Joint project for large-scale nuclear structure calculations

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A joint project for large-scale nuclear structure calculations has been under way since the year 2001, based on a collaboration agreement between RIKEN Nishina Center and Center for Nuclear Study, the University of Tokyo. We maintain PC servers, one of which has 1TB main memory and is suitable for large-scale nuclear shell-model calculations. In this project, we performed various shell-model calculations of the nuclides that had been measured at the RIKEN RI Beam Factory, such as ^{54}Ca, ^{34}Na, ^{35}Na, ^{37}Mg, ^{50}Ar, and ^{55}Sc, under collaborations with many experimentalists.[1,2] Since these collaborations are presented in other reports, we here introduce two theoretical achievements of this project in 2013: The extended Kuo-Krenciglowa method and the shell-model analysis of Cr isotopes.

Until recently, most shell-model calculations were confined to a single oscillator shell like the sd shell or the pf shell. However, recent interest in nuclei away from the stability line requires larger shell-model spaces. Because the derivation of microscopic effective interactions has been limited to degenerate model spaces, there are both conceptual and practical limits to shell-model calculations that utilize those interactions. We develop a method to calculate effective interactions for a nondegenerate model space, based on the extended Kuo-Krenciglowa method, which is a natural extension of the conventional Kuo-Krenciglowa method.[3,4] We calculated effective interactions within (i) a single oscillator shell (a so-called degenerate model space) like the sd shell or the pf shell and (ii) two major shells (nondegenerate model space) like the $sdf7p3$ shell (sd shell, $0f_{7/2}$ and $1p_{3/2}$) or the $pfg9$ shell (pf shell and $0g_{9/2}$). We also calculated the energy levels of several nuclei that have two valence nucleons on top of an inert core. Our results show that the present method works excellently in shell-model spaces that comprise several oscillator shells as well as in a single oscillator shell. This work is published in 2014.[5]

The experimental observation in odd-mass neutron-rich Cr isotopes revealed that the excitation energy of $9/2^+_1$ state decreases considerably with increasing neutron number.[6] We performed shell-model calculations for these Cr isotopes with $pfg9d5$ model space, which consists of a full pf shell, $0g_{9/2}$, $1d_{5/2}$ orbits, with a certain truncation. We introduced a new Hamiltonian, which is composed of the GXPF1Br effective interaction[1] for the pf shell and $V_{\rm MU}$[7] for the rest of the model space. The shell-model result agrees adequately with experimental data, as shown in Fig.1. We also discussed the deformation from the potential energy surfaces by the Q-constrained Hartree-Fock calculation.[8]

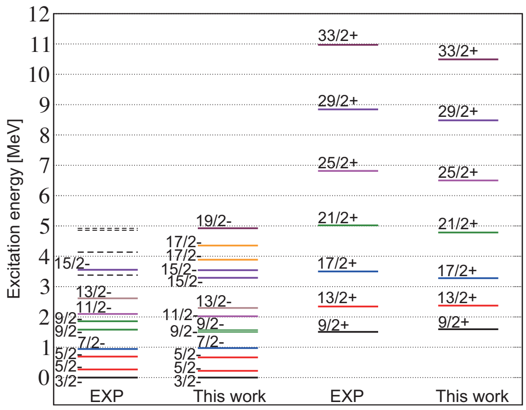

Fig. 1. The level scheme of ^{57}Cr. The columns labeled 'EXP' and 'This work' represent the experimental data and the results of the shell-model calculation, respectively. The dashed lines denote the unassigned spin states.

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