Four-body structure of $A = 7 - 10$ double-Λ hypernuclei

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Energy levels of the double-Λ hypernuclei ${}^{7}_{\Lambda\Lambda}$He, ${}^{7}_{\Lambda\Lambda}$Li, ${}^{8}_{\Lambda\Lambda}$Li, ${}^{9}_{\Lambda\Lambda}$Li, ${}^{9}_{\Lambda\Lambda}$Be and ${}^{10}_{\Lambda\Lambda}$Be are predicted on the basis of the $\alpha + x + \Lambda + \Lambda$ four-body model with $x = n, p, d, t, {}^3$He and α, respectively. Interactions between the constituent particles are determined so as to reproduce reasonably the observed low-energy properties of the $\alpha + x$ nuclei (^{5}He, ^{5}Li, ^{6}Li, ^{7}Li, ^{7}Be, ^{8}Be) and the existing data of Λ-binding energies of the $x + \Lambda$ and $\alpha + x + \Lambda$ systems (${}^{3}_{\Lambda}$H, ${}^{4}_{\Lambda}$H, ${}^{5}_{\Lambda}$He, ${}^{6}_{\Lambda}$He, ${}^{6}_{\Lambda}$Li, ${}^{7}_{\Lambda}$Li, ${}^{8}_{\Lambda}$Li, ${}^{8}_{\Lambda}$Be, ${}^{9}_{\Lambda}$Be). Here, an effective $\Lambda\Lambda$ interaction is constructed so as to to reproduce, within the $\alpha + \Lambda + \Lambda$ model, the $B_{\Lambda\Lambda}$ of ${}^{6}_{\Lambda\Lambda}$He which was discovered recently in the NAGARA event [1] of the emulsion experiment. With no adjustable parameters for the $\alpha + x + \Lambda + \Lambda$ systems, $B_{\Lambda\Lambda}$ of the ground and bound excited states of the double-Λ hypernuclei with $A = 7 - 10$ are accurately calculated with the Jacobian-coordinate Gaussian-basis coupled-rearrangement-channel method (for example, [2]).

It is striking that the calculated $B_{\Lambda\Lambda}$ of the 2^+ excited state in ${}^{10}_{\Lambda\Lambda}$Be, 12.28 MeV, agrees with the experimental value $B^{\rm exp}_{\Lambda\Lambda}$ (${}^{10}_{\Lambda\Lambda}$Be) $= 12.33 \pm^{0.35}_{0.21}$ MeV in the *Demachi-Yanagi* event [3]. We therefore interpret this event as discovery of the 2^+ excited state of ${}^{10}_{\Lambda\Lambda}$Be. The agreement indicates that our systematic calculations are predictive for coming events expected to be found in the further analysis of the E373 data, *etc.*

Dynamical change of the $\alpha + x$ nuclear core by the participation of the Λ particles is substantially seen in double-Λ hypernuclei; there occurs, averagely speaking, about 8 % shrinkage of the $\alpha - x$ distance compared with the distance in the single-Λ hypernucleus. This shrinkage is realized by the large energy gain in the $\Lambda - \alpha$ and $\Lambda - x$ parts which overcomes the energy loss in the $\alpha - x$ relative motion.

We estimated the $\Lambda\Lambda$ bond energy using the faithful definition $\mathcal{V}^{\rm bond}_{\Lambda\Lambda} = B_{\Lambda\Lambda} - B_{\Lambda\Lambda}(V_{\Lambda\Lambda} = 0)$ and found it to be 0.88 MeV for ${}^{6}_{\Lambda\Lambda}$He and $0.93 - 0.98$ MeV for the other double-Λ hypernuclei.

References

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