Determination of the collision geometry and measurement of the centrality dependence of $dN/d\eta$ at midrapidity.

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The charged particle pseudo-rapidity density at mid-rapidity has been measured as a function of centrality in gold-gold collisions at a center of mass energy of $\sqrt{s}_{NN} = 130$ GeV using the PHOBOS detector. The charged particle density per nucleon pair increases with the number of participants. The change is similar in shape to lower energy data from the SPS. The ratio of hadronic cross section to total cross section has been measured to be 0.62 ± 0.06, in agreement with theoretical predictions.

1. Introduction

The charged particle pseudo-rapidity density at midrapidity $dN_{ch}/d\eta|_{\eta=0}$, scaled by the number of participant pairs is about 40 % higher in central collisions at RHIC than in non-single-diffractive $p\bar{p}$ collisions at the same energy [1]. Here we analyze how this quantity evolves as a function of the number of nucleons participating in the collision (N_{part}).

At lower energies, where soft scattering processes dominate, a scaling of the produced particles with N_{part} has been observed, leading to the concept of the Wounded Nucleon Model. At SPS energies a violation of this scaling has been measured [2], which can be interpreted in terms of hard scattering processes that scale with the number of nucleon-nucleon collisions and thus to a different dependence on N_{part}.

Recent theoretical models, tuned to the charged particle density at mid-rapidity for the most central events at RHIC, predict a change of $dN/d\eta|_{\eta=0}/(0.5 * N_{part})$ with N_{part},

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but vary in the particulars of the dependence. These models make different assumptions regarding the interplay of hard and soft physics and the effect of gluon saturation. These data will therefore constrain these models more strongly than that for a single centrality.

2. Experimental set-up and Simulations

The measurement was performed using the PHOBOS detector [3]. Event selection and determination of N_{part} was carried out using two sets of sixteen scintillator paddle counters and two zero degree calorimeters (ZDCs) located symmetrically on both sides of the nominal interaction point, at $3 < |\eta| < 4.5$ and at $|\eta| > 6.7$ respectively.

The charged particle multiplicity was measured with the spectrometer and the vertex detector. The spectrometer consists of two arms with multiple layers of silicon modules covering $-1 < \eta < 2$ and $\delta\phi < 7^o$. The vertex detector consists of two double planes of silicon detectors located above and below the nominal interaction point. Each set covers about $|\eta| < 1$ and $\delta\phi = 45^o$.

During data taking, the read-out was triggered if at least one paddle counter on each side of the interaction region fired within a time interval of 10 ns. In the off-line analysis, a timing cut of 4 ns between the paddle signals was applied, which effectively reduces the acceptance to the interaction region of $|z_{vertex}| < 75$ cm. Background, e.g. from beam gas interactions, is separated by requiring consistent timing from the ZDCs.

The HIJING [4] event generator and the GEANT package were used for Monte Carlo simulations of the detector acceptance and response.

3. Determination of the number of participants

The number of participants was determined independently using signals either from the paddle counters or from the ZDCs. The signal in the paddle counters increases, and the signal from the ZDCs decreases monotonically with N_{part}, as demonstrated in Fig.1 by the anti-correlation between the two signals and by the predictions of simulations. Therefore, we have sorted the events into 18 bins of centrality such that events with the highest paddle signal are associated with the most central collisions. In order to associate an average number of participants to each centrality bin, the simulated paddle spectrum was binned in the same way as the data and $\langle N_{part} \rangle$ was obtained based on the correlation between N_{part} and the paddle signal as modelled with the HIJING event generator. Note this result does not depend on any detailed agreement between Monte Carlo and data, and only relies on the monotonic relation between N_{part} and paddle signal.

The systematic uncertainties in the determination of N_{part} are dominated for almost the full centrality range by the uncertainty in the trigger efficiency for hadronic events. From a detailed comparison of data to different models and corrections for the model inadequacies, we estimate that the trigger requirement should be fulfilled by $(97 \pm 3)\%$ of all hadronic interactions. Unfortunately, an uncertainty of 3% in the total cross-section leads to an increasing uncertainty in N_{part} towards peripheral bins, up to 10% for $\langle N_{part} \rangle = 50$.

An additional uncertainty is introduced by fluctuations of the measured signals from the paddles due to the detector acceptance, secondaries produced in the material in front and fluctuations of the number of produced particles with N_{part}. The size of this effect was quantified by comparing $\langle N_{part} \rangle$ obtained by sorting and binning the Monte Carlo events based on N_{part}. A maximum difference of 2% was found.

As an independent cross check, N_{part} was also extracted from the ZDC signals, which yield on average the same centrality bins and the same $\langle N_{part} \rangle$ within errors as the paddle method. $\langle N_{part} \rangle$ was thus determined, based on the paddle signals, in the range of $83 < \langle N_{part} \rangle < 353$ with a systematic uncertainty of 3-8% depending on centrality.

