PHENIX results on azimuthal correlations in small collision systems from the RHIC geometry and energy scan

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PHENIX

Motivation

What ?

Engineer the size and shape of the initial reaction

How?

- 3He+Au (2014)
- d+Au (2008)
- p+Au, p+Al (2015)

Why?

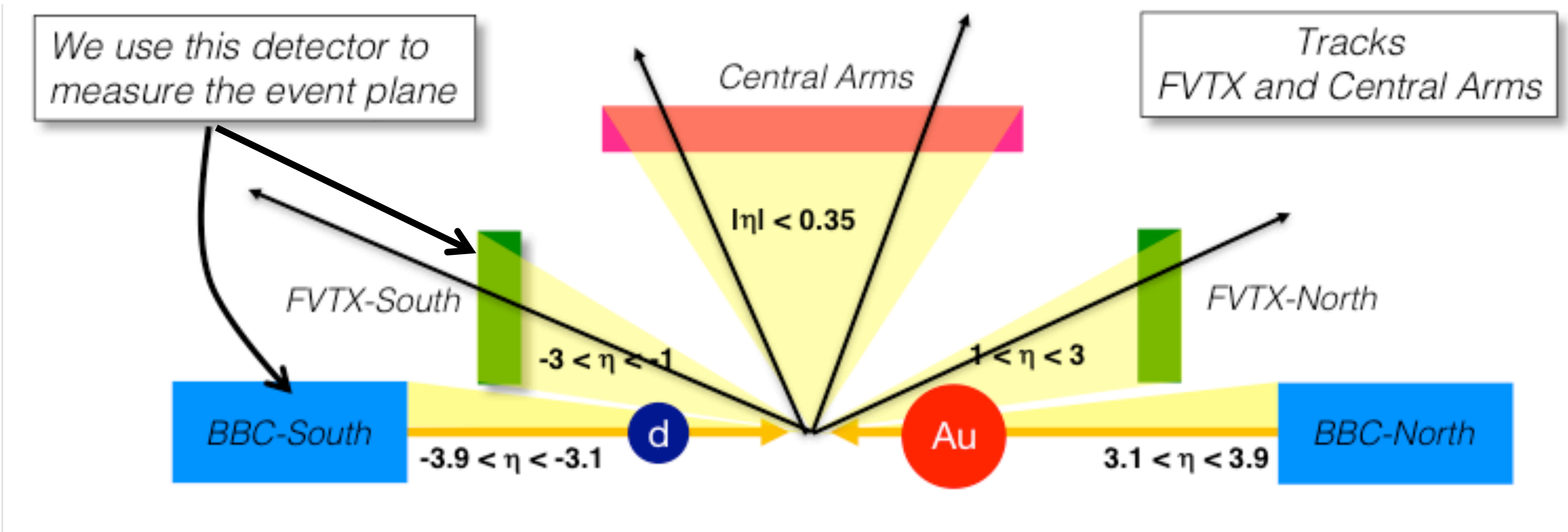
How the initial geometry is translated to final-state momentum anisotropy

Beam Energy Scan

- d+Au (2016)
- 20 GeV
- 39 GeV
- 62.4 GeV
- 200 GeV

Vary the duration of each stage to assess their relative importance

PHENIX Detectors in Rapidity Space



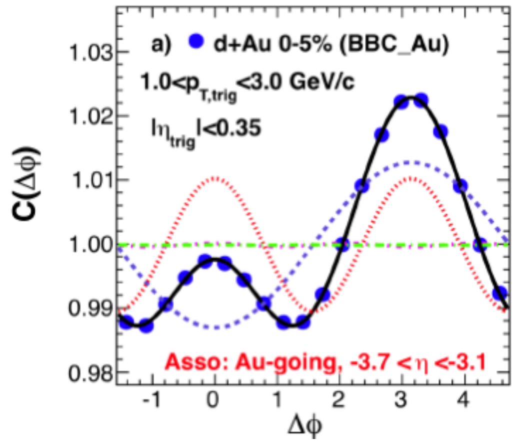
PHENIX Results in this Talk

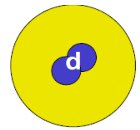
- Ridge in different systems
- Geometry scan: flow of inclusive and identified particles
- Energy scan with dAu

