# Calculations of $\bar{K}$ nuclear quasi-bound states using chiral $\bar{K}N$ amplitudes

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We review our latest calculations of $K^-$ quasi-bound states in few- and many-body nuclear systems using subthreshold energy dependent chiral $\bar{K}N$ amplitudes [1,2].

We performed calculations of three-body $\bar{K}NN$ and four-body $\bar{K}NNN$ and $\bar{K}\bar{K}NN$ nuclear clusters in the hyperspherical basis, with interactions practically identical to those used in ref. [3]. Results of previous $K^-pp$ calculations were reproduced and and upper bound was placed on the binding energy of a $K^-d$ quasibound state. In view of the low $K^-pp$ binding energy $B(K^-pp) \approx 16$ MeV and relatively large $\bar{K}N \to \pi Y$ mesonic width $\Gamma(K^-pp) \approx 40$ MeV, it might be difficult to identify the $K^-pp$ quasi-bound state unambiguously in ongoing experiments. A self-consistent handling of the energy dependence of the subthreshold $\bar{K}N$ amplitude was found to restrain binding of the four-body $\bar{K}$ nuclear clusters. We found relatively modest binding, about 30 MeV in both, with mesonic widths ranging from 30 MeV for $\bar{K}NNN$ to about 80 MeV for the lowest $\bar{K}\bar{K}NN$ quasi-bound state. However, the binding energies of $K^-$ nuclear clusters could be enhanced by dispersive contributions. Our recent fits to kaonic atoms [4,5] suggest that $\Delta B_{\rm disp} \sim \Delta\Gamma_{\rm nonmesonic}$, and the binding energies could reach values $B(K^-pp) \sim 25$ MeV and $B(\bar{K}NNN,\ \bar{K}\bar{K}NN) \sim 50$ MeV.

For many-body $K^-$ nuclear systems with densities close to nuclear matter density, the energy dependence of the chiral in-medium $\bar{K}N$ scattering amplitudes controls the self-consistent evaluation of the corresponding $K^-$ optical potentials. We considered two in-medium versions of the scattering amplitudes: a version which takes into account only Pauli blocking in the intermediate states, and a version which adds self-consistently hadron self-energies [2,4]. The $\bar{K}N$ amplitudes were constructed using the in-medium coupled-channel model [6] that reproduces all available low energy $\bar{K}N$ observables, including the latest $1s$ level shift and width in the $K^-$ hydrogen atom from the SIDDHARTA experiment [7]. While the two in-medium versions of the $\bar{K}N$ scattering amplitudes yield considerably different potential depths Re$V_K$ at threshold, they give similar depths in the self-consistent calculations with the subthreshold extrapolation, -Re$V_K \sim 80 - 120$ MeV. The mesonic widths of low-lying $K^-$ states are substantially reduced in the self-consistent calculations, thus reflecting the proximity of the $\pi\Sigma$ threshold. On the contrary, the widths of higher excited $K^-$ states are quite large even if only the pion conversion modes on a single nucleon are considered. After including 2 body $K^-NN \to YN$ nonmesonic modes, the total decay widths $\Gamma_K$ are comparable or even larger than the corresponding binding energies $B_K$ for *all* $K^-$ nuclear quasi-bound states, exceeding considerably the level spacing. Our conclusions should discourage attempts to search for isolated peaks corresponding to $K^-$ nuclear quasi-bound states in many-body nuclear systems.

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