Production of D± Mesons in Au+Au Collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV Measured by the STAR Experiment

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Abstract

Charm quarks are primarily produced at early stages of ultra-relativistic heavy ion collisions and can be used to probe the properties of the quark-gluon plasma (QGP) created in these collisions. Final-state open charm mesons are usually used experimentally to study the charm quark interaction with the medium. For example, suppression of D-meson production in heavy-ion collisions is sensitive to the energy loss of charm quarks in the QGP. In this poster, the production of D± mesons in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV measured by the STAR experiment using data taken in 2016 is presented. Precise topological reconstruction of secondary decay vertices enabled by the STAR Heavy Flavor Tracker through the hadronic decay channel, $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$, is used in this analysis. The nuclear modification factor of D± meson is presented as a function of transverse momentum in 0-10% central collisions.

Physics Motivation

- Suppression of high-p_{T} D^0 is observed in central Au+Au collisions and is comparable to that of pions [1].
- The study of D± production in Au+Au collisions is complementary to the study of D^0 and light mesons production in the effort to better understand properties of the QGP.
- New precision measurements of open charm mesons with the HFT by STAR will bring significant constraints on model calculations.

$$R_{\mathrm{AA}}(p_{\mathrm{T}}) = \frac{\mathrm{d}N^{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}} \rangle \, \mathrm{d}N^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

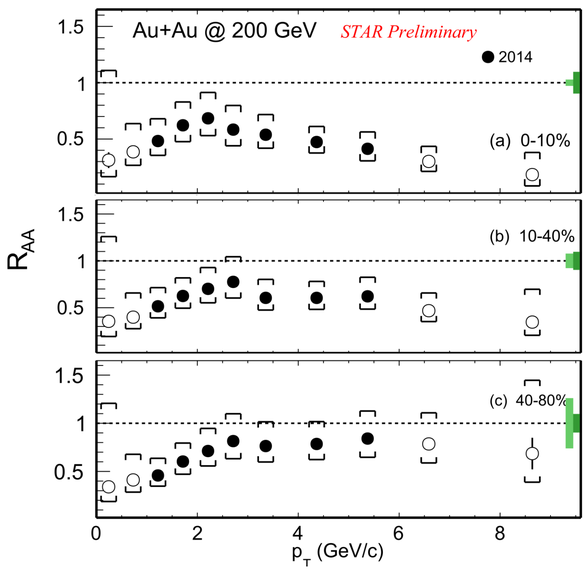

Fig. 1: R_{AA} of D^0 measured by STAR.

Raw Yield Extraction

- D± signal is extracted from Kππ invariant mass $M_{\mathrm{inv}}^{\mathrm{K}\pi\pi}$ spectrum.
- The wrong-sign distribution, an estimate of combinatorial background, is scaled using the side-band method and subtracted from the correct-sign spectrum.
- The raw yield Y_{raw} is calculated by the bin-counting method.
- Comparable significance to 2014 data.
- Comparison of Y_{raw} to signal extracted from the fit function is quoted as one of the systematic uncertainty sources.

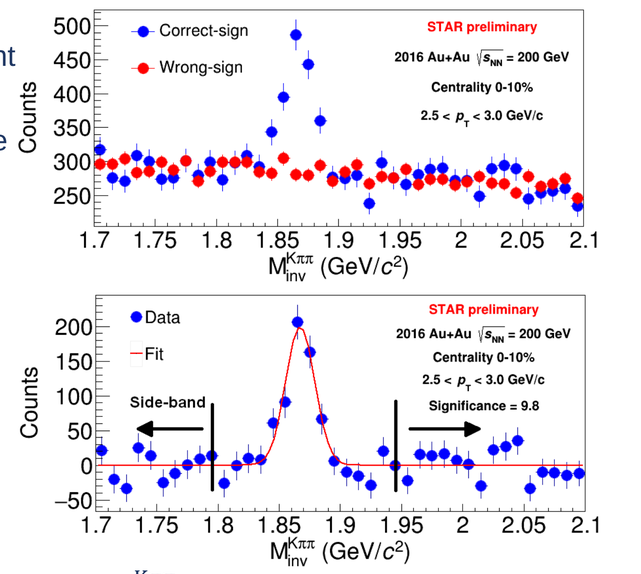

Fig. 5: $M_{\mathrm{inv}}^{\mathrm{K}\pi\pi}$ spectrum: (top) Correct and wrong-sign combinations, (bottom) After background subtraction.

