Rapidity dependence of strange particle ratios and spectra at $\sqrt{s_{NN}} = 200GeV$ Au-Au collisions

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The BRAHMS collaboration has measured identified particle spectra and ratios for $\pi^{\pm}, K^{\pm}, p$ and $\bar{p}$ for Au-Au collisions at $\sqrt{s_{NN}} = 200GeV$. Charge conjugate ratios are measured as functions of centrality, transverse momentum and rapidity. K/π is also studied as a function of $\sqrt{s_{NN}}$. Rapidity densities are deduced from integrated spectra.

1. INTRODUCTION

The BRAHMS experiment at the Relativistic Heavy Ion Collider at BNL is a two-spectrometer experiment. It is designed to identify charged hadrons over a wide range in rapidity and transverse momentum. By measuring spectra and ratios at various rapidities, one may probe the dynamics of collisions between two ultra-relativistic nuclei [1,2].

Each spectrometer can rotate independently in the horizontal plane about the nominal interaction point, where a small region of phase space is covered for each angular and magnetic setting. The mid-rapidity spectrometer (MRS) covers large polar angles, i.e. $30° < \theta < 95°$ relative to the beam direction. The forward spectrometer (FS) can be operated in its full extent (FFS + BFS) at small polar angles of $2.3° < \theta < 15°$ and using only its front part (FFS) for $2.3° < \theta < 30°$. We may therefore perform consistency checks between the spectrometers at $\theta = 30°$. The total rapidity coverage thus amounts to $-0.1 < y < 4$ for pions and $-0.1 < y < 3.4$ for protons.

In addition the experimental setup includes global detectors for event characterization and start time for the Time-of-Flight detectors. The setup is described fully in [3].

2. METHOD

Particle identification in the MRS is done with the Time-of-Flight wall. In the FS the Time-of-Flight detectors identify the low momentum particles, while the Cherenkov detectors are used for the high momentum range [4–6].

Since the BRAHMS spectrometers can only measure in a narrow range in y and p_T at a given angular and magnetic setting, several settings are combined to give reasonable acceptance in p_T for building spectra for a given y. The presented results are extracted from the MRS at $90°, 45°$ and $40°$, and the FS at $12°, 8°, 4°$ and $3°$.

From Monte-Carlo simulations of the detector setup using GEANT3 [7] we calculate geometrical acceptance maps in y and p_T for each particle species. Since the interaction vertex distribution is fairly wide ($\sigma_z \approx 25cm$), we take into account the fact that different vertex bins populate slightly different areas of the total phase space. We therefore apply the geometrical acceptance corrections as functions of interaction vertex.

Detector and reconstruction efficiency, decay, production[1] and absorption corrections are applied subsequently before spectra are projected out.

3. SPECTRA

Normalized p_T and m_T spectra are derived from the (y, p_T) and (y, m_T) distributions, respectively. Figure 1 shows measured p_T spectra at two selected rapidities. At mid-rapidity the spectra of positive particles are very similar to their negative counterparts, especially for pions and kaons. Fitting the m_T spectra with exponentials of the form $Ae^{-(m_T-m_0)/T}$ the inverse slope parameter increases from $\pi^\pm$ via $K^\pm$ to p and $\bar{p}$.

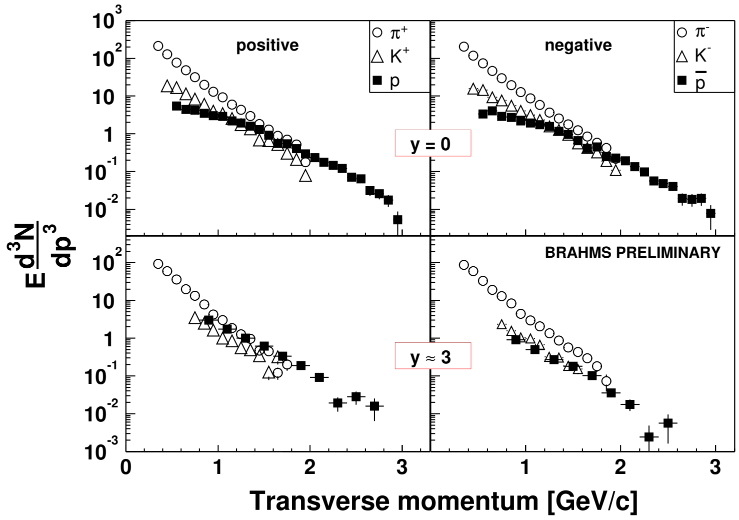

Figure 1. *Transverse momentum spectra from the 10% most central collisions for $\pi^\pm, K^\pm, p$ and $\bar{p}$. Positive particles are in the left panels, negatives in the right ones. The upper panels are spectra from rapidity $y = 0$ and the lower ones from $y \approx 3$.*

For the higher rapidity the spectra of charge conjugate particles differ clearly, except for $\pi^\pm$. The yields of both protons and positive kaons are higher than their negative counterparts within our p_T acceptance.

