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

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Herewith we present the production of identified hadrons in Au+Au and p+p collisions at $\sqrt{s_{NN}} = 200GeV$ at forward rapidity $y \approx 3.2$. Suppression of pions and kaons and enhancement peak for protons in Au+Au collisions is observed. This results are found to be very similar in strength to that observed at midrapidity. Furthermore, our results indicate the dependence of the observed suppression on centrality of the Au+Au collission.

1. Introduction

First collisions of gold ions at nucleon-nucleon center of mass energies $130GeV$ at RHIC revealed a dramatic decrease of pion productions 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 shadowing of the gluon distribution 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 $\sqrt{s_{NN}} = 200GeV$ were investigated. The measurements showed that the particle production from d+Au collisions around midrapidity is not suppressed [4–7]. The absence of this phenomena suggests that the suppression observed in the Au+Au collisions is due to final state interactions. However it was also observed in the BRAHMS experiment that at forward pseudorapidity $\eta = 2.2$ inclusive negatively charged hadrons are suppressed in both Au+Au and minimum-bias d+Au collisions [5,8], which is often attributed to the possible existence of the nuclei in the Color Glass Condensate phase [2] prior to the collisions.

2. Results

Identified hadrons differential yields per event in Au+Au collision as seen by the BRAHMS collaboration at rapidity $y \approx 3.2$ are presented in Figure 1. Also there we plot the differential cross section for p+p collisions.

To study the in-medium effects on the spectra it is often useful to plot 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

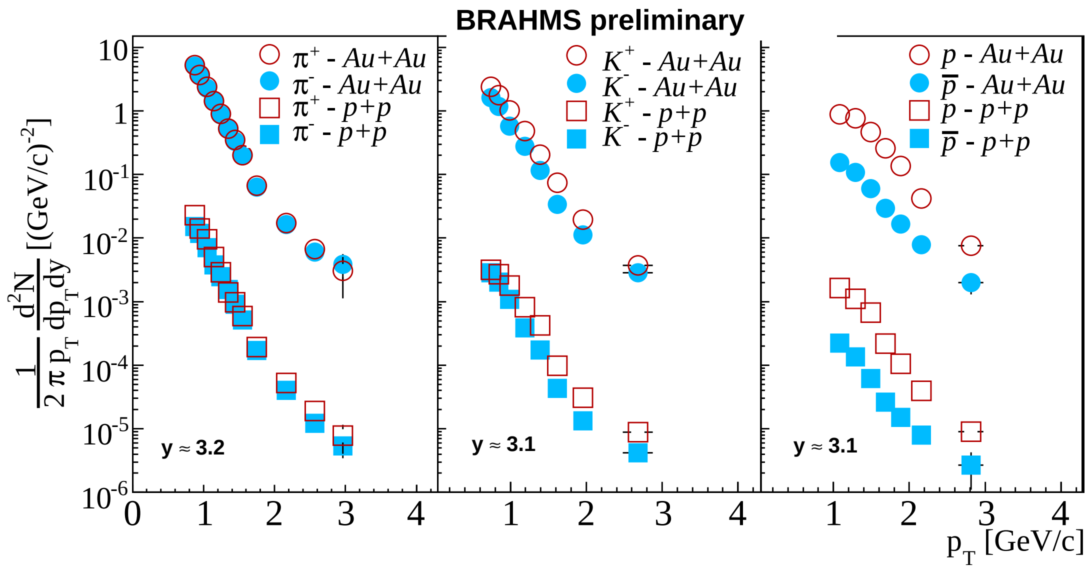

Figure 1. Identified particles spectra in transverse momentum from Au+Au (circles) and p+p (squares) collisions at $200 GeV$. Yields for pions (left-hand panel), kaons (middle), and protons (right-hand), both negative (red open) and positives (blue solid) are plotted.

collisions:

$$R_{AA} = \frac{\mathrm{d}^2 N_{AA}/\mathrm{d}p_T\mathrm{d}y}{n_{coll} \times \mathrm{d}^2 N_{NN}/\mathrm{d}p_T\mathrm{d}y} \quad (1)$$

It tells the relative difference of the production yields from nucleus-nucleus collisions to the simple elementary collisions. In the absence of any nuclear effects the ratio should saturate at unity for high p_T, where production in the heavy ion collisions is dominated by hard scatterings and is proportional to the number of binary collisions. Production in the low p_T region is triggered by soft processes and scales with the number of participants, which is *circa* three times smaller for central Au+Au collisions than n_{coll}. The ratio however, plotted in Figure 2 as a function of transverse momentum, show deviations from the expected values for all identified hadrons.

