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

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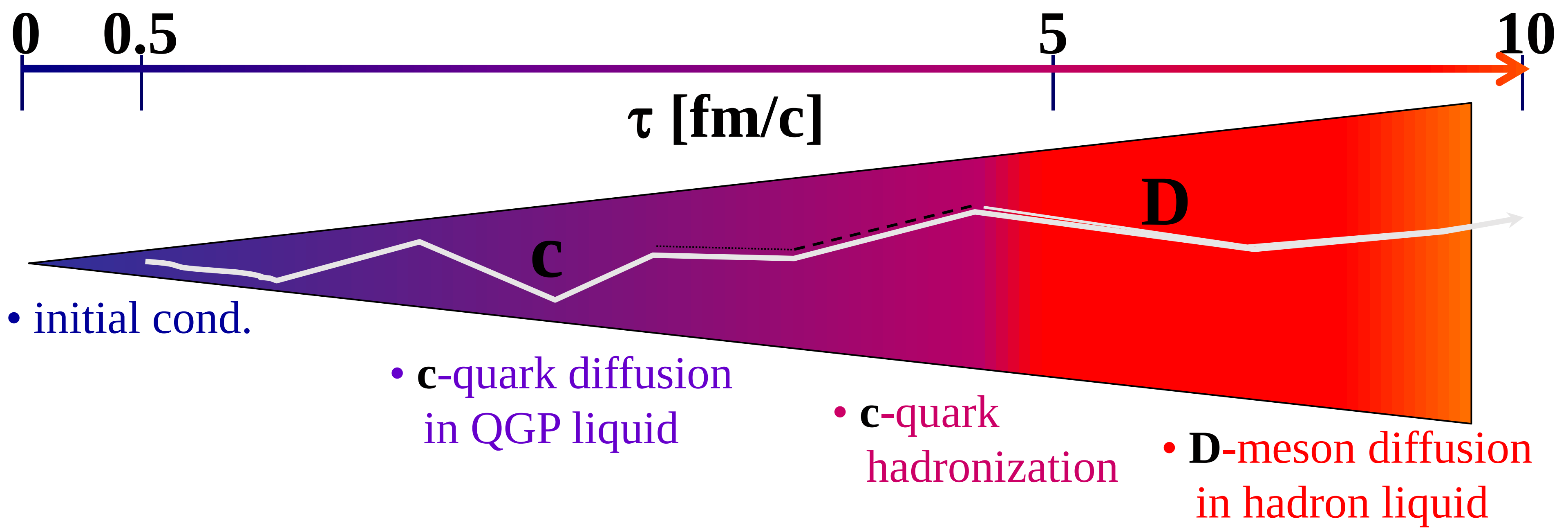
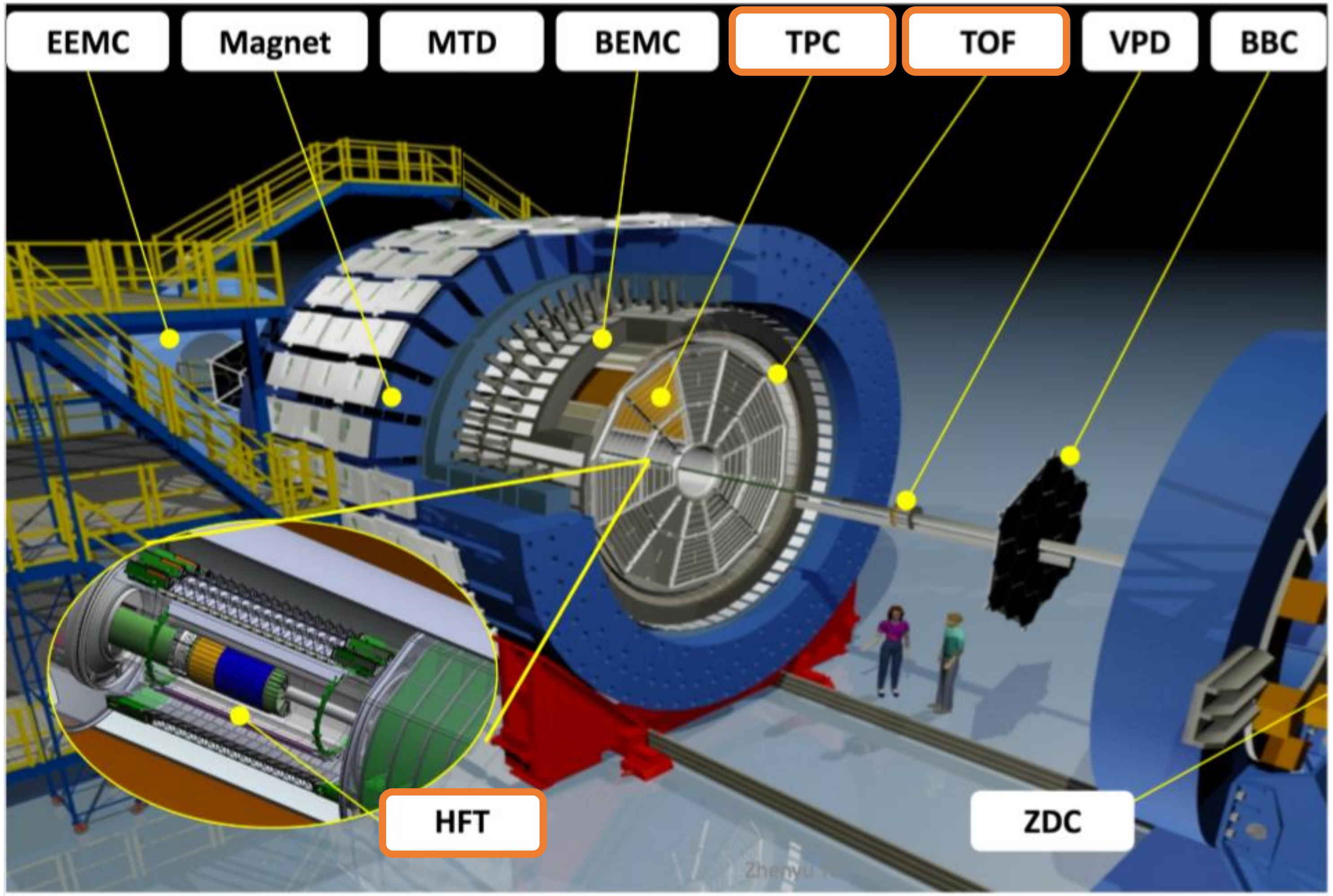
Introduction: Open Charm Transport in URHICs



- Produced predominantly in initial hard-scatterings
- Experience the whole evolution of the system
- sensitive probe to the QGP because of their large masses

