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T_{20} IN INCLUSIVE INELASTIC $(d, d')X$ SCATTERING AT 0° ON PROTONS AND ^{12}C

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T_{20} в инклюзивном неупругом $(d, d')X$ рассеянии под 0°

на протонах и ^{12}C

Представлены результаты измерения T_{20} для неупругой реакции $(d, d')X$ выше порога Δ изобары. Обнаружено, что T_{20} отрицательна, её абсолютная величина невелика при малых передачах энергии (в области рождения одного пиона и возбуждения Δ изобары) и растёт почти линейно к $|T_{20}| \cong (0.4—0.6)$ при передаче энергии $Q \cong 1$ ГэВ, где могут возбуждаться тяжёлые нуклонные резонансы. Значимой зависимости от типа мишени и начальной энергии не замечено; по-видимому, квадрат переданного 4-импульса, t, является адекватной переменной для анализа этой реакции.

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T_{20} in Inclusive Inelastic $(d, d')X$ Scattering at 0°

on Protons and ^{12}C

Results for T_{20} of the inelastic $(d, d')X$ scattering at 0° at energies above the Δ-threshold are presented. It is observed that T_{20} is negative; its absolute value is small at low energy transfer Q (the single pion production and Δ-excitation region) and rises almost linearly to $|T_{20}| \cong (0.4—0.6)$ at energy transfers $Q \cong 1$ GeV where heavy nucleonic resonances can be excited. No significant dependence on the type of the target and on the initial energy was observed; it appears that the 4-momentum transfer squared, t, is an adequate variable for analysis of this reaction.

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

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1. Introduction

Characteristics of broad hadronic resonances excited in nuclei and the related nuclear medium response on high energy excitations have been discussed intensively during the last decade[1].

The main interest and at the same time the main difficulties of these studies, is related to the fact that the behaviour of nuclear matter at high excitation energies is governed not only by its nucleonic degrees of freedom, but also by the internal degrees of freedom of the constituent nucleons. When the energy "pumped" into the nuclear medium is close to the characteristic energy of excitation of the internal degrees of freedom of a nucleon, these can no longer be treated independently. Such excitations reveal themselves as nuclear $N \rightarrow N^*$.. transitions followed by radiation of particles.

The non-trivial difference between resonance excitation off a free proton and off nuclei was first observed in experiments measuring inelastic charge–exchange cross sections; it was shown that the properties of Δ– excitations of nuclei cannot be described in the picture of quasifree production[2]. Non-quasifree mechanisms observed in inclusive experiments were confirmed in exclusive experiments[3] but a number of theoretical uncertainties still persist[4].

These new mechanisms can be "filtered"[5,4,1] by changing the initial energy and the quantum numbers in the initial state by choosing different projectiles (α, ^3He, t, d, p). In this respect inelastic (d,d') scattering[6] is as promising as the (α,α') reaction with coherent pion production[5] and excitation of the Roper $N^*(1440)$ resonance[7]. For example, excitation of Δ "in the target" is forbidden by isospin conservation both in the (d,d') and (α,α') reactions: Δ can be excited only "in the projectile"[5,1].

Another interesting feature of both $p(d,d')$ and $p(\alpha,\alpha')$ reactions at energy transfers sufficient for excitation of the $N^*(1440)$ resonance, is the Δ–$N^*(1440)$ interference. This effect appears, as pointed out in ref.[1] and confirmed in recent analysis[8] of the published $p(\alpha,\alpha')$ data, because the $N^*(1440)$ has a rather big branching ratio for decay into the $N+\pi$ channel.

Studies of polarization effects in the excitation of broad resonances in the nuclear medium[1] can bring new valuable information. A difference between proton and nuclear targets could be expected[9] for some polarization observables, but only a few of them were measured[10]. An example of the use of the (d,d') reaction with polarized deuterons as a filter of specific reaction mechanisms is given in ref.[11].

2. The experiment

The experiment was performed at the Laboratory for High Energies at the Joint Institute for Nuclear Research (JINR). The ALPHA–setup (shown in Fig.1) was used in the same configuration as in a concurrent investigation of deuteron breakup and $p(d,p)d$ backward elastic[13].

