$dN_{ch}/d\eta$ distributions from PHOBOS

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We have studied the charged particle pseudo-rapidity density $dN_{ch}/d\eta$ from Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV. The evolution of $dN_{ch}/d\eta$ with increasing centrality is presented and discussed within the context of theoretical predictions.

1. Introduction

The advent of nucleus-nucleus collisions at highly relativistic energies from the Relativistic Heavy Ion Collider (RHIC) presents a new opportunity to study strongly interacting matter under the conditions of very high temperature and energy density. The pseudo-rapidity distribution of charged particles, $dN_{ch}/d\eta$, is a simple observable that reflects all effects that contribute to charged particle production in heavy-ion collisions. It is sensitive to the interplay between hard and soft scattering processes, the initial conditions of the system, e.g. shadowing, and finally additional effects such as re-scattering or hadronic final-state interactions. In short, the full distribution of $dN_{ch}/d\eta$ represents a time-integral of particle production throughout the entire heavy-ion collision.

2. Experiment

The PHOBOS experiment at RHIC consists primarily of silicon pad detector arrays. The details of the experimental arrangement are described in Ref. [1,2]. The aspects of the measurement pertaining to the selection of events, the determination of the event centrality, the identification of the collision vertex, and the estimation of the number of participating nucleons, are largely the same as those described in Ref. [3–5]. The elements of the experiment used in the current measurement of $dN_{ch}/d\eta$ are described below.

The data sample included in the current analysis consisted of approximately 2600 events taken at a collision energy of $\sqrt{s_{NN}}$=130 GeV. For these events, collision vertices were confined to within ±10 cm of the nominal center of the apparatus ($z = 0$). The data were obtained using the PHOBOS multiplicity detector. At mid-rapidity, charged particles were detected, and their energy deposition measured, with an octagonal array of pad detectors approximately 1 m long which surrounds the beam pipe. The octagon subtends the full azimuth, except for locations where octagon sensors would obscure the acceptance of the vertex finding detectors and the tracking spectrometer arms. For collisions near the center of this device, the pseudorapidity (η) coverage of the central barrel array is complete for $|\eta| \leq 3.2$. Six silicon-pad rings at $|z|$=1,2 and 5 m detect particles to $|\eta| \leq 5.4$.

To analyze the data, for each event, once the vertex position had been determined, the energy deposited by each track (ΔE) was corrected for its angle of incidence and path length in the silicon. Following this correction the energy signals from all Minimum Ionizing Particles (MIPs) have an approximately common value of the Landau peak of the distribution of energy signals, at $\Delta E_c \approx \Delta E_{MIP}$ =80 keV. Hits that deposited less than $0.75\Delta E_{MIP}$ were rejected. This cut had the advantage that, especially in the high η regions of the octagon, due to their trajectories, most secondary particles were more normally incident upon the silicon than particles from the collision vertex. These particles deposited energy that was less than ΔE_{MIP} and hits arising from them were thus suppressed. The raw hit distribution was then corrected for the effects of occupancy, secondary production, absorption in the beam pipe, and weak hadronic decays, as described below.

The mean detector occupancy (μ) was estimated by counting the numbers of occupied, and unoccupied pads in regions of η for different centralities, and then assuming that ratio was determined by Poisson statistics. Typical average numbers of tracks per hit pad were between 1 (for very low occupancy) to approximately 1.6 for the highest multiplicity events in the most densely populated regions of the detector. This procedure was checked by studying the ΔE_c spectra as a function of η and centrality. These spectra show characteristic peaks corresponding to the energy deposited by one, or more, minimum-ionizing particles, that are fit to a collection of convoluted Landau distributions. The

