Two particle correlation measurements with respect to higher harmonic event planes at PHENIX

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Motivations

- ✧ **Dissect possible interplay between hard-scattered partons and hot dense medium**

- **Have definitive answer on what remains in correlations after v_n background subtractions**

- **Test path length dependence of parton energy loss via correlations relative to higher harmonic event planes**

Correlations and flow harmonics v_n at PHENIX

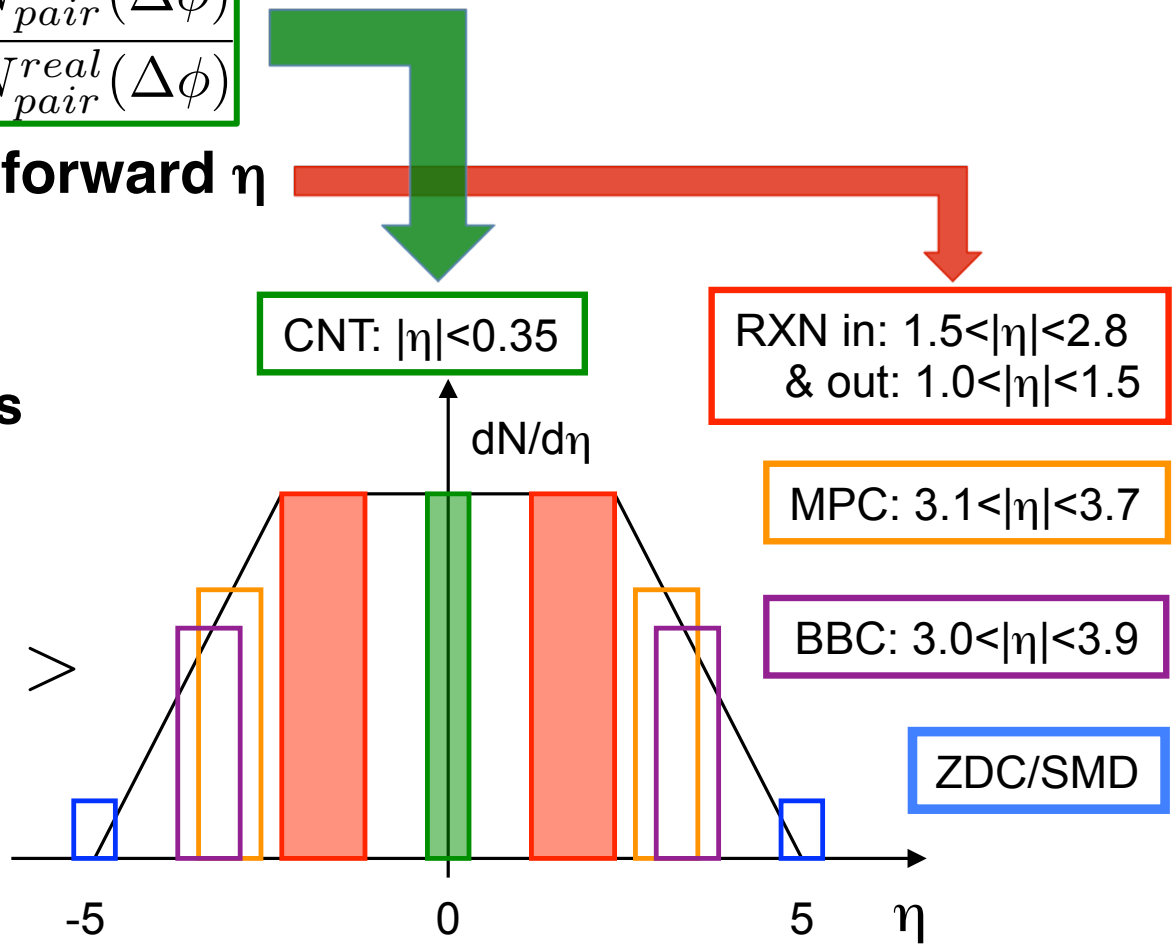
- **Two particle correlations**
  - » **Mid-rapidity hadrons, without η gap where jet contribution remains**

$$C(\Delta\phi) = \frac{N_{pair}^{real}(\Delta\phi)}{N_{pair}^{mix}(\Delta\phi)} \frac{\int \Delta\phi N_{pair}^{mix}(\Delta\phi)}{\int \Delta\phi N_{pair}^{real}(\Delta\phi)}$$

- **Event plane Ψ_n : RXN at forward η**
  - » **v_n measurements**
  - » **Trigger direction w.r.t. EP in sub-divided correlations**

- **v_n via EP method**

$$v_n = < \cos n(\phi - \Psi_n) >$$



Charged Hadron v_n and background shape in correlations

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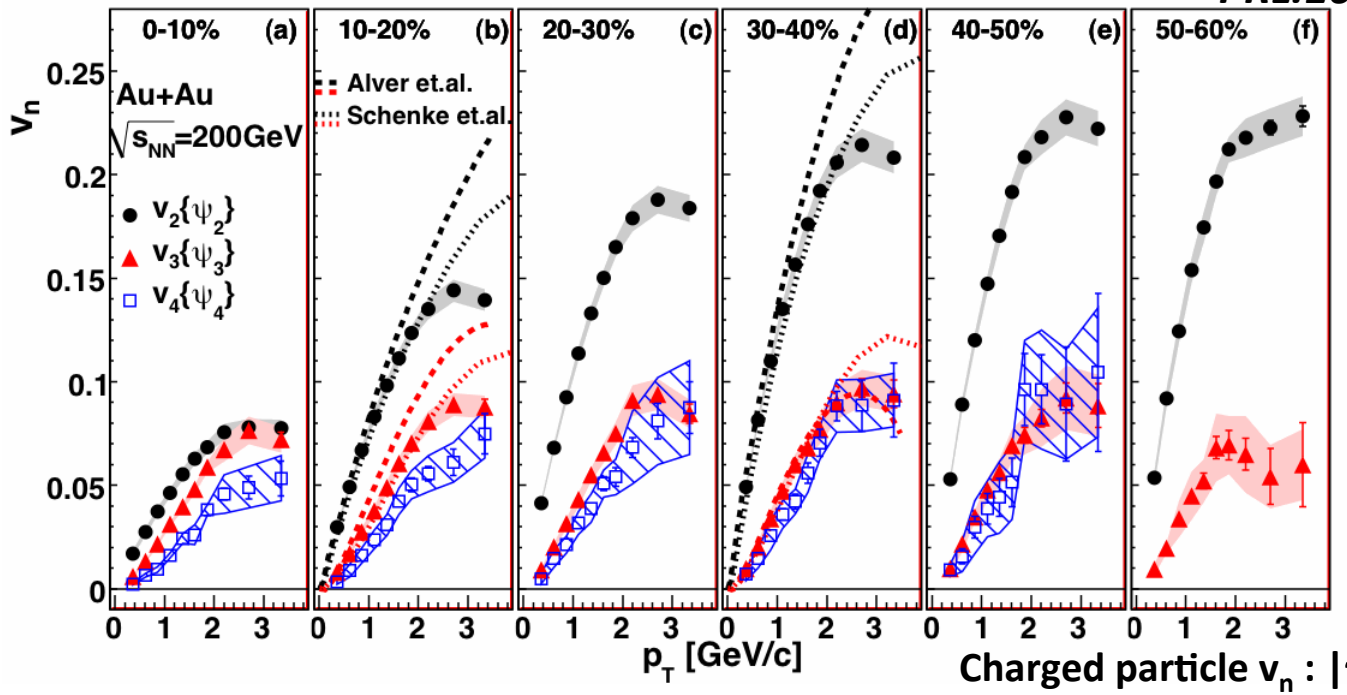


