Local Parity Violation or Local Charge Conservation/Flow?

A Reaction-Plane-Dependent Balance Function Study

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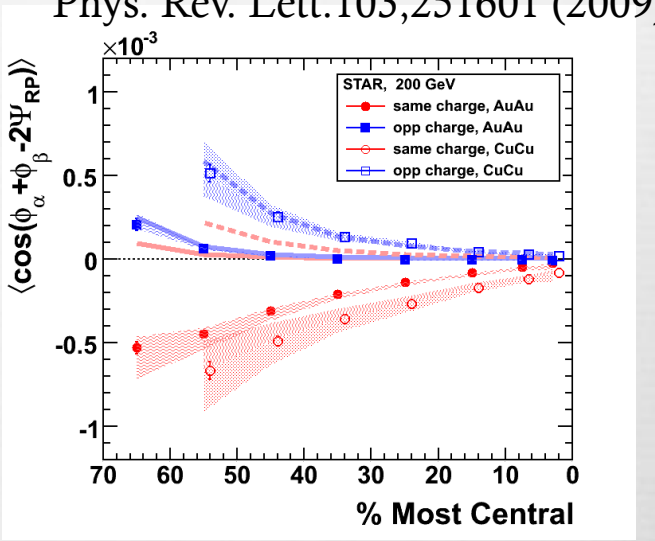
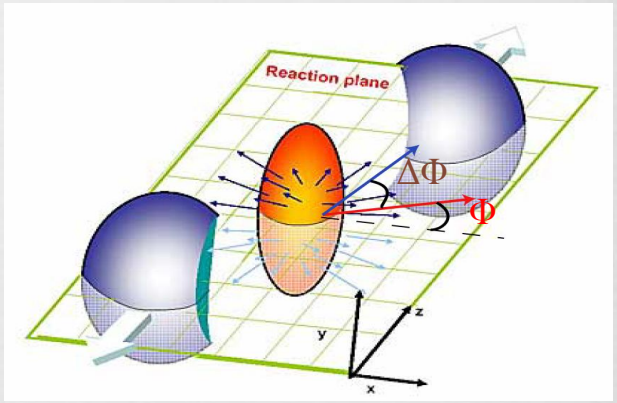
for the STAR Collaboration

Motivation

- In heavy ion collisions, most of the detected charge is created during the evolution of the system.
- Balance functions are sensitive to charge formation mechanisms and relative diffusion
- A **three point correlator** has been proposed to measure the possible Chiral Magnet Effect

Phys. Rev. Lett.103,251601 (2009)

