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Measurement of the hadron structure function in hadron-hadron interactions

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Abstract. Previously published data on low-p_T $\pi^+/K^+/p-p$ interactions at 250 GeV/c are used to analyze the rapidity charge distribution and hadron structure function for the projectile hadrons. It is shown that the rapidity charge distribution for projectile hadrons can be approximated by a Gauss distribution, and their structure functions are found.

1 Introduction

The proton structure function (SF) measurement is usually carried out using the data from $l-p$ interactions [1–3] whereas the measurement of the pion structure function [4, 5] is heavily based on the proton SF.

It is interesting to extract the hadron structure functions from the low-p_T hadron-hadron interactions. As known, the particles belonging to a hadron jet are moving in the projectile direction [8].

It was shown [6, 7] that the two quark meson SF can be expressed in the following way:

$$f(x_1, x_2) = C x_1^{a_1} x_2^{a_2} (1 - x_1 - x_2)^g \tag{1}$$

where x_i is the Feynman variable of the valence quark and C is a normalization factor defined by $\iint f(x_1, x_2)\, dx_1\, dx_2 = 1$.

By integrating (1) one gets for the mesons charge SF

$$F(x) = q_1 f_1(x) + q_2 f_2(x) \tag{2}$$

where q_i is the valence quark charge, and

$$f_i(x) = \int_0^{1-x_i} f(x_i, x_j)\, dx_j = C x^{a_i} (1-x)^{b_i} \tag{3}$$

is the single quark SF.

Two phenomena can hide the true behavior of the hadron SF

- charge spillover at small x,
- diffraction dissociation at x near 1.

The first phenomenon can not be eliminated, but can be estimated, the second one can be partially eliminated, however it is present in used data and can be estimated, as well.

The goal of this paper is to find the π^+ and K^+ and p SF and to investigate the charge distribution behavior of the π^+, K^+ and proton as a function of the c.m. rapidity (y^*).

The data used here originate from an experiment performed at the CERN SPS with the European Hybrid Spectrometer, using the rapid bubble chamber as a vertex detector [9]. This experiment was performed at 250 GeV/c.

Details of the experimental arrangement and data reduction have been published [8, 9]. It should be mentioned that the protons with laboratory momentum smaller than 1.2 GeV/c were excluded from the positive particle sample (C^+). Therefore the data for the negative Feynman-x and c.m. rapidity $y^* < -2.0$ are not used in our paper.

2 c.m. rapidity charge distribution

In order to investigate the c.m. rapidity charge distribution of the hadrons one can examine the plot of the function

$$F(y^*) = \left(\frac{d\sigma^+}{dy^*} - \frac{d\sigma^-}{dy^*}\right) \Big/ \sigma_{\text{tot}} \tag{4}$$

which is given in Figs. 1–3.

Those figures show that $F(y^* = 0) \neq 0$ and therefore the spillover of the valence quarks from the forward to the backward hemisphere and vice versa ex-

