Production of $D_s^{\pm}$ mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR

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  - $D_s^{\pm}/D^0$ ratio
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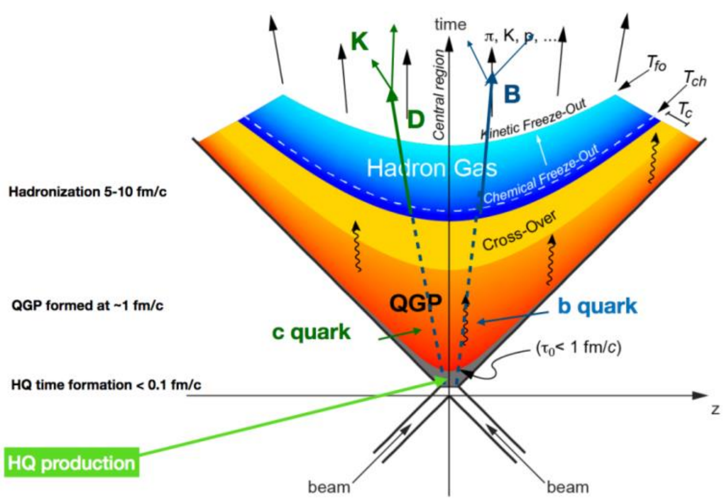
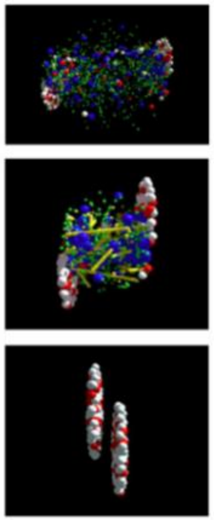
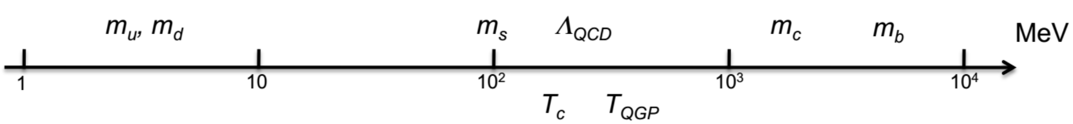
Heavy quarks



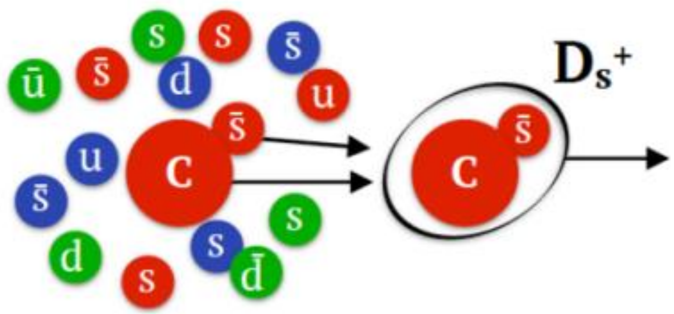


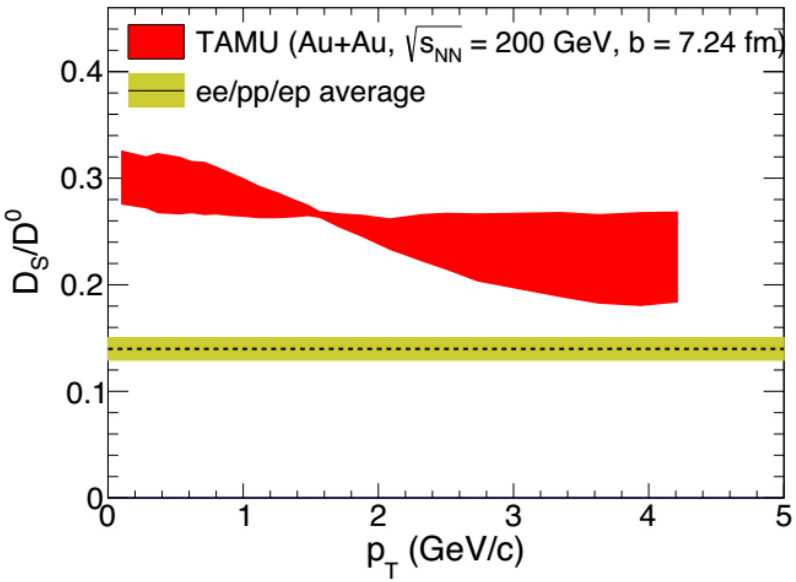
- ➢ Heavy quarks are an excellent probe of studying the properties of QGP:
  - ✓ Transport properties (diffusion coefficient)
  - ✓ Energy loss mechanism
- ➢ Hadronization in the presence of QGP medium - coalescence hadronization?



