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CROSS SECTIONS OF THE INCLUSIVE HADRON-HADRON PROCESSES AND A POSSIBLE GROWTH OF A NUMBER OF QUARK FLAVOURS

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1. As is known, the quark-gluon interaction in the processes of the deep inelastic lepton-hadron scattering and e^+e^- annihilation is satisfactorily described in the framework of the QCD perturbation theory.

At the same time, the study of the hadron-hadron interactions with large P_T offers some difficulties. Particularly, the character of the asymptotic cross section production of hadrons and jets in these reactions has to be clarified, as well as their relationship with the violation of the scalar invariance in deep inelastic lepton-hadron processes.

In [1,2] for the first time were formulated the rules of the quark counting of anomalous dimensions in QCD which determine the logarithmic corrections to the pointlike degree asymptotics of the cross sections of processes with large P_T. These rules have been obtained in the leading logarithmic approximation of QCD in the region of the relatively small $x_T = \frac{2P_T}{\sqrt{s}}$.

From the Table,where the data are collected of the experiments [3-10] carried out at the CERN ISR and SPS Collider, it is seen that the region of relatively small x_T is prominent, and the variable x_T is changed in the interval of

$0.5\cdot 10^{-2} < x_T \leq 0.54$, and at $s = 540$ GeV and $\theta = 90°$

$0.17\cdot 10^{-2} \leq x_T \leq 0.5\cdot 10^{-2}$.

However, it was shown in [11] that under some conditions the range of applicability of QCD formula for the cross section [2,11] could be enlarged:

$$\sigma(s, P_T, \theta) = \text{const}\left(\frac{P_T}{P_{T_0}}\right)^{-n_{eff}(s,\, x_T,\, \theta)} , \qquad (1)$$

where

$$n_{eff}(s, x_T, \theta) =$$

$$= 4 - 2[2 - 2r \ln\frac{2x_T}{\sin\theta} + hd(n, \frac{x_T}{\sin\theta}) + c \ln\frac{x_T}{\sin\theta} + d]/\ln(\frac{Q^2}{\Lambda^2}) ,$$

TABLE

N_{expt}	i	Process $AB \to C$	$\sqrt{s}$ GeV	P_T^{min} GeV	P_T^{max} GeV	θ	Number of points	χ^2/M_i	Normalized coefficients
I	1	$p\bar{p} \to \pi^0$	540	1.52	4.42	90^o	14	0.13	1.34 ± 0.10
2	2	$p\bar{p} \to \pi$	540	0.45	1.35	90	10	0.15	1.91 ± 0.16
	3	$p\bar{p} \to p + \bar{p}$	540	1.55	1.35	90	9	0.92	0.94 ± 0.08
3	4	$pp \to p$	44.6	1.15	3.10	45	7	0.57	1.60 ± 0.16
	5		52.8	1.15	2.60	45	6	0.63	1.38 ± 0.15
	6		52.8	1.35	3.40	62	5	0.63	1.38 ± 0.15
	7		52.8	0.82	4.75	89	10	1.32	0.94 ± 0.08
	8		63.0	0.82	2.35	89	7	0.85	0.74 ± 0.08
4	9	$pp \to \pi^0$	53.1	3.71	12.70	90	16	1.92	0.90 ± 0.06
	10		62.4	3.72	13.70	90	21	0.24	0.97 ± 0.06
5	11	$pp \to \gamma^0$	45.1	0.50	6.65	53	31	0.71	1.06 ± 0.05
	12		45.1	0.70	8.02	90	37	0.69	1.06 ± 0.05
	13		53.2	0.69	7.19	53	33	0.29	1.25 ± 0.06
	14		53.2	1.28	7.81	90	33	0.43	0.82 ± 0.04
	15		62.9	0.70	6.42	90	29	0.40	0.69 ± 0.04
6	16	$pp \to \pi^0$	53.0	5.25	14.30	90	15	0.65	1.03 ± 0.08
	17		63.0	5.25	14.60	90	15	1.21	0.88 ± 0.07
7	18	$pp \to$ jet	45.0	6.40	11.00	90	15	1.36	1.07 ± 0.14
	19		63.0	6.66	12.90	90	15	3.41	1.56 ± 0.18
8	20	$pp \to \pi^0$	52.7	3.05	11.00	90	23	0.61	1.07 ± 0.06
	21		62.8	3.05	13.50	90	26	0.76	0.93 ± 0.05

where c and d are the parameters of approximation (1), $r = \frac{16}{33 - 2n_f}$, h is the number of hadrons in the reaction; $d(n, x_T)$ is the function of anomalous dimensions:

$$d(n, x_T) = -r\left[\frac{3}{4} + \frac{1}{2n(n+1)} - \sum_{i=1}^{n}\frac{1}{i} + \frac{1}{n} + \ln(1 - x_T)\right]$$

n is the doubled number of noninteracting quarks (quark-spectators), n_f is the number of quark types (flavours).

