The “hidden secrets” of the event-shape fluctuations

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1. Introduction

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

$$dN/d\phi \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos n(\phi - \Phi_n)$$

and linear hydro-response from eccentricity vector $\vec{\epsilon}_n = \epsilon_n e^{in\Phi_n^*}$ is assumed for elliptic and triangular flow $\vec{v}_n = v_n e^{in\Phi_n}$(n=2,3) [1].

2. Since the F/B(Forward-going/Backward-going) participating nucleons fluctuate independently, thus one expects $\vec{\epsilon}_n^F, \vec{\epsilon}_n^B$ fluctuates relative to each other independently in both magnitude and orientation. This would lead to the EbyE fluctuations of $\vec{v}_n(\eta)$ in rapidity, ie:

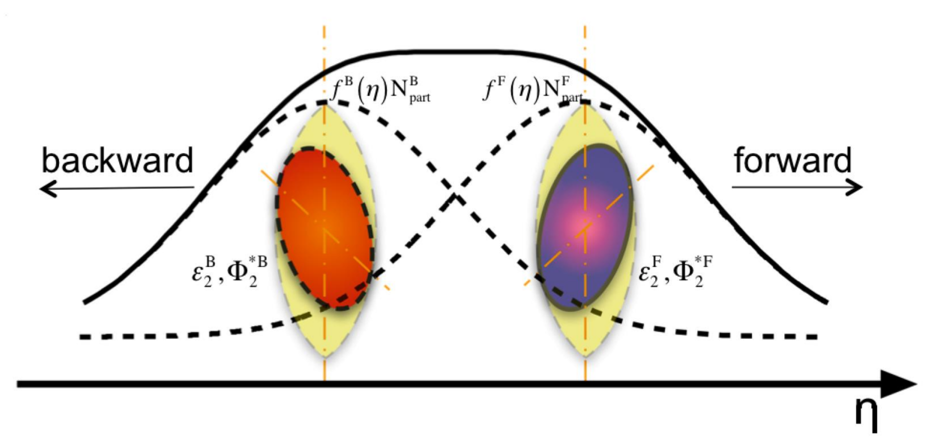
$$\vec{v_n}(\eta) = v_n(\eta)e^{in\Phi_n(\eta)} \propto \vec{\epsilon_n}(\eta) = \epsilon_n(\eta)e^{in\Phi_n^*(\eta)} \quad \text{(n=2,3)}$$

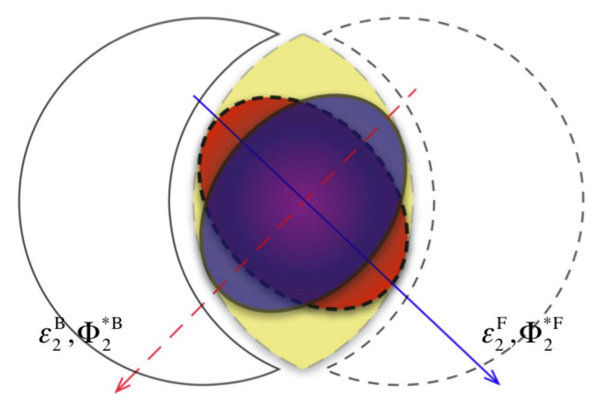
3. In this poster, we estimate the size of initial fluctuation in Glauber model and quantify the $\vec{v}_n(\eta)$ fluctuation using AMPT model.

