PHENIX v3 results

RHIC/AGS Users' Meeting, June 20, 2011

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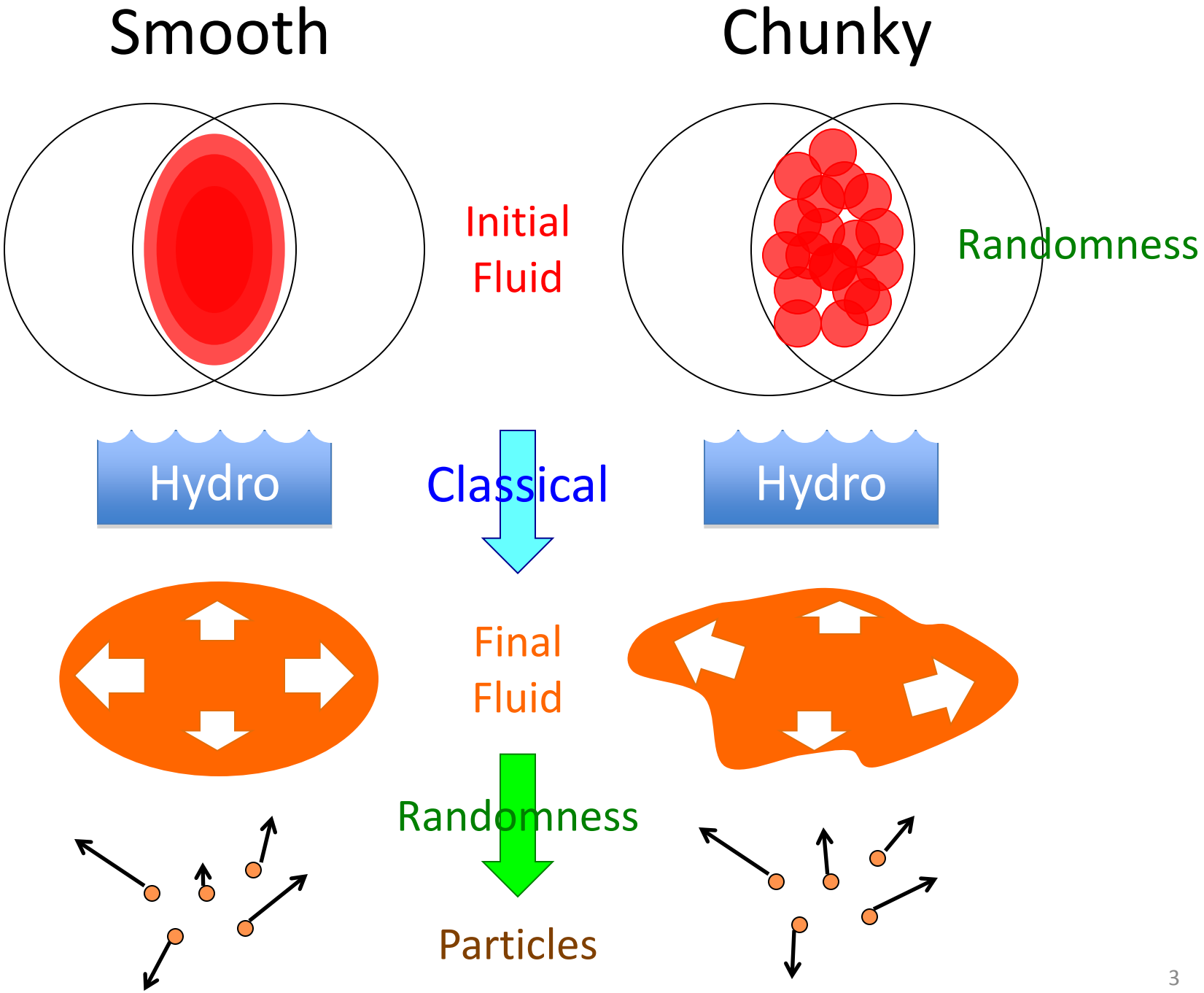
Oak Ridge National Lab

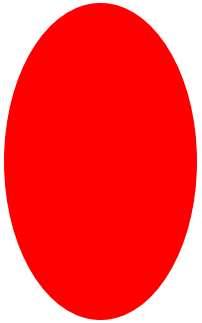
An eternal question:

OR

Smooth?

Chunky?

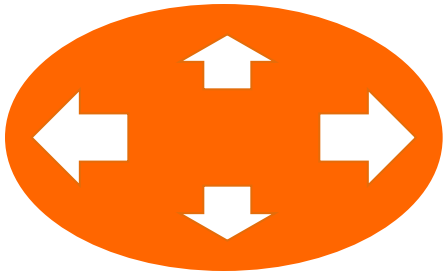

Smooth
Chunky
Initial
Fluid
Randomness
Hydro
Classical
Hydro
Final
Fluid
Randomness
Particles

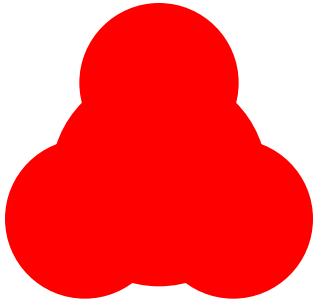


ε_2

Clear

v_2, v_4, v_6

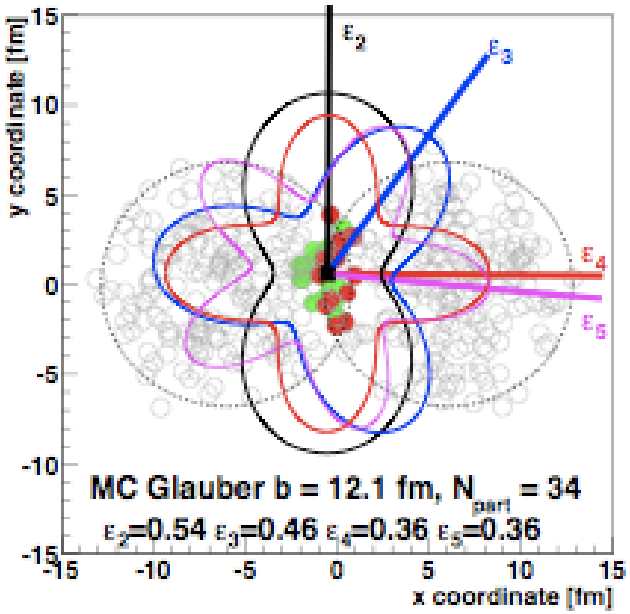




ε_3

Clear

v_3, v_6, v_9



Nagle, McCumber arXiv:1011.1853

ε_2, ε_3, ε_4, ε_5…

Unclear!

v_2, v_3, v_4, v_5…

?

- Reaction Plane ψ_{RP}

  Trivial unique property of any incoming/initial A+A state

- Participant Eccentricities ε_n

  Describe general initial state in 2D; could vary with rapidity

- "True" Event Planes ψ_n

  Hypothetical descriptors of the final state, such that

  $dN/d\Phi \sim 1 + \Sigma\, 2\, v_n \cos(n(\Phi-\psi_n))$ for singles; does $\varepsilon_n \rightarrow \psi_n$?

