D^0 meson production in Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV measured by the STAR experiment

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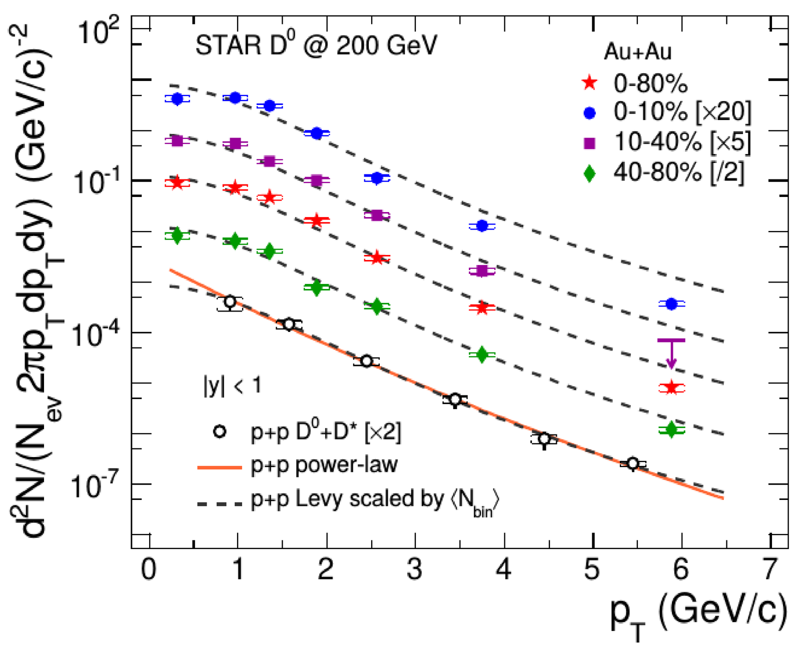
Abstract

Heavy quarks are mainly produced by hard processes during the early stage of heavy-ion collisions and before the formation of the Quark-Gluon Plasma (QGP). As most of the heavy quarks are expected to propagate through the medium during its evolution, they can encode information on different stages of the medium. The D^0 meson is the lightest meson containing a charm quark. Measurement of modifications to D^0 production in heavy-ion collisions relative to proton-proton collisions can be used to study properties of the nuclear medium. In addition, asymmetric collisions of ions create systems with asymmetric density distribution, pressure gradient and magnetic field, which provide a good opportunity to study the influence of the asymmetry on particle production.

In 2012, the STAR experiment at RHIC recorded data in Cu+Au collisions at the center-of-mass energy per nucleon pair of $\sqrt{s_{NN}} = 200$ GeV. The average number of binary collisions in 0-80% central Cu+Au collisions is similar to that in 40-50% central Au+Au collisions. The D^0 mesons are reconstructed via the hadronic decay channel ($D^0 \rightarrow K^-\pi^+$) in Cu+Au collisions. The invariant yield and the nuclear modification factor for D^0 meson are measured in the transverse momentum range between 0.8 and 2 GeV/*c*. These results are compared with existing results in Au+Au collisions at the same collision energy.

Motivation

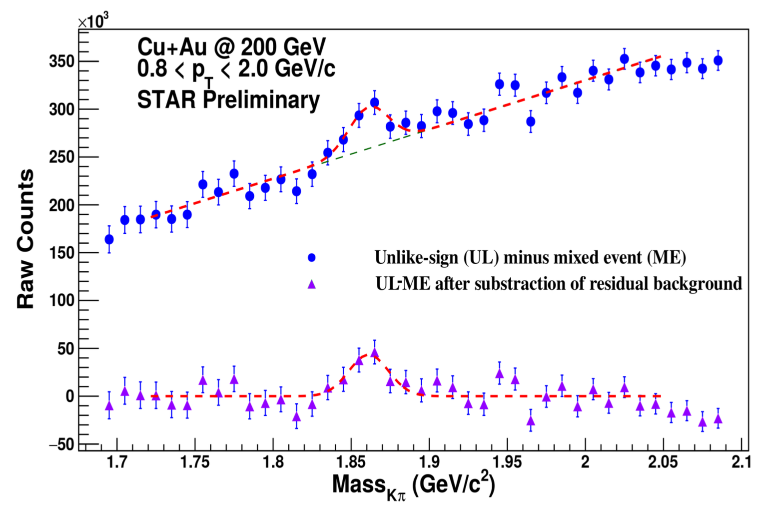
- Charm quarks are produced early in heavy-ion collisions (τ ~ 0.1 fm/*c*), and can serve as a probe to the properties of the QGP.
- The STAR experiment observed significant modification of D^0 production in Au+Au collisions.
- Comparing Cu+Au to Au+Au collisions to study properties of asymmetric collision systems and the influence on particle production.



