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Identified hadron production in a two component model.

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Abstract

The shapes of invariant differential cross sections for identified $\pi^{\pm}$,$K^{\pm}$, p and $\overline{p}$ production as function of transverse momentum measured in pp collisions by the PHENIX detector are analyzed in terms of a recently introduced approach. Simultaneous fits of these data to the sum of exponential and power-law terms show a significant difference in the exponential term contributions. This effect qualitatively explains the observed shape of the experimental K/π and p/π yield ratios measured as function of transverse momentum of produced hadrons.

Keywords identified hadron production, transverse momentum, phenomenology

There is a large volume of experimental data available on charged particle and identified hadron production in high energy particle collisions collected at RHIC and LHC. In most available publications the measured experimental spectra of produced hadrons become a subject for a phenomenological description or for a comparison with selected models in each experiment separately. However, a comparative simultaneous analysis of the whole available data volume could provide a new powerful lever arm to disclose a common underlying dynamics at work in the hadron production in high energy particle collisions. Such systematic analysis have been described in two of our recent papers [1, 2].

In [1] it was demonstrated that spectra of charged hadrons produced in collisions of baryons require an existence of a sizable fraction of an exponential (Boltzmann-like) statistical ensemble of charged hadrons on the top of a power-law (pQCD inspired spectrum shape) functional term. According to [1] the overall generic charged hadron spectrum as function of the produced hadron transverse momentum (p_T) is given by a sum of the exponential and power-law terms

$$\frac{d\sigma}{P_T dP_T} = A_e \exp\left(-E_{Tkin}/T_e\right) + \frac{A}{(1+\frac{P_T^2}{T^2\cdot n})^n}, \quad (1)$$

where $E_{Tkin} = \sqrt{P_T^2 + M^2} - M$ with M equal to the produced hadron mass. A_e, A, T_e, T, n are the free parameters to be determined by a fit to the data.

A typical charged particle spectrum as function of transverse energy, fit to the function (1) is shown in Fig 1. It is observed that the exponential Boltzman-like term dominates the charge particle spectrum at low p_T values.

In [2] it was shown that, contrary to the pions, the spectra of K and p leave relatively little room for the exponential term contribution and could be described by the power law term only within the experimental errors. Here we present a simultaneous comparative analysis of the π, K, and p spectra produced at the same collision energy and under the same experimental conditions published recently [4]. For this comparison the data from the PHENIX detector collected in pp collisions run at $\sqrt{(s)} = 200$ GeV were used [5].

As the first step one could note a peculiar behavior of the ratios of differential cross sections K/π and p/π measured in the experiment. These ratios plotted as

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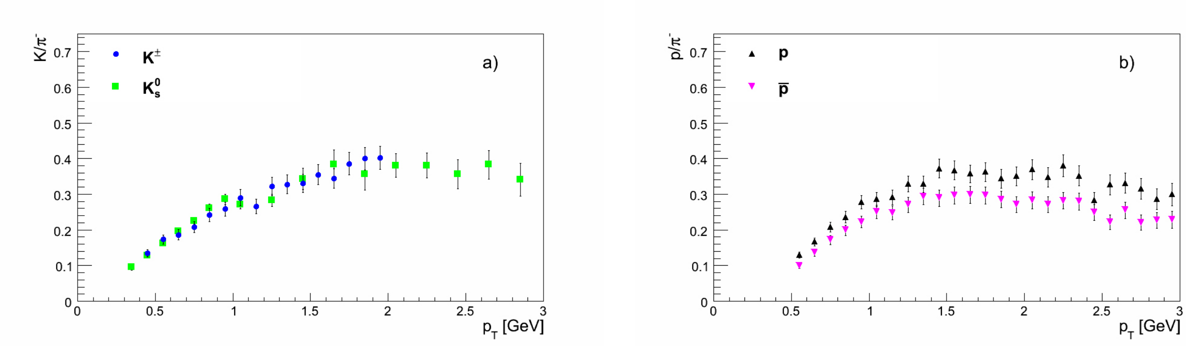

Figure 2: Ratios of the measured differential cross sections K/π (a) and p/π (b) measured at PHENIX [5]. For (a): $K^{\pm}$ - blue circles, K_s^0 - green squares [6]. For (b): p/π^- - black triangles, $\overline{p}/\pi^-$ - magenta inverted triangles.

