Measurement of directed flow of K^{*0} and ϕ resonances in Au+Au collisions at RHIC BES energies

Md Nasim (for the STAR Collaboration)

IISER Berhampur, India

Quark Matter 2025, Frankfurt, Germany

Supported in part by

U.S. DEPARTMENT OF ENERGY | Office of Science

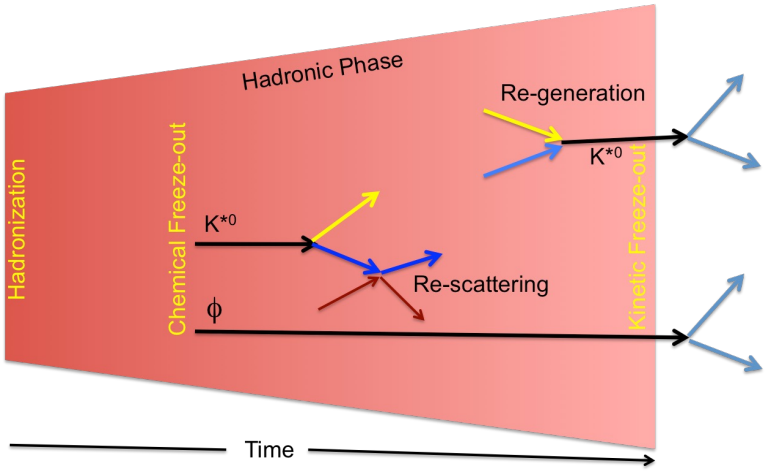
IISER BERHAMPUR

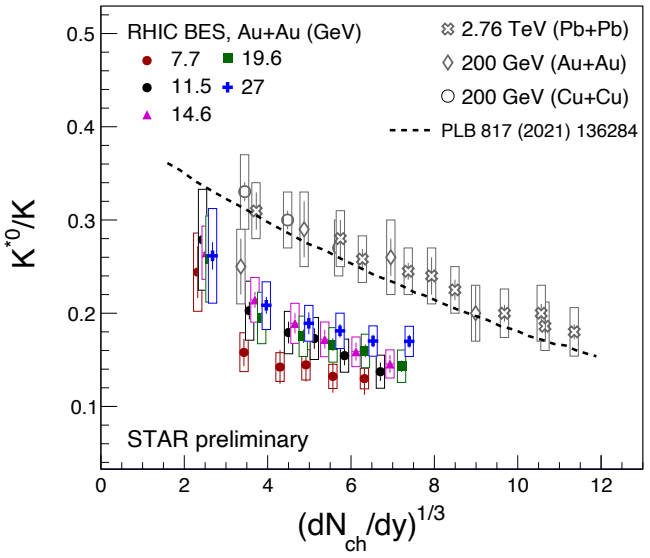
STAR Collaboration

Outline

- Introduction
- STAR Experiment
- Flow Measurement Method
- Results : Directed flow of K^{*0} and ϕ mesons
  - Rapidity dependence
  - Transverse momentum dependence
  - Centrality dependence
  - Comparison with model calculation
- Summary

K^{*0} probes hadronic medium

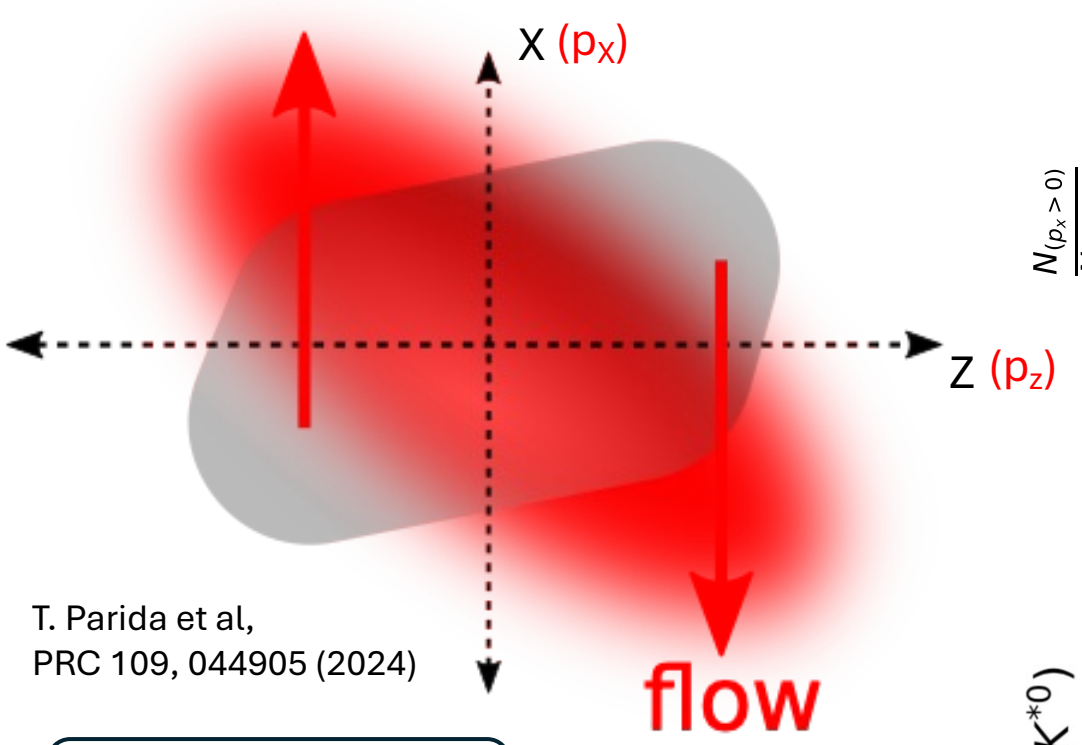




- Reconstructed K^{*0} yield can be affected by hadronic interaction suffered by its daughter particles between Chemical Freeze-out and Kinetic Freeze-out
- BES Program at RHIC allows us study rescattering/regeneration in baryon-rich matter.
- Larger suppression of K^{*0}/K ratio observed at RHIC BES data compared to top RHIC and LHC energies

ALICE: PLB 802, 135225 (2020) STAR: PRC 107, 037907 (2023)

