Forward fluctuations and correlations at RHIC

Shengli Huang
Vanderbilt University

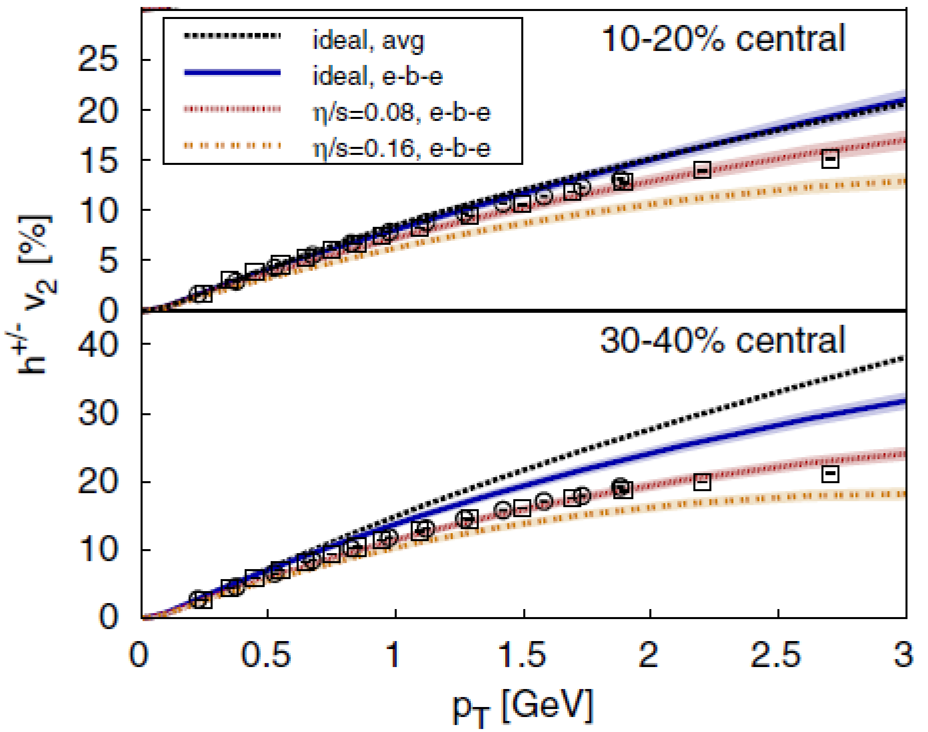
Outline

- The ridge and v_n at forward rapidity for different beam energy
- Longitudinal fluctuation and decorrelations
- The ridge and v_n in small collision systems
- Summary

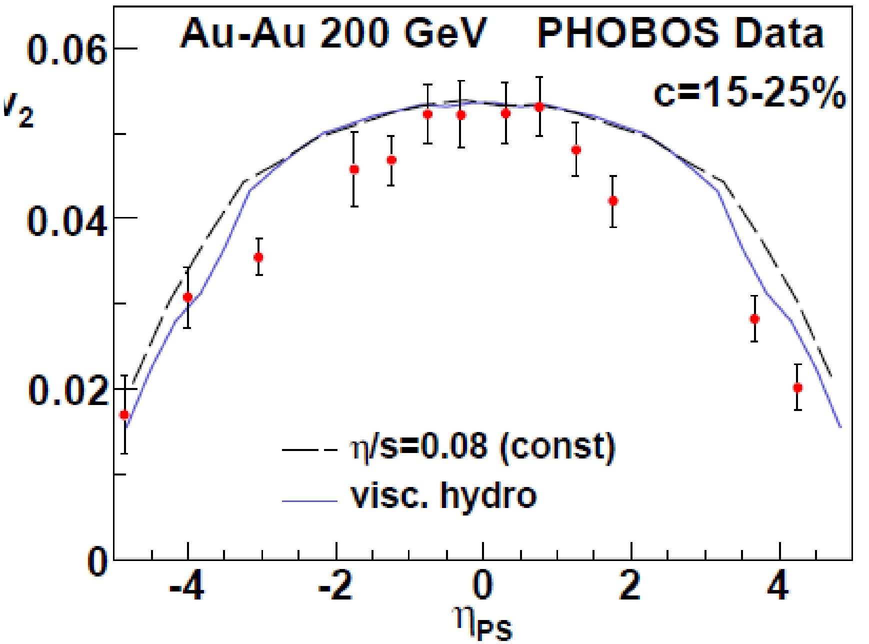
1. The ridge and $v_n(\eta)$ at forward rapidity for different beam energy

$V_2(\eta)$ in (3+1)D viscous hydro.

B. Schenke. et al Phys. Rev. Lett. 106, 042301(2011)



P. Bozek Phys. Rev. C 85, 034901 (2012)

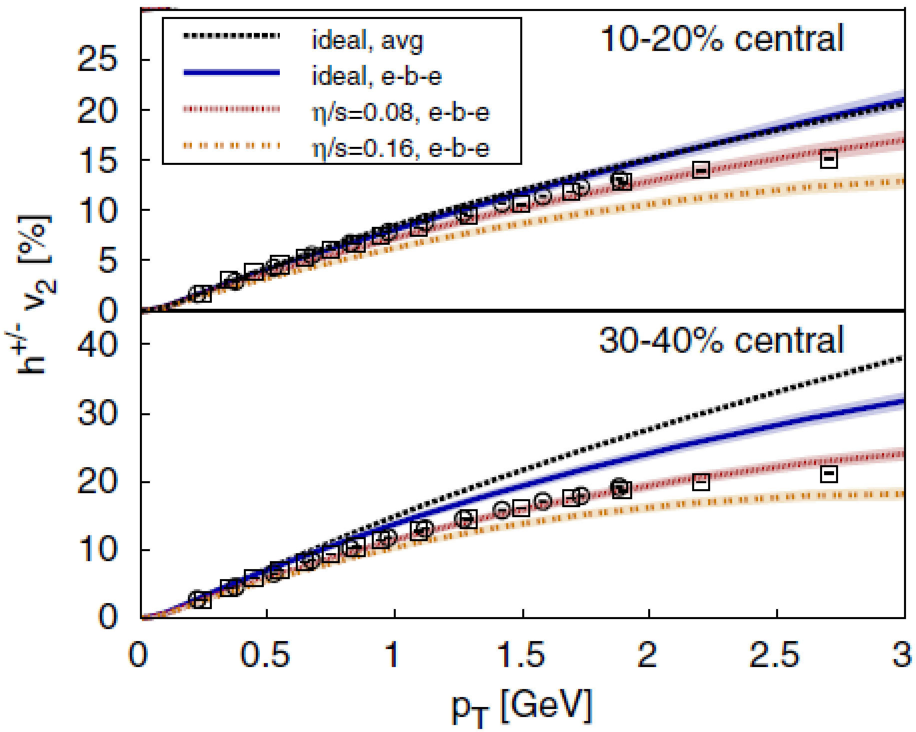


At middle rapidity, (3+1)D viscous hydro well describes the system evolution with E-by-E fluctuation

At forward rapidity, the improvement from hydro calculation is expected.

$V_2(\eta)$ in (3+1)D viscous hydro.

B. Schenke. et al Phys. Rev. Lett. 106, 042301(2011)



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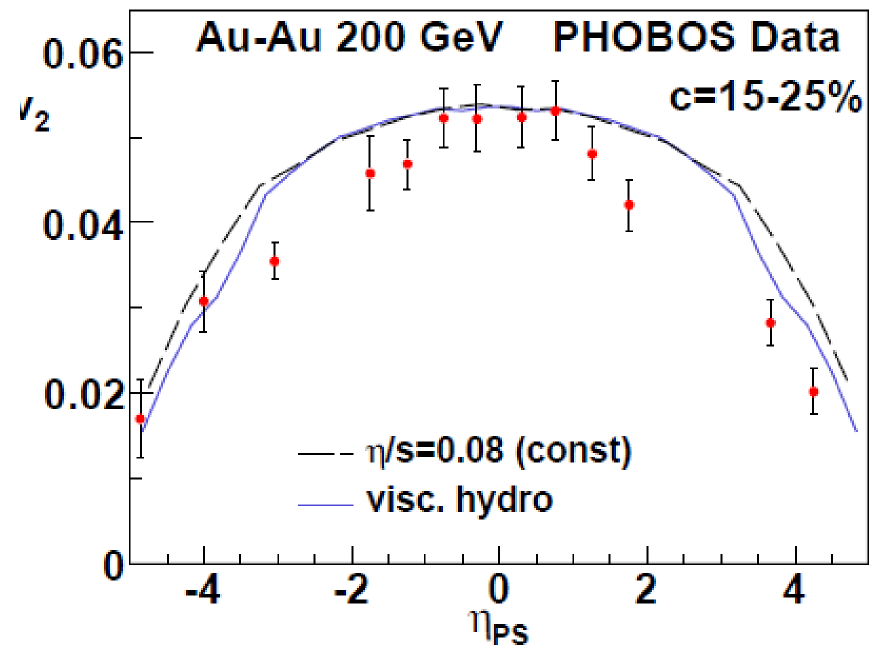
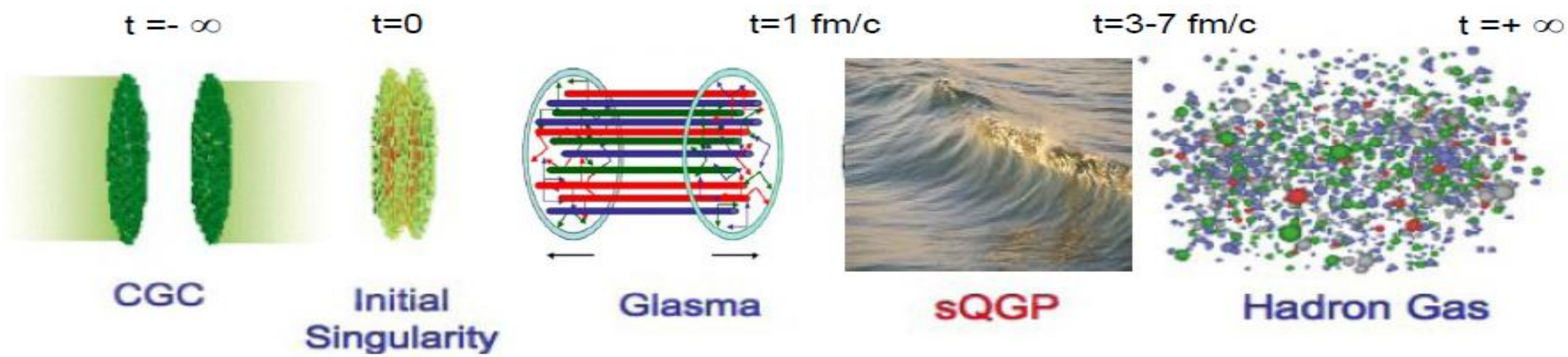
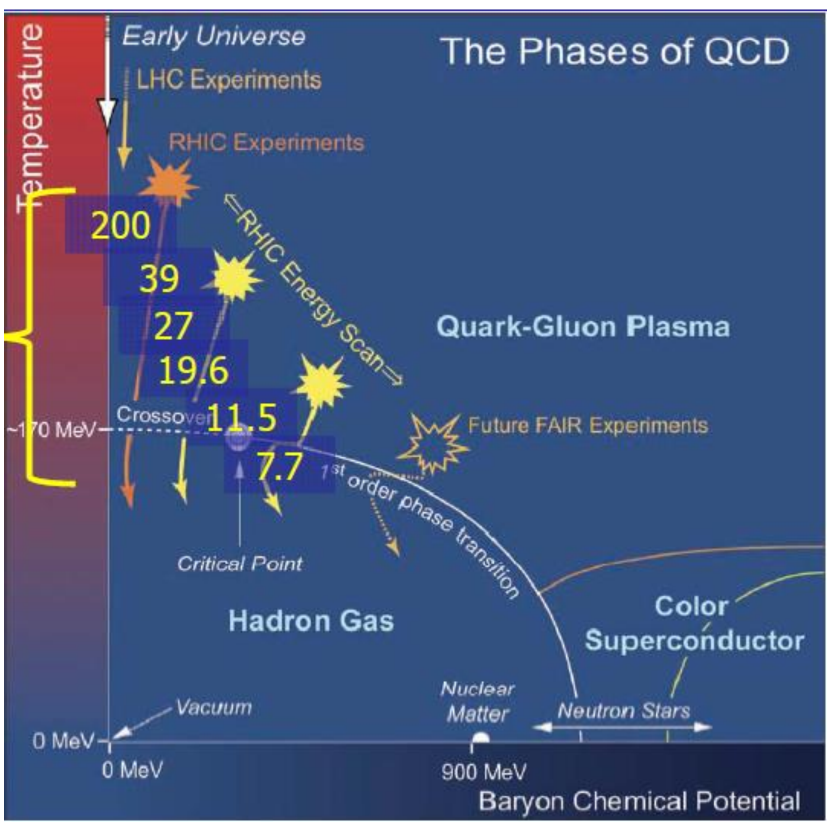


