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High p_{T} Results for Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

Zhongbao Yin[9]
for the BRAHMS Collaboration:
I. Arsene[10], I. G. Bearden[7], D. Beavis[1], C. Besliu[10], B. Budick[6], H. Bøggild[7], C. C[1], C. H. Christensen[7], P. Christiansen[7], J. Cibor[3], R. Debbe[1], E. Enger[12], J. J. Gaardhøje[7], M. Germinario[7], K. Hagel[8], O. Hansen[7], A. Holm[7], H. Ito[1,11], A. Jipa[10], F. Jundt[2], J. I. Jørdre[9], C. E. Jørgensen[7], R. Karabowicz[4], E. J. Kim[1], T. Kozik[4], T. M. Larsen[12], J. H. Lee[1], Y. K. Lee[5], S. Lindal[12], R. Lystad[9], G. Løvhøiden[12], Z. Majka[4], A. Makeev[8], B. McBreen[1], M. Mikelsen[12], M. Murray[8,11], J. Natowitz[8], B. Neumann[11], B. S. Nielsen[7], J. Norris[11], D. Ouerdane[7], R. Płaneta[4], F. Rami[2] taszel, C. Ristea[10], O. Ristea[10], D. Röhrich[9], B. H. Samset[12], D. Sandberg[7], S. J. Sanders[11], R. A. Scheetz[1], P. S[4,7], T. S. Tveter[12], F. Videbæk[1], R. Wada[8], Z. Yin[9], and I. S. Zgura[10]

[1] Brookhaven National Laboratory, Upton, New York 11973, USA
[2] Institut de Recherches Subatomiques and Université Louis Pasteur, Strasbourg, France
[3] Institute of Nuclear Physics, Krakow, Poland
[4] Smoluchkowski Inst. of Physics, Jagiellonian University, Krakow, Poland
[5] Johns Hopkins University, Baltimore 21218, USA
[6] New York University, New York 10003, USA
[7] Niels Bohr Institute, Blegdamsvej 17, University of Copenhagen, Copenhagen 2100, Denmark
[8] Texas A&M University, College Station, Texas, 17843, USA
[9] University of Bergen, Department of Physics, Bergen, Norway
[10] University of Bucharest, Romania
[11] University of Kansas, Lawrence, Kansas 66045, USA
[12] University of Oslo, Department of Physics, Oslo, Norway

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Abstract. We present transverse momentum spectra of unidentified charged hadrons at two pseudo-rapidities ($\eta = 0,\ 2.2$) as well as the first results on identified negatively charged pions at rapidity 2.2 from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The high p_T yields of charged hadrons in the most central collisions show a strong suppression when compared to expected binary-scaled yields from nucleon-nucleon collisions or semi-peripheral collisions. The π^- spectra at forward rapidity ($y = 2.2$) also indicate a clear suppression of high p_T π^- yields in central collisions.

PACS. 25.75.Dw Particle and resonance production

1 Introduction

High transverse momentum ($p_T > 2$ GeV/c) hadrons provide a probe of the high energy density matter created in relativistic heavy ion collisions[1,2]. They are believed to arise from the fragmentation of partons scattered with large momentum transfer, Q^2, in the initial parton-parton interactions. In the absence of medium effects, these hard scattering yields in nucleus-nucleus collisions should scale with the average number of inelastic nucleon-nucleon collisions N_{bin} (binary scaling). One of the most intriguing observations from all four experiments at the BNL Relativistic Heavy Ion Collider (RHIC) is the large suppression of high p_T hadron yields in central Au+Au collisions[3–5] with respect to the binary-scaled yields from elementary $N + N$ collisions. This is widely seen as experimental confirmation of jet quenching, the process in which high energy partons lose energy when they travel through the hot medium created in a heavy ion collision[1,2,6–9]. It has also been observed that at mid-rapidity the yield of neutral pions is more strongly suppressed than that for unidentified charged hadrons[3] in central Au+Au collisions. The (anti-) proton yields in central collisions are comparable to those of pions at intermediate p_T ($\approx 2-4$ GeV/c), differing from the expectation of pQCD. These observations suggest that a detailed study of particle composition at intermediate and high p_T is very important to understand hadron production and collision dynamics at RHIC.

