High p_T charged pion and proton production in $\sqrt{s_{NN}} = 200$ GeV Au+Au and d+Au collisions

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Abstract.
We present measurements of identified high p_T proton and charged pion production in Au+Au and d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at midrapidity and pseudorapidity $\eta = 2.2$. First results indicate a clear suppression of $\pi^{\pm}$ yields at mid-rapidity in central Au+Au collisions and π^- yields at forward rapidity ($y = 2.2$) in both central Au+Au and central d+Au collisions. Particle composition is further discussed in terms of $\bar{p}/h^-$ ratio at midrapidity and of the π^-/h^- ratio at forward rapidity.

1. Introduction

High transverse momentum hadrons, arising mainly from the fragmentation of energetic partons created by the initial parton-parton interactions, are considered as a good probe of the high energy density matter created in ultra-relativistic heavy ion collisions [1]. One of the most interesting observation from all four experiments at RHIC is that high p_T inclusive hadron yields in central Au+Au collisions are suppressed as compared to $p + p$ and d+Au interactions [3, 4, 5, 6]. This is widely seen as confirmation of jet quenching, the process in which, due to induced gluon radiation and multiple inelastic scattering, high energy partons lose energy when they travel through the hot medium created in a heavy ion collision. However, the amount of suppression for neutral pions is found to be much stronger than that for inclusive charged hadrons [2] in central Au+Au collisions leading to several suggestions on hadron production mechanisms [7, 8, 9, 10]. Therefore, a detailed study of particle composition at high p_T is very important to understand hadron production mechanisms at RHIC.

BRAHMS [11] consists of a set of global detectors for event characterization and two magnetic spectrometers, the mid-rapidity spectrometer and the forward spectrometer, which are optimized to 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. Trajectories of charged hadrons are reconstructed using tracking detectors located in magnetic field-free regions. The resulting straight-line track segments are then matched in intervening magnet sections and the particle momenta are determined. At mid-rapidity charged particle identification (PID) is performed by a time-of-flight wall using the combination of time-of-flight, momentum and flight path length measurements, whereas at forward rapidity a time-of-flight wall and a ring imaging Cherenkov detector are used for PID.

At mid-rapidity, protons and charged pions can be identified up to $p_T = 3$ GeV/c. At pseudorapidity $\eta = 2.2$, hadrons can be identified up to $p_T = 4.5$ GeV/c. This allows us to study the high p_T hadron production mechanism via the rapidity and species dependence of the hadron spectra.

In this paper, we present the relative yields of high p_T protons and charged pions at $\eta = 0$ and $\eta = 2.2$ from Au+Au and d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Measurements at various magnetic fields have been combined and corrected for the spectrometer acceptance, in-flight decay of pions, the effect of multiple scattering, anti-proton absorption and detection efficiencies estimated by using a GEANT based Monte Carlo simulation program of the BRAHMS detectors. No correction for feed-down from weak decays has been applied.

2. Results

2.1. Nuclear Modification Factors

To quantify nuclear medium effects on high p_T hadron yields in nucleus-nucleus collisions, it is common to compare it to the expectations from elementary nucleon-nucleon collisions and define the nuclear modification factor as:

$$R_{AB}(p_T) = \frac{d^2N^{AB}/dp_T dy}{(\langle N_{bin}\rangle/\sigma_{inel}^{NN})d^2\sigma_{inel}^{NN}/dp_T dy}, \qquad (1)$$

where $d^2N^{AB}/dp_T dy$ is the differential yield per event in the nuclear collision $A+B$, $\langle N_{bin}\rangle$ is the average number of binary collisions, and σ_{inel} and $d^2\sigma_{inel}^{NN}/dp_T dy$ are the cross section and differential cross section for inelastic nucleon-nucleon $(N+N)$ 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 $R_{AB} = 1$. Any departure from unity thus indicates nuclear medium effects.

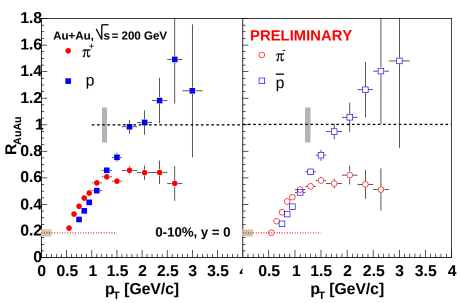

Figure 1. R_{AuAu} for $\pi^{\pm}$'s and (anti-)protons at mid-rapidity for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

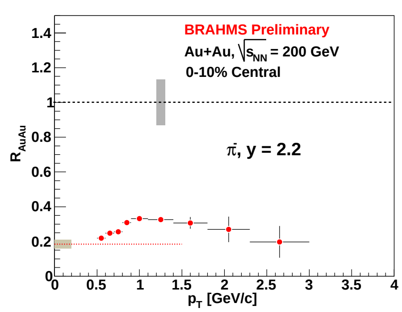

Figure 2. R_{AuAu} for π^-'s at forward rapidity for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

Figure 1 and Figure 2 show respectively R_{AuAu} as a function of p_T for $\pi^{\pm}$ and $p(\bar{p})$ at mid-rapidity and π^- at rapidity $y = 2.2$ for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The $N+N$ differential cross sections are based on neutral pion spectrum measured by PHENIX [12] and preliminary (anti-)proton spectrum measured by STAR [13] for p+p collisions at $\sqrt{s} = 200$ GeV and corrected properly for the difference in rapidity coverage via PYTHIA [14] simulation. The dotted and dashed lines in the figures indicate the expectations of participant scaling and binary scaling, respectively. The shaded bars represent the systematic errors associated with the determination of these quantities. The experimental error bars indicate statistical errors only. The data show that $p(\bar{p})$ reaches unity around 2.0 GeV/c, whereas charged pions are suppressed with respect to elementary p+p collisions at both mid-rapidity and forward rapidity.

