Study of the reaction $\pi^- + d \to p +$ all with maximum momentum transfer to the proton in the primary momentum interval from 1.68 to 3.28 GeV/c

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The cross section of the reaction $\pi^- + d \to p +$ all (with the proton emitted forward) (1) was measured in the interval from 1.68 to 3.28 GeV/c. A rapidly decreasing dependence of the cross section on the primary π^--meson energy was observed, similar to the energy dependence of the reaction $\pi^- + p \to p +$ all (2). The cross section of the reaction $\pi^- + n \to p +$ all (3) was determined from the difference of the reactions (1) and (2).

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The reaction

$$\pi^- + d \to p + \text{all} \tag{1}$$

was investigated in the region of large momentum transfers at incident π^--meson energies 1.68, 2.11, 2.64, and 3.28 GeV. The high-energy proton of reaction (1), emitted at a small angle relative to the primary π^- meson, was registered by an event-separation system[1] and analyzed with the 3-meter spectrometer of our Institute.[2] A total of about 40 thousand events of reaction (1) was accumulated. The procedure for determining the cross section is analogous to that described in[3]. In the calculation of the proton missing mass (M_x) in reaction (1), the mass of the target particle was assumed equal to the nucleon mass.

Figure 1 shows the dependence of the inclusive cross section $d^2\sigma/dU dM_x^2$ of reaction (1) on M_x^2 for different momenta (P_0) of the incident π^- meson. The experimental points for fixed P_0 are joined by straight lines. The same figure shows for comparison the cross section of the reaction

$$\pi^- + p \to p + \text{all} \tag{2}$$

which was investigated earlier.[3] It is seen from Fig. 1 that the cross sections of both reactions (1) and (2) can be factorized. At all P_0 and M_x^2, the cross section of reaction (1) exceeds that of (2), but by not more than two times. With increasing M_x^2 at fixed P_0, the cross sections of reactions (1) and (2) increase monotonically, and the rates of their growth are approximately the same. No sharply pronounced irregularities are observed.

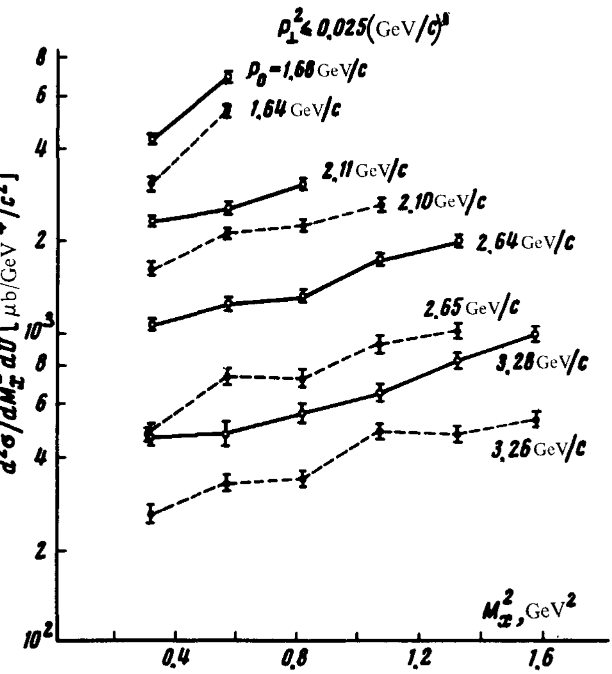

FIG. 1. Dependence of the cross sections of the reactions $\pi^- + d \to p +$ all (light circles) and $\pi^- + p \to p +$ all (dark circles) on M_x^2 at various P_0.

The experimental results are shown in Fig. 2 in the form of plots of the invariant inclusive cross section $\rho(X, P_\perp^2, P_0)$ against P_0 at fixed $X = 0.85 \pm 0.04$ (region of small M_x) and $P_\perp^2 \leq 0.025$ (GeV/c)^2, where $P_\perp$ is the transverse momentum of the emitted proton and X is the Feynman inclusive variable (ρ and X are defined as in[3]). As seen from Fig. 2, the cross section ρ_d of the reaction (1) decreases abruptly with increasing P_0, in analogy with the cross section ρ_p of reaction (2), for which such an abrupt decrease was observed up to 16 GeV/c.[3] Table 1 lists the average exponents (n) of the approximation $\rho(X, P_\perp^2, P_0) \sim P_0^n$, calculated from the outermost points of the investigated P_0 interval. It is evident that the exponents n for ρ_d and ρ_p are close to each other.

TABLE 1. $X = 0.85 \pm 0.04$; $P_\perp^2 \leq 0.025$ (GeV/c)^2.

Cross section	ρ_d	ρ_p	ρ_n
Exponent	2.12 ± 0.12	2.32 ± 0.11	1.72 ± 0.20

In addition to the cross section ρ_d and ρ_p, Fig. 2 shows also their difference $\rho_d - \rho_p$ and the cross section ρ_n of the reaction

$$\pi^- + n \to p + \text{all}. \qquad (3)$$

The exponent n for ρ_n is listed in Table 1. The values of ρ_n calculated from the data on ρ_d and ρ_p were subjected to shadow corrections for the absorption of the incident π^--meson wave and for the outgoing proton wave by the spectator

