

# Flow measurement of small collisions systems measured by **PHENIX** experiment at RHIC

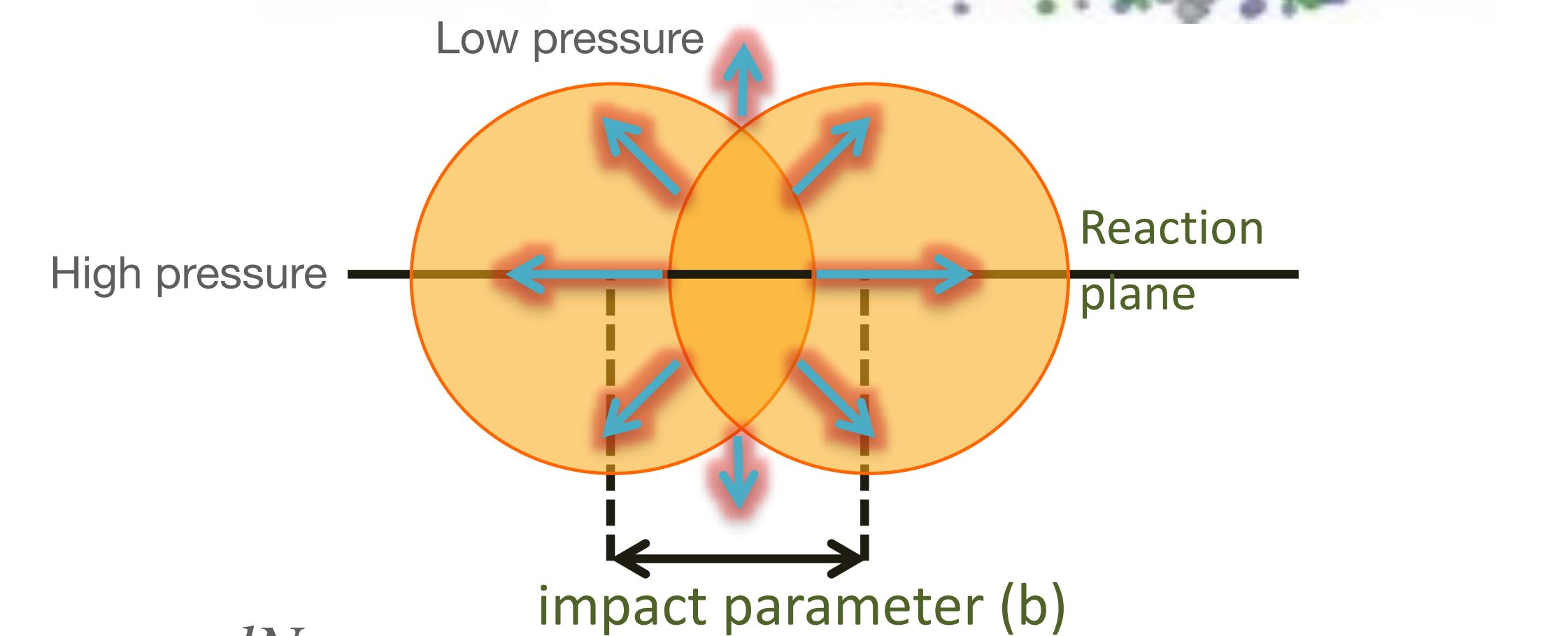
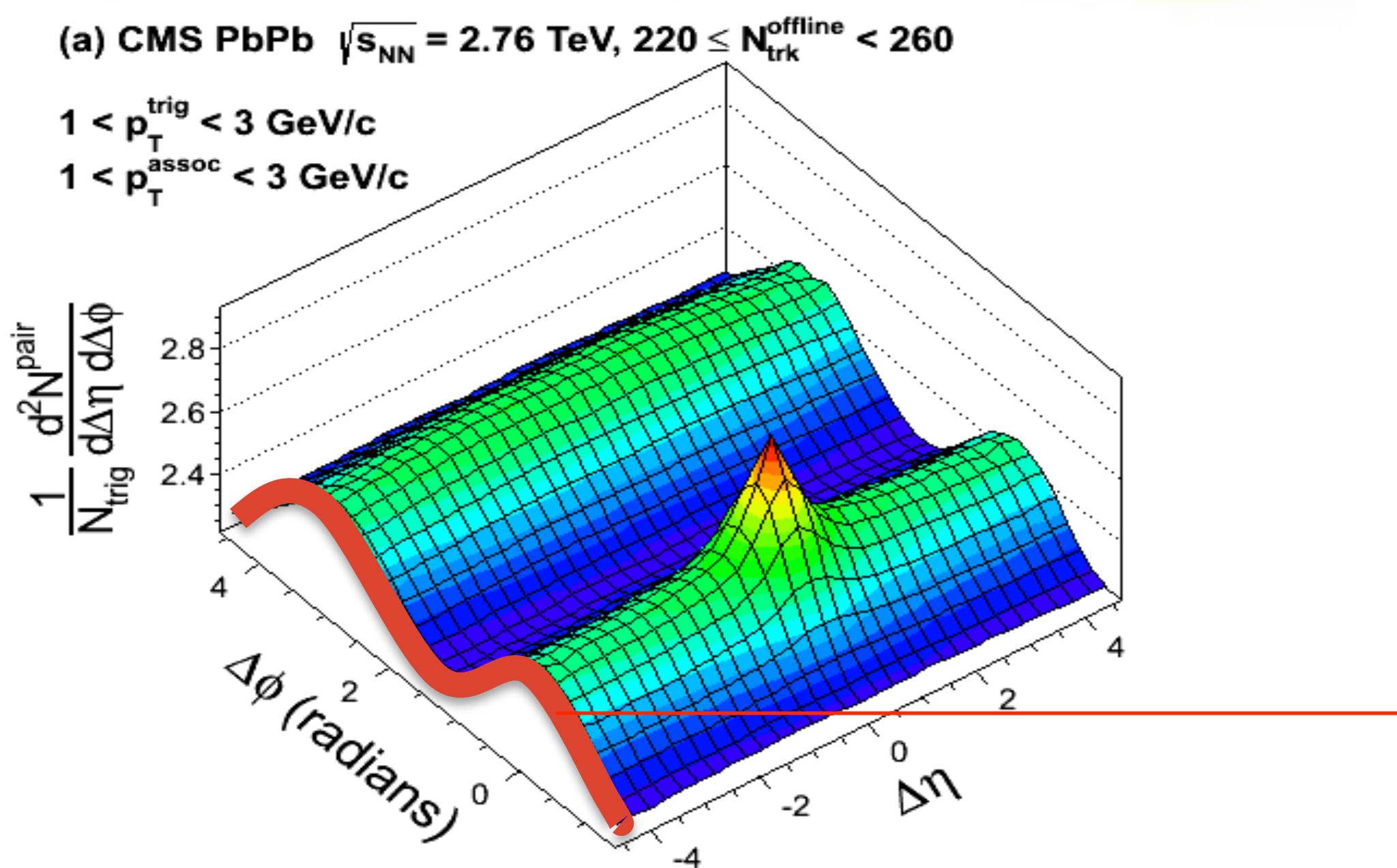
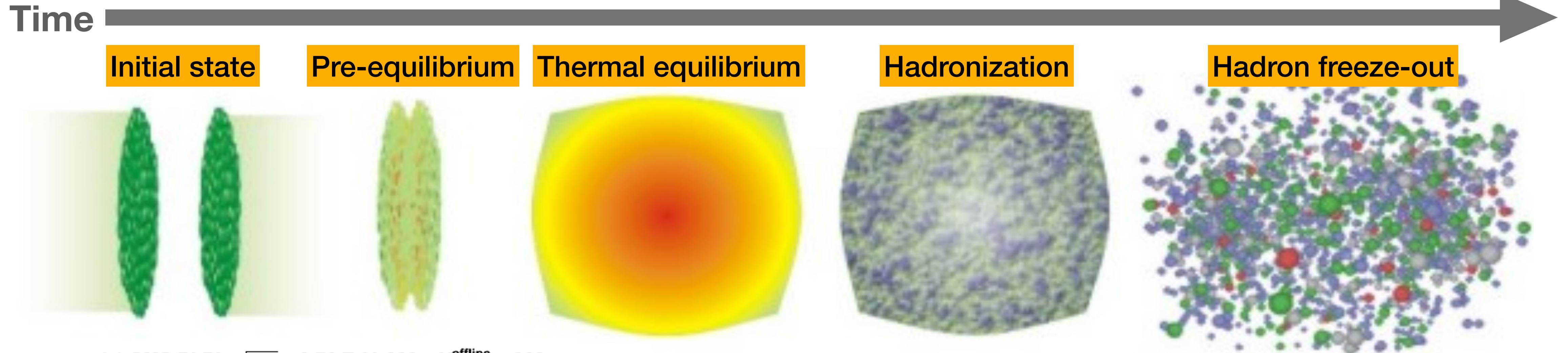
Seyoung Han for the PHENIX collaboration

