System Size and Energy Dependence of Elliptical Flow

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For the PHOBOS collaboration

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PHOBOS Collaboration (Aug 2005)



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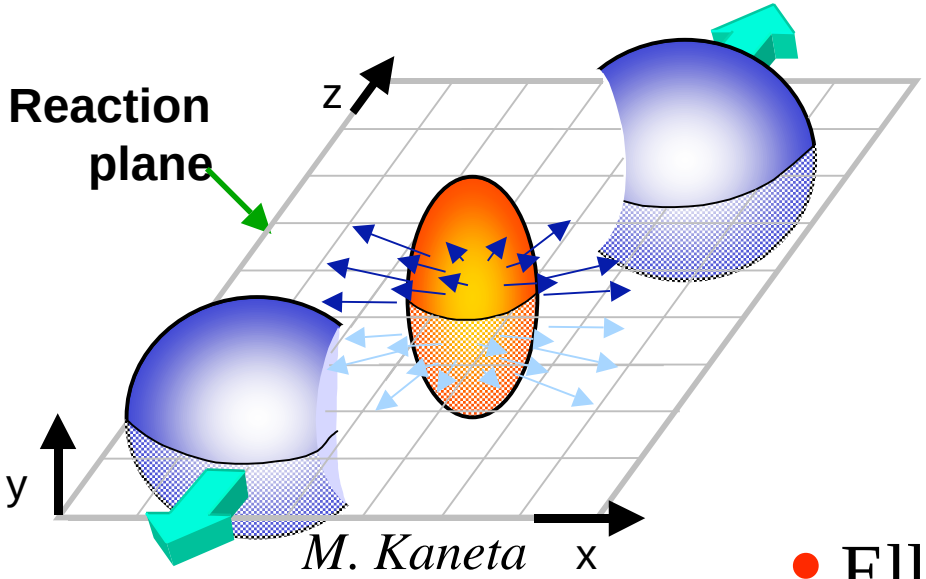
Motivation For Studying Flow



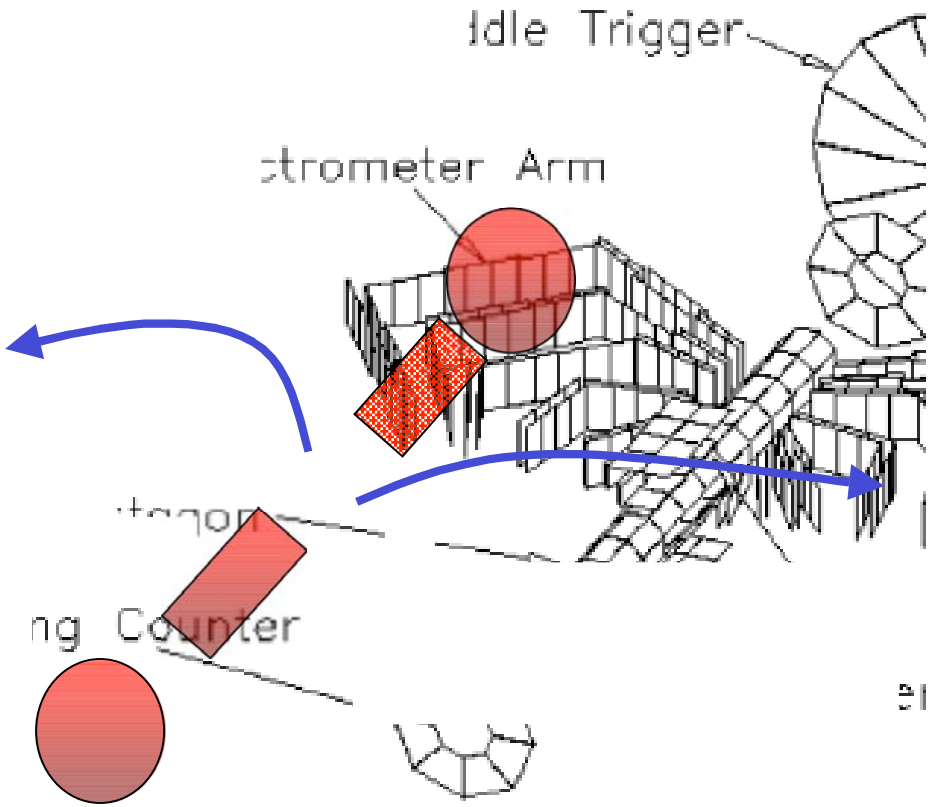
- Flow probes the very early thermalization of the system

- Elliptic flow as a function of:
  - Energy
  - Pseudorapidity
  - Centrality
  - Momentum

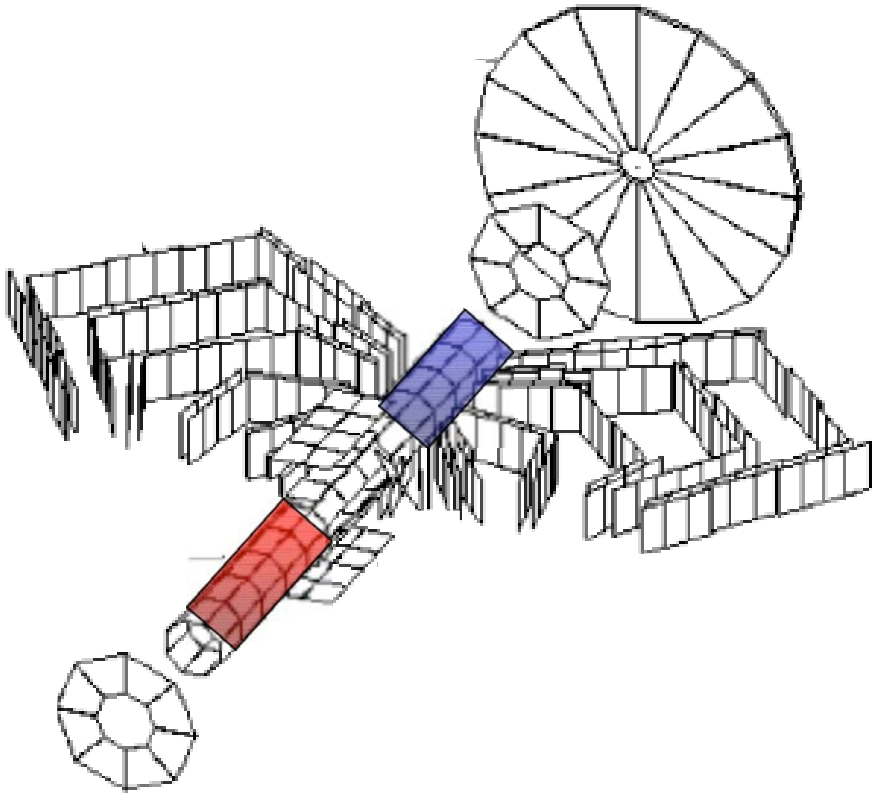
Can be used to constrain theory.