$M_{c,b} >> T_{QGP}$: predominately created from initial hard scatterings; relaxation time comparable with QGP lifetime.

Why study $D_s^{\pm}$?





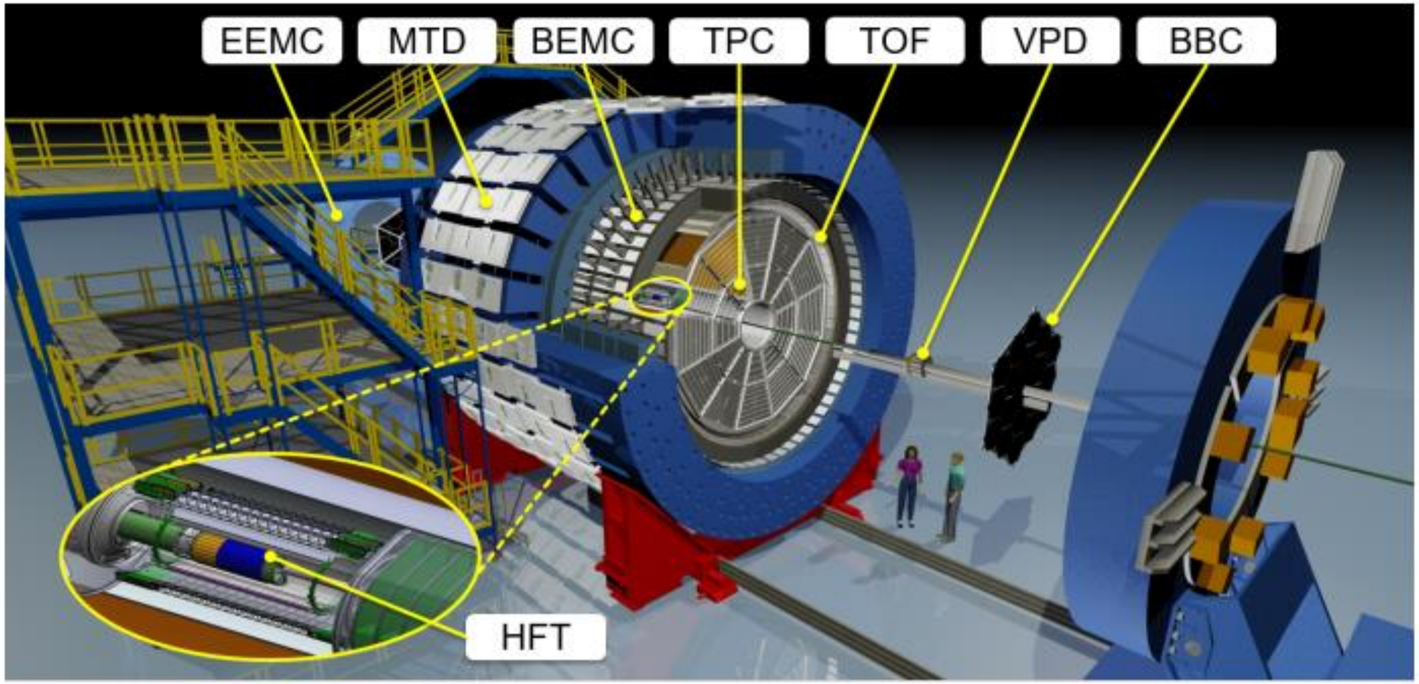
f (c->$D_s^{\pm}$)	f (c->D^0)	$D_s^{\pm}/D^0$
0.0802	0.6086	0.132 [2]

- Strangeness enhancement + coalescence of charm quarks with strange quarks in QGP

→ The $D_s^{\pm}/D^0$ yield ratio in Au+Au collisions expected to show an enhancement compared to that in ee/pp/ep collisions (fragmentation hardronization).