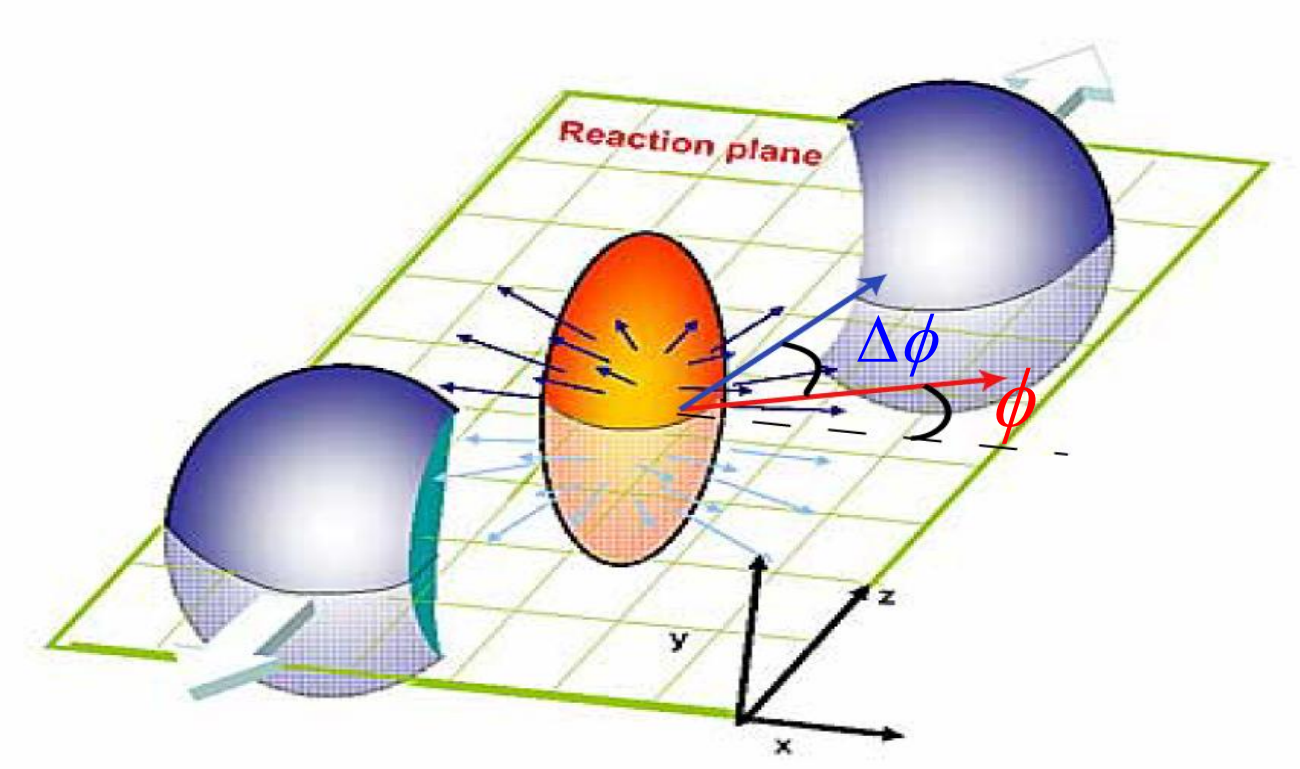




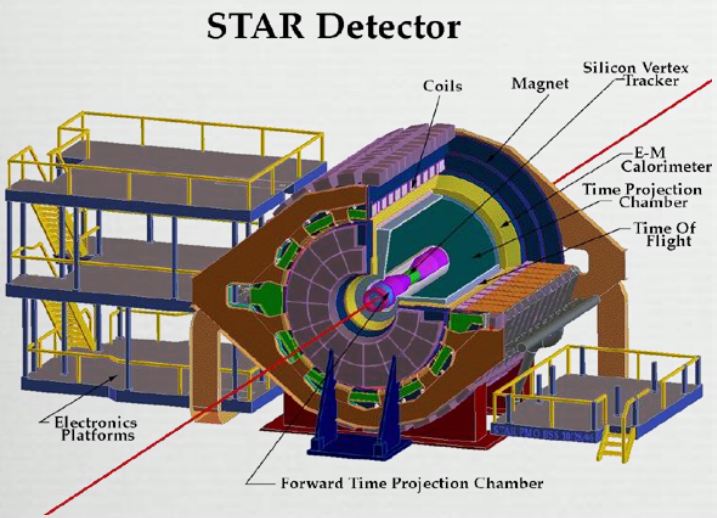
$$\gamma_{\alpha\beta} = \left\langle \cos\left(\phi_\alpha + \phi_\beta - 2\Psi_{EP}\right)\right\rangle$$

Balance Function

$$B(\phi,\Delta\phi)=\frac{1}{2}\{\frac{N_{+-}(\phi,\Delta\phi)-N_{++}(\phi,\Delta\phi)}{N_{+}(\phi)}+\frac{N_{-+}(\phi,\Delta\phi)-N_{--}(\phi,\Delta\phi)}{N_{-}(\phi)}\}$$



