



# Local Parity Violation or Local Charge Conservation/Flow?

## A Reaction-Plane-Dependent Balance Function Study

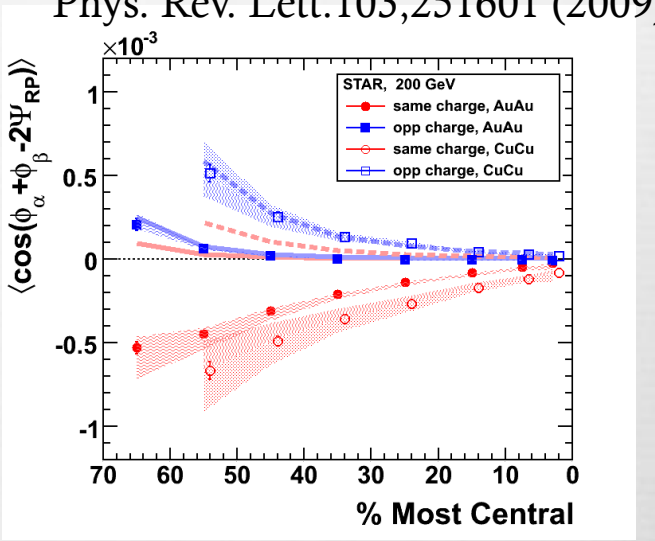
MICHIGAN STATE UNIVERSITY

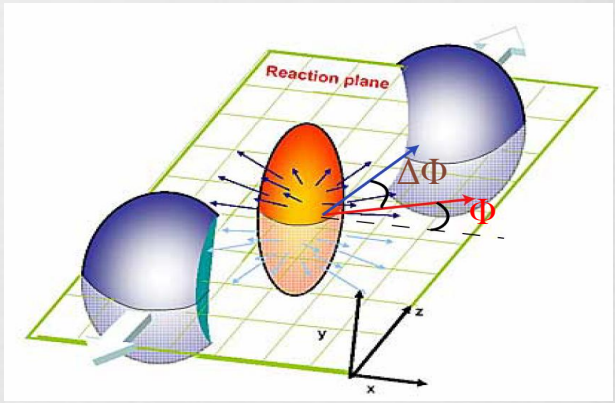
Hui Wang
for the STAR Collaboration

# 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
- STAR has proposed a **three point correlator** to measure the possible Chiral Magnet Effect

