Heavy-Flavor Production in pp via pA to AA Collisions

The heavy charm and bottom quarks ($Q = c, b$) play a special role in the investigation of QCD dynamics. On the one hand, their mass is much larger than the typical QCD scale, $M_Q \gg \Lambda_{\rm QCD}$, and on the other hand their lifetime is long enough to form hadronic bound states (which does not hold for the top quark). This renders them excellent probes of: i) hadronic structure in both open and hidden heavy-flavor (HF) sectors (where the large mass facilitates approximation schemes such as non-relativistic QCD or potential approaches); ii) particle production mechanisms in elementary collision systems (such as pp collisions, testing parton distribution functions and hadronization mechanisms); iii) nuclear effects in pA collisions (e.g., shadowing or absorption effects); iv) transport properties and hadronization of the deconfined medium in heavy-ion collisions.

The focus of the present activity is on interrelations of HF production mechanisms from small to large nuclear-collision systems. Several puzzling observations have been made in pp, pA and AA experiments at RHIC and the LHC in recent years that call for investigations of seemingly related (or maybe unrelated) mechanisms. For example, in pp collisions, a surprisingly large production yield of charm baryons has been reported, with a possibly strong dependence on rapidity; at the same time, a further enhancement of the Λ_c/D^0 ratio has been measured in AA collisions at both RHIC and the LHC. For quarkonium production an unexpected dependence on multiplicity has been measured in pp collisions; on the other hand, the enhancement in AA collisions was expected by predictions of transport and statistical hadronization models as a consequence of recombination of abundant anti-/charm quarks in the QGP and/or at the hadronization transition. In AA collisions, the spectra and elliptic flow of HF particles (D mesons and semileptonic decay leptons, and also charmonia) have shown remarkable evidence for collectivity (via the patterns in their nuclear modification factor ($R_{\rm AA}$) and the large elliptic flow) providing direct evidence for a strong coupling to the QGP; however, a large elliptic flow for these particles has been observed in pA collision as well, even though the QGP fireball, if any, is much smaller and shorter lived; furthermore, the pertinent $R_{\rm AA}$ shows only little modifications, except for the ψ'.

These observations raise several questions that will be addressed at the meeting, e.g.

(1) What is the nature of the hadronization mechanism of charm in pp collisions (string fragmentation, statistical hadronization, or else), and how does it evolve when going to pA and AA collisions?

(2) Is there a connection between the multiplicity dependence of charmonium production in pp collisions vs. AA collisions?

(3) While the collectivity of HF particles in AA collisions is successfully attributed to their transport and hadronization in a near thermalized QGP medium, what

drives their elliptic “flow” in small systems? Why does this collectivity not show up in their R_{AA}?

(4) Do potential initial-state effects currently not accounted for affect our interpretation of charm collectivity in AA collisions?

(5) What needs to be done to improve our extraction of the QCD medium's transport coefficients? What is the interplay of diffusion and hadronization?

(6) How can bottom/onium observables or HF exotics (such as $X(3872)$) improve our understanding of the issues in (1)-(5)?