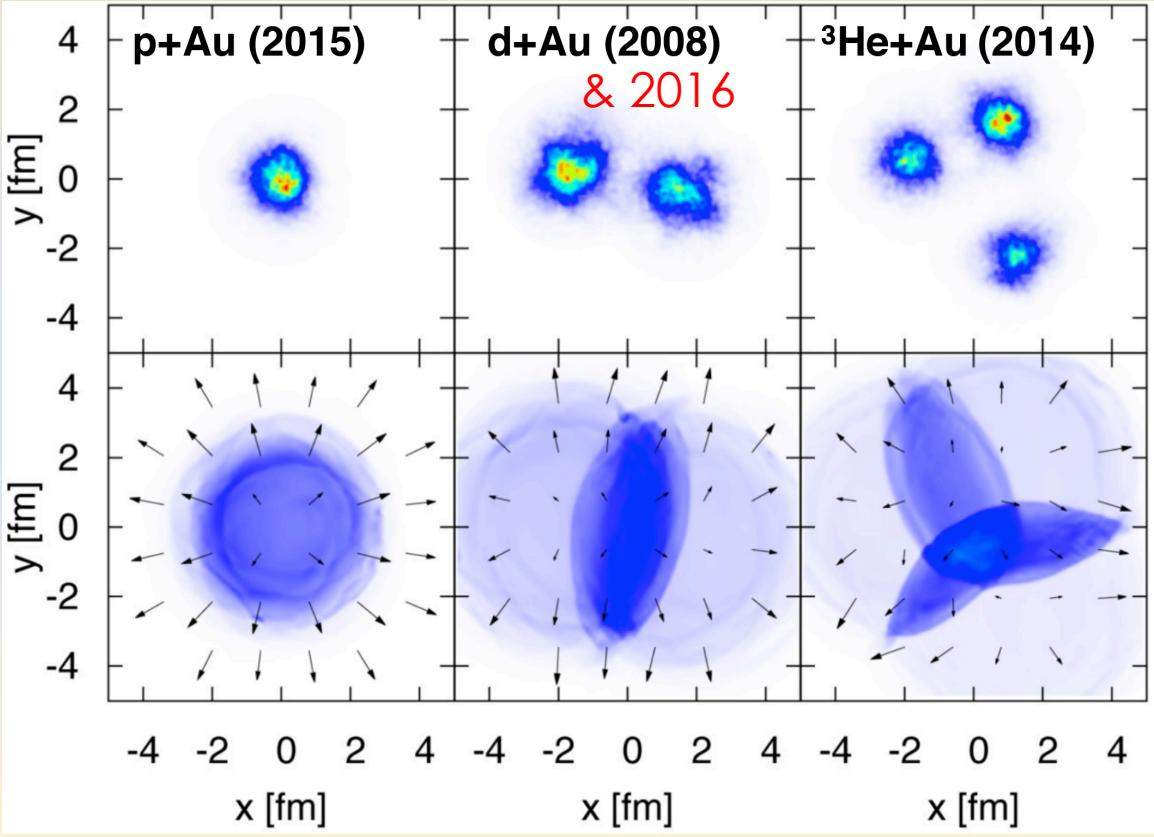
PHENIX Results on Geometry Engineering in Small Systems

Kurt Hill - University of Colorado
for the **PHENIX** Collaboration

Initial Stages 2017

200 GeV Geometry Scan

$\varepsilon_2^{\text{IPGlasma}} = 0.10$	$\varepsilon_2^{\text{IPGlasma}} = 0.59$	$\varepsilon_2^{\text{IPGlasma}} = 0.55$
$\varepsilon_2^{\text{Glauber}} = 0.23$	$\varepsilon_2^{\text{Glauber}} = 0.54$	$\varepsilon_2^{\text{Glauber}} = 0.50$



Courtesy of Björn Schenke

200 GeV Geometry Scan

How does initial collision geometry translate to final state momentum anisotropy?

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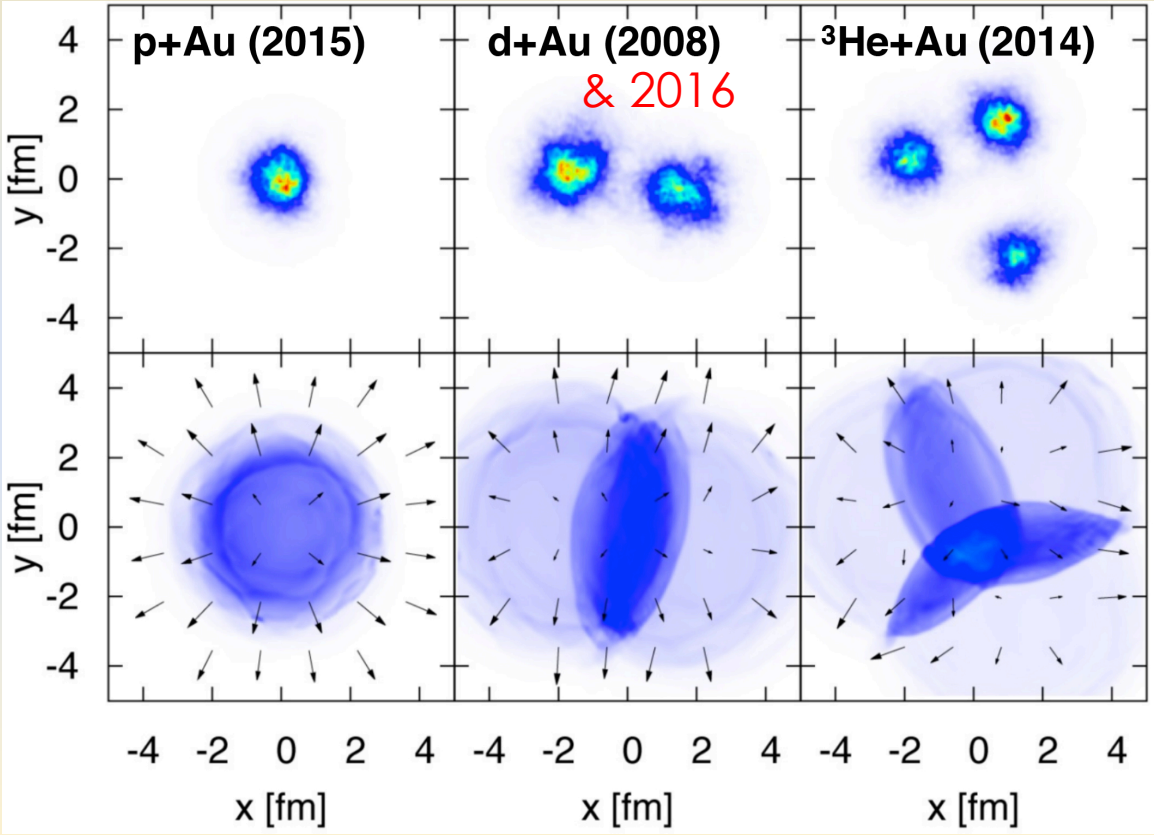

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How does initial collision geometry translate to final state momentum anisotropy?

Initial geometry for p+p and p+A are significantly model dependent

Not so for d+A and ^{3}He+A

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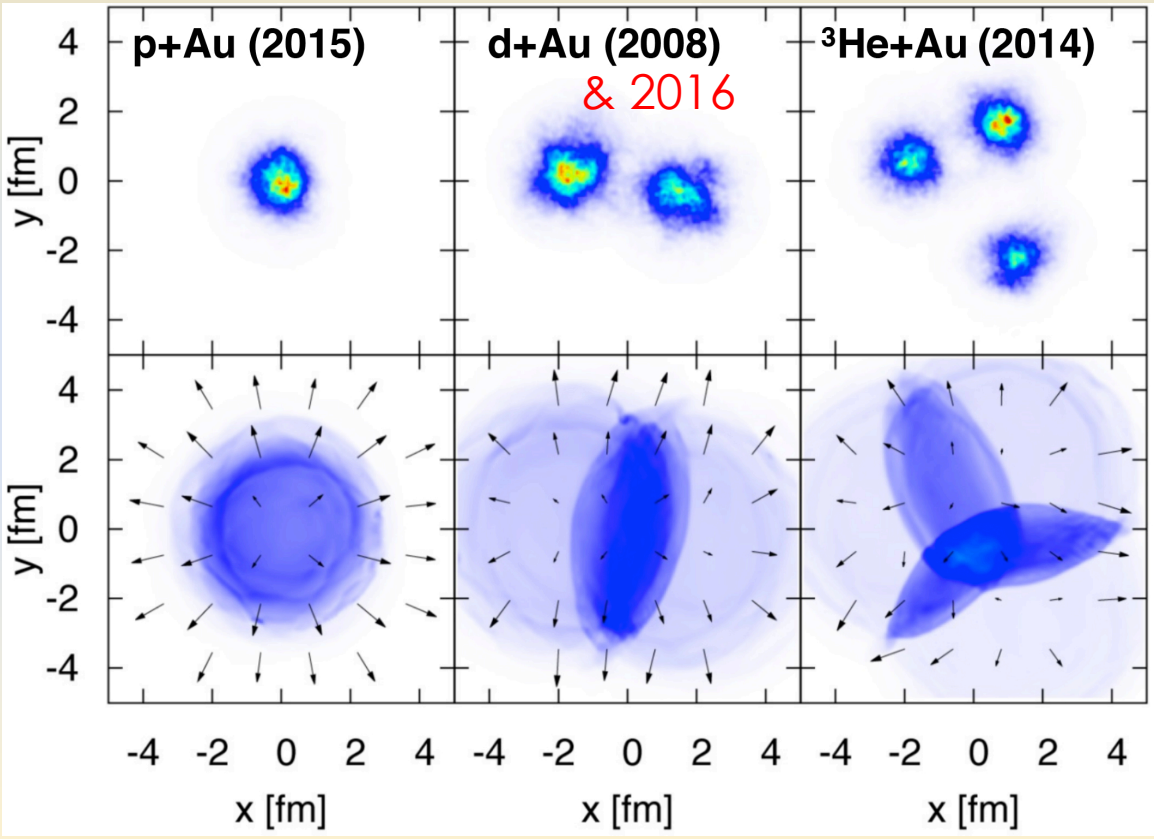

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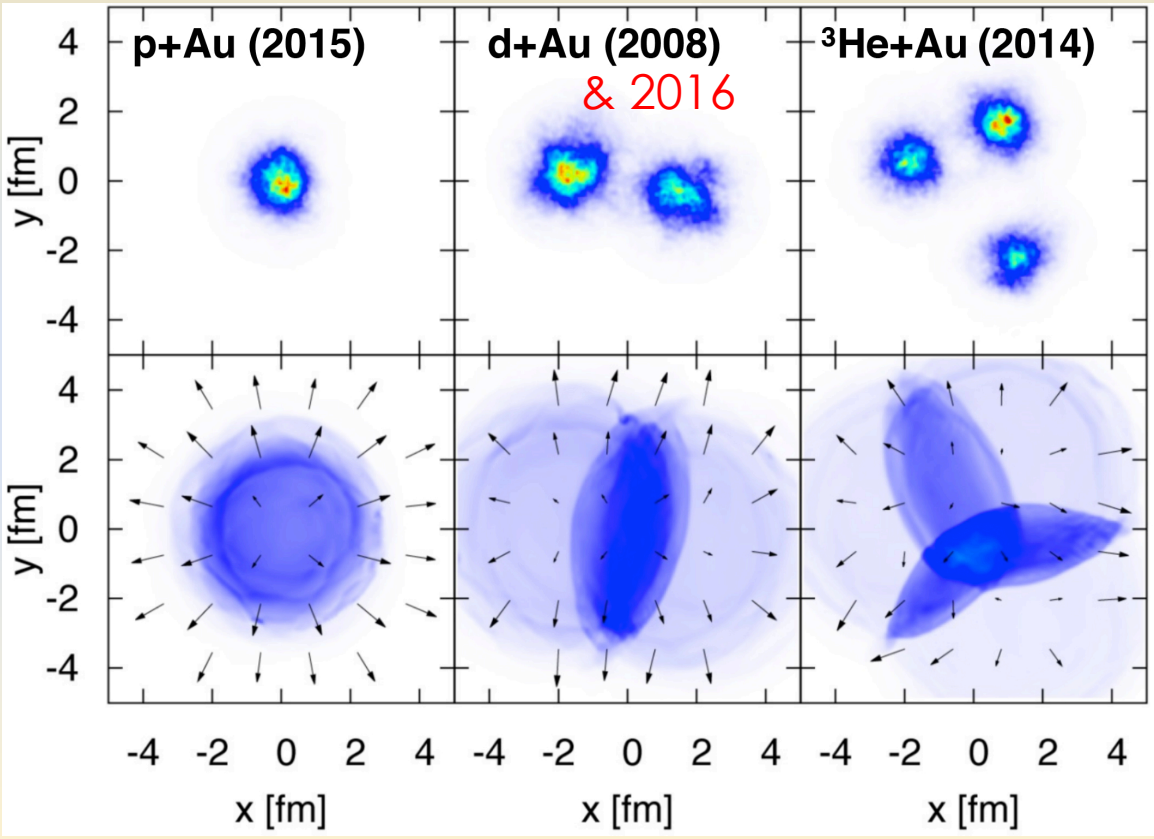

