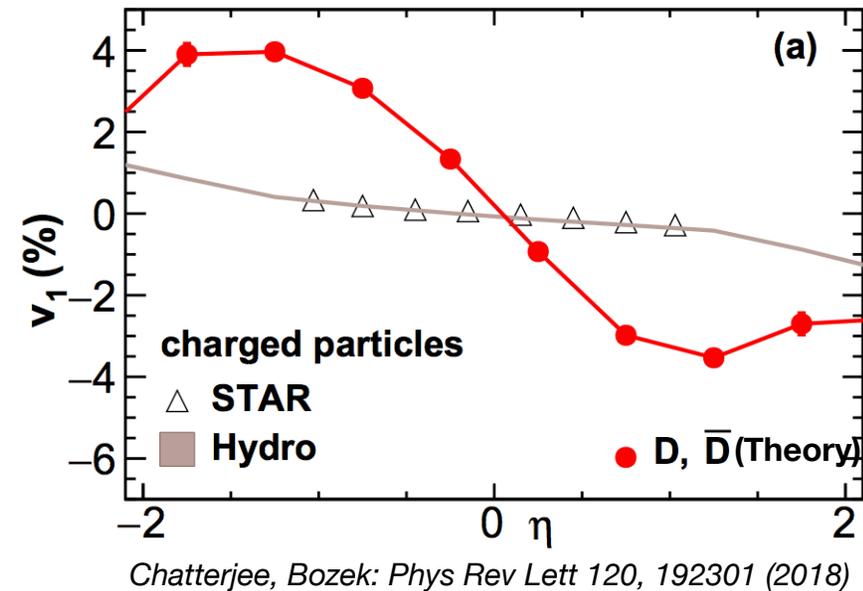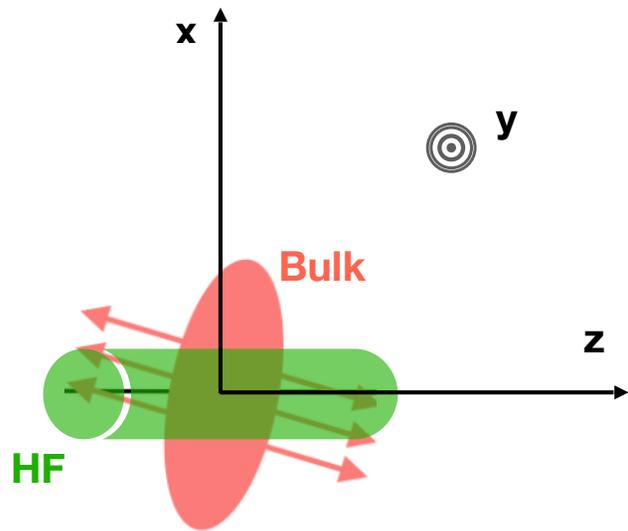# Measurements of directed flow of D^0 and $\overline{D^0}$ mesons in Au+Au at $\sqrt{s_{NN}} = 200$ GeV at STAR

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**For the STAR Collaboration**

Hard Probes 2018

Heavy quarks directed flow (v_1) from hydrodynamics

Chatterjee, Bozek: Phys Rev Lett 120, 192301 (2018)

- Symmetric production density of heavy quarks combined with a drag by an initially tilted bulk is predicted to result in a relatively large v_1 for heavy flavor compared to light flavor quarks

- The measurement of v_1 for D mesons can be used to constrain the drag coefficients of the tilted bulk

Hard Probes 2018

Liang He

Heavy flavor v_1 from EM field

Das et. al., Phys Lett B 768, 260 (2017)
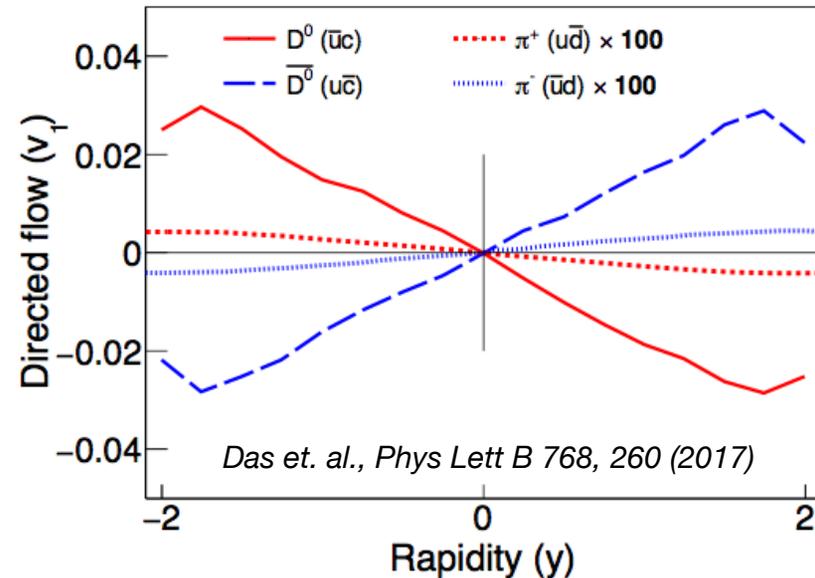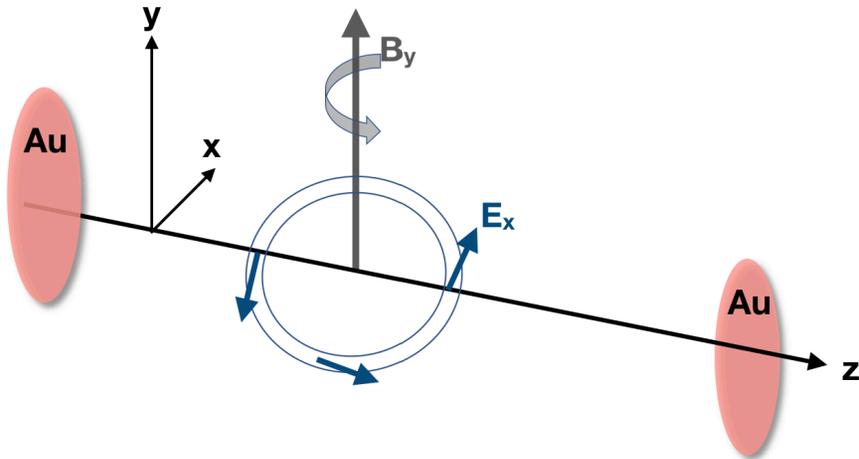
- Electromagnetic (EM) field generated in heavy ion collisions can induce opposite v_1 for charm and anti-charm quarks

