объединенный
институт
ядерных
исследований
дубна

E1-94-241

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EXPERIMENTAL RESULTS ON CHARGE EXCHANGE REACTIONS WITH Δ EXCITATIONS AND POLARIZATION STUDIES OF Δ AND $N^*(1440)$ RESONANCES

Submitted to «Ядерная физика»

1994

1. Introduction

Problems of excitation and behaviour of broad hadronic resonances in nuclei and the nuclear medium response on high energy excitations, intimately related with the former, are discussed intensively during last decade. Large amount of experimental and theoretical papers and reviews are published on these topics. Nevertheless, the presence of a wide gap between experiment and theory is the main feature of the current situation: most of the well established experimental observations don't have **quantitative** theoretical interpretation firmly grounded (apart from few exceptions); most of theoretical predictions are **qualitative** or sometimes even controversial.

The main reasons of interest to the problems considered and main difficulties as well, come from the simple circumstance that the behaviour of nuclear matter at high excitation energies is governed not only by the nucleonic degrees of freedom but also by the internal degrees of freedom of the constituent nucleons: they cannot be treated independently when the energy transferred to the medium is close to the characteristic energy of excitation of the internal degrees of freedom. Such excitations reveal themselves as $N \rightarrow N^*, \Delta$ transitions followed by radiation of particles from the nuclei. *A'priory* there is no grounds to expect that the main properties of resonances excited in medium should be the same as in the case of their excitation in the empty space: the strong interplay between "internal" and "external" degrees of freedom could change not only the characteristics of resonances but the very mechanism of the "elementary" reaction as well. On the other hand, a resonance, treated as an excited hadronic "drop", radiates its decay products as asymptotic states when it is placed in the "empty" space, or as non-asymptotic states when it is in a medium; therefore the corresponding radiation boundary conditions are different, resulting again in modifications of the resonance parameters such as masses or widths.

Historically, the first signal about non-trivial behaviour of the pion and Δ-isobar in the nuclear medium came from the measurements of the total cross sections of $\pi^{12}C$ scattering made in 1970. The idea of Δ-hole excitations was developed during the analysis of these data and data on differential cross sections of elastic pion-nuclei scattering. But detailed experimental investigation of Δ-excitations of nuclear medium with the Δ-isobar near its mass shell was started in the inclusive $(^3He, t)$ experiments at Dubna and Saclay. They were performed near the threshold (Saclay) and in the region of maximal $NN \rightarrow N\Delta$ cross section (Dubna). Analysis of these data has shown that there is a fundamental difference between charge-exchange (CEX) reactions with excitation of Δ-isobar in nuclei and the corresponding "elementary" process. The difference is due to the many-particle nature of the nuclear system and reveals itself in various ways.

It can be regarded as established that the properties of Δ-isobar excitations of nuclei cannot be accomodated in the picture of quasifree production and indicate a collective response of nuclear matter to high (~ 300 MeV) spin-isospin excitations.

The time has now come to go over from inclusive to exclusive experiments in which not only the most energetic charge-exchange product but also other "soft" particles – products of the de-excitation of the target nucleus – are detected. This is necessary in order to understand the nature of the "collectiveness" of the Δ-excitations.

Extensive exclusive – type experiments on Δ excitations in nuclei have been started at KEK (FANCY, $A(p,p')\Delta^0$ and $A(p,n)$), Saclay (DIOGEN, $A(^3He,t)$) and Dubna (GIBS, $(t,^3He)$) after the first results on $(^3He,t)$ charge exchange; earlier p(d,pp)n bubble chamber experiment at Dubna should be also mentioned, because there was demonstrated an important role of the intermediate virtual Δ in the charge exchande channel of the deuteron breakup. The main conclusions derived from results of the inclusive experiments have been confirmed; some channels of de-excitation of nuclei with Δ-isobar were separated and investigated; new unexpected information was also obtained. Some of new results were presented at the recent International Conference "Mesons and Nuclei at Intermediate Energies: M & N'94".

It is obvious that all the information obtained so far in charge exchange reactions with Δ excitation of nuclei cannot be treated separately from that collected for other reactions: pion absorption, electro- and photo-excitation of Δ in nuclei, pion elastic and charge - exchange scattering. Strong correlations and connections between these processes can be found.