Courtesy of Björn Schenke

Test hydrodynamics in d+Au and ^{3}He+Au which are less sensitive to initial condition model dependencies

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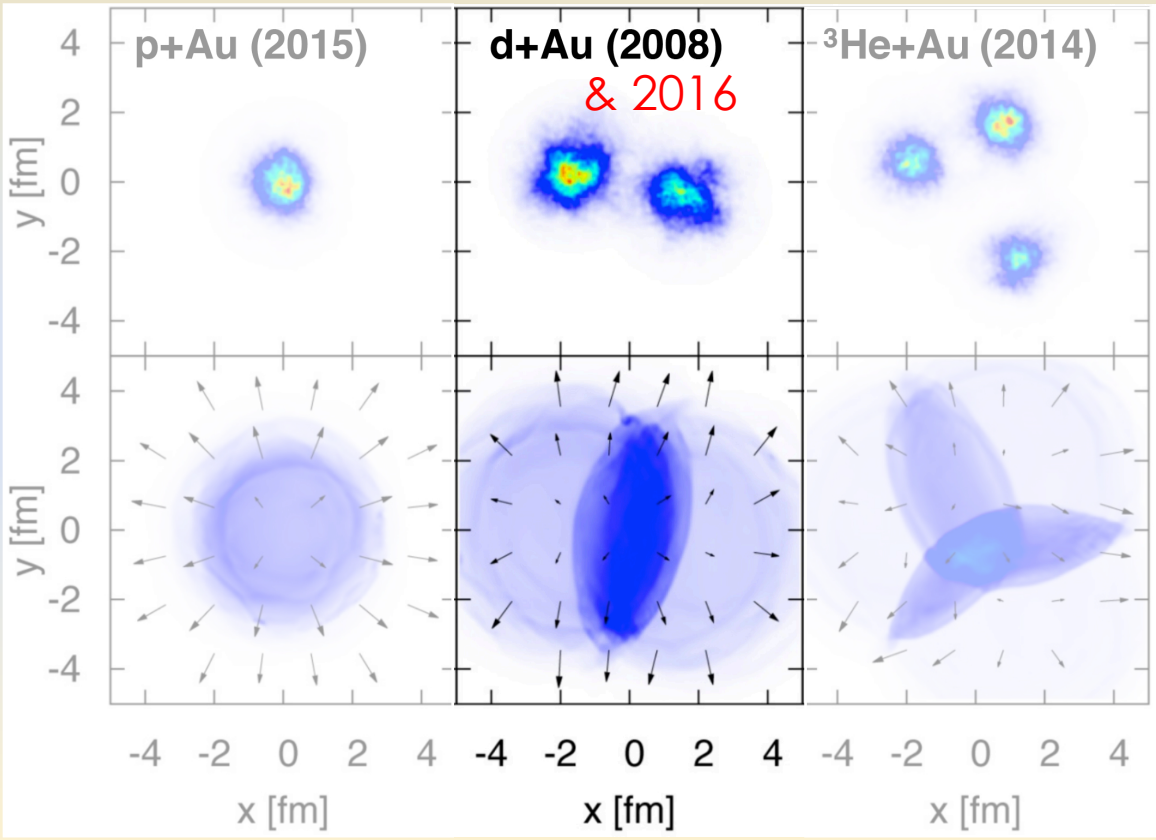

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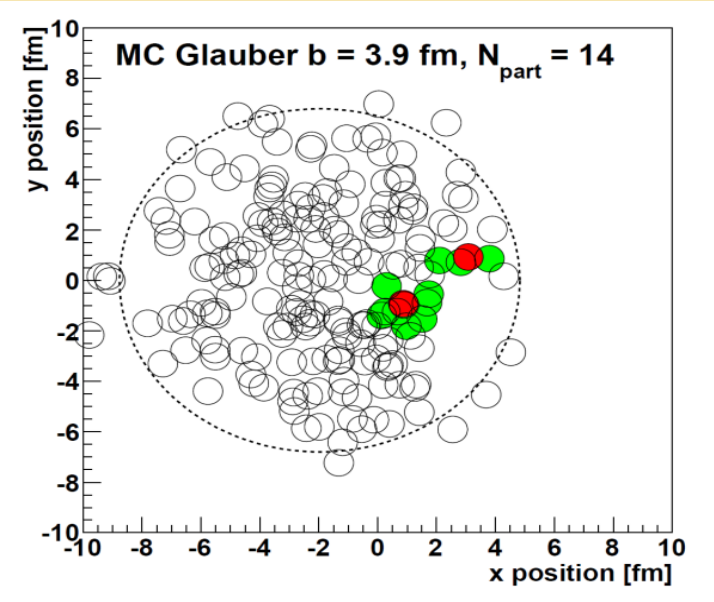
Test hydrodynamics in d+Au and ^{3}He+Au which are less sensitive to initial condition model dependencies

Deuteron structure is well understood

Phys. Rev. C **90**, 034902



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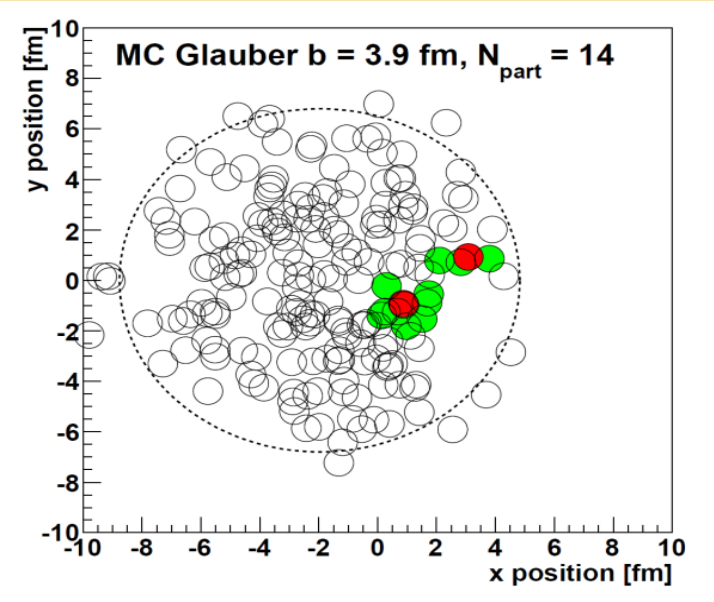

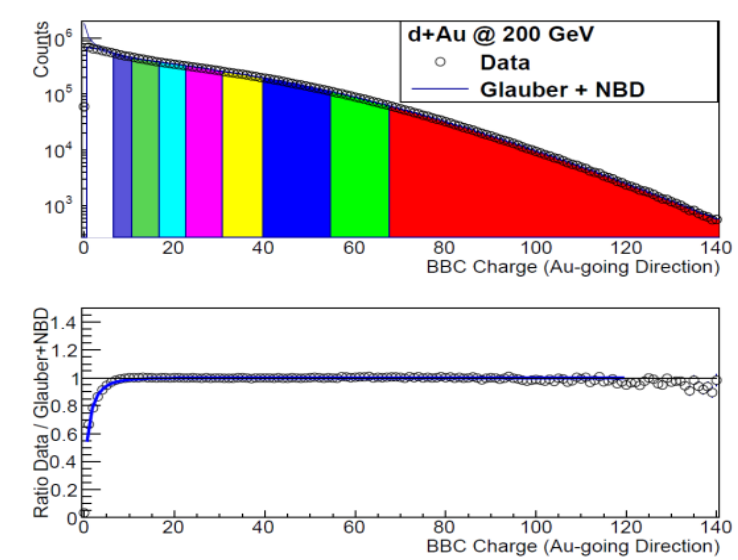

Deuteron wave function + Glauber ➡ Good fit to data

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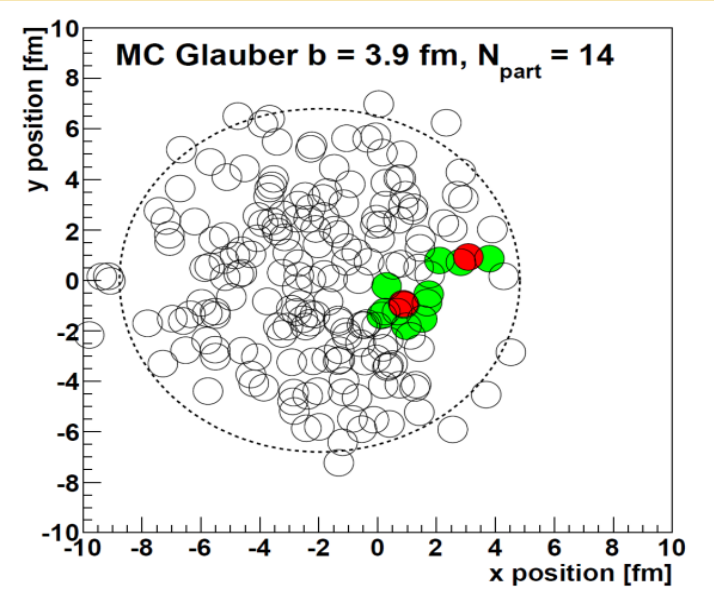
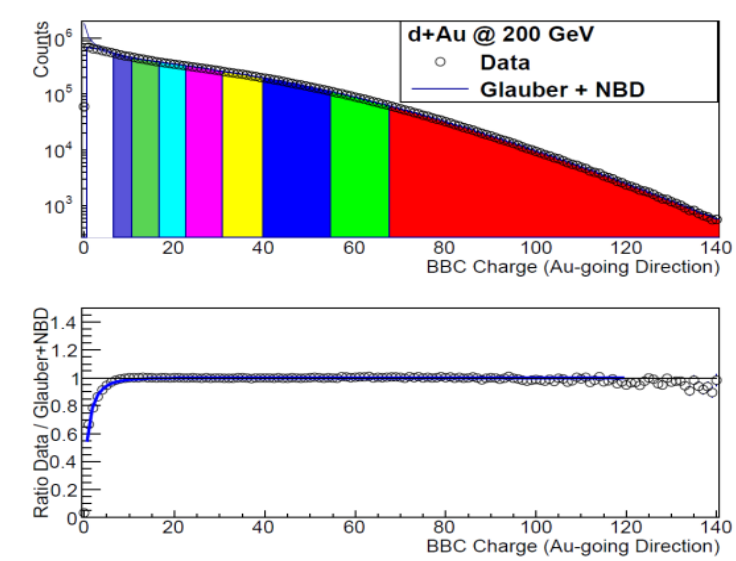
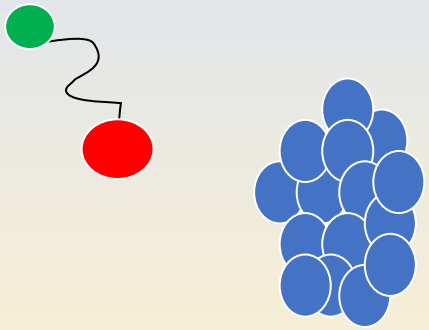
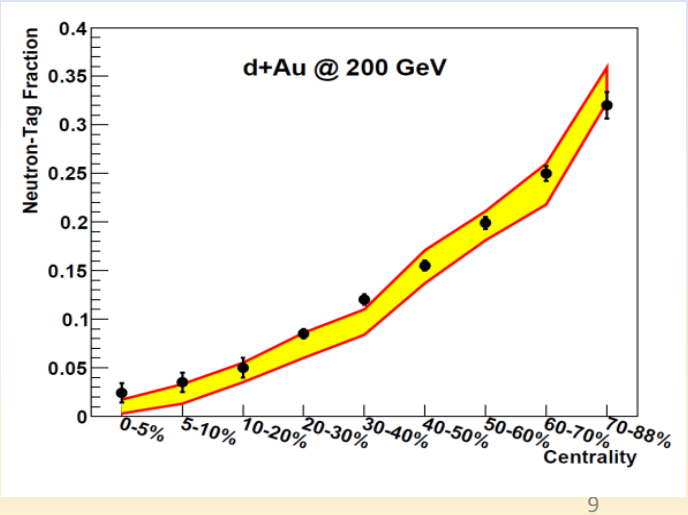




Deuteron wave function + Glauber ➡ Good fit to data

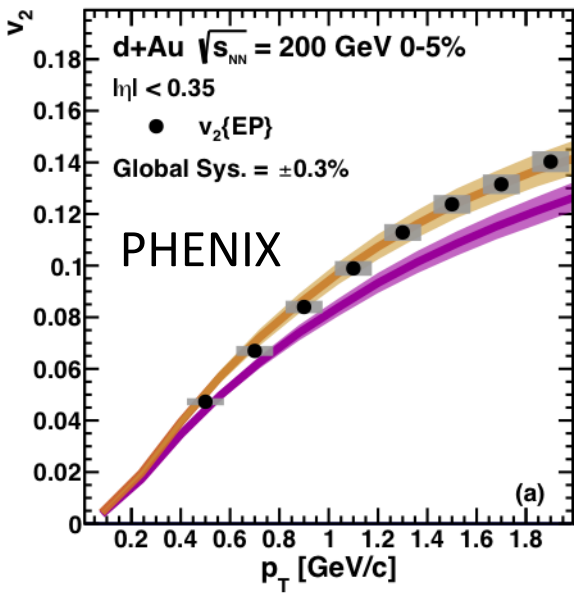
Sometimes the neutron misses!

