PARTON ENERGY LOSS, SATURATION, AND RECOMBINATION AT BRAHMS

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Particle production as observed with the BRAHMS experiment at RHIC is presented. Preliminary baryon/meson ratios and nuclear modification factors at different rapidities will be discussed.

1. Introduction

Hadrons with high transverse momentum provide a good probe of the high energy density matter created at RHIC, since the production of high p_T particles is dominated by the initial hard parton-parton scatterings with large momentum transfer Q^2. After hard-scattering, partons traverse a medium with a high density of color charges where they interact strongly, emit gluon radiation, and lose energy before fragmenting into hadrons. The production of hadrons depends on the initial parton distributions in the colliding nuclei, the elementary parton-parton cross section and the hadronization process of partons into hadrons. It is also important to distinguish nuclear effects from initial state effects, such as described by shadowing and/or color glass condensate models, and final state effects. To disentangle all these behaviors requires a very comprehensive data set. The BRAHMS experiment[1,2] has studied p+p, d+Au, and Au+Au collisions over a broad range of rapidity and transverse momentum. We will discuss these data in the context of the above processes.

2. Result

High p_T suppressions have been observed in central Au+Au collisions at RHIC[3,4,5] and are attributed to final-state interactions based on the absence of such suppressions in d+Au collisions[6,7,8,9]. The suppression is quantified by use of nuclear modification factors, which are defined as R_{AA} or R_{CP} :

$$R_{AA} \equiv \frac{1}{\langle N_{coll}\rangle}\frac{d^2N^{AA}/dp_Tdy}{d^2N^{pp}_{inel}/dp_Tdy}, R_{CP} \equiv \frac{\frac{1}{\langle N^C_{coll}\rangle}d^2N^C/dp_Tdy}{\frac{1}{\langle N^P_{coll}\rangle}d^2N^P/dp_Tdy} \quad (1)$$

R_{AA} gives the deviation in yields from AA collisions relative to the scaled yields from nucleon-nucleon collisions. R_{CP} can provide similar information based on the relative yield in central(C) and peripheral(P) collisions scaled by the mean number of binary collisions, but does not depend on the reference nucleon-nucleon system.

Figure 1 shows the rapidity(a) and particle dependence(b) of R_{CP} in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The observed suppression is similar at forward rapidities ($\eta \sim 2.2,\ 3.2$) as compared to midrapidity. This result may indicate quenching extends in the longitudinal direction. R_{CP} for protons reaches unity around $p_T \sim 1.5$ GeV/c, but R_{CP} for pions is suppressed at higher p_T. The difference between baryon and meson behaviors is discussed later.

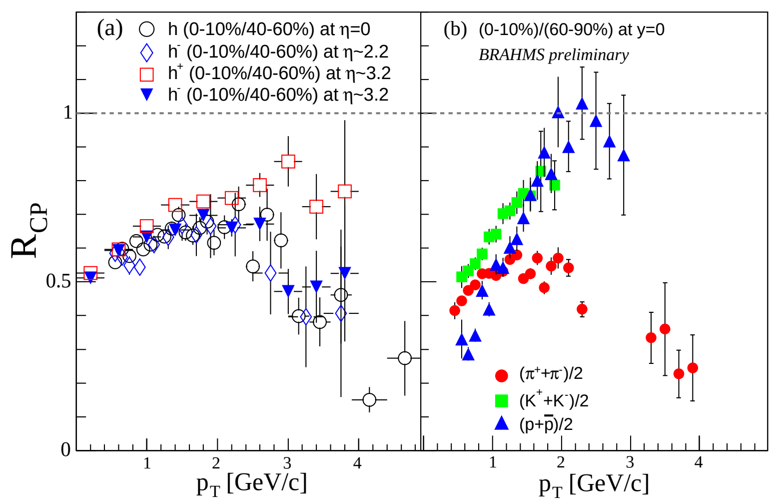

Figure 1. (a) Nuclear modification factor for the most central and peripheral collisions at pseudorapidities $\eta = 0,\ 2.2,\ 3.2$. The values for $\eta = 0,\ 2.2$ are from BRAHMS publication[6], and the one for $\eta = 3.2$ is preliminary result. (b) Central (0-10%) to peripheral (60-90%) ratios, R_{CP}, as a function of p_T for identified hadrons at midrapidity. (a) and (b) are from Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV. Error bars are statistical only.

