source (±5°) and to the inaccurate orientation of the crystal, although one cannot exclude fully the influence of the small contribution of other transitions.

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# SINGLE CHARGE EXCHANGE OF $\pi^+$ MESONS AND SPECTROSCOPY OF LIGHT NUCLEI

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In a recently published paper [1] it was proposed to use single charge exchange of $\pi^\pm$ mesons on light nuclei to obtain information on the np correlation in the nucleus. In the opinion of the author of [1], it is necessary to use for this purpose the differential cross section of the charge exchange $A(\pi^\pm, \pi^0)B$, summed over all possible states of the final nucleus, i.e., it is necessary to use the sum rules for the differential cross section.

In our opinion, the process of single charge exchange of $\pi^\pm$ mesons can be used also for spectroscopic purposes. In this paper we discuss such a possibility in the case of light nuclei, for which the isospin T (which plays an important role in our reasoning) is a sufficiently good quantum number. As is well known, T = 0 or 1/2 for stable light nuclei in the ground state. Therefore, the nucleus B obtained in the reaction $A(\pi^\pm, \pi^0)B$ will be characterized by an isospin value $T_b$ larger by one unit than the isospin of the nucleus A ($T_a$). It is clear that the production of a nucleus B in different energy states will correspond, generally speaking, to the different maxima in the energy spectrum of the $\pi^0$ mesons. One can expect the character of this spectrum to depend on the $\pi^0$-meson emission angle. By investigating the spectrum of the $\pi^0$ mesons and their angular distribution, it is possible in principle to obtain information on those excited states of the target nucleus A, which are characterized by the value of the isospin larger by unity than the isospin of the ground state. It is obvious that to obtain such information it is necessary that: 1) the reaction cross section be sufficiently large, 2) that the pion resolution energy (especially that of the $\pi^0$ mesons) be sufficiently good. As to the $\pi^0$-meson angular distribution, it can apparently be easily measured.

To illustrate the foregoing, let us consider by way of an example the charge exchange of $\pi^+$ and $\pi^-$ mesons on the nucleus $He^4$ ($T = 0$, $J^\pi = 0^+$) with production of the nuclei $Li^4$ and $H^4$ respectively in definite energy states. We chose this example because, first, the question of the existence of excited states of a four-nucleon system has recently attracted much attention and, second, experimental data are available for the nuclei and states considered by us [2]. In addition, for the levels of interest to us there are results of theoretical calculations [3,4], which we wish to use. In our calculations we shall use the results of [4], since the wave functions obtained in that investigation are more convenient for our purpose.

According to [4], the wave functions of definite states (JT) are represented in the form

$$|JTM_JM_T> = \sum_{N[f](\lambda\mu)\alpha LS} C^{JT}_{N[f](\lambda\mu)\alpha LS} \sum_{M_LM_S} (LSM_LM_S|JM_J) \times |AN[f](\lambda\mu)\alpha LSTM_LM_SM_T>, \qquad (1)$$

where N[f](λμ)αLST - aggregate of quantum numbers characterizing the state of the nucleus, and $C^{JT}_{N[f](\lambda\mu)\alpha LS}$ - coefficients determined as a result of diagonalization of the energy matrix. Since the quantum number α assumes only one value for the states considered by us, we shall henceforth omit it.

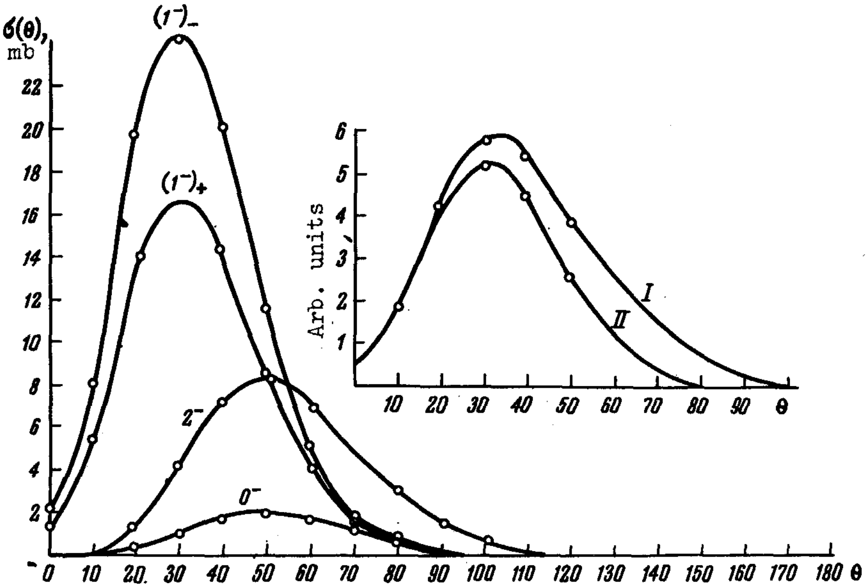
The results of the calculations [4] of the states of interest to us, carried out with the Tabakin potential [5] at ℏω = 18 MeV, are listed in the table together with the experimental data of [2]. The energies are reckoned from the ground state of the $He^4$ nucleus.

| $J^\pi T = 1$ | $E_{exp}$, MeV | $E_{theor}$, MeV | $C^{JT}_{1[31](10)11}$ | $C^{JT}_{1[31](10)10}$ |
|---|---|---|---|---|
| $2^-$ | 24.5 | 25.0 | 1 | 0 |
| $1^-$ | 25.9 | 28.1 | 0.770 | 0.638 |
| $0^-$ | 27.7 | 27.5 | 1 | 0 |
| $1^-$ | 29.7 | 31.3 | −0.638 | 0.770 |

