STAR

quarks Q2C cosmos

APRIL MEETING 2019

April 13-16, 2019 Denver, Colorado

Measurements of $D^{\pm}$ and $D^{*\pm}$ production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from STAR

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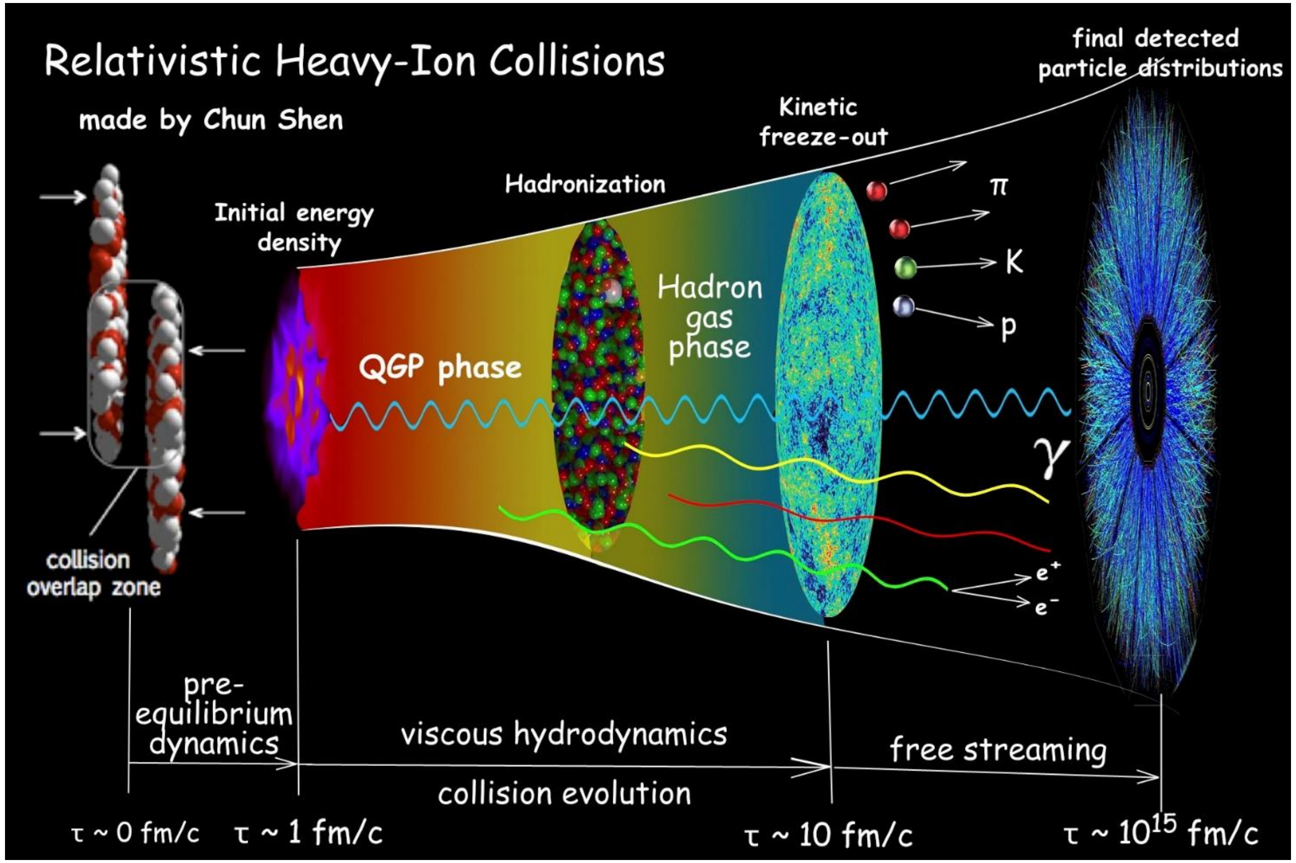
BERKELEY LAB

Heavy Quark in Heavy-Ion Collisions



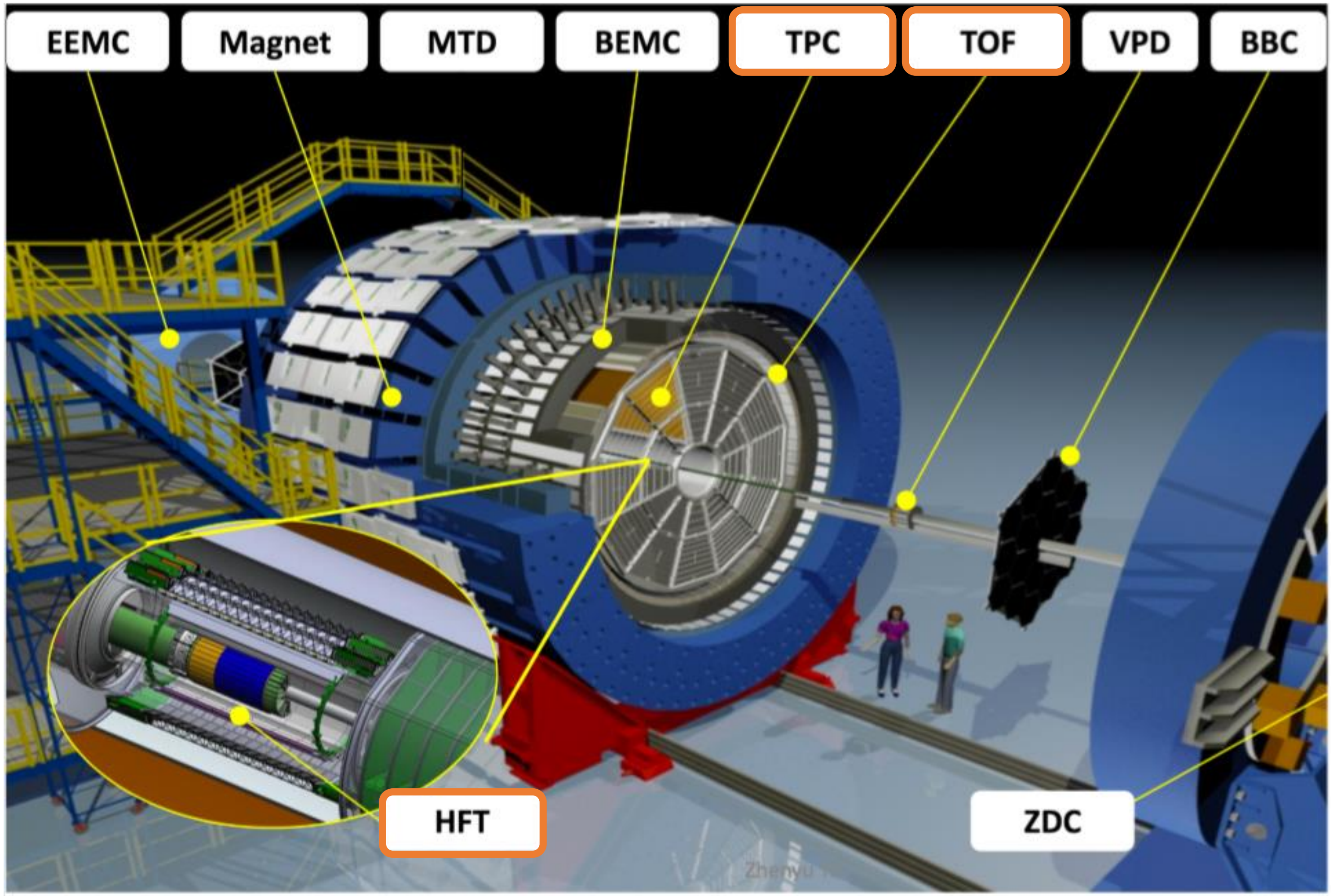
- Quark-Gluon Plasma (QGP) is created in ultra-relativistic heavy-ion collisions
- Heavy quarks serve as a sensitive probe to the QGP because of their large masses.
- We study interactions of heavy quarks with the medium:

