Identified particles in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

Barbara Wosiek for the PHOBOS Collaboration

B.B.Back[1], M.D.Baker[2], D.S.Barton[2], R.R.Betts[6], M.Ballintijn[4], A.A.Bickley[7], R.Bindel[7], A.Budzanowski[3], W.Busza[4], A.Carroll[2], M.P.Decowski[4], E.García[6], N.George[1,2], K.Gulbrandsen[4], S.Gushue[2], C.Halliwell[6], J.Hamblen[8], G.A.Heintzelman[2], C.Henderson[4], D.J.Hofman[6], R.S.Hollis[6], R.Hołyński[3], B.Holzman[2], A.Iordanova[6], E.Johnson[8], J.L.Kane[4], J.Katzy[4,6], N.Khan[8], W.Kucewicz[6], P.Kulinich[4], C.M.Kuo[5], W.T.Lin[5], S.Manly[8], D.McLeod[6], J.Michałowski[3], A.C.Mignerey[7], R.Nouicer[6], A.Olszewski[3], R.Pak[2], I.C.Park[8], H.Pernegger[4], C.Reed[4], L.P.Remsberg[2], M.Reuter[6], C.Roland[4], G.Roland[4], L.Rosenberg[4], J.Sagerer[6], P.Sarin[4], P.Sawicki[3], W.Skulski[8], S.G.Steadman[4], P.Steinberg[2], G.S.F.Stephans[4], M.Stodulski[3], A.Sukhanov[2], J.-L.Tang[5], R.Teng[8], A.Trzupek[3], C.Vale[4], G.J.van Nieuwenhuizen[4], R.Verdier[4], B.Wadsworth[4], F.L.H.Wolfs[8], B.Wosiek[3], K.Woźniak[3], A.H.Wuosmaa[1], B.Wysłouch[4]

[1] Argonne National Laboratory, [2] Brookhaven National Laboratory, [3] Institute of Nuclear Physics, Kraków, Poland, [4] Massachusetts Institute of Technology, [5] National Central University, Chung-Li, Taiwan, [6] University of Illinois at Chicago, [7] University of Maryland, [8] University of Rochester

The yields of identified particles have been measured at RHIC for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV using the PHOBOS spectrometer. The ratios of antiparticle to particle yields near mid-rapidity are presented. The first measurements of the invariant yields of charged pions, kaons and protons at very low transverse momenta are also shown.

1. INTRODUCTION

In the PHOBOS experiment, particles are measured and identified in a two-arm spectrometer [1] consisting of layers of Si detectors placed on either side of the beam axis in a 2 Tesla magnetic field. Unique features of the PHOBOS spectrometer, such as a close proximity of the sensitive detector layers to the interaction region, little material between the collision vertex and Si layers and high segmentation of Si detectors, permit precise measurements of particles down to very small transverse momenta.

In this paper we present the measured ratios of charged antiparticles to particles for pions, kaons and protons produced near mid-rapidity. These measurements provide information on properties of the system at the chemical freeze-out point and on baryon transport processes. The invariant yields of charged particles at very low transverse momenta are also shown. The results of these measurements are sensitive to large-volume physics phenomena and to the effects of collective radial expansion of the system. An enhancement of the production of very low transverse momentum particles could indicate new long distance scale physics in heavy ion collisions [2].

2. ANTIPARTICLE TO PARTICLE RATIOS

The ratio of negatively to positively charged particles was measured during the RHIC 2001 Run using spectrometer data taken with both polarities of the magnetic field. Event triggering and determination of the collision centrality was provided by two sets of scintillator paddle counters [3]. The rapidity coverage for the ratio measurements extends from about 0.2 to 0.8 for kaons and protons and 0.35 to 1.3 for pions. More details on the tracking, particle identification and details of the ratio measurements can be found elsewhere [4,5].

