

# Forward/Backward asymmetry of $v_n$ in Cu+Au at RHIC-PHENIX



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## Motivation: 3D-initial condition

✓ Rapidity dependence of initial condition ?

Signature of **breaking boost invariance** is observed by CMS

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- Forward/Backward flow fluctuation

Possible explanations

- Asymmetric initial geometry :  $\epsilon_n(\eta) \neq \epsilon_n(-\eta)$
- Twisted  $\Phi_n(\eta)$  :  $\Phi_n(\eta) \neq \Phi_n(-\eta)$

✓ Forward/Backward(F/B) asymmetric initial density/geometry in Cu+Au collisions at 200 GeV

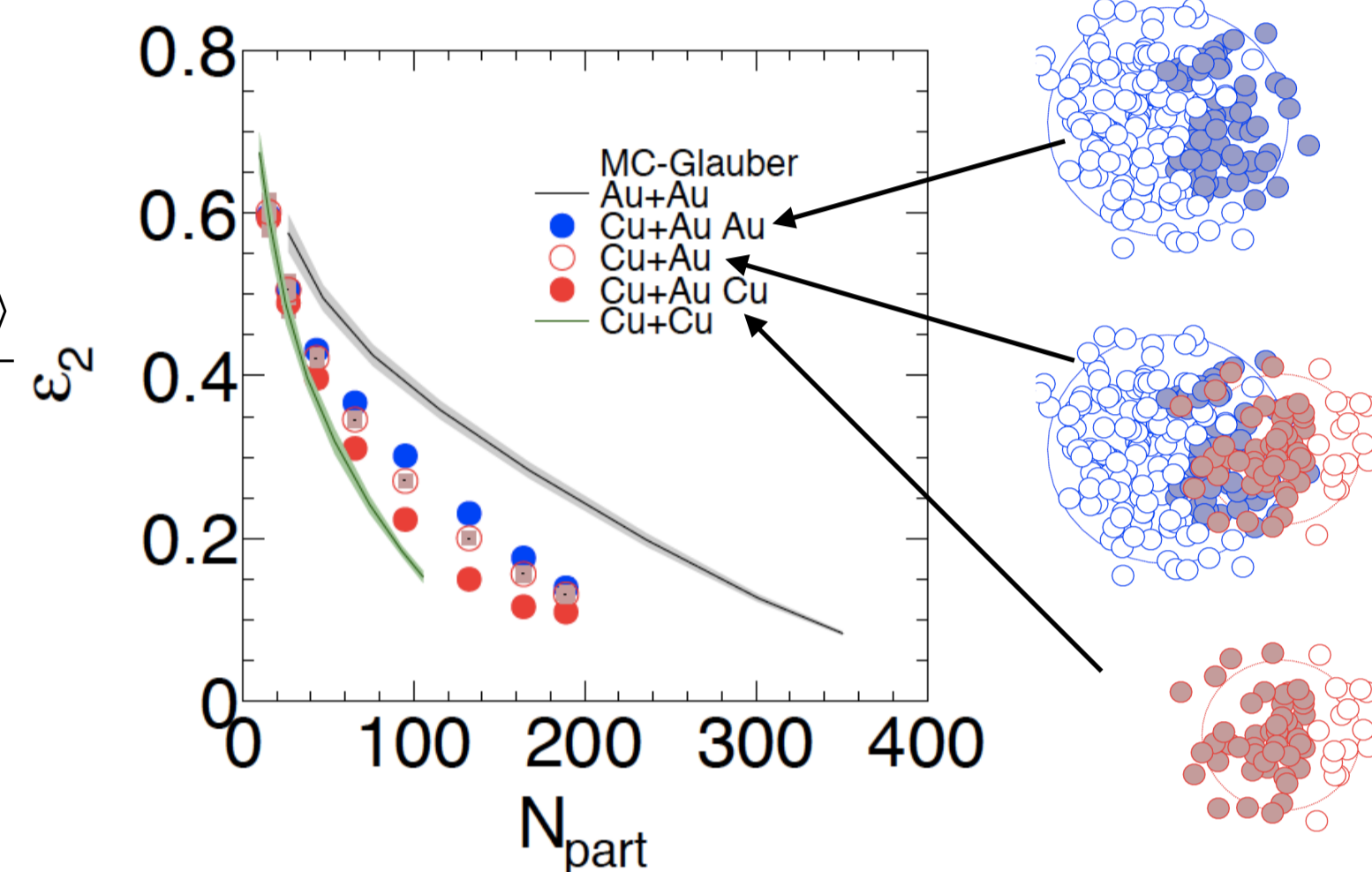
• More participants in Au than those in Cu

