



# Measurements of global and local polarization of hyperons in 200 GeV isobar collisions from STAR

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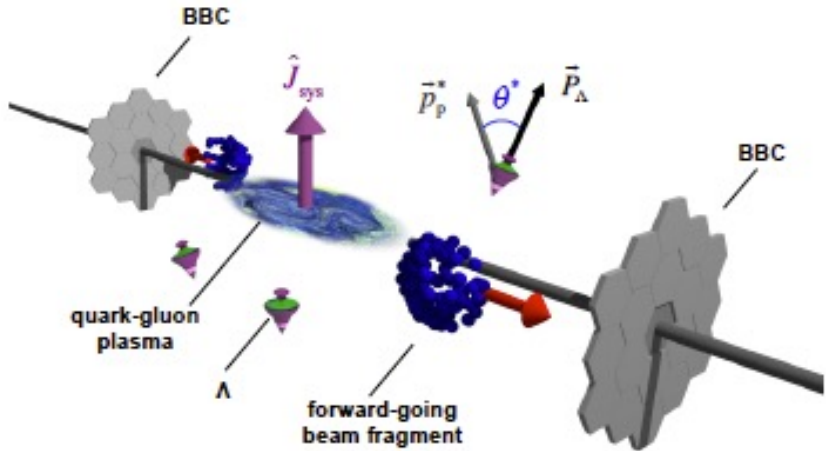
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- Motivation
- Part I : Hyperon global polarization
- Part II : Hyperon local polarization
- Summary

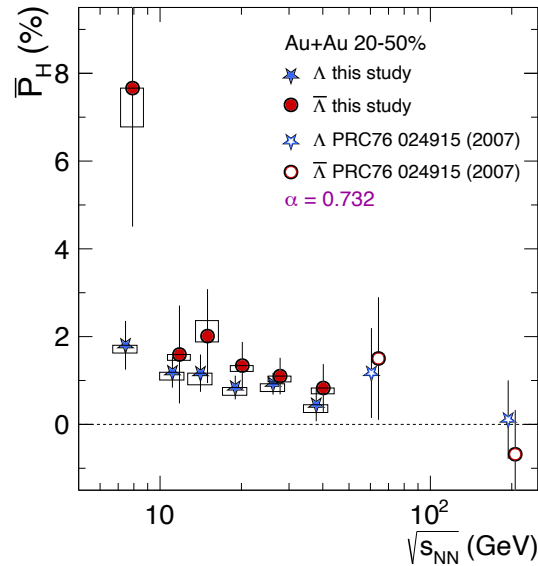


# Part I : Hyperon Global Polarization

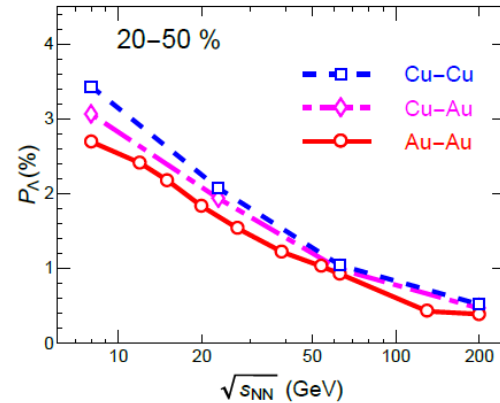
# Part I : Global Polarization Motivation



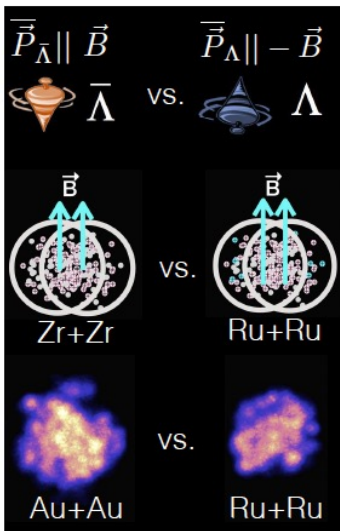
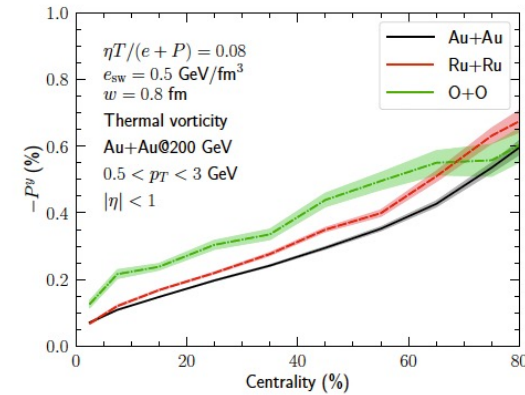
STAR, Nature 548, 62-65