CENuM, Korea University, Seoul

23rd Aug. 2021



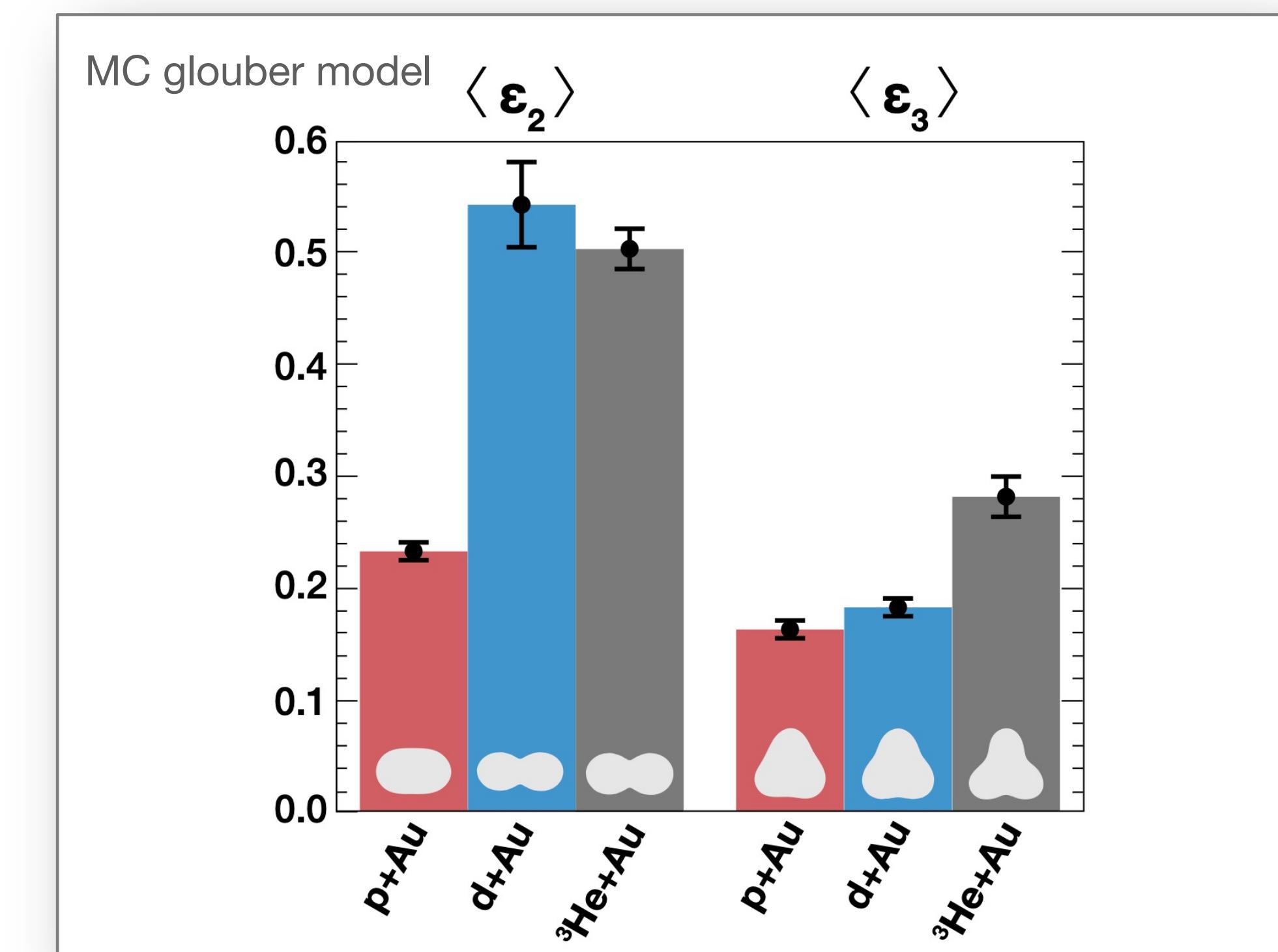
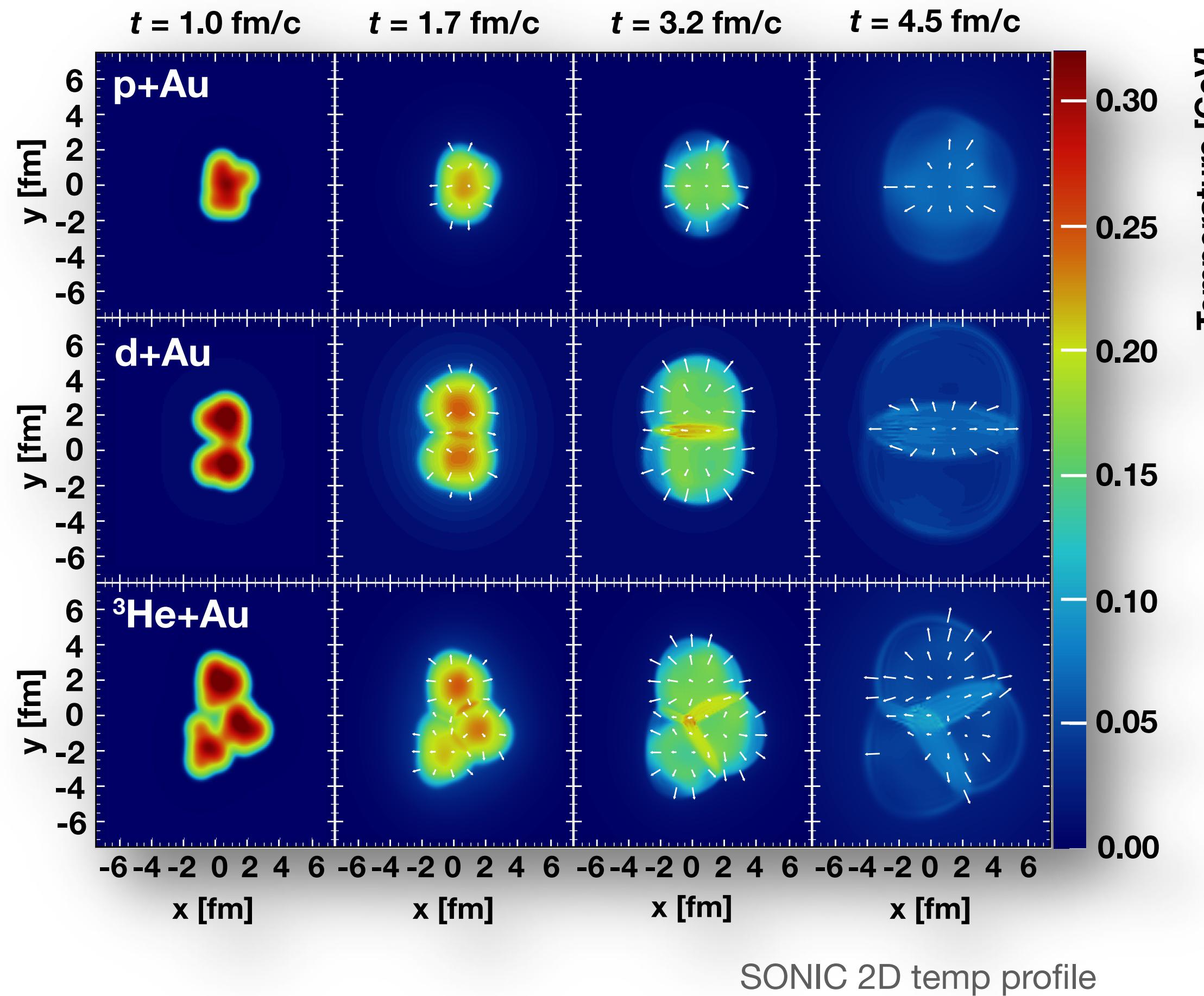
# Collective behavior in heavy ion collision



$$\frac{1}{N_{\text{trig}}} \frac{dN_{\text{pair}}}{d\Delta\phi} \propto 1 + 2(v_2^2)\cos(2\Delta\phi) + 2(v_3^2)\cos(3\Delta\phi)$$

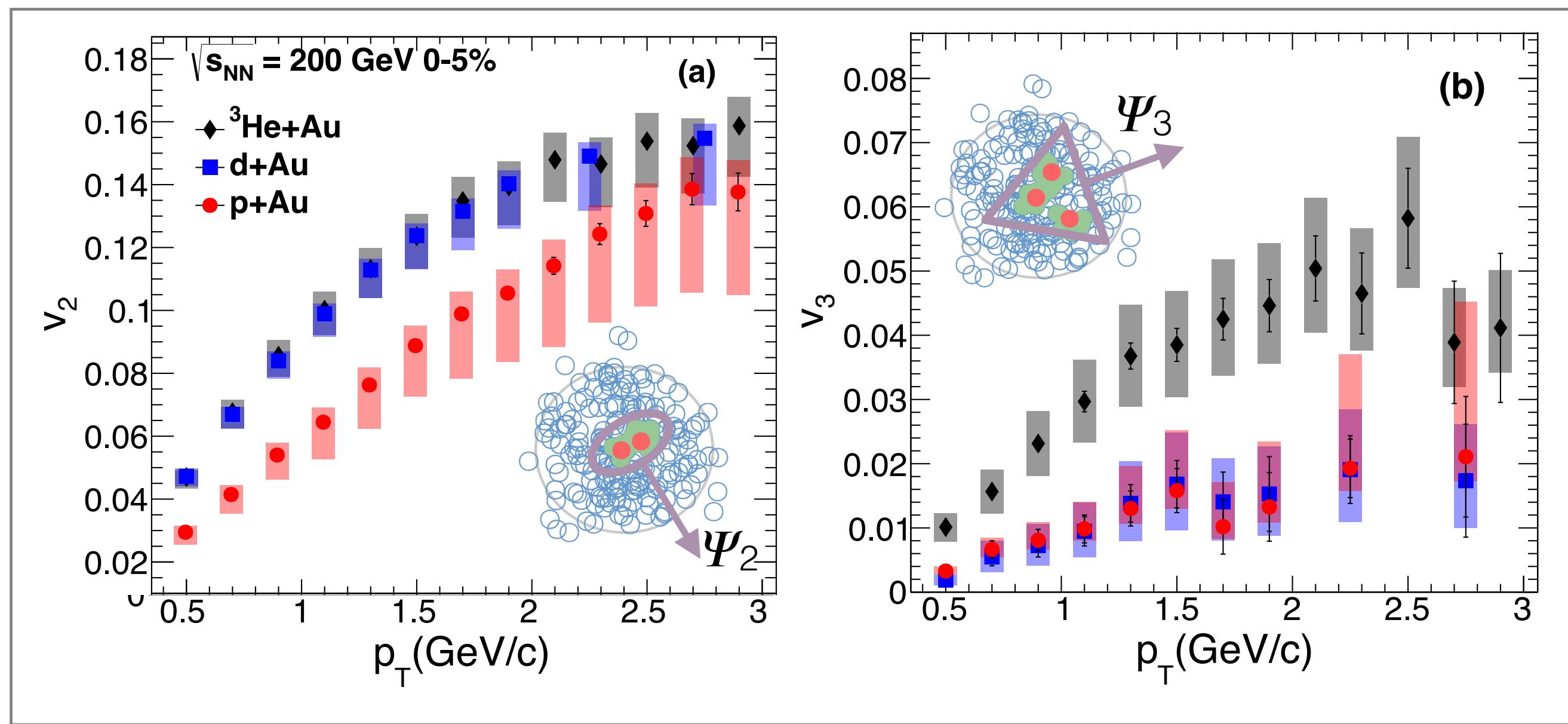
# Initial geometry effects at small collisions