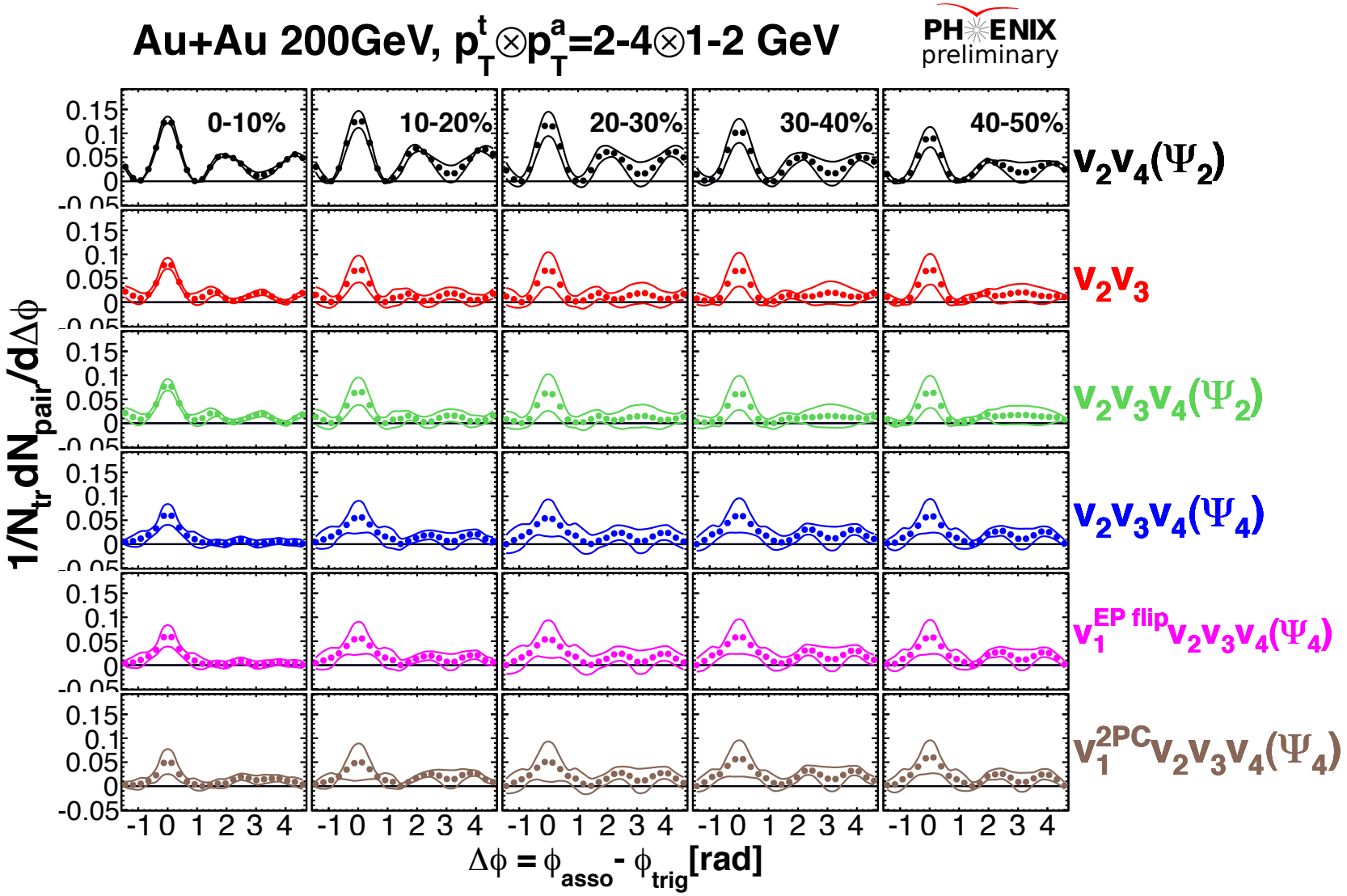
Charged particle v_n : $|\eta|<0.35$

Event plane Φ_n : $|\eta|=1.0\sim2.8$

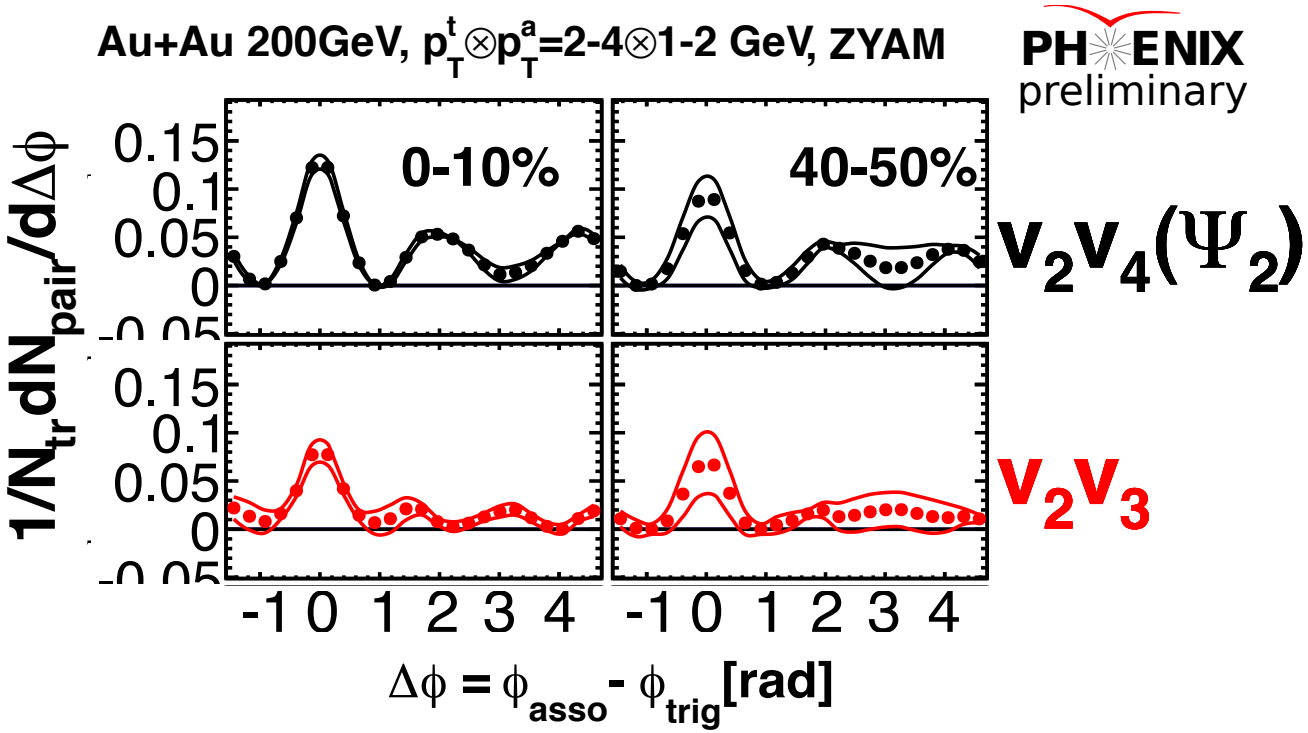
- **Input to v_n background subtractions**
- **Flow background shape**

$$\text{Flow} = b_0 \left\{ 1 + \sum_{i=1} 2 v_i^t v_i^a \cos\left(n\Delta\phi\right) \right\}$$

Correlations in fine centrality steps with various v_n background subtractions by ZYAM

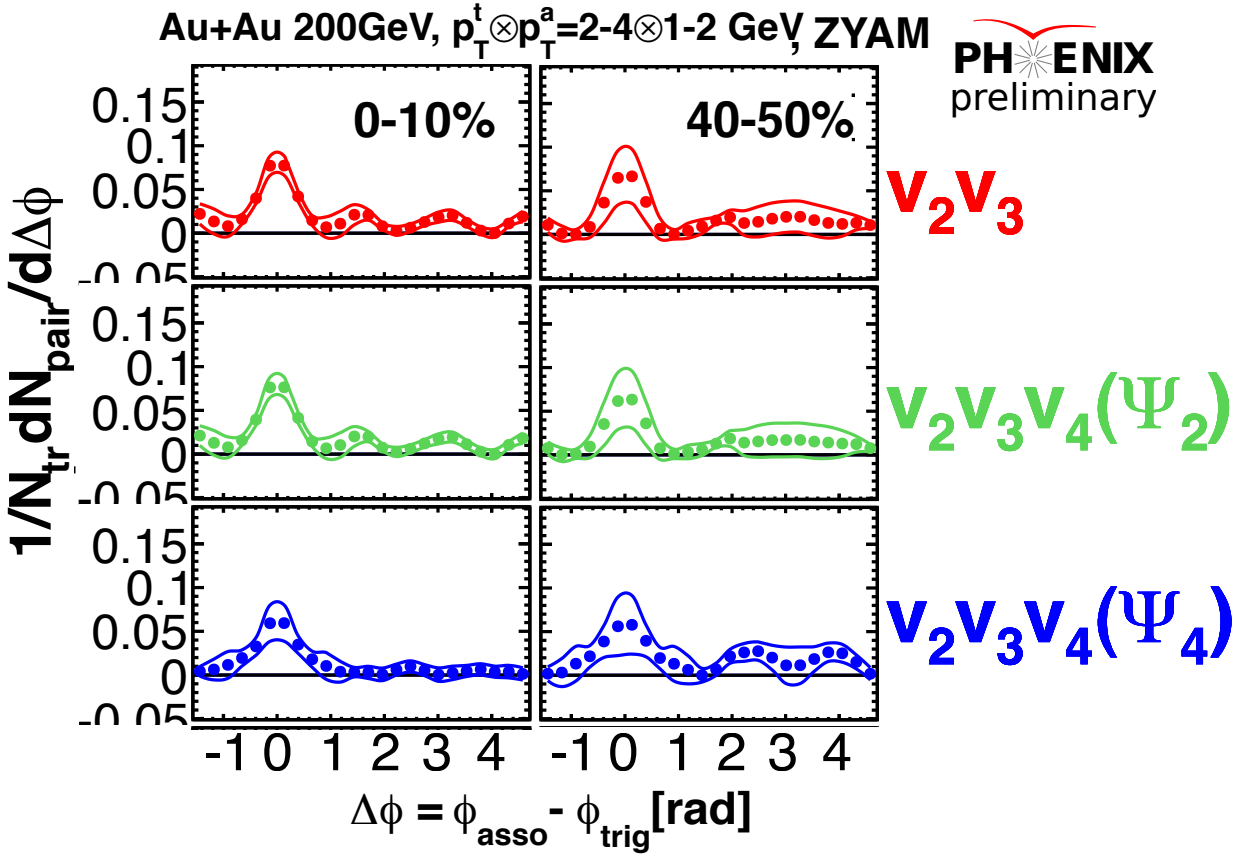


Impact of v_3 to away side residual



- **v_3 largely reduce away-side shoulder**
  - » Small residual at away side in most central
  - » Double hump almost gone in mid central

