A method study on removing flow backgrounds from the CME analysis

Fufang Wen
University of California, Los Angeles
8/10 2016

content

- Event-shape engineering
  - Handle on event-shape
  - Disappearance of background
  - Artificial signal/background
  - Application to 39GeV Au+Au
- Ensemble average

event-shape engineering

$\frac{dN}{d\phi} \propto 1 + 2v_{1,\alpha}\cos(\Delta\phi) + 2v_{2,\alpha}\cos(2\Delta\phi) + 2a_{1,\alpha}\sin(\Delta\phi) + \ldots$

- Where $\Delta\phi = \phi - \Psi_{RP}$, α(+ or -) denotes the charge sign of particle

v_1: directed flow v_2: elliptic flow

a_1: quantifies the charge separation due to CME

$$v_2 = \langle\langle \cos(2\phi - 2\Psi_{RP}\rangle_P\rangle_E$$

$$\gamma = \left\langle\left\langle \cos\left(\phi_\alpha + \phi_\beta - 2\Psi_{RP}\right)\right\rangle_P\right\rangle_E$$

$$= \left[\left\langle v_{1,\alpha}v_{1,\beta}\right\rangle + B_{in}\right] - \left[\left\langle a_{1,\alpha}a_{1,\beta}\right\rangle + B_{out}\right]$$

(B_{in}-B_{out}) :flow-related background

γ_{oppo}-γ_{same} quantifies the CME signal

Goal: find a handle to select spherical event(zero v_2) so the background can be removed

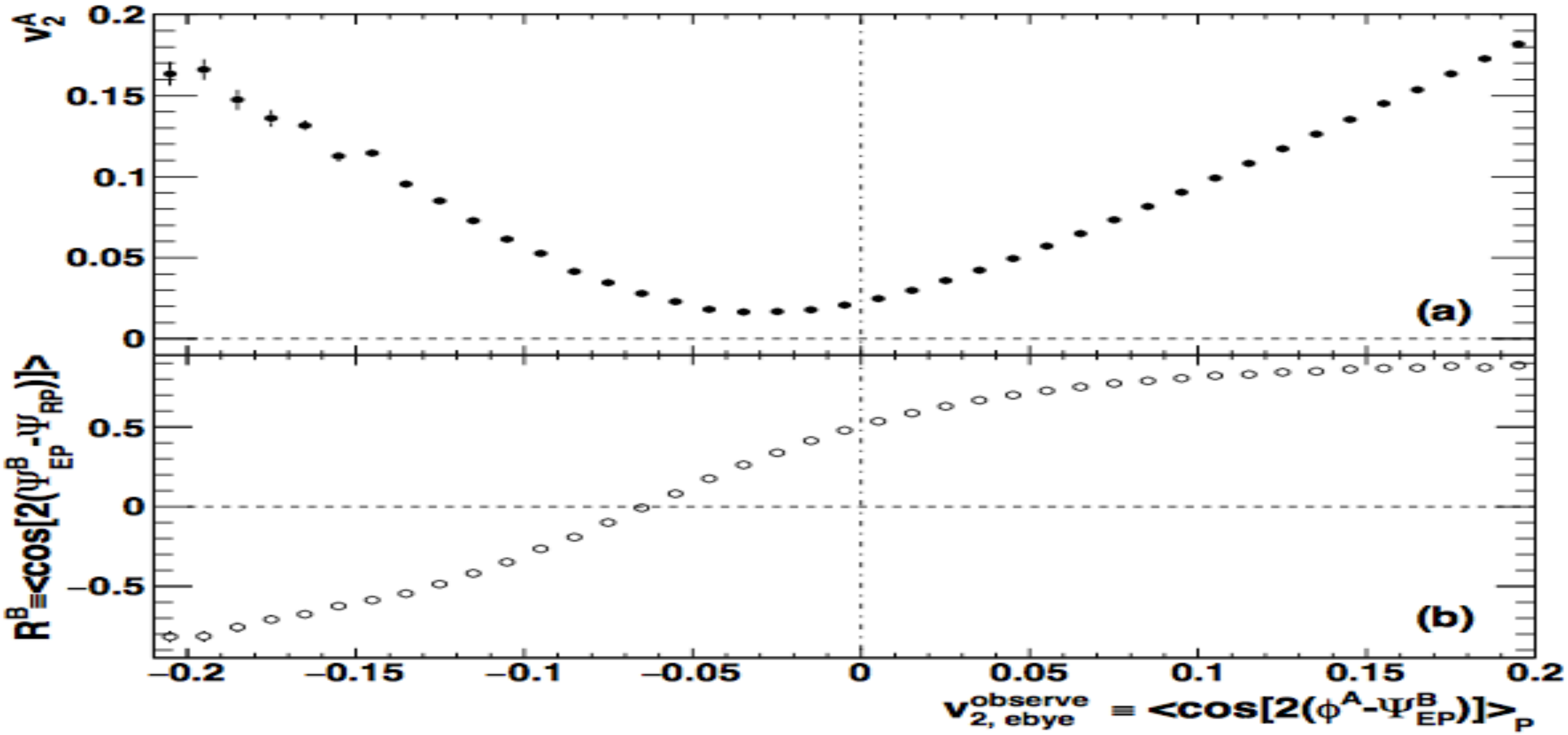
event-shape engineering-handle on event shape

- Monte Carlo simulation with input $a_{1,+}$=2%, $a_{1,-}$=-2% and v_2=5%
- There are only elliptic flow and the charge separation
- Each event is divided into 2 sub-events:

  sub-event A provides particles

  sub-event B provides event plane
- $v_2^{obs} \equiv \left\langle \left\langle \cos(2\phi^A - 2\Psi_{EP}^B) \right\rangle_P \right\rangle_E$
- $R^B \equiv \left\langle cos[2(\Psi_{EP}^B - \Psi_{RP})] \right\rangle_E$
- Ensemble average v_2^A=v_2^{obs}/R^B
- Can event-by-event $v_{2,ebye}^{obs}$ serve as handle on event shape?

event-shape engineering-handle on event shape



- v_2^{obs} is not a valid approach since it fails to select sub-event with zero v_2^A (spherical sub-event). Sphericity depends on beholder.
- Negative true event plane resolution.
- $v_2^A \neq v_2^{obs}/R^B$ on the $v_{2,ebye}^{obs}$ basis
- The correction fails for any observable using Ψ_{EP}^B on the $v_{2,ebye}^{obs}$ basis

event-shape engineering-handle on event shape

- Good handle on event-shape: $\vec{q}$

$\vec{q}^{A}$=(q_x^A, q_y^A)

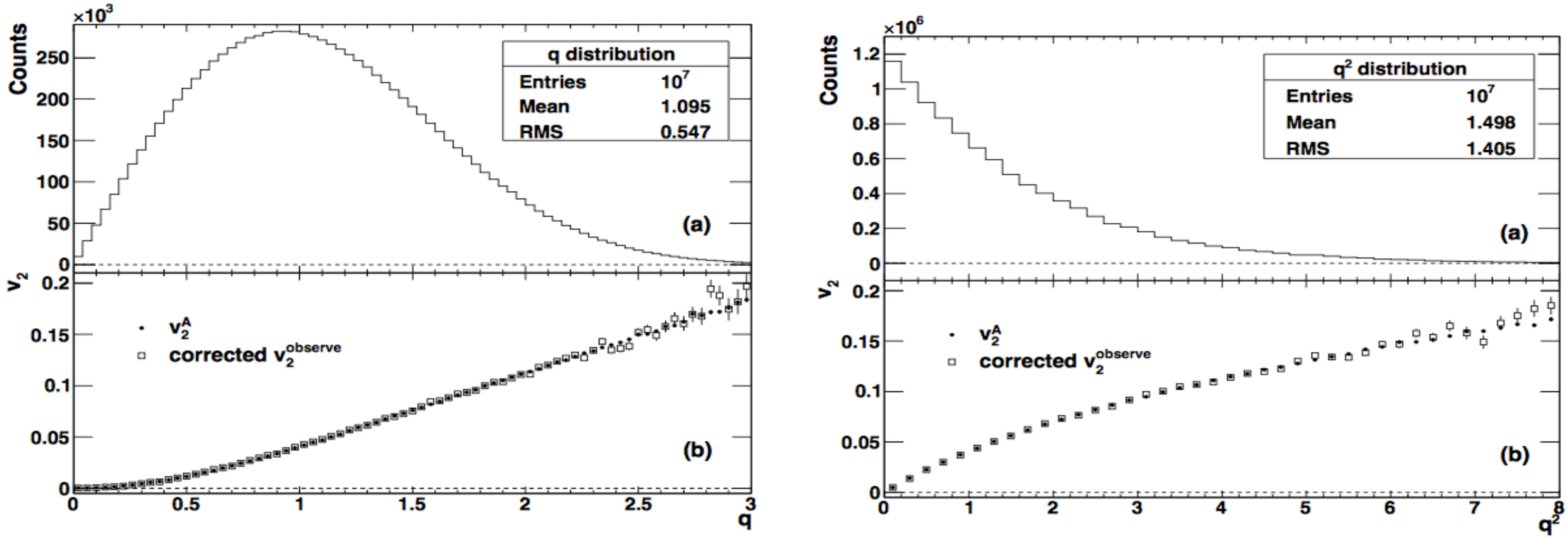
$q_x^A = \frac{1}{\sqrt{N}} \sum_i^N \cos(2\phi_i^A)$

$q_y^A = \frac{1}{\sqrt{N}} \sum_i^N \cos(2\phi_i^A)$

q has advantages over v_2:

- has only contributions from sub-event A
- Independent of the beholder

event-shape engineering-handle on event shape



- Both v_2 values approach zero at vanishing q(or q^2) on the q(or q^2) basis
- The correction for the event plane resolution is valid
- v_2 is linearly related to q^2 at small q^2
- q^2 distribution is "squeezed" in phase space towards zero

event-shape engineering-disappearance of background

- AMPT model (realistic event generator, only background, not CME)

