Bottom hadro-chemistry in high-energy hadronic collisions

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Heavy-flavor (HF) hadrons, containing either charm or bottom quarks (or both), are among the most promising probes of the strongly-coupled quark-gluon plasma (sQGP) and its hadronization as being investigated in high-energy collisions of heavy nuclei [1]. Low-momentum diffusion of heavy quarks through the QGP gives unique access to a fundamental transport parameter, the HF diffusion coefficient (scaled by the thermal wavelength), $\mathcal{D}_s(2\pi T)$. In addition, the abundances and transverse-momentum (p_T) distributions of different HF hadron species, emerging from the same underlying distribution of heavy quarks after transport through the QGP, open a direct window on the hadronization process in QCD. The theoretical implementation of these ideas *heavily* relies on the large scale provided by the charm- and bottom-quark masses, compared to other basic scales in the problem, such as the nonperturbative QCD scale, Λ_{QCD}, and the temperature, T, of the ambient medium. This allows the use of static-potential and Fokker-Planck transport approximations, which in turn facilitates the implementation of nonperturbative physics of the sQGP [1], such as string-like interactions, resummations and large-width (i.e., quantum) effects in the HQ coupling to the thermal medium [2,3].

In the present work [4] we extend our previously developed strongly-coupled approach to heavy-quark production in nuclear collisions [5], consisting of a macroscopic medium background simulated by relativistic hydrodynamics and the microscopic T-matrix approach [3] for HQ diffusion and hadronization (as well as diffusion in the hadronic phase), by systematically applying it to the open-bottom sector. We first consider the bottom hadro-chemistry in elementary proton-proton (*pp*) collisions, where the central ingredient is a statistical hadronization model (SHM) with excited bottom mesons and baryons predicted by relativistic quark models (RQMs). This spectrum goes much beyond the currently known states listed by the particle data group (PDG), which, based on observed states in the light- and strange-quark sector, are incomplete. Especially the rich spectrum of excited baryons plays a key role through their decay feeddown into ground-state baryons, such as the Λ_b, resulting in a much improved description of the
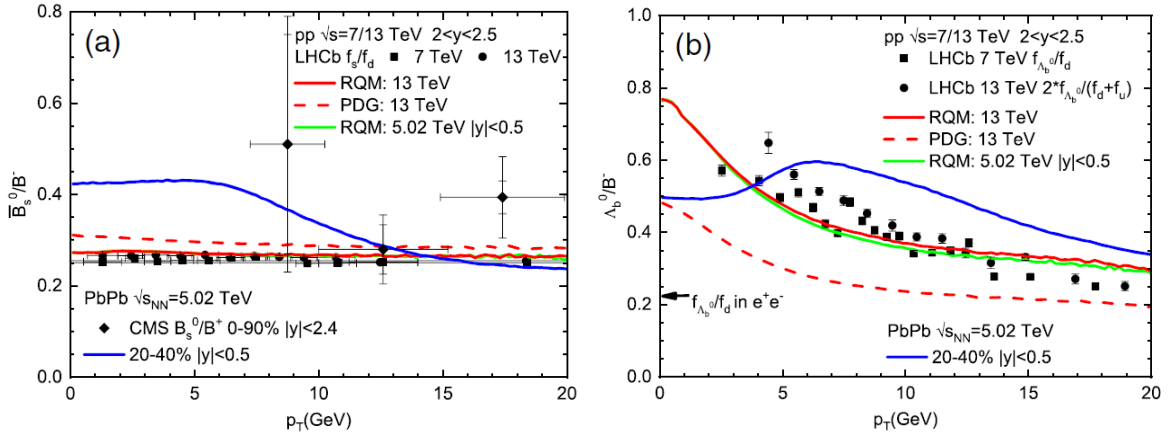

Fig. 1. Ratios of the ground-state strange-bottom meson, B_s (left), and bottom-baryon, Λ_b (right), to the B^- hadron in *pp* collisions within a combined SHM/fragmentation approach using either the states listed by the PDG (dashed lines) or from a relativistic quark model (solid lines), compared to LHCb data. The blue solid lines are the pertinent predictions for semicentral Pb-Pb(5TeV) collisions.

observed Λ_b/B ratio compared to using PDG states only, compare solid vs. dashed lines in the right panel of Fig. 1. Also, the B_s/B ratio slightly improves when using the RQM spectrum (left panel of Fig. 1), while predictions for the Ξ_b/B ratio are also provided (not shown).

The applications to heavy-ion collisions highlight the importance of the diffusion properties of the b-quark as well as its hadronization through recombination with thermal light and strange quarks in the flowing medium: for different b-hadrons we predict markedly different nuclear modification factors (i.e., the ratio between the p_T spectra in *pp* and AA collisions), featuring characteristic "flow bumps" at low p_T which are more pronounced for baryons than mesons, and a yield enhancement for b-hadrons containing strange quarks (B_s and Ξ_b), due to the enhanced concentration of (equilibrated) strange quarks in heavy-ion collisions, see left panel of Fig. 2. In the right panel, we compare our calculations to available LHC data, in terms of so-called "non-prompt" D and D_s mesons originating from decays of B mesons, showing fair agreement with ALICE data. With a much extended set of b-hadron data from future LHC and RHIC runs (with the new sPHENX detector), we believe that our comprehensive predictions will contribute to detailed interpretations and insights of hadronization mechanisms and refined, more accurate determinations of the HF transport coefficients in QCD matter.
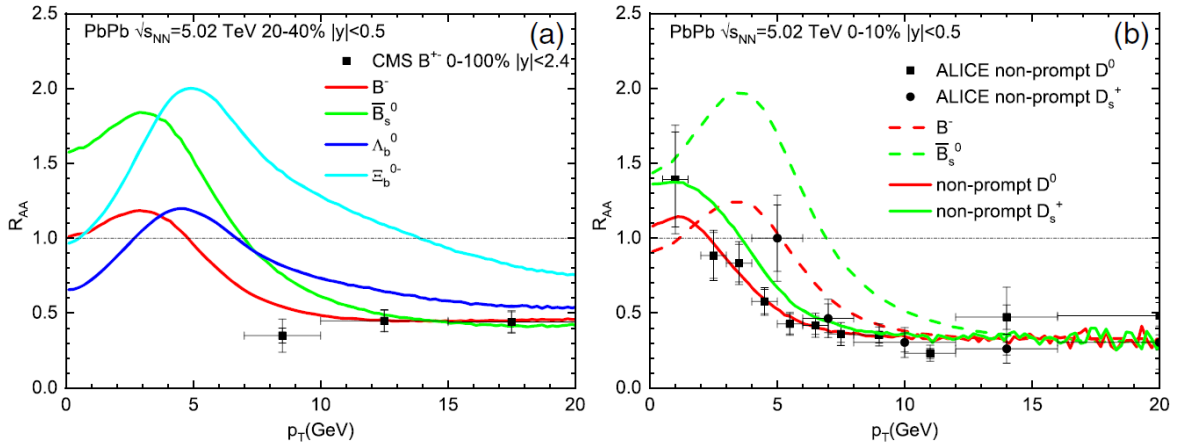

Fig. 2. Our predictions [4] for nuclear modification factors of various bottom hadrons in semicentral Pb-Pb collisions at the LHC (left), and the results of non-prompt D and D_s mesons (arising from pertinent b-hadron decays) compared to ALICE data in central Pb-Pb collisions (right).

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