

# PHENIX Results On Small Systems



Javier Orjuela-Koop

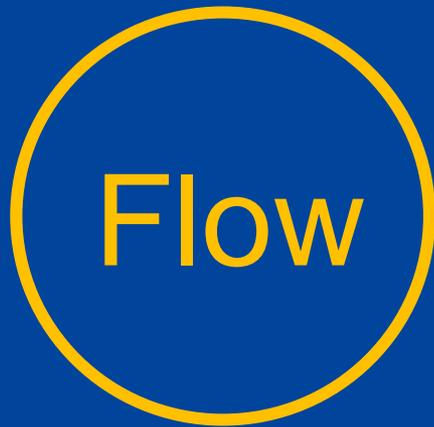
*For the PHENIX Collaboration*

University of Colorado Boulder

*3<sup>rd</sup> International Conference on the  
Initial Stages of Heavy Ion Collisions  
Lisbon, May 22-27, 2016*

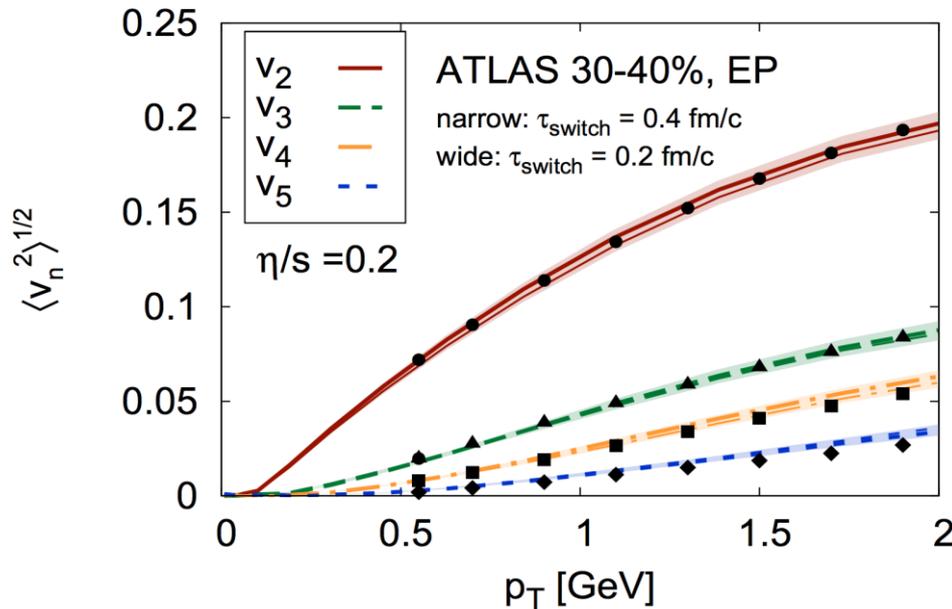
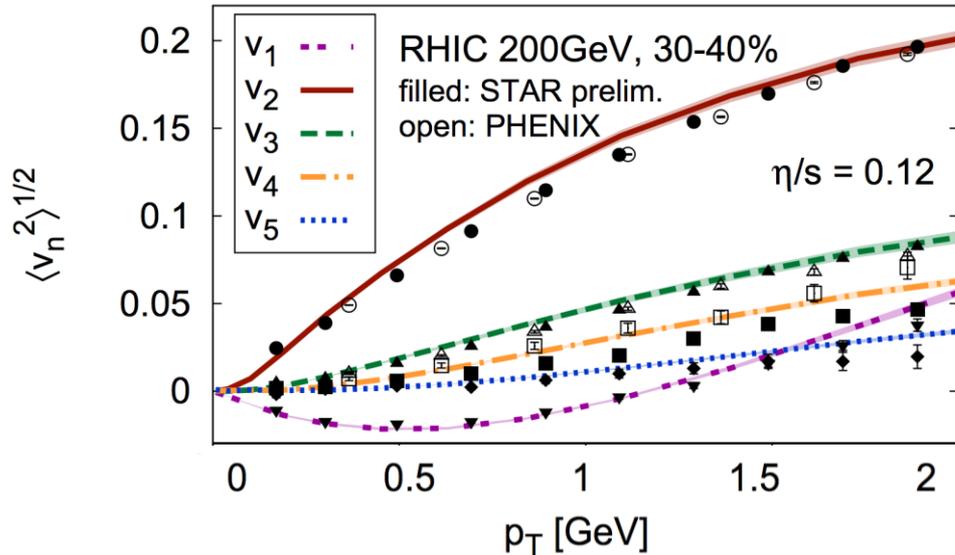
**PHENIX**

# Small Collision Systems



# Flow Dynamics in A+A

Gale, Jeon, et al., Phys. Rev. Lett. 110, 012302



- Similar flow dynamics at RHIC and the LHC
- Same hydro calculation for  $v_n$  measured at different collision energies
- Same underlying physics

# The Hydrodynamic Picture



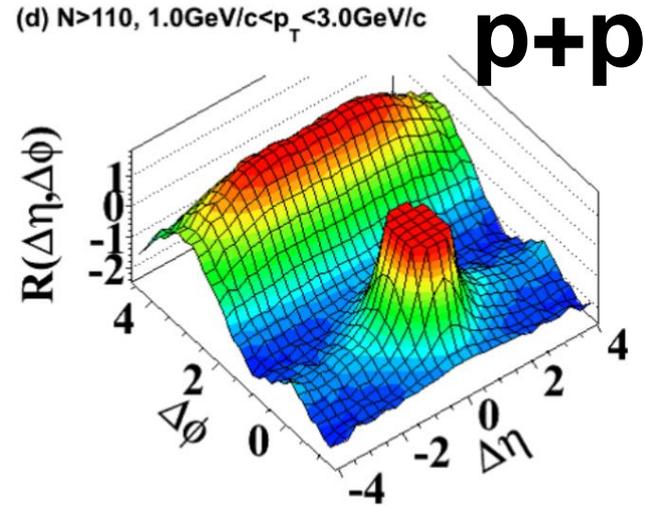
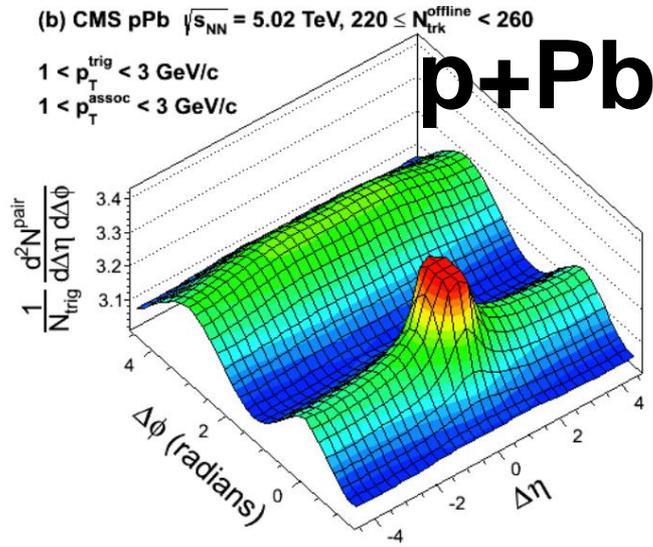
# The Hydrodynamic Picture



In Ideal Hydro

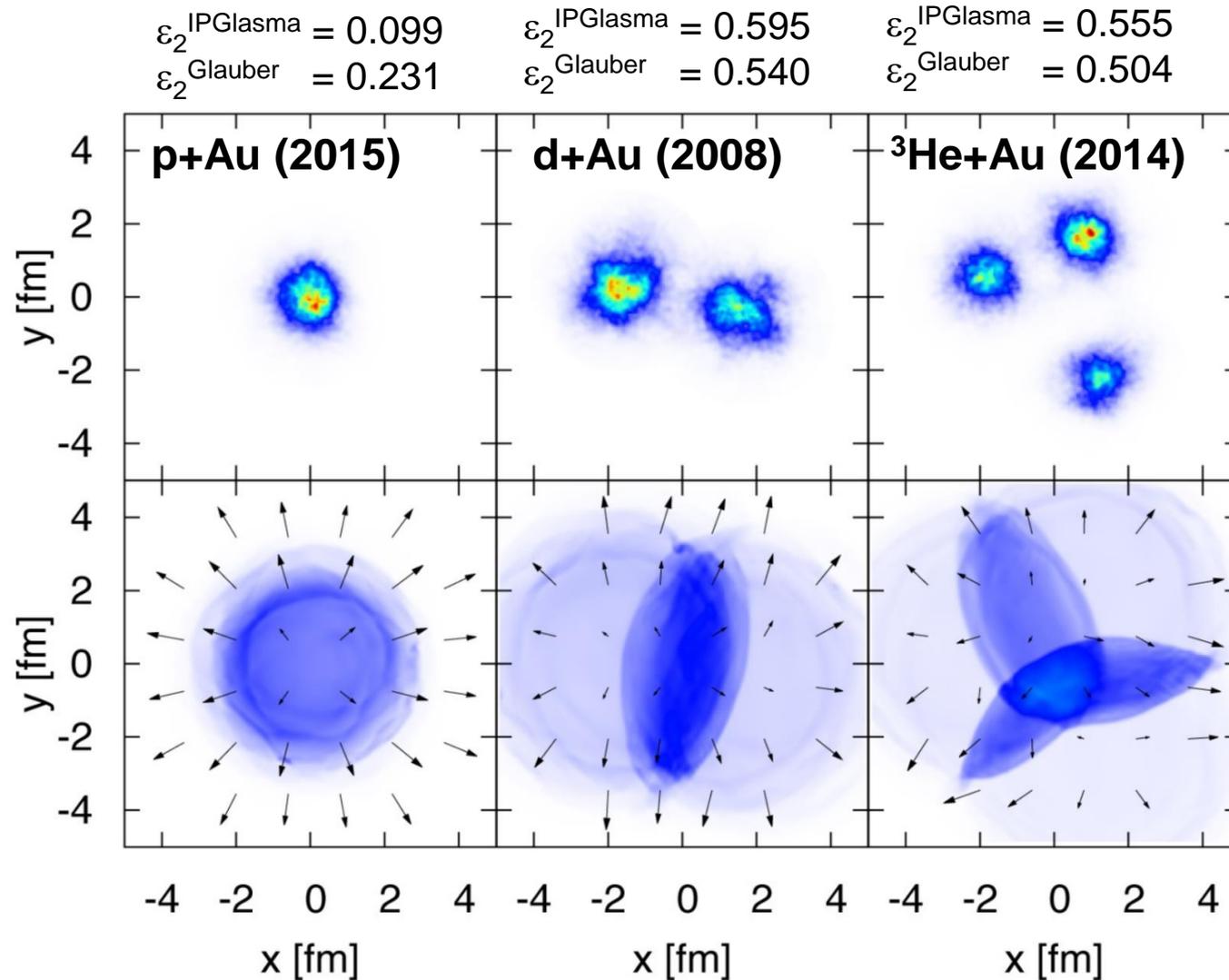
$$V_2 \propto \varepsilon_2$$

# The Hydrodynamic Picture in Small Systems?

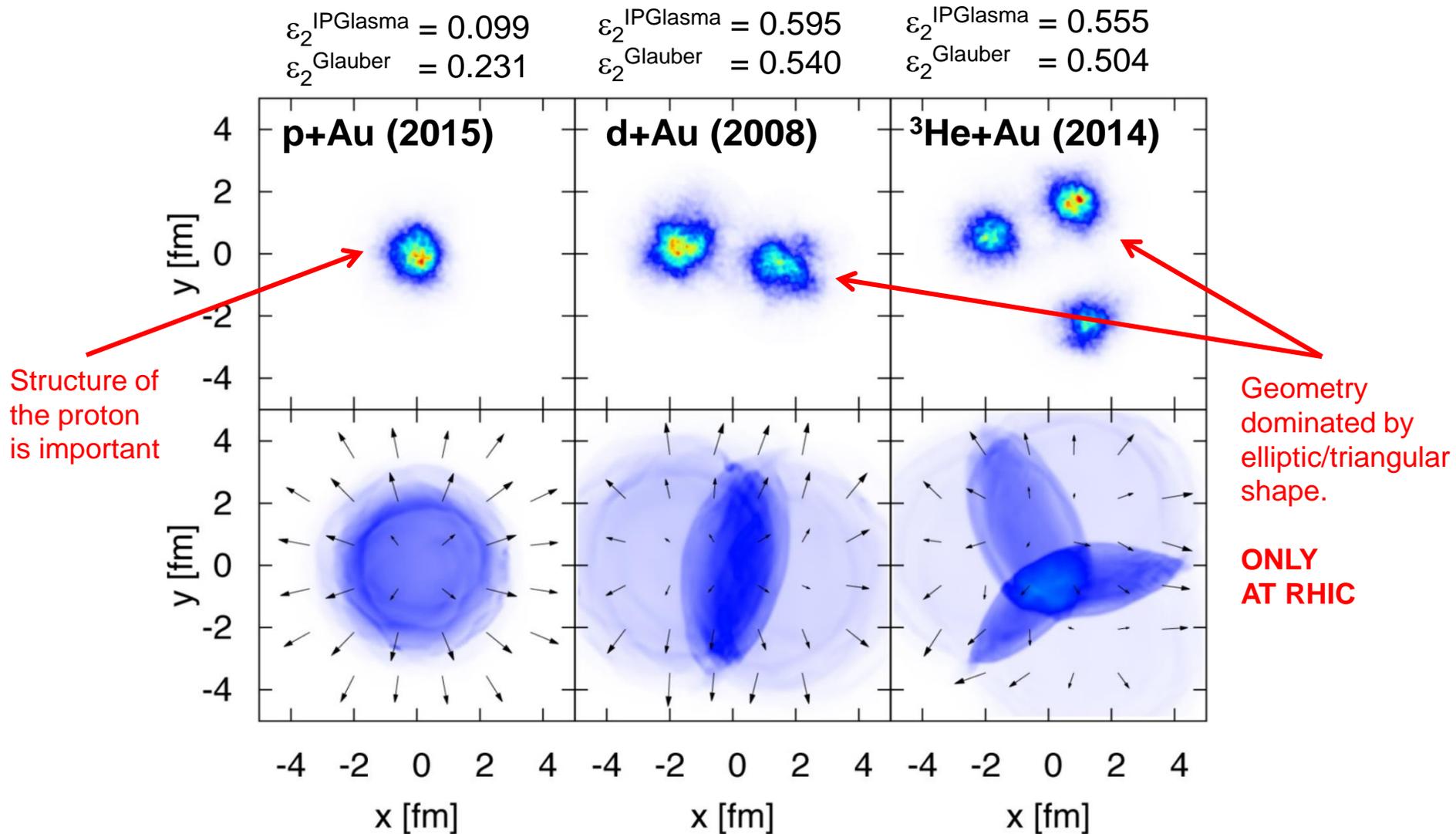


- Is it hot enough?
- Is it sufficiently long-lived?