Au+Au collisions at 200 GeV

- Each event has been divided into 3 sub-events

A: $|\eta| < 1.5$ contains particles of interest

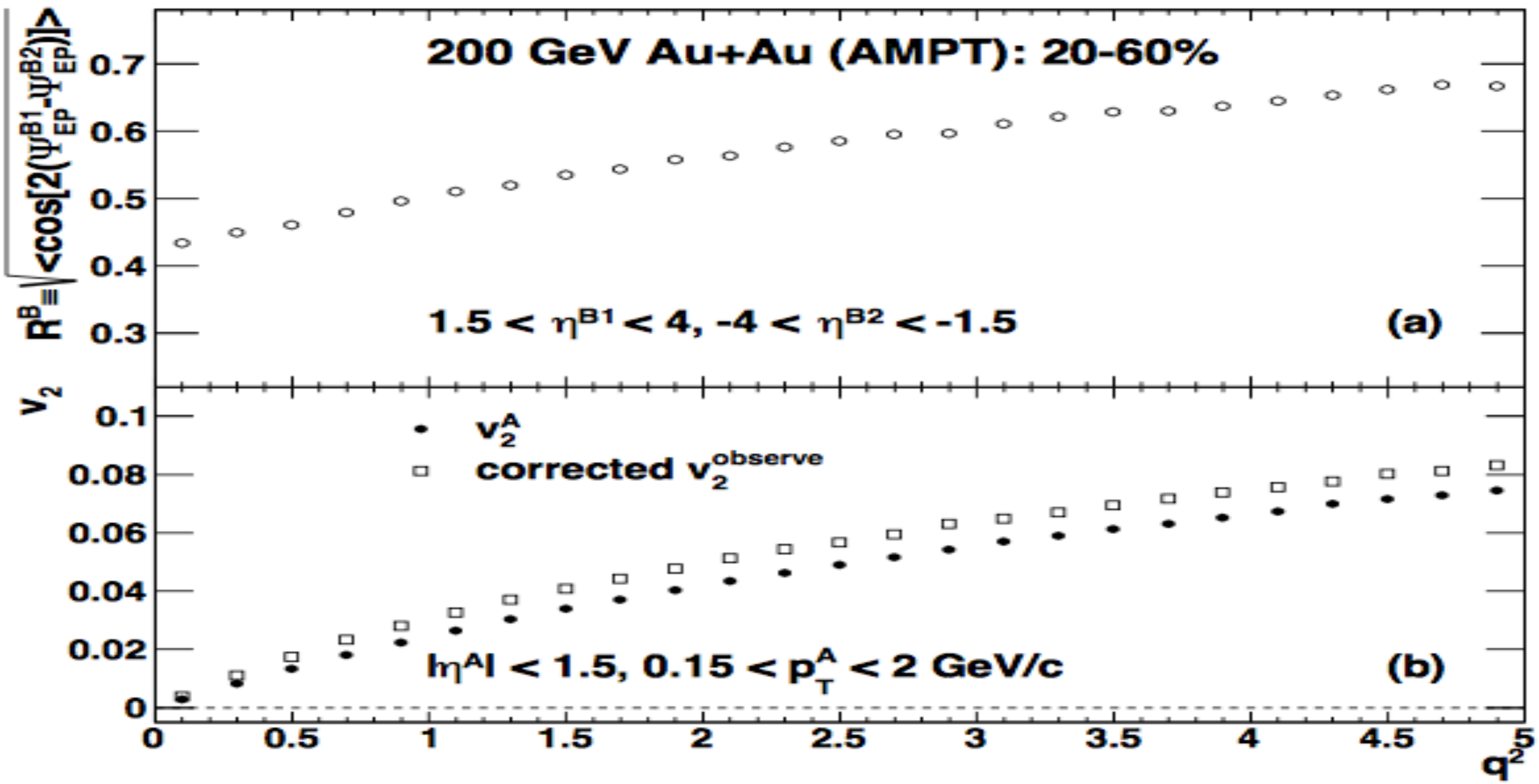
B_1: $1.5 < \eta < 4$

B_2: $-4 < \eta < -1.5$

B_1, B_2 serve as reconstructed sub-event plane

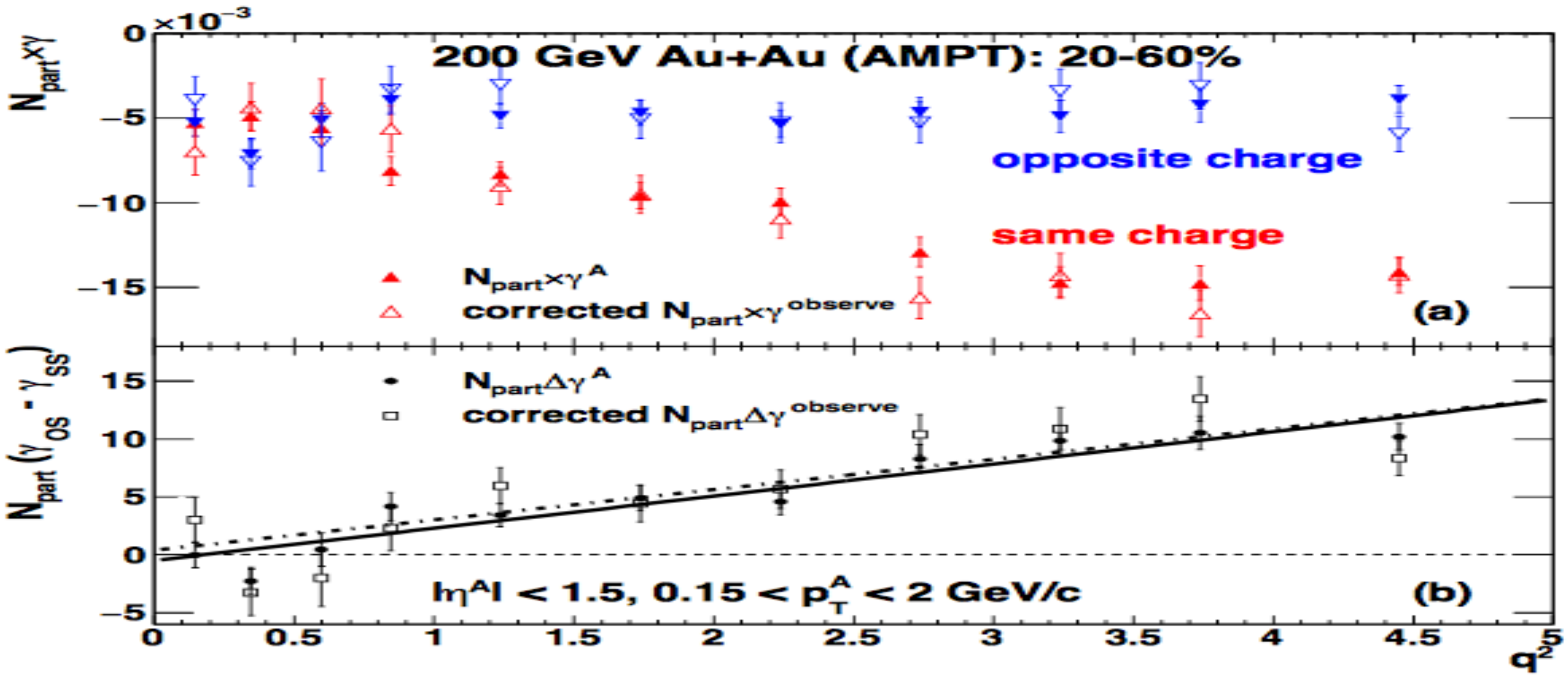
- Sub-event resolution: $R \equiv \sqrt{\langle cos[2(\psi_{EP}^{B1} - \psi_{EP}^{B2})] \rangle}$

event-shape engineering-disappearance of background



- Discrepancy between v_2^A and corrected $v_2^{observe}$ comes from non-flow and flow fluctuation.
- Both v_2 drop to 0 at vanishing q.

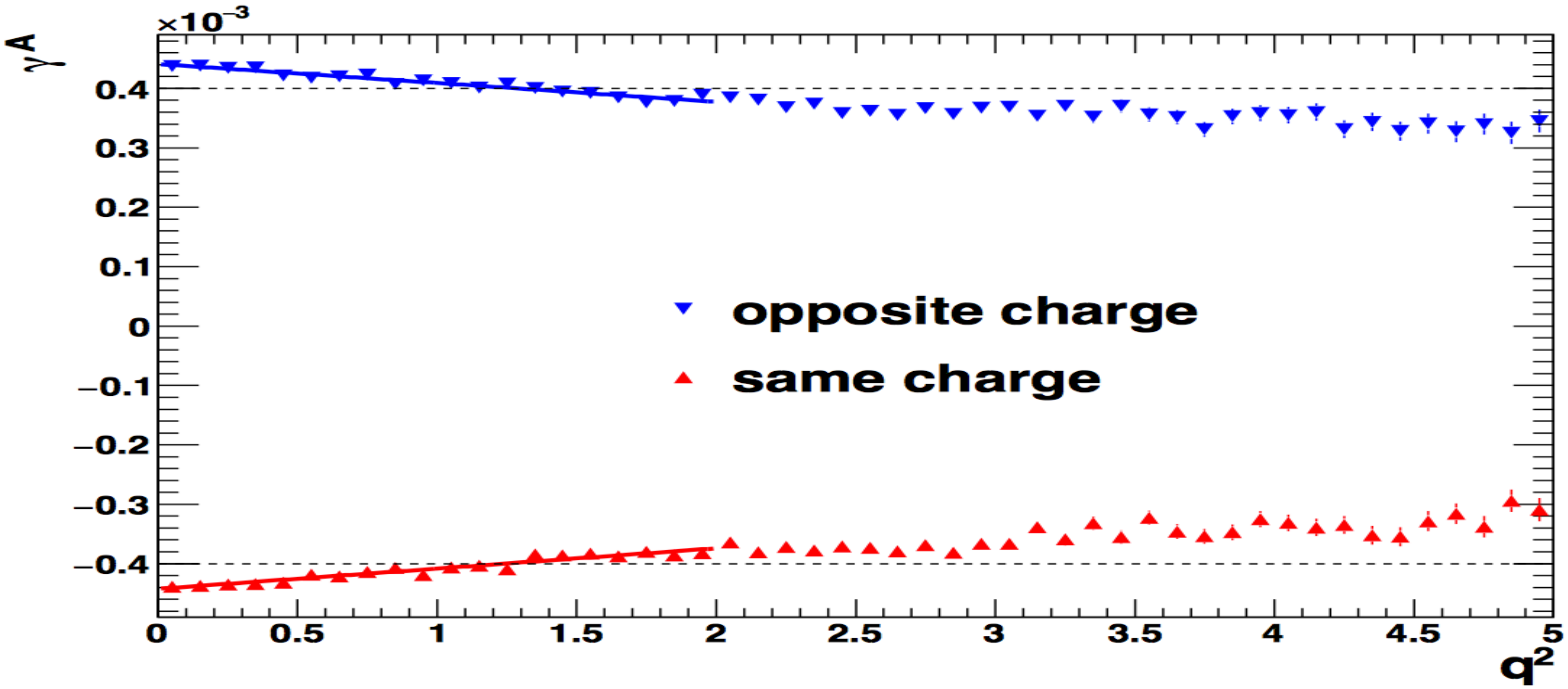
event-shape engineering-disappearance of background



- γ is less sensitive to non-flow and flow fluctuation
- Intercepts are consistent with zero $(-4.9 \pm 6.1)\times10^{-4}$ for $N_{part}\Delta\gamma^A$ and $(3.9 \pm 9.9)\times10^{-4}$ for $N_{part}\Delta\gamma^{observe}$.
- Disappearance of background at zero q is demonstrated.

