Anisotropic Flow and Two-Particle Correlation Measurements in p+Au Collisions at 200 GeV

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Abstract

Two-particle azimuthal correlations that extend over a long range in pseudorapidity have been found in d+Au and ^{3}He+Au collisions at RHIC, and in p+p and p+Pb collisions at LHC energies. Anisotropic flow coefficients have also been extracted. The study of p+Au collisions at RHIC provides a unique opportunity to address two important questions:

- Is there collective flow in p+Au collisions at RHIC?
- If collective flow is present in small collision systems, how does the initial geometry affect its strength?

We present the first measurements of long-range two-particle correlations in high multiplicity p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, and the second-order fourier coefficient v_2 as a function of transverse momentum p_T. The v_2 measurements are compared in p+Au, d+Au, and ^{3}He+Au collisions and to several theoretical predictions.

Experimental Details

The following data sets are analyzed:

Run 15 p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

- 1.15 billion high-multiplicity events triggered by BBC, corresponding to 0-5% most central collisions

Run 5,6,8,9 p+p collisions at $\sqrt{s_{NN}}$ = 200 GeV

- 3.09 billion events from a minimum bias trigger based on BBC

Each side of BBC has 64 photomultiplier tubes(PMTs)

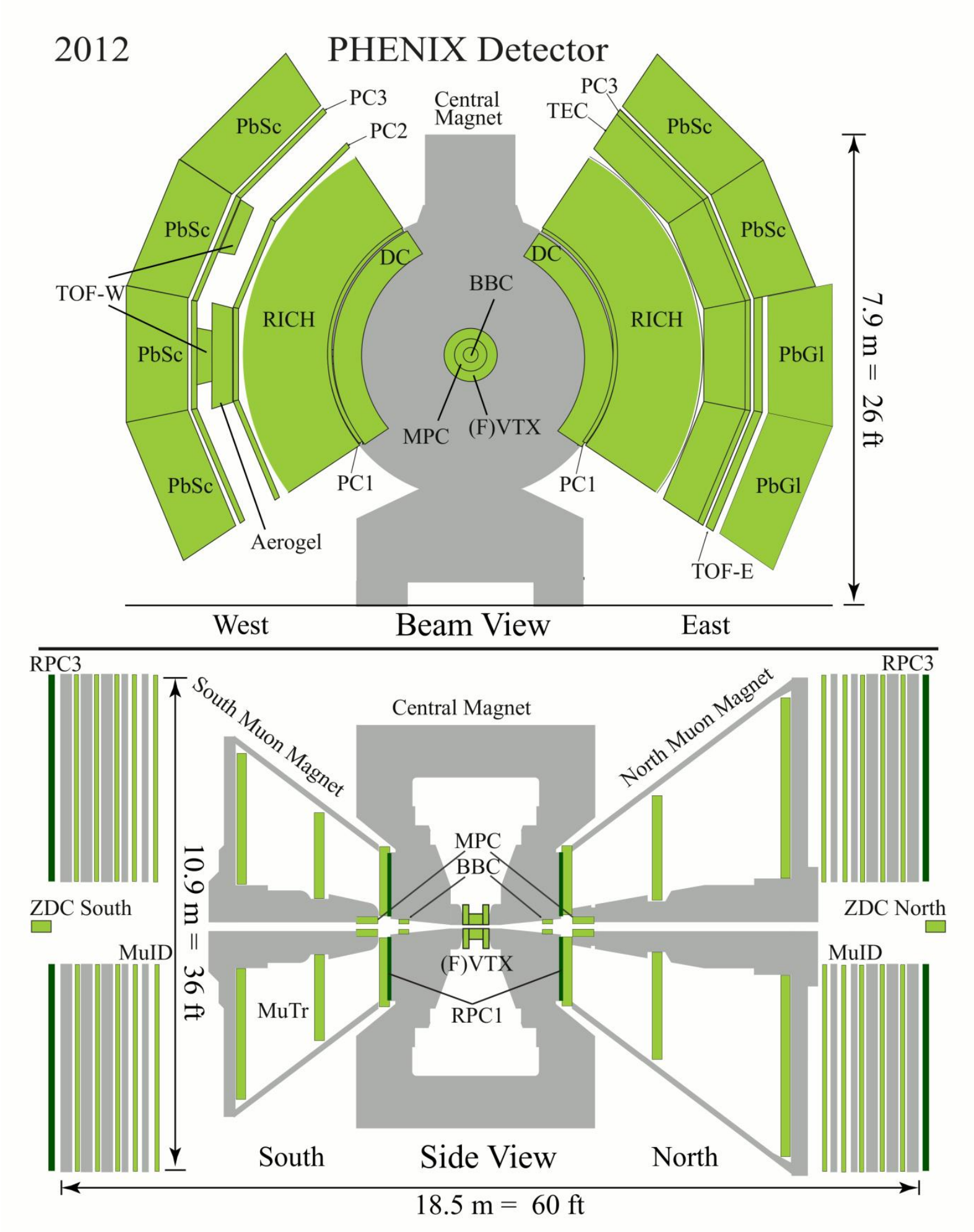


Figure 1. PHENIX Detector configuration for Run15. The top one is for Beam View, the bottom one is for Side View.

Methods

