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Global polarization measurements in Au+Au collisions

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Global hyperon's polarization

Source: **Large angular orbital momentum** $\vec{L}$ of the system in non central relativistic nuclear-nuclear collisions

Effect: **transformation of the angular momentum** $\vec{L}$ **into the particles spin**

Method: $\vec{L}$ is perpendicular to the reaction plane

→ Correlations wrt the reaction plane

→ **Anisotropic flow technique can be applied**

Analysis overview

Theory input:

Z.-T. Liang and X.-N. Wang	Phys. Rev. Lett. 94, 102301 (2005) [**erratum**: 039901(2006)]
Z.-T. Liang and X.-N. Wang	nucl-th/0411101
Sergei A. Voloshin	nucl-th/0410089

Measurement technique: Two particle correlations wrt reaction plane estimated from STAR Forward TPC ($2.7<|\eta|<3.9$)

Results: Lambda global polarization in Au+Au at 62 and 200 GeV

Systematics study: 2 different collision energies
Reversed Full Field vs Full Field data for 200GeV
Forward TPC event plane resolution: saturation in 200GeV
centrality cuts
different charges

Angular distribution for the global polarization

$$\frac{dN}{d\cos\theta^*} \sim 1+\alpha_H P_H \cos\theta^*$$

$P_H(\vec{p}_\Lambda)$ hyperon polarization wrt reaction plane (**global polarization**)

α_H decay constant ($\alpha_\Lambda = 0.642$ for $\Lambda \to p\pi^-$)

θ^* angle between normal for the reaction plane and the hyperon's decay product 3-momentum in the hyperon's rest frame

Observables for the global polarization

Directly from the definition

$$P_H = \frac{3}{\alpha_H}\langle \cos\theta^* \rangle$$

Averaging over all
reaction plane orientations and the hyperon's
decay product 3-momentum directions
in the hyperon's rest frame

Via azimuthal correlations [angles relation $\cos\theta^* = \sin\theta_p^* \sin(\phi_p^* - \Psi_{RP})$]

$$P_H = \frac{8}{\pi\,\alpha_H}\langle \sin(\phi_p^* - \Psi_{RP}) \rangle$$

ϕ_p^* decay product azimuthal angle

Ψ_{RP} reaction plane angle

Similar to the observable used to define **directed flow – anisotropic flow technique!**

Lambda global polarization: **measurement technique**

$$P_\Lambda = \frac{8}{\pi \alpha_\Lambda^-} \frac{\langle \sin(\varphi_{p_\Lambda^*} - \Psi_{EP}^1) \rangle}{R_{EP}^1}$$

$\varphi_{p_\Lambda^*}$ - angle of the decayed proton in the Λ rest frame

Scalar product technique
(two particle correlations)

$$P_\Lambda = \frac{8}{\pi \alpha} \frac{\langle \sin\varphi_{p_\Lambda^*} X_{EP}^1 \rangle - \langle \cos\varphi_{p_\Lambda^*} Y_{EP}^1 \rangle}{R_{EP}^1}$$

$Q_{EP}^1 = (X_{EP}^1, Y_{EP}^1)$ - **1st order event plane vector (from Forward TPC)**

R_{EP}^1 - **Forward TPC event plane resolution**:
from **two particle correlations**
(Forward TPC[East-West] to suppress non-flow from momentum conservation)
or **mixed harmonic**
(need more statistics, but efficiently suppress non-flow)

Acceptance corrections for the global polarization

Experimentally measured value:
(already integrated over Ψ_{RP}, "good" reaction plane determination assumed)

$$P_{\Lambda}^{\exp} = \frac{4}{\pi}\int \frac{d\,\Omega^{*}}{4\pi}\; A\left(\vec{p}_{\Lambda}, \vec{p}_{p}^{\,*}\right)\; \sin\theta_{p}^{*}\;\; P_{\Lambda}(\vec{p}_{\Lambda})$$

Perfect acceptance: $A\left(\vec{p}_{\Lambda}, \vec{p}_{p}^{\,*}\right) \equiv 1$ $\qquad \frac{4}{\pi}\int \frac{d\,\Omega^{*}}{4\pi}\; \sin\theta_{p}^{*} = 1$