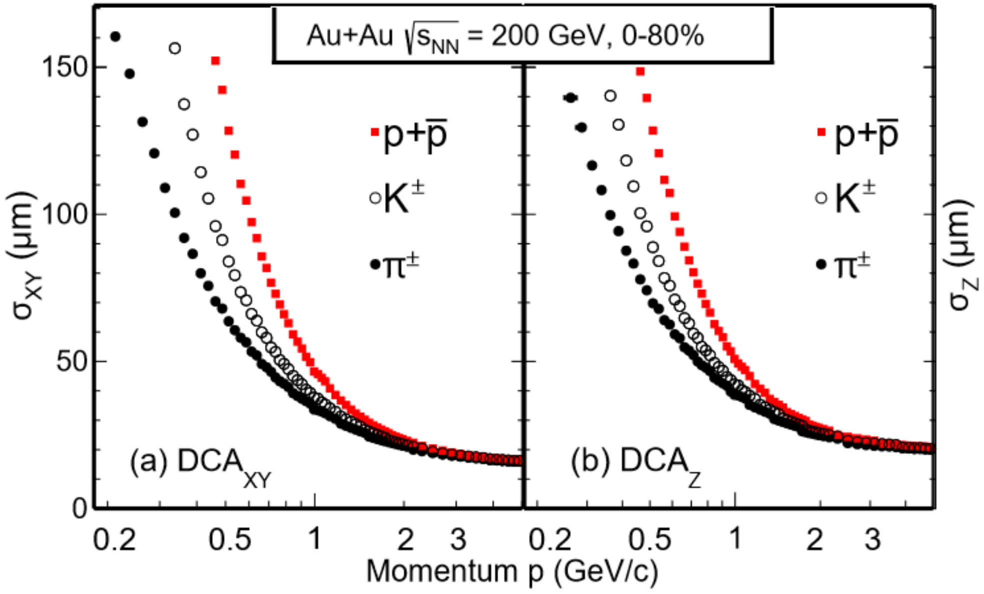
Introduction: The STAR Experiment



- TPC: Tracking and PID (dE/dx)
- TOF: PID (1/β)
- HFT: 2014 - 2016

  Excellent DCA resolution

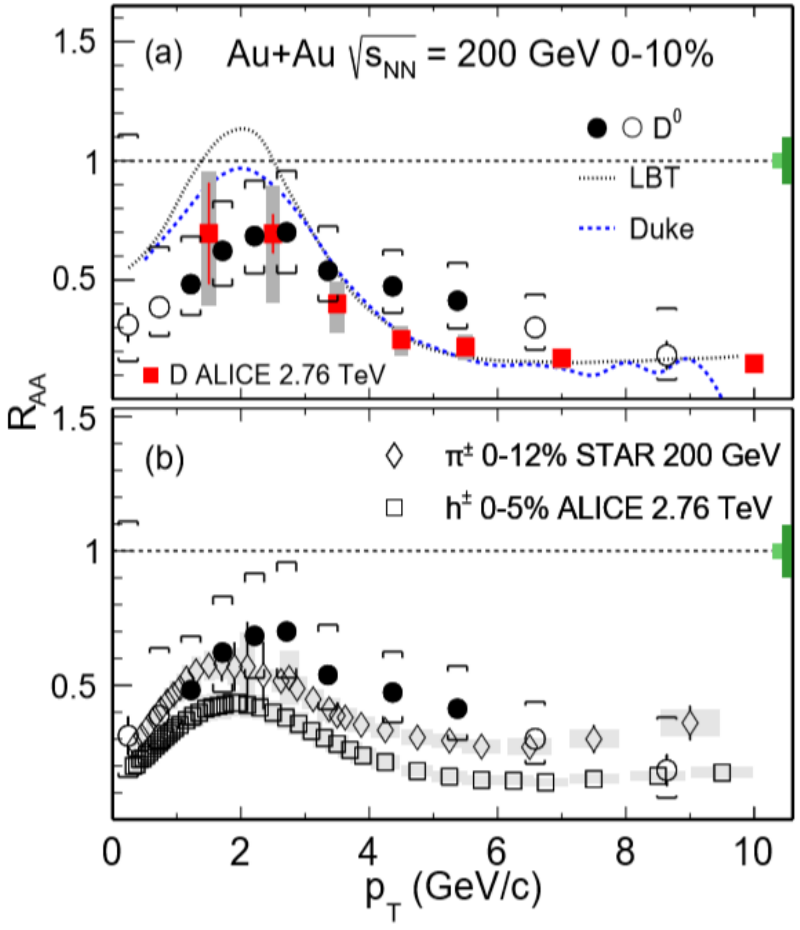
  ~ 35 μm @ p_T = 1 GeV/c



Phys. Rev. C ***99*** *(2019) 34908*

Introduction: Charm Hadron Measurement

1) D^0 R_{AA} measurement at STAR

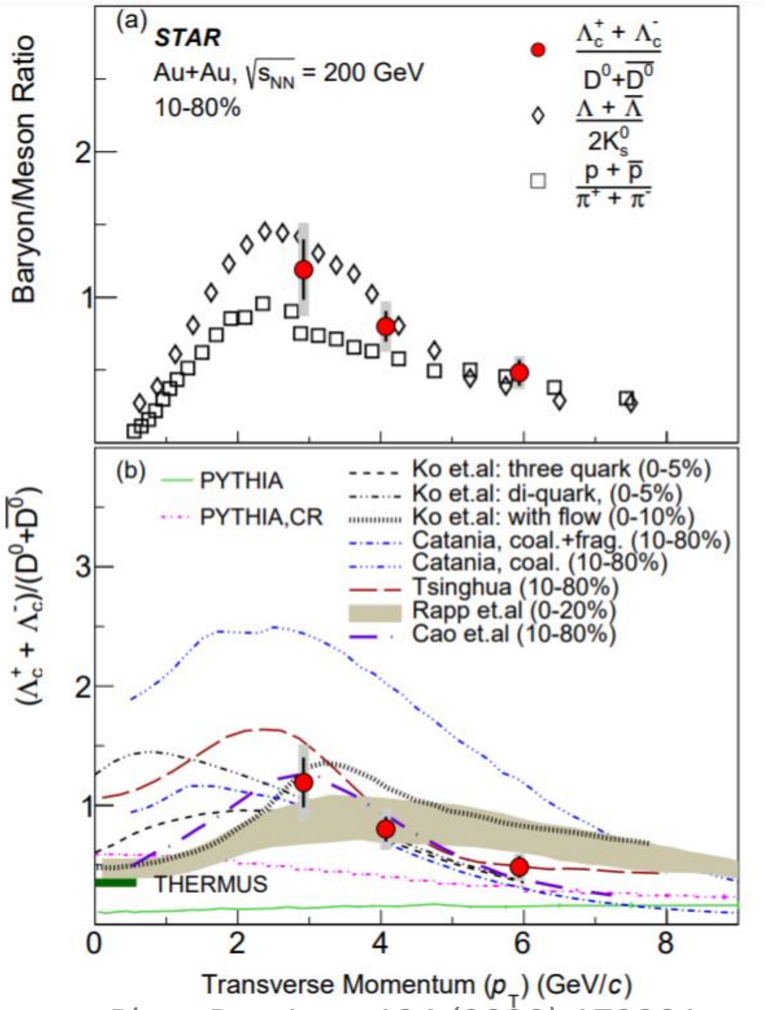


Phys. Rev. C ***99*** *(2019) 34908*

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

- D^0 shows similar suppression as light hadrons at high p_T in central collisions
- Transport models with charm quark energy loss can describe the data

