Strange hadron ($K^0_S$, $\Lambda$ and $\Xi$) elliptic flow from 200 GeV $Cu + Cu$ collisions

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Abstract. Collective flow reflects dynamical evolution in high-energy heavy ion collisions. In particular, the strange hadron elliptic flow reflects early collision dynamics [1]. We present results from a systematic analysis of the centrality dependence of strange hadron elliptic flow ($v_2$) measurement of $K^0_S$, $\Lambda$ and $\Xi$ for $Cu + Cu$ collisions at 200 GeV. Results for $Cu + Cu$ collisions are compared with results previously reported for $Au + Au$ collisions. We will also compare our data with results from ideal hydrodynamic calculations.

Keywords: heavy ion collisions, elliptic flow, hydrodynamic model
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1. Introduction

The characterization of the elliptic flow of produced particles by their azimuthal anisotropy has been proven to be one of the most fruitful probes of the dynamics in $Au + Au$ collisions at the Relativistic Heavy Ion Collider (RHIC) [3 4 5 6 7]. Study elliptic flow in smaller collision systems, such as $Cu + Cu$, which has one-third nucleons in $Au + Au$, is beneficial. Because exactly how flow scales with collision systems, such as system size, geometry, constituent quarks, transverse momentum and transverse energy, is crucial to the understanding of the properties of the produced matter. Hydrodynamic model calculations, with the assumption of ideal fluid behavior (no viscosity), have been successful when compared with the experimental data at RHIC [10 11]. In this proceeding, we extend the comparison with ideal hydrodynamic calculations to different systems.

2. Methods and Analysis

In this proceeding, we report results from $\sqrt{s_{NN}} = 200$ GeV $Cu + Cu$ collisions. Data were taken from Run 5 (2005). STAR’s Time Projection Chamber (TPC) [14] is used as the main detector for particle identifications. The centrality was deter-
Table 1. List of \(dN_{ch}/d\eta\), number of participants \(N_{part}\), number of binary collisions \(N_{bin}\), and participant eccentricity \(\varepsilon_{part}\) for three centrality bins in 200 GeV \(Cu + Cu\) collisions and 0-80% 200 GeV \(Au + Au\) collisions.

| Centrality   | \(Cu + Cu\) | \(Au + Au\) |
|--------------|-------------|-------------|
|              | 0-60%  | 0-20%  | 20-60%  | 0-80%  |
| \(dN_{ch}/d\eta\) | 74     | 132    | 45      | 225    |
| \(N_{part}\)   | 51     | 87     | 34      | 126    |
| \(N_{bin}\)    | 80     | 156    | 43      | 293    |
| \(\varepsilon_{part}\) | 0.252  | 0.184  | 0.393   | 0.214  |

Fig. 1. \(v_2\) as a function of \(p_T\) for \(K_0^S\) (open-circles), \(\Lambda\) (filled-squares) and \(\Xi\) (filled-triangles) in 0-60% \(Cu + Cu\) collisions at \(\sqrt{s_{NN}} = 200\) GeV.

The observed \(v_2\) is the second harmonic of the azimuthal distribution of particles with respect to this event plane:

\[
v_2^{obs} = \langle \cos[2(\phi - \Psi_2)] \rangle
\]
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FIG. 2. The eccentricity (ε_{part}) and number of quark (n_q) scaled v_2 versus (m_T - m)/n_q from 0-20% (filled-circles: K^0_S, open-squares: Λ) and 20-60% (open-circles: K^0_S, filled-squares: Λ) Cu+Cu collisions at √s_{NN} = 200 GeV.

Fig. 3. Number of quark (n_q) scaled v_2 for K^0_S (open-circles) and Λ (filled-squares) as a function of (m_T - m)/n_q from three centrality bins. The results of the fits [13] are shown as dashed-lines in the figure.

where angle brackets denote an average over all particles with their azimuthal angle φ in a given phase space. To take into account the smearing of the estimate event plane around the true reaction plane, the real v_2 has to be corrected for the event plane resolution by

\[ v_2 = \frac{v_2^{obs}}{\langle \cos[2(\Psi_2 - \Psi_r)] \rangle} \tag{2} \]

For v_2 of the identified particles, K^0_S, Λ and Ξ, the v_2 versus m_{inv} method [12] is used in this analysis. We use Λ (Ξ) to denote Λ + (Ξ⁻ + Ξ^+) unless stated otherwise.