Data Set

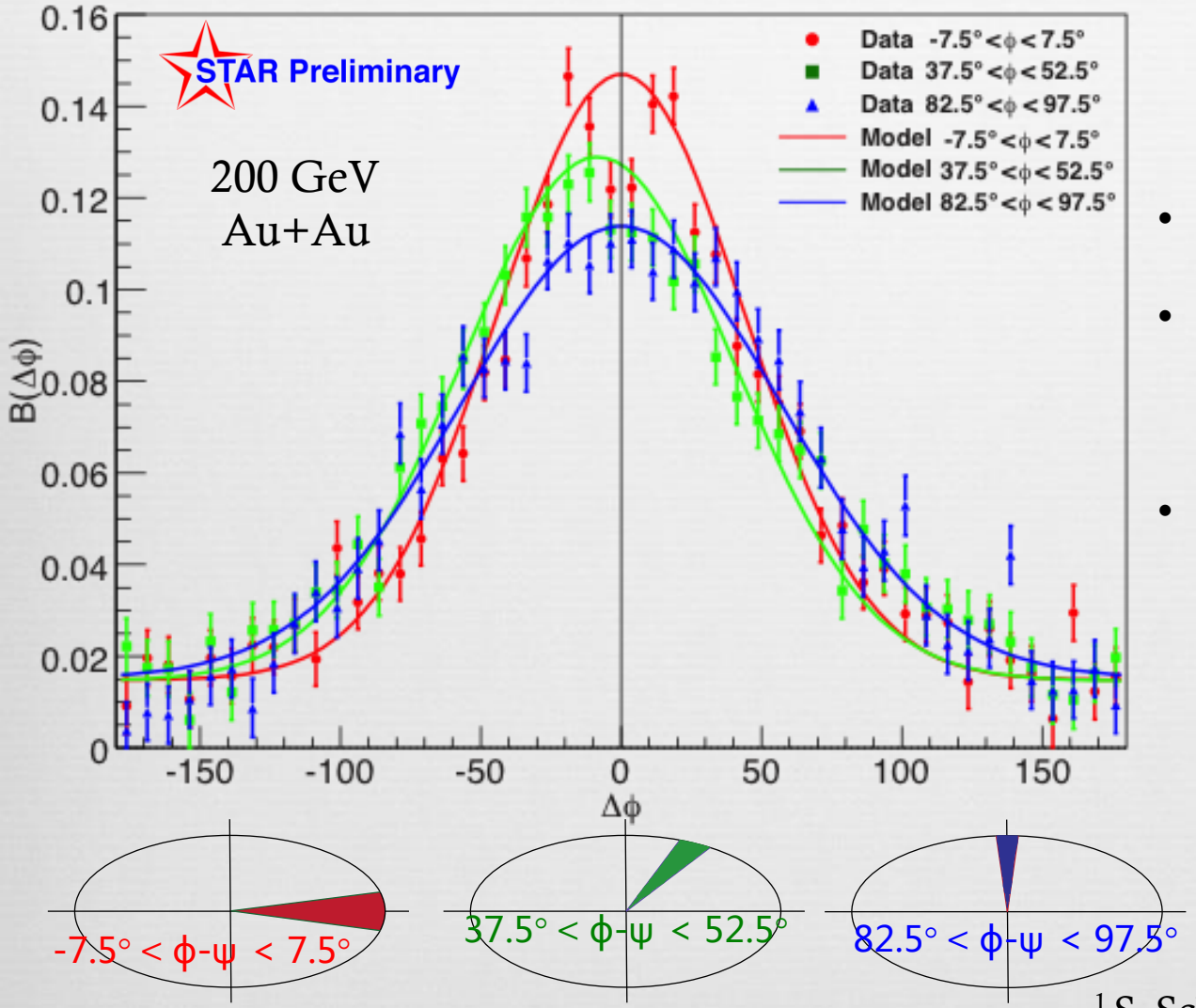


Energy (GeV)	Species	Year	Events (M)*
200	Au + Au	Run 4	14
62.4	Au + Au	Run 4	8
39	Au + Au	Run 10	10
11.5	Au + Au	Run 10	16
7.7	Au + Au	Run 10	4

- All charged particles
  - $|\eta| < 1.0$
  - Full azimuthal acceptance
  - $0.2 < p_t < 2.0$ GeV/c
  - Electrons are suppressed
  - 2nd order event plane from TPC

*Number of events used in balance function calculation

Balance Function



- 40-50% centrality
- 45° to event plane balance function is biased toward negative $\Delta\phi$ region
- The out-of-plane balance function is wider than the in-plane balance function

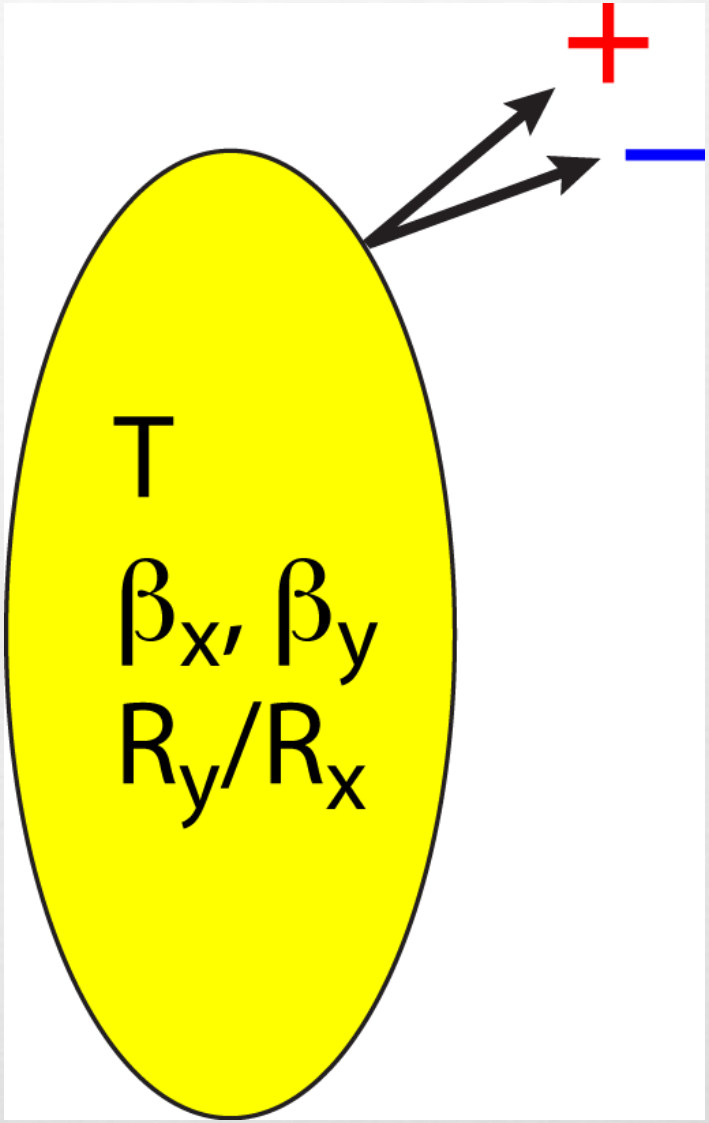
Compare to blast wave model calculations[1]