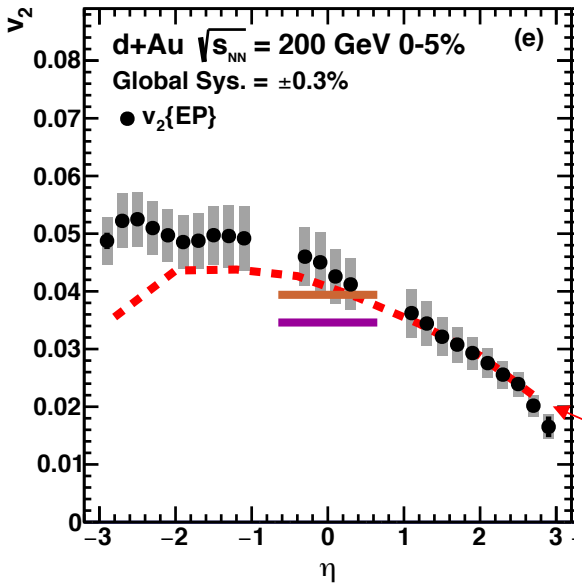




Geometry validated by experiment

Results from d+Au at 200 GeV





v_2 versus p_T and η in central (high multiplicity collisions)

SONIC v_2

superSONIC v_2

Well described by Hydro with Glauber initial conditions (**SONIC**/**Bozek**) and $\eta/s = 1/4\pi$

P. Bozek, W. Broniowski Phys. Lett. B747 (2015) 135

https://arxiv.org/abs/1708.06983

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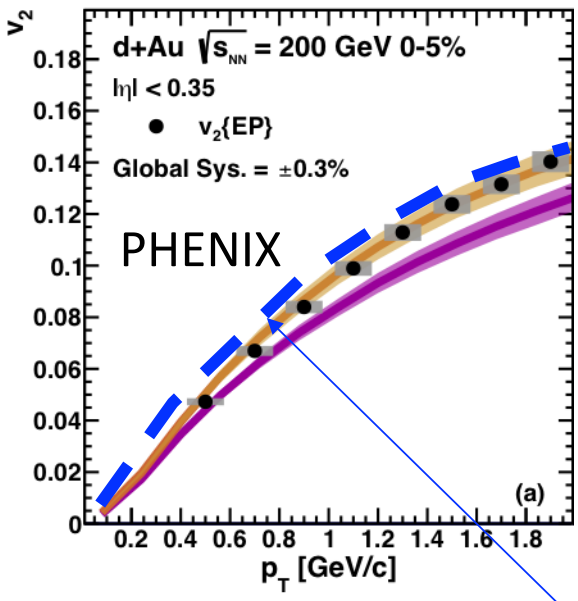

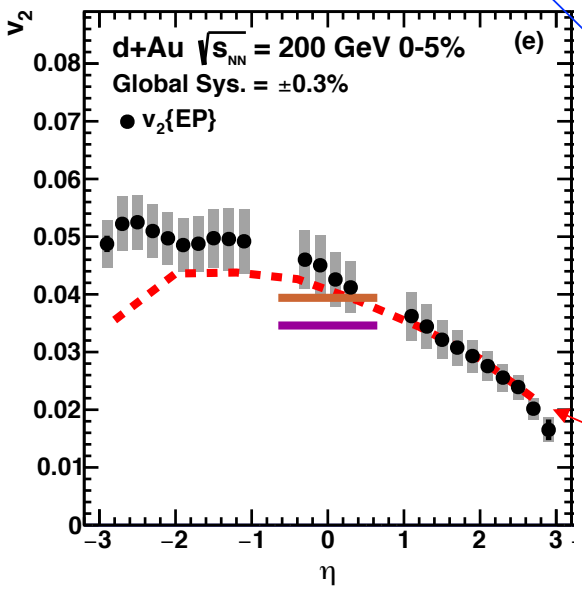

v_2 versus p_T and η in central (high multiplicity collisions)

SONIC v_2

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Well described by Hydro with Glauber initial conditions (**SONIC**/**Bozek**) and $\eta/s = 1/4\pi$

IP-Glasma + MUSIC also can describe the v_2 (p_T) dependence with $\eta/s = 2.26/4\pi$

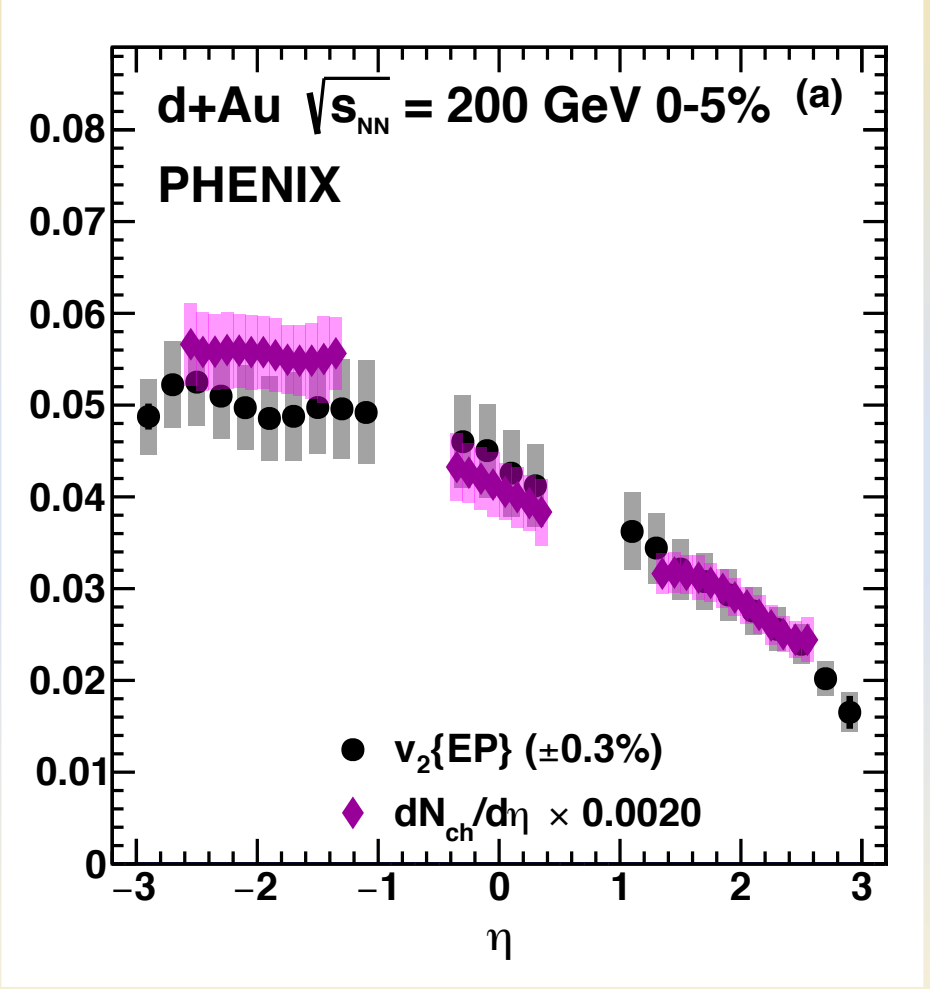
P. Bozek, W. Broniowski Phys. Lett. B747 (2015) 135

https://arxiv.org/abs/1708.06983

Results from d+Au at 200 GeV

v_2 and $dN_{ch}/d\eta$ have similar scaling with η

See Jamie Nagle's talk after the coffee break for more on this and results from the d+Au BES



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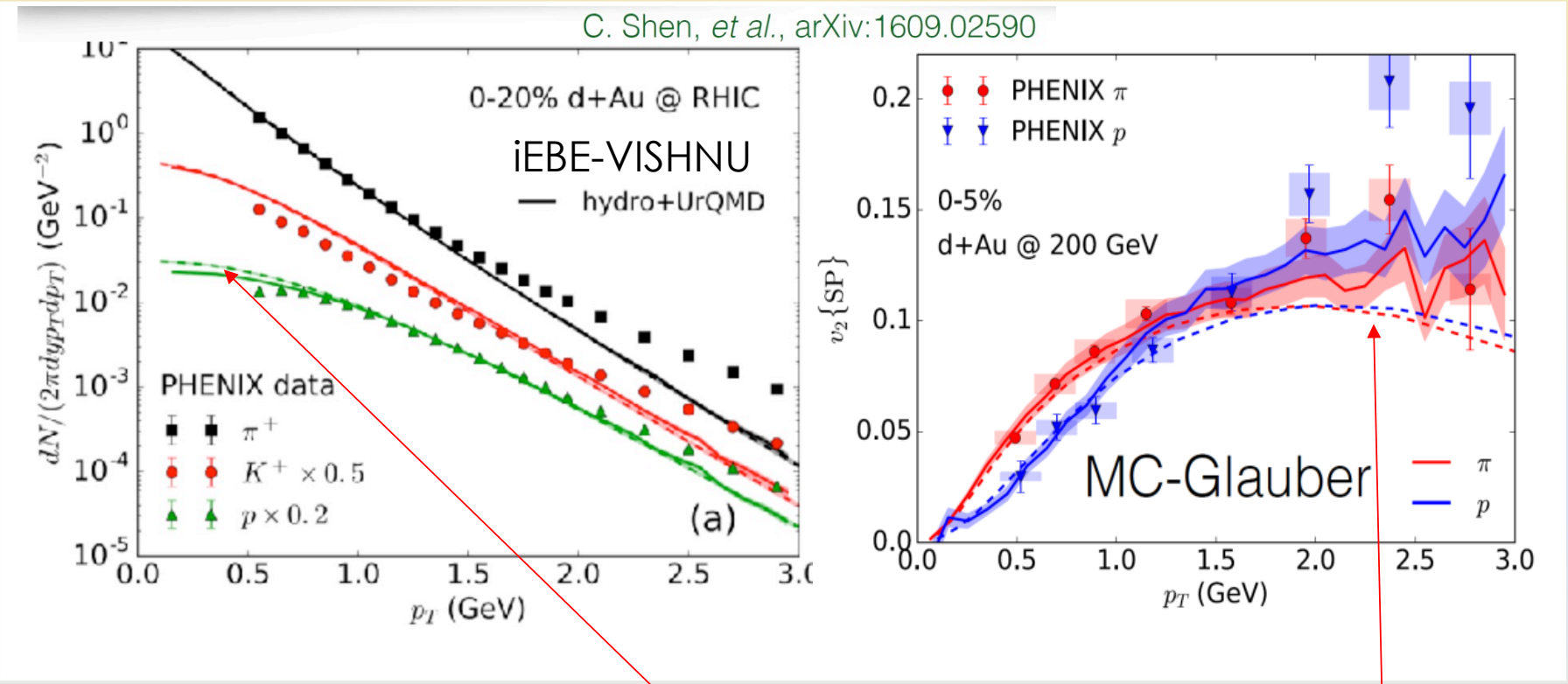


*Dashed lines are **without** hadronic rescattering*

Identified particle spectra and v_2 come naturally from radial flow and geometry anisotropy

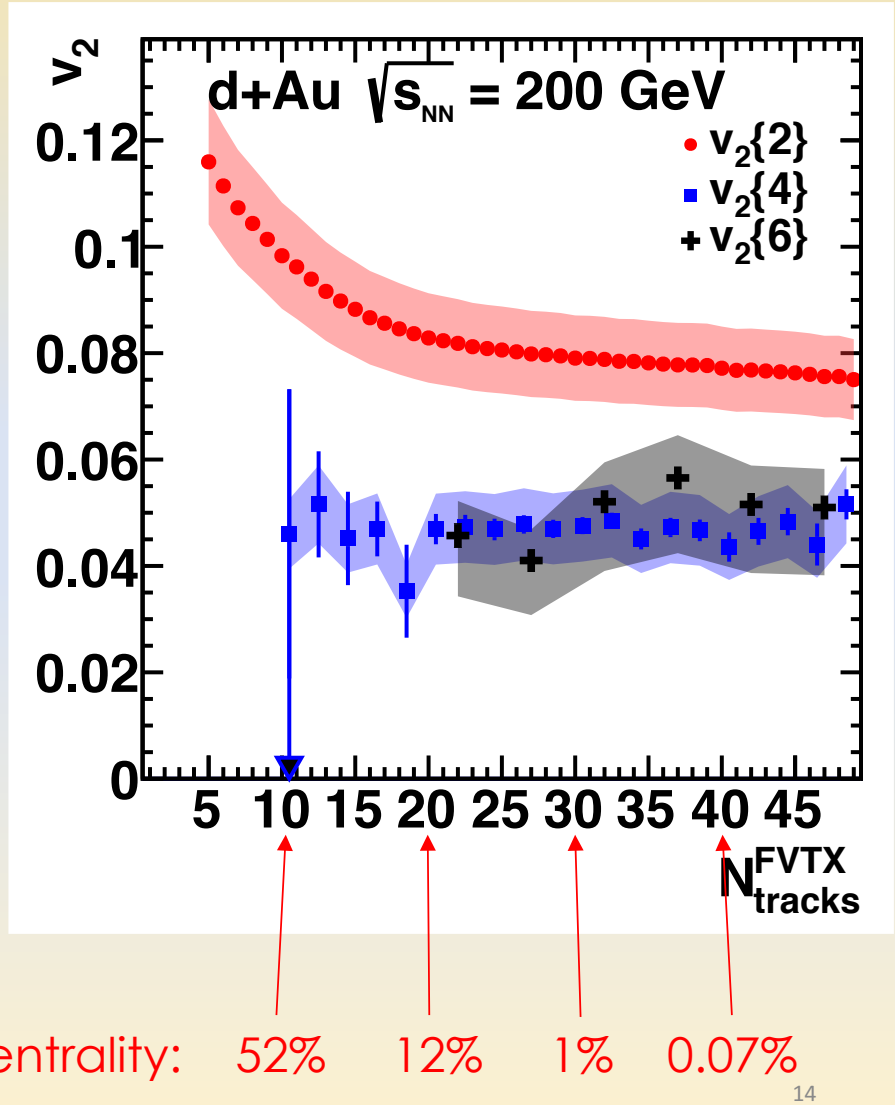
Results from d+Au at 200 GeV

https://arxiv.org/abs/1707.06108

v_2 from {2}, {4}, and {6} particle cumulants are real valued at high multiplicity

