Nuclear modification factor for identified hadrons at forward rapidity in Au+Au reactions at 200 GeV

Radoslaw Karabowicz[a] for the BRAHMS* Collaboration.

[a]M. Smoluchowski Institute of Physics,
Jagiellonian University,
Reymonta 4, Kraków 30-059, Poland

Herewith we present the production of identified hadrons in Au + Au and p + p collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ at forward rapidity, $y \approx 3.2$. Suppression of pions and kaons and enhancement for protons in central Au + Au collisions is observed. These results are found to be very similar in strength to that observed at mid-rapidity. Furthermore, we see a gradual decrease of the observed suppression towards more peripheral collisions.

First collisions of gold ions at nucleon-nucleon center of mass energies 130 GeV at RHIC revealed a dramatic decrease of pion production at high transverse momentum (p_T), as compared to an incoherent sum of pions produced in the p + p collisions at the same energy [1]. High p_T hadrons are primarily produced from the fragmentation of the hard-scattered partons and observed suppression could be either due to initial state parton saturation inside the nuclei [2] or due to final state jet energy degradation [3]. The crucial test of these different mechanisms has been performed during the third RHIC run when collisions between deuterium and gold ions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ were investigated. The measurements showed that the high p_T particle production from d + Au collisions around mid-rapidity is not suppressed [4–7]. The absence of this phenomena supports the interpretation that the observed suppression in the Au + Au collisions is due to the final interactions. However it was also observed in the BRAHMS experiment that at forward pseudo-rapidity $\eta = 2.2$ inclusive negatively charged hadrons are suppressed in both central Au + Au and minimum-bias d + Au collisions [5,8], which might be attributed to the possible existence of the nuclei in the Color Glass Condensate phase [2] prior to the collisions. Studying the magnitude of suppression as a function of rapidity and centrality is essential to help understanding different mechanism responsible for this phenomenon.

To study the in-medium effects on the spectra it is often useful to plot the nuclear modification factor, which is the ratio of the yield obtained from nucleus-nucleus collisions scaled with the number of binary collisions, to the yield from elementary nucleon-nucleon collisions:

$$R_{AA} = \frac{\mathrm{d}^2 N_{AA}/\mathrm{d}p_T \mathrm{d}y}{< N_{coll} > \times\, \mathrm{d}^2 N_{NN}/\mathrm{d}p_T \mathrm{d}y}. \tag{1}$$

*For the full BRAHMS Collaboration author list and acknowledgment, see appendix 'Collaborations' of this volume.

In the absence of any nuclear effects the ratio should saturate at unity for high p_T, where production is dominated by hard scatterings and is proportional to the number of binary collisions, N_{coll}. Production in the low p_T region is dominated by soft processes and scales with the number of participants, N_{part}, which is *circa* three times smaller for central Au + Au collisions than N_{coll}.

1. Results

Top panels of Figure 1 shows differential yields per event for identified hadrons in Au + Au collision at $\sqrt{s_{NN}} = 200\,\text{GeV}$ as seen by the BRAHMS experiment at rapidity $y \approx 3.2$. Also there we plot the differential yields for p + p collisions.