- **Two particle correlation**

We construct the signal distribution $S(\Delta\varphi, p_T)$of track-PMT pairs over relative azimuthal opening angle $\Delta\varphi = \varphi_{track} - \varphi_{PMT}$, each with weight from the charge measured by each PMTs in BBC, in bins of track transverse momentum p_T.

$$S(\Delta\varphi, p_T) = \frac{d(w_{PMT} N_{same\ event}^{track(p_T)-PMT})}{d\Delta\varphi}$$

To correct for PHENIX's non-uniform azimuthal acceptance, we then construct the corresponding "mixed-event" distribution $M(\Delta\varphi, p_T)$ over track-PMT pairs, where the tracks and tower signals are from different events in the same centrality and vertex position class. We then construct the normalized correlation function.

$$C(\Delta\varphi, p_T) = \frac{S(\Delta\varphi, p_T)}{M(\Delta\varphi, p_T)} \frac{\int M(\Delta\varphi', p_T) d\Delta\varphi'}{\int S(\Delta\varphi', p_T) d\Delta\varphi'}$$

Methods

- **Event plane method**

The second-order anisotropic flow coefficient v_2 is calculated by:

$$v_2 = \frac{< \cos[2(\varphi - \psi_{2,FVTXs})] >}{Res(\psi_{2,FVTXs})}$$

The event-plane angle is calculated by:

$$\psi_{2,FVTXs} = arctan\left(\frac{Q_y}{Q_x}\right) = arctan(\frac{\sum_{i=1}^{N} w_i \sin(2\varphi_{FVTX,i})}{\sum_{i=1}^{N} w_i \cos(2\varphi_{FVTX,i})})$$

A standard event-plane flattening technique has been applied to remove the residual non-uniformities in the distribution of event-plane angles.

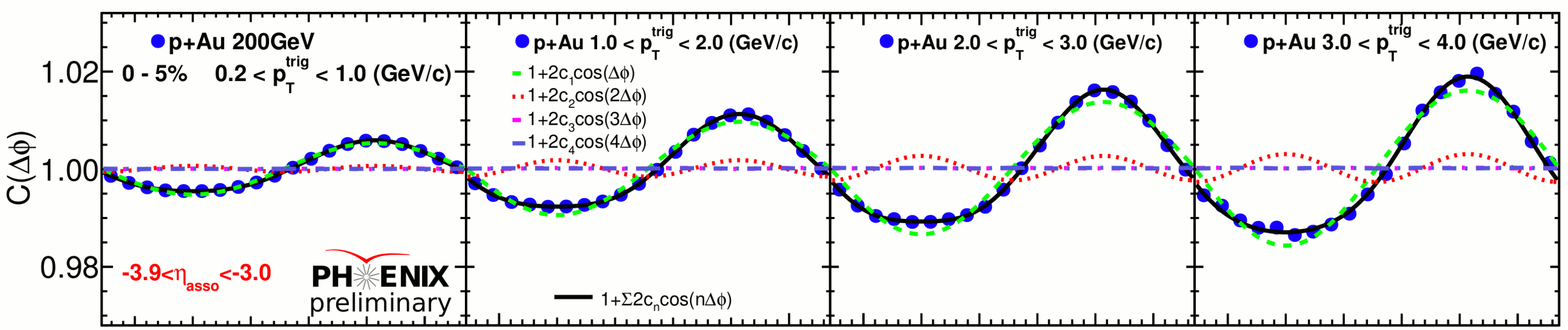
The three sub-events method is used to evaluate the resolution of the second-order event plane for FVTXs.

