High p_T Measurements with BRAHMS

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We present high transverse momentum particle spectra from Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV measured with the BRAHMS detector. At midrapidity, unidentified hadron spectra have been measured to a momentum of 5 GeV/c. The shape of the spectra indicates that hadron yields are suppressed at high p_T in central collisions relative to a nucleon-nucleon reference scaled for collision geometry. The ratio of protons to all hadrons has been measured up to p_T=3.5 GeV/c and exceeds 1/3 at $p_T > 2$ GeV/c. At $y \approx 2$ negative pion spectra have been measured over a broad p_T range to investigate the medium effects at forward rapidities.

1. Introduction

The production of high p_T particles is expected to be dominated by fragmentation of jets created at the early stages of the collision. Partons lose energy when traversing the dense medium created in heavy ion collisions. This energy loss softens the fragmentation of jets, leading to the suppression of hadrons at high p_T. The measurement of high p_T particle yields (> 2 GeV/c) relative to yields measured in nucleon-nucleon collisions therefore provides a unique probe for the conditions in the early stages of the collision [1]. Data from Au+Au at $\sqrt{s_{NN}}$=130 GeV [2,3] and 200 GeV (these proceedings) show a clear suppression indicating significant medium effects.

During the last two weeks of the 2001 RHIC running period BRAHMS focused on measurements of high p_T particles. The two spectrometers were set to measure high p_T particles emitted at angles around 90 deg. and around 12 deg. ($y_\pi \approx 2$).

2. Experimental Setup

The BRAHMS detector consists of two independent small angle magnetic spectrometers and a detector system to measure the global characteristics of the collision. The detector system is described in detail in [4]. The measurements of identified particles presented here are done with the time-of-flight wall (in the midrapidity spectrometer) and the ring imaging Cherenkov detector (in the forward spectrometer). Additional details on the detector particle identification capabilities are discussed in [5].

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3. High p_T physics at $y = 0$ and $y = 2$

The medium effects on the spectra can be investigated by comparing the spectra to similar spectra from N+N collisions at the same energy. This comparison is often done by constructing the nuclear modification factor, which is defined as

$$R_{AA} = \frac{d^2N^{A+A}/dp_T d\eta}{d^2\sigma^{N+N}/dp_T d\eta} \frac{\sigma^{N+N}}{\langle N_{bin} \rangle}, \tag{1}$$

where σ^{N+N} is the nucleon-nucleon interaction cross section and $\langle N_{bin} \rangle$ is the mean number of binary collisions (calculated from a Glauber model). The nuclear modification factor illustrates the difference in shape of the A+A and N+N spectra. Normalization to the number of binary collisions suggest that the A+A collisions can be considered as a superposition of N+N collisions (all at full energy) – this picture is very simplified and conclusions drawn from the level of the nuclear modification factor are not straightforward. Measurements of p+A, d+A and p+p collisions in this energy regime are therefore essential for a better understanding of the modifications of the high p_T spectra.

At higher rapidities no reference data are available and comparison can only be done between spectra from different centrality classes. To interpret these measurements one also needs a more sophisticated picture of the collision evolution: where do these high p_T particles originate and what matter do they traverse? A simple picture, where the particles are emitted at 90 deg. from different rapidity boosted sources, is described in [6]. In this simple picture the suppression of high p_T particles decreases at higher rapidities as a result of the decreasing density of the traversed matter.

