Supported in part by

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

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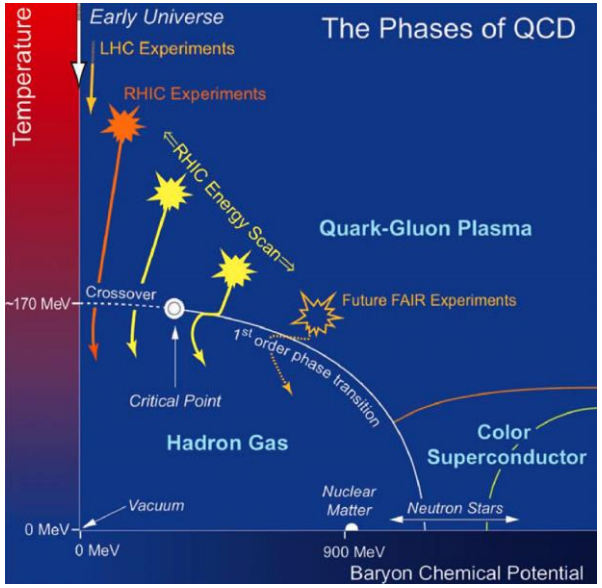
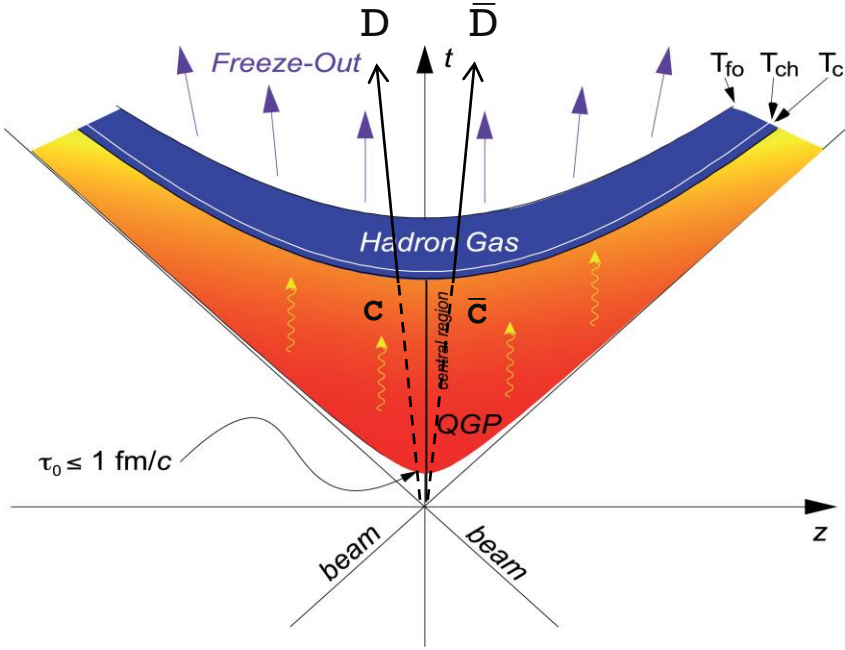
PHYSICS MOTIVATION

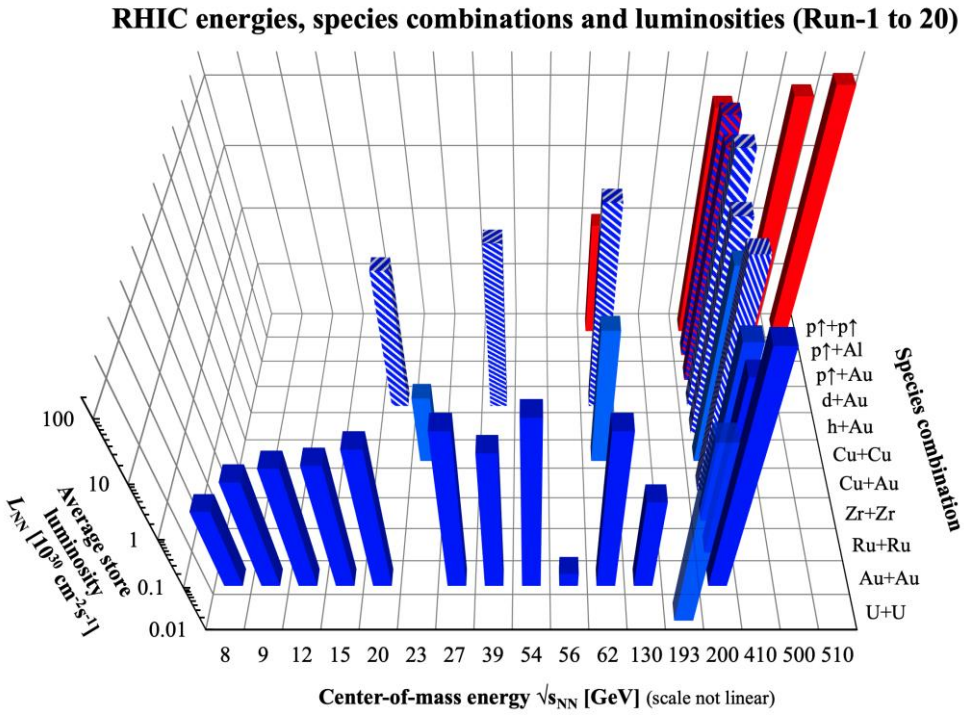
- **Quark-Gluon Plasma** (QGP) is the state of matter where quarks and gluons are no longer trapped inside colorless hadrons
- QGP is formed in relativistic heavy-ion collisions
- At RHIC energies, **charm quarks** are produced predominantly through hard partonic scatterings at **early stage** of Au+Au collisions
  - They experience **the whole evolution of the medium**

