Particle production at very low and intermediate transverse momenta in d+Au and Au+Au collisions

Adam Trzupek[3] for the PHOBOS Collaboration

B.Alver[4], B.B.Back[1], M.D.Baker[2], M.Ballintijn[4], D.S.Barton[2], R.R.Betts[6], A.A.Bickley[7], R.Bindel[7], A.Budzanowski[3], W.Busza[4], A.Carroll[2], Z.Chai[2], V.Chetluru[6], M.P.Decowski[4], E.García[6], T.Gburek[3], N.George[2], K.Gulbrandsen[4], S.Gushue[2], C.Halliwell[6], J.Hamblen[8], G.A.Heintzelman[2], C.Henderson[4], I.Harnarine[6], D.J.Hofman[6], R.S.Hollis[6], R.Hołyński[3], B.Holzman[2], A.Iordanova[6], E.Johnson[8], J.L.Kane[4], N.Khan[8], W.Kucewicz[6], P.Kulinich[4], C.M.Kuo[5], W.Li[4], W.T.Lin[5], C.Loizides[4], S.Manly[8], A.C.Mignerey[7], R.Nouicer[2,6], A.Olszewski[3], R.Pak[2], I.C.Park[8], C.Reed[4], L.P.Remsberg[2], M.Reuter[6], E.Richardson[7], C.Roland[4], G.Roland[4], L.Rosenberg[4], J.Sagerer[6], P.Sarin[4], P.Sawicki[3], I.Sedykh[2], W.Skulski[8], C.E.Smith[6], M.A.Stankiewicz[2], P.Steinberg[2], G.S.F.Stephans[4], A.Sukhanov[2], A.Szostak[2], J.-L.Tang[5], M.B.Tonjes[7], A.Trzupek[3], C.Vale[4], G.J.van Nieuwenhuizen[4], S.S.Vaurynovich[4], R.Verdier[4], G.I.Veres[4], P.Walters[8], E.Wenger[4], D.Willhelm[2], F.L.H.Wolfs[8], B.Wosiek[3], K.Woźniak[3], A.H.Wuosmaa[1], S.Wyngaardt[2], B.Wysłouch[4]

[1] Argonne National Laboratory, Argonne, IL 60439-4843, USA
[2] Brookhaven National Laboratory, Upton, NY 11973-5000, USA
[3] Institute of Nuclear Physics PAN, Kraków, Poland
[4] Massachusetts Institute of Technology, Cambridge, MA 02139-4307, USA
[5] National Central University, Chung-Li, Taiwan
[6] University of Illinois at Chicago, Chicago, IL 60607-7059, USA
[7] University of Maryland, College Park, MD 20742, USA
[8] University of Rochester, Rochester, NY 14627, USA

The transverse momentum (p_T) spectra of identified charged particles have been measured at very low and intermediate transverse momenta in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV and d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV using the PHOBOS detector at RHIC. New results on charged particle production at very low p_T in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV in the centrality intervals 0-6% and 6-15% are presented. A comparison of the PHOBOS low-p_T data with predictions of a recent optical model is shown. The shapes of m_T spectra for d+Au and Au+Au collisions are compared.

1. Introduction

In nucleus-nucleus collisions, an enhanced production of low-p_T particles could signal new long-wavelength physics phenomena [1, 2]. It is also expected that yields of particles with higher masses, like protons and antiprotons can be modified due to collective transverse expansion of the system [3, 4]. Measurements at very low p_T can also provide a critical test for models predicting a pronounced modification of the low-p_T particle emission pattern, e.g. [5].

The PHOBOS experiment has the unique capability to measure charged particles at transverse momenta as low as 30, 90 and 140 MeV/c for charged pions, kaons and for protons and antiprotons, respectively, using a multi-layer, magnetic spectrometer. Yields at very low transverse momenta are determined using a reconstruction procedure developed to look for particles which range out in the fifth silicon layer of the PHOBOS spectrometer. A description of the "stopping algorithm" is presented in [6]. At intermediate p_T, particle momentum and charge are obtained from the curvature of particle trajectories in a 2T magnetic field and particle identification is provided by the specific energy loss (dE/dx) in the spectrometer and by Time-of-Flight detectors. Details on tracking, particle identification, event selection and centrality determination in the PHOBOS detector can be found in [7].

