The Azimuthal Angle Dependence of Lambda (anti-Lambda) Polarization in Au+Au collisions from STAR

Biao Tu, for the STAR Collaboration

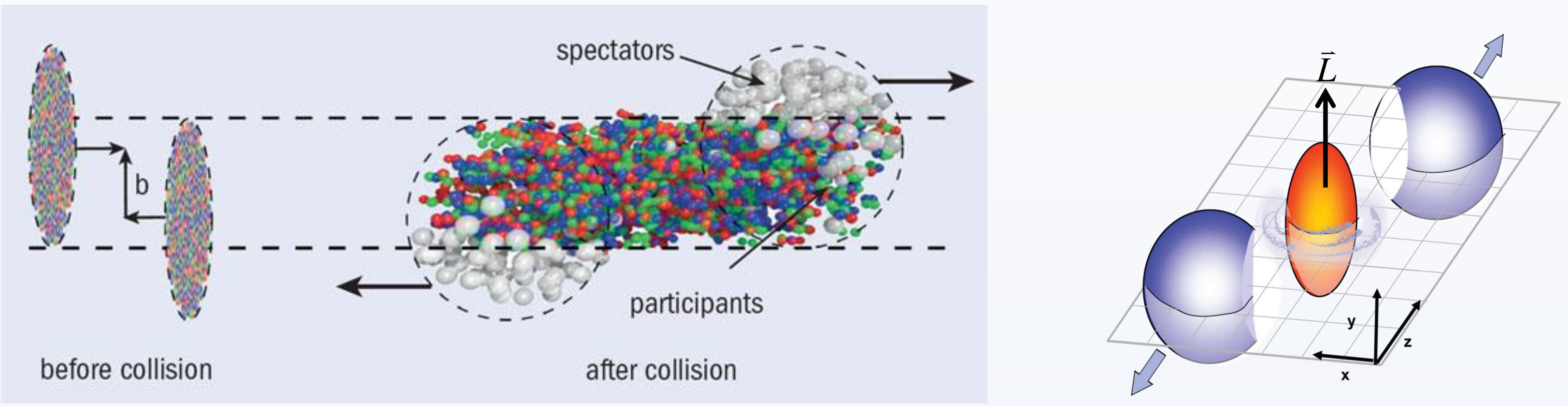
(Central China Normal University & BNL)

Abstract

The STAR experiment at RHIC has observed for the first time a significant alignment between the angular momentum of the medium produced in non-central collisions[1] and the spin of $\Lambda(\bar{\Lambda})$ hyperons (J=1/2), revealing that the matter produced in heavy-ion collisions is by far the most vortical system ever observed. Such vorticity is expected to be maximal at the equator, and due to the low viscosity of the system, the vorticity may not be propagated efficiently to the poles. This may lead to a larger in-plane than out-of-plane polarization for hyperons[2,3].

