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F.A.Gareev, Yu.L.Ratis, P.P.Korovin,
E.A.Strokovsky, J.S.Vaagen [1]

INTERFERENCE EFFECTS IN INCLUSIVE CHARGE-EXCHANGE $p + p \to n + X$ AND $n + p \to p + X$ REACTIONS AT INTERMEDIATE ENERGIES

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[1]Institute of Physics, University of Bergen, Norway

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Гареев Ф.А. и др. E2-92-7

Интерференционные эффекты в инклюзивных зарядово-обменных реакциях $p + p \to n + X$ и $n + p \to p + X$ при промежуточных энергиях

Мы используем формализм диаграмм Фейнмана для описания зарядово-обменных реакций $p + p \to n + X$ и $n + p \to p + X$ на протонной мишени с учетом спектаторных и распадных мод в $\pi + \rho + g'$-модели. Показано, что характер интерференции между этими модами зависит от используемых параметров вершинных функций. Также показано, что конструктивная интерференция между Δ^{+} и Δ^{0}-изобарами важна.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

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Interference Effects in Inclusive Charge-Exchange $p + p \to n + X$ and $n + p \to p + X$ Reactions at Intermediate Energies

We have used the formalism of Feynman diagrams to describe charge-exchange reactions $p + p \to n + X$ and $n + p \to p + X$ on a free proton target taking into account spectator and decay modes in the $\pi + \rho + g'$-model. We show that the interference between these modes depends on the set of vertex function parameters used. It is also shown that the constructive interference of the Δ^{+} and Δ^{0}-isobars is important.

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

1 Introduction

Comparison of different charge-exchange reactions (such as $p+p \to n+X$ and $n+p \to p+X$) at intermediate energies is relevant for a number of reasons. First, such reactions give the possibility to obtain information with high degree of reliability on relative contributions of the various isospin components of the nuclear forces. Second, they allow for study the different interactions in the final states and also to test manifestation of dibaryon resonances [1].

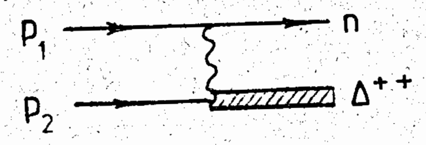
Finally, as it will be shown below, on the basis of these reactions it is possible to determine the limits of applicability of transition potentials and of the effective number formalism at intermediate energies.

The main conclusions of this work are obtained studying the energy and angular dependence of the ratio of the cross sections for charge-exchange reactions $p+p \to n+X$ and $n+p \to p+X$ in the Δ-isobar excitation region.

2 Approximations of currently used transition potentials

In most current publications (except [2]-[4]), for example [5]-[15], on inclusive charge-exchange reactions with Δ- isobar excitation, the meson exchange models (OPE-model, $\pi+\rho$+g'-model,...) is used in combination with a transition potential approximation. From the diagram technique

point of view this approximation corresponds to the direct and exchange diagrams depicted below,



and is described by the $NN \to N\Delta$ transition potential [5] in momentum representation:

$$V_{\sigma\tau}(\omega,q) = [V_L(\omega,q)(\vec{S}\bullet\hat{q})(\vec{\sigma}\bullet\hat{q}) + V_T(\omega,q)(\vec{S}\times\hat{q})(\vec{\sigma}\times\hat{q})](\vec{T}\bullet\vec{\tau}), \quad (1)$$

where $\omega(\vec{q})$ is the transferred energy (momentum), $\hat{q}=\vec{q}/q$ and $V_L(\omega,q)$ $(V_T(\omega,q))$ is the functional form of the longitudinal (transverse) component. The potential V_L (V_T) depends on the concrete model. With definitions from [5] the operators $\vec{T}$ and $\vec{S}$ have matrix elements

$$<\frac{3}{2}\tau_\Delta \mid T_\mu \mid \frac{1}{2}\tau_N> = (\frac{1}{2}1\tau_N\mu \mid \frac{3}{2}\tau_\Delta), \quad (2)$$

$$<\frac{3}{2}m_\Delta \mid S_\mu \mid \frac{1}{2}m_N> = (\frac{1}{2}1m_N\mu \mid \frac{3}{2}m_\Delta). \quad (3)$$

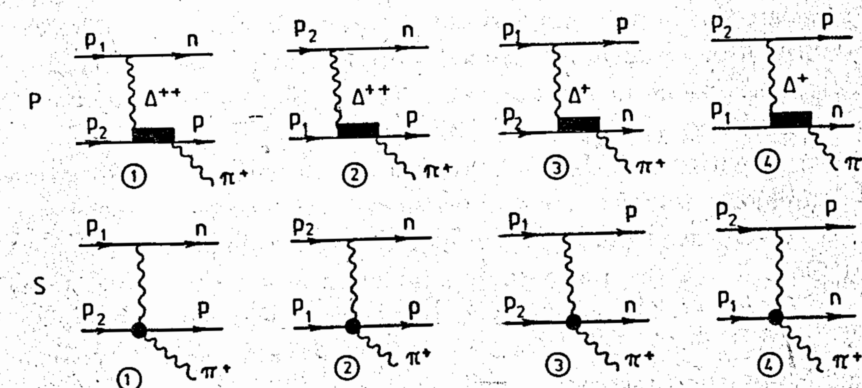


Fig.1 Upper diagrams: P means p-wave resonance πN scattering. Lower diagrams: S means s-wave potential πN scattering.

