Global polarization of Λ and Ξ hyperons in Au+Au collisions in the STAR experiment

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Global polarization of Λ hyperons appearing in non-central heavy-ion collisions was measured by the STAR experiment at RHIC for Au+Au collisions with $\sqrt{s_{NN}}$ = 3 - 200 GeV and at the LHC for Pb+Pb collisions with $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV. Global polarization reflects its vortical nature of quark-gluon matter at its initial evolution stage.

Global polarization of multistrange hyperons, such as Ξ, can provide new information on hydrodynamic description of the system and its vorticity nature. In these proceedings, we will report results of Ξ and Λ global polarization for Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6, 27, and 54.4 GeV.

I. INTRODUCTION

Relativistic hydrodynamics predicts that quark-gluon plasma, hot-dense matter produced in relativistic heavy-ion collisions, possess large vorticity in non-central collisions. It manifests itself in polarization of produced particles along the direction of vorticity. One can obtain polarization of hyperons from its parity violating weak decay properties [1, 2].

In the hyperon decays, the angular distribution of daughter baryon in the parent hyperon rest frame is given by:

$$\frac{dN}{d\cos\theta^*} \propto 1 + \alpha_H P_H \cos\theta^*, \tag{1}$$

α_H is the hyperon decay parameter, P_H is the hyperon polarization, $\cos\theta^*$ is the angle between the polarization vector and daughter baryon momentum in the hyperon rest frame [3].

Global polarization can be measured in respect to reaction plane (which is defined by the beam direction and impact parameter vector):

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$$P_H = \frac{8}{\pi \alpha_H} \frac{\left\langle \sin\left(\Psi_1^{obs} - \phi^*_{daughter}\right)\right\rangle}{Res(\Psi_1)}, \tag{2}$$

where $\phi^*_{daughter}$ is the azimuthal angle of the daughter baryon in the parent hyperon rest frame, $Res(\Psi_1)$ is event plane resolution. Decay parameter values are $\alpha_\Lambda = 0.732 \pm 0.014$, $\alpha_{\bar{\Lambda}} = -0.758 \pm 0.010$, $\alpha_{\Xi^-} = -\alpha_{\bar{\Xi}^+} = -0.401 \pm 0.010$ [4].

Global polarization of Λ hyperons was observed by the STAR for collision energies $\sqrt{s_{NN}} = 3 - 200$ GeV [5–8] and was described successfully by transport and hydrodynamic model calculations. Measurements of multistrange hyperon's global polarization could possibly achieve goal of understanding the nature of vorticity [9].

Λ hyperons are reconstructed via its decay $\Lambda \to p + \pi^-$, and for Ξ hyperons decay channel $\Xi^- \to \Lambda + \pi^-$ is analyzed. This cascade decay provides opportunity to measure its global polarization in two separate ways. One can use Equation 2 directly measuring angle of daughter Λ decaying from Ξ. Additionally, Ξ global polarization could transfer into its daughter Λ polarization with transfer factor $C_{\Xi^-\Lambda} = 0.932$ and global polarization of Ξ hyperons could be measured by examining its daughter Λ global polarization [10–12].

In this proceedings we report on the measurements of the global polarization of $\Xi^- + \bar{\Xi}^+$ hyperons in Au+Au collisions at $\sqrt{s_{NN}} = 27$, 54.4, and 200 GeV and compare them to those of $\Lambda + \bar{\Lambda}$.

II. DATA ANALYSIS

Data of Au+Au collisions at $\sqrt{s_{NN}} = 27$ and 54.4 GeV collected by STAR experiment was used for this analysis. STAR features cylindrical geometry detector for high-multiplicity collisions [13]. Events that passed minimum-bias trigger, with collision vertex within 70 cm along the beam axis from the center of Time-Projection Chamber (TPC) [14] and with vertex position within 2 cm from the beam line in the transverse plane were analyzed.

To reconstruct hyperons one needs daughter charged particle tracks that were measured in TPC within a pseudorapidity range $|\eta| < 1$ and with full azimuthal acceptance. Tracks with momentum above 0.15 GeV/c were identified via ionization energy losses, dE/dx, and by their squared mass obtained by TOF (Time-Of-Flight) [15]. Identified protons and pions were used for hyperon reconstruction.

