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SLOPE OF $d\sigma/dt$ DISTRIBUTIONS IN QUASI TWO-BODY INTERACTIONS OF 8 GEV/C POSITIVE PIONS

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In a study of the interactions of 8 GeV/c positive pions with protons it has been found that the reactions often proceed through formation of a two-body intermediate state. In this letter it is shown that for these processes the variation of the differential cross-section with $|t|$, the square of the four-momentum transfer, is essentially exponential and that the slope is in general about the same as that for elastic scattering. The results have been compared with calculations based on the absorption model. For processes in which one pion is exchanged, the calculations are found to agree, in general, with experiment, but for the reactions requiring vector meson exchange the calculations and the experimental results disagree to such an extent that it must be concluded that the absorption model is basically unsound.

About 18,000 events of two- and four-prong interactions of 8.04 ± 0.06 GeV/c positive pions in the 81cm hydrogen bubble chamber have been analysed using the THRESH-GRIND-SLICE-SUMX system of programs. The following reactions with two-

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body intermediate states are found to occur :[1]

$\pi^+ p \rightarrow p\rho^+ \rightarrow p\pi^+\pi^0$ a)

$\pi^+ p \rightarrow N^{*++}\rho^0 \rightarrow p\pi^+\pi^+\pi^-$ b)

$\pi^+ p \rightarrow N^{*++}f^0 \rightarrow p\pi^+\pi^+\pi^-$ c)

$\pi^+ p \rightarrow N^{*++}\pi^0 \rightarrow p\pi^+\pi^0$ d)

$\pi^+ p \rightarrow N^{*++}\omega \rightarrow p\pi^+\pi^+\pi^-\pi^0$ e)

$\pi^+ p \rightarrow pA_1 \rightarrow p\pi^+\pi^+\pi^-$ f)

$\pi^+ p \rightarrow pA_2 \rightarrow p\pi^+\pi^+\pi^-$ g)

$\pi^+ p \rightarrow N^{*++}\eta \rightarrow p\pi^+\pi^+\pi^-\pi^0$ h)

The plots of the differential cross-sections $d\sigma/dt$ versus $-t$, for these reactions and for elastic scattering

$\pi^+ p \rightarrow p\pi^+$, i)

are shown in Figure 1.

The total cross-sections, corrected for the unseen decay modes, are given in Table I, together with the slope, A, of the differential cross-section,

$$d\sigma/dt = \text{const. } \exp\ (-At).$$

For elastic scattering the slope is known[2,3] to vary slightly according to the interval of t studied. For this process as well as for the inelastic reactions, the limits of the t-interval used are indicated in Table I. For inelastic processes the finite width of the resonances causes the minimum kinematic limit of $|t|$, here called t_1, to be badly defined. Hence, here t_1 is chosen large enough that the effect of the resonance width is not important. Two values of the slope have been calculated corresponding to different upper limits, t_2, of $|t|$. The value of $8.6 \pm 0.4\ (\text{GeV/c})^{-2}$ for the slope of elastic scattering over the interval $t_1 = 0.02$ to $t_2 = 0.3\ (\text{GeV/c})^2$ is consistent with the values reported from counter experiments[3].

The outstanding feature of Fig. 1 and Table I is that most of the differential distributions have similar slopes and of the same order as that of elastic scattering. However, the following remarks can be made :

1) For the reactions $N^{*++}\omega$ and $N^{*++}\eta$ the differential cross-section has a t-dependence definitely flatter than that of elastic scattering, at least for the small values of the momentum transfer. It might be interesting to

remark that these reactions are the two processes corresponding to a 5-body final state.

2) The reactions $N^{*++}\rho^{o}$ and $N^{*++}f^{o}$ seem to have a $|t|$ -dependence steeper than elastic.

3) The slope of the differential cross-section for pA_1 seems greater than that for pA_2.

One may wonder whether the background present in the reactions studied may perturb the results. For channels (d), (e) and (f), the background can be considered as negligible. The first of these reactions has "normal" slope (i.e. similar to that observed for elastic scattering), while the other two have an abnormally low slope. For reactions (a) and (b), the background is smaller than 30°/o and 20°/o, respectively. For (c), (f) and (g), it is about 40°/o. However, it is important to point out that the t-dependence of the background, as observed in the various channels outside the resonance region, is always "normal". One may therefore feel confident that the slopes observed are not seriously affected by the background, and in particular that the background is not responsible for the anomalous slopes of some of the reactions.

The differences observed in the values of the slope of some channels do not seem obviously correlated with the nature of the particle exchanged. For example, $N^{*}\pi^{o}$ and $N^{*}\omega$, which are both thought to proceed via vector-meson exchange, have very different slopes. One may note that for the reaction $N^{*++}\eta$ the only known particle that could be exchanged is the A_2 meson ($J^P = 2^+$). One might have expected that its t-dependence be different from that for $N^{*}\omega$, for which a ρ-meson exchange is involved, but in fact the two distributions are similar.

