Global polarization and parity violation in Au+Au collisions

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Abstract The system created in noncentral relativistic nucleus-nucleus collisions possesses large angular orbital momentum. Some of the most interesting and important phenomena predicted to occur in such a system are strong parity violation and global system polarization. Strong P and CP violation should be revealed via preferential emission of the same charge particles in the direction along the system angular momentum. The global polarization originates from transformation of the orbital angular momentum of the system into the particle's spin.

We present results of measurements of parity violation effects and global system polarization 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.

Parity violation in hot QCD

Parity violation, predicted 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 [2]:

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

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

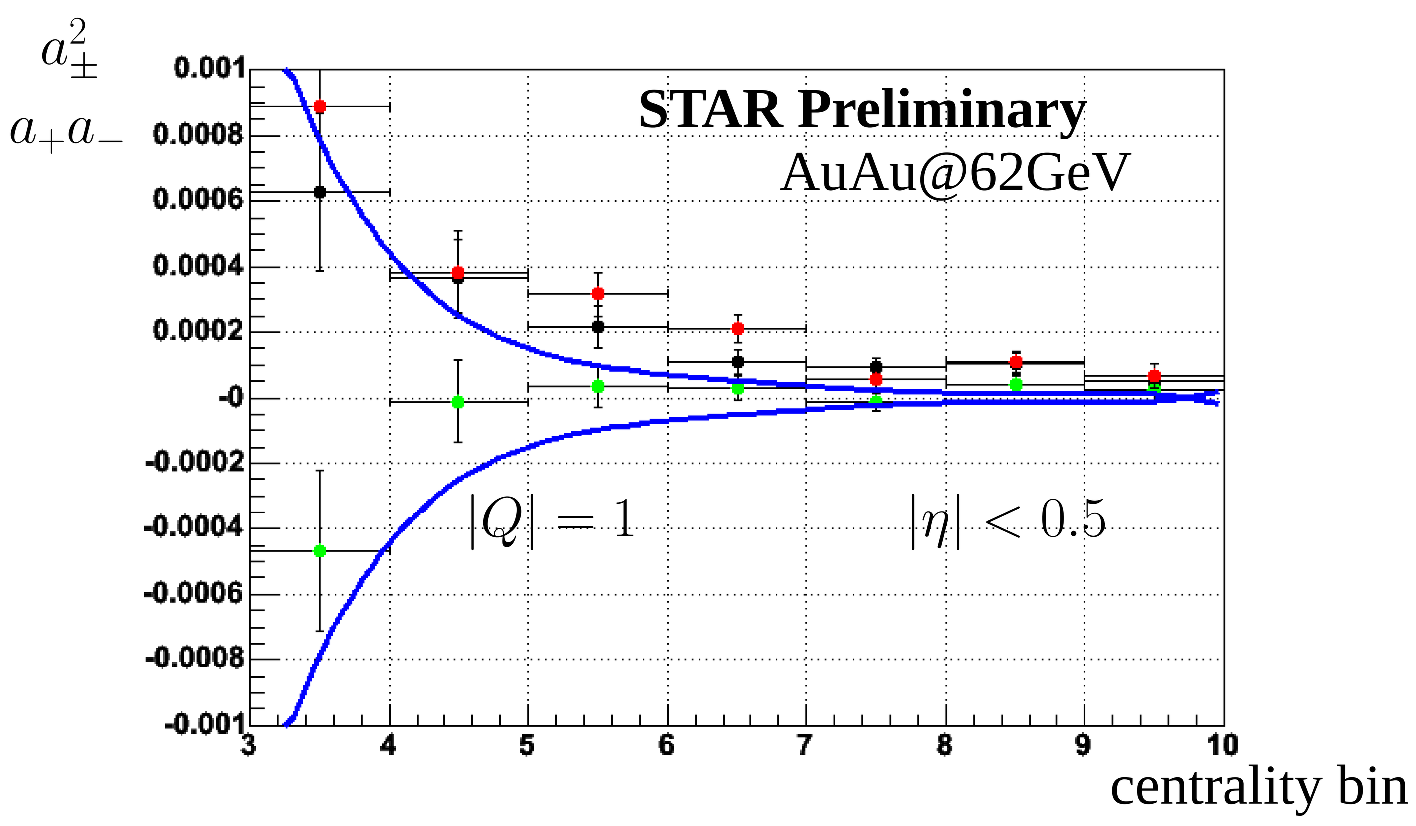
Search for parity violation

The measurement of the charged particle anisotropy (1) is based on the mixed harmonic method (three particle correlations) applied in the symmetric charged particle pseudo-rapidity region [2]:

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

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

Charged particle asymmetry parameter



Charged particle asymmetry parameter as a a function of centrality bin with $|\eta| < 0.5$ cut applied.
Points are STAR data for Au+Au at $\sqrt{s_{NN}} = 62$ GeV: black are a_+^2, red are a_-^2 and green are a_+a_-.
Blue lines – theory prediction [1] with topological charge $|Q| = 1$.

