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Two components in charged particle production in heavy-ion collisions

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Abstract

Transverse momentum spectra of charged particle production in heavy-ion collisions are considered in terms of a recently introduced Two Component parameterization combining exponential ("soft") and power-law ("hard") functional forms. The charged hadron densities calculated separately for them are plotted versus number of participating nucleons, N_{part}. The obtained dependences are discussed and the possible link between the two component parameterization introduced by the authors and the two component model historically used for the case of heavy-ion collisions is established. Next, the variations of the parameters of the introduced approach with the center of mass energy and centrality are studied using the available data from RHIC and LHC experiments. The spectra shapes are found to show universal dependences on N_{part} for all investigated collision energies.

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1. Introduction

Two-component models have been used in heavy-ion phenomenology for a long time. The reason for that is that there is no single theoretical approach that can simultaneously describe both low-p_T and high-p_T hadron production. The main object of study of such models [1] is charged particle density, $dN_{ch}/d\eta$, which is expected to scale with number of participating nucleons, N_{part}, or number of binary parton–parton collisions, N_{coll}, for "soft" and "hard" regimes of particle production, respectively. Such scaling becomes a subject of various phenomenological discussions – linear scaling with N_{part} is expected for "soft" processes, while scaling with N_{coll} is expected for the "hard" regime of particle production [2][1]:

$$dN_{ch}/d\eta = A \cdot N_{part} + B \cdot N_{coll}. \tag{1}$$

Recently, another two component approach accounting for another aspect of charged particle production – transverse momentum spectra $d^2\sigma/dp_T^2 d\eta$ – has been introduced by the authors [3]. Remarkably, it was also suggested to consider two sources of hadroproduction related to "soft" and "hard" regimes, respectively, and therefore parameterize transverse momentum spectra by a sum of an exponential (Boltzmann-like) and a power-law p_T distributions:

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\eta \mathrm{d}p_T^2} = A_e \exp(-E_{Tkin}/T_e) + \frac{A}{(1+\frac{p_T^2}{T^2 \cdot N})^N}, \tag{2}$$

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

Moreover, this approach was shown to effectively describe heavy-ion collision data [4] when the exponential term of (2) is substituted with the well-known Blast–Wave formula [5]:

$$\frac{\mathrm{d}n}{\mathrm{d}\eta \mathrm{d}p_T^2} \propto \int_0^R r\,\mathrm{d}r\, m_T\, I_0\left(\frac{p_T \sinh\rho}{T_e}\right) K_1\left(\frac{m_T \cosh\rho}{T_e}\right), \tag{3}$$

taking into account hydrodynamical expansion of the colliding system. In this approach the expanding under the pressure in the longitudinal direction system generates the transverse flow. The particle distribution is considered to be Boltzmann again but in the local fluid rest frame. In (3) $\rho = \tanh^{-1}\beta_r$ and $\beta_r(r) = \beta_s(\frac{r}{R})$, with β_s standing for the surface velocity, $m_T = \sqrt{m^2 + p_T^2}$, I_0 and K_1 are the modified Bessel functions.

In [4] it was also shown that an additional power-law term is needed to describe the charged hadron spectra in central PbPb collisions in the full range of transverse momenta. Thus, the experimental data are fitted to the function:

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\eta \mathrm{d}p_T^2} = A_e \cdot \int_0^R r\,\mathrm{d}r\, m_T\, I_0\left(\frac{p_T \sinh\rho}{T_e}\right) K_1\left(\frac{m_T \cosh\rho}{T_e}\right) + \frac{A}{(1+\frac{p_T^2}{T^2 \cdot N})^N} + \frac{A_1}{(1+\frac{p_T^2}{T_1^2 \cdot N_1})^{N_1}}. \tag{4}$$

[1] Also note that $N_{coll} \propto N_{part}^{4/3}$.