• MC-Glauber model shows

$$\epsilon_{2,Au} > \epsilon_{2,Cu+Au} > \epsilon_{2,Cu}$$

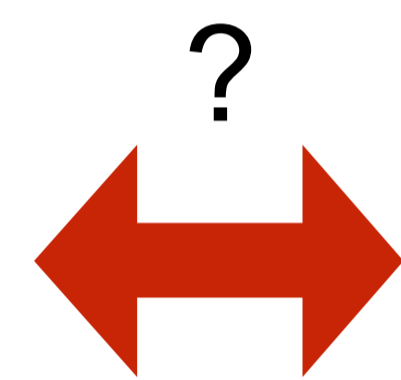
$$\epsilon_{n,Au(Cu)} = \frac{\langle r^n \cos[n(\phi_{Au(Cu)} - \Phi_{n,Cu+Au})] \rangle}{\langle r^n \rangle} \omega^n$$

$\epsilon_{2,Au}$ ,  $\epsilon_{2,Cu+Au}$  and  $\epsilon_{2,Cu}$  are calculated w.r.t same participant plane

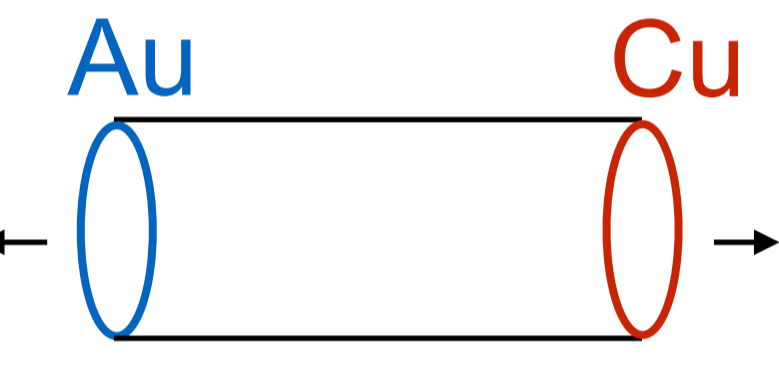


• F/B  $v_n$  will provide insight of longitudinal initial geometry

Asymmetric initial geometry

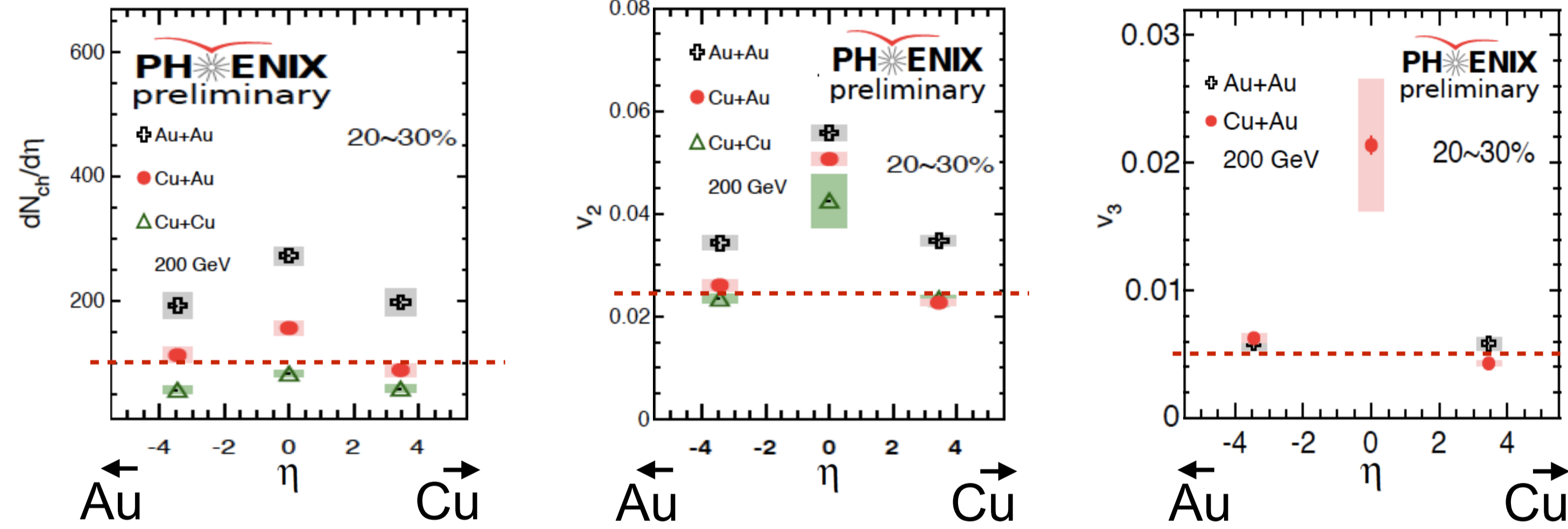


Boost invariance initial geometry



## Results: $dN/d\eta$ & $v_n$

✓  $\eta$  dependence of charged particle  $dN_{ch}/d\eta$  &  $v_n$



• Au-going  $dN/d\eta >$  Cu-going  $dN/d\eta$  in Cu+Au collisions

-  $N_{part,Au} > N_{part,Cu}$

→ Larger initial density in Au-going side

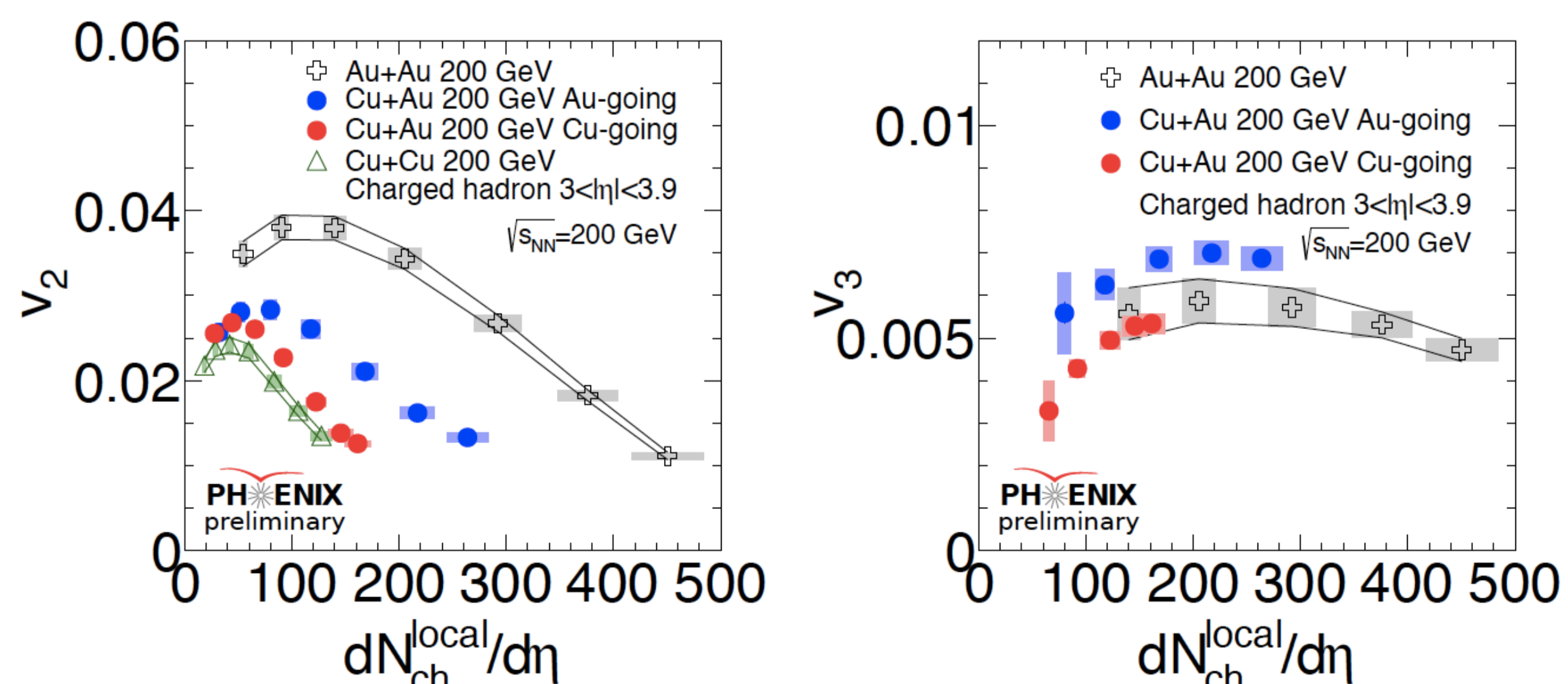
• Au-going  $v_n >$  Cu-going  $v_n$  in Cu+Au collisions

- Assume rapidity independent event plane,  $\Psi_n(\eta) = \Psi_n(-\eta)$

-  $\epsilon_{n,Au} > \epsilon_{n,Cu}$  &  $N_{part,Au} > N_{part,Cu}$

→ Asymmetry of  $v_n$  is caused by geometry and/or energy density

✓ F/B ( $3 < |\eta| < 3.9$ )  $v_n$  as a function of F/B ( $3 < |\eta| < 3.9$ )  $dN_{ch}/d\eta$



•  $v_n$  is plotted as a function of f/b-rapidity  $dN/d\eta$

- At same  $dN/d\eta$  bin, the similar initial energy density is expected

- In Cu+Au collisions, Au-going  $dN/d\eta >$  Cu-going  $dN/d\eta$

• Au-going side shows larger  $v_n$  than Cu-going side

→ Caused by difference of initial geometries between Au and Cu ?

## Discussion: initial density

~  $N_{part}$  scaling ~

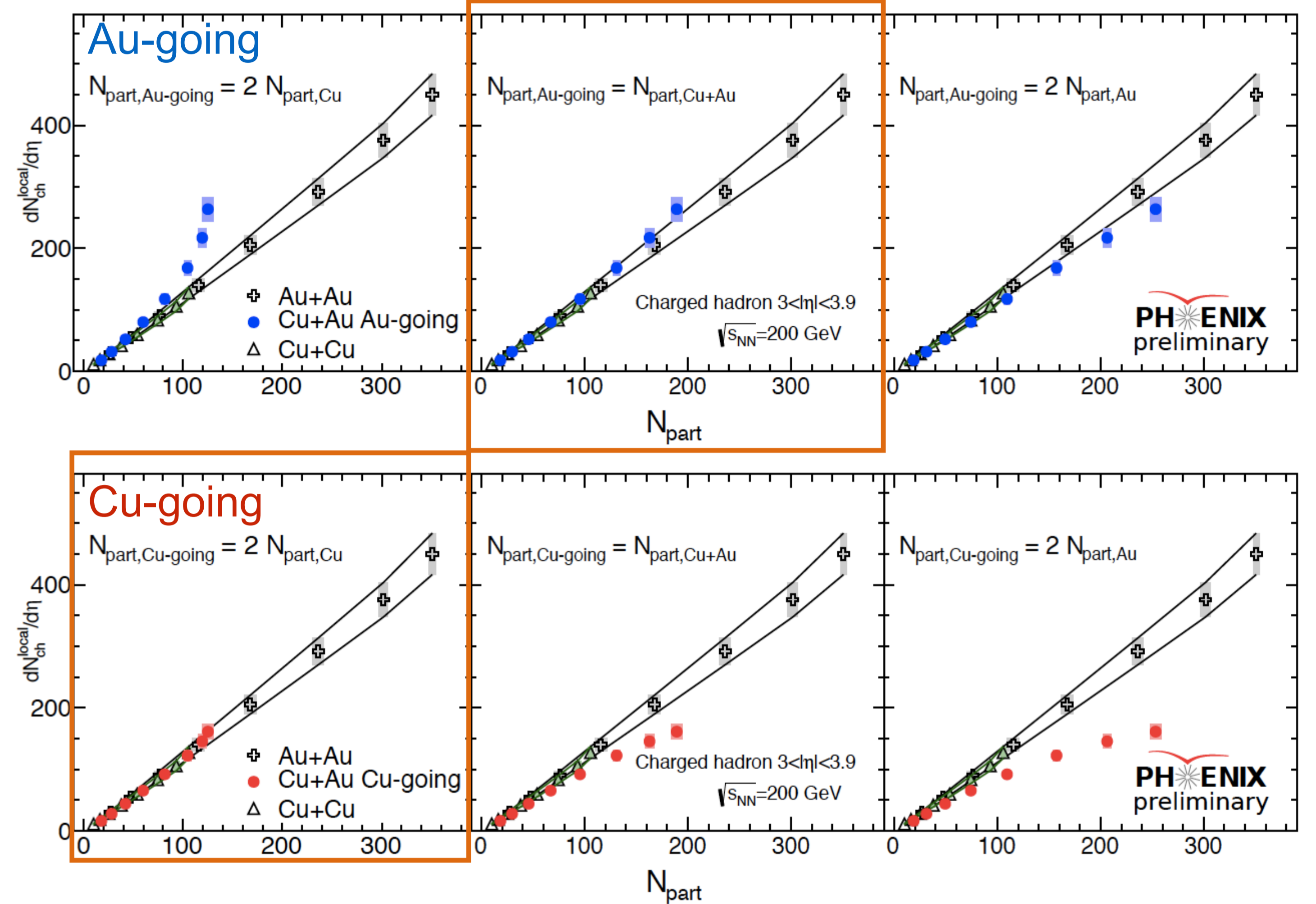
✓ F/B  $dN_{ch}/d\eta$  is plotted as a function of weighted  $N_{part}$

- Weighted  $N_{part}$  ranges  $2N_{part,Cu} < N_{part,Cu+Au} < 2N_{part,Au}$

-  $N_{part,Au}$  and  $N_{part,Cu}$  are participants in Au and Cu, respectively

