Elliptic and triangular flow of (multi-)strange hadrons and $\phi$ mesons in BES-II energies at STAR

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Outline

• Motivation
• Experimental Setup
• Analysis Method
• Results and Discussion
• Summary and Outlook
Motivation

- RHIC 200 GeV and LHC
  - Small viscosity, high temperature
  - Evidence of Quark-Gluon Plasma

- Beam energy scan program
  - Search for Critical Point
  - Locate the first-order phase boundary

Motivation

Heavy ion collisions: Initial spatial anisotropy $\rightarrow$ Pressure gradient $\rightarrow$ Anisotropic flow

$$E \frac{d^3N}{dp^3} = \frac{1}{2\pi} \frac{d^2N}{p_\perp dp_\perp dy} \left( 1 + \sum_{n=1}^{\infty} 2v_n \cos \left[ n(\phi - \psi_{RP}) \right] \right)$$

Self-quenching effect

- $v_2$ is sensitive to constituent interactions and degree of freedom
- $v_3$ is sensitive to event-by-event fluctuations in the overlap region
- $\phi$-meson and strange hadrons less affected by the hadronic phase
  - Small hadronic interaction cross sections
  - Freeze-out earlier than other light hadrons

Experimental Setup

- The STAR Detector
  - Full $2\pi$ azimuthal coverage
  - Large acceptance at mid-rapidity
  - Excellent particle identification

- Upgrade of inner-TPC
  - Better track quality
  - Larger acceptance ($|\eta| < 1.5$)

- Larger acceptance
- Excellent PID with uniform efficiency
- Modest rates

- iTPC, EPD & eTOF upgrades completed
- All are in data-taking for BES-II program
Event Plane Calculation


- The $n^{th}$ harmonic event plane was calculated as:

$$\vec{Q} = \begin{pmatrix} Q_y \\ Q_x \end{pmatrix} = \begin{pmatrix} \sum_i w_i \sin(n\phi_i) \\ \sum_i w_i \cos(n\phi_i) \end{pmatrix} \quad \Psi_n = \tan^{-1}\left(\frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)}\right)/n$$

- Since finite multiplicity limits the estimation of the reaction plane, this will bring resolution:

$$R_n = \left\langle \cos \left[ n \left( \Psi_{n,EP} - \Psi_{RP} \right) \right] \right\rangle \quad R_{n,sub} = \sqrt{\left\langle \cos \left[ n \left( \Psi_{n,east} - \Psi_{n,west} \right) \right] \right\rangle}$$

### STAR detector upgrades and higher statistics:

- 11% improvement of 2$^{nd}$ EP resolution
- Typical 3$^{rd}$ EP resolution achieved and first $v_3$ measurement

Prabhupada, 6/14 5:10 pm, POS-BLK-10
Particle Identification

- Good particle identification capability based on TPC and TOF
Decay Particle Reconstruction

- $K_s^0$, $\Lambda$, $\bar{\Lambda}$, $\Xi^\pm$, $\Omega^\pm$ are reconstructed by KF particle package
  - background described by first order polynomial

- $\phi$-mesons are reconstructed by $K^+K^-$ channel
  - background estimated by using mixed event method

• Clear mass ordering of $v_2(p_T)$ when $p_T < 1.5$ GeV/c

• Particles grouped according to hadron type (baryon or meson) when $p_T > 1.5$ GeV/c
• Weak centrality dependence for $v_3$

Event-by-event fluctuation is the dominant source
Test of NCQ Scaling at 19.6 GeV

NCQ scaling of $v_2$

- NCQ scaling of $v_2$ ($v_3$) holds within 10(15)% for anti-particles, 20(30)% for particles. Quantify the NCQ scaling -> benefit from enhanced statistics of BES-II.
- Indicating the collective flow has been built up in the partonic stage.
- NCQ scaling of anti-particles is better than particles: produced vs. transported quarks.

NCQ scaling of $v_3$
Test of NCQ Scaling at 14.6 GeV

- NCQ scaling holds at 20% level
v2 results at 3 GeV

- At this energy, $\mu_B \sim 750$ MeV, high baryon density region
- The values of $v_2$ for all particles are negative, and the NCQ scaling is absent
- The data can be qualitatively reproduced by baryonic mean-field transport models

**disappearance of partonic collectivity and likely dominated by baryonic interactions**

Summary

• NCQ scaling of $v_2$ and $v_3$ holds well at 19.6 GeV
  - Signature of partonic collectivity
  - Difference between transported and produced quarks

• NCQ scaling is absent at 3 GeV
  - Medium likely dominated by baryonic interactions
The data taking of BES-II has been finished, enhanced statistics, upgraded detectors

- Precise measurements of multi-strange hadron and $\phi$ meson $v_n$

- Explore the QCD phase diagram with BES-II 3-20 GeV datasets

Thank you for your attention!