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STUDY OF THE REACTION $\bar{p}p \to p + X$ AT 22.4 GeV/c

Alma-Ata - Dubna - Helsinki - Košice - Moscow - Prague - Tbilisi Collaboration

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The statistical separation of charged particles in the whole phase space region [1] has made it possible to study further the reaction

$$\bar{p}p \to p + X \qquad (1)$$

at 22.4 GeV/c [2]. This analysis is based on a sample of about 2.2×10^4 inelastic interactions from the 2 m hydrogen bubble chamber Ludmila.

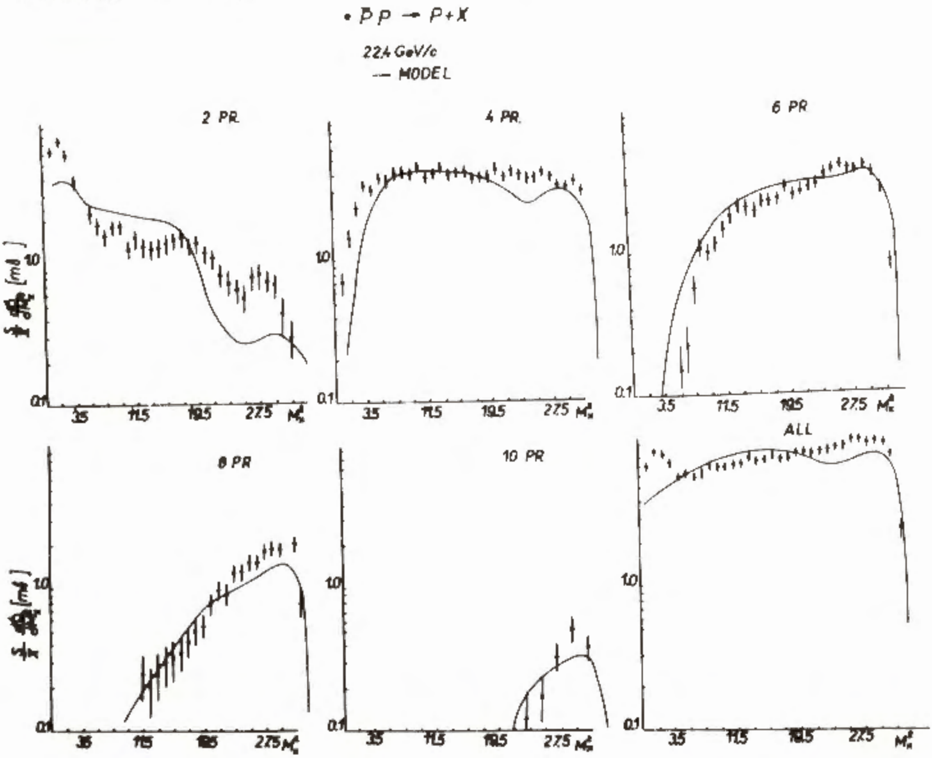

Fig.1. The semi-inclusive structure functions of protons $f_n^p(M_X^2)$ in $\bar{p}p$- interactions at 22.4 GeV/c. The solid curves are the quark-parton model predictions.

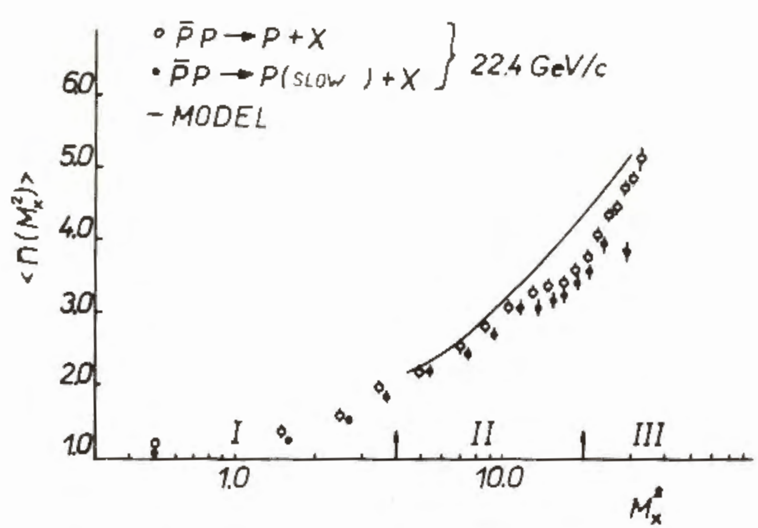

Fig.2. The mean multiplicity of charged particles in the system X associated with the proton as a function of M_X^2 in the reactions $\bar{p}p \to p + X$ and $\bar{p}p \to p\,(slow) + X$ at 22.4 GeV/c. The solid curve is the quark-parton model prediction.

