Possible signatures of baryonic mixing in double-Λ hypernuclei

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Abstract

Properties of mirror hypernuclei ${}^{5}_{\Lambda\Lambda}$H and ${}^{5}_{\Lambda\Lambda}$He are studied in a Hartree-Fock approach taking into account coupling of channels ${}^{3}\mathrm{Z}+\Lambda+\Lambda$ and $\alpha+\Xi$. Diagonal $\Lambda\Lambda$ and coupling $\Lambda\Lambda$-ΞN interactions are derived within G-matrix procedure from Nijmegen meson-exchange models. Bond energy $\Delta B_{\Lambda\Lambda}$ in ${}^{5}_{\Lambda\Lambda}$He exceeds significantly that in ${}^{5}_{\Lambda\Lambda}$H due to the $\Xi^0-\Xi^-$ mass difference. Diagonal $\Xi\alpha$ attraction amplifies the effect, which is sensitive also to Λ-core interaction. The difference of the $\Delta B_{\Lambda\Lambda}$ values can be an unambiguous signature of the $\Lambda\Lambda$-ΞN coupling in $\Lambda\Lambda$ hypernuclei.

1 Introduction

Baryonic mixing in nuclear systems is a long-standing problem. On the one hand, non-diagonal interactions like NN-ΔN inevitably result in Δ admixtures in nuclei. Similarly, since ΛN-ΣN interaction is nonzero, a Λ hypernucleus must contain a Σ admixture (thus, "Λ hypernucleus" means a nuclear system with $S=-1$ and dominant Λ component).

On the other hand, direct measurement of the baryonic admixtures remains an unresolved problem so far. Probing Δ admixtures in various processes, it is difficult to discriminate between Δ component preexisting in a nucleus and Δ baryons produced in a reaction. For the ΛN-ΣN mixing effect on Λ hypernuclear binding energies, alternative dynamical pictures without explicit Σ degrees of freedom exist. Some other suggestions for identification of Σ admixtures (see refs. in [1]) have not yet been realized.

The $\Lambda\Lambda$-ΞN coupling in double-strangeness hypernuclei is of particular interest, since the relevant mass difference (about 25 MeV) is the lowest among all possible known baryonic couplings. However, experimental information on $\Lambda\Lambda$ hypernuclei is rather scarce so far. Theoretically, the $\Lambda\Lambda$-ΞN coupling has been studied mostly in hypernuclei already observed: ${}^{6}_{\Lambda\Lambda}$He [2, 3, 4], ${}^{10}_{\Lambda\Lambda}$Be, ${}^{13}_{\Lambda\Lambda}$B [3, 5]. With meson-exchange coupling potentials, probabilities of Ξ admixtures less than 1% were obtained. Contributions of the coupling to the binding energies are as small as several tenths of MeV. Much larger coupling effect has been obtained [3] within a quark model predicting free bound H dibaryon.

Myint and Akaishi [6] argued that the $\Lambda\Lambda$-ΞN coupling is considerably enhanced in hypernucleus ${}^{5}_{\Lambda\Lambda}$H. A proton, appearing from the $\Lambda\Lambda\to\Xi^- p$ transition, can be bound rather strongly in the α particle. Thus, the difference between the thresholds of channels ${}^{3}\mathrm{H}+\Lambda+\Lambda$ and ${}^{4}\mathrm{He}+\Xi^-$ is reduced to 8 MeV from 29 MeV for free $\Lambda\Lambda$ and $\Xi^- p$ pairs. Myint and Akaishi [6] obtained 1% for the Ξ^- admixture probability and 0.5 MeV for the binding excess from the coupling. These values are larger than those typically obtained for other hypernuclei, but still small to provide unambiguous signature of the coupling.

