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CALCULATION OF SPIN-FLIP AMPLITUDE OF CHARGE-EXCHANGE PROCESS $\pi^- p \to \pi^0 n$

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It is shown that the spin-flip amplitude of the charge-exchange $\pi^- p \to \pi^0 n$ reaction calculated in the dynamical model of hadron interactions correctly reproduces basic features of the spin-flip amplitude determined by the amplitude analysis of experimental data at $p_L = 40$ GeV.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Вычисление амплитуды с изменением спиральности реакции перезарядки $\pi^- p \to \pi^0 n$

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Проведено вычисление амплитуды с переворотом спина реакции перезарядки $\pi^- p \to \pi^0 n$. Вычисления выполнены в рамках динамической модели взаимодействия адронов с учетом сильных формфакторов. Показано, что полученная амплитуда передает основные свойства соответствующей амплитуды, определенной на основе анализа экспериментальных данных при $p_L = 40$ ГэВ/с.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Large polarization [1] revealed in different charge-exchange processes at 40 GeV/c indicates a large size of the spin-flip amplitude in such reactions. It has been shown in works [2] on the basis of the amplitude analysis that the spin-flip amplitude of the reaction $\pi^- p \to \pi^0 n$ at $p_L = 40$ GeV/c and $|t| = 0.1 \div 0.2$ GeV^2 is about twice as great as the spin-non-flip amplitude. Such a large size of T_{+-} requires a theoretical explanation.

The purpose of this work is to calculate the spin-flip amplitude of the charge-exchange reaction $\pi^- p \to \pi^0 n$ in the framework of a dynamical model of hadron interactions [3]. The model allows us to calculate the contribution of quark-antiquark pairs, surrounding the hadron, which are regarded approximately as π-mesons, to the high energy scattering amplitude.

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Earlier, the description was obtained of polarization effects of pp-scattering [4] in which contributions of resonances in the s-channel were considered with the help of phenomenological parameters. In this work we calculate the contribution of the nucleon and Δ_{33}-isobar excitation to the spin-flip amplitude of the charge-exchange reaction $\pi^- p \to \pi^\circ n$.

Let us consider the meson-nucleon scattering. The contribution of the diagram, fig. 1, to the scattering amplitude with N (Δ-isobar) in the intermediate state looks as follows:

$$T_{N(\Delta)}^{\lambda_1\lambda_2}(s,t) = \frac{g^2_{\pi NN(\Delta)}}{i(2\pi)^4} \int d^4q \, T_{\pi\pi}(s',t)\, \phi_{N(\Delta)}[(k-q)^2, q^2]\, \phi_{N(\Delta)}[(p-q)^2, q^2] \times$$

$$\times \frac{\Gamma^{\lambda_1\lambda_2}_{N(\Delta)}(q,p,k)}{[q^2 - M^2_{N(\Delta)} + i\epsilon][(k-q)^2 - \mu^2 + i\epsilon][(p-q)^2 - \mu^2 + i\epsilon]}, \quad (1)$$

here λ_1 and λ_2 are relevant helicities of nucleons; $T_{\pi\pi}$ is the $\pi\pi$ scattering amplitude; Γ, the matrix element of the numerator of diagram; ϕ, the vertex functions chosen in the dipole form:

$$\phi_{N(\Delta)}(\ell^2, q^2 - M^2_{N(\Delta)}) = \frac{\beta^4_{N(\Delta)}}{(\beta^2_{N(\Delta)} - \ell^2)^2}. \quad (2)$$

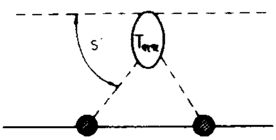

Fig. 1. Contribution of 2-meson exchange to the charge-exchange reaction $\pi^- p \to \pi^\circ n$.