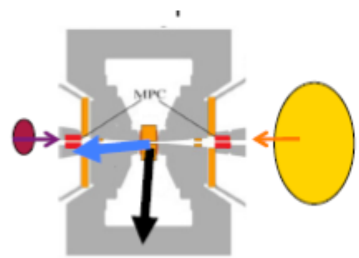
Ridge in different systems

Ridge in d/3He+Au but no ridge in pA

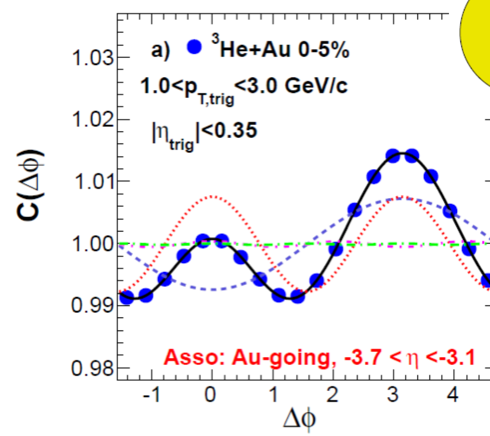
Phys. Rev. Lett. 114, 192301, 2015

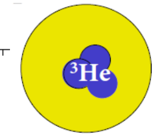




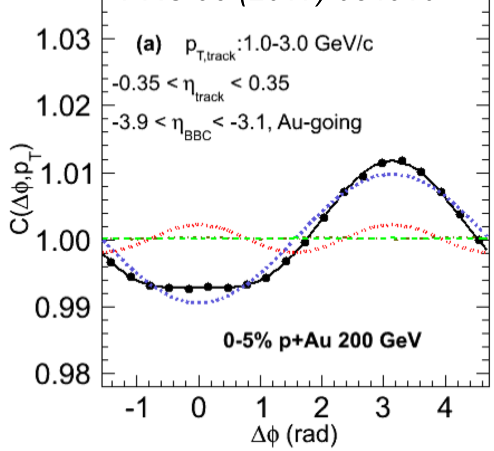


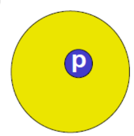
Phys. Rev. Lett. 115, 142301 , 2015



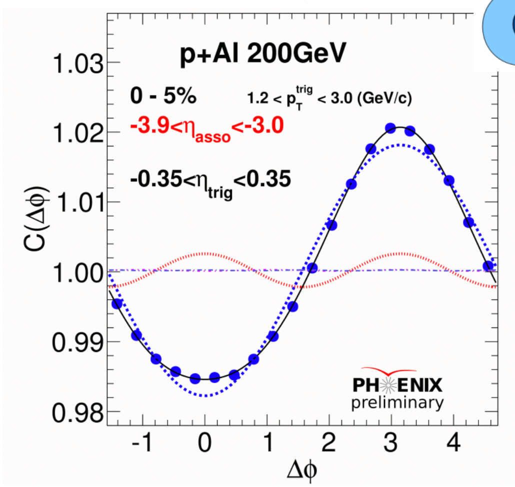


PRC 95 (2017) 034910

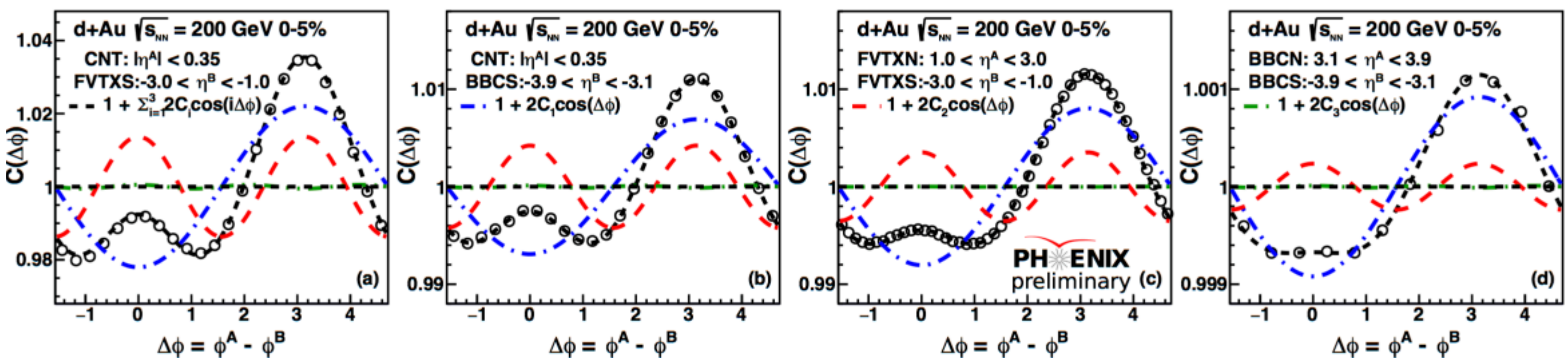


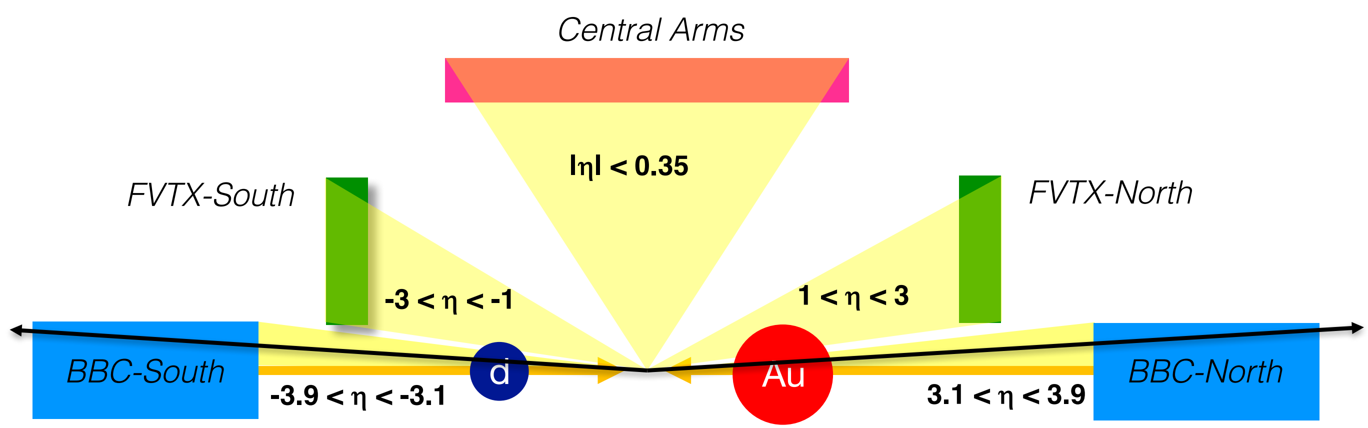


|Δη|>2.75



d+Au at 200 GeV: ridge evolution with Δη





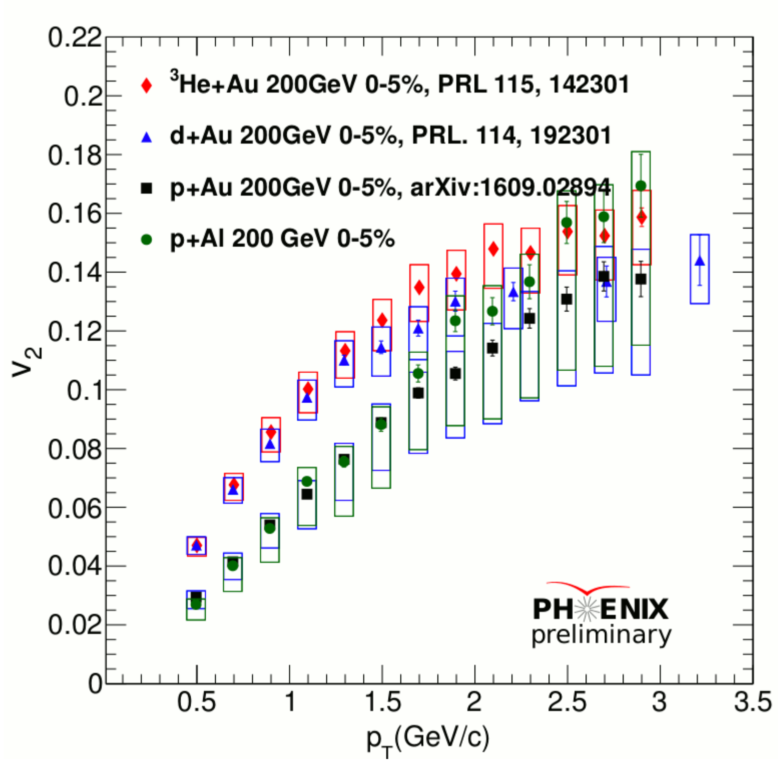
A clear ridge is seen with all detector combinations, even for Δη > 6.2