The formula (1) for the cross section of the inclusive reactions $AB \to CX$ was obtained in the leading logarithmic approximation of QCD by means of the quark counting rules of the anomalous dimensions at $\theta = 90°$.

In this case, the function of quark distribution and fragmentation is defined by solving the evolution equations with the boundary conditions imposed by the quark counting rules [6].

The purpose of this work is to describe data on the inclusive hadron-hadron cross sections at the above-mentioned energies and different angles. It will be seen from the following that the expansion of the considered experimental data leads to the interesting conclusion about the number of quark types.

2. In [11] it was shown that the formula (1) agrees with the measured cross sections at $x_T \geq 0.2$ and $\theta = 90°$. The range $10^{-2} \leq x_T \leq 0.6$; $\theta = 90°$ can be described if, instead of (1), the following formula has to be used:

$$\sigma(s, P_T, \theta) = a \cdot \exp[-b \cdot m \cdot \chi_{P_T} \cdot n_{eff}(s, x_T, \theta), \qquad (2)$$

where a, b, c are the unknown parameters; the rapidity $\chi_{P_T} = \ln\left(\sqrt{1 + \frac{P_T^2}{m^2}} + \frac{P_T}{m}\right)$, where $m = m(s)$ is the scale which defines the boundary region of the transition of cross section from the exponential to power regime [13].

According to [18] we reckon that m^2 is proportional to the cross section of the corresponding process.

The values of the unknown parameters in formula (2) are estimated by solving the overdeterminated nonlinear algebraic system [17] $\sigma_i^{expt}(s_i, P_{T_j}, \theta_k) = a_i \sigma_t^{th}(s_i, P_{T_j}, \theta_k)$, where indices i, j, k run through the region of changing s, P_T and θ.

By solving the system (3) it was found that $m(s) = \frac{m_0 \cdot n}{\ln s/\Lambda^2}$, $Q^2 = \frac{P_T^2}{1 - 4P_T/s}$. With the following values of parameters $\Lambda = 0.097$ GeV; $m_0 = 2.65 \pm 0.5$ GeV; $a = 38.2 \pm 6.1$ GeV^2; $b = 0.85 \pm 0.01$ GeV^{-1}; $c = 3.61 \pm 0.07$; $n_f = 10 \pm 0.2 - 2.2$ the value $\chi^2/df = 245/358-6$. The error of the parameter Λ is not indicated because it was found that its value could be changed in the interval $10^{-3} \leq \Lambda \leq 0.5$ GeV with a quite good accuracy of the description which is natural in the first logarithmic approximation. This value has been selected from the necessity of the parameter independence.

Figs.1-6 present descriptions of experimental data for the various processes at different energies and scattering angles.

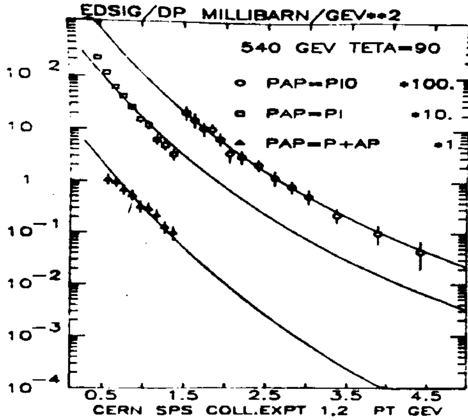

Fig.1. Description of the inclusive processes $p\bar{p} \to \pi^0$, $\pi^{\pm} \to p + \bar{p}$ at $\sqrt{s} = 540$ GeV and $\theta = 190°$ (see [3,4]).

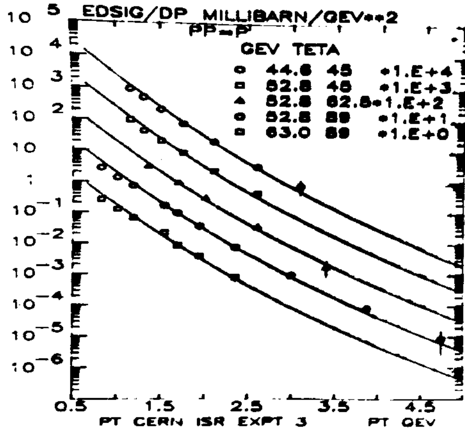

Fig.2. Description of the process $pp \to p$ at $\sqrt{s} = 44{,}6$; 52.8 and 63 GeV and $\theta = 45°$; 62.5° and 89° (see [5]).

