Elliptic flow of strange and multi-strange hadrons in isobar collisions at $\sqrt{s_{NN}}$ = 200 GeV

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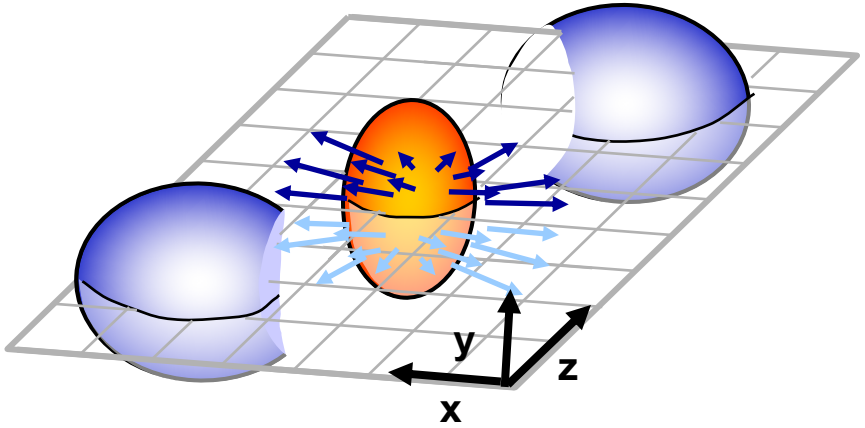
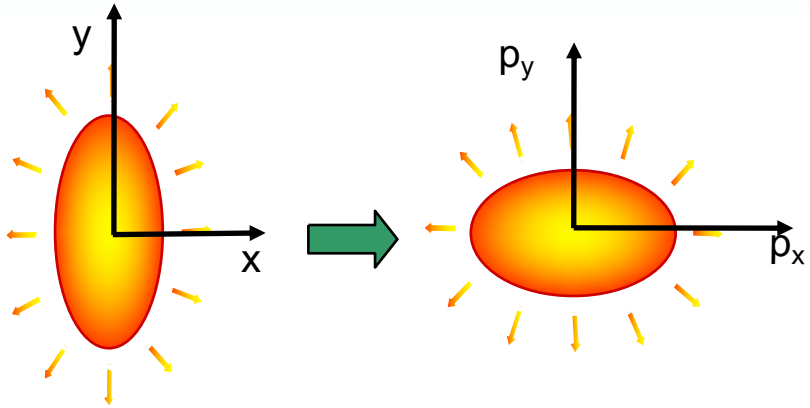
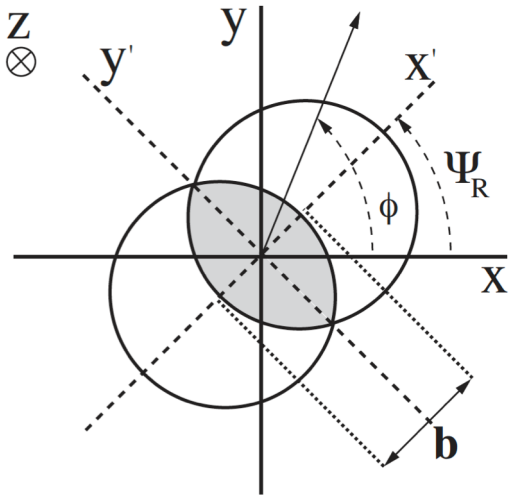
Introduction: Elliptic flow





Reaction plane: z-x plane



$$\frac{dN}{d\phi} \propto \frac{1}{2\pi}\left[1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_R))\right]$$

$$v_n = \langle \cos(n(\phi - \Psi_R)) \rangle$$

- Sensitive to early times in the evolution of the system
- Sensitive to the equation of state

Probe of the early (partonic) stage of the collision

A.M. Poskanzer & S.A. Voloshin, Phys. Rev. C 58 (1998) 1671

Motivation

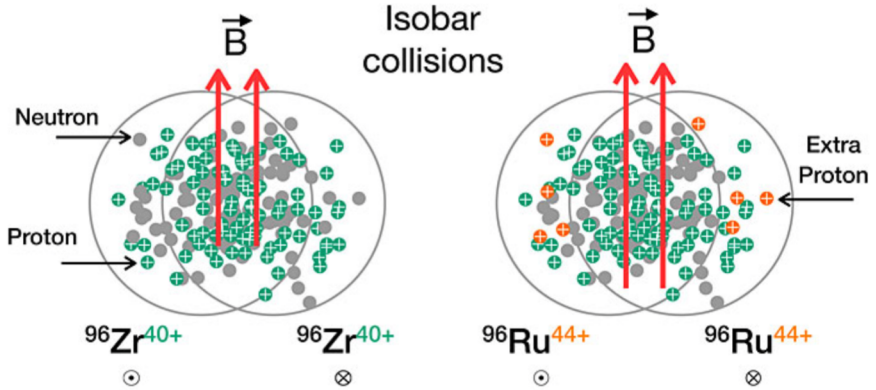
- Study of elliptic flow in isobar collisions may help in understanding the deformation of the colliding nuclei

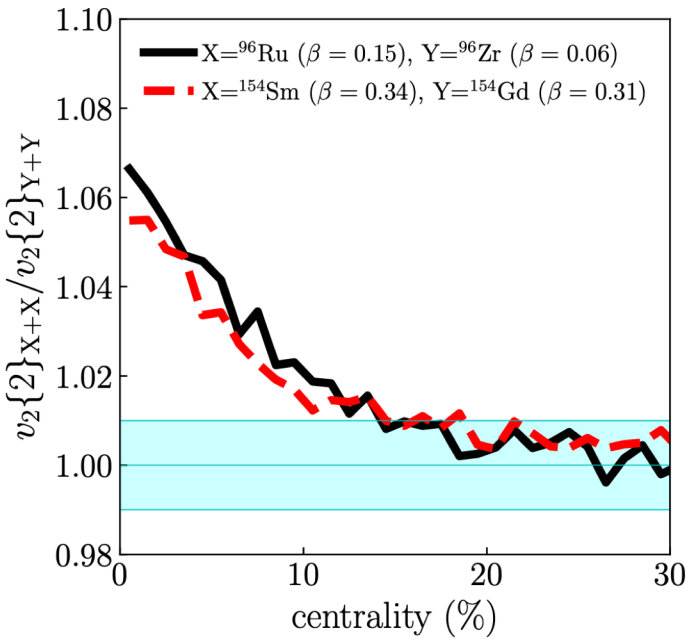
- Elliptic flow arises from the initial geometrical anisotropy of overlap region

  For identified particles, check if:

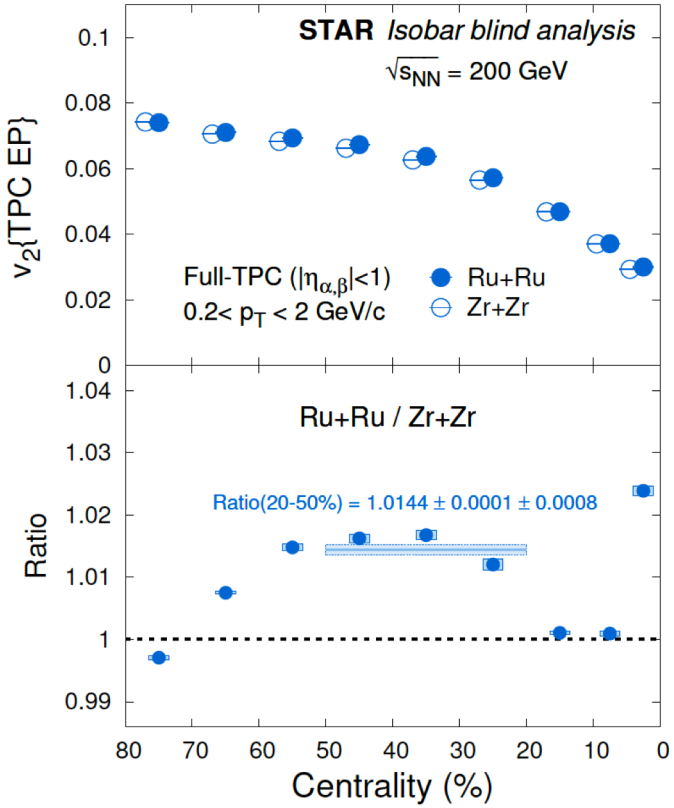
$$\frac{(v_2)_{\mathrm{Ru+Ru}}}{(v_2)_{\mathrm{Zr+Zr}}} \stackrel{?}{=} 1$$

