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Charged particle density distributions in Au+Au collisions at RHIC energies

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Abstract. Charged particle pseudorapidity distributions have been measured in Au+Au collisions using the BRAHMS detector at RHIC. The results are presented as a function of the collision centrality and the center of mass energy. They are compared to the predictions of different parton scattering models and the important role of hard scattering processes at RHIC energies is discussed.

Keywords. Relativistic heavy-ion collisions, charged hadron production, pseudorapidity distributions, centrality dependence, hard scattering processes

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1. Introduction

The number of hadrons produced per event is expected to provide valuable information on the reaction mechanisms involved in heavy-ion collisions at collider energies. This observable can be related to the entropy density produced during the initial stages of the collision. The formation of a Quark Gluon Plasma phase depends crucially on such initial conditions. The multiplicity of produced particles is also sensitive to the interplay between soft and hard scattering processes [1,2].

In this contribution, we report charged particle pseudorapidity density distributions, $dN_{ch}/d\eta$, for Au+Au collisions measured with the BRAHMS detector at the Relativistic Heavy-Ion Collider (RHIC). Data are compared to the results obtained at CERN-SPS for Pb+Pb collisions at lower c.m. energies and discussed within the framework of different theoretical models with a particular emphasis on the role of hard scattering processes.

2. Experimental conditions and event selection

The experimental results presented in this paper have been measured with the BRAHMS detector for Au+Au collisions at two c.m. energies, $\sqrt{S_{NN}} = 130$ GeV and 200 GeV.

The BRAHMS detector [3–5] consists of two movable small acceptance spectrometers designed to identify charged particles over a wide range of rapidities and momenta. Charged particle multiplicities are measured by a multiplicity array (MA) which is made of two components: an array of scintillator tiles called TMA and a silicon strip array (SiMA). The nominal angular coverage of the MA array is $-3 < \eta < 3$. At forward rapidities (up to $\eta \sim 4.7$), complementary information is obtained from two arrays of beam-beam Cerenkov detectors placed around the beam pipe at 2.15 m from the nominal intersection point. The first TPC of the MRS spectrometer is also used to extract additional information on the charged particle multiplicity in the mid-rapidity region. More details on the experimental setup can be found in [3–5].

The centrality of the collision in the BRAHMS experiment is based on the charged particle multiplicity measured with the MA detector. Events are sorted out by imposing multiplicity cuts corresponding to different fractions of the total reaction cross section. For each event class, the numbers of participant nucleons, N_{part}, and of binary collisions, N_{coll}, have been determined using the Glauber model [3,4].

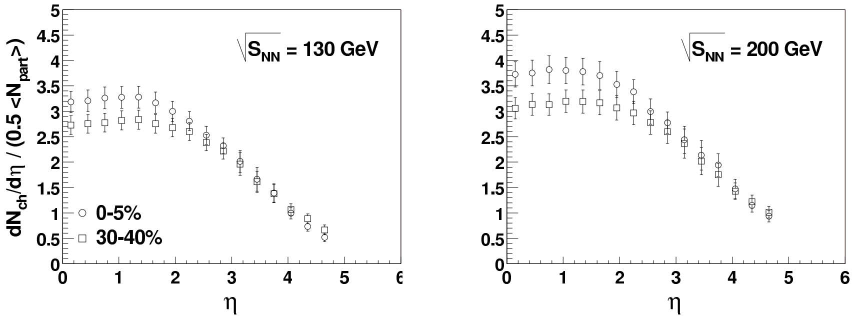

Figure 1. Charged particle multiplicities normalized to the number of participant pairs measured at $\sqrt{S_{NN}} = 130$ GeV (left panel) and $\sqrt{S_{NN}} = 200$ GeV (right panel). Data are shown for two centrality cuts: $0 - 5\%$ and $30 - 40\%$.

3. Experimental results and discussion

Fig.1 shows charged particle pseudorapidity distributions scaled by the number of participant pairs, measured for two centrality classes: $0 - 5\%$ and $30 - 40\%$. The $dN_{ch}/d\eta$ distributions have been obtained by averaging the results extracted from different multiplicity detectors and then symmetrized [3]. It is interesting to notice the broad range of pseudorapidity covered with the present data: $|\eta| \leq 4.7$. By integrating the most central ($0 - 5\%$ cut) distributions, we find an average of 3860 ± 300 and 4630 ± 370 charged particles per event at $\sqrt{s_{NN}} = 130$ GeV and 200 GeV, respectively. These numbers are much higher than those measured at SPS energies. At mid-rapidity, the observed particle density at $\sqrt{s_{NN}} = 200$ GeV is about 2.1 times greater than in Pb+Pb collisions at $\sqrt{s_{NN}} = 17.2$ GeV [6]. As can be seen in Fig.1, the particle density per pair of participants increases with the collision centrality in the mid-rapidity region ($\eta \sim 0$), whereas no significant change is observed in the fragmentation region (large η values). This is illustrated more quantitatively in the left panel of Fig.2 where the scaled pseudorapidity density is plotted as a function of the number of participant nucleons. At $\eta = 3$, one observes a flat dependence indicating that the particle density $dN_{ch}/d\eta$ scales with the number of participants.

