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NEW DELPHI DATA ON INCLUSIVE $e^+e^- \to h + X$ PROCESS AND CHECK OF QCD PREDICTIONS FOR SCALING VIOLATION IN FRAGMENTATION FUNCTIONS

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The appearance of the first DELPHI data on the processes of inclusive production of hadrons allows the check of the QCD-predictions on the fragmentation function $\bar{D}_q^h(z, s)$. For this purpose we firstly perform the QCD-analysis of TASSO data and then we perform the extrapolation of QCD expressions for $\bar{D}_q^h(z, s)$ (with fixed values of parameters found from TASSO data fitting) in the region of Z°-peak.

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

Новые данные ДЕЛФИ по инклюзивному процессу $e^+e^- \to h + X$ и проверка предсказаний КХД для нарушения скейлинга в функциях фрагментации

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Появление первых данных ДЕЛФИ относительно процесса инклюзивного рождения адронов позволяет осуществить проверку предсказаний КХД для функций фрагментации $\bar{D}_q^h(z, s)$. Для этой цели мы вначале осуществили КХД-анализ данных TASSO и затем провели экстраполяцию КХД выражения для $\bar{D}_q^h(z, s)$ (с параметрами, фиксированными по результатам фита данных TASSO) в область Z°-пика.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

The process of inclusive annihilation (IA) $e^+e^- \to h + X$ with the production of the distinguished hadron h ($h = \pi$, K, p...) in the final state (X — all other particles) belongs to a set of few processes about which QCD can give an unambiguous prediction /1-5/.

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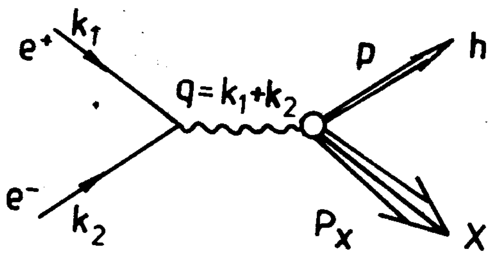

Fig.1

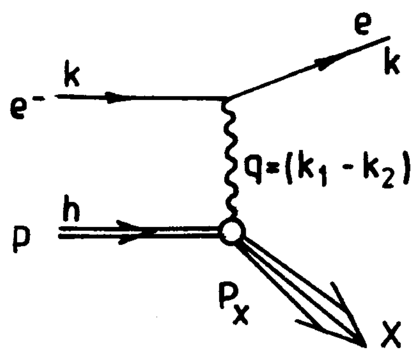

Fig.2

This process, shown in fig.1, is a cross channel analog of deep-inelastic scattering (DIS) $e^-p \to e^- + X$ (see fig.2, h = p) carefully studied in the last decade by EMC [6] and BCDMS [7] collaborations. The interest in this process is caused by the prediction of the existence (with the account of the QCD second order perturbation theory) of a stronger effect of the scalling violation in $e^+e^- \to h + X$ as compared with the channel $e^-h \to e^- + X$ [8-10]. Due to this reason the experimental measurement of the s-dependence of the $e^+e^- \to h + X$ cross section and its theoretical analysis is very important*.

The aim of the present paper is to study the question up to what extent new DELPHI data on the process $e^+e^- \to h + X$ taken at Z^0-peak $(W = \sqrt{(p_{e^+} + p_{e^-})^2} = \sqrt{s} = M_Z = 91$ GeV$)$ [13] do agree with the theoretical QCD predictions. For this purpose, we will perform firstly (part I) the QCD analysis of TASSO data [12] and then (part II) the extrapolation of the theoretical expressions (with the fixed values of the parameters of the fragmentation function $\bar{D}^h_{q_i}(z, s)$ of quarks q_i into hadrons) to the region of LEP energies. The obtained theoretical curve will be compared with the preliminary experimental DELPHI data [13].

I. QCD-analysis of TASSO data [12] was performed by us with the help of the previously proposed method of the expansion of structure functions in orthogonal Jacobi polynomials [14] and applied, in particular, for the analysis of BCDMS data [15]. Here, we shall use a more

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*The more detailed discussion in connection with the possibility of measuring the IA process $e^+e^- \to h + X$ at LEP can be found in [11].