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 [3]. Such global polarization can be defined from the angular distribution of hyperons decay product with respect to the collision reaction plane:

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

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

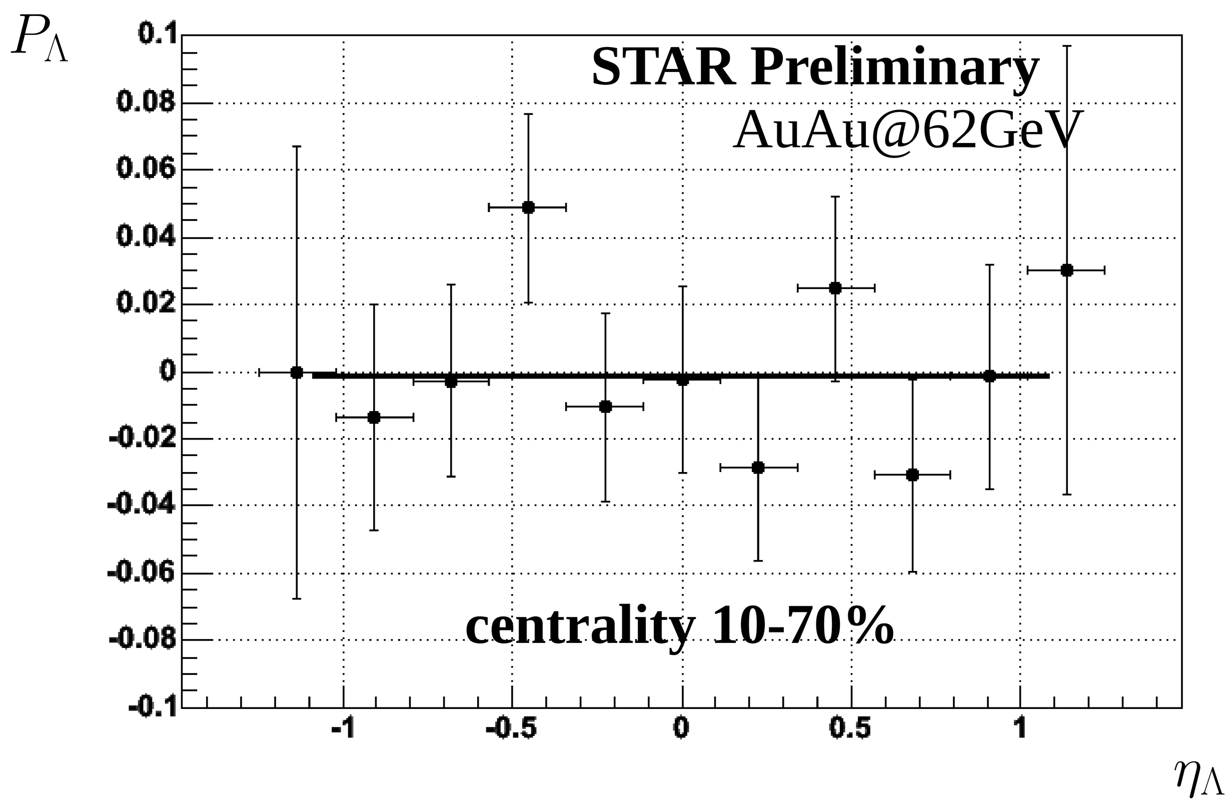
Polarization measurement

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

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

where φ is the hyperon azimuthal angle, and Ψ_{RP} is the collision reaction plane angle.

Lambda polarization upper limit



Λ polarization as a function of pseudo-rapidity for centrality 10-70%.
Black points are STAR data for Au+Au at $\sqrt{s_{NN}} = 62$ GeV.
Constant line fit to the data: $P_\Lambda \;=\; (-1.44 \,\pm\, 9.66) \times 10^{-3}$.
Theory prediction [3]: $P_\Lambda \;=\; -0.3$.

Conclusion

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 Λ hyperons is far below the value predicted in work [3].

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 predicted in [1].

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References

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[3] Z.-T. Liang, X.-N. Wang *"Globally Polarized Quark-Gluon Plasma in Noncentral A+A Collisions"* **PRL**94, 102301 (2005)