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L. Berny

*Deutsches Elektronen-Synchrotron DESY, Hamburg*

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2 Hamburg 52
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# Measurement of the proton structure function in low-$p_T$ hadron-hadron interactions

L.Berny
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**Abstract**

Previously published data on low-$p_T$ $p-p$ interactions at 250 GeV/c are used to analyze the proton structure function.

The quark structure function measurement is usually carried out using the data from lepton-$p$ interactions [1,2,3]. It is thus interesting to define and to extract the proton structure function from the low-$p_T$ hadron-hadron interactions.

It was shown [4,5] that assuming the proton to be described as a three quark system, one can express its structure function as:

$$f(x_1,x_2,x_3) = Cx_1^{a_1}x_2^{a_2}x_3^{a_3}(1-x_1-x_2-x_3)^g \qquad (1)$$

where $x_i$ is the Feynman variable of the valence quark,
$a_i$ and $g$ are the parameters
and $C$ is a normalization factor defined by
$\int\int\int f(x_1,x_2,x_3)dx_1dx_2dx_3 = 1$ .

Since the jets in hadron-hadron interactions are moving in the projectile direction [6] the charge structure function of the proton can be written as

$$F(x) = \sum_{i=1}^{3} q_i f_i(x)(1-x_1-x_2-x_3)^g \qquad (2)$$



where $q_i$ is the valence quark charge and

$$f_i(x) = \int_0^{1-x_i}\int_0^{1-x_i-x_j} f(x_i,x_j,x_k)dx_idx_j = Cx^{a_k}(1-x)^{b_k} \qquad (3)$$

is the single quark structure function. If $f(x_1,x_2,x_3)$ from eq. (1) is a symmetric function then the proton charge structure function F(x), defined in eq. (2), does not depend on the quark charge and is equal to the single quark structure function.

The proton can also be described as a quark-diquark system. This can be done by using the recombination function [7]

$$R(x;x_1,x_2) = x_1x_2\delta(x-x_1-x_2)/x \qquad (4)$$

in order to combine two quarks into diquark. In this case the proton structure function has the following form

$$f(x,v) = \sum_{i=1}^{3} x^{a_i}v^{b_i}(1-x-v)^g \qquad (5)$$

where
$b_i = 2 + a_1 + a_2 + a_3 - a_i$ and
x (v) is the Feynman variable of a quark (diquark).

The proton charge structure function for the quark-diquark case and for a symmetric function (1) can be written in the form

$$F(x) = <q_q> f_q(x) + <q_{dq}> f_{dq}(x) \qquad (6)$$

where
$<q_q>$ ($<q_{dq}>$) is the average charge of the quark (diquark) and
$f_q(x)$ ($f_{dq}(x)$) is the quark (diquark) Structure Function. In this case the proton charge structure function depends on the quark (diquark) structure function and their charges.

In order to check all the above mentioned conclusions, we analyzed the published data originating from an experiment performed at the CERN SPS with the European Hybrid Spectrometer, using the rapid bubble chamber as a vertex detector for a proton beam of 250 GeV/c [6,8].

Only forward projectile of the proton-proton interactions is investigated, because those data contain all charge particles, whereas the protons with laboratory momentum smaller then $1.2GeV/c$ were excluded from backward projectile data.

One can write the proton charge structure function as

$$F(x) = (\frac{d\sigma^+}{dx} - \frac{d\sigma^-}{dx})/\sigma_{tot} \tag{7}$$

where $\frac{d\sigma^+}{dx}$ ($\frac{d\sigma^-}{dx}$) is the Feynman x distribution of positive (negative) particles. These experimental data were used to find the best fit for the proton described as the three quark system and the quark-diquark system.

The diffractive events were described by the function [9]

$$Dif(x) = \frac{(1-x)^\gamma}{1+\gamma} \tag{8}$$

The proton structure function for the three quark system is taken in the form

$$F_p^{qqq}(x) = \frac{x^a(1-x)^{2+g+2a}}{B(1+a, 3+g+2a)} \tag{9}$$

where $B(\alpha, \beta)$ is beta-function.