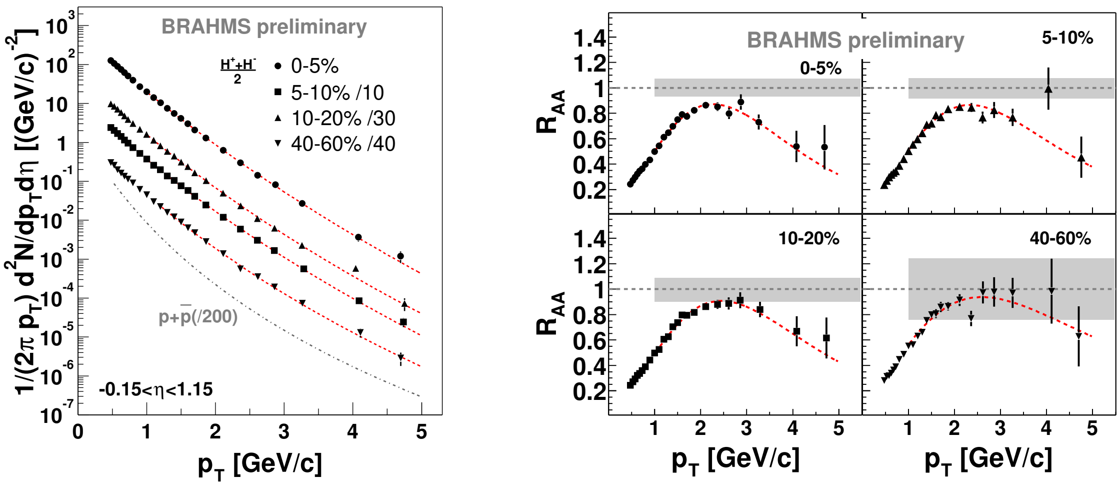

Figure 1. Left: Unidentified hadron spectra for different centrality classes. The dashed lines shows the power-law fits. The dashed-dotted line indicates the fit to the $p + \bar{p}$ reference data (acceptance corrected). Right: The nuclear modification factor for different centrality classes. The dashed lines indicates the ratio of the fits to the data and the reference data. The gray areas indicate the uncertainty on the $\langle N_{bin} \rangle$ scaling.

4. Midrapidity measurements

Figure 1 (left panel) shows unidentified hadron spectra at midrapidity for different centrality classes. The spectrometer covers $-0.15 \le \eta \le 0.15$. The data is fitted with the power-law function $1/(2\pi p_T) d^2N/dp_T d\eta = A(1 + p_T/p_0)^{-n}$ in the p_T range from 1 to 5 GeV/c. Corrections for absorption and feed-down have not been applied.

To deduce the nuclear modification factor UA1 measurements [7] (p+$\bar{p}$ at $\sqrt{s} = 200$GeV) are used as the reference. The UA1 data was fitted with a power-law function in the p_T range from 1 to 5 GeV/c (giving the fit parameters $A = 338$ mb/(GeV/c)^2, $p_0 = 1.45$ GeV/c and $n = 10.9$). The acceptance of UA1 is different ($-2.5 < \eta < 2.5$) from that of BRAHMS which changes the spectral shape slightly. PYTHIA [8] shows an approximately linear ratio between hadron spectra in these two η acceptance ranges in the covered p_T region, and the reference has been corrected for this by multiplying with $c = 1.08 + 0.05 p_T$. The fit to reference (including acceptance correction) is indicated in figure 1 (left panel). The mean number of binary collisions for each centrality class is taken from [3] and $\sigma^{p+\bar{p}} = 42 \pm 1$ mb.

The right panel in figure 1 shows the nuclear modification factor R_{AA} for the different centrality classes. For all centrality classes, R_{AA} increases monotonically up to $p_T \approx 2.5$ GeV/c, where it peaks. For $p_T > 2.5$ GeV/c R_{AA} decreases more rapidly for the more central collisions. At $p_T \approx 5$ GeV/c the spectra are closer to participant scaling than to binary collision scaling for central collisions, which indicates a significant suppression of the high p_T yields. It is remarkable that the RHIC high p_T data show very different behaviour than data from lower energy [9], where an enhancement (Cronin effect) was observed.

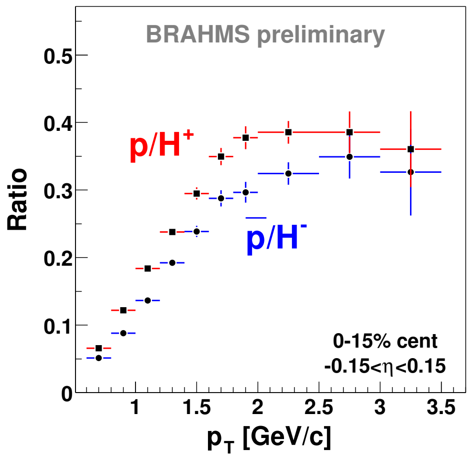

Figure 2: Ratio of protons to hadrons.