Motivation for K^{*0} v_1 study

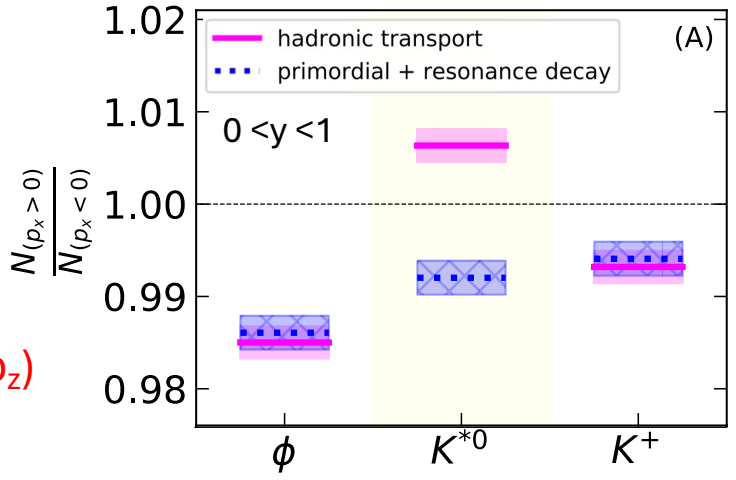


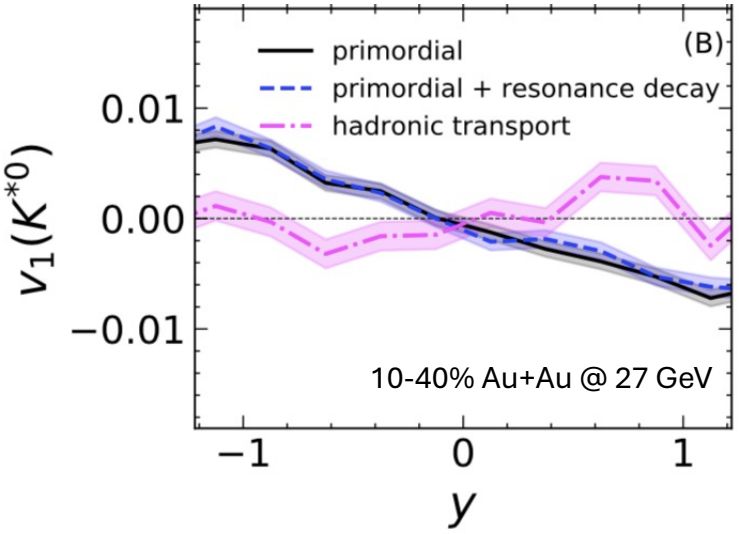
T. Parida et al,
PRC 109, 044905 (2024)

$v_1 = \langle \cos(\phi - \psi_1) \rangle$

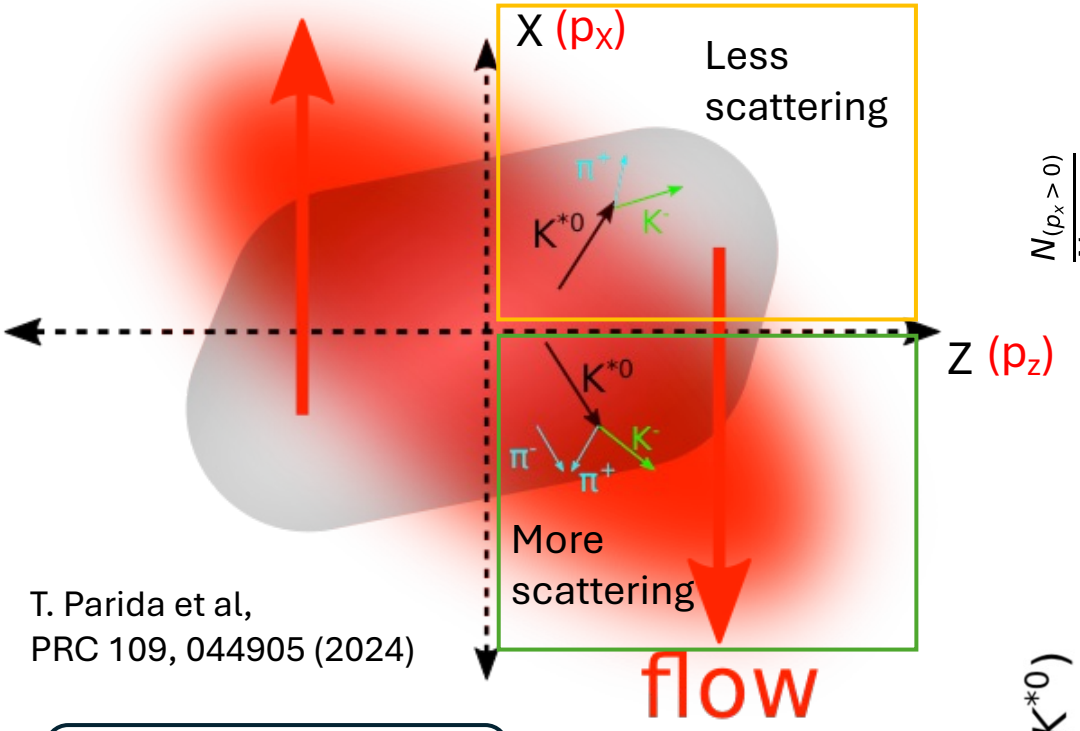
Asymmetric loss of K^{*0} yield in different sides of the p_x axis may lead slope change for K^{*0} v_1 as a function of rapidity

Model : Hydro +UrQMD





Motivation for K^{*0} v_1 study

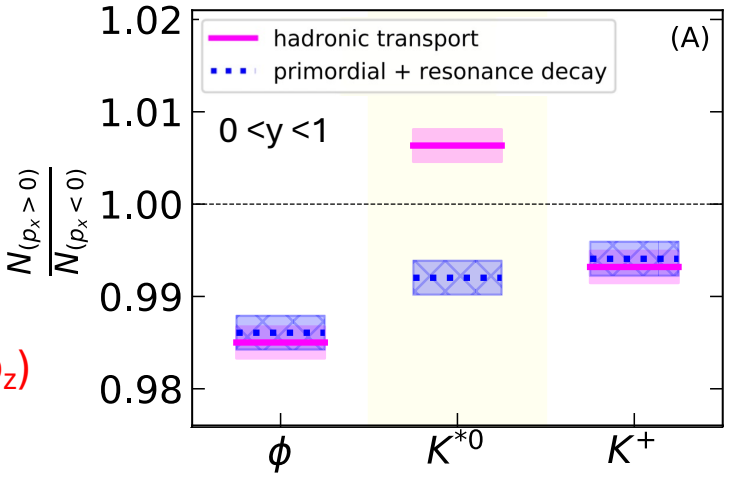


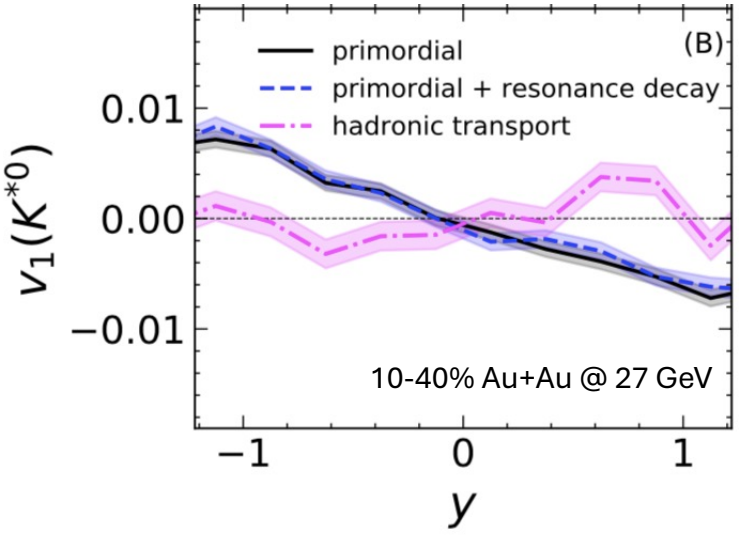
T. Parida et al,
PRC 109, 044905 (2024)

