Kaon Production in $\sqrt{s_{NN}}$ = 200 GeV Au-Au Collisions measured with the PHENIX experiment at RHIC

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Abstract

The PHENIX experiment has measured K^+ and K^- spectra from 200 GeV Au-Au collisions in a transverse momentum range p_T~(0.4 – 2.0) GeV/c, using a high-resolution time of flight detector. *dN/dy* at mid rapidity and $< p_T >$ were measured as a function of centrality, using 11 centrality classes. Comparisons to a simple hydrodynamic model are made. Ratios K^+/K^-, K^-/π^-, K^+/π^+ and $\bar{p}/p$ are shown as a function of p_T and centrality. These allow the extraction of the statistical thermal model parameters. The results are compared to earlier measurements at $\sqrt{s_{NN}}$ = 130 GeV. PHENIX can also identify K^0_S via its decay into $\pi^+ \ \pi^-$ pairs. First results from this measurement are presented.

1. Introduction

One of the valuable features of the PHENIX detector at RHIC is that it provides particle identification (PID) for charged particles over a broad momentum range [1]. Charged pions and kaons are identified up p_T = 2 GeV/c, and protons and anti-protons – up to p_T = 4 GeV/c at mid rapidity. The transverse momentum spectra of these six species provide information about the kinetic freeze out conditions: temperature and flow velocity. The ratios of $\bar{p}/p$ together with K^+/K^- reflect the baryon chemical potential and the strangeness production mechanism. Studying the mean transverse momentum ($<p_T>$) and integrated yields (*dN/dy*) of the above species as a function of the number of participants (N_{part}) allows a comparison with hydrodynamic models and testing their applicability ranges. Related to this is the puzzle of having comparable numbers of (anti) protons and pions in the intermediate (2-4) GeV/c p_T range in central Au-Au collisions [2]. Proposed explanations refer either to protons being pushed to higher p_T by the hydrodynamic flow [3], because of their mass or to baryon specific mechanisms for hadron production [4]. Studying the kaon production in this p_T range, may discriminate between models, as kaons are mesons, but with mass in between the pion and the proton. Although the charged kaon PID in PHENIX is limited to $p_T < 2$ GeV/c, kaon PID can be extended up to p_T ~5-6 GeV/c through the measurement of $K^0_S \rightarrow \pi^+ \pi^-$.

2. Hadron PID in PHENIX

For charged hadrons, a multi-layer drift chamber followed by a pad chamber provide a measurement of the momentum and the trajectory, while beam-beam counters (BBC) and a time-of-flight detector (TOF) provide the flight-time and consequently, their velocity. The TOF has resolution of σ=115 ps and the acceptance in rapidity depends on the particle species and p_T. Figure 1 shows the inverse momentum multiplied by the charge of the particle as a function of TOF. Pions, kaons and protons are separated in a wide momentum range. A GEANT-based Monte Carlo simulation is used to obtain corrections for p_T –dependent acceptance, decay-in-flight and reconstruction efficiency. Multiplicity dependent corrections are obtained by embedding simulated tracks into real events with different centrality.

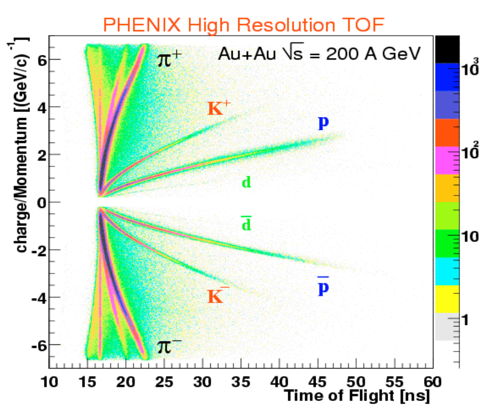

Fig. 1 TOF PID plot

3. Hadron spectra and freeze out parameters

Figure 2 shows the p_T spectra for K^+ and K^- for 9 centrality classes that are determined using signals from BBC and the zero degree calorimeter. A Glauber model calculation [5] is used to obtain N_{part} for each class. To obtain $< p_T >$ and dN/dy the spectra were fitted with m_T exponents, shown on the plots with lines.