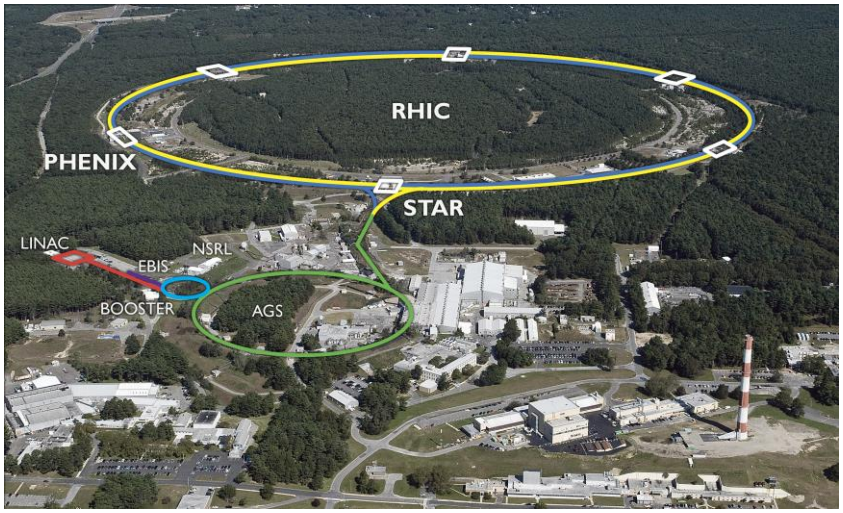




RELATIVISTIC HEAVY-ION COLLIDER

- Relativistic Heavy-Ion Collider (RHIC) is located in Brookhaven National Laboratory (BNL), Long Island, New York
  - RHIC is 3.8 km long with 6 interaction regions (IR)
  - STAR is located at 6'o clock IR and is the only running experiment at RHIC today
- RHIC is a very versatile collider:





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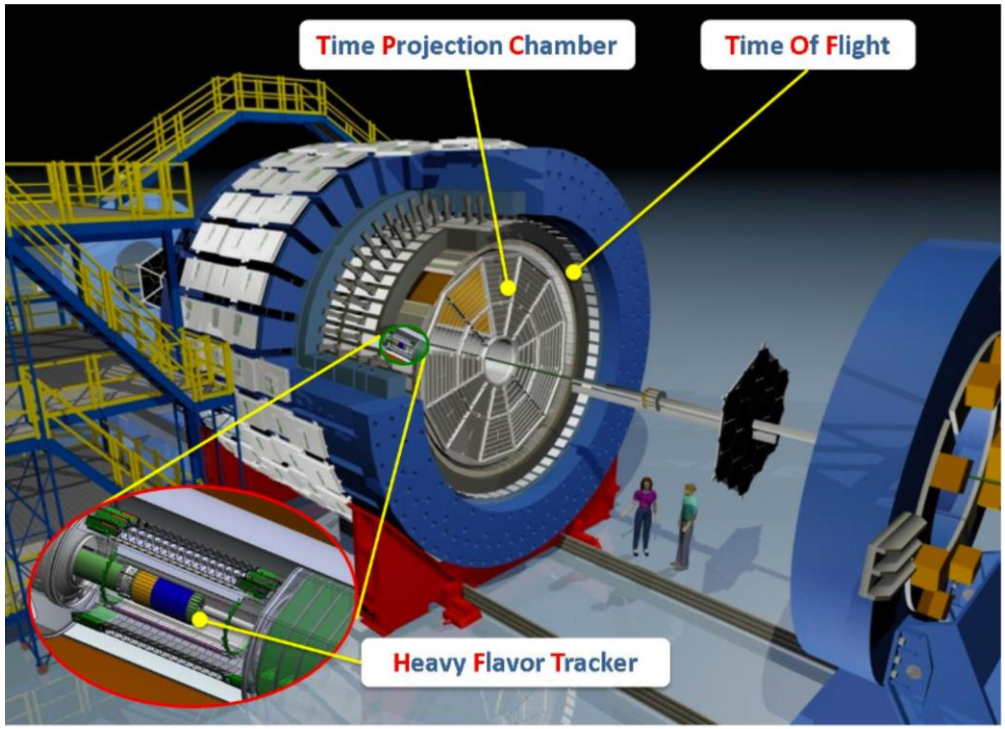
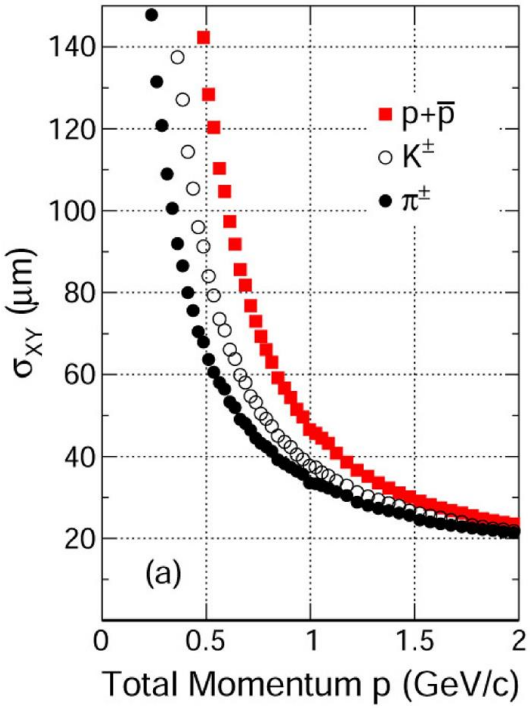
STAR DETECTOR