Two Flow Measurement Methods

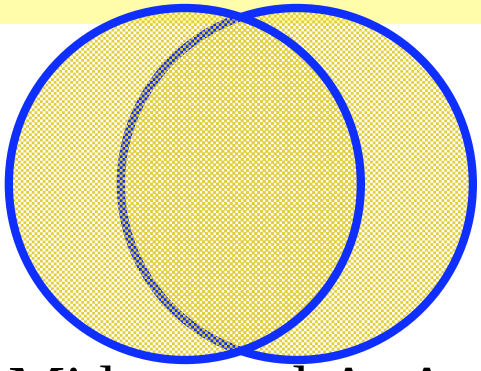
Track Based Method



Hit Based Method

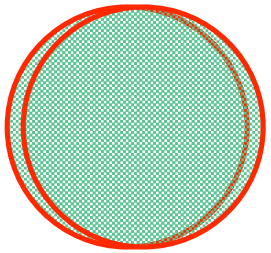


Motivation for Comparing Species



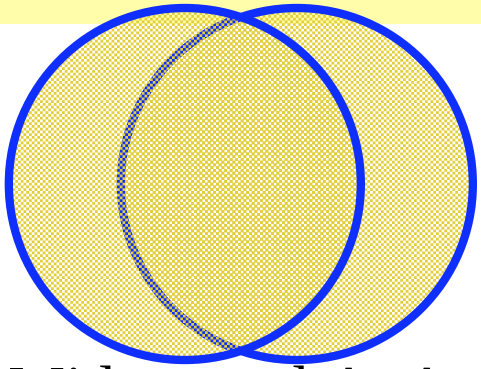
Mid-central AuAu collision

roughly same number of participants



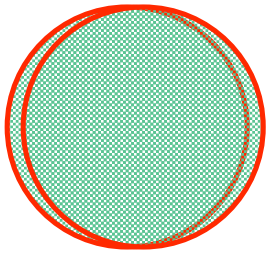
Central CuCu collision

Motivation for Comparing Species



Mid-central AuAu collision

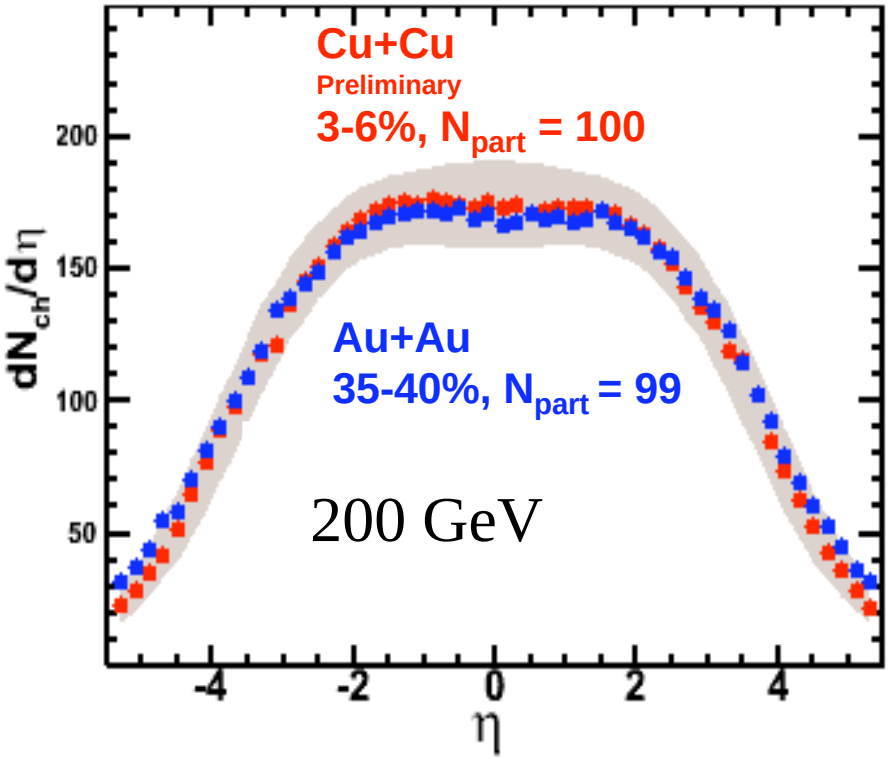
roughly same number of participants



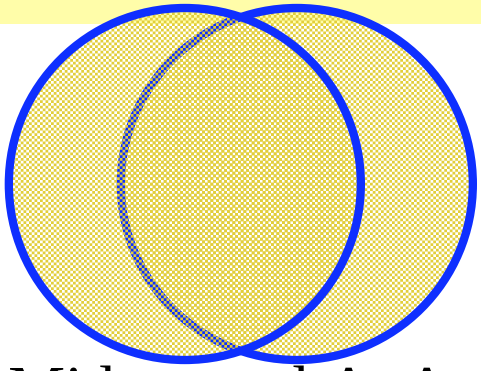
Central CuCu collision

Some observables scale with number of participants

Similar dN/dη

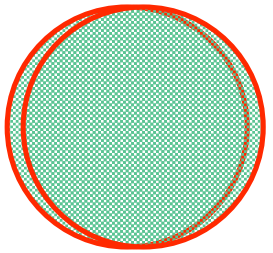


Motivation for Comparing Species

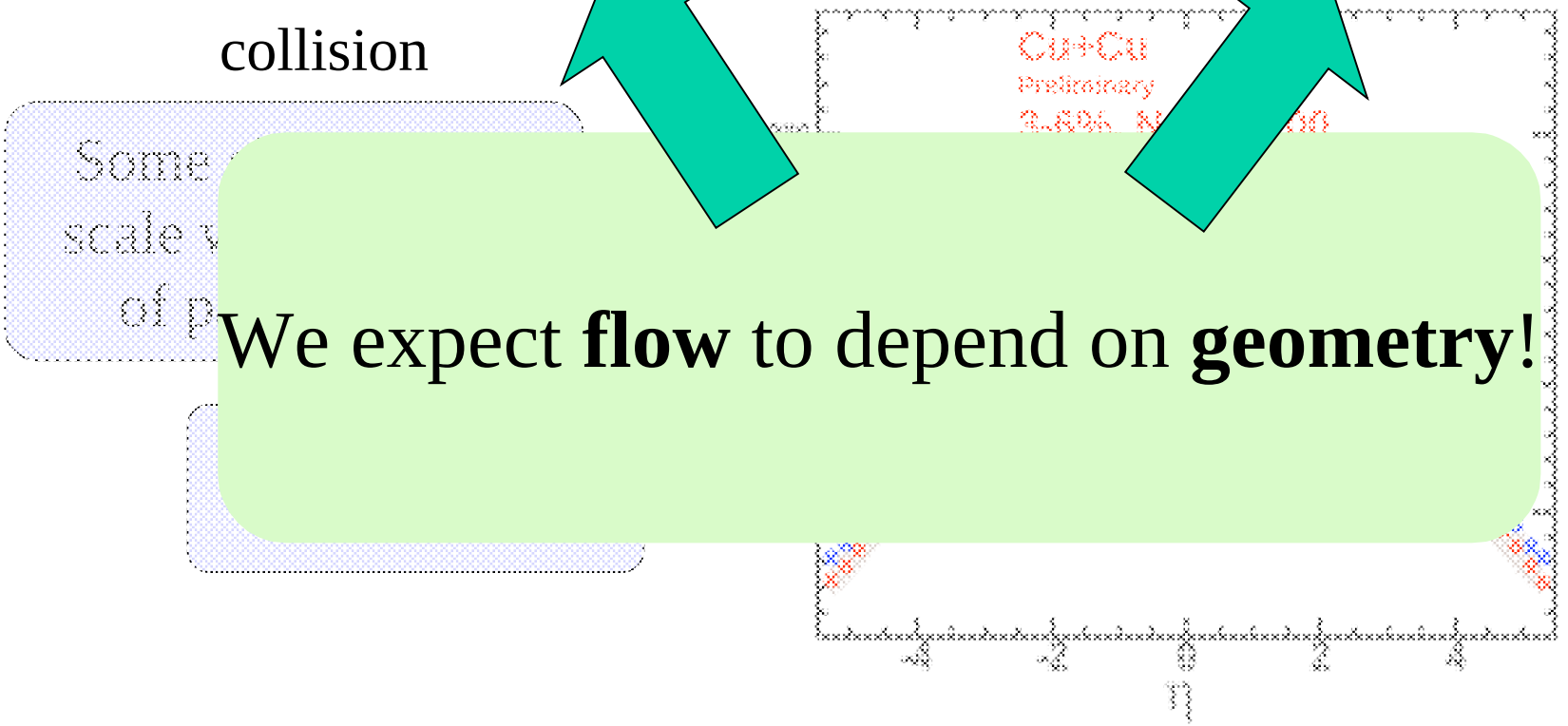


Mid-central AuAu collision

roughly same number of participants

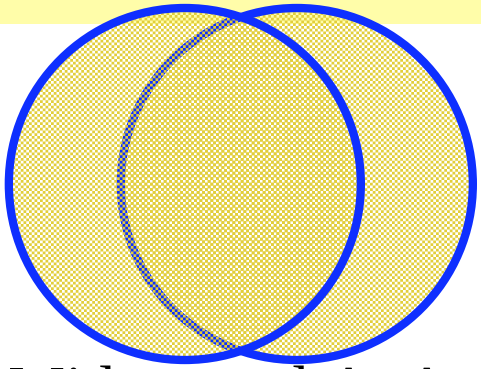


Central CuCu collision



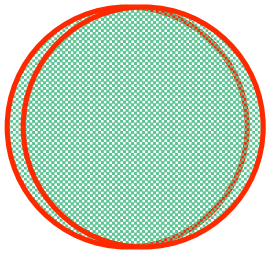
We expect **flow** to depend on **geometry**!

Motivation for Comparing Species



Mid-central AuAu collision

roughly same number of participants



Central CuCu collision

Elliptical

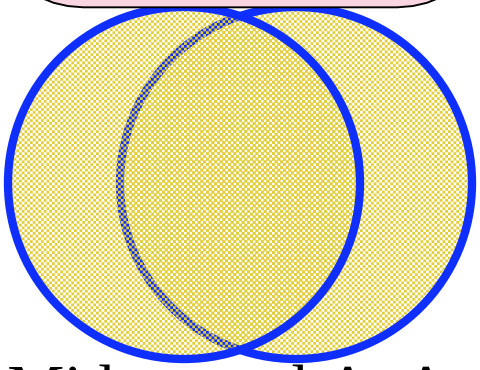
Circular

We expect flow to depend on geometry!

Using two species lets us change the geometry while holding the number of participants constant

Eccentricity: A measure of "Geometry"

Elliptical

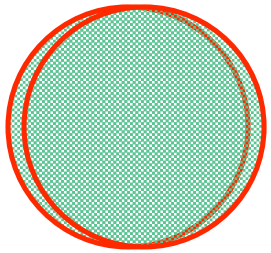


Mid-central AuAu collision

We need a way to quantify the geometry of the participating nucleons

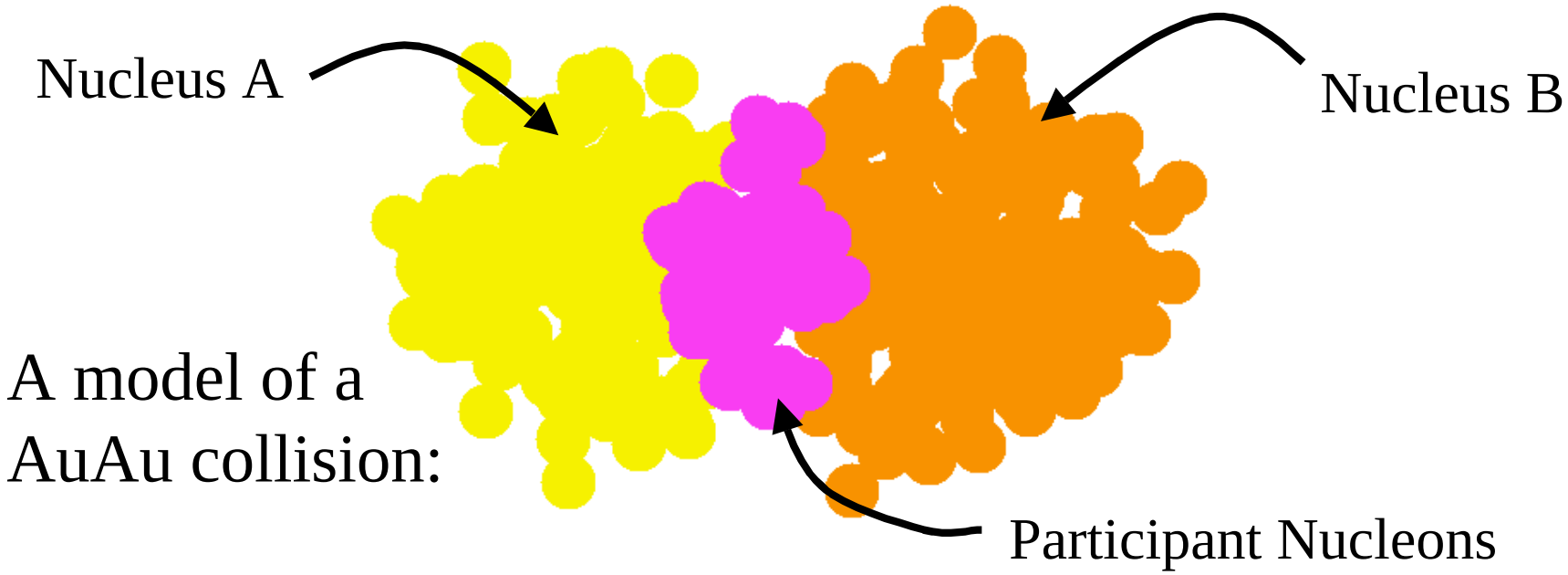
The shape is characterized by the **eccentricity** (ε)

Circular

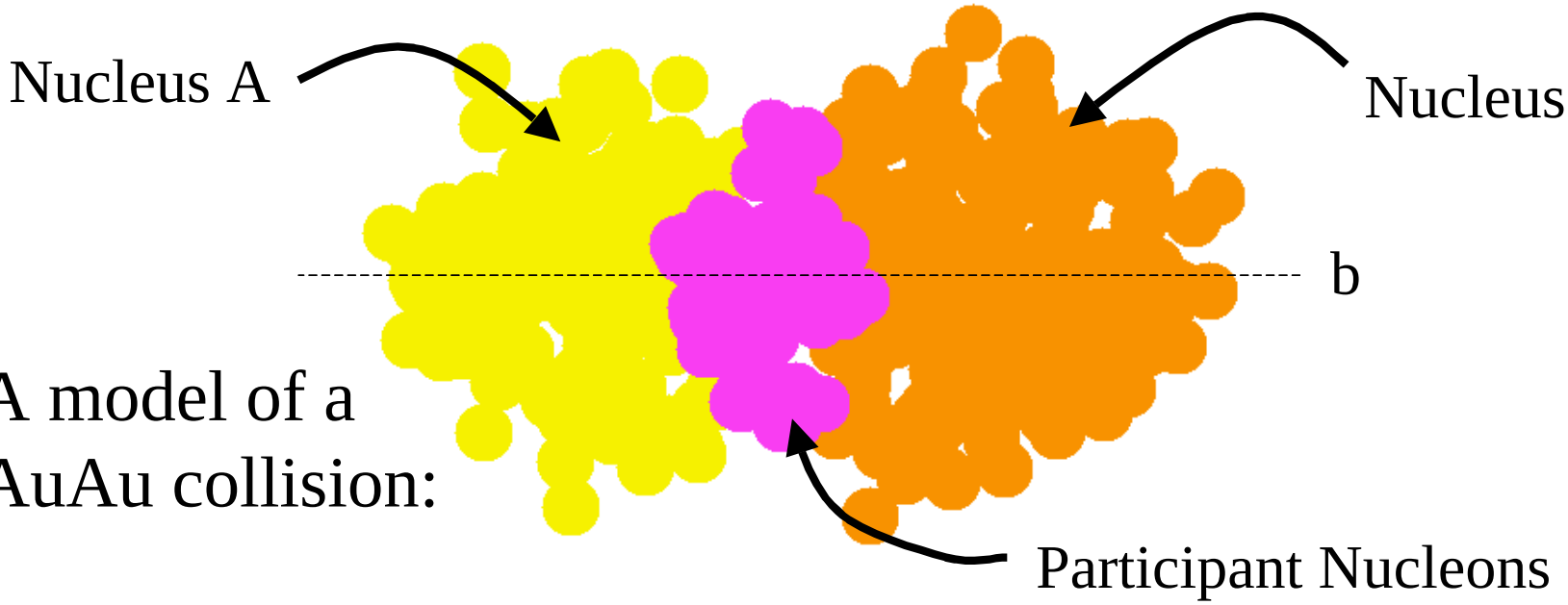


Central CuCu collision

Eccentricity: A measure of “Geometry”



