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Identified Hadron production in $\sqrt{s} = 130$ GeV Au-Au collisions at RHIC

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Abstract.
Identified $\pi^{+/-}$, $K^{+/-}$, p and $\overline{p}$ transverse momentum spectra at mid-rapidity in $\sqrt{s_{NN}}$ = 130 GeV Au-Au collisions were measured by the PHENIX experiment at RHIC as a function of collision centrality. Average transverse momenta increase with the number of participating nucleons (N_{part}) similarly for all particle species. The multiplicity densities scale faster than N_{part}. $K^{+/-}$ and $p^{+/-}$ yields per participant increase faster than the $\pi^{+/-}$ yields. We combine the PHENIX neutral and charged pion measurement and find that in central collisions for $p_T \geq 2$ GeV/c, $\overline{p}$ and p yields are comparable to or even exceed the pion yields.

Keywords. identified hadrons,RHIC

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1. Introduction

We report the first PHENIX measurement of mid-rapidity identified $\pi^{+/-}$, $K^{+/-}$, $p^{+/-}$ spectra, $\langle p_T \rangle$ and dN/dy as a function of collision centrality in $\sqrt{s_{NN}}$ = 130 GeV Au+Au collisions at RHIC. The PHENIX detector has excellent hadron identification over a broad momentum range [1]. Time-of-flight system with resolution of $\sigma \simeq 115$ ps was used in for hadron identification. Momentum measurement with resolution $\delta p/p \simeq 0.6\% \oplus 3.5\%\ p$ (GeV/c) is obtained with a drift chamber followed by a multi-wire proportional chamber with pixel-pad readout. The acceptance covers pseudo-rapidity $|\eta| < 0.35$ and $\Delta\phi = \pi/4$ in azimuthal angle.

Corrections for geometrical acceptance, decay-in-flight, momentum resolution and reconstruction efficiency are determined using a single-particle GEANT Monte Carlo simulation. Multiplicity dependent corrections are obtained by embedding simulated tracks into real events. A detailed description of the set-up, corrections and systematic uncertainties in $<p_T>$ and dN/dy derived from the spectra can be found elsewhere [1].

About 140,000 minimum bias events, representing $92 \pm 4\%$ of the total inelastic cross-section of 6.8 b [2] were analyzed. This sample was subdivided into five centrality classes: $0-5\%, 5-15\%, 15-30\%, 30-60\%$ and $60-92\%$, using Beam-Beam counters and Zero-Degree-Calorimeters for event characterization [2]. For each class, N_{part} is obtained from a Glauber model calculation [3]. We also measured $0-10\%$ central identified charged hadron spectra and used those in conjuction with the PHENIX π^0 spectra [3] to obtain high-p_T particle ratios. In the overlap p_T region the $\pi^{+/-}$ and the π^0 spectra which have very different systematic uncertainties agree to better than 10%.

2. Results and discussion

Fig. 1 shows the invariant yield as a function of p_T for the six measured particle species in three centrality classes. In peripheral events the $\pi^{+/-}$ spectra exhibit a concave shape, well described by a power-law parameterization as observed in hadron-hadron collisions. With increasing centrality the curvature in the spectra decreases, leading to an almost exponential dependence on p_T for the most central events. Over the measured p_T range, the $K^{+/-}$, p and $\overline{p}$ spectra are well described by an exponential distribution in $m_T = \sqrt{p_T^2 + m^2}$. The slopes of the m_T spectra flatten and $<p_T>$ (Fig.3) increases with particle mass and with centrality. This behavior has been previously observed in lower energy heavy ion collisions at the AGS [4] and at the SPS [5,6] and was attributed to collective radial motion (flow).

