



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

Xingrui Gou (苟兴瑞) for the STAR Collaboration

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山东大学  
SHANDONG UNIVERSITY

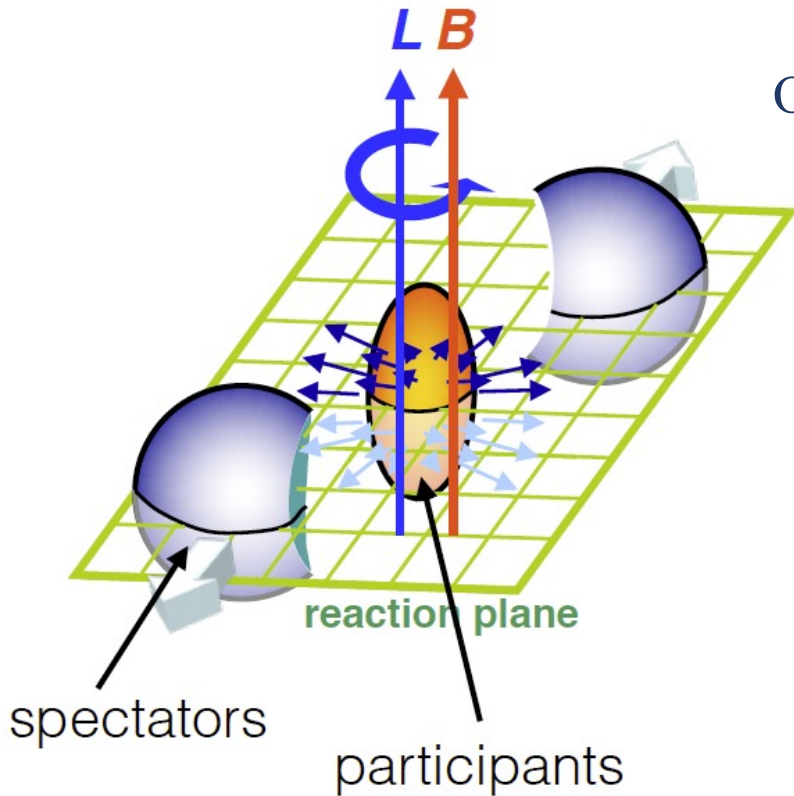


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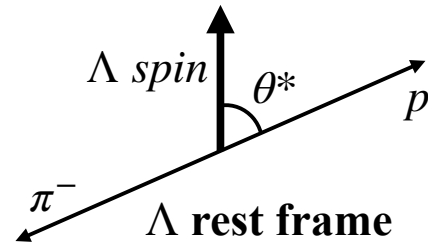
- Motivation
- Hyperon global polarization
- Hyperon local polarization
- Summary

# Global polarization of hyperons in heavy ion collisions



Orbital angular momentum  
 ↳ Lead to global polarization

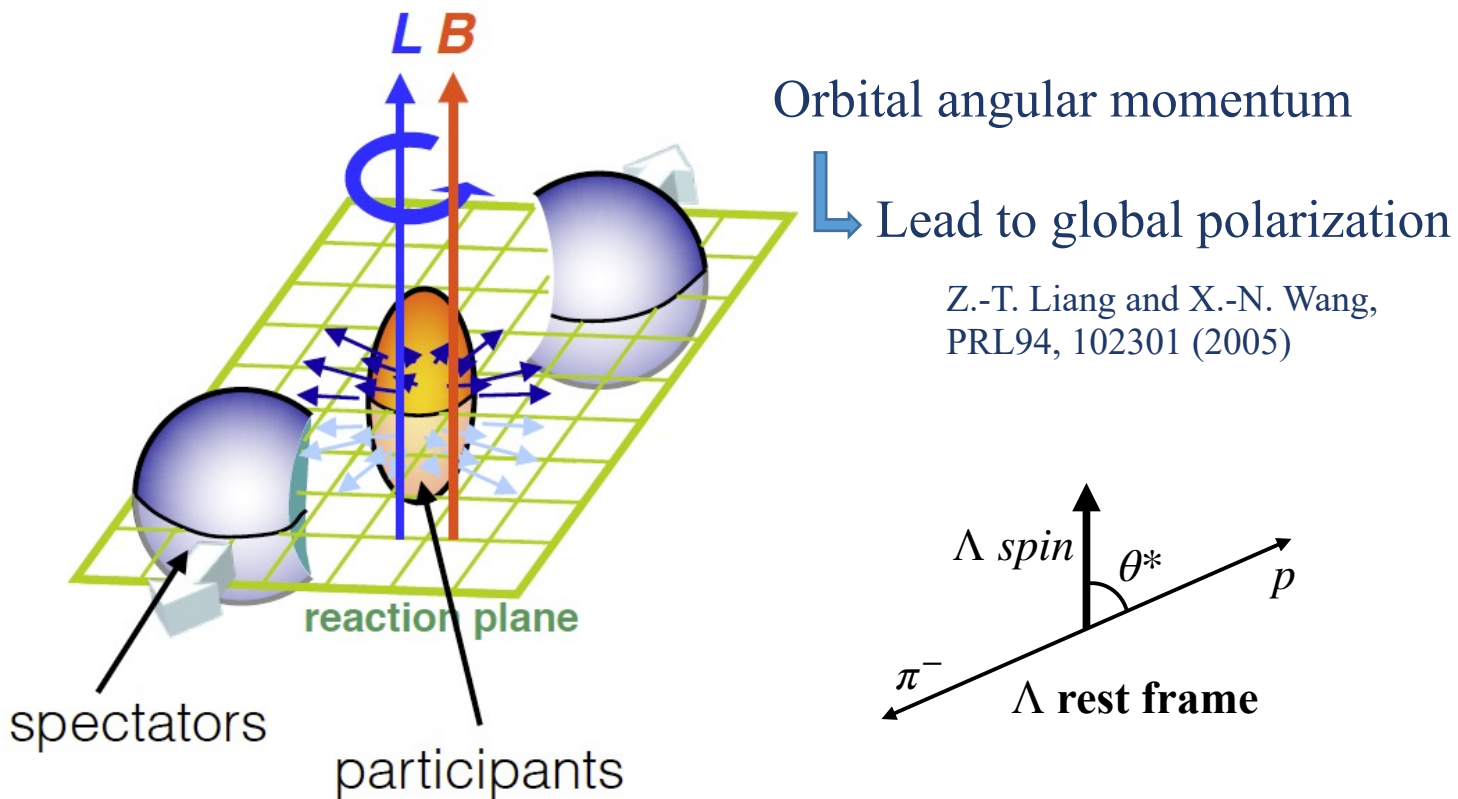
Z.-T. Liang and X.-N. Wang,  
 PRL94, 102301 (2005)



$$P_{\Lambda} = \frac{8}{\pi \alpha_{\Lambda} A_0} \frac{1}{Res(\Psi_1)} \langle \sin(\Psi_1 - \phi_p^*) \rangle$$

$\alpha_{\Lambda} = -\alpha_{\bar{\Lambda}} = 0.732 \pm 0.014$   
 $A_0$ : Acceptance correction factor  
 $\Psi_1$ : First - order event plane angle

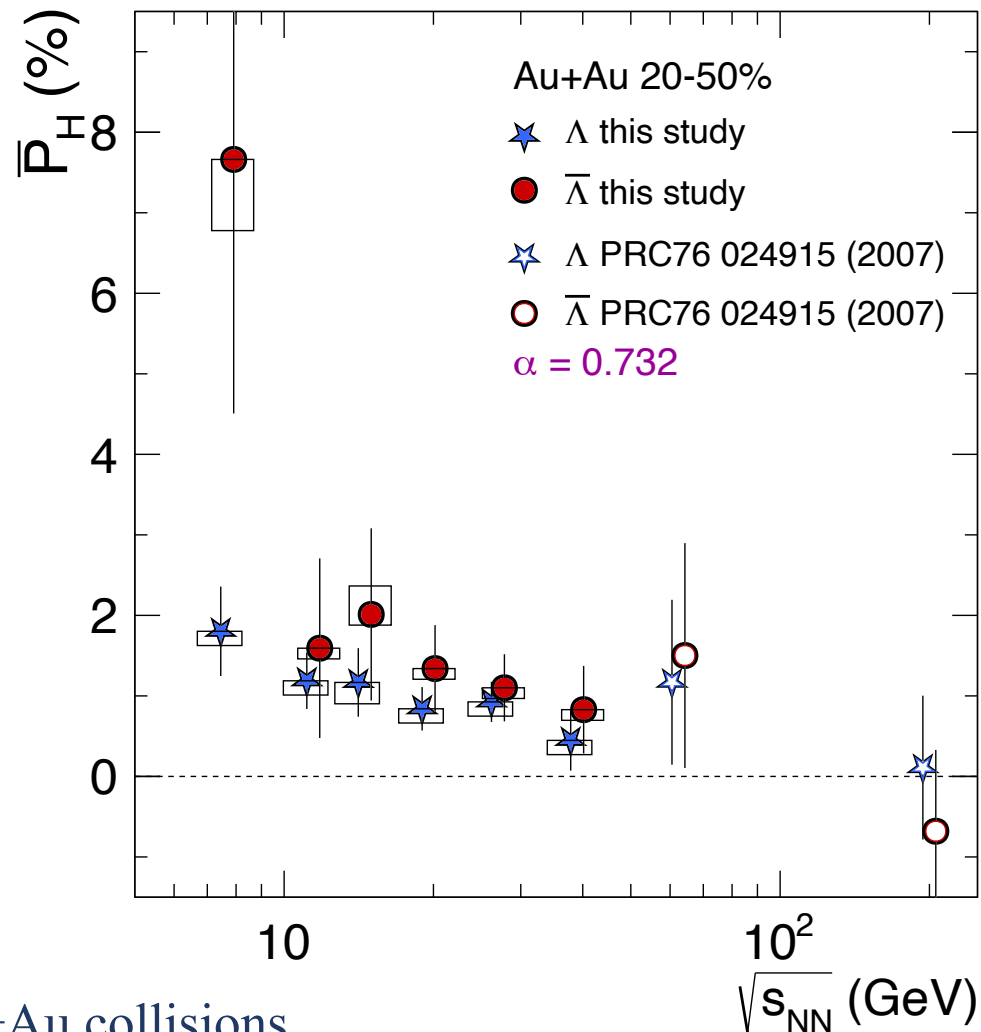
# Global polarization of hyperons in heavy ion collisions



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STAR, Nature 548, 62-65

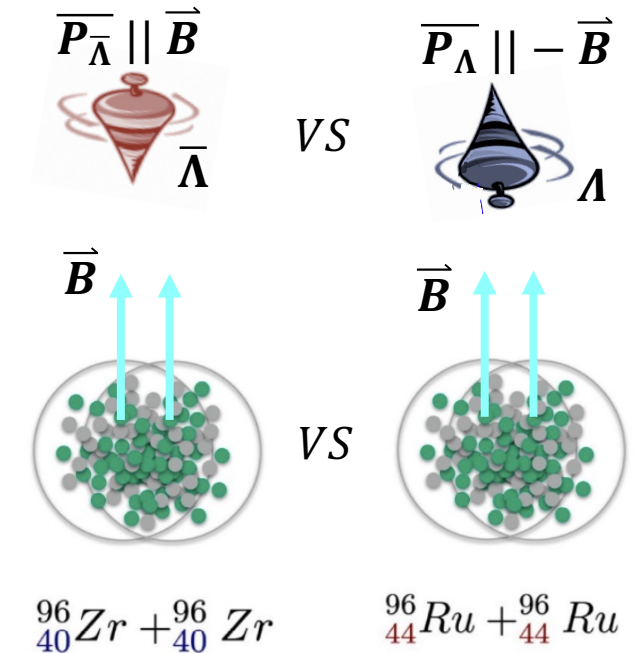
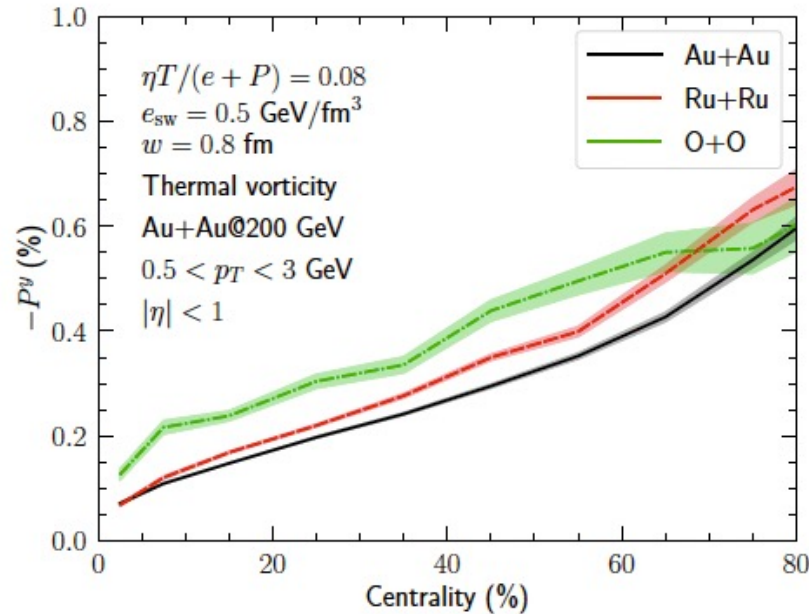
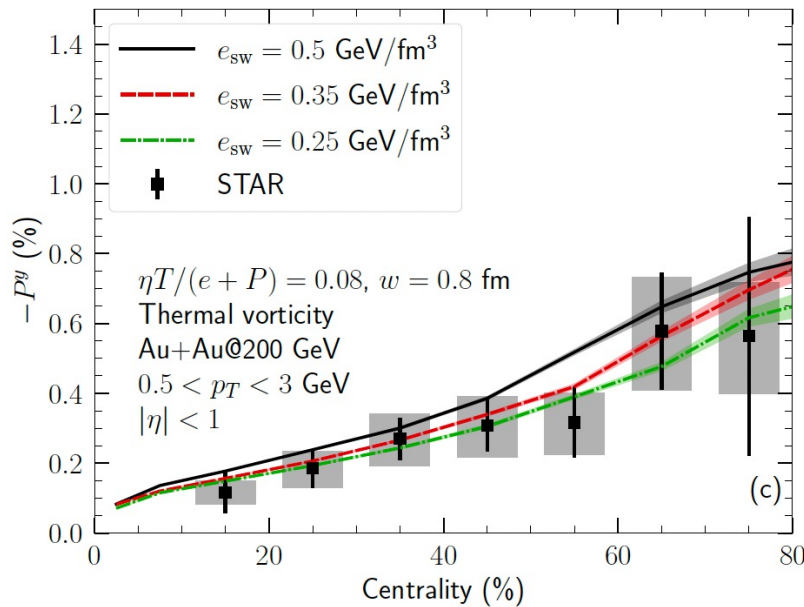


□ Significant global polarization of  $\Lambda$  and  $\bar{\Lambda}$  observed in Au+Au collisions.