- Since heavy quarks are produced early, the EM field-induced v_1 for heavy quarks is orders of magnitude larger than those of light flavor quarks

- The measurement of v_1 for D^0 and $\overline{D^0}$ may provide insights into the early-time electromagnetic field

Heavy flavor v_1 from hydro + EM
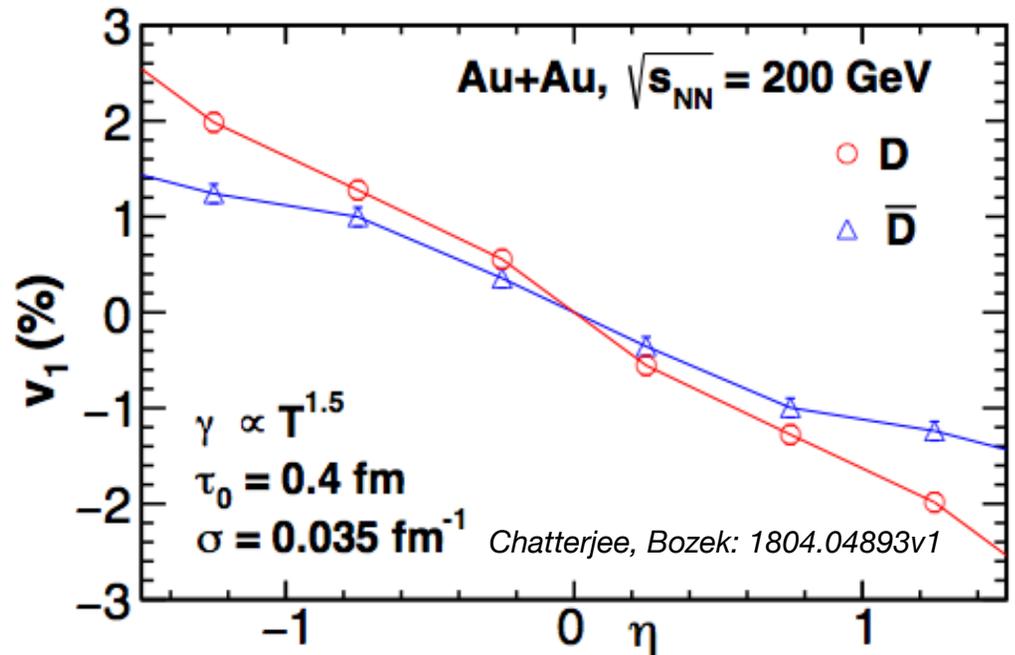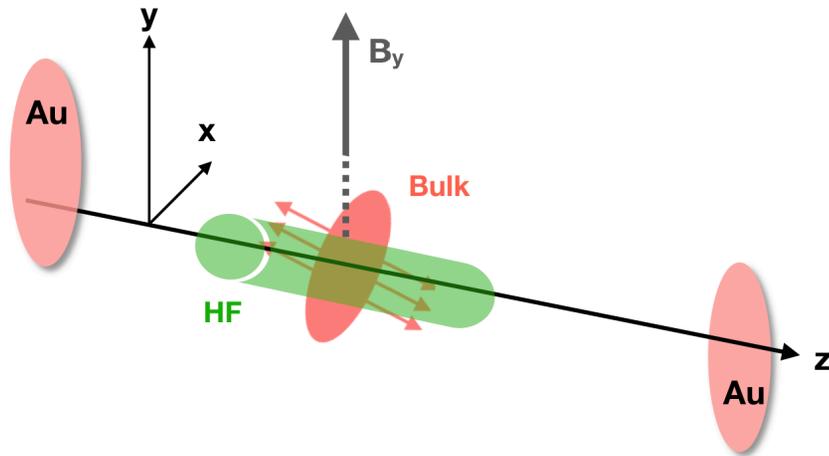
- Recent hydro model with initial EM field predicts v_1-split between the D and $\overline{D}$ mesons

- Predicted difference in v_1 is about 10 times smaller than the average v_1

- The model calculation demonstrates the sensitivity of D-mesons v_1 slope to the initially tilted geometry and the charm drag coefficient

STAR detector

Time Of Flight detector
PID (1/β)

Time Projection Chamber
Tracking, PID (dE/dx)

ZDC-SMD

-1<η<1, 0≤φ<2π
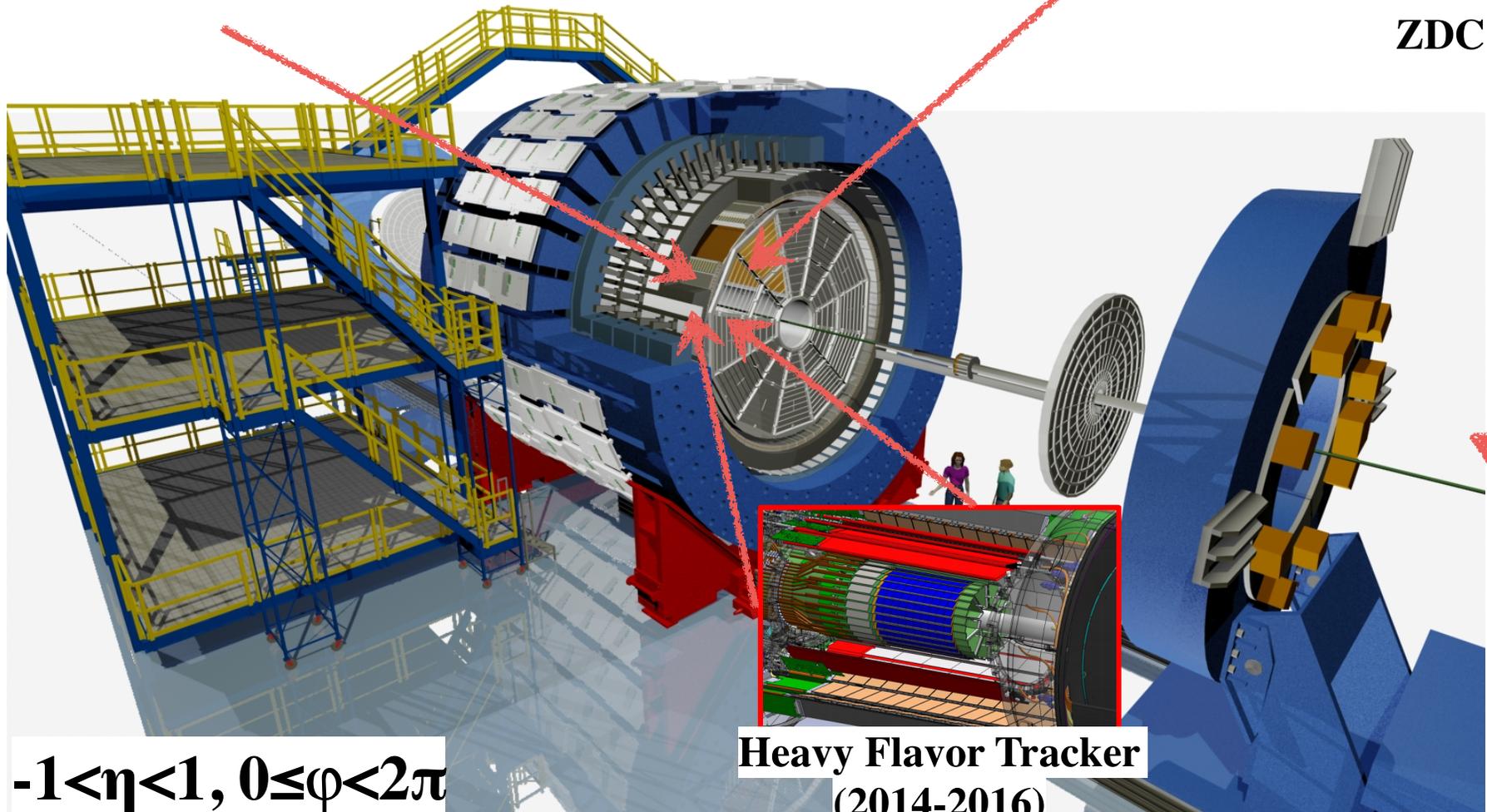
Heavy Flavor Tracker
(2014-2016)

D⁰ reconstruction

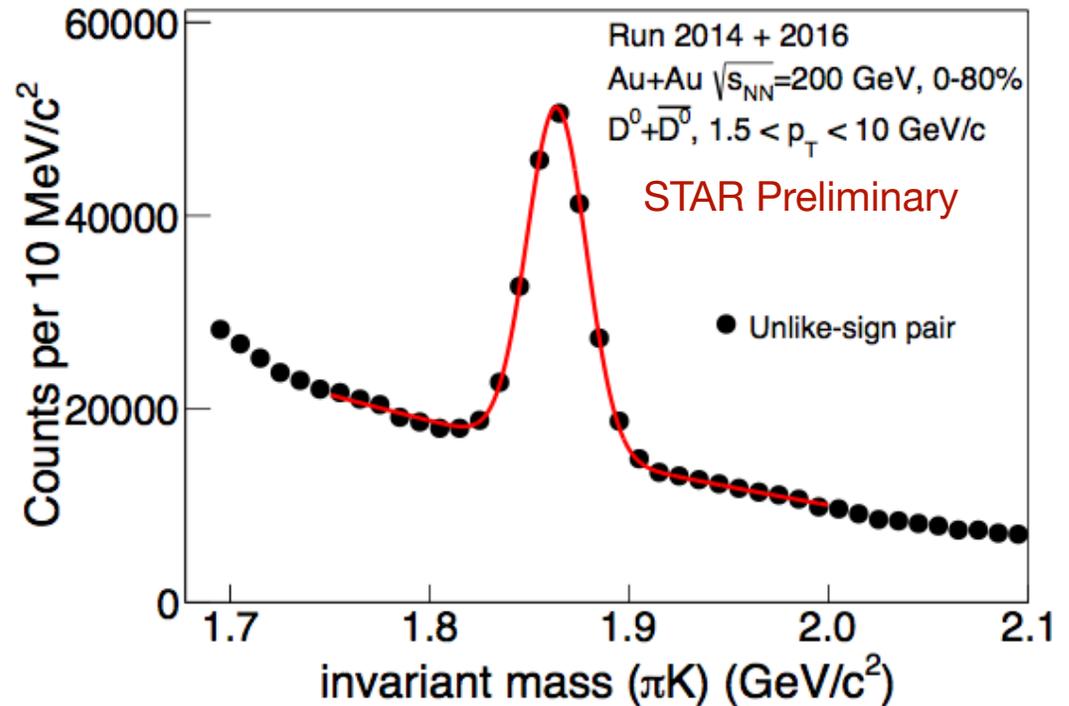$$D^0(\overline{D^0}) \to K^{\mp}\pi^{\pm}$$

