JET AND BACKGROUND MULTIPLICITY DISTRIBUTION ASSOCIATED WITH HIGH $p_{\perp}$ PARTICLE IN pp-COLLISIONS

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A relation between jet, background, total multiplicity distributions, average multiplicities and the high $p_{\perp}$ particle spectrum is derived. Specific forms of distributions and spectra, KNO-scaling and possible connections with experimental data are discussed.

In this note we relate jet and background multiplicity distributions with single high $p_{\perp}$ particle spectra. This relation and specific forms of distributions can provide us with useful information about the underlying hard scattering of hadron constituents and processes of particle production.

The ISR and FNAL data [1–4] establish three component structure of the final state in pp collisions with high $p_{\perp}$ particle production: 1) high $p_{\perp}$ trigger accompanied by a small number of particles emitted from the same side ("trigger bias"); 2) low $p_{\perp}$ particle background with average multiplicity $\bar{n}^{B}(\sqrt{s}-2p_{\perp})$ dependent most probably only on the variable $\sqrt{s}-2p_{\perp}$; 3) jet of hadrons balancing high $p_{\perp}$ momentum with average multiplicity $\bar{n}^{J}(p_{\perp}) \sim p_{\perp}$ dependent only on $p_{\perp}$.

It is natural to expect weak correlation between the jet (parton fragmentation) and the low $p_{\perp}$ background produced by two independent mechanisms. In this case the multiplicity distribution associated with high $p_{\perp}$ trigger takes on the form [5]

$$\tilde{P}_{n-1}(s, p_{\perp}) = \sum_{k=0}^{n-1} P_{k}^{B}(\sqrt{s}-2p_{\perp})P_{n-1-k}^{J}(p_{\perp}) \tag{1}$$

where P_{k}^{B} and P_{n-1-k}^{J} are multiplicity distributions in the low $p_{\perp}$ background and the jet, respectively.

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According to the experimental data [3] one can see either slight or no correlation between trigger and away particles. It allows us to write the following form for the total multiplicity distribution[1]

$$P_n(s) = \frac{1}{\sigma(s)} \int_{2p_{\perp 0}/\sqrt{s}}^{1} f(s, x_\perp) \sum_{k=0}^{n-1} P_k^{B}(\sqrt{s}\,(1-x_\perp))P_{n-1-k}^{J}(\sqrt{s}\,x_\perp)dx_\perp \tag{2}$$

where $2p_{\perp 0}/\sqrt{s} \sim 1/\sqrt{s}$ is the lower boundary of the high $p_\perp$ events, $f(s, x_\perp)$ is the high $p_\perp$ particle spectrum, the rest of variables are fixed and the normalization condition is

$$\sigma(s) = \int_{2p_{\perp 0}/\sqrt{s}}^{1} f(s, x_\perp)dx_\perp. \tag{3}$$

It is more convenient for our aim to write (2) in terms of generating functions $Q(z) = \sum_n (z+1)^n P_n$

$$P_n(s) = \frac{1}{n!} \frac{\partial^n}{\partial z^n}\left[\frac{(z+1)}{\sigma(s)} \int_{2p_{\perp 0}/\sqrt{s}}^{1} f(s, x_\perp)Q^{B}(s, x_\perp, z)Q^{J}(x_\perp, z)dx_\perp\right]\Bigg|_{z=-1}. \tag{4}$$

Expressions (2), (4) connect total, associative, jet and background multiplicity distributions, average multiplicities $\bar{n}(s)$, $\bar{n}^{J}(p_\perp)$, $\bar{n}^{B}(\sqrt{s}-2p_\perp)$ with the form of the single high $p_\perp$ particle spectrum $f(s, x_\perp)$ and allow us to predict the underlying mechanisms of high $p_\perp$ trigger and associative particle production.