Figure 2 show R_{AA} for identified hadrons at rapidity $y \approx 3.2$ for $0-10\%$ central Au+Au events at $\sqrt{s_{NN}} = 200 GeV$. Dashed and dotted lines represent the expectation of scaling with the number of binary collisions and the number of participants, respectively, while the shaded boxes are the systematic errors of these values. The figure shows suppression of the light mesons: pions (left-hand panel) and kaons (middle panel), similar for both signs, and basically independent of the transverse momenta, at values of about 0.4 and 0.7, respectively. Nuclear modification factor for protons however, plotted in the right panel, exhibit an enhancement peak at $p_T \approx 2 GeV/c$.

In Figure 3 we compare the nuclear modification factors calculated for pions and protons at $y \approx 3.2$ with the ratios obtained by the PHENIX Collaboration at midrapidity. Data show very similar behaviour for both rapidities which suggests very similar behaviour for all rapidities in-between.

The magnitude of the quenching can also be studied as a function of the system size. Averaged nuclear modification factor for pions in the p_T range: $2 < p_T < 3.0 GeV/c$ has

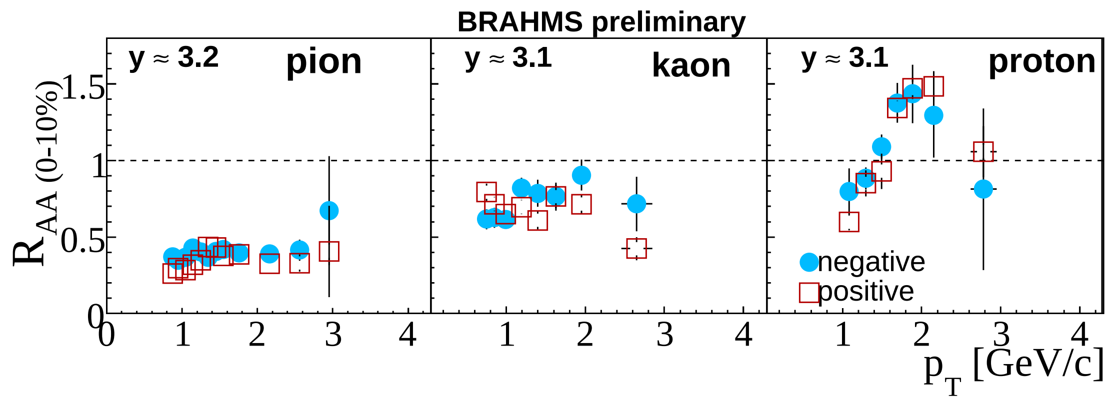

Figure 2. Nuclear modification factors for identified particles: pions, kaons and protons, panels from left to right, respectively. Blue solid circles are for negative particles, while red open squares for positive.