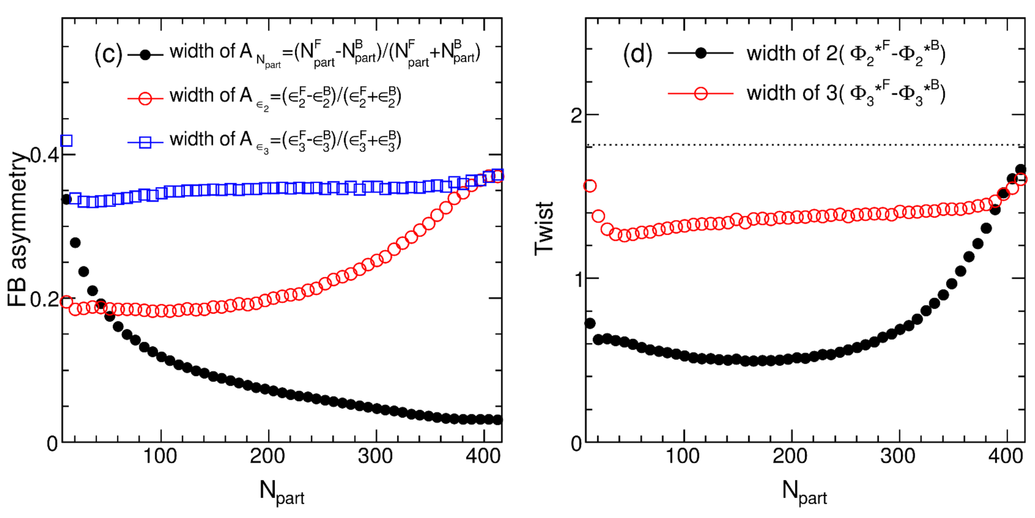
2. A simple model based on the Glauber model

1. Wounded nucleon mode

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







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

3. We naturally expect the default $\vec{\epsilon}_n$interpolates between $\vec{\epsilon}_n^F$and $\vec{\epsilon}_n^B$ and thus we get:

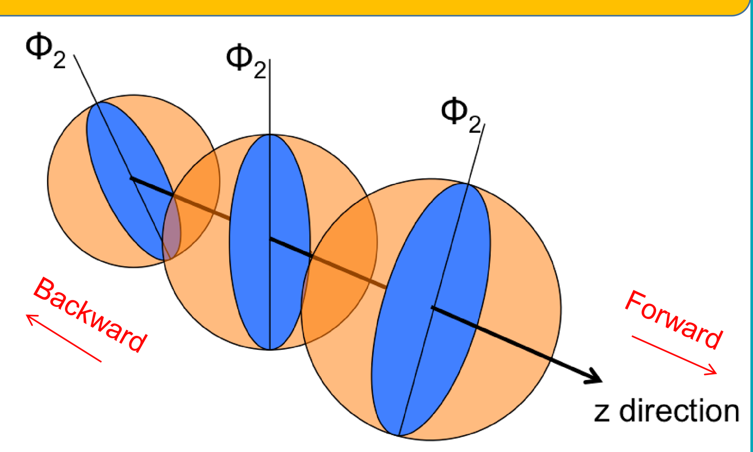
$$\vec{v}_n(\eta) \propto \vec{\epsilon}_n^{tot}(\eta) \approx \alpha(\eta)\vec{\epsilon}_n^{\rm F} + (1-\alpha(\eta))\vec{\epsilon}_n^{\rm B} \qquad \alpha(\eta) = \frac{f^{\rm F}(\eta)\langle r^n\rangle^{\rm F}}{f^{\rm F}(\eta)\langle r^n\rangle^{\rm F} + f^{\rm B}(\eta)\langle r^n\rangle^{\rm B}}$$