## PHENIX collaboration, Nature Physics 15, 214–220 (2019)

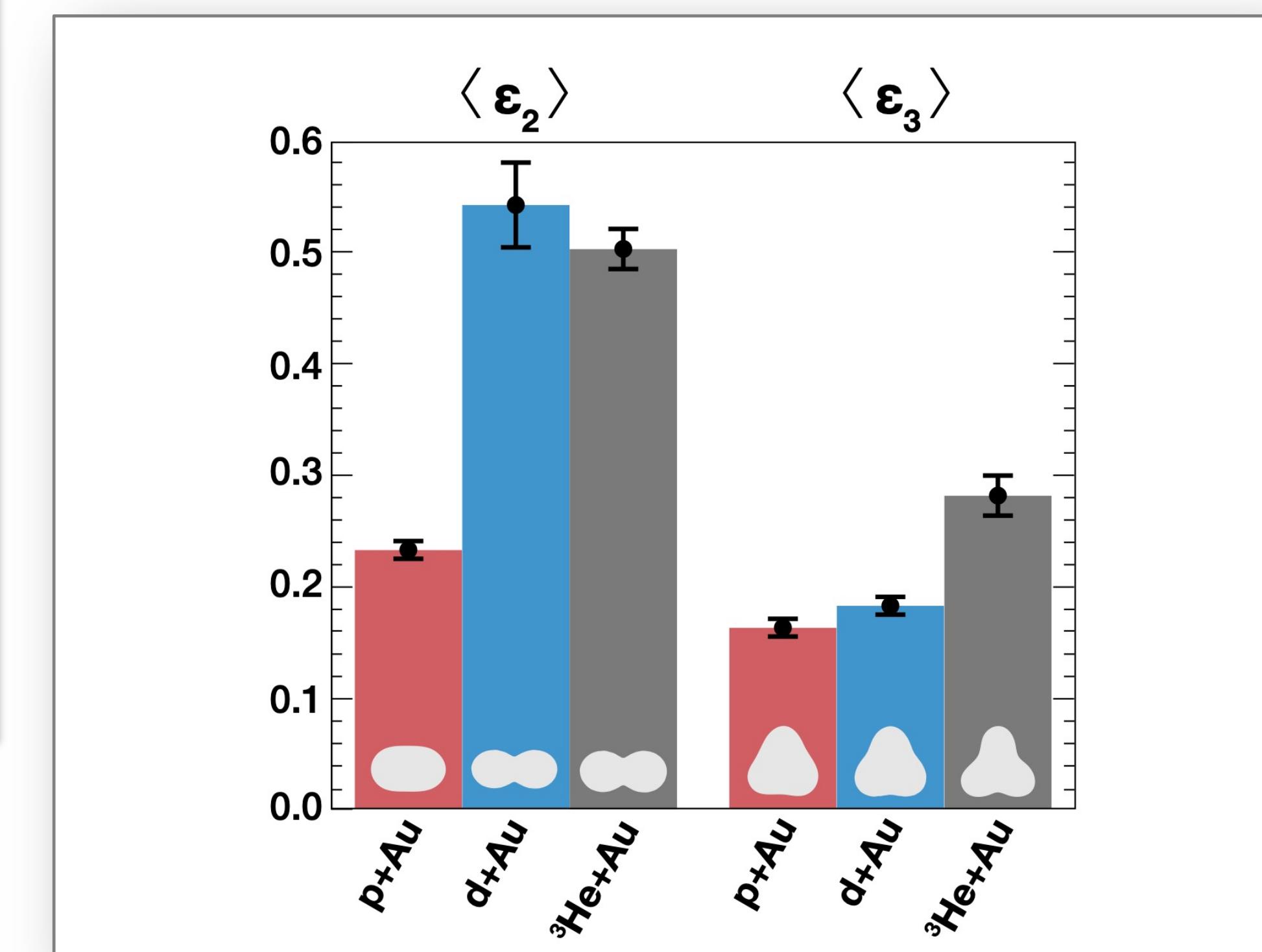


# Initial geometry effects at small collisions

## PHENIX collaboration, Nature Physics 15, 214–220 (2019)



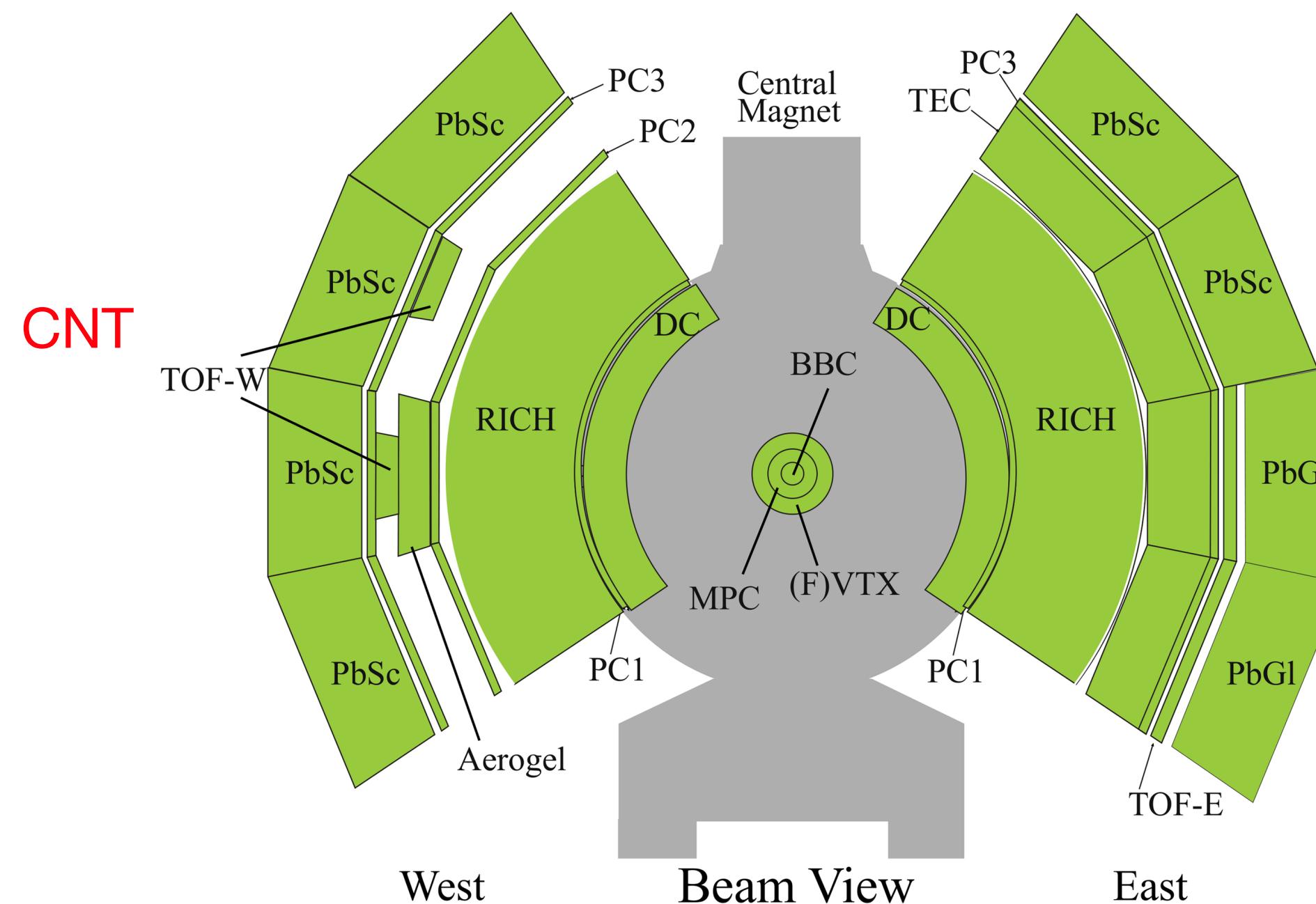
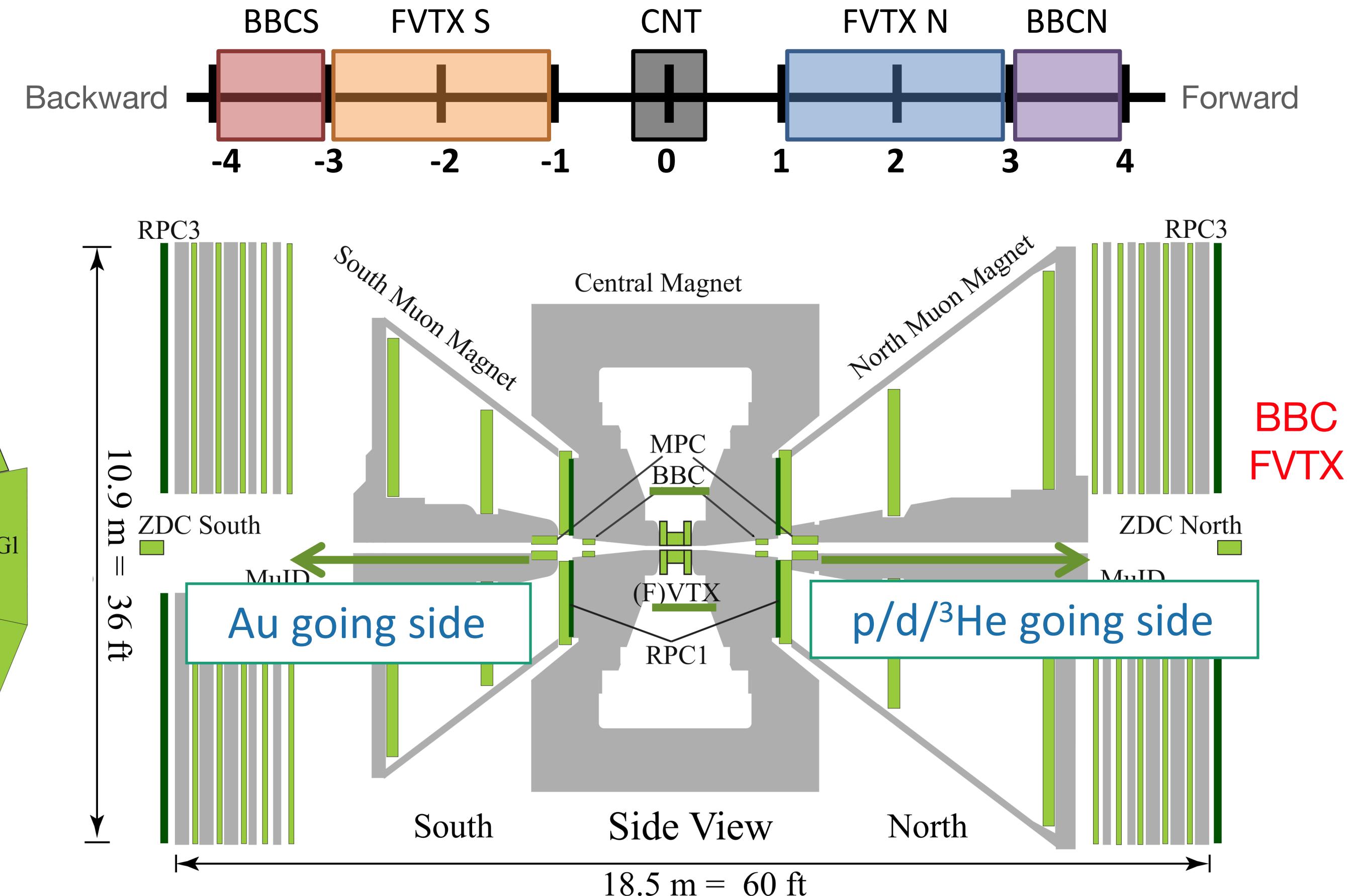
Initial geometry effect propagates to the final stages  
Hydrodynamic calculation has a good estimation in measured data



Consistent hierarchy shown in eccentricity and measured flow

# The PHENIX experiment at RHIC

## Overview of detectors



- Charged particle measurement
- Particle identification

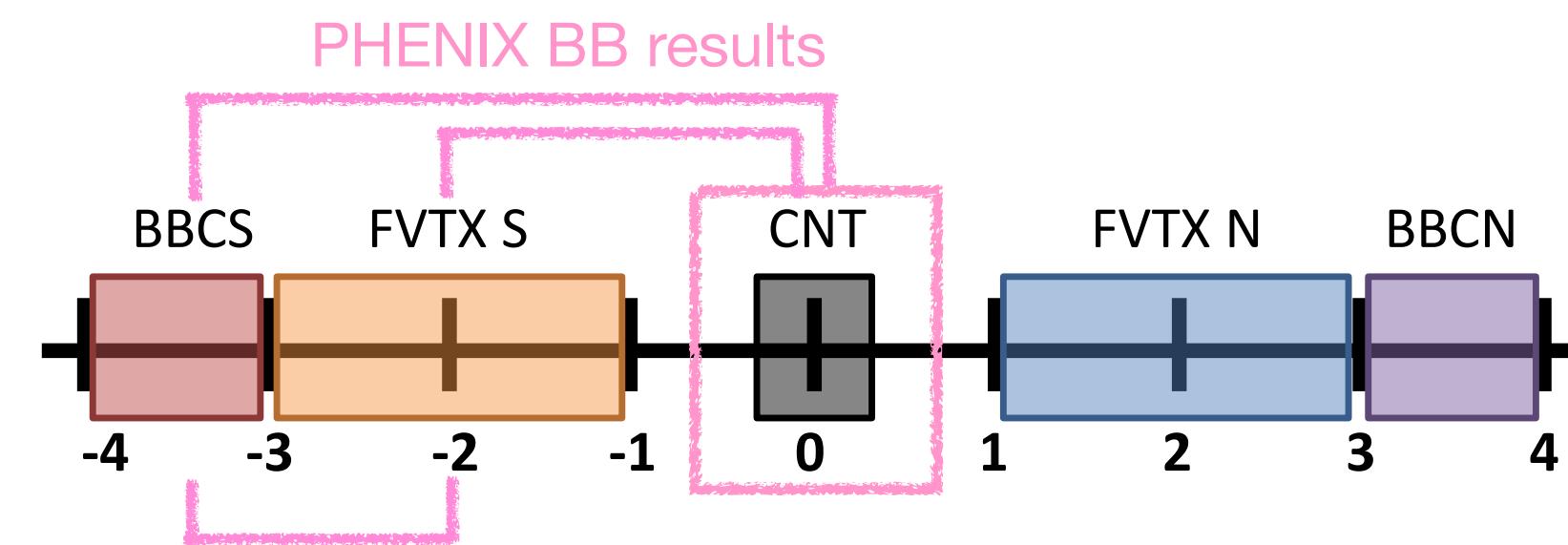
- Charged particle measurement
- Triggering
- Event-plane determination

# Flow factorization

$$c_2^{AB} = v_2^A v_2^B$$

Medium particles are correlated  
but are uncorrelated with the nonflow particles such as jet.

Larger multiplicity events;  
Larger fraction of the particles are expected to be from the medium  
influences of jet particles are reduced



