

## CHARGED PARTICLE MULTIPLICITY DISTRIBUTIONS FROM p+p TO Au+Au COLLISIONS AT RHIC

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*Abstract.* The distributions of charged particles from heavy ion collisions have been measured by the PHOBOS collaboration. Results from Au+Au collisions at various energies and over a broad range of centrality are presented and discussed. This data are compared to p+p, d+Au and Cu+Cu collisions at the corresponding energy and centrality.

*Key words:* multiplicity, heavy ion, RHIC, PHOBOS, centrality.

### 1. INTRODUCTION

PHOBOS has developed multiple techniques to measure the number of charged particles produced in the collision of two heavy nuclei. For a global view of the collision, the charged particle pseudorapidity density is measured over a

large range of pseudorapidity,  $|\eta| < 5.4$  units, using a combination of detectors: the barrel-shaped Octagon ( $|\eta| < 3.2$ ) and annular Ring counters ( $3.0 < |\eta| < 5.4$ ). These detectors are based on silicon pad technology and are described in detail in [1]. The techniques used for measuring the multiplicity can be found in [2, 3]. The data presented here are divided into bins of inelastic cross section or centrality. This allows one to study the evolution of produced particles as more nucleons participate in a collision. Additionally, RHIC has created collisions at several center-of-mass energies ( $\sqrt{s_{NN}} = 19.6$  to 200 GeV). The systematic measurement of the multiplicity at each energy and centrality has led to conclusions of the underlying dynamics of particle production. These measurements and observations are discussed in the following sections.

## 2. COMPARISON OF p+p, d+Au AND Au+Au COLLISIONS

In order to interpret any measurement made with a large collision system (for example Au+Au) it is important to analyze much simpler systems to find any similarities or differences. The interpretation of the pseudorapidity density in Au+Au collisions therefore requires some knowledge of the simplest system (p+p). The modification of the multiplicity in the nuclear environment can be studied using the asymmetric d+Au collisions as well. As is illustrated in Fig. 1, the p+p data and Au+Au data (for the 6% most central collisions, scaled by the number of participant pairs ( $N_{part}/2$ )) differ substantially – the total number of particles (per  $N_{part}/2$ ) produced in Au+Au collisions is approximately 30% higher than in p+p. Au+Au collisions therefore cannot be thought of as only a product of single ‘wounded nucleons’ [4] within the colliding gold nuclei. Collisions of deuteron and gold nuclei produce a multiplicity (per participant pair) which is asymmetric, but the overall number of particles produced is closer to p+p collisions than the Au+Au collisions.

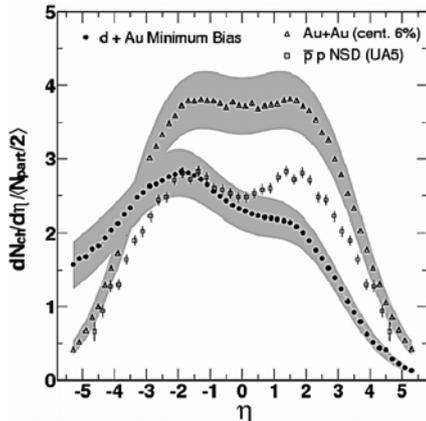


Fig. 1 – Comparison of the measured charged particle pseudorapidity density in p+p (UA5 [5]), d+Au [6] and Au+Au [7] collisions.

From these two observations it is clear that the number of multiply interacting nucleons (number of collisions –  $N_{\text{coll}}$ ) plays an important role as well. For comparison, the number of collisions (per participant pair) can be estimated from a Glauber Model calculation and is found to be 1 (p+p), 1–2 (d+Au) and  $\sim 6$  (central Au+Au). The precise nature of how the number of collisions influences the multiplicity is not fully apparent, although arguments that the ‘leading hadron’ effect can partially explain this phenomenon have been made [8].

### 3. COMPARISON OF Au+Au AND Cu+Cu COLLISIONS

From the p+p, d+Au and Au+Au collision data there is no overlap in participant-space, and hence no direct comparison of different collision systems is possible. The most recent RHIC run produced collisions of copper nuclei with 13.5 to 110 participants – overlapping with both peripheral Au+Au and central d+Au collisions. The multiplicity density distributions for Cu+Cu and Au+Au collisions with the same number of participants are essentially indistinguishable (Fig. 2 (left panel)). Considering that the same systematic constraints are imposed on both measurements, it appears as though the number of participants is the controlling parameter in the charged particle multiplicity in heavy ion collisions.

