ABSORPTION MODEL FOR REACTIONS $\pi+p \to n\pi+N$

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The application of the absorption model to many body reactions $\pi+p \to n\pi+N$, with the group of n pions treated as a quasiparticle, with the variable mass, and spin zero, is presented. Predictions of this model are compared with the experimental data for reactions $\pi^{+}+p \to 5\pi+p$ and $\pi^{+}+p \to 6\pi+p$ at laboratory momentum of π^{+} 8 GeV/c. It is demonstrated that at a given energy the absorption model can roughly describe many body reactions if the absorption factor of Jackson and Gottfried is used. On the contrary the absorption factor of Dar, Weisskopf and Watts leads to a complete disagreement with the data.

Some phenomenological analysis of experimental data for high multiplicity, high energy reactions $\pi+p \to n\pi+N$ was carried out by Białkowski and Sosnowski [1] and by Ziemiński [2]. The authors found, that the main features of these reactions can be explained by a transition matrix element depending only on the square of energy s, and on the square of four momentum transfer t from the initial to the final nucleon. The t-dependence is very similar to that of the two body processes, idependently of energy and of the multiplicity of reactions. This suggests a similarity in the production mechanism of two body and many body reactions.

Taking into account the n-pion system as a quasiparticle, with a variable mass, one can treat many body processes similarly as two and quasi-two body reactions. In this paper we consider many body reactions $\pi+p \to n\pi+N$ as a two body reaction $a+b \to c+d$, where c is the quasiparticle with the variable mass m_c. In our approach the transition amplitude can be expressed as a function of s, t, m_c^2 and the differential cross-section is

$$\frac{d\sigma}{dt}(s,t) = \frac{1}{64\pi s p^2}\int F(s,t,m_c^2)R_n(m_c^2)dm_c^2 \tag{1}$$

where p is the momentum of initial particle in the centre of-mass-system. $R_n(m_c^2)$ is the phase space integral for n final particles, while $F(s,t,m_c^2)$ is the function describing the

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dynamics of the reaction. For an unpolarized incident beam the factor F is given by

$$F(s, t, m_c^2) = \frac{1}{(2s_a+1)(2s_b+1)} \sum_{\substack{\lambda_c, \lambda_d \\ \lambda_a, \lambda_b}} |T^{\lambda_c, \lambda_d}_{\lambda_a, \lambda_b}(s, t, m_c^2)|^2 \tag{2}$$

where s_i, λ_i denote spin, helicity of the particle i. $T^{\lambda_c, \lambda_d}_{\lambda_a, \lambda_b}(s, t, m_c^2)$ is the relativistic transition amplitude.

To obtain the dynamical factor $F(s, t, m_c^2)$ we assume the absorption model which was very successful in explaining many two and quasi-two body reactions in the laboratory momentum range 1–18 GeV/c [3, 4, 5]. For considered reactions the absorption amplitude is given by

$$T^{\lambda_c, \lambda_d}_{\lambda_a, \lambda_b}(s, t, m_c^2) = \sum_j (2j+1) M^j_{\lambda_c, \lambda_d; \lambda_a, \lambda_b}(s, m_c^2) \times$$
$$k^j(s, m_c^2) d^j_{\lambda_c - \lambda_d, \lambda_a - \lambda_b}(\theta) \tag{3}$$

where $M^j_{\lambda_c, \lambda_d; \lambda_a, \lambda_b}(s, t, m_c^2)$ is the partial wave peripheral amplitude corresponding to the Feynman's diagram (Fig. 1), $k^j(s, m_c^2)$ is the absorption factor.

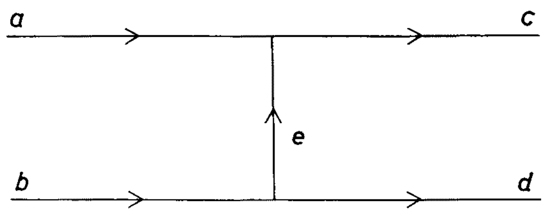

Fig. 1. Feynman's diagram for the quasi-two body reaction $a+b \to c+d$ in the peripherical model with the exchange of e particle

Jackson and Gottfried [3] calculate the absorption factor directly from the data of elastic scattering. We shall call this model the Old Absorption model. It gives the following expression for the absorption factor

$$k^j = (1 - C \exp(-\gamma j^2))^{1/2} (1 - C' \exp(-\gamma' j^2))^{1/2}. \tag{4}$$

The parameters corresponding to the initial state, C and γ, can be found directly from experiment. Parameters of the final state, C' and γ', are usually not known and can be taken as adjustable parameters.

Another way of calculating absorption factors has been proposed by Dar, Weisskopf and Watts [5] and we shall call their model the New Absorption model. In this model the absorption factor takes on the following form

$$k^j = \frac{1}{1 + \exp\left(\frac{R - j/(pp')^{1/2}}{d}\right)} \tag{5}$$

where R and d are to be functions of the energy square and are the same for all final channels to which a given entrance may lead.

The comparison of absorption factors in the OA and NA models as functions of the impact parameter b $(j+1/2 = \sqrt{pp'}\,b)$ is presented in Fig. 2. It is observed that in the NA model the absorption is very strong for small b and rapidly decreases for $b \approx R$. In the OA model the absorption in the region of small b is smaller than in the NA model and

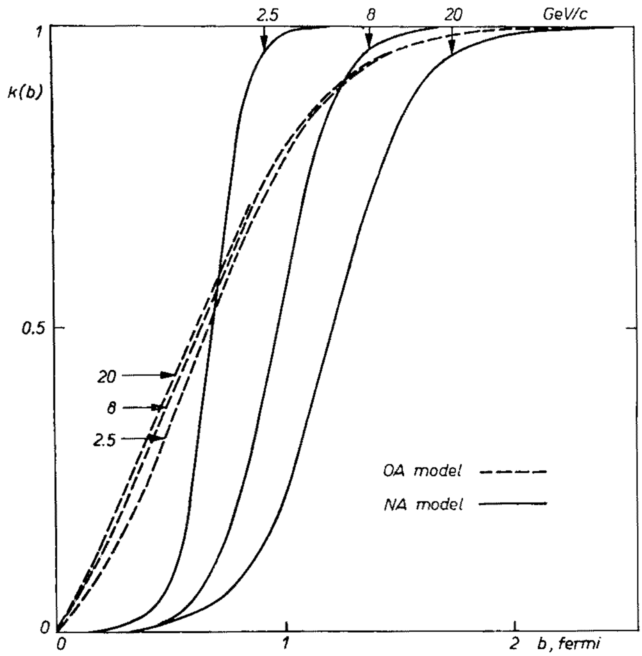

Fig. 2. Absorption factor $k(b)$ in the OA model and the NA model for π^+p collision at the laboratory momentum π^+ 2.5 – 20 GeV/c. Parameters C and γ were obtained from experimental data [8, 9], C' and γ' were assumed: $C' = 1$, $\gamma' = 3/4\gamma$; R and d were taken from [5]

decreases when b increases. When the energy of the scattering increases the absorption strongly increases in the NA model, while in the OA model we observe a small decrease of the absorption. For the quasi-two body reactions this leads to a unsatisfactory energy dependence of the cross-section when the OA model is used. In that respect the NA model seems to be better. The problem of the energy dependence, has not been, however, investigated in our paper for the multiparticle processes. We concentrate on the differential cross-section at a given energy. Let us consider two reactions

$$\pi^+ + p \rightarrow 5\pi + p \tag{6}$$

$$\pi^+ + p \rightarrow 6\pi + p \tag{7}$$

at the laboratory momentum of π^+ 8 GeV/c. The system of 5 and 6 pions we describe as a quasiparticle with a variable mass and zero spin.[1]

[1] Our assumption that the spin of these quasiparticle is 0 is the simplest assumption, and is in accordance with the isotropy of the experimental angular distributions of pions in their rest frame [7].