-- energy loss

-- collective flow

-- hadronization

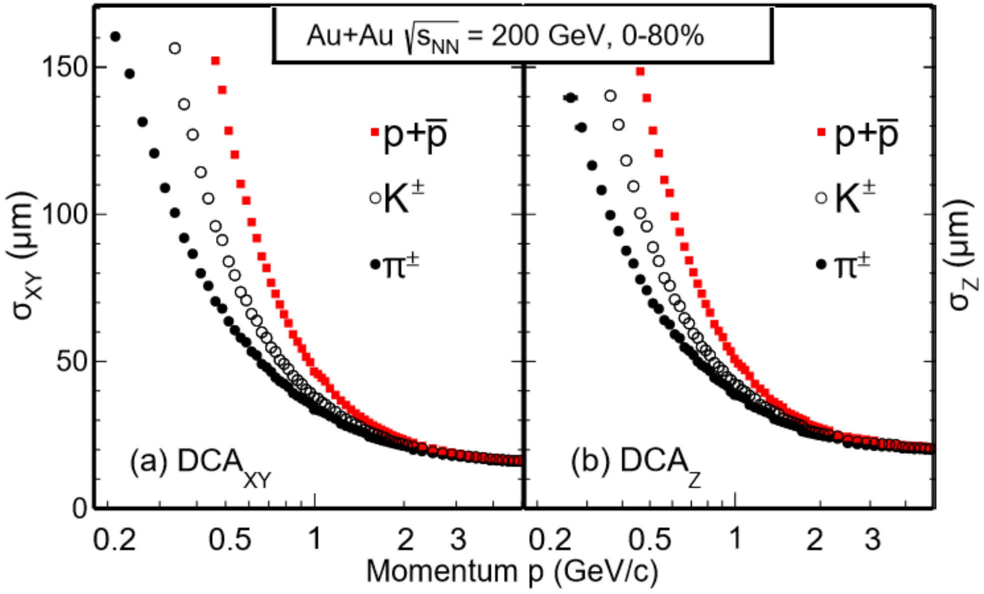
The STAR Experiment



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

  Excellent DCA resolution

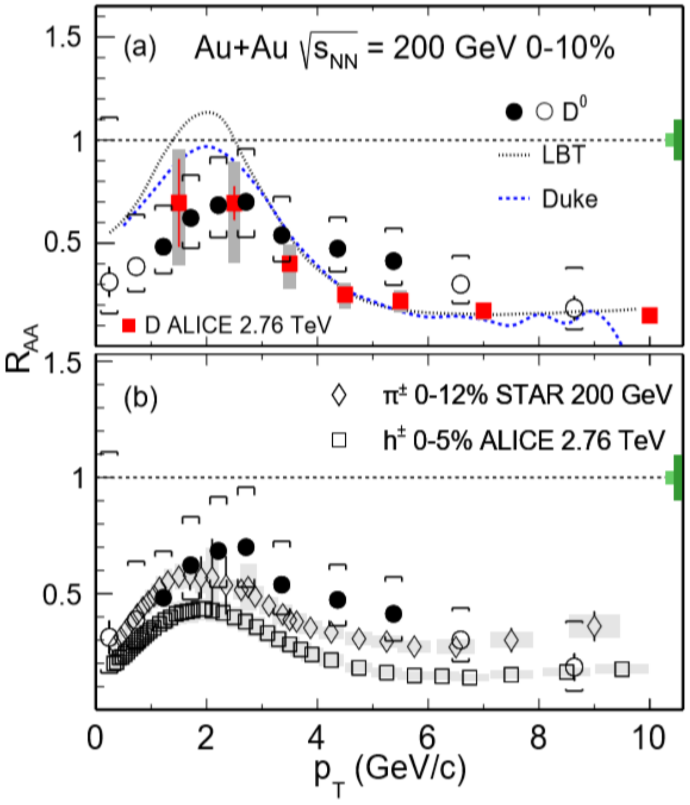
  ~ 35 μm @ p_T = 1 GeV/c



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

$D^{\pm}$ Measurement: Introduction

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



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

- 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) D^+ and D^0

Particle symbol	Quark content	Rest mass (MeV/c²)	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

