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PRODUCED IN π^+p INTERACTIONS BETWEEN 3 AND 4 GeV/c

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QUASI-TWO-BODY FINAL STATES PRODUCED IN π^+p INTERACTIONS BETWEEN 3 AND 4 GeV/c*

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ABSTRACT

Cross sections and angular distributions for the quasi-two-body final states $N^{*++}\rho^0$, $N^{*++}\omega^0$, and $N^{*++}\eta^0$ were measured at five incident π^+ momenta between 3 and 4 GeV/c. These cross sections, when combined with results at higher momenta, indicate that the momentum dependence of the $N^{*++}\rho^0$ cross section deviates from that expected for a meson-exchange reaction, and that there is shrinking of the diffraction peak. Dips in the production angular distributions are observed, similar to those observed in two-body final states.

*Work done under the auspices of the U. S. Atomic Energy Commission.

In an effort to extend the available data on the quasi-two-body final states encountered in resonance production, we have studied four-prong events of the types

$$\pi^+ p \rightarrow \pi^+ p\, \pi^+ \pi^-, \qquad (1)$$

$$\pi^+ p \rightarrow \pi^+ p\, \pi^+ \pi^- \pi^0 \qquad (2)$$

at the five incident π^+ momenta 2.95, 3.2, 3.5, 3.75, and 4.1 GeV/c. Many experiments have been performed in recent years on the angular distributions and polarizations for the elastic and two-body inelastic final states.[1] In the intermediate-energy region (i.e., 2 to 5 GeV/c incident pion momentum) the available data have been parameterized with limited success by the peripheral model with absorption,[2] and by Regge pole models,[3] some of which include the effects of direct-channel resonances.[4]

Reactions (1) and (2) have long been known to be dominated by such quasi-two-body final states as $N^{*++}\rho^0$, $N^{*++}\omega^0$, pA_2, etc.[1] As new resonances are discovered the fraction of events attributable to such two-body reactions increases and is to date approximately 50% for these reactions. In this paper, data are presented on the final states $N^{*++}\rho^0$, $N^{*++}\omega^0$, and $N^{*++}\eta^0$. The momentum-transfer distributions for these reactions are known to be dominated by a peak at low momentum transfer; to study the structure of this peak and associated density matrix elements we have added all our events together, regardless of incident beam momentum. The $I = 3/2$, $N^*(2830)$ lies within this energy region,[5] but its effect is neglected at this time. The variation with energy of our data will be presented in a future communication.

The 72-inch hydrogen bubble chamber was exposed to a separated π^+ beam at the Bevatron to obtain 0.37 μb/event of pion track length. The

proton contamination varied from 5% at the lower energies to more than 20% at 4.1 GeV/c. The experiment yielded 40 000 four-prong events, which were measured on the Flying-Spot Digitizer (FSD) and constrained to Hypotheses (1) and (2); 7800 events of Reaction (1) and 9400 of Reaction (2) were obtained. FSD ionization measurements were particularly useful when more than one hypothesis was satisfied. The 10% of ambiguous events which remained were resolved on the scanning table or by choosing the hypothesis with the lower χ^2. Constraining the events to the corresponding proton hypotheses showed that the proton contamination in the beam presented no problem, since the pp events were clearly distinguished from the πp events by the kinematic and ionization criteria.

Cross sections were obtained by normalizing to the δ-ray cross section. A δ-ray scan was made over about 20% of the film. The muon contamination was measured and found to be about 5% of the pion beam by making a count of secondary interactions on tracks with δ-rays. The known cross section for δ-rays with momenta greater than 18 MeV was used to obtain the pion path length.

The events attributed to a particular resonance were selected from the observed mass distributions solely on the basis of cuts in the respective invariant-mass intervals as follows: N^{*++} 1.12 GeV $\leq M(\pi^+p) \leq 1.32$ GeV; ρ^0, 0.68 GeV $\leq M(\pi^+\pi^-) \leq 0.86$ GeV; ω^0, 0.75 GeV $\leq M(\pi^+\pi^-\pi^0) \leq 0.82$ GeV; η^0, 0.525 GeV $\leq M(\pi^+\pi^-\pi^0) \leq 0.575$ GeV. For 5% of the events more than one combination of particles satisfied the mass criteria,[6] and in those cases the events were assigned on the basis of lowest momentum transfer. Our cross sections for the major quasi-two-body reactions together with results reported in the literature are shown in Fig. 1.[7] Morrison has made extensive compilations[1] of