Geometry scan: flow of inclusive and identified particles

Geometry scan: flow harmonics of inclusive particles

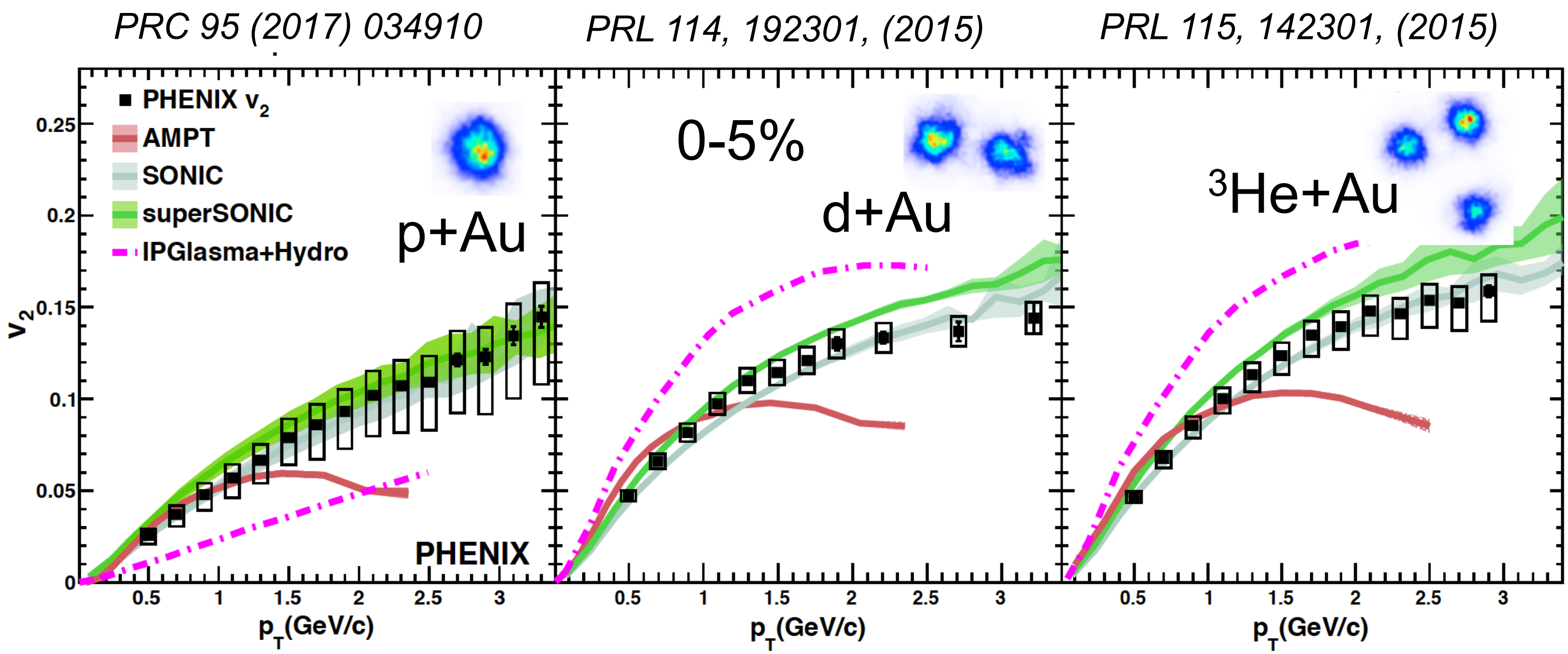
$\varepsilon 2(3HeAu) = 0.50$
$\varepsilon 2(dAu) = 0.54$
$\varepsilon 2(pAu) = 0.23$
$\varepsilon 2(pAl) = 0.30$

(growing) asymmetric systematics from nonflow



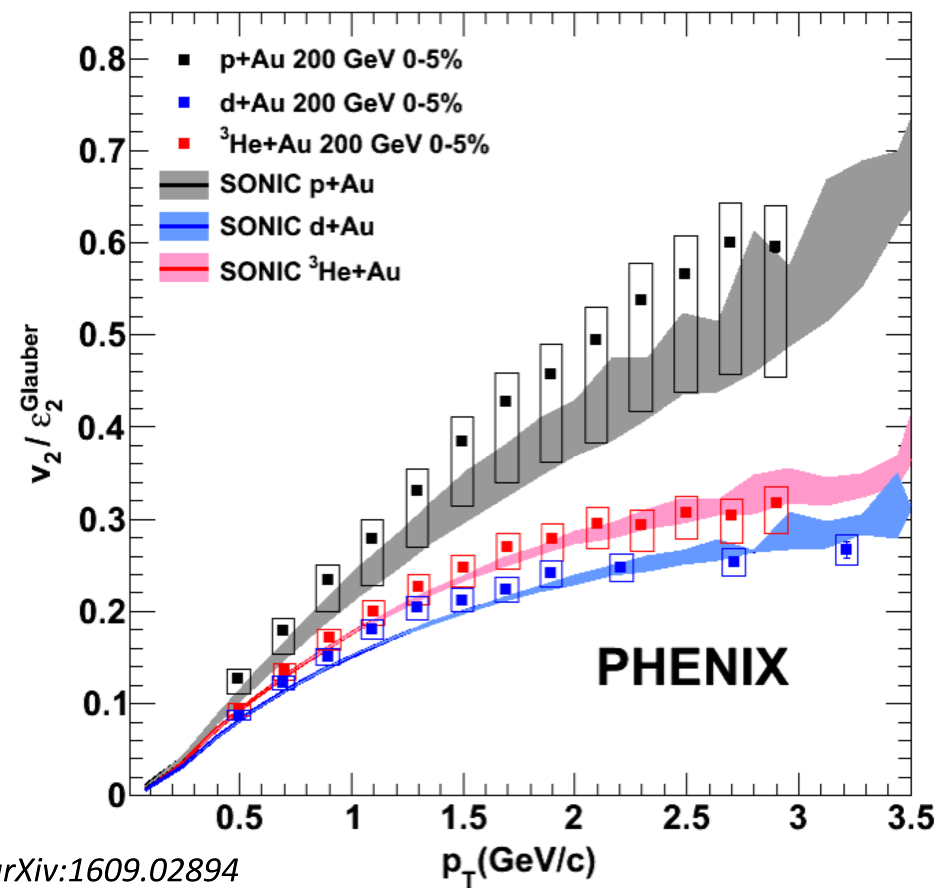
- $v_2(^3HeAu) \sim v_2(dAu) > v_2(pAu) \sim v_2(pAl)$
- Geometry control works!

Geometry engineering, v_2 (p_T), and models



- Hydrodynamics with small η/s works!
- AMPT: weakly coupled partonic cascade+quark coallescence+hadronic cascade also works at low p_T.
- Other obesrvables ?

v_2/ε_2 in systems with different geometry



arXiv:1609.02894

The v_2/ε_2 in p+Au is higher than that of d+Au and ^{3}He+Au collisions

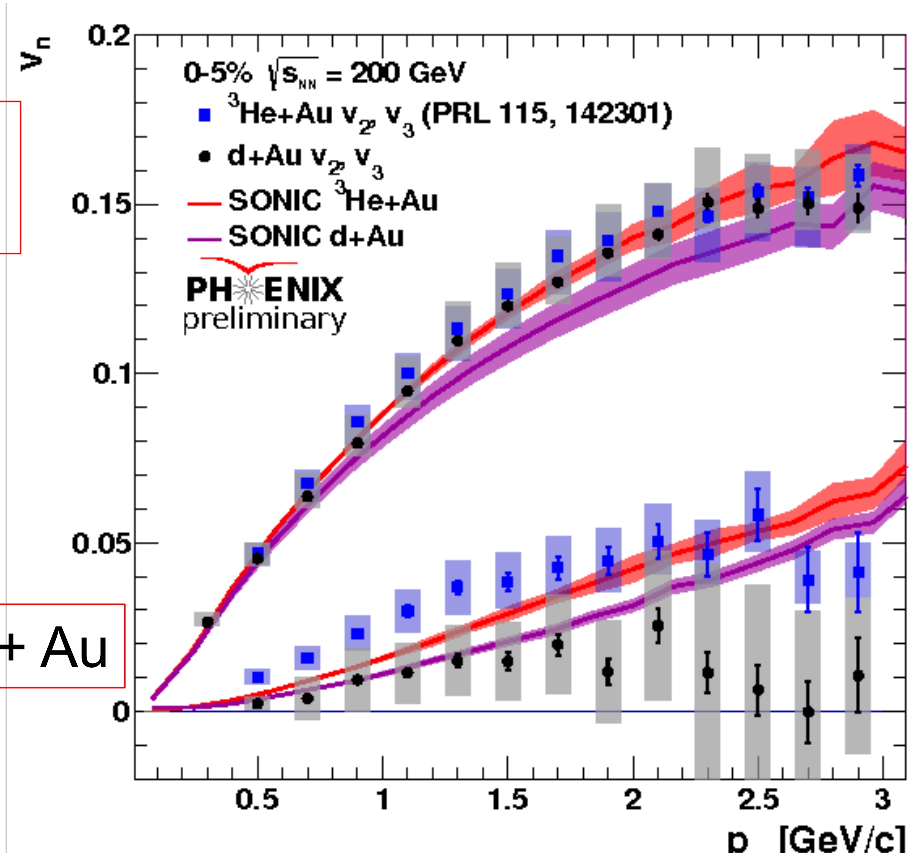
^{3}He/d+Au – some events hot spots never connect and so $\varepsilon_2 \rightarrow v_2$ translation incomplete

This behavior is within the expectation of SONIC model, which includes Glauber initial geometry and viscous hydro evolution.

