Measurements of Higher-Order Flow Harmonics at PHENIX

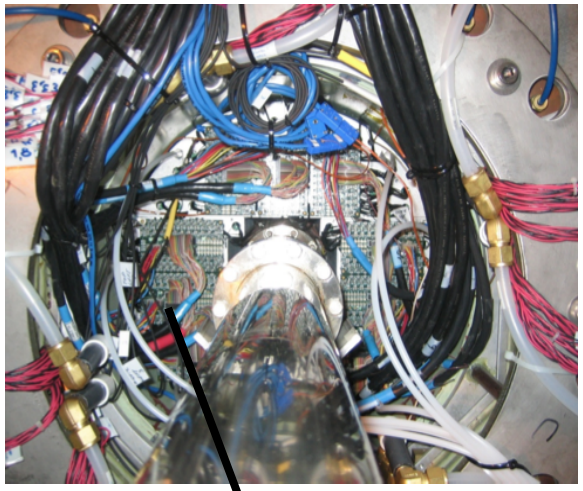
Robert Pak

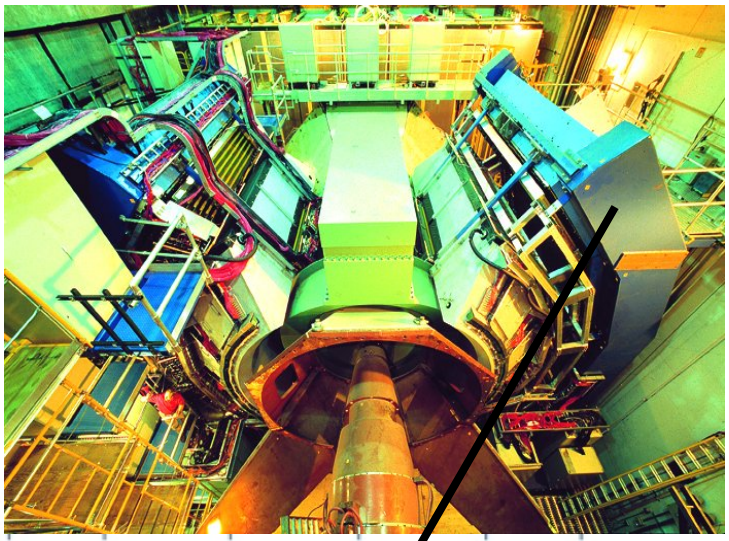
BROOKHAVEN NATIONAL LABORATORY

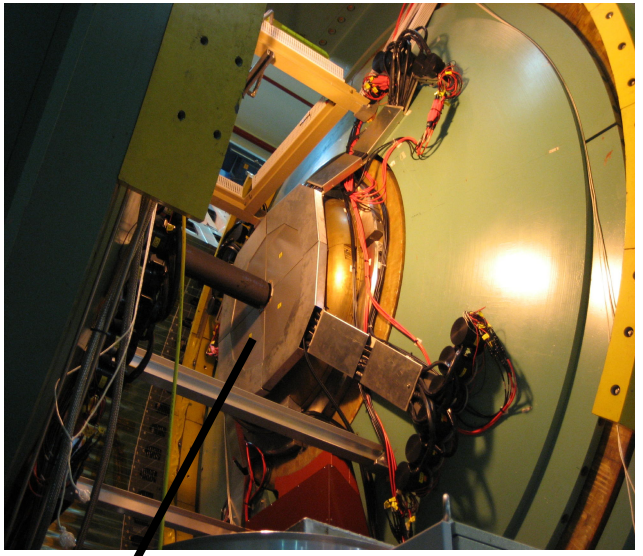
International Europhysics Conference on High Energy Physics
Grenoble, Rhône-Alpes France July 21-27 2011

