# Correlations and Fluctuations over a Broad Range in Pseudorapidity using the PHOBOS Detector

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The PHOBOS apparatus includes a charged particle multiplicity detector covering almost all of $4\pi$ in solid angle. The broad coverage in pseudorapidity, $\eta$, which is unique at RHIC, combined with the ability to collect a large sample of events with minimal bias, makes possible a study of correlations and fluctuations over most of the pseudorapidity range, even at the highest beam energy. Long range correlations, short range correlations at large $|\eta|$, event-by-event fluctuations in the total number of charged particles, and event-by-event variation in the full shape of the pseudorapidity distribution can all be studied. Preliminary results for the first exploration of these capabilities of the PHOBOS detector, along with some average properties of the pseudorapidity distributions, are presented.

## 1. Introduction

Studies of correlations and fluctuations can reveal a wealth of detailed information concerning the underlying mechanism of particle production in collisions of both heavy ions and simpler systems. The PHOBOS multiplicity detector consists of single layer Si pad detectors supported in an octagonal frame surrounding the interaction region as well as in ring-shaped frames arranged along the beam pipe [1]. Additional details of the detector layout as well as information on the triggering and centrality selections for the various systems studied can be found in [2]. The uniquely broad pseudorapidity ($\eta$) coverage of the PHOBOS multiplicity detector ($|\eta| \leq 5.4$) enables a wide variety of studies of both correlations and fluctuations. This paper presents the results of a few preliminary studies exploiting these unique capabilities.

## 2. Two particle correlations

The utility of broad $\eta$ coverage is illustrated in Fig. 1 which shows the raw two-particle correlation function measured for collisions of d+Au at $\sqrt{s_{_{NN}}} = 200$ GeV. It is clear that these data can be used to study both correlations of particles widely separated in $\eta$ as well as particles closely separated in $\eta$ but far from mid-rapidity. The histogram shown in Fig. 1 was obtained by counting all pairs of particles within an event in bins of $\Delta\eta$ and $\Delta\phi$ and dividing by the same binning of randomly selected pairs of particles from different events.

*For the full author list and acknowledgments, see appendix 'Collaborations' of this volume.

In a small system like d+Au, this uncorrected correlation function is dominated by detector effects such as $\delta$-electrons which cause a peak at small $\Delta\eta$ and $\Delta\phi$ and momentum conservation which causes a ridge at small $\Delta\eta$ and $\Delta\phi \approx 180\,$deg. Work is ongoing to correct for these uninteresting effects and study the remaining correlations in the data.

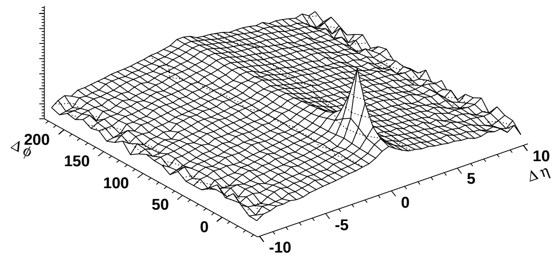


Figure 1. Uncorrected two particle correlation function measured in collisions of d+Au at $\sqrt{s_{NN}} = 200$ GeV. See text for discussion.

## 3. Properties of the pseudorapidity distributions

Before discussing the fluctuations in the distributions of charged particles, it is useful to review the properties of the distributions averaged over all events. Fig. 2 summarizes the dominant feature of such distributions, namely extended longitudinal scaling. Distributions of dN/d$\eta$ for charged particles emitted in central collisions of Au+Au at four energies are shown [3]. The data at positive and negative $\eta$ have been averaged and then plotted versus $|\eta| - y_{beam}$, thereby approximating the rest frame of one of the colliding nuclei. The distribution of charged particles, when viewed in this rest frame, is clearly

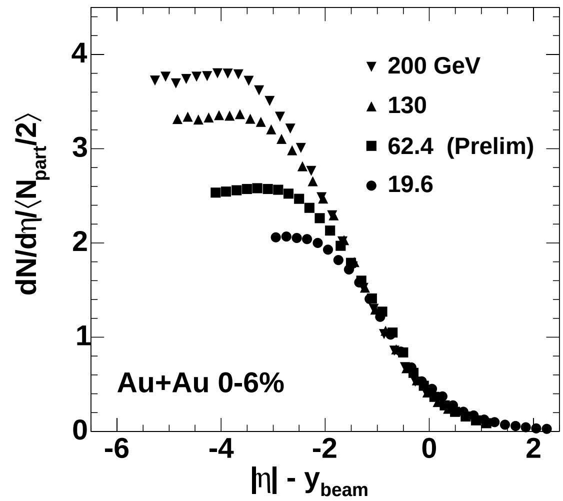


Figure 2. Pseudorapidity density distributions of charged particles emitted in central collisions of Au+Au at four energies plotted in the approximate rest frame of one of the colliding nuclei [3]. See text for discussion.

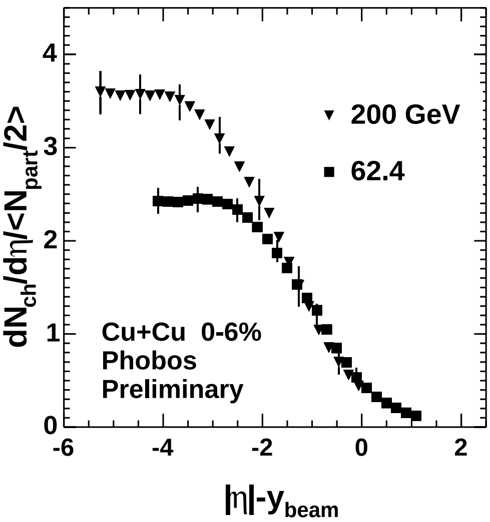


Figure 3. Pseudorapidity density distributions of charged particles emitted in central collisions of Cu+Cu at two energies plotted in the approximate rest frame of one of the colliding nuclei. See text for discussion.

independent of energy over a large range of longitudinal phase space. Preliminary results from the recent Cu+Cu run show identical behavior (see Fig. 3).

