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# Low-$p_T$ Spectra of Identified Charged Particles in $\sqrt{s_{NN}}$ = 200 GeV Au+Au Collisions from PHOBOS Experiment at RHIC

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**Abstract.** The PHOBOS experiment at the Relativistic Heavy Ion Collider (RHIC), comprising the spectrometer with multiple layers of silicon wafers, is an excellent detector for very low transverse momentum ($p_T$) particles. Transverse momentum distributions of $\pi^- + \pi^+$, $K^- + K^+$ and $p + \overline{p}$ produced at mid-rapidity are presented for the 15% most central Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The momentum ranges for measured particles are from 30 to 50 MeV/c for pions, 90 to 130 MeV/c for kaons and 140 to 210 MeV/c for protons and antiprotons. The measurement method is briefly described. A comparison of the $p_T$ spectra to experimental results at higher particle momenta and to model predictions is discussed.

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## 1 Introduction

The study of properties of dense matter created in heavy ion collisions at RHIC offers the opportunity to explore new physics phenomena, such as creation of a quark-gluon plasma or disoriented chiral condensates (DCC) [1,2]. The expected long lifetime and/or large volume of the system may lead to enhanced particle production, especially in the low-$p_T$ regime. In particular an enhanced pion production at low $p_T$ is predicted in the case of DCC formation [3]. On the other hand, a strong transverse expansion induced by high, initial pressure may accelerate produced particles leading to flattening of particle spectra [4–6]. Non-relativistic heavy particles are expected to be more sensitive to this phenomenon.

## 2 Data analysis

The PHOBOS two arm magnetic spectrometer is used to perform particle identification and momentum measurements [7]. The spectrometer arms are located horizontally on either side of the beam pipe. Each arm consists of 16 layers of highly segmented Si pad detectors. Six inner layers, the closest to the beam pipe, are in an approximately field free region. The outer layers, used to determine particle trajectory curvatures, are located in a 2 Tesla magnetic field.

In order to perform measurements in the low $p_T$ regime we search for particles which range out in the first silicon layers. Based on a Monte Carlo (MC) study, the $5^{th}$ layer of the spectrometer was found to be optimal to search for stopping particles. For each event, hits with large amounts of deposited energy (>0.5MeV) in the first

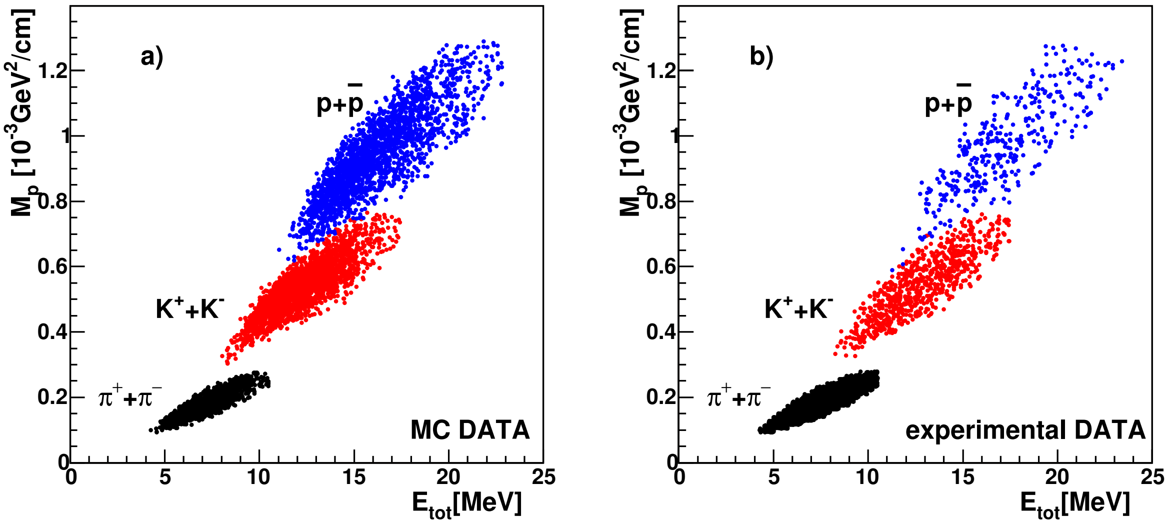


**Fig. 1.** ($M_p$,$E_{tot}$) scatter plots for simulated pions, kaons and protons/antiproton stopping in the $5^{th}$ layer of the PHOBOS spectrometer, a) and for the reconstructed particles from about 400000 Au+Au central collisions, b).

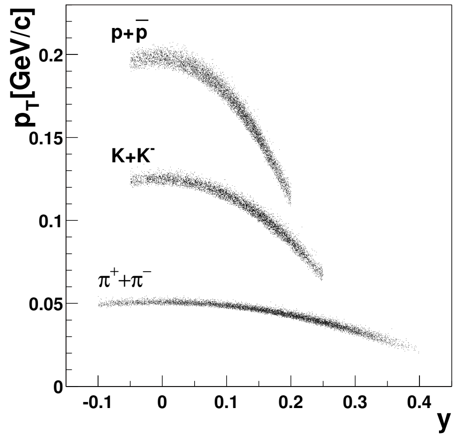


**Fig. 2.** Acceptance plots for reconstructed low-$p_T$ charged pions, kaons and protons/antiprotons.

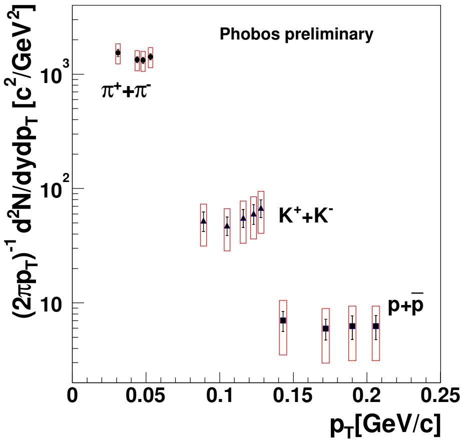


**Fig. 3.** Preliminary invariant yields of low-$p_T$ charged particles in the 15% most central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The boxes show systematic uncertainties.