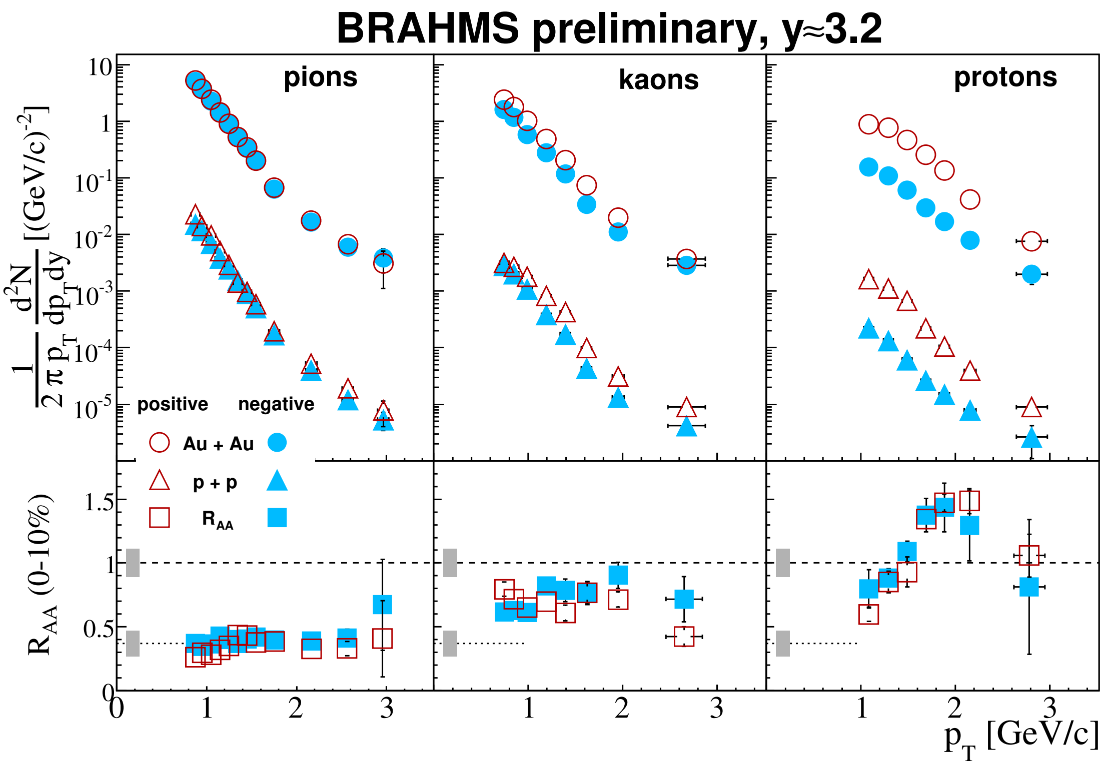

Figure 1. Top panels show particle transverse momentum spectra for pions (left-hand panel), kaons (middle) and protons (right-hand) from 0 − 10% central Au + Au (circles) and p + p (triangles) collisions at 200 GeV. Bottom panels show nuclear modification factors (squares) for those particles. Solid symbols represent negative particles, while open positive. No correction for decay, absorption or feed-down has been applied to the data. Only statistical errors are shown.

In the bottom panels of Figure 1 we plot the R_{AA} for identified particles at rapidity $y \approx 3.2$ for 0 − 10% central Au + Au collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$. Dashed and dotted lines represent the expectation of scaling with N_{coll} and N_{part}, respectively, while the shaded boxes are the systematic errors resulting from the uncertainties of N_{coll} and N_{part}. This figure shows suppression of pions (left-hand panel) and kaons (middle panel) at values of about 0.4 and 0.7, respectively, similar for both particle signs, and basically independent of p_T in the measured p_T ranges. R_{AA} for protons however, plotted in the right-hand panel, exhibit an enhancement peak at $p_T \approx 2\,\mathrm{GeV}/c$. The increase of the calculated nuclear modification factor with increasing mass from pions via kaons to protons may be attributed to coalescence or radial flow. However explanation of the different shape of R_{AA} for protons requires invoking particle production mechanisms that depend on the number of quarks, such as baryon junction [11,12] or parton recombination [13].

In Figure 2 we compare the R_{AA} calculated for pions and protons at $y \approx 3.2$ with the ratios obtained by the PHENIX Collaboration at mid-rapidity. Data show very similar behavior for both rapidities in the p_T range covered by BRAHMS, which, combined with other BRAHMS results [5], indicate the flatness of R_{AA} with rapidity for central Au + Au collisions.

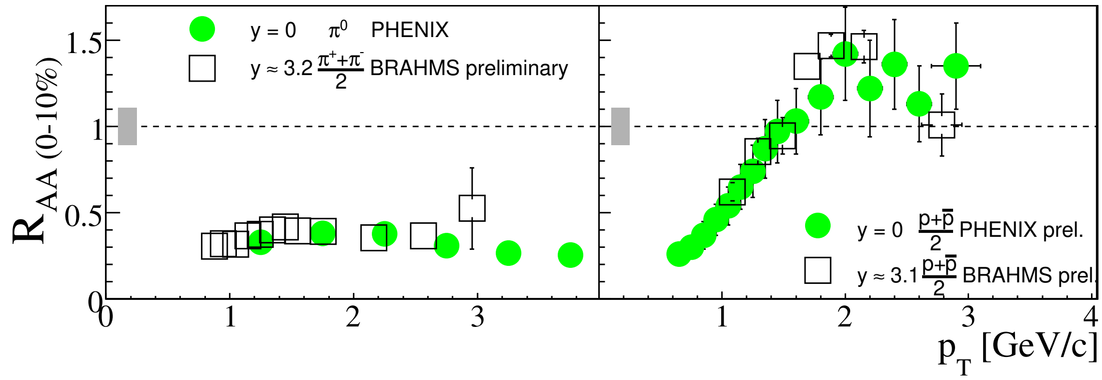

Figure 2. Comparison of R_{AA} for pions (left-hand panel) and protons (right-hand panel) at mid-rapidity and $y \approx 3.2$. Solid circles are PHENIX data [9,10] at mid-rapidity, open squares show BRAHMS preliminary data.

