Azimuthal anisotropy of strange hadrons in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV at RHIC

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Introduction

Quantum Chromodynamics (QCD) is the underlying theory of strong interactions. It predicts that at sufficiently high temperature T and/or baryon chemical potential, μ_B, normal nuclear matter converts into a de-confined state of quarks and gluons, known as Quark-Gluon Plasma (QGP) [1]. An experimental way to understand the formation of the QGP is studying observables as a function of collision centrality, transverse momentum (p_T) and rapidity (y). The azimuthal anisotropy of produced particles is one of the most studied observable. In non-central heavy-ion collisions, the overlap region of the colliding nuclei has an almond shape. The initial spatial anisotropy and subsequent interactions among the quarks and gluons result in pressure gradients, which in turn result in an azimuthal anisotropy of the produced particles in momentum space. This anisotropy can be extracted in experiment by using Fourier expansion of the azimuthal distribution of the produced particles with respect to the reaction plane [2]. The reaction plane is defined by the beam direction and the impact parameter vector between the two colliding nuclei. The reaction plane angle cannot be directly measured in an experiment, therefore the Fourier coefficients are determined with respect to the event plane angle,

$$v_n = \langle \cos n(\phi - \psi_n) \rangle \tag{1}$$

where ϕ is the azimuthal angle of produced particles and ψ_n is the estimated event plane angle for various orders, n. The measured flow coefficients v_n are corrected for the event plane angle resolution. In year 2012, RHIC collided deformed nuclei ^{238}U+^{238}U, which are believed to produce higher energy density and number of particles than is possible using ^{197}Au+^{197}Au at the same incident energy. In this work we report the measurements of the azimuthal anisotropy of strange hadrons ($K_s^0, \phi, \Lambda, \Xi$ and Ω) in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV at mid-rapidity ($|y| < 1$). Approximately 270 million minimum bias events are analysed. We present the centrality and p_T dependence of the flow coefficients (v_2, v_3 and v_4). Particle mass dependence and Number of Constituent Quarks (NCQ) scaling are discussed. A systematic comparison of the results with those in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR is presented. We also present a detail comparison of the results with model calculations using the AMPT and ideal-hydrodynamic models in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV.

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Analysis Method

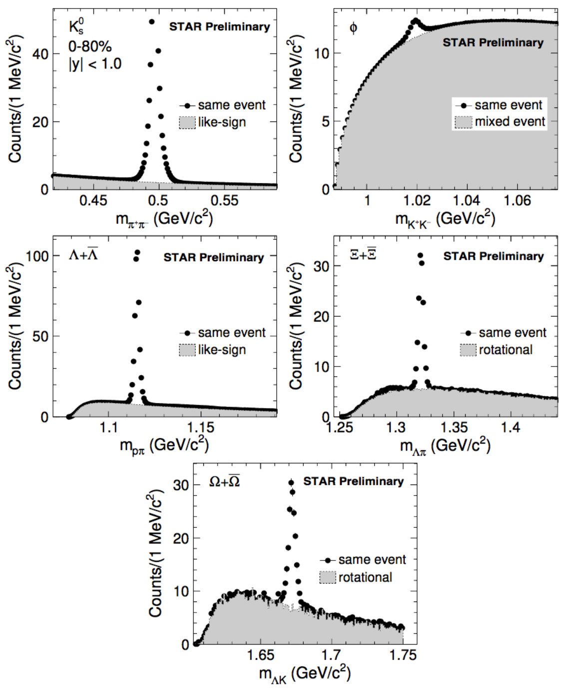

FIG. 1: Invariant mass distributions for $K_s^0, \phi, \Lambda, \Xi$ and Ω in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV. The grey bands represent the combinatorial background. Mixed event technique is used for ϕ-meson. For K_s^0 and Λ like-sign and for Ξ and Ω rotational technique is used for background reconstruction.