Thus the isospin matrix elements are equal to the Clebsch-Gordon coefficients $(\frac{1}{2}1\frac{1}{2}1 \mid \frac{3}{2}\frac{3}{2}) = 1$ and $(\frac{1}{2}1 - \frac{1}{2}1 \mid \frac{3}{2}\frac{1}{2}) = 1/\sqrt{3}$ for the reactions $p+p \to n+X$ and $n+p \to p+X$ respectively. Consequently the simplest consideration gives

$$R = \frac{\frac{d^2\sigma}{d\Omega_n dE_n}(p+p \to n+X)}{\frac{d^2\sigma}{d\Omega_p dE_p}(n+p \to p+X)} = 3. \qquad (4)$$

The ratio (4) obtained for charge-exchange reactions on a free protons is widely used for analysis of analogous inclusive processes on nuclei [2, 5, 7, 11]. In most cases the inclusive cross section of the charge-exchange on nuclei is proportional to the cross section of the corresponding process on a free proton multiplied by the effective number of nucleons participating in the reaction. For example in the impuls approximation and neglecting effects of Fermi motion and Pauli blocking in the target nuclei, the cross section of the charge-exchange reactions on nuclei is given [2] by:

$$\frac{d\sigma[A(p,n)_\Delta B]}{d\Omega_n} \approx (Z + \frac{N}{< R >}) < f^2 > \frac{d\sigma[p+p \to n+\Delta^{++}]}{d\Omega_n}, \qquad (5)$$

where $< R >$ is the integrated value taken as $< R >= 3$, while $< f^2 >$ is the effective absorption factor which can be calculated in the Glauber model or some analogous model taking into account the distortion and absorption effects in the entrance and exit channels. Similar approximations have been used by many authors [5, 7, 11, 12].

The use of the impuls approximation, and therefore also effective number formalism, is formally argued from the fact, that the binding energy of the nucleons in the target nuclei is negligible compared with the projectile energy ($T_p \sim 1$ GeV) [15].

However experimental data tell us that the potential approximation cannot completely describe essential features of the charge-exchange processes. As one can see from Fig.2, the experimental value of ratio $R(P,\theta)$ at T_p=1 GeV, $\theta = 0°$ is considerably smaller than the theoretical value R_{theor}=3. Moreover, the suppression of value R near the upper kinematical limit is practically an order. This observation is qualitatively explained [1] by the constructive interference of the Δ^+ and Δ^0-isobars in the reaction $n+p \to p+X$ and the destructive interference of the Δ^{++} and Δ^+-isobars in the process $p+p \to n+X$. Detailed calculations

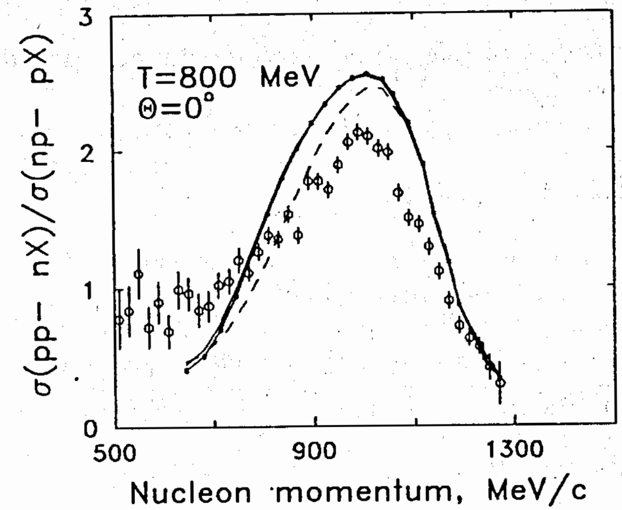


Fig.2a The calculated ratio R(P,Θ) compared with the experimental data taken from ref./1/.

—— JAIN
-•-•- OSET
- - - DMIT

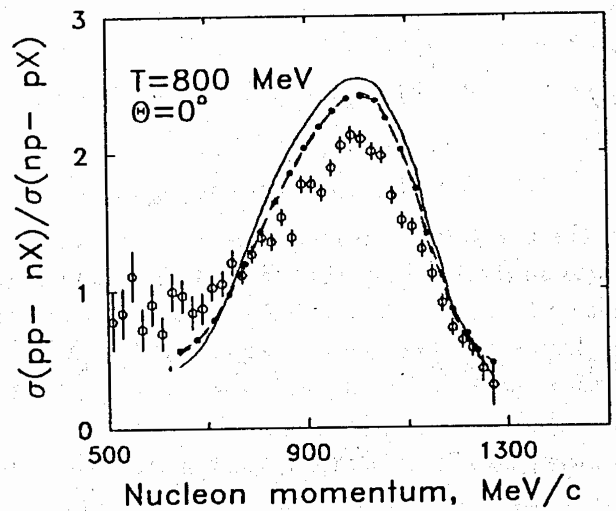


Fig.2b The calculated ratio R(P,Θ) compared with the experimental data taken from ref./1/.

—— Only Δ; Jain's set
- - - S−wave contrib. is included
-•-•- The same after folding with resolution function of exp./1/

explaining whole picture of this effect were however not carried out in [1], but are described below.