Using the light-cone variables and integrating (1) we obtain for the spin-flip amplitude:

$$T^{+-}_{N(\Delta)}(s,t) = \frac{g^2_{\pi NN(\Delta)}\, \beta^8_{N(\Delta)}}{2(2\pi)^3} \int_0^1 dx\, x^5 M_{\pi\pi}(s',t) \times$$

$$\times \int \frac{d^2\vec{q}_\perp \Gamma^{+-}_{N(\Delta)}(q_\perp, p, k)}{(\vec{q}^{\,2}_\perp + d)(\vec{q}'^{\,2}_\perp + d)(\vec{q}^{\,2}_\perp + a)^2(\vec{q}'^{\,2}_\perp + a)^2}; \quad (3)$$

$$\vec{q}\,' = \vec{q} + x(\vec{p} - \vec{k})\,; \quad d = (M^2_{N(\Delta)} - x M^2_N)(1 - x) + \mu^2 x\,;$$

$$a = (M^2_{N(\Delta)} - x M^2_N)(1 - x) + \beta^2_{N(\Delta)} x\,. \qquad (3)$$

The matrix element of the nucleon-intermediate-state contribution has the form:

$$\Gamma^{+-}_N = \Delta M_N (x - 1)\,,$$

here Δ is a transfer momentum.

For a standard choice of the lagrangian of the $\pi N \Delta$ — interaction and Δ_{33} — propagator (see, for example [4]) we have:

$$\Gamma^{\lambda_1 \lambda_2}_\Delta = \bar{u}^{\lambda_1}(p)(\hat{q} + M_\Delta)\left[(pk) - \frac{1}{3}\hat{p}\hat{k} - \frac{2(pq)(kq)}{3M^2_\Delta} + \frac{(pq)\hat{k} - (kq)\hat{p}}{3M_\Delta}\right] u^{\lambda_2}(k)\,.$$

As a result, we obtain for the helicity-flip matrix element:

$$\Gamma^{+-}_\Delta = \Delta\{(pk)(x M_N + M_\Delta) + \frac{M^2_N}{3}(xM_N - M_\Delta) -$$

$$- \frac{2(pq)(kq)}{3M^2_\Delta}(xM_N + 2M_\Delta) + \frac{M_N}{3M_\Delta}((pq) + (kq))(xM_N - M_\Delta)\}\,, \qquad (4)$$

where

$$(pk) = M^2_N + \frac{\Delta^2}{2}\,; \quad (kq) = \frac{q^2_\perp + M^2_\Delta}{2x} + \frac{xM^2_N}{2}\,,$$

$$(pq) = \frac{q^2_\perp + M^2_\Delta}{2x} + x\frac{M^2_N + \Delta^2}{2} - \vec{\Delta}_\perp \vec{q}_\perp\,.$$

In calculating integrals (3) we used the simplest Gaussian parametrization of the charge-exchange amplitude of $\pi\pi$ scattering:

$$T(s, \Delta) = (1 + i) H \exp(-b\Delta^2)\sqrt{s}\,,$$

$$H = 3.3 \text{ GeV}^{-1}, \; b = b_0 + a(\ln s - i\,\pi/2)\,; \; b_0 = 3.3\,(\text{GeV})^{-2}; \; a = 0.9\,, \qquad (5)$$

which is close to that used in [6]. We also used the following values of the parameters:

$$\beta_N^2 = 3.4 \ (\mathrm{GeV})^2 ; \quad \beta_\Delta^2 = 1.5 \ (\mathrm{GeV})^2 ,$$

which corresponds to [7], and the coupling constants

$$\frac{g_{\pi NN}^2}{4\pi} = 14.6 ; \quad \frac{g_{\pi N\Delta}^2}{4\pi} = 21 \ (\mathrm{GeV})^{-2} .$$

The consideration of isotopic factors in integrals (3) leads to the following expressions for the amplitude of interaction:

$$T_0^{+-} = \frac{1}{2}(T^{\pi^+ p} + T^{\pi^- p})^{+-} = 3T_N^{+-} + 2T_\Delta^{+-}$$
$$T^{+-}_{\pi^- p \to \pi^\circ n} = \frac{1}{\sqrt{2}}(T^{\pi^+ p} - T^{\pi^- p})^{+-} = 2\sqrt{2}\, T^{+-} - \frac{2\sqrt{2}}{2} T_\Delta^{+-} . \qquad (6)$$

As a result, the contributions of N and Δ states are essentially compensated in elastic processes. These contributions add together in the charge-exchange processes [6]. It makes the spin-flip amplitude large in $\pi^- p \to \pi^\circ n$ reactions.

