

Measurements of Global and Local Polarization of Hyperons in 200 GeV Isobar Collisions from STAR

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(for the STAR Collaboration)

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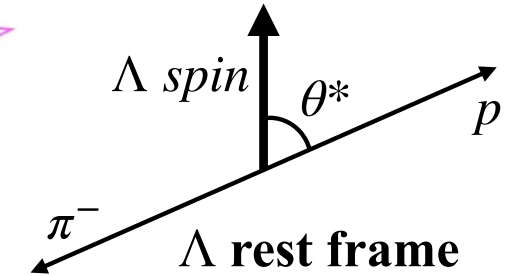
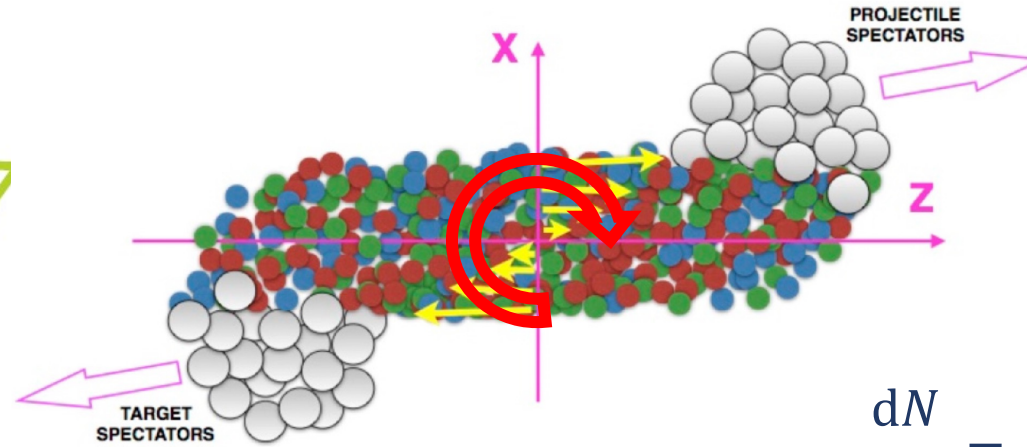
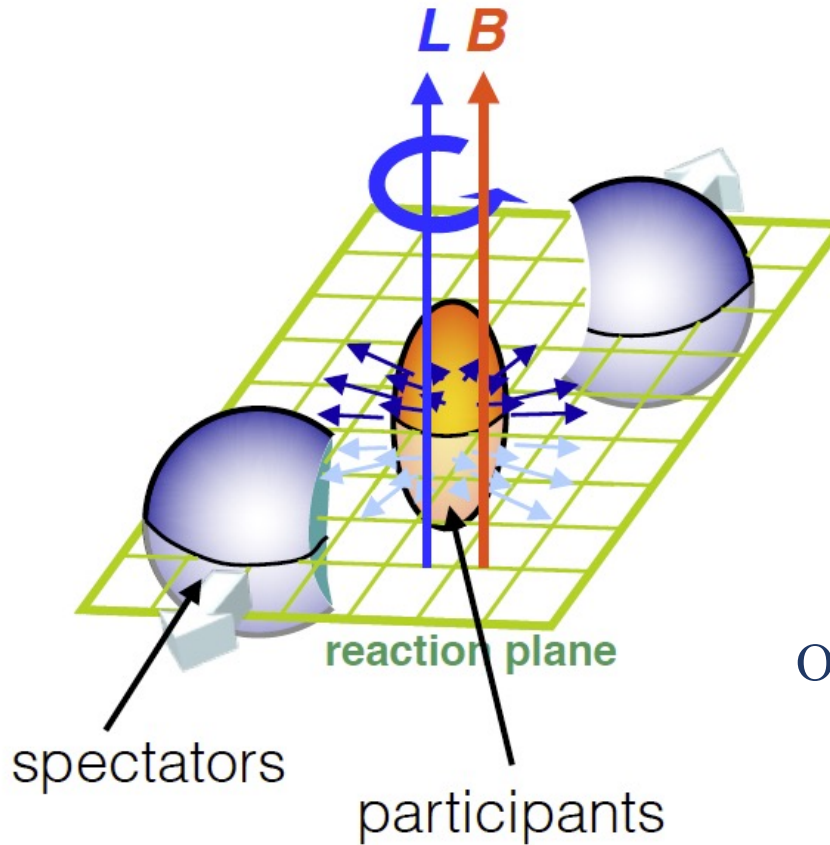
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25th International Spin Symposium (SPIN 2023)



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

Hyperon polarization in heavy ion collisions



$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi} (1 + \alpha_\Lambda P_\Lambda \cos\theta^*)$$

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

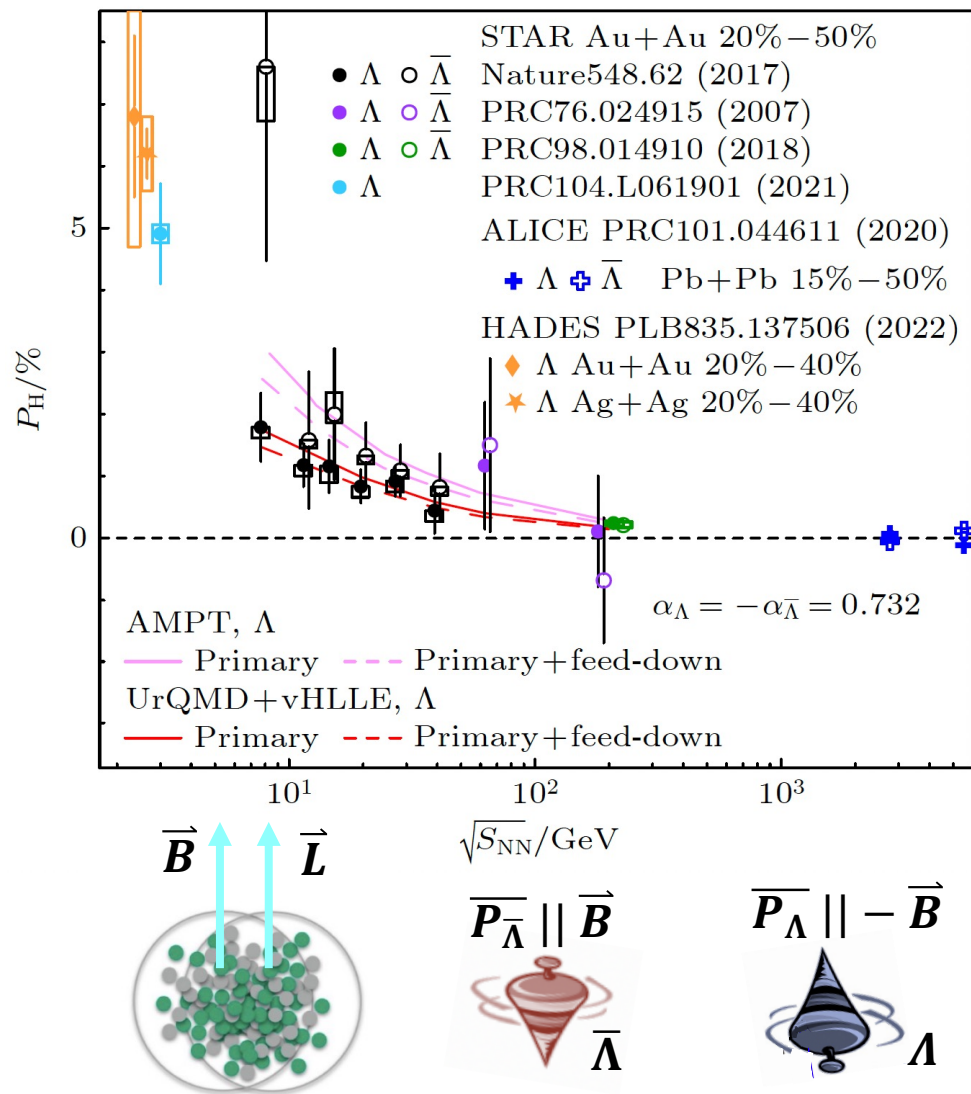
Orbital angular momentum

↳ Leads to global polarization

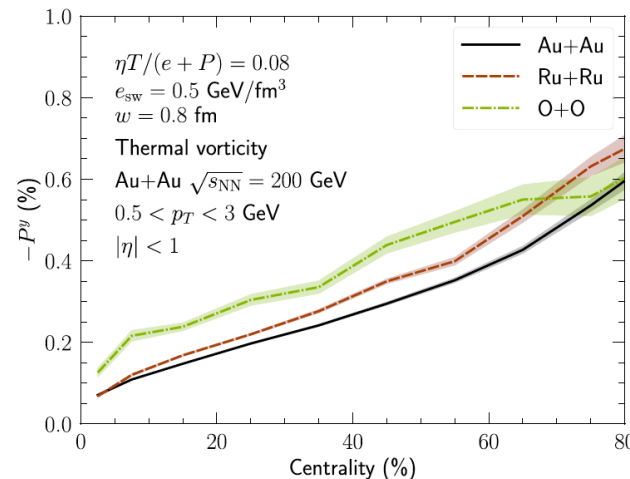
Z.-T. Liang and X.-N. Wang,
PRL 94, 102301 (2005)

$\alpha_\Lambda = -\alpha_{\bar{\Lambda}} = 0.732 \pm 0.014$
 A_0 : Acceptance correction factor
 Ψ_1 : First-order event plane angle
 $Res(\Psi_1)$: Event plane resolution

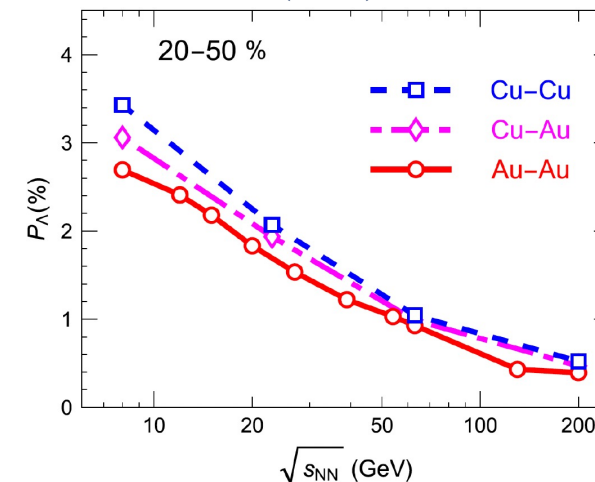
Acta Phys. Sin. Vol. 72, No. 7(2023) 072401



S. Alzhrani et al.,
PRC 106.014905




S.Z, Shi, K.L. Li, J.F. Liao,
PLB 788 (2019) 409–413



□ $\Lambda / \bar{\Lambda}$ global polarization splitting ?

