Pseudorapidity distribution of charged particles from pp and Au+Au collisions at RHIC energies

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Charged-particle multiplicities as a function of pseudorapidity and collision centrality for Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and 200 GeV are presented. For the 5% most central events, $dN_{ch}/d\eta|_{\eta=0}$ and $N_{ch}|_{-4.7<\eta<4.7}$ are found to increase by 14% and 21% from the lower to higher energy, respectively. In addition, $dN_{ch}/d\eta$ results for pp collisions at $\sqrt{s_{NN}}$ = 200 GeV are presented. A significant increase is found for the charged-particle production per participant nucleon pairs in going from pp to the most central Au+Au collisions.

1. Introduction

Charged-particle multiplicities provide a global measure of the dynamics of the ultra-relativistic heavy-ion collisions. The particle densities are sensitive to the relative contributions of “soft” and “hard” scattering between partons [1,2]. For example, it has been suggested that a saturation of the number of parton collisions in central Au+Au collisions could lead to a limit on the charged-particle production [2–4]. As a result, by comparing multiplicity distributions of emitted particles from nucleus-nucleus collisions, nucleon-nucleon collisions and nucleus-nucleon collisions, we gain new insights into the collision dynamics.

In this talk, charged-particle multiplicities for relativistic collisions between Au+Au and pp are presented. The data were collected at the Relativistic Heavy-Ion Collider (RHIC) using the several subsystems of the BRAHMS experiment [6]: the Multiplicity Array (MA), the Beam-Beam Counter (BBC) arrays, and the Zero-Degree Calorimeters (ZDCs). For pp data, the inelastic counters from the pp2pp experiment [5] were also utilized. Further details on the Au+Au charged-particle multiplicity analysis can be found in ref. [7,8].

2. Detector Setup

The MA determines $dN_{ch}/d\eta$ around mid-rapidity with a modestly segmented Si-strip-detector array (SiMA) surrounded by an outer plastic-scintillator tile array (TMA) in a double, hexagonal-sided barrel arrangement. The effective coverage of the MA is $-3.0 \leq \eta \leq 3.0$. Particle multiplicities are deduced from the observed energy loss in the SiMA and TMA elements by using GEANT simulations [9] to relate energy loss to the number of particles hitting a given detector element [7].

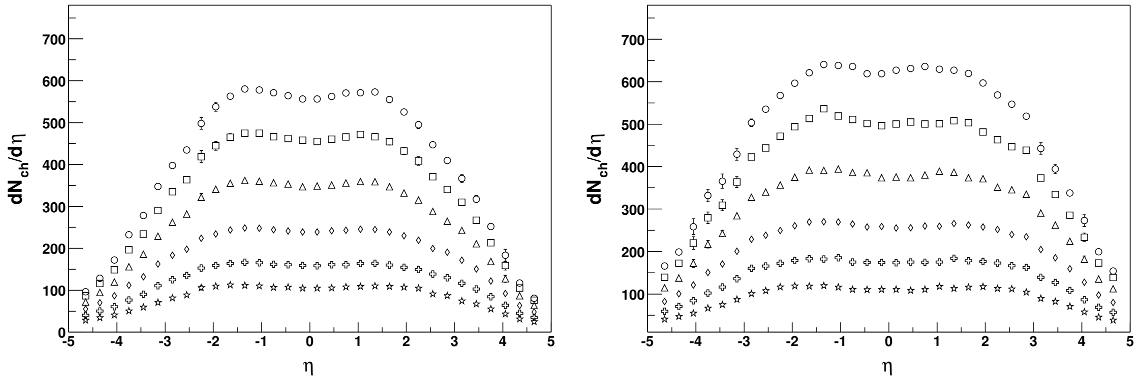

Figure 1. Distributions of $dN_{ch}/d\eta$ for centrality ranges of, top to bottom, 0-5%, 5-10%, 10-20%, 20-30%, 30-40%, and 40-50%. Statistical uncertainties are shown where larger than the symbol size. The left and right figures are from the $\sqrt{s_{NN}}$ =130 GeV and 200 GeV Au+Au data, respectively.

The BBC arrays consist of two sets of Cherenkov UV-transmitting plastic radiators coupled to photomultiplier tubes. The Cherenkov radiators are positioned around the beam pipe with one set on either side of the nominal interaction point at a distance of 2.20 m. Charged-particle multiplicities with $2.1 \leq |\eta| \leq 4.7$ are deduced from the number of particles hitting each detector, as found by dividing the measured detector signal by the average response of the detector to a single particle.

