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

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STAR

Outline

- Motivation
- STAR experiment
- Results
  - p_T spectra of D_S
  - R_{AA} of D_S
  - D_S/D^0 ratio
  - Elliptic flow of D_S
- Summary

Motivation

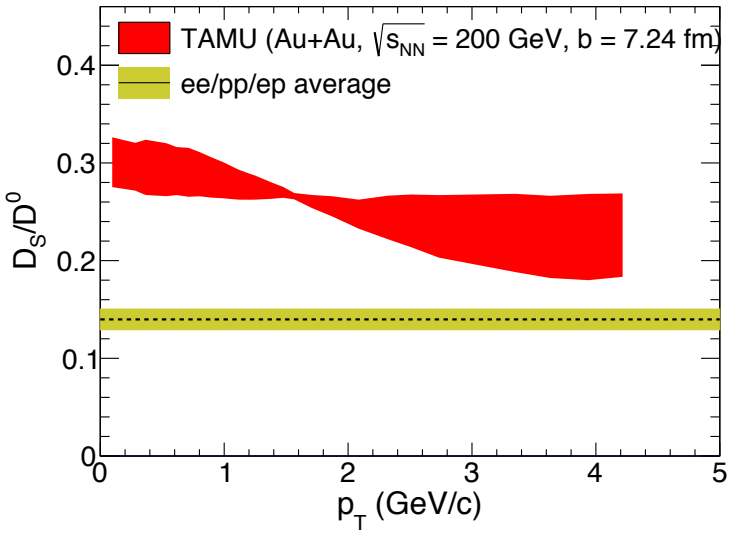
- Strangeness enhancement in QGP is expected to affect the yield of D_S (if charm quarks participate in coalescence)

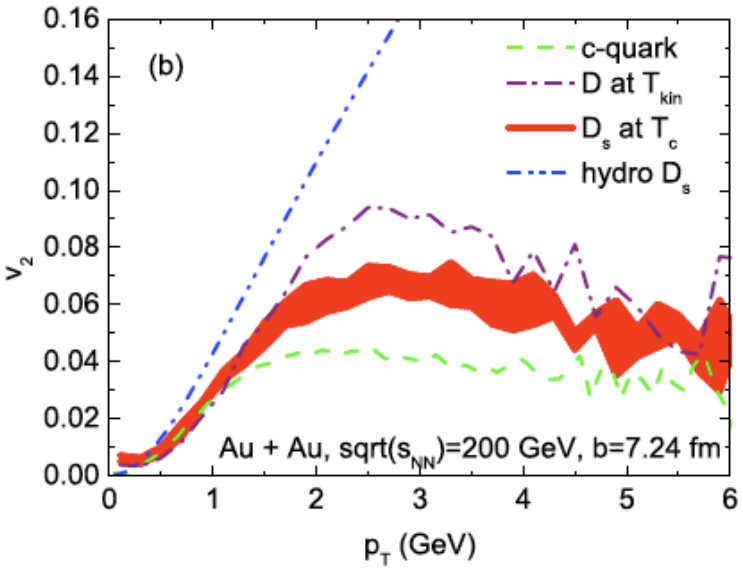
- D_S/D^0 (Au+Au) > D_S/D^0 (p+p) predicted

Good Probe to study the charm quark hadronization

D_S freezes out early and expected to have smaller hadronic interaction cross-sections compared to D^0

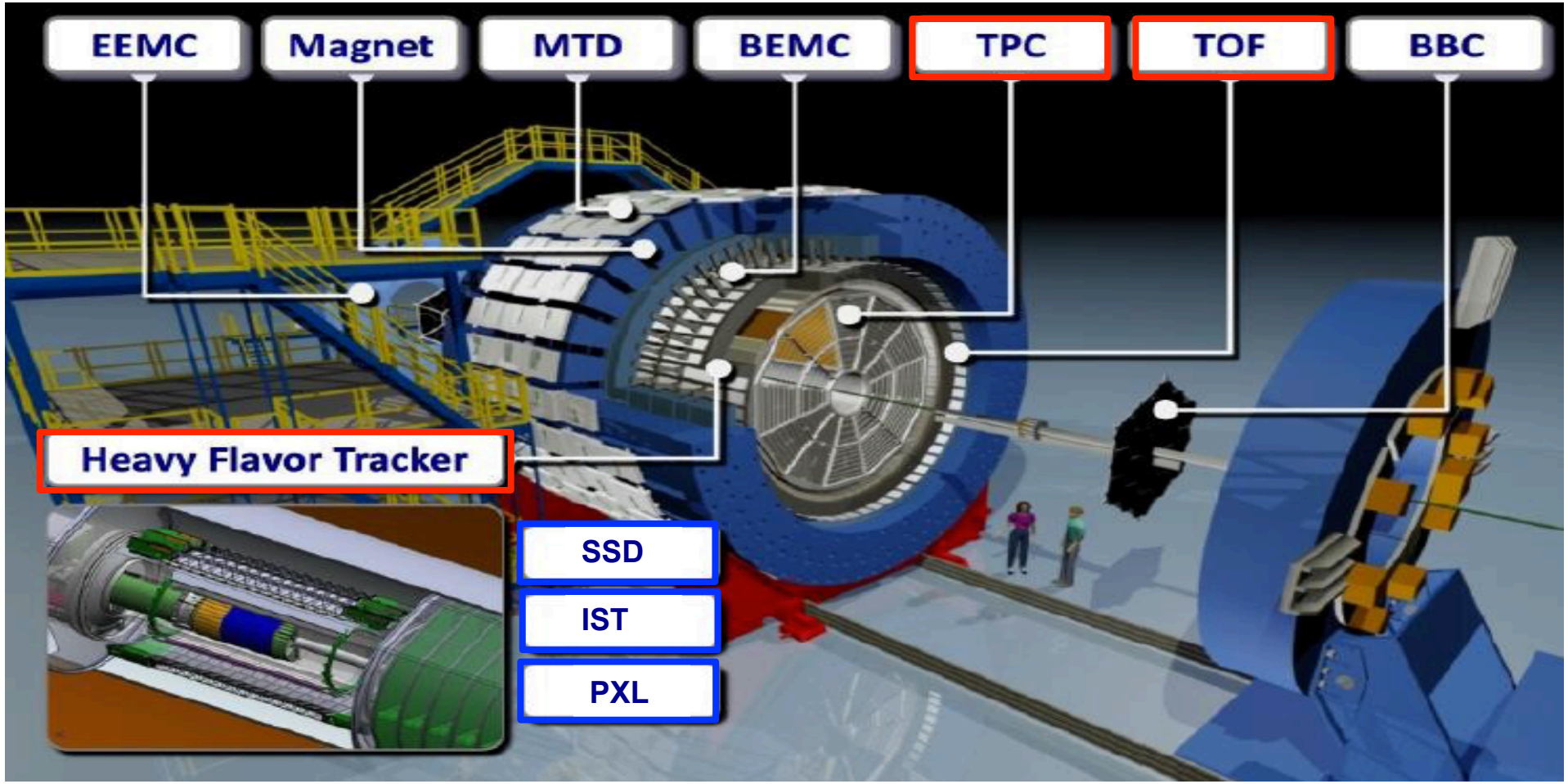
Better measure of the partonic contribution to the charm hadron v_2





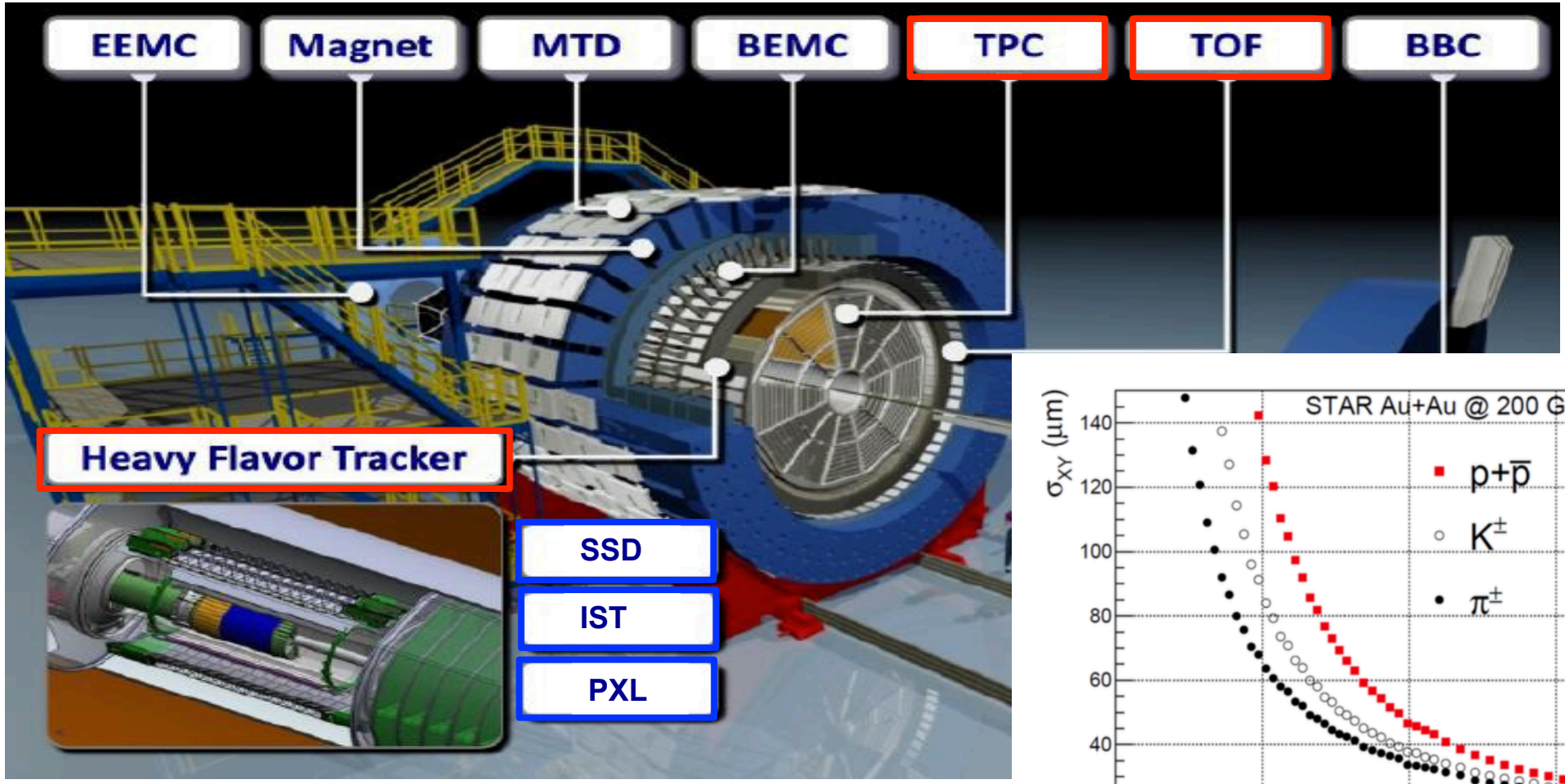
Ref: M. He et al., PRL 110, 112301 (2013)

