集体流测量新进展

从小系统到大系统

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中国物理学会高能物理分会第十一届全国会员代表大会

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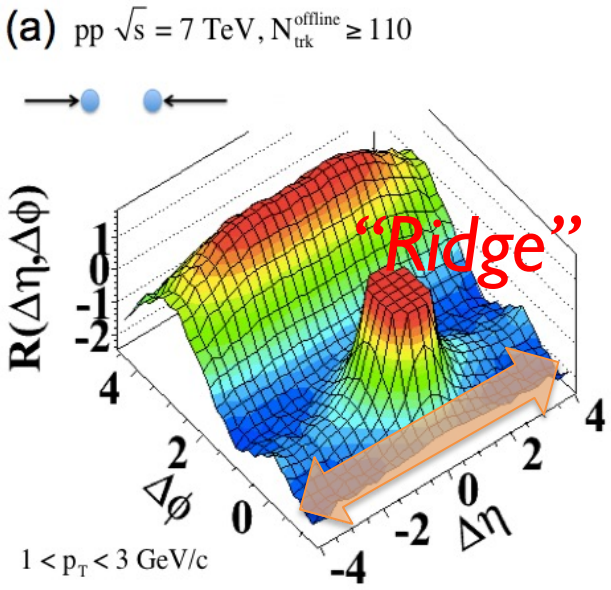
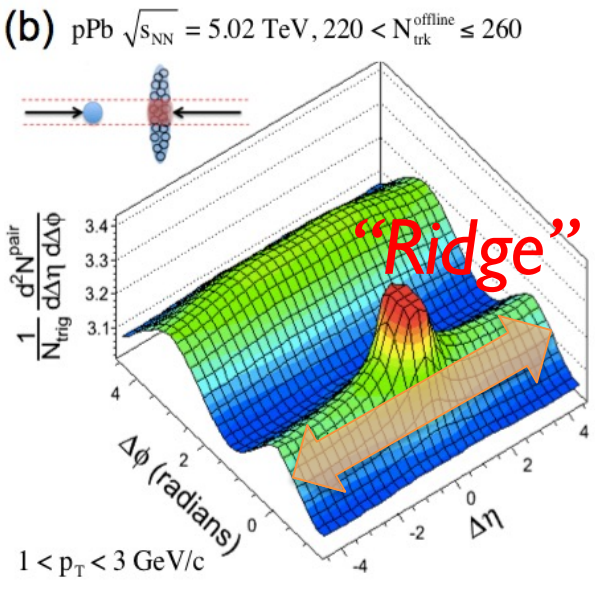
山东大学

SHANDONG UNIVERSITY

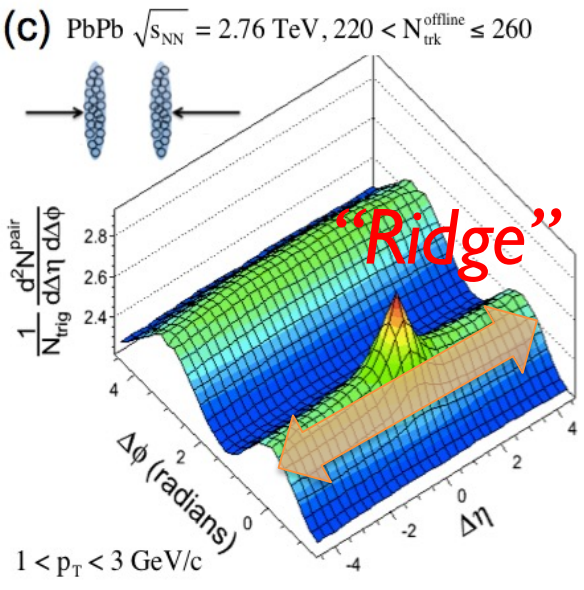
“Ridge” in small systems



JHEP 09 (2010) 091



PLB 724 (2013) 213

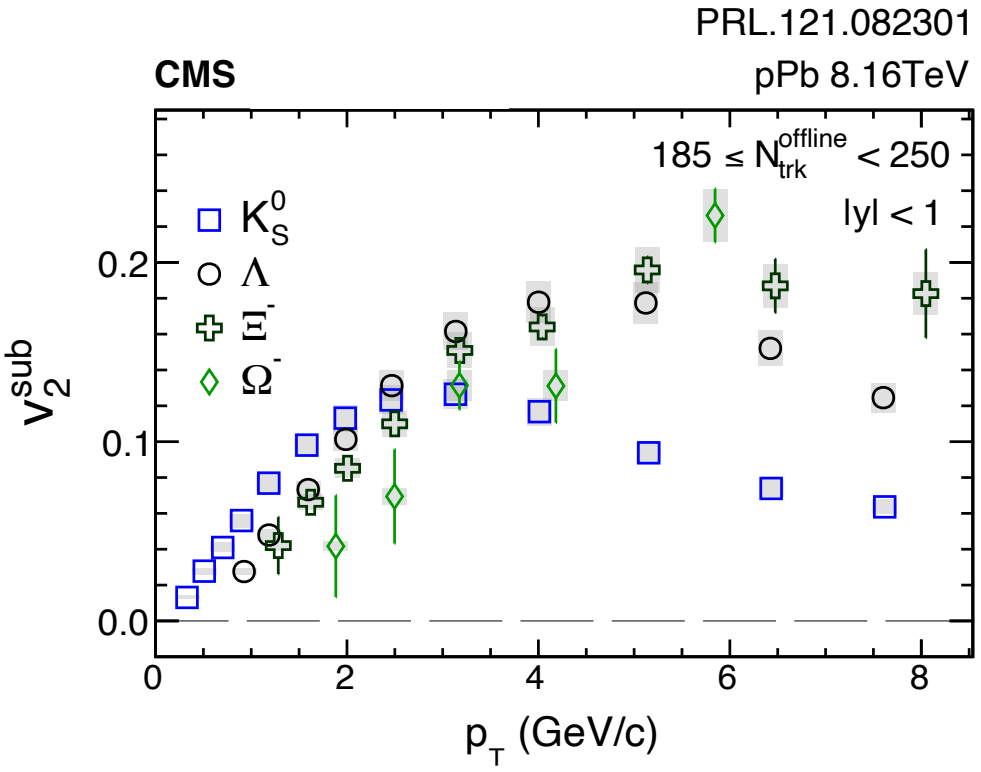


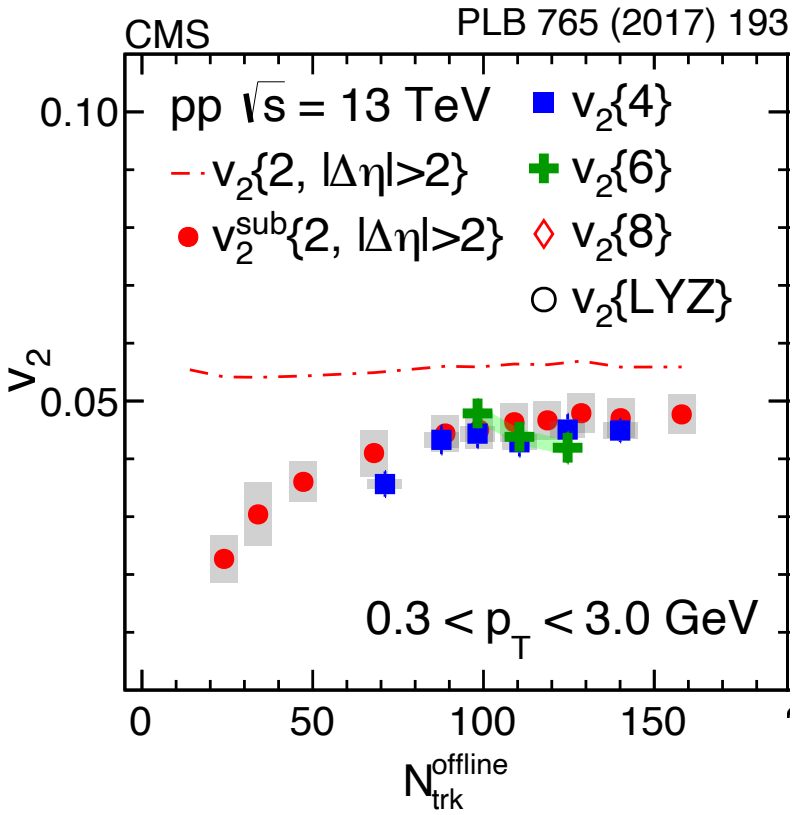
PLB 724 (2013) 213

Beginning of the story:

“Ridge” in all hadronic high-multiplicity collisions

Collective natures in small system





Dozens of results from LHC and RHIC

Similar collective natures as in AA!!

A small droplet of QGP? Other novel QCD effects?

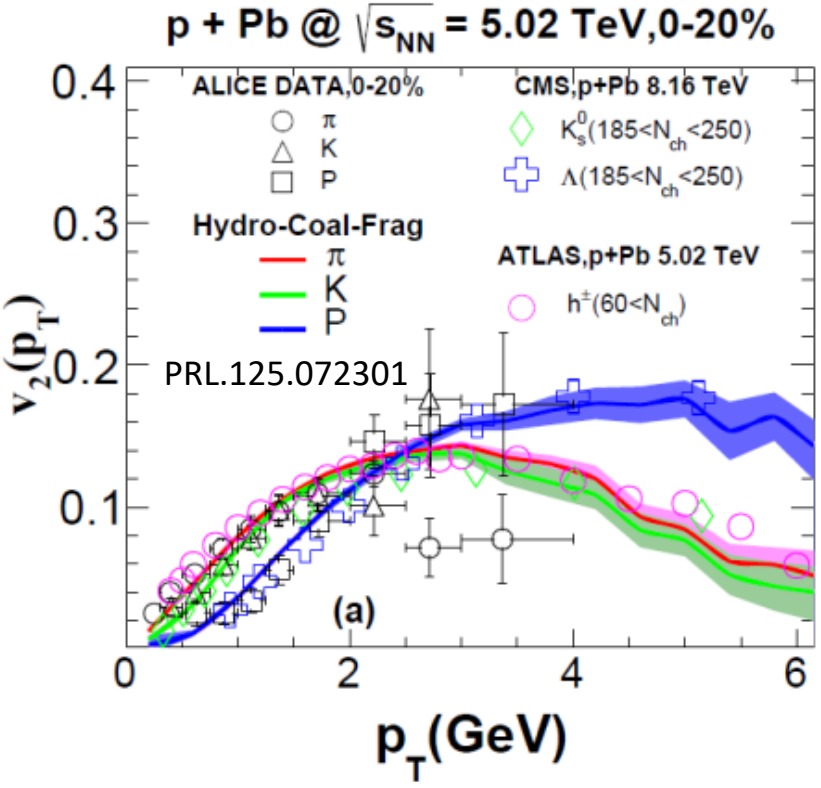
Overviews: K.Dusling, W.Li, B.Schenke arXiv:1509.07939; J.L.Nagle, W.A.Zajc arXiv:1801.03477

Origin of collectivity?

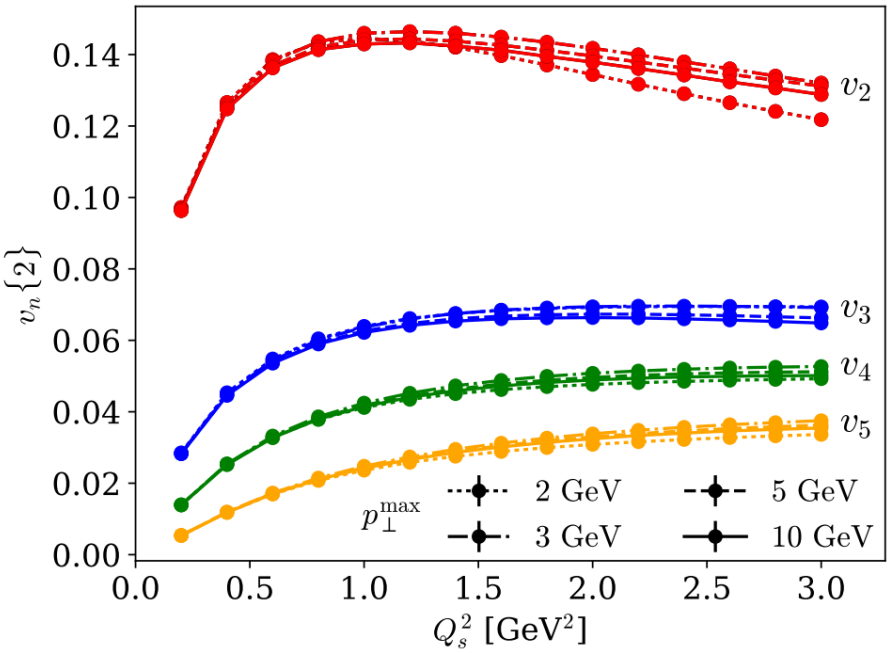
Final-state interactions
(Hydro or transport)

vs

Initial-state dynamics
(Color-Glass-Condensate)



PRL.120.042002



Both scenarios describe collective natures

Origin of collectivity?

Final-state interactions
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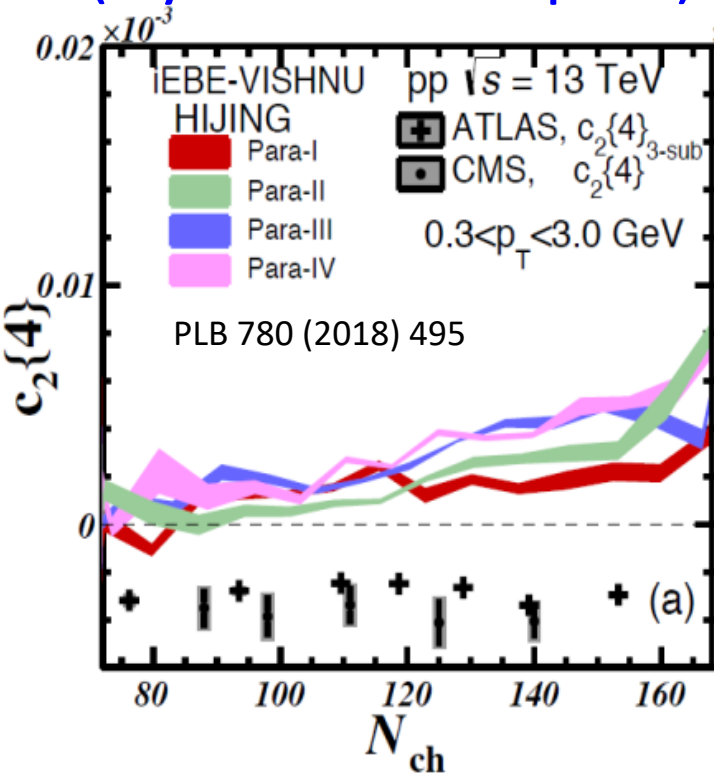

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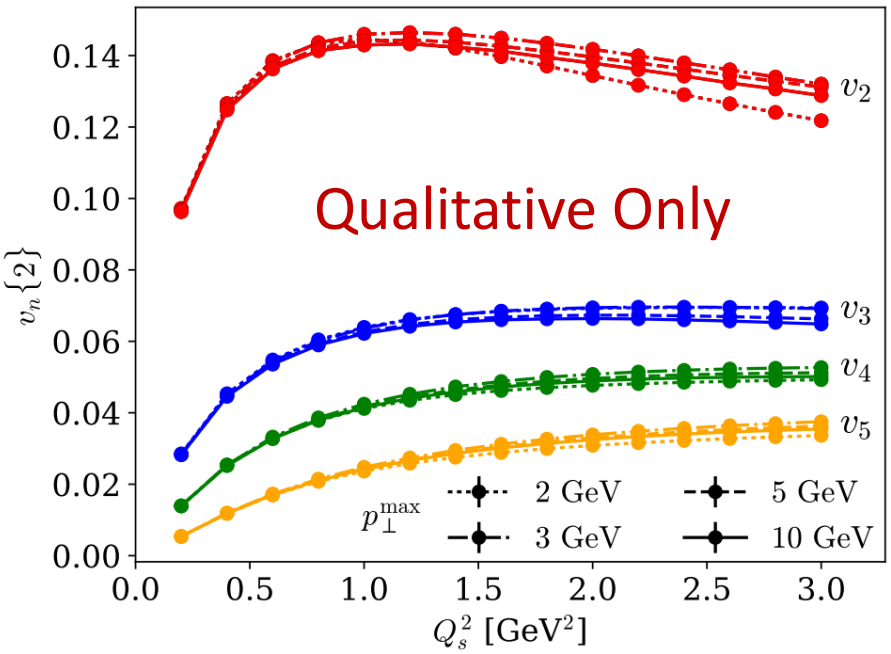

Both scenarios describe collective natures with caveats

Origin of collectivity?