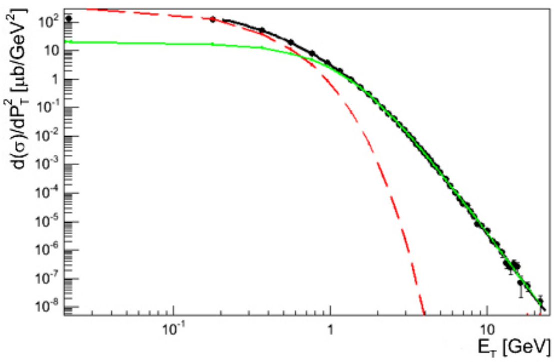

Figure 1: Charged particle spectrum [3] fit to the function (1): the red (dashed) curve shows the exponential term and the green (solid) curve stands for the power law term.

function of P_T of produced hadrons are shown in Fig 2a, b. In both cases the ratio reaches a plateau above $P_T \approx 2$ GeV and drops down for low P_T values. Within the framework of the proposed approach based on the formula (1) the observation of this plateau suggests that the parameter n of the power law term in (1) is likely to be similar for K, p and π. In the QCD model this is correct at high P_T values since the produced hadron distributions are largely driven by the gluon momentum distribution in the colliding particles. If so, the identified π,K and p spectra are fitted simultaneously to the function (1) with a constraint to have the same value for the n parameter in the power law term for all three spectra together. As the measured charged kaon spectrum is restricted to the low-P_T values it was extended using the available K_s^0 data [6].

The result of this fit procedure is shown in Fig 3 and table 1. It is important to note that the values for the parameter T obtained from such a fit procedure turns

Type of hadron	Power law contribution [%]	T [MeV]	T_e [MeV]
π	25 ± 2	530 ± 17	130 ± 3
K	72 ± 7	544 ± 46	135 ± 19
p	82 ± 8	528 ± 25	245 ± 18

Table 1: Contribution of the power-law (Boltzmann-like) term to the charge particle spectra and T and T_e parameters values obtained from the simultaneous fit (1) of $\pi^{\pm}$, $K^{\pm}$ and $p, \bar{p}$ spectra [5].

out to be practically the same for all types of produced hadrons. Such a surprising result was not obvious a priori. The relative amount of the exponential term contribution to the hadron spectra estimated from the simultaneous fit of the π, K and p differential cross sections to the function (1) are given in Table 1. It is important to note that the observed significant difference in the exponential contributions to the hadron spectra implies that there is a difference in the hadron production mechanisms rather than an artifact of the fit procedure.

Within the framework of the proposed approach the hadron production mechanism could be represented as a sum of two different contributions [7, 8]:

1) release of quasi-thermalized hadrons (mostly π, and much less probable K and p), described by the exponential Boltzmann spectrum and

2) pQCD-like production of hadrons described by the power law statistical distribution. The parameters of this distribution do not depend on the type of hadron produced in pp collisions.

It is worthwhile to note that as was found in [9] a sizable contribution of the thermalized hadrons shows up in the baryonic or heavy-ion collisions only. Whilst the interactions with the high energy photons involved as colliding particles do not require an extra exponential statistical distribution to describe the produced

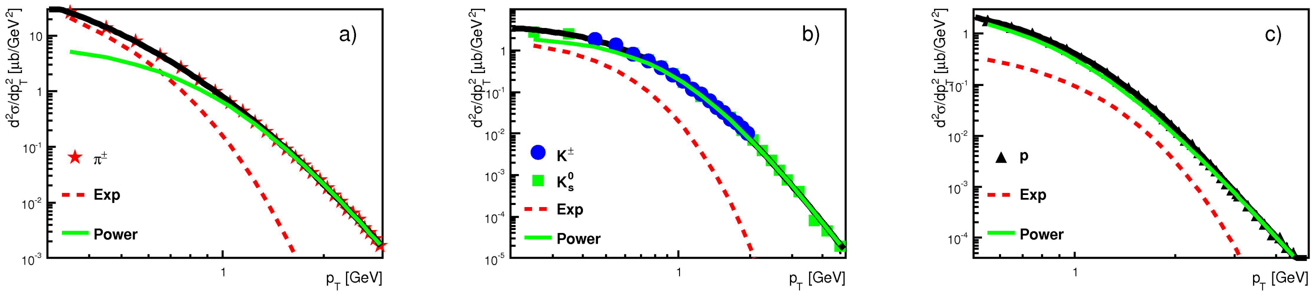

Figure 3: π, K and p spectra [5] fit simultaneously: the red line shows the exponential term and the green one stands for the power law. The exponential term dominates for π spectra only.

hadronic spectra. Moreover, J/Ψ spectra produced in pp-collisions at CDF have been also shown [1] to have no exponential term contribution.

In conclusion, it is found that the π production in pp collisions is dominated by a release of quasi-thermalized particles, while the spectra of heavier K, p and $\overline{p}$ are dominated by pQCD-like production mechanisms, leaving relatively small room for thermalized particle production. For π, K and p production the parameters of the power law contribution are practically the same (within the errors) values which depend on global conditions like collision energy [1], or type of colliding particles rather than type of produced hadron.

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