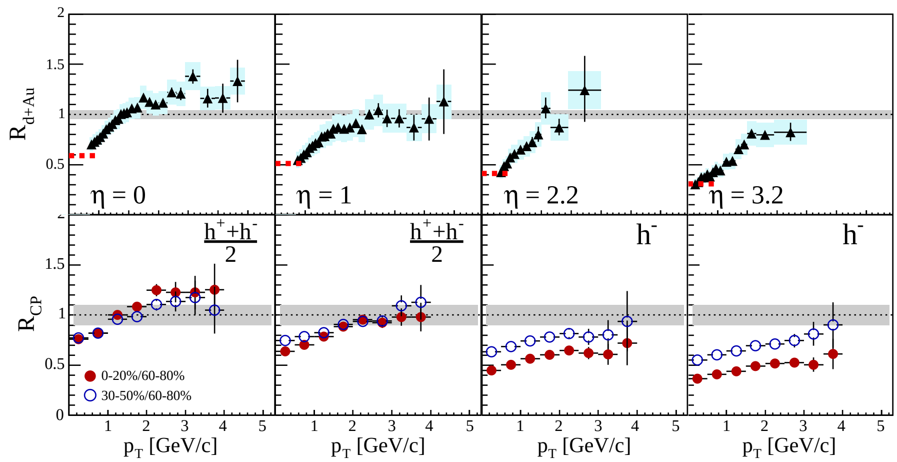

Figure 2. Top row : Nuclear modification factor for charged hadrons at pseudorapidities $\eta = 0,\ 1.0,\ 2.2,\ 3.2$. Systematic errors are shown with shaded boxes with widths set by the bin sizes. Bottom row : Central(field circles) and semi-central(empty circles) R_{CP} ratios in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Shaded bands indicate the uncertainty in the calculation of $\langle N_{coll} \rangle$ in the peripheral collisions (12%).

The rapidity dependence of R_{dA} and R_{CP} for d+Au collisions [10] is shown in Fig. 2. At midrapidity, $R_{dA}(p_T > 2\ \text{GeV}/c)$ shows a Cronin type enhancement compared to the binary scaling limit. At higher rapidity, this enhancement is followed by a suppression which becomes stronger at forward rapidity. Along the bottom row, the R_{CP} for two different centrality ranges is shown as function of pseudorapidity. The more central R_{CP} exhibits greater suppression as the rapidity increases. This is consistent with the picture of parton saturation in the Au-wave function[11]. However, the suppression of R_{CP} at forward rapidity can also be reproduced in the framework of parton recombination in the final state[12], without involving multiple scattering and gluon saturation in the initial state.

Figure 3 shows the dependence of the high p_T behavior on the type of particle in d+Au and Au+Au collisions. Results in Au+Au collisions show π^- are suppressed at midrapidity and forward rapidity. At forward rapidity, the suppression is stronger for π^-, while the $\overline{p}$ yields are enhanced at both rapidities. In d+Au collisions, the π^- yields are more suppressed at $\eta \sim 3.2$, while, again, the $\overline{p}$ yields are enhanced at forward η. This different behavior between π^- and $\overline{p}$ is not consistent with standard fragmentation functions, and indicates pions experience high p_T suppression while protons do not. This is not yet fully understood. Proton excess might arise