Final-state interactions
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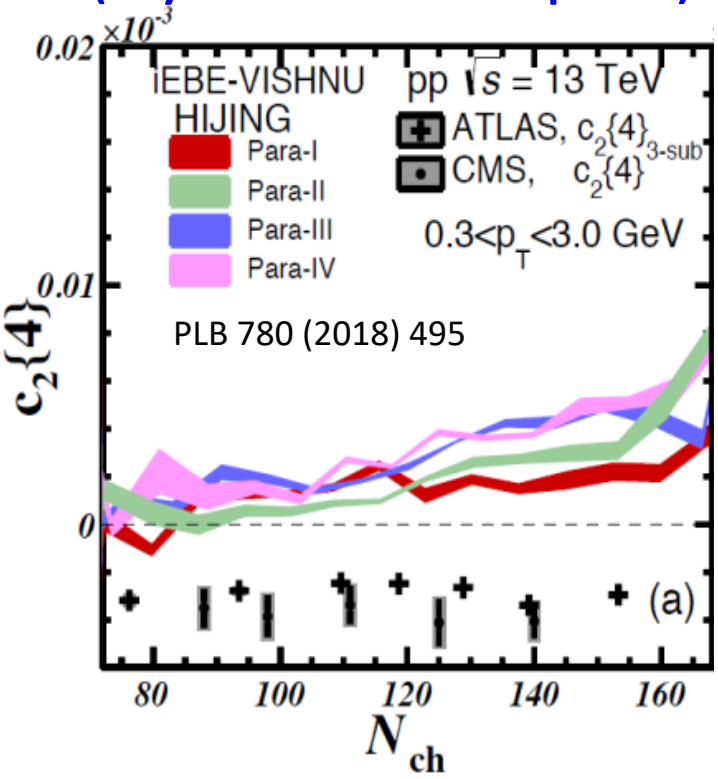

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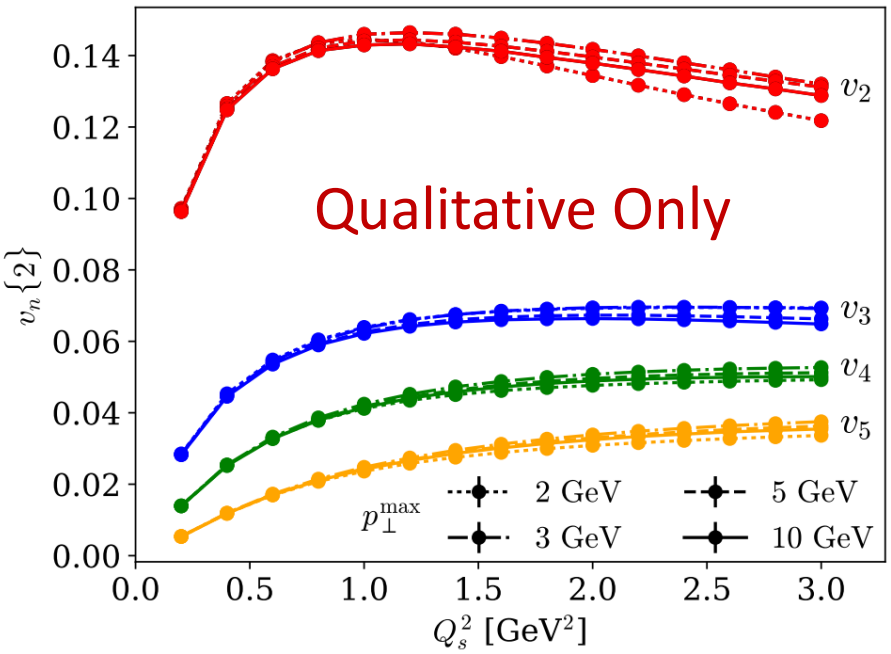
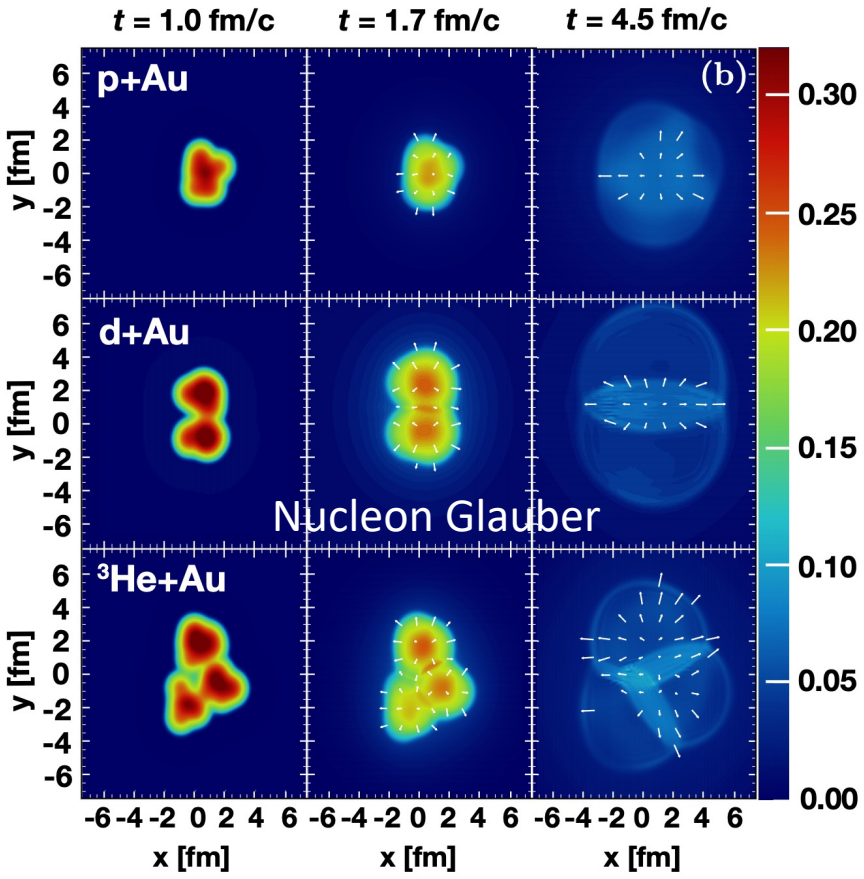


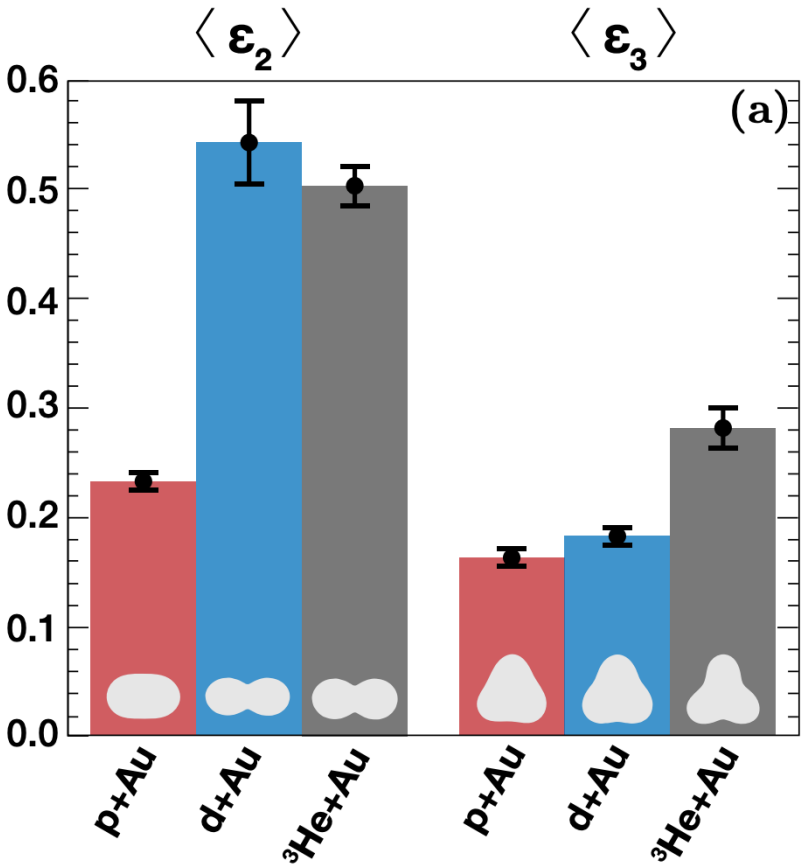
Both scenarios describe collective natures with caveats

What more can we do to distinguish them?

Geometry response in small systems



Nature Phys. 15 (2019) no.3, 214-220



v_n expected to reflect eccentricity ordering

Small system scan PHENIX

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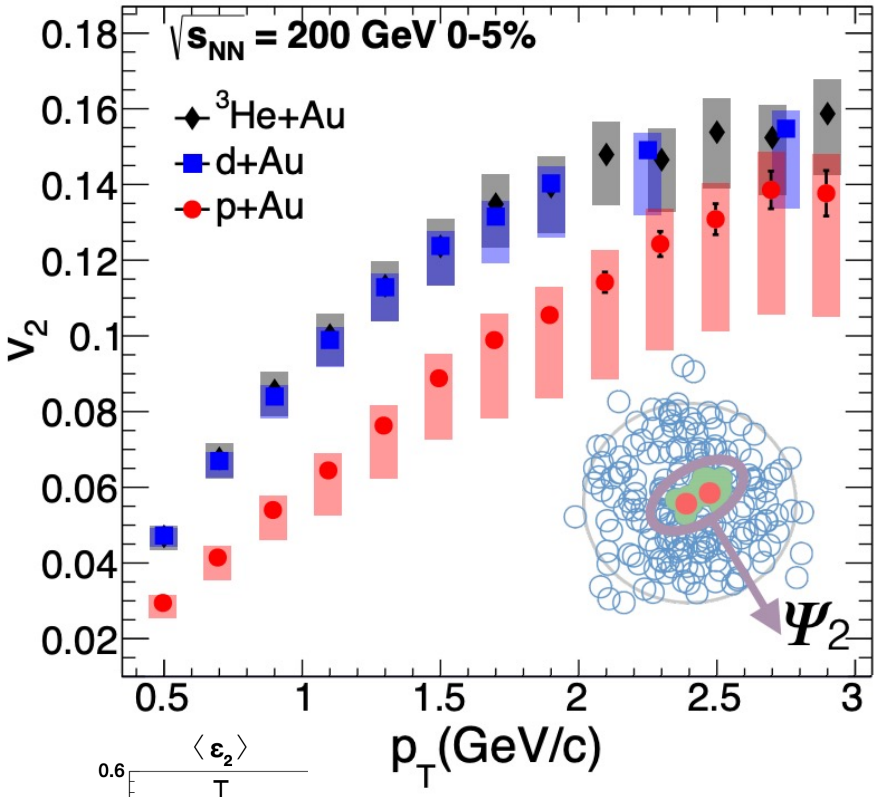

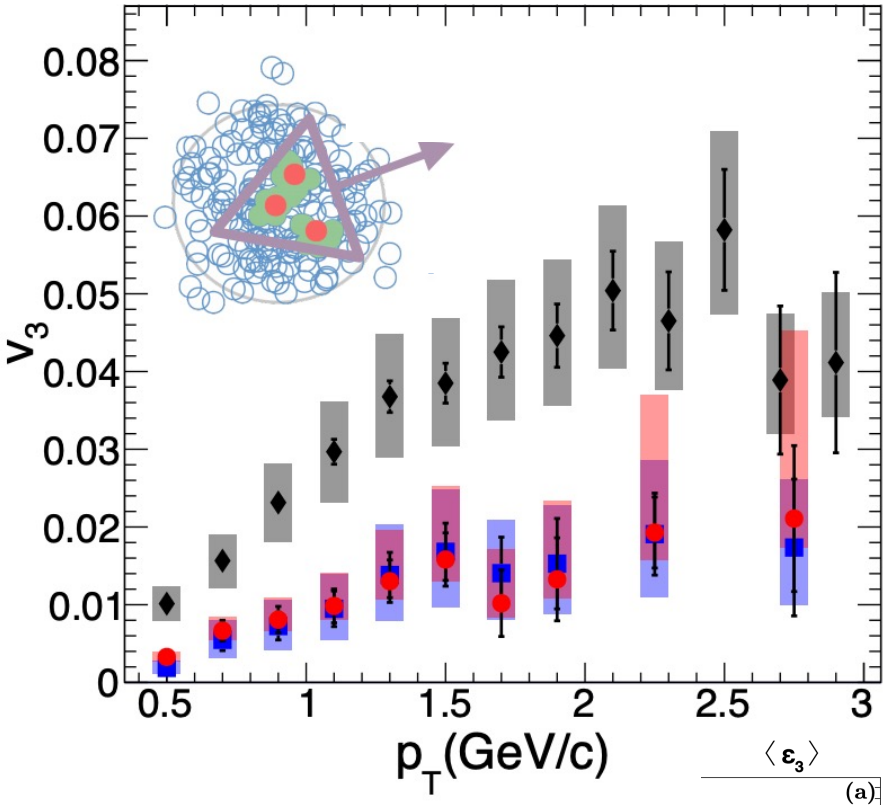

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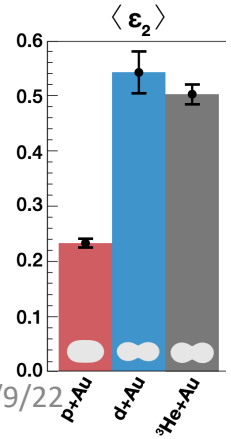
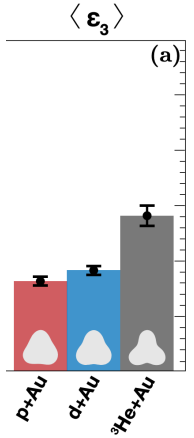
Confirmed by data





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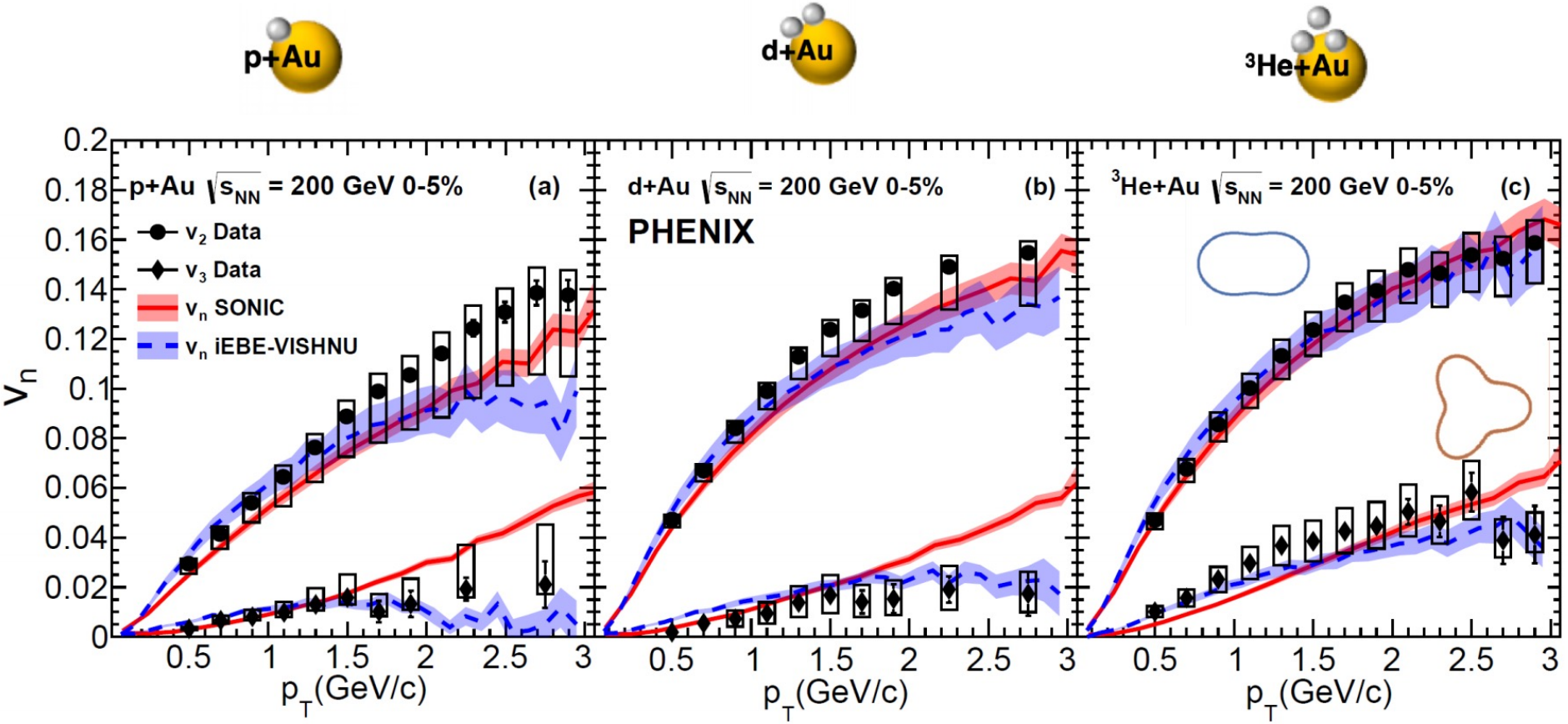

