Measurements of harmonic flow and their fluctuations in ^{16}O+^{16}O collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR

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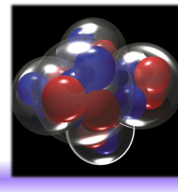
Abstract

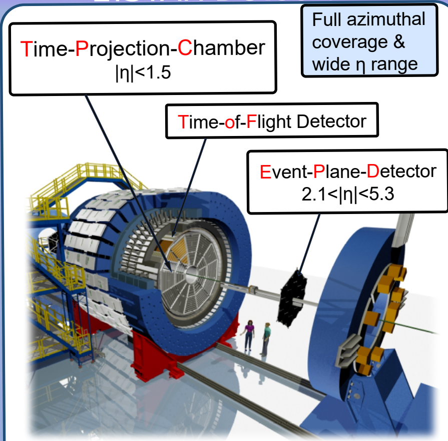
Understanding of QGP formation and evolution is limited by various uncertainties in the initial stages of the heavy-ion collision. Small-sized systems, due to their reduced system size and lifetime, may provide a better understanding of the possible formation and evolution of QGP. The recently reconstructed data from minimum bias and central triggered ^{16}O+^{16}O collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR provide an unqiue and exciting opportunity to study the small system. We measure v_n as a function of p_T and multiplicity in O+O collisions using various method to minimize non-flow and to provide insights into initial condition and the emergence of collectivity in small systems.

1.Motivation: flow in small system

- **Collectivity**: Mechanisms for emergence of collectivity in small systems are not well understood. Previous study demonstrates the importance of sub-nucleon fluctuation.
- **Initial state**: More direct study with reduced final state interactions compared to larger systems, yielding insights unique to those compact systems, where many-body correlations may significantly influence the nuclear density distribution.



2.STAR Detector



- Dataset: 2021 $\sqrt{s_{NN}} = 200$ GeV ^{16}O+^{16}O collisions
- Events: 600M min-bias, 250M high-multiplicity trigger
- Use charged particle tracks with pT $\in$(0.2, 2) GeV.

3.Methods

Anisotropic flow

Two-particle correlation method

- Require pair |Δη| > 1.0

$$\frac{1}{N^{\rm pair}}\frac{dN^{\rm pair}}{d\Delta\phi} = \frac{1}{2\pi}\left(1+2\sum_{n=1}^{\infty} c_{n\Delta}\cos n\Delta\phi\right)$$

$$c_n\left(p_T^a, p_T^b\right) = v_n\left(p_T^a\right)v_n\left(p_T^b\right) + \delta_{\rm Non-Flow}$$

- c1 non-flow substraction

$$\delta_{Non-Flow} = c_1/c_1^{peripheral} \times c_n^{peripheral}$$

TPC-EPD two-particle correlation

- Wide η gap supresses non-flow

$$v_n(TPCa, p_T) = \frac{Q_n^{TPCa}Q_n^{*EPD}}{\sqrt{\frac{(Q_n^{TPCb}Q_n^{*EPD})\times(Q_n^{TPCc}Q_n^{*EPD})}{Q_n^{TPCb}Q_n^{*TPCc}}}}$$

TPCa: $|\eta| < 1.0$

TPCb: $0.5 < \eta < 1.5$

TPCc: $-1.5 < \eta < -0.5$

EPD: $2.1 < |\eta| < 5.3$

2 sub-event method & Q-vector

$$Q_n = e^{in\phi}$$

Two-particle:

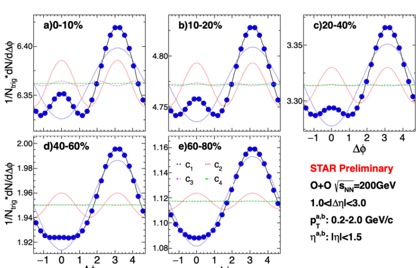
$$v_n^2\{2\} = \langle\langle e^{in(\phi_1^b - \phi_2^c)}\rangle\rangle$$

Four-particle:

$$-v_n^4\{4\} = \langle\langle e^{in(\phi_1^b+\phi_2^b-\phi_3^c-\phi_4^c)}\rangle\rangle - 2v_n^4\{2\}$$

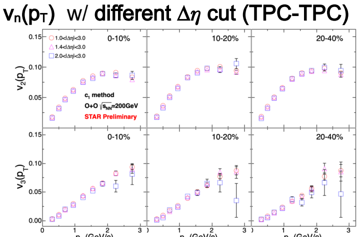
4.Results

1 **Di-hadron correlation** w/ c_1 non-flow subtraction method



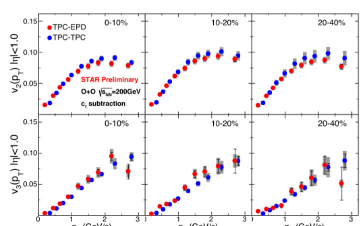
- Fourier fitting of the flow coefficients.
- Non-flow subtraction using 60-80% centrality collisions.

$v_n(p_T)$ w/ different Δη cut (TPC-TPC)



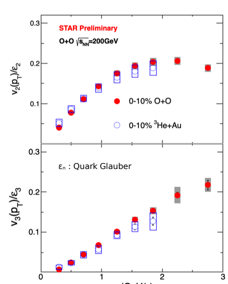
- Consistent results w/ different cuts.

$v_n(p_T)$ from TPC-TPC vs. TPC-EPD



- Mid-rapidity |η| gap method (TPC-TPC) consistent with mid-forward/backward rapidity correlation method (TPC-EPD).

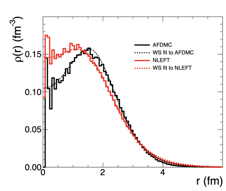
$v_n(p_T)$ in different systems



$v_2/\varepsilon_2, v_3/\varepsilon_3$: O+O ≈ ^{3}He+Au

- v_n/ε_n scaling agrees in two system using quark glauber calculation.
- Similar agreement is found in earlier study[2]. It suggests the importance of sub-nucleon fluctuations.

2 **Multi-body correlation** in **initial state**



- NLEFT includes **many-body correlation** in calculating the 3D geometry of oxygen.
- Radial distribution (2D) obtained from fitting Woods-Saxon function to NLEFT.

$v_2\{4\}/v_2\{2\}$ vs. centrality

Correction Needed for This Figure

- $v_2\{4\}/v_2\{2\}$ is a sensitive probe to the initial state geomery and fluctuations.
- Data agrees more with realistic 3D geometry with many body correlations.

5.Summary and outook

- First azimuthal anisotropy flow coefficients measurement in ^{16}O+^{16}O collisions.
  - v_n(pT) consistent with sub-nucleonic eccentricity fluctuations.
  - $v_2\{4\}/v_2\{2\}$ indicates many-body correlations and detailed 3D nuclear structure beyond radial distribution.
- In the future, compare measurements with hydro/transport model calculations to investigate the roles of different evolution stages in developing collectivity within small system collisions.

6.Reference

[1] A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C 58, 1671 (1998)

[2] M. I. Abdulhamid et al. (STAR Collaboration) Phys. Rev. Lett. 130, 242301 (2023)

[3] B. Schenke, C. Shen, and P. Tribedy, Phys. Lett. B 803, 135322 (2020)

[4] NLEFT: Lu et al., Phys. Lett. B 797, 134863 (2019)

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The STAR Collaboration, https://drupal.star.bnl.gov/STAR/presentation