$$Res(\psi_{2,FVTXs}) = < \cos[2(\psi_{2,FVTXs} - \psi_{RP})] >$$
$$= \sqrt{\frac{< \cos[2(\psi_{2,FVTXs} - \psi_{2,CNT})] >< \cos[2(\psi_{2,FVTXs} - \psi_{2,BBCs})] >}{< \cos[2(\psi_{2,BBCs} - \psi_{2,CNT})] >}}$$

where, the <> denotes averaging over all the events. The $\psi_{2,CNT}$ is the second-order event plane measured with low p_T (0.2 GeV/c < p_T < 2 GeV/c) tracks from the drift chamber to avoid jet contributions. The $\psi_{2,BBCs}$ and $\psi_{2,FVTXs}$ are the second-order event planes measured with the BBC and FVTX located in the Au-going direction, covering the pseudorapidity ranges of $-3.9 < \eta < -3.0$ and $-3.0 < \eta < -1.0$, respectively.

Results

Figure 2. The azimuthal correlation functions $C(\Delta\varphi, p_T)$, for track-PMT pairs with different transverse momentum selections in 0-5% central p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. The pairs are formed between charged tracks measured in the central arms at |η|<0.35 and BBC in the Au-going direction covering the range -3.9 < η < -3.0. The color lines are from fourier fitting of the correlation function for different orders.