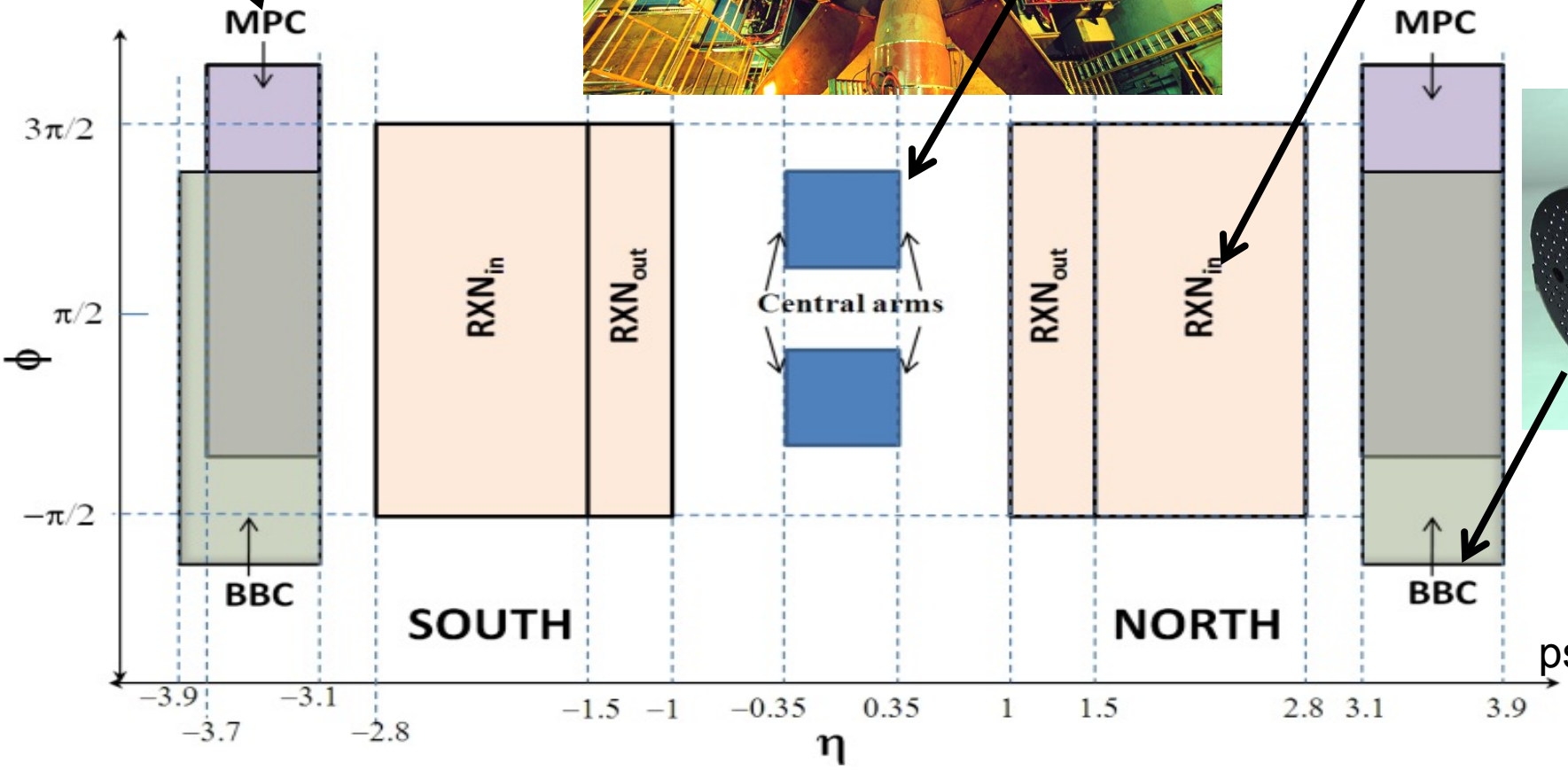
European Physical Society
HEP 2011

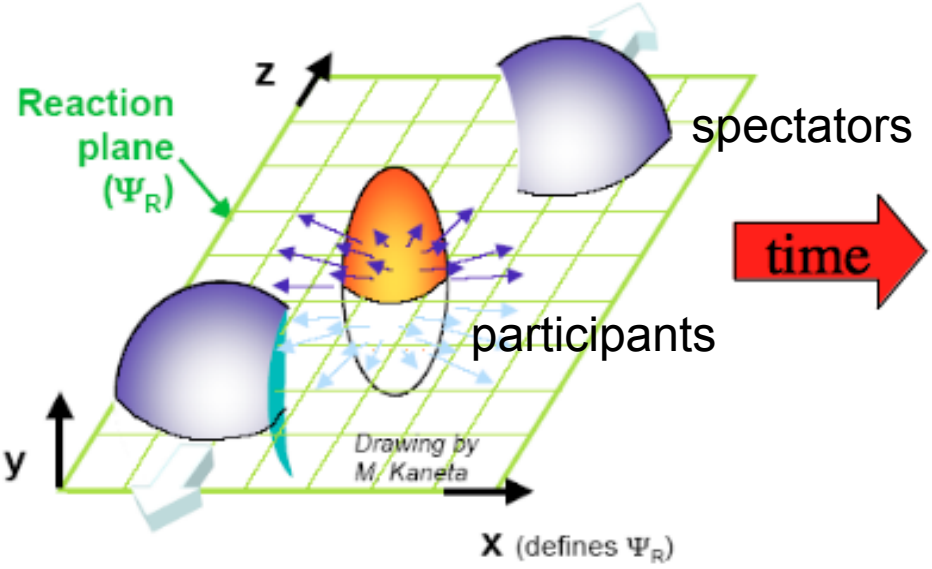
PHENIX



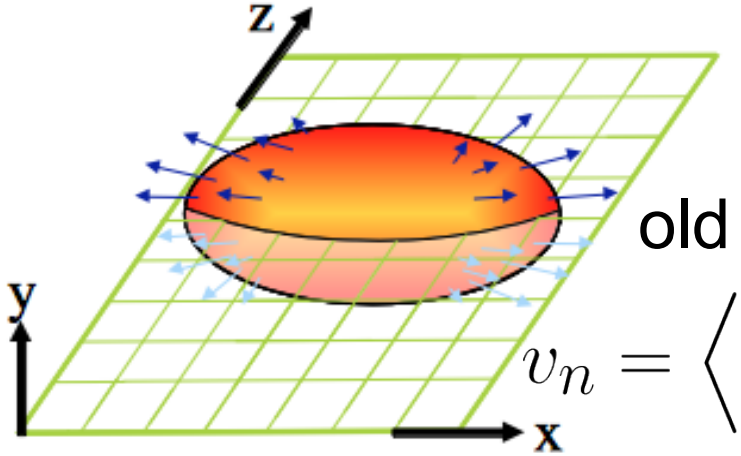





MPC
MPC
3π/2
π/2
−π/2
ϕ
RXN$_{in}$
RXN$_{out}$
Central arms
RXN$_{out}$
RXN$_{in}$
BBC
BBC
SOUTH
NORTH
−3.9
−3.7
−3.1
−2.8
−1.5
−1
−0.35
0.35
1
1.5
2.8
3.1
3.9
η
pseudorapidity



time



old school

$$v_n = \left\langle e^{in(\phi_p - \Psi_R)} \right\rangle$$

What's newer:

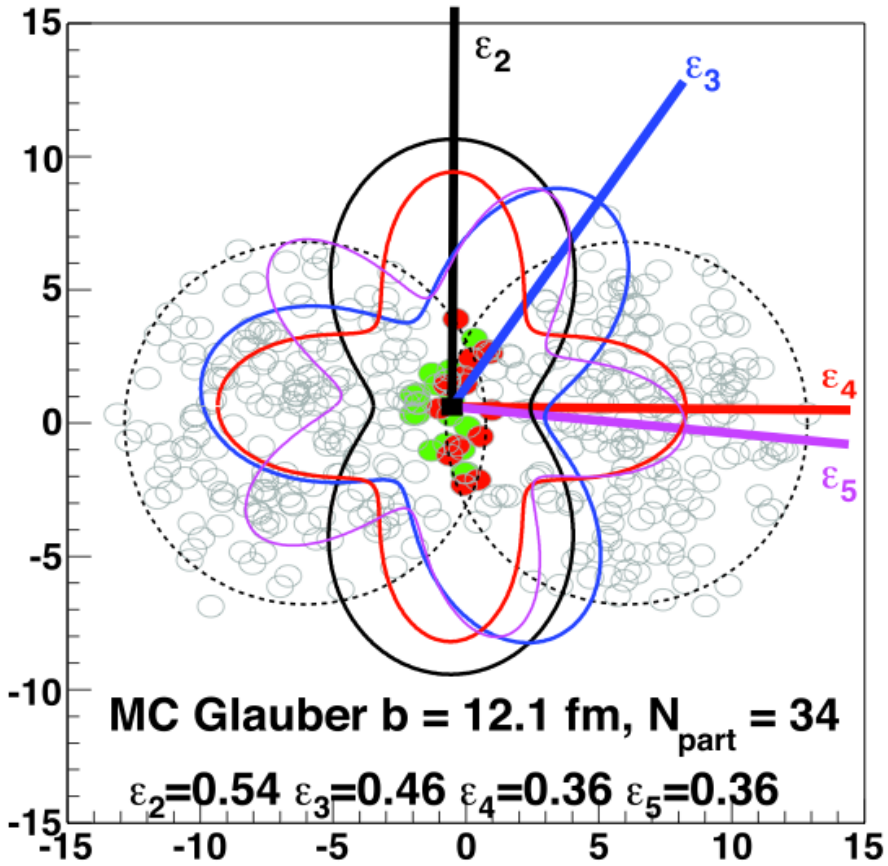
- Generalized eccentricities for higher flow moments

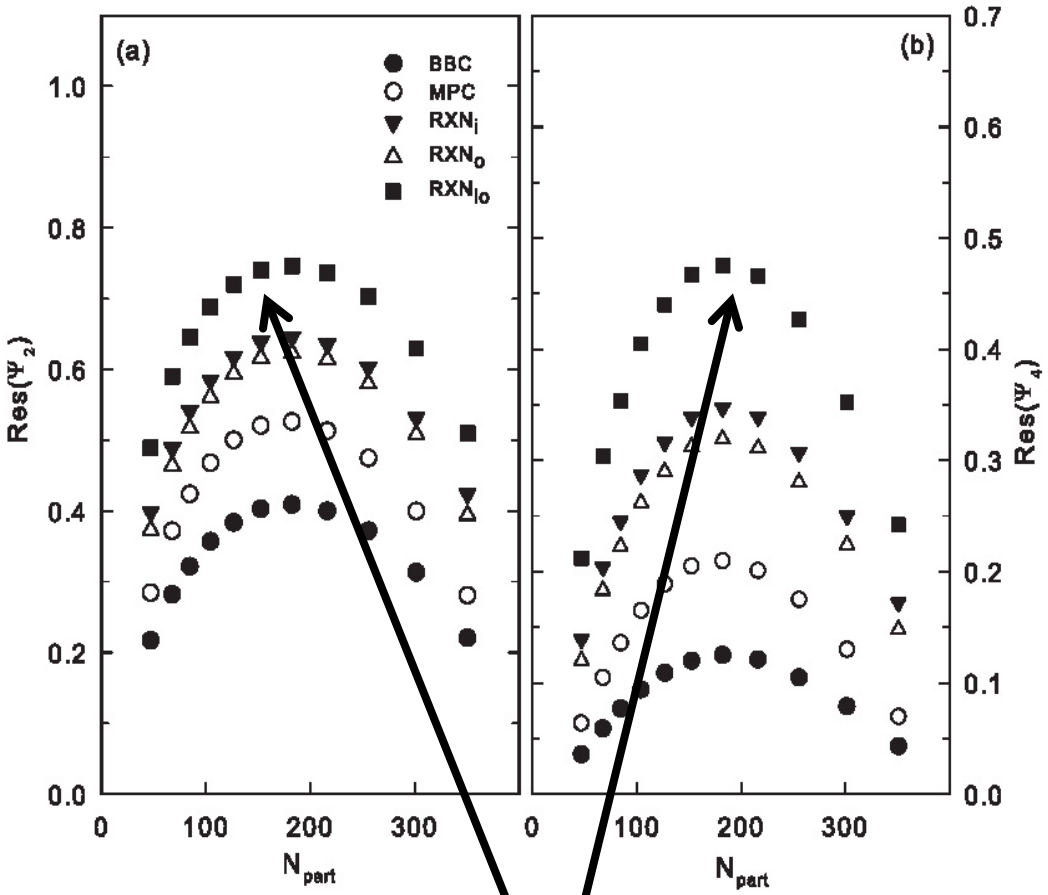
$$v_n = \left\langle e^{in(\phi_p - \Psi_n)} \right\rangle$$