# Global polarization of hyperons in heavy ion collisions

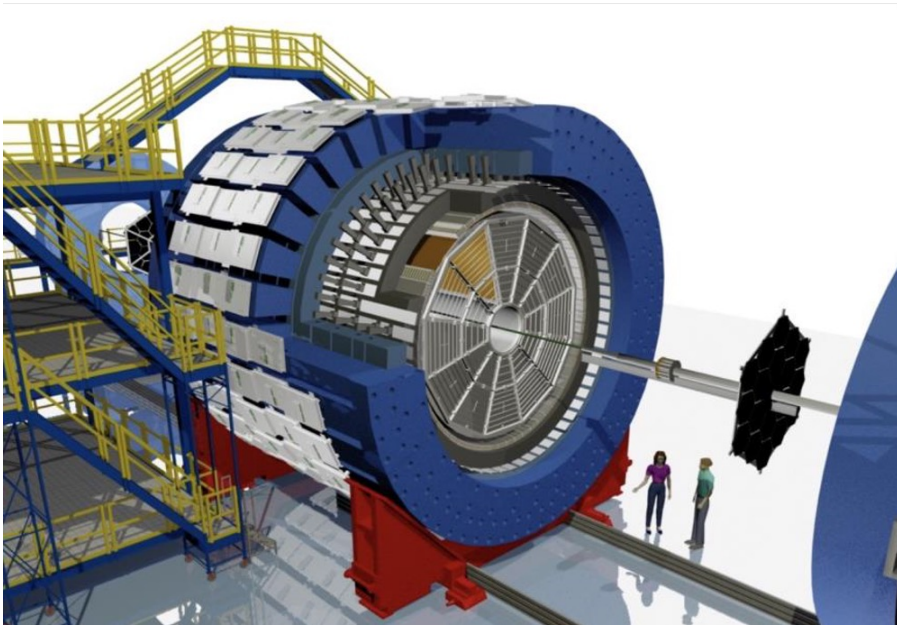


S. Alzhrani et al., arXiv:2203.15718



- System size dependence of global polarization?
- Global polarization difference from different magnetic fields in Zr+Zr and Ru+Ru?





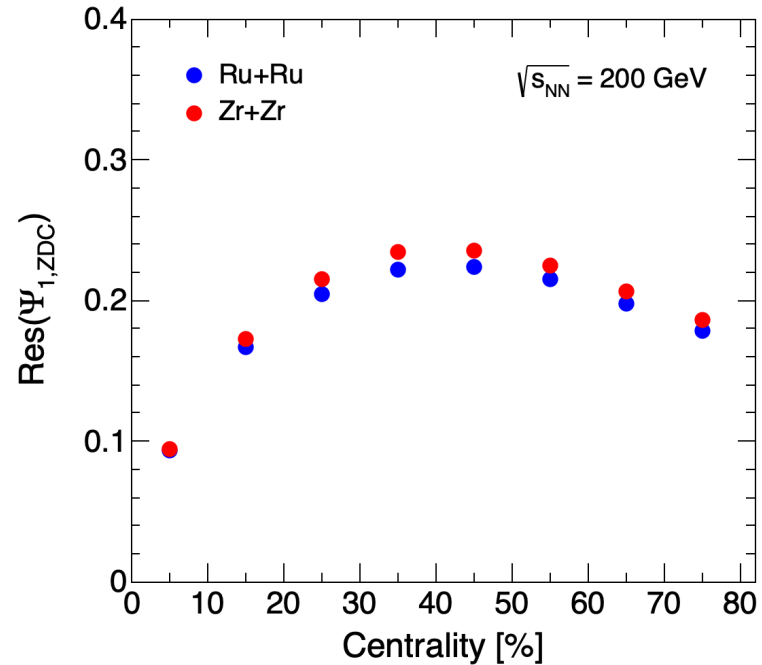
## Event plane reconstruction:

Time Projection Chamber  
Zero Degree Calorimeters

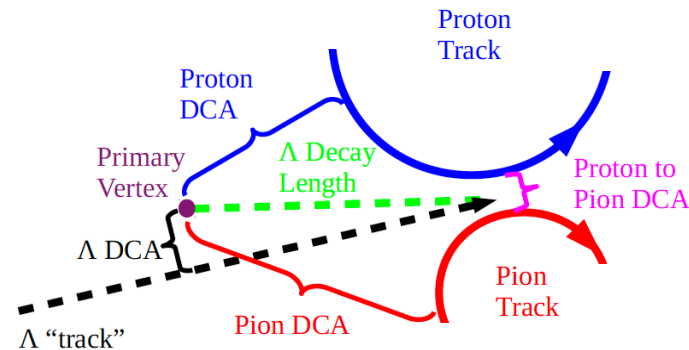
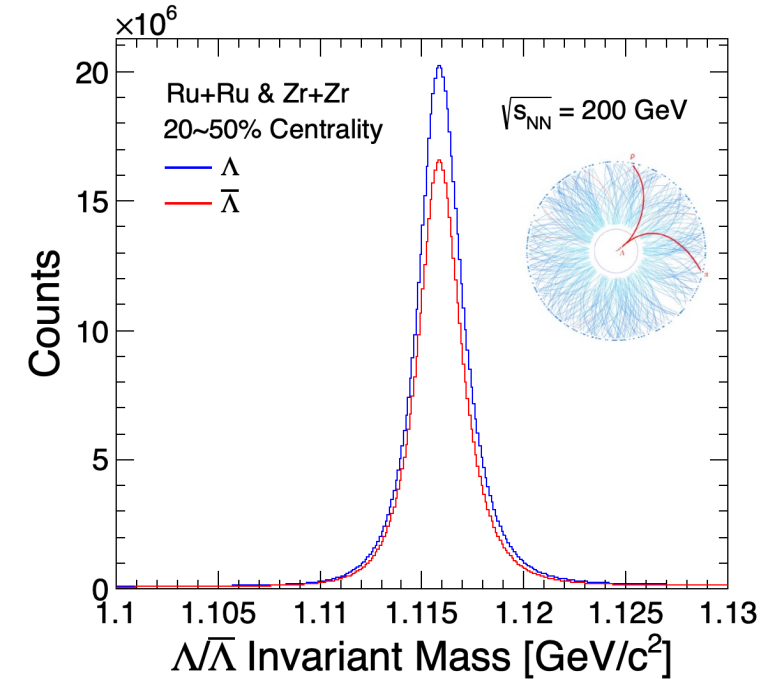
## $\Lambda/\bar{\Lambda}$ reconstruction:

Time Projection Chamber  
Time Of Flight

## Event plane resolution

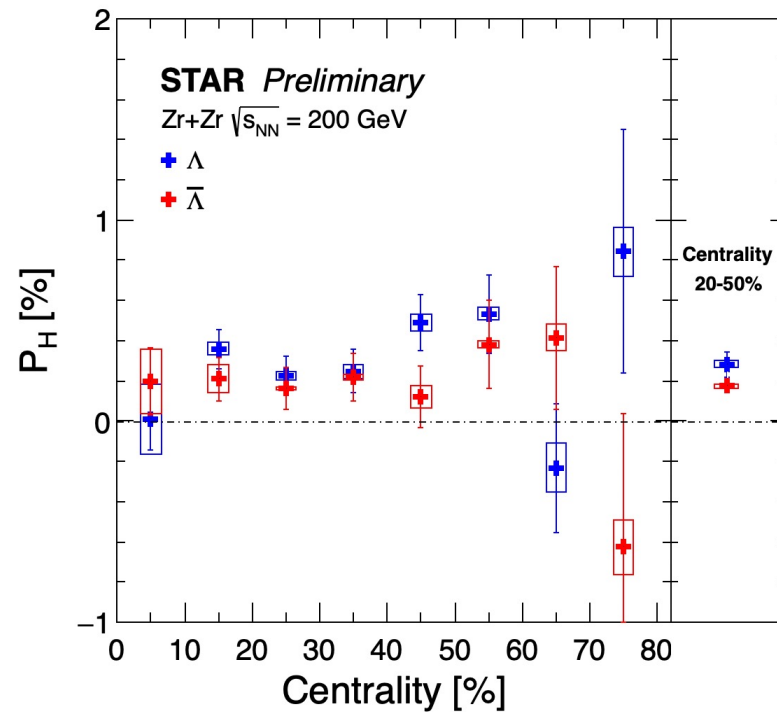
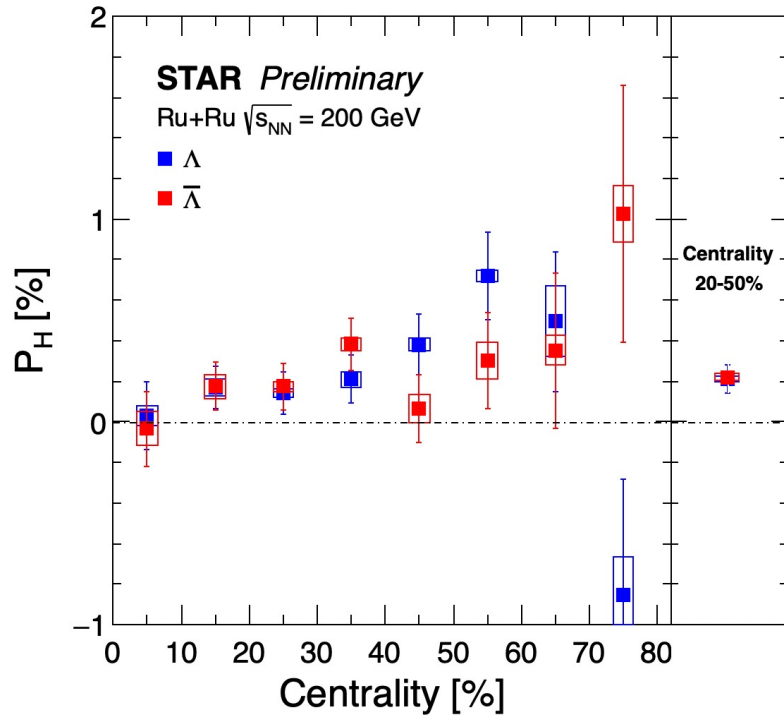


