Are charmed mesons thermalized in heavy ion collisions at RHIC and LHC?

I.P. Lokhtin1, A.V. Belyaev1, G.Kh. Eyyubova1,2, G. Ponimatin2 and E.Yu. Pronina1

1 Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
2 FNSPE, Czech Technical University in Prague, Czech Republic
3 Ostrov Industrial High School, Ostrov, Karlovy Vary District, Czech Republic

HYDJET++

Event generator to simulate heavy ion event as merging of two independent components (soft hydro-type part + hard multi-partonic state); http://cern.ch/lokhtin/hydjet++

Soft (“thermal”)

The “thermal” hadronic state generated on the chemical and thermal freeze-out hypersurfaces obtained from the parametrization of relativistic hydrodynamics with preset freeze-out conditions (the adapted generator FAST MC).

Hard (“non-thermal”)

Fragmentation of medium-modified PYTHIA partonic state taking into account nuclear shadowing, multiple scattering, radiative and collisional energy loss of hard partons in expanding quark-gluon plasma (based on PYQUEN model).

The RHIC and LHC data on various characteristics of charm hadrons ($J/\psi$ and $D$ mesons) are analyzed and interpreted within two-component HYDJET++ model.

**J/ψ-mesons ($y$- and $p_{T}$-spectra)**

Points: PHENIX data PRL 98 (2007) 232301; Histories: HYDJET++ (solid) = soft (dotted) + hard (dashed)

If $J/\psi$'s are produced at the same freeze-out parameters as for inclusive (light) hadrons, then simulated spectra are much wider than the data.

If thermal freeze-out for $J/\psi$ happens at the same temperature as chemical freeze-out (with reduced collective velocities), then simulated spectra match the data.

**D-mesons ($p_{T}$-spectrum)**

Points: STAR data PRL 113 (2014) 142301; Histories: HYDJET++

Simulated $p_{T}$-spectrum matches the data if freeze-out parameters for $D$ are the same as for $J/\psi$.

**Charmed mesons at RHIC (summary)**

Momentum spectra of $D$ and $J/\psi$ mesons in most central AuAu collisions may be reproduced (with the same freeze-out parameters) by two-component model including thermal (soft) and non-thermal (hard) components. Thermal freeze-out of charmed mesons happens before thermal freeze-out of light hadrons, presumably at chemical freeze-out (with reduced radial and longitudinal collective velocities). Thus $D$ and $J/\psi$ mesons seem not to be in a kinetic equilibrium with the medium.

**LHC, PbPb @ $\sqrt{s_{NN}}=2.76$ TeV**

**J/ψ-mesons ($p_{T}$-spectrum, $R_{AA}$ and $v_{2}$)**

Points: ALICE data, arXiv:1506.08804 (top left), PHB 734 (214) 314 (top right), and PRL 113 (2014) 162301 (bottom); Histories: HYDJET++

If thermal freeze-out for $J/\psi$ happens at the same temperature as chemical freeze-out (with reduced collective velocities), then simulated spectra match the data up to $p_{T}$~3 GeV/c. Elliptic flow $v_{2}(p_{T}, N_{part})$ is reproduced well.

**D-mesons ($p_{T}$-spectrum, $R_{AA}$ and $v_{2}$)**

Points: ALICE data, JHEP 1209 (2012) 112 (top) and PRC 90 (2014) 034904 (bottom); Histories: HYDJET++

The simulated $p_{T}$-spectra and elliptic flow $v_{2}(p_{T})$ of $D$ with the same freeze-out parameters as for inclusive (light) hadrons match the data. Nuclear modification factor $R_{AA}(p_{T})$ is reproduced at high $p_{T}$.

**Charmed mesons at LHC (summary)**

Momentum spectra and elliptic flow of $D$ and $J/\psi$ mesons in PbPb collisions may be reproduced by two-component model including thermal (soft) and non-thermal (hard) components. Thermal freeze-out of $D$ mesons happens simultaneously with thermal freeze-out of light hadrons; thermal freeze-out of $J/\psi$-mesons happens appreciably before, presumably at chemical freeze-out (with reduced radial and longitudinal collective velocities). Thus the significant part of $D$ mesons (up to $p_{T}$~4 GeV/c) seems to be in a kinetic equilibrium with the medium, while $J/\psi$ mesons – not.

Non-thermal charm production mechanism and in-medium heavy quark energy loss are important at high $p_{T}$.