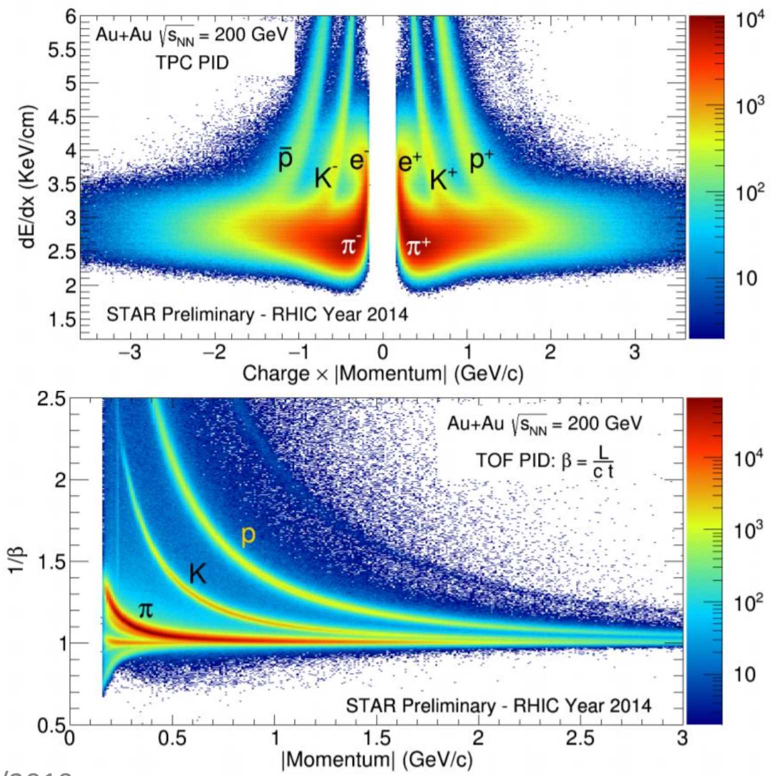
$D^{\pm}$ Reconstruction Method

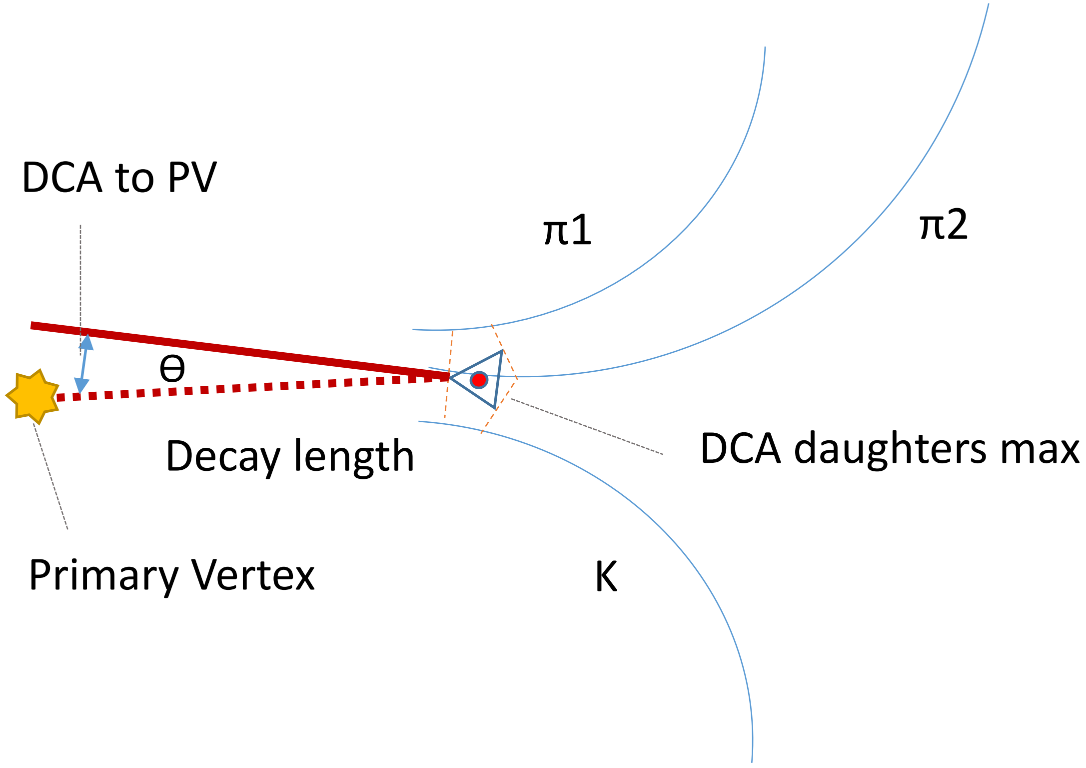
- STAR Run2014 @200GeV Au+Au

  ~ 900 million minbias events

- 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,

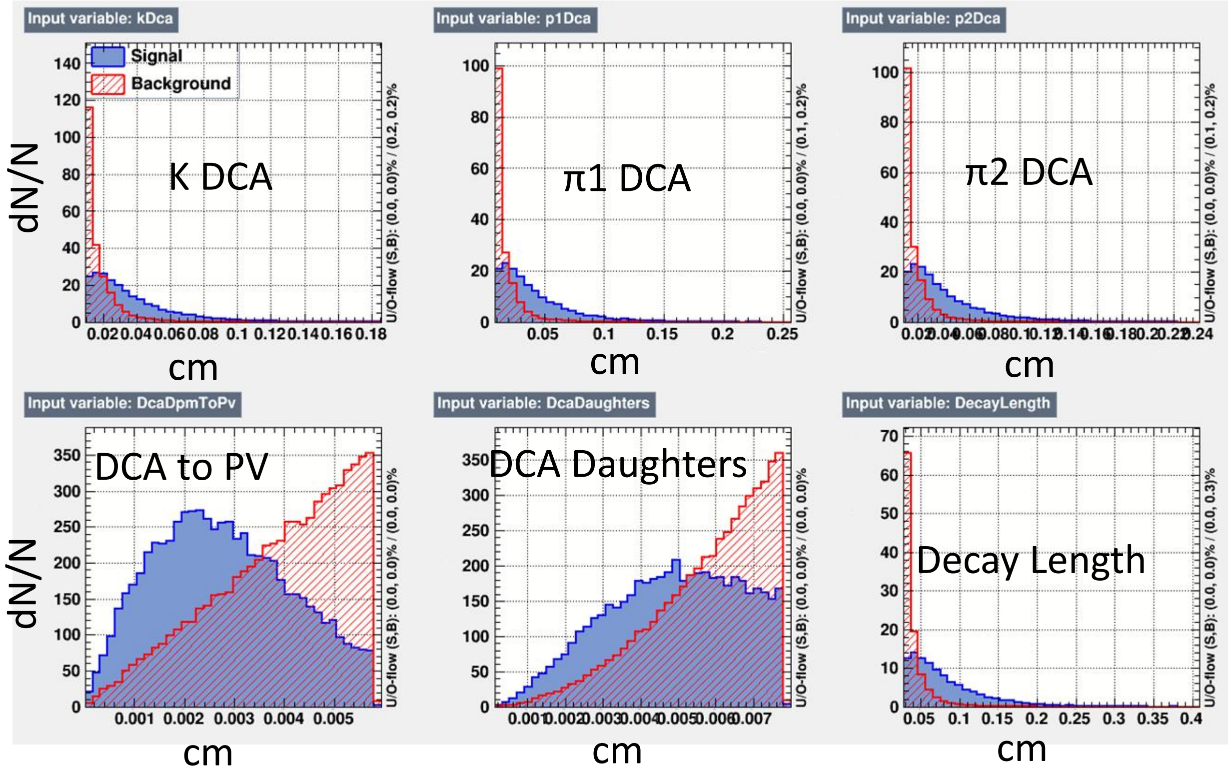
DCA daughters max

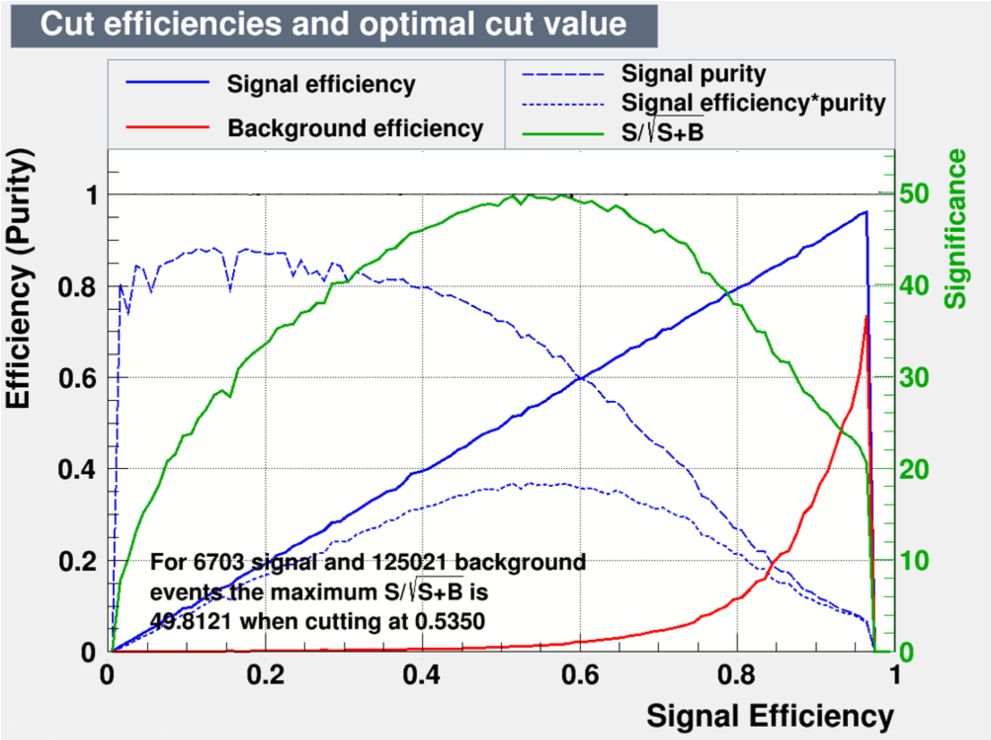
(max DCA between two daughters)

K DCA, π1 DCA, π2 DCA

