Heavy Flavour Mesons in Hadronic Medium

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Thesis Abstract

This thesis attempts to understand the properties of various heavy flavor mesons such as open charm mesons, open bottom mesons, charmonium states, and upsilon states in the nuclear and strange hadronic medium at finite baryon densities and/or temperature in the presence of strong magnetic fields. In Heavy-Ion Collision experiments where such extreme conditions are created, this study is necessary as these medium modifications can affect the experimental observables. To study the in-medium properties of these mesons, we shall follow a chiral effective Lagrangian approach based on the non-linear realization of chiral symmetry and the broken scale invariance of QCD. In the chiral effective model, the scalar fields (the non-strange field σ, strange field ζ, isovector field δ) mimic the chiral condensates and the dilaton field χ mimics the gluon condensates of QCD. From the mean-field Lagrangian density, the coupled equations of motion of scalar fields are obtained, which are expressed in terms of scalar densities of the baryons. In the presence of the magnetic field, the number density and scalar density of charged baryons will have contributions from Landau energy levels. The effects of the anomalous magnetic moments of the baryons are also incorporated. At finite temperatures, the number density and scalar density of baryons also contain thermal distribution functions. The equations of motion of these scalar fields are solved to obtain their values at different baryon densities, isospin asymmetry, magnetic field, strangeness fraction, and temperature, using which we calculate the mass modifications of heavy flavor mesons in the magnetized hadronic medium.

Initially, we investigate the effective masses of pseudoscalar open charm mesons ($D(D^0$, $D^+)$, $\bar{D}(\bar{D^0}$, $D^-)$, $D_s({D_s}^+$, ${D_s}^-))$ as well as pseudoscalar open bottom mesons ($B(B^+$,$B^0)$, $\bar{B}(B^-$,$\bar{B^0})$, $B_s({B_s}^0$, $\bar{{B_s}^0}))$ in the magnetized hadronic medium. The chiral $SU(3)$ model has been generalized to chiral $SU(4)$ in the case of open charm mesons and chiral $SU(5)$ in the case of open bottom mesons to incorporate their interactions with the light hadronic sector. The masses of these open

heavy flavor mesons get modified through their interactions with the baryons and the scalar mesons (σ, ζ, and δ), which undergo modifications in the magnetized medium. The charged open heavy flavor mesons have additional positive mass shifts due to Landau quantization in the presence of the magnetic field. We also investigate the mass shifts of heavy quarkonium states such as charmonium states (J/ψ, $\psi(3686)$, $\psi(3770)$, χ_{c0}, χ_{c2}) and upsilon states ($\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$, $\Upsilon(4S)$, and $\Upsilon(1D)$) in the magnetized hadronic medium using the chiral effective model. The mass shifts of these heavy quarkonium states originate from the modification of the gluon condensates in the magnetized medium simulated by the variation of the dilaton field (χ). The effect of masses of light quarks on the modification of gluon condensates and subsequently on these mass shifts are also considered in the present work. From the obtained in-medium masses of charmonia and open charm mesons, we also calculate the partial decay widths of various charmonium states to $D\bar{D}$ in the magnetized nuclear medium, using a light quark pair creation model, namely the $^3P_0$ model. Finally, we investigate the effects of magnetically induced spin mixing between the pseudoscalar and the corresponding vector open charm mesons, as well as the pseudoscalar and vector charmonium states on their in-medium properties. The effects of spin mixing are incorporated through a phenomenological effective Lagrangian interaction.

The heavy flavor mesons experience a mass drop in the magnetized medium with an increase in baryon density. At high densities, the effects of the isospin asymmetry and the anomalous magnetic moments of the baryons on the meson masses are also quite prominent. The effective masses of open heavy flavor mesons decrease more in the strange hadronic medium than in the nuclear medium. The masses of these mesons initially increase with a rise in temperature, and beyond a high-temperature value, their masses are observed to drop. Due to Landau quantization, the charged mesons have substantial mass modifications in the presence of the magnetic field. An increase in the magnetic field is observed to result in larger in-medium masses of these heavy flavor mesons when the temperature is moderate. However, at higher temperatures, the in-medium masses of all mesons become smaller with an increase in the magnetic field. The decay widths of the charmonium state to D^+D^- are observed to be suppressed in the magnetic field at low baryon densities. When the spin mixing effect is incorporated, the mass of the longitudinal component of the neutral vector meson increases, and the mass of the pseudoscalar neutral mesons decreases with the magnetic field. For charged mesons, the effect of Landau quantization is observed to be dominant compared to the effect of spin mixing. These in-medium modifications can have experimental consequences, such as the production and propagation of these mesons in various asymmetric heavy-ion collision experiments.