SYSTEMATICS OF CHARGED PARTICLE PRODUCTION IN HEAVY-ION COLLISIONS WITH THE PHOBOS DETECTOR AT RHIC

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The multiplicity of charged particles produced in Au+Au collisions as a function of energy, centrality, rapidity and azimuthal angle has been measured with the PHOBOS detector at RHIC. These results contribute to our understanding of the initial state of heavy ion collisions and provide a means to compare basic features of particle production in nuclear collisions with more elementary systems.

1 Introduction

Gold-gold collisions at RHIC provide the largest and densest partonic system available in the laboratory. The multiplicity of charged particles has been studied as a function of center-of-mass energy ($\sqrt{s}$), centrality, rapidity and azimuthal angle using the PHOBOS detector[1], which covers most of the available phase space. These studies provide an understanding of the basic properties of the initial state, such as the effects of the collision geometry and parton saturation[2]. They also allow systematic comparisons of particle production in nuclear collisions with more elementary systems like proton-(anti)proton and proton-nucleus collisions.

2 Experimental Setup

The PHOBOS detector[1] consists primarily of silicon pad detectors mounted close to the RHIC beampipe. Charged particle multiplicity is measured in 4π using a combination of the "octagon" detector which covers $|\eta| < 3$ (where $\eta = -\log\tan(\theta/2)$) and a set of six "ring" detectors that cover $3 < |\eta| < 5.4$ with pads sized such that they cover approximately equal bins in pseudorapidity. The vertex position is measured by two subdetectors, a high-precision vertex detector consisting of two silicon planes above and below the beampipe as well as a 16-plane spectrometer covering $-1 < |\eta| < 2$.

To detect collisions and estimate centrality[3] (here characterized as the number of nucleons that interact inelastically), we use a combination of two sets of 16 paddle counters and two zero-degree calorimeters (ZDCs) located along the beam-line at distances of 3.28m and 18m from the interaction point in either direction.

3 Charged Particle Distributions

PHOBOS has produced the first measurements of $dN_{ch}/d\eta$ near mid-rapidity at all RHIC energies to-date[4], as well as detailed studies of the centrality dependence of $dN_{ch}/d\eta$[3]. These measurements are important for understanding the initial gluon density and are discussed elsewhere in these proceedings[5].

To measure $dN_{ch}/d\eta$ with the octagon and ring detectors, we use two different techniques[6]. The first ("hit counting") is based on a determination of the number of hits in the silicon as a function of η. We correct the raw hit multiplicity, as a function of η, for occupancy (assuming Poisson statistics), geometrical acceptance, and background expected from Monte Carlo simulations. The second method is based on associating the energy deposition in each pad with the charged particle multiplicity.

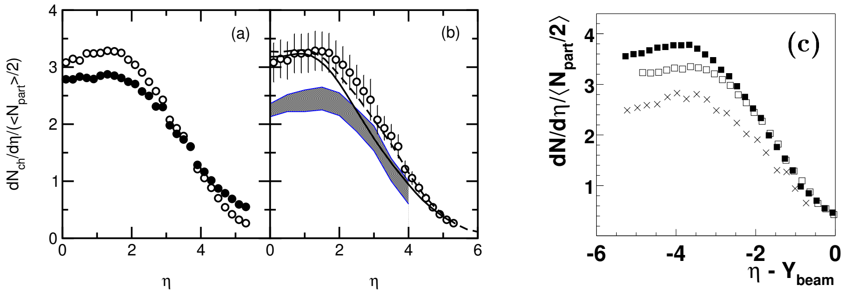
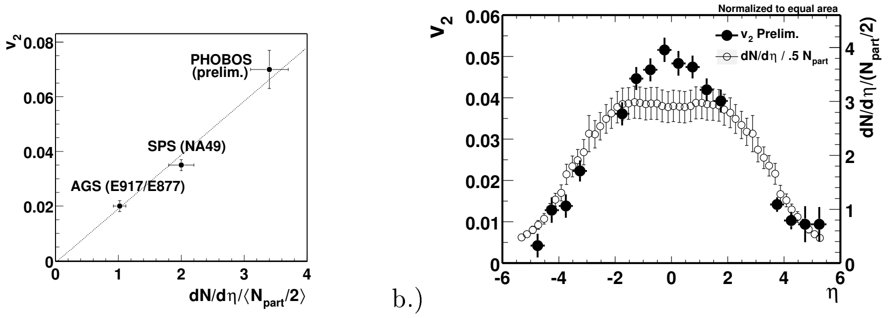


