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

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Vortical structure of hot-dense matter in heavy ion collisions can be probed through global polarization of emitted particles. Hyperon's weak decays provides opportunity to measure this phenomenon. Global polarization of Λ hyperons 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 of multistrange hyperons, such as Ξ, can provide new information for hydrodynamic description of the system and its vorticity structure. In these proceedings, we report results of Ξ global polarization measurement for Au+Au collisions at $\sqrt{s_{NN}} = 19.6$ and 27 GeV.

Introduction

Ultrarelativistic heavy-ion collisions provide an opportunity to create and examine quark-gluon plasma - hot-dense matter characterized by deconfined state of quarks and gluons. The results from experiments at RHIC and LHC have shown that the expansion dynamics of the quark-gluon plasma (QGP) can be described by relativistic hydrodynamics [1].

Non-central collisions are characterized be vorticity creation in the medium. An experimental indicator of vorticity is the polarization of particles produced in the collision along the direction of the vorticity. This quantity, known as global polarization, can be obtained by studying weak decays of hyperons, in which the daughter particle is emitted predominantly in the direction of its parent spin. [2, 3].

In the hyperon decays the angular distribution of daughter baryons 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 [4].

Initial angular momentum direction is expected to be perpendicular to reaction plane (which is defined by the beam direction and impact parameter vector), and global polarization value can be obtained by measuring daughter baryon's momentum projection on initial angular momentum direction.

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Assuming first-order event plane as reaction plane, and taking event plane resolution into account:

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

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 $\alpha_\Lambda = 0.732 \pm 0.014$, $\alpha_{\bar{\Lambda}} = -0.758 \pm 0.010$, $\alpha_{\Xi^-} = -\alpha_{\bar{\Xi}^+} = -0.401 \pm 0.010$ [5].

In the STAR experiment global polarization of Λ hyperons was measured for $\sqrt{s_{NN}} = 3 - 200$ GeV [6–8]. While transport and hydrodynamic models successfully describe experimental results, multi-strange hyperons will provide more constraints for the understanding of nature of vorticity. Ξ and Ω global polarization were measured at $\sqrt{s_{NN}} = 200$ GeV [9].

Ξ hyperons can be reconstructed by its decay topology $\Xi^- \to \pi^- + \Lambda \to p + \pi^-$. This cascade decay provides opportunity to measure its global polarization in two separate ways. One can use Equation 2 to directly measure angle of daughter Λ decaying from Ξ. Additionally, a fraction of 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 $\sqrt{s_{NN}} = 19.6$ and 27 GeV and compare it to that of $\Lambda + \bar{\Lambda}$.

Data analysis

Data from Au+Au collissions at $\sqrt{s_{NN}} = 19.6$ and 27 GeV collected by STAR experiment as part of Beam-Energy Scan II (BES-II) program were used for this analysis. STAR features cylindrical geometry detector [13]. Events that passed minimum-bias trigger with collision vertex within 70 cm from the center of Time-Projection Chamber (TPC) and with vertex position within 2 cm from the beam line in the transverse plane were analyzed.

BES-II have detector upgrades compared to that from BES-I [7]. For both $\sqrt{s_{NN}} = 19.6$ and 27 GeV datasets new detector EPD (Event-Plane Detector) [14] was installed, which provides better event-plane resolution due to higher granularity and acceptance than BBC [15]. At $\sqrt{s_{NN}} = 19.6$ GeV TPC update (iTPC) was installed with acceptance enhanced by one unit in rapidity. The collision centrality (extend of overlap between colliding nuclei) 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.

