Abstract

Key words:

1.

References

[1]
Forward-rapidity azimuthal and radial flow of identified particles for $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions

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Abstract

A strong azimuthal flow signature at RHIC suggests rapid system equilibration leading to an almost perfect fluid state. The longitudinal extent of the flow behavior depends on how this state is formed and can be studied by measuring the pseudorapidity and transverse momentum dependence of the second Fourier component ($v_2(p_T)$) of the azimuthal angular distribution. We report on a measurement of identified-particle $v_2$ as a function of $p_T$ (0.5-2.0 GeV/c), centrality (0-25%, 25-50%), and pseudorapidity ($0 \leq \eta < 3.2$) for $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions. The BRAHMS spectrometers are used for particle identification ($\pi$, K, p) and momentum determination and the BRAHMS global detectors are used to determine the corresponding reaction-plane angles. The results are discussed in terms of the pseudorapidity dependence of constituent quark scaling and in terms of models that develop the complete (azimuthal and radial) hydrodynamic aspects of the forward dynamics at RHIC.

In a non-central collision of two relativistic heavy-ions, strong pressure gradients are set up in the almond-shaped interaction region. Early results from RHIC have shown that this overlap region behaves as an almost perfect fluid, with the greater pressure that exists at the waist of the almond leading to greater particle production near the reaction plane. This azimuthal asymmetry in particle production is characterized by the strength of the second Fourier component ($v_2$) of a harmonic expansion of the angular distribution. The outward pressure can also lead to an outward radial flow of the streaming particles, giving a velocity boost to these particles. To fully understand the hydrodynamic properties of RHIC collisions, it is necessary to determine the integral and differential $v_2$ behavior, as well as establish the particle spectra and relative particle yields [1]. By exploring the interplay of elliptic and radial flow at both mid- and forward pseudorapidity, the BRAHMS results better constrain models of the initial conditions and longitudinal extent of the interaction region.

The measurement explores the correlation of charged hadrons and identified particles detected in the two BRAHMS spectrometers with respect to reaction planes deduced using four azimuthally symmetric rings of detectors arranged around the beam line as part of the experiment’s multiplicity array [2]. The $v_2(p_T)$ dependence of particles detected in the spectrometers was determined by the standard reaction-plane method [3]. The reaction-plane resolution correction was based on a full GEANT simulation of the BRAHMS experimental response. A pseudoevent generator was used to obtain a particle throw consistent with previously established particle spectra measured using the BRAHMS spectrometers, with the azimuthal asymmetry of the particle throw set to reproduce the PHOBOS integral $v_2$ results [4]. The correction factor was taken as the ratio of the $v_2(p_T)$ values obtained from the reconstructed events with that input to...
the event generator.

Figure 1 shows the resulting charged-hadron $v_2(p_T)$ values for 0-25% and 25-50% central events. The increasing $v_2$ behavior up to $p_T \approx 1.5$ GeV/c is characteristic of hydrodynamic flow [6]. Near mid-rapidity the results show very little pseudorapidity dependence. In going to forward pseudorapidity with $\eta \approx 3$, the slope is found to decrease for both centrality selections, with a greater decrease for the mid-central events. The curves show the results of 3D Hydro+Cascade calculations employing Glauber motivated initial conditions [5]. Good agreement is found with experiment for all but the mid-central, forward-pseudorapidity results. Turning off the hadronic cascade part of the calculation leads to near pseudorapidity independence of the $v_2(p_T)$ results, in strong disagreement with the observed slopes at $\eta \approx 3$. Folding the Fig. 1 results with the corresponding charged hadron spectra measured at $\eta \approx 0$ and 3 yield integral $v_2$ values of $0.036 \pm 0.005$ and $0.027 \pm 0.004$, respectively, at the two pseudorapidities, in good agreement with the PHOBOS integral $v_2$ results [4].

The identified particle $v_2(p_T)$ results are shown in Fig. 2. Again, the 3D Hydro+Cascade calculations, as shown by the smooth curves, are in good agreement with experiment except for the forward-pseudorapidity, mid-central events. In addition to reproducing the experimental slopes, the calculations also do a good job reproducing the observed mass ordering.

One of the remarkable features of the RHIC elliptic flow behavior is how closely it follows that expected for a perfect fluid. This is particularly evident when the elliptic flow $v_2(p_T)$ values are scaled by the eccentricity $\epsilon$ of the overlap region and the number of constituent quarks of the detected particle $n_q$ and then plotted against the mean transverse energy per constituent quark, $\langle E_T \rangle/n_q$, as shown in Fig. 3 for the BRAHMS results at $\eta \approx 0$, 1, and 3. With this scaling, the elliptic flow observed for $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions for a large number of different outgoing particle types are found to follow a common trend [7], as shown by the curve in the figure. Such behavior is consistent with the creation of a near-perfect fluid, with the constituent quark scaling suggesting this fluid involves quark degrees-of-freedom, as expected in coalescence models. Our central results are consistent with the established systematics at all three
pseudorapidities. For mid-central collisions, the data continue to track well with the systematics for $\eta \approx 0$ and 1, but show significantly reduced elliptic flow at forward pseudorapidity. As also found in comparison of 3D Hydro+Cascade results to our data, the mid-central events at forward pseudorapidity suggest a process other than ideal hydrodynamics is playing a role.

The elliptic flow behavior is believed to be established at an early stage of the reaction, with the integral elliptic flow largely fixed at the point of chemical freeze out [1]. The differential elliptic flow also depends on the subsequent hadronization stage, where radial flow can significantly affect the final particle spectra. Radial flow results in a velocity boost of the outwardly
streaming particles. Figure 4 shows the observed $\langle E_T \rangle$ values for pions and protons at rapidities $y=0$ and $y\approx 3$. It is observed that the transverse energy decreases in going to forward rapidity, suggesting a possible reduction in the radial flow. This change in the radial flow can strongly influence the differential elliptic flow behavior, but is expected to have less of an effect on the integral flow.

In conclusion, BRAHMS has measured identified particle $v_2(p_T)$ at $\eta \approx 0$, 1, and 3 for the Au+Au system at $\sqrt{s_{NN}} = 200$ GeV. The differential elliptic flow decreases at forward pseudorapidity, with the decrease for central events consistent with the expectations of 3D Hydro+Cascade calculations. For mid-central collisions at forward pseudorapidity the elliptic flow is found to be significantly less than expected by hydrodynamic calculations. This reduction in the elliptic flow is also evident when the current results are compared to previous mid-rapidity results using constituent quark scaling. A decrease is observed in the mean transverse energy of particles going to forward pseudorapidity, suggesting a reduction in the radial flow component. This change in radial flow has a significant influence on the differential $v_2(p_T)$ values. In general, the forward pseudorapidity elliptic and radial flow results place significant constraints on rapidity dependent model calculations of the dynamics of RHIC collisions.

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