THE REACTION $\pi^+ + p \to N^{*++}_{33} + \pi^0$ AT 3.5 GeV/c *

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In this paper we want to report a study of the reaction

$$\pi^+ + p \to N^{*++}_{33} + \pi^0 \quad (1)$$

at 3.54 GeV/c. We find a very good agreement between the angular correlations observed

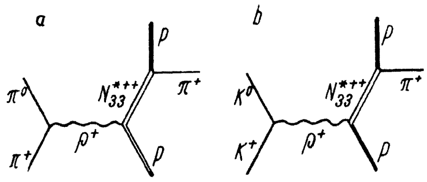

Fig. 1. ϱ Exchange mechanism for isobar production:
a) for reaction $\pi^+ + p \to N^{*++}_{33} + \pi^0$;
b) for reaction $K^+ + p \to N^{*++}_{33} + K^0$

in the decay of the N^*_{33} and the predictions by Stodolsky and Sakurai based on a single ϱ exchange model [1] (see Fig. 1, a). The reaction

$$K^+ + p \to N^{*++}_{33} + K^0 \quad (2)$$

has also been found to display similar angular correlations [2—4] in agreement with the single ϱ exchange mechanism as illustrated in Fig. 1, b. But we want to point out that the energy dependence of the cross section of both reactions (1) and (2) is in strong contradiction with the results derived from a simple ϱ exchange model as used, for example, by Jackson and Pilkuhn [5].

After analyzing about 7000 two prong events from a π^+ exposure at 3.54 GeV/c in the Brookhaven 20″ hydrogen bubble chamber, we identified 1061 events as

$$\pi^+ + p \to \pi^+ + p + \pi^0. \quad (3)$$

The details of the analyzing methods will be described in another publication. Fig. 2, *a* shows the Dalitz plot of the reaction (3). One can see the formation of ϱ^+ around $M^2_{\pi^+\pi^0} = .56\ \mathrm{GeV}^2$ and the formation of N^{*++}_{33} around

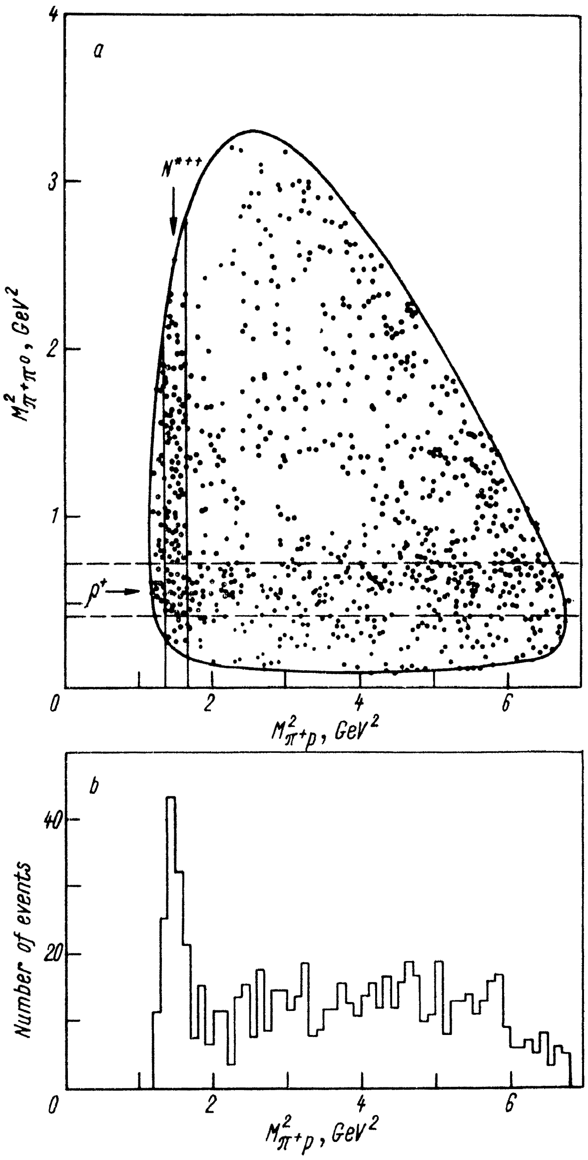

Fig. 2 (a) Dalitz plot of the reaction $\pi^+ + p \to \pi^+ + p + \pi^0$
(b) Distribution of $M^2_{\pi^+p}$ from the reaction $\pi^+ p \to \pi^+ p \pi^0$ when $M^2_{\pi^+\pi^0}$ is outside the range of the ϱ^+ meson. $M^2_{\pi^+\pi^0} > .72\ \mathrm{GeV}^2$ and $M^2_{\pi^+\pi^0} < .42\ \mathrm{GeV}^2$.