A hydrodynamics-motivated function was fit simultaneously to all identified hadron spectra in the low m_T range: $(m_T - m_0) < 1$ GeV. The freeze out parameters of the fireball: temperature T and transverse flow velocity β_T were extracted [6].

For the 5% most central:
$\beta_T = 0.7 \pm 0.2$ syst.
($<\beta_T> = 0.5 \pm 0.2$ syst.)
$T_{fo} = 110 \pm 23$ MeV

For the 80-91% peripheral:
$\beta_T = 0.5 \pm 0.2$ syst.
($<\beta_T> = 0.3 \pm 0.2$ syst.)
$T_{fo} = 135 \pm 23$ MeV

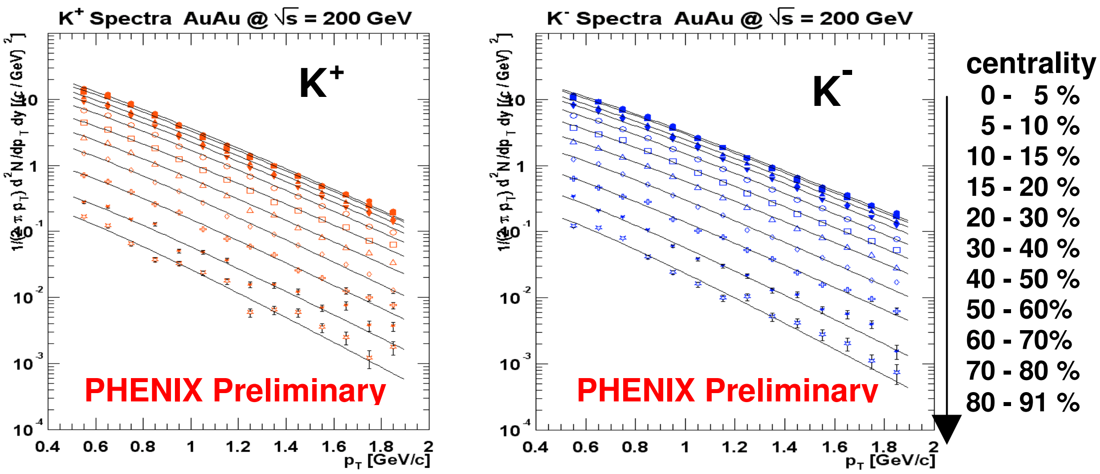

Fig. 2 Kaon p_T spectra for different centrality classes

4. Hadron ratios and the baryon chemical potential

The statistical thermal model relates the temperature and the chemical potentials for all particle species with the particle yield ratios. In the simple case when only the baryon chemical potential is included, the two most important ratios are $\bar{p}/p$ and K^-/K^+. They are shown on Fig. 3 for the central and peripheral Au-Au events and also for the proton-proton collisions. All ratios change very little with centrality and also with p_T. Only the ratio for the peripheral events seem to drop above 2.5 GeV, but it is consistent with the proton-proton data, which goes only up to 2 GeV. The integrated yield ratios are: $\pi^- / \pi^+ = 1.02 \pm 0.02 \pm 0.1$, $K^- / K^+ = 0.92 \pm 0.03 \pm 0.1$, $\bar{p}/p = 0.70 \pm 0.04 \pm 0.1$. The $\bar{p}/p$ ratio, measured in different experiments is shown on Fig. 4 as a function of $\sqrt{s_{NN}}$.

From the statistical thermal model, one can find dependence of different h^+/h^- ratios on the baryon chemical potential μ_B. PHENIX $\sqrt{s_{NN}}$ =130 and 200 GeV points for a K^+/K^- vs. are shown. They correspond to $\mu_B \sim 30$MeV (200 GeV), $\mu_B \sim 46$MeV (130 GeV).

