# Rapidity dependent particle production in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV

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We present preliminary results for identified hadrons ($\pi^{\pm}$, $K^{\pm}$ and $p^{\pm}$) measured from Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV in BRAHMS experiment at RHIC. The results coming out of the collisions at this energy are an important consistency check between the lower energies (AGS, SPS) and RHIC full energies. Here we investigate the $p_T$ and rapidity dependence of the anti-particle to particle ratios and also of the strangeness ratios $K^{\pm}/\pi^{\pm}$. A comparison with the predictions of the statistical model is also made.

## 1 Introduction

This work presents identified particle spectra and ratios at the different rapidity ranges measured by the BRAHMS spectrometer. The data come from the most central 10% Au+Au collisions at $\sqrt{s_{NN}} = 62.4$GeV. The covered rapidity range starts from $y = 0$, where we use the Mid-Rapidity Spectrometer, up to $y \propto 3.5$ where the Forward Spectrometer can identify particles at the most forward angles.

The results from Au+Au collisions at $\sqrt{s_{NN}} = 62.4$GeV are of interest due to a large gap in energy between AGS-SPS and the RHIC energies. In particular, the particle ratios and their evolution with rapidity were studied in this work. It was seen that at $\sqrt{s_{NN}} = 200$GeV the anti-particle/particle ratios were 1 (for pions) and approaching 1 (kaons and protons). This leads to the conclusion that at mid-rapidity most of these particles were created through pair creation from an almost net-baryon free medium. Moving to higher rapidities, the kaon production depends on hadronic processes such as $p+p \rightarrow p+\Lambda+K^{+}$ which produce an excess of $K^{+}$. The $\bar{p}/p$ ratio also decreases as we move towards the fragmentation region. At $62.4$GeV, the like ratios have the same behaviour as for $200$GeV, but the values for $K^{-}/K^{+}$ and $\bar{p}/p$ at mid-rapidity are lower due to the higher net-proton content, and they fall off more quickly at forward rapidity than for the higher energy.

The $K^{-}/\pi^{-}$ ratio, both integrated over $4\pi$ and at mid-rapidity, shows a monotonous rise as a function of energy, while the $K^{+}/\pi^{+}$ ratio peaks sharply at lower SPS energies [5] and then falls off with increasing transparency of the reaction. An interesting question is whether there exists a correlation between the local, rapidity dependent $K/\pi$ ratios and the baryochemical potential, similar to the behaviour of the like-particle ratios. For the Au-Au $62.4$GeV run, with BRAHMS's setup we can cover a part of the Au fragmentation region where the $\bar{p}/p$ ratio approaches the values measured by the SPS experiments at mid-rapidity.

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## 2 Data analysis

The data used in this analysis were collected with the BRAHMS detector system [1]. The BRAHMS setup consists of two hadron spectrometers, a mid-rapidity arm (MRS) and a forward rapidity arm (FS), as well as a set of detectors for global event characterization.

Particle spectra were obtained by combining data from several spectrometer settings (magnetic field and angle), each of which covers a portion of the phase space $(y, p_T)$.

Tracking and momentum determination was done using time projection chambers (TPCs) and drift chambers (DCs) separated by dipole magnets. For particle identification we used time of flight and Cerenkov detectors. In the MRS arm we used the TOFW [1] to separate the particles. The $\pi/K$ separation goes well up to momenta of $\approx 2.0$GeV/c, while the $K/p$ separation extends to $\approx 3.0$GeV/c. In the forward arm we used two time of flight hodoscopes (H1 and H2) and a Ring Imaging Cerenkov detector (RICH) [1] which allows particle identification up to $\approx 30$GeV/c in full momenta.

The data were corrected for the limited acceptance of the spectrometers using a Monte-Carlo calculation simulating the geometry and tracking of the BRAHMS detector system [1]. Detector efficiency, multiple scattering, in-flight decay and hadronic absorption corrections have been estimated using similar techniques. The data were not corrected for feed-down from resonance and hyperon-decays. More details can be found in [1] and [2].

