Electric dipole responses of ^{50}Ca and ^{52}Ca

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The electric dipole (E1) strength distributions in ^{50}Ca and ^{52}Ca were measured using relativistic Coulomb excitation.

The equation of state (EOS) of neutron-rich matter is important to understand the properties of neutron-rich nuclei and astrophysical events, such as supernovae and neutron-star mergers. The constraint on the density dependence of the symmetry energy, the isospin-asymmetric part of EOS, is important to evaluate the EOS of neutron-rich matter, while it is not well constrained experimentally.

Recent theoretical work showed that the pygmy dipole resonance (PDR) and the dipole polarizability α_D of nucleus is well correlated to the density dependence of the symmetry energy close to saturation density.[1)] PDR is the low-energy E1 mode located at the excitation energies of about 6 to 10 MeV. It is indicated that the PDR strength of Ca isotopes rapidly increases from ^{48}Ca to ^{54}Ca, and the strength in these nuclei is well correlated with the density dependence of the symmetry energy.[2)] The dipole polarizability α_D corresponds to the inversely energy weighted sum of E1 strength distribution, and it is pointed out as a less model-dependent observable for the extraction of the symmetry energy parameters.[3)] Given that the PDR of neutron-rich Ca isotopes and α_D are correlated to the density dependence of the symmetry energy, the Coulomb excitation of ^{50}Ca and ^{52}Ca was performed to measure their E1 responses.

The experiment was performed using the SAMURAI spectrometer[4)] at RIBF. The secondary beams of ^{50}Ca and ^{52}Ca were produced via fragmentation of a 345 MeV/nucleon ^{70}Zn beam on a 10-mm thick Be target. The ^{50}Ca and ^{52}Ca beams were separated using the BigRIPS with an Al degrader with a thickness of 5 mm placed at the focal plane F1. For the ^{50}Ca beam, an additional 1-mm thick Al degrader was placed at the focal plane F5 to increase the purity of ^{50}Ca. At the focal planes F3, F5 and F7, 1-mm-thick plastic scintillators are installed. The ^{50}Ca and ^{52}Ca beams were impinged on Pb and C secondary targets. The typical ^{50}Ca and ^{52}Ca intensities were 14 and 1 kHz, respectively.

The ^{50}Ca and ^{52}Ca beams were monitored event-by-event using two 0.2-mm thick plastic scintillators (SBTs), an ionization chamber (ICB), and two drift chambers (BDC1 and BDC2) placed at the upstream of the secondary target. The γ-ray detector CATANA [5)] and 8 large-volume $LaBr_3$ detectors were placed to surround the secondary target to measure the de-excitation γ-rays from the reaction residues. The outgoing charged particles were characterized using the detectors located at the entrance and exit of the SAMURAI magnet with 2.7T at the center. Two drift chambers (FDC1 and FDC2) and a plastic scintillator wall (HODF24) were used to identify the charged particles and reconstruct their momenta. The outgoing neutrons were detected by the combination of the NeuLAND demonstrator[6)] and NEBULA.

The data analysis is now in progress.

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References

1) J. Piekarewicz, Phys. Rev. C **83**, 034319 (2011).
2) T. Inakura *et al.*, Phys. Rev. C **84**, 921302(R) (2011).
3) P.-G. Reinhard *et al.*, Phys. Rev. C **81**, 051303 (2010).
4) T. Kobayashi *et al.*, Nucl. Instrum. Methods in Phys. Res. Sect. B **317**, 294 (2013).
5) Y. Togano *et al.*, RIKEN Accel. Prog. Rep. **48**, 207 (2015).
6) NeuLAND Technical Design Report, `https://edms.cern.ch/document/1865739`