CMW Search in Isobar Collision

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Outline

★ Introduction
★ Method
★ Data Selection
★ Results
★ Summary and Outlook

Introduction and motivation

Chiral anomalies and strong magnetic field induces interesting macroscopic effects in QGP.

Chiral Magnetic Effect (CME)

★ Generation of electric current due to chirality imbalance in the presence of an external magnetic field.

★ Electric Charges gets seperated perpendicular to reaction plane, along magnetic field created by spectator protons.

$$j_V = \frac{N_c e}{2\Pi^2}\mu_A B$$

Chiral Separation Effect (CSE)

★ Generation of axial current along the direction of external magnetic field due to the presence of non zero electric charge density.

★ Axial Charges get separated perpendicular to reaction plane, along magnetic field created by spectator protons.

$$j_A = \frac{N_c e}{2\Pi^2}\mu_V B$$

Chiral Magnetic Wave (CMW)

Coupling of chiral and electric charge densities and currents created by both CSE and CME respectively, results in collective excitation of QGP.

- ★ CMW creates Electric Quadrupole.
- ★ Electric Quadrupole results in a greater concentration of positive charges at poles (as **B** is oriented out of plane) than at Equator (within reaction plane).
- ★ Charge separation leads to different elliptic flow for positive and negative charge particles.
- ★ Thus CMW leads to charge dependent elliptic flow.

Method

- ★ Electric Quadrupole moment induced by CMW leading to splitting in v_2 of charge particles is predicted to be proportional to charge asymmetry (A).

$$\mathrm{v}_2^{\pm} - \mathrm{v}_{2,\mathrm{base}}^{\pm} = \mp \frac{\mathrm{r}}{2}\mathrm{A} \qquad\qquad \mathrm{A} = \frac{\mathrm{N}_+ - \mathrm{N}_-}{\mathrm{N}_+ + \mathrm{N}_-}$$

- ★ Experimentally, $\Delta \mathrm{v}_2$ vs A_{ch} gives r.
- ★ Another way is measuring covariance of $\mathrm{v}_2^{\pm}$ and A, $< \mathrm{v}_2^{\pm}\mathrm{A} > - < \mathrm{A} >< \mathrm{v}_2^{\pm} >$ as function of centrality (3-point correlator or 3-particle correlator),

$$< \mathrm{v}_2^{\pm}\mathrm{A} > - < \mathrm{A} >< \mathrm{v}_2^{\pm} > \;\approx\; \mp \mathrm{r}(<\mathrm{A}^2 > - < \mathrm{A}>^2)/2 \approx \; \mp \mathrm{r}\sigma_{\mathrm{A}}^2/2$$

- ★ Δ Integral correlator (ΔIC) ,

$$\Delta\mathrm{IC} = < \mathrm{v}_2^{-}\mathrm{A} > - < \mathrm{A} >< \mathrm{v}_2^{-} > - \; < \mathrm{v}_2^{+}\mathrm{A} > - < \mathrm{A} >< \mathrm{v}_2^{+} > \; = \mathrm{r}\sigma_A^2$$

ALICE Collab.: Phys. Rev. C 93 (2016) 044903, arXiv:2308.16123v1 [nucl-ex]

Data selection

★ Run 18

★ Collision Type:
Zr+Zr @ 200 GeV (~1.5B Events Analysed)
Ru+Ru @ 200 GeV (~1.5B Events Analysed)