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$M^2_{\pi^+p} = 1.53$ GeV². In the Fig. 2, *b* we take off the ϱ band (.42 GeV² $< M^2_{\pi^+\pi^0} <$ 72 GeV²) and plot the projection of the remaining Dalitz plot on the $M^2_{\pi^+p}$ axis. This histogram shows a big N^{*++} peak above a small background. We estimate the cross section of the reaction

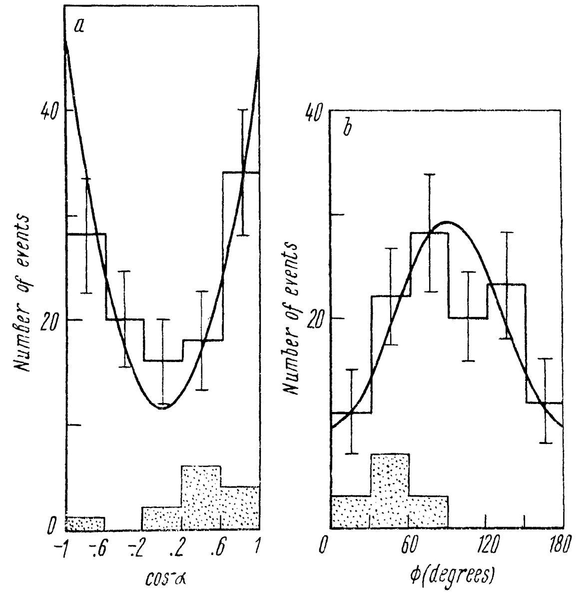

Fig. 3. a) Angular distribution in cos α, the angle between the normal to the plane of production and the direction of the π^+ from N^{*++}_{33} decay measured in the N^{*++}_{33} rest frame for the reaction $\pi^+ + p \to N^{*++}_{33} + \pi^0$ The curve is $1 + 3\cos^2\alpha$, normalized to the data. b) Histogram of the Treiman-Yang angle φ for the reaction $\pi^+ + p \to N^{*++}_{33} + \pi^0$. φ is the angle between the production plane and the decay plane of the N^{*++}_{33} measured in the rest frame of N^{*++}_{33}. The curve is $1 + 2\sin^2\varphi$ normalized to the data. In both a) and b) the shaded area is the contribution from «bidon» events (see text)

(1) to be .20 ± .04 mb at 3.54 GeV/c. In the following, we discuss only the reaction (1), i. e. we use only events with an effective mass M_{π^+p} in the N^*_{33} region (1.240 ± .060 GeV). To avoid the overlap region of N^{*++}_{33} and ϱ^+ we analyzed the properties of the N^{*++}_{33} resonance using the Method of Eberhard and Pripstein [6] whereby we ignored all the events on the Dalitz plot having .42 GeV² $< M^2_{\pi^+\pi^0} <$ .72 GeV² and repopulated this region with a sample of fictitious conjuguated events constructed from the remaining events. (We call these fictitious events: «bidon» events; they represent only 15% of the data). We plotted in Fig. 3, *a* the histogram of the angular distribution in cos α where α is the angle between the normal to the plane of production and the direction of the π^+ from the N^*_{33} decay, measured in the N^*_{33} rest frame. The shaded area represents the contribution of «bidon» events. The solid curve represents the distribution «$1 + 2\cos^2\alpha$», normalized to the data. This is the

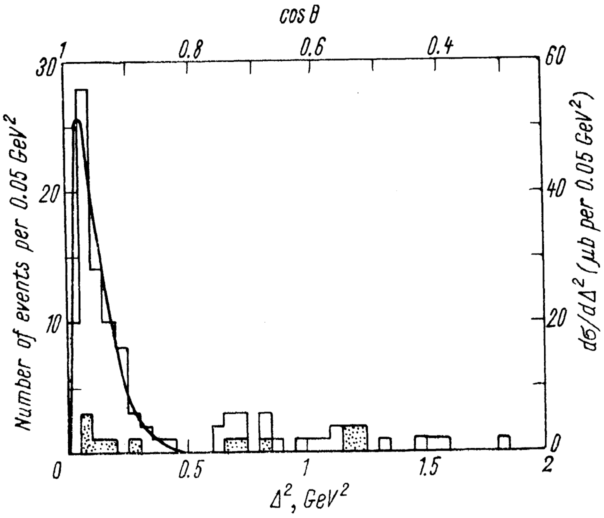

Fig. 4. Distribution of momentum transfer between incident π^+ and outgoing π^0 of the reaction $\pi^+p \to N^{*++}_{33}\pi^0$; the shaded area is the contribution form «bidon» events (see text). On top we plot the scale in cos θ where θ is the angle between π^0 and π^+ incident in the center of mass frame. The solid curve is the best fit using the Jackson-Pilkuhn Formula. (See text).

prediction by Stodolsky and Sakurai [1] using a single ϱ exchange model (Fig. 1, *a*) in which the vertex ϱ^+pN^* behaves like an $ML \to p_{3/2}$ electromagnetic transition in accordance with the «ϱ photon analogy». Our data are in very good agreement with this prediction. We plot in Fig. 3, *b* the histogram of the Treiman—Yang angle φ, where φ is the angle between the decay plane and the production plane in the N^*_{33} rest frame. The shaded area is the contribution from «bidon» events. The solid line represents the distribution «$1 + 2\sin^2\varphi'$» which can be derived from the preceding prediction ($1 + 3\cos^2\alpha$) assuming that the vertex ϱpN^* is pure $ML \to p_{3/2}$ transition. Here also our data agree very well with the prediction.

