HIGH P_T SUPPRESSION AT FORWARD RAPIDITIES IN D+AU AND AU+AU AT $\sqrt{s_{NN}} = 200$ GEV

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We present centrality dependent charged hadron yields at several pseudo-rapidities from Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV measured with BRAHMS spectrometers. Nuclear modification factors R_{AA} and R_{CP} for charged hadrons at forward angles in Au+Au and d+Au collisions at RHIC will be discussed.

1 Introduction

From the nucleon-nucleon interactions it is known that when two partons undergo a scattering with large momentum transfer Q^2 in the early stages of collision, the hard-scattered partons fragment into jets of hadrons with high transverse momentum ($p_T > 2$GeV/c) [1]. When the hard scattered partons will traverse the hot and dense nuclear matter created in a high energy nucleus-nucleus collision, they lose energy through gluon bremsstrahlung with the energy lost depending on the density of color charges in the matter through they pass [2,3]. This effect is called jet quenching and the most directly measurable consequence is the suppression of high transverse momentum hadrons in the final state. Therefore any modification in the high p_T spectrum is probing the high density medium created in the collision.

All four experiments at RHIC have been reported that the high p_T inclusive hadron yields in central Au+Au collisions are largely suppressed as compared to p+p or peripheral Au+Au collisions, scaled by the number of contributing binary (nucleon-nucleon) collisions. In the midrapidity region such suppression was not seen in d+Au collisions at RHIC, indicating that it is a final state effect associated with the hot and dense matter produced in Au+Au collisions [5,6,7,8].

The observed suppression cannot be explained by energy loss at the hadronic stage, but rather by the existence of a high color field which leads to the depletion of high momentum particles. The amount of energy loss is not so straightforward to deduce, because there could be processes like modifications of the parton distribution functions and the scatterings of the incoming partons prior to the hard scattering, which are termed as initial state effects. In order to disentangle the initial from final state effects, the BRAHMS experiment study different collision systems p+p, d+Au, Au+Au, Cu+Cu, at different energies.

In this paper we are presenting preliminary results from Au+Au at 200 GeV from the high statistics run in 2004, and also d+Au data, in the context of the above processes.

In order to measure the high p_T hadron suppression in nucleus-nucleus collisions, the comparison of the hadron p_T spectra relative to reference data from nucleon-nucleon collisions at the same collision energy is needed. The nuclear modification factor is defined as:

$$R_{AA}(p_T) = \frac{d^2N/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta} \tag{1}$$

where $T_{AA} = < N_{bin} > /\sigma_{inel}^{NN}$ accounts for the collision geometry, averaged over the event centrality class. $< N_{bin} >$, the equivalent number of binary NN collisions, is calculated using the Glauber model. σ_{inel} and $d^2\sigma^{NN}/dp_T d\eta$ are the cross section and differential cross section for inelastic nucleon-nucleon (NN) collisions, respectively. In the absence of nuclear medium effects such as shadowing, the Cronin effect or gluon saturation, hard processes are expected to scale with $< N_{bin} >$ and R_{AA}=1. Any deviation from unity indicate nuclear medium effects.

In order to remove the systematic errors introduced by the comparison of the measurements of nucleus-nucleus and p+p collisions, we construct the ratio of central to peripheral collisions, R_{CP}, defined as:

$$R_{CP} = \frac{1/ < N_{bin}^C > dN^C/dp_T d\eta}{1/ < N_{bin}^P > dN^P/dp_T d\eta} \tag{2}$$

where $dN^{C(P)}/dp_T d\eta$ are the differential yields in a central (peripheral) collision, respectively. Nuclear medium effects are expected to be much stronger in central relative to peripheral collisions, which makes R_{CP} another measure of these effects. If the yield of the process scales with the number of binary collisions, R_{CP}=1.

2 Results

The data presented here were collected with BRAHMS detector system [9]. BRAHMS consists of a set of global detectors for event characterization and two magnetic spectrometers, the midrapidity spectrometer (MRS) and the forward spectrometer (FS), which identify charged hadrons over a broad range of rapidity and transverse momentum. Collision centrality is determined from the charged particle multiplicity measured by multiplicity detectors. Since BRAHMS is a small solid angle device, the average spectrum is obtained by mapping out the particle phase space by collecting data with many different spectrometer settings. BRAHMS is the only experiment from RHIC to perform detailed measurements away from midrapidity.