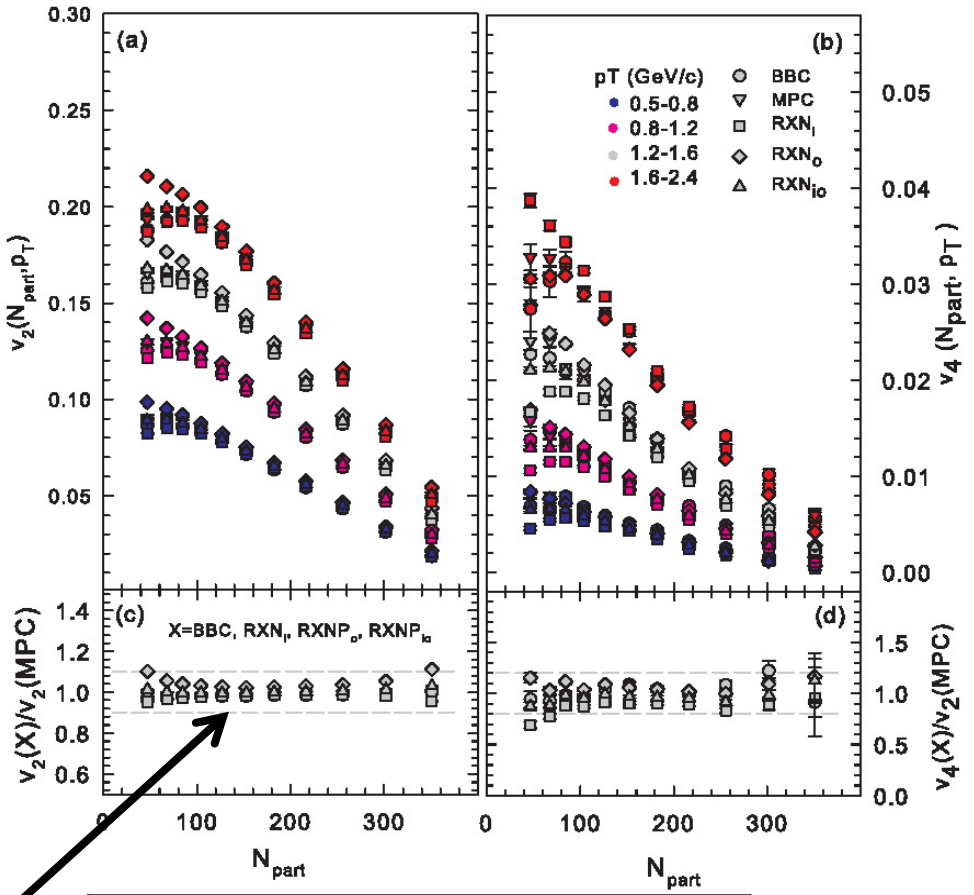
- For smooth profile: Odd harmonics cancel out
- For "lumpy" profile: Odd harmonics persist

Aside: number of participants defines centrality of collision

Fig. from PRC **83**, 044908 (2011)

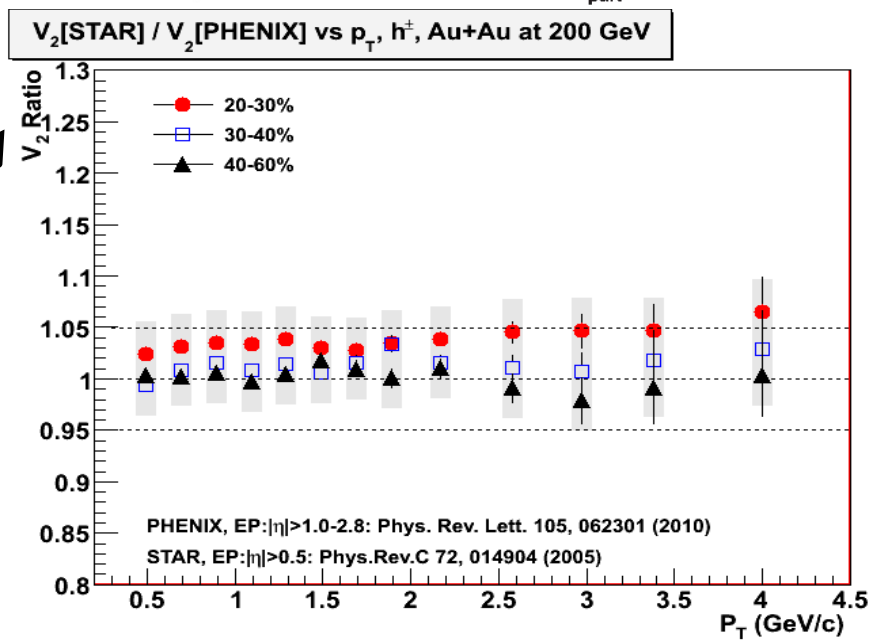




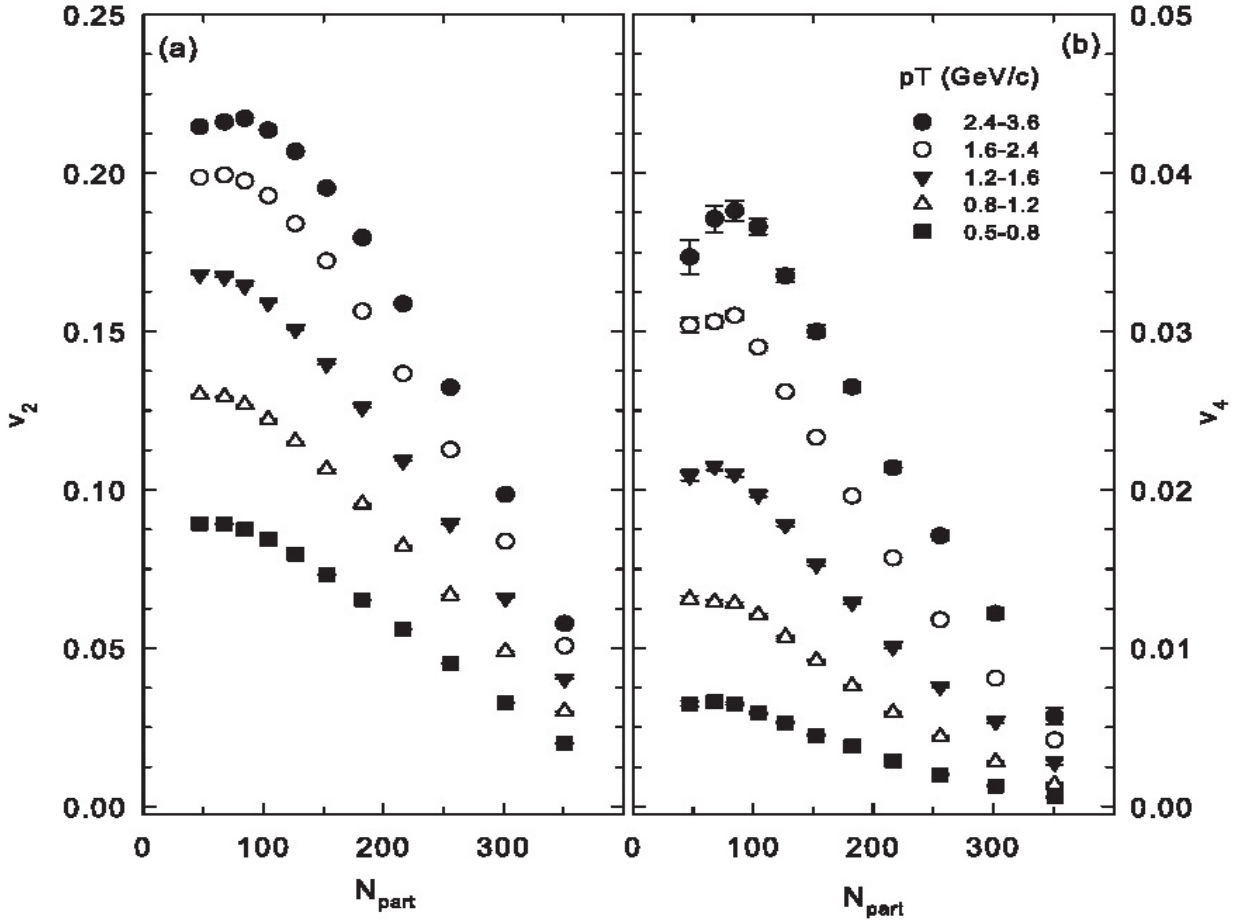


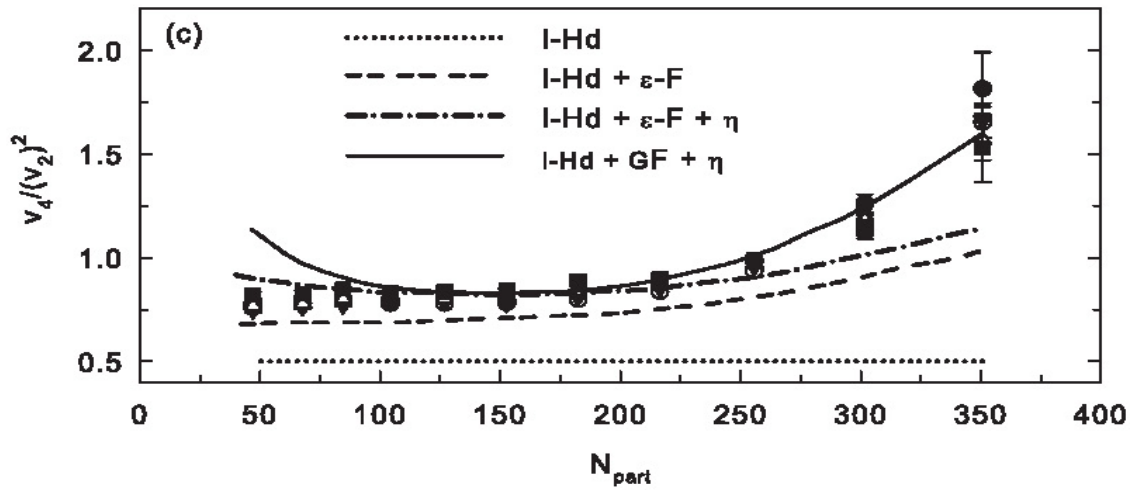
Data QA:

- Improved resolution with RXN detector
- Agreement using different PHENIX sub-systems
- Agreement between STAR and PHENIX

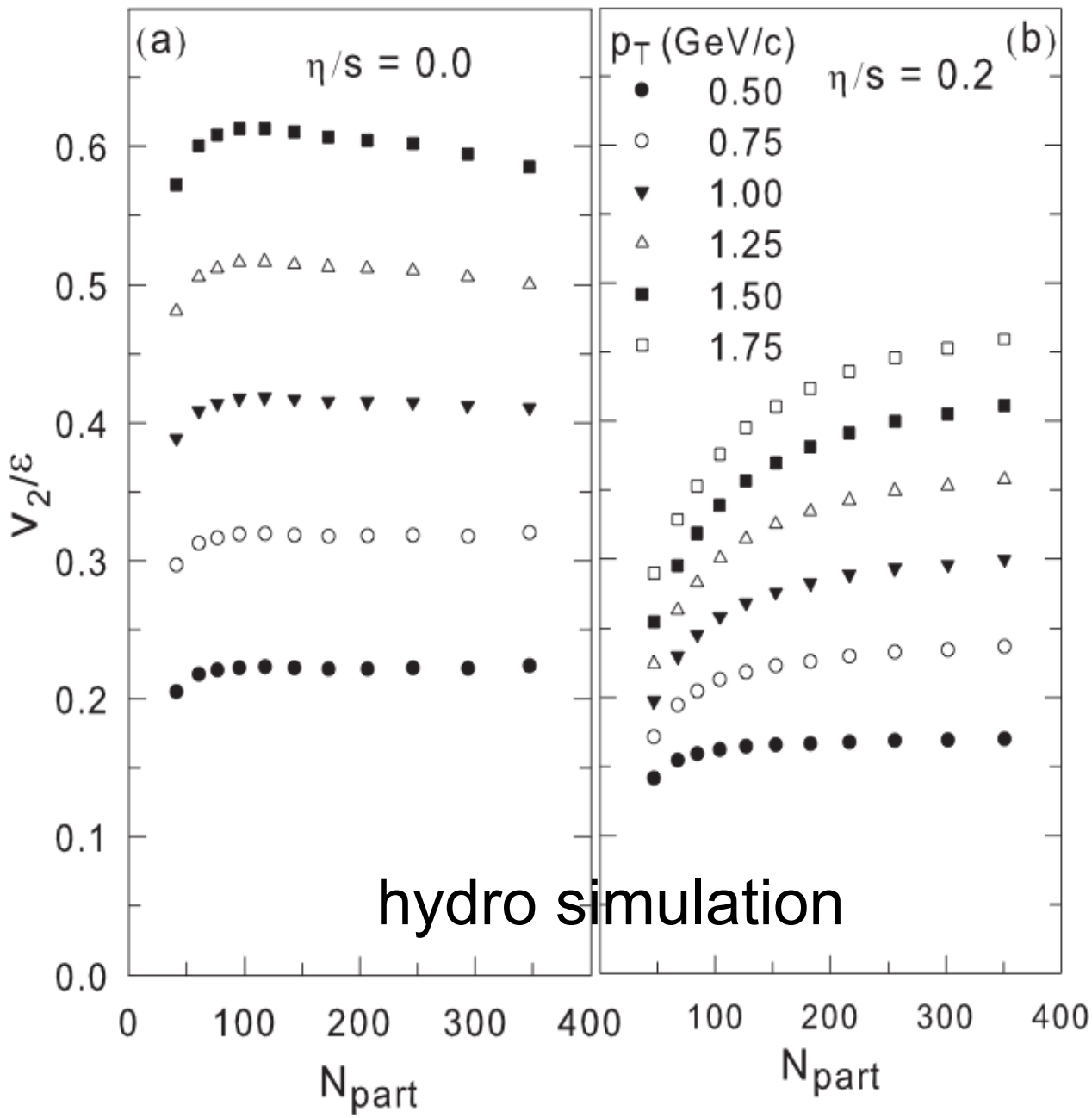


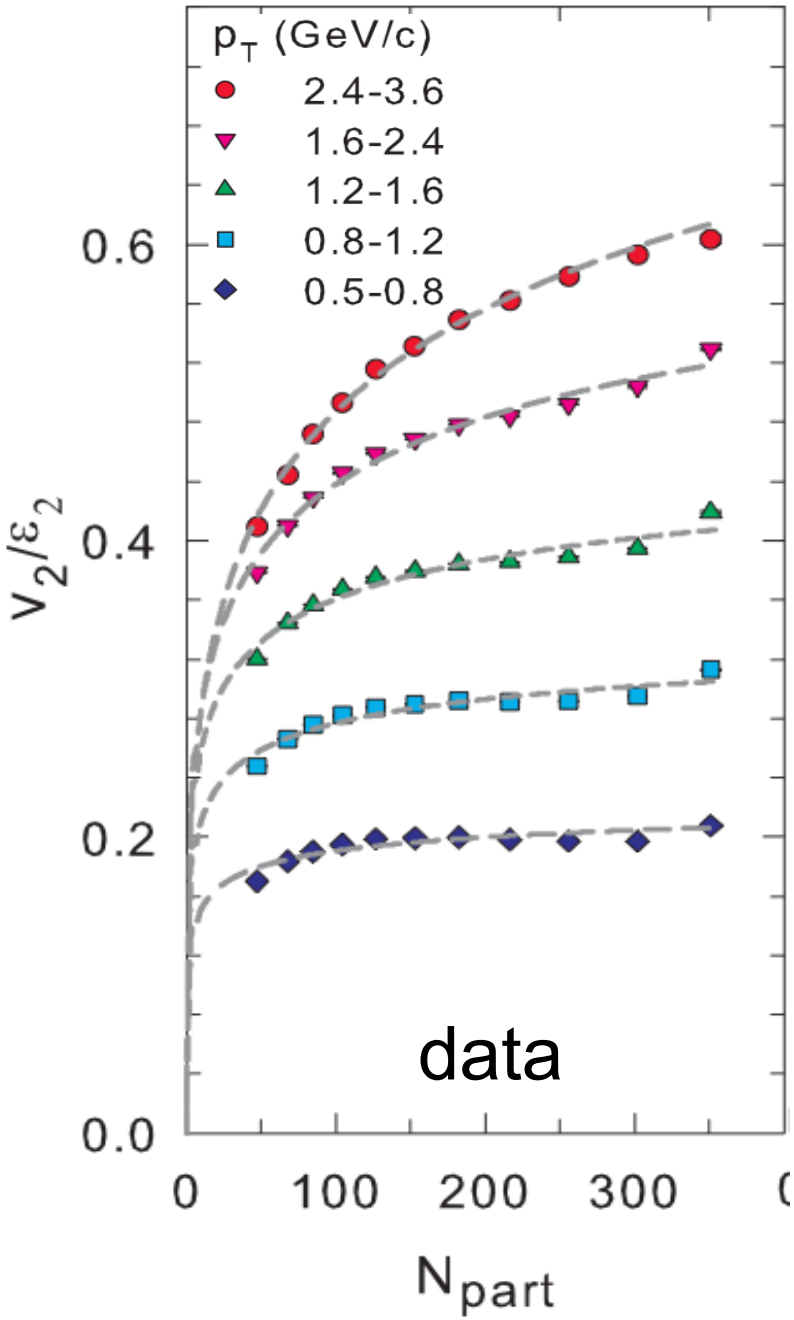
PRL **105**, 062301 (2010)





