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Recent results on open heavy-flavour observables in relativistic nuclear collisions

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Abstract

This article summarizes recent results on open heavy-flavour observables from selective experiments in relativistic nuclear collisions as presented during the Quark Matter 2014 conference. Commonalities and differences of their results are highlighted as a function of energy and relative to pp and pA collisions.

Keywords: Heavy-flavour; Energy loss; Nuclear modification factor

1. Introduction

Hadrons carrying open heavy-flavour, i.e. single charm or bottom quarks, are believed to be key probes for the study of the hot and dense state of strongly interacting matter since they are produced at an early stage of heavy-ion collisions in the initial hard scattering processes. Measurements of medium modifications of heavy-flavour transverse momentum (p_T) and rapidity (y) distributions in AA collisions relative to pp interactions allow us to study the mechanisms of heavy-quark energy loss in the medium. Measurements of the azimuthal distribution of heavy-flavour hadrons relative to the symmetry plane of the collision can provide the degree of thermalization of heavy-quarks within the medium. Apart from providing the crucial reference for AA collisions, measurements in pp collisions serve as a sensitive test of perturbative QCD (pQCD). Measurements in pA collisions allow us to quantify the cold nuclear matter effect in the initial state and to deduce the role of final-state effects in AA collisions.

At RHIC, a large suppression of high p_T electrons from semi-leptonic heavy-flavour decays was observed in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV relative to pp collisions [1,2]. At the

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LHC, the first ALICE results on the nuclear modification factor for charm hadrons in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV also indicate strong suppression [3]. The suppressions are almost as large as those observed for light-flavour hadrons [1,3] in contrast to the predicted smaller suppressions for heavy quarks relative to light quarks due to color-charge and quark-mass dependence of the energy loss [4–8]. The quantitative description of the experimental data has proven to be a challenge for many theoretical calculations [9,10] and the recent data measured differentially in multiple observables at different collision energies and systems, presented at this conference, provide significant additional constraints.

2. Experimental results

2.1. pp collisions

Heavy quark production cross sections in pp collisions have been measured in multiple observables since the beginning of the heavy-ion experiments at RHIC and at the LHC, extending their kinetic reaches and exploring different collision energies. PHENIX performed initial measurements of the charm and bottom cross sections in pp collisions via dielectron mass spectra [11] and electron–hadron correlations [12]. STAR measured the $b\bar{b}$ cross section in pp collisions [13] via single electron spectra. As new results the p_T-differential production cross sections of D^0 and D^{*+} mesons measured at $\sqrt{s} = 200$ GeV and 500 GeV were reported by STAR (down to $p_T \sim 0.4$ GeV/c for 200 GeV and $p_T \sim 1$ GeV/c for 500 GeV). ALICE reported on heavy-flavour measurements at $\sqrt{s} = 2.76$ TeV in pp collisions, besides the measurements at $\sqrt{s} = 7$ TeV shown in the previous Quark Matter conference, for D-mesons production via hadronic decays at mid-rapidity [14], heavy-flavour electron (mid-rapidity) and muon (forward rapidity) production from semi-leptonic decays [15,16], as well as electron production from B meson decays via semi-leptonic decays [17]. Theory predictions based on pQCD calculations for heavy-flavour production are in good agreement for all measurements within their uncertainties and also describe consistently the energy dependence of total cross sections [18,19].

To improve the understanding on the heavy-flavour production mechanisms, the multiplicity dependence of charm production was studied by ALICE via the per-event yields of D mesons normalized to their multiplicity-integrated value in different multiplicity classes for pp and p–Pb collisions [20]. It was observed that the D-meson yields increase with charged-particle multiplicity, which could be interpreted as presence of multi-parton interactions affecting the hard momentum scale relevant for charm quark production besides involving light quarks and gluons [21].

2.2. pA collisions

The R_{pPb}^{FONLL} of B mesons (B^+, B^0, B_s), evaluated using FONLL (Fixed Order plus Next-to-Leading Logarithms) calculations as pp references, were presented by CMS. As shown in top left panel of Fig. 1 for B^+ mesons, R_{pPb}^{FONLL} was found to be consistent with unity within uncertainties [22]. At mid-rapidity, the R_{pPb} of D mesons [23], electrons from heavy-flavour hadron decays and electrons from beauty-hadron decays measured by ALICE [24] is compatible with unity, showing that cold nuclear matter effects are smaller than their uncertainties. In the forward region (in the p-going direction), R_{pPb} of J/ψ from B meson decays measured by LHCb shows a modest suppression of J/ψ from beauty production, and the theoretical predictions including cold nuclear matter effects agree with the measurement (top right panel of Fig. 1) [26].