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

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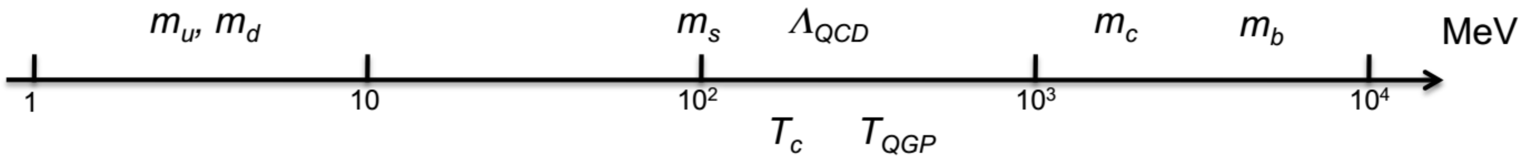
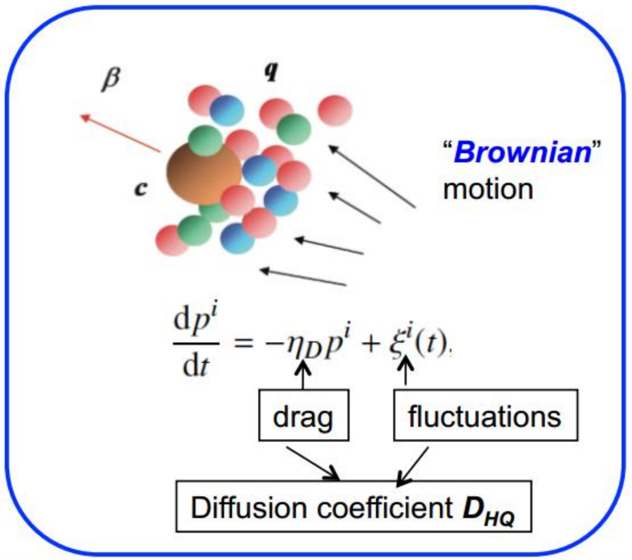
Outline

- Motivation
- Experiment setup
- Results
  - $D_s^{\pm}$ signal extraction
  - $D_s^{\pm}$ p_T spectrum
  - $D_s^{\pm}/D^0$ ratio
- Summary

Heavy quarks



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



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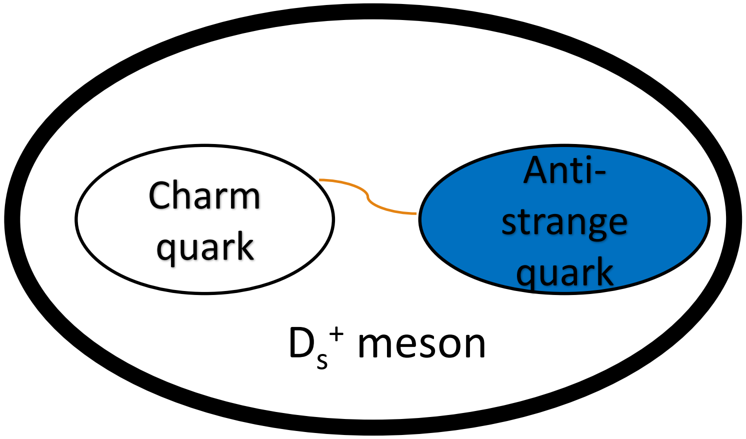
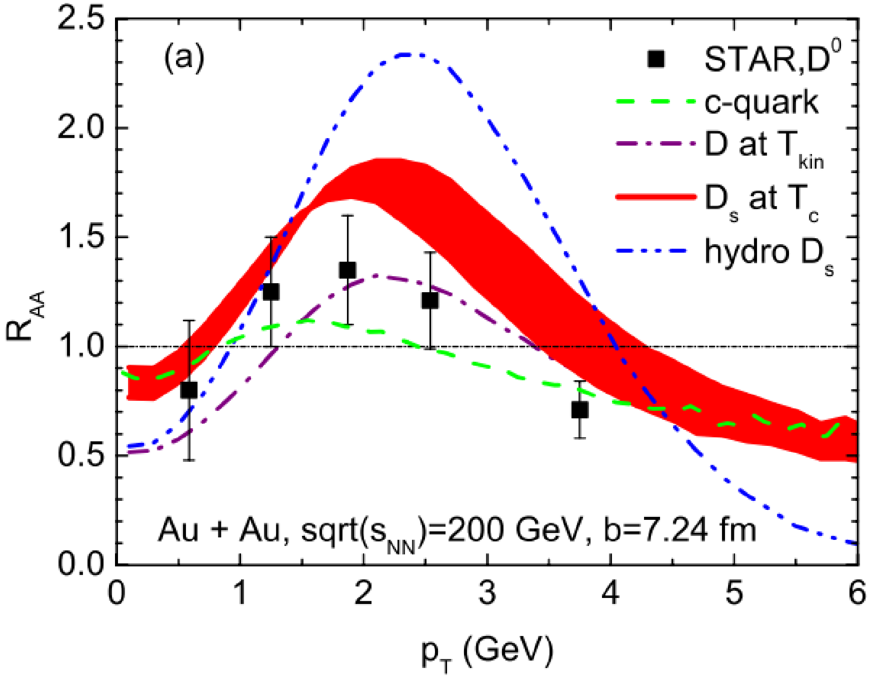
- Measurements of nuclear modification factors (R_{AA}), azimuthal anisotropies and particle yield ratios
  -- Investigate the energy loss, transport and hadronization of heavy quarks in QGP.
  -- Constrain diffusion coefficient D and reveal the sub-structure of the surrounding medium.