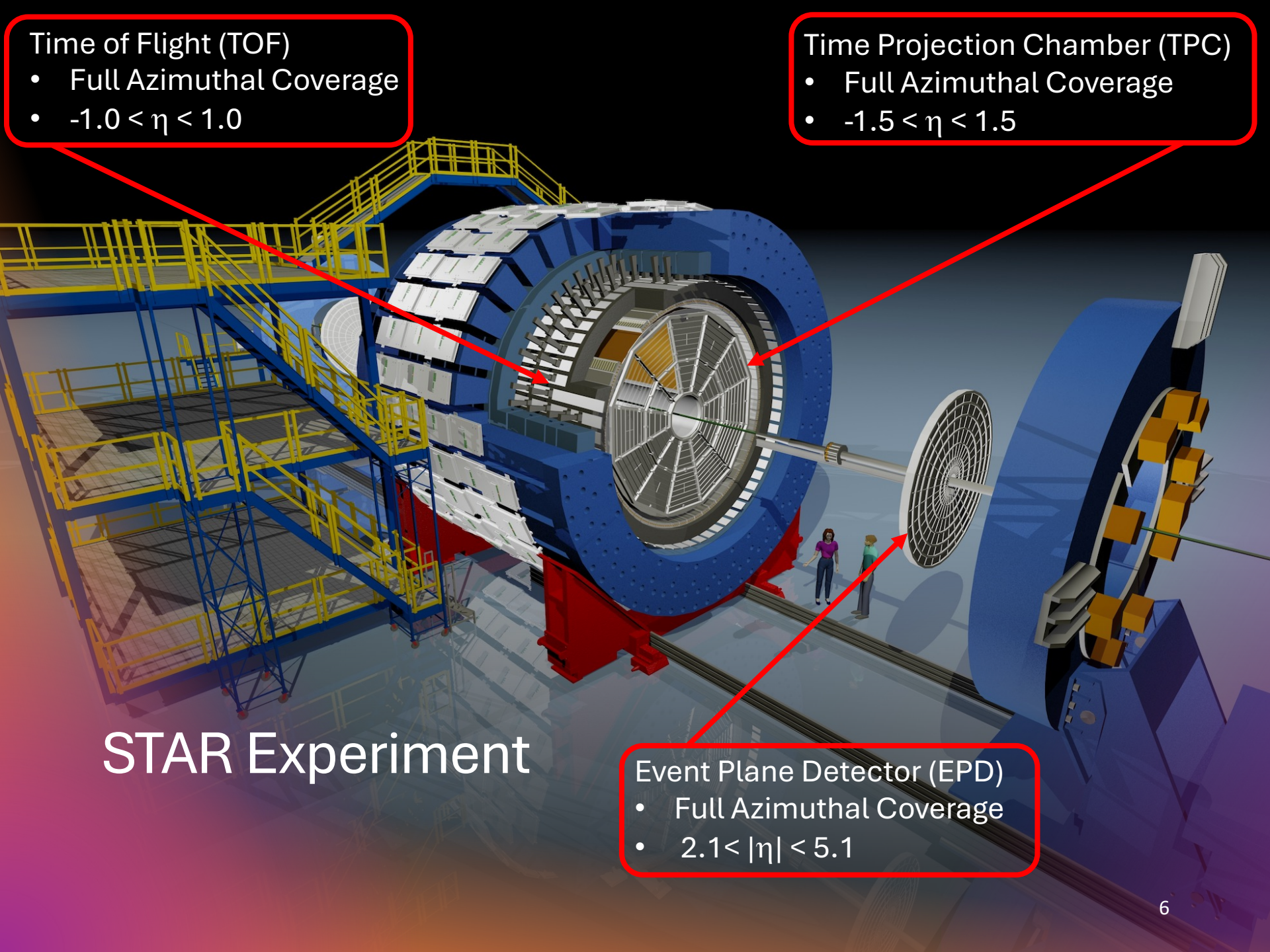
$v_1 = \langle \cos(\phi - \psi_1) \rangle$

Asymmetric loss of K^{*0} yield in different sides of the p_x axis may lead slope change for K^{*0} v_1 as a function of rapidity

Model : Hydro +UrQMD



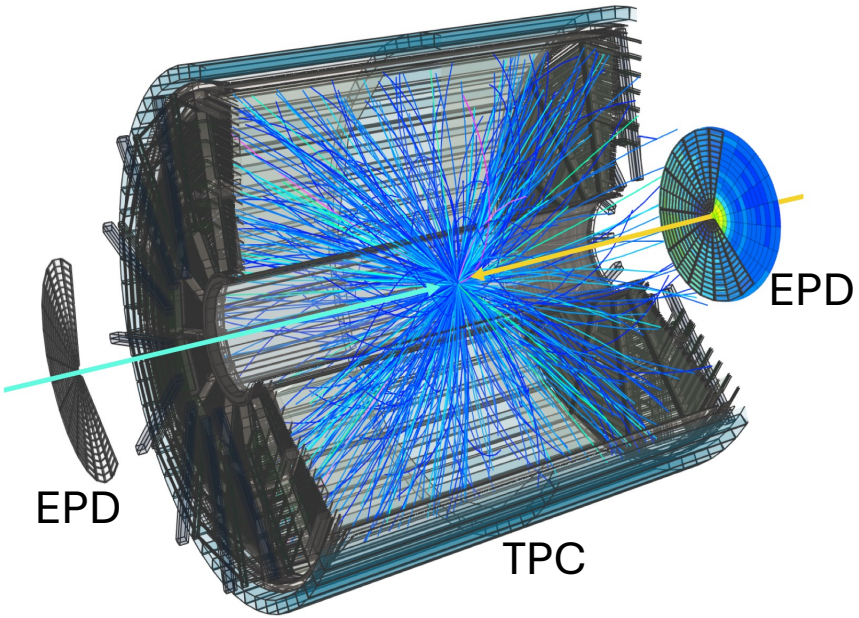


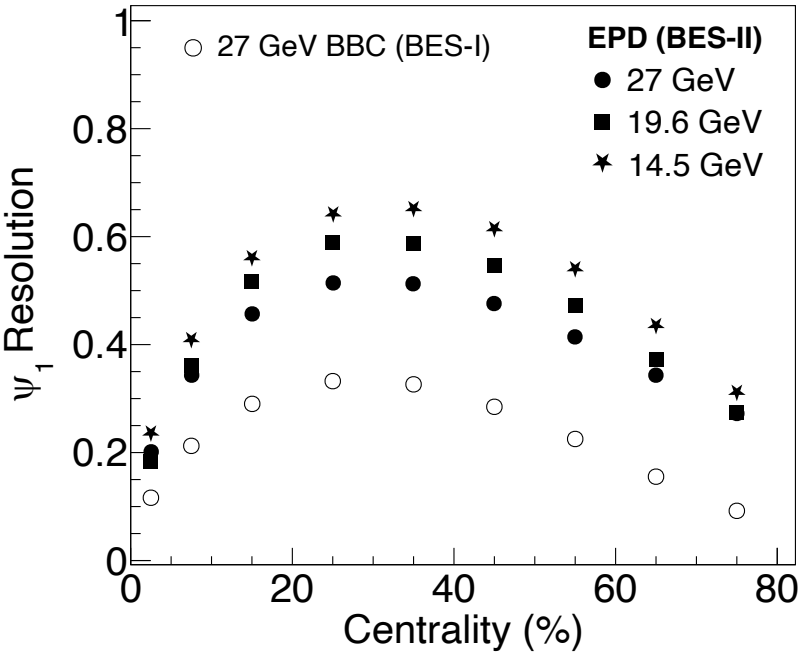

Time of Flight (TOF)
• Full Azimuthal Coverage
• -1.0 < η < 1.0
Time Projection Chamber (TPC)
• Full Azimuthal Coverage
• -1.5 < η < 1.5
STAR Experiment
Event Plane Detector (EPD)
• Full Azimuthal Coverage
• 2.1< |η| < 5.1

