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LIGHT HYPERNUCLEI AT THE BOUNDARY OF NEUTRON STABILITY

Modern nuclear physics relies on studies of nuclei with proton or neutron excess. The corresponding area of research in hypernuclear physics is also of particular interest. Weakly bound hypernuclei near the nucleon drip lines may allow to test hypernuclear interactions at low nuclear densities, such as those manifesting in halo systems.

Furthermore, the role of 3-body ΛNN force or density-dependent ΛN force, as well as charge symmetry breaking can also be further investigated in exotic hypernuclei [1,2]. Another interesting effect, and one we study in detail in this work, is the changes in binding of the system in response to addition of the Λ-hyperon to it. Due to their glue-like role, Λ-hyperons are able to stabilize loosely unbound non-strange nuclei, leading to formation of bound hypernuclei and thus shifting the nucleon drip lines on the hypernuclear chart as compared to the nuclear one.

Previously, we studied the light Λ-hypernuclei with an excess of protons [3,4]. The focus of this article is neutron-rich helium and lithium hypernuclei. The location of the neutron drip line is dictated by the change in the sign of the separation energy of one or two neutrons. For isotopes ^{7}He, ^{9}He and ^{10}Li, decay with the emission of one neutron is critical, whereas the two-neutron decay mode should be considered in ^{10}He. The experimental values of one/two neutron separation energies for these isotopes are negative. Since Λ-hyperons additionally bind nuclei, the goal was to test whether hypernuclei $^{8}_{\Lambda}$He, $^{10}_{\Lambda}$He, $^{11}_{\Lambda}$He and $^{11}_{\Lambda}$Li decay via neutron emission.

In this work, all calculations were performed using the Skyrme-Hartree-Fock method. This method is effective in realistic description of ordinary nuclei and can also be utilized to describe Λ-hypernuclei. We employed various parametrizations of nucleon-nucleon (NN) and hyperon-nucleon (ΛN) interactions for description of the basic characteristics of light exotic nuclei and hypernuclei.
To examine the boundness of isotopes $^{8}_{\Lambda}$He, $^{10}_{\Lambda}$He, $^{11}_{\Lambda}$He and $^{11}_{\Lambda}$Li, it is necessary to estimate their one- or two-neutron separation energies:

$S_n(^{A+1}_{\Lambda}\mathrm{Z}) = S_n(^{A}\mathrm{Z}) + \delta B^{n}_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z})$

$S_{2n}(^{A+1}_{\Lambda}\mathrm{Z}) = S_{2n}(^{A}\mathrm{Z}) + \delta B^{2n}_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z})$

where

$\delta B^{n}_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) = B_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) - B_{\Lambda}(^{A}_{\Lambda}\mathrm{Z})$

$\delta B^{2n}_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) = B_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) - B_{\Lambda}(^{A-1}_{\Lambda}\mathrm{Z})$

Here B_{Λ} is the Λ-hyperon binding energy equal to the difference between the binding energies of the hypernucleus and the corresponding nucleus:

$B_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) = B.E(^{A+1}_{\Lambda}\mathrm{Z})$
$B_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) = B.E(^{A+1}_{\Lambda}\mathrm{Z}) - B.E(^{A}_{\Lambda}\mathrm{Z})$.

In order to determine the neutron separation energy in the considered hypernuclei, we used the values of the neutron separation energies in the corresponding nuclei
$B_{\Lambda}(^{A+1}_{\Lambda}\mathrm{Z}) = B.E(^{A+1}_{\Lambda}\mathrm{Z}) - B.E(^{A}_{\Lambda}\mathrm{Z})$.

In order to determine the neutron separation energy in the considered hypernuclei, we used the values of the neutron separation energies in the corresponding nuclei $S_n(^{7}\mathrm{He})$, $S_n(^{9}\mathrm{He})$, $S_n(^{10}\mathrm{Li})$ and $S_{2n}(^{10}\mathrm{He})$, as well as the hyperon binding energy $B_{\Lambda}(^{7}\mathrm{He})$ also known from experiment. The Skyrme-Hartree-Fock approach was employed for calculating the remaining values. The table displays the experimental values of the neutron separation energies in the nuclei and the range of estimations for the extra binding energy, δB_{Λ} for the respective hypernuclei.

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We inferred from our calculations that hypernuclei ${}^{8}_{\Lambda}$He and ${}^{11}_{\Lambda}$Li appear to be bound as a result of the values of δB_Λ exceeding the value of the neutron separation S_n energy in the nucleon core. Adding a Λ-hyperon to ${}^{10}_{\Lambda}$He and ${}^{11}_{\Lambda}$He, on the other hand, does not result in formation of bound hypernuclei.

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Section

Nuclear structure: theory and experiment

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