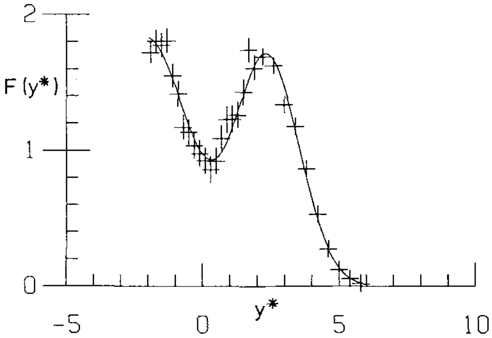

Fig. 1. The rapidity charge distribution for K^+p interactions at 250 GeV/c

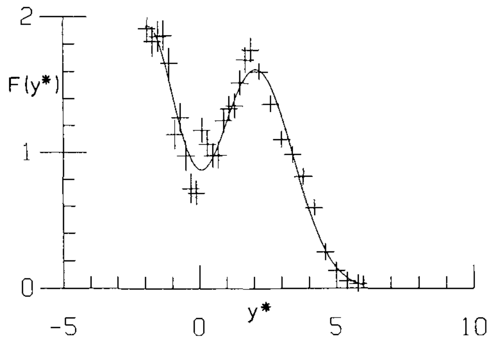

Fig. 2. The rapidity charge distribution for π^+p interactions at 250 GeV/c

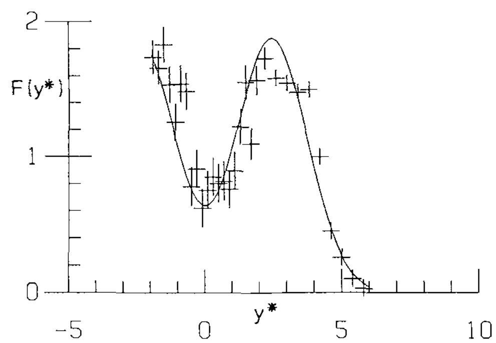

Fig. 3. The rapidity charge distribution for pp interactions at 250 GeV/c

ists and depends on the type of the interacting hadrons. The c.m. rapidity distribution of the hadron can be described – as a first approximation – as a sum of two Gauss distributions

$$F(y^*) = A e^{\frac{-(y^*-a)^2}{2\sigma_a}} + B e^{\frac{-(y^*+b)^2}{2\sigma_b}} \quad (a, b > 0). \tag{5}$$

The first one describes the forward particle rapidity distribution, the second one describes the backward particle rapidity distribution and serves only for finding the best forward distribution.

Table 1. Fits of (5) to the c.m. rapidity charge distribution

Reaction	a	σ_a	b	σ_b	χ^2/N
πP	2.06 ± 0.03	1.35 ± 0.01	1.90 ± 0.01	1.05 ± 0.01	142/30
KP	2.36 ± 0.03	1.17 ± 0.01	2.08 ± 0.03	1.56 ± 0.02	46/30
PP	2.44 ± 0.01	1.29 ± 0.01	2.44	1.29	216/30

Table 1 shows that the mean value (a) of the distribution is different for different hadrons. (The comparison with [10] shows that it also depends on $s^{1/2}$.)

In order to estimate the charge spillover the value of the forward particle distribution tail for negative values of y^* is computed. The charge spillover from π, K and proton is about 6, 4 and 3%, respectively. The charge spillover in the π^-p reaction decreases the charge of π^- by 9%. This result agrees in sign with the previous reported results [11]. However, the value of the charge spillover found there is about twice as large.

3 Hadron structure function

In order to investigate the hadron structure function one can examine the plot of the function

$$xF(x) = x\left(\frac{d\sigma^+}{dx} - \frac{d\sigma^-}{dx}\right) \Big/ \sigma_{\text{tot}} \tag{6}$$

which is given on Figs. 4–6.

Those figures show the presence of diffractive events. The Feynman-x distribution of hadron charge can be described as a sum of the quark charge distribution and the distribution of the charge of the diffractive events. Attempts to estimate the parameters of a two-dimensional quark distribution for mesons show that function (1) is approximately symmetric. In the symmetric case the experimental hadron charge

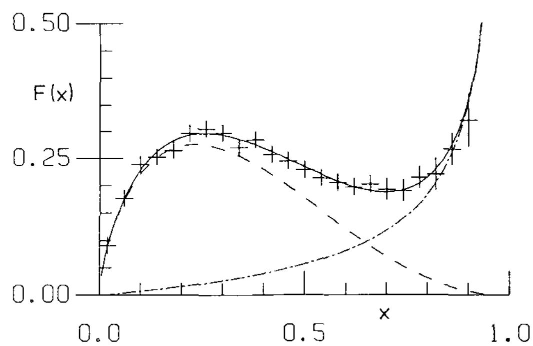

Fig. 4. The K^+ structure function for K^+p interactions. The solid line is the fit to (7). The dashed line is the structure function of K^+. The dash-dot line is the fitted distribution of diffractive events