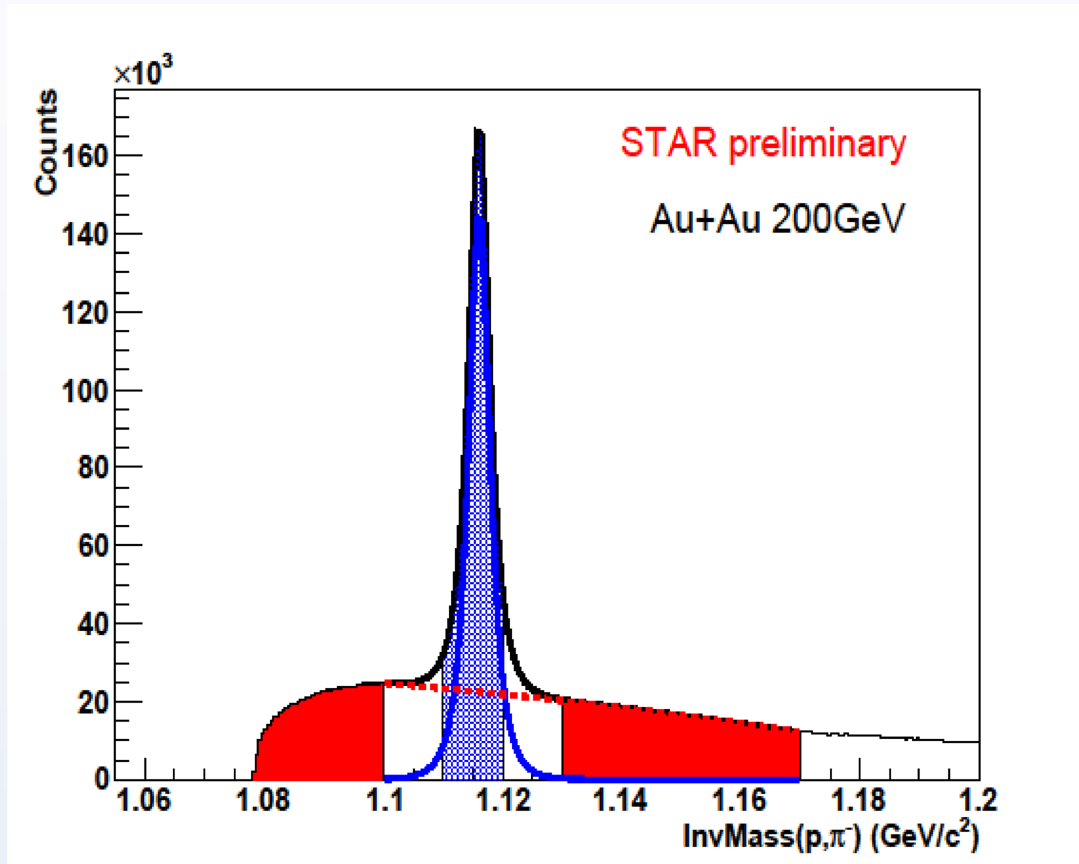
In this poster, we will present the azimuthal angle (with respect to the reaction plane) dependence of Λ and $\bar{\Lambda}$ polarization in 20-50% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV. The implications of our results will be discussed.

Motivation



- Initial angular momentum$|\boldsymbol{L}| \sim 10^3\hbar$ in non-central heavy-ion collisions.
- Baryon stopping may transfer this angular momentum, in part, to the fireball.
- Due to vorticity and spin-orbit coupling, Λ may align with $\boldsymbol{L}$.
- Vorticity, maximum in the reaction plane, may not propagate efficiently from in to out of reaction plane due to the low viscosity of the system. This may lead to a larger in-plane than out-of-plane polarization for both Λ and $\bar{\Lambda}$.

Λ reconstruction



$$P_H = \frac{S+B}{S} P_{H\,peak} - \frac{B}{S} P_{H\,off\,peak}$$

Mass-peak range (1.11-1.12)

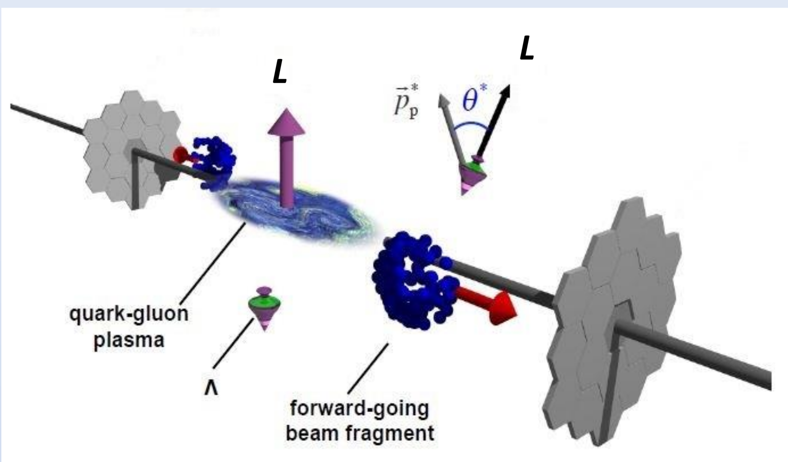
Off mass-peak range (1.07-1.1, 1.13-1.17)