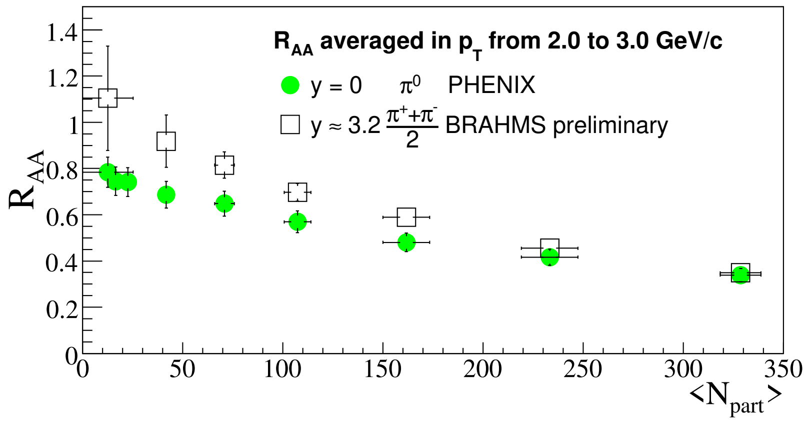

Figure 3. Change of averaged nuclear modification factor with centrality. Solid circles are PHENIX data [9] at mid-rapidity, open squares show BRAHMS preliminary data.

The magnitude of the suppression can also be studied as a function of the system size. Averaged R_{AA} for pions in the p_T range from 2.0 to 3.0 GeV/c has been plotted in Figure 3 as a function of $< N_{part} >$. As expected, there is less suppression at peripheral events. When compared with the PHENIX data obtained for neutral pions at mid-rapidity we can see that although for central events R_{AA} seems to be independent of rapidity, for the peripheral events nuclear modification factor seen at forward rapidity reaches value close to unity, larger than the PHENIX data. A simple finding is that similar mechanisms such as parton recombination occur at central collisions at mid- and forward rapidities, however this similarity breaks down for peripheral events.

2. Conclusions

BRAHMS experiment has measured particle distributions for identified hadrons in Au + Au and p + p collisions at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$ at forward rapidity of $y \approx 3.2$. Spectra were used to construct the nuclear modification factor, which shows suppression for mesons independent of the transverse momenta, and enhancement for protons and antiprotons around $p_T \approx 2\,\mathrm{GeV}/c$. Systematic difference between mesons and baryons, which moreover seems to be independent of rapidity for central events (at least up to rapidity $y \approx 3.2$), indicates existence of various mechanisms of particle production. Remarkable independence of the investigated ratios on rapidity can be attributed to the surface emission picture [14], where changes in $\mathrm{d}N/\mathrm{d}\eta$ result in a nearly flat dependence of R_{AA}, albeit an increase of R_{AA} is expected for $y > 3$.

Surprising feature is revealed when comparing nuclear modification factor dependence on centrality at mid-rapidity and at large rapidity. Observed enhancement of the ratio at $y \approx 3.2$ for the peripheral events may indicate change of the medium properties when going from mid- to forward rapidity. The conclusion might be drawn that the strongly interacting matter that quenches particle production at high p_T extends to much higher rapidities in the central events than in the peripheral events.

REFERENCES

1. K. Adcox *et al.*, PHENIX Collaboration, Phys. Rev. Lett. **88**, 022301 (2002).
2. D. Kharzeev, E. Levin and L. McLerran, Phys. Lett. B **561**, 93 (2003).
3. J. D. Bjorken, Fermilab-Pub-82-059 THY; D. Appell, Phys. Rev. D **33**, 717 (1986); M. Gyulassy and M. Plümer, Phys. Lett. B **243**, 432 (1990).
4. S.S. Adler *et al.*, PHENIX Collaboration, Phys. Rev. Lett. **91**, 072303 (2003).
5. I. Arsene *et al.*, BRAHMS Collaboration, Phys. Rev. Lett. **91**, 072305 (2003).
6. J. Adams *et al.*, STAR Collaboration, Phys. Rev. Lett. **91**, 072304 (2003).
7. B. B. Back *et al.*, PHOBOS Collaboration, Phys. Rev. Lett. **91**, 072302 (2003).
8. I. Arsene *et al.*, BRAHMS Collaboration, Phys. Rev. Lett. **93**, 242303 (2004).
9. S.S. Adler *et al.*, PHENIX Collaboration, Phys. Rev. Lett. **91**, 072301 (2003).
10. D. Pal for the PHENIX Collaboration, QM2005 talk and proceedings in this volume.
11. I. Vitev and M. Gyulassy, Nucl. Phys. A **715** 779 (2003); Phys. Rev. C **65**, 041902 (2002).
12. V. Topor Pop, M. Gyulassy, J. Barrette, C. Gale, S. E. Vance, X. N. Wang, N. Xu, and K. Filimonov, Phys. Rev. C **68**, 054902 (2003).
13. R. C. Hwa and C. B. Yang, Phys. Rev. C **70**, 024905 (2004).
14. A. Dainese, C. Loizides and G. Paić, Eur. Phys. J. C **38**, 461 (2005).