

The D_s Meson as a quantitative probe of diffusion and hadronization in heavy ion collisions

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Heavy charm and bottom quarks are powerful probes of the hot matter created in collisions of nuclei at high energies. Due to their large mass and the short lifetime of the system they are not expected to reach full kinetic equilibrium. However, the approach to thermalization encodes valuable information about the strength of the heavy-quark coupling to the medium.

Previously we have reported the development of a comprehensive formalism to calculate heavy-quark (HQ) diffusion in quark-gluon plasma (QGP), HQ hadronization with recombination and fragmentation, and subsequent diffusion of heavy mesons in hot hadronic matter [1]. Heavy-flavor relaxation rates are obtained from non-perturbative T-matrix calculations [2] in the QGP and phenomenological cross sections of D-mesons in the hadronic phase [3]. The background medium is modeled through ideal hydrodynamics carefully fitted to bulk-hadron observables from RHIC and LHC.

In the current reporting period we have suggested using the D_s meson (a charm-strange quark bound state) as a tool to disentangle the HQ hadronization mechanism and the importance of the hadronic phase for heavy-flavor diffusion [4]. We have checked the viability of our idea using our formalism [1]. We find that the nuclear modification factor R_{AA} of the D_s , when compared to the R_{AA} of the D meson, exhibits the influence of charm-quark recombination with thermal partons through the enhanced production of strange quarks in the fireball. On the contrary, charm fragmentation mechanisms would be undisturbed by the presence of thermal partons. Since the evolution of charm quarks figuring into the D_s and the D is identical up to hadronization, and since the hadronic phase does not significantly affect the R_{AA} of both D and D_s , a difference in their R_{AA} is associated with the amount of charm-quark recombination.

A similar idea applies when comparing the elliptic flow (v_2) of D_s and D mesons. Since the v_2 is very similar for both mesons after hadronization, and since the cross section for the D_s meson in hadronic matter is expected to be suppressed similar to that of multi-strange hadrons (which are known to exhibit an early freeze-out in heavy ion collisions), an observed splitting carries information about heavy-meson diffusion in the hadronic phase.

Fig.1 summarizes the predictions from our formalism for RHIC energies. Preliminary data from the ALICE experiment at LHC report a D_s R_{AA} which is consistently larger than the R_{AA} for the D meson, confirming the viability of our idea and hinting at an important role of quark recombination in open-charm meson observables.

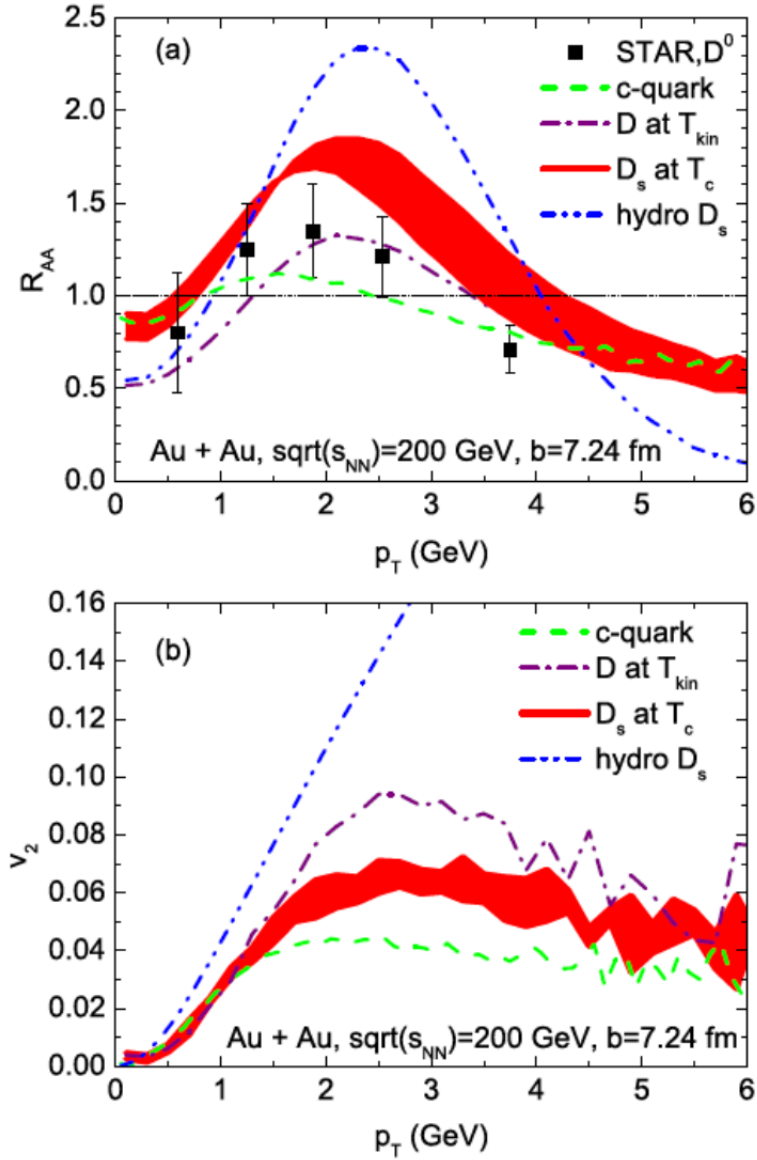


FIG. 1. Upper Panel: Nuclear modification factor R_{AA} for charm quarks before hadronization, D mesons at kinetic freeze-out and D_s mesons assumed to freeze-out just after hadronization, compared to fully thermalized D_s mesons calculated from hydrodynamics. The band for D_s mesons (due to uncertainties in the Cronin effect for the initial charm-quark spectra) is consistently above the D meson R_{AA} . STAR data are for minimum-bias D^0 mesons [5]. Lower Panel: The same set of curves for the elliptic flow v_2 . The D meson picks up a significant amount of additional flow in the hadronic phase. All curves are for semi-central Au+Au collisions at a center-of-mass energy of 200 GeV per nucleon pair.

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