Λ hyperons were reconstructed via topology of its decay $\Lambda \to p + \pi^-$ ($\bar{\Lambda} \to \bar{p} + \pi^+$), and

after Λ hyperons were obtained, the same procedure was performed for decays $\Xi^- \to \Lambda + \pi$ ($\bar{\Xi}^+ \to \bar{\Lambda} + \pi^+$). Hyperon reconstruction was performed with KFParticleFinder package [16].

The collision centrality was determined based on the measured multiplicity of charged tracks within midrapidity region. Centrality and trigger efficiency were obtained by fitting it to a Monte Carlo Glauber simulation.

For event plane reconstruction, EPD [17] ($2.1 < \eta < 5.1$) and BBC [18] ($3.3 < \eta < 5.1$) were used separately for $\sqrt{s_{NN}} = 27$ GeV, ZDC [19] ($\eta > 5.2$) and BBC for $\sqrt{s_{NN}} = 54.4$ GeV collision energy. The first-order event plane, a proxy for reaction plane, was reconstructed using the spectator particles.

Global polarization measurements include correction for event plane resolution. Resolution was calculated via two-subevent method, with use of East (forward rapidity) and West (backward rapidity) detectors in combination.

Following Equation 2, $\langle \sin(\Psi_1 - \phi^*_{daughter}) \rangle$ should be measured. To differentiate signal of real hyperons from combinatoric pairs of its daughter candidates, so-called "event-plane method" was used. This method consists in measuring number of hyperons as a function of $(\Psi_1 - \phi^*_{daughter})$, and then fitting it with Fourier function to obtain the sine coefficient $\langle \sin(\Psi_1 - \phi^*_{daughter}) \rangle$.

III. RESULTS

Figure 1 presents global polarization of $\Lambda + \bar{\Lambda}$ and $\Xi^- + \bar{\Xi}^+$ hyperons as a function of collision energy for the centrality 20-50% (20-80% for $\Xi^- + \bar{\Xi}^+$ at $\sqrt{s_{NN}} = 200$ GeV due to smaller signal). Results of this analysis are shown together with $\sqrt{s_{NN}} = 7.7$-200 GeV Λ global polarization results and preliminary results for new data at $\sqrt{s_{NN}} = 27$ and 54.4 GeV and the first $\sqrt{s_{NN}} = 200$ GeV study of Ξ global polarization. Theoretical calculations obtained from AMPT model [20] are shown together with the experimental results.

Global polarization was measured for Ξ hyperons directly via the angle of daughter Λ and via its daughter Λ decays considering the polarization transfer. Both measurements are consistent within large uncertainties.

Experimental trend for Ξ global polarization is consistent with AMPT calculations. Within uncertainties it is also consistent with Λ global polarization which could indicate the same nature of this phenomena for both particle species as expected.

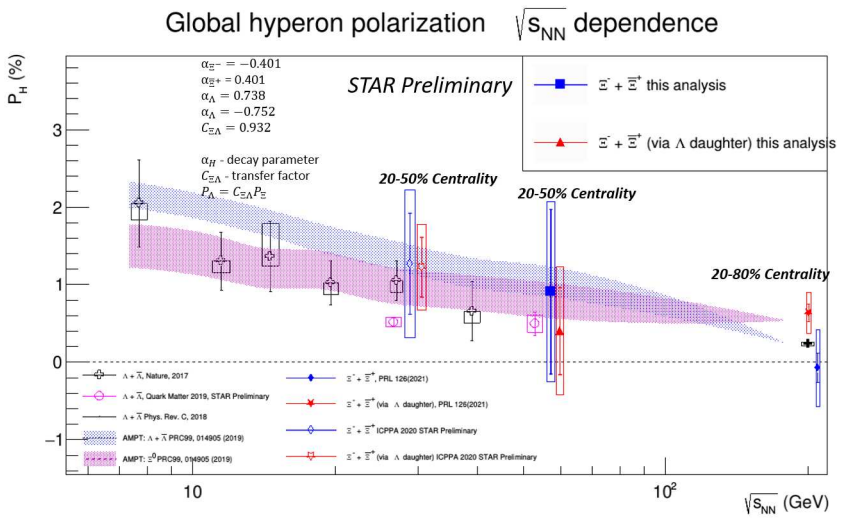

FIG. 1. Collision energy dependence of global polarization of hyperons in Au+Au collisions.

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