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ABSTRACT

The asymmetry $\Sigma(\theta)$ for the reaction $^2H(\gamma,n)p$ has been measured at nine angles and for E_γ =19.8 MeV. The source of monochromatic and linearly polarized γ-rays was the Frascati Ladon facility, obtained by Compton scattering of laser light against high energy electrons. The experimental results are compared with the theoretical calculations obtained with the Reid-soft-core and with the De Tourreil-Sprung (version B) interactions.

In a previous paper(1) meson exchange contributions have been shown to play a significant role in the deuteron photodisintegration process. In particular, the asymmetry function $\Sigma(\theta)$ at $\theta=\pi/2$ showed a progressive departure with increasing energy of the experimental points from any theoretical calculation not explicitly including (MEC-IC) contributions.

In the low energy region ($E_\gamma \lesssim 25$ MeV) such a contribution is expected to provide small effects (only few percent), but nevertheless the current theoretical calculations(2-5) do not satisfactorily reproduce the forward cross section measured by the Mainz group(6).

Further information on this subject is reported in this paper where measurements of $\Sigma(\theta)$ for E_γ =19.8 MeV are quoted at nine different angles.

The source of monochromatic and linearly polarized γ-rays was the Ladon facility developed at Frascati(7) and obtained by backward Compton scattering of laser light against the high-energy electrons circulating in the

Adone storage ring.

The center of mass (CM) differential cross section for the $^2H(\gamma,n)p$ reaction induced by linearly polarized γ-rays can be written in the standard Partovi's form$^{(8)}$

$$\frac{d\sigma}{d\Omega} = I_o(\theta) + P\, I_1(\theta) \cos 2\phi = I_o(\theta) \left[1 + P\Sigma(\theta) \cos 2\phi \right] \qquad (1)$$

where θ is the CM angle between the proton and photon momenta and ϕ is the angle between the polarization and reaction planes; P represents the degree of linear polarization of the photon beam and

$$\Sigma(\theta) = \frac{I_1(\theta)}{I_o(\theta)} \qquad (2)$$

determines the asymmetry of the differential cross section.

An overall view of our experimental set-up is shown in Fig. 1. The photon beam of $E_\gamma = 19.8$ MeV, with an intensity of $\sim 2 \times 10^4$ γ/s, 2% energy resolution and polarization $P = 0.999$, impinged upon a 3.8 cm-diam x 10.2 cm-long NE-230 deuterated scintillator. Five NE-102A plastic detectors 15 cm-diam x 14 cm-long, placed at 116 cm from the deuterium target, were employed to detect the photoneutrons. The energy released by the protons in the target and the neutron time of flight were measured in coincidence with the electron bunch in the storage ring. The events were recorded via Camac by a PDP-11/34 minicomputer.

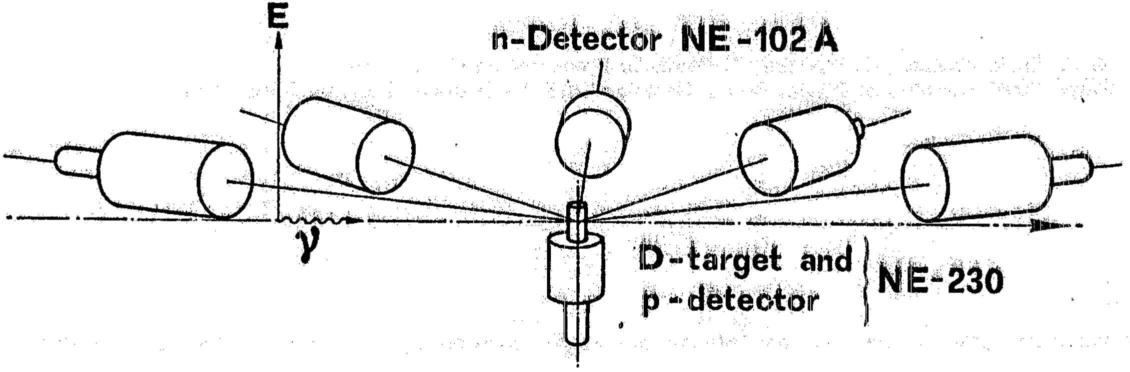

FIG. 1 - A schematic picture of the experimental set-up.

Proton/ γ-ray pulse-shape discrimination in the target reduced γ-rays background. The photon beam flux was monitored by a 12.5 cm-diam x 15.4 cm-long NaI(Tl) crystal and the energy spectrum was continuously recorded by a magnetic pair spectrometer located before the beam monitor.