Event Plane

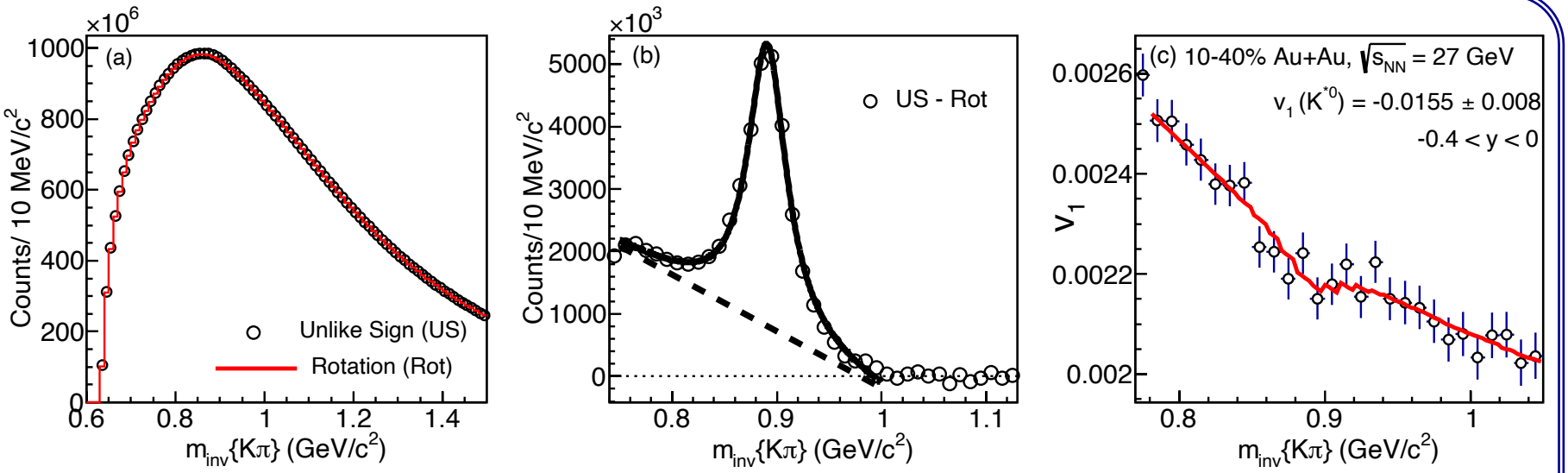
- Directed flow of K*^{0} and ϕ is measured at mid-rapidity region (|y| <1.0).
- Event plane is determined using event plane detector (2.1 <|η| <5.1)
- Large eta gap reduces non-flow
- EPD greatly improves 1st order event plane resolution

$$\psi_1 = \tan^{-1}\frac{\sum_i w_i \sin(\phi_i)}{\sum_i w_i \cos(\phi_i)}$$





v_1 Measurement Method

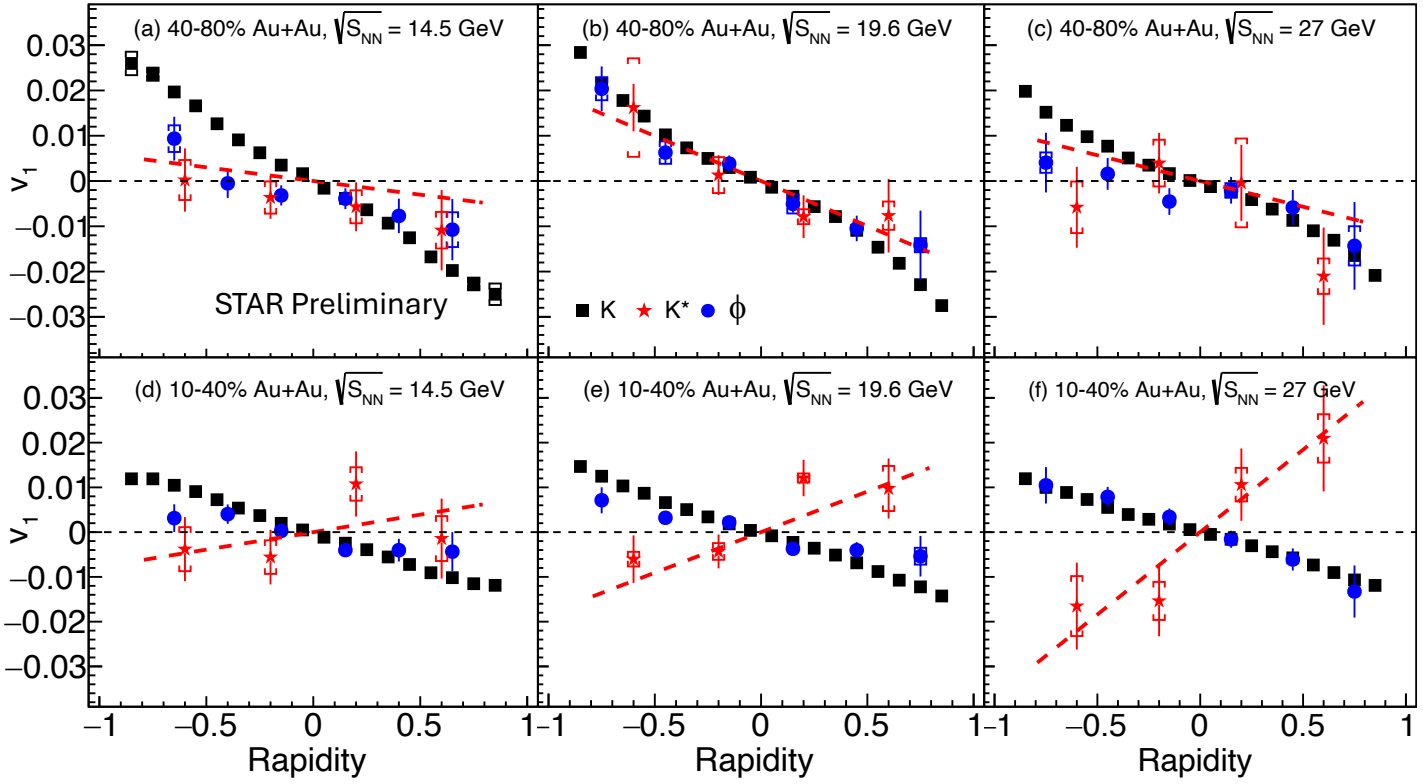


- Invariant mass method for resonance reconstruction
- A Breit-Wigner function and a 1st order polynomial function are used to describe the signal and residual background.
- Invariant mass method is used to extract v_1 of resonances

$$v_1^{s+b}(\mathrm{m}_{inv}) = v_1^s \frac{s}{s+b}(m_{inv}) + v_1^b \frac{b}{s+b}(m_{inv}) \qquad v_1^b = p_1 + p_2 m_{inv} + p_3 m_{inv}^2$$