general method of expanding in arbitrary polynomials

$$P_n^{\alpha}(x) = \sum_{i=0}^{n} A_i^n(\alpha)\, x^i$$

(see [16]) that are orthogonal in the interval $0 \le x \le 1$ with the weigth function $w(x, \alpha)$

$$\int_0^1 w(x, \alpha)\, P_k^{\alpha}(x)\, P_n^{\alpha}(x)\, dx = \delta_{kn}, \tag{1}$$

the exact form of which is defined by a set of parameters denoted as α. The expansion of the fragmentation functions $\bar{D}^h_{q_i}(z, s)$, defining the cross section of the process $e^+e^- \to h + X$

$$s\frac{d\sigma}{dz} = \frac{4\pi\alpha^2}{3}\cdot 3\cdot \bar{D}(z, s) = \frac{4\pi\alpha^2}{3}\cdot 3\cdot \sum_h \sum_{q_i=1}^{n_f} e^2_{q_i}[\bar{D}_{q_i}(z, s) + \bar{D}_{\bar{q}_i}(z, s)], \tag{2}$$

has the form $\left(z = \dfrac{E^h}{E_{beam}} = \dfrac{2p^h q}{s}\right)$

$$\bar{D}(z, s) = w(z, \alpha) \lim_{N_{MAX}\to\infty} \sum_{k=0}^{N_{MAX}} C_k(\alpha, s)\, P_k^{\alpha}(z). \tag{3}$$

Here, the coefficients

$$C_k(\alpha, s) = \sum_{n=0}^{k} A_n^k(\alpha)\, M_{n+2}(s)$$

are the sum of the moments of the fragmentation function

$$M_n(s) = \int_0^1 dz \cdot z^{n-2}\cdot \bar{D}^h(z, s)$$

the analytical expressions for which $M_n^{QCD}(s)$ are calculated in the framework of QCD up to the second order of perturbation theory [8-10].

Here, we shall restrict our analysis to the use of the leading order (LO) in the running coupling constant of QCD $\alpha_s(Q^2)$ ($Q^2 = s$). In the case of IA, the QCD formulae for the moments have the same structure as in the case of the muon-proton deep-inelastic scattering but with the only exchange of nondiagonal anomalous dimensions γ_{qg} and γ_{gq} responsible for the quark-gluon mixing (see for details, for example,[17]).

The results of fitting TASSO data[12] at $W = \sqrt{(p_e + p_{\bar{e}})^2} = \sqrt{s} = 14, 22, 34$ and 44 GeV with the restriction of the sum (3) only to seven terms ($N_{MAX} = 7$) and with the use, except for Λ, of only 4 free parameters (that define the form of the weight function as well as distribution of nonsinglet, singlet quark and gluon distributions) lead us to the next value of QCD scale parameter Λ (that was also taken as a free one): $\Lambda = 150 \pm 76$ MeV at $\chi^2_{d.f.} = 76/55 \simeq 1.38$. Only the points with $z > 0.05$ we included in fitting among which 2 points were excluded ($z = 0.15$, $W = 34$) and ($z = 0.225$, $W = 44$) with the contribution larger than 10. The total number of fitted points was 60. In[18] TASSO data with $z > 0.1$ were fitted and a larger value of Λ was obtained.

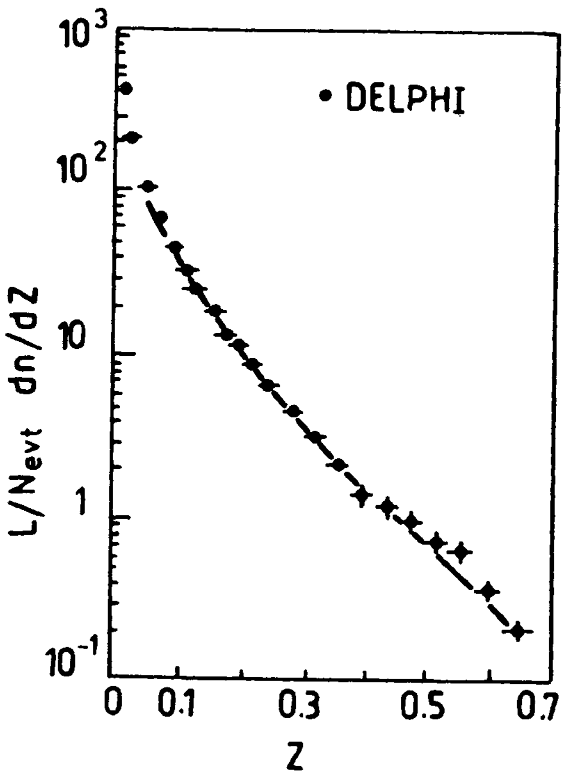

Fig.3

II. The extrapolation of QCD-fit into z^0-region and the comparison with the preliminary DELPHI data was done with the help of the same formula (3) (with $N_{MAX} = 7$) with the values of parameters fixed by TASSO data fitting. Due to the absence of the DELPHI data presented as a table the results of this extrapolation are shown in fig.3 by the solid line as compared to the new DELPHI data taken from fig.(3b) of[13]. From this figure we see that the DELPHI preliminary data on IA agree well with the QCD prediction. So we hope that the appearance of more precise data in future would allow one to perform a more detailed QCD-analysis with the account of the 2nd order perturbation theory and with the discussion of the form of the fragmentation functions of quarks $\bar{D}_q^h(z, s)$ and gluons what would give the opportunity to check an interesting QCD prediction.

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