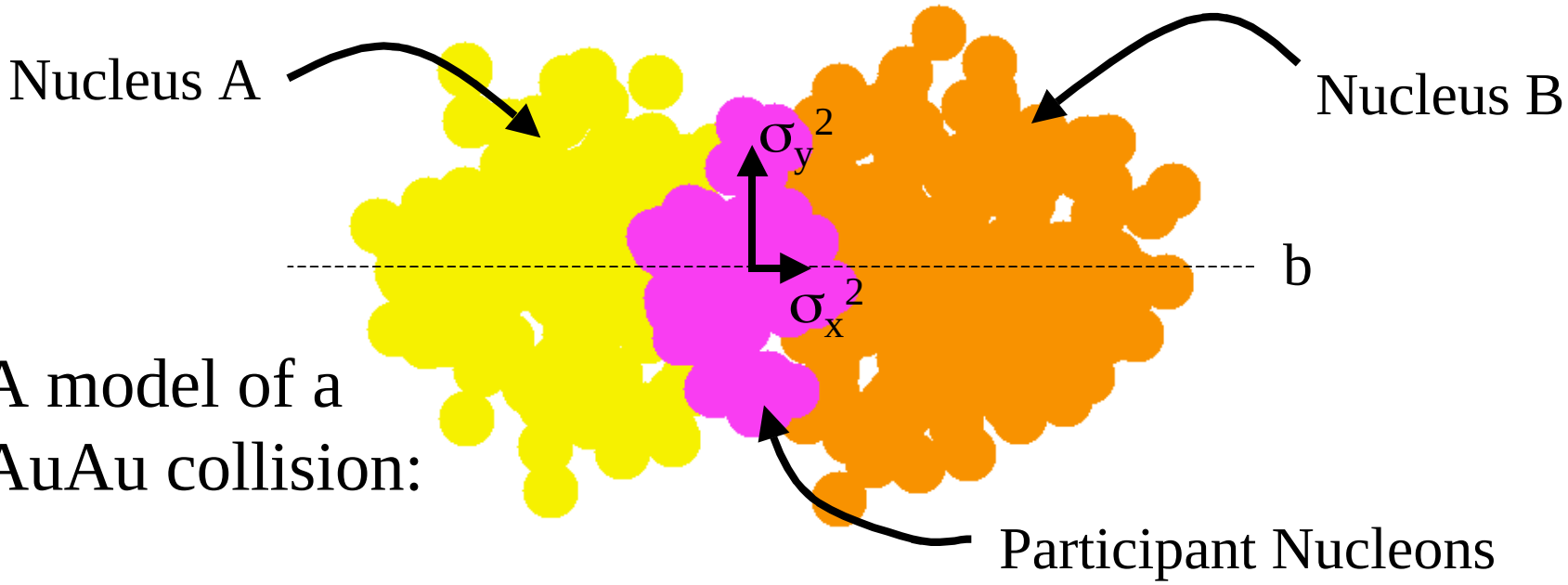
Eccentricity: A measure of “Geometry”



A model of a AuAu collision:

Using the impact parameter as the x-axis

Eccentricity: A measure of "Geometry"

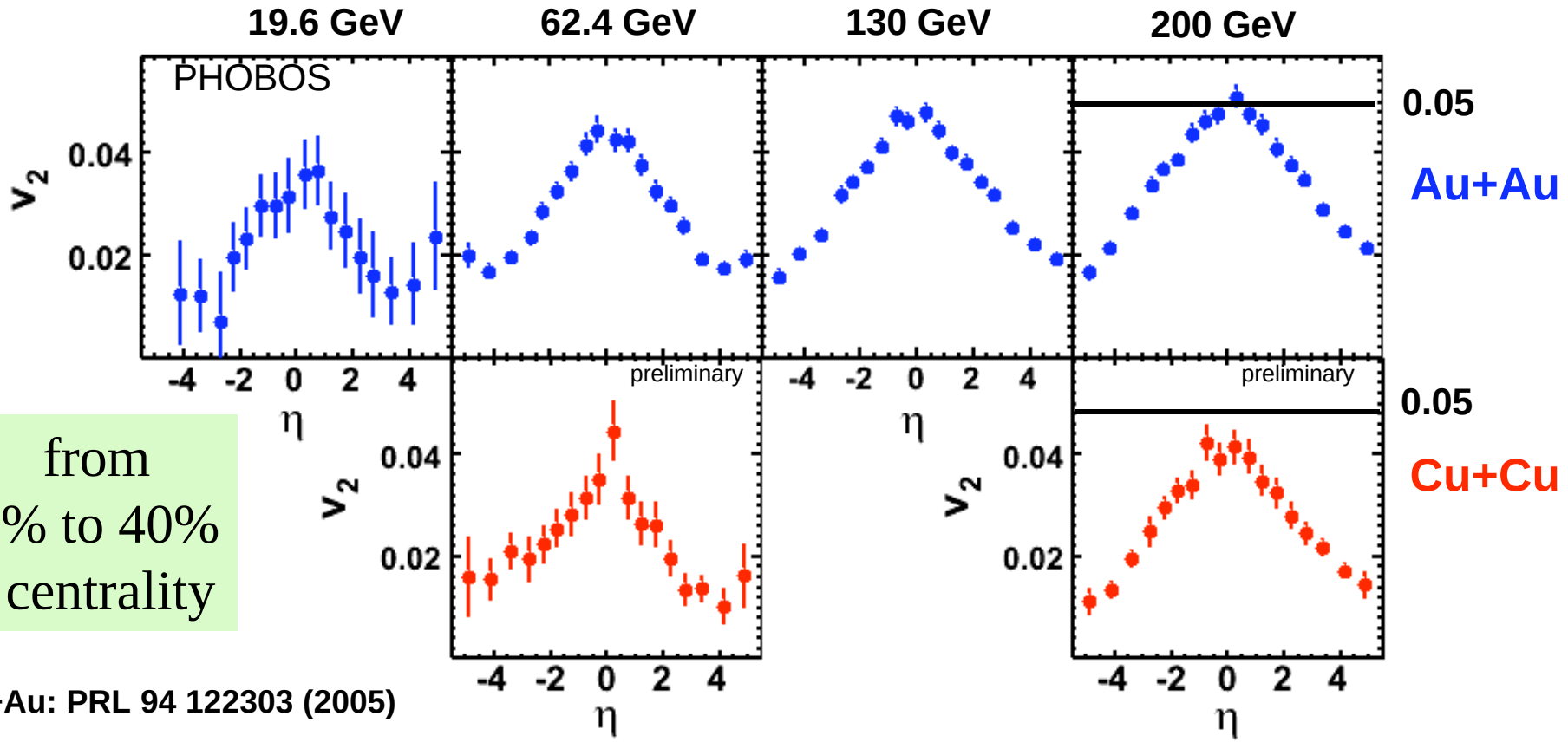


A model of a AuAu collision:

Using the impact parameter as the x-axis, we define the standard eccentricity using the widths of the distribution in the x and y directions

$$\varepsilon = \frac{\sigma_y^{\,2} - \sigma_x^{\,2}}{\sigma_y^{\,2} + \sigma_x^{\,2}}$$

The Phobos Elliptic Flow Data Set

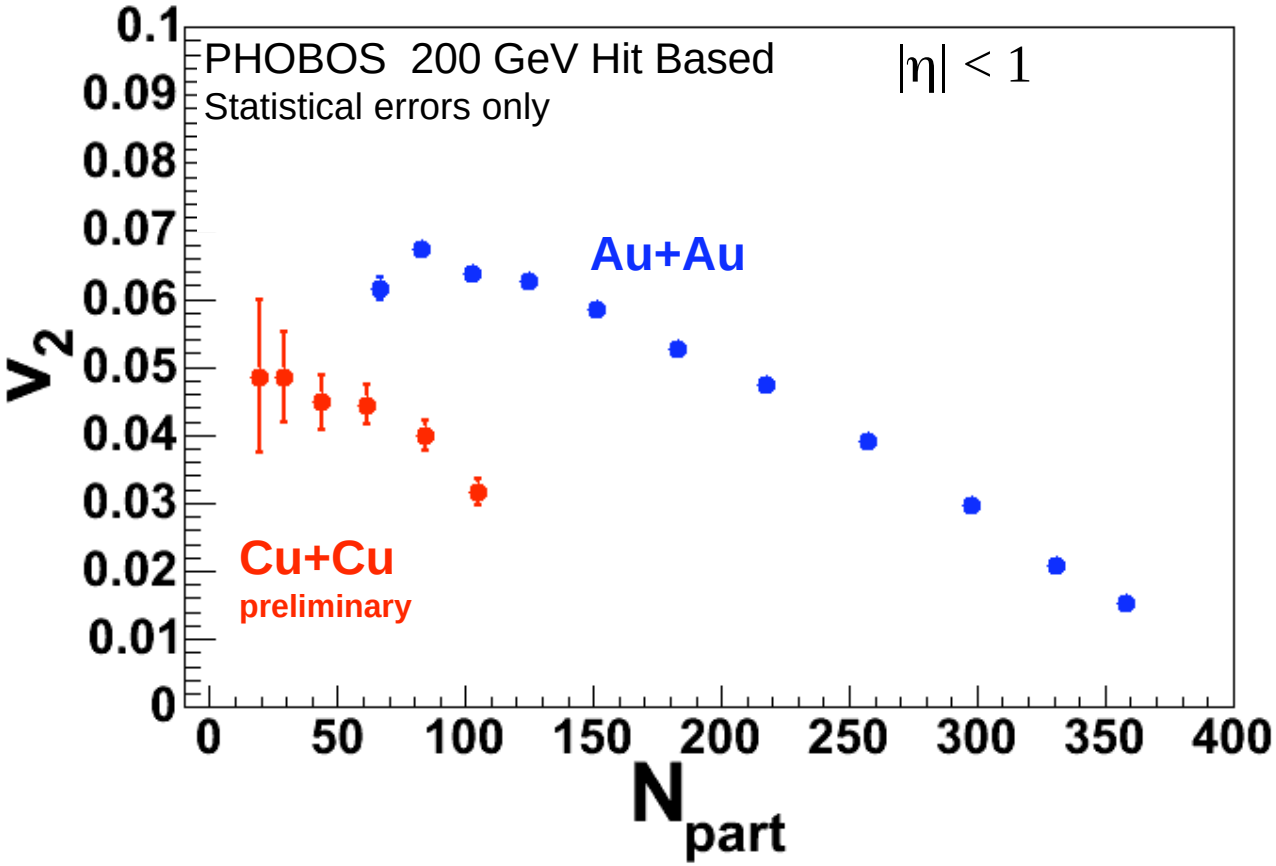


from 0% to 40% centrality

Au+Au: PRL 94 122303 (2005)

Sizable v_2 for Cu+Cu

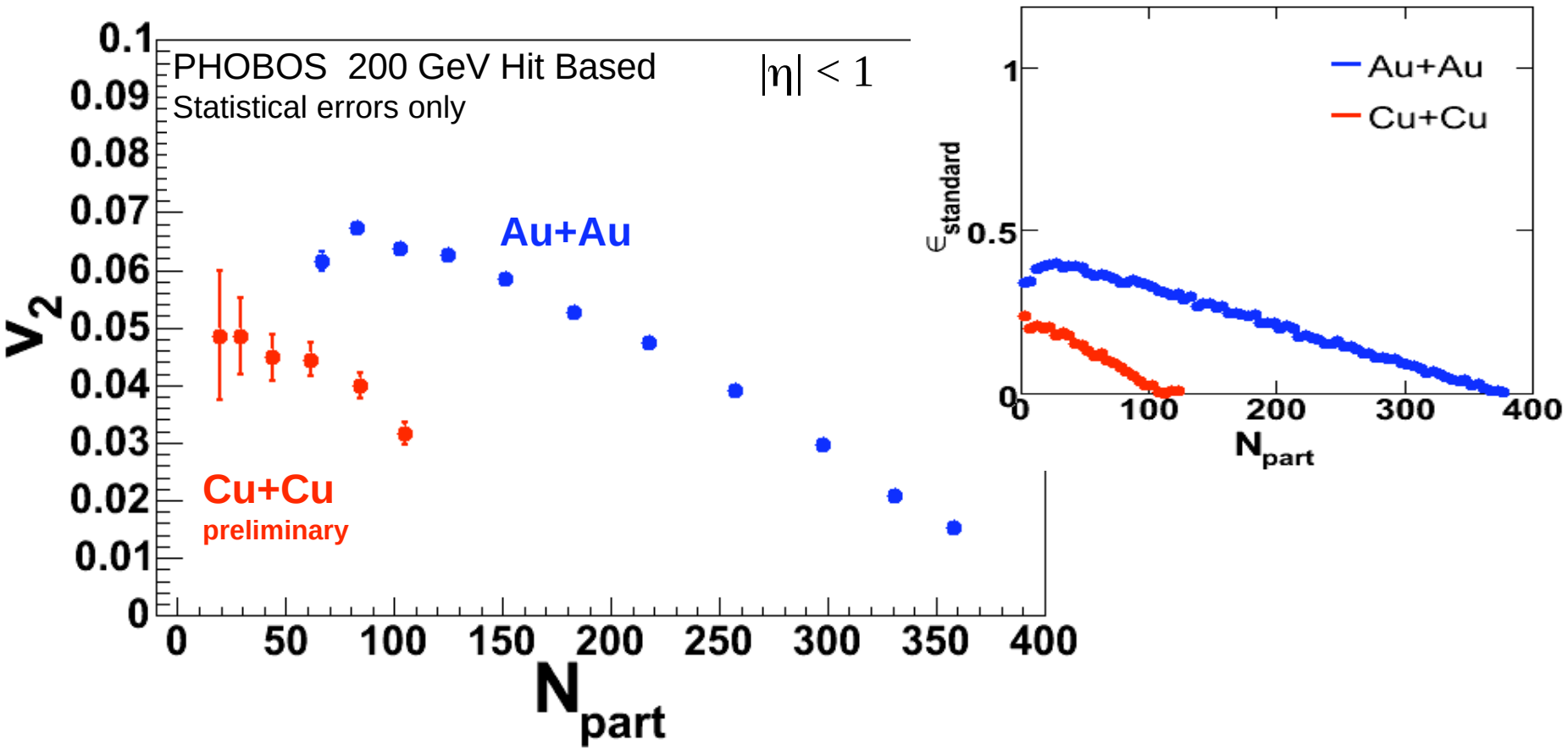
The Data: Something's Amiss…



Elliptic flow is high even for the most central bin in Cu+Cu

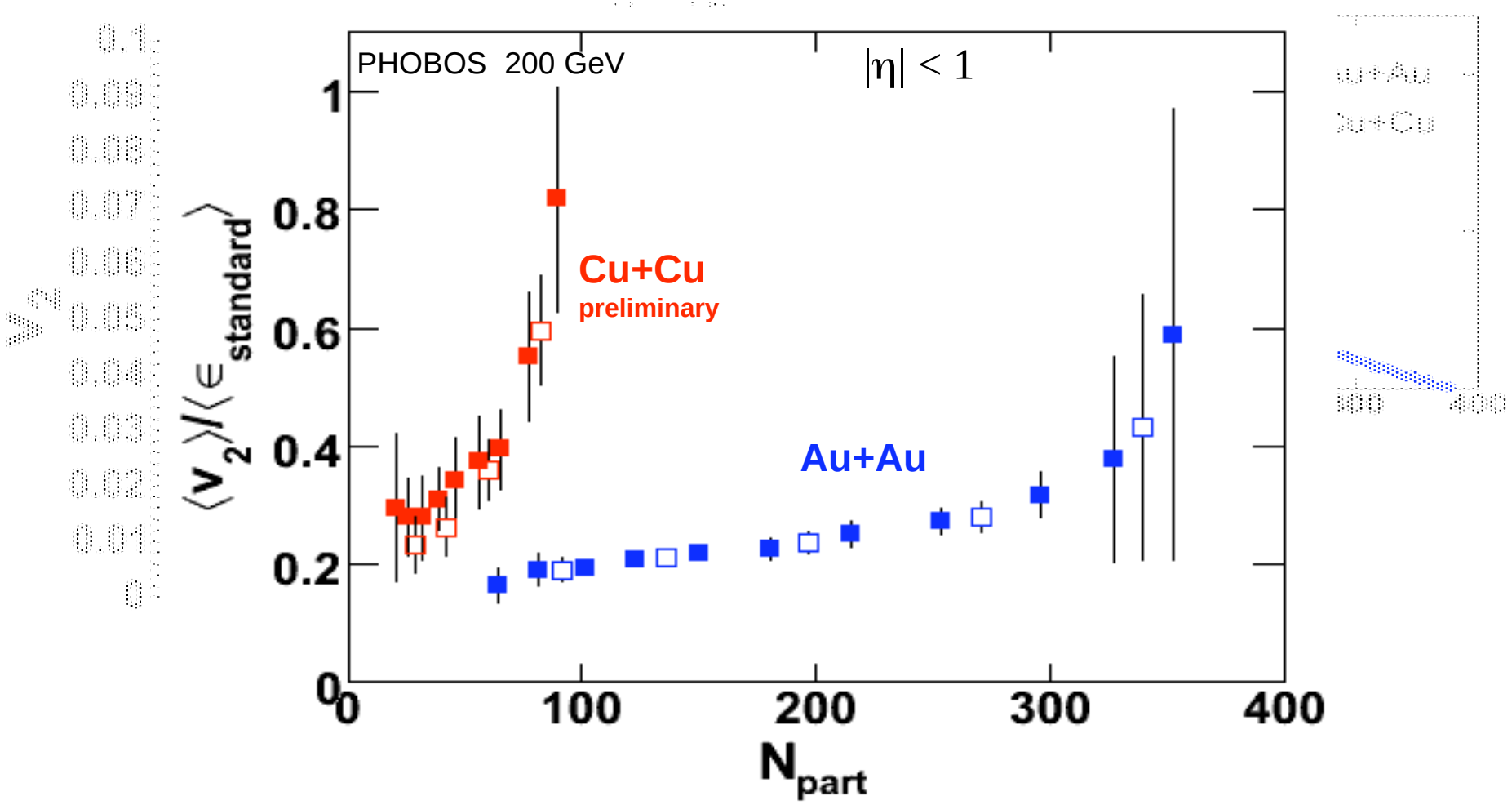
How does it relate to the eccentricity?

The Data: Something's Amiss…



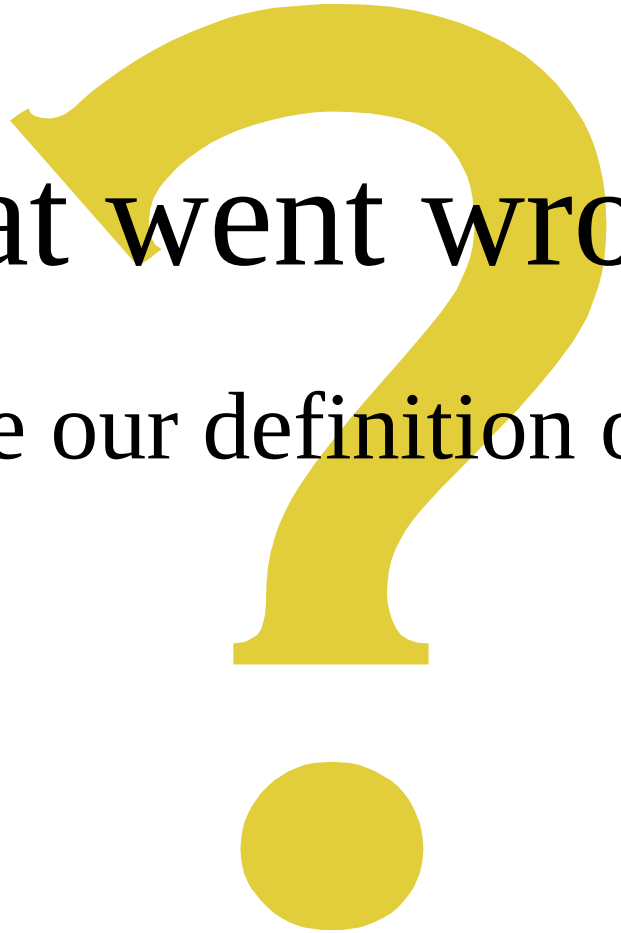
For CuCu, the eccentricity drops to zero by N_{Part} of 100

The Data: Something's Amiss…



Dividing by the eccentricity shows no connection between the two species.

The Data: Something's Amiss…



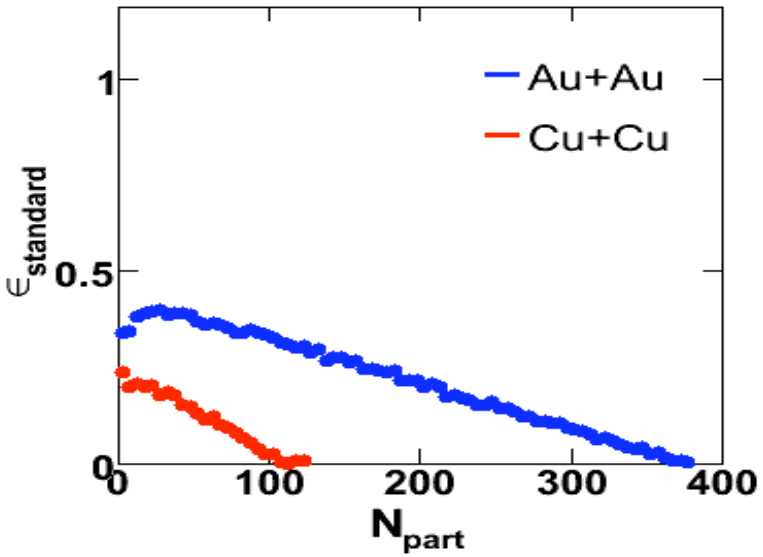
What went wrong?

