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V.G.Ableev, S.M.Eliseev, V.I.Inozemtsev,
B.Naumann, L.Naumann, A.A.Nomofilov,
N.M.Piskunov, I.M.Sitnik, E.A.Strokovsky,
L.N.Strunov, V.I.Sharov, S.A.Zaporozhets

Δ-ISOBAR EXCITATIONS OF NUCLEI IN CHARGE-EXCHANGE REACTIONS

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I. Introduction

Experimental studies of nuclear matter spin-isospin ($\vec{\sigma}\cdot\vec{\tau}$) excitations at an energy of about 300 MeV assimilated by nuclear matter have been carried out intensively in the last few years. A nucleus can assimilate such excitations (which will be referred to as Δ-excitations) not only through the excitations of the nucleonic internal degrees of freedom (i.e., the $N\rightarrow\Delta$ transitions) but also through some other kinds of excitations, including collective ones, for example, intranuclear mesonic field excitations (like a "spin-isospin sound"[1]); one could even expect the isonucleus[2] formation. In general, the internal structure of the bound nucleon differs from the free nucleon one due to medium effects. So, not only the Δ-isobar in nuclear matter but also the very $N\rightarrow\Delta$ transition can be modified (under the influence of the nucleonic environment) as compared with the empty space case. This has to lead to differences between the observed Δ-excitation characteristics and the ones expected in the commonly used picture of quasi-free Δ-isobar production from a moving intranuclear nucleon. Such differences can be more pronounced if one provides good conditions for the strong final state interaction between the Δ and the rest of the nucleus, i.e. when their relative momentum is small and comparable to the Fermi-momentum of nucleons in the nucleus.

The (^{3}He,t) charge-exchange experiments[3,4] at small momentum transfers ($\Delta p_\perp \sim 0$, $\Delta p_\parallel \sim 350$-$400$ MeV/c) have opened experimental investigations of the nuclear Δ-excitations. The very first results [3a,b] have shown that the A(^{3}He,t) cross sections at projectile momenta, p_o, of 1.4 GeV/c/nucl. are determined by the Δ-excitation channel. The corresponding peak at energy transfers $Q = (E_o - E_t) \sim 300$ MeV has clear signatures of a collective nature of the nuclear Δ-excitations: (i) the peak is shifted down to lower Q-values and (ii) its width is much larger than that of a similar peak in the p(^{3}He,t)Δ^{++} cross sections (nearly by a factor of about 2). This downshift cannot be explained by Fermi-motion effects/3c,d/.

The downshift and broadening of the nuclear Δ-peak have been confirmed in the subsequent experiments/5,6/ with an enlarged set of projectile and target nuclei. The analysis/3d/ of the A(p,n) cross sections/7,8/ has shown that the characteristics of the nuclear Δ-peak in this case also differ from the ones in the p(p,n)Δ^{++} charge exchange. (This fact has slipped away from the authors of papers/7,8/ and has not been reported there).

Thus, the nuclear Δ-excitation characteristics differ completely from the ones expected in the quasi-free Δ-production picture and show a collective nature of the nuclear matter response to the high energy (~300 MeV) spin-isospin excitations.

Nowadays a theoretical understanding/9/ of the mechanisms, leading to the collective response of nuclear matter to the Δ-excitations, is not quantitative while it provides a good description of the charge exchange on free protons/3c/. But there is/3d/ a remarkable similarity between the features of the nuclear response to the Δ-excitations, the energy dependence of the total πA cross sections/10,11/ in the Δ-resonance region and the cross sections of Δ-electroproduction in nuclei at small electron scattering angles/12/. This similarity is unlikely to be accidental; perhaps, it is caused by some general reasons of nuclear Δ-excitation collectivity.

II. Δ-Excitations of Nuclei: Experimental Data

The nuclear Δ-excitations in the (^{3}He,t) charge exchange have been studied at Dubna/3/ for kinetic energies from 800 MeV/nucl. up to 5.23 GeV/nucl. and at Saclay/4/ at 767, 667 and 500 MeV/nucl. The Q-dependence of the cross sections has been measured at fixed triton emission angles (θ_t~0°). At energies below 800 MeV/nucl. the Q-dependence is strongly affected by the ^{3}He formfactor (and also by strong final state interaction effects at 500 MeV/nucl.), so we shall mainly discuss JINR data.