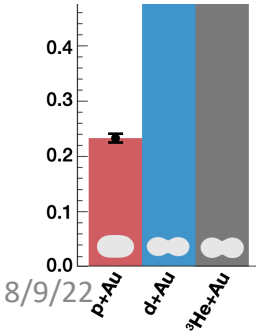

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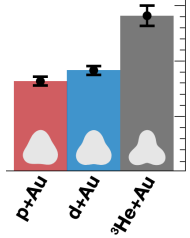
Agree with hydro calculations



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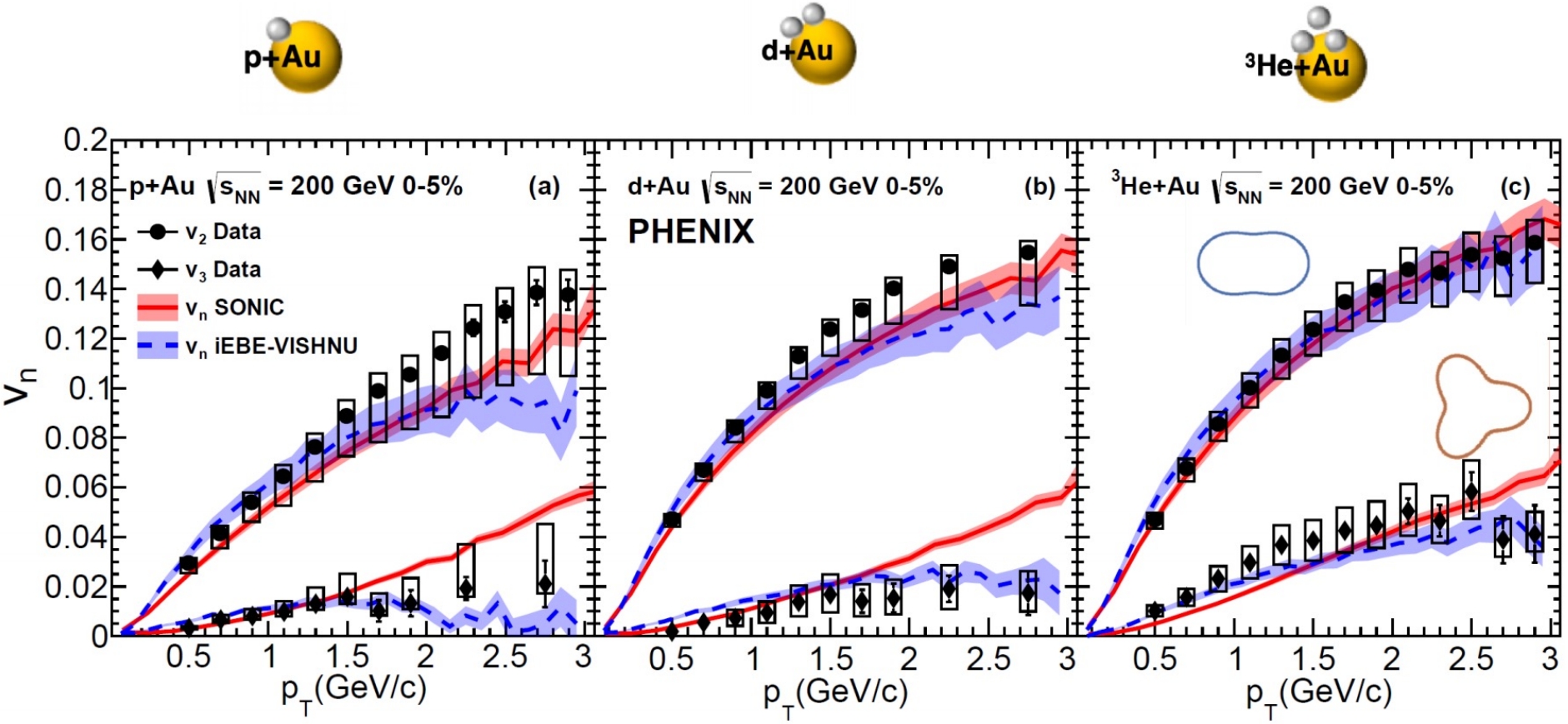

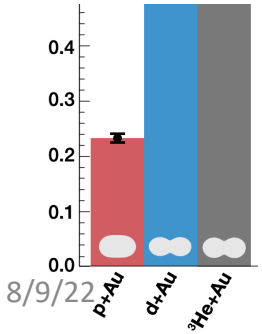

v_n expected to reflect eccentricity ordering

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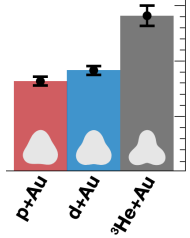
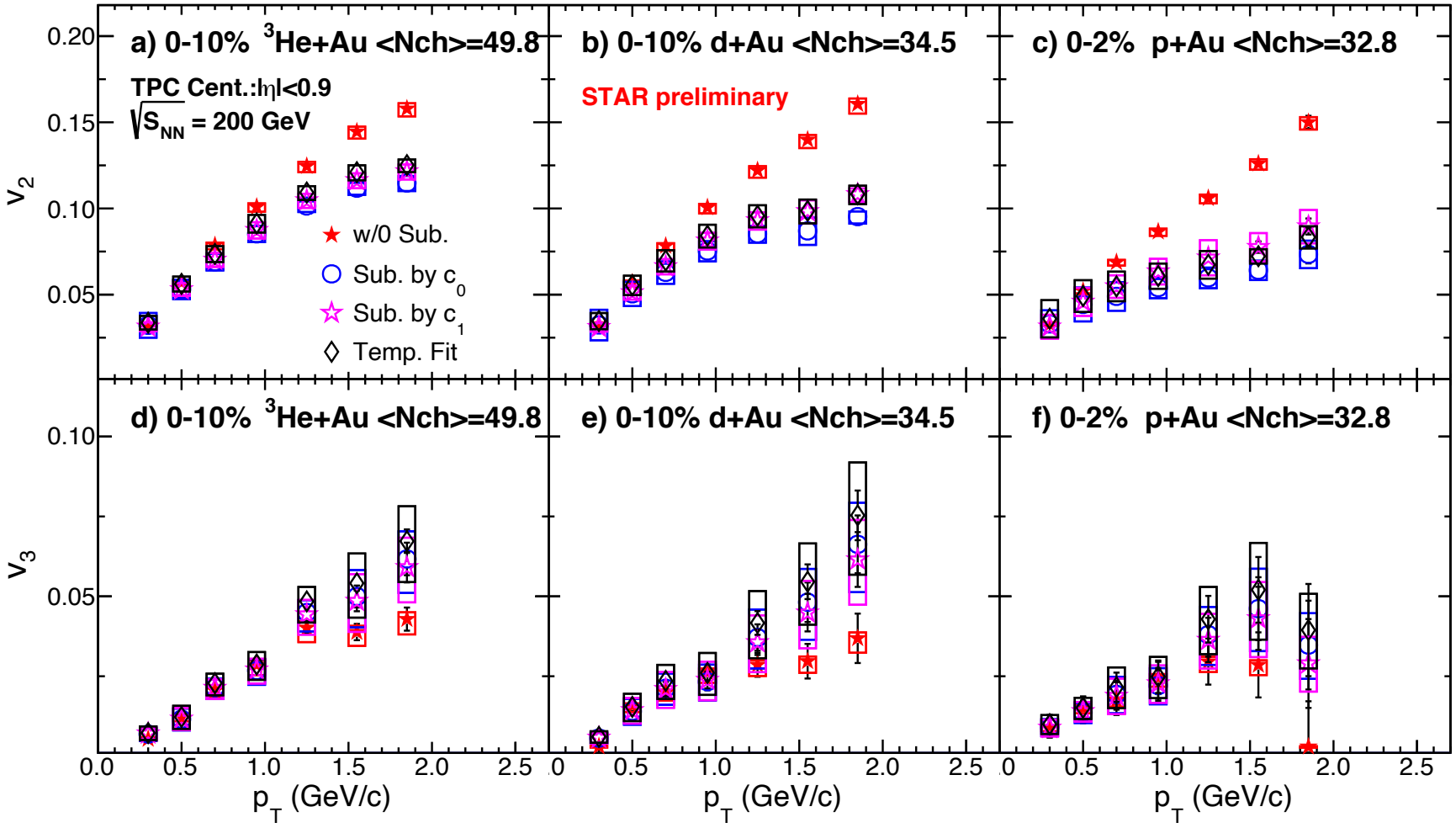
Easy and simple?