Also worth noting is the relative contribution between pions and (anti-)protons. At mid-rapidity the p and $\bar{p}$ start to dominate over $\pi^\pm$ around $p_T \approx 2GeV/c$, similar to what was observed at $\sqrt{s_{NN}} = 130GeV$ [10]. For rapidity $y \approx 3$, however, p dominate over π^+ already at $p_T \approx 1.2 - 1.4GeV/c$, while the $\bar{p}$ are below π^- within the entire region of acceptance.

Comparing the two rapidities above we find that the inverse slope parameters for $\pi^\pm$ and $K^\pm$ decrease $6 - 13\%$ when going from $y = 0$ to $y \approx 3$. The inverse slopes for p and $\bar{p}$ decrease about 27% [6].

4. RATIOS

Using measured results of Λ/p, $\bar{\Lambda}/\bar{p}$ and $\bar{\Lambda}/\Lambda$ at $\sqrt{s_{NN}} = 130GeV$, presented by PHENIX [8] and STAR [9], in GEANT3 simulations we find that hyperon decay corrections change the presented $\bar{p}/p$ less than 5%.

Evaluating the charge conjugate ratios, our results are consistent with no dependence on p_T or centrality. This we find both for $y = 0$ and $y \approx 2$ [4].

[1]We correct for secondary protons produced from pions hitting the Be beam pipe.

We find, however, strong dependence of the ratios on rapidity, as shown in Fig. 2. Throughout our acceptance in y, π^-/π^+ is consistent with unity. The K^-/K^+ and $\bar{p}/p$ ratios both show little variation for $|y| < 1$ and a subsequent decrease toward high rapidity. K^-/K^+ decreases from 0.95 ± 0.05 at $y = 0$ to 0.67 ± 0.06 at $y = 3.05$, while $\bar{p}/p$ decreases from 0.75 ± 0.04 at $y = 0$ to 0.23 ± 0.03 at $y = 3.1$. Comparing $\bar{p}/p$ at $y = 0$ to Au-Au collisions at $\sqrt{s_{NN}} = 130 GeV$ we find an increase of 17% [11–13].

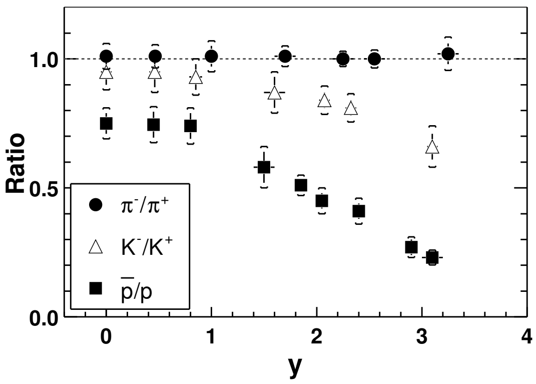

Figure 2. *Charge conjugate ratios as function of rapidity. Statistical errors are indicated with vertical bars and statistical+systematical by caps on the data points.*

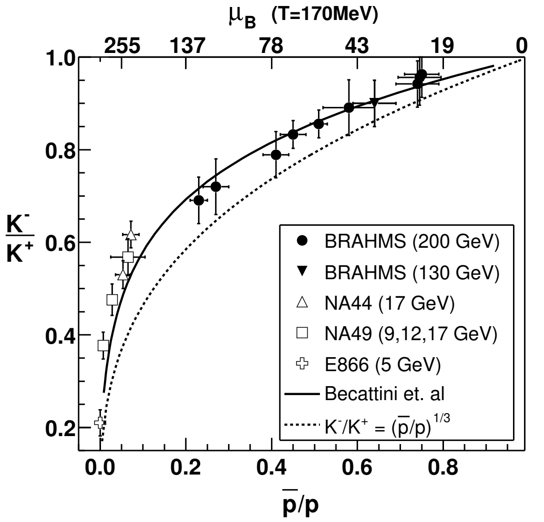

Figure 3. *K^-/K^+ vs $\bar{p}/p$. Error bars are statistical+systematical errors. Note that kaons and (anti-)protons are measured at somewhat different rapidities.*

