Production of pion pairs with symmetric momenta in the transverse-momentum region $0.5 \leq P_\perp \leq 2.0$ GeV/c in the pp collisions at 70 GeV

V. V. Abramov, B. Yu. Baldin, A. F. Buzulutskov, S. I. Bityukov, Yu. N. Vrazhnov, V. Yu. Glebov, A. S. Dyshkant, , V. N. Evdokimov, V. V. Zmushko, A. N. Krinitsyn, V. I. Kryshkin, N. Yu. Kul'man, V. M. Podstavkov, R. M. Sulyaev, and L. K. Turchanovich

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The slope of the invariant cross section of the process $pp \to \pi^+ \pi^- + X$ varies near 1 GeV/c as a function of $P_\perp$. If the slope is described by the sum of the two exponents, then the exponents must be equal to 12.3 ± 0.9 $(\text{GeV}/c)^{-1}$ and 8.7 ± 0.6 $(\text{GeV}/c)^{-1}$. The experimental values in the region $P_\perp > 1$ GeV/c are much higher than the values predicted by the QCD model (Ref. 1) and by the CIM model (Ref. 2) for inelastic collisions.

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The production of hadron pairs with large $P_\perp$, whose identical momenta in the c.m. frame of the colliding particles are directed in the opposite directions (symmetric momenta), in addition to yielding information simultaneously about two structural constituent partons, which directly participate in the interaction, has another remarkable feature. In it the effect of the internal transverse motion of partons is reduced to a minimum[3] and the correlation between the kinematic variables of partons and the transverse momenta of the produced hadrons is more specific. Because of this, the experimental results can be compared more easily with the theoretical predictions.

Using a focusing double-arm spectrometer,[4] we have measured, in the pp collisions at 70 GeV, the invariant cross sections for production of oppositely charged pion pairs with equal but oppositely directed momenta at a 90° angle in the c.m. frame of colliding protons in the transverse-momentum region $0.45 \leqslant P_\perp \leqslant 1.99$ GeV/c. Since we have used the same measurement procedure and evaluation of experimental data here as in our previous experiment,[5] we shall consider only the important features of the experiment. The intensity of the proton beam incident on the hydrogen target was measured with an absolute accuracy of $\pm 6\%$ and relative accuracy of $\pm 1\%$, using calibrated, secondary-emission chambers. The π mesons were identified in Cerenkov counters and their momenta were measured with an accuracy of $\pm 1\%$ from the angle of deflection of the trajectory in the magnetic field of the spectrometer, using drift chambers. Each arm of the spectrometer recorded a momentum interval $\Delta P/P = 20\%$. We measured the ratios of the yields of pion pairs normalized over the number of proton interactions in the target to the product of the yields of single pions with like signs in each arm of the spectrometer. Assuming that the acceptance of the spectrometer during recording of a pair is equal to the product of the acceptances of the spectrometer arms, this ratio coincides with the correlation function R, which is defined as the ratio of the protons normalized over the total cross section for inelastic

Table I. Correlation functions and invariant cross sections of the reaction $pp \to \pi^+\pi^- + X$

$P_\perp$ GeV/c	R	$E_1E_2\frac{d^6\sigma}{d^3p_1\,,\,d^3p_2}$ mb·GeV^{-4}
0.45	1.40 ±0.11	3.02 ±0.24
0.51	1.72 ±0.14	1.93 ± 0.21
0.69	1.63 ±0.14	0.18 ±0.02
0.99	2.24 ±0.30	$(8.69 \pm 1.12)\times 10^{-3}$
1.35	4.38 ±0.47	$(1.73 \pm 0.20)\times 10^{-4}$
1.61	11.9 ±1.1	$(2.35 \pm 0.22)\times 10^{-5}$
1.75	15.8 ±1.4	$(4.7 \pm 0.4)\times 10^{-6}$
1.99	29.5 ±6.5	$(6.0 \pm 1.3)\times 10^{-7}$

interaction with protons of invariant cross section for production of a pion pair to the product of invariant cross sections for a single production. We determined the invariant cross sections for production of pion pairs from the measured values of R and from the invariant cross sections for production of π^+ and π^- mesons in pp collisions, which were obtained by us previously using the same apparatus.[4] Our results are given in Table I.