□ Global polarization collision system size dependence

$$^{197}_{79}\text{Au} > ^{96}_{44}\text{Ru}, ^{96}_{40}\text{Zr} > ^{63}_{29}\text{Cu} > ^{16}_8\text{O}$$

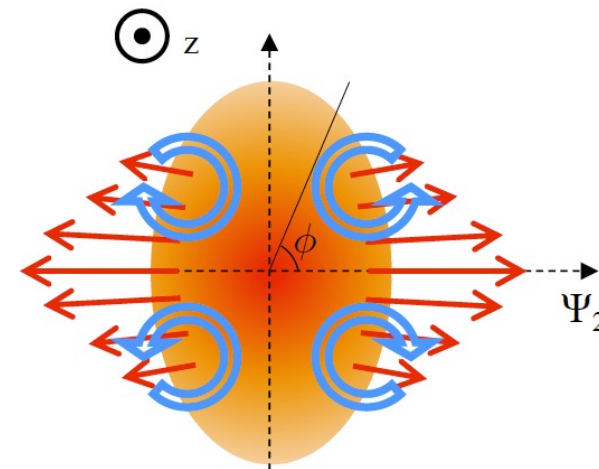
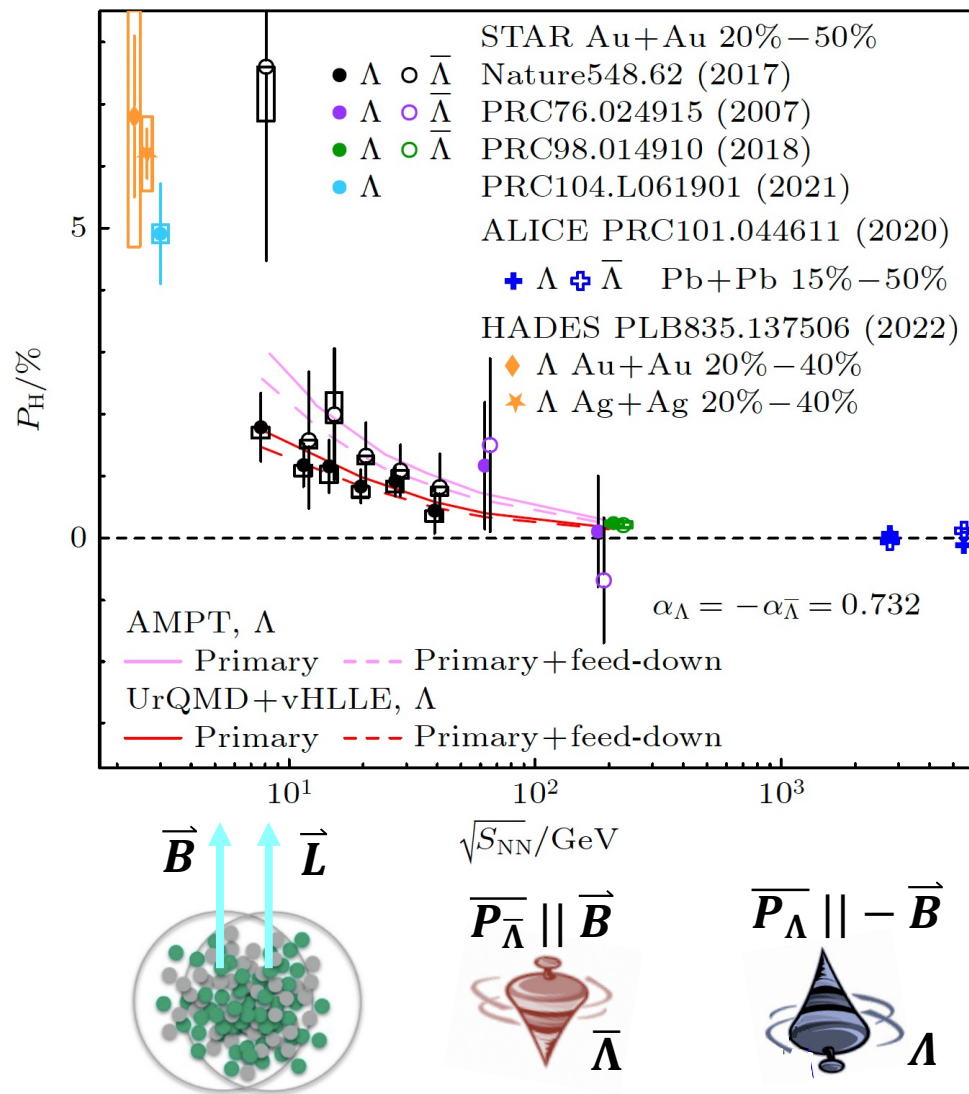
 $p_{\Lambda}^{Au} < p_{\Lambda}^{Ru} \approx p_{\Lambda}^{Zr} < p_{\Lambda}^{Cu} < p_{\Lambda}^O$

□ Local polarization in isobar collisions

Hyperon polarization in heavy ion collisions



Acta Phys. Sin. Vol. 72, No. 7(2023) 072401



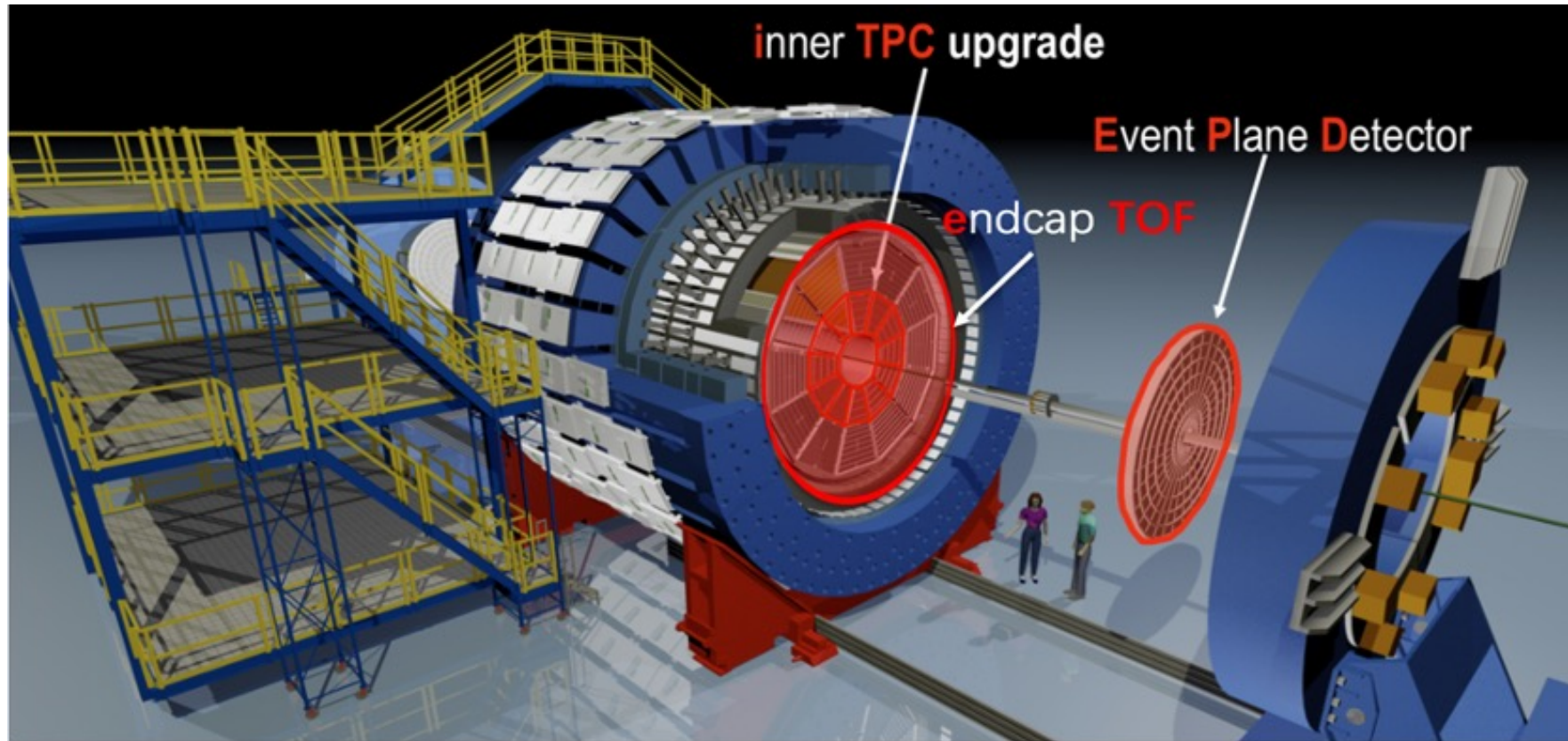
□ $\Lambda / \bar{\Lambda}$ global polarization splitting with BES-II data?

□ Global polarization collision system size dependence

$$^{197}_{79}\text{Au} > ^{96}_{44}\text{Ru}, ^{96}_{40}\text{Zr} > ^{63}_{29}\text{Cu} > ^{16}_8\text{O}$$

$$\text{?} \rightarrow P_\Lambda^{\text{Au}} < P_\Lambda^{\text{Ru}} \approx P_\Lambda^{\text{Zr}} < P_\Lambda^{\text{Cu}} < P_\Lambda^{\text{O}}$$

□ Local polarization in isobar collisions



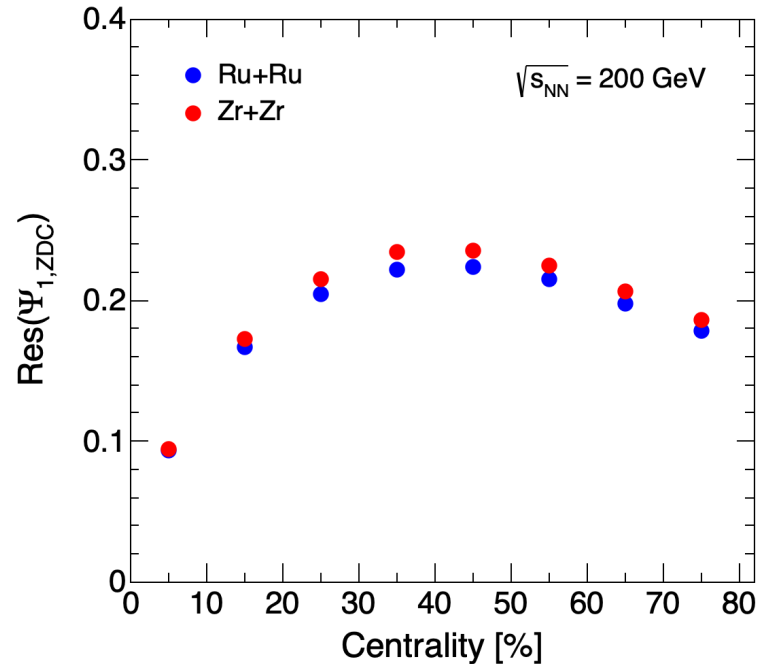
□ Event plane reconstruction:

Zero Degree Calorimeters
Time Projection Chamber

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

Time Projection Chamber
Time Of Flight

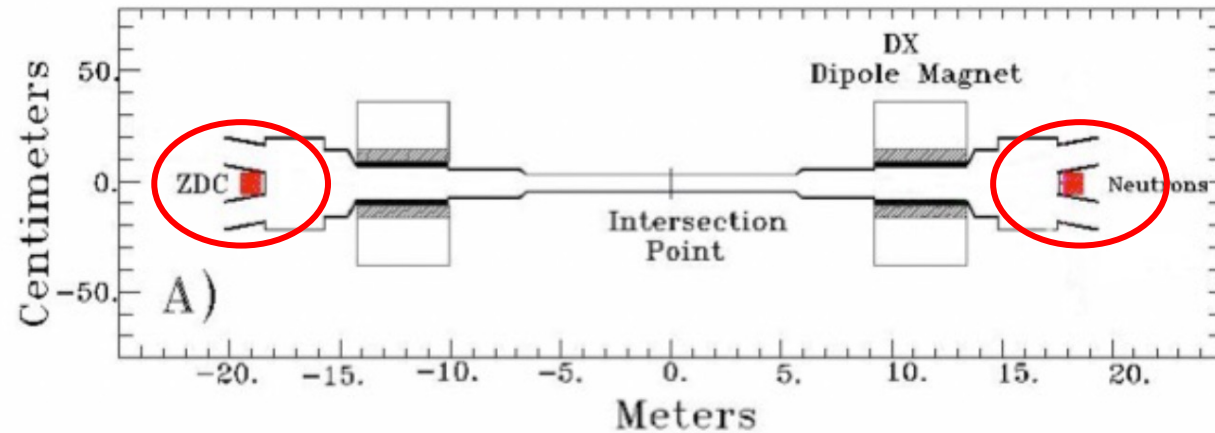
First-order event plane resolution



Event plane reconstruction:

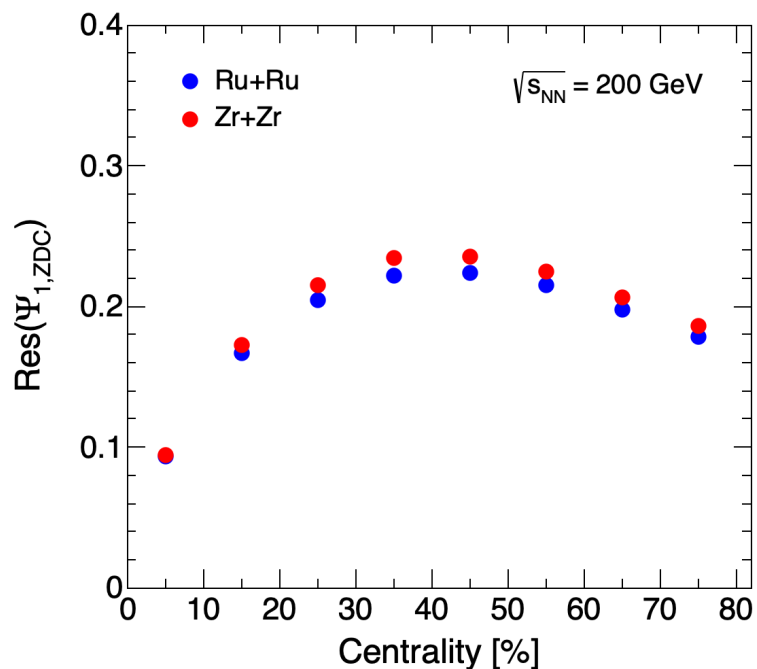
Zero Degree Calorimeters

Time Projection Chamber

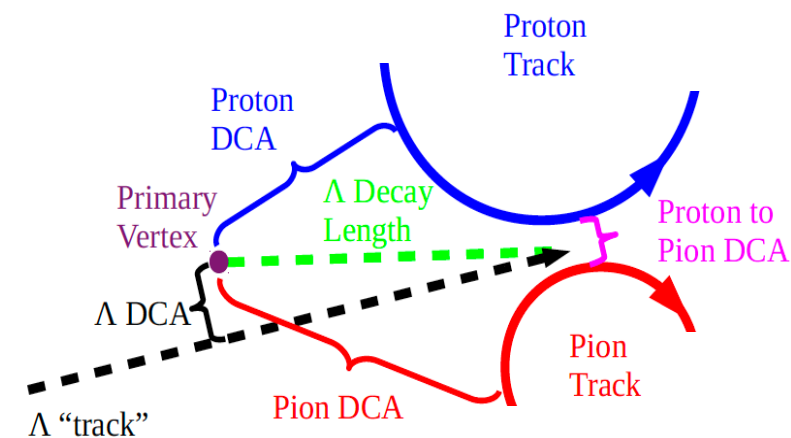
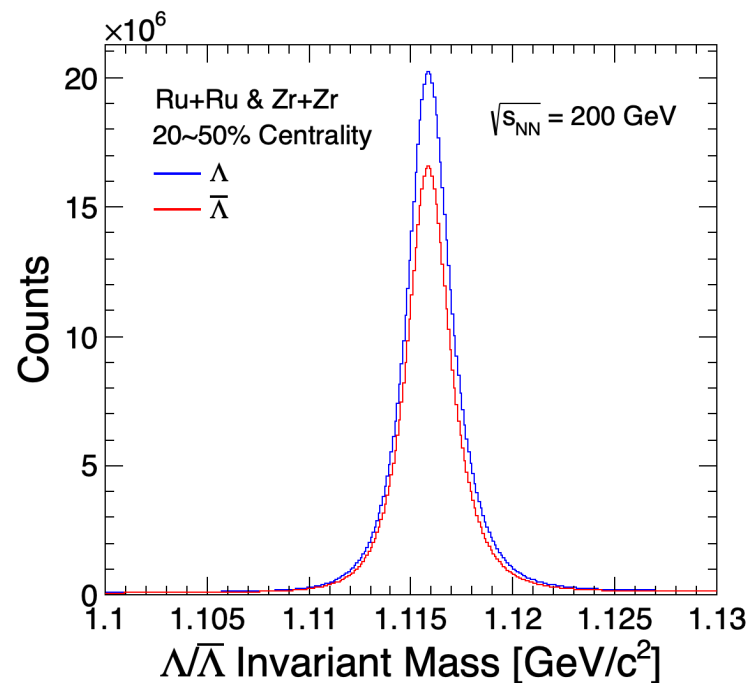


- First-order event plane reconstruct by ZDC
 - $|\eta| > 6.3$
- Second and third-order event plane reconstruct by TPC
 - $|\eta| < 1.0$

First-order event plane resolution



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



Event plane reconstruction:

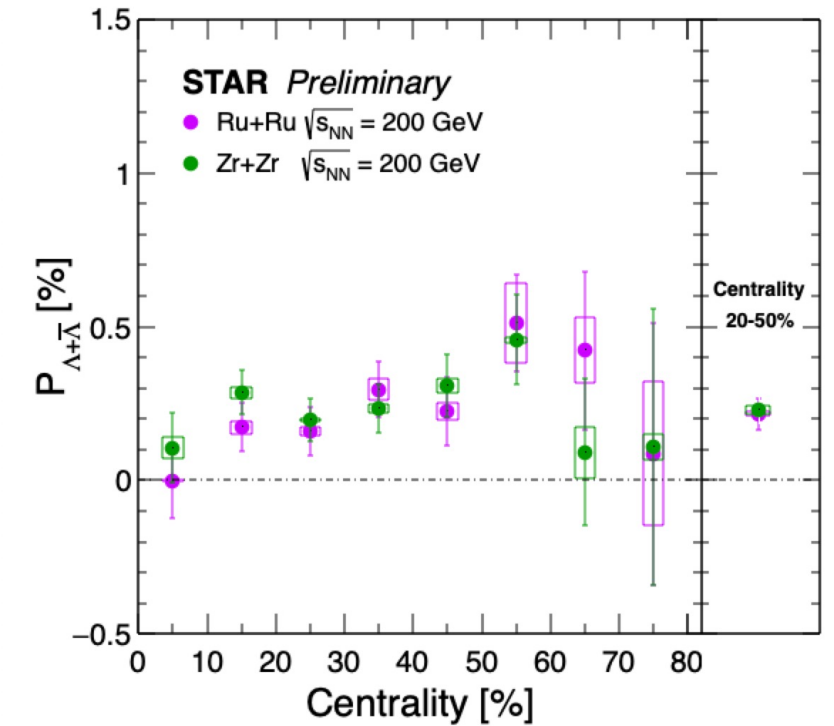
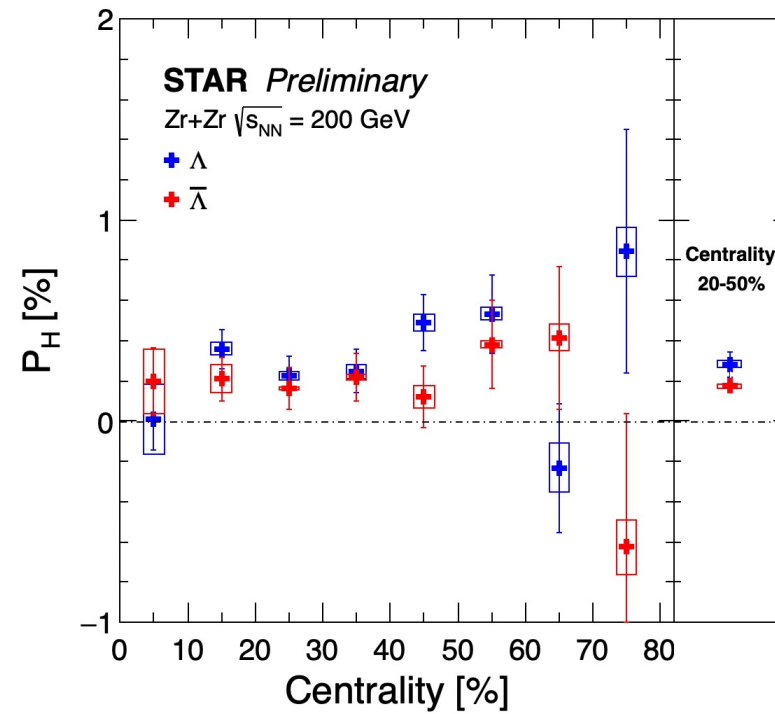
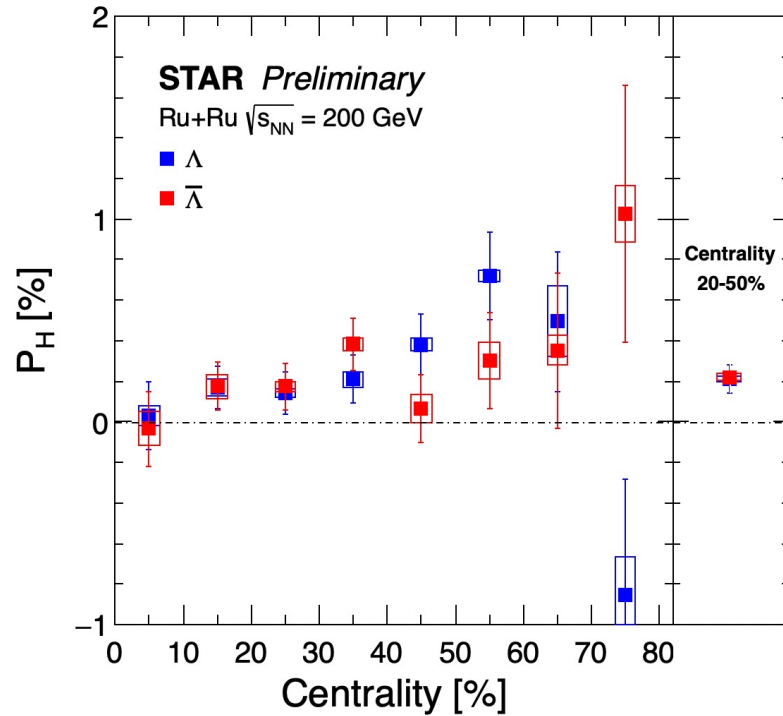
Zero Degree Calorimeters
Time Projection Chamber