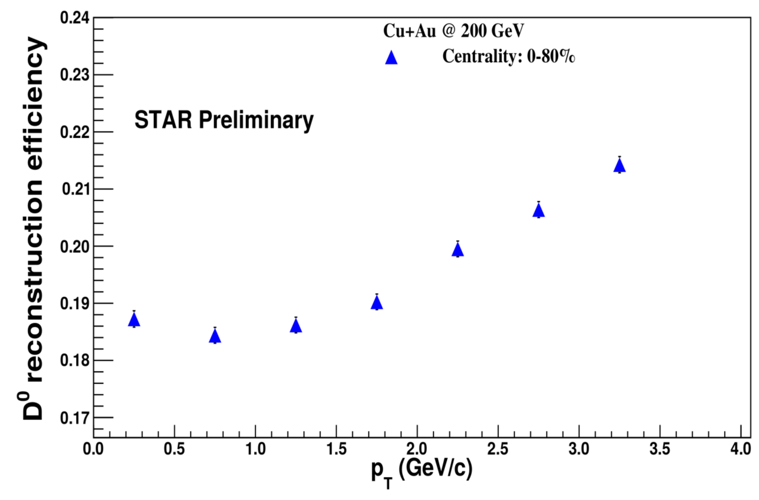
Centrality dependence of D^0 meson p_T spectra in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [1].

D^0 raw yield

- The D^0 meson raw yield is calculated by the bin counting method in the invariant-mass region 1.8 < $m_{K\pi}$ < 1.9 GeV/*c*.



Raw signal of D^0 meson for 0.8 < p_T < 2.0 GeV/*c* . Raw yield: (132 ± 32) × 10^3

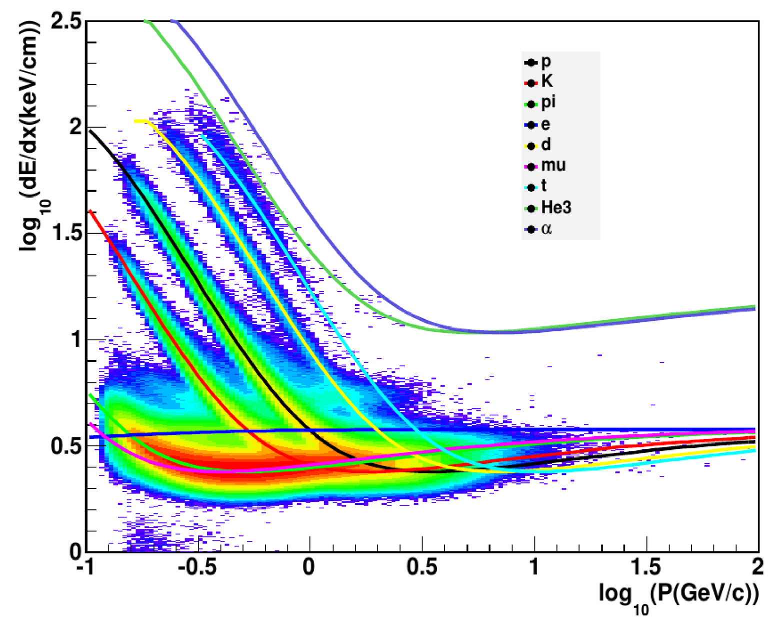


Reconstruction efficiency for D^0 meson.

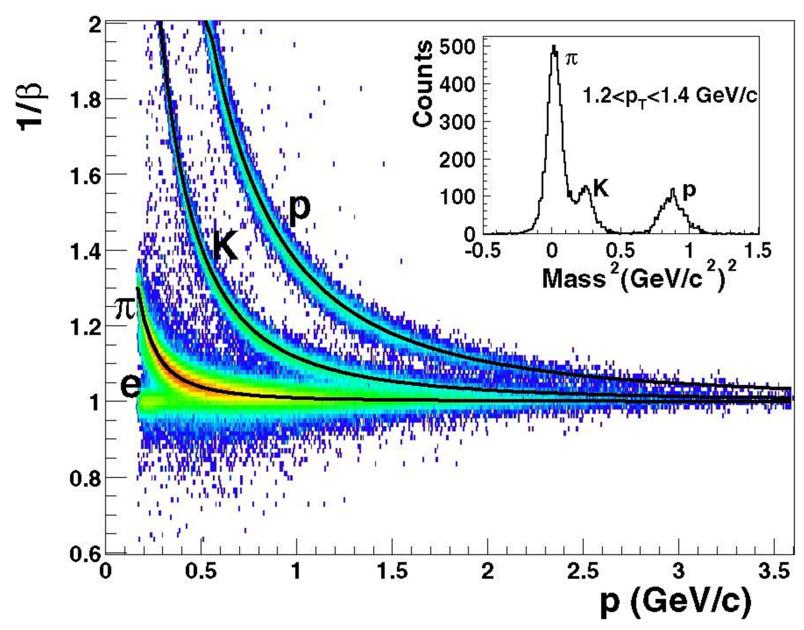
- The combinatorial background is estimated using the event mixing, where pions and kaons of opposite signs from different events are paired.

