Brueckner Rearrangement Energy in s-shell Hypernuclei

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Masses of hypernuclei and double hypernuclei are an invaluable source of information on hyperon-nucleon and hyperon-hyperon interactions. Since these bound systems are the results of the many-body correlations, it is necessary to entangle the interplay between hypernuclear structures and interactions in order to obtain the information on interactions. Recently, Nemura, Akaishi and Suzuki [1] showed by variational calculations that the internal energy of the ^{4}He is strongly affected by the addition of a Λ particle. In this study we consider the corresponding effect in a standard nuclear many-body theory. Namely we estimate Brueckner rearrangement energy [2] ΔE_r of the ^{4}He core when a Λ particle is added to produce $^5_\Lambda$He. It is known that in the ^{4}He a single harmonic oscillator function provides a very good approximation and also that the ^{4}He core in the $^5_\Lambda$He differs little from the ^{4}He . In the following discussion we suppose that wave functions are given by the same h.o. function both for the ^{4}He and the $^5_\Lambda$He . In the lowest order Brueckner theory, the energy difference ΔE_r for a given NN interaction v_{NN} is given by introducing G-matrix elements with a standard QTQ choice for intermediate spectra H_0:

$$\Delta E_r = \frac{1}{2}\sum_{hh'} < hh'|G_{NN}(5, \omega = e_h(5) + e_{h'}(5)) - G_{NN}(4, \omega = e_h(4) + e_{h'}(4))|hh' >_{as}, \quad (1)$$

$$G_{NN}(n, \omega) = v_{NN} + v_{NN}\frac{Q}{\omega - H_0}G_{NN}(n, \omega), \quad (2)$$

$$e_h(n) =< h|t_N|h> + \sum_{h'} < hh'|G_{NN}(n, \omega = e_h(n) + e_{h'}(n))|hh' >_{as}, \quad (3)$$

where Q represents a Pauli exclusion operator and t_N a kinetic energy operator. The self-consistency of e_h and G means that the hole-line potential insertion, a part of three-body correlations, is taken into account. Noting that the Λ separation energy $\epsilon_\Lambda(5)$, which is experimentally -3.12 MeV, is expressed as

$$\epsilon_\Lambda(5) = E(^5_\Lambda\text{He}\ ) - E(^4\text{He}\ ) =< \Lambda|t_\Lambda|\Lambda> + \sum_h < \Lambda h|G_{\Lambda N}|\Lambda h> + \Delta E_r, \quad (4)$$

it is lengthy but straightforward to derive the following expression:

$$\Delta E_r \simeq \frac{\chi_\omega}{1-\chi_\omega}(\epsilon_\Lambda(5) - < \Lambda|t_\Lambda|\Lambda>), \quad (5)$$

where χ_ω stands for $\sum_{h''} < hh''|\frac{\partial G_{NN}}{\partial\omega}|hh''>_{as}$ which is known as a wound integral. Explicit calculations tell us that χ_ω is about -0.2. Expecting the Λ oscillator constant ν_Λ to be $0.3 \sim 0.4$ fm^{-2}, we obtain ΔE_r to be $1.8 \sim 2.3$ MeV. Similar effects have to be estimated to establish the strength of $\Lambda\Lambda$ interaction from the mass of the $^{\ 6}_{\Lambda\Lambda}$He .

References

[1] H. Nemura, Y. Akaishi and Y. Suzuki, nucl-th/0203013.
[2] K.A. Brueckner and D.T. Goldman, Phys. Rev. 117 (1960) 207.