MEASUREMENT OF TENSOR POLARIZATION OBSERVABLES IN DEUTERON PHOTODISINTEGRATION

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Abstract

The deuteron photodisintegration was a subject of extensive experimental and theoretical studies for a long time. However, a tensor analyzing power was measured only in two experiments. Here we report the results of experiment performed recently in Novosibirsk. The measurements were performed in the photon energy range $E_\gamma = 40 - 500$ MeV and $\theta_p^{cm} \approx 20^\circ - 100^\circ$. Preliminary data and comparison of them with some theoretical predictions are presented.

Deuteron two-body photodisintegration (PD) was being investigated during almost 70 years. In that period the different aspects of PD were becoming more and more clear. At present, the investigation of subnuclear degrees of freedom like meson, isobar and quark-gluon degrees of freedom as well as the study of important relativistic contributions are carried out for PD in the different theoretical approaches [1]. Concerning to the experiments, in spite of great number of works devoted to the study of total and differential cross sections, different polarization observables [1], the tensor polarization observables are very poor investigated experimentally. Such a study was not accessible until recently, because of great difficulties in creating a solid deuterium target with a high degree of tensor polarization, required for a conventional experimental set-up. First measurements of these observables were performed at Novosibirsk where the method of super-thin internal target was implemented. An internal gas target features are a high degree of tensor polarization, a possibility of fast changing its sign and direction. This creates the prerequisites to measure experimental asymmetries with small systematic uncertainties.

In 1985 at VEPP–2 electron storage ring the component T_{21} was measured [2] and in 1989–90 at VEPP–3 that was done for the components T_{20} and T_{22} [3].

The presented experiment has been performed at the VEPP-3 storage ring, where a new deuterium polarized gas target [4] was implemented. The main part of the target, a cryogenic atomic beam source (ABS) provides a record flux of polarized deuterium atoms ($8.2 \times 10^{16} at/s$) due to application of strong superconducting sextupole magnets [5]. The polarized beam from the ABS was injected into an open-ended, T-shaped storage cell resulting in an increased target thickness ~ 100 times as compared with the thickness of jet target. Cooling the cell with liquid nitrogen further increased the density, to achieve an estimated target thickness of $\sim 8\times10^{13}\mathrm{at/cm}^2$. The inner surface of the cell was coated with drifilm to inhibit an atom depolarization during collisions with the cell walls. During the experiment, the sign of the deuteron beam tensor polarization was changed regularly every 30 seconds. The tensor polarization of the atoms was $P_{zz}^+ \approx 1$ or $P_{zz}^- \approx -2$ while the vector polarization was zero [4]. The polarization of the ABS beam was usually very high ($\approx 98\%$). However, depolarization effects decreased the polarization of the deuterium atoms inside the target cell. The target polarization was determined by means of the polarimeter [4] which is based on a measurement of asymmetry in elastic *ed* scattering at small momentum transfer. The polarimeter data taking was performed simultaneously with the experimental run of the main detector. The average degree of target polarization during the experiment was found to be $P_{zz}^+ = 0.378 \pm 0.022$ (statistical uncertainty). The polarized target was successfully used before in the elastic electron-deuteron scattering experiment, where deuteron electric monopole (G_C) and quadrupole (G_Q) form factors were determined separately [6].

In the present experiment the counting rate asymmetry was measured for two signs of tensor polarization of the target in disintegration of the deuteron by a 2-GeV electron scattered forward, i.e. at an angle $\vartheta_e = 0°$. Proton and neutron were detected in coincidence. Scattering of an electron at 0° is equivalent to radiation of a real photon, which is then absorbed by a deuteron. This explains why in such set-up it is the photodisintegration that is studied.

A general expression for the cross-section of the two-body PD of the tensor polarized deuteron can be written as follows:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega}\left\{1 + \frac{1}{\sqrt{2}}P_{zz}\left[\frac{3\cos^2\theta - 1}{2}T_{20} + \sqrt{\frac{3}{8}}\sin 2\theta\,\cos\varphi\, T_{21} + \sqrt{\frac{3}{8}}\sin^2\theta\,\cos 2\varphi\, T_{22}\right]\right\},$$

where σ_0 – cross section for PD of unpolarized deuteron, P_{zz} – degree of the tensor polarization; θ – angle between polarization axis and the photon momentum, φ – angle between the polarization plane (containing polarization axis and the photon momentum) and the scattering plane (containing momenta of proton and neutron).

