PROCEEDINGS OF SCIENCE

Measurements of $D^{\pm}$ meson production and total charm quark production yield at midrapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment

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Charm quarks are produced at very early stage of ultra-relativistic Au+Au collisions at RHIC top energy. This makes them an ideal probe of the Quark-Gluon Plasma, as they experience the whole evolution of the hot and dense medium. At STAR, production of charm quarks can be accessed via a direct topological reconstruction of hadronic decays of open charm hadrons, utilizing the excellent resolution of the Heavy Flavor Tracker. In these proceedings, we present measurements of $D^{\pm}$ meson production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The invariant yields are extracted in 0-10%, 10-40%, and 40-80% central Au+Au collisions. The result is then used to calculate the nuclear modification factor, which reveals a strong suppression of high-p_T $D^{\pm}$ mesons in Au+Au collisions with respect to p+p collisions. In addition, the $D^{\pm}/D^0$ yield ratio as a function of transverse momentum is calculated and compared to PYTHA 8 prediction. No significant modification of the ratio in Au+Au collisions is observed. The measurement of $D^{\pm}$ completed the measurements of the major ground states of open charm hadrons (D^0, $D^{\pm}$, D_s, Λ_c), that are used to calculate the total charm quark production cross section per binary nucleon-nucleon collision in 10-40% central Au+Au collisions. The measured value in Au+Au collisions is consistent with that measured in p+p collisions.

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1. Physics motivation

One of the main goals of the STAR experiment is to study properties of the Quark-Gluon Plasma (QGP) created in Au+Au collisions. One very important probe to the QGP is by measurement of charm quark production, as the charm quarks are produced in hard partonic scatterings before the formation of the hot and dense medium. This means that they experience the whole evolution of the QGP medium. When traversing the medium, charm quarks lose energy via radiative and collisional processes. The information about the charm quark production at the STAR experiment can be accessed via direct topological reconstruction of hadronic decays of open charm hadrons, which is made possible thanks to the excellent pointing resolution of the Heavy Flavor Tracker [1].

STAR has measured the nuclear modification factor R_{AA} of directly reconstructed D^0 mesons, as shown in Fig. 1. The D^0 mesons show a strong suppression for $p_T > 3\,\mathrm{GeV}/c$ in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV compared to $p+p$ collisions at the same energy. The level of suppression is similar that of charged pions at $\sqrt{s_{NN}}$ = 200 GeV, which suggests that the charm quarks interact stronlgy with the QGP and loose significant portion of their momentum and energies.

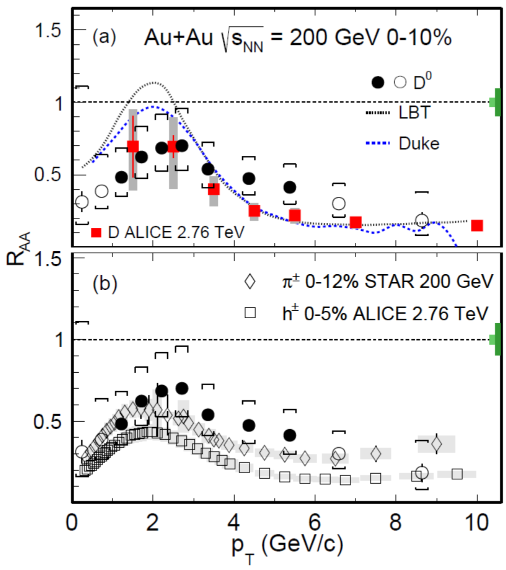

Figure 1: Nuclear modification factor of D^0 mesons as a function of p_T measured in 0-10% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. The open circles indicate data points for which the p+p reference [2] had to be extrapolated. The data are compared to measurements of $\pi^{\pm}$ mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR [3] and to D mesons [4] and charged hadrons [5] in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV by ALICE. Taken from Ref. [6].

The measurement of $D^{\pm}$ mesons in Au+Au collisions provides additional insight into the charm quark production in heavy-ion collisions and can help to better understand charm quark energy loss in the QGP. The $D^{\pm}$ measurement, together with measurements of other major ground state open charm hadrons (D^0, D_s, Λ_c) [6–8], are used for calculation of the total charm quark production cross section in Au+Au collisions.

