Molecular Structures of ^{12}Be studied with Antisymmetrized Molecular Dynamics

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We study structure of the excited states of ^{12}Be with variational calculations after spin-parity projection (VAP) in the framework of Antisymmetrized Molecular Dynamics (called as AMD) [1, 2, 3, 4]. The theoretical results reproduce the β transition strength from $^{12}\mathrm{Be}(0_1^+)$ to $^{12}\mathrm{B}(1^+)$ and the level spacing between 0_1^+ and 2_1^+. It is surprising that the ground state of ^{12}Be has a molecule-like structure with the large deformation. It means that the neutron magic number $N = 8$ may vanish in ^{12}Be and the ground state is a $2p-2h$ state of the neutron p-shell.

With the help of the recent progress of experimental techniques, informations of unstable nuclei for the excited states are increasing rapidly. Molecular structures are suggested to appear in low-lying states of the light unstable nuclei, which is one of the hot subject in the study of the unstable nuclei. The systematic study of excited states as well as ground states of the unstable nuclei is expected to be performed.

For this aim, we adopt the framework of Antisymmetrized Molecular Dynamics(AMD) [1, 2, 3, 4] which has been already proved to be very useful to make systematic studies of the structure of the ground states and also the excited states of the general light unstable nuclei.

As for the formulation of VAP calculations in AMD, the reader is referred to the papers [3, 4]. The adopted parameters for the effective interactions, MV1 (case 3)+ G3RS + Coulomb are $m = 0.65$, $b = h = 0$ and $u_I = -u_{II} = 3700$ MeV which are chosen so as to reproduce the parity inversion of the ground state of ^{11}Be.

The excitation energies of the levels of ^{12}Be are shown in Fig.1. The theoretical results predict that many levels may exist in the low energy region. By analyzing the intrinsic structures, the excited levels are found to form rotational bands such as $K^\pi = 0_1^+, 0_2^+, 1^-$. In the $K^\pi = 0_1^+$ band which starts the ground state, we found the large deformation due to the developed $2\alpha + 2n$ clustering structure. The valence two neutrons are in the molecular orbit surrounding 2α with positive parity which is analogous to σ orbits in terms of the molecule. Similarly, in the 1^- state one valence neutron surrounding 2α is in the σ orbit. These states with neutrons in the σ orbit have the developed clustering structure because the σ orbit gains its kinetic energy with the development of clustering structure. From the other view point of the shell model, the ground state is considered to be a $2p-2h$ state of the neutron p-shell because σ orbit corresponds to a sd orbit, while the second 0+ is the more spherical state with the neutron closed shell. It means that the neutron magic number $N = 8$ vanishes in ^{12}Be. One of the experimental evidence for the structure of ground states is the strength of β transition to $^{12}\mathrm{B}(1^+)$. The observed strength is much smaller than expected by an assumption of the normal state with the closed neutron p-shell. According to our results, the small strength of β transition to $^{12}\mathrm{B}(1^+)$ is well reproduced by the largely deformed ground state with the $2p-2h$ configuration.

In the calculated results the third $K = 0^+$ band appears in not so high energy region.

The intrinsic structure of this band has the developed clustering structure like ^{6}He+^{6}He. In terms of molecule-like structure, it is considered to be another $2p-2h$ state with two neutrons in the *sd* orbit different from the σ orbit. The moment of inertia of 0^+_3 is larger than the first $K = 0^+$ band. The spin $J = 4^+$ and 6^+ states in the third 0^+ band appear in the energy region above 10 MeV. They are considered to correspond to the recently observed levels [5].

References

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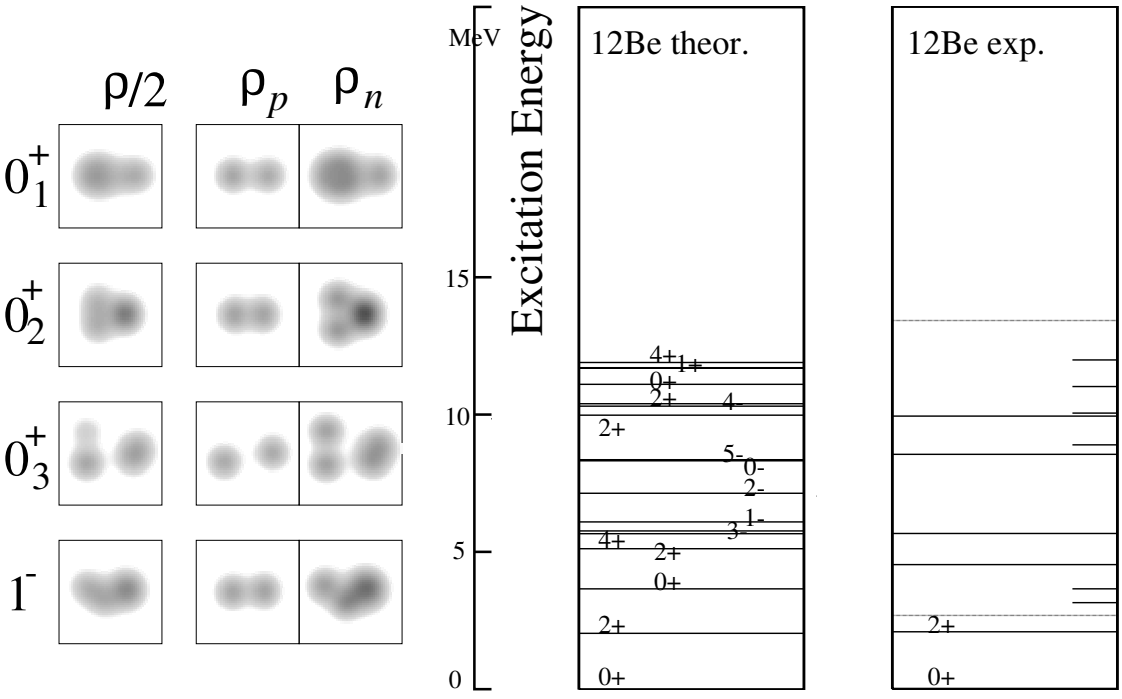

Figure 1: Excitation energies of the levels of ^{12}Be. The theoretical results obtained by VAP calculations in the framework of AMD (in the right) are compared with the experimental data(in the left) from Nuclear Data Table. Density distributions of protons(neutrons) of the intrinsic states are also displayed in the middle(right) column.