4. Cross section ratios

The ratios of the hadronic Au+Au cross section (σ_{hadron}) and the cross section for mutual Coulomb dissociation ($\sigma_{Coulomb}$) to the total inelastic cross section ($\sigma_{tot} = \sigma_{hadron} + \sigma_{Coulomb}$) have also been measured. Hadronic events are selected as mentioned before. Events with Mutual Coulomb Dissociation were identified by a coincidence between the ZDC signals, but no coincidence between the paddle counters. The number of Coulomb events has been corrected for acceptance and background, such as random coincidences. The ratio of $\sigma_{hadron}/\sigma_{tot} = 0.62 \pm 0.06$ thus determined is in agreement with theoretical predictions. The theoretical predictions for the mutual Coulomb dissociation have been further confirmed by measuring rates of the following sub-samples: the rate of events with exactly one neutron in both ZDCs (σ_{1n1n}) to events with one neutron in one ZDC and at least one neutron in the other ZDC (σ_{1nX}) was measured to be 0.341 ± 0.015 (theory:0.329 [5]). $\sigma_{1nX}/\sigma_{tot}$ was measured to be 0.123 ± 0.011 (theory: 0.125 [5]).

5. Charged particle density at mid-rapidity

For this analysis, a reconstructed vertex in the region of -4 cm $< z <$ 12 cm was required. The vertex was reconstructed with an efficiency of more then 97% and a resolution of $\sigma_z = \sigma_y = 200$ μm and $\sigma_x = 450$ μm. The charged particle density was measured at $|\eta| < 1$ using two hit combinations that point back to the vertex. The two hit combinations were reconstructed in two spectrometer layers and in the two layers of the vertex detector requiring $\sqrt{\Delta\eta^2 + \Delta\phi^2} \leq 0.15$ and $\Delta\eta \leq 0.04$, $\Delta\phi \leq 0.3$ respectively. Simulations showed that 95% of the particles within the detector acceptance fullfill these requirements. The background consisted of 1-15% combinatorial background, dependent on occupancy, (6.5 ± 1)% secondaries and (0.5 ± 0.5)% decaying particles.

The charged particle pseudo-rapidity density per nucleon pair rises with the number of participants, as shown in Fig.1. The present data are in good agreement with the previous PHOBOS measurement for the most central events [1]. A steep rise is observed from the $p\bar{p}$ data point [6] to our first data point at $\langle N_{part} \rangle = 83$, followed by a slower rise up to the most central events at $\langle N_{part} \rangle = 353$. This dependence is similar in shape to that measured by the WA98 experiment at lower energies [2]. It differs qualitativly from the predictions from [4], where a constant slope between $p\bar{p}$ and the most central point is predicted, and the model of EKRT [7], that predicts a rise towards more peripheral events. For the near future, an even deeper understanding of the interplay between hard and soft physics should be expected from measurements of collisions with different nuclear species which will be an important part of the near-term RHIC program.

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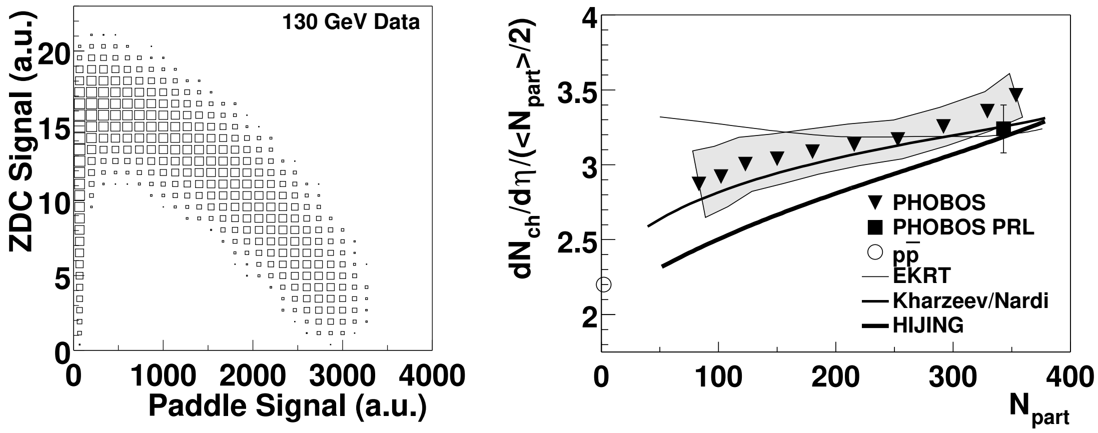

Figure 1. *left:* ZDC signal versus Paddle signal. The anti-correlation for the 60% most central events demonstrates the monotonic change of both variables with centrality. The ZDC signal is suppressed for the peripheral events due to fragmentation of the spectator matter. *right:* $dN/d\eta|_{\eta=0}$ normalized to the number of participant pairs as a function of N_{part}. The band indicates the, highly correlated, systematic uncertainties. There is an additional theoretical uncertainty (not shown) in the Glauber calculation of the N_{part} distribution. Estimates based on Monte-Carlo methods, used here (HIJING) as well as in [9] are not fully consistent with those based on methods that numerically integrate over the nuclear density function [8].

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