The target asymmetry is defined as

$$A^t = \sqrt{2}\,\frac{(N^+ - N^-)}{(N^- P_{zz}^+ - N^+ P_{zz}^-)};$$

where N^+ and N^- are the event counts of a detector when the target polarization is P_{zz}^+ and P_{zz}^-, respectively. N^+ and N^- are normalized to the electron beam charge.

For separation T_{20}, T_{21} and T_{22} tensor analyzing power components the three set of polarization axis were realized, namely $\theta_0 \approx 0°$, $\theta_1 \approx 55°$ and $\theta_2 \approx 125°$. As a result

$$A_0^t \sim c_0 \cdot T_{20}, \quad A_1^t \sim c_1 \cdot T_{21} + c_2 \cdot T_{22}, \quad A_2^t \sim c_1 \cdot T_{21} - c_2 \cdot T_{22}.$$

Large-acceptance non-magnetic particle detectors were composed of two pairs of detector arms (see Fig. 1). Two proton detecting arms were placed below the electron beam line and two neutron detecting arms were above the beam line.

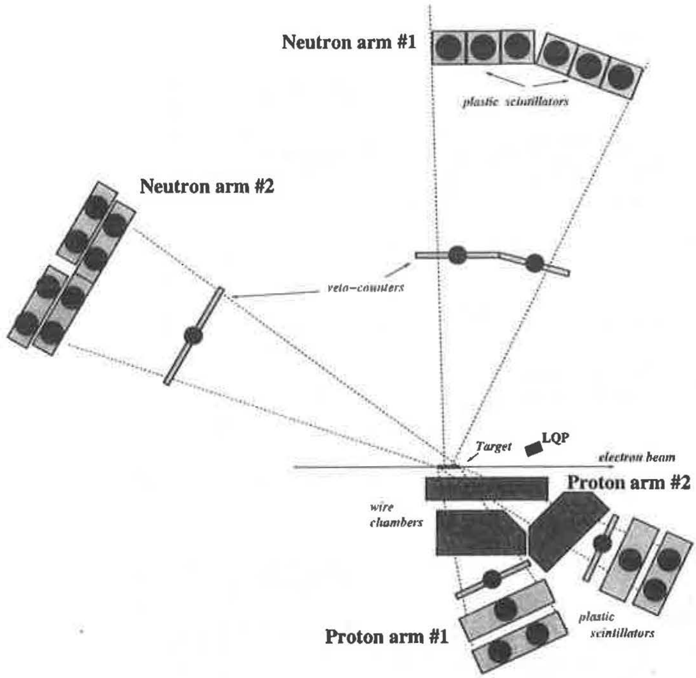

Figure 1: The layout of the detector system, side view.

The proton arms were equipped with scintillation hodoscopes, each having three layers of plastic scintillators. The scintillators were used for proton energy measurement and for particle identification. The particle trajectories were reconstructed by means of tracking information from different sets of drift chambers.

The neutron arms were also equipped with the plastic scintillators: six scintillators with dimensions $200 \times 200 \times 1000$ mm for one arm, and four scintillators with dimensions $120 \times 400 \times 1000$ mm for the other one. Plastic scintillator bars were placed at the maximal available distance from the target chamber (2.7 – 3.0 m) to provide the best energy (by TOF method) and angular resolution. Thin scintillators installed in front of neutron detectors were used as veto counters of charged particles.

Cuts on three kinematic correlations were employed to select PD events: proton energy versus neutron energy, (p-n) polar angle, and (p-n) azimuthal angle.

Preliminary data for T_{20}, T_{21} and T_{22} are presented in Fig.2. The uncertainties are statistical only. For comparison with previous data [3] here θ_p^{cm} was restricted in interval $83 - 93°$ (approximately same as in [3]). One can see that new data have substantially smaller uncertainties. In general, new results are in agreement with previous measurements (some difference for T_{20} at $E_\gamma \sim 100$ MeV).

New measurements were performed in more wide kinematical region. In Fig. 3 – 8 the dependences T_{20}, T_{21} and T_{22} from θ_p^{cm} for different intervals of E_γ are presented. The theoretical predictions shown by the solid lines [7], and by the dashed lines [8] both

