Effective $\bar{K}N$ interaction in chiral dynamics

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The study of $\bar{K}$-nuclear systems attracts considerable interest in nuclear and hadron physics. The basic ingredient to study the few-body kaonic nuclei is the $\bar{K}N$ interaction. While the experimental data of K^-p scattering are available above the $\bar{K}N$ threshold, the only piece of information about the interaction below $\bar{K}N$ threshold is the $\pi\Sigma$ mass spectrum which is dominated by the $\Lambda(1405)$ resonance. It is therefore indispensable to study the extrapolation of the $\bar{K}N$ interaction below the threshold, by properly treating the $\Lambda(1405)$. Historically, the $\Lambda(1405)$ has been successfully described in the coupled-channel approach with vector-meson exchange potential. This framework is now refined into the chiral coupled-channel approach, where the interaction is determined by chiral SU(3)$\times$SU(3) symmetry of QCD. The experimental data of K^-p scattering are well reproduced above threshold (Total cross sections to different channels), at threshold (threshold branching ratios), and below threshold ($\pi\Sigma$ invariant mass spectrum). It is our aim to derive the effective single-channel $\bar{K}N$ interaction based on chiral SU(3) dynamics [1].

We first study the structure of the $\Lambda(1405)$ in chiral dynamics. It is pointed out that chiral low energy theorem requires the strong attractive interaction not only in the $\bar{K}N$ channel but also in the $\pi\Sigma$ channel. As a consequence, the $\Lambda(1405)$ is described as a $\bar{K}N$ quasi-bound state embedded in the resonant $\pi\Sigma$ continuum. Because of the strong $\pi\Sigma$ dynamics, the resonance structure of the $\Lambda(1405)$ in the $\bar{K}N$ channel appears at around 1420 MeV, not in the nominal position of the 1405 MeV deduced from the maximum of the $\pi\Sigma$ mass spectrum.

Next, we derive an effective single-channel $\bar{K}N$ interaction in this framework, by including the effect of the coupled-channel dynamics. For the estimation of the theoretical uncertainties, we adopt four different chiral models to construct the local potential. The effects of the higher order terms of the chiral expansion in the interaction kernel are also examined. The occurrence of the quasibound state at $\sqrt{s} \simeq 1420$ MeV turns out to be model independent, as far as the interaction is constrained by chiral symmetry and by the experimental database. Since the binding energy of the $\Lambda(1405)$ is small, the effective single-channel $\bar{K}N$ interaction is less attractive than the previously obtained phenomenological potential.

We then construct an equivalent local potential, with a Gaussian coordinate space form factor reflecting finite range effects. The range parameter is adjusted so as to reproduce the position of the $\bar{K}N$ quasibound state. In any case, a local parametrization of the $\bar{K}N$ effective interaction works only with an adjustment of its energy dependence. This extra energy dependence considerably reduces the attractive strength of the potential in the subthreshold region as compared to naive expectations.

This chiral effective $\bar{K}N$ potential is applied to the variational calculation of the K^-pp system together with the realistic NN interaction [2]. The K^-pp system is found to be weakly bound, reflecting the strength of the effective $\bar{K}N$ interaction.

References

[1] T. Hyodo and W. Weise, Phys. Rev. C **77**, 035204 (2008).
[2] A. Doté, T. Hyodo and W. Weise, Nucl. Phys. A **804** 197 (2008); arXiv:0806.4917 [nucl-th].