Why study $D_s^{\pm}$?



- $D_s^{\pm}$: $c\bar{s}$ ($\bar{c}s$)
- Better understand the transport properties of the charm quark in QGP.
- Study hadronization process: coalescence of charm quarks together with strangeness enhancement.

Why study $D_s^{\pm}$?

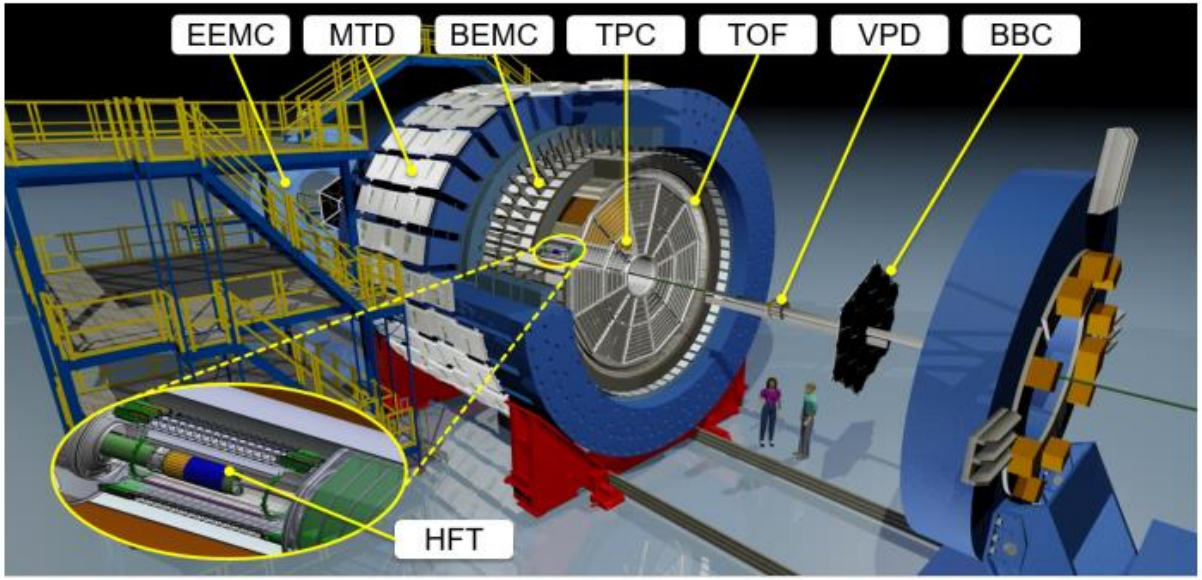


Ref: M. He et al., PRL 110, 112301 (2013)

Charm quark coalescence hadronization + strangeness enhancement -> $D_s^{\pm}/D^0$ ratio in A+A collisions predicted to show an enhancement compared to that in p+p collisions.