event-shape engineering-removal of artificial background(monte carlo simulation)

restore ensemble average of signal by 2nd projection



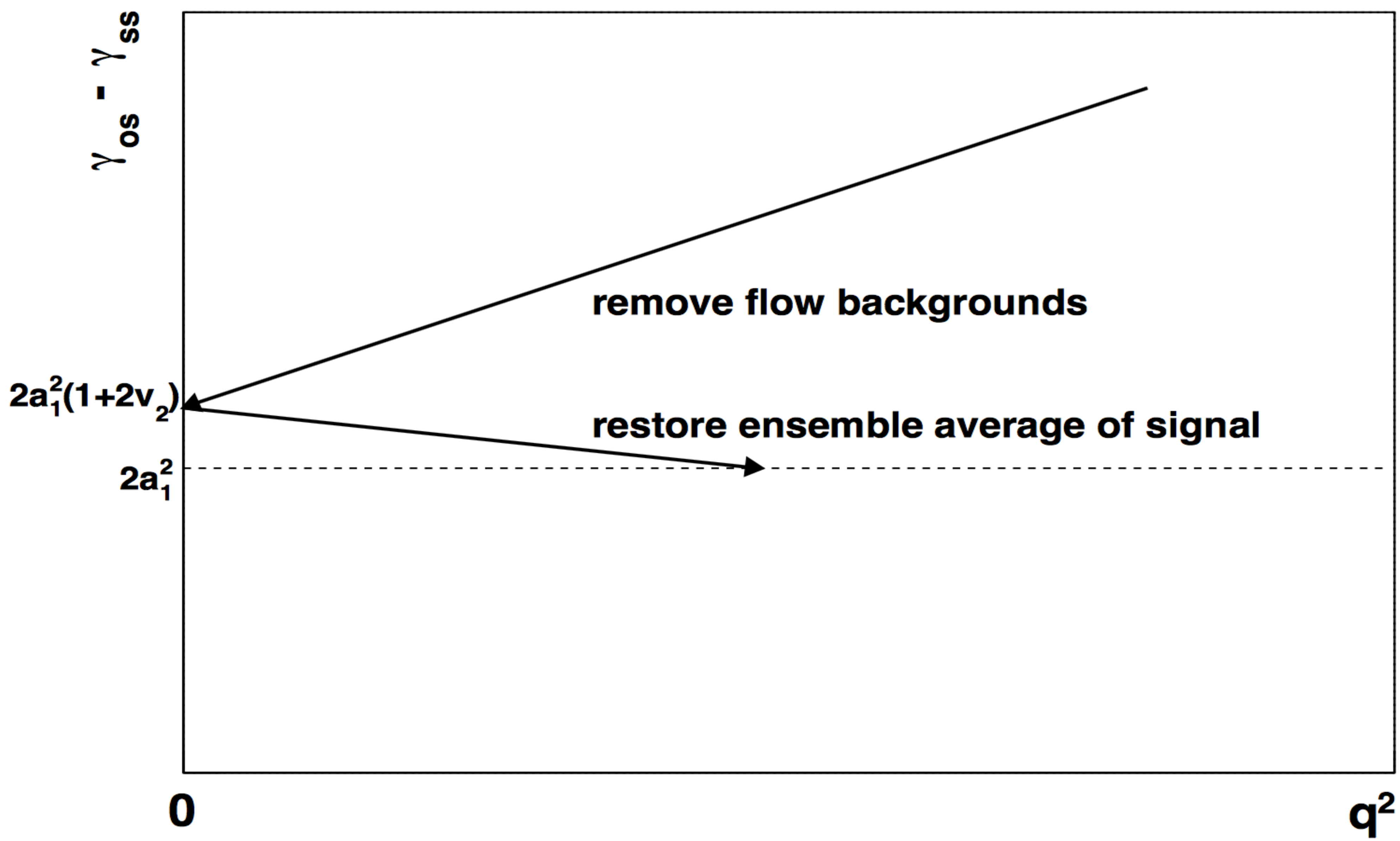
- $\gamma_{ebye} = \langle \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP}) \rangle_p \approx 2\delta_{ebye} v_{2,ebye}$

where $\delta_{ebye} = \langle \cos(\phi_\alpha - \phi_\beta) \rangle_p = a_1^2$

- The apparent value at zero q^2 exaggerates the charge separation: ensemble average can be restored by: $\Delta\gamma = \Delta\gamma(q^2 = 0)/(1 + 2v_2)$

event-shape engineering

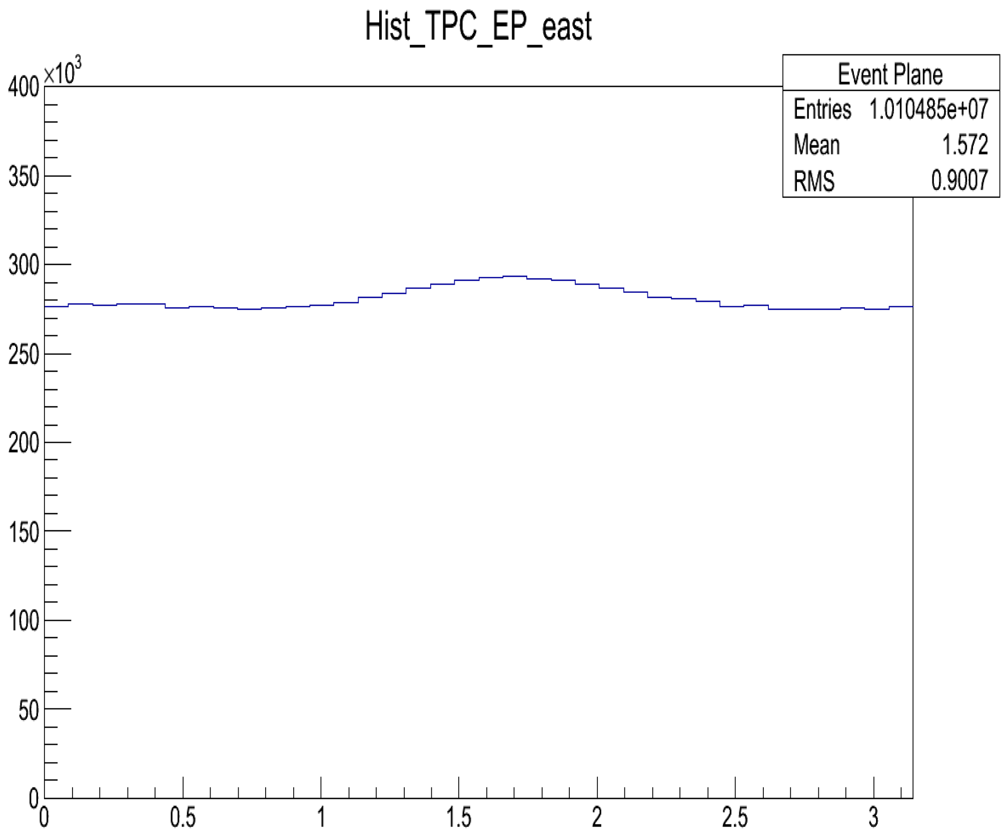
A schematic diagram of how to reveal the ensemble average CME signal via event-shape engineering