The fully corrected ratios measured within our rapidity acceptance for the 12% most central Au+Au collisions at 200 GeV are [5]: $< \pi^- > / < \pi^+ >= 1.025 \pm 0.006(stat.) \pm 0.018(syst.)$, $< K^- > / < K^+ >= 0.95 \pm 0.03(stat.) \pm 0.03(syst.)$ and $< \overline{p} > / < p >= 0.73 \pm 0.02(stat.) \pm 0.03(syst.)$. The $< \overline{p} > / < p >$ ratio increases by about 25% over the value at $\sqrt{s_{NN}} = 130$ GeV [4], indicating a rapidly decreasing net-baryon density near mid-rapidity. The estimated baryochemical potential (μ_B) for the system formed in central Au+Au collisions at 200 GeV is $\mu_B = 27 \pm 2$ MeV [5].

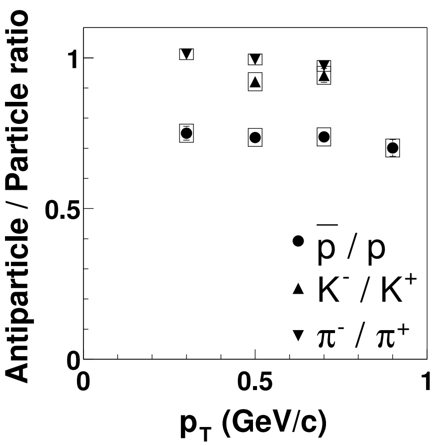

Figure 1. Antiparticle to particle ratios as a function of transverse momentum for selected central collisions. Boxes denote systematic errors.

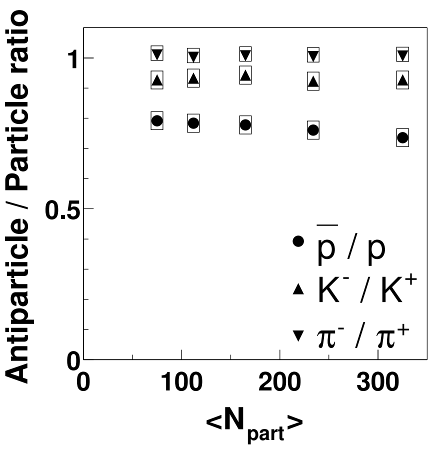

Figure 2. Antiparticle to particle ratios as a function of the collision centrality. Boxes represent systematic uncertainties.

Figure 1 shows preliminary results for the dependence of antiparticle to particle ratios on transverse momentum (p_T) for the 10% most central collisions at the top RHIC energy. Within our current estimates of the systematic uncertainties, the ratios are independent of p_T in the measured rapidity range. The centrality dependence of the measured ratios is shown in Fig. 2. The pion and kaon ratios are consistent with a constant value over the measured centrality range. For the $< \overline{p} > / < p >$ ratio, a weak but systematic drop with $< N_{part} >$ can be observed. However, within our uncertainties, the ratio is also consistent with a constant value, independent of centrality.

3. YIELDS AT VERY LOW TRANSVERSE MOMENTA

To extend our identified particle measurements to lower transverse momenta, we have searched for particles which stop in the fifth Si plane of the spectrometer. The reconstruction procedure is based on the analysis of tracks with large energy depositions in the first five spectrometer planes which are located in the field free region of the spectrometer. To determine the particle mass we check the mass and momentum hypotheses by making cuts on the energy deposited per unit length in every plane and the total deposited energy obtained by summing all the energy depositions. The analysis procedure was tested successfully on samples of simulated low momentum pions, kaons and protons. The measured raw yields were corrected for acceptance and efficiency. The correction factors were obtained by embedding simulated low momentum particles into real data events. Additional corrections, including feed-down from weak decays and contributions from secondary, misidentified and ghost particles, were also applied. Our current estimates of the systematic uncertainties are ±20% for pions, ±40% for kaons and ±50% for protons and include systematic effects in the measured yields and in the estimated correction factors.

