Investigation of the $\pi^- p \to \pi^0 n$ reaction at large momentum transfers

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Data are presented on the charge-exchange $\pi^- p$ scattering at a momentum 40 GeV/c at large momentum transfers. The experiment was performed with the 70-GeV Serpukhov accelerator using a 648-channel hodoscopic γ spectrometer. The total statistics amounted to more than a million π^0 mesons, making it possible to advance into the momentum-transfer region up to $-t = 1.8$ (GeV/c)^2. The experimental data are compared with the optical model of the impact parameter. The imaginary part of the trajectory of the $b_0(s)$ pole is determined from the slopes of the maxima of the function $\sqrt{-t}\, d\sigma/dt$. A linear increase of $\mathrm{Im}\, b_0(s)$ with log s is observed.

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We present here preliminary results of the investigation of the reaction

$$\pi^- + p \to \pi^0 + n \qquad (1)$$

in the region of large momentum transfers.[6)] The experiment was performed with the Serpukhov 70-GeV accelerator as part of an extensive research program on the neutral final states in $\pi^- p$ collisions. The reaction (1) is among the simplest ones from the point of view of theoretical interpretation. At high energies, the dominant contribution to its amplitude is made by exchange of only a particle with ρ-meson quantum numbers in the t-channel.

The experiments were performed with the NICE installation described in the preeding papers.[1,2] The energies and the coordinates of the γ quanta from the π^0-meson decays were recorded with a 648-channel hodoscopic spectrometer[3] on line with a computer. The triggering electronics separated interactions in the liquid-hydrogen bubble chamber with neutral final states. The point of interaction was localized in the target by measuring the intensity of the Cerenkov radiation in the liquid hydrogen.[4] A guarding system of sandwich counters excluded all events with lateral emission of charged particles and γ quanta, with the exception of the γ quanta traveling in the forward cone in the direction of the γ spectrometer. This has made it possible to suppress effectively registration of background processes in which N^* were produced and decayed. During the measurement time, a total of 10^{11} π^--mesons passed through the target, corresponding to an exprimental sensitivity of 10^{-35} cm^2/event.

In the described experiments, the γ spectrometer was located close to the target, at a distance 3 m. The minimal distance separating the γ quanta from the π^0-meson decay in reaction (1) was in this case 2.2 cm, and the γ quanta were usually only partly separated in the specotrometer. To determine the coordinates of the π^0 meson we used the center of gravity of two showers. The combined pulse amplitude yielded the π^0-meson energy. Other processes were excluded, first, by

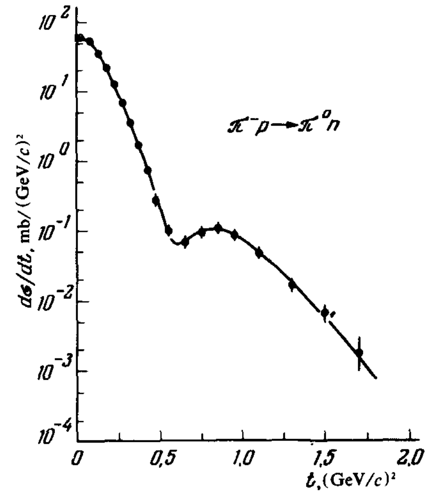

FIG. 1. Differential cross section of the reaction (1) at 40 GeV/c. A structure, wherein the cross section decreases towards $t=0$, cannot be seen in the region of small $-t$ because of the large t intervals employed. The curve is drawn freehand through the points.

the condition that there be no additional γ quanta outside the aperture angle of the pair from the π^0 meson, and second by the limitation on the invariant mass of the system that decays into γ quanta. The mass was determined by measuring the first and second moments of the spectrometer pulse amplitudes.[5]

The background due to the events in which the decay γ quanta are produced with low energy and are therefore not recorded (for example, highly asymmetrical decays of η mesons) was determined by varying the energy threshold of the program used to identify the γ quanta. The