- System size dependence of the azimuthal anisotropy



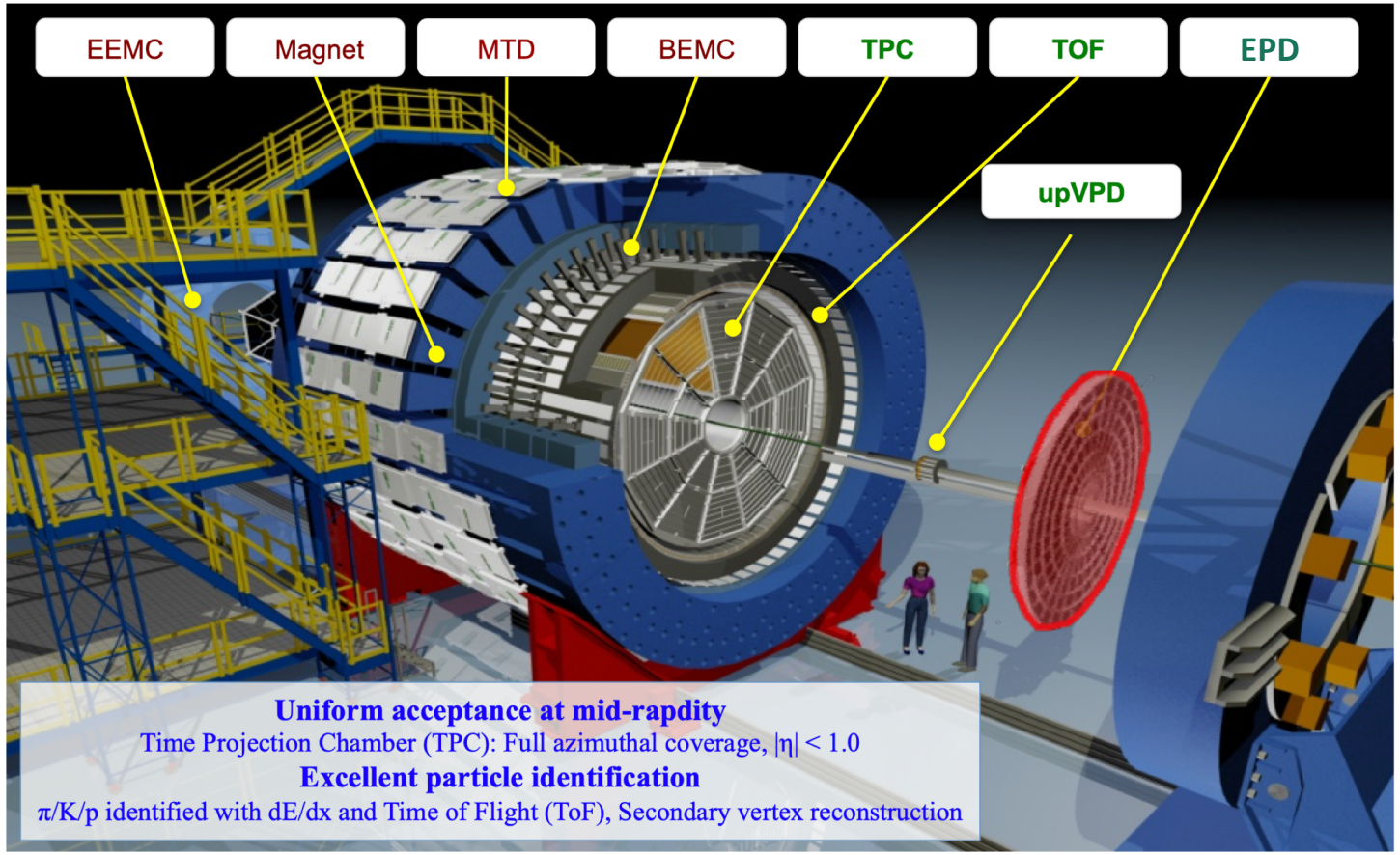


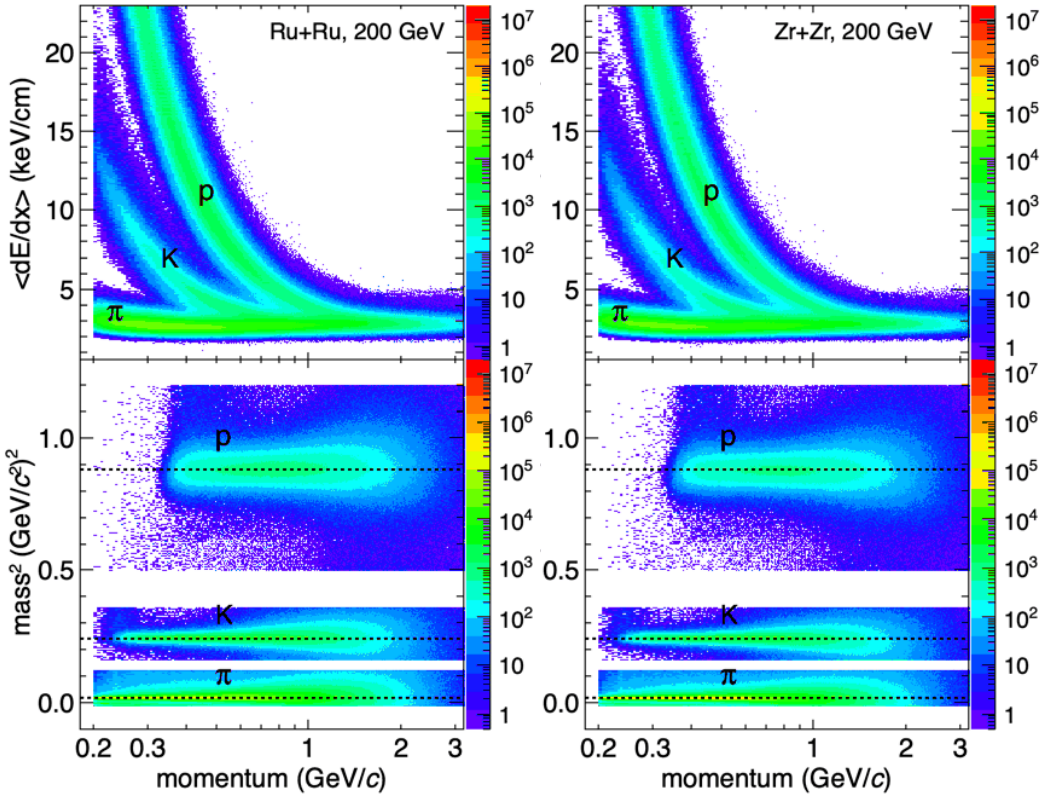
G. Giacalone, J. Jia, and V. Somà, Phys. Rev. C 104 (2021) L041903



STAR, Phys. Rev. C 105 (2022) 14901

STAR experiment





Dataset: Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV (2018)

- Approximately 1.3 B events have been analysed

Event plane method

- Event plane angle is defined as :