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

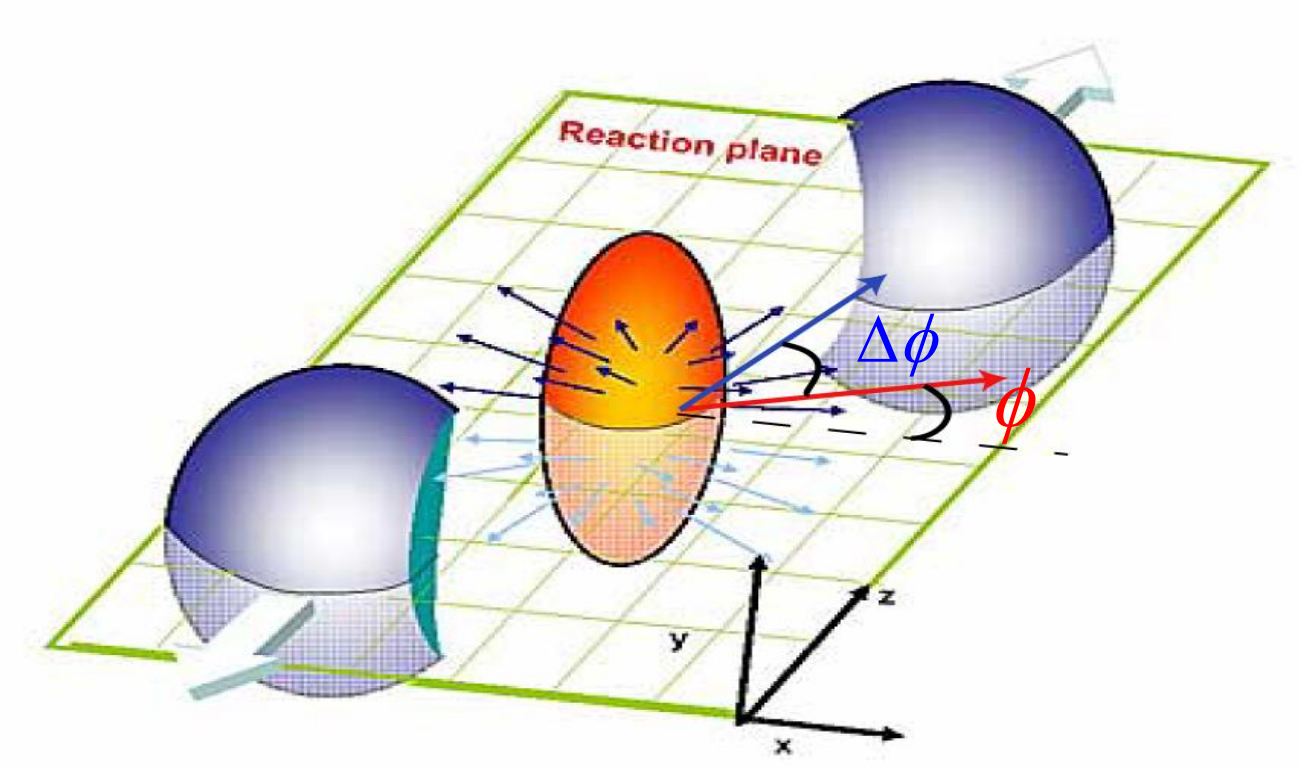


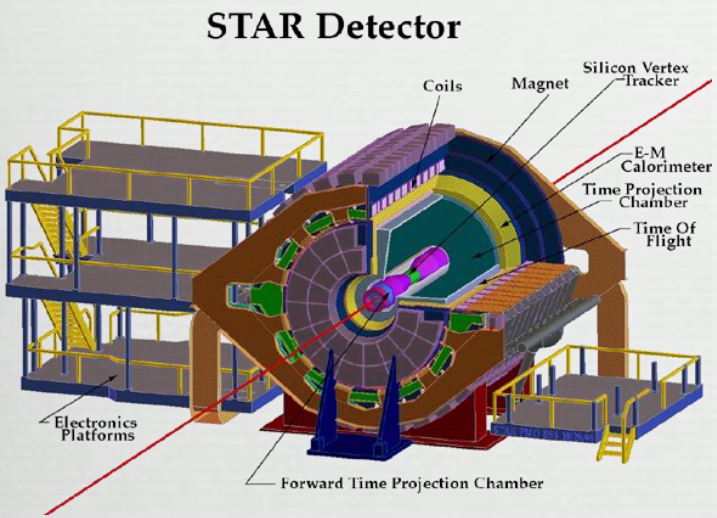

$$\gamma_{\alpha\beta} = \left\langle \cos\left(\phi_\alpha + \phi_\beta - 2\Psi_{EP}\right) \right\rangle$$