such cross sections and finds that meson-exchange reactions are characterized by a $p_{inc.}^{-1.5}$ to $p_{inc.}^{-2.0}$ momentum dependence, whereas diffraction-like processes such as elastic scattering show a much slower fall-off. The observed cross sections for $N^*\rho^0$ production have a momentum dependence more like a diffraction process than the expected meson-exchange dependence, being roughly proportional to $p_{inc.}^{-0.5}$. The cross sections for $N^*\omega^0$ and $N^*\eta^0$ production show the expected meson-exchange behavior, as does the other ρ^0 production process, $\pi^- p \rightarrow \rho^0 n$, and the reaction $K^+ p \rightarrow K^{*0} N^{*++}$.

In Fig. 2a we show the t dependence of the $N^*\rho^0$ events together with results of other experiments performed at 2.3 and 7.0 GeV/c.[7a] At the lower energies the initial diffraction peak, the abrupt change in slope near $t = -0.4$, and the secondary maximum whose slope decreases with incident momentum are reminiscent of the behavior of elastic $\pi^\pm p$ scattering[8] in the same energy region. A fit of the diffraction peak to $(d\sigma/dt) \propto e^{At}$ gives $A = 8.8 \pm 0.3$, compared with average values of $A = 8.0$ for $\pi^- p$ and $A = 6.7$ for $\pi^+ p$ elastic scattering in the same energy region.[9] The initial slope of 12 to 14 at the higher momentum implies a shrinking of the diffraction peak and a displacement of the point at which the change in slope occurs to $t = -0.2$. The same rate of shrinkage, $\Delta A/\Delta p_{inc.} \approx 1.4\ (\mathrm{GeV/c})^{-3}$, is observed for the reaction $K^+ p \rightarrow K^{*0} N^{*++}$ [7c] up to 9 GeV/c incident momentum, and for $\gamma p \rightarrow \rho^0 p$ up to 5 GeV/c.[7e] The reaction $\pi^- p \rightarrow \rho^0 n$ shows no shrinking up to 7 GeV/c.[7b] In Table I we summarize the momentum dependences and initial slopes of $(d\sigma/dt)$ for the various processes discussed.

The form of the t distribution for our events appears to be independent of dipion mass up to 1 GeV and of π^+p mass within the N^*. Very low momentum transfers are kinematically prohibited for high invariant-mass values. To explore the very low momentum transfer region in our data, we used events with low invariant masses within the N^* and ρ^0 mass limits at the highest incident momenta, and find a flattening of the t distributions below $t = -0.15\ (\mathrm{GeV}/c)^2$.

Figure 3a shows the density matrix elements for the N^{*++} and ρ^0 decay angular distributions. Again changes in character can be discerned near $t = -0.2$ and -0.4. The solid lines are the predications of the one-pion-exchange model with absorption[2] calculated at 4 GeV/c incident momentum.

Figure 2b shows the momentum-transfer distributions for the reactions $\pi^+p \rightarrow N^{*++}\omega^0$ and $\pi^+p \rightarrow N^{*++}\eta^0$. The comparative shallowness ($A = 3.3 \pm 0.5$ for $N^*\omega$) of these angular distributions has already been noted.[1] For $N^*\omega$, increased statistics in this experiment make evident a dip near $t = -0.8$, and a flattening below $t = -0.2$. Independent samples at lower momenta[7a] also show evidence for this dip.[10] The distribution for $N^*\eta^0$ events has limited statistics (102 events) but is flat until $t = -0.5$, after which it drops quickly. A similar behavior has been noted for this reaction at 8 GeV/c and also for the reaction on $\pi^-p \rightarrow \eta n$. The density matrix elements for $N^*\omega^0$ events are shown in Fig. 3b. No characteristic changes are evident within statistics, but the predictions of the ρ-exchange model with absorption[2] are clearly inadequate.

We wish to express our gratitude to Dr. Robert P. Ely, Jr., and Dr. George Kalmus for their efforts during the beam tuning and the exposure. We thank Dennis Hall and Howard S. White, Jr., for their work in making the FSD a useful instrument, especially for ionization measurements.

