POLARIZATION EFFECTS IN DISPERSION RELATION
FOR PHOTOPRODUCTION OF π-MESONS ON DEUTER

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The photoproduction amplitude of π-mesons on deuterons is calculated for different cases of polarization of the spin of deuterons by means of impulse approximation. The calculations carried out in the two-nucleon approximation in the Breit system are valid up to a maximum photon energy ~ 236 MeV. In the unobservable region only a free proton and a free neutron contribute to the continuous part of the spectrum.

The dispersion relations are given for all cases of deuteron-spin polarization.

1. INTRODUCTION

At present, the most effective method in the quantum theory of wave fields appears to be the method of dispersion relations. Although the results achieved by means of this method are often in many cases complicated and are of a test-like character, they can be considered as a satisfactory verification of the fundamental principles of the quantum theory of wave fields.

The method of dispersion relations has proved especially satisfactory in the interactions of π-mesons with nucleons, for it is in accordance with this type of interactions and its efficiency and exactness have recently been proved in a number of papers [1].

An extension of the method of dispersion relations by its application to the processes containing the simplest bound states such as a deuteron, can be achieved by means of impulse approximation. The results obtained by using the method of impulse approximation for elastic processes containing bound states in dispersion relations have been successfully compared with the experimental values for elastic scattering of π-mesons on deuterons by Kaschluhn [2].

The method of dispersion relations with bound states for non-elastic processes has been used for the photoproduction of neutral π-mesons on deuterons with the help of the impulse approximation in the author's paper [3] for the case of deuterons with spin perpendicularly polarized to the scattering plane. Only for this case of polarization could simpler results be obtained, because in the interaction non-relativistic Hamiltonian of nucleons with the electromagnetic field no interaction occurs between the charge of the proton and the field.

The charge term responsible for the interaction of protons with the electromagnetic field occurs in the two remaining cases of polarization of deuterons with spin polarized in the direction of or in the opposite direction to the propagation

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of photons and mesons. Calculations of this kind, involving an extension of the method of dispersion relations to any case of the polarization of deuterons in the photoproduction of neutral pions on deuterons and the derivation of appropriate dispersion relations, have been the purpose of this paper.

The rigorous theory of the process of photoproduction of neutral pions on deuterons has been given in reference [3] and remains valid for our two cases of the polarization of deuteron spin in the direction of or in the opposite direction to the propagation of photons and mesons. Thus all the paragraphs at the beginning, including part of the fourth paragraph, remain without any changes. We shall regard all the derivations in these parts as known and the paper itself, containing the theory of the process \( \gamma + d \rightarrow d + \pi^0 \), will be quoted as paper 1. Similarly, all the mathematical symbols used there will be kept in the present paper.

2. CALCULATION OF PHOTOPRODUCTION AMPLITUDES

For the process of the photoproduction of neutral pions on deuterons we gave in paper [1] the general form of the photoproduction amplitude in the interaction representation

\[
Y^{\gamma 
\nu}(E, \lambda \epsilon) = \pi \left[ 1 - \frac{E_p}{\sqrt{(M^2 + p^2)}} \sum_p \left( M_1 \delta(E + E_p) - M_2 \delta(E - E_p) \right) \right].
\]

The term \( M_1 \) obtained after spectral splitting is given in the two-nucleon approximation as a product of two matrix elements

\[
M_1 = \langle d' | j^{\nu'}(0) n, p | n, p | d' \rangle,
\]

where \( j^{\nu'}(0) \) and \( i^{\mu}(0) \) denote the mesonic and electromagnetic current respectively; the deuteron in its initial \((d)\) and final state \((d')\) is characterized by momenta \( p \) or \( p' = -p \) resp. and by quantum numbers \( m \) and \( m' \) and the system of neutron and proton in the intermediate state by momenta \( q \) and quantum numbers \( l \). The term \( M_2 \) is expressed by the exchange of currents in (2) and by substituting the momenta \( p - q \) for \( q - p \).

It has been proved in paper I that the amplitude (1) is reduced to only one term in each term \( M \) given in expression (2) with one free neutron and proton in the intermediate state.

Owing to the small coupling constant of nucleons in the nucleus of the deuteron, we have used the impulse approximation. The general type of the matrix element in expression (2), which contains the meson current, is

\[
\langle q', l | j(x) \rangle | p, s \rangle = -i \frac{g_{\gamma M}}{M_s} \left\{ \int dx_2 \chi_d'(x, x_2, t) Y_1 X_{LZ} \sigma_1 \cdot q' \chi_d(x, x_2, t) Y_2 X_S + \right.

\[
+ \int dx_1 \chi_d(x_1, x, t) Y_1 X_{LZ} \sigma_2 \cdot q' \chi_d(x, x, t) Y_2 X_S ,
\]

\]