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Charm Meson Production in Pb–Pb Collisions at the LHC in HYDJET++ Model[1]

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Abstract—The phenomenological analysis of J/ψ and D meson production in Pb–Pb collisions at a center-of-mass energy of 2.76 TeV per nucleon pair is fulfilled in the framework of the two-component HYDJET++ model, which includes the thermal and nonthermal production mechanisms. A significant fraction of D-mesons is found to be in a kinetic equilibrium with the created matter, while J/ψ-mesons are characterized by earlier (as compared to light hadrons) freeze-out.

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INTRODUCTION

Signals of various types are used to investigate the properties of quark-gluon matter produced in collisions of relativistic nuclei; among such signals, one can consider the processes occurring with heavy quark production. Heavy quarks are produced mainly in hard parton-parton interactions. When passing through a hot dense medium, they interact with its constituents. On the other hand, the soft mechanisms of the charm hadron production can be significant at LHC energies.

CHARM MESON PRODUCTION IN Pb–Pb COLLISIONS AT $\sqrt{s_{\rm NN}} = 2.76$ TeV AND HYDJET++ MODEL

The generator of collisions of relativistic nuclei HYDJET++ [1] consists of two components: thermal (soft production of hadrons) and nonthermal (hard processes of parton production in QCD with the subsequent modification of the spectrum in the medium and hadronization.)

In the soft component, the hadron production is modeled at the hypersurfaces of chemical and thermal freeze-out of a relativistic liquid, obtained with the help of parametrization of relativistic hydrodynamics. The hard component is based on the PYQUEN model [2]. The contribution of the hard component to the total multiplicity is controlled by the parameter $p_{\rm T}^{\rm min}$, the minimum transverse momentum transferred in the parton-parton scattering. The left-hand side of Fig. 1 represents the comparison of the modeling with the data [3] for the inclusive J/ψ-meson spectrum with respect to $p_{\rm T}$ in Pb–Pb collisions in the centrality range of 0–20% with two sets of input parameters: (1) the same as for the inclusive hadrons (temperature of chemical and thermal freeze-out $T_{\rm ch} = 165$ MeV and $T_{\rm th} = 105$ MeV, respectively; maximum longitudinal and transverse flow rate $Y_{\rm L}^{\rm max} = 4.5$ and $Y_{\rm T}^{\rm max} = 1.265$, $p_{\rm T}^{rmmin} = 8.2$ GeV/c) and (2) for the early kinetic freeze-out ($T_{\rm ch} = T_{\rm th} = 165$ MeV, $Y_{\rm L}^{\rm max} = 2.3$, $Y_{\rm T}^{\rm max} = 0.6$, and $p_{\rm T}^{\rm min} = 3.0$ GeV/c). The modeled spectra describe experimental data (up to $p_{\rm T} \sim 3$ GeV/c) only under assumption of the early thermal freeze-out. It was also found that the elliptic flow depending on the transverse momentum $v_2(p_{\rm T})$ for the inclusive J/ψ-mesons [4] is described with the parameters 2) (Fig. 1, right panel). At large $p_{\rm T}$, it is necessary to adjust the parameters in the hard component of the model to better describe the charmonium production. It should be also noted that the model does not consider the effect of color screening of the coupled pairs of heavy quarks in the quark-gluon matter. In contrast to the J/ψ-mesons, the data for the $p_{\rm T}$-spectra of D-mesons [5] are well described with the same freeze-out parameters as for the inclusive hadrons (Fig. 2, left panel). The data on $v_2(p_{\rm T})$ are reproduced also with these parameters [6] (Fig. 2, right panel).

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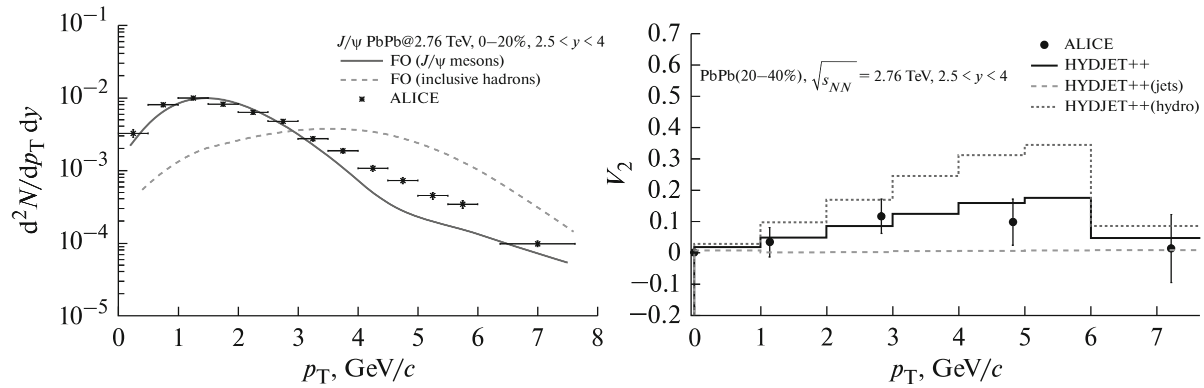