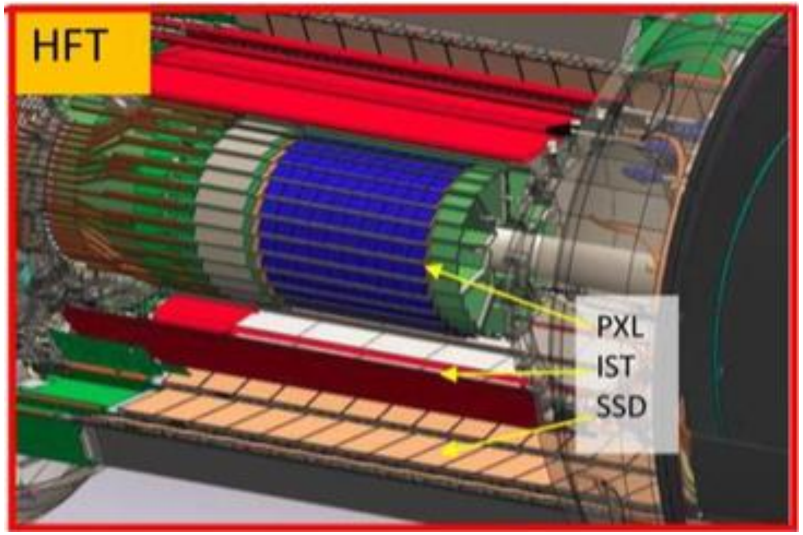
[1] He M, Fries R, Ralf R., Phys. Rev. Lett. (2013) 110: 112301.
[2] Lisovyi M, Verbytskyi A, Zenaiev O., Eur. Phys. J. C (2016) 76: 397.

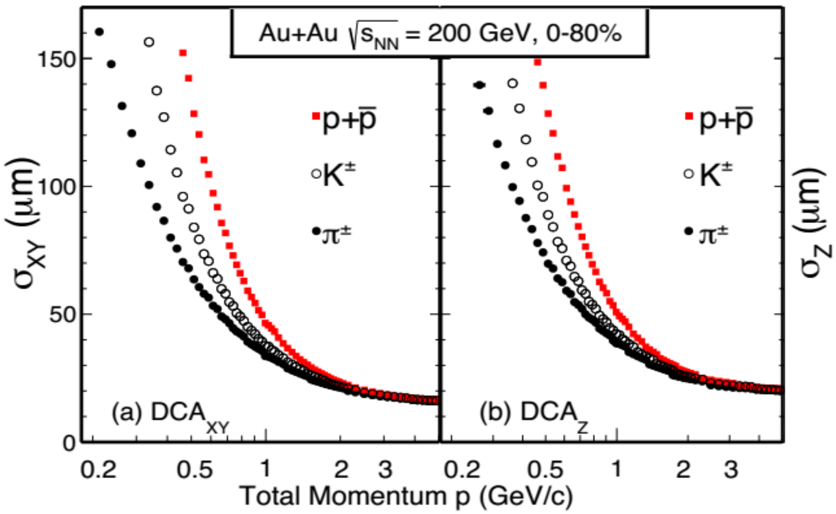
STAR experiment



- TPC + HFT: trajectories and momenta of charged particles ($\pi^{\pm}, K^{\pm}$)
- TPC + TOF: identification of charged particles