- Experimental Event Planes ϕ_n^A

  For each detector A, $\tan(n\phi_n^A)=\Sigma w_i \sin(n\Phi_i)/\Sigma w_i \cos(n\Phi_i)$

Event Plane Correlations

Measurements of Higher-Order Flow Harmonics in Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

arXiv:1105.3928v1 [nucl-ex] 19 May 2011

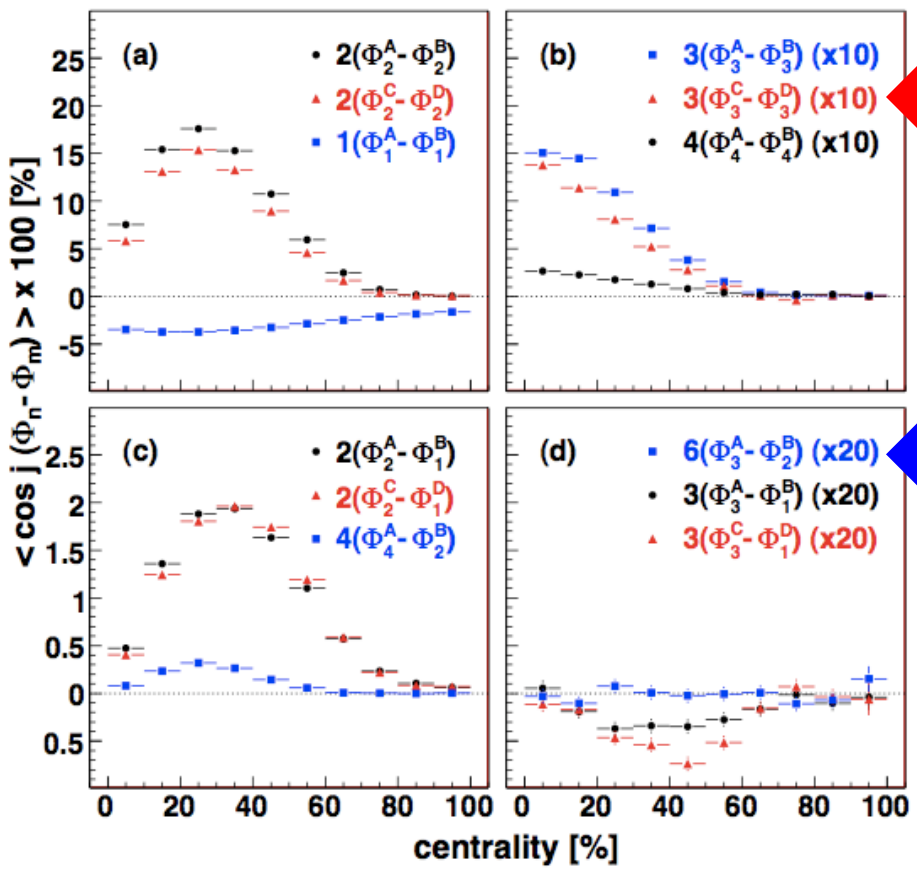


FIG. 1: (color online) Raw correlation strengths (see text) of the event planes for various detector combinations as a function of collision centrality. The detectors in which the event plane is measured are: (a) RXN North, (b) BBC South, (c) MPC North, and (d) MPC South.

North ϕ_3 positively correlated with South ϕ_3; indicates dominance of long-$\Delta\eta$ fluctuations.

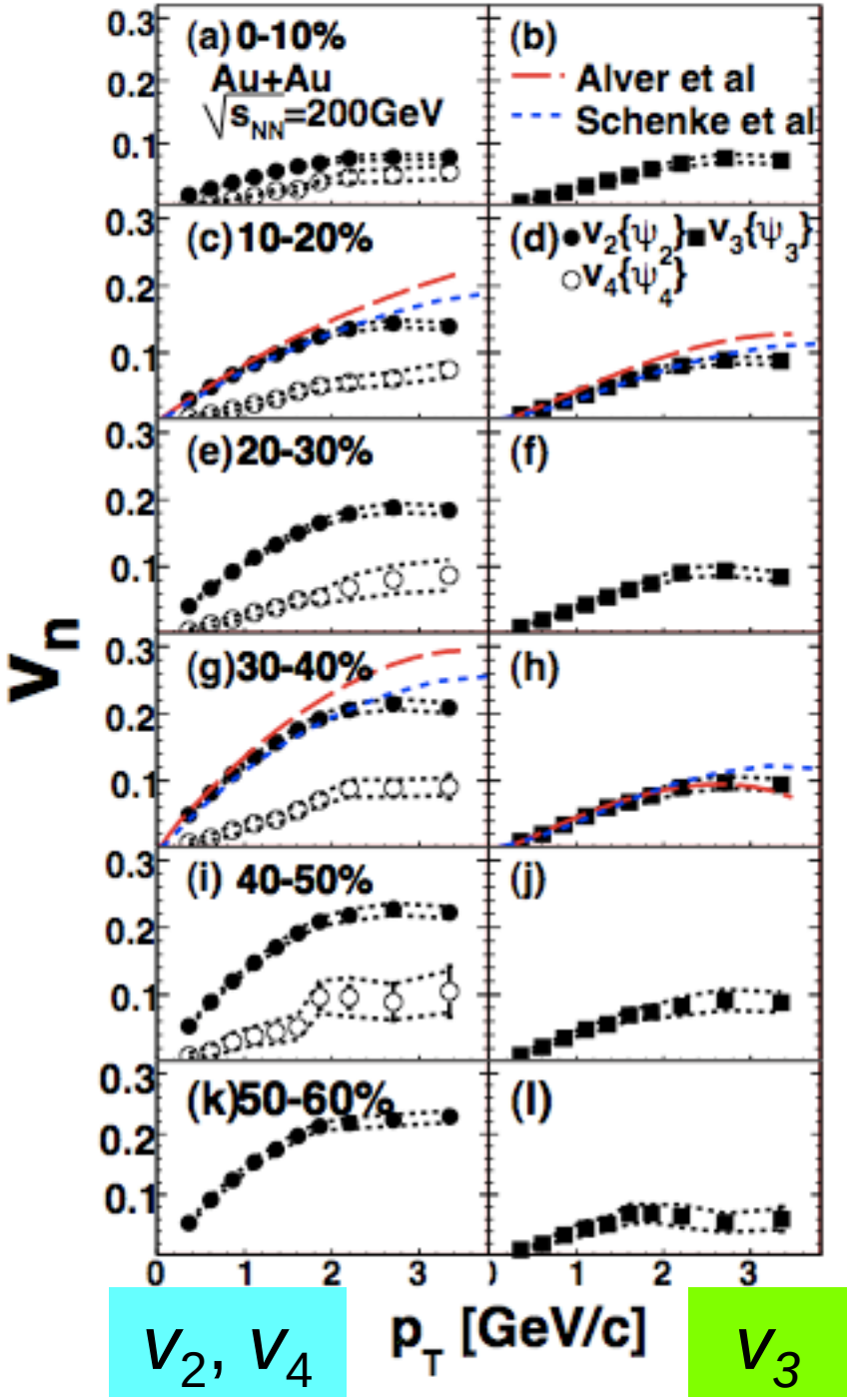
No visible correlation between ϕ_2 and φ_3 event planes; direct test of fluctuation models

