

Universality of identified hadron production in a two component model

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Introduction

There is a large volume of experimental data available on charged particle and identified hadron production in high energy particle collisions collected starting from the very first experiments performed on the Intersecting Storage Rings (ISR) at CERN throughout contemporary high statistics measurements carried out 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.

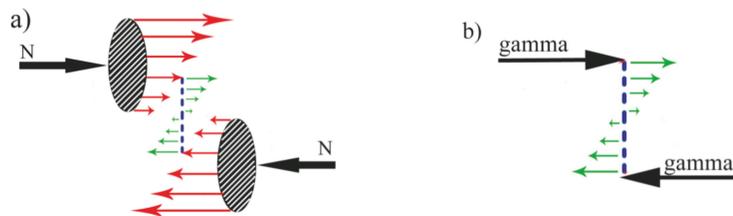


EPJ C May 2014, 74:2898

Qualitative Model

The baryon-baryon high energy interactions one could decompose into at least two distinct sources of produced hadrons. The first one is associated with the baryon valence quarks and a quark-gluon cloud coupled to the valence quarks. Those partons preexist long time before the interaction and could be considered as being a thermalized statistical ensemble. When a coherence of these partonic systems is destroyed via strong interaction between the two colliding baryons, these partons hadronize into particles released from the collision. The hadrons from this source are distributed presumably according to the Boltzmann-like exponential statistical distribution in transverse plane w.r.t. the interaction axis.

The second source of hadrons is directly related to the mini-jet fragmentation of the virtual partons (pomeron in pQCD) exchanged between two colliding partonic systems. The radiated partons from this pomeron have presumably a typical for the pQCD power-law spectrum. Schematically figure shows these two sources of particles produced in high energy pp and $\gamma\gamma$ -collisions, respectively.



According to this model, it was suggested to approximate the charged particle spectra as function of the particles transverse momentum by a sum of an exponential (Boltzmann-like) and a power-law statistical distributions:

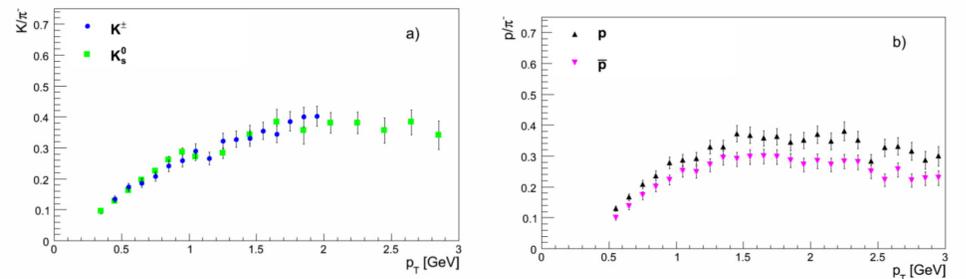
$$\frac{d^2\sigma}{\pi dy (dp_T^2)} = A_1 \exp(-E_{Tkin}/T_e) + \frac{A_2}{(1 + \frac{P_T^2}{T^2 N})^N} \quad (1)$$

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 fit to the data. The relative contribution of these terms is characterized by ratio R of the power-law term alone to the parameterization function integrated over P_T^2 :

