STRUCTURE OF ${}^{12}_{\Lambda}$C HYPERNUCLEUS IN ANTISYMMETRIZED MOLECULAR DYNAMICS

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We investigate the structure of light p-shell hypernuclei using Antisymmetrized Molecular Dynamics with double parity projection, in which the core and total parities are projected. Double parity projection effectively reduces the excitation energy of states which couple to p_Λ. There might be low-lying core excited positive parity states below the simple p_Λ state in ${}^{12}_{\Lambda}$C as a result of the parity-mixing intershell coupling.

1 Introduction

Recent developments of hypernuclear spectroscopy provides us with with precious information to understand the excitation mechanism and YN interaction in more detail. For example, recent γ-ray spectroscopy with Ge detectors has revealed hypernuclear fine structures, spin-dependent ΛN interactions, and hypernuclear shrinking effects.[1] Also in ^{12}C$(\pi^+, K^+){}^{12}_{\Lambda}$C reaction, several core excited states are found in a recent high-resolution experiment,[2] in addition to the two well-known prominent peaks which correspond to single particle levels of Λ (s_Λ and p_Λ).[3,4,5]

These observations clearly suggest the importance of new roles of Λ; Λ makes the core polarize or shrink. Among these roles, Motoba proposed an interesting idea of parity-mixing intershell coupling.[6] For ${}^{12}_{\Lambda}$C, the Λ single particle excitation energy to the p_Λ is around 10 MeV, while in ^{11}C core positive parity states appear at around 6 MeV and above. Thus the former can couple to the latter. The mixing of different parity states of the ^{11}C core suggests the existence of reflection asymmetric states in a spin-isospin unsaturated system.

Although there are many theoretical works on hypernuclei with cluster models in 1980's,[7,8] there are only a few studies on ${}^{12}_{\Lambda}$C nucleus, which is the most extensively studied hypernuclei experimentally. One of the reason is that there is a technical problem in treating four-body ($\alpha\alpha{}^3$HeΛ) systems.

In this work, we study light p-shell hypernuclear structure in Antisymmetrized Molecular Dynamics (AMD). The purposes of this work are two-fold. One of them is to investigate how the Λ particle polarizes the core nucleus. Another one is to estimate the effects of parity mixing intershell coupling.

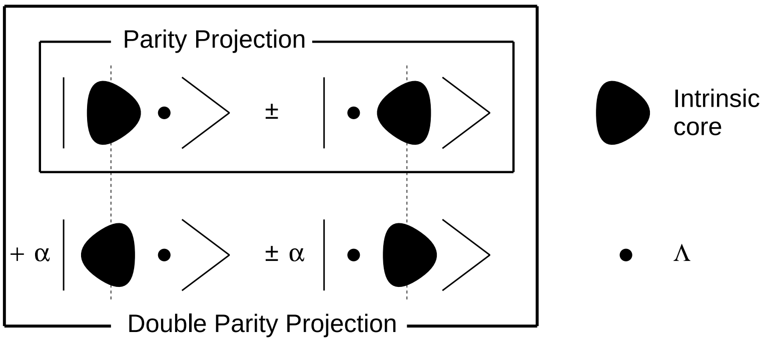

Figure 1. Double parity projection of total system and core. Core reflected states are shown.

2 AMD with Double Parity Projection

AMD has been successfully applied to nuclear structure and reaction studies,[9,10] including those related to unstable nuclei. In AMD, each baryon single particle wave function is expressed by a Gaussian wave packet, and complex centroid parameters of Gaussian can move in phase space to minimize energy or action. Then there is no model assumption on the shape and clustering. In actual calculations, first the intrinsic state of the total system is prepared with the frictional cooling method starting from a random initial condition. Then, we project this intrinsic state into J^π fixed states.

One of the superior points of AMD is that it is easy to perform variation after parity projection of the total system. In hypernuclear study, parities of hyperon single particle states are also important and should be projected. Therefore, we have performed Double Parity Projection (DPP) of the total system and core both in the cooling and projection processes by superposing core reflected states as shown in Fig. 1. As a result of DPP, hyperon single particle states are made to have a good parity, and it becomes possible to discuss intershell coupling by analyzing amplitudes of these core reflected states.

We use Volkov No.1 and G3RS LS interaction for NN, and one range Gaussian for YN interaction. We adjust the LS strength in NN interaction to fit low-lying levels of core nuclei, and YN interaction strength to reproduce Λ separation energies of hypernuclei. In this work, we have ignored spin-dependent YN interactions, and a common width parameter is adopted in nucleons and Λ.