PHENIX Forward 2π Detectors

RXN: $1.0<|\eta|<2.8$

MPC: $3.1<|\eta|<3.7$

BBC: $3.1<|\eta|<3.9$



Mid-Rapidity Charged Particle v_n

arXiv:1105.3928

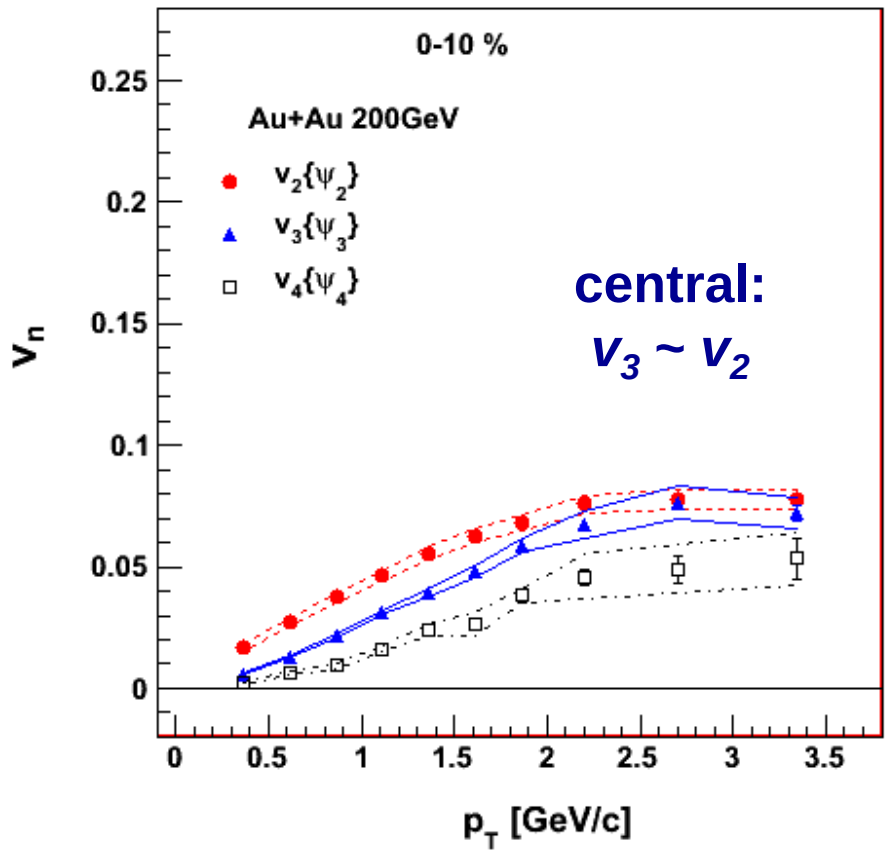
$$v_n\{\Psi_n\} = \frac{\left\langle \cos\left(n(\phi - \Phi_n^{\mathrm{Avg}})\right)\right\rangle}{\mathrm{Res}(\Psi_n)}$$

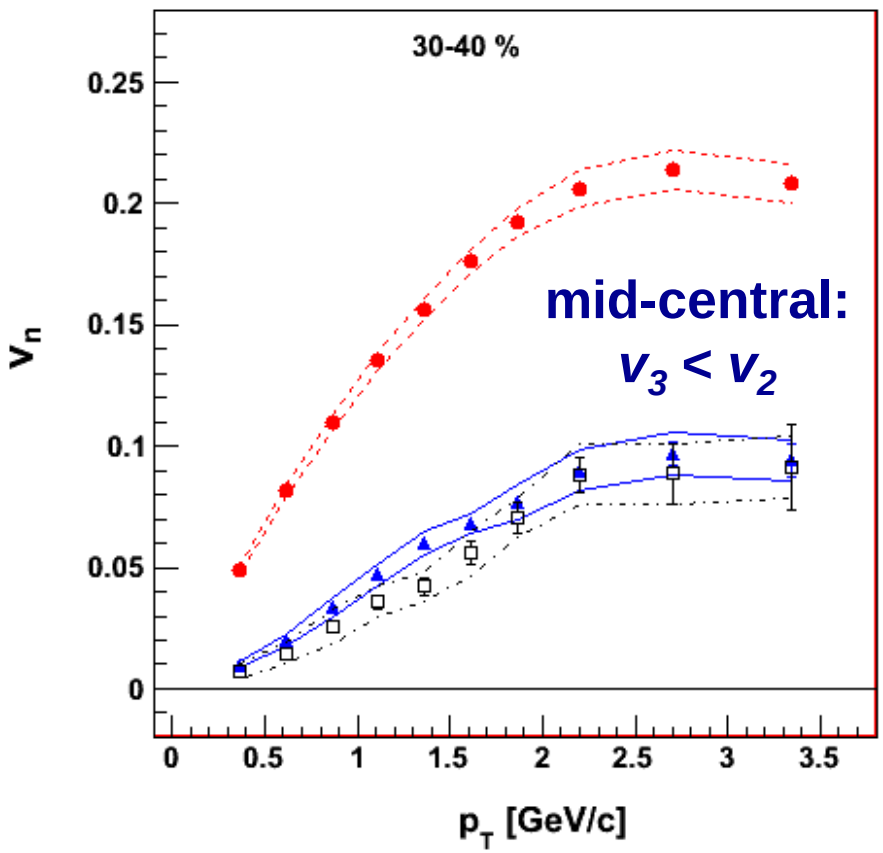
Standard Event-Plane Method using RXN detector

- Generally follows hydrodynamically-predicted shape vs p_T
- Very little centrality dependence for v_3

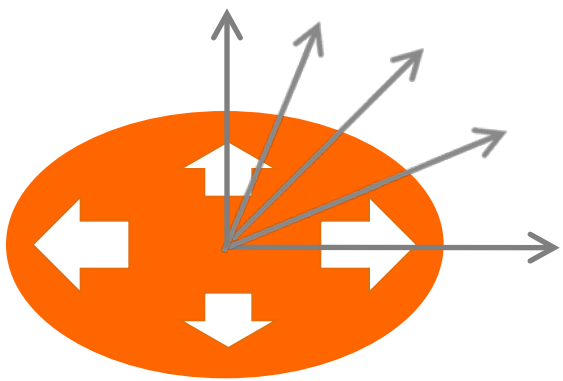
Mid-Rapidity Charged Particle v_n

arXiv:1105.3928

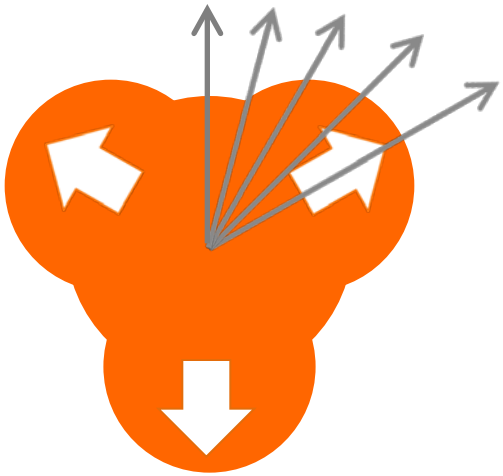




Almost geometry-independent magnitude of v_3 consistent with "chunky" origin in fluctuations