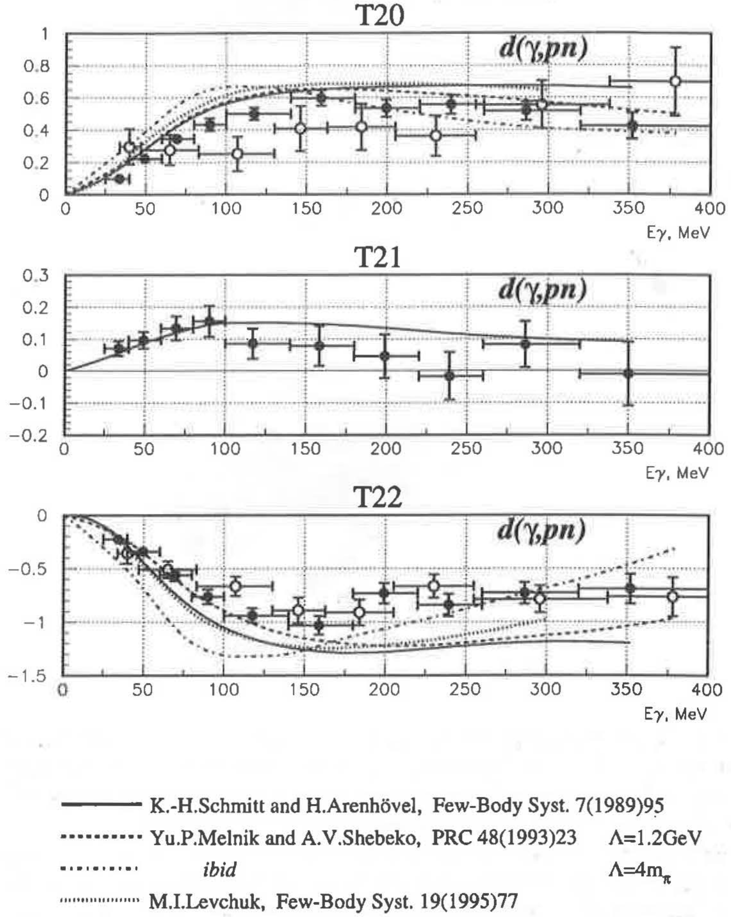

Figure 2: Preliminary results with $\theta_p^{cm} = 83 - 93°$ (full circles) and old data [3] (open circles).

take into account nucleon final state interaction and meson exchange currents. They are very close one to another although different approaches were used. In calculations [7] the contributions of isobar configuration and relativistic corrections were also accounted but, obviously, these two contributions play an important role at relatively high energy. One can see that, in general, new measurements are compatible with the theoretical predictions, but, especially for E_γ more $\sim 100 MeV$, the discrepancies between theory and experiment for T20 at small θ_p^{cm} and T22 at big θ_p^{cm} are sizable.

In conclusion :

- New measurement of the tensor analyzing power components T_{20}, T_{21} and T_{22} in

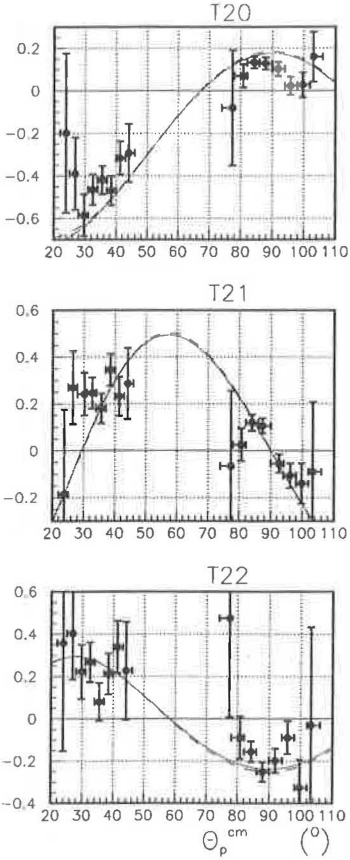

Figure 3: Preliminary results for E_γ =25-45 MeV.

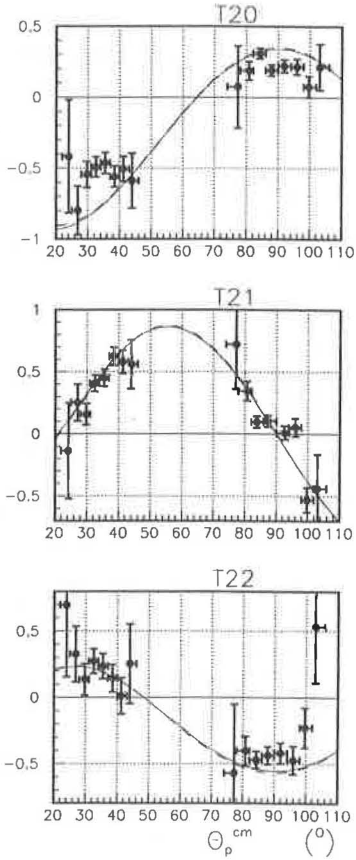

Figure 4: Preliminary results for E_γ =45-65 MeV.

two-body deuteron photodisintegration, in the range of gamma energy $30-500$ MeV and proton θ_{cm} angle ranges $20° - 30°$ and $70° - 100°$ has been performed.

