High p_T Suppression in Au+Au at $\sqrt{s_{NN}} = 200$ GeV Measured with BRAHMS

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Abstract. We present the pseudorapidity evolution of high p_T suppression for unidentified charged hadrons, from $\eta \sim 0$ to $\eta \sim 4$. The study provides a test of the correlation between high p_T suppression and the total multiplicity of charged particles. High p_T spectra and nuclear modification factors R_{AA} and R_{CP} for inclusive charged hadrons will be discussed.

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INTRODUCTION

From the study of nucleon-nucleon interactions it is known that when two partons undergo a scattering with large momentum transfer Q^2 in the early stages of the 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 traverse the hot and dense nuclear matter that is created in a high energy heavy ion collision, they may lose energy through gluon bremsstrahlung. The energy lost depends on the density of color charges in the matter which parton propagates[2, 3]. This effect is called jet-quenching or high p_T suppression, termed as final state effect, whereas modifications of the parton distribution functions, gluon shadowing or saturation are initial state effects. The most directly measurable consequence is the suppression of high transverse momentum hadrons in the final state.

BRAHMS has shown that in d-Au collisions at 200 GeV the nuclear modification factors are less than unity in the forward region, suggesting that initial state effects are important for $\eta > 0$, in contrast to the situation for $\eta \sim 0$[4]. In the Au-Au system, we observe that the suppression of high p_T particles persists to higher rapidities suggesting that the medium causing the nuclear modification is longitudinally extended[5, 6]. In order to disentangle initial and final state effects in Au+Au collisions, we use a high statistics data set from 200 GeV to study charged hadron yields.

DATA ANALYSIS

The data presented here were collected with BRAHMS detector system[7]. BRAHMS consists of a set of global detectors for event characterization and two magnetic spectrometers, the mid-rapidity spectrometer (MRS) and the forward spectrometer (FS), which identify charged hadrons over a broad range in rapidity and transverse momentum. Collision centrality is determined from the charged particle multiplicity measured

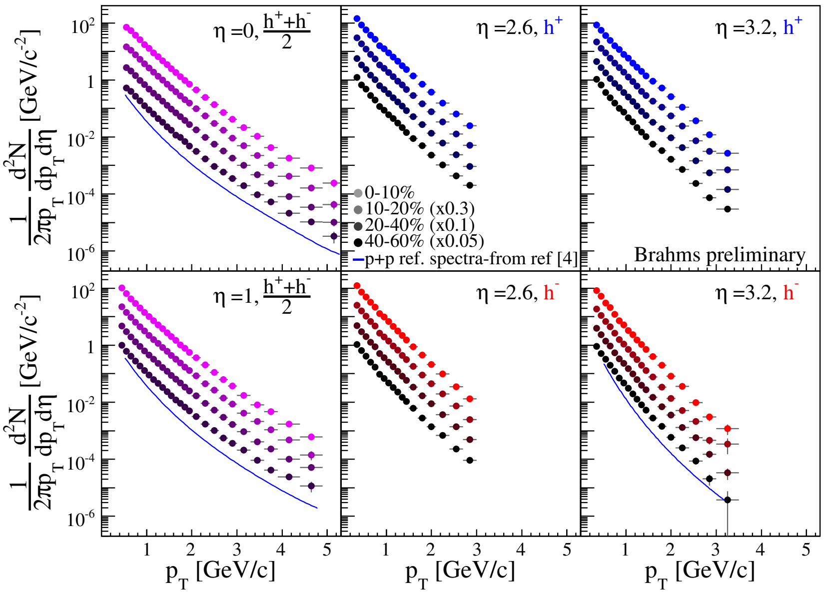

FIGURE 1. Invariant p_T spectra for charged hadrons produced in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV GeV at $\eta = 0$, $\eta = 1$, $\eta = 2.6$, $\eta = 3.2$ for 0-10%, 10-20%, 20-40% and 40-60% centrality. The p+p reference spectra (from [4]) used for calculating R_{AA} are shown with solid lines. For clarity, some spectra have been divided by the indicated factors.

by a set of global detectors.

Since BRAHMS is a small solid angle device, the charged particle spectra 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.