The amplitude for the reaction (6) is calculated from the ϱ^0-exchange, while for the reaction (7) from the π^0-or ω-exchange. The coupling constants of the exchanged particle with the initial pion and the final group of pions are not known and they are taken in

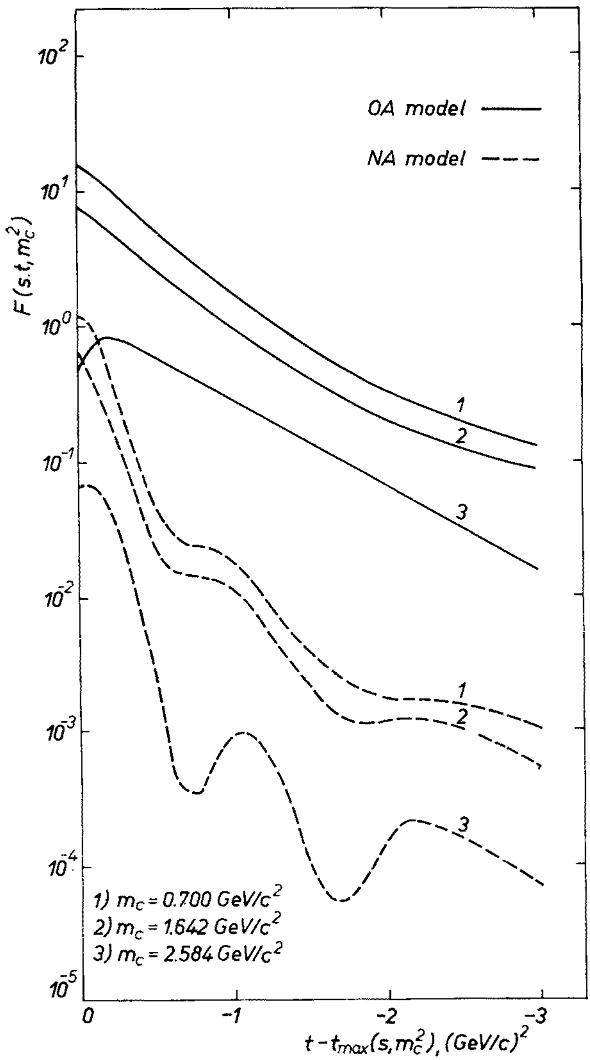

Fig. 3. Dynamical factor $F(s, t, m_c^2)$ in the OA model and the NA model with ϱ^0-exchange for $\pi^+ + p \to 5\pi + p$ at $p_{lab} = 8$ GeV/c

our model as free parameters. The absorption parameters of the OA and NA model were taken the same as for the quasi-two body reactions, namely $C = 0.7$, $C' = 1$, $\gamma = 0.019$, $\gamma' = 3/4\,\gamma$, $R = 0.96$ fm, $d = 0.13$.

As an example we present in Fig. 3 the dynamical factor F for the OA and NA models for the reaction $\pi^+ + p \to 5\pi + p$. The factor $F(s, t, m_c^2)$ is shown as a function of $t' = t - t_{max}(s, m_c^2)$ at various masses m_c. It is observed that the behaviour of curves in the OA model is different from that in the NA model. At a given mass m_c the curves in the OA model monotonically decrease while in the NA model the curves have a strong diffraction structure. This effect results from the shape of the absorption factor k. In the NA model this factor corresponds to the absorption region with a sharp edge. The increase of the mass results in a more pronounced diffractive structure of curves. In the region of small $|t|$ a sharp exponential peak is obtained in both models. The slope of curves is bigger in the NA model than in the OA model.