The measured $p_T$ spectra in different rapidity bins was fitted and integrated over the entire $p_T$ range in order to get the $dN/dy$ values. It was found that the pion spectra were well described at all rapidities by a power law function, $A(1 + p_T/p_0)^{-n}$, while the kaon and proton spectra was fitted by a Boltzmann distribution, $AE_T \mathrm{e}^{-\frac{E_T}{T}}$. The shapes of these spectra reflect the conditions of the medium and the different mechanisms responsible for the creation of each type of particle. The kaons and protons are more affected by the radial flow due to their higher masses and number of quarks (in the case of protons). Also, at low $p_T$ a large fraction of the pion yield comes from resonance decays. In Fig. 1, the spectra for identified particles at rapidities in the range $(0, 1.2)$ are shown. The top panels show the spectra for positive pions, kaons and protons while in the bottom panels the spectra for the negative partners are plotted.

## 3 Particle ratios

Fig. 2 shows the anti-particle/particle ratios as a function of $p_T$ which were obtained by dividing the $p_T$ spectra of the individual particles in a given rapidity slice. The top panels shows the ratios measured at $y \approx 0$ while the bottom panels shows the ratios around $y \approx 1$. Within the experimental errors the ratios are constant over the entire transverse momenta covered.

The rapidity dependence of the $\pi^-/\pi^+$, $K^-/K^+$ and $\bar{p}/p$ ratios can be determined by dividing the yields obtained from the integration of the $p_T$ spectra (see Fig. 3). A comparison with the $200$AGeV [3,4] results shows lower values of the kaon and proton ratios leading to the conclusion that, in the $62.4$AGeV nuclear collisions, the pair creation mechanism has smaller contribution to the particle production. At higher rapidities, the kaon and the proton ratio decrease, while the pion ratio remains constant.

For rapidity ranges where the kaon and pion data map overlaps, the $K/\pi$ ratios can be calculated. The $K^+/\pi^+$ and $K^-/\pi^-$ ratios (Fig. 4) both increase with transverse momentum.