New valuable information should come from polarization experiments. Polarization effects in processes with excitations of broad hadronic resonances in nuclear medium remain almost untouched up to now, but they seems rather promising for the discussed topics, as was shown in talks at the "M & N '94" Conference. It should be noted that an interference of such broad resonances as the Δ and $N^*(1440)$ could manifests itself in polarization effects (due to their interference nature) in an unexpected way. Moreover, it seems for us that the present data on the N^* resonance excitation show that many problems of the Δ excitation and propagation in nuclei should not be treated independently of the $N^*(1440)$. For example, in the coherent pion production studies one should take into account not only the Δ-contribution but the contributions from the N^* excitations in the target and projectile as well, when the initial energy is large enough to allow for such processes. Experiment with polarized deuterons devoted to the problem under discussion was started in Dubna. The T_{20} is being measured at 0° in the inelastic $p(d,d')X$ and $A(d,d')X$ scattering, which is in a full analogy with the $p(\alpha,\alpha')X$ process. The coherent pion production on the proton target at the lowest allowed transferred energy is possible only through Δ excitation in projectiles for both d and α, because target excitation is forbidden for the d-beam by isospin and for the α-beam by both isospin and angular momentum conservation.

Short discussion of the main experimental results obtained for charge exchange reactions with protons and nuclei is given in the Sect. 2; both types of experiments are considered: inclusive and exclusive. Sect. 3 is devoted to the coherent pion production and to the investigations of the Roper $N^*(1440)$ resonance; attention is paid to the polarization observables in the (d,d') inelastic scattering (Sect. 4). The main points of the discussion are summarized in the concluding section.

2. Data on charge-exchange reactions on protons and nuclei at intermediate energies

The detailed **inclusive-type experiments** on $(^3He,t)$ charge exchange were performed at Dubna[1] and Saclay[3] in the kinetic energy interval from 667 MeV/nucleon up to 2.8 GeV/nucleon; less precise data were obtained at 5.9 GeV/nucleon[1]. The invariant differential cross sections at fixed angle close to 0° were measured in dependence on the energy transfer $Q = E_{^3He} - E_t$ (Fig. 1); at some energies the dependence of the cross sections (integrated over the Δ-peak) on the transverse momentum transfer was measured[2, 3]. The dependence of the cross sections on atomic number of the target was studied at the near-threshold energy at Saclay; later on similar experiments were performed with heavier projectiles[4]. The tensor analysing power of the (d,2p) reaction on protons and carbon was measured with detection of two protons at small relative momentum[5].

The most detailed fixed-angle inclusive measurements of the $A(p,n)$ charge exchange cross sections were performed at Gatchina at 1 GeV kinetic energy[6]. These data were obtained and tabulated at several angles from 4° up to 13.2° with target nuclei from d up to ^{nat}Pb. While this experiment was done before that on $(^3He,t)$ charge exchange, the Δ-excitation region was not inspected carefully and these data were re-analysed only when the results on $(^3He,t)$ charge exchange were published. Other (p,n) experiments were done mostly with proton target[7]; the data published in refs.[8] were not tabulated. The $p(p,n)X$ data set[7] provide rather firm "reference basis" needed for analysis of the inelastic charge exchange on nuclei.

All this bulk of the inclusive data on charge exchange with excitation of Δ-isobar in nuclei was discussed in more detail in a number of reviews and survey talks (see refs.[9, 10, 11, 12, 13] and references therein for original papers). This makes it possible to summarize here only the main results following to ref.[9].

1. With increasing of projectile energy, the contribution of "quasielastic" charge exchange (CEX) to the $d\sigma/d\Omega(0°)$ decreases rapidly compared with the contribution from CEX with nuclear Δ excitations. At high energies the latter determines the magnitude of the $d\sigma/d\Omega(0°)$.

2. The nuclear Δ peak is shifted to lower energy transfers compared with the case of proton target and has almost 2 time larger width. This is observed for CEX at small p_t of all investigated baryon systems on nuclei. Therefore it is obvious that the origin of the shift and broadening of the nuclear Δ peak is to be sought in the response of the target nucleus on the appearance of Δ isobar in it and has little to do with some specific properties of projectiles.

3. The mechanism of quasifree production of the Δ in the nucleus with allowance for the Fermi motion effects cannot reproduce the main features of the cross sections and the ratio of yields of the $C(^3He,t)$ and $p(^3He,t)$ reactions.

4. The general dependence of the (p,n) and $(^3He,t)$ CEX on the atomic number of the target nucleus at the maximum of the Δ peak is determined first of all by absorption of the projectile/ejectile in the target nucleus and by ratio of numbers of protons and neutrons in the target. It is close to $A^{1/3}$ law; the cross sections integrated over