Figs 4 and 5 show a comparison of the differential cross-sections $d\sigma/dt$ predicted by the OA model and the NA model with the experimental data. The reaction $\pi^+ + p \to 6\pi + p$

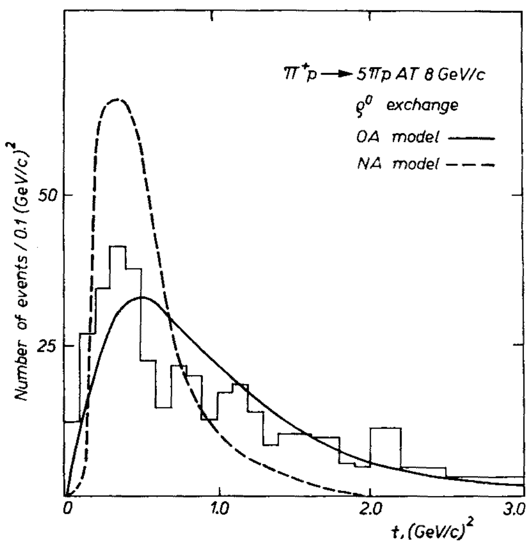

Fig. 4. Differential cross-section $d\sigma/dt$ for $\pi^+ + p \to 5\pi + p$ at $p_{lab} = 8$ GeV/c calculated from the OA model and the NA model with ϱ^0-exchange, and experimental results taken from [7]

with π^0-exchange is described unsatisfactorily by both models. For reactions (6), (7) with vector-meson exchange we get a reasonable agreement of the OA model predictions with experimental data. The NA model strongly disagrees with experiment.

We conclude that one can describe many body reactions of the type $\pi + p \to n\pi + N$ similarly as two body reactions, using the absorption model. It was shown that for considered reactions the model of Jackson and Gottfried agrees roughly with experiment, whereas that of Dar, Weisskopf and Watts disagrees with the data. It can be suspected, however, that the OA model would yield a worse energy behaviour than the NA model.

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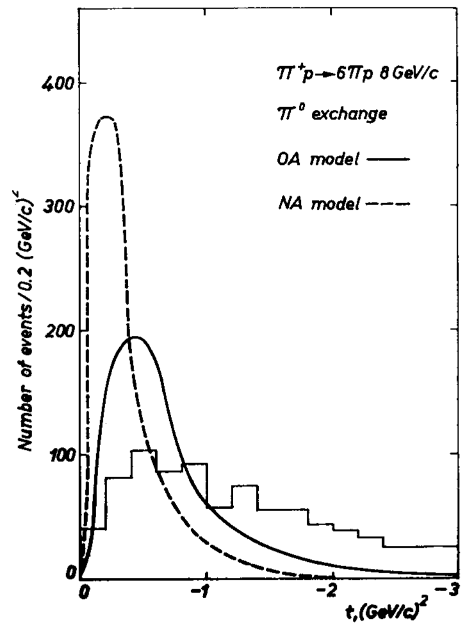

Fig. 5a. Differential cross-section $d\sigma/dt$ for $\pi^{+}+p \rightarrow 6\pi+p$ at $p_{\text{lab}} = 8$ GeV/c calculated from the OA model and the NA model, with π^{0}-exchange and experimental results taken from [7]

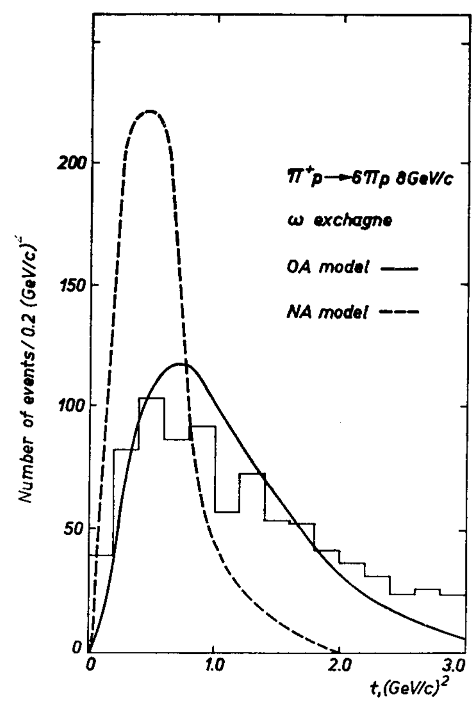

Fig. 5b. Differential cross-section $d\sigma/dt$ for $\pi^{+}+p \rightarrow 6\pi+p$ at $p_{\text{lab}} = 8$ GeV/c calculated from the OA model and the NA model, with ω-exchange and the experimental results taken from [7]

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