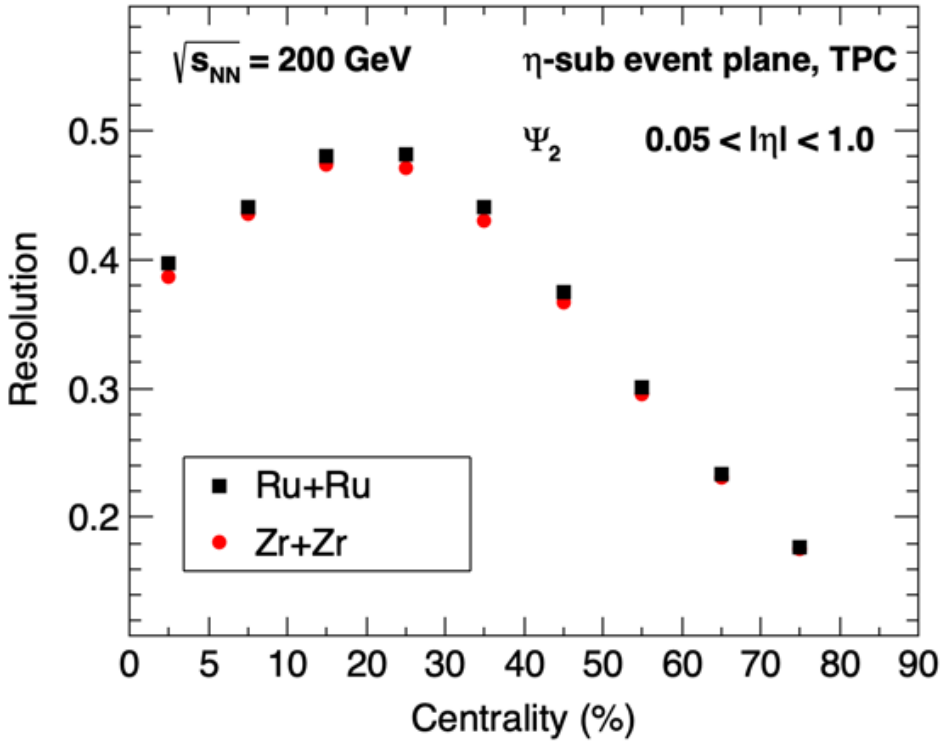
$$\Psi_2 = \left[\tan^{-1}\left(\frac{\sum_i w_i \sin(2\phi_i)}{\sum_i w_i \cos(2\phi_i)}\right)\right]/2$$

- Event plane has been calculated in two different windows ‘a’ (-1.0 < η < -0.05) and ‘b’ (0.05 < η < 1.0)

- The event plane resolution is :

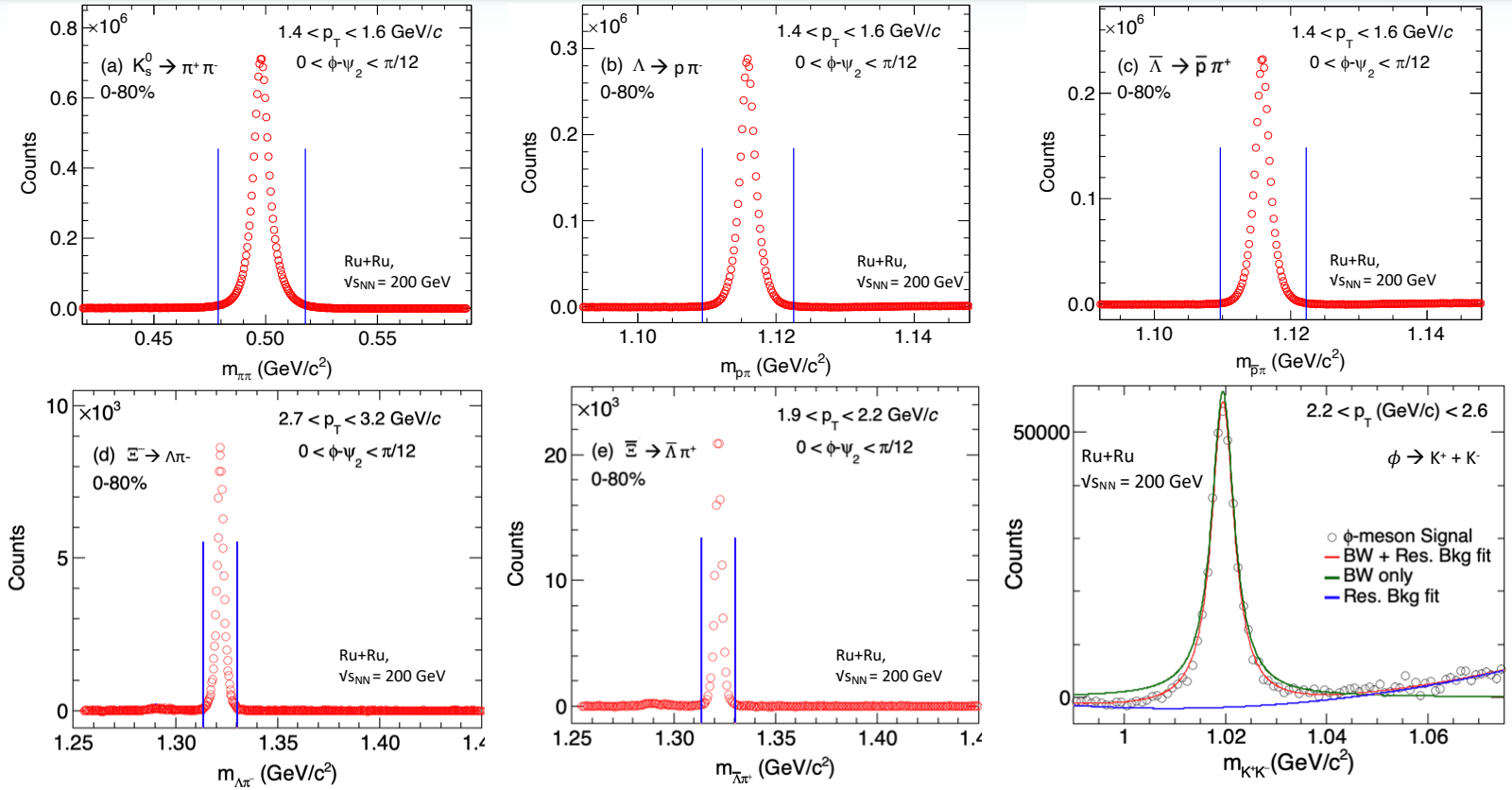
$$R = \sqrt{\cos 2(\Psi_2{}^a - \Psi_2{}^b)}$$