STAR Detector in Year 2014



- Full 2π coverage
- Pseudorapidity coverage ~ ±1 unit

STAR Detector in Year 2014



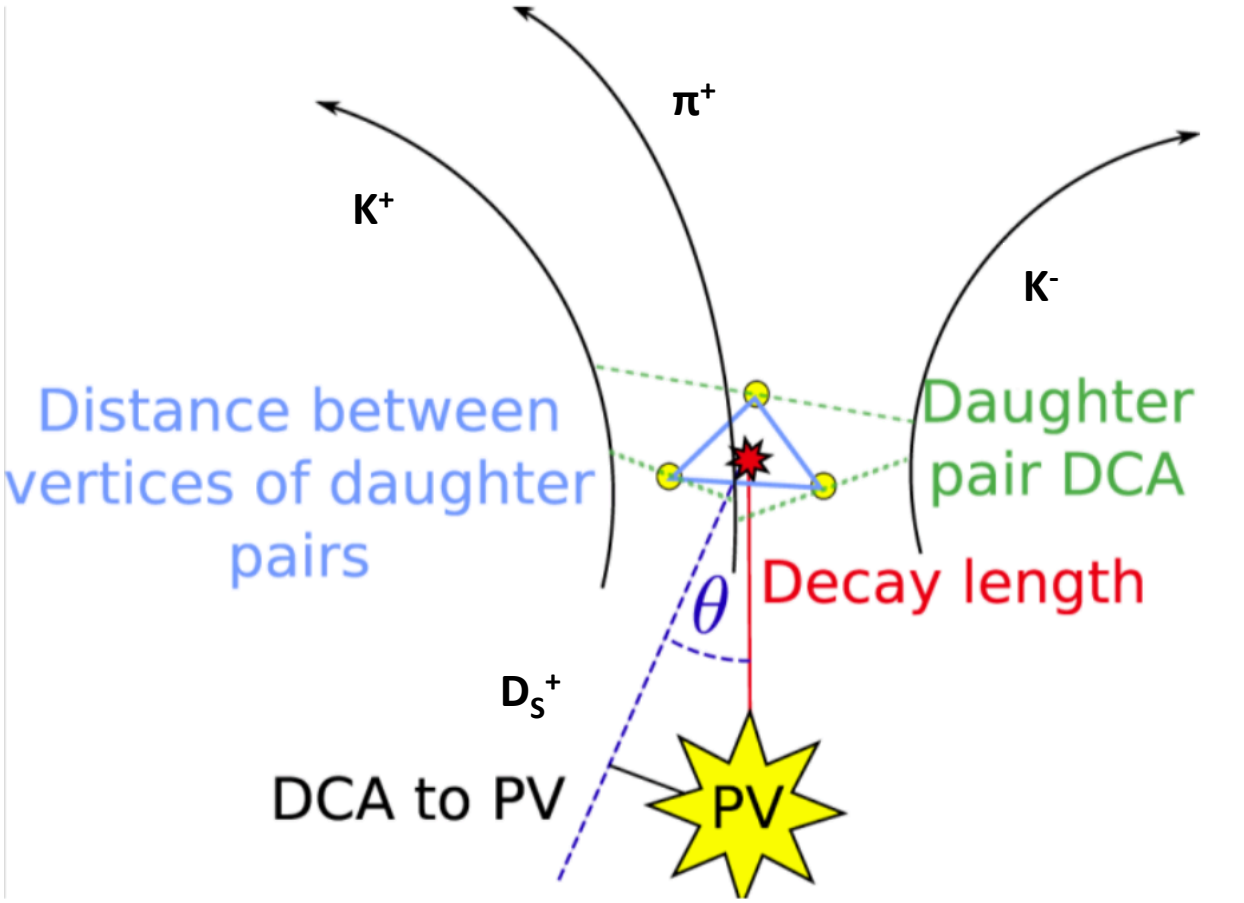
- Full 2π coverage
- Pseudorapidity coverage ~ ±1 unit

Analysis Details

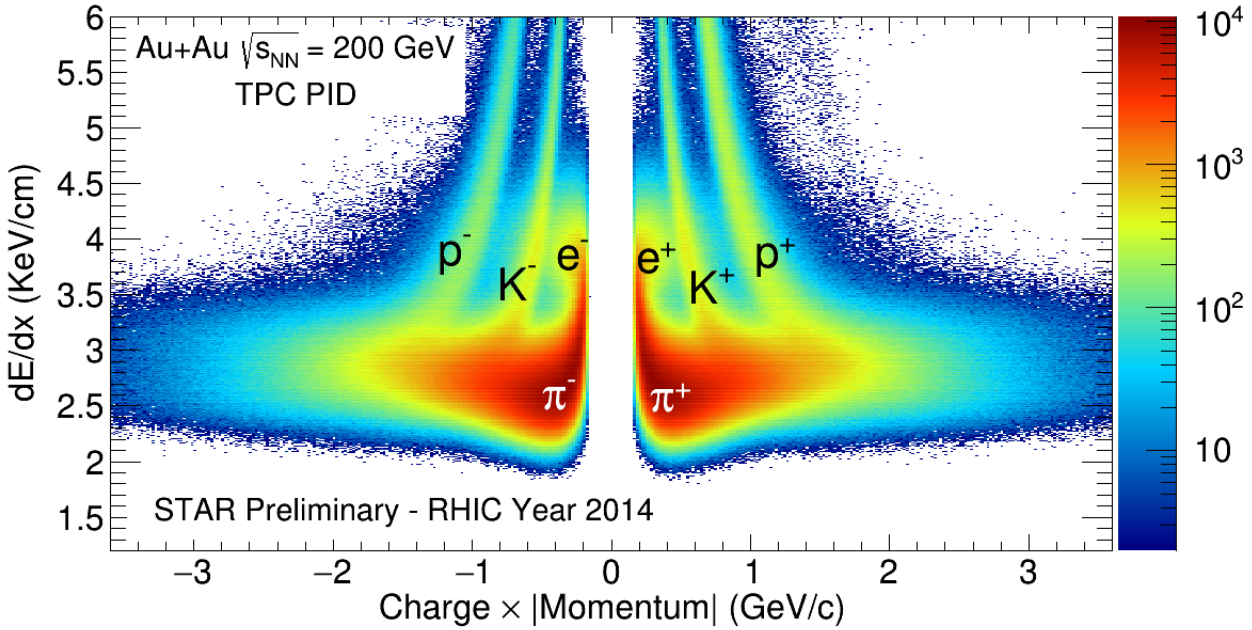
- Au+Au at $\sqrt{s_{NN}}$ = 200 GeV in 2014
- ~ 900 M minimum bias events analyzed
- |Vz| <= 6 cm

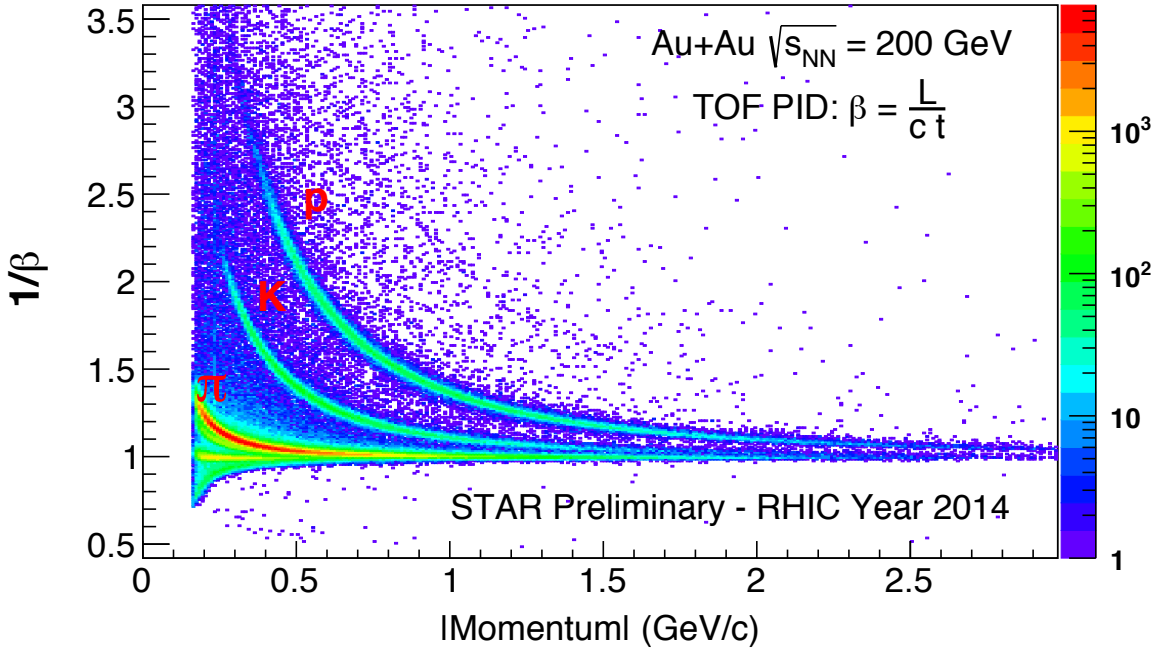
- Decay channel : $D_s^{\pm} \longrightarrow \phi (\longrightarrow K^+ + K^-) + \pi^{\pm}$
- Branching ratio: 2.32 ± 0.14 %
- Decay length : 150 ± 2 μm
- Mass : 1.96847 ± 0.00033 GeV/c^2

Decay Topology :