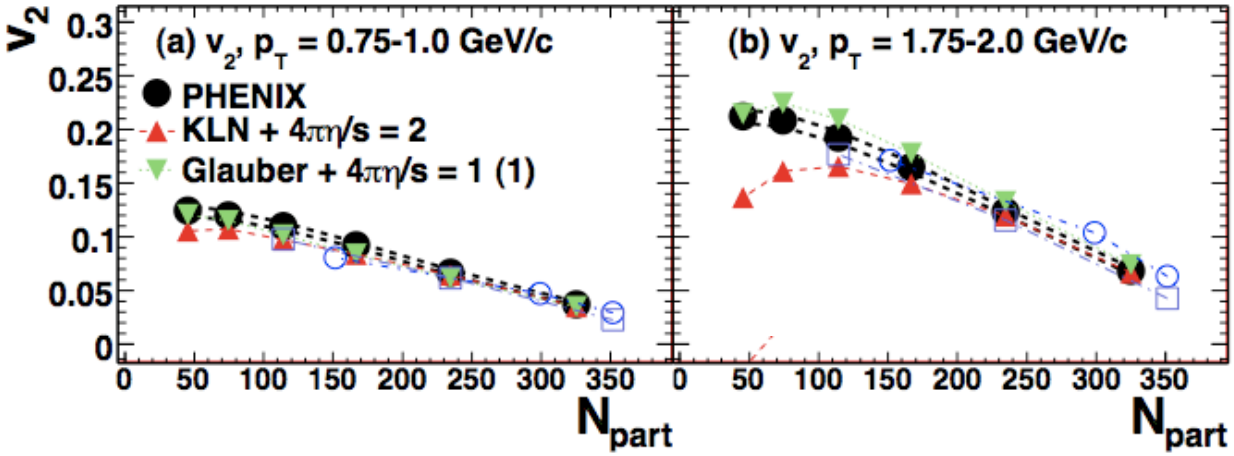
Shear viscosity dissipates transverse velocity gradients and reduces v_2.



For higher harmonics, transverse gradients are steeper; so viscosity has a larger effect on v_3.

Testing Against Viscosities and Models

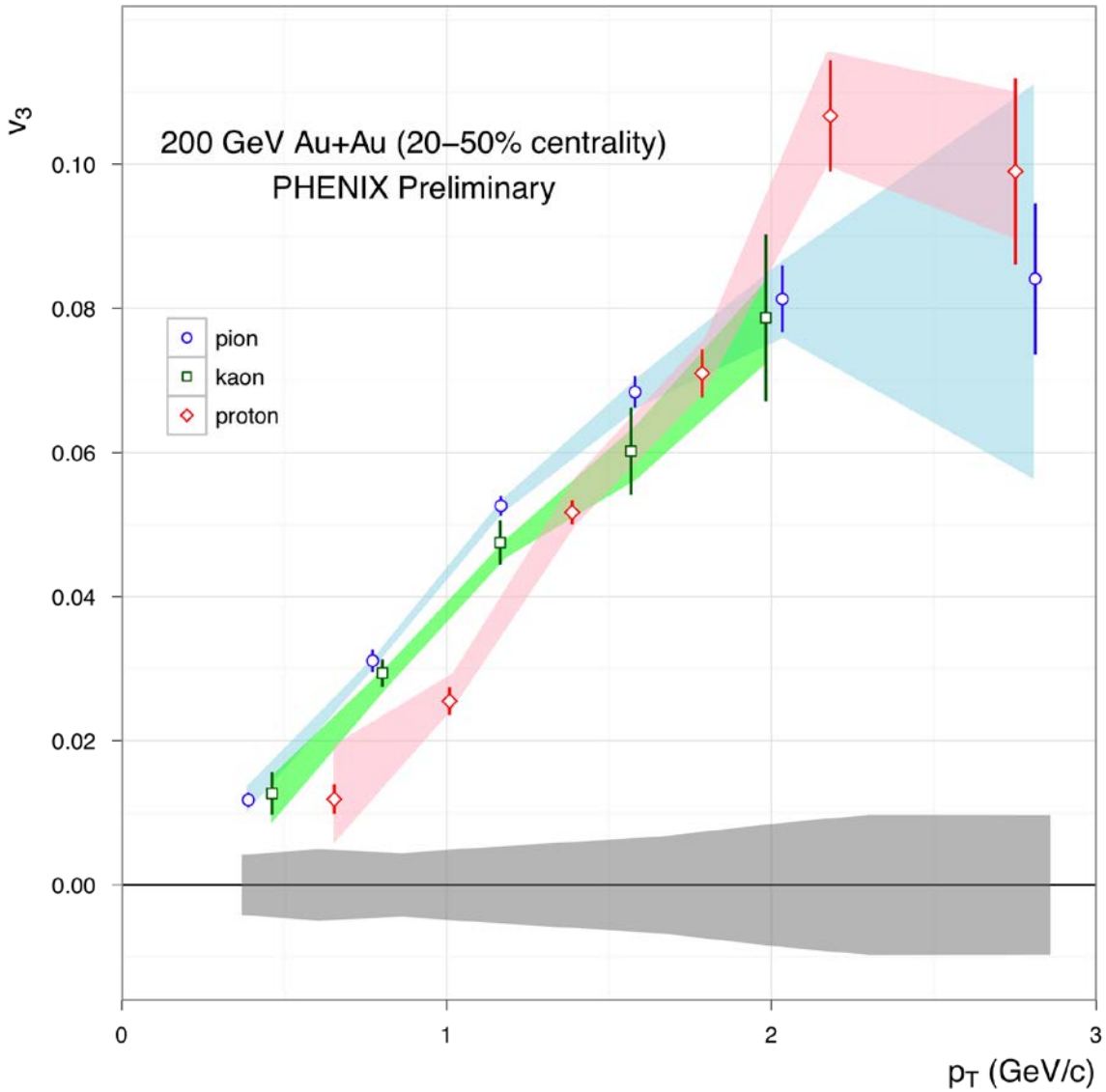
arXiv:1105.3928



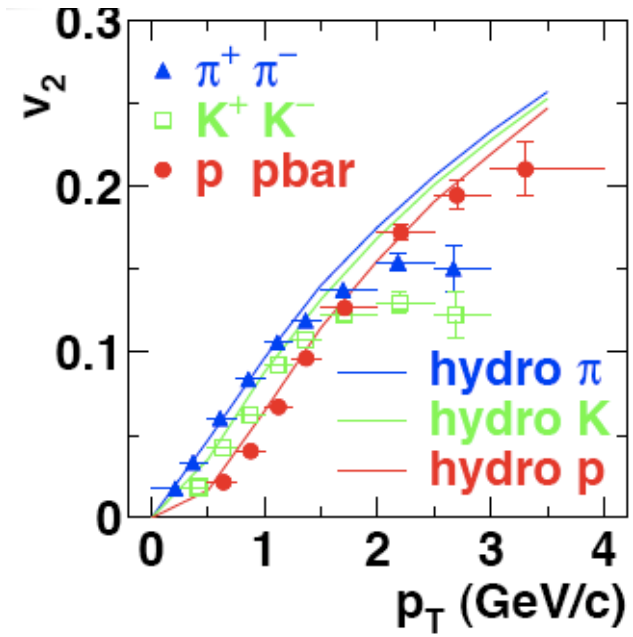
The v_3 data provide new discrimination

B. Alver et. al., Phys. Rev. C82, 034913(2010).
B. Schenke et. al., Phys. Rev. Lett. 106, 042301(2011).
H. Petersen et. al., Phys. Rev. C82, 041901(2010).