3 Formalism

The cross section of the reaction $p + p \to n + X$ can (in the notation Bjorken and Drell $\hbar$=c=1) be written as

$$d\sigma = \frac{2m^2}{\lambda^{1/2}(s, m^2, m^2)} \frac{m}{E_n} \frac{d\vec{P}_n}{(2\pi)^3} \frac{m}{E_p} \frac{d\vec{P}_p}{(2\pi)^3} \frac{d\vec{P}_\pi}{2E_\pi(2\pi)^3}$$

$$(2\pi)^4\delta(P_1 + P_2 - P_n - P_p - P_\pi)S_f <| M |^2>, \tag{6}$$

where indices p, n and π refer to the proton, neutron and pion, respectively, S_f is the statistical factor, s the square of the invariant mass of the system p+p and P_i the four-momenta.

In the Feynman diagram technique the invariant amplitudes can be represented by the graphs (see Fig.1). Each graph has a corresponding matrix element (we follow to the convention of [16])

$$M_j(p) = (-)^{j+1} ISF_j G_\Delta(S_\Delta) \frac{f_{\pi N\Delta}}{m_\pi} (\vec{S}^+ \circ \vec{P}_\pi)$$

$$[V_C(q_j)(\vec{S} \circ \vec{\sigma}) + V_{NC}(q_j) S_{12}(\hat{q}_j)], \tag{7}$$

where j=1,2,3,4 is the graph label, p means p-wave resonance πN scattering, ISF is the isospin factor [3], q_j the momentum of a virtual pion (ρ meson) in the Breit system ($q_j^0 = 0$, $t_j = -\vec{q}_j^{\,2}$), P_π the momentum of real pion in the rest Δ frame and G_Δ the propagator of the Δ-isobar. The renormalized transition potential is, in the notations of [3, 5], given by

$$V_L(q) = \frac{f_{\pi NN}}{m_\pi} \frac{f_{\pi N\Delta}}{m_\pi} F_\pi^2(q) q^2 G_\pi(q), \tag{8}$$

$$V_T(q) = C_\rho \frac{f_{\pi NN}}{m_\pi} \frac{f_{\pi N\Delta}}{m_\pi} F_\rho^2(q) q^2 G_\rho(q), \tag{9}$$

$$V_C(q) = \frac{1}{3}[V_L(q) + 2V_T(q)] + g'_{N\Delta} \frac{f_{\pi NN}}{m_\pi} \frac{f_{\pi N\Delta}}{m_\pi} F_\pi^2(q), \tag{10}$$

$$V_{NC}(q) = \frac{1}{3}[V_L(q) - V_T(q)]. \tag{11}$$

Here G_π and G_ρ are the standard meson propagators [16] while the form-factors are given by

$$F_B(t) = \frac{\Lambda_B^2 - m_B^2}{\Lambda_B^2 - t}, \tag{12}$$

where B=π, ρ and $t = -\vec{q}^{\,2}$ in the Breit frame.

The graphs in Fig.1b containing "bullets" (s-wave potential πN scattering) correspond to the matrix elements

$$M_j(s) = (-1)^{j+1} \frac{f_{\pi NN}}{m_\pi} \sqrt{4\pi} q_j \sum_\lambda (-1)^\lambda Y_{1\lambda}(\hat{q}_j) (\frac{1}{2} 1 m_i(1,j) \mid \frac{1}{2} m_f(1,j)))$$

$$G_\pi(q_j) \frac{8\pi}{m_\pi} \delta_{m_i(2,j), m_f(2,j)} K_{sw}^{\pi N}, \tag{13}$$

where

$$m_i(1,1) = m_1, m_i(2,1) = m_2, m_f(1,1) = m_n, m_f(2,1) = m_p,$$

$$m_i(1,3) = m_1, m_i(2,3) = m_2, m_f(1,3) = m_p, m_f(2,3) = m_n,$$

$$m_i(1,2) = m_2, m_i(2,2) = m_1, m_f(1,2) = m_n, m_f(2,2) = m_p,$$

$$m_i(1,4) = m_2, m_i(2,3) = m_1, m_f(1,4) = m_p, m_f(2,4) = m_n. \tag{14}$$

Here the coefficients $K_{sw}^{\pi N}$ are given as

$$K_{sw}^{\pi N} = (-1)^{\tau_v} \sqrt{3} (\frac{1}{2} 1 \tau_i(1) - \tau_v \mid \frac{1}{2} \tau_f(1)) [\lambda_1 \delta_{\tau_v, \tau_r} \delta_{\tau_i(2), \tau_f(2)} +$$

$$\lambda_2 (-1)^\nu \sqrt{6} (11 \tau_v \nu \mid 1 \tau_r) (\frac{1}{2} 1 \tau_i(2) - \nu \mid \frac{1}{2} \tau_f(2))], \tag{15}$$

where $\tau_v(\tau_r)$ means the isospin projection, the index v(r) corresponds to a virtual (real) pion, i(f) to initial (final) nucleon, numbers (1) and (2) in the parenthesis- to the lower and upper lines in the diagrams respectively. The parameters λ_1 and λ_2 are taken from [3]. The detailed description of the correspondence rules between the elements of the diagrams and the analytic expressions is given in [16, 17].