BRAHMS can identify protons up to a momenta of 3.5 GeV/c at midrapidity. In figure 2 the p/H^+ and $\bar{p}/H^-$ ratios are shown. The ratios show that in the region from 2 to 3.5 GeV/c the protons and antiprotons constitute approximately one third of the charged particles.

5. High p_T measurements at forward rapidities

BRAHMS has the unique capability to measure spectra to high p_T at forward rapidities. With the forward spectrometer positioned at 12 deg. a p_T spectrum of negative pions at $y = 2.2$ has been obtained, see figure 3 (left panel). Reference data (from $p+p$ or $p+\bar{p}$) at this energy is not available yet and nuclear modification factors can therefore not be deduced. Instead central and semi-peripheral collisions have been compared (figure 3, right panel). The figure shows the ratio of negative pion yields from two centrality classes (0-10% over 40-60%) normalized to the number of binary collisions. This ratio points to a suppression setting in at a lower p_T (≈ 1.2 GeV) than what was observed for hadrons at midrapidity. However, higher statistics and more theoretical work on high p_T spectra at higher rapidities is needed before one can draw conclusions.

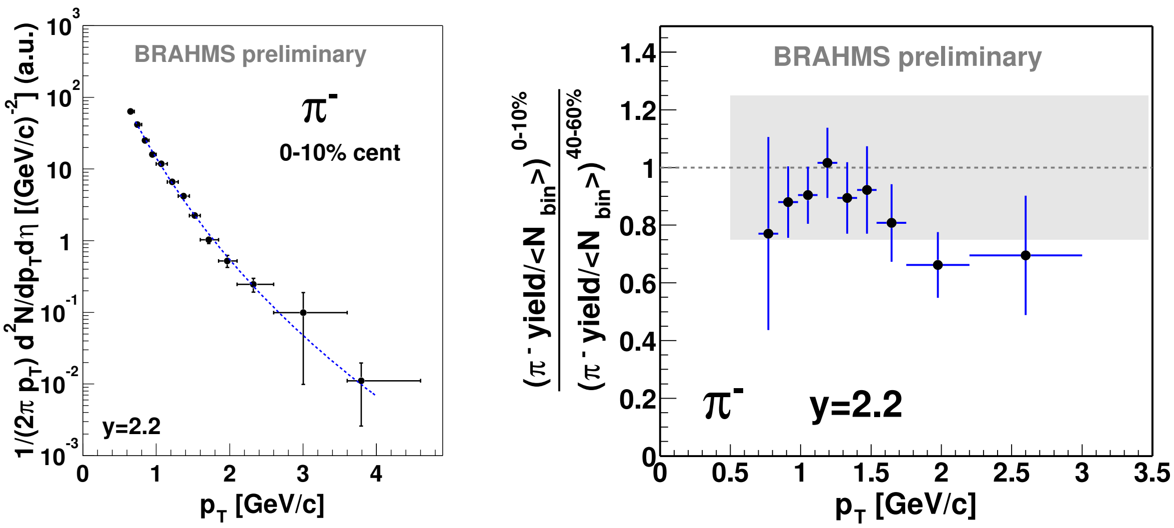

Figure 3. Left: Negative pion spectra measured at $y \approx 2.2$. The dashed curve is a power-law fit to the data ($p_0 = 1.5$ GeV/c, $n = 9.7$) Right: Ratio of negative pion yield for central (0-10%) and semi-peripheral (40-60%) collisions, normalized to the mean number of binary collisions. The gray area indicates the uncertainty on the $\langle N_{bin} \rangle$ scaling.

6. Conclusion and Outlook

BRAHMS has measured p_T spectra of unidentified hadrons up to 5 GeV/c at midrapidity. The data indicates a suppression of the high p_T yield when compared to $p + \bar{p}$ data. Negative pion spectra have been measured at $y = 2.2$ and the spectral shape has been found to change from central to semi-peripheral collisions. Interpretation of these kind of data calls for additional theoretical work. Future detector upgrades and higher beam luminosity will give unique high p_T measurements over a broad rapidity range in the coming RHIC runs.

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