$$v_2^{CNT} = \sqrt{\frac{c_2^{CNT-BBCs} c_2^{CNT-FVTXs}}{c_2^{BBCs-FVTXs}}}$$

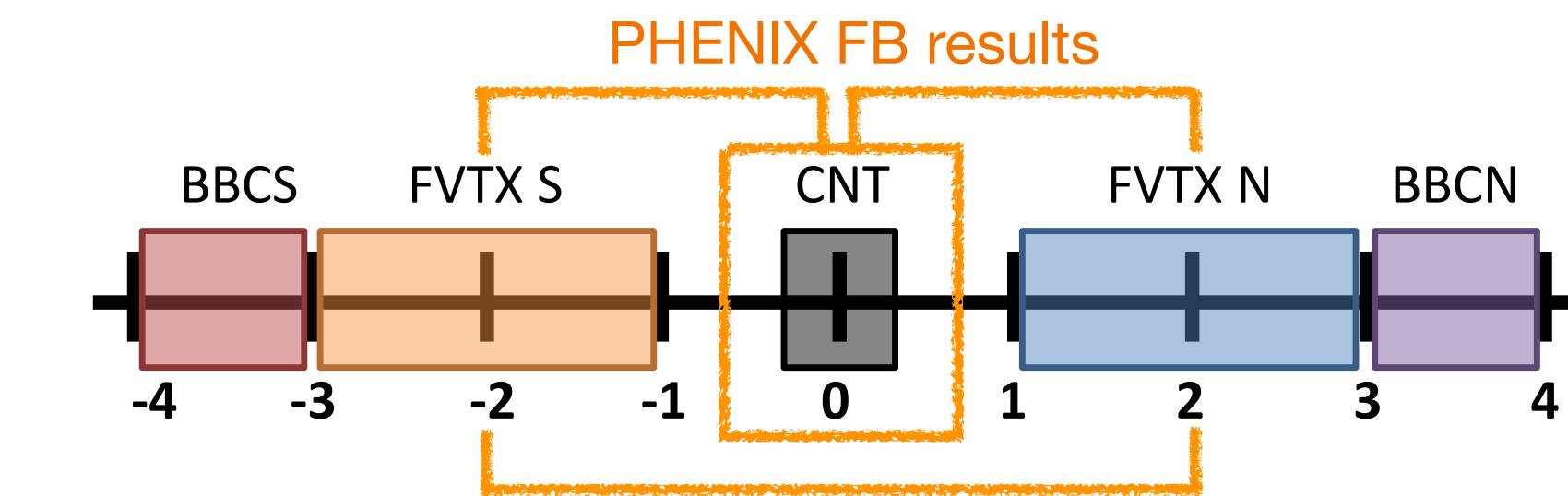
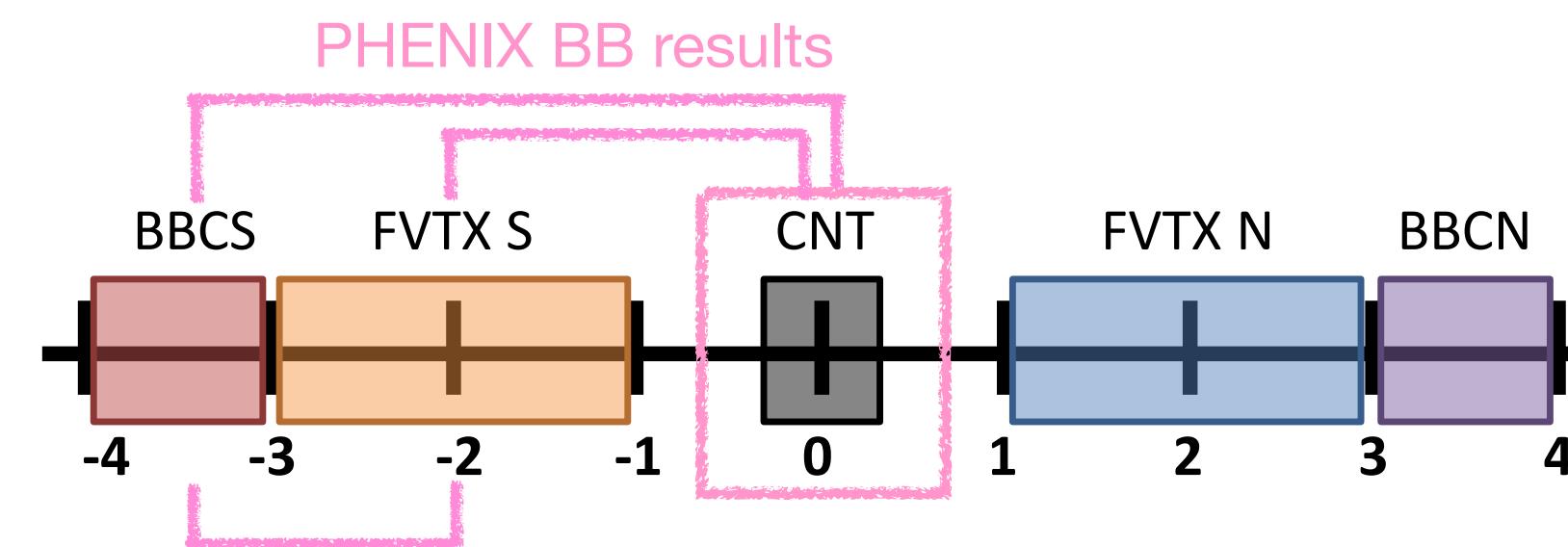
N.B. Kinematics for PHENIX Nature Physics published results

# Flow factorization

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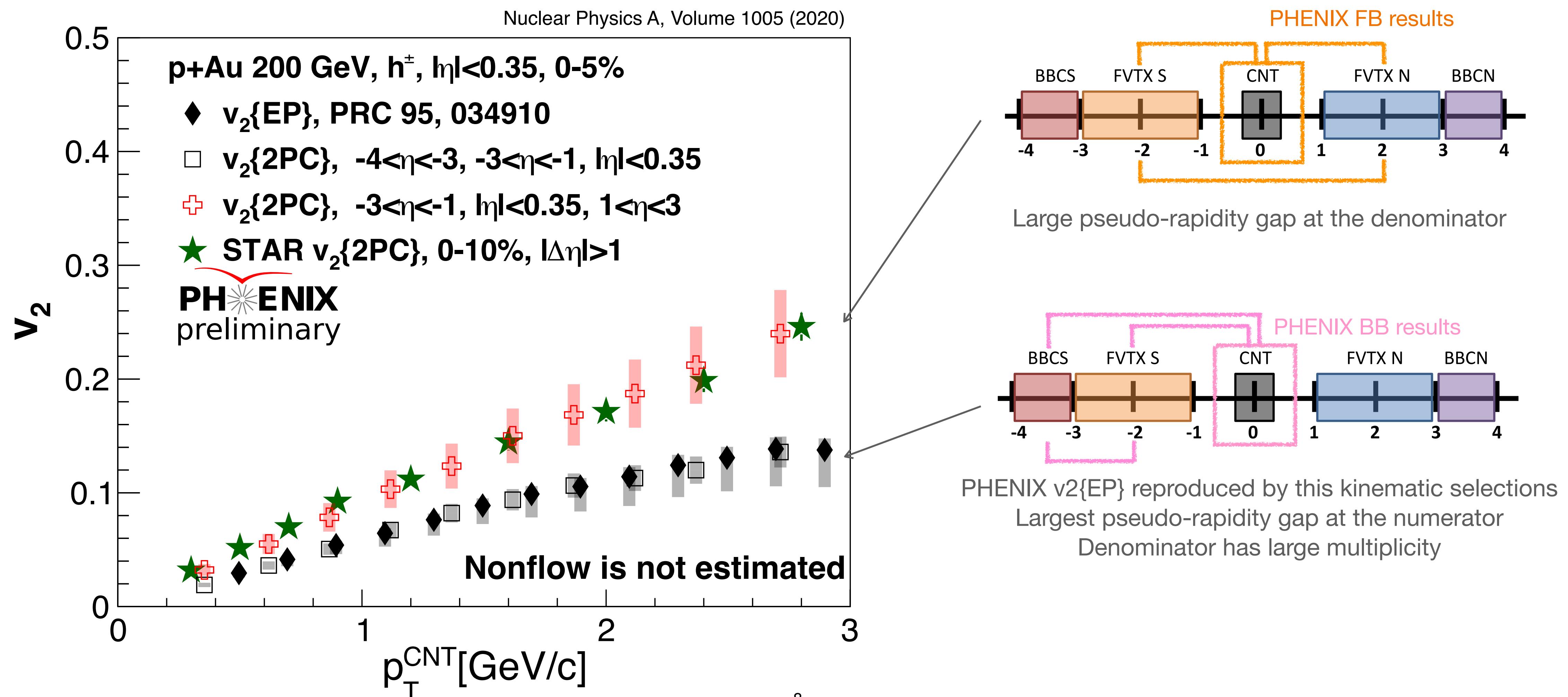
$$v_2^{CNT} = \sqrt{\frac{c_2^{CNT-BBCs} c_2^{CNT-FVTXs}}{c_2^{BBCs-FVTXs}}}$$