Agreement of $v_2\{4\}$ and $v_2\{6\}$ suggest non-flow contributions to $v_2\{4\}$ are sub dominant

See Ron Belmont's talk on Thursday for more details on cumulant measurements and the d+Au BES



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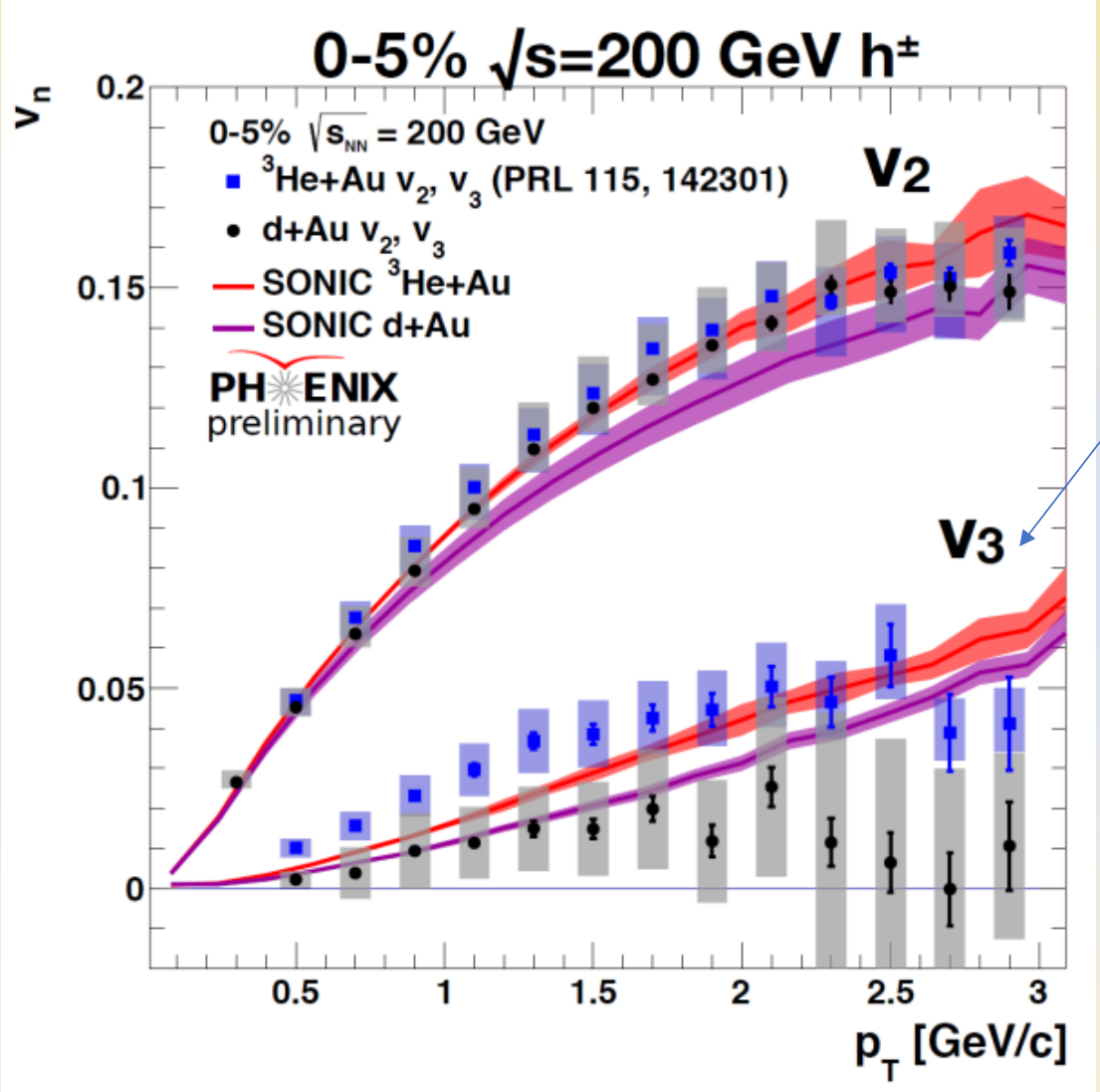
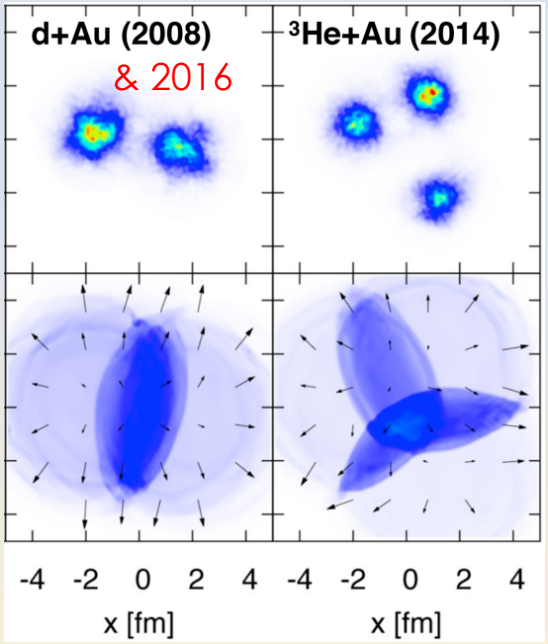


d+Au and ^{3}He+Au v_3 comparison

$\varepsilon_2^{\text{IPGlasma}} = 0.59$ $\varepsilon_2^{\text{IPGlasma}} = 0.55$

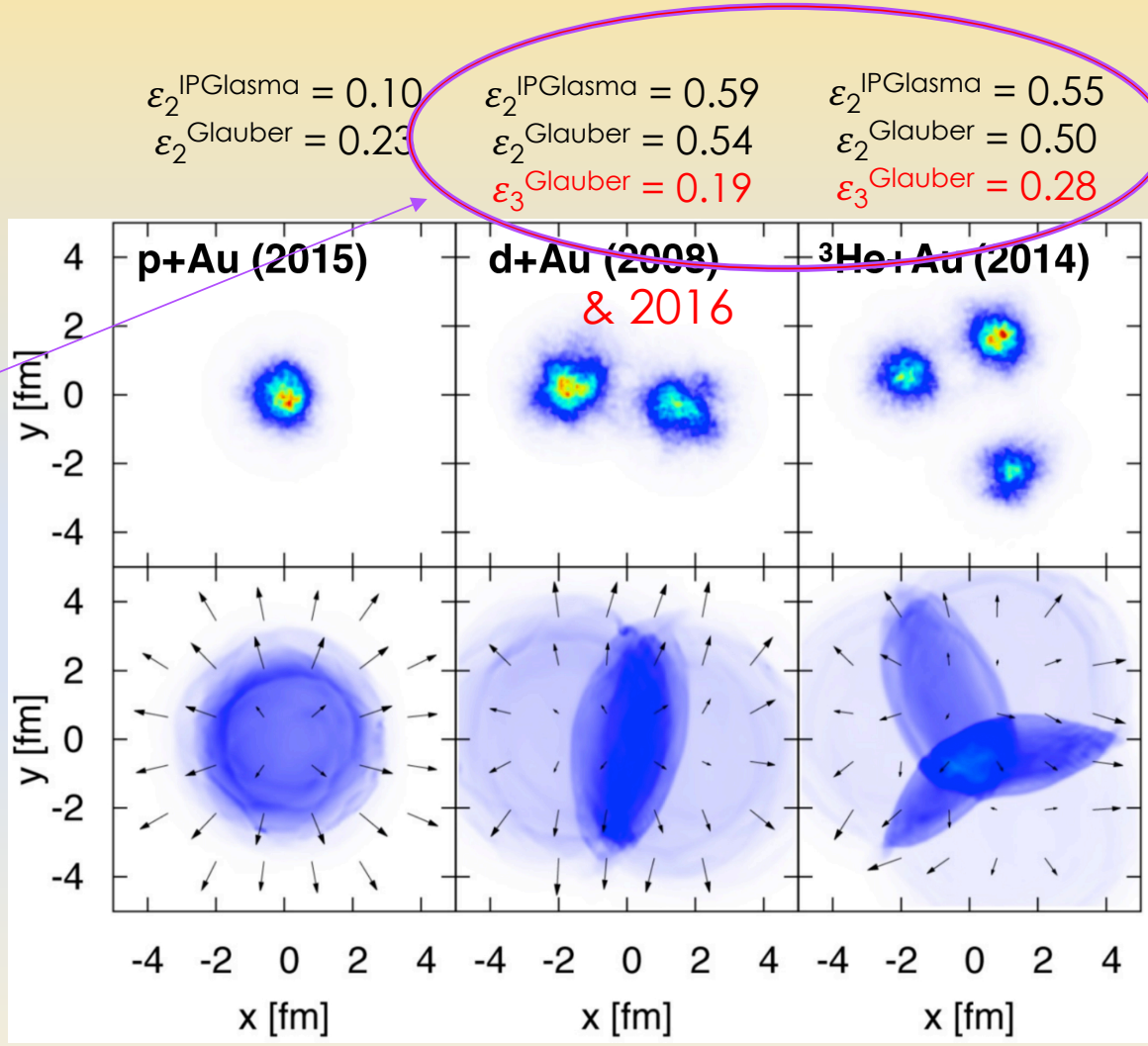
$\varepsilon_2^{\text{Glauber}} = 0.54$ $\varepsilon_2^{\text{Glauber}} = 0.50$

$\varepsilon_3^{\text{Glauber}} = 0.19$ $\varepsilon_3^{\text{Glauber}} = 0.28$



p+A as a testing ground

Initial geometry translating through hydro describes d+Au & ^{3}He+Au with minimal initial state model dependence

