Various nuclear structures in ^{140}Xe studied by β decay of ground and isomeric states in ^{140}I†

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Nuclear-shape transition with the increase of neutron and/or proton numbers is one of the most important subjects to disentangle competition between single-particle and collective structures in the finite quantum many-body system. The neutron-rich $N = 86$ isotope ^{140}Xe, located northeast of a doubly-magic nucleus ^{132}Sn, was investigated by β-γ spectroscopy, as one of experiments in the Euroball RIKEN Cluster Array (EURICA) project.[1,2)]

Neutron-rich Sb, Te, I, Xe, and Cs isotopes with $A \sim 140$ were produced by in-flight fission of a 345-MeV/nucleon ^{238}U beam with an average intensity of 5 particle nA. These isotopes were transported based on in-flight separation technique by using BigRIPS separator and ZeroDegree spectrometer[3)] up to the last focal plane (F11) with setting magnetic rigidity ($B\rho$) for ^{142}Te^{52+}. The isotopes were implanted into a position sensitive active stopper, Wide-range Active Silicon Strip Stopper Array for Beta and Ion detection (WAS3ABi), which consists of five double-sided Si strip detectors (DSSSDs). In addition, the WAS3ABi was used as a β counter. Parent β-decaying nuclei were identified by position correlation of the implanted fragments with information of particle identification (PI) and the detected β rays in WAS3ABi. Gamma rays emitted after the β decay were detected by a γ-ray detector array, EURICA, which consists of twelve cluster-type high-purity Ge detectors with seven crystals. To study the β decay of ^{140}I in this work, two data sets with PI of hydrogen-like ^{140}I^{52+} and fully stripped ^{140}Te^{52+} were analyzed. Namely, the parent nucleus ^{140}I was produced by two different reactions of (i) direct in-flight fission at primary target and (ii) β decay of ^{140}Te inside WAS3ABi. Relative intensity of γ ray was obtained by using γ-ray photo-peak efficiency, which was simulated using the Geant4 code for the EURICA Ge array with distribution of the ^{140}I and ^{140}Te particles on five DSSSD detectors in WAS3ABi.

Two β-decay isomers in ^{140}I are newly found in the study of two different β decays of ^{140}I (^{140}I $\rightarrow$ ^{140}Xe) and ^{140}Te (^{140}Te $\rightarrow$ ^{140}I $\rightarrow$ ^{140}Xe). Half-lives of the β decays of the ground state (g.s.), low-spin isomer (LSI), and high-spin isomer (HSI) are determined to be 0.38(2), 0.91(5), and 0.47(4) sec, respectively, by the analysis of time-difference (implanted particle and β-decay event) spectra gated by the γ rays in ^{140}Xe. Decay schemes of the β decay of the HSI and of the mixed β decays of the g.s. and the LSI in ^{140}I to ^{140}Xe are constructed using the information on γ-ray coincidence relation and γ-ray intensity.

Nuclear structures of the low-lying states in ^{140}Xe are compared between the experimental results and two theoretical calculations based on the large-scale shell model and the deformed Skyrme Hartree-Fock-Bogoliubov (HFB) plus deformed quasiparticle-random-phase approximation (QRPA), as shown in Fig. 1. Low-lying states can be classified into (a) g.s. band, (b) (quasi-)γ-band, and (c) octupole collective states. Possible candidates for the (quasi-)γ-band members of 2^+ and 4^+ and the octupole collective 1^- state are proposed in ^{140}Xe. This work demonstrates that in the low-lying states of ^{140}Xe, coexistence of nuclear structures, such as vibrational nature with prolate collectivity, large-γ collectivity (γ softness), and octupole-vibrational nature, could appear due to four valence protons and four valence neutrons being coupled to the doubly-magic nucleus ^{132}Sn.

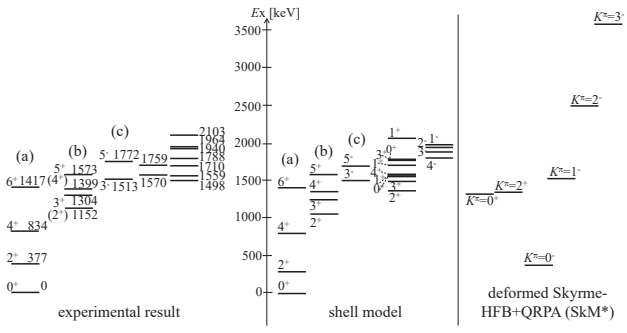

Fig. 1. Experimental low-lying states are compared to those calculated in the shell model and the deformed Skyrme-HFB + QRPA (SkM*).

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