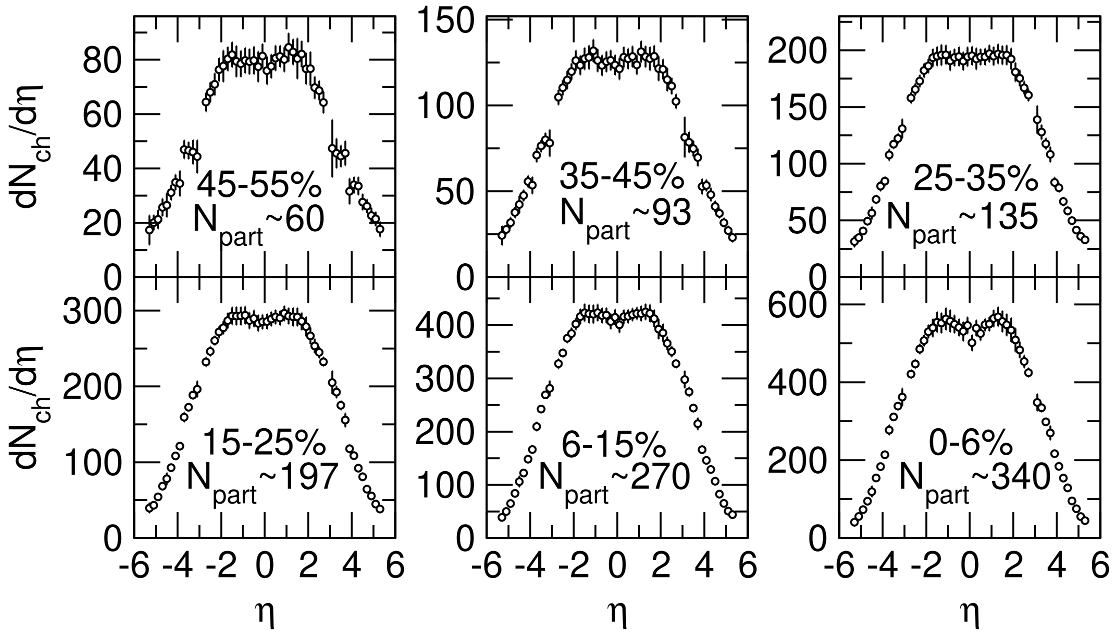

Figure 1. Pseudo-rapidity density distributions $dN_{ch}/d\eta$ from Au+Au collisions at $\sqrt{s_{NN}}$=130 GeV, for several centrality bins (PHOBOS preliminary results).

areas of the peaks extracted from this procedure independently determine the detector occupancy, in reasonable agreement with values obtained assuming a Poisson distribution.

Effects not treated by either ΔE_c cuts or occupancy corrections are accounted for by a final correction determined from comparisons to Monte-Carlo simulations. Events from HIJING[6] were processed through a detailed simulation of the PHOBOS detector, and analyzed in the same manner as the data. The ratios of the"truth" distributions of $dN_{ch}/d\eta$ and those obtained following the full analysis of the Monte-Carlo "data," with occupancy corrections derived from the Monte-Carlo events themselves, formed the basis for the final corrections to the real data. For the octagon, these background corrections were typically of the order of 10-20%, roughly independent of the collision centrality. For the ring detectors, secondary particles cannot be distinguished by a measurement of their ΔE. Here, the correction factors were somewhat larger, ranging from 10-20% for the ring farthest from the interaction point, to as large as 50% for the ring very close to the magnet region.

3. Results

The resulting $dN_{ch}/d\eta$ distributions are shown in Fig. 1 for six different centralities, denoted by the corresponding fraction of the total cross section, as well as the deduced number of participants N_{part}. The error bars reflect statistical uncertainties only. The smooth merging of the data between the different sub-detectors gives confidence in the analysis procedure. The $dN_{ch}/d\eta$ distributions evolve smoothly with increasing centrality.

