Deuteron Compton scattering below pion photoproduction threshold is considered in the framework of the non-relativistic diagrammatic approach with the Bonn OBE potential. The complete gauge-invariant set of diagrams is taken into account which includes resonance diagrams without and with rescattering and diagrams with one- and two-body seagulls. The obtained results are compared with predictions of other models and with experimental data. A possibility of determining isospin-averaged electromagnetic polarizabilities of the nucleon is discussed.

The electric $\alpha_N$ and magnetic $\beta_N$ polarizabilities of the nucleon are structure parameters characterizing the ability of the nucleon to be deformed in external electromagnetic fields. In the case of the proton, the polarizabilities have been successfully measured in low-energy $\gamma p$-scattering. The polarizabilities of the neutron have so far been measured only in low-energy experiments on neutron transmission by the lead and on quasi-free Compton scattering off deuterons, both giving not very certain results. Elastic $\gamma d$-scattering provides another attractive option for measurements. In the present work we consider the amplitude of this process in the framework of the non-relativistic diagrammatic approach which consistently takes into account electromagnetic interactions of nucleons and those mesons which determine $NN$ interaction in the deuteron, as contained in the non-relativistic versions of the Bonn OBE potential $^{1,2}$.

In such an approach, the total $\gamma d$-scattering amplitude consists of the resonance and seagull parts. The resonance part is determined by two deuteron photodisintegration amplitudes of $\gamma d \to pn$ and $pn \to \gamma d$, which are taken from Ref. $^3$ with the relativistic spin-orbit correction included, and by the
full $T$-matrix of rescattering the intermediate off-shell nucleons. The seagull operator, which involves both photons together, consists of one-body parts (they are the Thomson term, a term with the nucleon polarizabilities, and a relativistic spin-orbit contribution) and two-body pieces which are determined by $\pi$, $\rho$, $\omega$, $\sigma$, and $\delta$-meson exchanges consistently with the $NN$-potential used. Moreover, effects of the meson-nucleon form factors, retardation effects in the meson propagators, and the $\Delta$-isobar excitation are also included.

Our results are as follows. For the success of determining the isospin-averaged nucleon polarizabilities $\alpha = \frac{1}{2}(\alpha_p + \alpha_n)$ and $\beta = \frac{1}{2}(\beta_p + \beta_n)$ from $\gamma\delta$-scattering, the one-body seagull contribution should be large at energies of the major interest (50–100 MeV). It is indeed the case, as is shown in Fig. 1. However, the resonance contribution and the two-body seagull corrections are not small. Only rescattering of intermediate nucleons (which is most difficult for numerical computations) has a little impact on the differential cross section $d\sigma/d\Omega$. Our results confirm findings of other approaches$^{5,6,7}$ that the rescattering decreases $d\sigma/d\Omega$ by 7% to 12% at forward angles and energies 50 to 100 MeV and that it increases$^{6,7} d\sigma/d\Omega$ by 7% to 3% at backward angles and the same energies.

A comparison of our predictions with results of previous calculations$^{5,6,7,8}$ is shown in Fig. 2. There is good agreement with Refs. $^{5,7}$ at 50 MeV and $\Theta_{\gamma} < 90^\circ$, but a big difference with predictions of Ref. $^6$ there. Our previous calculation $^7$ ("the minimal gauge-invariant model") used a less sophisticated treatment of mesonic contributions to electromagnetic currents and seagulls and did not include the $\Delta$-isobar, retardation effects and the spin-orbit correc
That is mainly why there is an increasing difference between our present and older results when the energy increases. Much bigger difference is found at higher energies with Ref. 6, in which a very different angular dependence is obtained, and with Refs. 5,8 at backward angles. We have no explanation for that. As a cross check of our results at $\Theta_{\gamma} = 0^\circ$ and $\alpha = \beta = 0$, we evaluated the Gell-Mann–Goldberger–Thirring dispersion relation for the spin-averaged forward amplitude of $\gamma d$-scattering using the available total cross sections of deuteron photodisintegration and found very good agreement with the diagrammatic calculation which was better than 3% for all energies below 100 MeV.

When the nucleon polarizabilities are off, all the predictions overshoot the available experimental data 4. With the polarizabilities on, a much better agreement can be achieved. Using $\alpha + \beta = 15$ (in units of $10^{-4}$ fm$^3$), as was estimated 9 from dispersion relations, a few curves with different $\alpha - \beta$ close to a theoretically expected range are shown in Fig. 3. The variation of $\alpha - \beta$ from 9 to 15 decreases the backward differential cross section by 8% and 20% at 50 and 100 MeV, respectively. This supports a hope to determine $\alpha$ and $\beta$ and eventually the polarizabilities of the neutron from measuring $\gamma d$-scattering.

Before, of course, reasons for large disagreements between different theoretical computations must be understood.

The presented calculation is able to describe all the experimental points except those at the largest angle $\Theta_{\gamma} = 140^\circ$. Since at larger angles and hence at higher momentum transfers the experimental separation of elastic $\gamma d$-scattering from inelastic one ($\gamma d \to \gamma np$) is more difficult, it would be desirable to independently confirm the strong increase of $d\sigma/d\Omega$ at backward an-
Figure 3: The differential cross section at various isospin-averaged polarizabilities. Dashed, solid, and dash-dotted lines: $\alpha - \beta = 9, 12, \text{ and } 15$, respectively, and $\alpha + \beta = 15$ fixed (in units of $10^{-4}$ fm$^3$). Dotted lines: $\alpha = \beta = 0$. Data are from Ref. 4.

gles found in Ref. 4. Currently, two experiments at Lund 10 and Saskatoon 11 promise to bring new data.

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References