Event Cuts

★ $-35 < V_Z < 25$ cm

★ $|V_{Z,TPC} - V_{Z,VPD}| < 5$ cm

★ $\sqrt{V_x^2 + V_y^2} < 2.0$ cm

Track Cuts

★ $N_{Hits} > 15$

★ $N_{HitsFit}/N_{HitsPoss} > 0.52$

★ DCA < 3 cm

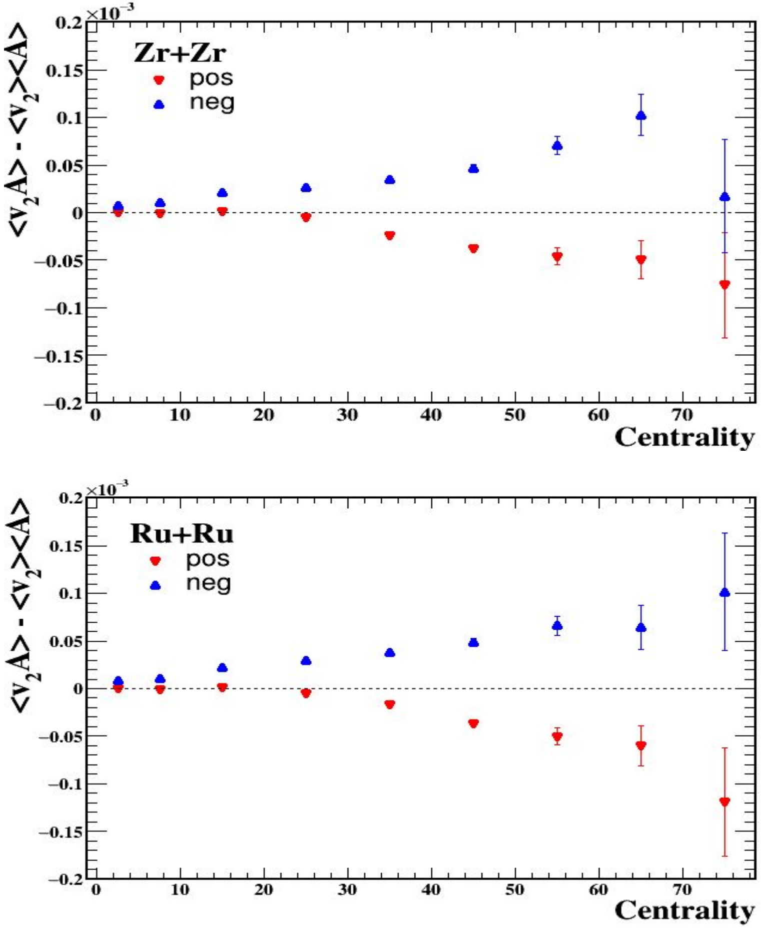
★ $0.2 < p_T < 2$ GeV/c

★ $|\eta| < 1$

RESULTS

Integral covariance of v_2 and A

- ★ v_2 is calculated using cumulant method.
- ★ η gap of 0.4 is taken between RFP and POI.
- ★ Both Ru+Ru and Zr+Zr shows similar splitting of v_2 and **A** covariance.



Slope (r) vs Centrality

★ Slope r,

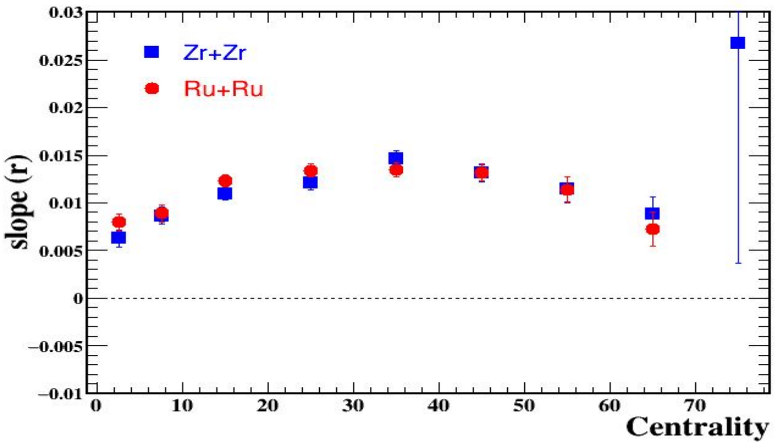
$$r = \frac{\Delta IC}{\sigma_A^2}$$

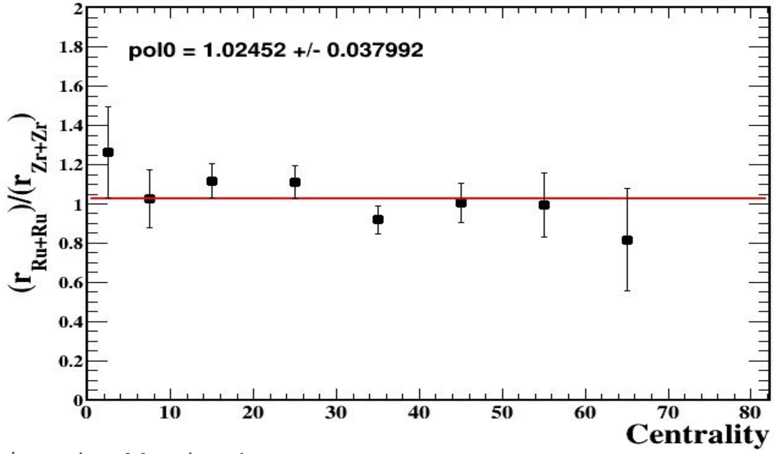
★ σ_A^2 is determined by fitting **A** distribution with gaussian distribution.

