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Probing Chiral Magnetic Wave in isobar collisions at $\sqrt{s_{NN}}$ = 200 GeV at RHIC-STAR

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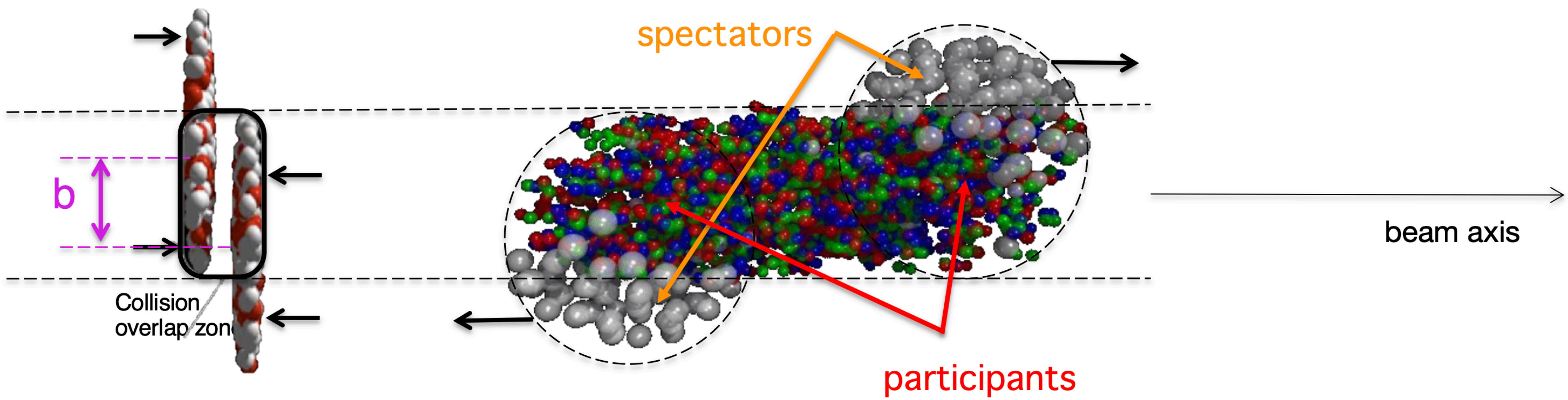
Outline

- Introduction
- Motivation
- Methodology
- Data Set
- Results
- Summary

Introduction

Non-Central Heavy Ion Collision



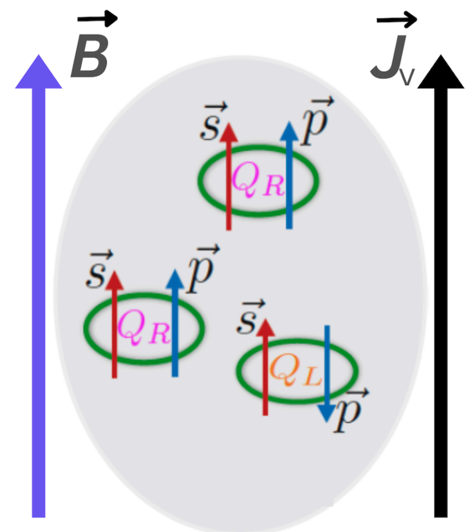
**Francesca Bellini, CERN SSL 2022*

- **QGP Formation:** Nucleons in the overlap region interact violently, creating an extremely hot and dense Quark Gluon Plasma (QGP), where quarks and gluons are deconfined.

- **Spectator Protons and Magnetic Field**: Spectator protons create a strong magnetic field perpendicular to the reaction plane.

Introduction

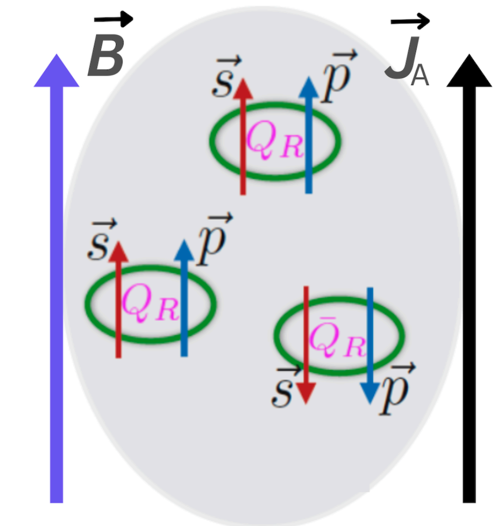
Chiral Magnetic Effect (CME)



$\mu_A \neq 0$

Electric currents aligned with the magnetic field due to chirality imbalance.

