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Exotic Neutron-rich Medium-mass Nuclei with Realistic Nuclear Force

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The nuclear shell model provides a successful and unified description of both stable and unstable nuclei. Especially for the unstable nuclei, experimental information is less abundant than for stable ones, theoretical challenges play an ever increasing role.
In this work, we will first report on the physics in so-called "island of inversion" with the model space of the sd+pf shell, and then move to the description of the shell structure of N=28,32,34 and 40 with the model space of pf+sdg shell.
In both cases, it is crucial that the newly developed extended Kuo-Krenciglowa (EKK) theory of effective nucleon-nucleon interaction enables us to derive an interaction suitable for several major shells (sd + pf or pf + sdg in this case), unlike conventional Kuo-Krenciglowa (KK) theory.
In the first half of this talk, we will present such an application to the island of inversion, including the cases where conventional approaches with fitted interactions encounter difficulties. By using such an effective interaction obtained from the Entem-Machleidt QCD-based χN3LO interaction and the Fujita-Miyazawa three-body force, the energies, E2 properties, and spectroscopic factors of low-lying states of neutron-rich Ne, Mg, and Si isotopes are nicely described, as the first shell-model description of the "island of inversion" without fit of the interaction. The long-standing question as to how particle-hole excitations occur across the sd-pf magic gap is clarified with distinct differences from the conventional approaches. The shell evolution is shown to appear similarly to earlier studies.
In the second half, we need to incorporate the effective interaction for pf + sdg shell at least, to describe N=28,32,34 and 40 magic numbers in a unified manner. Starting from a fundamental nuclear force has a great advantage in this case, because too few experimental data are available to fit two-body matrix elements in such a large model space. We will present results of a large-scale calculation on Ca, Ti, Cr, Fe and Ni isotopes with a wide range of neutron number.

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