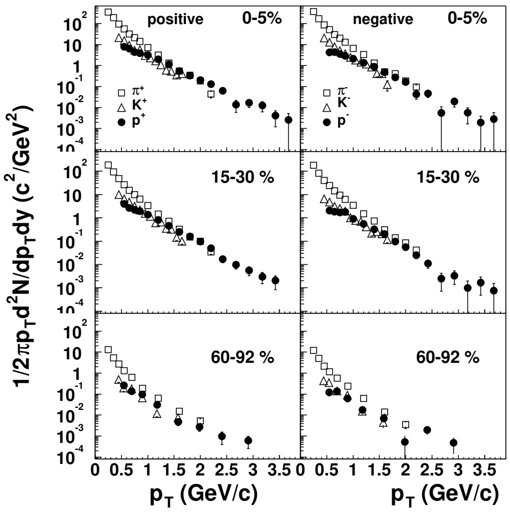

Figure 1. Transverse momentum spectra measured at mid-rapidity for π^+, K^+, p (left) and $\pi^-, K^-, \overline{p}$ (right) at the three different centrality selections indicated in each panel. Error bars are statistical. Sytematic error on normalization is 11% for all species.

At lower energies, it is not uncommon for the proton yields to equal or exceed the π^+ yields, since many of the protons come from the initial state. A new feature observed for the first time at RHIC is that in central collisions at $p_T \approx 2$ GeV/c the $\overline{p}$ yields are comparable to the π^- yields. In central events the proton spectra cross the π^+ spectra around $p_T \simeq 1.6$ GeV/c. As the centrality decreases, this happens at larger p_T. In peripheral events, both the p and $\overline{p}$ spectra are below the $\pi^{+/-}$ spectra over the whole measured p_T range. To examine the high-p_T (anti)proton/pion ratios, we combine the 10% central $\pi^{+/-}$ and

π^0 [3] spectra and obtain the $p/\pi^{+,0}$ and $\overline{p}/\pi^{-,0}$ ratio up to $p_T = 3.5$ GeV/c (Fig.2). The ratios in pp collisions measured at the ISR [7] are shown with open points. The difference in the high-p_T ratios at RHIC and the ISR is striking. In the ISR data the peak at $p_t \simeq 1.8$ GeV/c marks the transition region above which the hadron spectra are dominated by jet fragments. There is no clear sign of such a transition in the RHIC central data.

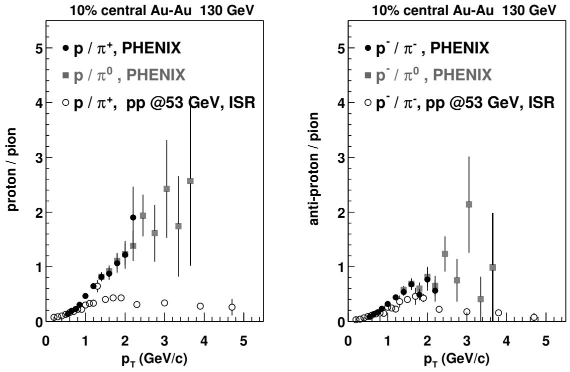

Figure 2. Proton/pion(left) and anti-proton/pion ratio as a function of p_T. The open circles represent measurements in pp collisions (data from ref. [7]). The filled points show the 10 % most central Au+Au collisions. The neutral pion spectra are from the data published in [3].

It has been suggested that hydrodynamic expansion [9] is responsible for the baryon dominance at high p_T. Alternative explanations [10] include protons/anti-protons produced via a baryon junction mechanism combined with jet-quenching in the pion channel or initial state p_T broadening caused by gluon saturation. The above theories have different predictions for the high-p_T baryon/pion ratios, however due to the limited statistics in the present data set, no clear distinction can be made from the data, yet.