STAR Detector

- STAR is an experiment designed primarily to study properties of strongly-interacting matter and proton spin structure.
- Heavy Flavor Tracker (HFT) is a 4-layer silicon detector used for precise topological reconstruction of heavy-flavor hadrons, such as D±.
  - Pixel detectors – 2 layers, Strip detectors – 2 layers.
- Time Projection Chamber (TPC) and Time Of Flight (TOF).
  - Particle momentum (TPC) and identification (TOF).

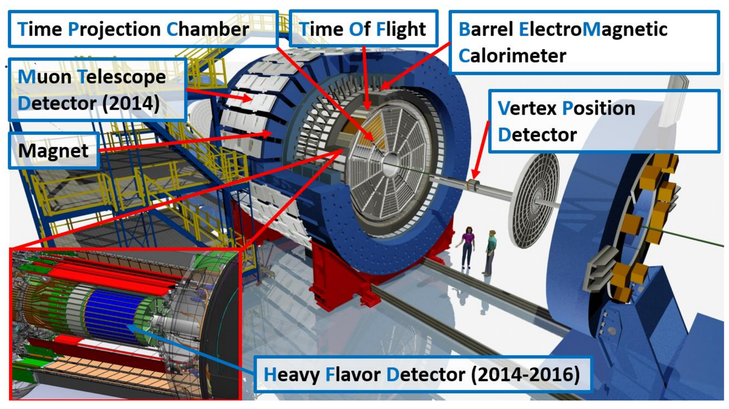

Fig. 2: The STAR detector and its sub-detectors.

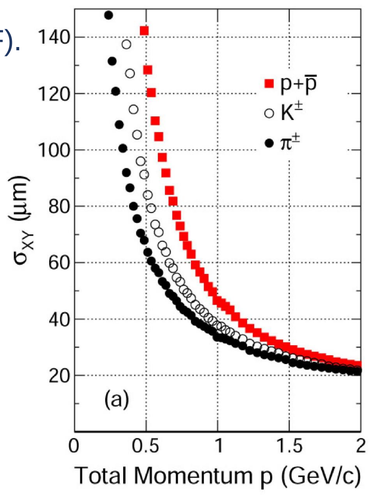

Fig. 3: HFT spatial resolution [2].

Event and Track Selection

- Analyzed 1.03 billion events of Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV taken in 2016.
- $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$ decay channel at mid-rapidity $|y| < 1$, $BR = (8.98 \pm 0.28)\%$.
- Particle identification (PID): HFT+TPC+(TOF).
  - TOF used only for tracks which have valid TOF information.

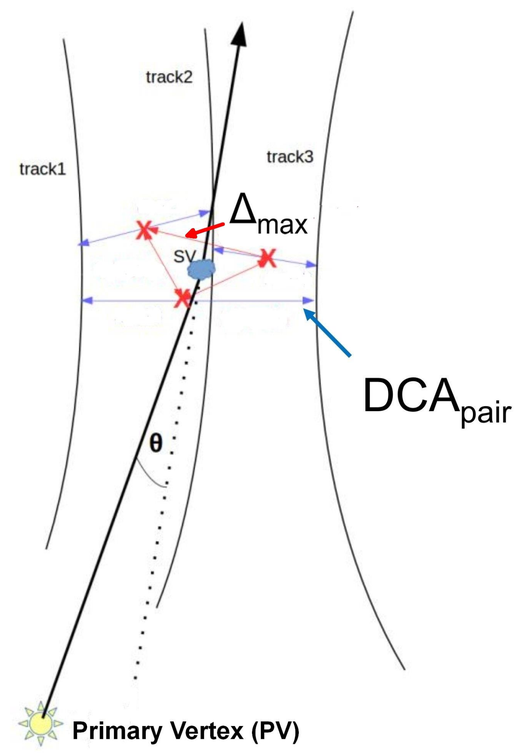

Fig. 4: Topology of the $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$ decay.

Event selection	$\lvert v_{z(\mathrm{TPC})} \rvert < 6$ cm	
	$\lvert v_{z(\mathrm{TPC})} - v_{z(\mathrm{VPD})} \rvert < 3$ cm	
Track selection	$p_{\mathrm{T}} > 500$ MeV/c	
	$\lvert\eta\rvert < 1$	
	nHitsFit > 20	
	nHitsFit/nHitsMax > 0.52	
PID cuts	TPC	$\lvert n\sigma_{\pi} \rvert < 3$
		$\lvert n\sigma_{\mathrm{K}} \rvert < 2$
	TOF	$\lvert 1/\beta - 1/\beta_{\pi} \rvert < 0.03$
		$\lvert 1/\beta - 1/\beta_{\mathrm{K}} \rvert < 0.03$
Topological cuts	$\mathrm{DCA}_{\mathrm{pair}} < 80$ μm	
	30 μm < $c\tau_{\mathrm{D+/-}} < 2000$ μm	
	$\cos(\theta) > 0.998$	
	$\Delta_{\mathrm{max}} < 200$ μm	
	$\mathrm{DCA}_{\pi\text{-PV}} > 100$ μm	
	$\mathrm{DCA}_{\mathrm{K\text{-}PV}} > 80$ μm	