For the reaction

$$\pi^- p \dashrightarrow n\eta \qquad \text{j)}$$

Guisan et al.(4) found that the $d\sigma/dt$ distribution is essentially flat between $t = 0$ and at $t = 0.2$ $(GeV/c)^2$, which may be interpreted as due to the influence of spin-flip terms. If one assumes that a similar effect exists in the reaction $\pi^+ p \dashrightarrow N^{*++}\eta$, then the slopes given in Table I for the range 0.02 to 0.3 or 0.4 $(GeV/c)^2$ should not be compared with those of elastic scattering and of the other inelastic reactions. For the region 0.2 to 0.7 $(GeV/c)^2$, Guisan et al.

report a slope $A \approx 4$. Our data in that t-interval are not inconsistent with the slope reported for reaction (j).

Results for the t-distributions of the cross-sections for several of the two-body inelastic reactions discussed here have been reported by the ABBBHLM-collaboration[5], for 4 GeV/c π^+p interactions. Though the actual values of the slopes are not reported by the Authors, the data are all in qualitative agreement with the 8 GeV/c results. In particular, small slopes are observed for pA_2 and $N^*\omega$.

Recently, Byers and Yang[6] have proposed a model, the Coherent Droplet Model, which implies slopes for all the differential cross-sections for two-body and quasi-two-body processes similar to the slope of elastic scattering.

A possible interpretation of the anomalous slopes of $N^*\eta$ and $N^*\omega$, in the framework of the Coherent Droplet Model, is suggested by A. Bialas in the following Letter.

Calculations, using a Regge pole model, have been made for reaction (a) by Bermawi[7], who found good agreement with 4 and 8 GeV/c incident pions, both for the slope and the absolute value of the cross-section.

Attempts have been made, in particular by Ferrari and Selleri[8], to describe the production mechanism of reactions with two-body intermediate states in terms of a one-pion exchange (O.P.E.) model. However, disagreement between theory and experiment was often large and the model could not explain details of angular distributions and correlations. The O.P.E. model was later extended[9,10,11,12] to include the effect of interactions between the incoming particles and between the outgoing particles (absorption model). In both types of calculations the basic assumption is made that a particle is exchanged between the two interaction vertices, the nature of this particle being determined by the conservation of the quantum numbers at each vertex.

In the work reported here, the absorption model was tested for reaction channels requiring the exchange of a pion or the exchange of a rho-meson.

For reactions (a) and (b) for which π-exchange is possible, the results of the absorption model calculations shown by the solid lines in Fig. 1a and 1b are in reasonable agreement with the experimental values. In reactions (d), (e), (f) and (g), rho-exchange (or more generally vector-meson exchange) is needed.

As can be seen from Fig. 1d, 1f and 1g, the absorption model calculations are in disagreement with the experimental results as they predict a cross-section which is too large and a slope which is not great enough. In the calculation of reaction (g), where the A_2-meson was taken to have $J^P = 2^+$, a form factor was introduced in an attempt to obtain better agreement with experiment, but, as can be seen in Fig. 1g, the curve obtained still gives too large a cross-section and the wrong slope.

At lower energies, namely for 2 to 4 GeV/c incident pions, similar absorption model calculations had led either to agreement or to small disagreement with the experimental results, for all processes investigated. At 8 GeV/c instead, the disagreement observed for the reactions involving vector meson exchange is so great that one must conclude that the model is incapable of describing those processes. If the absorption model cannot be applied hatever the nature of the particle exchanged, it must be concluded that the model is basically unsound, even if it may produce results in close agreement with experiment for some reactions at some energies.

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Caption for Figure

Figure 1 Differential cross-sections, $d\sigma/dt$, for reactions (a) to (i), versus $-t$, the four-momentum transfer squared. The two-body intermediate state of reactions (a) to (h) is indicated in the figure. The solid lines are the results of calculations based on the absorption model.