For the quark-diquark picture we need to descibe the quark structure function, $F_q^{qdq}$, and the diquark structure function, $F_{dq}^{qdq}$, which will then combine to give the proton structure function, $F_p^{qdq}$ :

$$F_q^{qdq}(x) = \frac{x^a(1-x)^{3+g+2a}}{B(1+a, 4+g+2a)} \tag{10}$$

$$F_{dq}^{qdq}(x) = \frac{x^{2+2a}(1-x)^{1+g+a}}{B(3+2a, 2+g+a)} \tag{11}$$

$$F_p^{qdq}(x) = B_1 F_q^{qdq}(x) + B_2 F_{dq}^{qdq}(x) \tag{12}$$

The fit for the three quark system was performed using form

$$F_{qqq}(x) = AF_p^{qqq}(x) + (1-A)Dif(x) \tag{13}$$

while for the quark-diquark system we used the form

$$F_{qdq}(x) = F_p^{qdq}(x) + (1 - B_1 - B_2)Dif(x) \tag{14}$$



The experimental data and fitted curves are given in fig. 1.
The resulting parameters for the three quark system $F_{qqq}$ are

| | | |
|---|---|---|
| $a$ =-036±.03 | $g$ =0.09±0.16 | $\gamma$ =-0.55±.05 |
| $A$ =0.72±.01 | $\chi^2/N$ =68/21 | |

and those for quark-diquark system $F_{qdq}$ are

| | | |
|---|---|---|
| $a$ =-0.28±.03 | $g$ =1.45±0.20 | $\gamma$ =-0.55±.05 |
| $B_1$ =0.43±.01 | $B_2$ =0.20±.01 | $\chi^2/N$ =59/20 |

Therefore one can express the proton structure function as

$$F_p^{qqq}(x) = 1.2x^{-0.36}(1-x)^{1.3} \tag{15}$$

for the three quark picture, and as

$$F_p^{qdq}(x) = < q_q > 2.5x^{-0.28}(1-x)^{3.9} + < q_{dq} > 21.5x^{1.42}(1-x)^{2.2} \tag{16}$$

for the quark-diquark one.

These results show that both fits have about the same $\chi^2/N$. It seems that the presence of the diffractive events does not permit to decide which of the two hypoteses is better.

It is worth noticing that the behavior of $F_p^{qqq}$ at large $x$ is very different from that measured in the lepton-$p$ experiments [10]
$F_q = 3.6x^{-0.45}(1-x)^{3.2}$
whereas $F_q^{qdq}$ is closer to the lepton-$p$ measurements.

Using the best fit parameters $B_1$ and $B_2$ of the quark-diquark system one can find that
$< q_q > = 0.69 \pm 0.02$
$< q_{dq} > = 0.31 \pm 0.02$ .

These results are somewhat surprising because if all quarks in the proton have the same probability to compose a diquark, then $< q_{dq} >$ should be 2/3 and not 1/3. Therefore our result seems to indicate that if the proton is composed of a quark-diquark system, then the diquark is always a $(ud)$ composition.

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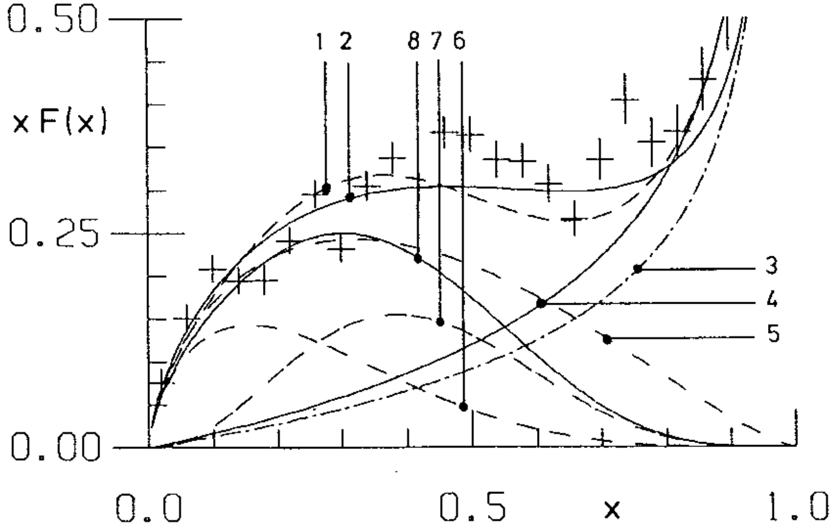


Figure 1: The $p$ structure function for $p - p$ interactions.
1 - $F_{qdq}(x)$ the quark-diquark system.
2 - $F_{qqq}(x)$ the three quark system.
3 - $Dif(x)$ distribution of diffractive events for the three quark system.
4 - $Dif(x)$ distribution of diffractive events for the quark-diquark system.
5 - $F_p^{qqq}(x)$ the proton structure function for the three quark system.
6 - $F_q^{qdq}(x)$ the quark structure function for the quark-diquark system.
7 - $F_{dq}^{qdq}(x)$ the diquark structure function for the quark-diquark system.
8 - $F_p^{qdq}(x)$ the proton structure function for the quark-diquark system.