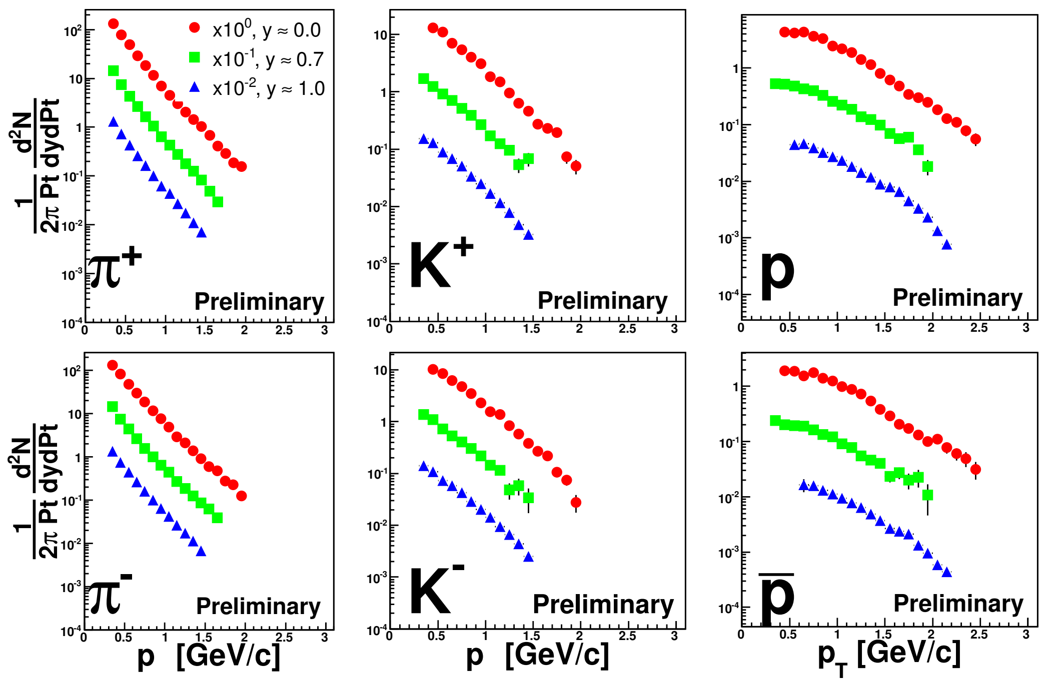


Fig. 1. Spectra for identified particles ($\pi^{+/-}$, $K^{+/-}$, $p^{+/-}$) at rapidities 0.0; 0.7 and 1.0. The distributions are scaled with a constant factor to be better viewed.

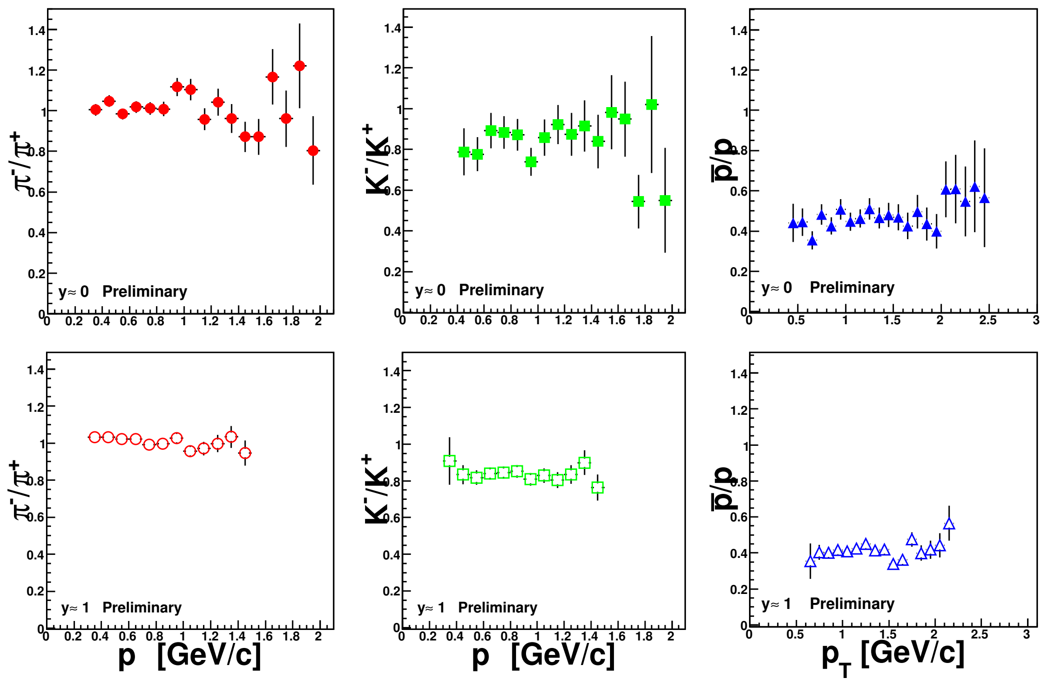


Fig. 2. $\pi^-/\pi^+$, $K^-/K^+$, $\bar{p}/p$ ratios vs. transverse momenta in two rapidity bins. Top: $y \approx 0$; Bottom: $y \approx 1$.