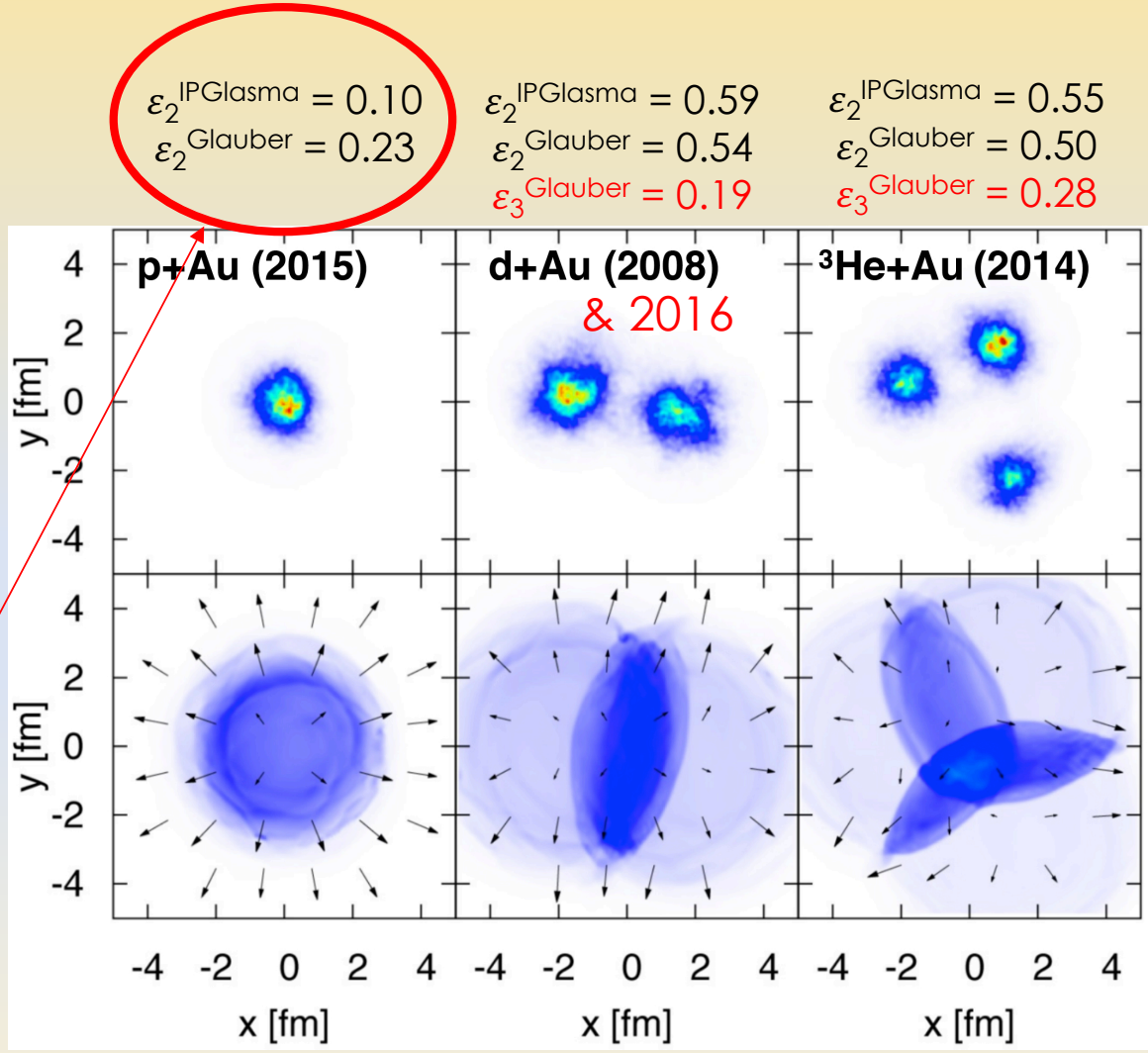


Courtesy of Björn Schenke

Complications with p+p and p+A

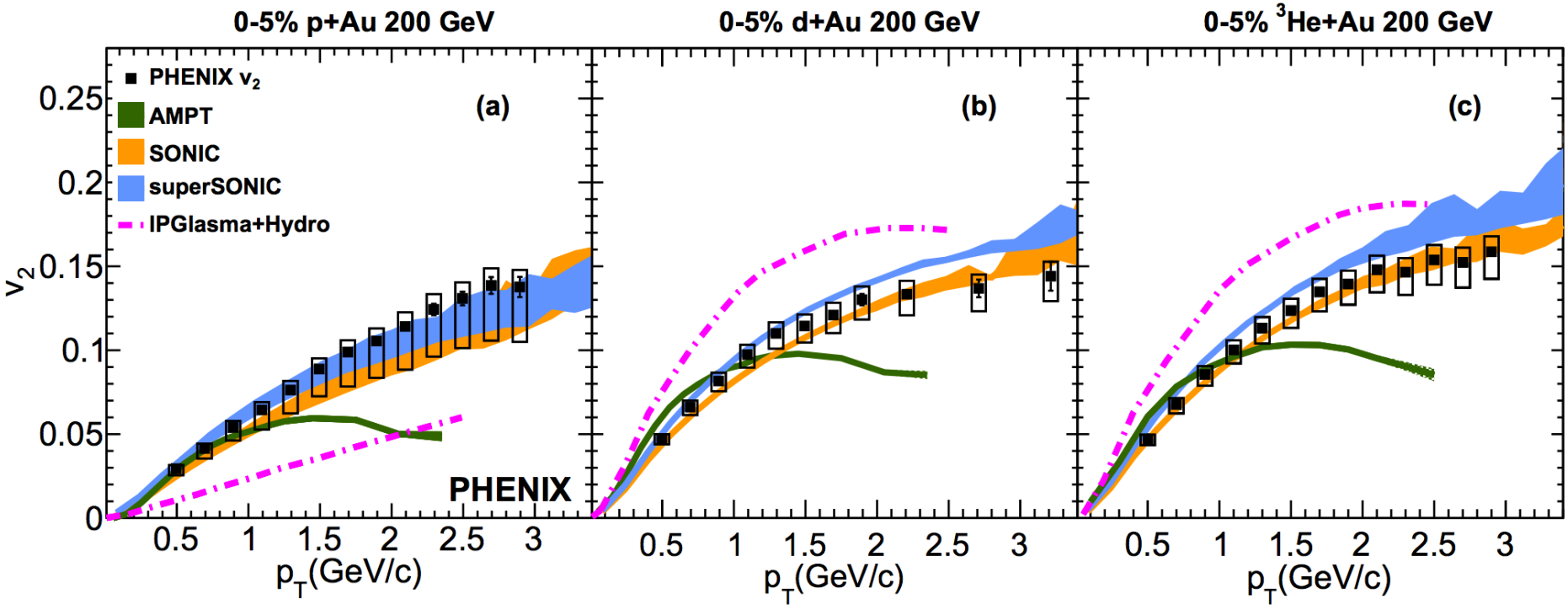
Initial geometry translating through hydo describes d+Au & ^{3}He+Au with minimal initial state model dependence

Now test initial state models in the translation framework of hydro



Courtesy of Björn Schenke

200 GeV System Scan

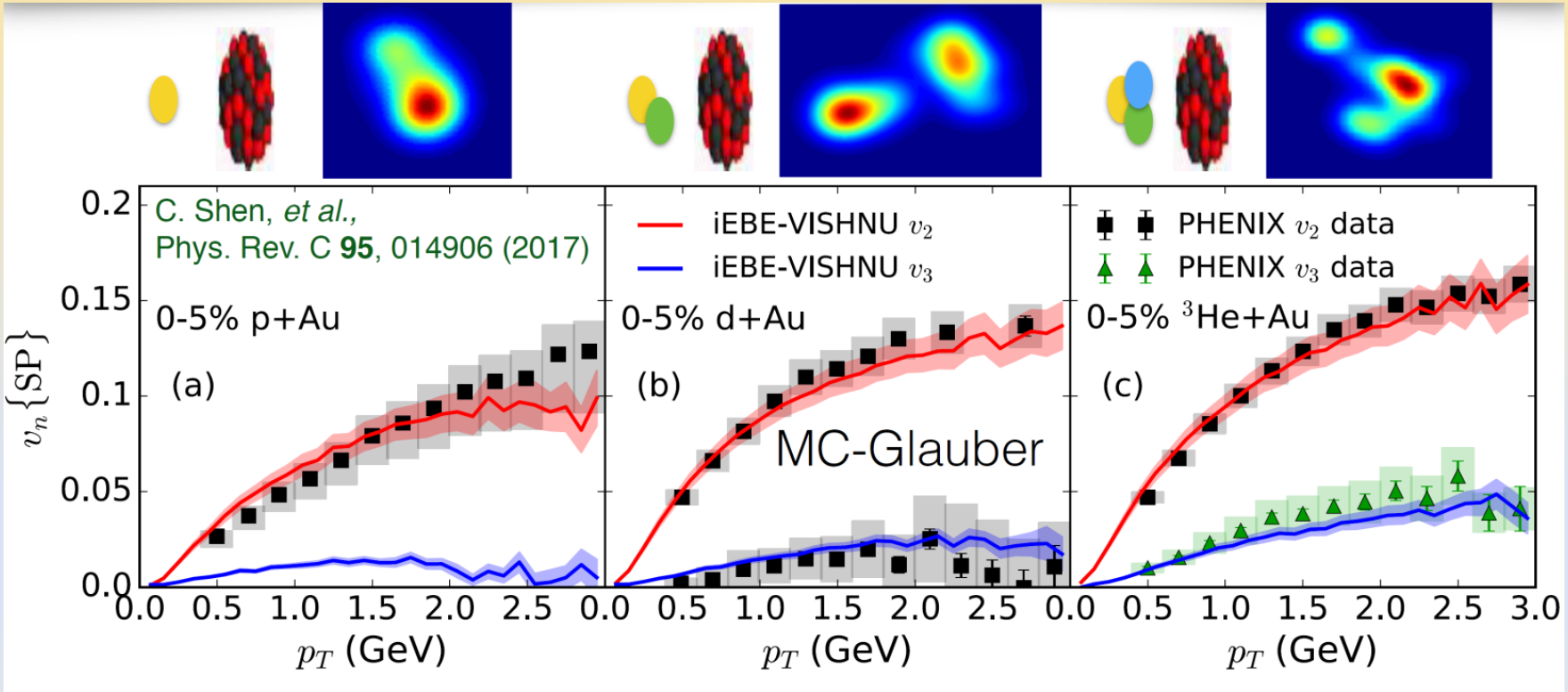


Phys. Rev. C95 (2017) 034910
Phys. Rev. Lett. 114 (2015) 192301
Phys. Rev. Lett. 115 (2015) 142301

Hydro-models and parton−cascade can generally describe the measurements.

IPGlasma (w/o shape fluctuations) + Hydro cannot simultaneously describe p+Au and d+Au (^{3}He+Au) data with a given η/s

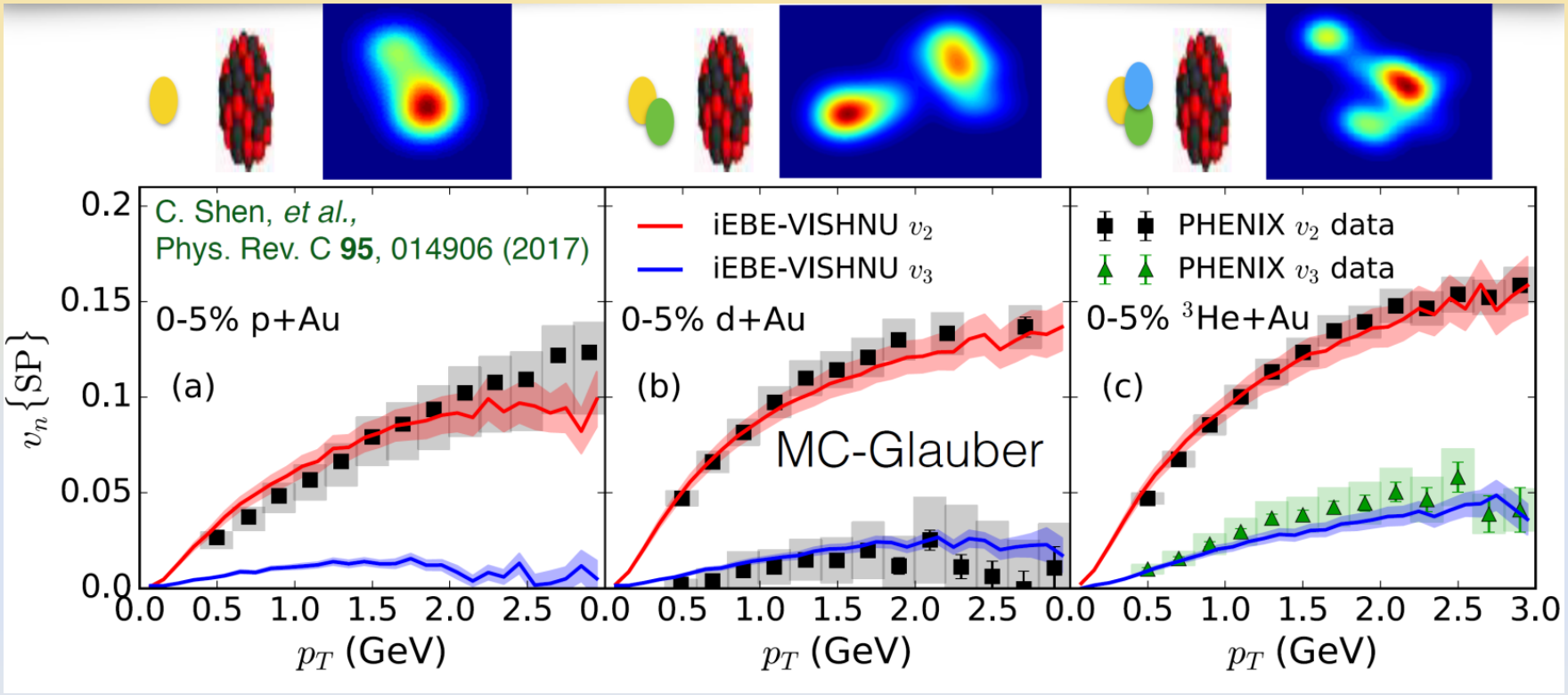
200 GeV System Scan



Chun Shen – RHIC & AGS Users Meeting

Glauber + hydrodynamics describes triangular flow v_3 in both d+Au and ^{3}He+Au data

200 GeV System Scan



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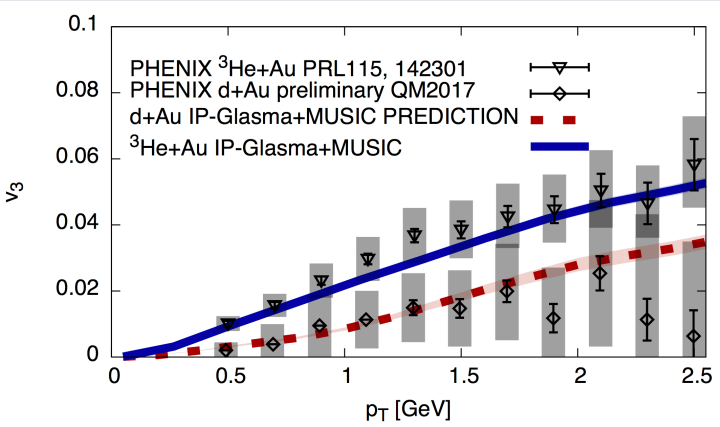
Glauber + hydrodynamics describes triangular flow v_3 in both d+Au and ^{3}He+Au data

