D-meson observables in Pb-Pb and p-Pb collisions at LHC with EPOSHQ model

V Ozvenchuk[1], J Aichelin[2], P B Gossiaux[2], B Guiot[3], M Nahrgang[2] and K Werner[2]

[1] Institute of Nuclear Physics, Polish Academy of Science, Radzikowskiego 152, 31-342 Krakow, Poland

[2] Subatech, UMR 6457, IN2P3/CNRS, Universite de Nantes, Ecole des Mines de Nantes, 4 rue Alfred Kastler, 44307 Nantes cedex 3, France

[3] Universidad Tecnica Federico Santa Maria, Valparaiso, Chile

E-mail: `Vitalii.Ozvenchuk@ifj.edu.pl`

Abstract. We study the propagation of charm quarks in the quark-gluon plasma (QGP) created in ultrarelativistic heavy-ion and proton-nucleus collisions at LHC within EPOSHQ model. The interactions of heavy quarks with the light partons in ultrarelativistic heavy-ion collisions through the collisional and radiative processes lead to a large suppression of final D-meson spectra at high transverse momentum and a finite D-meson elliptic flow, v_2, whereas in proton-nucleus collisions the D-meson nuclear modification factor, R_{pA}, at high transverse momentum is compatible with unity. Our results are in good agreement with the available experimental data.

1. Introduction

The nuclear modification factor, R_{AA}, and the elliptic flow, $v2$, of D mesons are measured in ultrarelativistic heavy-ion ($PbPb$) collisions [1, 2, 3] and in proton-nucleus (pPb) collisions [4] at LHC. The R_{AA} of intermediate- and high-p_T D mesons measured in $PbPb$ collisions [1, 2] is significantly below unity. It demonstrates a large energy loss of high-p_T heavy quarks in the QGP produced in heavy-ion collisions. On the other hand, the R_{AA} of D mesons with intermediate- and high-p_T measured in pPb collisions [4] is compatible with unity. Many theoretical models describing the D-meson observables either in $PbPb$ collisions [5, 6, 7, 8] or in pPb collisions [9, 10, 11], but it is still a big challenge to describe both systems with the same model input.

In this contribution we present the nuclear modification factor and the elliptic flow of D mesons in $PbPb$ collisions calculated in MC@sHQ+EPOS2 model. Then we compare the MC@sHQ+EPOS2 results with the results for the R_{AA} and v_2 of D mesons obtained in MC@sHQ+EPOS3 model. These models couple a Monte Carlo propagation of heavy quarks to the 3+1 dimensional fluid dynamical evolution of the QGP from EPOS2 and EPOS3 initial conditions, respectively. Finally we calculate the R_{AA} of D mesons in $PbPb$ and pPb collisions within MC@sHQ+EPOS3 model implementing, in addition, the heavy quarks from EPOS3 initial conditions (EPOSHQ model).

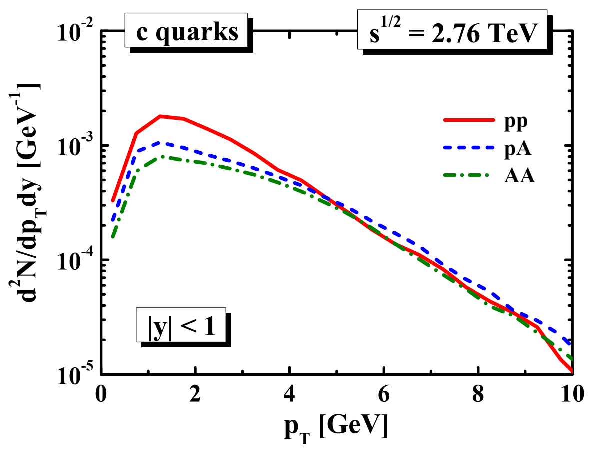


Figure 1. The initial spectrum of charm quarks obtained from EPOS3 for pp, pA and AA collisions.

2. The model

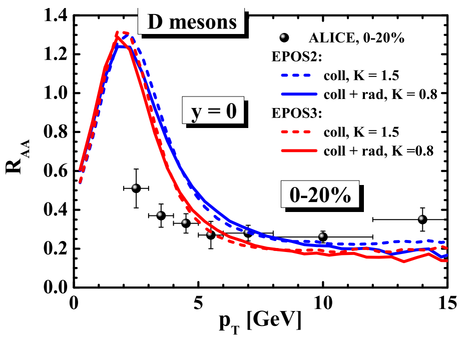
We calculate the D-meson observables using the different iterations of the EPOSHQ model, in particular, MC@sHQ+EPOS2, MC@sHQ+EPOS3 and EPOSHQ models. MC@sHQ+EPOS2 model couples a Monte Carlo propagation of heavy quarks [12, 13, 14], MC@sHQ, to the 3+1 dimensional ideal fluid dynamical evolution of the QGP from EPOS2 initial conditions [15, 16], which combine perturbative QCD (pQCD) calculations of the hard scattering with the Gribov-Regge theory. In MC@sHQ+EPOS3 model we couple MC@sHQ with the recent upgrade EPOS3 that includes a viscous fluid dynamical evolution, based on [17].