2. $\mathbf{p_T}$ spectra in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV

The preliminary particle yields for $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ are presented in Fig. 1 for three centrality intervals: 0-15%, 15-30% and 30-50%. The data are corrected for detector effects (acceptance, efficiency, momentum resolution) and background particles including feed-down from weak decays and secondary particles produced in the beam pipe and detector material. The rapidity coverage of measured yields extends from about 0.4 to 1.4 for $\pi^{\pm}$, from 0.2 to 1.2 for $K^{\pm}$ and from 0.2 to 1.1 for p and $\bar{p}$. The preliminary results on antiparticle to particle ratios have been obtained for the 15% most central collisions. The results of 0.84 $\pm$ 0.02(stat.) $\pm$ 0.08(syst.) for K^-/K^+ and 0.37 $\pm$ 0.01(stat.) $\pm$ 0.06(syst.) for $\bar{p}/p$ fit smoothly into the energy evolution of antiparticle to particle ratios from the AGS up to the highest RHIC energy.

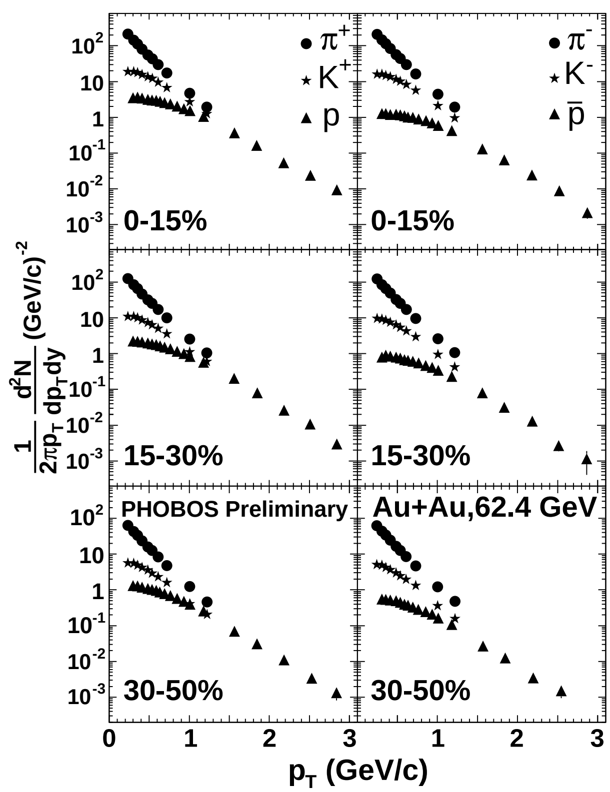

Figure 1. p_T spectra of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV.

Low-p_T yields of ($\pi^{+}+\pi^{-}$), ($K^{+}+K^{-}$) and ($p+\bar{p}$) near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV, corrected for detector effects and background particles, are shown in Fig. 2 in the same centrality bins. One can see that ($K^{+}+K^{-}$) and ($p+\bar{p}$) yields are quite consistent with extrapolations of blast wave functions (BWF) [4] fitted to the spectra at higher transverse momenta. Some disagreement between the measured yield of pions and BWF at low p_T could be attributed to a contribution from resonances which is not included in the model. A similar behavior was observed for p_T yields measured in the 15% most central Au+Au collisions at

$\sqrt{s_{NN}}$ = 200 GeV [6], indicating that at both energies no significant enhancement of particle production is observed at very low p_T. Also, a flattening of the $(p + \bar{p})$ spectra down to very low transverse momentum is observed. This could be a consequence of collective transverse expansion of the medium created in heavy ion collisions at RHIC.