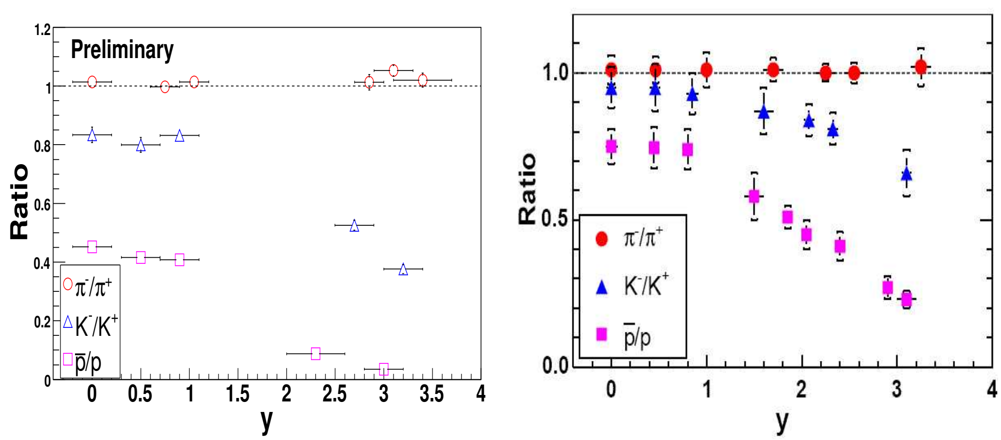


Fig. 3. $\pi^-/\pi^+$, $K^-/K^+$, $\bar{p}/p$ ratios vs. rapidity in Au+Au collisions. Left: $\sqrt{s_{NN}} = 62.4GeV$; Right: $\sqrt{s_{NN}} = 200GeV$.

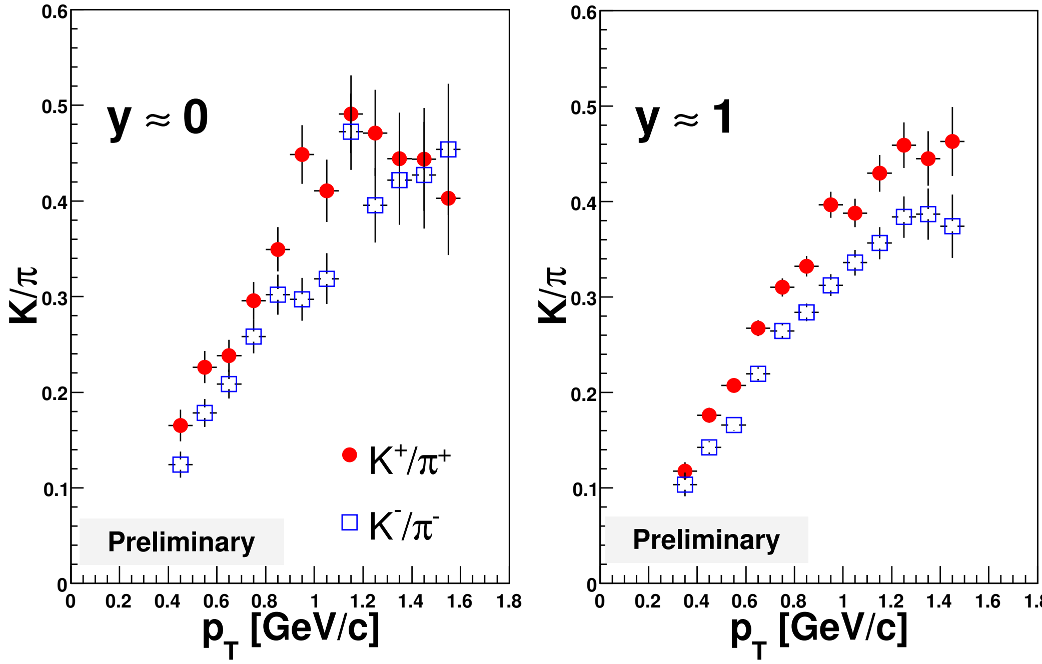


Fig. 4. $K^{\pm}/\pi^{\pm}$ ratios vs. transverse momenta. Left: $y \approx 0$; Right: $y \approx 1$.