First, we shall focus attention on the weak dependence of the correlation function on $P_\perp$ in the transverse-momentum region < 1 GeV/c and on its rapid rise at large transverse momenta. Such a behavior of R is also reflected in the dependence of the invariant cross section for production of a pion pair on the transverse momentum. It decreases sharply in the region of $R_\perp < 1$ GeV/c, and then its decrease becomes flatter. Such a behavior of the cross section can easily be described by the sum of two exponents (see Fig. 1). The exponents turn out to be equal to 12.3 ± 0.9 (GeV/c)$^{-1}$ and 8.7 ± 0.6 (GeV/c)$^{-1}$, respectively.

The component, which dominated at large $P_\perp$ and which had a large value of the correlation function, apparently is associated with the so-called inelastic collisions that occur at the level of the structure components of protons. The second component, which is characterized by a small, average transverse momentum and small value of R, is the result of elastic collisions. The fact that these two components are not seen clearly in the inclusive spectra at 70 GeV (Ref. 6) can possibly be accounted for by a smearing out of the picture, due to internal transverse motion of partons.

The existence of two components during the formation of pion pairs with symmetric pulses can be deduced from the measurements of the correlation function carried out elswhere at 24 GeV (Ref. 7) and at 70 GeV (Ref. 8). We, however, made no such interferences. Special attention should be given to the results of a study of azimuthal correlations of neutral pion pairs at 70 GeV (Ref. 8), which reveal not only the characteristic behavior of the correlation function R but also the isotropic distribution

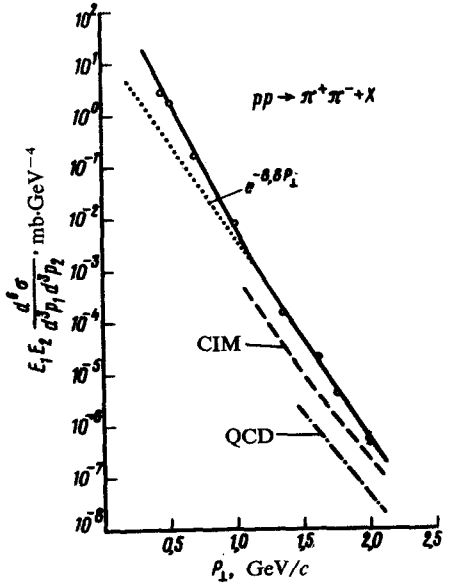

FIG. 1. Invariant cross sections of the reaction $pp \to \pi^+\pi^- + X$ at 70 GeV. The solid curve represents an approximation of the experimental data using the sum of two exponents (see the text). The calculations based on the quantum-chromodynamic model and the constituent-interchange model are represented by the dot-dashed curve and the dashed curve, respectively.

of the "soft" component over the azimuthal angle. Unfortunately, nuclear targets, which complicate the explanation of experimental results, were used in the cited experiments.

The measured invariant cross sections of the process $pp \to \pi^+\pi^- + X$ in the region of $P_\perp$ are equal to the calculations based on the parton quantum chromodynamic (QCD) model (Ref. 1),[1)] in which partons are understood to be quarks and gluons, and on the constituent-interchange model (CIM).[2] The results are shown in Fig. 1. A common feature of the theoretical predictions is the approximate equality of the slopes in the plot of the cross sections vs $P_\perp$; moreover, the relative behavior of the cross section is in qualitative agreement with the experimental data. The results of theoretical calculations turn out to be appreciably lower in absolute value. The calculations based on the QCD model reveal the largest disagreement with the experimental data. The observed discrepancy is much greater than that in the description of inclusive spectra.[6] This result seem unexpected because, as mentioned in the beginning of this letter, one of the uncertainties of this model, which is associated with the initial transverse motion of partons, can be virtually eliminated in the description of the production of symmetric hadron pairs. We also note that at higher energies both models describe the experimental data sufficiently well.[3,9]

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[1)]It should be noted that Ryskin and Troyan[10] derived an expression for the cross section for production of a symmetric hadron pair in the main logarithmic approximation in QCD. This expression is different from that used in the model of Feynman, Field, and Fox.[1] However, it can be used presumably only at very high energies.

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