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

Time Projection Chamber
Time Of Flight

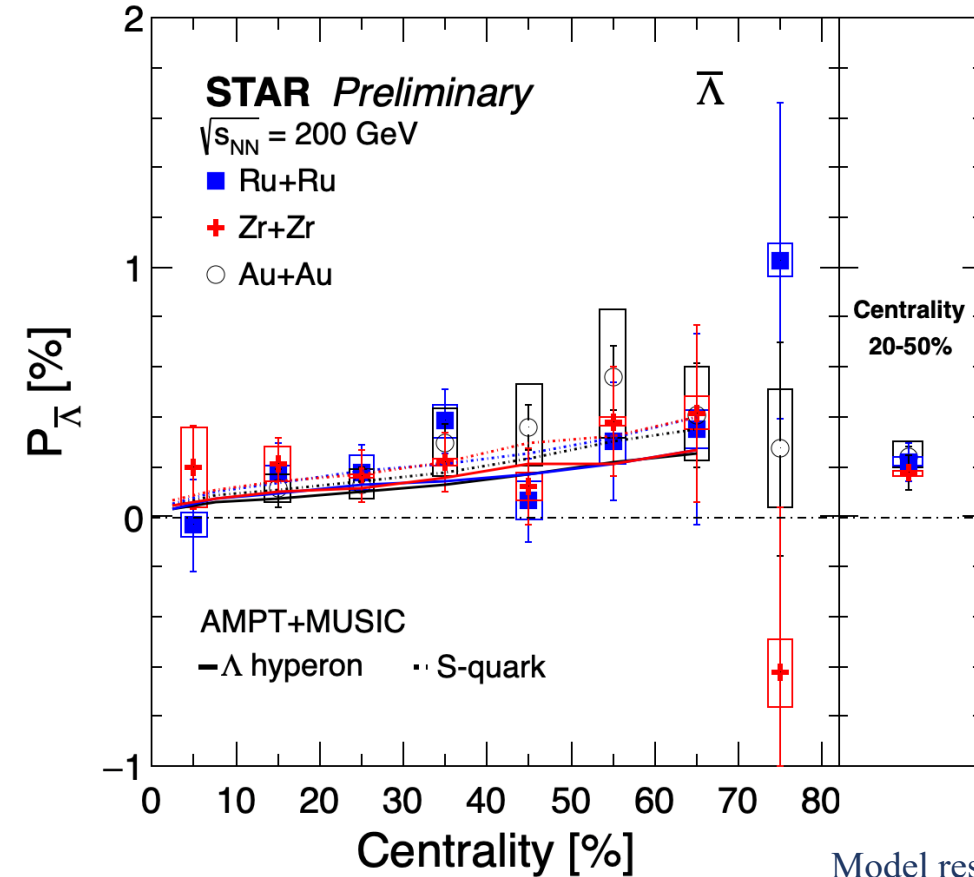
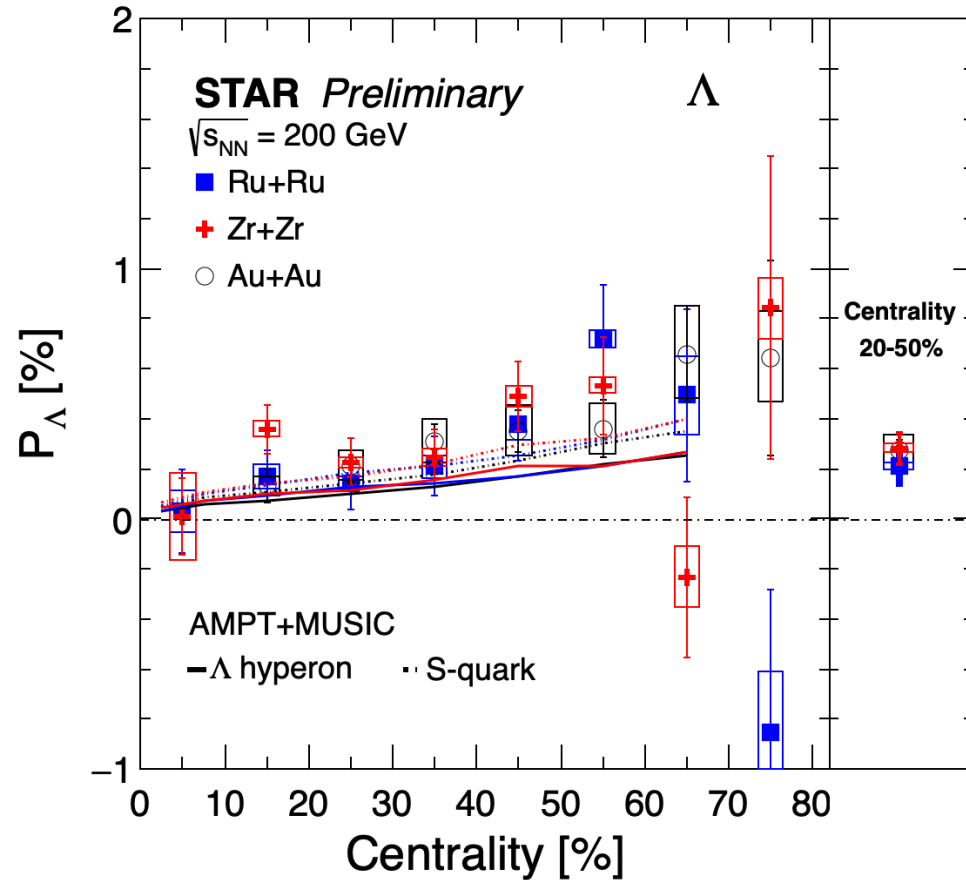
- $\Lambda \rightarrow p + \pi^-$
- $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$
- Background fraction $< 3\%$

Global polarization in Ru+Ru and Zr+Zr at 200 GeV



- Significant global polarization observed, P_{Λ} and $P_{\bar{\Lambda}}$ increase with centrality
- No significant difference between P_{Λ} 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

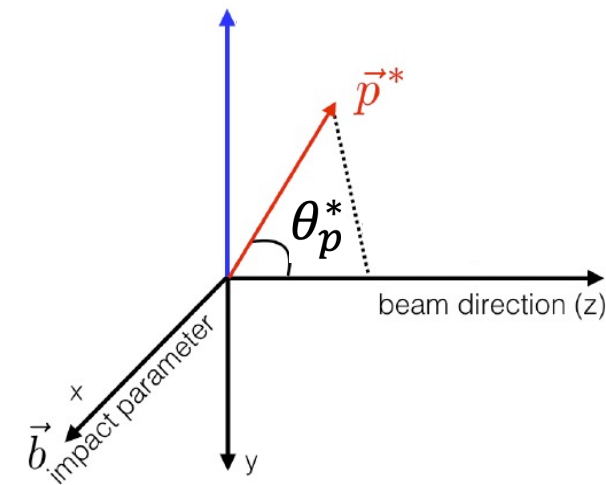
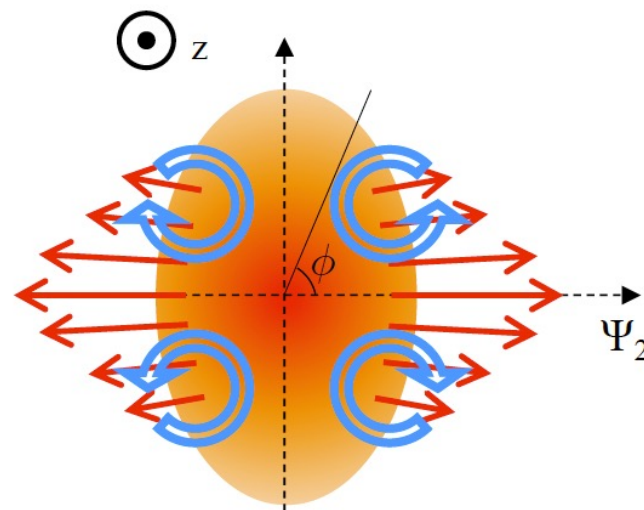
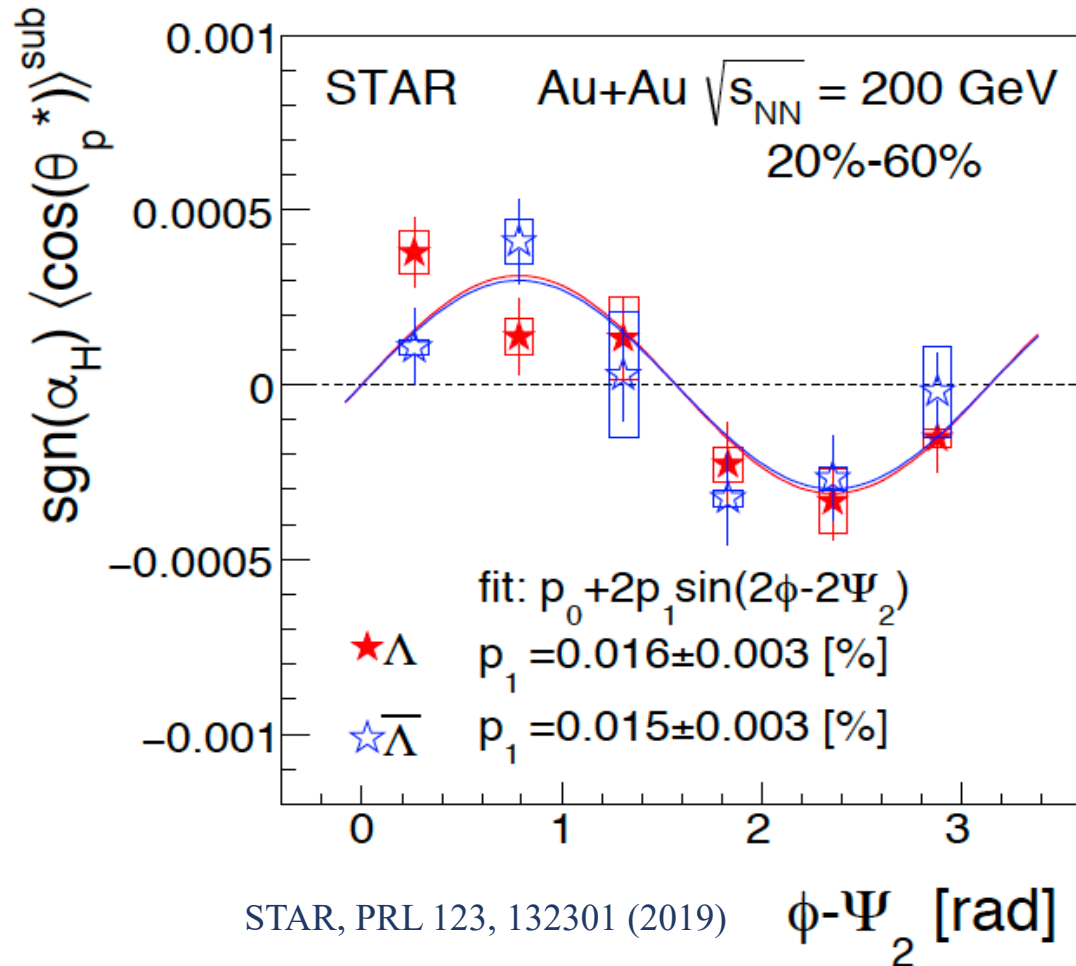
Global polarization in Ru+Ru, Zr+Zr and Au+Au at 200 GeV