- **S**olenoidal **T**racker **A**t **R**HIC
- **H**eavy **F**lavor **T**racker (HFT, 2014–2016) is a 4-layer silicon detector
  - MAPS – 2 innermost layers (PXL1, PXL2), Strip detectors – 2 outer layers (IST, SSD)
- **T**ime **P**rojection **C**hamber (TPC) and **T**ime **O**f **F**light (TOF)
  - Particle momentum (TPC) and identification (TPC and TOF)

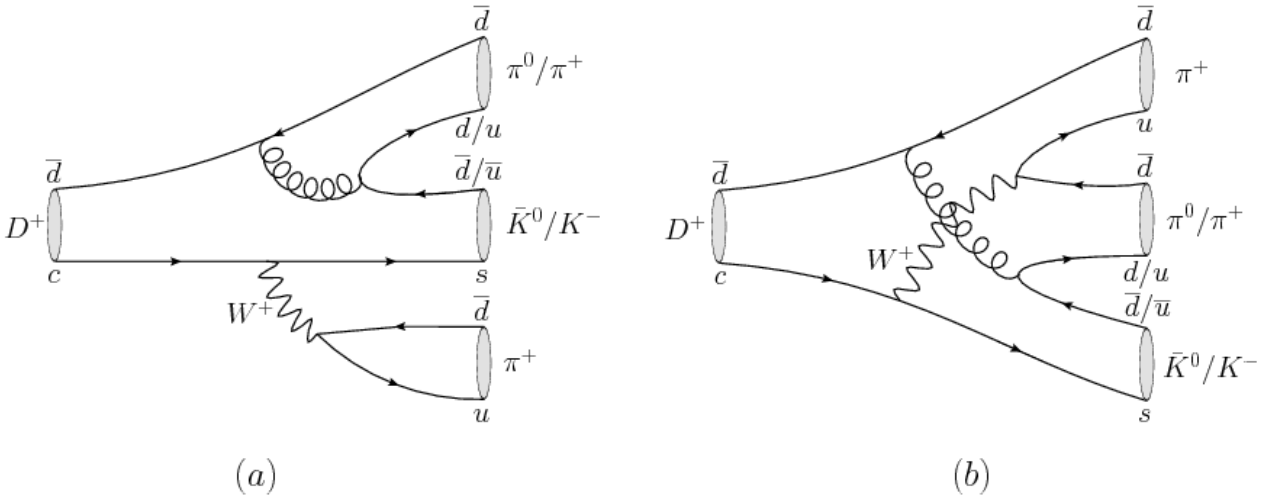


STAR: PRL 118, 212301, (2017)



$D^{\pm}$ MEASUREMENTS WITH THE HFT

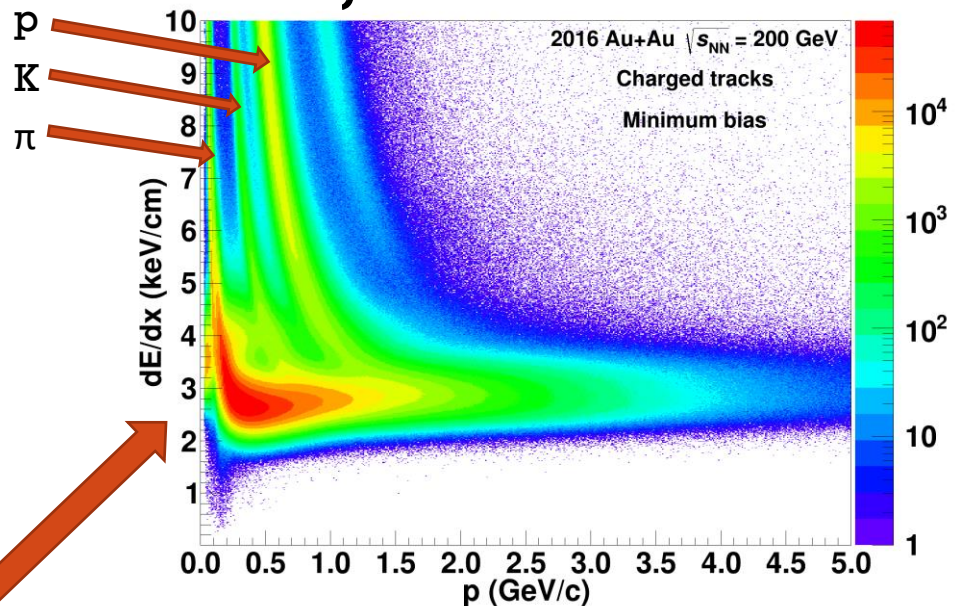
- Data used in this analysis are from 2014 and 2016 for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV
- Total of ca. 2.3B good minimum bias events after event selection
- The HFT allows direct topological reconstruction of $D^{\pm}$ mesons through their hadronic decay
  - $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$ $c\tau$ = (311.8 ± 2.1) μm BR = (8.98 ± 0.28) %

