Tensor optimized shell model with unitary correlation operator using bare interaction for ^{4}He

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In the nuclear force, the tensor force plays an important role in the nuclear structure[1, 2]. In the nuclear wave function, it is known that the $2p2h$ excitation is important to produce the dominant part of the tensor correlation[1, 3]. In this study, we employ a shell model type prescription, in which the $2p2h$ configurations are introduced to describe the strong coupling between the $0p0h$ and $2p2h$ configurations by the tensor force. We further take into account the spatial shrinkage of the particle states variationally in order to include the high momentum component induced by the tensor force into the nuclear wave function[3, 4]. Extending the $2p2h$ states as much as possible, we successfully get the convergence of the energy and the large tensor force contribution. We call this method as the tensor-optimized shell model (TOSM), which can describe the strong tensor correlation in nuclei arising from the bare nuclear force.

When TOSM is applied to ^{4}He, the major $2p2h$ state is $(0p_{1/2})^2(0s_{1/2})^{-2}$ of a proton-neutron pair. This is a pionic excitation with the 0^- coupling in the particle-hole picture[5]. Furthermore, this $2p2h$ excitation causes the Pauli blocking in the ^{4}He+n system for the $p_{1/2}$ orbit of an extra neutron, which contributes to the p-wave doublet splitting of ^{5}He by about 30%[4]. The same phenomenon was also confirmed for Li isotope, in particular, the neutron halo formation in ^{11}Li. The coupling between the tensor correlation of the ^{9}Li core and the extra two neutrons emerges the Pauli blocking, which naturally increases the s^2 component and develops the neutron halo structure in ^{11}Li[6].

In addition to the tensor correlation, we further describe the short-range correlation arising from the short-range repulsive core in the bare nuclear force by the unitary correlation operator method (UCOM)[7]. In UCOM, the unitary operator is introduced in order to reduce the amplitude of the short distance region in the relative wave function of two-nucleon pair in nuclei. The form of the unitary operator is determined to minimize the energy of nuclei. We use TOSM as the basis states to describe the tensor correlation coming from the bare tensor force. We propose a new framework of TOSM combined with UCOM (TOSM+UCOM) for the nuclear structure study starting from the bare nuclear force. In Fig. 1, we show the results of the TOSM+UCOM for ^{4}He using the AV8' bare interaction[8]. Increasing the maximum orbital angular momentum ($L_{\rm max}$) of the particle states, we get the convergence with a good binding energy reproduction of ^{4}He. The contributions of the central and tensor forces are about -55 and -52 in MeV, respectively.

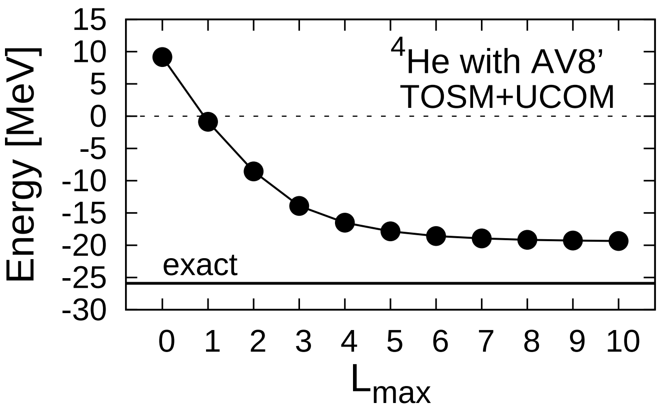

Figure 1: Energy of ^{4}He in TOSM+UCOM. Exact calculation is taken from Ref. 2.

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