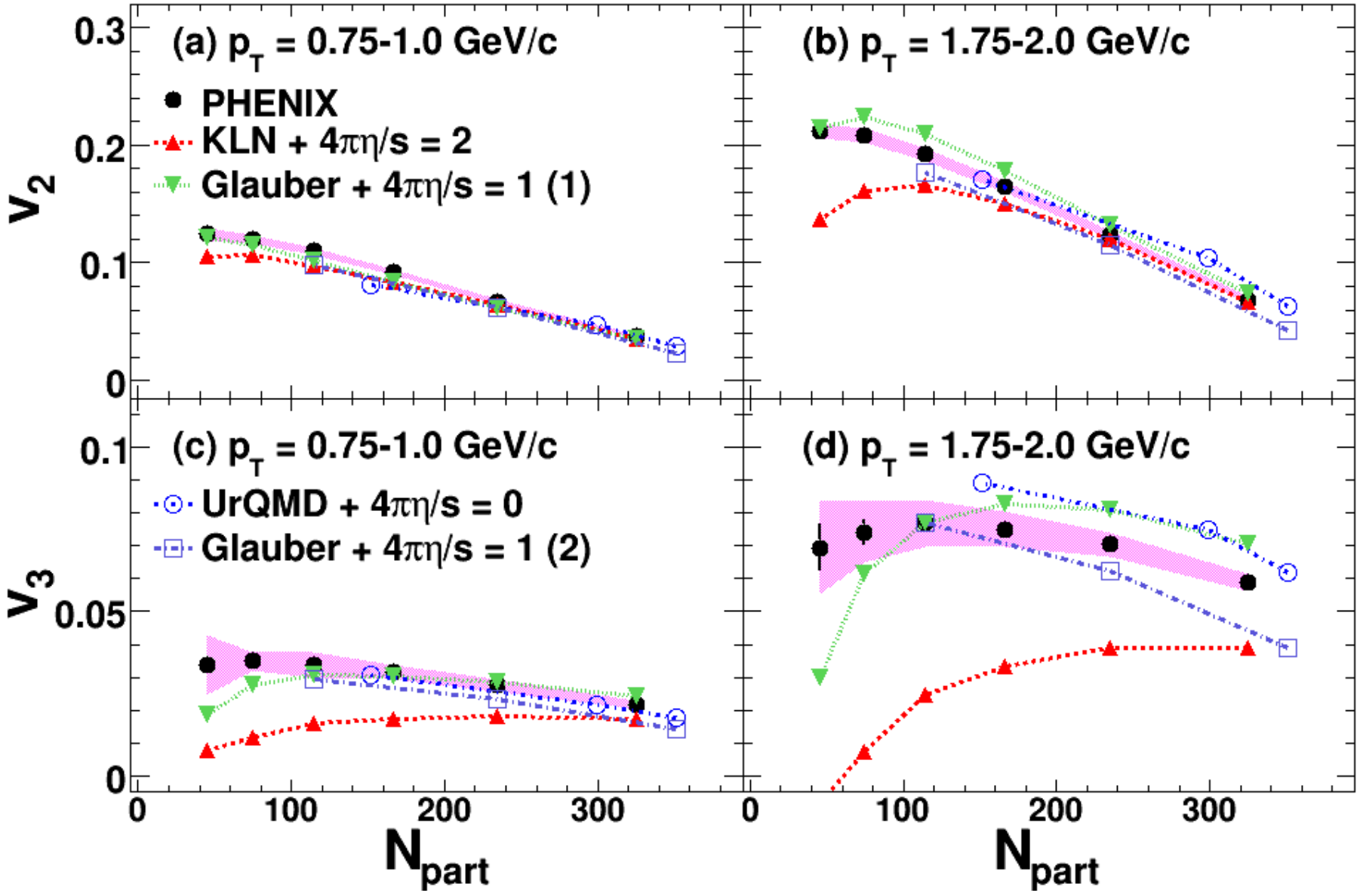
Including fluctuations improves agreement with data, but adding viscosity is even better



