Measurements of Higher-Order Flow Harmonics at PHENIX

Robert Pak
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

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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)
Higher-order flow harmonics help to discriminate between models
Progress constraining viscosity to entropy density ratio

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

between 1 and 2x the conjectured quantum limit.
Decomposition of two-particle $\Delta\phi$ 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.
• 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:

\[ v_{2}^{\text{dir.}} = \frac{R_{\gamma} v_{2}^{\text{inc.}} - v_{2}^{BG}}{R_{\gamma} - 1} \]

Direct photon \( v_{2} \) observed

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 \( \eta/s \)
• 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