We initialize the heavy quarks at the original nucleon-nucleon scattering points according to the p_T-distribution from pQCD results in fixed order plus next-to-leading logarithm (FONLL) [18, 19, 20]. In EPOSHQ model we implement the heavy quarks directly from EPOS3 initial conditions with initial state shadowing included. The heavy quarks in EPOS3 can be produced during the spacelike cascade, the born process and the partonic shower. In Fig. 1 we show the initial spectrum of charm quarks from EPOS3 for pp, pA and AA collisions. Heavy quarks interact with plasma partons by either elastic or radiative collisions. The evolution of heavy quarks is described by the Boltzmann equation. The heavy quarks form hadrons via coalescence [12], predominantly for low-p_T heavy quarks, or fragmentation [21], predominantly for intermediate- and high-p_T quarks on the hypersurface of constant temperature $T = 155$ MeV.

3. The nuclear modification factor and elliptic flow

In Figs. 2 and 3 we present the D-meson nuclear modification factor and elliptic flow calculated within the MC@sHQ+EPOS2 model (blue lines) and the MC@sHQ+EPOS3 model (red lines) for the $PbPb$@2.76 TeV collisions at LHC. The MC@sHQ+EPOS2 results are taken from [22]. In each model we perform calculations for two scenarios, with purely collisional energy loss (dashed lines) or with collisional+radiative energy loss (solid lines). Both models show a reasonable agreement with the experimental data for the R_{AA} of D mesons at $p_T > 5$ GeV. The larger suppression of D-meson yield is seen for the MC@sHQ+EPOS3 results at intermediate p_T. If the initial state shadowing is not included the results from both models are overestimated at low p_T. For the whole range of p_T MC@sHQ+EPOS2 and MC@sHQ+EPOS3 model well describe the elliptic flow of D mesons. MC@sHQ+EPOS3 results show the enhancement of v_2 at intermediate p_T in comparison to MC@sHQ+EPOS2 results. The final elliptic flow of D mesons can be sensitive to the D-meson rescattering in the hadronic phase [23], we need to include the hadronic contribution for further study.

In Figs. 4 and 5 we show the c-quark and D-meson R_{pA} obtained within EPOSHQ model for the pPb@5.02 TeV collisions at LHC. The suppression of c-quark yield at low p_T for the scenario



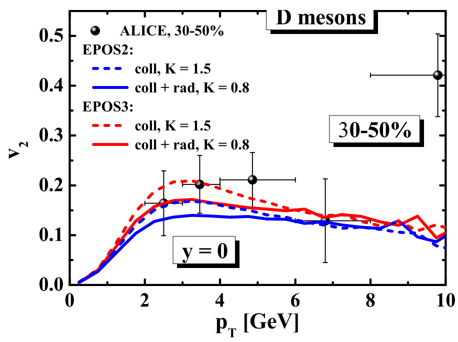
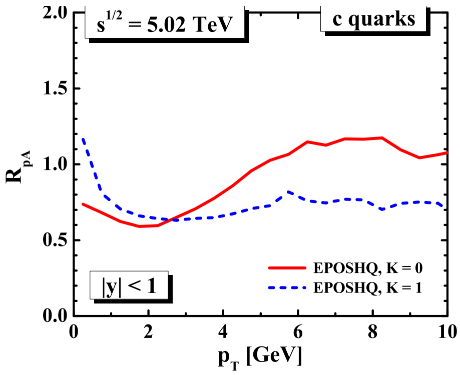


Figure 2. D-meson nuclear modification factor calculated in MC@sHQ+EPOS2 model (blue lines) in comparison to the MC@sHQ+EPOS3 results (red lines). Experimental data are taken from [1].

Figure 3. D-meson elliptic flow calculated in MC@sHQ+EPOS2 model (blue lines) in comparison to the MC@sHQ+EPOS3 results (red lines). Experimental data are taken from [3].



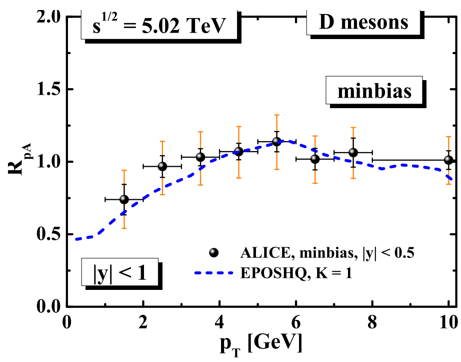


Figure 4. c-quark R_{pA} calculated in EPOSHQ model with (dashed line) and without (solid line) interactions with the bulk medium.