STAR detector

The Solenoidal Tracker At RHIC (STAR) detector is designed to study the QGP created in heavy-ion collisions. It consists of subsystems immersed in a room-temperature solenoid magnet with full strength *B* = 0.5 T. The STAR detector is capable of detecting, tracking and identifying charged particles at mid-rapidity. The main sub-detectors used in this analysis are the Time Projection Chamber (TPC) and the Time Of Flight (TOF) detector.



Particle identification via d*E*/d*x* with the TPC, data from Au+Au at $\sqrt{s_{NN}} = 200$ GeV [2].



Particle identification via 1/β with the TOF, data from d+Au collisons at $\sqrt{s_{NN}} = 200$ GeV [3].

D^0 nuclear modification factor

- Invariant yield is defined as: $Y = \frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy}$

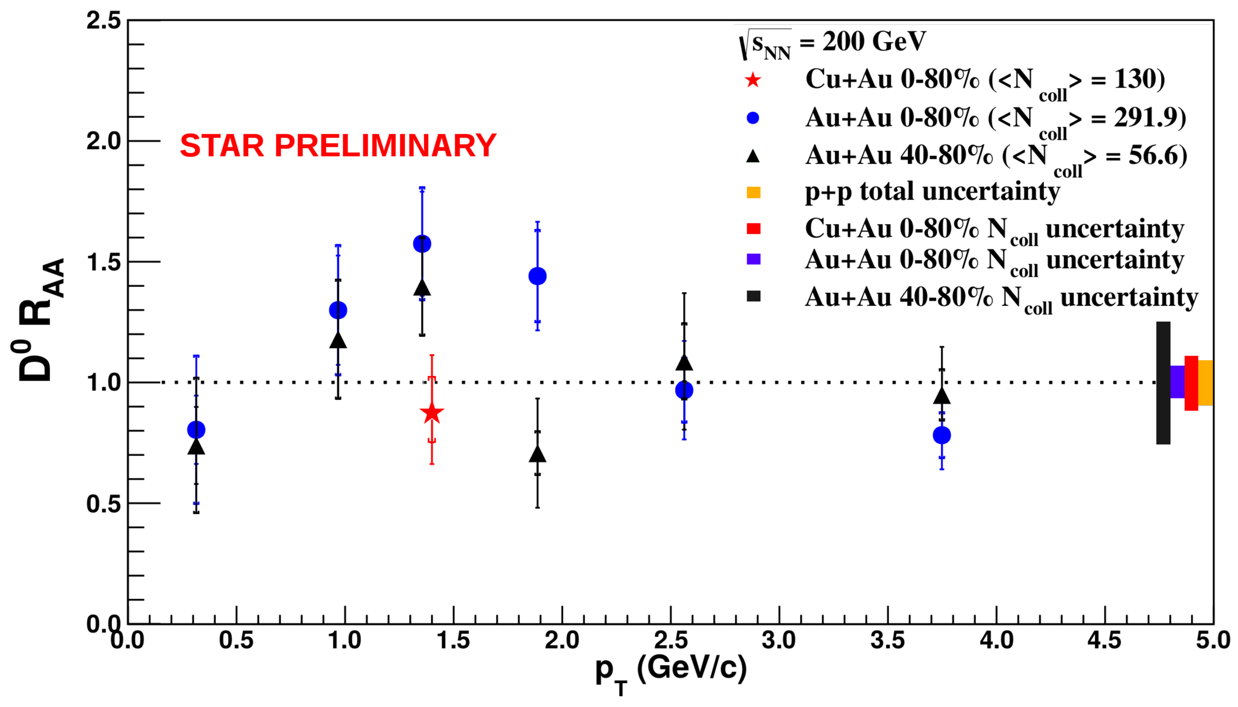
Table: Cu+Au and p+p [5] invariant yield measured in the range 0.8 < p_T < 2.0 GeV/*c*

System	Invariant yield [(GeV/c)$^{-2}$]
p+p	$(1.10 \pm 0.05 \pm 0.15) \times 10^{-4}$
Cu+Au	$(1.13 \pm 0.29 \pm 0.19) \times 10^{-2}$