The diagrams included in our calculations dominate in the energy region $0.8 \leq T_p \leq 1.5$ GeV when the neutrons are registered in the angular

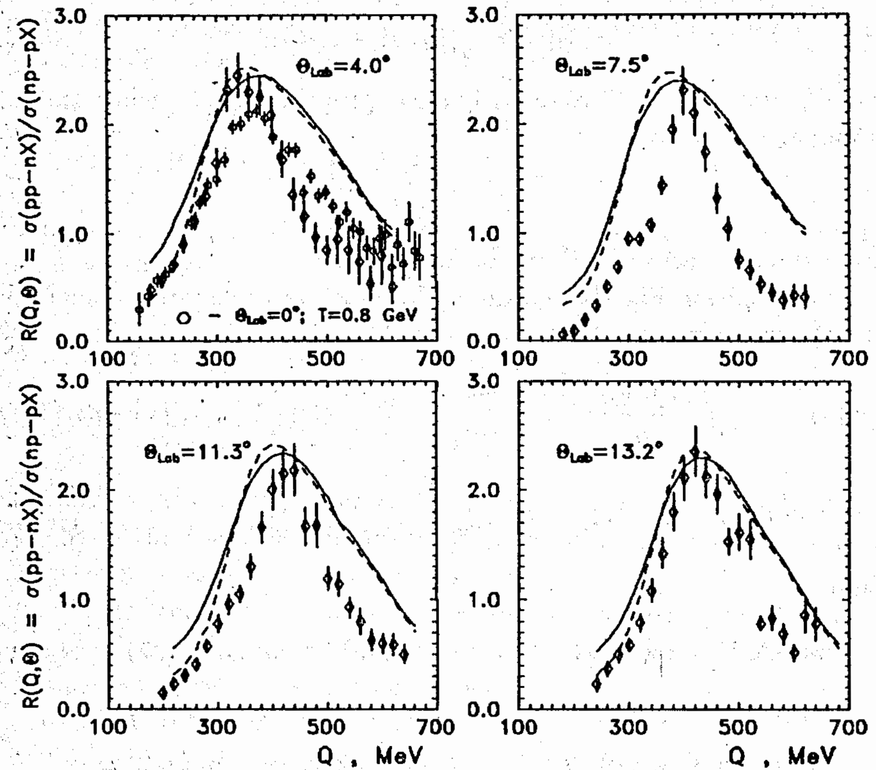


Fig.3 Ratio $R(Q,\theta_{Lab})$ calculated with the Jain's parameter set. Lines: dashed – only Δ, full – the same folded with resolution function of exp./21/. Data points are extracted from the p(p,n) and d(p,n) data /21/ at T_p=1 GeV.

interval corresponding to the first diffraction peak and the momentum spectra are investigated around the Δ-isobar peak.

It is necessary to stress that the technique used is based not on perturbation theory in the interaction representation but on the decomposition of the total amplitude over the renormalized diagrams. It means that the effects of renormalization, polarization of the vacuum, contributions of the another mesons and resonances and of-shell effects ..., are included in the formfactors F_B. Such a treatment can be argued by reference to potential models at low energy scattering.

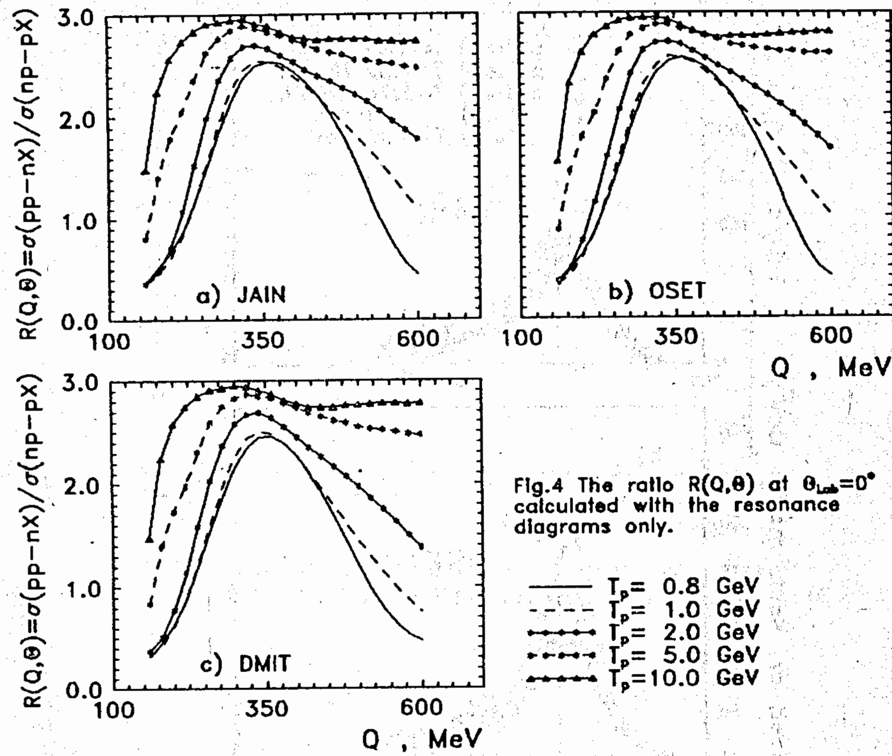


Fig.4 The ratio $R(Q,\theta)$ at $\theta_{Lab}=0°$ calculated with the resonance diagrams only.

4 Results

We investigate the effects of interference Δ^{++}- and Δ^{+}- isobars (Δ^{+}- and Δ^{0}) in the energy region $0.8 \leq T_p \leq 10$ GeV. The calculations of the cross sections were performed for three very different sets of the vertex function parameters: OSET (Λ_π=1.3 GeV, Λ_ρ=1.4 GeV, C_ρ=3.95, $g'_{N\Delta}$=0.6 [3]); JAIN (Λ_π=1.2 GeV, Λ_ρ=2.0 GeV, C_ρ=2.0, $g'_{N\Delta}$=0.3 [5]); DMIT (Λ_π=0.65 GeV, Λ_ρ=0.0 GeV, C_ρ=0.0, $g'_{N\Delta}$=0.9 [18]). The coupling constants are standard and equal to $f^2_{\pi NN}/4\pi$=0.081 and $f^2_{\pi N\Delta}/4\pi$=0.36.