Heavy Flavor Tracker

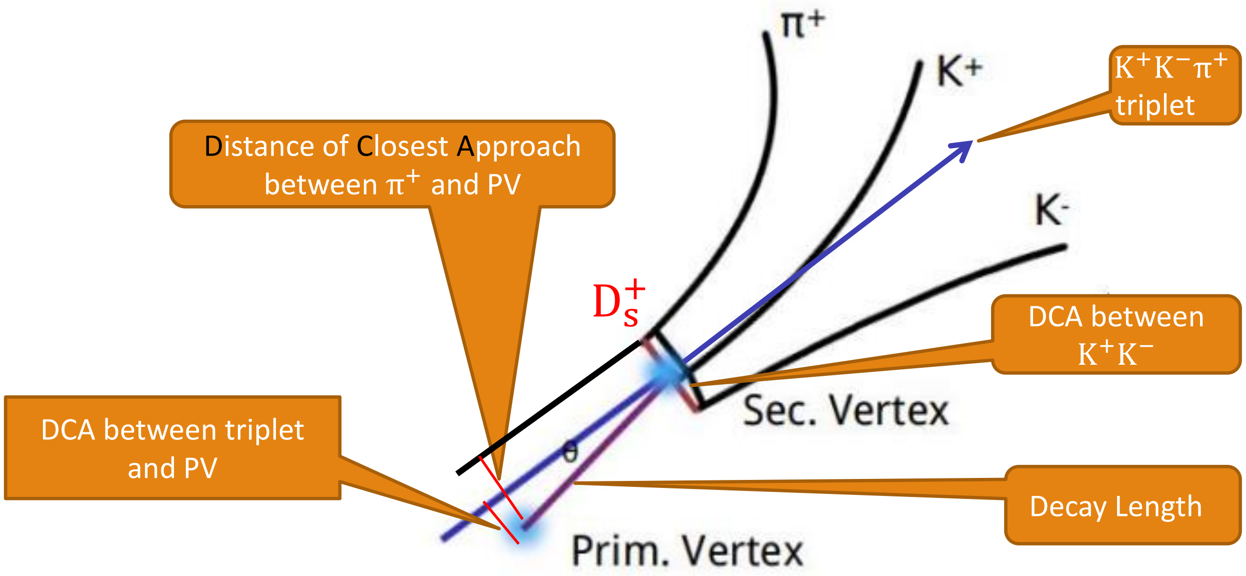




- Heavy Flavor Tracker (HFT, 2014-2016): innermost two layers of Pixel detectors (PXL) + Intermediate Silicon Tracker (IST) + outermost layer of Silicon Strip Detector (SSD).
- Excellent pointing resolution, allows reconstruction of charm hadron decays.

G. Contin et al., Nucl. Instrum. Meth. A907, 60 (2018)

$D_s^{\pm}$ reconstruction

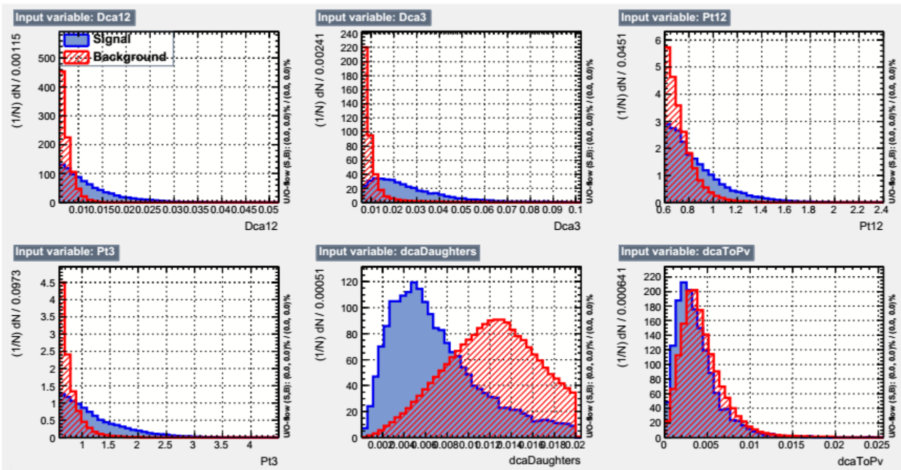


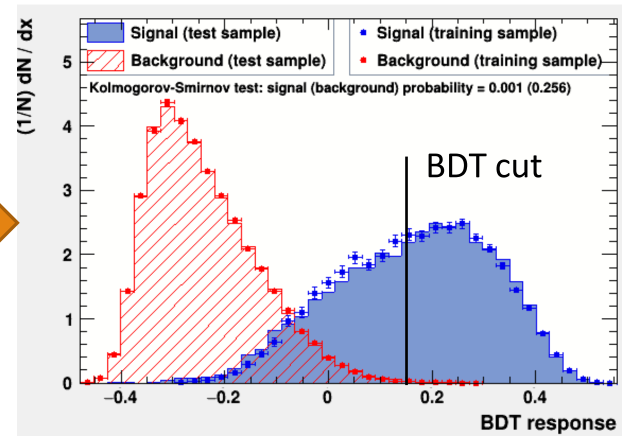
$D_s^{\pm}$	
Quark constituent	$c\bar{s}$ ($\bar{c}s$)
Branching ratio	2.27 %
$c\tau$	150 μm
Rest mass	1967 MeV/c²

$$D_s^{\pm} \to \phi + \pi^{\pm} \to K^{+} + K^{-} + \pi^{\pm}$$
$$c\tau(\phi) = 4.65 \times 10^{-8}\mu m$$