- Resolution correction is applied to obtain the final v_2



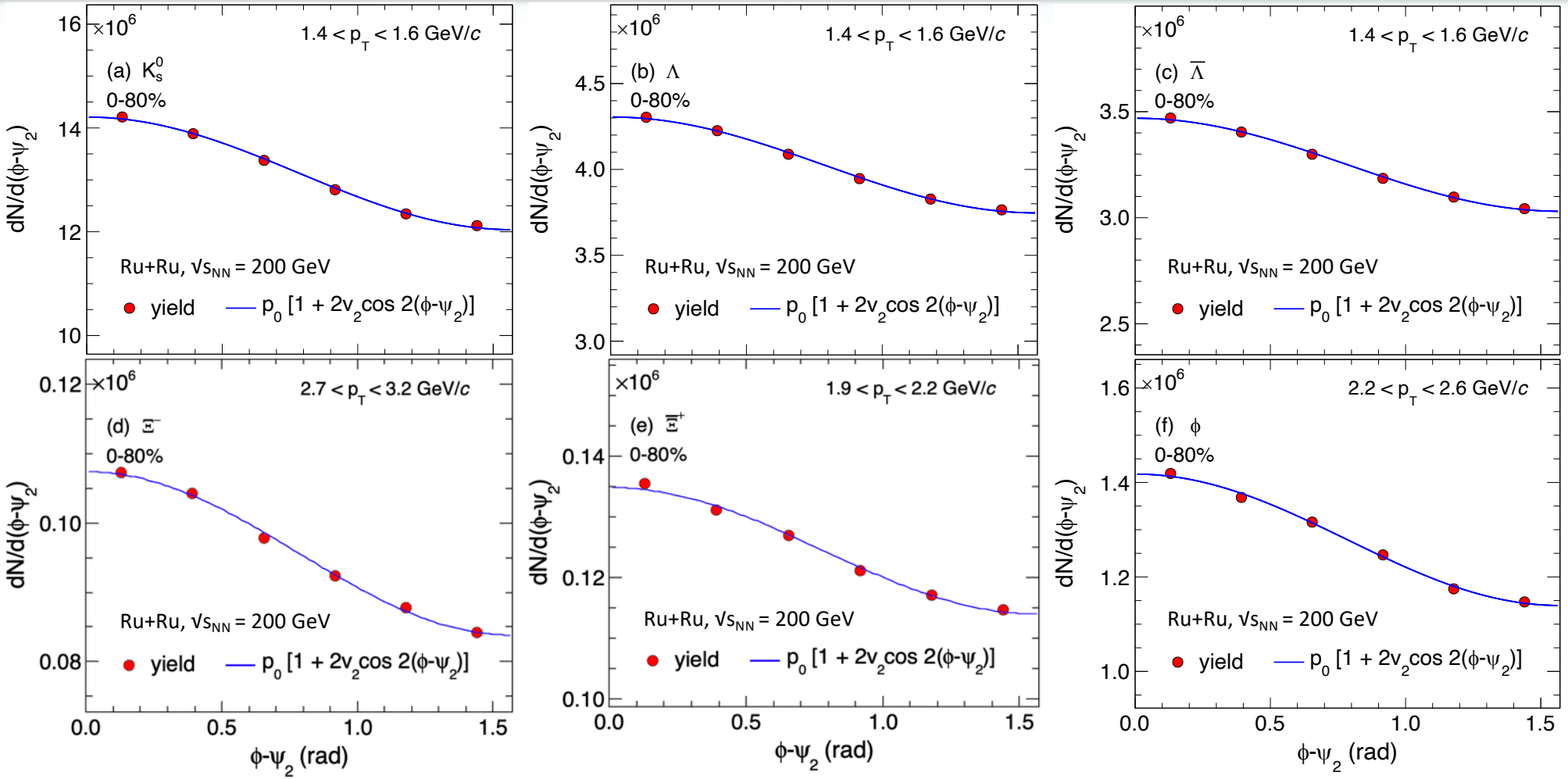
A.M. Poskanzer & S.A. Voloshin, Phys. Rev. C 58 (1998) 1671

Particle identification



- K_s^0, ϕ, Λ, and Ξ have been reconstructed from their decay products
- Signal reconstruction using invariant mass technique : $m_{inv} = \sqrt{(E_1 + E_2)^2 - (\overrightarrow{p_1} + \overrightarrow{p_2})^2}$
- Background reconstruction using various methods: Event-mixing method for ϕ-mesons, rotation method for K_s^0, Λ, and Ξ

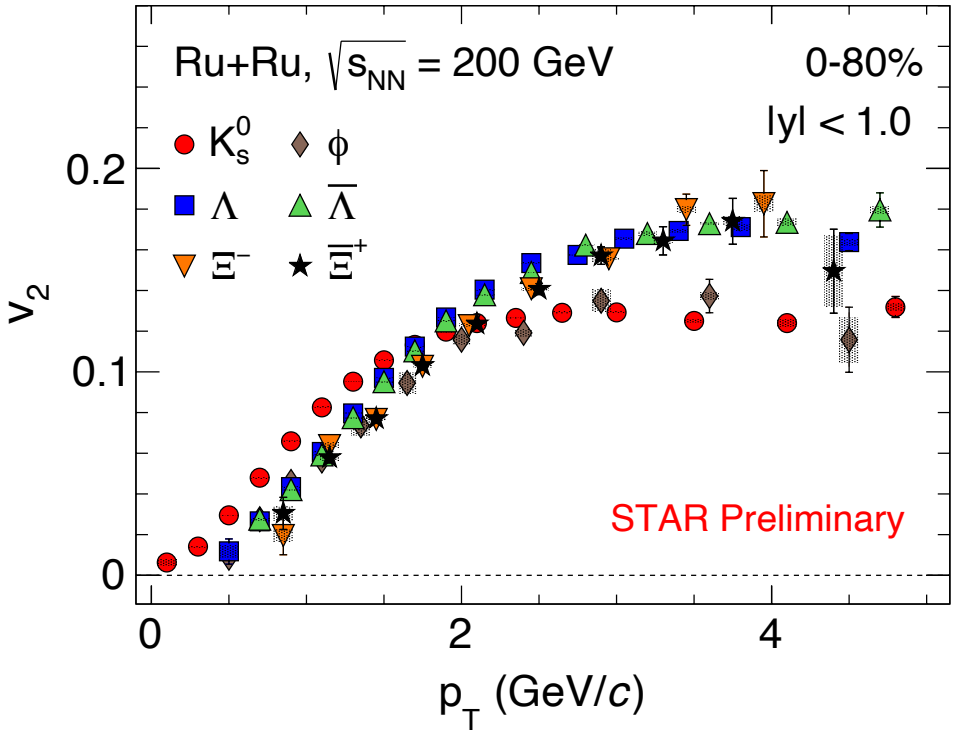
Flow analysis method

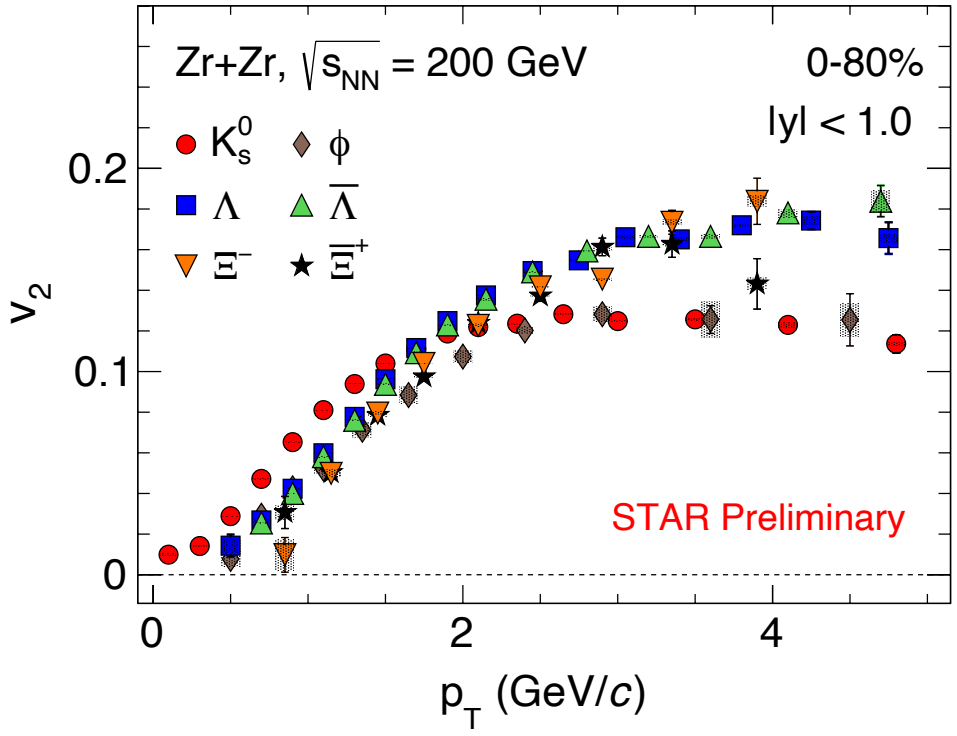


ϕ - Ψ_2 binning method:

- Particle raw-yield as a function of ϕ - Ψ_2 is fitted with a function for different p_T ranges to extract v_2 coefficients