The structure functions $f_n^p(M_X^2) = \frac{s}{\pi} \frac{d\sigma_n^p}{dM_X^2}$ for charged multiplicities n = 2,4,...10 are shown in fig.1. The region of large missing masses ($M_X^2 \geq 20$ GeV^2) is the main point of interest now. It is seen that the maxima of the semi-inclusive structure functions $f_n^p(M_X^2)$ are shifted towards higher missing masses with increasing multiplicity.

The mean associated multiplicity of charged particles, which is connected with the semi-inclusive structure functions in the following way

$$<n(M_X^2)> = \frac{\sum_n (n-1) f_n^p(M_X^2)}{\sum_n f_n^p(M_X^2)} \qquad (2)$$

is presented in fig.2 as a function of M_X^2. It is seen from the figure that at $M_X^2 = 20$ GeV^2 there is a change from the general trend in the dependence of $<n(M_X^2)>$ on M_X^2. In regions II ($4 \leq M_X^2 \leq 20$ GeV^2) and III ($M_X^2 \geq 20$ GeV^2) this dependence is fairly well approximated by a logarithmic function

$$<n(M_X^2)> = a + b\ \ln(M_X^2/M_0^2), \qquad M_0^2 = 1\ \mathrm{GeV}^2. \qquad (3)$$

The slope b in region III is essentially larger than that in region II (see table 1). The logarithmic dependence of the associated multiplicity on M_X^2 is predicted by the multiperipheral model[3,4] and the slope is proportional to the π-meson multiplicity in the multiperipheral chain vertices (see, e.g., ref.[5]). Consequently, the increase of the slope b may be due to the clusterization of particles.

Table 1

Fits to $<n(M_X^2)>$ distributions in different M_X^2 regions.

M_X^2 region / Formula	a	b	χ^2/ND
I $M_X^2 \leq 4$ GeV^2 $a + b\sqrt{M_X^2}$	0.63±0.09	0.61±0.06	5/2
II $4 \leq M_X^2 \leq 20$ GeV^2 $a + b\ \ln(M_X^2/M_0^2)$	0.69±0.11	0.94±0.05	8/7
III $M_X^2 \geq 20$ GeV^2 $a + b\ \ln(M_X^2/M_0^2)$	-4.66±0.61	2.78±0.19	4/5

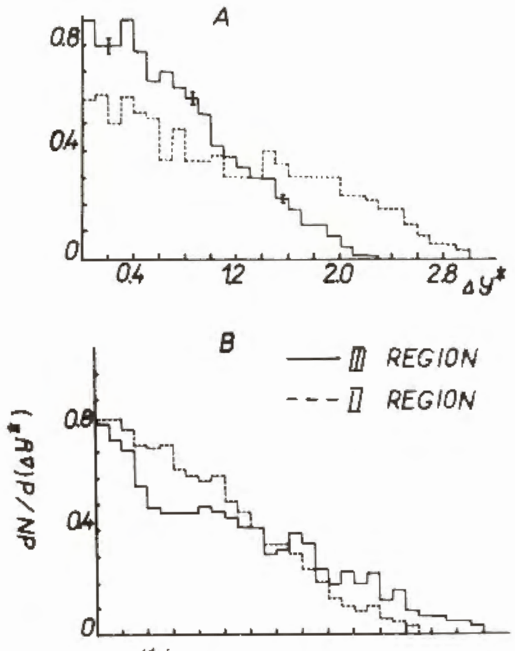

Fig.3. a) The experimental rapidity gap distributions normalized to unity for 4-prong events in regions II ($4 \le M \le 20$ GeV) and III ($M \ge 20$ GeV). b) The same distributions from the quark-parton model.