The ZDCs are located ±18 m from the nominal interaction point and measure neutrons that are emitted at small angles with respect to the beam direction [10]. Clean selection of minimum-biased events required a coincidence between the two ZDC detectors and a minimum of 4 "hits" in the TMA. It is estimated that this selection includes 95% of the Au+Au total inelastic cross section.

The inelastic counters are positioned around the beam pipe at four different locations (75cm, 155cm, 416cm and 660cm) on either side of the nominal interaction point [5]. For pp collisions, the trigger efficiency of the BBC arrays and the ZDCs are quite small. As a result, the inelastic counters are used to provide a minimum-biased event trigger by requiring a coincidence between any one of the left and any one of the right counters. The location of the collision vertex is also obtained based on these counters.

3. Results

Fig 1 presents the measured $dN_{ch}/d\eta$ distributions for several centrality ranges from Au+Au collisions at the two center-of-mass energies of $\sqrt{s_{NN}}$ =130 GeV and 200 GeV, respectively. In general, statistical errors on the measurements are less than 1%, with systematic errors of 8%, 10% and 10% for the SiMA, TMA and BBC arrays, respectively. An increase in charged-particle multiplicity as a function of energy for a central-plateau region ($|\eta| < 2.5$) is observed, with a comparable increase of 10% to 20% observed for all centralities.

Fig 2 presents the $dN_{ch}/d\eta$ distributions obtained by averaging the values for negative and positive pseudorapidities to further decrease the experimental uncertainties. As seen in the figure, the saturation model of Kharzeev and Levin [3], which is based on a classical

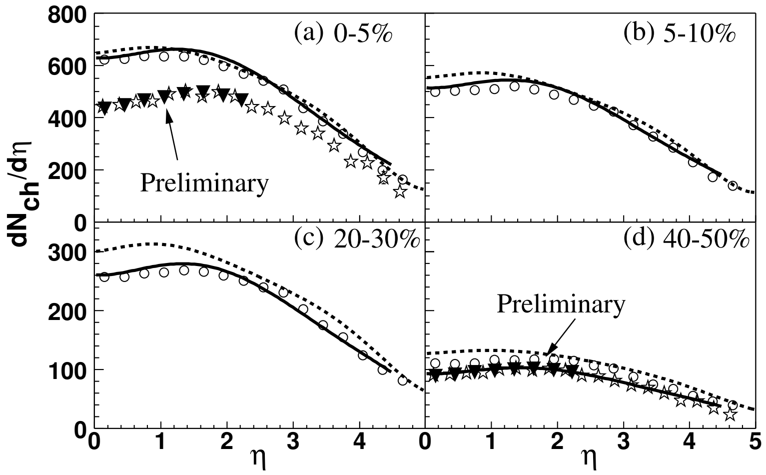

Figure 2. (a-d) Measured $dN_{ch}/d\eta$ distributions for centrality ranges of 0-5%, 5-10%, 20-30% and 40-50%. Theoretical predictions by Kharzeev and Levin (solid line) and by the AMPT model (dashed line) are also shown. The preliminary pp results, scaled by the Au+Au values of $\langle N_{part}\rangle/2$, are shown with closed triangles (a,d). In the same figures, scaled result from $p\bar{p}$ collisions at $\sqrt{s}$=200 GeV [14] are shown with open stars (a,d).

QCD calculation using parameters fixed to the $\sqrt{s_{NN}}$=130 GeV data, is able to reproduce the magnitude and shape of the observed multiplicity distributions quite well. A multiphase transport model (AMPT) [11,12], which is a cascade model based on HIJING [13] but including final-state rescattering of produced particles, is also able to account for the general trend of the measured distributions, particularly for the most central collisions. The distributions from the preliminary pp results scaled by the corresponding number of Au+Au participant pairs for the 0-5% and 40-50% centralities are also shown with those from $p\bar{p}$ collisions [14]. The pp results are obtained only from the TMA. Because the vertex resolution of the inelastic counters in pp collisions is worse than those of the BBC and the ZDC in Au+Au collisions, systematic errors is expected to be larger than the previously quoted value of 10%. As expected, pp and $p\bar{p}$ result in remarkably similar multiplicity distribution. For the most central collision, at mid-rapidity, there is a large enhancement (approximately 40%) of particle density from Au+Au collisions over from the scaled results of the pp collision data.