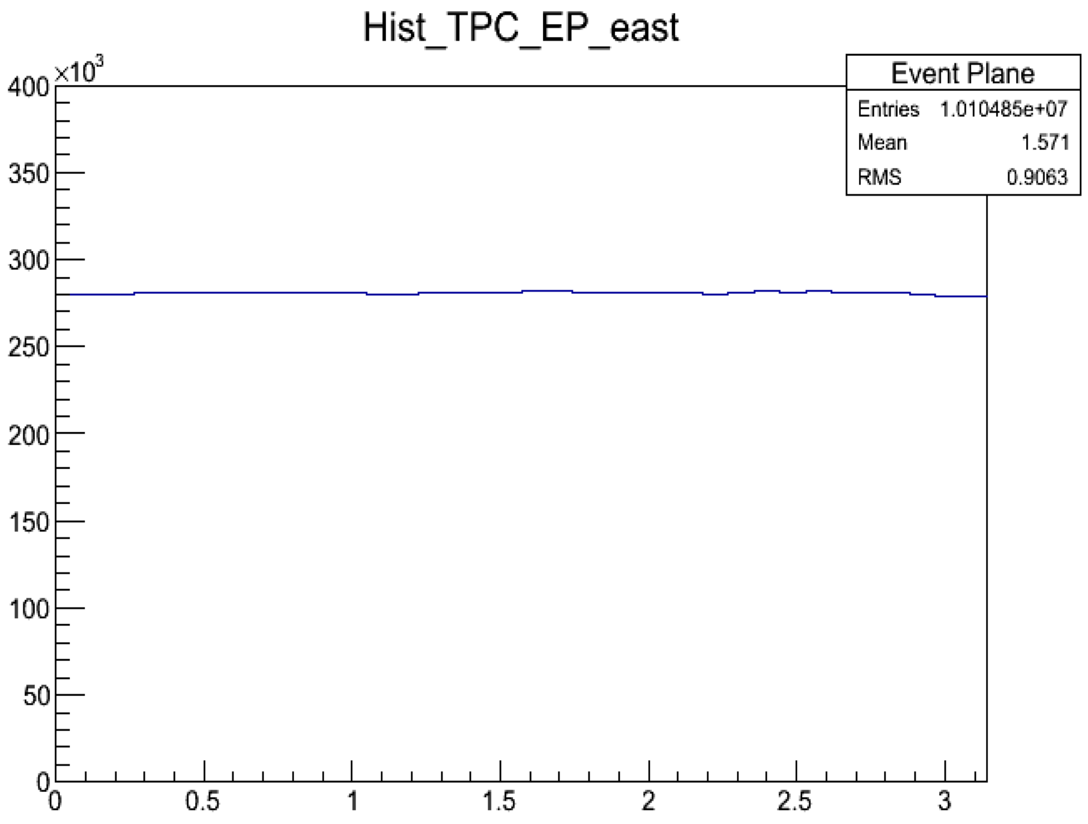
event-shape engineering-application to 39GeV Au+Au