[1] S. Schlichting and S. Pratt
Phys. Rev. C 83, 014913 (2011)

Blast Wave Model

- STAR parameterization
  (STAR,PRC,72,14904(2005))

- Local charge conservation



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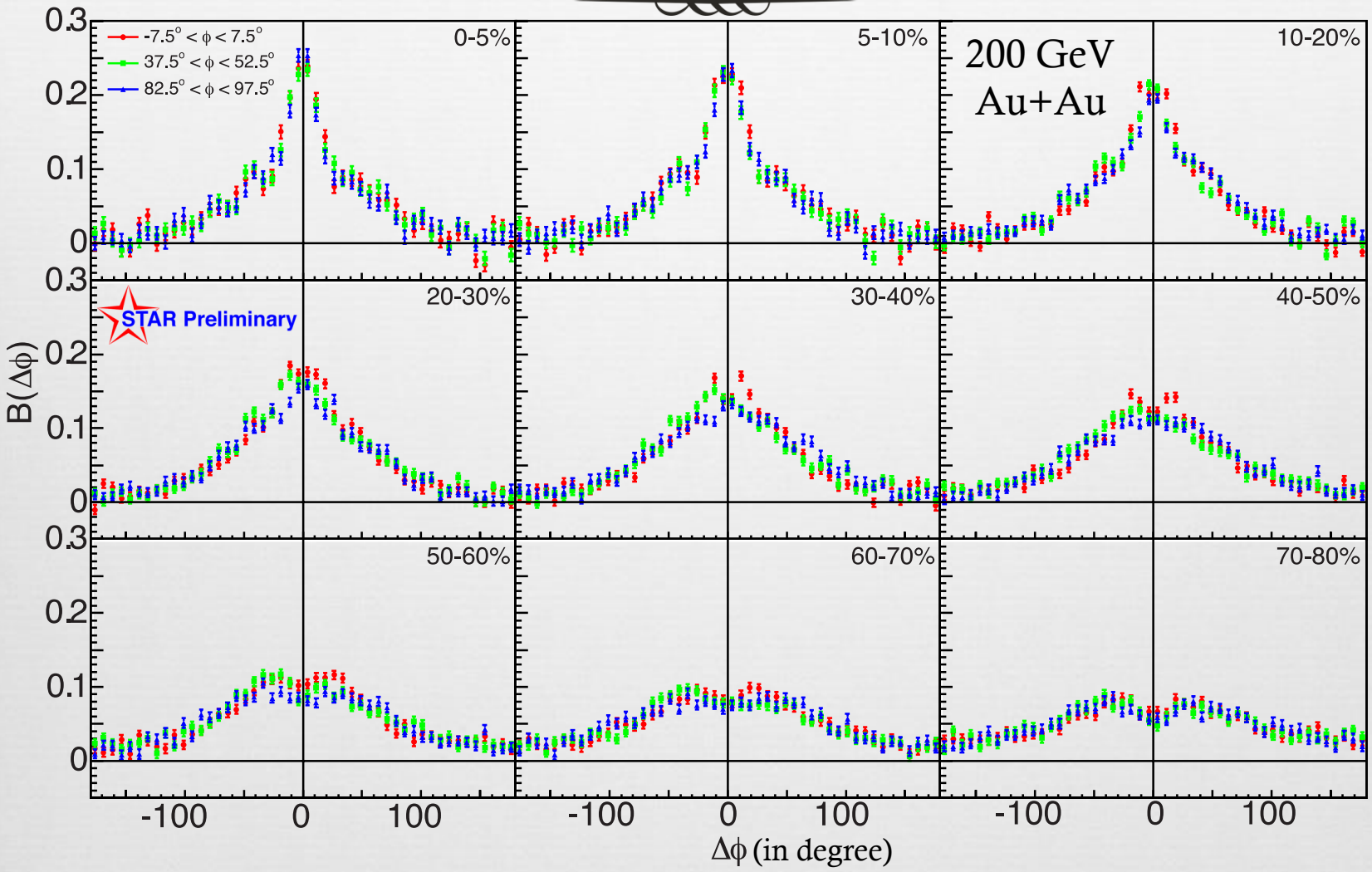
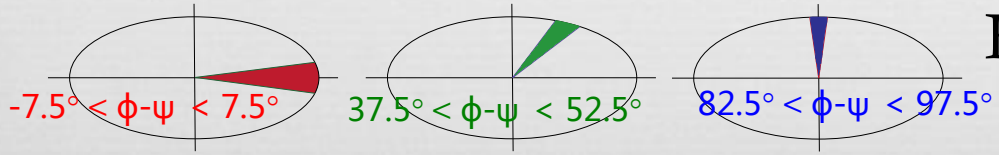
Balance Function v.s. Centrality