Model results from
 arXiv:2201.12970v1

■ Global polarization of Λ and $\bar{\Lambda}$ are consistent in isobar and Au+Au collision systems

Local polarization in heavy ion collisions



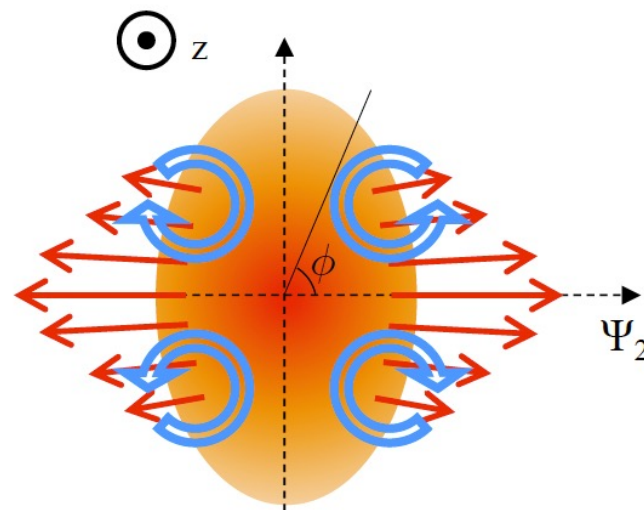
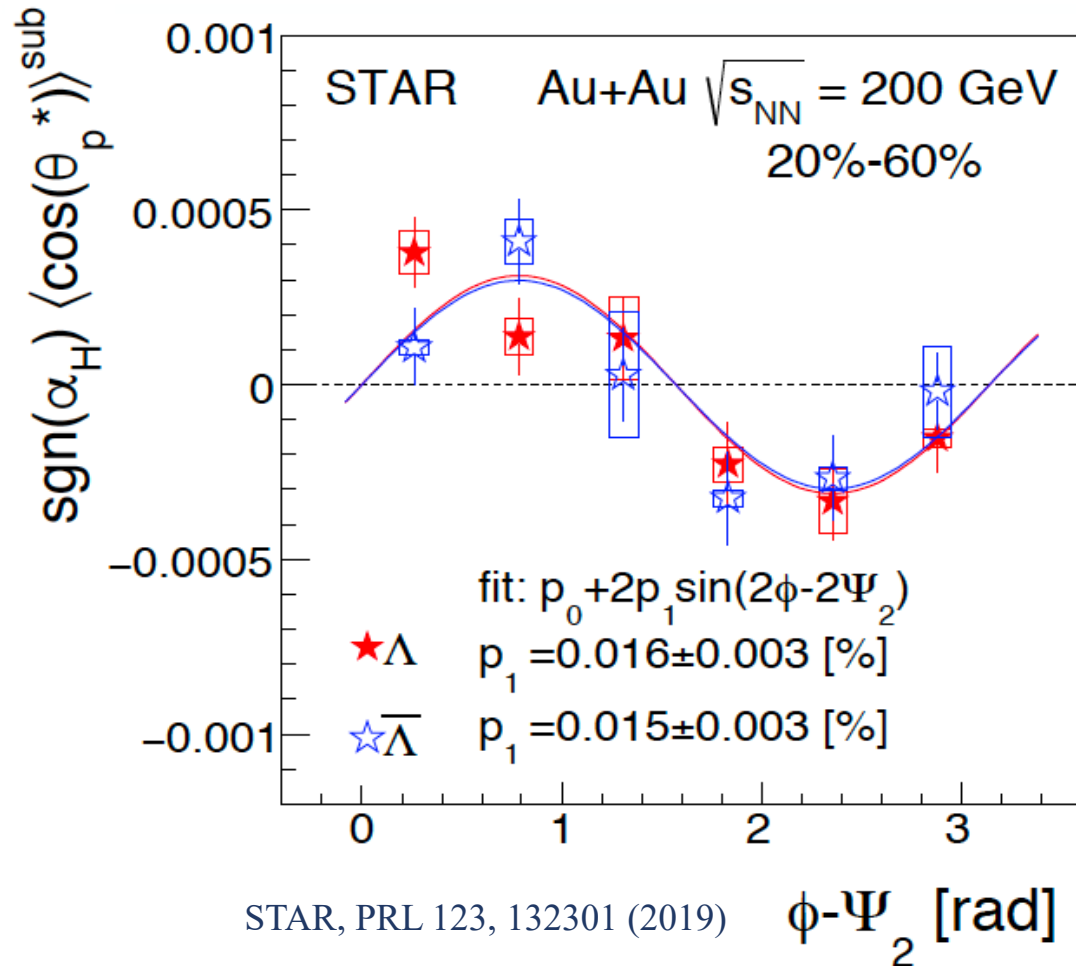
- Collision system size and energy dependence
- Measurements in smaller systems and relative to higher harmonic event planes provide new insights into polarization phenomena

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

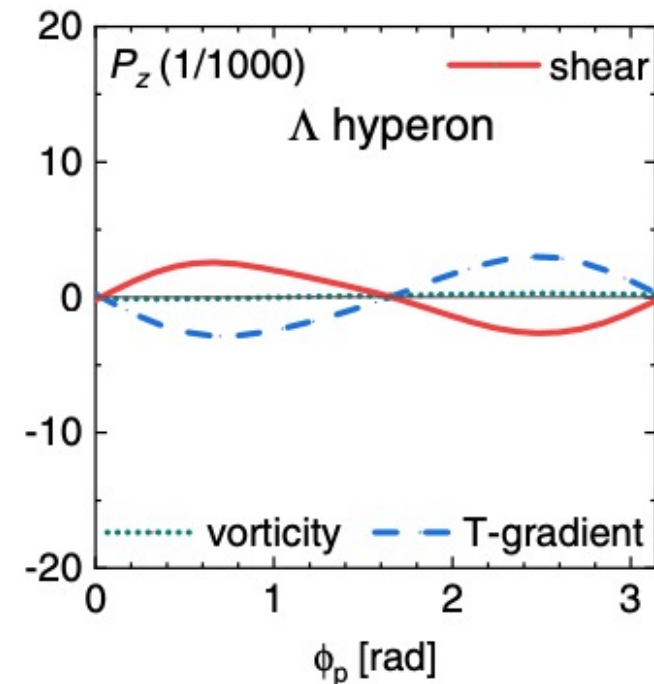
$$= \alpha_\Lambda P_z \langle (\cos \theta_p^*)^2 \rangle$$

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

Local polarization in heavy ion collisions

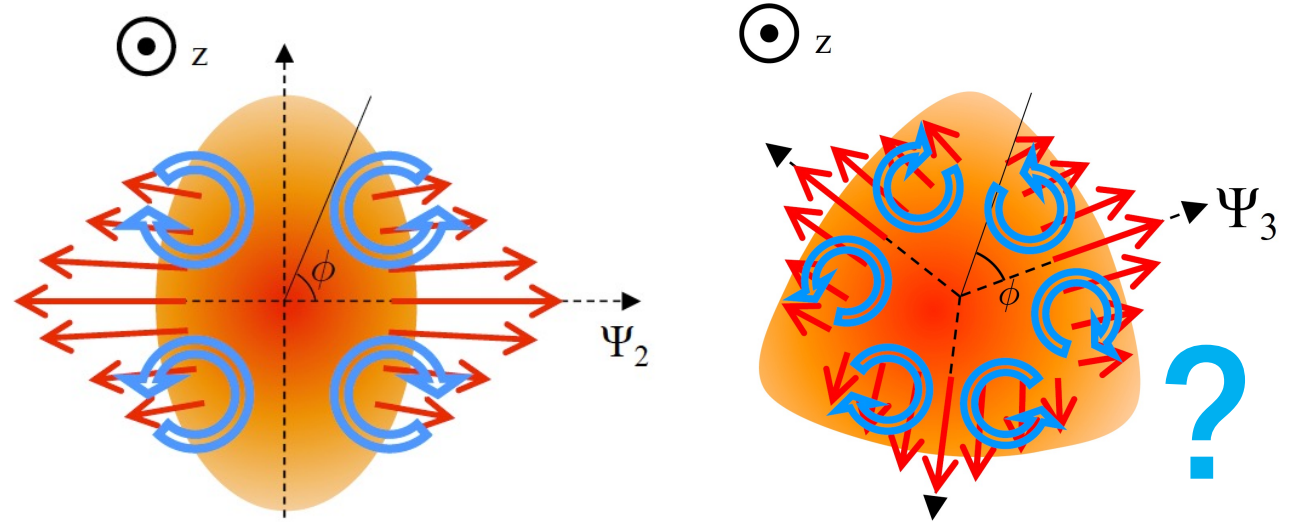
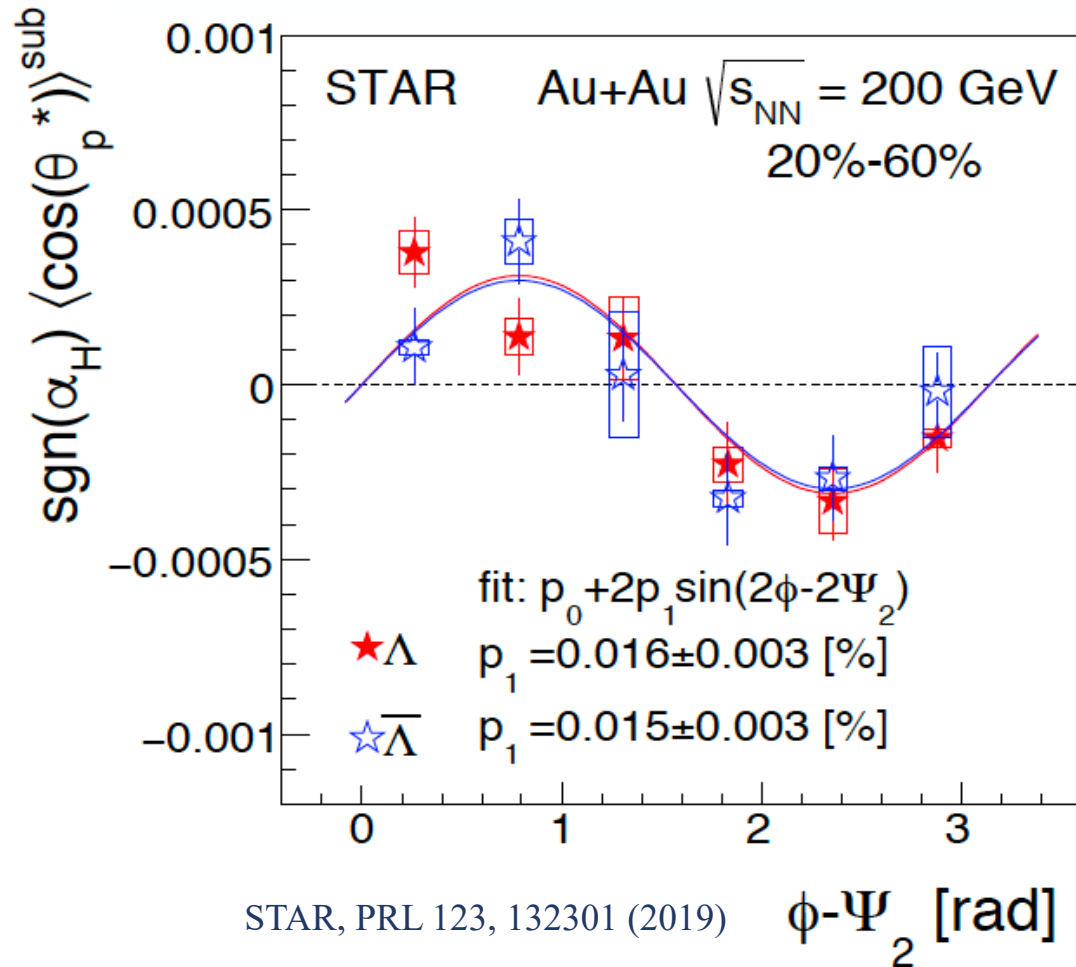