Shuzhe Shi, Kangle Li, Jinfeng Liao  
PLB 788(2019) 409413



S. Alzhvani et al., arXiv:2203.15718



picture from P. Tribedy (QM22)

$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi} (1 + \alpha_H \mathbf{P}_H^* \cdot \hat{\mathbf{p}}_B^*)$$

$\mathbf{P}_H$ : hyperon polarization

$\hat{\mathbf{p}}_B$ : unit vector of daughter baryon momentum

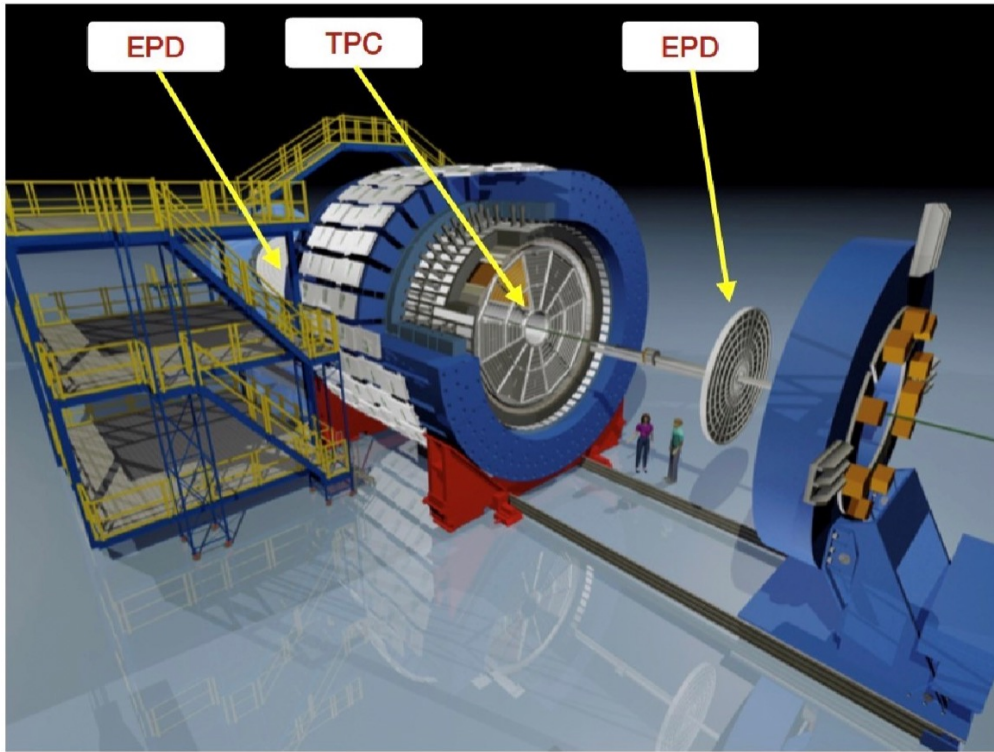
$\alpha_H$ : hyperon decay parameter

$$P_H = \frac{8}{\pi \alpha_H A_0} \frac{\langle \sin(\Psi_1 - \phi_B^*) \rangle}{Res(\Psi_1)}$$

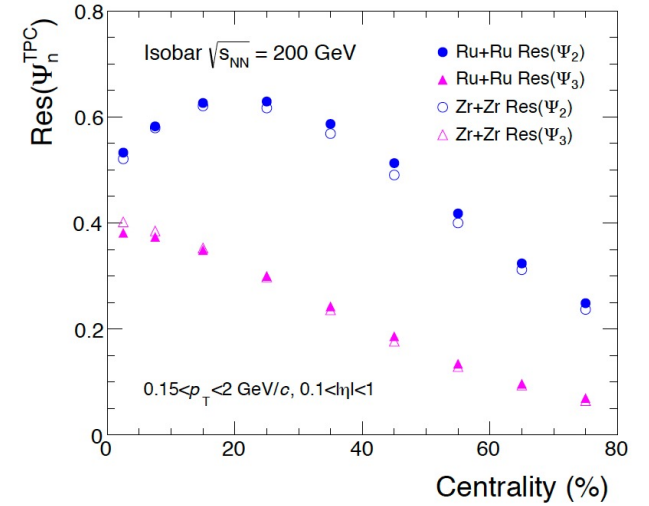
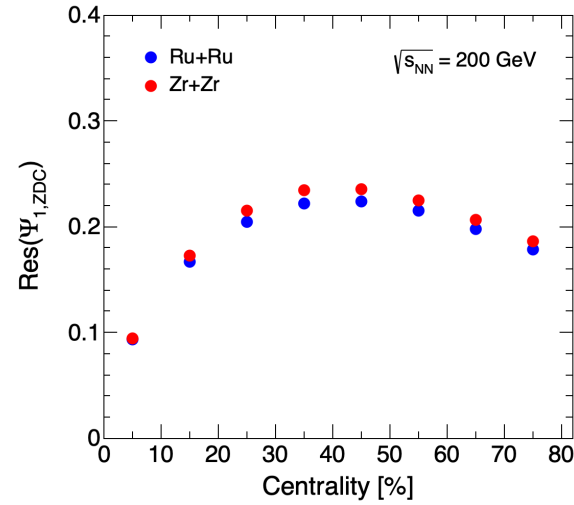
$$\alpha_\Lambda = -\alpha_{\bar{\Lambda}} = 0.732 \pm 0.014$$