While the scaled pseudorapidity density increases with centrality at mid-rapidity, Fig 3 shows it is independent of both collision centrality and the beam energy in the fragmentation region, with pseudorapidity close to the beam rapidity. This is found for energies ranging from the CERN-SPS energy to the RHIC energy and is consistent with a limiting-fragmentation picture in which the excitations of the fragment baryons saturate at a moderate collision energy, independent of system size [7].

4. Conclusion

The BRAHMS experiment has developed a detailed characterization of global charged-particle densities at RHIC energies. At midrapidity, it is found that the charged-particle densities remain relatively constant for about four units of pseudorapidity. The Au+Au

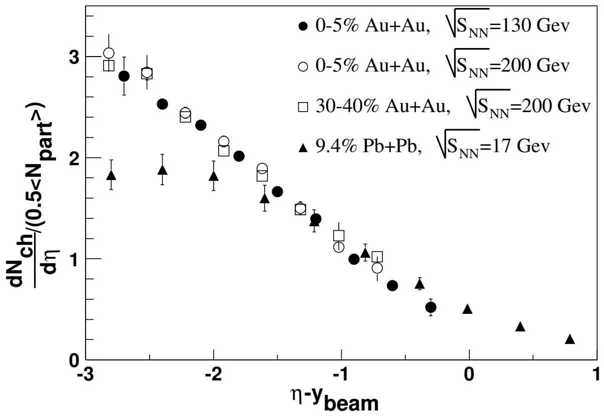

Figure 3. Charged-particle multiplicities normalized to the number of participant nucleon pairs for the present 0-5% central (open circles) and 40-50% central (open squares) Au+Au results at $\sqrt{s_{NN}}$=200 GeV, the BRAHMS 0-5% Au+Au results [7] at $\sqrt{s_{NN}}$=130 GeV (closed circles) and the 9.4% central Pb+Pb data at $\sqrt{s_{NN}}$=17 GeV(closed triangles) of ref [15]. Data are plotted as a function of the pseudorapidity shifted by the relevant beam rapidity. Representative total uncertainties are shown for a few Au+Au points.

results show a 40% increase in charged-particle production over the pp results for 0-5% central collisions near midrapidity. At pseudorapidities close to the beam rapidity, the particle production scales as a number of the participating nucleons and is consistent with a limiting-fragmentation picture.

REFERENCES

1. Xin-Nian Wang and Miklos Gyulassy, Phys. Rev. Lett. 86 (2001) 3496.
2. K.J. Eskola, K. Kajantie, and K. Tuominen, Phys. Lett. B 497 (2001) 39.
3. D. Kharzeev and E. Levin, Phys. Lett. B **523** 79 (2001).
4. L. V. Gribov, E. M. Levin and M. G. Ryskin, Phys.Rep. **100**, 1 (1983).
5. see; http://www.rhic.bnl.gov/pp2pp .
6. M. Adamczyk *et al.*, submitted to Nucl. Inst. Meth A. (2002).
7. I. G. Bearden *et al.*, Phys. Lett. **B523** 227 (2001).
8. I. G. Bearden *et al.*, Phys. Rev. Lett. 88, 202301(2002).
9. GEANT 3.2.1, CERN program library.
10. C. Adler *et al.*, Nucl. Instrum. Methods Phys. Res., Sec. A. **470**, 488 (2001).
11. Bin Zhang, C. M. Ko, Bao-An Li and Zi-wei Lin, Phys. Rev. C **61**, 067901 (2001).
12. Zi-wei Lin, Subrata Pal, C. M. Ko, Bao-An Li and Bin Zhang, Phys. Rev. C **64**, 011902(R) (2001); Zi-wei Lin, Subrata Pal, C.M. Ko, Bao-An Li and Bin Zhang, Nucl. Phys. **A698**, 375c-378c (2002); and Zi-wei Lin, private communication.
13. X. N. Wang and M. Gyulassy, Phys. Rev. D **44**, 3501 (1991).
14. G. J. Alner *et al.*, Zeit. Phys. C **33**, 1 (1986).
15. P. Deines-Jones *et al.*, Phys. Rev. C **62**, 014903(2000).