★ Both Ru+Ru and Zr+Zr shows similar trend within error bars.

★ Slope (r) for mid centrality is around 0.013 .

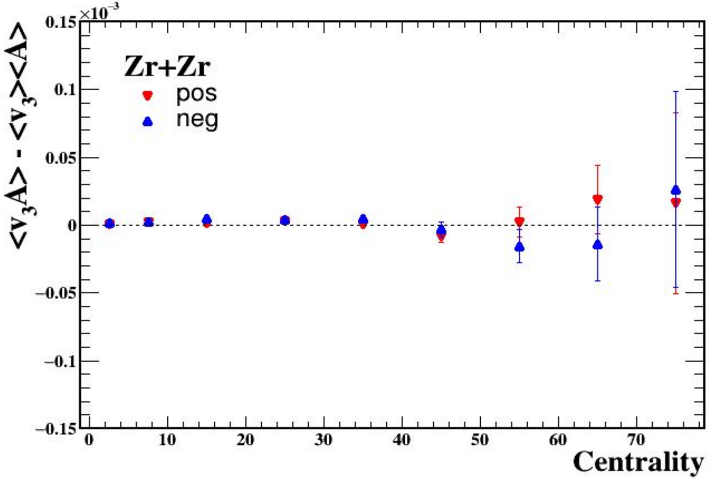
★ Ratio, $(r_{Ru+Ru})/(r_{Zr+Zr})$ is around 1 within error bars.

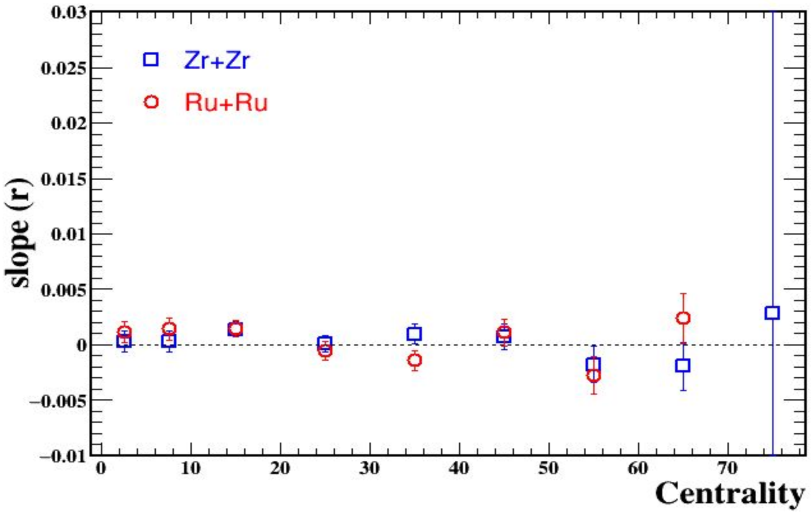


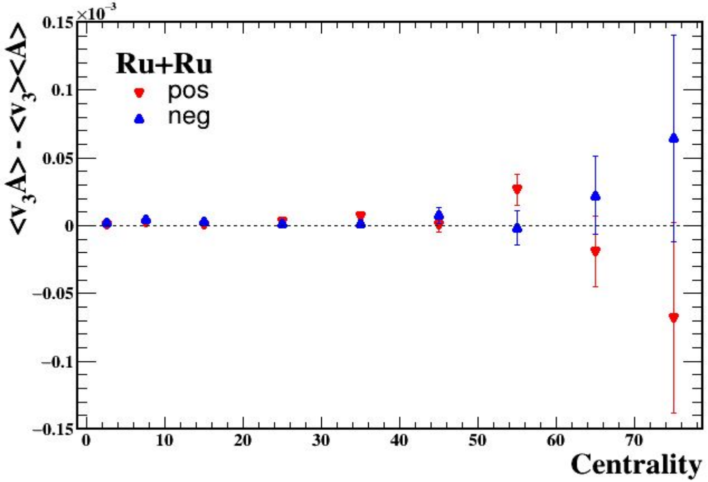


Integral covariance of v_3 and A

- ★ No separation in covariance of v_3 and **A** for positive and negative charged particles.
- ★ Slope (r) for third harmonic is observed to be close to zero.