The BRAHMS spectrometers have the unique ability to identify hadrons over a broad range of rapidity and transverse momentum. This allows us to study the production of identified high p_T hadrons at different rapidities. In this paper, we present measurements of high p_T yields of charged hadrons at $\eta = 0$ and $\eta = 2.2$ and of identified π^- at $y = 2.2$ from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

2 Experimental setup and data analysis

BRAHMS consists of two magnetic spectrometers (the Mid-Rapidity Spectrometer, MRS, and the Forward Spectrometer, FS) that for the present measurements were positioned at 90° (MRS) and 12° (FS) relative to the beam direction. In addition, a set of global detectors were used for event characterization. The experimental setup and operation is described in detail in [10]. Centrality selection for the Au+Au collisions was done using multiplicity detectors positioned around the nominal intersection point. Charged hadron tracks are reconstructed using information from tracking detectors (TPCs and DCs). The straight line tracks, found in the tracking detectors, are matched in the intervening magnet and the particle momenta are determined using an effective edge approximation. Identification of π^- particles at forward rapidity is done by using a time-of-flight wall and a ring imaging Cherenkov detector. All spectra are from measurements at various magnetic fields and have been corrected for the acceptance of the spectrometers and for tracking efficiency. No corrections for feed-down, decay or absorption have been applied for unidentified charged hadron spectra, while for π^- measurements at forward rapidity corrections are applied for decay effects and particle identification efficiencies.

3 Results

Figure 1 shows the centrality dependence of invariant p_T spectra for charged hadrons $(h^+ + h^-)$ at pseudo-rapidities $\eta = 0$ (left panel) and for negatively charged hadrons (h^-) at $\eta = 2.2$ (right panel), respectively. Also shown in the figure is a constructed reference spectrum from the UA1 measurements for $p + \bar{p}$ collisions at CERN[11], suitably corrected for the respective η coverage.

To quantify nuclear medium effect on the measured hadron yield in nucleus-nucleus collisions, one compares it to the expectations from $N + N$ collisions, which must be appropriately scaled to the large systems. As hard scatterings have a very small cross section and are expected to be incoherent, it is traditional to introduce the nuclear modification factor:

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{(N_{bin}/\sigma_{inel}^{NN}) d^2\sigma^{NN}/dp_T d\eta} \qquad (1)$$

In the absence of nuclear modifications to hard scattering, the ratio R_{AA} will be unity; thus departure from unity indicates nuclear medium effects. In fact, for $p + A$ collisions it has been shown that R_{AA} is larger than one[4, 12–15]. A qualitatively similar enhancement compared to $p + p$ collisions was found in central Pb + Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV[16,17]. This is commonly referred to as the Cronin effect[18], attributed to multiple parton scattering in the initial stage of the collision.

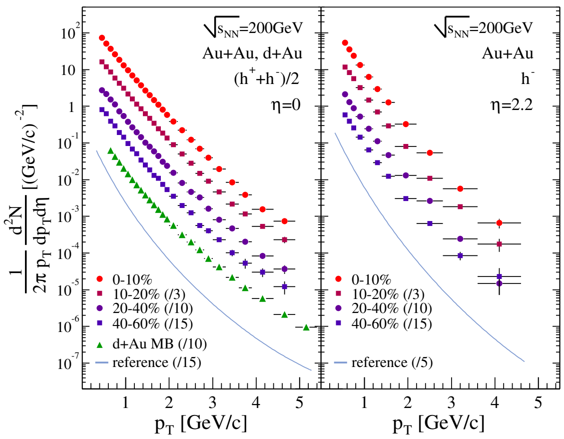

Fig. 1. Invariant p_T spectra of charged hadrons for different centralities from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at pseudo-rapidities $\eta = 0$ (left panel) and $\eta = 2.2$ (right panel).