## $\Lambda/\bar{\Lambda}$ reconstructed with TPC tracks



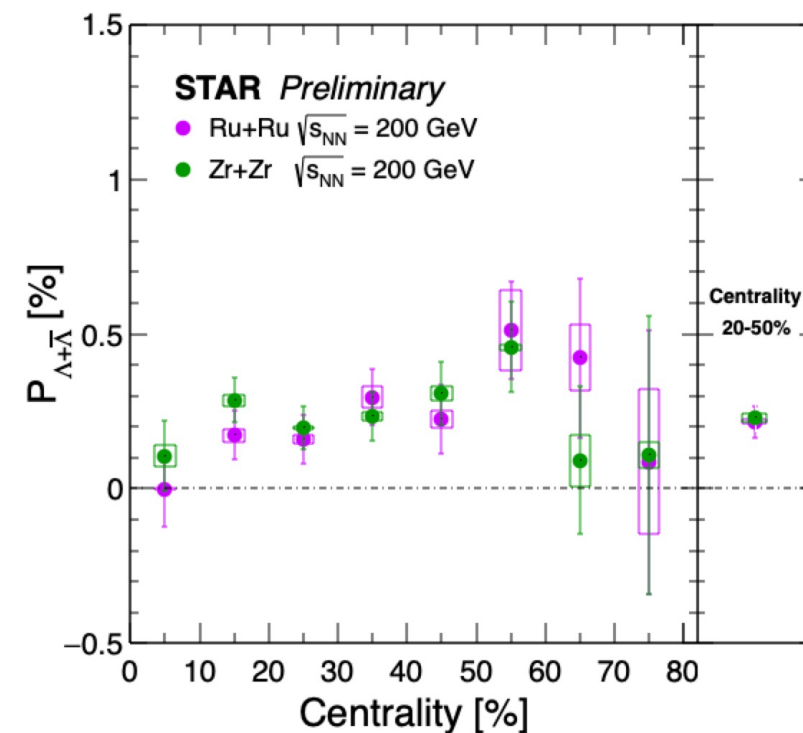
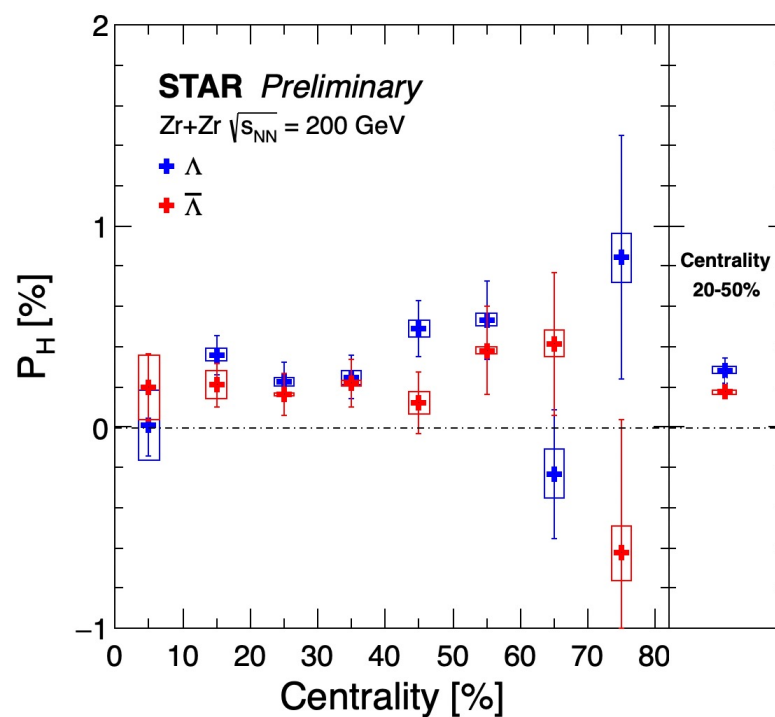
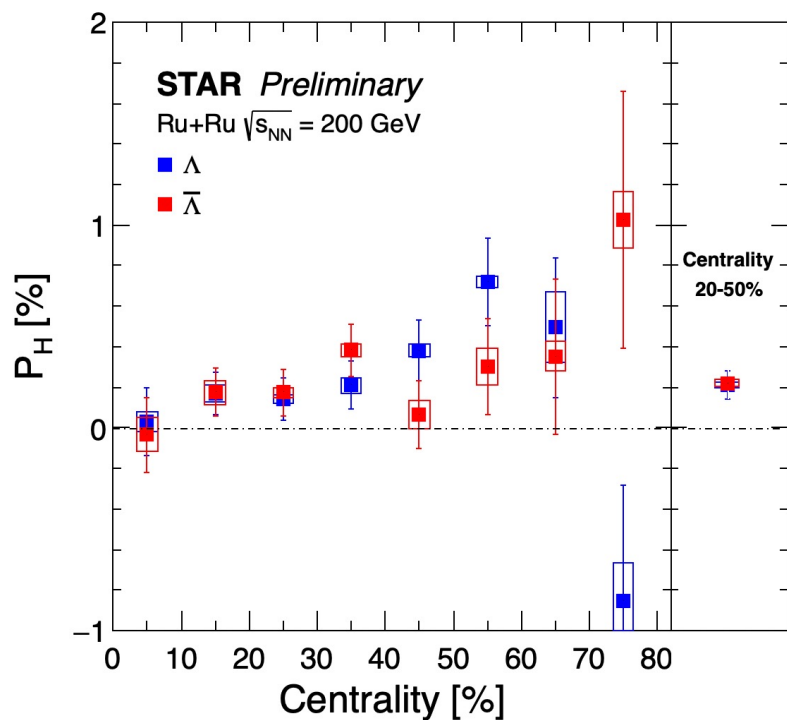
- $\Lambda \rightarrow p + \pi^-$
- $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$
- Background fraction  $< 3\%$

# Global polarization of $\Lambda$ and $\bar{\Lambda}$ in isobar collisions



- 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

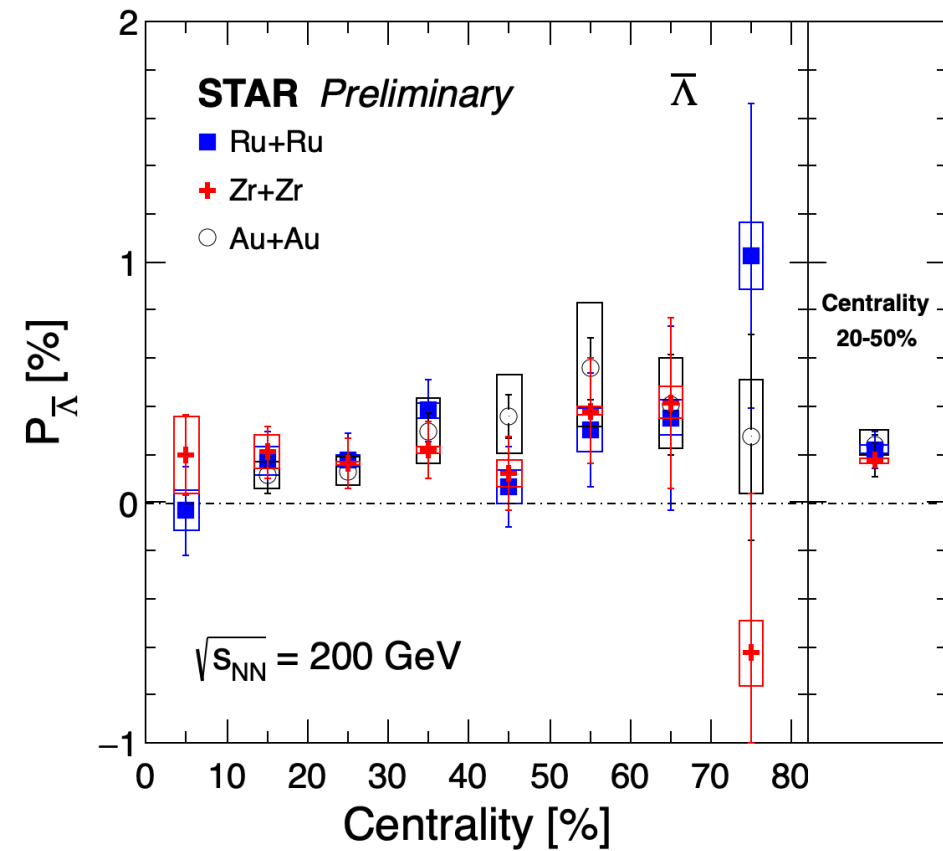
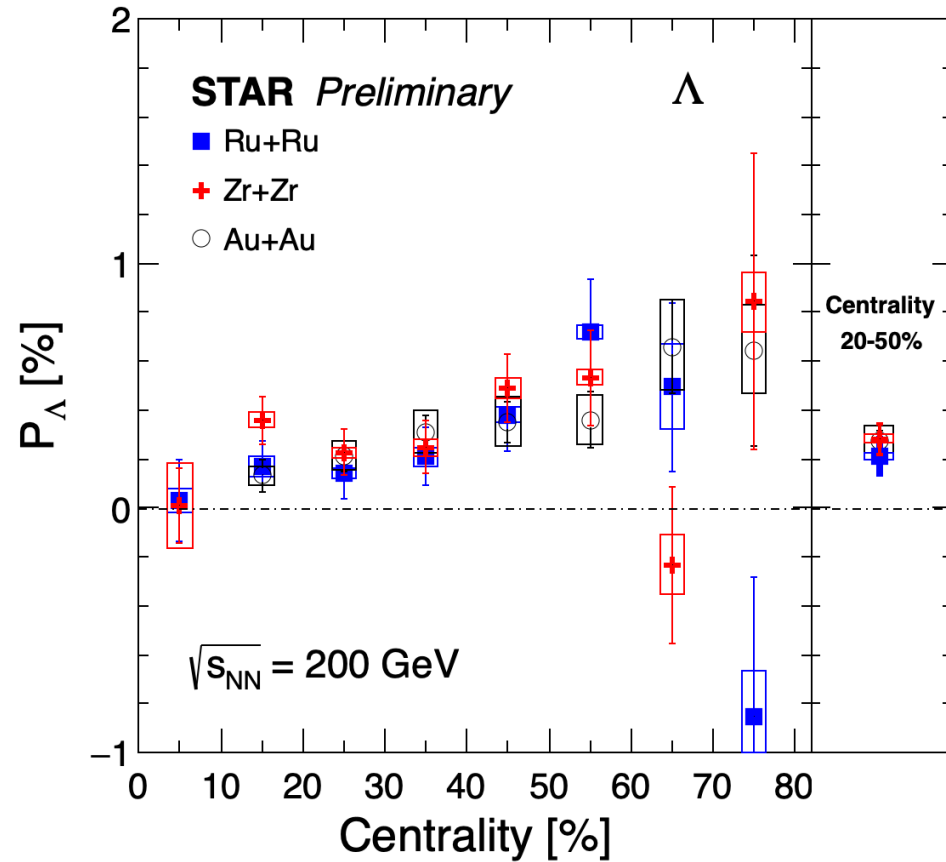
# Global polarization of $\Lambda$ and $\bar{\Lambda}$ in isobar collisions



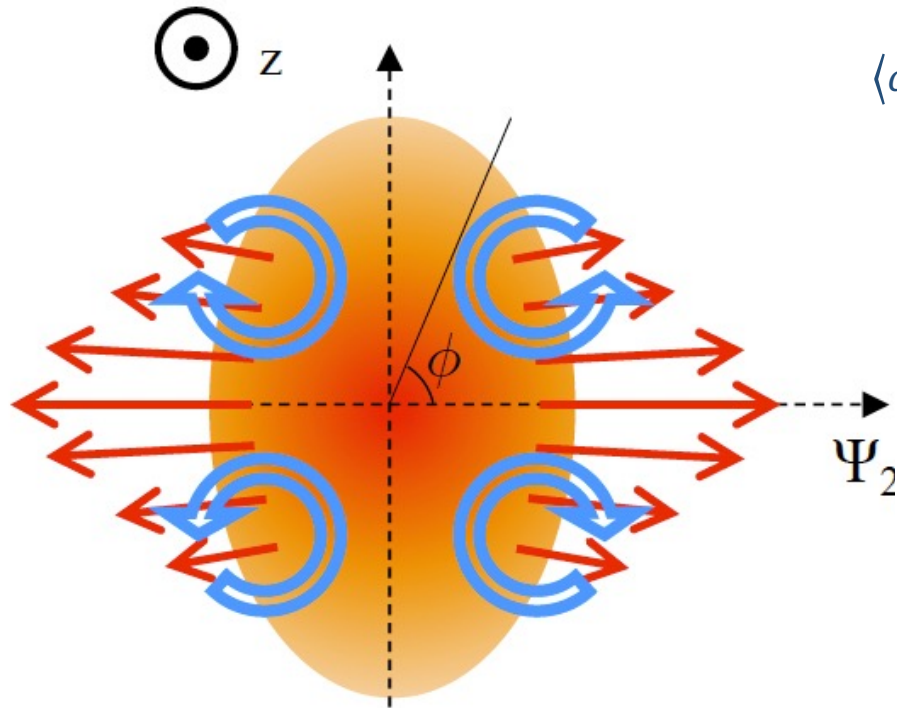
- Significant global polarization observed,  $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  increase with centrality
- No significant difference between  $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  in Ru+Ru and Zr+Zr collisions
- Global polarization of  $\Lambda + \bar{\Lambda}$  are consistent between Ru+Ru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



# Global polarization of hyperons in isobar and Au+Au collisions



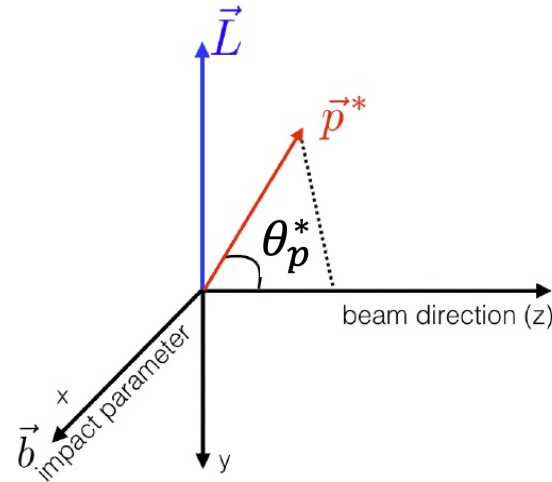
- Global polarization of  $\Lambda$  and  $\bar{\Lambda}$  are consistent between isobar and Au+Au collision systems
- No collision system size dependence for a given centrality is observed



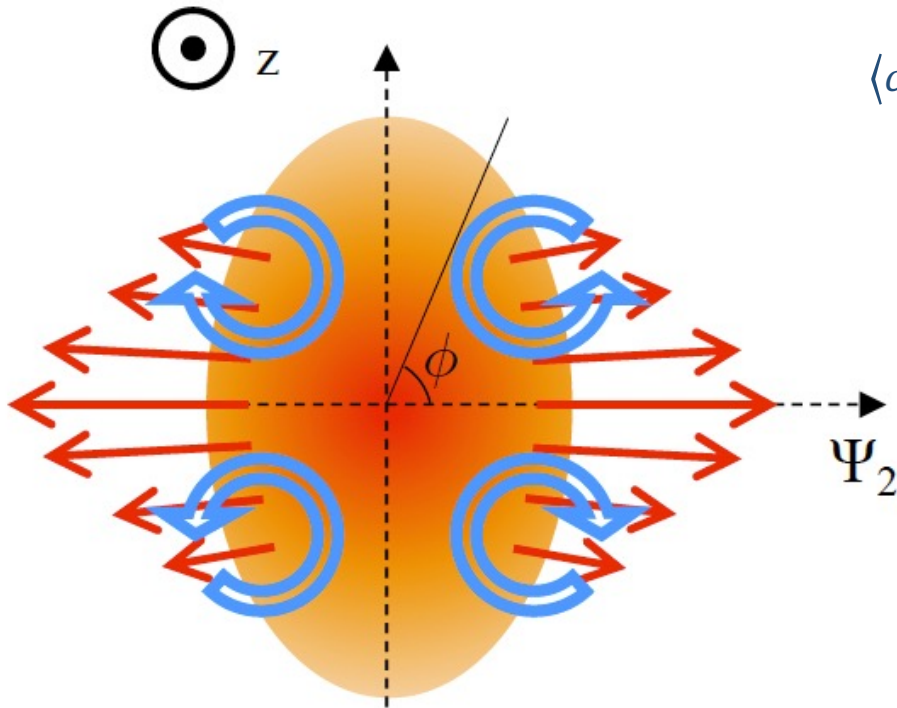
$$\langle \cos\theta_p^* \rangle = \int \frac{dN}{d\Omega^*} \cos\theta_p^* d\Omega^*$$

$$= \alpha_\Lambda P_z \langle (\cos\theta_p^*)^2 \rangle$$

$$P_z = \frac{\langle \cos\theta_p^* \rangle}{\alpha_\Lambda \langle (\cos\theta_p^*)^2 \rangle}$$



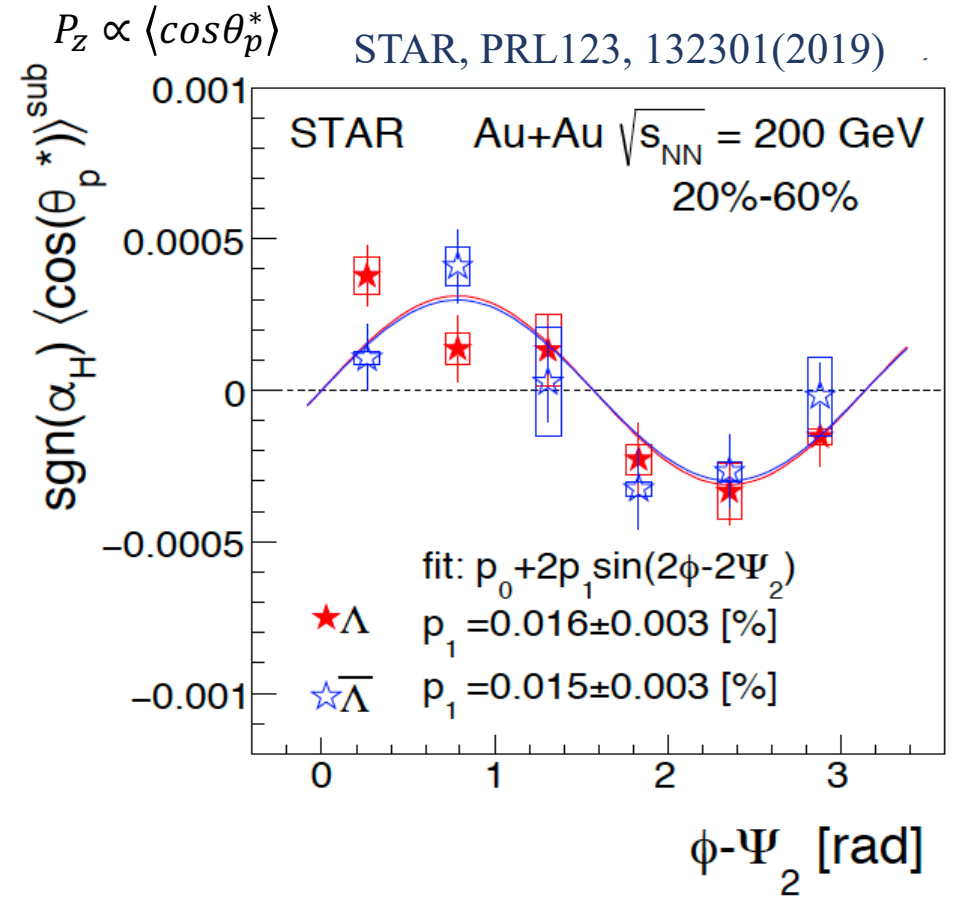
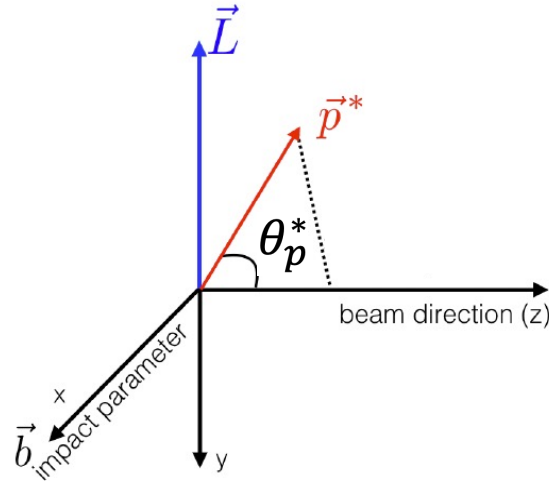
- ❑ Polarization along the beam direction expected from the “elliptic flow”
- ❑ STAR has observed the local polarization with second order event plane in Au+Au collisions



$$\langle \cos\theta_p^* \rangle = \int \frac{dN}{d\Omega^*} \cos\theta_p^* d\Omega^*$$

$$= \alpha_\Lambda P_z \langle (\cos\theta_p^*)^2 \rangle$$

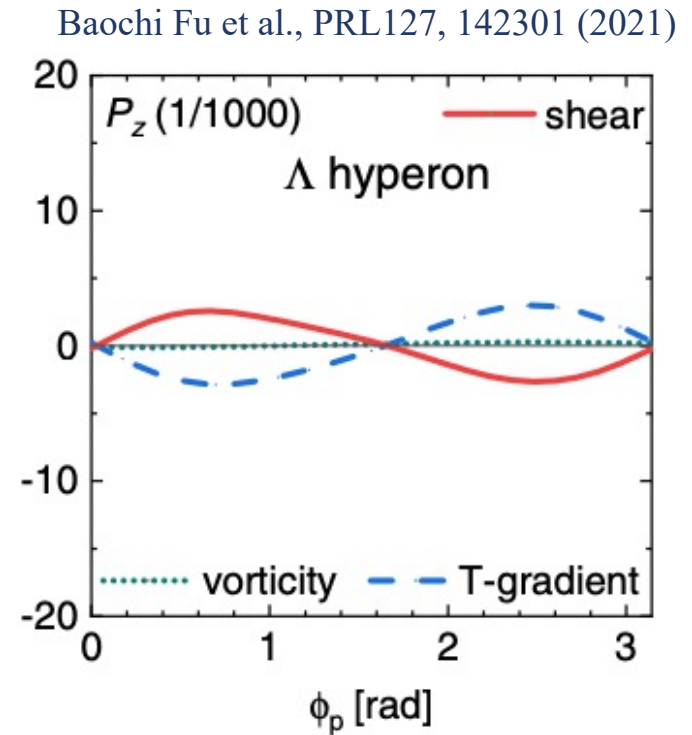
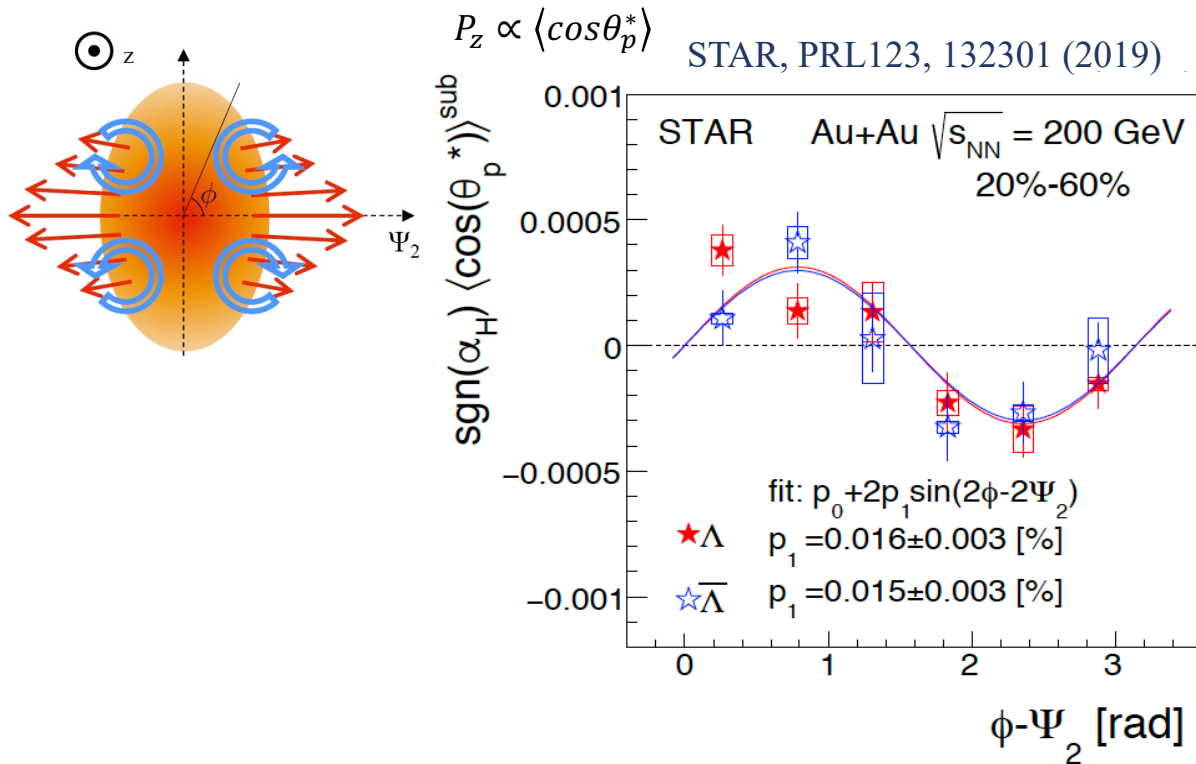
$$P_z = \frac{\langle \cos\theta_p^* \rangle}{\alpha_\Lambda \langle (\cos\theta_p^*)^2 \rangle}$$



Local vorticity induced by anisotropic flow results in polarization along the beam direction, expected from the “elliptic flow”

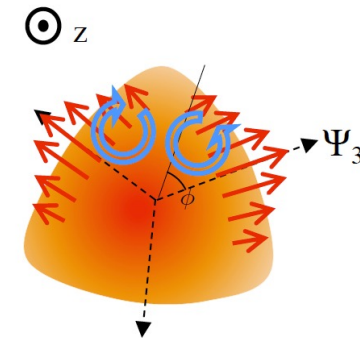
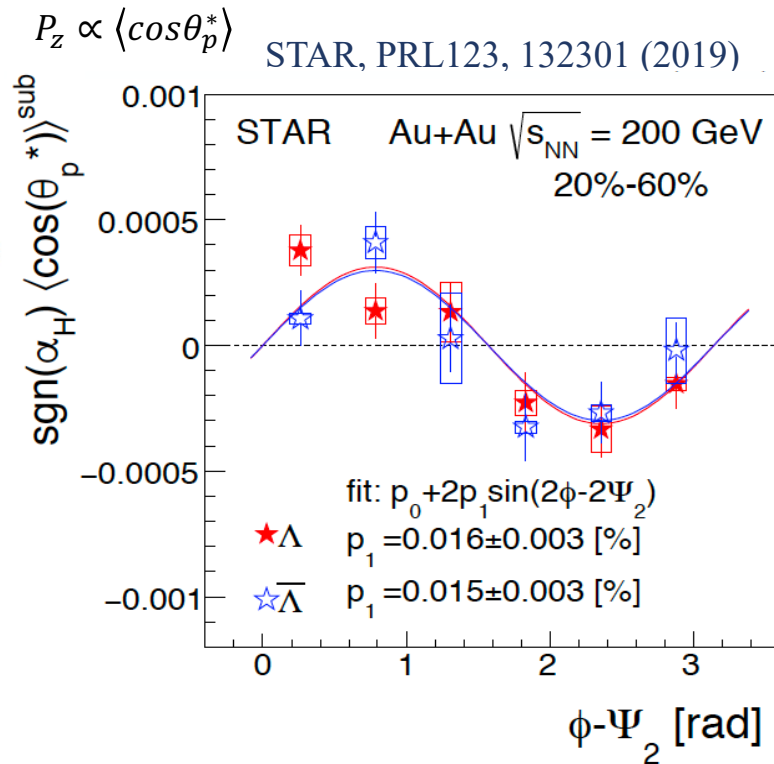
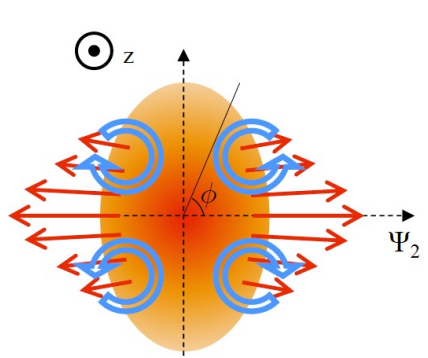
STAR has observed the local polarization with second order event plane in Au+Au collisions