For the charge-exchange operator $T^{\pm}$ of the $\pi^{\pm}$ mesons we use an expression given in [1]

$$T^{\pm} = \pm 2\pi \frac{(\hbar c)^2}{3\sqrt{E_{k_0} E_k}} \sum_{a=1}^{A} \{e^{i(\mathbf{k}-\mathbf{k}_0)\vec{r}}\tau^{\pm}(2\mathbf{k}_0\,\mathbf{k} - i\sigma\,[\mathbf{k}_0,\mathbf{k}]\Delta(k_0)\}_a = \sum_{a=1}^{A} t_a^{\pm}, \qquad (2)$$

where each term of the sum describes πN scattering in the region of the (3, 3) resonance; k, $E_k$ and $k_0$, $E_{k_0}$ - wave vectors and energies of the $\pi^{\pm}$ and $\pi^0$ mesons respectively, $\tau^{\pm}$ and $\vec{\sigma}$ - known isospin and spin operators of the nucleon, and $\Delta(k_0)$ - a quantity that depends on the phase of the πN scattering in the resonance region and can be parametrized in accordance with [6] as a function of $k_0$.



Angular distribution of the $\pi^0$ mesons in the $He^4(\pi^+, \pi^0)Li^4$ reaction

Using expressions (1) and (2) we can readily calculate the differential cross section of the reaction $He^4(\pi^+, \pi^0)Li^4$ with excitation of individual levels of the $Li^4$ nucleus. The figure shows plots of the differential cross sections of this reaction with excitation of the $Li^4$ levels indicated on them. It is seen from the figure that when $\theta \lesssim 10°$ there are excited in the main the levels $(1^-)_-$ and $(1^-)_+$, and the probabilities of the excitation of the levels $2^-$ and $0^-$ are practically equal to zero. This result can be readily understood by taking into consideration the form of the operator (2) and the structure of the states listed in the table. The spin ($S_a$) and the orbital angular momentum ($L_a$) of the ground state of the $He^4$ nucleus, as is well known, are equal to zero, and the spin of the final nucleus ($S_b$) in the states $2^-$ and $0^-$, as seen from the table, is equal to unity. Therefore the excitation of these levels is possible only by flipping of the spins of the individual nucleons in the initial nucleus, which experience the charge exchange. This process is brought about by the second term of expression (2), and this leads to a characteristic relation for small $\theta$, namely $\sigma(\theta) \simeq \sin^2\theta$. On the other hand, excitation of the levels $(1^-)_-$ and $(1^-)_+$ occurs with spin flip ($S_b = 1$) and without it ($S_b = 0$), and the last process is due to the first term of the expression (2), which leads to $\sigma(\theta) \simeq \cos^2\theta$ at small values of $\theta$.

Thus, by measuring the spectrum of the $\pi^0$ mesons in the reactions $He^4(\pi^+, \pi^0)Li^4$ at $\theta \lesssim 10°$ and observing the presence of a maximum in this spectrum at $\approx$(26 - 30) MeV, we can assert that it corresponds to excitation of the levels $(1^-)_-$ and $(1^-)_+$. Unfortunately, it is hardly possible to separate these two levels at the present time, since, first, their natural widths are of the order of 5 MeV [2] and, second, the accuracy of the measurement of the $\pi^\pm$-meson energy is of the same order and is comparable with the distance between these levels.

We shall now discuss the question of how to obtain information concerning the presence of the levels $2^-$ and $0^-$ of nuclei with A = 4 by investigating the reaction $He^4(\pi^+, \pi^0)Li^4$. To this end, we consider the $\pi^0$-meson angular distributions corresponding to the excitation of all the levels listed above, and to excitation of the levels $(1^-)_-$ and $(1^-)_+$ only. They are shown in the figure as curves I and II respectively. We see that II is practically symmetrical with respect to the 30° angle, whereas curve I is clearly asymmetrical. This asymmetry is due to the contribution corresponding to excitation of the levels $2^-$ and $0^-$. Thus, if the experiment reveals a noticeable asymmetry in the angular distribution of the $\pi^0$ mesons with respect to 30°, then this asymmetry can be ascribed to excitation of the levels $2^-$ and $0^-$. In principle, the obtained experimental curve can be resolved into the curves shown in the figure and corresponding to excitation of individual levels, and by the same token we can determine the relative contributions made by them to the total differential cross sections.

It should be noted that the reasoning presented above was based on the assumption that nuclei with A = 4 have in the considered energy region ($\lesssim 30$ MeV) no levels with T = 1 other than those considered here. This is apparently the real situation [2-4].

It is seen from the foregoing example that single charge exchange of $\pi^\pm$ mesons at energies close to the (3, 3) resonance on light nuclei can be used in principle to obtain spectroscopic information concerning the nucleus. It is necessary to use for this purpose such characteristics of this process as the angular distribution of the $\pi^0$ mesons and their spectrum at definite scattering angles. As seen from the figure, these processes have a sufficiently large probability.

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# POSSIBILITY OF TRANSFORMATION OF AN ANTIFERROMAGNETIC SEMICONDUCTOR INTO A METAL IN A STRONG MAGNETIC FIELD

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It follows from both theoretical considerations and experiments (see the references in [1-4]) that in some cases the existence of a gap in an antiferromagnetic semiconductor is es-