Chiral Separation Effect (CSE)



$\mu_v \neq 0$

Axial currents aligned with the magnetic field due to charge imbalance.

$$\vec{J}_V = \frac{N_c e}{2\pi^2} \mu_A \vec{B}$$

$$\vec{J}_A = \frac{N_c e}{2\pi^2} \mu_V \vec{B}$$

*Progress in Particle and Nuclear Physics 88 (2016) 1-28

CME + CSE = Chiral Magnetic Wave (CMW)

- The combination of the CME and CSE creates a feedback loop between charge and chiral densities, leading to the formation of the CMW.

Motivation

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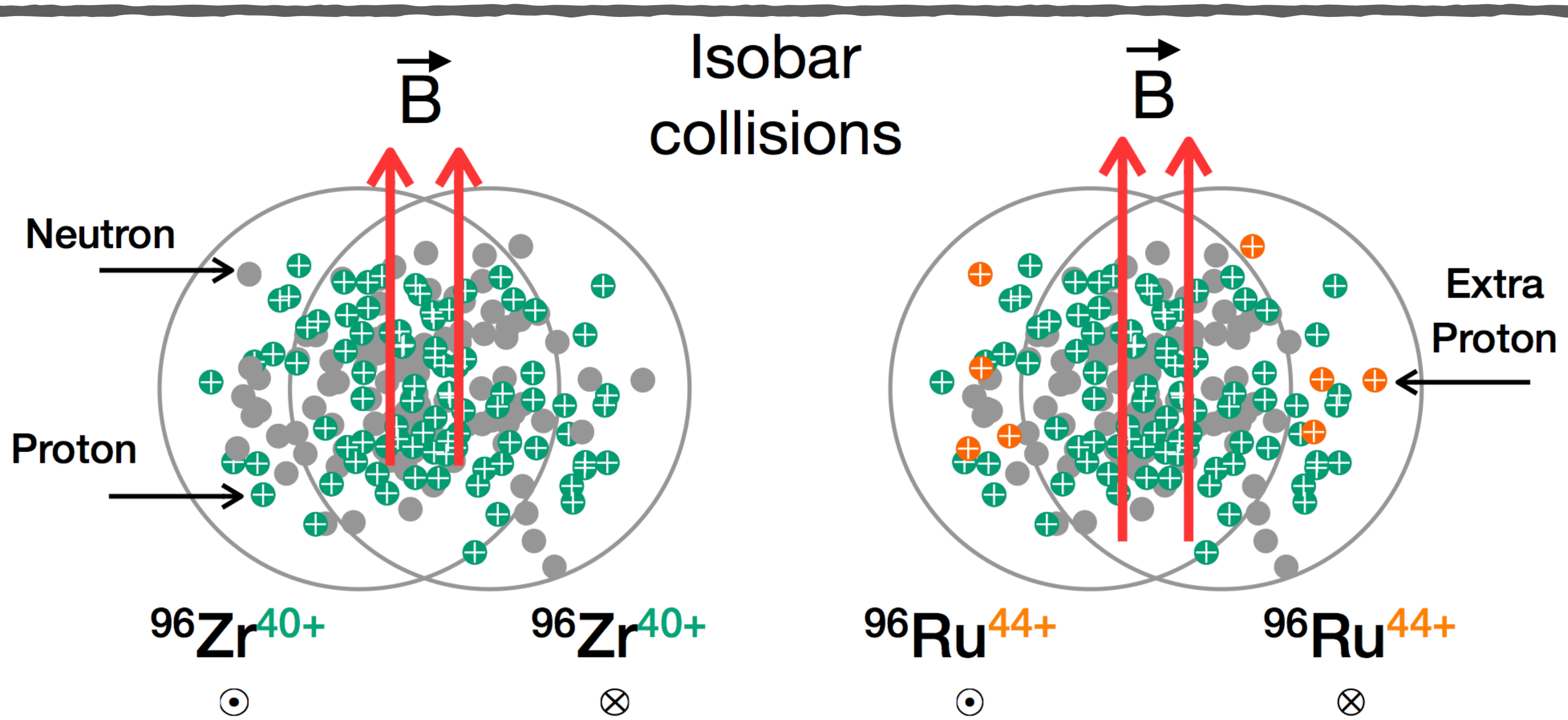
- As the CMW propagates, it induces an **electric quadrupole moment** in the QGP medium, where positive charges accumulate at the poles and negative charges at the equator of the nuclear overlap region resulting in charge-dependent elliptic flow asymmetry.
- Isobar collisions: Ru+Ru collisions expected to have 10-18% stronger magnetic field than Zr+Zr collisions due to the presence of 4 extra protons in Ru than Zr.
- Enhanced magnetic fields in Ru+Ru collisions are expected to give rise to larger CMW in Ru+Ru collisions compared to Zr+Zr collisions.