2. Results

The $D^{\pm}$ mesons are reconstructed through the topological reconstruction of their hadronic decays $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$. The topological selection criteria are optimized using rectangular cut optimization (CutsSA method) from the TMVA ROOT package [9] in order to maximize the signal significance. The invariant yields are extracted in 0-10%, 10-40%, and 40-80% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

The invariant yields are then used to calculate the R_{AA} of $D^{\pm}$ mesons as a function of transverse momentum (p_T), as shown in Fig. 2. The $D^{\pm}$ measurement is compared to that of the D^0 mesons [6]. Both $D^{\pm}$ and D^0 mesons show comparable level of suppression in all three centrality classes, within the uncertainties. The high-p_T $D^{\pm}$ mesons show a significant suppression in central Au+Au collisions, which indicates strong interactions of the charm quarks with the QGP. The suppression gets weaker towards more peripheral collisions, further supporting that the attenuation is caused by a medium created in the central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. At the same time, both the $D^{\pm}$ and D^0 mesons show a suppression for $p_T < 2\,\mathrm{GeV}/c$. The p+p reference used for calculation of the R_{AA} is taken from Ref. [2].

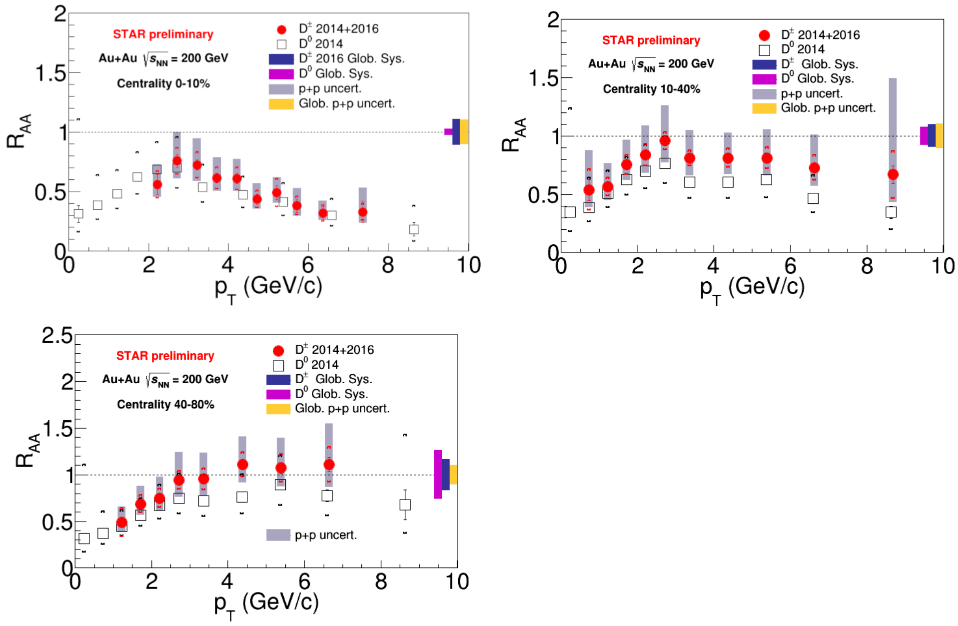

Figure 2: Nuclear modification factor of D^0 [6] and $D^{\pm}$ mesons measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. High-p_T D^0 and $D^{\pm}$ mesons show a significant suppression in 0-10% central Au+Au collisions, suggesting strong interactions of the charm quarks with the QGP.

To better understand the charm quark hadronization process one can examine the $D^{\pm}/D^0$ yield ratio, which is shown in Fig. 3. The measured ratio is consistent with PYTHIA 8 calculation [10] indicating that the ratio is not modified in Au+Au collisions with respect to p+p collisions. This observation suggests that both mesons are suppressed by the same mechanism and their hadronization mechanisms are likely very similar in Au+Au collisions.

In order to have a better understanding of the hadronization process of the charm quarks in Au+Au collisions, STAR has calculated the total charm production cross section per binary

