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Strangeness 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 $\sqrt{s_{NN}} = 200$ GeV. The transverse momentum spectra of $K^{\pm}$, $\pi^{\pm}$ and $p(\bar{p})$ at different rapidities will be presented. The rapidity dependence of particle ratios, such as like-particle ratios, K/π ratios and p/π ratios, in p+p collisions at $\sqrt{s_{NN}} = 200$ GeV is studied. The measured net-proton yields (stopping) are compared to models.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Ultra-relativistic heavy-ion collisions are a way to create a deconfined nuclear matter, the so-called quark–gluon plasma (QGP) in laboratory [1]. By the measurement of hadrons produced in the relativistic heavy-ion collisions over a wide range of rapidity, one can constrain various dynamical evolution pictures and initial conditions.

The high p_T hadron production in the most central Au+Au collisions at RHIC has suggested the creation of the new state of matter [2], while the d+Au collisions at RHIC are an ideal experimental method to study the initial conditions in relativistic heavy-ion collisions because the details of the system at initial stages which are carried over to the final state are almost unchanged [3, 4]. In other words, p+p and d+Au collisions provide an important system to study the initial-state effect since one does not expect the final-state interactions to play a dominant role in such a small system. It is also interesting to study the rapidity dependence of the identified hadrons including the net-proton yield in the d+Au and p+p system in order to better understand the high energy collision scenarios.

[1] A list of members of the BRAHMS Collaboration is given at the end of this issue.

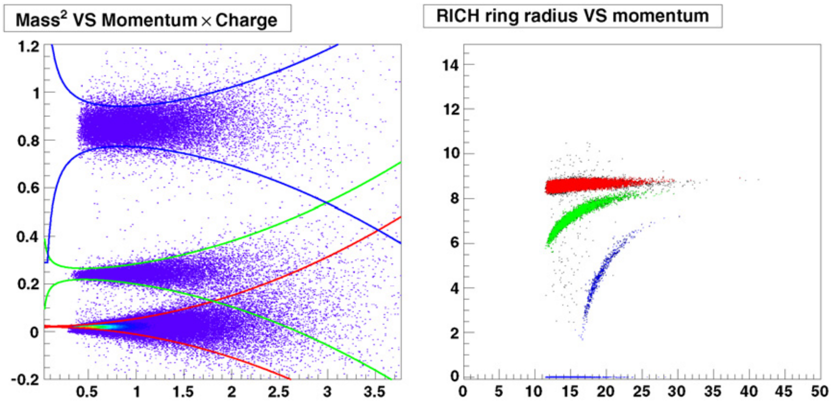

Figure 1. Particle identification at the MRS obtained by a 2σ cut on the m^2 versus $p \times$ charge resolution function (left panel). At the FS, a 3σ cut on the RICH ring radius versus momentum function (right panel), in which the red band stands for pions, green for kaons and blue for protons.

2. Analysis and results

BRAHMS (Broad Range Hadron Magnetic Spectrometers) is one of the four major detectors at RHIC and is located at the 2 o'clock experimental hall of the RHIC collider. It 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.

BRAHMS uses the time-of-flight (TOF) technique in the 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, pion and kaon separation is achieved up to 1.8 GeV/c in momentum by the TOF in the MRS, and the separation of pion and kaon in the FS has been extended up to 25–30 GeV/c by the RICH (see figure 1). Details on the BRAHMS detector system can be found in [5].

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 the left plot in figure 2. The spectra have been rescaled by different factors for comparison. The invariant transverse momentum spectra in d+Au collisions at different centralities have been shown in [6].

The right panel in figure 2 shows the dependence of the temperatures, which are extracted by fitting the spectra by an exponential function in m_T over a limited p_T range (0.5–1.5 GeV/c). We see a decreasing trend of the effective temperature from mid-rapidities to forward rapidities for all identified particles.

Rapidity densities dN/dy for identified particles are obtained by integrating the particle spectra over full p_T range at a certain rapidity range using power law, exponential (in m_T) and Boltzmann fit functions. Figure 3 shows the rapidity dependence of the like-particle ratios, K/π and p/π ratios in the p+p collisions, from the left to the right panel, respectively. From the like-particle ratios, we see that at mid-rapidity the difference between particles and their corresponding anti-particles is not very large, while at more forward rapidity the ratios