Event cuts	**$|V_z| < 6$ cm**	**$V_r < 2$ cm**	**$|V_z - V_z^{VPD}| < 3$ cm**

Topological cuts optimization using TMVA-BDT



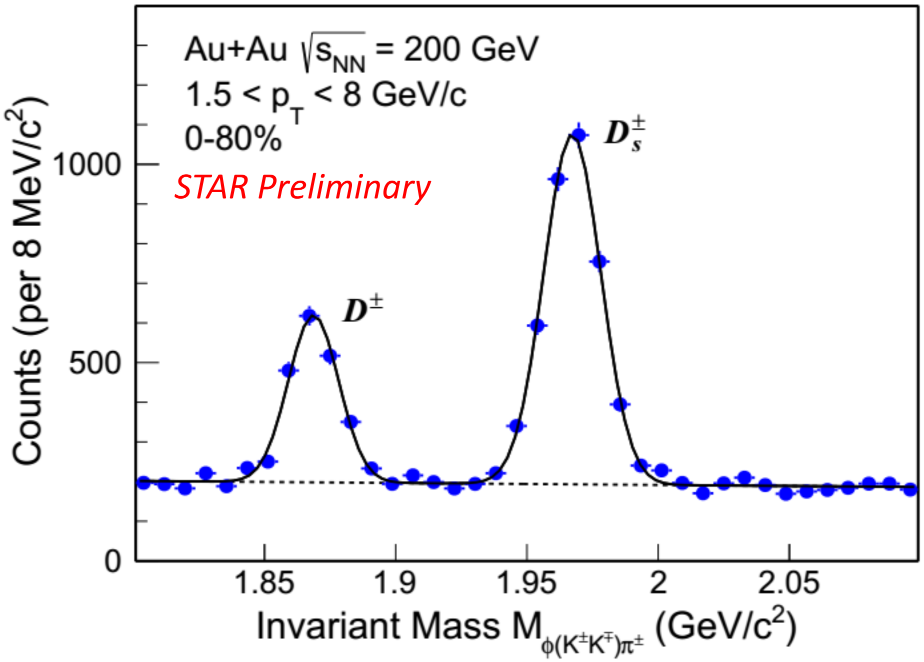


6 topological variables → BDT training → BDT response

- Boosted Decision Tree (BDT) method from the Toolkit for MultiVariate Analysis [1] was used to improve signal and background separation in $D_s^{\pm}$ reconstruction.
- Signal sample from simulation taking into account detector response; background sample from wrong-sign combinations in data.
- BDT cut was applied to reconstruct $D_s^{\pm}$ signal with best significance.

[1] Hoecker A, et al., PoS ACAT (2007) 040.

