Scalar D_0 and B_0 mesons in hot and dense strange hadronic medium

Rahul Chhabra* and Arvind Kumar†
Dr. B.R. Ambedkar National Institute of Technology, Jalandhar-144011

Introduction

We observed the medium modification of masses and decay constants of scalar D and B mesons in hot and dense strange medium using chiral SU(3) model and QCD sum rule approach. If D meson get large mass reduction, then higher charmonium states can decay to these mesons instead of $J/\psi(c\bar{c})$, hence J/ψ is suppressed. Similarly, $\Upsilon(b\bar{b})$ will be suppressed if B meson undergo large mass reduction in the medium. The understanding of in-medium properties of D and B mesons will be important for experiments, like, CBM(Compressed Baryonic Matter) and PANDA(anti-Proton Annihilation at Darmstadt) under FAIR project at GSI, Germany.

Methodology

In this section, we will discuss the methodology used in the present investigation. We start with chiral SU(3) model, which is based on the broken scale invariance, non-realization and broken scale invariance properties of chiral symmetry. It includes an effective Lagrangian density, which can be solved using mean field approximation, to calculate the coupled equations of motion for scalar field σ, ζ and scalar dilaton field χ. We can solve these coupled equations of motion to calculate the temperature and density dependence of fields in strange medium. Using broken scale invariance we can evaluate gluon condensates in term of above mentioned fields and also scalar quark condensates $< q\bar{q} >$, can be evaluated through explicit symmetry breaking term of the Lagrangian density within chiral SU(3) model [2]. Condensates, which we found from chiral model, acts as input in QCD sum rule equation of D_0 and B_0 mesons. In QCD Sum rule, we start with two point correlation function, which is divided into a vacuum part, a static nucleon part and pion bath term. In present investigation, we observed the temperature dependence through the scalar fields of chiral SU(3) model, instead of considering the contribution through pion bath term. The nuclear expectation value of quark and gluon condensates are substituted in QCD sum rule of scalar meson [2, 3]. These condensates can be further used to calculate the shift in masses and decay constants of D_0 and B_0 mesons [3].

*Electronic address: rahulchhabra@ymail.com
†Electronic address: kumara@nitj.ac.in

Results and Discussion

The values of masses, decay constants and threshold parameters of $D_0(B_0)$ mesons are 2.355(5.74), 0.334(0.28) GeV and 8(39) GeV^2, respectively. Nuclear saturation density chosen in this paper is 0.15 fm^{-3}. The value of coupling constants $g_{D_0 N\Lambda_c} \approx g_{D_0 N\Sigma_c} \approx g_{B_0 N\Lambda_b} \approx g_{B_0 N\Sigma_b}$ is approximated to 6.74 [2]. The Borel window, chosen to neglect the uncertainty originated from Borel transformation, for D_0 and B_0 are, (5-9) GeV^2 and (27-35) GeV^2, respectively. In fig.1(fig.2) we show the variation of masses(decay constants) of D_0 and B_0 mesons with squared Borel mass parameter, M^2 for different values of baryonic density ρ_B , strangeness fractions f_s and temperature T of the medium. Strangeness fraction f_s, is defined as, $f_s = \frac{\sum_i |s_i|\rho_i}{\rho_B}$. Here, s_i, is the number of strange quarks and ρ_i is the number density of i^{th} baryon [1]. In non-strange medium, i.e, $f_s = 0$ and at temperature $T = 0$, when we increase the density from $\rho_B = \rho_0$ to $\rho_B = 4\rho_0$, then, the value of shift in mass(decay constant) of D_0 and B_0 changes from 74(-8) to 146(-16) MeV, whereas, for B_0 meson, it changes from 222(19) to 414(51) MeV, respectively. Hence, masses of D_0, B_0 mesons increase more as compared to their vacuum values. Positive mass shift indicates