The new measurements is crucial for (3+1) hydro:

- **long range correlation between middle and forward rapidity**
- **V_n at forward rapidity**

Ridge/v_n vs. beam energy



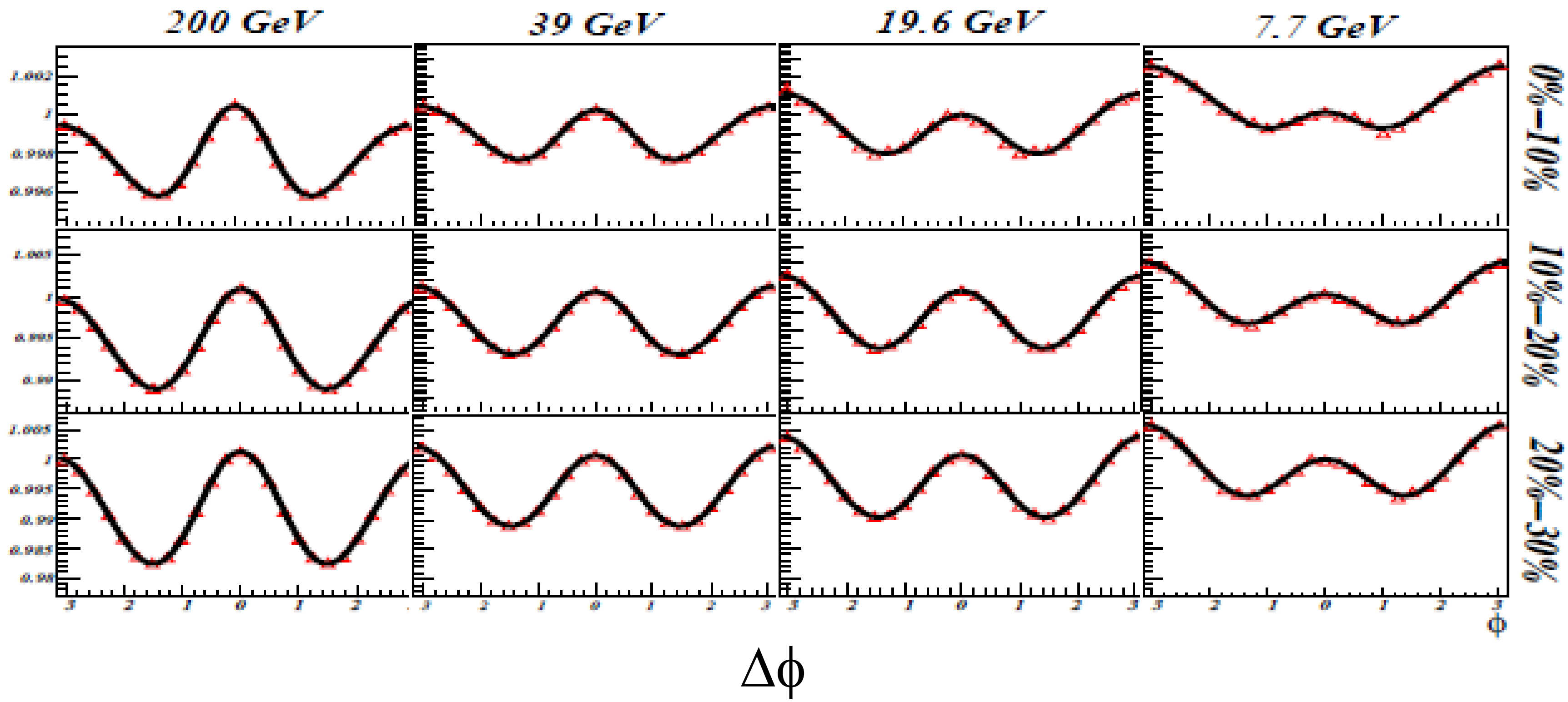


Whether will the long-range correlation from flux tube in Glasma disappear at lower beam energy?

How will the dynamics change at forward rapidity?

Ridge vs. beam energy(I)

Long range correlation for TPC-TPC



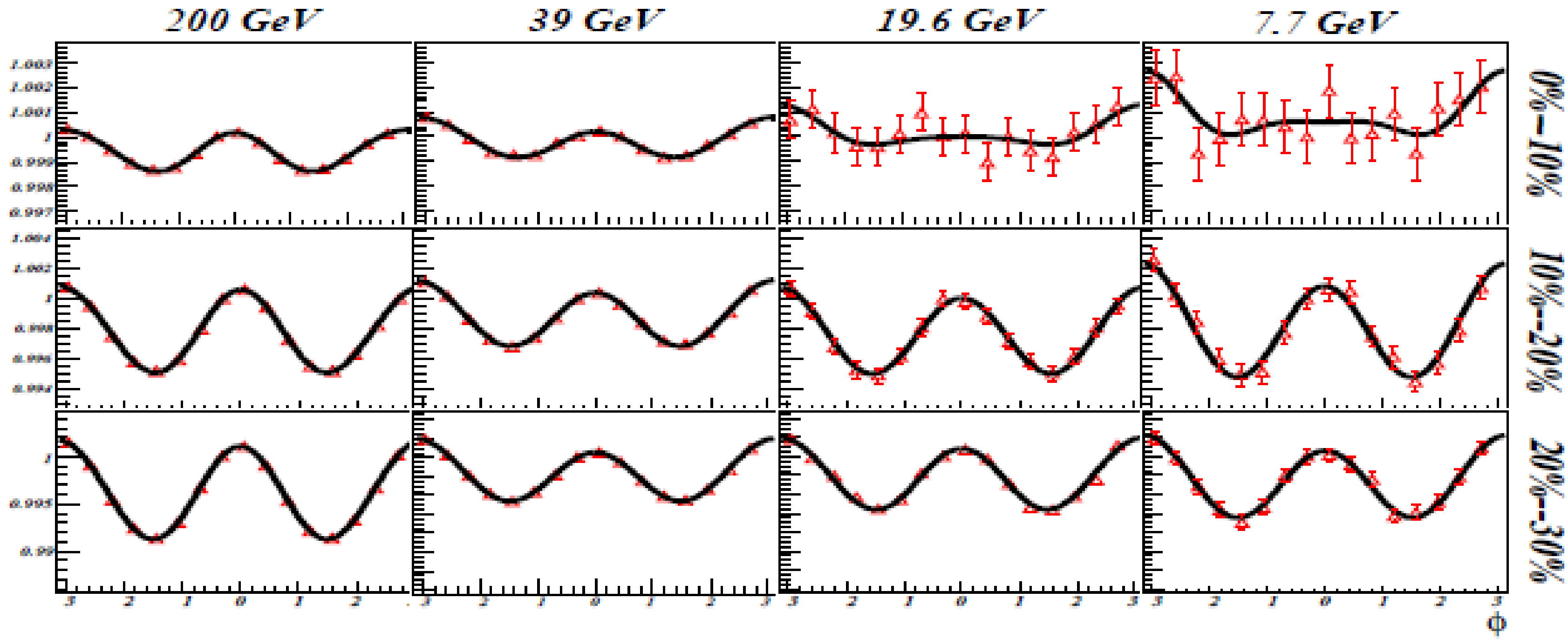
$0.2 < p_{T,a}, p_{T,b} < 4$ GeV/c
$-0.9 < \eta_a, \eta_b < 0.9$; $\Delta\eta > 0.7$

Niseem Magdy Abdelrahman Thursday

A double-peak ridge at $|\eta| < 0.9$ is observed till 7.7 GeV

Ridge vs. Beam Energy(II)