Table 2. Fits of (7) to the Feynman-x charge distribution

Hadron	a	b	C	g	D	χ^2/N
π	-0.52 ± 0.03	1.94 ± 0.20	0.80 ± 0.01	-0.72 ± 0.01	0.29 ± 0.01	22/20
π [4]	-0.50 fixed	1.56 ± 0.18				
π [5]	-0.56 ± 0.12	0.97 ± 0.15				
p	-0.47 ± 0.03	0.70 ± 0.30	0.82 ± 0.04	-0.73 ± 0.1	0.28 ± 0.01	58.0/20
K	-0.31 ± 0.03	2.25 ± 0.14	0.82 ± 0.02	-0.77 ± 0.04	0.29 ± 0.02	8.63/20

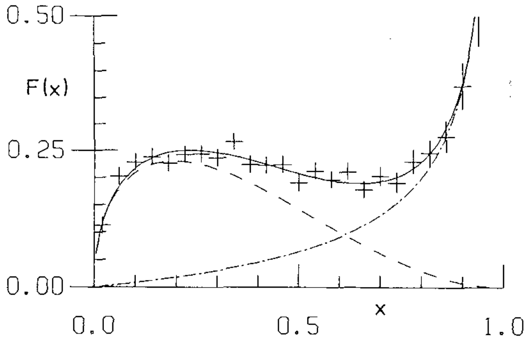

Fig. 5. The π^+ structure function for π^+p interactions. The solid line is the fit to (7). The dashed line is the structure function of π^+. The dash-dot line is the fitted distribution of diffractive events

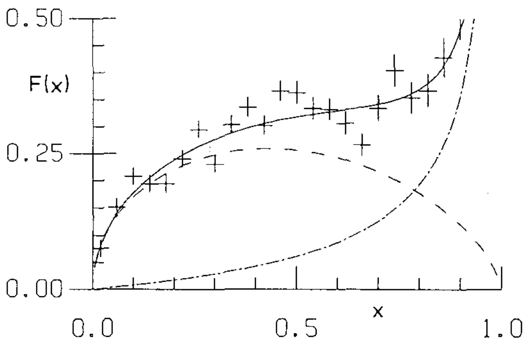

Fig. 6. The p structure function for pp interactions. The solid line is the fit to (7). The dashed line is the structure function of p. The dash-dot line is the fitted distribution of diffractive events

distribution reduces to

$$F(x)=C\frac{x^a(1-x)^b}{B(1+a,1+b)}+D\frac{(1-x)^g}{1+g}, \tag{7}$$

Table 2 shows that the behavior of the diffractive distribution (D, g) is about the same for π, K and p whereas the parameters of the quark distributions are different. The proton distribution has large errors which can distort the b value.

4 Summary and conclusions

This paper reports on the measurement of the hadron SF using data from low-p_T hadron-hadron interactions at 250 GeV/c. The results lead to the following conclusions.

- The c.m. rapidity charge distribution of the valence quarks is different for different hadrons.
- The charge spillover from π, K and proton is about 6, 4 and 3%, respectively.
- The contribution of the diffractive events is about 30% and it is in agreement with published data [8].
- The π-meson SF can be described as $f(x)=0.86x^{-0.5}(1-x)^{2.0}$ and it is in a good agreement with published data.
- The K-meson SF can be described as $f(x)=1.65x^{-0.3}(1-x)^{2.2}$ and it contradicts the data used in [12].
- The p SF can be described as $f(x)=x^{-0.5}(1-x)^{0.7}$ and it contradicts the data from [13] because the proton was treated as the three quarks system. The large errors and the diffractive events contribution did not permit to treat the proton as quark-diquark system.
- The distribution of the diffractive events can be described as $f(x)=3.3(1-x)^{-0.7}$.

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