Baochi Fu et al., PRL 127, 142301 (2021)



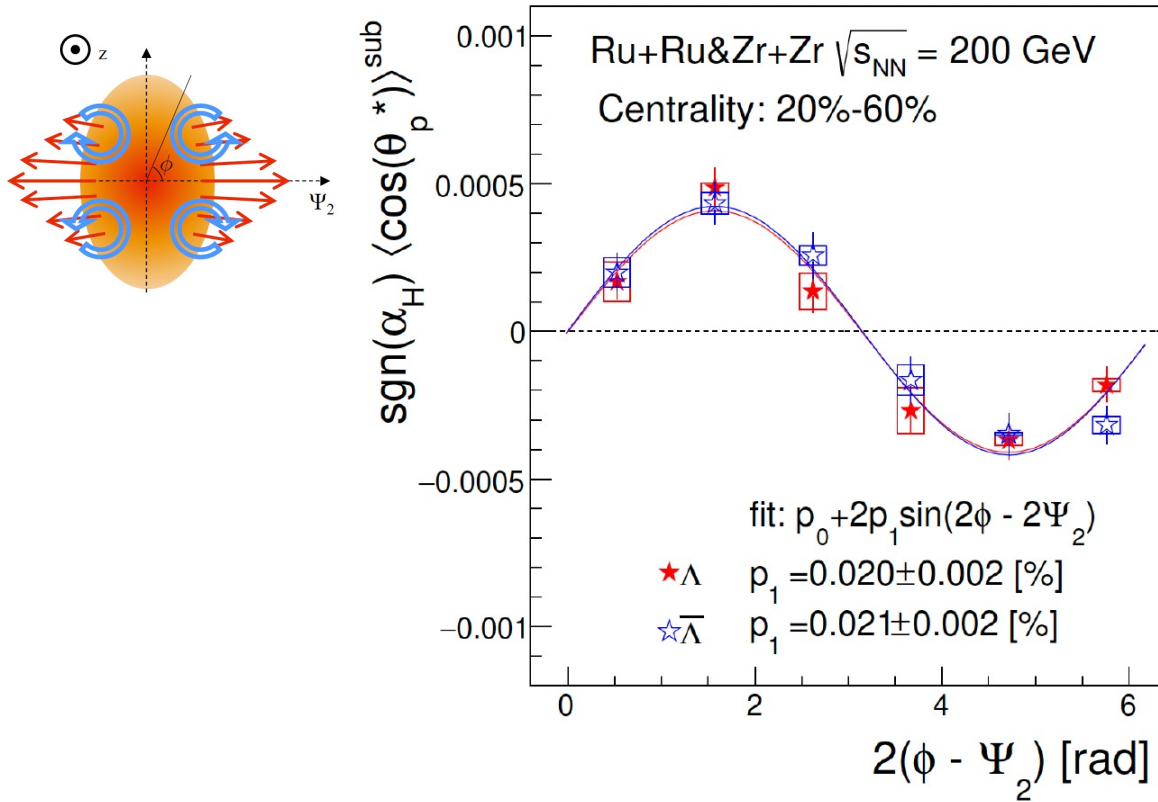
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Local polarization in heavy ion collisions



- Collision system size and energy dependence
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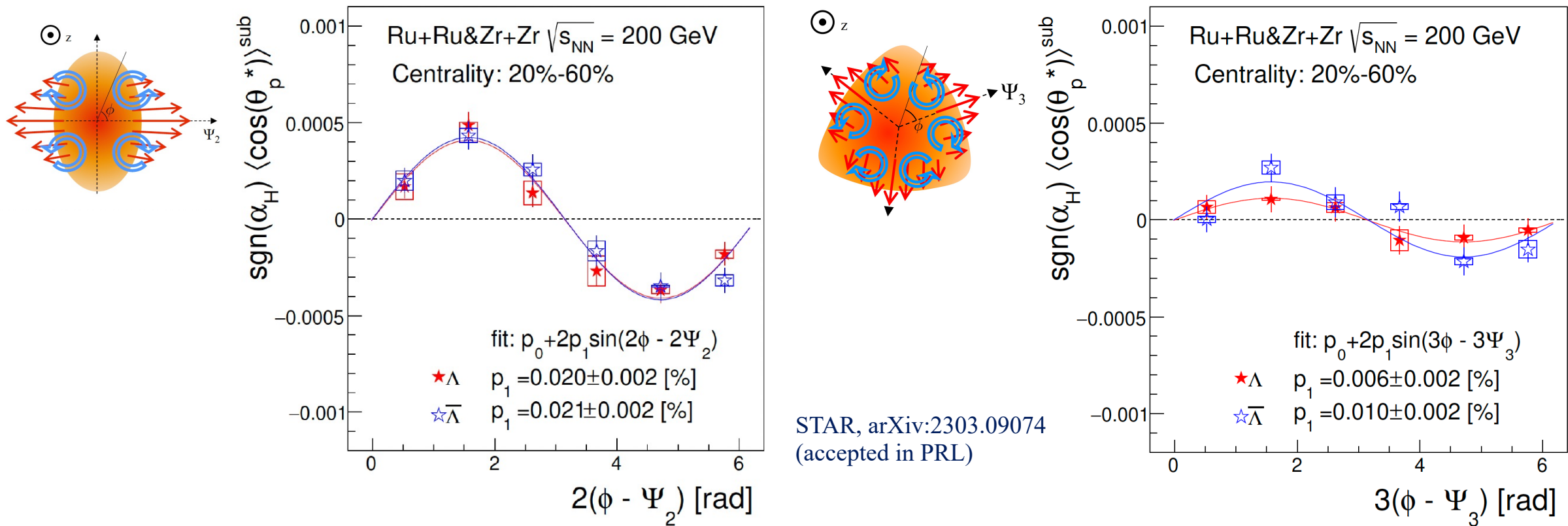
Local polarization in Ru+Ru&Zr+Zr at 200 GeV



STAR, arXiv:2303.09074
(accepted in PRL)

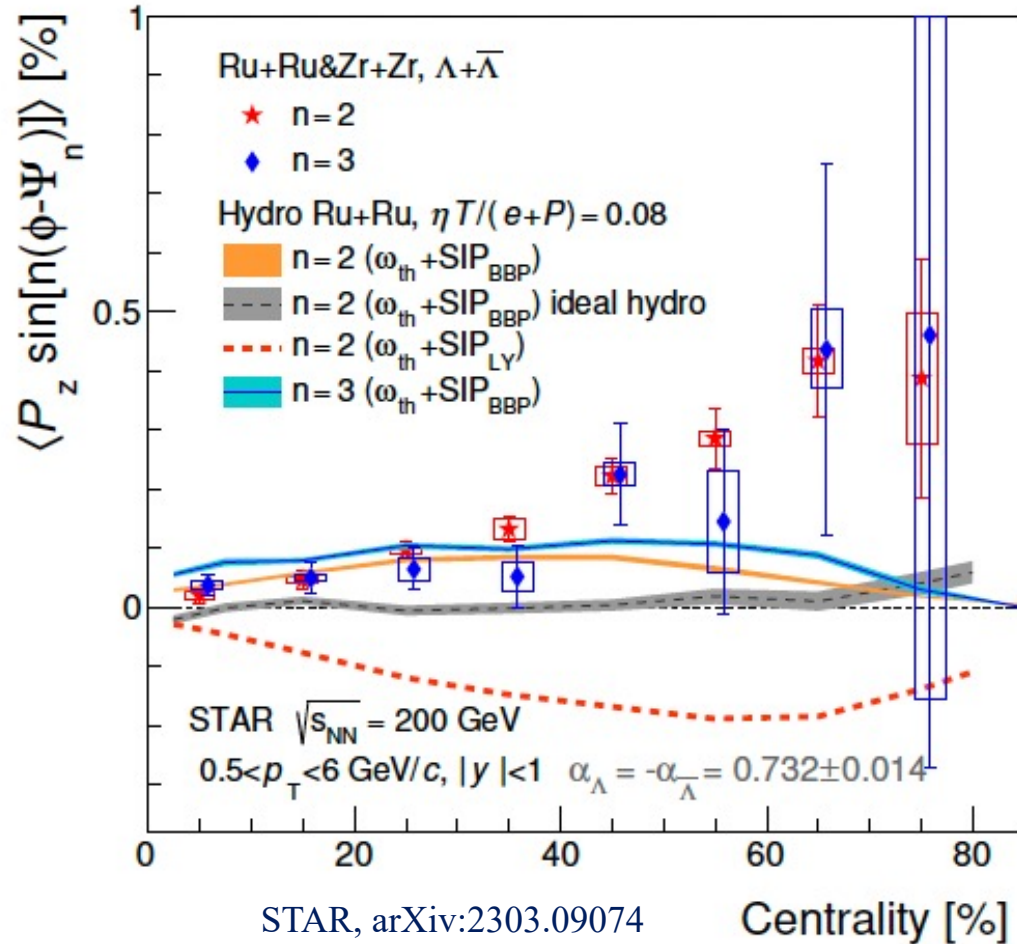
- Significant local polarization w.r.t second-order event plane observed in isobar collisions