# 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

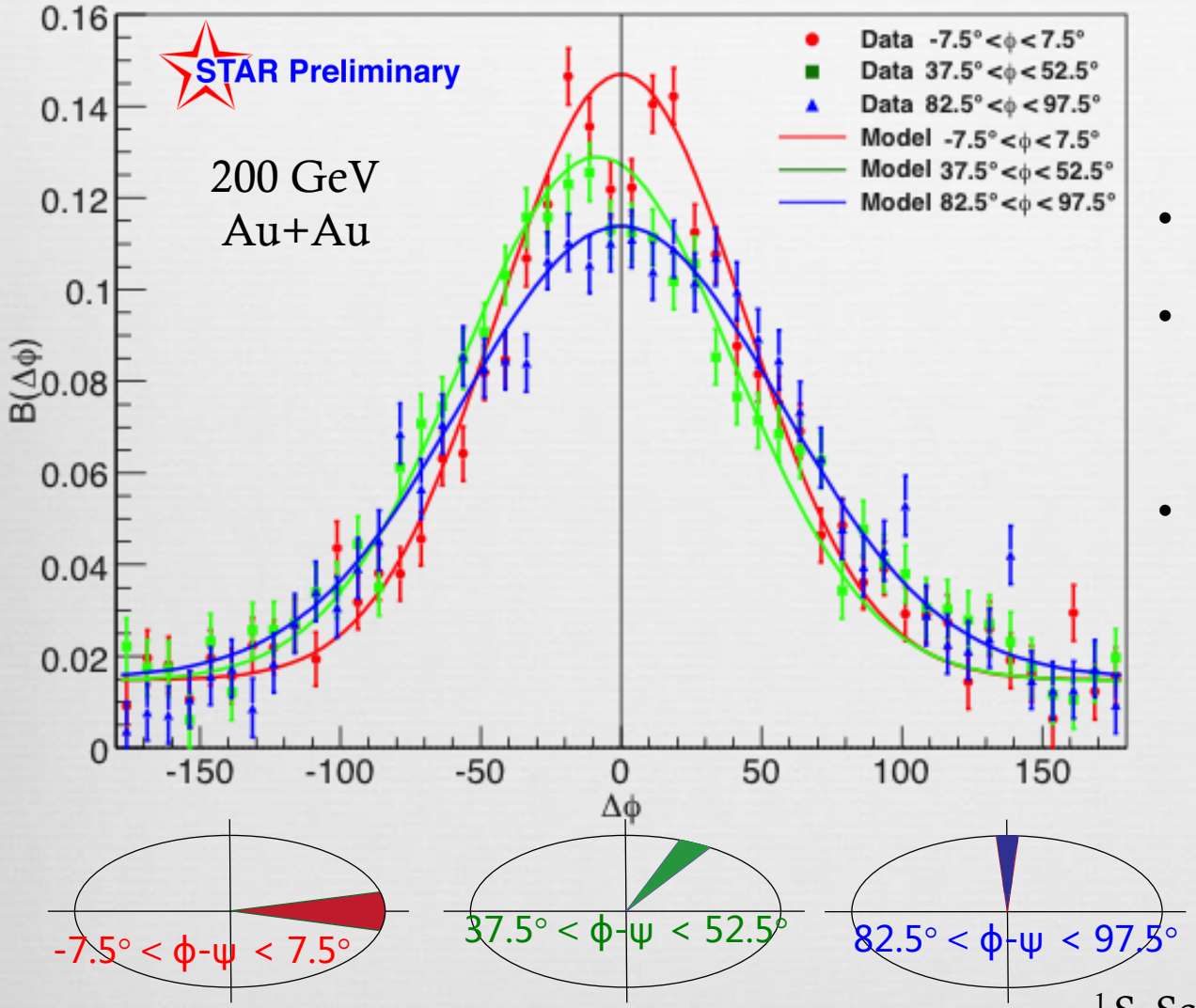



| Energy (GeV) | Species | Year | Events (M)* |
|---|---|---|---|
| 200 | Au + Au | Run 4 | 14 |
| 62.4 | Au + Au | Run 4 | 8 |
| 39 | Au + Au | Run 10 | 10 |
| 11.5 | Au + Au | Run 10 | 16 |
| 7.7 | Au + Au | Run 10 | 4 |

- 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]

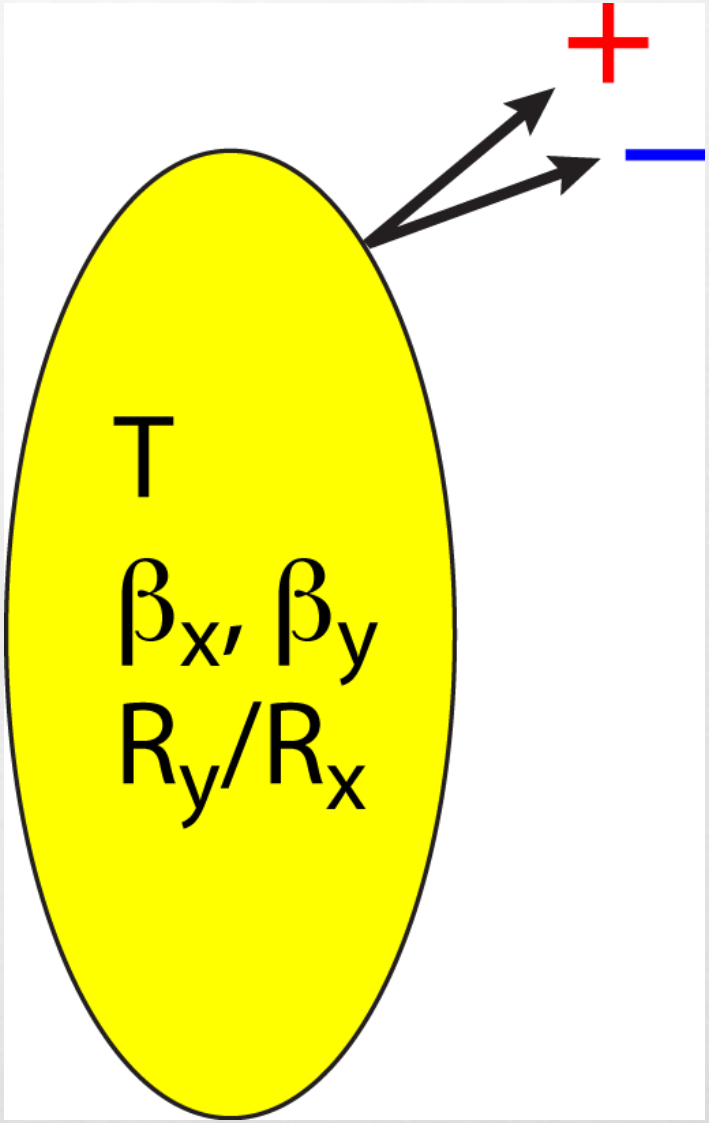
[1] S. Schlichting and S. Pratt
Phys. Rev. C 83, 014913 (2011)

