Measurements of $\Lambda(\bar{\Lambda})$ hyperons' local spin polarization in Au+Au collisions from the RHIC Beam Energy Scan-II

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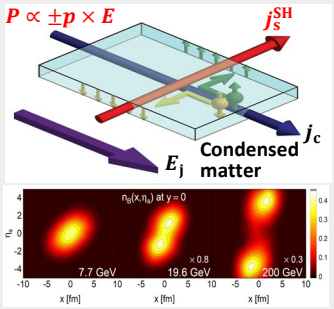
Abstract

The second harmonic cosine and sine modulations of the local spin polarization of $\Lambda(\bar{\Lambda})$ hyperons out-of-plane and in-plane, denoted as $P_{2,y}$ and $P_{2,z}$, respectively, are newly proposed observables for probing spin Hall effect (SHE) in the high baryon density region. $P_{2,y}$ and $P_{2,z}$ are measured in Au+Au collisions at $\sqrt{s_{NN}}$= 7.7, 9.2, 11.5, 14.6, 19.6 and 27 GeV from the RHIC Beam Energy Scan-II. A monotonic decrease of $P_{2,y}$ for Λ with increasing collision energy, and smaller positive $P_{2,z}$ with hints of sign change at $\sqrt{s_{NN}}$= 7.7 GeV are observed. However, $P_{2,y}$ and $P_{2,z}$ for $\bar{\Lambda}$ show no significant energy dependence within the large statistical uncertainties. The local polarization components are influenced by thermal vorticity, shear-induced effects, and baryon chemical potential. The measured Λ and $\bar{\Lambda}$ local polarization offer a promising avenue for probing the SHE. These measurements provide valuable insights into the spin dynamics of QCD matter in high baryon density environments.

Motivation

The spin Hall effect (SHE) is driven by the gradient of baryon chemical potential. It can be probed with the newly proposed observables $P^{net}_{2,z(y)} = P_{2,z(y)}(\Lambda) - P_{2,z(y)}(\bar{\Lambda})$ in Au+Au collisions



QCD matter: $P \propto \pm p \times \nabla\mu_B$

Analysis

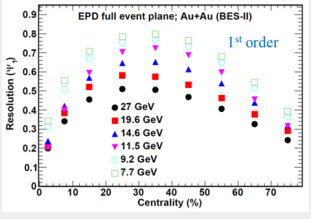
$$P_y = \frac{8}{\pi\alpha_\Lambda}\frac{1}{R^{(1)}_{EP}}\langle \sin(\psi_1 - \phi^*_p)\rangle$$

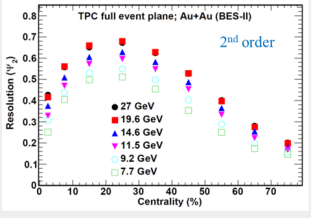
$$P_z = \frac{1}{\alpha_\Lambda}\frac{\langle cos\theta^*_p\rangle}{\langle cos^2\theta^*_p\rangle}$$

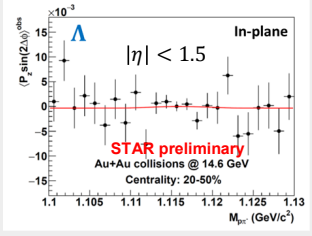
$$P_{2,y} = \langle P_y cos(2(\phi_\Lambda - \Psi_2))\rangle / R^{(2)}_{EP}$$

$$P_{2,z} = \langle P_z\, sin(2(\phi_\Lambda - \Psi_2))\rangle / R^{(2)}_{EP}$$

α_Λ: Λ's decay parameter
Ψ_1, Ψ_2 : 1st and 2nd order event-plane angle
ϕ^*_p:azimuthal angle of the daughter (anti)proton in Λ rest frame
$R^{(1)}_{EP}$, $R^{(2)}_{EP}$:1st and 2nd order event-plane resolution



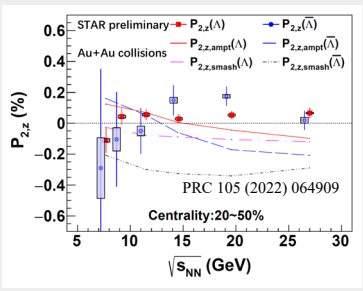


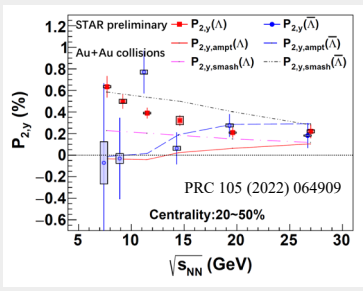


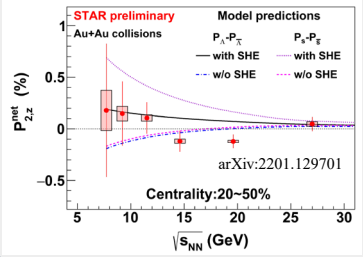
$$\langle P_z sin(2(\phi_\Lambda - \psi_2))\rangle^{obs} = (1 - f^{Bg}(M_{inv}))\langle P_z sin(2(\phi_\Lambda - \psi_2))\rangle^{Sg} + f^{Bg}(M_{inv})\langle P_z sin(2(\phi_\Lambda - \psi_2))\rangle^{Bg}$$

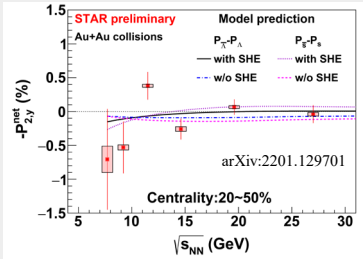
- $f^{Bg}(M_{inv})$: ratio of signal to background
- linear Bg ($\alpha+\beta M_{inv.}$) is implemented for signal extraction

Results









Summary

✓Local polarization of Λ and $\bar{\Lambda}$ in Au+Au collisions at 7.7, 9.2, 11.5, 14.6, 19.6, 27 GeV (BES-II)
- Monotonic energy dependence in $P_{2,y}$ of Λ with the decreasing energy

✓**Baryonic SHE**
- First study of baryonic spin Hall effect by measuring net local polarization $P^{net}_{2,z(y)}$ in Au+Au from 7.7 to 27 GeV
- A simultaneous model fit for $P_{2,z}$ and $P_{2,y}$ is required to help understand the energy dependence of local polarization and the expected non-trivial contribution from SHE

S. Y. F. Liu et al., Phys. Rev. D 104, 054043 (2021).
B. Fu et al., arXiv:2201.129701.
Model: X. Wu et al., PRC 105 (2022) 064909

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The STAR Collaboration