$$= \sqrt{\frac{c_2^{CNT-FVTXs} c_2^{CNT-FVTXn}}{c_2^{FVTXn-FVTXs}}}$$

When flow factorization works

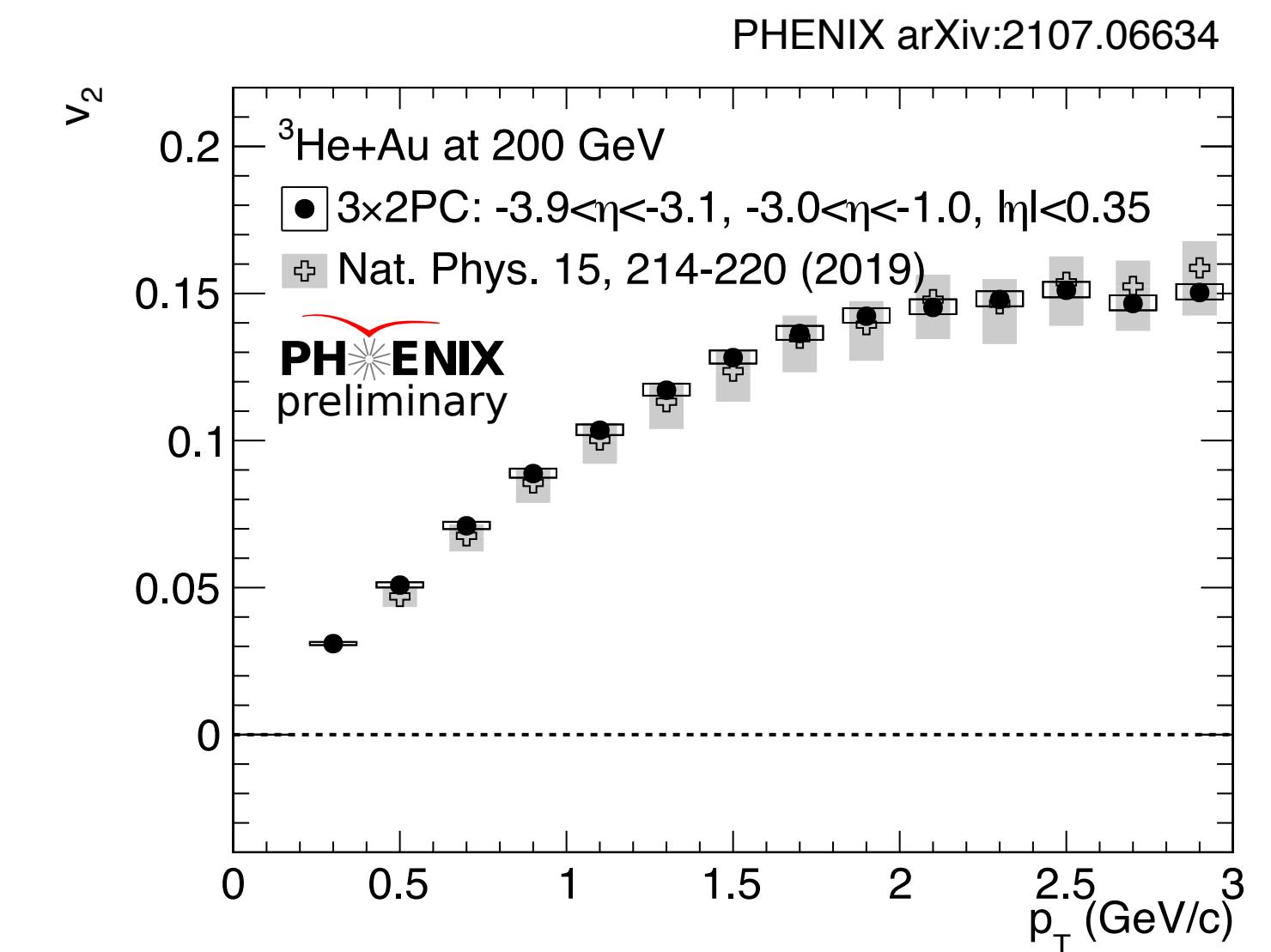
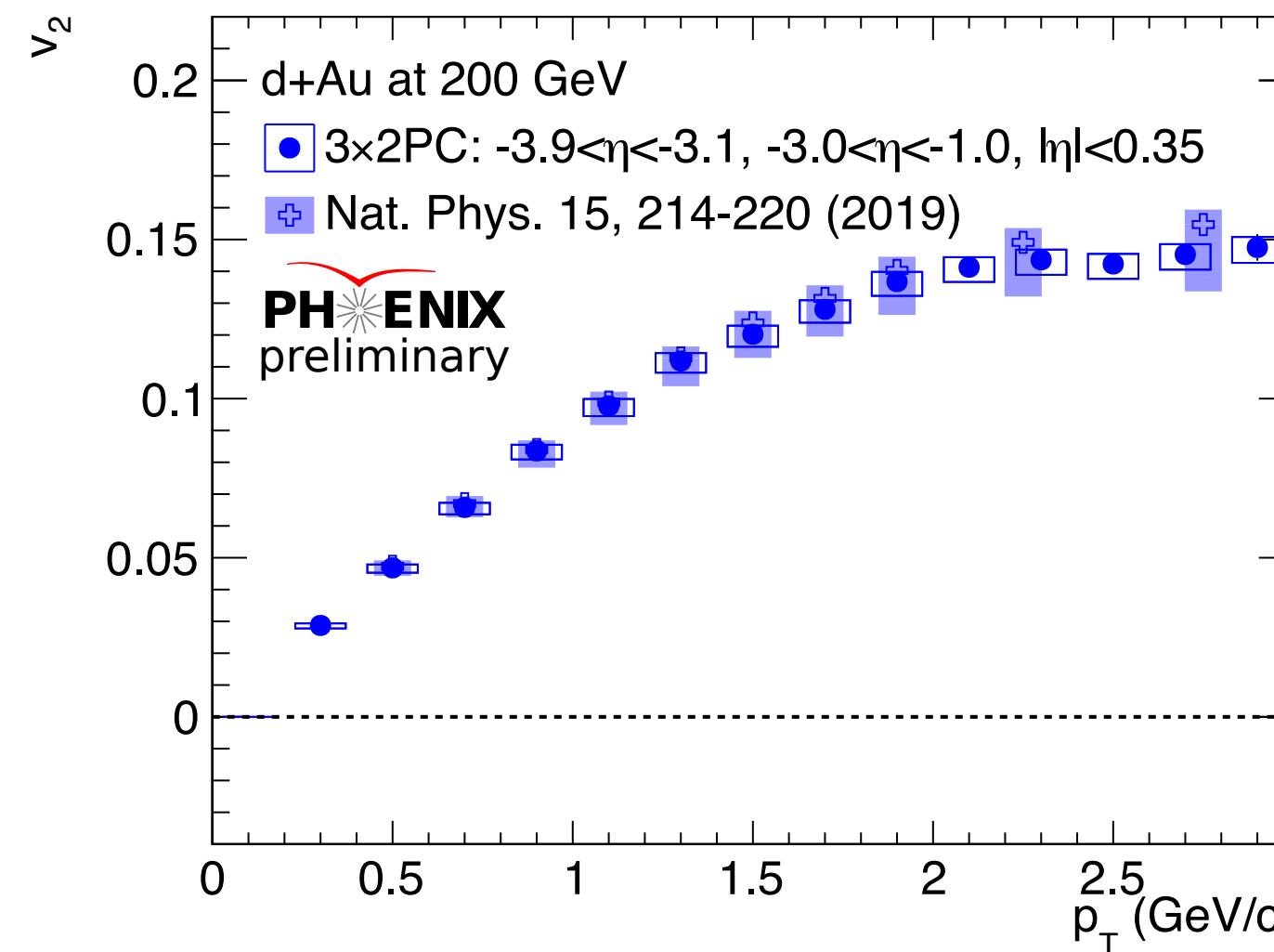
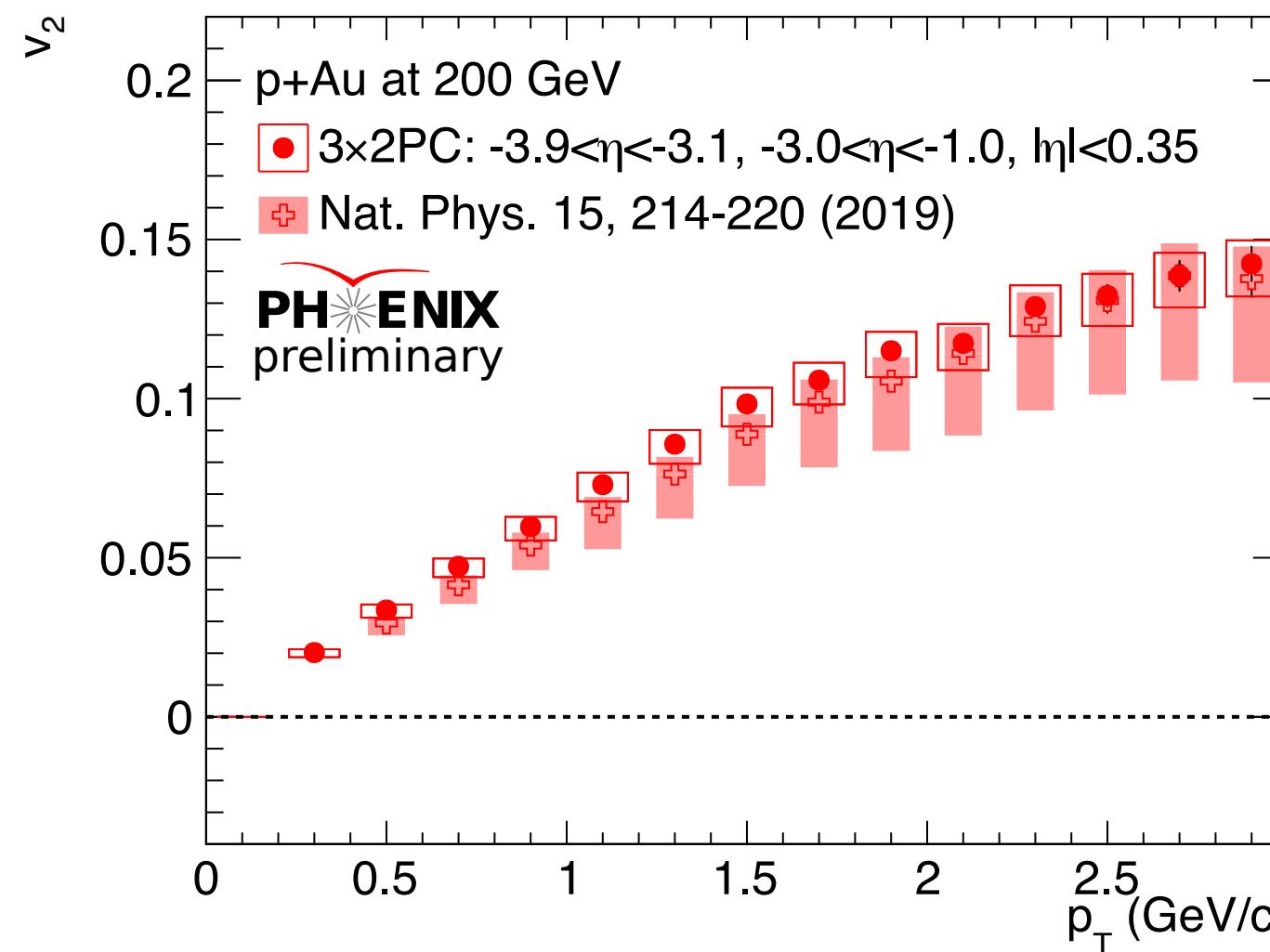
# v<sub>2</sub> as a function of pT; different kinematic selections

## QM2019 presented



# $v_2\{3\times 2PC\}$ as a function of $p_T$

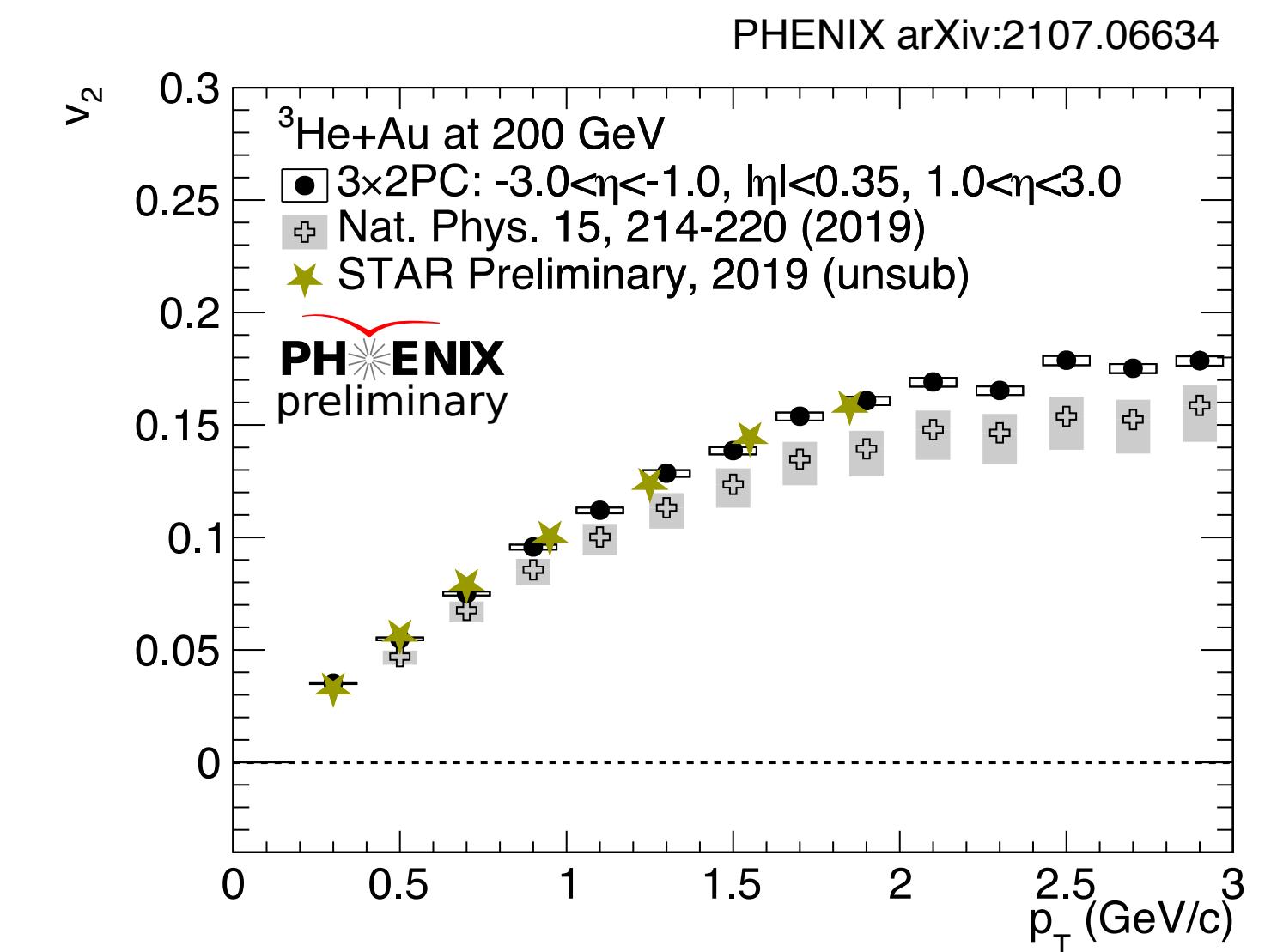
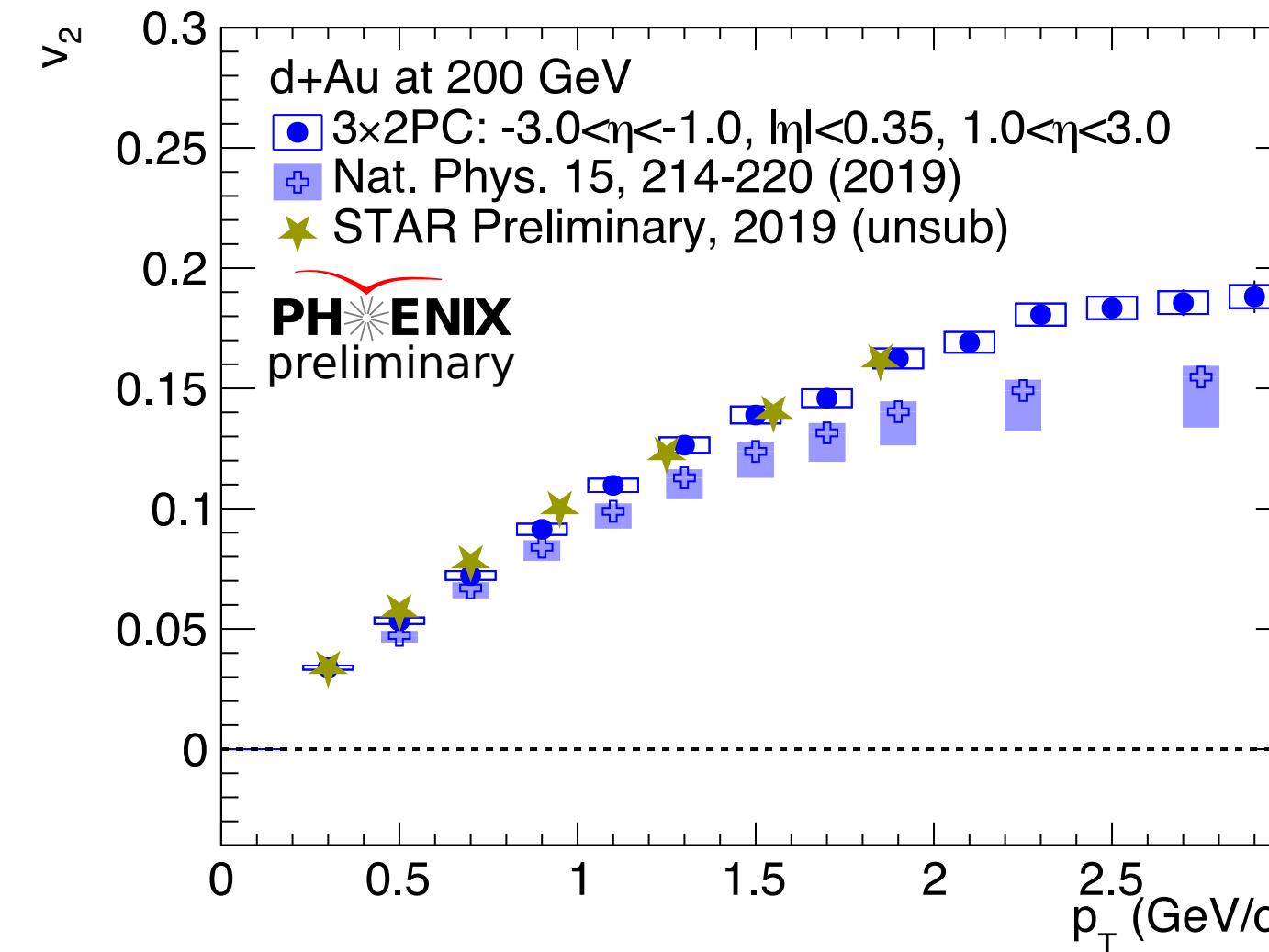
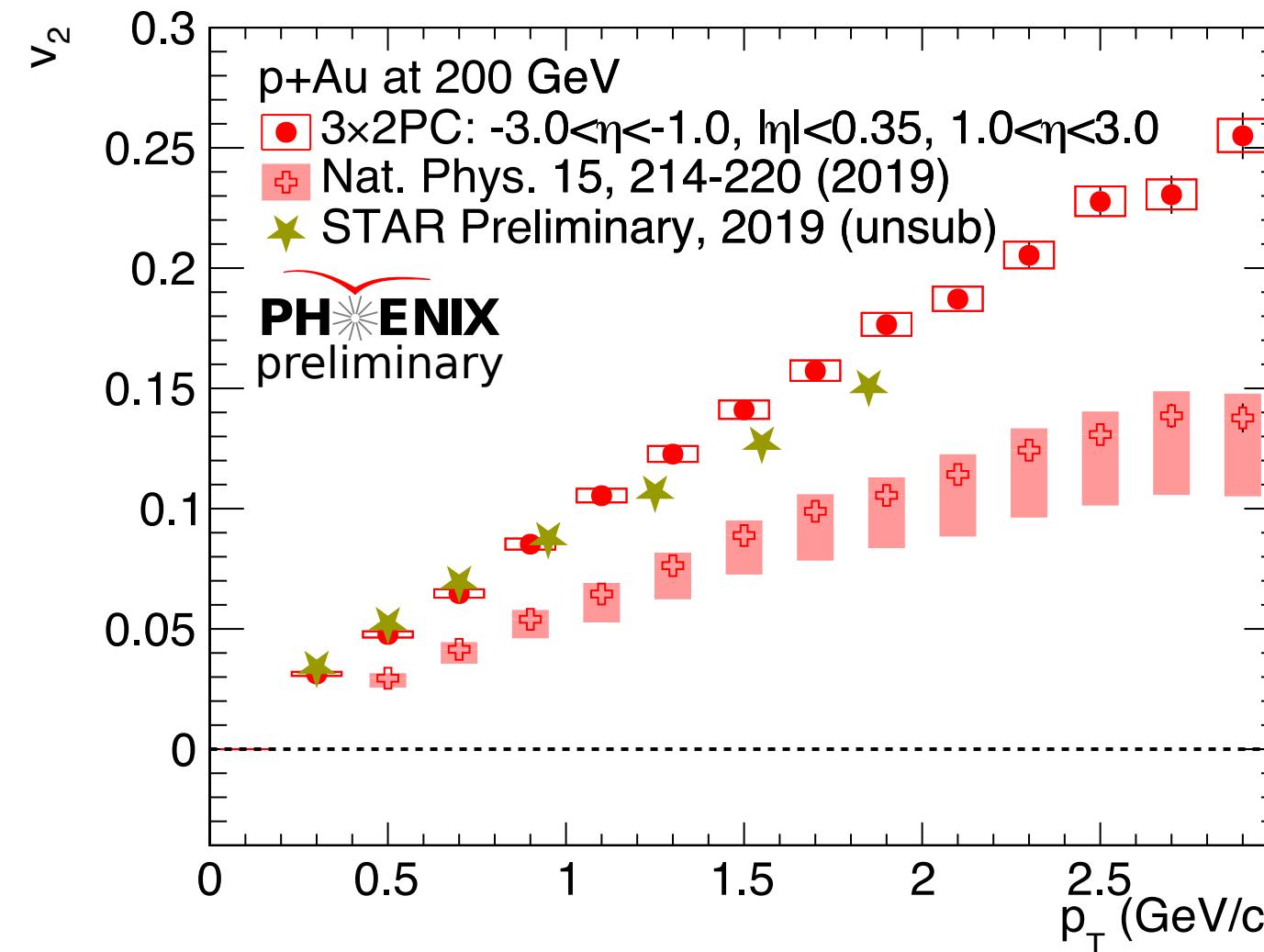
## Compare BB results with EP calculates