# Blast Wave Model

- STAR parameterization

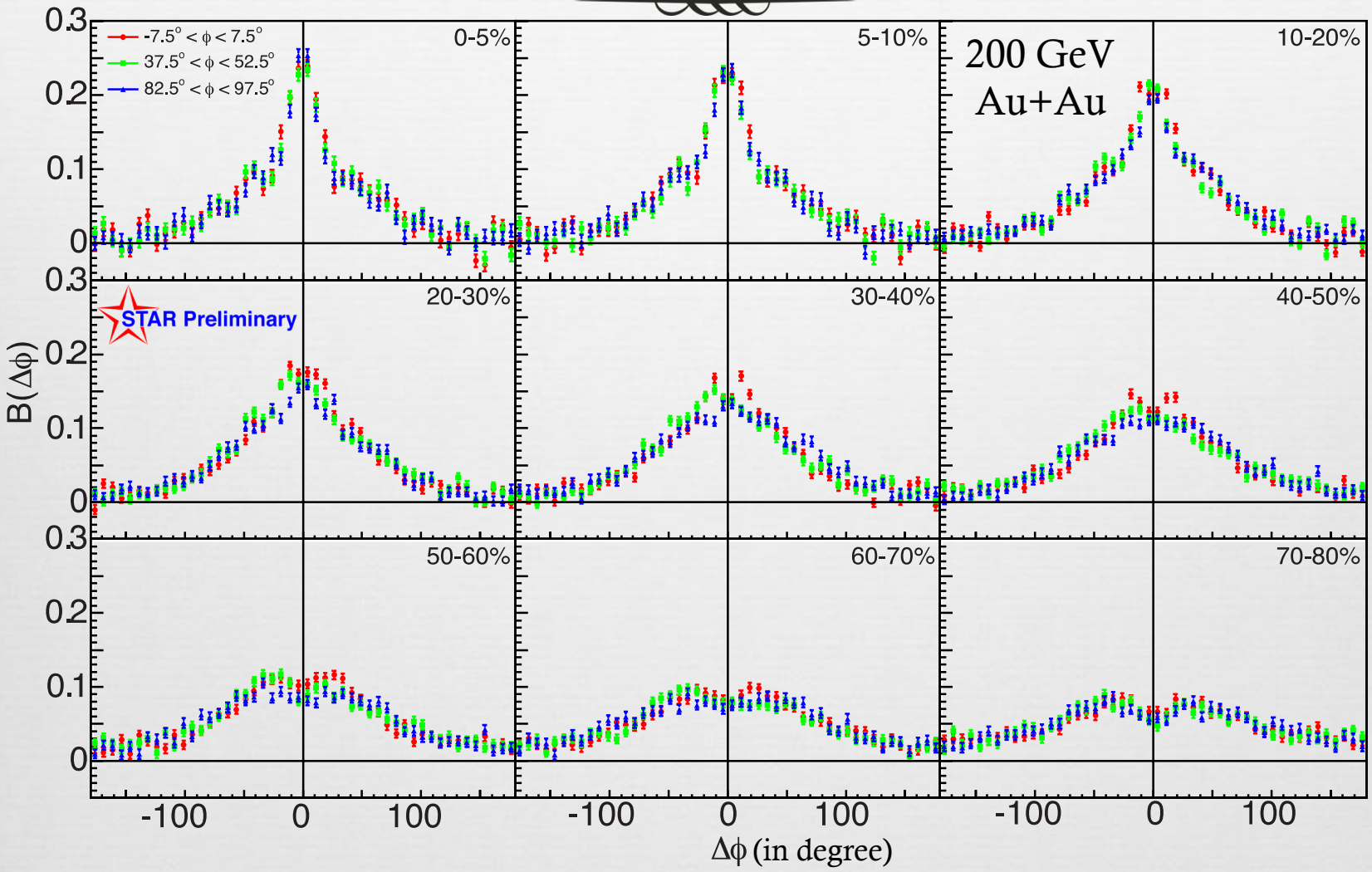
  (STAR,PRC,72,14904(2005))