The leading asymptotic term of the spin-flip amplitude of the charge-exchange process $\pi^- p \to \pi^\circ n$, obtained in the framework of the model, is shown in fig. 2. It is seen that it correctly reproduces basic features of the spin-flip amplitude determined by the amplitude analysis of the experimental data at $p_L = 40$ GeV. It is to be emphasized that this model leads to the identical energy dependence of the spin-flip and non-flip amplitudes. Consequently the spin effect obtained on its basis does not disappear in the asymptotic energy range. Note that a somewhat smaller size of the spin-flip amplitude calculated by us, T_{+-}^{cal}, (see fig. 1) can be connected not only with neglected $1/s$ — terms of the scattering amplitude but also with the spin-flip amplitude determined by a quark-antiquark pair which appears in the $^3P_0$ state upon disruption of a coloured tube [8]. The same behaviour of the spin-flip amplitude is typical of the models [9].

Note in conclusion that the spin-non-flip amplitude T^{++} should also be known for the calculation of particular physical effects. However, it is known that it is insufficient to regard only the contribution of large-distance effects defined by the diagram in fig. 1 for the defini-

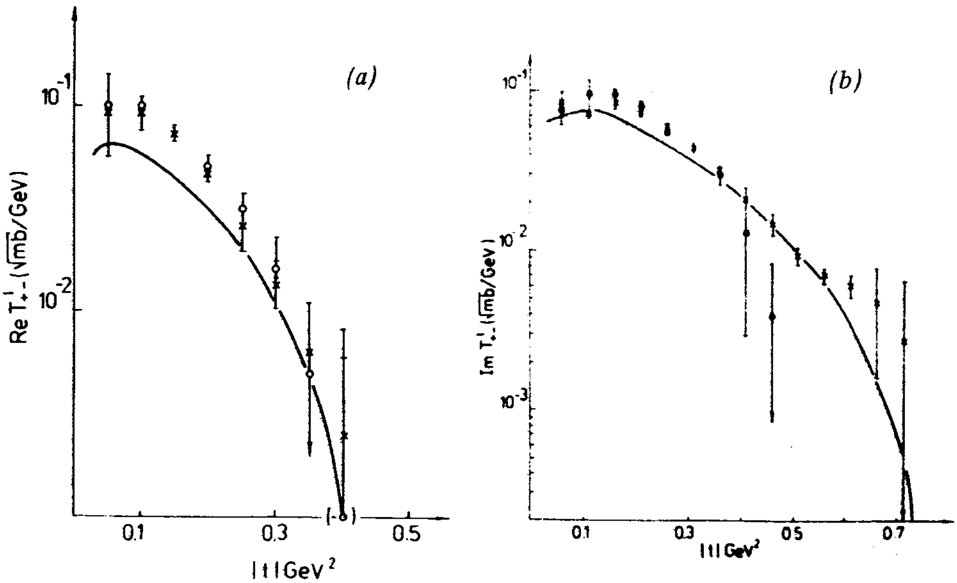

Fig. 2. Real (a) and imaginary (b) parts of the amplitude T_1^{+-}; *from the work* /2a/; *the decision "B" from the work* /2b/.

tion of the spin-flip amplitude and it is necessary to take into account the interaction of the central parts of hadrons /10/. At present, this contribution cannot be calculated and it should be taken into account phenomenologically. This permits us to carry out the analysis of experimental data on the elastic $\pi^{\pm}p$ scattering and to make predictions on the size of polarization effects in these reactions.

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