In the 1990s, Nijmegen hard-core model D (NHC-D) [7] was mainly used as a standard OBE model for $S = -2$ interactions, since it is compatible with strong $\Lambda\Lambda$ attraction ($\Delta B_{\Lambda\Lambda} = 4$–5 MeV) supported by earlier data on $\Lambda\Lambda$ hypernuclei [8, 9]. But the $\Lambda\Lambda$-ΞN coupling of NHC-D is weak, which leads to small Ξ admixtures [5]. The $\Lambda\Lambda$-ΞN coupling of the NHC-F model [10], for instance, is about twice as strong as that of NHC-D.

Since the discovery of Nagara event identified uniquely as ${}^{6}_{\Lambda\Lambda}$He [11], $\Lambda\Lambda$ attraction is believed to be rather less ($\Delta B_{\Lambda\Lambda} \approx 1$ MeV). The meson-exchange part of the NHC-F model gives a similar attraction. Therefore, possibly a stronger $\Lambda\Lambda$-ΞN coupling is more realistic and the mixing in $\Lambda\Lambda$ hypernuclei is more significant.

Recently, Myint *et al.* [12] revisited the five-baryon $\Lambda\Lambda$ hypernuclei (${}^{5}_{\Lambda\Lambda}$H as well as ${}^{5}_{\Lambda\Lambda}$He) and showed the coupling effect in ${}^{5}_{\Lambda\Lambda}$He exceeds considerably that in ${}^{5}_{\Lambda\Lambda}$H. Since Ξ^0 is lighter than Ξ^- by 6.4 MeV, the threshold difference of channels ${}^3\mathrm{He} + \Lambda + \Lambda$ and ${}^4\mathrm{He} + \Xi^0$ is as small as 2.4 MeV. Similar suggestions have been made also in [13].

We study properties of ${}^{5}_{\Lambda\Lambda}$H and ${}^{5}_{\Lambda\Lambda}$He with diagonal $\Lambda\Lambda$ and coupling $\Lambda\Lambda$-ΞN G-matrix interactions deduced from various Nijmegen OBE models. While Myint *et al.* [12] employed a single-channel approach, in which the coupling is involved effectively in the diagonal potential, we solve the relevant two-channel problem explicitly. Particularly, we incorporate the diagonal $\Xi\alpha$ potential and emphasize that effect of this potential is rather important. We investigate also the role of the other inputs ($\Lambda - {}^3\mathrm{Z}$ and $\Lambda\Lambda$ potentials).

2 Theoretical framework and choice of potentials

Here, we adopt the Hartree-Fock (HF) description, which is suitable for the G-matrix formalism defined in a single-particle model space. Because density distributions of the lightest nuclei are known to be described poorly in the HF approximation, we do not apply the HF description to all the five baryons. Instead, we treat the hypernuclei as ${}^3\mathrm{Z}+\Lambda+\Lambda$ and ${}^4\mathrm{He}+\Xi$ in the $\Lambda\Lambda$ and Ξ channels, respectively. The nuclear cores are treated as inert, and hyperon-nucleus interactions are described fully by $\Lambda - {}^3\mathrm{Z}$ and $\Xi - {}^4\mathrm{He}$ potentials.

We adopt the wave function of the five-baryon hypernucleus as $\Psi = \psi_3\psi_\Lambda(\mathbf{r}_1)\psi_\Lambda(\mathbf{r}_2) + \psi_3\psi_N(\mathbf{r}_1)\psi_\Xi(\mathbf{r}_2)$, where ψ_3, ψ_Λ, ψ_N, and ψ_Ξ are the three-nucleon core wave function and single-particle wave functions of Λ, nucleon N, and Ξ, respectively. Spin parts are not shown explicitly in the wave function above. We restrict ourselves to the single ψ_N state corresponding to the ground state α particle and also to the $1s$ states of the hyperons.

