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HADRON MULTIPLICITIES AT THE ENERGIES OF LEP-1.5 AND LEP-2

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Abstract

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Total hadron multiplicities and multiplicities of hadrons in events with heavy quarks in e^+e^- annihilation at the energies of LEP-1.5 and LEP-2 are calculated on the basis of QCD.

Аннотация

Киселев А.В., Петров В.А. Адронные множественности при энергиях LEP-1,5 и LEP-2: Препринт ИФВЭ 96-87. – Протвино, 1996. – 3 с., 1 табл., библиогр.: 13.

На базе КХД вычислены полные множественности адронов и множественности адронов в событиях с тяжелыми кварками в e^+e^-–аннигиляции при энергиях LEP-1.5 и LEP-2.

One of the most important overall characteristics of final hadronic states in e^+e^- annihilation is an average multiplicity of (charged) hadrons, $\langle n \rangle_{had}$. The rise of $\langle n \rangle_{had}$ in W enables one to make conclusions on a mechanism of multiple hadron production in hard processes.

The data on $\langle n \rangle_{had}(W)$ with the high energy data from LEP-1 [1] and SLC [2] included are well approximated by the QCD–based expressions (see, for instance, [3]). Let us remind that at $W = m_Z$ the world average is equal to

$$\langle n \rangle_{had} = 20.94 \pm 0.20. \tag{1}$$

The total multiplicity in e^+e^- annihilation is given by the formula:

$$\langle n \rangle_{had} \sum_q P_q = \sum_q \langle n \rangle_q P_q, \tag{2}$$

where P_q is a SM weight of an event with primary quarks of type q $(q = u, d, s, c, b)$ and $\langle n \rangle_q$ is an average multiplicity in such an event.

In Ref. [4] in the framework of QCD we have derived the following expression for $\langle n \rangle_q$ (see [4] for details):

$$\langle n \rangle_q = \langle n \rangle_q^0 + C_F \int \frac{dk^2}{k^2} \frac{\alpha_s(k^2)}{\pi} E(W^2, k^2) n_g(k^2). \tag{3}$$

Here $\langle n \rangle_q^0$ means the average multiplicity of fragmentation products of the primary quark q. $E(W^2, k^2)$ describes an inclusive distribution of gluon jets in their invariant masses k^2, while $n_g(k^2)$ is a hadron multiplicity inside the gluon jet with the virtuality k^2.

Formulae (2), (3) made it possible to describe well hadron multiplicities in e^+e^-–events induced by b–quarks, $\langle n \rangle_b$, [5,6] and to predict the values of hadron multiplicities in events induced by c–quarks, $\langle n \rangle_c$. In particular, our result, $(\langle n \rangle_c - \langle n \rangle_{uds})(m_Z) = 1.01$, where $\langle n \rangle_{uds}$ means an average multiplicity of hadrons in events with light primary quarks, have appeared to be in good agreement with the data from OPAL and SLD Collaborations [6,7].

In the present paper we calculate hadron multiplicities at the energies of LEP-1.5 (133 GeV) and LEP-2 (161, 175, 192 GeV), with the use of Eqs. (2), (3). The results for $m_c = 1.5$ GeV/c^2, $m_b = 4.8$ GeV/c^2 are presented in Table.

Table 1.

W, ГэВ	133	161	175	192
$\langle n\rangle_{uds}$	23.13	25.02	25.87	26.85
$\langle n\rangle_{c}$	24.13	26.02	26.88	27.85
$\langle n\rangle_{b}$	26.80	28.65	29.54	30.51
$\langle n\rangle_{had}$	24.10	26.00	26.85	27.82

Recently the data on the total multiplicity at $W = 130$ GeV and $W = 133$ GeV have been obtained [8,9]:

$$\begin{aligned} \text{DELPHI}(W = 130\text{GeV}):\ \langle n\rangle_{had} &= 23.84 \pm 0.51 \pm 0.52, \\ \text{OPAL}(W = 133\text{GeV}):\ \langle n\rangle_{had} &= 23.40 \pm 0.45 \pm 0.47. \end{aligned} \tag{4}$$

In Ref. [3] the corrected data at $W = 133$ GeV are presented:

$$\begin{aligned} \text{DELPHI:}\ \langle n\rangle_{had} &= 23.3 \pm 0.6, \\ \text{OPAL:}\ \langle n\rangle_{had} &= 23.24 \pm 0.32 \pm 0.41. \end{aligned} \tag{5}$$

Finally, there are LEP-2 data on the total multiplicity [10]:

$$\langle n\rangle_{had}(161\text{GeV}) = 25.78 \pm 0.45 \pm 0.53. \tag{6}$$

As one can see from Table, our values $\langle n\rangle_{had}(133\text{GeV}) = 24.10$ and $\langle n\rangle_{had}(161\text{GeV}) = 26.00$ agree well with the data (4)-(6). Note, that Monte Carlo models accounting for the quark masses give the values $24.1 \div 24.2$ at $W = 133$ GeV [9], which are very closed to our prediction.

At the same time, empirical fits and QCD–formulae that do not take into account the specific features of the events with the heavy quarks (see, for instance, [11]), result in somewhat higher value $\langle n\rangle_{had} = 24.4$ at $W = 133$ GeV [3,9].

These discrepancies can be, of course, "improved" provided one adds the value of $\langle n\rangle_{had}$ at the point $W = 133$ GeV in a fit. It is clear, however, that such an "improvement" could be hardly considered to be satisfactory as it actually lowers a predictive power of a theory.

Our results for $W = 175$ GeV (see Table) can be compared, for instance, with those in Ref. [12], where the values $\langle n\rangle_c = 28.8$, $\langle n\rangle_b = 30.6$, $\langle n\rangle_{had} = 27.0$ are obtained and with the value $\langle n\rangle_{had} = 27.3$ in Ref. [13].

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