Long range correlation for TPC-FTPC



$0.2<p_{T,a}, p_{T,b}<4$ GeV/c

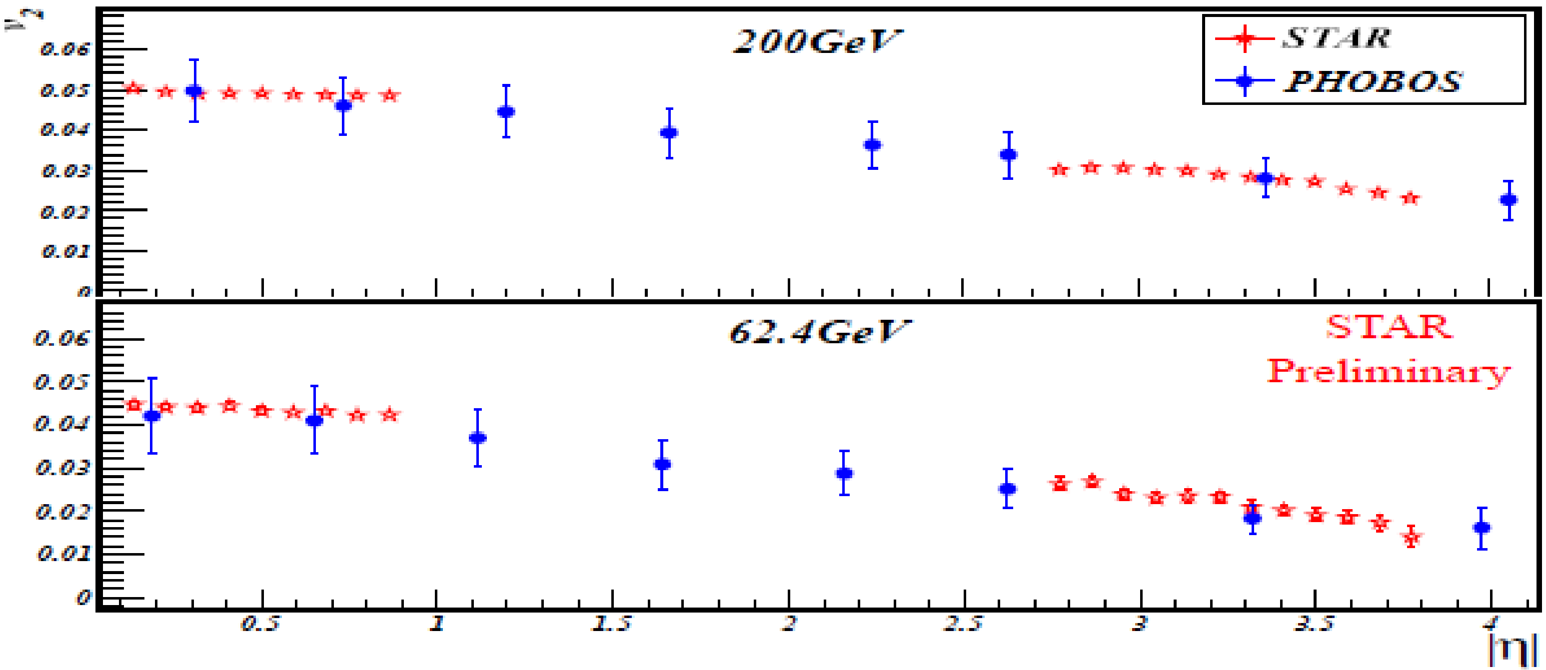
$|\eta_a|<0.9, 2.8<|\eta_b|<3.8,$

$\Delta\eta$~3.3

Niseem Magdy Abdelrahman Thursday

A Ridge between forward and middle rapidity is also observed till 7.7 GeV

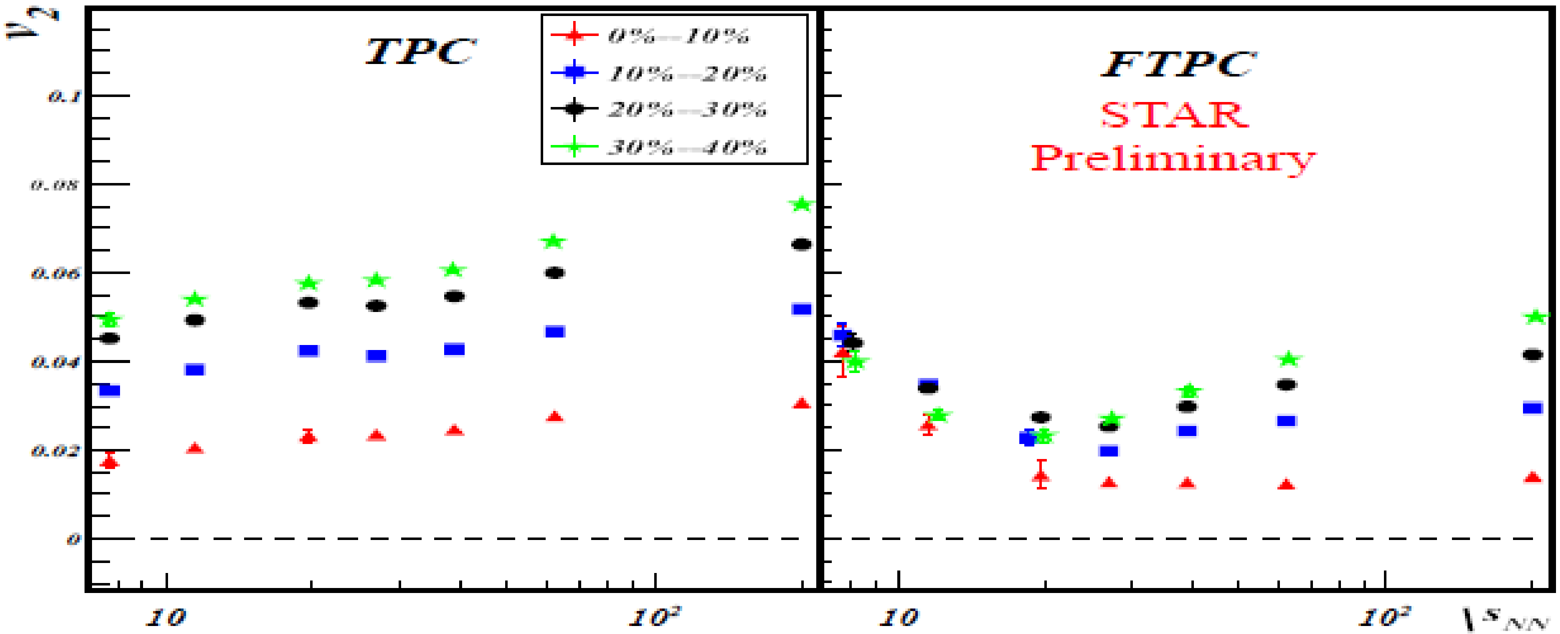
V_2 at forward rapidity



The v_2 extracted from long-range correlation from STAR are consistent with that from PHOBOS in Au+Au collisions at both 62 and 200 GeV

V_2 vs. beam energy

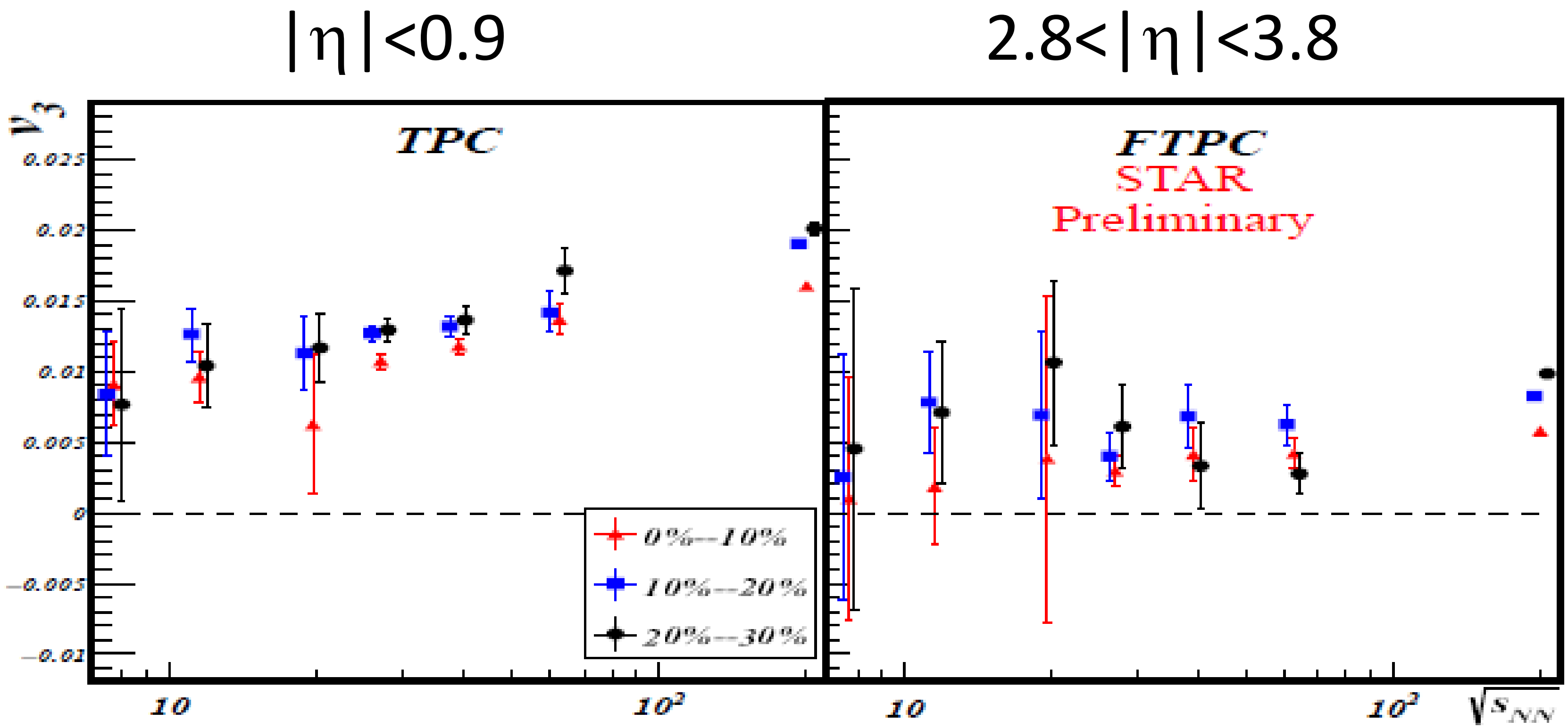
|η|<0.9 2.8<|η|<3.8



V_2 increases with the beam energy at middle rapidity

At forward rapidity, non-monotonic behaviors are found for v_2 vs. beam energy

V_3 vs. beam energy



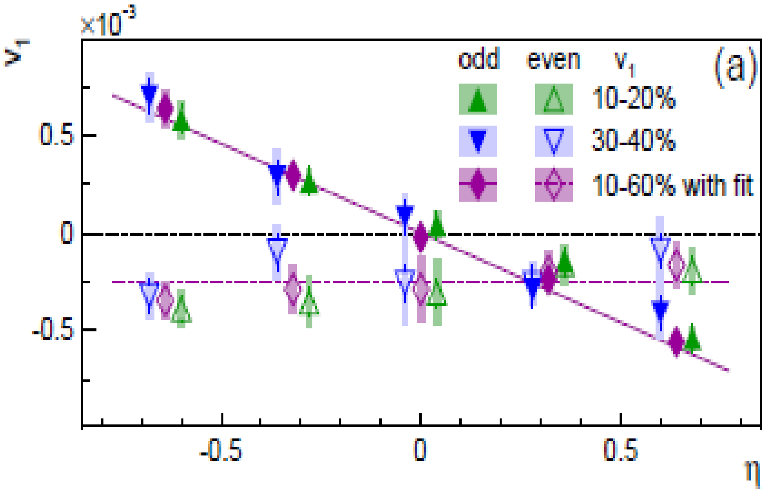
V_3 increases with the beam energy at middle rapidity

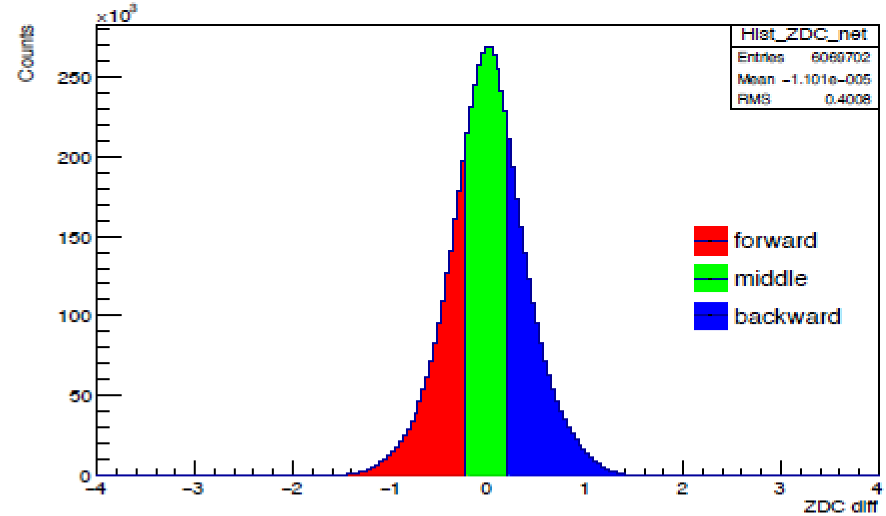
At forward rapidity, it is approximately constant

- II. Longitudinal fluctuation and decorrelations

V_1 in AuAu 200GeV

Phys. Rev. Lett. 111 (2013) 232302





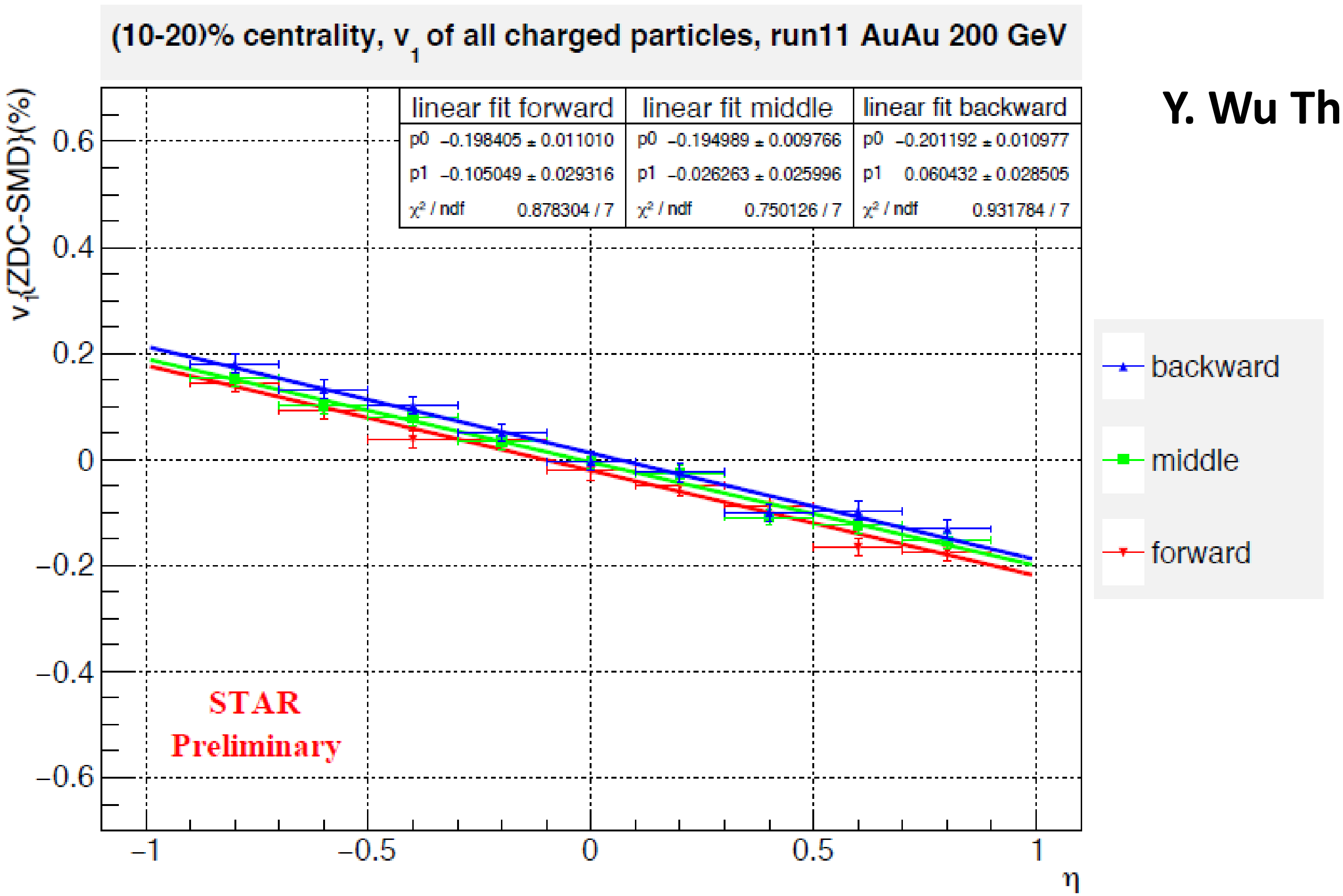
ZDC(backward) –ZDC(Forward)