$D^{\pm}$ Cuts Optimization: TMVA

Toolkit for Multivariate Data Analysis with ROOT





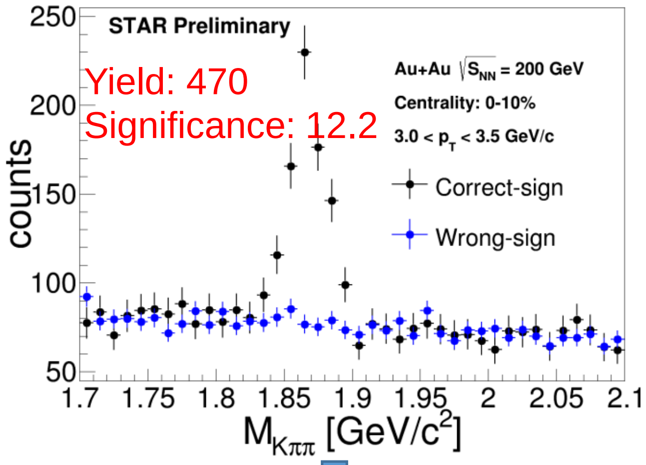
Input variable distributions and Cut efficiencies for centrality 10-40% pt 2.0-3.0 GeV/c

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

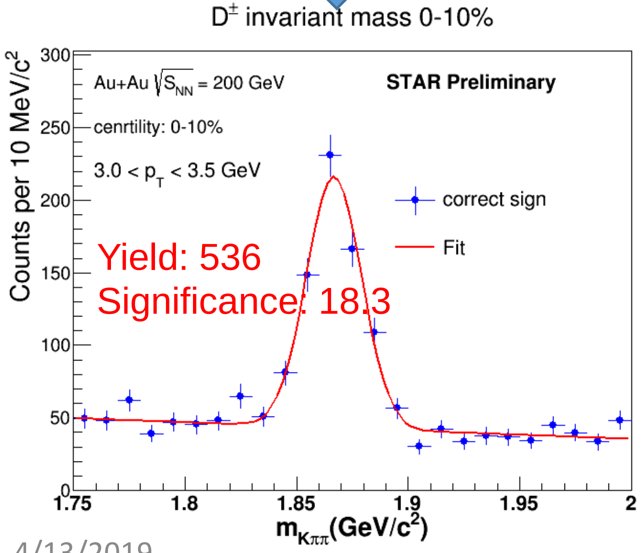
Signal sample: EventGen generator ($D^{\pm}$ decay) & data-driven fast simulation (detector response)