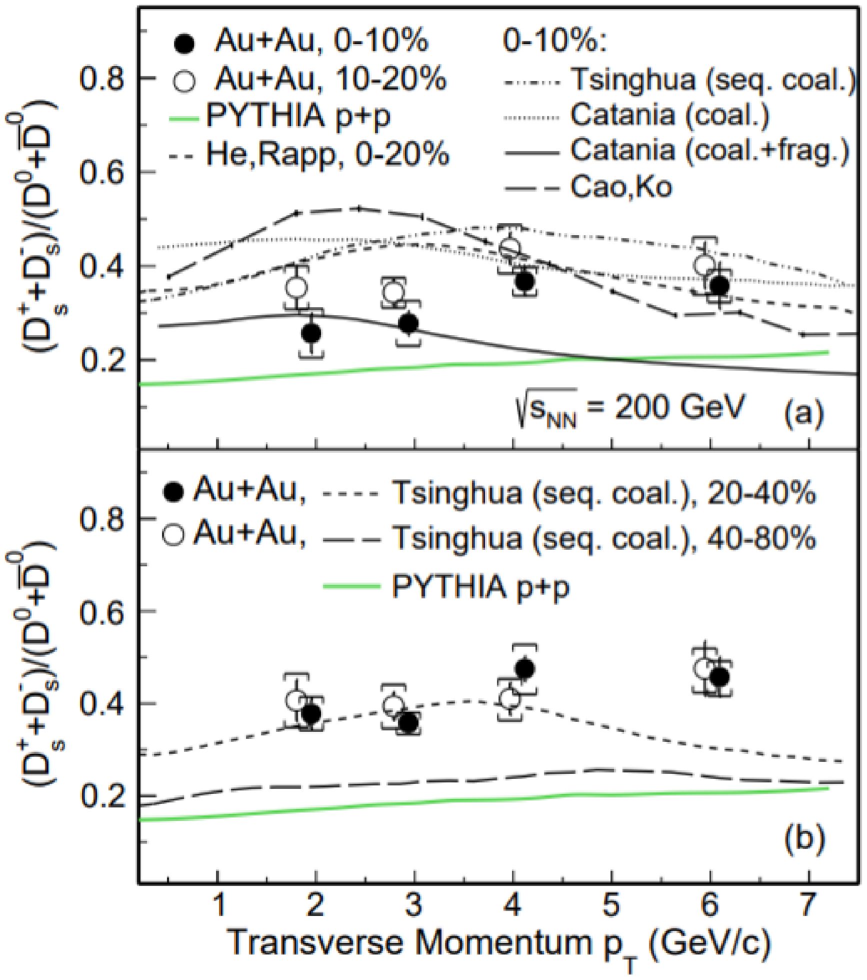
2) Λ_c measurement at STAR



Phys. Rev. Lett. 124 (2020) 172301

Introduction: Charm Hadron Measurement

3) D_s measurement at STAR



arXiv:2101.11793

4) D^+ and D^0

Particle symbol	Quark content	Rest mass (MeV/c^2)	Decay channel	Proper decay length (μm)
D^0	$c\bar{u}$	1864.84 ± 0.17	$K^- \pi^+$ 3.89%	~120
D^+	$c\bar{d}$	1869.62 ± 0.20	$K^- \pi^+ \pi^+$ 8.98%	~312

Charm quark fragmentation

f (c —> D): D^0 ~ 0.55, D^+ ~ 0.23

(D. E. Groom et al. Eur. Phys. J. C 15 (2000))

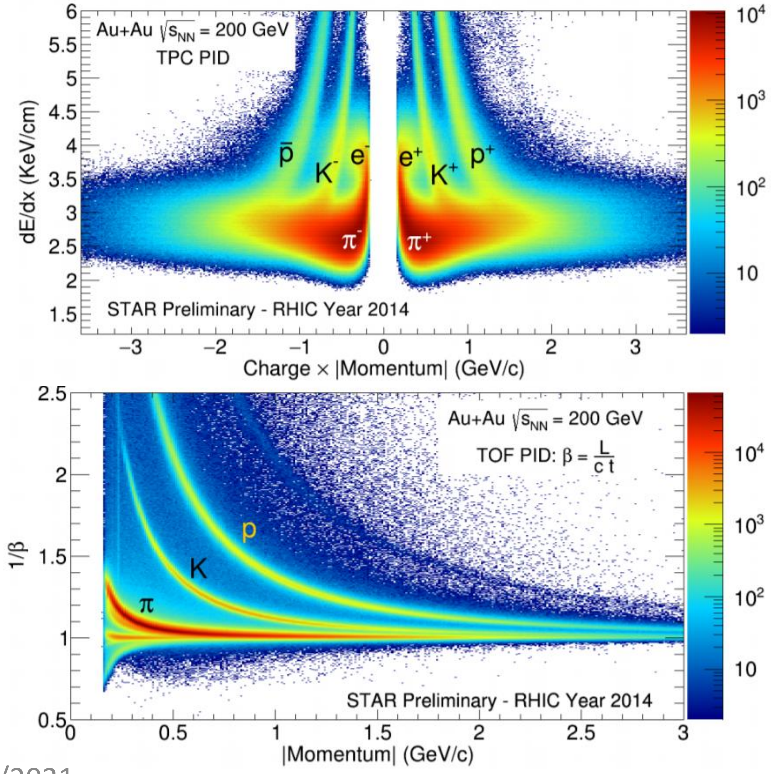
D^+ is important to :

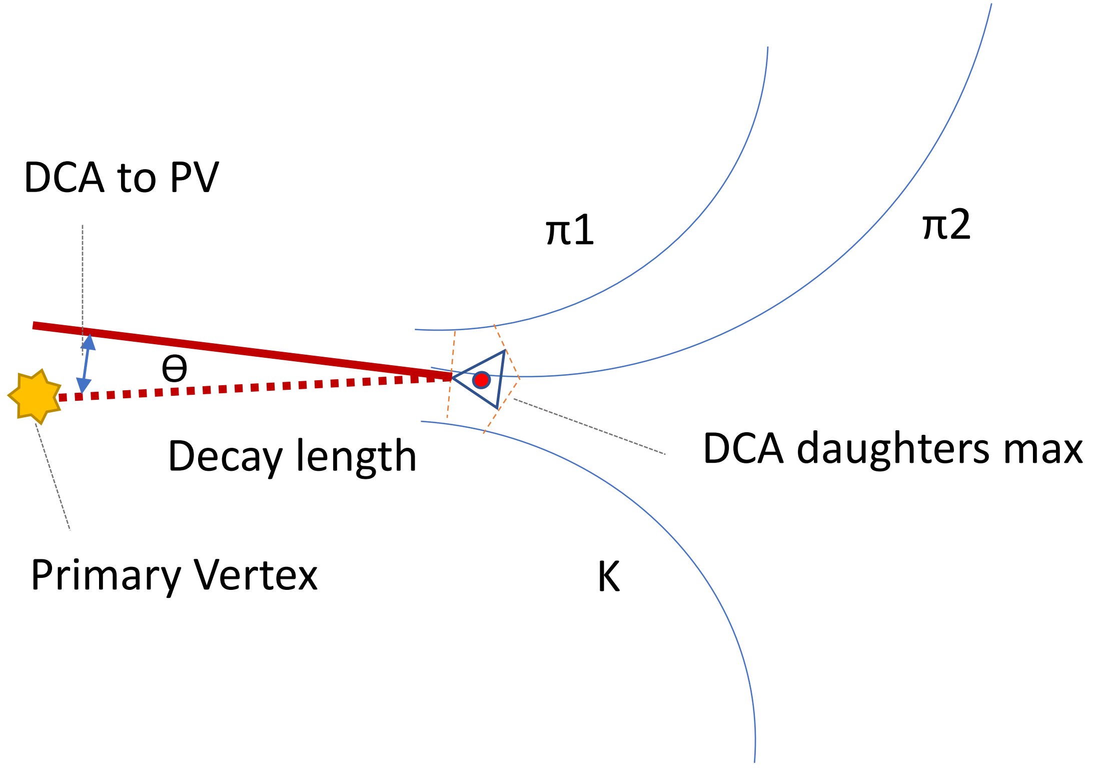
- Constrain total charm cross section
- Offer complementary information to study charm quark dynamics in QGP