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

3. Expectations:

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

1. FB asymmetry of $v_n(\eta)$
2. A twist of final state event plane angles $\Phi_n(\eta)$



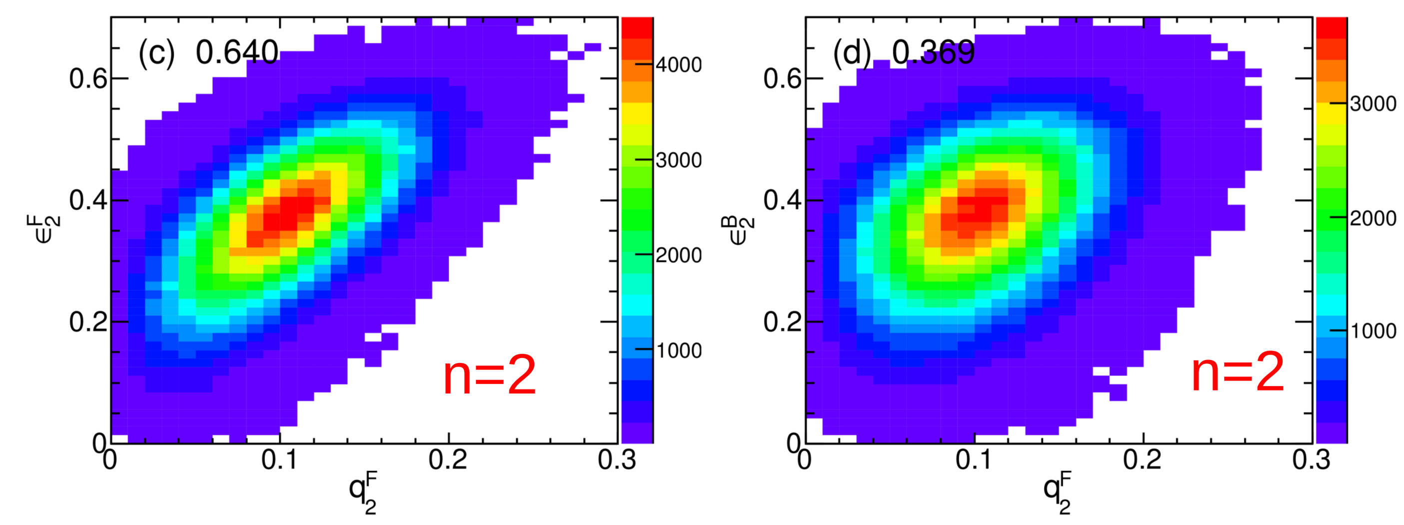
4. Analysis with the AMPT model

AMPT model

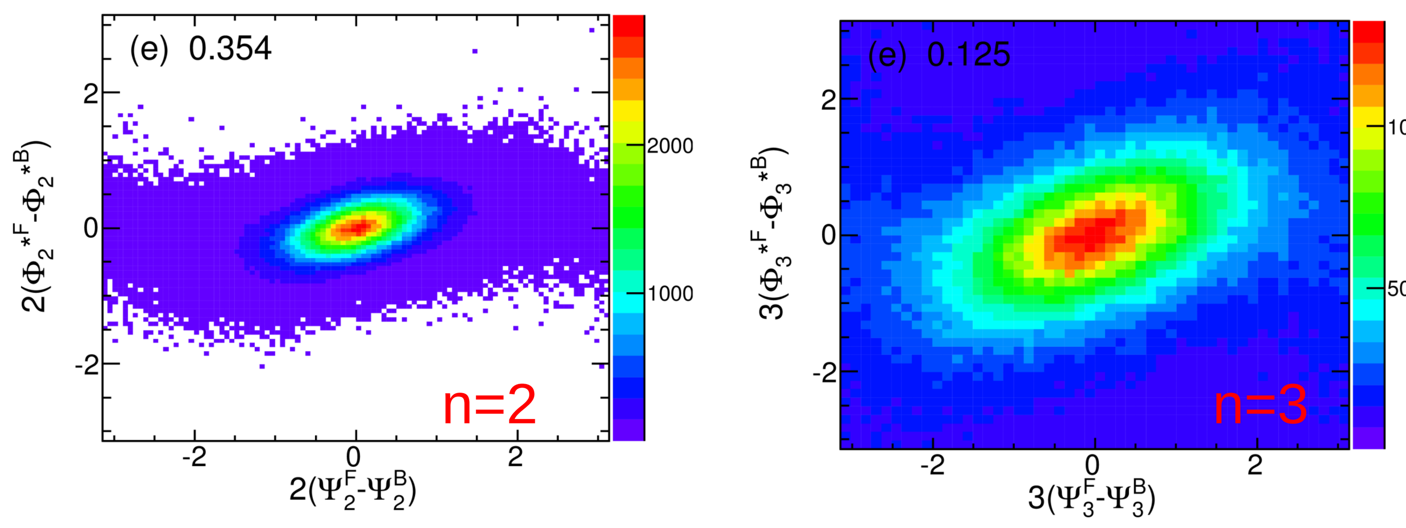
1. Glauber+HIJING+transport.
2. Contains longitudinal fluctuations and collective flow