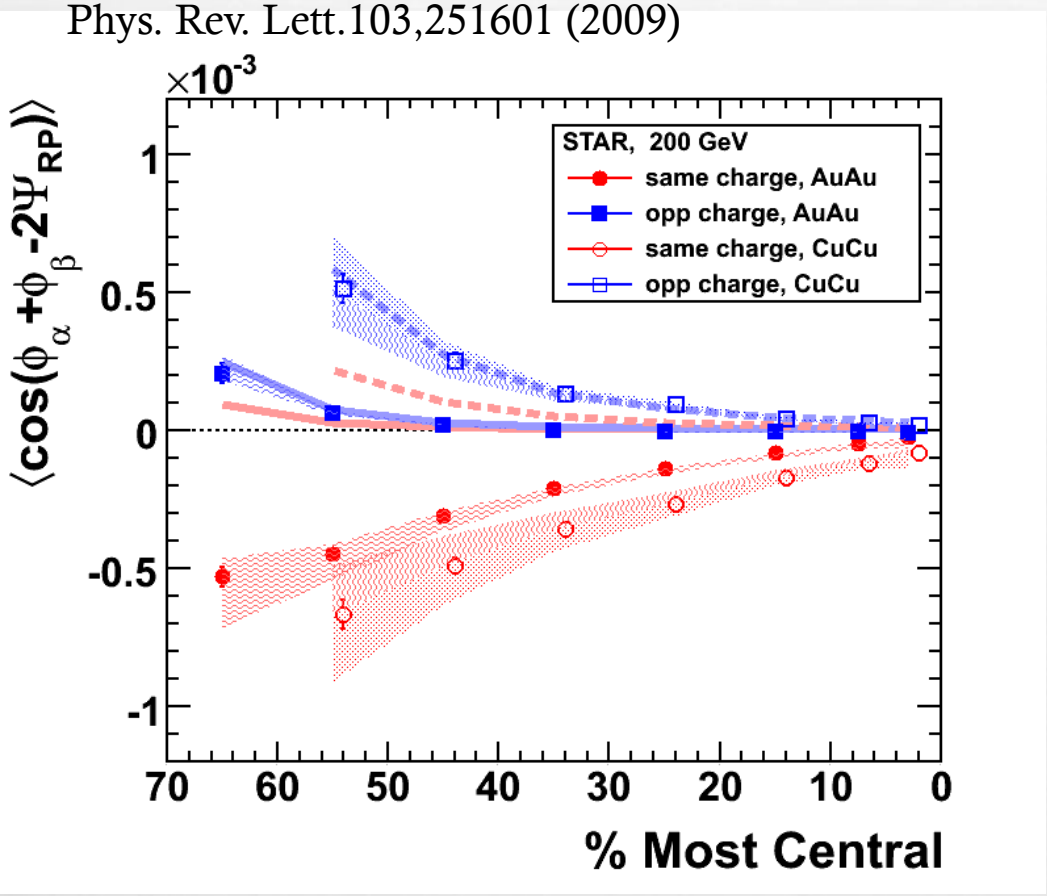




Balance function narrows in central collision due to collective flow

Three Point Correlator

Phys. Rev. Lett.103,251601 (2009)



- γ_P is the difference between unlike- and like-sign correlations
- Blast wave model reproduces observed difference between unlike- and like-sign azimuthal correlations

$$\gamma_{\alpha\beta} = < \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP}) >$$

$$\gamma_p = \frac{1}{2}(2\gamma_{+-} - \gamma_{++} - \gamma_{--}) = \frac{2}{M^2}\int d\phi d\Delta\phi \frac{dM}{d\phi} B(\phi, \Delta\phi)[\cos 2\phi \cos\Delta\phi - \sin 2\phi \sin\Delta\phi]$$

