Heavy flavor at the large hadron collider in a strong coupling approach

M. He, R.J. Fries, and R. Rapp

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 relatively short lifetime of the fireball they are not expected to reach full kinetic equilibrium. However, their 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 (HF) 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.

In the current reporting period we have conducted a systematic study of HF probes in Pb+Pb collisions at LHC energies (2.76 TeV per nucleon pair) [4]. We have tuned our hydrodynamic simulation to fit data on bulk-hadron spectra and elliptic flow at the LHC. We have run our strong-coupling HF formalism [1], which does not have any tunable parameters, within the fluid-dynamic simulation. Similar to our previous results at RHIC energies we find a characteristic "flow bump" in the nuclear modification factor of D mesons, indicating that HF particles are dragged along with the collective flow of the expanding fireball in central collisions, due to their strong coupling to the medium. The ALICE data for the D meson nuclear modification factor, R_{AA}, are reasonably well reproduced (see Fig. 1), but they

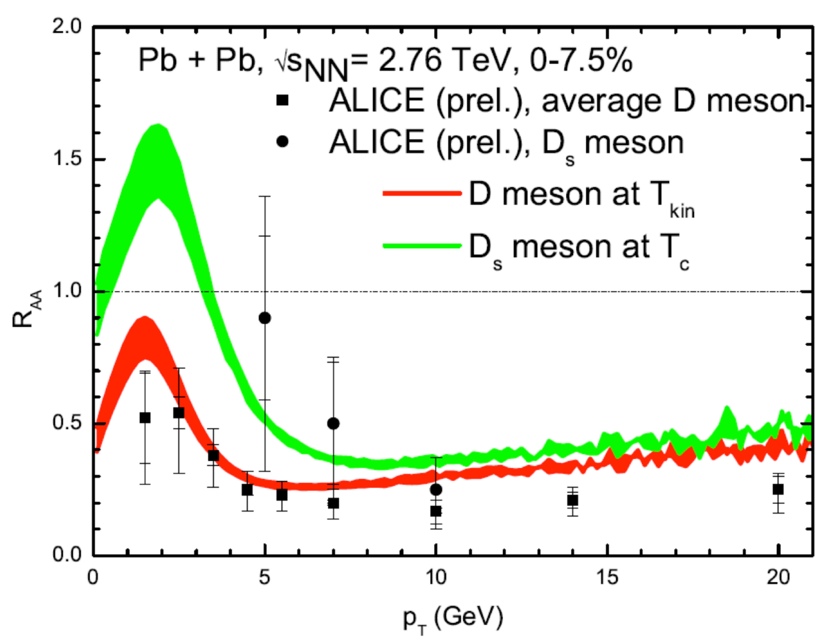

FIG. 1. Nuclear modification factor R_{AA} for D mesons at kinetic freeze-out and D_s mesons assumed to freeze-out just after hadronization in central Pb+Pb collisions at a center of mass energy of 2.76 TeV per nucleon pair, compared to preliminary data from the ALICE experiment [6]. The bands indicate uncertainties due to shadowing effects in the initial charm production.

currently do not extend to low enough momentum to fully resolve the predicted structure of the "flow-bump".

Recently, we predicted that the D_s meson (a bound state of a charm and strange quark) is a unique tool to disentangle effects from the HQ hadronization mechanism, and the impact of the hadronic phase on HF diffusion [5]. We had found that the 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 strange quarks whose production is well known to be enhanced in the fireball of high-energy heavy-ion collisions. We have implemented this mechanism into our calculation at LHC energies. First data on the D_s R_{AA} are now available from the ALICE experiment and indeed indicate a notable enhancement (see Fig. 1), in qualitative agreement with our prediction. More precise data on this observable are expected soon from RHIC and LHC.

We have also evaluated the sensitivity of open HF transport properties to the azimuthal anisotropy in semi-central Pb+Pb collisions, by comparing our calculations to data for the R_{AA} in- and out-of-plane (see Fig. 2) and the elliptic flow (v_2) of D mesons and HF decay electrons. A fair overall description of ALICE data on in- vs. out-of-plane suppression, the resulting v_2 for D-mesons (which tends to be somewhat underestimated) and HF leptons, as well as CMS data on non-prompt J/ψ R_{AA} from B meson decays emerges. This provides a significant improvement on the challenge of simultaneously describing HF R_{AA} and v_2 data at the LHC.

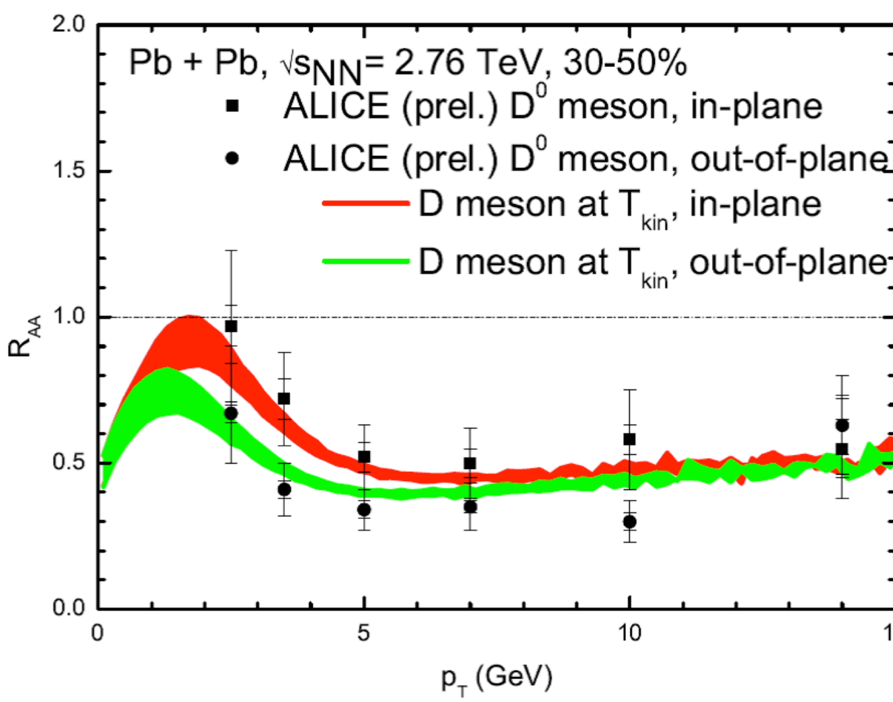

FIG. 2. Nuclear modification factor R_{AA} for D mesons at kinetic freeze-out in the reaction plane and out of the reaction plane for semi-central (30-50%) Pb+Pb collisions at a center of mass energy of 2.76 TeV per nucleon pair, compared to preliminary ALICE data [7].

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