Tracks of charged particles were measured in TPC [16] within a pseudo-rapidity range $|\eta| < 1$ for 27 GeV and $|\eta| < 1.5$ for 19.6 GeV and with full azimuthal acceptance. Pion and proton tracks with momentum > 0.15 GeV/c

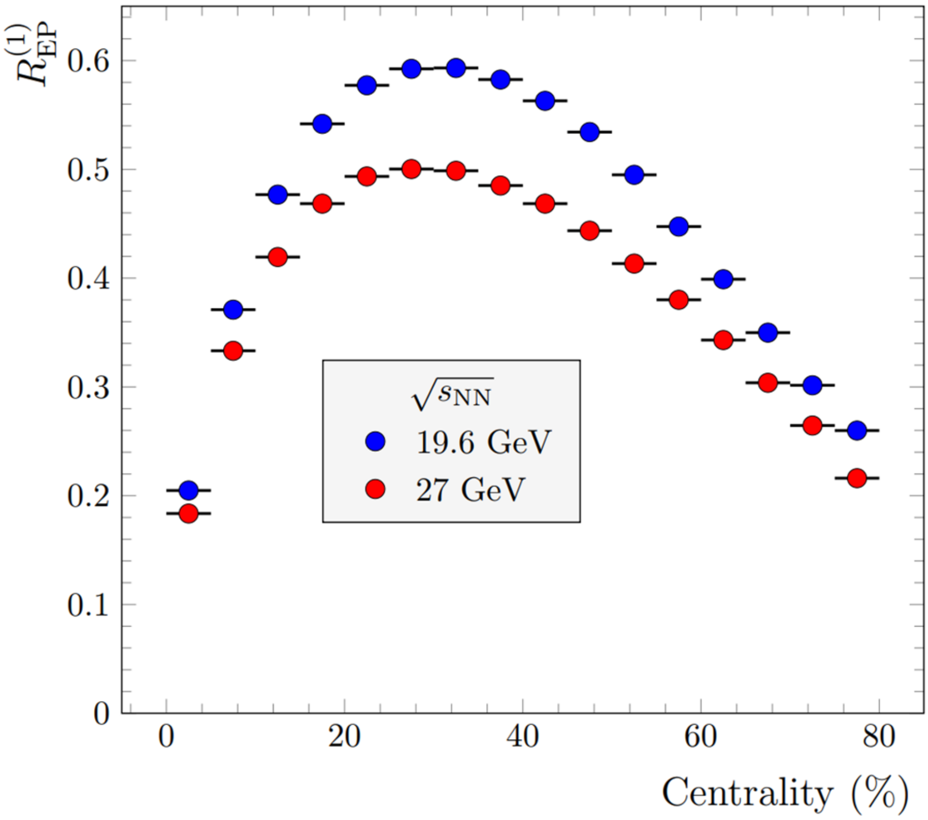

Fig. 1. Resolution of the first order event-plane at $\sqrt{s_{NN}}$ = 19.6 and 27 GeV.

were identified via energy loss in the TPC, dE/dx, and by their squared mass obtained by TOF [17] and used for hyperon reconstruction.

Λ hyperons were reconstructed via topology of its decay $\Lambda \rightarrow p + \pi^-$ ($\bar{\Lambda} \rightarrow \bar{p} + \pi^+$). After that the same procedure was performed for decay $\Xi^- \rightarrow \Lambda + \pi$ ($\bar{\Xi}^+ \rightarrow \bar{\Lambda} + \pi^+$). KFParticle [18] package was used for hyperon reconstruction.

For event plane reconstruction EPD ($2.1 < \eta < 5.1$) and BBC ($3.3 < \eta < 5.1$) were used separately. The first-order event plane of the spectator particles was used as a proxy for reaction plane. Presented results were obtained in respect to event-plane measured via EPD, and BBC-measured event-plane was used for systematic uncertainties estimation. Global polarization calculations with respect to event plane should take into account event plane resolution. Resolution was calculated via two-subevent method, with the usage of East (forward rapidity) and West (backward rapidity) detectors, and is shown in Fig. 1.

