Flow and Bose-Einstein Correlations in Au-Au Collisions at RHIC

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Elliptic flow and Bose-Einstein correlations have been measured in Au-Au collisions at \(\sqrt{s_{NN}} = 130\) and 200 GeV using the PHOBOS detector at RHIC. The systematic dependencies of the flow signal on the transverse momentum, pseudorapidity, and centrality of the collision, as well as the beam energy are shown. In addition, results of a 3-dimensional analysis of two-pion correlations in the 200 GeV data are presented.

1. Introduction

The evolution of the space-time structure of the particle emitting source created in heavy ion collisions can be probed by measuring the azimuthal anisotropy (e.g., elliptic flow) and two-particle interferometry in the final state particle distributions. Elliptic flow is thought to provide information on the early stages of the collision, the nuclear equation of state and the degree of equilibration attained during the evolution of the collision \[\square\], while two-particle interferometry provides information on the temporal and spatial extent of the source \[\square\].

The results presented here are based on data taken during the first two RHIC physics runs for Au-Au collisions at \(\sqrt{s_{NN}} = 130\) and 200 GeV. All 200 GeV results presented here are preliminary. The PHOBOS detector employs silicon pad detectors to perform tracking, vertex detection and multiplicity measurements. Details of the setup and the layout of the silicon sensors can be found elsewhere \[\square\]. Event triggering and the determination of
the centrality were based on the information provided by two sets of scintillating paddle counters [4]. The raw data for these analyses came in the form of energy depositions from the passage of charged particles through individual detector pads, known as hits. The hit definition and signal processing procedure used for the flow analysis is described in reference [6]. The position of the primary collision vertex was determined on an event-by-event basis by extrapolating tracks found in the spectrometer arms and/or the vertex detector. The event plane was determined by a standard subevent technique [7] using hits in symmetric and uniform regions of the octagonal multiplicity detector. Charged particle tracks were reconstructed in the spectrometer arms using techniques described previously [8,9]. Pions were identified using the measured momentum and the specific ionization loss observed in the spectrometer silicon detectors.

2. Flow

Flow results from two independent analyses are presented here. In the first, known as the hit-based analysis, the event plane was determined from hits in the single layer Si multiplicity detectors and the second Fourier coefficient of the hit azimuthal angle distribution (also known as the elliptic flow), $v_2$, was evaluated by correlating the event plane to hits in a different region of the multiplicity detectors. In the second flow analysis, known as the track-based analysis, $v_2$ was determined by correlating the event plane to tracks found in the spectrometer arms.

For the hit-based analysis, events were chosen in a fiducial region that maximized the $\eta$ coverage and event plane sensitivity for the analysis. Equal multiplicity subevents were defined in the regions $0.1 < |\eta| < 2$ for the event plane determination and evaluation of the event plane resolution. Details of this analysis are provided in reference [6]. Results from the hit-based flow analysis are shown in Figures 1 and 2. The 1σ statistical errors are shown for both analyses. The 90% confidence level systematic errors are shown as boxes for the 200 GeV data points. As can be seen in these two figures, the flow signal is little changed with the increase in the center-of-mass energy of the collision from 130 to 200 GeV. The unique, and very nearly complete, $\eta$ coverage shown in Figure 2 shows a substantial drop in $v_2$ as a function of $|\eta|$ that is not yet understood [6].

In the track-based analysis, events were chosen in a fiducial region that maximized the tracking efficiency and the reaction plane sensitivity. Subevents were defined roughly in the regions $2 < |\eta| < 3$ for the event plane determination and the evaluation of the reaction plane resolution. Charged tracks reconstructed in the spectrometer arms in the region $0 < \eta < 2.5$ were used to determine the elliptic flow. In detail, the track-based flow analysis is quite different from our previously released flow analysis. Differences include the use of a vertex dependent reaction plane weighting and resolution correction, as well as a larger separation of the subevents in $\eta$. The flow signal is determined as the asymmetry in the track azimuthal angle distribution measured relative to the event plane. The track-based flow results are less dependent on Monte Carlo corrections and less sensitive to background and non-flow correlations as compared to the hit-based flow measurements.

Results from this procedure are shown in Figures 3 and 4. The graphical representation of the errors in these figures is similar to that for the first two figures. Figure 3 shows the
elliptic flow signal as a function of the number of participants for the track-based analysis overlayed with that from the hit-based analysis for 200 GeV data. The two techniques agree very well. This is significant because of the differing sensitivity to background and non-flow correlations. Figure 2 gives the transverse momentum dependence of the elliptic flow of charged hadrons in the 200 GeV data. The saturation observed at a transverse momentum greater than 2 GeV/c is similar to what was observed at 130 GeV, and has been interpreted as evidence for partonic energy loss through gluon radiation in a dense system [10].

3. Bose-Einstein correlations

Pairs of identified same-sign pions were used to calculate the two-particle correlation functions. The results were corrected for the effects of the tracking algorithm and the Coulomb repulsion of the pions. The 3-dimensional analysis of the correlation function using the Bertsch-Pratt parameterization was performed in the LCMS frame in the region of acceptance $0.2 < y < 1.5$ and $150 < k_T < 350$ MeV/c. For the 15% most central events, the preliminary fitted source parameters for $\pi^-\pi^- (\pi^+\pi^+)$ pairs are as follows: $\lambda = 0.54 \pm 0.02(0.57 \pm 0.03)$, $R_{out} = 5.8 \pm 0.2(5.8 \pm 0.2)$ fm, $R_{side} = 5.1 \pm 0.4(4.9 \pm 0.4)$ fm, $R_{long} = 6.8 \pm 0.3(7.3 \pm 0.3)$ fm, and $R_{out-long} = 4.9 \pm 1.7(4.5 \pm 1.9)$ fm. The errors listed are statistical only. In addition, there are systematic errors of $\pm 0.06$ on the values of $\lambda$ and $\pm 1$ fm on the radii. The results reported here are similar to those observed in Au-Au collisions at $\sqrt{s_{NN}} = 130$ GeV [11,12].

4. Summary

Recent PHOBOS measurements of elliptic flow and two-particle correlations in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV are very similar to values observed at $\sqrt{s_{NN}} = 130$ GeV.
Figure 3. Elliptic flow as a function of the number of participants for Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV for the hit-based and track-based analyses.

Figure 4. Elliptic flow as a function of transverse momentum for Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

Notably, the new results at 200 GeV clearly show a saturation of $v_2$ for $p_T > 2$ GeV/c and a dramatic drop of $v_2$ as a function of $|\eta|$.

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