Cuts are tuned in 5 p_T bins × 3 centrality bins

$D^{\pm}$ Signal and Invariant Yields



TMVA cuts optimization



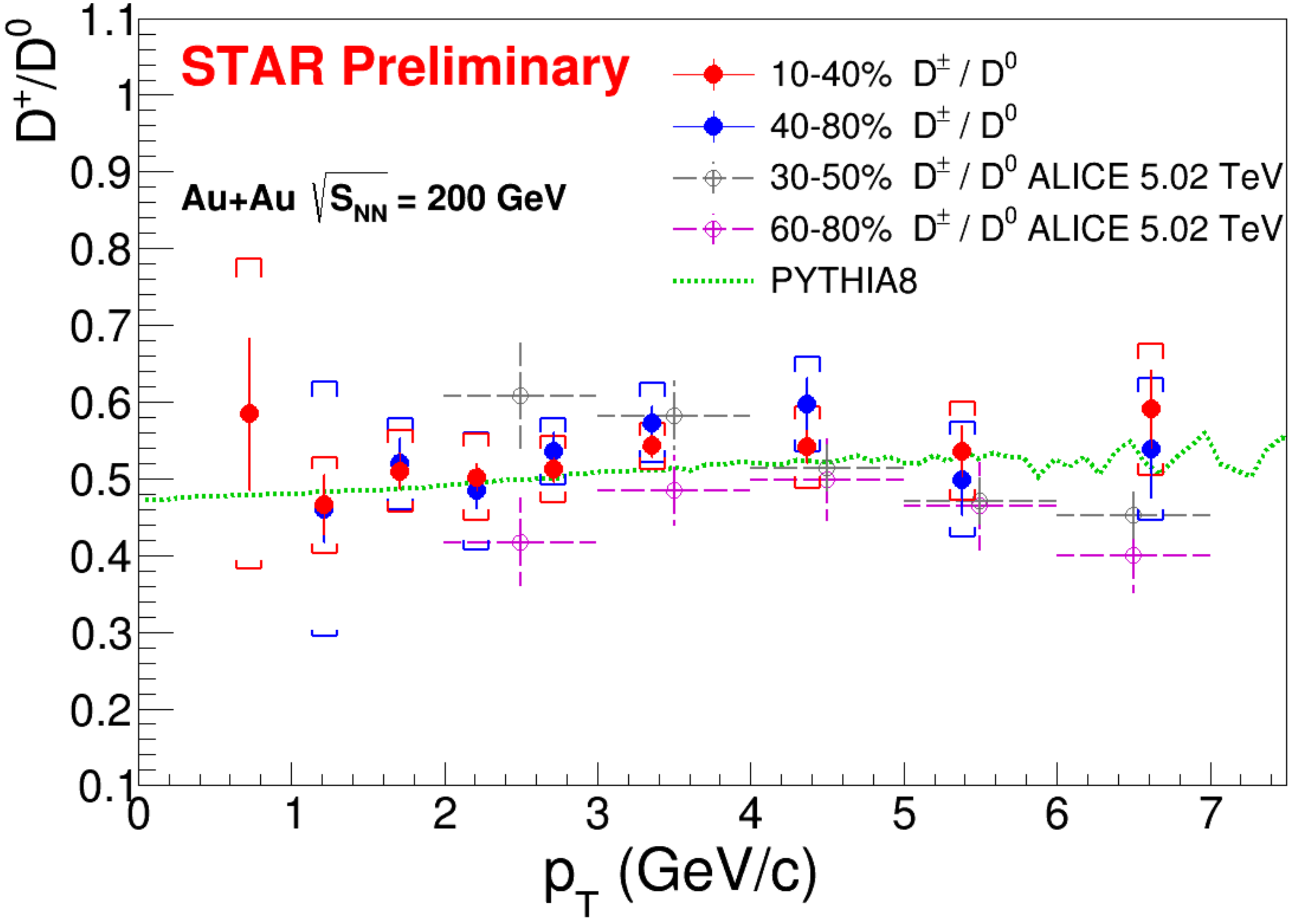
Centrality 0-10%

p_T (Gev/c)	Significance w/o TMVA	Significance with TMVA	p_T (Gev/c)	Significance w/o TMVA	Significance with TMVA
1.0-2.0	1.1	10.9	4.5-5.0	7.9	9.9
2.0-2.5	4.2	18.4	5.0-5.5	6.1	8.1
2.5-3.0	10.8	21.4	5.5-6.0	5.8	7.0
3.0-3.5	12.2	18.3	6.0-7.0	4.4	6.8
3.5-4.0	11.9	16.0	7.0-8.0	3.7	4.0
4.0-4.5	11.1	13.53	8.0-10.0	2.8	4.9

TMVA cuts optimization improves $D^{\pm}$ signal significance, especially at low p_T:

Helps to better constrain the p_T integrated yield

$D^{\pm}/D^0$ Ratio in Au+Au Collisions



ALICE Collaboration, JHEP 1810 (2018) 174

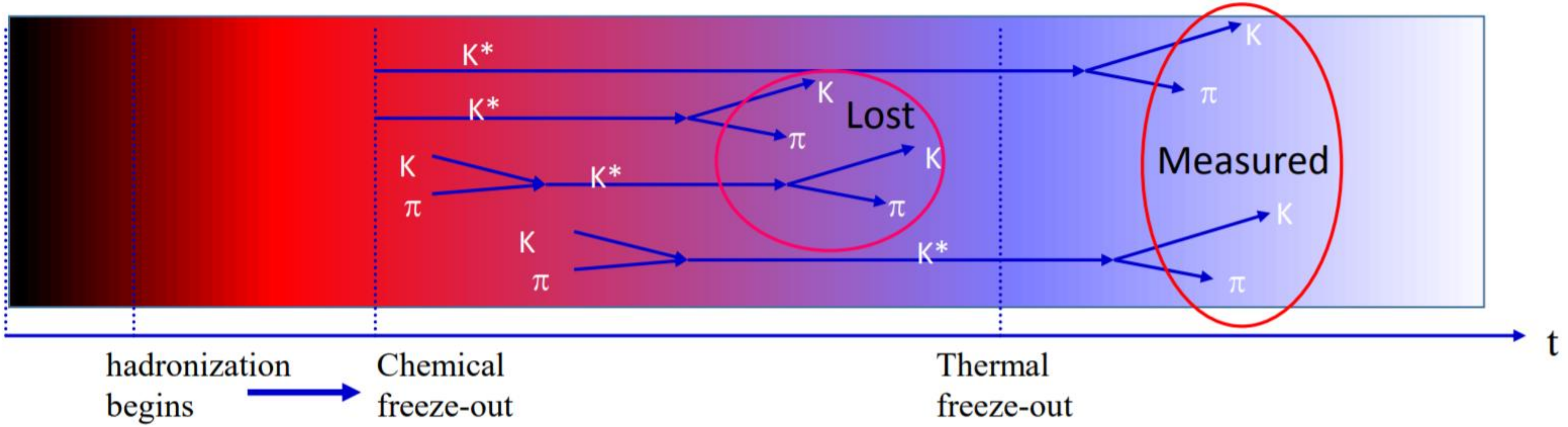
- $D^{\pm}/D^0$ yield ratio is consistent with PYTHIA (p+p @200GeV) and ALICE results @5.02 TeV
- No modification of the relative abundances of $D^{\pm}$ and D^0 species in Au+Au relative to p+p
- **D^0 and $D^{\pm}$ have same suppression in Au+Au collisions**

D^{*+} Production in Au+Au Collisions

- D^{*+} feeds down to D^0 yields $D^{*+} \rightarrow D^0 + \pi^+_{soft}$ $c\tau$~2[pm/c]
- Possible hot medium effects :

-- D-meson spectral functions predicted to broaden in hot medium [1]

-- Re-scattering can lead to yield suppression -- already seen in K^*/K

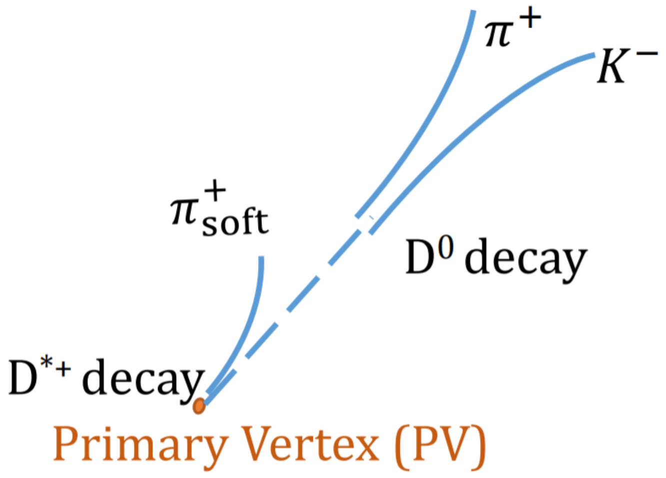


[1] Shuai Y. F. Liu and Ralf Rapp. Phys. Rev. C 97 (2018) 034918

D^{*+} Reconstruction Method

- Data set:
  Run2014 Au+Au @ 200 GeV
  ~ 900Million minimum-bias events
- Reconstruction channel:

$D^{*+} \rightarrow D^0 + \pi^+_{soft}$ $B.R. = 67.7\%$
$D^0 \rightarrow K^- + \pi^+$ $B.R. = 3.89\%$
and its charge conjugate channel