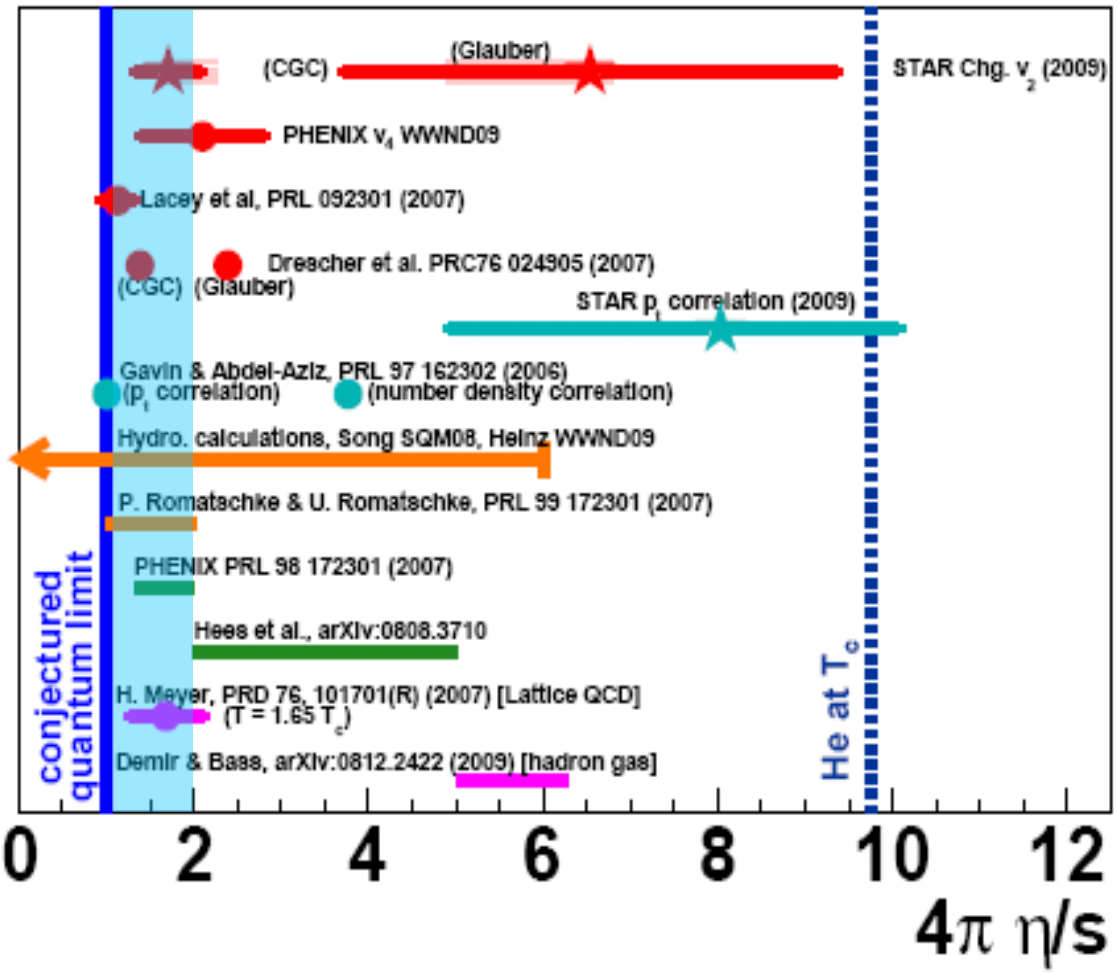


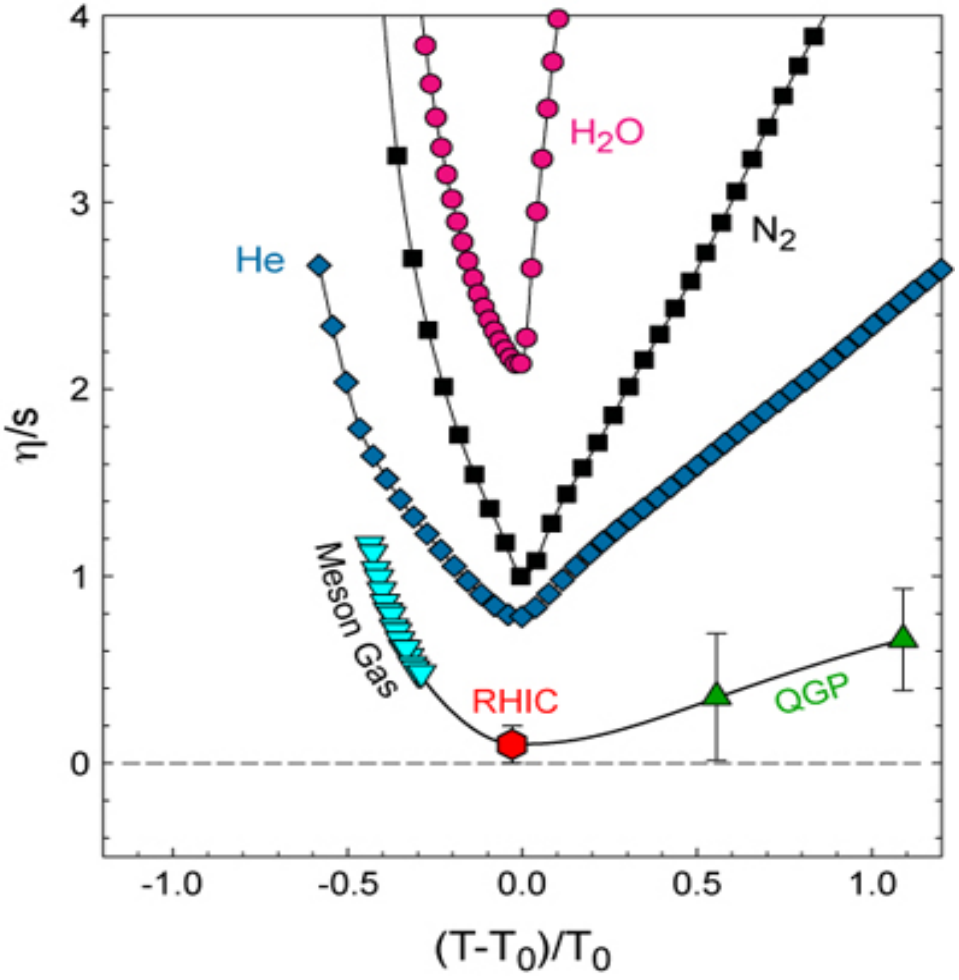
Simultaneous fit using Knudsen number $(K = \lambda/\bar{R})$ parameterization does a reasonable job. Details in PRC **82**, 034910 (2010)

arXiv:1105.3928 [nucl-ex]



Higher-order flow harmonics help to discriminate between models



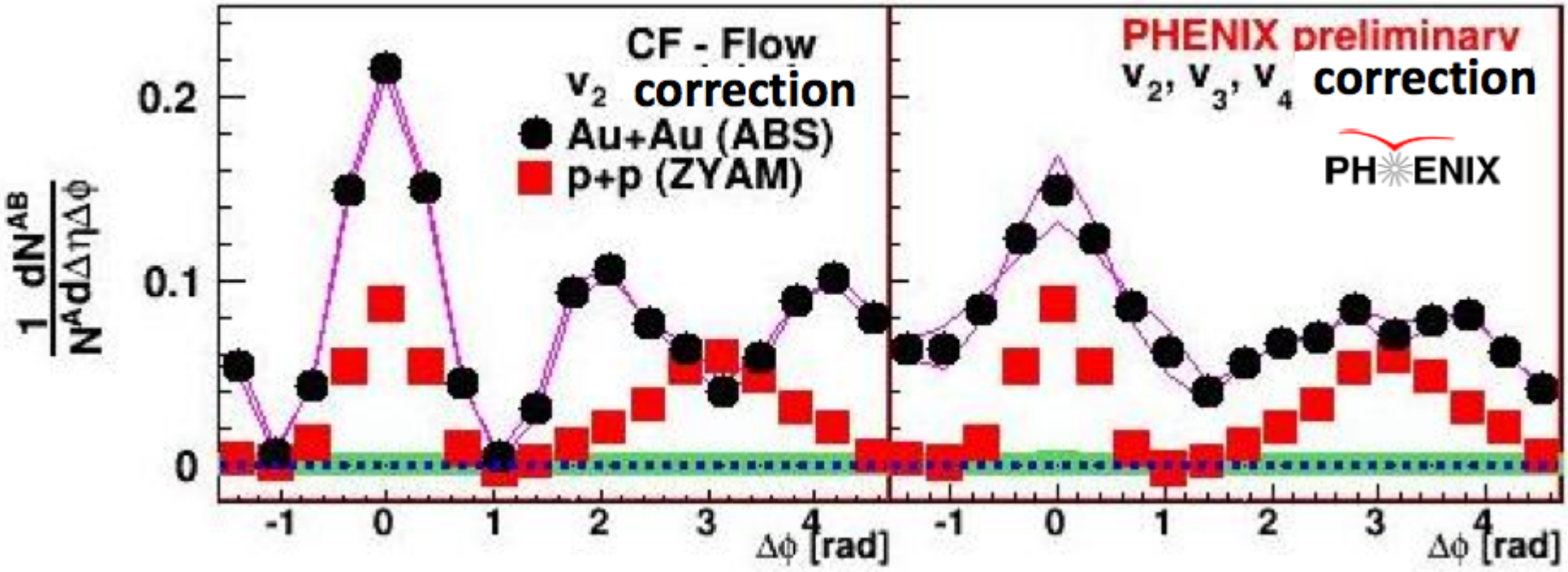


Progress constraining viscosity to entropy density ratio

$$\frac{\eta}{s} \approx \lambda T c_s \equiv (\bar{R} K T c_s)$$

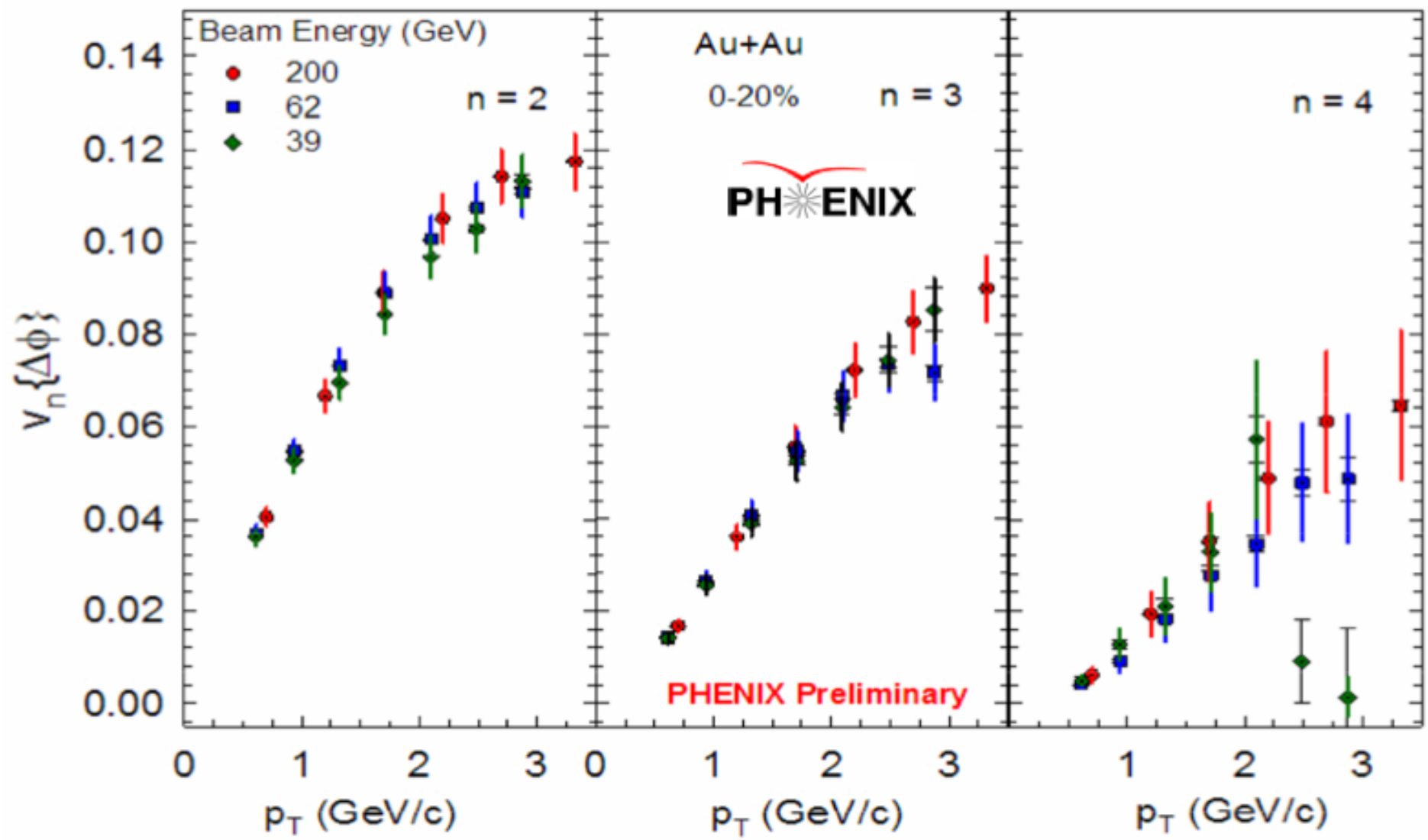
between 1 and 2x the conjectured quantum limit.