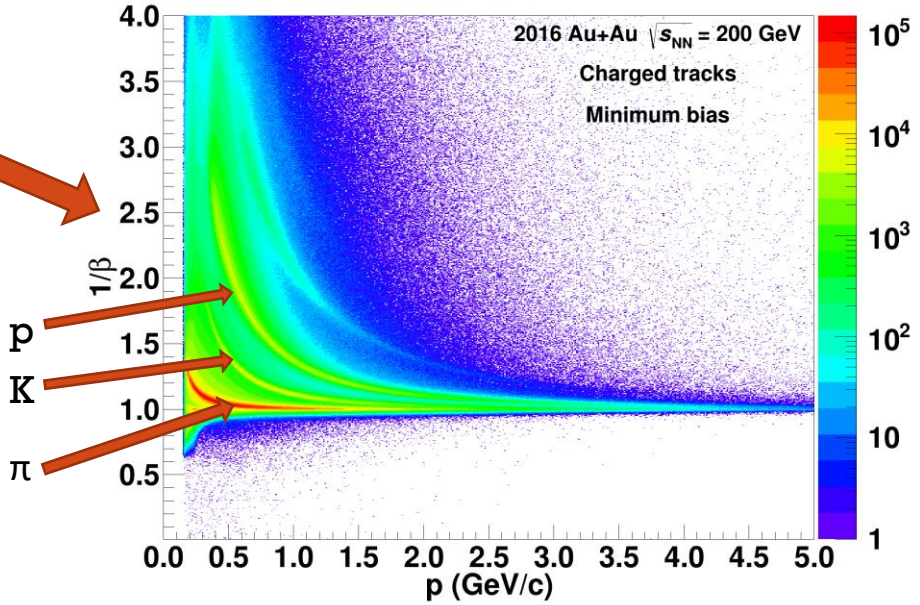


F. Niecknig, B. Kubis: JHEP 1510, 142, (2015)

EVENT AND TRACK SELECTION, PID

- **Event selection**
  - Position of primary vertex along the beam axis
- **Track selection**
  - Low p_T cut – suppression of combinatorial background from low-p_T particles
  - $|\eta| < 1$ – detector acceptance
  - Minimum number of hits on each track in the TPC – good track quality
  - At least three hits in HFT, one in PXL1, one in PXL2 and at least one in IST or SSD
- **Particle identification (PID)**
  - TPC – energy loss of charged particles in the TPC gas
  - TOF – velocity of the charged particles
- **Topological selection criteria**
  - Possible only with use of the HFT
  - Constrain topology of the reconstructed secondary vertex
  - Suppress combinatorial background
  - Optimized using multivariate analysis package TMVA





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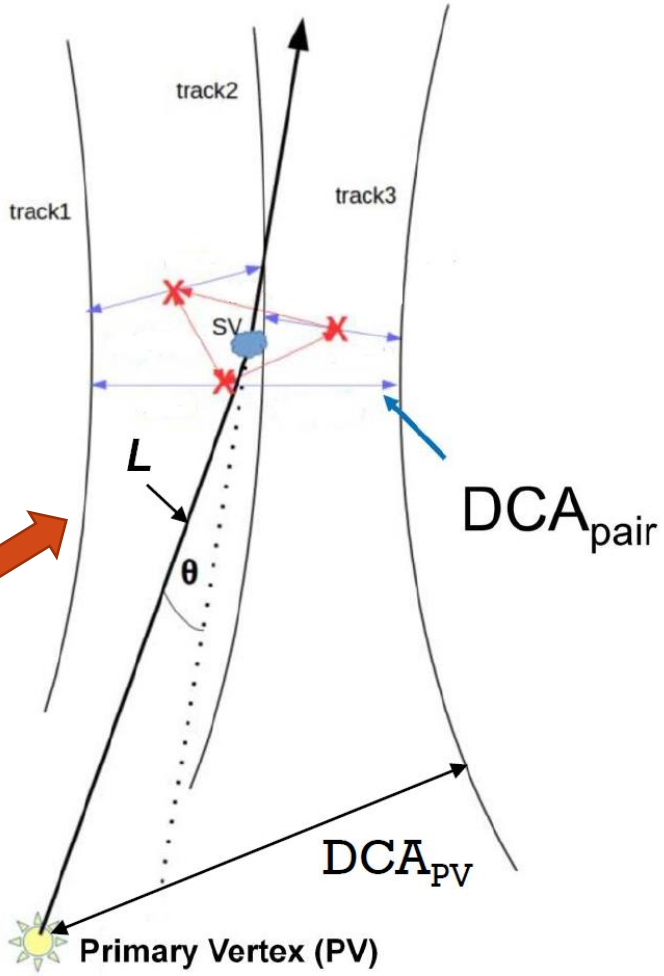
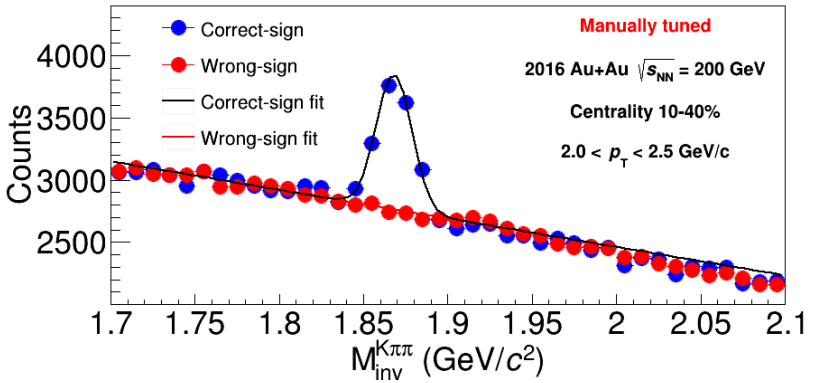
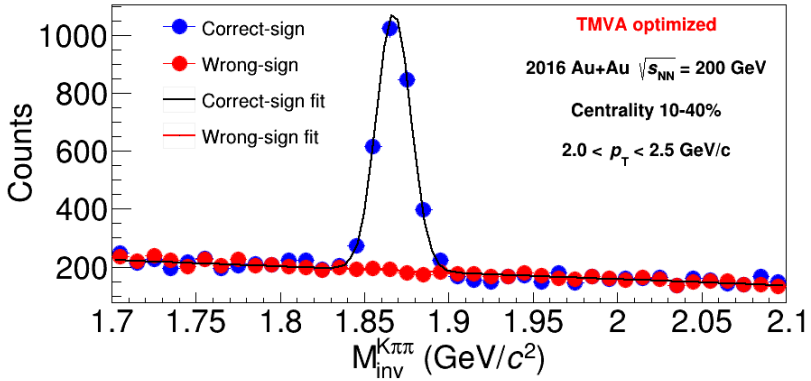
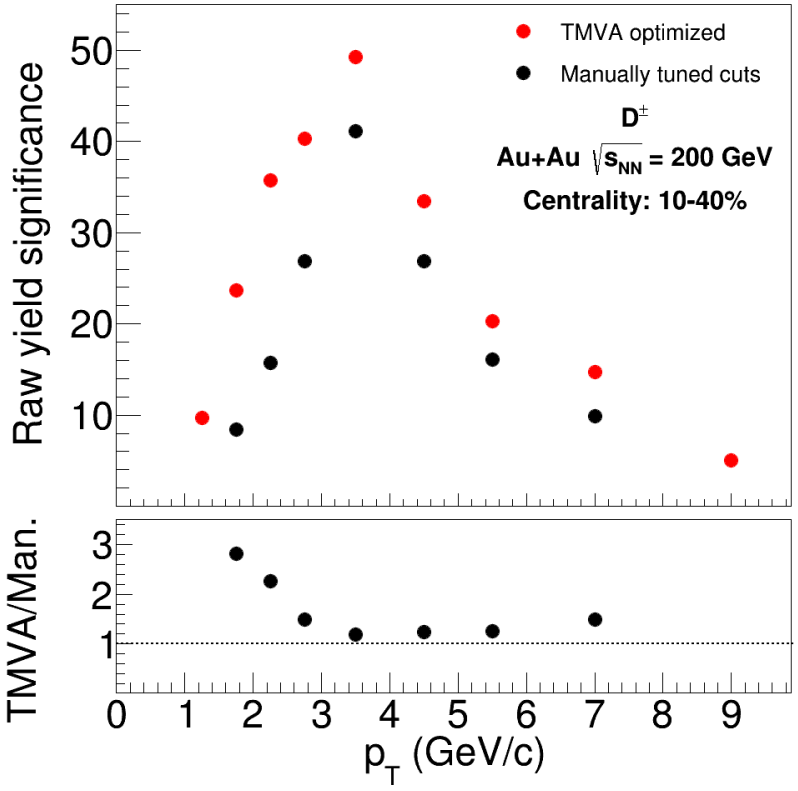