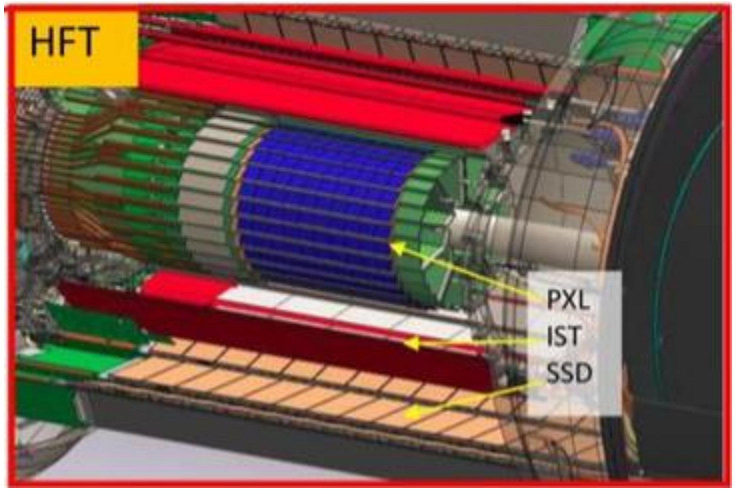
$$\left(\frac{D_s}{D^0}\right)_{AA} = \frac{R_{AA}(D_s)}{R_{AA}(D^0)} * \left(\frac{D_s}{D^0}\right)_{pp}$$

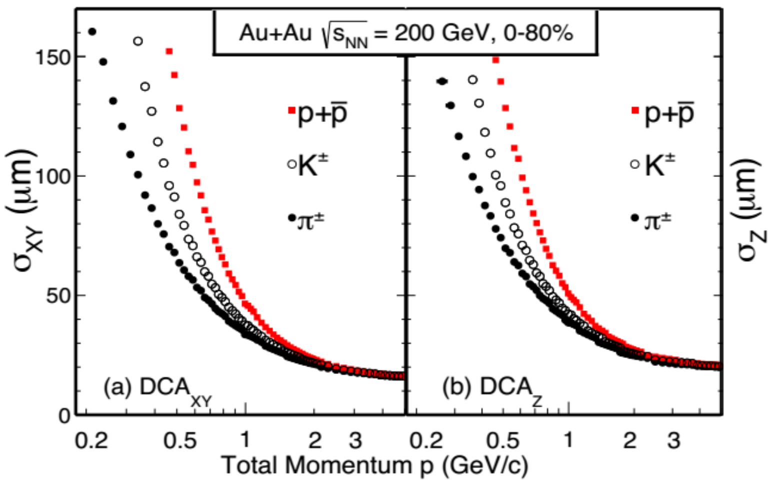
Experiment setup



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

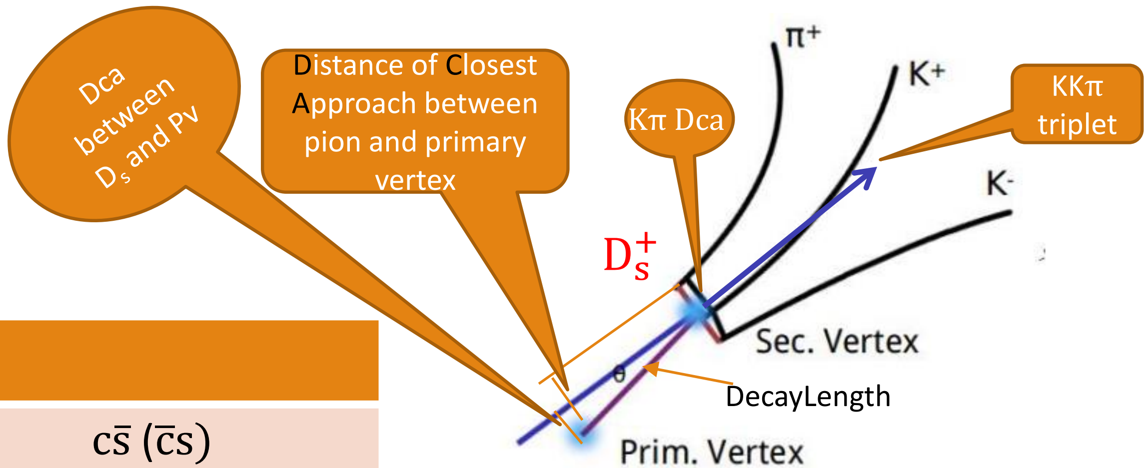
Heavy Flavor Tracker





- Heavy Flavor Tracker (HFT, 2014-2016): four-layers of silicon detectors — two layers of MAPS pixel detectors and two outer layers of strip detectors.
- Excellent vertex resolution allows reconstruction of charm hadron decays.