Methodology

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- Electric Quadrupole moment induced by CMW leading to difference in v_2 of charge particles, predicted to be proportional to charge asymmetry (**A**).

$$v_2^{\pm} - v_{2,base}^{\pm} = \mp \frac{r}{2} A$$

$$A = \frac{N_+ - N_-}{N_+ + N_-}$$

- Another way is measuring covariance of $v_2^{\pm}$ and **A**, as a function of centrality (3-point correlator or 3-particle correlator),

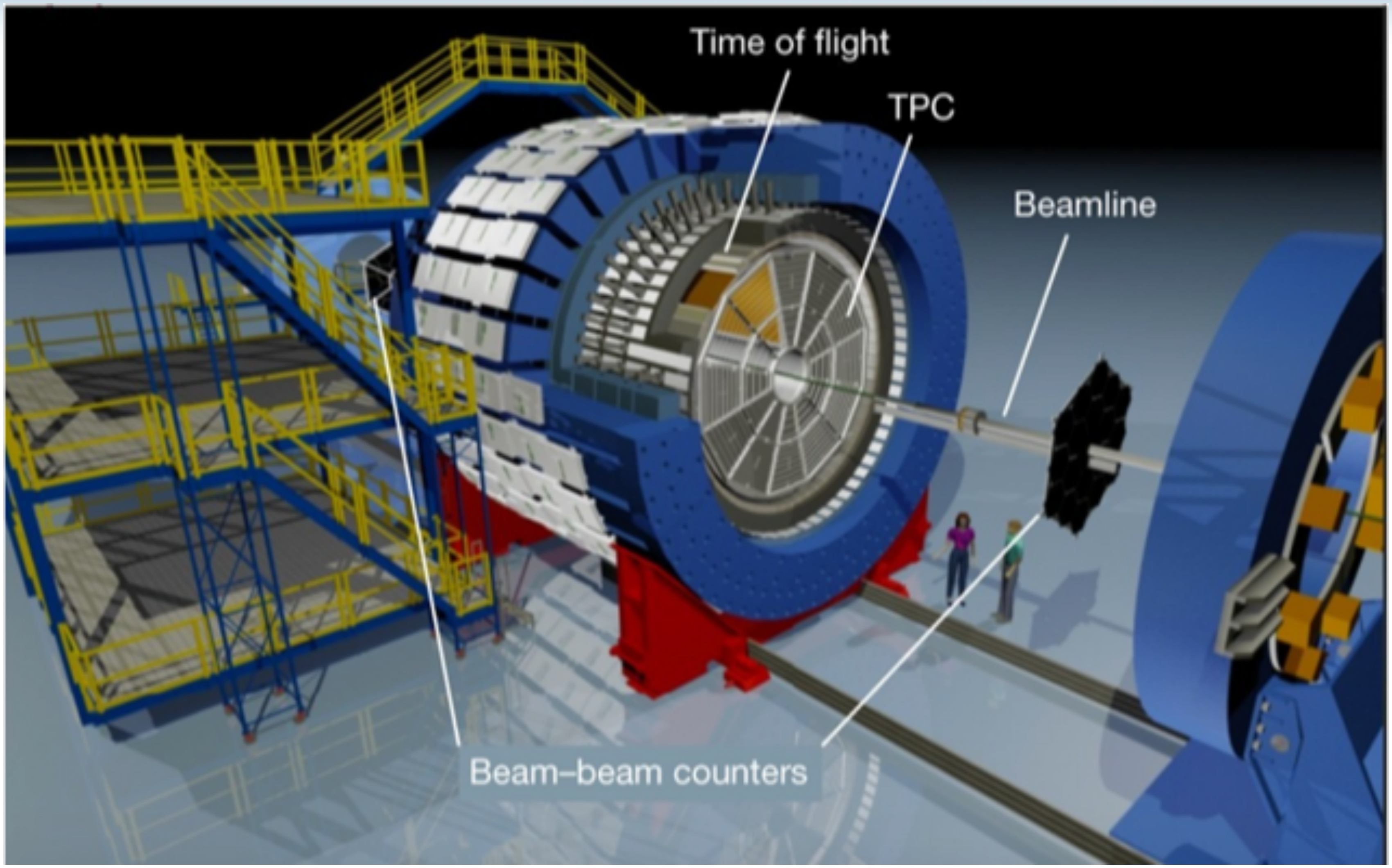
$$< v_2^{\pm} . A > - < A > < v_2^{\pm} > \approx \mp r(< A^2 > - < A >^2)/2 \approx \mp r\sigma_A^2/2$$

