Heavy flavor as a probe to quark gluon plasma

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The nuclear collisions at Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider(LHC) energies are aimed at creating a phase where the bulk properties of the matter are governed by (light) quarks and gluons. Such a phase of matter is called Quark Gluon Plasma (QGP). The study of the bulk properties of QGP is a field of great contemporary interest and the heavy flavors, mainly, charm and bottom quark, play a crucial role in such studies.As the relaxation time for heavy quarks are larger than the corresponding quantities for light partons, the light quarks and the gluons get thermalized faster than the heavy quarks. Therefore, the propagation of heavy quarks through QGP (mainly contains light quarks and gluons) may be treated as the interactions between equilibrium and non-equilibrium degrees of freedom and the Fokker-Planck (FP) equation provides an appropriate framework [1] for such studies. Since heavy quarks remain out of equilibrium *i.e* they are not a part of the equilibrated system and their production is restricted to the primordial stages of the collision, they can not decide the bulk properties of the system, rather act as an efficient probe to extract information about the system. Therefore, in the present work we will use the nuclear suppression factor[1], $R_{\rm AA}$ and the elliptic flow v_2^{HF} of heavy quarks [2, 3] as a probe to extract the properties of QGP. Here we have made an attempt to reproduced both the nuclear suppression factor, $R_{\rm AA}$ and the elliptic flow v_2^{HF} of heavy quarks for the same set of inputs, with in the pQCD framework.

The evolution of heavy quarks momentum distribution function, while propagating through the QGP are assumed to be governed by the FP equation which reads,

$$\frac{\partial f}{\partial t} = \frac{\partial}{\partial p_i}\left[A_i(p)f + \frac{\partial}{\partial p_j}[B_{ij}(p)f]\right] \quad (1)$$

where the kernels A_i and B_{ij} are given by

$$A_i = \int d^3k\omega(p,k)k_i$$
$$B_{ij} = \int d^3k\omega(p,k)k_ik_j. \quad (2)$$

for $\mid \mathbf{p} \mid \rightarrow \mathbf{0}$, $A_i \rightarrow \gamma p_i$ and $B_{ij} \rightarrow D\delta_{ij}$ where γ and D stand for drag and diffusion co-efficients respectively.

The basic inputs required for solving the FP equation are the dissipation co-efficients and initial momentum distributions of heavy the quarks. The drag and diffusion coefficients have been evaluated by taking in to account both the collisional and radiative processes [1]. In the radiative process the dead cone and Landau-Pomerenchuk-Migdal (LPM) effects are included [1]. In evaluating the drag co-efficient we have used temperature dependent strong coupling, α_s [4].The Debye mass, $\sim g(T)T$ is also a temperature dependent quantity used as cut-off to shield the infrared divergences arising due to the exchange of massless gluons. The initial momentum distribution of heavy quarks in pp collisions have been taken from the NLO MNR code. The solution of the FP equation for the heavy (charm and bottom) quarks is convoluted with the fragmentation functions of the heavy quarks to obtain the p_T distribution of the D and B mesons. For heavy-quark fragmentation function, we use the Peterson function.

The STAR [5] and the PHENIX [6] collaborations have measured the non-photonic single electron inclusive p_T spectra recently both for Au+Au and p+p collisions at $\sqrt{s_{NN}} = 200$

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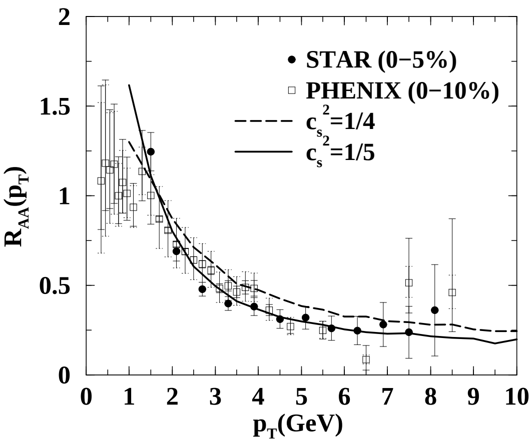

FIG. 1: Comparison of R_{AA} obtained in the present work with the highest RHIC energy

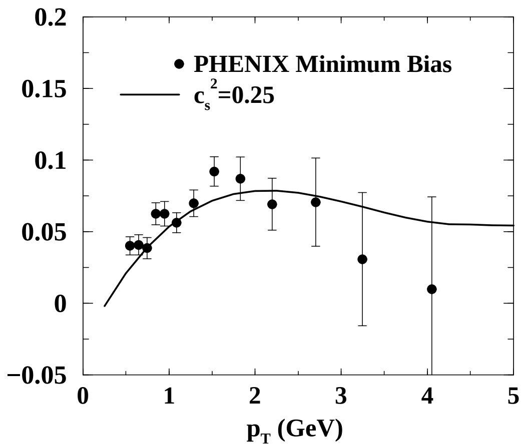

FIG. 2: Comparison of v_2^{HF} obtained in the present work with the highest RHIC energy, taken from [7]

GeV. The quantity

$$R_{AA}(p_T) = \frac{\frac{dN^e}{d^2p_T dy}^{\mathrm{Au+Au}}}{N_{coll} \times \frac{dN^e}{d^2p_T dy}^{\mathrm{p+p}}} \quad (3)$$

called the nuclear suppression factor, will be unity in the absence of any medium. However, the experimental data from both the collaborations [5, 6] shows substantial suppression ($R_{AA} < 1$) for $p_T \geq 2$ GeV indicating the interaction of the plasma particles. The resulting spectra describes the data reasonably well in Fig. 1 Lower value of c_s makes the expansion of the plasma slower enabling the propagating heavy quarks to spend more time to interact in the medium and hence lose more energy before exiting from the plasma which results in less particle production at high p_T. Further lowering of c_s gives further suppressions.

The coefficient of elliptic flow, $v_2^{e^-}$ then can be obtained as:

$$v_2^{HF}(p_T) = \langle cos(2\phi) \rangle = \frac{\int d\phi \frac{dN}{dy dp_T d\phi}|_{y=0} cos(2\phi)}{\int d\phi \frac{dN}{dy dp_T d\phi}|_{y=0}} \quad (4)$$

The time evolution of this systems has been studied by using the (2+1) dimensional hydrodynamical model with boost invariance along the longitudinal direction. The data is well reproduced with the pQCD cross section in Fig. 2. The sensitivity of the R_{AA} and the v_2^{HF} on the initial distribution as well as the initial condition will be discussed. The nonzero baryonic chemical potential dependent of the drag and diffusion coefficients as well as the R_{AA} and the v_2^{HF} will be presented at the symposium.

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