Explicit Δ(1232) Degrees of Freedom in Compton Scattering off the Deuteron ◇

R.P. Hildebrandt, H.W. Grießhammer [a], T.R. Hemmert [a], and D.R. Phillips [b]
[a] ECT*, Trento [b] Ohio University, Athens

In nucleon Compton scattering the external electromagnetic field of the photon attempts to deform the nucleon. The electromagnetic polarizabilities provide a measure of the global resistance of the nucleon's "internal" degrees of freedom against displacement in an external electric or magnetic field, which makes them an excellent tool to study the nucleon's degrees of freedom. Experimentally the best-known nucleon polarizabilities are the electric and magnetic dipole polarizabilities of the proton, α_E^p and β_M^p. Due to the lack of stable single-neutron targets for Compton scattering it is much harder to access the neutron polarizabilities experimentally. One way to determine the neutron polarizabilities is elastic low-energy Compton scattering from light nuclei, e.g. from the deuteron. Several experiments have already been performed and further proposals exist – e.g. Compton scattering on the deuteron or He^3 at TUNL/HIγS and on deuteron targets at MAXlab. Chiral Effective Field Theory provides a consistent, controlled framework for elastic γd scattering within which nucleon effects can be disentangled from meson-exchange currents, deuteron binding, etc. In this work (Ref. [1]) we calculate γd scattering using an Effective Field Theory with pions, nucleons and the Δ(1232) resonance as explicit degrees of freedom. The ordering scheme ('power counting') is designed in such a way that we may expect to achieve correct results for photon energies between 50 MeV and 100 MeV, which is the energy region where one starts to be sensitive to the nucleon polarizabilities.

In Fig. 1 we compare the parameter free NLO predictions with (solid) and without (dashed) explicit Δ degrees of freedom. The dotted line is the LO result (here the explicit Δ does not yet appear). Obviously, the explicit Δ degrees of freedom may well be neglected for low energies. However, for higher energies – i.e. for describing the 94.2 MeV data correctly – the inclusion of the explicit Δ field seems to be advantageous in a third-order calculation, demonstrating once again the well-known importance of the Δ resonance in Compton backscattering, due to the strong $M1 \to M1$ transition. As mentioned before there is a lower energy bound to our calculation due to the ordering scheme employed. As both NLO curves are slightly above the 49 MeV data, this limit seems to be at the order of 50 MeV. An extension to lower energies is in progress [2].

The good agreement of our results with experiment at 69 MeV and 94.2 MeV encourages us to determine the isoscalar dipole polarizabilities α_E^s and β_M^s – i.e. the average between proton and neutron values – directly from the deuteron Compton cross sections. Motivated by the statistical imbalance between experimental data around 94.2 MeV and 69 MeV (cf. Fig. 1), we reduce for the fit the nine data points plotted as stars to only two by *rebinning*, in order to obtain an equal weighting between the two energy sets. The results are

$$\begin{aligned}\alpha_E^s &= (12.8 \pm 1.4\,(\mathrm{stat}) \pm 1.1\,(\mathrm{wf})) \cdot 10^{-4}\ \mathrm{fm}^3\,,\\ \beta_M^s &= (2.1 \pm 1.7\,(\mathrm{stat}) \pm 0.1\,(\mathrm{wf})) \cdot 10^{-4}\ \mathrm{fm}^3\end{aligned} \tag{1}$$

with "wf" denoting the error due to the dependence on the deuteron wave function (cf. [1]). A previous analysis of γp data within the same Chiral Effective Field Theory used here yielded the values $\alpha_E^p = (11.04 \pm 1.36) \cdot 10^{-4}\ \mathrm{fm}^3$, $\beta_M^p = (2.76 \mp 1.36) \cdot 10^{-4}\ \mathrm{fm}^3$ for the proton polarizabilities [3]. Combining the numbers of Eq. (1) with these results, we obtain a consistent Effective Field Theory determination of the neutron polarizabilities:

$$\begin{aligned}\alpha_E^n &= (14.6 \pm 2.0\,(\mathrm{stat}) \pm 1.1\,(\mathrm{wf})) \cdot 10^{-4}\ \mathrm{fm}^3\\ \beta_M^n &= (1.4 \pm 2.2\,(\mathrm{stat}) \pm 0.1\,(\mathrm{wf})) \cdot 10^{-4}\ \mathrm{fm}^3\end{aligned} \tag{2}$$

From these results we deduce that small isovector polarizabilities are not in contradiction with elastic deuteron Compton scattering data, or, in other words, we conclude that

$$\alpha_E^p \approx \alpha_E^n, \qquad \beta_M^p \approx \beta_M^n. \tag{3}$$

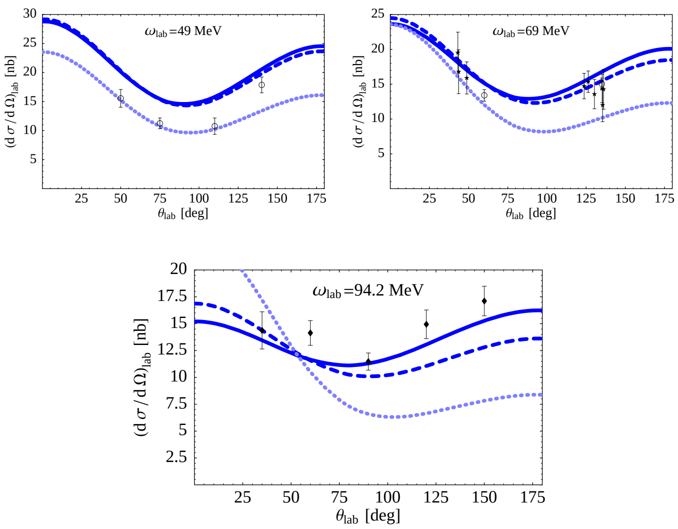

Figure 1: Comparison of the NLO prediction with (solid) and without (dashed) explicit Δ degrees of freedom at $\omega_{\mathrm{lab}} = 49$ MeV, $\omega_{\mathrm{lab}} = 69$ MeV and $\omega_{\mathrm{lab}} = 94.2$ MeV. For the data and the wave function used cf. Ref. [1]. The dotted line is the LO result.

References

[1] R.P. Hildebrandt, H.W. Grießhammer, T.R. Hemmert and D.R. Phillips, nucl-th/0405077, Nucl. Phys. A in press.

[2] R.P. Hildebrandt, H.W. Grießhammer and T.R. Hemmert, in preparation.

[3] R.P. Hildebrandt, H.W. Grießhammer, T.R. Hemmert and B. Pasquini, Eur. Phys. J. **A20** (2004) 293

◇ Supported in part by the Bundesministerium für Forschung und Technologie, and by Deutsche Forschungsgemeinschaft under contract GR1887/2-2 (HWG, RPH and TRH)