A rapidity independent v_1(even) is observed by ALICE in PbPb

It could be due to the E-by-E fluctuation of initial energy density, shift of center of mass, or momentum conservation

To further test these effects, the v_1(odd) is measured in three event groups separated by energy of **ZDC(backward) –ZDC(Forward)**

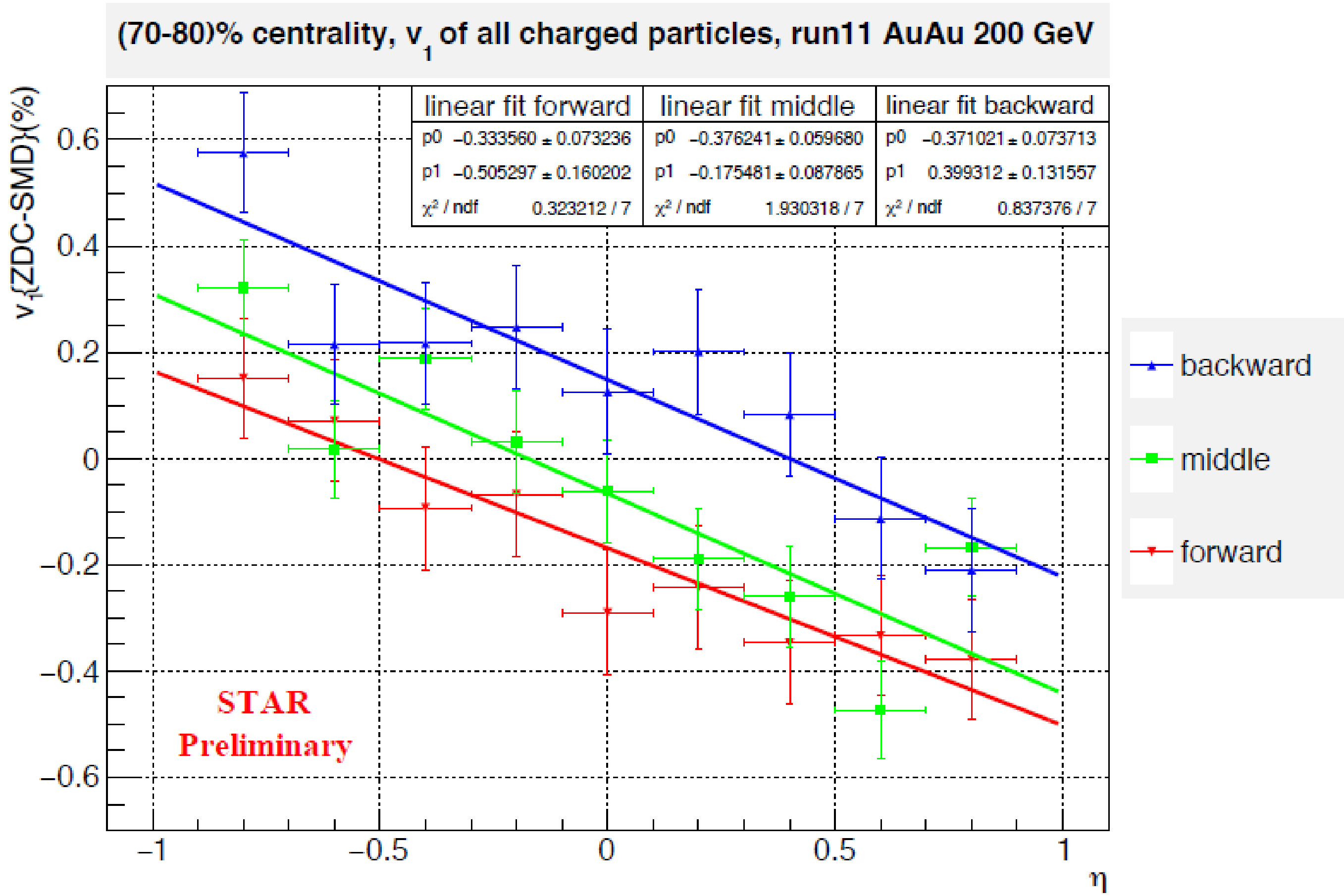
Results for Centrality 10-20%



Y. Wu Thursday

In central AuAu collisions, the v_1(odd) in three event groups are similar with each other and all are around 0 at η~0

Results for Centrality 70-80%



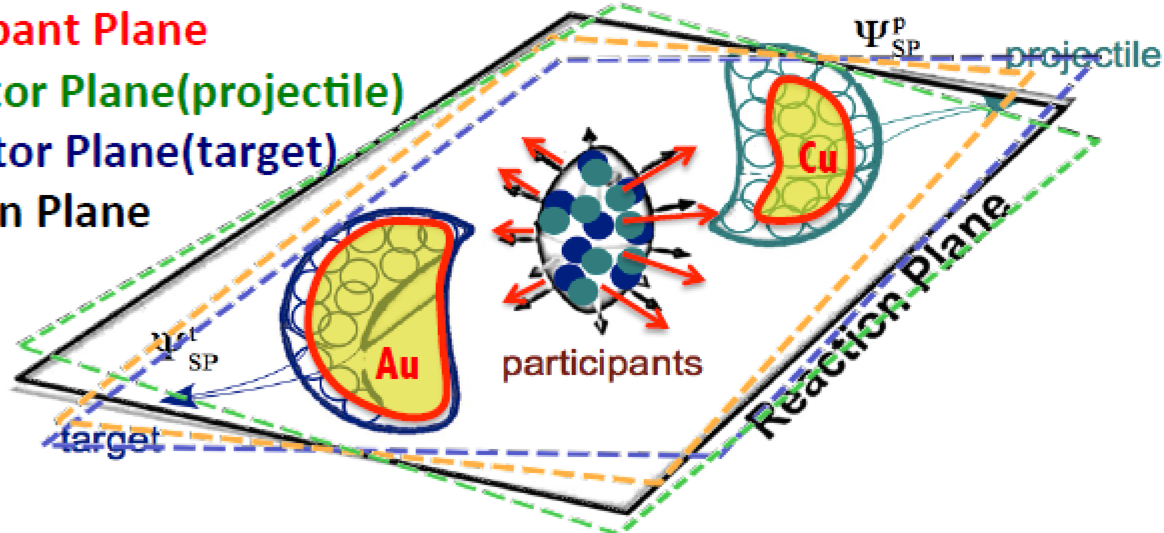
Linear fit formula: $y = p0*(x - p1)$.

Y. Wu (Thursday)

In the 70-80% AuAu collisions, the difference between v_1(forward) and v_1(backward) is weakly dependent on the η. It could be due to initial longitudinal fluctuation.

v_1 fluctuation in CuAu 200GeV

$\Psi^{(n)}_{PP}$: Participant Plane
Ψ^{p}_{SP} : Spectator Plane(projectile)
Ψ^{t}_{SP} : Spectator Plane(target)
Ψ_{RP} : Reaction Plane



- ✓ **Spectator is expected to fluctuate**

  $\rightarrow \Psi^{p}_{SP} \neq \Psi_{PP} \neq \Psi^{t}_{SP}$ $\rightarrow v_1(\Psi^{p}_{SP}) \neq v_1(\Psi^{t}_{SP})$

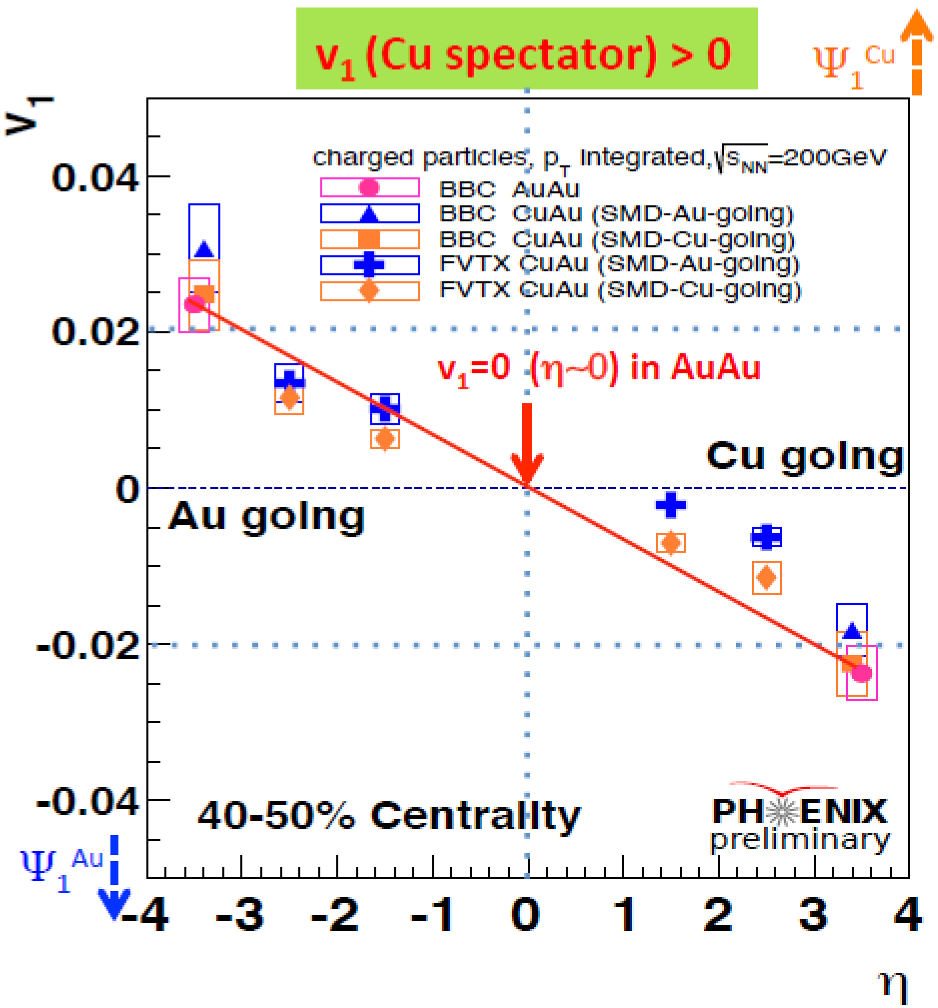
  $\rightarrow v_1 = v_1(\text{Traditional}) + v_1(\text{SP fluctuation})$

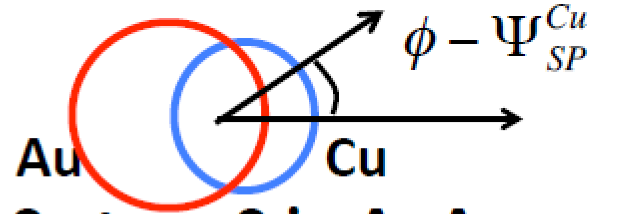
  $v_1(\text{Traditional})$: $v_1(\eta) = -v_1(-\eta)$

  $v_1(\text{SP Fluctuation})$: $v_1(\eta) = v_1(-\eta)$

- ✓ **Are there two v_1 components in CuAu ?**
- ✓ **How asymmetric two v_1 components are in CuAu ?**