# Local polarization of hyperons in heavy ion collisions



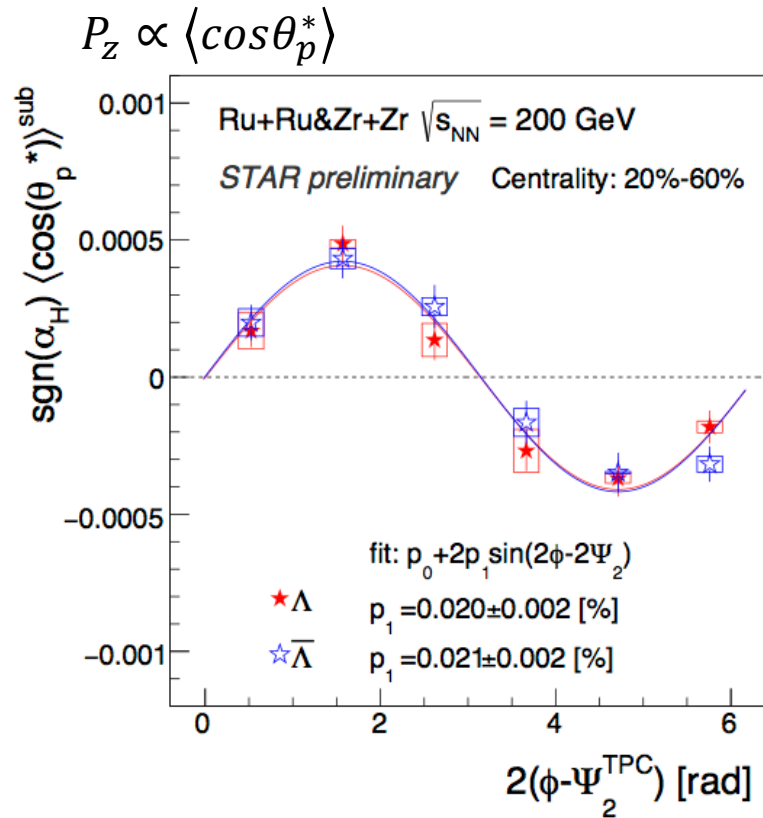
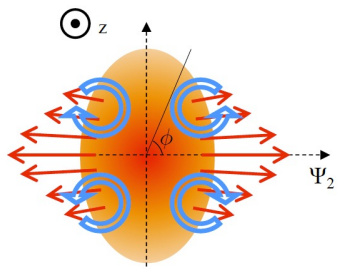
- Models based on thermal vorticity cannot explain the data, but inclusion of a shear term might explain the  $P_z$  measurement qualitatively

# Local polarization of hyperons in heavy ion collisions



- ❑ Models based on thermal vorticity cannot explain the data, but inclusion of a shear term might explain the  $P_z$  measurement qualitatively
- ❑ Measurements in smaller systems and relative to higher harmonic event planes provide new insights into polarization phenomena

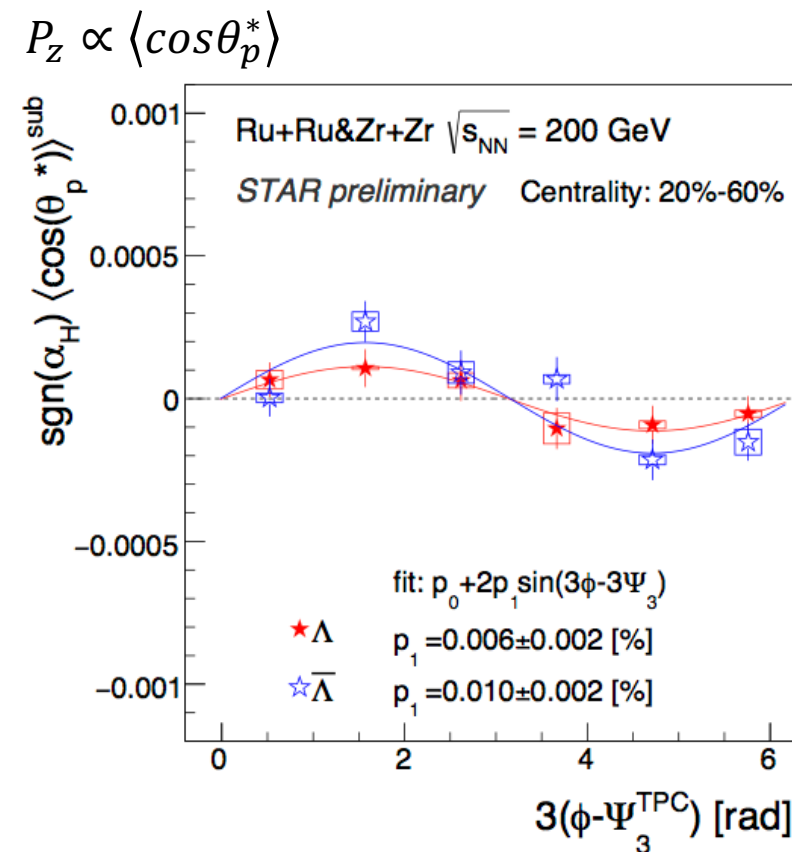
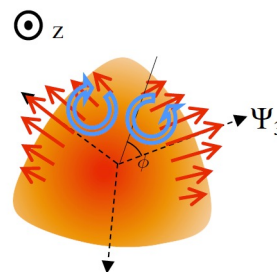
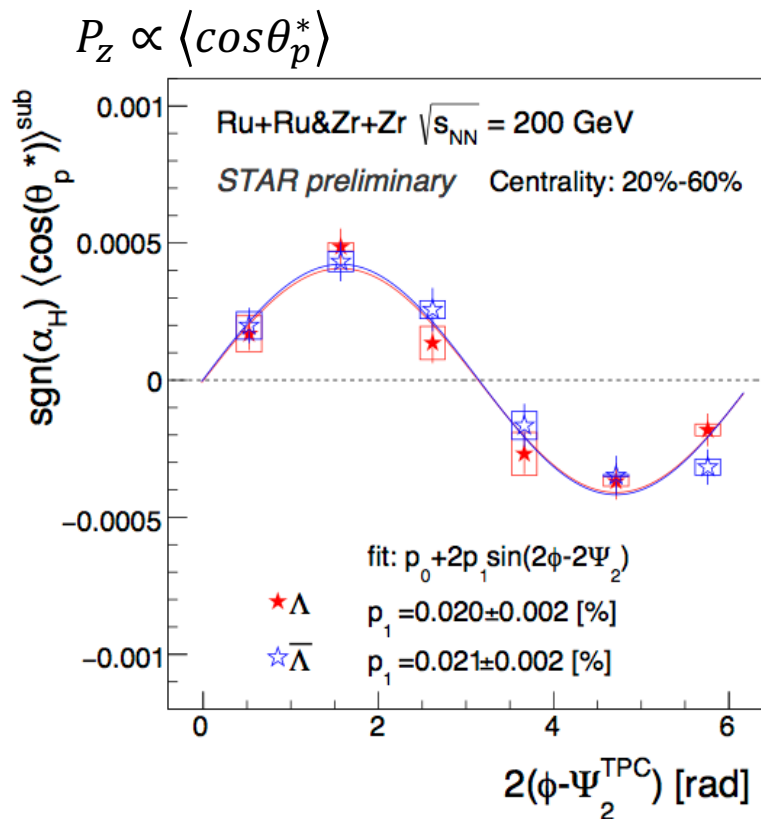
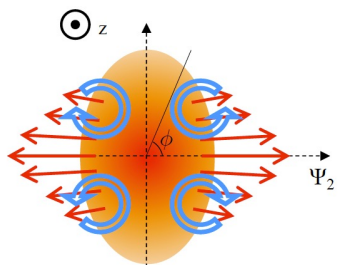
# Local polarization in isobar collisions



- Significant local polarization w.r.t second order event plane observed in isobar collisions



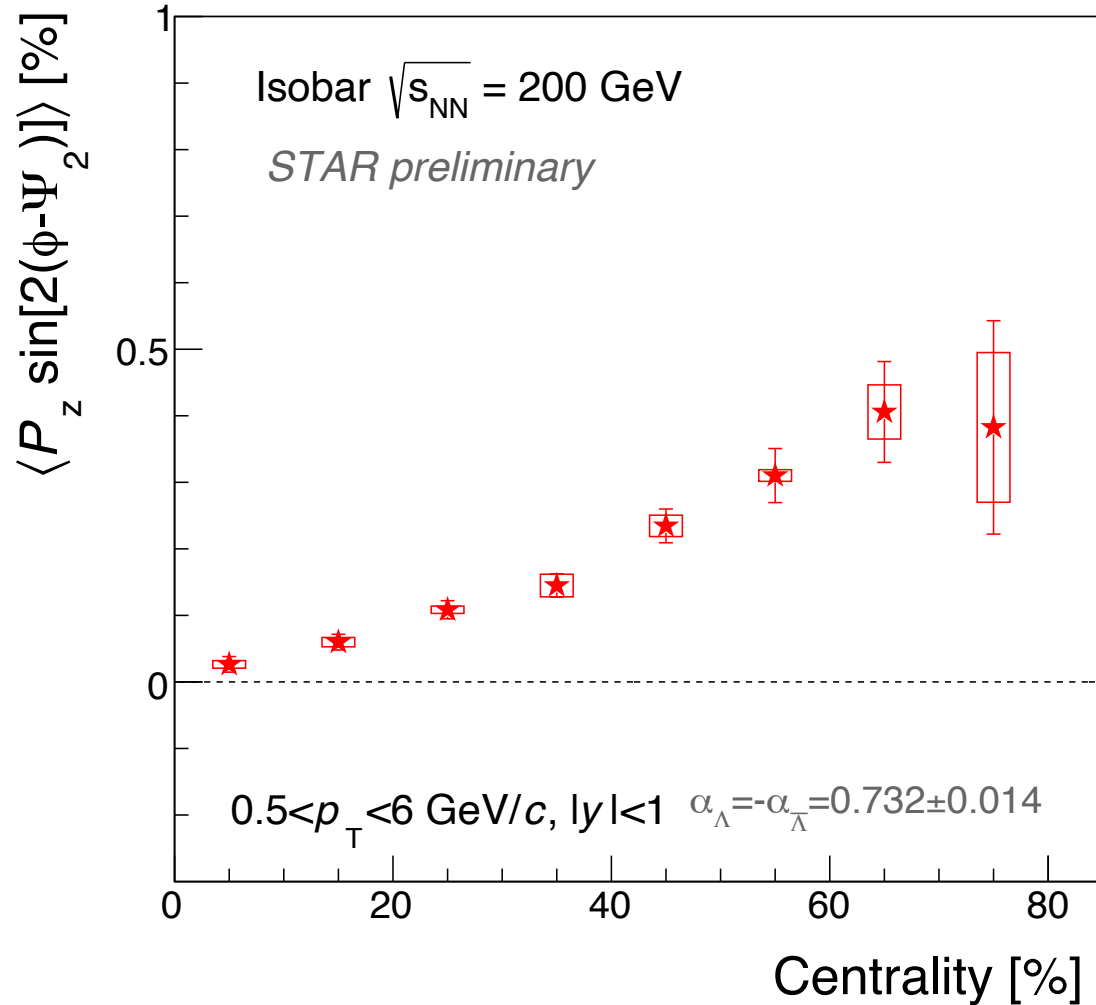
# Local polarization in isobar collisions



- Significant local polarization w.r.t second-order event plane observed in isobar collisions
- First observation of local polarization w.r.t the third-order event plane