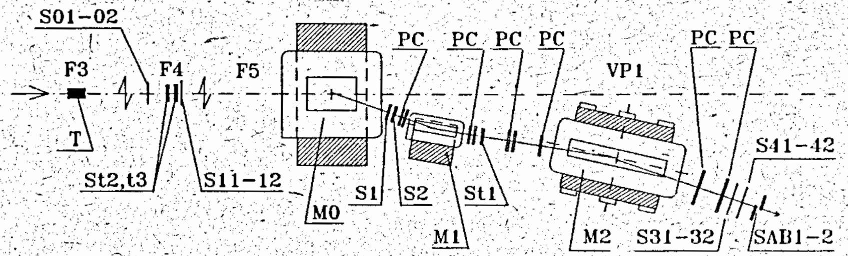

Figure 1: ALPHA–spectrometer at the VP1 beam line. PC: multi-wire proportional chambers; S01-02,St1-St3, S11-12, S31-32,S41-42: scintillation counters of the TOF–system; S1, S2, SAB1-2: trigger scintillation counters; M2: the analysing magnet. The TOF–base between S11-12 and S41-42 was about 50 m.

Here only the key points of the experiment are outlined. The measurements were done using the tensorially polarized deuteron beam of the Dubna Synchrophasotron. The sign of the beam polarization was changed in a cyclic fashion, "burst-after-burst", as $(0,-,+)$, where "0" means absence of polarization, "$-$" and "$+$" correspond to the sign of $P_{zz} = \sqrt{2}\,\rho_{20}$; the quantization axis was perpendicular to the plane containing the mean beam orbit in the accelerator. The polarization of the beam was measured with the ALPHA-polarimeter[14] before and after data taking; averaged values of the polarization are: $P_{zz}^{(-)} = -0.822 \pm 0.007 \pm 0.008$ and $P_{zz}^{(+)} = +0.800 \pm 0.011 \pm 0.024$ where both statistical and systematical uncertainties are shown. Other beam parameters (positions and widths of the beam spot at control points etc.) were monitored by the beam control system of the accelerator.

The 30 cm liquid hydrogen or 5.7 cm carbon targets (T) were placed at the focus F3 of the slowly extracted beam (Fig.1). The deuterons scattered at 0° and the unscattered part of the primary beam entered the beam line VP1; dipole magnets placed between the foci F3 and F4 (not shown in Fig.1) removed the unscattered particles while the scattered deuterons were transported to the ALPHA-spectrometer. The momentum acceptance of the setup was $\Delta p/p \simeq \pm 5\%$. The measurements were performed in several steps by changing the magnetic field in the spectrometer and the VP1 beam line tuning, for a continious coverage of the momentum spectrum.

3. Data analysis and results

The tensor analysing power T_{20} can be calculated directly from the numbers $n_{\pm}$ of "good" events detected for the "+" and "$-$" modes of the beam polarization, normalized to the corresponding monitor numbers:

$$T_{20} = \frac{2(n_- - n_+)}{\rho_{20}^{(+)} n_- - \rho_{20}^{(-)} n_+} \simeq \frac{4}{|\,\rho_{20}^{(+)}\,| + |\,\rho_{20}^{(-)}\,|} \cdot \frac{n_- - n_+}{n_+ + n_-} \qquad (1)$$

(the last part of the Eq.(1) is valid when $|\,\rho_{20}^{(+)}\,| \simeq |\,\rho_{20}^{(-)}\,|$).

We estimate the overall systematical uncertainty in T_{20} as $\sigma_{T20,syst} \simeq 0.05$ which is about the same size as the typical statistical uncertainty.

The data[12] for T_{20} are presented in Fig.2 as a function of the energy transfer $Q = E_d - E_{d'}$, where E_d is the energy of the projectile and $E_{d'}$ the energy of the scattered deuteron. The resolution on Q was $\sigma_Q \simeq 15$ MeV.

The systematic uncertainty of the "zero-point" of the Q-scale was $\sigma_{Q,syst} \simeq 20$ MeV, i.e. the data shown in Fig.2 might be shifted as a whole within this corridor.

The main features of the data are the following:
1) T_{20} is negative and increases almost linearly in absolute value when Q increases.
2) T_{20} is small and compatible with zero in the region of coherent pion production where the 4-momentum transfer squared is small: $|\,t\,| \leq 0.05$ GeV^2/c^2. It significantly differs from zero in the region of the $N^*(1440)$ resonance excitation and above.
3) $|\,T_{20}\,|$ becomes relatively big at large Q (about 0.4 to 0.6 at $Q \simeq 1$ GeV).
4) There is no visible difference between the $p(d,d')X$ and $C(d,d')X$ data at 0°.