Three Point Correlator

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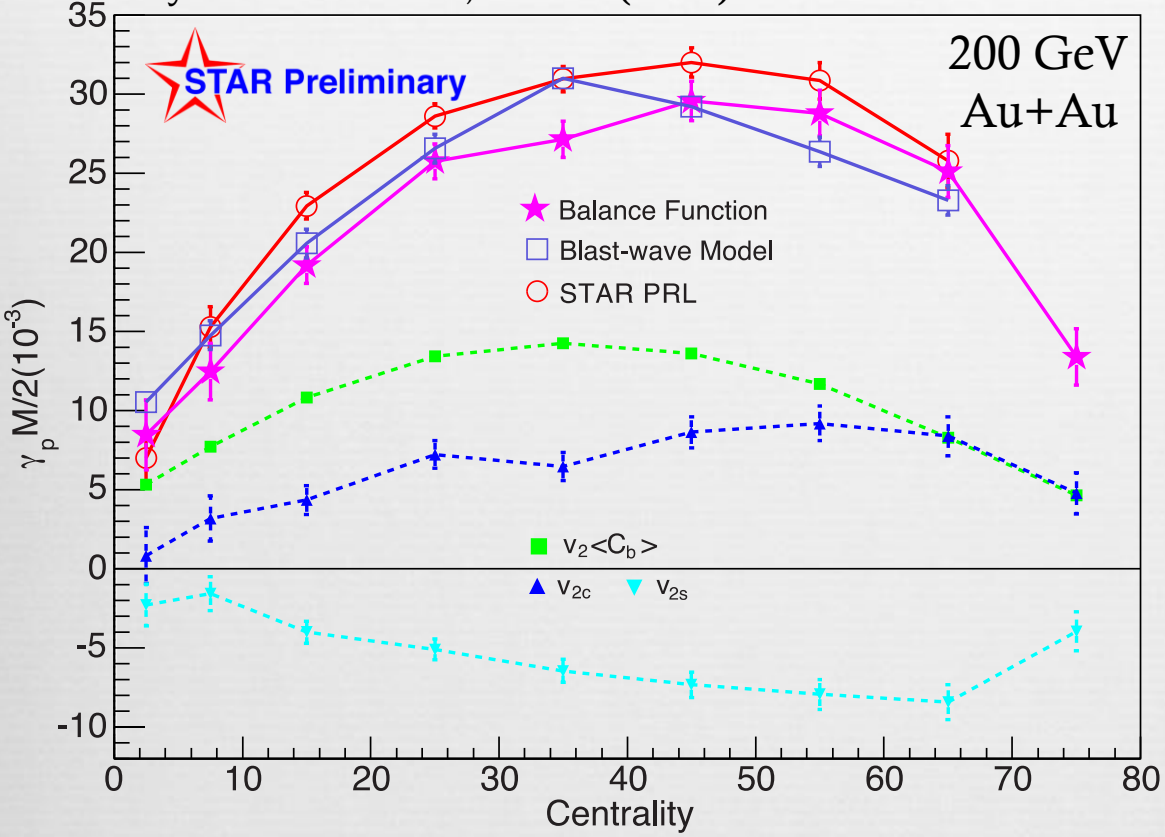

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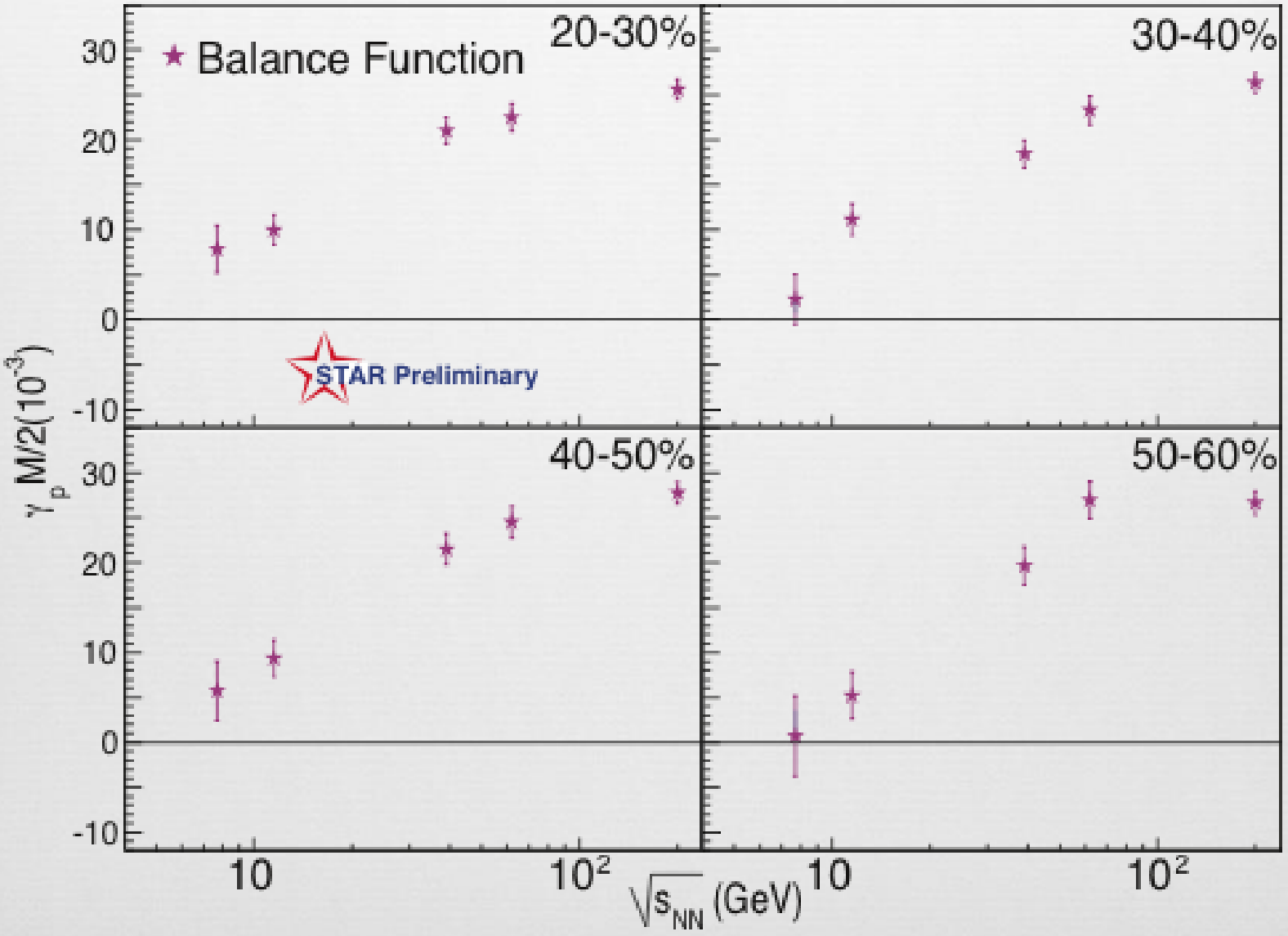
Summary