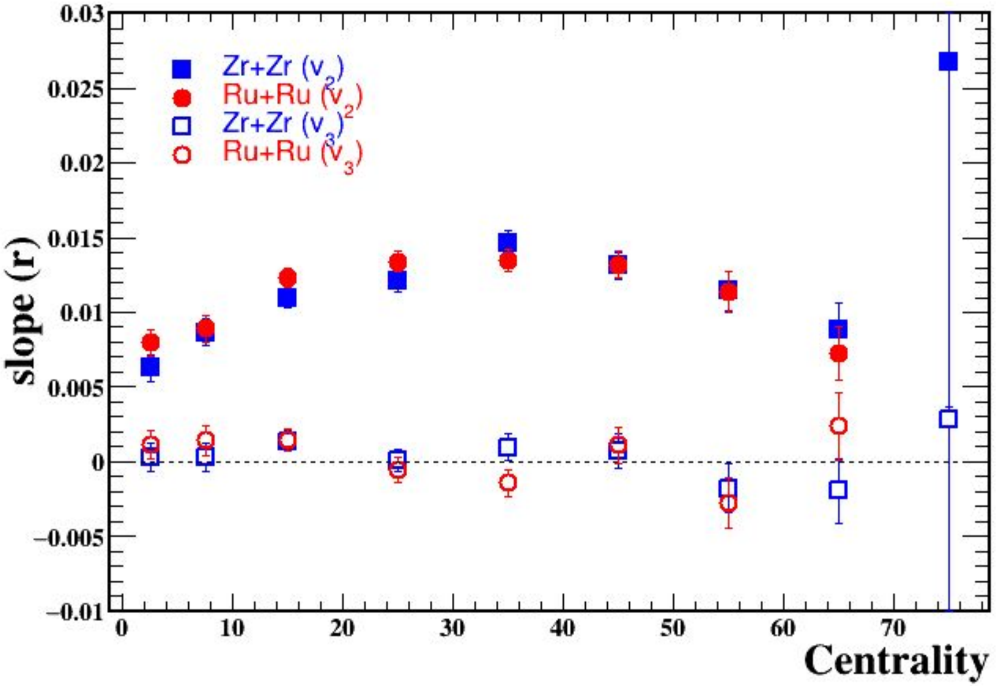






Comparison of slope (r) for 2nd and 3rd harmonics

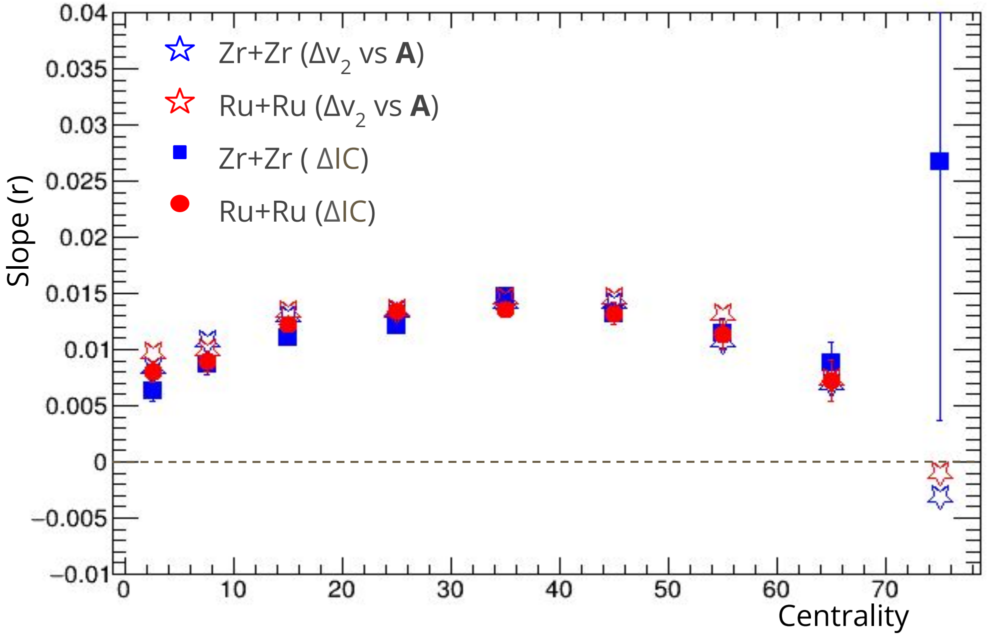
★ Slope (r) for 3rd harmonic is reduced significantly compared to 2nd harmonic and is close to zero.