# Centrality dependence of $P_{z,n}$

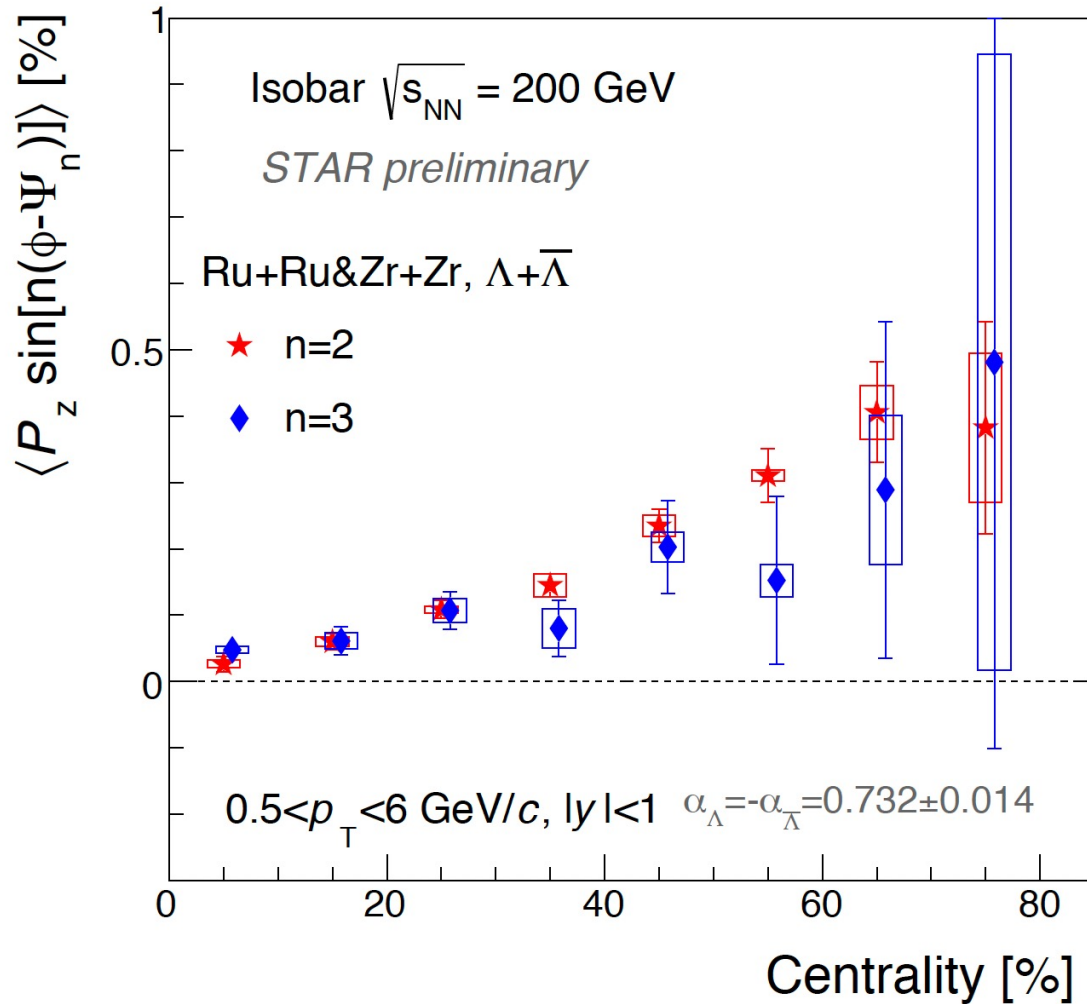
$$P_{z,n} = \langle P_z \sin[n(\phi - \Psi_n)] \rangle$$



- Second Fourier sine coefficient of the local polarization increases with centrality

# Centrality dependence of $P_{z,n}$

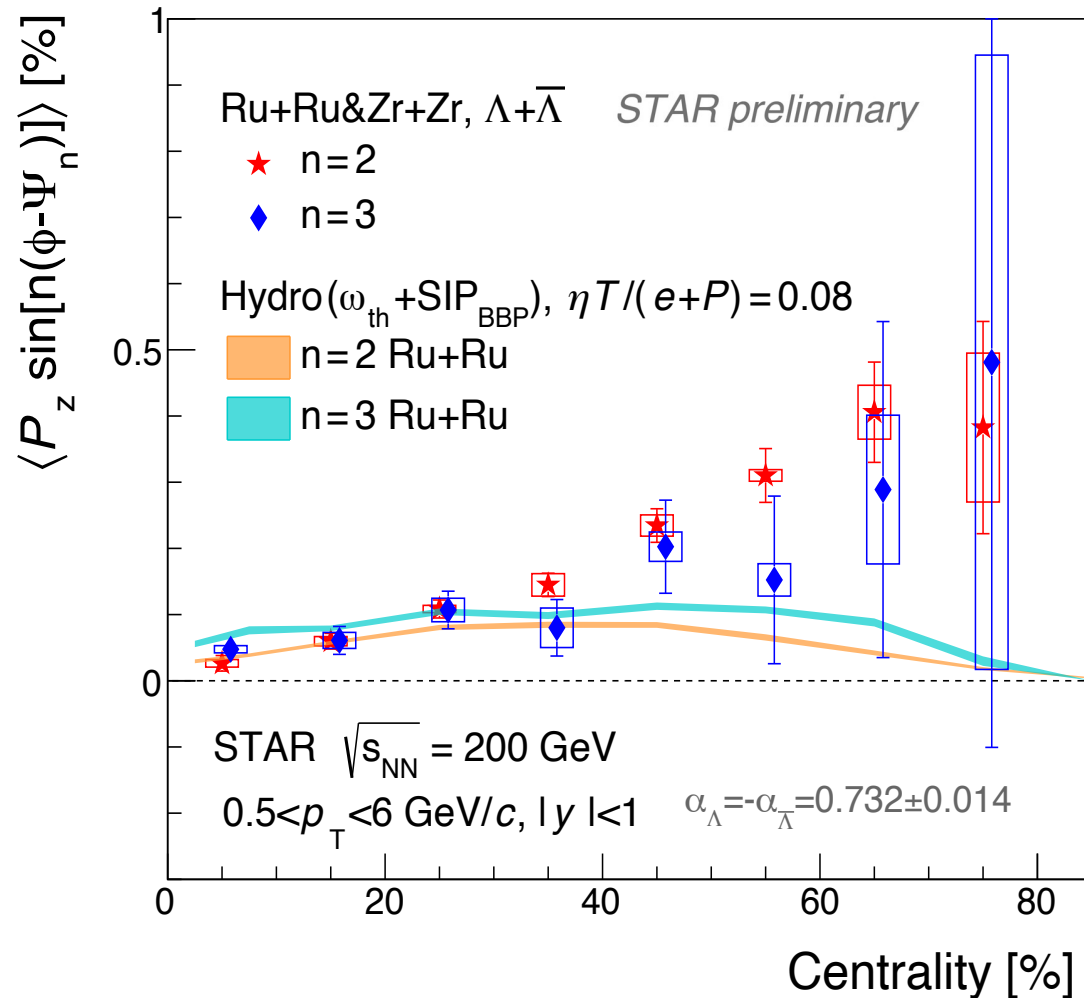
$$P_{z,n} = \langle P_z \sin[n(\phi - \Psi_n)] \rangle$$



- Second Fourier sine coefficient of the local polarization increases with centrality
- Significant local polarization w.r.t third-order event plane
- Comparable second and third order sine coefficients of  $P_{z,n}$ , consistent with each other

# Centrality dependence of $P_{z,n}$

$$P_{z,n} = \langle P_z \sin[n(\phi - \Psi_n)] \rangle$$

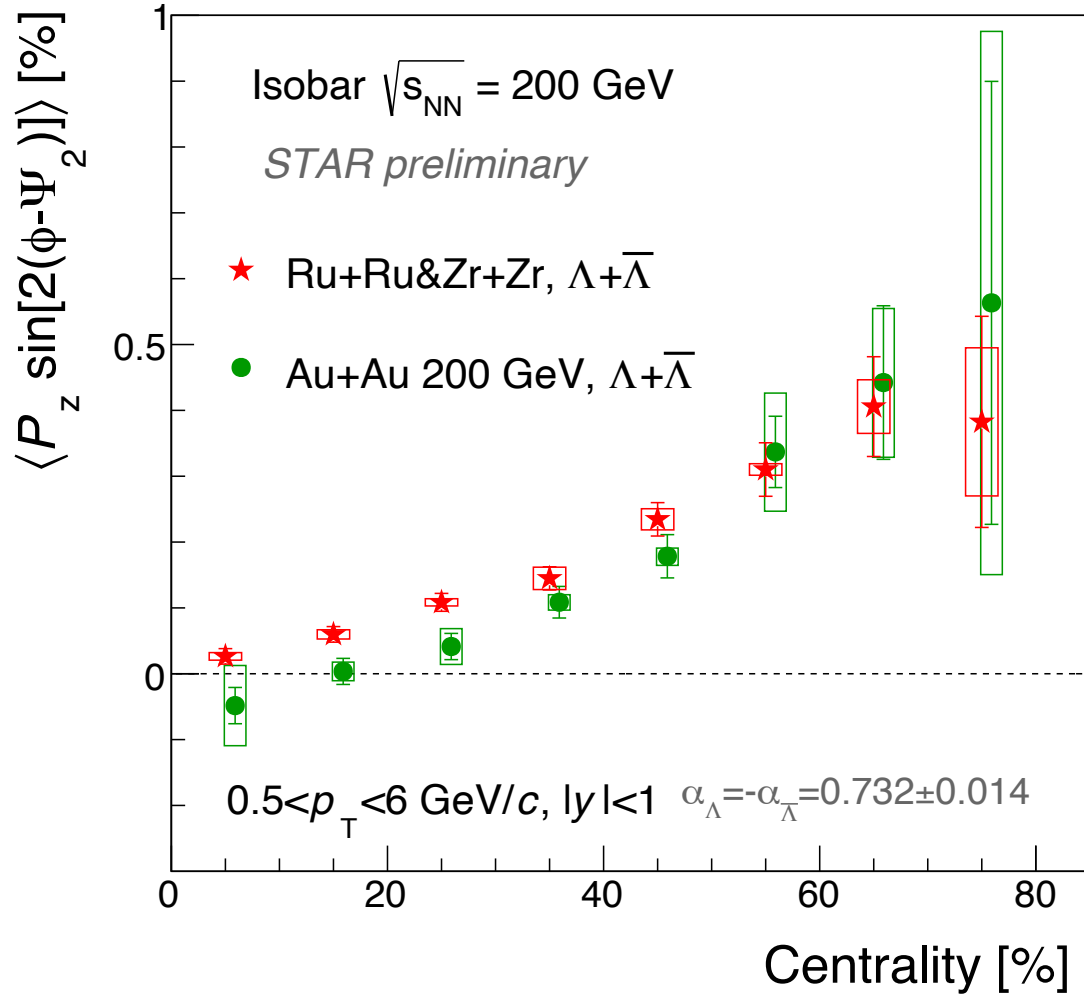


- Second Fourier sine coefficient of the local polarization increases with centrality
- Significant local polarization w.r.t third-order event plane
- Comparable second and third order sine coefficients of  $P_{z,n}$ , consistent with each other
- Hydrodynamic models with shear term reasonably describe the data for central collisions, but not for peripheral
- Additional constraint on shear viscosity

S. Alzhrani et al., arXiv:2203.15718

# $P_{z,2}$ in different collision systems

$$P_{z,n} = \langle P_z \sin[n(\phi - \Psi_n)] \rangle$$



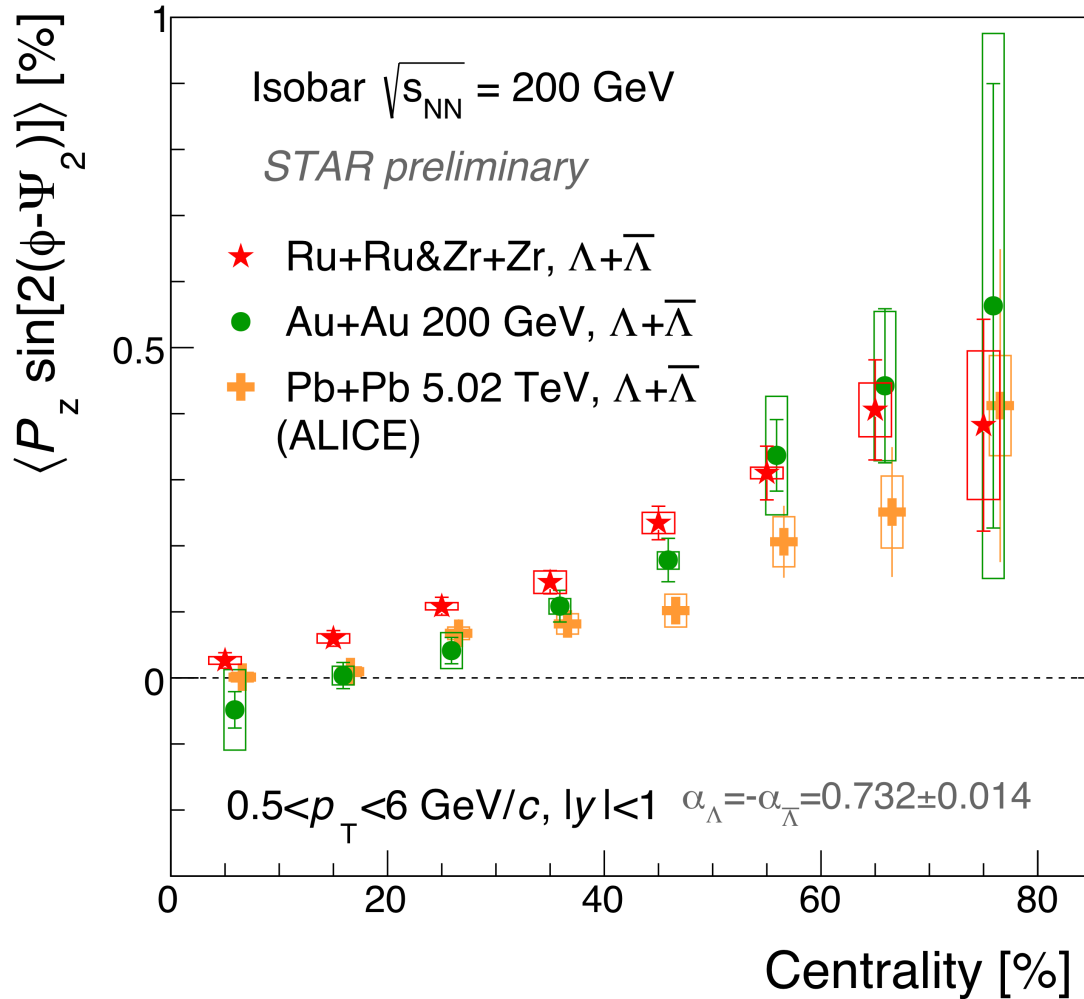
□  $P_{z,2}$  from isobar data compared to Au+Au collisions