Particle Identification





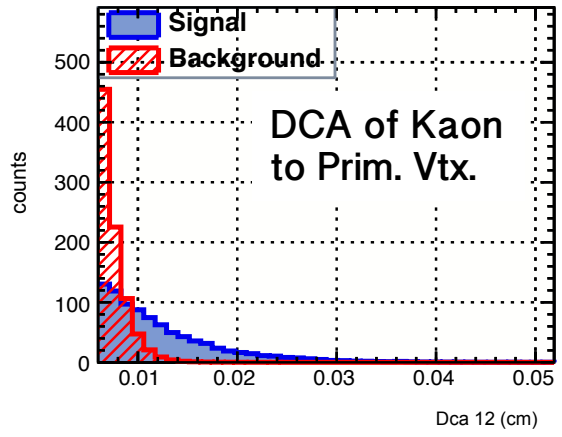
TPC PID: Energy loss dE/dx

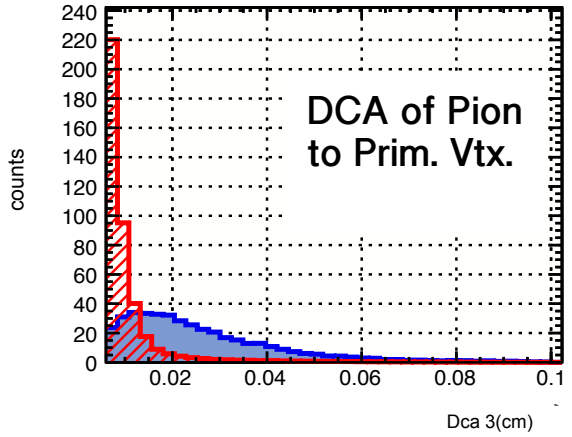
TOF PID: Flight time (β)*

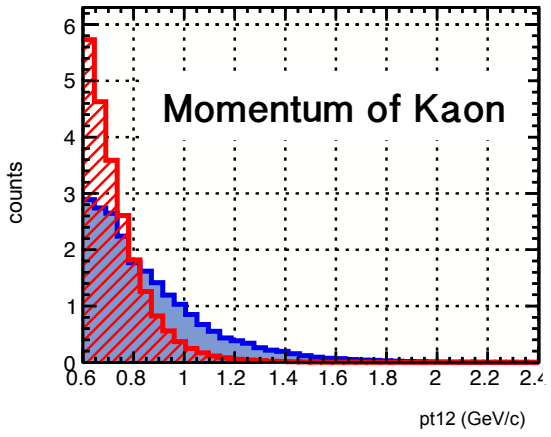
* TOF PID has been applied only when β information is available.

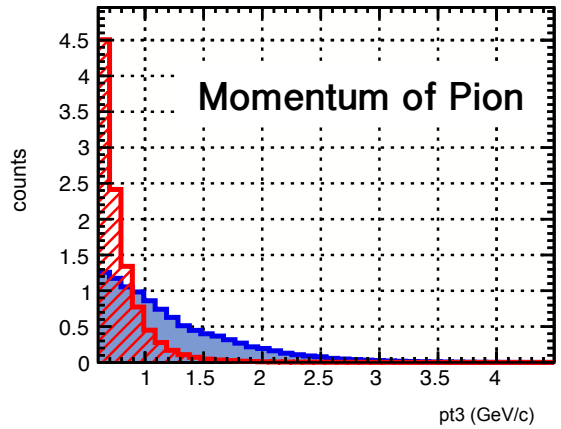
Cut Optimization

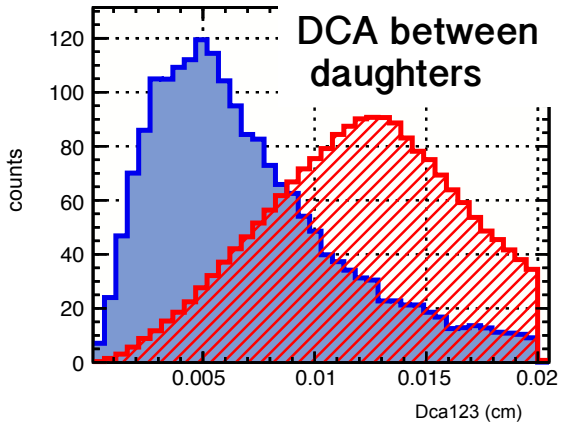
- Topological cuts optimized using TMVA package.
- Background extracted from real data using wrong-sign method
- Signal simulated with data-driven fast simulation

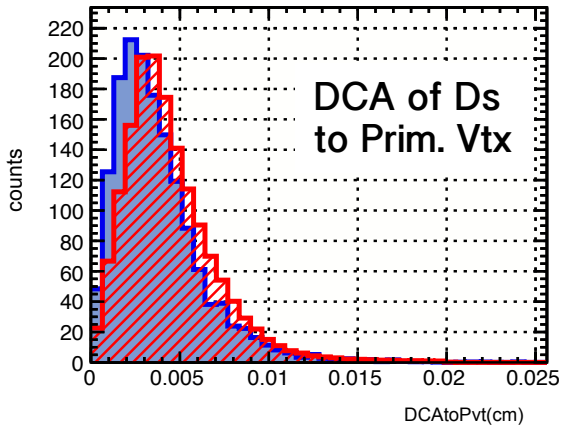






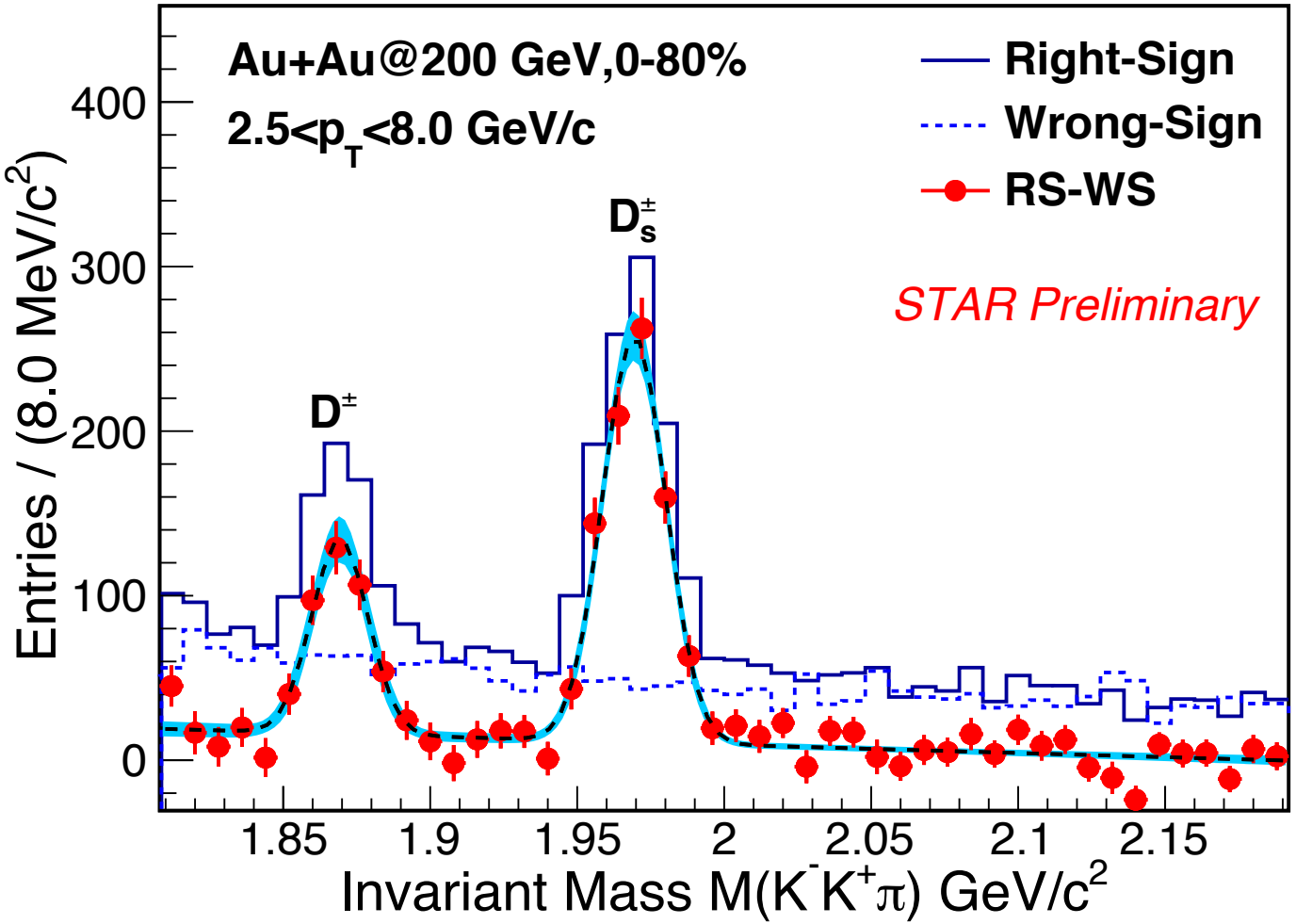






Ref: A. Hoecker et. al, PoS ACAT:040,2007

D_S Meson Reconstruction



Clear signal of $D_S^{\pm}$ and $D^{\pm}$

Significance of $D_S^{\pm}$ ~ 25

Efficiency and Acceptance Correction

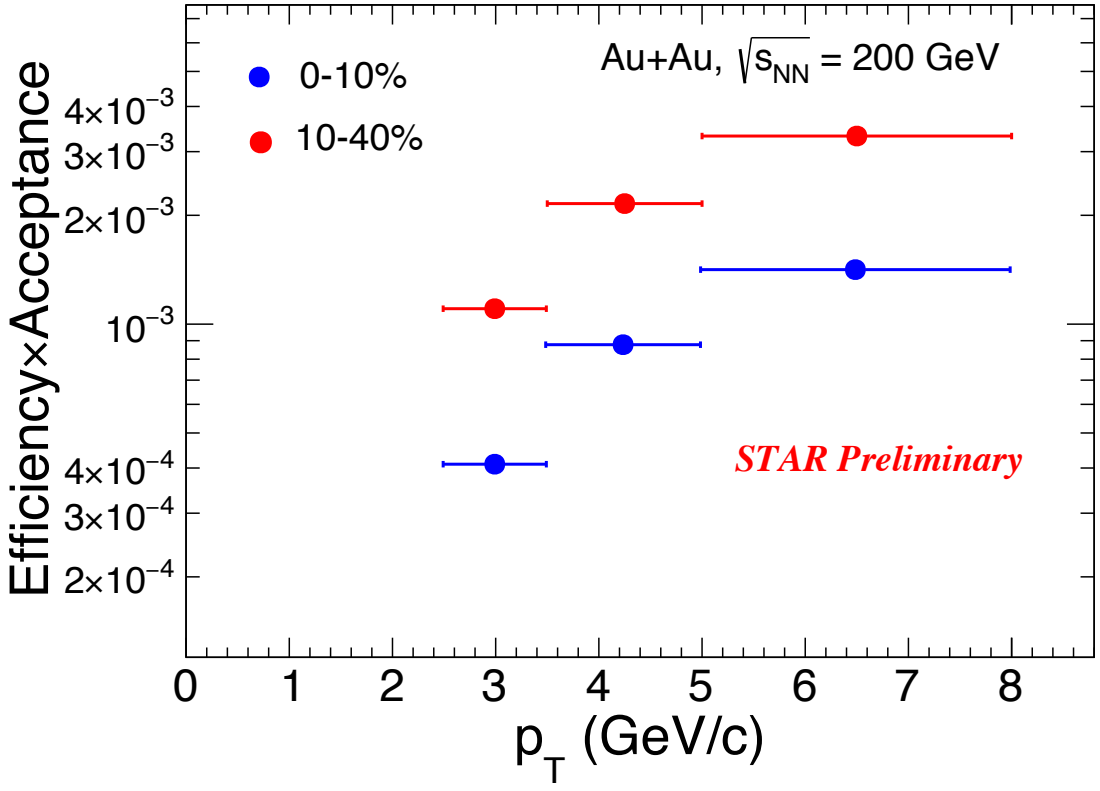
D_S efficiency = TPC tracking eff. ⊗ HFT tracking eff. ⊗ topological cuts

