Rapidity dependence of pion elliptic flow

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This paper shows the preliminary results on charged hadron and identified pion elliptic flow obtained by BRAHMS during the RHIC RUN 4 of AuAu at $\sqrt{s_{NN}} = 200$ GeV. It is shown that the dependence of the elliptic flow on transverse momentum is quite large at both mid- and forward rapidities. The p_T differential v_2 is found to have a very small dependence on pseudorapidity.

The relativistic heavy-ion collider (RHIC) was built to create the hot and dense state of matter, the Quark-Gluon Plasma (QGP), in which constituent quarks and gluons are free from their confinement[1]. It is now believed that the QGP formed at RHIC achieves local thermalization and can be well described by hydrodynamic models[2]. The azimuthal anisotropy of emitted particles from such RHIC collisions are thought to be sensitive to the evolution of the created medium. The second order Fourier coefficient of the anisotropy is called elliptic flow[3–5], and it has been observed at various energies and for the different particle species[6–9].

Elliptic flow has been measured extensively by the RHIC experiments. Near mid-rapidity, the transverse momentum dependence of elliptic flow for unidentified as well as identified charged hadrons have been measured by the STAR, PHENIX and PHOBOS experiments[10–12]. Generally, it is an increasing function of p_T up to 1.5 GeV/c, at which point it saturates. The magnitude of elliptic flow increases linearly from central to semi-peripheral collisions. Up to roughly 1.5 GeV/c, hydrodynamic calculations show very good agreement with experiment data for the v_2 dependence on p_T and centrality. Experimental data also indicates a dependence on particle type, with the magnitude of the v_2 signal lower for mesons than for baryons at large transverse momentum. One possible explanation for this result involves the idea of quark coalescence[13]. Since v_2 depends on the number of constituent quarks, it is suggested that the measured v_2 originates from the underlining initial quark-gluon interactions rather than the final state interactions.

For the forward rapidity region, p_T-integrated, charged hadron v_2 as a function of pseudorapidity has also been measured by the STAR and PHOBOS experiments[14,15], and found to follow a monotonically decreasing function of pseudorapidity from mid-rapidity to forward rapidity. Going from mid-rapidity to forward rapidity by three units, the magnitude of the integrated v_2 falls by roughly 30%. The p_T differential elliptic flow of unidentified charged hadrons has also been measured at forward rapidities, showing a large dependence on p_T at $\eta \sim 4$[15].

[*]For the full list of BRAHMS authors and acknowledgments, see appendix 'Collaborations' of this volume.

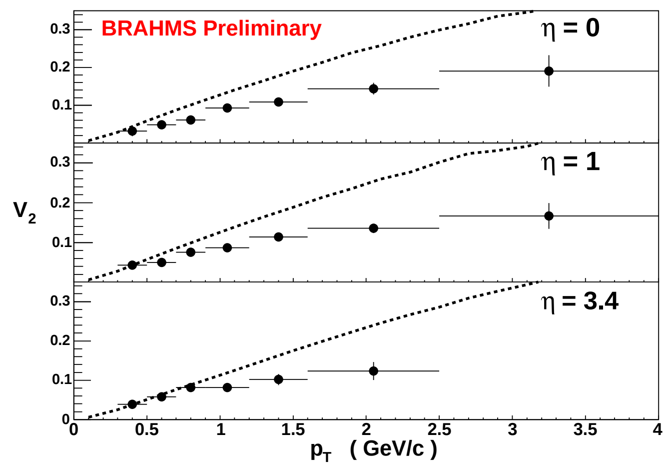

Figure 1. The experimental $v_2(p_T)$ values for charged hadrons (circless) corresponding to 10%-30% central events. Going from the top to the bottom, elliptic flow of unidentified charged hadrons as a function of transverse momentum at three pseudorapidities: 0, 1, 3.4. Only statistical errors are shown in this figure. The dashed line is a three dimensional hydrodynamic calculation[18].

The BRAHMS detector system consists of forward- and mid-rapidity spectrometers, FS and MRS, which provide particle identification of charged particles over a wide rapidity and momentum range, and several global detectors to determine the general features of the collisions. The BRAHMS silicon multiplicity detector (SMA) has been reconfigured for RUN 04 to achieve a more segmented coverage in azimuthal angles[16]. In conjunction with the BRAHMS scintillator tile multiplicity array (TMA)[17] and the Beam-Beam counters (BBC), they allow for a determination of the reaction plane.

For the analysis of this paper, the standard azimuthal multiplicity technique was used[3]. For each event, event planes were deduced independently using the BBC, SMA and TMA data. The correction to the measured elliptic flow due to the event plane resolution was obtained by studying correlations between the three independent measurements. The event plane measurement by TMA was used as the principal event plane, with the BBC and SMA planes used to obtain the event plane resolution correction, with

$$< \cos(2(\psi_{TMA} - \Psi_R)) >= \sqrt{\frac{< \cos(2(\psi_{BBC} - \psi_{TMA})) >< \cos(2(\psi_{SMA} - \psi_{TMA})) >}{< \cos(2(\psi_{BBC} - \psi_{SMA})) >}} \quad (1)$$

A correction factor (Eq. 1) of ~ 0.2 was found.