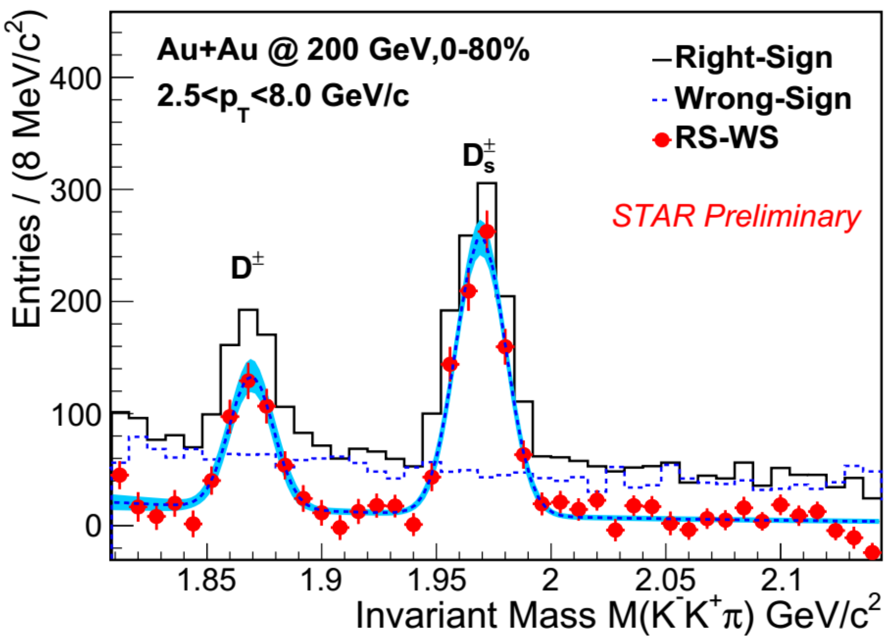
How to measure $D_s^{\pm}$?



$D_s^{\pm}$	
Quark constituent	$c\bar{s}$ $(\bar{c}s)$
Branching ratio	2.27 %
$c\tau$	150 μm
Rest mass	1967 MeV/c^2

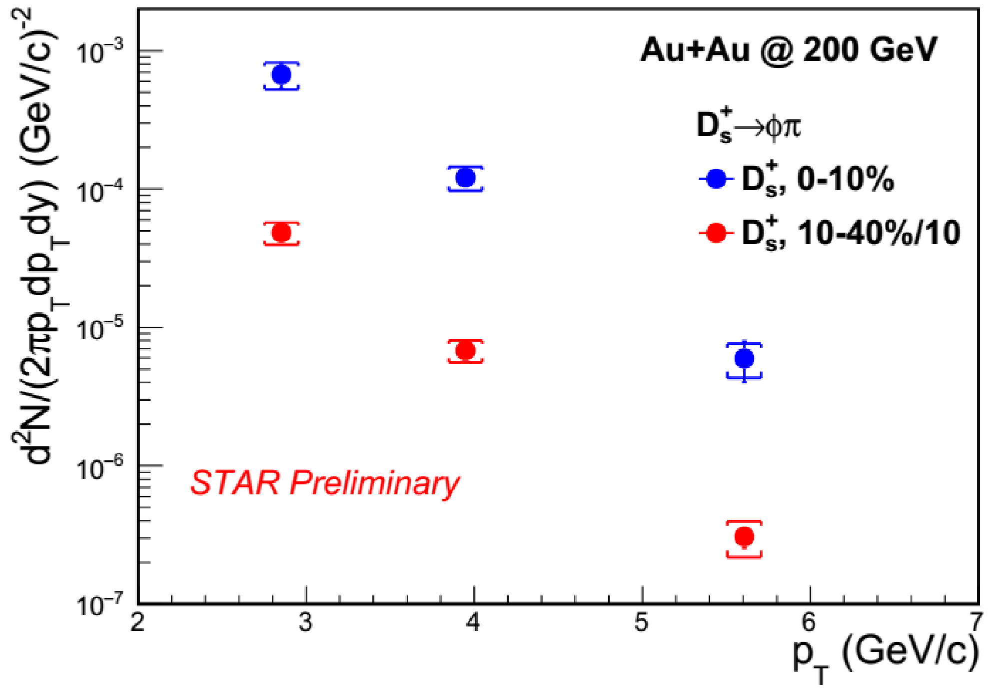
$$D_s^{\pm} \to \phi + \pi^{\pm} \to K^{+} + K^{-} + \pi^{\pm}$$
$$c\tau(\phi) = 4.65 \times 10^{-8}\mu m$$

