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 rapidity distribution of charged pions, kaons and (anti-)protons in d+Au and p+p collisions at $\sqrt{s_{NN}} = 200GeV$. The transverse momentum spectra of of identified particles at different rapidity will be presented. The nuclear modification factor R_{dAu} at the forward rapidities, i. e. y=3.0, for identified particles shows a suppression for π^+, while a significant enhancement for protons at intermediate p_T. The measured net-proton yields (stopping) in p+p collisions are compared to models.

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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 the deconfined nuclear matter, the so called quark-gluon plasma (QGP) in laboratory [1]. By the measurement of hadrons produced in the relativistic d+Au and p+p collisions over a wide range of rapidity, one can constrain various dynamical evolution pictures and initial conditions, and disentangle the nuclear modification of the parton distributions in nuclei and change of p_T spectra of produced particles caused by initial and final state multiple scattering in the cold nuclei.

Experimental data in d+Au collisions at RHIC from BRAHMS, PHENIX and STAR Collaborations [2, 3, 4] has verified the prediction of Cronin effect at mid-rapidity, i. e. nuclear enhancement of intermediate-p_T hadrons, which might correspond to the initial state multiple parton interactions. When going to forward rapidity $\eta \sim 3.2$, the suppression of hadron spectra was consistent with the predictions made by the CGC model [5]. This Cronin enhancement at mid-rapidity and high-p_T suppression at forward rapidity are characterized by means of the nuclear modification factor R_{dAu}, which is defined as a ratio of the invariant particle spectra from d+Au collisions to

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a reference spectra in p+p collisions scaled by the average number of binary nucleon-nucleon collisions in the d+Au collisions N_{coll}:

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

It is interesting to study the identified particles at forward rapidity in d+Au collision at RHIC energy, because of the different production mechanism of baryons and mesons at smaller x. It is also interesting to investigate the rapidity dependence of the net-proton yield in the d+Au and p+p system in order to understand the stopping and transparency scenarios in heavy ion collisions better.

2. Analysis and results

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

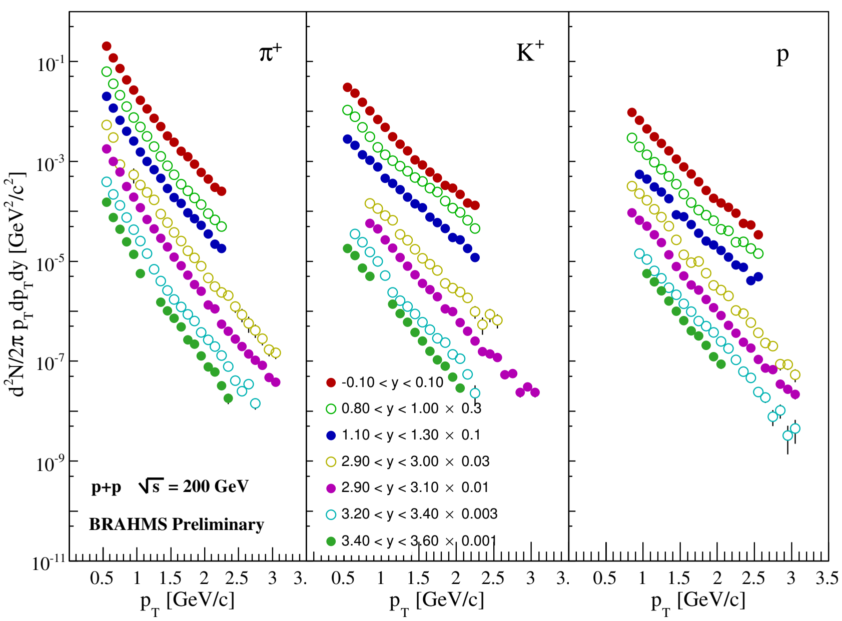

Figure 1. Left: Invariant p_T spectra of identified particles at different rapidities in p+p collisions at $\sqrt{s} = 200\ GeV$. Here, only the spectra of positive particles are shown. From up to down, rapidity y centers vary from 0 to 3.5, and spectra are scaled by certain factors for clarity.

BRAHMS uses the Time-of-Flight (TOF) technique in mid-rapidity spectrometer (MRS) and 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 [6].