B.R. 3.9% $c\tau \sim 120 \ \mu m$
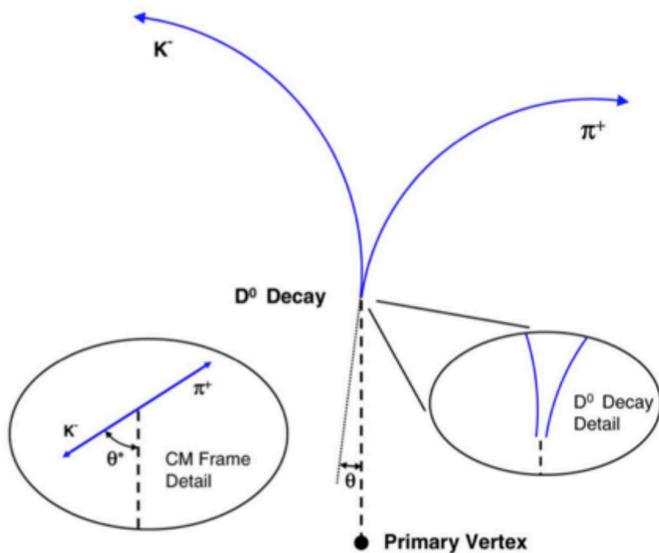
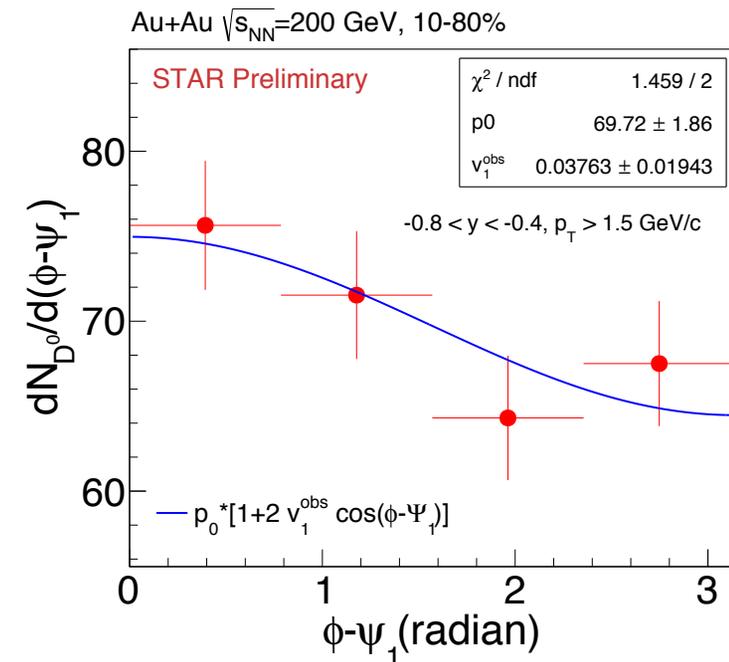**Topological cuts optimized using TMVA
(Toolkit for Multivariate Analysis)**

- HFT data from 2014 and 2016 runs
- Total ~ 2 billion minimum-bias events

D⁰ v₁ from event plane method

Au+Au $\sqrt{s_{NN}}$ = 200 GeV

STAR Preliminary
○ Run 2014
☆ Run 2016

Au+Au $\sqrt{s_{NN}}$=200 GeV, 10-80%

STAR Preliminary

χ^2 / ndf	1.459 / 2
p0	69.72 ± 1.86
v_1^{obs}	0.03763 ± 0.01943

-0.8 < y < -0.4, p_T > 1.5 GeV/c

$p_0 * [1 + 2\, v_1^{obs} \cos(\phi - \Psi_1)]$
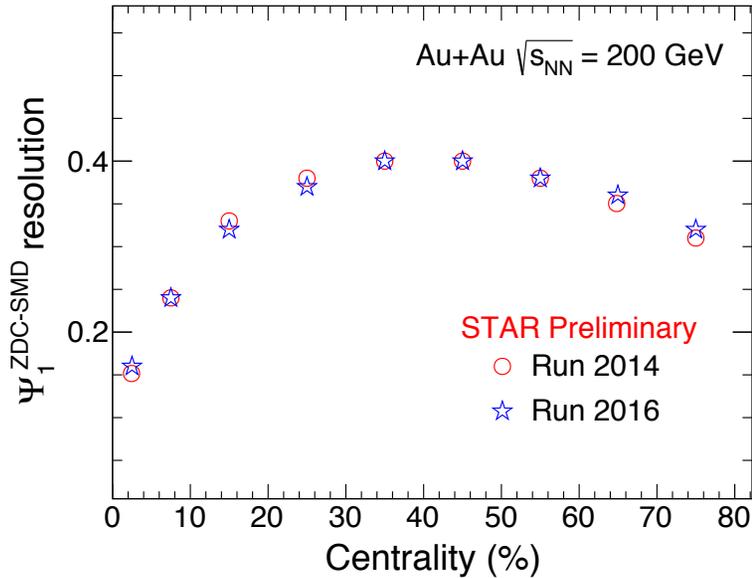
- The first-order event plane measured using ZDC-SMD ($|\eta|$>6.3)

- v_1 signal is significant at forward rapidity

- Better ψ_1 resolution at forward-rapidity than mid-rapidity

- Large η-gap significantly reduces non-flow contribution

- D⁰ v_1 measured using ϕ-ψ_1 method

- Results are corrected for event-plane resolution $v_1 \sim \dfrac{\langle \cos(\phi - \psi_1) \rangle}{\psi_1 \text{ res.}} \sim \dfrac{v_1^{obs}}{\psi_1 \text{ res.}}$

