Coexistence of particle-hole and cluster structure in light nuclei

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The competition of particle-hole and cluster excitation is an important ingredient for describing light nuclei. For example, the mysterious 0_2^+ state in ^{16}O has been a long-standing problem. In contrast to the shell model like the ground state (0_1^+), the ^{16}O has ^{12}C+α cluster structure according to the cluster model calculation [1]. The different aspects of nuclear excitations coexist in low-lying spectrum. Both excitations are usually described in different models, so a unified description is desired for deeply understanding the coexisting structure in light nuclei.

In this contribution, we will show some examples addressing this problem in a single scheme. A realistic force is used as an interaction between nucleons. We use the correlated Gaussian with double global vectors that enables us to obtain a precise solution of many-body equation with a realistic force [2]. The topics are the following:

- The excitation spectrum of ^{4}He [3].
- Towards a unified description of the low-lying states in ^{16}O.

According to the shell model, negative parity states should appear first in the excited spectrum of ^{4}He, but 0^+, like ^{16}O. The state (0_2^+) has been interpreted as a cluster structure of $3N+N$ (^{3}H+p and ^{3}He+n) with a relative S wave [4]. Two questions arise from this interpretation. One is the possibility of four states with different $J^\pi T$=0^+0, 0^+1, 1^+0, 1^+1, which all have the same $3N+N$ structure. But these are not observed except for the 0_2^+ state. The second one is a negative parity partner in which the $3N$ and N clusters move in a relative P wave.

To clarify these questions, we apply a four-body calculation which does not impose any model assumption on the ^{4}He structure. All the levels below $E_{\rm x}$=26 MeV are reproduced fairly well using a realistic potential. The calculation of spectroscopic amplitudes and spin-dipole transition strengths demonstrates that the 0_2^+ state and the low-lying negative parity states with 0^- and 2^- are inversion doublet partners that have $3N+N$ cluster configurations. We explain why only the 0_2^+ state is actually observed.

A ^{12}C+p+p+n+n five-body model of ^{16}O could describe the coexistence of particle-hole and cluster configuration in both the ground and excited 0^+ states in the same sense. We have analyzed the motion of the four valence nucleons carefully, so the next step is to determine an N-^{12}C potential which includes the effect of the excitation of ^{12}C. We will present our progress on these related subjects and discuss the feasibility of a five-body calculation including the core excitation and the N-^{12}C Pauli effect.

References

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