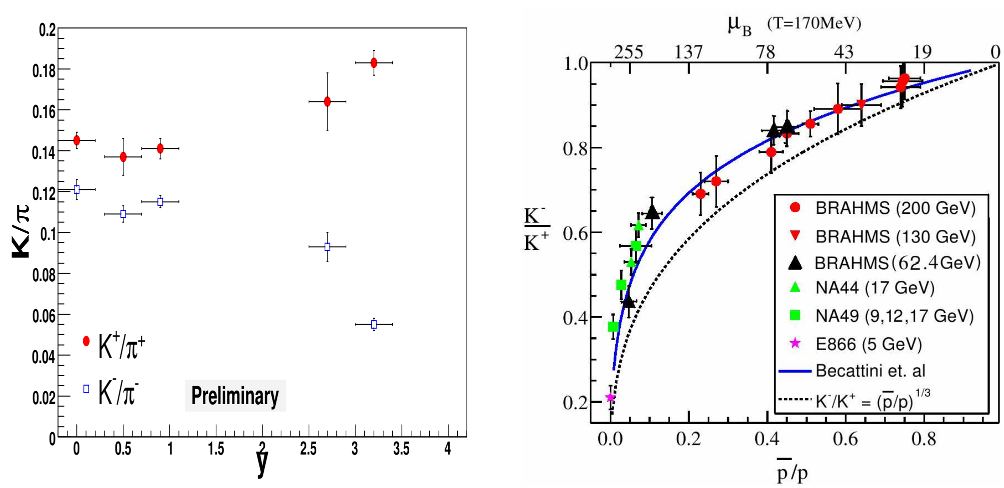


Fig. 5. Left: $K^{\pm}/\pi^{\pm}$ ratios vs. rapidity; Right: Correlation between $K^-/K^+$ and $\bar{p}/p$ ratios using data coming from a wide energy interval. The solid curve is a statistical model calculation with a chemical freeze-out temperature fixed to 170 MeV but allowing the baryo-chemical potential to vary [6].

However, the rapidity dependence of these ratios is different (see Fig. 5 left). At midrapidity the two ratios are about the same, while at forward rapidity the ratio of positive kaons and pions increases, while the corresponding ratio of negatives decreases. This may be explained by the high net-baryon content of this rapidity region which favours hadronic processes that leads to an excess of $K^+$ particles.

Fig. 5 right shows a correlation between $K^-/K^+$ and $\bar{p}/p$ ratios for various rapidities and energies at RHIC [4]. The data are for central collisions , and the figure displays similar ratios for heavy ion collisions at AGS and SPS energies [7]. The new points coming from Au+Au collisions at $\sqrt{s_{NN}} = 62.4$GeV are in striking agreement with the older NA44 and NA49 results coming from lower energies but having the same baryochemical potential. The solid curve is a statistical model calculation with a chemical freeze-out temperature fixed to 170 MeV but allowing the baryo-chemical potential to vary [6].

## 4 Discussions and Conclusions

We showed that the anti-particle to particle ratios in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV are constant around mid-rapidity. At higher rapidities, the $K^-/K^+$ and $\bar{p}/p$ ratios have a steeper decrease than the similar ratios at RHIC full energies, while the pion ratio remains 1 for the entire range of rapidity covered. These results are consistent with the ones obtained at higher RHIC energies. The strangeness ratios have little dependence on rapidity, in the mid-rapidity region. At forward rapidities the $K^+/\pi^+$ ratio is increasing while the negative ratio decreases steeply. This behaviour can be explained by the high net-baryon values which produce an asymmetry in the production of kaons. Finally, the correlation between $K^-/K^+$ and $\bar{p}/p$ ratios obtained in the present analysis is consistent with the data coming from RHIC's higher energies and also with the older AGS and SPS results.

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**References**


[1] BRAHMS Collaboration, M. Adamczyk et al.: *Nucl.Instr.Meth.* **A 499** (2003) 437

[2] D. Ouerdane, Ph.D thesis: *Copenhagen University* (2003)

[3] BRAHMS Collaboration, I. Arsene et al.: *Nucl.Phys.* **A 757** (2005) 1-27

[4] BRAHMS Collaboration, I.G. Bearden et al.: *Phys.Rev.Lett.* **90** (2003) 102301

[5] M.Gazdzicki: *J.Phys.G* **30** (2004) S701

[6] F. Becattini et al.: *Phys.Rev.* **C 64** (2001) 024901

[7] NA49 Collaboration, S.V.Afanasiev et al.: *Phys.Rev.* **C 66** (2002) 054902