Triangular flow at 200 GeV in different systems: insights about the role of preflow

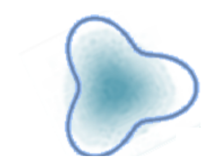
v_2 in d/^{3}He+ Au
Nearly identical

v_3 smaller in d+ Au



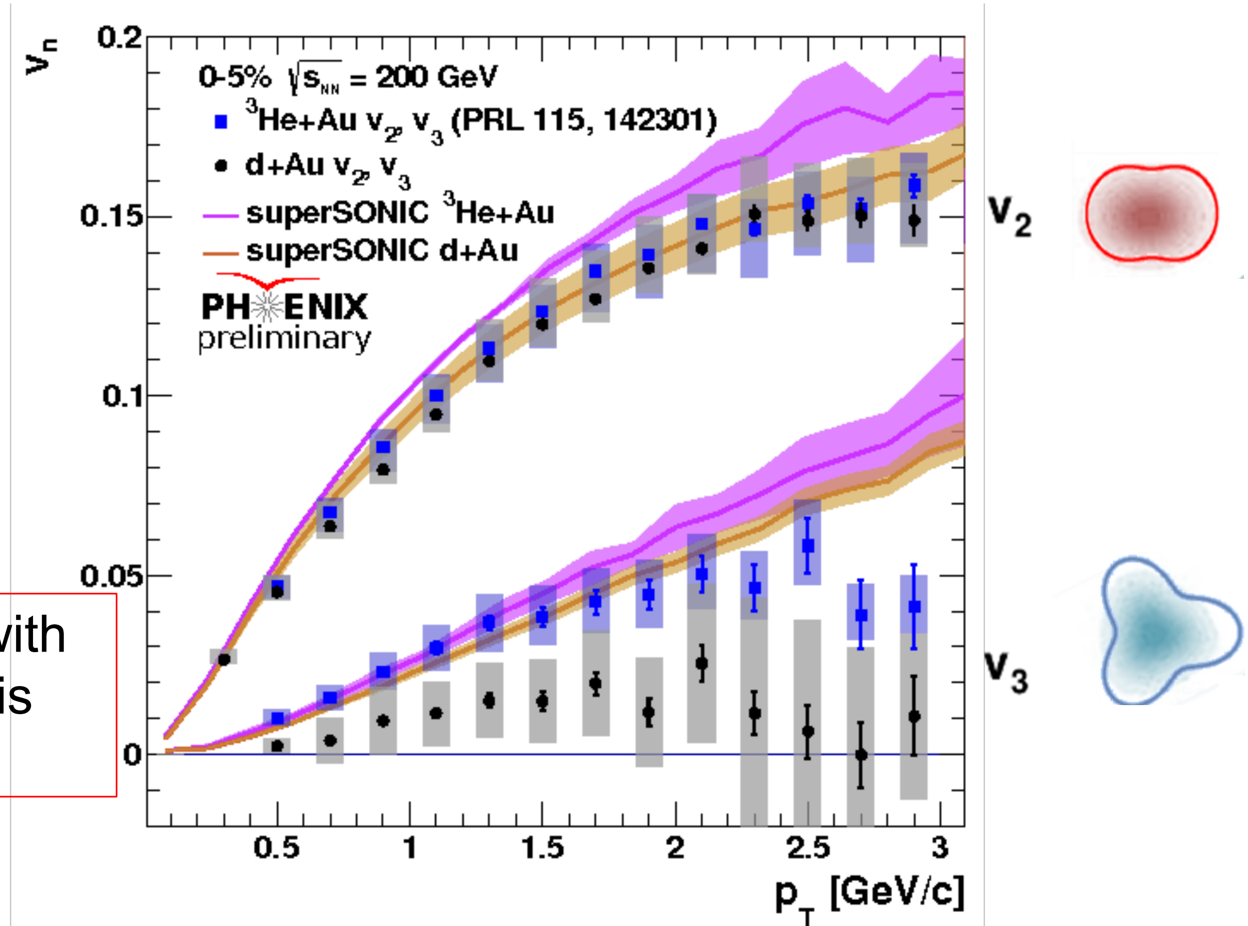
v_2

v_3



- Trends well described with hydro without preflow

Include pre-equilibrium flow

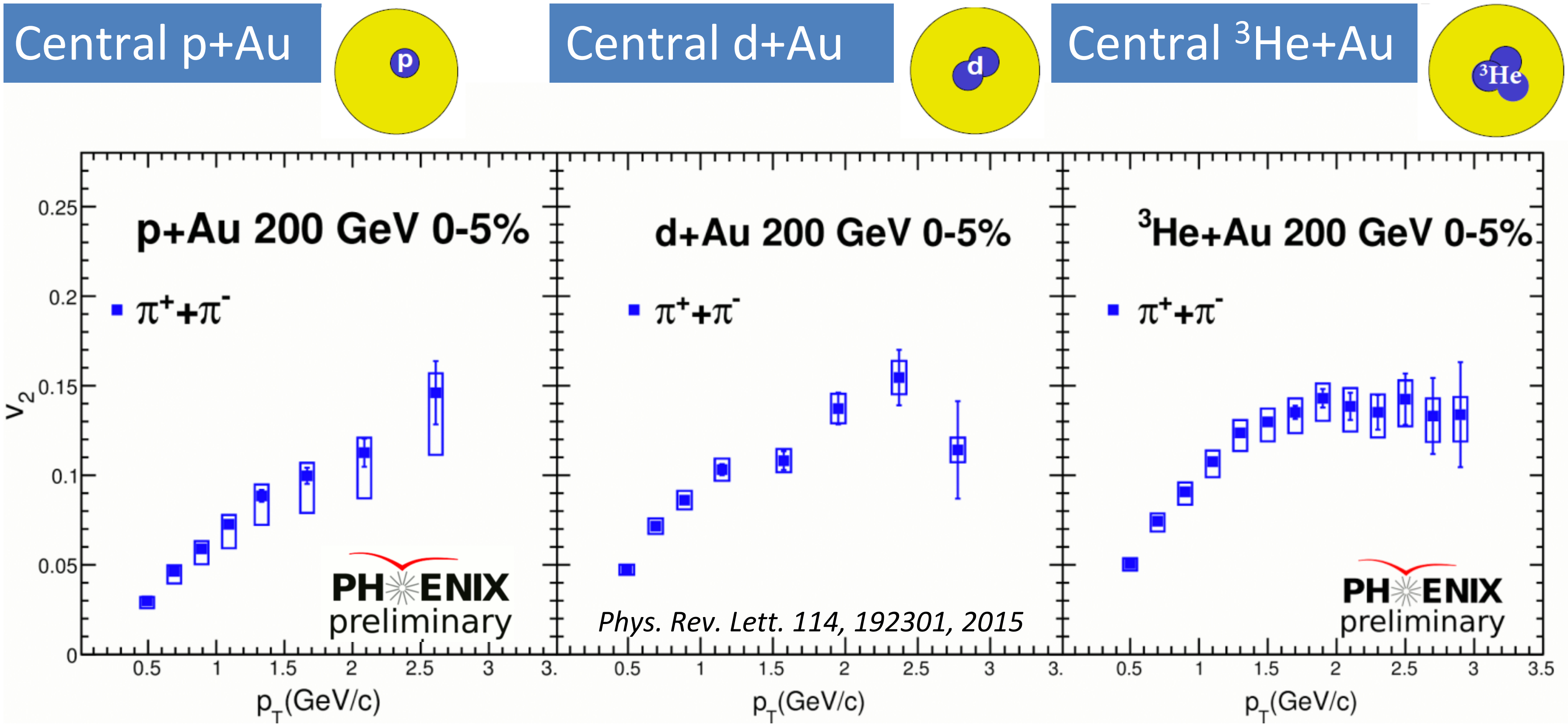


worse agreement with data when preflow is included