We reexamine our definition of eccentricity

Reexamining Eccentricity

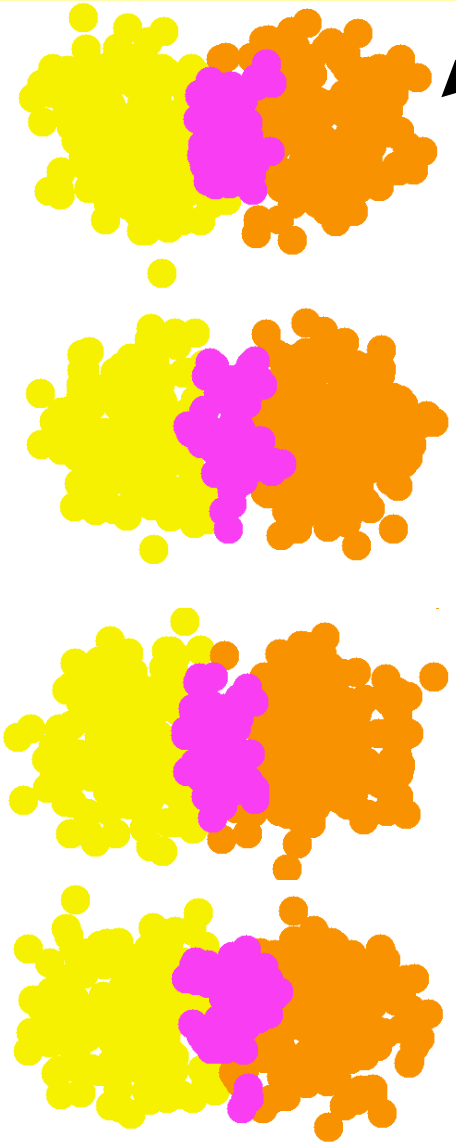
Eccentricity is not directly measurable

We use a Glauber model to relate eccentricity to our N_{Part} bins.



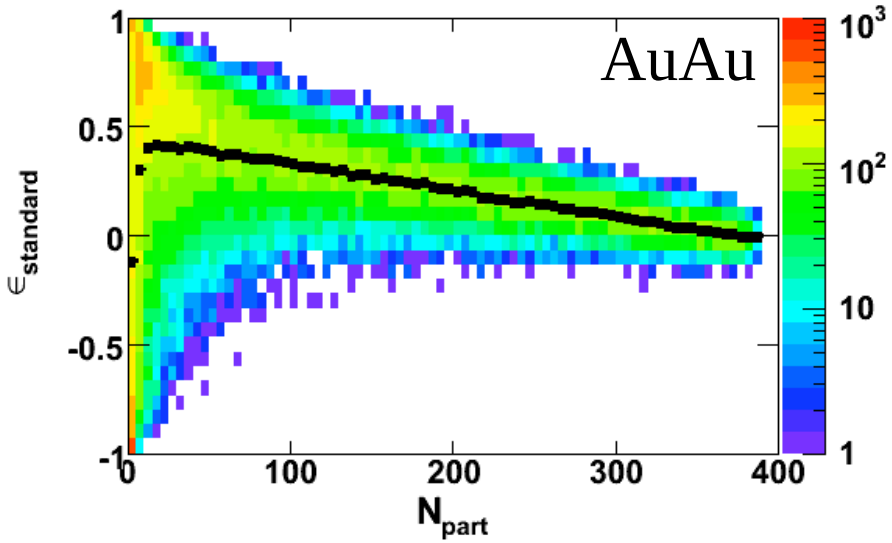
What goes into making this plot…?

Reexamining Eccentricity



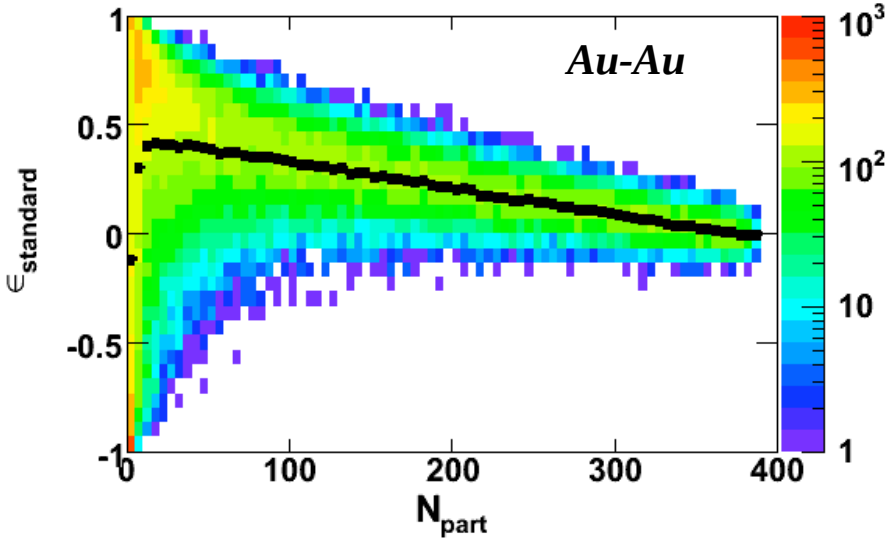
AuAu collisions with same N_{Part}

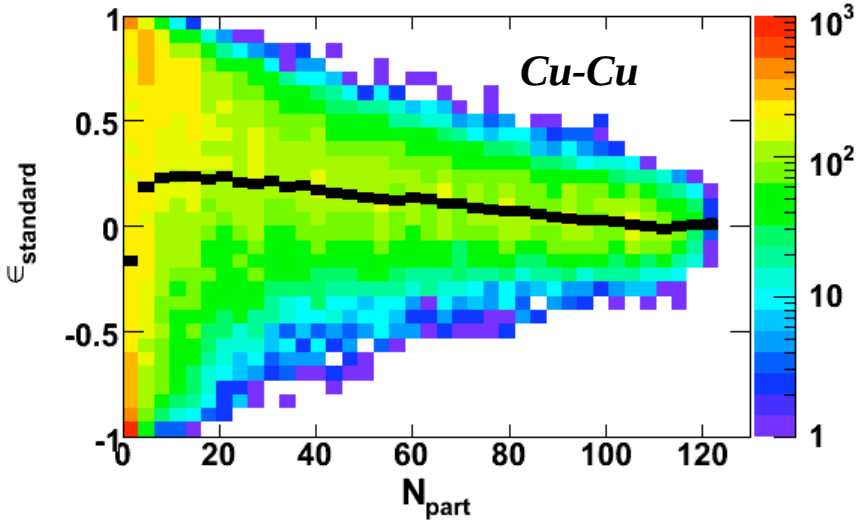
- Glauber collisions are modeled over a range of impact parameters and are sorted by the number of participants.
- An eccentricity distribution is built up for each N_{Part}



- The black line shows the average eccentricity

Reexamining Eccentricity

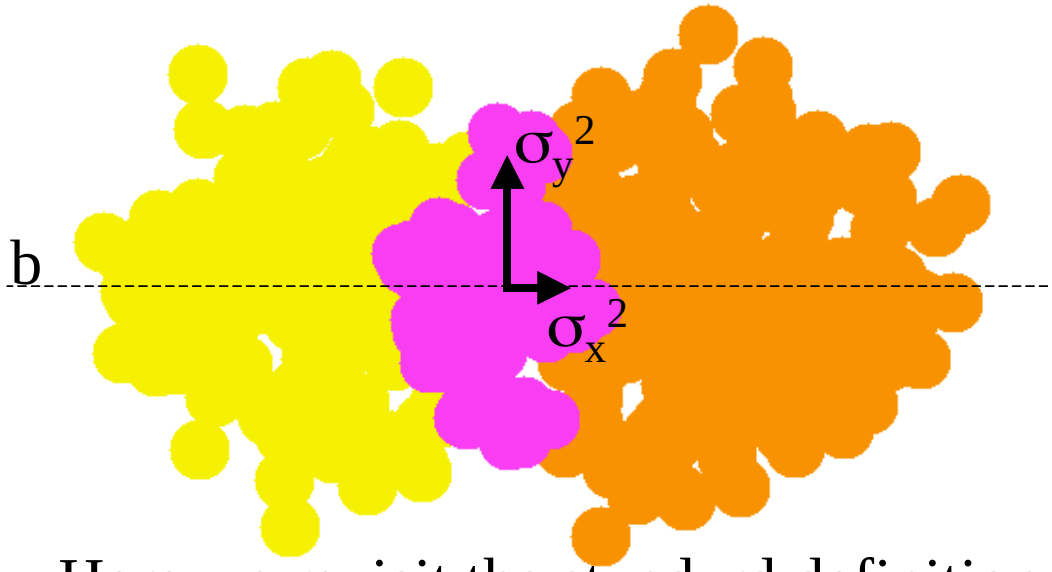




- When we examine the eccentricity distribution for CuCu, it looks much broader than AuAu

- Also, notice that there are many more events with ***negative*** eccentricity.

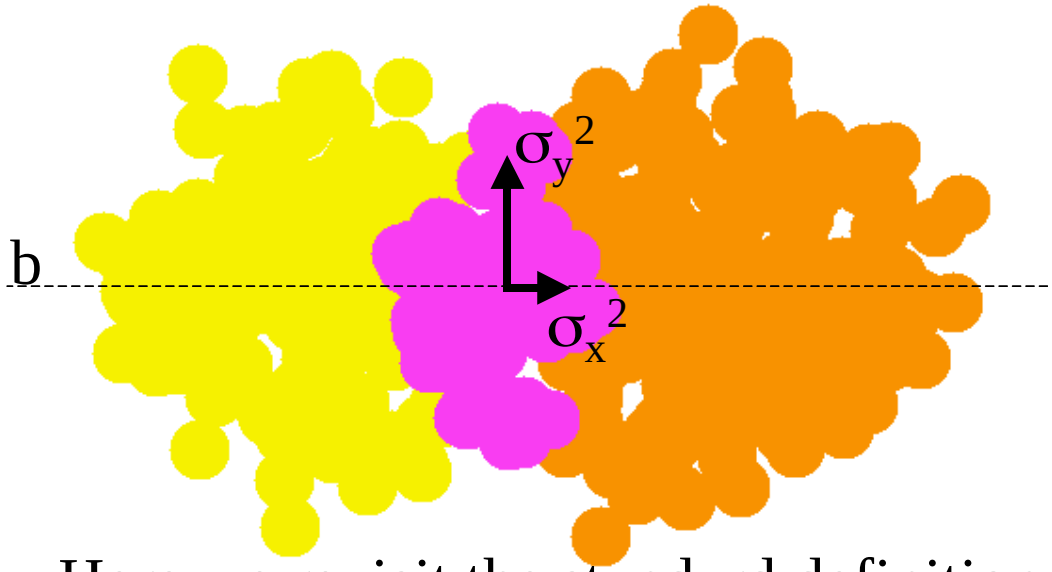
Meaning of Negative Eccentricity



$$\varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$

Here we revisit the standard definition of eccentricity applied to a Gluaber model.