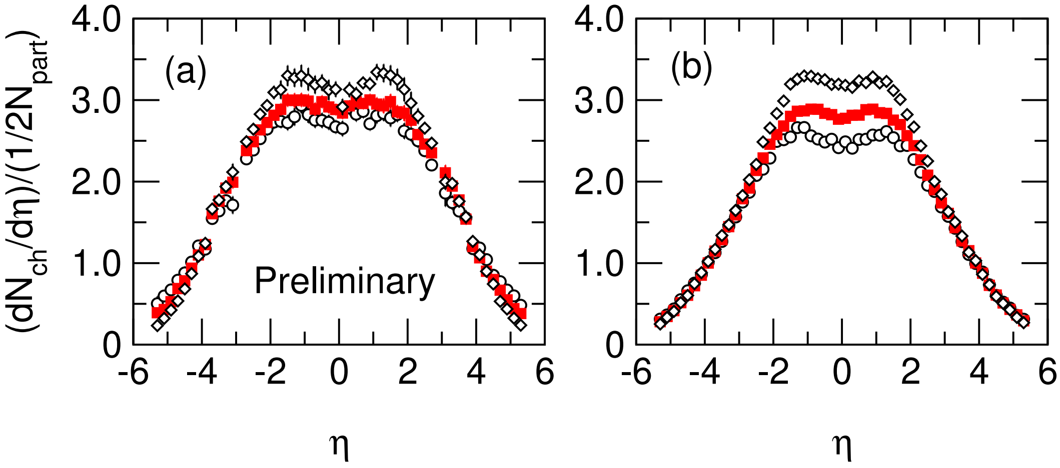

Figure 2. (a). Measured $dN_{ch}/d\eta/N_{pair}$ for N_{part}=102 (open circles), 216 (filled squares) and 354 (open diamonds) (PHOBOS preliminary results). (b). Same as (a) from HIJING

There is a plateau region for all centralities between $|\eta| \lesssim 2$, where $dN_{ch}/d\eta$ is either flat, or shows a slight dip at η=0. Also, the average value of $dN_{ch}/d\eta$ near mid rapidity increases faster with centrality than in the large $|\eta|$ regions.

In order to estimate the systematic uncertainties in our results from the treatment of detector occupancy, we have compared results obtained from the full analysis chains using Poisson-derived, and ΔE_c fitting methods. The average deviations between these two methods are less than 3%. The fluctuations in the estimated occupancy within a given bin of η and centrality for the mid-rapidity region, however, lead to an estimate of $\approx$ 10% for the systematic uncertainty arising from this aspect of the analysis. To estimate the systematic uncertainties from the Monte-Carlo simulations, we have obtained these corrections using different assumptions in the GEANT simulation. The variation observed in the derived background corrections are less than order of 3% for the octagon, but somewhat larger ($\approx$ 8%) in the rings. These estimates result in a total systematic error contribution of approximately 10% to the absolute scale throughout the entire rapidity region.

From these data we have deduced the total integral of the charged particle distribution $N_{ch}(total) = \int(dN_{ch}/d\eta)d\eta$, for which predictions have varied by as much as a factor of two[7]. From our data, for the most central 3% of the collisions, within the fiducial range of the detector $|\eta| < 5.4$, the average number of charged particles produced is approximately $4100 \pm 100(stat) \pm 400(syst)$. Assuming approximately equal production of all isospin species, the total number of particles produced at $\sqrt{s_{NN}}$ = 130 GeV is then roughly 6000 for the 3% most central collisions.

Figure 2(a) shows the measured $dN_{ch}/d\eta$ distributions for three centrality bins, scaled by the number of participant pairs ($N_{pair} = 0.5 \times N_{part}$). For comparison, the predictions of HIJING appear in Fig. 2(b). At mid rapidity, the non-central data are higher than the predictions, as previously reported. Also, whereas HIJING predicts that for large η the