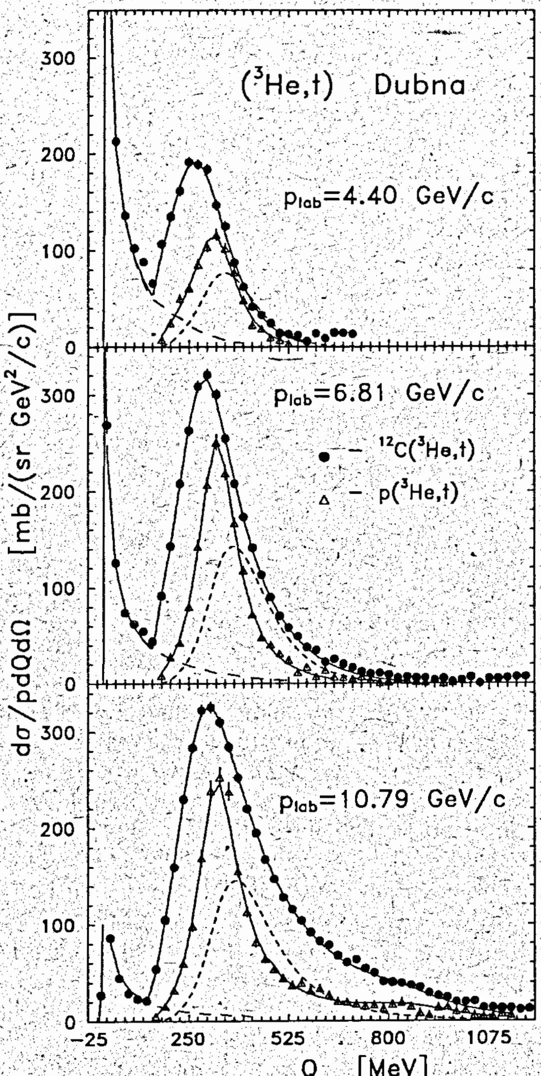

Fig.1 Invariant cross sections of the $(^3He,t)$ charge exchange on protons (triangles) and carbon (full circles) from ref.[1]. Solid lines: our approximation; long dashes: extrapolation of quasielastic peak at $Q < 150\,MeV$ to the Δ region; short dashes: estimated contribution from quasi-free Δ production.

the Δ-peak have slightly stronger A-dependence in agreement with predictions of ref.[14], where mesonless $\Delta N \to NN$ process has been taken into account.

5. The "genuine" shape of the nuclear Δ peak, not distorted by the projectile/ejectile transition formfactor, depends on the A: the larger A, the broader this peak. As it was pointed earlier (see refs.[12, 9] and references therein) this indicates (qualitatively) on the significant contribution from mesonless modes of the Δ decays and, possibly, of the ΔN charge exchange in the nuclear medium.

6. There are no fundamental differences in the mechanism of Δ excitation of the target nucleus between the (p,n) and $(^3He,t)$ CEX; quantitative differences are due to the formfactor of the $^3He \to t$ transition and due to different sizes of the projectiles.

7. The energy dependence of the cross sections reflects the energy dependence of the total cross sections of the corresponding "elementary" reactions.

8. The angular dependence of the cross sections integrated over the Δ peak is governed by the radii of the projectiles and by the p_t dependence of the corresponding "elementary" reactions.

Before discussion of new data obtained in exclusive-type experiments, it is necessary to disentangle those effects, which are related mostly with the properties of Δ in nuclear medium and with nuclear response on such excitation, and those, which are related mostly with particular projectile/ejectile features and kinematical conditions of the experiments. First of all it would be misleading to forget about the important role of the transition formfactor and choice of the optimal energy interval.

The role of chosen projectile energy is **twofold** (see for details and references the review[9]). *First*, it determines the probability of Δ excitation in the relevant "elementary" reaction, which is $pp \to pn\pi$ for baryonic charge exchange. It is known that the total cross section of this reaction reaches its maximum ($\sim$ 18 mbarn) at proton kinetic energies between 0.8 – 3 GeV; near the nominal $\Delta(1232)$ threshold ($\sim$ 0.647 GeV) it is about 3 times smaller (Fig. 2). The total cross section for two-pion production in the NN collisions reaches its maximum at kinetic energies above $\sim$ 1.6 GeV. This defines the optimal energy interval. *Second*, most experiments are performed in the so-called "fixed-angle" kinematic, where ejectile is detected at small fixed angle and cross sections (or multiple coincidence spectra) are measured in dependence on the energy transfer $Q = E_{proj} - E_{eject}$ as the primary kinematical variable. A characteristic feature of such kinematics is that variation of Q corresponds to simultaneous variation of the 4-momentum transfer squared (t) and the effective mass (ω) of the recoiling system (the excited target). This is illustrated by Fig. 3, in which any point belonging to any of the lines 1-4 in the (ω, t) plot corresponds to a certain value of Q in the $(^3He,t)$ reaction with triton emission at 0^o at kinetic energy of the projectile corresponding to this line. It can be seen that in the region $1100 < \omega < 1400$ the value of $\mid t \mid$ changes. This change is comparatively small at higher energies but rather big at low energies. If the formfactor of the projectile-to-ejectile transition is steep (as in the $(^3He,t)$ case) this results in a drastic energy-dependent distortion of the resonance line. The effect of such distortion is shown on Fig. 4, where data from refs.[1, 15] are divided on the $^3He \to t$ transition formfactor taken as $3exp(-27.74 \mid t \mid)$.