- ❑ STAR has observed the energy dependence of global polarization in Au+Au collision.
- ❑ Global polarization difference from different magnetic field in Zr+Zr and Ru+Ru?
- ❑ System size dependence of global polarization?

# Part I : STAR detector and $\Lambda/\bar{\Lambda}$ reconstruction

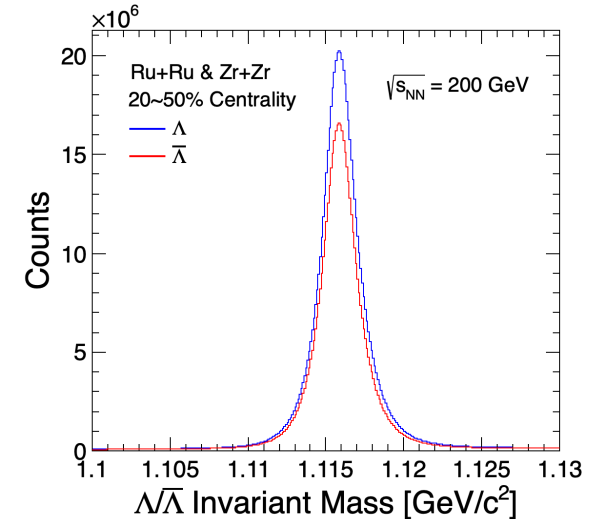
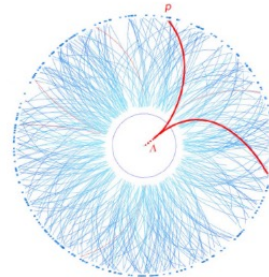


## Event plane reconstruction



## $\Lambda/\bar{\Lambda}$ reconstructed with TPC tracks

- $\Lambda \rightarrow p + \pi^-$
- $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$



### Time Projection Chamber:

- $|\eta| < 1$ , full azimuth momentum
- PID via energy loss
- Event plane reconstruction

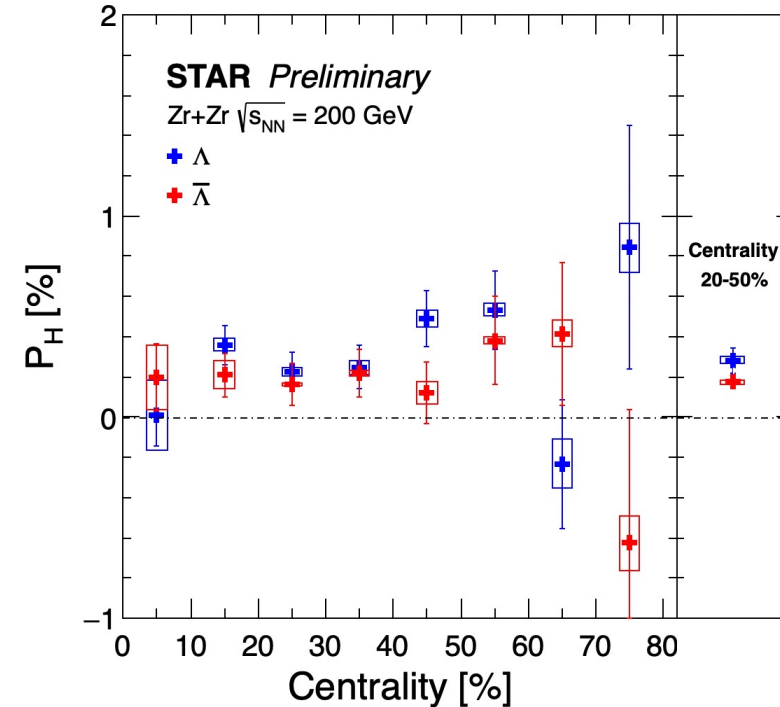
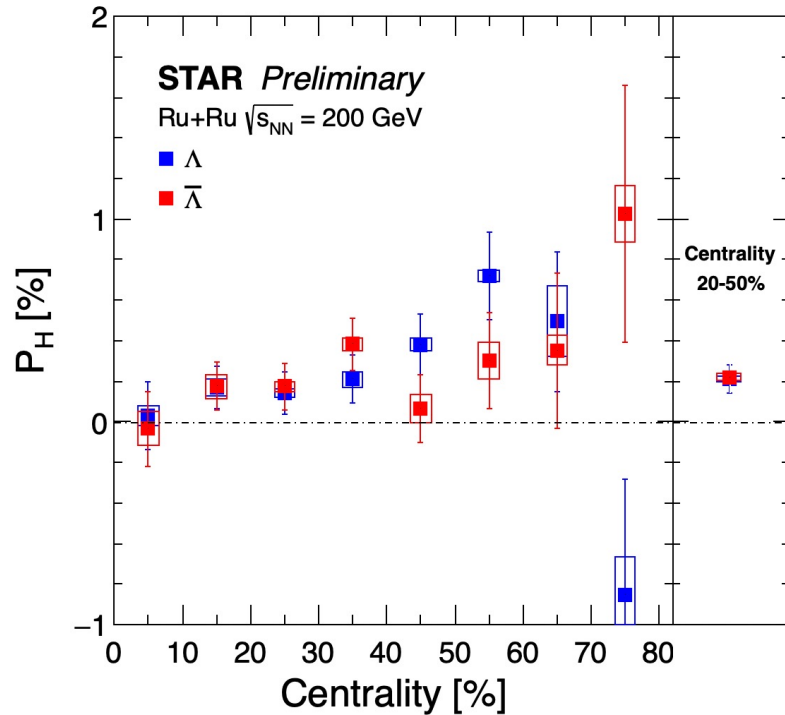
### Time Of Flight:

- $|\eta| < 0.9$ , full azimuth
- PID via particle velocity

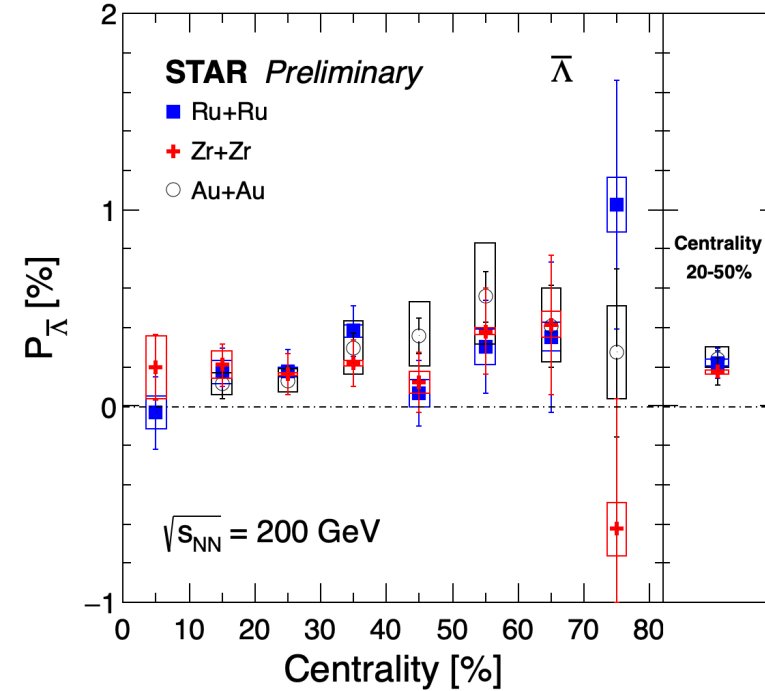
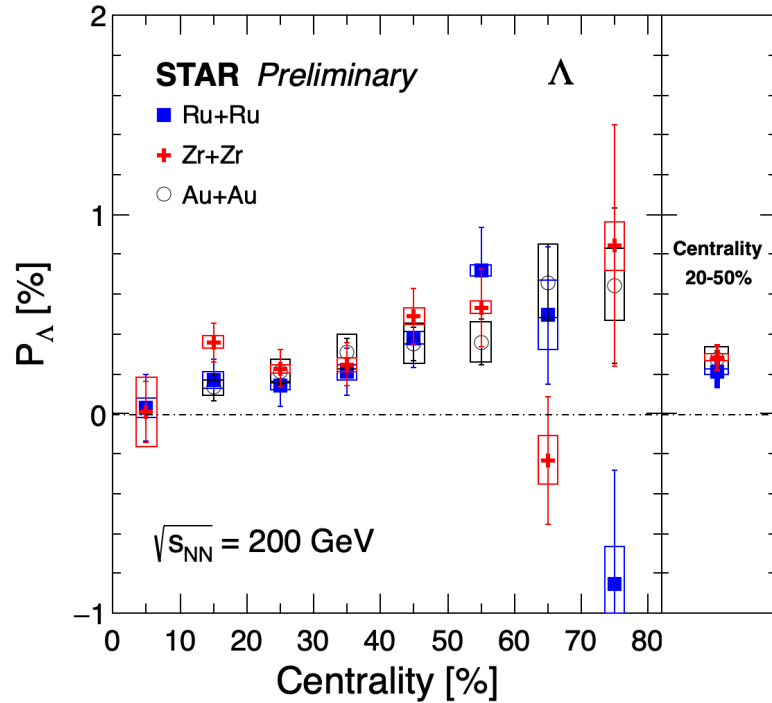
### Zero Degree Calorimeters