$D^{\pm}$ Reconstruction Method

- STAR Run14&16 @200GeV Au+Au

  ~ 900 (1200) million minbias events in run14 (16)
- D^{+} Decay channel : $D^{\pm} \rightarrow \pi^{\pm}\ \pi^{\pm}\ K^{\mp}$ (~ 8.98%)
- PID in TPC and TOF：





Topological Cut variables:

Decay length, DCA to PV,

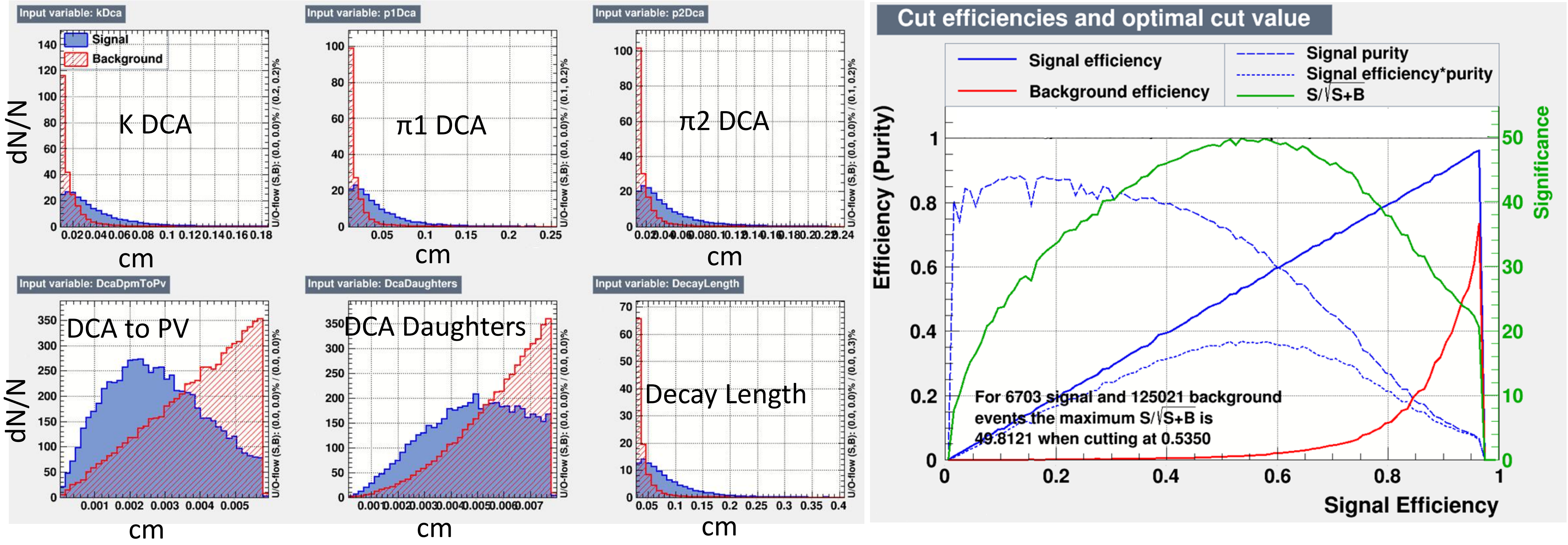
DCA daughters max

(max DCA between two daughters)

K DCA, π1 DCA, π2 DCA

D± Cuts Optimization: TMVA

Toolkit for Multivariate Data Analysis with ROOT



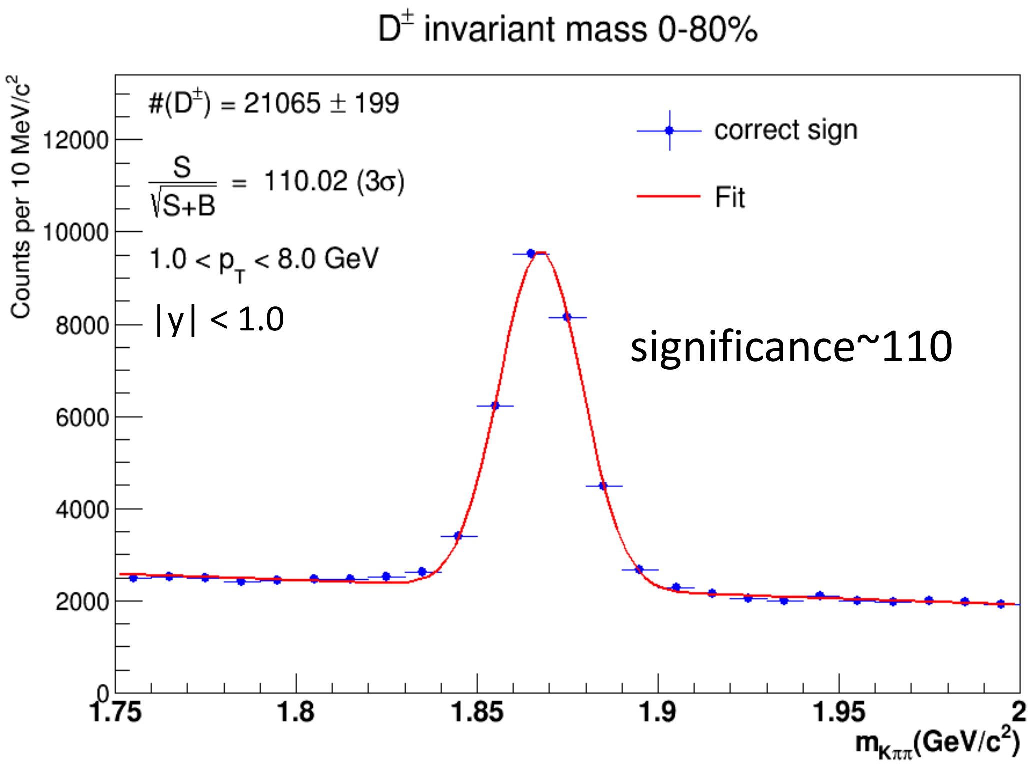
Input variable distributions and Cut efficiencies for centrality 10-40% pt 2.0-3.0 GeV/c

Background sample : wrong-sign π π K combination from real data

Signal sample: EventGen generator (D± decay) & data-driven fast simulation (detector response)