η Symmetric/Anti-symmetric v_1 in CuAu

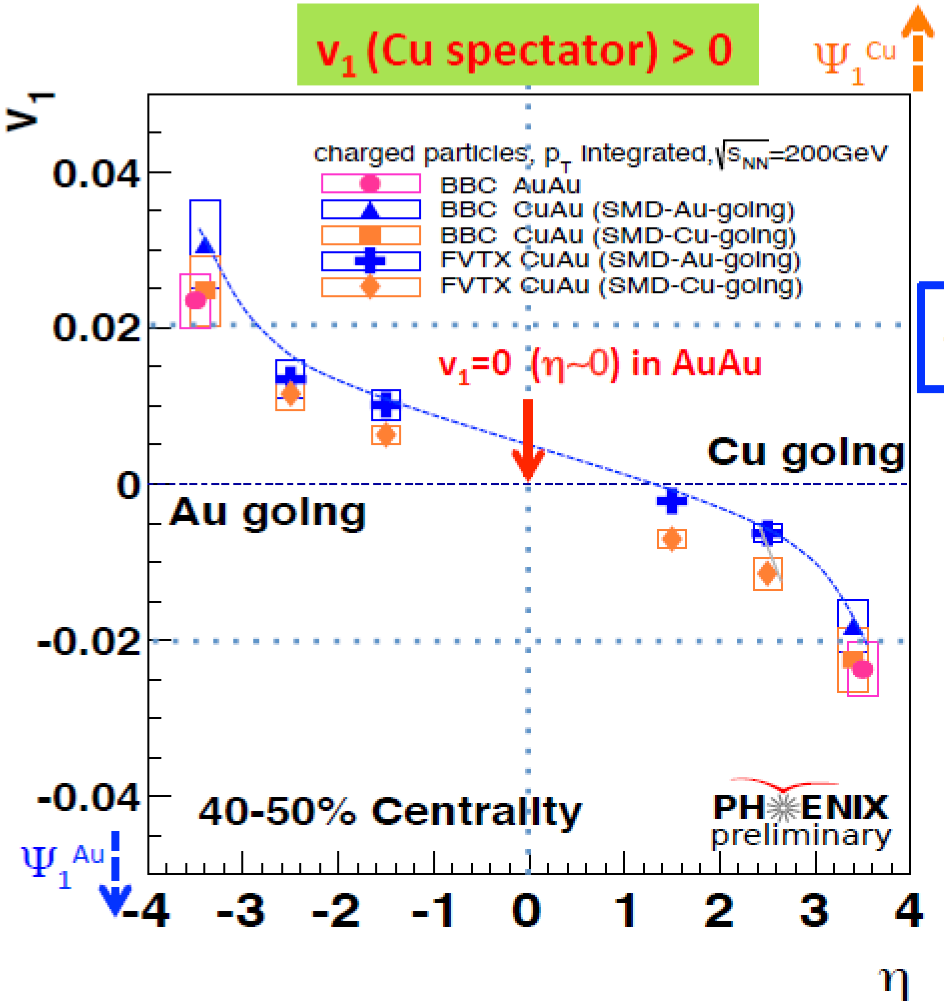


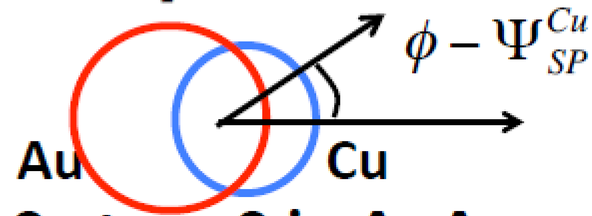


✓ $v_1 = 0$ at $\eta=0$ in AuAu

Hiroshi Nakagomi, QM14

η Symmetric/Anti-symmetric v_1 in CuAu

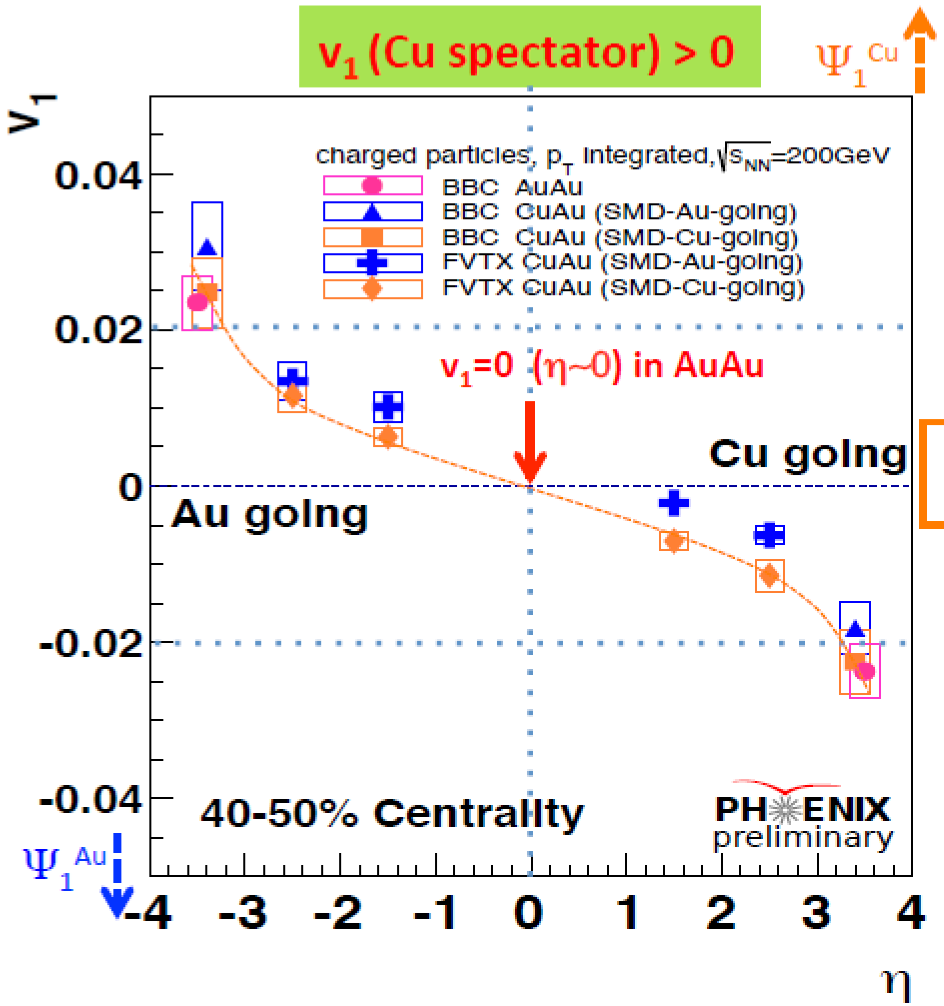


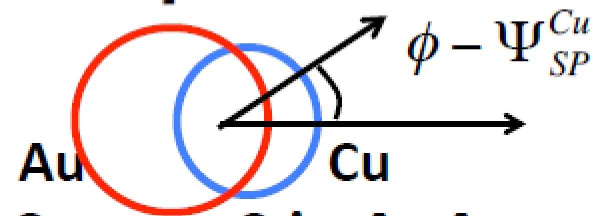


✓ v_1= 0 at η=0 in AuAu

✓ v_1 w.r.t Ψ^{Au}_{SP}

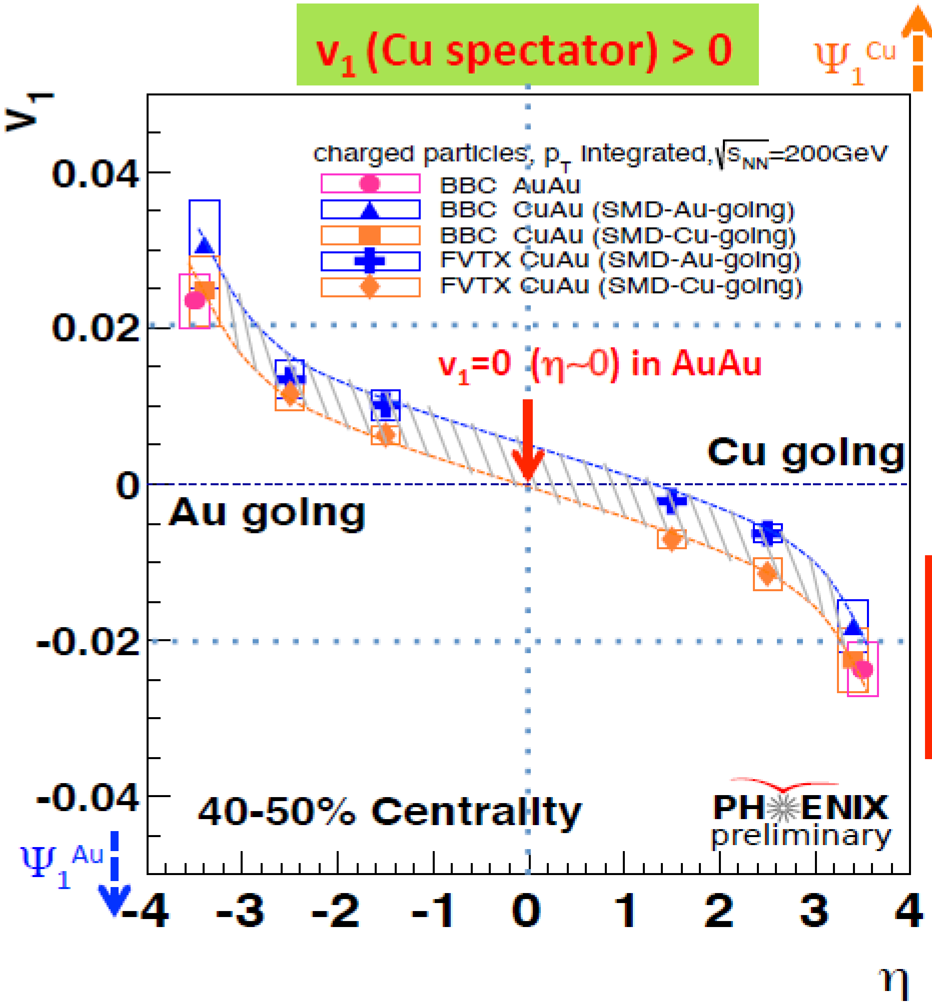
η Symmetric/Anti-symmetric v_1 in CuAu

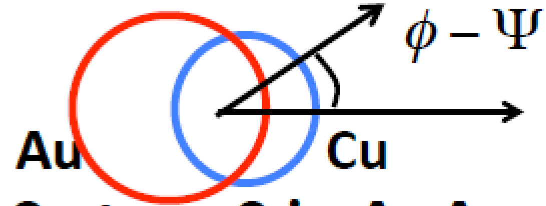




- ✓ v_1= 0 at η=0 in AuAu
- ✓ v_1 w.r.t Ψ_{SP}^{Au}
- ✓ v_1 w.r.t Ψ_{SP}^{Cu}

η Symmetric/Anti-symmetric v_1 in CuAu

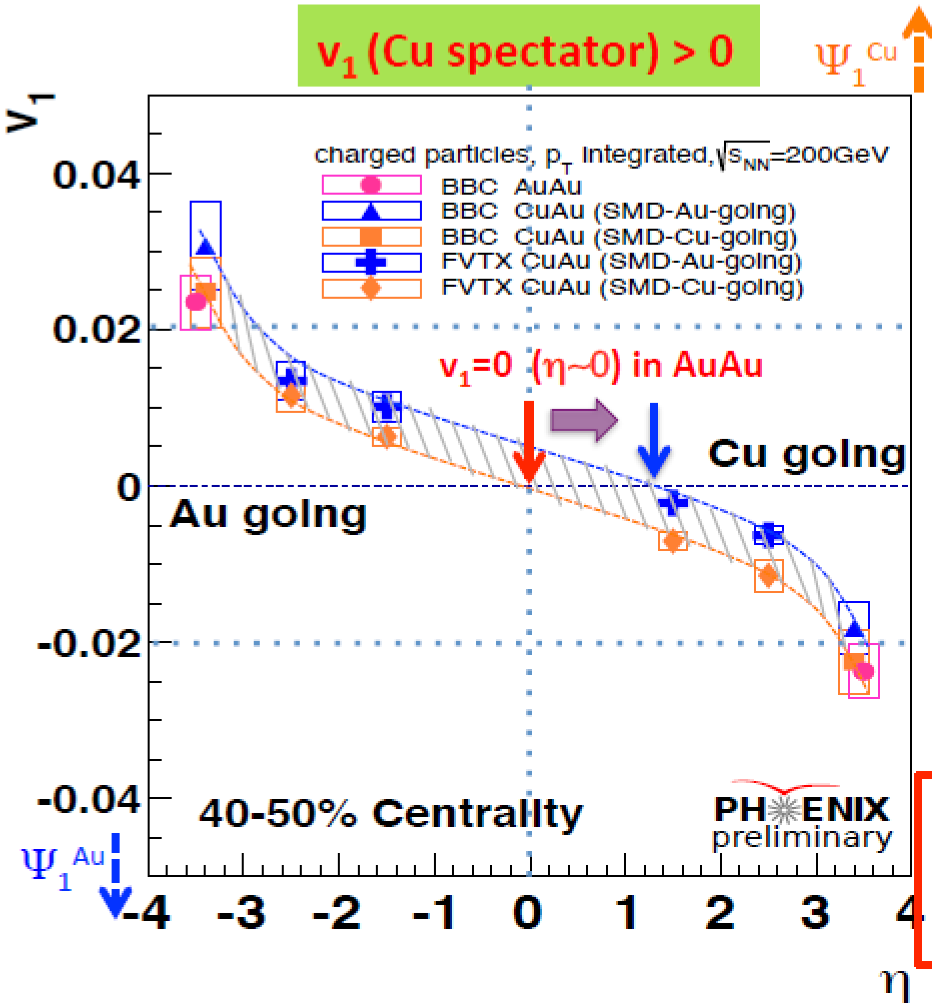


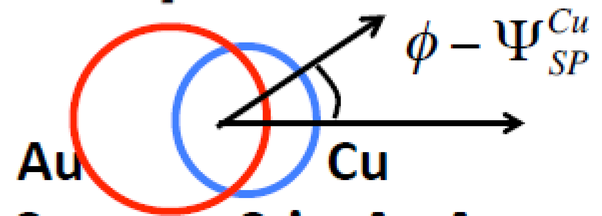


$\phi - \Psi_{SP}^{Cu}$

- ✓ v_1= 0 at η=0 in AuAu
- ✓ v_1 w.r.t Ψ_{SP}^{Au}
- ✓ v_1 w.r.t Ψ_{SP}^{Cu}
- ✓ v_1(flu) = (blue−orange)/2
- ✓ v_1(tra) = (blue+orange)/2