Meaning of Negative Eccentricity



$$\varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$

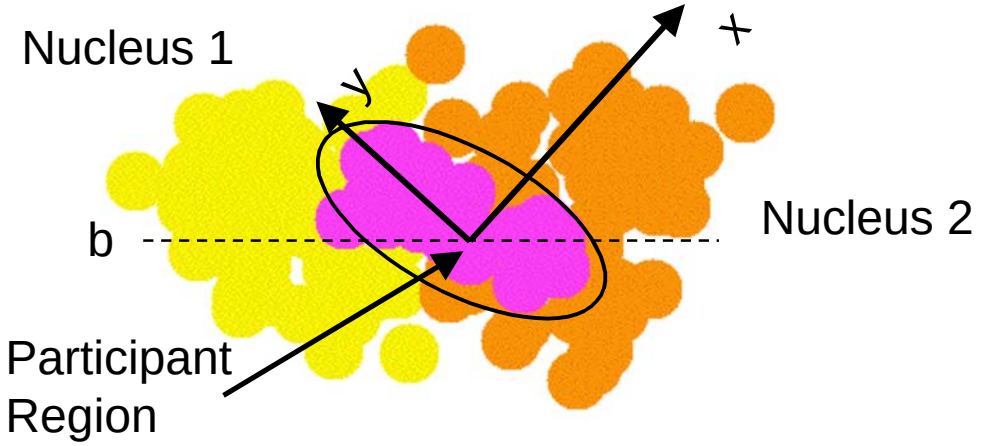
Here we revisit the standard definition of eccentricity applied to a Gluaber model.

Negative eccentricity results when $\sigma_x^2 > \sigma_y^2$, apparently due to fluctuations in the positions of the nucleons.

Because of its smaller size, CuCu is more susceptible to fluctuations

Redefining Eccentricity

One reasonable method is to realign the coordinate system
to maximize the ellipsoidal shape (a principal axis transformation)

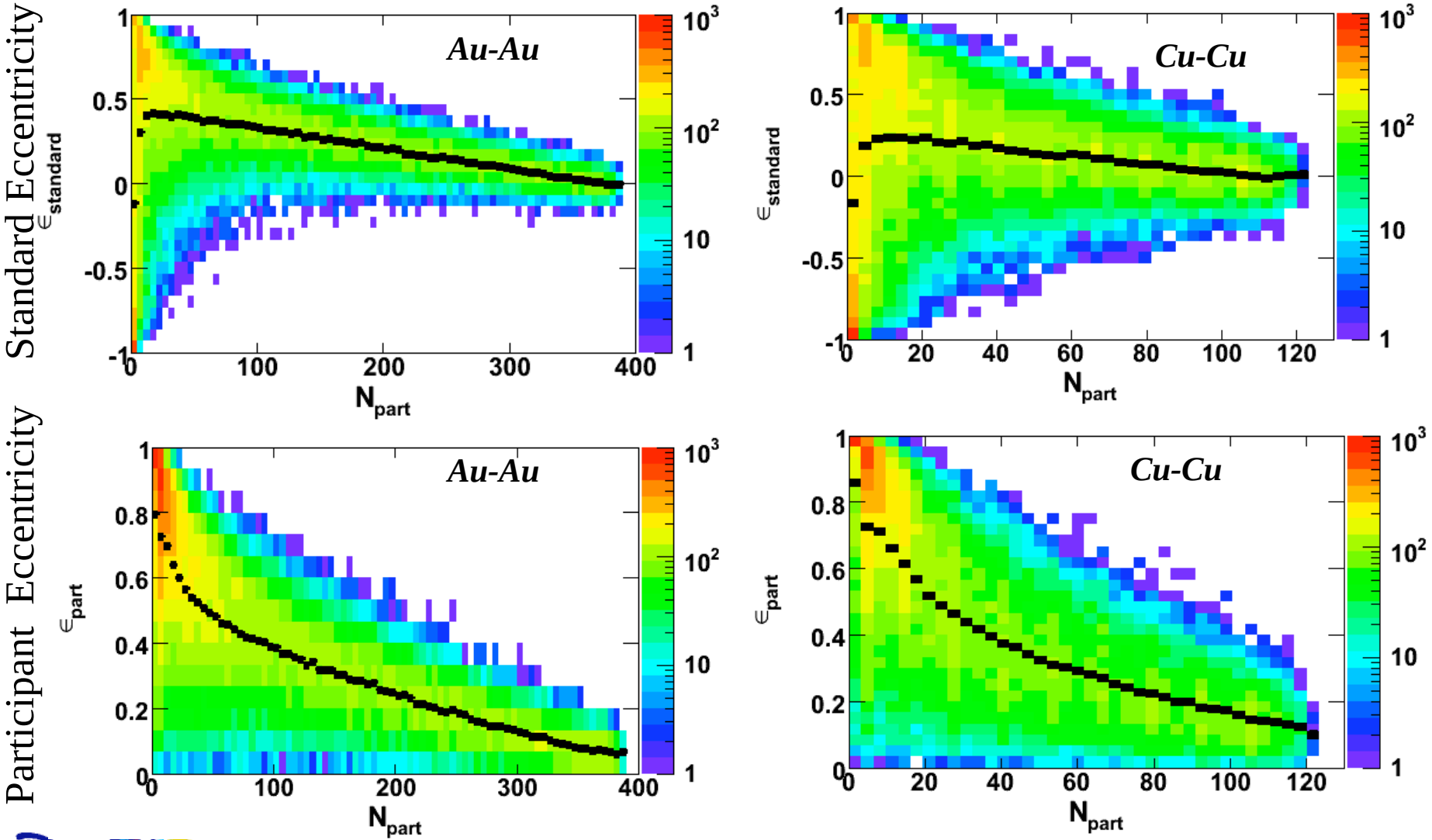


"Participant" eccentricity

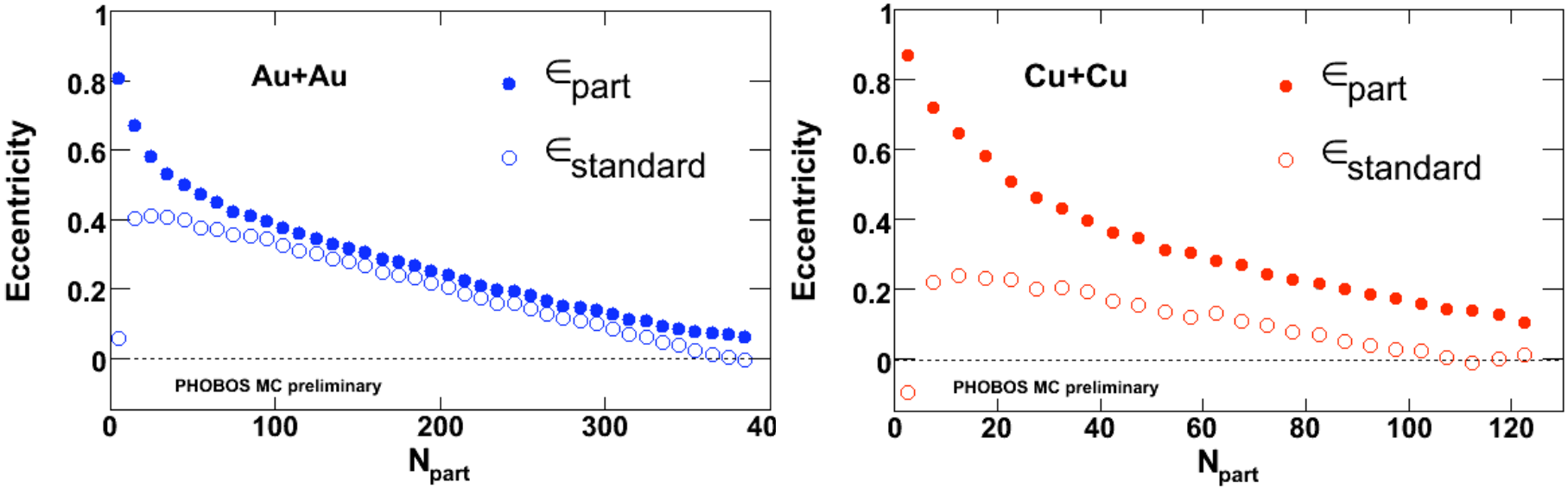
Opposed to "standard" eccentricity

Standard and Participant Eccentricity

Mean eccentricity shown in black



Impact of Eccentricity Fluctuations

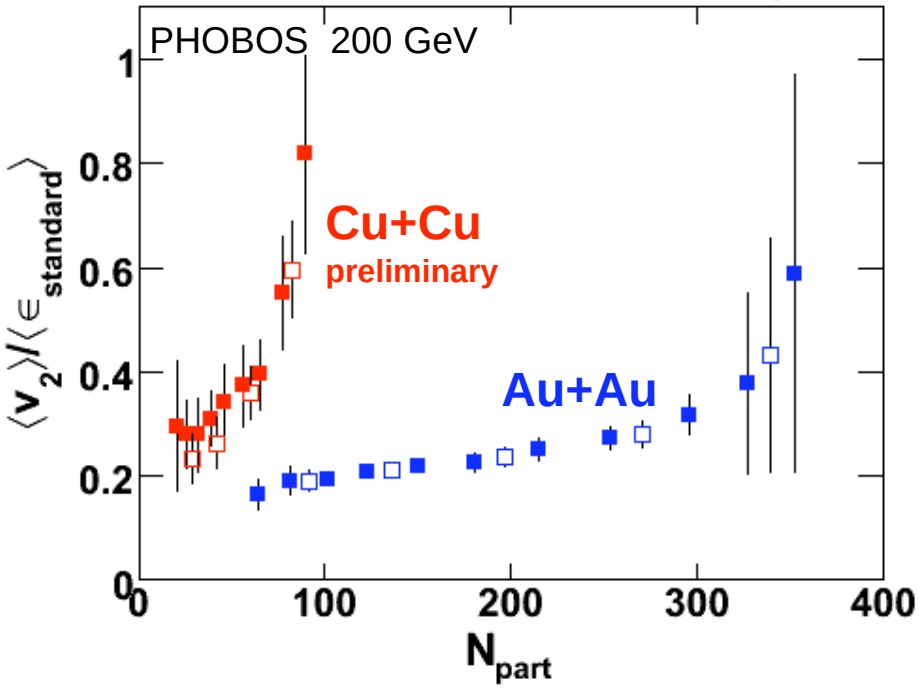


Fluctuations in eccentricity are important for the Cu-Cu system.