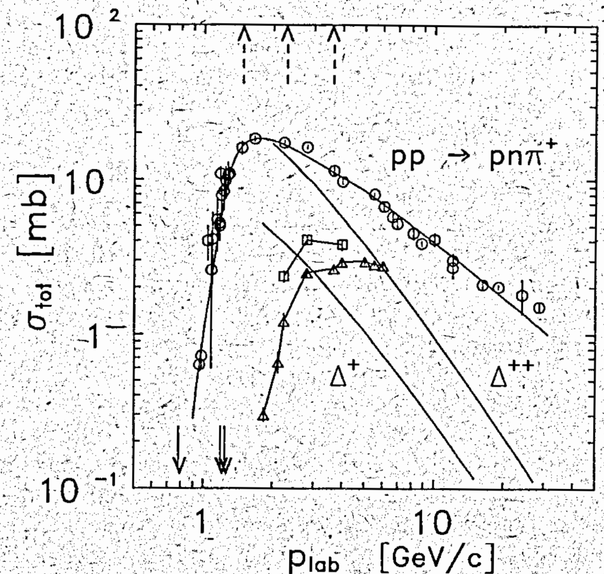

Fig.2 Behaviour of total cross sections of $pp \to pn\pi$ (circles), $pp \to pn\pi^+\pi^-$ (triangles) and $pp \to pn\pi^+\pi^0$ (squares) on the lab. incident momentum. Solid lines: approximations of the data for reactions $pp \to pn\pi$, $pp \to p\Delta^+$ and $pp \to n\Delta^{++}$. Lower arrows: thresholds of pion production (single) and Δ (double); upper arrows: momenta per nucleon in experiment[1].

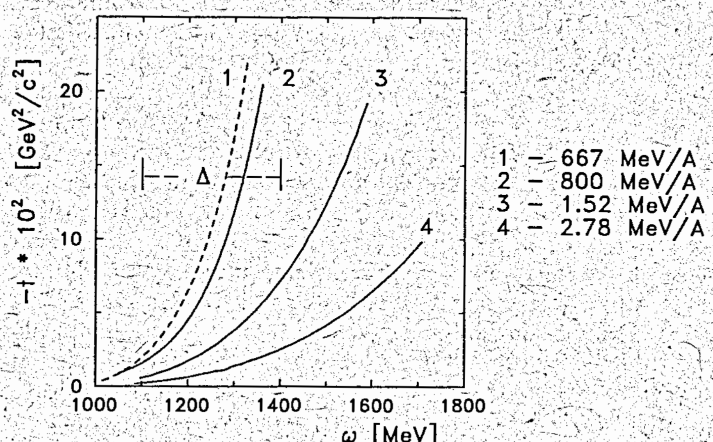

Fig.3 The dependence $t(Q)$ and $\omega(Q)$ in the (t,ω) plane at different incident energies; the region of Δ peak is indicated.

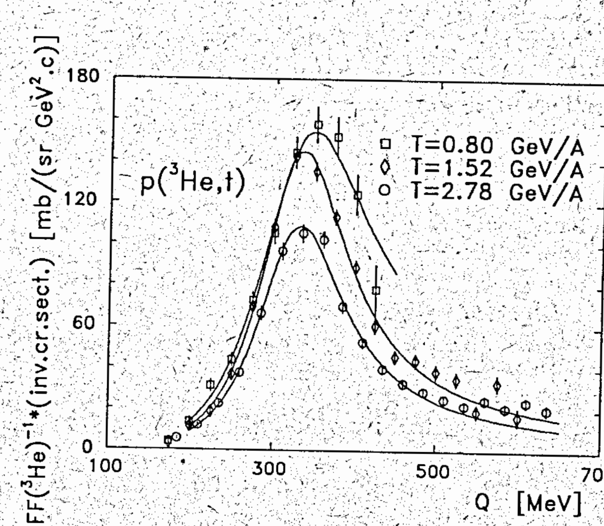

Fig.4a Invariant cross sections of the reaction $p({}^3He,t)$ after compensation of the ${}^3He$ formfactor. Lines: relativistic p-wave Breit-Wigner approximation.