For the radial wave functions, the coupled equations to be solved are as follows:

$$-\frac{1}{2\mu_\Lambda}\varphi'' + U_\Lambda\varphi = e\varphi - \sigma\chi, \tag{1}$$

$$-\frac{1}{2\mu_\Xi}\chi'' + U_\Xi\chi = (e - \Delta e)\chi - \sigma\varphi. \tag{2}$$

Here φ and χ are the Λ and Ξ radial wave functions, respectively. The threshold-energy difference $\Delta e = 8.4$ (2.4) MeV for ${}^{5}_{\Lambda\Lambda}$H (${}^{5}_{\Lambda\Lambda}$He). Then, $U_\Lambda = U_{c\Lambda} + \langle\varphi\,|V_{\Lambda\Lambda}|\,\varphi\rangle$ and U_Ξ are the diagonal potentials, whereas $\sigma \propto \langle\varphi\,|V_{\Lambda\Lambda,\Xi N}|\,\varphi_N\rangle$ is the nondiagonal one. Potentials $U_{c\Lambda}$, U_Ξ, $V_{\Lambda\Lambda}$ and $V_{\Lambda\Lambda,\Xi N}$ correspond to Λ-core, $\Xi\alpha$, $\Lambda\Lambda$ diagonal and $\Lambda\Lambda$-ΞN coupling interactions, respectively. Since U_Λ and σ depend on φ, the system must be solved self-consistently as usually in HF approaches.

Our main goal is the quantity defined as $\Delta B_{\Lambda\Lambda} = B_{\Lambda\Lambda} - 2B_\Lambda$, where B_Λ and $B_{\Lambda\Lambda}$ are the binding energies of Λ and a pair of Λ's in a nuclear core, respectively. To obtain $\Delta B_{\Lambda\Lambda}$ values of ${}^{5}_{\Lambda\Lambda}$H, ${}^{5}_{\Lambda\Lambda}$He, and ${}^{6}_{\Lambda\Lambda}$He, we need Λ–^{3}H, Λ–^{3}He, and Λ–^{4}He potentials.

For Λ-core interactions, we use phenomenological prescriptions. For $\Lambda - {}^3$Z potential $U_{c\Lambda}$, the Isle-type form [14] is used: $U_{c\Lambda} = U_0^{\rm Isle}(1.106\exp(-r^2/r_1^2) - \exp(-r^2/r_2^2))$ with $r_1 = 1.25$ fm, $r_2 = 1.41$ fm. We fit the strength to binding energies of ${}^4_\Lambda$H and ${}^4_\Lambda$He in the ground and the first excited states, and then average the potential over the singlet and triplet states. Quantity B_Λ in the $\Delta B_{\Lambda\Lambda}$ definition is calculated in this averaged potential. For the $\Lambda - {}^4$He potential, fitting is performed to $B_\Lambda({}^5_\Lambda\text{He})$.

To address sensitivity of the results to the shape of $U_{c\Lambda}$, we examine also another force, namely, $U_{c\Lambda}$ is taken as one-range Gaussian (ORG): $U_{c\Lambda} = U_0^{\rm ORG}\exp(-r^2/r_0^2)$ with $r_0 = 1.5656$ fm [15]. The fitting procedure is the same as described above.

Unfortunately, too little is known about Ξ-nucleus interaction. The Ξ-core attractions comparable to Λ-core ones were deduced from the compilation of the old emulsion events of "Ξ hypernuclei" [16], although none of individual events was identified unambiguously. The recent data on ^{12}C(K^-, K^+) reaction [17, 18] give some evidence that the Ξ-nucleus interaction, being attractive, is weaker by about half than the Λ-nucleus interaction. We consider this information as most reliable in the present stage. We adopt a simple folding model to obtain the strength of ΞN interaction compatible with Ξ well depth [17, 18] of 14 MeV in ^{11}B. The $\Xi\alpha$ potential is deduced by folding of the obtained ΞN interaction with the α density, and then Ξ binding energies in the $\Xi\alpha$ systems are calculated. We find no bound state of ${}^5_{\Xi^0}$He, while Ξ^- hyperon is bound by α particle with $B_{\Xi^-}({}^5_{\Xi^-}\text{H})$= 0.4–0.5 MeV (depending on details of the folding procedure). We consider also the Ξ well depth in ^{11}B of 24 MeV according to the earlier analysis [16]. In this case, bound ${}^5_{\Xi^0}$He appears with $B_{\Xi^0} = 0.9$–1.1 MeV. The much stronger $\Xi\alpha$ potential of Filikhin and Gal [19] gives $B_{\Xi^0} = 2.1$ MeV and thus it is probably incompatible with the data [17, 18].