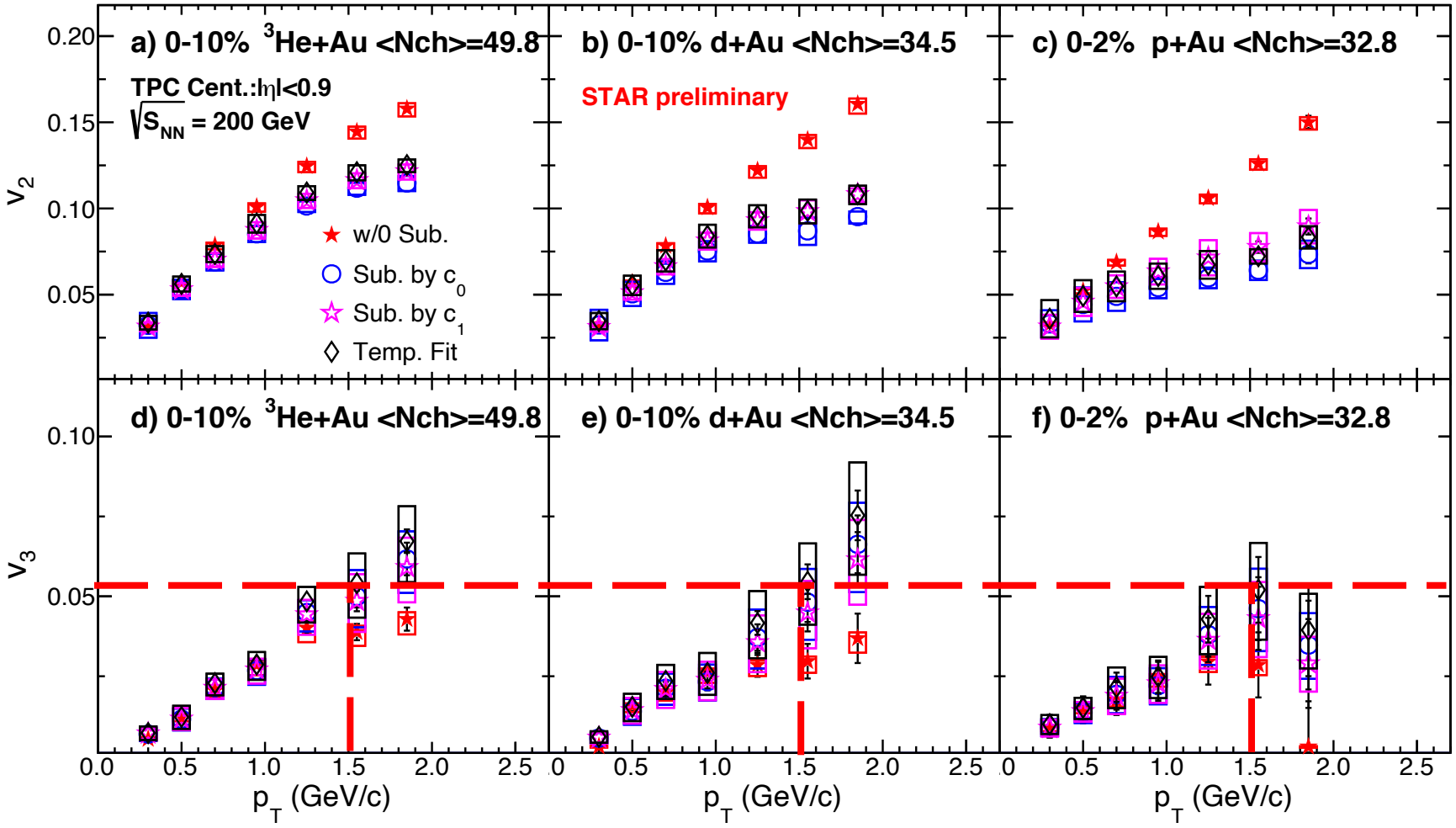


Small system scan STAR



STAR utilizes multiple non-flow removal methods

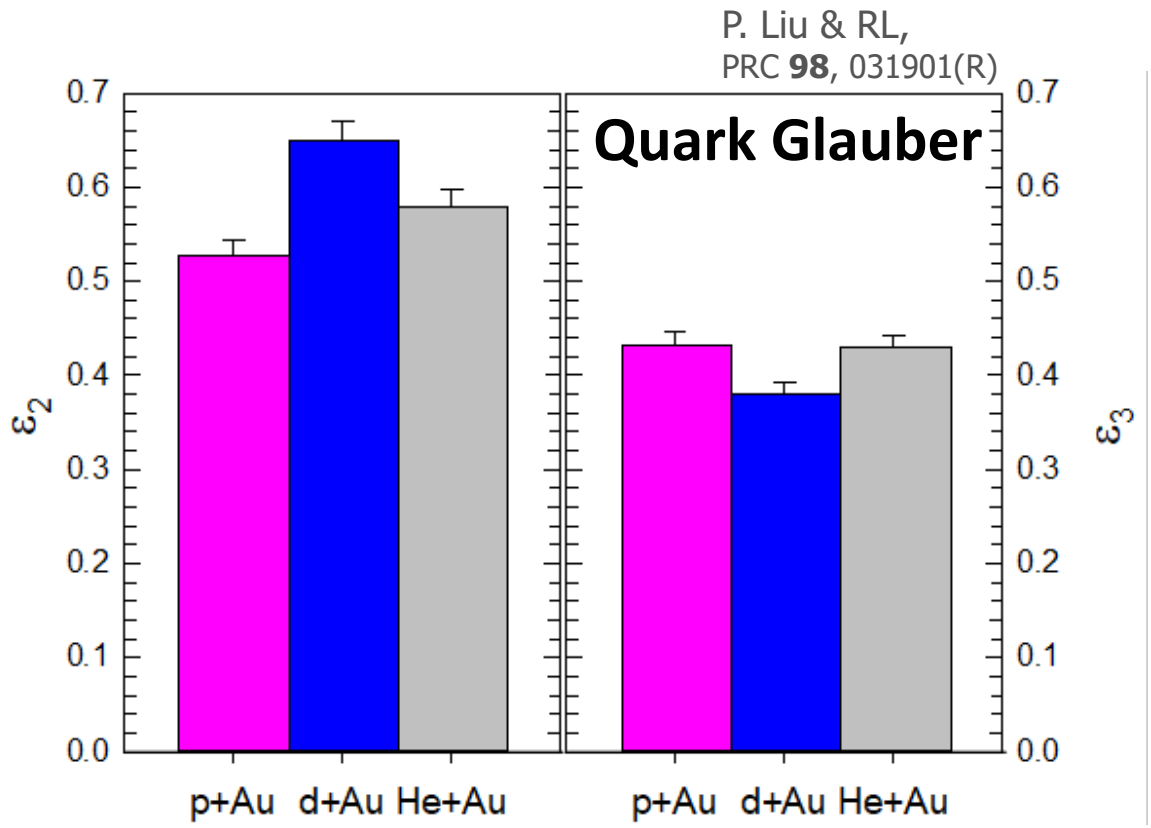
Small system scan STAR



STAR utilizes multiple non-flow removal methods

Weaker system dependence of v_3

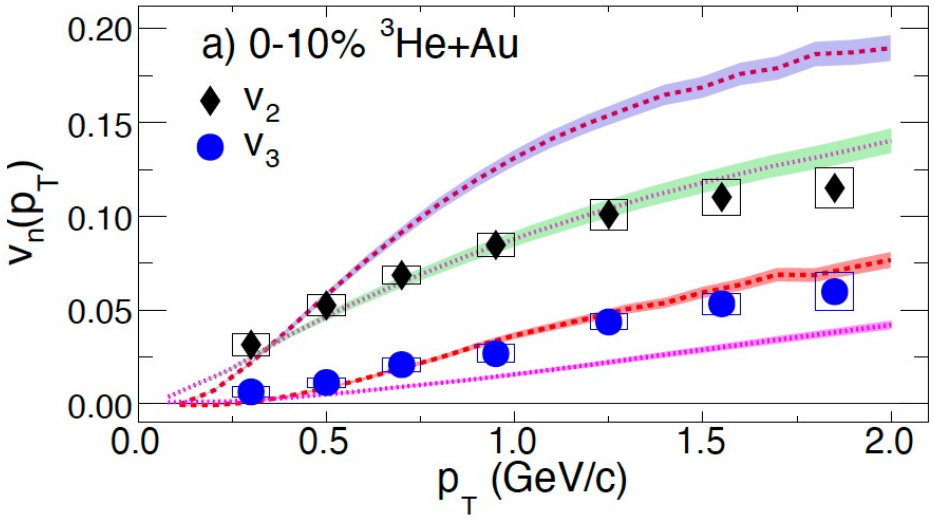
Comparison to models

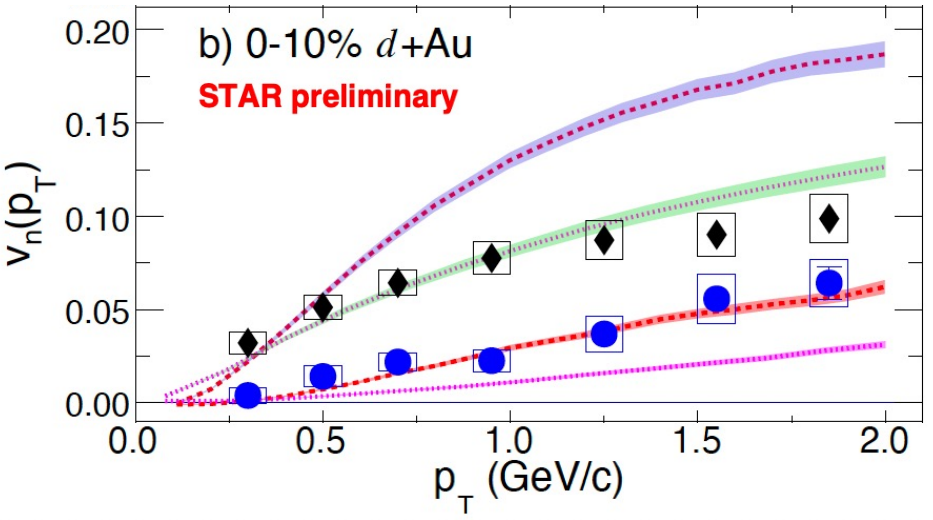


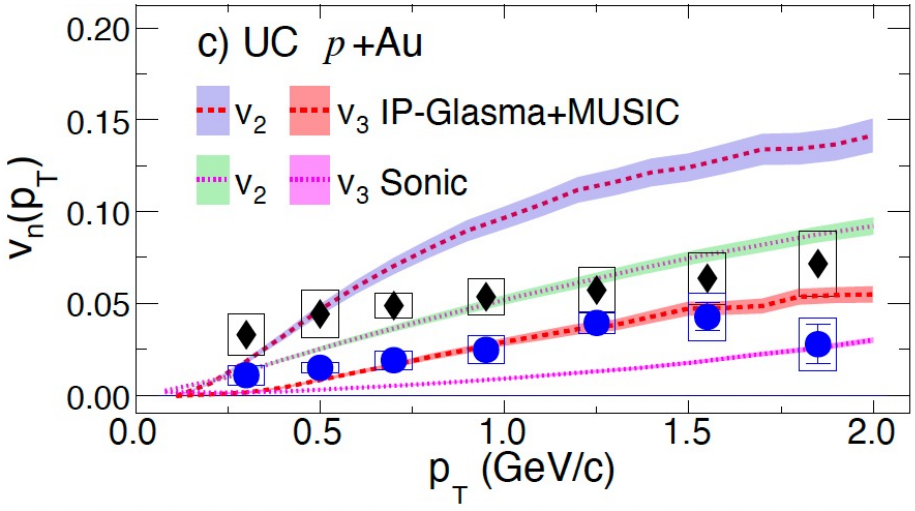
Models include sub-nucleon structure

Weaker ε ordering

Comparison to models



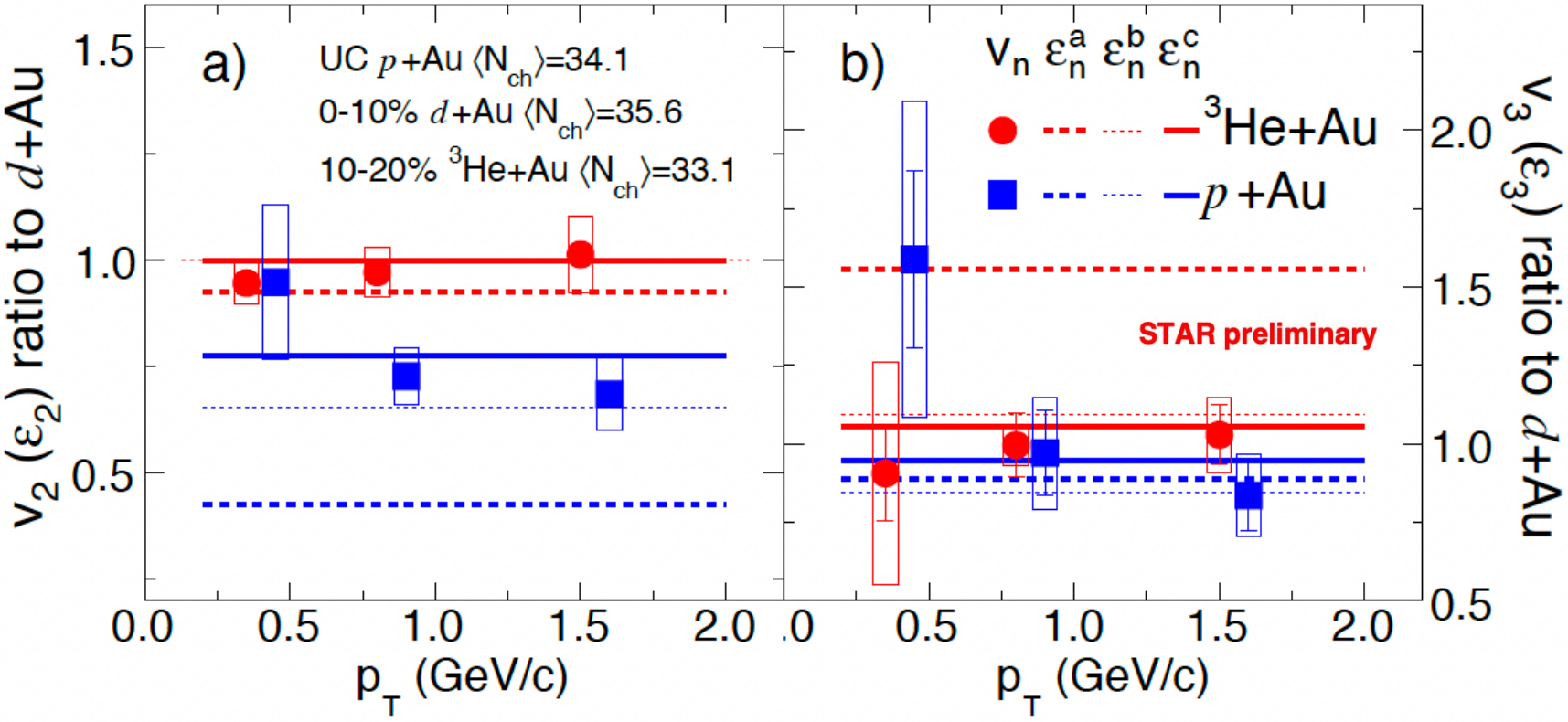




Current models cannot describe v_2 & v_3 simultaneously

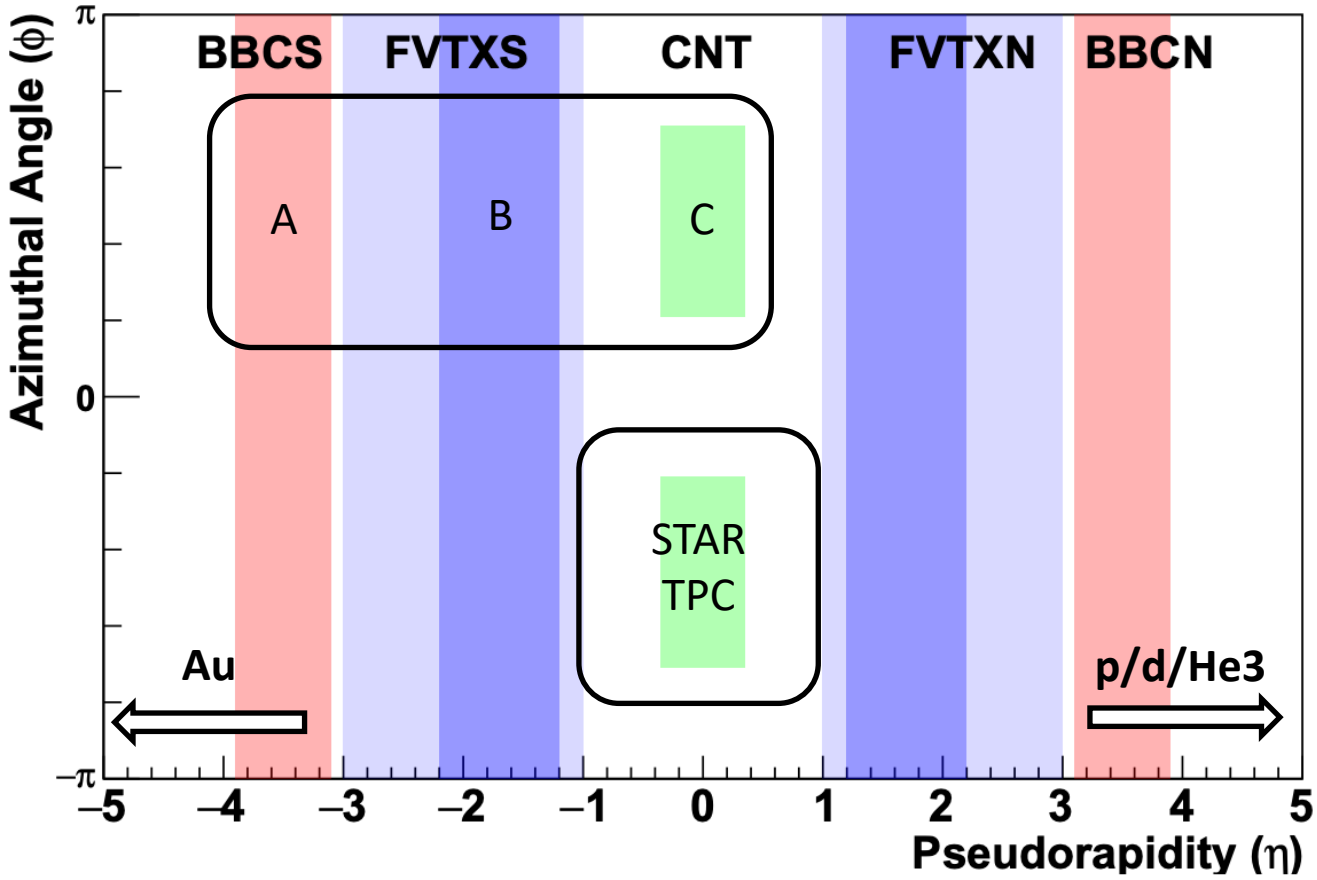
Comparison to models

Models
(a) no fluctuation
(b) nucleonic fluctuation
(c) sub-nucleonic fluctuation



Nevertheless the results reveal the importance of
nucleonic & sub-nucleonic fluctuation

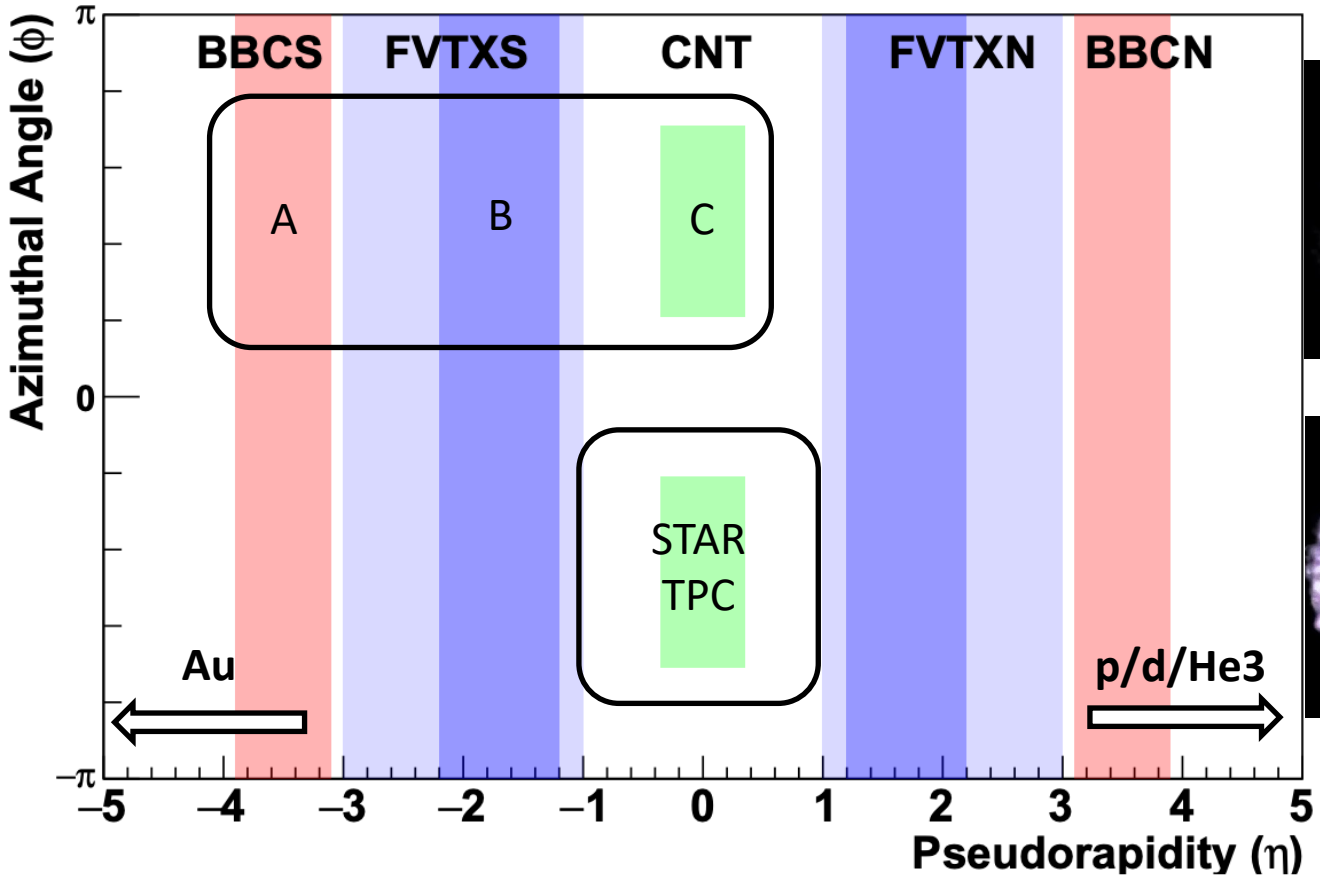
STAR or PHENIX?



Why different?

1. Physics; 2. Non-flow; 3. three-dimension evolution

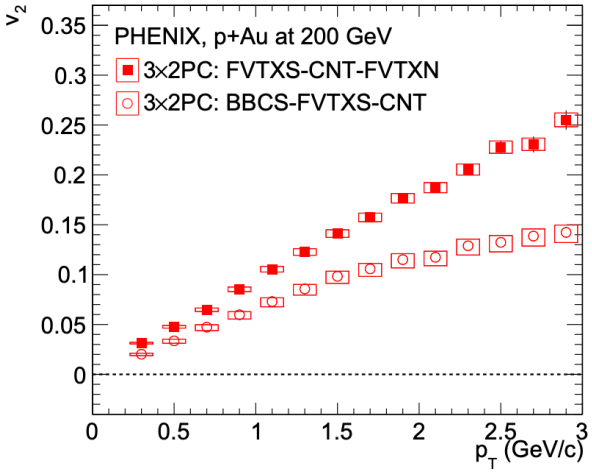
STAR or PHENIX?