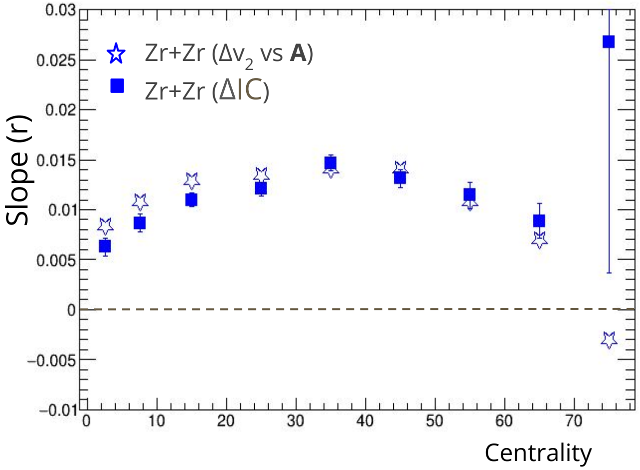


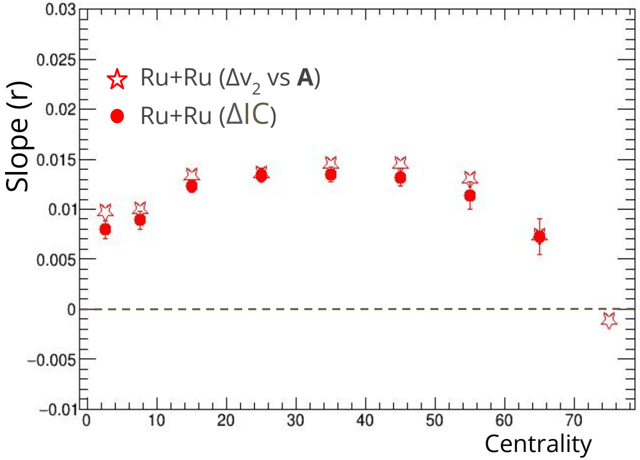
Comparing both methods

Gang Wang (UCLA) (Δv_2 vs **A**)

- ★ Pions ($0.15 < p_T < 0.5$ GeV/c)
- ★ Both results are comparable.







Summary

★ ΔIC of $\mathbf{v}_2$ and **A** is used to calculate CMW slope (**r**).

★ Both Ru+Ru and Zr+Zr shows similar splitting of integral correlator for positive and negative charged particles. Also exhibit similar value of slope (**r**) for different collisions centralities.

★ Integral covariance of $\mathbf{v}_3$ and **A** for positive and negative charged particle agrees within errors.

★ Slope (**r**) measured from delta integral correlator method are comparable with slope (**r**) measured from Δv_2 vs **A** method.

Outlook

★ Extract CMW fraction using ESE.

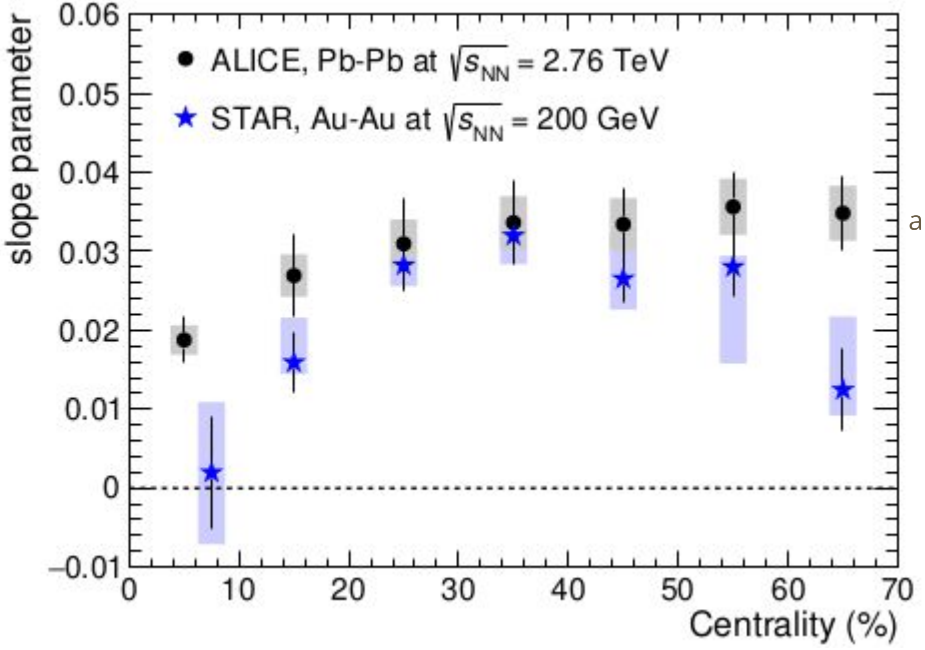
★ Do the analysis for pions.

THANK YOU

Backup

Backup

Different energies and cuts



arXiv:1512.05739v2 [nucl-ex]