Open bottom and hidden bottom mesons in the medium

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Introduction

Medium modifications of mesons is an important problem of contemporary research in strong interaction physics. Extensive investigations have been carried out over the years for the medium modifications of light vector mesons as well as for kaons and antikaons, which were subsequently generalized to charmed mesons, as well as for charmonium states within a chiral effective theory. We consider here a further generalization to the bottom sector, as described in the following sections.

Open bottom mesons

We study the in-medium behavior of B and $\bar{B}$ mesons [1], using a generalization of the chiral effective approach that was earlier used to study kaons and antikaons, as well as D mesons, as mentioned before in the introduction. In particular, we study their effective masses in isospin asymmetric, hot and dense hadronic matter, and also the sensitivity of these medium effects to characteristic parameters - the total baryonic density (ρ_B) of the medium, temperature (T), isospin asymmetry parameter (defined by the equation $\eta = -\sum_i I_{3i}\rho_i/\rho_B$, where I_{3i} is the $z-$component of isospin of the i^{th} baryon) and, strangeness fraction, ($f_s = \sum_i s_i\rho_i/\rho_B$, where s_i is the number of strange quarks in the i^{th} baryon). However, since the mass of the bottom quark is well above the energy scale of hadronic physics, we treat the bottom degrees of freedom as frozen in the medium and all medium modifications arise because of the light quark content of these open-bottom mesons.

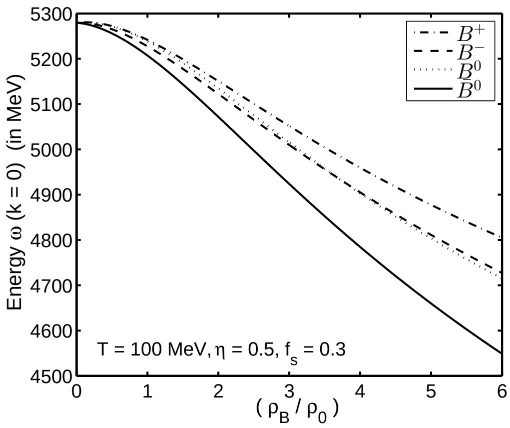

FIG. 1: Effective medium mass for the $B(B^+, B^0)$ and $\bar{B}(B^-, \bar{B}^0)$ mesons, as a function of the baryonic density ρ_B (measured in units of the nuclear saturation density, ρ_0), for typical values of temperature ($T = 100$ MeV), isospin asymmetry parameter ($\eta = 0.5$), and strangeness fraction ($f_s = 0.3$).

Both B and $\bar{B}$ mesons are observed to experience net attractive interactions in the medium, hence reducing their effective medium masses. The same is conveyed through Fig. 1, where their medium masses are shown as a function of baryonic density, at typical values of other parameters. Owing to equal and opposite contributions from the Weinberg-Tomozawa interaction term, medium masses of particles and antiparticles, (B^+, B^-) as well as (B^0, $\bar{B}^0$), are observed to be unequal, as is conspicuous from Fig. 1. This Weinberg-Tomozawa term is observed to give a larger drop to the two $\bar{B}$ mesons as compared to the two B mesons. An increase in the value of f_s is observed to further reduce the in-medium mass for each of these four mesons, while in an asymmetric

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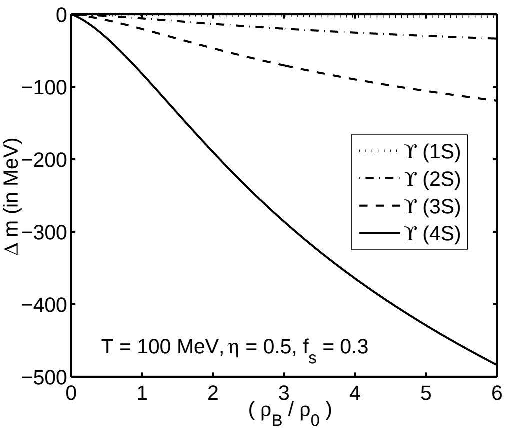

FIG. 2: Mass shifts for the bottomonium S-states, in hot, isospin asymmetric hyperonic matter, as a function of baryonic density ρ_B expressed in units of the nuclear saturation density ρ_0, at typical values of temperature ($T = 100$ MeV), isospin asymmetry parameter ($\eta = 0.5$), and strangeness fraction ($f_s = 0.3$).

medium, isospin pairs are observed to acquire unequal masses. The temperature dependence of these effects is observed to be considerably weaker. Overall, out of the four, $\bar{B}^0$ meson is observed to experience the largest mass drop, due to adding up of attractive contributions from the extra isospin asymmetric contributions, and an attractive contribution from the Weinberg-Tomozawa term.

Hidden bottom mesons

We also calculate the effective medium-masses of the bottomonium S-states ($\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ and $\Upsilon(4S)$), in the same context of an asymmetric hadronic medium [2]. Their medium modifications arise due to the interaction of these heavy quarkonium states with the gluon condensates of QCD. We calculate the in-medium gluon condensates from the medium modification of a scalar dilaton field within the chiral $SU(3)$ model, which was introduced in the model to incorporate the broken scale invariance of QCD. The mass shift in these states is calculated using the leading order mass shift formula, derived in the large bottom quark mass limit. In the limit of zero current quark masses (for the light quarks u, d and s), the change in the gluon condensate is directly proportional to the changes in fourth power of this dilaton field, and hence, its dependence on the aforementioned parameters directly extends over to these bottomonia states. As with their open bottom counterparts, we also analyze the effects of density, strangeness, isospin asymmetry parameter and temperature on their effective masses. We observe a drop in the masses of these bottomonium states, which is again observed to be highly density dependent. Fig. 2 shows the typical magnitude of their mass shifts as a function of baryonic density, at typical values of the other parameters. In general, the excited states are modified more strongly as compared to the ground state, as can be clearly seen from the figure.

We have, thus, investigated the in-medium behavior of open bottom (B and $\bar{B}$ mesons), as well as hidden bottom mesons (bottomonia S-states). In general, we find an appreciable dependence of the medium mass of these mesons on the total baryonic density as well as the strangeness content of the medium. These medium effects can affect the propagation and flow of these mesons in heavy-ion collision experiments, apart from affecting other observables like particle ratios and dilepton spectra emanating from relativistic heavy ion collisions.

Acknowledgments

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References

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