

Rapidity dependent K/π ratios in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV

I.C.Arsene[‡] for BRAHMS collaboration

Department of Physics, University of Oslo, Norway

E-mail: i.c.arsene@fys.uio.no

Abstract. We report on measurements of identified particle yields from Au-Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV made with the BRAHMS spectrometer. Here we will concentrate on the charged K/π ratios as function of rapidity and baryo-chemical potential. We find that the K/π ratios measured at different rapidities in the analysed dataset have a common dependence with the same ratios measured in mid-rapidity at SPS energies when plotted as function of the \bar{p}/p ratio. The theoretical models used for comparison, UrQMD and AMPT, give a reasonable description of the particle yields at mid-rapidity but fail to do so for the K/π ratios at forward rapidity.

The strange particle production in nucleus-nucleus and nucleon-nucleon collisions has been studied extensively. Experimentally, at AGS energies it has been observed that the strangeness ratio (*i.e.* the number of strange particles divided by the number of pions) sharply increases with the beam energy in A-A collisions [1]. In the SPS experiments [2] the strangeness ratio reached a maximum value at $E_{LAB} = 30A$ GeV and continued with a very weak dependence on beam energy up to the highest RHIC energy. It has been also observed that the strangeness ratio increases with the size of the colliding system [3]. At AGS energies, the strangeness enhancement in A-A collisions was explained phenomenologically by cascade models from rescatterings with heavy baryon resonances. The saturation of the strangeness ratio seen at the SPS experiments and later at RHIC was interpreted by some [4] as a signal of the transition to a deconfined state of nuclear matter.

The K^+/π^+ and K^-/π^- ratios have a slightly different excitation function than the strangeness ratio. At AGS and lower SPS energies, the K^+/π^+ ratio at mid-rapidity is approximately proportional to the strangeness ratio but at $E_{LAB} = 30A$ GeV exhibits a "horn"-like shape and decreases slowly with increasing collision energy. The overall behaviour has been accounted for by effects like isospin, increasing yields of (anti)strange baryons which get an increasing with energy share of the strange quarks created in the collision [5], transition from baryon to meson dominated matter and possibly a phase transition.

The BRAHMS [8, 9] experiment consists of two rotatable spectrometer arms for particle identification and momenta measurement. It contains also a set of global

[‡] Also at Institute for Space Sciences, Bucharest, Romania

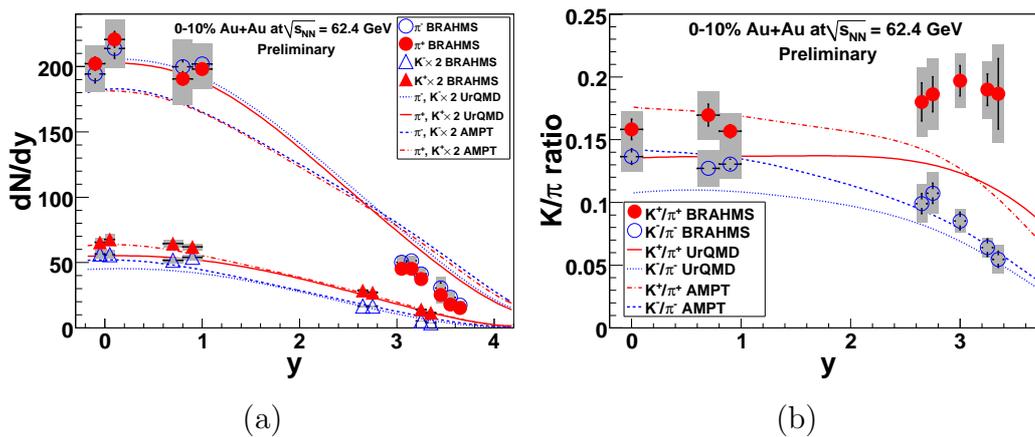


Figure 1. Left: Rapidity density for charged pions and kaons in 0-10% Au+Au collisions as a function of rapidity. Right: K/π ratios as a function of rapidity. The data points in both figures are BRAHMS measurements. The error bars are statistical and the shaded rectangles are systematic errors from the yield extrapolation. The curves are UrQMD [6] and AMPT [7] model calculations. The solid curves denote the K^+ , π^+ yields and K^+/π^+ ratio while the dotted curve stands for the K^- , π^- yields and K^-/π^- ratio obtained with UrQMD. The dot-dashed line represents the K^+ , π^+ yields and K^+/π^+ ratio and the dashed line represents the K^- , π^- yields and K^-/π^- ratio obtained with AMPT.

detectors for bulk event characterization. BRAHMS has a very wide phase space coverage with very good particle identification. In the $\sqrt{s_{NN}} = 62.4$ GeV dataset BRAHMS identified charged particles up to rapidity 3.4 which is less than one rapidity unit away from the beam. The π/K separation can be made up to $p \approx 2.5$ GeV/ c near mid-rapidity and $p \approx 20$ GeV/ c at $y > 2$. The protons are well identified up to $p \approx 3.0$ GeV/ c near mid-rapidity and $p \approx 30$ GeV/ c at $y > 2$.