- Event plane reconstruction

# Part I : Global polarization of $\Lambda$ and $\bar{\Lambda}$



- Significant global polarization observed,  $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  increase with centrality.
- No significant difference between  $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  in Ru+Ru and Zr+Zr collisions.
- Global polarization of  $\Lambda + \bar{\Lambda}$  are consistent between Ru+Ru and Zr+Zr collisions.



- Global polarization of  $\Lambda$  and  $\bar{\Lambda}$  are consistent between Isobar and Au+Au collision systems, no collision system dependence is observed within uncertainties.

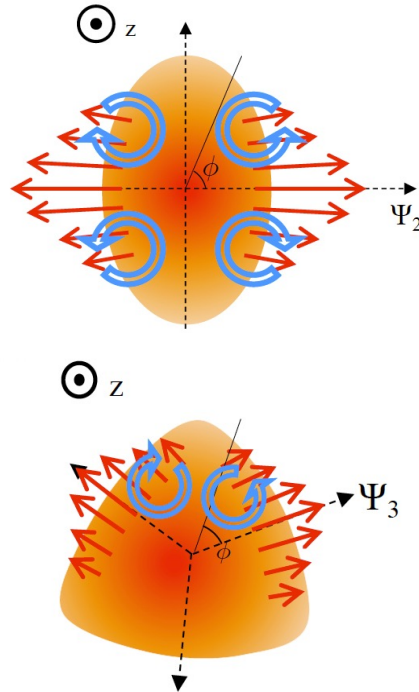
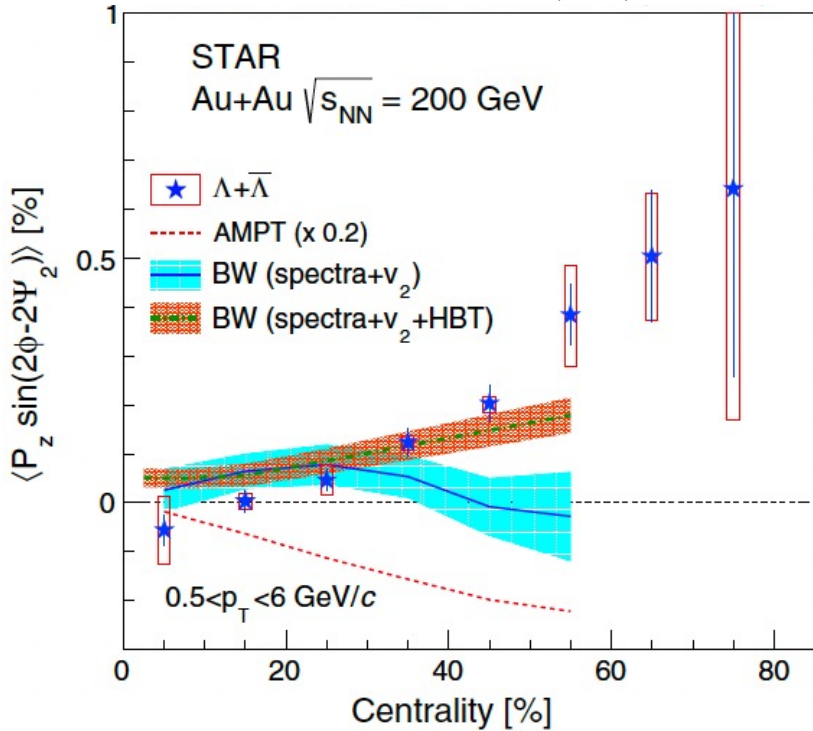


## Part II : Hyperon Local Polarization



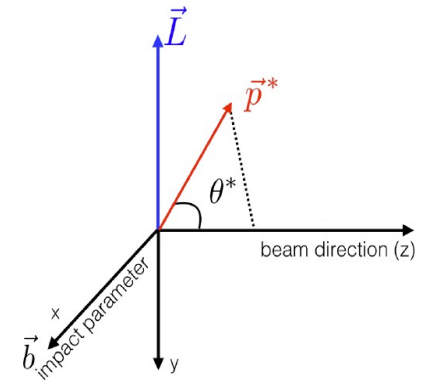
# Part II : Local Polarization Motivation

