STAR Measurement of Longitudinal Decorrelation of Elliptic Flow from Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

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Abstract

Measurement of pseudorapidity dependence of local event plane correlations may reveal the possible existence of twist in participant matter density distribution, which provides a novel input in initial conditions of heavy-ion collisions. The factorization ratio, F_2, has been extensively used to quantify this longitudinal decorrelation of elliptic flow. However, non-flow effects could also contribute to the r_2 value. In this poster, in order to distinguish these mechanisms, we explore the dependence of F_2 on the coverage of the event plane, p_T of particles of interest, and event shape as a function of centrality based on the STAR data of Au+Au collisions at 200 GeV. Observation of η , p_T and beam energy dependence implies possible non-flow contribution. An alternative observable T_2, correlating the forward, backward and midrapidity event planes, will be carried out to further probe the genuine flow decorrelation. We also also compare the STAR measurement with simulation from AMPT, where the model results seem to overpredict the magnitude of F_2, presumably arising from the difference in the initial tial geometry.

Introduction

○ **Flow Decorrelation**

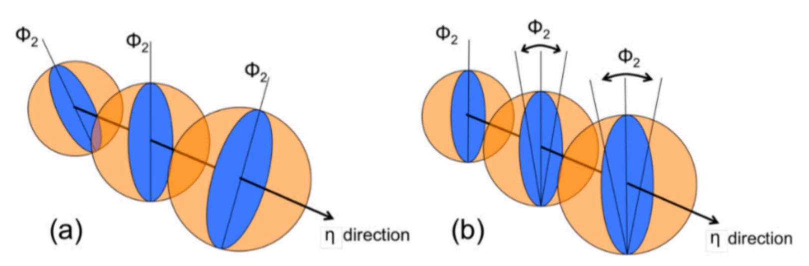


Fig 1. Two scenarios for the expansion of system: (a) systematic rotation; (b) random η dependence.

○ **Hydrodynamic evolution**

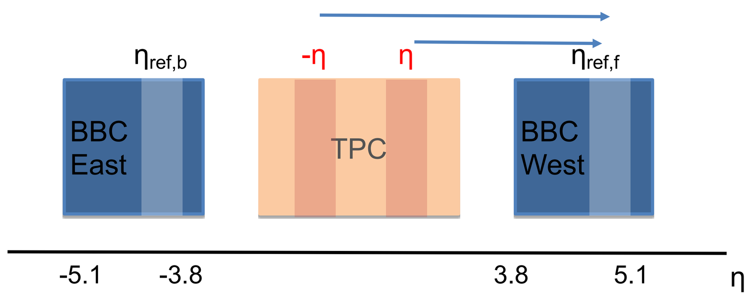
a) QGP matter produced in STAR Au+Au collisions exhibits behaviors a fluid

b) Study the evolution of collectivity [3]:

❖ flow effect → v_2

❖ non-flow → unrelated to reaction plane

○ **Conventional observable: Factorization ratio r_2 and F_2**

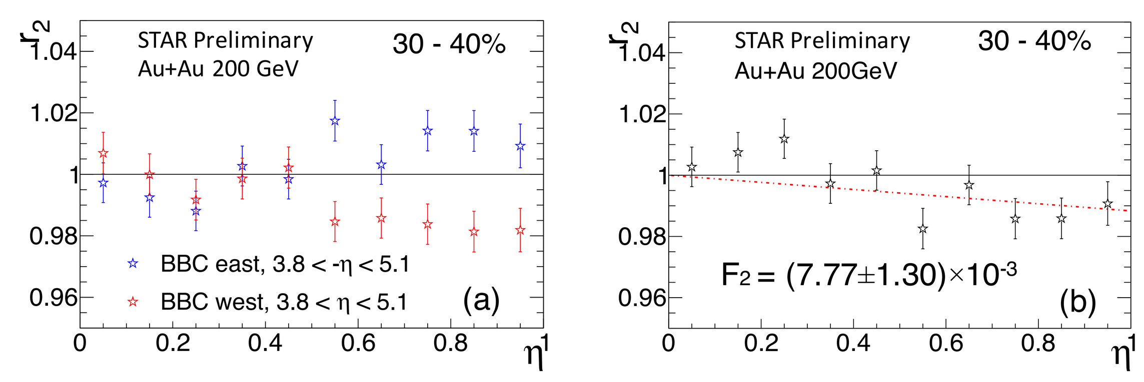


○ **r_2 is obtained from the Fourier coefficients for particles**

$$r_n(\eta) = \frac{\langle V_n(-\eta)V_n^*(\eta_{\rm ref})\rangle}{\langle V_n(\eta)V_n^*(\eta_{\rm ref})\rangle} = \frac{\langle v_n(-\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(-\eta)-\Psi_n(\eta_{\rm ref}))\rangle}{\langle v_n(\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(\eta)-\Psi_n(\eta_{\rm ref}))\rangle}$$

