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Diffusion of hidden charm mesons in hadronic medium

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Abstract

The drag and diffusion coefficients of a hot hadronic medium have been evaluated by using hidden charm mesons as probes. The scattering amplitudes required for the evaluation of these coefficients are calculated using an effective theory and scattering lengths obtained from lattice QCD calculations. It is found that although the magnitude of the transport coefficients are small their temperature variation is strong. The insignificant momentum diffusion of J/ψ in the hadronic medium keeps their momentum distribution largely unaltered. Therefore, the task of characterization of quark gluon plasma by using the observed suppression of J/ψ at high momentum will be comparatively easier.

Keywords: Drag and diffusion coefficients; Hidden charm meson; Heavy ion collision

1. Introduction

The experimental evidence of J/ψ suppression by NA50 [1], NA60 [2] as well as by the PHENIX [3] Collaboration has long been suggested as a signal of quark–gluon plasma (QGP) formation in heavy ion collisions [4]. However, other mechanisms such as the J/ψ absorp-

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tion by comoving hadrons have also been proposed as an alternative mechanism to explain the suppression [5], indicating that the inelastic scattering rates of J/ψ in the hadronic phase is significant [6–8]. In addition, the opening of $J/\psi \to D\overline{D}$ decay in the medium due to in-medium modification of D mesons [9,10] may also play a significant role in J/ψ suppression in a hadronic environment.

Heavy quark transport in hadronic matter is a topic of high contemporary interest [11–17]. The drag and diffusion of open charm [13] and bottom [15] mesons and the role of hadronic matter in their suppression in heavy ion collisions [18] have been investigated using effective hadronic interactions based on heavy quark effective theory. The suppression of heavy flavors in the hadronic phase in comparison to QGP was found to be smaller at LHC than at RHIC, suggesting that the characterization of QGP at LHC would be less complicated than at RHIC [18].

Recently we have obtained the drag and diffusion of the Λ_c baryon in hadronic matter [19] and found those to be significant. In fact, the drag of the Λ_c being lower than that of the D mesons was seen to non-trivially affect the p_T dependence of the Λ_c/D ratio and thus the R_{AA} of single electrons originating from the decay of Λ_c. Motivated by these results we proceed to study the temperature variation of the drag and diffusion coefficients of J/ψ and η_c in a comoving hadronic medium. For evaluating these quantities the required interaction cross sections have been evaluated employing an effective hadronic Lagrangian. Drag and diffusion coefficients have also been estimated using T-matrix elements extracted from scattering lengths obtained from lattice QCD calculations.

In the next section we provide the formulae for the drag and diffusion coefficients followed by a discussion on the matrix elements of elastic scattering of the J/ψ with the light vector mesons in section 3. Results are given in Section 4 and finally a summary in Section 5. We provide the squared matrix elements in the appendix.

2. Formalism

The drag (γ) and diffusion (D) coefficients of J/ψ and η_c are obtained from the elastic scattering of J/ψ with the light thermal hadrons (H) which constitute the equilibrated thermal medium. For the process $J/\psi, \eta_c(p_1) + H(p_2) \to J/\psi, \eta_c(p_3) + H(p_4)$, the drag γ can be expressed as [20]:

$$\gamma = p_i A_i / p^2 \,, \tag{1}$$

where A_i is given by

$$\begin{aligned} A_i = {} & \frac{1}{2E_{p_1}} \int \frac{d^3 p_2}{(2\pi)^3 E_{p_2}} \int \frac{d^3 p_3}{(2\pi)^3 E_{p_3}} \int \frac{d^3 p_4}{(2\pi)^3 E_{p_4}} \frac{1}{g_{(J/\psi,\eta_c)}} \\ & \sum \overline{|M|^2} (2\pi)^4 \delta^4(p_1 + p_2 - p_3 - p_4) f(p_2)\{1 \pm f(p_4)\}[(p_1 - p_3)_i] \\ \equiv {} & \langle\langle (p_1 - p_3) \rangle\rangle \,. \end{aligned} \tag{2}$$

The $g_{(J/\psi,\eta_c)}$ is the statistical degeneracy of the probes, J/ψ or η_c. The thermal distribution function $f(p_2)$ of the hadron H in the incident channel takes the form of Bose–Einstein or Fermi–Dirac distribution depending on its spin and $1 \pm f(p_4)$ are their corresponding Bose enhanced or Pauli blocked phase space factor in their final states. The drag coefficient of Eq. (2) is just a measure of the thermal average of the momentum transfer, $p_1 - p_3$ weighted by the square of the invariant amplitude $\overline{|M|^2}$ for the elastic scattering of J/ψ and η_c with thermal hadrons, generically denoted as H.