Rapidity Dependence of High-p_T suppression

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Abstract. The rapidity dependence of nuclear modifications factor in d-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at RHIC is discussed.

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INTRODUCTION

Particle production at forward rapidities in p(d)-A reactions probes partons in the target at low-x values. At sufficient high energy, large rapidities or large nucleii the initial gluon distribution will saturate, and is expected to modify the particle pseudo rapidity densities, as well as the p_{T} spectra of hadrons. A theory based on QCD has been developed for dense low-x systems, termed the Color Glass Condensate (CGC) [1]. This description has inspired much theoretical and experimental work, and was also a motivation for the BRAHMS measurements of charged hadrons at forward rapidities in 200 GeV d-Au collisions at RHIC.

RESULTS

The data reported here were all obtained with the BRAHMS spectrometers. The BRAHMS forward spectrometer consists of 4 dipole magnets, 5 tracking chambers, two Time-Of-Flight systems and a Ring Imaging Chrenkov Detector (RICH) for particle identification. The angular coverage of the spectrometer extends from 2.3^{o} to $15^{\mathrm{o}}$with solid angle of msr. The mid-rapidity spectrometer covers angles from 40^{o} and 90^{o} . Details of experimental setup can be found in [2]. The collision vertex is determined from timing measurements done with a set of symmetricaly placed scintillator counters around the beam pipe at 1.5, 4.15 and 6.7 meters [3]. The resolution of the vertex determination is $\approx$ 10 cm. This set of counters also provides the minimum bias normalization. It is estimated that for pp collisions they record 70% of the inelastic cross section. Additional details of the setup as well as the analysis can be found in [3, 4] where most of the data discussed here were first published. Spectra of charged hadrons in d-Au and pp collisions at 200 GeV are presented in Fig. 1 for several pseudorapidities. The data at $\eta = 0$ and 1 are for the average of the positive and negatives charges, while the high rapidity data are for negative only. Both the pp and dAu cross sections becomes steeper with increasing η.

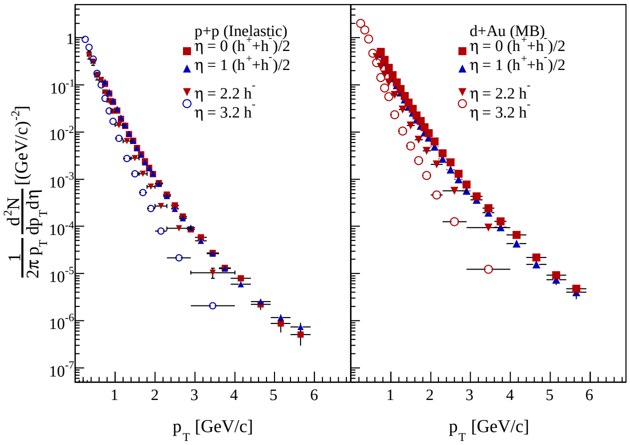

FIGURE 1. Spectra for dAu and pp

The data collected from d-Au collisions is compared to p-p using the nuclear modification factor defined as: $R_{dAu} = \frac{1}{N_{coll}} \frac{\frac{dN^{dAu}}{dp_T d\eta}}{\frac{dN^{pp}}{dp_T d\eta}}$. where N_{coll} is the number of binary collisions estimated to be equal to 7.2 ± 0.6 for minimum biased d+Au collisions. The pt dependence of the factor is shown in Fig.2. Each panel shows the ratio calculated at a different η value. At mid-rapidity ($\eta = 0$), the nuclear modification factor exceeds 1 for transverse momenta greater than 2 GeV/c in a similar, although less pronounced way as Cronin's p+A measurements performed at lower energies [5].