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6. Other laboratories have used different criteria, so only trends in the momentum dependence, rather than detailed structure, are reliable. Nonresonant background and the resonance tails are assumed to cancel with use of our criteria.
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Table I

Reaction	Momentum dependence	A
$\pi^+ p \rightarrow \rho^\circ N^{*++}$	$P^{-0.5}$	Shrinking $9 \longrightarrow 20$
$\pi^- p \rightarrow \rho^\circ n$	$P^{-1.7}$	No shrinking 13
$\pi^- p \longrightarrow \rho^\circ N^{*\circ}$	$\sim P^{-0.5}$	——
$\gamma p \longrightarrow \rho^\circ P$	$P^{-0.3}$	Shrinking $4 \longrightarrow 8$
$K^+ p \longrightarrow K^{*\circ} N^{*++}$	$\sim P^{-1.7}$	Shrinking $8 \longrightarrow 15$
πp Elastic	$P^{-0.3}$	No shrinking 7—8

FIGURE LEGENDS

Fig. 1. Cross sections for the resonance production reactions $\pi^- p \to \rho^0 n$ ( ), $\pi^+ p \to \omega^0 N^{*++}$ (,), $K^+ p \to K^{*0} N^{*++}$ ( ), $\pi^+ p \to \rho^0 N^{*++}$ (,), $\pi^- p \to \rho^0 N^{*0}$ ( ), and $\gamma p \to \rho^0 p$ ( ).

Fig. 2. Distributions in the square of the momentum transfer, t, for the reactions (a) $\pi^+ p \to \rho^0 N^{*++}$, (b) $\pi^+ p \to \omega^0 N^{*++}$ and $\pi^+ p \to \eta^0 N^{*++}$.

Fig. 3. Momentum transfer distributions of the density matrix elements for (a) $\pi^+ p \to \rho^0 N^{*++}$ and (b) $\pi^+ p \to \omega^0 N^{*++}$. The solid lines are the predictions of the OPE model with absorption, calculated at 4 GeV/c in Ref. 7a.