Decomposition of two-particle Δφ Correlation Functions

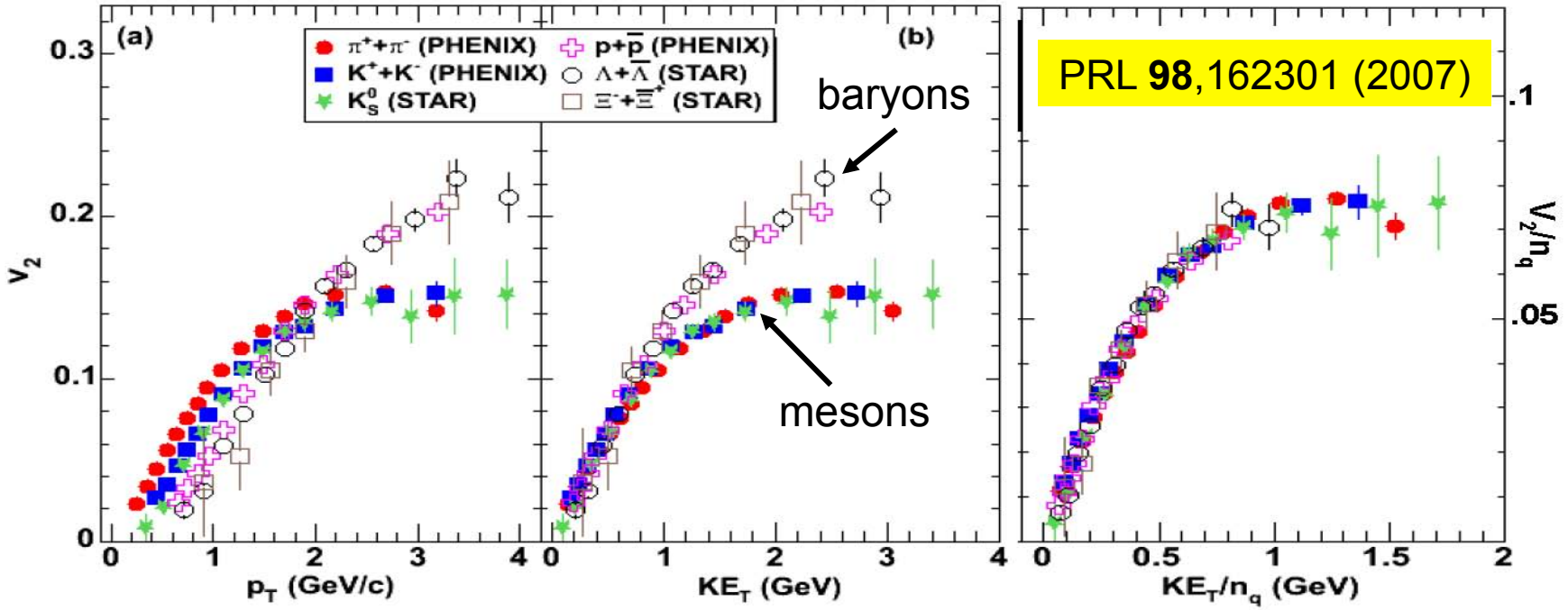


Accounting for higher-order flow harmonics in bulk flow significantly changes interpretation of pair correlations shape*, e.g.*, Mach cone, ridge, etc…

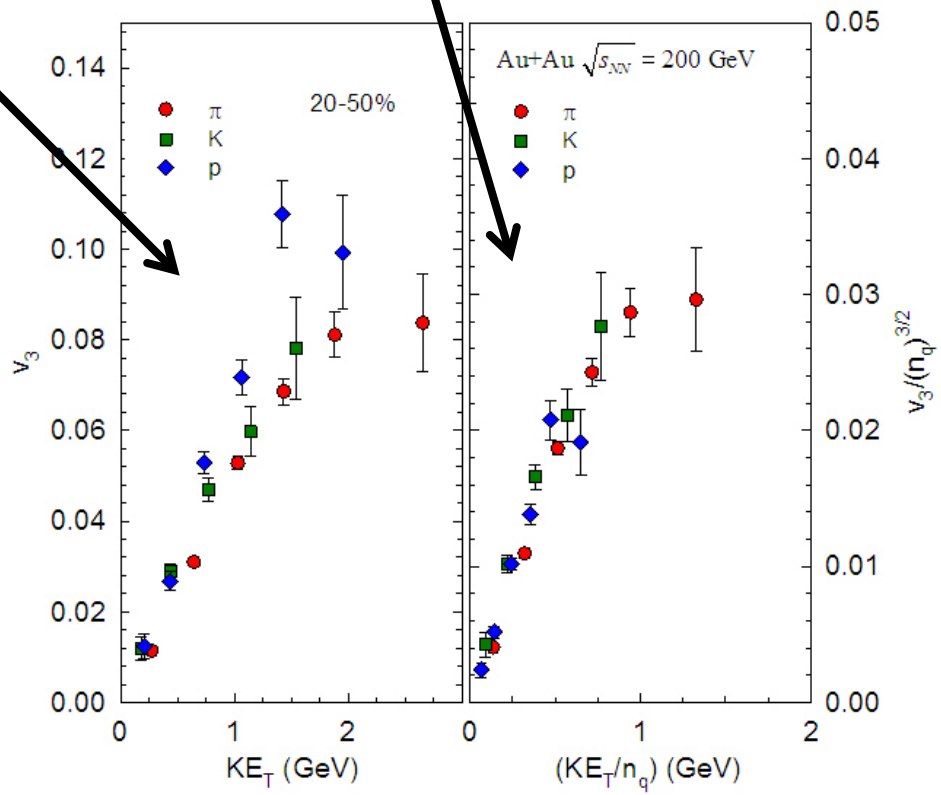
From the recent energy scan at RHIC:



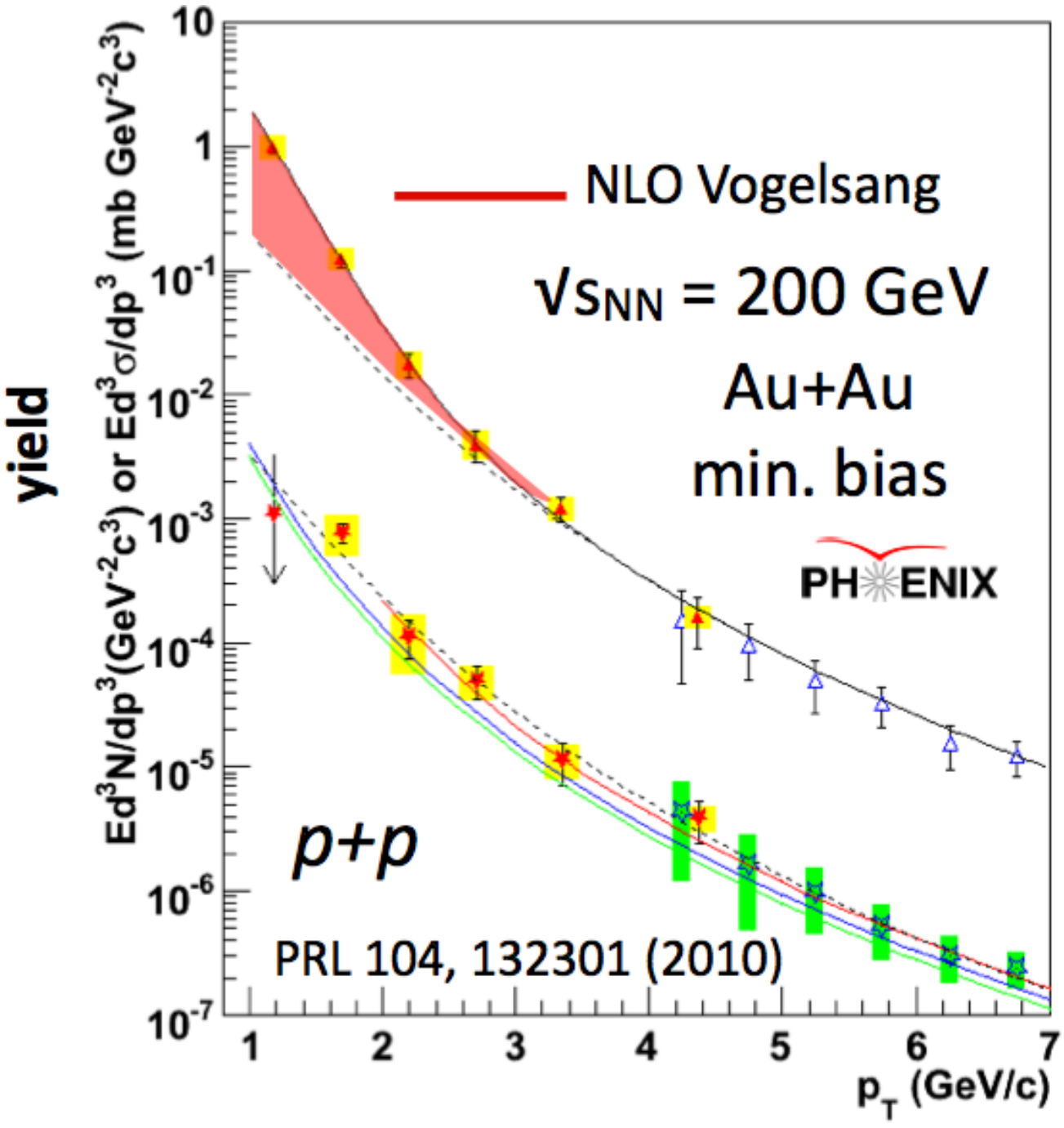
Little change over this energy range; more beam energies to be added.