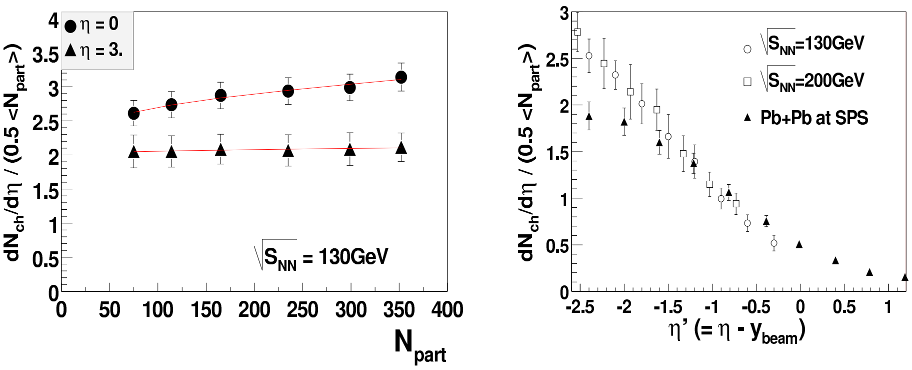

Figure 2. Left panel: charged particle multiplicities per pair of participants as a function of the number of participants measured at $\sqrt{S_{NN}} = 130$ GeV for $\eta = 0$ and 3. Right panel: Same quantity is plotted as a function of $\eta^{'} = \eta - y_{beam}$ where data at $\sqrt{S_{NN}} = 130$ GeV and $\sqrt{S_{NN}} = 200$ GeV are compared to Pb+Pb data from the CERN-SPS.

In the mid-rapidity region $\eta = 0$, a very different trend is found: here one observes a steady increase of the scaled pseudorapidity density from the most peripheral to the most central collisions. The latter effect is consistent with that observed by the PHENIX [7] and PHOBOS [8] experiments and can be attributed to the onset of hard scattering processes which depend on the number of binary collisions N_{coll} rather than N_{part}. An estimate of the relative contribution of hard processes to the produced particles has been obtained by fitting the data to a functional $dN_{ch}/\eta = \alpha \cdot N_{part} + \beta \cdot N_{coll}$. This contribution was found [4] to be almost constant, with values of 36 ±6% and 37 ±7% at $\sqrt{s_{NN}} = 130$ GeV and 200 GeV, respectively.

In the fragmentation region, the multiplicity of produced particles seems to be independent of the c.m. energy over the whole range from CERN-SPS to RHIC. This is clearly visible in the right panel of Fig.2 where our results, plotted as a function of $\eta^{'} = \eta - y_{beam}$ (translating to the beam's reference frame), are compared to Pb+Pb data at $\sqrt{s_{NN}} = 17.2$ GeV [6]. This observation is consistent with a limiting fragmentation picture in which the excitations of the fragment baryons saturate already at moderate collision energies independently of the system size [3,4].

In Fig.3, the $dN_{ch}/d\eta$ distributions measured at $\sqrt{s_{NN}} = 200$ GeV are compared to the predictions of two different theoretical models: i) the high density gluon saturation model of Kharzeev&Levin [9] which is based on a classical QCD calculation using parameters fixed to the $\sqrt{s_{NN}} = 130$ GeV data and ii) the AMPT model [10–12] which uses HIJING [13] to generate the initial phase space of partons and then extends the calculations to model the parton-parton collisions and the the final state hadronic interactions. As can be seen, both models reproduce quite well the magnitude and shape of the measured distributions, in particular for central collisions. Small differences in the predictions of the two models appear in the case of peripheral events but within error bars it is difficult to draw any conclusion. Further detailed comparisons including several experimental observables are therefore needed for more stringent tests of the proposed theoretical models.

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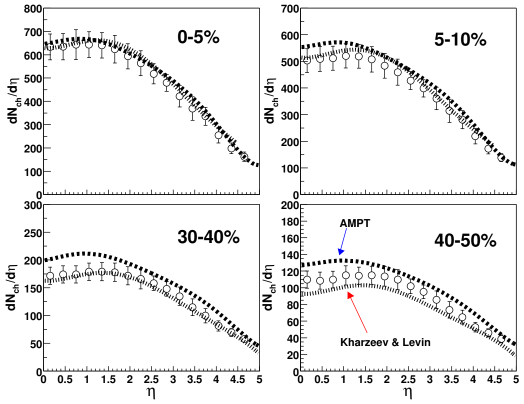

Figure 3. Pseudorapidity density distributions measured at $\sqrt{s_{NN}}$=200 GeV for different centrality cuts. Theoretical predictions by Kharzeev and Levin and by the AMPT model are also shown.

4. Summary and conclusion

Results on charged hadron production in Au+Au collisions, measured with the BRAHMS detector at $\sqrt{s_{NN}}$ = 130 GeV and 200 GeV, have been presented. In the mid-rapidity region, the pseudorapidity density scaled by the number of participant pairs was found to increase with the collision centrality. This effect has been interpreted within a simple picture in terms of a superposition of soft and hard scattering processes. Very different trends were observed in the fragmentation region, where the production of charged particles seems to be independent on the collision centrality and the c.m. energy. Such features are consistent with the limiting fragmentation picture. The measured pseudorapidity distributions were compared to the predictions of the gluon saturation model of Kharzeev & Levin and the AMPT model. It was found that, within the experimental uncertainties, both models reproduce quite well the data. However, more detailed studies including several observables are still needed in order to provide stronger constraints for the theory.

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