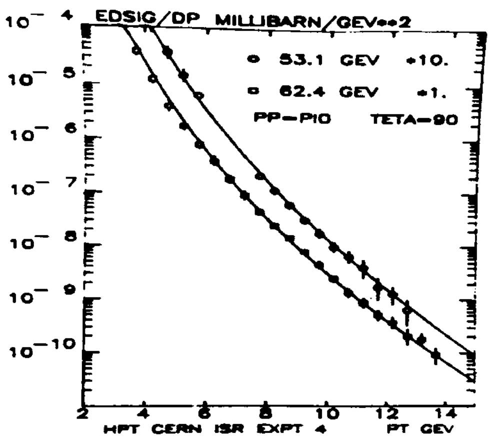

Fig.3. Description of the process $pp \to \pi^0$ at $\sqrt{s} = 53.1$; 62.4 GeV and $\theta = 90°$ (see [6]).

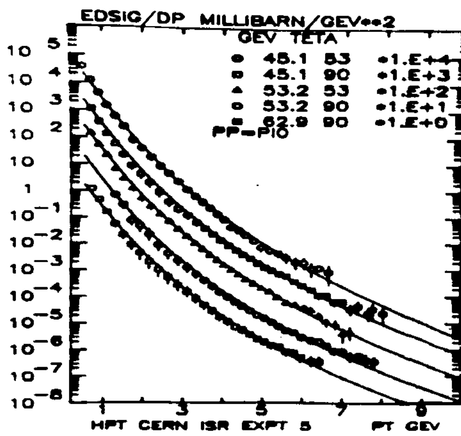

Fig.4. Description of the process $pp \to \pi^0$ at $\sqrt{s} = 45.1$; 53.2 and 62.9 GeV and $\theta = 53°$ and 90° (see [7]).

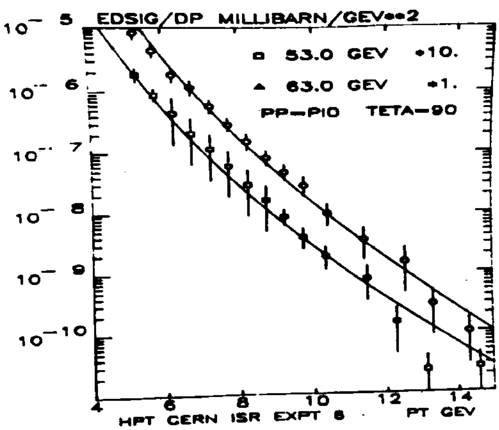

Fig.5. Description of the process $pp \to \pi^0$ at $\sqrt{s} = 53$ and 63 GeV and $\theta = 90°$ (see [8]).

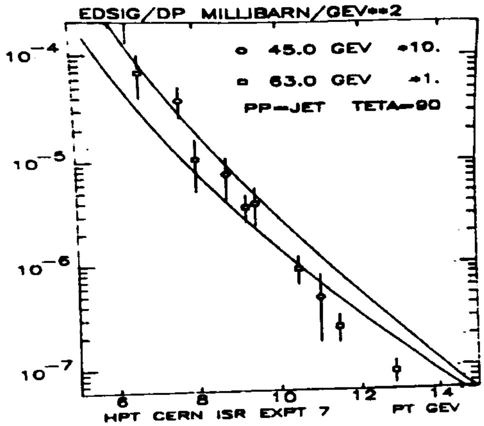

Fig.6. Description of the process $pp \to$ jet at $\sqrt{s} = 45$ and 53 GeV and $\theta = 90°$ (see [9]).

The reliability of this description is confirmed by the data collected in the Table where the normalized coefficients are also given. When the data are considered only at the energies of ISR, the value of χ^2/df is left the same but $n_f = 4+2.1-0.2$.

The modified formulae for the inclusive cross sections (see (2)) proved to be effective for the description of experimental data in the broad range of energies of 40-540 GeV and accessible angles. The following fact should be noted. In case of the ISR energies [5-11] the analysis of data with formula (2) gives the number of quark types as $n_f = 4^{+2.2}_{-0.2}$. The number of quark types is increased up to $n_f = 10^{+0.2}_{-2.2}$. when we take into account data obtained at the CERN SPS Collider.

This indicates a possible observation of new quark freedom degrees (quark tapes) with the energy increasing including the scalar charged quarks [19].

This problem has a special interest in relation with the existence of colour scalar quarks [19]. Particularly, it has been found that in considering the e^+e^- annihilation the scale mass of new hadrons, which represents the coherent states of scalar particles, had a value of order 110-100 GeV at the different zero condensate $<\phi^+\phi^->$.

The assumption given in [20,21] on the scalar quarks belonging to the super multiplets of the colour SU(3C) group leads to the large inclusive cross sections of the scalar quark jets which may be observed at the already accessible energies of hadron collisions.

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