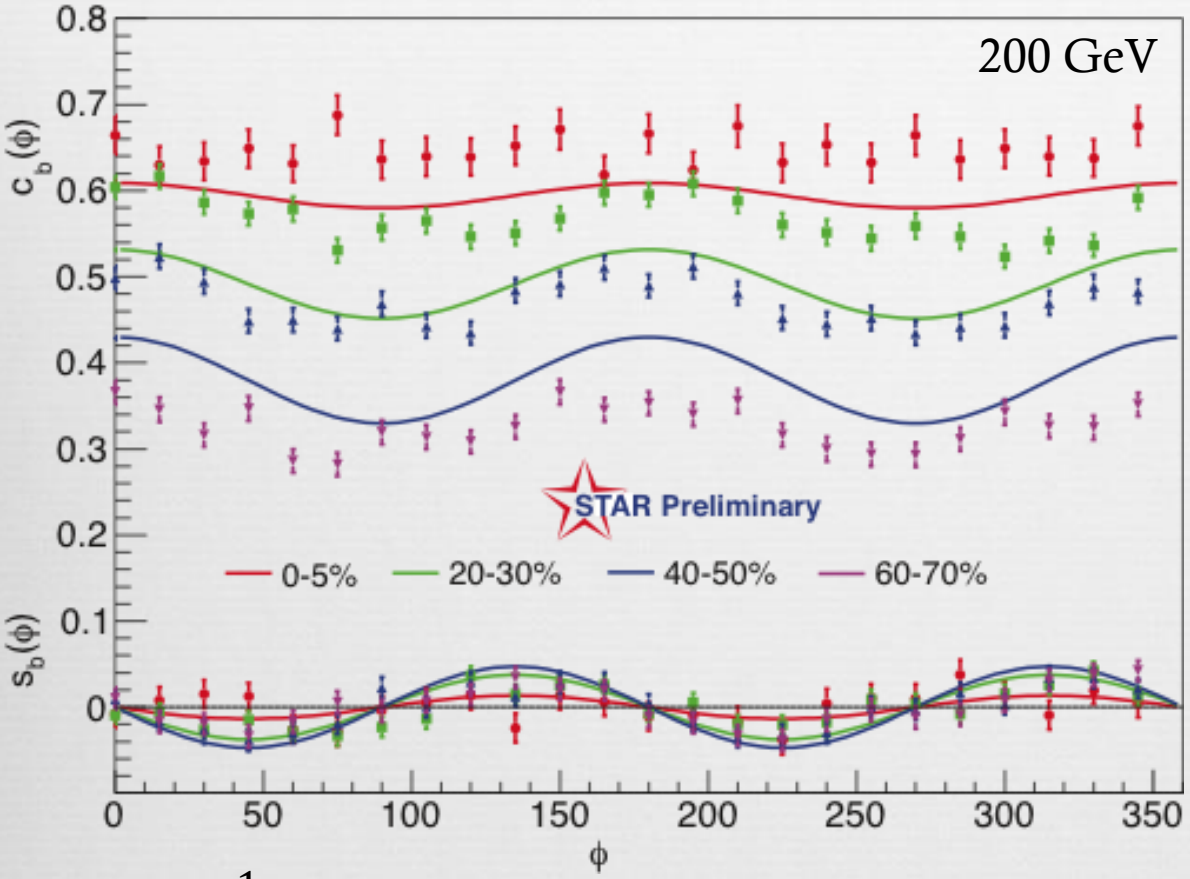
- The reaction-plane-dependent balance function analysis gives the same difference between the like-sign and unlike-sign charge dependent azimuthal correlations as the three point correlator results published by STAR
- This thermal blast wave model **reproduces most of the difference** between like- and unlike-sign charge-dependent azimuthal correlation incorporating local charge conservation and flow