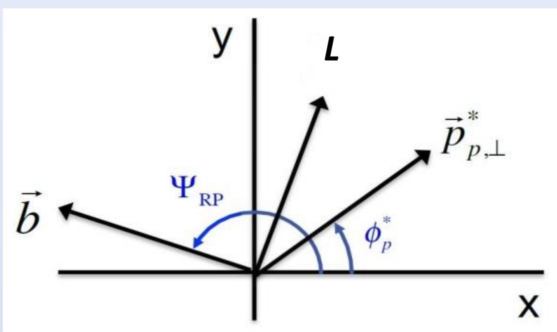
- S is the raw yield of the signal in the peak
- B is the raw yield of the background under the peak

Extraction of the Polarization P_H

The global polarization of Λ hyperons can be determined from the angular distribution of Λ decay products relative to the system orbital momentum $\boldsymbol{L}$ [4].

$$\frac{dN}{dcos\theta^*} = \frac{1}{2}\left(1 + \alpha_H |\vec{P}_H| cos\theta^*\right)$$





averaged over events

$$P_H = \frac{\frac{8}{\pi\alpha_H}\langle \sin(\Psi - \phi_p^*)\rangle}{\text{Res}(\Psi)}$$

- Λ's are "self analyzing": Daughter proton preferentially decays into the direction of Λ spin.
- θ^* is the angle between the system orbital momentum $\boldsymbol{L}$ and the momentum of the daughter proton in the Λ rest frame.
- ϕ_p^* is the daughter proton azimuthal angle in the Λ rest frame.
- Ψ is the 1st order event plane reconstructed by ZDCSMD in this analysis.
- α_H is the Λ decay parameter ($\alpha_\Lambda = -\alpha_{\bar{\Lambda}}$=0.642$\pm$0.013)

Resolution correction

When the event-plane is different from reaction-plane, both $(\Psi - \phi_p^*)$ and $(\phi - \Psi)$ are affected. The smearing of reaction-plane not only reduces the observed overall polarization, but also makes its observed azimuthal dependence weaker than what it actually is. A correction method [5] was applied:

$$P_H^{obs} = A \times P_H^{real} \qquad P_H^{real} = A^{-1} \times P_H^{obs}$$

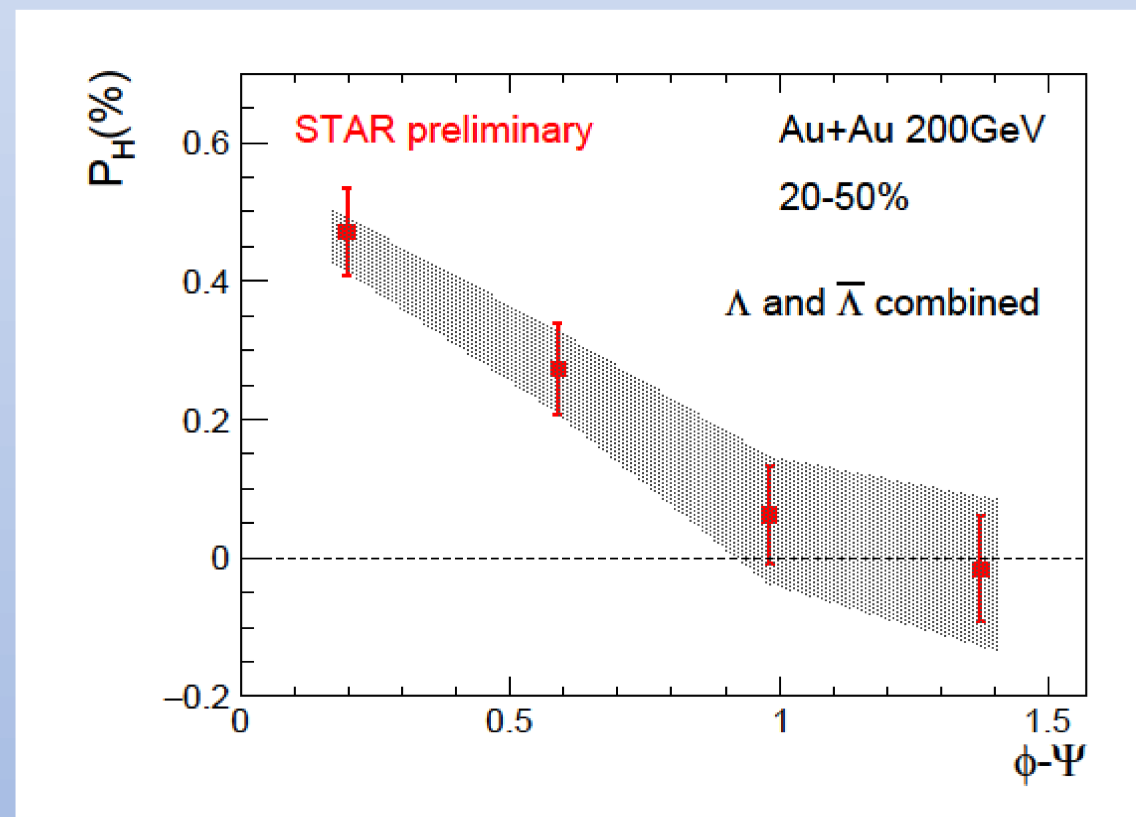
The matrix A can be define as

$$\begin{bmatrix} P_{H,1}^{obs} \\ P_{H,2}^{obs} \\ \vdots \\ P_{H,n}^{obs} \end{bmatrix} = \begin{bmatrix} a_{1,1} & a_{2,1} & \cdots & a_{1,n} \\ a_{1,2} & a_{2,2} & & a_{2,n} \\ & \vdots & \ddots & \vdots \\ a_{1,n} & a_{2,n} & \cdots & a_{n,n} \end{bmatrix} \begin{bmatrix} P_{H,1}^{real} \\ P_{H,2}^{real} \\ \vdots \\ P_{H,n}^{real} \end{bmatrix}$$