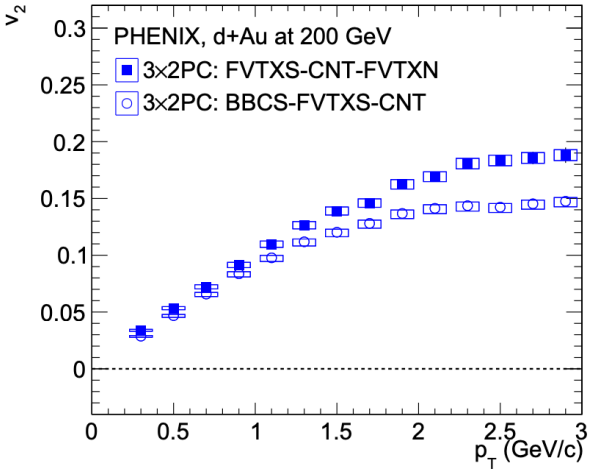


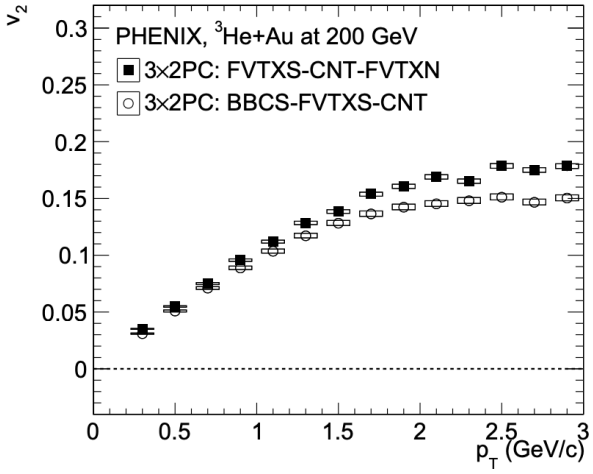
Different kinematic regions might probe partons with different x

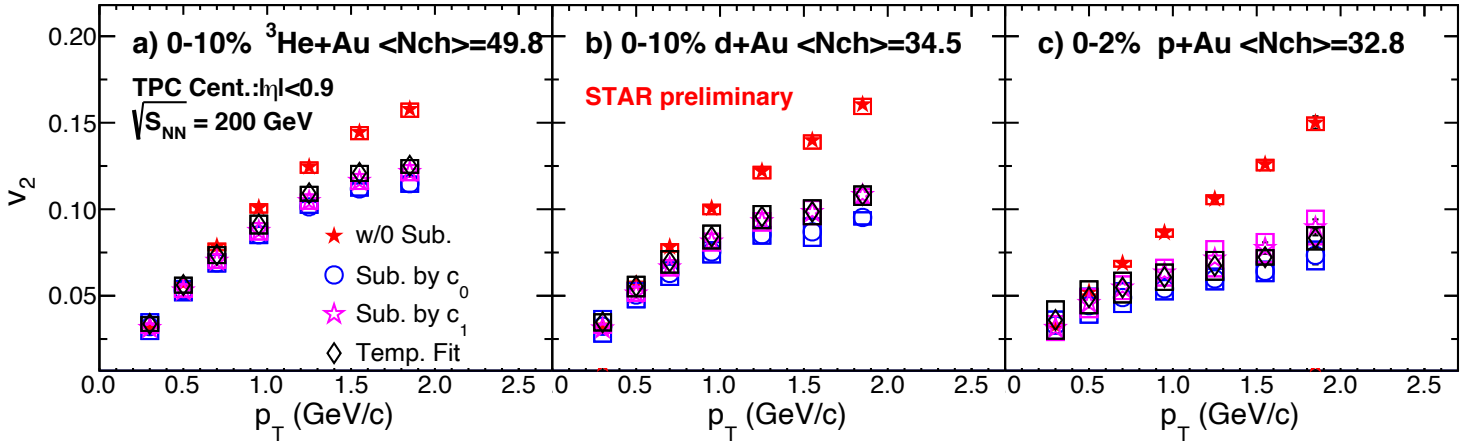
STAR or PHENIX?

arXiv: 2107.06634









Different kinematic regions might probe partons with different x

Non-flow controlled by experimental techniques

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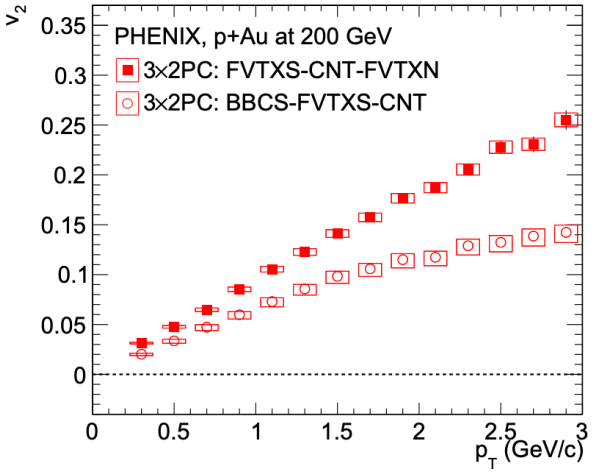
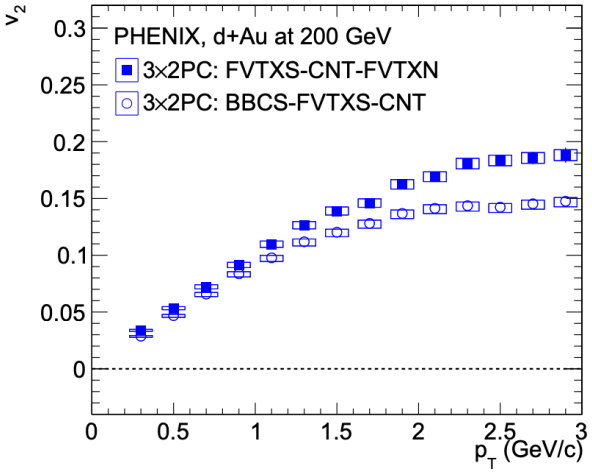
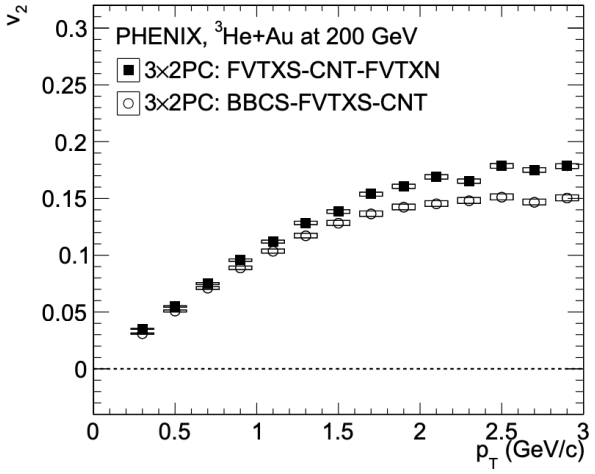
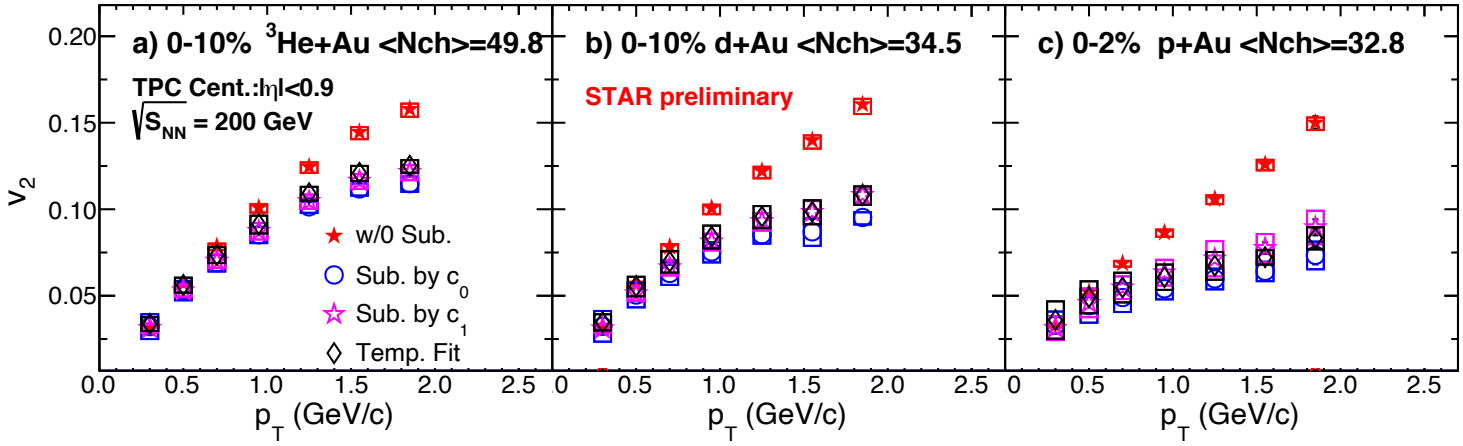






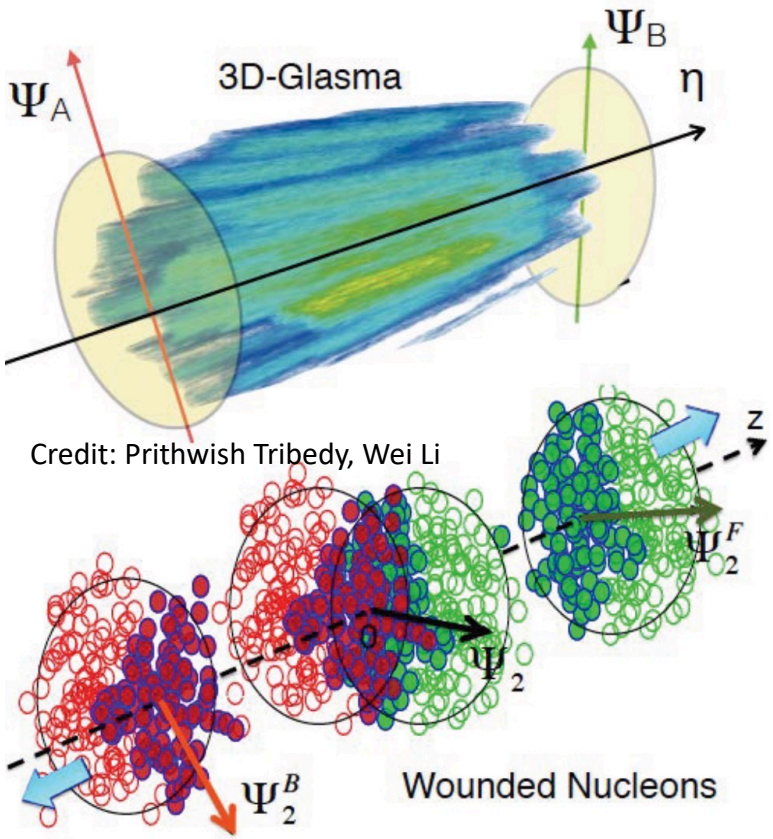


Different kinematic regions might probe partons with different x

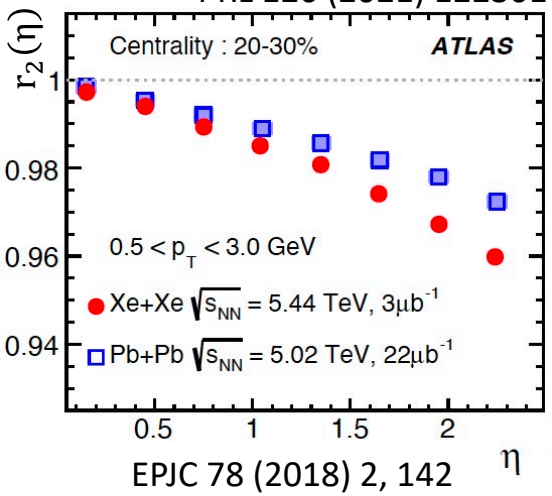
Non-flow controlled by experimental techniques

Urgent needs to understand 3D initial state and dynamic evolution

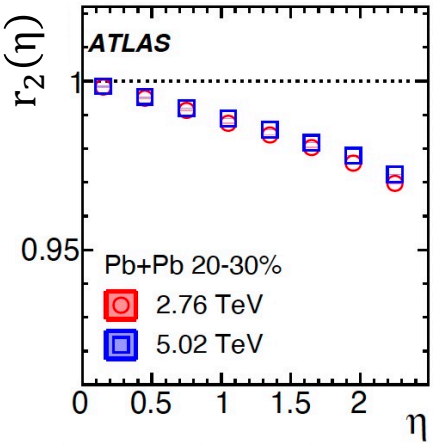
Probing 3D initial state in AA



PRL 126 (2021) 122301



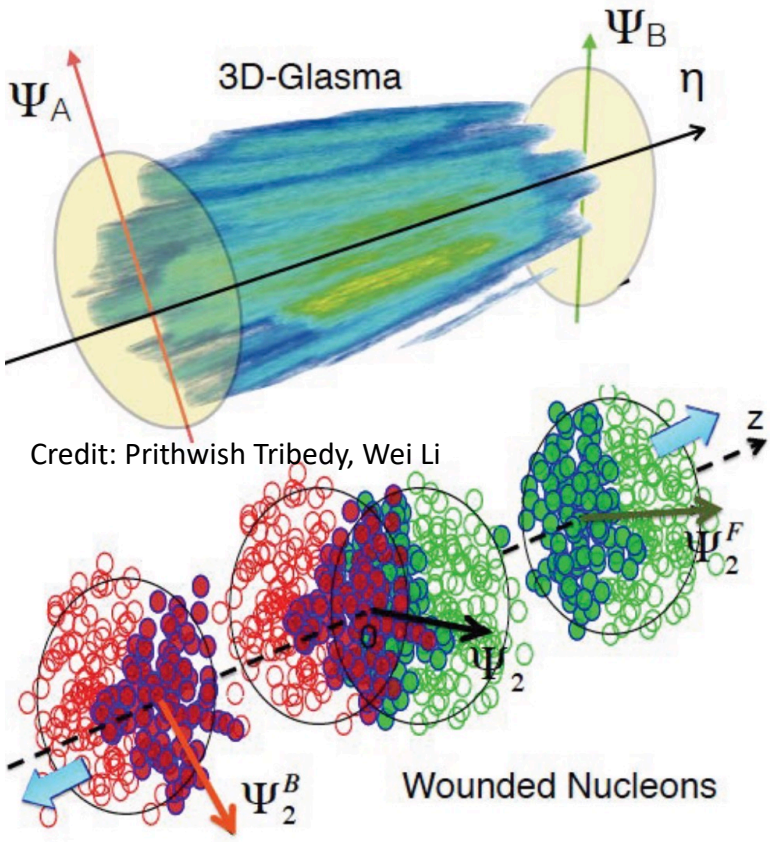
EPJC 78 (2018) 2, 142



Longitudinal decorrelation is a unique probe

LHC has limited ability to probe system size and energy dependence

Probing 3D initial state in AA



From Xiaofeng Luo

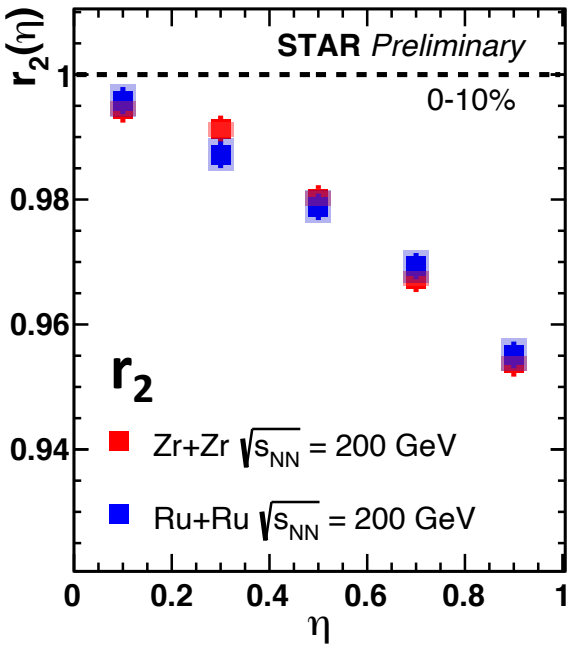
$\sqrt{s_{NN}}$ (GeV)	Events (10^6)	BES II / BES I
200	238	2010
62.4	46	2010
54.4	1200	2017
39	86	2010
27	30 (560)	2011/2018
19.6	**538** / 15	**2019**/2011
14.5	**325** / 13	**2019**/2014
11.5	**230** / 7	**2020**/2010
9.2	**160** / 0.3	**2020**/2008
7.7	**100** / 3	**2021**/2010
17.3	**250**	**2021**

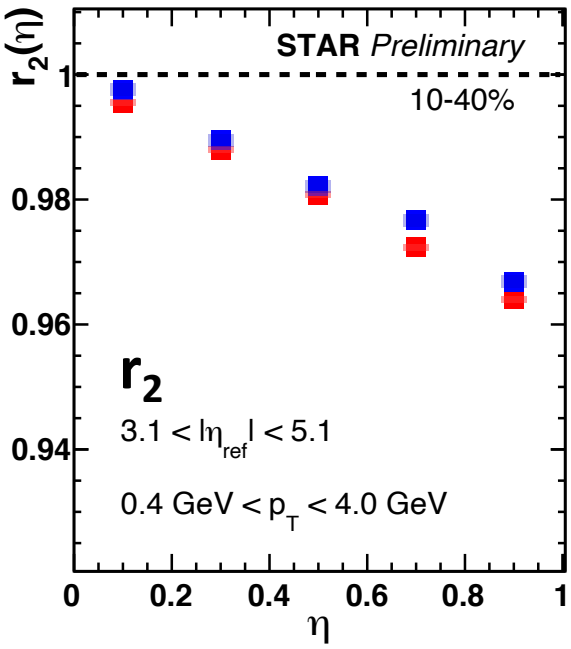
Longitudinal decorrelation is a unique probe