STAR, PRL123, 132301 (2019)



$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi} (1 + \alpha_H \mathbf{P}_H^* \cdot \hat{\mathbf{p}}_B^*)$$

$$\begin{aligned} \langle \cos\theta_B^* \rangle &= \int \frac{dN}{d\Omega^*} \cos\theta_B^* d\Omega^* \\ &= \alpha_H P_z \langle (\cos\theta_B^*)^2 \rangle \end{aligned}$$

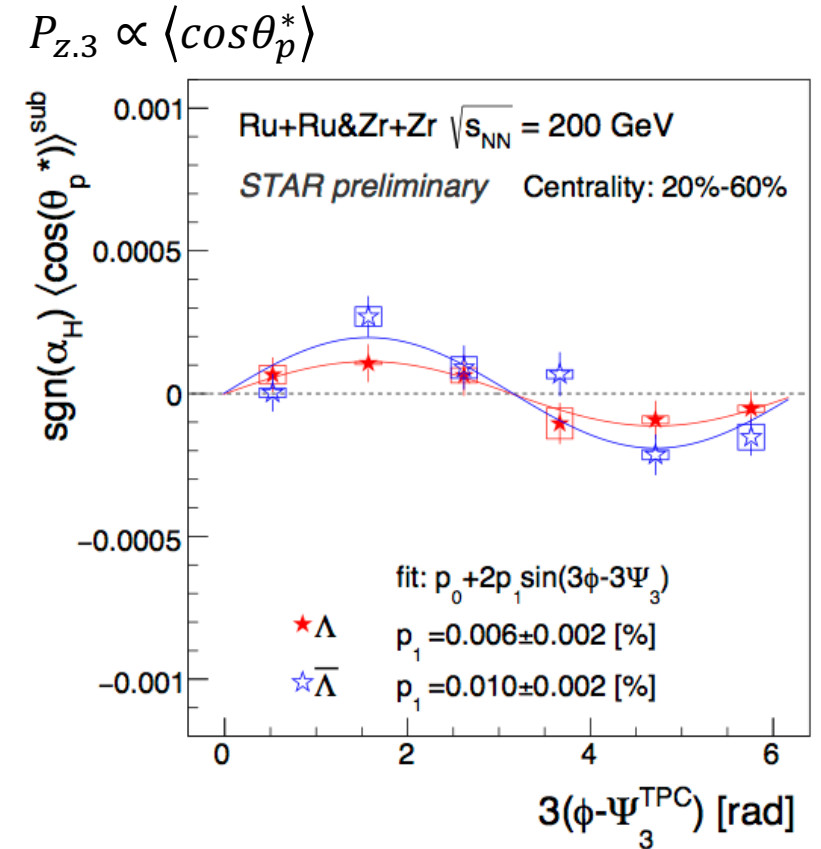
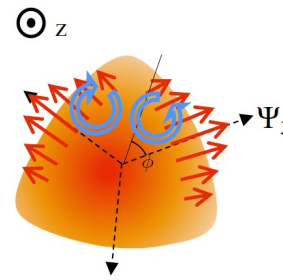
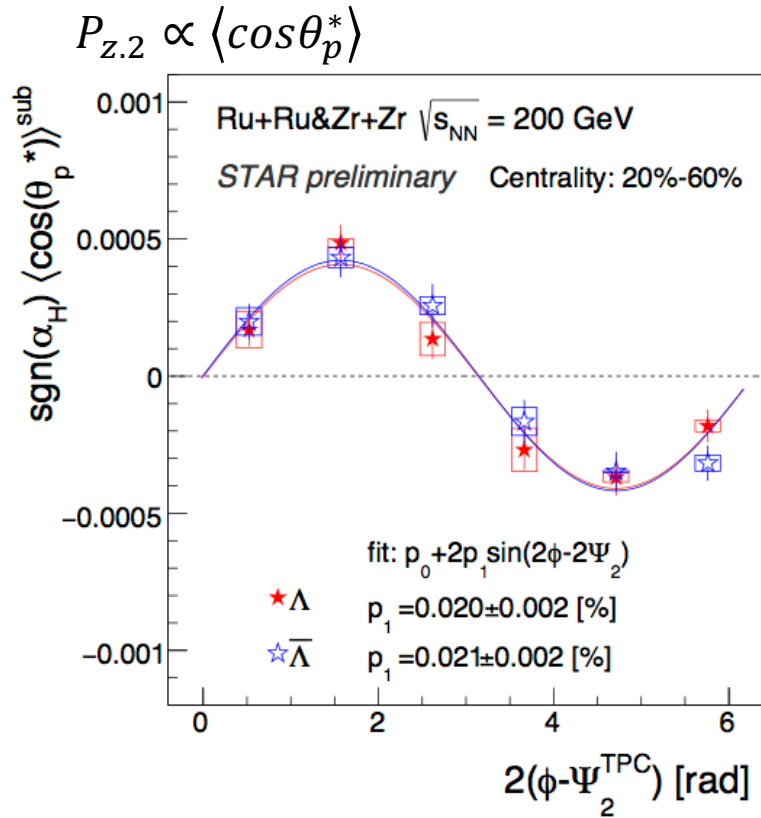
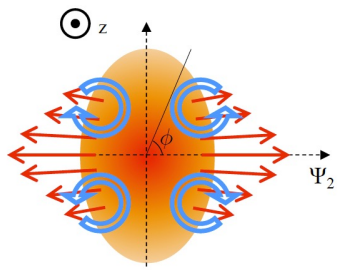