Local polarization in Ru+Ru&Zr+Zr at 200 GeV



- 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

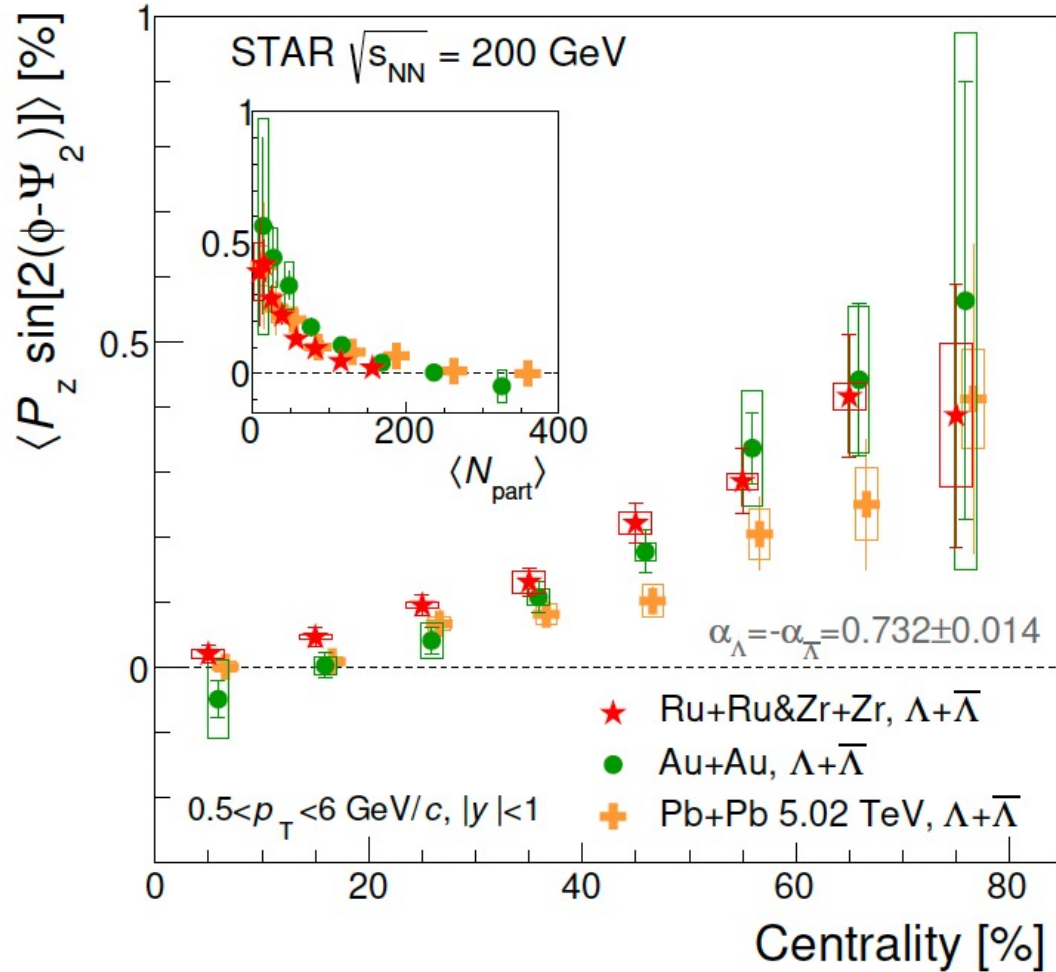
Centrality dependence of local polarization



- Local polarization w.r.t second-order event plane increases with centrality
- Significant local polarization w.r.t third-order event plane
- Comparable local polarization w.r.t second and third order event plane
- Hydrodynamic models with shear term reasonably describe the data for central collisions, but not for peripheral

S. Alzhvani et al., PRC 106.014905

Local polarization in different collisions



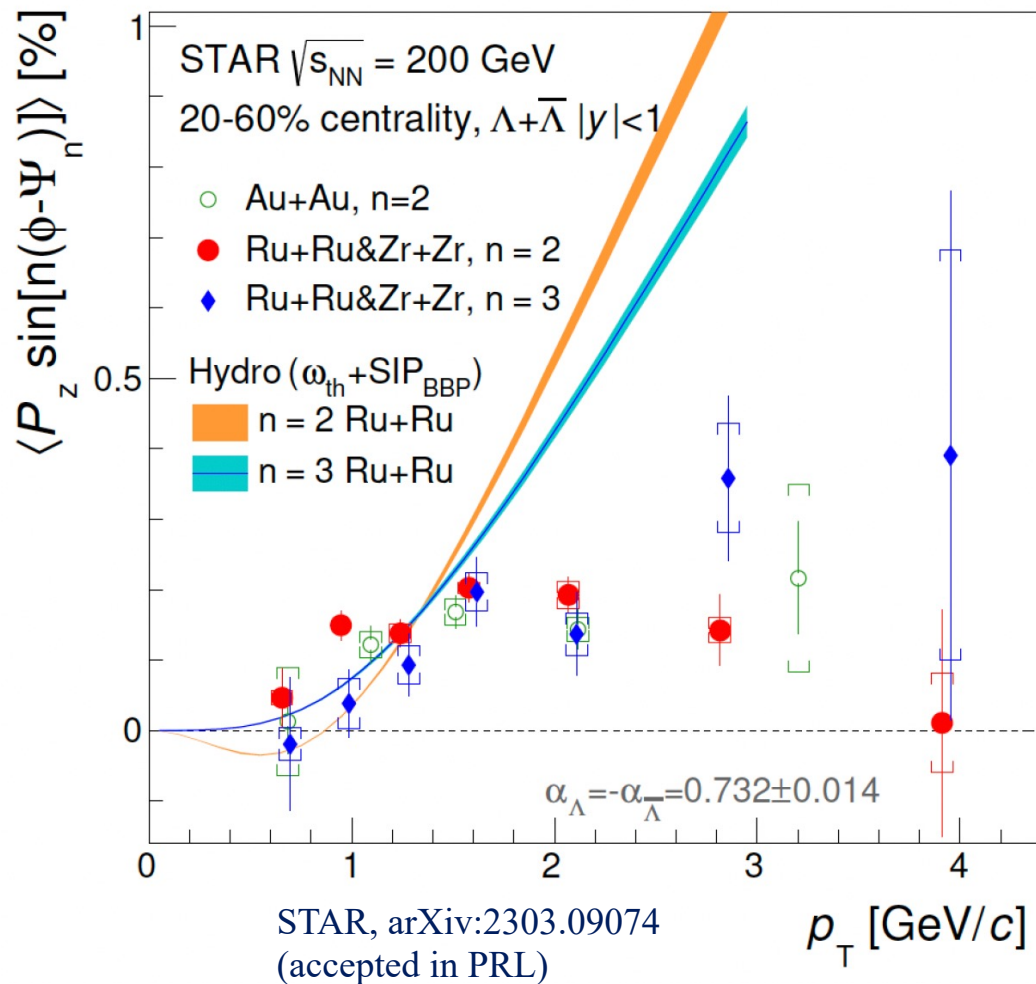
- Hint of system size dependence between isobar and Au+Au collisions
- Energy dependence is not obvious between 200 GeV Au+Au and 5.02 TeV Pb+Pb collisions

STAR, arXiv:2303.09074 (accepted in PRL)

Au+Au: STAR, PRL 123, 132301 (2019)

Pb+Pb: ALICE, arXiv:2107.11183

p_T dependence of local polarization



- Local polarization p_T dependence is observed
- Observed p_T dependence similar to that of elliptic (v_2) and triangular (v_3) flow
- Results are consistent between isobar and Au+Au collisions

Global polarization

- ❑ No splitting observed between Λ and $\bar{\Lambda}$ global polarization in ${}^{96}_{44}\text{Ru} + {}^{96}_{44}\text{Ru}$, ${}^{96}_{40}\text{Zr} + {}^{96}_{40}\text{Zr}$ collisions
- ❑ No collision system size dependence between Ru+Ru, Zr+Zr and Au+Au collisions at 200 GeV

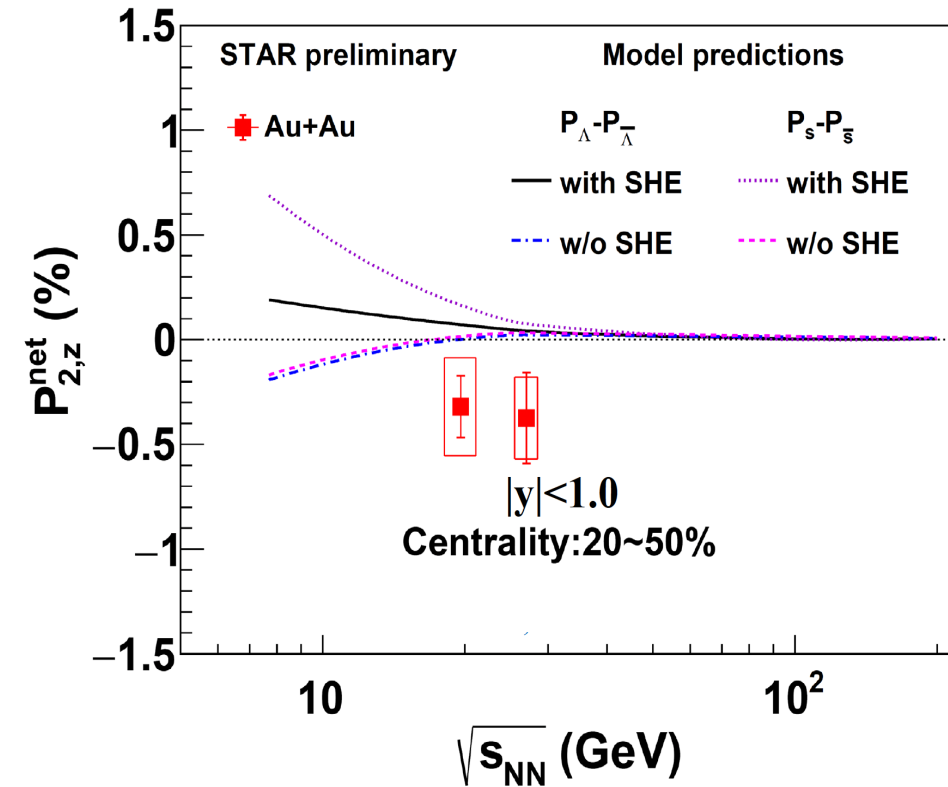
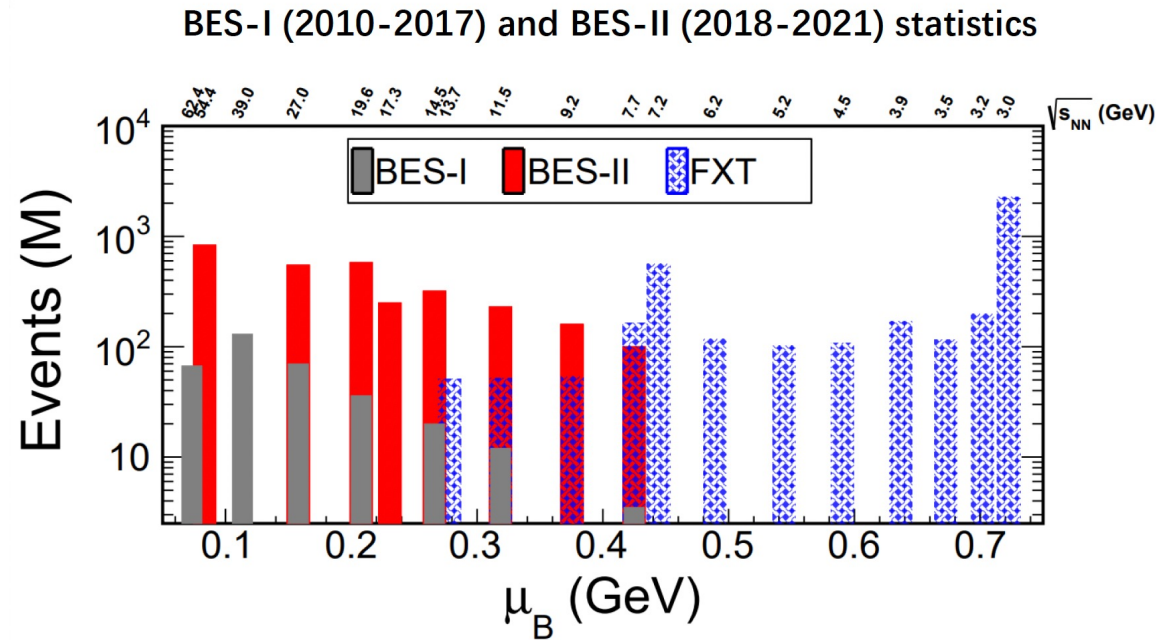
Local polarization