Data were taken at nine neutron θ_n-angles in the laboratory system in a serie of alternating runs at $\phi = 0$ and $\phi = \pi/2$ in the same experimental conditions. The ratio of events in the photoneutron peak to the γ-rays flux gives the relative photoneutron yield $Y(\theta_n, \phi)$. From this one can obtain the ratio $R(\theta_n)$ defined as follows:

$$R(\theta_n) = \frac{Y(\theta_n, \pi/2)}{Y(\theta_n, 0)} \qquad (3)$$

The quantity $\Sigma(\theta)$ can be expressed in terms of $R(\theta_n)$ and is given by:

$$\Sigma(\theta) = \frac{1}{P} \, \frac{1 - k\, R(\theta_n)}{1 + k\, R(\theta_n)} \qquad (4)$$

where θ is the CM proton angle corresponding to θ_n. Moreover k corrects for finite solid angle effects and for neutron multiple scattering and absorption processes in the target. This correction factor has been evaluated by a Montecarlo calculation accounting for effects due to both ^{2}H and ^{12}C nuclides present in the target.

The measured $\Sigma(\theta)$ values are shown in Fig. 2 and Table I. The quoted errors are only statistical; in addition, the uncertainty in the factor k evaluation ($\Delta k/k \lesssim 10\%$) gives a systematic error, depending upon θ, quoted in column 4, Table I.

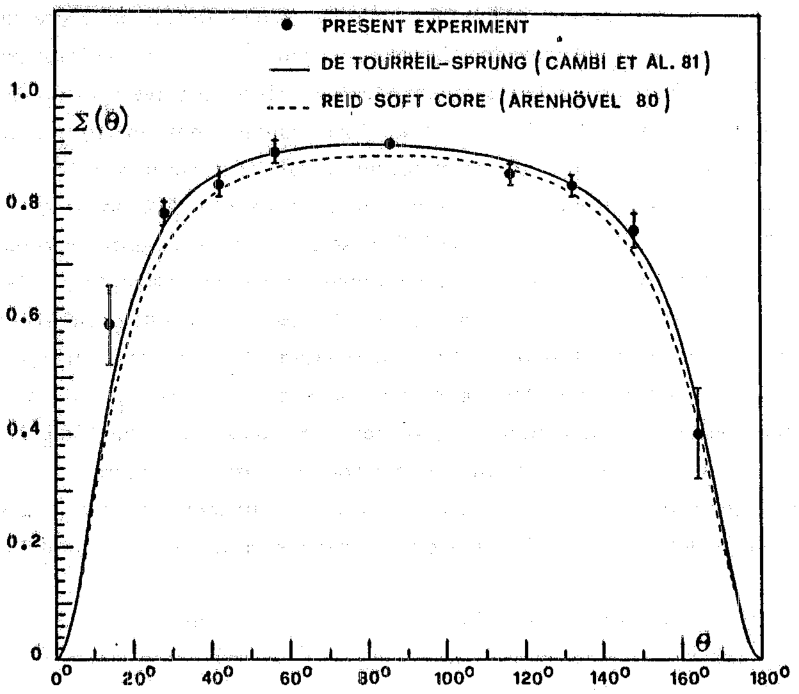

FIG. 2 - Plot of $\Sigma(\theta)$ vs θ (CM proton angle) for the reaction $^{2}H(\gamma,n)p$ at E_γ =19.8 MeV. Dotted and full curves are the theoretical calculation of Refs. (9) and (11) with the RSC and DTS potentials, respectively.

TABLE I - Experimental values of $\Sigma(\theta)$ (column 3) and theoretical previsions of Ref. (11,9), (columns 5, 6). Column 4 shows a systematic uncertainty on $\Sigma(\theta)$ as described in the text.

$\theta_n^{(\circ)}$	θ (°)	Σ_{exp}	$\Delta\Sigma_{syst.}$	DTS (11)	RSC (11)
15	163.8	0.40 ± 0.08	0.017	0.461	0.428
30	147.8	0.76 ± 0.03	0.016	0.748	0.721
45	131.9	0.84 ± 0.02	0.012	0.846	0.827
60	116.2	0.82 ± 0.02	0.011	0.887	0.872
90	85.6	0.915 ± 0.008	0.007	0.915	0.901
120	56.2	0.90 ± 0.02	0.009	0.900	0.883
135	41.9	0.84 ± 0.02	0.012	0.862	0.841
150	27.8	0.79 ± 0.02	0.015	0.764	0.733
165	13.9	0.59 ± 0.07	0.019	0.469	0.430

In comparing the present data with available theories and following the conclusions of our previous paper(1) any further reference to the approximation called "normal" and based upon the standard Partovi's theory(8), will be disregarded. Thus, we will consider only those calculations where some relevant contributions associated with one pion exchange and Δ-isobar excitations are explicitly added to the "normal" term, under the Siegert hypothesis.