Sensitivity of away-side residual to v_4

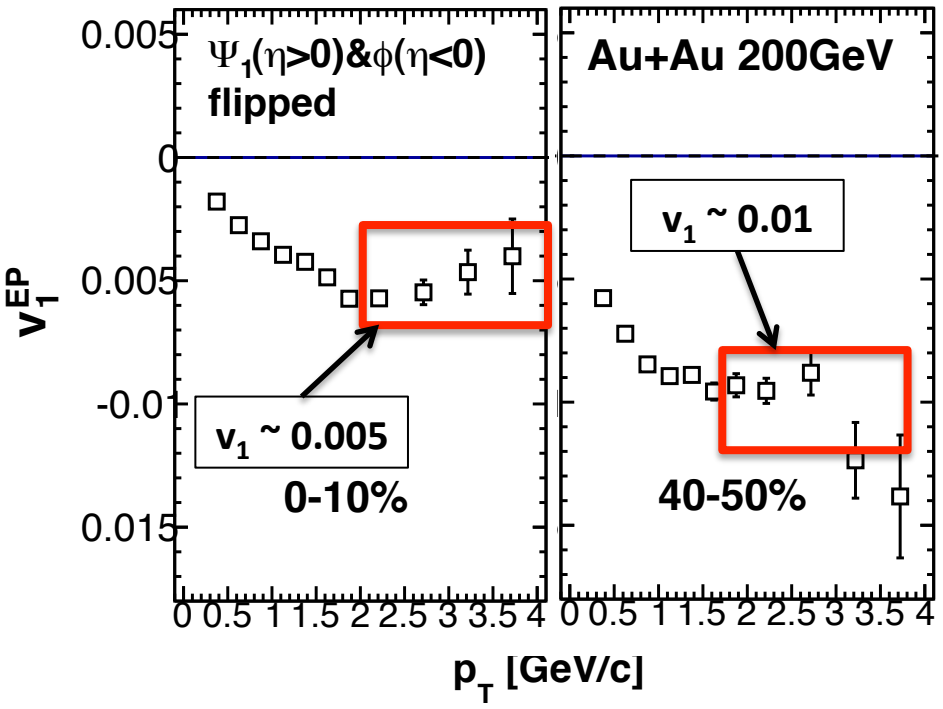


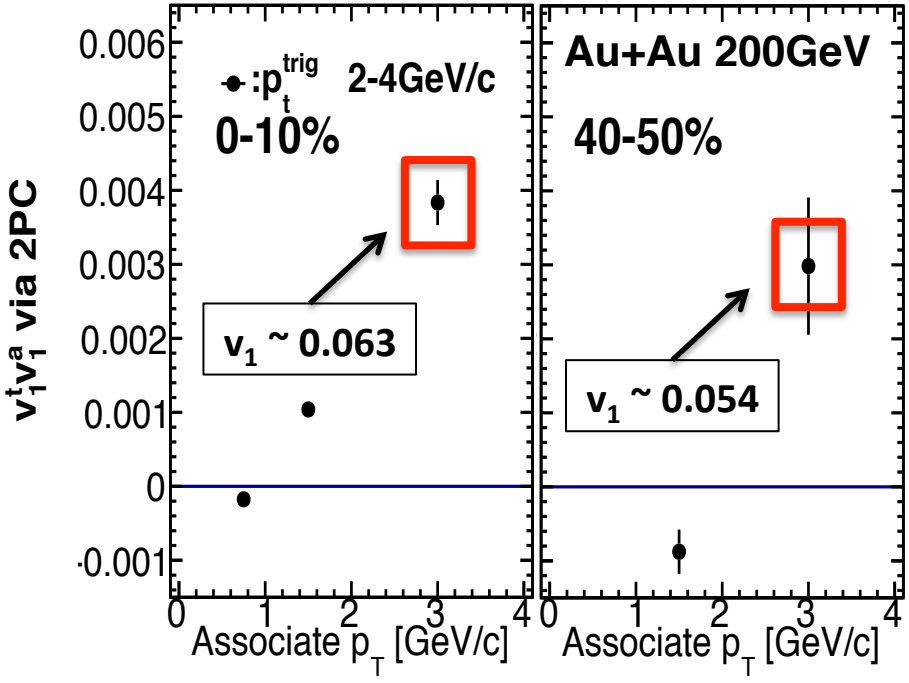
- $v_4(\Psi_2)$ doesn't change away-side trends in most & mid-central
- $v_4(\Psi_4)$ removes away-side residual in mid-central but reproduce double hump in mid-central

✧ Away-side residual shape depends on treatment of v_4

v_1 estimations by two methods

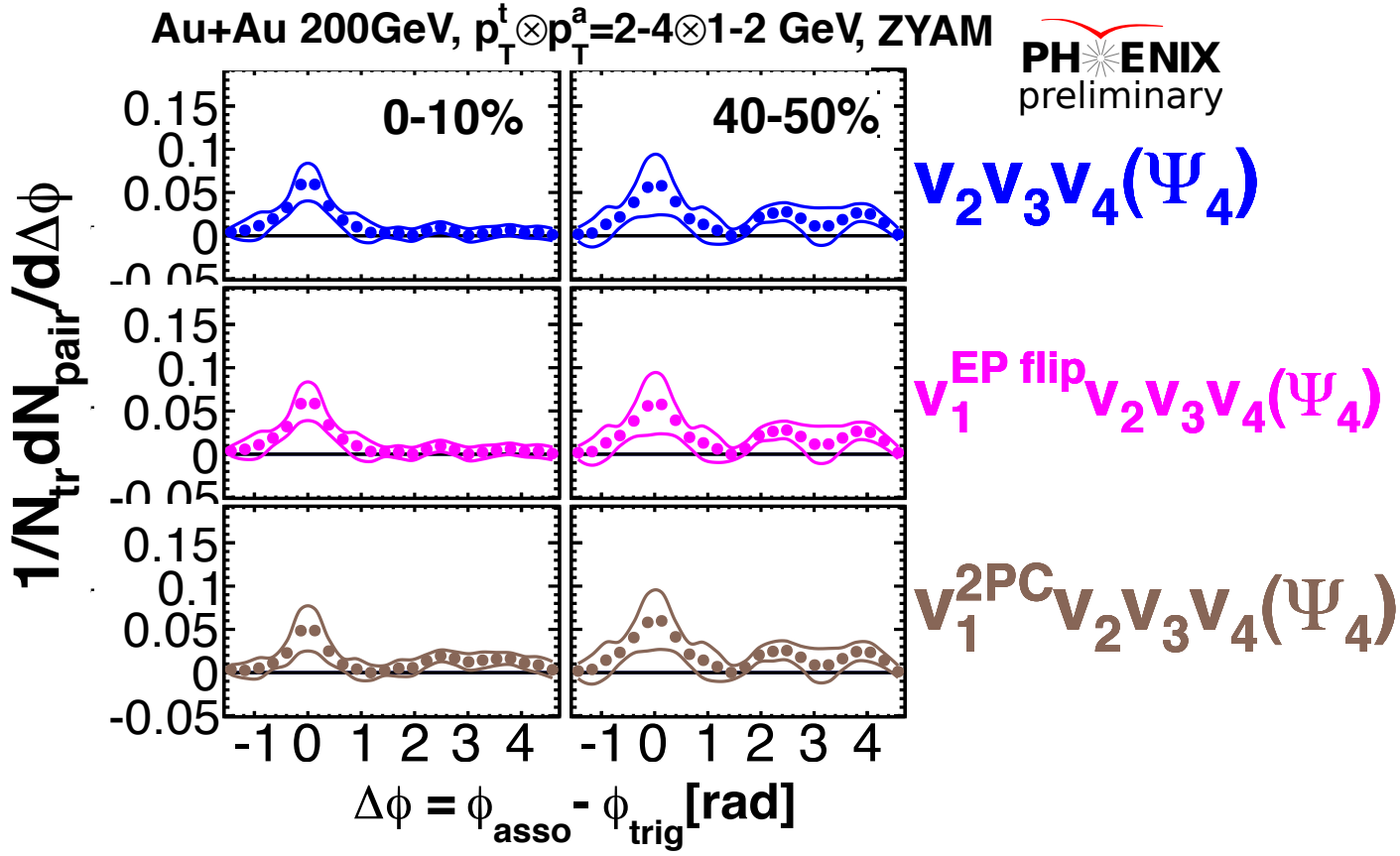
- **Event plane method**
  - » $v_1 = < \cos 1(\phi - \Psi_1) >$
- **Two particle correlation method**
  - » Correlations with $|\Delta\eta|>0.5$
  - » Fourier decomposition





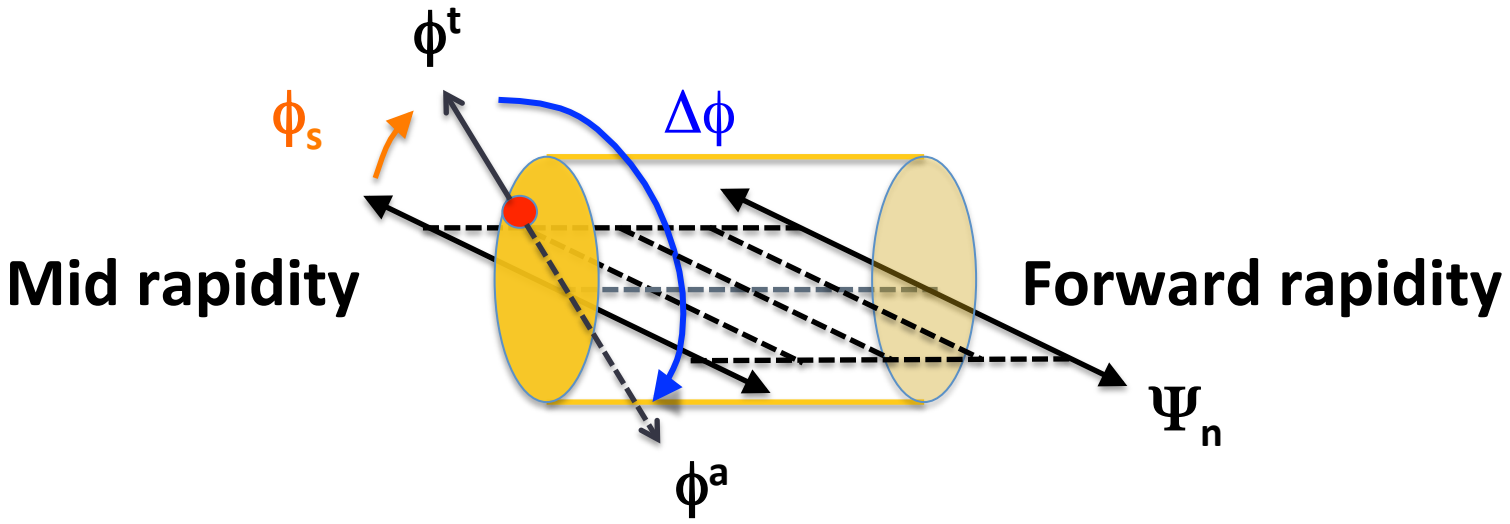
- **Two methods provide two different amplitude v_1**

