Rapidity Dependence of Elliptic Flow at RHIC

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Abstract. The measured elliptic flow (v_2) of identified particles as a function of p_T and centrality at RHIC suggests the created medium in Au+Au collisions achieves early local thermal equilibrium that is followed by hydrodynamic expansion. It is not known if the η dependence on v_2 [1, 2] is a general feature of elliptic flow or reflects other changes in the particle spectra in going from mid-rapidity to foward rapidities. The BRAHMS experiment provides a unique capability compared to the other RHIC experiments to measure v_2 for identified particles over a wide rapidity range. From Run 4 Au+Au collision at $\sqrt{s_{NN}}$ = 200GeV, identified elliptic flow is studied using the BRAHMS spectrometers, which cover $0<\eta<3.4$. The BRAHMS multiplicity array is used to determine the v_2 event plane for the identified particle elliptic flow and to measure the p_T-integrated flow for charged hadrons.

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The Relativisitic Heavy-Ion Collider has produced Au-Au collisions at $\sqrt{s_{NN}}$ = 200GeV in order to create a novel state of matter, the quark-gluon plasma (QGP), in which quarks and gluons are no longer confined [3]. Hydrodynamical models that assume the formation of a QGP have been used to model the behavior of the created medium [4]. The data presented by the STAR, Phobos, and PHENIX collaborations in ref. [1, 2, 5] show strong evidence that the created medium behaves as a fluid. These studies have been limited, however, to the mid-rapidity region of the collision.

BRAHMS studies elliptic flow as a function of the longitudinal expansion of the created medium. The STAR and Phobos collaborations have shown that the p_T-integrated elliptic flow is monotonically dependent on pseudorapidity [1, 2]. Phobos reports on a "limiting framentation" behavior [6], showing a universal dependence of elliptic flow on η' (= η - y_{beam}) as η' goes to zero for various collision energies. We seek to better understand this behavior by studying its rapidity and transverse-momentum dependence.

Elliptic flow is directly influenced by the initial state of the system but is also affected by final state dynamics. The p_T-integrated elliptic flow shows a centrality dependence that is attributed to the inital collision geometry. The mid-rapidity elliptic flow dependence on p_T has a number of signals suggesting an interplay between final and initial state effects. The elliptic flow for charged-hadrons shows a strong dependence on p_T, and initial state hydrodynamical models are in good agreement with the measurement up to about 1.5 GeV/c [2, 5]. At this point, the signal seems to saturate for the higher p_T particles. The elliptic flow at intermediate p_T is found to scale with the number of constituent quarks, n, (i.e. v_2/n vs. p_T/n has a universal dependence), which is consistent with a final state effect of quark coalescence [7]. This dependence holds well for baryons and kaons for p_T/n > 0.75 GeV/c, as shown in ref. [2, 5], but the pions behave somewhat differently. The deviation seen for pions could be due to resonance decays or the difference in mass between the pion and the constituent quarks.

The BRAHMS experiment [8] consists of two spectrometers, one covering angles near mid-rapidity (MRS) and one covering forward rapidities (FS). A number of global detector arrays characterize the overall charged-particle production. The collision region is surrounded by arrays of silicon detectors (SMA) and scintillating tile detectors (TMA). Three azimuthally symmetric rings of Si detectors, and one ring of tile detectors are used in the reaction-plane analysis. The BRAHMS azimuthally symmetric, left large-tube beam-beam counters (BBL) are also used for this analysis.

The basic procedure to measure the elliptic flow signal is outlined in ref. [9]. Once a reaction plane is determined for the five detector rings (3Si, 1 Tile, 1BBL), the ϕ of the particles measured in one detector is correlated to the reaction plane in another. Several combinations of the detector rings were used for the integrated v_2 analysis, while p_T dependent v_2 analysis only correlated the tile reaction plane with the particles identified in the spectrometers.

To obtain the correct v_2 value, signal distortions resulting from the reaction-plane resolution, the background, and other non-flow effects, need to be removed. Since the BRAHMS experiment is not symmetric about $\eta = 0$, the reaction-plane resolution measurement requires using three independent reaction planes. Auto-correlations are removed by correlating detectors that are seperated by at least 0.2 units in η. Normalized weights based on averages over many events are used to remove any anisotropic effects. These weights are determined using minimum biased events for the intergated flow analysis, but all events are used in the spectrometer analysis. To further remove any first order effects, the $\Sigma w_i \sin(2\phi_i)$ and $\Sigma w_i \cos(2\phi_i)$ terms in the reaction plane calculation are centered to zero on average. From ref. [10], the final reaction plane distribution can be completely flattened by taking a Fourier decomposition of the distribution over minimum bias events. Background and geometrical effects are removed using GEANT simulations with a known elliptic flow signal.