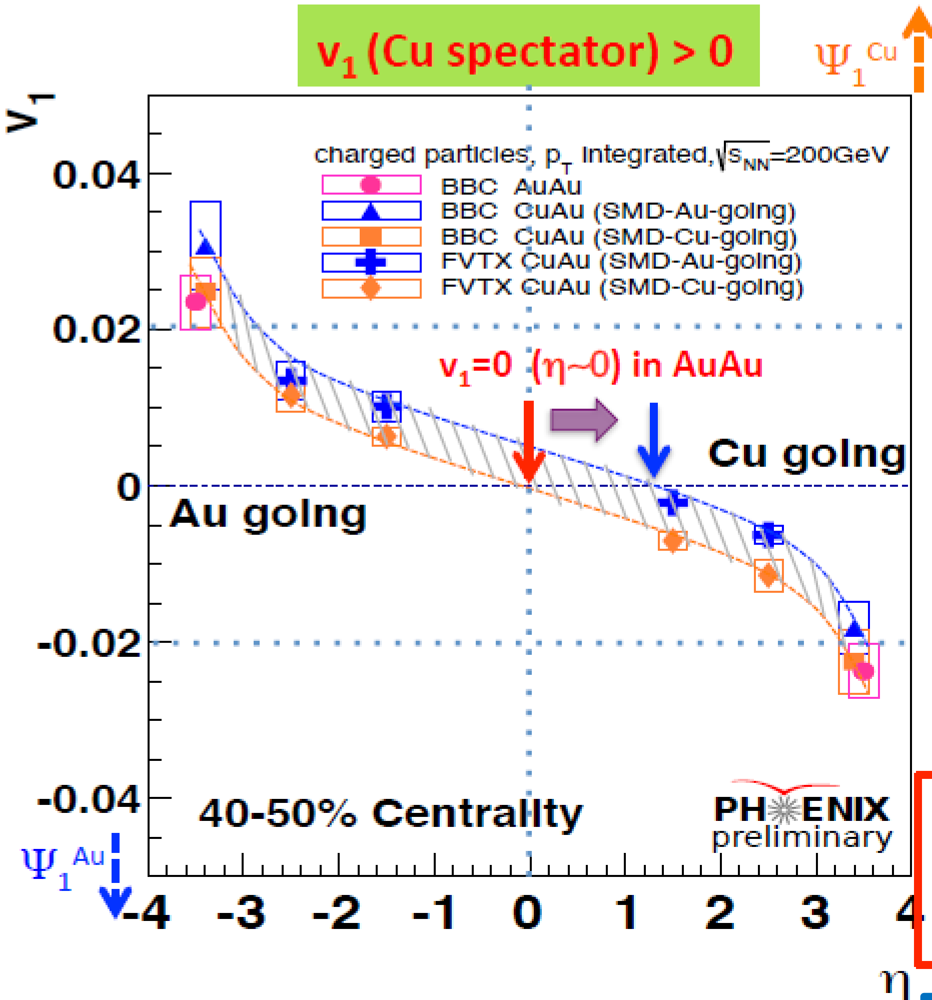
η Symmetric/Anti-symmetric v_1 in CuAu

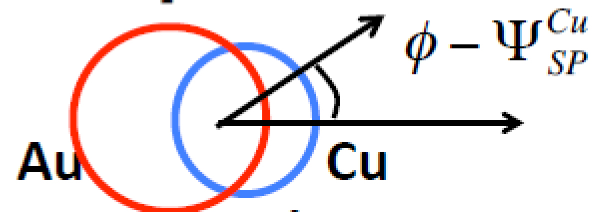




- ✓ v_1= 0 at η=0 in AuAu
- ✓ v_1 w.r.t Ψ_{SP}^{Au}
- ✓ v_1 w.r.t Ψ_{SP}^{Cu}
- ✓ v_1(flu) = (blue−orange)/2
- ✓ v_1(tra) = (blue+orange)/2
- ✓ v_1(tra) is shifted to Cu going side

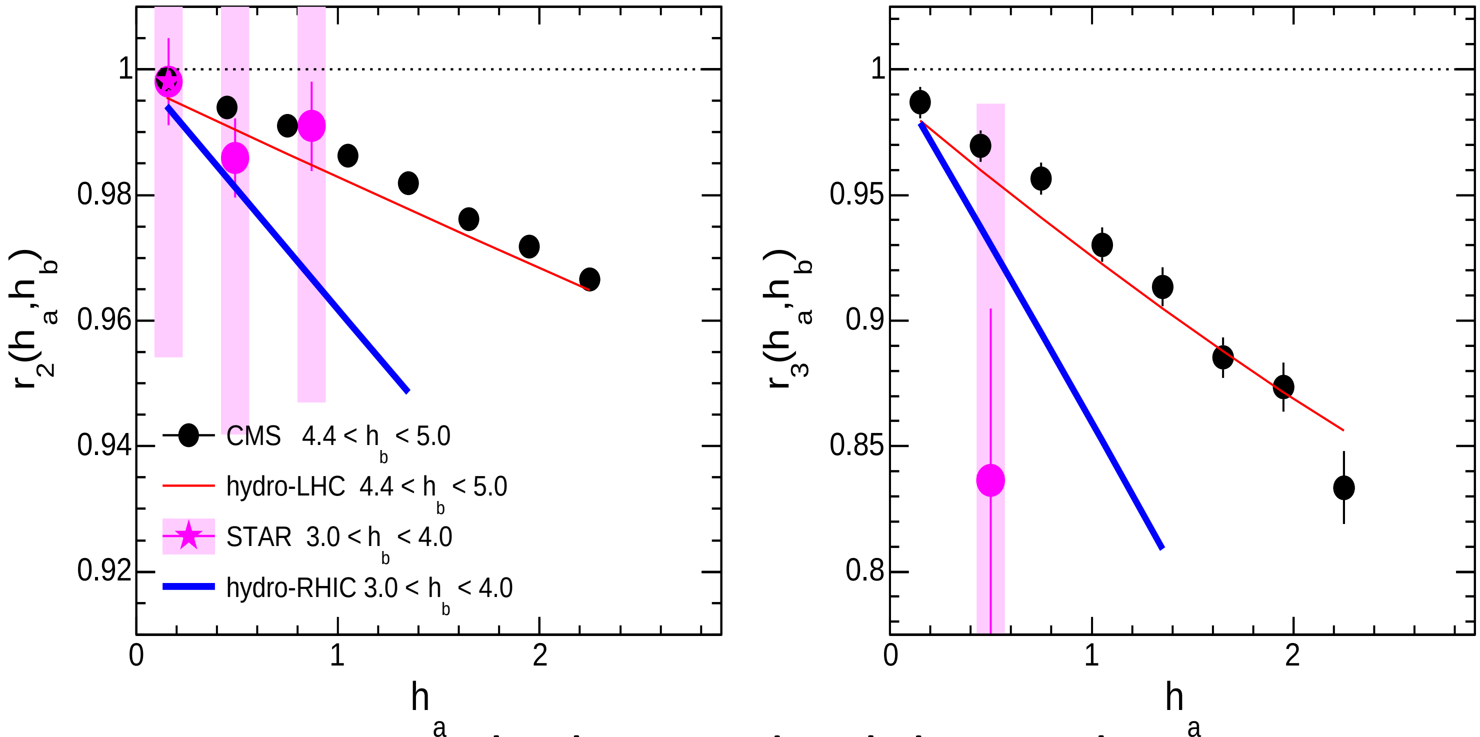
η Symmetric/Anti-symmetric v_1 in CuAu





- ✓ $v_1 = 0$ at $\eta=0$ in AuAu
- ✓ v_1 w.r.t Ψ_{SP}^{Au}
- ✓ v_1 w.r.t Ψ_{SP}^{Cu}
- ✓ $v_1(\text{flu}) = (\text{blue} - \text{orange})/2$
- ✓ $v_1(\text{tra}) = (\text{blue} + \text{orange})/2$
- ✓ $v_1(\text{tra})$ is shifted to Cu going side
- ✓ $V_1(\text{flu}) > 0 : v_1(\Psi_{sp}^{Au}) > v_1(\Psi_{sp}^{Cu})$

Longitudinal decorrelations of anisotropic flow



The longitudinal decorrelations is stronger in RHIC comparing with LHC

$$\mathbf{r_n(\eta^a,\eta^b) \equiv \frac{V_{n\Delta}(-\eta^a,\eta^b)}{V_{n\Delta}(\eta^a,\eta^b)}}$$

$$V_{n\Delta}(\eta^a,\eta^b) = \left\langle\left\langle \cos\left[n\left(\phi^a - \phi^b\right)\right]\right\rangle\right\rangle$$

Upgrade of iTPC(|η|<1.7) and Forward Hadron Cal (2.4<|η|<4) in STAR will much improve the current measurements

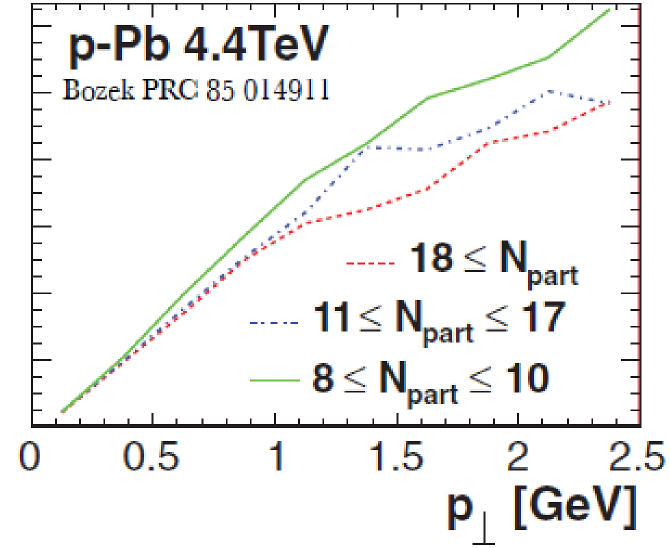
II. The Ridge in Small Collision System: p+Au, d+Au and ^{3}He+Au

What is the origin of the ridge in p+A?

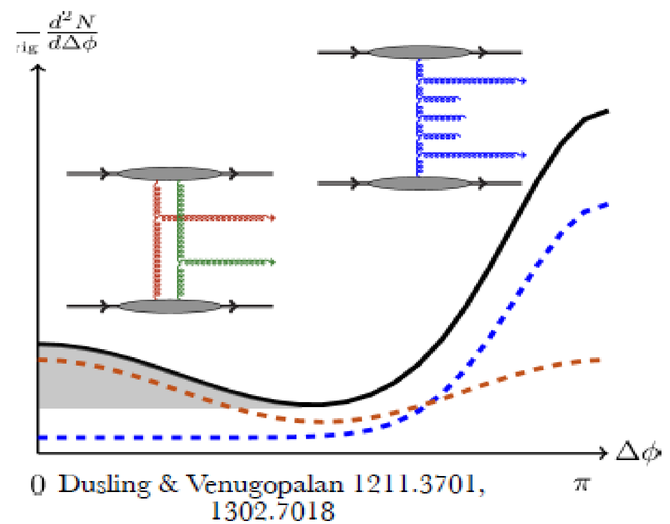
Key Question I: What generates the ridge in small collision systems?

✓ Final state interaction: Hydrodynamics?