v_n (n=1,2,3,4) subtracted correlations



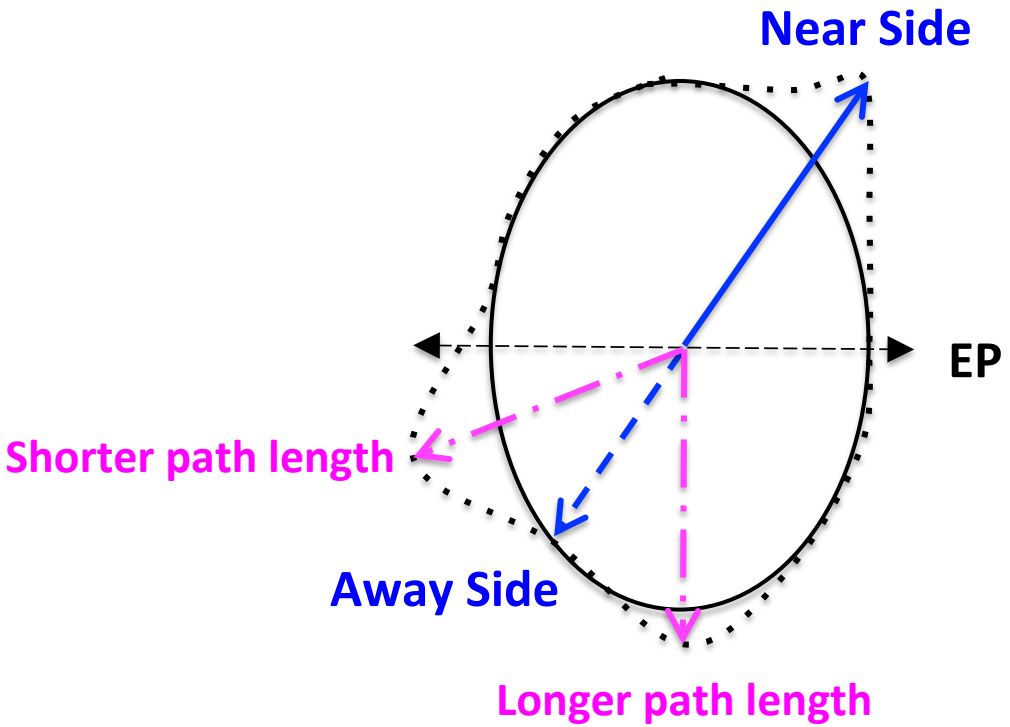
- **Inclusion of v_1 term to v_n background subtractions doesn't change away side residual so much**
  - » Confirmed with two v_1 have different amplitude

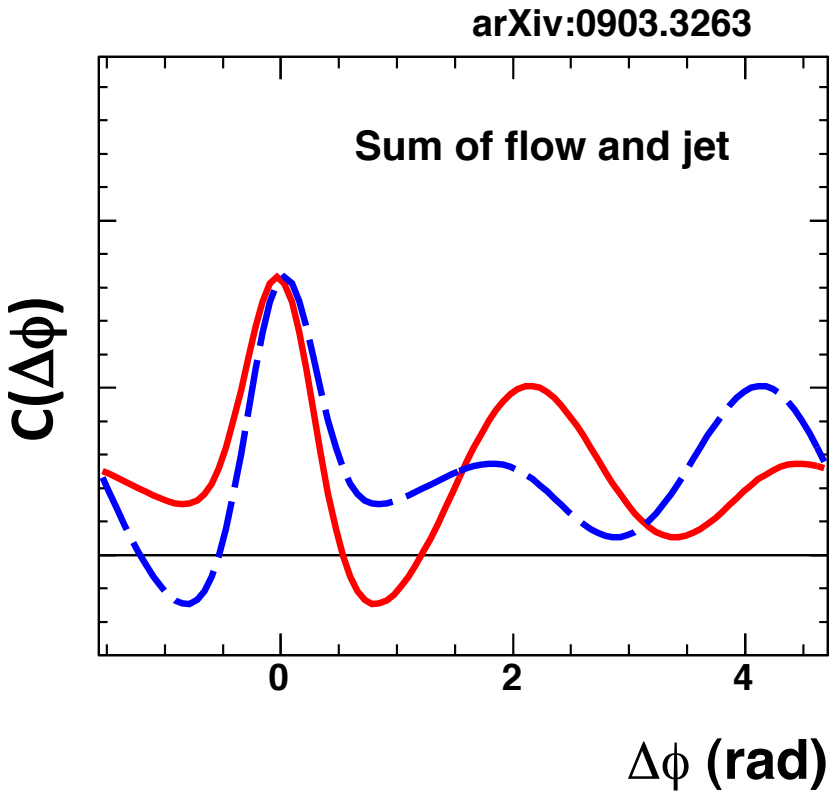
Correlations relative to Ψ_2 & Ψ_3



- **Rapidity gap between trigger and event planes**
  - » Reduce autocorrelations of jet itself
- **Control parton path length (mainly Ψ_2)**
- **Sensitivity of correlations to different harmonic event planes**

Parton path length in Left/Right correlations



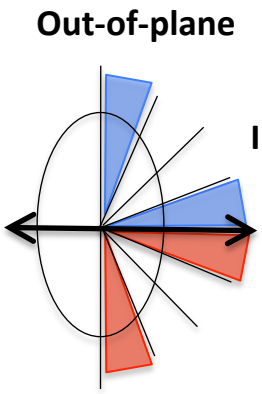


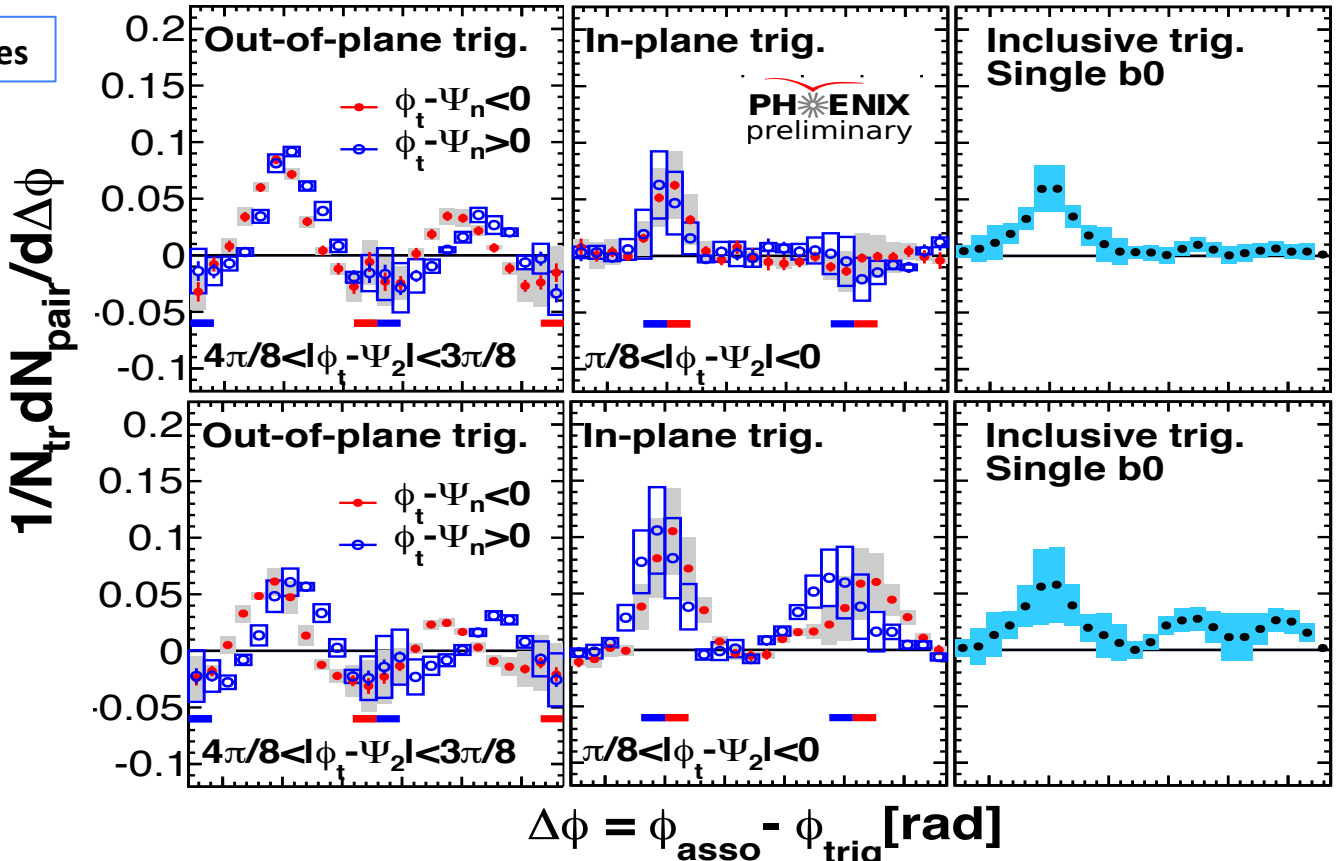
- **Left/Right trigger selection relative to event plane results in non-uniform path length at away-side**
- **Modification expected in away-side as Left/Right asymmetry**

Correlations relative to Ψ_2

2-4⊗1-2 GeV, $v_2v_3v_4(\Psi_4)$ subtracted with $\langle\cos 4(\Psi_2-\Psi_4)\rangle = v_4(\Psi_2)/v_4(\Psi_4)$ by ZYAM