In Figure 3 R_{dAu} is shown as a function of p_T for π^-'s at rapidity $y = 2.2$ for minimum bias (left) and different centrality (right) d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Data show that the high p_T yields of π^-'s are suppressed in central d+Au collisions at $y = 2.2$ as well.

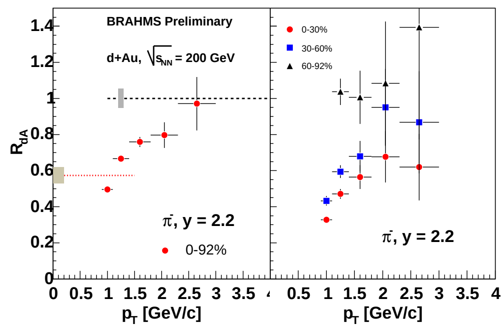

Figure 3. R_{dAu} of π^-'s at $y = 2.2$ for d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

2.2. Particle Ratios

Figure 4 shows the p/π^+ and $\bar{p}/\pi^-$ ratios as a function of p_T measured at two different rapidities for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. At mid-rapidity p/π^+ ratio reaches unity and $\bar{p}/\pi^-$ reaches 0.8 at p_T around 2.5 GeV/c, whereas $\bar{p}/\pi^-$ at pseudo-rapidity $\eta = 2.2$ reaches a maximum of ~ 0.5 at $p_T \sim 2.5$ GeV/c. In Figure 5 the ratios of $\bar{p}/h^-$ (similar for p/h^+) at mid-rapidity (top) and π^-/h^- at $\eta = 2.2$ (bottom) are shown as a function of p_T for 0-10% central Au+Au, 0-30% central d+Au and minimum-bias p+p collisions at $\sqrt{s_{NN}} = 200$ GeV. The $\bar{p}/h^-$ ratio from central Au+Au collisions are about a factor of 2 higher than that from d+Au and p+p collisions for $p_T > 2.0$ GeV/c. At $\eta = 2.2$ and $p_T > 1.5$ GeV/c, the abundance of π^- relative to inclusive negatively charged hadrons in d+Au and p+p collisions are about a factor of 1.5 higher than that in central Au+Au collisions.

3. Conclusion

The BRAHMS measurements demonstrate a significant suppression of high p_T charged pion yields at both mid-rapidity and forward rapidity in central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. However, at mid-rapidity the proton and anti-proton yields show no suppression for $p_T > 2$ GeV/c. The observed suppression of the charged pion yields in central Au+Au collisions may be attributed to jet quenching, while the absence of suppression for baryons at intermediate p_T requires additional particle production mechanisms, e.g. parton recombination [7, 9, 10] or baryon junction [8]. A suppression of high p_T π^- yields has also been observed at forward rapidity ($y = 2.2$) in central d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. This indicates that a fraction of charged pion suppression at forward rapidity in central Au+Au collisions may be attributed to initial state quantum evolution effects [15].

The p/π^+ and $\bar{p}/\pi^-$ ratios in central Au+Au events indicate that at mid-rapidity

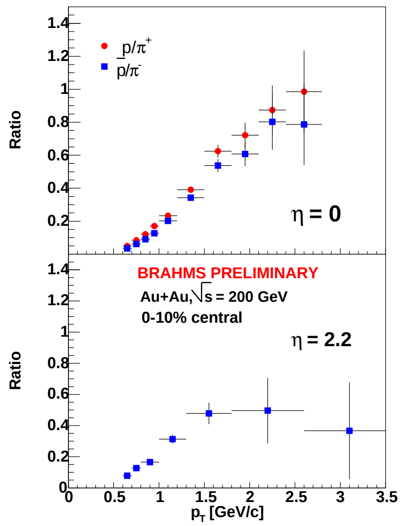

Figure 4. p/π^+ and $\bar{p}/\pi^-$ ratios at $\eta = 0$ (top) and $\bar{p}/\pi^-$ ratio at $\eta = 2.2$ (bottom) for 0-10% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

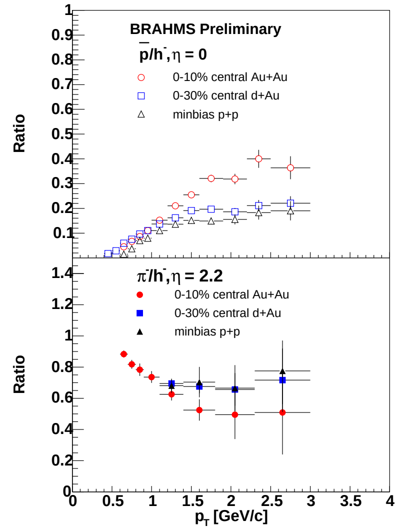

Figure 5. $\bar{p}/h^-$ ratio at $\eta = 0$ (top) and π^-/h^- ratio at $\eta = 2.2$ (bottom) for 0-10% central Au+Au, 0-30% central d+Au and minimum-bias p+p collisions at $\sqrt{s_{NN}} = 200$ GeV.

the p and $\bar{p}$ yields are comparable to the pion yields at around $p_T = 2.0$ GeV/c. The ratios of (anti-)protons over charged hadrons at mid-rapidity in d+Au and p+p collisions are found to be about a factor of 2 lower than that from central Au+Au collisions, while at forward rapidity the ratios of π^- over negatively charged hadrons in d+Au and p+p collisions are about a factor of 1.5 higher than that in Au+Au collisions.

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