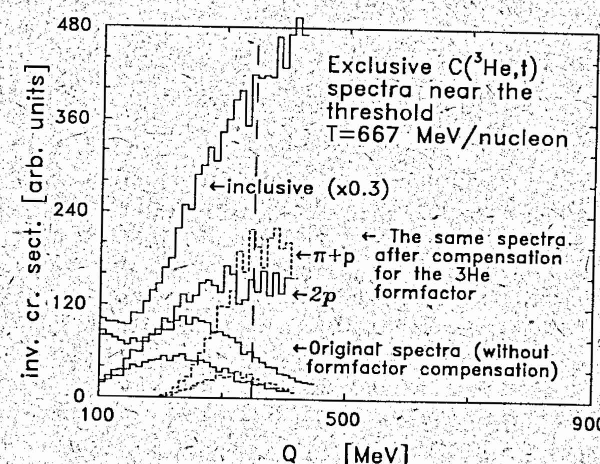

Fig.4b Data taken from ref.[15]; spectra are shown before and after the compensation for the ${}^3He$ formfactor.

One can try to compensate the energy dependence of the "elementary" cross section in order to compare CEX data obtained at different energies, as was suggested in our papers (see ref.[9] and references therein). To do this one can normalize the differential cross sections (obtained after compensation for the transition formfactor) on the total cross section of the relevant "elementary" reaction (σ_{tot}^{elem}) taken at the corresponding energy per nucleon. In this way one gets a dimensionless function, but for practical purposes it is more convenient to restore the absolute units multiplying this function on the σ_{tot}^{elem} at some "basic" energy (which was set at 800 MeV in papers cited in ref.[9]). The resulting cross sections were called *reduced invariant cross sections.* They show an approximate scaling (within the normalization accuracy) on the sort of the projectile and its energy, as one can see from Fig. 5. That means, that energy dependence of the CEX cross sections with Δ excitations follows the energy dependence of the σ_{tot}^{elem}. Deviations from this scaling are related in part with absorption corrections for nucleon or Δ in projectile. Further we will systematically use the reduced invariant cross sections σ_{red} during discussion of the "exclusive" data.

The **exclusive-type experiments** with Δ excitations of $A > 2$ nuclei were performed at KEK[16, 17], Dubna[18] and Saclay[15, 19]; they were discussed in part in refs.[9, 20]. The GIBS and DIOGEN groups are continuing their studies; new results are reported at "M & N '94" Conference (see talks[18, 19]).

An important observation was made in the experiment on quasifree Δ^0 production on nuclei in (p, p') reaction at KEK[16]. In this experiment inelastically scattered hard protons were detected at 0° in coincidences with soft protons and pions coming from the target. Spectra of hard protons were separated into different groups according to the numbers of pions and soft protons. We will discuss the sample with one pion and one soft proton ($1\pi 1p$ topology) with the effective mass of the πp pair between 1.1 and 1.4 GeV (Δ region). The detection of the $\pi^- p$ pair with $1.1 < M_{eff} < 1.4$ GeV in coincidence with hard scattered proton is the signature of quasifree Δ^0 production. What was an unexpected observation[16], was the big amount of $\pi^+ p$ pairs with M_{eff} in the Δ region, detected in coincidence with p'. Events of this class are absent in data taken with proton and deuteron targets; their relative contribution seems to be increasing with the atomic number of the target. It was pointed in refs.[9, 20] that these pairs give a strong indication on a two-step process with ΔN charge-exchange in nuclei: the corresponding reactions are $p +$"p"$\rightarrow p' + \Delta^+$ followed by $\Delta^+ +$"p"$\rightarrow \Delta^{++} +$"$n$" with subsequent decay $\Delta^{++} \rightarrow p + \pi^+$; here "$N$" denotes the bound quasifree nucleon. As was mentioned, first indirect indication on the "charge-exchange" modes for Δ decay in nuclei were obtained in $A(p, n)$ charge exchange[12], but these modes were theoretically not analysed yet.

The "exclusive" $(^3He, t)$, (p, n) and $(t, ^3He)$ experiments confirmed the main conclusions drawn from the inclusive data. They provide also a separation of different contributions to the total inclusive Δ peak. Here we will discuss briefly 3 of the most investigated channels of the $(^3He, t)$, (p, n) reactions: (i) the "quasifree-like" class $1\pi 1p$, (ii) non-quasifree $0\pi 2p$ (mesonless) class which could be related with processes of absorption of both virtual and real pions, and (iii) non-quasifree $1\pi 0p$ class containing contribution from coherent pion production. The forward emitted

