Identified particle production in p+p and d+Au collisions at RHIC

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Abstract. The BRAHMS experiment at RHIC has measured the transverse momentum spectra of charged pions, kaons and (anti-)protons over a wide range of rapidity in d+Au and p+p collisions at $\sqrt{s_{NN}} = 200$ GeV. The nuclear modification factor R_{dAu} at forward rapidities shows a clear suppression for π^+. The measured net-proton yields in p+p collisions are compared to PYTHIA and HIJING/B and seem to prefer the latter.

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1. Introduction

Ultra-relativistic p+A collisions are used to understand the initial state effects in heavy-ion collisions, which may have produced deconfined nuclear matter [1]. By the measurement of hadrons produced in relativistic d+Au and p+p collisions over a wide range of rapidity, one can try to disentangle the modification of the parton distributions in nuclei (e.g. shadowing) and the change of p_T spectra of produced particles caused by initial and final state multiple scattering in cold nuclear matter (e.g. Cronin effect [2]) and thus constrain various dynamical evolution scenarios and initial conditions (e.g. Color Glass Condensate [3]).

Experimental data from d+Au collisions at RHIC from the BRAHMS, PHENIX and STAR Collaborations [4, 5, 6] has verified the prediction of the Cronin effect at mid-rapidity, i. e. the enhancement of intermediate-p_T hadrons in d+Au collisions as compared to p+p, which might be due to the initial state multiple parton scattering. When going to forward rapidity $\eta \sim 3.2$ the suppression of hadron spectra is consistent with predictions by the CGC model [7]. The Cronin enhancement at mid-rapidity and the high-p_T suppression at forward rapidity are characterized by the nuclear modification factor R_{dAu}, which is defined as a ratio of the invariant particle spectra from d+Au

† For a full author list and acknowledgments, see the appendix of this volume.

collisions to reference spectra in p+p collisions scaled by the average number of binary nucleon-nucleon collisions in d+Au ($< N_{coll} >$):

$$R_{dAu} = \frac{d^2N_{dAu}/2\pi p_T dy dp_T}{< N_{coll} > \times d^2N_{pp}/2\pi p_T dy dp_T}. \quad (1)$$

2. Analysis

BRAHMS (Broad Range Hadron Magnetic Spectrometers) has two rotatable magnetic spectrometers with particle identification capabilities for hadrons, which allow the study of particle production in a broad range of both transverse momenta and rapidities.

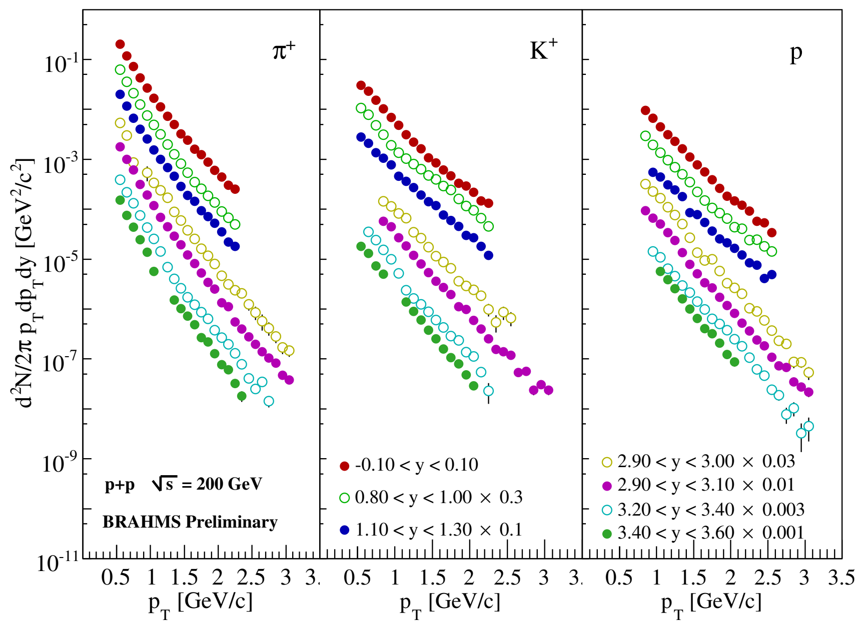

Figure 1. Invariant p_T spectra of identified particles at different rapidities (from 0 to 3.5) in p+p collisions at $\sqrt{s} = 200$ GeV. Only the spectra of positive particles are shown. Spectra at different rapidities are scaled for clarity.