In addition, $v_1{}^b$ has been varied to study the systematic error on $v_1{}^s$

Rapidity dependence of v_1



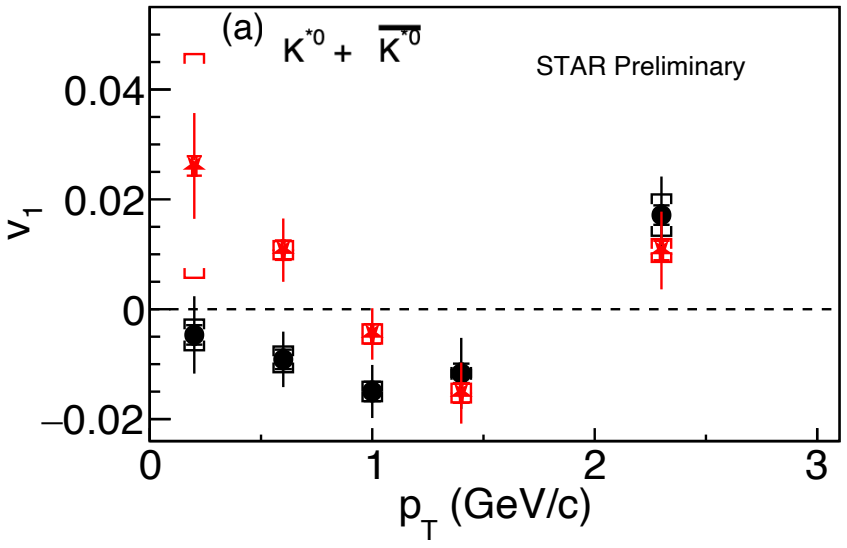
$K^* = K^{*0} + \overline{K^{*0}}$

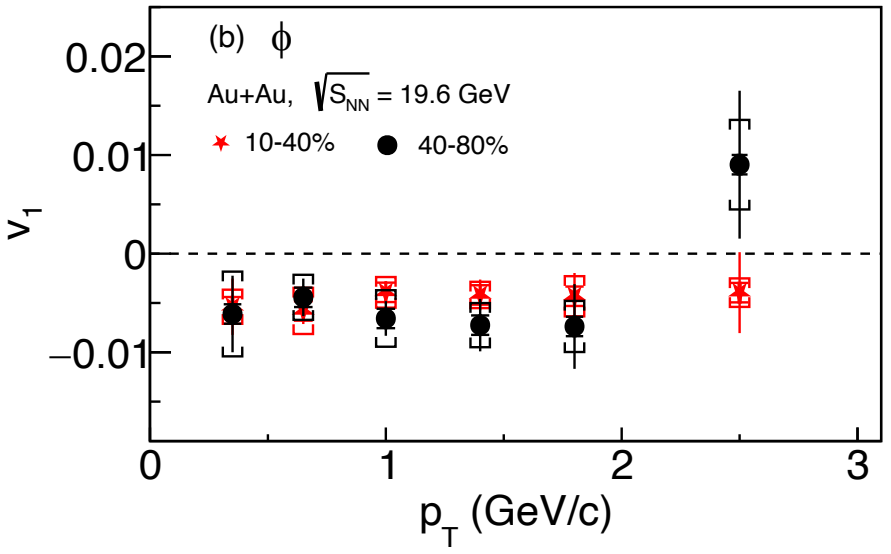
$K = K^+ + K^-$

40-80% Au+Au collisions: Negative v_1 slope for charged Kaon, ϕ and K^{*0} resonances

10-40% Au+Au collisions : Opposite v_1 slope for K^{*0} resonances compared to peripheral