For radial dependence of $\Xi\alpha$ potential U_Ξ, we adopt the Isle-type form as well. We fit strength $U_0^{\rm Isle}$ to $B_{\Xi^-}({}^5_{\Xi^-}\text{H})$= 0.5 MeV (potential Xa1). For comparison, we examine the Filikhin and Gal [19] choice ($B_{\Xi^0}({}^5_{\Xi^0}\text{He})$= 2.1 MeV, potential Xa2). At last, we test zero $\Xi\alpha$ potential Xa0. We prepare also the $\Xi\alpha$ potentials in the ORG form with $r_0 = 2.145$ fm, which corresponds to folding of a ΞN ORG-type potential with Gaussian α density. Potential Xa3 is fitted to the same value $B_{\Xi^-}({}^5_{\Xi^-}\text{H})$ as potential Xa1. The stronger ORG-type $\Xi\alpha$ potential Xa4 is fitted to $B_{\Xi^0}({}^5_{\Xi^0}\text{H})$= 1.06 MeV, which is compatible with Ξ well depth of 24 MeV [16] in ^{11}B. The $\Xi\alpha$ potentials used are presented in Table 1.

Table 1: Parameters of the Isle-type ($U_0^{\rm Isle}$) and ORG ($U_0^{\rm ORG}$) $\Xi\alpha$ potentials. Corresponding Ξ binding energies are also shown. All the quantities are in MeV.

Isle				ORG, $r_0 = 2.145$ fm			
No.	$U_0^{\rm Isle}$	$B_{\Xi^0}({}^5_{\Xi^0}\text{He})$	$B_{\Xi^-}({}^5_{\Xi^-}\text{H})$	No.	$U_0^{\rm ORG}$	$B_{\Xi^0}({}^5_{\Xi^0}\text{He})$	$B_{\Xi^-}({}^5_{\Xi^-}\text{H})$
Xa1	158.8	unbound	0.50	Xa3	−1.816	unbound	0.50
Xa2	319.9	2.09	3.25	Xa4	−3.108	1.06	2.14
Xa0	0	–	–	Xa0	0	–	–

We derive the effective $\Lambda\Lambda$-$\Lambda\Lambda$ and $\Lambda\Lambda$-ΞN interactions suitable for our HF model space, starting from the underlying free-space interactions. We adopt the $S = -2$ sector of the Nijmegen models: NHC-D and -F as well as soft-core NSC89 [20] and NSC97 (e and f versions) [21]. We construct the G-matrix interactions in symmetric nuclear matter [5], which approximate the effective interactions in our finite model space. This approach is sufficient for our purpose, considering uncertainties of free-space interactions. The coupled-channel G-matrix equation at Fermi momentum k_F is written as

$$G_{cc_0} = v_{cc_0} + \sum_{c'} v_{cc'} \frac{Q_{y'}}{e_{yy'}} G_{c'c_0} \ , \tag{3}$$

where c denotes a relative state for a pair $y = \Lambda\Lambda$ or ΞN, and $v_{cc'}$ are free-space potentials. Starting channel c_0 corresponds to $y = \Lambda\Lambda$. For $y = \Xi N$ the Pauli operator $Q_{\Xi N}$ acts on nucleon states. The energy denominator for $y \to y'$ transition is given by $e_{yy'}$.

This approach can be evidently extended to the $\Lambda\Lambda$-ΞN-$\Sigma\Sigma$ three-channel case. With NHC-D, -F, and NSC89, for simplicity, we derive the G-matrix interactions in the two-channel treatment. For the NSC97 models, however, we perform the three-channel calculations since the coupling features of the e and f versions are fairly different. The diagonal potential derived from NSC97e in the two-channel treatment is much more attractive than that from NSC97f, but they become similar to each other in the three-channel treatment, i.e., the effect of $\Sigma\Sigma$ channel is (not) strong in the case of NSC97e (f).

