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# GLOBAL POLARIZATION AND PARITY VIOLATION STUDY IN Au+Au COLLISIONS

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*Abstract*. We present results on the parity violation effects and global system polarization measurements in Au+Au collisions at $\sqrt{s_{NN}}$ = 62 GeV obtained with the STAR detector at RHIC. The parity violation effects are studied by three particle azimuthal correlations of charged particles. The global polarization of the system is examined by measuring the polarization of strange hyperons with respect to the collision reaction plane.

*Key words:* relativistic heavy ion collisions, global polarization, parity violation.

## 1. INTRODUCTION

The system created in non central relativistic nucleus-nucleus collision possess large angular orbital momentum. Some of the most interesting and important phenomena predicted to occur in such a system are the strong parity violation [1] and the global system polarization [2]. Strong *P* and *CP* violation should be revealed via preferential emission of the same charge particles in the direction along the system angular momentum. This effect is already known for a few years [3–5] but only recently clear theoretical estimates and experimental observables were suggested [6]. The effect of the global system polarization was first discussed in [3] where theoretical arguments for the globally polarized system produced in non central nucleus-nucleus collision were presented and possible observable consequences and theory prediction were given. The global polarization originates from transformation of the orbital angular momentum of the system into the particle's spin. The latter leads to the polarization of secondary produced particles along the system orbital momentum.

The effects of the parity violation and global system polarization are both defined by the presence of the large angular momentum in the colliding system. Since the angular momentum of the system is perpendicular to the collision reaction plane the effects under consideration can be studied by the correlations with respect to the collision reaction plane and technique developed for anisotropic flow analysis can be applied. In this paper the parity violation effects are studied by three particle azimuthal correlations of charged particles. The technique is based on the mixed harmonic method [7, 8]. The global polarization of the system is examined by measuring the polarization of strange hyperons with respect to the collision reaction plane. The hyperon polarization can be assessed via anisotropy in azimuthal distribution of decay product measured with respect to the collision reaction plane. This measurement is similar to the standard method of extracting directed flow [7].

## 2. GLOBAL POLARIZATION OF HYPERONS

Particles produced in the system with large angular orbital momentum are predicted to be polarized along the collision reaction plane direction due to spin-orbital coupling [2]. Such polarization can be defined from the angular distribution of hyperon decay products with respect to the collision reaction plane:

$$\frac{dN}{d\cos\theta^*} \sim 1 + \alpha P_H \cos\theta^*,$$

where $P_H$ is the hyperon polarization with respect to the collision reaction plane, $\alpha$ is the hyperon decay constant ($\alpha = 0.642$ for $\Lambda \to p + \pi^-$), and $\theta^*$ is the angle between the normal for the collision reaction plane and the nucleon 3-momentum in the hyperon's rest frame.

Global polarization can be defined from two particle azimuthal correlations with respect to the collision reaction plane:

$$P_H = \frac{8}{\pi\alpha}\left\langle \cos\left(\varphi - \Psi_{RP}\right)\right\rangle,$$

where $\varphi$ is the hyperon azimuthal angle, and $\Psi_{RP}$ is the collision reaction plane angle.

In Fig. 1 the $\Lambda$ polarization as a function of $\Lambda$ pseudo-rapidity is given. In the calculation the reaction plane is obtained from directed flow of charged particles in the pseudo-rapidity range $2.7 < |\eta| < 3.9$ from STAR Forward Time Projection Chamber (FTPC) and from fragmentation neutrons with $|\eta| > 6.3$ from STAR Zero Degree Calorimeter-Shower Maximum Detector (ZDC-SMD). Points in Fig. 1 represent the preliminary results from the experimental data for Au+Au collisions at $\sqrt{s_{NN}} = 62$ GeV. Constant line fit to the data gives the upper limit for $\Lambda$ polarization: $P_\Lambda = (-1.44 \pm 9.66) \times 10^{-3}$. The obtained results in the errors range are consistent with zero. The theory prediction [2] for the $\Lambda$ polarization gives $P_\Lambda = -0.3$ with the magnitude far larger than observed in the current measurement.