Figure 1 presents the p_T dependence of v_2 for unidentified, charged hadrons measured at three different pseudorapidities, 0, 1 and 3.4, and corresponding to a centrality range of 10%-30%. For each pseudorapidity, the $v_2(p_T)$ values show the expected behavior of increasing with increasing transverse momentum. The slope of the $v_2(p_T)$ decreases as p_T reaches values above 1 to 1.5 GeV/c. It is also seen that the function is relatively independent of pseudorapidity. The dashed line indicates the prediction from three dimensional hydrodynamic calculation[18]. For all ranges of pseudorapidities, the model overestimates the experimental v_2 signal for p_T greater than about 1 GeV/c. For p_T values that are

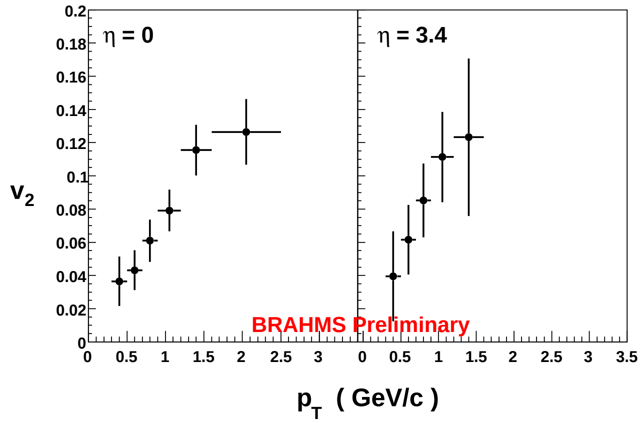

Figure 2. Elliptic flow of charged pions at $\eta = 0$ (left) and $\eta = 3.4$ (right). The data correspond to 10%-20% central events. Only the statistical errors are shown in the figure.

close to the mean transverse momentum ($\sim$ 0.5 GeV/c), the model generally describes the experimental data, although slightly overestimating the mid-rapidity value.

Figure 2 shows the results of v_2 of charged pions as a function of transverse momentum at two pseudorapidities: 0 and 3.4. For the data at mid-rapidity, the particle identification is determined by a Time-of-Flight wall located at 5.5m from the collision interaction point. The particle identification by the forward rapidity is done using a RICH detector[16]. Similar to that found for charged hadrons, the v_2 behavior for identified pions is an increasing function of p_T at both rapidities, with indication of saturation above 1.5 GeV/c. Again, the dependence on pseudorapidity is very small.

To obtain the p_T integrated elliptic flow, the following procedure is used. The transverse momentum spectra, $d^2N/p_Tdp_Td\eta$, was obtained using the MRS and the FS spectrometers at the same pseudorapidities shown in Figure 1. Multiplying these functions by p_T provides the weighting functions, which are used to scale the data from Figure 1 before integrating over p_T. The solid squares in Figure 3 shows the results of p_T integrated v_2 as a function of pseudorapidity. The open rectangle surrounding the data represents the systematic uncertainty of 20%, which originates primarily from the systematic uncertainty in the event plane resolution correction (Eq 1), which is common to all pseudorapidities, and to the uncertainty in the transverse momentum spectra, which is not constant with pseudorapidity. The transverse momentum spectra are measured down to about 0.3 GeV/c in p_T, and thus miss a large fraction ($\sim$ 35%) of the particle yields. The extrapolation of the spectra to zero transverse momentum is a significant source of uncertainty. The integrated v_2 data shows a relatively small dependence in pseudorapidity in contrast to the STAR (open star)[15] and PHOBOS(solid circle)[12] data. This may be due to the uncertainty in the underlining spectra as discussed above. The 3D hydrodynamic model reproduces the general trend of STAR and PHOBOS data despite the fact that its p_T differential elliptic flow also has very small pseudorapidity dependence.

In conclusion, BRAHMS has measured p_T integrated and differential elliptic flow of charged hadrons over a wide range of pseudorapidities. In addition, the differential elliptic

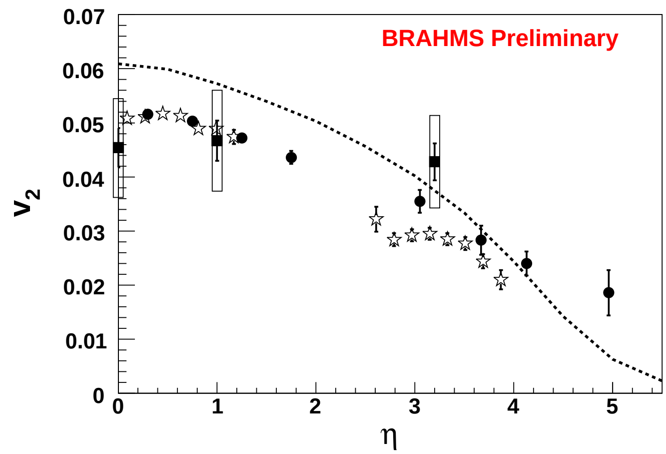

Figure 3. The p_T integrated elliptic flow of unidentified charged hadrons as function of pseudorapidity. The square, circle and star symbols corresponds to the BRAHMS, PHOBOS[12], STAR[15] data, respectively. Statistical errors are shown by vertical lines. Open boxes represent the systematic uncertainties of BRAHMS data. The dotted line is a 3D hydrodynamic calculation[18].

flow of pions is measured at mid- and forward- rapidities. It is found that v_2 as a function of p_T has only a weak dependence on pseudorapidity.

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