Shell and α cluster structures in ^{8}Be with tensor-optimized shell model

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We study the shell and α cluster structures of ^{8}Be in terms of the tensor-optimized shell model (TOSM) using a bare nucleon-nucleon interaction, AV8$'$. In TOSM, the tensor correlation is optimized in the full space of the 2p2h configurations involving the high momentum components [1]. The short-range correlation is treated in the UCOM. Using TOSM+UCOM, we investigate the role of the tensor force in ^{8}Be. Experimentally, the ^{8}Be nucleus shows two kinds of interesting aspects of the α clustering in the yrast band states and the highly excited states coexisting the T=0 and T=1 states, in which the α decay process is not necessarily favored.

We give the TOSM wave function Ψ as

$$\Psi = \sum_{k_0} A_{k_0}|0\mathrm{p}0\mathrm{h};k_0\rangle + \sum_{k_1} A_{k_1}|1\mathrm{p}1\mathrm{h};k_1\rangle + \sum_{k_2} A_{k_2}|2\mathrm{p}2\mathrm{h};\mathrm{k}_2\rangle, \quad (1)$$

where all the amplitudes $\{A_{k_0}, A_{k_1}, A_{k_2}\}$ are variational coefficients. The 2p2h states play an important role on the description of the strong tensor correlation, The hole states are described by harmonic oscillator basis states, and for particle states, we employ the Gaussian expansion method to describe the single-particle basis states including high momentum components[2].

The results of ^{8}Be in TOSM are shown in Fig. 1. We normalize the energy spectrum to the $2^+(T{=}1)$ state in the highly excited states, because this state is the isobaric analog state of ^{8}Li and TOSM has sufficiently described the structures of Li isotopes [3]. It is found that TOSM reproduces fairly well the excitation energy spectrum of ^{8}Be, except for the energy spacing between the yrast three states (0^+, 2^+ and 4^+) and the highly excited states. The resulting small energy spacing is related to the lack of the α clustering component in the yrast states in TOSM. In fact, the ^{8}Be ground state possesses almost twice of the ^{4}He values for kinetic energies and the central contributions, which can be the signature of two-α clustering of ^{8}Be.

In the highly excited states, the calculated spectrum in TOSM reproduces the experimental level order and the relative energies of each level for both T=0 and T=1 states. This result indicates that the highly excited states of ^{8}Be are regarded as the shell-like states and TOSM can treat these states. It is also found that the tensor contributions in the T=0 states are stronger than the T=1 states, which is consistent to the state dependence of the tensor force.

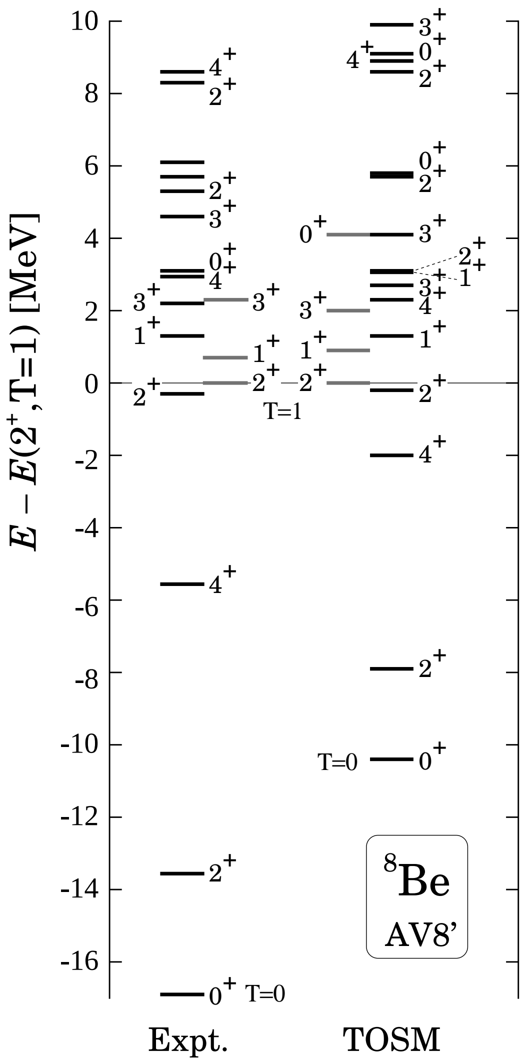

Figure 1: Energy spectrum of ^{8}Be using TOSM, normalized to the $2^+(T{=}1)$ state.

References

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