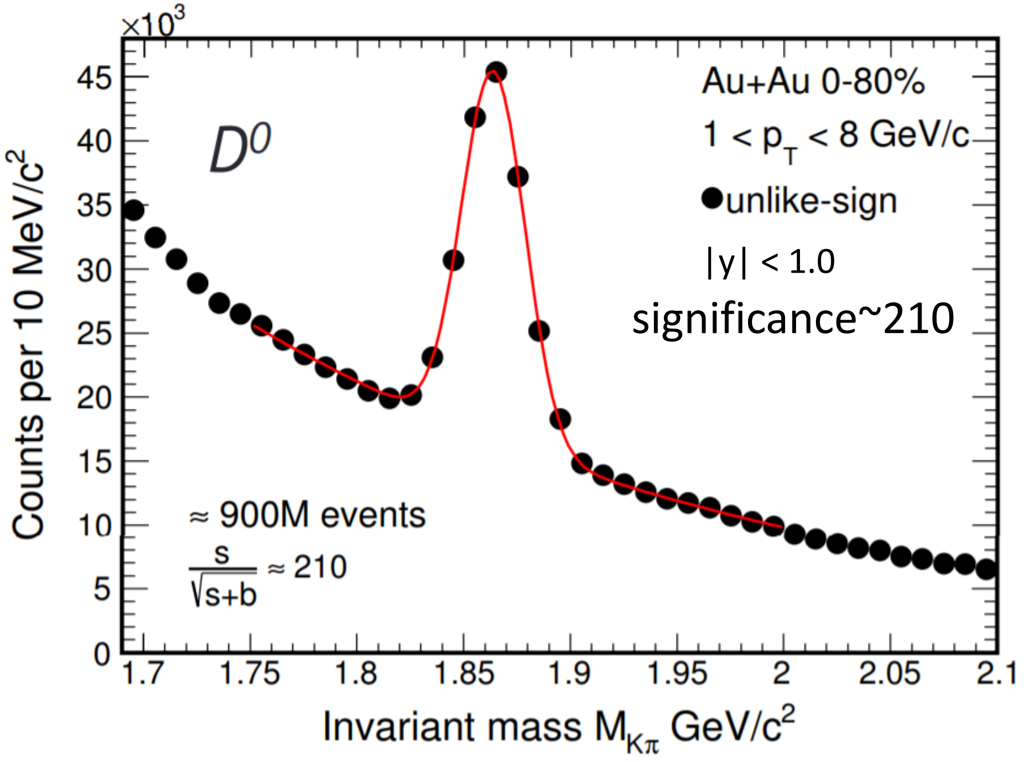
Cuts are tuned in 5 p_T bins × 3 centrality bins

$D^{\pm}$ Invariant Mass spectra



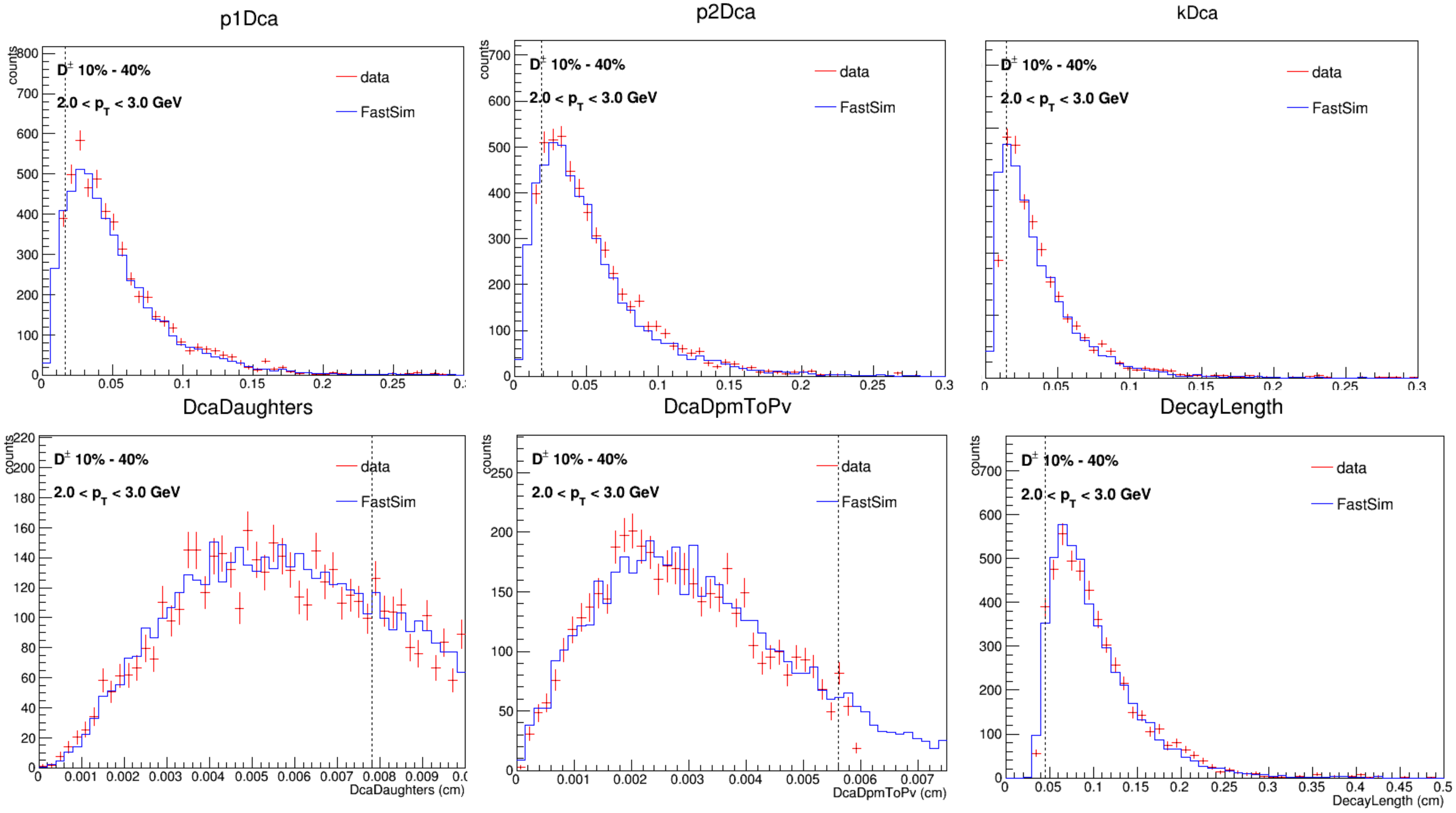
$D^{\pm}$ p_T integral Signal in STAR run2014