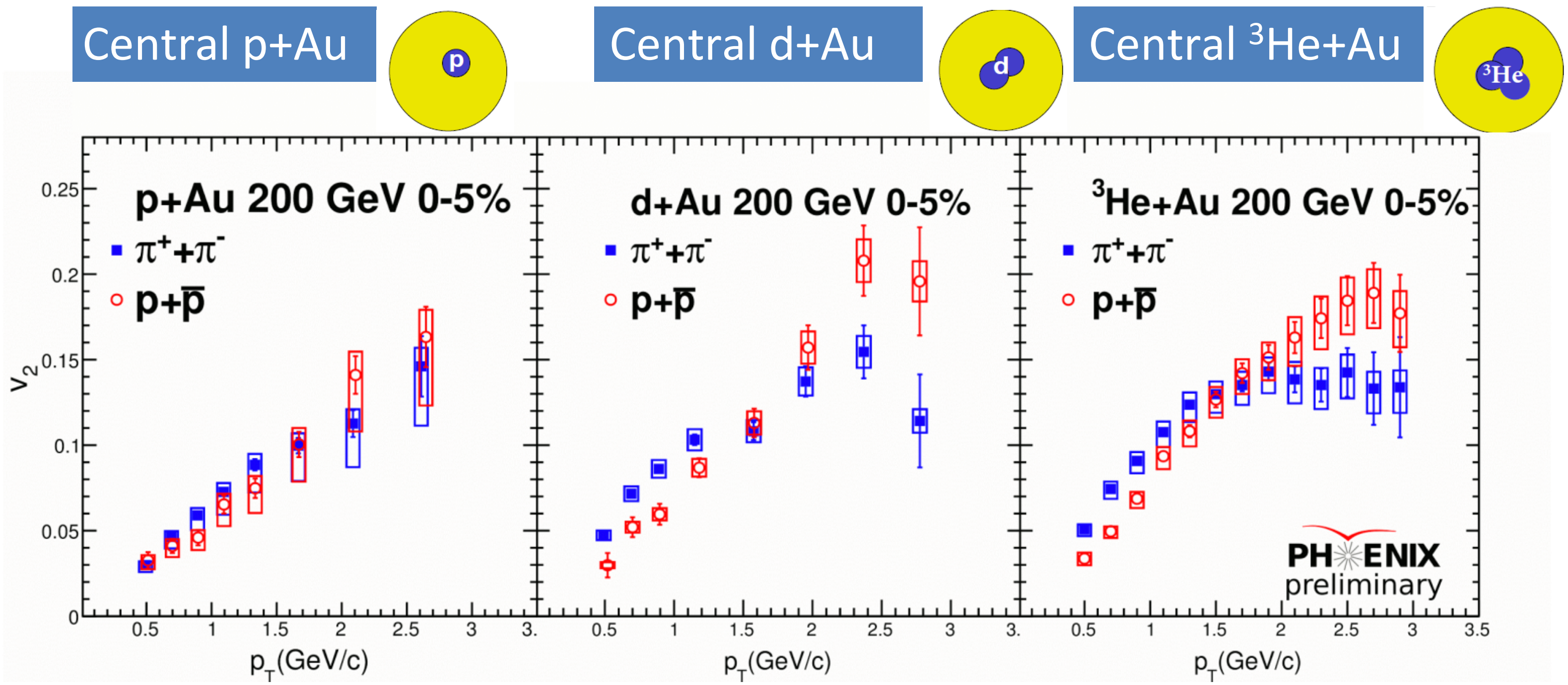
Relative contributions from pre-equilibrium and QGP need retuning ?

Identified particle v_2 in different systems

Central p+Au | Central d+Au | Central ^{3}He+Au



Identified particle v_2 in different systems

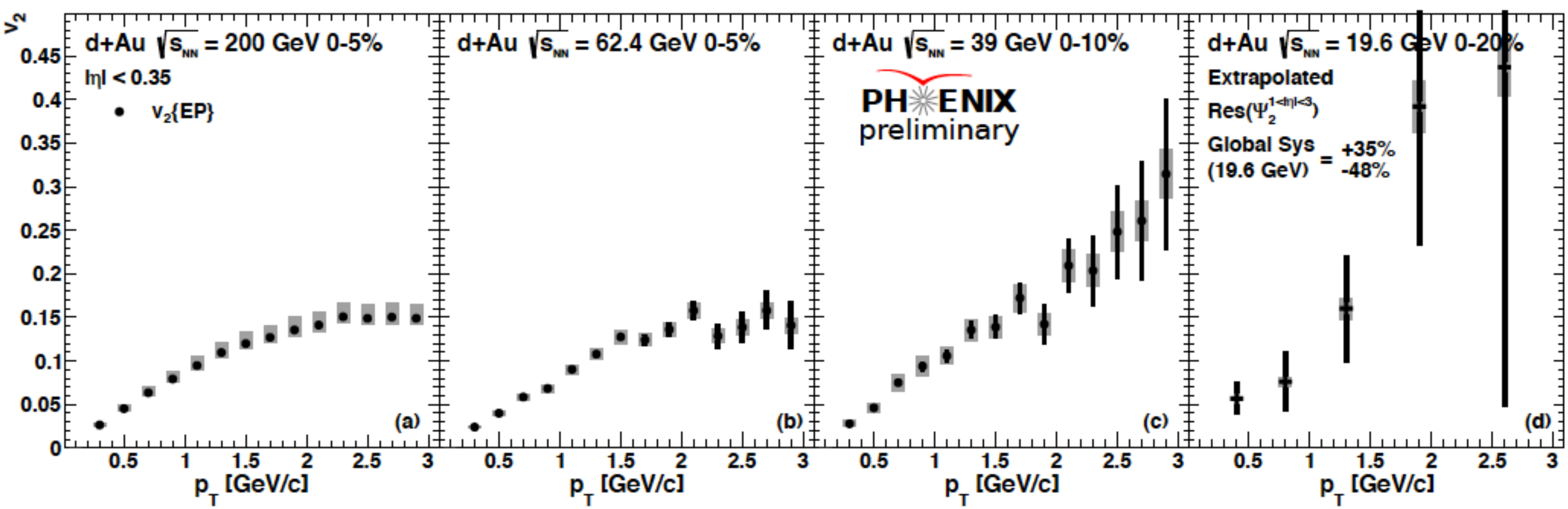


- Mass-ordering in all three systems
- Less pronounced in p+Au than in d+Au and ^{3}He+Au
- Need to compare to models