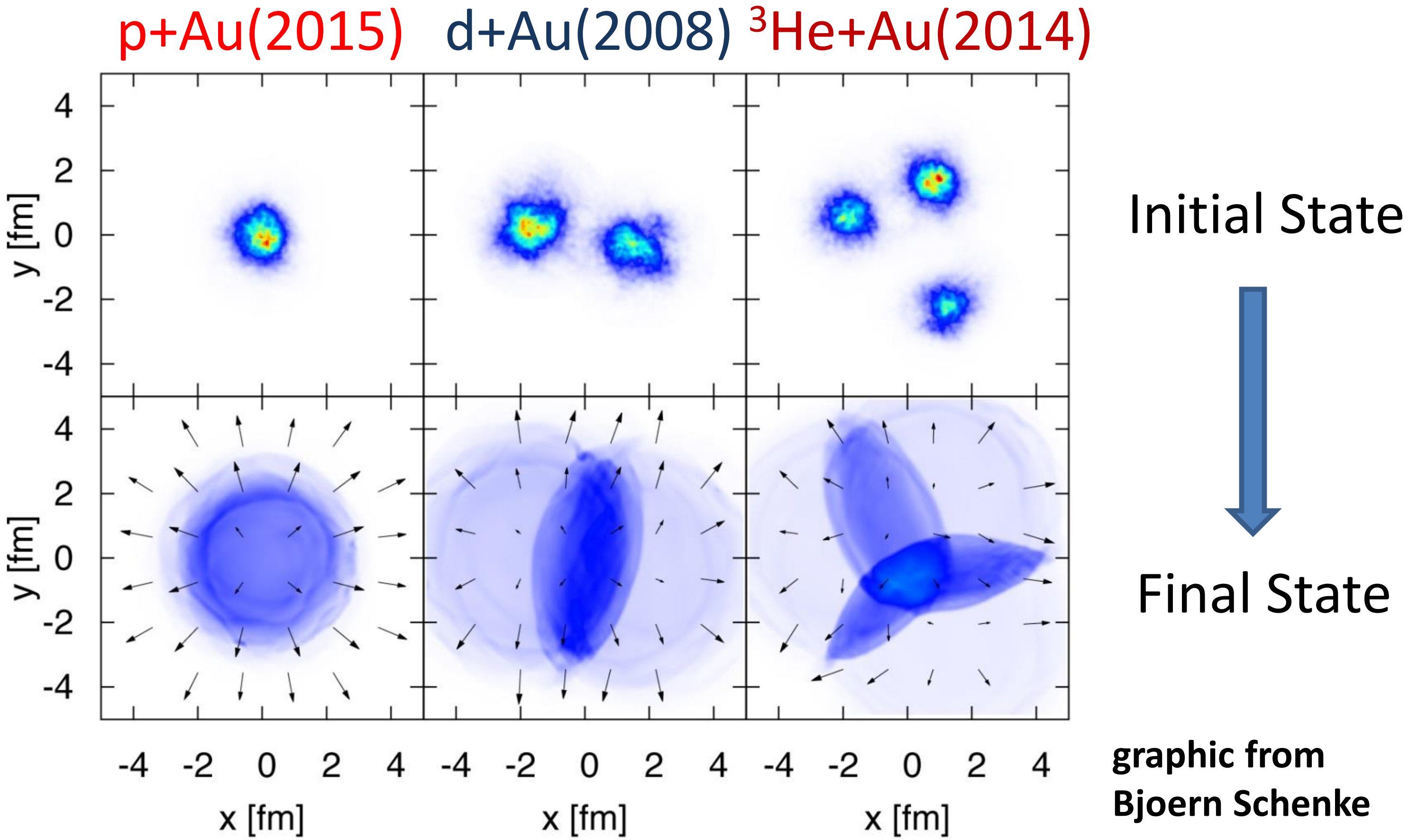
✓ Initial momentum correlation: CGC?



Key Question II: Could the Glasma transverse expansion give the QGP fluid an ***initial radial boost***(pre-equilibrium flow)?



Geometry engineering

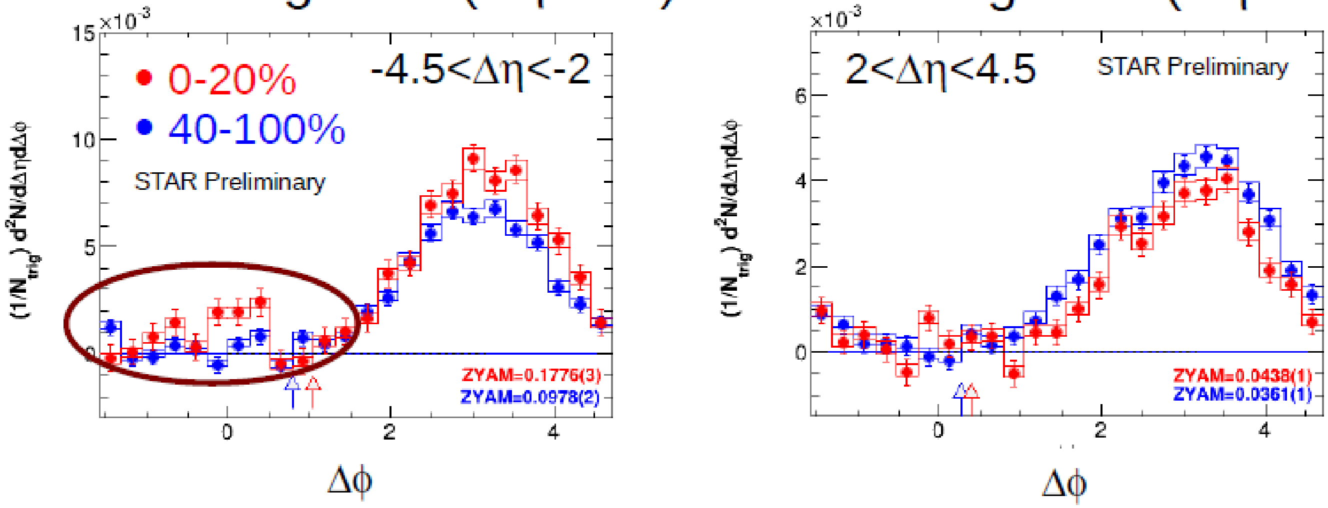


graphic from Bjoern Schenke

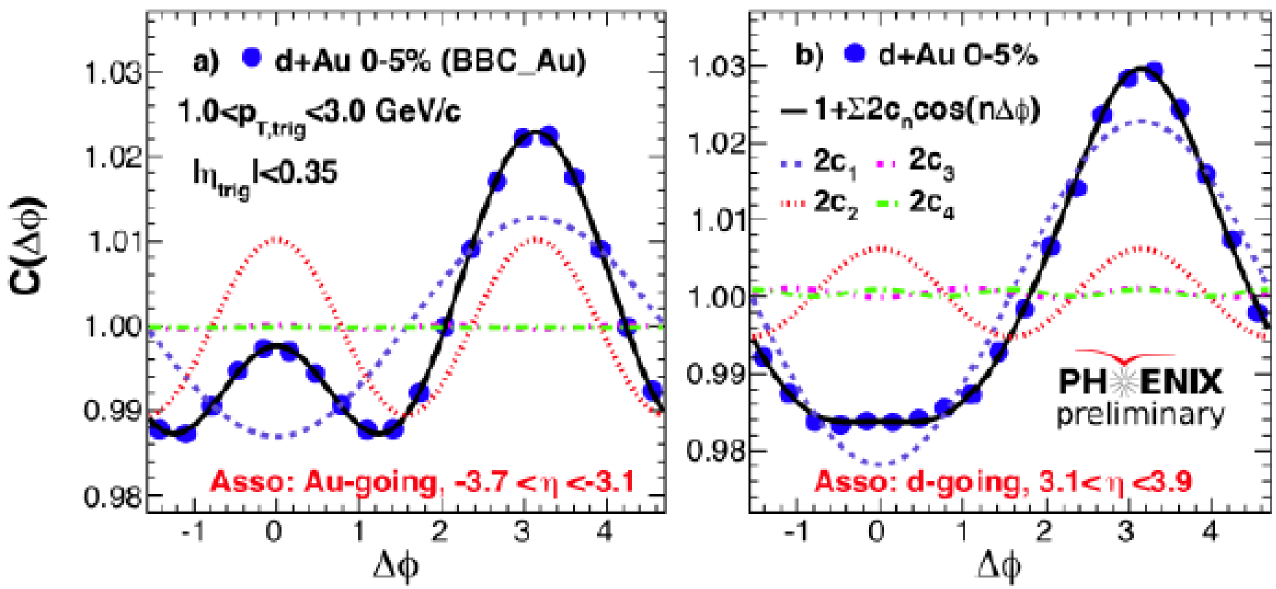
- Different initial geometry → different final state particle emission for p+Au, d+Au and ^{3}He+Au collisions
- The dedicated heavy ion machine RHIC can provide this kind of test with its unmatched versatility

Ridge in dAu

Au-Going Side (Δη ≈ -3) d-Going Side (Δη ≈ 3)