Embedding for TPC tracking efficiency

- Full STAR GEANT simulation
  -> single tracks embedded in raw data
  -> data reconstruction chain

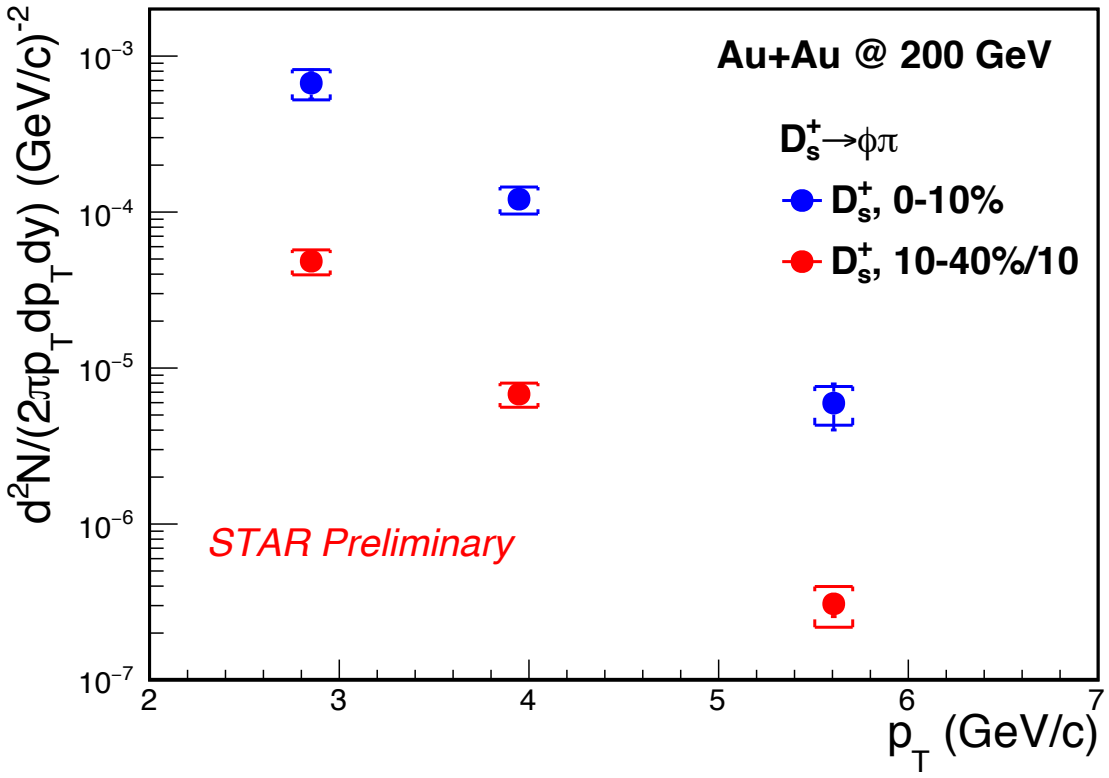
Data-driven simulation

- HFT matching efficiency and resolution extracted from data:
  - HFT eff. × geometrical acceptance: (HFT matched tracks) / (TPC tracks).
  - Spatial resolution: DCA distributions of HFT matched tracks (in XY plane and Z direction).



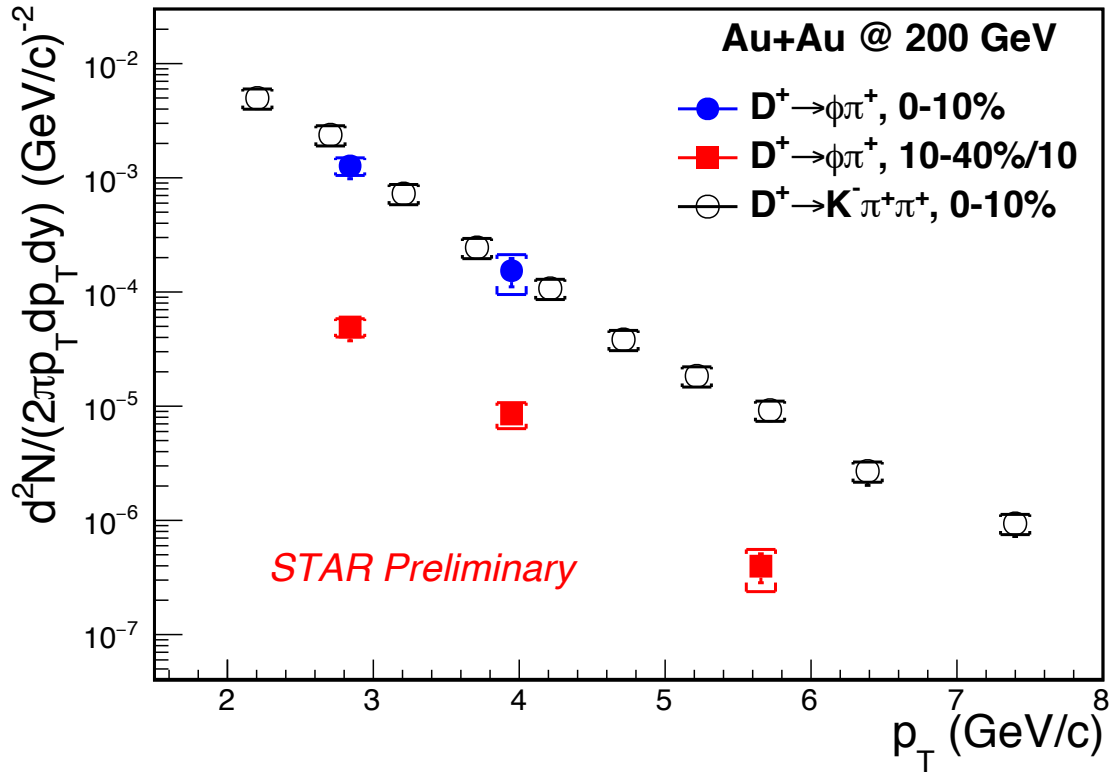
Transverse Momentum Spectra

$D_S = D_S^+ + D_S^-$



- The D_S p_T spectra in 0-10% and 10-40% collision centralities

$D^+ = D^+ + D^-$



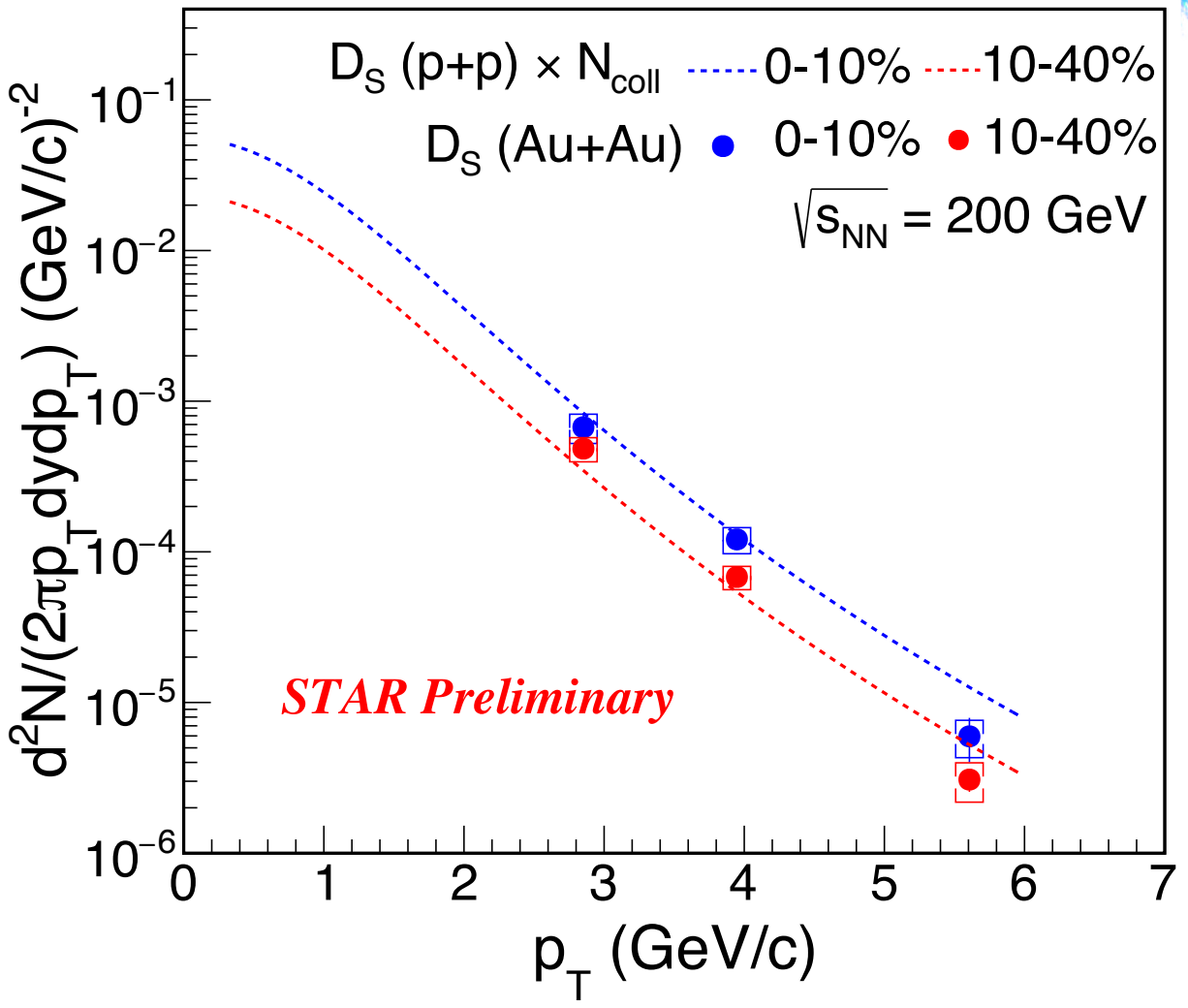
- The D^+ p_T spectra from two decay channels are consistent