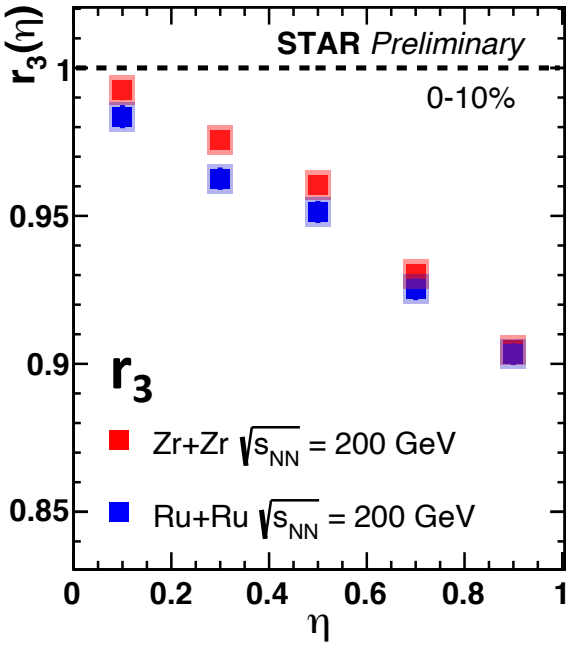
LHC has limited ability to probe system size and energy dependence

RHIC is the ideal place with isobar and BESII programs

Decorrelation in RuRu & ZrZr





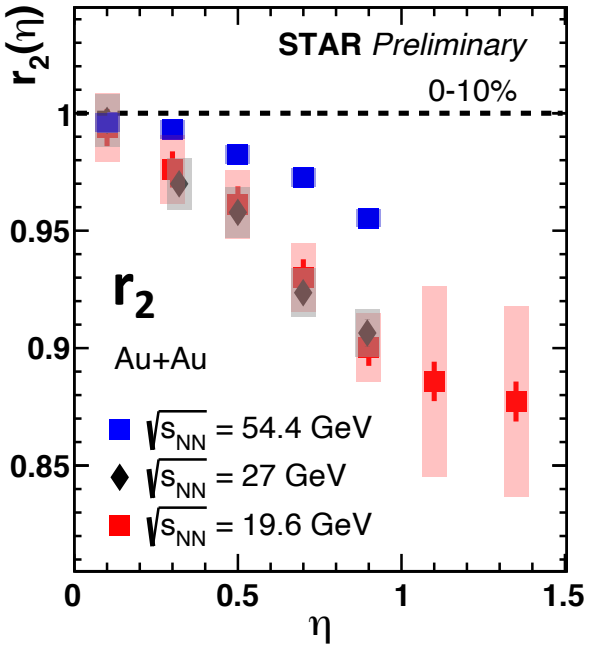


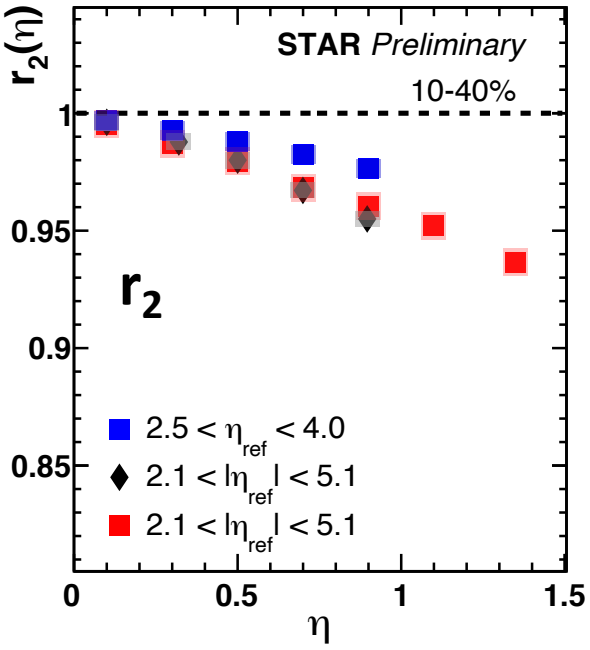
Most precise results at RHIC

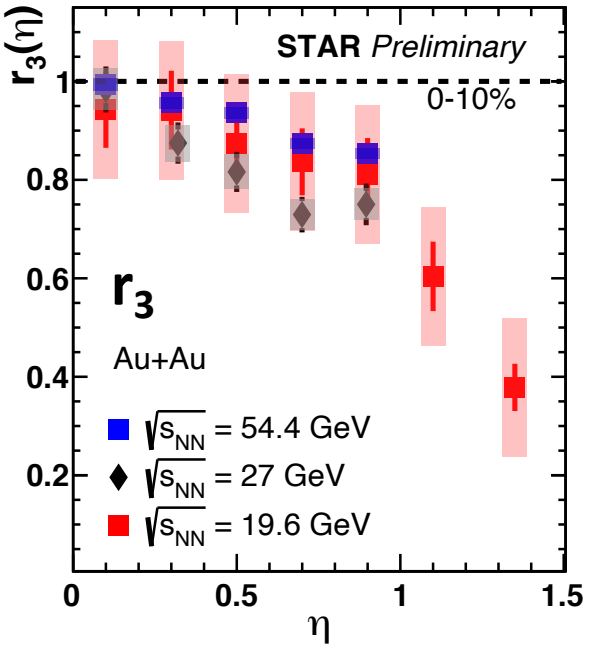
Comparable to 200 GeV AuAu results

See a model study by 聂茂武 (Aug. 9 17:00)

Decorrelation vs. collision energy





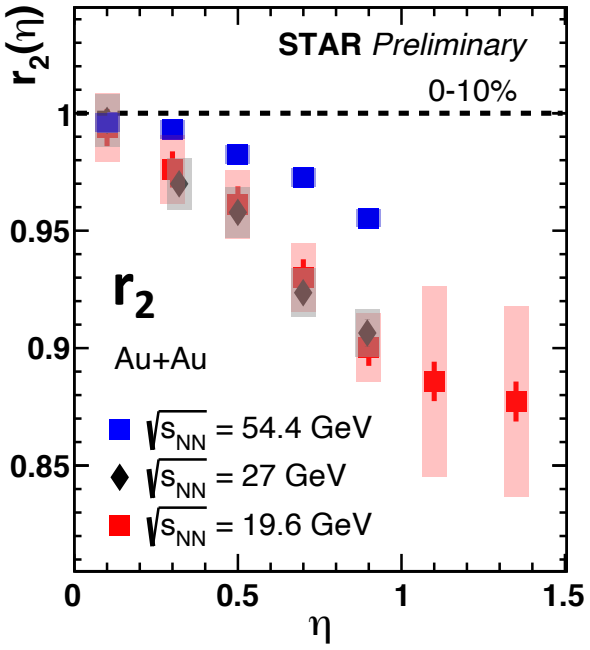


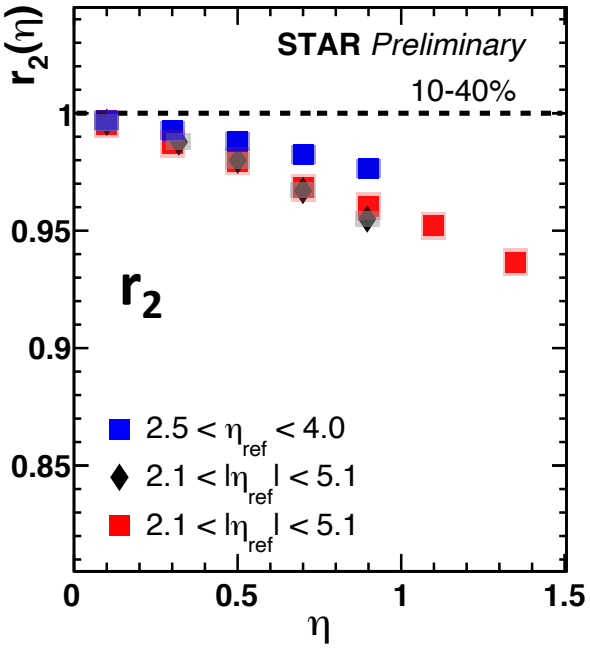
Clear energy dependence observed

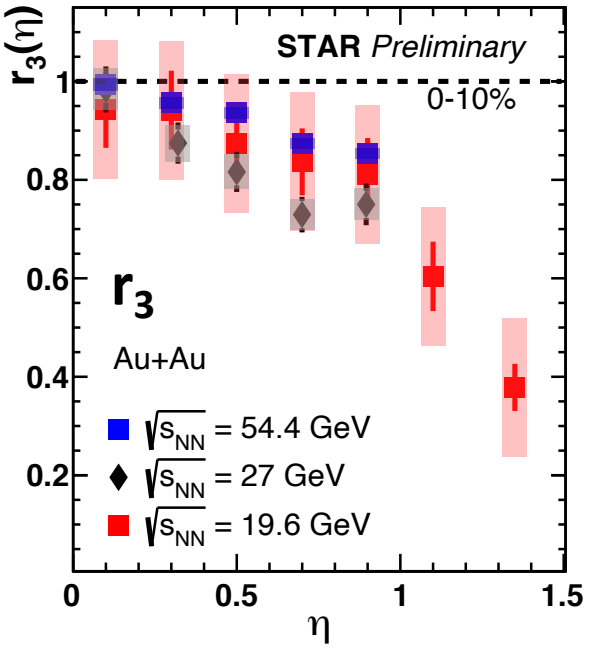
Hint of nonlinear energy dependence?

Stringent constrains on initial states with finite μ_B

Decorrelation vs. collision energy







Clear energy dependence observed

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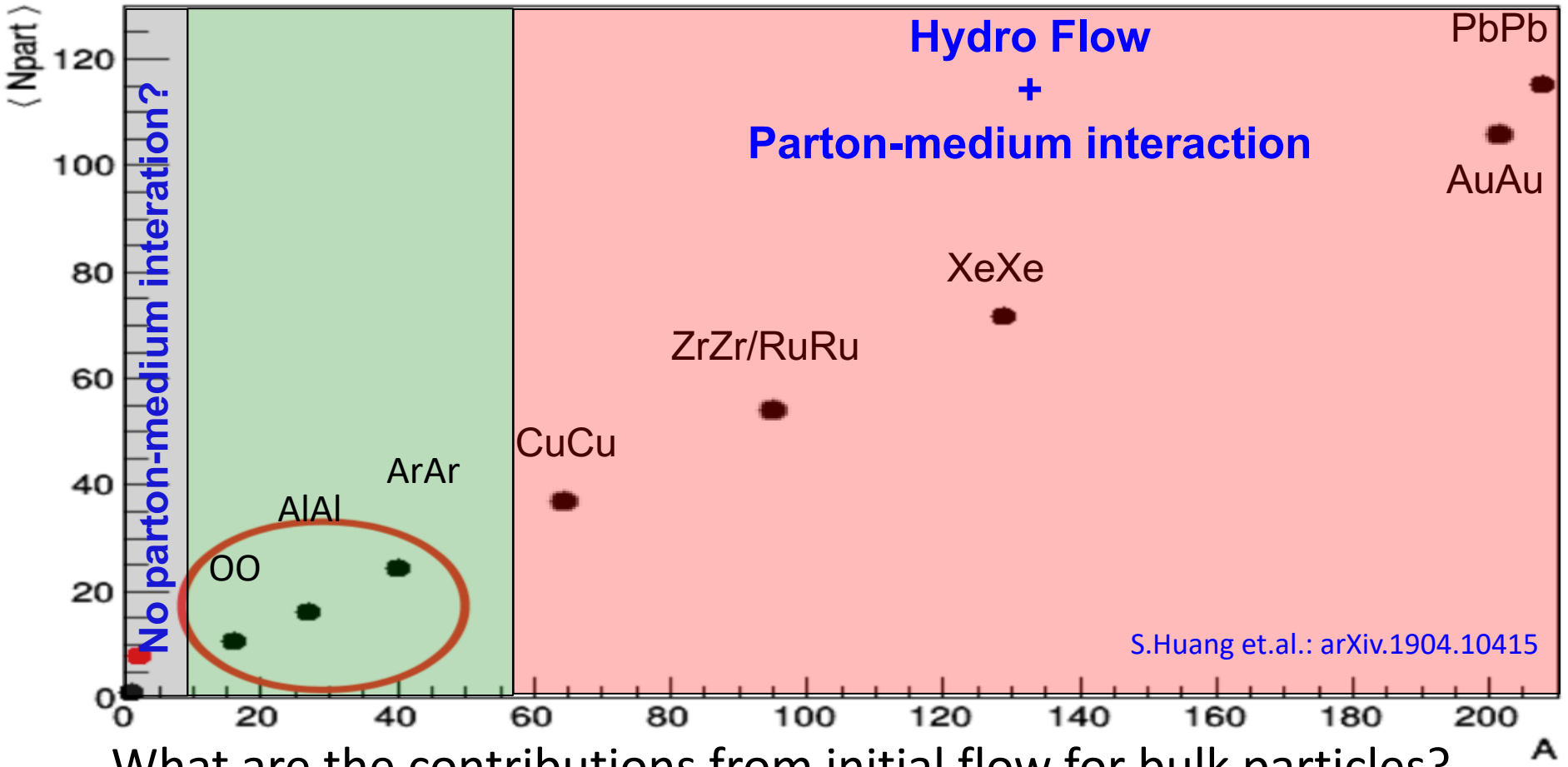
Stay tuned for results with more energies!

Future opportunities – intermediate collisions



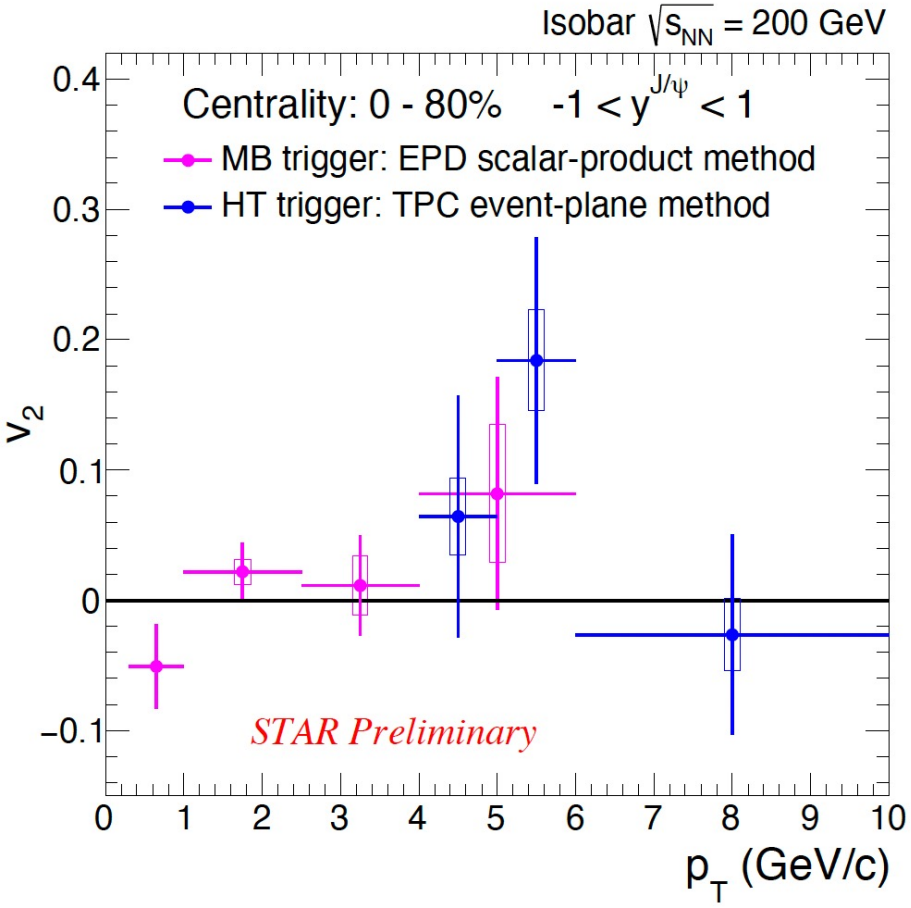
What are the contributions from initial flow for bulk particles?