In Fig. 3 we show the correlation of the K^-/K^+ ratio with $\bar{p}/p$ and a comparison to thermal model calculations [14]. Since K^-/K^+ is measured at a somewhat different rapidity than $\bar{p}/p$, the kaon ratio is interpolated to the (anti-)proton rapidity.

We find that the dependence of K^-/K^+ on $\bar{p}/p$ is well described by statistical model calculations. What makes this particularly noteworthy is that BRAHMS' measured ratios are from the entire acceptance in rapidity, thus probing different parts of the reaction zone with widely different baryonic chemical potentials.

Figure 4 shows rapidity density for pions and kaons as function of rapidity. The data points are obtained from exponential fits of m_T spectra. The dominant errors here are systematical, between 15% and 20%. Its main contribution comes from extrapolations at low m_T.

The densities of positive and negative pions depend on y in the same manner, decreasing by a factor of 2 from mid-rapidity to $y \approx 3$. Consistent with Fig. 2, positive and negative kaons occur with similar densities at mid-rapidity. Going to higher rapidities, however, K^- decreases markedly more than K^+. This appears consistent with the behavior of anti-proton and proton densities, respectively [15].

Plotting positive and negative K/π as function of $\sqrt{s_{NN}}$ the BRAHMS results in Fig. 5 fit into the trend obtained at lower energies. At mid-rapidity K^-/π^- continues to increase with increasing $\sqrt{s_{NN}}$, while K^+/π^+ manifests its picture of saturation within uncertainty. K^-/π^- at $\sqrt{s_{NN}} = 200 GeV$ and $y \approx 3$ differs significantly from its mid-rapidity value,

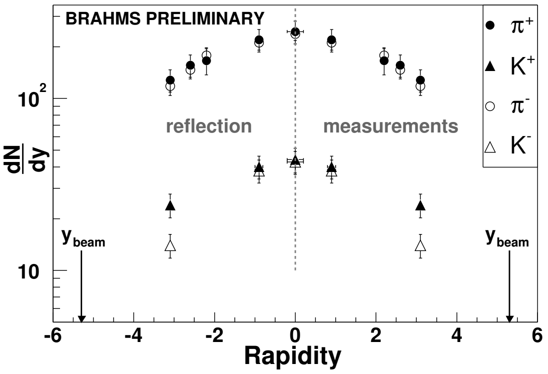

Figure 4. *Rapidity density for pions and kaons. Note that BRAHMS measures only for $y \geq 0$.*

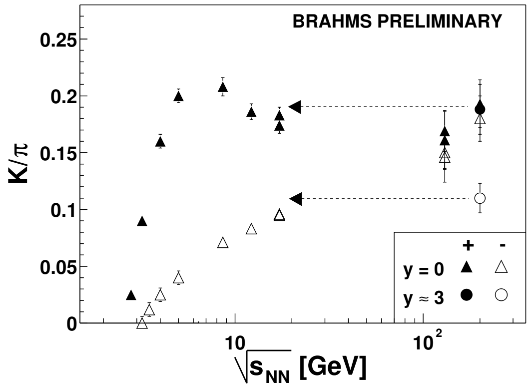

Figure 5. *Positive and negative K/π as function of $\sqrt{s_{NN}}$. Data points at $\sqrt{s_{NN}} < 20GeV$ are from E802, E866, NA44, N49. $\sqrt{s_{NN}} = 130GeV$ points are from PHENIX and STAR.*

and combined with K^+/π^+ at $y \approx 3$ they could possibly point to similar conditions as at SPS energies.

5. CONCLUSION

The BRAHMS experiment has measured rapidity spectra for kaons and pions. The measured distributions have Gaussian-like shapes. We have also deduced K^-/K^+ and $\bar{p}/p$ which both have a broad peak at mid-rapidity and a following decrease toward higher rapidities. The correlation between charge conjugate ratios for kaons and protons follow expectations from statistical models over the entire acceptance in rapidity. Positive and negative K/π at high rapidity point to similar conditions met at SPS energies.

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