In the absence of high density medium, that is of jet-quenching process, d+Au collisions are used to study the modifications due to initial state effects. Figure 1 shows the pseudorapidity dependence of R_{dA} and R_{CP} for d+Au collisions [10]. At midrapidity, R_{dA} is showing a Cronin like enhancement with respect to binary scaling limit, for transverse momenta greater than 2 GeV/c. This enhancement is thought to be due to the multiple scattering of the parton traversing the nucleus prior to the high Q^2 scattering that produces the observed high p_T hadron. At higher rapidities, the ratio becomes smaller than 1 indicating a suppression in d+Au collisions compared to scaled p+p collisions at the same energy, which becomes stronger when going to forward angles. The bottom row shows the R_{CP} factors as a function of pseudorapidity. At midrapidity the central(0-20%)-to-peripheral(60-80%) ratio is larger than semicentral(30-50%)-to-peripheral ratio suggesting also an increased Cronin type multiple scattering effect in the more central

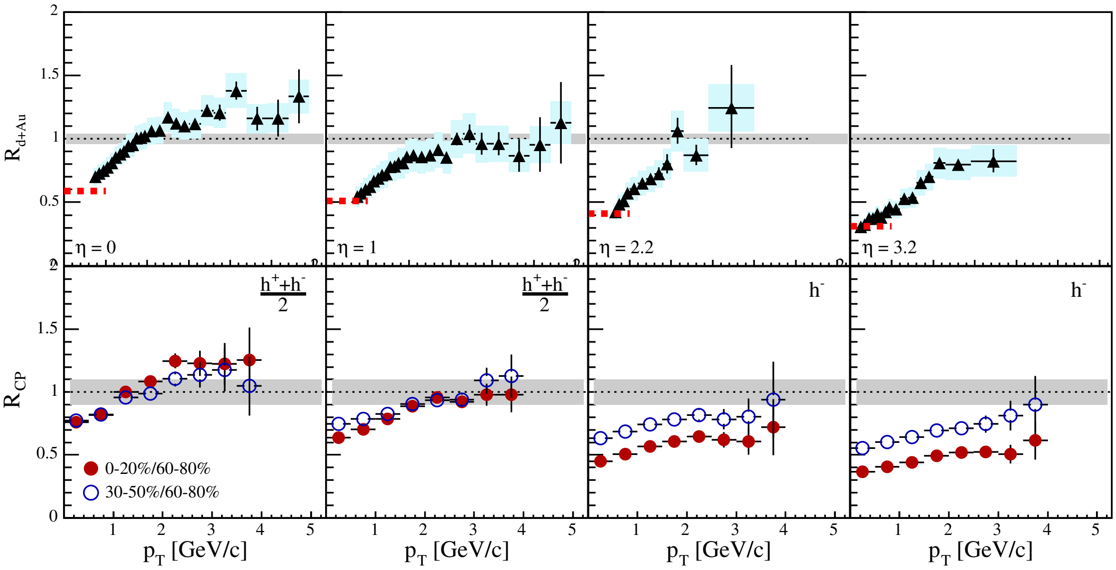

Figure 1: Top row: Nuclear modification factor for charged hadrons at $\eta = 0, 1.0, 2.2, 3.2$. Systematic errors are shown with shaded boxes with widths set by the bin sizes. The shaded band around unity indicates the estimated error on the normalization to $< N_{bin} >$. Bottom row: Central (red circles) and semi-central (blue circles) R_{CP} ratios. Shaded bands indicate the uncertainty in the calculation of $< N_{bin} >$ in the peripheral collisions (12%).

collisions. Conversely, at forward pseudorapidities the more central ratio is more suppressed, indicating a mechanism for suppression dependent on the centrality of the collision.

It has been proposed that this suppression at forward rapidity is related to the initial conditions of the colliding d and Au nuclei, in particular to the possible formation of the Color Glass Condensate (CGC) in the initial state at RHIC [11].