- Shifting method is applied to flatten event plane distribution

Before

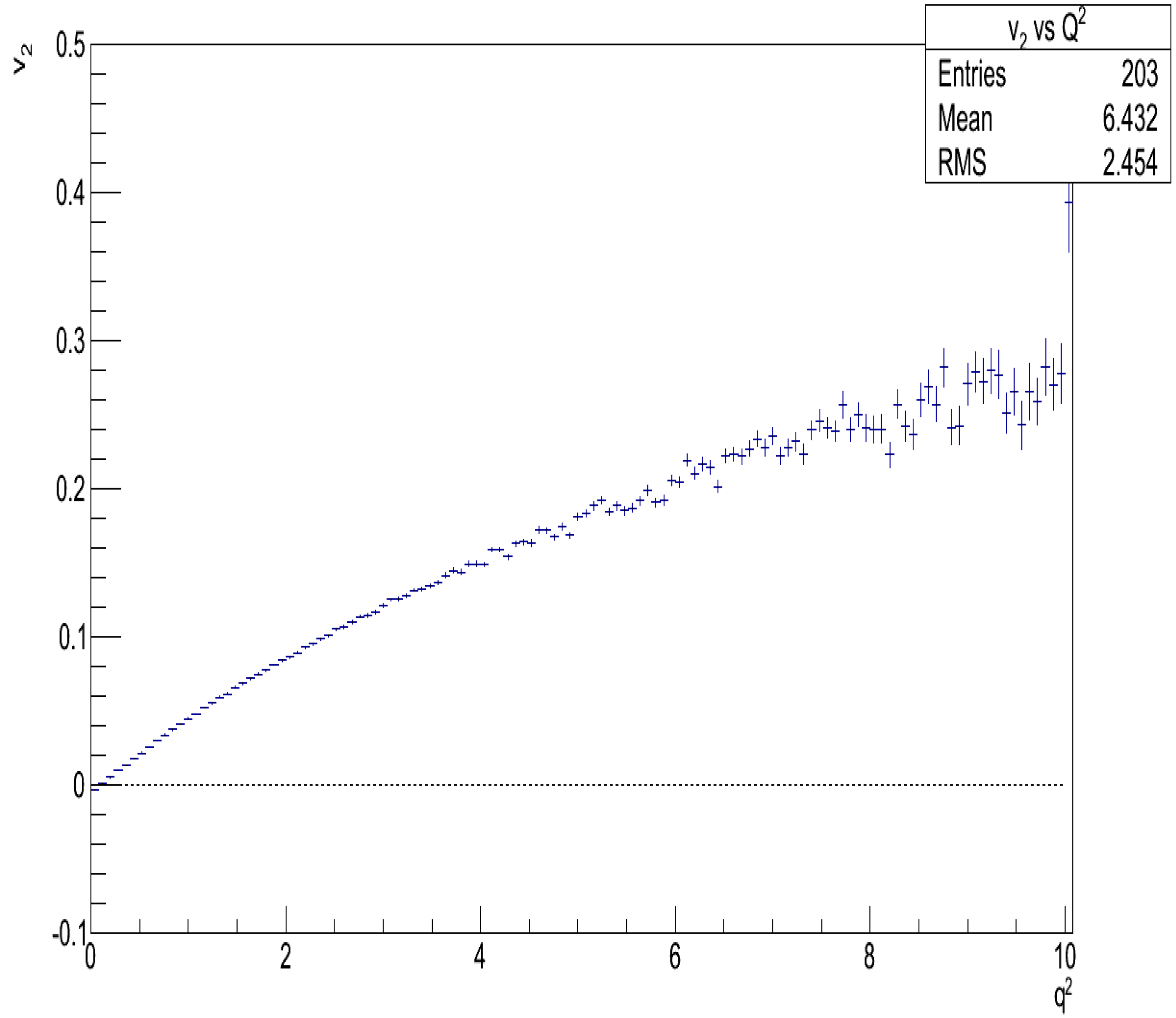


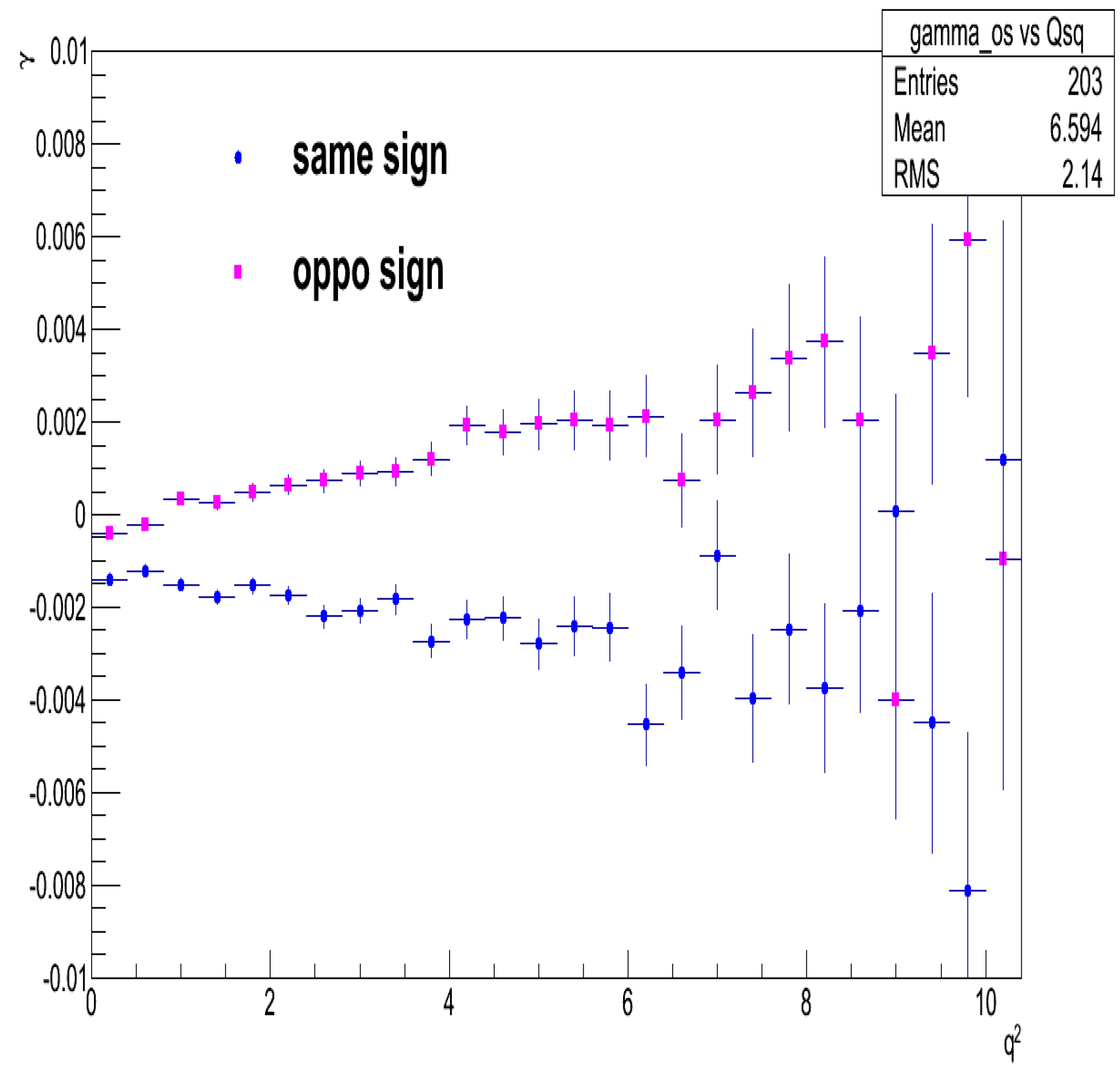
after



event-shape engineering-application to 39GeV Au+Au

- v_2 vs q^2 and γ vs q^2 (30%-40% most central)