The experiment/3/ has been performed at the Dubna synchrophasotron by the spectrometer "ALPHA"/13/ (Fig.1). The measured cross sections are shown in Fig.2. For the p(^{3}He,t) reaction they have a peak at Q~300 MeV; its shape is well described by the Δ-resonance line/14/ distorted by the ^{3}He formfactor. The Breit-Wigner parameters of the peak, ω_0 and Γ_0, are in good agreement with each other at all energies. Their average values, $\overline{\omega}_0 = 1234 \pm 3$ MeV and $\overline{\Gamma}_0 = 116 \pm 7$ MeV, are consistent with the tabulated ones[15]. The contribution from the excitations of heavy isobars with isospin 3/2 of the families $\Delta(1600)$ and $\Delta(1900)$ is evident at $p_o > 7$ GeV/c in the cross sections of the $p(^3He,t)$ reaction at $Q > 500$ MeV. At $p_o = 18.3$ GeV/c this contribution reaches 30-35%.

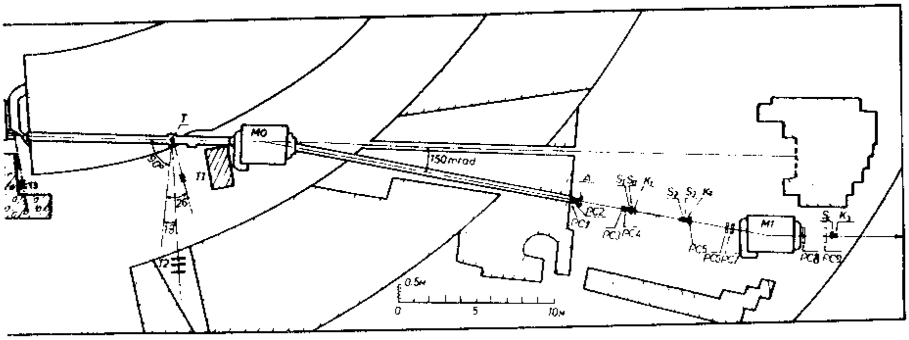


Fig.1. ALPHA spectrometer layout with multiwire proportional chambers (PC_i), scintillation counters (S_i, K_i, A) and monitors of beam intensity (T_i). The target point is denoted as T.

The $^{12}C(^3He,t)$ cross section is characterized by two peaks at low and high ($Q \sim 300$ MeV) excitation energies. The first peak corresponds to usual nuclear level excitations. The second one corresponds to the Δ-excitations. As seen from Fig.2 and the Table, with increasing the projectile energy the first peak fastly disappears and the Δ-excitations begin to dominate at $p_o > 4.4$ GeV/c. The maximum of the Δ-peak is shifted down to lower Q as compared to its position in the $p(^3He,t)\Delta^{++}$ reaction; its width is considerably larger; the ratio of the cross sections $\frac{d\sigma(C)}{d\Omega} / \frac{d\sigma(P)}{d\Omega}$ amounts to about 2.

Table

P_o GeV/c	Relat. contrib. to $d\sigma/d\Omega(0°)$ from the region $Q \leq 150$ MeV	Δ-peak position Q^{max}, MeV		FWHM, MeV		$\frac{d\sigma(C)/d\Omega}{d\sigma(P)/d\Omega}$
		$p(^3He,t)$	$C(^3He,t)$	$p(^3He,t)$	$C(^3He,t)$	
4.40	0.38	322 ± 2.5	274 ± 2.5	138 ± 9	182 ± 16	1.82 ±.5
6.81	0.18	327 ± 1.5	295 ± 1.5	109 ± 5	204 ± 9	1.77 ±.3
10.79	0.08	327 ± 2.	305 ± 2.	129 ± 7	257 ± 14	1.95 ±.3
18.3	-	-	-	-	-	2.14 ±.2

Describing the shape of the nuclear Δ-peak by the same Breit-Wigner function as in the $p(^3He,t)\,\Delta^{++}$ case, we have obtained significantly different parameters ω_o and Γ_o. The contribution from the higher isobars is also present at $p_o \gtrsim 10.79$ GeV/c and $Q > 600$ MeV. It equals about 40% at $p_o = 18.3$ GeV/c.

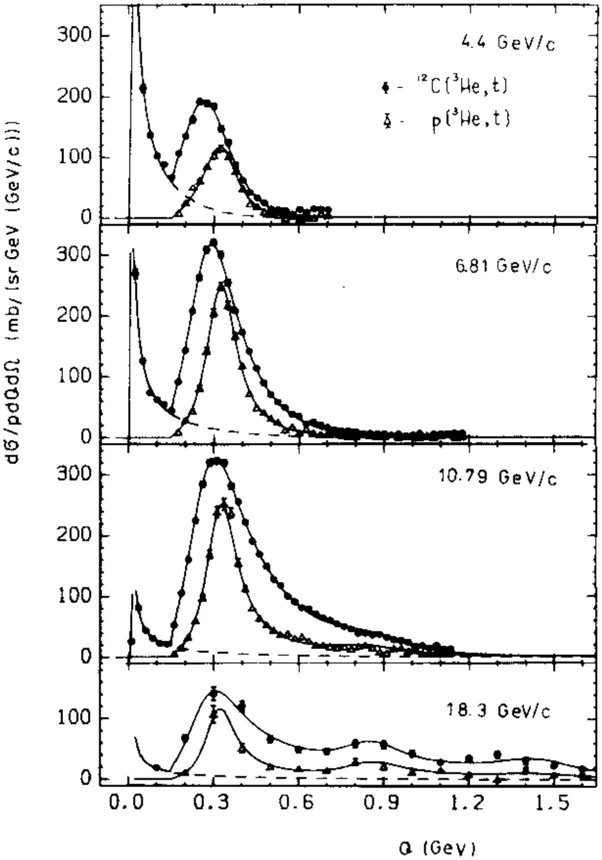
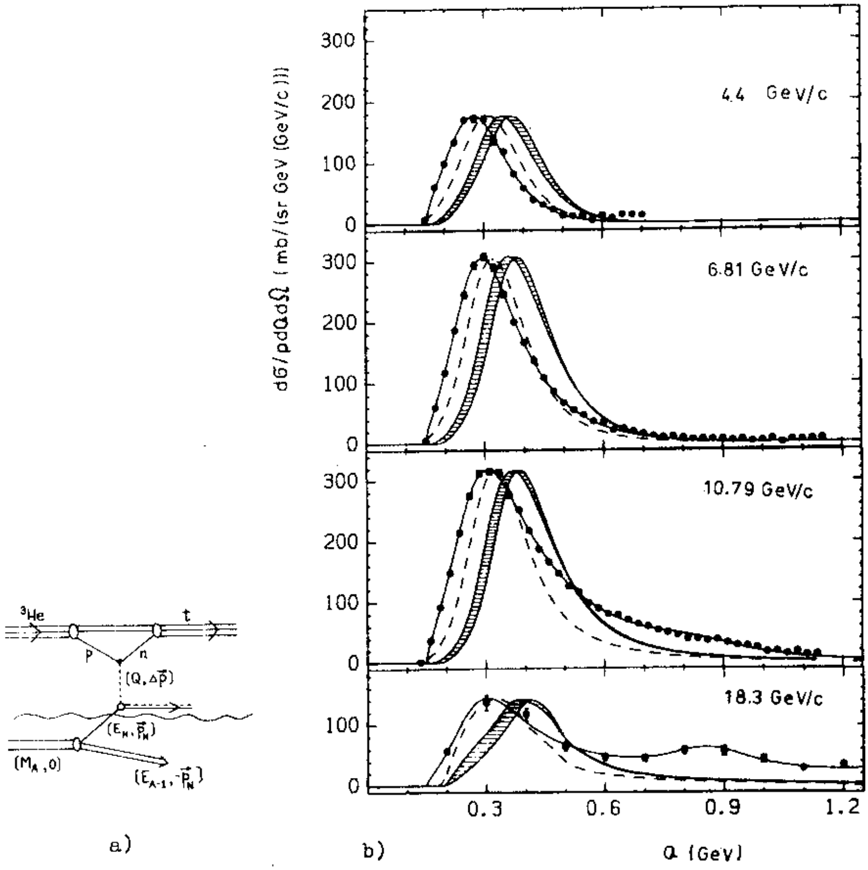


Fig.2. Measured invariant cross sections of the $^{12}C(^3He,t)$ (full circles) and $p(^3He,t)\Delta^{++}$ (triangles) reactions obtained after unfolding from the energy resolution effects/3c/. The dashed line represents an expected contribution from the "tail" of the low-Q peak of the nuclear level excitations. The full line is an approximation of the data points.

Our analysis/3c,d/ has led us to the conclusion that it is impossible to explain the observed downshift of the Δ-peak by quasi-free Δ-production from a moving intranuclear nucleon (see Fig.3). Using this picture, the value of $R_\Delta = \frac{d\sigma(C)}{d\Omega} / \frac{d\sigma(p)}{d\Omega}$ cannot be also reproduced: the one, calculated with the Glauber-Sitenko model, is only about 0.8/3b,c/.

Other data on the charge-exchange reactions with the Δ-excitations of nuclei confirm the presence of the observed downshift of the nuclear Δ-peak. It has been observed at $T_d = 2$ GeV in the (d,2p) reaction[5] and in the heavy-ion charge exchange[7]. The downshift and broadening of the nuclear Δ-peak is evident when one examines the A(p,n) data[7] at T_p = 1000 MeV.



a) b)

Fig.3. a) Impulse approximation diagram for quasi-free Δ-production on a moving intranuclear nucleon. The upper part of this diagram (over the wave line) corresponds to the $p(^3He,t)\Delta^{++}$ cross section. b) Nuclear Δ-excitation cross sections obtained after the subtraction of the "tail" from the low-Q peak (see Fig.2) - open circles. The shaded areas correspond to the expected cross sections calculated within the framework of quasi-free Δ-production (in accordance with the diagram of Fig.3a) and normalized to the experimental cross sections at the maxima. Dashed line - the same calculations but with the Δ -isobar bound in the nucleus.