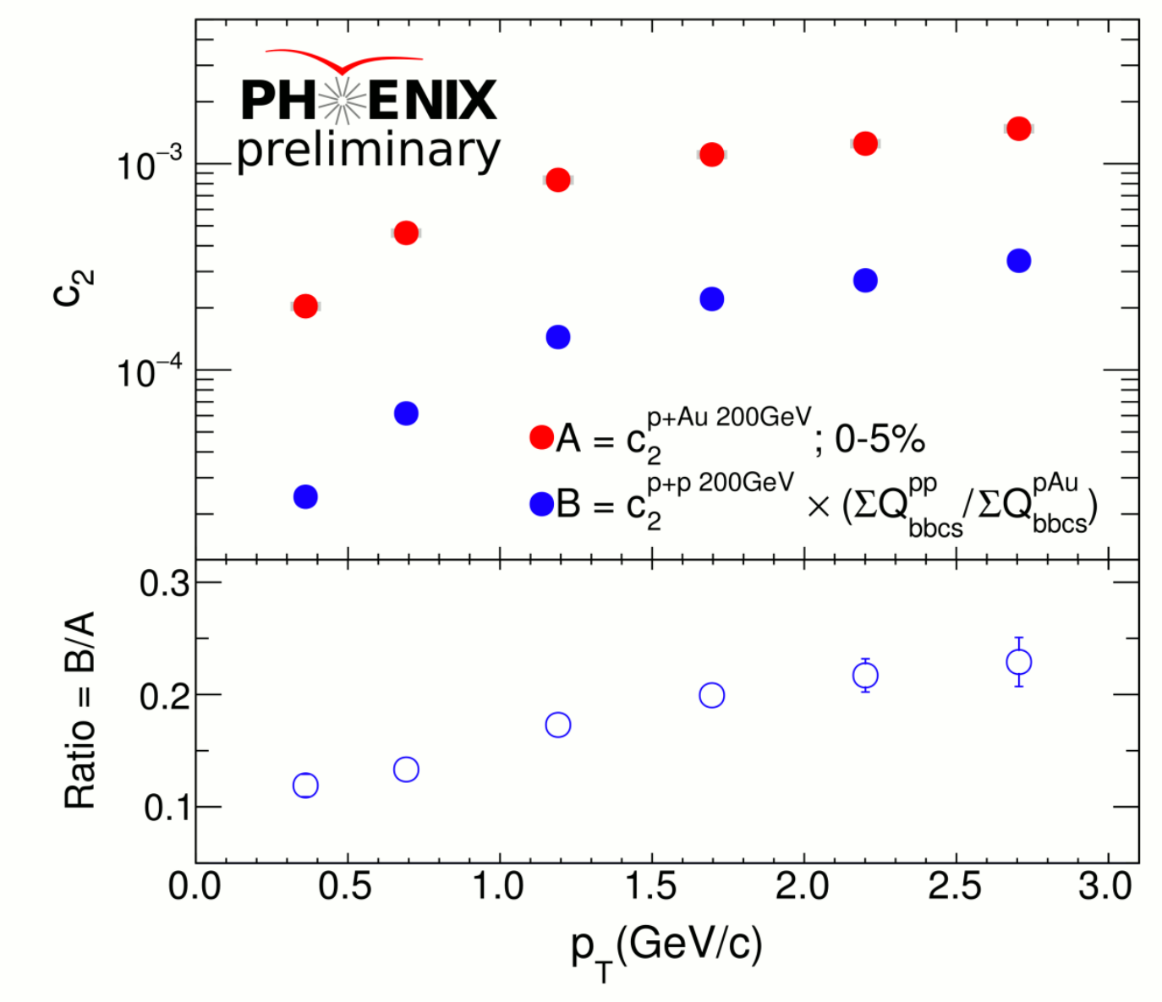


Figure 3. The c_2 Fourier coefficient from 0-5% central p+Au collisions in comparison to the c_2 from minbias p+p collisions scaled by a dilution factor based on average charge in BBC in the two systems.

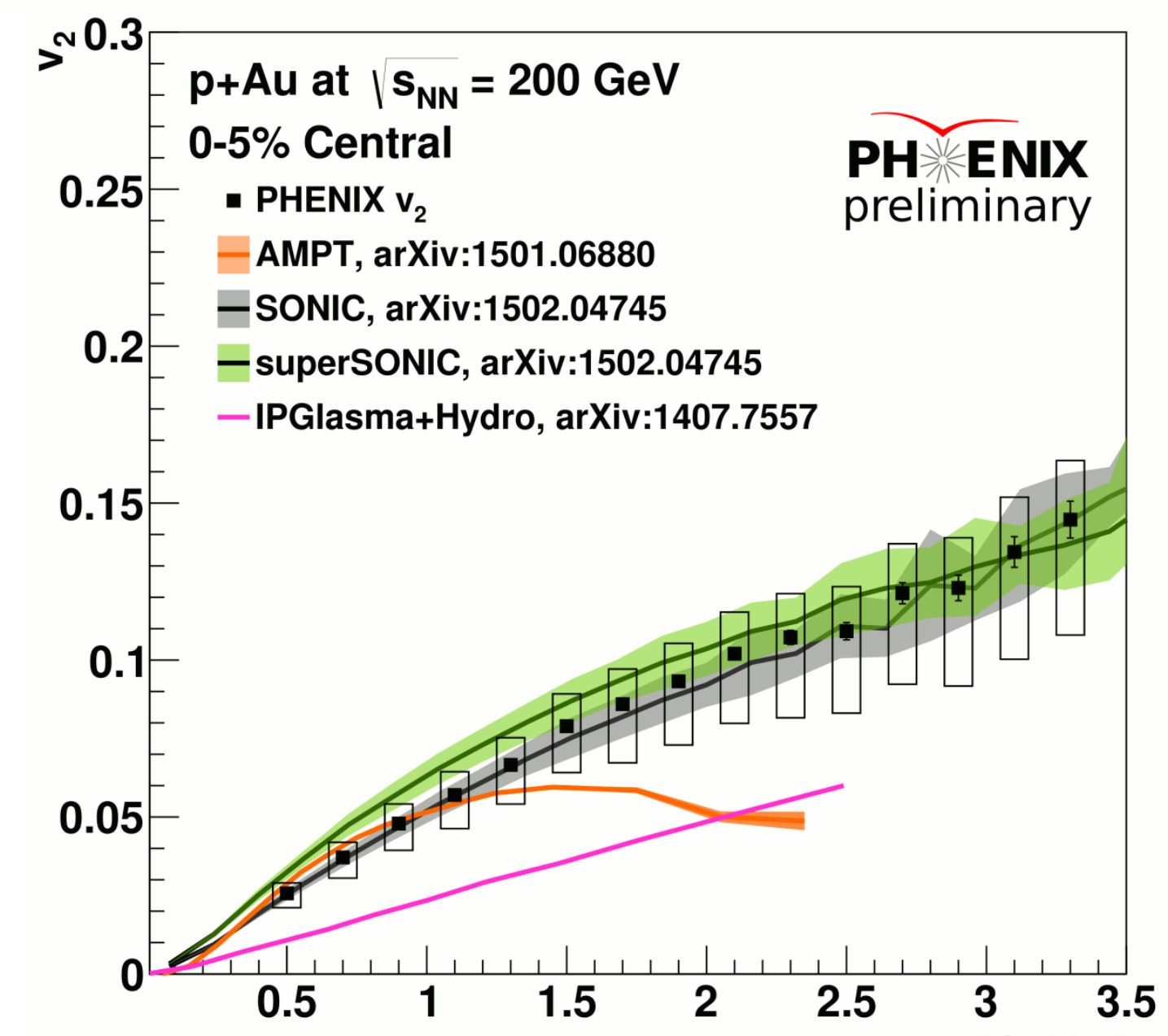


Figure 4. Second-order Fourier coefficient v_2 measured in 0-5% p+Au collisions compared to several theoretical model[3-5] predictions.

