1. Introduction

1. In heavy-ion collisions, the particle distribution in azimuthal is usually expressed in terms of a Fourier series:

\[ dN/d\phi \propto 1 + 2 \sum_{n=1} v_n \cos n(\phi - \phi_0) \]

and linear hydro-response from eccentricity vector \( \vec{\varepsilon}_n = \varepsilon_n e^{in\phi_0} \) is assumed for elliptic and triangular flow \( \vec{v}_n = n e^{in\phi_0} \)\(^{(n=2,3)} \) [1].

2. Since the FB asymmetry \( \varepsilon^F \) is more correlated with \( n=3 \) in forward rapidity, we estimate the size of initial fluctuation in Glauber model and quantify the \( \varepsilon^F \) fluctuation using AMPT model.

2. A simple model based on the Glauber model

1. Wounded nucleon mode

The emission function \( f(\eta) \) of the participant is asymmetric along its moving direction, and \( f^{+/−}(\eta) \) reaches its peak at \( f(\eta) = \pm 2 \) [2].

2. In Glauber model, the eccentricity vectors \( \varepsilon^F, \varepsilon^B \) (n=2,3) exhibit a large FB asymmetry in their magnitude, and a sizable twist in angle.

3. We naturally expect the deficit \( \eta^F, \eta^B \) to interполate between \( \varepsilon^F \) and \( \eta^F \) and thus we get:

\[ \varepsilon^F(\eta) \propto \varepsilon^B(\eta) \approx \alpha(\eta) \varepsilon^F(\eta) \]

\[ \alpha(\eta) = f(\eta)/f^{+/−}(\eta) \]

since the density profile is controlled by participants from the two nuclei, which is rapidly dependent [3].

3. Expectations:

Thus these generic initial fluctuations can survive the collective expansion and we expect:

1. FB asymmetry of \( \varepsilon^F(\eta) \)
2. A twist of final state event plane angles \( \Phi_\eta(\eta) \)

4. Analysis with the AMPT model

**AMPT model**

1. Glauber+HIJING+transport.
2. Contains longitudinal fluctuations and collective flow

- FB asymmetry \( \varepsilon^F \) survives Magnitude of flow vector \( Q^F \) in forward rapidity \( \eta \in (4.6) \) is more correlated with \( \varepsilon^F \) than \( \varepsilon^B \) and is similar for \( n=3 \)

5. Selecting different initial longitudinal configurations

- To better study how the initial longitudinal configurations influence the final \( \varepsilon^F(\eta) \), we select 3 classes of events with different fluctuations between \( \varepsilon^F \) and \( \varepsilon^B \)

- Then measure harmonic flow relative to the participant planes: \( \varepsilon^F(\eta) = \langle \cos n(\phi (\eta) - \phi_0) \rangle \)

6. Results

**Type 1**

- Initial: \( \varepsilon^F = \varepsilon^B \), \( \Phi^F = \Phi^B \)
- Final: symmetric \( \varepsilon^F(\eta) \), no twist

**Type 2**

- Initial: \( \varepsilon^F = \varepsilon^B \), \( \Phi^F = \Phi^B \)
- Final: \( \varepsilon^F(\eta) \), FB asymmetry, no twist

**Type 3**

- Initial: \( \varepsilon^F = \varepsilon^B \), \( \Phi^F = \Phi^B \)
- Final: twist observed!

**Inclusive**

- The twist leads to EP decorrelation in rapidity. \( \varepsilon^F(\eta) \) decreases when it is away from reference EP

Conclusion

1. By using event shape engineering [4] and “event-shape twist” method [5], the FB asymmetry \( \varepsilon^F(\eta) \) and/or twist of event-plane angles are observed for events with a certain selection criteria.

2. If similar effects can be observed in RHIC and LHC data, it could greatly improve our understanding of the space-time evolution of heavy ion collisions

References: