PHENIX Results On Small Systems

Javier Orjuela-Koop

For the PHENIX Collaboration

University of Colorado Boulder

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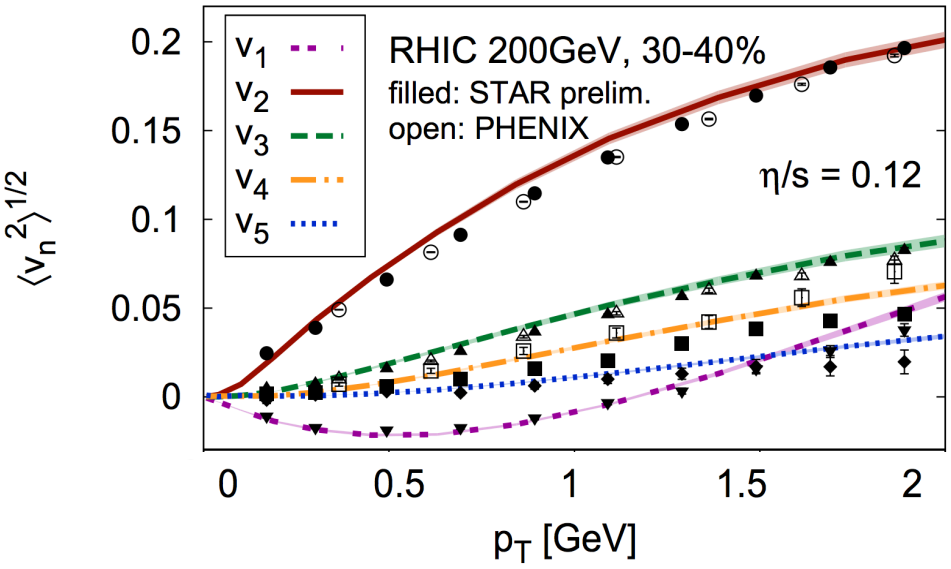
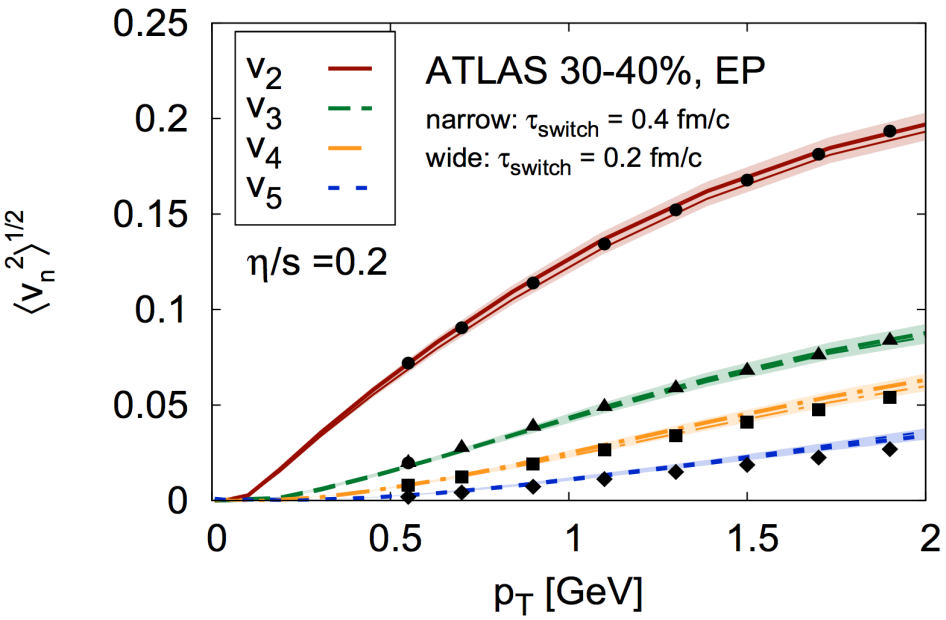
Lisbon, May 22-27, 2016

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

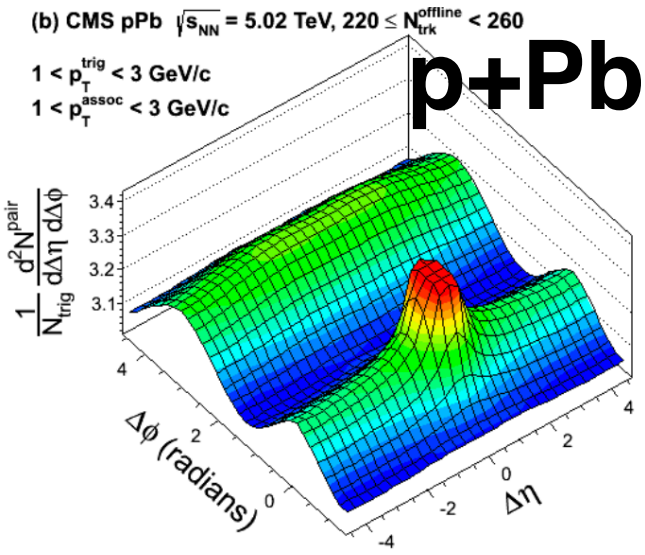
The Hydrodynamic Picture

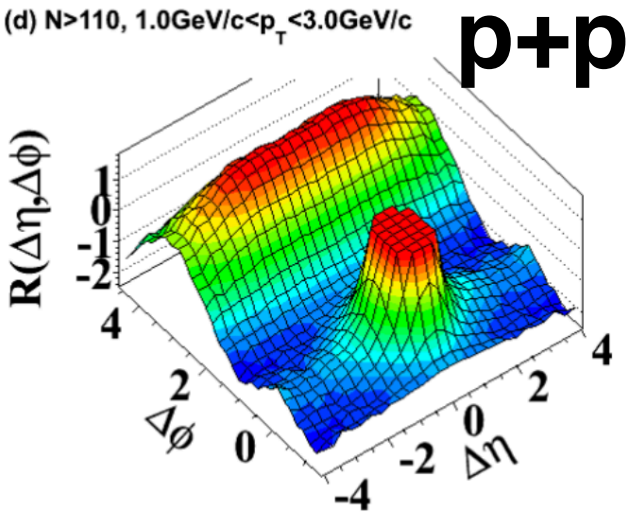
The Hydrodynamic Picture

In Ideal Hydro

$$v_2 \propto \varepsilon_2$$

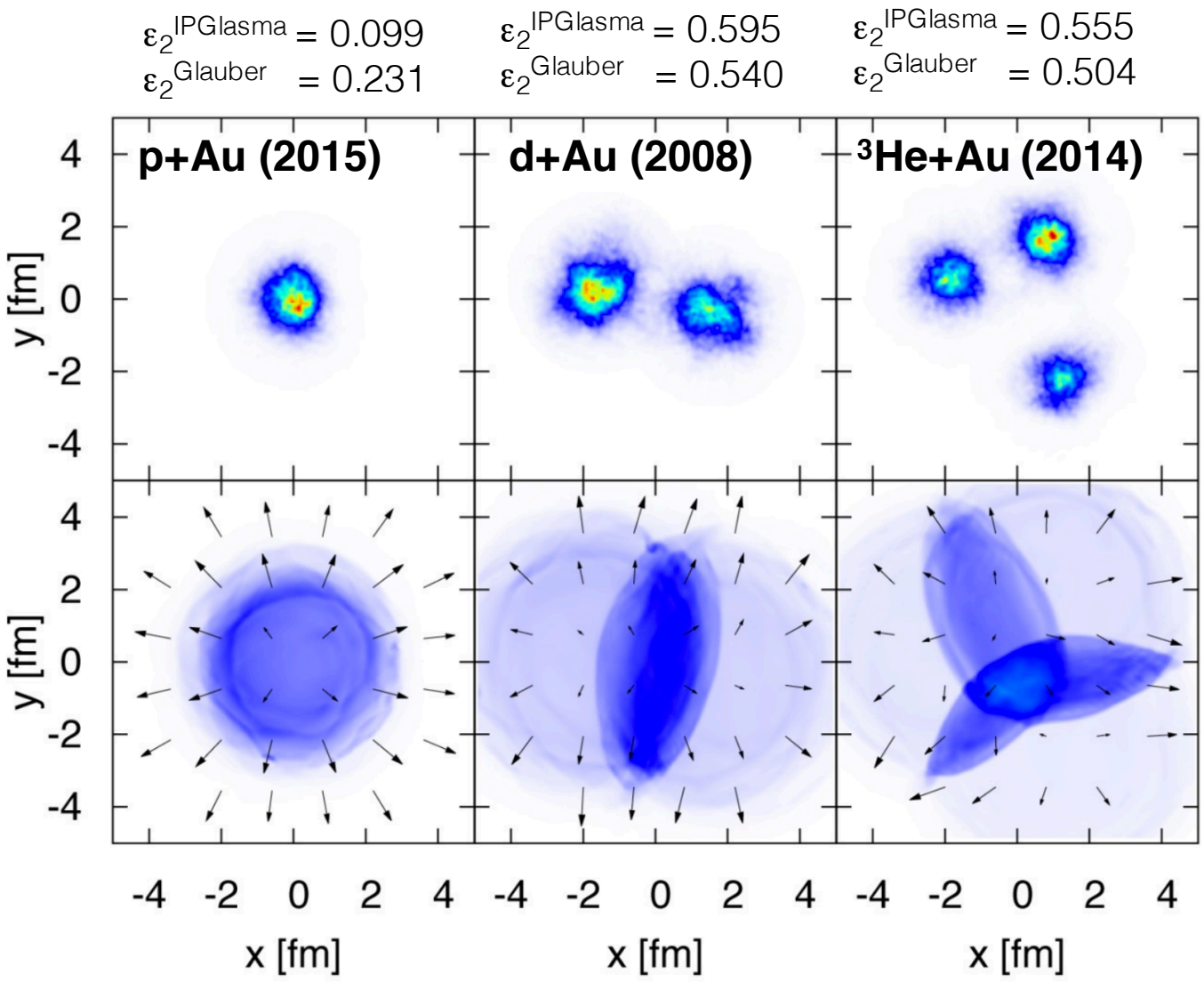
The Hydrodynamic Picture in Small Systems?





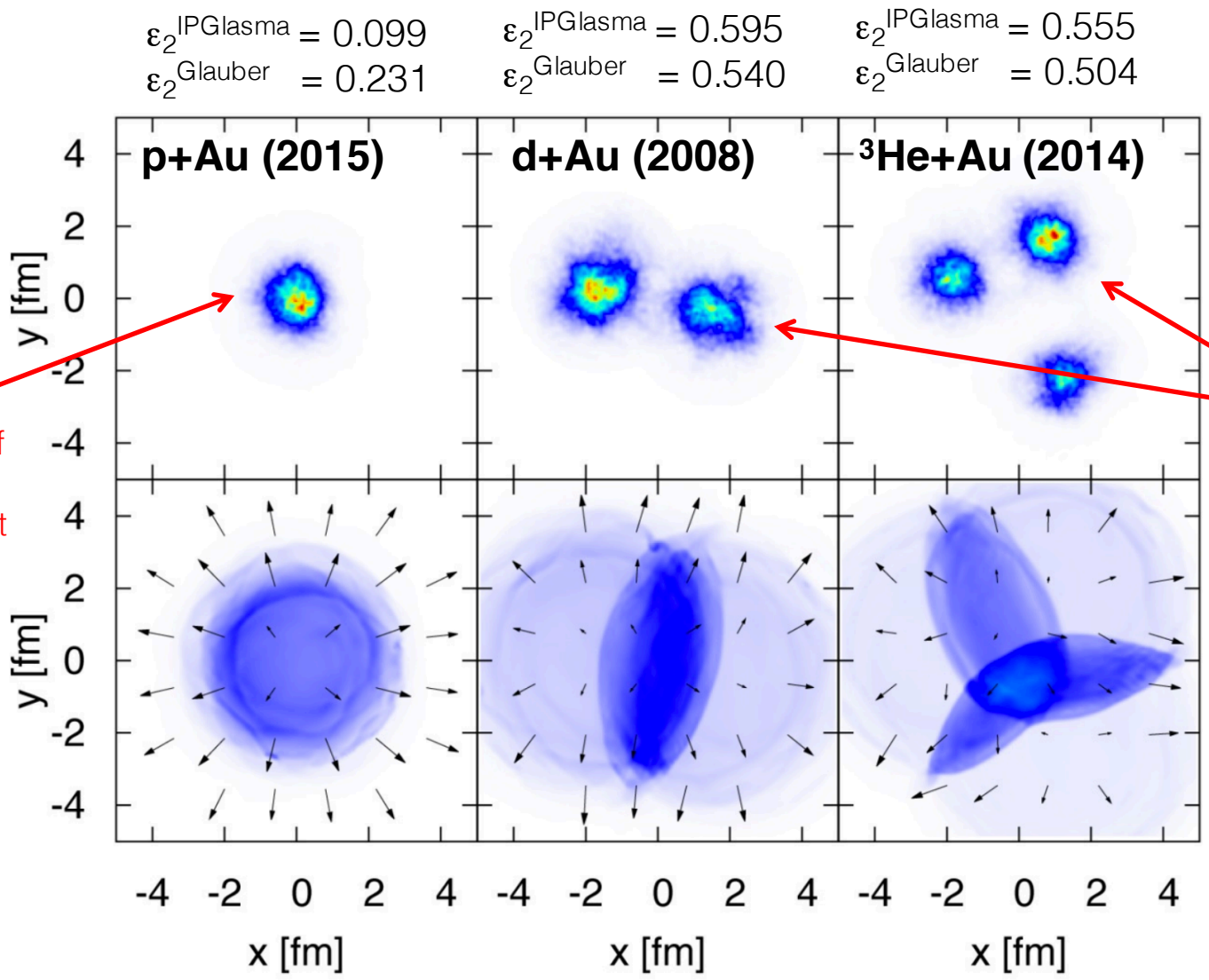
- Is it hot enough?
- Is it sufficiently long-lived?

Geometry Engineering at RHIC



Courtesy of Björn Schenke

Geometry Engineering at RHIC



Structure of the proton is important

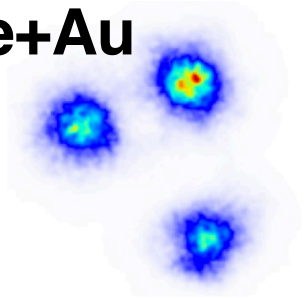
Geometry dominated by elliptic/triangular shape.

ONLY AT RHIC

Courtesy of Björn Schenke

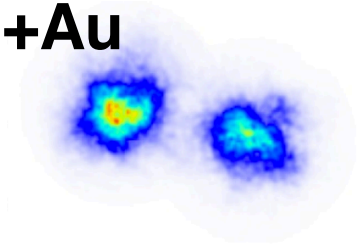
PHENIX Azimuthal Correlation and v_n Measurements

^{3}He+Au



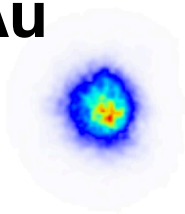
Phys. Rev. Lett. 115, 142301 (2015)

d+Au



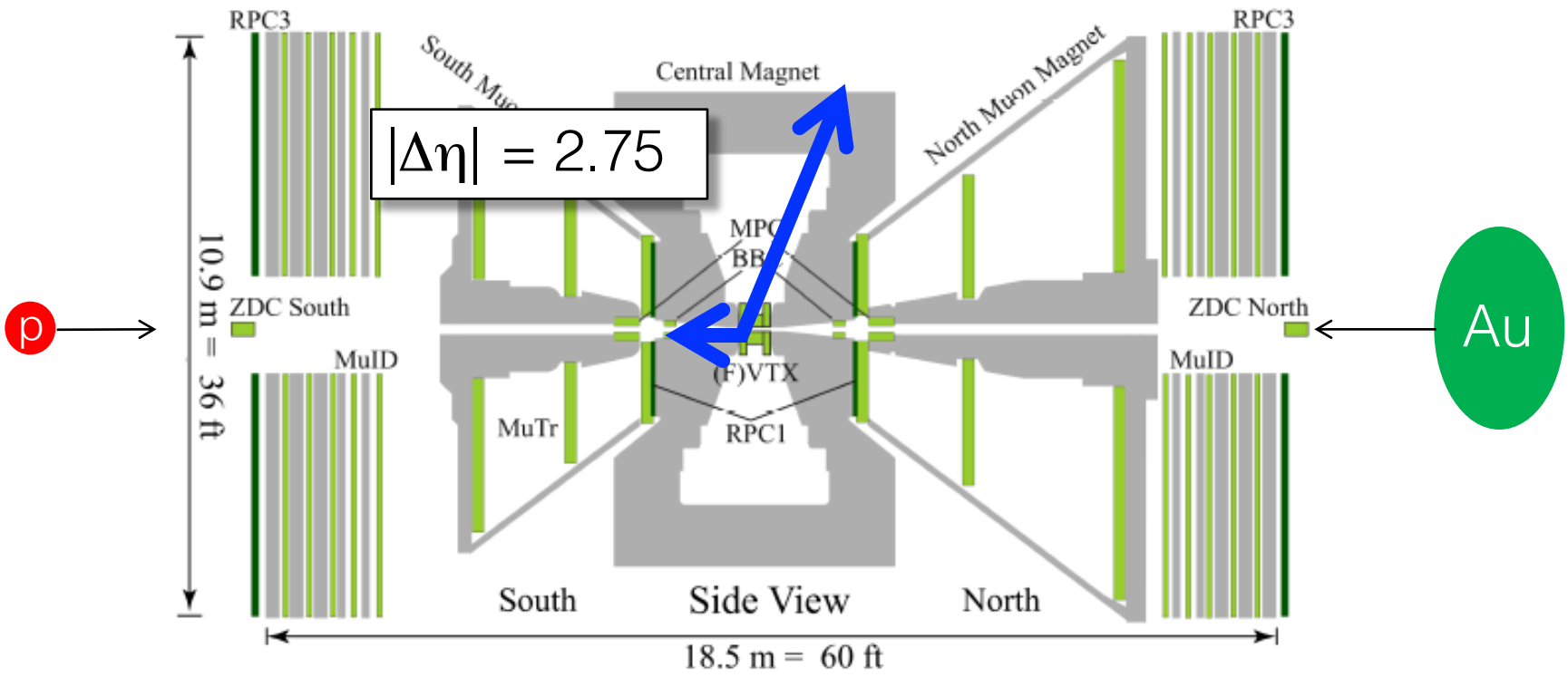
Phys. Rev. Lett. 114, 192301 (2015)

p+Au

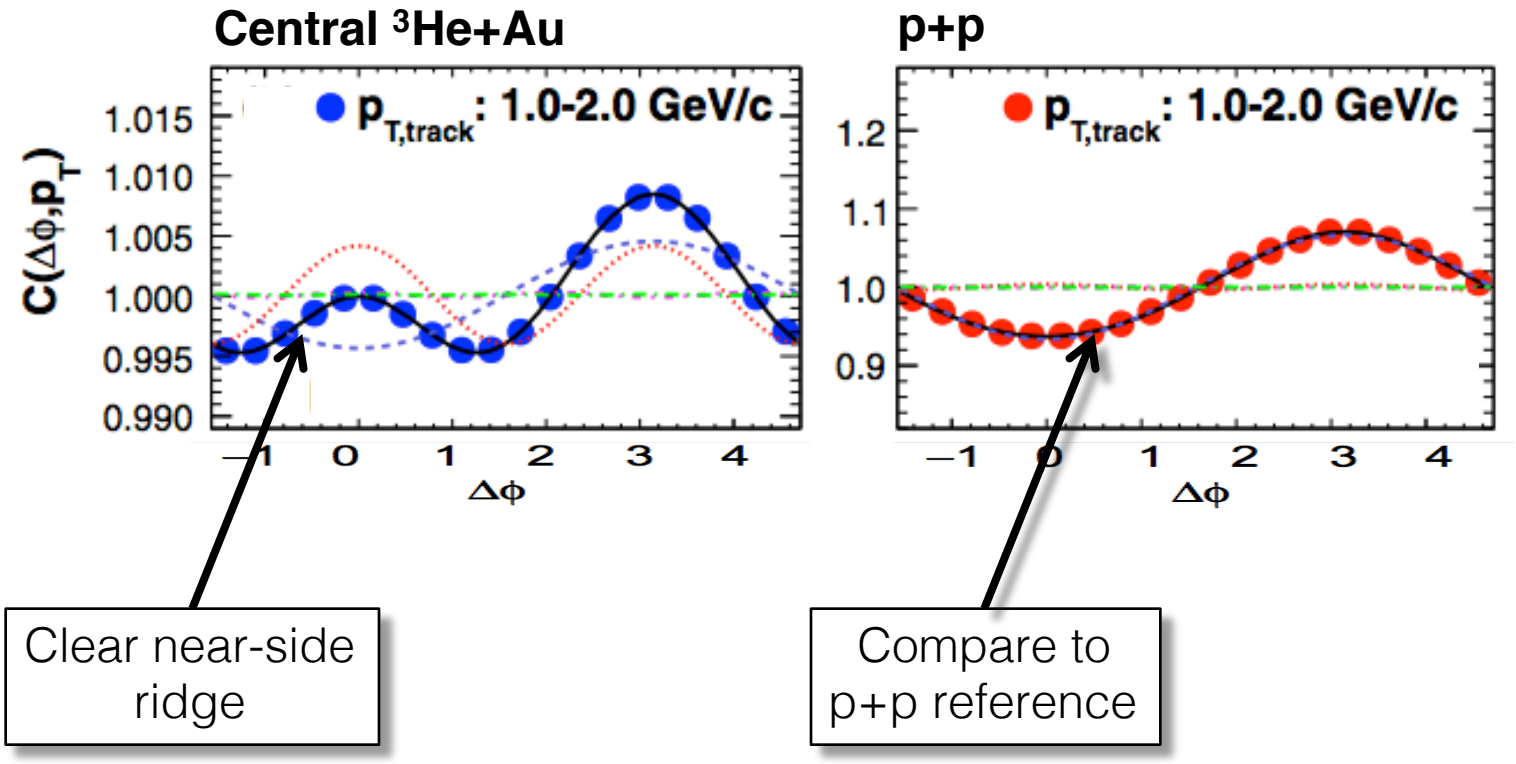


Preliminary Status

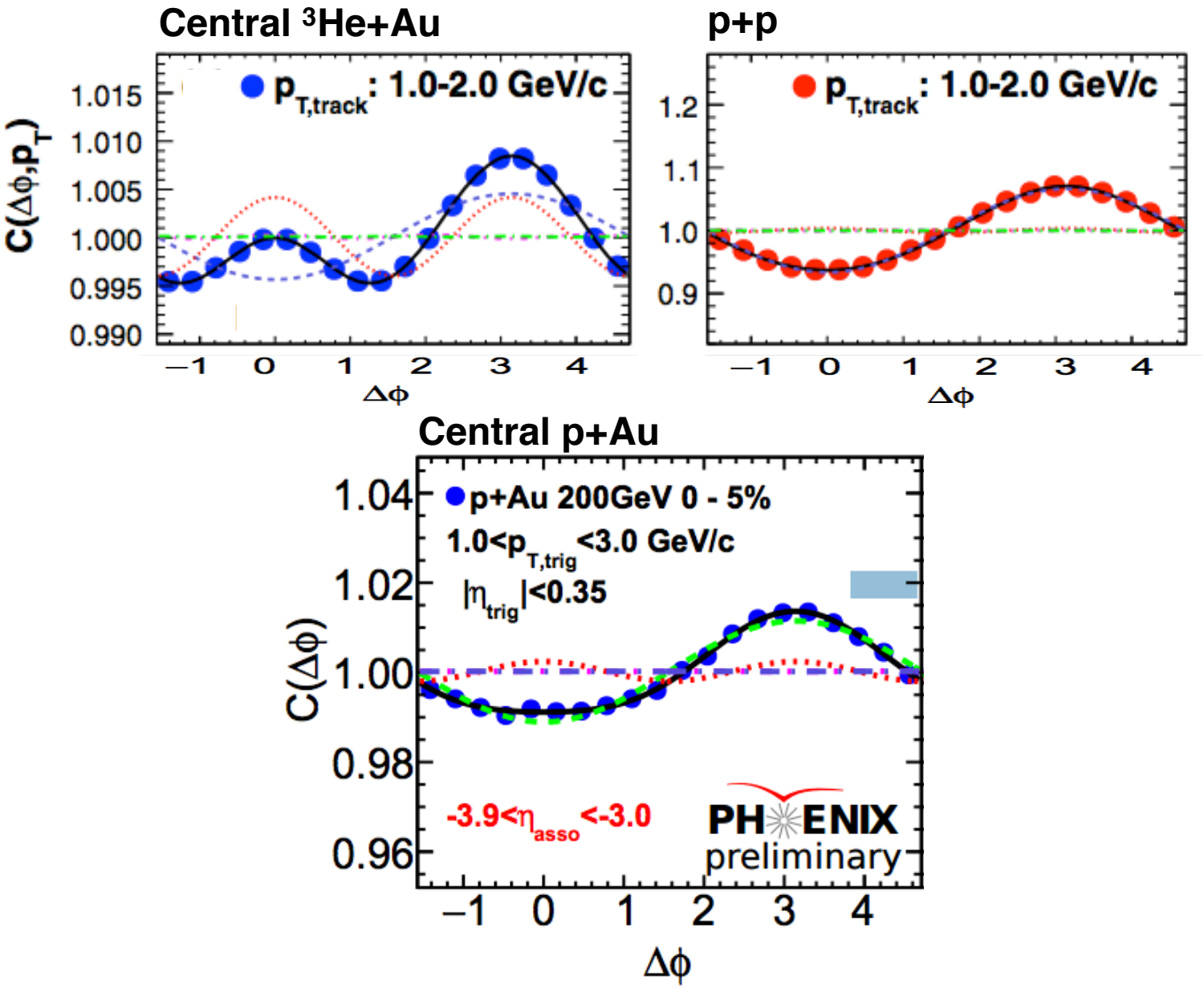
Long Range Azimuthal Correlations in p+Au



Long Range Azimuthal Correlations

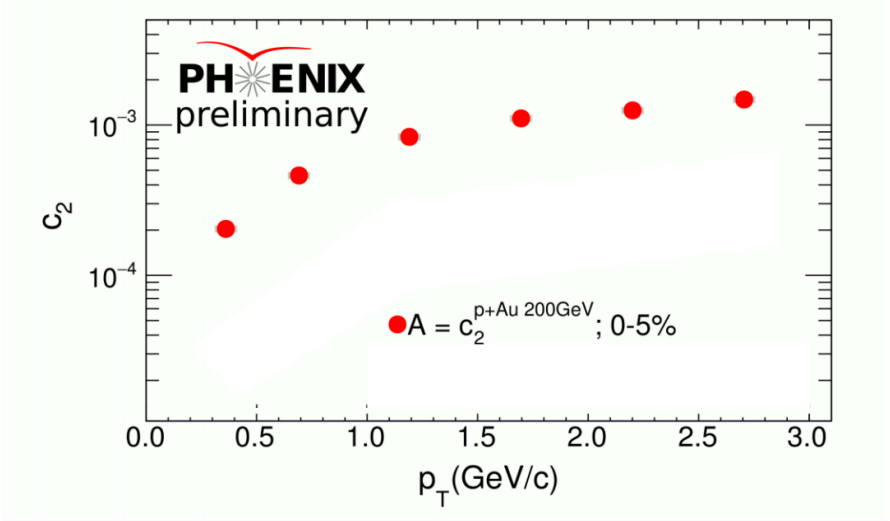


Long Range Azimuthal Correlations



Estimating Non-Flow

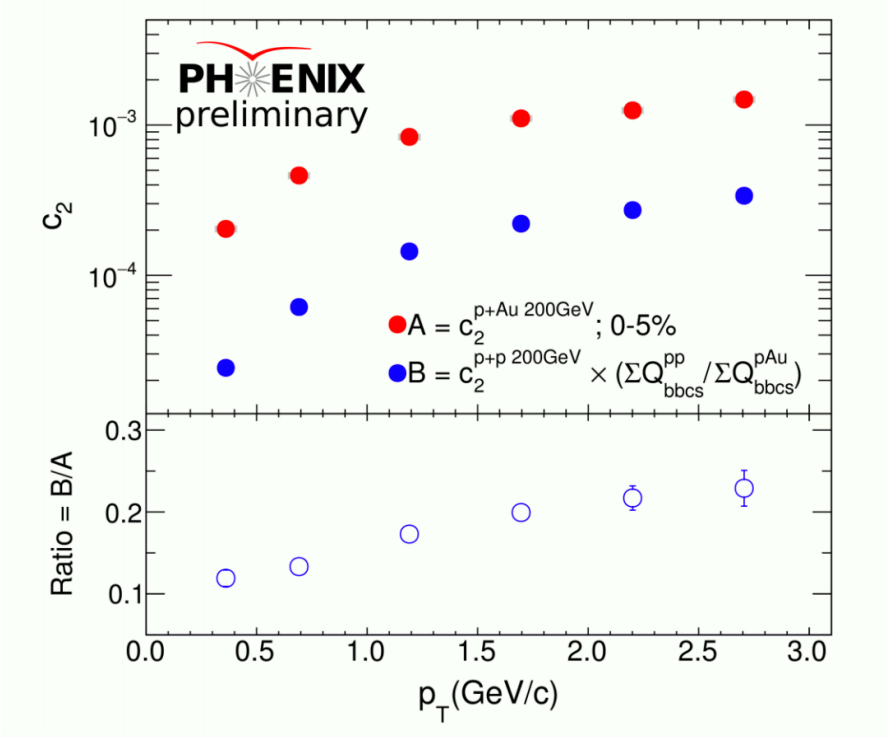
$$c_2(p_T) = c_2^{\text{Non-Elementary}} + c_2^{\text{Elementary}}$$



Estimating Non-Flow

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

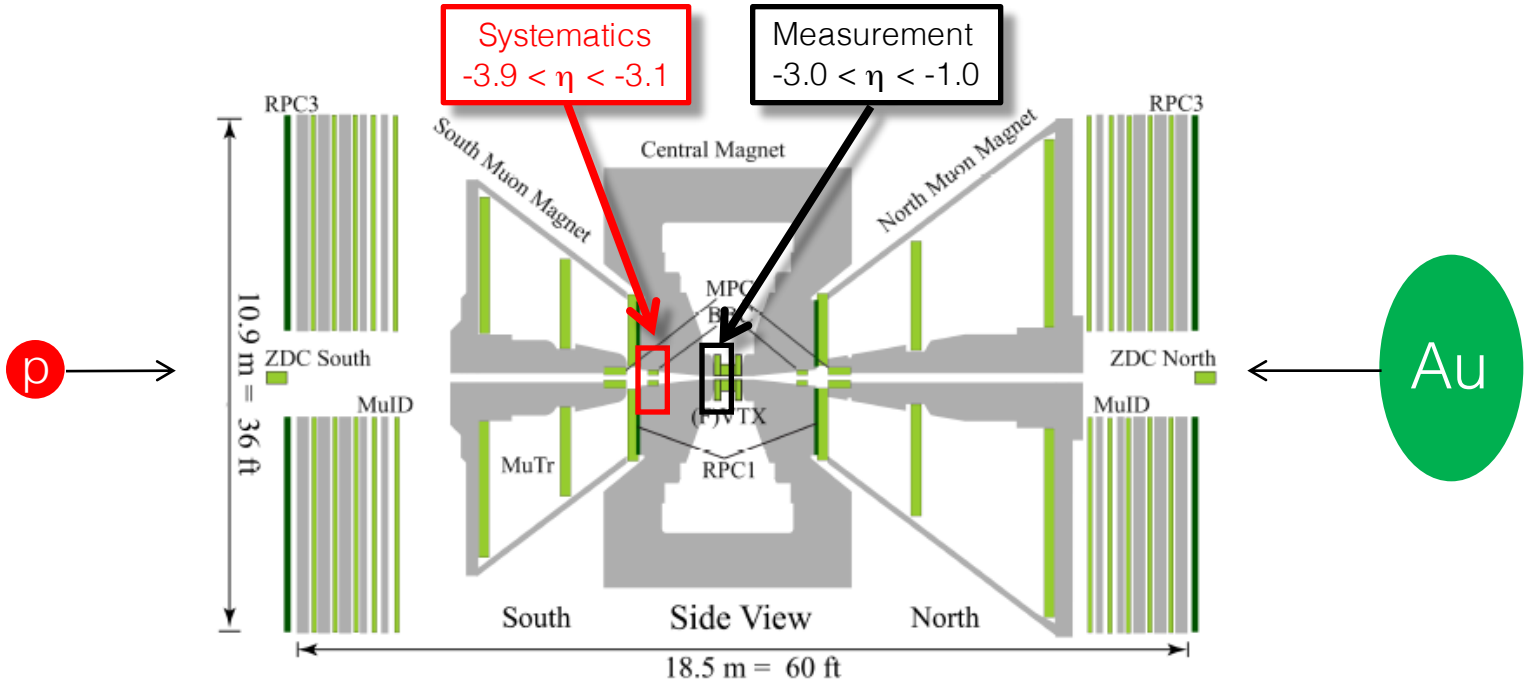
$$c_2(p_T) = c_2^{\text{Non-Elementary}} + c_2^{p+p} \times \frac{\text{Charge at Forward } \eta \text{ in p+p}}{\text{Charge at Forward } \eta \text{ in p+Au}}$$



Use p+p as a reference

Scale it down by relative multiplicity

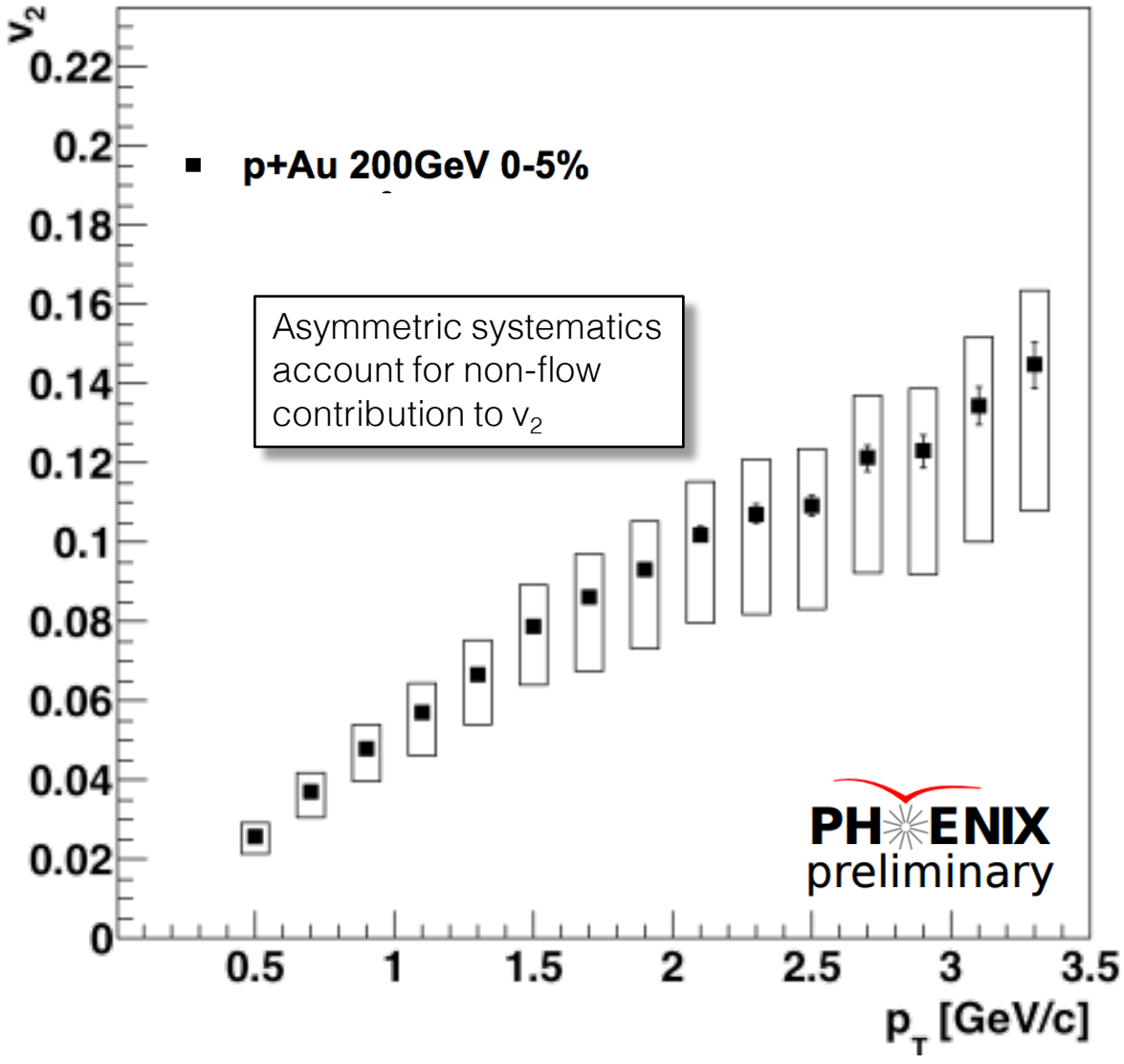
Event Plane Method



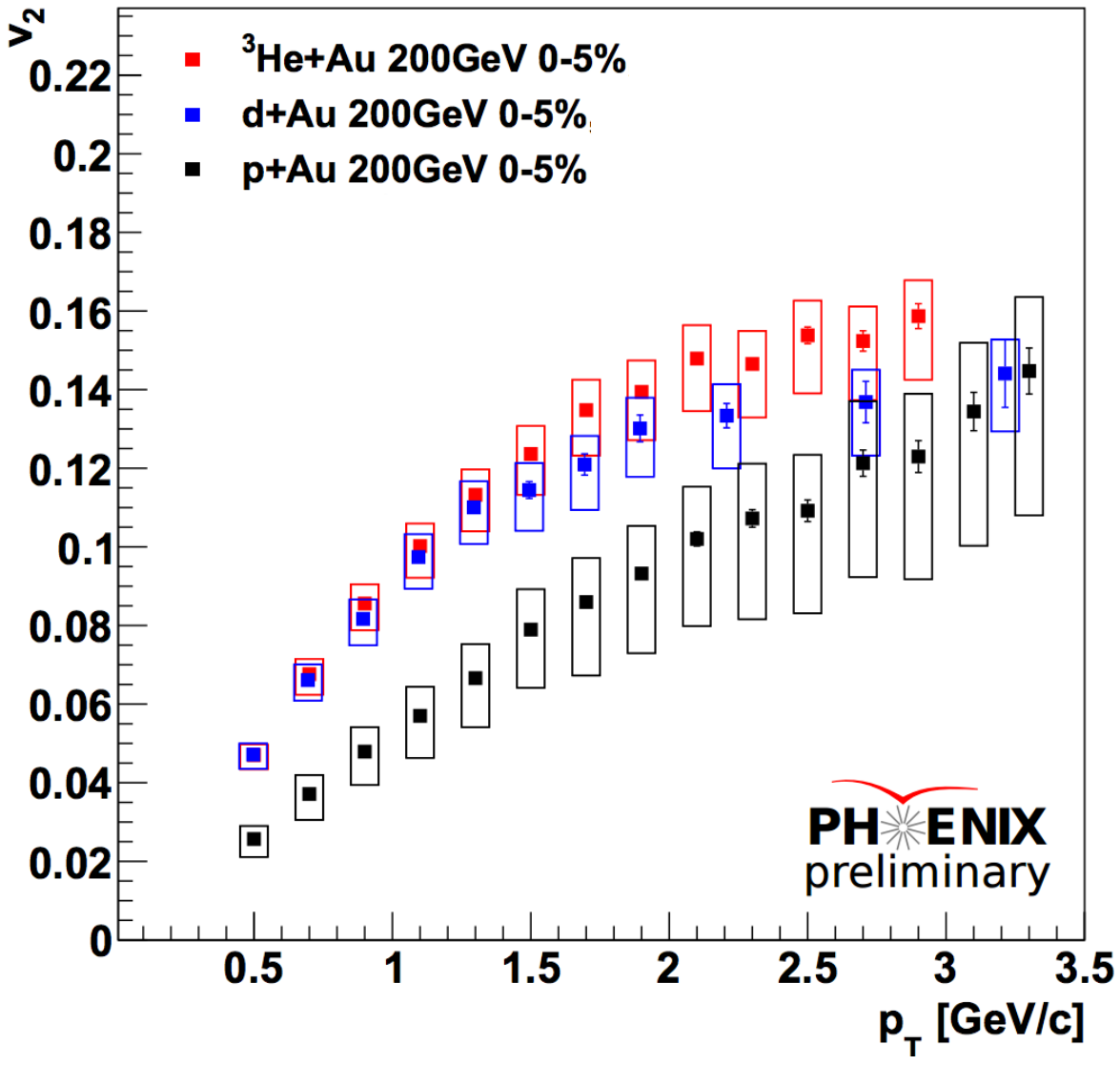
$$v_2 = \frac{\langle \sum \cos 2(\phi - \Psi_2) \rangle}{\mathrm{Res}(\Psi_2)}$$

Resolution *Res* (Ψ) estimated from correlation of three independent sub-events

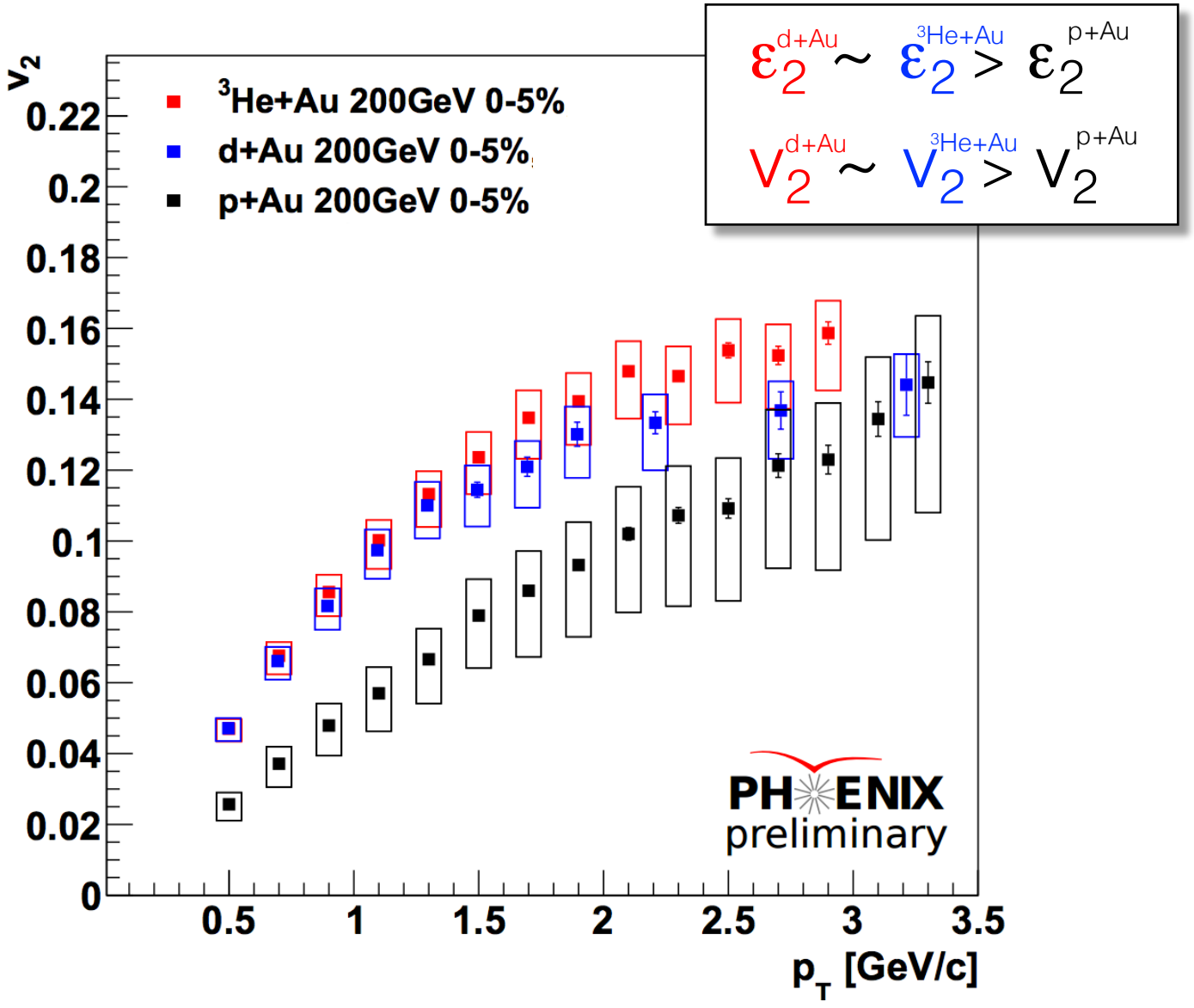
Elliptic Flow in p+Au



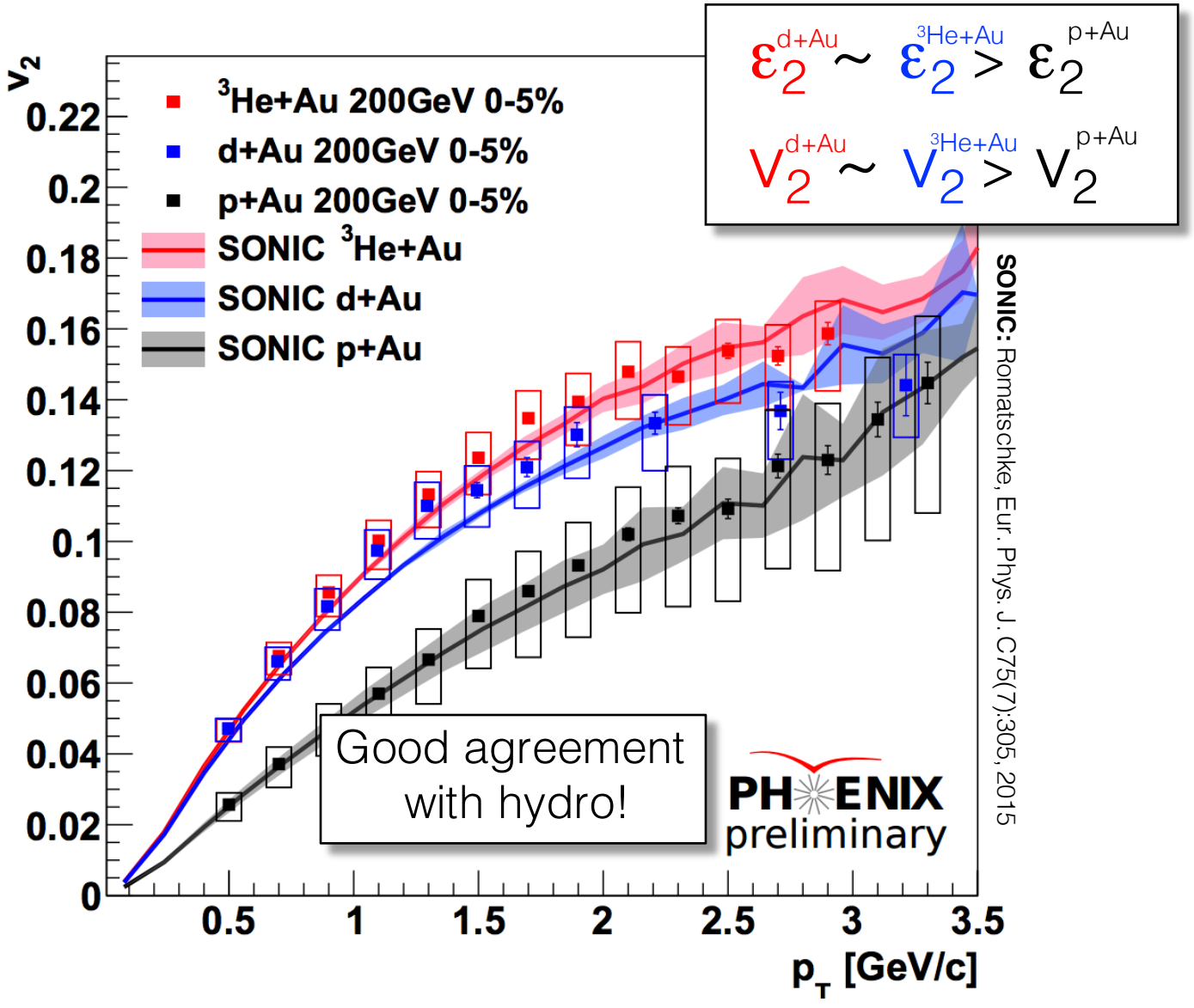
Elliptic Flow in all Systems



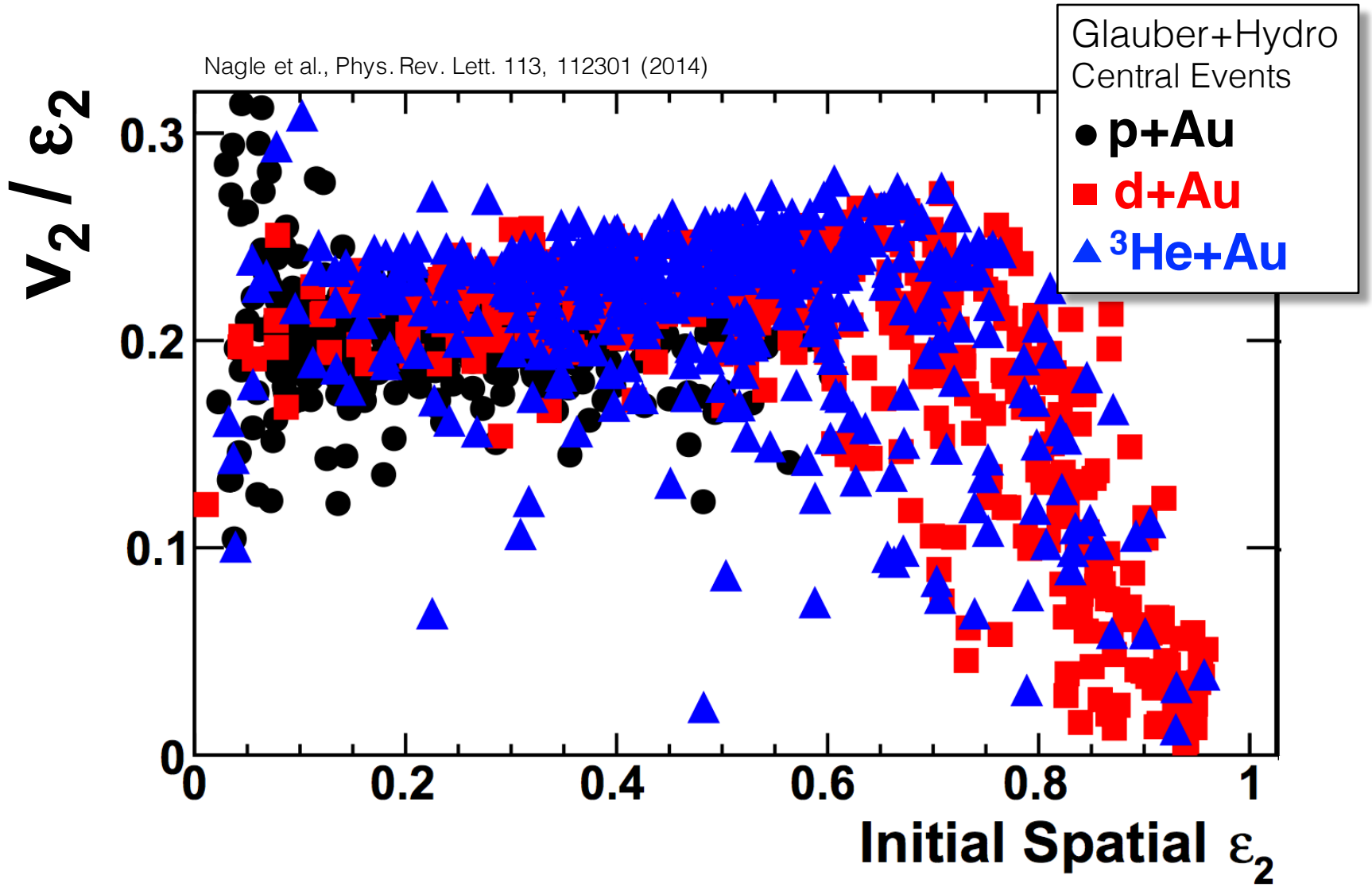
Elliptic Flow in all Systems



Elliptic Flow in All Systems



Elliptic Flow Scaling?



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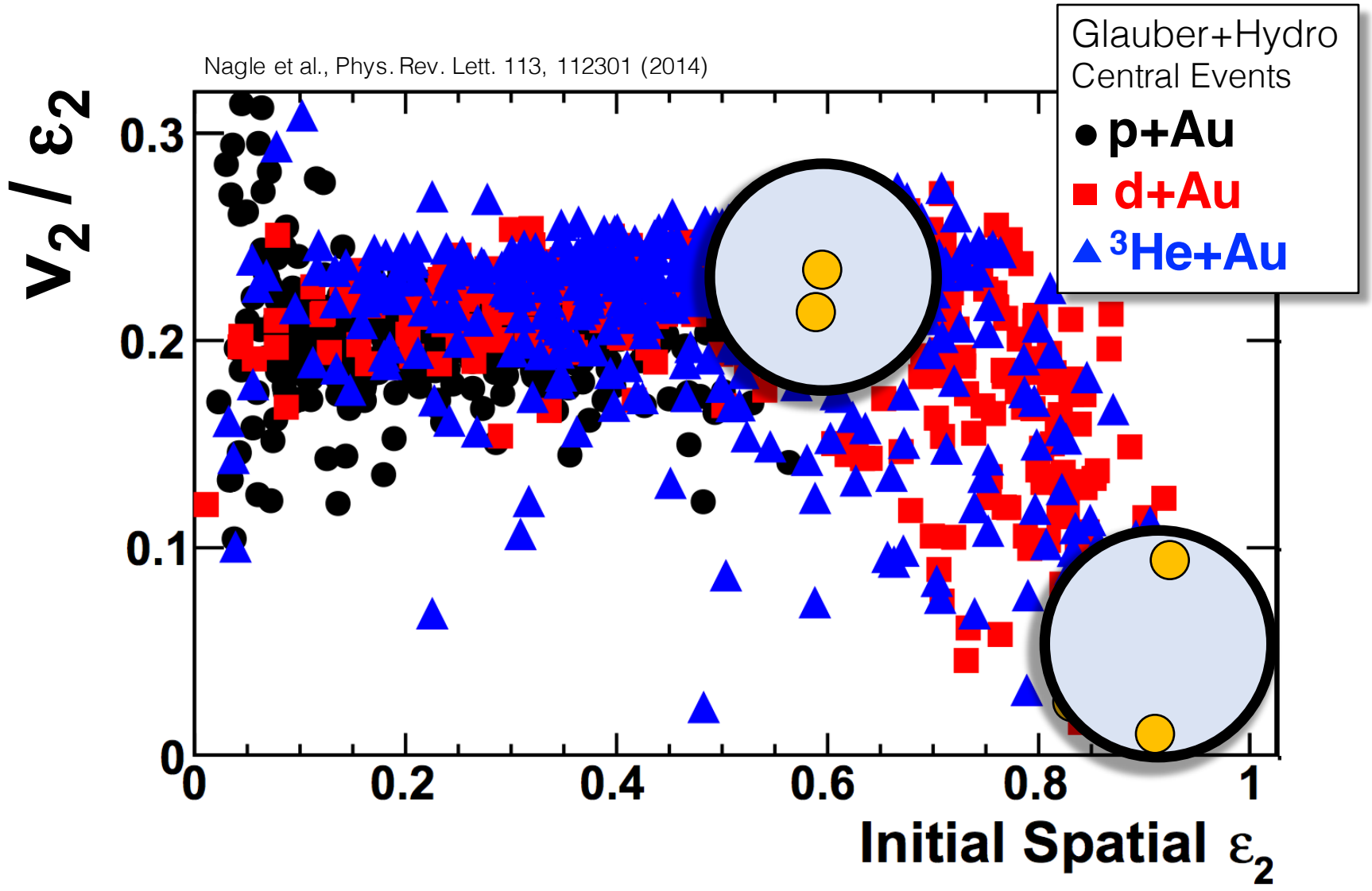
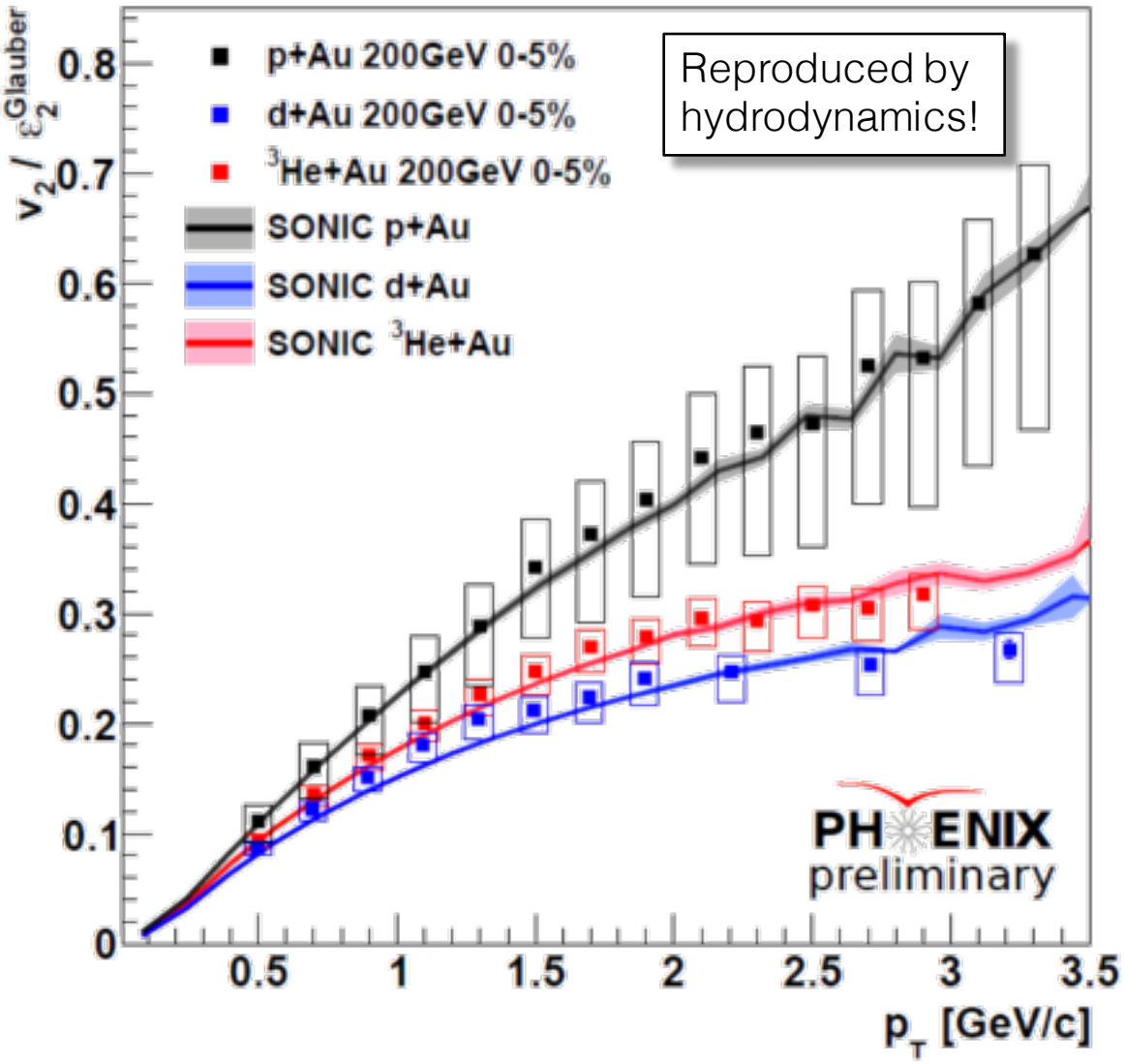
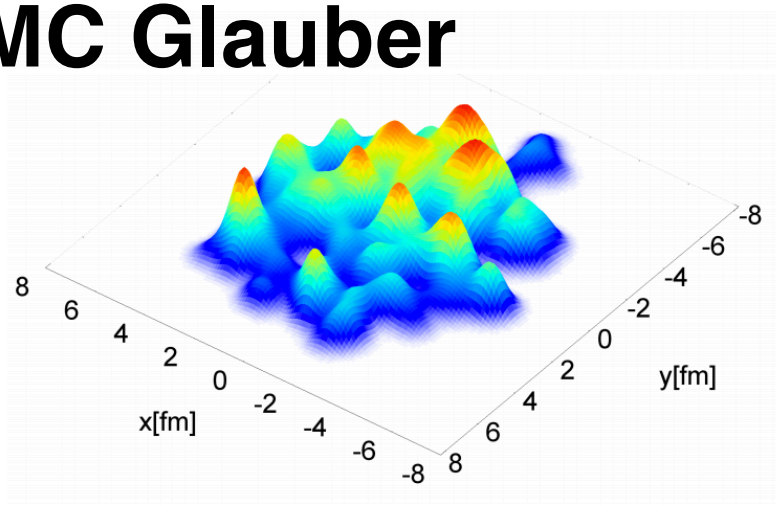


Imperfect Elliptic Flow Scaling



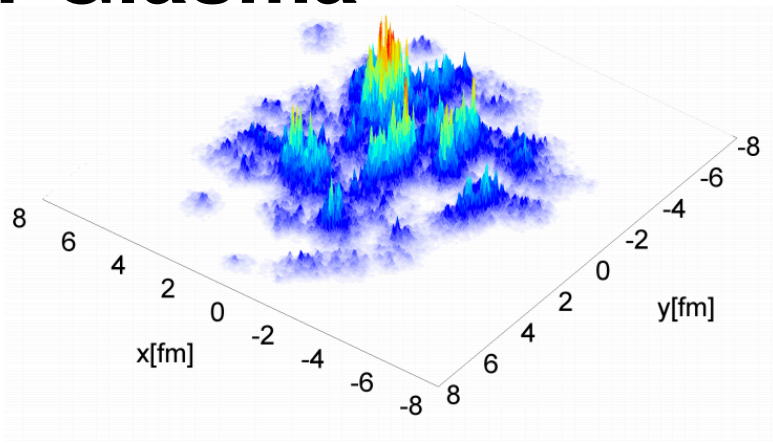
IPGlasma Initial Conditions

MC Glauber



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

IPGlasma

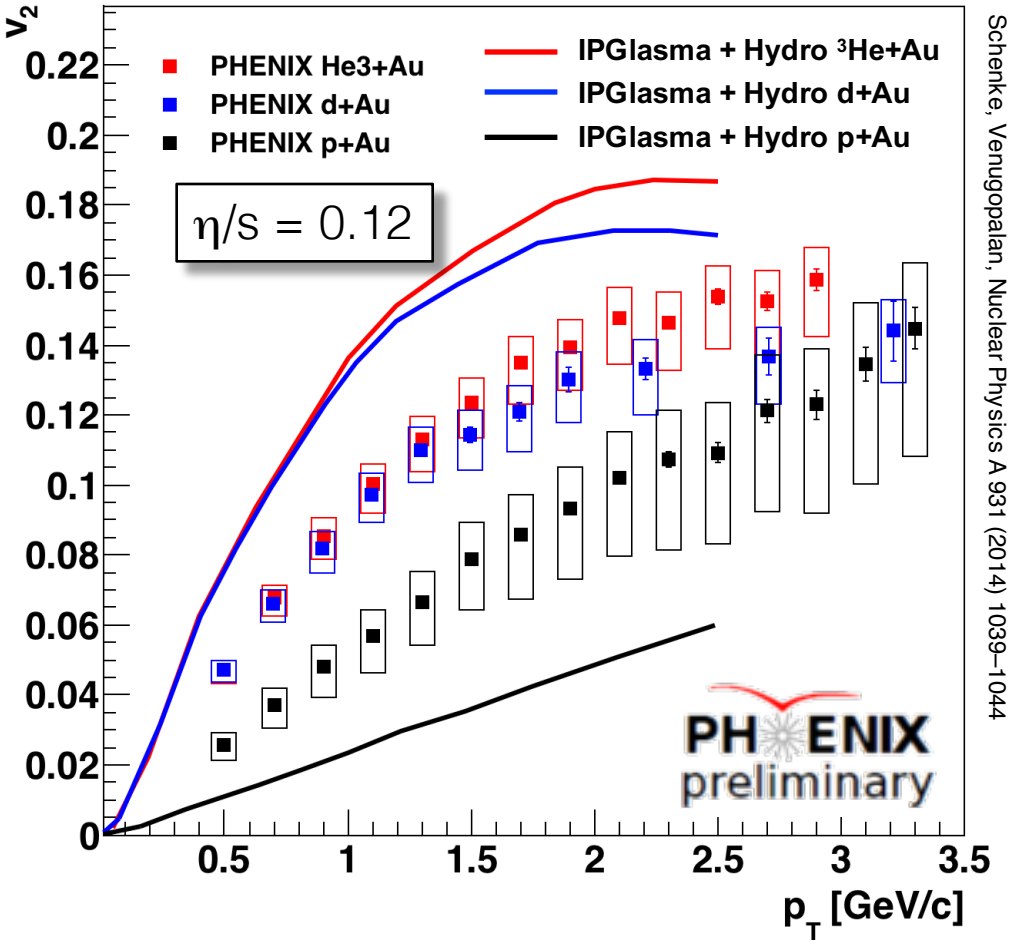


- Fluctuations in nucleon coordinates
- Fluctuations in color charge within nucleons
- Look at region where nucleons overlap

Schenke, Tribedy, Venugopalan: Phys. Rev. Lett. 108, 252301

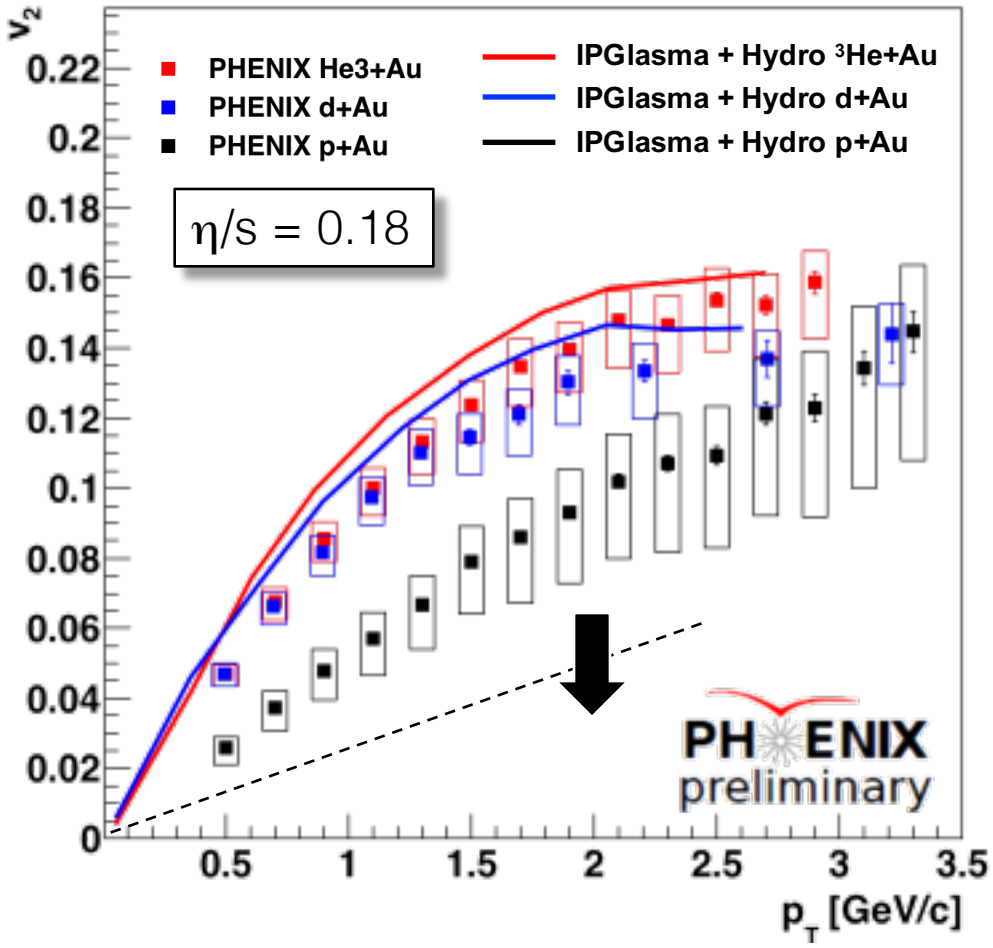
Hydro + IPGlasma Initial Conditions

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



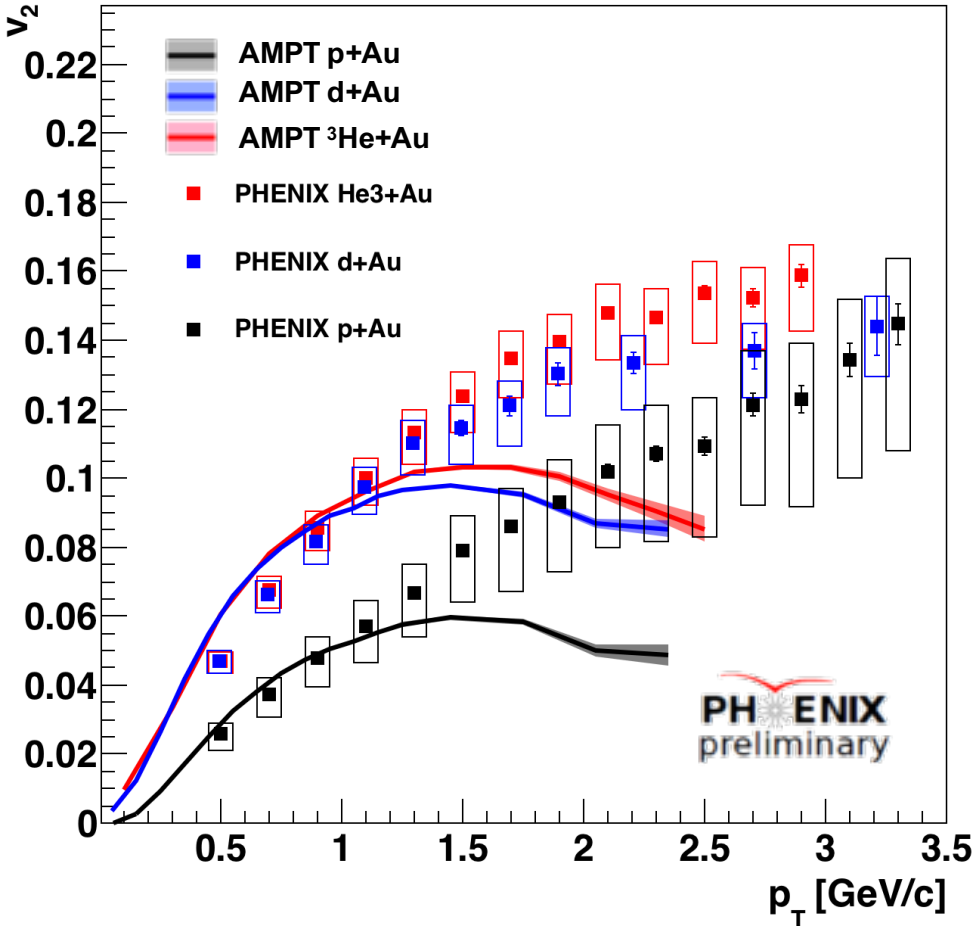
Hydro + IPGlasma Initial Conditions

Changing η/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 ~1 GeV/c

MC Glauber Initial Geo

+

String Melting

+

Partonic Scattering
σ = 1.5 mb

+

Spatial Coalescence

+

Hadronic Scattering

Take-Home Message

Geometry drives flow in small systems

- **AMPT**
- **Hydro**

Going Down in Size and Energy

Going Down in Size and Energy

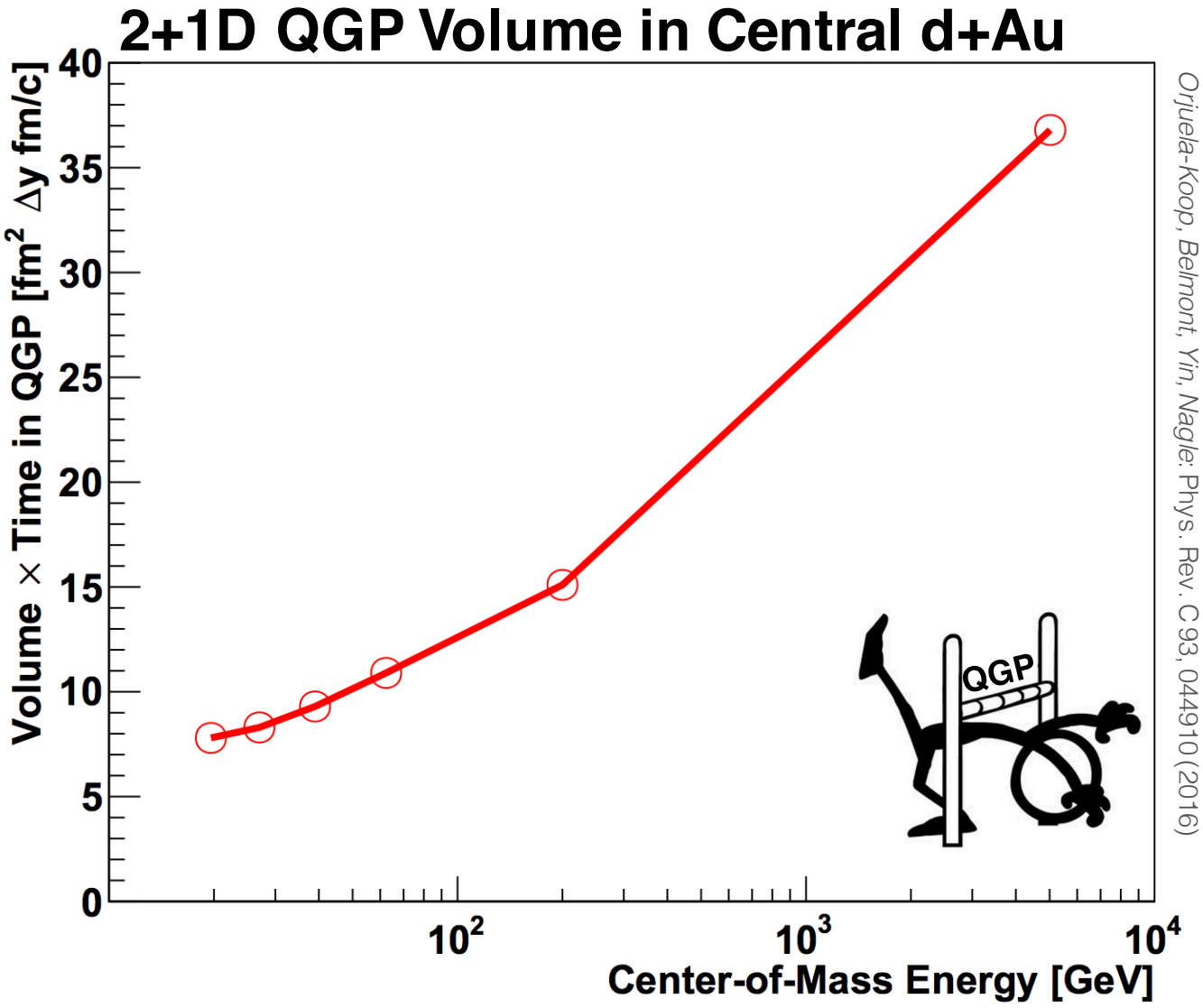
Other stages become relevant for small system collectivity

d+Au Beam Energy Scan

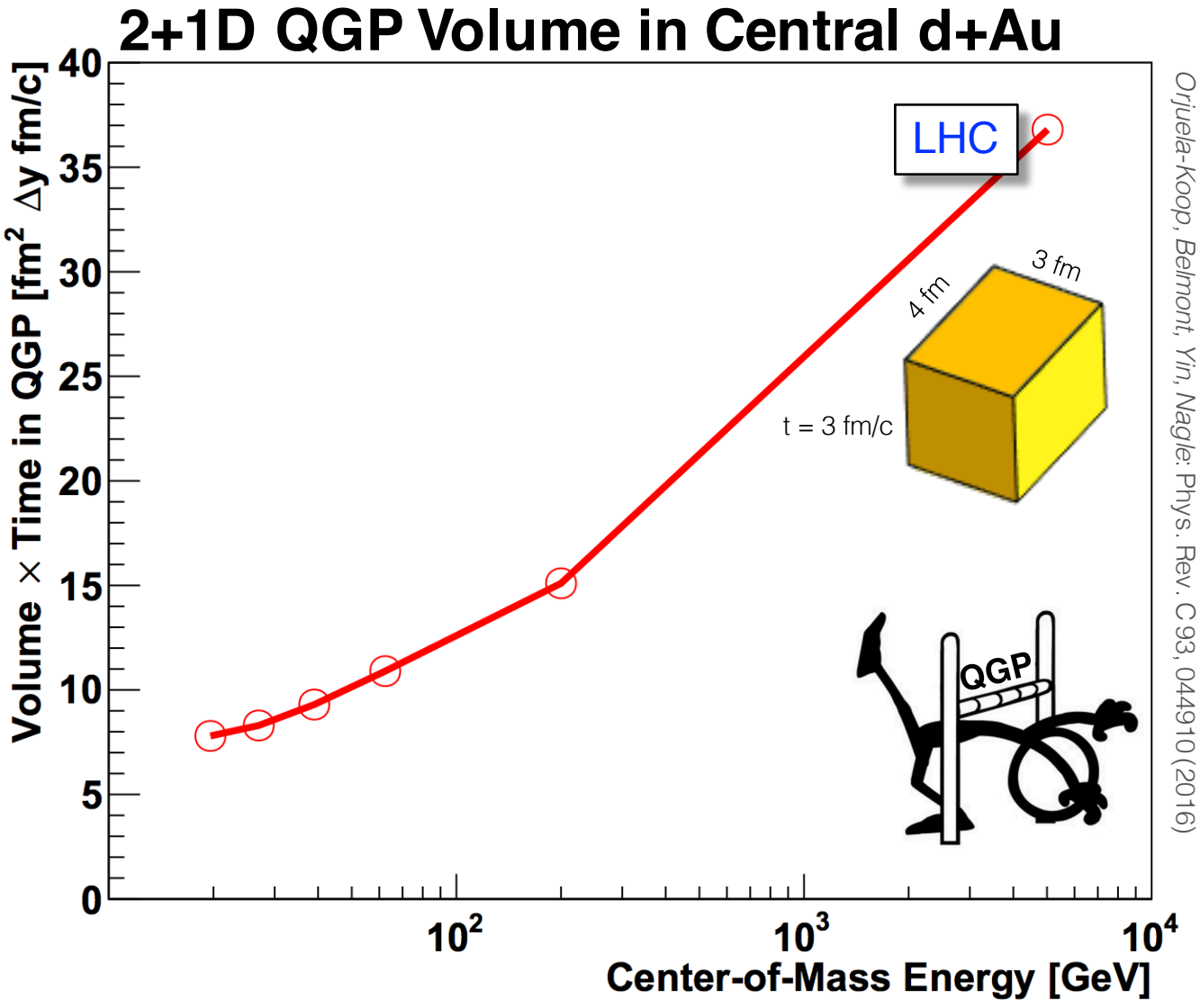
+

Model Comparisons

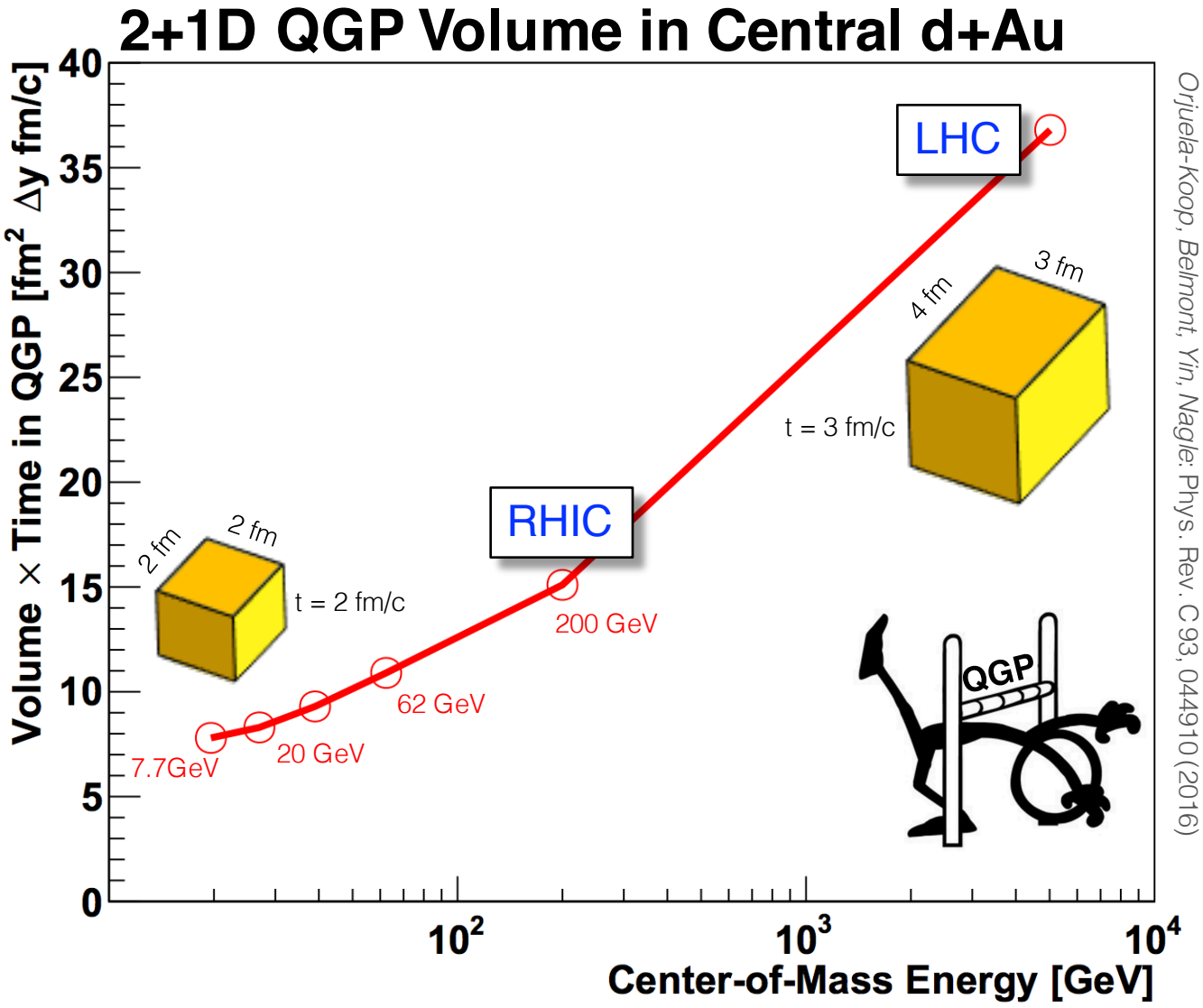
How Low Can You Go?



How Low Can You Go?

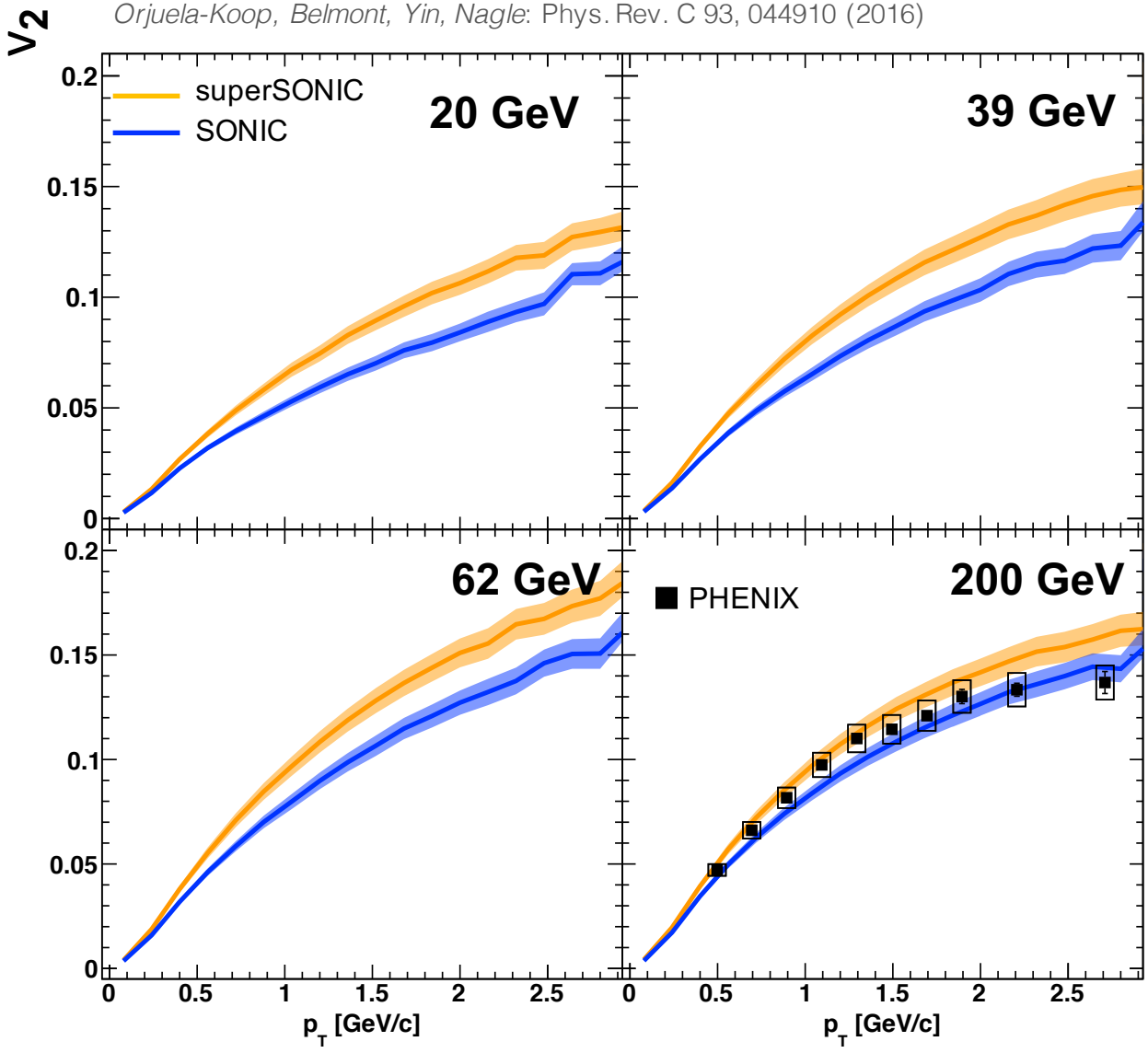


How Low Can You Go?



d+Au Beam Energy Scan

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

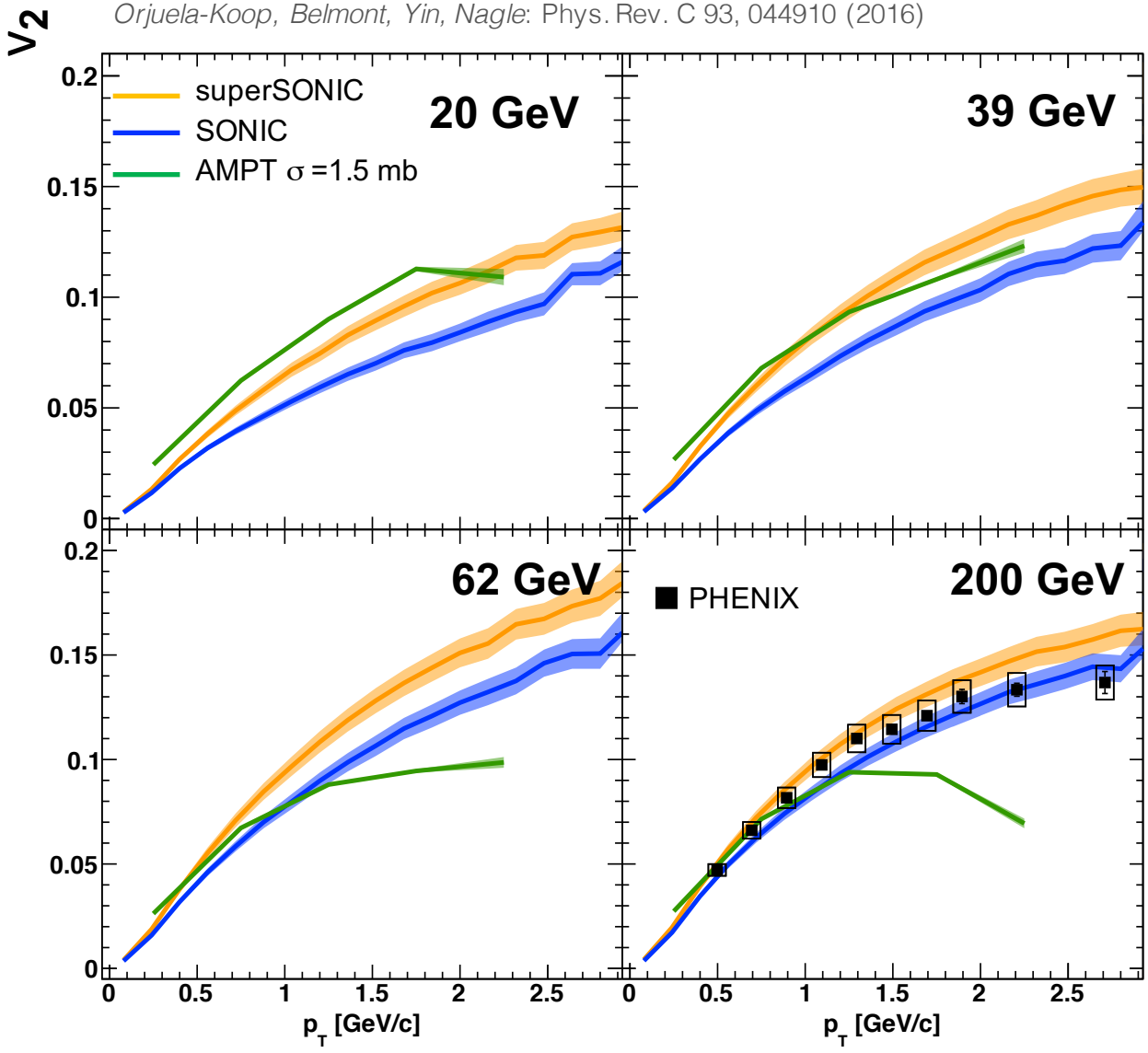


Hydro With Pre-Equilibrium

Hydro Without Pre-Equlibrium

d+Au Beam Energy Scan

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



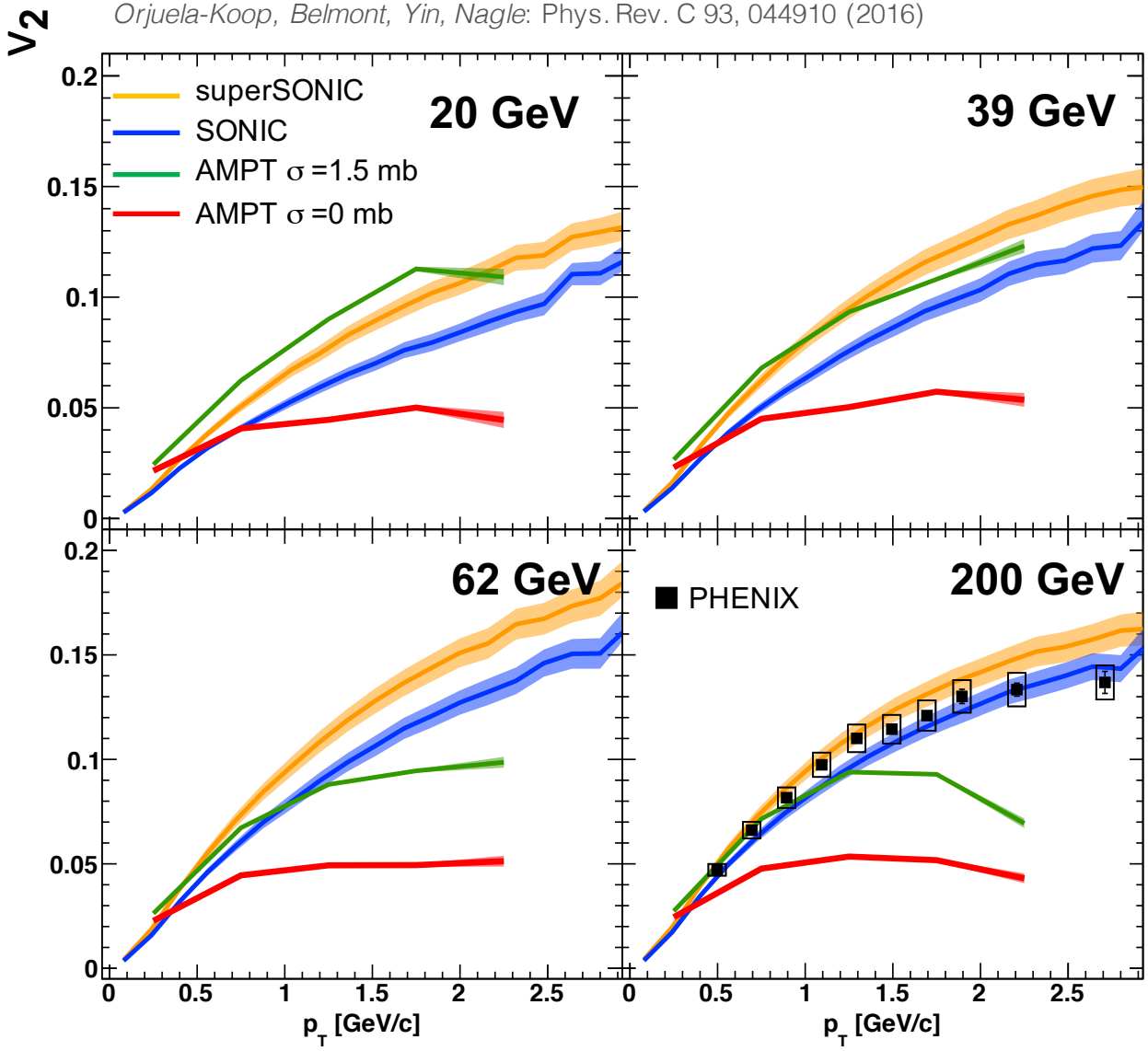
Hydro With Pre-Equilibrium

Hydro Without Pre-Equlibrium

AMPT Parton + Hadron

d+Au Beam Energy Scan

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



Hydro With Pre-Equilibrium

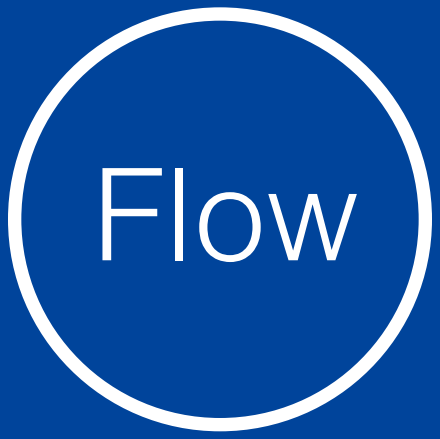
Hydro Without Pre-Equlibrium

AMPT Parton + Hadron

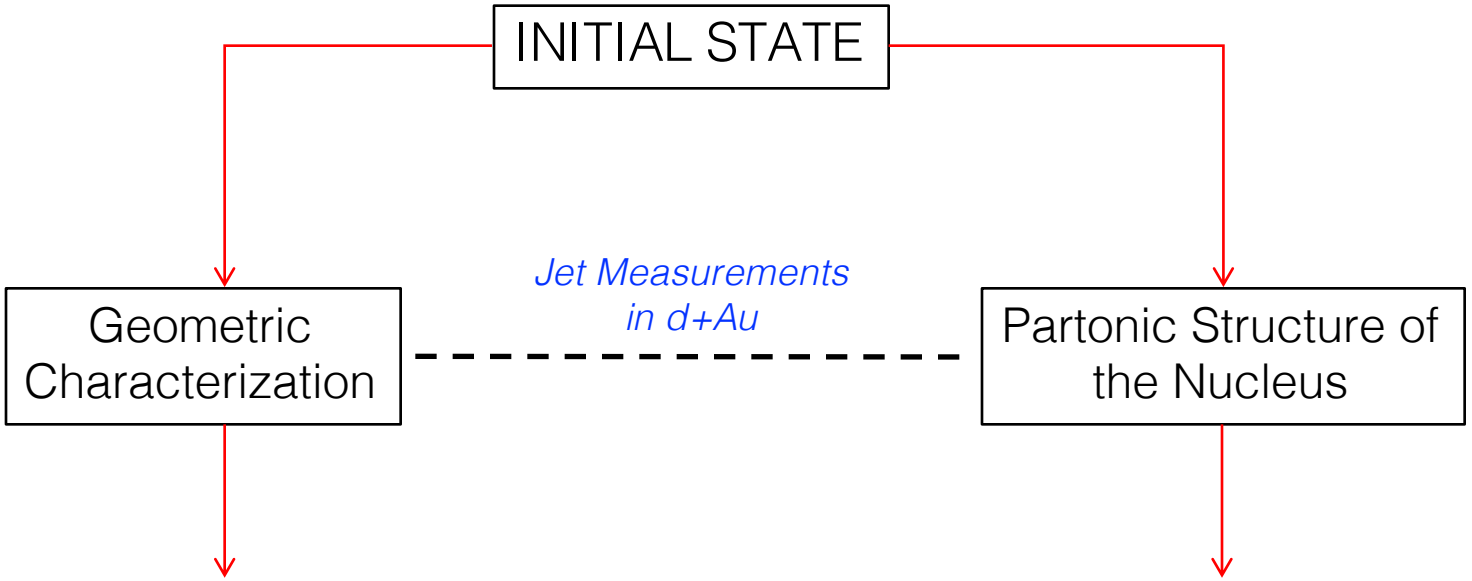
AMPT Hadron Only

Stay tuned for PHENIX Run16 results!

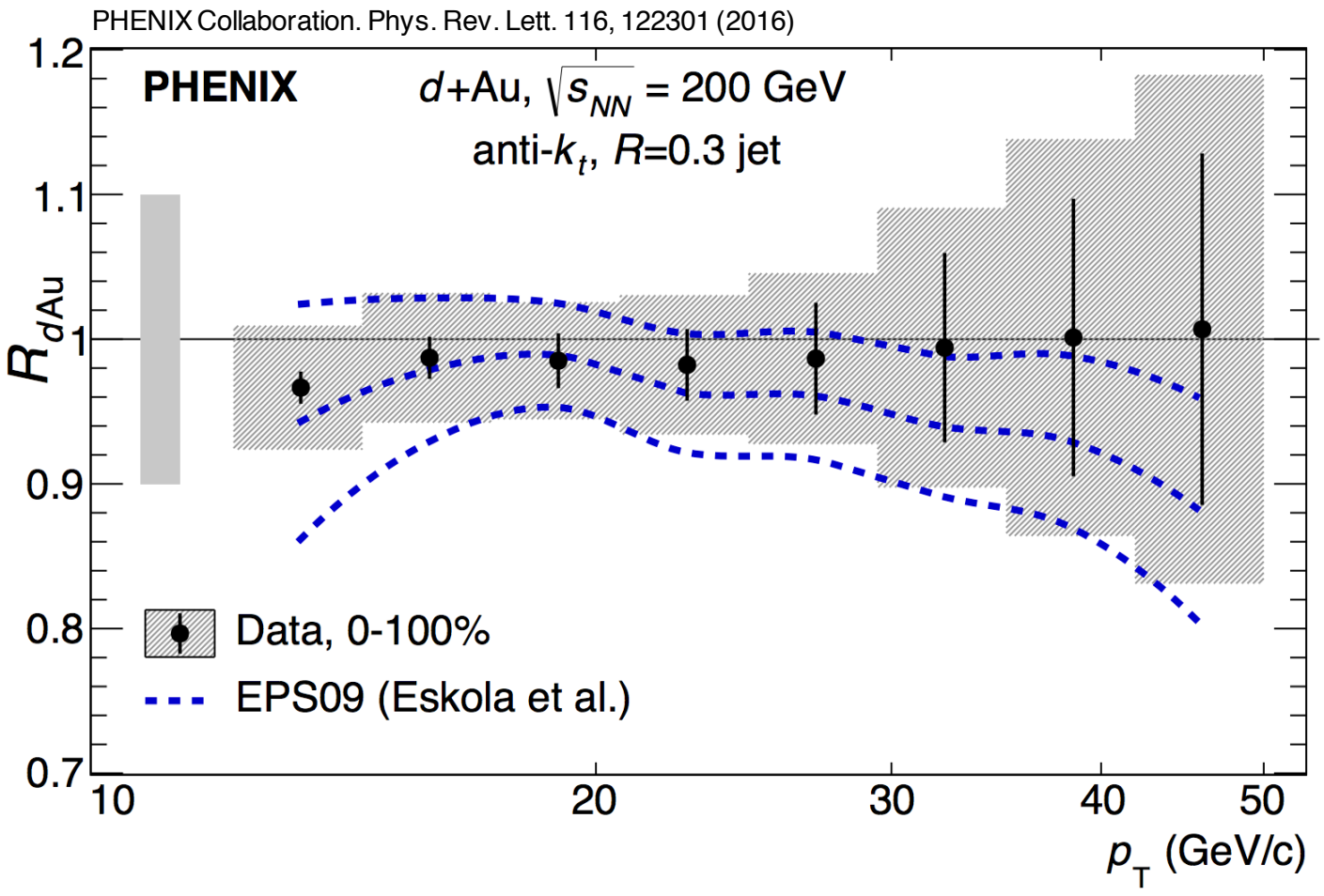
Small Collision Systems



Jets in d+Au


INITIAL STATE
Jet Measurements in d+Au
Geometric Characterization
Partonic Structure of the Nucleus
• Centrality
• N_{coll}
• N_{part}
• Eccentricity
• Cold nuclear matter effects
• Nuclear parton densities

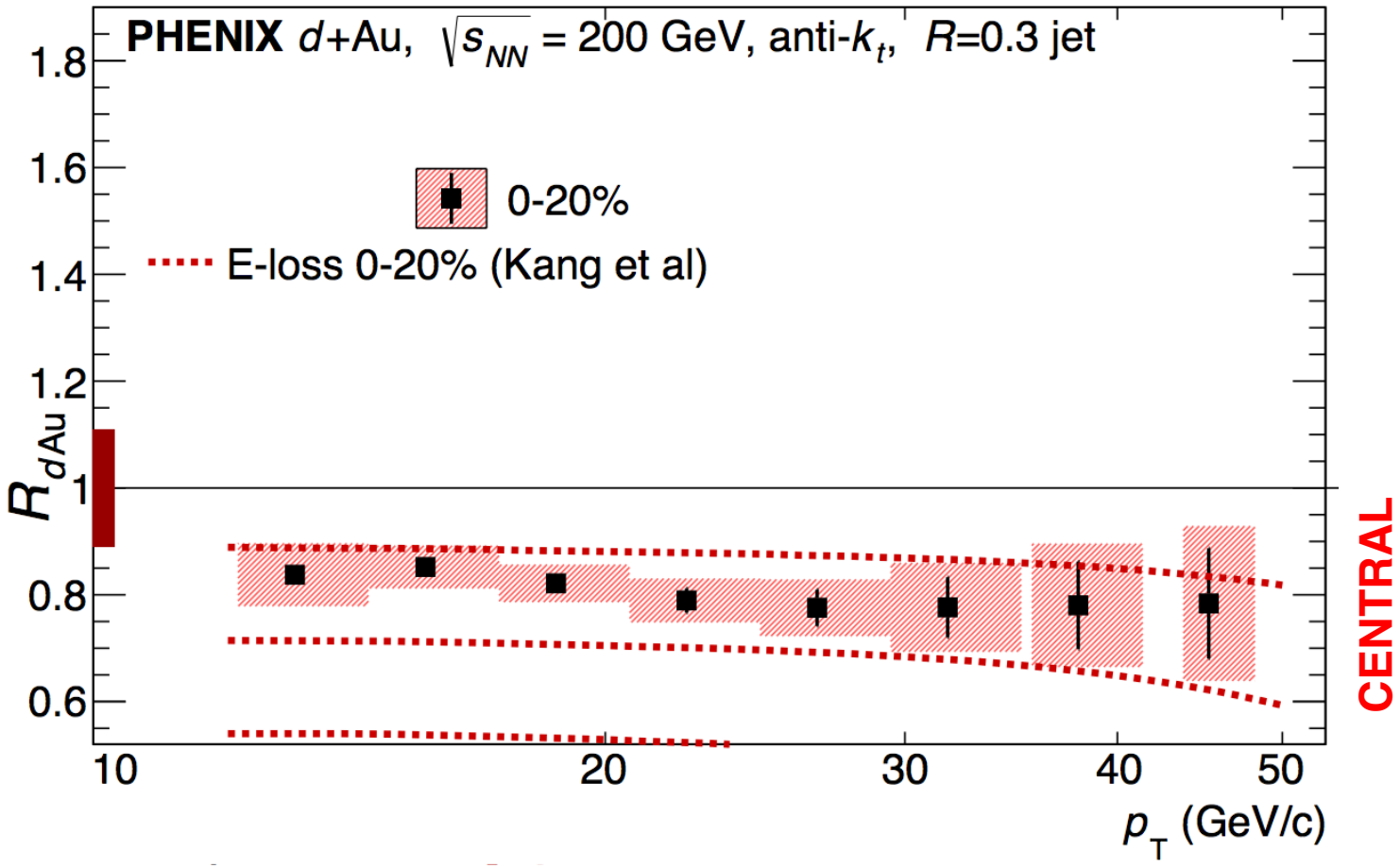
Minimum Bias Jet R_{dAu}



No modification in minimum bias collisions

Centrality-Dependent Jet R_{dAu} Modification

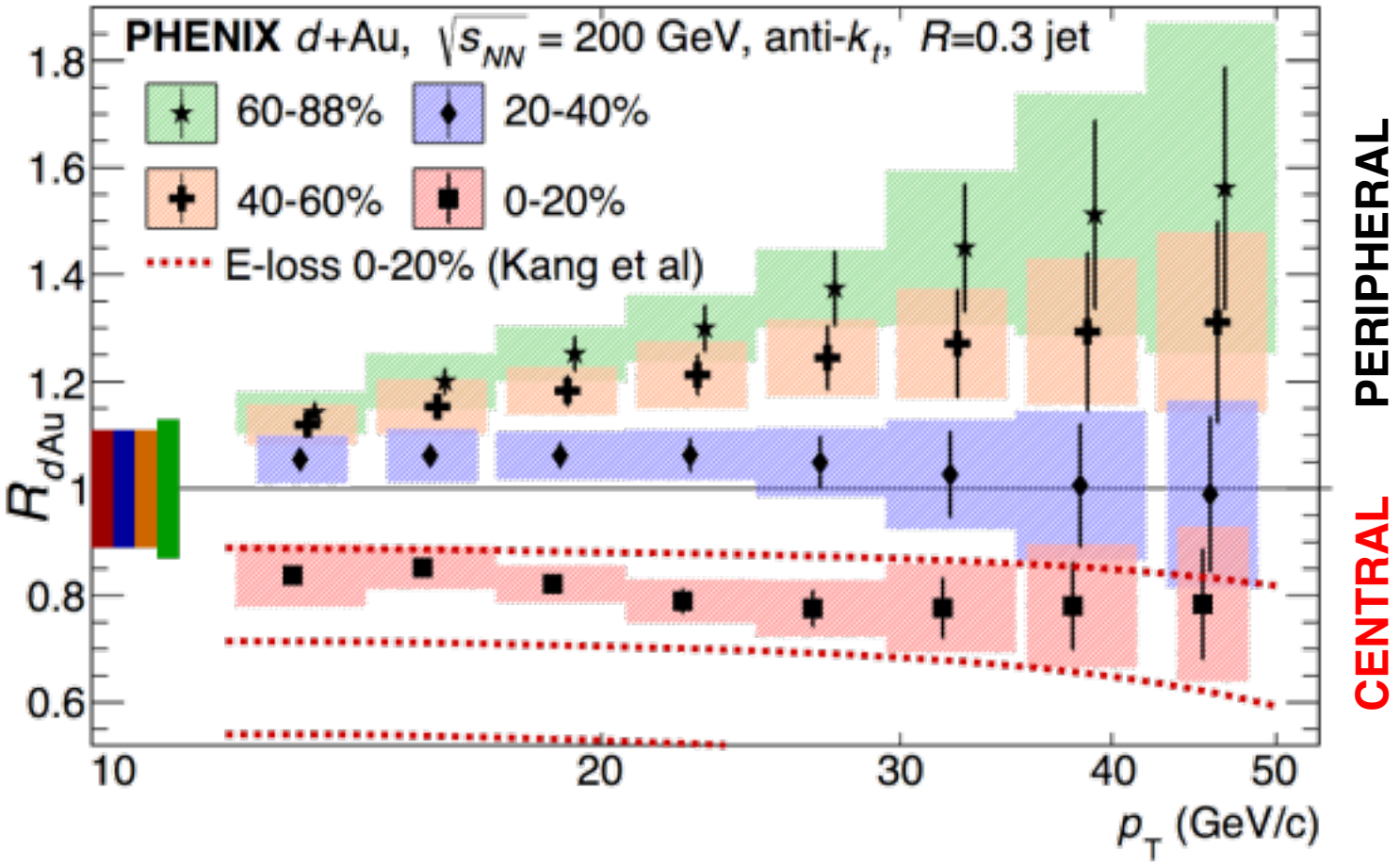
PHENIX Collaboration. Phys. Rev. Lett. 116, 122301 (2016)



Central suppression consistent with energy loss models

Centrality-Dependent Jet Modification in d+Au

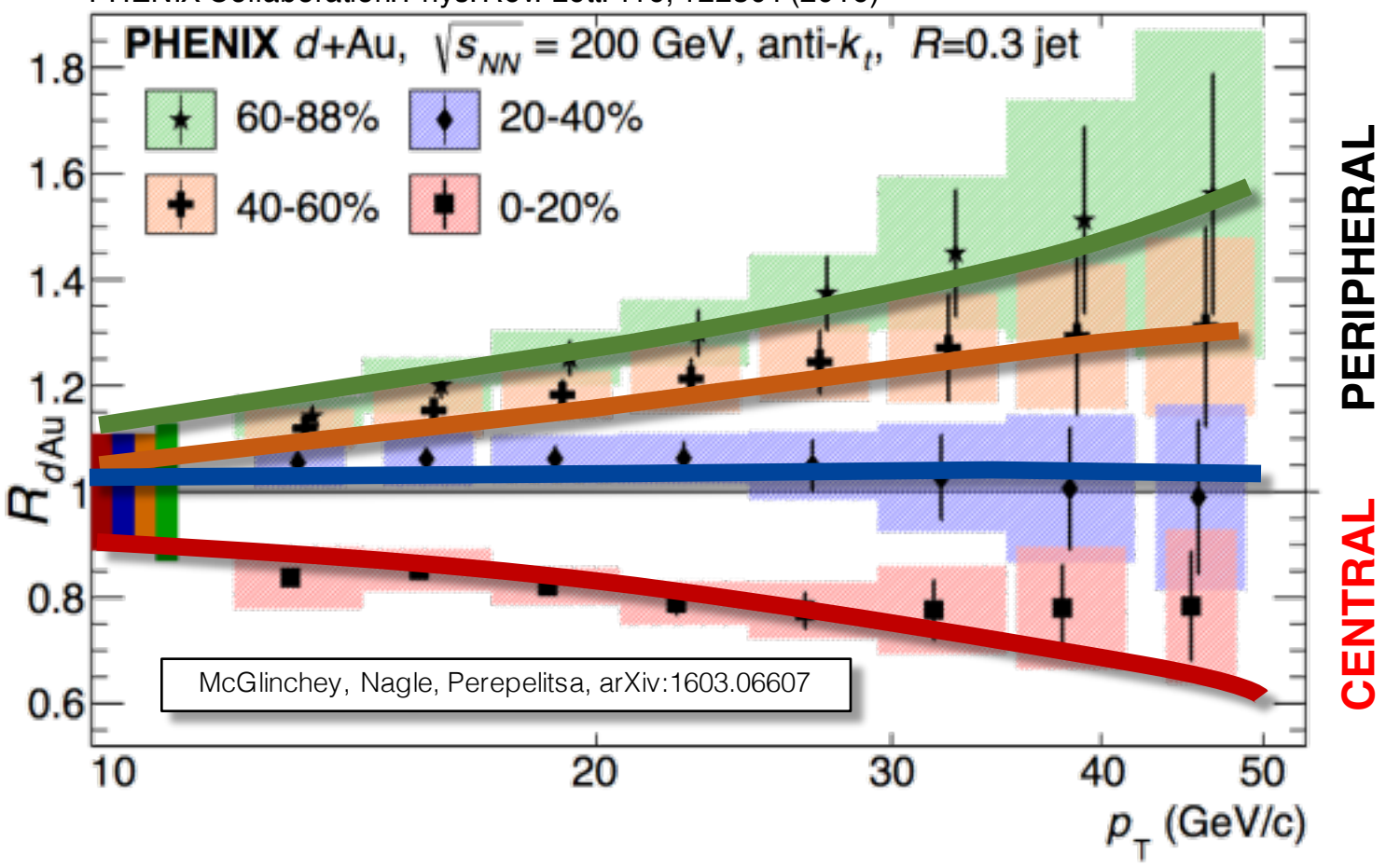
PHENIX Collaboration. Phys. Rev. Lett. 116, 122301 (2016)



How can we explain this?

Centrality-Dependent Jet Modification in d+Au

PHENIX Collaboration. Phys. Rev. Lett. 116, 122301 (2016)

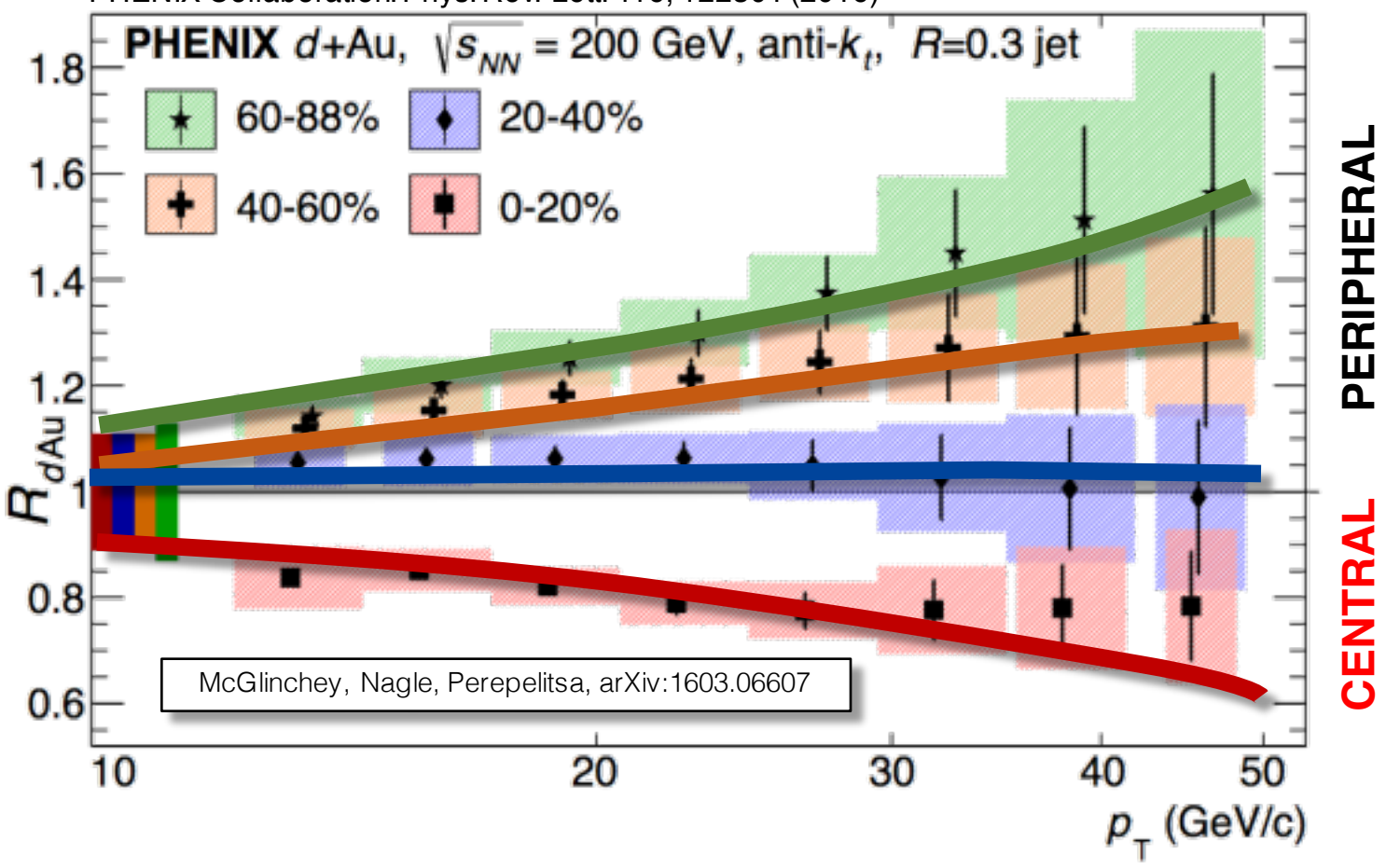


x-dependent proton size fluctuations?

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

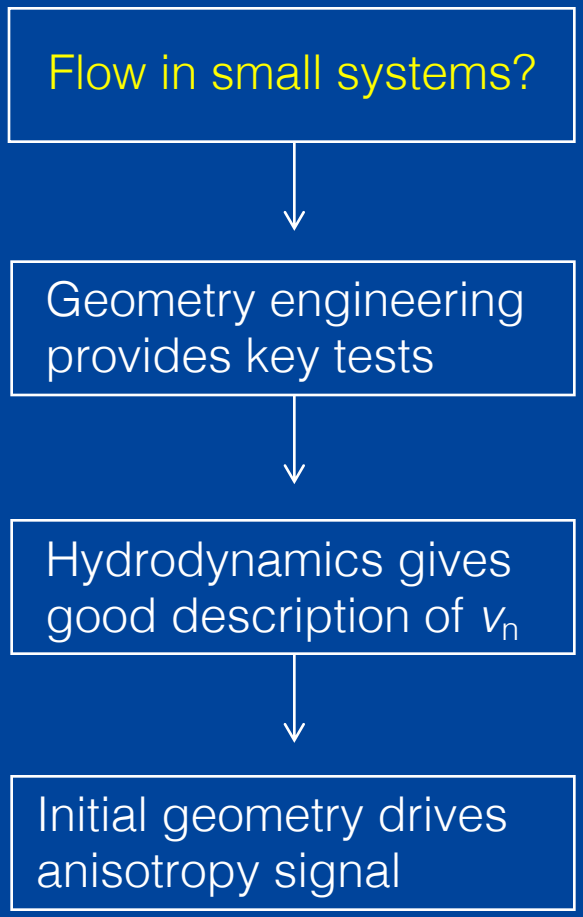
Centrality-Dependent Jet Modification in d+Au

PHENIX Collaboration. Phys. Rev. Lett. 116, 122301 (2016)



See D. Perepelitsa's Talk Tomorrow!

Summary


Flow in small systems?
Geometry engineering provides key tests
Hydrodynamics gives good description of v_n
Initial geometry drives anisotropy signal

Summary

Flow in small systems?

↓

Geometry engineering provides key tests

↓

Hydrodynamics gives good description of v_n

↓

Initial geometry drives anisotropy signal

Jets in d+Au

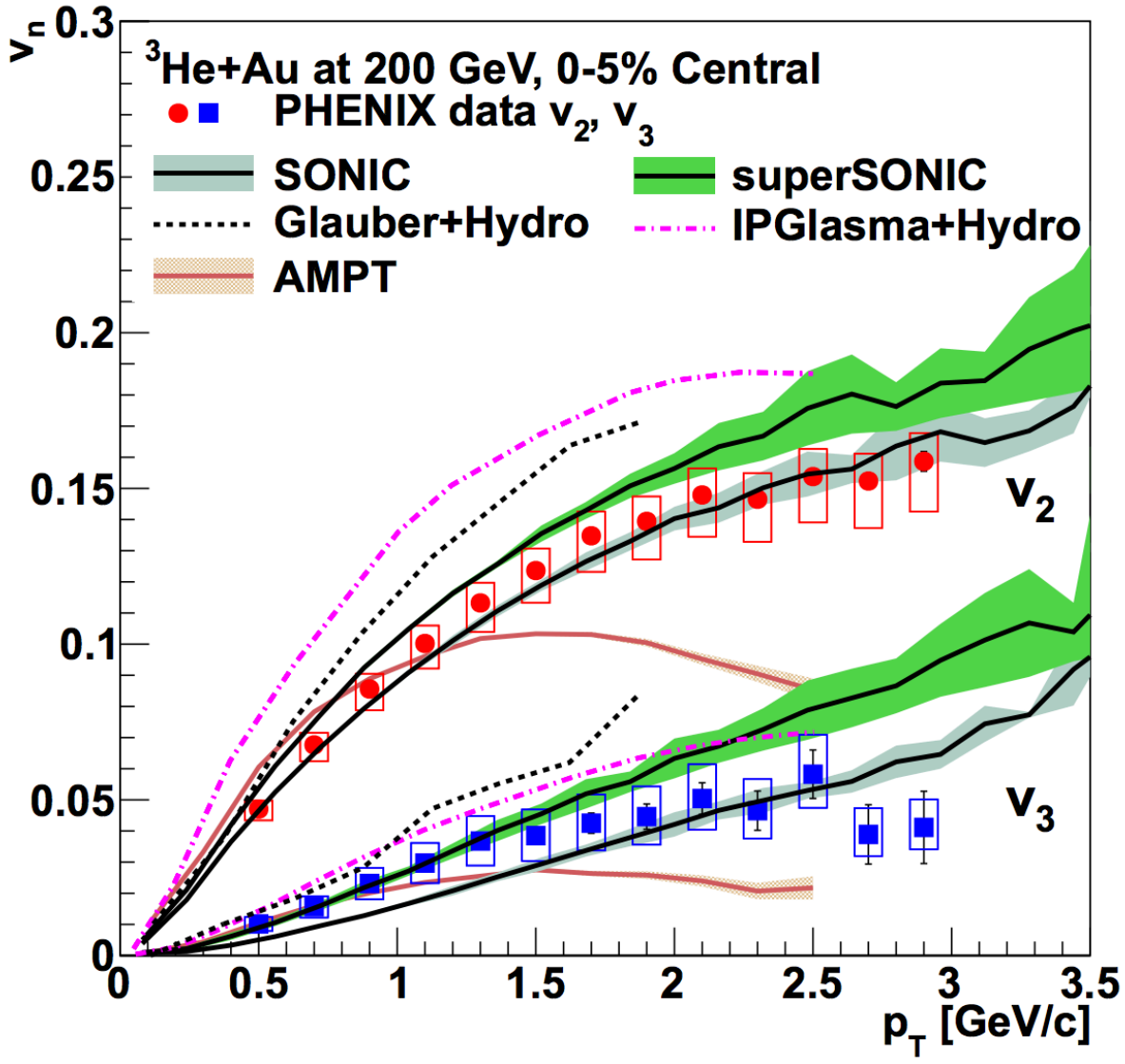
↓

Test relation between hard and soft processes

↓

Intriguing centrality-dependent modification of jet production rates

Backup


v_n
0.3
0.25
0.2
0.15
0.1
0.05
0
^{3}He+Au at 200 GeV, 0-5% Central
PHENIX data v_2, v_3
SONIC
superSONIC
Glauber+Hydro
IPGlasma+Hydro
AMPT
v_2
v_3
0
0.5
1
1.5
2
2.5
3
3.5
p_T [GeV/c]