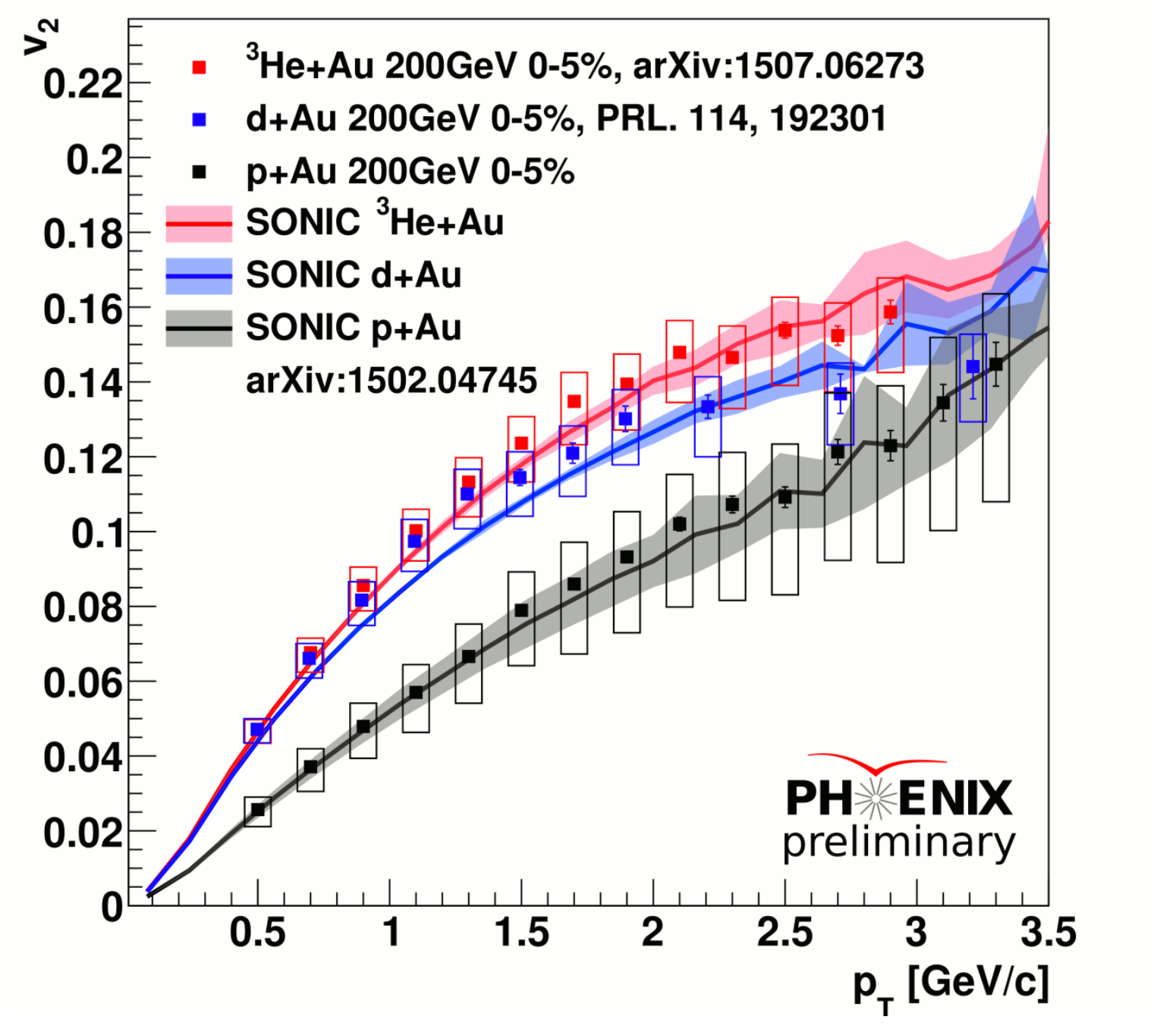


Figure 5. Second-order Fourier coefficient v_2 measured in 0-5% p/d/^{3}He+Au collisions compared to SONIC model[3] predictions.