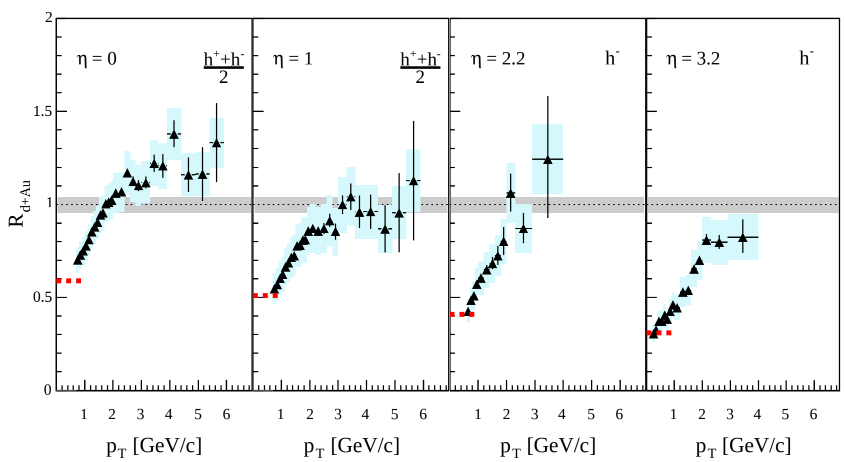

FIGURE 2. Nuclear modification factor for charged hadrons at pseudorapidities $\eta = 0, 1.0, 2.2, 3.2$. Statistical errors are shown with error bars. Systematic errors are shown with shaded boxes with widths set by the bin sizes. The shaded band around unity indicates the estimated error on the normalization to $\langle N_{coll} \rangle$. Dashed lines at $p_T < 1$ GeV/c show the normalized charged particle density ratio $\frac{1}{\langle N_{coll} \rangle} \frac{dN/d\eta(d+Au)}{dN/d\eta(pp)}$.

A shift of one unit of rapidity is enough to make the Cronin type enhancement disappear, and as the measurements are done at higher rapidities, the ratio becomes consistently smaller than 1 indicating a suppression in dAu collisions compared to scaled pp systems at the same energy. In all four panels, the statistical errors, shown as error bars (vertical lines), are dominant specially in the most forward measurements.

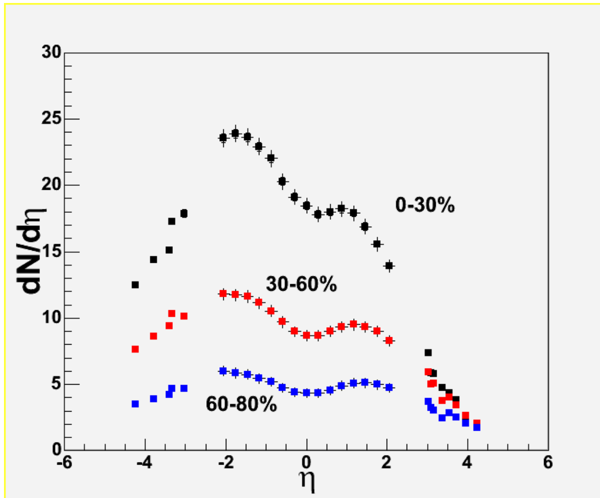

FIGURE 3. Pseudo rapidity dependence of dN/deta in dAu for 3 centrality bins.

These results have been described within the context of the Color Glass Condensate [1]; the evolution of the nuclear modification factor with rapidity and centrality is consistent with a description of the Au target where the rate of gluon fusion becomes comparable with that of gluon emmission as the rapidity increases and it slows down the overall growth of the gluon density. The measured nuclear modification factor compares the slowed down growth of the numerator to a sum of incoherent p+p collisions, considered as dilute systems, whose gluon densities grow faster with rapidity because of the abscence of gluon fusion in dilute systems [6]. Other explanations for the measured suppression have been proposed and they also reproduce the data [9, 10, 11].