$D^{\pm}$ significance~100 in STAR run16



D^0 p_T integral Signal from STAR run2014

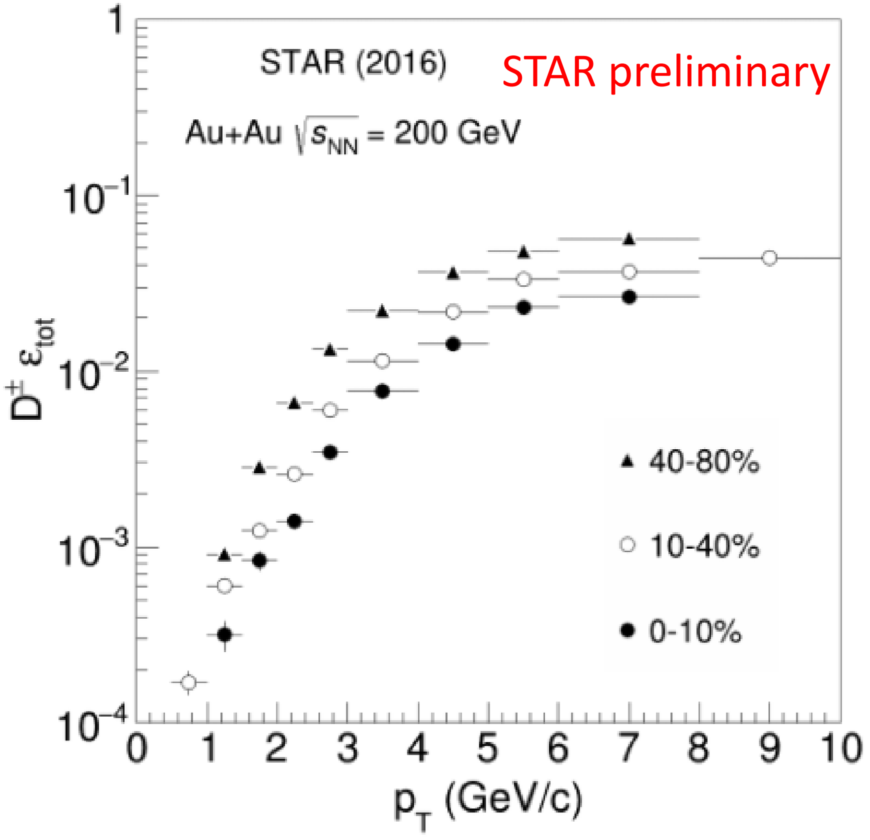
Cut Variables distribution



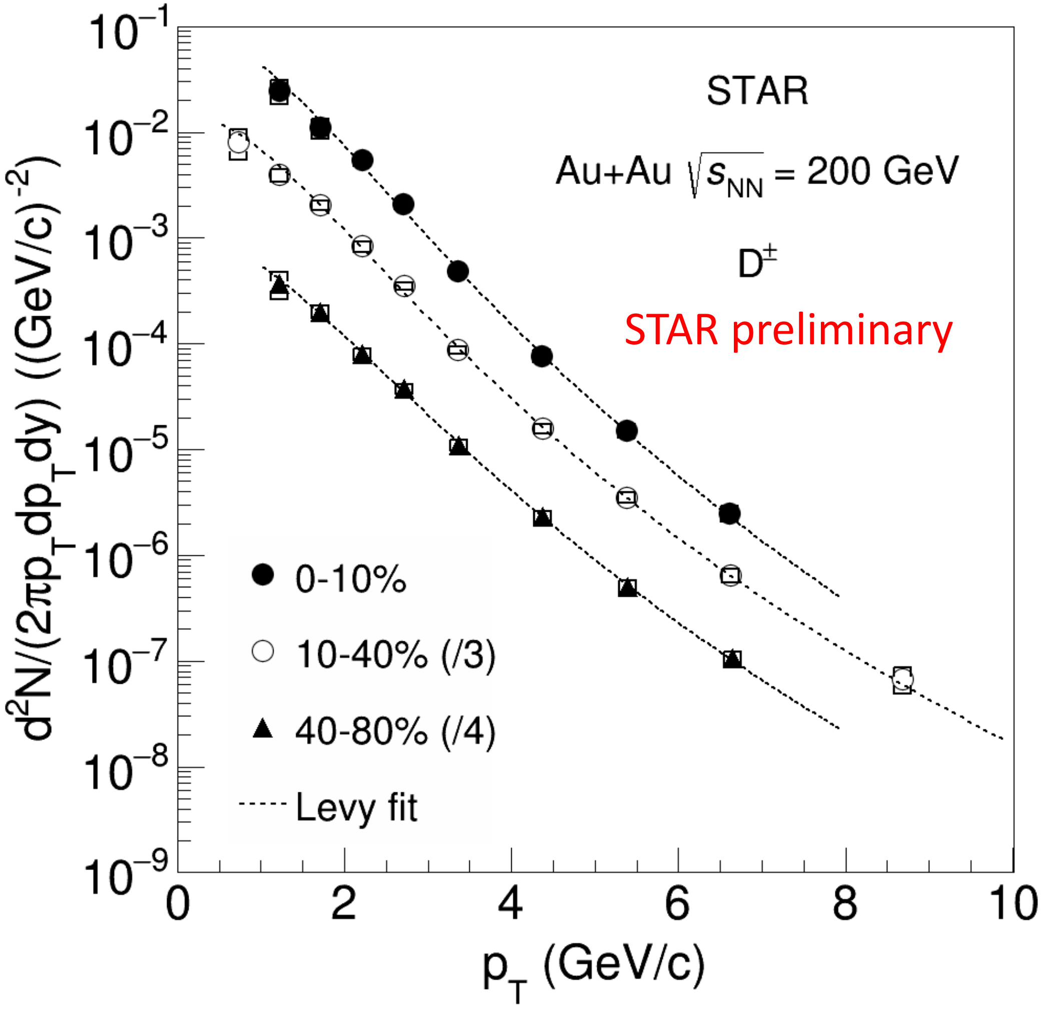
The distribution of cut variables is consistent between data and data-driven fast simulation

$D^{\pm}$ p_T spectra

$$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{1}{2 \cdot B.R.} \frac{\Delta N^{raw}}{N_{evt} \cdot 2\pi \cdot p_T \Delta p_T \Delta y} \frac{1}{\varepsilon_{\mathrm{TPC}} \cdot \varepsilon_{\mathrm{PID}} \cdot \varepsilon_{\mathrm{HFT}} \cdot \varepsilon_{\mathrm{Topo}}}$$

