Self consistent propagation of hyperons and antikaons in nuclear matter based on relativistic chiral $SU(3)$ dynamics

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Results on antikaon production in heavy ion collisions at subthreshold energies may help to study the modification of the K^- properties inside a dense nuclear medium [1, 2, 3, 4, 5].

An antikaon spectral function with support at energies smaller than the free-space kaon mass was already anticipated in the 70's by the many K-matrix analyses of the antikaon-nucleon scattering process (see e.g. [6]) which predicted considerable attraction in the subthreshold scattering amplitudes. This leads in conjunction with the low-density theorem to an attractive antikaon spectral function in nuclear matter. Nevertheless, the quantitative evaluation of the antikaon spectral function is still an interesting problem [7, 8, 9]. The challenge is first to establish a solid understanding of the vacuum antikaon-nucleon scattering process, in particular reliable subthreshold antikaon-nucleon scattering amplitudes are required, and secondly, to evaluate the antikaon spectral function in a systematic many-body approach.

The antikaon-nucleon scattering is complicated due to the open inelastic $\pi\Sigma$ and $\pi\Lambda$ channels and the presence of the s-wave $\Lambda(1405)$ and p-wave $\Sigma(1385)$ resonances just below and the d-wave $\Lambda(1520)$ resonance not too far above the antikaon-nucleon threshold. In this work we apply the newly formulated χ-BS(3) approach, for chiral Bethe-Salpeter approach to the SU(3) flavor group [10]. It constitutes a systematic and non-perturbative application of the chiral SU(3) Lagrangian to the meson-baryon scattering problem consistent with covariance, crossing symmetry, large-N_c sum rules of QCD and the chiral counting concept. The low-energy pion-, kaon- and antikaon-nucleon scattering data were reproduced successfully demonstrating that the chiral SU(3)flavor symmetry is a powerful tool to analyze and predict hadron interactions systematically. The amplitudes obtained in that scheme are particularly well suited for an application to the nuclear kaon dynamics, because it was demonstrated that they are approximately crossing symmetric in the sense that the KN and $\bar{K}N$ amplitudes smoothly match at subthreshold energies.

As was pointed out in [8] the realistic evaluation of the antikaon self energy in nuclear matter requires a self consistent scheme. In particular the feedback effect of an in-medium modified antikaon spectral function on the antikaon-nucleon scattering process was found to be important for the $\Lambda(1405)$ resonance structure in nuclear matter. We present a selection of results obtained in our novel covariant many-body framework [11]. Self consistency was implemented in terms of the free-space meson-nucleon scattering amplitudes, where the amplitudes of the χ-BS(3) approach were used. We computed a realistic antikaon spectral function and studied the in-medium structure of the s-wave $\Lambda(1405)$ and p-wave $\Sigma(1385)$ resonances.

In Fig. 1 we present the antikaon spectral function together with the antikaon-nucleon scattering amplitudes of selected channels at various nuclear matter densities [11]. The antikaon spectral function exhibits a rich structure with a pronounced dependence on the antikaon three-momentum. That reflects the coupling of the $\Lambda(1405)$ and $\Sigma(1385)$ hyperon states to the $\bar{K}N$ channel. Typically the peaks seen are quite broad and not always of quasi-particle type. The most important contributions, the s-wave $\Lambda(1405)$ and p-wave $\Sigma(1385)$ resonances, experience strong medium modifications as demonstrated in Fig. 1. Whereas for pure s-wave dynamics the $\Lambda(1405)$ effective mass is changed very little [8], the consideration of higher partial waves leads to an attractive mass shift of about 60 MeV at nuclear saturation density. The results at $2\,\rho_0$ should be considered cautiously because nuclear binding and correlation effects were not yet included in [11].

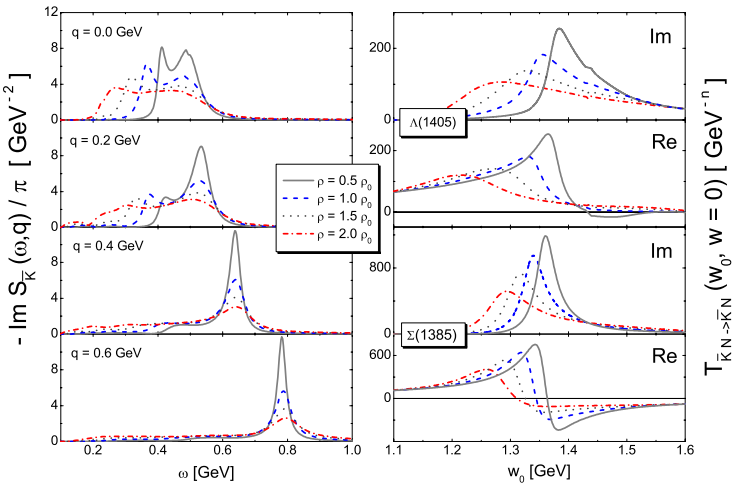

Figure 1: Spectral functions of antikaons and hyperon resonances in cold nuclear matter.

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