Detector Efficiency and Acceptance

- HFT+TPC efficiency determined by data-driven fast-simulator.
- D± decays are generated by PYTHIA.
- Detector efficiency and resolution effects are applied to the D decayed daughters according to inputs from embedding and data:
  - TPC momentum resolution (embedding)
  - TPC tracking efficiency (embedding)
  - HFT matching efficiency (data)
  - DCA resolution (data)
  - Primary vertex position along beam axis (data)
- Efficiency $\varepsilon(p_{\mathrm{T}})$ obtained from fraction of simulated D± passing the analysis cuts.
- PID efficiency of TPC and TOF.
  - Enriched K sample at low p_{T} from data using strict TOF PID cuts.
  - Pure π sample obtained by reconstruction of K^0_S.

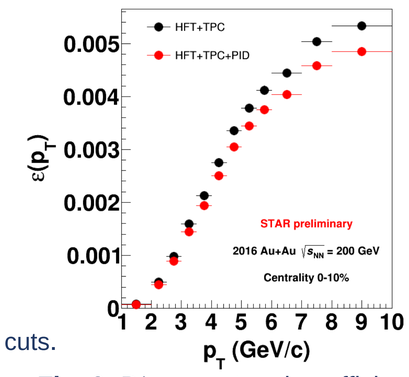

Fig. 6: D± reconstruction efficiency.

D± Nuclear Modification Factor

- Invariant yield is calculated according to:

$$\frac{\mathrm{d}^2N}{2\,\pi\,p_{\mathrm{T}}\;\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} = \frac{Y_{\mathrm{raw}}}{2\,\pi\,N_{\mathrm{evt}}\,BR\,p_{\mathrm{T}}\Delta p_{\mathrm{T}}\Delta y\,\varepsilon(p_{\mathrm{T}})}$$

- Number of events N_{evt}.
- Reference: combined D^0 and D* measurement in 200 GeV p+p collisions [3].
- High-p_{T} D± and D^0 suppressed in central Au+Au collisions.
- 2016 D± suppression comparable to that of 2014 D^0.
- Other centralities are currently being studied.

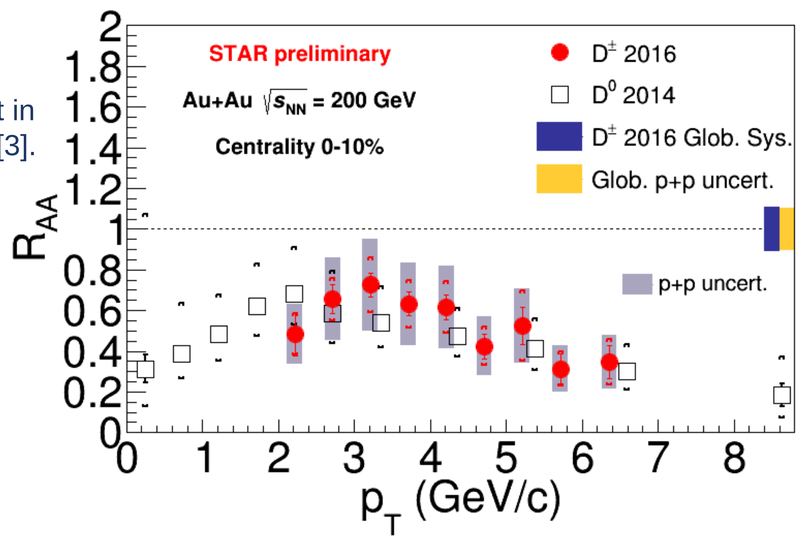

Fig. 7: R_{AA} of D-mesons in central Au+Au collisions.

Conclusion

- D± has been measured in central Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV by STAR using data taken in 2016.
- A significant suppression of the high-p_{T} D± production is observed in central Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV and is comparable to that of D^0.
- These high precision measurements can provide stringent constraints on model calculations.

References

[1] G. Xie, for the STAR Collaboration, Nucl. Phys. A, 956, 473-476
[2] Adamczyk L. *et al.* (STAR) 2017 Phys. Rev. Lett. **118** 212301
[3] Adamczyk L. et al. (STAR) 2012 Phys. Rev. D **86** 072013

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