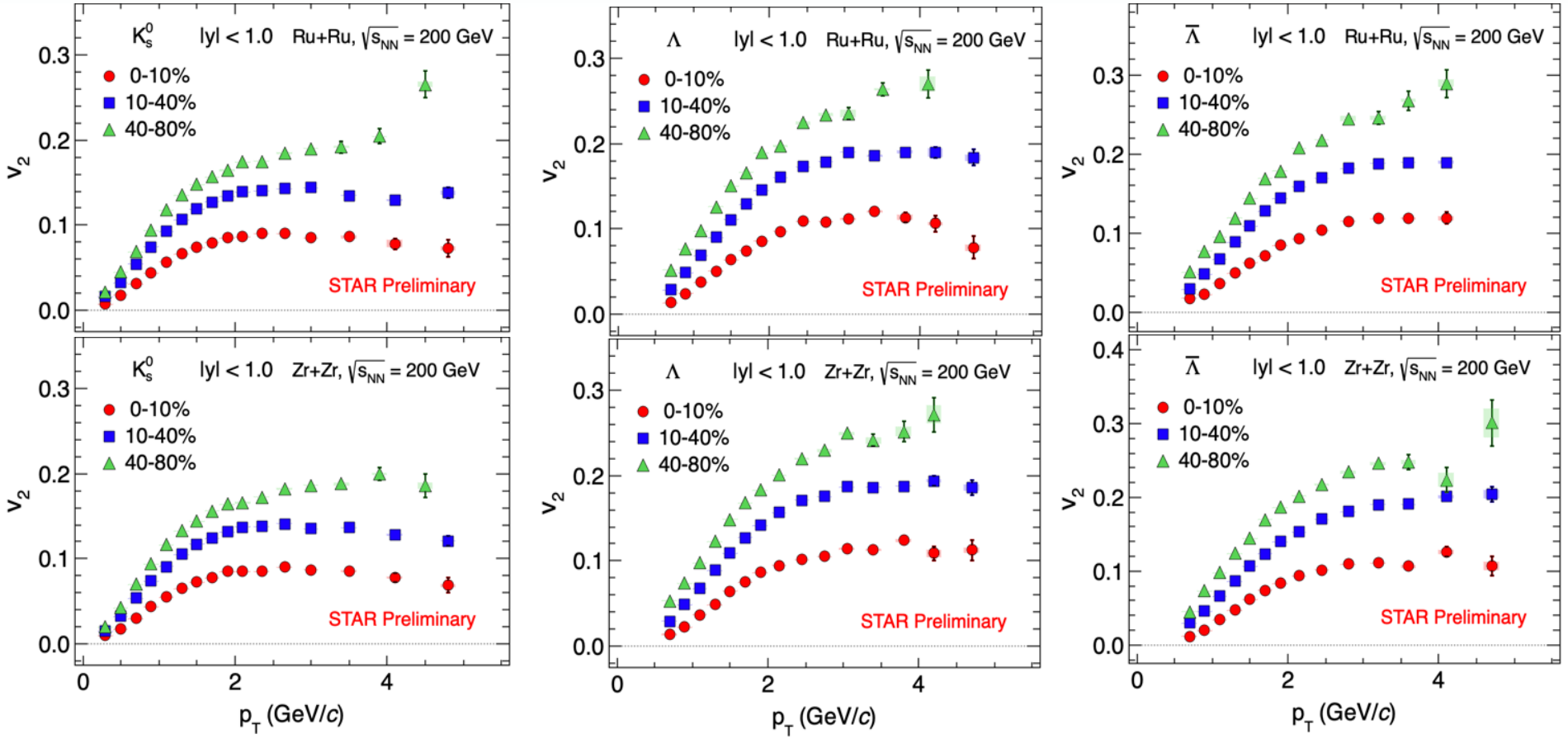
Results: Elliptic flow





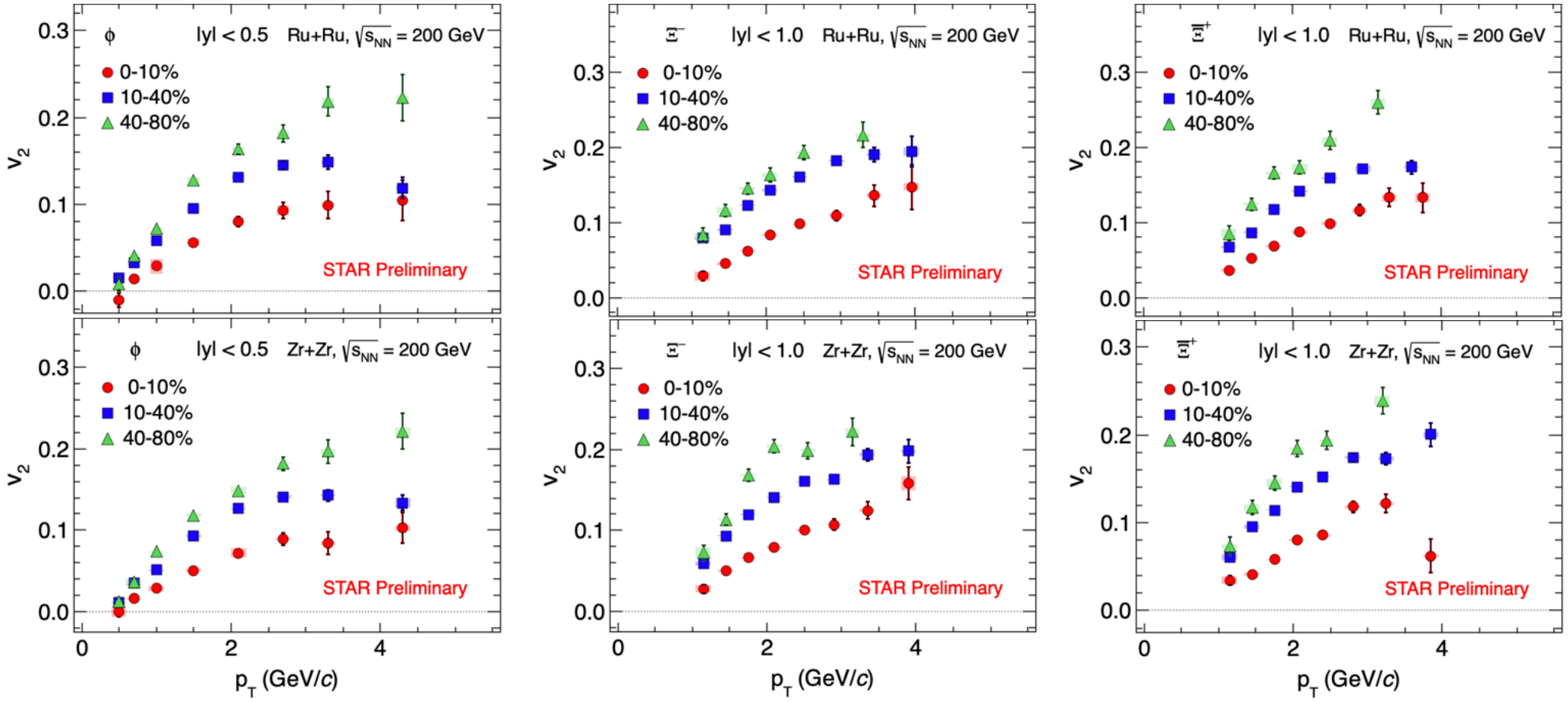
- v_2 shows a mass ordering at low p_T in isobar collisions
- Baryon-meson splitting at intermediate p_T region (> 2 GeV/c)
- v_2 values have similar p_T dependence in Ru+Ru and Zr+Zr collisions for 0-80% centrality