$D^{\pm}$ RAW YIELD EXTRACTION

- Raw yields extracted from invariant mass spectra of Kππ triplets
  - Significant background suppression with TMVA optimization of the topological selection criteria
  - Improved signal significance, especially at low-p_T







$D^{\pm}$ INVARIANT SPECTRUM

- Invariant yield is calculated according to:

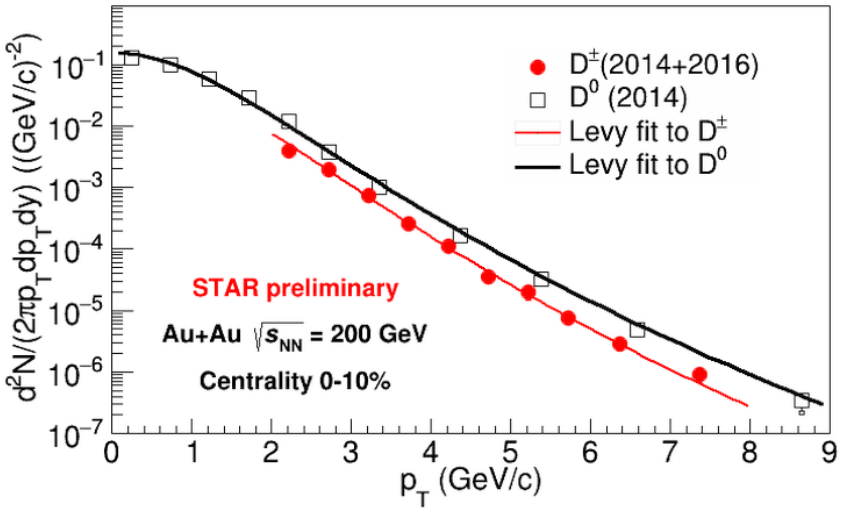
$$\frac{\mathrm{d}^2N}{2\pi p_{\mathrm{T}}\,\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} = \frac{Y_{\mathrm{raw}}}{2\,\pi\,N_{\mathrm{evt}}\,BR\,p_{\mathrm{T}}\Delta p_{\mathrm{T}}\Delta y\,\varepsilon(p_{\mathrm{T}})}$$

- Y_{raw} = raw yield, N_{evt} = number of events, BR = branching ratio, $\varepsilon(p_{\mathrm{T}})$ = total $D^{\pm}$ reconstruction efficiency

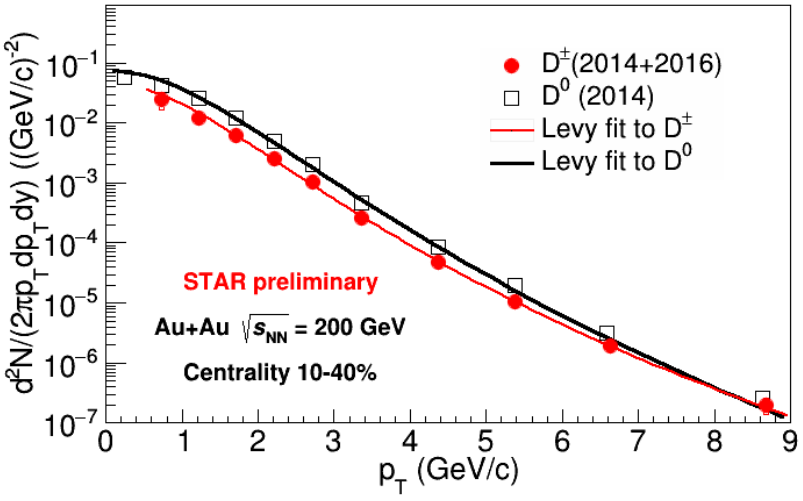
- **Collision centrality classes: 0-10%, 10-40%, 40-80%**
  - Determined from Glauber model simulation matched to charged track multiplicity in TPC

