New constraints on 3D initial state and transport parameters of QGP using the Beam Energy Scan phase II data of STAR

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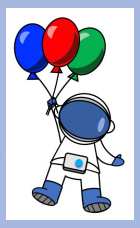
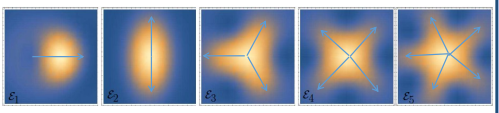


Abstract

Recent studies of flow harmonics angular correlations and flow harmonics magnitude correlations and fluctuations have indicated their weak sensitivity to final state effects in heavy-ion collisions, suggesting that they are sensitive probes for the initial state of heavy-ion collisions. These studies suggest that detailed measurements over a broad range of beam energies can provide additional constraints on the initial conditions and medium properties. In this work, we used the two- through six-particle correlations to extract the beam energy dependence of the higher-order event-plane angular correlations, the flow fluctuations, and the flow correlations. Our new results are presented and discussed for several centrality intervals for Au+Au collisions at RHIC BES-I and BES-II energies.

Motivation

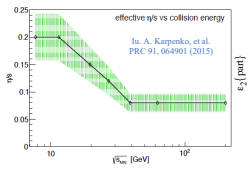


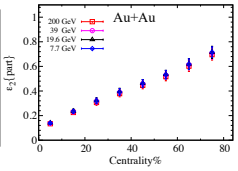
Normalized higher-order flow correlations:

- Give the correlation strength between different flow harmonics magnitudes and directions
- Less sensitive to the medium properties, i.e., $\frac{\eta}{s}(T)$ [1]
- More sensitive to the initial state in heavy ion collisions

Beam-energy dependence for a given system:

- Initial-state ε_2 is approximately energy independent
- Viscous attenuation ($\propto \frac{\eta}{s}(T)$) is beam energy dependent



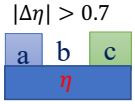


Analysis method

The cumulant method is extensively discussed in Refs [1,2,3,4]. We used k- particle cumulant methods (k > 1) to measure,

- Two, three, and four event plane angular correlations
- Four and six-particle (normalized) symmetric cumulants

Two subevents method is used to measure the two, three, and four-particle cumulants, and the full-event method is used for higher orders.



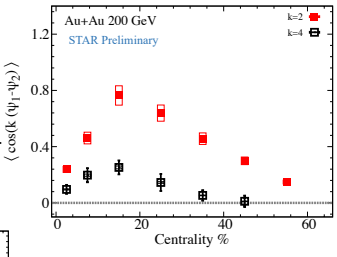
Event plane angular correlations

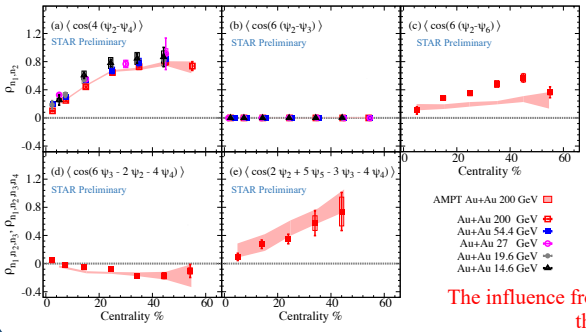
Comparison of the three-, four-, five- and six-particle event plan angular correlations vs. centrality

$$\langle\cos(2\psi_1 - 2\psi_2)\rangle = \langle v_1^2 v_2 \cos(2\psi_1 - 2\psi_2)\rangle / \sqrt{\langle v_1^4\rangle\langle v_2^2\rangle}$$

$$\langle\cos(4\psi_1 - 4\psi_2)\rangle = \langle v_1^4 v_2^2 \cos(4\psi_1 - 4\psi_2)\rangle / \langle v_1^4 v_2^2\rangle$$

- Similar trends were observed for $\langle\cos(k[\psi_1 - \psi_2])\rangle$, with k=2 and 4.
- The $\langle\cos(4\psi_1 - 4\psi_2)\rangle$ is less affected by the global momentum conservation [1].
- Positive correlations between ψ_1 and ψ_2 observed.



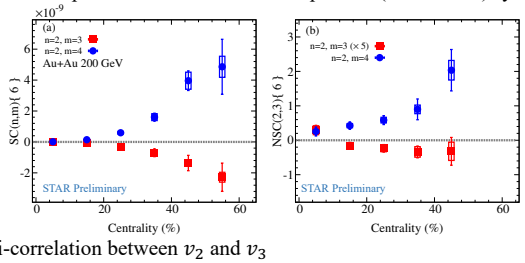


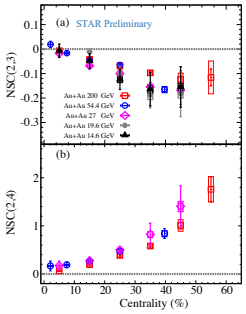
- The ψ_2-ψ_4 correlation shows similar values, however, ψ_2-ψ_3 correlation is consistent with zero for different beam energies
- No correlations were observed between ψ_2 and ψ_3
- Except for $\rho_{2,6}$ we observe reasonable agreement with the AMPT model

The influence from the final state is less than from the initial state's [1].

Flow harmonics correlations

Comparison of the four- and six-particle (normalized) symmetric cumulants vs. centrality





Anti-correlation between v_2 and v_3

- Consistent with the expected anti-correlation between ϵ_2 and ϵ_3

Correlation between v_2 and v_4

- Consistent with the expectations from mode coupling between v_2 and v_4

The weak beam energy dependence of the NSC suggests that the influence from the final state is less than that from the initial state [1].

References

[1] N. Magdy, PRC 107 (2023) 2, 024905
[2] J. Jia, et al. PRC 96 034906 (2017)
[3] A. Bilandzic et al. PRC 83, 044913 (2011)
[4] A. Bilandzic et al. PRC 102 2 024910 (2020)

Conclusion

Using two- and multi-particle correlations, we studied the flow harmonics direction and magnitude correlations;

- Nonvanishing $\langle\cos(4\psi_1 - 4\psi_2)\rangle$ which is expected to eliminate the GMC effects
- $\langle\cos(4\psi_2 - 4\psi_4)\rangle$ shows weak beam energy dependance.
- $\langle\cos(6\psi_2 - 6\psi_3)\rangle$ shows no correlations between ψ_2 and ψ_3
- Using four and six particle correlations we found (anti) correlation between v_2 and (v_3) v_4

Our multi-particle correlation measurements can be used to constrain initial state models.

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