Study of the relative scale invariance in the reaction $\pi^- + p \to \Lambda + x$ (Λ forward)

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We measured the cross section of the reaction $\pi^- p \to \Lambda K^0$ and the ratio of the cross sections $\gamma = d\sigma/du|_{u_{max}}(\pi^- p \to \Lambda K^0)/\, d^2\sigma/dudM_x^2|_{u=u_{max}}(\pi^- p \to \Lambda X)$ ($M_x^2 = 0.45$–0.70 GeV^2) at momenta $p_0 = 2.13$, 2.69, and 3.25 GeV/c. This ratio depends little on p_0 in the interval from 2.13 to 8 GeV/c (calculated from the data of Foley *et al.*, Phys. Rev. 10D, 2763, 1974). This points to the existence of a relative scale invariance in the reaction $\pi^- p \to \Lambda X$.

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An analysis of the dependence of the cross section of the process

$$\pi^- + p \to p + X(p - \text{forward}) \tag{1}$$

on the primary energy has revealed a phenomenon called relative scale invariance (RSI).[3] The invariant cross section of the inclusive reaction (1) decreases randomly (by approximately two orders of magnitude) in the primary-momentum interval $p_0 = 1.68$—16 GeV/c, so that ordinary scaling is

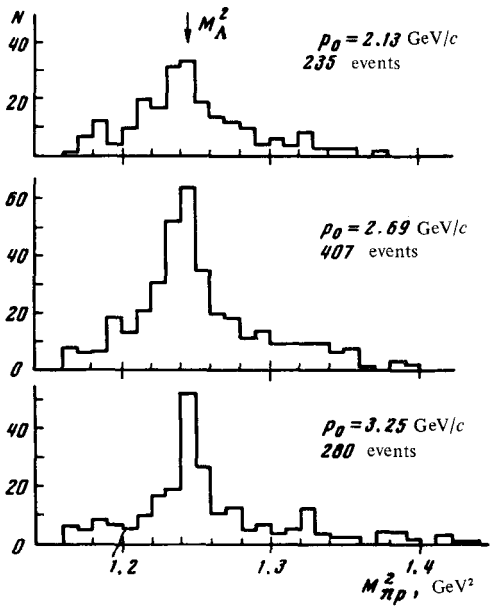

FIG. 1. Distribution with respect to the effective mass squared $M_{\pi p}^2$ of the reaction $\pi^- \to p\pi^- X$ (p and π^-—forward).

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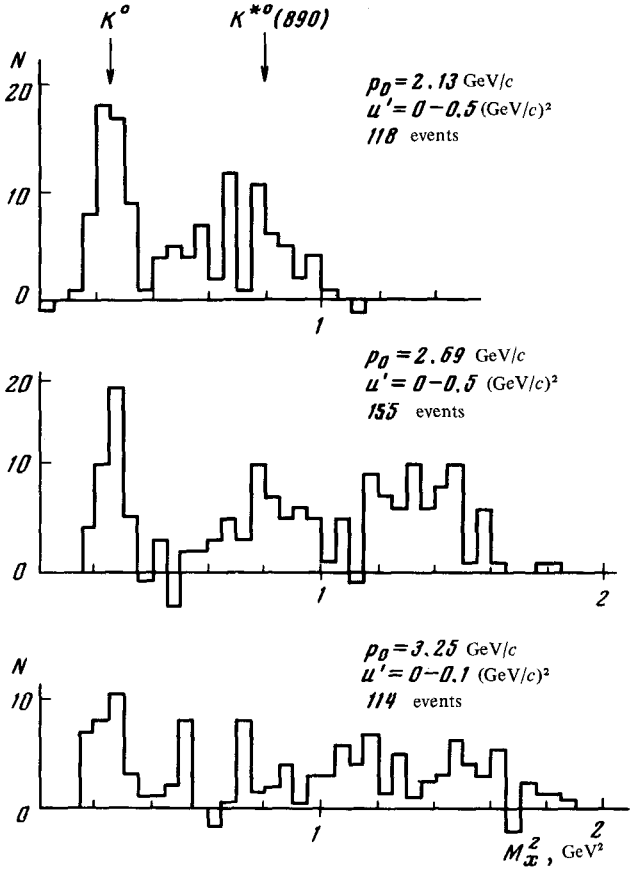