7

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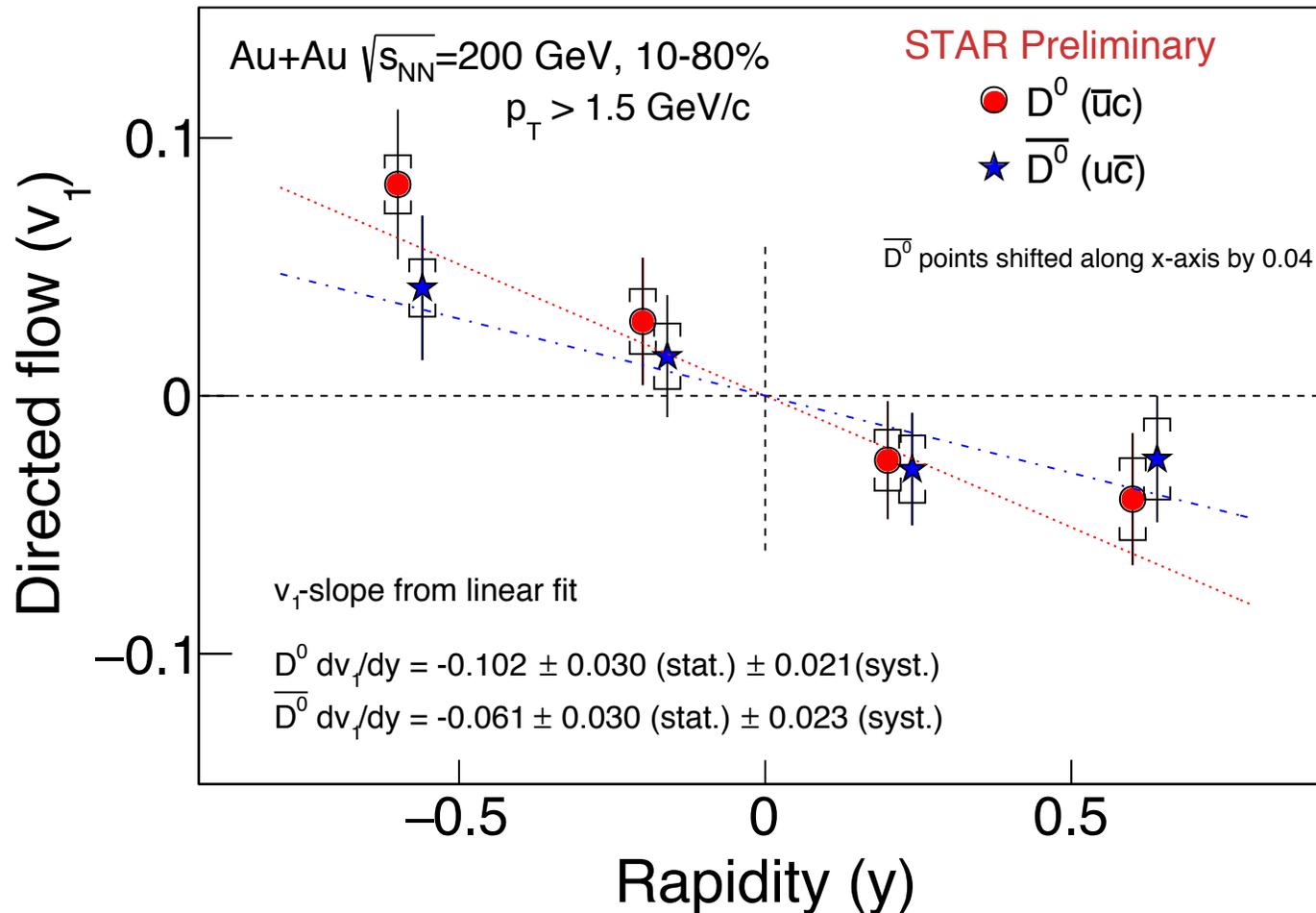
D^0 and $\overline{D}^0$ v_1

- First evidence of non-zero D^0 v_1-slope : -0.081 ± 0.021 (stat) ± 0.017 (syst)

- Both D^0 and $\overline{D}^0$ v_1 show a negative slope at mid-rapidity

D⁰ compare to kaon

Au+Au $\sqrt{s_{NN}}$=200 GeV, 10-80%
p_T > 1.5 GeV/c

STAR Preliminary

● D⁰ ($\bar{u}c$)
★ $\overline{D^0}$ ($u\bar{c}$)
□ K⁺ + K⁻ ($u\bar{s}$ + $\bar{u}s$)

$\overline{D^0}$ points shifted along x-axis by 0.04

v_1-slope from linear fit
D⁰ dv_1/dy = -0.102 ± 0.030 (stat.) ± 0.021(syst.)
$\overline{D^0}$ dv_1/dy = -0.061 ± 0.030 (stat.) ± 0.023 (syst.)
Kaons dv_1/dy = -0.0030 ± 0.0001(stat.) ± 0.0002(syst.)

Directed flow (v_1)

Rapidity (y)

*Charged Kaons:
L Adamczyk et. al. (STAR Collaboration),
Phys Rev. Lett. 120, 62301 (2018)*
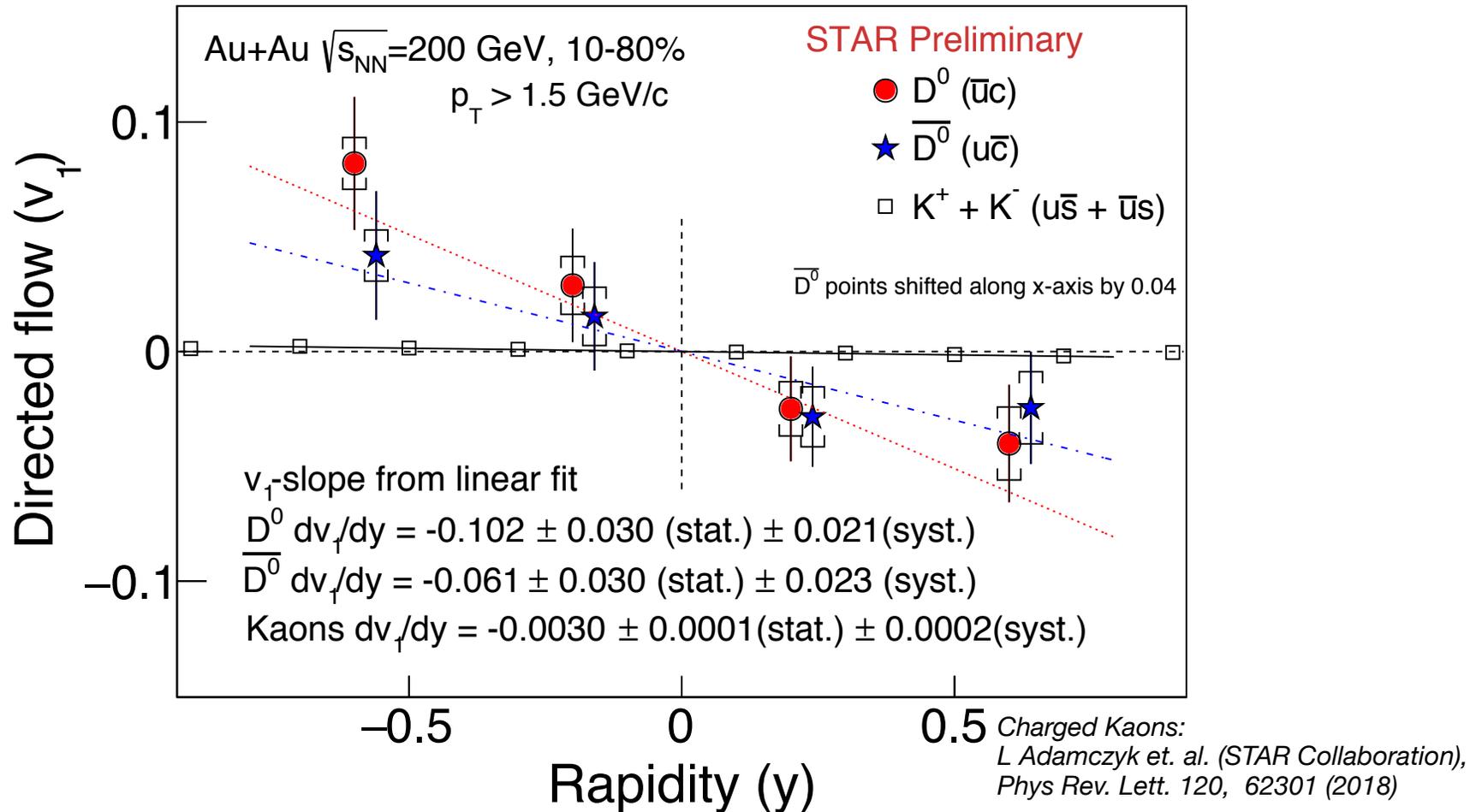
- First evidence of non-zero D⁰ v_1-slope