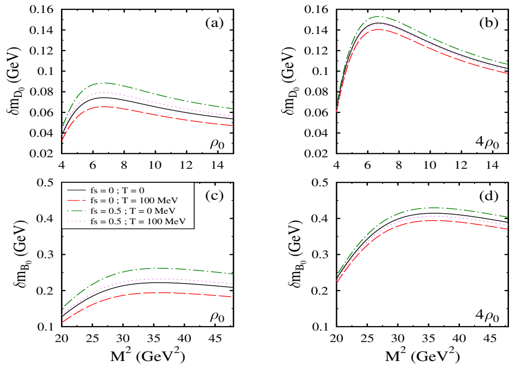

FIG. 1: (Color online) Figure shows the effect of temperature T, strangeness fraction f_s and density ρ_B on the shift in masses of D_0 and B_0 mesons as a function of square of Borel mass parameter,M^2.

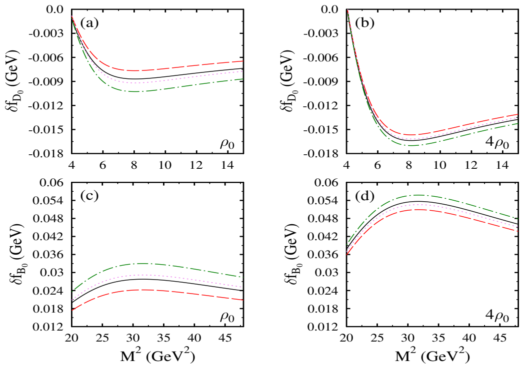

FIG. 2: (Color online) Figure shows the effect of temperature T, strangeness fraction f_s and density ρ_B on the decay shift of D_0 and B_0 mesons as a function of square of Borel mass parameter,M^2.

repulsive interaction with the nucleons, hence its difficult to form D_0N and B_0N bound states. On the other hand, shift in the decay constants, indicate the change in decay rates of D and B mesons. At nuclear saturation density, $\rho_B = \rho_0$ and temperature $T = 0$, on shifting from non-strange medium ($f_s = 0$) to strange medium ($f_s = 0.5$), the above values change to 88(-10) and 262(33) MeV for D_0 and B_0 mesons respectively. Modification of masses and decay constants of these mesons get modified through the modification of quark and gluon condensates [2]. Effect of temperature on shift is complimentary to the above discussion. When we increase the temperature of the medium from 0 to 100 MeV, then decrease in the magnitude of shift in mass(decay constant) for D_0, B_0 mesons is observed, e.g, for, $\rho_B = \rho_0$ and in non-strange medium, i.e, $f_s = 0$, values of shift in masses(decay constants) are observed to be 65(-7.6) and 194(19)MeV for scalar D and B mesons respectively. Previous works [3, 4] using QCD and Quark meson coupling model indicate the positive mass shift, which is consistent with our results. It indicates that decay of higher charmonium states to D_0, B_0 mesons may be suppressed and these mesons may not cause a decrease in J/ψ mesons in heavy ion collision experiments.

Conclusion

In summary, we observe that, the finite density or strangeness fraction of the medium cause an increase in the masses of scalar D and B mesons. However, for fixed baryonic density and strangeness fraction, finite temperature of the medium cause decrease in the magnitude of shift in masses and decay constants of D_0 and B_0 mesons. These observation may be verified in upcoming CBM experiment of FAIR project at GSI, Germany.

Acknowledgements

Authors greatfully acknowledge the Department of Science and Technology(Government of India) for providing the financial help under project(SR/FTP/PS-209/2012).

References

[1] Arvind Kumar, Rahul Chhabra, arXiv:1506.02115

[2] Arvind Kumar, Adv. in High Energy Physics **2014**, 549726 (2014) .

[3] Zhi-Gang Wang, Tao Huang, Phys. Rev. C **84**, 048201 (2011).

[4] Laura Tolós, Raquel Molina, Daniel Gamermann and Eulogio Oset, Nucl. Phys. A **827**, 249c (2009).