five layers are used to form track candidates. Each candidate is subjected to angular cuts to eliminate ghost tracks. To determine the particle mass and momentum hypotheses were checked by making cuts on the energy deposited per unit length in each layer. As energies deposited in the $5^{th}$ layer, where particles stop, contain contributions from decay or absorption debris a correction to account for these effects was applied under the assumption that particles stop in this layer. For each candidate, the mass parameter, $M_p$ and the total deposited energy, $E_{tot} = \sum_1^5 E_i$ are calculated. The mass parameter for layer $i$ is defined as $(M_p)_i = (dE/dx)_i E_{tot}^i$, where $E_{tot}^i = \sum_i^5 E_i$. According to the Bethe-Bloch formula for non-relativistic particles, $(M_p)_i$ should be proportional to hadron mass ($\propto 1/\beta^2 \times m_h \beta^2 = m_h$). In Fig.1a, scatter plots of $E_{tot}$ and $M_p$ are shown for simulated $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \overline{p}$. A clear separation between the three particle species is observed. Cuts in the $M_p$ vs. $E_{tot}$ scatter plots were defined and applied to identify candidates in the experimental data (see Fig.1b). The analysis procedure was tested successfully on simulated data samples. The estimated transverse momentum resolution for reconstructed particles was found to be of the order of 5% and angular resolution of about $1^o$.

To obtain invariant transverse momentum distributions, corrections for the detector acceptance and the reconstruction inefficiency have to be applied. The corrections were obtained by embedding single simulated low momentum particles into data events. The corrections were determined in $\Delta y$, $\Delta p_T$ windows covering the rapidity and transverse momentum acceptance shown in Fig.2. The measured yields are corrected for background contamination. The sources of background include weak decays, secondary interactions (mostly in the beam pipe) and misiden-

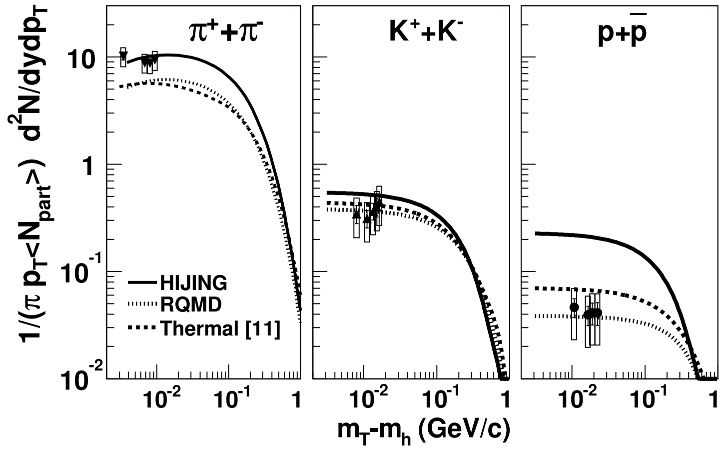


**Fig. 4.** Invariant yields of low $p_T$ $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \overline{p}$ compared to Hijing (solid line), RQMD (dotted line) and single-freeze-out (dashed line) model predictions.

tified and ghost particles. The estimate of the background correction for $p + \overline{p}$ is based on a detailed analysis of the distribution of the distance of closest approach (DCA) of the particle trajectory to the event vertex. In the reconstructed data the DCA distribution is much broader than the distribution for simulated primary $p + \overline{p}$. The background estimation in pion and kaon samples is based on an analysis of HIJING events with simulated detector response. The fraction of the background was estimated to be 41±8%, 16±11% and 39±3% in $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \overline{p}$ samples. The fully corrected invariant yields measured in 15% most central Au+Au collisions are shown in Fig.3. In Fig.3 preliminary data are presented. In ongoing analysis much larger event statistics and improved algorithm is used [8].

## 3 Discussion of results

The success of thermal models in describing the soft particle production in a wide range of energies [9–11] indicates that hadrons originate from an equilibrated system. Hence, it is interesting to see how the new data measured by PHOBOS at very low $p_T$ compare with the spectra measured at higher transverse momenta. In [6] it was shown that smooth extrapolations from medium $p_T$ measurements are consistent with particle yields at very low $p_T$, so no enhancement in the low $p_T$ yields is expected. Spectra of heavier particles, for example $p + \overline{p}$, flatten at low $p_T$. The flattening of $p + \overline{p}$ spectra can be attributed to the transverse expansion. The lack of transverse expansion implementation in HIJING model [12] may lead to the overestimated heavier particle yields as observed in Fig.4. The predictions for $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \overline{p}$ yields from RQMD [13] and single-freeze-out model are also shown in this figure. The RQMD model, in which transverse expansion is generated through rescattering of hadrons, correctly reproduces the yields of $K^+ + K^-$ and $p+\overline{p}$ but underestimates the low-$p_T$ yield of charged pions. These low-$p_T$ measurements provide strong constraints on models and allow to reduce uncertainties in the extrapolations of spectra to $p_T \approx 0$.

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