Identified $\pi/K/p$ $v_3\{\Phi_3\}$



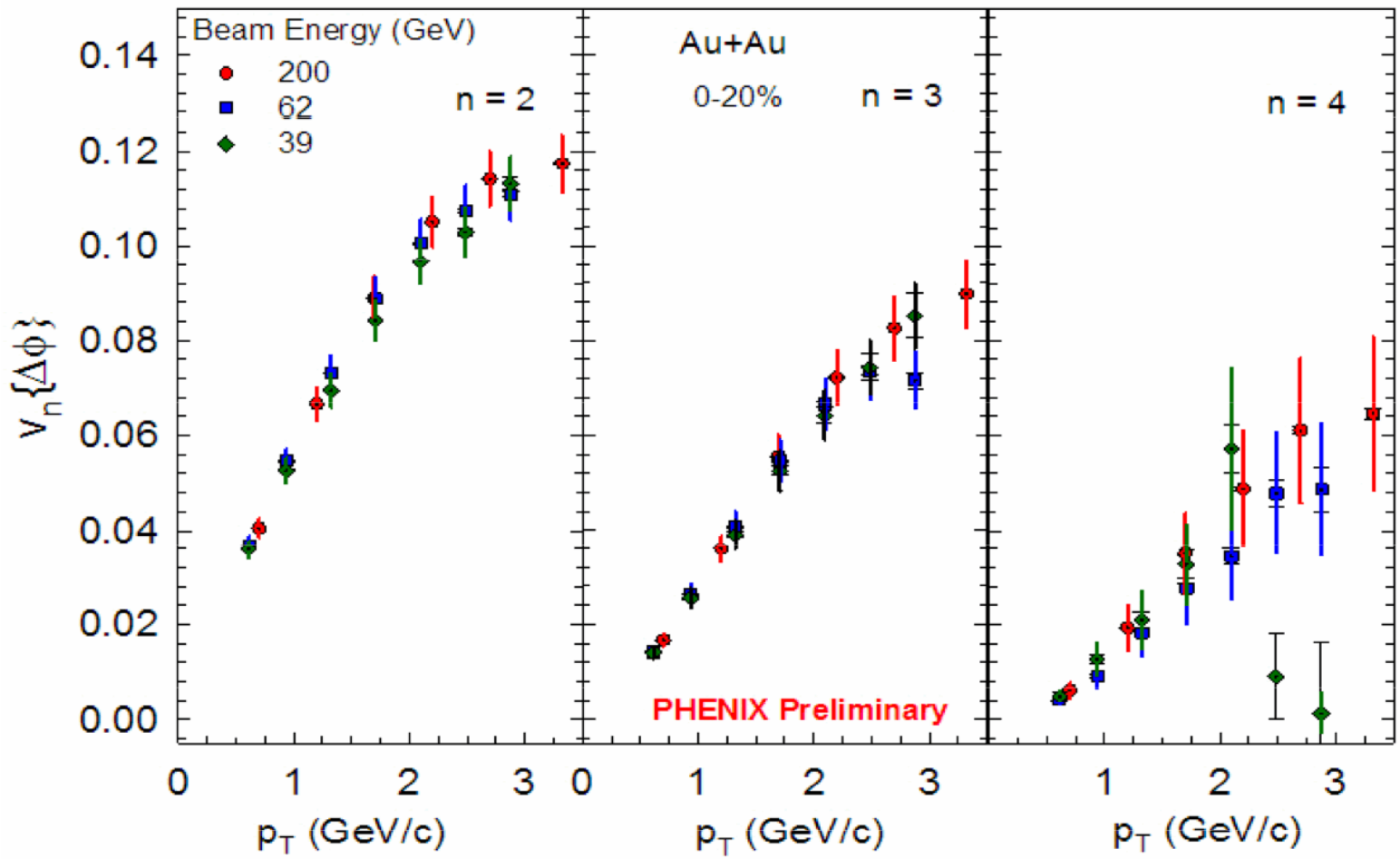
Mass splittings confirm hydrodynamic behavior



PHENIX Phys. Rev. Lett. 91, 182301 (2003)

Beam Energy Dependence

Similar saturation for all harmonics



Re-visiting the 2-source model

Singles:

Jet

Bulk/Flow

$$\frac{dN^A}{d\phi^A} \propto 1 + \sum 2 v_n^A \cos\left(n(\phi^A - \Psi_n)\right)$$

$$\frac{dN^B}{d\phi^B} \propto 1 + \sum 2 v_n^B \cos\left(n(\phi^B - \Psi_n)\right)$$

Pairs:

Jet-jet

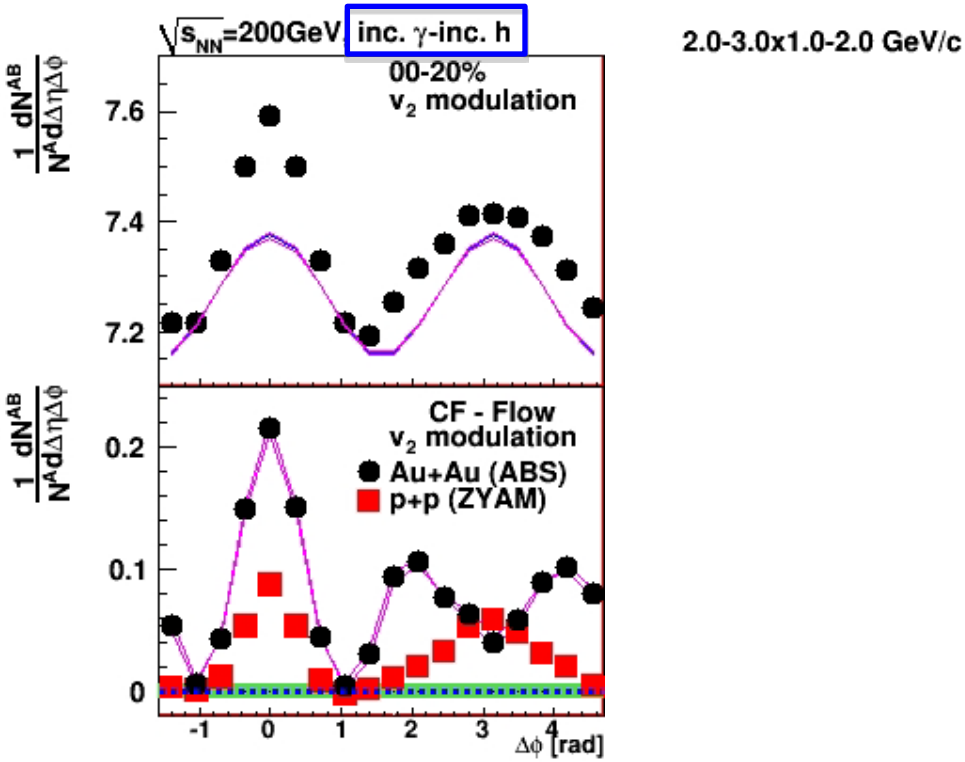
All other (bkgd)

$$\frac{d^2N^{AB}}{d\phi^A d\phi^B} \propto J(\Delta\phi^{AB}) + B_0\left[1 + \underbrace{2 v_2^A v_2^B \cos\left(2\Delta\phi^{AB}\right)}_{\text{Mandatory under “smooth”}} + \underbrace{2 v_3^A v_3^B \cos\left(3\Delta\phi^{AB}\right)}_{\text{New under “chunky”}} + \ldots\right]$$