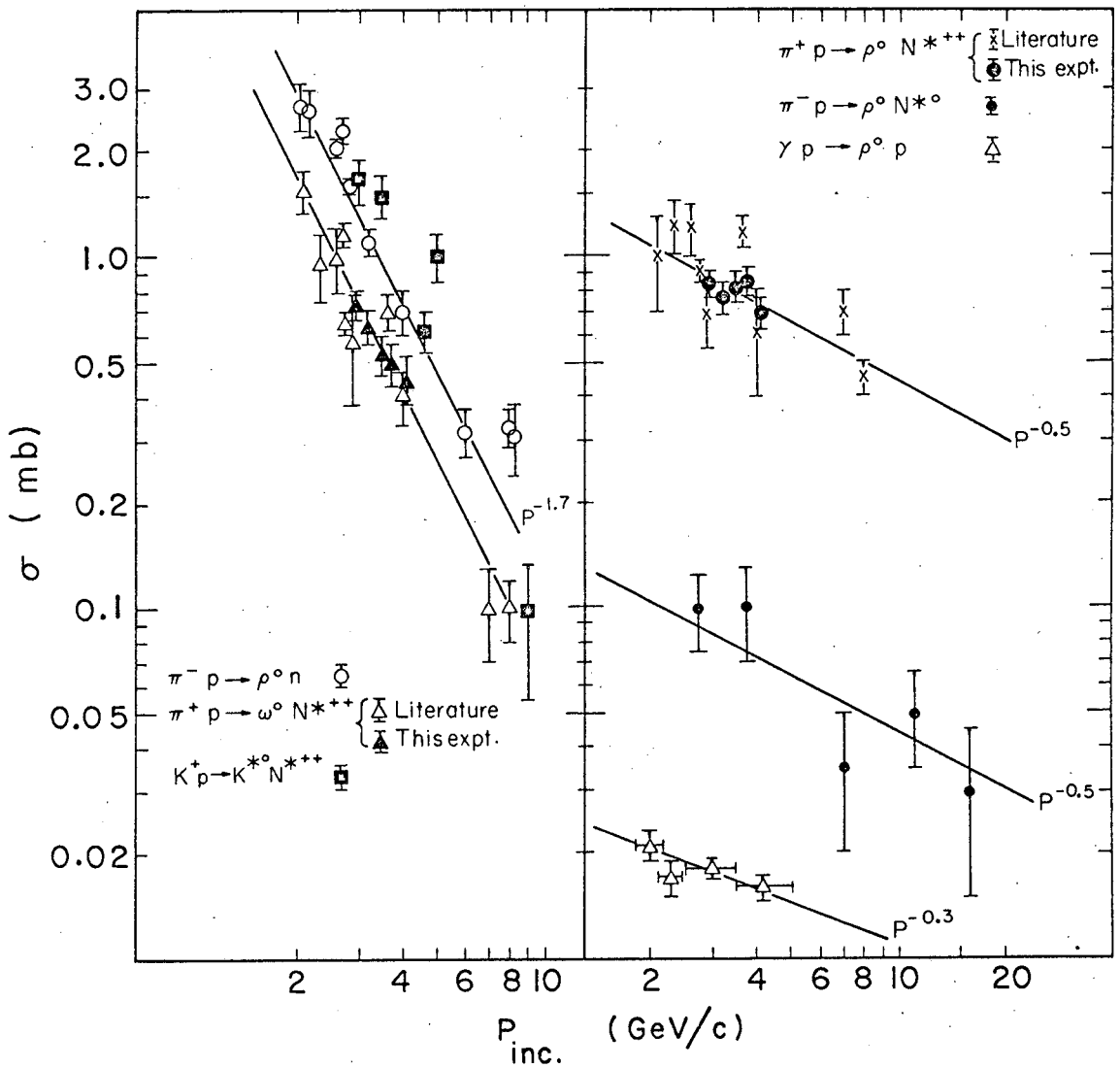

Fig. 1

XBL677-3471

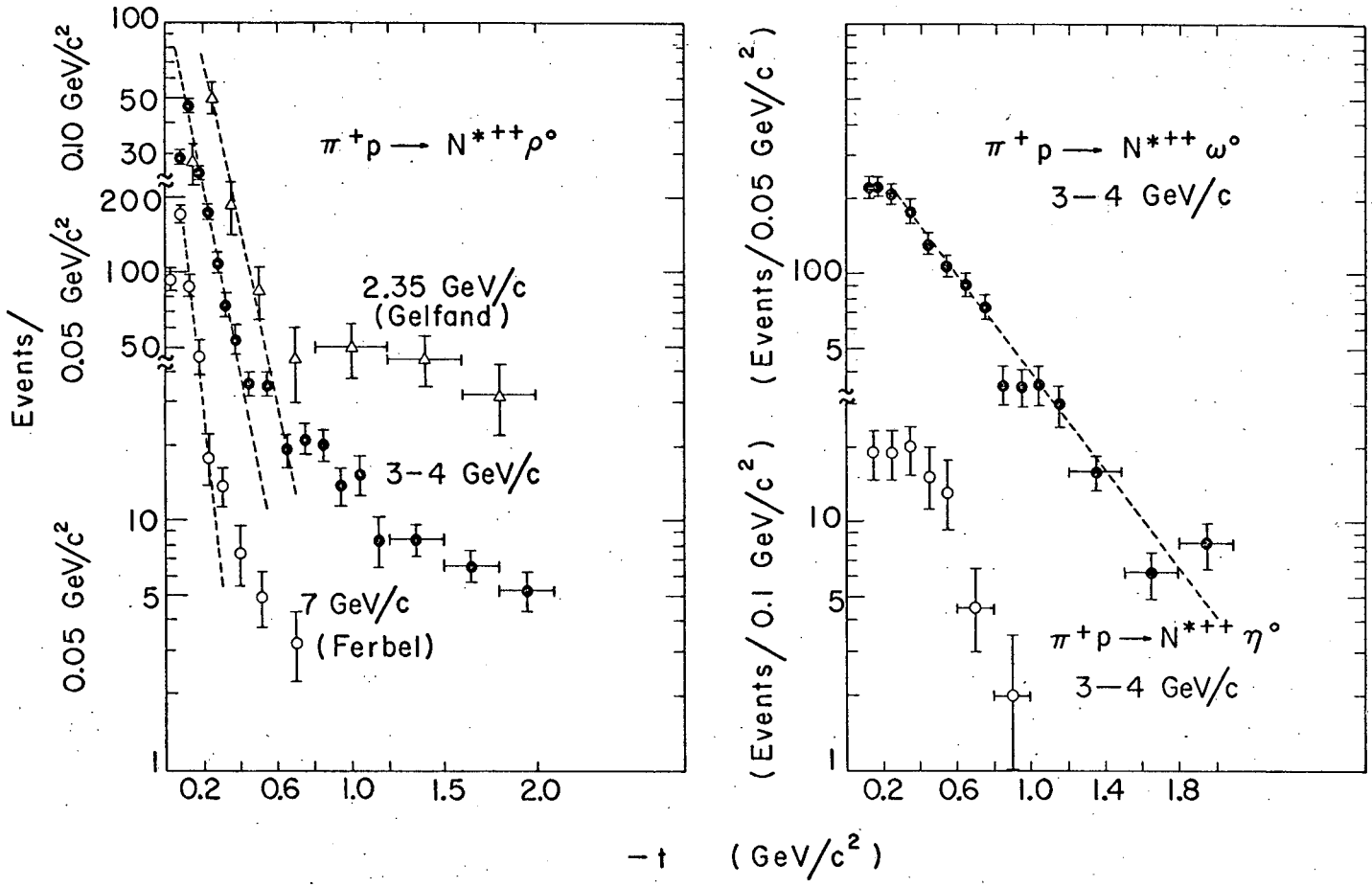

Fig. 2

XBL677-3470