Fig. 1. Left panel: the spectrum of J/ψ-mesons as a function of p_T for the flow rates $2.5 < y < 4$ in Pb–Pb collisions with centralities of 0–20% at $\sqrt{s_{NN}} = 2.76$ TeV. Dots refer to data [3], bar charts, to the results of modeling with the help of HYDJET++ (dotted curve refers to the freeze-out parameters as for the inclusive hadrons; solid curve refers to the early thermal freeze-out). Right panel: the elliptic flow $v_2(p_T)$ of J/ψ-mesons at $2.5 < y < 4$ in the Pb–Pb collisions with centrality 20–40%, $\sqrt{s_{NN}} = 2.76$ TeV. Dots refer to the data [4]; bar charts, to the results of modeling with the help of HYDJET++ (dotted chart refers to the soft component; dashed line, to the hard component; and solid chart, to the sum of components).

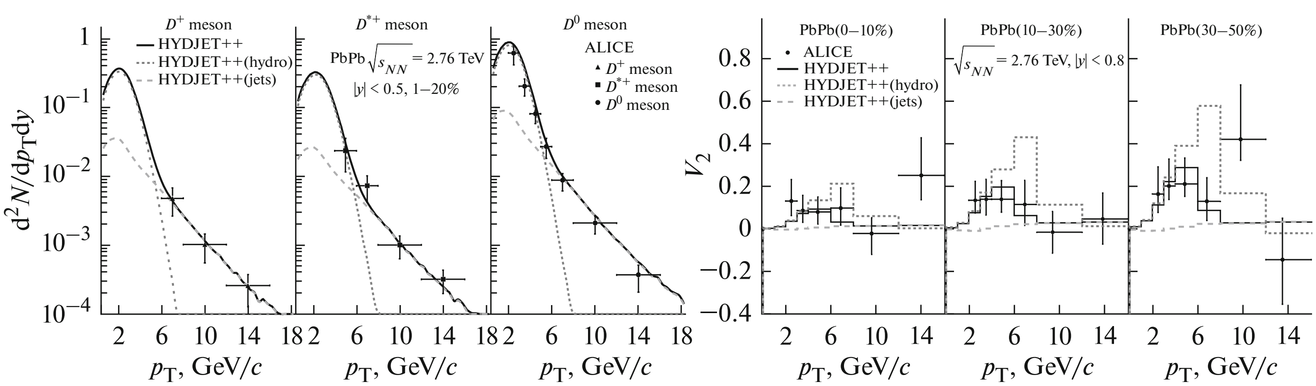

Fig. 2. Left panel: spectra of $D^{\pm}$, $D^{*\pm}$, D^0 mesons as a function of p_T for $|y| < 0.5$ in Pb–Pb collisions with centralities 0–20% at $\sqrt{s_{NN}} = 2.76$ TeV. Points with error bars refer to data [5]; the histograms refer to the result of modeling using HYDJET++ (dotted lines refer to the soft component; dashed lines, to the hard component; and the solid line, to the total spectrum). Right panel: $v_2(p_T)$ of D^0-mesons for $|y| < 0.8$ in Pb–Pb collisions with various centralities: 0–10%, 10–30%, 30–50%. Points with error bars refer to data [6], the histograms show the results of modeling with the help of HYDJET++. (Dotted lines refer to the soft component; dashed lines, to the hard component; and solid line, to the sum of components).

CONCLUSIONS

The experimental data on the momentum spectra and elliptic flow of charm mesons at LHC energy are reproduced by HYDJET++ model on the assumption that the kinetic freeze-out of D-mesons occurs simultaneously with the kinetic freeze-out of light hadrons, whereas the kinetic freeze-out of J/ψ-mesons occurs considerably earlier, supposedly, at the moment of chemical freeze-out. Therefore, a significant fraction of D-mesons (up to $p_T \sim 4$ GeV/c), as distinct from J/ψ-mesons, are in the kinetic equilibrium with the hot hadron matter produced in the Pb–Pb collision. It can mean that the interaction cross section of D-mesons becomes comparable to the interaction cross section of light hadrons, while the cross section of J/ψ-mesons remains substantially lower.

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