- $v_2$  via 3x2PC using BB rapidity combination are in excellent agreement with the PHENIX Nature results in p+Au, d+Au, and  $^3\text{He}+\text{Au}$  collisions that used the same rapidity combination
- We can find the event plane method gives consistent  $v_2$  results with the 3x2PC method
- The robustness of the Nature results is confirmed

# $v_2\{3\times 2PC\}$ as a function of $p_T$

## Comparison with additional FB combinations

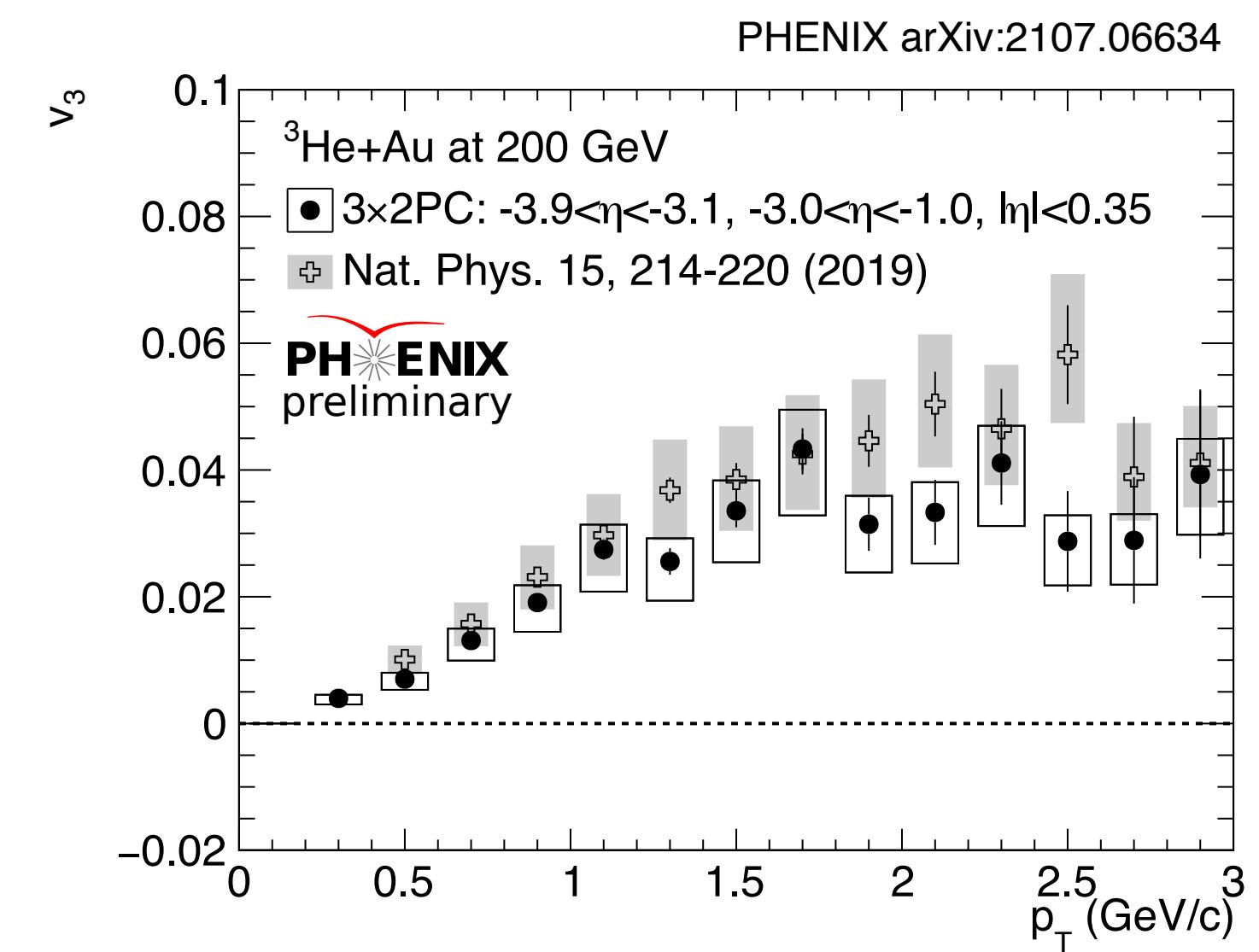
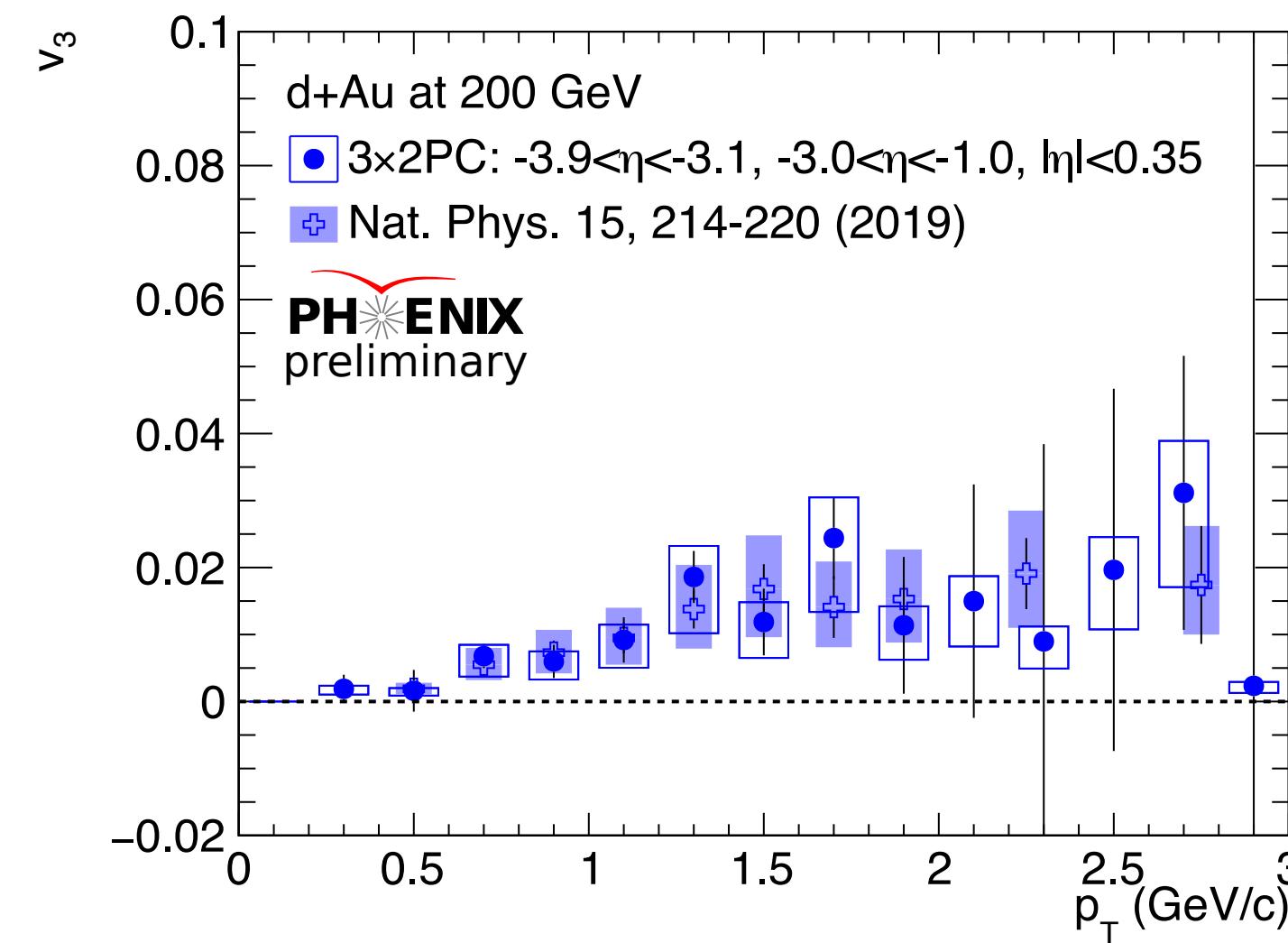
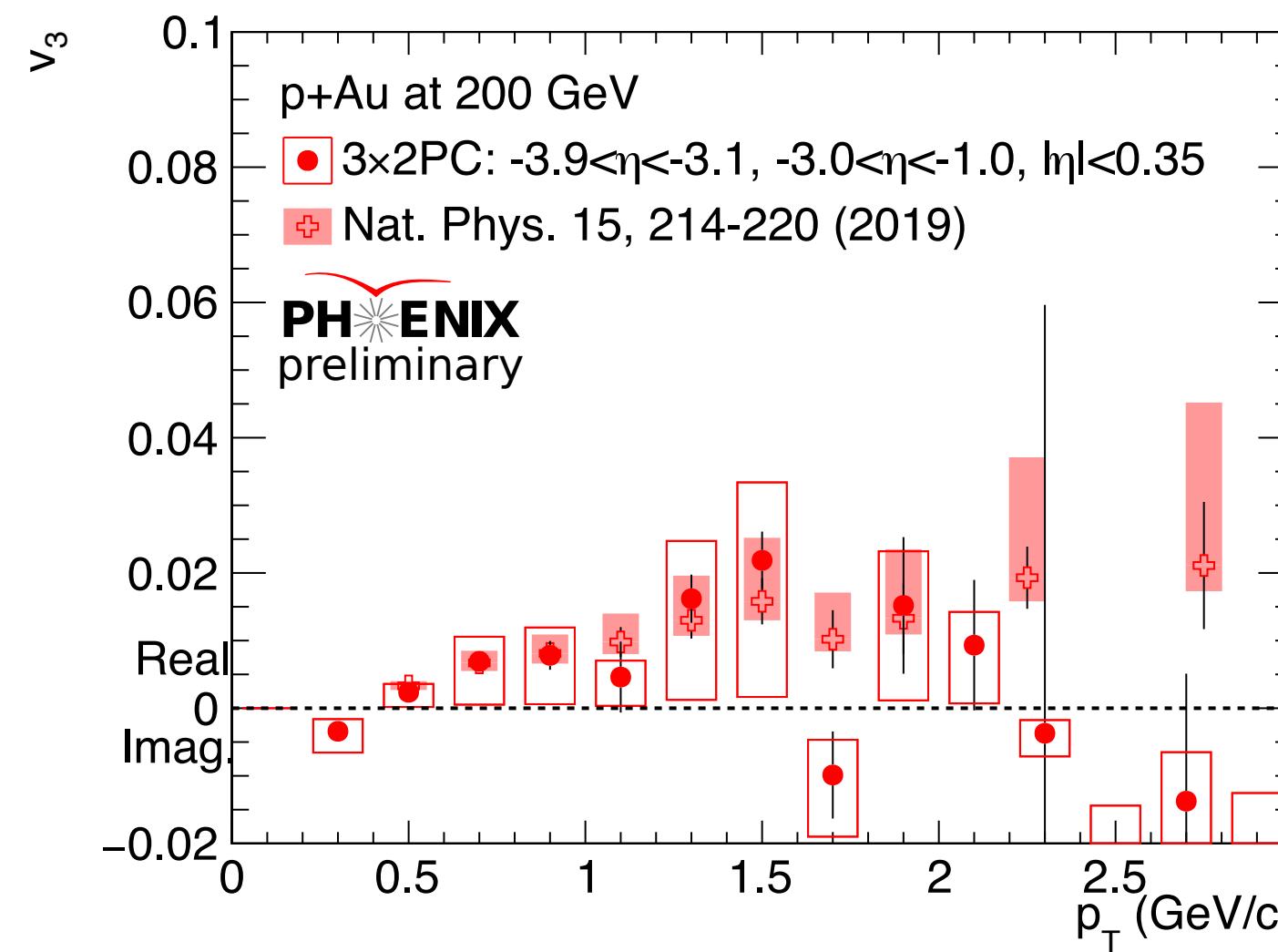