$D^{\pm}$ INVARIANT SPECTRUM

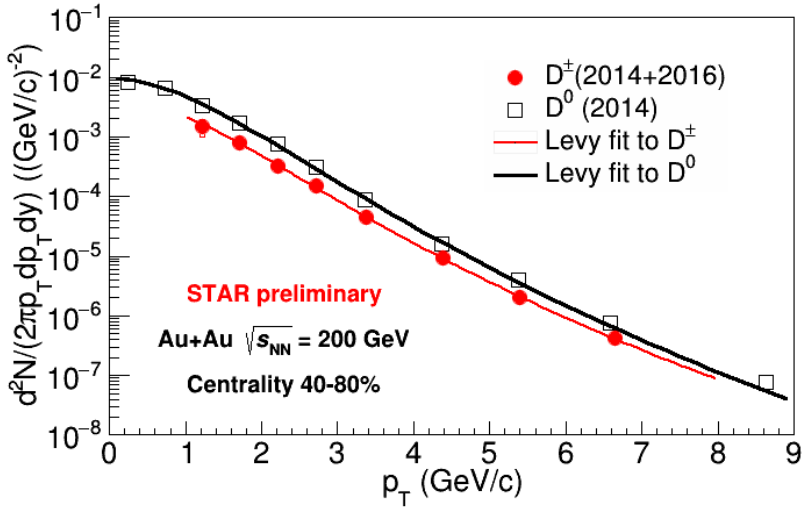
0-10%



10-40%



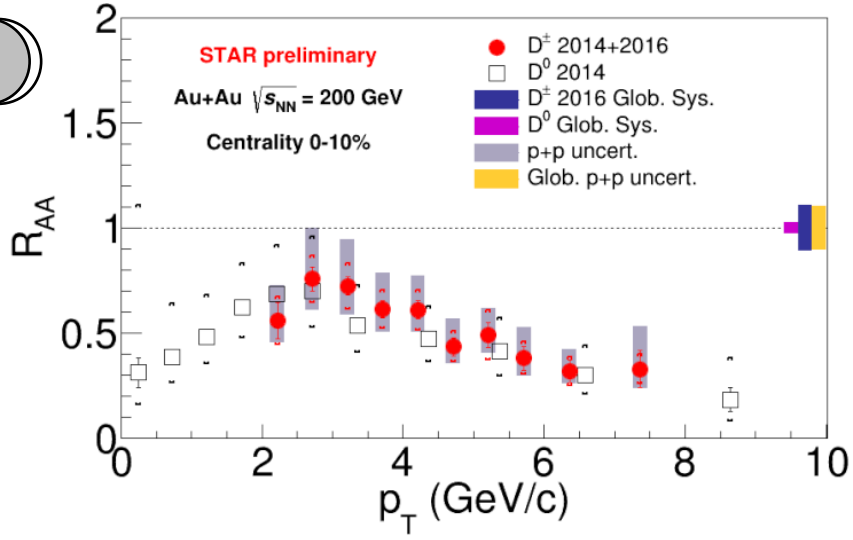
40-80%

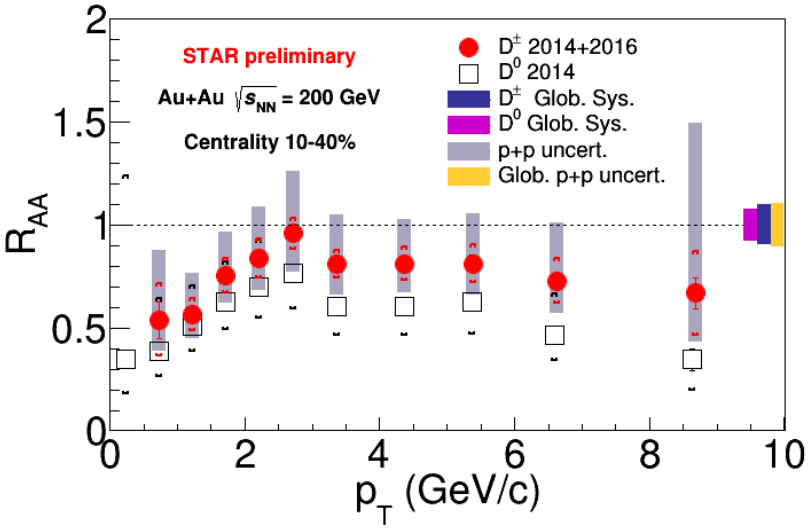


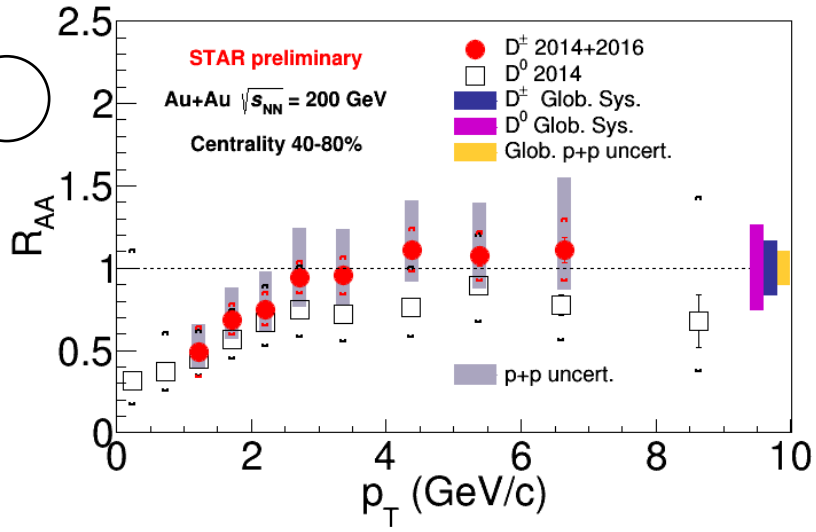
- Invariant spectra of $D^{\pm}$ and D^0 mesons measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- Spectra are fitted by Levy function
- The $D^{\pm}$ results help to constrain the total open charm cross section and for better understanding of charm quark hadrochemistry in Au+Au collisions

D^0 (STAR): Phys. Rev. C 99, 034908, (2019).