- Nuclear modification factor is defined as: $R_{AA} = \frac{1}{\langle N_{coll}\rangle}\frac{(dN/dp_T)^{A+A}}{(dN/dp_T)^{p+p}}$

$\langle N_{coll}\rangle$: average number of nucleon-nucleon collisions
$(dN/dp_T)^{A+A}$: yield in A+A collisions
$(dN/dp_T)^{p+p}$: yield in p+p collisions

Uncertainty sources	Tracking + PID	Background estimation	Signal extraction	Branching ratio	Efficiency
Value [%]	12.6	9.5	4.9	1.3	0.9
Total systematic uncertainty [%]:			16.9		



Obtained nuclear modification factor for D^0 meson in p_T bin: 0.8-2.0 GeV/c compared with results in Au+Au collisions. Au+Au data taken from [1].

Analysis method

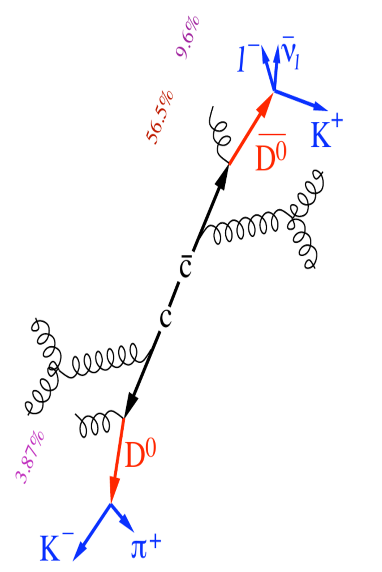
Data sample

- Cu+Au collisions, $\sqrt{s_{NN}} = 200$ GeV
- 59 × 10^6 events, 1/3 of statistics used for analysis

D^0 reconstruction

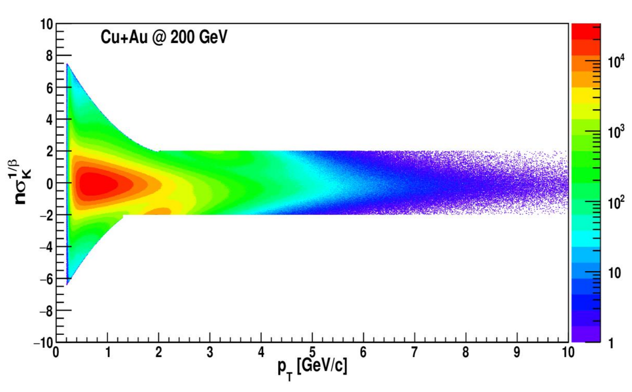
- D^0 reconstructed in hadronic decay channel $D^0 \rightarrow K^-\pi^+$ [BR: (3.88 ± 0.05) %]

$$n\sigma_X^{1/\beta} = \frac{\frac{1}{\beta^{measured}} - \frac{1}{\beta_X^{theory}}}{R^{1/\beta}} \qquad n\sigma_X^{dE/dx} = \frac{1}{R^{dE/dx}}\ln\frac{(dE/dx)^{measured}}{(dE/dx)_X^{theory}}$$



Charm quark fragmentation to D^0 and consequent D^0 hadronic and semi-leptonic decays [4].

	Kaon	Pion
p_T	> 0.2 GeV/*c*	> 0.2 GeV/*c*
$\lvert n\sigma^{1/\beta}\rvert$	See right	-
$\lvert n\sigma^{dE/dx}\rvert$	< 2	< 2
PID	p_T < 1.6 GeV/*c* → TOF p_T > 1.6 GeV/*c* → TPC and TOF if available	Only TPC



Conclusion

- D^0 candidates have been reconstructed via the hadronic decay channel ($D^0 \rightarrow K^-\pi^+$) in Cu+Au collisions.
- Invariant yield and nuclear modification factor are obtained for 0.8 < p_T < 2.0 GeV/*c*.
- No significant difference is seen within the sizable statistical and systematic uncertainties for R$_{AA}$ measured in Cu+Au and Au+Au collisions despite the different geometries.

References

[1] Adamczyk L. *et al.* (STAR) 2014 *Phys. Rev. Lett.* **134** 142301
[2] Guo Y., *Dielectron production in* $\sqrt{s_{NN}}$ = 200 GeV *p+p and Au+Au collisions at RHIC*, Dissertation thesis 2014
[3] Adams J. *et al.* (STAR), 2005, *Phys. Rev. B* **616** 04041
[4] Tlusty D. *A Study of Open Charm Production in p+p Collisions at STAR*, Dissertation thesis, 2013
[5] Adamczyk L. *et al.* (STAR) 2014 *Phys. Rev. D* **86** 072013

Acknowledgement

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