IP-Glasma + hydro also effective description of v_3 in each system



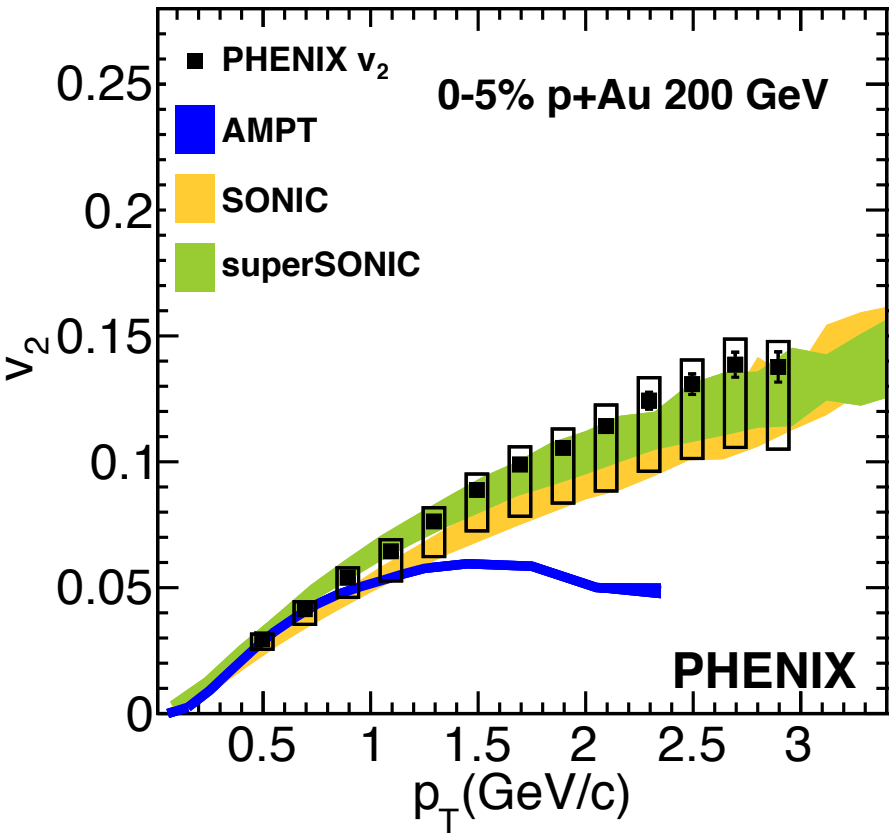
Björn Schenke 2017 J. Phys.: Conf. Ser. 779 012011

Target Dependence

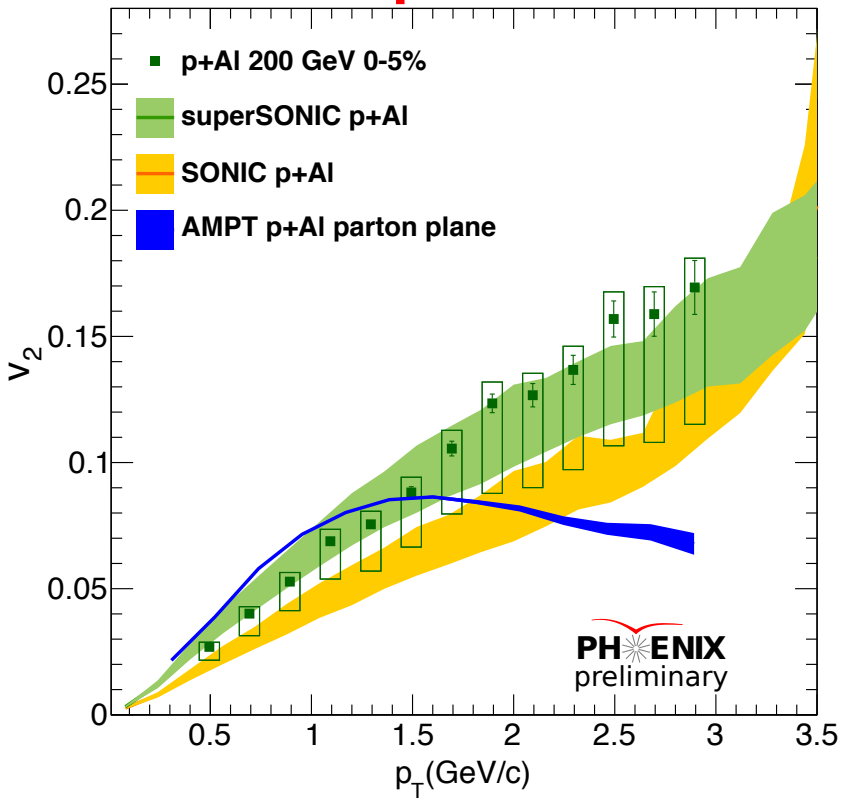
$\varepsilon_2^{Glauber} = 0.23$
A = 197

$\varepsilon_2^{Glauber} = 0.30$
A = 27

p+Au

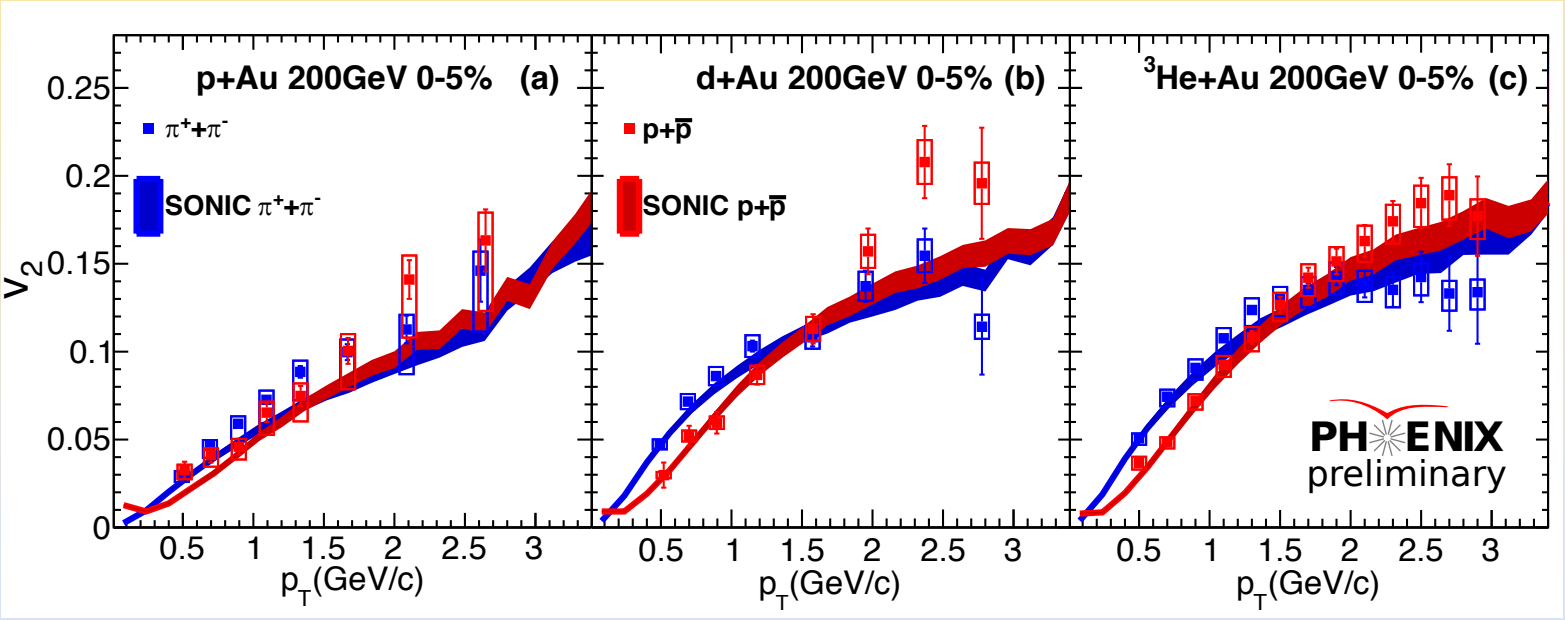


p+Al



We expect $0.55 \times dN_{ch}^{p+Au}/d\eta = dN_{ch}^{p+Al}/d\eta$

200 GeV System Scan - PID



Glauber + hydrodynamics + hadron re-scattering describes mass splitting in all systems at low p_T

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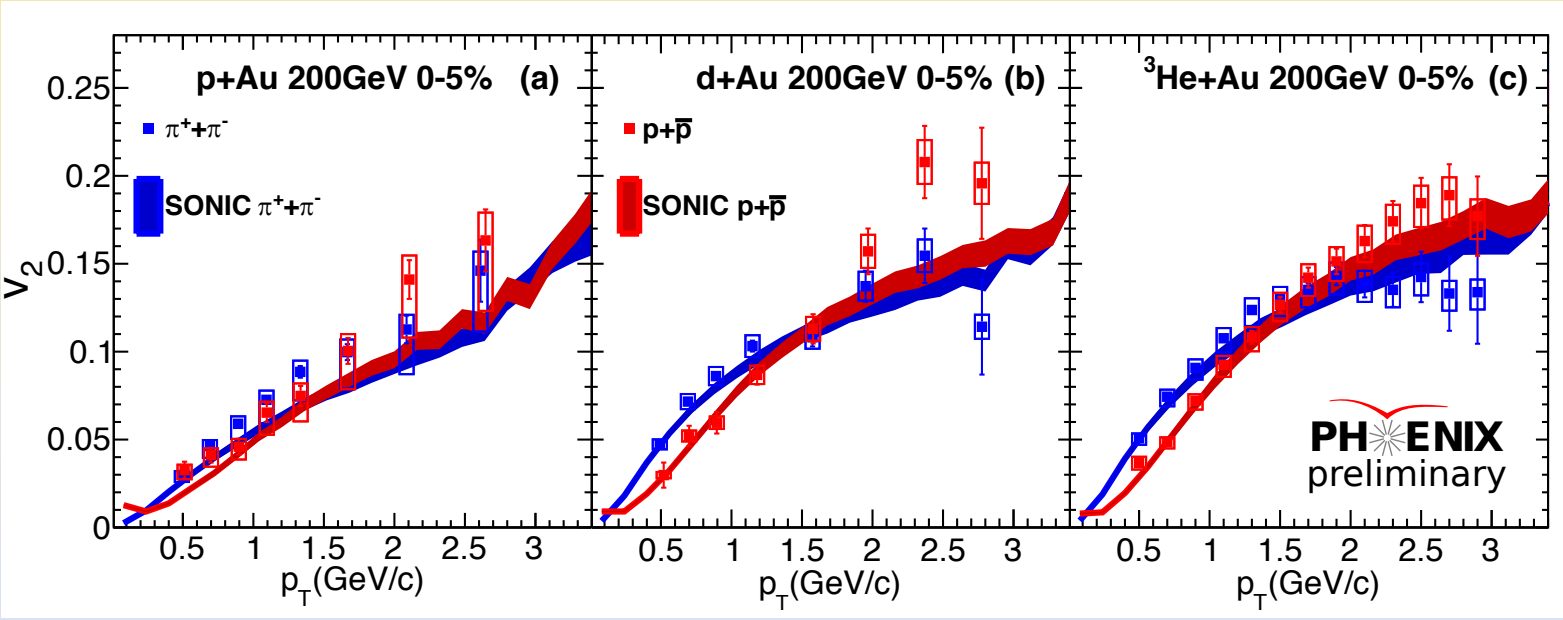