When combining different settings, the deviation of the single settings spectra to the final spectra are within 20% in the low p_T regions. In the high p_T region, the different settings are consistent within the statistical errors.

RESULTS

Spectra

For the Au-Au data which are presented here, the midrapidity spectrometer was positioned at 90 and 40 degrees relative to the beam axis, and measured charged hadrons at pseudorapidities in the range $\eta \in$[-0.1, 0.1] and $\eta \in$[0.9, 1.1] respectively ($\eta = -ln(tan(\theta/2))$, where θ is the angle of emission relative to the beam direction). The forward spectrometer (FS) was placed at 8 and 4 degrees, for the ranges in pseudorapidity [2.4, 2.8] and [3.0, 3.5] respectively. For the results presented here only the front part of the forward spectrometer (FFS) was used. At the most forward angle, the

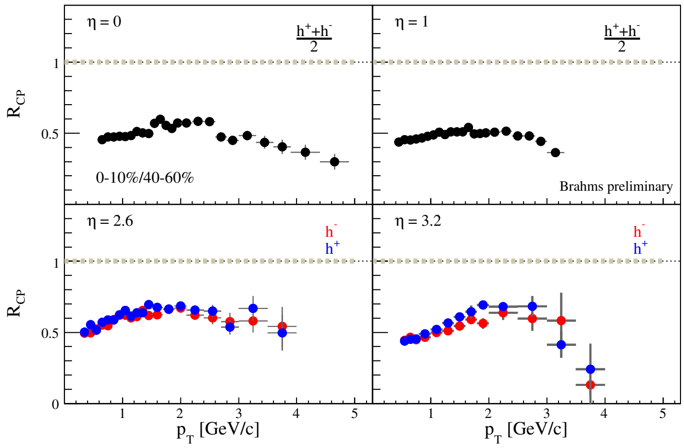

FIGURE 2. R_{CP} ratio for charged hadrons in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV for pseudorapidities $\eta = 0, 1, 2.6, 3.2$ as a function of transverse momentum p_T.

consistency with the full FS spectra has been investigated in order to identify the effects of increased background. The global detectors were used for the minimum bias trigger and event characterization. This trigger selects 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 1 shows the measured invariant p_T spectra for inclusive charged hadrons $(h^+ + h^-)/2$ at 90^0 and 40^0 (left panel), for negative hadrons (h^-) and positive hadrons (h^+) at 8^o (middle panel) and at 4^o (right panel), corresponding to $\eta = 0$, $\eta = 1$, $\eta = 2.6$ and $\eta = 3.2$. The displayed spectra correspond to centralities of 0-10%, 10-20%, 20-40% and 40-60% of the total interaction cross section. The spectra are from measurements at various magnetic fields (mostly high magnetic field chosen in order to increase the statistics at high p_T) and have been corrected for the acceptance of the spectrometers and for centrality dependent tracking efficiencies. No corrections for feed-down, decay or absorption have been applied for the FFS data.

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

The dN/dη values extracted from fits to these data are consistent with the measured multiplicities for charged particles[8] extracted from the global detectors, for all the centrality cuts.

Nuclear Modifications

In order to determine the high p_T hadron suppression in nucleus- nucleus collisions, the hadron p_T spectra have to be compared to the reference data from nucleon-nucleon collisions at the same collision energy. The nuclear modification factor is defined as:

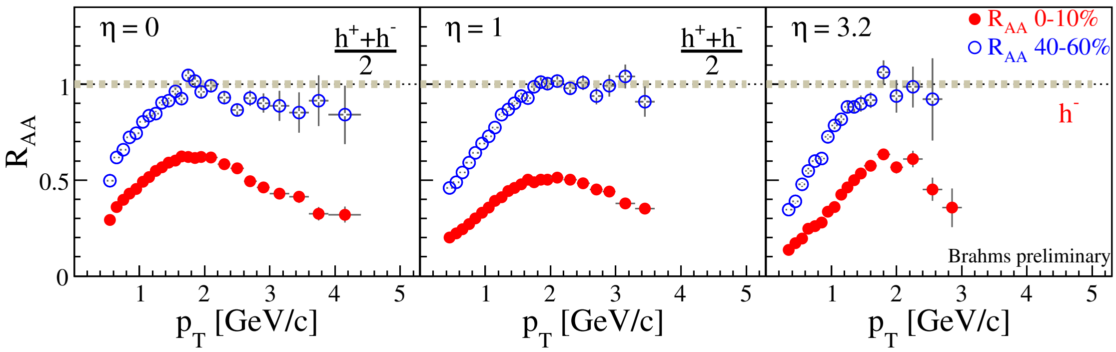

FIGURE 3. Nuclear modification factor for charged hadrons at pseudorapidities $\eta = 0, 1, 3.2$. Red points are the R_{AA} for the most central collisions (0-10% centrality) and blue points are the R_{AA} for semi-peripheral collisions (40-60% centrality).

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

where $T_{AA} = \langle N_{bin} \rangle / \sigma_{inel}^{NN}$ accounts for the collision geometry, averaged over the event centrality class. $\langle N_{bin} \rangle$, the number of binary NN collisions, is calculated using the Glauber model. σ_{inel}^{NN} and $d^2\sigma_{inel}^{NN}/dp_T d\eta$ 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 $\langle N_{bin} \rangle$ and consequently, R_{AA}=1. Any deviation from unity indicate nuclear medium effects, especially for the high p_T region ($p_T > 2GeV/c$) where the hard production dominates.

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:

$$R_{CP} = \frac{1/\langle N_{bin}^C \rangle}{1/\langle N_{bin}^P \rangle} \frac{d^2N_C/dp_T d\eta}{d^2N_P/dp_T d\eta} \tag{2}$$

where $dN^2_{C(P)}/dp_T d\eta$ 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.

Figure 2 shows the pseudorapidity dependence of the R_{CP} ratio in Au-Au collisions, at $\eta = 0$, $\eta = 1$, $\eta = 2.6$ and $\eta = 3.2$. The observed suppression is similar at forward rapidities as compared to midrapidity. This result may indicate that quenching extends also in the longitudinal direction.

It has been proposed that this suppression at forward rapidity might be related to the initial conditions of the colliding nuclei, in particular to the possible formation of the Color Glass Condensate (CGC) in the initial state at RHIC[9]. This effect has been observed in d-Au collisions at $\eta \sim 3$ [4].

Figure 3 shows the R_{AA}, as a function of p_T for two centrality cuts for the Au-Au measurements at $\eta = 0$, $\eta = 1$ and $\eta = 3.2$. For the most central $(0-10\%)$ bin we use $N_{bin} = 897 \pm 117$, and for the most peripheral $(40-60\%)$ $N_{bin} = 78 \pm 26$. All the $p+p$ reference spectra used are from ref. [4]. The R_{AA} rise from values of 0.2–0.4 at low p_T to a maximum at $p_T \approx 2$ GeV/c. The low p_T part of the spectrum is associated with soft collisions and should therefore scale with the number of participants. Thus the applied scaling with the (larger) N_{bin} value reduces R_{AA} at the lower p_T.

For central collisions, above $p_T \approx 2$ GeV/c, the R_{AA} distributions decrease and are systematically lower than unity. We observe that the suppression persists over a wide range in pseudorapidity and it is almost constant for all the studied angles. As expected, the semi-central events follow the pp spectra, and the R_{AA} reach the unity in the p_T range [1.5, 2.0] GeV/c for all data. The observed behavior of nuclear modification factors is consistent with jet surface emission[10, 11], modeled in the frame of PQM.

The study of nuclear modification factors for the identified particle performed over the Brahms wide rapidity coverage could bring additional information on the high p_T suppression phenomenon observed at Rhic.

CONCLUSIONS

BRAHMS has measured the pseudorapidity dependence of nuclear modification factors in Au-Au collisions. In Au-Au collisions the suppression persists over 3 units in pseudorapidity, indicating that the hot and dense partonic matter may be extended also along the beam direction. The similarity observed in the forward direction both in Au-Au and d-Au collisions at large pseudorapidities suggest that initial state effects play a significant role in this region.

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