Correlation function decomposition, revisited

Correlation functions and background pairs distribution

Jet-jet pairs distribution after subtraction



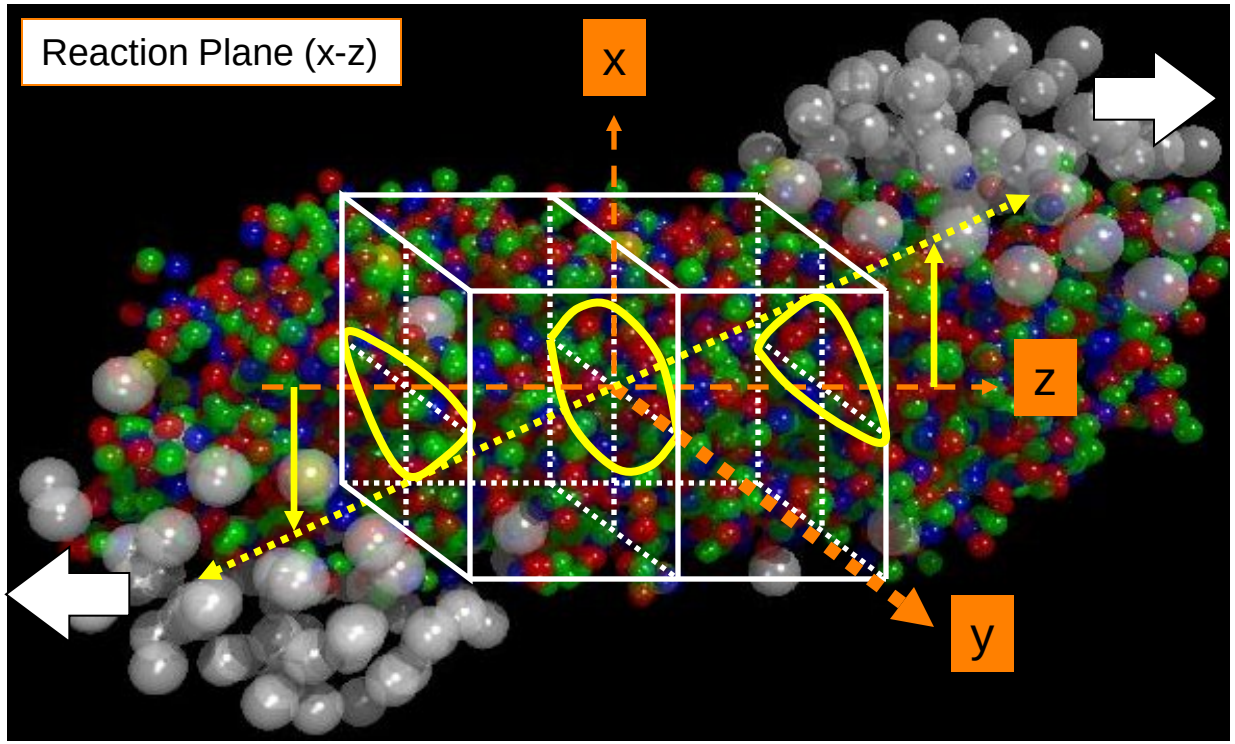
Away-side shoulder in A+A with only *n*=2 modulated bkgd.

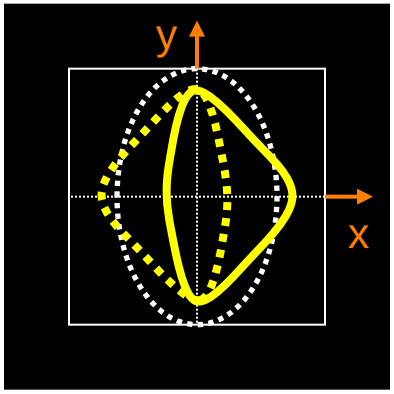
What have we seen?

- Magnitude of 3rd-order harmonics is substantial.
- Correlations between different event planes at different rapidities could be very informative.
- Dependence of single-particle v_3 on p_T, centrality, particle type and beam energy all consistent with hydrodynamical behavior.
- Data on v_3 can provide discriminating power among models (init. cond., viscosity) beyond v_2 alone.
- Accounting for v_3 in bulk flow changes interpretation of pair correlations shape significantly.

