Strong binding and shrinkage of single and double $\bar{K}$ nuclear systems (K$^{-}$pp, K$^{-}$ppn, K$^{-}$K$^{-}$p and K$^{-}$K$^{-}$pp) predicted by Faddeev-Yakubovsky calculations

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Fig. 1. Global view of the calculated bound-state energies (upper) and sizes (lower), R$_{KNC}$ and R$_{NN}$ of K nuclear clusters as functions of the $KN$ interaction strength, $s^{(1=0)}_{NN}$, which is normalized so as to be -1 at the binding threshold. The zones of the standard “$\Lambda(1405)$ ansatz” (s = -1.37) and the “Chiral” ansatz (s = -1.22) are shown by vertical broken lines. The experimental value of the mass of K$^{-}$pp as observed by DISTO[7] is shown by a horizontal broken line, where a relativistic correction for the binding energy around 10 MeV is not taken into account.

Non-relativistic Faddeev and Faddeev-Yakubovsky calculations were made for K$^{-}$pp, K$^{-}$ppn, K$^{-}$K$^{-}$p and K$^{-}$K$^{-}$pp kaonic nuclear clusters, where the quasi bound states were treated as bound states by employing real separable potential models for the K$^{-}$K$^{-}$ and the K$^{-}$nucleon interactions as well as for the nucleon-nucleon interaction[1].

The binding energies and spatial shrinkages of these states, obtained for various values of the $KN$ interaction, were found to increase rapidly with the $KN$ interaction strength. Their behaviors are shown in a reference diagram, Fig. 1, where possible changes by varying the $KN$ interaction in the dense nuclear medium are given. Using the $\Lambda(1405)$ ansatz with a PDG mass of 1405 MeV/c$^2$ for K$^{-}$p, the following ground-state binding energies together with the wave functions were obtained: 51.5 MeV (K$^{-}$pp), 69 MeV (K$^{-}$ppn), 30.4 MeV (K$^{-}$K$^{-}$p) and 93 MeV (K$^{-}$K$^{-}$pp), which are in good agreement with previous results of variational calculation based on the Akaishi-Yamazaki coupled-channel potential[2–5]. The K$^{-}$K$^{-}$pp state has a significantly increased density where the two nucleons are located very close to each other, in spite of the inner $NN$ repulsion. Relativistic corrections on the calculated non-relativistic results indicate substantial lowering of the bound-state masses, especially of K$^{-}$K$^{-}$p and K$^{-}$K$^{-}$pp states. A proper treatment of the inner $NN$ interaction is necessary to describe these states.

References