$D^{\pm}$ NUCLEAR MODIFICATION FACTOR







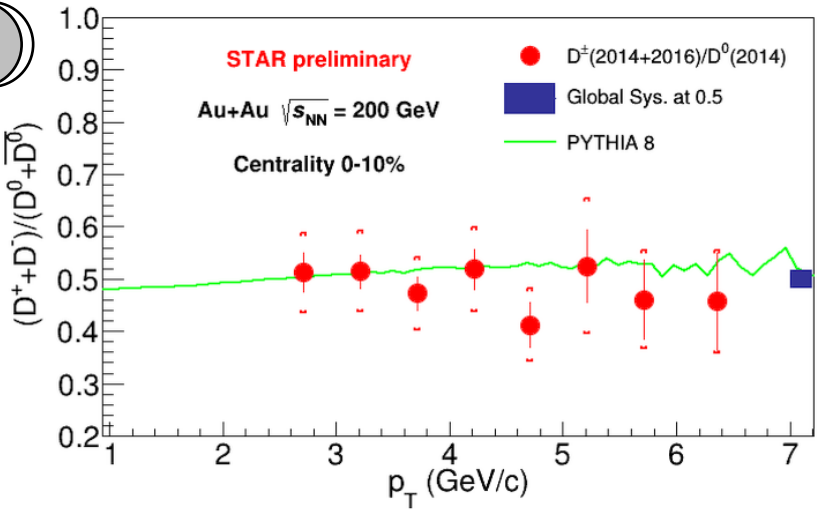
- Nuclear modification factor:

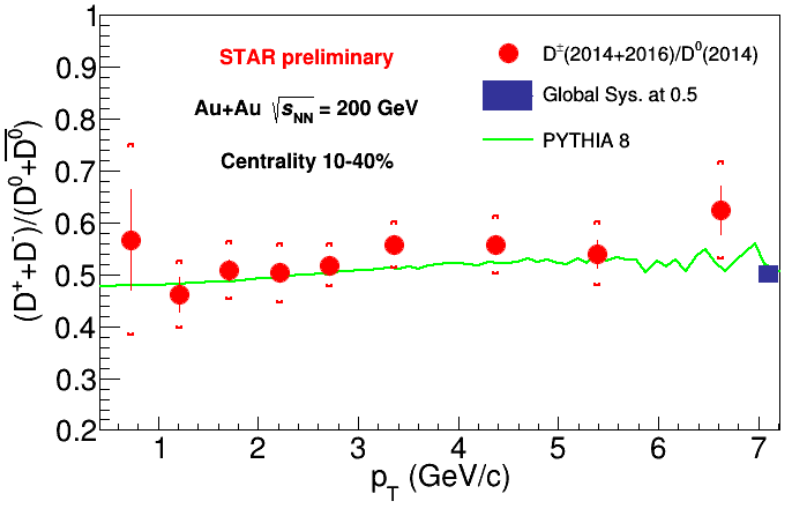
$$R_{AA}(p_T) = \frac{dN^{AA}/dp_T}{\langle N_{coll}\rangle\, dN^{pp}/dp_T}$$

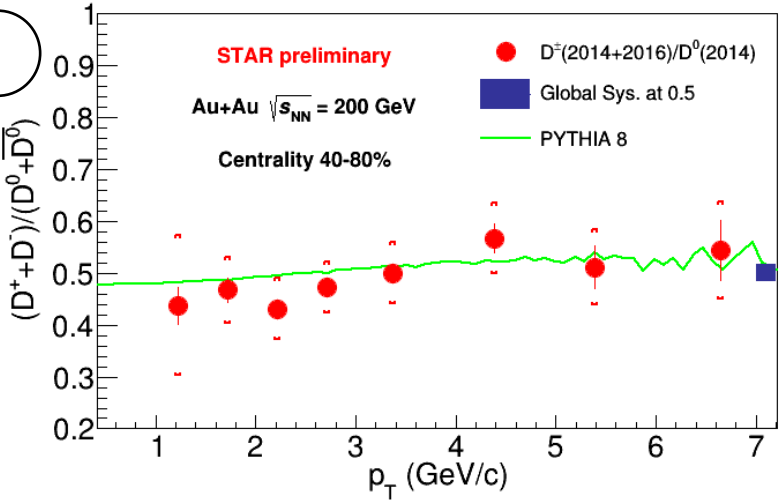
- Similar suppression and centrality dependence for $D^{\pm}$ and D^0
- High-p_T $D^{\pm}$ and D^0 suppressed in central Au+Au collisions
  - Strong interactions between charm quarks and the medium

p+p reference (STAR): Phys. Rev. D 86, 072013, (2012)
D^0 (STAR): Phys. Rev. C 99, 034908, (2019).