3. Results

Figure 1 shows v_2 as a function of p_T for K^0_S (open-circles), Λ (filled-squares) and Ξ (filled-triangles) in 0-60% Cu+Cu collisions at √s_{NN} = 200 GeV. At low p_T, Λ
$v_2$ is smaller than $K_S^0$; At high $p_T$, baryon($\Lambda$, $\Xi$) $v_2$ is systematically greater than meson($K_S^0$). $K_S^0$ and $\Lambda$ $v_2$ cross over at $p_T \approx 1.5 - 2.0$ GeV.

Figure 2 shows $n_q$-scaled $v_2$ normalized by participant eccentricity as a function of $(m_T - m)/n_q$ for $K_S^0$ and $\Lambda$ from 0-20% and 20-60% $Cu + Cu$ collisions at $\sqrt{s_{NN}} = 200$ GeV. The participant eccentricity $\varepsilon_{part}$ are from a Monte Carlo Glauber calculation. (See Table I for $\varepsilon_{part}$.) After the geometric effect has been removed by dividing by $\varepsilon_{part}$, the build-up of stronger collective motion in more central collisions becomes obvious in the measured elliptic flow.

Number of quark scaling was observed in 200 GeV $Au + Au$ collisions firstly. In Figure 3 we test $n_q$ scaling in 200 GeV $Cu + Cu$ collisions. At low and intermediate $p_T$, scaling works well; At high $p_T$, $v_2$ for $K_S^0$ and $\Lambda$ have large error bars, but are consistent with $n_q$ fitted curve. We can draw the conclusion: Number-of-Quark scaling was also observed in 200 GeV $Cu + Cu$ collisions.

Hydrodynamic model can be used to calculate elliptic flow in heavy ion collisions, preliminary ideal hydrodynamic model results are from Pasi Huovinen. In
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Fig. 5. The eccentricity ($\varepsilon_{\text{part}}$) and number of quark ($n_q$) scaled $v_2$ versus $(m_T - m)/n_q$ from 0-60% $Cu + Cu$ (open-circles: $K^0_S$, filled-squares: $\Lambda$) and 0-80% $Au + Au$ collisions (filled-circles: $K^0_S$, open-squares: $\Lambda$) at $\sqrt{s_{NN}} = 200$ GeV.

In order to study the system size dependence of scaling behavior, we normalize the $n_q$-scaled elliptic flow($v_2$) by the participant for different systems. Figure 5 shows the doubly scaled quantities from 200 GeV 0-60% $Cu + Cu$ and 0-80% $Au + Au$ collisions. After the geometric effect has been removed by dividing by $\varepsilon_{\text{part}}$, the build up of stronger collective motion in larger system becomes obvious, which is similar to the centrality dependence in $Cu + Cu$ and $Au + Au$ collisions [15] at $\sqrt{s_{NN}} = 200$ GeV. If hydrodynamic limit has been reached, $v_2/\varepsilon_{\text{part}}$ should be a constant for $Cu + Cu$ and $Au + Au$ collisions [16]. This indicates that hydrodynamic limit has not been saturated in $Cu + Cu$ collisions.

4. Summary

We present STAR preliminary results of $v_2$ for $K^0_S$, $\Lambda$ and $\Xi$ from 200 GeV $Cu + Cu$ collisions at RHIC. In order to reduce non-flow effects, FTPC tracks have been used to estimate the event plane. At low $p_T$, $v_2$ is found to be consistent with mass ordering. Number-of-Quark scaling was also observed in 200 GeV $Cu + Cu$ collisions at three centrality bins. Preliminary ideal Hydrodynamic model results are used to compare with experimental data. It under-predicts the elliptic flow in central collisions, over-predicts the elliptic flow in peripheral collisions. Stronger collective flow can be observed in the more central collisions or the larger system. $v_2/\varepsilon_{\text{part}}$ is not a constant for $Cu + Cu$ and $Au + Au$ collisions. This indicates that
hydrodynamic limit has not been saturated in $Cu + Cu$ collisions.

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