The G-matrix interactions are parametrized in three-range Gaussian forms:

$$V(r) = a \exp(-r^2/r_1^2) + b \exp(-r^2/r_2^2) + c \exp(-r^2/r_3^2) \tag{4}$$

with $r_1 = 1.5$ fm, $r_2 = 0.9$ fm, $r_3 = 0.5$ fm. Parameters a, b, c are fitted so as $\langle k|V_{\Lambda\Lambda}|k\rangle$ and $\langle k|V_{\Lambda\Lambda,\Xi N}|k\rangle$ simulate G-matrix elements $\langle k|G_{\Lambda\Lambda,\Lambda\Lambda}|k\rangle$ and $\langle k|G_{\Lambda\Lambda,\Xi N}|k\rangle$, respectively. The G-matrix is calculated at a low $k_F = 1.0\ \mathrm{fm}^{-1}$, since our concern is light hypernuclei.

Old models NHC-D and NHC-F incorporate hard cores, whose radii r_c can be treated as free parameters. We choose $r_c = 0.535$ fm (D) and $r_c = 0.475$ fm (F) which give (for the Isle-type $\Lambda-{}^4$He potential) $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 0.90$ and 1.02 MeV, respectively, rather close to $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 1.0$ MeV [11]. These radii are purely phenomenological and the results are quite sensitive to their values. The cores of the soft-core models are modeled more thoroughly on the basis of the SU(3) symmetry. The NSC89 model somewhat overestimates $\Lambda\Lambda$ attraction ($\Delta B_{\Lambda\Lambda} = 1.43$ MeV) while the NSC97 models give a slight $\Lambda\Lambda$ repulsion: $\Delta B_{\Lambda\Lambda} = -0.32$ MeV (e) and -0.04 MeV (f). In all the cases, we change the short-range part c in the diagonal $\Lambda\Lambda$ interaction (4) so as to reproduce the Nagara datum. Since the existing models as well as data are far from being certain, we do not consider the (dis)agreement too seriously. Instead, we consider the potential models as examples of possible effective interactions motivated by microscopic pictures, but phenomenological to some extent. For the ORG-type Λ-core potentials, the procedure is the same. Parameters of the diagonal and coupling interactions are presented in Table 2. The last column shows the volume integrals $\int V_{\Lambda\Lambda,\Xi N}(r)\, d^3r$ measuring the strength of the coupling potentials.

All the $\Lambda\Lambda$ diagonal potentials are fitted so as to reproduce $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) = 1.0$ MeV [11] using the single-channel approximation [eq. (1) without the coupling term]. Generally, it is more reasonable to treat the $\Lambda\Lambda$-ΞN mixing explicitly not only in ${}^{5}_{\Lambda\Lambda}\mathrm{H}$ (${}^{5}_{\Lambda\Lambda}\mathrm{He}$), but also in ${}^{6}_{\Lambda\Lambda}\mathrm{He}$. In our approximation for ${}^{6}_{\Lambda\Lambda}\mathrm{He}$, however, the "diagonal" $\Lambda\Lambda$ potential fitted

Table 2: Parameters of the diagonal ($V_{\Lambda\Lambda}$) and coupling ($V_{\Lambda\Lambda,\Xi N}$) potentials and volume integrals $\int V_{\Lambda\Lambda,\Xi N}(r)\, d^3r$ for various potential models. All the entries are in MeV except the rightmost column, which is in MeV fm^3.