Invariant mass distribution



- Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from 2014 data, about 900 M minimum bias events.
- Rectangular Cut method from the Toolkit for MultiVariate Analysis is used to optimize separation of signal and background in $D_s^{\pm}$ reconstruction.

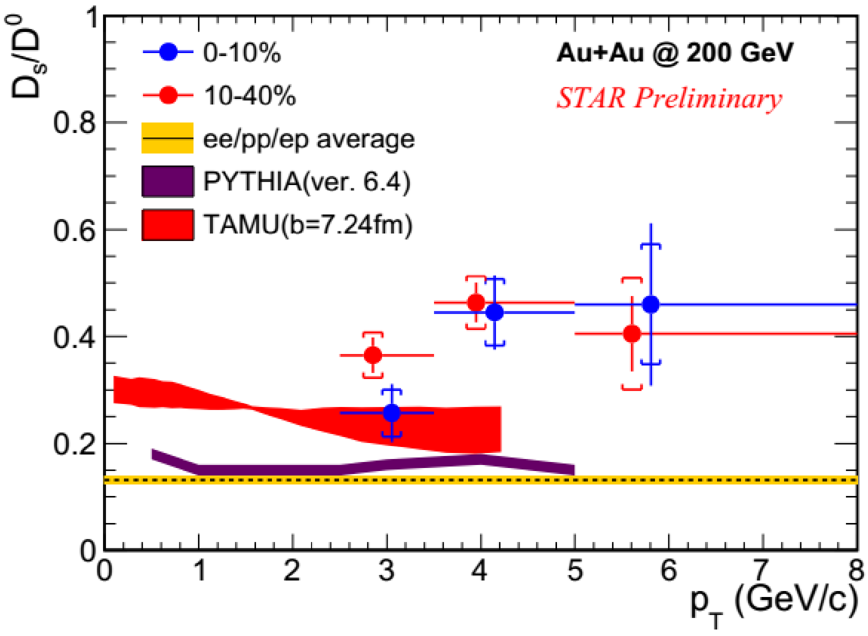
$D_s^{\pm}$ p_T spectrum



$D_s^{\pm}$ p_T spectra are measured for two centrality bins (0-10% and 10-40%)

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

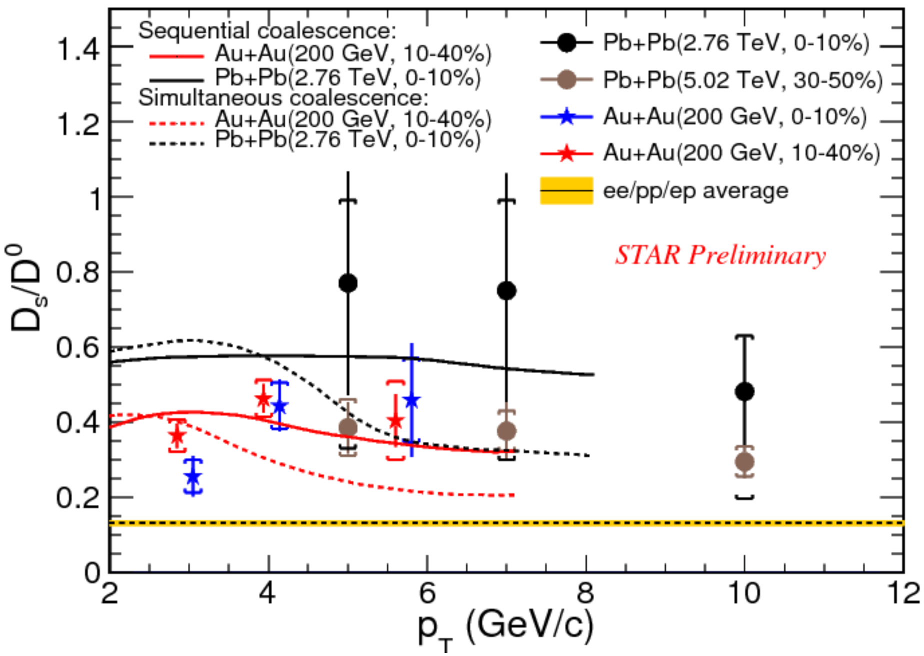
$D_s^{\pm}/D^0$ ratio



[1] G. Agakishiev et al. (STAR Collaboration), PRL 108, 072301 (2012)
[2] Ref: M. He et al., PRL 110, 112301 (2013)

- $D_s^{\pm}/D^0$ ratio: large enhancement (~1.8-3.3 times) relative to PYTHIA and the average from ee/ep/pp. No clear centrality dependence.
- Strangeness enhancement[1] + coalescence hadronization mechanism.
- TAMU model calculation[2] with coalescence hadronization in 10-40% centrality bin shows enhancement, but lower than data.

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



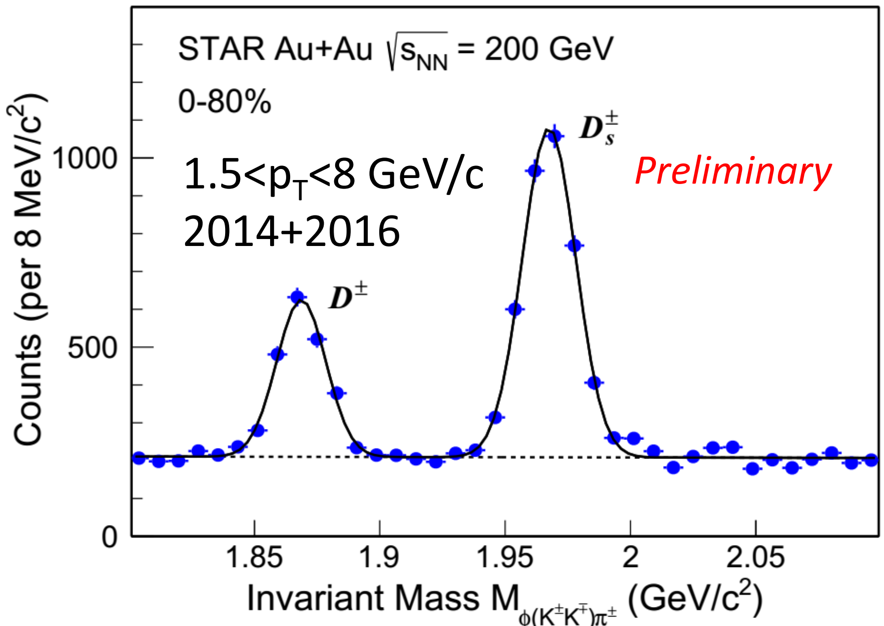
- Our measurement is consistent with ALICE result[1][2] on prompt $D_s^{\pm}$ within uncertainties.
- Data seem to favor sequential coalescence hadronization[3].
  - $D_s^{\pm}$ is formed earlier than D^0.

[1] ALICE, JHEP10 (2018) 174
[2] ALICE, JHEP03 (2016) 082
[3] J.Zhao, S.Shi, N.Xu, P.Zhuang, arXiv preprint arXiv:1805.10858, 2018

Summary

- $D_s^{\pm}$ measurements at STAR in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV enabled by the HFT.
- $D_s^{\pm}/D^0$ enhancement with respect to PYTHIA and the ee/pp/ep average :
  - Coalescence hadronization play an important role for charm quark hadronization.
  - Our measurement seem to favor sequential coalescence hadronization.

Outlook



- 2014+2016 data, about 1.9B events.
- Boosted Decision Tree method from the Toolkit for MultiVariate Analysis is used to optimize the topological variables in $D_s^{\pm}$ reconstruction.
- Significance (0-80%): 25 (rectangular cuts, 2.5<p_T<8 GeV/c, 2014) --> 45 (BDT, 1.5<p_T<8 GeV/c, 2014+2016).