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

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Abstract

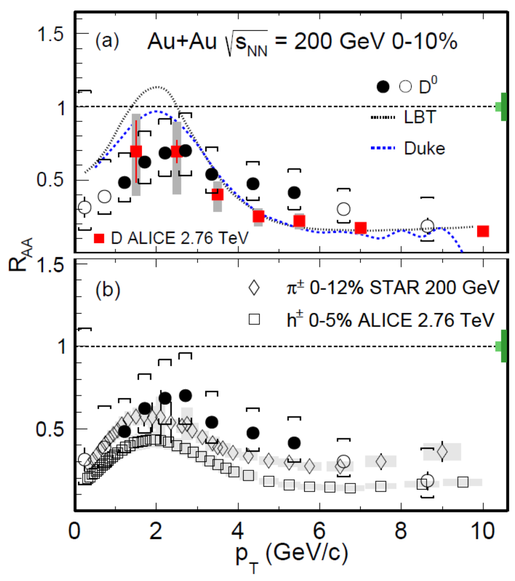
Charm quarks are a unique probe of the QGP created in heavy-ion collisions as they are produced at very early stages of these collisions and subsequently experience the whole evolution of the system. Information on charm quark production and dynamics in the QGP medium can be accessed through open charm hadrons. At STAR, measurement of the open charm hadrons is enabled by the Heavy Flavor Tracker which allows their direct topological reconstruction, thanks to its excellent track pointing resolution. In this poster, we present a measurement of D± meson production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV by the STAR using data collected in year 2016. In particular, we focus on optimization of topological selection criteria using a machine learning technique from the Toolkit for Multivariate Data Analysis (TMVA) which has been done separately for each studied p_{T} bin of D± and each collision centrality class. The optimization uses 160M simulated D± meson decays as a signal sample and wrong-sign Kππ triplets from data as a background. The TMVA-optimized topological criteria help to significantly suppress the combinatorial background for $p_{\mathrm{T}} < 4$ GeV/c and improve the significance of the D± raw yield.

Physics Motivation

- Suppression of high-p_{T} D^0 is observed in central Au+Au collisions and is comparable to that of pions [1]

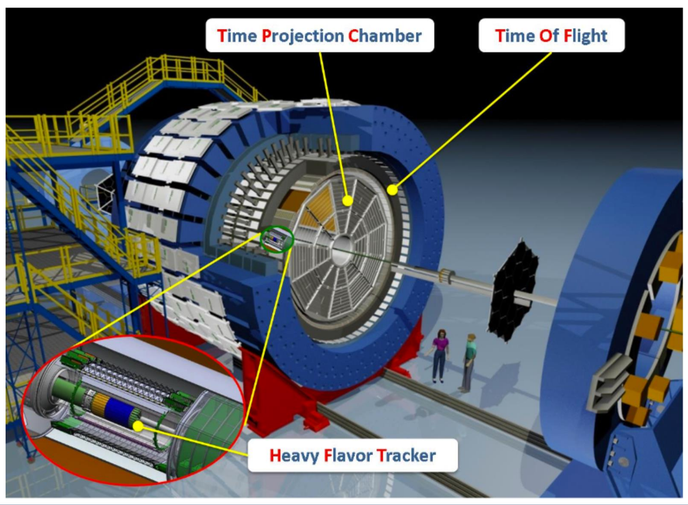
$$R_{\mathrm{AA}}(p_{\mathrm{T}}) = \frac{\mathrm{d}N^{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}N^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}}$$

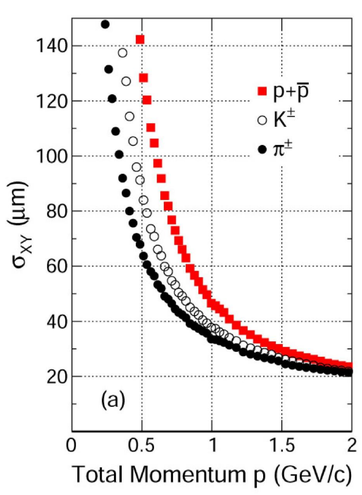
- The study of D± production is complementary to that of D^0 and also provides constraints on the total charm cross-section in heavy-ion collisions
- Precise measurements of open-charm mesons with the HFT by STAR will provide constraints for model calculations