So, we conclude that a universal picture is observed in the charge exchange of a baryon system on nuclei with the target Δ-excitations at small $p_\perp$. This picture does not depend on the type of the projectile: the peak of the target nucleus Δ-excitation is shifted down to lower excitation energy and is broadened in comparison with the similar Δ-peak in the cross sections of these reactions on a free proton target.

III. A-Dependence of the Nuclear Δ-Peak Shape

The data on the A-dependence of the charge-exchange cross sections with the nuclear Δ-excitations have been obtained at T_p= 1000 MeV for the (p,n) reaction and at $T_{^3He}$= 767 MeV/nucleon for the (^{3}He, t) reaction/4/. We shall discuss the former data because they are measured at higher energies where the nuclear Δ-excitations begin to dominate. They are also not damped by the ^{3}He formfactor as the (^{3}He,t) data/4/. The strong damping due to the ^{3}He formfactor can mask a possible A-dependence of the nuclear Δ-peak shape, and it actually does it imitating "A-universality"/4,5/.

3.1. A-dependence of Cross Section at Δ-Peak Maximum

If the A(p,n) charge exchange is a one-step process, then the A(p,n) and p(p,n) cross sections can be related at the Δ-peak maximum:

$$\left(\frac{d\sigma}{dT_n d\Omega}\right)^A_{max} \simeq \frac{1}{3}\left(1+2\frac{Z}{A}\right)\varepsilon_{abs}(A)\left(\frac{d\sigma}{dT_n d\Omega}\right)^p_{max} . \qquad (1)$$

The factor 1/3(1 + 2Z/A) originates from the isospin invariance arguments. The factor ε_{abs}(A) takes into account the absorption of projectile particles in the target nucleus and can be calculated, for example, following the ideology of paper/16/. As can be seen from Fig.4, ansatz (1) works fairly well within the present accurancy of the absolute normalization of the data/7/. This suggests the peripherality of the process.

3.2. The variations of the shape of the nuclear Δ-peak with A are more interesting. Figs.5 and 6 present data on the ratio

$$\left(\frac{d\sigma}{dT_n d\Omega}\right)^A \Big/ \left(\frac{d\sigma}{dT_n d\Omega}\right)^A_{max}$$

for several target nuclei.

The Δ-peak downshift discussed earlier is seen. It is about 30-35 MeV at a 4° neutron emission angle and about 40-45 MeV at 13.2°. For the deuteron target no downshift is observed.

The width of the nuclear Δ-peak is larger than the one in the p(p,n)Δ^{++} and d(p,n) reactions. We have already argued that the

Fermi-motion cannot be the main source of the nuclear Δ -peak broadening; the growth of the nuclear Δ -peak width with A (see Fig.5) is another evidence for this. The nuclear Δ -peak width can be assumed to increase due to the contribution of the non-mesonic modes of Δ-deexcitation: $n\Delta \rightarrow NN$ and $p\Delta \rightarrow NN$. For the Δ^{++} isobar in the nucleus only the $n\Delta^{++} \rightarrow pp$ mode is allowed. As the Δ^{++} is excited in the nucleus 3 times more frequently than the Δ^{+}, then a relative contribution of the non-mesonic modes to the nuclear Δ-peak width would increase with increasing the neutron excess in the target nucleus. This is just the tendency which the data /7/ show.

The data on the A(p,n) reaction with separated isotopes as a target (^{40}Ca, ^{44}Ca, ^{24}Mg, ^{25}Mg, ^{26}Mg) give some reasons to suspect a minor structure at the top of the nuclear Δ -peak (see Fig.6). Now it is quite unclear whether such peculiarities are significant; more precise data are required.

The main results concerning the A-dependence of the nuclear Δ-peak shape can be summarized as follows:

- The A-dependence of the absolute value of the cross sections at the nuclear Δ-peak maximum is mainly determined by projectile and ejectile absorption in the target nucleus; it implies a peripheral character of the reaction mechanism.
- The shape of the nuclear Δ-peak depends on A: the width of the nuclear Δ -peak increases with increasing A. This implies that the non-mesonic modes of the Δ-deexcitation may be the main sources of the large width of the nuclear Δ -peak.
- There is some weak evidence for a minor structure at the top of the nuclear Δ -peak.

IV. Discussion of the Data on the Nuclear Δ -Excitations

The general features of the processes at small $p_\perp$, discussed so far, namely: (i) spin and isospin transfer into a target, (ii) a pronounced peak at energy transfers of about 300 MeV and small values of $|t|$ - 4-momentum transfer squared, (iii) a dip at $|t| \lesssim 0.03$ GeV^2/c^2 in the t-dependence of the $\frac{d\sigma}{dt}(^3\text{He}p \rightarrow t\Delta^{++})$ (see Fig.7) imply an essential role of one-pion exchange in these processes. The OPE-model in this region of energies forms a good basis to connect the (^{3}He,t), (p,n) and other reactions.

The analysis /3,9/ of the p(^{3}He,t) Δ^{++} and p(p,n) Δ^{++} data justifies the applicability of the OPEM. As known, the diagram of Fig.8 makes a main contribution to these reactions. From here follows the relation

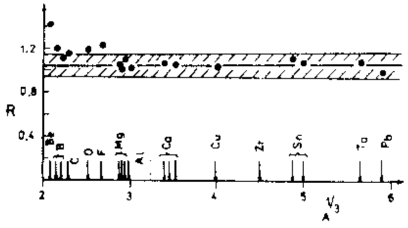


Fig.4. A-dependence of the ratio $R = \frac{(d\sigma/dTd\Omega)^A_{max}}{\frac{1}{3}(1+2Z/A)\varepsilon_{abs}(A)(d\sigma/dTd\Omega)^p_{max}}$ of the data of Ref.[7]. The shaded area corresponds to the normalization accuracy (±10%) of the data.

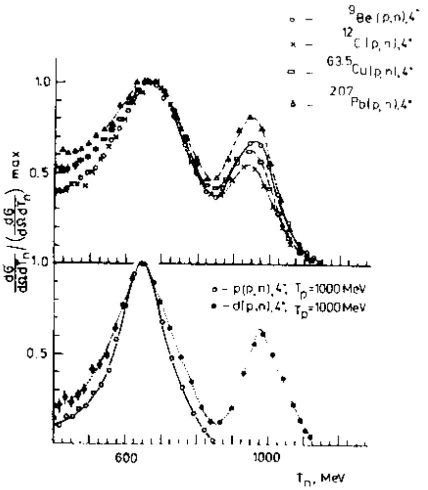


Fig.5. Nuclear Δ -peak shape for several nuclei from the A(p,n) reaction at T_p= 1000 MeV[7]. The lines are drawn by hand.

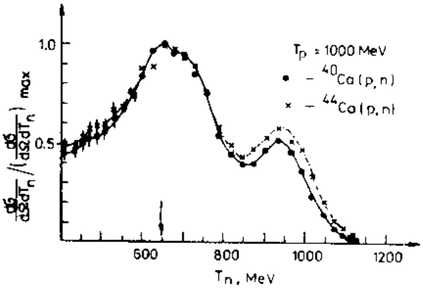


Fig.6. The same as in Fig.5. The arrow indicates the position of the Δ -peak maximum in the d(p,n) cross sections.

$$\frac{d\sigma}{p_t\, d\Omega\, dQ}(^3He \to t) = \frac{m_p\, p_{^3He}}{\pi\,\omega}\, g_{rs}(t)\, e^{R^2 t/3}\, \frac{d\sigma}{dt\, d\omega}(pp \to n\Delta^{++}). \qquad (2)$$

Here $\exp(R^2t/3)$ is the ^{3}He formfactor[3] (R = 1.8 Fm), $g_{rs}(t) \simeq g_{rs}(0) \simeq 0.7$ the correction for rescattering of target nucleon and produced Δ -isobar by projectile nucleons (it is calculated[3] using the Glauber-Sitenko model),

$\omega^2=(Q+m_p)^2-(\vec{p}_{^3He}-\vec{p}_t)^2$ and $\frac{d\sigma}{dt\,d\omega}(pp\to n\Delta^{++})$ the cross section of the $p(p,n)\Delta^{++}$ reaction at momentum $1/3p_{^3He}$. This cross section, proportional to the $\sigma_{tot}^{\pi^+p}(\omega)$, was calculated/3/ according to Wolf's paper/17/ using the parameters of the OPEM obtained there and the data on $\sigma_{tot}^{\pi^+p}$ from Ref./18/. One can see a good accordance with the $p(^3He,t)$ data/3,4/ at energies higher than 700 MeV/nucleon (see Figs. 7,9-12) and the $p(p,n)\Delta^{++}$ data/7,19/ at $T_p>700$ MeV. But at lower energies it is necessary/19a) to take into account the contributions from the final-state-interaction (FSI) diagrams like that in Fig.11.

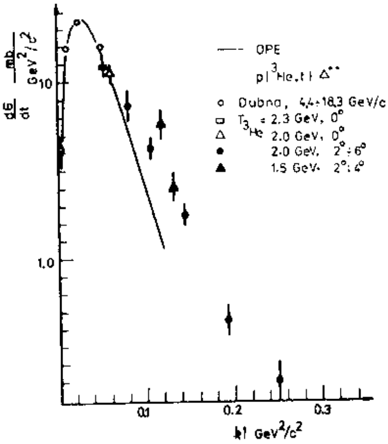


Fig.7. Cross section $d\sigma/dt$ of the $p(^3He,t)\Delta^{++}$ reaction from the data of Refs./3,4/. The full line – OPEM calculation.