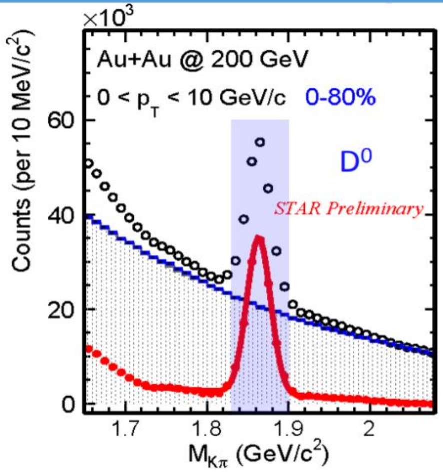


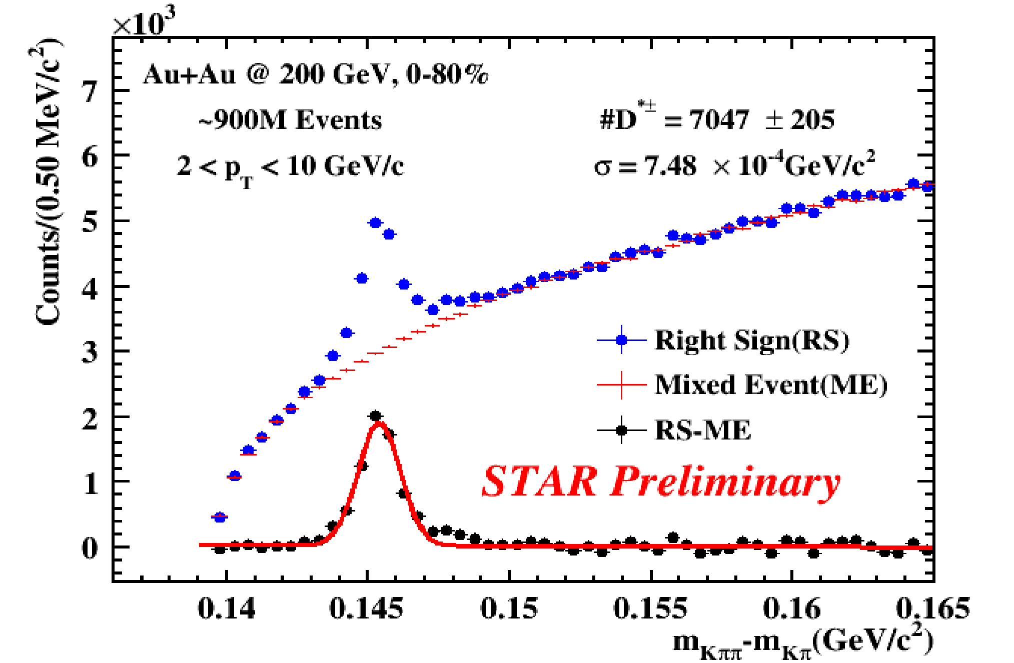
π^{soft}

- $p_T > 0.15$ GeV/c
- $|\eta| < 1$

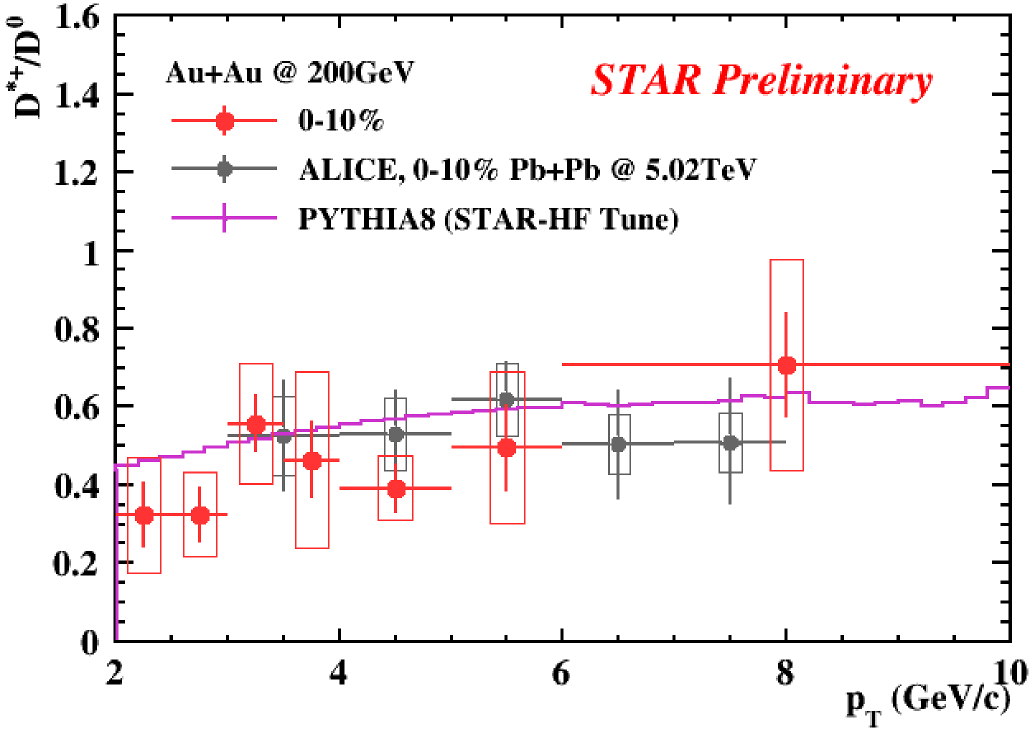
D^0

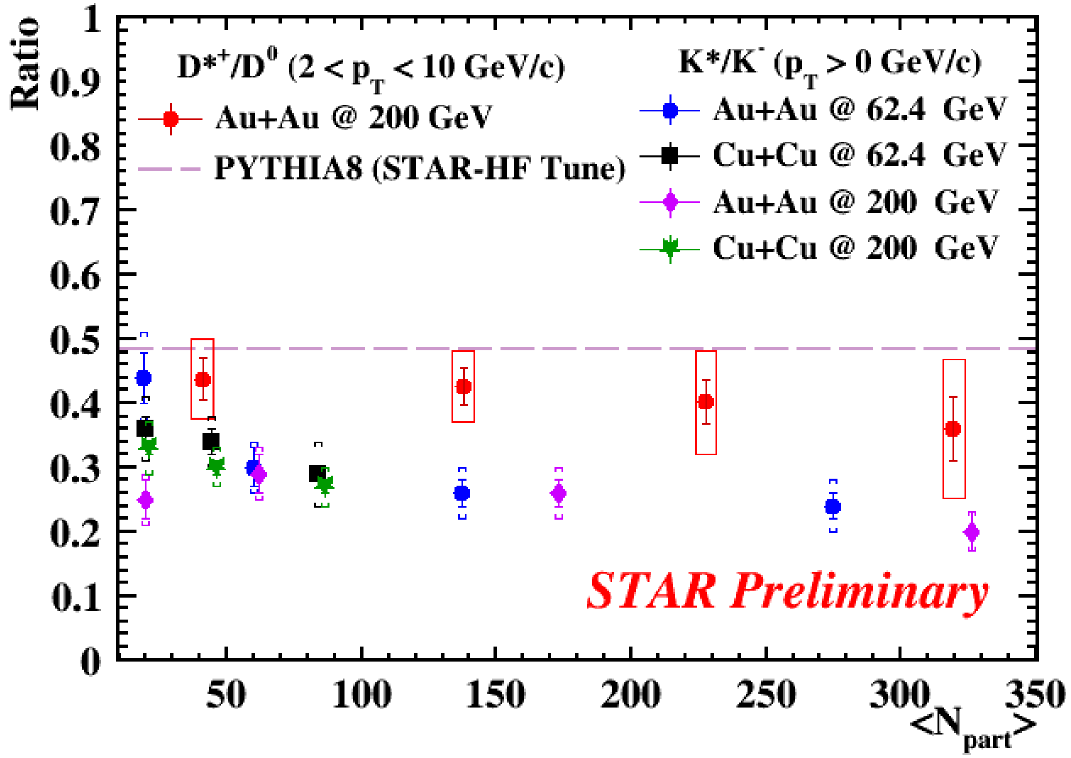
- $|y|_{D^0} < 1$
- K/π : $p_T > 0.3$ GeV/c
- K/π : $|\eta| < 1$





D^{*+}/D^0 Ratio in Au+Au Collisions





- D^{*+}/D^0 yield ratio in Au+Au collisions @200 GeV is consistent with PYTHIA (p+p @200GeV) and with ALICE results @5.02 TeV
- Ratio of the integrated yields (in $2 < p_T < 10$ GeV/c) shows no strong centrality dependence