STAR Experiment

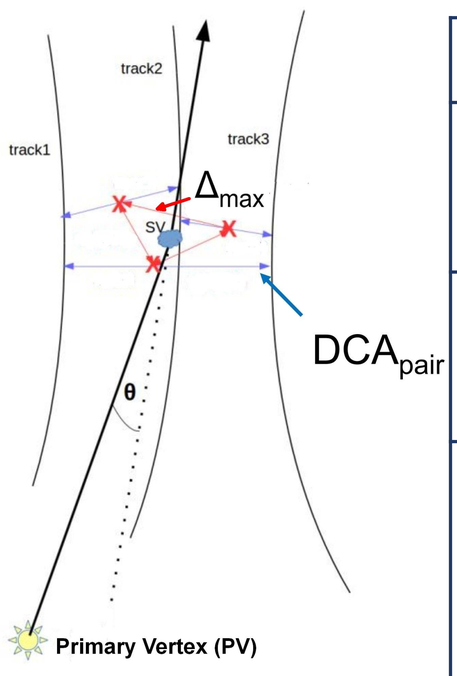
- **Heavy Flavor Tracker** (HFT): 4-layer silicon detector used for precise topological reconstruction of heavy-flavor hadrons, such as D±
  - MAPS-based pixel detectors – 2 layers, Strip detectors – 2 layers
- **Time Projection Chamber** (TPC) and **Time Of Flight** (TOF) detector
  - Particle momentum (TPC) and identification (TPC and TOF)





Event and Track Selection

- Analyzed 1.3 billion Au+Au events at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV taken in 2016 with the HFT
  - 1 billion events used previously for the Preliminary
- $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$ decay channel at mid-rapidity:
  - $|y| < 1$, $BR = (8.98 \pm 0.28)\%$, $c\tau = (311.8 \pm 2.1)$ μm
- Particle selection and identification: HFT+TPC+(TOF)
  - TOF used only for tracks which have valid TOF information
- Precise topological reconstruction utilizing excellent vertex resolution of the HFT
  - Topological selection criteria tuned using TMVA rectangular cuts optimization

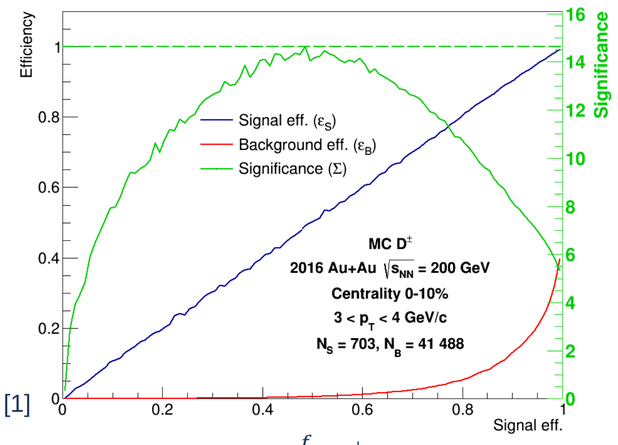


Δ_{max} = maximum distance between the secondary vertices of track pairs

Event selection	$\lvert v_{z(\mathrm{TPC})}\rvert < 6$ cm	
	$\lvert v_{z(\mathrm{TPC})} - v_{z(\mathrm{VPD})}\rvert < 3$ cm	
Track selection	$p_{\mathrm{T}} > 300$ MeV/c	
	$\lvert\eta\rvert < 1$	
	nHitsFit > 20	
	nHitsFit/nHitsMax > 0.52	
Particle identification	TPC	$\lvert n\sigma_{\pi}\rvert < 3$
		$\lvert n\sigma_{K}\rvert < 2$
	TOF	$\lvert 1/\beta - 1/\beta_{\pi}\rvert < 0.03$
		$\lvert 1/\beta - 1/\beta_{K}\rvert < 0.03$
Topological variables (Optimized)	$\mathrm{DCA}_{\mathrm{pair}}$	
	$L_{\mathrm{D+/-}} < 2$ mm	
	$\cos(\theta)$	
	Δ_{max}	
	$\mathrm{DCA}_{\pi 1\text{-PV}}$	
	$\mathrm{DCA}_{\pi 2\text{-PV}}$	
	$\mathrm{DCA}_{\mathrm{K\text{-}PV}}$	

TMVA Topological Selection Criteria Optimization

- Rectangular cuts optimization method from the Toolkit for Multivariate Data Analysis [3]
- **Inputs to TMVA**
  - Background sample
    - From data
    - Wrong-sign Kππ triplets
  - Signal sample
    - From data-driven fast-simulation
    - 160M simulated D± decays
- **Number of background events $N_{\mathrm{B}}(p_{\mathrm{T}})$**
  - From combinatorial background in data
- **Number of signal events $N_{\mathrm{S}}(p_{\mathrm{T}})$**
  - Estimated using measured D^0 spectrum [1]