○ **F_2 is the ratio of r_2** $\quad r_2 = 1 - 2F_2\eta \quad$ [2]

Fig 2. Illustration for F_2 calculation. The reference rapidity planes are obtained from BBC. Data from both bins are combined, as shown in the right (a),(b).



T_2 : New Observable of Twist

○ **Global Twist**

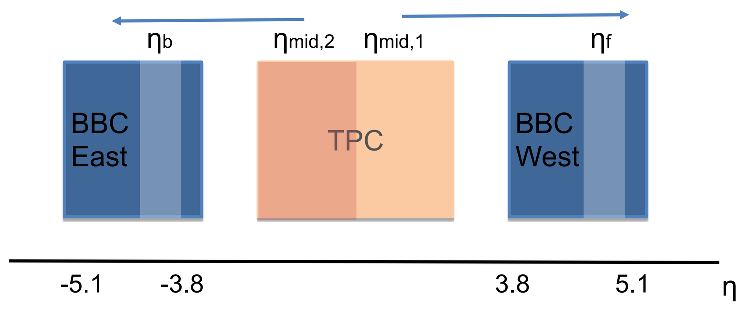


Fig 3. Illustration for T_2 calculation. Here the TPC tracks are randomly divided into two subevent planes to avoid cross terms in expansion.

○ **Motivation: to suppress the non-flow effect**

❖ v_2 → involves $\cos 2\Delta\phi \sim 1$ at small angle

❖ Instead, T_2 → $\sin 2\Delta\phi \sim 0$

○ **Alternatively, we have:**

$$T_2 = \frac{\langle \sin 2(\Psi_f - \Psi_{m,1})\sin 2(\Psi_b - \Psi_{m,2})\rangle}{Res_1 Res_2 Res_f Res_b} = \frac{\langle \sin 2(\Psi_f - \Psi_{m,1})\sin 2(\Psi_b - \Psi_{m,2})\rangle}{\langle \cos 2(\Psi_f - \Psi_{m,2})\rangle\langle \cos 2(\Psi_b - \Psi_{m,2})\rangle}$$

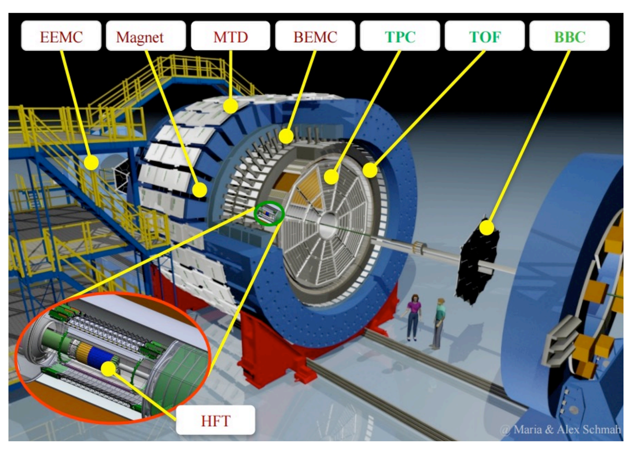
❖ TPC: randomly divided into two sub-event plane, mid-1,2

❖ BBC: forward and backward event planes

a) Negative → decorrelation

b) Non-negative → non-flow

The STAR Detector



○ **Au+Au at $\sqrt{s_{NN}}$ = 200 GeV from year 2011**

a) TPC : particles of interest

b) BBC: reference EP

❖ $0.2 < p_T < 2.0$ GeV/c

❖ TPC: $|\eta| < 1$

❖ BBC: $3.8 < |\eta_{ref}| < 5.1$

❖ $|V_z| < 30$ cm

❖ DCA < 2 cm

Event Shape Engineering

○ **Motivation: Check the sensibility of both methods @200 GeV**

○ **Divide** $|\langle \sin 2(\Psi_f - \Psi_b)\rangle|$ **into 4 bins:**

a) forward and backward EP are chosen from BBC

b) larger signal are expected at [0.75,1)