The BRAHMS integrated v_2 versus centrality and η dependencies are consistent with the Phobos results [1] (see Fig 1a and 1b). The p_T dependent elliptic flow signal is determined for charged-hadrons and protons at mid-rapidity, and these results agree

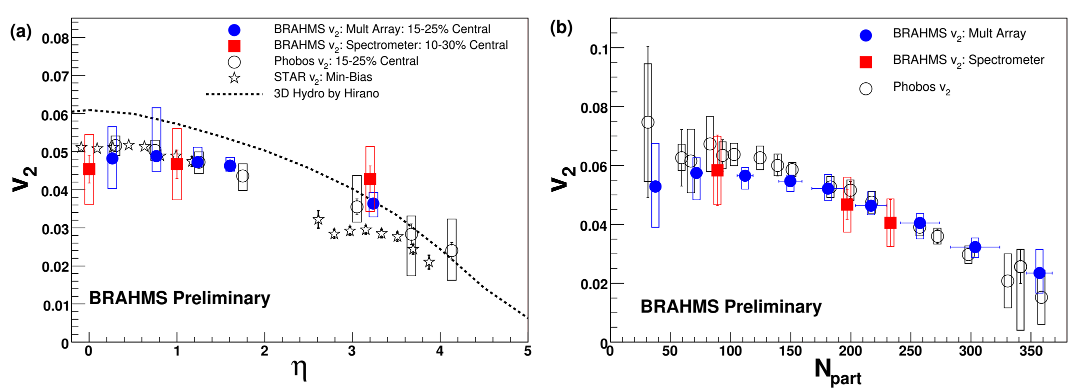

FIGURE 1. (a) Integrated v_2 versus η for charged hadrons. The BRAHMS spectrometer results are consistent, but systemmatic errors with the spectra may distort the shape. For comparison, a 3D hydro model results [11] are plotted. (b) Integrated v_2 versus N_{Part} for charged hadrons within $-1.0 < \eta < 1.0$.

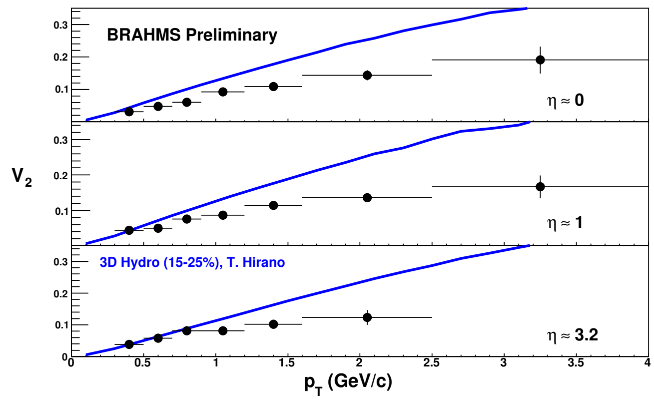

FIGURE 2. p_T dependent elliptic flow for charged hadrons for the 10% to 30% most central events. The top panel is for $\eta \approx 0$, the middle shows $\eta \approx 1$, and the bottom panel displays $\eta \approx 3.2$. The 3D hydro calculations are also given for the 15% to 25% most central events.

with the data presented by the STAR [2] and PHENIX [5] collaborations. The charged-hadron spectrum at mid-rapidity is used to determine the integrated v_2 as a function of centrality for the spectrometer measurements, with results that agree within errors with the integrated v_2 determined from the BRAHMS global detectors (see Fig. 1a and 1b). The measured charged-hadron v_2 dependence on p_T for centralities from 10% to 30% does not seem to change much over rapidity, as shown in Fig. 2. This rapidity independent behavior is consistent with a 3D hydrodynamical model [11]. The result suggests that the η dependence of the integrated v_2 is not an inherent feature but reflects the charged-particle p_T spectrum with rapidity.

The BRAHMS experiment is able to reproduce the elliptic flow signitures seen in the other RHIC experiments and expand the study of identified-particle elliptic flow to forward rapidity. The study of the elliptic flow over a large rapidity range will allow a better understanding of the longitudinal expansion of the created medium. Current work is focussed on establishing the elliptic flow for protons, pions, and kaons over the rapidity acceptance of BRAHMS.

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