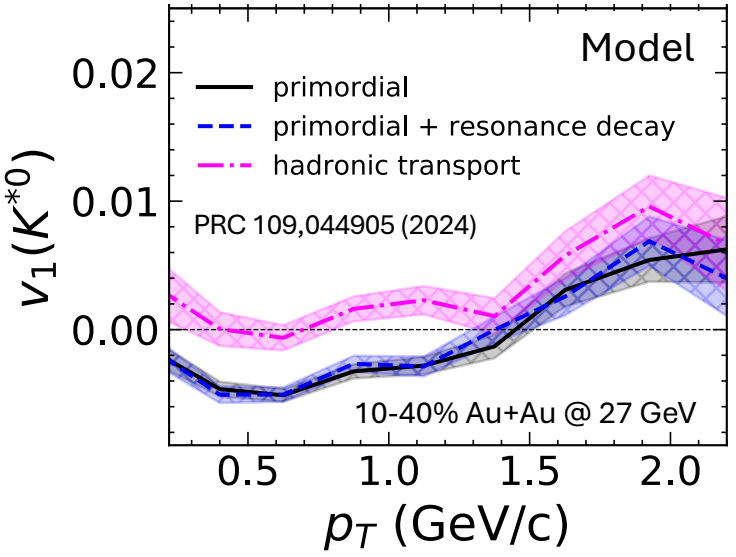
Transverse momentum dependence of v_1



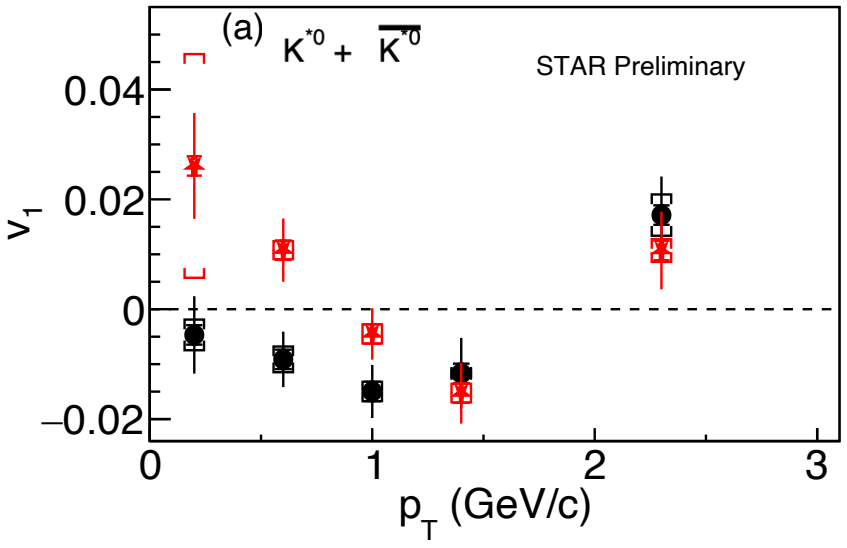


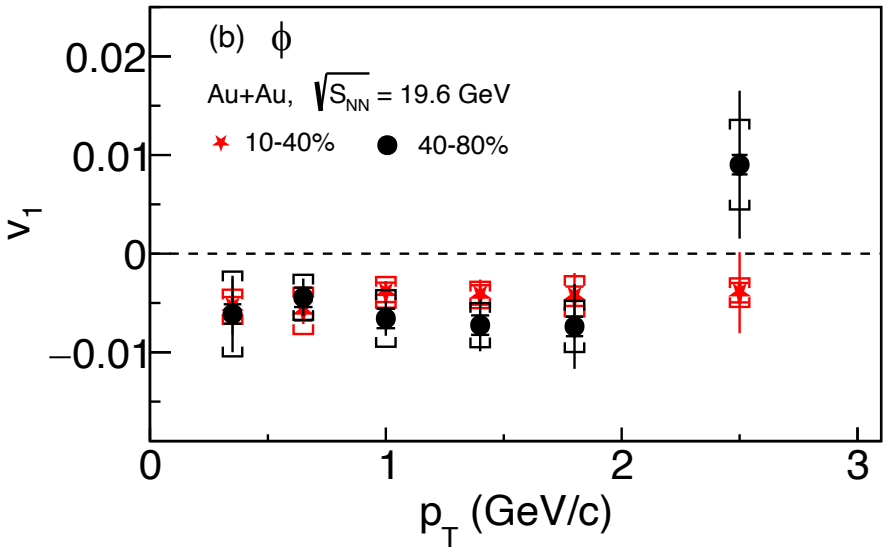
- K^{*0} v_1 shows a nontrivial p_T dependence in 10-40% centrality: positive at low p_T

This may be due to the hadronic rescattering, which dominates at low p_T



Transverse momentum dependence of v_1

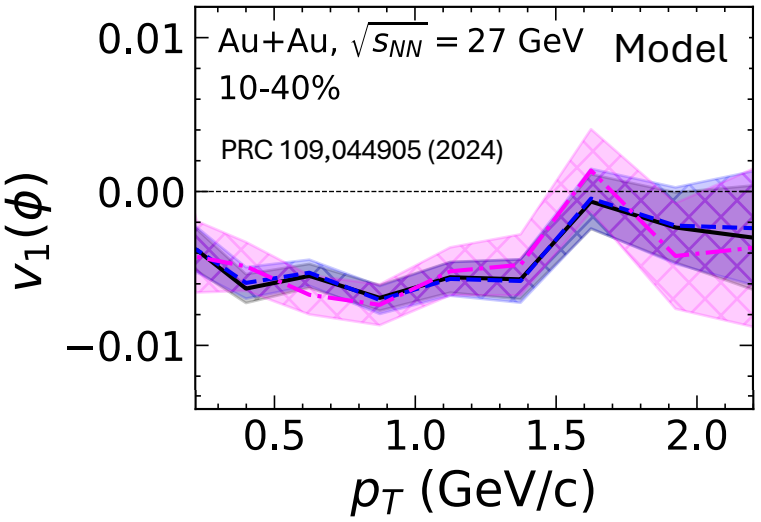




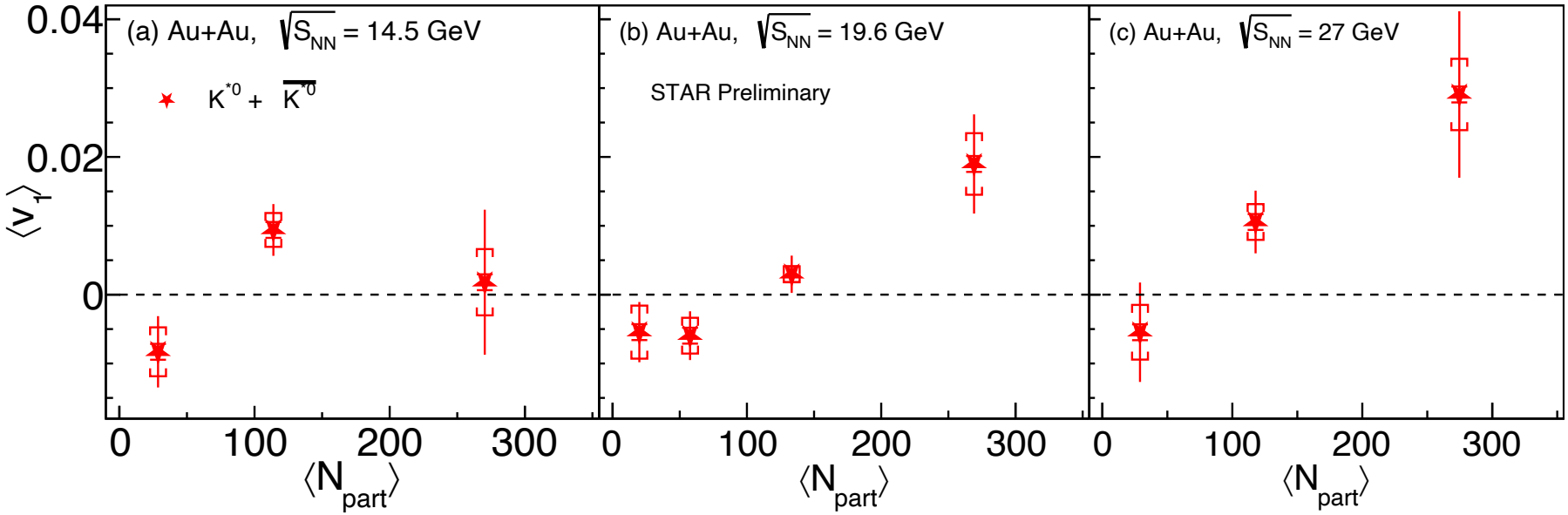
- K^{*0} v_1 shows a nontrivial p_T dependence in 10-40% centrality: positive at low p_T

This may be due to the hadronic rescattering, which dominates at low p_T

- ϕ meson v_1 is not affected by hadronic rescattering due to its longer lifetime.