Let us start with a discussion of the results for the ratio $R(Q,\theta)$. From the comparison in Figs.2a with data at T=0.8 GeV and $\theta = 0°$ and the theory curves, one can see that all three parameter sets give

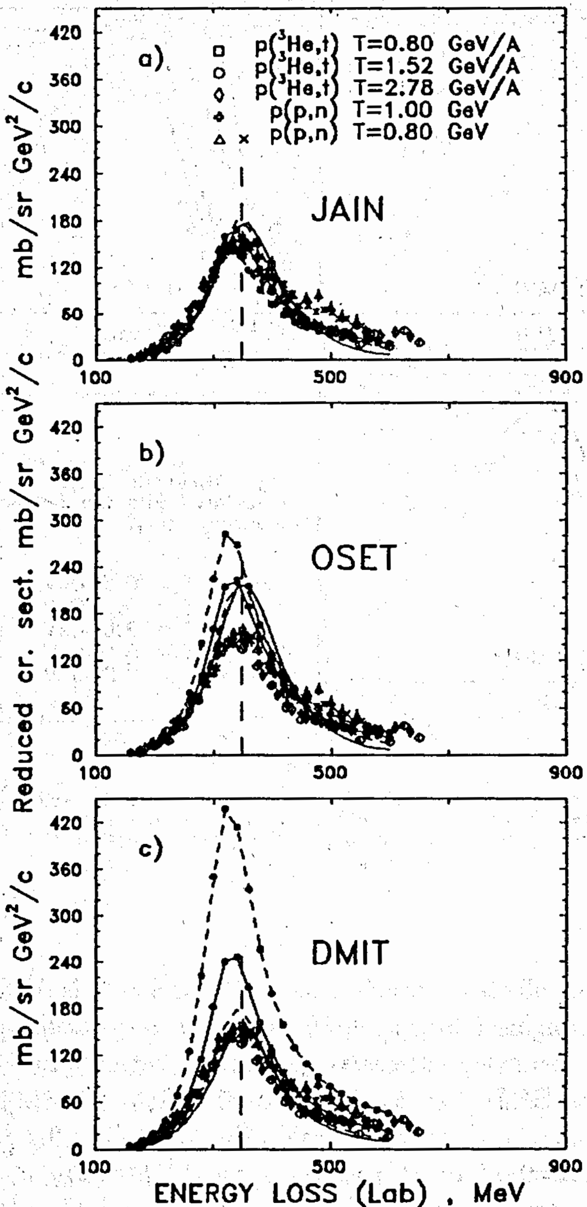


Fig.5 Reduced invariant cross sections for the p(^{3}He,t) and p(p,n) reactions at 0°. Data are taken from compilation /2/. The lines represent our calculations with parameters from /3,5,18/. Full – T=0.8; dashed – T=1.0; full with dots – T=1.52 and dashed with dots – T=2.78 GeV/A

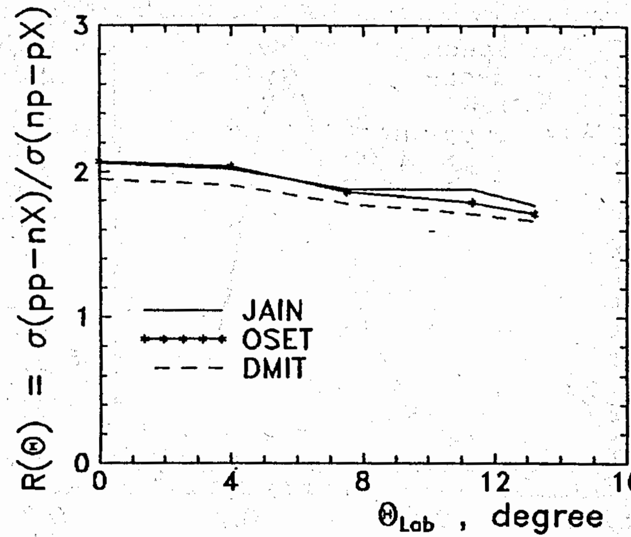


Fig.6 Angular dependence of the averaged $R(\Theta) = \sigma(pp-nX)/\sigma(np-pX)$ at T=1 GeV

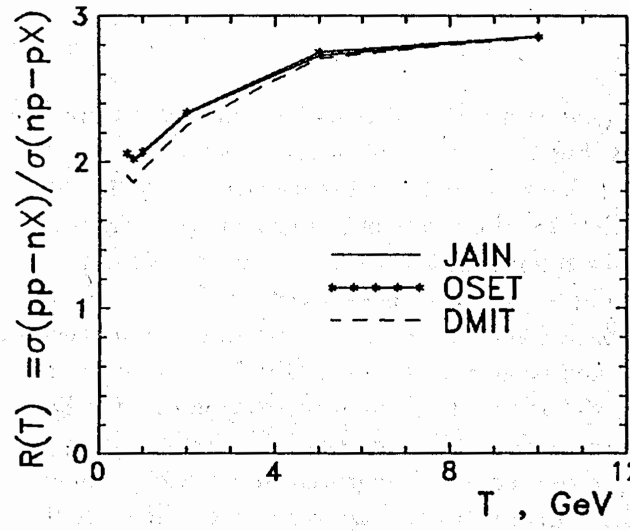


Fig.7 Energy dependence of the averaged $R(T) = \sigma(pp-nX)/\sigma(np-pX)$ at $\Theta=0°$