Energy scan with dAu

dAu BES: Event plane measurements of v2

200 GeV **62 GeV** **39 GeV** **20 GeV**

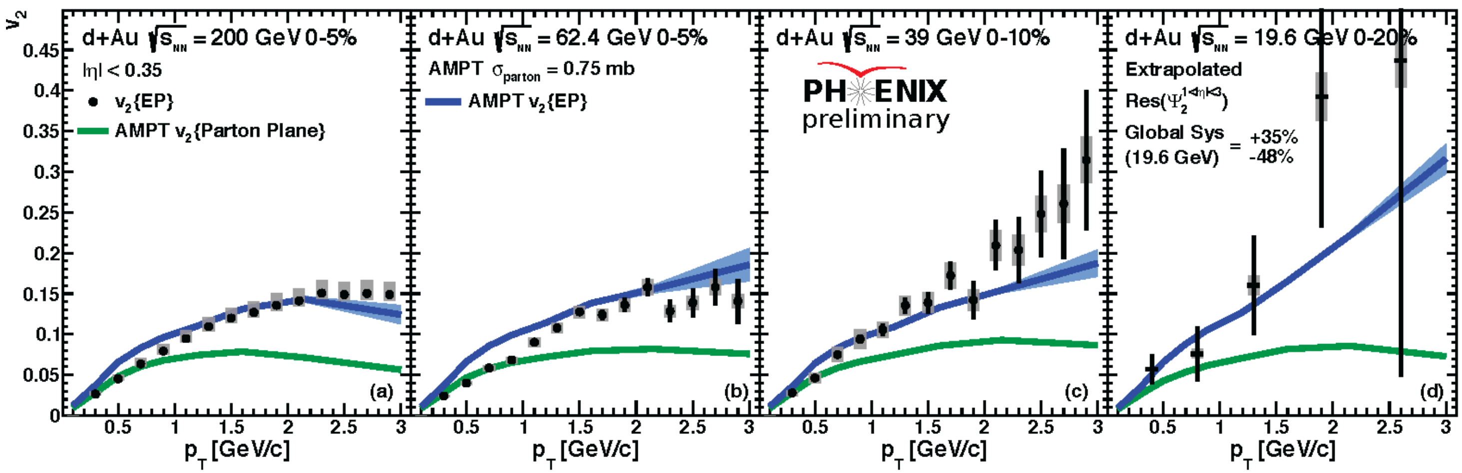


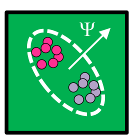
Nearly identical

Increase at high p_T ?

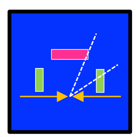
Nonflow correlations: insights from AMPT

200 GeV | 62 GeV | 39 GeV | 20 GeV





Pure Flow

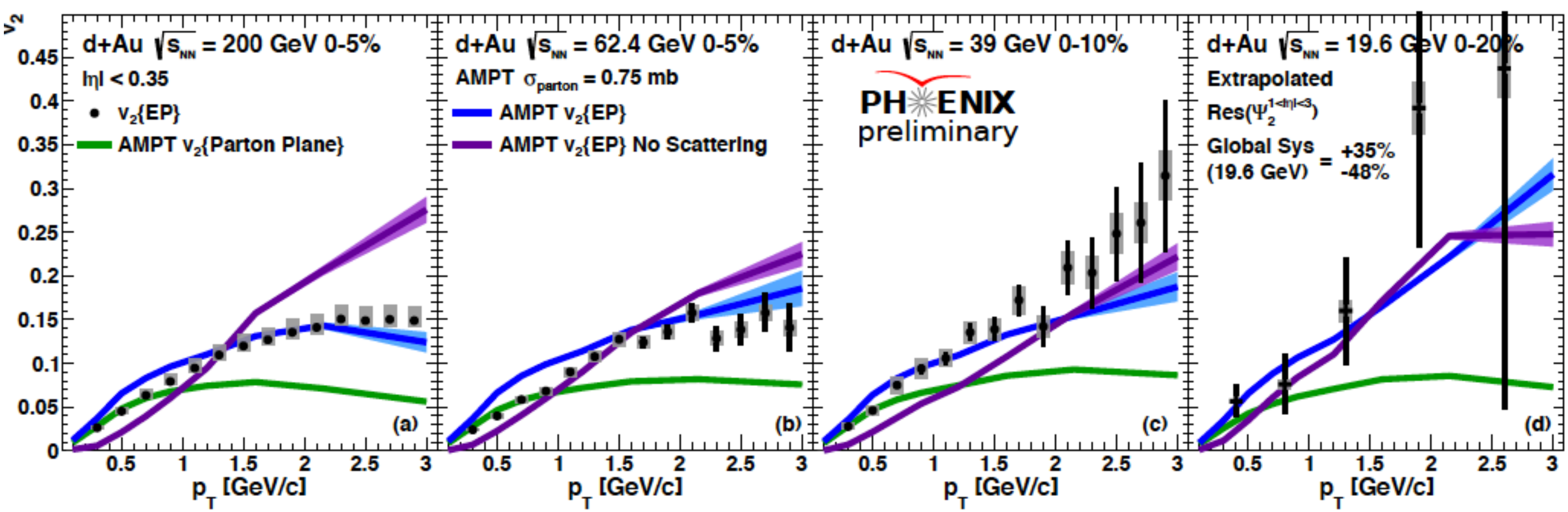


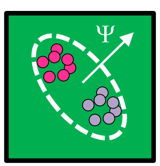
With Non-Flow

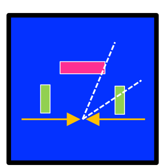
- Evidence for collective effects down to 39 GeV
- Nonflow correlations at 20 GeV require further studies

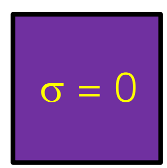
Nonflow correlations: insights from AMPT