Following the Equation 2, by taking detector event-plane resolution into account, global polarization value can be calculated. Track efficiency correction has negligible impact on polarization and hence not applied. Acceptance correction, proposed in previous measurements of Λ global polarization, was applied [7]. Finite detector acceptance leads to small dependence of Equation 2 from daughter momentum in parent rest frame. For this reason it can

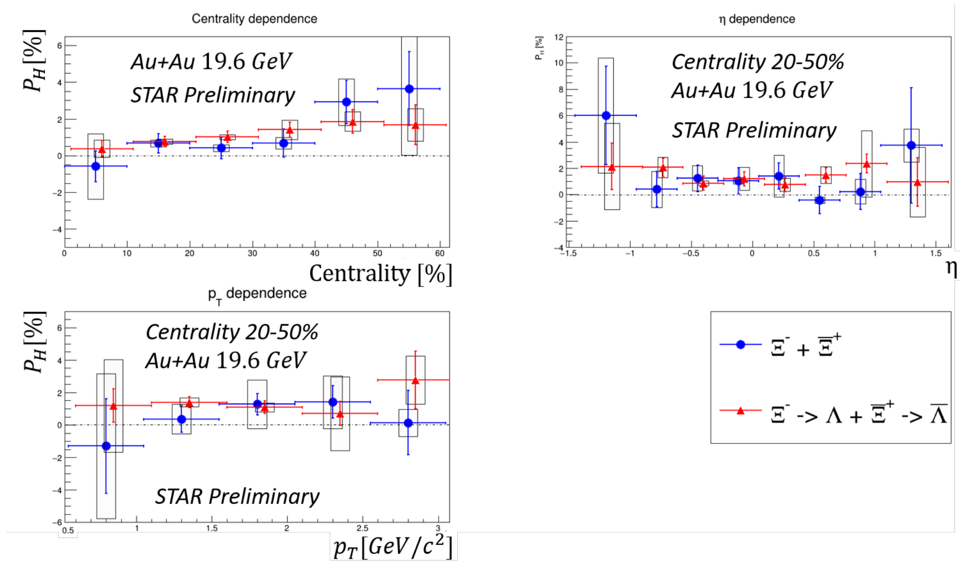

Fig. 2. Global polarization of Ξ hyperons in $\sqrt{s_{NN}}$ = 19.6 GeV Au+Au collisions.

be rewritten as:

$$\frac{8}{\pi\alpha_H}\langle\sin(\phi_b^* - \Psi_{RP})\rangle = \frac{4}{\pi}\overline{\sin\theta_b^*}P_H(p_t^H,\eta^H) = A_0(p_t^H,\eta^H)P_H(p_t^H,\eta^H), \quad (3)$$

where θ_b^* is polar angle of daughter baryon in parent's rest frame and $A_0(p_t^H,\eta^H) = \frac{4}{\pi}\overline{\sin\theta_b^*}$ is correction factor depending on p_t^H, η^H and collision centrality.

Results

Figure 2 and 3 presents global polarization of $\Xi^- + \bar{\Xi}^+$ hyperons measured directly and via daughter global polarization as a function of collision centrality, p_T and η for $\sqrt{s_{NN}}$ = 19.6 and 27 GeV. Directly measured global polarization is consistent with measurements via daughter's global polarization. Global polarization increases with centrality as expected from theoretical predictions and and previous Λ global polarization measurements. No obvious p_T or η dependence of global polarization observed.

Figure 4 shows polarization as a function of collision energy. The results of this analysis are shown together with that from $\sqrt{s_{NN}}$ = 7.7-200 GeV Λ global polarization studies, BES-II Λ polarization results at $\sqrt{s_{NN}}$ = 19.6 and 27 GeV and the first $\sqrt{s_{NN}}$ =200 GeV study of Ξ global polarization. Theoretical curves obtained from AMPT [19] model are shown together with the experimental results. The global polarization of cascade follows a similar trend as observed for Λ and is consistent with theoretical AMPT calculations, which indicate global nature of hyperon global polarization.