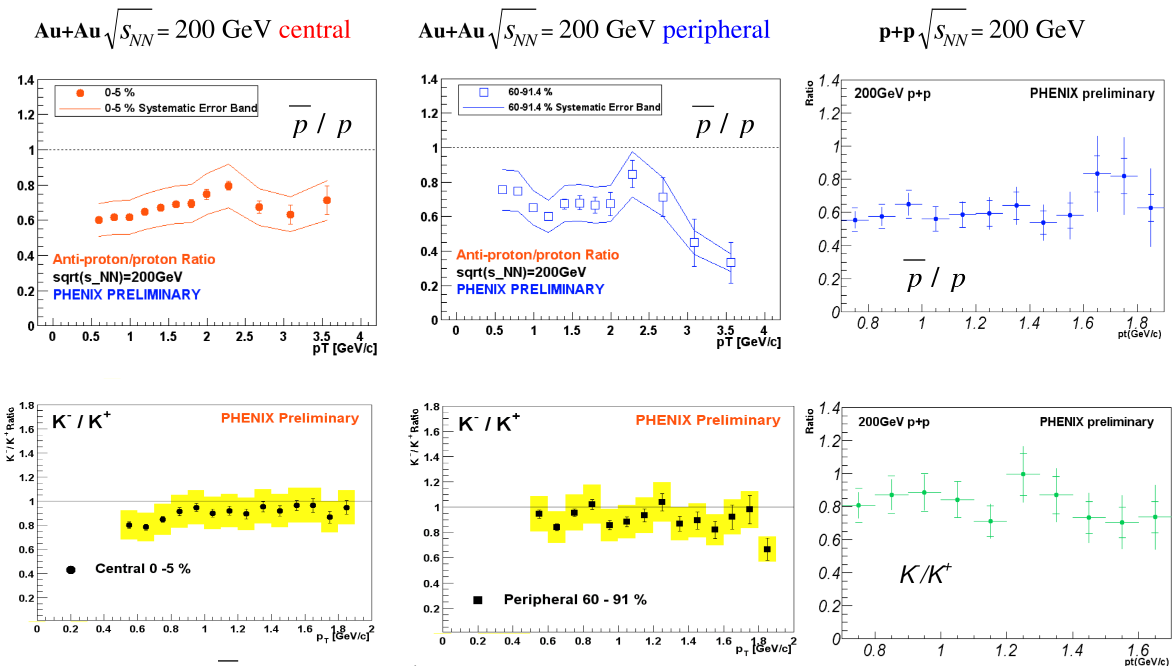

Fig. 3 $\bar{p}/p$ *and* K^-/K^+ *for central and peripheral Au-Au and p-p collisions*