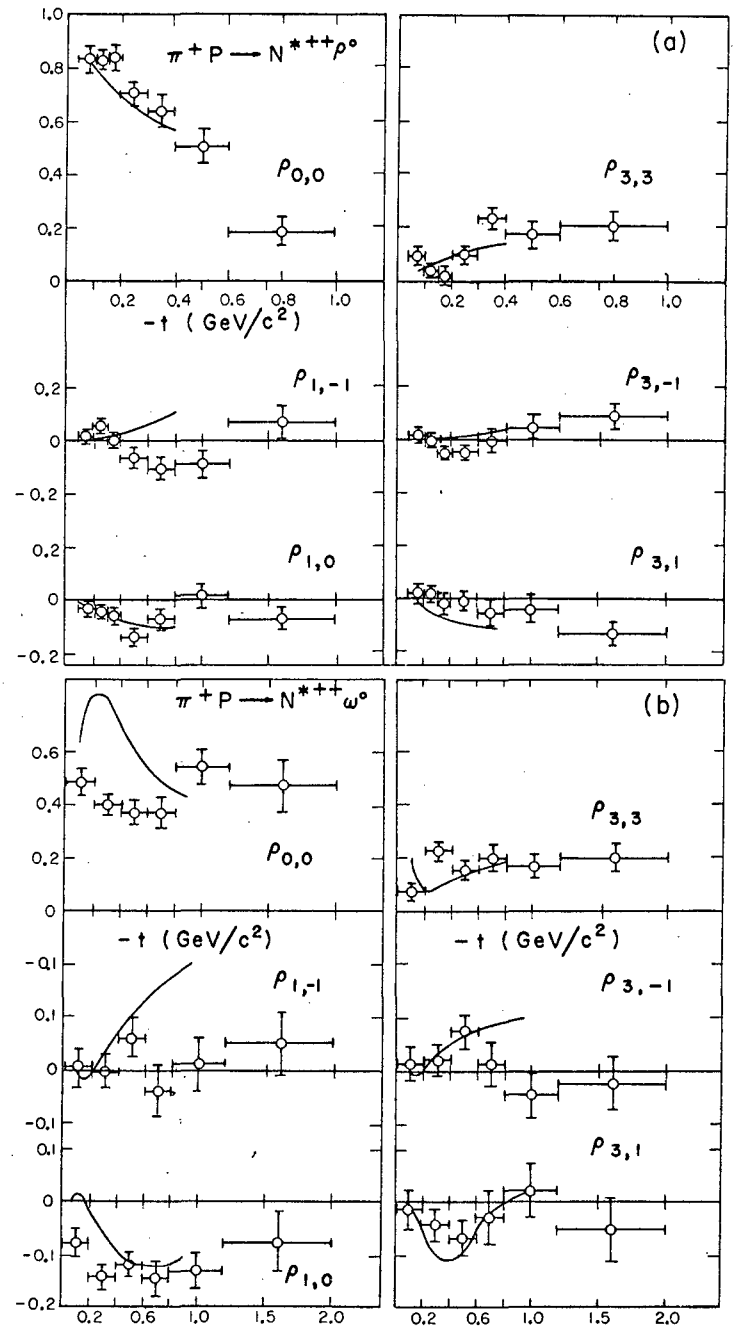

Fig. 3 XBL677-3472

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