- Preliminary data are available.
- Results, in general, are compatible with the theoretical predictions, but discrepancies with available calculations especially for E_γ more then $\sim 100MeV$ are sizable.

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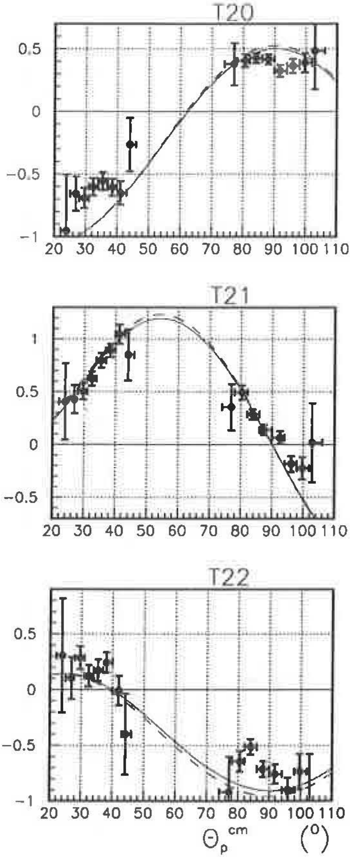

Figure 5: Preliminary results for E_γ =65-100 MeV.

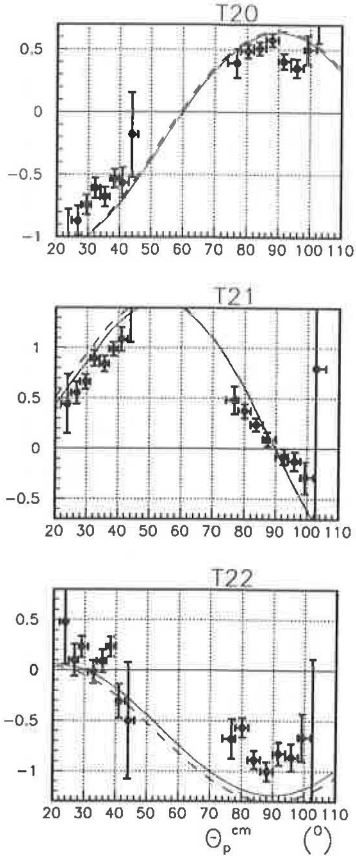

Figure 6: Preliminary results for E_γ =100-150 MeV.

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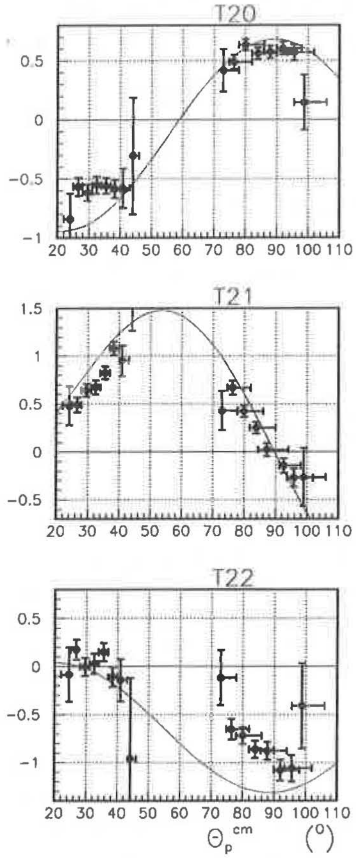

Figure 7: Preliminary results for E_γ =150-250 MeV.

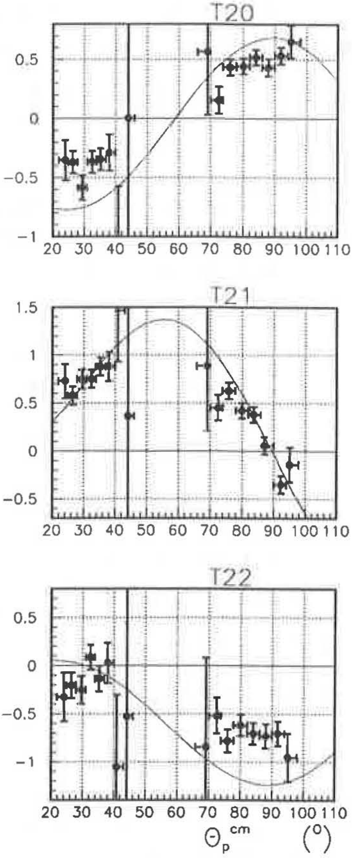

Figure 8: Preliminary results for E_γ =250-400 MeV.

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