BRAHMS uses the Time-of-Flight (TOF) technique in the mid-rapidity spectrometer (MRS) and the Forward Spectrometer (FS) and a Ring Imaging Čerenkov (RICH) detector at the back of the FS for the identification of particles with high momentum. In this analysis pions and kaons are separated up to 1.8 GeV/c in momentum by the TOF in the MRS, and the separation of pions and kaons in the FS has been extended up to 25-30 GeV/c by RICH. Details on the BRAHMS detector system can be found in [8, 9].

Settings at different magnetic fields in both MRS and FS spectrometers were combined and each setting has been corrected for the spectrometer acceptance, tracking and PID efficiencies, in-flight decay, absorption and multiple scattering. Weak decays and feed-down corrections for protons and antiprotons have not been implemented. After each setting has been corrected, all settings were combined and normalized by the number of events. The resulting invariant spectra in p+p collisions at different rapidities are shown in Figure 1. The invariant transverse momentum spectra in d+Au collisions at different centralities have already been shown in [10].

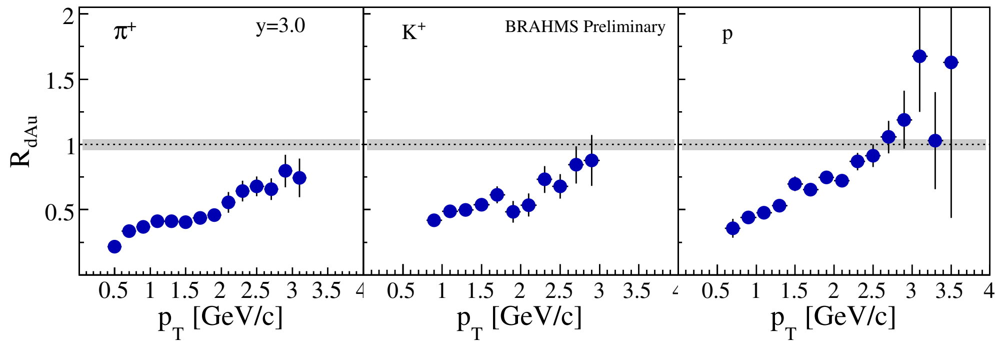

Figure 2. R_{dAu} of π^+, K^+ and protons at forward rapidity $y = 3.0$ in minimum bias d+Au collisions ($N_{coll} = 7.2$). A 8% systematic error is included.

3. Nuclear modifaction factor

The nuclear modification factor (Figure 2) for identified particles at forward rapidity in minimum bias d+Au collisions was constructed using $< N_{coll} >= 7.2$. A clear suppression for π^+ is observed and R_{dAu} reaches $\sim$ 0.7 at $p_T \sim$ 2.5 GeV/c. The suppression of π^+ is even stronger than that for negative hadrons h^- where negative pions are the main contribution [4]. This difference between positive and negative pions could be due to isospin effects in p+p collisions at forward rapidity [11]. Kaons show a similar suppression while protons cross $R_{dAu} = 1$ (no suppression) at $p_T \sim$ 2.5 GeV/c.

4. Stopping

The rapidity dependence of the net-proton yield in d+Au and p+p collisions may shed light on the stopping and baryon number transport process in nuclear collisions. The net-proton transverse momentum spectra are constructed by subtracting the antiproton spectra from the proton spectra p_T-bin-by-p_T-bin. Due to our limited acceptance at low transverse momenta (see Fig. 1), the yields at low p_T have to be determined by fitting the data to a fit-function and extrapolating the function to low p_T. Within our acceptance both a Boltzmann function and an exponential in p_T describe the data equally well. Therefore, both function were used for the extrapolation which results in a lower (Boltzmann) and upper (exponential in p_T) limit for the integrated yield. The functions were extrapolated to the low p_T region to calculate the integrated yield at low p_T, which was then combined with the yield calculated from data by summing up the p_T-bins in order to obtain the total net-proton rapidity density over the full p_T range.