Model	$V_{\Lambda\Lambda}$				$V_{\Lambda\Lambda,\Xi N}$			
	a	b	c (Isle)	c (ORG)	a	b	c	Vol. int.
NHC-D	−5.659	−177.8	925.0	916.0	0.1841	102.8	−244.1	250.9
NSC97f	−5.380	−157.3	810.0	808.0	1.361	109.2	−193.5	334.2
NSC97e	−5.227	−168.7	867.0	863.0	1.146	96.07	−59.37	370.2
NSC89	−2.447	−98.60	436.0	463.0	−0.5035	128.7	−68.23	465.5
NHC-F	−1.768	−105.9	462.0	488.0	−0.9449	199.3	−300.5	582.3

to the experimental datum involves effectively contributions from ΞN intermediate states with the nucleon beyond the $1s$ shell. The reasons to justify our procedure are as follows: First, such contributions are expected to be not high due to large energy differences and small overlaps of wave functions of the $\Lambda\Lambda$ bound and ΞN continuum states. Second, these contributions in ${}^{6}_{\Lambda\Lambda}$He and ${}^{5}_{\Lambda\Lambda}$H (${}^{5}_{\Lambda\Lambda}$He) are supposed to be close to each other and, thus, to be simulated well by the diagonal $\Lambda\Lambda$ interaction. Being simplified, our approach enables us to avoid uncertainties from a treatment of the coupling in ${}^{6}_{\Lambda\Lambda}$He.

3 Results and discussion

In Fig. 1(a), $\Delta B_{\Lambda\Lambda}$ values obtained with various Isle-type $\Xi\alpha$ potentials are shown as functions of $\int V_{\Lambda\Lambda,\Xi N}(r)\, d^3r$. It is seen that the coupling effect is meaningful and may be rather high. Even with moderate $\Xi\alpha$ potential Xa1, full $\Delta B_{\Lambda\Lambda}$ is more than twice as large as the single-channel value for strong couplings. For the NHC-F model, the difference $\Delta B_{\Lambda\Lambda}({}^{5}_{\Lambda\Lambda}\mathrm{He}) - \Delta B_{\Lambda\Lambda}({}^{5}_{\Lambda\Lambda}\mathrm{H})$ is about 0.4 MeV. For the strongest potential Xa2, $\Delta B_{\Lambda\Lambda}({}^{5}_{\Lambda\Lambda}\mathrm{He})$ can reach 2.3 MeV (recall that $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})=$ 1.0 MeV). Even for zero potential Xa0, $\Delta B_{\Lambda\Lambda}({}^{5}_{\Lambda\Lambda}\mathrm{He})$ can exceed $\Delta B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$ as has been pointed out in [12].

The Ξ admixture probability $p_\Xi = \int_0^\infty \chi^2\, dr$ is presented in Fig. 1(b). Most of the values exceed considerably p_Ξ obtained in $\Lambda\Lambda$ hypernuclei with OBE models earlier. In the extreme case of the strong coupling and strong $\Xi\alpha$ potential, p_Ξ reaches 14%. The same value has been obtained in ${}^{10}_{\Lambda\Lambda}$Be [3] in a quark model with strong dibaryonic mixing.

The coupling contributions to $\Delta B_{\Lambda\Lambda}$'s in our calculations without $\Xi\alpha$ potential are smaller than those obtained by Myint *et al.* [12]. For instance, with the NSC97e model they obtained $\Delta B_{\Lambda\Lambda} = 0.96$ (1.28) MeV for ${}^{5}_{\Lambda\Lambda}$H (${}^{5}_{\Lambda\Lambda}$He) [12]. These values are notably larger than our values not only with Xa0 (0.79 and 0.94 MeV), but also with Xa1 (0.85 and 1.05 MeV). For some possible reasons and criticism of approach [12], see [1].