Centrality dependence of $v_2(p_T)$



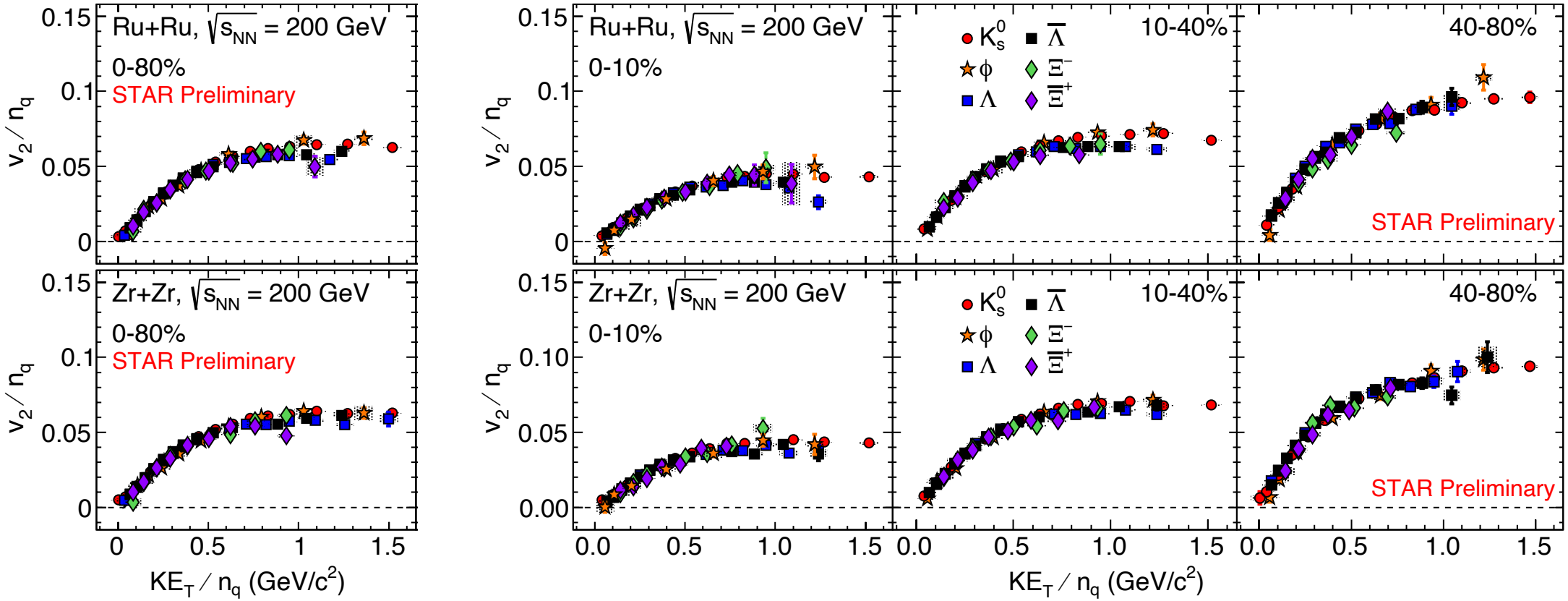
- Strong centrality dependence is observed for v_2 of K_s^0, Λ, and $\bar{\Lambda}$, in both Ru+Ru and Zr+Zr collisions
- $v_2(p_T)$ increases from central to peripheral collisions

Centrality dependence of $v_2(p_T)$



- Strong centrality dependence is observed for v_2 of ϕ, Ξ^-, and $\bar{\Xi}^+$ in both Ru+Ru and Zr+Zr collisions
- $v_2(p_T)$ increases from central to peripheral collisions

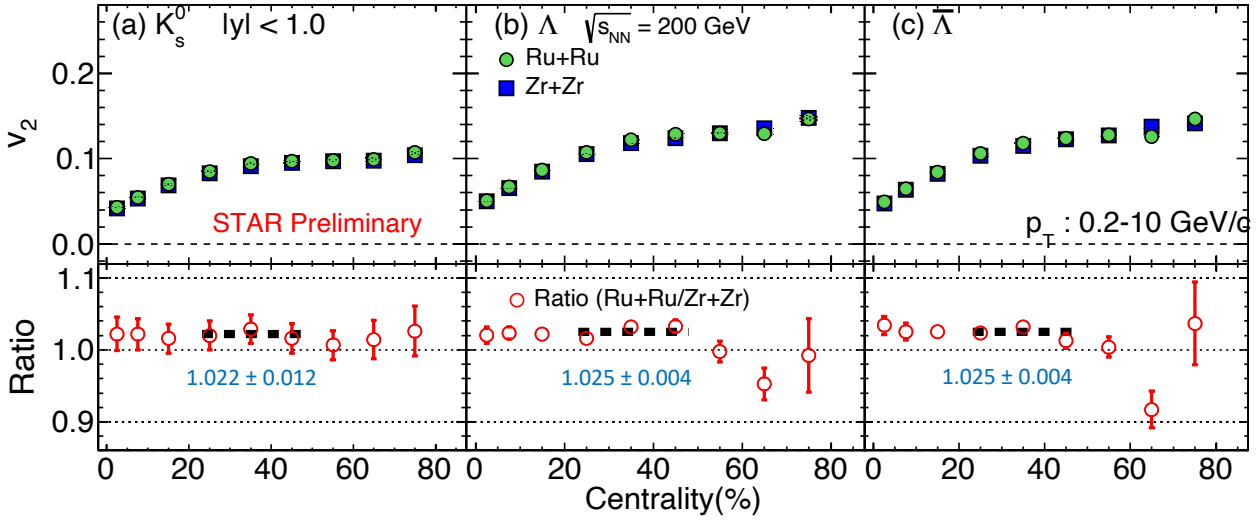
NCQ scaling

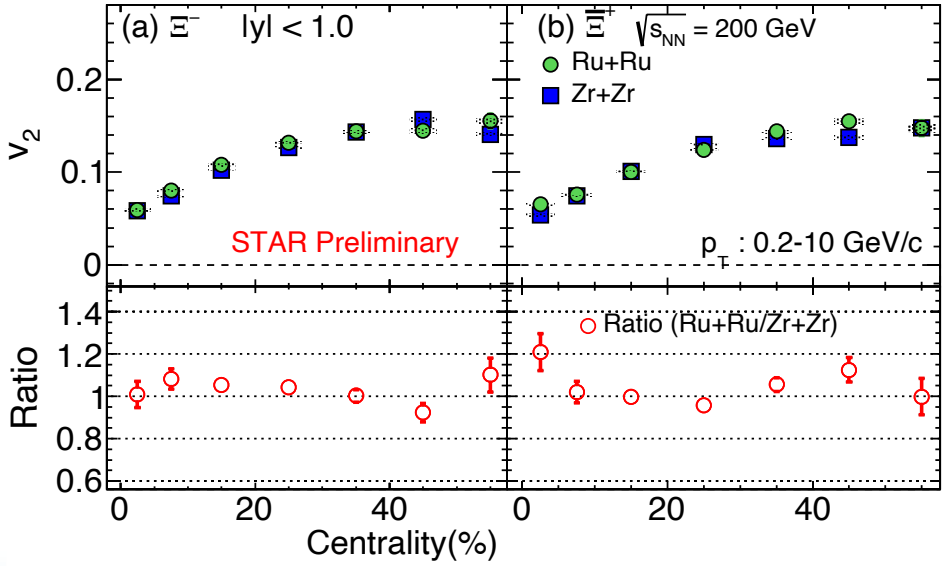


n_q = Number of constituent quarks, 3 for baryons and 2 for mesons ; Transverse kinetic energy (KE_T) = $m_T - m_0$

- NCQ scaling holds good to 10% within uncertainties in both Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV
  - → Indicative of partonic collectivity in the system