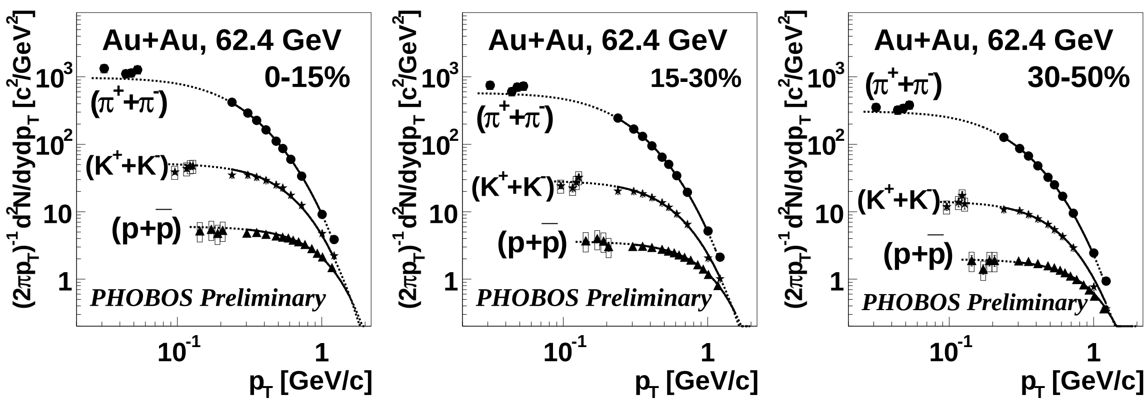

Figure 2. $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ yields at very low p_T in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV. Blast wave fits to the intermediate p_T data (solid lines) are extrapolated to low p_T (dashed lines).

3. Low-p_T yields in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

The spectra of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ at very low transverse momentum in the 15% most central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, measured in the PHOBOS experiment, are presented in [6]. In order to confront the extrapolations from a recent optical model [5], which were available only for more central collisions, with measurements, the published data sample was split into two finer centrality bins. Fig. 3 shows the p_T yields, corrected for detector effects and background particles, measured in the centrality intervals 0-6% and 6-15%. In Fig. 4, the pion yield measured in the 6% most central Au+Au collisions is compared to the optical model predictions for the spectrum of negative pions at mid-rapidity. The originally published

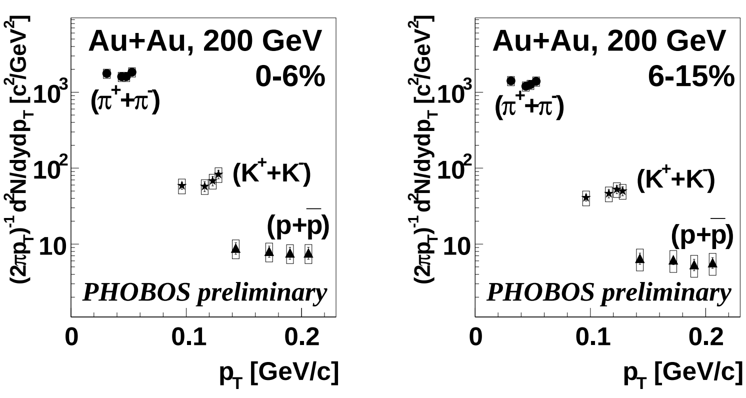

Figure 3. $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ yields at very low p_T in 0-6% and 6-15% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

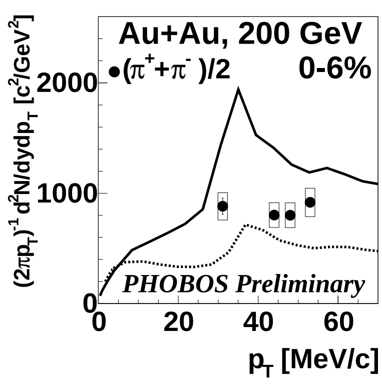

Figure 4. Optical model predictions [5, 8] for pion spectra at low p_T compared to PHOBOS data (see text for details).