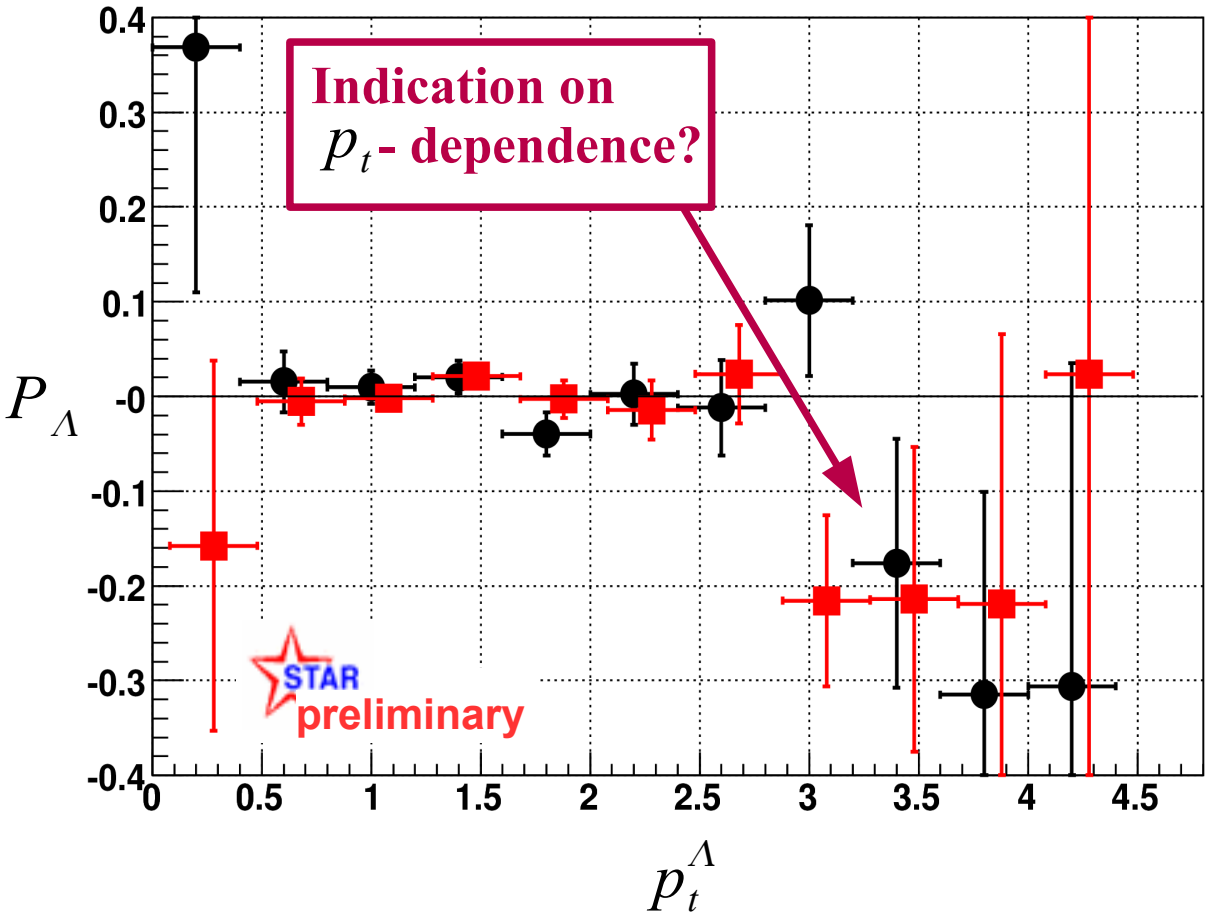
If global polarization independent of $\eta_{\Lambda}, \phi_{\Lambda}$ within STAR acceptance

one have to correct the results on $\frac{4}{\pi}\int \frac{d\,\Omega^{*}}{4\pi}\; A\left(\vec{p}_{\Lambda}, \vec{p}_{p}^{\,*}\right)\; \sin\theta_{p}^{*}$

Results are not yet corrected on Λ reconstruction acceptance

Lambda global polarization: **transverse momentum dependence**

RHIC Run IV data



AuAu@200GeV (20-70%)