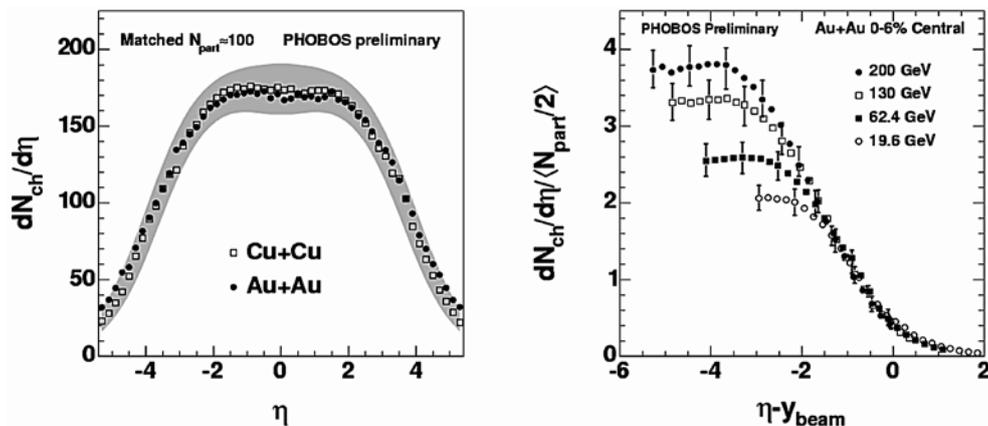


Fig. 2 – The left panel shows a comparison of peripheral Au+Au data [7] and central Cu+Cu data (preliminary). The right panel shows the extended longitudinal scaling in central Au+Au collisions [12].

### 4. DATA SCALING OBSERVATIONS

In a given collision system the particle production close to the rest frame of one of the colliding nuclei (lab frame) is hypothesized to be the same for all

collision energies [9], a phenomenon known as ‘Limiting Fragmentation’. To observe this effect one can take the pseudorapidity distribution at each energy and perform the transformation  $\eta \rightarrow \eta - y_{\text{beam}}$ , where  $y_{\text{beam}}$  is the beam rapidity.  $y_{\text{beam}}$  grows with energy so higher energy collisions must be shifted further. Fig. 2, right panel, shows an impressive similarity of charged hadron yields (around  $\eta - y_{\text{beam}} \approx 0$ ) for all energies in Au+Au collisions; in fact the data exhibits an ‘extended longitudinal scaling’ meaning that the yield is the same over an extended region of pseudorapidity, which increases with energy. This phenomenon was first observed in p+p collision data [5] and subsequently in d+Au data [10] in comparison to proton collisions with various nuclear targets. This also persists for the preliminary Cu+Cu data in each measured centrality bin. This effect has also been observed in elliptic flow [11].

The mid-rapidity region of particle production ( $|\eta| < 1$ ) was considered very interesting in the context of minijet production – leading to an enhancement in the number of particles produced [13] with energy and centrality. This enhancement was believed to be closely related to the number of binary collisions ( $N_{\text{coll}}$ ) for a given energy and centrality. From Glauber Model calculations,  $N_{\text{coll}}$  grows strongly with the overlap volume ( $N_{\text{part}}$ ) and with collision energy. The mid-rapidity data (Fig. 3 – left panel) shows that the particle production grows with centrality, over the measured  $N_{\text{part}}$  range, and is higher than the p+p data at the same energy. Interestingly, the rate of increase is found to be constant for all energies. This observation is best represented by the ratio of data at two energies (for example a ratio of 200/19.6 GeV), Fig. 3 – right panel. This figure illustrates that the data exhibits a strong collision geometry scaling [3], *i.e.* with the number of participants. Scaling with the number of collisions would show evidence of a

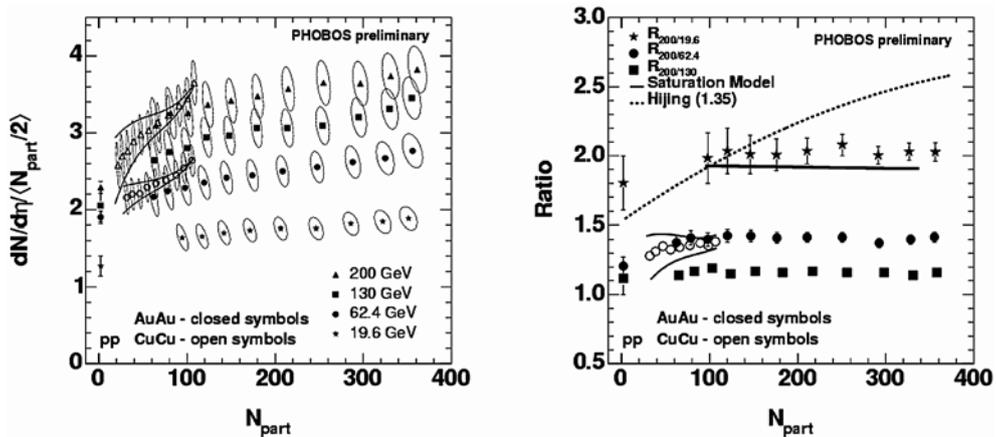


Fig. 3 – The left panel shows the mid-rapidity data for Au+Au collisions at the four RHIC energies. The right panel shows the ratio of results (200/X), no centrality dependence is observed.

growth with energy and centrality – similar to the HIJING curve (see [3]). Within systematic errors, the Cu+Cu data, which overlaps with peripheral Au+Au collisions, do not contradict the observations made from that collision system.

## 5. SUMMARY

In summary, PHOBOS has a comprehensive set of multiplicity measurements from a wide range of energies, centralities and collision systems. The data show a similarity in the pseudorapidity density of particles from the p+p and d+Au collisions, but differ from the Au+Au and Cu+Cu data which are indistinguishable (at the same  $N_{\text{part}}$ ) within the systematic uncertainty. The data presented exhibit general features in all collision systems, extended longitudinal scaling and collision geometry scaling.

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