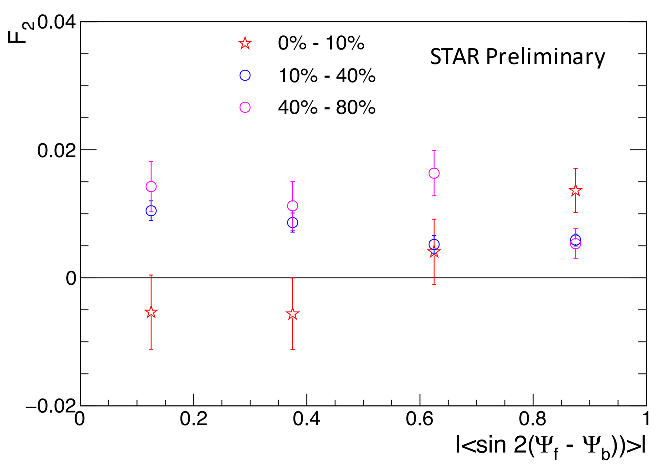


Fig 4. Event Shape Engineering for F_2 at 200 GeV Au+Au collision. Straight lines are to guide eyes.

○ **F_2 signal is positive (+)**

○ **Expect:**

a) Increasing → decorrelation

b) Uncorrelated → non-flow

○ **Result:**

a) In most case F_2 does not increase

b) Seems to fail this test

c) Not sensitive to twist picture

❖ Non-flow contribution

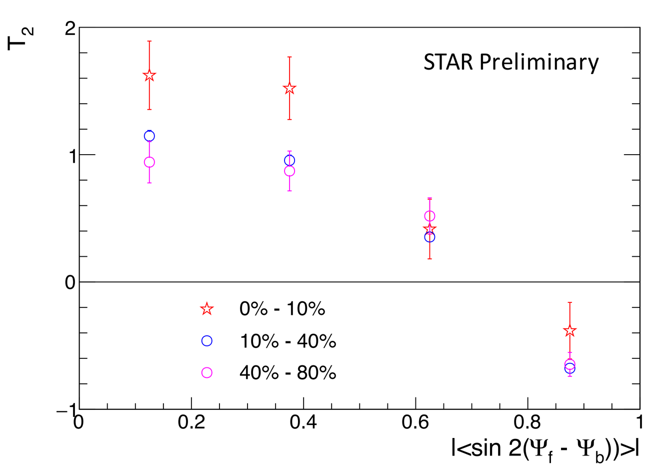


Fig 5. Event Shape Engineering results for T_2 at 200 GeV Au+Au collision. Same recipe as above.

○ **T_2 signal is negative (-)**

○ **Expect:**

a) Decreasing → decorrelation

b) Uncorrelated → non-flow

○ **Result:**

a) Decreasing trend

b) T_2 seems to be more sensitive to possible twist picture

c) More reliable than F_2 for suppressing non-flow

Results at 200 GeV

○ **First observable: Factorization ratio F_2**

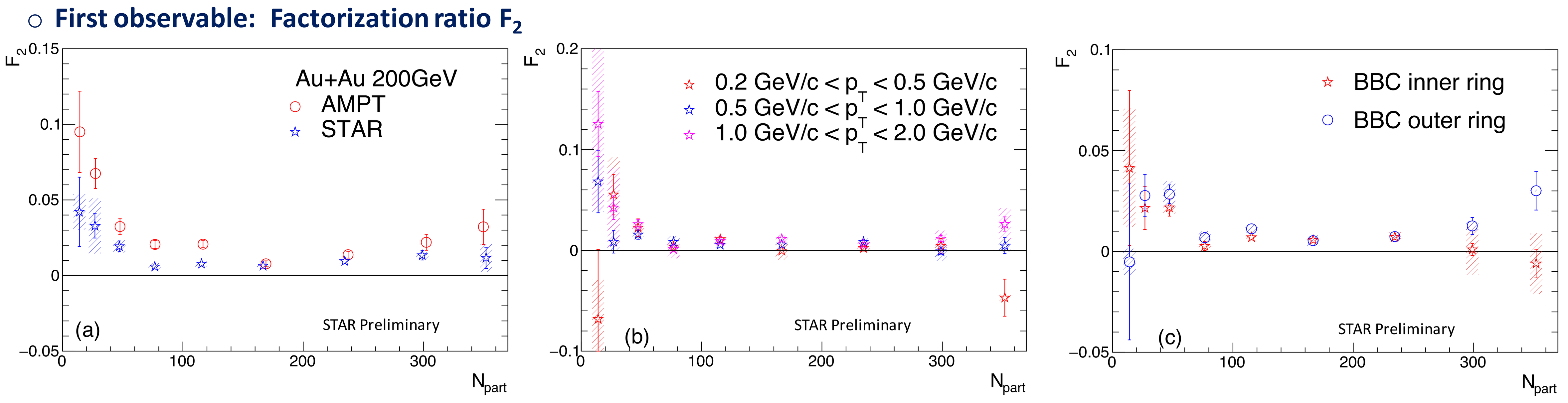


Fig 6. F_2 dependence on (a) centrality vs AMPT, (b) p_T and (c) η at 200 GeV Au+Au collision