➢ FB asymmetry $\epsilon_n^F \neq \epsilon_n^B$survives

Magnitude of flow vector $\vec{q}_2^F$ in forward rapidity $\eta \in (4,6)$ is more correlated with ϵ_2^F than ϵ_2^B and the effect is similar for n=3



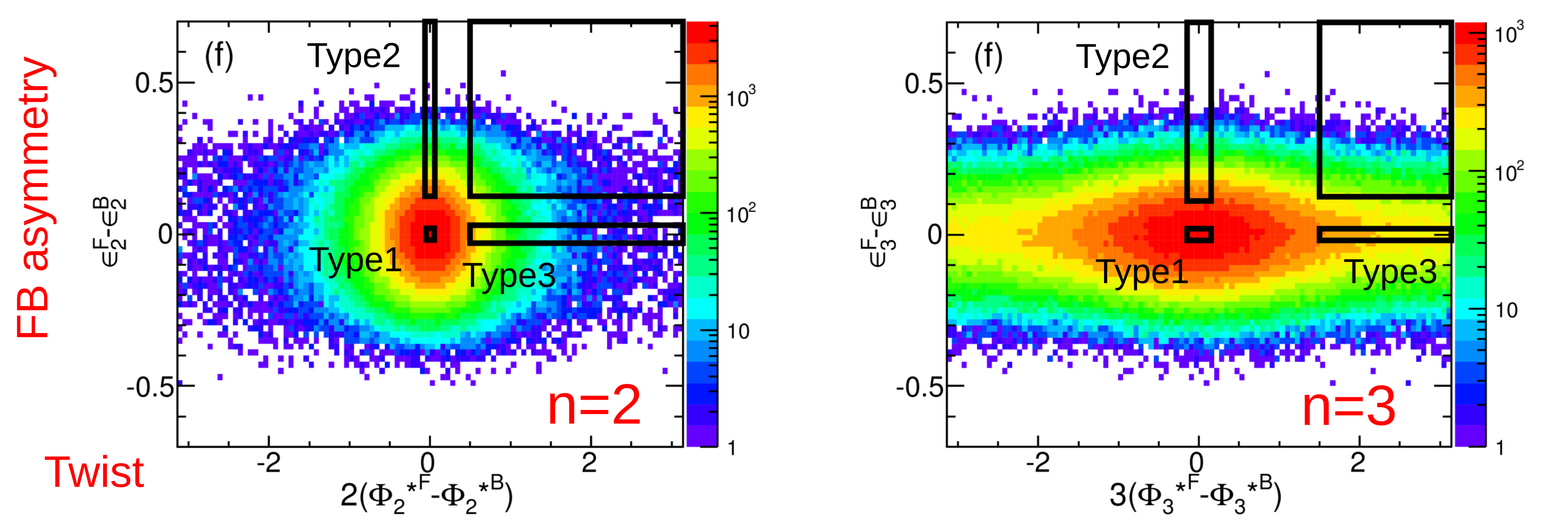
➢ Initial participant plane twist survives as the final event plane twist



Φ_n^*: initial participant plane angle, Ψ_n raw event-plane angle

5. Selecting different initial longitudinal configurations

- To better study how the initial longitudinal configurations influence the final $\vec{v}_n(\eta)$, we select 3 classes of events with different fluctuations between $\vec{\epsilon}_n{}^F$ *and* $\vec{\epsilon}_n{}^B$



event classes in ellipticity

	Cuts	$\langle\epsilon_2^{\rm F}\rangle$	$\langle\epsilon_2^{\rm B}\rangle$
type1	$\lvert 2\Delta\Phi_2^{*\rm FB}\rvert < 0.05, \lvert\Delta\epsilon_2^{\rm FB}\rvert < 0.02$	0.4	
type2	$\lvert 2\Delta\Phi_2^{*\rm FB}\rvert < 0.05, \Delta\epsilon_2^{\rm FB} > 0.125$	0.456	0.282
type3	$2\Delta\Phi_2^{*\rm FB} > 0.5, \lvert\Delta\epsilon_2^{\rm FB}\rvert < 0.03$	0.314	

