Excitation of Δ isobars in carbon nuclei in the (^{3}He, t) charge exchange at 4.37, 6.78, and 10.78 GeV/c

V. G. Ableev,[1)] G. G. Vorob'ev, S. M. Eliseev, S. A. Zaporozhets, V. I. Inozemtsev, A. P. Kobushkin,[2)] A. B. Kurepin,[3)] D. K. Nikitin,[4)] A. A. Nomofilov, N. M. Piskunov, I. M. Sitnik, E. A. Strokovskiĭ, L. N. Strunov, and V. I. Sharov
Joint Institute for Nuclear Research

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The cross sections for the reaction (^{3}He, t) at the proton and at the ^{12}C nucleus, accompanied by the excitation of Δ isobars in the target, have been measured at high energies for the first time. The statistical error is $\lesssim 5\%$, and the normalization error is $\lesssim 10\%$. The mechanisms of importance to the production of the isobar in the nucleus in this reaction do not reduce to the production of this isobar at one of the nucleons of the nucleus.

1. The AL'FA apparatus[1] has been used to measure the invariant cross sections of the (^{3}He, t) reaction in C and CH_2 targets accompanied by the emission of tritons at angles $\theta \lesssim 0.4\,^\circ$ in the same arrangement as for experiments on the (d, p) fragmentation reaction[2] (the "A geometry").

The cross sections for the (^{3}He, d) reactions were measured simultaneously in the same targets. Using the same apparatus but another arrangement[3] (the "B geometry," we measured the absolute differential cross sections of the (^{3}He, d) reactions at 10.78 GeV/c in the reaction $p_d \simeq (2/3)p_{^3\mathrm{He}}$, where the stripping cross sections are essentially independent of the initial energy.[4] It was thus possible to carry out an absolute normalization of the (^{3}He, t) charge-exchange cross sections at all the energies involved here. In the same geometry we carried out absolute measurements of the cross section for the (^{3}He, t) reaction at 6.78 GeV/c; preliminary results of these measurements were reported in Ref. 5. Comparison of the data on the charge-exchange cross sections obtained in the A and B geometries confirms the estimate (10%) of the systematic error of the absolute normalization in our data found in the A geometry. The statistical error is basically less than 5%. The background contribution does not exceed 7% and does not depend on the momentum of the detected tritons.

2. Figures 1 and 2 show the cross sections of the charge-exchange reaction (^{3}He, t) at the proton and at the ^{12}C nucleus as a function of the energy transferred to the target nucelus: $Q = T_{^3\mathrm{He}}$ where T is the kinetic energy (the curves in these figures are eyeball fits of the points). The resolution in terms of θ was $\sigma_Q \simeq 20$, 30, and 70 MeV for the initial momenta of 4.37, 6.78, and 10.78 GeV/c, respectively.

In the cross section for the reaction at the proton (Fig. 1) we see a peak whose position and width are approximately as expected for the $p(^3\mathrm{He}, t)\Delta^{++}$ reaction. The shape and position of this peak are distorted by the ^{3}He form factor. This distortion disappears with increasing initial energy, since there is an accompanying decrease in

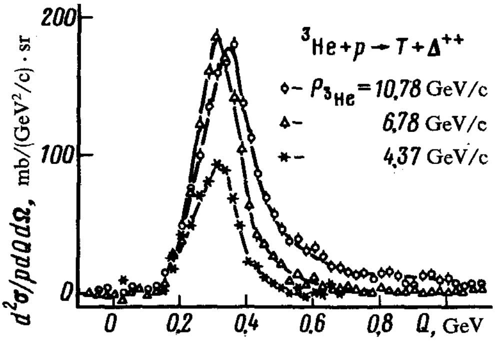

FIG. 1.

the longitudinal momentum transfer in the rest frame of ^{3}He[$\Delta p_{\parallel}(Q)$] at a fixed Q. The peaks crest at $Q_0^{(p)} = 298 \pm 2$, 307 ± 1, and 325 ± 1 MeV for the initial momenta of 4.37, 6.78, and 10.78 GeV/c, respectively.

In the cross sections for the reaction at the carbon nucleus we see two peaks (Fig. 2). The first, small-Q, peak is due[6] to spin-isospin excitations of levels of the residual nucleus. The shrinkage of this peak with increasing energy is due only in part to the degradation of the resolution.

The second peak lies in the same Q region as for the charge exchange at the proton, so we will call this the "Δ peak." Its position, width, and height at 4.37 and 6.78 GeV/c may be shifted by a contribution from the tail of the nuclear-excitation peak. An estimate shows, however, that the effect of this tail on the position of the crest of the Δ peak is slight even at 4.37 GeV/c, shifting this peak by no more than 10 MeV. We accordingly give the estimated values of Q_0 without consideration of this

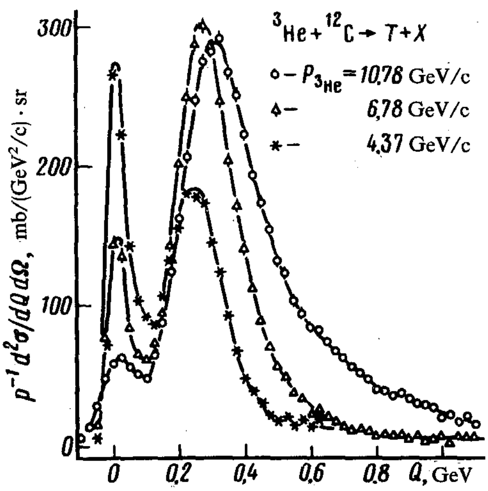

FIG. 2.

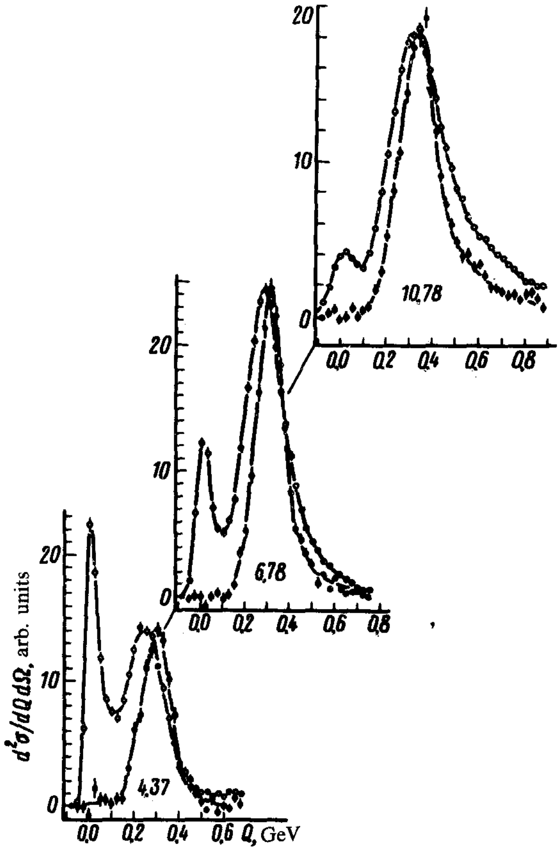

FIG. 3. The Q spectra of tritons from the p (^{3}He, t)Δ^{++} reaction (filled circles) and from the C(^{3}He, t) reaction (open circles). The data for the reaction with the proton are normalized to the crest of the Δ peak in the reaction with the nucleus.

effect:

$$Q_0^{(C)} = 245 \pm 2, \quad 275 \pm 1, \text{ and } 315 \pm 1 \text{ MeV}.$$

3. Comparison of the results leads to several conclusions. The mechanism which gives rise to the Δ peak essentially entirely determines the magnitude of the cross section for the (^{3}He, t) charge exchange at the nucleus at 6.78 and 10.78 GeV/c

The ratio of the values of $(d\sigma/d\Omega)(0) = \int(d^2\sigma/dpd\Omega)dp$ near the Δ peak ($Q > 75$ MeV) for the charge exchange at the carbon nucleus and the proton (R) increases with increasing initial momentum, having values ~ 0.5 (according to Saclay data[6]) at 3.9 GeV/c), ~ 1.6 at 4.37 GeV/c (the contribution of the tail from the nuclear-excitation peak has been subtracted), and $\simeq 2.3$ at 6.78 and 10.78 GeV/c.

We see a shift in the positions of the Δ peaks at a given energy for the charge-exchange reactions with the carbon nucleus and the proton; see Fig. 3 and the estimates of Q_0 given above. This shift can be explained on a kinematic basis if we assume that a group of nucleons of the nucleus are involved in the elementary event [since $\Delta p_{\parallel}(Q)$ decreases with increasing target mass at a fixed initial energy and a fixed value of Q].

4. To verify that the facts listed in Section 3 and in Ref. 5 cannot be explained under the assumption that a Δ isobar is produced in one of the moving nucleons of the nucleus, we calculated the cross sections for charge exchange at the proton and the carbon nucleus at 6.78 GeV/c in the Glauber-Sitenko model, but we took the transfer of longitudinal momentum into account. We worked from experimental data on the characteristics of the $NN \rightarrow N\Delta$ reaction and on the ^{3}He form factor. To calculate the cross section for the reaction with carbon we used both an oscillator wave function and a shell-model wave function. We found that the particular wave function used for the ^{12}C has essentially no effect on the results. The calculations for the reaction with the proton agree satisfactorily with experimental data, while for the reaction with the carbon there is a complete disagreement: We find a ratio $R \sim 0.8$ instead of 2.3, and we find $Q_0^{(C)} > Q_0^{(p)}$, in contrast with the opposite shift which is observed experimentally, $Q_0^{(C)} < Q_0^{(p)}$. We were unable to achieve even a qualitative agreement with experiment by varying the initial parameters of the model within the accuracy with which they have been determined or by taking into account the final-state interaction.

5. In summary, a comparison of data on the absolute cross sections for the (^{3}He, t) charge exchange at the proton and the carbon nucleus and the results of Glauber calculations shows that at high energies the mechanisms which are important in the charge exchange at nuclei involving the production of a Δ isobar do not reduce to the production of this isobar at one of the nucleons of the nucleus.

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[1)]Institute of Nuclear Physics, Moscow State University.
[2)]Institute of Theoretical Physics, Academy of Sciences of the Ukrainian SSR.
[3)]Institute of Nuclear Research, Academy of Sciences of the USSR.
[4)]P. N. Lebedev Physics Institute, Academy of Sciences of the USSR, Moscow.

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