Figure 1 shows the signal reconstruction using invariant mass technique for various particles in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV. The combinatorial background is constructed using the mixed event, like-sign or rotational techniques. The raw yields are extracted for particles K^0_s, ϕ, Λ, Ξ and Ω by subtracting the corresponding combinatorial background. This procedure has been done for each fixed p_T range in different $\phi - \psi_n$ angle bins for a given centrality class. The raw yield are then plotted as a function of $\phi - \psi_n$ and fitted to a function,

$$\frac{dN}{d(\phi - \psi_n)} = p_0[1 + 2v_n \cos n(\phi - \psi_n)] \qquad (2)$$

where p_0 and v_n are fit parameters. The observed v_n values are divided by the event plane resolution of the corresponding centrality class. Figure 2 shows an illustration of the procedure to extract v_2 of K^0_s for $1.6 < p_T < 1.8$ GeV/c in the 0-80% centrality interval. The same procedure is used to calculated higher order harmonics v_3 and v_4 for all the particles studied, with respect to ψ_3 and ψ_4, respectively.

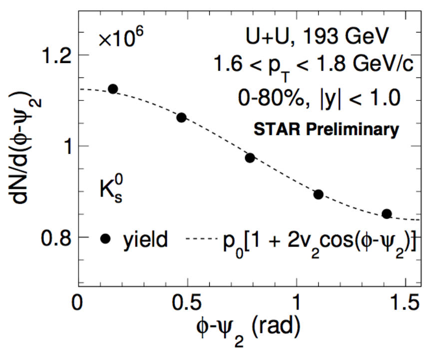

FIG. 2: Raw yield as a function of $\phi - \psi_2$ for K^0_s, in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV. The distribution is fitted to the function given in Eq. 2 to get v_2.

Results

Figure 3 shows the flow coefficients v_2, v_3 and v_4 as function of p_T for strange hadrons K^0_s, ϕ, Λ, Ξ and Ω produced in minimum bias U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV. The results are compared with the AMPT string melting (SM) model [3] and ideal-hydrodynamic model [4]. The AMPT (SM) model with 3-mb parton cross-section describes the data at low p_T (< 2 GeV/c) in U+U collisions for all the particles studied. Ideal-hydrodynamics model results over-predict the data, suggesting the need of viscous corrections to the model.

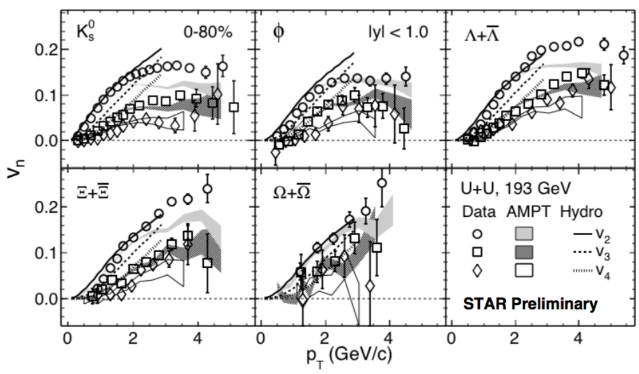

FIG. 3: Comparison of v_n coefficients at mid-rapidity ($|y| <$ 1.0) in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV for centrality 0-80%. The open markers represent the results from data. Error bars shown are statistical only. AMPT model calculations are shown by the bands and different lines represent the corresponding results from hydrodynamic model.

Conclusions

We have carried out the measurement of various order azimuthal anisotropy for strange hadrons K^0_s, ϕ, Λ, Ξ and Ω in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV. The p_T dependence for the flow coefficients v_2, v_3 and v_4 is discussed. The magnitude of flow coefficients $v_2 > v_3 > v_4$ is observed. The AMPT model with 3-mb parton cross-section describes the data at low p_T (< 2 GeV/c) in U+U collisions for all the particles studied. Ideal-hydrodynamics model results over-predict the data, suggesting the need of viscous corrections to the model.

Acknowledgments

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