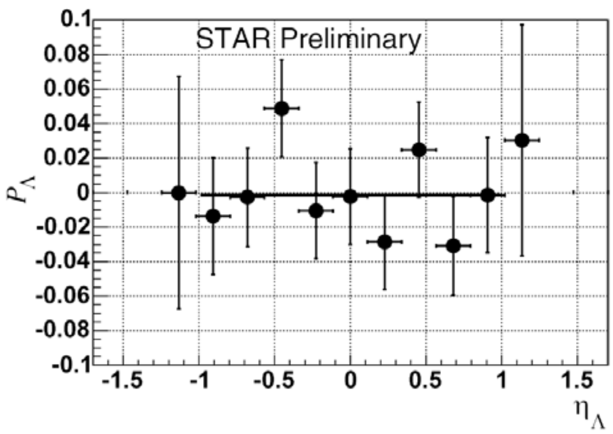


Fig. 1 – Λ polarization as a function of pseudo-rapidity for centrality 10–70%. Black points are STAR (Preliminary) data for Au+Au at $\sqrt{s_{NN}} = 62$ GeV. The line is a constant line fit to experimental data (see text for more details).

## 3. PARITY VIOLATION IN HOT QCD

Parity violation, discussed in work [1], implies anisotropy in the emission of the same charged particles along the system orbital momentum. This preferential emission results in the following azimuthal distribution [6]:

$$\frac{dN_\pm}{d\varphi} \sim 1 + 2a_\pm \sin\varphi, \quad (1)$$

where φ is the particle emission azimuthal angle relative to the reaction plane, $a_\pm = \frac{4}{\pi} Q/N_\pm$ is the asymmetry[1] in charged particle production, defined by the ratio of topological charge $Q$ ($|Q| \geq 1$) to the corresponding charged particle multiplicity $N_\pm$.

It was shown in [6] that one can measure charged particle anisotropy (1) by using mixed harmonic method [7, 8] applied in the symmetric charged particle pseudo-rapidity region:

$$a_i a_j = -\left\langle \cos\left(\varphi_i + \varphi_j - 2\Psi_{RP}\right)\right\rangle,$$

where $\varphi_{i,j}$ is the azimuthal angle of particles/antiparticles (for example $\pi^+$ and $\pi^-$), and $\Psi_{RP}$ is the collision reaction plane angle.

[1] $a_\pm$ is related to the asymmetry $A_\pm$ defined in [1] via: $a_\pm = \frac{4}{\pi} A_\pm$.

Fig. 2 shows the charged particle asymmetry parameter as a function of centrality. In this analysis the reaction plane is obtained from elliptic flow of charged particles with pseudo-rapidity $|\eta| < 1.3$ from STAR Time Projection Chamber (TPC). Points represents the preliminary results from the experimental data for the Au+Au collisions at $\sqrt{s_{NN}} = 62$ GeV. The lines are theoretical predictions from the work [1] for the minimum value of topological charge $|Q| = 1$.

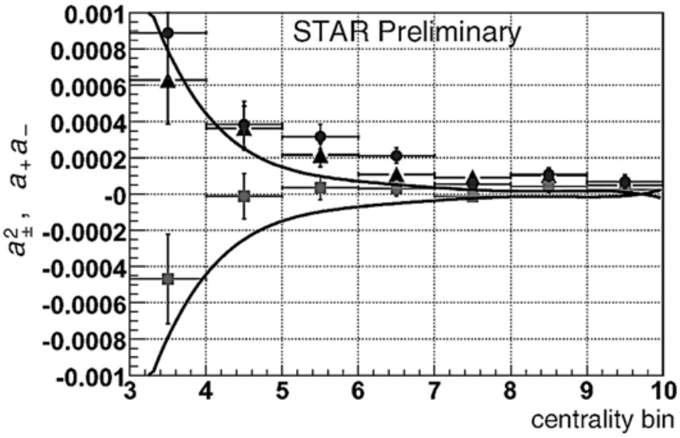


Fig. 2 – Charged particle asymmetry parameters as a a function of centrality bin with $|\eta| < 0.5$ cut applied. Points are STAR (Preliminary) data for Au+Au at $\sqrt{s_{NN}} = 62$ GeV: circles are $a_+^2$, triangles are $a_-^2$ and squares are $a_+a_-$. Black lines are theory prediction [1] with topological charge $|Q| = 1$.

## 4. SUMMARY

The full statistics for Au+Au data at $\sqrt{s_{NN}} = 62$ GeV for strange hyperons have been analyzed. The obtained upper limit for the global polarization of $\Lambda$ hyperons is far below the value predicted in work [2].

Although the systematic uncertainties have not been yet clearly understood, the current analysis is capable of setting an upper limit on the effect of strong *C* and *CP* violation in nucleus-nucleus collisions discussed in [1].

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