Shape evolution of $^{106, 108, 110}$Mo in the triaxial degree of freedom

J. Ha,$^{1,2,3}$ T. Sumikama,$^{2,3}$ F. Browne,$^{2,4}$ N. Hinohara,$^{5}$ A. M. Bruce,$^{4}$ S. Choi,$^{1}$ I. Nishizuka,$^{3}$ S. Nishimura,$^{2}$ P. Doornenbal,$^{2,4}$ G. Lorusso,$^{2,6,7}$ P. -Å. Söderström,$^{2}$ H. Watanabe,$^{2,8,9}$ R. Daido,$^{9}$ Z. Patek,$^{2,4,10}$ S. Rice,$^{2,4}$ L. Sinclair,$^{2,10}$ J. Wu,$^{2,11}$ Z. Y. Xu,$^{12,13}$ A. Yagi,$^{9}$ H. Baba,$^{2,9}$ N. Chiga,$^{2,3}$ R. Carroll,$^{4}$ F. Didierjean,$^{14}$ Y. Fung,$^{9}$ N. Fukuda,$^{2}$ G. Gey,$^{15,16}$ E. Ideguchi,$^{9}$ N. Inabe,$^{2}$ T. Isobe,$^{2}$ D. Kameda,$^{2}$ I. Kojouharov,$^{17}$ N. Kurz,$^{17}$ T. Kubo,$^{2}$ S. Lalkovski,$^{18}$ Z. Li,$^{11}$ R. Lozeva,$^{14,19}$ H. Nishibata,$^{9}$ A. Odahara,$^{9}$ Zs. Podyolák,$^{4}$ P. H. Regan,$^{6,7}$ O. J. Roberts,$^{4}$ H. Sakurai,$^{2}$ H. Schaffner,$^{17}$ G. S. Simpson,$^{15}$ H. Suzuki,$^{2,9}$ H. Takeda,$^{2,9}$ M. Tanaka,$^{9}$ J. Taponnere,$^{2,20,21}$ V. Werner,$^{22,23}$ and O. Wieland$^{24}$

The properties of the $2^+_3$ band in even-even nuclei are closely connected with the triaxial motion in the direction of the $\gamma$ degree of freedom, such as the $\gamma$-vibration, rigid triaxial rotor,$^{1}$ or $\gamma$-unstable rotor.$^{2}$ The lowering of the known $2^+_3$-state energy in neutron-rich molybdenum isotopes ($Z = 42$) is interpreted as the development of these triaxial motions associated with the ground-state shape. We studied the neutron-rich $^{106, 108, 110}$Mo isotopes with higher statistics by measuring the $\beta$-delayed $\gamma$ rays.

A neutron-rich cocktail beam was produced from the fragmentation of a 345–MeV/nucleon $^{238}$U$^{6+}$ beam. The nuclides were separated and identified on the BigRIPS separator and delivered to F11. The ions and $\beta$ particles were detected by the WAS3ABi active stopper. A high-purity Ge array, EURICA,$^{3,4}$ and fast-timeing $\text{LaBr}_3$ array were used to measure the energy and time of $\gamma$ rays.

Figure 1 shows $B(E2)$ determined from the lifetime measurement of the $2^+_1$ states using the $\text{LaBr}_3$ array. The quadrupole deformation parameters $\beta_2$ of $^{106, 108, 110}$Mo were deduced to be 0.349(13), 0.327(10), and 0.305(7), respectively. The results were compared

1 Condensed from the article in Phys. Rev. C 101, 044311 (2020)
2 Department of Physics and Astronomy, Seoul National University
3 RIKEN Nishina Center
4 Department of Physics, Tohoku University
5 School of Computing, Engineering, and Mathematics, University of Brighton
6 Center for Computational Sciences, University of Tsukuba
7 Department of Physics, University of Surrey
8 National Physical Laboratory
9 IRCNCP, School of Physics and Nuclear Energy Engineering, Beihang University
10 Department of Physics, Osaka University
11 Department of Physics, University of York
12 Department of Physics, Peking University
13 Department of Physics, University of Tokyo
14 Department of Physics, University of Hong Kong
15 IPHC, CNRS/IN2P3, Université de Strasbourg
16 LPS, Université Grenoble-Alpes
17 GSI Helmholtzzentrum für Schwerionenforschung GmbH
18 Department of Physics, University of Sofia
19 CSNSM, CNRS/IN2P3, Université Paris-Sud
20 Departamento de Física Teórica, Universidad Autónoma de Madrid
21 Instituto de Estructura de la Materia, CSIC
22 A.W. Wright Nuclear Structure Laboratory, Yale University
23 Institut für Kernphysik, Technische Universität Darmstadt
24 INFN Sezione di Milano

Fig. 1. $B(E2; 2^+_1 \rightarrow 0^+_1)$ of the neutron-rich Mo isotopes. The theoretical results calculated with SLy4 and SLy5+T interactions are shown.

with beyond-mean-field calculations using SLy4 and SLy5+T interactions, for which the predicted ground-state shapes were oblate and prolate, respectively. The prolate shape was indicated because the calculation with the SLy5+T interaction reproduces both $B(E2)$ and the energies of the ground-state band.

The $2^+_2$ band in $^{110}$Mo was extended up to the $7^+$ state. The energy staggering of the $2^+_2$ bands in $^{106, 108, 110}$Mo are close to that of the axially symmetric rotor of the $\gamma$-vibrational state, rather than Davydov’s rigid-triaxial rotor model or Wilets-Jean model for $\gamma$-unstable nuclei. A candidate of the two-phonon $\gamma$ vibrational band with $K^\pi = 4^+$, which has not been well established yet, was found in $^{110}$Mo. The $K^\pi = 4^+$ band decays only to the $\gamma$-vibrational band, and the energy of the $K^\pi = 4^+$ state is 2.5 times larger than that of the $2^+_1$ state. Moreover, new $0^+_2$ states were assigned in $^{108}$Mo and $^{110}$Mo.

The spin and parity of parent nuclei were assigned from the log ft values to be 4$^-$ and 2$^-$ for the ground state in $^{106}$Nb and $^{108}$Nb, respectively. Two $\beta$-decaying states were identified in $^{110}$Nb, and their spin-parities were assigned as 2$^-$ and 6$^-$.

References
2) L. Wilets, M. Jean, Phys. Rev. 102, 788 (1956).