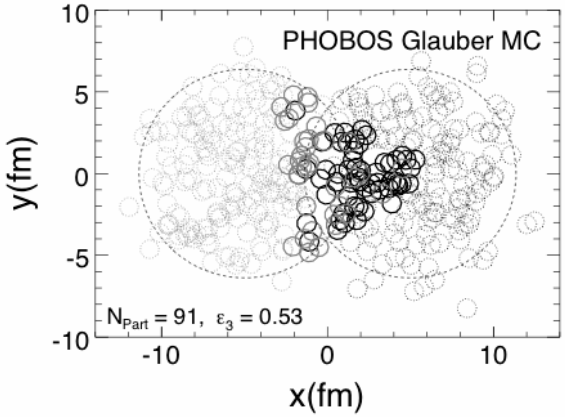
Backup material

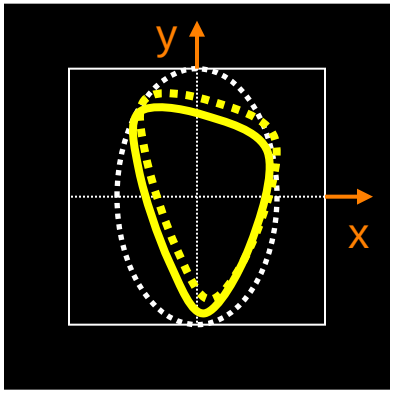
v_3 and Initial Fluctuation





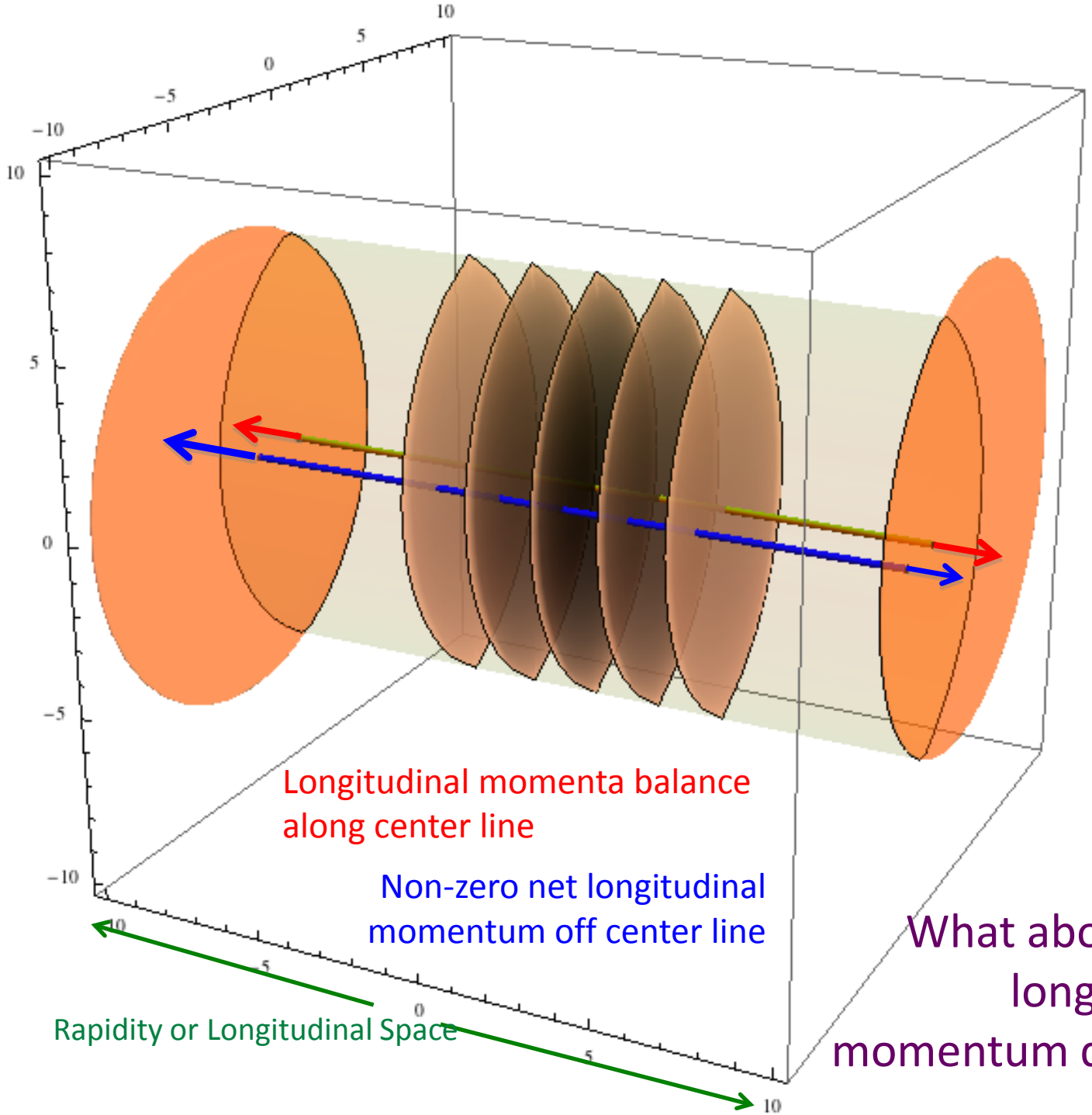
arXiv:1003.0194





black-disk --> sign-flipping v_3

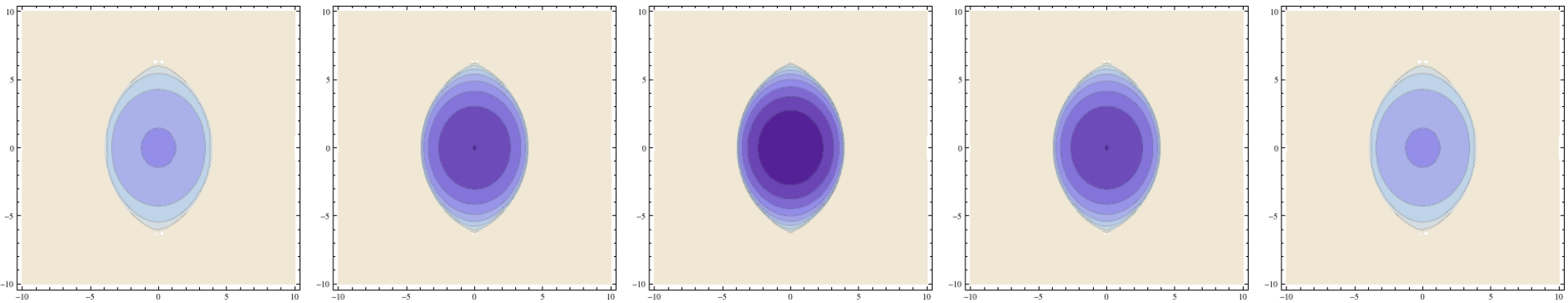
initial fluctuation --> no-sign-flipping v_3



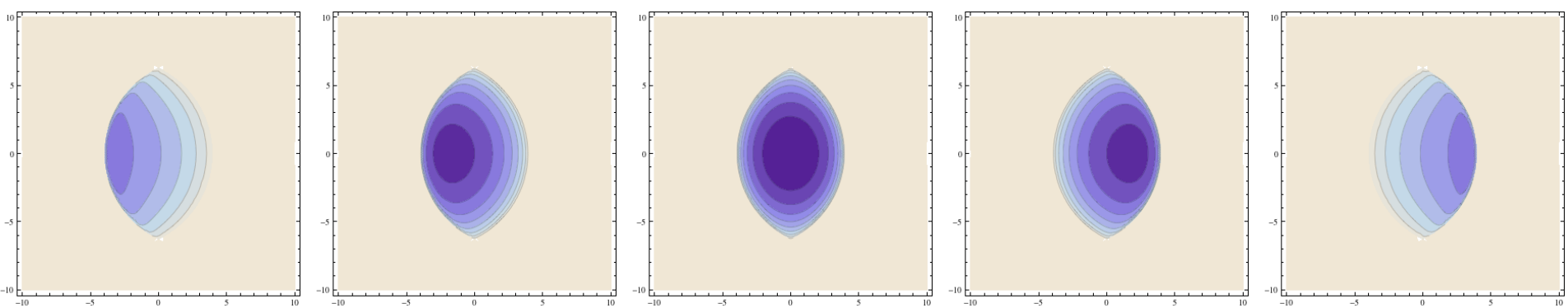
What about local longitudinal momentum density?