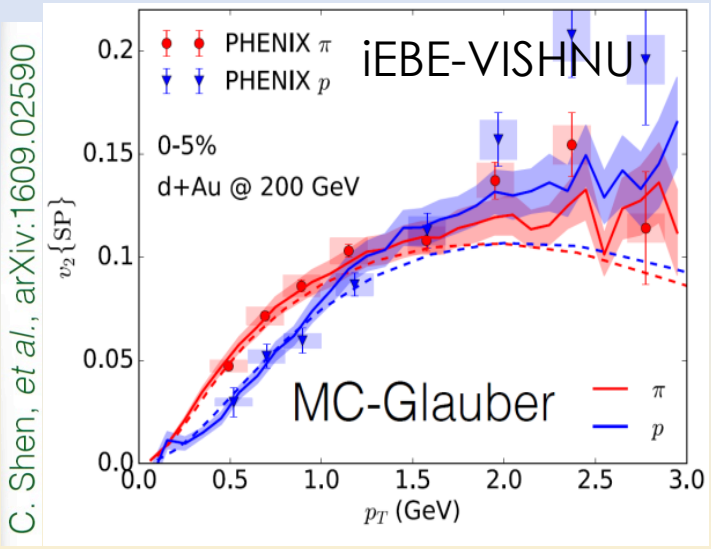

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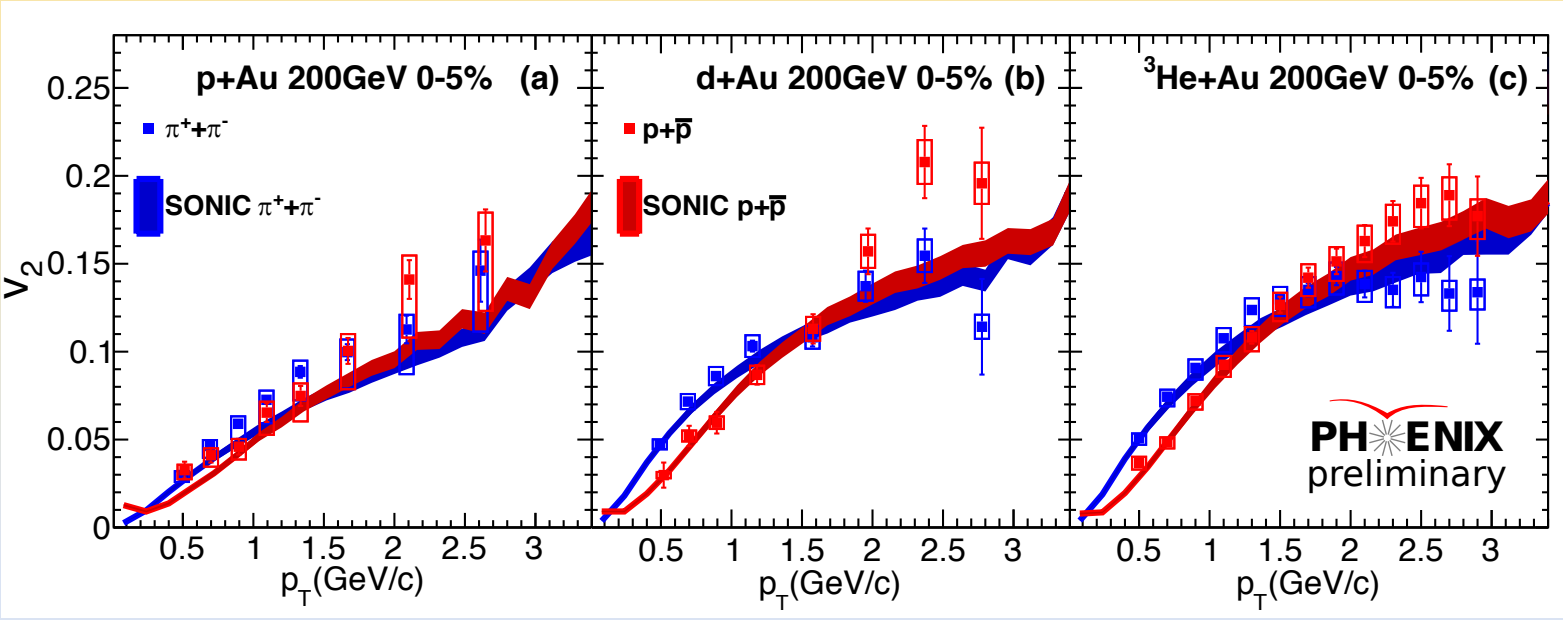
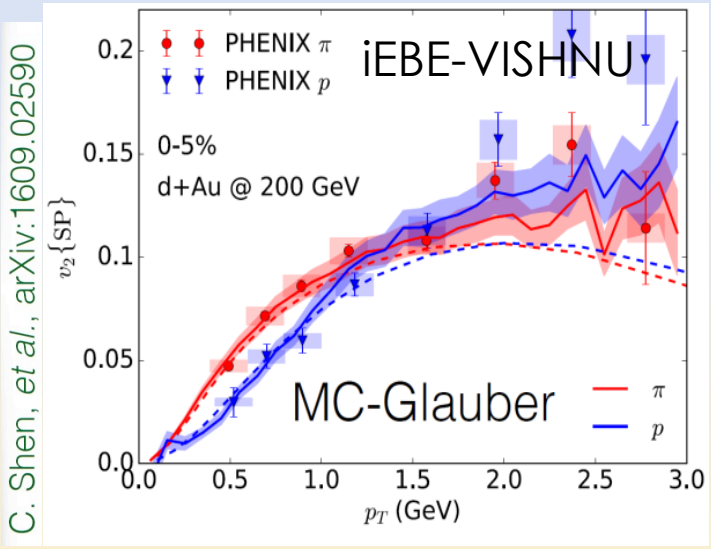


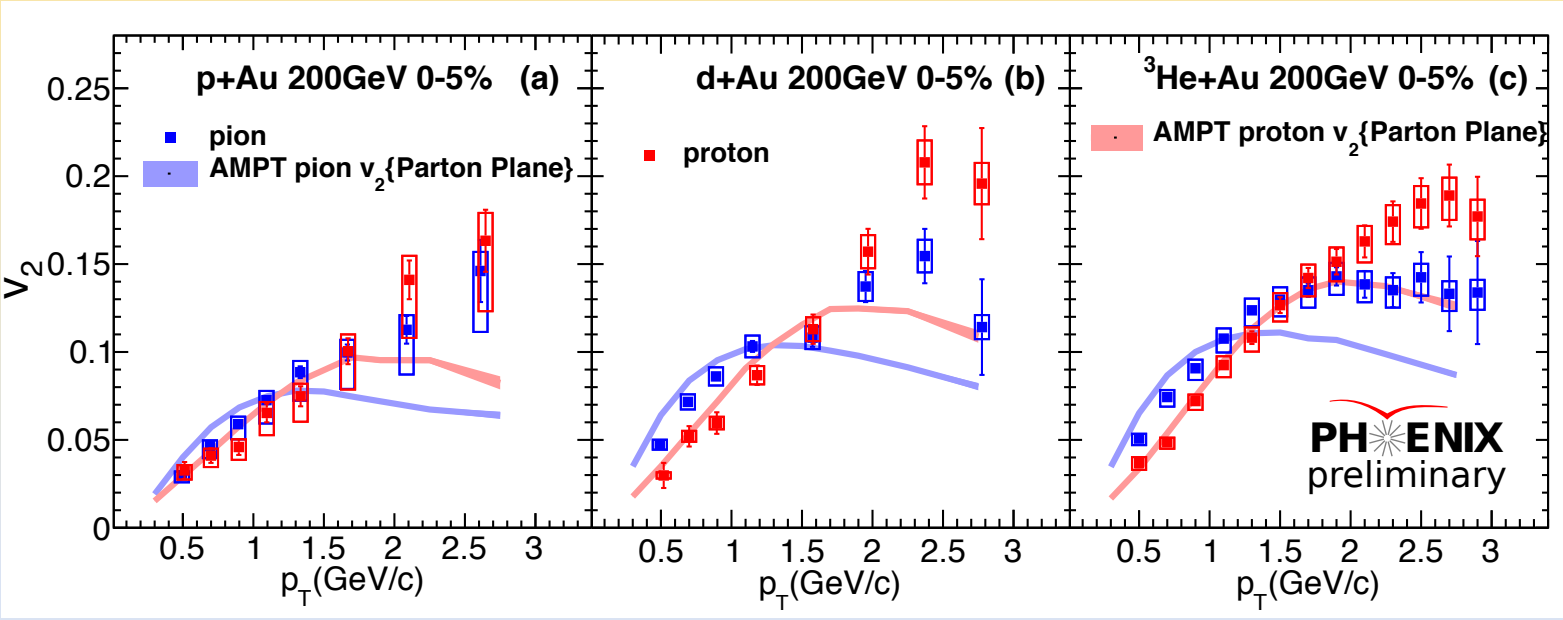


C. Shen, *et al.*, arXiv:1609.02590

Glauber + hydrodynamics + hadron re-scattering describes mass splitting in all systems at low p_T

Turn off rescattering and low p_T behavior is unchanged

200 GeV System Scan - PID



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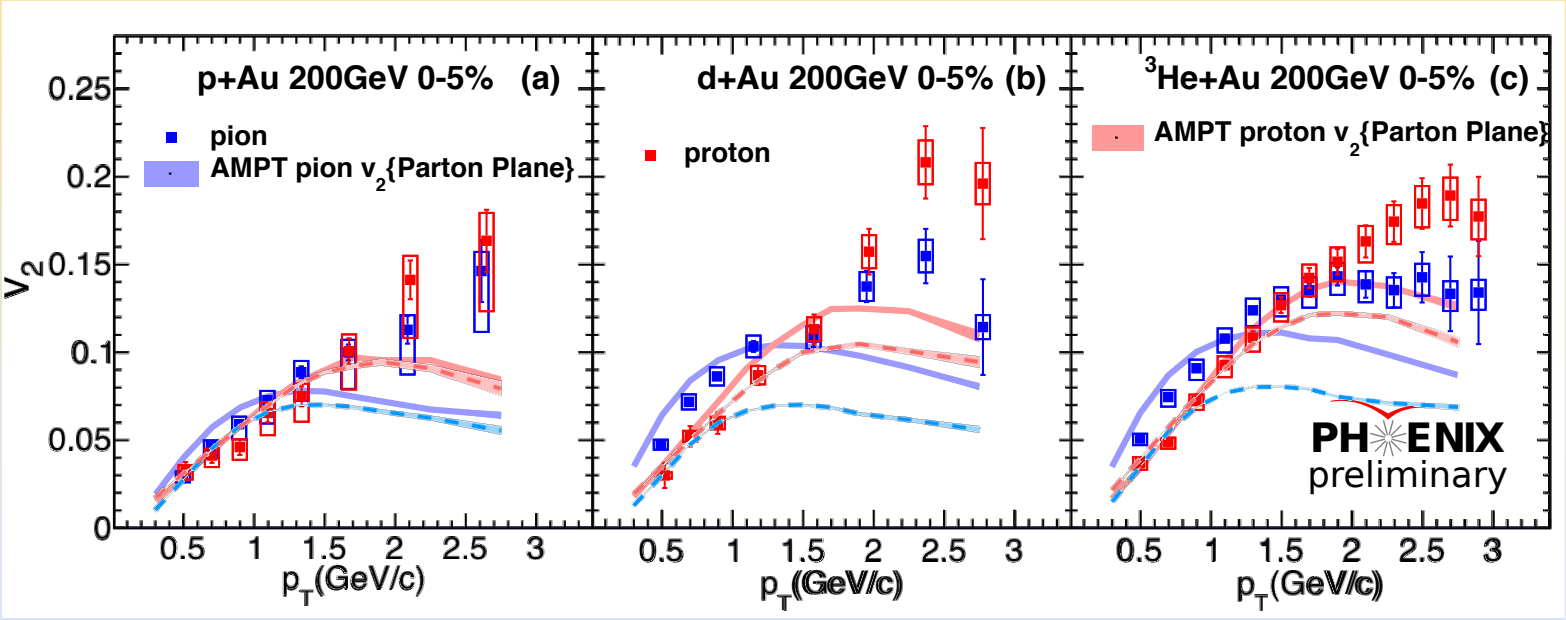

https://arxiv.org/abs/1601.05390

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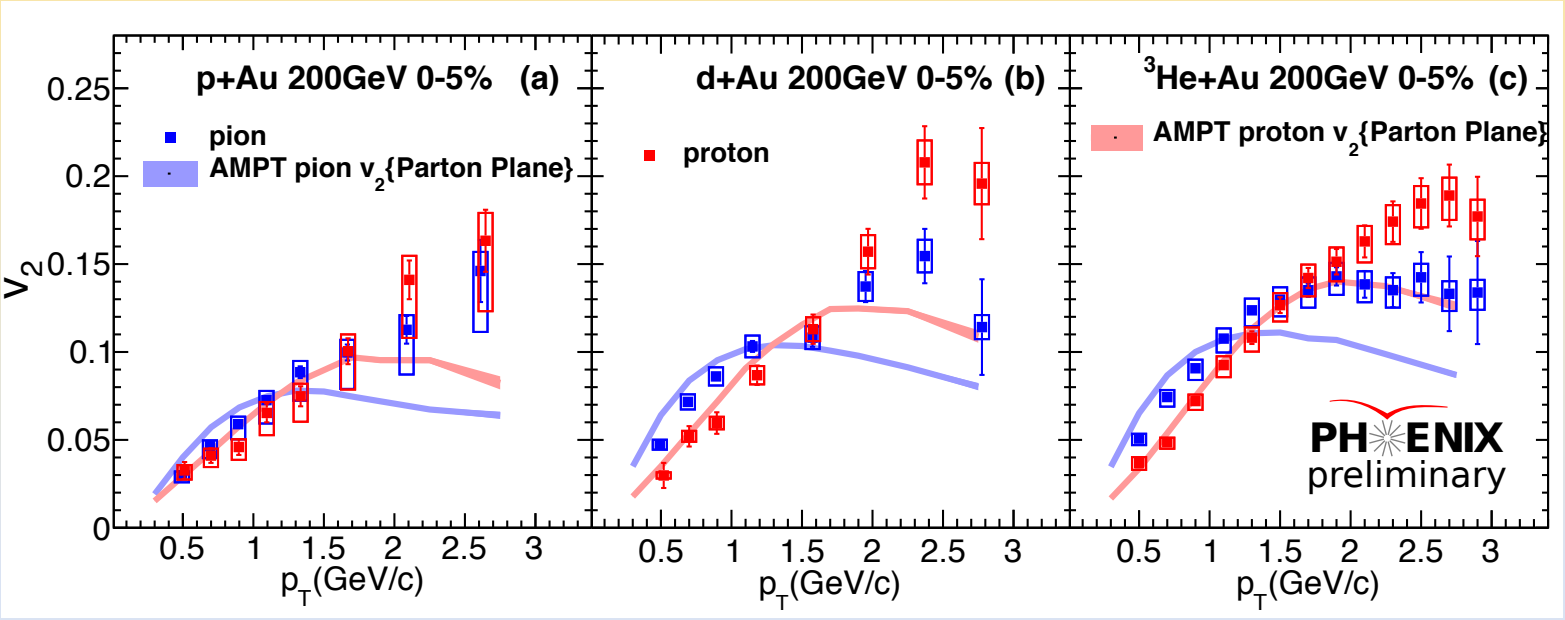