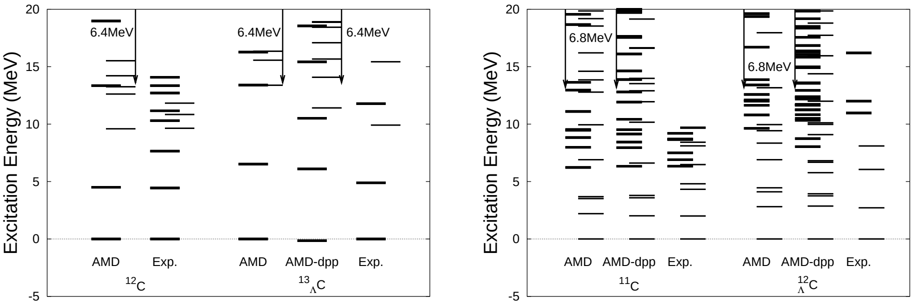

Figure 2. Calculated energy levels of ${}^{13}_{\Lambda}$C (Left) and ${}^{12}_{\Lambda}$C (Right) in comparison with data. Thick and thin lines show positive and negative parity states, respectively.

3 Results

Figure 2 shows excitation spectra of ${}^{13}_{\Lambda}$C and ${}^{12}_{\Lambda}$C. There are several levels such as 3^-_1 in ^{12}C, which is a well-developed α-cluster state and requires superposition of several AMD states (GCM). Therefore, we display downwards shifted levels by 6.4 (6.8) MeV in calculated negative (positive) parity states in ${}^{13}_{\Lambda}$C (${}^{12}_{\Lambda}$C), as well as in the core nucleus ^{12}C (^{11}C).

There is a clear difference of DPP effects in normal and hypernuclei. For ^{11}C, in which ^{10}C is regarded as a core, we cannot find meaningful difference in AMD with and without DPP. This may be because the valence neutron wave function would have a good parity already in AMD due to the antisymmetrization with other neutrons. This observation supports that core-particle assumption in AMD is not necessary in normal nuclei. On the other hand, DPP significantly changes the spectra of hypernuclei. In the case of ${}^{13}_{\Lambda}$C (${}^{12}_{\Lambda}$C), negative (positive) parity states, to which the p_Λ state couples, get down more strongly by including core reflected states. As a result, in a present calculation, there appear low-lying positive parity states below the experimentally observed p_Λ state. Although core excitation to positive parity and Λ single particle excitation are necessarily mixed up in the intrinsic state without DPP, we can separate them into two different basis states with DPP.

The above situation can be seen in the density distribution as shown in Fig. 3. Figure 3 shows density distribution in ^{11}C and ${}^{12}_{\Lambda}$C intrinsic states. In DPP with $(\pi, \pi_c) = (+1, -1)$ (right-upper panel), the core nucleus is slightly expanded by p-state Λ, but it is less excited than in the case without DPP (right-lower).

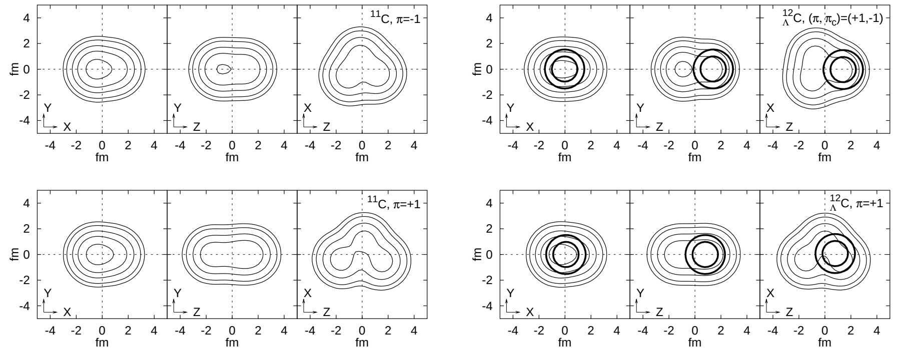

Figure 3. Intrinsic density contour of ^{11}C (left) and $^{12}_{\Lambda}$C (right). Thin and thick lines show density of nucleons and Λ, respectively. Density before parity projection is shown, then the hyperon density is spherical (Gaussian). For ^{11}C, density of cooled states projected to negative (upper) and positive (lower) parities are shown. For $^{12}_{\Lambda}$C, density of cooled states with parity (lower) and with double parity (upper) projection are shown.

4 Summary

In this work, we have included core reflected states in AMD in order to take account of hyperon single particle wave function having a good parity, and to discuss parity mixing intershell coupling. In $^{12}_{\Lambda}$C, core reflected states affects positive parity states more strongly. For the discussion of the intershell coupling, more detailed analyses of amplitudes would be necessary.

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