Centrality dependence of v_1

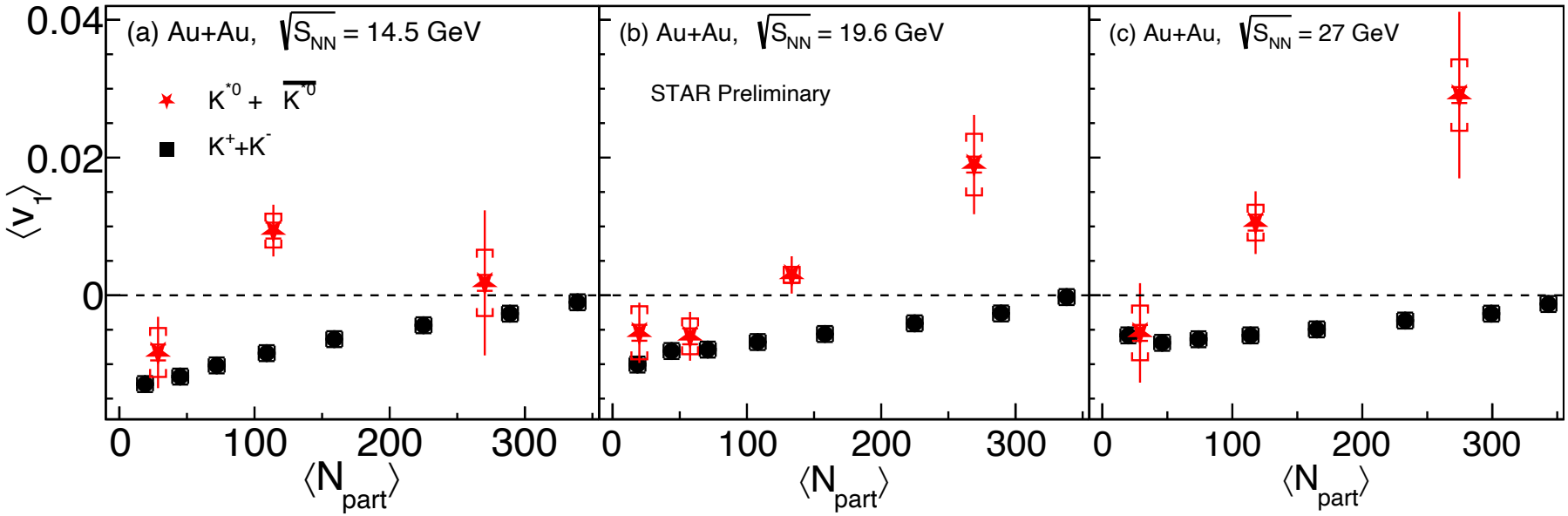


Rapidity and p_T integrated ($|y|<1.0$ and $0 < p_T < 3.0$ GeV/c) v_1 as a function of Number of participants (N_{part})

→ K^{*0} v_1 changes sign from peripheral to central collisions.

Centrality dependence of v_1

Comparison with charged kaons (A meson with similar quark content)

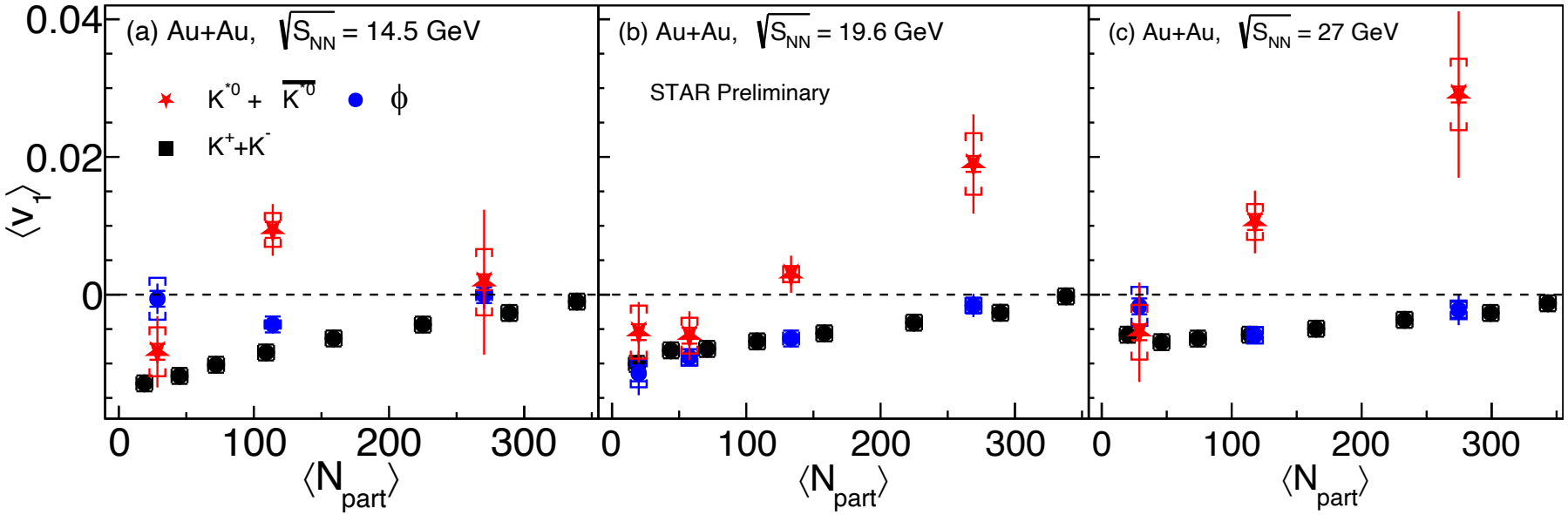


Rapidity and p_T integrated (|y|<1.0 and $0 < p_T < 3.0$ GeV/c) v_1 as a function of Number of participants (N_{part})

→ K^{*0} v_1 changes sign from peripheral to central collisions, unlike charged kaons

Centrality dependence of v_1

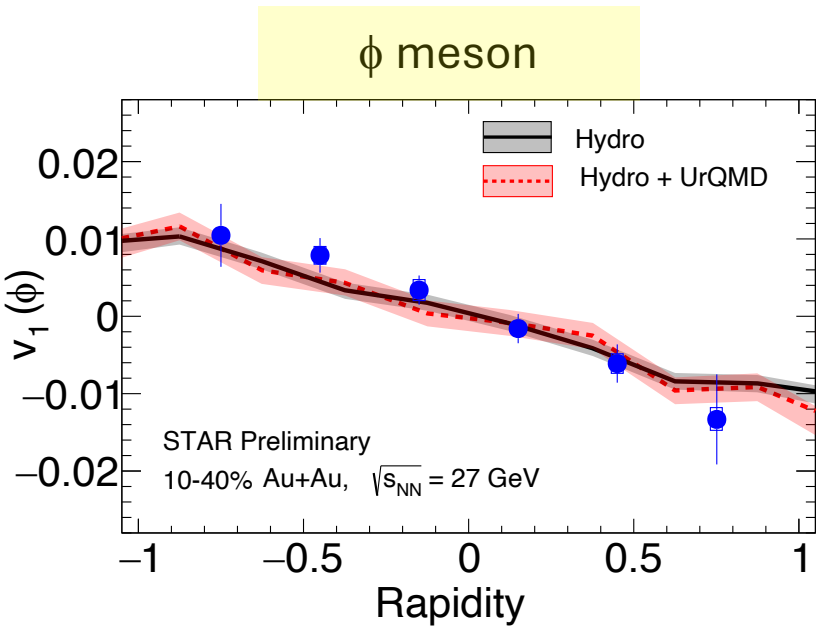
Comparison with ϕ mesons (A meson with similar mass)

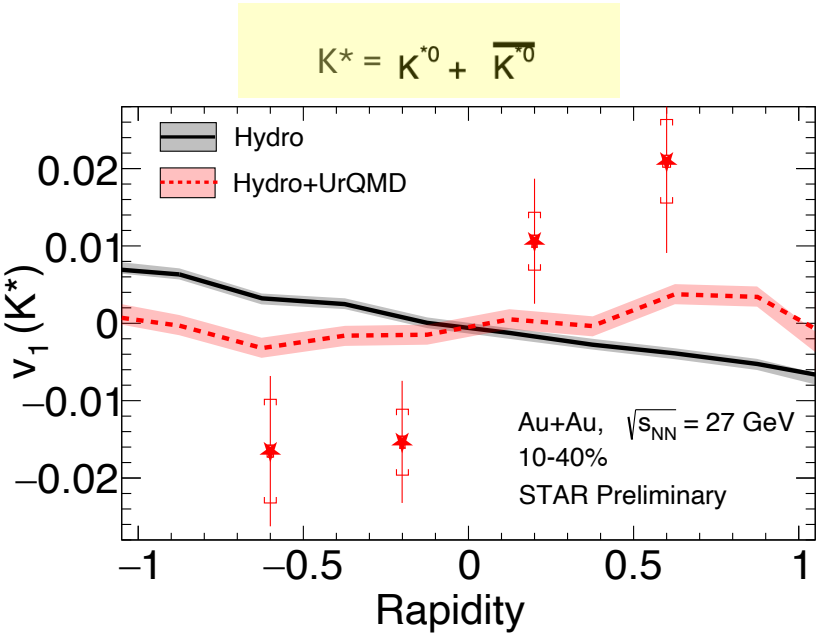


Rapidity and p_T integrated (|y|<1.0 and $0 < p_T < 3.0$ GeV/c) v_1 as a function of Number of participants (N_{part})