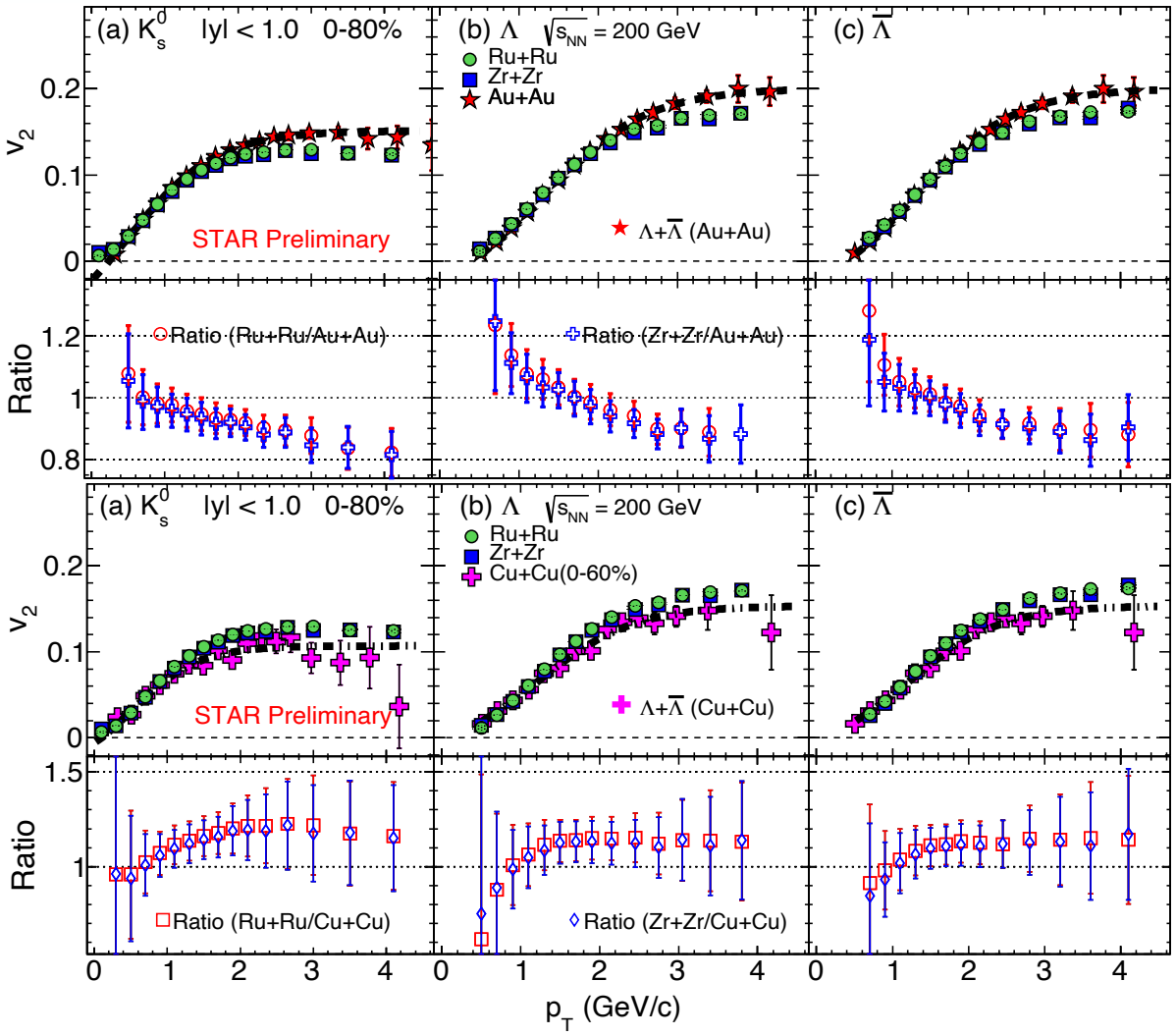
v_2 vs centrality





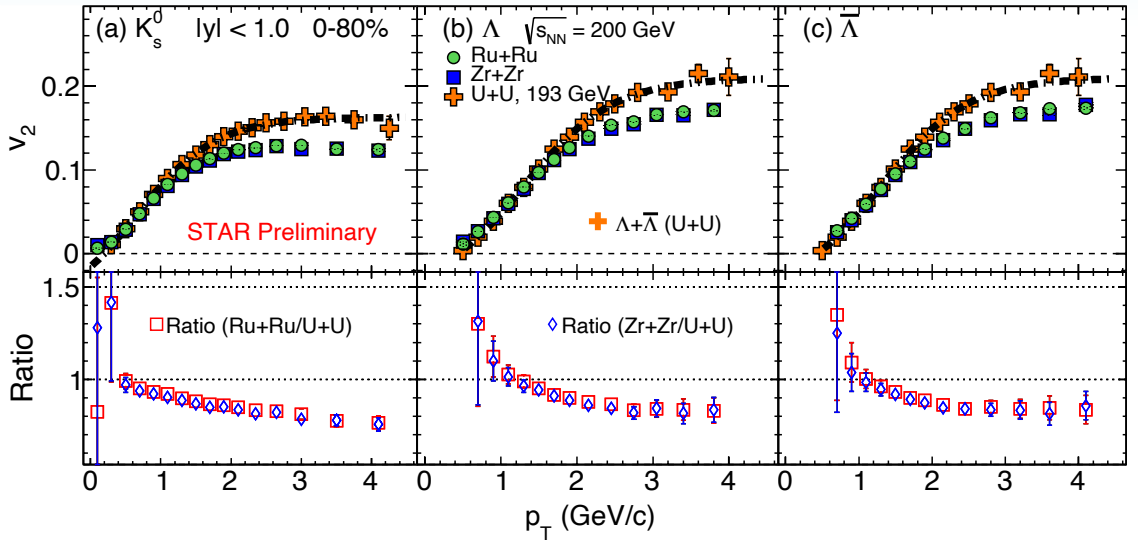
- p_T-integrated elliptic flow increases from central to peripheral collisions
- Ratio of v_2 between Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV for K_s^0, Λ and $\bar{\Lambda}$ seems to deviate from unity by ~2% at central and mid-central collisions
  → May indicate larger nuclear deformity in Ru than in Zr nucleus

System size dependence (strangeness)



**Errors bars denote the combined statistical and systematic uncertainties*

STAR, Phys. Rev. C 77 (2008) 054901; Phys. Rev. C 81 (2010) 044902



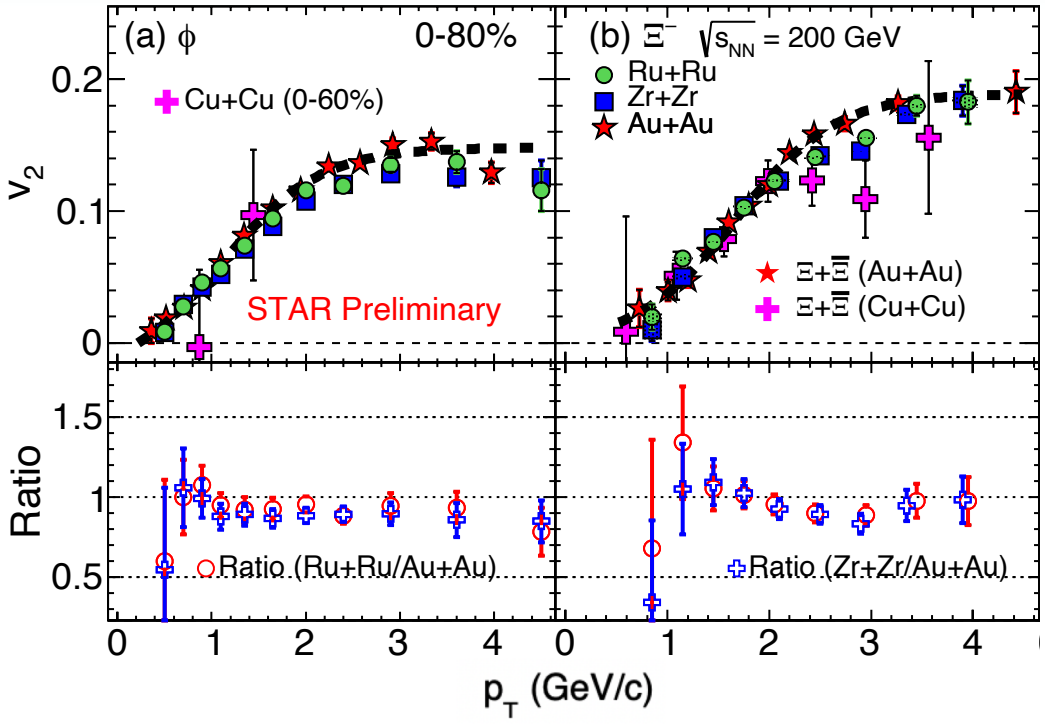
STAR, Phys. Rev. C 103 (2021) 064907

Fitting function : $f_{v_2}(n) = \frac{an}{1+e^{-(p_T/n-b)/c}} - dn$

n: number of quarks; a, b, c, d: free parameters

- v_2 of K_s^0, Λ, and $\bar{\Lambda}$ in isobar collisions is smaller than in ^{197}Au+^{197}Au and ^{238}U+^{238}U collisions at higher p_T
- v_2 in isobar collisions is higher as compared to ^{63}Cu+^{63}Cu collisions at higher p_T