$$P_z = \frac{\langle \cos\theta_B^* \rangle}{\alpha_H \langle (\cos\theta_B^*)^2 \rangle}$$

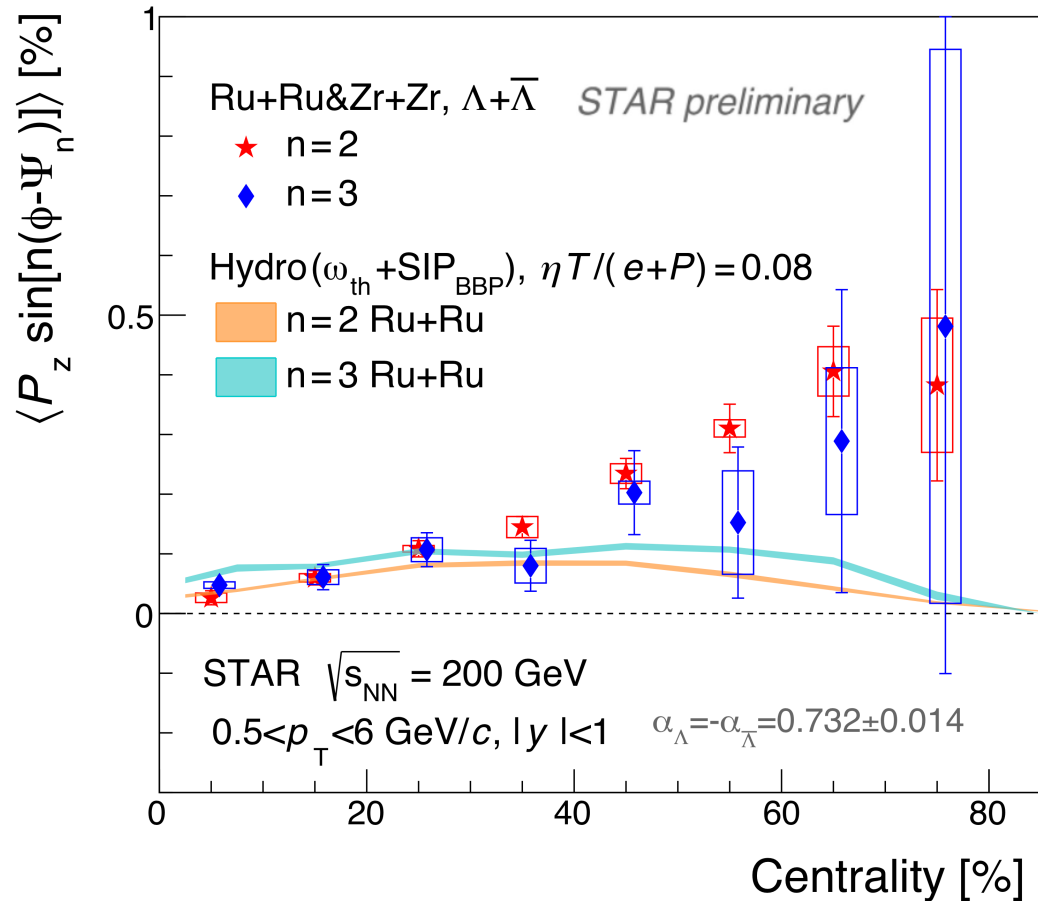
$\langle (\cos\theta_B^*)^2 \rangle$  : accounts for acceptance effect (close to 1/3)

- ❑ Local vorticity induced by anisotropic flow results in polarization along the beam direction.
- ❑ Measurements in smaller systems and relative to higher harmonic event planes provides new insights into polarization phenomena.

