Measurements of Ξ, Ω Hyperons Global Polarization in Au+Au Collisions at BES-II Energies from RHIC-STAR

Xingrui Gou(Gouxr@sdu.edu.cn),
for the STAR Collaboration
Shandong University

Quark Matter 2025

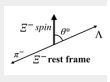
Abstract

The observation of hyperon global polarization along the system's angular momentum has revealed the existence of large vorticities in the medium created by heavy-ion collisions. Using the high-statistics data collected by the STAR experiment during the RHIC Beam Energy Scan II (BES-II) program with upgraded detector systems, we present the global polarization measurements of Ξ and Ω hyperons in Au+Au collisions at BES-II energies ($\sqrt{s_{NN}}$= 7.7, 9.2, 11.5, 14.6, 17.3, 19.6, and 27 GeV). Specifically, we focus on the polarization behaviors observed in different hyperons (Λ, Ξ, Ω). These results provide new insights into the polarization mechanism and vorticity fields in heavy-ion collisions as well as additional constraints on the properties and dynamics of the hot and dense matter created in these collisions.

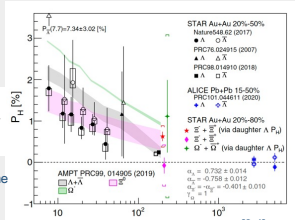
Introduction

The polarization along the initial angular momentum direction, can be described as[1,2]

$$P_H = \frac{8}{\pi \alpha_H} \frac{1}{A_0} \frac{\langle \sin(\Psi_1 - \phi_B^*) \rangle}{Res(\Psi_1)}$$



Ψ_1: first-order event plane
α_H: hyperon decay parameter
ϕ_B^*: azimuthal angle of the daughter baryon in hyperon rest frame
A_0: acceptance correction factor



[3,4]

Motivation

Multi-strange hyperon global polarization properties

- Collision energy, centrality, p_T, η dependence?
- Possible Λ, Ξ, Ω global polarization difference?

Hyperon	Deacy mode	α_H	Spin
$\Lambda(uds)$	$\Lambda \to p + \pi^-$	0.732	1/2
$\Xi^-(dss)$	$\Xi^- \to \Lambda + \pi^-$	-0.401	1/2
$\bar{\Omega}^-(\bar{s}\bar{s}\bar{s})$	$\bar{\Omega}^- \to \bar{\Lambda} + \bar{K}^-$	0.0157	3/2

PDG2021

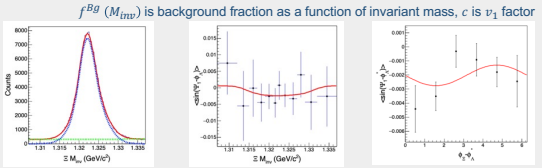
Global Polarization Signal Extraction

- Direct measurement : via daughter Λ angle distribution in Ξ, Ω rest frame
- Indirect measurement : via daughter Λ polarization with spin transfer factor ($C_{\Xi\to\Lambda}\sim0.944, C_{\Omega\to\Lambda}\sim1.0$ is assumed)
- Generalized Invariant Mass method(IM) for signal extraction

$$\langle \sin(\Psi_1 - \phi_B^*) \rangle = (1 - f^{Bg}(M_{inv}))\langle \sin(\Psi_1 - \phi_B^*) \rangle^{Sig} + f^{Bg}(M_{inv})\langle \sin(\Psi_1 - \phi_B^*) \rangle^{Bg}$$

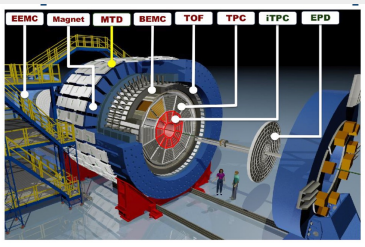
$$\langle \sin(\Psi_1 - \phi_B^*) \rangle^{Sig} = \langle \sin(\Psi_1 - \phi_B^*) \rangle^{True} + c\ sin(\phi_H - \phi_B^*)$$