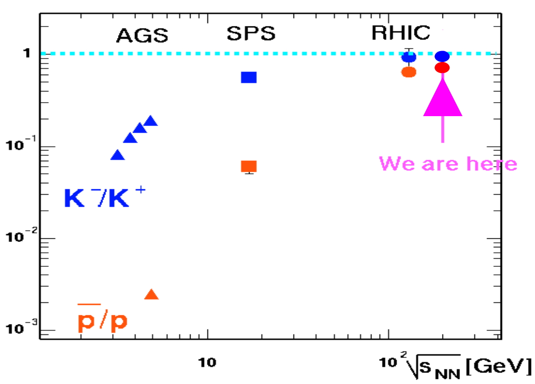

Fig. 4 $\bar{p}/p$ *ratio in different experiments*

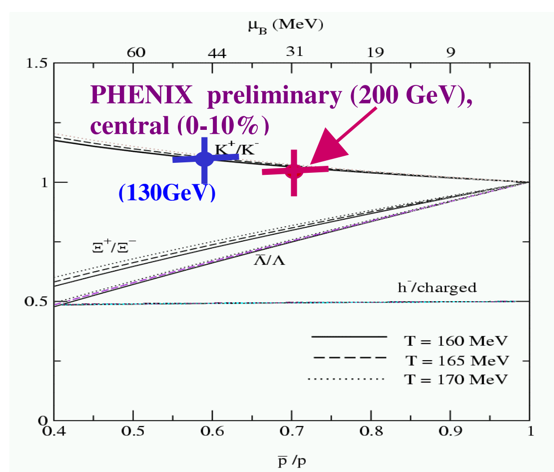

Fig. 5 K^+/K^- *vs.* $\bar{p}/p$ *from a model*

5. Integrated yields and $<p_T>$ as a function of N_{part}

The dependence of $<p_T>$ and dN/dy on N_{part} provides a test for different hydrodynamic models. One such model [7], with only one free parameter – the initial p_T kick, has its predictions shown on Figures. 6 and 7.

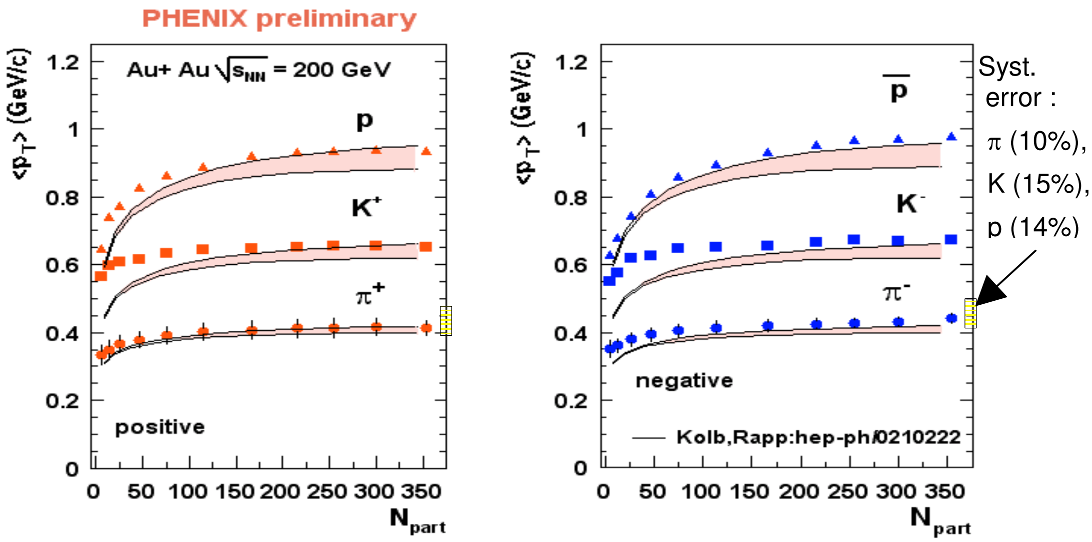

Fig. 6 <p_T> versus the number of participants. The model is shown with a strip.

The model fails below N_{part} ~ 150, when the conditions for a hydrodynamic description are not satisfied. The discrepancy is largest for the $K^{+/-}$, suggesting that strangeness is not completely thermalized. This is most evident in the K/π ratio, which grows with N_{part}.

