Role of Space-Exchange Correlation in Light Hypernuclei.

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1. Introduction.

Strangeness degree of freedom when trapped in a bound nuclear system induces new symmetries to the system replacing older ones. A hyperon injected to a bound nuclear system may induce a change in nuclear structure such as shape, size, density profile, halo/skin structure and nuclear core polarization etc. Study of few-body systems including strangeness degree of freedom is important not only to explore the exotic nuclear structure but also to clarify the characteristic features of hyperon-nucleon interactions. A hyperon which is not Pauli blocked can reside deep inside a nucleus and act as a probe to explore low lying states which is otherwise very difficult. In this paper, we have presented the variational Monte Carlo(VMC) study of ${}^{4}_{\Lambda}$He with Space-Exchange Correlation(SEC). The aim of this work is to test the sensitivity of the SEC on the binding energy(BE) as well as on the density distributions and compare with those available in the literature. SEC is found to be affecting every physical observable significantly. The results provide significant information about the role of SEC in hypernuclear studies.

2. Formalism

The Λ-separation energy of a hypernucleus can be calculated as

$$B_\Lambda = \frac{\langle \Psi_{NC} | H_{NC} | \Psi_{NC} \rangle}{\langle \Psi_{NC} | \Psi_{NC} \rangle} - \frac{\langle \Psi | H | \Psi \rangle}{\langle \Psi | \Psi \rangle}, \quad (1)$$

where Ψ and H represents the ground state Wave function (WF) and Hamiltonian of hypernucleus.

Then phenomenological non-relativistic Hamiltonian of a hypernucleus can be written as a sum of the Hamiltonian due to the non-strange nuclear core(NC) and the Hamiltonian due to Λ hyperon,

$$H = H_{NC} + H_\Lambda \quad (2)$$

The basic ingredients in these Hamiltonian are two-and three-body NN and YN potentials. For S=0 sector, we employed AV18 and for NNN potential we used Urbana type UIX three-body potential [1]. Details of charge symmetric ΛN and three-body ΛNN potential can be found in Ref. [2]. The variational WF of a single-Λ hypernucleus with a single-Λ baryon and $A-1$ nucleons with all dynamical correlations may be written as in Ref. [3].

$$| \Psi \rangle = \left[1 + U^3 + \sum_{i<j}^{A-1} U_{ij}^{LS} \right] \left[\prod_{j=1}^{A-1} (1 + u_{\Lambda j}^{\sigma}) \right] \left[\prod_{i<j}^{A-1} (1 + U_{ij}) \right] \Psi_J + \eta \sum_{n=1}^{A-1} [1 + U^3] \left[S \prod_{i<j}^{A-1} (1 + U_{ij}) \right] u_{\Lambda n}^{x} P_x \Psi_J, \quad (3)$$

where, S is symmetrization operator and η is a variational parameter. A detailed description of the WF can be found in Ref. [3, 4].

3. Results and Discussions.

VMC study of ${}^{4}_{\Lambda}$He hypernucleus was performed using NN, ΛN, NNN and ΛNN potentials for both choices of WF i.e. with and without SEC. For spin-averaged strength $\bar{v}$, we use three different sets of v_s and v_t which gives $\bar{v}$=6.15, 6.10 and 6.05 MeV at an interval of 0.05 MeV along with a constant value

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TABLE I: BE of ${}^{4}_{\Lambda}$He hypernucleus for both choices of WF i.e SEC and No SEC. Except ε, all quantities are in units of MeV.

	SEC	No SEC	A-B
		ε=0.1	
$\bar{v} = 6.15$	2.39(2)	1.91(2)	0.48(3)
$\bar{v} = 6.10$	2.39(2)	1.88(2)	0.51(3)
$\bar{v} = 6.05$	2.39(2)	1.80(2)	0.59(3)
		ε=0.2	
$\bar{v} = 6.15$	2.39(2)	1.87(2)	0.52(3)
$\bar{v} = 6.10$	2.38(2)	1.83(2)	0.55(3)
$\bar{v} = 6.05$	2.38(2)	1.76(2)	0.62(3)
		ε=0.3	
$\bar{v} = 6.15$	2.39(2)	1.87(2)	0.52(3)
$\bar{v} = 6.10$	2.39(2)	1.82(2)	0.57(3)
$\bar{v} = 6.05$	2.38(2)	1.69(2)	0.69(3)

TABLE II: The ΛN strengths in units of MeV.

v_s	v_t	$\bar{v} = (v_s + 3v_t)/4$	$v_\sigma = v_s - v_t$
6.33	6.09	6.15	0.24
6.28	6.04	6.10	0.24
6.23	5.99	6.05	0.24

of spin-dependent strength v_σ as given in Table II. For each set of v_s and v_t, we use three sets of space-exchange parameter ε as 0.1, 0.2 and 0.3. Calculations for each set of $\bar{v}$ and ε were carried out with a constant value of three-body ΛNN attractive potential strength C^P=1.75 MeV. The repulsive potential strength W^D is adjusted to reproduce experimental BE which is 2.39(4) MeV. It is interesting to note that the repulsive potential strength W^D that reproduces the BE of ${}^{4}_{\Lambda}$He hypernucleus fall within the earlier mentioned range [5]. We start our calculations by invoking SEC in the WF and best variational parameters are obtained. With every choice of $\bar{v}$ and ε, calculations are also performed for both choices of WF to infer the effect of SEC. The results obtained so far provide significant information about the role of SEC in hypernuclear study. When SEC is invoked in the WF, the BE of hypernucleus is found to be increased by a factor of ∼0.5 MeV. Similar effects of the SEC are also noticed for $\bar{v}$=6.10 and $\bar{v}$=6.05 with slight in-

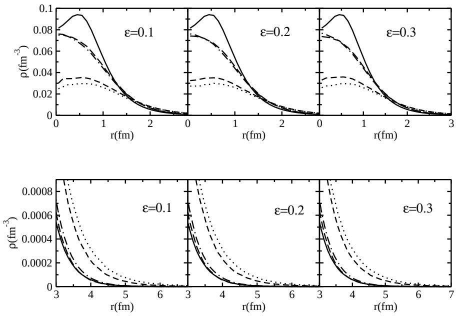

FIG. 1: One-body densities for p and Λ. Solid line represents p density in isolated ^{3}He nucleus. The long dashed and chain dashed lines shows p densities in ${}^{4}_{\Lambda}$He hypernucleus with and without SEC respectively. The dashed line and dotted lines shows Λ densities in ${}^{4}_{\Lambda}$He with and without SEC respectively.

crease in total energy. Nucleons are pushed towards periphery by Λ hyperon, which stays deep inside the hypernucleus most of the time. It is also found that when SEC is invoked in the WF, central correlation function $f^c_{\Lambda N}$is reduced significantly. As a results of this reduction, all baryons receive an inward pull leading to enhancement of density at centre. The ${}^{4}_{\Lambda}$He hypernucleus and its NC both are found more compact with SEC. We can understand these results from density profile which is presented in Fig 1. Similar results are also evident from the earlier study of ${}^{4}_{\Lambda}$H and ${}^{5}_{\Lambda}$He hypernuclei [3, 4]. Thus, SEC plays an important role in hypernuclei study and a study without incorporating SEC in the WF would be deficient.

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