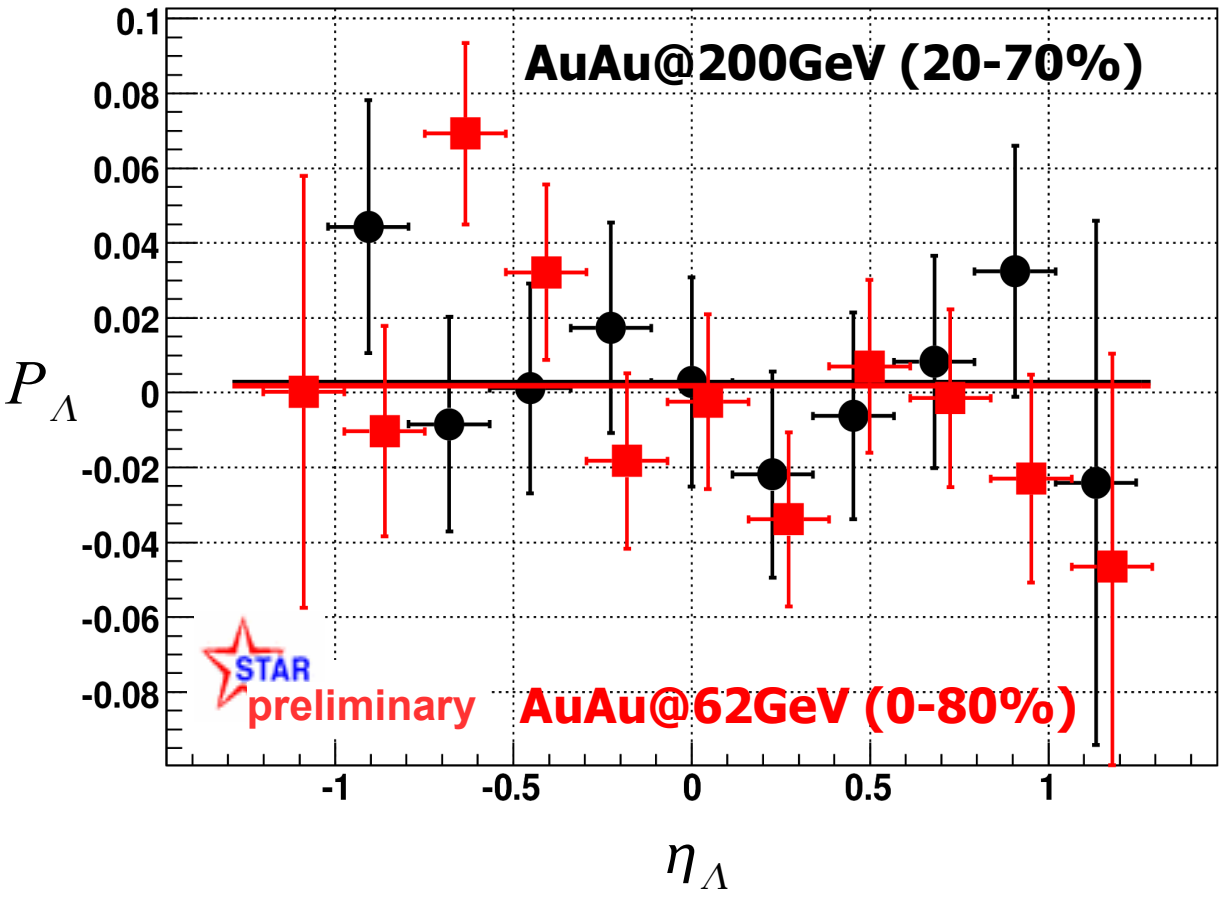
AuAu@62GeV (0-80%)

Global polarization is zero for small Lambda p_t

No theory curves on p_t dependence for the moment

Lambda global polarization: **pseudo-rapidity dependence**

RHIC Run IV data



Line fit for AuAu@200GeV

$$P_\Lambda = (2.6 \pm 9.5) \times 10^{-3}$$

line fit for AuAu@62GeV

$$P_\Lambda = (1.9 \pm 8.0) \times 10^{-3}$$

Available theory value

$$P_\Lambda = -0.3$$

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

Conclusion

- The **Lambda global polarization has been measured in Au+Au** collisions at the center of mass **energies 62 and 200 GeV** with the **STAR detector** at RHIC

- An **upper limit for the Lambda global polarization** is obtained:

$$\left|P_{\Lambda}\right| \leq 10^{-2}$$

This **value is far below** the one **discussed in the recent theoretical papers**:

$$P_{\Lambda}^{theor} = -0.3$$

- The **reason for this** significant **discrepancy is not clear** now and there are still extensive **theoretical discussion** on this subject. As it was found later by the original authors the **predicted value of** $P_{\Lambda}^{theor} = -0.3$ **could be incorrect** due to inapplicability of the approximations used and the correct estimation for RHIC energies requires **more realistic theoretical calculations** (see **Phys. Rev. Lett. 96, 039901 (2005)** for details).