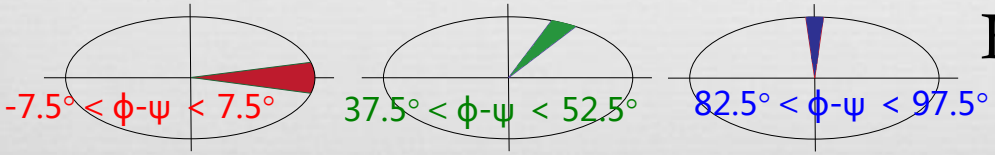
- Local charge conservation




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

# Balance Function v.s. Centrality

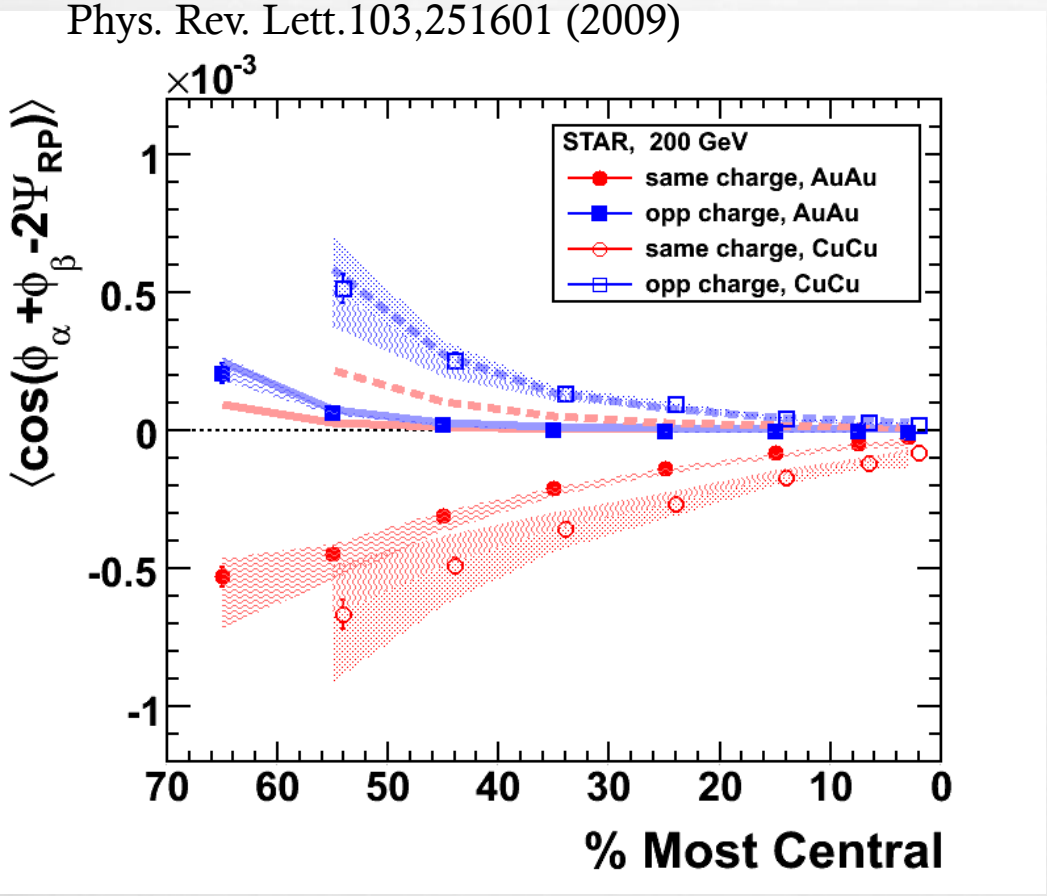



Balance function narrows in central collision due to collective flow

# Three Point Correlator

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



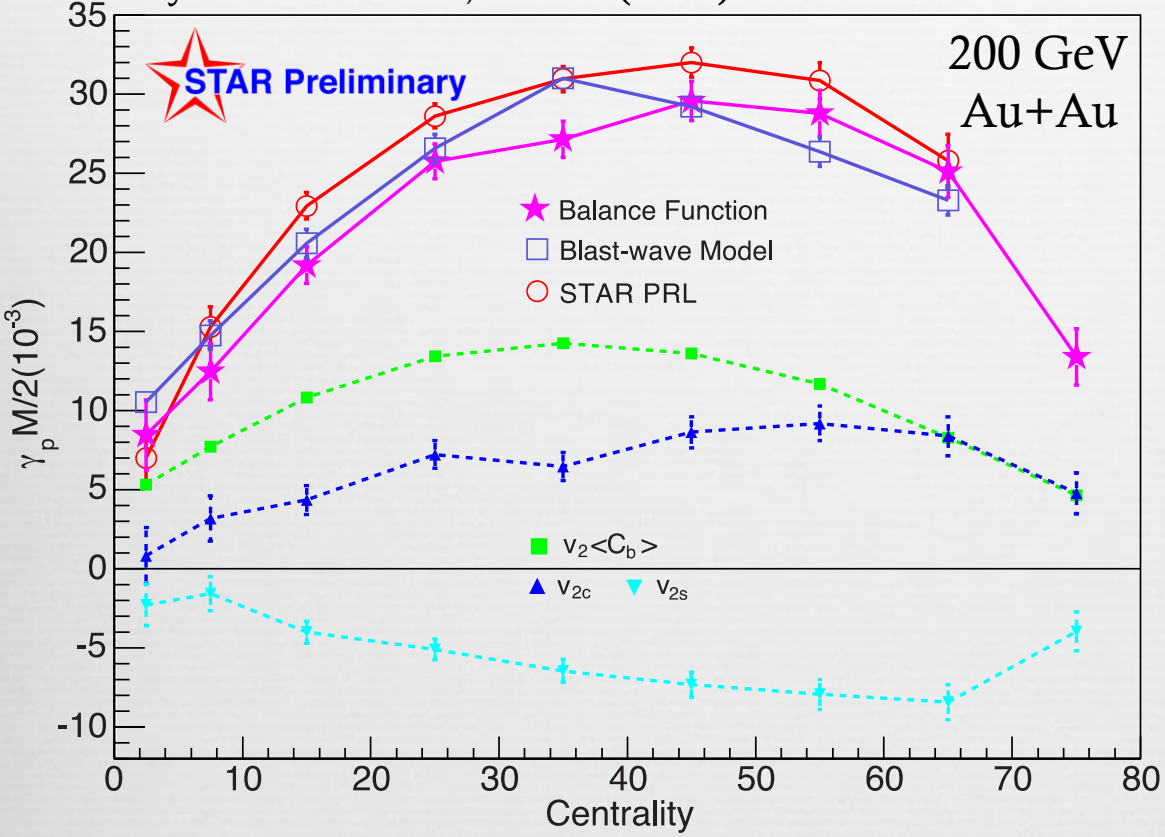

- $\gamma_P$ is the difference between unlike- and like-sign correlations
- Blast wave model reproduces observed difference between unlike- and like-sign azimuthal correlations