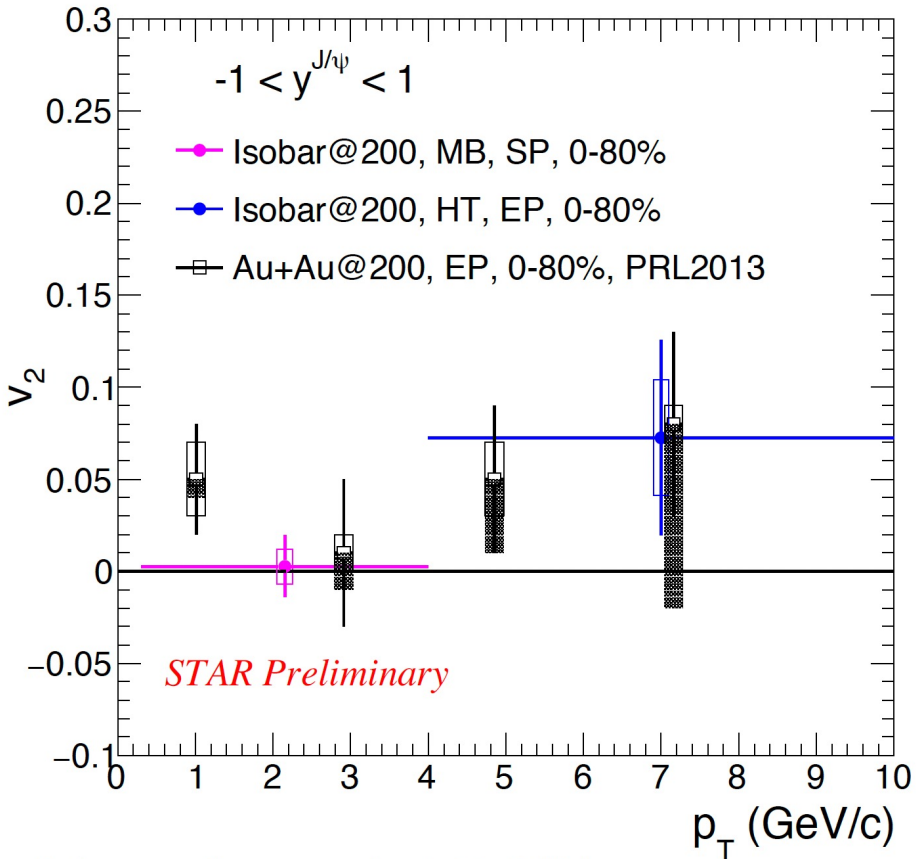
At what system size CGC effects become less dominant for HF?

Where does jet quenching turns on?

STAR Has taken OO; LHC will run OO in 2024(?)

Future opportunities – intermediate collisions

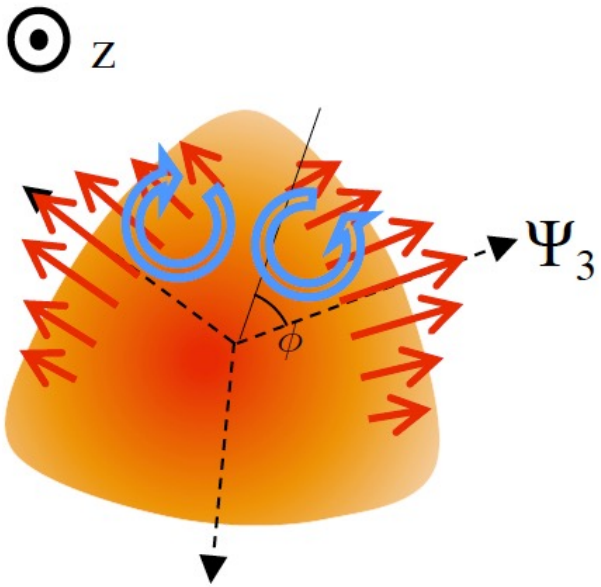


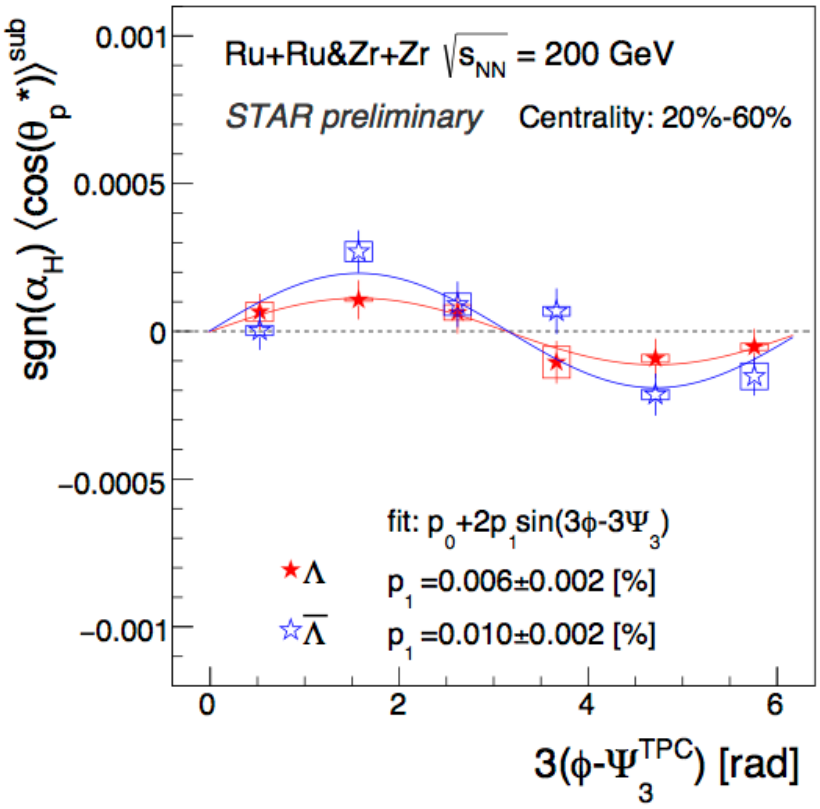


First step to extend HF flow measurement to smaller systems @ RHIC

See talk by 杨钱 (Aug.11 9:40)

Future opportunities – more observables



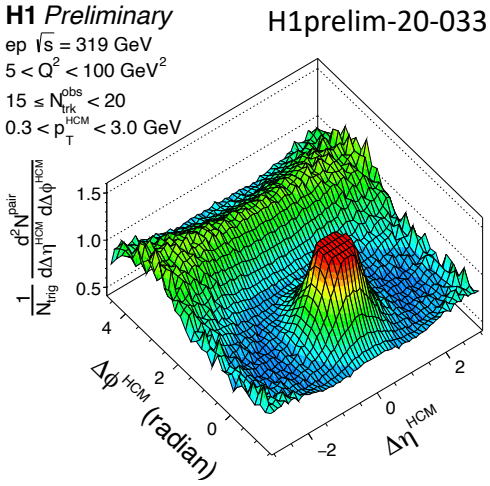


Hint of local polarization linking to collective flow

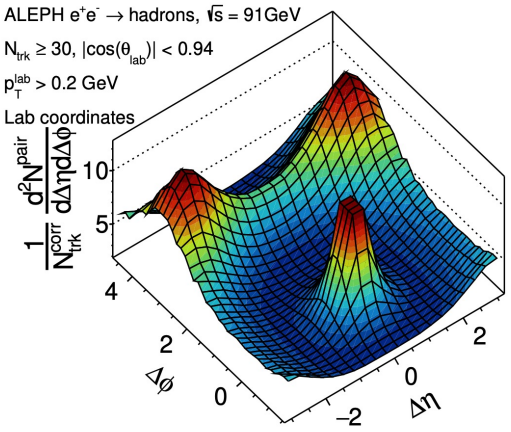
See talk by 苟兴瑞 (Aug.11 15:40)

Is it there in smaller systems?

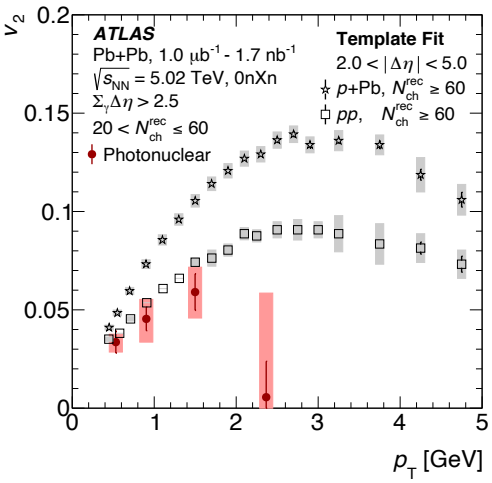
Future opportunities – smaller collisions



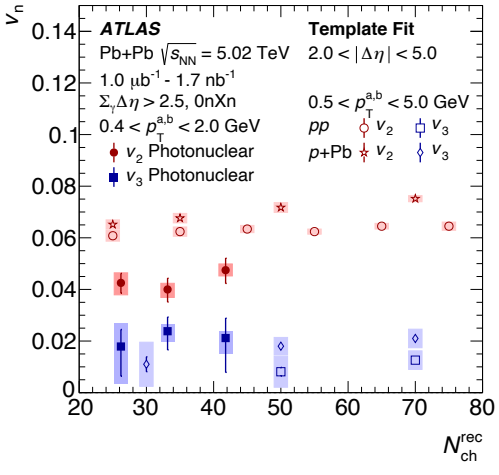
H1prelim-20-033

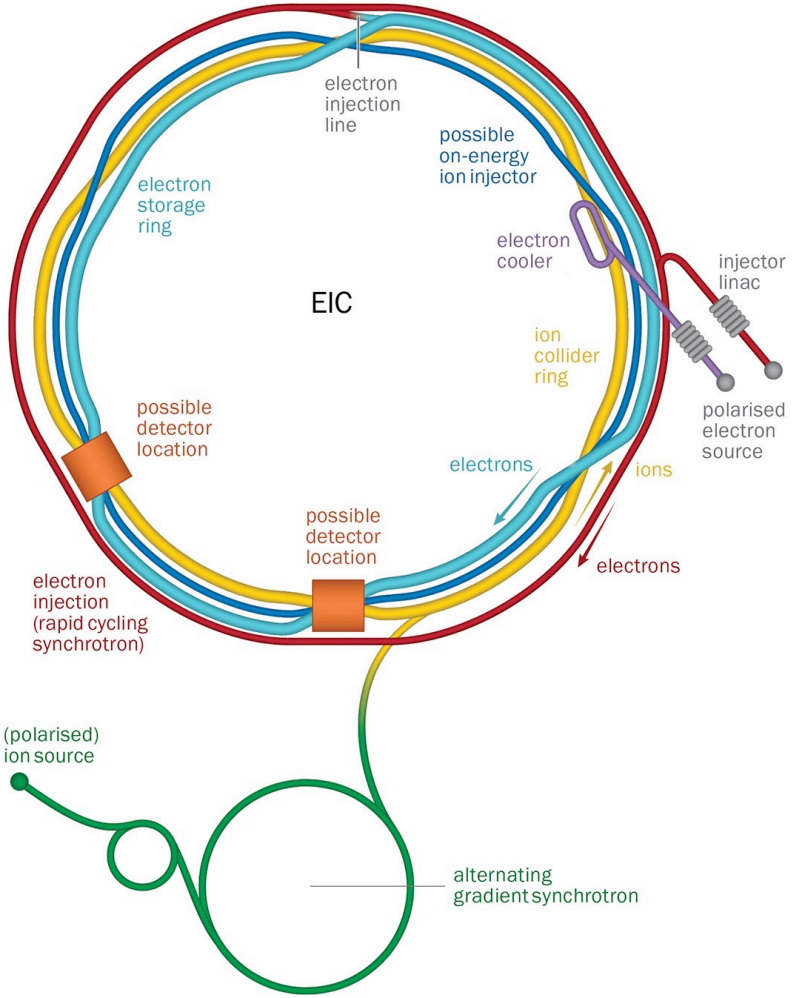


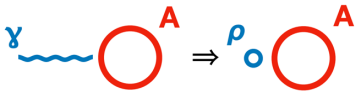
PRL 123 (2019) 21



PRC 104, 014903 (2021)







Lower limit of size for QGP droplet?

Stay tuned for EIC

Future opportunities – fill the table

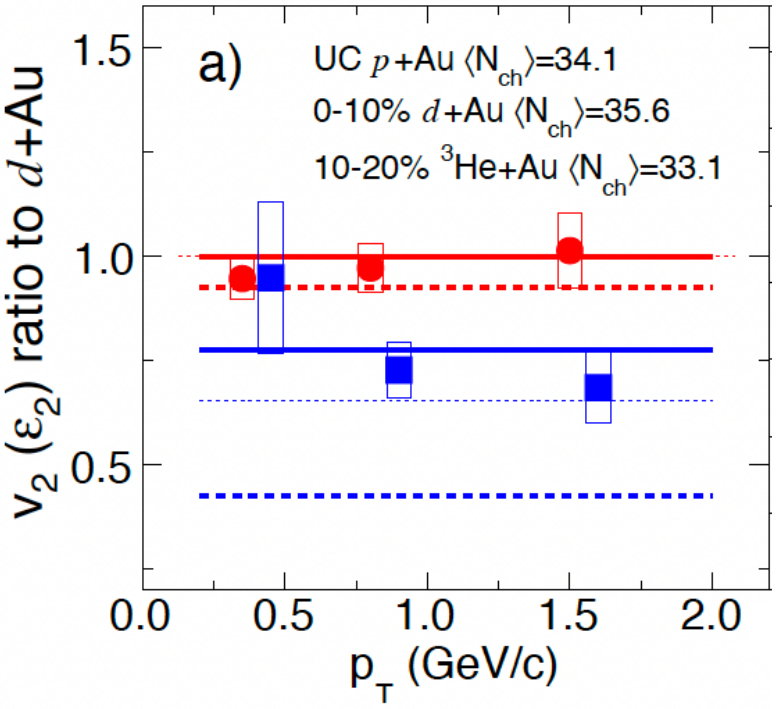
	RHIC			LHC		
	pp	p/d/He^{3}Au	Zr/Ru/O…	pp	pA	Xe/Ar/O…
Ridge v_n	?	✓	✓/?	✓	✓	✓/?
Flow fluctuation	?	✓/?	✓/?	✓	✓	✓/?
Jet quenching	?	?	?	X	X	✓/?
Strangeness enhancement	?	?	?	✓	✓	?
Heavy Flavor v_n	?	?	?	✓	✓	?
Hyperon Polarization	?	?	✓/?	?	?	?

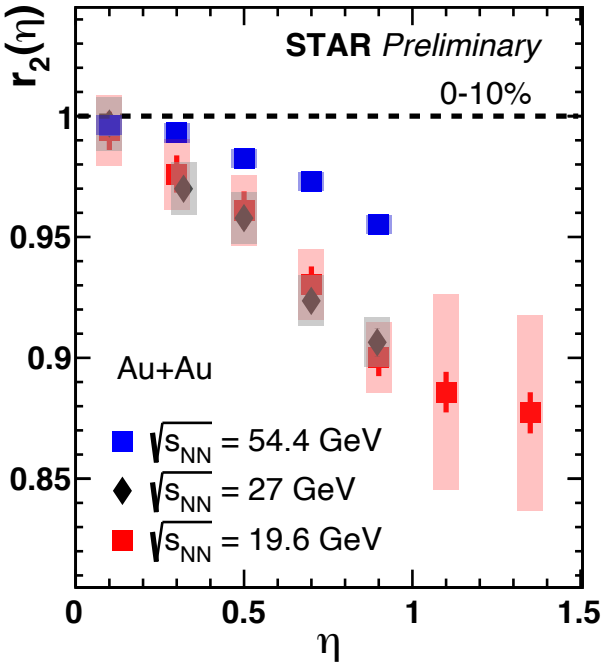
Plenty of treasure boxes to open

Summary

Investigation of collectivity in p/d/He^{3}Au collisions has revealed

- Key role of nucleonic & sub-nucleonic fluctuations
- Urgent needs to understand 3D initial states & dynamic evolution





Summary

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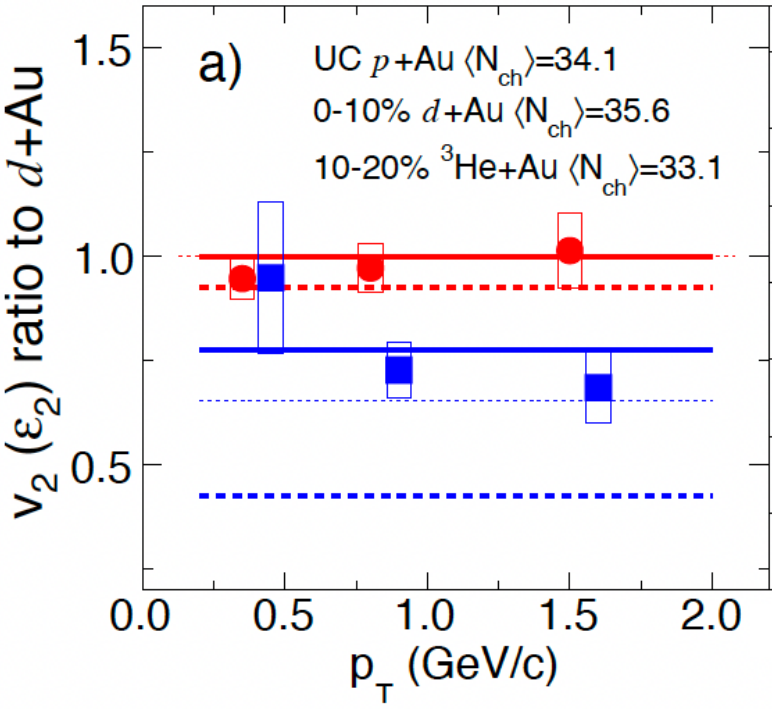
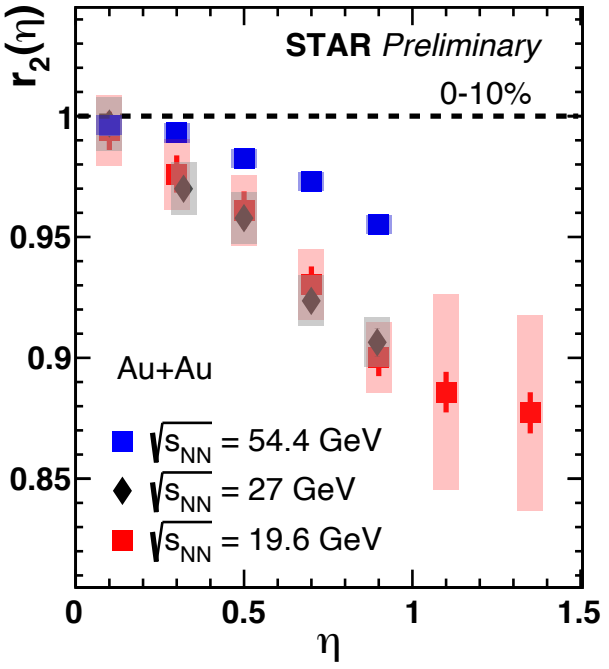