$$a_{ij} = \frac{M_{ij}}{\sum_i M_{ij}} * r_{ij}$$

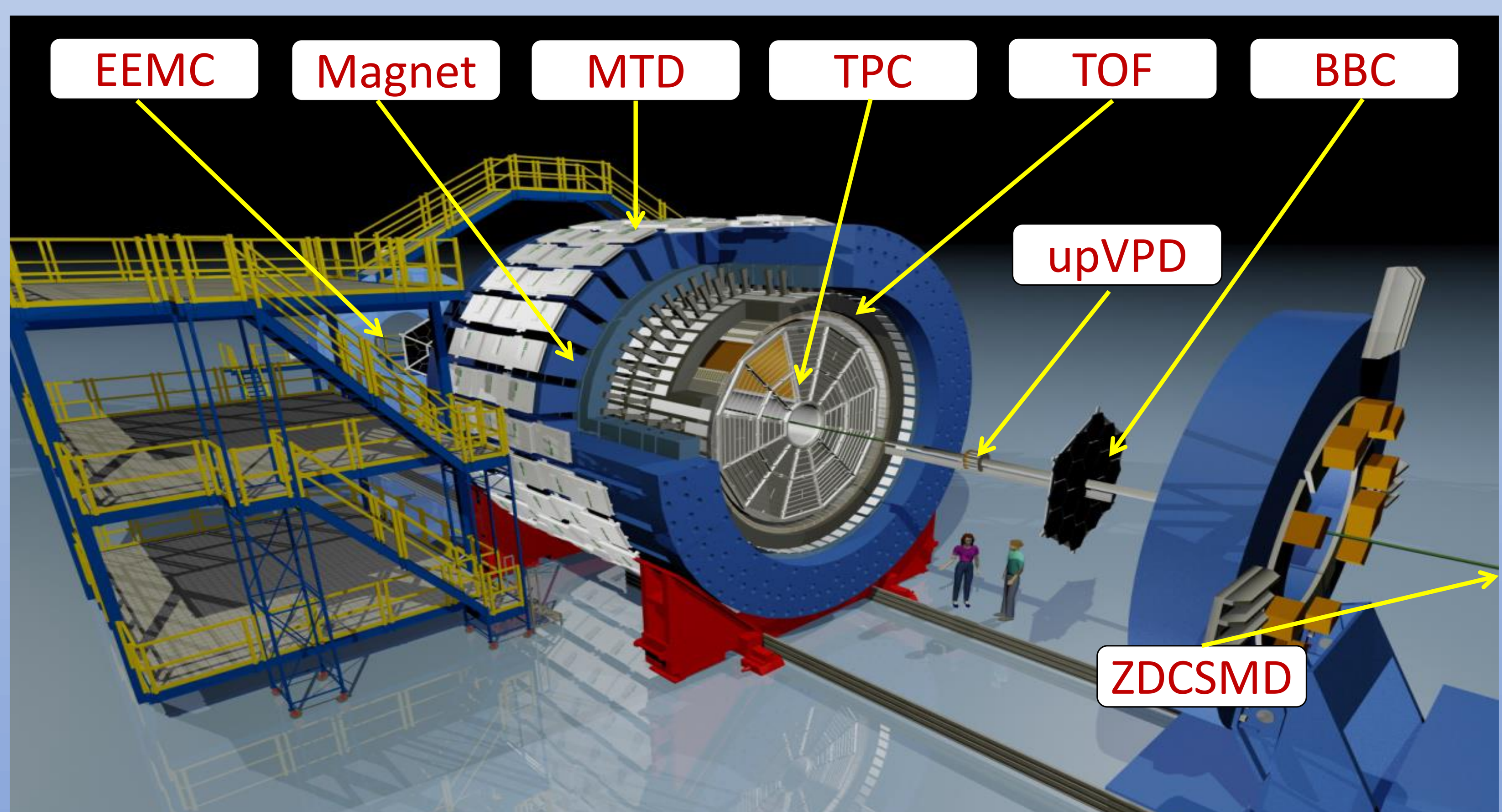
Here $M_{ij}$is particle yield, r_{ij} is particle level resolution.

Azimuthal angle dependence



- P_H, for Λ and $\bar{\Lambda}$ combined, shows a azimuthal angle dependence.
- Consistent with the picture of maximum vorticity in the equator.

STAR Detector



- Full azimuthal coverage and large acceptance
- Excellent particle identification
- Λ reconstruction
  identify daughters(π, p) with TPC and TOF
- Event planes reconstructed by ZDCSMD (1st order EP)

Summary

- A event-plane resolution correction method was presented.
- P_H, for Λ and $\bar{\Lambda}$ combined, shows a azimuthal angle dependence.
- Consistent with the picture of maximum vorticity in the equator.

Reference

[1] L. Adamczyk, et al. (STAR Collaboration), Nature 548, 62 (2017)
[2] F. Becattini, et al. Phys. Rev. C **88**, 034905 (2013)
[3] Y. L. Xie, et al. Phys. Rev. C **94**, 054907 (2016)
[4] B. Abelev, et al. (STAR Collaboration), Phy. Rev. C **76**, 024915 (2007)
[5] A. H. Tang, et al. arXiv:1803.05777