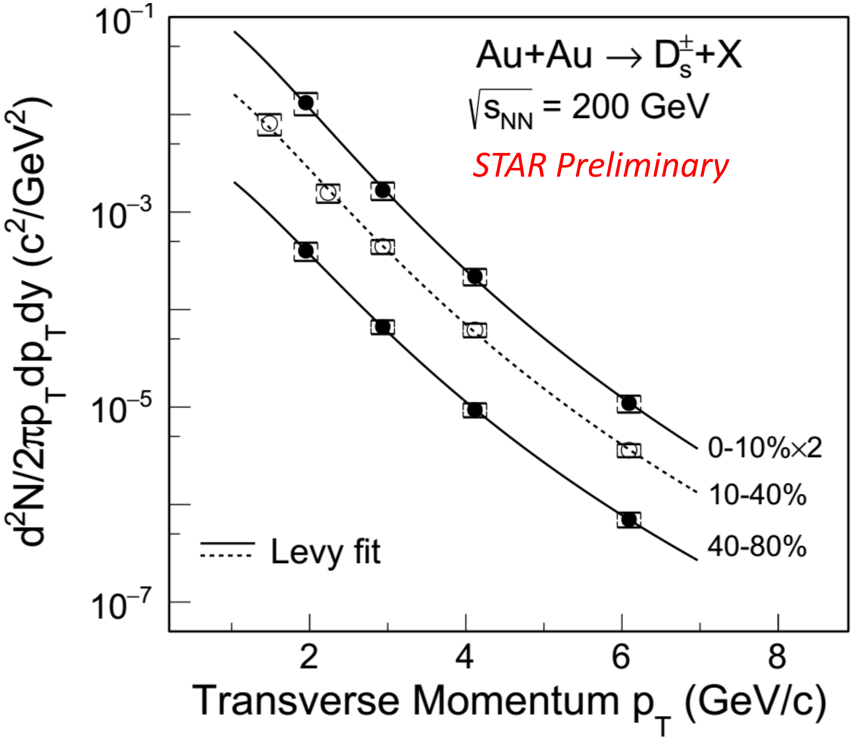
Invariant mass distribution



	Significance
0-80%, 1.5<p_T<8 GeV/c	
Traditional cuts, 2014	26
BDT method, 2014	34
BDT method, 2014+2016	45

- 2014+2016 data, ~ 2 billion events. The Gaussian + linear function was used to fit data.
- Background described by the linear function.
- Significance is greatly improved with BDT.

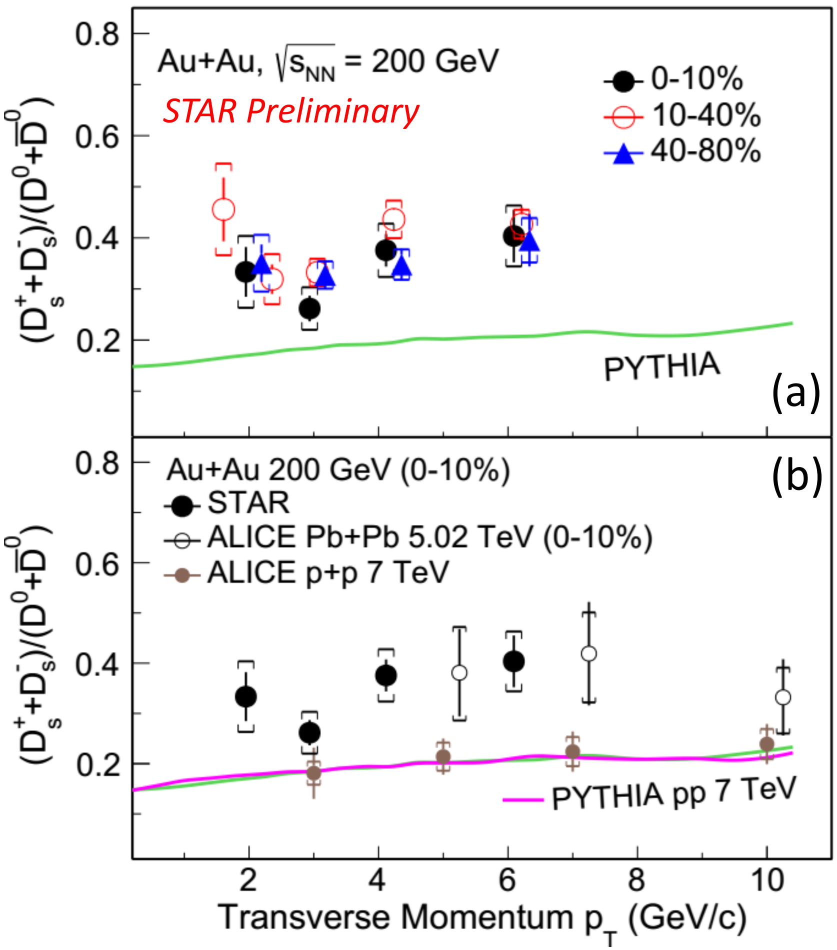
$D_s^{\pm}$ p_T spectrum



$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} = \frac{N(D_s^+ + D_s^-)}{4\pi.\, p_T.\, \Delta p_T \Delta y.\, BR.\, N_{evt}.\, Eff_{rec}}$$

- $D_s^{\pm}$ invariant yield fitted by Levy function in various centrality
- Efficiency correction
  - ✓ The acceptance cuts ($|\eta| < 1$), TPC tracking cuts, TPC-to-HFT matching, PID cuts and topological variable cuts/BDT cuts are applied in fast simulation to evaluate efficiencies.
- The measurement reaches to low p_T (1 GeV/c), providing better constraints on the total $D_s^{\pm}$ production.
  - ✓ Fraction of the total production from measured p_T region is ~60%.