In order to obtain a wider rapidity and transverse momentum coverage in the spectra, settings at different magnetic fields in both MRS and FS spectrometers are combined. In this analysis, each setting has been corrected for the spectrometer acceptance, tracking and PID efficiencies, in-flight decay and multiple scattering. After each setting is corrected, all settings are combined and normalized by the number of events. The resulting invariant spectra in p+p collisions at both mid-rapidity and forward rapidity are shown in Figure 1. The spectra have been scaled by different constant factor for comparison. The invariant transverse momentum spectra in d+Au collisions at different centralities have been shown in [7]. The nuclear modification

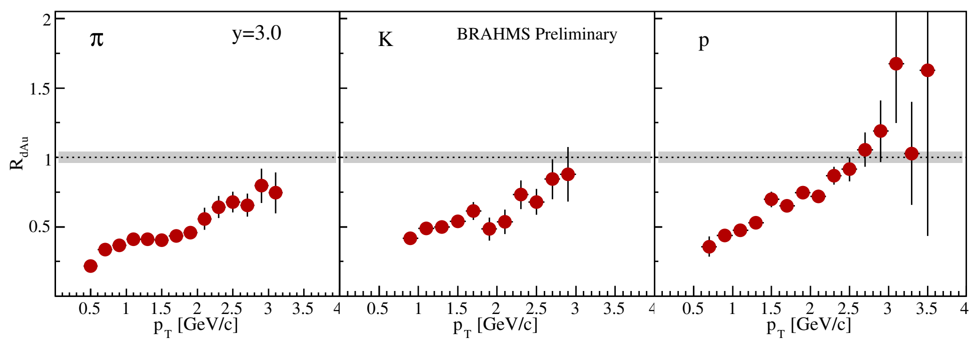

Figure 2. R_{d+Au} of identified π^+, K^+ and protons at forward rapidity $y = 3.0$ in minimum bias d+Au collisions, where $N_{coll} = 7.2$. A 8% systematic error is included.

factor of identified particles at the most forward rapidity $y = 3.0$ for the minimum bias d+Au collisions was constructed using $N_{coll} = 7.2$. (See Figure 2.) It provides us a good probe to study partons at smaller x scales. The suppression for π^+ was seen, it saturates at $\sim$ 0.65 at higher p_T, which confirms the suppression of negative hadrons at forward rapidity [2]. The suppression of π^+ is even lower than that for negative hadrons h^-, in which negative pions are the main source. The excess of π^-s over π^+s could be due to the isospin effect in p+p collisions. For protons, no suppression is seen, on the contrary, there is an enhancement at $p_T \sim 3.0\ GeV/c$.

Rapidity densities dN/dy for identified particles are obtained by integrating the particle spectra over the full p_T range at a certain rapidity range using power-law (for pions), exponential (in m_T for kaons) and Boltzmann fit-functions (for protons). Using a similar mechanism, we extract the net-proton rapidity density by fitting the net-proton spectra, namely subtracting spectra of $\bar{p}$ from that of protons, by a fit function. The function was extrapolated to the lower p_T region to calculate the integrated yield at low p_T, which was combined with the yield calculated from data to obtain the total net-proton yield over the full p_T range. Figure 3 shows the net-proton rapidity in p+p collisons at 200 GeV, and a comparison to the net-proton production by PYTHIA [8] and the HIJING model with baryon junction [9]. The red squares are the results when a Boltzmann function was used, while the green dots represent that from an exponential function in p_T. The calculated net-proton yield could be affected when different fit function was used to extrapolate to the lower p_T, in fact, a factor of ~ 1.5 difference was seen between the results from using these two functions, which may suggest different explanation at low p_T soft physics. The gray boxes between two sets of result from these two functions, just to show the upper and lower limit of yields, when different function was extrapolated to the low p_T range.

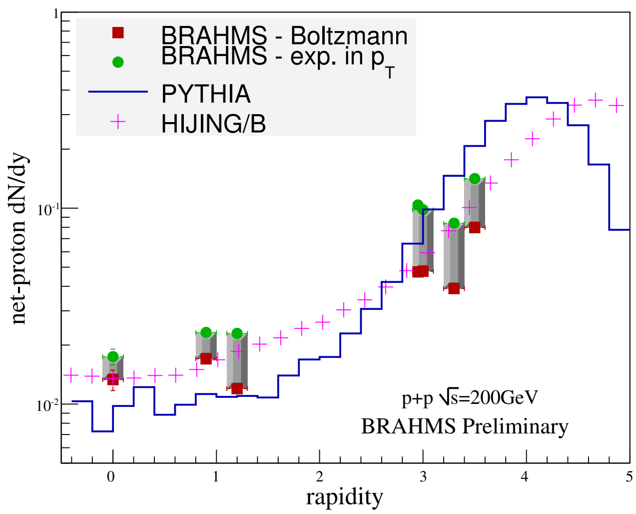

Figure 3. Net-proton rapidity density in p+p collisions. The red squares are the net-proton yield obtained by using a Boltzmann function to extrapolate to the lower p_T, and the green dots are the results obtained using an exponential in p_T function.

The region around mid-rapidity is almost baryon-free, while a large net-proton density was observed at the forward. Even we have seen a difference when different functions were used to extrapolate to the lower p_T, HIJING/B's estimate is still systematically closer to our data, while PYTHIA's are lower at mid-rapidity, and higher at the forward.

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