- D⁰ v_1-slope much larger than that of kaons

D⁰ v₁: data compare to hydro+EM
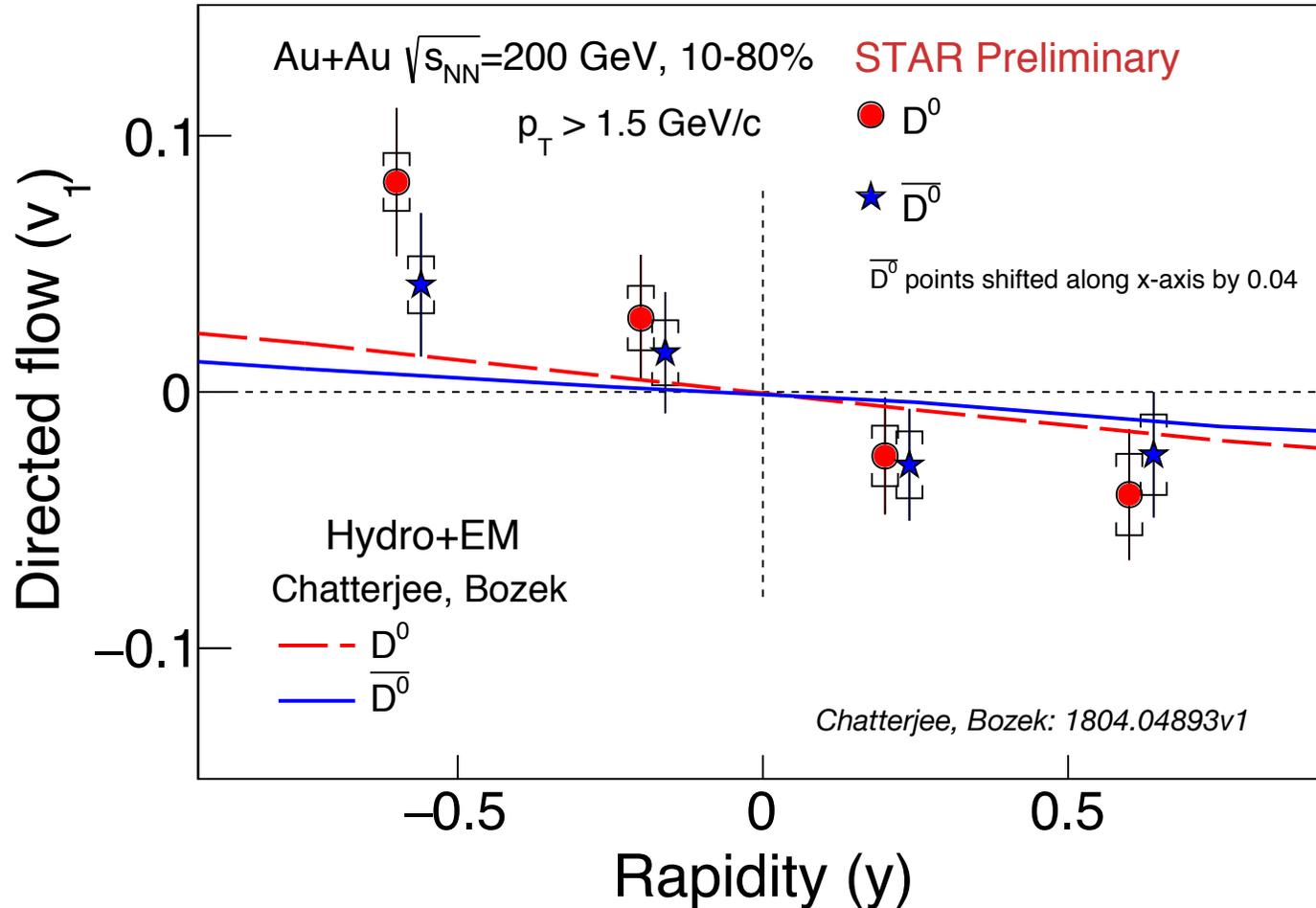
- The model predicts correct sign of v_1-slope for D^0 and $\overline{D}^0$

- Data will help to constrain model parameters (tilt and drag parameters)