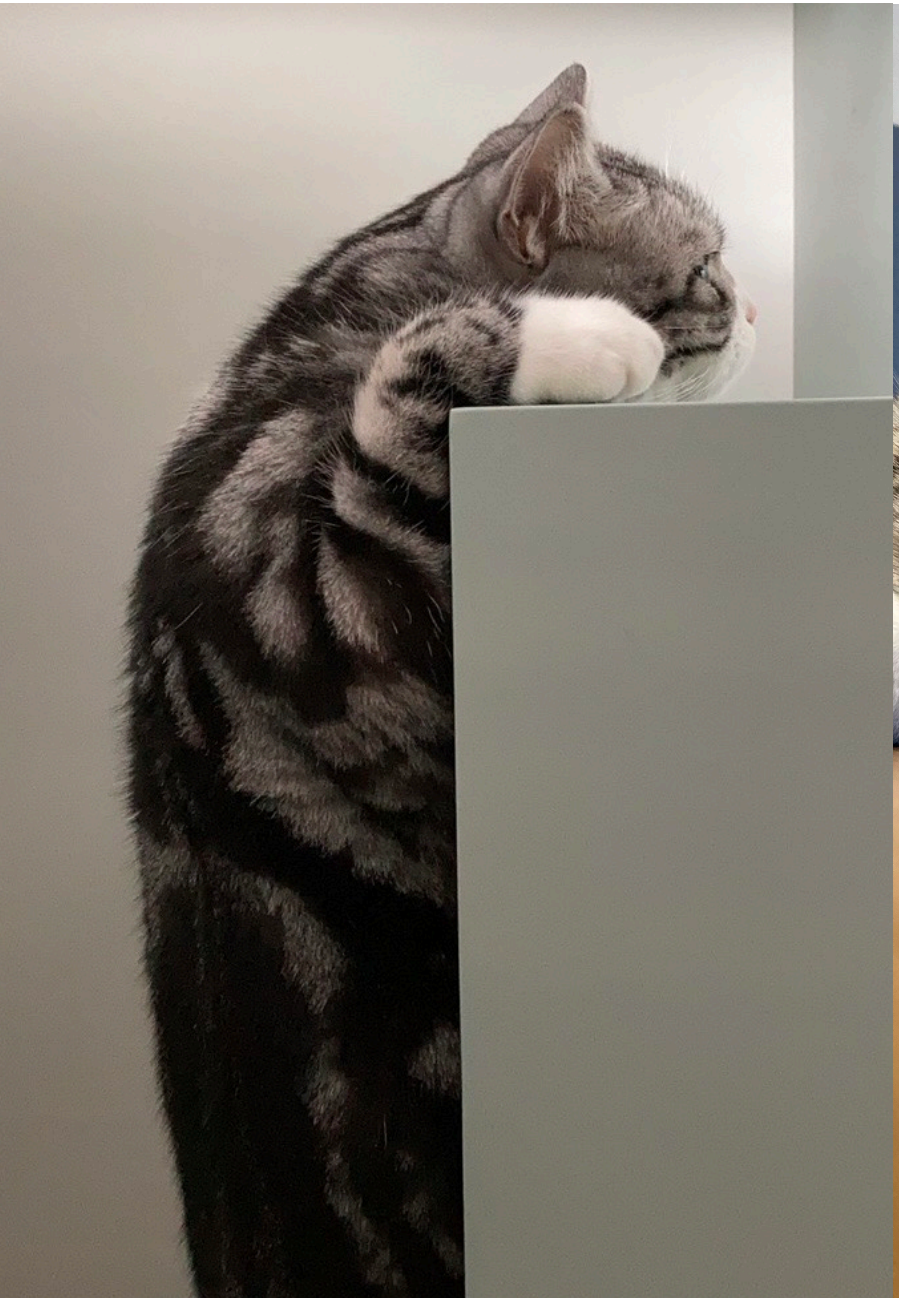


Future works

Intermediate collisions Even smaller collisions

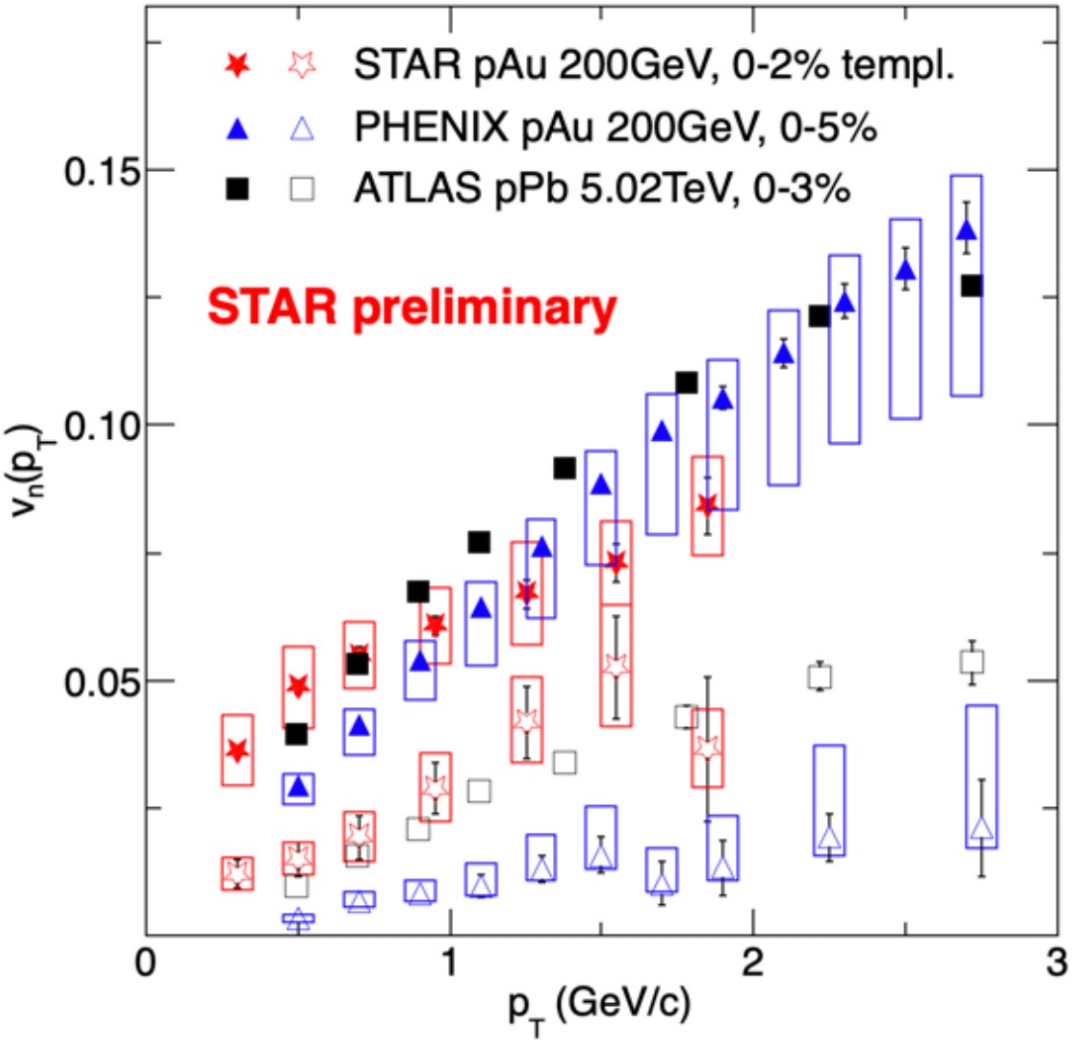
More observables & energies

Thank you



Back up

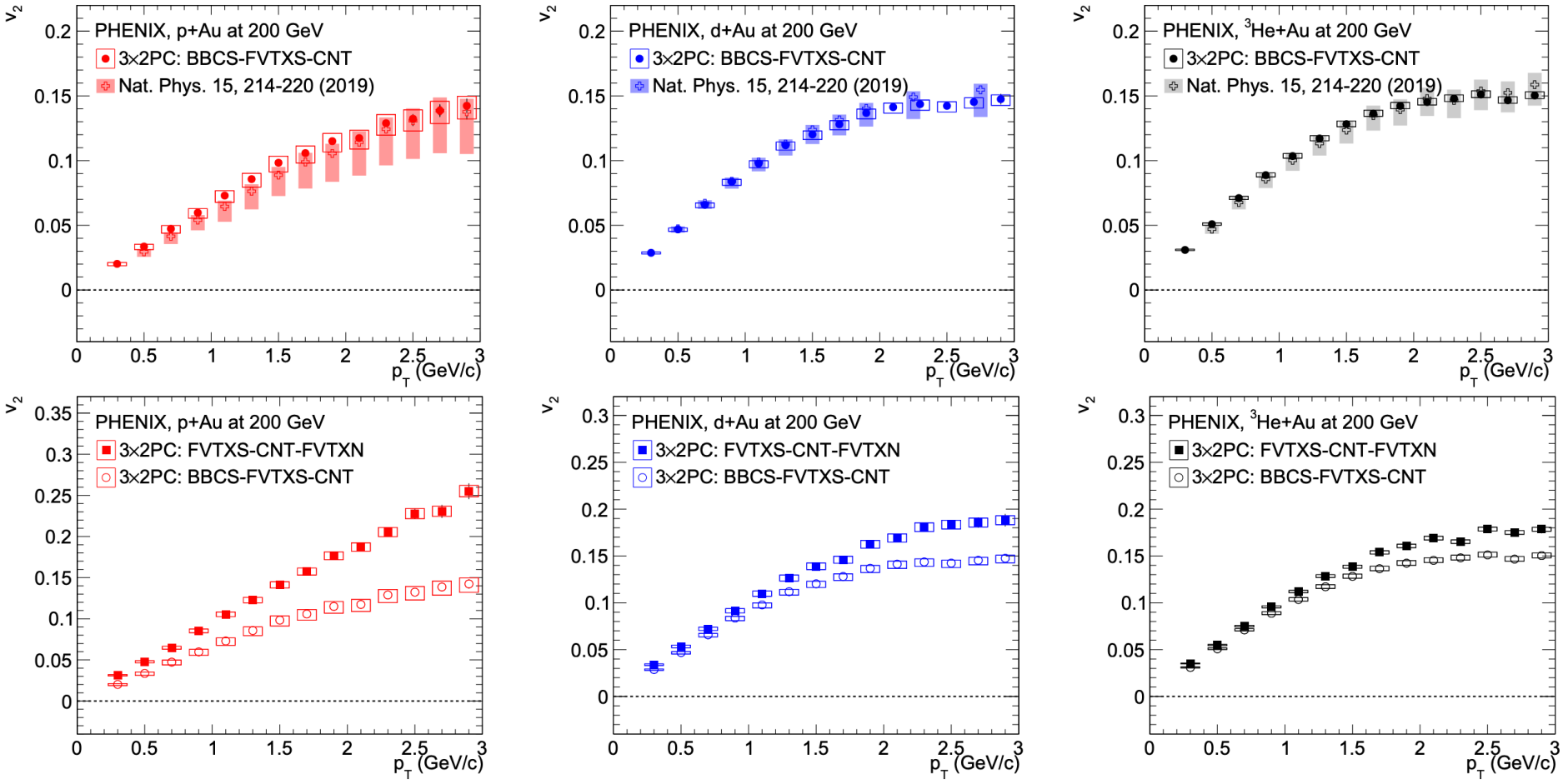
STAR PHENIX comparison



ATLAS: Phys. Rev. C 90, 044906 (2014)
PHNEIX: Nature Phys. 15, 214 (2019)

Geometry response in small systems

arXiv: 2107.06634

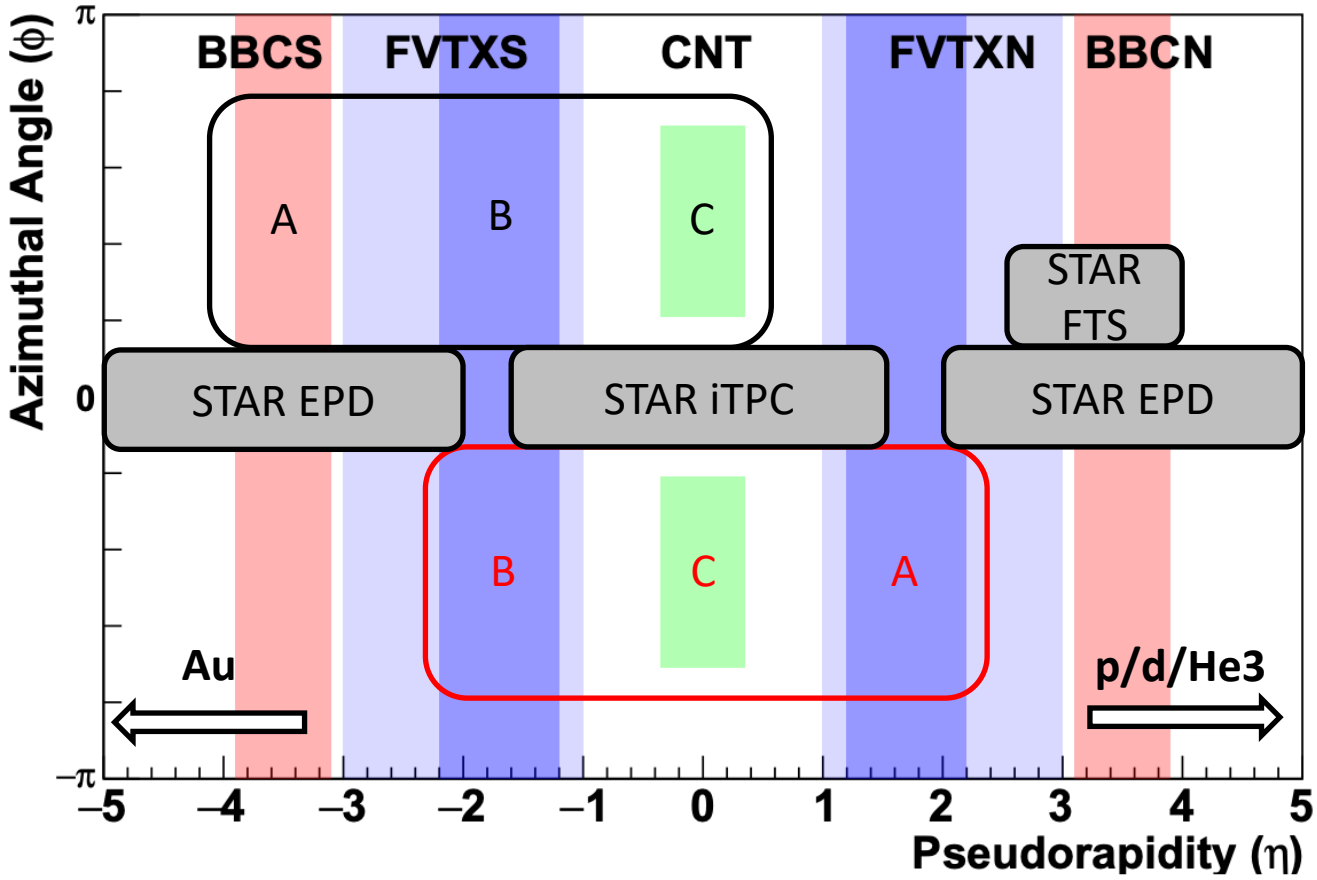


Different results with different kinematics range

Reveal the impact of decorrelation & non-flow

Important for cross-experiment & theory comparison

Geometry response in small systems



STAR has taken dAu with iTPC+EPD

Will take pAu with iTPC+EPD+forward upgrade

Stay Tuned!