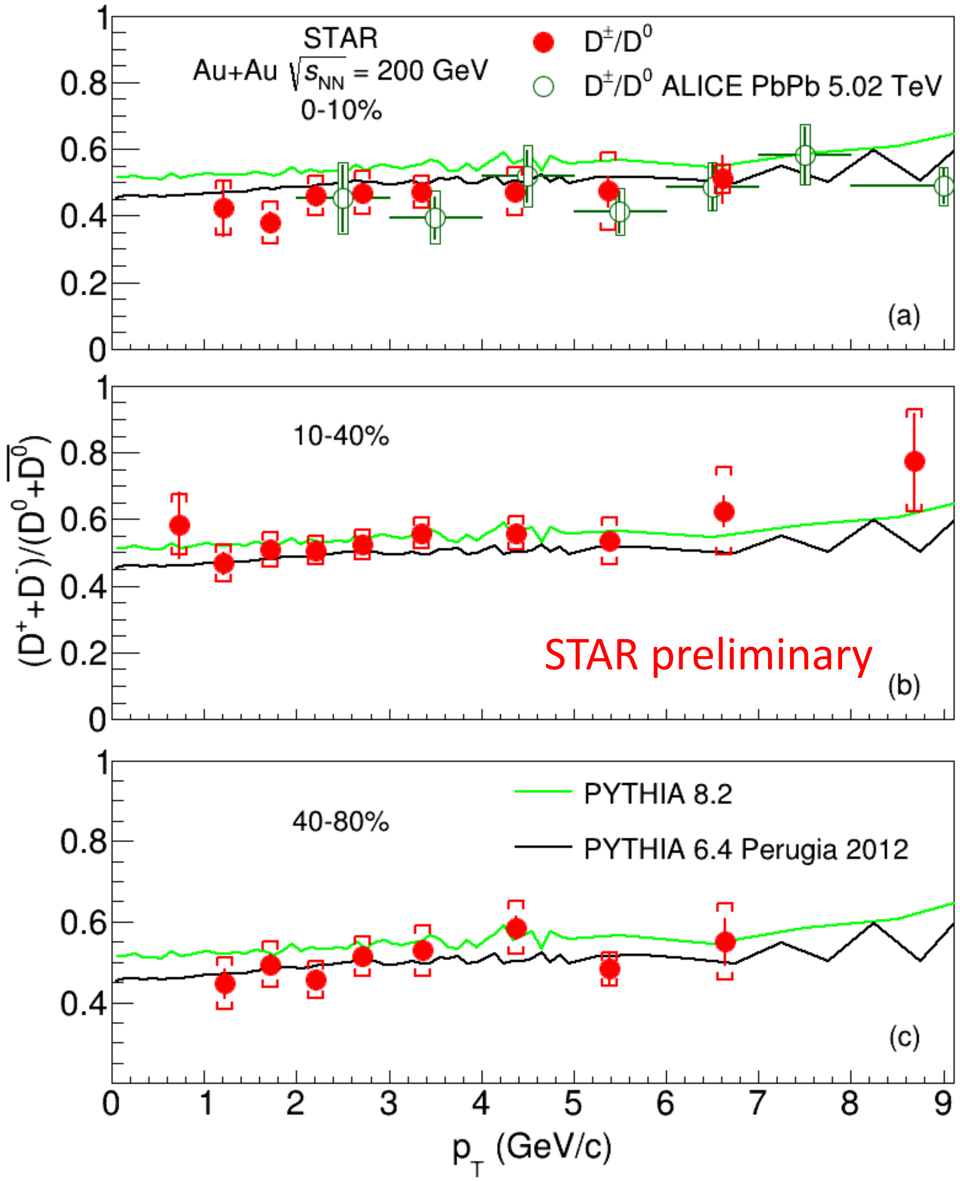


Total reconstruction efficiency



$D^{\pm}$ invariant spectra from STAR run14&run16

Results: D±/D⁰ Yield Ratio



- $D^{\pm}/D^0$ yield ratio vs. p_T is consistent with PYTHIA (p+p @200GeV) and ALICE PbPb results @5.02 TeV
- **D^0 and $D^{\pm}$ have same suppression in Au+Au collisions**

ALICE Collaboration, JHEP 1810 (2018) 174

Results: D^+/D^0 Yield Ratio

$D^{\pm}/D^0$ yield ratio as a function of N_{part} compared to other collision systems

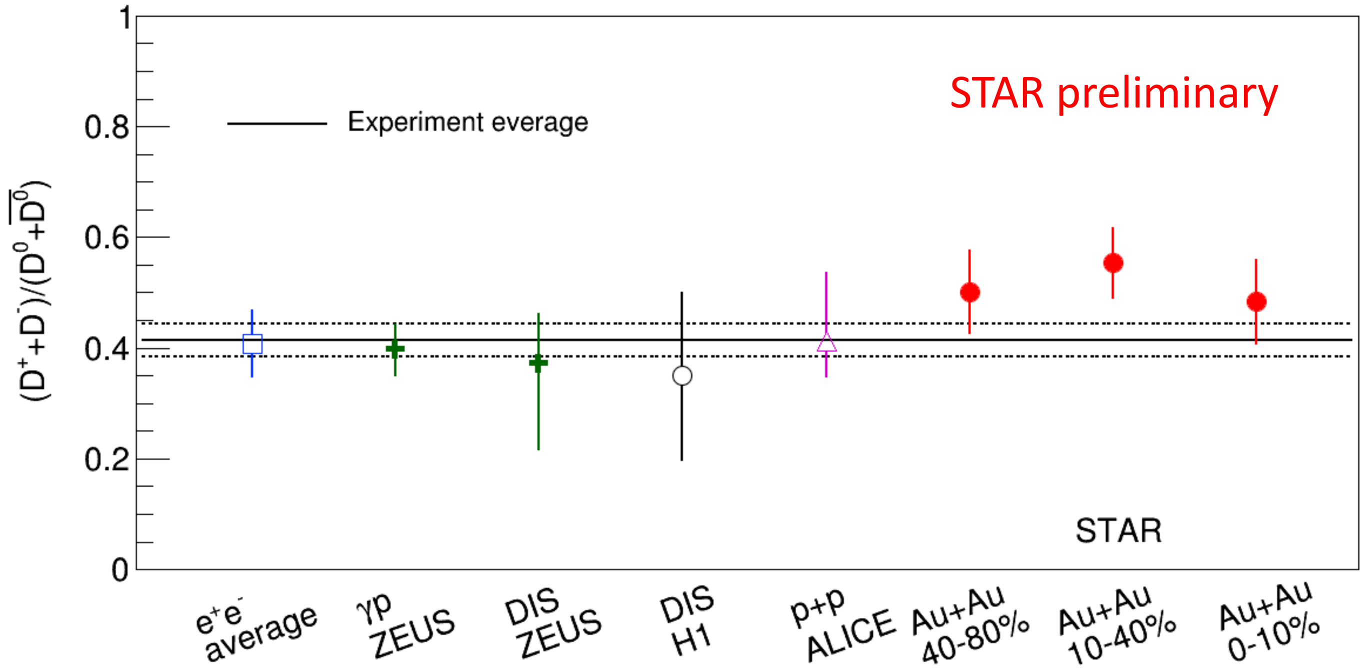
- Reasonable agreement of different experiments

