PROCEEDINGS OF SCIENCE

New phenomenological model for hadron production in high energy particle collisions

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The shapes of invariant differential cross section for charged particle production as function of transverse momentum measured in high energy collisions are analyzed. To describe recently observed effects a simple qualitative model for hadroproduction mechanism is proposed. Predictions of this model are described and measurements for its tests that can be performed at LHC are proposed.

The European Physical Society Conference on High Energy Physics
18-24 July, 2013
Stockholm, Sweden

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PoS(EPS-HEP 2013)040

1. Introduction

The hadroproduction process in baryon-baryon high energy interactions could be decomposed into at least two distinct parts [1] characterized by two different 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 [2].

The second source of hadrons is directly related to the virtual partons exchanged between two colliding partonic systems. In QCD this mechanism is described by the BFKL Pomeron exchange [3]. The radiated partons from this Pomeron have presumably a typical for the pQCD power law spectrum [4]. Schematically figure 1 shows these two sources of particles produced in high energy baryonic collisions.

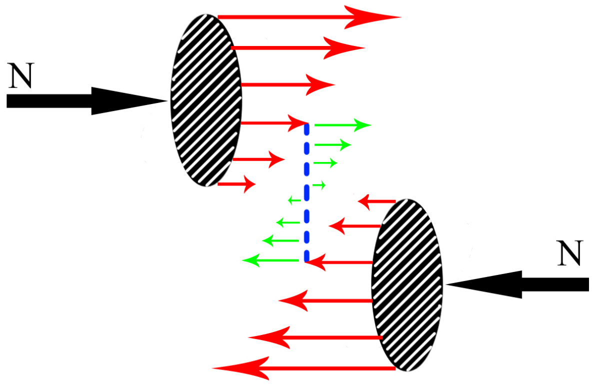

Figure 1: Two different sources of hadroproduction: red arrows - particles produced by the preexisted partons, green - particles produced via the Pomeron exchange.

To express this idea a new unified approach was proposed recently [1]. It was suggested to approximate the charged particle spectra as function of the particle's transverse momentum by a sum of an exponential (Boltzmann-like) and a power law distributions:

$$\frac{d\sigma}{P_T dP_T} = A_e \exp\left(-E_{Tkin}/T_e\right) + \frac{A}{(1+\frac{P_T^2}{T^2 \cdot N})^N}, \tag{1.1}$$

where $E_{Tkin} = \sqrt{P_T^2 + M^2} - M$ and 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:

$$R = \frac{ANT^2}{ANT^2 + A_e(2MT_e + 2T_e^2)(N-1)} \tag{1.2}$$

This simple model is naive, though it allows to make a number of predictions which could be checked experimentally.

2. Predictions of the Model

1. **Dependence of the power-law term contribution on the type of produced particle.**
   In pp-collisions the QCD-fluctuations are more flavor democratic with respect to the valence quark related radiation. This results in much smaller exponential contribution to the $K^{\pm}$ spectra then that to the $\pi^{\pm}$ spectra [5]. To test this hypothesis a simultaneous comparative analysis of $\pi^{\pm}$, $K^{\pm}$ and $p, \bar{p}$ spectra produced at the same collision energy and under the same experimental conditions can be performed [6].

2. **Dependence of the power-law term contribution on the charged particle multiplicity.**
   The AGK cutting rules [7] state that charge multiplicity in hadronic interactions is proportional to the number of Pomerons involved in this interaction. Therefore, the relative contribution of the power law part of the approximation (1.1) related to the Pomeron exchange will become larger with the increase of charged multiplicity in pp interactions [8].

3. **Dependence of the power-law term contribution on the collision energy.**
   The number of Pomerons involved in the interaction should logarithmically increase with $\sqrt{s}$ in the collision [9], therefore, the power-law term is expected to increase respectively. This prediction can be tested on different experimental data measured in pp and $p\bar{p}$-collisions with $\sqrt{s}$ varying from ISR to LHC energies.

4. **Dependence of the power-law term contribution on rapidity in pp collisions.**
   Another prediction could be made about an absolute dominance of the exponential contribution to the spectra of particles produced in the high rapidity proton fragmentation region where the role of valence quark in charged particle production becomes more important [10]. Test of this prediction can be performed at the LHCb experiment allowing to measure charged particles produced in the very forward region ($\eta > 2.5$).

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