Nuclear structure studies through nuclear moment measurements on short-lived isomeric state with TDPAC technique

S. Go,[*1] G. Georgiev,[*2,*1] K. Stoychev,[*3] M. Niikura,[*1] H. Baba,[*1] D. L. Balabanski,[*4] S.R. Ban,[*4] D. Choudhury,[*4,*6] A. Coman,[*5] C. Costache,[*5] J. M. Daugas,[*7,*1] L. M. Fraile,[*8] N. Fukuda,[*1] Y. Fukuzawa,[*9,*1] G. Garcia De Lorenzo,[*8] Y. Ichikawa,[*10] Y. Ichinohe,[*1] N. Imai,[*11] D. Kalaydjieva,[*3] T. Kato,[*9,*1] N. Kitamura,[*11] A. Kusoglu,[*4] G. Li,[*12] Z. Liu,[*12] M. Matsuda,[*13] H. Matsufuji,[*10] R. Matsui,[*10] Y. Matsuo,[*9,*1] S. Michimasa,[*1] C. Mihai,[*5] R. Mizuno,[*14] M. Mochizuki,[*9,*1] S. Motomura,[*1] M. Mukai,[*15] H. Nishibata,[*11] A. Odahara,[*13] S. Ohno,[*9,*1] S. Pascu,[*5] S. Shimano,[*9,*1] K. Shimizu,[*16,*1] Y. Shimizu,[*1] M. Si,[*12] H. Suzuki,[*1] S. Takahashi,[*9,*1] A. Takamine,[*10] H. Takeda,[*1] Y. Togano,[*1] A. Turturica,[*5] G. Turturica,[*4] S. Ujeniuc,[*5] Y. Yamamoto,[*11] M. Yoshimoto,[*1] and H. Ueno[*1]

Nuclear magnetic dipole moments are sensitive observables for proton and neutron configurations in nuclei. The ^{132}Sn region is important to discuss the robustness of the double-shell closure of $Z = 50$ and $N = 82$. So far, the g factors of the $h_{11/2}$ states in the odd-mass Sn isotopes have been estimated to be quite constant in the close vicinity of the effective Schmidt limit values. These results are interpreted as very pure states in semi-magic nuclei. Under these circumstances, a recent measurement on ^{131}In ($Z = 49, N = 82$) indicated that the g factor is different from the entire chain of indium ground-state g factors. The value is near the free-nucleon Schmidt limit[1)], though its uncertainty is large.

To understand the anomaly of g-factor in ^{131}In, systematic study of the nuclear magnetic moments in this mass region is quite important. An isomeric state of the 6^+ (20 ns) isomer in ^{132}Sn is a candidate to estimate the purity of the nuclear wave function. Since the state is expected to have a single-particle structure very similar to one of the 8^+ isomer with the only difference being the spin-coupling between the $h_{11/2}$ neutron hole and the $f_{7/2}$ neutron particle, the measurement is expected to provide a stringent test to theoretical models.

Time Dependent Perturbed Angular Correlations (TDPAC) method has been applied on nuclear moment studies of states with half lives down to few nanoseconds. The method does not require initial spin orientation for the measurement and provides access to isomers lying below long-lived isomers, that are practically inaccessible by Time Differential Perturbed Angular Distribution (TDPAD) method in fragmentation facilities. The spin-oriented ensemble is obtained from the γ-γ correlations between the transition populating the state of interest and the one depopulating it. In spite of the effectiveness of the method, the application has been limited around nuclei near the stability line.

The NP2212-RIBF225 experiment was conducted in December 2024. It was the first attempt to apply the TDPAC method to neutron-rich nuclei at RIBF. A secondary beam of ^{132}Sn was produced following the fission of 345-MeV/u ^{238}U beam on a ^{9}Be target, separated with the BigRIPS separator, and provided to the experimental setup at the F12 focus position downstream. A purity of about 88% was achieved for the secondary beam of ^{132}Sn.

The secondary beam of ^{132}Sn was implanted in a ferromagnetic Fe host (immersed in an external polarizing magnetic field), which provided field strength suitable for the measurement. Two Ge planar and two $LaBr_3$ detectors were used. The detectors were placed at an angle of 90° with respect to each other at a distance of 70 mm from the host.

The online analysis indicated the presence of expected oscillation pattern in the ratio function $R(t)$. It is constructed using the γ-ray coincidence intensities $I(t)$ between the γ-ray populating the isomeric state (detected e.g. in detector 1) with depopulating the isomer (detected e.g. in detectors 2 and 3) where the last two detectors are positioned at angle of 90° with respect to each other

$$R(t) = \frac{I_{12}(t) - \epsilon I_{13}(t)}{I_{12}(t) + \epsilon I_{13}(t)} = \frac{3A_{22}}{4 + A_{22}} \cos 2(\omega_L t), \quad (1)$$

where ϵ is relative detection efficiencies between different γ-ray detectors, $\omega_L = -g\mu_N B/\hbar$ is the Larmor frequency and A_{22} is the angular correlation coefficient. The detailed data analysis to extract the g-factor of the 6^+ state in ^{132}Sn is in progress.

*1 RIKEN Nishina Center
*2 Université Paris-Saclay, IJCLab, CNRS/IN2P3
*3 Department of Physics, University of Guelph
*4 Extreme Light Infrastructure-Nuclear Physics (ELI-NP)
*5 Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)
*6 Department of Physics, Indian Institute of Technology Ropar
*7 Institut Laue-Langevin
*8 Grupo de Física Nuclear, Universidad Complutense de Madrid
*9 Department of Advanced Sciences, Hosei University
*10 Department of Physics, Kyushu University
*11 Center for Nuclear Study, University of Tokyo
*12 Institute of Modern Physics, Chinese Academy of Sciences
*13 Department of Physics, Osaka University
*14 Department of Physics, University of Tokyo
*15 Wako Nuclear Science Center (WNSC), IPNS, KEK
*16 Department of Physics, Meiji University

References
1) A. Vernon *et al.*, Nature **607**, 260 (2022).

DOI:10.34448/RIKEN.APR.58-117