Possible molecular bound states: $\Lambda_c N$ and $\Lambda_c \Lambda_c$

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The $\Lambda_c N$ and $\Lambda_c \Lambda_c$ bound state problems are explored in the coupled channel one-boson-exchange approach. The model involves a free cutoff parameter and several coupling constants which are determined by various methods. The coupled channel effects may finally result in $\Lambda_c N$ and $\Lambda_c \Lambda_c$ molecular bound states for a reasonable cutoff parameter.

Study of possible bound states may help us to understand the strong interaction in the non-perturbative region, which is always an interesting topic. In the heavy quark sector, molecule-like bound states are more likely to exist due to two reasons. The first one is the larger reduced mass of the system which renders the relatively smaller kinetic energy and is advantageous for the formation of hadronic molecules. The other one is the degeneracy of hadrons in the heavy quark limit which accounts for the coupled channel effects. As the lowest heavy quark baryon, Λ_c is interesting in that possible low-lying hadronic bound states containing it are stable. The channel couplings of Σ_c and Σ_c^* may give important contributions. Here we consider two charmed systems: $\Lambda_c N$ and $\Lambda_c \Lambda_c$. Frameworks to study them are similar. We construct effective Lagrangian, determine the coupling constants from various symmetries, derive one-meson-exchange potentials, and get binding energies by solving the coupled channel equations with the variational method [1]. We introduce a phenomenological cutoff parameter in the final potential to compensate the extended structure of the hadrons. Details of the formulations and results are given in Refs. [2, 3].

For the $\Lambda_c N$ system, an early study using the SU(4) symmetry [4] concluded that whether there is a bound state needs further detailed coupled channel calculation. It is interesting to give the system a serious study with the modern effective theory and couplings to $\Sigma_c N$ and $\Sigma_c^* N$. We consider three coupled channels for the spin-singlet case: $\Lambda_c N(^1S_0)$, $\Sigma_c N(^1S_0)$, and $\Sigma_c^* N(^5D_0)$. For the spin-triplet case, we consider seven channels: $\Lambda_c N(^3S_1)$, $\Sigma_c N(^3S_1)$, $\Sigma_c^* N(^3S_1)$, $\Lambda_c N(^3D_1)$, $\Sigma_c N(^3D_1)$, $\Sigma_c^* N(^3D_1)$, and $\Sigma_c^* N(^5D_1)$. For comparison, we use both the one-pion-exchange potential (OPEP) model and the one-boson-exchange potential (OBEP) model in our study. A key feature is that one pion exchange is forbidden in the dominant channel $\Lambda_c N$ because of the isospin conservation. In the OPEP model, it is the coupled channel effect that one can get binding solutions with a reasonable cutoff parameter. By inspecting contributions of individual channel, one observes that the tensor interaction plays a key role. In the OBEP model, additional scalar and vector meson exchanges contribute significantly. It is more possible to have bound states in this model. In brief, one expects the existence of $\Lambda_c N$ hadronic molecules.

For the $\Lambda_c\Lambda_c$ system, the allowed S-wave state is only spin-singlet because of Pauli principle. Channels which can couple with it are $\Sigma_c\Sigma_c(^1S_0)$, $\Sigma_c^*\Sigma_c^*(^1S_0)$, $\Sigma_c^*\Sigma_c^*(^5D_0)$, and $\Sigma_c\Sigma_c^*(^5D_0)$. Although Λ_c does not decay through strong interaction, $\Lambda_c\Lambda_c$ may mix with $\Xi_{cc}N$ by the exchange of charmed mesons. Since we consider the possible loosely bound molecular state, the mixing occurring at short distance may be unimportant and we neglect this channel. In addition, Ξ_{cc} has not been well established yet. For a study of possible bound states in the $\Xi_{cc}N$ system, one may consult Ref. [5]. We use only the long-range OPEP model in our study. Numerically, we can get a loosely bound $\Lambda_c\Lambda_c$ hadronic state with a reasonable cutoff parameter. Although the diagonal potentials are all repulsive, the channel coupling may result in binding solutions. The tensor force between S-wave channel and D-wave channel again plays a key role.

To summarize, we find that bound states in both $\Lambda_c N$ and $\Lambda_c\Lambda_c$ systems are possible although the binding energies depend on a phenomenological cutoff parameter. One expects that these hadronic molecular states may be looked for at experimental facilities.

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