□ Hint of system size dependence between isobar and Au+Au collisions

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

# $P_{z,2}$ in different collision systems

$$P_{z,n} = \langle P_z \sin[n(\phi - \Psi_n)] \rangle$$



- $P_{z,2}$  from isobar data compared to Au+Au and Pb+Pb collisions
- Hint of system size dependence between isobar and Au+Au collisions
- Energy dependence is not obvious between 200 GeV Au+Au and 5.02 TeV Pb+Pb collisions

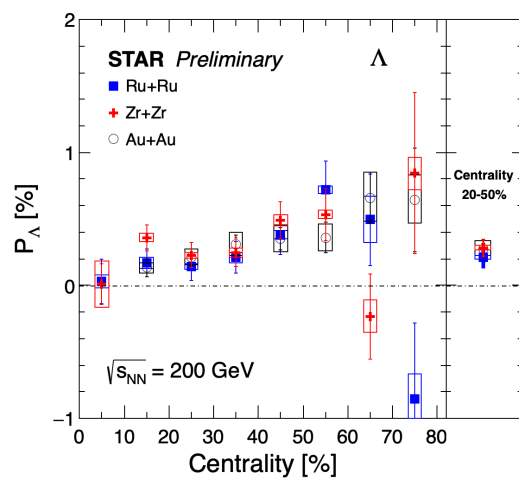
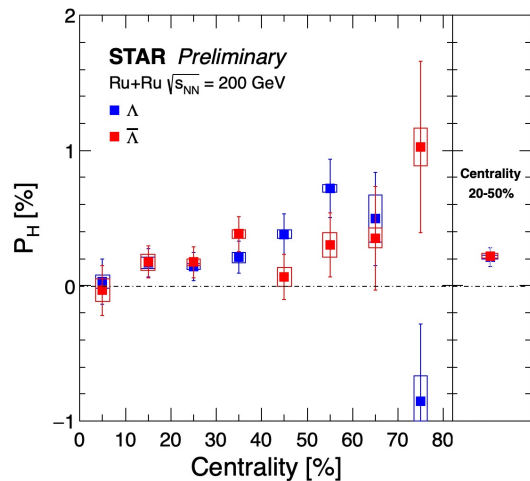
Au+Au: STAR, PRL123, 132301 (2019)  
 Pb+Pb: ALICE, arXiv:2107.11183



## Measurements of $\Lambda/\bar{\Lambda}$ polarization in Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}} = 200$ GeV

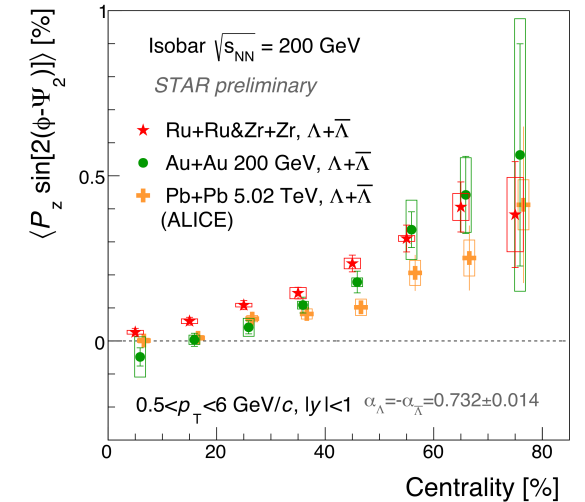
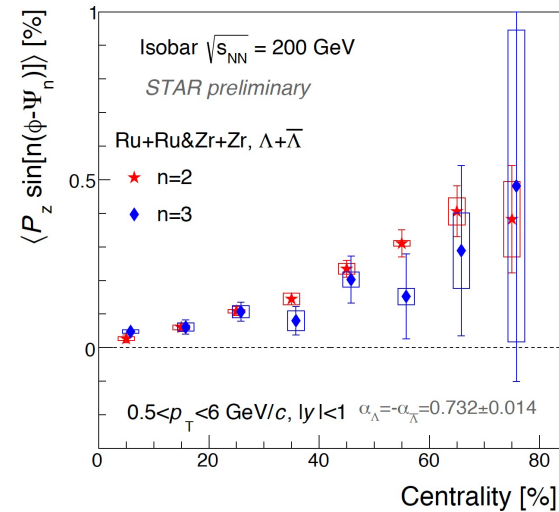
### Global polarization

- ✓  $P_{\Lambda}$  and  $P_{\bar{\Lambda}}$  are consistent with each other
- ✓  $P_{\Lambda}$  &  $P_{\bar{\Lambda}}$  are consistent between Ru+Ru, Zr+Zr and Au+Au collisions, no collision system size dependence is observed



### Local polarization

- ✓ First observation of local polarization w.r.t third-order event plane
- ✓ Hint of collision system size dependence of  $P_{z,2}$  when comparing with Au+Au and Pb+Pb.

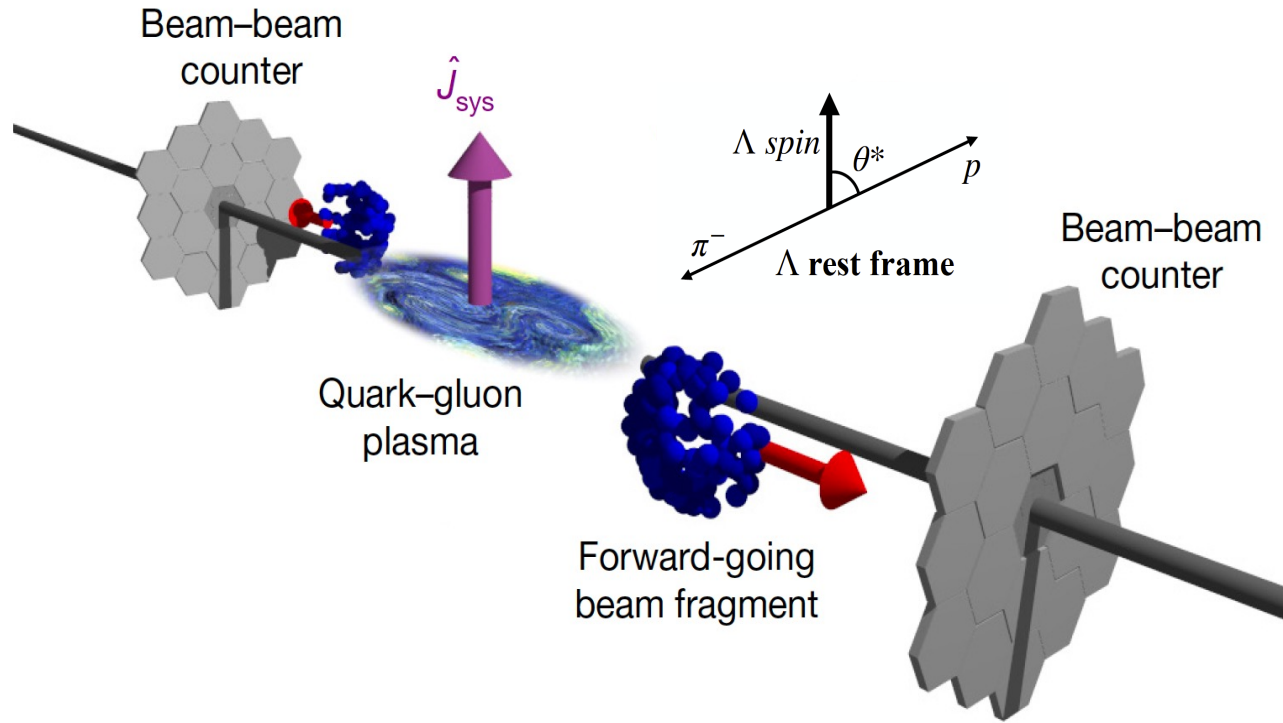


*Thank you*

# Global polarization of hyperons in heavy ion collision

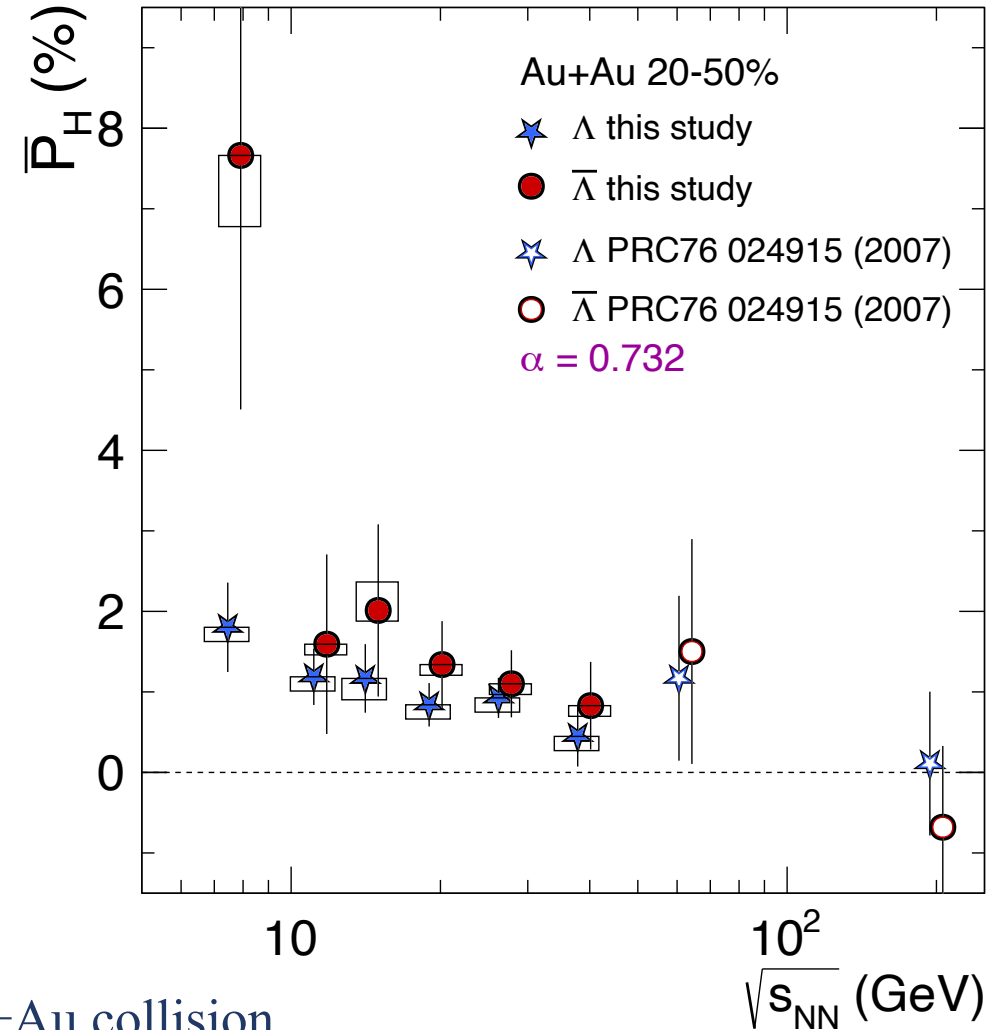


STAR, Nature 548, 62-65



$$P_{\Lambda} = \frac{8}{\pi \alpha_{\Lambda} A_0} \frac{1}{Res(\Psi_1)} \langle \sin(\Psi_1 - \phi_p^*) \rangle$$

$\alpha_{\Lambda} = -\alpha_{\bar{\Lambda}} = 0.732 \pm 0.014$   
 $A_0$ : acceptance effect  
 $\Psi_1$ : first-order event plane angle

