

Azimuthal anisotropy measurement of multi-strange hadrons in Au+Au collision at $\sqrt{s_{NN}} = 27$ and 54.4 GeV at STAR

Prabhupada Dixit (for the STAR collaboration)^{1,*}

¹Indian Institute of Science Education and Research, Berhampur, 760010, India

Abstract. In these proceedings, we present the second order (v_2) and the third order (v_3) azimuthal anisotropy measurements of strange and multi-strange hadrons such as K_S^0 , Λ , $\bar{\Lambda}$, ϕ , Ξ^- , Ξ^+ , Ω^- , Ω^+ in Au+Au collisions at $\sqrt{s_{NN}} = 27$ and 54.4 GeV at STAR. The centrality dependence of v_2 and v_3 as well as the number of constituent quark scaling (NCQ scaling) for all the particles mentioned above are discussed. The ratio of v_2 of ϕ mesons to that of \bar{p} is presented at $\sqrt{s_{NN}} = 54.4$ GeV which gives a hint of mass ordering violation at low p_T .

1 Introduction

Relativistic heavy-ion collision is a unique tool to study matter at the extreme conditions of temperature and density. The collective expansion of the medium formed in heavy-ion collision is called flow. Depending on the initial spatial configuration of the colliding system and fluctuations, there can be the presence of different orders of anisotropy in the azimuthal distributions, known as anisotropic flow. In non-central nucleus-nucleus collisions, the overlap region of two colliding nuclei looks like the shape of an almond and in this region the pressure gradient is different along different axis of the system. The difference in pressure gradient leads to momentum anisotropy which is the dominant cause for the development of elliptic flow. But the event-by-event fluctuations of the nucleons in the colliding nuclei can give rise to other types of flow such as triangular flow, rectangular flow, etc. All these flow coefficients can be studied by using Fourier series expansion of the azimuthal distribution of particles given by

$$E \frac{d^3N}{dp^3} = \frac{1}{2\pi} \frac{d^2N}{p_T dp_T dy} \left[1 + \sum_n 2v_n \cos n(\phi - \Psi_R) \right]. \quad (1)$$

Here v_2 and v_3 represent elliptic flow coefficient and triangular flow coefficient respectively. The n^{th} order flow coefficient is given by

$$v_n = \langle \cos n(\phi - \psi_n) \rangle. \quad (2)$$

Here ϕ is the azimuthal angle of the particles and ψ_n is the n^{th} order event plane angle. The simultaneous measurement of v_2 and v_3 is important to constrain the shear viscosity over entropy density ratio (η/s) [1]. In this study, we have used strange and multi-strange hadrons because of their small hadronic interaction cross-section and early freeze-out [2], the measured flow coefficients remain least affected in the hadronic phase.

*e-mail: dixitprabhupada471@gmail.com

2 Analysis method

The n^{th} order event plane is given by

$$\psi_n = \frac{1}{n} \tan^{-1} \left(\frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)} \right), \quad (3)$$

where ϕ_i is the azimuthal angle of the particle track and w_i is the weight factor equal to $p_T \times \phi$ -weight. The factor ϕ -weight is the correction factor for azimuthal acceptance of the detector. Due to the finite resolution of the event plane, the v_n needs to be corrected by event plane resolution given by

$$R_n = \sqrt{\langle \cos n(\psi_A - \psi_B) \rangle}. \quad (4)$$

Here ψ_A and ψ_B are two sub-event planes in $-1 < \eta < -0.05$ and $0.05 < \eta < 1$ regions respectively. In Eq. 2, the particle's ϕ and the event plane ψ_n are taken from opposite η region.

Invariant mass method [3] is used to calculate v_n . A detailed procedure to apply this method can be found in Ref. [8].

3 Results and discussion

Figure 1 shows v_2 and v_3 plotted as a function of p_T for K_S^0 , Λ , ϕ , Ξ^- , Ω^- at $\sqrt{s_{NN}} = 54.4$ GeV in 0-80% centrality. In low p_T both v_2 and v_3 show a mass ordering which is due to the radial flow of the system [4], but at p_T above 2 GeV/c a separation between baryons and mesons is observed which can be explained by the quark recombination model of hadronization [5]. A

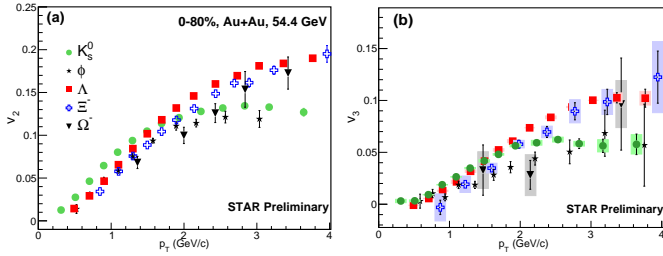


Figure 1. Panel-a shows v_2 and panel-b shows v_3 as a function of p_T for K_S^0 , Λ , ϕ , Ξ^- , Ω^- in 0-80% centrality. The vertical lines represent the statistical error bars and the shaded boxes represent the systematic error bars.

centrality dependence study for both v_2 and v_3 is shown in Fig. 2 and Fig. 3 in three different centrality classes, 0-10%, 10-40% and 40-80%. The elliptic flow v_2 shows a strong centrality dependence because of initial spatial anisotropy dominance, whereas v_3 does not because it arises mostly due to event-by-event fluctuations in the initial state.

The NCQ scaled v_2 is studied as a function of NCQ scaled transverse kinetic energy for 0-80% centrality at $\sqrt{s_{NN}} = 27$ and 54.4 GeV. The NCQ scaled v_2 for all the particles shown in Fig. 4 is found to fall on a single curve which suggests that the collectivity is developed during the QGP stage of the collision. The same result is found for v_3 also as shown in Fig. 5.

