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Правила кваркового счета при больших $P_\perp$

Рассмотрена связь между наблюдаемым отклонением от размерного кваркового счета в рождении адронов с большими $P_\perp$ и явлением нарушения скейлинга в глубоконеупругом рассеянии лептонов. Экспериментальное поведение инклюзивных сечений образования частиц при больших $P_\perp$ связывается с экранированием канонического кваркового закона $P_\perp^{-4}$.

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Quark Counting Rules at Large $P_\perp$

Observed deviation from the dimensional quark counting in high $P_\perp$ hadron production and the scale breaking phenomena in deep inelastic lepton scattering are related. Experimental results on inclusive large $P_\perp$ production in terms of the screening of canonical $P_\perp^{-4}$ quark behaviour are explained.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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As is known, dimensional quark counting [1] gives the power law asymptotics of the wide angle binary processes and e.m. form factors in fair agreement with experiment. The same arguments applied to the high $P_\perp$ hadron production provide the canonical $P_\perp^{-4}$ scaling for inclusive cross sections. Such a behaviour contradicts, however, to the recent experimental data on high $P_\perp$ production.

It appears that the observed deviation from the dimensional $P_\perp^{-4}$ reflects the scale breaking phenomena in deep inelastic lepton scattering. Particularly, results of the analysis [2] allow one to relate in an analytical way the power law exponent N versus the scale breaking parameters and establish the role of the different nonscaling regimes of quark distributions at different values of x- and Q^2-variables. This demonstrates how the observed experimental results on high $P_\perp$ particle production can be explained as a certain screening of the canonical $P_\perp^{-4}$ quark behaviour*. It is convenient to represent our results for the inclusive cross section $E\,d\sigma/d^3p(AB \to C+X) \sim P_\perp^{-N(x_R)}$ in the following *table*

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* We do not review here various attempts to the inclusive power analysis, made since Tbilisi Conference. See, e.g., [3].

$pp \to c + X$	$X_R \sim 0$ $P_\perp^{-4(1+\epsilon_0)}$	$X_R \sim 1$ $P_\perp^{-(4+\epsilon_1)}$
$c = \pi$ meson production	$\epsilon_0 = a + 3/8\,c$ $N \simeq 4.0$	$\epsilon_1 = 4(a+b+c/2)$ $N \simeq 8.0$
$c = p$ baryon production	$\epsilon_0 = a + 3/8\,b$ $N \simeq 4{,}5$	$\epsilon_1 = 4a + 6b$ $N \simeq 9.0$
$c = j$ jet production	$\epsilon_0 = a$ $N \gtrsim 3.0$	$\epsilon_1 = 4(a+b)$ $N \simeq 7.0$

(1)

Parameters a , b , c entered in the expressions (1) specify the scale breaking in the quark (gluon) distribution and decay functions known from the deep inelastic lepton scattering data /4/

$$F(x,Q^2) \sim (Q^2/Q_0^2)^{-f_p(x)} , \quad f_p(x) = a + bx$$
$$D(z,Q^2) \sim (Q^2/Q_0^2)^{-f_\pi(z)} , \quad f_\pi(z) = cz \cdot \qquad (2)$$

The pattern of $f_\pi(z)$ refers to the experiments on hadron distribution inside the jet, produced in pp-collision at different $P_{trigger}$.

Using the standard arguments of the hard scattering model $(d\hat{\sigma}/d\hat{t}\,(\substack{qq\to qq\\ gg\to gg}) \sim \hat{s}^{-2})$ the extra $P_\perp^{-N}$ powers arise from the averaging procedure of the nonscaling Q^2-dependence of the hadronic structure functions *

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* We do not consider here the quark internal $k_\perp$ -effects, which could give rise to some enhancement in $P_\perp^{-N}$ See, e.g., ref./5/.

$$P_\perp^4\, E\, d\sigma^c / d^3p \sim \langle P_\perp^{-2f} \rangle_{y_1 y_2} . \qquad (3)$$

Here the function f is specified by nonscaling exponents in structure function. For the π-production case we obtain:

$$f\left(1/2\left[1+\frac{x_1x_2-(1-\bar{x})^2y_1y_2}{x_1x_2+(1-\bar{x})(x_1y_2-x_2y_1)+(1-\bar{x})^2y_1y_2}\right], \bar{x}+(1-\bar{x})(y_1+y_2)\right) \cong$$

$$2f_p\left(1/2\left[1+\frac{x_1x_2-(1-\bar{x})^2y_1y_2}{x_1x_2+(1-\bar{x})(x_1y_2+x_2y_1)+(1-\bar{x})^2y_1y_2}\right]\right) +$$

$$+f_\pi(\bar{x}+(1-\bar{x})(y_1+y_2)), \qquad (4)$$

where $x_2 = -t/s = -x_\perp/2\,\mathrm{ctg}\,\theta/2$, $x_1 = -u/s = -x_\perp/2\,\mathrm{tg}\,\theta/2$, $x_1+x_2 = \bar{x}$

and y_1 , y_2 are the integration variables.