These features indicate that T_{20} in the inelastic $(d,d')X$ scattering at 0° is not highly sensitive to nuclear medium effects in excitation of broad nucleonic resonances. Perhaps the deuteron forme factor determines most of the overall Q-dependence of T_{20}, as it appears to be the case for the general trend of the cross sections[6]. For example, the $p(d,d')$ scattering at low Q (i.e. low $|\,t\,|$) should be determined by the coherent pion production via the Δ excitation in the projectile[5]. The qualitative picture of ref.[16] explains this process as coherent scattering of a virtual pion on the deuteron; one could then understand the smallness of T_{20} at low Q as resulting from dominance of the S-wave part in the deuteron forme factor at small $|\,t\,|$. On the other hand, the D-wave contribution is significant at $|\,t\,| \sim 0.2 - 0.4$ GeV^2/c^2 so that significant T_{20} could be expected within this range of t-values, as is observed (Fig.3). In this case the 4-momentum transfer squared, t, should be the adequate variable for analysis of this reaction.

Study of the energy dependence of T_{20} in a bigger energy interval from the $N^*(1440)$ threshold (Saclay synchrotron energies) to the highest Dubna energies and in a wider Q interval would be interesting in this respect.

A better theoretical input is necessary to answer questions about the mechanism of this reaction. In particular, the role of interference between the Roper and Δ resonances as well as sensitivity of the data to the parameters of the Roper resonance need to be understood. In the perspective of further experiments with the Movable Polarized Target[17], recently installed at the Laboratory for High Energies, it would be important to have a better understanding of what one could expect to learn from additional data on spin transfer coefficient or spin–spin correlations in this reaction.

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Figure 2: Tensor analysing power of the $C(d,d')X$ (squares) and $p(d,d')X$ (full circles) inelastic scattering at 0° versus the energy transfer Q defined in the text.

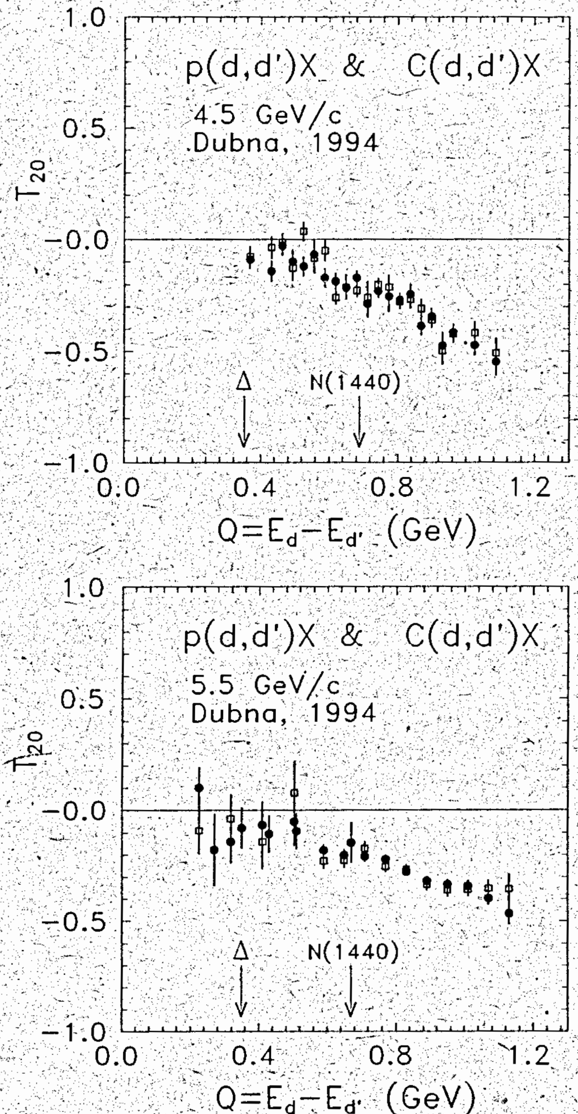
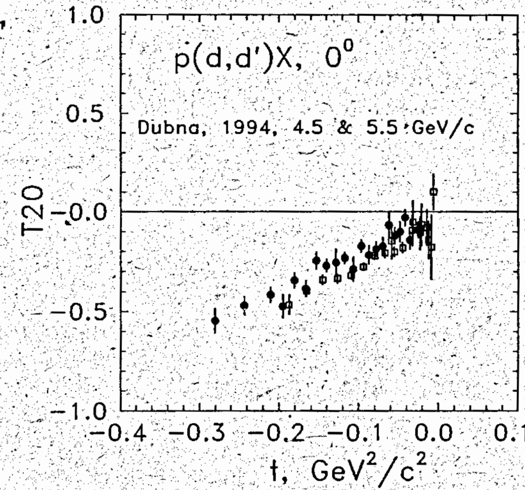


Figure 3: Data for $p(d,d')X$ inelastic scattering at 0° in dependence on 4-momentum transfer squared, t, at initial deuteron momenta of 4.495 GeV/c (full circles) and 5.532 GeV/c (squares).



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