We stress also the role of the $\Xi\alpha$ potential omitted in [12]. Naturally, the stronger is the $\Xi\alpha$ attraction, the greater is the coupling. Substitution of zero $\Xi\alpha$ potential Xa0 by even relatively weak attractive Xa1 gives an energy gain up to 0.2 MeV in ${}^{5}_{\Lambda\Lambda}$H and 0.3 MeV in ${}^{5}_{\Lambda\Lambda}$He. For the Xa2 potential, the gain can reach 0.5 MeV (${}^{5}_{\Lambda\Lambda}$H) and 1.1 MeV (${}^{5}_{\Lambda\Lambda}$He). The $\Xi\alpha$ potential amplifies the effect, making it observable more simply. On the other hand, it is clear that quantitative extraction of the coupling strength from future

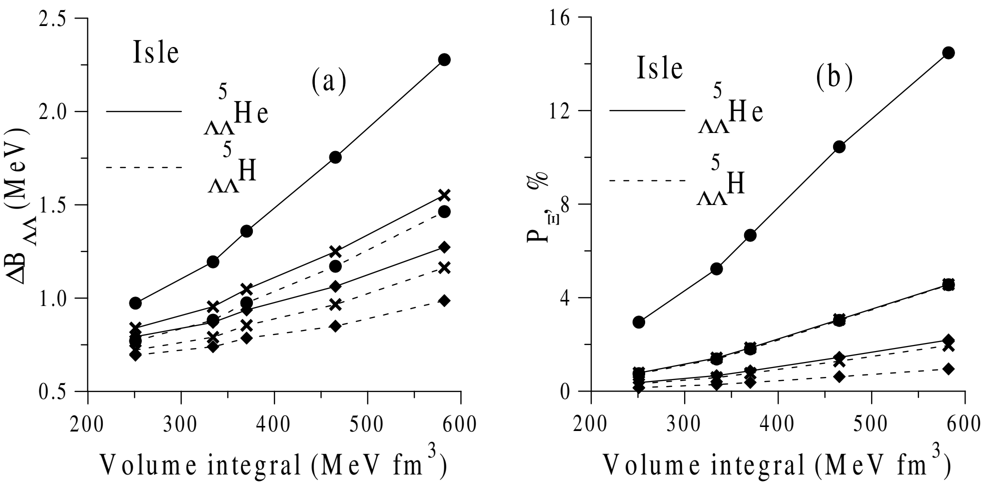

Figure 1: $\Delta B_{\Lambda\Lambda}$ (a) and Ξ admixture probabilities p_{Ξ} (b) as functions of volume integral $\int V_{\Lambda\Lambda,\Xi N}\, d^3r$ in $^{5}_{\Lambda\Lambda}$H and $^{5}_{\Lambda\Lambda}$He for $\Xi\alpha$ Isle-type potentials Xa1 (crosses), Xa2 (circles), and Xa0 (diamonds) and the Isle-type Λ-core potentials. Solid ($^{5}_{\Lambda\Lambda}$He) and dashed ($^{5}_{\Lambda\Lambda}$H) lines are drawn as a guide for eyes. Diagonal $\Lambda\Lambda$ and coupling $\Lambda\Lambda$-ΞN potentials are (from left to right) NHC-D, NSC97f, NSC97e, NSC89, and NHC-F.

data is hard until one deduces reliable $\Xi\alpha$ potential.

Qualitatively, the effect of the $\Xi\alpha$ potential can be described as follows. Introducing $\Xi\alpha$ attraction, one essentially moves the unmixed $^{5}_{\Xi}$Z state closer to the unmixed $^{5}_{\Lambda\Lambda}$Z state. Naturally, the smaller is the energy difference, the greater is the mixing. Seemingly, similar effect can be provided by changing of the $\Lambda\Lambda$ diagonal potential, but this is not the case. If the diagonal $\Lambda\Lambda$ interaction increases (the $^{5}_{\Lambda\Lambda}$Z level moves down and away from the $^{5}_{\Xi}$Z one), the coupling can even grow [13]. The reason is that the weaker is $\Lambda\Lambda$ attraction, the more extended is Λ spatial distribution. Therefore, overlap of the Λ wave function with the nucleonic one becomes poorer and the coupling is reduced.