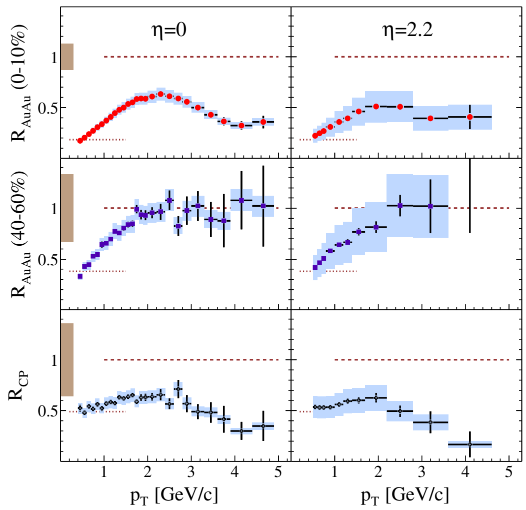

Fig. 2. Nuclear modification factor R_{AA} as a function of p_T for Au + Au collisions at $\eta = 0$ and $\eta = 2.2$ for the 0-10% most central (top row) and semi-peripheral (40-60%, middle row) collisions. Bottom row: R_{CP} at the two rapidities. The dotted and dashed lines show the expected value of R_{AA} using a scaling by the number of participants and by the number of binary collisions, respectively. Error bars are statistical. The grey bands indicate the estimate systematic errors. The grey band at $p_T = 0$ GeV/c is the uncertainty on the scale.

Figure 2 (upper two rows) shows the ratios R_{AA} as a function of p_T for two different centralities at $\eta = 0$ and $\eta = 2.2$. At low p_T R_{AA} is smaller than one since the bulk of particle production scales with the number of participants. Above $p_T \approx 2$ GeV/c the data from semi-peripheral collisions agree with the binary-scaling prediction, while the ratios R_{AA} decrease and are systematically lower than unity for central collisions at both pseudo-rapidities. In

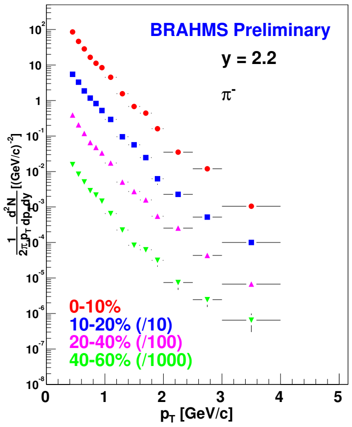

Fig. 3. Invariant p_T spectra of π^- for different centralities at rapidity $y = 2.2$ in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

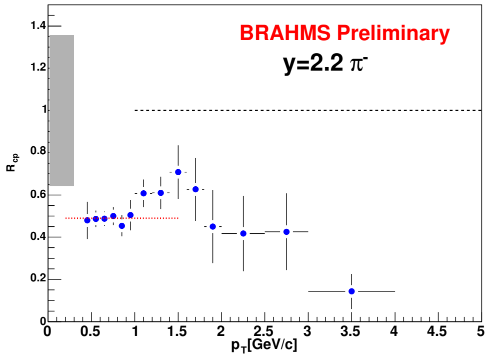

Fig. 4. R_{CP} as a function of p_T for π^- at rapidity $y = 2.2$ in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

order to remove the model dependent systematic error introduced by the constructed reference spectra, the bottom panels show the ratios of the R_{AA} for the most central collisions relative to the least central ones at the two pseudo-rapidities. This ratio is denoted R_{CP}. The nuclear medium effects are expected to be much stronger in central relative to peripheral collisions, which makes R_{CP} another measure of these effects. Indeed, R_{CP} shows a clear decrease at p_T above 2 GeV/c for both $\eta = 0$ and $\eta = 2.2$. It is intriguing that, within experimental uncertainties, the degree of high p_T suppression (for $p_T > 2$ GeV/c) observed at $\eta = 2.2$ is similar to or larger than that at $\eta = 0$.

Since at forward rapidity we see a similar degree of high p_T charged hadron suppression, it is important to investigate if the suppression at forward rapidity has the same species dependence as that at mid-rapidity. Figure 3 shows the invariant p_T spectra of π^- for different centralities at rapidity $y = 2.2$ in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Figure 4 shows the central (0-10%) to semi-peripheral (40-60%) ratio for N_{bin} scaled p_T spectra, R_{CP}, as a function of p_T for π^- at forward rapidity ($y = 2.2$). The dashed and dotted lines indicate the expectations of a scaling by the number of binary collisions and by the number of participants, respectively. The grey band at $p_T = 0$ GeV/c is the uncertainty on the scale. The error bars are statistical only. This figure shows clearly that high p_T π^- yields at forward rapidity are strongly suppressed for central Au+Au collision. Comparing to the bottom right panel of figure 2, the degree of suppression of π^- is quite similar to or even stronger than that of negatively charged hadrons. A stronger suppression of π^- may imply that at high p_T (anti-)proton yields are less suppressed at rapidity $y = 2.2$.

4 Conclusion and outlook

The BRAHMS measurements demonstrate a significant suppression of the high p_T spectra for hadrons at both mid-rapidity and forward rapidity for central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The persistence of the suppression up to $\eta = 2.2$ suggests that the nuclear medium which cause the suppression is extended also in the longitudinal direction. At rapidity $y = 2.2$ identified π^- particles seem to show stronger suppression than that of negatively charged hadrons. This may imply that (anti-) protons are less suppressed or even enhanced in forward rapidity for central Au + Au collisions. Further detailed measurements of high p_T particle composition as a function of rapidity will provide important information on the hadron production mechanism at RHIC.

References

1. M. Gyulassy and M. Plümer, Phys. Lett. **B234** (1990) 432; X. N. Wang and M. Gyulassy, Phys. Rev. Lett. **68** (1992) 1480.
2. R. Baier *et al.*, Phys. Lett. **B345** (1995) 277.
3. K. Adcox *et al.*, Phys. Rev. Lett. **88** (2002) 022301; K. Adcox *et al.*, Phys. Lett. **B561** (2003) 82; S. S. Adler *et al.*, Phys. Rev. Lett. **91** (2003) 072301.
4. I. Arsene *et al.*, Phys. Rev. Lett. **91** (2003) 072304.
5. C. Adler *et al.*, Phys. Rev. Lett. **89** (2002) 202301.
6. M. Gyulassy and X. N. Wang, Nucl. Phys. **B420** (1994) 583; X. N. Wang, Phys. Rev. **C58** (1998) 2321.
7. I. Vitev and M. Gyulassy, Phys. Rev. Lett. **89** (2002) 252301.
8. S. Jeon, J. Jalilian-Marian and I. Sarcevic, Phys. Lett. **B562** (2003) 45.
9. V. Greco, C. M. Ko and P. Lévai, Phys. Rev. Lett. **90** (2003) 202302.
10. M. Adamczyk *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. **A499** (2003) 437.
11. C. Albajar *et al.*, Nucl. Phys. **B335** (1990) 261.
12. D. Antreasyan *et al.*, Phys. Rev. **D20** (1979) 53.
13. D. A. Garbutt *et al.*, Phys. Lett. **B67** (1977) 355.
14. D. Chaney *et al.*, Phys. Rev. **D19** (1979) 3210.
15. H. J. Frisch *et al.*, Phys. Rev. **D27** (1983) 1001.
16. M. M. Aggarwal *et al.*, Eur. Phys. J. **C18** (2001) 651.
17. H. Appelshauser *et al.*, Phys. Rev. Lett. **82** (1999) 2471.
18. J. W. Cronin *et al.*, Phys. Rev. **D11** (1975) 3105.