event classes in triangularity

	Cuts	$\langle\epsilon_3^{\rm B}\rangle$	$\langle\epsilon_3^{\rm B}\rangle$
type1	$\lvert 3\Delta\Phi_3^{*\rm FB}\rvert < 0.15, \lvert\Delta\epsilon_3^{\rm FB}\rvert < 0.02$	0.182	
type2	$\lvert 3\Delta\Phi_3^{*\rm FB}\rvert < 0.15, \Delta\epsilon_3^{\rm FB} > 0.125$	0.293	0.126
type3	$3\Delta\Phi_3^{*\rm FB} > 1.5, \lvert\Delta\epsilon_3^{\rm FB}\rvert < 0.02$	0.112	

- Then measure harmonic flow relative to the participant planes: $\Theta_n \in \{\Phi_n^{*F}, \Phi_n^{*B}, \Phi_n^*\}$

$$v_n^c(\eta) = \langle\cos n(\phi(\eta) - \Theta_n)\rangle \qquad v_n^s(\eta) = \langle\sin n(\phi(\eta) - \Theta_n)\rangle$$

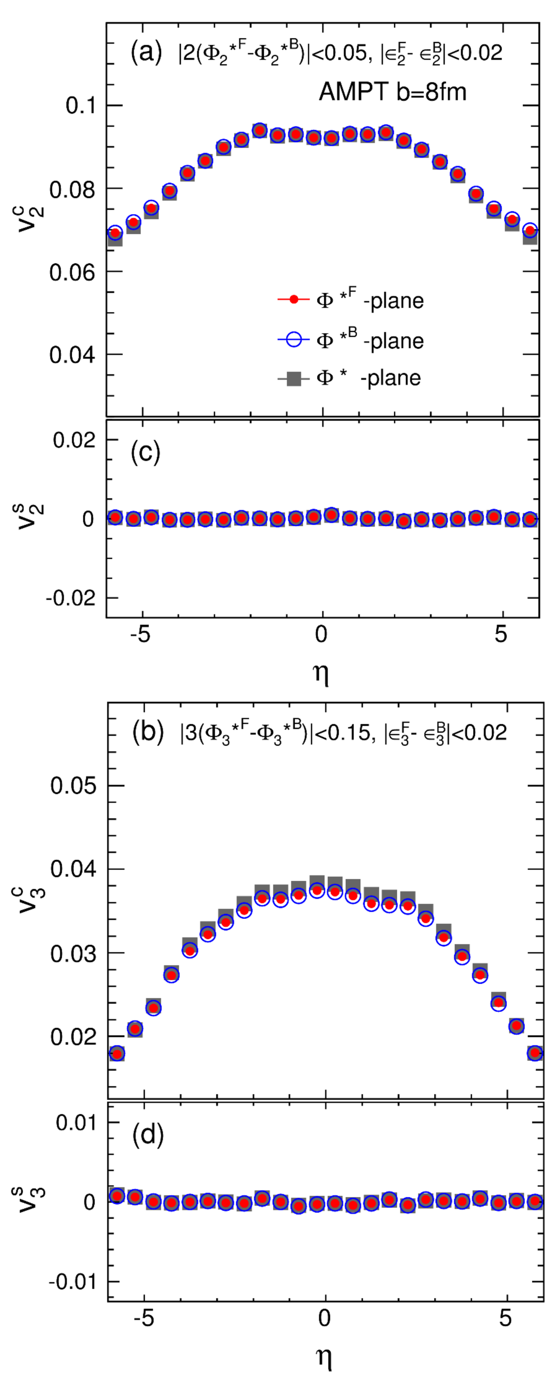
6. Results

Type 1

Initial: $\epsilon_n^F = \epsilon_n^B$, $\Phi_n^{*F} = \Phi_n^{*B}$
final: symmetric $v_n(\eta)$, no twist