All results in back up slides



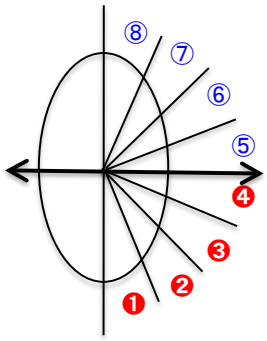


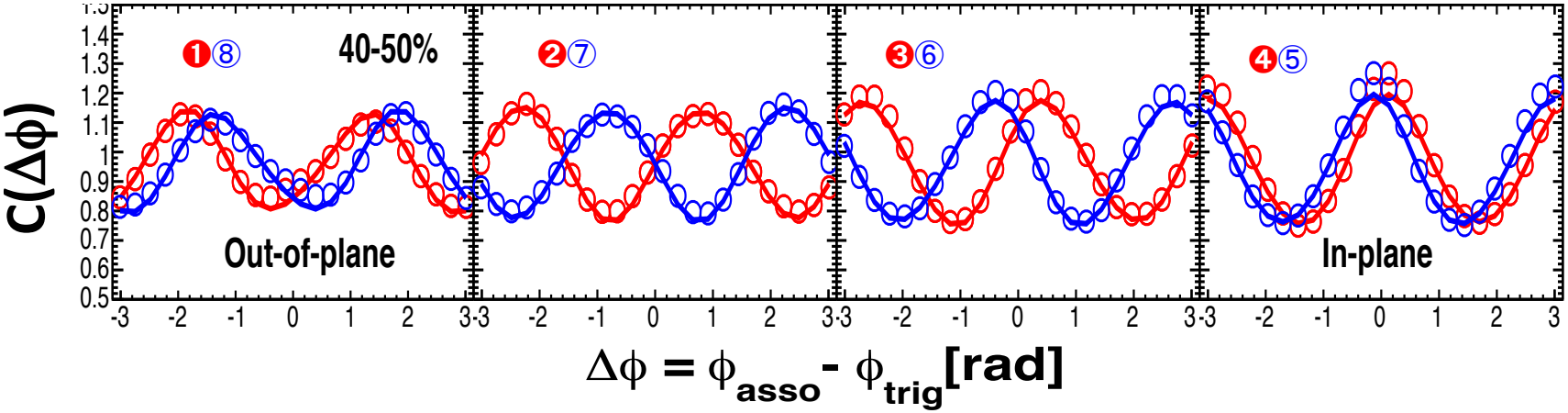
- Clear Ψ_2 dependence of correlation shape
- Left/Right asymmetry observed
  - » More pronounced in mid-central collisions

Interpretation of Left/Right Asymmetry

○ : Raw data correlations

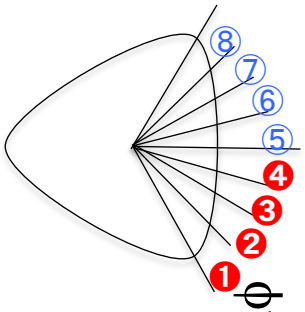
- : Flow function by v_2 v_3 $v_4(\Psi_4)$ with $\langle\cos4(\Psi_2-\Psi_4)\rangle=v_4(\Psi_2)/v_4(\Psi_4)$



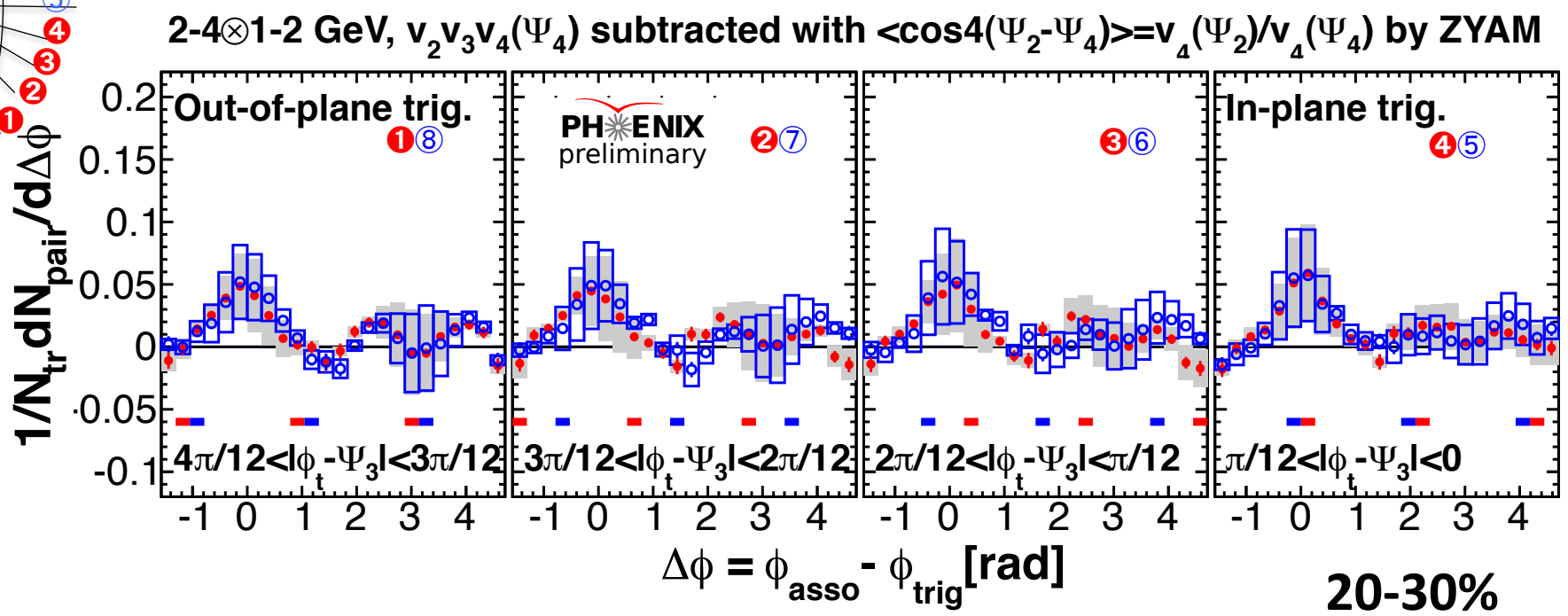


- **What is the implication of observed Left/Right asymmetry?**
- **Path length dependence of jet modification?**
- **Flow function has left/right asymmetry**
  - » Subtracted results has ambiguity in flow subtractions?
  - » Additional jet-flow coupling?

Correlations relative to Ψ_3



All results in back up slides



- Same analysis method followed as in Ψ_2 dependent correlations
- Ψ_3 dependent correlations are independent of trigger within systematics
- Discrepancy between Left/Right correlations are consistent within systematics

Summary

- **Correlations with v_n background subtractions**
  - **Treatment of v_4 is crucial for away-side residual shapes at intermediate p_T**
  - **Effect of v_1 is not so significant in symmetric collision systems at mid-rapidity**

- **Correlations relative to higher harmonic event planes**
  - **On correlation shapes depending on Ψ_n**
    - » Ψ_2 dependent correlations show clear trigger dependence
    - » Ψ_3 dependent correlations are independent of trigger direction within systematics

- **Further understanding of reaction plane dependence & Left/Right asymmetry will inform interpretation of inclusive correlations**

PHENIX talks

- Plenary talks
  - M. Wysocki (Mon, *Initial state, Global & Collective Dymanics*)
  - M. McCumber (Tue, *Jets*)
  - M. Rosati (Tue, *Heavy Flavor*)
  - I. Tserruya (Thu, *Quarkonia, Real & Virtual Photons*)
  - E. O'Brien (Fri, *Exploring the QCD Phase Diagram*)
- Parallel talks (Tue)
  - T. Niida (*Correlations & Fluctuations, Parallel #3*)
  - Y. Gu (*Global & Collective Dynamics, Parallel #1*)
  - J. Frantz (*Jets, Parallel #2*)
  - D. McGlinchey (*Heavy Flavor & Quarkonia, Parallel #4*)
- Parallel talks (Wed)
  - E. Atomssa (*Electro-Weak Probes, Parallel #7*)
  - M. Kurosawa (*Global & Collective Dynamics Parallel #5*)
  - B. Sahlmueller (*Pre-Equilibrium & Initial State, Parallel #8*)
  - S. Huang (*Global & Collective Dynamics Parallel #5*)
- Parallel talks (Thu)
  - P. Shukula (*High pT and Jets, Parallel #11*)
- Parallel talks (Fri)
  - J. Haggerty (*New Experimental Developments, Parallel #15*)
  - R. Nouicer (*Heavy Flavor & Quarkonia, Parallel #13*)
  - J. Seele (*New Experimental Developments, Parallel #15*)
  - T. Todoroki (*Correlations & Fluctuations,,Parallel #16*)
  - R. Hollis (*Correlations & Fluctuations,,Parallel #16*)
  - J. Mitchell (*Exploring the QCD Phase Diagram, Parallel #14*)