→ K^{*0} v_1 changes sign from peripheral to central collisions, unlike ϕ mesons

Data vs Model





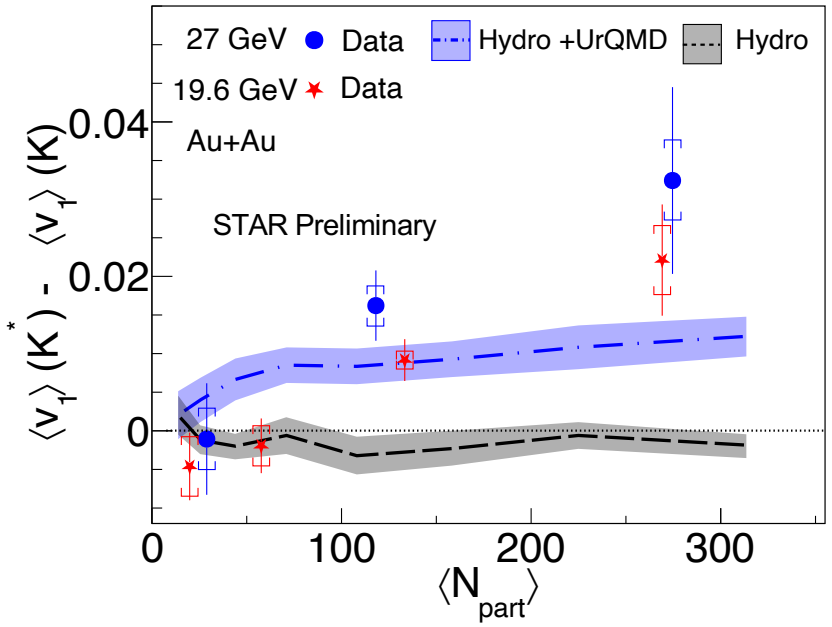
ϕ v_1: Model calculation successfully reproduces measured ϕ meson v_1

K^{*0} v_1: Hydro model calculation shows opposite slope compared to data.

→ Hydro+Hadronic afterburner qualitatively explain the data.

Model: PRC109, 044905 (2024)

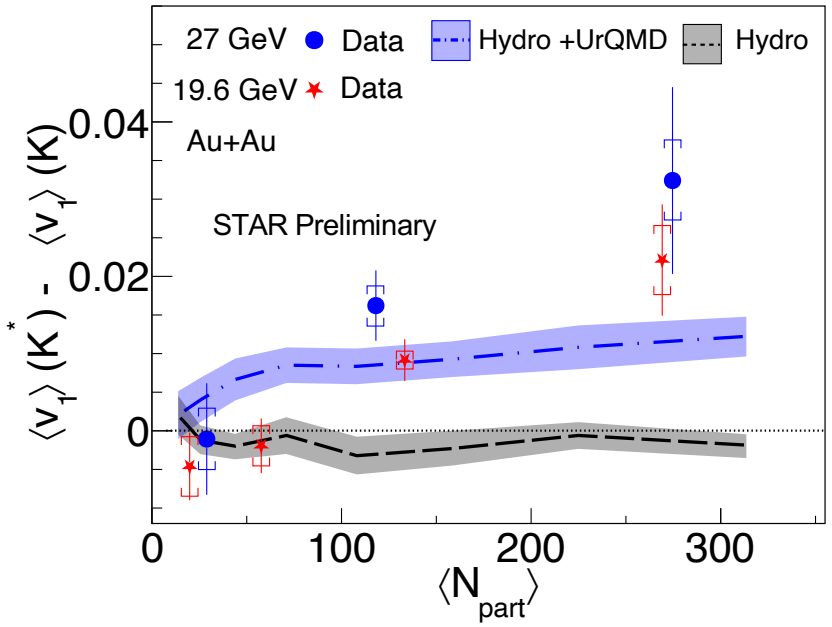
Centrality dependent : K^{*0} and $K^{\pm}$ v_1

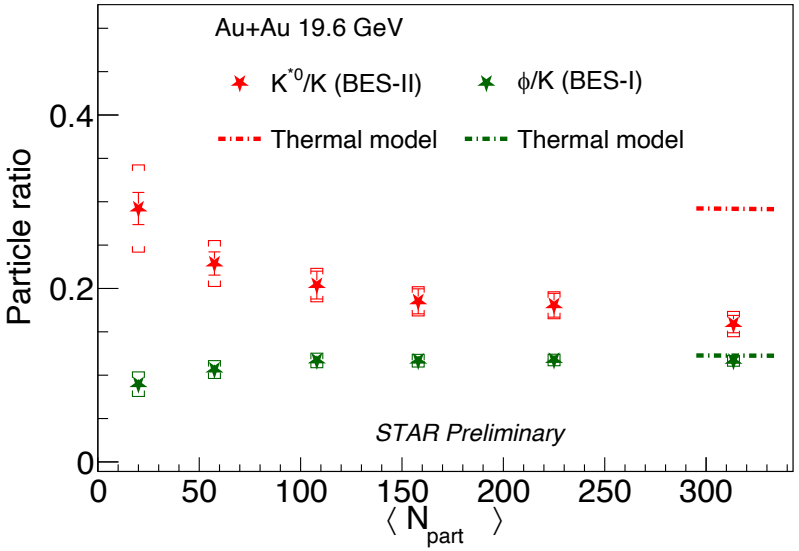


- Hydro without UrQMD fails to explain, but Hydro+UrQMD can explain the centrality dependence of v_1 difference;

Model comparison suggests rescattering causes asymmetric loss of K^{*0} yield in momentum space.

Centrality dependent : K^{*0} and $K^{\pm}$ v_1





- Hydro without UrQMD fails to explain, but Hydro+UrQMD can explain the centrality dependence of v_1 difference;

Model comparison suggests rescattering causes asymmetric loss of K^{*0} yield in momentum space.

Summary

- *Measurement of v_1 of K^{*0}, ϕ and charged kaons in Au+Au collisions at 14.5, 19.6 and 27 GeV. First measurement of K^{*0} v_1 in heavy-ion collisions.*
- *In peripheral collisions, K^{*0} $v_1(y)$ shows a negative slope like ϕ and kaons, but a positive slope in mid-central collisions.*
- *Model calculation suggests that asymmetric K^{*0} yield loss due to re-scattering may cause positive v_1 slope in central Au+Au collisions.*

Thanks....