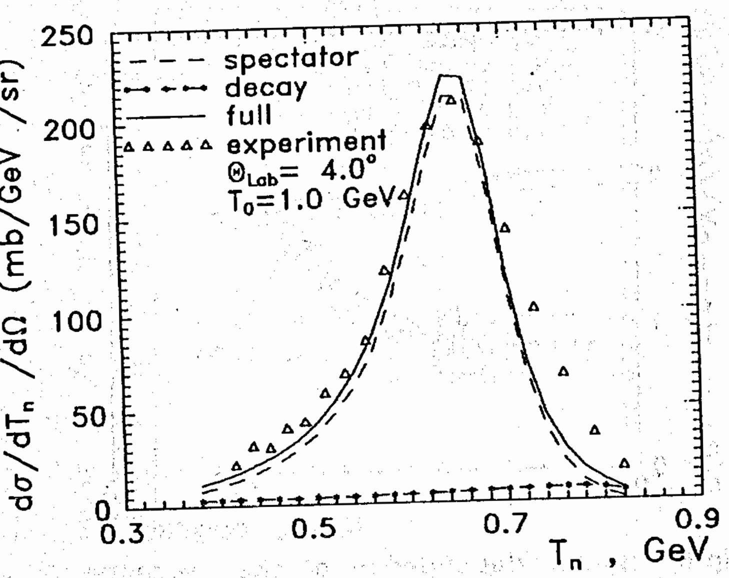


Fig.8 Partial cross sections for p+p– n+X for the Jain's parameter set compared with data /21/

similar angular (see also [2]) and ,what is especially important, energy dependence (see Fig.4) in spite of the fact that the $p+p \rightarrow n+X$ and $n+p \rightarrow p+X$ cross sections themselves are quite different in the region $T_p >1.5$ GeV for these sets of parameters (see Fig.5). The angular dependence of the integral ratio $< R >$ changes only little from one set to another (see Fig.6, the differences are $\leq 10\%$).

The interference between the Δ^{+}- and Δ^{0}-isobars becomes weaker with increasing energy and $< R > \rightarrow 3$ (Fig.7). The value of $< R >$ lies in the interval $2 \leq < R > \leq 3$ for the whole region of investigated energies which helps to understand the success of estimations of type (4) for the charge-exchange cross sections integrated over a wide momentum spectra while the momentum spectra themselves can be different due to the interference effects. The mechanism of this phenomenon is seen from Fig.9. It is evident that the interference Δ^{++}- and Δ^{+}-isobars give negligible

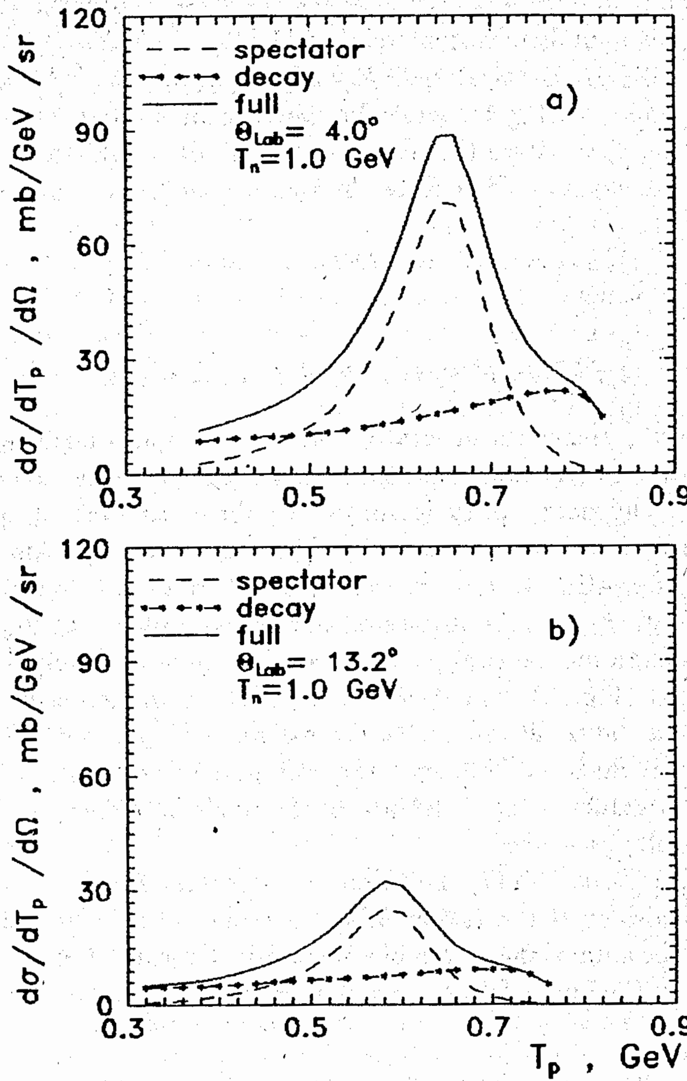


Fig.9 Partial cross sections for n+p– p+X for the Jain's parameter set.