- $D^+ \to \pi^+ \pi^+ K^-$ (B.R. = 9.46%)
- $D^+ \to \phi\pi^+ \to \pi^+ K^- K^+$ (B.R. = 0.27%)

Nuclear Modification Factor (R_{AA})

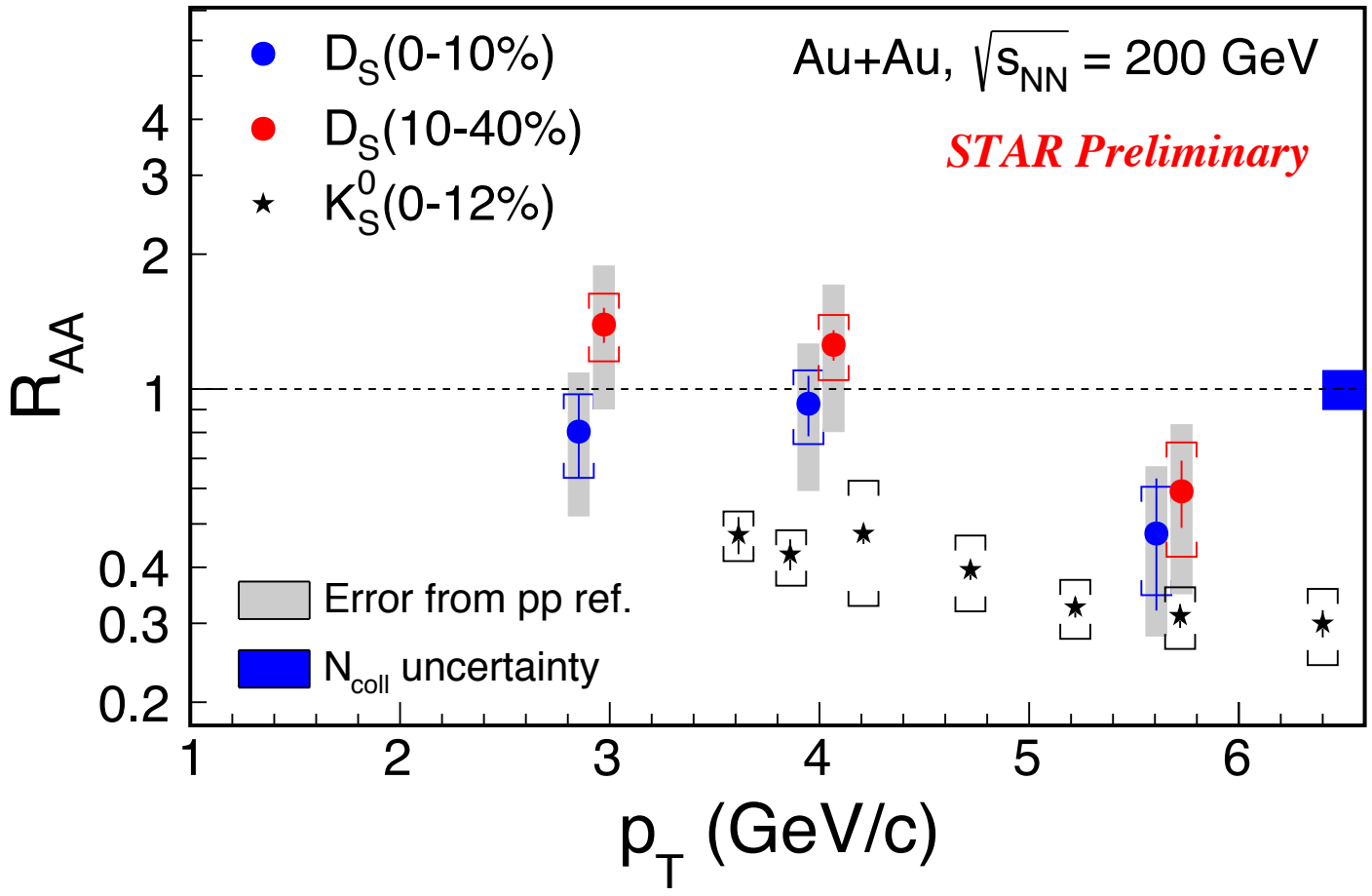
$$R_{AA} = \frac{1}{N_{coll}} \times \frac{dN^{AA}/dp_T}{dN^{pp}/dp_T}$$

D_S spectra for p+p collisions have been calculated from measured D^0/D* cross-section by STAR. Fragmentation factor (c to D_S) = 0.079±0.004



Ref: M Lisovyi, et. al. EPJ C 76, 397 (2016)
STAR: PRD 86, 72013 (2012)

R_{AA} of D_S

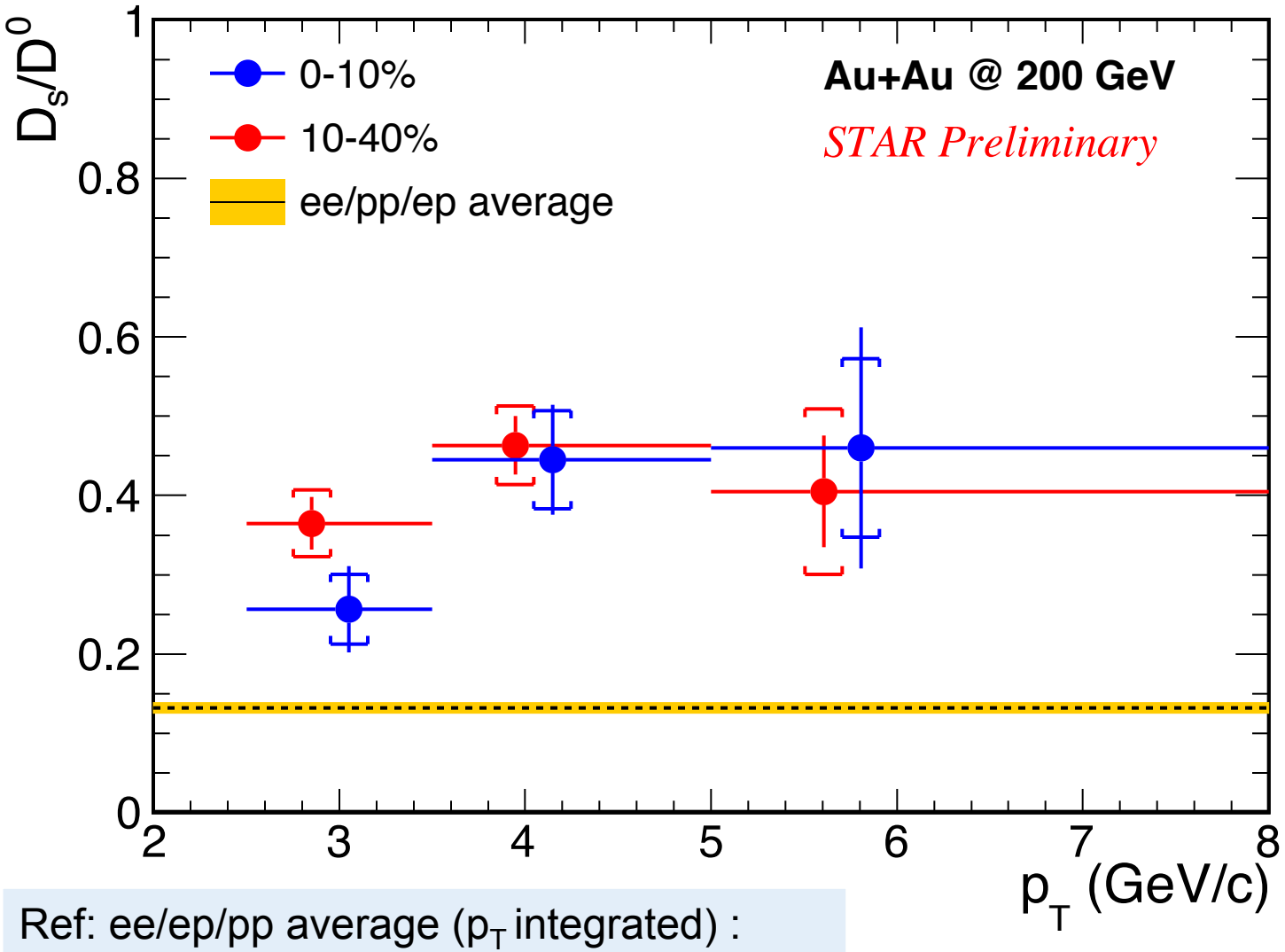


Indication of suppression for high p_T (> 5 GeV/c) D_S w.r.t. the p+p reference

R_{AA} (K^0_S) ≤ R_{AA} (D_S)

Ref: K^0_S R_{AA} : PRL **108** (2012) 72302 [STAR]