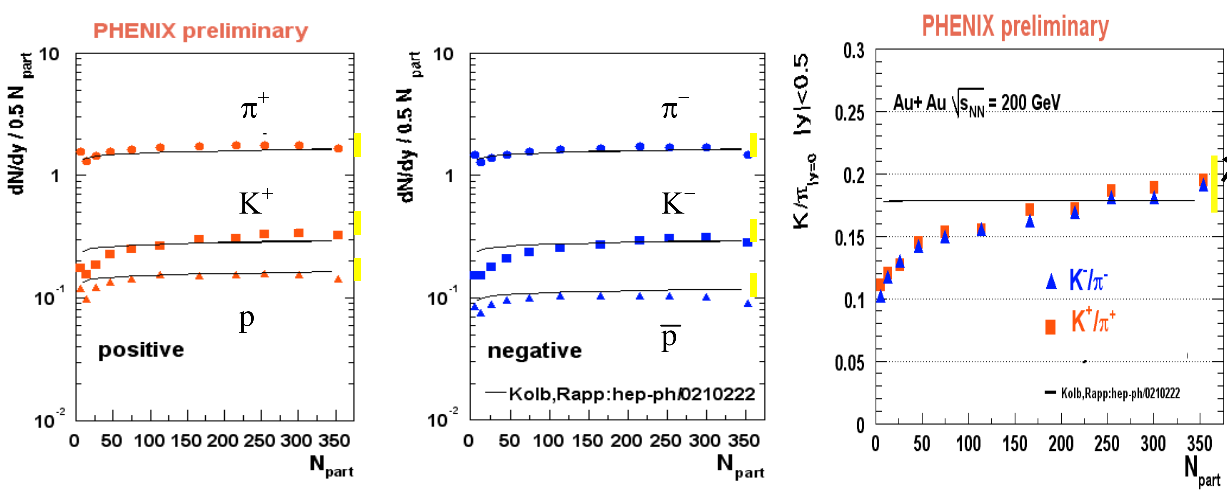

Fig. 7 dN/dy at mid rapidity per participant pair for $\pi^{+/-}$, $K^{+/-}$, p, $\bar{p}$. The right plot shows the K/π ratio versus N_{part}. Systematic errors are shown with bars. The lines are the Kolb-Rapp hydrodynamic predictions.

6. K^0_s measurement in PHENIX

PHENIX has the ability to measure K^0_s through its dominant decay into $\pi^+ \pi^-$ pairs. This will extend the kaon p_T spectra up to 5 GeV/c. Preliminary results on the K^0_s peak in the $\pi^+ \pi^-$ pair invariant mass are shown on Fig. 8.

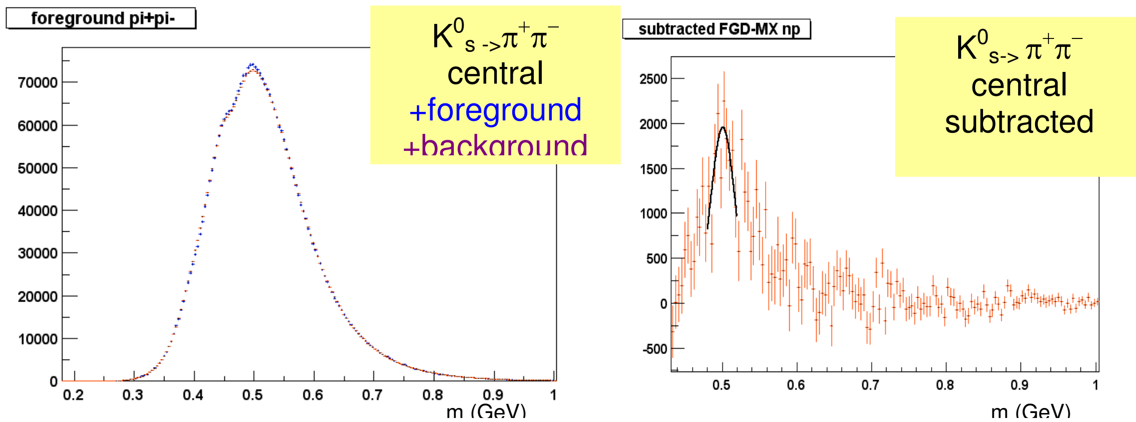

Fig. 8 $\pi^+ \pi^-$ invariant mass spectrum for central events.

7. Conclusions

From the measured π^+, π^-, K^+, K^-, $\bar{p}$, p spectra we extract β_T=0.7±0.2, T_{FO}=110 ±23 MeV, μ_B~30 MeV for the most central events at $\sqrt{s_{NN}}$ =200 MeV. The K^+/K^- ratio is flat in p_T and centrality, consistent with thermal production. K yield grows faster than N_{part} and faster than the π one. Hydrodynamic models describe the $\bar{p}$, p spectra, but fail for meson dN/dy, $\langle p_T \rangle$ and the K/π ratio in peripheral events (N_{part}<150). Measuring K^0_s up to high p_T will shed light on the p-π puzzle.

References:

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