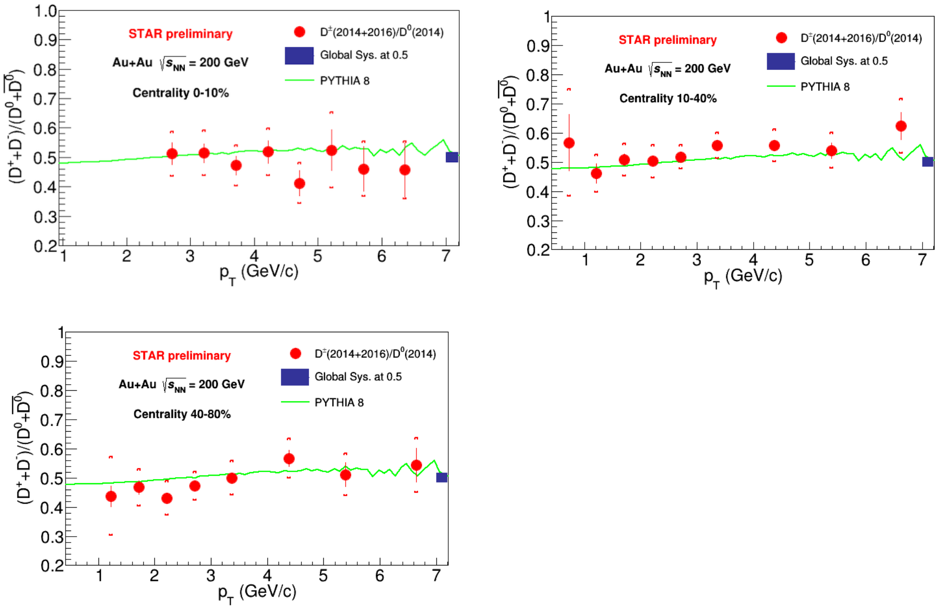

Figure 3: The $D^{\pm}/D^{0}$ yield ratio as a function of p_T measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. The data are in a good agreement with PYTHIA 8 prediction [10].

nucleon-nucleon collision in 10-40% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, using four major ground states of open charm hadrons: D^0, $D^{\pm}$, D_s, Λ_c. The resulting cross section $d\sigma_{Au+Au}/dy$ = 152 ± 13 (stat.) ± 29 (sys.) μb is consistent with that measured in *p+p* collisions at the same energy [2], i.e. $d\sigma_{p+p}/dy$ = 130 ± 30 (stat.) ± 26 (sys.) μb, as listed in Tab. 1. The cross section appears to follow the number-of-binary-collision scaling. However, the individual contributions to the total cross section are different. The cross sections of D^0 and $D^{\pm}$ mesons are smaller than those in *p+p* collisions in central and mid-central collisions, as shown in Fig. 1, but the cross sections of D_s [7] and Λ_c [8] are enhanced, most likely due to coalescence hadronization of charm quarks. This calculation indicates that the production of charm quarks is likely unaffected by nuclear effects in Au+Au collisions, but the hadronization process is modified by the medium which leads to a re-distribution of the charm quarks among the open charm hadron species.

Collision system	**Hadron**	$d\sigma/dy$ [μb]
Au+Au at 200 GeV Centrality: 10-40%	D^0	41 ± 1 (stat.) ± 5 (sys.)
	$D^{\pm}$	18 ± 1 (stat.) ± 3 (sys.)
	D_s	15 ± 1 (stat.) ± 5 (sys.)
	Λ_c	78 ± 13 (stat.) ± 28 (sys.)
	Total:	152 ± 13 (stat.) ± 29 (sys.)
p+p at 200 GeV	Total:	130 ± 30 (stat.) ± 26 (sys.)

Table 1: Total open charm hadron cross section as measured in 10-40% central Au+Au collisions and in *p+p* collisions at 200 GeV.

Summary

Measurements of open charm hadrons is an essential part of the physics program of the STAR experiment. An important contribution to this effort is the measurement of $D^{\pm}$ mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Similar to the D^0 mesons, the high-p_T $D^{\pm}$ mesons show a significant suppression in central Au+Au collisions, which is likely caused by strong interactions of the charm quarks with the QGP. The mechanism of the suppression is probably the same for $D^{\pm}$ and D^0 mesons, as the $D^{\pm}/D^0$ yield ratio measured in Au+Au is compatible with the ratio calculated using PYTHIA 8. The D^0, $D^{\pm}$, D_s, and Λ_c invariant yields are used to calculate the total charm quark production cross section per binary nucleon-nucleon collision in Au+Au collisions. The calculated value is comparable with that measured in p+p collisions within the uncertainties, indicating that the total charm yield in heavy-ion collisions follows the number-of-binary-collision scaling. The individual contributions to the cross section are different, on the other hand, with D^0 and $D^{\pm}$ being suppressed, and D_s and Λ_c enhanced in the Au+Au collisions. This observation is consistent with a significant contribution of the coalescence hadronization in the QGP in Au+Au collisions, leading to a re-distribution of charm quarks among the open-charm hadron species.

Acknowledgments

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