D_s/D^0 Ratio: Probe of Charm Hadronization

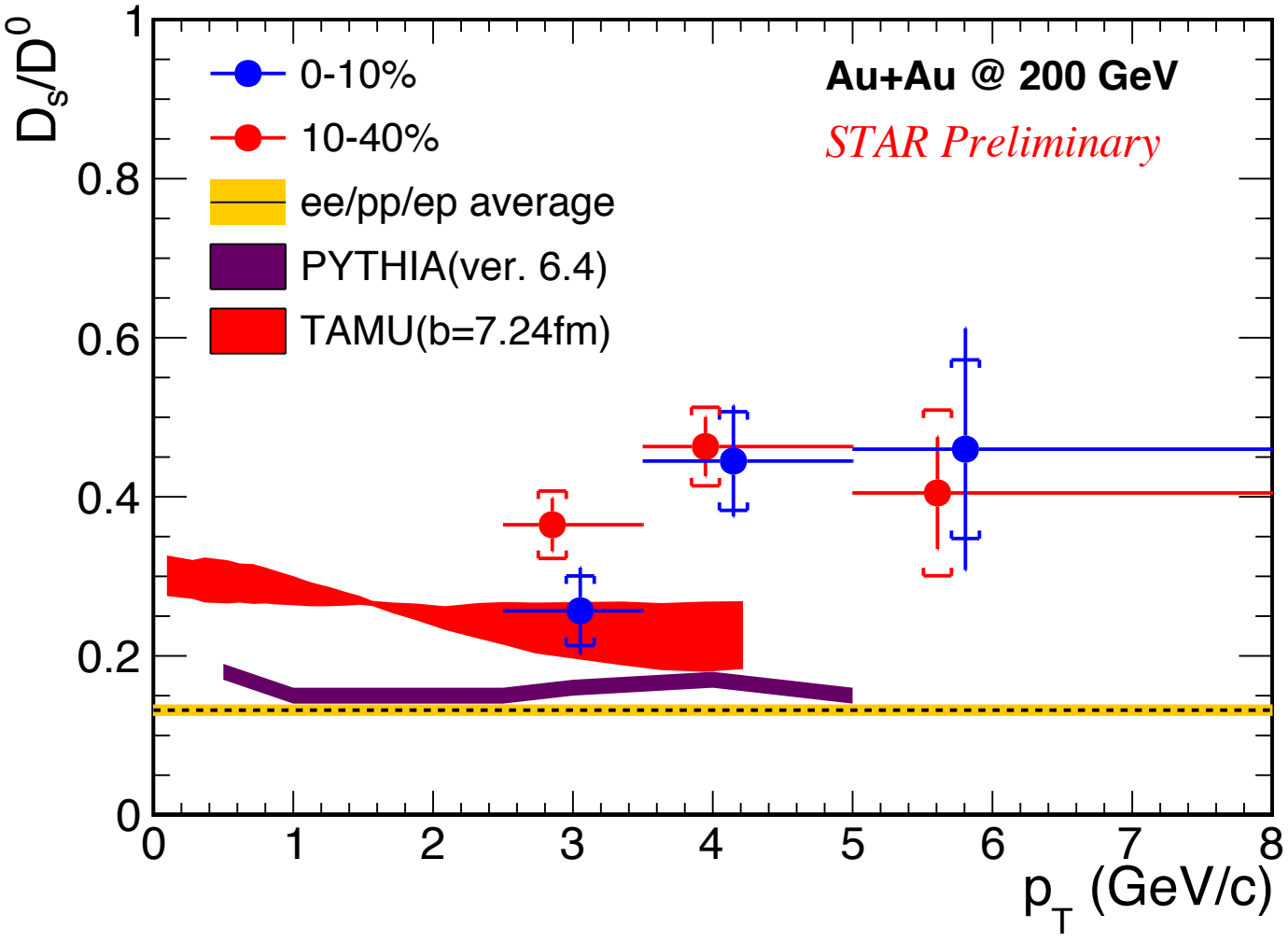


- **Substantial enhancement in D_s/D^0 ratio in Au+Au collisions w.r.t. the fragmentation baseline.**

– Indicates that the charm quark recombination plays a crucial role in open charm meson production in central Au+Au collisions.

Ref: ee/ep/pp average (p_T integrated) :
M Lisovyi, et. al. EPJ C 76, 397 (2016)

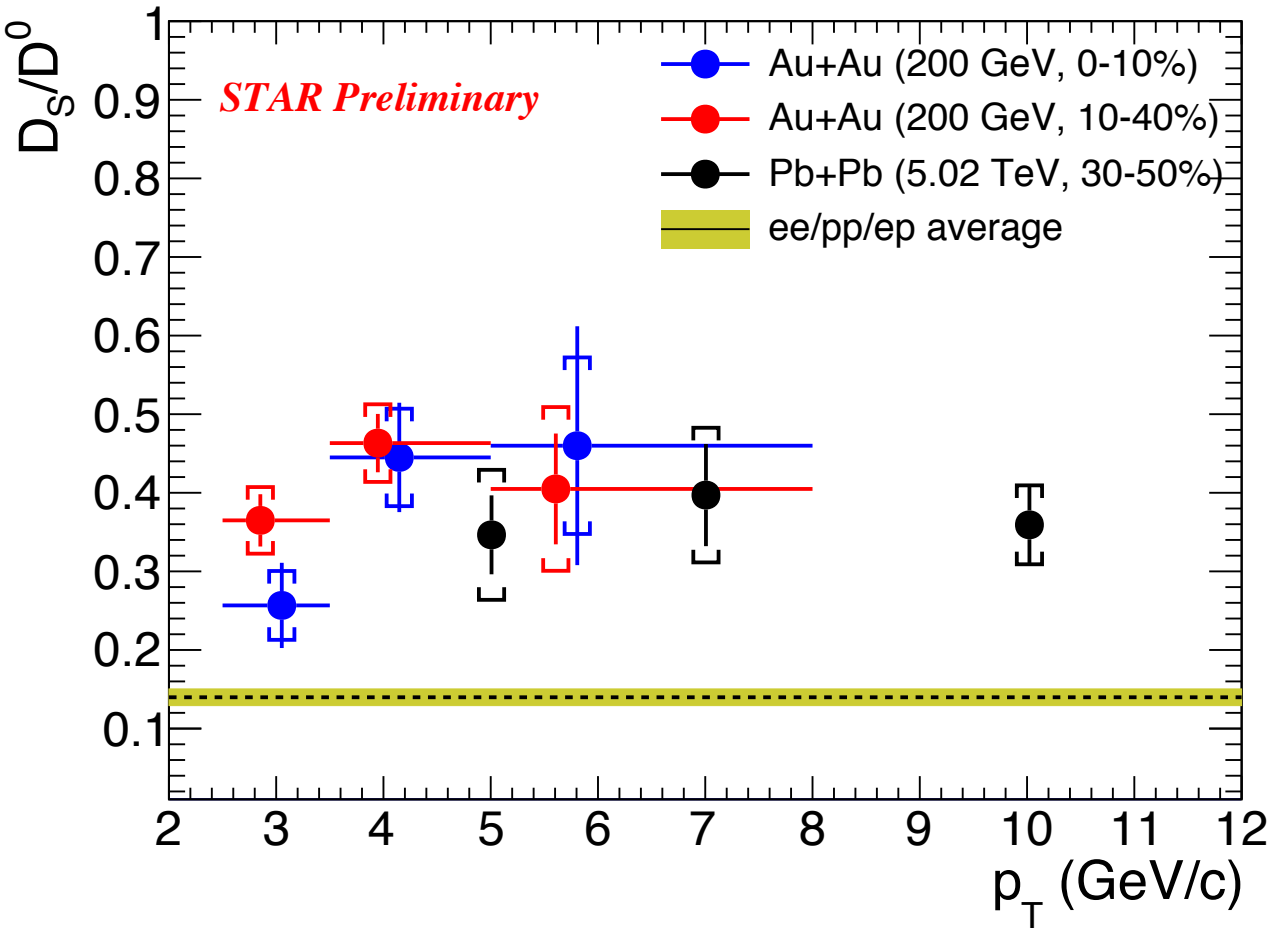
D_s/D^0 Ratio : Comparison with Model Prediction



- **Substantial enhancement in D_s/D^0 ratio in Au+Au collisions w.r.t. the fragmentation baseline.**
- **D_s/D^0 in Au+Au is higher than the PYTHIA model prediction.**
- **TAMU model under-predicts measured D_s/D^0 ratio.**

Ref: TAMU: H. Min et al. PRL 110, 112301 (2013)

D_S/D^0 Ratio : Comparison with LHC



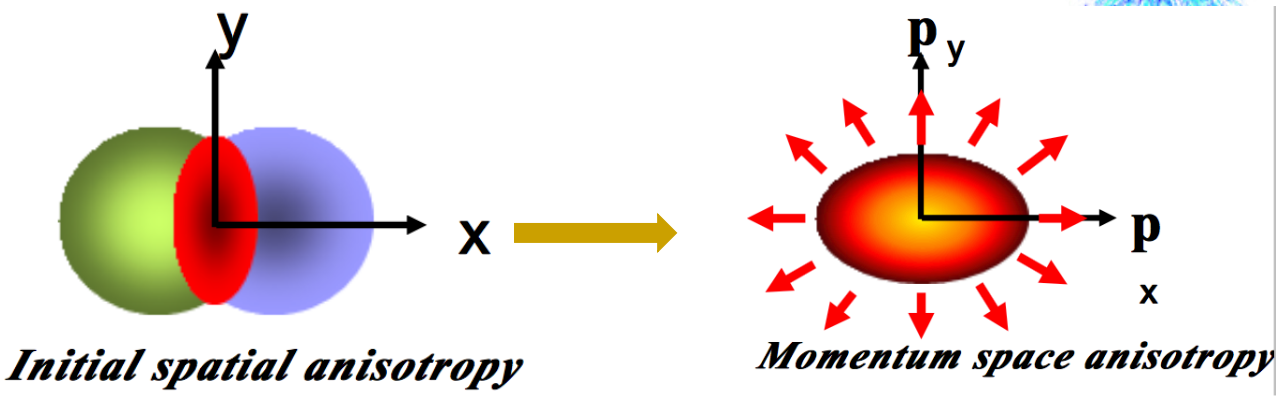
- **Substantial enhancement in D_S/D^0 ratio in Au+Au collisions w.r.t. the fragmentation baseline.**
- **Comparable to LHC data.**

Ref: Pb+Pb : Quark Matter 17 (ALICE Preliminary)