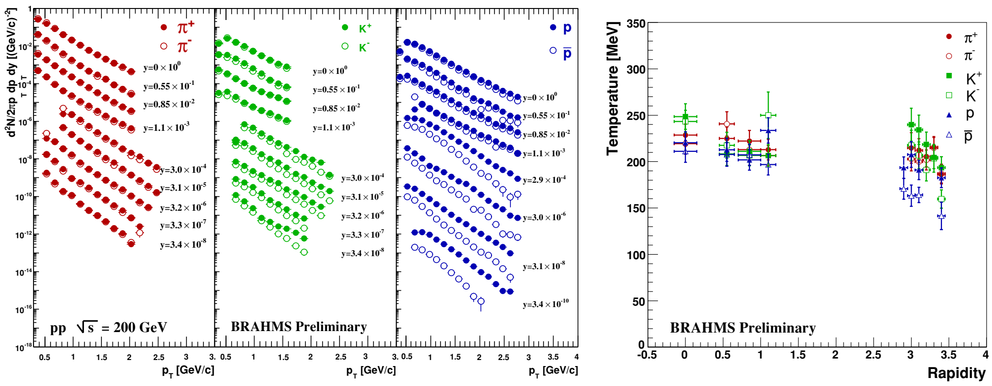

Figure 2. Left: invariant p_T spectra of identified particles at different rapidities in p+p collisions at $\sqrt{s} = 200$ GeV. Right: the effective temperature obtained from the fit versus rapidity in p+p, a 5% systematic error was included in the distribution.

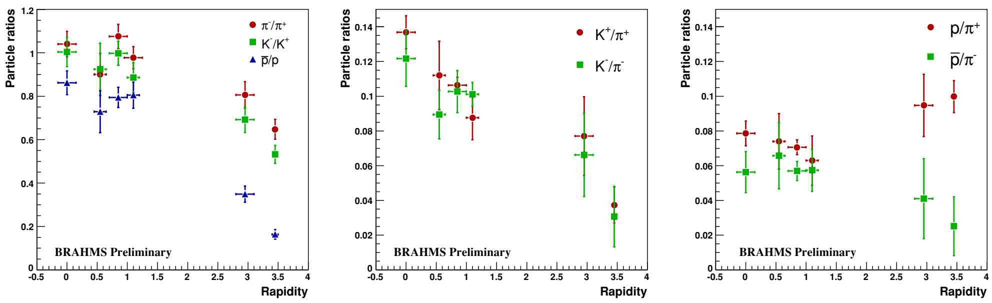

Figure 3. Left: rapidity dependence of like-particle ratios; middle: rapidity dependence of K/π ratio; right: rapidity dependence of p/π ratio. A 10% systematic error was included.

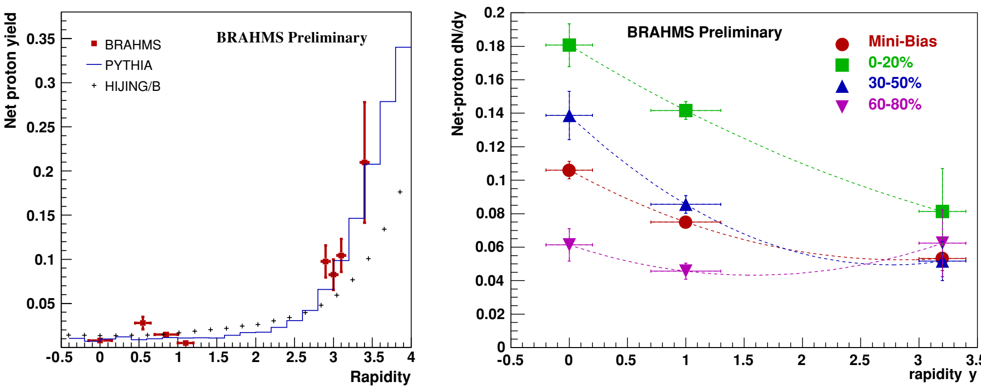

Figure 4. Net-proton production in p+p (left), d+Au (right) collisions at $\sqrt{s} = 200$ GeV. A 30% systematic error was included at the most forward rapidity in the p+p collision.

decrease, which means that at forward rapidities there is a large excess of particles over anti-particles in p+p collisions at RHIC energy. Especially, very low $\bar{p}$/p ratios at forward rapidity suggest a large net-proton production at forward rapidities. We have also observed that the p/π^+ ratios differ very much from $\bar{p}/\pi^-$ at forward rapidity, while not at mid-rapidities.

Figure 4 shows the net-proton rapidity in both systems. The comparison between the net-proton production in p+p collisions to the estimation by PYTHIA [7] and the HIJING model with baryon junction [8] was made, see the left panel. Obviously, the estimation by the PYTHIA model is closer to the net-proton yields at different rapidity, while HIJING/B underestimates the net-proton yields at forward rapidity.

On the other hand, from the centrality dependence of the net-proton distribution in d+Au collisions at different rapidities, we have observed that the net-proton yield decreases when going to forward rapidity from mid-rapidity in most central and semi-central collisions.

3. Summary

The p_T spectra for identified particles in p+p collisions at $\sqrt{s} = 200$ GeV at both mid-rapidity and forward rapidity were measured. The rapidity dependence of the like-particle ratios, K/π ratios and p/π ratios, shows a change in chemistry from mid-rapidity to forward rapidity. The region around mid-rapidity is almost baryon free, while a large net-proton density was observed at forward rapidity. The asymmetric net-proton rapidity distribution in central d+Au collisions can be understood as a strong contribution from the baryon source on the gold fragmentation side. Further study on the particle specie dependence of the nuclear modification factor in d+Au is underway.

Acknowledgments

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