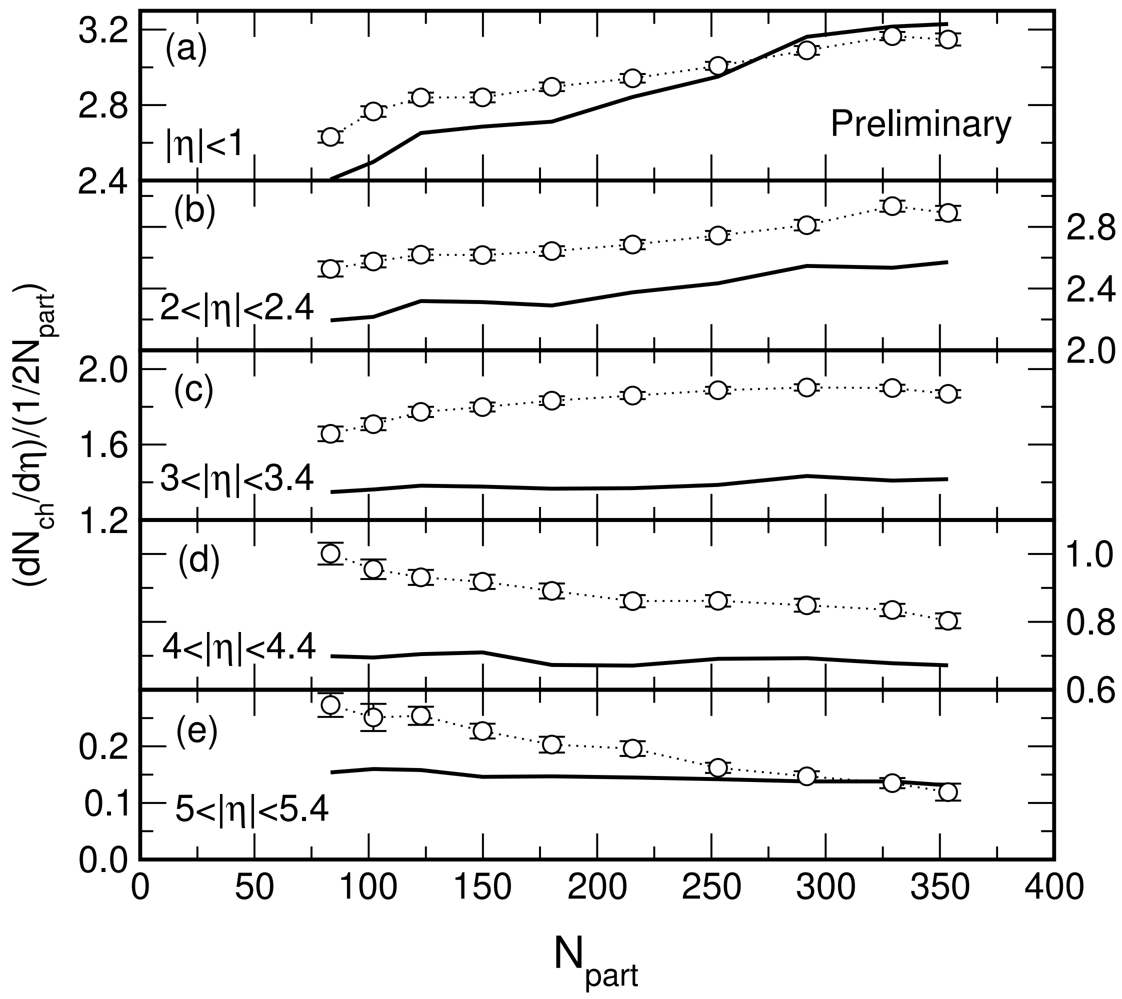

Figure 3. Centrality dependence of $dN_{ch}/d\eta$ at different values of $|\eta|$ (PHOBOS preliminary results). The solid lines are the predictions of HIJING.

distributions should be roughly equal, the data show a clear sensitivity of $dN_{ch}/d\eta/N_{pair}$ on N_{part}, dropping by nearly a factor of two near $\eta = 5$.

In order to examine more closely the evolution of the shapes of the pseudo-rapidity density distributions with centrality, Fig. 3 shows the average value of $(dN_{ch}/d\eta)/(0.5 \times N_{part})$ plotted for various ranges of $|\eta|$, as a function of N_{part}. The solid lines in Fig. 3 represent the predictions of HIJING. The statistical uncertainties are small; systematic uncertainties are as described above. As previously reported[5,8], the data at mid-rapidity ($|\eta| \leq 1$) rise less steeply with N_{part} than the HIJING prediction. A comparison of the mid-rapidity data with those from larger $|\eta|$ clearly shows that the enhancement of the yield with increasing number of participants is concentrated in the mid-rapidity region. In fact, in the regions beyond $|\eta| > 4$, when scaled by the number of participants, $dN_{ch}/d\eta$ actually falls with N_{part}. That the $dN_{ch}/d\eta$ distributions are wider than predicted by

HIJING is further underscored by the results from $|\eta| \approx 2$ and 3; here the calculation substantially under-predicts the data to a greater degree than at other values of $|\eta|$.

4. Summary

From these results one may deduce that even though important physical processes such as hadronic final state interactions and re-scattering are not included in the HIJING model, it is able to reproduce approximately the measured pseudo-rapidity distributions. In detail, however, some elements are clearly lacking. As reported previously[5,8] the centrality dependence for $|\eta| < 1$ is not well reproduced. The deficiency in the region of $|\eta| \approx$1.8-4 observed for essentially all centralities may suggest a possible sensitivity to re-scattering or final-state-interaction effects. A comparison of the centrality dependence of the pseudo-rapidity distributions from other models, that include additional dynamics, would be very interesting and could provide a basis for separating the effects of new phenomena from "conventional" physics backgrounds.

Acknowledgements

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