# Geometry Engineering at RHIC

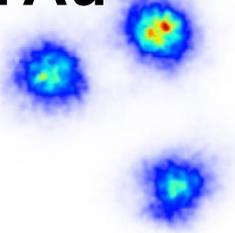


# Geometry Engineering at RHIC



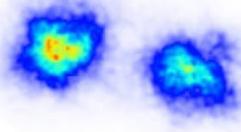
# PHENIX Azimuthal Correlation and $v_n$ Measurements

**$^3\text{He}+\text{Au}$**



Phys. Rev. Lett. 115, 142301  
(2015)

**d+Au**



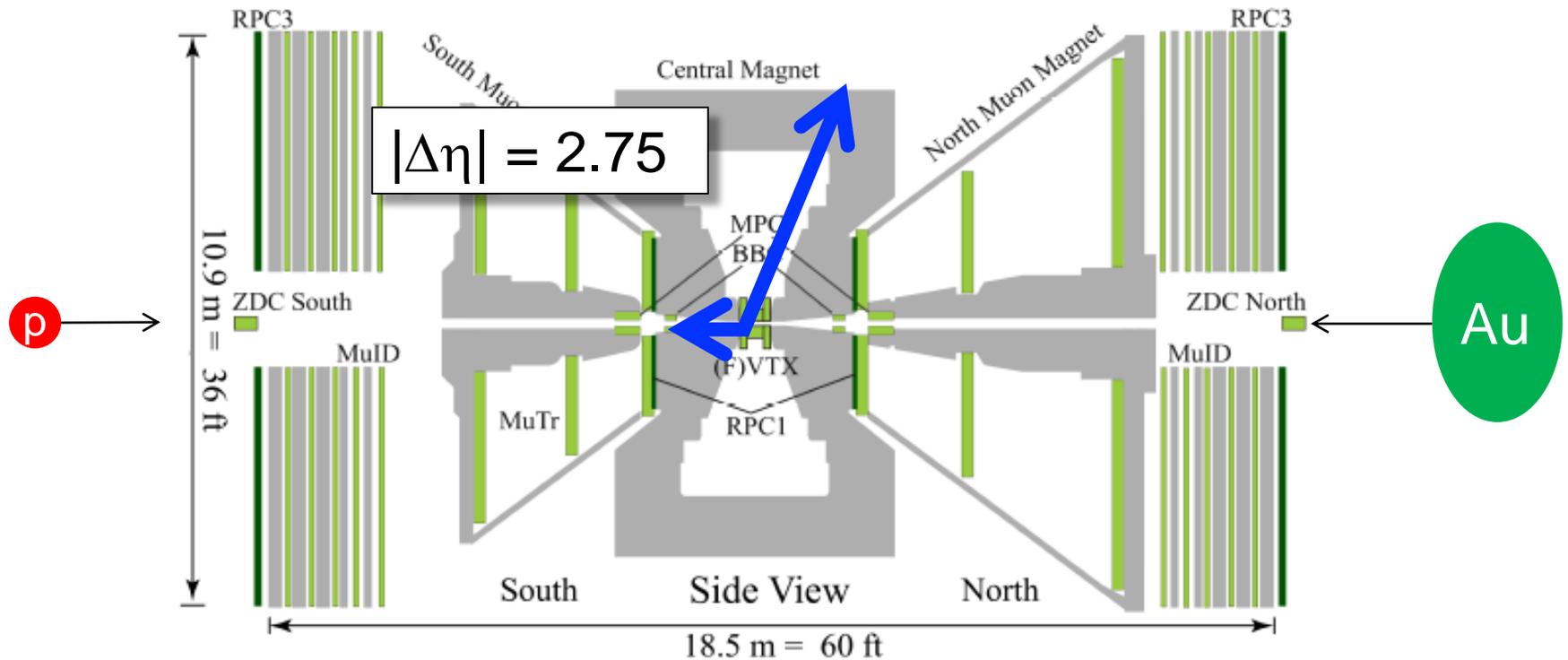
Phys. Rev. Lett. 114, 192301  
(2015)

**p+Au**

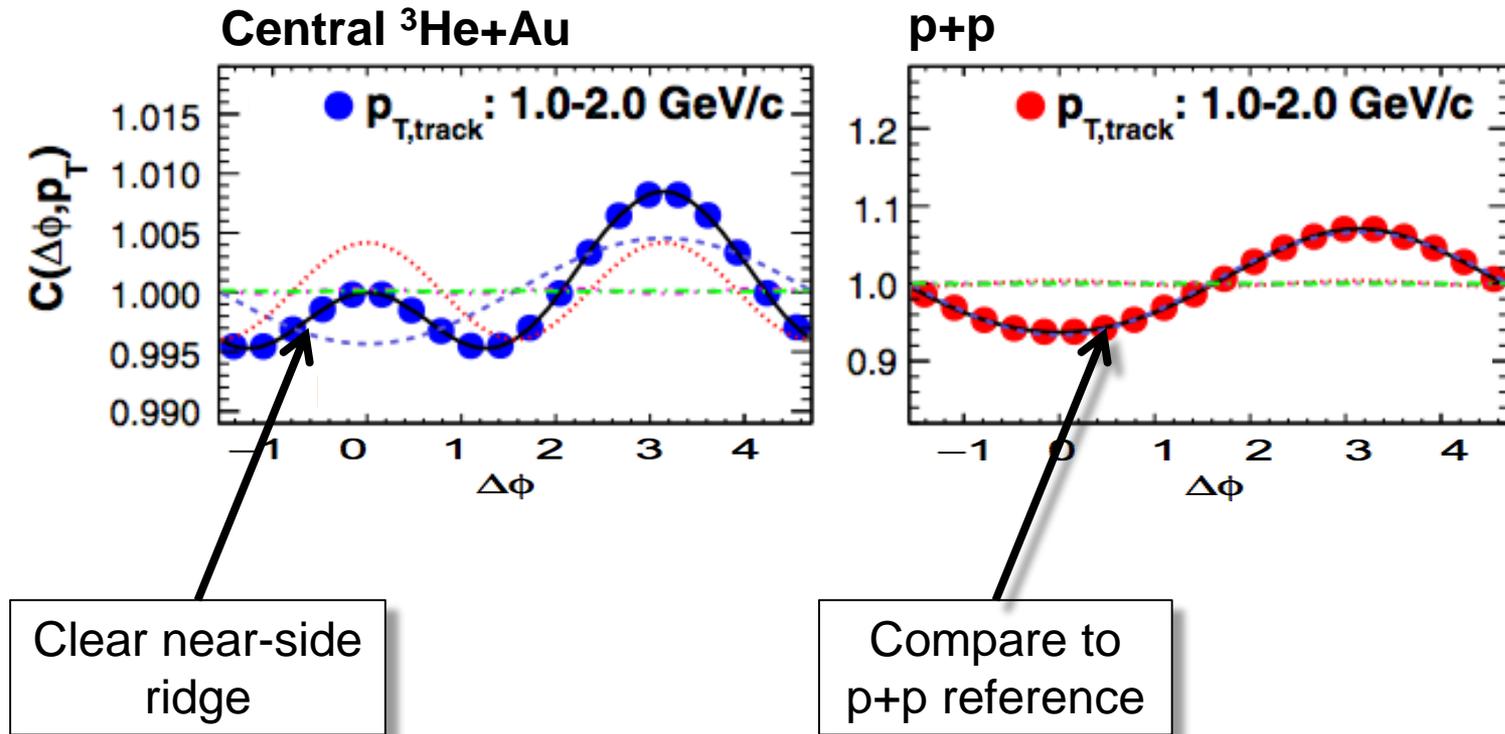


Preliminary Status

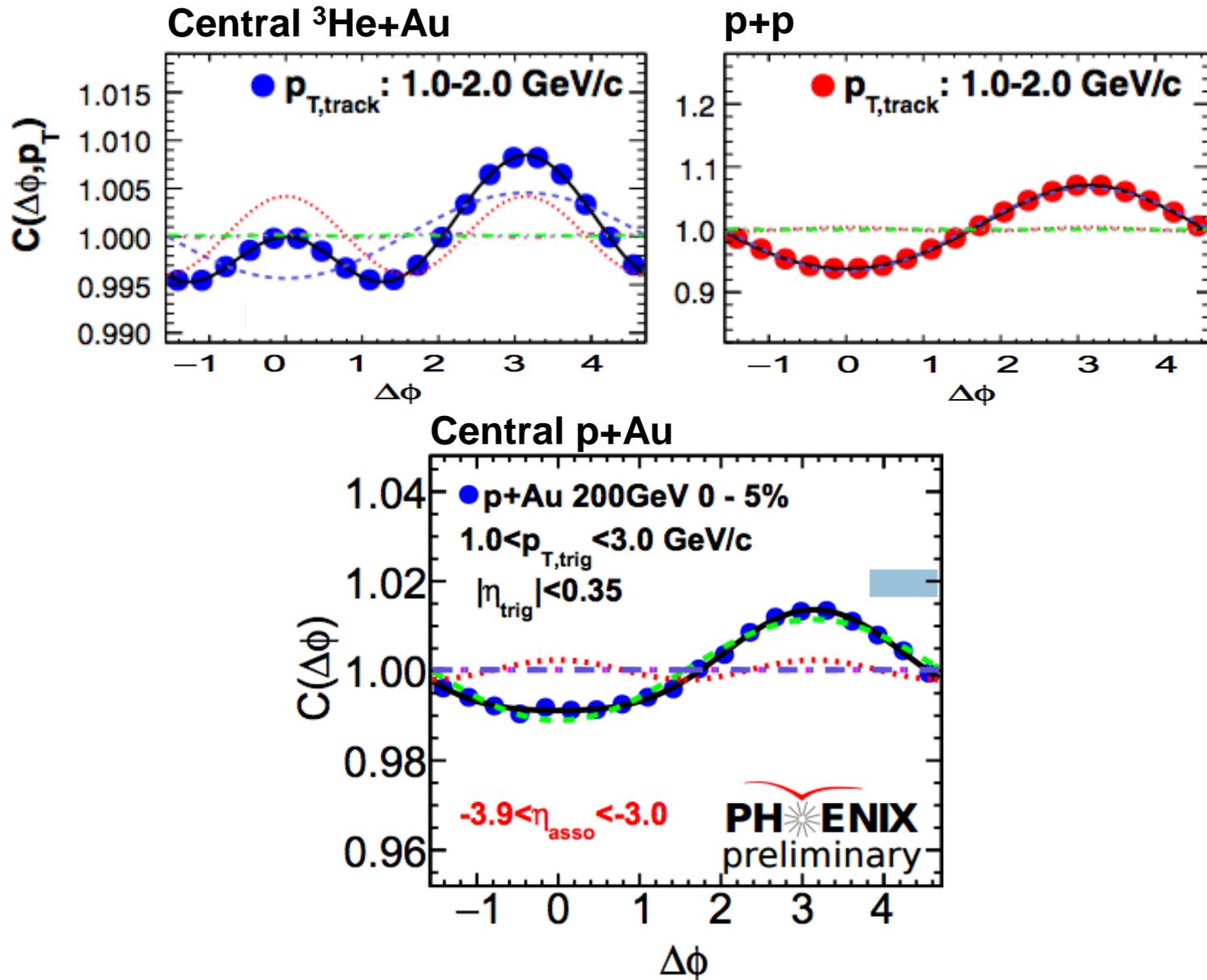
# Long Range Azimuthal Correlations in p+Au



# Long Range Azimuthal Correlations

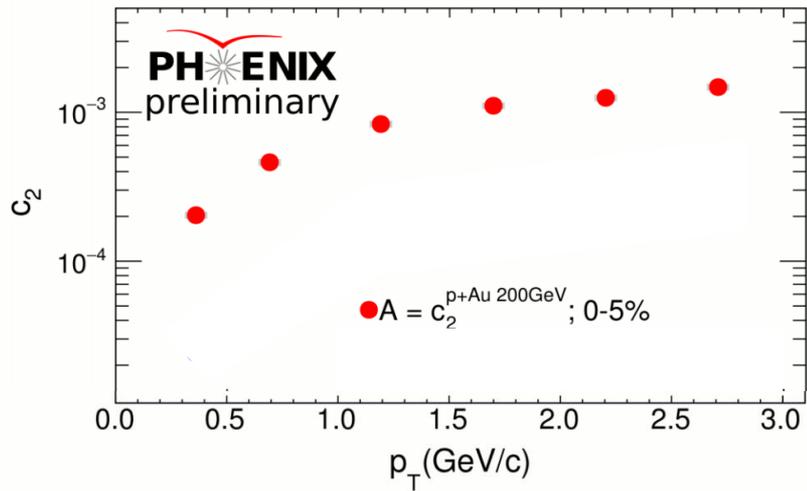


# Long Range Azimuthal Correlations



# Estimating Non-Flow

$$c_2(p_T) = c_2^{\text{Non-Elementary}} + c_2^{\text{Elementary}}$$



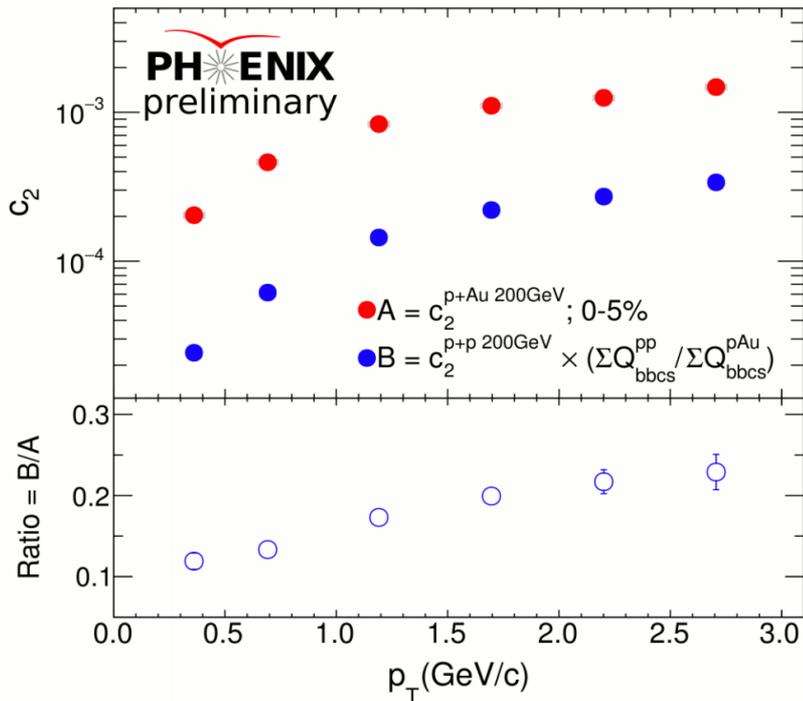
# Estimating Non-Flow

$$C_2(p_T) = C_2^{\text{Non-Elementary}} + C_2^{\text{Elementary}}$$

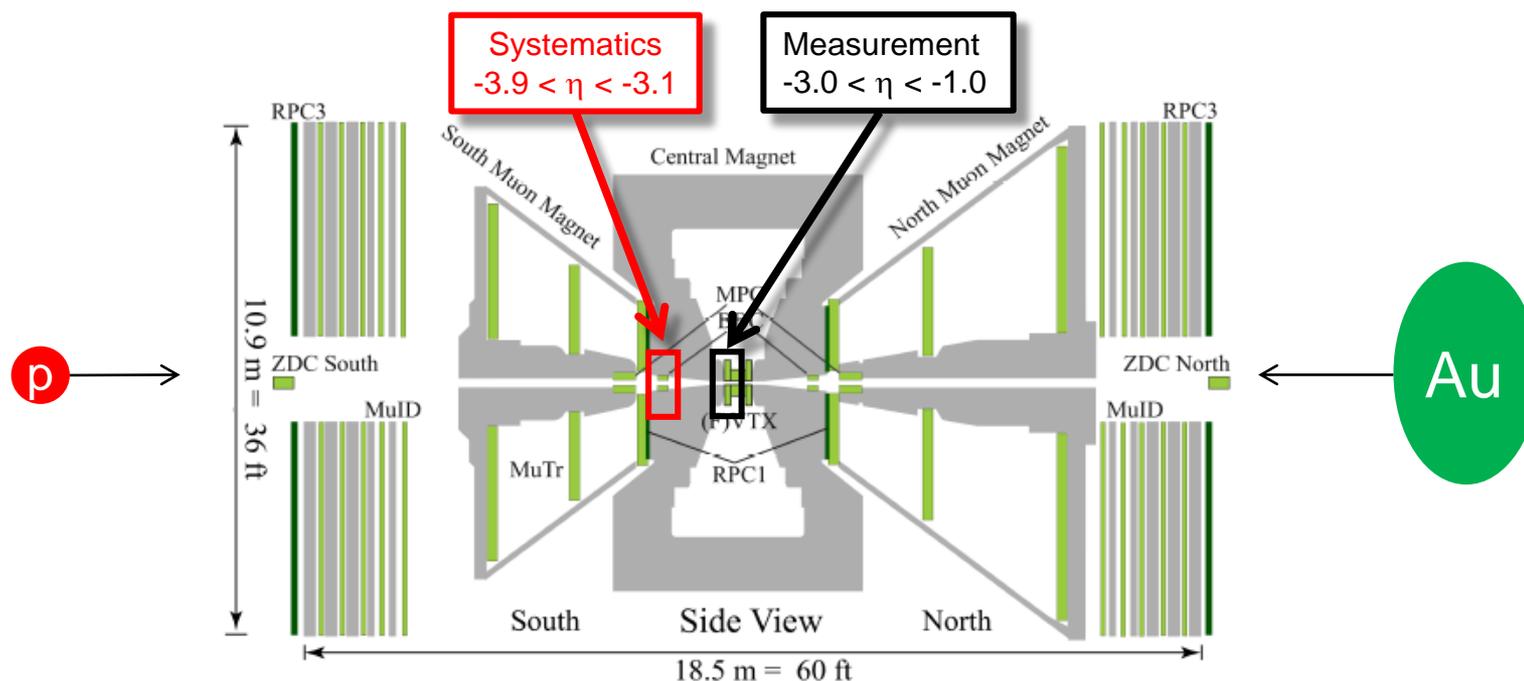
$$C_2(p_T) = C_2^{\text{Non-Elementary}} + C_2^{p+p} \times \frac{\text{Charge at Forward } \eta \text{ in } p+p}{\text{Charge at Forward } \eta \text{ in } p+Au}$$

Use p+p as a reference

Scale it down by relative multiplicity



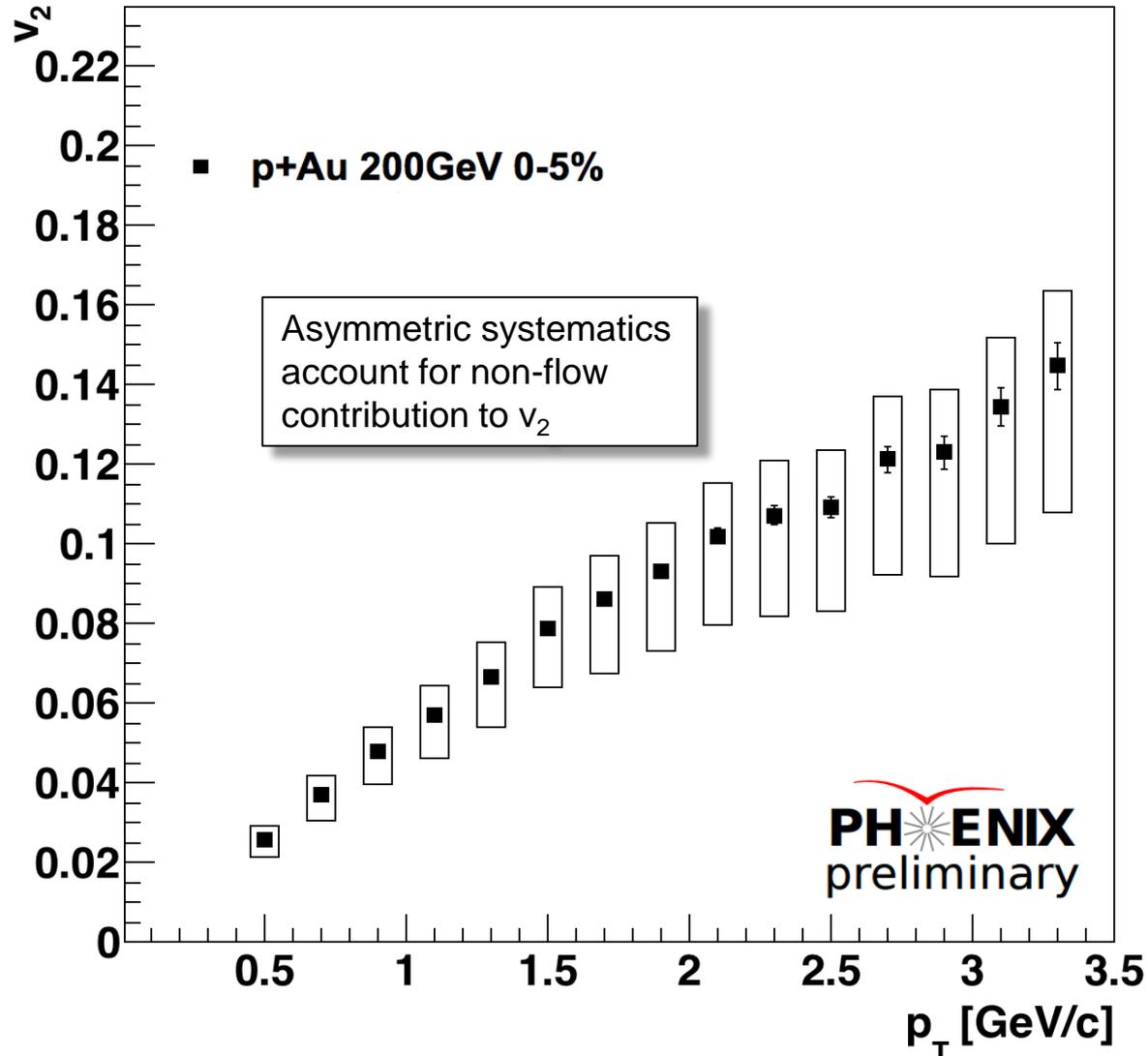
# Event Plane Method



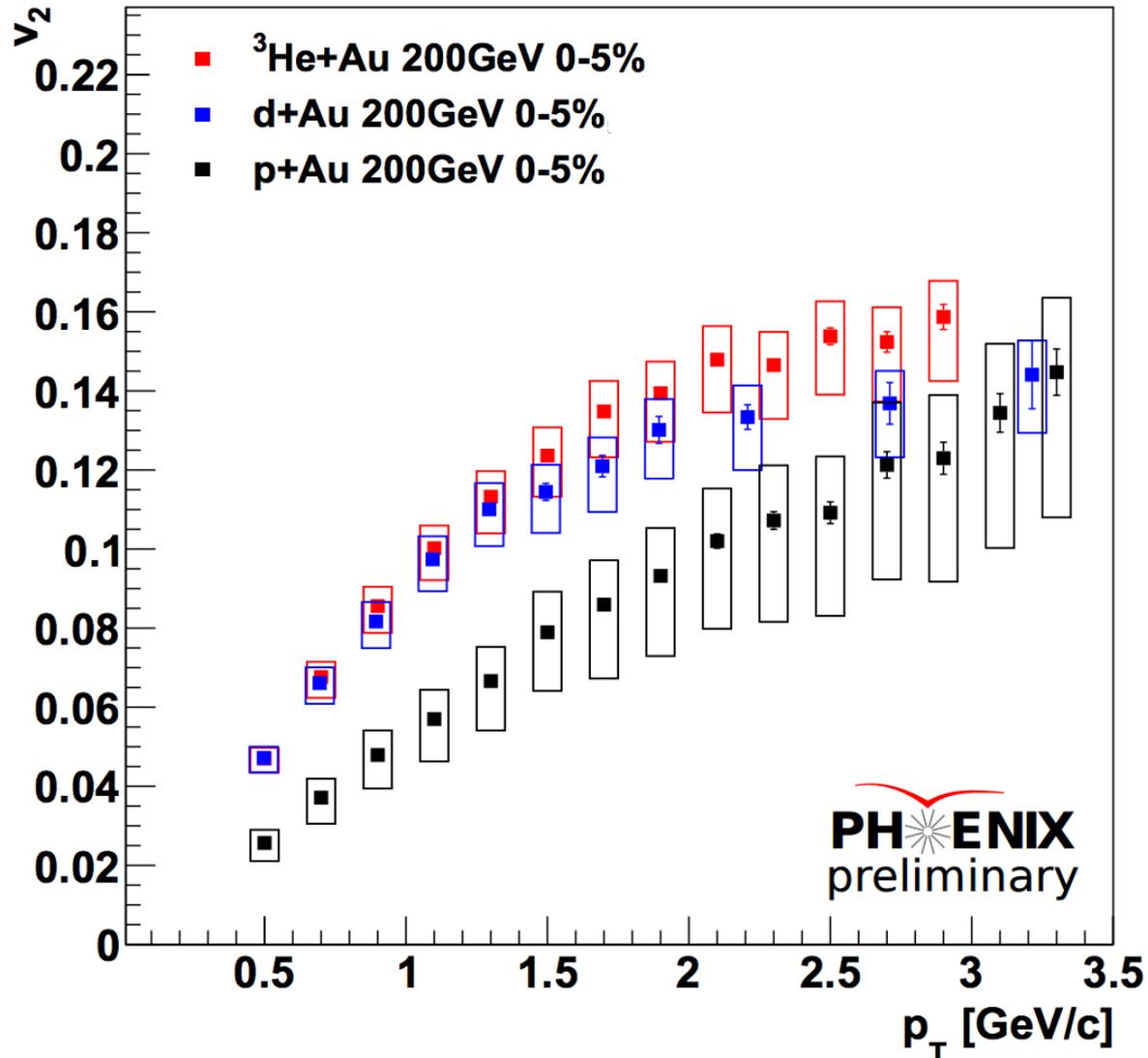
$$v_2 = \frac{\langle \sum \cos 2(\phi - \Psi_2) \rangle}{\text{Res}(\Psi_2)}$$

Resolution  $\text{Res}(\Psi)$  estimated from correlation of three independent sub-events

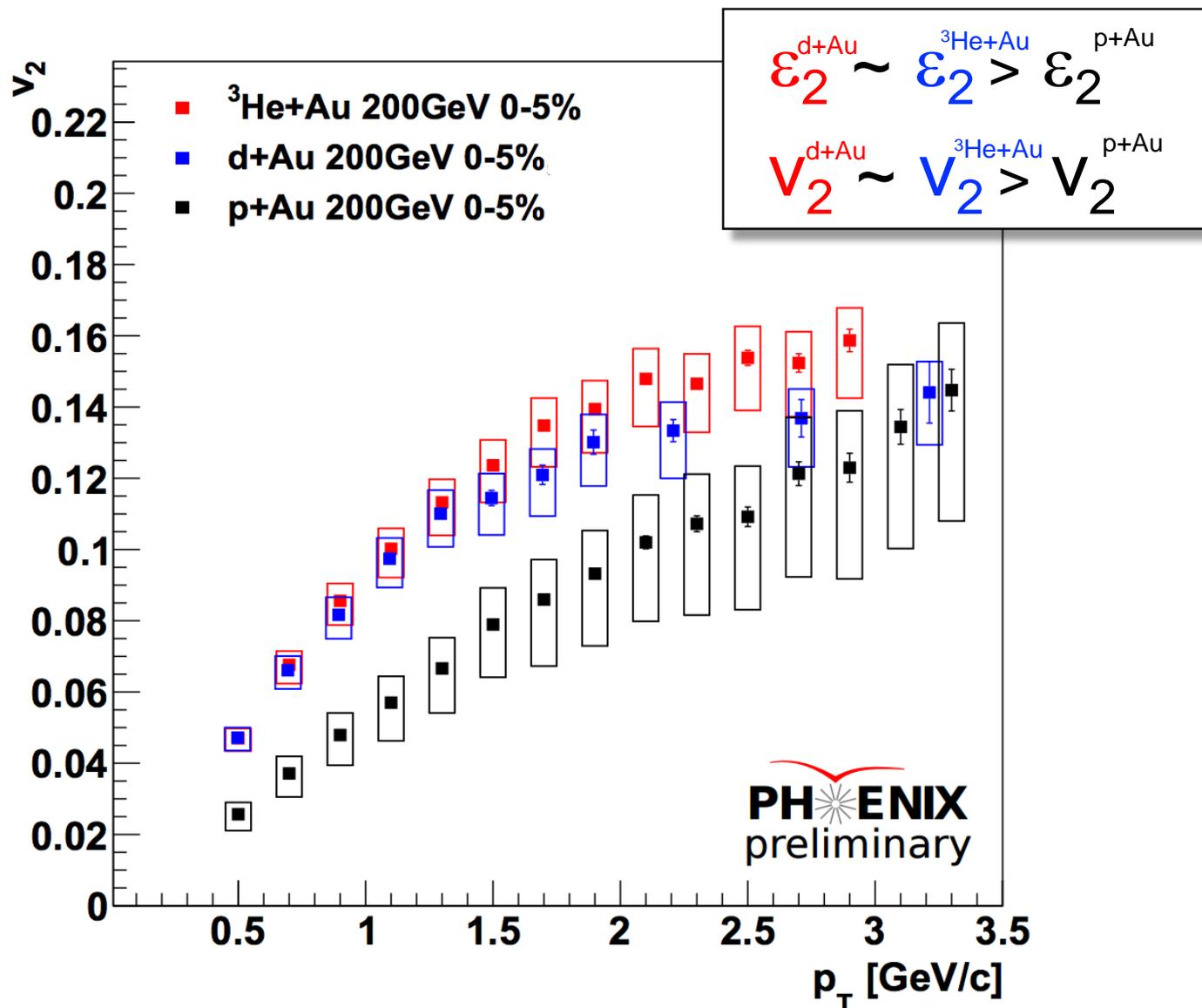
# Elliptic Flow in p+Au



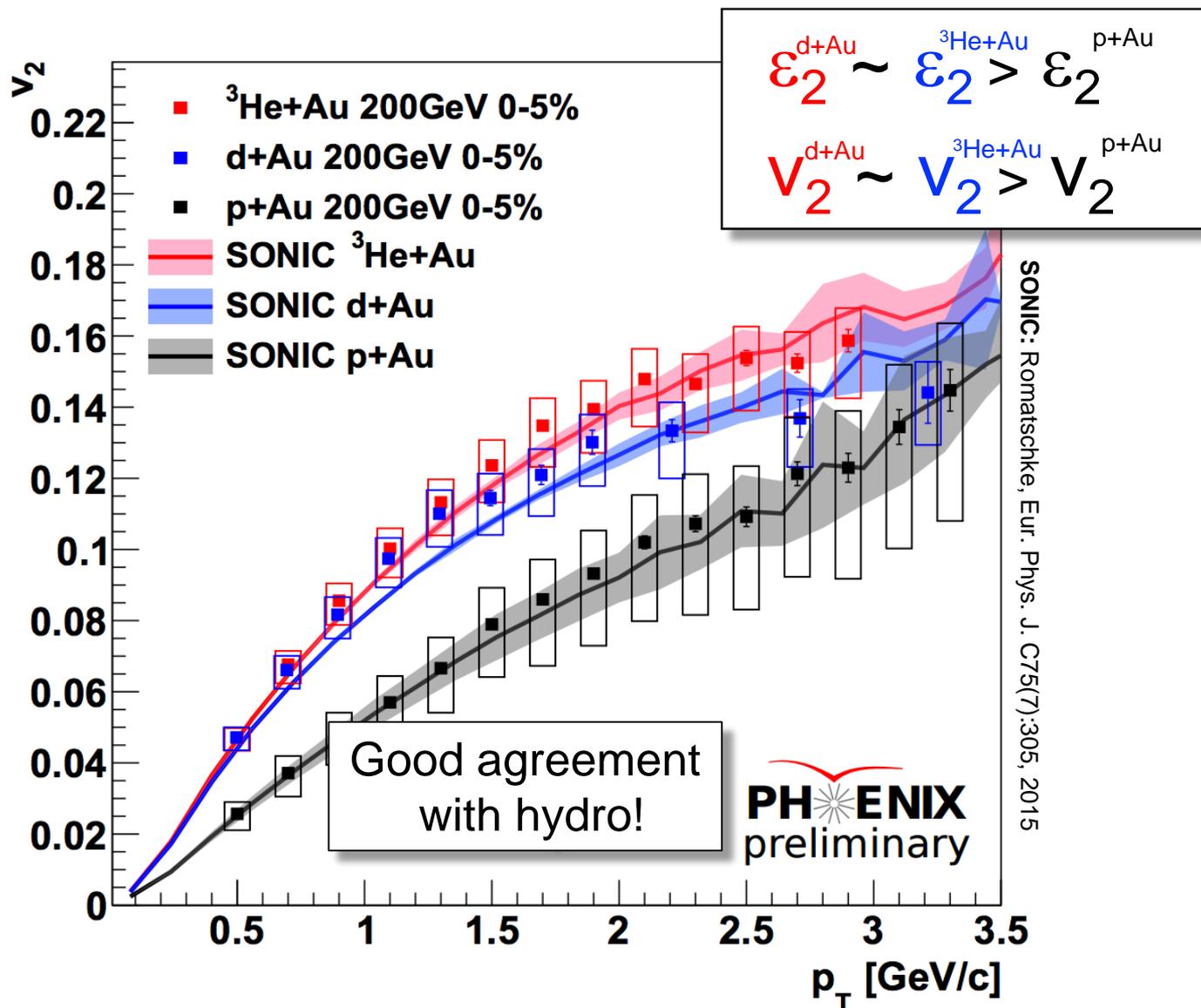
# Elliptic Flow in all Systems



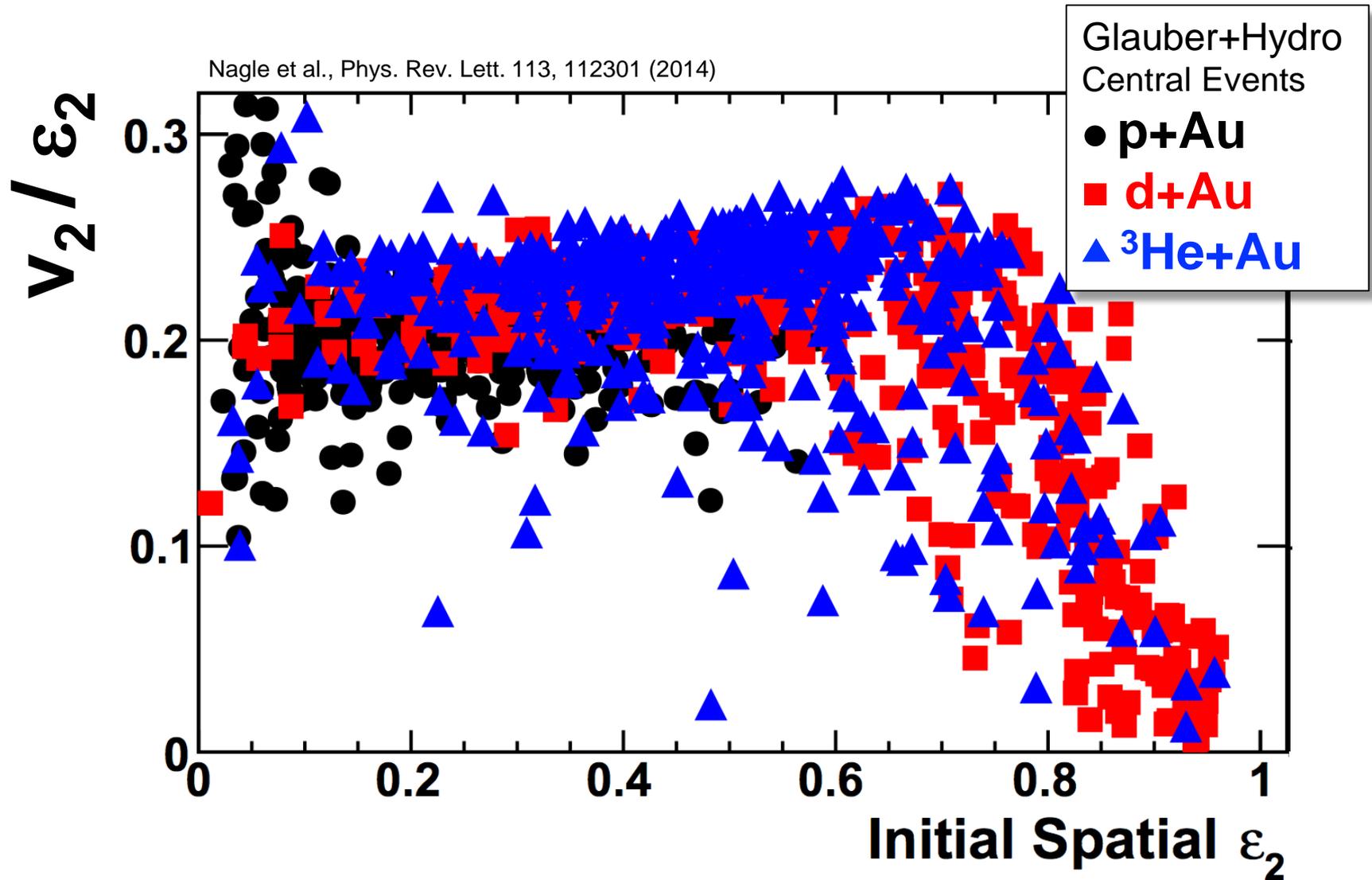
# Elliptic Flow in all Systems



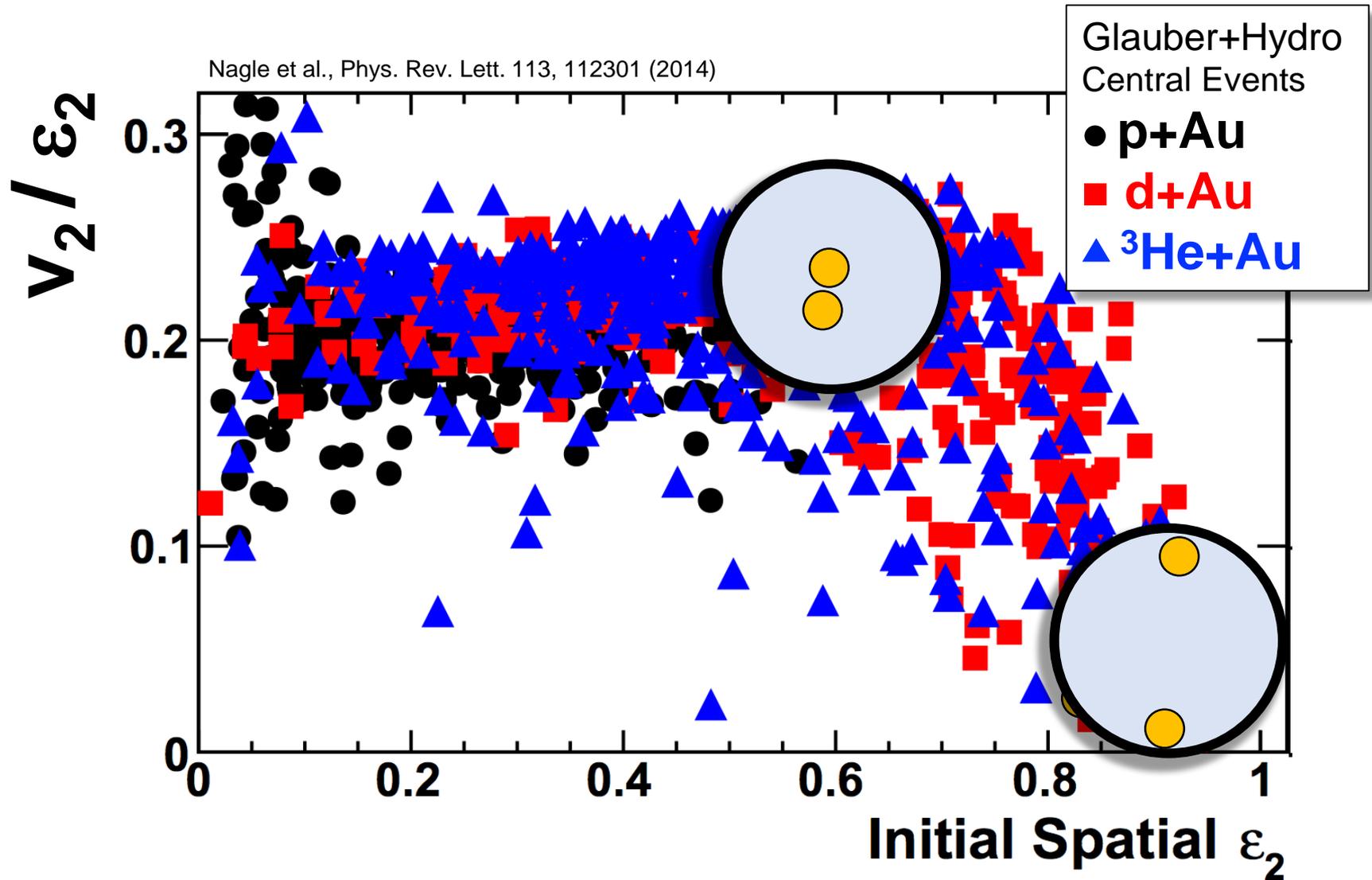
# Elliptic Flow in All Systems



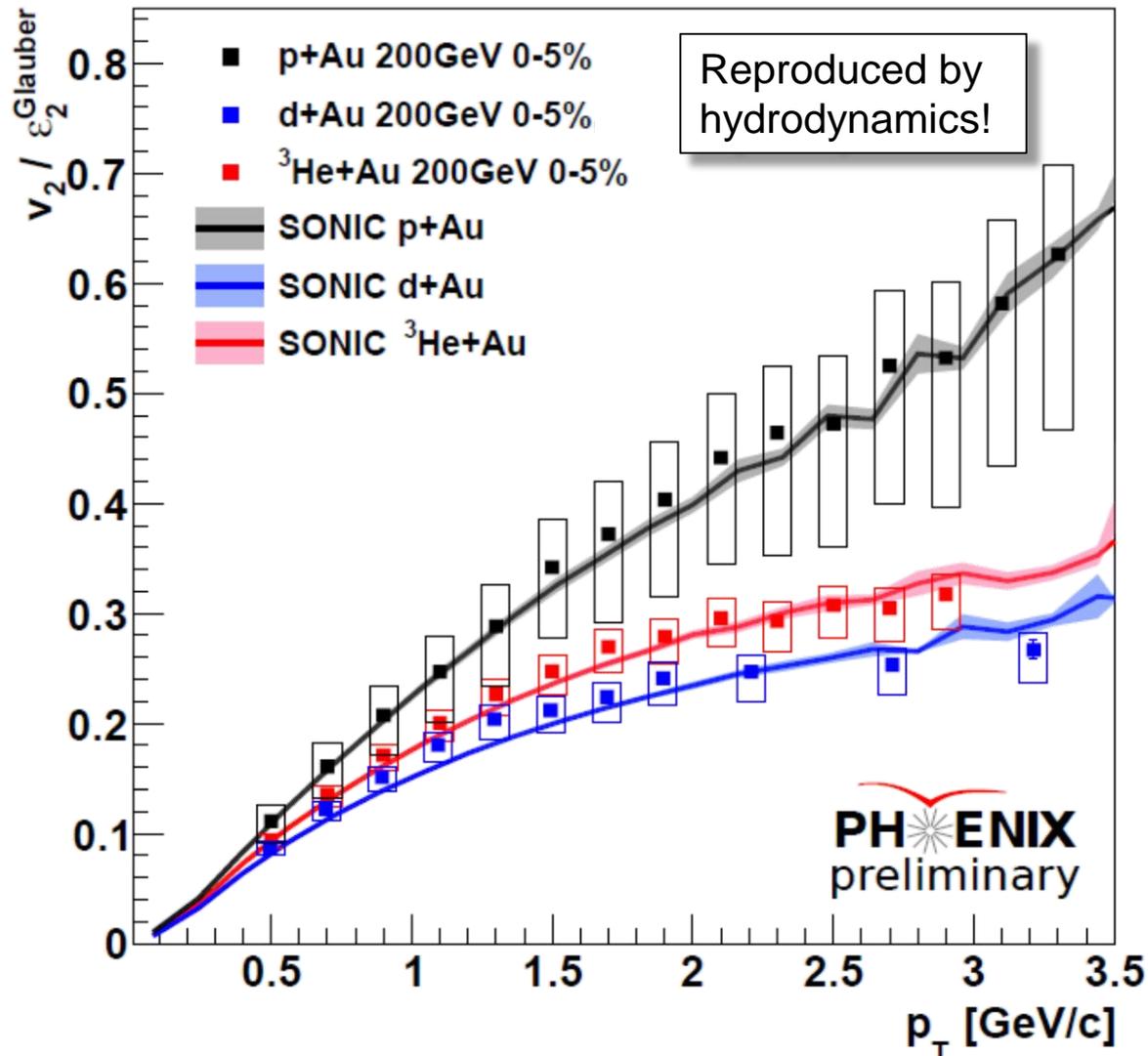
# Elliptic Flow Scaling?



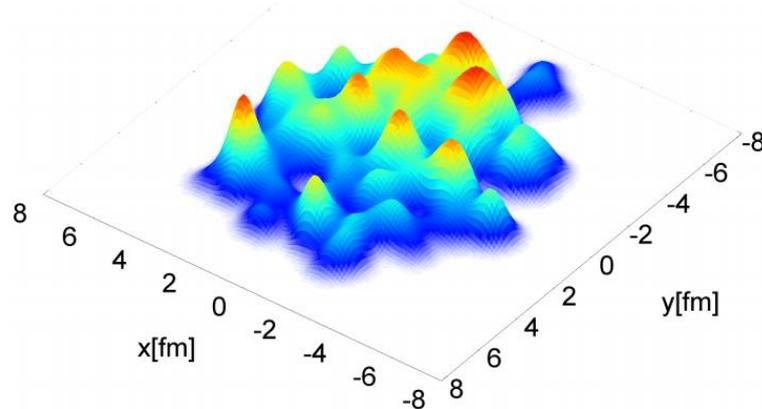
# Elliptic Flow Scaling?



# Imperfect Elliptic Flow Scaling

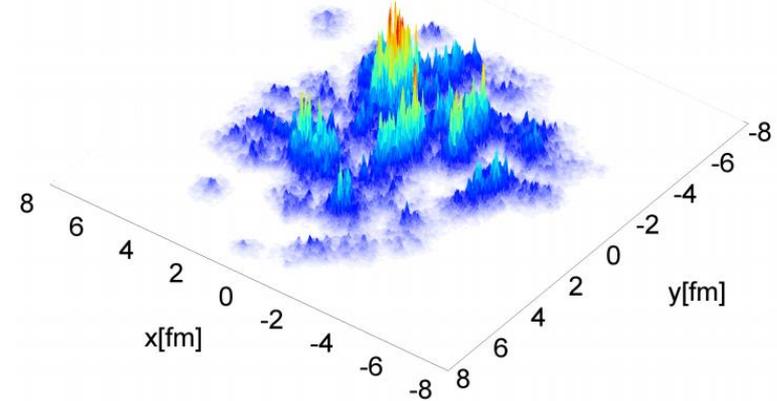


## MC Glauber



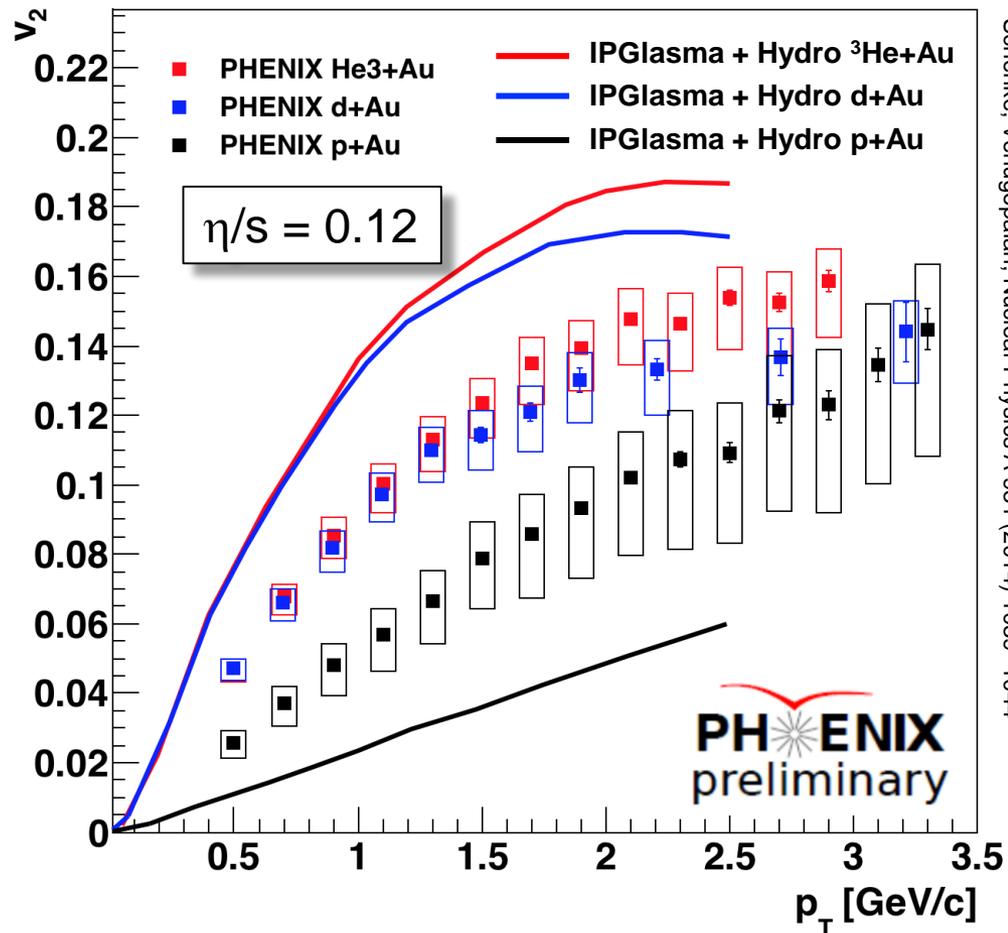
- Fluctuations in nucleon coordinates
- Smear energy deposition by Gaussian
- Use all participants

## IPGlasma

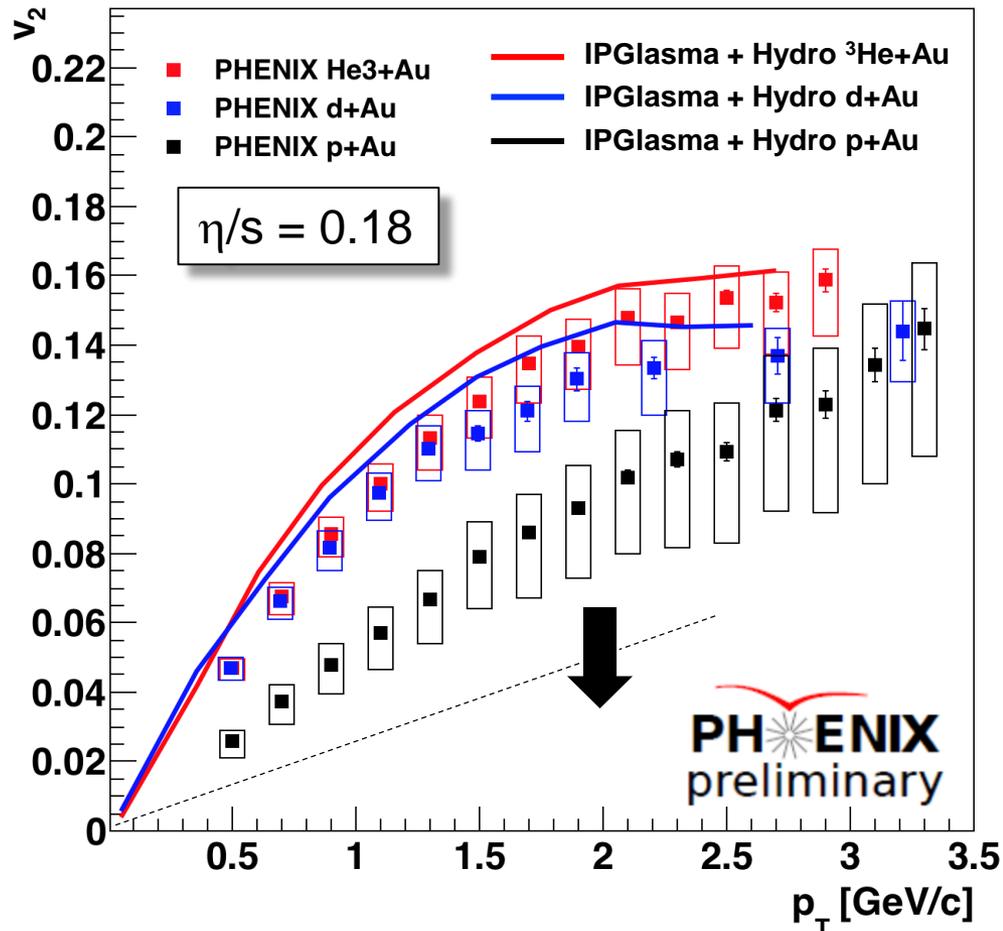


- Fluctuations in nucleon coordinates
- Fluctuations in color charge within nucleons
- Look at region where nucleons overlap

d+Au and  $^3\text{He}+\text{Au}$  are overpredicted  
p+Au is underpredicted

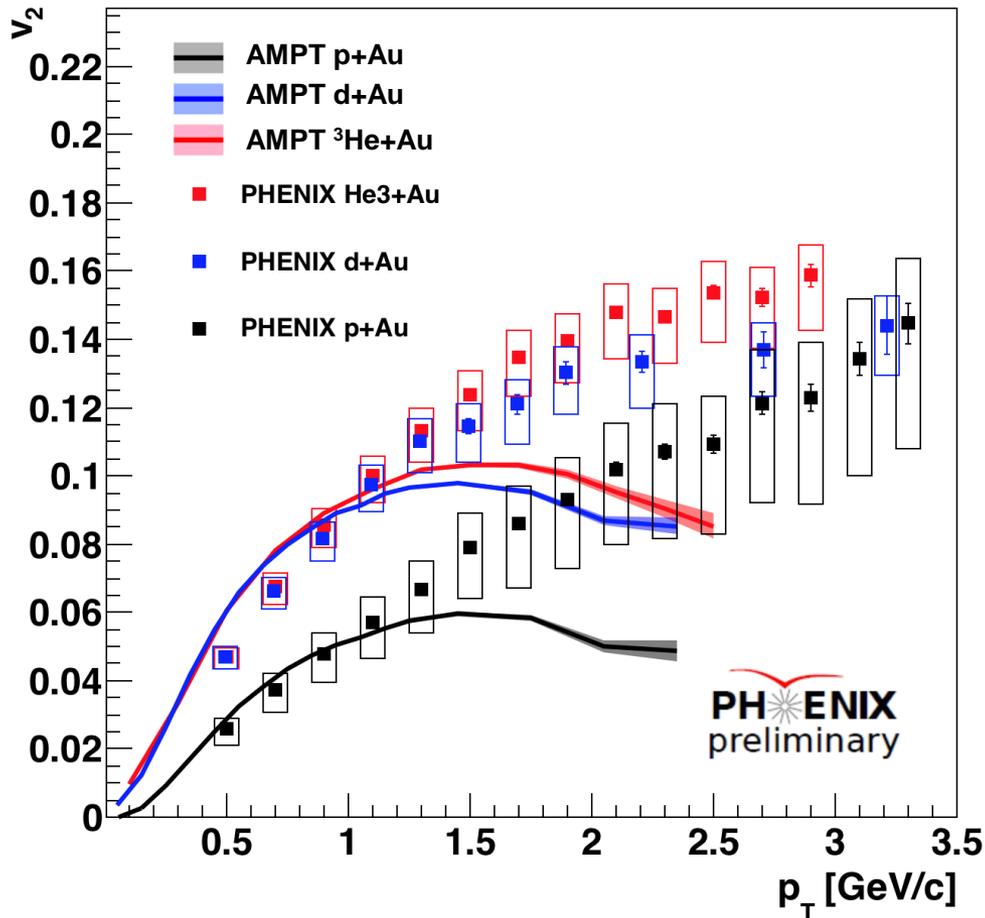


Changing  $\eta/s$  makes all curves move in the same direction



# Partonic Scattering in AMPT

AMPT: Orjuela-Koop, Adare, McGlinchey, Nagle, Phys. Rev. C 92, 054903 (2015)



Reasonable agreement below  $\sim 1$  GeV/c

MC Glauber Initial Geo

+

String Melting

+

Partonic Scattering

$\sigma = 1.5$  mb

+

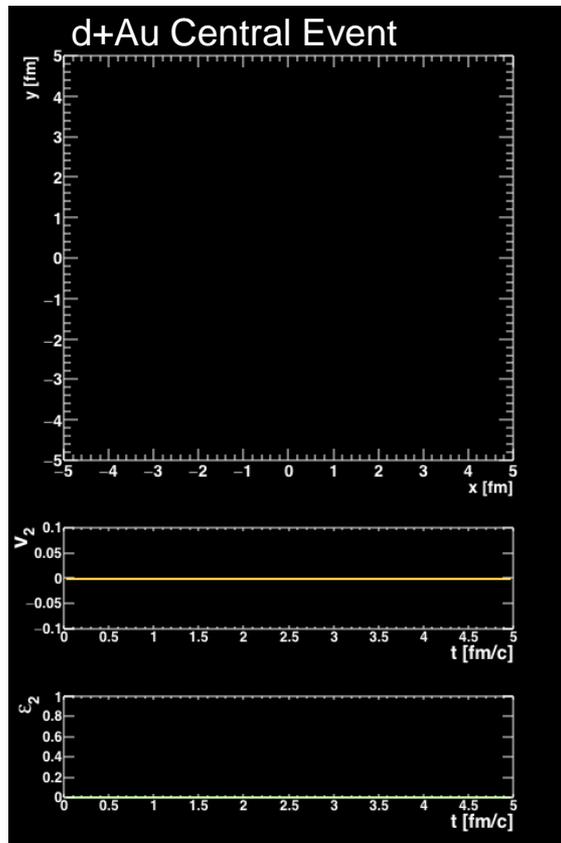
Spatial Coalescence

+

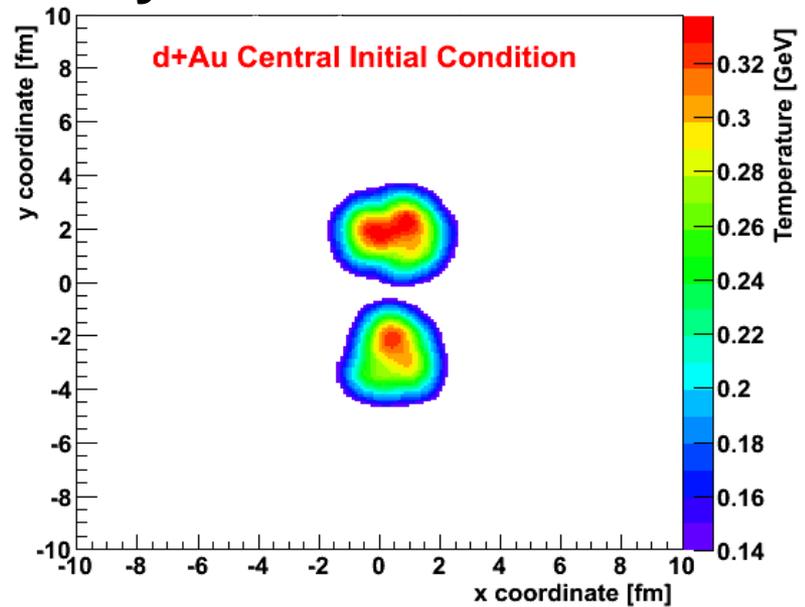
Hadronic Scattering

## Geometry drives flow in small systems

### AMPT



### Hydro



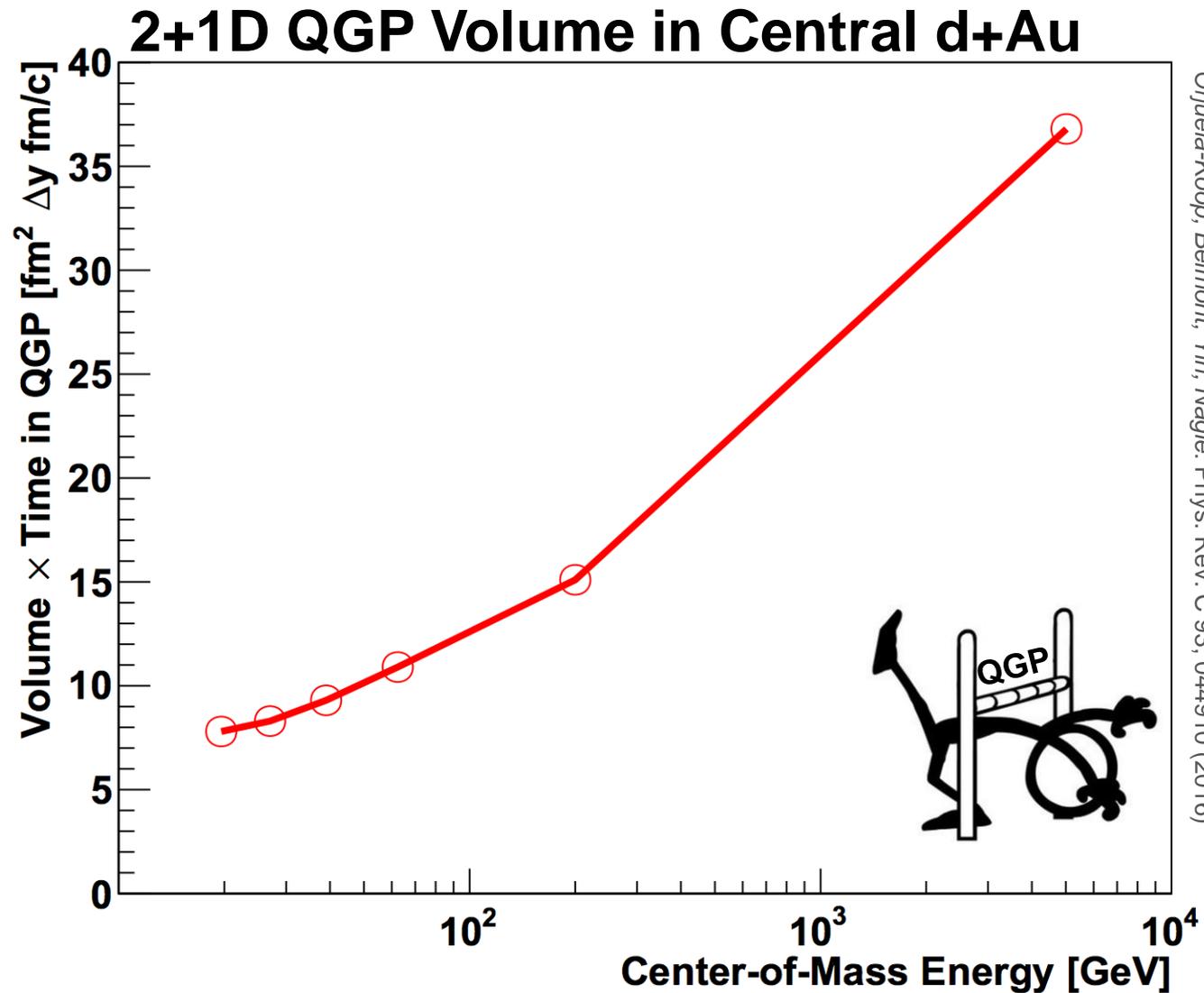
# Going Down in Size and Energy

Other stages become relevant for small system collectivity



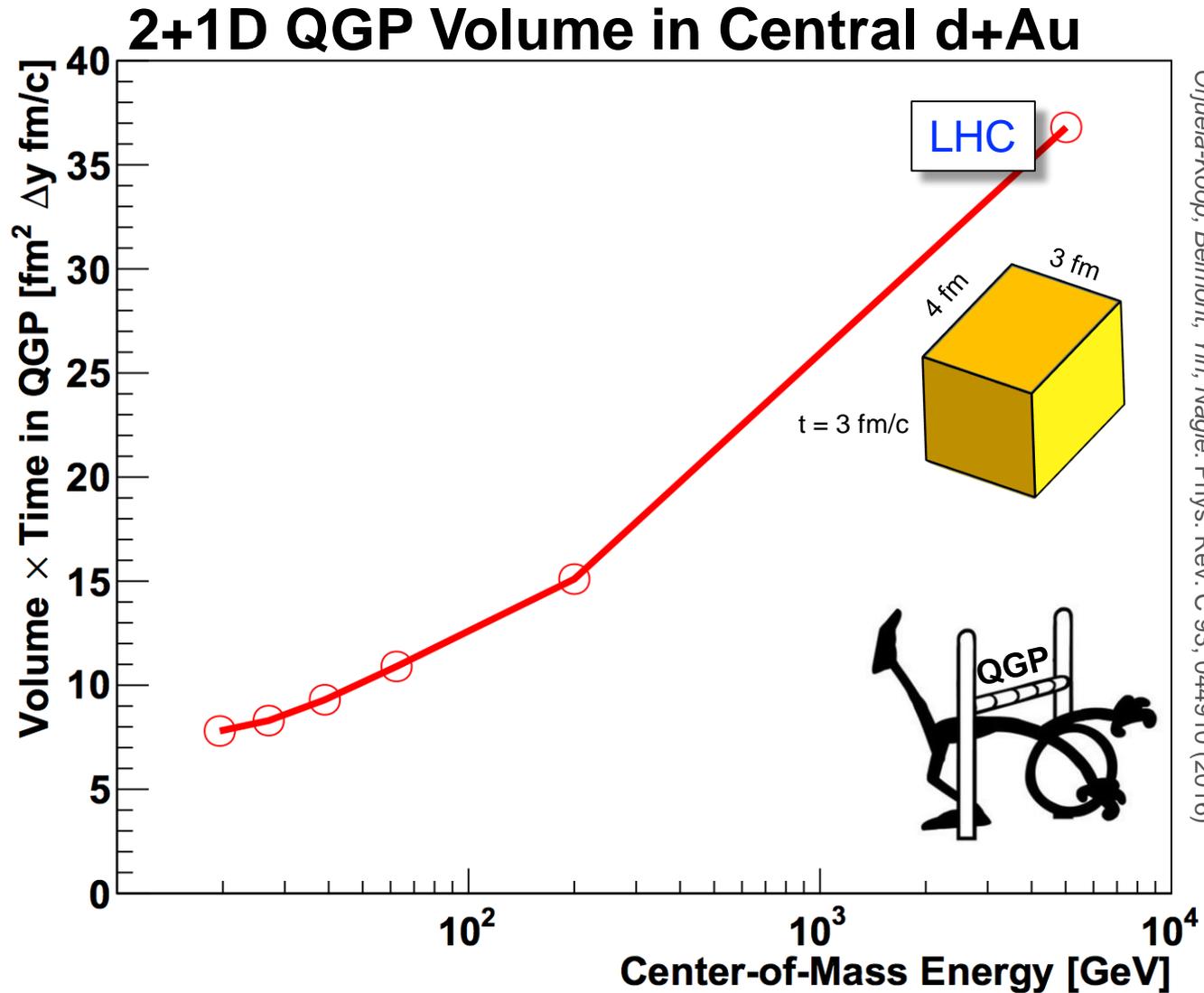
**d+Au Beam Energy Scan  
+  
Model Comparisons**

# How Low Can You Go?



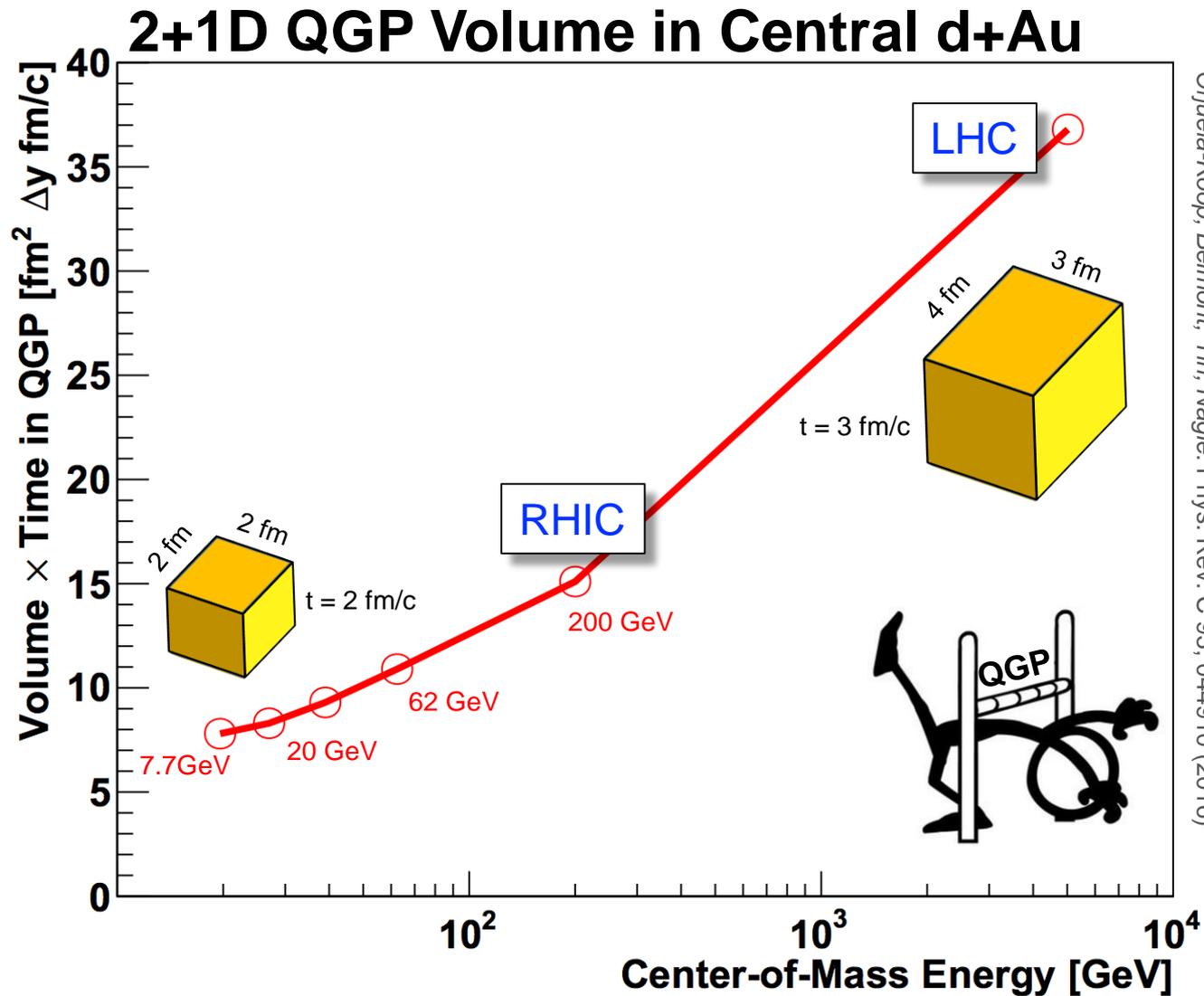
Orjuela-Koop, Belmont, Yin, Nagle: Phys. Rev. C 93, 044910 (2016)

# How Low Can You Go?



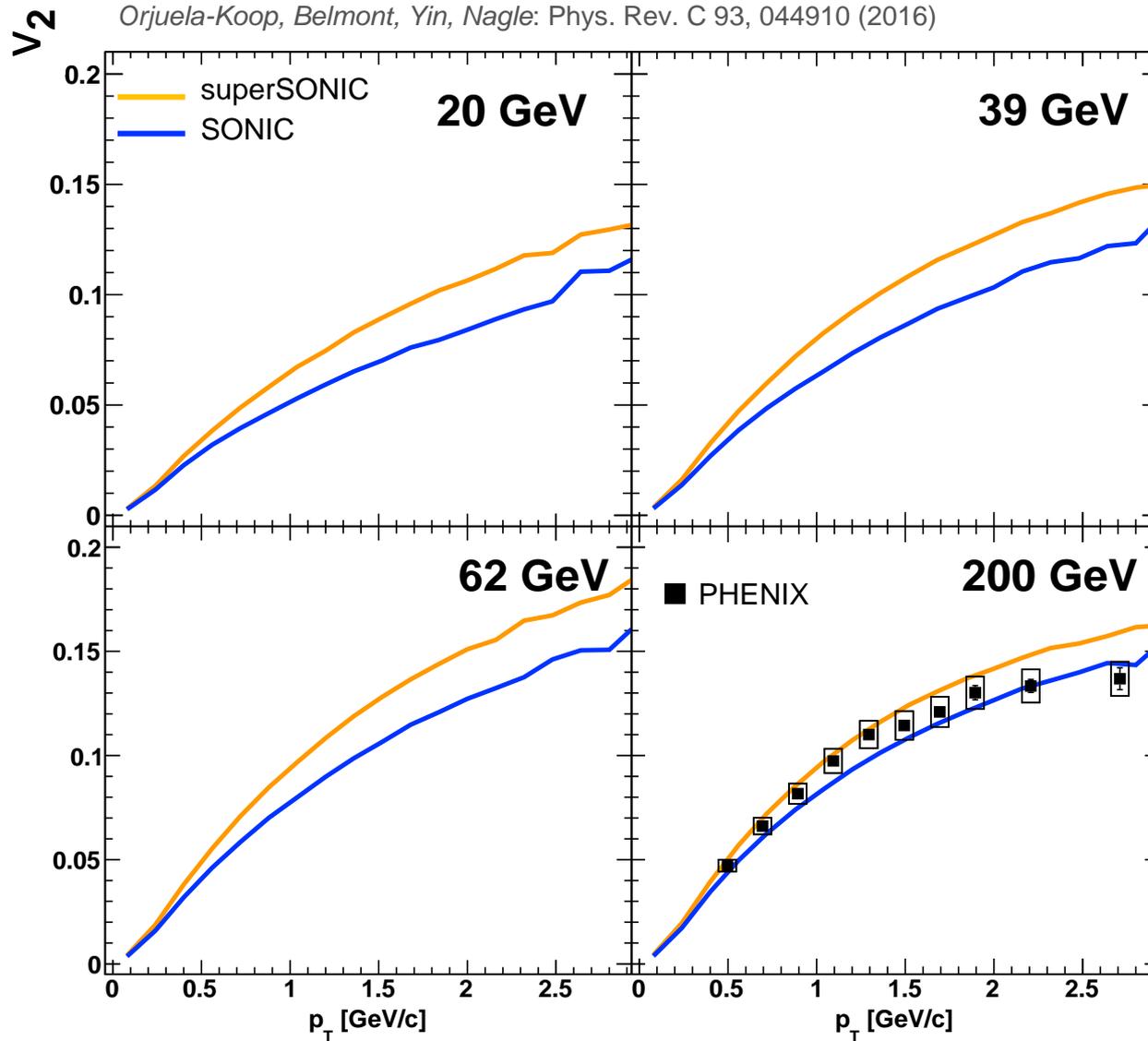
Orjuela-Koop, Belmont, Yin, Nagle: Phys. Rev. C 93, 044910 (2016)

# How Low Can You Go?



Orjuela-Koop, Belmont, Yin, Nagle: Phys. Rev. C 93, 044910 (2016)