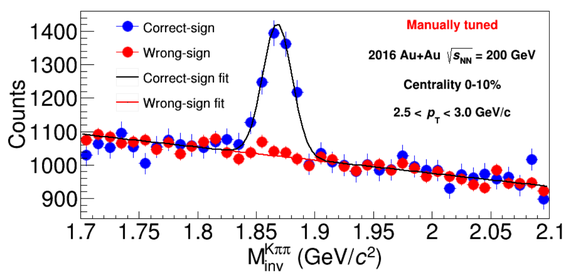


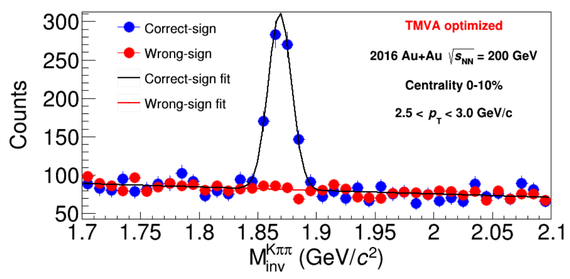
$$N_{\mathrm{S}}(p_{\mathrm{T}}) = \left(\frac{\mathrm{d}^2N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\right)_{D^0} N_{\mathrm{evt}}\, BR_{D^{\pm}}\, \Delta p_{\mathrm{T}} \Delta y\, \varepsilon(p_{\mathrm{T}}) \frac{f_{c\rightarrow D^{\pm}}}{f_{c\rightarrow D^0}}$$

- N_{evt} – number of events, f – fragmentation ratios, $\varepsilon(p_{\mathrm{T}})$ – D± reconstruction efficiency from data-driven fast simulator
- **Optimal cuts selected based on maximum significance**

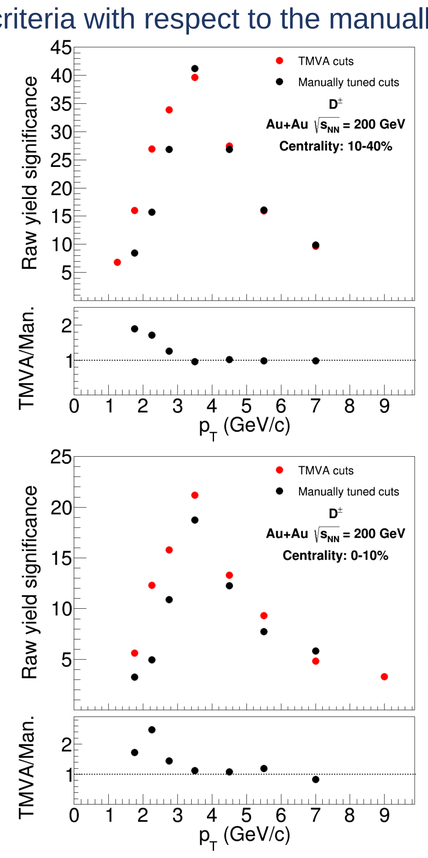
TMVA Optimization Performance

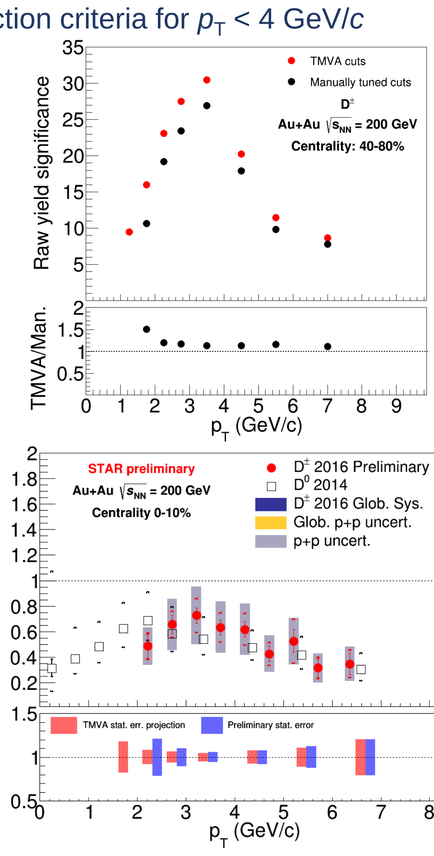
- Improved D± mesons raw yield extraction with TMVA-optimized topological selection criteria thanks to significantly suppressed combinatorial background





- Improved D± meson raw yield significance extracted with TMVA topological selection criteria with respect to the manually tuned selection criteria for $p_{\mathrm{T}} < 4$ GeV/c





Stat. error projection

Conclusions

- Optimization of rectangular selection criteria using the TMVA has significantly suppressed the combinatorial background and improved the D± raw yield significance
- Expecting improved statistical precision of D± R_{AA} with the TMVA-optimized topological selection criteria
- Better statistical precision at $p_{\mathrm{T}} < 4$ GeV/c will allow more precise determination of total D± production cross-section

References

[1] Adam J., *et al*. (STAR), Phys. Rev. C **99**, 034908, (2019).
[2] Adamczyk L., *et al.* (STAR), Phys. Rev. Lett. **118** 212301 (2017)
[3] Tanabashi M., *et al.* (PDG), Phys. Rev. Lett. **98** 030001 (2018)
[4] TMVA official website: http://tmva.sourceforge.net, (October 11, 2019)

This work is supported by project LTT18002 of Ministry of Education, Youth and Sports of the Czech Republic.

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS

Poster supported by:
U.S. DEPARTMENT OF ENERGY | Office of Science

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