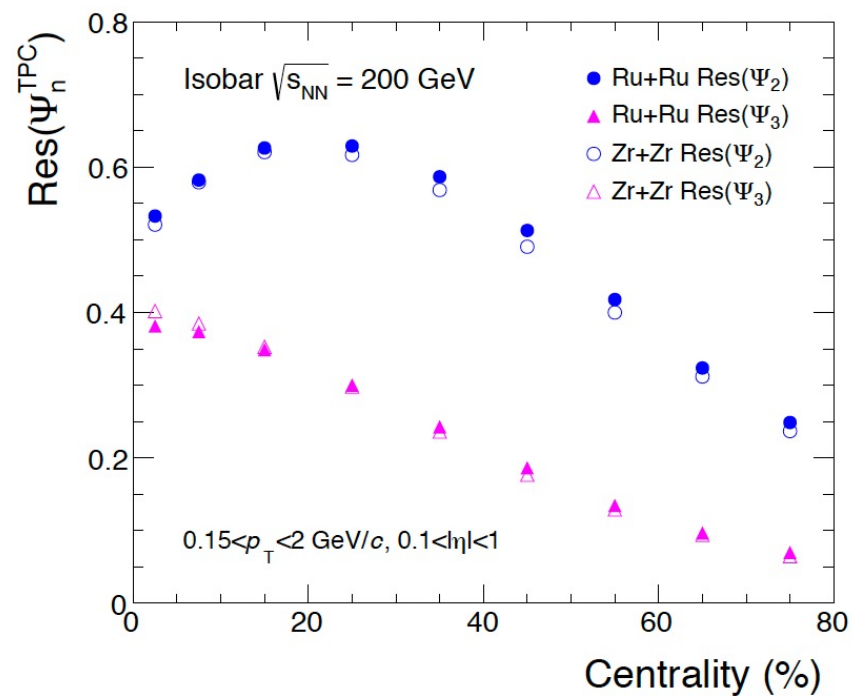
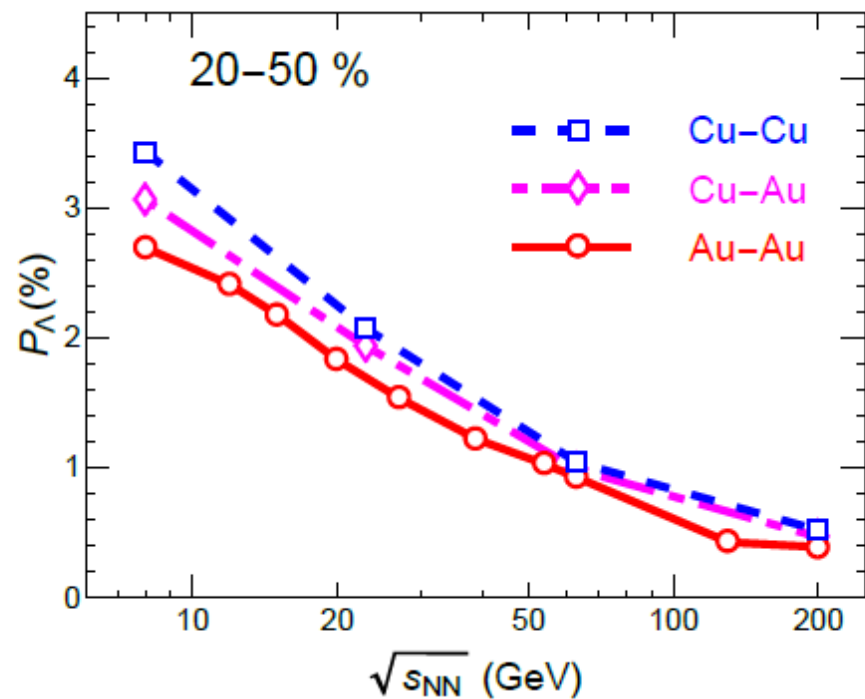


□ Significant global polarization of  $\Lambda$  and  $\bar{\Lambda}$  observed in Au+Au collision.

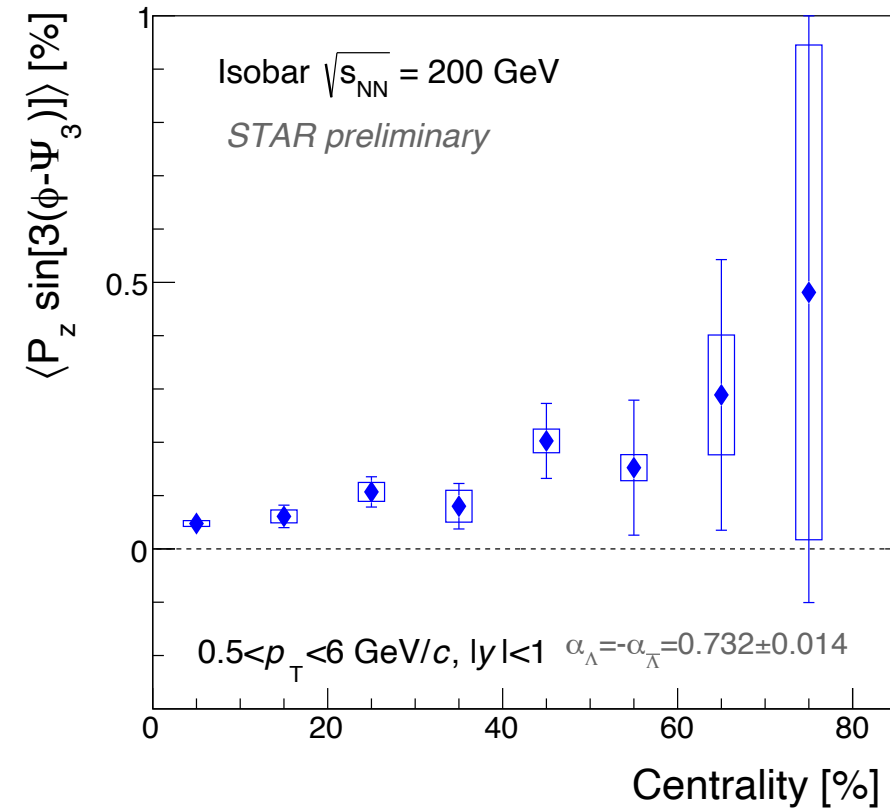
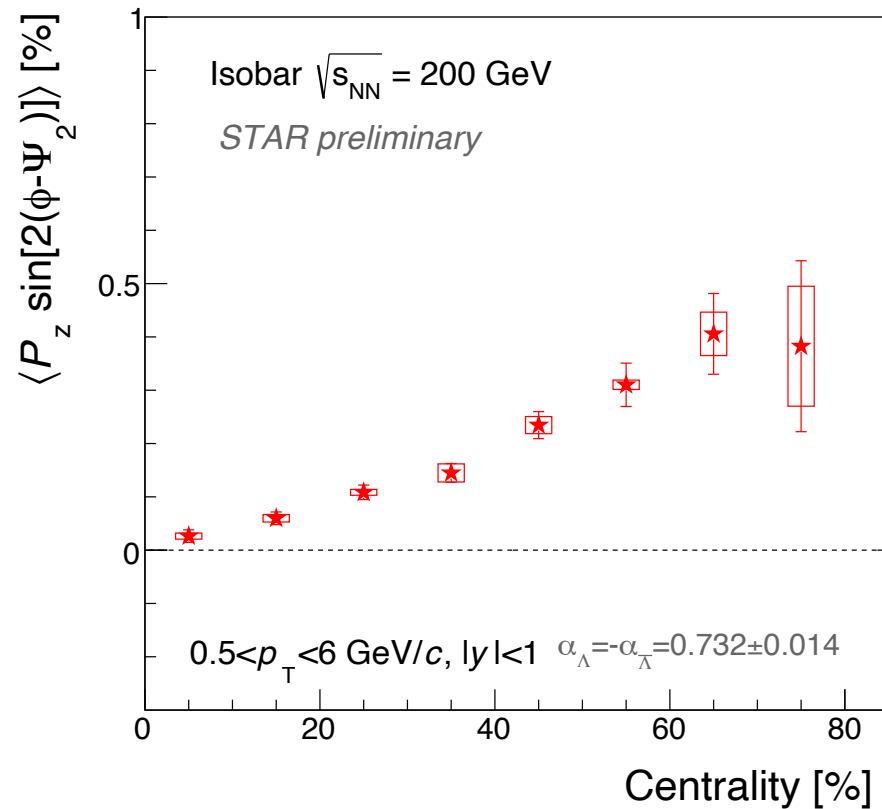
# Global polarization of hyperons in heavy ion collision



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

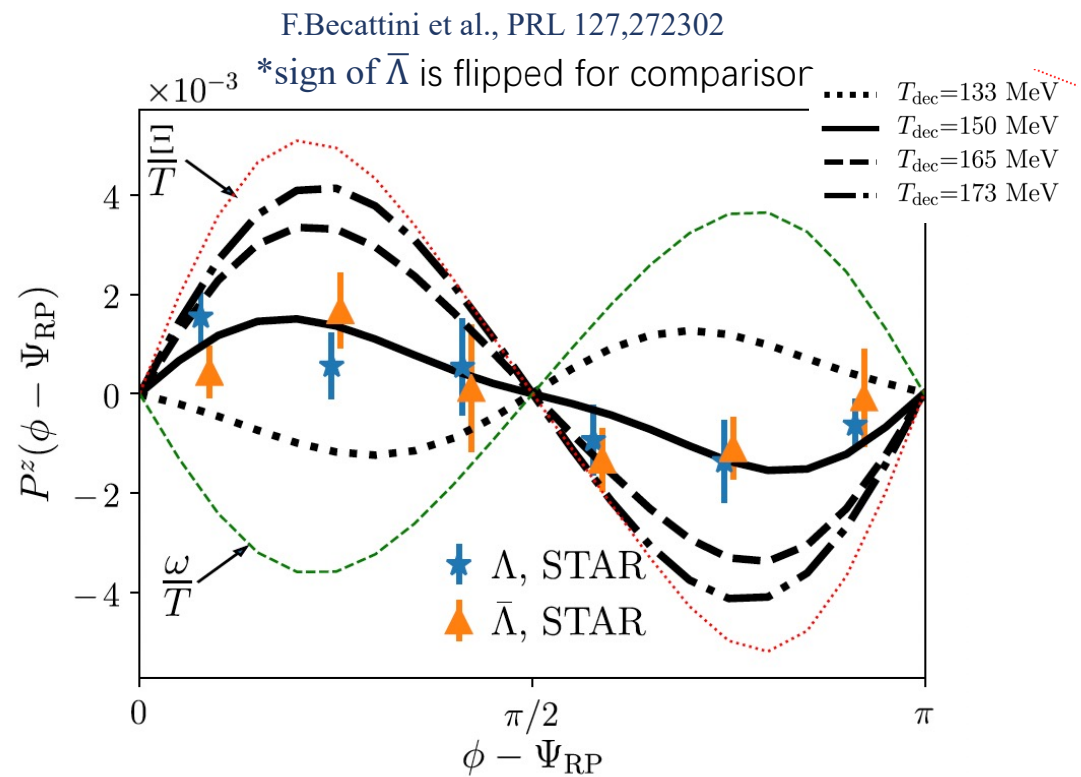
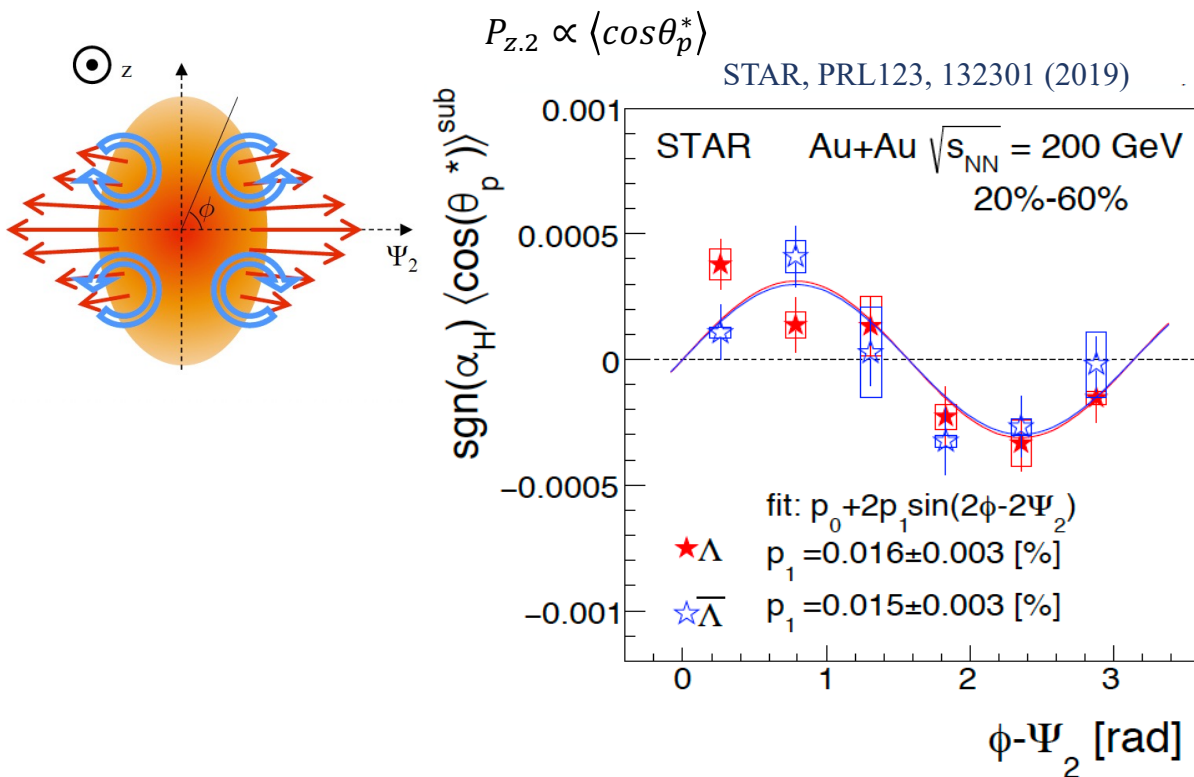


# Centrality dependence of $P_{z,n}$



- Local polarization increase with centrality
- Significant local polarization w.r.t third-order event plane

# Local polarization of hyperons in heavy ion collision



- ▣ Models based on thermal vorticity cannot explain the data, but inclusion of a shear term might explain the  $P_z$  measurement qualitatively
 F. Becattini et al., PRL 127, 272302. S. Alzhrani et al., arXiv:2203.15718
- ▣ Measurements in smaller systems and relative to higher harmonic event planes provides new insights into polarization phenomena