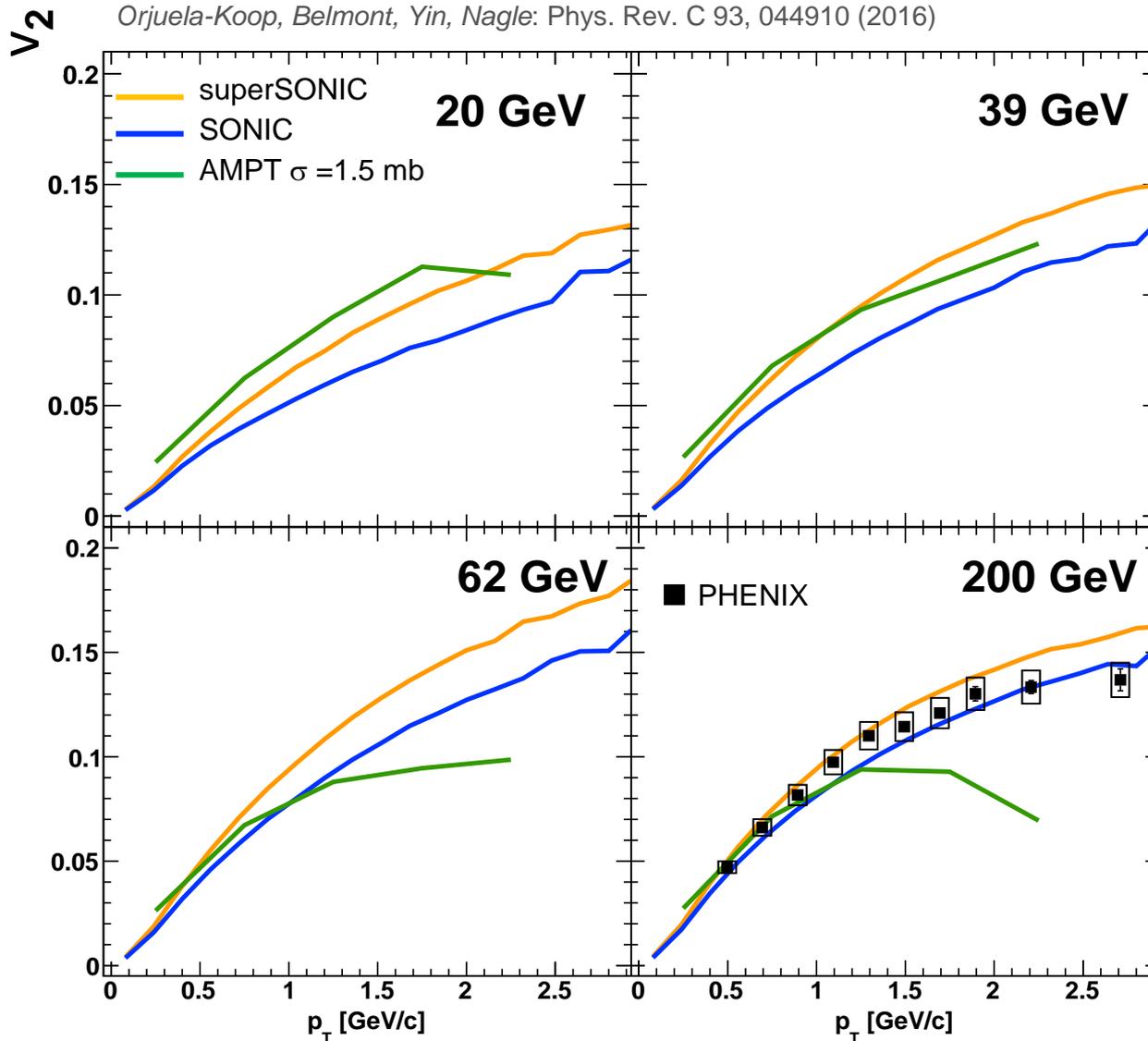
# d+Au Beam Energy Scan



Hydro With  
Pre-Equilibrium

Hydro Without  
Pre-Equilibrium

# d+Au Beam Energy Scan

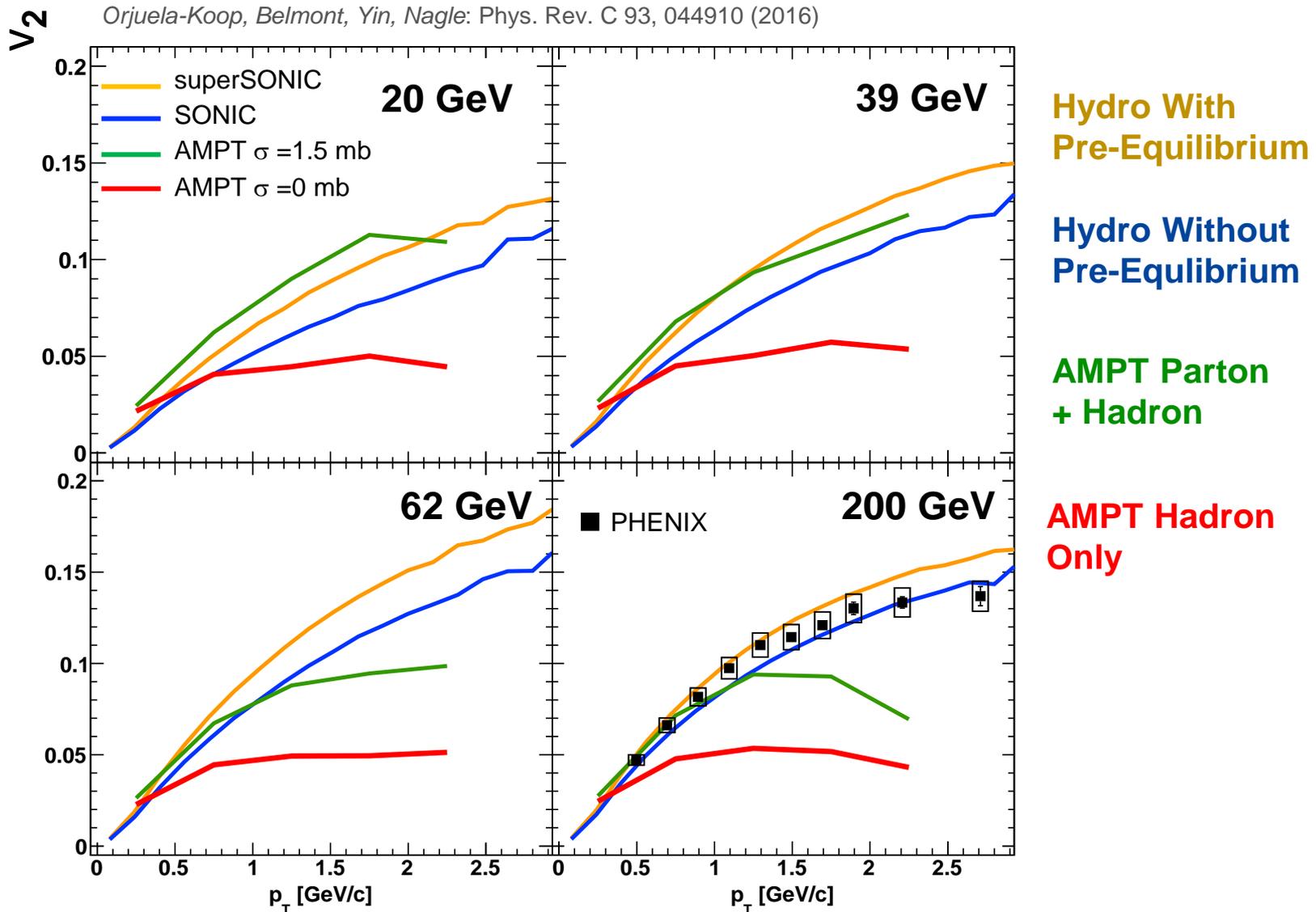


Hydro With  
Pre-Equilibrium

Hydro Without  
Pre-Equilibrium

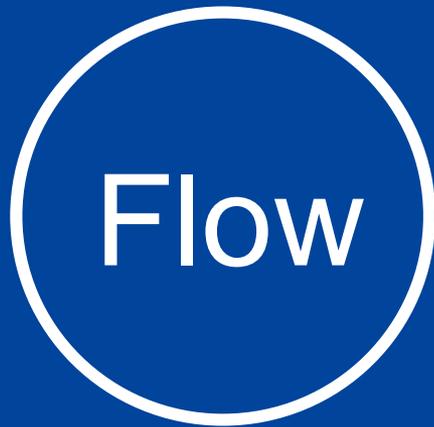
AMPT Parton  
+ Hadron

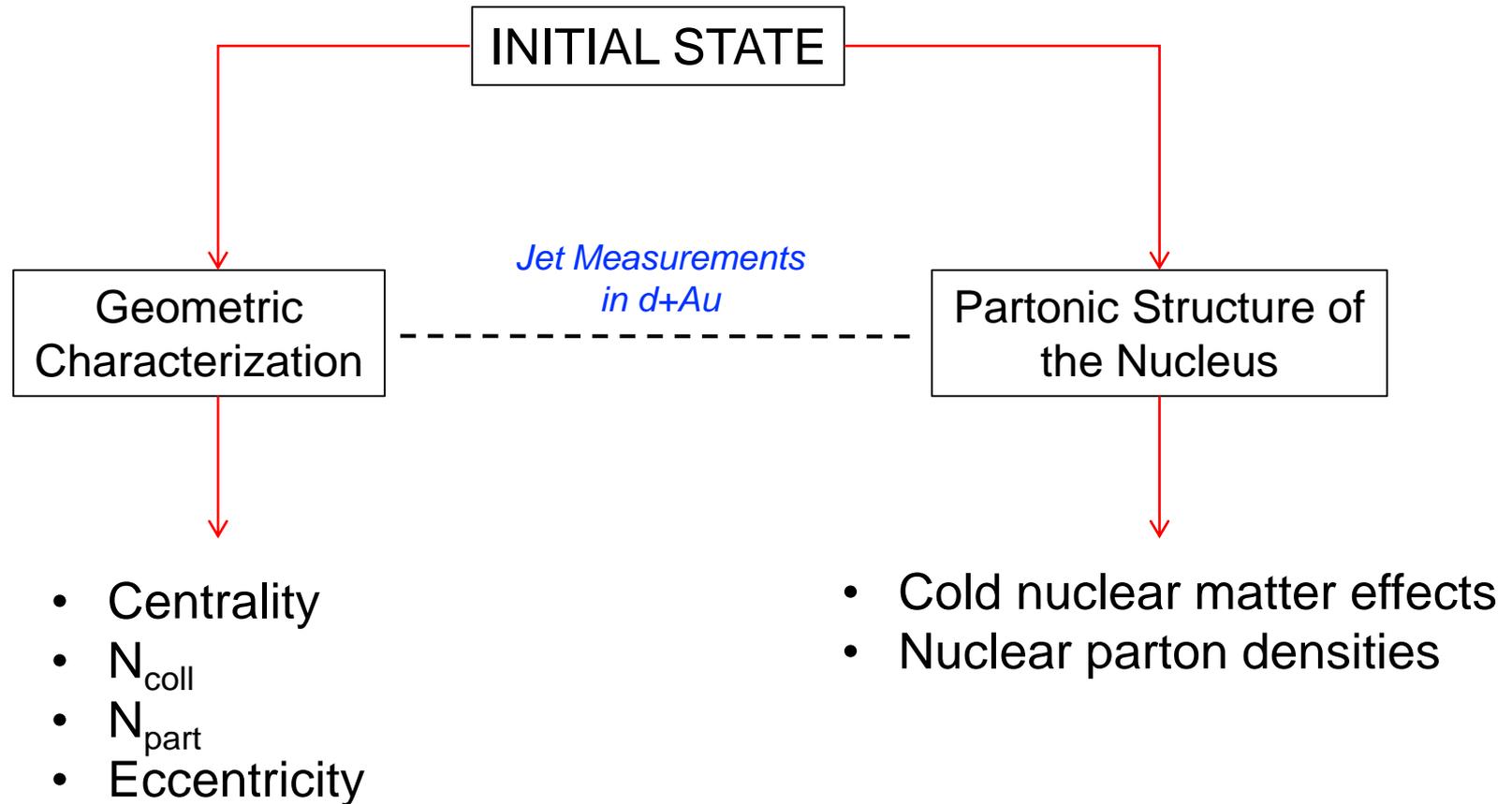
# d+Au Beam Energy Scan



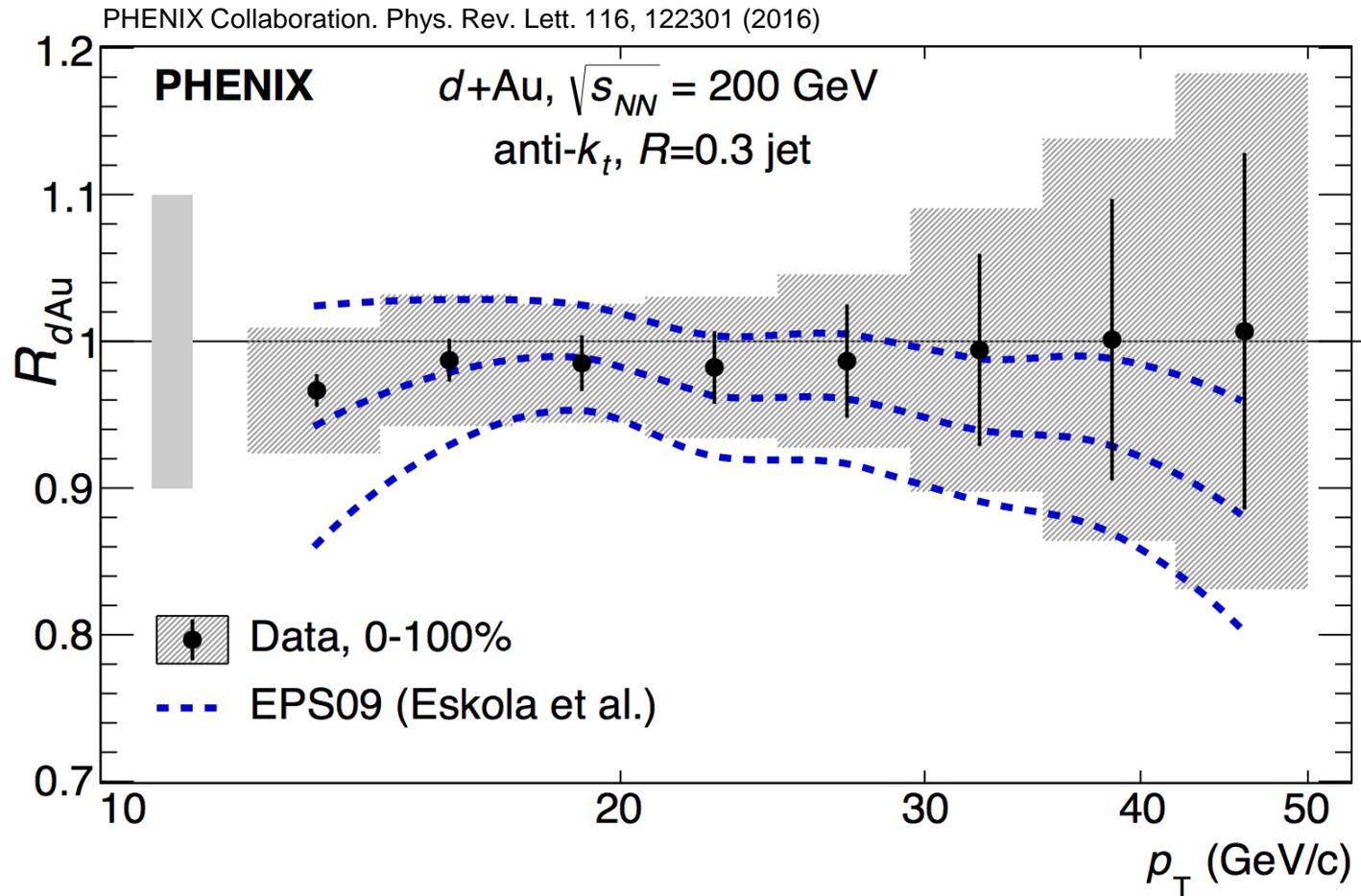
Stay tuned for PHENIX Run16 results!