- Δ Integral Correlator:

$$\Delta IC = < v_2^{-} . A > - < A > < v_2^{-} > - (< v_2^{+} . A > - < A > < v_2^{+} >) \approx r\sigma_A^2$$

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

STAR Detector



https://www.star.bnl.gov

- Solenoid Tracker At RHIC (**STAR**).
- Time Projection Chamber (TPC) covers $|\eta| < 1$ and full azimuthal angle (ϕ = (0, 2π).
- TPC and Time Of Flight (TOF) are main detectors used for particle identification.

Data set

- Run 18
- Collision Type:

  Zr+Zr @ 200 GeV (~ 1.6B Events after cuts)

  Ru+Ru @ 200 GeV (~ 1.6B Events after cuts)

Event and Track cuts:

- $0.15 < p_T < 1$ GeV/*c*.
- $|\eta| < 1$.
- Vertex cut: $-35 < V_Z < 25$ cm
- DCA < 3 cm.

Results

Covariance of v_2 and A

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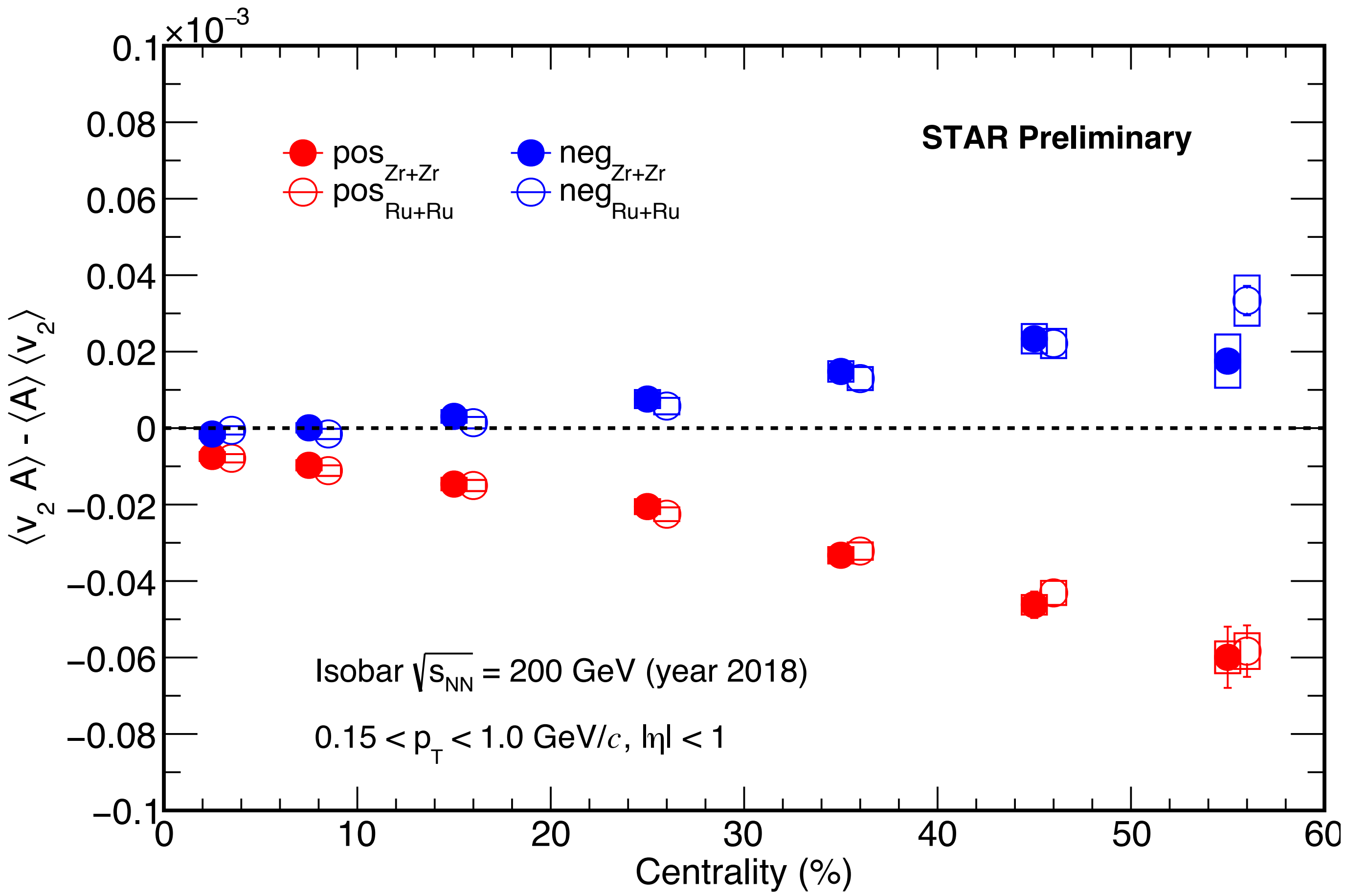
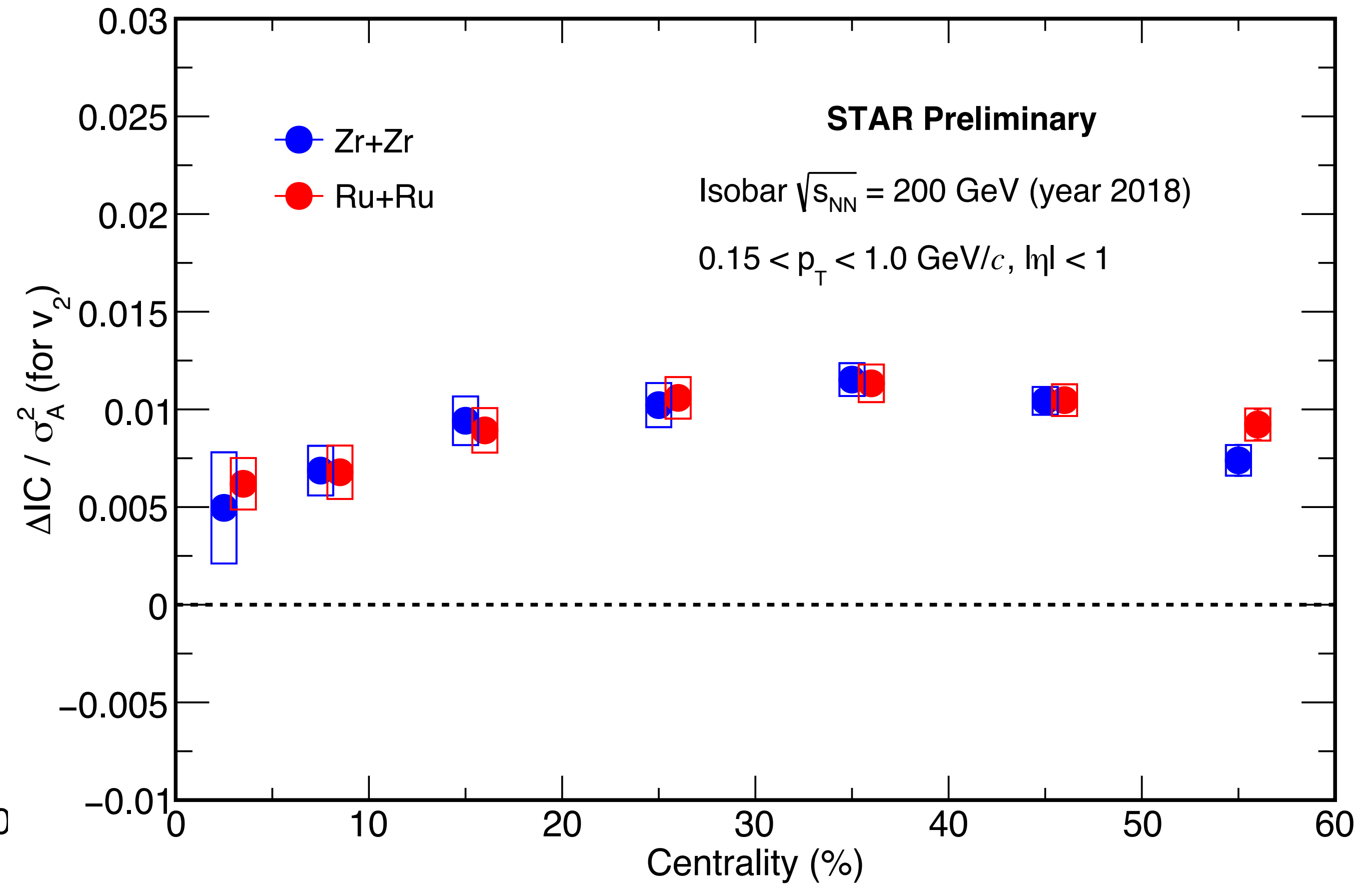
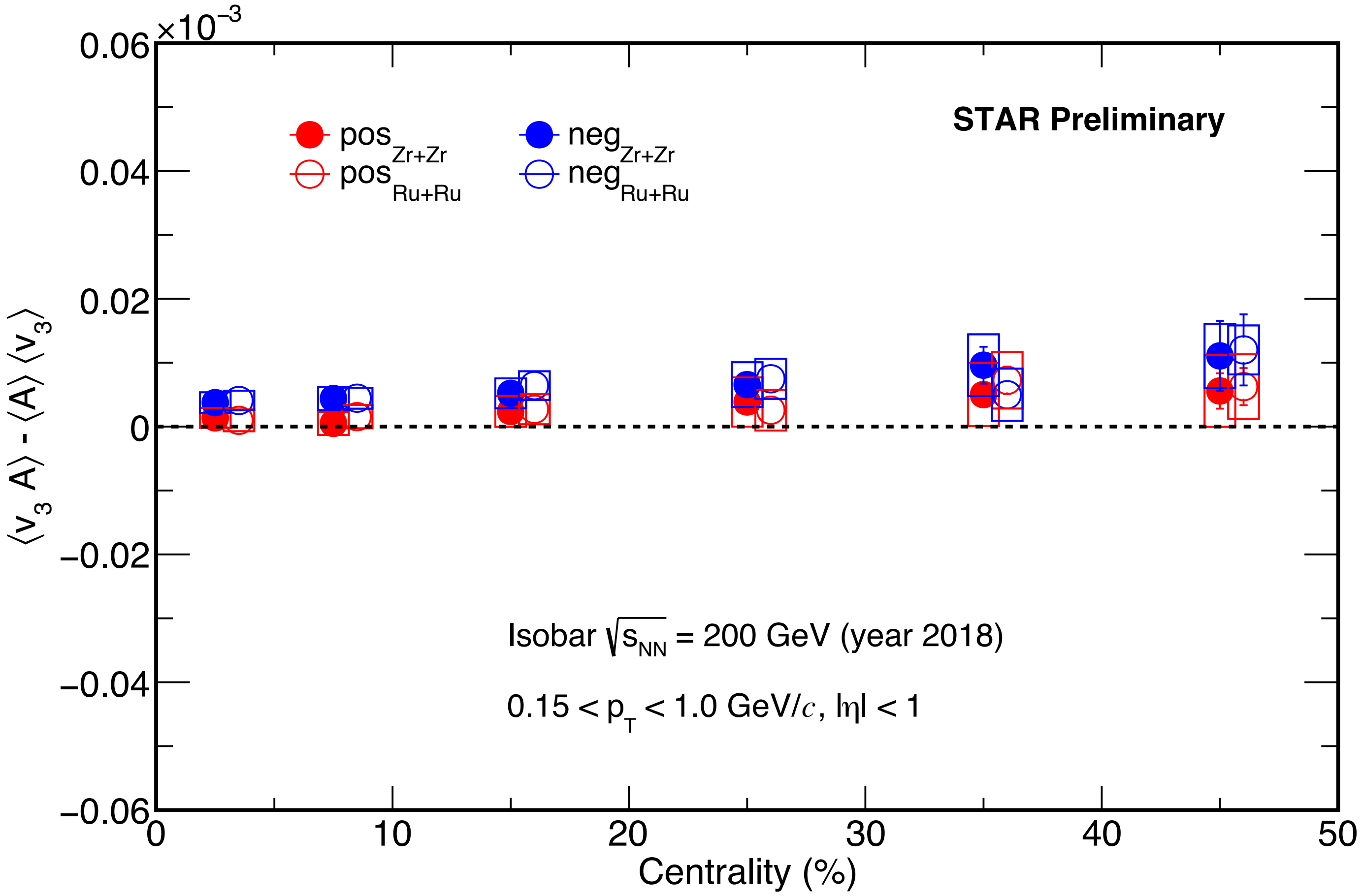
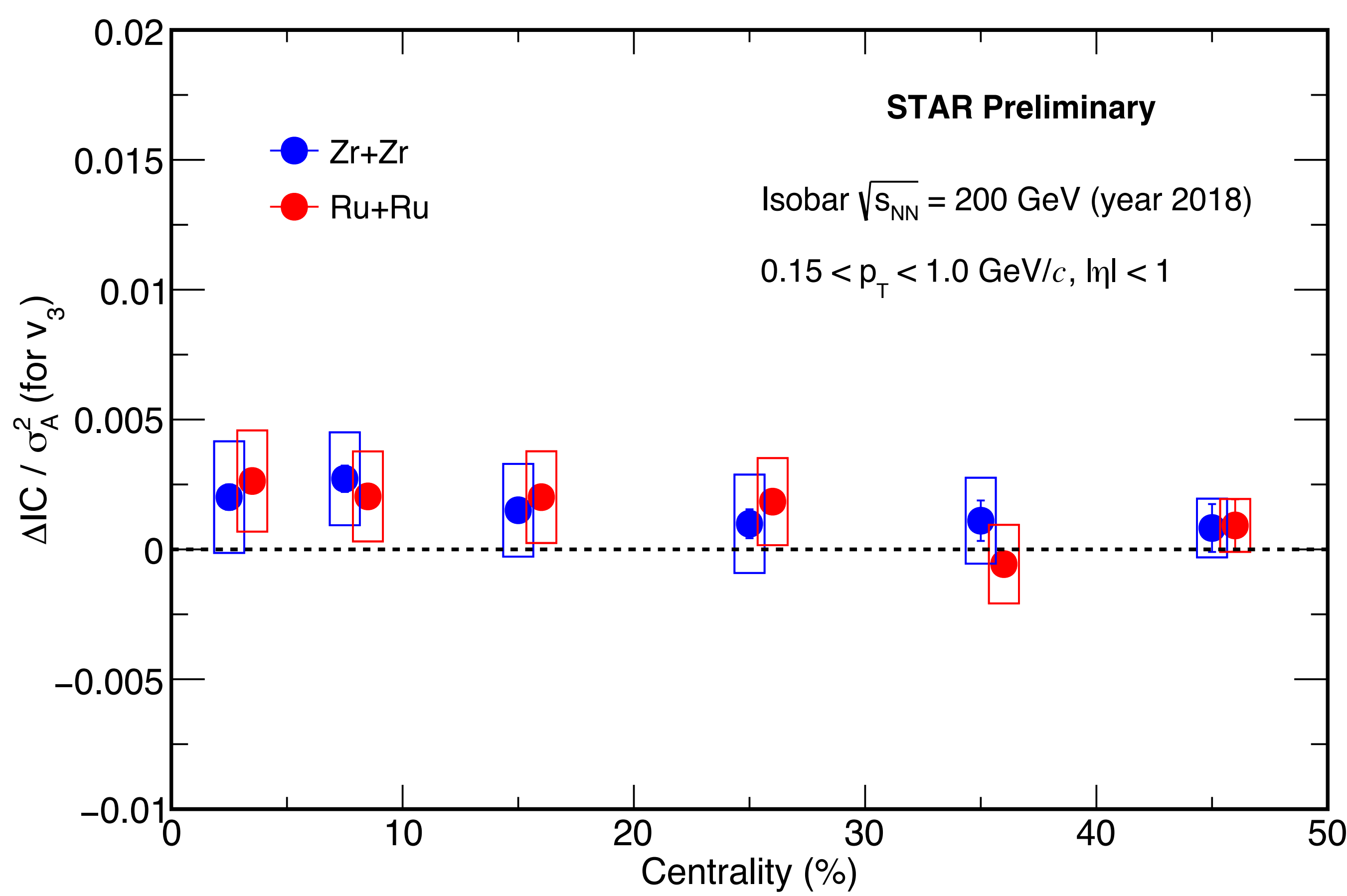