- ❑ First observation of local polarization w.r.t third-order event plane in isobar collisions at 200 GeV
- ❑ Hint of collision system size dependence of local polarization when comparing between isobar and Au+Au
- ❑ Local polarization p_T dependence is observed, trend are similar to that of elliptic (v_2) and triangular (v_3) flow

Outlook – Local polarization in Au+Au at BES-II



Model predictions from Baochi Fu et al., arXiv:2201.12970v1



- Hyperon local polarization collision energy dependence in BES-II?
- First study of baryonic spin Hall effect by measuring net local polarization



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Thanks for your attention

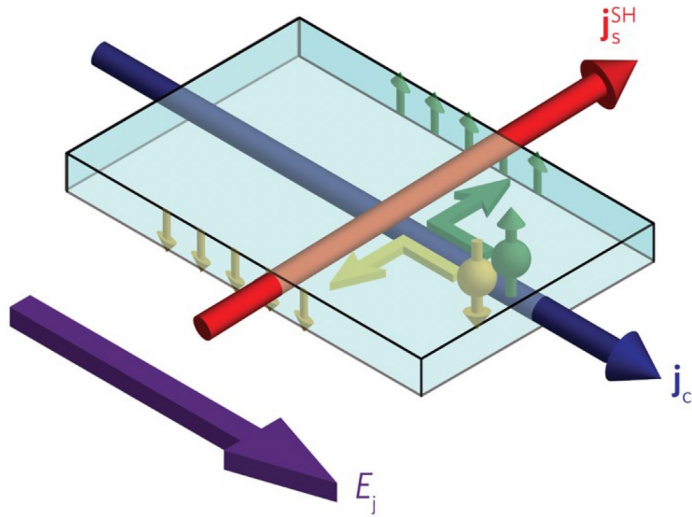


**25TH INTERNATIONAL
SPIN PHYSICS
SYMPOSIUM**

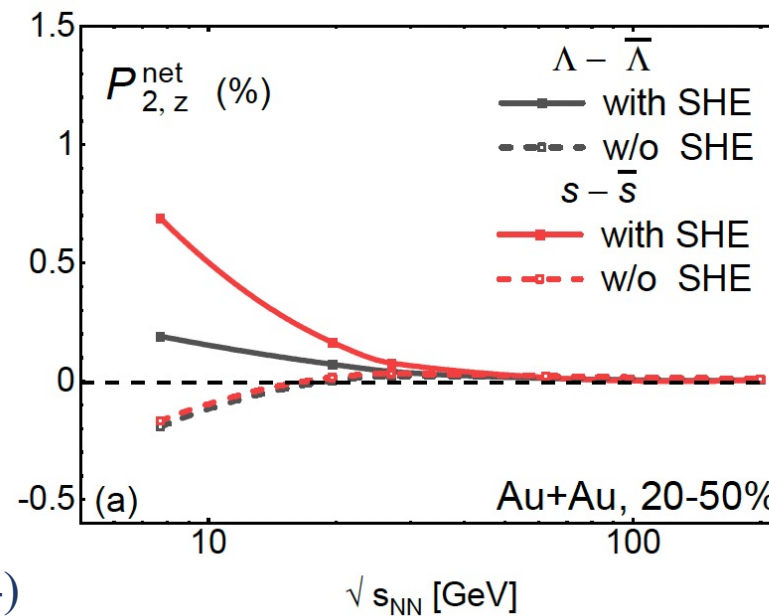
Outlook - Baryonic Spin Hall Effect (SHE)



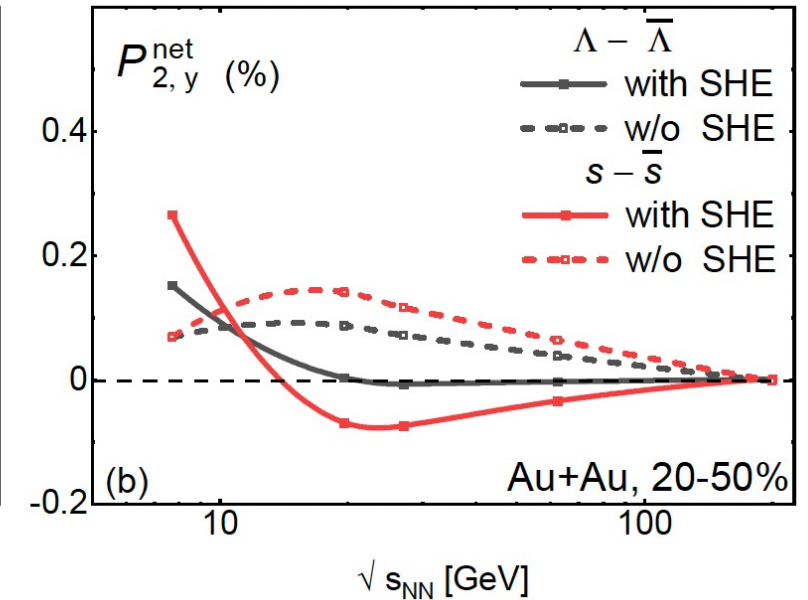
Baochi Fu et al., arXiv:2201.12970v1



Spin Hall effect : spin imbalance (2004)

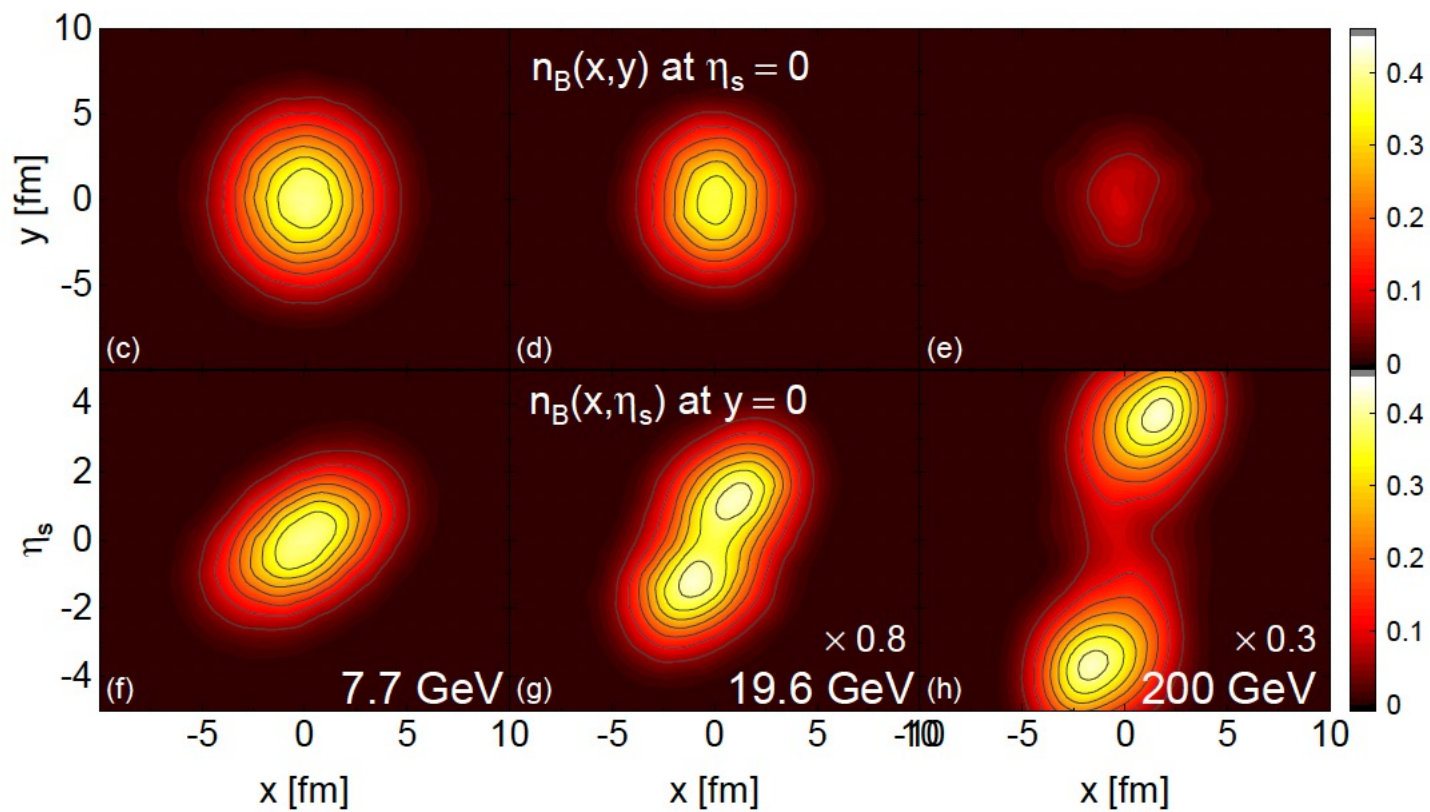


$$P_{2,z}^{net} \equiv \langle P_z^{\Lambda-\bar{\Lambda}} \sin(2\phi_{\Lambda} - 2\Psi_2) \rangle$$



$$P_{2,y}^{net} \equiv \langle P_y^{\Lambda-\bar{\Lambda}} \cos(2\phi_{\Lambda} - 2\Psi_2) \rangle$$

□ Probing baryonic spin Hall effect in heavy-ion collisions via $\Lambda / \bar{\Lambda}$ local polarization



Baochi Fu et al., arXiv:2201.12970v1