# Small Collision Systems



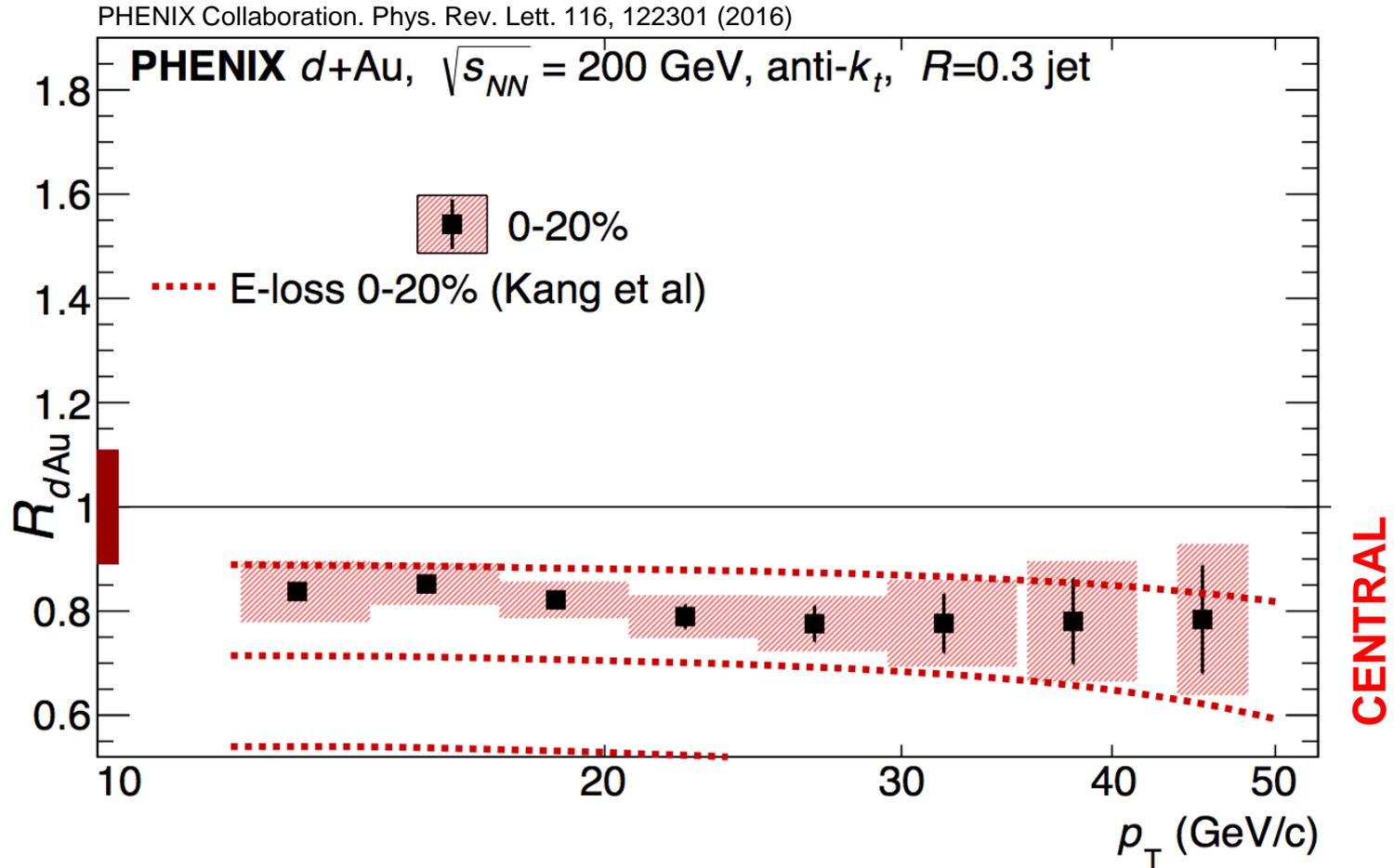


# Minimum Bias Jet $R_{dAu}$



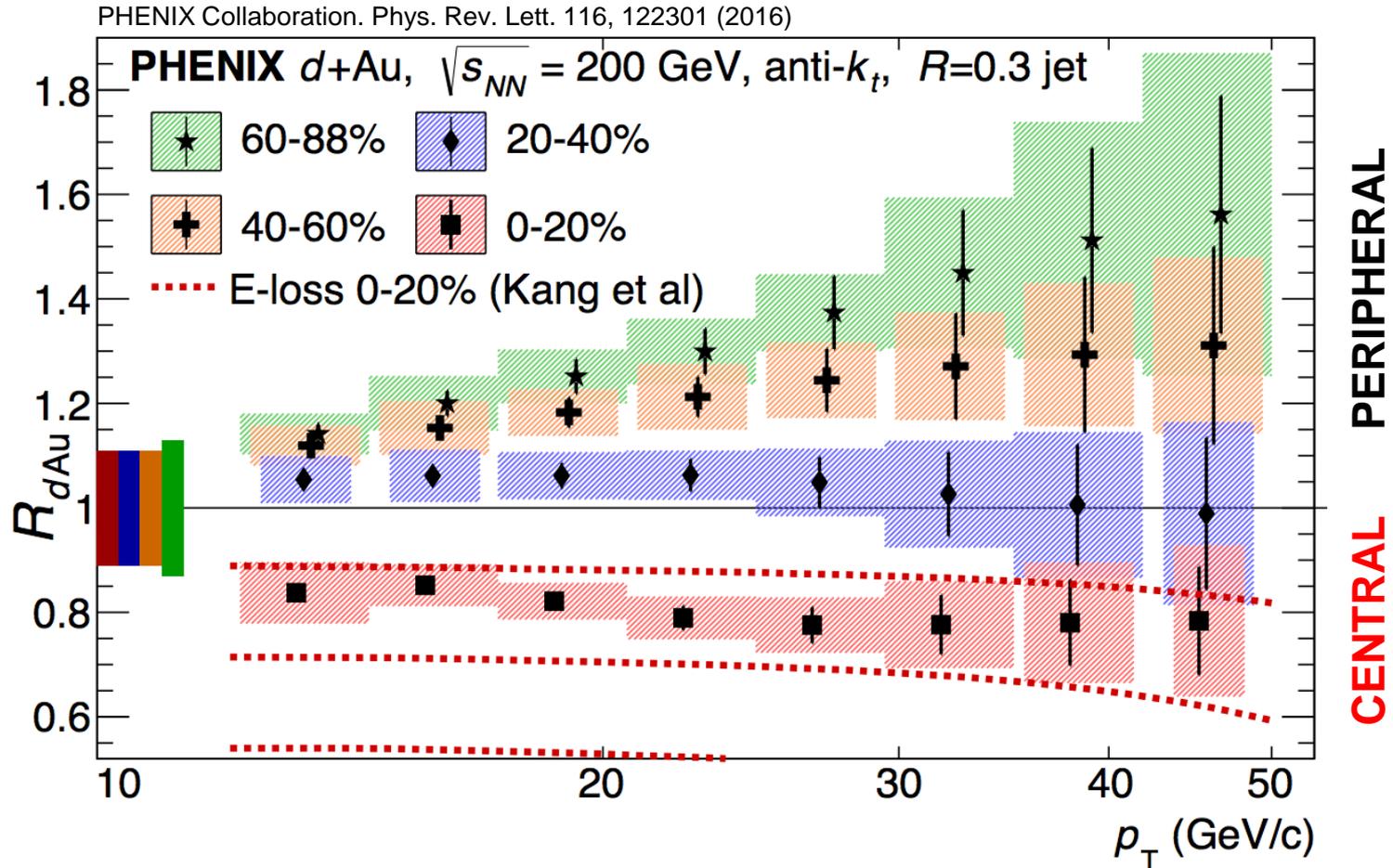
No modification in minimum bias collisions

# Centrality-Dependent Jet $R_{dAu}$ Modification



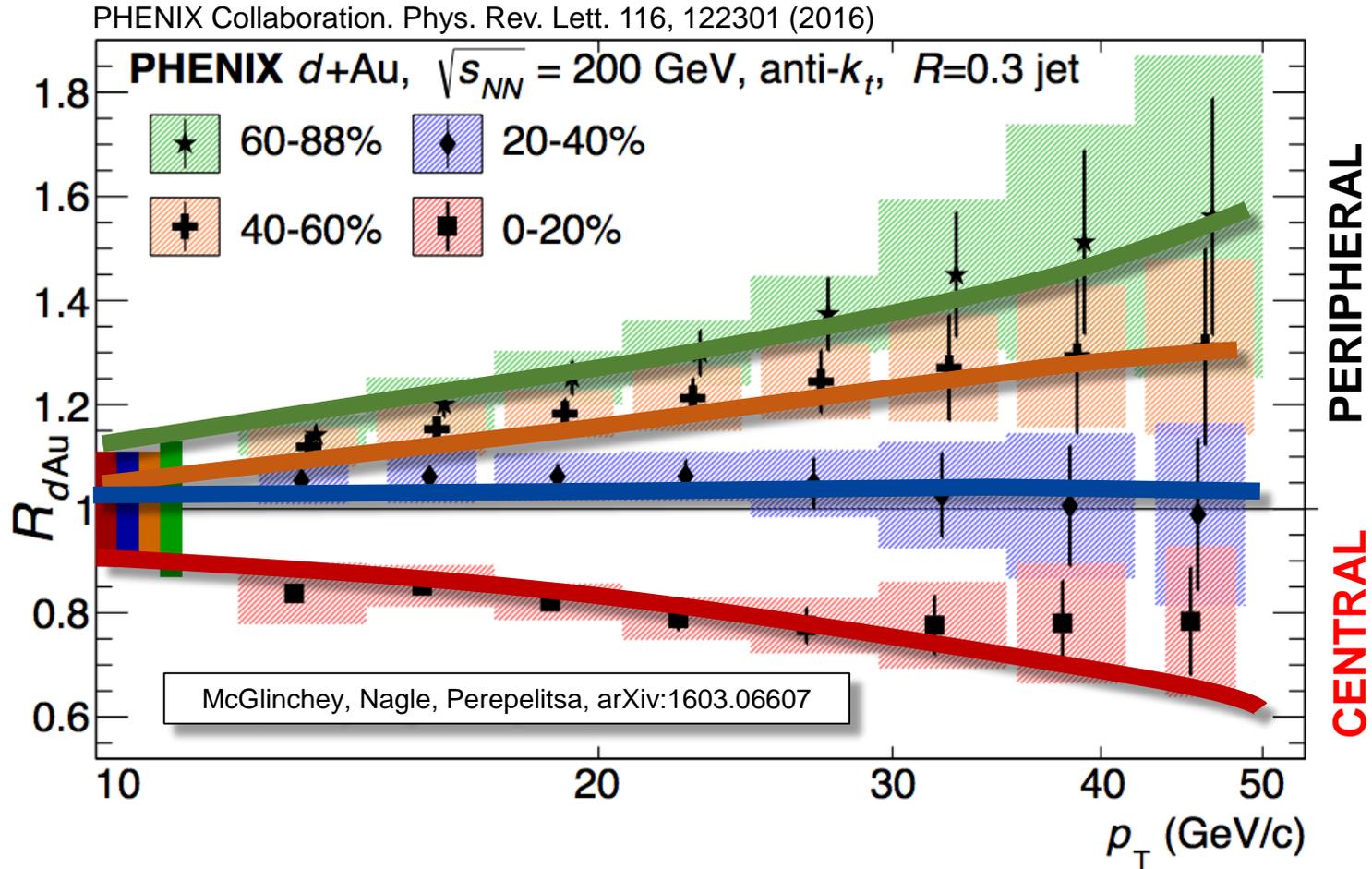
Central suppression consistent  
with energy loss models

# Centrality-Dependent Jet Modification in d+Au



How can we explain this?

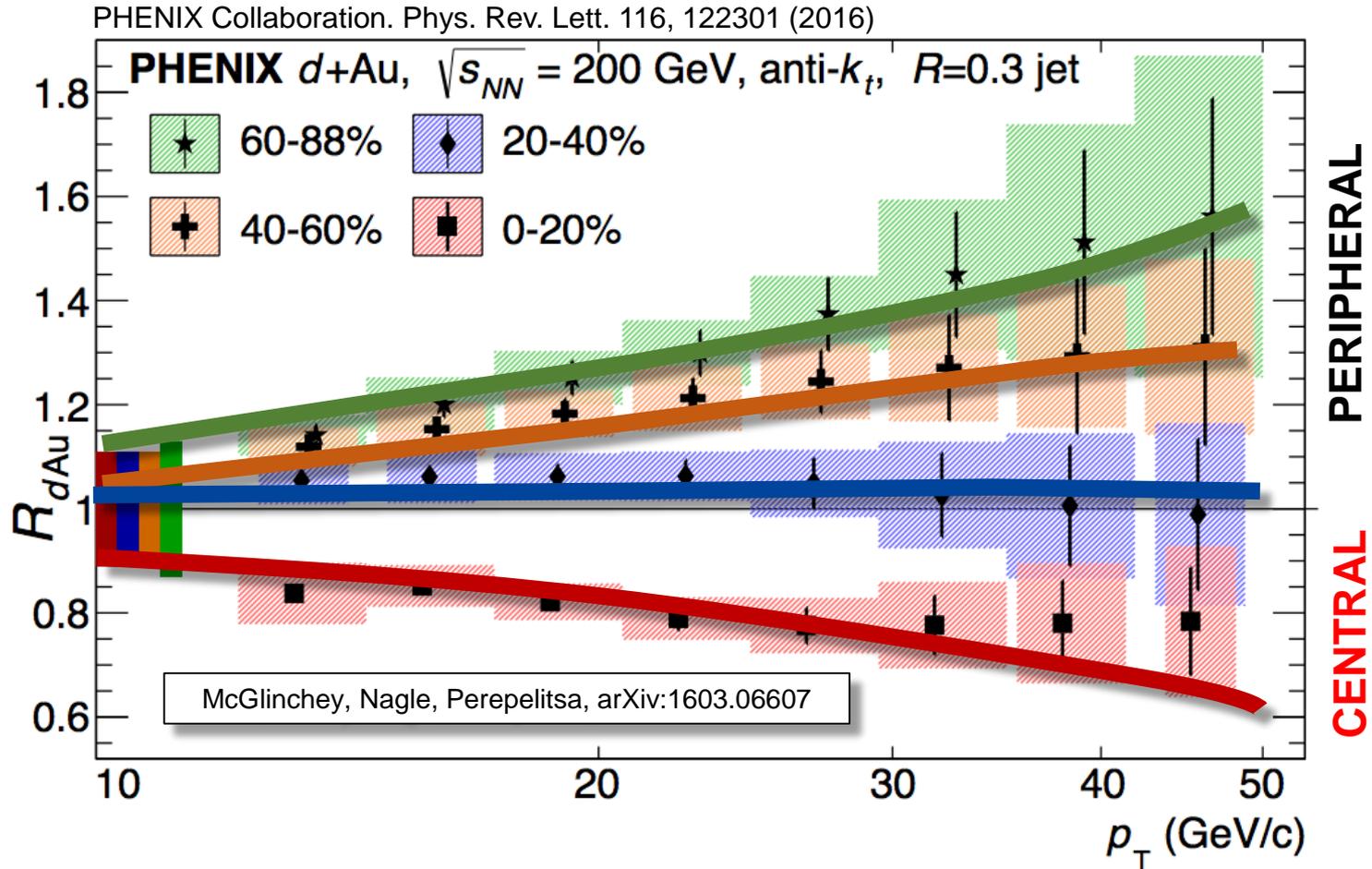
# Centrality-Dependent Jet Modification in d+Au



x-dependent proton size fluctuations?

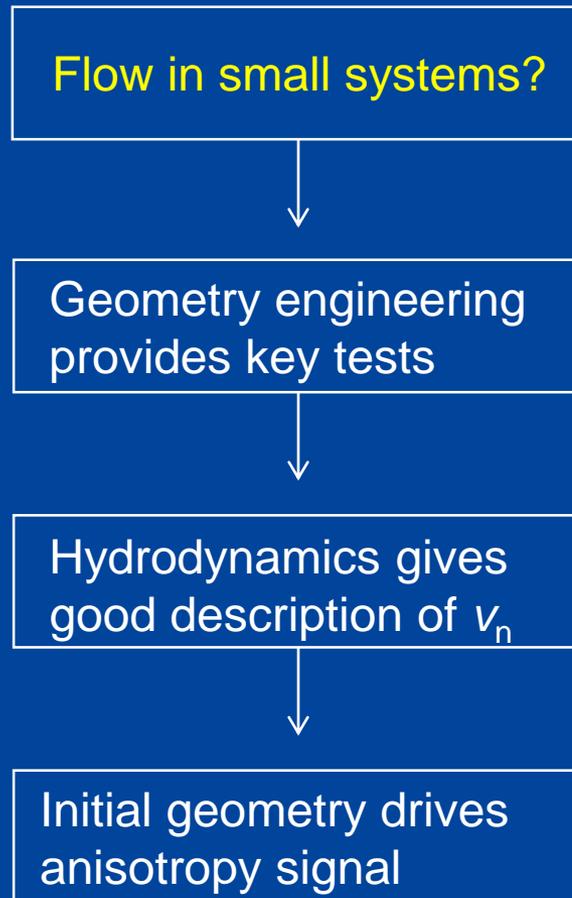
See: Alvioli, Cole, Frankfurt, Perepelitsa, Strickman, Phys. Rev. C 93, 011902

# Centrality-Dependent Jet Modification in d+Au



See D. Perepelitsa's Talk Tomorrow!

# Summary



# Summary