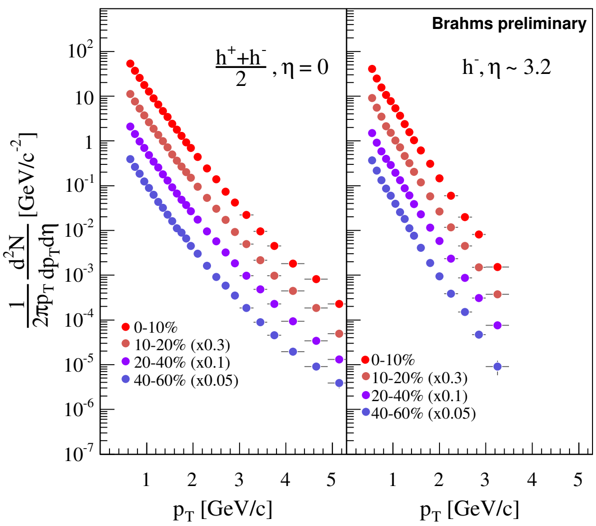

Figure 2: Invariant spectra for charged hadrons produced in Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV at $\eta = 0$ (left panel) and $\eta \sim 3.2$ (right panel).

For the Au+Au data which will be presented next, the midrapidity spectrometer was positioned at 90 degrees relative to the beam axis, and measured charged hadrons at pseudorapidities in the range $\eta < 0.1$. The forward spectrometer was placed at 8 and 4 degrees, for the ranges in pseudorapidity [2.4, 2.8] and [3.0, 3.5] respectively. The global detectors were used for the minimum bias trigger and event characterization. This trigger is selecting approximately 95% of the Au+Au interaction cross section. Spectrometer triggers are also used to enhance the track sample. The IP position is determined with a precision $\sigma < 0.85cm$ by the use of beam counters (BB) placed at $z = \pm 2.2m$.

Figure 2 shows the measured invariant spectra for inclusive charged hadrons $(h^+ + h^-)/2$ at 90^0 (left panel) and for negative hadrons (h^-) at 4^o (right panel), corresponding to $\eta = 0$ and $\eta \sim 3.2$. The displayed spectra are for centralities of 0-10%, 10-20%, 20-40% and 40-60%. The spectra are from measurements at various magnetic fields (high magnetic field chosen in order to increase the statistics at high p_T) and have been corrected for the acceptance of the

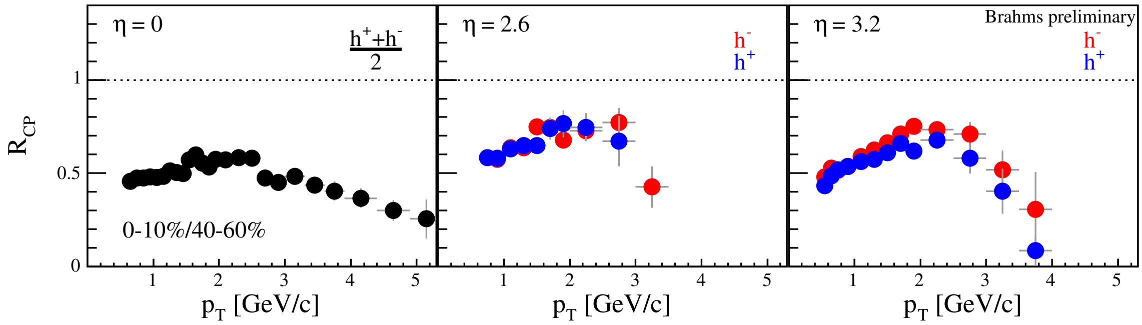

Figure 3: R_{CP} ratio for charged hadrons in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV for pseudorapidities $\eta = 0, 2.6, 3.2$ as a function of transverse momentum p_T.

spectrometers and for centrality dependent tracking efficiencies. No corrections for feed-down, decay or absorption have been applied for the FS data.

All the charged hadron spectra exhibit the power law shape, where at forward angles 90% of the particles are emitted in the region $p_T < 2GeV/c$.

Figure 3 shows the pseudorapidity dependence of the R_{CP} ratio in Au+Au collisions, at $\eta = 0$, $\eta \sim 2.6$ and $\eta \sim 3.2$. The observed suppression is similar at forward rapidities as compared to midrapidity. This result may indicate that quenching extends in the longitudinal direction.

Summary

BRAHMS has measured the rapidity dependence of nuclear modification factors in d+Au and Au+Au collisions. Away from midrapidity we observe a suppression of charged hadrons in d+Au collisions, suggesting the enhancement of the initial state effects in these regions. In Au+Au collisions the suppression persists over 3 units in pseudorapidity, indicating that the hot and dense partonic matter could further extend to forward regions.

Acknowledgments

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