The spectra were corrected for tracking and PID efficiencies, acceptance, in-flight weak decays, multiple scattering and hadronic interactions. The invariant p_T spectra was extracted in different rapidity windows and fitted with several theoretically motivated functions in order to extract the integrated yields. The charged pion spectra was fitted best with a power law function $A(1 + p_T/p_0)^{-B}$ at mid-rapidity and with an m_T exponential function $A \exp(-m_T/T)$ at forward rapidity $y \geq 3.0$. The kaon and proton spectra were fitted equally well with the m_T exponential function and with an m_T Boltzmann distribution over the entire rapidity range [10]. The resulting p_T integrated yields are shown in Fig.1(a) as a function of rapidity and includes the systematic errors that in part comes from the extrapolations to low p_T . The data are compared to the predictions of two microscopic models, UrQMD v2.2 [6] and AMPT v1.11 [7]. Both of the models include a partonic initial stage followed by a Lund-type string fragmentation and hadronic rescatterings. At mid-rapidity there is some disagreement between models but at forward rapidity it looks like the models converge. Both of the models overestimate the measured pionic yields at forward rapidity while they describe the kaon yield within errors.

In Fig.1(b) we show the K/π ratios dependence on rapidity. The ratios are obtained by dividing the kaon and pion p_T integrated yields. Because the phase space covered by the two species is quite different at forward rapidity, for the points at $y \approx 2.7$ and $y = 3.0$ we used linear interpolation to calculate the pion and kaon yields respectively. We observe that the K^-/π^- ratio drops from a value of ≈ 0.13 at mid-rapidity to ≈ 0.05 at $y = 3.3$ while the corresponding positive ratio exhibits a slow increase from $K^+/\pi^+ \approx 0.16$ at $y = 0$ to a value of ≈ 0.2 at $y = 3$. Both UrQMD and AMPT models describe the rapidity behaviour of the K^-/π^- ratio but fail to do so for the K^+/π^+ ratio.

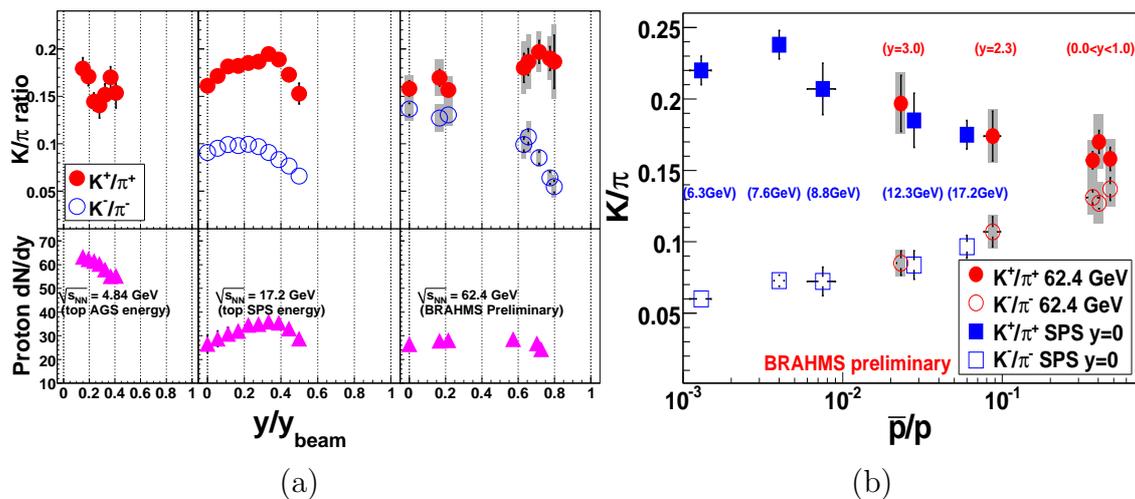


Figure 2. Left: K/π ratios and proton densities from central A+A collisions as a function of the normalized rapidity. The solid circles are for the K^+/π^+ ratio and the open circles for the K^-/π^- ratio. Right: K/π ratios dependence on the \bar{p}/p ratio in central A+A collisions from SPS [2] and RHIC measurements. The solid and open symbols are the K^+/π^+ and K^-/π^- ratios, respectively. The squares are for the ratios measured at mid-rapidity in SPS experiments at (from left to right) $\sqrt{s_{NN}} = 6.3, 7.6, 8.8, 12.3$ and 17.2 GeV. The circles denote the points measured by BRAHMS at $\sqrt{s_{NN}} = 62.4$ GeV at different rapidities.

In Fig.2(a) and (b) we show a comparison of our K/π ratios measurements with the lower energy data. The first row of Fig.2(a) shows the rapidity dependence of the K/π ratios (left to right) at top AGS energy [3, 11], top SPS energy [12] and BRAHMS at 62.4 GeV [13]. On the second row we show the corresponding proton density distributions. In all the three situations we observe that the K^+/π^+ ratios are enhanced compared to the ones measured in p+p or p+A experiments [14, 15]. The enhanced production of strange kaons at AGS is believed to be the effect of additional scatterings of bound hadrons during the collision, *e.g.* $\pi + N \rightarrow K^+ + \Lambda$. The corresponding anti-particle channel which creates K^- and $\bar{\Lambda}$ gives a much smaller contribution because of the very small anti-nucleon densities. From SPS towards RHIC energies we observe a transition from baryon to meson dominated matter together with the appearance of collision transparency. However, there is no sizeable change in the values of the K^+/π^+

ratios at mid-rapidity. The large strangeness ratios measured at SPS energies were interpreted as one of the signals to the formation of quark-gluon plasma. From the SPS data at $E_{LAB} = 158$ GeV/c (see middle row in Fig.2(a)) we observe a correlation in the behaviour of the K^+/π^+ ratio with the proton rapidity density. At $y \approx 1.2$, where the proton density has a maximum, the K^+/π^+ peaks as well and this might be due partly to the same hadronic channels which created extra strangeness at lower AGS energies. At $\sqrt{s_{NN}} = 62.4$ GeV kaons and pions are measured up to $y \approx 3.4$ which is very close to the beam rapidity ($y_{beam} \approx 4.2$). The K^+/π^+ ratio is 0.16 at mid-rapidity and grows to a value of approximately 0.2 at rapidity $y \approx 3$ where the fragmentation peak is located.

In Fig.2(b) we show the dependence of the K/π ratios with the \bar{p}/p ratio. There is a common dependence of the K/π ratios with the \bar{p}/p ratio, whether measured for different energies at mid-rapidity at SPS, or at different rapidities at 62.4 GeV. The K^-/K^+ ratio exhibits a similar feature. Also the pionic and protonic yields in the range where the baryo-chemical potential from RHIC and SPS overlap are approximately the same. This suggests that the local system formed at high rapidity at RHIC (62.4 GeV) is chemically equivalent with the system formed at SPS at mid-rapidity.

In this work we presented experimental results from the most central 10% Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV measured in the BRAHMS experiment. The rapidity dependence of the K^+/π^+ ratio shows higher values at forward rapidity than at mid-rapidity which is in contradiction with the expectations of the UrQMD and AMPT microscopic transport models. We showed that there is a common dependence of the K/π and K^-/K^+ ratios with the \bar{p}/p ratio when looking at SPS results in mid-rapidity together with our results from different rapidity slices. The nuclear mediums formed in nuclear collisions at mid-rapidity at SPS experiments and at forward rapidity in RHIC(62.4 GeV) develop the same chemistry which seems to be driven by the baryo-chemical potential.

References

- [1] Ahle *et al.*, E866 and E917 Collaborations, *Phys.Lett.* **B476** (2000) 1
- [2] Alt *et al.*, NA49 Collaboration, *Phys.Rev.* **C73** (2006) 044910
- [3] Ahle *et al.*, E802 Collaboration, *Phys.Rev.* **C58** (1998) 6, and references therein
- [4] Gazdzicki and Gorenstein, *Acta Phys.Polon.* **B30** (1999) 2705
- [5] Gazdzicki and Rohrich, *Z.Phys.* **C71** (1996) 55
- [6] Bass *et al.*, *Prog.Part.Nucl.Phys.* **41** (1998) 225
- [7] Zhang *et al.*, *Phys.Rev.* **C61** (2000) 067901
- [8] Adamczyk *et al.*, BRAHMS Collaboration, *Nucl.Instr.Meth.* **A499** (2003) 437
- [9] Arsene *et al.*, BRAHMS Collaboration, *Nucl.Phys.* **A757** (2005) 1
- [10] Arsene *et al.*, BRAHMS Collaboration, *Int.J.Mod.Phys.* **E16**(2007)2035
- [11] Ahle *et al.*, E802 Collaboration, *Phys.Rev.* **C59** (1999) 4
- [12] Gazdzicki *et al.*, NA49 Collaboration, Compilation of NA49 results
- [13] Dalsgaard *et al.*, BRAHMS Collaboration, *Int.J.Mod.Phys.* **E16** (2007) 1813
- [14] Abbott *et al.*, E802 Collaboration, *Phys.Rev.* **D45** (1992) 3906
- [15] Alper *et al.*, ISR Collaboration, *Phys.Lett.* **B44** (1973) 521
- [16] Debbe *et al.*, BRAHMS Collaboration, in these proceedings.