Transverse profiles of initially-deposited energy density

Rapidity or Longitudinal Space

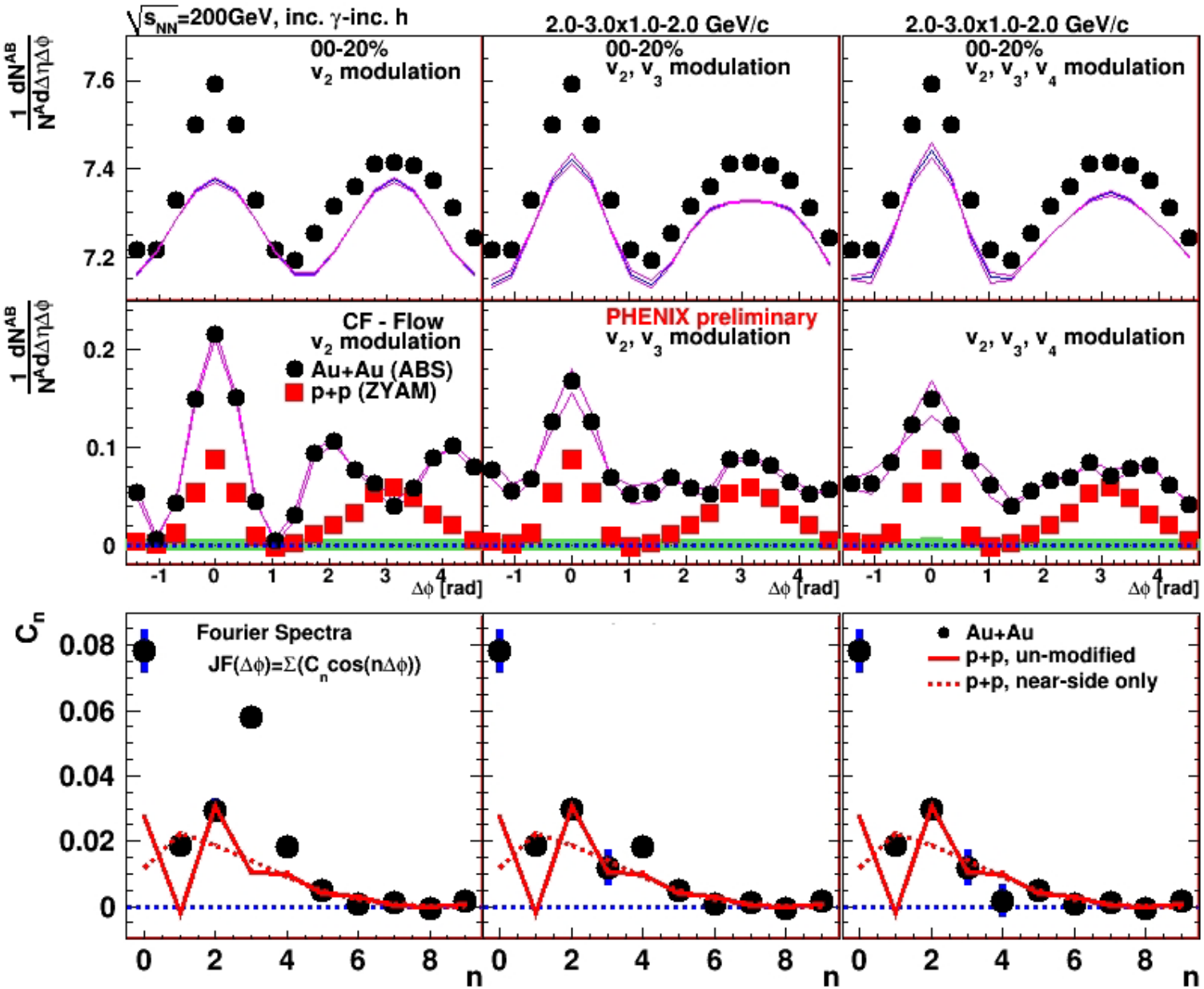


Assuming no rapidity dependence of transverse profile



With rapidity dependence based on local longitudinal momentum density *and* a particular choice for the initial spread along z/Y

Correlation function decomposition, revisited



Correlation functions and background pairs distribution

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Fourier breakdown of jet-jet pairs

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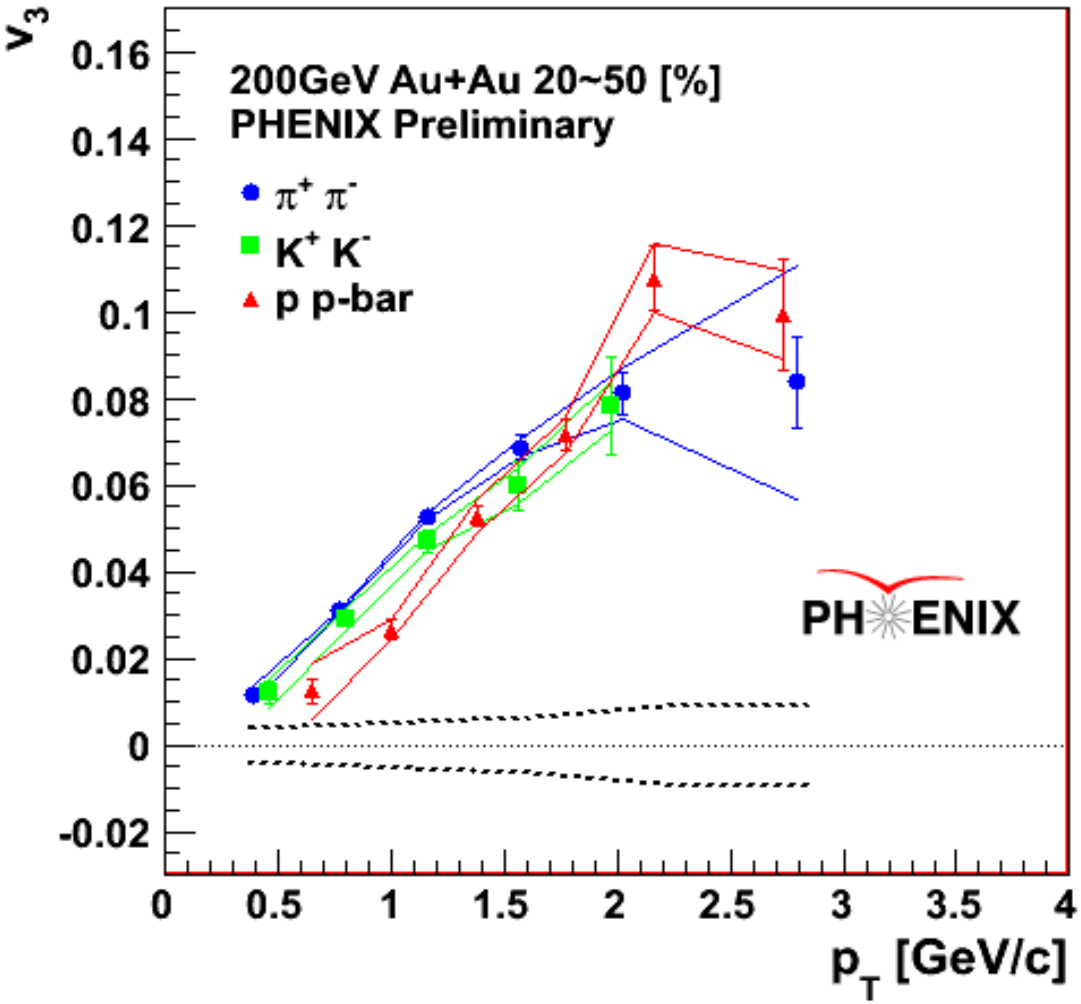

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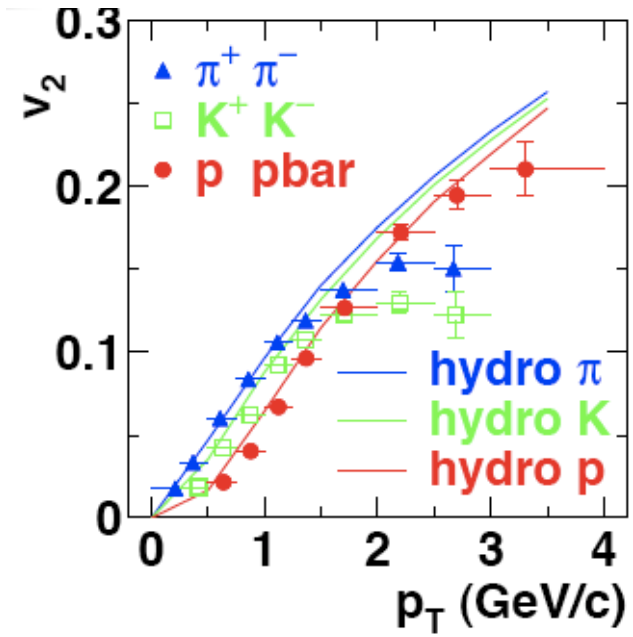

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