Structure of Neutron-rich Calcium Isotopes and Roles of Three-body Interaction

Toshio Suzuki[1], Takaharu Otsuka[2,3]
[1] Department of Physics, Nihon University, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan.
[2] Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.
[3] Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, and RIKEN, Hirosawa, Wako-shi, Saitama 351-0198, Japan.

Structure of neutron-rich calcium isotopes are studied by shell model calculations with the use of microscopic two-body and three-body interactions. Microscopic G-matrix elements with core polarization effects [1] are used for the two-nucleon interaction. The Fujita-Miyazawa force [2] induced by Δ-isobar-hole excitations is included as the dominant part of the three-nucleon interaction. We found the following important roles of the three-body force on the structure of exotic nuclei. The three-body interaction can solve several serious problems in nuclear structure inherent in the microscopic two-body interactions.

The three-body force induces repulsive contributions to the monopole terms of the valence neutron-neutron interaction. The need for the repulsive components in the isospin T=1 monopole terms in phenomenological interactions such as GXPF1 [3] in the pf-shell can be naturally explained.

Ground state energies of the isotopes, which have deviations from the experimental values near drip-lines only with the two-body interaction, are found to be well reproduced up to the observed ones when the three-body interaction is included. This is quite similar to the case of oxygen isotopes, where the three-body interaction is found to be important to explain why the drip-line of oxygen isotopes is ^{24}O and the isotopes with neutron number N≥17 do not exist [4].

Besides the monopoles, we further investigate the effects of the contributions of the three-body force to the multipole terms of the valence two-nucleon matrix elements. We discuss the effects on the energy levels of the Ca isotopes as well as the O isotopes. We discuss also the excitation energies of the 2_1^+ states in Ca isotopes, and show that those in ^{48}Ca and ^{54}Ca are enhanced with the inclusion of the three-body interaction. The three-body force thus plays a key role for the magicity of ^{48}Ca and ^{54}Ca. Similar results are obtained with the use of microscopic V_{lowk} two-nucleon interaction and chiral 3N nucleon interaction [5].

The magnetic dipole (M1) strength in ^{48}Ca is fragmented in case with the microscopic two-body interaction only. The strength is found to be concentrated and pushed up to higher excitation energy when the three-body interarction is included. An important role of the multipole components is pointed out for the concentration of the strength. The single-particle structure of ^{48}Ca is reproduced with the inclusion of the three-body interaction.

We will also show that the three-body interaction improves the agreement of the calculated ground state energies of helium isotopes with the observation.

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