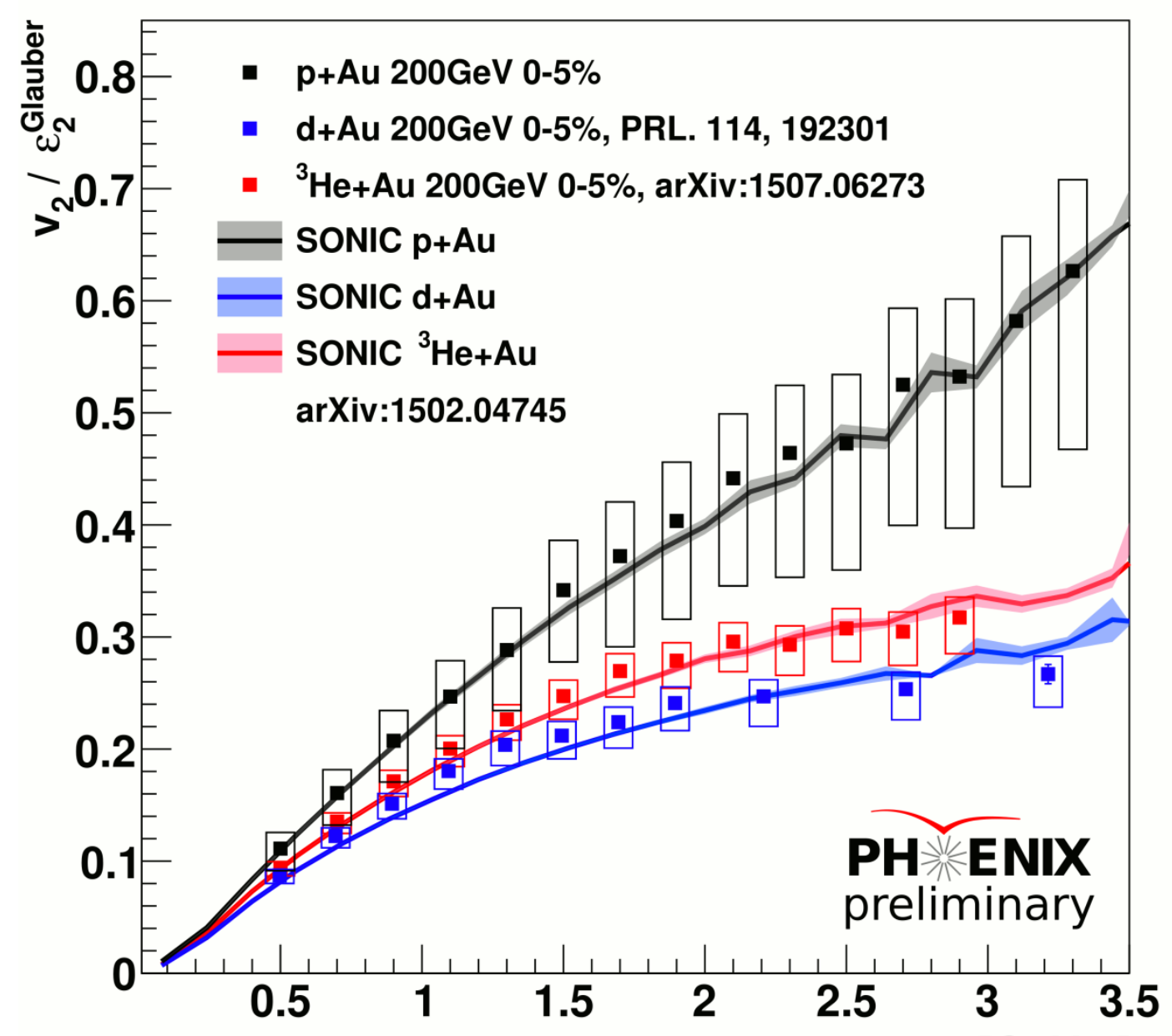


Figure 6. Second-order Fourier coefficient v_2 from 0-5% central p/d/^{3}He+Au collisions scaled by eccentricity ε_2 from Glauber model by smearing participants with 2D Gaussian with width = 0.4fm is compared to SONIC model[3] predictions.