We repeat the calculations using ORG-type $U_{c\Lambda}$ and U_{Ξ}. The $\Delta B_{\Lambda\Lambda}$ values and Ξ probabilities are presented in Fig. 2. The coupling effect increases considerably with respect to the Isle-type potentials. In the extreme cases, $\Delta B_{\Lambda\Lambda}(^{5}_{\Lambda\Lambda}\mathrm{He})$ reaches huge values, almost five times as $\Delta B_{\Lambda\Lambda}(^{5}_{\Lambda\Lambda}\mathrm{He})$ from the single-channel calculation (recall that "extreme" ORG-type $\Xi\alpha$ potential Xa4 is weaker than Xa2 of the Isle-type). The reason for this enhancement is similar to that discussed above. The ORG-type Λ-core potential gives more concentrated hyperon spatial distributions than the Isle-type potential does. Thus, the overlap becomes larger, and the mixing matrix element σ in (1) and (2) increases.

Usually, the Isle-type potentials are treated as realistic for light hypernuclei. However, such a high sensitivity of the effect to the shape of the potentials is instructive. Though the coupling effect with the ORG-type potentials is probably overestimated, it is still possible that the true effect is larger than that obtained with the Isle-type potentials.

To conclude, we studied properties of mirror hypernuclei $^{5}_{\Lambda\Lambda}$H and $^{5}_{\Lambda\Lambda}$He in the two-channel approach with G-matrix effective interactions. The $\Lambda\Lambda$-ΞN coupling is particularly efficient in these hypernuclei owing to the small energy-differences between the $\Lambda\Lambda$ and ΞN states. Most importantly, the $\Lambda\Lambda$-ΞN coupling leads to considerable difference

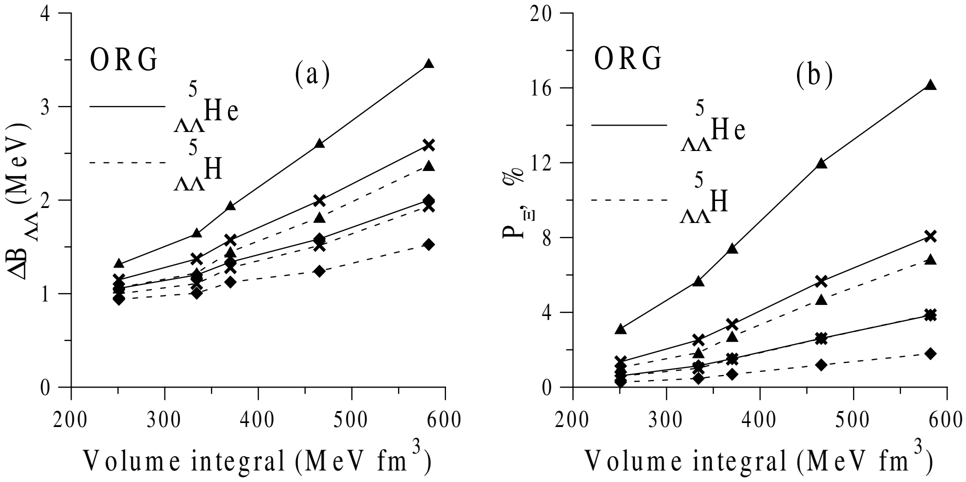

Figure 2: The same as in Fig. 1 for the ORG-type $\Xi\alpha$ potentials Xa3 (crosses), Xa4 (triangles), and Xa0 (diamonds) and the ORG-type Λ-core potentials.

of the binding energies of $^{5}_{\Lambda\Lambda}$He and $^{5}_{\Lambda\Lambda}$H. This difference can be hardly explained by another reason and can be a clear signature of the baryonic mixing. Possibly, it is the most unambiguous signature of baryonic mixing among various suggestions considered so far for ordinary nuclei as well as hypernuclei. Essentially, the effect analyzed here is a charge symmetry breaking effect of an unusual (many-body) nature: The $\Lambda\Lambda$ interaction in the mirror $\Lambda\Lambda$ hypernuclei appears to be different due to electromagnetic mass splitting of Ξ^- and Ξ^0, since different nucleonic states in the mirror cores are occupied.

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