○ **Results:**

a) Data similar to AMPT.

b) Higher F_2 at larger p_T compared to lower p_T

c) Lower F_2 measured with inner ring (more forward) than outer.

❖ The role of non-flow need to be further studied

○ **Second observable: Twist T_2**

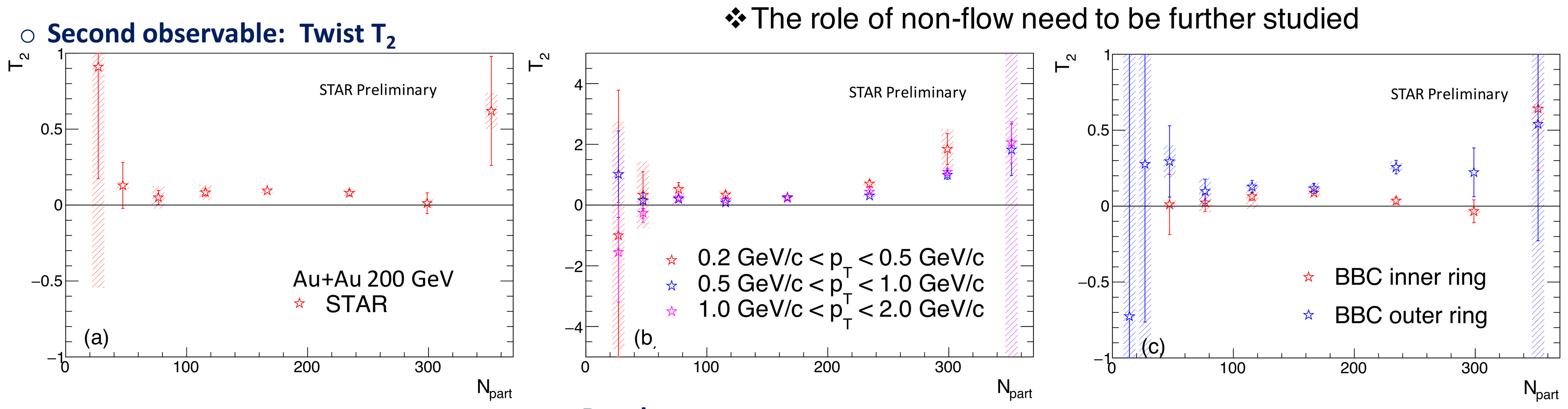


Fig 7. T_2 dependence on (a) centrality, (b) p_T and (c) η at 200 GeV Au+Au collision

○ **Results:**

a) T_2 is above 0, except in peripheral collisions

b) Lower T_2 measured with inner ring (more forward) than outer

c) Needs to be negative to support a twist.

❖ Positive values may indicate some further systematics.

Conclusions

- We employed a new observable T_2 to study the decorrelation of Au+Au collision at STAR, and compared it with the conventional factorization ratio F_2 at 200 GeV.
- F_2 and T_2 were studied using Event Shape Engineering technique to test their validity. F_2 in general is less sensitive than new observable T_2 against possible twist picture.
- Differential measurements of F_2 show possible non-flow effects. T_2 is either positive or consistent with zero, not supporting the twist picture.
- The transverse momentum and pseudorapidity dependence for both F_2 and T_2 are not quite clear, we may expect further investigation in the future.

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References

[1] Jia, Jiangyong, and Peng Huo. Method for Studying the Rapidity Fluctuation and de-Correlation of Harmonic Flow in Heavy-Ion Collisions. Physical Review C 90.3 (2014)

[2] V. Khachatryan et al. (CMS Collaboration), Evidence for transverse-momentum- and pseudorapidity-dependent event-plane fluctuations in PbPb and pPb collisions: Phys. Rev. C 92, 034911 (2015).

[3] P. Bozek et al, Torqued fireballs in relativistic heavy-ion collisions, Phys. Rev. C 83 (2011) 034911

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