$f^{Bg}(M_{inv})$ is background fraction as a function of invariant mass, c is v_1 factor



$f^{Bg}(M_{inv})$ estimation → IM extract $\langle \sin(\Psi_1 - \phi_B^*) \rangle^{Sig}$ → G-IM extract $\langle \sin(\Psi_1 - \phi_B^*) \rangle^{True}$

The STAR Detector

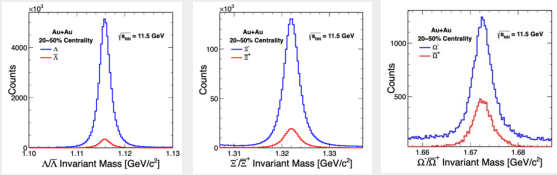


Time Projection Chamber
- Upgrade with inner TPC
- Better track quality
- Larger acceptance
- $|\eta| < 1.0 \to |\eta| < 1.5$

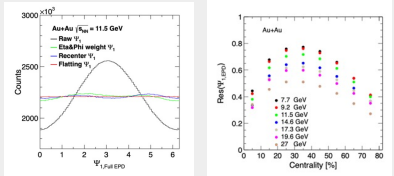
Time Of Flight
- PID via particle velocity
- $|\eta| < 0.9$

Event Plane Detector
- Event plane reconstruction
- $2.1 < |\eta| < 5.1$

Hyperon and Event Plane Reconstruction

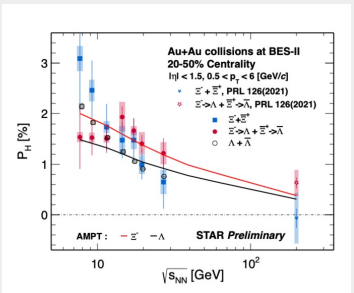


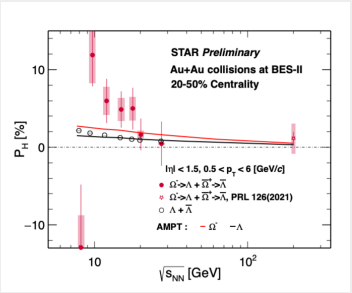
- Λ, Ξ, Ω hyperons reconstructed using KF Particle package



- First-order event plane reconstructed by EPD
- Event plane correction: η-weight, ϕ-weight, recenter, flattening
- Two-sub event plane method to estimate resolution with Bessel function

Results





- Significant $\Xi^- + \bar{\Xi}^+$ global polarization observed (~ 5σ)
- Global polarization of $\Xi^- + \bar{\Xi}^+$ and $\Omega^- + \bar{\Omega}^+$ seems to decrease with increase in collision energy
- $\Xi^- + \Xi^+$ global polarization are consistent between direct and indirect measurement methods
- No significant difference between $\Lambda + \bar{\Lambda}$ and $\Xi^- + \Xi^+$ global polarization within uncertainties
- A hint of larger $\Omega^- + \bar{\Omega}^+$ polarization than $\Lambda + \bar{\Lambda}$ and $\Xi^- + \bar{\Xi}^+$ in lower energies

Summary

- The first measurement of $\Xi^- + \bar{\Xi}^+$ and $\Omega^- + \bar{\Omega}^+$ global polarization vs. collision energy at $\sqrt{s_{NN}}$= 7.7, 9.2, 11.5, 14.6, 17.3, 19.6, and 27 GeV
- Global polarization of $\Xi^- + \bar{\Xi}^+$ and $\Omega^- + \bar{\Omega}^+$ seems to decrease with collision energy, with a hint of larger $\Omega^- + \bar{\Omega}^+$ polarization

References

[1] Z.-T. Liang and X.-N. Wang, PRL 94, 102301 (2005)
[2] STAR Collaboration, Nature 548, 62 (2017).
[3] STAR Collaboration, PRL 126, 162301(2021)
[4] Hui Li et al., PLB 827, 136971(2022)

Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

SHANDONG UNIVERSITY

The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations