

# Forward/backward J/ $\psi$ production and hadron $v_n$ in Cu+Au collisions in PHENIX

*Richard Hollis*

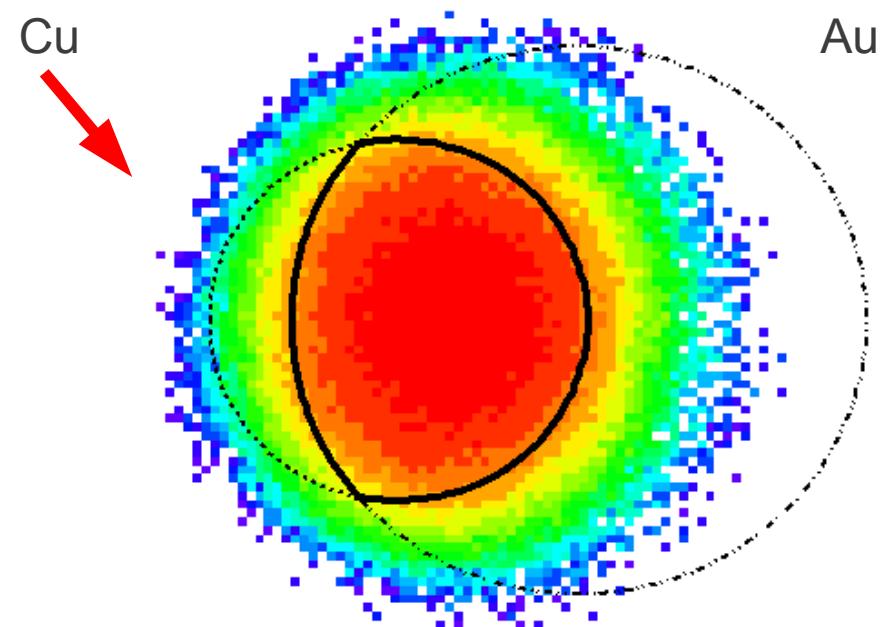
For the  **PHENIX** Collaboration

Quark Matter 2012, Washington, D.C.

# CuAu Collisions – Exploiting the flexibility of RHIC

- Why interesting?
  - Naturally odd harmonics
    - Possibility to investigate a “true  $v_3$ ”
  - Large “corona” on Au-side
    - Giving rise to more detailed investigation of its size
    - “ $v_1$ -like” azimuthal dependence
  - Completely swallowed Cu-nucleus in central collisions
    - Cu-going corona vanishes

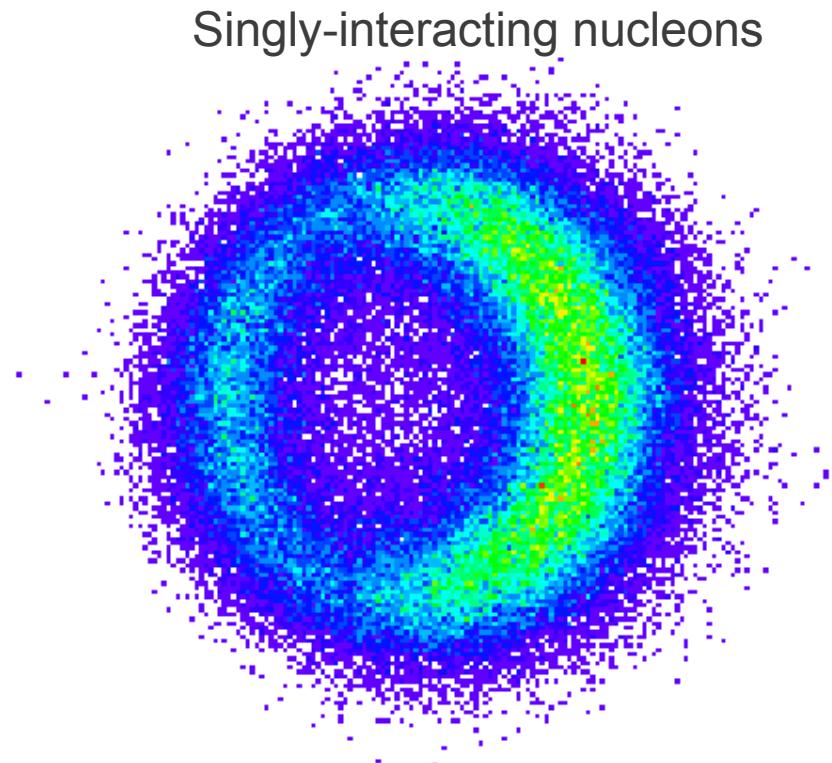
Participant density (log-z scale)



Glauber model CuAu,  $b=4\text{fm}$

# CuAu Collisions – Exploiting the flexibility of RHIC

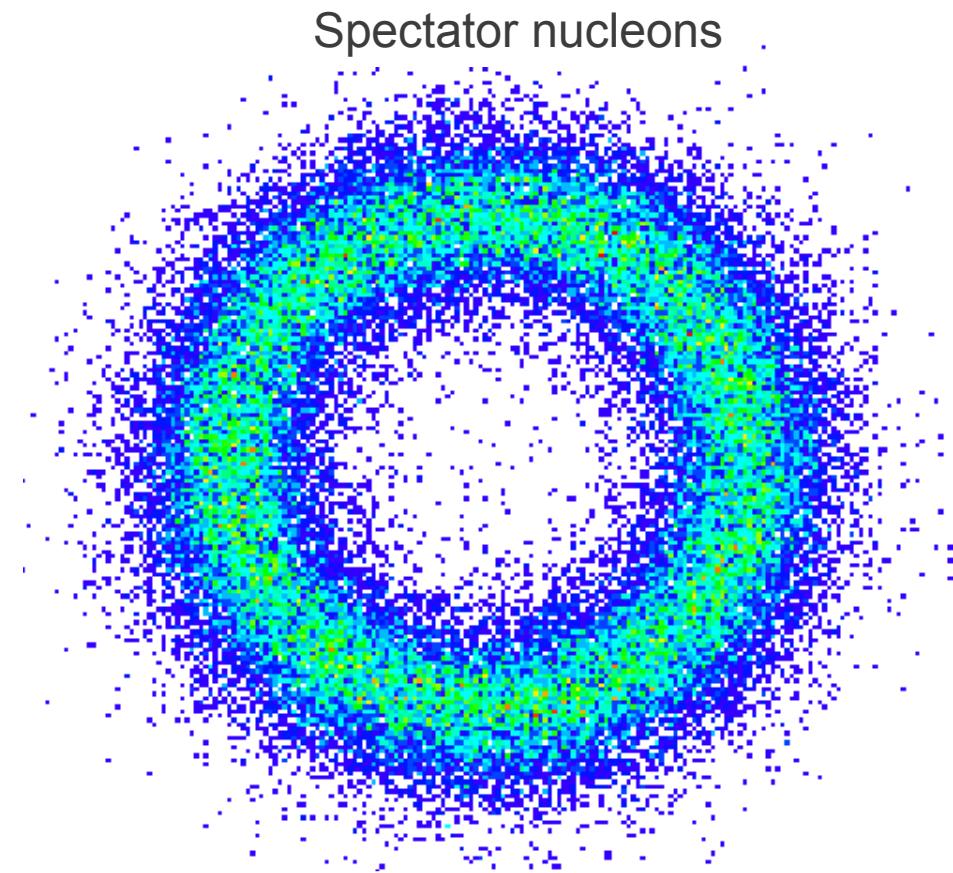
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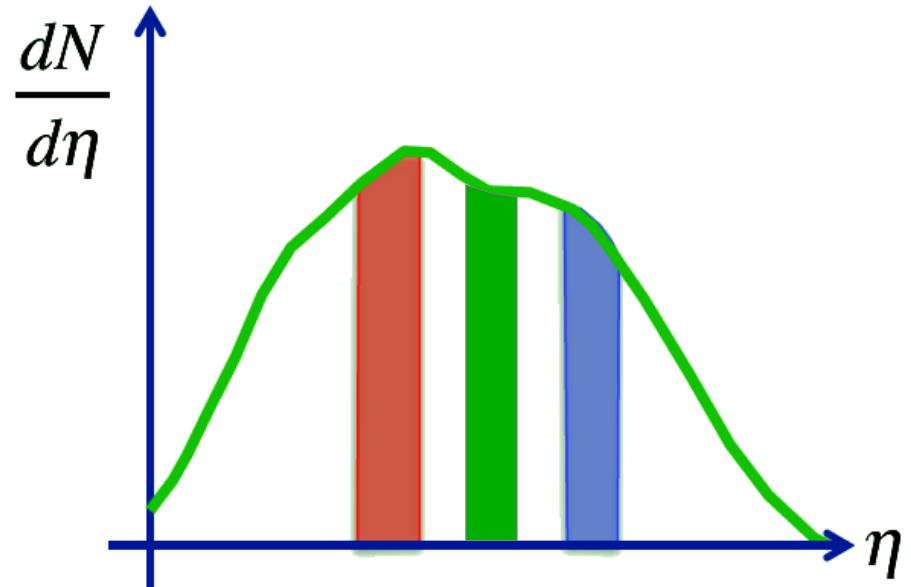
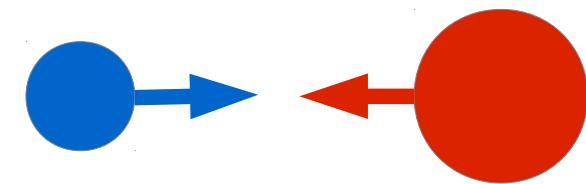
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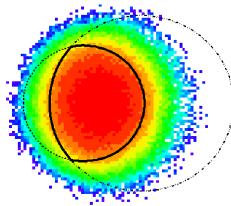
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# Outline

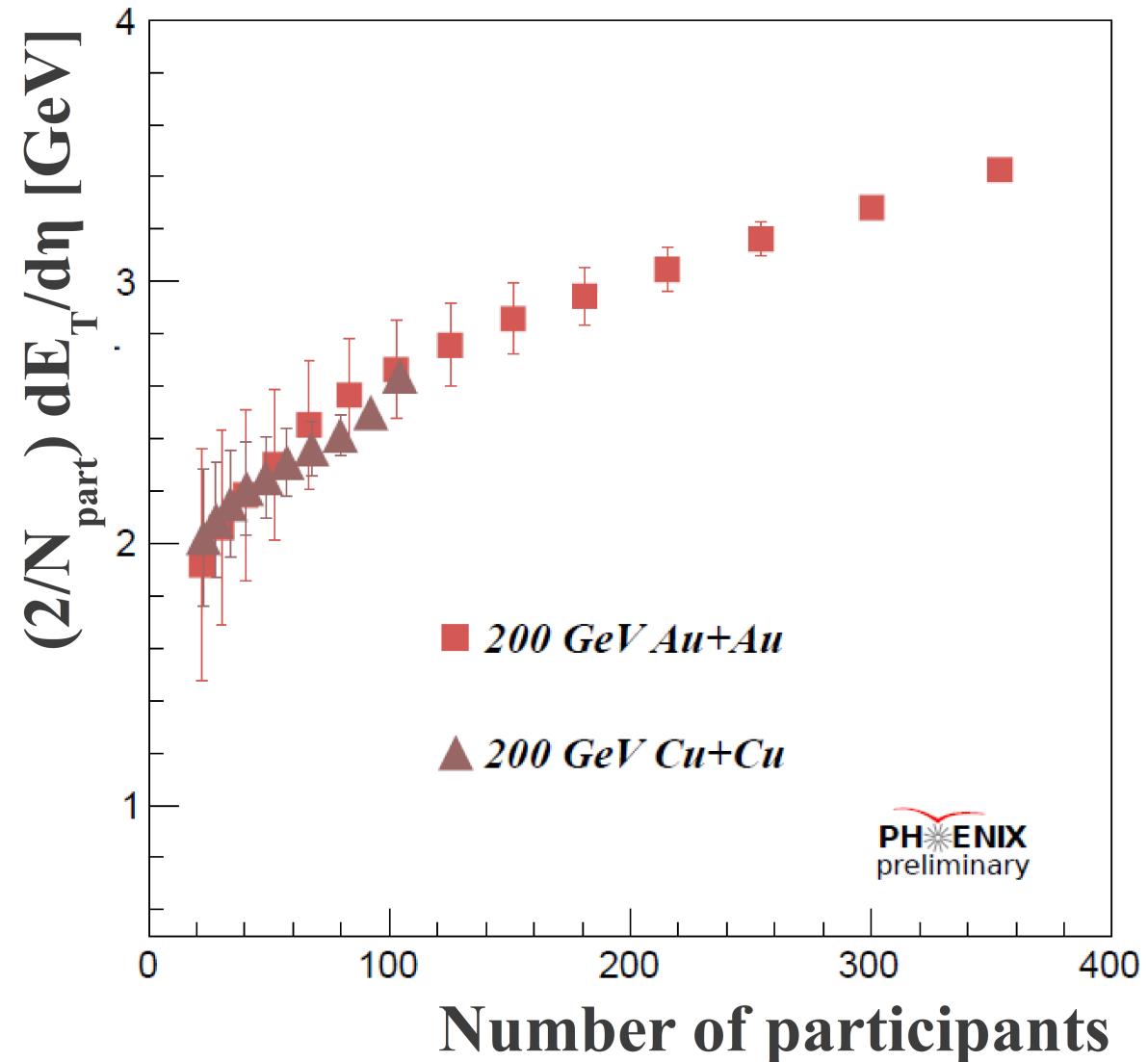
- Measuring the ***bulk*** properties of the system
  - Mid-rapidity energy density
  - Mid-rapidity anisotropic Flow
- Measuring ***hard*** properties
  - Forward-rapidity J/ $\psi$   
 $1.2 < y < 2.2$
  - Backward-rapidity J/ $\psi$   
 $-2.2 < y < -1.2$
- Summary



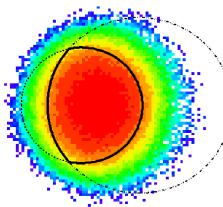


# Transverse Energy

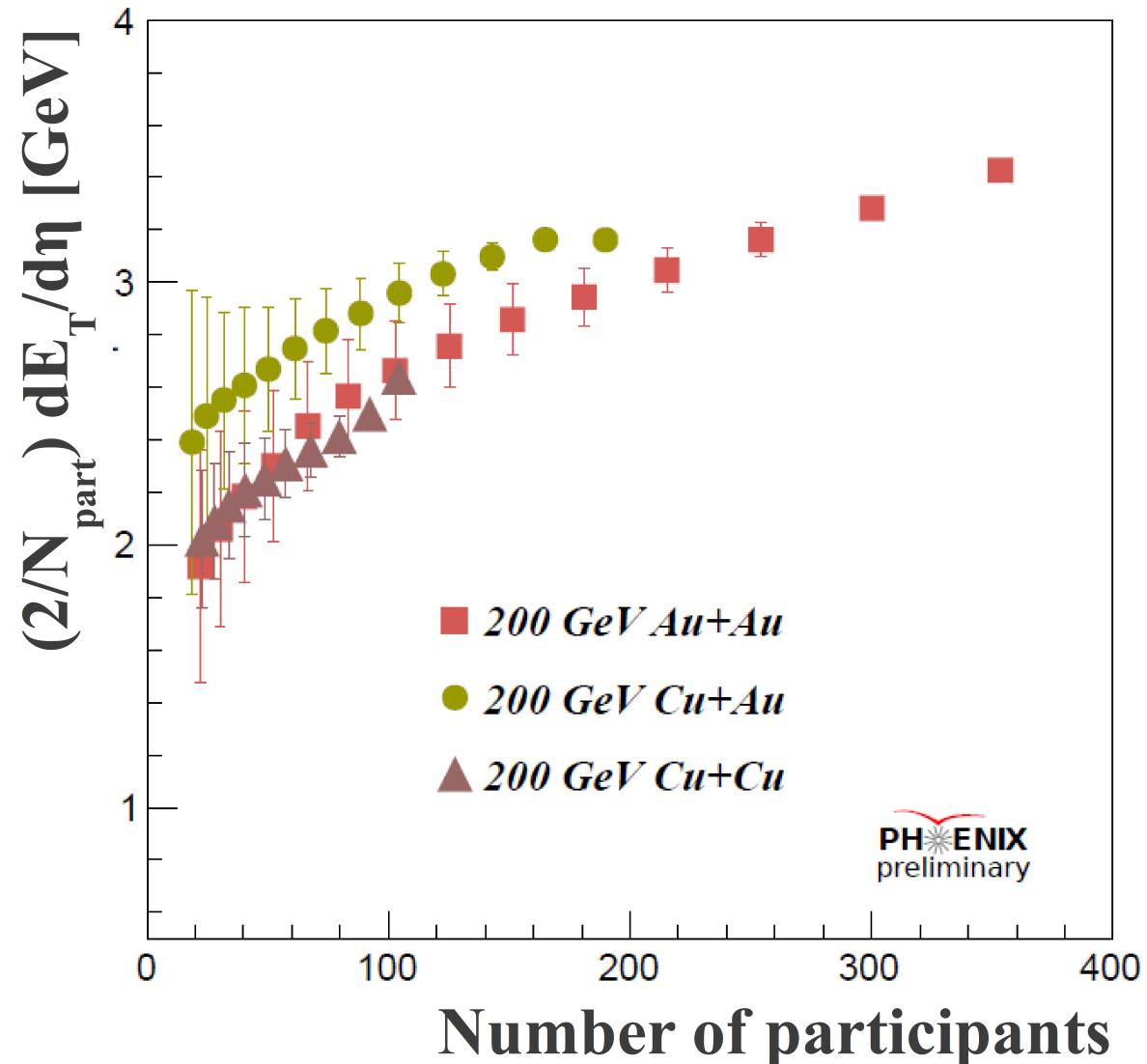
- Transverse energy of the system:
  - Independent of collision system
  - At the same  $N_{\text{part}}$



# Transverse Energy

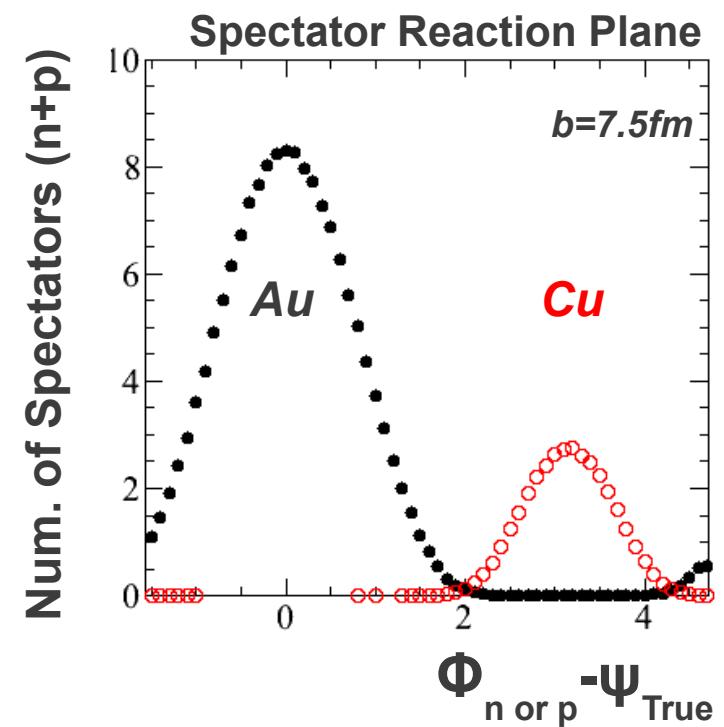
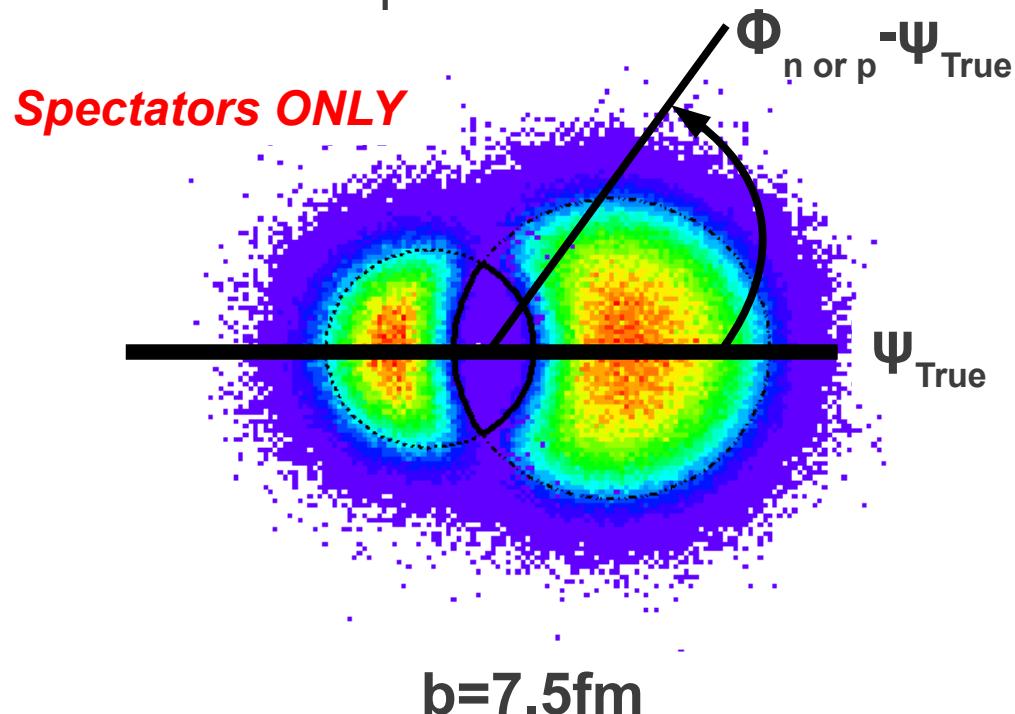


- Transverse energy of the system:
  - Independent of collision system
  - At the same  $N_{\text{part}}$
  - Higher CuAu energy density in central collisions reflects larger **core** at the same  $N_{\text{part}}$



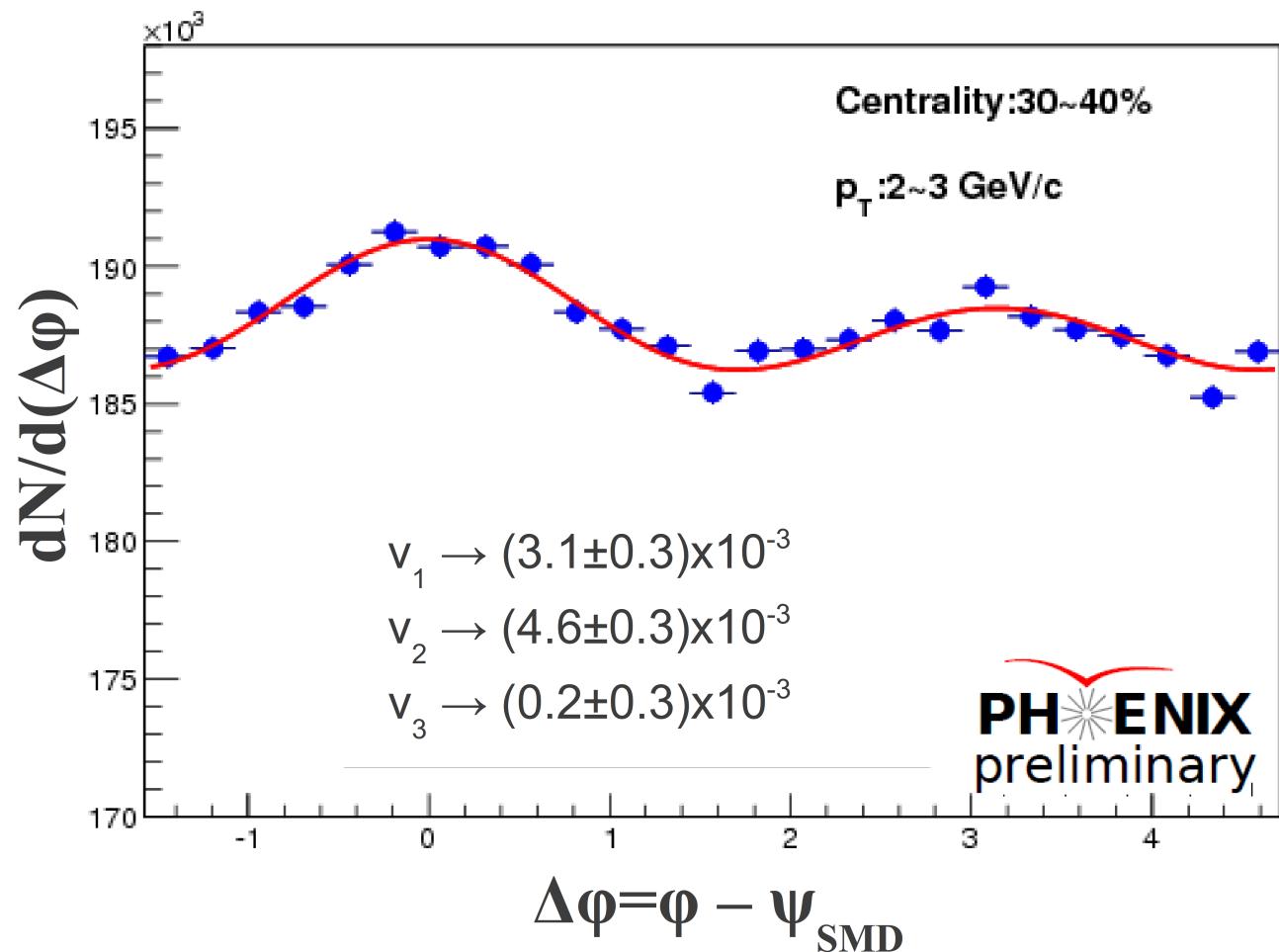
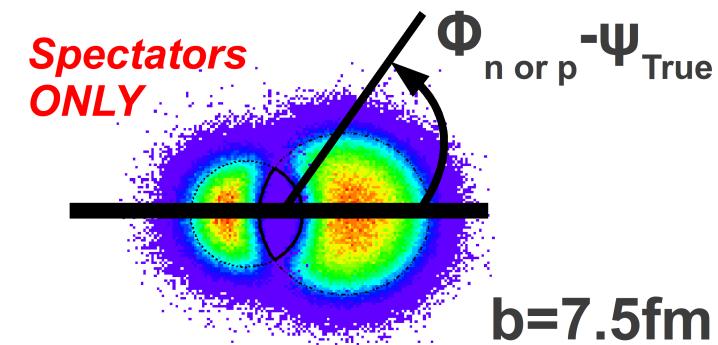
$V_n$

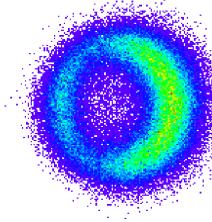
- Measure particle production relative to **Au-spectator** plane
  - Representative of the true reaction-plane



$v_n$

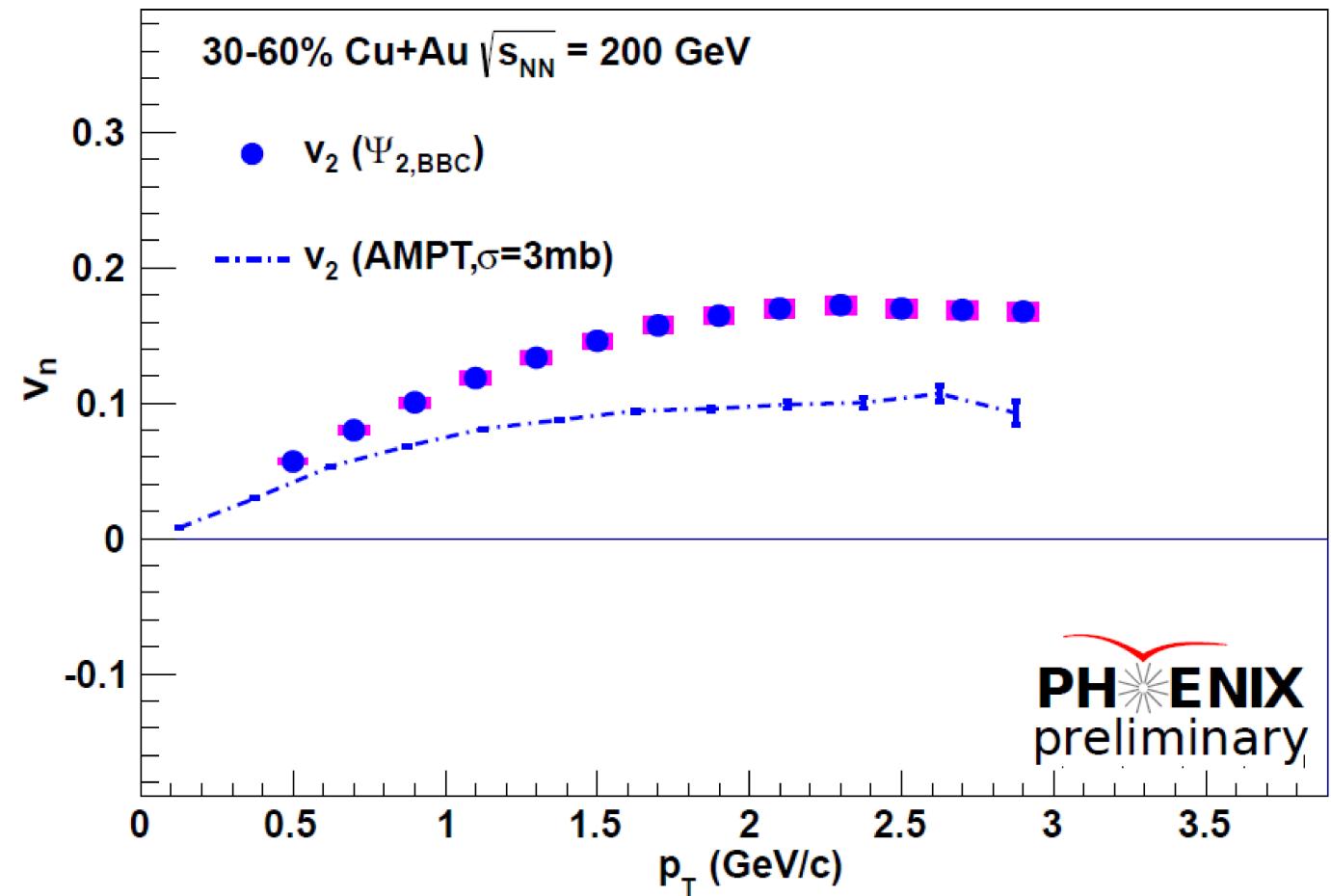
- Measure particle production relative to **Au-spectator** plane
  - Representative of the true reaction-plane
- In data → use the shower-max in the ZDCs (neutron reaction-plane)
  - Hadrons at mid-rapidity exhibit large  $v_2$  **and**  $v_1$  (not observed in AuAu)
  - Not consistent with a large  $v_3$ .

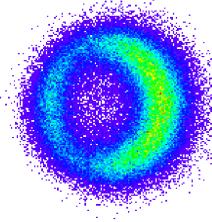




# Modeling $V_n$

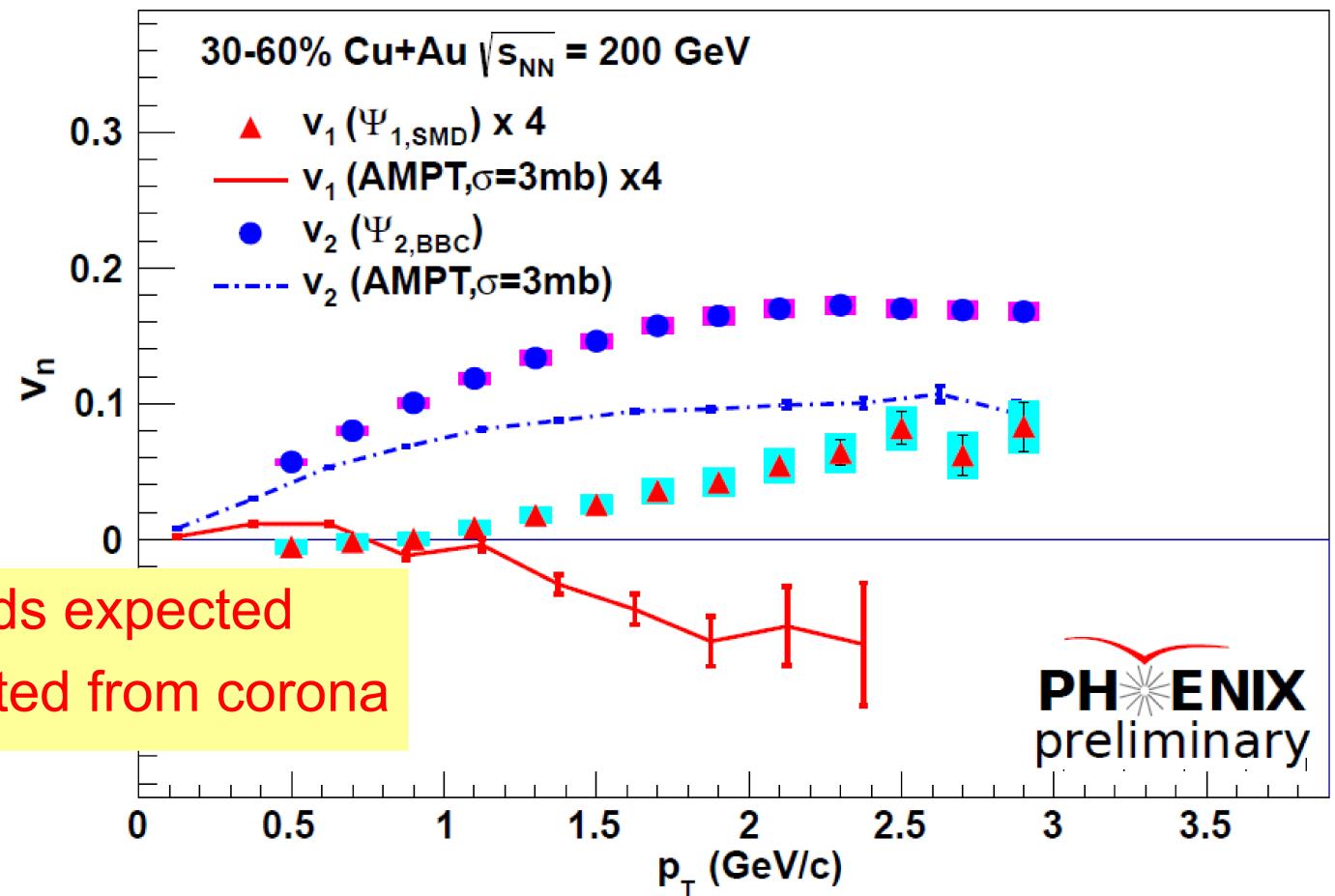
- Comparison to AMPT





# Modeling $V_n$

- Comparison to AMPT
- At mid-rapidity expects:
  - Stronger  $v_1$  (than AuAu)
  - Wrong sign





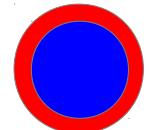
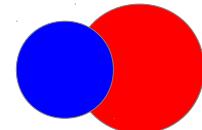
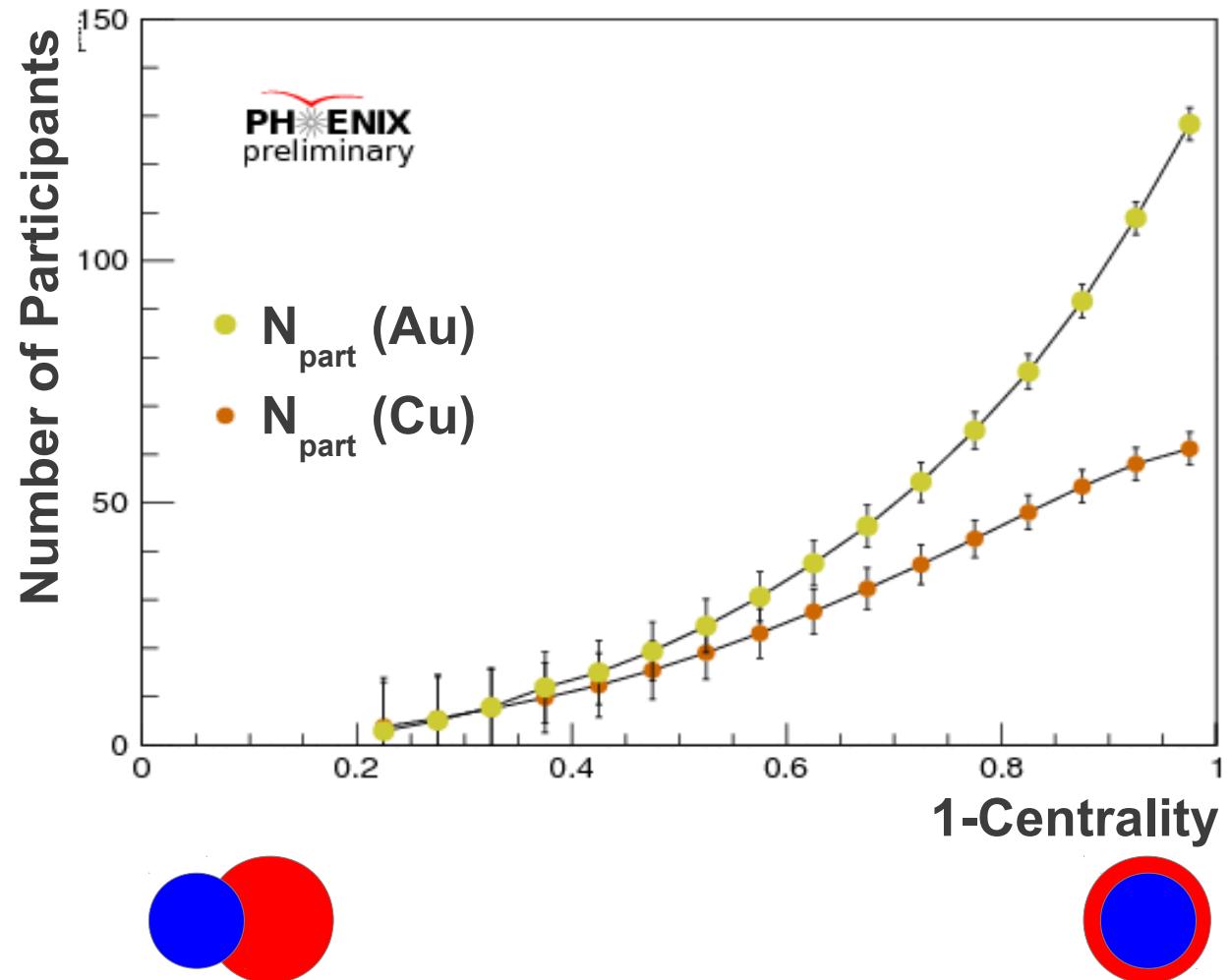
# *Forward/Backward Hard properties*

# Expected J/ $\psi$ production

- Binary scaled process
  - No inherent asymmetry
- Modulo nuclear effects
  - CNM
    - different in smaller Cu and larger Au
  - QGP effects
    - smaller  $dN/d\eta$  in Cu-going compare to Au-going direction

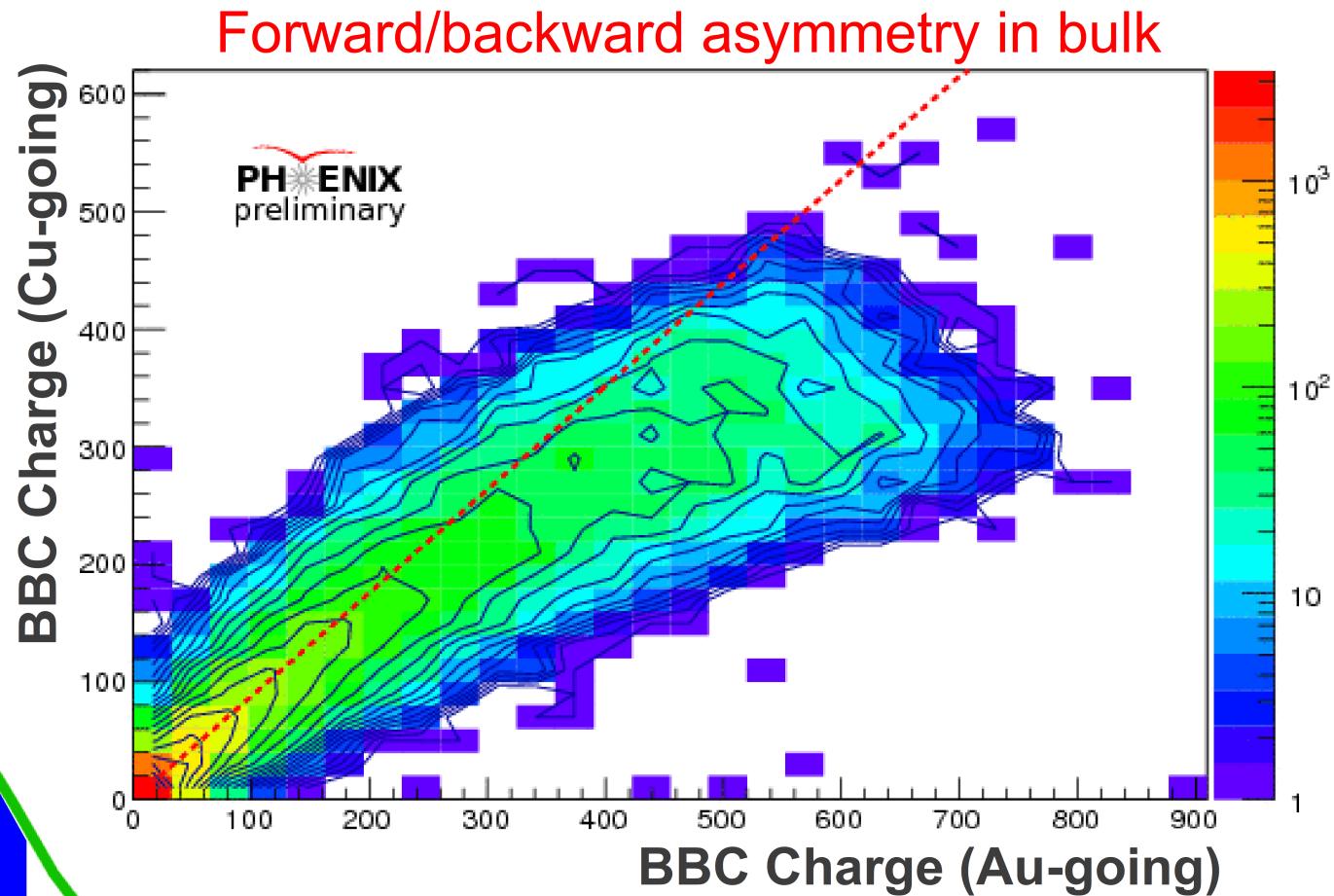
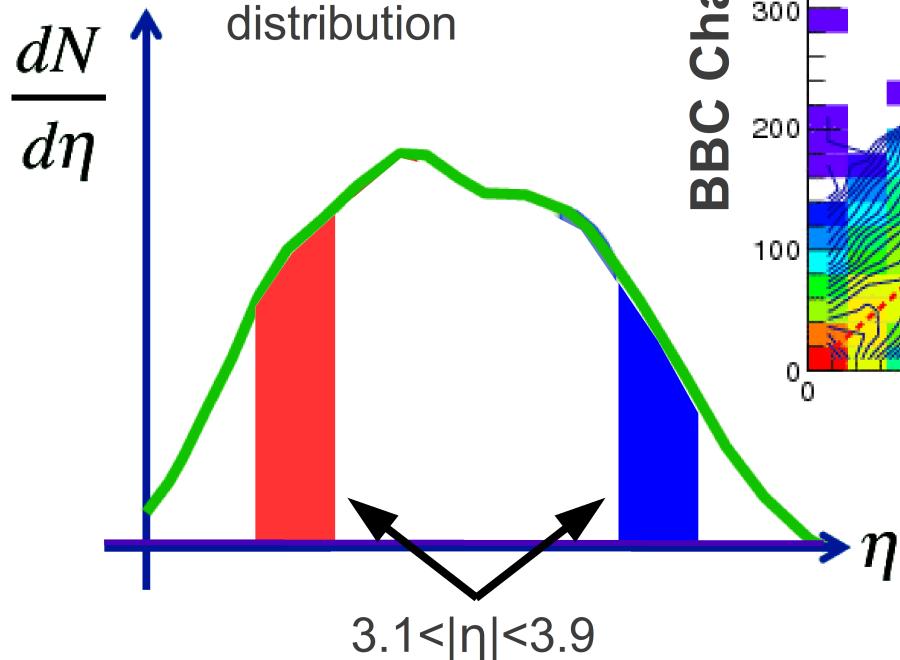
# Energy density asymmetry

- Initial asymmetry in the number of participants from Au and Cu



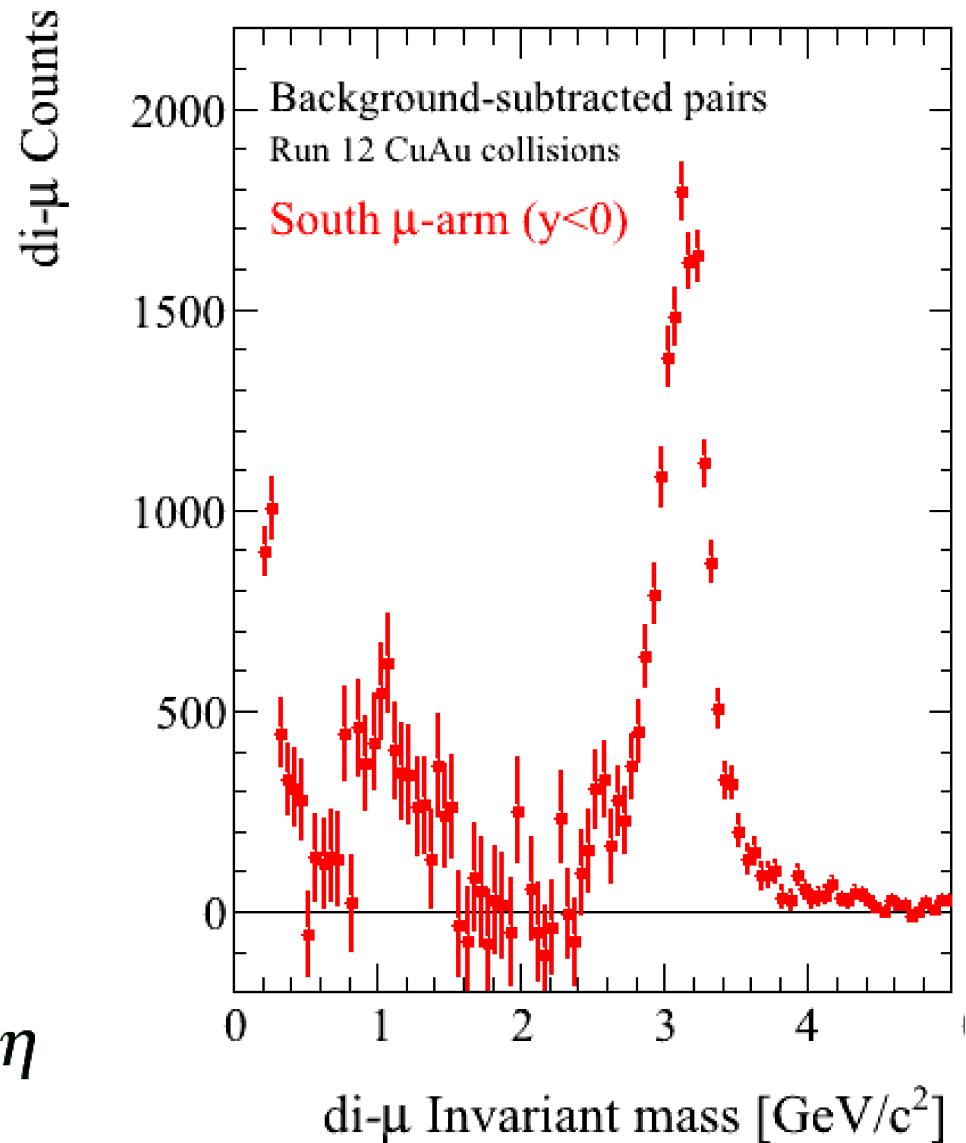
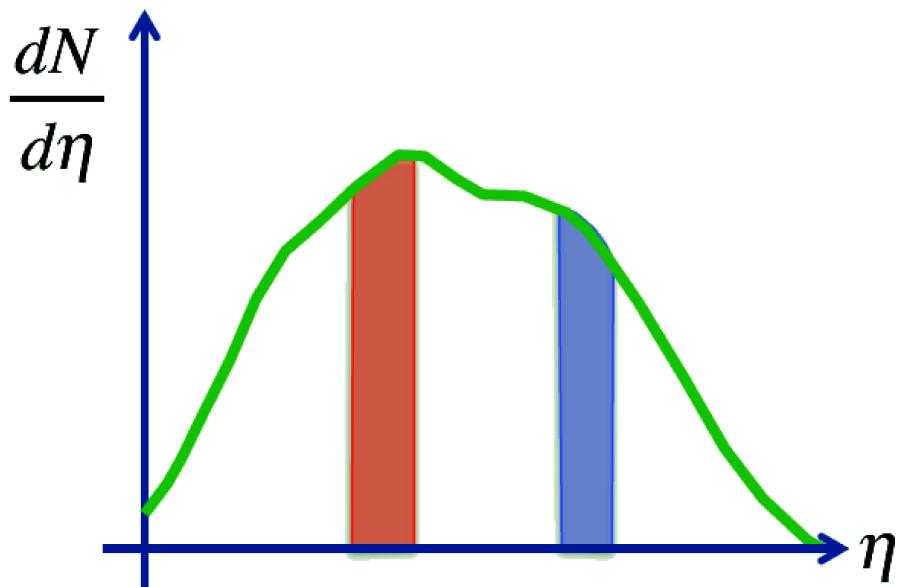
# Energy density asymmetry

- Expect an asymmetric  $dN/d\eta$ 
  - Measured in the Beam-Beam Counters (BBC) charge distribution



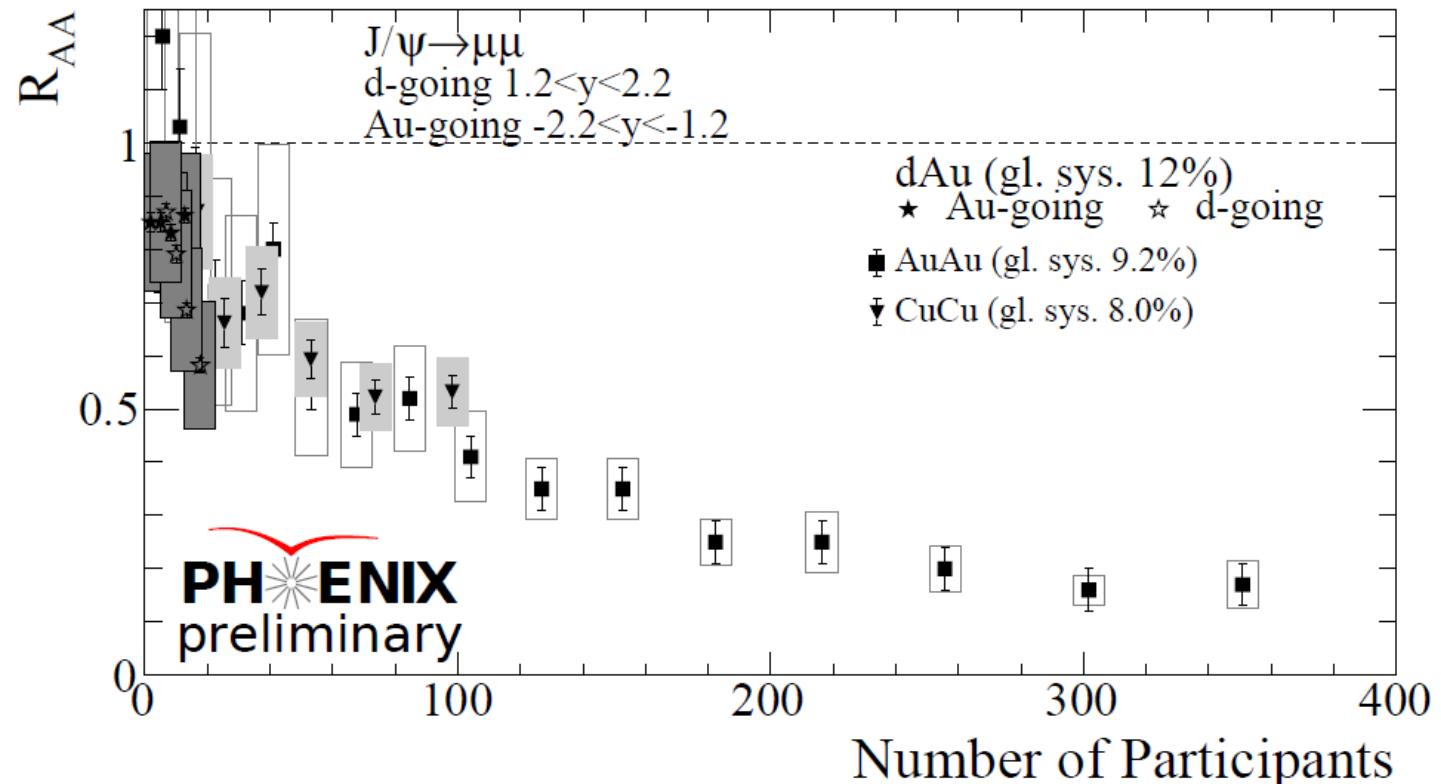
# J/ $\psi$ measurement: forward rapidity

- Measure J/ $\psi$ 
  - Forward,  $y>0$ , (Cu(d)-going)
  - Backward,  $y<0$ , (Au-going)



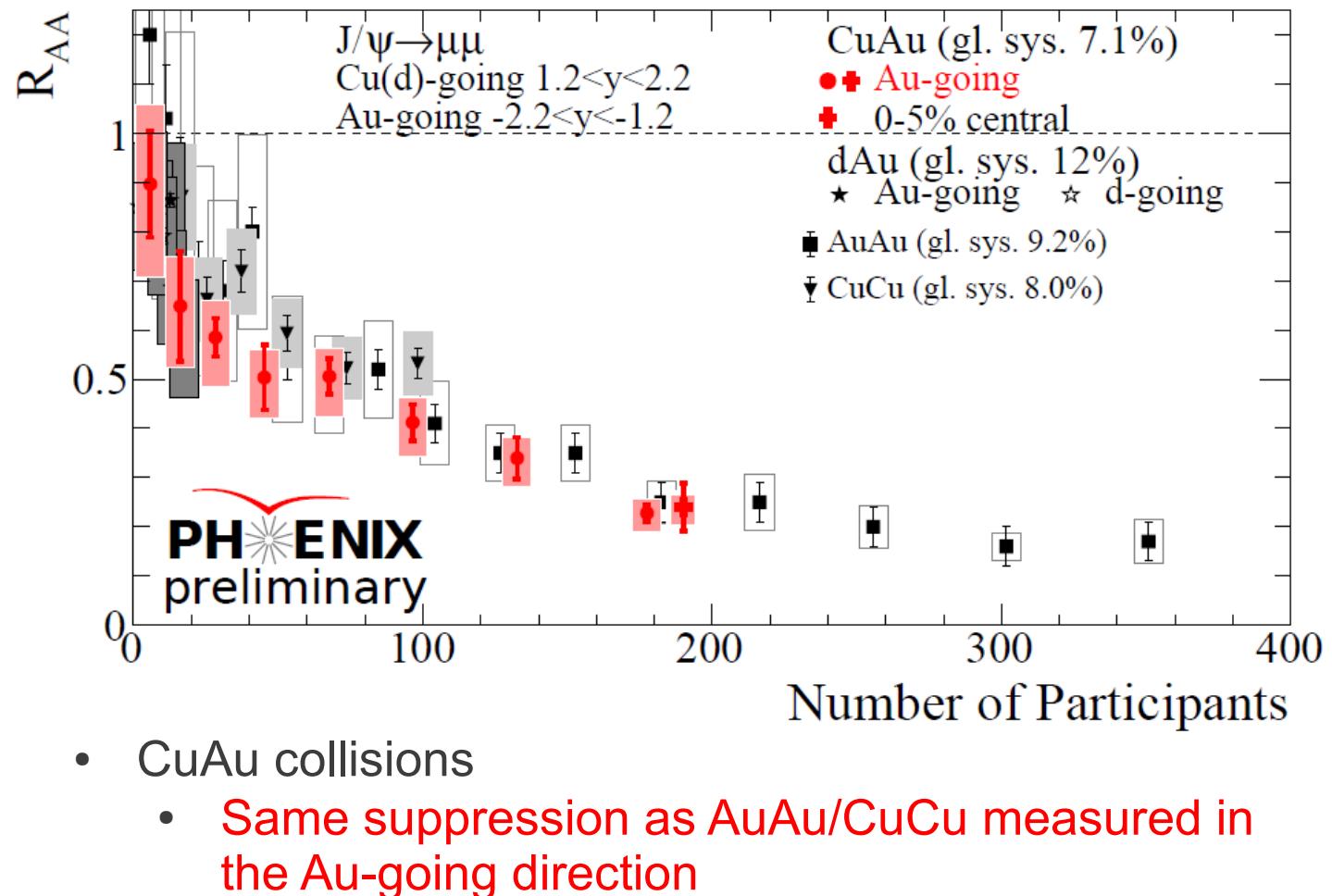
# Nuclear Modification Factor

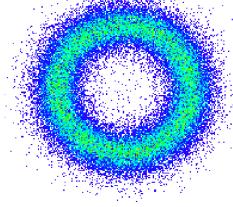
- Comparison between particle yields in AA to pp (scaled by the expected number of collisions)
- CuCu and AuAu
  - CNM and final-state effects
  - Suppression observed
  - Independent of collision system



# Nuclear Modification Factor

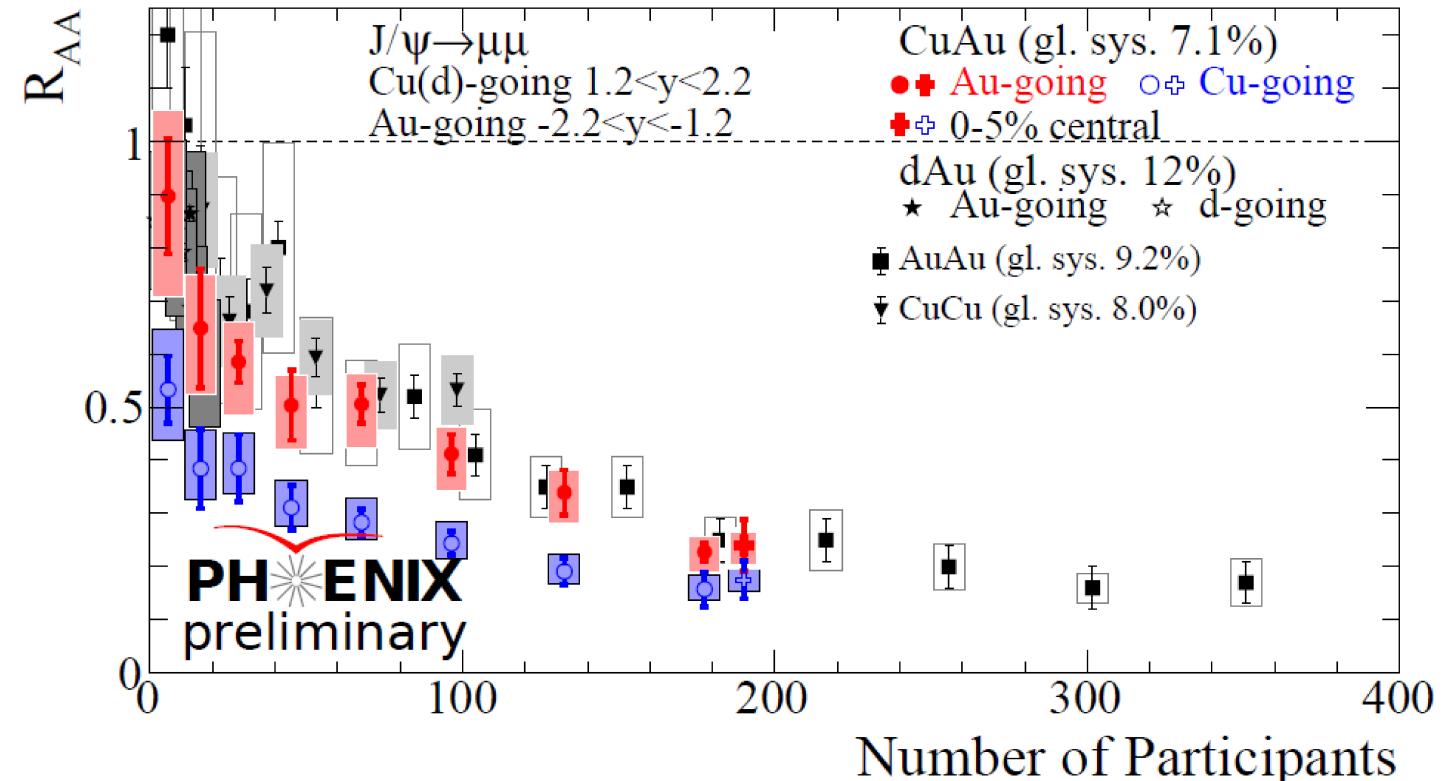
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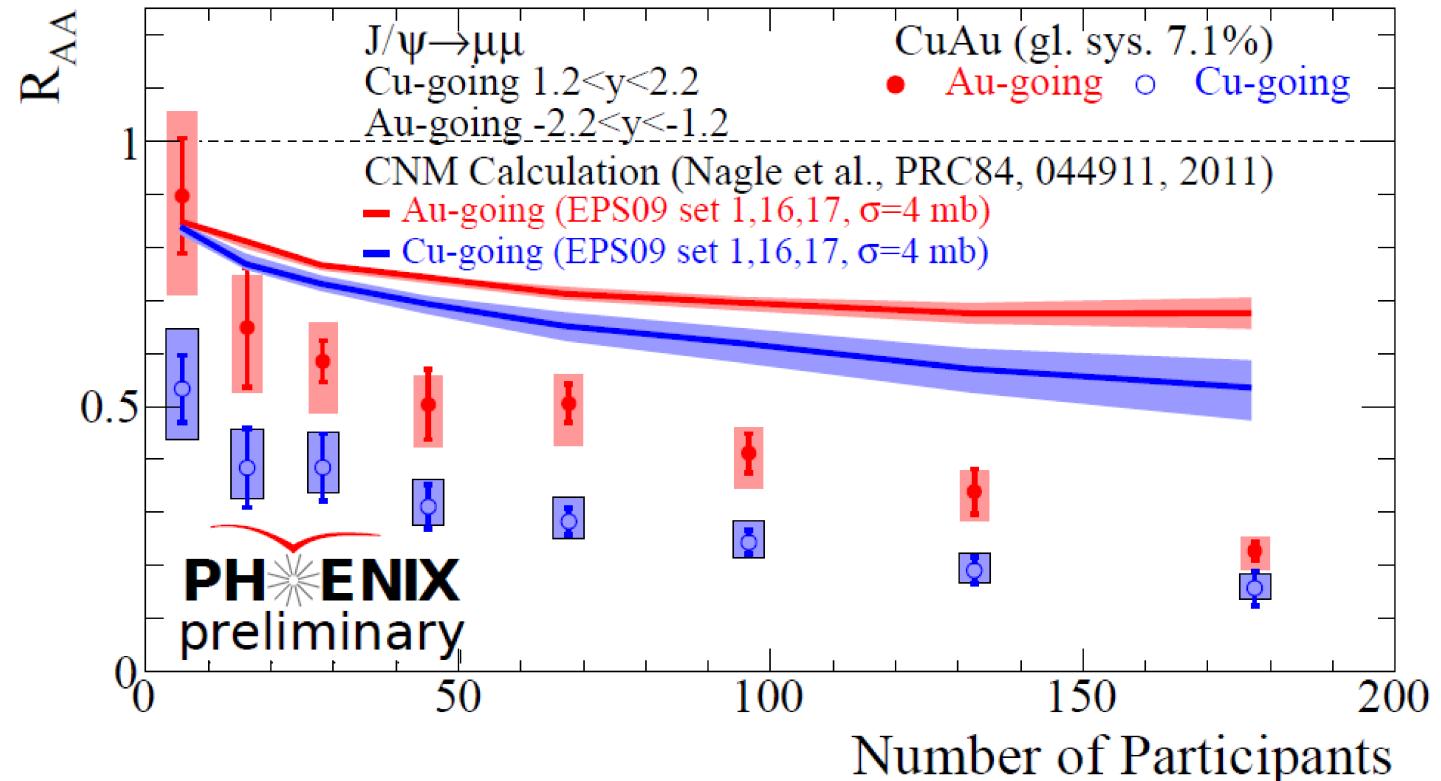
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- CuAu collisions
  - Same suppression as AuAu/CuCu measured in the Au-going direction
  - More suppressed in the Cu-going direction
  - $J/\psi$  not significantly more suppressed in completely swallowed-Cu (top 5%) events

# Nuclear Modification Factor

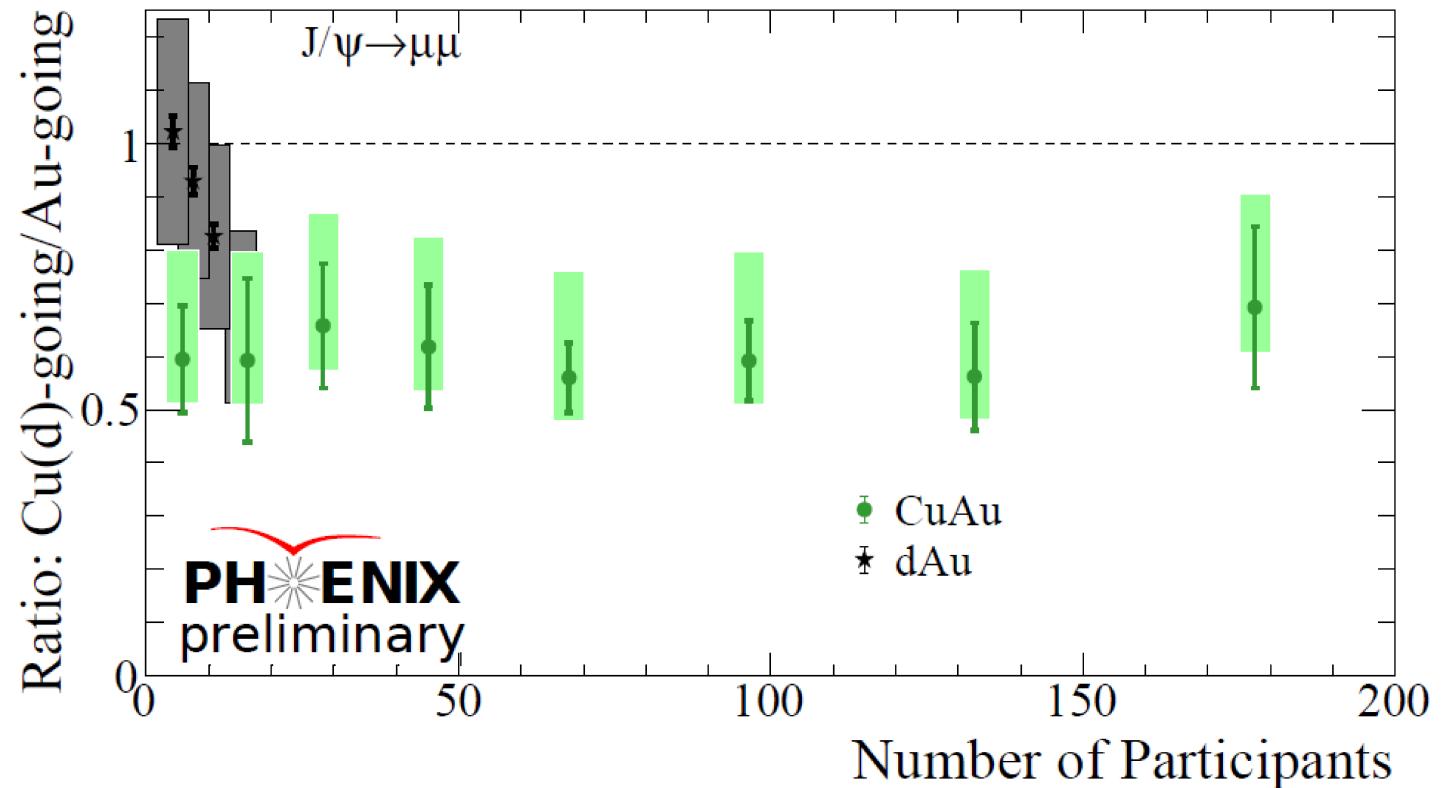
- One example of CNM effects
  - Can partially explain forward / backward difference
  - Final state effects must account for additional suppression
- Similar CNM observations in AuAu collisions



- Model:
  - 4mb break-up cross-section
    - Best describes dAu data
  - Center line → best EPS09 fit
    - Band limits → outer limit of EPS09 nPDFs
  - Linear thickness dependence on shadowing
    - No centrality dependence

# Relative suppression

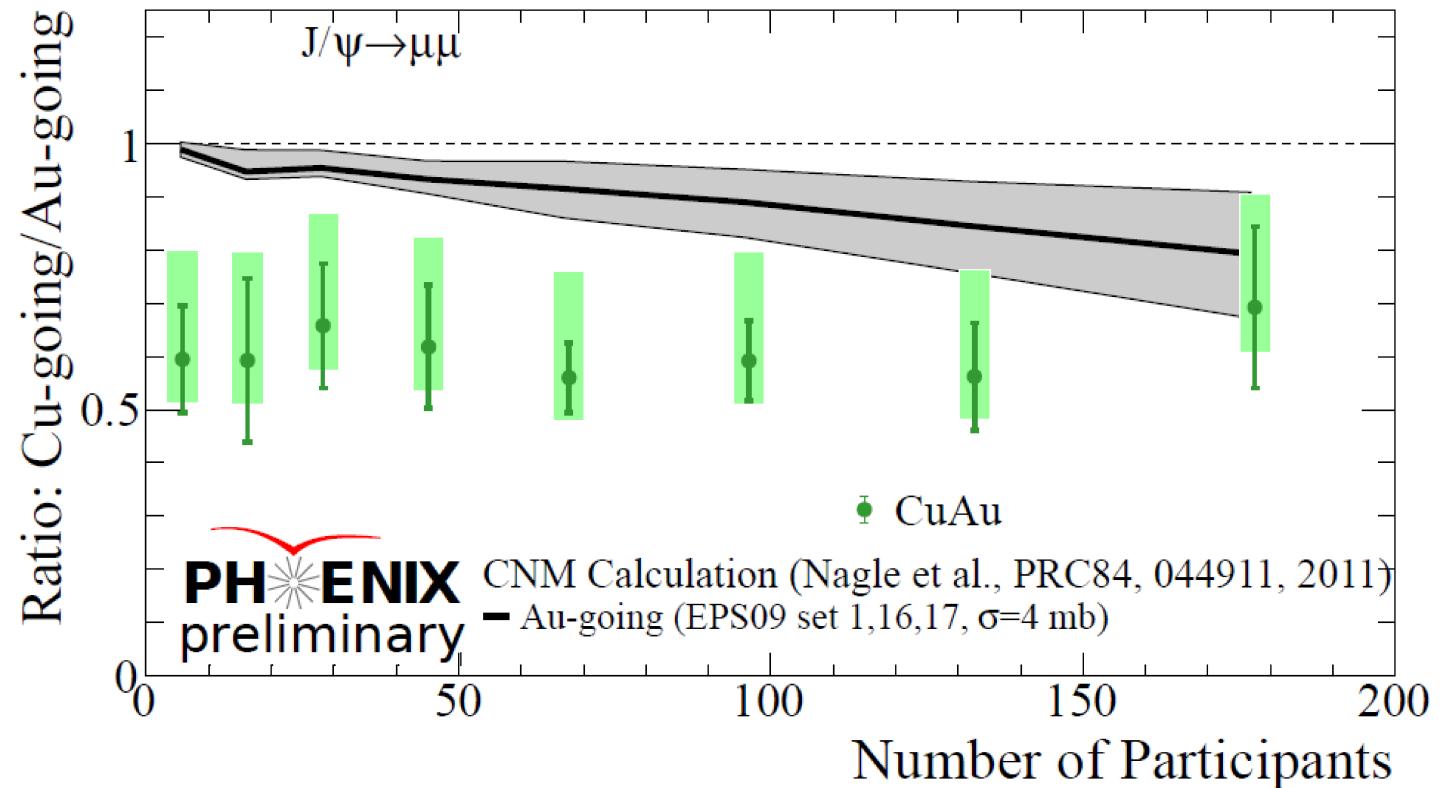
- Ratios of yields at fixed centrality
- Relative suppression observed forward/backward
- Centrality-independent



Presents a challenge to theories trying to describe the data

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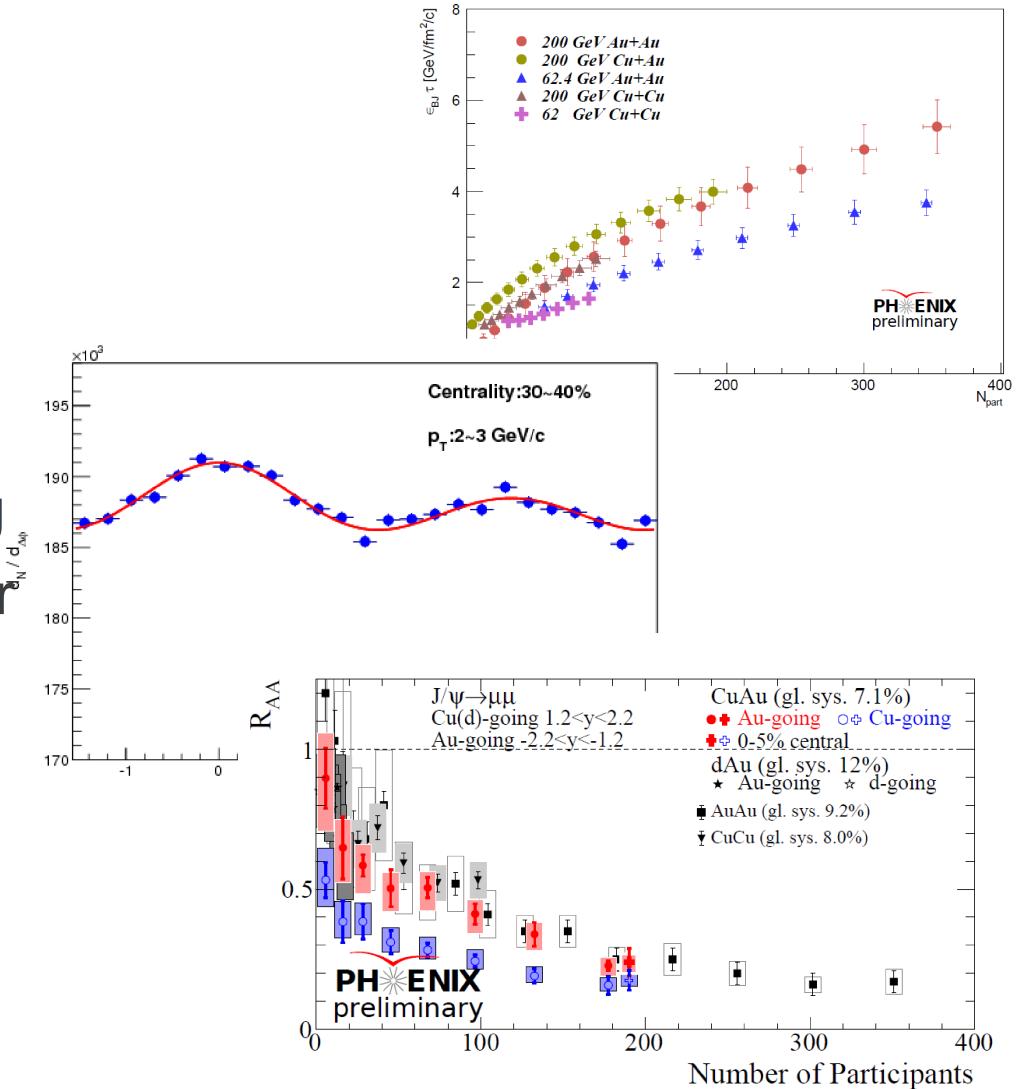


Presents a challenge to theories trying to describe the data

# Summary

## First measurements of CuAu collisions at RHIC

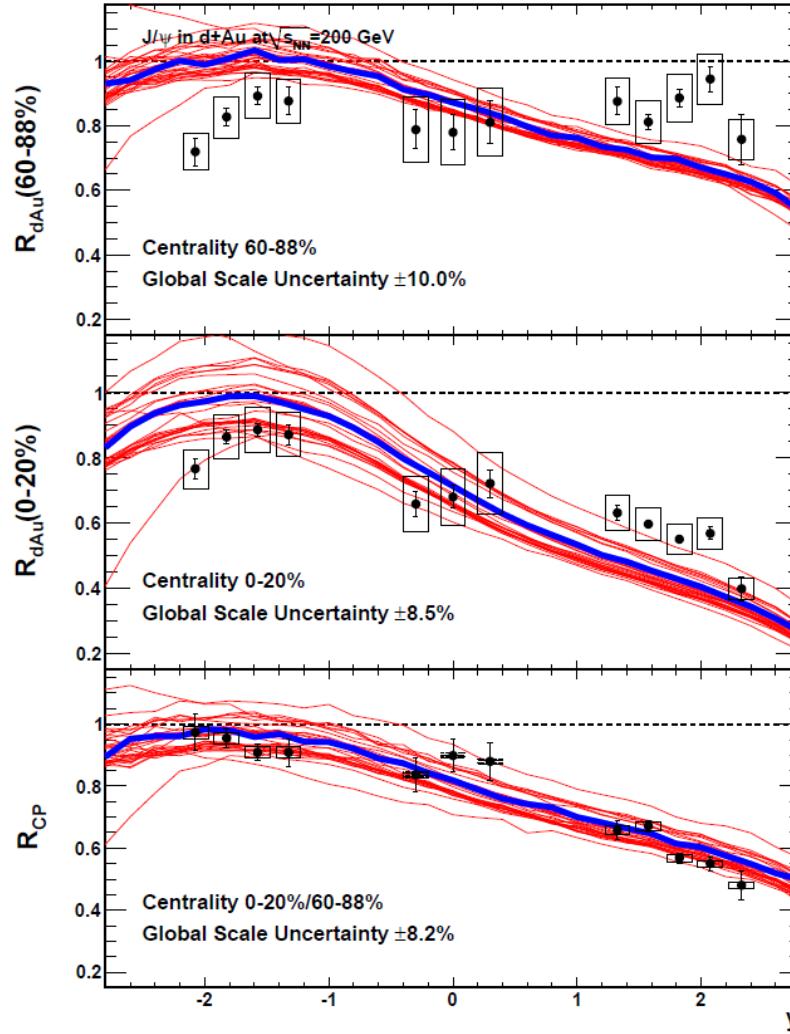
- Higher energy density measured
- Finite  $v_1$  measured along Au-going direction (with respect to spectator plane)
  - No significant  $v_3$
- Stronger suppression observed in forward direction for  $J/\psi$



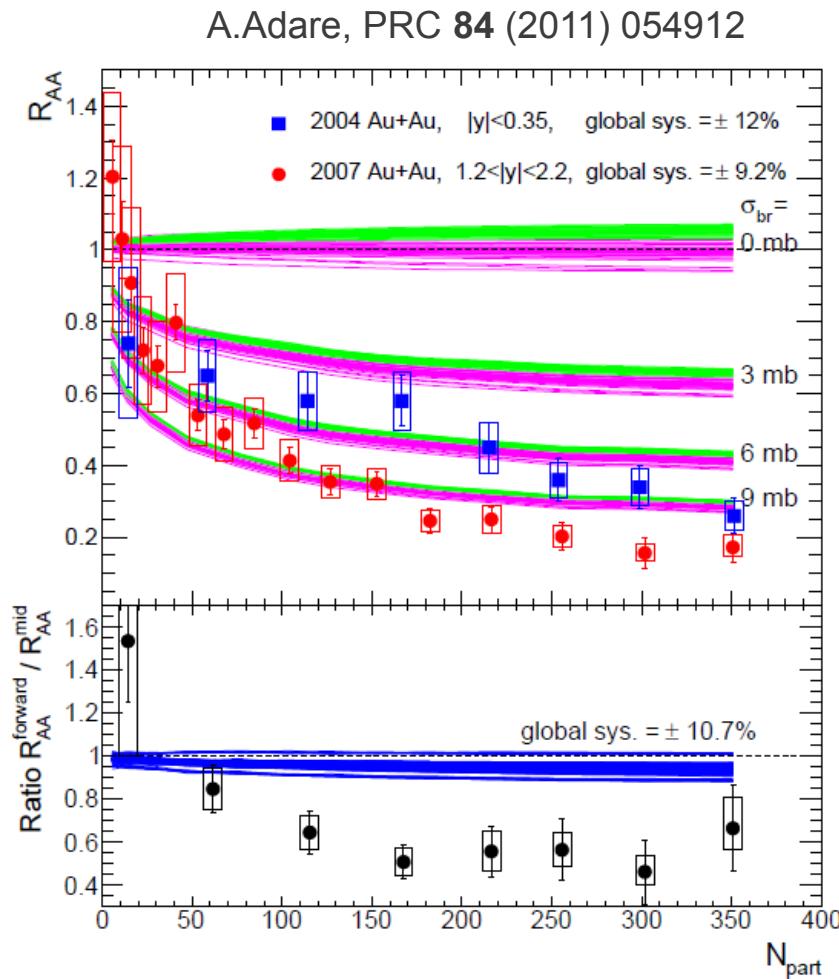
# *Auxiliary Slides*

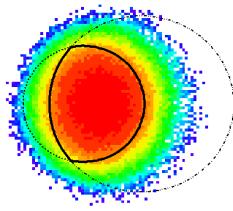
# Model Comparison to dAu

J.Nagle et al, PRC 84 (2011) 044911



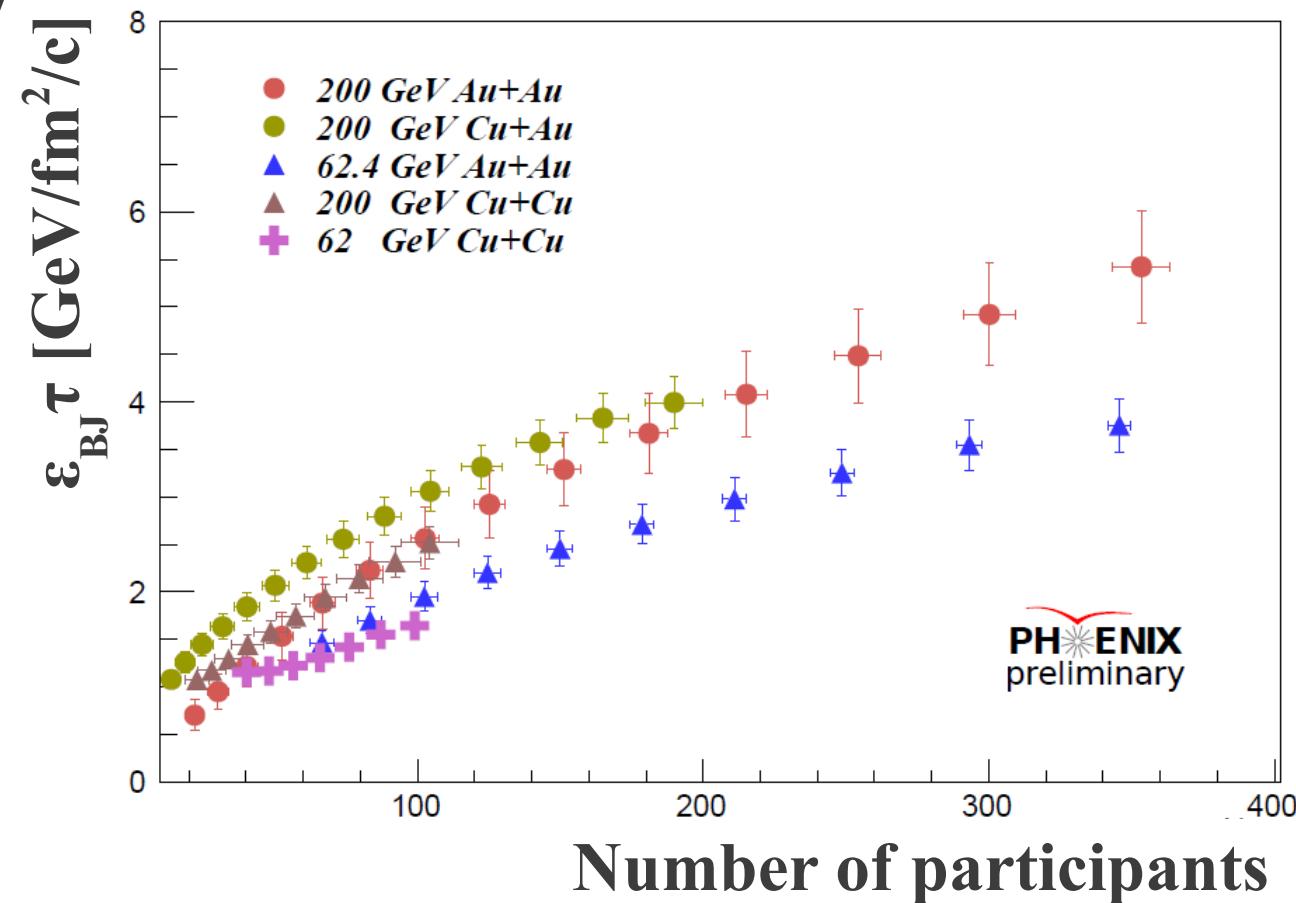
# Model Comparison to AuAu





# Energy density

- Bjorken energy density ( $\varepsilon_{\text{BJ}} \tau$ ) independent of collision system
  - At the same  $N_{\text{part}}$
  - Higher CuAu energy density in central collisions reflects larger **core** at the same  $N_{\text{part}}$



# Energy density

- Highest energy density produced at RHIC recently observed in UU collisions