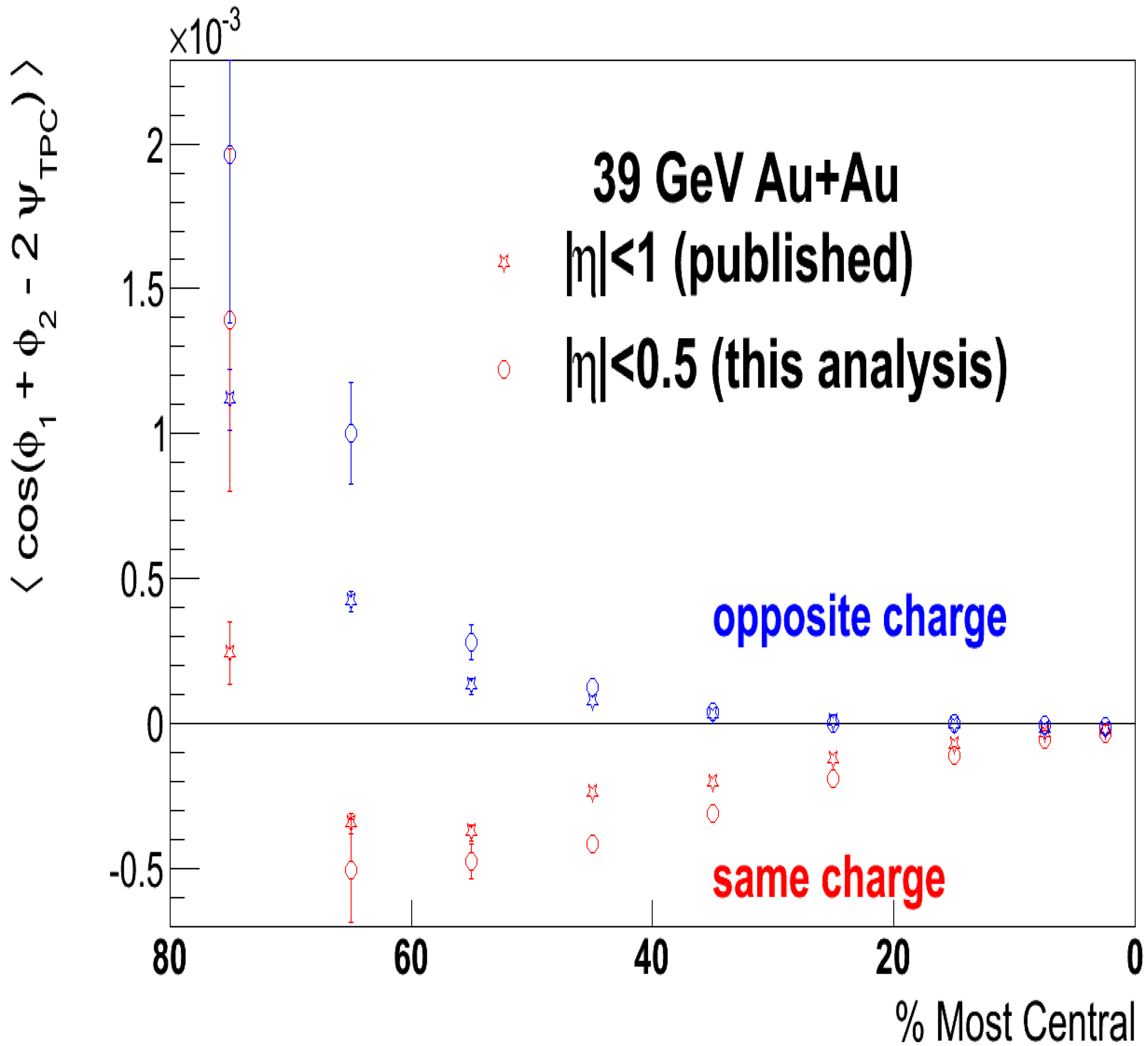


- Pattern is similar to Monte Carlo and AMPT simulation

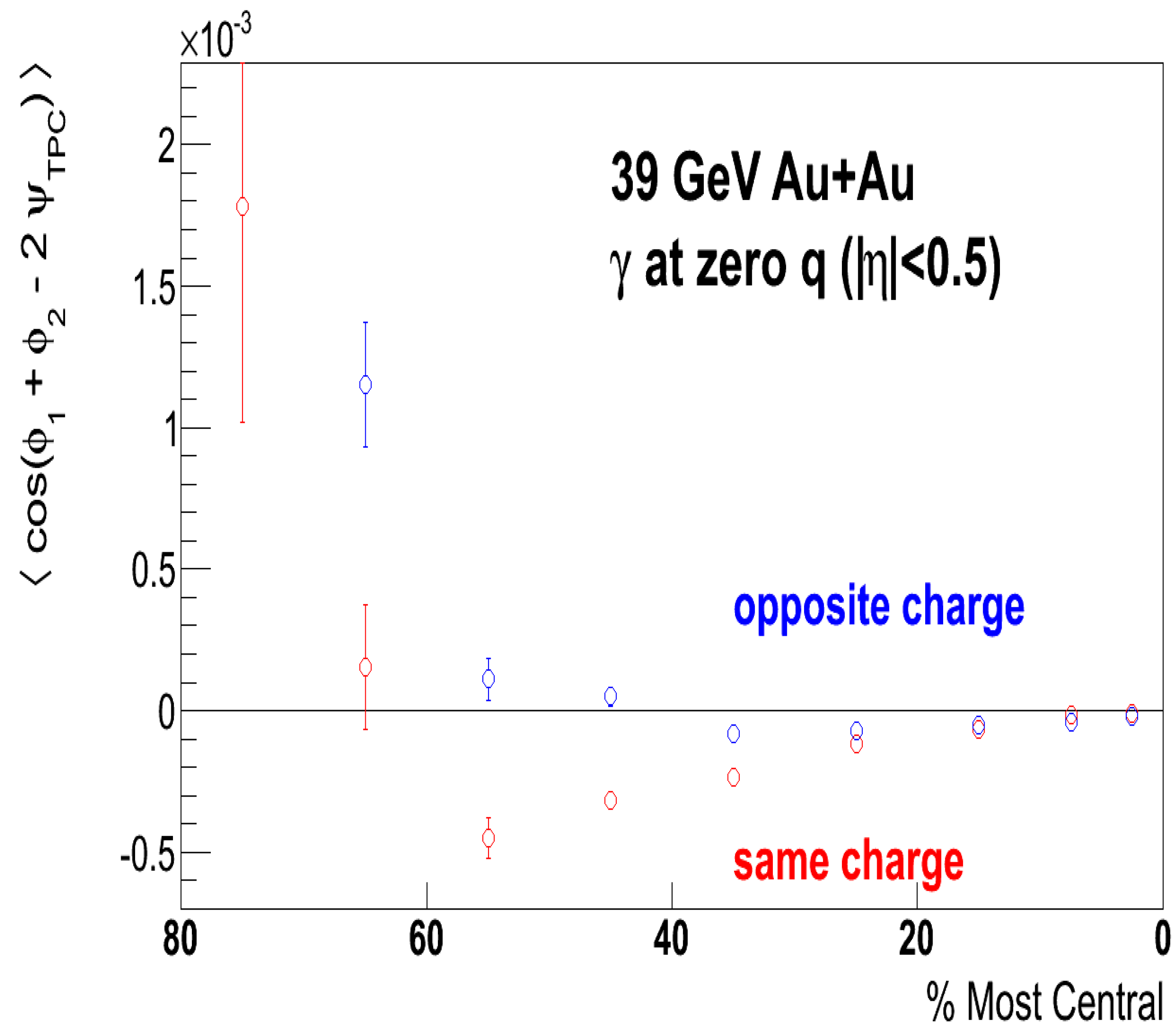
event-shape engineering-application to 39GeV Au+Au

charge separation obtained from q method.

w/i flow background

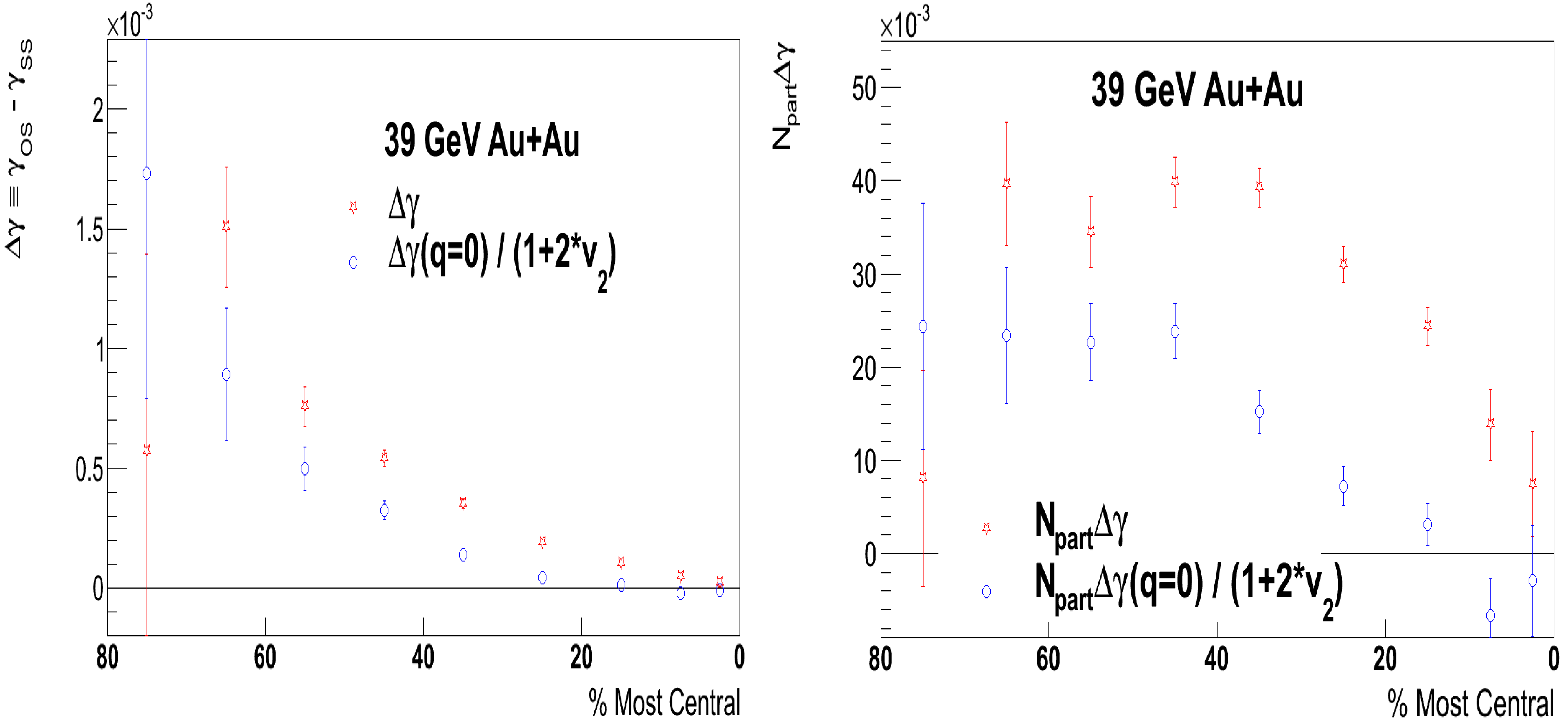


w/o flow background



- The result indicates the existence of CME signal.