D^0 Δv_1: data compared to hydro+EM
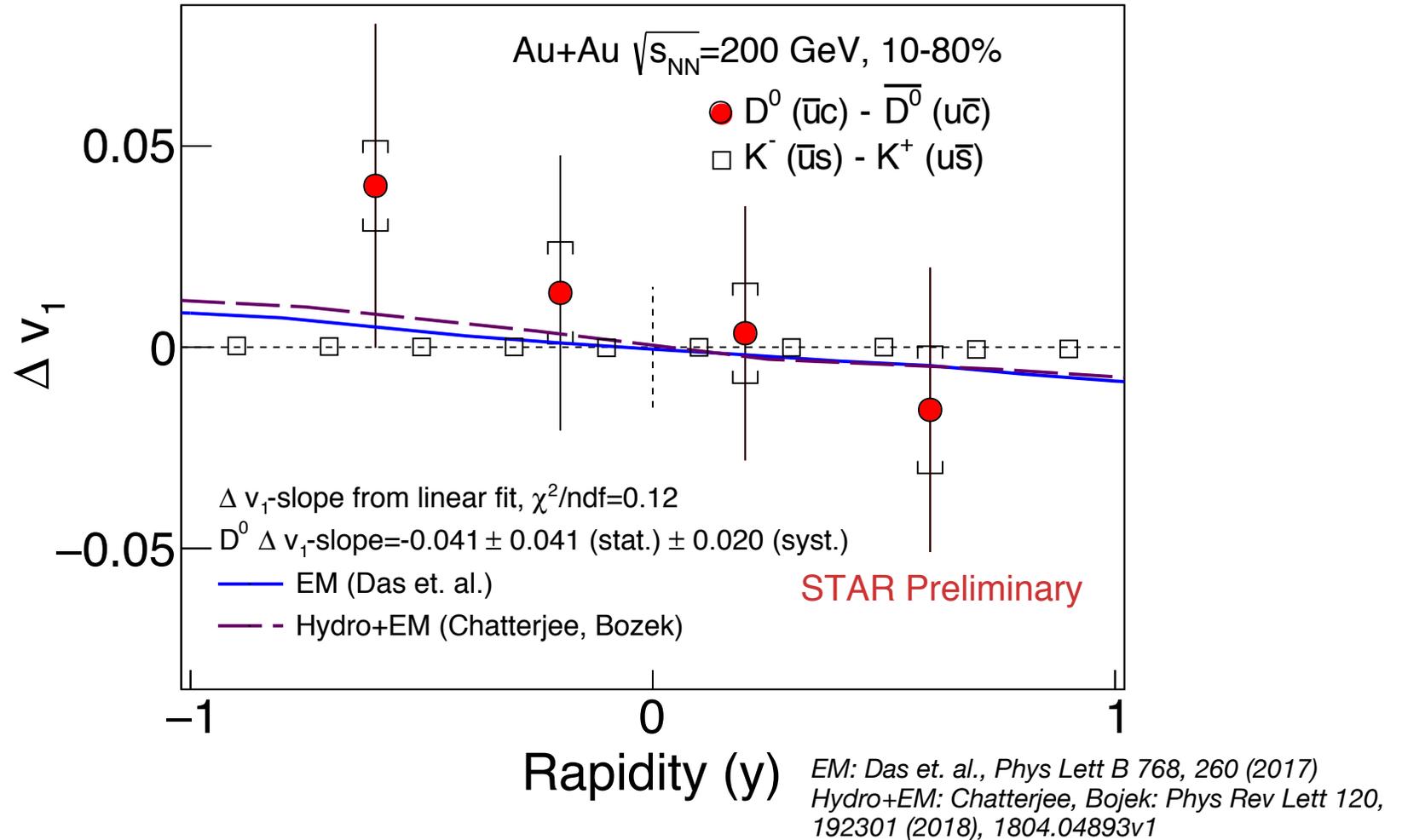

Au+Au $\sqrt{s_{NN}}$=200 GeV, 10-80%

● D^0 ($\bar{u}c$) - $\overline{D^0}$ ($u\bar{c}$)
□ K^- ($\bar{u}s$) - K^+ ($u\bar{s}$)

Δv_1-slope from linear fit, χ^2/ndf=0.12
D^0 Δv_1-slope=-0.041 ± 0.041 (stat.) ± 0.020 (syst.)

—— EM (Das et. al.)
– – Hydro+EM (Chatterjee, Bozek)

STAR Preliminary

Rapidity (y)

EM: Das et. al., Phys Lett B 768, 260 (2017)
Hydro+EM: Chatterjee, Bojek: Phys Rev Lett 120,
192301 (2018), 1804.04893v1

- Current precision does not allow to draw firm conclusion on magnetic field induced v_1 splitting

Summary

- First evidence of non-zero rapidity-odd directed flow for D^0 and $\overline{D^0}$

- Large v_1 of the D^0 mesons indicates strong interaction of charm quarks with the initially tilted source

- Significantly larger v_1-slope for the D^0 mesons compared to the charged kaons

- Not sufficient precision to draw firm conclusions on magnetic field induced v_1 splitting of charm and anti-charm quarks
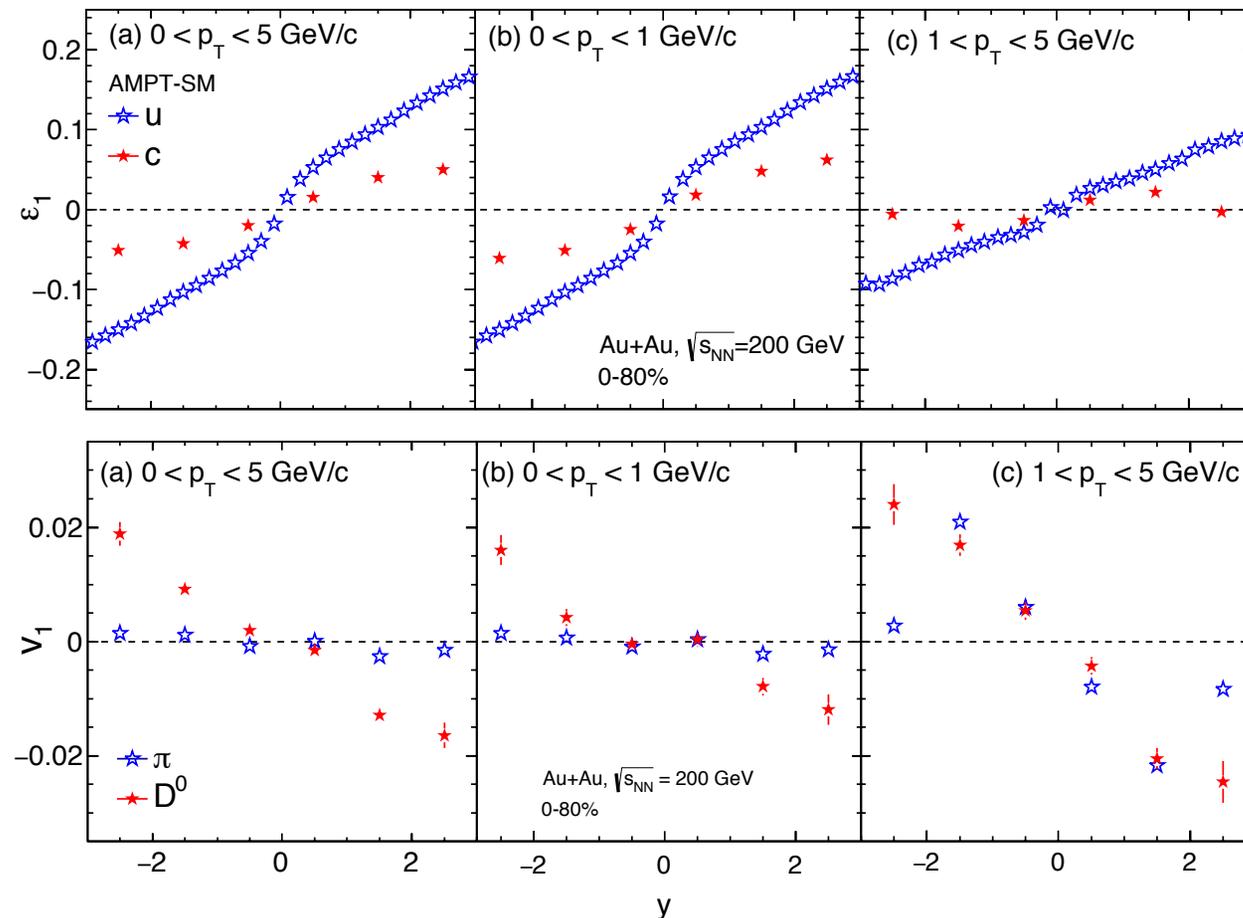