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

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

# Three Point Correlator

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




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

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

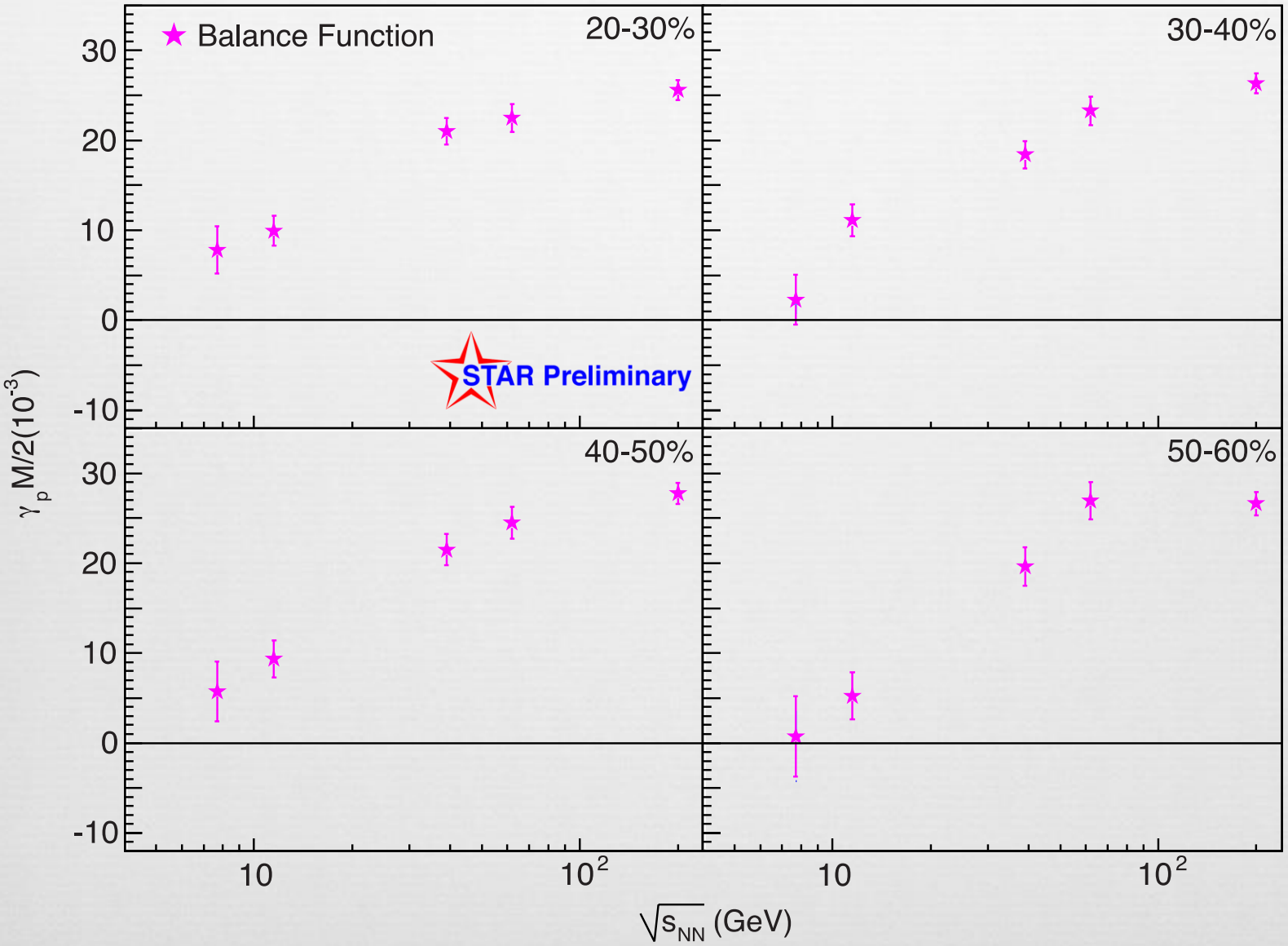
$$\gamma_p = \frac{1}{2}(2\gamma_{+-} - \gamma_{++} - \gamma_{--}) = \frac{2}{M^2}\int d\phi d\Delta\phi \frac{dM}{d\phi} B(\phi, \Delta\phi)[\cos 2\phi \cos\Delta\phi - \sin 2\phi \sin\Delta\phi]$$