Thus, integral $\langle p_\perp^{-2f} \rangle$ depends parametrically on the external variables $\bar{x} = x_\perp/\sin\theta \simeq x_R$, θ and can be reduced for the physically interesting cases of small and threshold values of $\bar{x}$. Consider now two extreme cases.

A. WEAK SCREENING LIMIT $(\bar{x} \sim 0)$

This case corresponds to the small $x_\perp(x)$ range and is specified as approach to some boundary quark transverse momenta $P_\perp \gtrsim P_\perp^*$ for increasing and sufficient large energies $\sqrt{s}$. In this limit eqs. (3), (4) give

$$E\, d\sigma^\pi / d^3p \xrightarrow[\bar{x}\sim 0]{} c_0\, P_\perp^{-4(1+\epsilon_0)} , \qquad (5)$$

where $\epsilon_0 = 1/2\ f(0, \overline{y_1+y_2})$, i.e., are defined by the scale breaking effects near the origin and correspond to the small deviations from the $P_\perp^{-4}$ behaviour.

B. STRONG SCREENING REGION ($\bar{x} \to \bar{x}_{thr.}$)

In this limit characterized by the threshold region of $x_\perp = \sin\theta$ variable or $x_R \to 1$ (neglecting the masses), anomalous $P_\perp$-dependence from nonscaling effects can provide maximal deviations from the canonical value $N = 4$, seen now in the available FNAL-ISR range, i.e.,

$$E\, d\sigma^\pi / d^3p \xrightarrow[\bar{x}\to 1]{} c_1 P_\perp^{-(4+\epsilon_1)} \tag{6}$$
$$\epsilon_1 = 2f(1,1).$$

Thus. eq. (6) corresponds to an increase in power exponent $N - 4 = \epsilon_1$. Generally speaking, the nonscaling behaviour of the quark distribution (and decay) functions, which define the precise form of the (6) and (5) limits could be obtained within AF gauge theories as the effect of different gluon corrections. In the framework of QCD, however, there is no selfconsistent method for the perturbative calculations of higher orders, and we restrict ourselves to the phenomenological ansatz (2).

This pattern of empirical scale breaking is not related, however, with the AF predictions of logarithmic Q^2-dependence for the $\nu W_2(x)$-moments, but is still applicable (numerically) as a guide to the recent deep inelastic experimental data. These power behaved breaking terms, in principle, can play a role of transient phenomena, and the right asymptotic region can be considered as the change of regime $(Q^2)^{-a} \to (\ln Q^2)^{-a}$.

SOME CONCLUDING REMARKS

i) As was previously mentioned, the case of the weak screening (5) should be valid at rather high energies of colliding hadrons and fixed final $P_\perp \geq P_\perp^* \sim 1 \div 2$ *GeV/c*, i.e., $x_\perp \to 0$. This interval of the transverse momenta

could be associated with the passing to the high $P_\perp$ regime in production cross sections. This phenomenon is already seen in cosmic ray data [6] and has support in the available accelerator energy range. For instance, there is some evidence from data analysis on the basis of radial scaling [7] at $x_R \to 0$ and world data analysis [8]. A similar transition region manifests itself also in the fixed angle elastic cross section [9] at the small $|t|$ values (corresp. $P_\perp^* \sim 1.7$ *GeV/c*) in accordance with the exclusive-inclusive connection [10].

ii) In the case of the medium $x_\perp$ range, averaging between the strong and weak screening limits provides the resulting values of power law exponent N which are less than 8 for meson, and 10 for baryon production, respectively. It should be noted that the results of the world data analysis [8] support the absence of the stable values $N = 8(12)$ for π, K, $(p^\pm)$ -production cross sections. Besides, some evidence of the decreasing character of exponent N comes from ISR experiments and preliminary data of CCOR, CZS groups [11], where $N \approx 6.5$ for mesons.

iii) We should like to emphasize that the weak decrease in $N(\theta)$ dependence for the small values of production angle θ in sense of eq. (4)* reflects the trend of the high $P_\perp$ experimental data [8] and is similar to the behaviour of the corresponding elastic cross sections showing the smaller values of N_{excl} $(\frac{d\sigma}{dt} \sim s^{-N_{excl}})$ for smaller fixed angles [13].

Finally, we notice that the approaching at very high energy the canonical quark-jet regime $P_\perp^{-4}$ does not contradict to rigorous asymptotic bounds [14] derived by Logunov and Mestvirishvili in the theory of inclusive reactions.

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*Note, that the effective power analysis $P_\perp^{-N_{eff}}$ could mix all these effects, and the corresponding results can be considered only in the sense of average values [12].

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