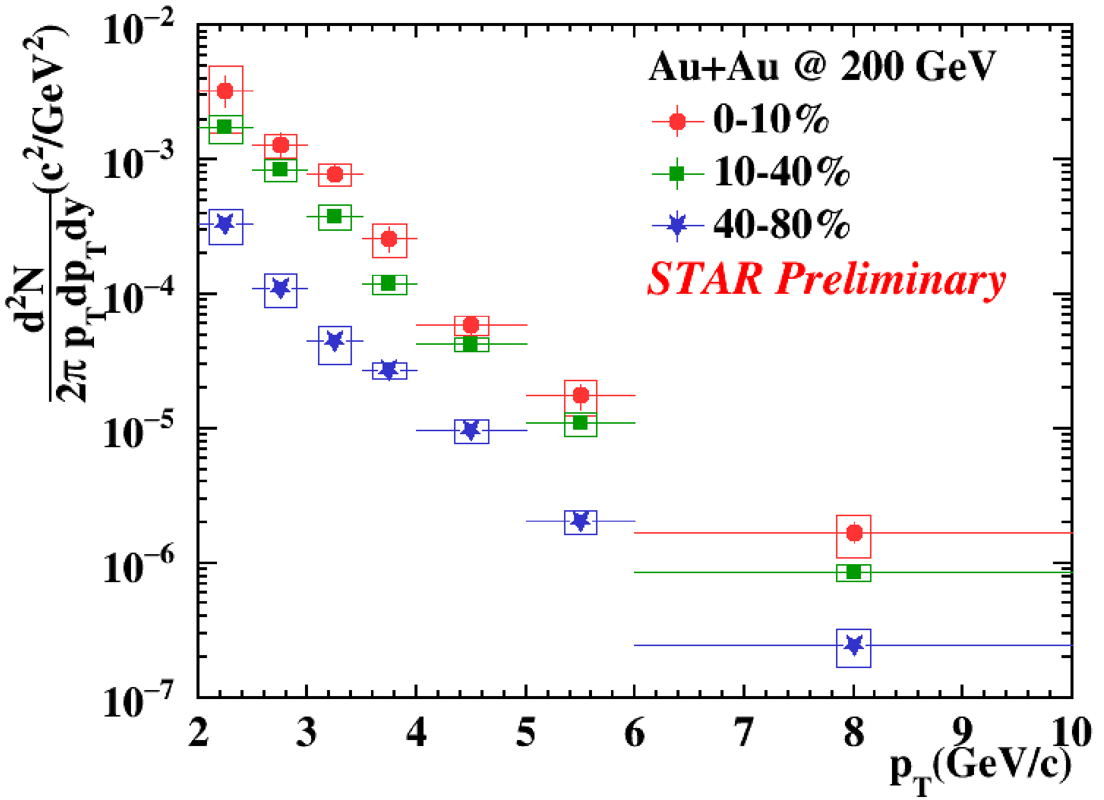
K/K, Phys. Rev. C (2011) 84. 034909.*
ALICE Collaboration, JHEP 1810 (2018) 174.

Summary

- Better signal significance for $D^{\pm}$ reconstruction using TMVA
- $D^{\pm}/D^{0}$ and $D^{*\pm}/D^{0}$ yield ratios consistent with PYTHIA. No modification of the relative abundances of these three D-meson species in Au+Au relative to p+p
- $D^{*\pm}/D^{0}$ integrated yields ratio shows no strong centrality dependence.
- D^{0}, $D^{\pm}$ and $D^{*\pm}$ can be combined together to provide one D-meson spectrum/R_{AA} and can be used to further deepen our understanding of charm-medium interactions

Backups

$D^{*\pm}$ Invariant Yields vs p_T

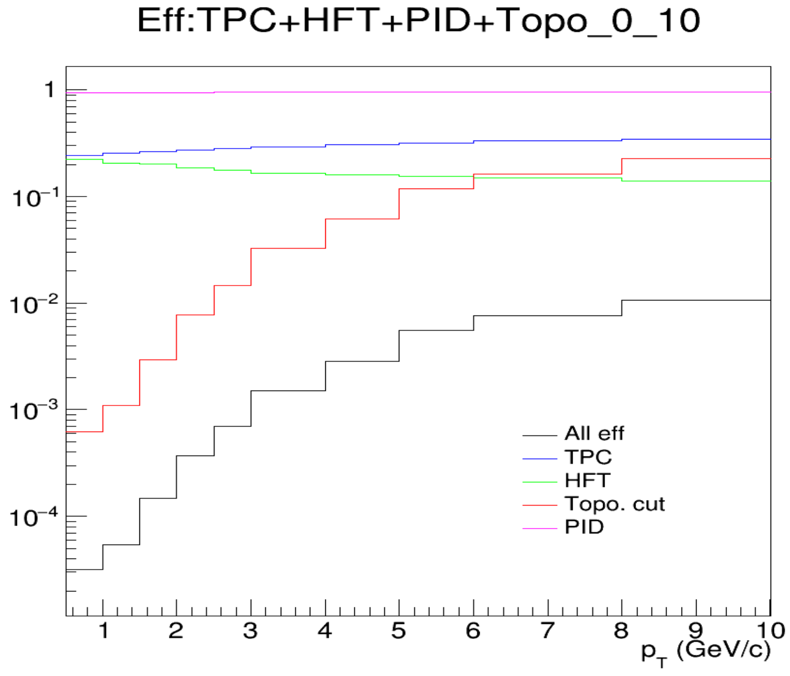


$$\frac{d^2N}{2\pi p_T dp_T dy} = \frac{Yield}{2\pi \cdot 2 \cdot BR \cdot N_{evt} \cdot p_T \Delta p_T \Delta y \cdot \varepsilon}$$

- Branching ratio = 67.7%*3.89%
- D*+ efficiency = D0 efficiency $\otimes$ $\pi soft$ efficiency
- $\varepsilon_{particle} = \varepsilon_{TPC} \cdot \varepsilon_{PID} \cdot \varepsilon_{HFT} \cdot \varepsilon_{\mathrm{Topo\_cuts}}$

Efficiency Correction Procedures

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



- $\Delta Nraw$: 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)