To investigate clusterization in the system X, the method of rapidity gaps for each topology [6,7] is used. In doing so, each positive particle is in turn assumed to be a proton (i.e., the event is assigned an appropriate proton weight [1]). For other charged particles taken as pions $\Delta y^* = y^*_{i+1} - y^*_i$ is determined in an interval $-Y \le y^* \le Y$, where Y defines the width of the "central" region. The weight function [1] allows one to represent correctly any one-particle spectrum of protons. But the distribution of the two-particle variable Δy^* is distorted. These distortions are small in the "central region" where all charged particles are essentially π-mesons. Y is chosen from the condition of maximal relative difference between average Δy^* in the regions II and III for each topology.

The rapidity gap distributions, dN/dy^*, normalized to unity are given in fig.3a for regions II and III for 4-prong events. The enchanced contribution of small Δy^* in region III indicates the increase of short-range correlations between the particles in system X for large M_X^2. A similar effect is seen in higher multiplicities although the difference between the Δy^* distributions in regions II and III becomes smaller with increasing multiplicity (see table 2). The decrease of $\langle \Delta y^* \rangle_n$, as well as of the relative difference of the values of $\langle \Delta y^* \rangle_n$, with increasing n in regions II and III has a simple kinematical origin ($\langle \Delta y^* \rangle_n \sim (\ln s)/n$).

Table 2

Average values $\langle \Delta y^* \rangle$ for regions II and III for different multiplicities. For each pair of numbers, the lower one is for the quark-parton model.

M_X^2 region \ multiplicity, $\|Y\|$		4-pronged 1.6	6-pronged 1.2	8-pronged 0.8
II	$4 \le M_X^2 \le 20$ GeV^2	1.08±0.02 0.79±0.03	0.53±0.02 0.45±0.02	0.32±0.03 0.29±0.04
III	$M_X^2 \ge 20$ GeV^2	0.71±0.02 0.98±0.03	0.42±0.01 0.52±0.02	0.28±0.01 0.31±0.02

In fig.3b* we plot the Δy^*-distributions for Monte-Carlo simulated events according to the quark-parton model [8] which contains only resonances from the lowest-lying SU(6) multiplets (see table 2). These distributions show a tendency opposite to that of the experimental ones. An increase of $\langle \Delta y^* \rangle$ with increasing the value of M_X^2 can be expected from kinematical considerations. Therefore the model also supports an evidence for clusterization in region III.

In figures 1 and 2 is shown a comparison of the one-particle structure functions $f_n^p(M_X^2)$, $f^p(M_X^2)$ and of the mean associated multiplicity to proton $\langle n(M_X^2) \rangle$ with the quark-parton model [8] normalized to the non-diffractive inclusive cross section for $\bar{p}p$ reactions at 22.4 GeV/c (diffraction is not taken into account by the model). One can see that the experimental distributions $f_n^p(M_X^2)$ and $f^p(M_X^2)$ are qualitatively described by the model. In the case of the associated multiplicity the model prediction differs from the experimental data. In principle, one can have a better agreement

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* The Δy^*-distributions for Monte-Carlo events obtained without the weight function [1] do not differ significantly from those given in fig.3b.

modifying the distribution of valence quarks by increasing their spread over x (the distribution of the Kuti-Weisskopf type is used in the model [9]). This well lead to a decrease of the mean proton multiplicity (it is too large in the present model) and will increase the contribution of events with large values of M_X^2. As for the model reproduction of the clusterization of π-mesons at $M_X^2 \geq 20$ GeV^2, this phenomenon may be described within the framework of the model by modifying the distributions of valence and sea quarks without the help of clusters (heavy resonances).

The following results have been obtained:

1. The maxima of the structure functions $f_n^p(M_X^2)$ are shifted towards larger missing masses with increasing multiplicity n.
2. The general trend of the dependence of the associated multiplicity on M_X^2 changes at $M_X^2 \simeq 20$ GeV^2. The increase of the slope at $M_X^2 \geq 20$ GeV^2 may indicate a clusterization of pions in this region.
3. A confirmation of clusterization for $M_X^2 \geq 20$ GeV^2 is made when analysing the rapidity gap distributions.
4. The quark-parton model [8] describes qualitatively the one-particle structure functions but does not reproduce the clusterization observed in the experimental data.

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