PRL **98**,162301 (2007)

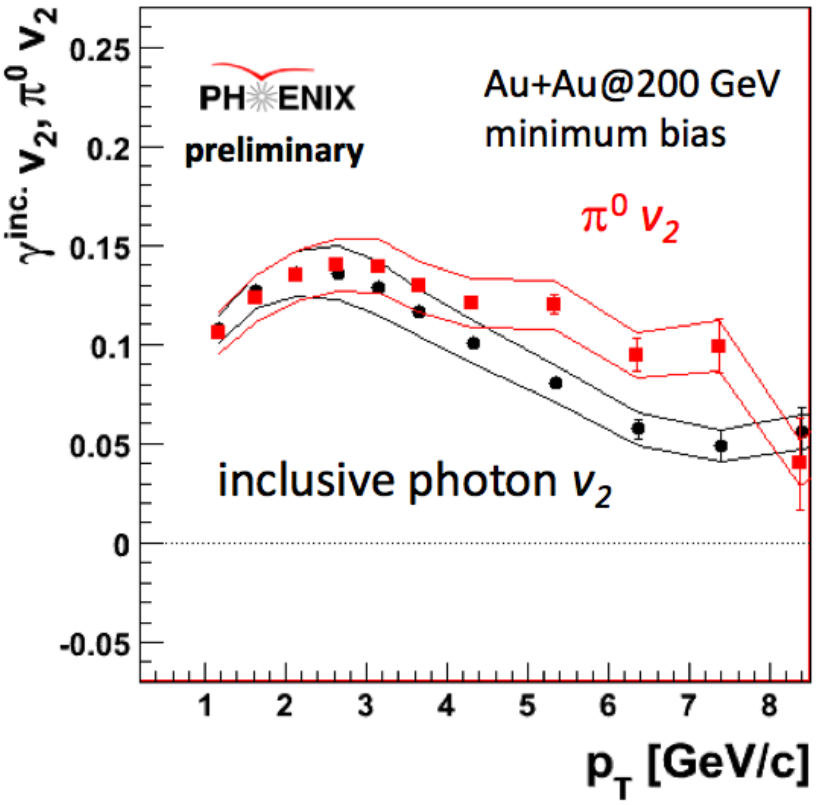


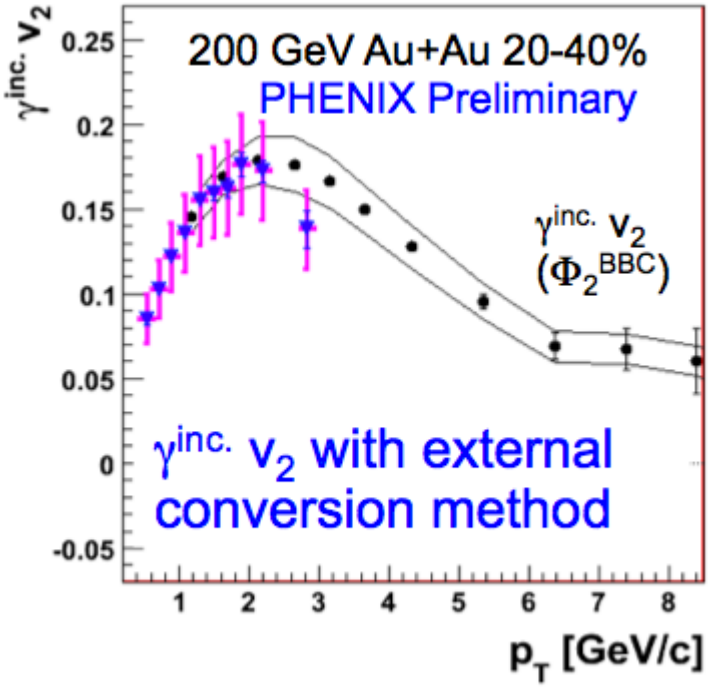
- Flow for identified particles
- Constituent quark scaling
- Evidence for partonic flow
- Validated by v_3 measurement



PHENIX measured direct photon excess at low transverse momentum in heavy-ion collisions (see talk from C. Pinkenburg).

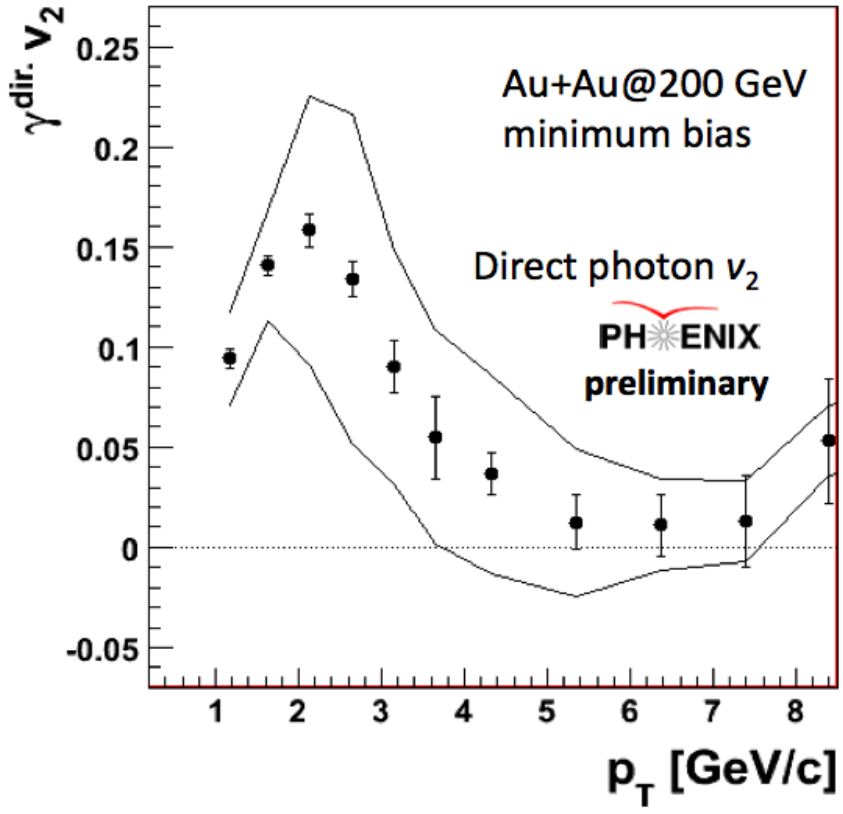
But do these photons "flow"?





Statistical subtraction:

$$v_2^{dir.} = \frac{R_\gamma v_2^{inc.} - v_2^{BG}}{R_\gamma - 1}$$



Direct photon v_2 observed

details in: arXiv:1105.4126 [nucl-ex]

Summary and Outlook

- Significant higher-order event anisotropy has been measured:
  - Fluctuations are important → initial state is “lumpy”
  - v_3 helps disentangle initial state from η/s
- Almost perfect fluidity above 39 GeV
- Partonic flow validated by v_3 measurement
- Direct photon v_2 observed:
  - Small at high p_T → consistent with pQCD
  - Large at low p_T → challenge to theory