(see Fig.8) contribution to the process $p+p \to n+X$ because the decay amplitudes have smaller isospin weights ($ISF_{1,2} \equiv ISF_{SD(SE)} = -\sqrt{2}$- for spectator diagrams 1 and 2, $ISF_{3,4} \equiv ISF_{DD(DE)} = \sqrt{2}/3$- for decay diagrams 3 and 4 in Fig.1), while in the case of $n+p \to p+X$ the situation is opposite. Here there are two possibilities: the $\Delta^0 \to n+\pi^0$ and the $\Delta^0 \to p+\pi^-$. Therefore, the isospin coefficients are equal for this case:

$$1) ISF_1 = ISF_2 = -ISF_3 = -ISF_4 = 2/3, \qquad (16)$$

for $\Delta^0 \to n+\pi^0$,

$$2) ISF_1 = ISF_2 = ISF_3 = ISF_4 = \sqrt{2}/3, \qquad (17)$$

for $\Delta^0 \to p+\pi^-$. Hence the spectator and decay isospin weights are equal and the interference between spectator and decay modes is constructive (see Fig.9). The decay peak is shifted to the hard part of spectrum (Figs.9a-9b) by a value $\omega \approx m_\pi \approx 140$ MeV, thus having a kinematical origin. It is interesting to remark that this shift does not depend on the laboratory angle θ_{Lab} of the registered neutrons (protons) at $\theta_{Lab} < 15°$, although the high momentum part of cross section is relatively enhanced at larger angles (Fig.10). The decrease of $R(T,\theta)$ with increasing θ is due to this effect at the small value of the transfered energy $\omega \leq 0.4$ GeV. The indicated effect does not influence the soft part of spectrum where the momentum loss due to the deflection of the nucleon is smaller than due to the nonelastic processes.

From expressions (16-17) the important conclusion can be done. We have now introduce the notation $M_S(p)$ for the matrix elements corresponding to the sum of the resonance spectator diagrams 1 and 2 in Fig.1 and $M_D(p)$ to the sum of the resonance decay diagrams 3 and 4. It is evident that

$$| M_S(p) + M_D(p) |^2 = | M_S(p) |^2 + | M_D(p) |^2 + 2Re(M_S(p) M_D^*(p)).$$

The absolute value of each terms is two times larger for the exclusive charge-exchange reaction with creating the π^0 than for the kinematically equivalent reaction with creating the π^- while the nondiagonal term have the opposite signs for $n+p \to p+p+\pi^-$ and $n+p \to n+p+\pi^0$. This means that for analogous inclusive reaction $n+p \to p+X$ the corresponding nondiagonal terms will subtracted from each other. Physically

this means that due to completeness, the intermediate Δ^0-isobars, decaying to the channels $(p+\pi^-)$ and $(n+\pi^0)$ interfere destructively. In the exclusive treatment such a interference is vanished. The corrections from the contributions of s-wave potential πN scattering change negligibly the value of the described effect, keeping untouched the qualitative conclusion about the possibility to study the coherent states $p+\pi^- = \Delta^0$ and $n+\pi^0 = \Delta^0$ with the isospin 3/2.

The contributions of the decay modes and the s-wave πN potential scattering amplitudes improve the description of the experimental data only slightly (Fig.2b). The folding of the calculated results with the resolution function of the experiment [1] renormalize negligibly the theoretical curve.

The results of a theoretical analysis of the experimental data [21] for the reaction $p+d \to n+X$ are shown in Fig.3. The value of ratio $R(Q,\theta_{Lab})$ is calculated assuming that

$$\sigma_{p+d \to n+X} \approx < f_d^2 > (\sigma_{p+p \to n+X} + \sigma_{n+p \to p+X}), \qquad (18)$$

where $< f_d^2 >$ is the screening factor ($< f_d^2 > = 0.7$ at $\theta = 4°$; $< f_d^2 > = 0.75$ at $\theta = 7.5°$ and $11.3°$ and $< f_d^2 > = 0.8$ at $\theta = 13.2°$). We obtain qualitative agreement between theory and data. Some quantitative deviations are expected: eq.(18) does not take into account the fact that the hard part of the spectrum of the reaction $p+d \to n+X$ is enhanced by neutrons from the quasielastic knock-out while the soft part is enhanced by interaction in the final states [20]. Both of these effects are suppressed only in the vicinity of the Δ-isobar peak. The used values of $< f_d^2 >$ are in good agreement with calculations in the Glauber approximation and clearly demonstrate the tendency of the screen effects to decrease with increasing neutron registration angle.

The anomalous behaviour of the ratio $R(Q,\theta)_{exp} > R(Q,\theta)_{theor}$ at $\theta = 4°$ (Fig.3) near the upper kinematical limit has a simple explanation. The energy resolution of the experiment [21] at high momentum part of the spectrum was worse than the one of experiment [1] (the different methods of the neutron energy measurements were used). Taking properly this circumstance into account by the folding of the theoretical results with the corresponding resolution function, we improve the description and remove the above-mentioned anomaly.

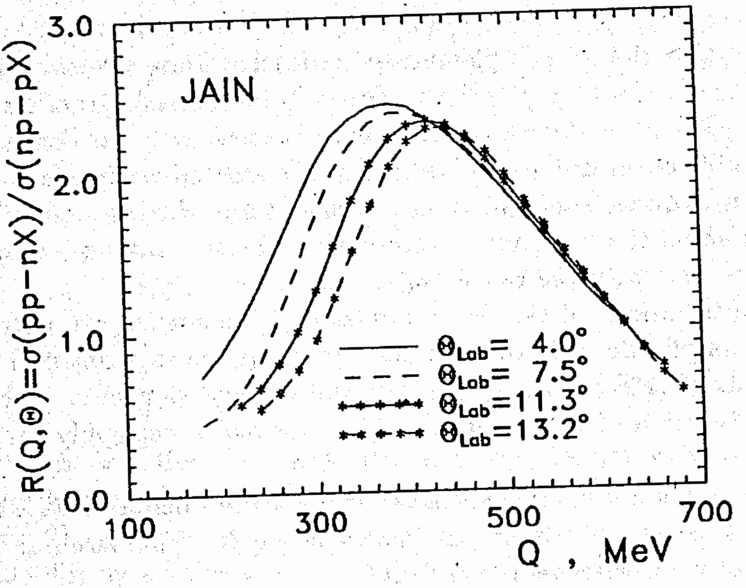


Fig.10 The ratio $R(Q,\Theta)=\sigma(pp-nX)/\sigma(np-pX)$ at T=1 GeV. The calculated cross sections were folded with the resolution function taken in accordance with the experiment /21/.