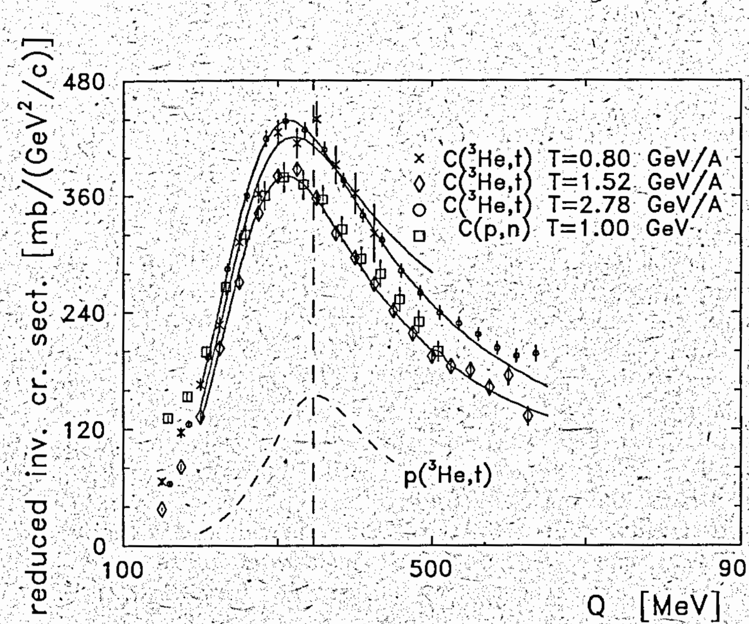

Fig.5 Reduced invariant cross sections of the $C(^3He, t)$ and $C(p, n)$ reactions. Solid lines: relativistic p-wave Breit-Wigner approximation; short dashed line: the similar approximation of the reduced $p(^3He, t)$ invariant cross sections.

tritons or neutrons (the ejectiles) were detected in coincidences with particles which define the listed topologies.

Spectra of ejectiles taken for the quasi-free topology have the same shape in reactions $A(p,n)$, $A(p,p')$ and $A(^3He,t)$ when they are plotted versus transferred energy Q and distortion due to the transition $^3He \rightarrow t$ formfactor is removed (Fig. 6). They have maximum which is shifted **upward** on the Q-axis, as was expected[20]. Comparing with the inclusive Q-spectrum, one can see that quasi-free channel of charge exchange with Δ-excitation in nuclei contibute not more than 50% to the inclusive cross section (or, probably, even less[18]); i.e. it is not the dominant channel.

Ejectile Q-spectra for the non-quasifree $0\pi 2p$ channel of $A(p,n)$ and $A(^3He,t)$ charge-exchange with nuclear Δ-excitations have the same shape also (Fig. 6), when the transition formfactor is taken into account as described above; maxima of these spectra are strongly shifted **downward** on the Q-axis; these spectra are much broader than in the quasi-free case. An important role of this "mesonless" channel has been discussed above; it contributes to the downshift of the inclusive nuclear Δ peak and could be related with processes of absorption of both virtual and real pions. In the latter case a 2-step process must be considered together with others: on the 1-st step the real pion is created after decay of Δ excited on a bound nucleon (this corresponds to the $1\pi 1p$ topology) and on the 2-nd step this pion is absorbed in the target nucleus with emission of one or two nucleons. Dependence of the ejectile spectra for the $0\pi 2p$ channel on the target atomic number, studied at Saclay (see ref.[19]), gives evidences in favour of such picture and must help in understanding the A-dependence of the shape of the Δ-peak observed for inclusive $A(p,n)$ reaction[6, 9].

The Q-spectra of ejectiles in the $1\pi 0p$ channel also have maxima shifted to lower Q (Fig. 6); this channel must have strong contribution from the coherent pion production mechanism[21]. The first experimental evidences for this mechanism have been obtained at Saclay with DIOGEN[22] in the $(^3He,t)$ reaction and in Dubna with GIBS[18] in the $(t,^3He)$ reaction.

We see that the exclusive-type experiments give direct information about significant role of the non-quasifree channels in charge-exchange on nuclei with excitation of Δ-isobars. Some new observations were made (for example, the A-dependence of the peak maximum in the $0\pi 2p$ channel). It is interesting that even for the channel with quasi-free topology not all details are clear: too many hard pions[18] were found. This might be a new signal about excitation of resonances others than Δ. For example, one could put a question about coherent pion production with the virtual $N(1440)$ resonance in an intermediate state. All this needs further investigations.

3. Coherent π production: new possibilities

There exist many theoretical papers devoted to the coherent pion production mechanism, which contributes to the $1\pi 0p$ channel of charge exchange with nuclear Δ-excitations[21, 23]. The most theoretically clear process with coherent pion production is $p(\alpha,\alpha')p\pi$ reaction. At low transferred energy Q the main mechanism for pion production is excitation of virtual Δ in the α-particle with subsequent decay of Δ,

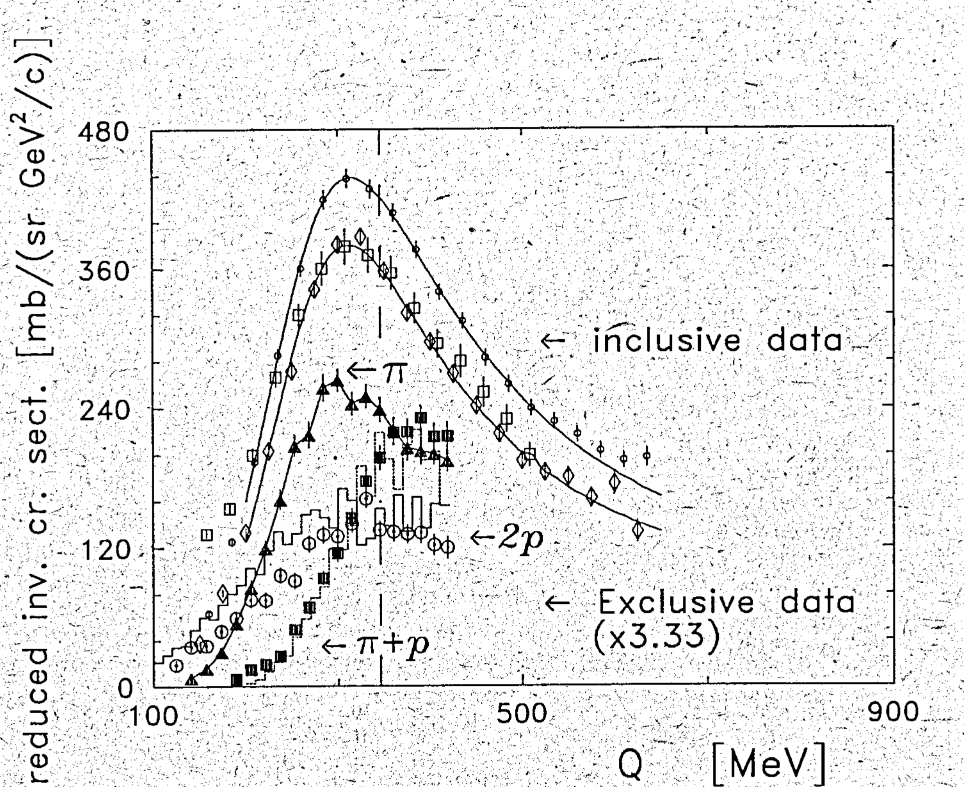

Fig.6 Data of "exclusive" experiments discussed in this talk. The inclusive data from Fig.5 are shown for comparison. The cross sections of the (p,n) reaction at $T = 800\,MeV$ (measured in exp.[17] in absolute units) are multiplied by a factor of 3.33 for better clarity (open circles, full triangles and full squares). Histograms: the same data from ref.[15] as shown in Fig.4b; here and in Fig.4b they are normalized by the $(\pi + p)$ cross sections from KEK[17] and this normalization factor was also used for the $2p$ spectra of ref.[15].

when pion is emitted and nucleon remains bound in the α-particle. Such mechanism was called "excitation of Δ in projectile (DEP)"[21]. Excitation of Δ in the proton target (DET) is forbidded for the $p(\alpha,\alpha')$ reaction by spin and isospin conservation.

It was noted, during investigations of $(^3He,t)$ charge exchange, that the DEP-mechanism is strongly energy dependent: while its contribution to the inclusive invariant $(^3He,t)$ cross sections is more-or-less significant at low (subthreshold) energies of projectiles, it becomes negligible in comparison with DET-mechanism at energies about 1 GeV and higher (see ref.[9, 23] and references therein). Still, the DEP mechanism is relatively less important than the DET one in the $(^3He,t)$ reaction. The reversed situation exists in the case of $(^3He,^3He')$ reaction, as was shown recently[23].

Therefore playing with quantum numbers and initial energies by studying $p(\alpha,\alpha')$, $p(^3He,^3He')$ and $p(^3He,t)$ reactions, one gets an opportunity to separate contributions of the different partial mechanisms. Such information is especially valuable for the present theory of meson-nucleon and nucleon-nucleon interactions, where a number of uncertainties exist sofar[9].

On the other hand, at sufficiently high transferred energies Q and at projectile energies far from the Δ-production threshold, processes with excitation of next nucleonic resonances can take place. A contribution from heavier resonances from Δ-family has been reported for the $(^3He,t)$ charge exchange (see references in review[9]). Excitation of the $N(1440)$ resonance was reported in the $p(\alpha,\alpha')$ reaction[24] (but this experiment was done at energies close to the $NN \to N^*N$ threshold and the α-particle formfactor strongly changes the resonance line in a way similar to the $(^3He,t)$ case discussed before). Therefore other nucleonic resonances can also contribute to the coherent pion production at moderate and high Q if the initial energy is chosen properly. This interesting possibility has to be investigated both theoretically and experimentally (see talk[18]).

The excitation of N^* is of a special importance in this context because of several reasons. First, the Roper $N^*(1440)$ resonance has the same quantum numbers as the nucleon and the relative importance of mechanisms with N^* excitation in the projectile and in the target will be different from the Δ case. Second, this resonance has rather big $N\pi$ decay branching ratio and, being as wide as Δ, it partially overlaps with the Δ-resonance. Therefore some interference effects from processes with Δ and $N^*(1440)$ excitations should take place.