# Part II : Local polarization : “z-component” of polarization $P_{z,n}$



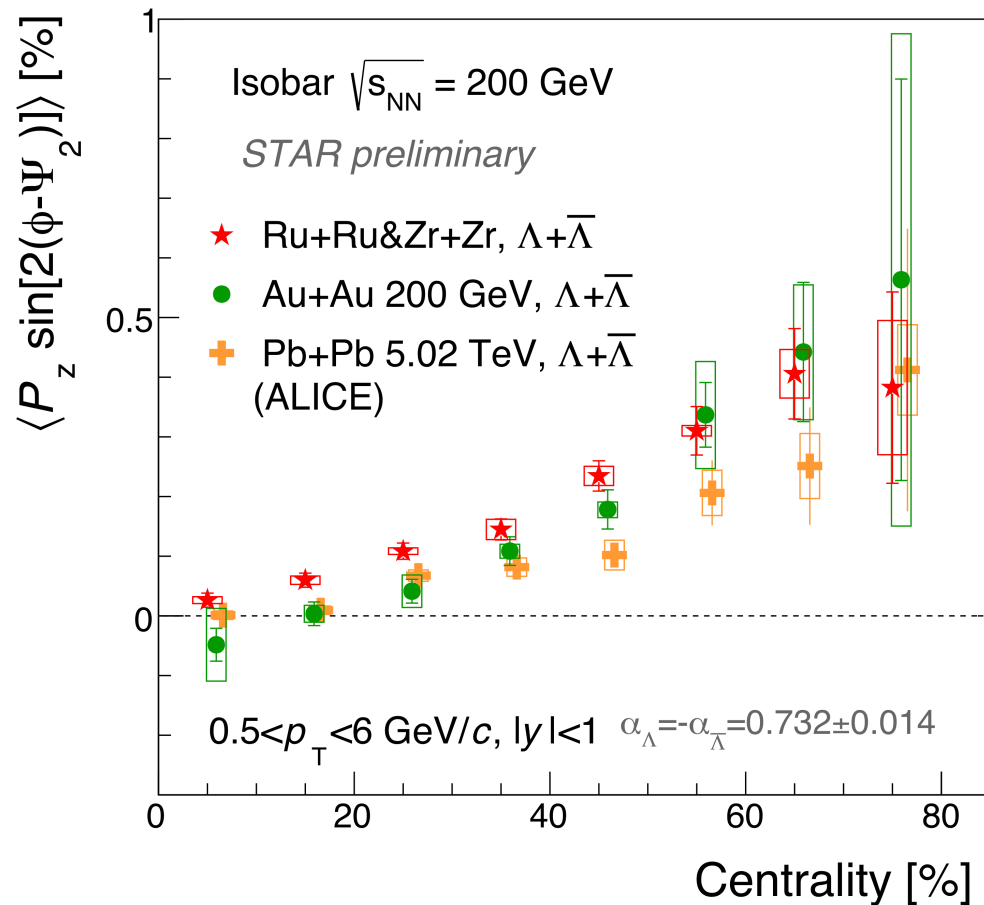
- Polarization along the beam direction expected from the “elliptic flow”
- STAR data indeed show such a longitudinal polarization depending on azimuthal angle(sine function)
- First measurement relative to the 3<sup>rd</sup>-order event plane  $\Psi_3$ 
  - Similar pattern to the 2<sup>nd</sup>-order, indicating  $v_3$ -driven polarization



- Comparable 2<sup>nd</sup> and 3<sup>rd</sup> order sine coefficients of  $P_{z,n}$ , especially in most central events
- Hydrodynamic models with shear term reasonably describes the data for central collisions, but not for peripheral, Additional constraint on shear viscosity

S. Alzhrani et al., arXiv:2203.15718

# Part II : Collision system size dependence of $P_{z,2}$



- $P_{z,n}$  from Isobar data comparable to Au+Au and Pb+Pb
  - A hint of system size dependence rather than energy dependence

Au+Au: STAR, PRL123, 132301 (2019)

Pb+Pb: ALICE, arXiv:2107.11183

- Measurements of  $\Lambda/\bar{\Lambda}$  global polarization in Ru+Ru and Zr+Zr collisions at  $\sqrt{s_{NN}} = 200$  GeV.
  - $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  are consistent with each other.
  - $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  are consistent between Ru+Ru and Zr+Zr collisions.
  - $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  in Isobar collision are consistent with Au+Au collisions, no collision system dependence is observed.
  
- Measurements of  $\Lambda/\bar{\Lambda}$  polarization along the beam direction relative to the second and third-order event planes in isobar collisions at  $\sqrt{s_{NN}} = 200$  GeV.
  - Clear second-order Event Plane dependence in Ru+Ru&Zr+Zr similar to Au+Au.
  - First measurement of the third-order Event Plane dependence, indicating vorticity induced by triangular flow.
  - The sine Fourier coefficients of  $P_z$  are comparable between the second and third orders, with increasing trend towards peripheral collisions.
  - A hint of collision system size dependence by comparison with Au+Au and Pb+Pb.