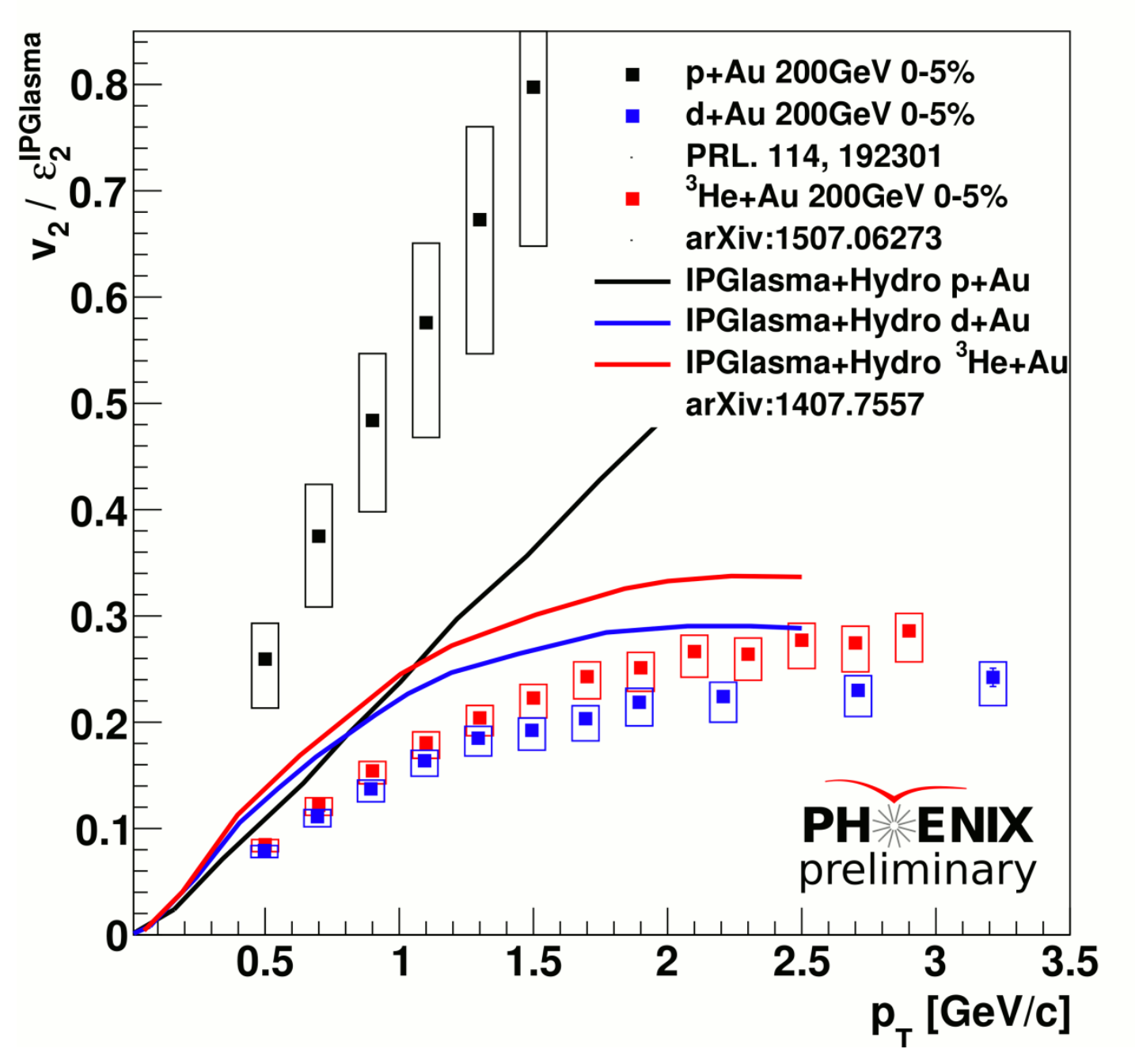


Figure 7. 0-5% p/d/^{3}He+Au v2 scaled by eccentricity ε_2 from IPGlasma standard model[5], compared to hydrodynamic model predictions.