In Fig. 4, we plot the distribution of the differential cross section versus the four momentum transfer (Δ^2) between the indicent π^+ and the outgoing π°. Our data peak sharply in the region of small momentum transfer. Jackson and Pilkuhn [5] have derived the differential production cross section of reactions (1) and (2) assuming a single ϱ exchange mechanism with a magnetic dipole coupling model. Their formula is similar to the Stodolsky—Sakurai Formula quoted dy Daudin et al. [7]. To make a fit to the momentum transfer distribution of reaction (2) at 3.0 GeV/c (which has almost the same total energy in the Center of Mass as in our case), they must use a form factor of the form F_ρ (0) $e^{-\lambda\Delta^2}$. They get good fits for:

$$\lambda = 2.5 \text{ with } (g^2_{\rho^+K^+K^0}/4\pi) \times$$
$$\times (G^2_{\rho NN^*}/4\pi) \mid F_\rho (0) \mid^2 = 31$$
$$\lambda = 2.0 \text{ with } (g^2_{\rho^+K^+K^0}/4\pi) \times$$
$$\times (G^2_{\rho NN^*}/4\pi) \mid F_\rho (0) \mid^2 = 21.$$

Using their formula we get a good fit to our data (solid curve in Fig. 4) for $\lambda = 7.0$ with

By dividing the preceding relations we get a ratio of $g^2_{\rho^+\pi^+\pi^0}/g^2_{\rho^+K^+K^0}$ between. 9 and 1.3 which is not too far from 2.0: the predicted value of SU_3 But there are two criticisms of the results derived directly from ρ exchange mechanism as with the Stodolsky—Sakurai Formula 7 or with the Jackson-Pilkuhn Formula [5]:

a) One needs very drastic form factors to fit the data. The form factors are so rapidly varying that the momentum dependence of $\frac{1}{\Delta^2 + M^2_\rho}$ is completely obscured ($e^{-7\cdot\Delta^2}$ is almost equivalent to $\frac{1}{\Delta^2+.1}$ whereas $\frac{1}{\Delta^2+M^2_\rho} = \frac{1}{\Delta^2+.56}$ with Δ^2 in GeV^2). This fact has been pointed out by many authors [5, 7].

b) A stronger criticism is that the measured cross-sections of both reactions (1) and (2) decrease rapidly with increasing incident momentum (See Table) in contradiction with both the Stodolsky — Sakurai Formula [7] and the Jackson—Pilkuhn Formula [5] which predict an increasing cross section. In the Stodolsky-Sakurai Formula [7] the cross-section is almost proportional to $P_i \cdot P^3_f$ with Pi-momentum of the incident π^+ and P_f-momentum of the outgoing π^0 in the center of mass frame. For the Jackson—Pilkuhn Formula [5] we list in Table its predictions for reaction (1) at 3.54 GeV/c and 1.59 GeV/c (with $\lambda = 7.0$), and its predictions for reaction (2) at 3.0 GeV/c, 1.96 GeV/c, 1.14 GeV/c and .91 GeV/c (with $\lambda = 2.5$). We also list the corresponding experimental results in the same table. Except for the momenta, where the calculations have been normalized to the data (3.54 GeV/c for the reaction (1) and 3.0 GeV/c for reaction (2)), all the predicted cross-sections are very different from the expérimental values, sometimes by an order of magnitude *.

Cross section of reaction $\pi^+p \to N^{*++}_{33} + \pi^0$ and $K^+p \to N^{*++}_{33} + K^0$ at different incident momentum

Reaction	Incident momentum in GeV/c	Cross-section predicted by Jackson-Pilkuhn formula	Experimental cross section	Reference number
$\pi^+p \to N^{*++}_{33} + \pi^0$	3.54	.16 mb	.2—.04 mb	This Letter
	1.59	.13 mb	1.5—.2 mb	[7]
$K^+p \to N^{*++}_{33} + K^0$	3.0	.8 mb	.9—.2 mb	[4]
	1.96	.66 mb	2.7—.4 mb	[3]
	1.14	.28 mb	3.6—.5 mb	[8]
	.91	.08 mb	2.1—.2 mb	[2]

* We have verified that for all λ between 1.0 and 10.0, the Jackson-Pilkuhn Formula gives values of cross-section increasing with energy.

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