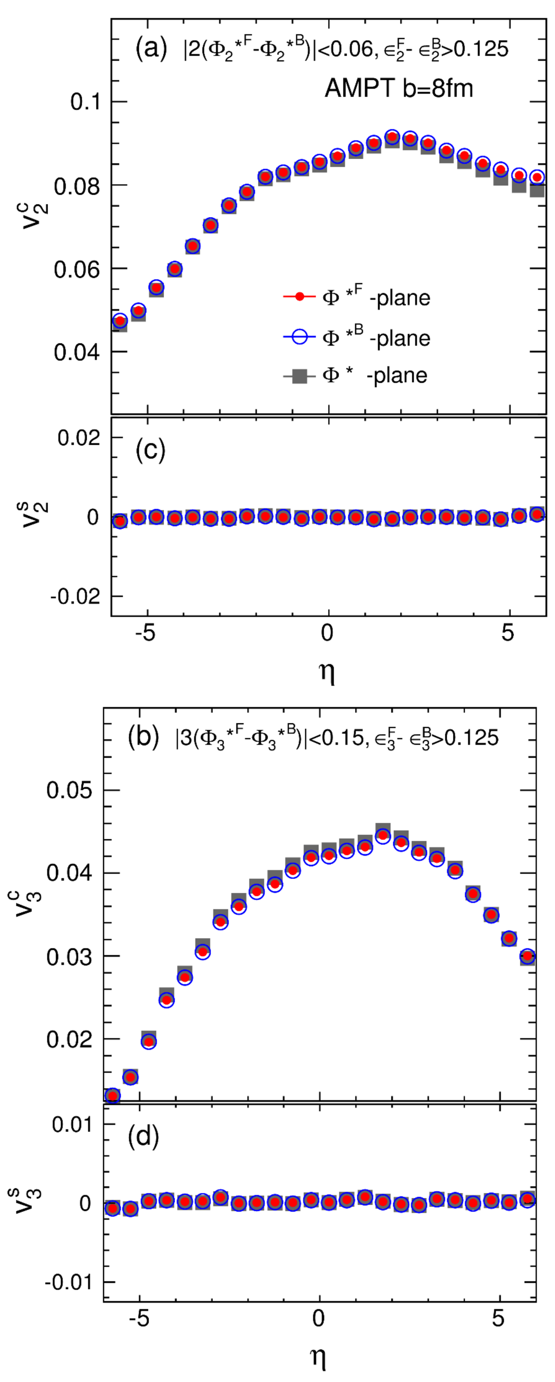
n=2

n=3



Type 2

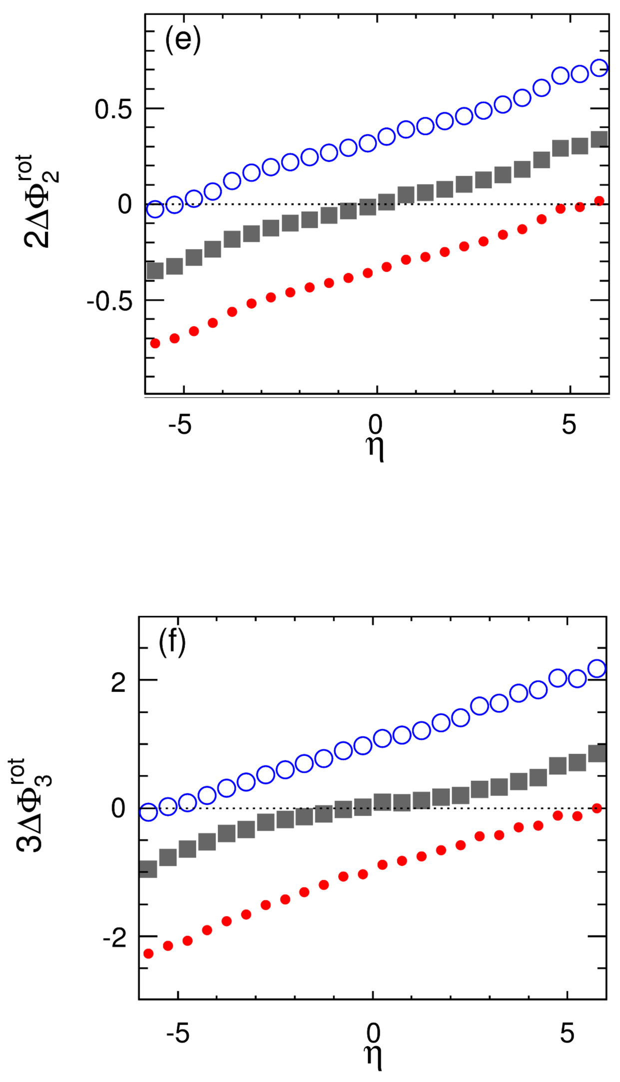
Initial: $\epsilon_n^F \neq \epsilon_n^B$, $\Phi_n^{*F} = \Phi_n^{*B}$
final: $v_n(\eta)$ FB asymmetry, no twist