Figure 3 shows the net-proton rapidity distribution in p+p collisons at 200 GeV and a comparison to PYTHIA [12] and the HIJING model with baryon junction [13] including single diffractive processes. The squares are the results of a Boltzmann extrapolation, while the dots represent those from an exponential function in p_T.

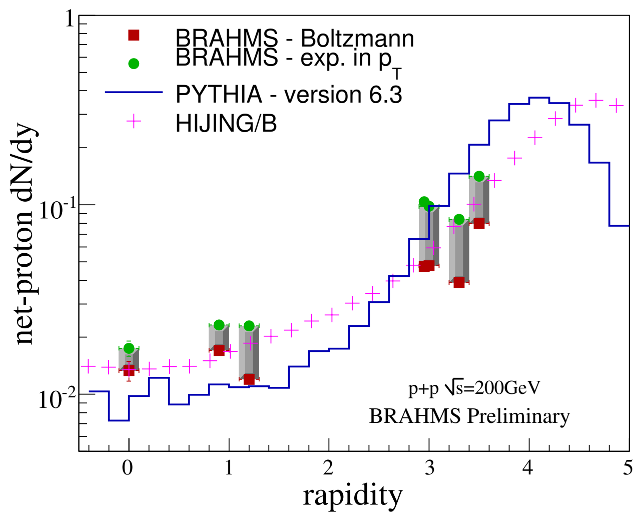

Figure 3. Net-proton rapidity density in p+p collisions. The squares are the net-proton yields obtained by using a Boltzmann function, and the dots are those obtained using an exponential function in p_T. The gray boxes between the two sets of extrapolations indicate the range of solutions which cannot be distinguished by our data.

The region around mid-rapidity (between 0 and 1) is almost baryon-free, while a large net-proton density is observed at forward rapidity (around 3). Even though we have an uncertainty of about 50% due to the extrapolation procedure HIJING/B's estimate is closer to our data, while PYTHIA's is systematically lower at mid-rapidity and higher at forward.

References

[1] Heinz U 2003 *Nucl. Phys.* A **721** 30

[2] Cronin J W, Frisch H J, Schochet M J *et al* 1975 *Phys. Rev.* D **11** 3105;
Antreasyan D, Cronin J W, Frisch H J *et al* 1979 *Phys. Rev.* D **19** 764

[3] McLerran L ,Venugopalan R 1994 *Phys. Rev.* D **49**2233; 1999 *Phys. Rev.* D **59** 094002

[4] Arsene I *et al* (the BRAHMS Collaboration) 2004 *Phys. Rev. Lett.* **93** 242303

[5] Adler S *et al* (the PHENIX Collaboration) 2003 *Phys. Rev. Lett.* **91** 072303

[6] Adams J *et al* (the STAR Collaboration) 2003 *Phys. Rev. Lett.* **91** 072304

[7] Kharzeev D, Kovchegov Y, and Tuchin K 2003 *Phys. Rev.* D **68** 094013

[8] Adamczyk M *et al* (the BRAHMS Collaboration) 2003 *Nucl Inst Meth* A **499** 437

[9] Debbe R, Jorgensen C E, Olness J, Yin Z 2007 *Nucl Instr Meth* A **570** 216

[10] Yang H (for the BRAHMS Collaboration) 2006 *Proc. (Poster Session) 18th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions (Budapest, Hungary, 4-9 August 2005) Rom. Rep. Phys.* **58-1** 5

[11] Bearden I G *et al* (the BRAHMS Collaboration) 2005 *Phys. Lett.* **607** 42

[12] Sjostrand T, Eden P, Friberg C *et al* 2001 *Comput. Phys. Commun.* **135** 238

[13] Vance S E, Gyulassy M, Wang X N 1998 *Phys. Lett.* B **443** 45