200 GeV **62 GeV** **39 GeV** **20 GeV**



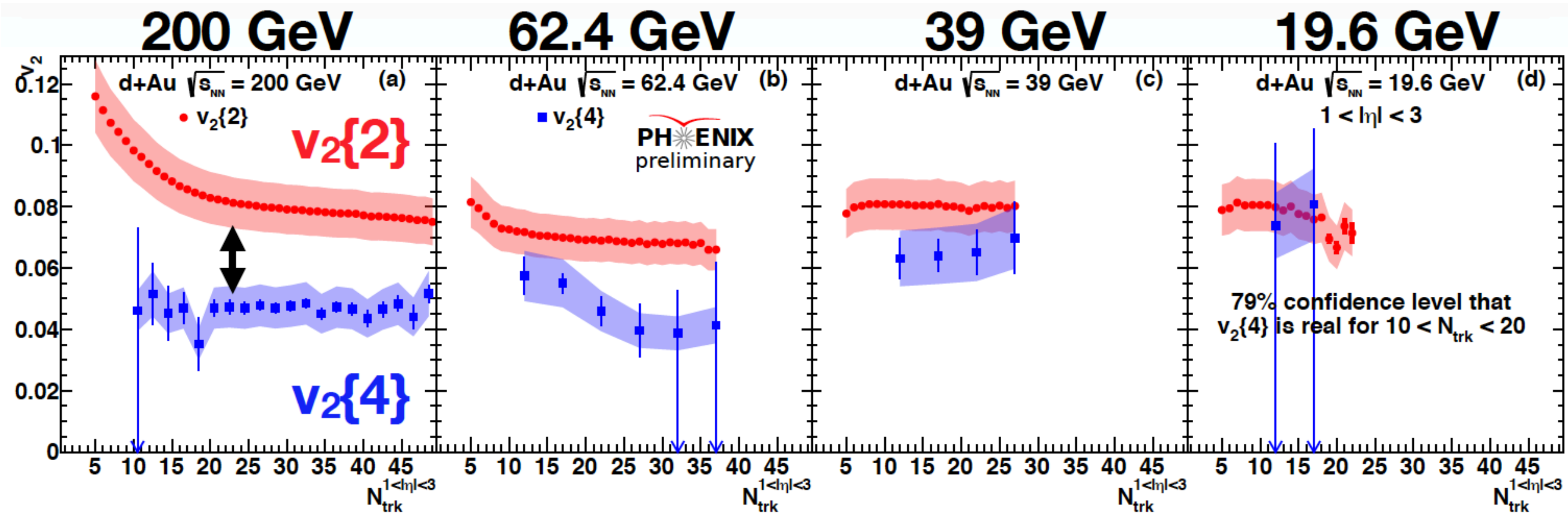






Pure Flow **With Non-Flow** **All Non-Flow**

dAu BES: v_2 vs. multiplicity from cumulants



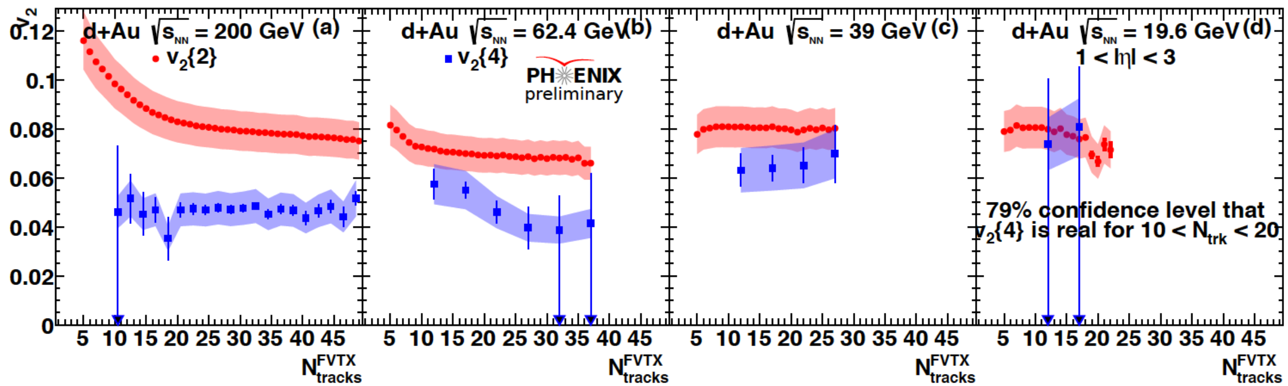
The difference can be attributed to nonflow + fluctuations

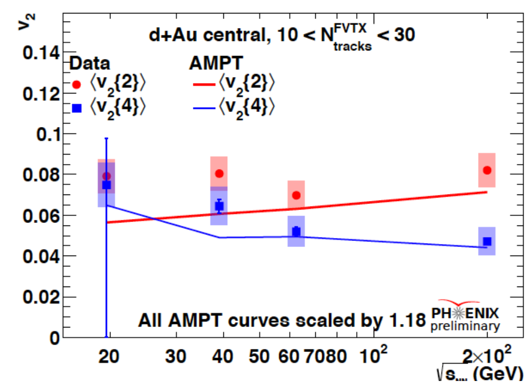
Real v2{4} at all 4 energies!

Evidence of collectivity down to 19.6 GeV

dAu BES: v2 vs multiplicity from cumulants

200 GeV 62.4 GeV 39 GeV 19.6 GeV





- Select $10 < N^{FVTX}_{tracks} < 30$, integrate
- Trend of $v_2\{2\}$ and $v_2\{4\}$ merging as $\sqrt{s_{NN}}$ is lowered
- AMPT sees the same trend

Interesting correlation at low multiplicities needs to be understood further !

$$v_2\{2\} = (v_2^2 + \sigma^2 + \delta^2)^{1/2}$$
$$v_2\{4\} \approx v_2\{6\} \approx (v_2^2 - \sigma^2)^{1/2},$$

CONCLUSIONS

1) Ridge in different systems at 200 GeV

Pronounced ridge in d/3He+Au, but not in pAl

In d+Au, the ridge seen for $\Delta\eta$ > 6.2-> **truly long-range**

2) Geometry scan: flow of inclusive and identified particles

$v_2(p_T)$ and $v_3(p_T)$ follow initial geometry

hydro and AMPT describe the data up to p_T ~ 3 or 1 GeV

v_3 in dAu and 3HeAu discriminate against preflow/flow

identified particle $v_2(p_T)$ shows mass ordering (data/theory comparison needed)

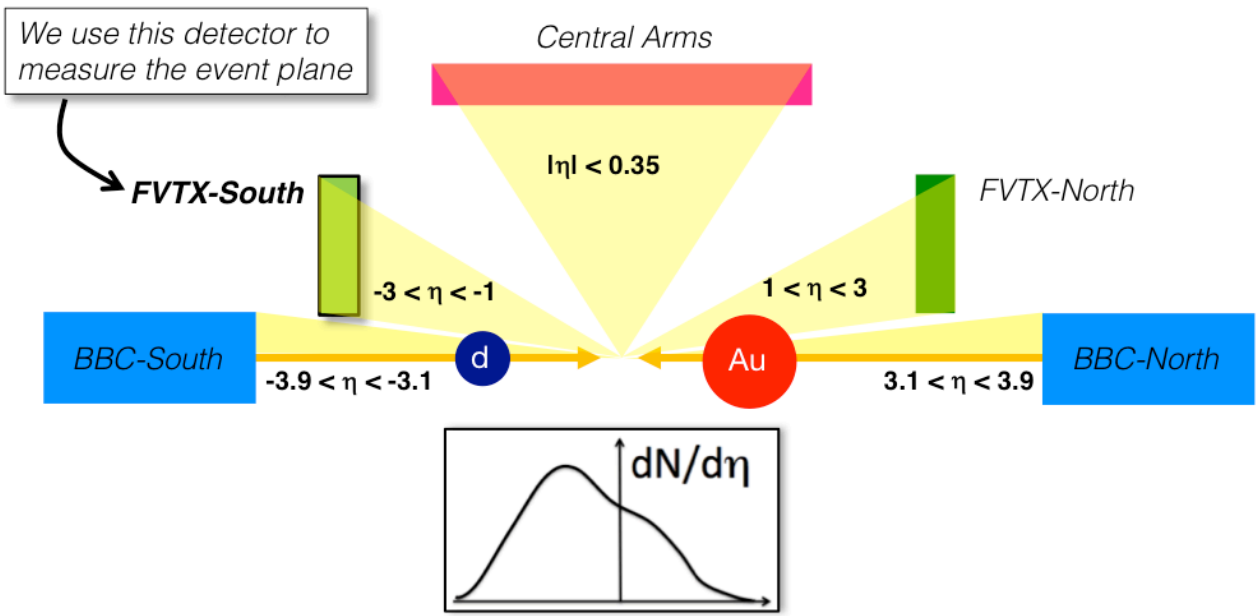
3) Energy scan with dAu

$v_2(p_T)$ at midrapidity – nonzero v_2 at all energies

$v_2\{2\}$ and $v_2\{4\}$ vs. multiplicity: evidence for collectivity down to 20 GeV !