5 Conclusions

Our conclusions are the following:

We have shown that the intereference of the virtual Δ^{++}- and Δ^{+}-isobars for the reaction $p+p\rightarrow n+X$ is negligibly small, while the Δ^{+}- and Δ^{0}-isobars interfere strongly and constructively for the reaction $n+p\rightarrow p+X$ thus renormalizing the ratio R in an essential way.

A satisfactory description of the experimental data [1, 21] is achieved. The contribution of s-wave potential scattering πN amplitudes slightly improves the description of existing data.

We have found that the ratio R does not discriminate between three rather different vertex parameter sets, i.e. discrete ambiguities revive. We meet here a variant of Bohr's complementarity principle: We can distinguish the physically suitable set of vertex parameters in the $\pi+\rho+g'$ model for the reaction $p+p\rightarrow n+X$ by varying the projectile energy, while we cannot reveal the interference between Δ^{++}- and Δ^{+}-isobars due its smallness. On the other hand, the measurements of the ratio R exhibit the interference of the virtual Δ-isobars at the fixed energy T while the three vertex parameter sets investigated give approximately the same value $R(Q,\theta)_{theor}$. This complementarity of "energy" and "isospin" may be considered as a nonusual example of the dialectic of the discrete and continuous.

We have demonstrated that the superposition principle is applicable with high accuracy in the Δ-isobar excitation region and therefore the theory of the processes formulated in terms of effective amplitudes has to be linear.

We have proved, that the states $(p+\pi^{-})$ and $(n+\pi^{0})$ exhibited as Δ^{0}-isobar, can interfere in the inclusive reactions due to the condition of the completeness of final states.

Thus we can conclude that the presence of pronounced interference effects of the Δ^{+}- and Δ^{0}-isobars in the charge-exchange reactions gives indications on existing additional restrictions on applications of the impuls approximation, the formalism of effective numbers, the Glauber approximation, the cascade calculations and also the models of consecutive decay for multiple creation of particles [22].

References

[1] G.Glass, M.Jain, L.C.Northcliffe et al., Phys. Rev. D28(1983)1045.

[2] F.A.Gareev, Yu.L.Ratis, E.A.Strokovsky and J.S.Vaagen, in "The International Conference on Nuclear Reaction Mechanisms", Varenna, 10-15 June, 1991.

[3] E.Oset, E.Shiino and H.Toki, Phys. Lett. B224(1989)249. See also: P.Fernandez de Cordoba and E.Oset, Talk at Workshop "Pions in Nuclei", June 4-11, 1991, Peniscola, Spain.

[4] B.J.VerWest, Phys. Lett., 83B(1979)161.

[5] B.K.Jain, Phys. Rev. C29(1984)1396.

[6] C.Gaarde, Preprint NBI, DK-2100, Copenhagen, 1990.

[7] V.G.Ableev et al., Preprint JINR E1-83-486, Dubna,(1983); Pis'ma ZHETP, 40(1984)35; Yad. Fiz. 46(1987)549; 48(1988)27.

[8] S.-W.Hong, F.Osterfeld and T.Udagawa, Phys.Lett. B245(1990)1.

[9] C.Guet, M.Soyeur, J.Bowlin and G.E.Brown, Nucl. Phys. A494(1989)558.

[10] B.K.Jain, Phys. Rev. C32(1985)1253.

[11] B.K.Jain and A.B.Santra, Nucl. Phys. A500(1989)681.

[12] W.Weise, Nucl. Phys. A396(1983)373.

[13] H.Esbensen and T.-S.H.Lee, Phys.Rev. C32(1985)1966.

[14] B.K.Jain and A.B.Santra, Nucl. Phys. A519(1990)687.

[15] M.L.Goldberger and K.M.Batson, "Collision theory", (Wiley, New York) 1969,p.549.

[16] J.D.Bjorken and S.D.Drell, "Relativictic quantum field theory", McGrow Hill, New York, 1965.

[17] F.A.Gareev, Yu.L.Ratis, P.P.Korovin and E.A.Strokovsky, in preparation.

[18] V.F.Dmitriev, O.P.Sushkov and C.Gaarde, Nucl. Phys. A459(1986)503.

[19] D.A.Varschalovich, A.N.Moskalev and V.K.Hersonsky, "Theory of angular momentum in quantum mechaniks". M, Nauka, 1975, p.438.

[20] B.E.Bonner, C.L.Hollas, C.R. Newsom et al., Phys. Rev. D27(1983)497.

[21] V.N.Baturin, A.V.Hanzadeev, V.P.Koptev et al., JETP Lett. 30(1979)86; Preprint LIYAPH, N 1322, (1987).

[22] E.Byckling and K.Kajantie, Particle Kinematics, London,1973.

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