# Summary

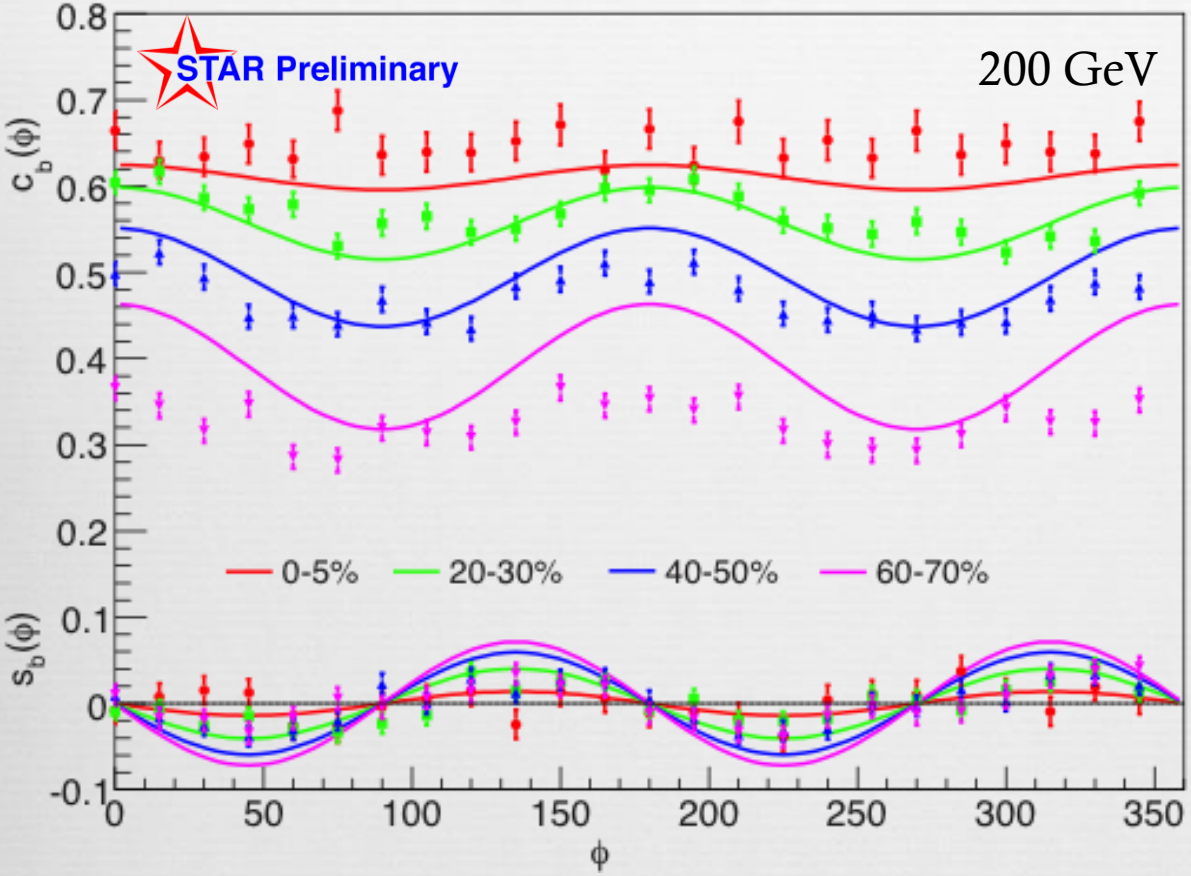
- The reaction-plane-dependent balance function analysis gives the same difference between the like-sign and unlike-sign charge dependent azimuthal correlations as the three point correlator results published by STAR
- This thermal blast wave model **reproduces most of the difference** between like-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

