A contribution of isovector-scalar meson on $\Sigma-$hypernuclei

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Introduction

Hypernuclei are composite body of nucleons and hyperons (eg. Λ, Σ, Ξ) have additional strangeness degree of freedom compared with ordinary nuclei. Presence of these hyperons induces many effects on nuclear core, such as shrinkage effect, deformation, extend the drip line and halo/skin structure [1]. The most discussed is Λ hypernuclei among the hypernuclear species has attaracted worldwide interest in both experimental [2] and theoretical aspects [3]. The main goal to study the hypernuclei is to extract information on baryon-baryon interaction which is crucial to understand the nature of high density matter. The heavy hyperons other than Λ are supposed to be expected in high density matter such as neutron star. Even though Σ has a repulsive potential in nuclear matter but one of the bound state $^{4}_{\Sigma}He$ is experimentally found [4, 5]. In this work our main focus is to find out; What are possible physical parameters in our model that can effect the binding mechanism of $\Sigma-$hypernuclei? The exchange of different types of meson in baryon-baryon interaction is crucial and fundamental facts. We suppose to be exchange of isovector scalar $\delta-$meson in nuclone-nucleon (NN) and sigma-nucleon (ΣN) interactions and extract its contibutions in $\Sigma-$hypernuclei.

Formalism

Relativistic mean field (RMF) model has been remarkable successful in describing finite as well as infinite many-body systems and also reproduces significant results on hypernuclei [1, 6–8]. For describing the hypernuclear systems, the relativistic Lagrangian density is extended which is the sum of nucleonic part and hypronic part written by $\mathcal{L}_{total} = \mathcal{L}_N + \mathcal{L}_Y$. Here, Y stands for $\Sigma-$hyperons. In present calculation, the simple nucleonic parameter NL3* is used and sigma-nucleon couplings are taken from Ref. [9] to simulate ΣN interaction.

TABLE I: Binding energy and radii for considered closed shell nuclei and their $\Sigma-$ and double$\Sigma-$hypernuclei.

Nuclei	BE	r_c	r_t	r_p	r_n	r_Σ
^{48}Ca	414.1676	3.444	3.496	3.359	3.591	
$^{48}_{\Sigma^+}$Ca	426.8899	3.447	3.460	3.361	3.548	2.945
$^{48}_{2\Sigma^+}$Ca	437.8088	3.451	3.423	3.365	3.503	2.897
$^{48}_{\Sigma^-}$Ca	431.9731	3.421	3.453	3.335	3.566	2.598
$^{48}_{2\Sigma^-}$Ca	448.4698	3.397	3.409	3.310	3.538	2.565
^{208}Pb	1639.323	5.499	5.624	5.448	5.736	
$^{208}_{\Sigma^+}$Pb	1659.206	5.494	5.604	5.443	5.715	4.673
$^{208}_{2\Sigma^+}$Pb	1678.014	5.489	5.585	5.437	5.694	4.661
$^{208}_{\Sigma^-}$Pb	1679.102	5.478	5.596	5.427	5.718	3.579
$^{208}_{2\Sigma^-}$Pb	1710.278	5.457	5.568	5.405	5.699	3.529

Results and discussion

We employed spherical RMF model to study the $\Sigma-$hypernucl: $^{48}_{\Sigma}$Ca, $^{208}_{\Sigma}$Pb whose nuclear core is double magic and extract the contribution of $\delta-$meson in considered $\Sigma-$hypernuclei. The structural properties of considered $\Sigma-$hypernuclei and their ordinary nuclei are given in Table 1. It is revealing that the presence of Σ hyperons increases the binding and compact the size of the systems as like as the Λ hyperon. The individual contribution of delta meson from over all interaction in re-

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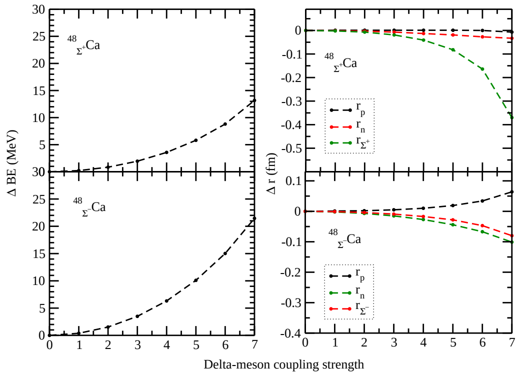

FIG. 1: Contribution in total BE and different radii (r_c, r_t, r_Σ) with respect to possible $\delta-$meson

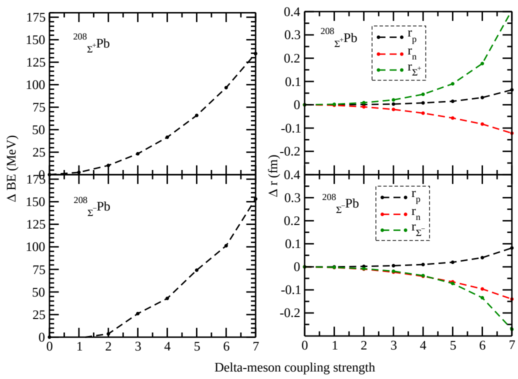

FIG. 2: Same as Fig2 but for $^{208}_{\Sigma^+}Pb$ and $^{208}_{\Sigma^-}Pb$.

spect of BE and radii is extracted using the following expressions;

$$\Delta BE = BE(g_\rho, g_\delta \neq 0.0) - BE(g_\rho, g_\delta = 0.0) \quad (1)$$

$$\Delta r = r(g_\rho, g_\delta \neq 0.0) - BE(g_\rho, g_\delta = 0.0) \quad (2)$$

It is difference of physical observables with nonzero strength to zero strength of $\delta-$meson coupling. The evaluation of ΔBE and Δr for $^{48}_{\Sigma^+}Ca$, $^{48}_{\Sigma^-}Ca$ and $^{208}_{\Sigma^+}Pb$, $^{208}_{\Sigma^-}Pb$) are plotted in Fig. 1 and Fig 2. It is evident from Figs that binding energy increases with increases delta-meson coupling strength and radii are in opposite trend. A very large change in sigma radius is observed with delta-meson coupling strength. The impact of $\delta-$meson even more in Σ^-−hypernuclei compared with Σ^+ case. Further, it is observed that the impact of $\delta-$meson coupling strength on ΔBE and Δr is large in case of $^{208}_{\Sigma}Pb$ compared to $^{48}_{\Sigma}Ca$ hypernuclei. Ofcourse results have physical meaning, because delta-meson impact is strong for large isospin asymmetric systems. The extracted value of ΔBE and Δr are good some amount which can not be ignored for consideration. Thus, it is concluding that addition of $\delta-$meson in present model has a significant role in binding mechanism of $\Sigma-$hypernuclei.

Acknowledgments

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