- The STAR preliminary  $v_2$  results in p+Au, d+Au, and  $^3\text{He}+\text{Au}$  collisions can be reproduced by FB combinations of the 3x2PC method
- Higher  $v_2$  observed at all three collisions
- Flow factorization seems to be broken because of the nonflow effect which is not eliminated

$$\sqrt{\frac{c_2^{CNT-FVTXs} c_2^{CNT-FVTXn}}{c_2^{FVTXn-FVTXs}}} \neq \sqrt{\frac{c_2^{CNT-BBCs} c_2^{CNT-FVTXs}}{c_2^{BBCs-FVTXs}}}$$

# $v_3\{3\times 2PC\}$ as a function of $p_T$

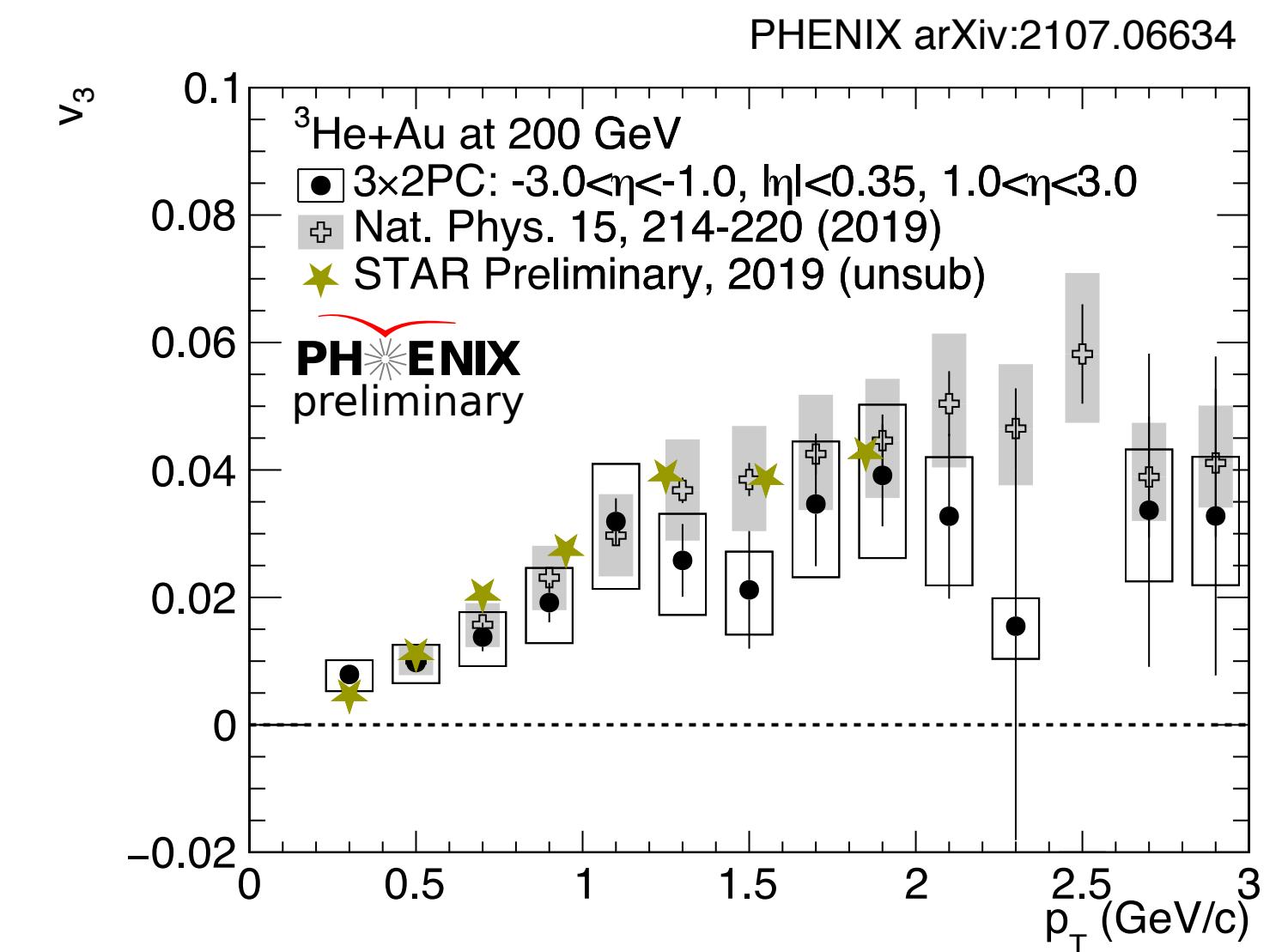
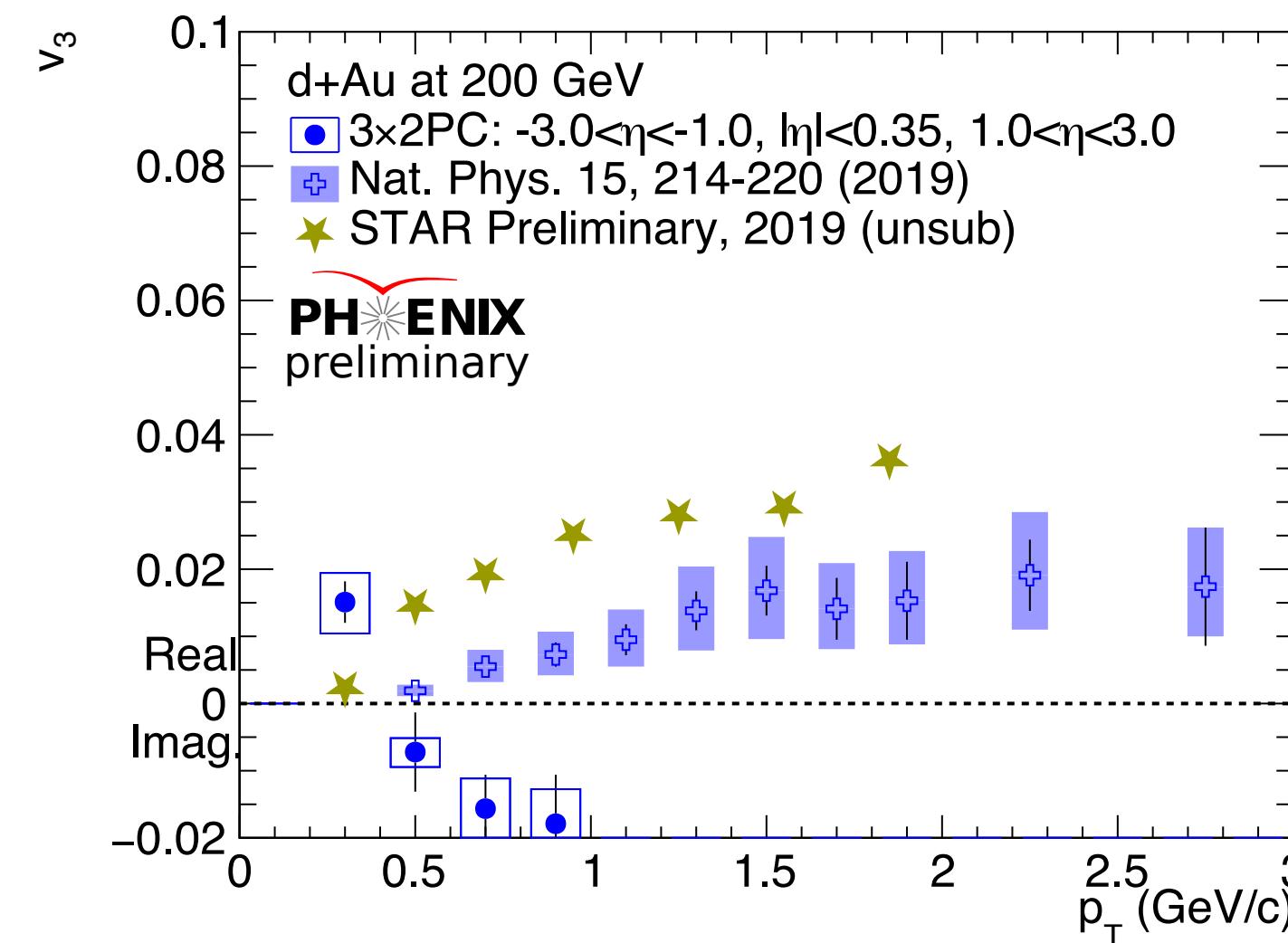
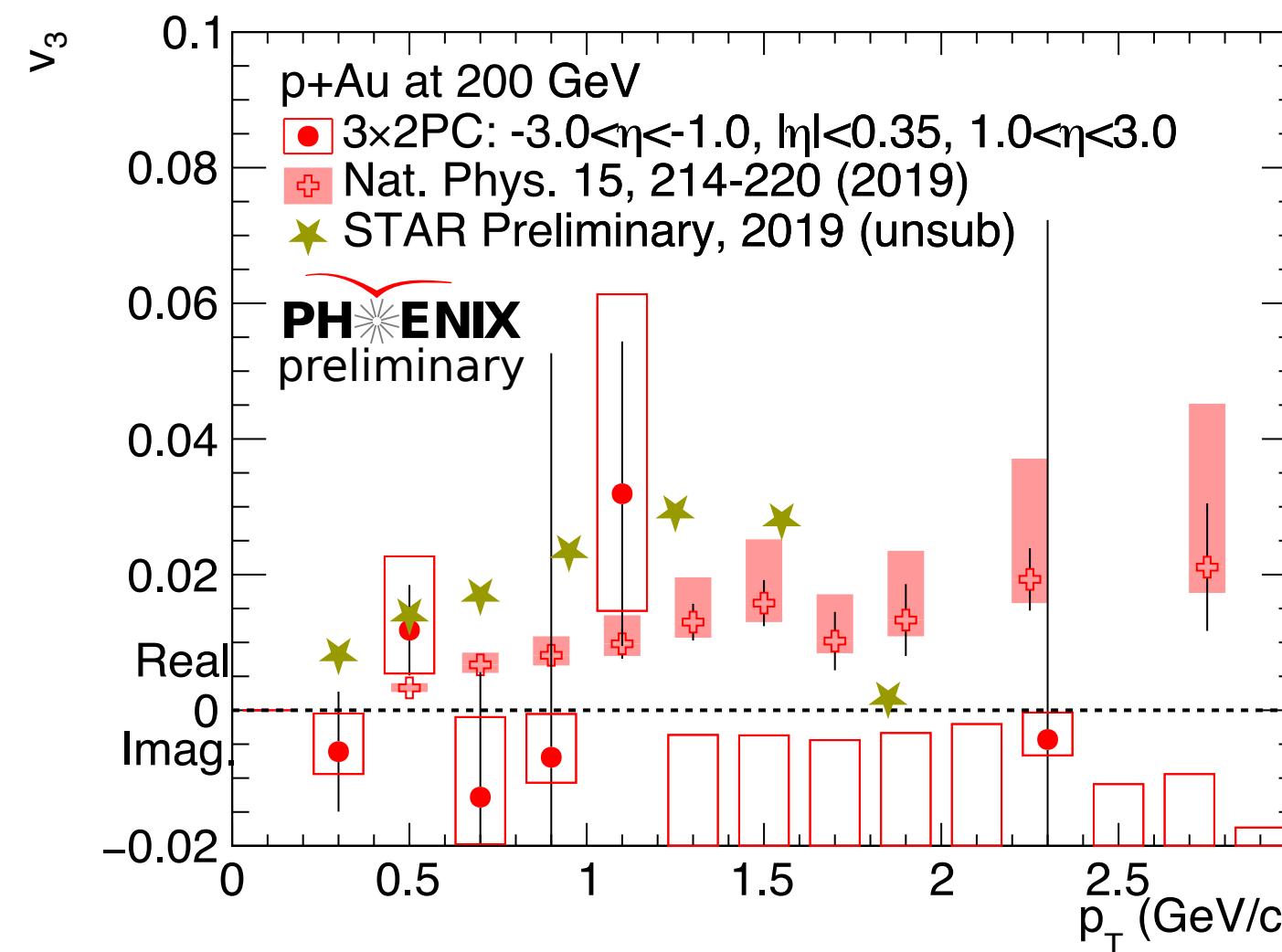
## Compare with EP results from Nature Physics