FIG. 2. Distributions with respect to the square of the Λ-hyperon missing mass M_x^2 in the reaction $\pi^- p \to \Lambda X$ (Λ forward).

not observed in this case. This cross section, however, divided by the cross section of the elastic reaction [$M_x^2 = M_\pi^2$ in reaction (1)], is approximately constant in the indicated range of p_0.

To verify the validity of the RSI for other processes, we have undertaken a study of the reaction

$$\pi^- + p \to \Lambda + X(\Lambda - \text{forward}). \tag{2}$$

Among the photographs obtained with the three-meter spectrometer of our institute,[3] we selected events in which a proton and a π^- meson were emitted forward in an angle, momentum, and coordinate interval bounded by the values corresponding to Λ-hyperon production. The distribution with respect to the square $M_{\pi p}^2$ of the effective mass of the secondary proton and π^- meson are shown in Fig. 1. The width of the signal from the Λ hyperon is determined by the apparatus resolution for the secondary π^- meson.

For events that fall in the interval $M_{\pi p}^2 = 1.24 \pm 0.04$ GeV^2, we constructed

TABLE I.

p_0, GeV/c	$d\sigma/du\|_{u_{max}}$ $(\pi^- p \to \Lambda K^0)$, μb/(GeV/c)^2	$\gamma(\pi^- p \to \Lambda X)$, GeV^2, M_x^2 = 0.45–0.70 GeV^2	$d\sigma/du\|_{u_{max}}$ $(\pi^- p \to p\pi^-)$, μb(GeV/c)^2	$\gamma(\pi^- p \to pX^-)$, GeV^2, M_x^2 = 0.20 – 0.45 GeV^2	$d\sigma/du\|_{u_{max}}$ $(\pi^- d \to d\pi^-)$, μb/(GeV/c)^2	$\gamma(\pi^- d \to dX^-)$, GeV^2, M_x^2 = 0.20 – 0.45 GeV^2
1.25	—	—	—	—	$5.49 \pm \frac{2.32}{1.23}$ [11]	0.07 ± 0.02 [11]
1.48	—	—	—	—	$1.12 \pm \frac{0.67}{0.31}$ [11]	0.06 ± 0.02 [11]
2.13	165 ± 36	0.30 ± 0.16	12.4 ± 2.9 [9]	0.09 ± 0.01 [2]	—	—
2.69	79 ± 17	0.54 ± 0.35	110 ± 12 [9]	0.26 ± 0.03 [2]	—	—
3.25	41 ± 13	1.01 ± 0.59	38.3 ± 4.2 [9]	0.23 ± 0.02 [2]	—	—
8	1.25 ± 0.15 [1] 0.91 ± 0.09 [7]	0.81 ± 0.25	3.83 ± 0.48 [10]	.....	—	—
8[1)]	—	1.12 ± 0.39	—	0.25 ± 0.03 [2]	—	—

[1)]With the signal subtracted from the resonance.

the histograms of the Λ-hyperon missing masses M_x^2. These histograms include the events of reaction (2) with a certain admixture of a background from the reaction

$$\pi^- + p \to p + \pi^- + X. \tag{3}$$

In the calculation of the background we used data from intervals neighboring to the indicated $M_{\pi p}^2$ intervals. Figure 2 shows the histograms obtained after subtracting the background.