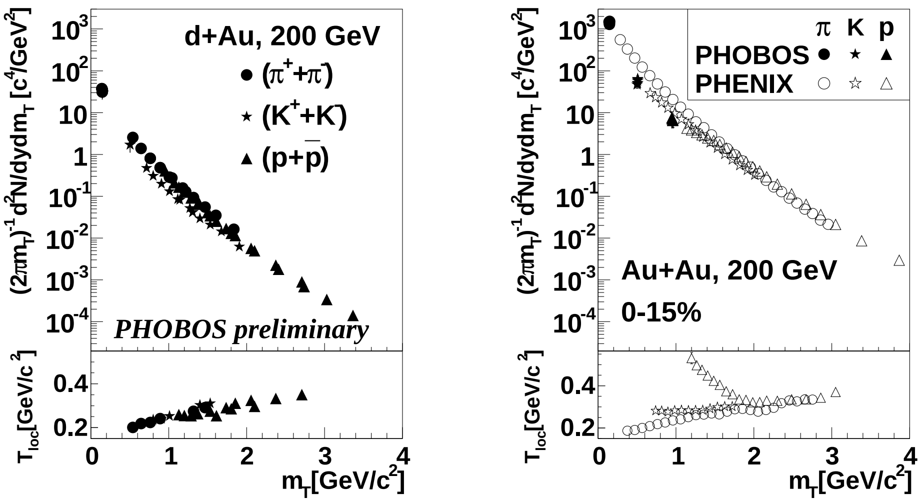

Figure 5. m_T spectra of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ at very low and intermediate p_T measured in d+Au (left plot) and central Au+Au collisions (right plot). Inverse local slope parameters of m_T spectra are shown in the lower panels of each figure.

extrapolation is shown by the dashed curve, while the solid curve depicts the recently modified model calculations [5, 8].

4. $\mathbf{m_T}$ scaling

It is interesting to compare the particle yields at very low and intermediate p_T in d+Au and central Au+Au collision at the same energy of $\sqrt{s_{NN}}$ = 200 GeV. Yields of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ in d+Au collisions, corrected for detector effects and background particles, are shown in Fig. 5. One can see that in d+Au collisions $(\pi^+ + \pi^-)$ and $(p + \bar{p})$ m_T spectra are similar while the $(K^+ + K^-)$ spectrum is systematically lower (by a factor of about 2) due to strangeness suppression. The m_T spectra for the 15% most central Au+Au collisions measured by the PHOBOS [6] and PHENIX [9] experiments at very low and intermediate tranverse momenta, respectively, are also shown in Fig. 5. In order to compare the shapes of the m_T spectra, inverse local slope parameters were calculated by fitting locally exponential functions to each spectrum (see bottom panels of Fig. 5). We can see that for d+Au collisions local slopes are similar for all particle species both at low and intermediate p_T. In contrast, Au+Au spectral shapes are similar at higher transverse masses ($m_T >$ 1.7 GeV) while at low m_T a flattening of $(K^+ + K^-)$ and $(p + \bar{p})$ spectra is observed. This flattening of the $(p + \bar{p})$ spectrum is significantly stronger than the one observed for the spectra of charged kaons. One can also see that the m_T dependence of the local slopes of the $(\pi^+ + \pi^-)$ m_T spectrum for Au+Au collision is consistent with that found for the local slopes of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ spectra in d+Au collisions.

5. Summary

Yields of pions, kaons and protons and antiprotons at very low and intermediate p_T near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 and 200 GeV, measured in the PHOBOS experiment, indicate that there is no evidence for enhanced production of particles at very low transverse momentum. The pion low-p_T data can constrain the recent optical model predictions. A significant flattening of the $(p + \bar{p})$ m_T spectrum down to very low p_T is observed in central Au+Au collisions at both energies which could be a consequence of the collective transverse expansion of the system. In d+Au collisions, no flattening is observed and the shapes of the m_T spectra are similar at very low and intermediate p_T.

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