Figure 1. a.) Comparison of charged-particle pseudorapidity density for central and peripheral events at $\sqrt{s_{NN}} = 130$ GeV and b.) Comparison of central data with HIJING (solid line), AMPT (dashed line) and $p\overline{p}$ data (shaded band). c.) Pseudorapidity distribution for the most central events at $\sqrt{s_{NN}} = 130$ (open squares) and 200 GeV (closed squares), shifted by the beam rapidity. Limiting fragmentation is observed for $\eta - Y_{beam} > -2$. The crosses show data from UA5 for proton-antiproton collisions. Systematic errors are not shown, but are the same as in b.)

The data obtained at $\sqrt{s_{NN}} = 130$ GeV shows several interesting features[6]. As can be seen in Fig.1a, while the multiplicity density scaled per participating nucleon pair increases at mid-rapidity for more central collisions, it *decreases* outside of $|\eta| = 3 - 4$. Fig.1b shows that the HIJING model[7], which includes no additional parton cascading, is unable to reproduce the data near $|\eta| = 3 - 4$, unlike models like AMPT[8] which add such effects. Finally, by comparing central events at $\sqrt{s_{NN}} = 130$ and 200 GeV as a function of $\eta' = \eta - Y_{beam}$ in Fig. 1b, we observe that the distributions obey "limiting fragmentation" for $\eta' > -2$ as seen in the UA5 $p\overline{p}$ data[9]. The UA5 distribution at $\sqrt{s} = 200$ GeV has a shape similar to the PHOBOS 200 GeV data but is 30-40% lower at all pseudorapidities.

4 Elliptic Flow

To look for effects from initial state pressure gradients in peripheral collisions, we have studied the second Fourier coefficient, v_2, of the azimuthal distribution relative to the reaction plane defined by the impact parameter[10]. We have measured v_2 vs. centrality and found that it is at a maximum (5-6%) in peripheral events and decreases to 2-3% in the 6% most central events. This maximum value scales with energy in a similar way to the charged-particle multiplicity, as shown in Fig. 2a. A preliminary analysis also indicates that v_2 vs. η has a shape approximately similar to $dN/d\eta$, as shown in Fig. 2b. Both of these facts are consistent with the flow reflecting the asymmetry in the particle density, with no additional contribution from hydrodynamic evolution.



a.) b.)

Figure 2. a.) Data on v_2 vs. the multiplicity per participant pair for three different energies (AGS, SPS and RHIC). b.) Preliminary data on v_2 vs. η compared with a pseudorapidity density distribution of charged particles for a similar centrality, normalized to equal area.

Conclusions

The PHOBOS collaboration has studied charged particle distributions as a function of $\sqrt{s}$, centrality, rapidity, and azimuthal angle. The multiplicity studies provide information about the initial gluon density and provide a direct connection between high-energy pp and AA collisions. The elliptic flow results imply the presence of initial state pressure and subsequent hydrodynamic evolution, but they are also broadly consistent with a simple scaling with the rapidity density.

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References

1. B.B. Back *et al.*, to be submitted to Nucl. Inst. Meth. (2001).
2. D. Kharzeev and E. Levin, nucl-th/0108006.
3. B. B. Back *et al.*, nucl-ex/0105011.
4. B. B. Back *et al.*, nucl-ex/0108009.
5. I. Tserruya, these proceedings.
6. B. B. Back *et al.*, Phys. Rev. Lett. **87**, 102303 (2001).
7. X. N. Wang and M. Gyulassy, Phys. Rev. D **44**, 3501 (1991).
8. B. Zhang *et al.*, Phys. Rev. C **61**, 067901 (2000)
9. G. J. Alner *et al.*, Z. Phys. C **33**, 1 (1986).
10. I.C. Park, proceedings of Quark Matter 2001, Stony Brook.