On the basis of the results we calculated the cross section $d\sigma/du$ of the reaction (2) for $M_x^2 = M_{k0}^2$ at $u' = u - u_{max} \simeq 0.03 \pm 0.03$ (GeV/c)^2 (see Table I), where u is the square of the four-momentum transferred from the π^- meson

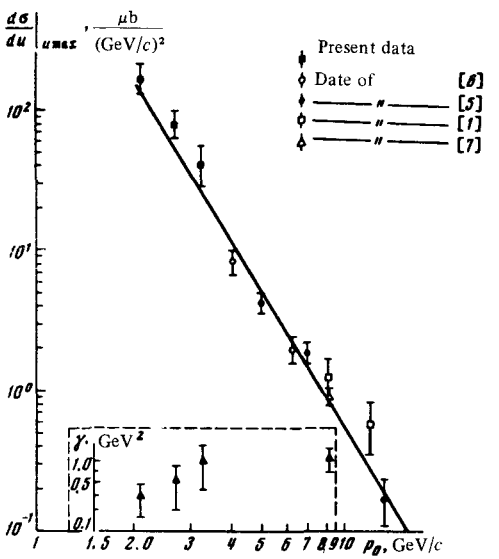

FIG. 3. Cross section of the reaction $\pi^- p \to \Lambda K^0$ and the ratio of the cross sections γ (below) at $u \approx u_{max}$ as functions of the primary momentum p_p. The straight line is an approximation of the data by the relation p_0^{-n}.

to the Λ hyperon. We introduced here a correction coefficient (an average of ~ 5 for each of the momenta, with an accuracy $\sim 20\%$), to allow for the admixture of the μ mesons and electrons in the beam, for the background due to the empty chamber, for the nuclear absorption of the secondary π^- meson, for the decay mode of the Λ hyperon, and for the loss of tracks in the course of scanning. The cross sections measured by us do not contradict the results of[4].

The data of[1,5-7] jointly with ours were approximated by the relation $d\sigma/du\,|_{u_{max}} \sim p_0^{-n}$ (Fig. 3). This yielded a value $n = 3.75 \pm 0.16$. In the Regge-pole model $n = 2\alpha(0) - 2$. The deduced value $\alpha(0) = -0.875 \pm 0.043$ corresponds to exchange of degenerate $(\Sigma_\alpha, \Sigma_\gamma)$ trajectories in the u channel ($\alpha_{theor}(0) = -0.86$[8]).

To check on the RSI hypothesis[2] we calculated the ratio of the cross section

$$\gamma = \frac{d\sigma}{du}\Big|_{u_{max}}(\pi^- p \to \Lambda K^0) \Big/ \frac{d^2\sigma}{du dM_x^2}\Big|_{u_{max}}(\pi^- p \to \Lambda X) \tag{4}$$

at $M_x^2 = 0.45-0.70$ GeV^2, for our data at $u' = 0.03 \pm 0.03$ (GeV/c)^2, and for the data of[11] at 8 GeV/c ($u' = 0-0.05$ (GeV/c)^2). The obtained values of γ are shown in Fig. 3 and in Table I, and for 8 GeV/c the ratio was obtained in two ways, with and without allowance for the signal from the K^{*0} meson. Allowance for the possible signal from the K^{*0} meson at our energies hardly alters the value of γ. We have estimated the possible imitation of the Λ hyperon by a forward-moving K^0 meson whose decay π^+ mesons are not suppressed by the Cerenkov counter: it amounts to $\lesssim 8\%$ and makes a contribution to the part of the spectrum with $M_x^2 > 0.4$ GeV^2. In addition, a contribution to the inclusive part of the spectrum is made by the contribution of the reaction with forward emission of a Σ^0 hyperon, but if it is assumed that the ratio γ for this reaction is the same as for the reaction (2), then the contribution should be negligibly small at our energies.

It is seen from the presented data that γ depends little on the energy in the interval 2.13—8 GeV/c, whereas the cross section of the reaction (2) decreases in this interval by more than two orders of magnitude if $M_x^2 = M_{k0}^2$. It is interesting that the value of γ itself for the reaction (2) turned out to be approximately four times larger than for the reaction (1) (see Table I).

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