The dashed line in Fig. 2 has been obtained independently by Arenhövel(9) and Cambi et al.(5-11), using the Reid-soft-core (RSC) nucleon-nucleon potential(10). Moreover, according to (11), no appreciable differences with respect to this result can be evidenced by using the Hamada-Johnston (HJ)(13) or the Paris potentials(14). On the contrary, the full line of Fig. 2, obtained by using the De Tourreil-Sprung (version B) (DTS)(11) potential, is sensibly higher (~ 1.5% at θ=90° and ~ 8% at θ=15°). In all these calculations, multipoles up to L=4 have been included. Moreover, no other predictions for $\Sigma(\theta)$ are at present available in our knowledge.

The χ^2-test with our experimental points gives a confidence level of ~ 50% and ~ 2% for the DTS and RSC potentials respectively. This result clearly favours the DTS case and is not substantially affected by any possible systematic displacement of the experimental points. Moreover, since the strength of the isotensor term at intermediate distances is smaller for the DTS than for RSC or HJ cases this result could also be interpreted as an indication to previlege low values for the D-wave deuteron percentage (P_D). However any speculation in this sense would certainly require a much better understanding of the connection relating P_D with the asymmetry $\Sigma(\theta)$. In particular all the available theoretical calculations of $\Sigma(\theta)$ have been done under the "Siegert hypothesis" without including relativistic and exchange corrections to the nuclear charge density operators.

From the phenomenological point of view this conclusion can be further explored by looking at the detailed structure of the functions $I_0(\theta)$ and $I_1(\theta)$ of eq. (1). Including multipoles up to L=4, they take the form:

$$I_0(\theta) = a+b \sin^2\theta + c \cos\theta + d \sin^2\theta \cos\theta + e \sin^4\theta, \qquad (5)$$

$$I_1(\theta) = f \sin^2\theta + g \sin^2\theta \cos\theta + h \sin^4\theta, \qquad (6)$$

where the coefficients are energy dependent.

In the first place, the ratios c/b, d/b and e/b have been extracted from a numerical analysis(15) of the world wide experimental data obtained with unpolarized photons where only $I_0(\theta)$ is involved. These values, together with h/b, currently assumed to be equal to e/b, have been fed into a fit procedure to extract a/b, f/b, g/b from the experimental values of $\Sigma(\theta)$. The obtained results are summarized in Table II, where theoretical previsions given

TABLE II - Comparison between our values for the ratios a/b, f/b, g/b at E_γ =19.8 MeV and the corresponding theoretical predictions as given by the Refs: 10(RSC), 12(DTS), 13(HJ), 14(Paris). Our best estimates of the other coefficients appearing in eq. (5) are: b=(65.7 ± 1.2) μb/sr, c=(0.47 ± 0.27) μb/sr, d=(20.6 ± 1.2) μb/sr, e=(-4.75 ± 0.57) μb/sr.

Fitted values		Theoretical values			
		DTS	RSC	HJ	Paris
a/b	0.0622 ± 0.0041	0.0718	0.0827	0.0852	0.0850
f/b	0.9706 ± 0.0061	0.984	0.980	0.980	0.981
g/b	0.319 ± 0.013	0.272	0.270	0.272	0.273

by four different potentials are also reported. The systematic errors, quoted in Table I, reflect in a maximum uncertainty of 7%, 1%, and 7% for the values of a/b, f/b, g/b respectively. This means that, at the limit of the quoted errors, f/b and g/b can reproduce available theories but a/b remains somewhat lower except for the DTS case.

Finally, by assuming $b = (65.7 \pm 1.2)\ \mu b/sr$ and $c = (0.47 \pm 0.27)\ \mu b/sr$ as given by the above mentioned numerical analysis(15), our best estimate for (a+c) at $E_\gamma = 19.8$ MeV is $(a+c) = (4.6 \pm 0.5)\ \mu b/sr$ in substantial agreement with the Mainz value $(a+c) = (5.0 \pm 0.5)\ \mu b/sr$ obtained at $E_\gamma = 23$ MeV(6).

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