Only STAR and ALICE cover p_T from 0 GeV/c

- ZEUS: $p_T > 3.5$ GeV/c, H1: $p_T > 2.5$ GeV/c

Generally different η coverage

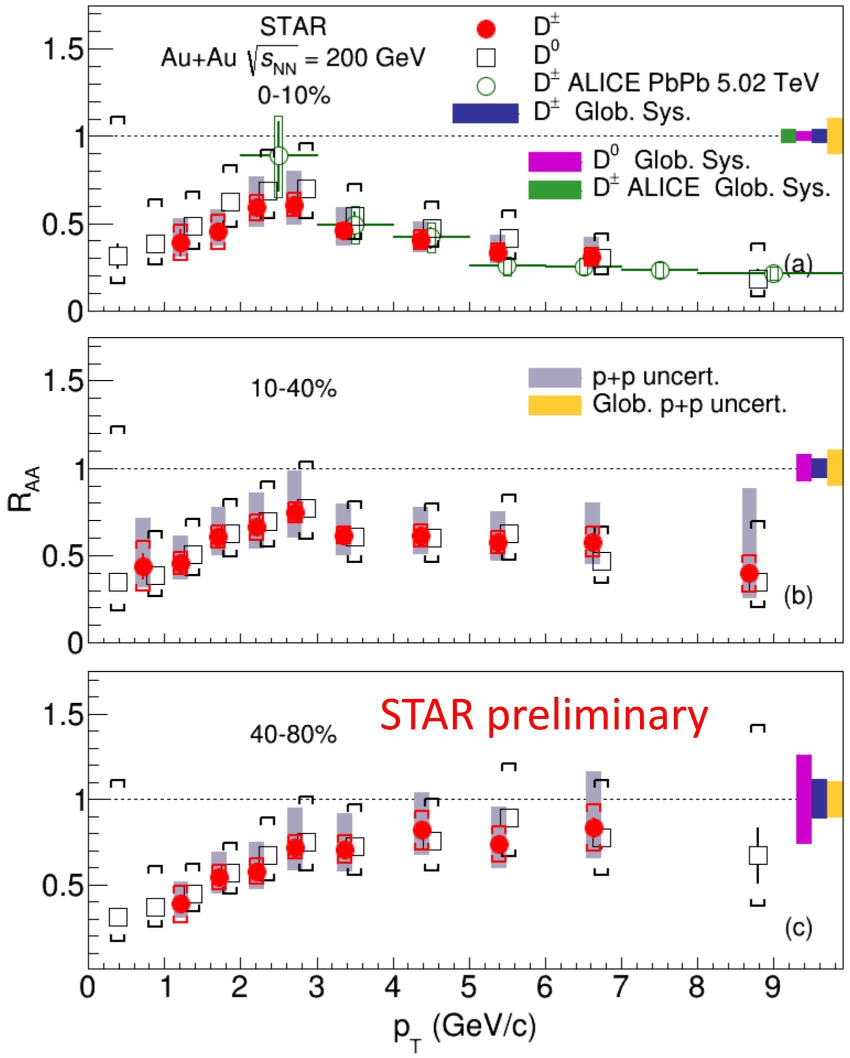
- STAR: |η| < 1, ZEUS: |η| < 1.6, H1: |η| < 1.5, ALICE: |η| < 0.5



- **No modification of the relative abundances of $D^{\pm}$ and D^0 species observed in different collision system and energy**

HERA, (e+e-, γp, DIS): JHEP 1309 (2013) 058
ALICE, (pp 5.02 TeV): Eur.Phys.J. C79 (2019) no.5, 388

Results: $D^{\pm}$ R_{AA}



D mesons suppressed at high p_T

- Level of suppression increases towards more central Au+Au collisions
- Interactions of c-quarks with the QGP

Suppression of low p_T D mesons

- Independent of centrality
- Possibly due to coalescence hadronization of c-quarks

  * Supported by measurements of Ds and Λc

  * Re-distribution of charm among open charm hadron species

Good agreement of D^0 , $D^{\pm}$ and ALICE

ALICE Collaboration, JHEP 1810 (2018) 174

Results: Charm Hadron Production Cross-section

Charm Hardon STAR preliminary		Cross-section $\frac{d\sigma}{dy}\|_{y=0}$ (μb) (per nucleon-nucleon collision)
AuAu 200 GeV (10-40% p_T 0-8 Gev/c)	D^0	**39.0 ± 0.6 (stat.) ± 1.1 (sys.)**
	D^+	**20.7 ± 1.2 (stat.) ± 3.8 (sys.)**
	D_s^+	**15.4 ± 1.7 (stat.) ± 3.6(sys.)**
	Λ_c^+	**36.4 ± 5.3 (stat.) ± 22.3 (sys.) ***
	Total	**112.4 ± 5.7 (stat.) ± 22.9 (sys.) ***
P+P 200 GeV	Total:	130 ± 30 ± 26

* Λ_c^+ results are using 10-80% centrality

* 8% uncertainty on σ_{pp} and $N_{collision}$ are not included

First measurement of open-charm hadron cross section per nucleon pair in Au+Au collision for major open-charm hadron ground states

- All cross sections calculated in 0 < pT < 8 GeV/c

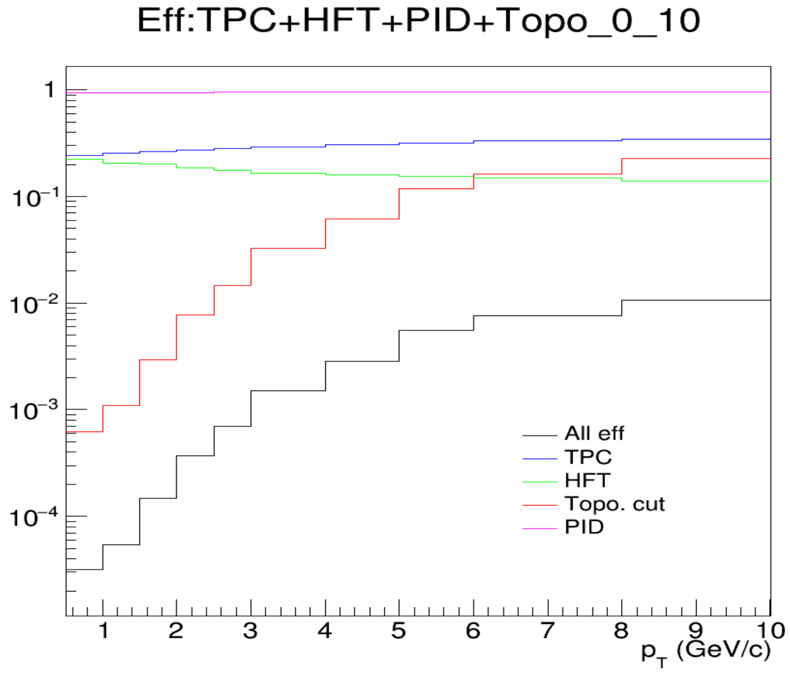
Agreement with total charm cross section measured in p+p at 200 GeV

- Charm quark production follows the number-of-binary collisions scaling in heavy-ion collisions
- Charm quark production predominantly in hard partonic scattering

Back up

Efficiency Correction Procedures

$$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{1}{2 \cdot B.R.} \frac{\Delta N_{raw}}{N_{evt} \cdot 2\pi \cdot p_T \Delta p_T \Delta y} \frac{1}{\varepsilon_{\mathrm{TPC}} \cdot \varepsilon_{\mathrm{PID}} \cdot \varepsilon_{\mathrm{HFT}} \cdot \varepsilon_{\mathrm{Topo}}}$$



- ΔNr_{aw} : reconstructed particle counts in each p_T and centrality bin
- $\varepsilon_{\mathrm{TPC}}$: TPC acceptance and tracking efficiency (calculated by data embedding)
- $\varepsilon_{\mathrm{HFT}} \cdot \varepsilon_{\mathrm{Topo}}$: HFT acceptance and tracking plus topological cut efficiency (calculated by data-driven fast simulation)
- $\varepsilon_{\mathrm{PID}}$: particle identification efficiency (calculated by K π sample from data)

Systematic Error