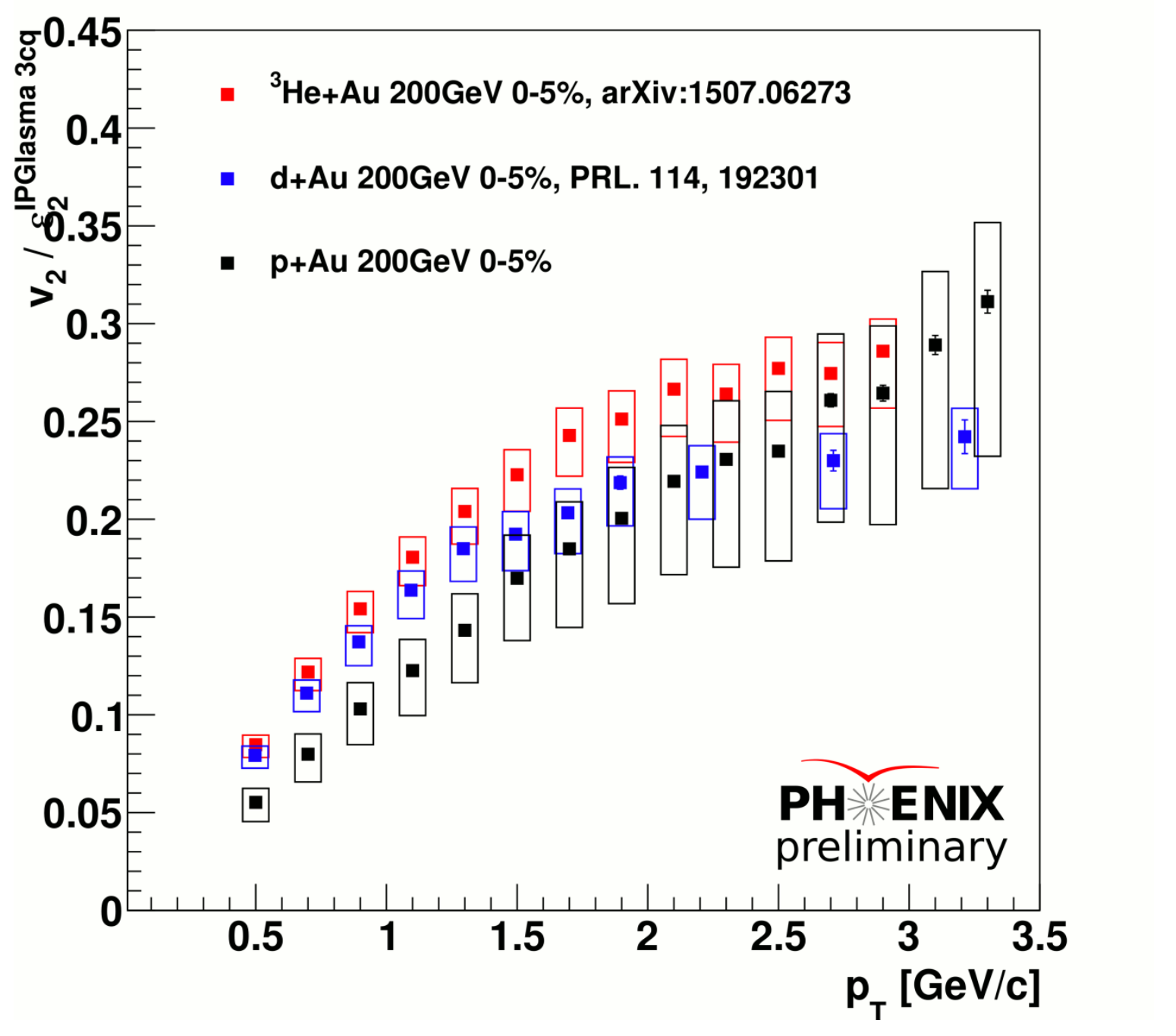


Figure 8. Second-order Fourier coefficient v_2 from 0-5% central p/d/^{3}He+Au collisions scaled by eccentricity ε_2 from IPGlasma model with 3 constituent quarks[6] in the proton.

Conclusions

- Long-range two-particle correlations are observed in central p+Au at $\sqrt{s_{NN}}$ = 200 GeV. Non-flow contributions are estimated to be in the range 10-25%, and are not subtracted in the presented results.
- The second-order Fourier coefficient v_2 is measured using the event-plane method.
- Comparison of v_2 results in p+Au, d+Au, and ^{3}He+Au to theoretical models is performed:
  - SONIC model[3] predicts the v_2 values in all three systems
  - AMPT model[4] and IPGlasma+Hydrodynamic model[5] underpredict the p+Au results
  - Eccentricity scaling is not so dominant in small systems, since they do not live long enough to completely translate initial geometry into a flow field
  - The IPGlasma round proton model[5] underestimates the eccentricity in p+Au collisions, whereas the 3 constituent quarks model[6] seems to have a better eccentricity scaling

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