Very interesting reaction for such studies is the (d,d') inelastic scattering. *First*, the DET mechanism of coherent pion production at low Q is forbidded here because of isospin conservation as in the (α,α') case; in this sense these reactions are similar, but the deuteron is obviously much simple object for theoretical analysis. Excitation of Roper $N^*(1440)$ resonance in the (d,d') reaction, as it was done in the (α,α') case, was not investigated yet. *Second*, the incident deuterons can be polarized and polarization observables can be studied in the inelastic (d,d') scattering with Δ and Roper $N^*(1440)$ excitations. Such information must be very useful for understanding of the resonance excitation mechanisms and behaviour of these resonances in nuclear medium. The (d,d') reaction with polarized deuterons can be also used for investigations of nuclear response on high energy spin-isoscalar excitations; for low energy spin-isoscalar excitations it has been done recently[25].

4. Polarization studies of Δ and Roper resonance region in (d,d') reactions

Polarization observables in processes with Δ excitation at intermediate energies are not thoroughly investigated even for elementary $NN \to N\Delta$ reactions[26, 27]. For nuclear Δ excitations only data from Saclay $(d,2p)$ experiment[5] exist, whose interpretation is rather difficult because of the poorly known $d \to 2p$ transition formfactor. On other hand, it was theoretically demonstrated, that the Q-dependence of the polarization observables could be sensitive to nuclear medium effects when Δ is excited in nuclei[27]. The spin-density matrix of Δ-isobar is also sensitive to Δ-hole states, as was shown in ref.[28]. Therefore it is necessary to analyse data from the exclusive-type experiments discussed before, in order to get experimental information about polarization of Δ in nuclear medium. Polarized projectiles (deuterons, protons, ^3He) would provide a possibility to change polarization state of Δ and to study it's different decay modes in the nuclear medium.

Experiments in this direction are in progress at Dubna synchrophasotron, where tensor analysing power (T_{20}) is being measured for $p(d,d')$ and $C(d,d')$ reactions. The tensorially polarized deuterons, inelastically scattered from different targets, are detected at 0°; the region of transferred energy Q is scanned from the pion production threshold through Δ and Roper $N^*(1440)$ regions up to $Q \sim 0.8$ GeV at kinetic energies about 2 GeV/nucleon. The region of possible interference between Δ and Roper $N^*(1440)$ is being measured also. Data on $p(d,d')$ and $C(d,d')$ reactions will be compared in order to look for a possible nuclear medium effects, as was done in the first $(^3He,t)$ experiments[1]. The polarization signal has been reported; the experiment is in progress. It should be stressed, that this experiment is being performed at energies which are optimal for studies of Δ and $N^*(1440)$ resonances: the total cross sections of corresponding "elementary" reactions are close to their maximal values.

5. Conclusions

- New data from "exclusive"-type charge-exchange experiments agree well with each other and confirm the main conclusions drawn from the previous inclusive experiments on Δ excitation in nuclei.
- Quasifree Δ-production in charge exchange on nuclei is not the dominant channel of this reaction.
- Some channels of the charge exchange reaction with Δ excitation in nuclei could be considered in terms of scattering and absorption of virtual or real pions in nuclear medium.
- The "exclusive"-type experiments gave qualitative new observations which must be explained by theory (the A-dependence of the ejectile spectrum for $0\pi 2p$

channel, the excess of hard pions in the quasi-free-like channel, the Δ-like πN pairs with "wrong" total charge).

- Experiments at various energies with different projectiles, including measurements of polarization observables, must help in separation of partial contributions to the Δ and $N^*(1440)$ excitations in nuclei. Possible interference effects should be taken into account in theoretical analysis of these data.
- The charge exchange reactions with excitation of Δ (and other broad nucleonic resonances) in nuclei cannot be treated separately from π-absorption, photo- and electro-excitation of these resonances in nuclei. They should be investigated in a coherent way. Significant correlations between all these processes must exist and some of them are found.

6. Acknowledgments

We a grateful to our colleagues from ALPHA – collaboration (JINR) with whom the discussed experimental results on $(^3He, t)$ charge-exchange were obtained. Most of theoretical results, we referred to, were obtained together with Yu.L.Ratis from Samara Air-Space University and his team; we enjoined with this fruitfull collaboration. We are grateful to E.Oset, M.Ericson, P.Fernandez de Cordoba and members of GIBS collaboration for many interesting and fruitful discussions of problems related with the topics discussed in this talk.

The work on preparation of this review talk was supported in part by grant N^o RFU000 from the International Science Foundation.

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Received by Publishing Department
on June 23, 1994.