Some of these other explanations particluar focus on the observation that the charged particle pseudo-rapidity density distributions exhibits a change in shape vs. centrality. This is illustrated in Fig.2 by the dashed lines at low p_T where the ratios where obtained from the BRAHMS data[4] (shown in Fig.3) and the UA5 pp results[7]. Thus already the overall soft spectrum shows suppression when going to forward angles.

The nuclear modification factor of baryons is different from the one calculated with mesons, whenever the factor shows the so called Cronin enhancement, baryons show a stronger enhancement. Such difference, seen at lower energies, has also been found at RHIC energies at all rapidities, in particular, Fig. 4 presents the minimum bias nuclear modification R_{dAu} for anti-protons and negative pions at $\eta = 3.2$. These ratios were obtained making use of ratios of raw counts of identified particles compared to those of charged particles in each p_T bin. This nuclear modification factor was calculated from the measured ratios between anti-protons and pions to changed particles for dAu and pp and applying these factors to the minimum bias nuclear modification factor for negatively charged hadrons[8]. No attempt was made to estimate the contributions from anti-lambda feed down to the anti-proton result. The remarkable difference between

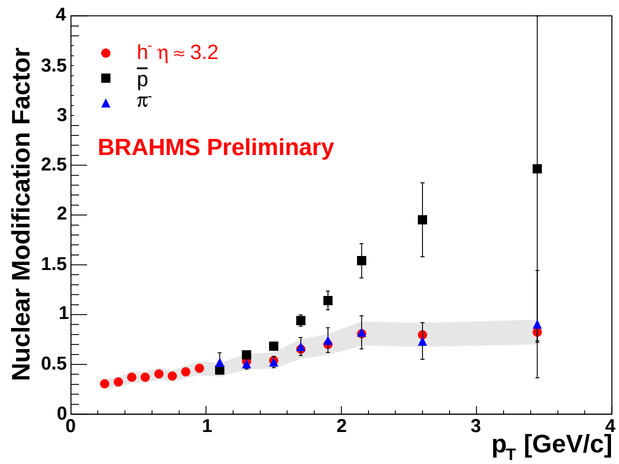

FIGURE 4. The nuclear modification factor R_{dAu} calculated for anti-protons (filled squares) and negative pions (filled triangles) at $\eta = 3.2$. The same ratio calcutated for negative particles is shown with filled circles, and the systematic error for that measurement is shown as grey band.

baryons and mesons has been related to parton recombination [9] for heavy ion reactions. It is though surprising that this effect in the dA system at forward rapidities where only a small soft parton component should be able to account for this increase.

In summary, particle production from dAu and pp collisions at $\sqrt{s_{NN}} = 200$ GeV and at different rapidities with the BRAHMS setup offers a window to the small-x components of the Au wave function. The suppression found in the particle production at high rapidities from d+Au collisions may be the first indication of the onset of saturation in the gluon distribution function of the Au target.

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REFERENCES

1. L.McLerran and R.Venugopalan,*Phys. Rev.* **D49** 1994, 2233.
2. J.Adamczyk et.al. *Nucl. Instr. Meth.* **A499** 2003, 437
3. I. Arsene *et al.* [BRAHMS Collaboration], *Phys. Rev. Lett.* **9**3, 2004, 242303
4. I. Arsene at.al. *Phys. Rev. Letter*, **94** 2005, 032301
5. D. Antreasyan et. al. *Phys. Rev.* **D19** 1979, 764
6. D. Kharzeev, Y. V. Kovchegov and K. Tuchin *Phys. Rev.* **D68**,2003, 094013 ; hep-ph/0307037;
7. G.J.Almer et.al *Z.Phys.***C33** 1986, 1
8. R. Debbe. proceedings CINPP05; nucl-ex/0506022
9. R. Hwa,C. .B .Yang and R. .J. Fries *Phys. Rev.* **C71** 2004, 024902
10. Jian-Wei Qiu and Ivan Vitev hep-ph/0410218; Ivan Vitev hep-ph/0506039.
11. B.Z. Kopeliovich *et al.* hep-ph/0501260.