The $<p_T>$ and yields per participant as a function of N_{part} are shown in Fig. 3. Both quantities increase with N_{part} for all particle species. Most of the increase occurs between the two most peripheral centrality selections (i.e. N_{part} 14 to 79). The total increase (from peripheral to central) in $<p_T>$ is $\approx 20 \pm 5\%$ independent of particle species. However, we see an indication that the total increase in the yields per participant differs among particle species. The pion yield per participant rises by $21\% \pm 6\%(stat) \pm 8\%(syst)$. The kaon yields per participant rise faster than the pion yields: $94\% \pm 11\%(stat) \pm 26\%(syst)$ and $66\% \pm 12\%(stat) \pm 20\%(syst)$, for K^+ and K^-, respectively. Similar trends in the centrality dependence of strangeness production have been observed in lower energy heavy ion collisions at AGS and at SPS. It is interesting to note that at RHIC proton and anti-proton yields per participant behave similarly to the kaon yields and also rise faster than the pions with increasing N_{part}. The increase is $58\% \pm 5\%(stat) \pm 16\%(syst)$ and $72\% \pm 9\%(stat) \pm 20\%(syst)$, respectively.In heavy ion collisions at AGS energies [4] the anti-proton production is close to threshold, the yields per participant are lower than in pp collisions and decrease from peripheral to central collisions. At SPS energies, the anti-proton yield per participant is larger than the pp value and has almost no centrality dependence [6]. At RHIC, the total yield of anti-protons at mid-rapidity in central Au-Au collisions is a factor of $\simeq 1000$ larger than at the AGS [4], nearly an order of magnitude above that in Pb+Pb collisions at CERN [5] and increases with centrality.

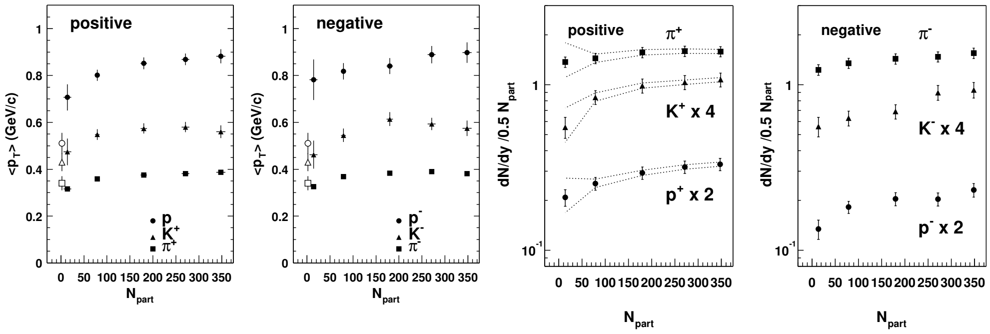

Figure 3. Average transverse momentum as a function of N_{part} (left). Error bars are statistical. The systematic errors are $7\%, 10\%, 8\%$ for $\pi^{+/-}, K^{+/-}, p^{+/-}$, respectively. The open points are interpolations from pp [7] and $p\overline{p}$ [8]data. $dN/dy_{|y=0}$ per participant for $\pi^{+/-}, K^{+/-}, p^{+/-}$ as a function of N_{part} (right). Error bars include statistical and systematic errors in dN/dy. The dashed lines around the positive hadrons show the effect of the systematic error on N_{part}.

It has been suggested by theory [11] that the increase of the yield per participant with centrality is due to the increased contribution of particles produced in hard scattering. Having seen that the $K^{+/-}$, p and $\overline{p}$ yields increase with centrality faster than the $\pi^{+/-}$ yields and at the same time the high-p_T baryon/pion ratios are well above the expected hard-scattering scaling, we argue that there is no clear experimental evidence that the increase in the yields per participant with N_{part} is due to hard scattering.

In conclusion, an intriguing new behavior in identified hadron production at RHIC is reported. In central Au-Au collisions the $\overline{p}$ yield is comparable to the pion yield at high p_T - a behavior never observed before in elementary or in heavy-ion collisions. Average p_T rises with centrality similarly for all particle species, while $K^{+/-}$,p and $\overline{p}$ yields per participant increase faster than the pion yields.

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