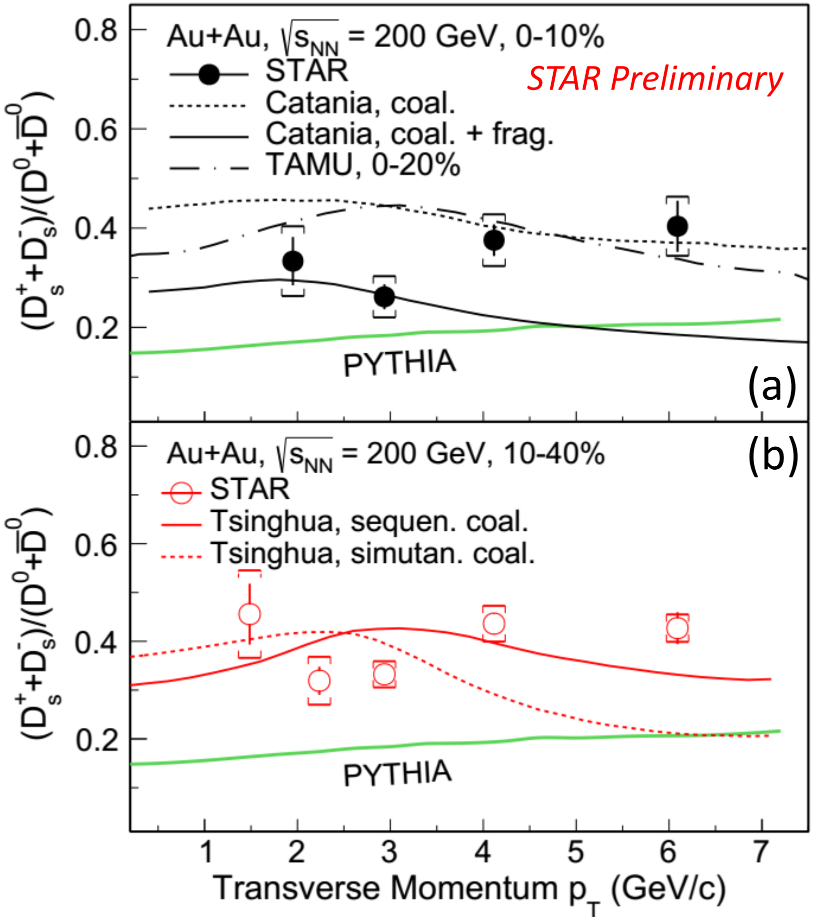
$D_s^{\pm}/D^0$ ratio



- $D_s^{\pm}/D^0$ yield ratio: large enhancement (~1.5-2 times) relative to PYTHIA; no obvious p_T dependence.
- PYTHIA calculation consistent with ALICE data for 7 TeV p+p collisions [1].
- Compatible with ALICE data in Pb+Pb collisions [2] in the overlapping p_T region.

[1] ALICE Collaboration, Acharya S, et al., Eur. Phys. J. C (2017) 77: 550.
[2] ALICE Collaboration, Acharya S, et al., J. High Energ. Phys. (2018) 2018: 174.

Comparisons with model calculations



- The Catania [1] and TAMU [2] models (only coalescence hadronization): describe the data for $p_T > 4$ GeV/c, but deviates at lower p_T.
- The Catania model (coalescence + fragmentation hadronization): describe the data for $p_T < 4$ GeV/c, but disagrees with data for $p_T > 4$ GeV/c.
- Tsinghua model [3] (sequential coalescence hadronization): qualitatively describe our measurements.

[1] Plumari S, Minissale V, Das S K, et al., Eur. Phys. J. C (2018) 78: 348.
[2] He M, Ralf R., In preparation (2019).
[3] Zhao J, Shi S, Xu N, Zhuang P., arXiv (2018):1805.10858.

Summary

- The $D_s^{\pm}$ invariant yield and $D_s^{\pm}/D^0$ yield ratio are measured as a function of p_T for different collision centrality at mid-rapidity ($|y| < 1$) in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

- $D_s^{\pm}/D^0$ yield ratio shows large enhancement compared to PYTHIA at 200 GeV.
  - ✓ The data can be qualitatively described by model calculation incorporating strangeness enhancement and (sequential) coalescence hadronization of charm quarks.

- Coalescence hadronization plays an important role in charm quark hadronization in heavy-ion collisions.