The distributions for non-central collisions at a given energy differ from those of central collisions, both in shape and height but all show the same beam energy scaling. The degree to which the energy and centrality dependencies factorize is shown in Fig. 4. The dN/d$\eta$ distributions for collisions in the centrality bin 35−40% are normalized by the number of participating nucleons and divided by the similarly normalized distribution for central collisions. Again, the data are plotted in the approximate rest frame of one of the colliding nuclei. The variation in shape (represented by the large deviations from a constant value) are seen to be remarkably independent of energy over the entire range measured.

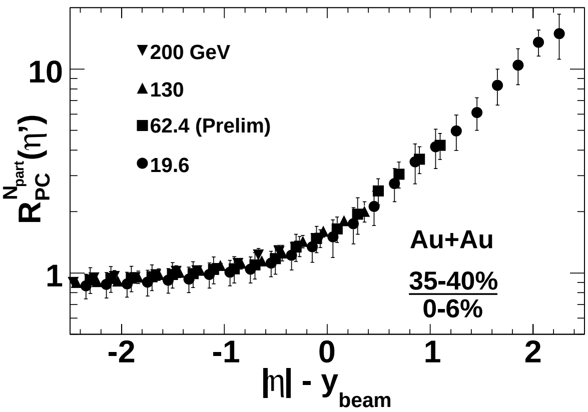


Figure 4. The ratio of dN/d$\eta$ distributions of charged particles for semi-peripheral over central collisions for Au+Au at four energies, normalized by the number of participating nucleons, plotted in the approximate rest frame of one of the colliding nuclei [3]. See text for discussion.

## 4. Fluctuations in the dN/d$\eta$ distributions

Having established the average properties of the dN/d$\eta$ distributions, two preliminary studies of fluctuations in the distributions were performed. Data for the most central 3% Au+Au collisions from the high statistics run at $\sqrt{s_{NN}}$=200 GeV were used, a total of about 2 million events. The first investigation looked for events with unusually high total number of charged particles. The results are shown in Fig. 5. A clear, but small, tail extending to high multiplicity is evident. A preliminary conclusion can be drawn that events with larger than expected total multiplicity are rarer than a few times $10^{-4}$. One obvious source of such events is pile-up in which two collisions occur within the read-out time of the experiment. In order to study this possibility, the rate of events with a number of hits above 4400 (about 570 in total) was plotted versus a crude measure of the event rate, with the results shown in Fig. 6. A clear correlation is evident which extrapolates to zero events at zero luminosity to within less than $2\sigma$.

An additional study was performed to look for events with unusual shapes of the dN/d$\eta$ distribution. Events from the same central Au+Au sample were used. Within bins in vertex location (to eliminate trivial acceptance effects), the average dN/d$\eta$ shape and variance was determined. Each event was normalized to the same total number of hits

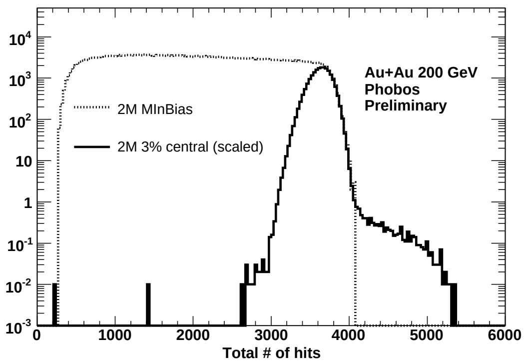


Figure 5. The distribution of the total number of detected charged particles emitted in events without centrality selection and in the 3% most central Au+Au events.

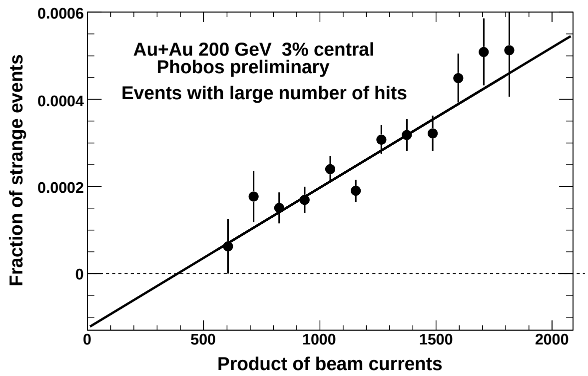


Figure 6. The number of events with more than 4400 detected charged particles versus the product of the currents in the two RHIC beams.

and then a $\chi^2$ was calculated comparing to the average event shape. A clear excess of events with large $\chi^2$ was observed, about 200 in total. In this case, a slightly smaller preliminary limit of about $1 \times 10^{-4}$ is found. However, as with the high multiplicity events, the number of these unusual events was correlated with the event rate with an extrapolation close to zero, suggesting the possibility of smaller values.

## 5. Summary

The unique properties of the PHOBOS charged particle multiplicity detector are being exploited in the study of correlations and fluctuations in the production of particles in collisions at RHIC. Average pseudorapidity density distributions in Au+Au and preliminary Cu+Cu data show extended longitudinal scaling and a striking factorization of the dependencies on energy and centrality. Preliminary searches for events with unusually high total number of charged particles and with unusual shapes in $dN/d\eta$ have yielded small numbers (frequencies on the order of $10^{-4}$) with strong indications that a large fraction, possibly close to all of the events, are due to simple pileup. Work is ongoing to determine more precise limits for these two classes of unusual events.

## REFERENCES


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