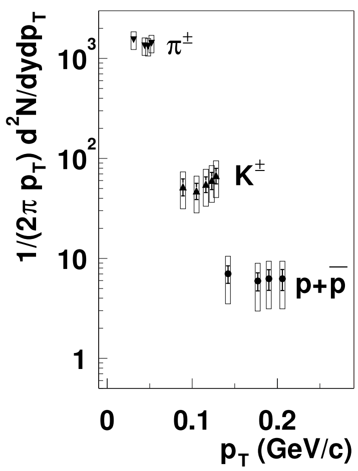

Figure 3. Invariant yields as a function of p_T. The boxes show systematic uncertainties.

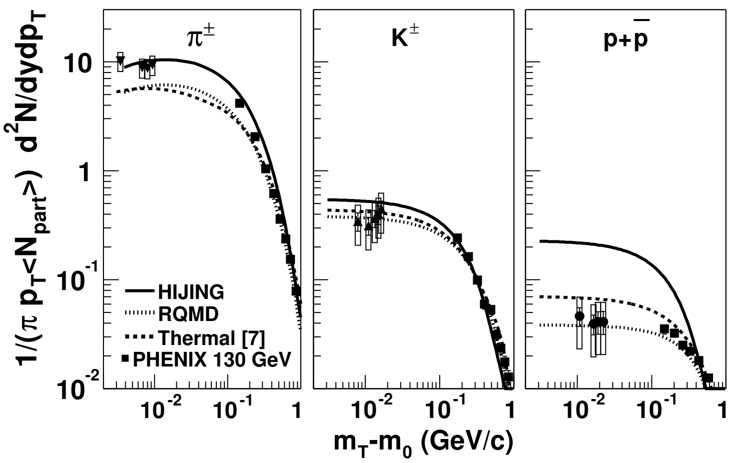

Figure 4. Invariant yields divided by $0.5 < N_{part} >$ as a function of $m_T - m_0$. Note the logarithmic horizontal scale.

Figure 3 shows preliminary results for invariant yields of ($\pi^\pm$), ($K^\pm$) and ($p+\overline{p}$) measured at mid-rapidity in the transverse momentum ranges from 30 to 50 MeV/c for charged pions, 90 to 130 MeV/c for kaons and 140 to 210 MeV/c for protons and antiprotons for the 15% most central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV . Our results are compared in Fig.4 to the predictions of HIJING[6], RQMD [7] and single freeze-out model of Broniowski and Florkowski [8]. Also shown in Fig. 4 are PHENIX measurements at 130 GeV

[9]. All data and the model predictions shown in Fig.4 have been corrected for feed-down from weak decays. It is evident that our measurements explored the range of very low transverse momenta, below the current measurements from other RHIC experiments (see also [10]). The yields of $(p + \overline{p})$ seem to agree with the extrapolation of the PHENIX measurements at higher p_T, indicating that the flattening of proton spectra attributed to the collective radial expansion extends down to very low p_T. Comparison with the model predictions also shows that none of the models presented in Fig.4 can consistently describe the pion, kaon and proton data. Particularly striking differences between the model predictions can be seen for the $(p + \overline{p})$ yields where the models differ by a factor of 2 to 6.

4. SUMMARY

The PHOBOS Collaboration has measured the yields of identified particles in Au+Au collisions at $\sqrt{s_{_{NN}}} = 200$ GeV. The $< \overline{p} > / < p >$ ratio reaches a value of 0.73 indicating that only one quarter of the protons at mid-rapidity have been transported from the beam rapidity regions. The estimated baryochemical potential is a factor of 2 smaller at 200 GeV than at 130 GeV. The antiparticle to particle ratios are consistent with the constant values as a function of transverse momentum and collision centrality.

At very low transverse momenta, we see no enhancement in the particle yields. On the contrary, particle production, particularly for protons and antiprotons, seems to be suppressed, which can result from a rapid transverse expansion of the system. These measurements provide constraints on models and suggest that dynamical processes (rescattering, expansion) play an important role in the description of baryon spectra at low transverse momenta.

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