$D^{\pm}/D^{0}$ YIELD RATIO







- The $D^{\pm}/D^{0}$ yield ratio in Au+Au collisions is compared to that from MC simulation of p+p collisions (PYTHIA 8)
  - Good agreement in all Au+Au centrality classes
- No modification of the $D^{\pm}/D^{0}$ yield ratio compared to PYTHIA

TOTAL CHARM PRODUCTION CROSS SECTION

- Total charm production **cross section per binary nucleon-nucleon collision** in Au+Au extracted from the measurements of open-charm hadrons
- The Au+Au result is consistent with that measured in p+p collisions within the uncertainties
- **Redistribution of charm quarks among open –charm hadron species in Au+Au compared to p+p**

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

*The Λ_c cross section is derived using the Λ_c/D^0 yield ratio

D^0 2014 (STAR): Phys. Rev. C 99, 034908, (2019).
D^0 2010/11 (STAR): Phys. Rev. Lett. 113, 142301 (2014), erratum: Phys. Rev. Lett. 121, 229901 (2018).
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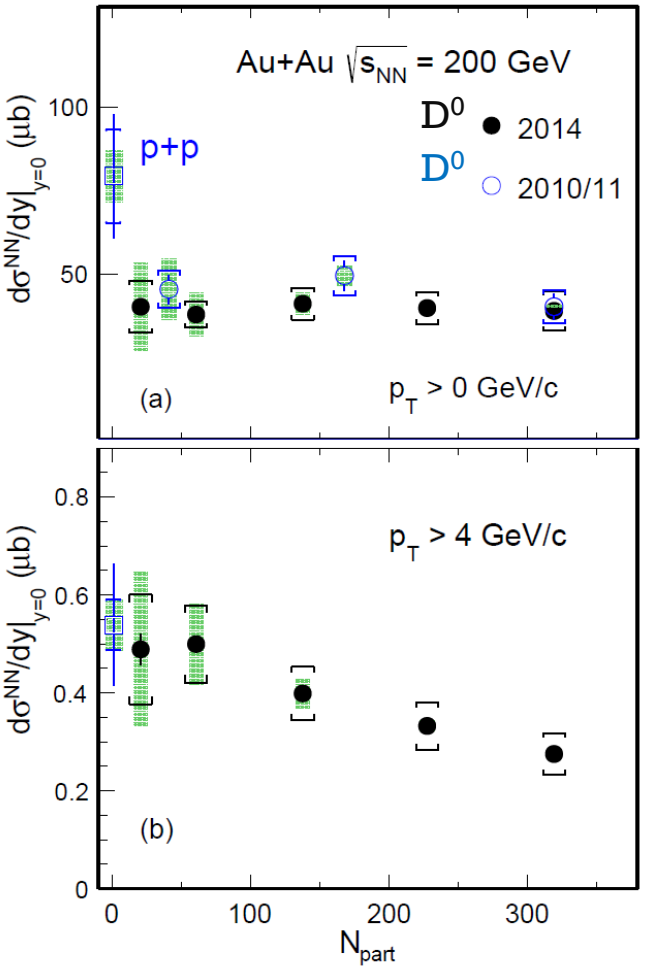

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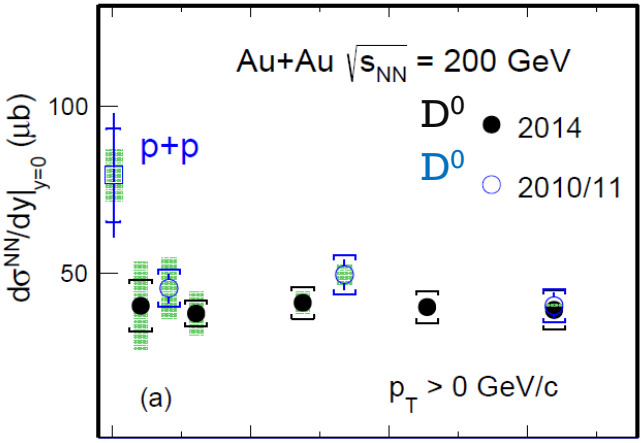

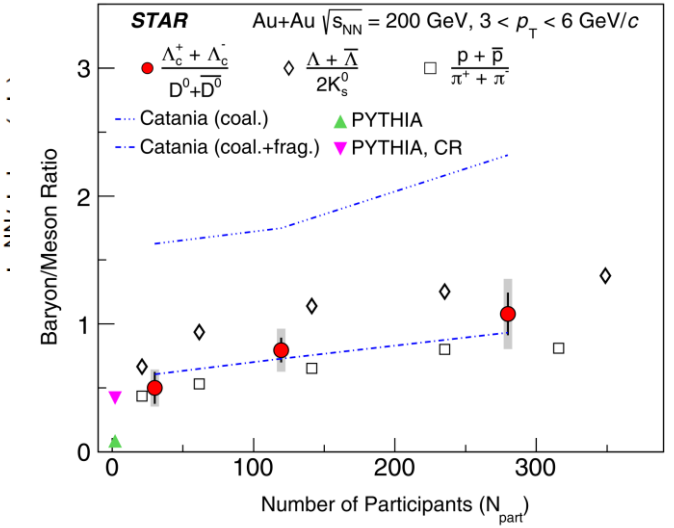

CONCLUSION

- STAR has extensively studied production of open-charm hadrons in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV utilizing the HFT
- The HFT allows direct topological reconstruction of hadronic decays of open-charm hadrons
- $D^{\pm}$ invariant yields measured for three centrality classes of Au+Au collisions
  - 0-10%, 10-40%, 40-80%
- High p_{T} $D^{\pm}$ mesons suppressed in central Au+Au cillisions
  - Charm quarks interact strongly with the QGP
- $D^{\pm}/D^{0}$ yield ratio measured in Au+Au collisions agrees with PYTHIA 8 calculation
  - No modification of the ratio in Au+Au with respect to p+p collisions
- Total charm quark production cross section per binary collision measured in Au+Au collisions is consistent with that measured in p+p collisions

THANK YOU FOR ATTENTION