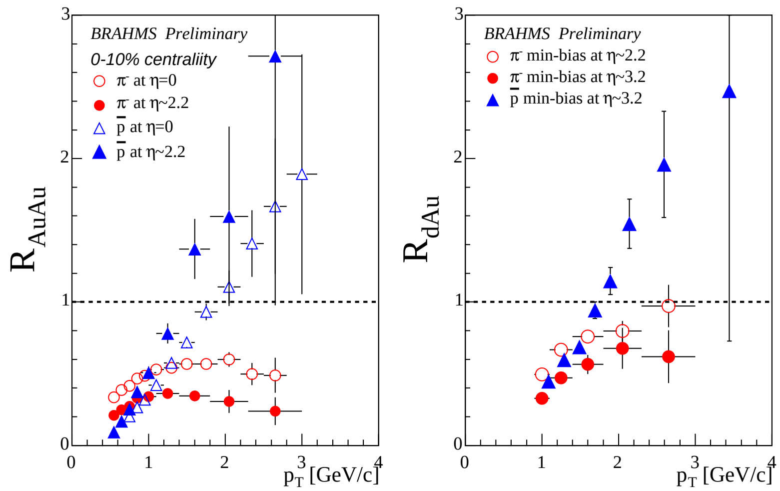

Figure 3. (left panel) R_{AuAu} for π^- and $\overline{p}$ at midrapidity and forward rapidity for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. (right panel) R_{dAu} of π^- and $\overline{p}$ at forward rapidity, $\eta = 2.2$ and 3.2 for d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. No weak decay feed-down correction applied.

from hydrodynamic expansion, or parton recombination[13] and/or quark coalescence[14] processes that enhance the yield of baryons containing three quarks by pulling them from the medium rather than relying on a simple fragmentation origin.

The measured p/π^+ and $\overline{p}/\pi^-$ ratios as a function of p_T for central Au+Au collisions at different rapidities are shown in Fig. 4. There is a clear increase of the p/π ratios at intermediate p_T ($2 < p_T < 5$ GeV/c) relative to the level seen in nucleon-nucleon collisions[15,16]. There is no significant difference for the ratios at rapidity $y = 0$ and $y \sim 1$, and $\overline{p}/\pi^-$ ratio shows a similar tendency up to $p_T \sim 1.5$ GeV/c at $\eta \sim 2.2$.

3. Summary

BRAHMS has measured rapidity dependent nuclear modification factors and particle ratios in different colliding systems. The evolution of nuclear modification factors in d+Au collisions may indicate parton saturation in the initial state. The high p_T suppression in Au+Au collisions at midrapidity also exists at forward rapidity, and depends on particle type. The recombination/coalescence models seem to give a reasonable explanation of the observed baryon-meson production mechanism at intermediate p_T.

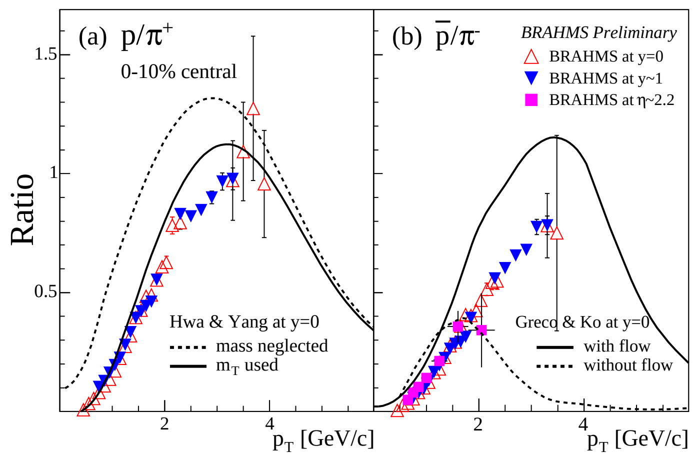

Figure 4. p/π^+ (a) and $\overline{p}/\pi^-$ (b) ratios at rapidity $y = 0$, 1.0 and $\eta = 2.2$. for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Feed-down corrections applied. Comparisons with model calculations[13,14] are shown.

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