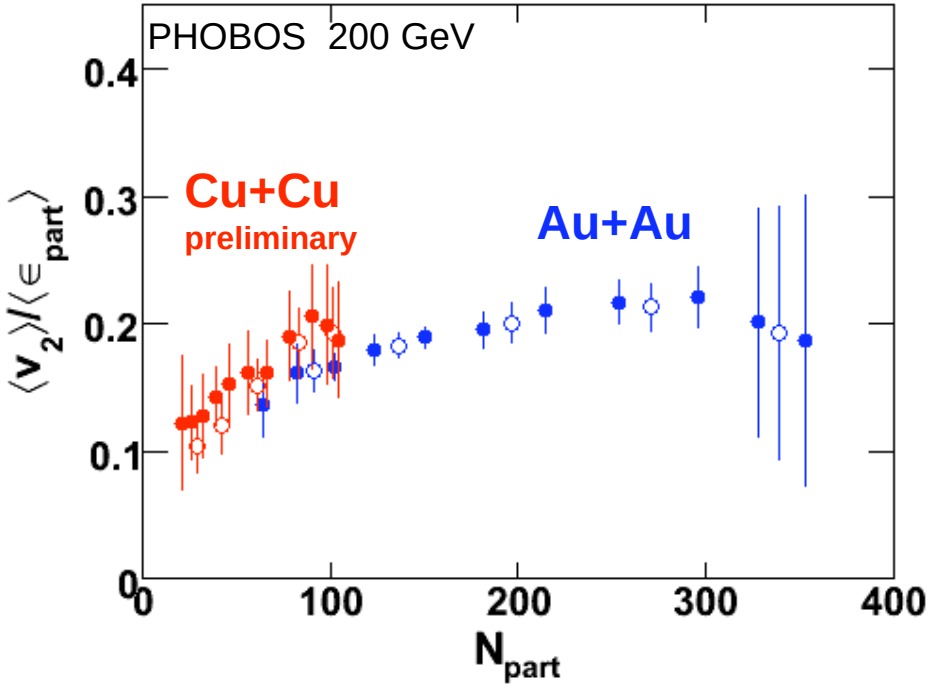
Must use care in doing Au-Au to Cu-Cu flow comparisons.
Eccentricity scaling depends on definition of eccentricity.

Elliptic Flow Puzzle Solved?

Standard Eccentricity



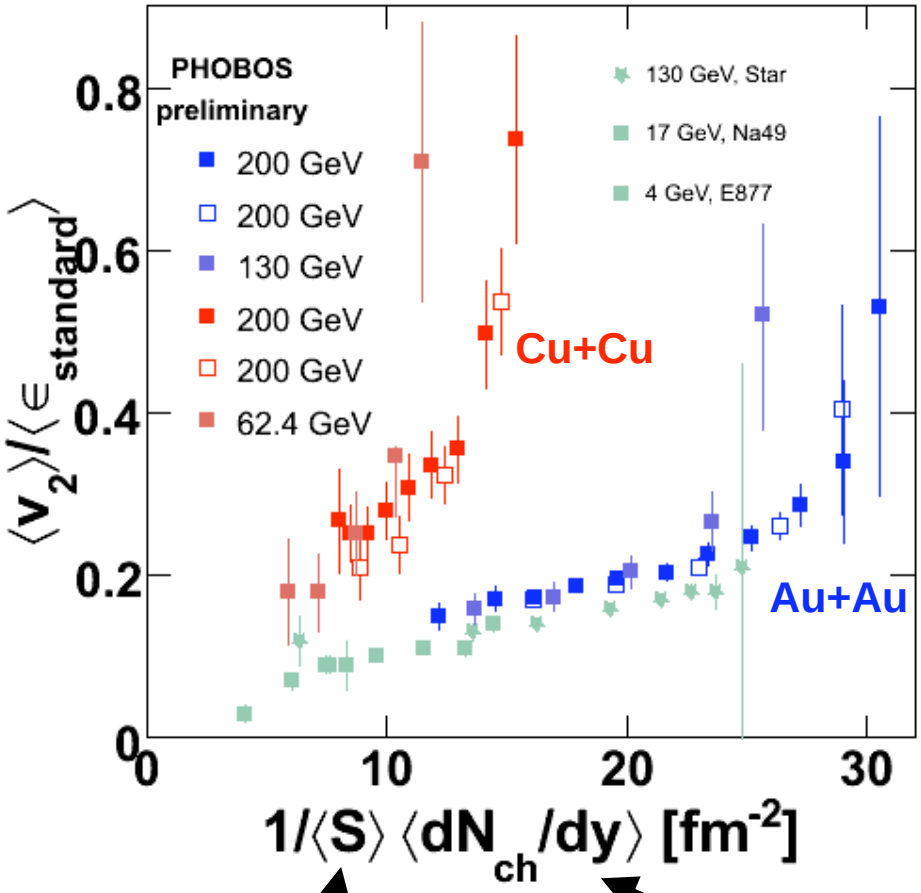
Participant Eccentricity



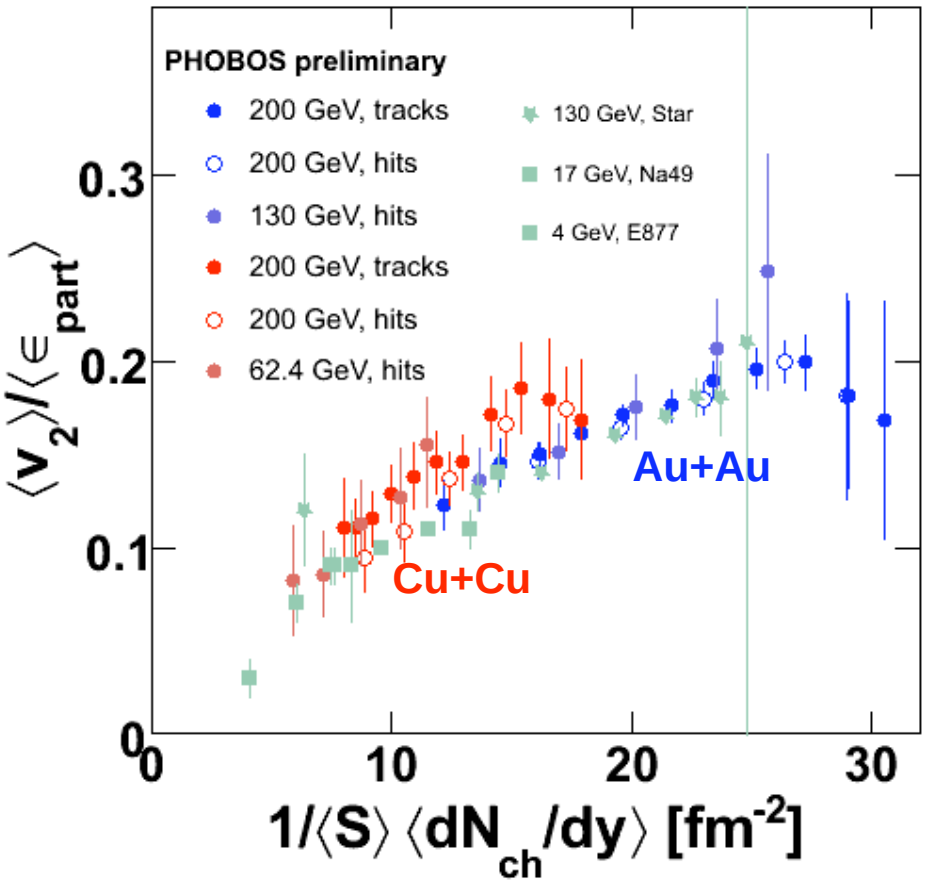
"Participant Eccentricity" allows v_2 scaling from Cu+Cu to Au+Au

<dN/dy> / <S> scaling

Standard Eccentricity



Participant Eccentricity



Overlap Area

Caveat: $dN_{ch}/d\eta$ corrected to dN_{ch}/dy

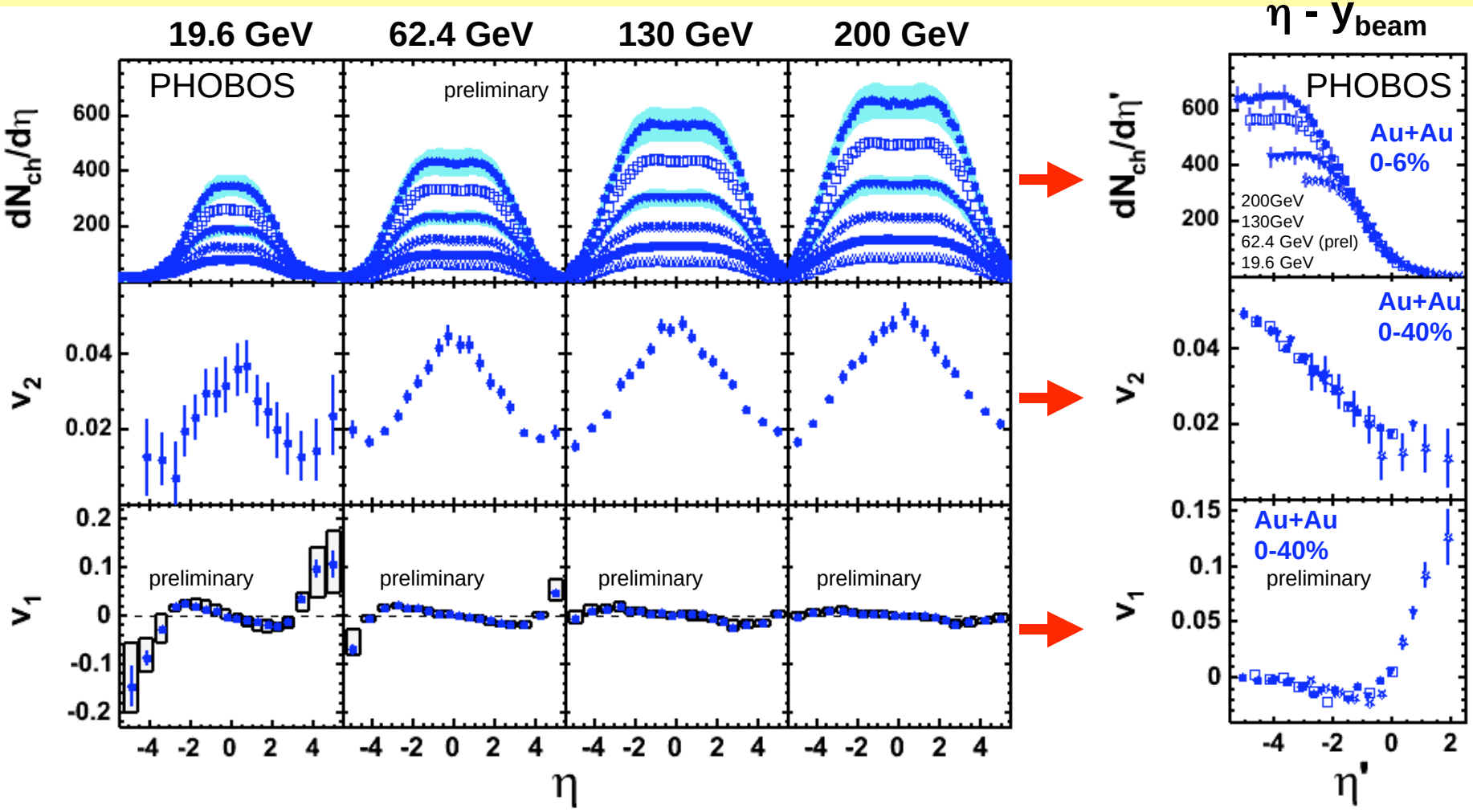
<dN/dy> / <S> scaling:
STAR, PRC 66 034904 (2002)
Voloshin, Poskanzer, PLB 474 27 (2000)
Heiselberg, Levy, PRC 59 2716, (1999)

Conclusions

- Phobos has continued to expand its extensive flow data set using two techniques
- Studying CuCu compared to AuAu allows us to vary the geometry while holding N_{part} constant
- The expectation that elliptic flow scales with eccentricity continues to seem reasonable
- Careful consideration is needed when using eccentricity

