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What Part of the Reaction $\pi p \to (n\,\pi)p$ is Nondiffractive?*

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A prescription for parametrizing πp reactions is given. As a first step towards a correct model, only pion dissociation is considered. Therefore, a reaction with an even number of pions is assumed to be totally nondiffractive, while one with an odd number of pions has, in addition, a diffractive part. Using the prescription we predict the energy dependence of various exclusive reactions. The agreement with data is found to be fairly good. The nondiffractive component dominates the inelastic reactions at intermediate energies.

The problem of diffractive reactions has been extensively studied by many authors.[1] Today it appears less understood, though on a higher level, than ever before. In particular, it is not known to what extent the magnitude of the total cross section and of other quantities should be attributed to diffractive dissociation. In this note we study this problem.

We consider the specific process of multiple production of pions in π^+p collisions at intermediate energies. The amplitude for the reaction

$$\pi^+p \to (n\pi)^+p \tag{1}$$

may be divided into two parts, the diffractive and the nondiffractive amplitudes.[2] The diffractive amplitude is represented by the exchange of the Pomeron and the cut associated with it. This gives an energy-independent contribution to the cross section. The nondiffractive amplitude may, for example, be represented by the exchange of Regge particles. The nondiffractive cross section falls with incoming energy like $s^{-\alpha}$ (say). We neglect the interference between the two production mechanisms. We further assume that in the nondiffractive mode there is a strong correlation between charged and neutral pions produced. The data on neutral particles show an almost linear increase in the average number of neutrals produced with the number of charged particles.[3] Such a correlation can be accounted for in the multiperipheral model by assuming a definite isospin structure of the multiperipheral chain, e.g., if the pions are produced in pairs with "s-channel" isospin $I=1$, for every charged pair, we have a neutral one.[4] Recently Berger, Horn, and Thomas have discussed such correlations in detail.[5]

For our purpose, we *assume* that the *nondiffractive* part of the cross section for the reaction (1) is given by

$$\sigma_{\text{nondiffractive}}(n_-, n_0) \sim A(s)\, e^{-(n_- - n_0)^2/\lambda^2} Z\,, \tag{2}$$

where n_- = number of negative pions, n_0 = number of neutral pions, and Z is a function which relates the average multiplicity to the c.m. energy. Z may, for example, be

$$e^{-(2n_- + n_0 - \bar{n})^2/\lambda'^2}, \quad \bar{n} \sim \ln s \text{ (Ref. 5)} \tag{3}$$

or a Poisson distribution in the total number of particles produced $(=2n_- + n_0 + 2)$.

As a first step toward a correct model, we shall consider the diffractive excitation of the incoming pion only[6] (into the state A_J, with $J^P = 1^+, 2^-, \ldots$). Since a pion can dissociate into only an odd number of pions, it follows that reactions like $\pi^+ p \to \pi^+ p \pi^0$ will be considered nondiffractive in this model. This, of course, is not exact. We observe, however, that data on $\pi^+ p$ reactions with an even number of pions in the final state show no sign of flattening with incoming energy and can be parametrized by a power law,[7] as opposed to those with an odd number of pions. We therefore take as a working hypothesis that dissociation of protons is negligible, at least at the energies of concern.

Now one can write down the cross section for various production processes. For example,

$$\sigma(\pi^+ p \to \pi^+ p) = d_1 + A(s) e^{-(\ln s)^2/\lambda'^2}, \tag{4}$$

$$\sigma(\pi^+ p \to \pi^+ \pi^0 p) = A(s) e^{-(1-\ln s)^2/\lambda'^2} e^{-1/\lambda^2}, \tag{5}$$

$$\sigma(\pi^+ p \to \pi^+ \pi^+ \pi^- p) = d_2 + A(s) e^{-(2-\ln s)^2/\lambda'^2} e^{-1/\lambda^2}, \tag{6}$$

$$\sigma(\pi^+ p \to \pi^+ \pi^+ \pi^- \pi^0 p) = A(s) e^{-(3-\ln s)^2/\lambda'^2}, \tag{7}$$

$$\sigma(\pi^+ p \to \pi^+ \pi^+ \pi^+ \pi^- \pi^- p) = d_3 + A(s) \times e^{-(4-\ln s)^2/\lambda'^2} e^{-4/\lambda^2}, \tag{8}$$

and so on. Here d_1, d_2, d_3 are the diffractive contributions to the cross section, and are assumed to be independent of energy. We take $d_1 = 3.8$ mb,[7] $d_2 = 0.5 \pm 0.06$ mb,[8] and $d_3 \sim 0.1$ mb.[9] $A(s)$ is determined by parametrizing the reaction $\sigma(\pi^+ p \to \pi^+ \pi^+ \pi^- \pi^0 p)$ as $\sigma = 8.2(P_{\text{lab}})^{-0.69}$ mb,[7] and solving for $A(s)$ from Eq. (7).