The important experimental feature of the function $f(s, x_\perp)$ is its factorization of $f(s, x_\perp) \sim (1-x_\perp)^F/s^N x_\perp^{2N}$ [1]. Using this fact we obtain from (3) (at high s)

$$\sigma(s) \sim \frac{1}{\sqrt{s}} \quad \text{for } N > \tfrac{1}{2}, \qquad \frac{\ln s}{\sqrt{s}} \quad \text{for } N = \tfrac{1}{2}, \qquad \frac{1}{s^N} \quad \text{for } N < \tfrac{1}{2} \tag{5}$$

and for any F. Let us consider some experimentally allowed possibilities in terms of relation (4). At first we suppose that both jet and background multiplicity distributions are wide and correspond to the long-range correlations with inclusive moments of the form $A(\bar{n}^{J,B})^k$. In this case we have for $Q^{J,B}$

$$Q^{J,B} = \exp\left(\sum_{k=1}^{\infty} z^k A(\bar{n}^{J,B})^k\right) = \exp\left(Ae^{\bar{n}^{J,B}z}\right) \tag{6}$$

and multiplicity distributions have KNO-scaling form [7]. We calculate the integral (4) by the saddle-point method in the KNO-limit: $n, \bar{n} \to \infty$, $n/\bar{n}$ fixed[2]. Substantial saddle-

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[1] The expression similar to (2) was used earlier [6, 7] for the connection between multiplicity distribution and a single particle spectrum in the pp → pX for the case of low $p_\perp$.

[2] We consider the KNO-scaling $\bar{n}P_n \simeq \Psi(n/\bar{n}) \neq \delta(n/\bar{n}-1)$ (wide distributions) to be important and probably independent of Feynman-scaling condition because of its experimental justification for hadron-hadron and hadron-nucleus collisions at very broad region of energies.

-point depends on correlation between average multiplicity of the jet and the background. According to the data [8] $\bar{n}^J \sim \sqrt{s}\, x_\perp$, $\bar{n}^B \sim \ln \sqrt{s}\,(1-x_\perp)$, $\bar{n}(s) \sim \ln \sqrt{s}$. Assuming that $n/\ln \sqrt{s} \equiv \xi$ is fixed we find that the saddle-point is $x_{\perp s} \sim 1/\sqrt{s}$. Then we obtain for the KNO-function $(n/\bar{n} > 1)$ the expression

$$\bar{n}(s)P_n(s) \simeq \frac{e^{-A}A^{\xi}}{\xi!}\,\frac{f(s, x_{\perp s})}{\sigma(s)}\,\frac{\ln \sqrt{s}}{\sqrt{s}}\,. \tag{7}$$

This form is kept in the cases when we suppose that there are no wide but the Poisson-like distributions in the jet[3].

Thus, the KNO-scaling will take place in the case of $f(s, x_{\perp s}) \ln \sqrt{s}/\sigma(s)\sqrt{s} \sim$ const. Since $f(s, x_{\perp s} \sim 1/\sqrt{s}) \sim$ const, $\sigma(s)$ must be of the order of $\ln \sqrt{s}/\sqrt{s}$ and the corresponding value of N is equal to 1/2 in (5). The experimental values of N and F in the process $pp \to hX$ for various inclusive hadron h are [1]: N from 8.5 (for π^+-mesons) to 11.9 (for antiprotons) and F from 6.8 (for protons) to 9.7 (for π^--mesons). In all these cases we have $\sigma(s) \sim 1/\sqrt{s}$ from (5) and for the KNO-function $\bar{n}(s)P_n(s) \simeq \ln \sqrt{s}\, e^{-A}A^{\xi}/\xi!$ (for $n/\bar{n} > 1$). Thus, we can expect wide distributions with the weak violation of the KNO-scaling by the factor $\ln \sqrt{s}$. We note that the relation (4) reduces again to Poisson-like distribution $\bar{n}(s)\,P_n(s) \simeq \delta(n/\bar{n}(s)-1)$ when Poisson multiplicity distributions are realized both in the jet and in the background. There is some experimental evidence [9] that $\bar{n}^J(p_\perp) \to$ const when $p_\perp$ is considerably growing. In this case we have $\bar{n}(s)P_n(s) \simeq \ln \sqrt{s}\, e^{-A}A^{\xi}f(s, 1/\sqrt{s})$ $/\xi!\sigma(s)$, i. e. violation of the KNO-scaling for any $f(s, x_\perp)$.

In conclusion we see that relation scheme between average multiplicities in the jet, the background and the total system of produced particles and multiplicity distributions in these systems and the single high $p_\perp$ particle spectrum points out wide multiplicity distributions in all these systems, probably with the weak KNO-scaling violation.

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[3] The result (7) is not very sensitive to a small variation of the assumed $x_\perp$ dependence of $\bar{n}^J$. For example for $\bar{n}^J \sim (\sqrt{s}/\alpha) \ln (1+\alpha x_\perp)$ we obtain the same expression (7) in the first two orders in the parameter α.