Back Up Slides

EP: Measurements of v_n (p_T) at mid rapidity

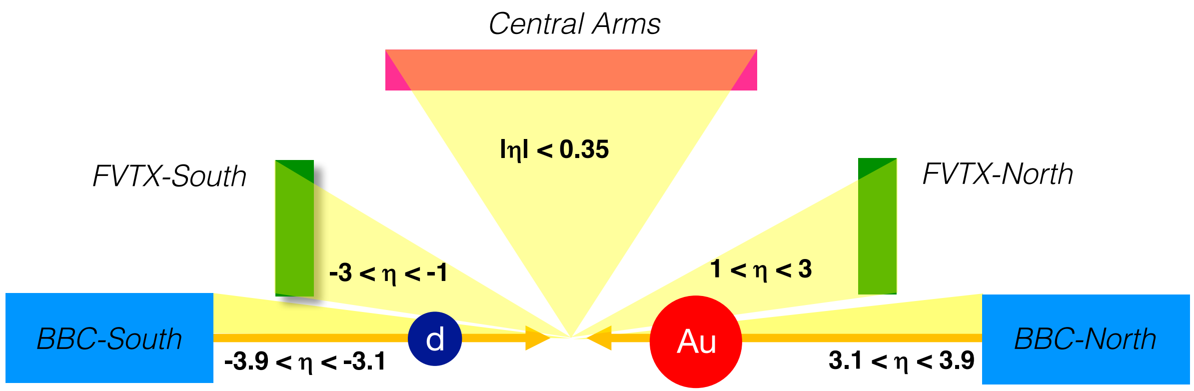


$$v_2 = \frac{\langle \cos 2(\phi - \Psi_2) \rangle}{\mathrm{Res}(\Psi_2)}$$

To optimize Resolution, we use:

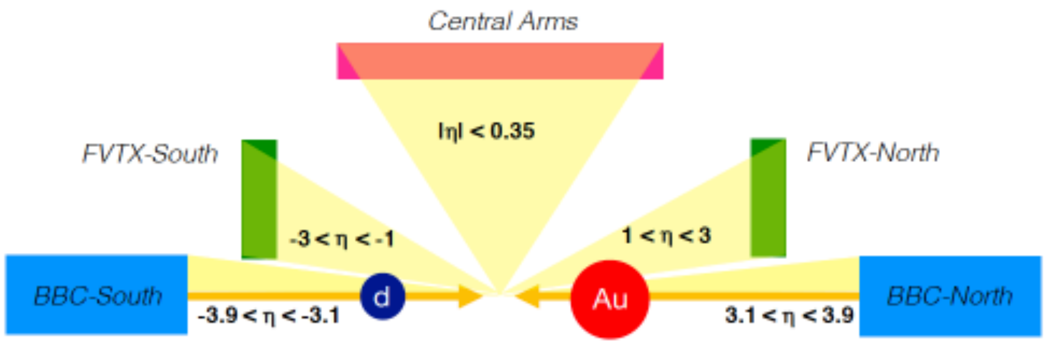
- Central Arms
- FVTX-South
- BBC-South

2-particle correlations

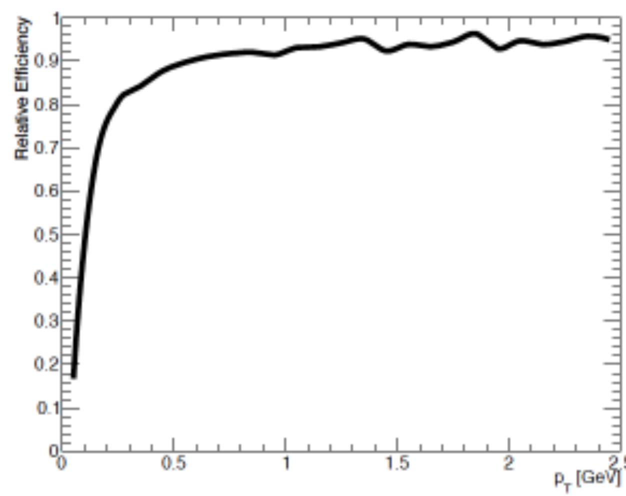


- various detector combinations are used
- 2-particle correlations used for:
  - estimate nonflow (in conjunction with min bias pp data)
  - look for the ridge
  - in some cases -> to confirm the EP measurements

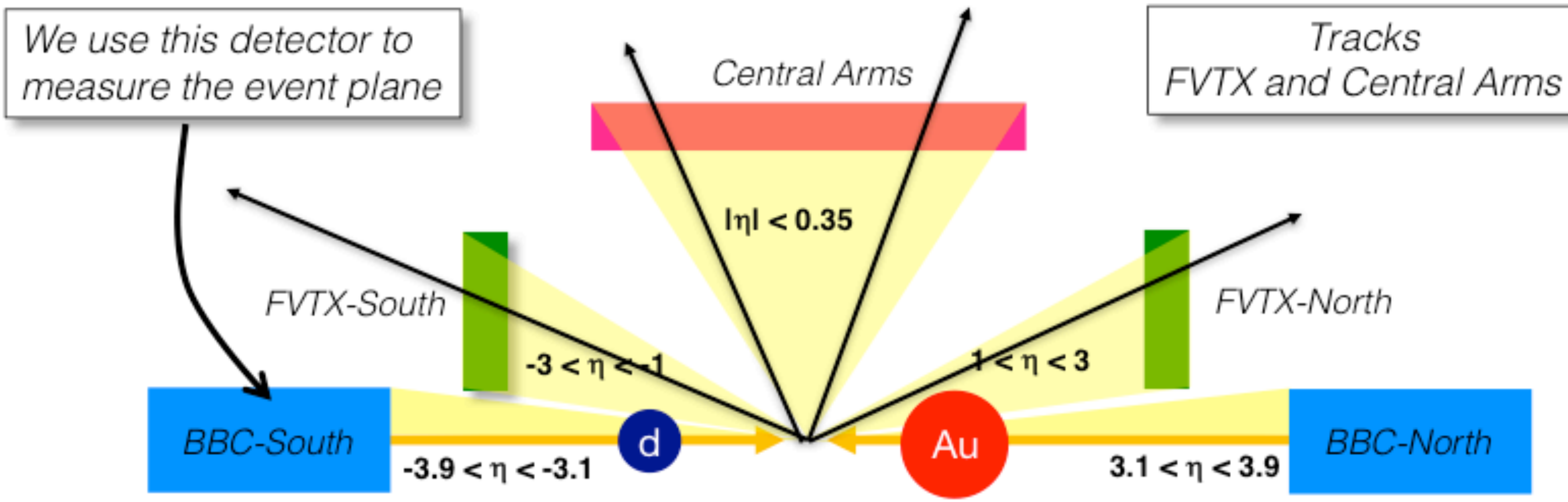
Cumulants: measure integrated v_2 from tracks in FVTX as a function of N_{trk}



- FVTX: forward vertex detector —silicon strip technology
- Very precise vertex/DCA determination
- No momentum determination, p_T dependent efficiency — measured v_2 roughly 18% higher than true



v2 vs η: analysis method



- We want to measure integrated v_2 ($0<p_T<\infty$)
- No p_T information available from FVTX
- Devise a correction based on AMPT