Caption for Table

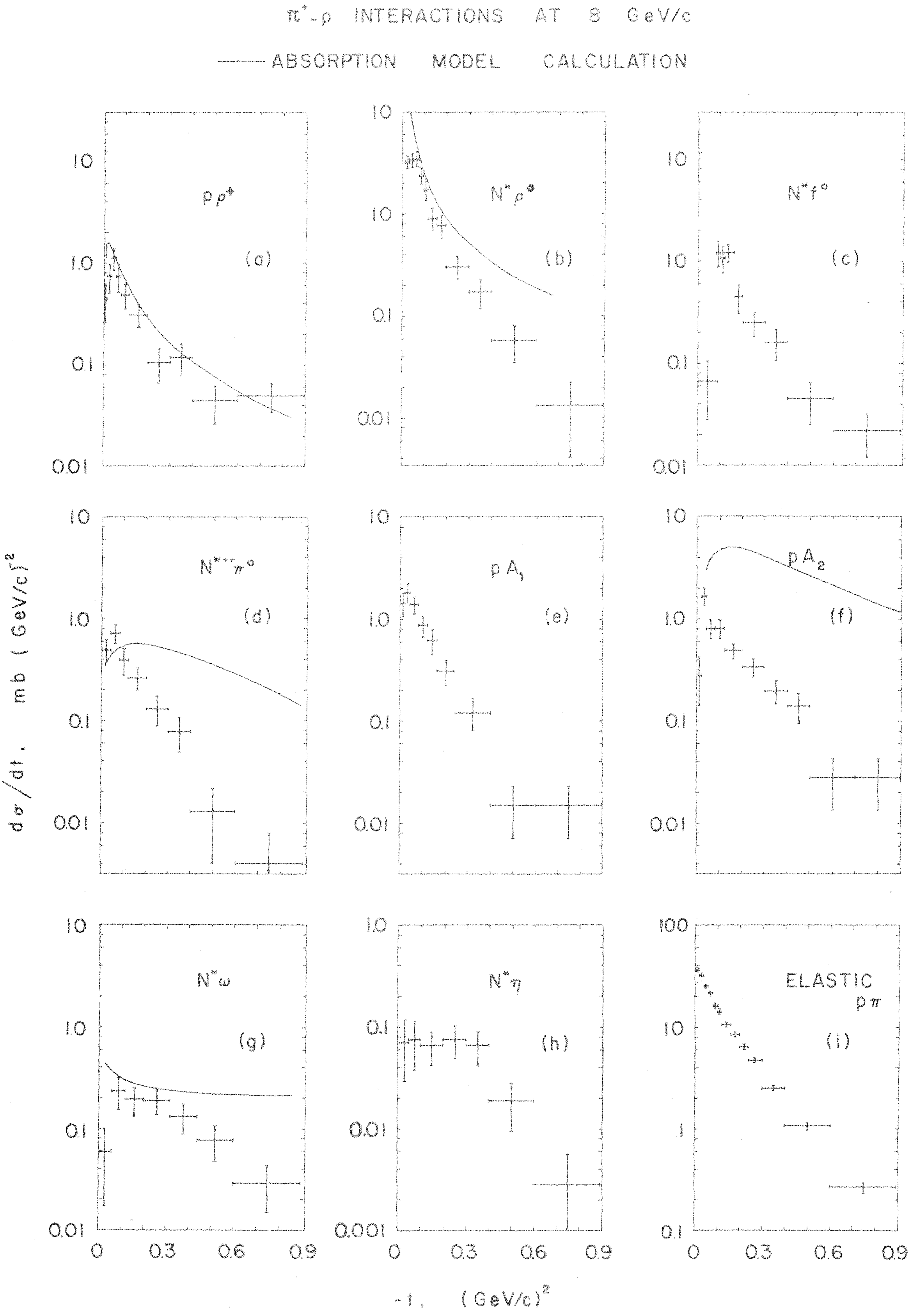
Table I Total cross-sections, corrected for unseen decay modes, for reactions (a) to (i) as determined experimentally and as calculated on the basis of the absorption model. The experimental values of the slope, A, of the t-distribution of the differential cross-sections are given for the two indicated t-intervals.

Table I

π^+-p Interactions at 8 GeV/c

Reaction Products	Cross-sections, mb		Particle assumed to be exchanged	t_1 $(GeV/c)^2$	Slope, A, $(GeV/c)^{-2}$	
	Expt.	Theory			$t_2 = 0.3$	$t_2 = 0.4$
$p \rho^+$	0.12 ± 0.04	0.14	π	0.02	10.1 ± 1.8	7.6 ± 1.2
$N^{*++} \rho^o$	0.43 ± 0.04	0.82	π	0.06	13.9 ± 1.6	11.7 ± 1.1
$N^{*++} f^o$	0.18 ± 0.045	-	π	0.12	13.7 ± 2.9	10.0 ± 1.7
$N^{*++} \pi^o$	0.11 ± 0.01	0.72	ρ	0.04	8.9 ± 1.9	7.9 ± 1.4
$N^{*++} \omega$	0.10 ± 0.012	8	ρ	0.04	≈ 0	2.0 ± 2.0
$p A_1$	0.24 ± 0.04	2.1	ρ	0.02	11.3 ± 1.6	9.4 ± 1.1
$p A_2$	0.23 ± 0.04	-	ρ	0.02	7.0 ± 1.1	6.9 ± 0.8
$N^{*++} \eta$	0.034 ± 0.011	-	A_2	-	≈ 0	≈ 0
$\pi^+ p$ (Elastic)	4.82 ± 0.07	-	-	0.02	8.6 ± 0.04	8.0 ± 0.3

FIG. 1



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