isotope, as predicted by different theoretical models. Additionally, theoretical studies suggest that Mo isotopes from $A = 102$ to 110 may exhibit triaxiality. Notably, the second 2^+ states in these isotopes significantly drop in energy, falling below the first 4^+ states starting with ^{108}Mo, a feature strongly tied to triaxial motion. However, debates on triaxiality persist due to differing interpretations of γ vibration, the rigid triaxial rotor, and the γ-unstable rotor models. Consequently, more advanced experimental evidence, such as lifetime measurements for transition rates, is essential to determine the triaxial nature of these nuclides.

To address these questions, a high-resolution in-beam γ-ray spectroscopy study of nuclei near ^{110}Zr was conducted as part of the HiCARI (High-resolution Cluster Array at RIBF) campaign at RIBF, aiming to measure level lifetimes. The HiCARI array consisted of several types of high-purity germanium detectors, including six Miniball triple clusters, four segmented Clover detectors, and two GRETINA-type tracking detectors. Through this experiment, ^{108}Zr, ^{110}Zr, ^{110}Mo, and ^{112}Mo were produced via nucleon-removal reactions of radioactive beams.

In this presentation, we will discuss the experimental results for ^{108}Zr, ^{110}Zr, ^{110}Mo, and ^{112}Mo. Lifetimes of excited states in these nuclei were analyzed using the line-shape method, and new level schemes were established. Advanced theoretical models were applied to interpret our experimental findings and to explore triaxiality in neutron-rich Zr and Mo isotopes.

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