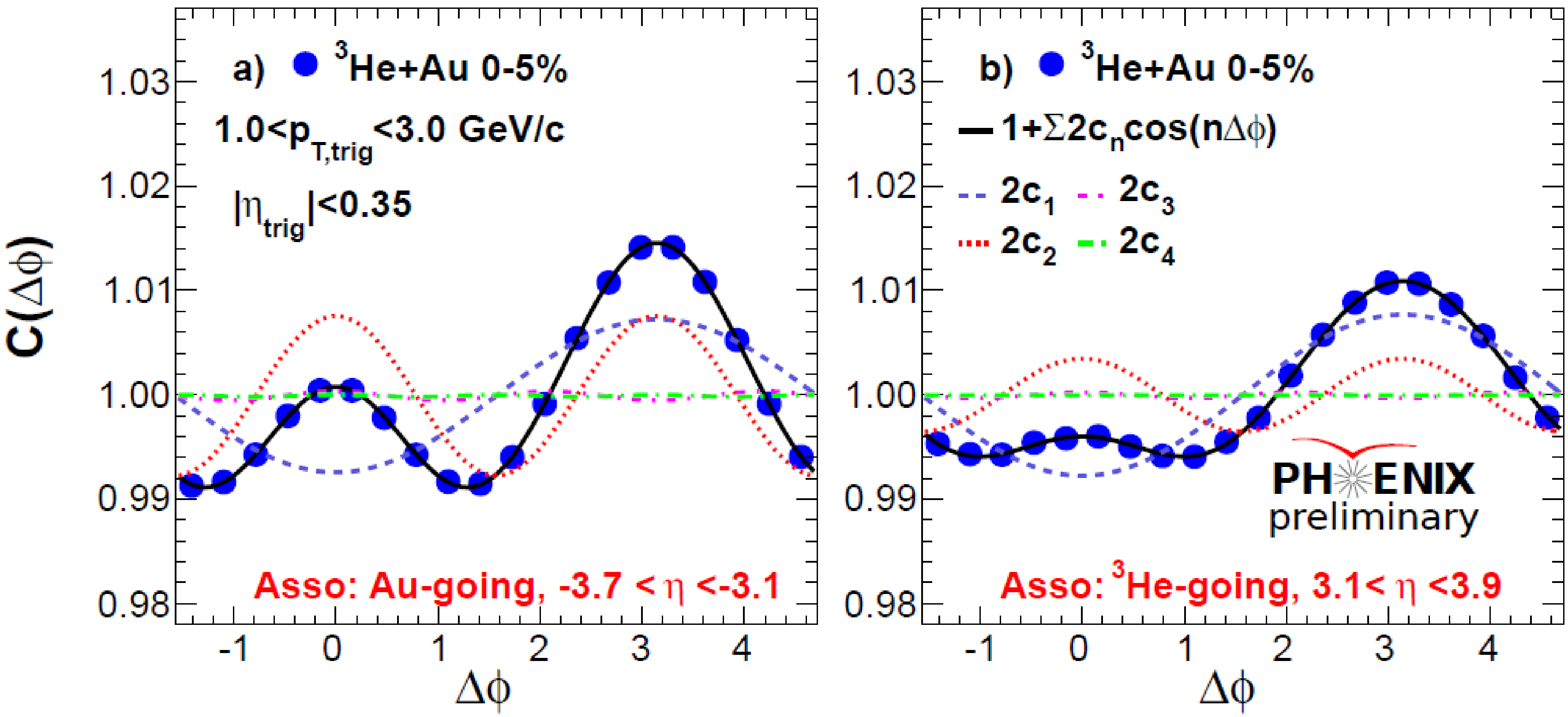
Y. Li QM14



S. Huang QM14

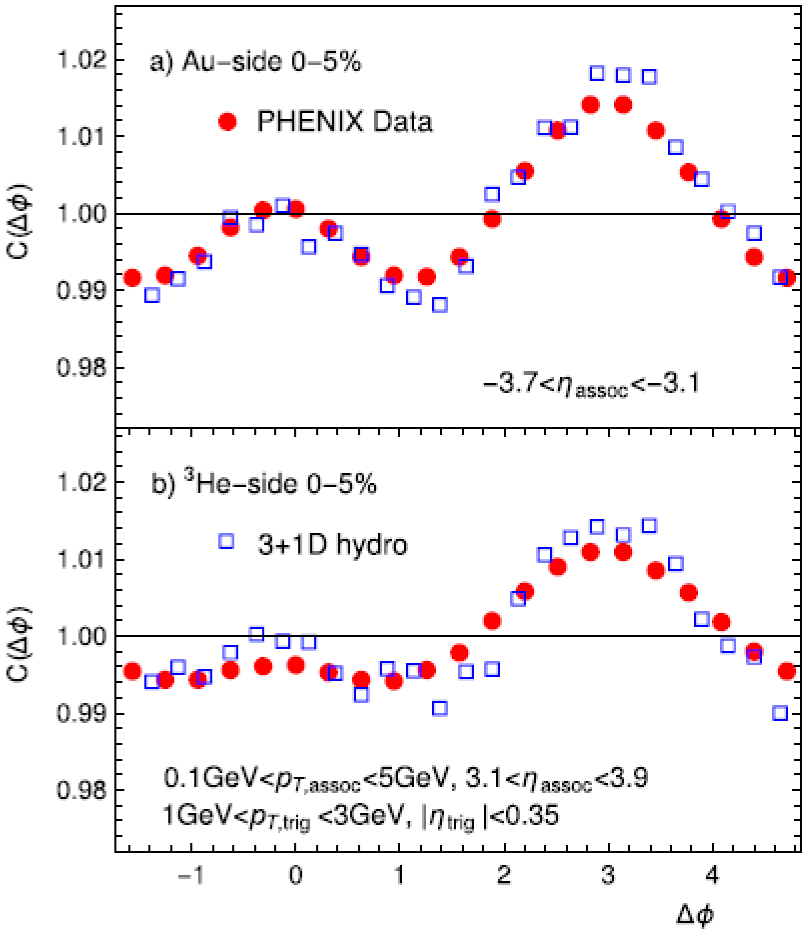
Both STAR and PHENIX observed the Ridge in central dAu on Au-going side

Ridge in ^{3}He+ Au



A ridge is even seen at ^{3}He going side

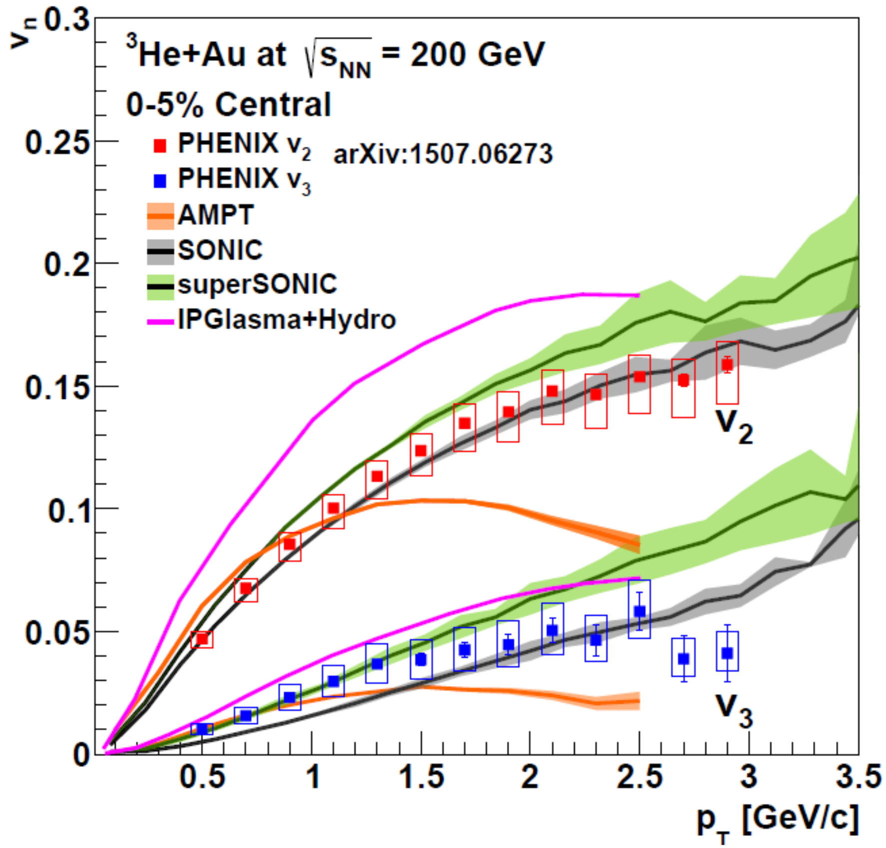
Comparing with (3+1)D hydro. calculation



- The calculation from 3+1 dimension hydro can reproduce the ridge on both Au-going and ^{3}He-going side

P. Bożek, W. Broniowski / Physics Letters B 747 (2015) 135–138

V_n in ^{3}He+Au



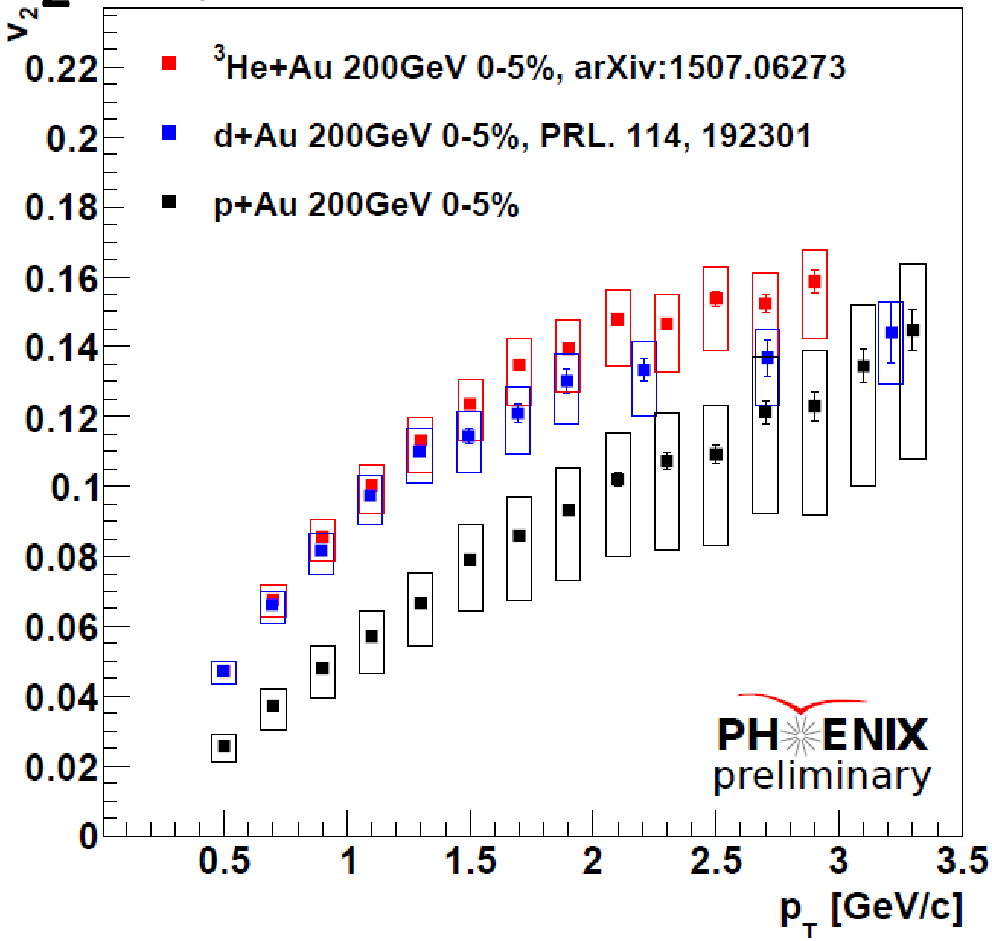
AMPT: arXiv:1501.06880 SONIC: arXiv:1502.04745 IP+Hydro:arXiv:1407:7557

Several models can reproduce the v_n measurements in ^{3}He+Au collisions

The v_3 from superSONIC with pre-equilibrium flow is almost a factor two larger than that from SONIC(w/o pre-equ flow)

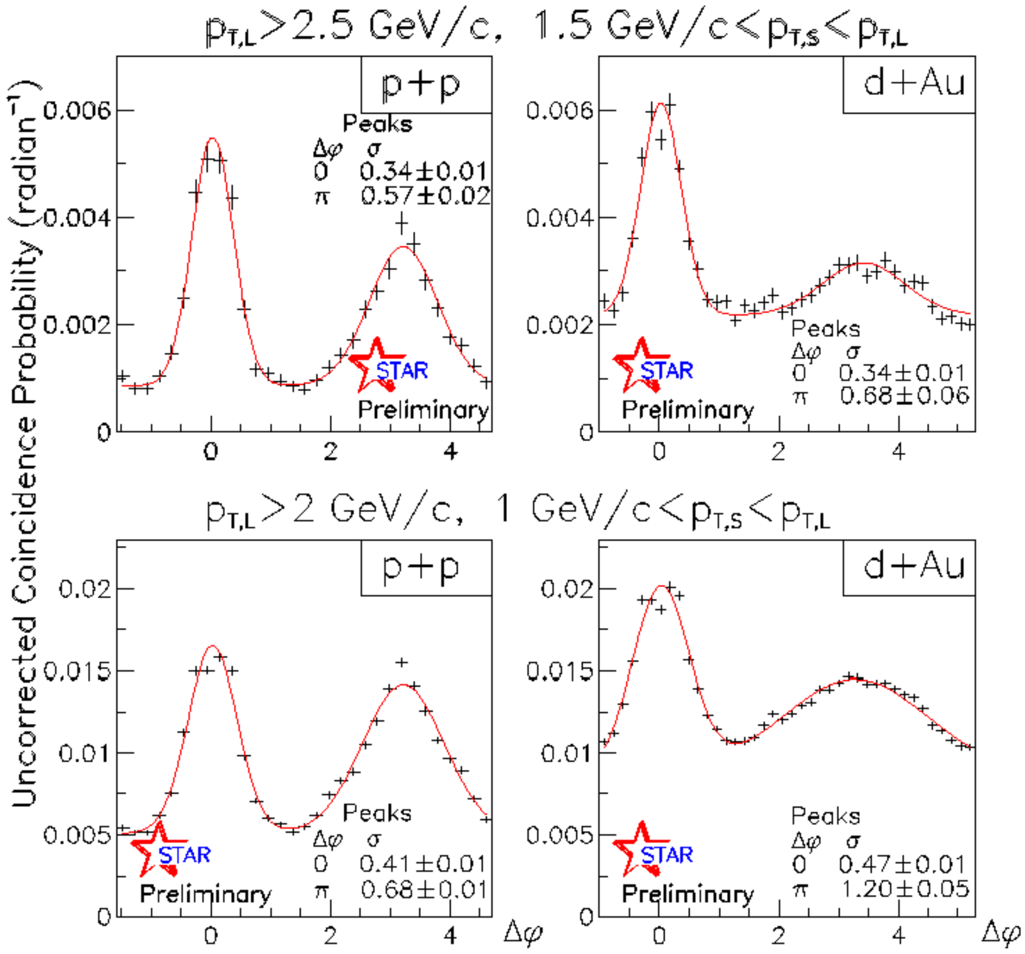
More precise measurement of v_3 are required to distinguish them

V_2 in p(d,^{3}He)+Au 200 GeV



- The v_2 from central p+Au collisions is lower than that of central d+Au and ^{3}He+Au collisions
- Smaller initial geometry eccentricity → smaller v_2

Forward di-hadon azimuthal correlations



A direct evidence for CGC in dAu 200 GeV !?

Will the suppression disappear at lower energy dAu collisions?

Answer will be found with dAu energy scan in 2016

Summary

- In AuAu collision, both v_2 and v_3 increase with beam energy at the middle rapidity. While at the forward rapidity, a non-monotonic behavior is found for v_2 with beam energy, and v_3 is almost constant
- The v_1(odd) from events with large forward ZDC energy is different with that from events with large backward ZDC energy. The difference is weekly dependent on η, and could be due to the longitudinal fluctuation. This fluctuation may also lead to $v_1(\Psi_{sp}^{Au})>v_1(\Psi_{sp}^{Cu})$
- The ridge in small collision system is related to the initial geometry . More precise v_3 measurement in future is crucial for studying of pre-equilibrium flow