# Back Up

# Beam Energy Dependence



# Weighted Average



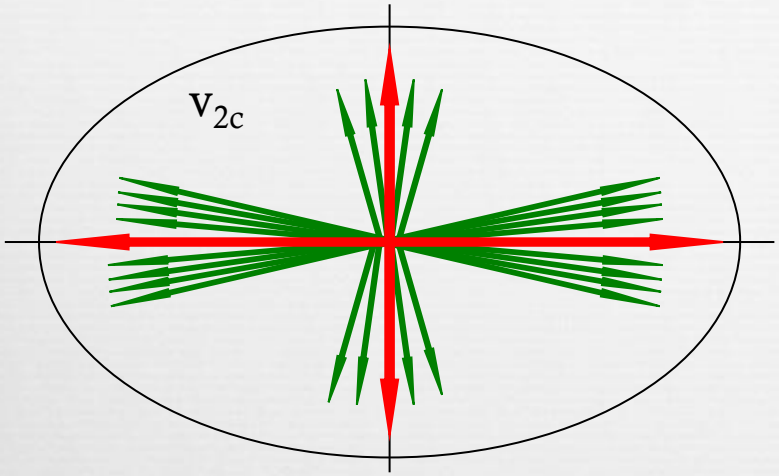

$$c_b(\phi) \equiv \frac{1}{z_b(\phi)} \int d\Delta\phi B(\phi, \Delta\phi) \cos(\Delta\phi)$$

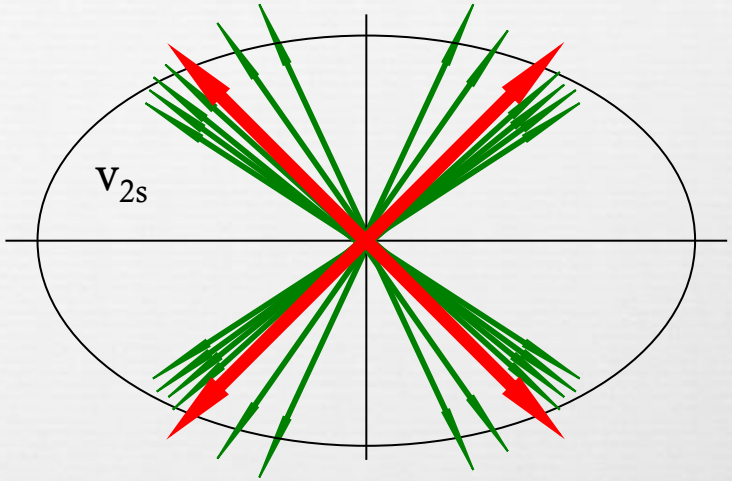
$$s_b(\phi) \equiv \frac{1}{z_b(\phi)} \int d\Delta\phi B(\phi, \Delta\phi) \sin(\Delta\phi)$$

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

- 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

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

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

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

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