Mesic nuclei with a heavy antiquark [†]

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Multiflavor nuclei are one of the interesting topics of research in the field of hadron and nuclear physics. Strangeness nuclei such as kaonic and hypernuclei have been extensively studied both experimentally and theoretically.1) As a new direction, new flavors such as charm and bottom are studied, and nuclei with these flavors have different properties from those of strangeness nuclei.2) Such multiflavor nuclei are important for studying (i) hadron and nucleon interaction, (ii) the properties of hadrons in a nuclear medium, and (iii) the effect of impurities on nuclear properties. These are related to the fundamental problems in quantum chromodynamics (QCD).

We study the bound and resonant systems of the heavy meson ($P = \bar{D}$ or B) and the nucleus with nucleon number $A = 16, \cdots, 208$, where the $\bar{D}$ (B) meson is a pseudoscalar meson composed of a charm (bottom) antiquark $\bar{c}$ ($\bar{b}$), and a light quark $q = u, d$. The $\bar{D}$ (B) mesons in nuclei have no $q\bar{q}$ annihilation, and therefore the bound state is stable against strong decay. The attraction between the heavy meson and nucleon N, where the $PN - P^*N$ mixing plays an important role, has been discussed. P^* is a vector meson of $\bar{c}q$ or $\bar{b}q$, and the small mass splitting of P and P^* due to the heavy quark spin symmetry3) enhances the $PN - P^*N$ mixing effect.

We analyze the mesic nuclei as two-body systems of the P meson and the nucleus. The P-nucleus potential is given by the folding potential,

$$V_{fold}(r) = \int V^{PN}(r - r')\rho(r')d^3r', \tag{1}$$

with the P-nucleon potential $V^{PN}(r)$ and the nucleon number distribution function $\rho(r)$. As for the potential $V^{PN}(r)$, we employ the one pion exchange potential (OPEP). The OPEP is given by the Born term of the pion exchange scattering amplitude described by the effective Lagrangians. Although the $PN - P^*N$ mixing gives coupled-channel potentials, it can be expressed as a single channel potential,

$$V^{PN}(r) = V_{11}(r) + V_{12}(r)\frac{\psi_2^E}{\psi_1^E} + V_{13}(r)\frac{\psi_3^E}{\psi_1^E}, \tag{2}$$

where $V_{ij}(r)$ is the (i, j) component of the OPEP, and ψ_i^E is i component of the eigenfunction of the PN system.4,5) Here, we focus on the OPEP in the $I(J^P) = 0(1/2^-)$ state, because it is the most attractive one. The distribution function $\rho(r)$ is given by

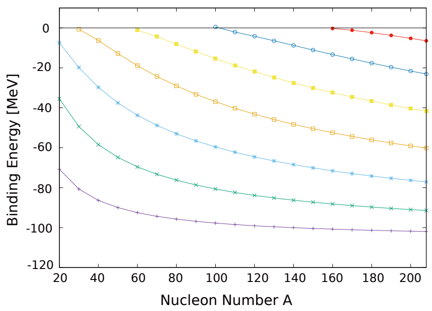

Fig. 1. Energy obtained for the $\bar{D}$-nucleus systems with S-wave for various nucleon numbers A.

$$\rho(r) = \frac{\rho_0}{1 + \exp\left[(r - R)/a\right]}, \tag{3}$$

where $\rho_0 = 0.17$ fm^{-3}, $a = 0.54$ fm, and R is chosen to satisfy $\int \rho(r)d^3r = A$.6)

To obtain the bound and resonant states of the two-body P-nucleus system, the Schrödinger equations are solved for the nucleon number $A = 16, \ldots, 208$. As a result, many states are obtained for the P-nucleus systems with S, P, D, and F-waves. Figure 1 shows the energy obtained for the $\bar{D}$-nucleus systems with S-wave. We see that the binding energy increases as the nucleon number A increases. For states with P, D and F-waves, the resonances are also obtained by the centrifugal barrier. We also found many bound and resonant states in the bottom sector. The binding energy and number of bound states of the B-nucleus are larger than those of the $\bar{D}$-nucleus, because small mass splitting between B and B^* mesons enhances the attraction from the OPEP. The information on the energy spectra of mesic nuclei with a heavy antiquark will be useful for future experiments at the Facility for Antiproton and Ion Research (FAIR), the Japan Proton Accelerator Research Complex (J-PARC), the Relativistic Heavy Ion Collider (RHIC), the Large Hadron Collider (LHC), and so forth.

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