System size dependence (multi-strangeness)



Fitting function : $f_{v_2}(n) = \frac{an}{1+e^{-(p_T/n-b)/c}} - dn$

n: number of quarks; a, b, c, d: free parameters

- v_2 of ϕ and Ξ is similar in the measured p_T range for different collision systems within uncertainties

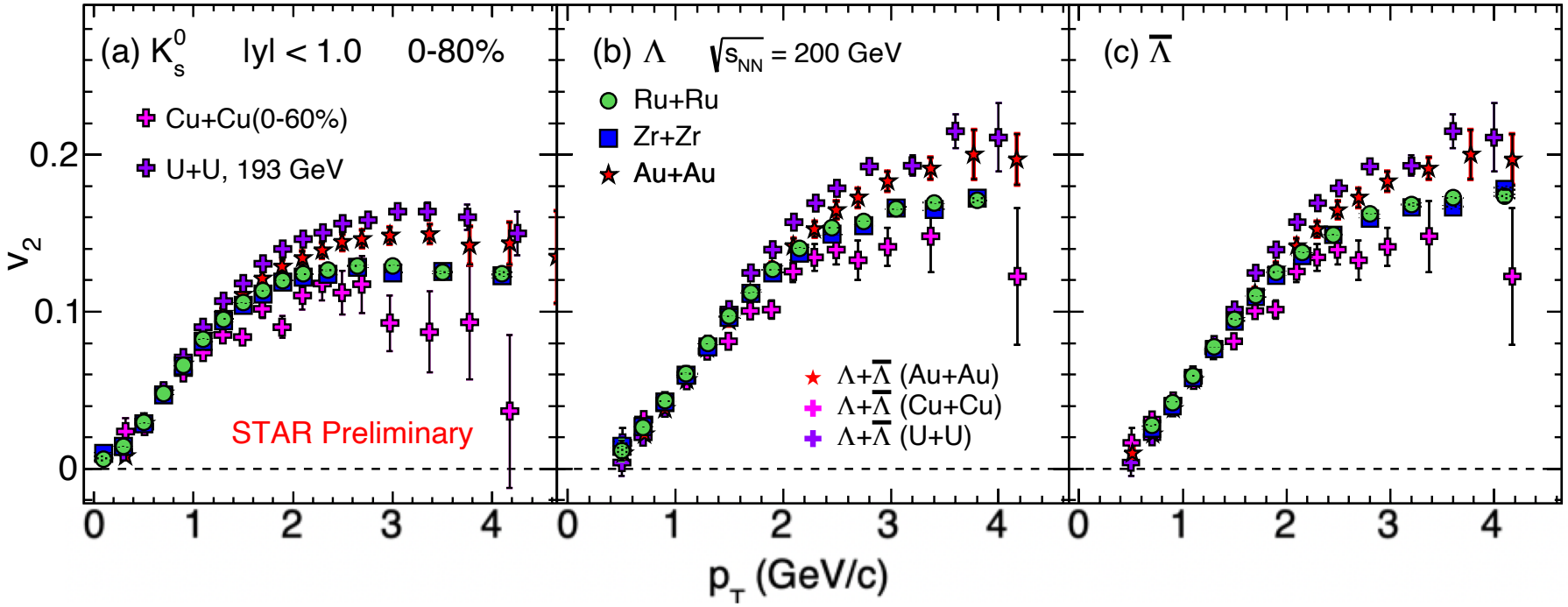
STAR, Phys. Rev. Lett. 116 (2016) 062301, Phys. Rev. C 81 (2010) 044902, Phys. Rev. C 77 (2008) 054901

Summary

- Elliptic flow of K_s^0, Λ, $\bar{\Lambda}$, ϕ, and Ξ has been measured using event plane method for Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV
- Strong centrality dependence of v_2 for all particles has been observed
- NCQ scaling holds good to 10% for all particles in all centralities for the isobar collisions
- Elliptic flow ratio for Ru+Ru over Zr+Zr seems to show a deviation of nearly 2% in central and mid-central collisions
  - → May indicate higher deformation in Ru than in Zr nuclei
- v_2 of strange hadrons in isobar collisions
  - At high p_T : Smaller compared to Au+Au and U+U collisions, and larger compared to Cu+Cu collisions
  - At low p_T : Similar for all collision systems studied

Thank you for your attention!

System size dependence (strangeness)



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- v_2 in isobar collisions is larger as compared to ^{63}Cu+^{63}Cu collisions at higher p_T

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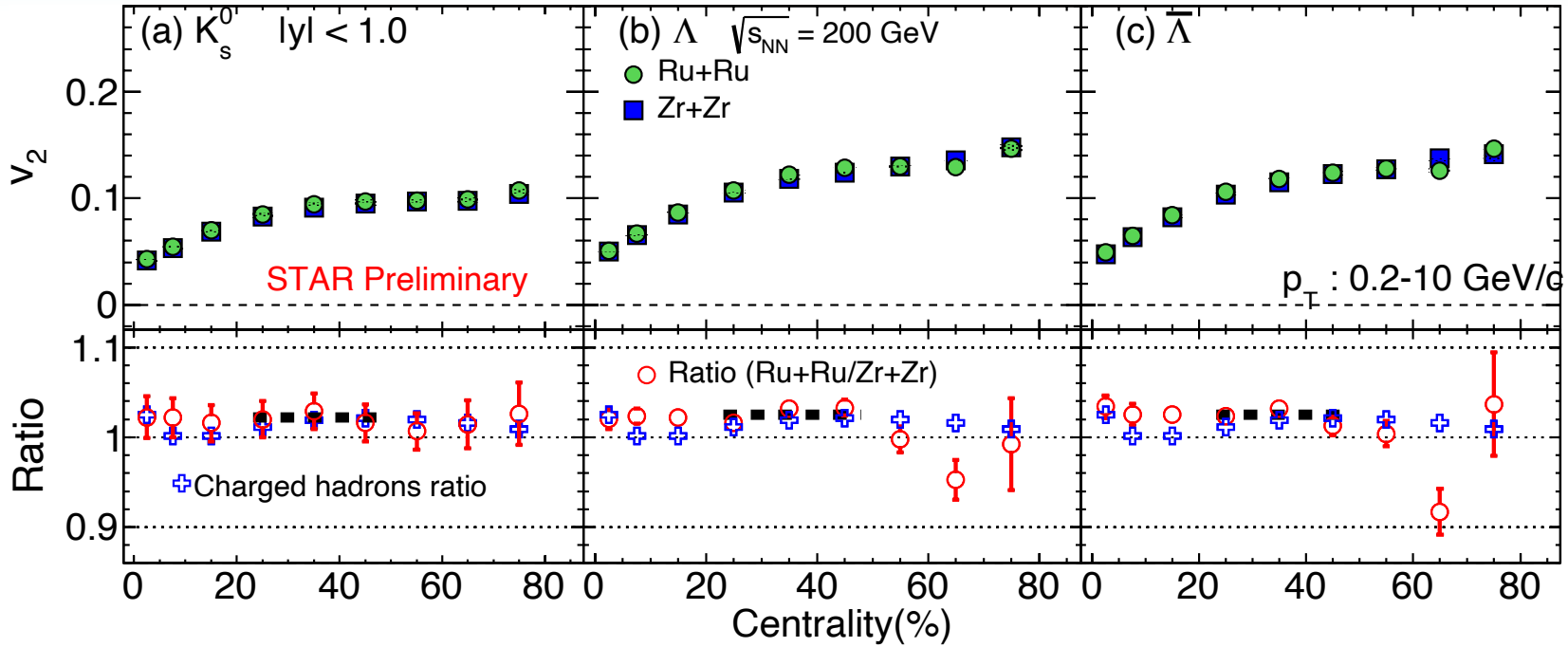
v_2 vs centrality



STAR, Phys. Rev. C 105 (2022) 14901

- p_T -integrated elliptic flow increases from central to peripheral collisions
- Ratio of v_2 between Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV for charged hadrons are comparable within the current uncertainties