ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

95-263

E1-95-263

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FIRST MEASUREMENT OF THE TENSOR ANALYSING POWER T_{20} IN INELASTIC $(d, d')X$ SCATTERING AT 0° ON ^{1}H AND ^{12}C AT 4.5 AND 5.5 GeV/c

Submitted to «Physics Letters B»

1995

Characteristics of broad hadronic resonances excited in nuclei and the related nuclear medium response on high energy excitations have been discussed intensively during last decade. Still, a wide gap remains between experimental results and theory[1]: apart from a few exceptions, most of the well established experimental observations don't have *a quantitative* theoretical interpretation.

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 $N \to N^*$.. 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 $\Delta-$ 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].

The relative contributions of these new mechanisms can be studied[5, 4, 1] by changing the initial energy and the quantum numbers in the initial state by choosing different projectiles $(\alpha, {}^3He, t, d, p)$. In this respect inelastic (d, d') scattering[6] is as promising as the (α, α') reaction with coherent pion production[5], and excitation of $N^*(1440)$ 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].

New valuable information may come from studies of polarization effects when broad hadronic resonances are excited in the nuclear medium[1]. A difference between proton and nuclear targets could be expected[8] for some polarization observables, but there are only a few experiments exploring the polarization observables of these reactions[9]. An example of the use of the (d, d') reaction with polarized deuterons as a filter of specific reaction mechanisms was demonstrated in ref.[10].

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

backward elastic scattering[11]. The (d, d') data were taken before and after the data for T_{20} in $p(d,p)d$ at $\vartheta_{cm} = 180°$; the systematic uncertainty of the final results was estimated using this circumstance.

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 the $P_{zz} = \sqrt{2}\,\rho_{20}$; 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[12] 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) together with parameters of the machine, were monitored by the beam control system of the accelerator. They were transmitted to our on-line computer after each burst and were used in the off-line analysis.

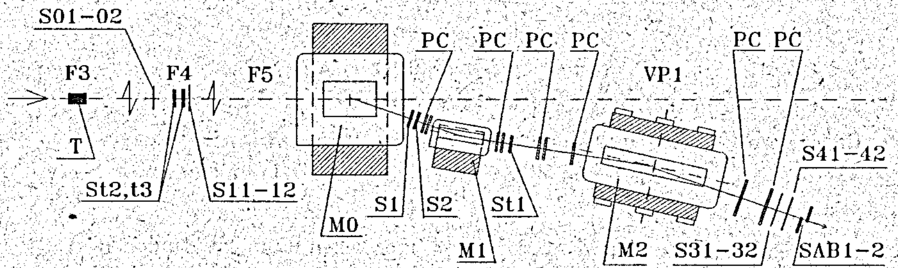


Fig.1 ALPHA–spectrometer at the VP1 beam line. PC: multi–wire proportional chambers; S01-02,St1-St3, S11-12, S31-32,S41-42: scintillation counters of the TOF–system; S1, S2, SAB1-2: trigger scintillation counters; M2: the analysing magnet. The TOF–base between S11-12 and S41-42 was about 50 m.

The 30 cm liquid hydrogen ($LH2$) or 5.7 cm carbon (C) targets (T) were placed at the focus F3 of the slowly extracted beam. Two beam intensity monitors were placed upstream from the target: an ionization chamber and a scintillation counter operated in the counting mode but at lowered high voltage in order to avoid overloading at intensities 10^7 deuterons per burst or higher.

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 part of the beam while the scattered deuterons were transported further to the ALPHA-spectrometer (Fig.1). The momentum acceptance $\Delta p/p \simeq \pm 5\%$ of the setup was mostly determined by the sizes of the trigger scintillation counters S1, S2, St1 and SAB1,2. The measurements were performed in several steps by changing the spectrometer and the VP1 beam line tuning for a continious coverage of the momentum spectrum. At every setting the intensity of the primary beam was optimized for a reasonable counting rates in the counters at the F4 point; the typical intensity varied from 10^7 to $5 \cdot 10^8$ per burst with a spill duration of $\simeq 400$ msec. At each setting data were taken with both the $LH2$ and C target; at most settings data were also taken without target; the "no-target" background was not more than 10% at $Q > 0.6$ GeV and less than 50% at $Q \simeq 0.4$ GeV. Here $Q = E_d - E_{d'}$ is the transferred energy; E_d is the energy of the projectile and $E_{d'}$ the energy of the scattered deuteron.

The momentum of the detected particles was measured with accuracy $\sigma_p/p \simeq 0.25\%$. The final resolution of the TOF system after all corrections was $\sigma_{TOF} \simeq 0.24$ nsec. Particle identification was performed using momentum and TOF information: this resolution provided a complete separation between protons, pions and deuterons.