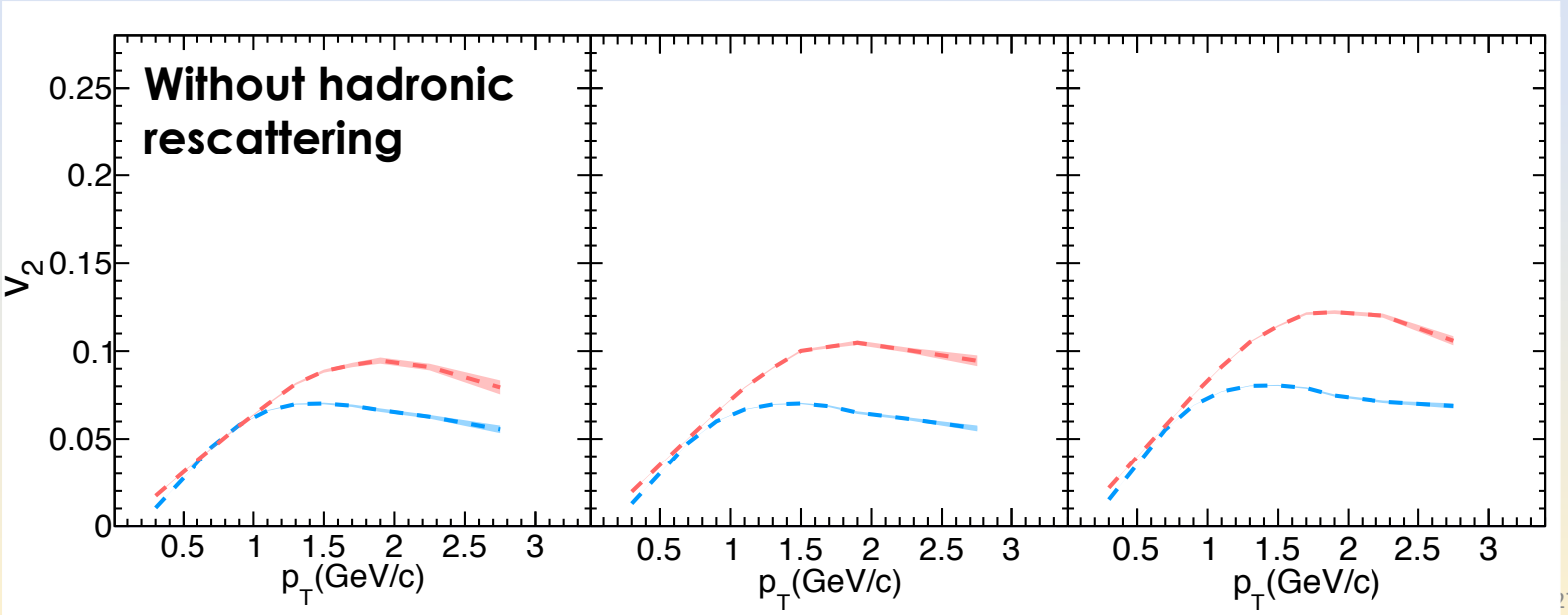

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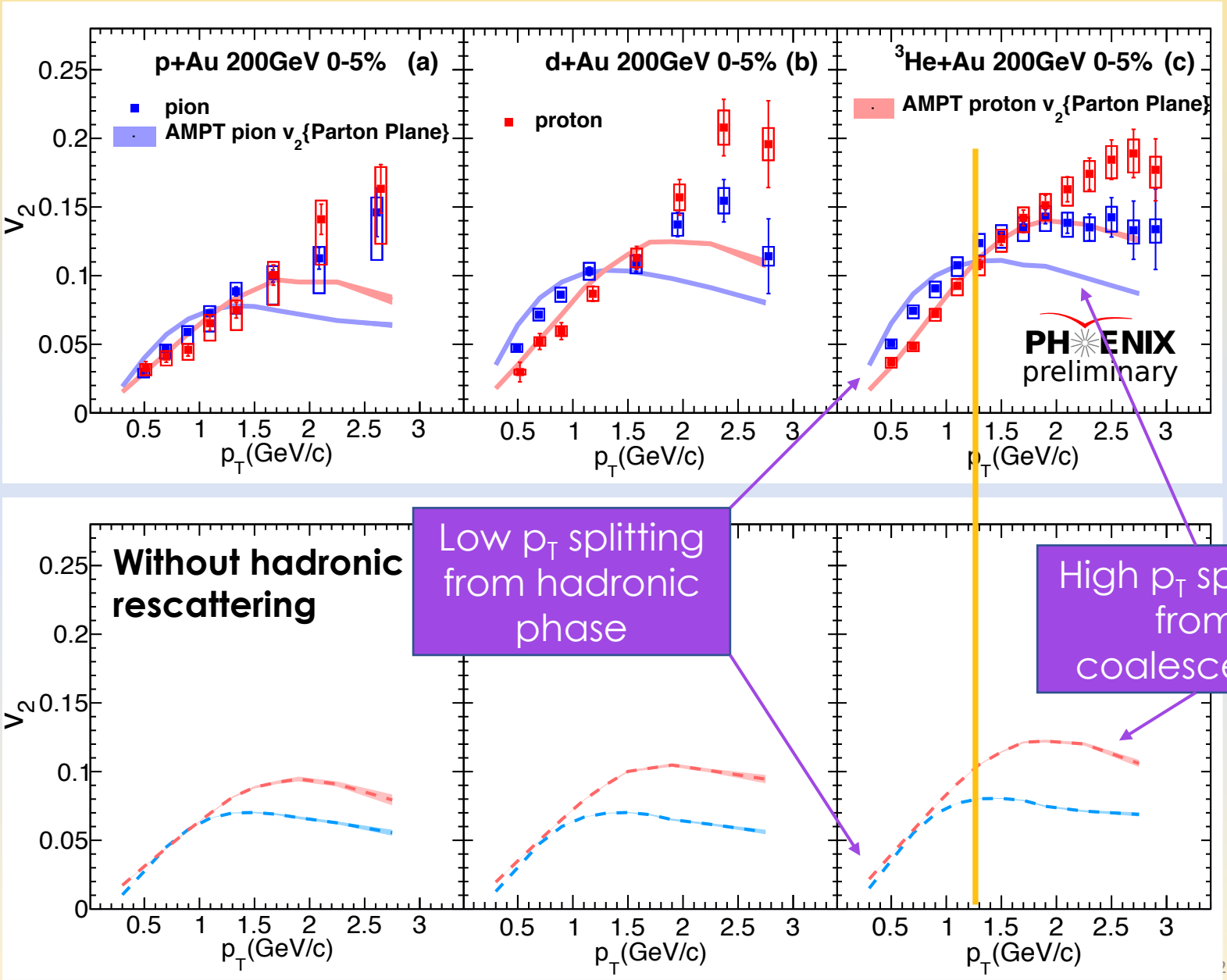

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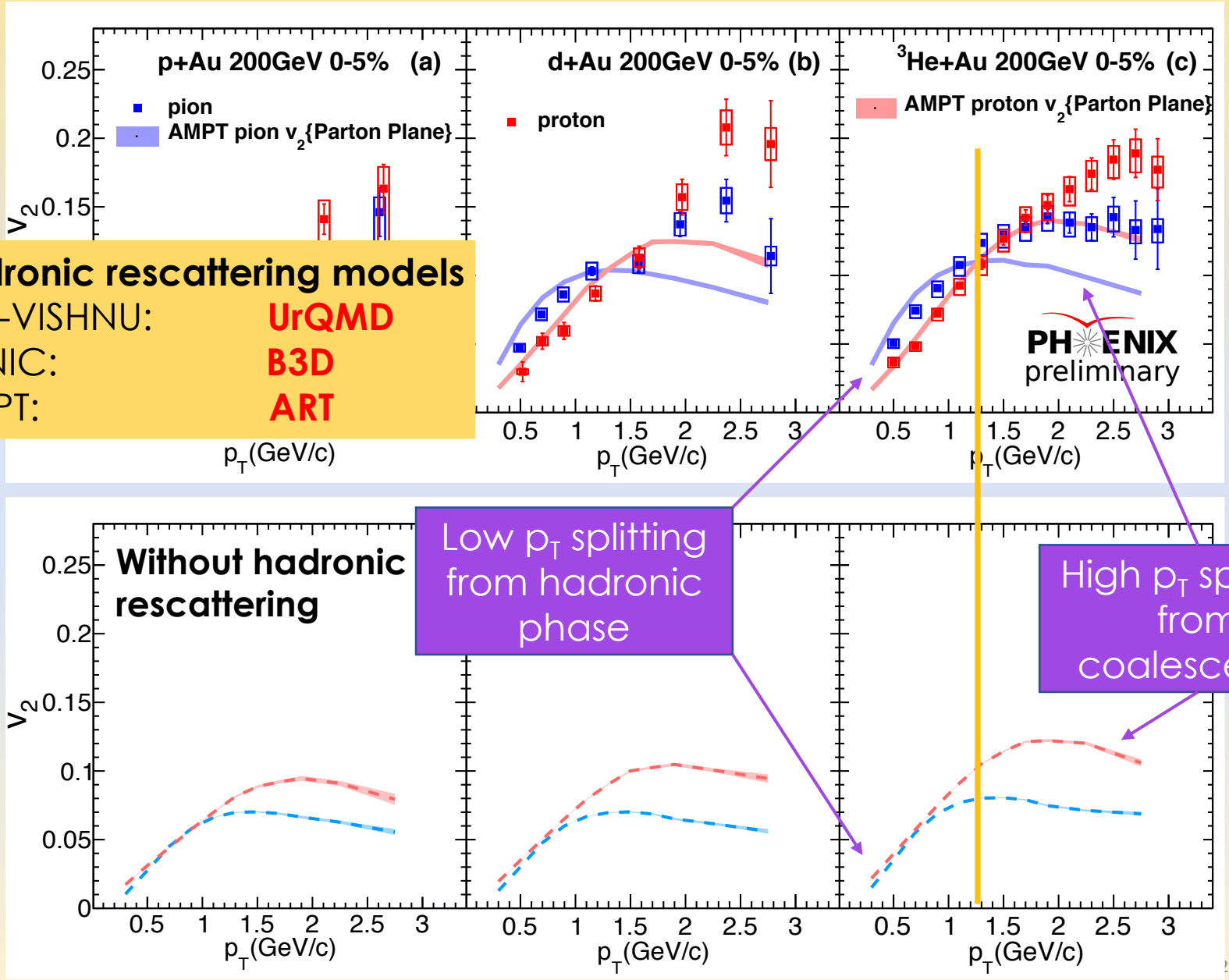

Hadronic rescattering models

iEBE-VISHNU: **UrQMD**

SONIC: **B3D**

AMPT: **ART**

https://arxiv.org/abs/1601.05390

Conclusions

Many exciting results from the *PHENIX* 200 GeV small system geometry scan

Strong evidence for initial geometry translating to hadronic momentum anisotropy through final state interactions

p+A is sensitive to geometry of proton and can provide a testing ground for initial state models

Both hydro and AMPT similarly describe mass splitting at low p_T but the origin of the effect is quite different

Model Comparison

- **SONIC:**
  - MC Glauber initial conditions
  - 2+1d Hydro evolution
  - Hadronic rescattering (B3D package)
- **Super SONIC:** SONIC + pre-equilibrium flow
- **iEBE-VISHNU:**
  - MC Glauber initial conditions
  - 2+1d Hydro evolution
  - Hadronic rescattering (UrQMD package)
- **Bozek – Broniowski:**
  - MC Glauber initial conditions
  - 3+1d Hydro evolution
- **IP-Glasma+MUSIC:**
  - IP-Glasma initial conditions
  - 3+1d Hydro evolution
- **AMPT**
  - MC Glauber initial conditions
  - Partonic transport
  - Hadronic rescattering (ART package)