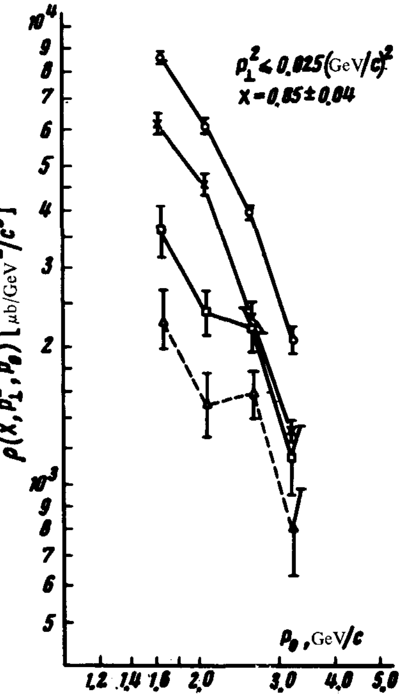

FIG. 2. Invariant inclusive cross sections $\rho_d(\bullet)$, $\rho_p(\times)$, $p_n(\square)$ and the difference $\rho_d - \rho_p(\Delta)$ as functions of P_0.

nucleon: $\rho_d = \rho_p(1-\delta_p) + \rho_n(1-\delta_n)$. Typical values of the shadow corrections δ_p and δ_n lie in the interval 11 to 15%. There is no need to indicate the shadow corrections for the particles that are not registered, by virtue of the unitarity condition.[4]

The error in the determination of ρ_n is connected with the errors in the measurement of ρ_d and ρ_p. To reduce to a minimum the influence of the systematic measurement errors on the value of ρ_n, the reaction (1) was investigated under

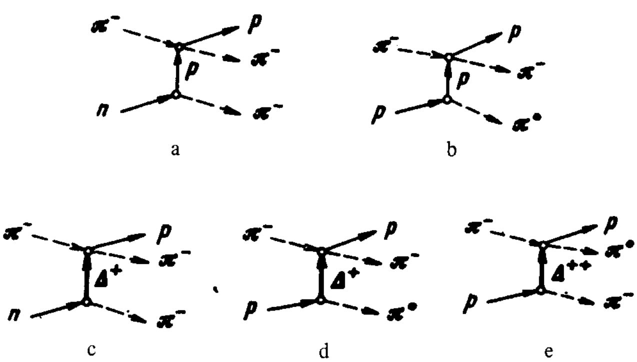

FIG. 3. Feynman diagrams for the description of the reactions $\pi^- + n \to p + \text{all}$ and $\pi^- + p \to p + \text{all}$ in the region of small M_x.

TABLE 2. $X=0.85\pm0.04$; $P_{\perp}^2\leq 0.025$ (GeV/c)^2.

P_0, GeV/c	1.68	2.10	2.64	3.28
ρ_d/ρ_p	1.41 ± 0.08	1.35 ± 0.06	1.67 ± 0.13	1.62 ± 0.15
ρ_n/ρ_p	0.59 ± 0.07	0.52 ± 0.06	0.94 ± 0.12	0.88 ± 0.16

the same conditions (the same magnetic field and the same arrangement of the recording apparatus) as reaction (2). The check on the correctness of the measurement of ρ_p, the cross sections of $\rho^- p$ backward elastic scattering previously obtained[5] for the statistical material of reaction (2) were compared with the published data. Good agreement was observed. The cross section of the reaction

$$\pi^- + d \rightarrow p + n + \pi^- \qquad (1')$$

(with proton emission forward), previously obtained[6] for the statistical material of reaction (1), is equal within the limits of statistical accuracy to the cross section of backward elastic $\pi^- p$ scattering. This agrees with the prevailing theoretical concepts.[4]

It follows from Fig. 2 and Table 1 that the cross section ρ_n decreases on the average more slowly with energy than ρ_p. At $P_0 = 1.68$ and 2.10 GeV/c, ρ_n is smaller than ρ_p, and at $P_0 = 2.64$ and 3.28 GeV/c the values of ρ_n and ρ_p are approximately equal. An irregularity is observed in the energy dependence of ρ_n. This may be due to isobar-production effects in the S channel.

Table 2 lists the ratios ρ_d/ρ_p and ρ_n/ρ_p for different P_0. It should be noted that although the cross sections ρ_d and ρ_p in the investigated interval of P_0 decrease by a factor of more than four, their ratio does not change by more than 12%.

It is of interest to compare the ratios ρ_n/ρ_p obtained by us with those calculated on the basis of concrete diagrams. In the region of small M_x, the main contribution to the inclusive reactions (2) and (3) is made by reactions with production of two pions in the final state. Figure 3 shows the diagrams capable of making the dominant contributions to (2) and (3). Analogous diagrams with emission of two pions from the lower vertex make apparently a small contribution, since the cross section for the production of resonances in processes with large momentum transfer to the nucleon is negligible in the P_0 interval of interest to us.[7] If the largest contribution to (3) and (2) is made by diagrams a and b (p exchange), then the ratio ρ_n/ρ_p should equal to two (the ratio of the amplitudes, starting from the isotopic relations, is equal to $\sqrt{2}$). This is essentially larger than the ratios obtained by us (see Table 2), which changes from 0.52 ± 0.06 to 0.94 ± 0.12. On the other hand, if the diagrams c, d, and e predominate (Δ exchange), then the ratio ρ_n/ρ_p should equal $2/13\approx 0.154$ (the amplitudes c, d, and e are in the ratio $1:\sqrt{2}:\sqrt{9/2}$). This is lower than the ratios obtained by us. Thus, a model with superposition of p and Δ exchanges is in a position to explain the ratios ρ_n/ρ_p obtained by us. The more gently sloping n plot of ρ_n against energy (compared with ρ_p) may be due to the interference of the Δ and p exchanges (for example, constructive in the case of ρ_n and destructive in the case of ρ_p), and also with the contribution of the S-channel resonances, which can still not be regarded as negligibly small in the considered energy interval.

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