The spectrometer acceptance is symmetrical over azimuthal angle for deuterons detected at 0°. When the spin quantization axis is perpendicular to the particles momenta, the cross section expressed[13] in terms of spherical tensor analyzing powers contains only the T_{20} term, as the contribution with T_{22} is zero for reasons of symmetry. Therefore 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 (the last part of the Eq.(1) is valid when $|\rho_{20}^{(+)}| \simeq |\rho_{20}^{(-)}|$):

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

The values of T_{20} were obtained separately for both parts of the run as mentioned above. Because several overlapped setup settings were available at each initial energy and for each target, further checks of systematics could be made. 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.

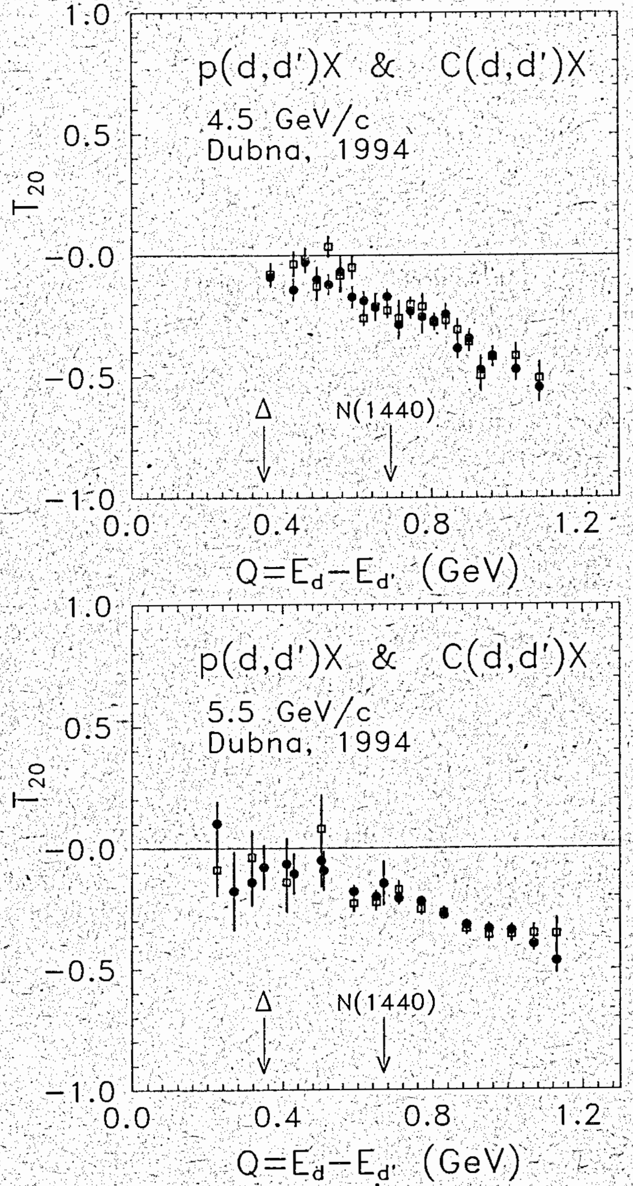
The final data for T_{20} are presented in Fig.2 as a function of Q; the data points shown are weighted averages (with weights $1/\sigma^2_{T20}$) from both parts of the run.

The systematic uncertainty of the "zero-point" of the Q-scale was $\sigma_{Q,syst} \simeq 20$ MeV; as a consequence the data shown in Fig.2 might be shifted as a whole within this corridor. The resolution on Q was $\sigma_Q \simeq 15$ MeV.

The main features of the data are the following:

1) T_{20} is negative and increases (almost linearly) in absolute value when Q increases.

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



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 formfactor 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]. Interpreting this process as a coherent scattering of a virtual pion[14] on the deuteron, one could explain the smallness of T_{20} at low Q as a result of the dominance of the S-wave part in the deuteron formfactor at small $|\, t \,|$.

Independently of any interpretation, the data demonstrate that this reaction can be used for the polarimetry of tensorially polarized deuterons at high energies.

We are grateful to the LHE accelerator staff, the POLARIS team and A.D. Kirillov, P.A. Rykoyatkin, A.L. Svetov, L.B. Golovanov, Yu.T. Borzynov, A.P. Tsvinev for providing good conditions for the experiment, L.N. Strunov, A.A. Nomofilov and V.I. Sharov for measurements of the polarization of the primary deuteron beam; L.V. Budkin, A.I. Obukhovsky, Z.P. Motina and O.N. Piskunov for their help during the experiment and preparation the manuscript.

The research described in this publication was supported in part by grants: $N°$ 93-02-3961 of the Russian Foundation for Fundamental Research, $N°$ RFU000 from the International Science Foundation, $N°$ RFU300 from the International Science Foundation and Russian Government, PHY-94-11620 from the US National Science Foundation and DE-FG05 89ER40525 from the US Department of Energy.

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Received by Publishing Department
on June 21, 1995.