Thus we are left with only two parameters, λ and λ', which do not depend upon energy or any particular reaction. In Fig. 1, we show the calculated cross sections for various exclusive reactions (with $\lambda^2 \simeq 3$ and $\lambda'^2 \simeq 5$). The agreement with the data on 2, 4, and 6 prongs is fairly good.

Discussion: We have proposed a simple parametrization for the energy dependence of a general πp exclusive reaction $\pi p \to (n_+ \pi^+)(n_- \pi^-)(n_0 \pi^0) p$. A heuristic formula is given to calculate the nondiffractive part of the above process [Eq. (2)] for the specific case of $\pi^+ p$. This equation simply says that the cross section for the above reaction is maximum when $n_- = (n_+ - 1) = n_0$, and that the mean multiplicity in the collision is $\sim \ln s$. This relates, for example, the energy dependence of the reactions $\pi^+ p \to \pi^+ p$ and $\pi^+ p \to \pi^+ \pi^0 p$. The latter is assumed to be totally nondiffractive, while the former has in addition a diffractive (energy-independent) contribution to the cross section. The above prescription, however, *does not* tell us anything about the size of the diffractive part.

Using as input the experimental values for the diffractive part for a few $\pi^+ p$ reactions, we have tried to check this parametrization. It seems to work reasonably well over a wide range of lab momentum. The energy dependence of the elastic reaction $\pi^+ p \to \pi^+ p$, for example, can be fitted with a constant part ≈ 3.8 mb and a part which is [as

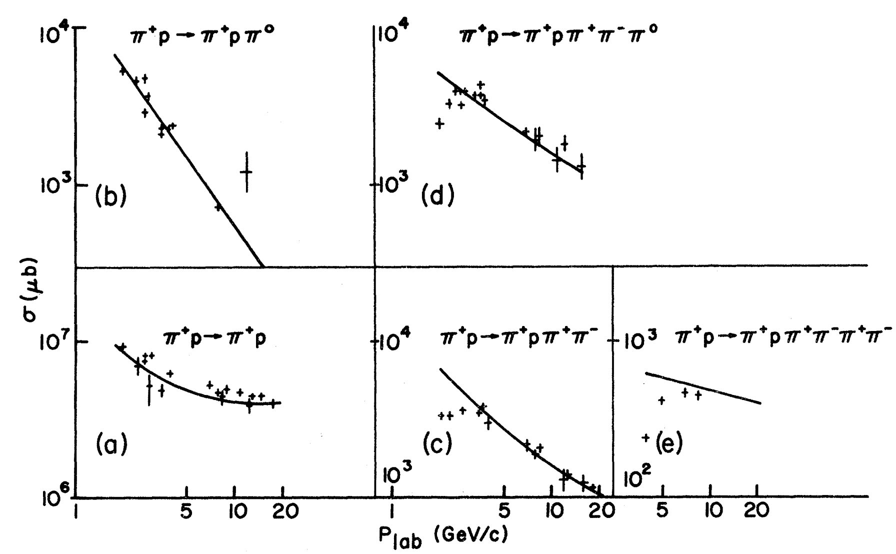

FIG. 1. Energy dependence of various $\pi^+ p$ reactions. Solid curves show the calculated cross sections for $\lambda^2 = 3$ and $\lambda'^2 = 5$. The experimental data are taken from Ref. 7.

Eqs. (4) and (5) show] equal to almost the entire cross section for the reaction $\pi^+ p \rightarrow \pi^+ \pi^0 p$. The latter, nondiffractive part of the cross section for a particular channel decreases with energy as $(s^{-0.69})$ apart from some logarithmic factors.

The parametrization of πp reactions given above may be useful in the extrapolation of cross sections to higher energies. Some examples of the cross sections predicted at $P_{\rm lab} = 70$ and 100 GeV/c are given in Table I. By adding up the contribution of all the neutral pions produced in association with a given number of charged pions, one can estimate a lower bound on the πp topological cross sections. For this we should take into account the threshold effects, etc., which we have neglected so far. Details of these and related topics will be discussed elsewhere.

In conclusion, the proposed prescription for parametrizing $\pi^+ p$ reactions seems to be successful. We note that the nondiffractive part dominates the inelastic cross section at intermediate energies.

TABLE I. Predicted exclusive cross sections at 70 and 100 GeV/c.

Reaction	$P_{\rm lab}$ 70 GeV/c	100 GeV/c
	σ (mb)	
$\pi^+ p \rightarrow \pi^+ p$	3.81	3.80
$\rightarrow (3\pi)^+ p$	0.62	0.58
$\rightarrow (3\pi)^+ \pi^0 p$	0.44	0.34
$\rightarrow (5\pi)^+ p$	0.30	0.28
$\rightarrow (5\pi)^+ \pi^0 p$	0.63	0.66

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