event-shape engineering-application to 39GeV Au+Au

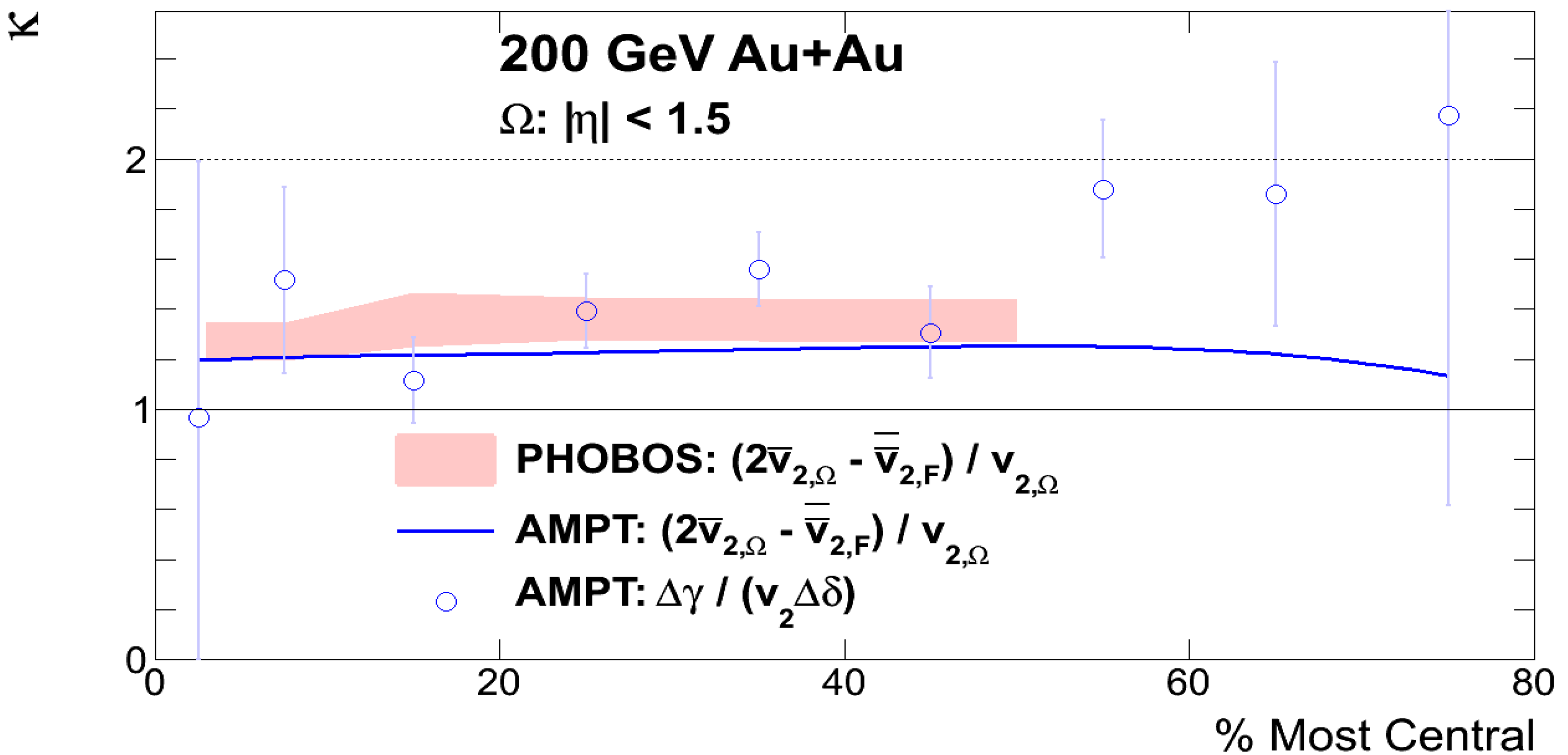


- CME signal is more significant in collision with large centrality

ensemble average

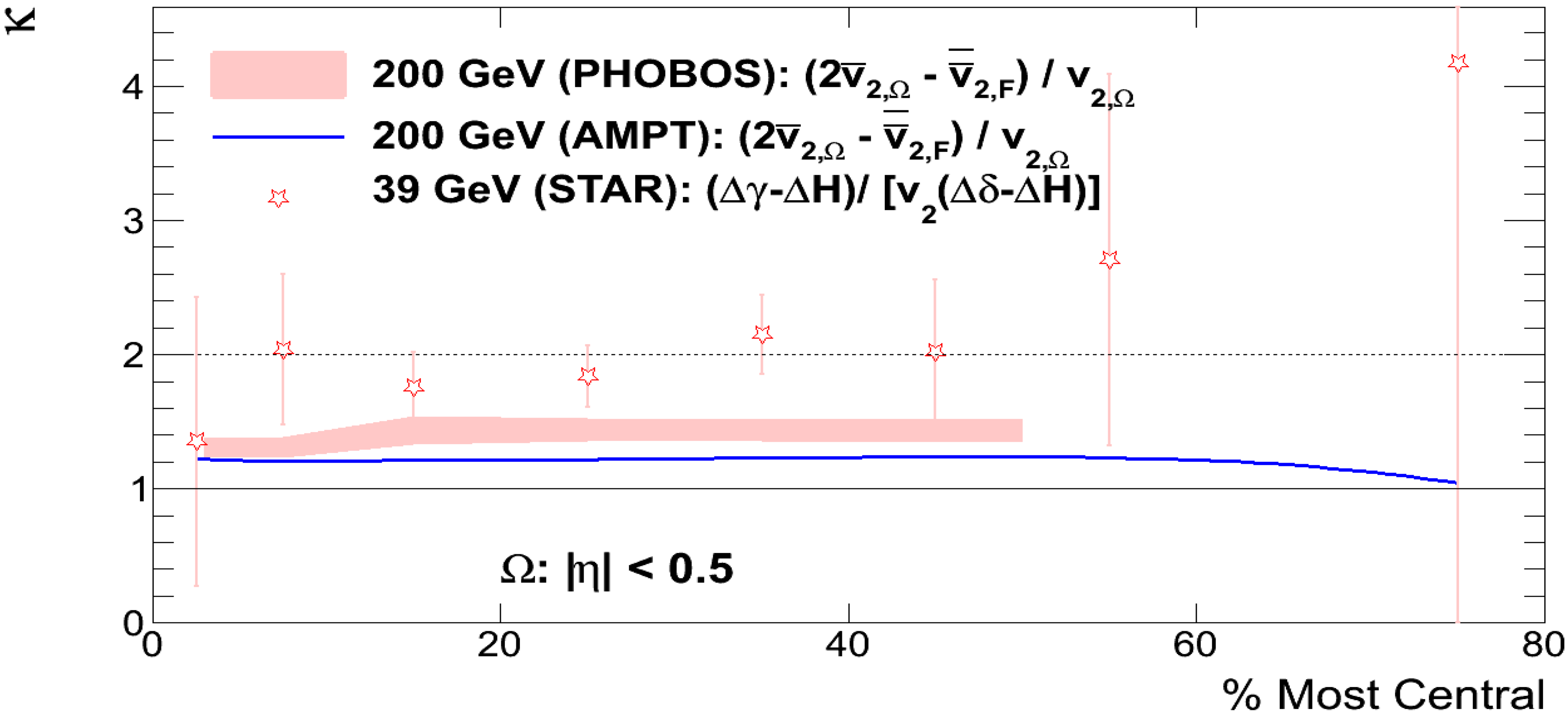
κ can be used to calculate CME background

- $\gamma \equiv \ll \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP}) \gg = \kappa v_2 B - H$
- $\delta \equiv \ll \cos(\phi_\alpha - \phi_\beta) \gg = B + H$
- H:CME signal B: flow background
- $H^\kappa = (\kappa v_2 \delta - \gamma)/(1 + \kappa v_2)$
- κ estimation from Gang



ensemble average

- κ obtained from 39GeV Au + Au compared to previous approaches



- $\kappa = (\Delta\Upsilon - \Delta H)/(v_2(\Delta\delta - \Delta H))$, around 2

summary

- q is valid basis to select spherical sub-event instead of v_2^{obs}.
- q^2 is a better handle than q.
- Event-shape engineering can be applied when number of particles per event is large.
- When number of particles per event is low, κ is a better method to calculate the background.