Figure 5. D-meson R_{pA} calculated in EPOSHQ model in comparison to the experimental data from [4].

with $K = 0$ (no interactions with the bulk medium) indicates the present of the initial state shadowing (see Fig. 1). The scenario with $K = 1$ corresponds to the collisional+radiative energy loss, where the suppression of c-quark yield at intermediate and high p_T is seen. The R_pA of D mesons is compatible with unity for $p_T > 4$ TeV, which is in agreement with experimental data.

Finally, in Fig. 6 we present the D-meson nuclear modification factor calculated in EPOSHQ model for the central $PbPb$@2.76 TeV collisions at LHC. The calculations show a reasonable agreement with the experimental data for whole range of p_T. For two scenarios (pure collisional and collisional+radiative) we obtained almost the same behavior. The presence of the initial state shadowing helped us to describe well the R_{AA} of D mesons at low p_T.

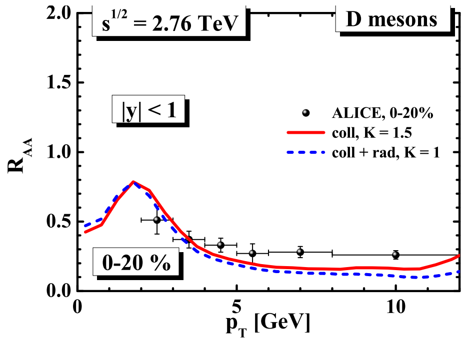


Figure 6. D-meson R_{AA} obtained within EPOSHQ model in comparison to the experimental data [1].

4. Conclusions

We have presented the results for D-meson observables in heavy-ion and proton-nucleus collisions at LHC within EPOSHQ model. EPOSHQ model is able to describe the nuclear modification factor and elliptic flow of D mesons both for the $PbPb$ and pPb collisions at LHC with the same initial setup. For the central $PbPb$ collisions the importance of including initial state shadowing was shown.

Acknowledgments

We thank J. Steinheimer and Iu. Karpenko for fruitful discussions. This work was supported by the Project TOGETHER (Pays de la Loire) and by the National Science Center, Poland under Grant No. 2014/14/E/ST2/00018.

References

[1] Abelev B *et al.* [ALICE Collaboration] 2012 *JHEP* **09** 112
[2] Sakai S *et al.* [ALICE Collaboration] 2013 *Nucl. Phys.* A **904-905** 661c
[3] Abelev B *et al.* [ALICE Collaboration] 2013 *Phys. Rev. Lett.* **111** 102301
[4] Abelev B *et al.* [ALICE Collaboration] 2014 *Phys. Rev. Lett.* **113** 232301
[5] Nahrgang M, Aichelin J, Bass S A, Gossiaux P B and Werner K 2014 *Nucl. Phys.* A **931** 575
[6] Song T, Berrehrah H, Cabrera D, Cassing W and Bratkovskaya E 2016 *Phys. Rev.* C **93** 034906
[7] Das S K, Scardina F, Plumari S and Greco V 2015 *Phys. Lett.* B **747** 260
[8] Cao S, Qin G Y and Bass S A 2013 *Phys. Rev.* C **88** 044907
[9] Mangano M, Nason P and Ridolfi G 1992 *Nucl. Phys.* B **373** 295
[10] Stump D, Huston J, Pumplin J, Tung W K, Lai H L, Kuhlmann S and Owens J F 2003 *JHEP* **0310** 046
[11] Xu Y, Cao S, Ke W, Nahrgang M, Auvinen J and Bass S A 2016 *Nucl. Part. Phys. Proc.* **276-278** 225
[12] Gossiaux P B, Bierkandt R and Aichelin J 2009 *Phys. Rev.* C **79** 044906
[13] Gossiaux P B and Aichelin J 2008 *Phys. Rev.* C **78** 014904
[14] Gossiaux P B, Aichelin J, Gousset T and Guiho V 2010 *J. Phys.* G **37** 094019
[15] Werner K, Karpenko I, Pierog T, Bleicher M and Mikhailov K 2010 *Phys. Rev.* C **82** 044904
[16] Werner K, Karpenko I, Bleicher M, Pierog T and Porteboeuf-Houssais S 2012 *Phys. Rev.* C **85** 064907
[17] Karpenko I, Huovinen P and Bleicher M 2014 *Comput. Phys. Commun.* **185** 3016
[18] Cacciari M, Greco M and Nason P 1998 *JHEP* **05** 007
[19] Cacciari M, Frixione S and Nason P 2001 *JHEP* **03** 006
[20] Cacciari M, Frixione S, Houdeau N, Mangano M L, Nason P and Ridolfi G 2012 *JHEP* **10** 137
[21] Cacciari M, Nason P, and Vogt R 2005 *Phys. Rev. Lett.* **95** 122001
[22] Nahrgang M, Aichelin J, Gossiaux P B and Werner K 2014 *Phys. Rev.* C **89** 014905
[23] Ozvenchuk V, Torres-Rincon J M, Gossiaux P B, Tolos L and Aichelin J 2014 *Phys. Rev.* C **90** 054909