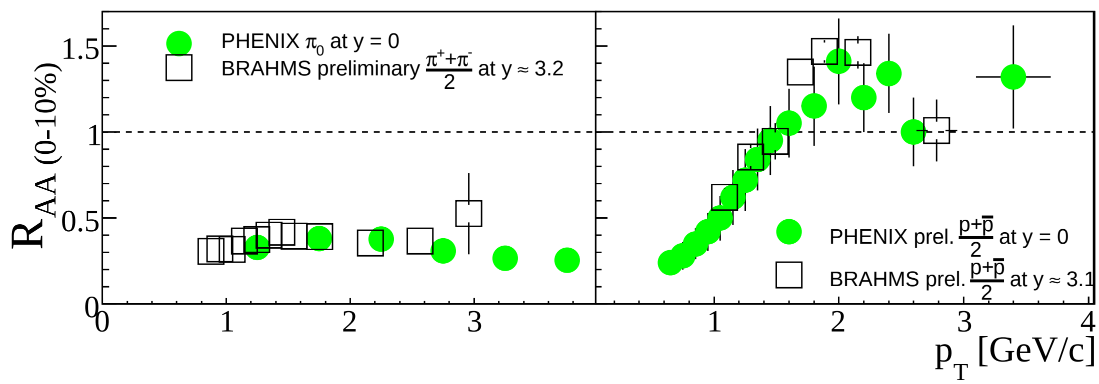

Figure 3. Comparison of R_{AA} for pions (left-hand panel) and protons(right-hand panel) at midrapidity and $y \approx 3.2$. Green solid circles are PHENIX [9] data at midrapidity, black open squares show BRAHMS preliminary data.

been plotted in Figure 4 as a function of the number of participants. As expected, the strength of suppression is decreasing for peripheral events. When compared with the PHENIX data obtained for neutral pions at midrapidity we can see that although for central events R_{AA} seems to be independent of rapidity, for peripheral events the two shown rapidities differ significantly.

3. Conclusions

BRAHMS experiment has measured particle distributions for identified hadrons in Au+Au and p+p collisions at $\sqrt{s_{NN}} = 200 GeV$ 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 at $p_T \approx 2GeV/c$. Observed suppression in Au+Au central collisions and decreasing of the effect with decreasing centrality, as well as with decreasing system size [8] may be due to jet quenching. Systematic difference between mesons and baryons, which moreover

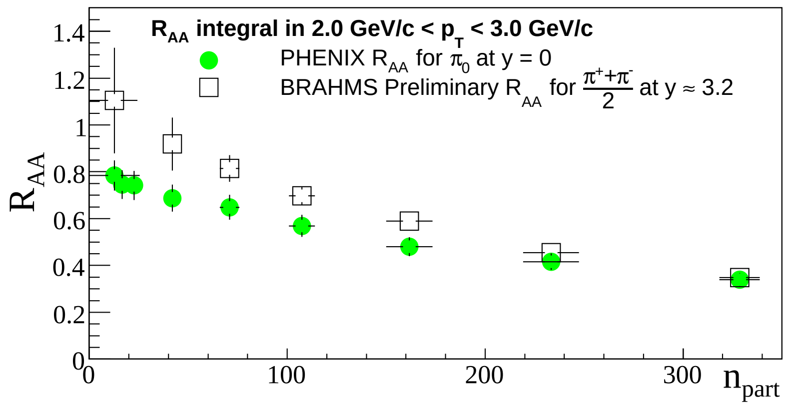

Figure 4. Change of averagend nuclear modification factor with centrality. Green solid circles are PHENIX [9] data at midrapidity, black open squares show BRAHMS preliminary data.

seems to be independent of rapidity (at least up to rapidity $y \approx 3.2$ for central events), suggests existence of other mechanisms of particle production, which depend on the quark content, such as baryon junction or parton recombination. Puzzling consistency of the investigated ratios with rapidity can be relatively easy explained in the frame described by Dainese in [10,11], where only surface emission is responsible for data production. This picture predicts independence of the nuclear modification factor with rapidity up to rapidity $y \approx 3$.

Surprising feature is revealed when comparing nuclear modification factor dependence on centrality at midrapidity 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 central to peripheral events at this rapidity. One could think that while for central events sQGP is extending in a large rapidity region around $y = 0$ (and hence similar effect of jet-quenching throughout the region), then for peripheral events sQGP is created only in much narrower region of rapidity.

REFERENCES

1. K. Adcox et al., PHENIX Colaboration, 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. Plamer, Phys. Lett. B 243, 432 (1990).
4. K. Adcox et al., STAR Collaboration, Phys. Rev. Lett. 88 022301 (2002).
5. I. Arsene et al., BRAHMS Collaboration, Phys. Rev. Lett. 91 072305 (2003).
6. J. Adams et al., PHENIX Collaboration, Phys. Rev. Lett. 91 72304 (2003).
7. B. B. Back et al., PHOBOS Collaboration, Phys. Rev. Lett. 91 72302 (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. A. Dainese, Eur. Phys. J. C 33, 495 (2004).
11. A. Dainese, C. Loizides and G. Paić, Eur. Phys. J. C 38, 461 (2005).