And, Many posters

Backup Slides

Ψ_n resolutions & Ψ_i - Ψ_j correlations

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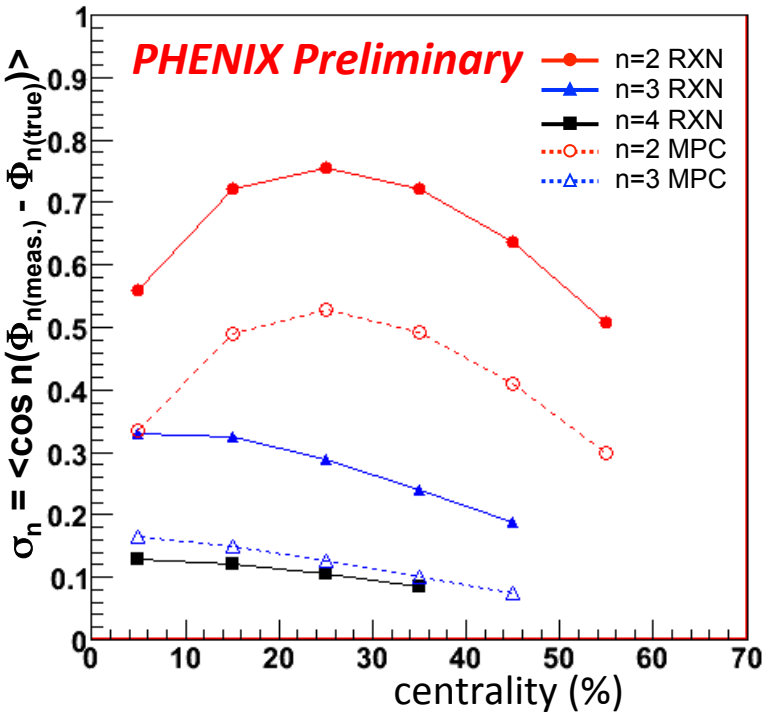
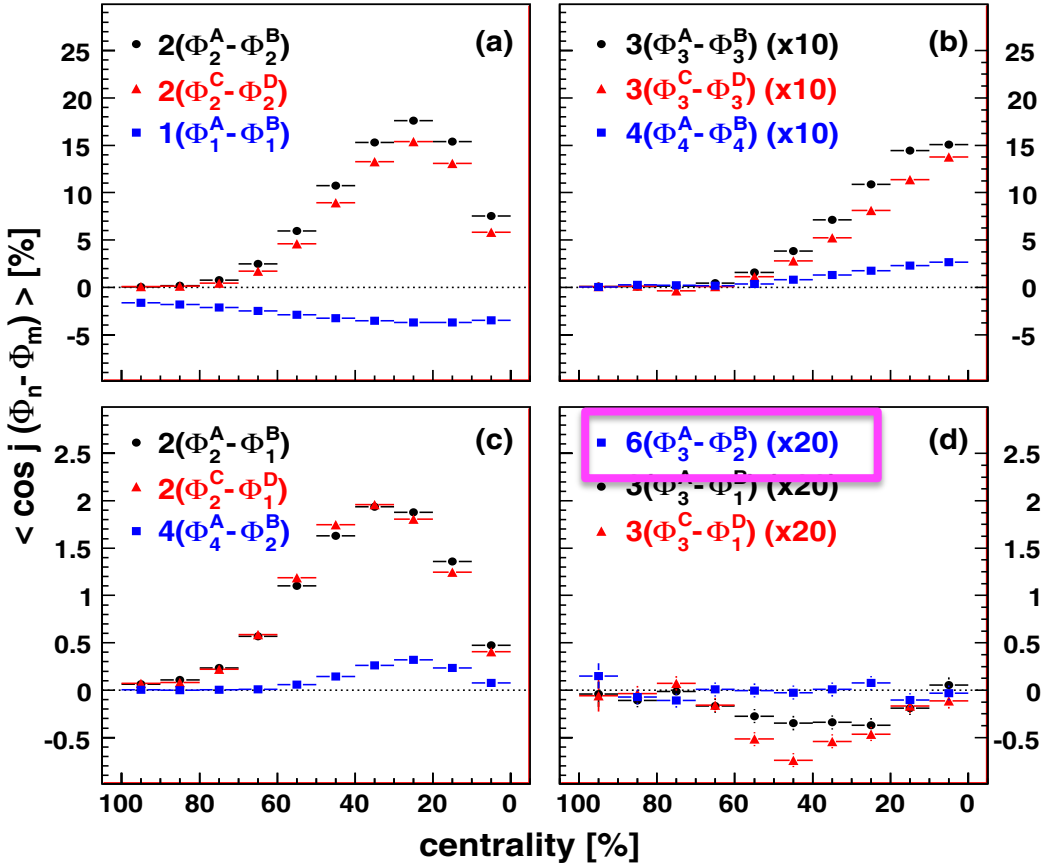
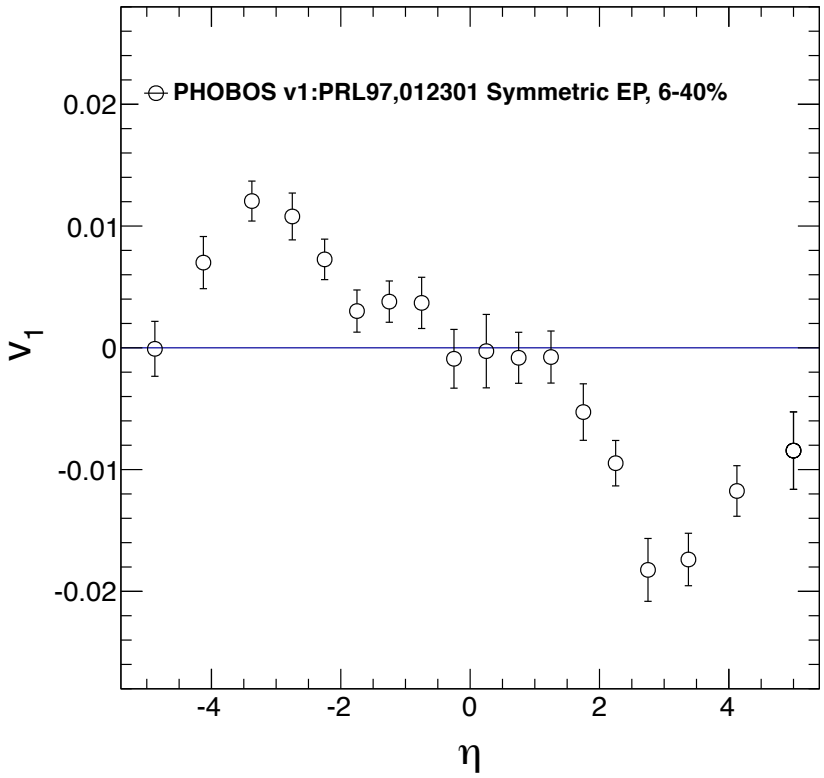
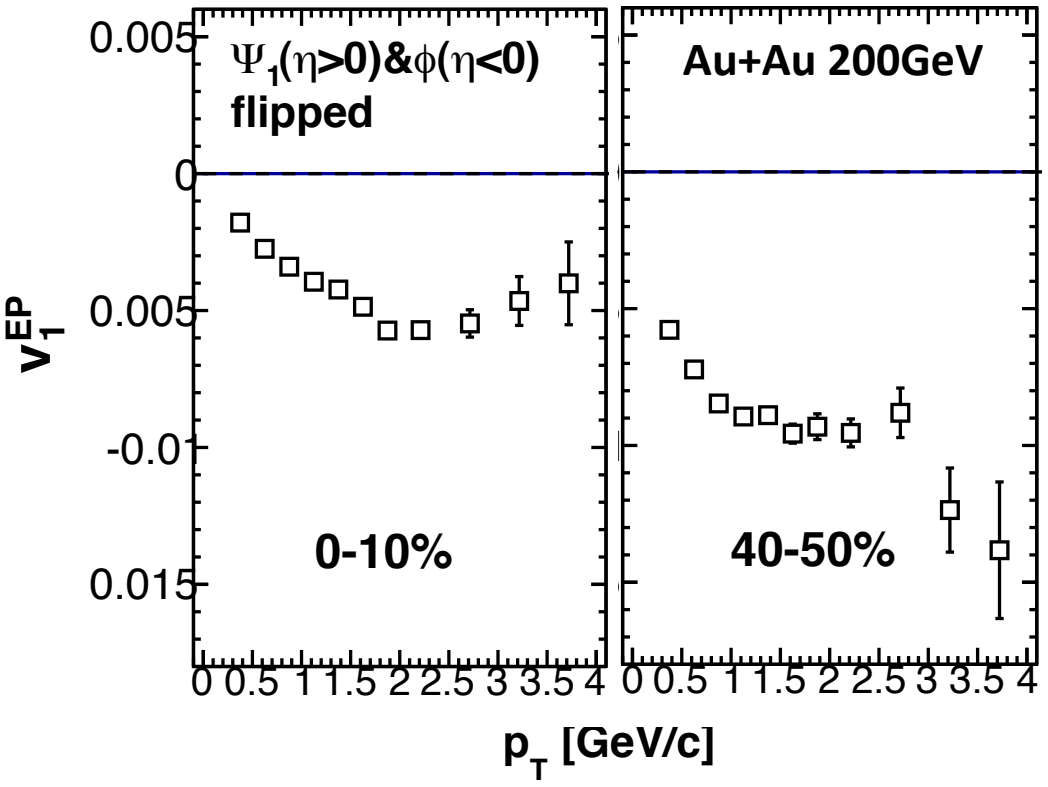




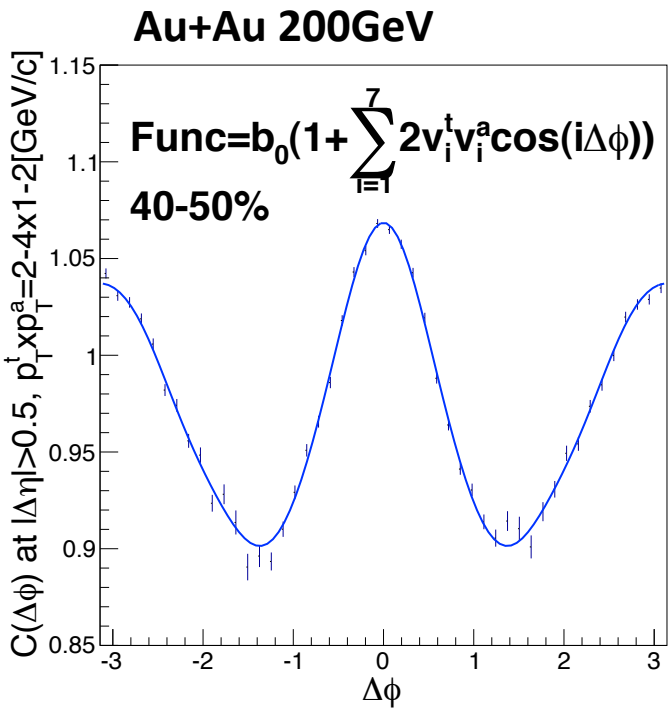
v_1 by event plane method

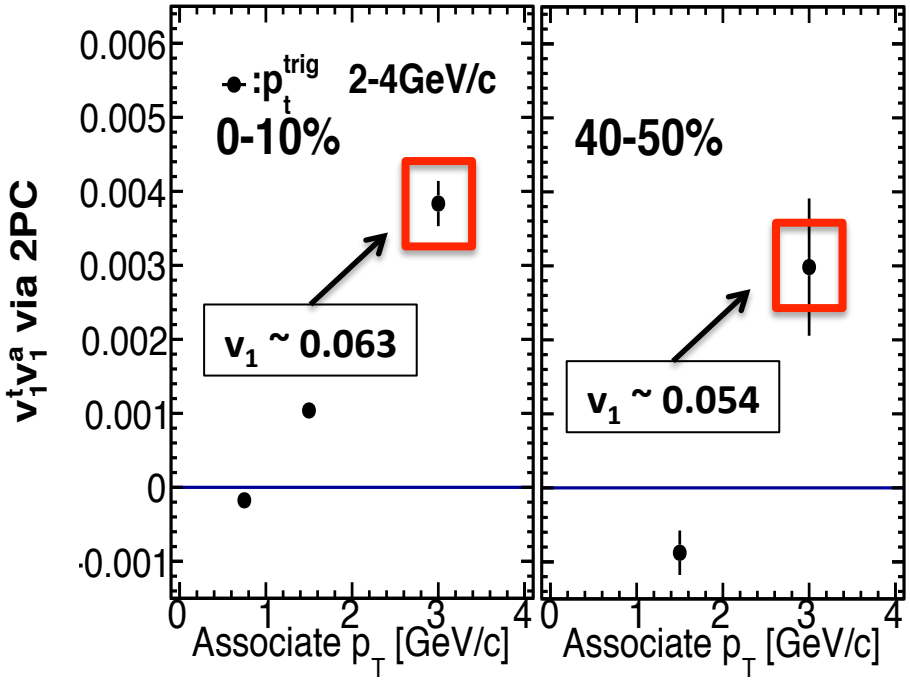




- **Event plane method**
  - » Inclusive measurements of v_1 over η compensate signal due to opposite sign of v_1 in forward/backward rapidity
  - » Flipping of Ψ_1 and ϕ to keep v_1 signal