- Study of relative contribution between Au and Cu nuclei

$$2N_{part,Cu} \leftarrow N_{part,Cu+Au} \rightarrow 2N_{part,Au}$$



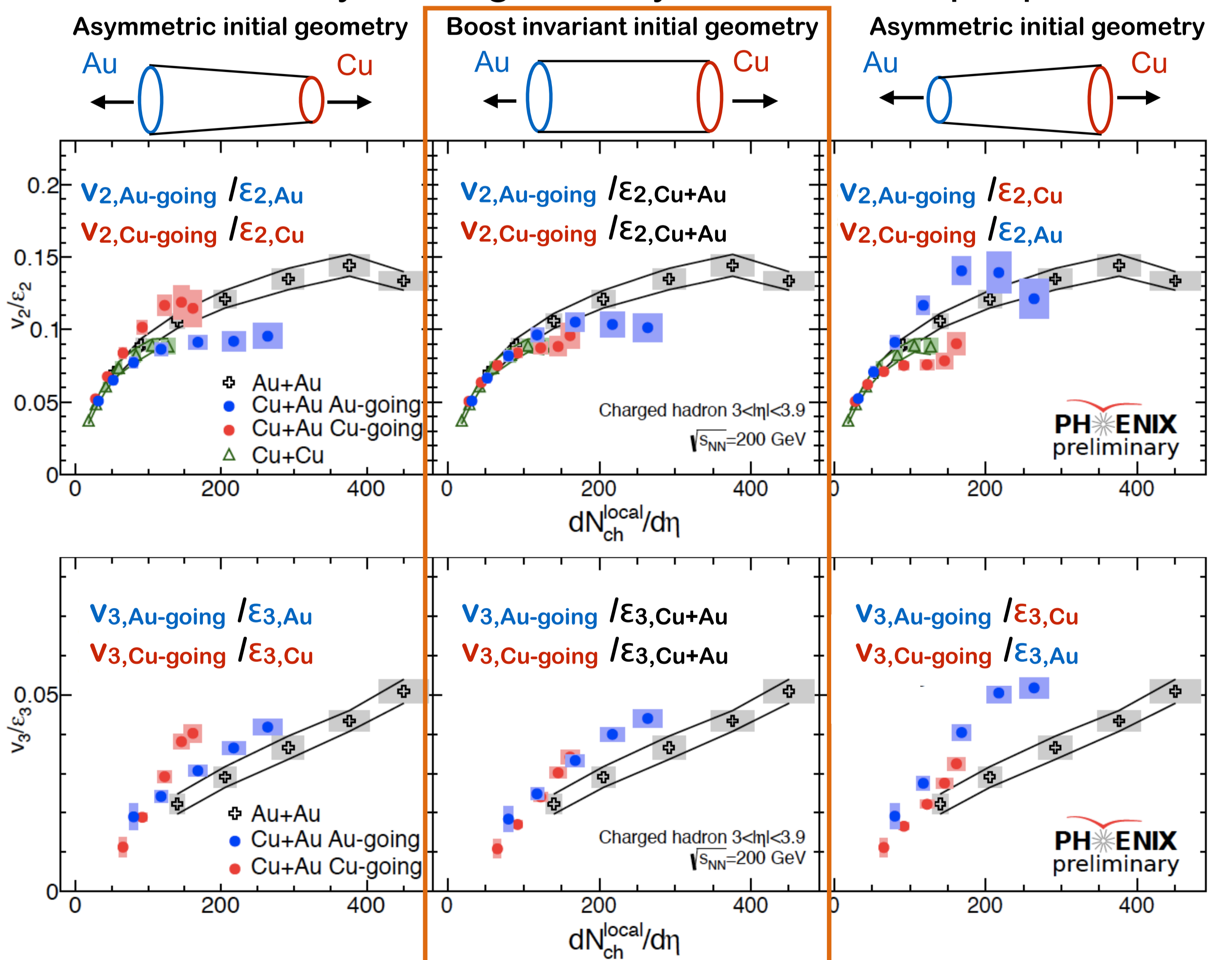
• Au-going side is determined by both of  $N_{part,Au}$  and  $N_{part,Cu}$

• Cu-going side is determined pure  $N_{part,Cu}$

## Discussion: initial geometry

~ Eccentricity scaling of  $v_n$  ~

✓ F/B  $v_n$  scaled by initial geometry with/without  $\eta$  dependence



• Failed to scale with rapidity dependence of  $\epsilon_n$

- Deviation is seen between Au-going and Cu-going  $v_n$

- Not consistent among 3 collision systems

•  $\epsilon_{n,Cu+Au}$  is favored

- F/B asymmetry is caused by initial energy density ( $dN/d\eta$ )

## Conclusion

• Initial geometry at F/B is common between  $-4 < \eta < +4$

• F/B asymmetry of  $v_n$  is originally from the initial densities in those regions.