Summary

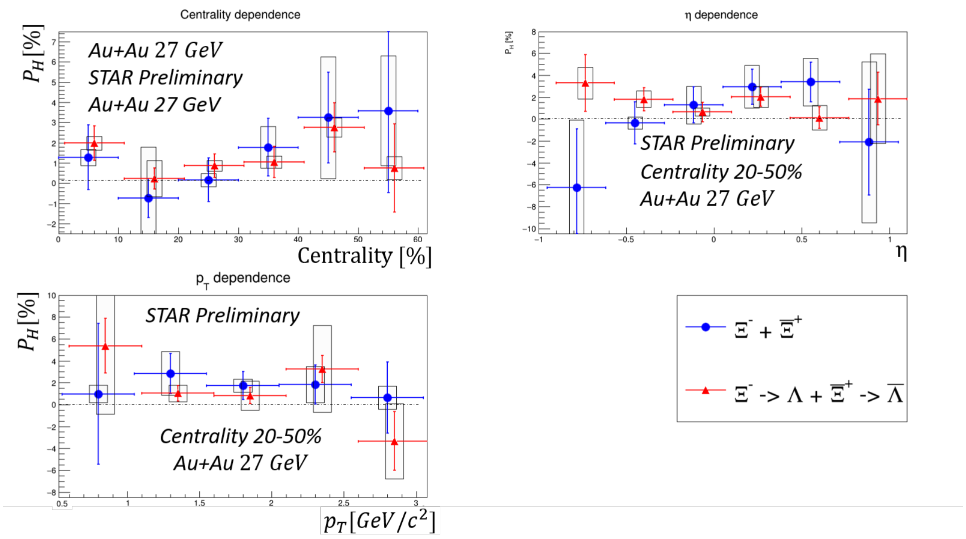

Fig. 3. Global polarization of Ξ hyperons in $\sqrt{s_{NN}} = 27$ GeV Au+Au collisions.

We presented the results of global polarization measurements for $\Xi^- + \bar{\Xi}^+$ in Au+Au collisions at $\sqrt{s_{NN}} = 19.6$ and 27 GeV measured directly via the angle of daughter Λ and via transfer to Λ daughter global polarization. Results stay within experimental trend and consistent with theoretical predictions within uncertainties.

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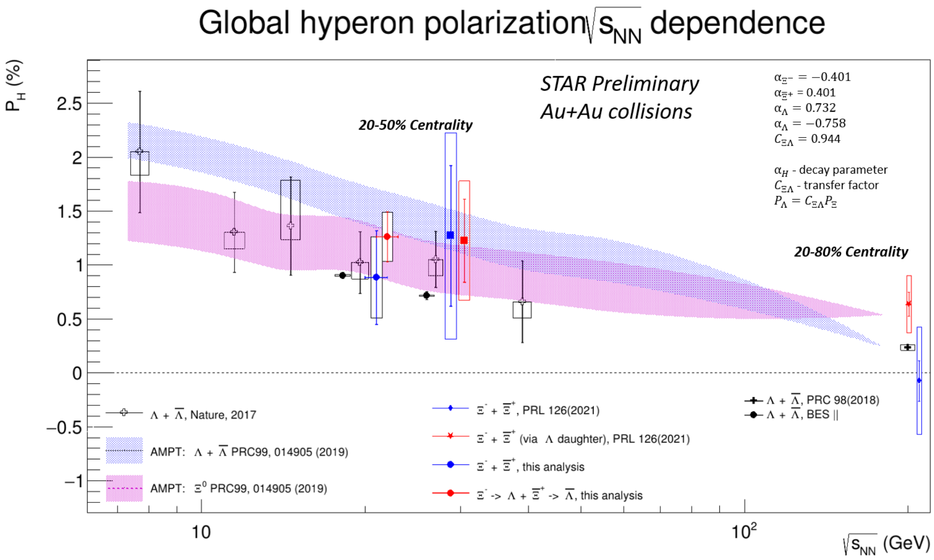

Fig. 4. Energy dependence of hyperon global polarization

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