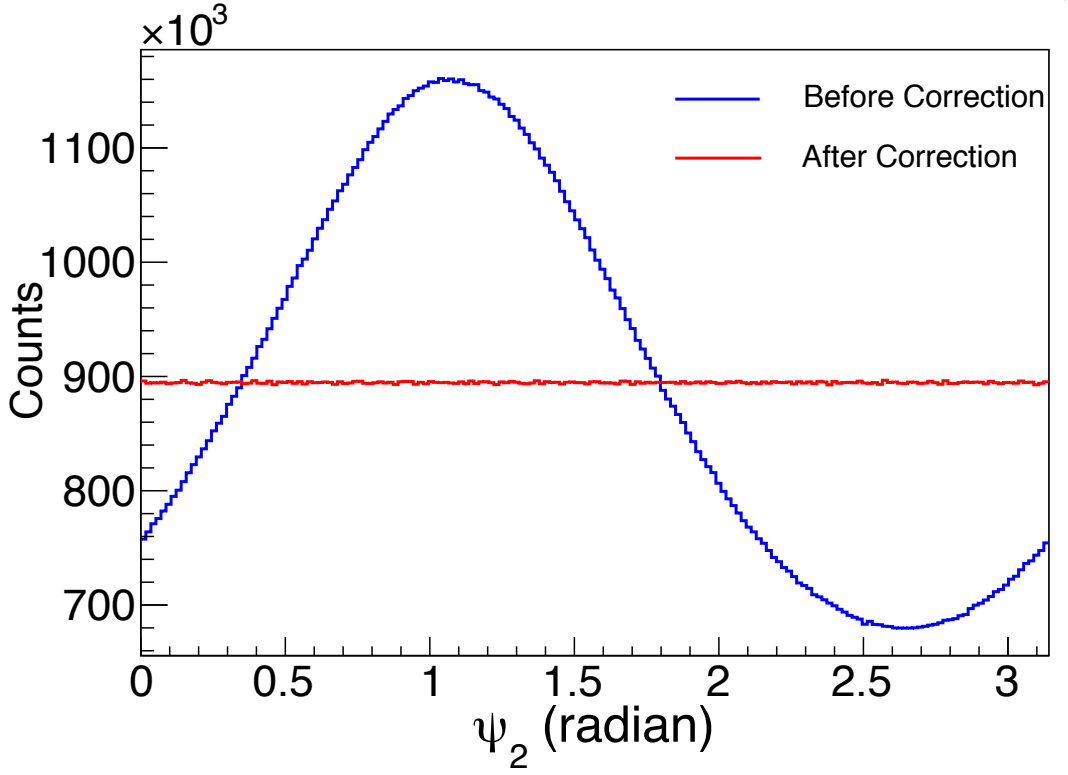
D_s v_2 Measurement: Event Plane Method

Pressure gradient transfers initial spatial anisotropy to final state momentum space anisotropy

$$v_2 = \langle \cos 2(\varphi - \psi_2) \rangle$$



- Event plane (ψ_2) is reconstructed using TPC tracks
- Non-uniformity in acceptance is corrected by re-centering and shifting



Ref: A.M. Poskanzer and S.A. Voloshin. PRC 58 (1998) 1671

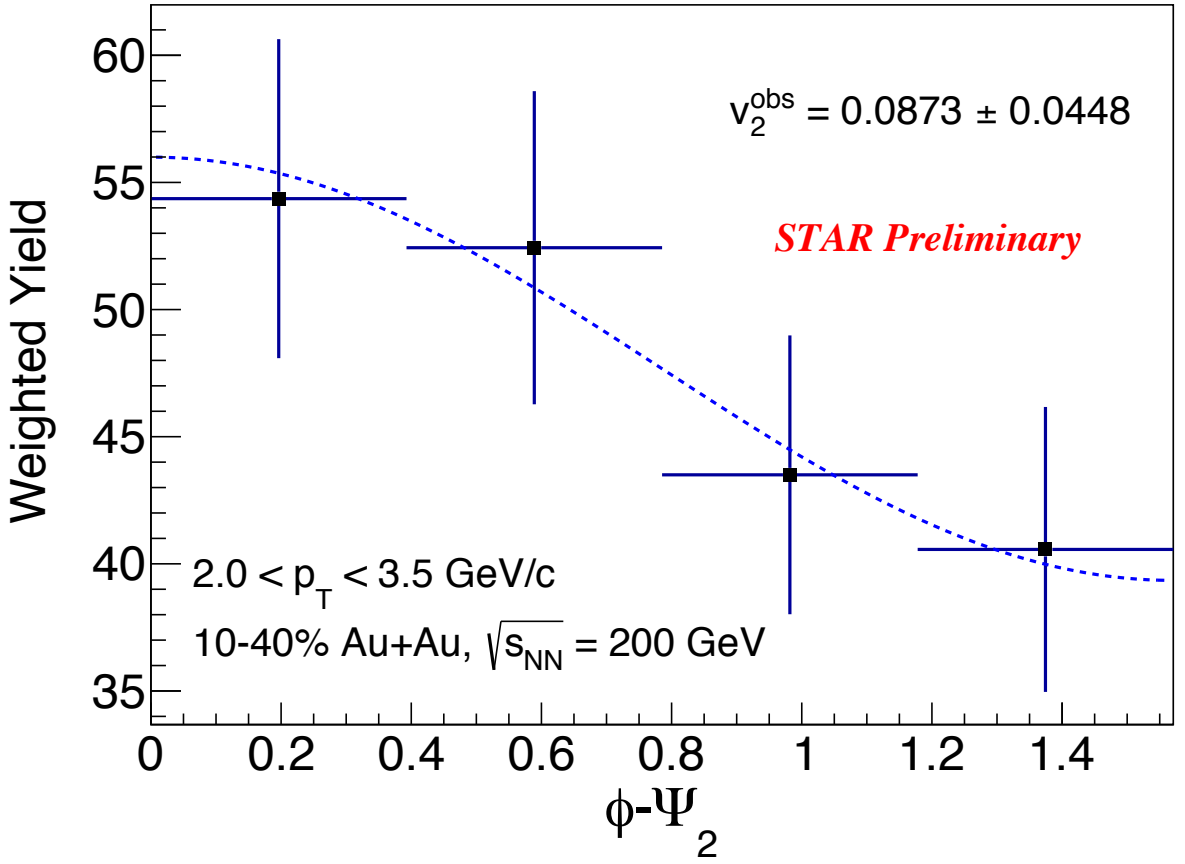
D_S v_2 Measurement: Event Plane Method

D_S yield as a function of $(\varphi - \psi_2)$ is fitted with the following function,

$$\frac{dN}{d(\phi-\psi_2)} = p_0[1+2v_2^{obs}\cos\{2(\phi-\psi_2)\}]$$

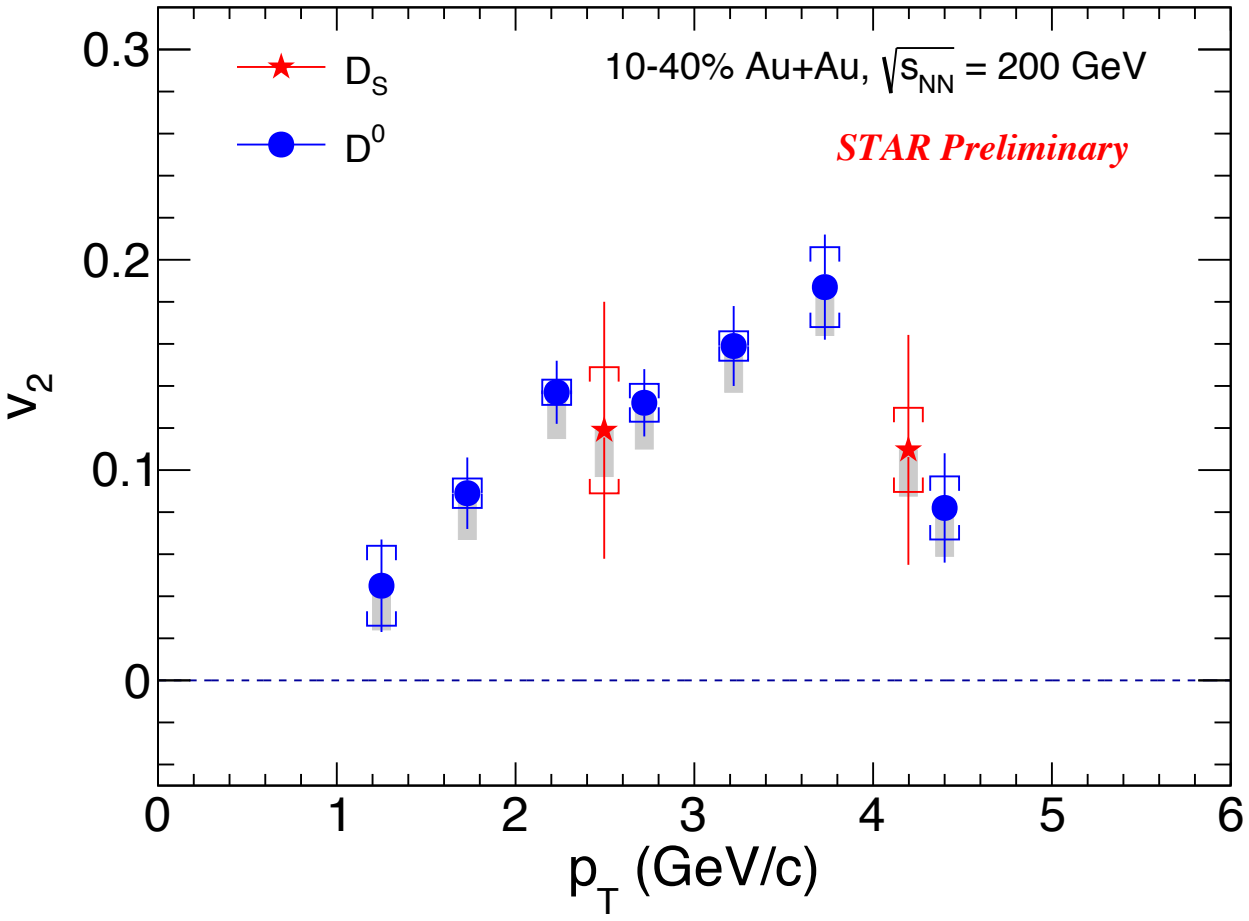
where p_0 and v_2^{obs} are fit parameters.

$$v_n\{EP\} = v_n^{obs}\{EP\} \times \left\langle \frac{1}{\text{EP Resolution}} \right\rangle$$



Ref: A.M. Poskanzer and S.A. Voloshin. PRC 58 (1998) 1671

Elliptic Flow vs Transverse Momentum

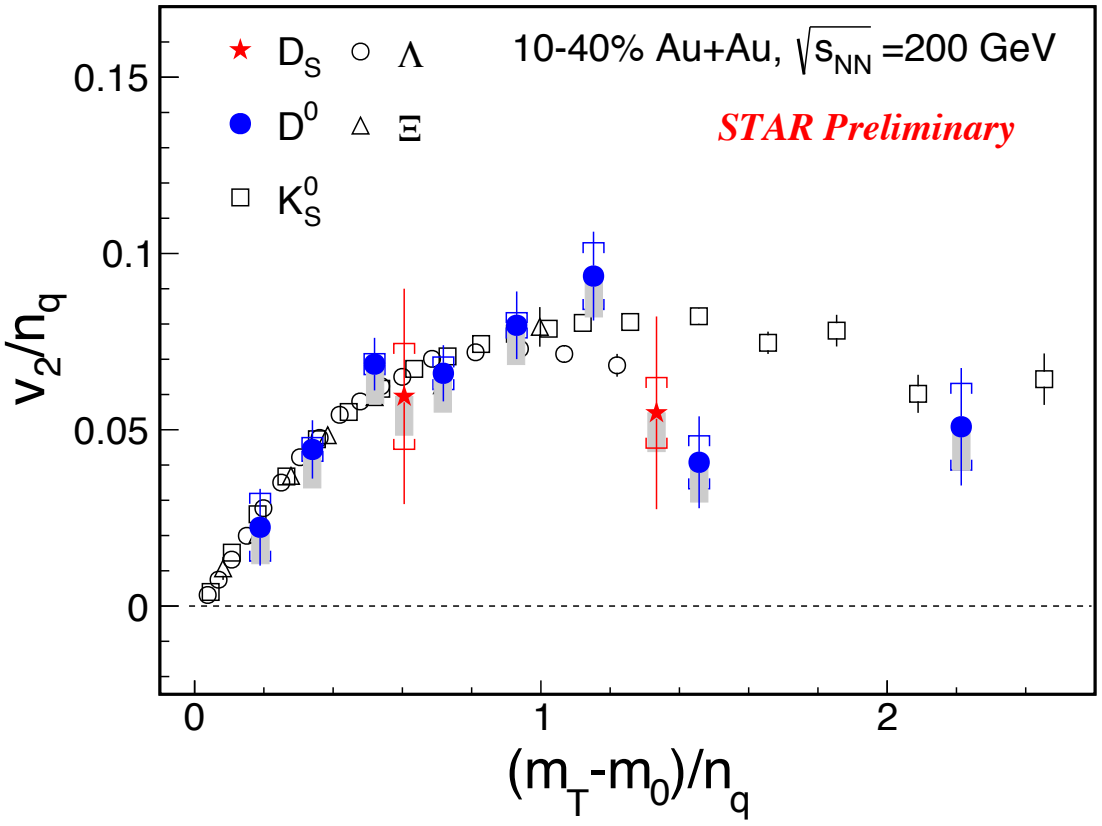


- Finite positive D_S v_2 observed
- D_S v_2 is comparable to non-strange D^0 meson within large uncertainties.

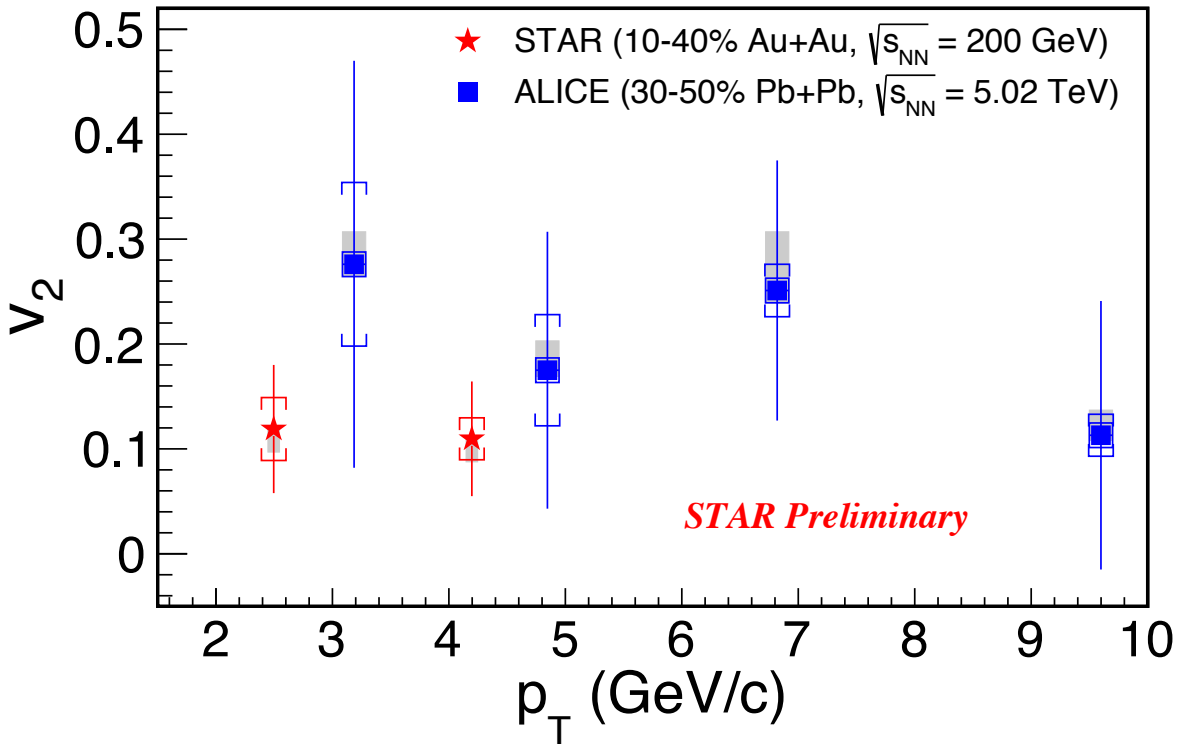
More precise measurements of D_S v_2 are underway including 2016 data.

Ref: D^0 v_2 : PRL **118** (2017) 212301 [STAR]

D_s v_2: NCQ Scaling and Comparison with LHC



Hints of NCQ scaling in D_s v_2



STAR and ALICE data are consistent within large uncertainties

Ref: STAR: PRL **118** (2017) 212301
ALICE: arXiv:1707.01005[nucl-ex]

D_s v_2 : Model Comparison

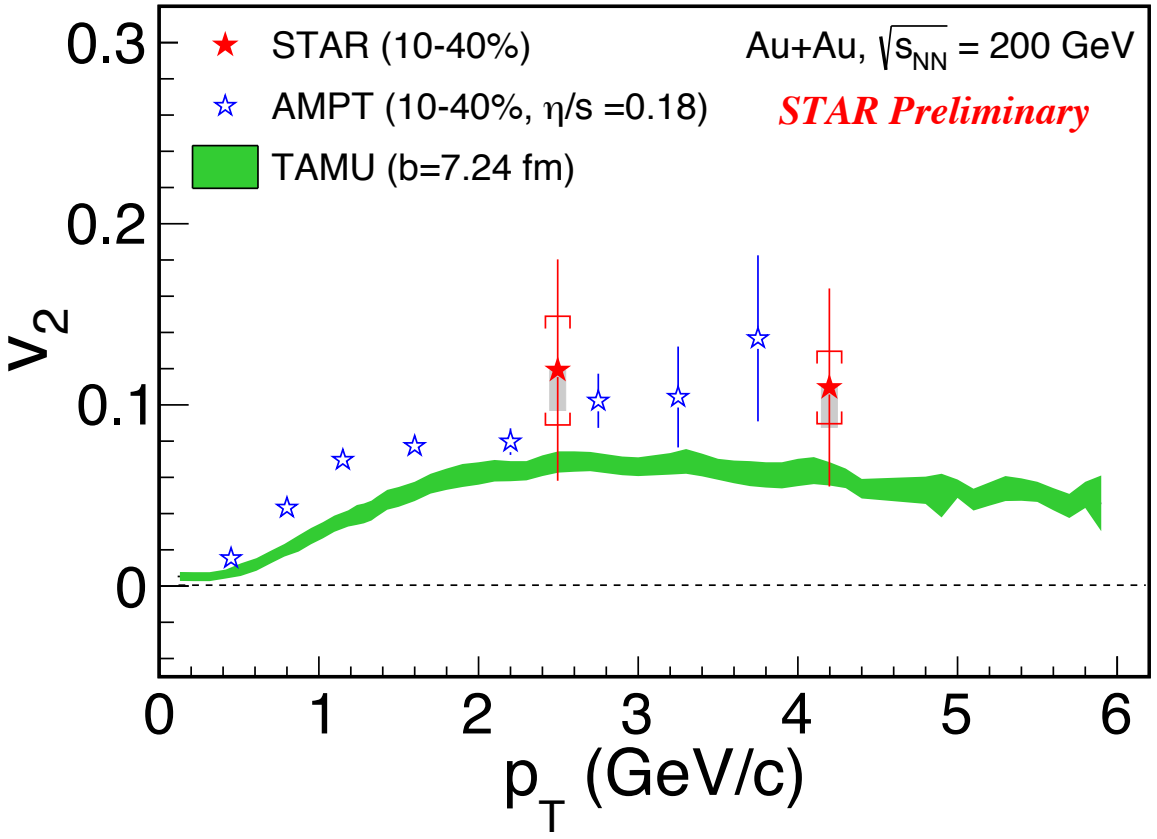
TAMU:

Charm-quark coupling to the QGP and subsequent recombination with equilibrated strange quarks.

AMPT:

Partonic interaction generates v_2.
Hadronization via Dynamic Coalescence Model.

Model predictions are consistent with data within 1σ confidence level.



Ref: TAMU: H. Min et al. PRL 110, 112301 (2013)
AMPT: R. Esha et al. JPG 44, 045107 (2017)

Summary

✧ Nuclear modification factor of D_S is measured in 0-40% Au+Au collisions at 200 GeV:

- Production of high p_T (> 5 GeV/c) D_S seems to be suppressed w.r.t. the p+p reference
- R_{AA} (K^0_S) ≤ R_{AA} (D_S) : light strange mesons seem to be more suppressed than heavy D_S

✧ The production ratio D_S/D^0 is measured in 0-40% Au+Au collisions at 200 GeV:

- Enhancement in D_S/D^0 ratio w.r.t. the fragmentation baseline is observed
- This indicates that coalescence plays an important role for charm quark hadronization in the QGP

✧ Elliptic flow of D_S meson is measured in Au+Au collisions (10-40%) at 200 GeV:

- Observed D_S v_2 is comparable to non-strange D^0 v_2 within large uncertainties

Back-Up

Heavy Flavor Tracker

The Pixel detector: First MAPS technology in a collider experiment

Pointing resolution: ~20 µm at high pT (exceeds the requirement of 55 µm for 750 MeV/c kaons)