$$R = \frac{ANT}{ANT + A_e(2mT_e + 2T^2)(N - 1)}$$

K/ π and p/ π Ratios

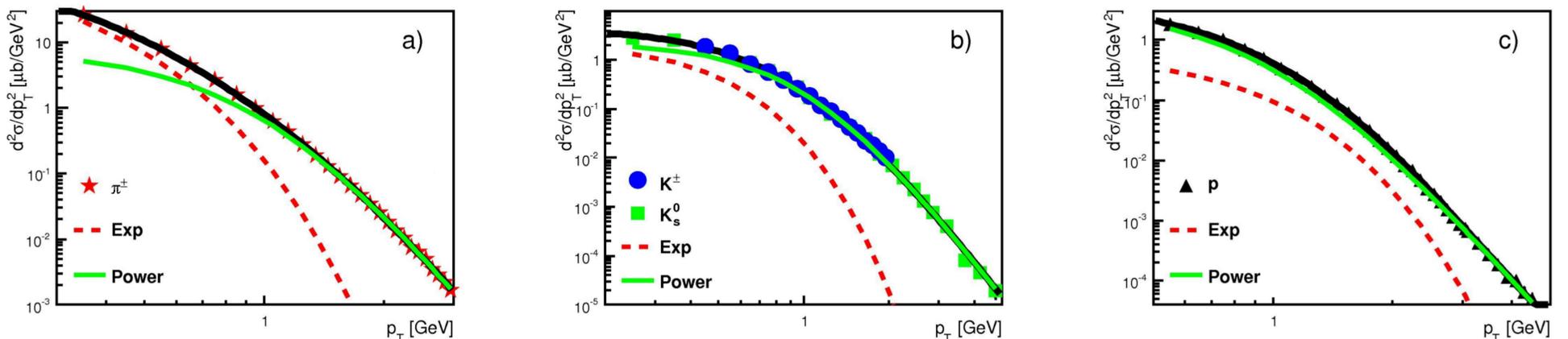
Here an attempt is made to make a simultaneous comparative analysis of the π , K and p spectra produced at the same collision energy and under the same experimental conditions in terms of this model. For this comparison the data from the PHENIX detector collected in pp -collisions at $\sqrt{s}=200$ GeV were used.



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. In both cases the ratio reaches a plateau above $p_T \sim 2$ GeV and drops down for low- p_T values. Within the framework of the proposed approach the observation of this plateau suggests that the parameter N of the power law term 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.

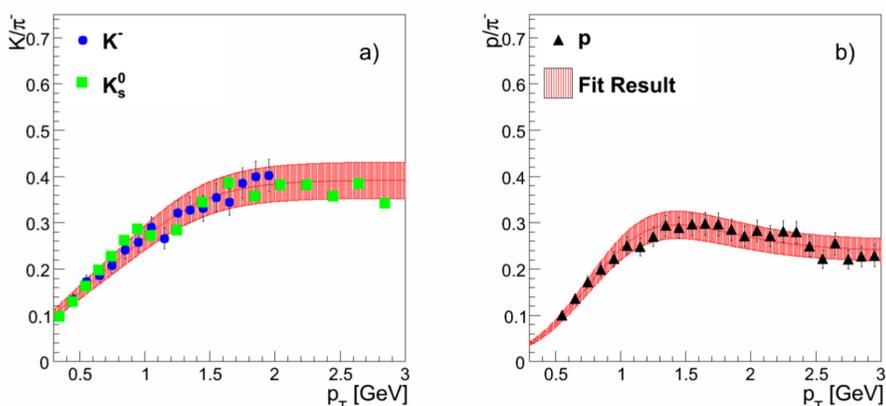
Simultaneous fit of the π , K and p spectra

If so, the identified π , K and p spectra are fitted simultaneously to the introduced 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. The result of this fit procedure is shown in the figure. It is important to note that the values for the parameter T obtained from such a fit procedure turn out to be practically the same for all types of produced hadrons. Moreover, 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 contributions:

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



The ratios of differential cross sections K/π and p/π are suppressed at low- p_T values due to a large fraction of thermalized π production represented by the Boltzmann-like exponential distribution.

Conclusions

1. Qualitative model considering two sources of hadroproduction has been proposed.
2. Simultaneous fit of the π , K and p spectra was performed using the introduced approach.
3. π production in pp -collisions is dominated by a release of quasi-thermalized particles, while the spectra of heavier K and p are dominated by pQCD-like production mechanism.
4. This mechanism is shown to be universal for π , K and p production in high-energy collisions.