The ratio of ϕ meson v_2 to \bar{p} v_2 is calculated as a function of p_T as shown in Fig. 6. Since the mass of the ϕ meson ($1.019 \text{ GeV}/c^2$) is greater than that of \bar{p} ($0.938 \text{ GeV}/c^2$), according to mass ordering at low p_T the ratio should have been less than one. But we observe a hint of mass ordering violation at low p_T which can be explained by larger hadronic rescattering effect on \bar{p} compared to ϕ meson [6]. A similar result is found in previous STAR measurement in minimum biased Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [7].

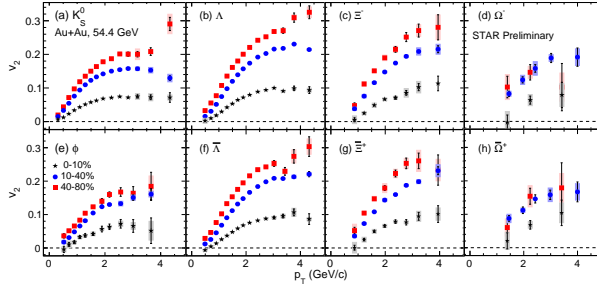


Figure 2. v_2 is plotted as a function of p_T for 0-10%, 10-40% and 40-80% centrality classes. The vertical lines represent the statistical error bars and the shaded boxes represent the systematic error bars.

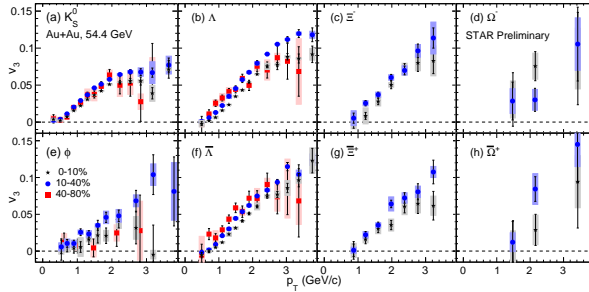


Figure 3. v_3 is plotted as a function of p_T for 0-10%, 10-40% and 40-80% centrality classes. The vertical lines represent the statistical error bars and the shaded boxes represent the systematic error bars.

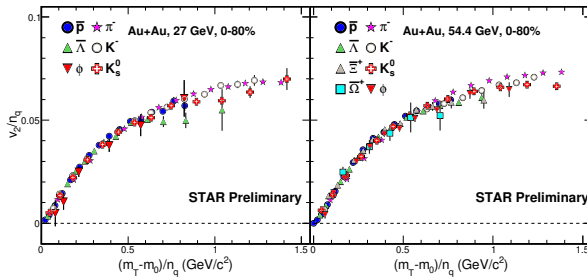


Figure 4. NCQ scaled v_2 is plotted as a function of NCQ scaled transverse kinetic energy for 0-80% centrality for $\sqrt{s_{NN}} = 27$ (left) and 54.4 GeV (right).

4 Summary

Measurements of v_2 and v_3 as a function of p_T of strange and multi-strange hadrons, K_S^0 , Λ , $\bar{\Lambda}$, ϕ , Ξ^- , Ξ^+ , Ω^- , $\bar{\Omega}^+$ is presented in Au+Au collisions at midrapidity for 0-80% centrality. A mass ordering is observed in the low p_T . At high p_T (> 2 GeV/c), we observe a baryon to meson separation. A strong centrality dependence is observed for v_2 , but the centrality dependence is absent for v_3 . The NCQ scaling is found to hold for all the particles at $\sqrt{s_{NN}}$

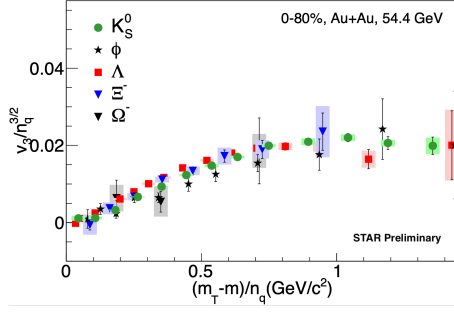


Figure 5. NCQ scaled v_3 is plotted as a function of NCQ scaled transverse kinetic energy for 0-80% centrality for $\sqrt{s_{NN}} = 54.4$ GeV. The vertical lines represent the statistical error bars and the shaded boxes represent the systematic error bars.

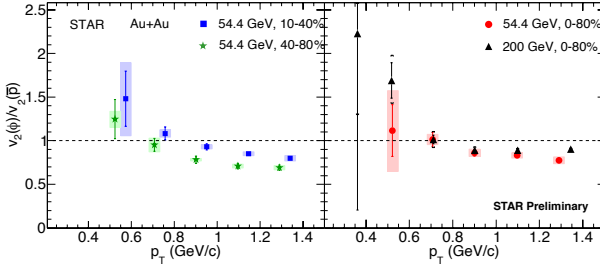


Figure 6. The left panel shows the ratio of ϕ meson v_2 to \bar{p} v_2 in Au+Au collision at $\sqrt{s_{NN}} = 54.4$ GeV in 10-40% and 40-80% centralities. The right panel shows the comparison of the ratio with 200 GeV data points for minimum bias events. The vertical lines represent the statistical error bars and the shaded boxes represent the systematic error bars.

= 27 and 54.4 GeV. The ratio of v_2 of ϕ meson to that of \bar{p} gives a hint of mass ordering violation at low p_T .

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