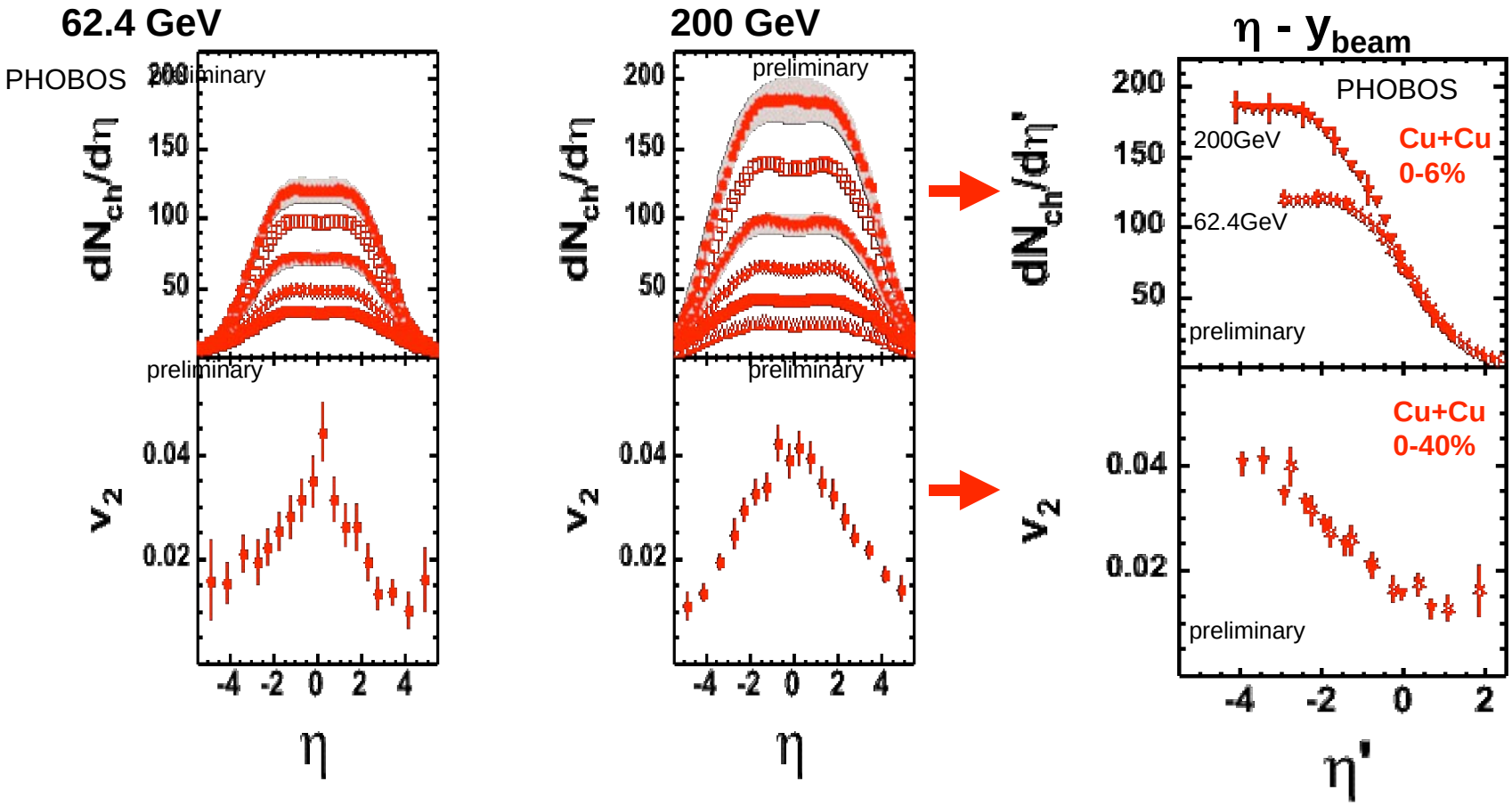
Back-up Slides

Limiting Fragmentation (Au+Au)



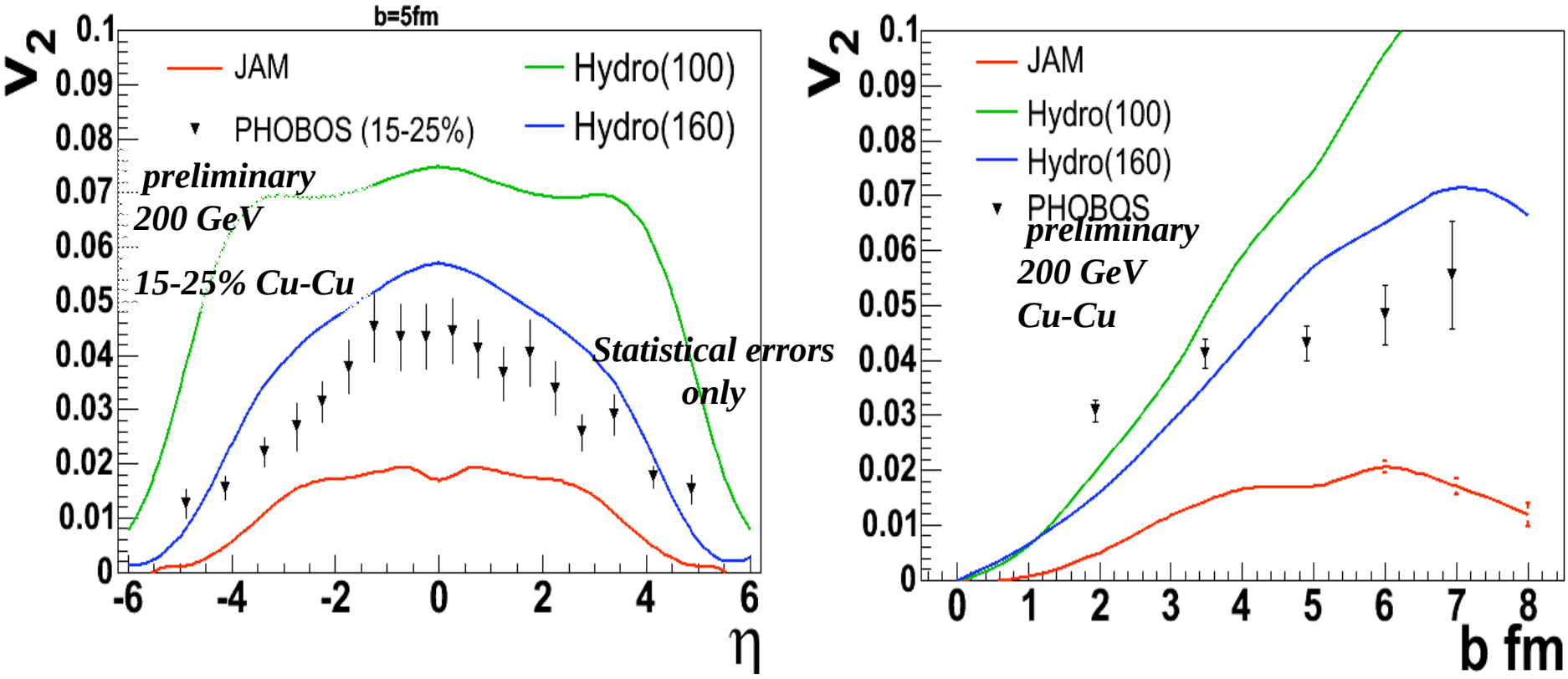
"Extended Longitudinal Scaling" of all longitudinal distributions

Limiting Fragmentation (Cu+Cu)



'Extended Longitudinal Scaling' also seen in Cu+Cu
Persists from p+p to Au+Au over large range in η_

Compared to JAM Model

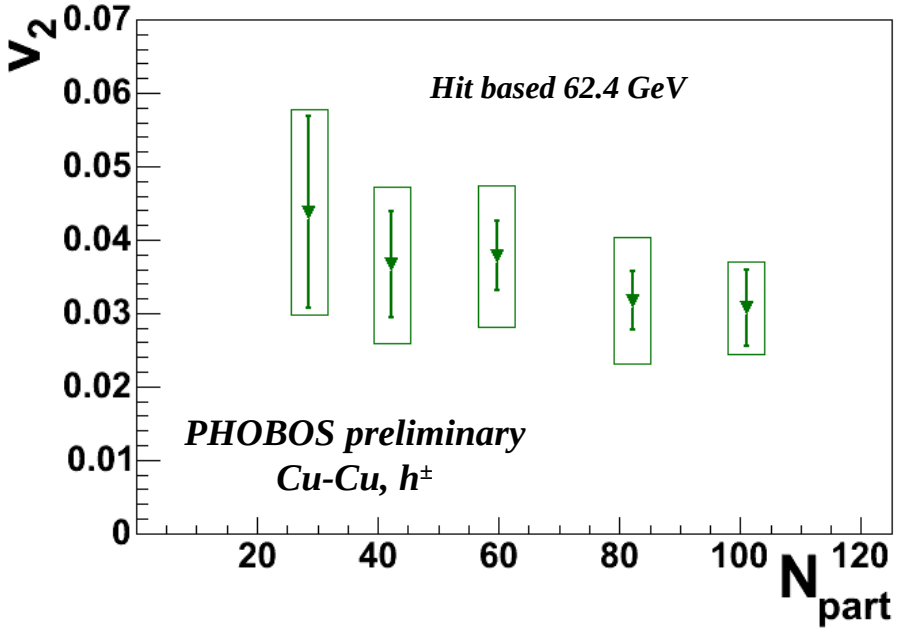


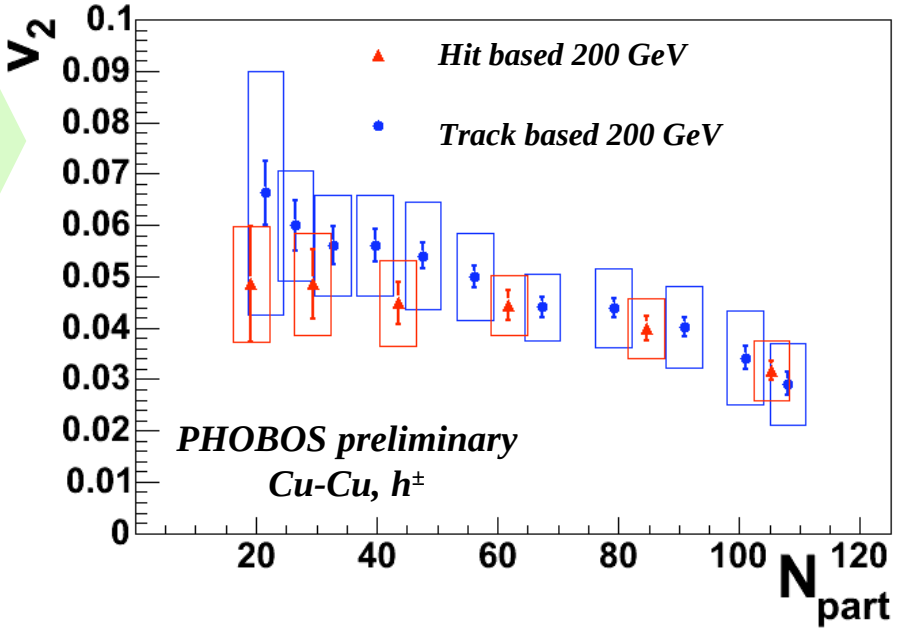
Cu-Cu more like Hydro than JAM hadron string cascade model

Here JAM uses a 1 fm/c formation time. Hydro (160) has kinetic freezeout temperature at 160 MeV

Two Flow Measurement Methods

Good agreement between methods





$|\eta| < 1$