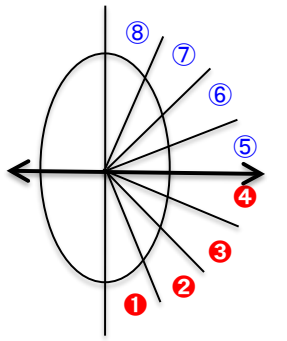
v_1 by two particle correlation method

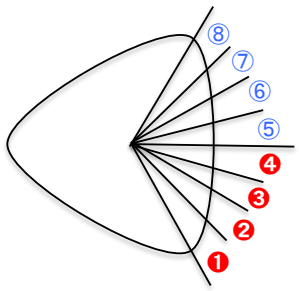




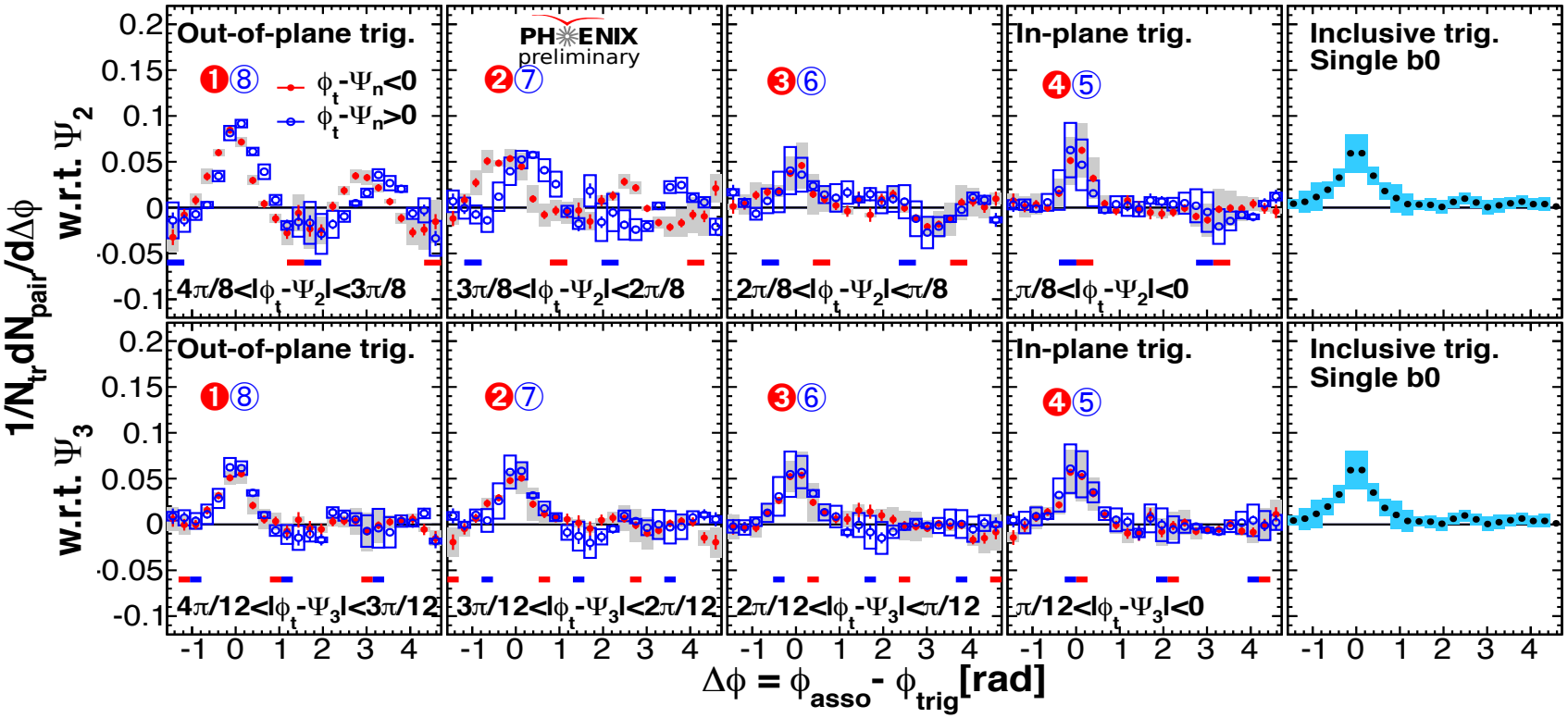
- **Two particle correlation method**
  - » Correlations with $|\Delta\eta|>0.5$
  - » Decomposed by Fourier fitting & extract $v_1^{tr} * v_1^{as}$

Correlations relative to Ψ_2 & Ψ_3, 0-10%

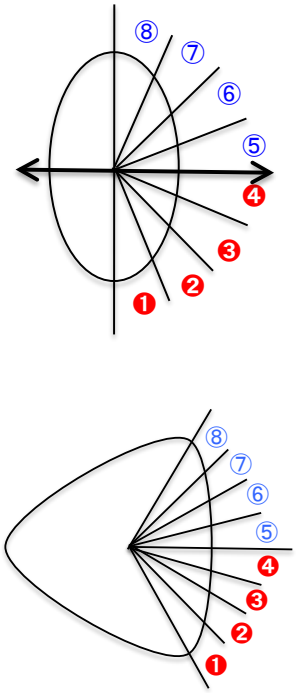




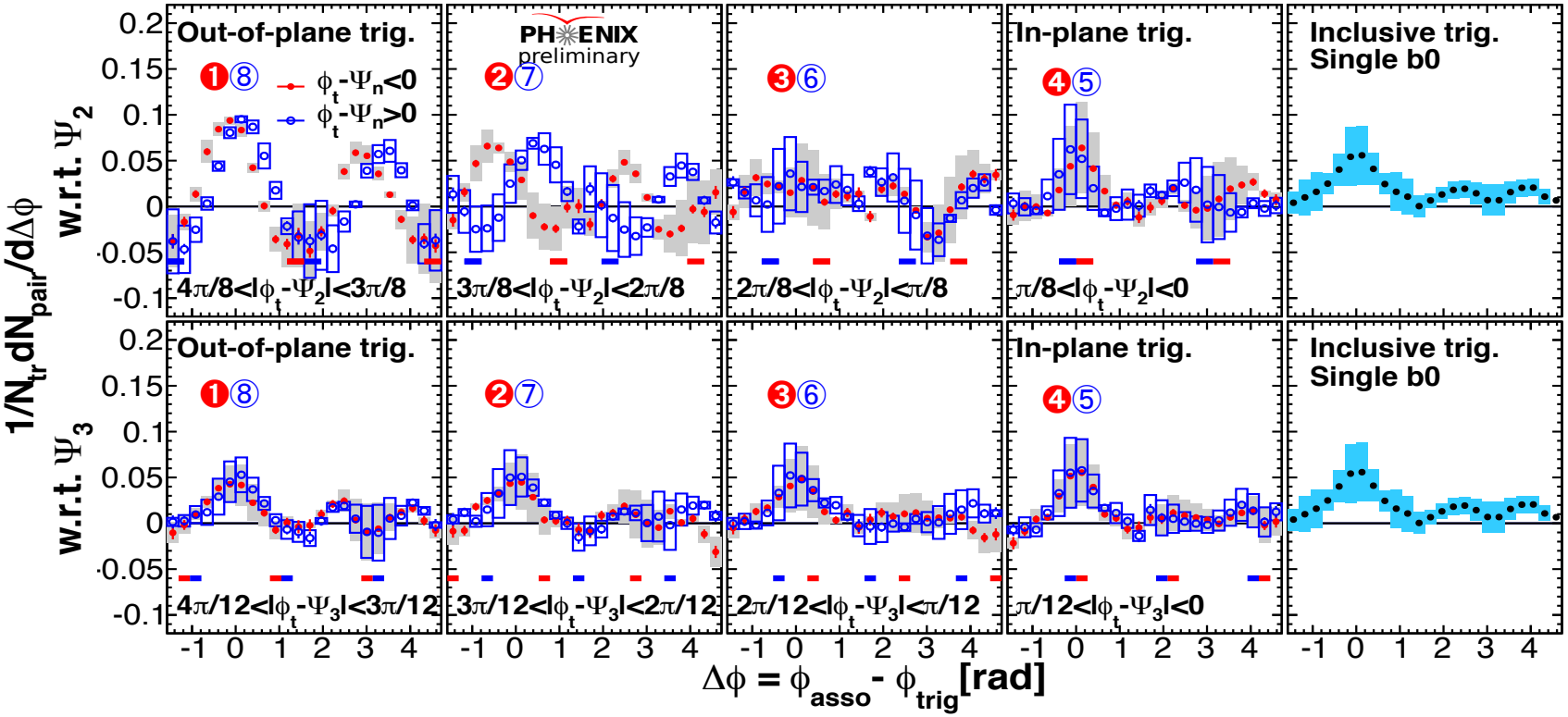
Au+Au 200GeV, 0-10%, 2-4⊗1-2 GeV, $v_2v_3v_4(\Psi_4)$ subtracted with $\langle\cos4(\Psi_2-\Psi_4)\rangle=v_4(\Psi_2)/v_4(\Psi_4)$ by ZYAM