a) Au+Au $\sqrt{s_{NN}}$=200 GeV, 10-80%
$K^- + K^+$ ($\overline{u}s + u\overline{s}$)
□ STAR

$D^0 + \overline{D^0}$ ($\overline{u}c + u\overline{c}$)
● STAR Preliminary
— Hydro+EM (Chatterjee, Bozek)
—·· AMPT

STAR Preliminary

b) $K^- - K^+$ ($\overline{u}s - u\overline{s}$)
△ STAR

$D^0 - \overline{D^0}$ ($\overline{u}c - u\overline{c}$)
■ STAR Preliminary
— EM (Das et. al.)
— Hydro+EM (Chatterjee, Bozek)

Rapidity (y)

Liang He
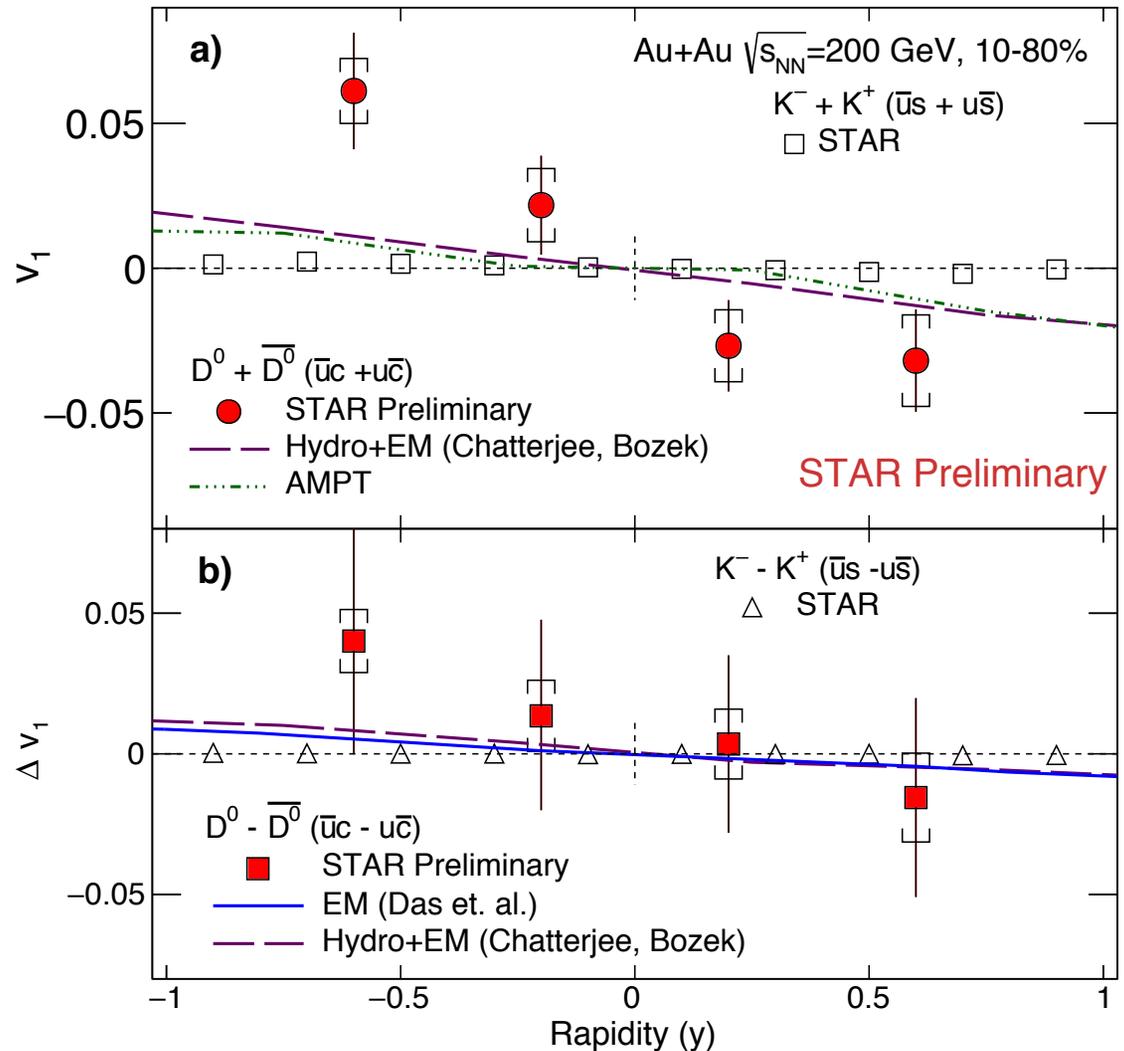
Backups

Heavy flavor v₁ from AMPT model

- AMPT model calculation shows a larger v_1 for D mesons compared to pions

- Suggesting that charm-hadrons are able to retain information about initial dynamics

S. Singha and M. Nasim, Phys. Rev. C 97, 064917 (2018)

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D⁰ v₁-slope fitting