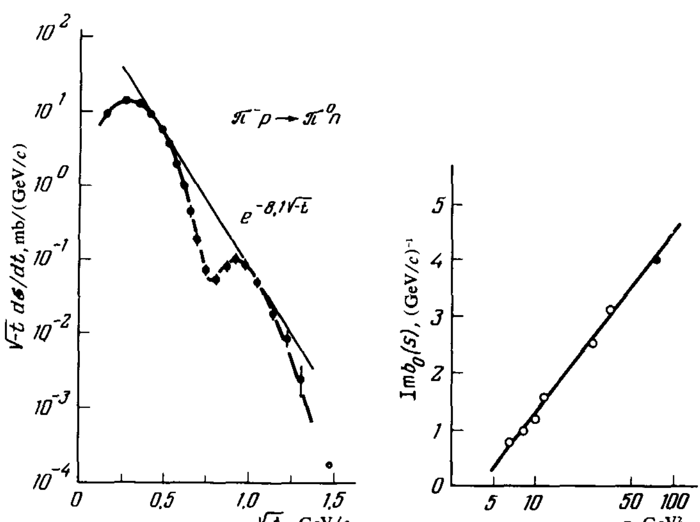

FIG. 2. a) Plot of $\sqrt{-t}\, d\sigma/dt$ vs. $\sqrt{-t}$ at 40 GeV/c in reaction (1). The tangent of the maxima [see (2)] determines the imaginary part of the trajectory of the $b_0(s)$ pole in the impact-parameter model.[8] Curve—the same as in Fig. 1. b) Imaginary part of the complex pole, $\mathrm{Im}b_0(s)$, as a function of log$s$. Points: •—our data at 40 GeV/c, ○—data at 3–18 GeV/c.

contribution of the background turned out to be negligibly small. At very large $-t$. where the cross section decreases by more than a factor of 10^4 in comparison with the small angles, the admixture of the "inelastic" processes $\pi^- p \to \pi^0 + X$, where X is not a neutron becomes significant. It is this background, and not the statistics, which limits in final analysis the region of attainable values of t. The increase of this background manifests itself in a growth of the number of events in which the π^0 meson has an energy lower than at the peak corresponding to the reaction (1). The contribution of this background was monitored by extrapolating the spectrum of the π^0 mesons in "inelastic" processes in the region of the peak of the reaction (1). In the last measured t-intervals, 1.6–1.8 $(\mathrm{GeV}/c)^2$, the background ranged from 20 to 50%.

The measured differential cross sections $d\sigma/dt$ of reaction (1), with account taken of the resolution of the apparatus (by the Monte Carlo method), are shown in Fig. 1. Our data agree with the earlier results[6,7] at 40 GeV/c, which cover the region of $-t$ up to 1.4 $(\mathrm{GeV}/c)^2$, and exceed them in statistics by one or two orders of magnitude—we registered more than $10^6 \pi^0$ mesons in the reaction (1).

The large values of the momentum transfers attained in the present study allow a comparison to be made between the experimental data and the predictions of the model of the geometric S-channel approximation.[8] According to that model the differential cross section is determined by the contribution of the complex pole $b_0(s)$, which moves in the plane of the impact parameter. A large class of binary reactions can be described by this model at medium and large momentum transfers, $-t > 0.25$ $(\mathrm{GeV}/c)^2$, using the universal pole $b_0(s)$. The model predicts that in the case of the charge-exchange reaction the quantity $\sqrt{-t}\, d\sigma/dt$ should oscillate with increasing $\sqrt{-t}$ and has an upper bound

$$\sqrt{-t}\, d\sigma/dt_{\max} \sim \exp(-2\mathrm{Im}\, b_0(s)\sqrt{-t}) \ . \tag{2}$$

The quantity $2\mathrm{Im}\, b_0(s)$ is determined by the tangent to the maxima of the cross sections in a semilog scale [see Fig. 2(a)]. The value of $\mathrm{Im}\, b_0(s)$ obtained from our data at a momentum 40 GeV/c is shown in Fig. 2(b) together with the quantities obtained from data at lower energies, from 3 to 18 GeV/c.[9] Our point lies on a line continued from the region of low energies and shows that $\mathrm{Im}\, b_0(s) \propto \log s$ up to $s \approx 100$ GeV^2.

On the basis of analyticity we can find from this logarithmic dependence also the value of $\mathrm{Re}\, b_0(s)$. It turns out to be ≈ 5 $(\mathrm{GeV}/c)^{-1}$, corresponding to an interaction-region radius ≈ 1 F.

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