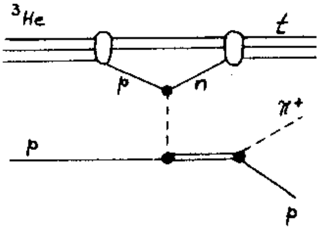


Fig.8. Main OPEM diagram for the $p(^3He,t)\Delta^{++}$ reaction.

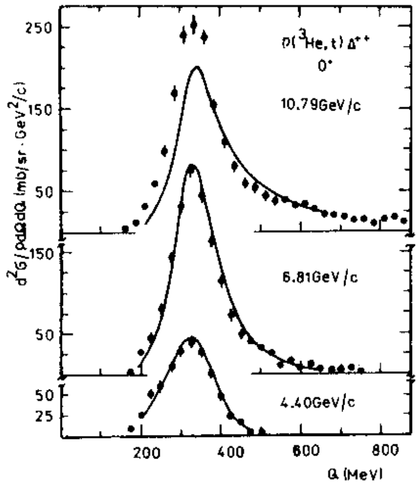


Fig.9. Invariant cross sections for the $p(^3He,t)\Delta^{++}$ reactions/3/. The full lines are calculated with the OPEM /3c/.

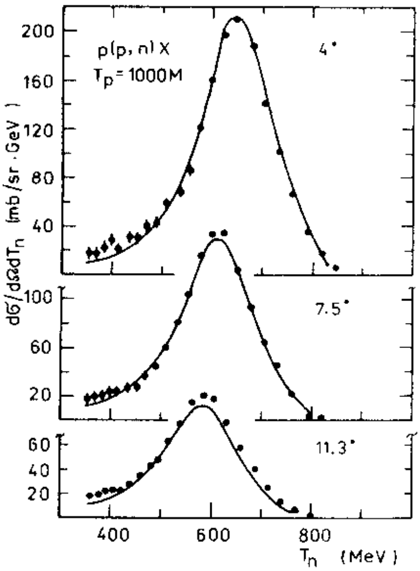
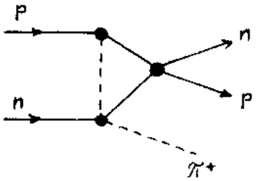


Fig.10. The $p(p,n)\Delta^{++}$ data from Ref./7/ and our OPEM calculations /3d/ (full lines) when energy resolution is taken into account. The initial proton energy is varied within the accuracy (±2%) of its determination: 980 MeV for a 7.5° emission angle and 900 MeV for 11.3°. This affects only the position of maximum of the resonance peak without visible changing the shape and height.

Fig.11. Diagram of the FSI taken into account in Ref./19a/ at 647 MeV.



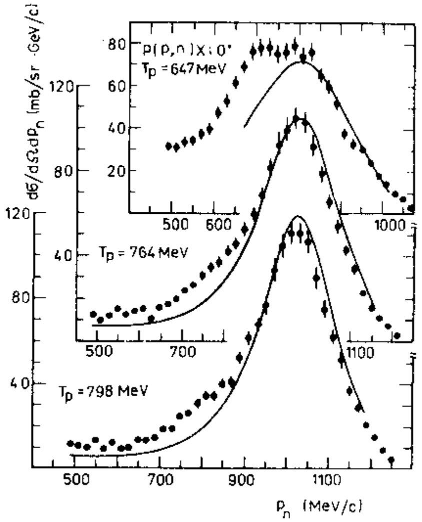


Fig.12. The same as in Fig.10 but for the data of Ref./19a/ at 764 and 798 MeV. The calculated cross sections are multiplied by the factor 0.85 (within a ±15% normalization accuracy of the data).

Neglecting the FSI leads to the underestimation of the cross sections (see, for example, Fig.7 in the region $|t|>0.1$ GeV^2/c). Therefore, it can be very doubtful to interpret the (^{3}He,t) data[4] at 500 MeV/nucl. (i.e., near the Δ-production threshold) as Δ-excitation data.

This successful description of the present $p(p,n)\Delta^{++}$ and $p(^3\mathrm{He},t)$ data in the explored energy region (but higher than 700 MeV/nucl.) implies that π-exchange dominates also in the charge exchange on nuclei with the Δ-excitations. Therefore, one can expect that the observed downshift of the nuclear Δ-peak and its broadening in comparison with the charge exchange on a free proton should be connected with the energy dependence of the pion-nucleus cross sections over the resonance energy region.

The downshift and broadening of the "resonance" peak in the $\sigma_{tot}(\pi A)$ cross sections are well known[10] and are being extensively discussed up to now (see, e.g., Fig.14 and Ref.[11]). We have tried to estimate the ^{12}C(p,n) cross section in the nuclear Δ-peak region using just the same OPEM as above replacing the $\sigma_{tot}^{\pi^+p}$ with the $\sigma_{tot}^{\pi C}$ [10]. The value of the cross section as well as the Δ-peak position and width have been satisfactorily reproduced. This allows us to assume the domination of the OPE in the nuclear Δ-excitation in small $p_\perp$ charge-exchange processes with nucleons and relativistic nuclei.

The distinguishing feature of the OPE is its longitudinal $(\vec{\sigma}\cdot\vec{q})$ character[11]. The OPE domination in the charge exchange with the nuclear Δ-excitations would thus mean that the observed collective effects are caused by a collective nature of the longitudinal part of the nuclear spin-isospin response. Therefore, such collective effects would display themselves in those reactions, in which this part of the nuclear response is dominant. Perhaps, just this reason may be responsible for the downshift of the nuclear delta-peak in Δ-electroproduction at small angles[12] which is absent at large electron scattering angles[12b] (see Fig.13). It might be that only the longitudinal spin-isospin response possesses such collective properties while the transverse one does not. Data on $A(\pi^+,\pi^0)$ charge exchange can help in this respect because only the transverse nuclear response works here. But at present such data have a too low accuracy[20] to draw some definite conclusions.

V. Conclusion

For the first time the nuclear Δ-excitations have been actually observed just in the (^{3}He,t) charge-exchange experiments[3,4].

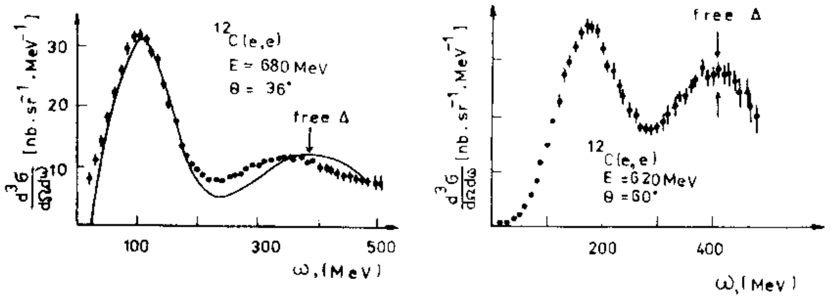


Fig.13. Cross sections of the A(e,e') reaction with Δ-electroexcitations from Ref.[12b]. The downshift of the nuclear Δ -peak is visible at $\Theta_e \sim 36°$ and is absent at $\Theta_e \sim 60°$.

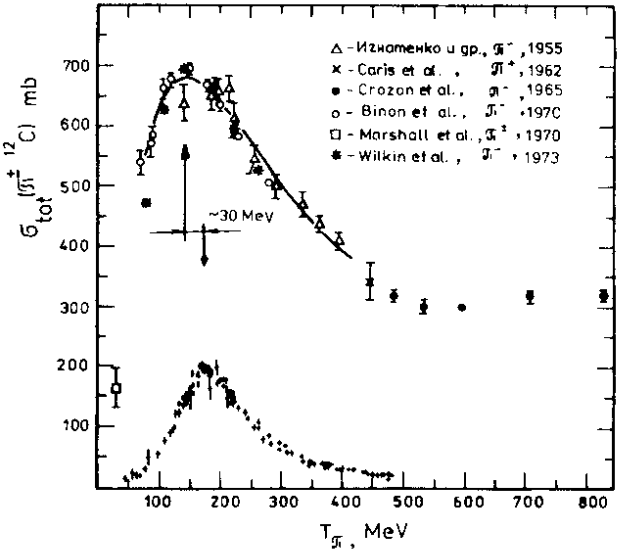


Fig.14. Our compilation of the $\sigma_{tot}(\pi^\pm C)$ data[10]. The full line is our approximation a'la Breit-Wigner. For comparison we also present the $\sigma^{\pi^+ p}_{tot}$ data from the compilation[18]. T_π is the kinetic energy of pions.

In Dubna experiments[3] it has been first shown that at small $p_\perp$ and sufficiently large (more than 800 MeV/nucl.) projectile kinetic energies the charge-exchange cross sections are dominated by the processes of the nuclear Δ-excitations. The collective nature of these excitations has been first observed and reported.

The data[3,4] on (^{3}He,t) charge exchange as well as on other charge-exchange reactions with relativistic nuclei[5,6] along with the results of our analysis[3d] of the old A(p,n) data[7,8] allow us to conclude that the main nuclear Δ-excitation characteristics do not depend on the projectile type and are governed by properties of the nuclear response on high energy ($\sim$300 MeV) spin-isospin excitations.

The present data on the A-dependence of the nuclear Δ-peak shape show that its width increases with increasing the target atomic number A (or N = A-Z). It increases at the expense of increasing the cross section in the transferred energy region $Q > Q_{max}$ (where Q_{max} is the position of the nuclear Δ-peak maximum). (The absence of such an A-dependence in the A(^{3}He,t) data of Saclay/4/ is caused by the strong damping due to the ^{3}He formfactor.) This A-dependence of the nuclear Δ-peak width can result from the non-mesonic modes of the Δ-deexcitations. There is a possibility for the presence of minor structures at the top of the nuclear Δ-peak.

The bulk of the available data on the charge exchange with nuclear Δ-excitations and the success of the OPEM in explaining the charge-exchange cross sections on a proton target allow us to suppose that at small $p_\perp$ the charge exchange with Δ-excitations goes mainly through the one-pion exchange. This assumption makes it possible to outline the connection between the discussed effects in the charge exchange with Δ-excitations and the effects investigated in the πA physics, as well as with the behaviour of the longitudinal nuclear spin-isospin response. These problems should be studied taking into account the electroexcitation data on nuclei, particularly at small electron scattering angles/12/.

A theoretical understanding of the nature of the collective effects, discovered in the Δ-excitation charge exchange experiments, is not quantitative to date/9/. Therefore, it seems very urgent to continue experimental investigations of the nuclear matter Δ-excitations.

First, it is necessary to make precise measurements of the A-dependence of the nuclear Δ-peak shape at energies higher than 800 MeV/nucleon, where Δ-excitations dominate in the charge-exchange cross sections at small $p_\perp$. Using such data, one can elucidate the questions concerning possible A-dependent structures of the nuclear Δ-peak and the A-dependence of its position. In such experiment is would be possible to separate the mesonic and non-mesonic modes of Δ-deexcitations and to determine their relative contributions to the full width of the nuclear Δ-peak. Comparing this information with π-absorption data, one could learn a lot about Δ-s in nuclear matter.

Experiments like A(d, 2p) with polarized deuterons or measurements of the D_{nn} parameter in the A(p,n) reaction with the nuclear

Δ-excitations would allow one to obtain very important information on the reaction mechanism.

There exists a long-standing problem of Gamov-Theller strength quenching. This quenching may be connected with the nuclear Δ-excitations. In view of this, it is worth-while to measure the cross sections of direct and inverse reactions such as (p,n) and (n,p) or (^{3}He,t) and (t,^{3}He) at the same energies and emission angles. Such a comparison is much less model-dependent than the comparison between the (d,2p) and (^{3}He,t) or (p,n) data.

It looks desirable to investigate a possible analogy between the charge exchange with nuclear Δ-excitations and Δ-electroexcitations of nuclei at small $p_\perp$.

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Аблеев В.Г. и др. E1-87-797

Дельта-изобарные возбуждения ядер в реакциях перезарядки

Приведены результаты измерений дифференциальных сечений перезарядки (^{3}He,t) на ядрах углерода и протонах в области энергий 800 МэВ/нуклон до 5 ГэВ/нуклон. Показано: а/ реакция на ядре идет, в основном, через возбуждения Δ-изобар; б/ процесс не сводится к рождению изобары на отдельном внутриядерном нуклоне и последующему свободному движению изобары сквозь ядро. Эффекты коллективной природы, обусловленные участием других нуклонов ядра-мишени, играют существенную роль. Этот вывод подтверждается результатами проведенного в работе анализа других известных данных о ядерных Δ-возбуждениях в реакциях перезарядки релятивистских ядер и в A(p,n) реакции. Отмечается связь обсуждаемых эффектов с эффектами, обнаруженными при изучении πA взаимодействий, в том числе с энергозависимостью полных сечений πA взаимодействия.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Ableev V.G. et al. E1-87-797

Δ-Isobar Excitations of Nuclei in Charge-Exchange Reactions

We present our measurement results of differential cross sections of the (^{3}He,t) change exchange on carbon nuclei and protons at energies from 800 MeV/nucl up to 5 GeV/nucl. They imply that a) the reaction on a nucleus proceeds mainly through the excitation of the Δ-isobars; b) the process is not reduced to the quasi-free production of the Δ-isobar on an individual intranuclear nucleon with a subsequent free motion of the isobar through the nucleus. The collective effects caused by other nucleons are important. This conclusion is confirmed by our analysis of the information on the nuclear Δ-excitations in the charge exchange of relativistic nuclei and A(p,n). We note a possible connection between the discussed effects and those observed in pion-nucleus studies, in particular, with the energy dependence of the πA cross sections.

The investigation has been performed at the Laboratory of High Energies, JINR.

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