- v_2 calculated using Q cumulant method.
- η gap of 0.3 is taken between Reference Particles (RFP) and Particle of Interest (POI).
- Both Ru+Ru and Zr+Zr show splitting of covariance between v_2 and **A.**
- Both Collision systems shows similar values of $\Delta IC/\sigma_A^2$ (for v_2).

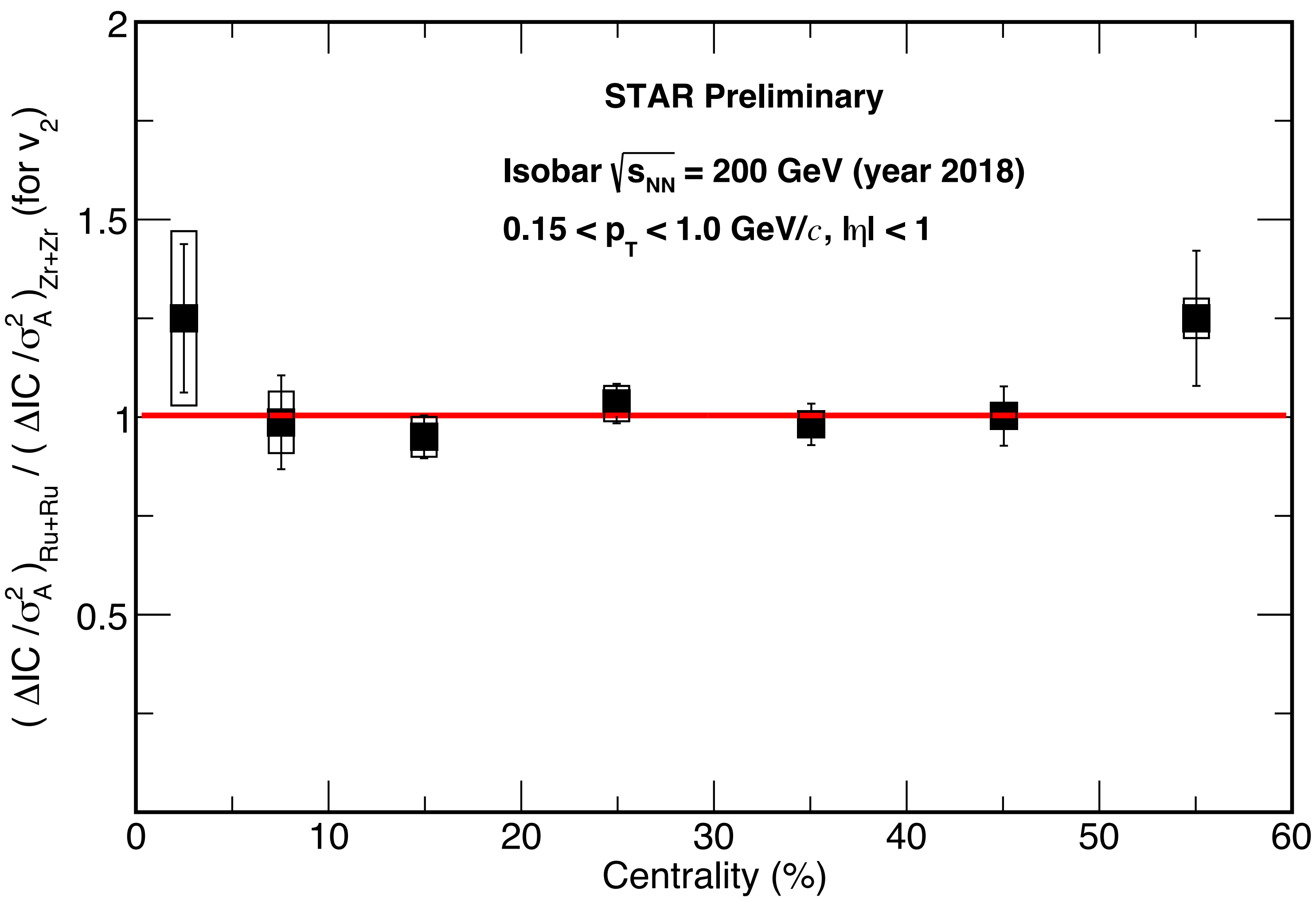
Covariance of v_3 and A





- v_3 calculated using Q cumulant method.
- η gap of 0.3 is taken between RFP and POI.
- Both Ru+Ru and Zr+Zr shows no splitting of covariance between v_3 and **A**.
- Both Collision systems shows similar values of $\Delta IC/\sigma_A^2$ (for v_3).

Ratio



- No enhancement is observed in $\Delta IC/\sigma_A^2$ for Ru+Ru collisions compared to Zr+Zr collisions, despite the Ru+Ru having 4 more protons than the Zr+Zr.
- pol0 fit value is 1.0042 +/- 0.0265.

Summary

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- Both Ru+Ru and Zr+Zr shows similar splitting of integral correlator for positive and negative charged particles.
- Integral covariance of v_3 and **A** for positive and negative charged particle agrees within errors.
- No enhanced splitting is observed in the Ru+Ru compared to the Zr+Zr, despite the Ru+Ru having 4 more protons than the Zr+Zr.

Outlook

- Comparison of results with other collision systems to study system size dependence.
- To determine f_{CMW} using Event Shape Engineering (ESE) technique.

Thank you for your attention