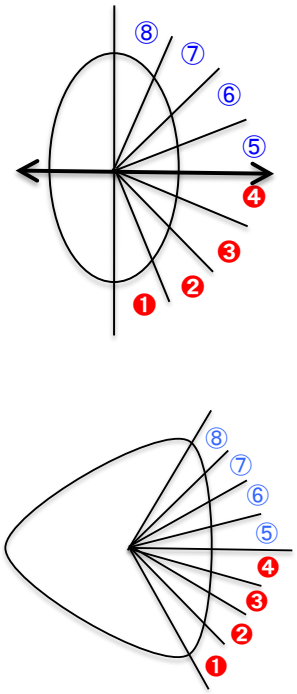
Correlations relative to Ψ_2 & Ψ_3 10-20%



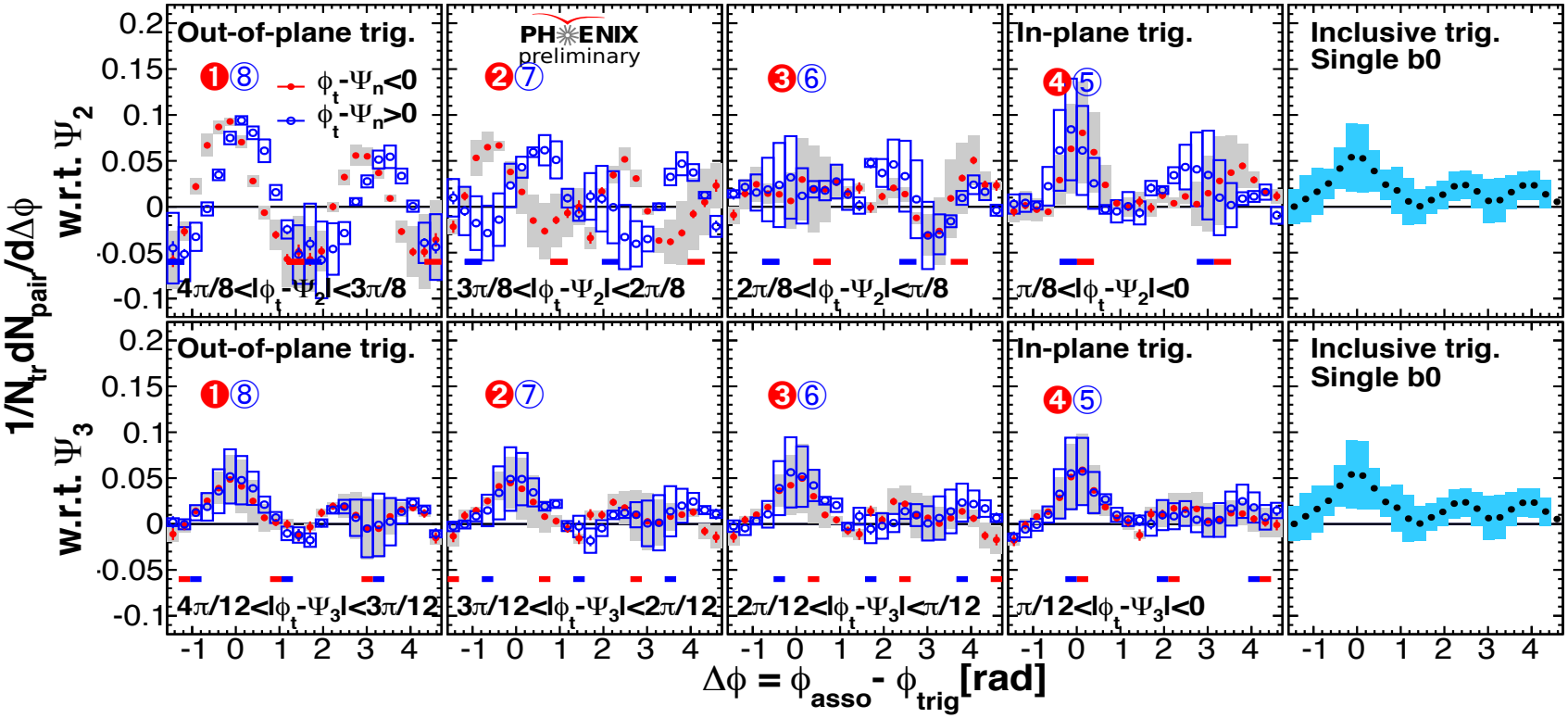
Au+Au 200GeV, 10-20%, 2-4⊗1-2 GeV, $v_2v_3v_4(\Psi_4)$ subtracted with $\langle\cos4(\Psi_2-\Psi_4)\rangle=v_4(\Psi_2)/v_4(\Psi_4)$ by ZYAM



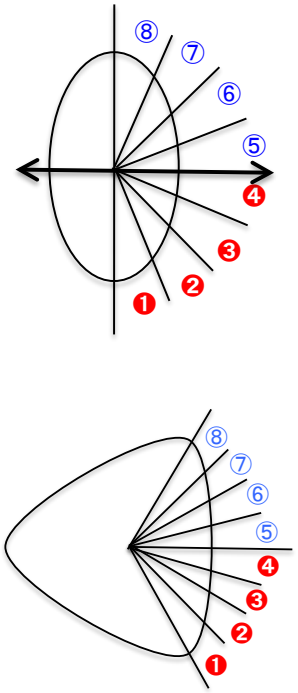
Correlations relative to Ψ_2 & Ψ_3 20-30%



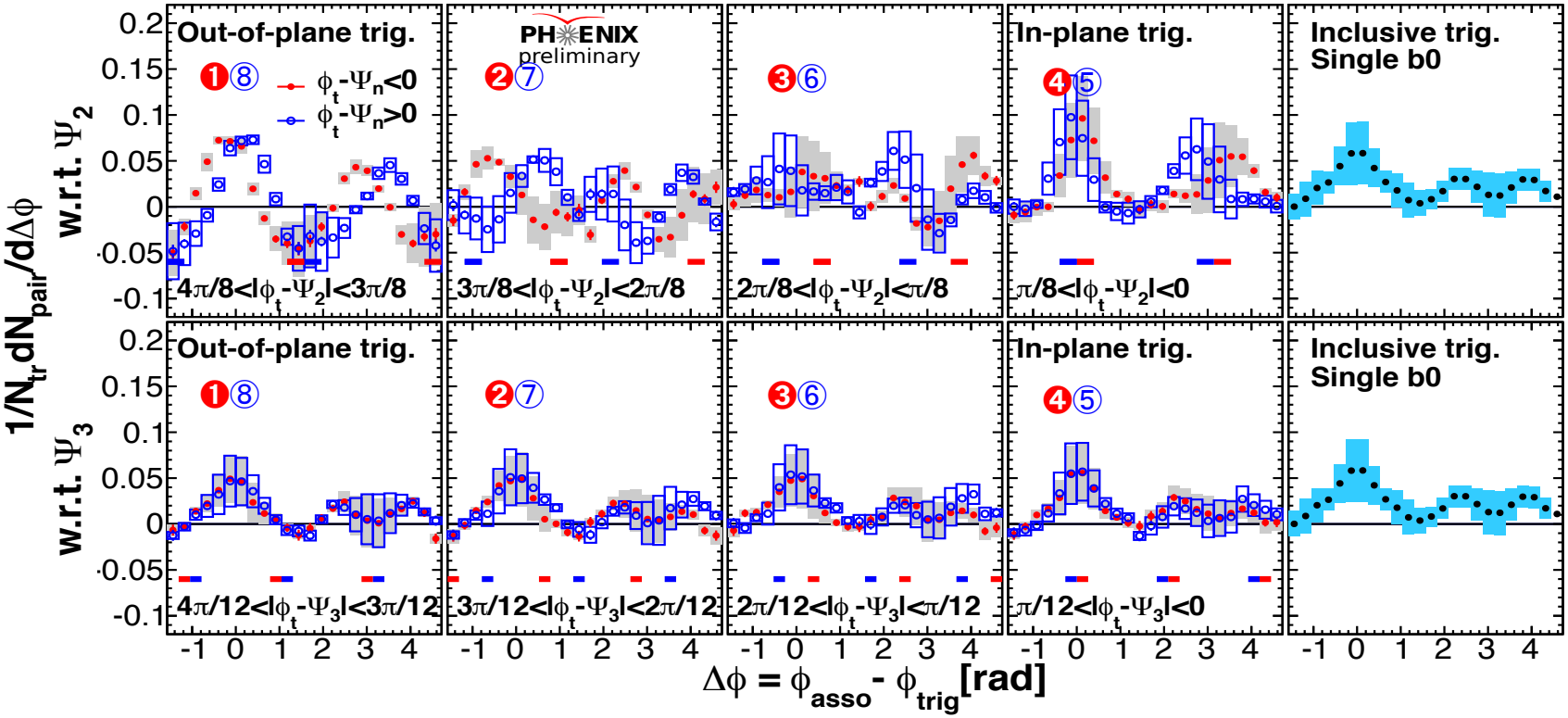
Au+Au 200GeV, 20-30%, 2-4⊗1-2 GeV, $v_2v_3v_4(\Psi_4)$ subtracted with $\langle\cos4(\Psi_2-\Psi_4)\rangle=v_4(\Psi_2)/v_4(\Psi_4)$ by ZYAM



Correlations relative to Ψ_2 & Ψ_3 30-40%



Au+Au 200GeV, 30-40%, 2-4⊗1-2 GeV, $v_2v_3v_4(\Psi_4)$ subtracted with $\langle\cos4(\Psi_2-\Psi_4)\rangle=v_4(\Psi_2)/v_4(\Psi_4)$ by ZYAM



Correlations relative to Ψ_2 & Ψ_3, 40-50%