Type 3

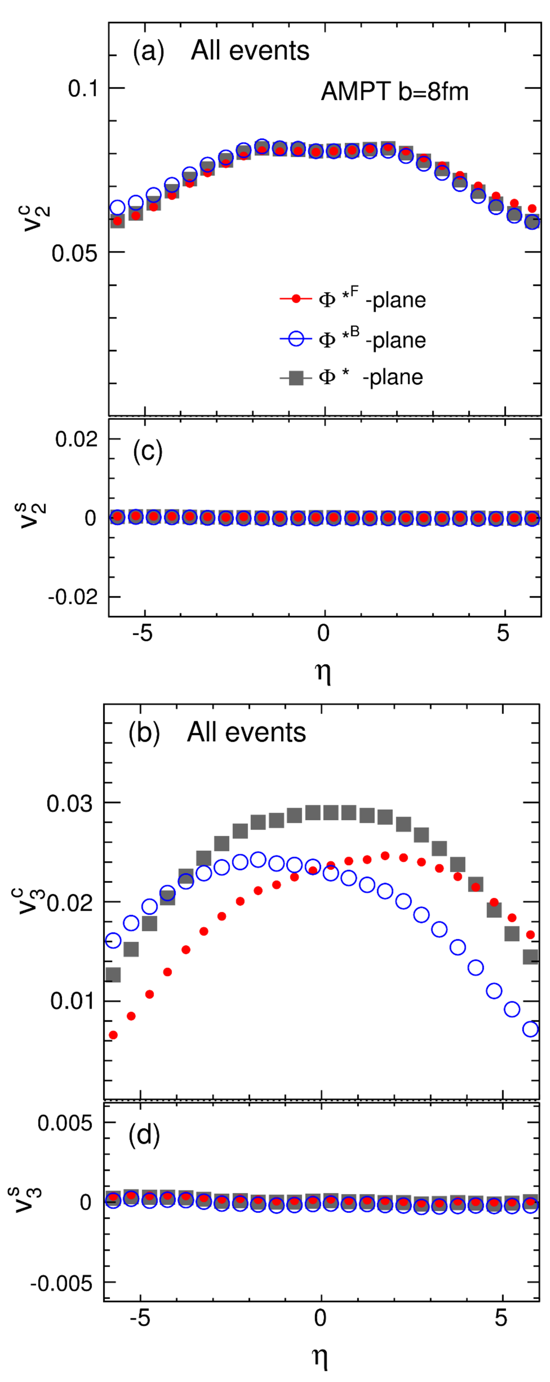
Initial: $\epsilon_n^F = \epsilon_n^B$, $\Phi_n^{*F} \neq \Phi_n^{*B}$
Final: twist observed!

$$\tan\left[n\Delta\Phi_n^{\rm rot}(\eta)\right] = \frac{\langle\sin n\left(\phi(\eta) - \Theta_n\right)\rangle}{\langle\cos n\left(\phi(\eta) - \Theta_n\right)\rangle} = \frac{v_n^s(\eta)}{v_n^c(\eta)}$$



Inclusive

The twist leads to EP decorrelation in rapidity.
$v_n(\eta)$ 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 $v_n(\eta)$ 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:

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