- $v_3$  via 3x2PC using BB rapidity combination show good agreement with the PHENIX Nature results in p+Au, d+Au, and  $^3\text{He}+\text{Au}$  collisions that used the same rapidity combination
- The robustness of the Nature results for the  $v_3$  are confirmed

# $v_3\{3\times 2\text{PC}\}$ as a function of $p_T$

## Comparison with additional FB combinations

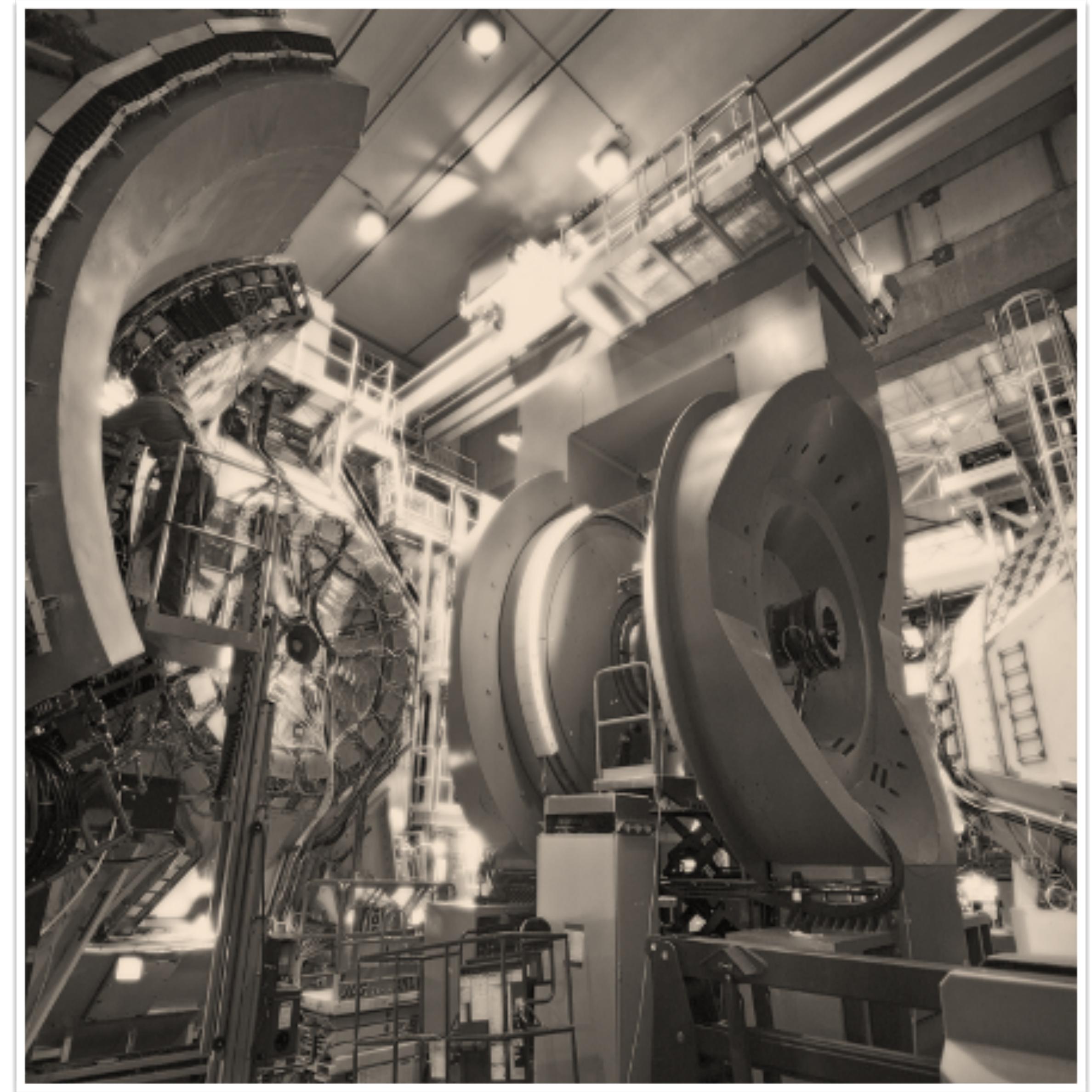


- New  $v_3$  via 3x2PC using FB rapidity combination have the imaginary size of  $v_2$  at  $p+\text{Au}$  and  $d+\text{Au}$ , while  $v_2$  at  ${}^3\text{He}+\text{Au}$  collisions can have the real value
- Stronger nonflow at denominator or event-plane de-correlation effect at numerator can cause the imaginary size of  $v_3$  at smaller collision systems

# Summary

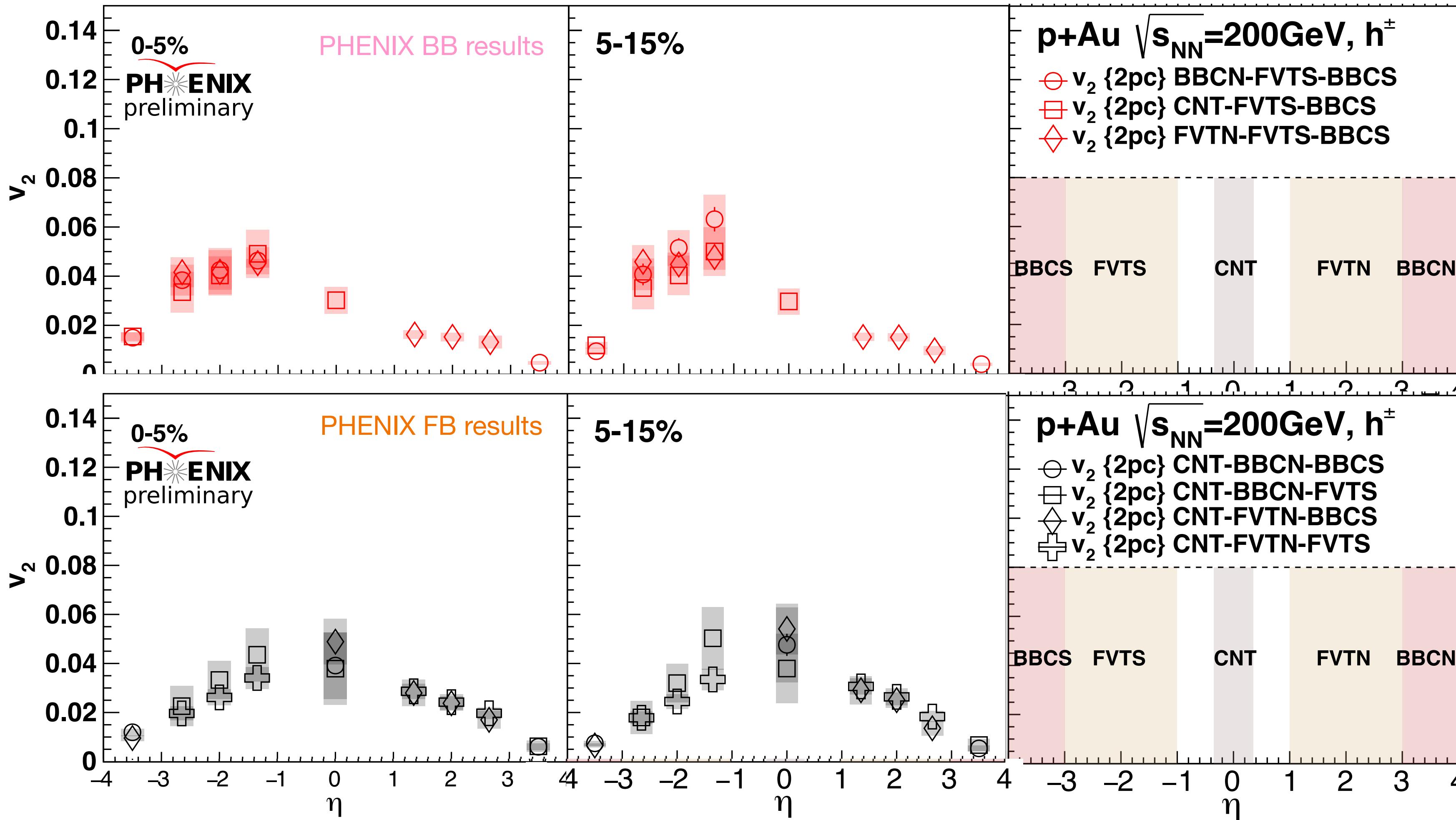
- Published results calculated by EP method are confirmed by 3x2PC calculations
- Kinematic selections are very important to understand the flow at small collision systems
- PHENIX has an analysis effort on explaining/quantitating the difference between kinematic selections

**Thanks for your attention**  
backups



# $v_2\{3 \times 2\text{PC}\}$ as a function of pseudo-rapidity

## Comparison with different kinematics



- The breaking of flow factorization appears not only at mid-rapidity but also at the forward and backward rapidities in different centrality ranges