Back Up

Beam Energy Dependence



Weighted Average



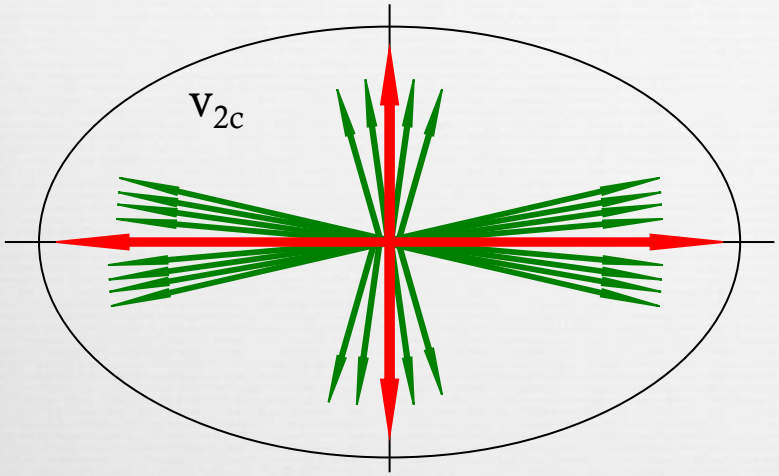
$$c_b(\phi) \equiv \frac{1}{z_b(\phi)} \int d\Delta\phi B(\phi, \Delta\phi) \cos(\Delta\phi)$$

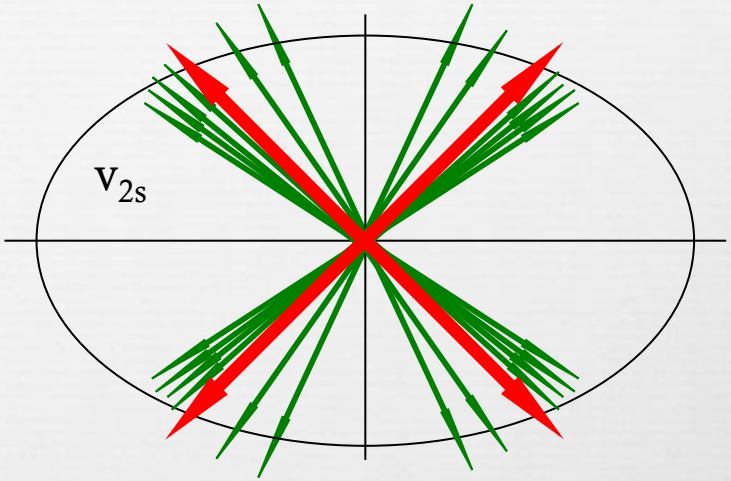
$$s_b(\phi) \equiv \frac{1}{z_b(\phi)} \int d\Delta\phi B(\phi, \Delta\phi) \sin(\Delta\phi)$$

$$z_b(\phi) \equiv \int d\Delta\phi B(\phi, \Delta\phi)$$

- Compare data (points) with blast wave model calculations (solid lines)
- Data are not corrected for event plane resolution (differences between data and model)
- c_b is related to the balance function width, while s_b quantifies the asymmetry of balance function
- Data show a stronger collective behavior in plane, while the asymmetry is most significant 45° to the reaction plane

Calculate v_{2c} and v_{2s}





- Red arrows are the first particle in balance function calculation, while green ones are its opposite sign charge pairs
- $v_2<c_b>$ is positive if more charged pairs are found in plane
- v_{2c} is positive if charges are more correlated in plane
- v_{2s} is negative if charges are more correlated on the in plane side

$$v_{2c} \equiv < c_b(\phi)\cos(2\phi) > - v_2 < c_b(\phi) >$$

$$v_{2s} \equiv < s_b(\phi)\sin(2\phi) >$$

$$< f(\phi) > \equiv \frac{1}{M}\int d\phi \frac{dM}{d\phi} z_b(\phi) f(\phi)$$

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