Spin Polarizabilities of the Nucleon from Polarized Low Energy Compton Scattering ◇

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As guideline for forthcoming experiments, we present predictions from Chiral Effective Field Theory with explicit $\Delta(1232)$ degrees of freedom (Small Scale Expansion – SSE) for polarized cross sections in low energy Compton scattering for photon energies below 170 MeV, both on the proton and on the neutron. Special interest is put on the role of the nucleon spin polarizabilities which can be examined especially well in polarized Compton scattering and which are not yet well known: Only two of the four static spin dipole polarizabilities have been measured so far and the energy-dependence of the nucleon polarizabilities – energy dependent, i.e. dynamical polarizabilities, have first been introduced in [1] and have further been studied in [2] – has not yet been determined from experiment at all.

As there is no hope to compare with experimental data for absolute values of polarized Compton cross sections within the next few years, we show our results for the asymmetries, choosing the spin configuration which is suited best to investigate spin polarizabilities and their dynamics. As demonstrated in [3] it is the configuration with the nucleon spin aligned perpendicular to the direction of the incoming photon, which we call Σ_x:

$$\Sigma_x = \left(\frac{d\sigma_{\uparrow\rightarrow}}{d\Omega_{\mathrm{cm}}} - \frac{d\sigma_{\uparrow\leftarrow}}{d\Omega_{\mathrm{cm}}}\right) \Big/ \left(\frac{d\sigma_{\uparrow\rightarrow}}{d\Omega_{\mathrm{cm}}} + \frac{d\sigma_{\uparrow\leftarrow}}{d\Omega_{\mathrm{cm}}}\right) \qquad (1)$$

The first arrow in our notation denotes the direction of the incoming, right-circularly polarized photon, the second one the direction of the nucleon spin.

In Figs. 1 and 2 we show our SSE-results for Σ_x, Fig. 1 corresponding to a proton target, Fig. 2 to a (hypothetical) free neutron target. The full calculation is compared to the results that we get, when we do not include polarizabilities with higher multipolarity than the six (two spin independent and four spin dependent) dipole polarizabilities (dot-dashed lines) and the ones, which include only *spin-independent* polarizabilities (dotted lines). The whole formalism of the multipole decomposition of the Compton scattering amplitude can be found in [2].

As it is our primary aim, to demonstrate the possibility to determine spin polarizabilities experimentally, we are interested in observables having two features:

- spin polarizabilities should give a large contribution
- as few polarizabilities as possible should be visible in the observable, i.e. we want a fast convergence of our multipole expansion, in order to reduce the number of free parameters

Obviously Σ_x fulfills both demands: The spin polarizabilities do give huge contributions and quadrupole polarizabilities are nearly invisible, for the proton as well as for the neutron, see Figs. 1 and 2. The latter observation also holds for spin-averaged Compton cross sections, cf. [2]. Therefore we think it is possible to determine the four spin dipole polarizabilities from experiment, which lead us in [3] to the proposal of a model-independent extraction method of their static values and their energy dependence, based on the multipole decomposition of the Compton amplitude and a combination of spin-averaged and polarized experiments.

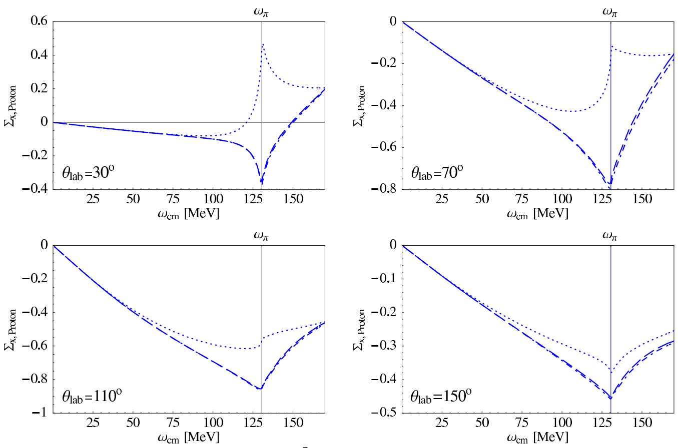

Figure 1: Complete $\mathcal{O}(\epsilon^3)$-SSE-predictions (dashed) for the proton asymmetry Σ_x^p; dotted: spin polarizabilities not included, dotdashed: quadrupole polarizabilities not included. ω_π denotes the pion production threshold.

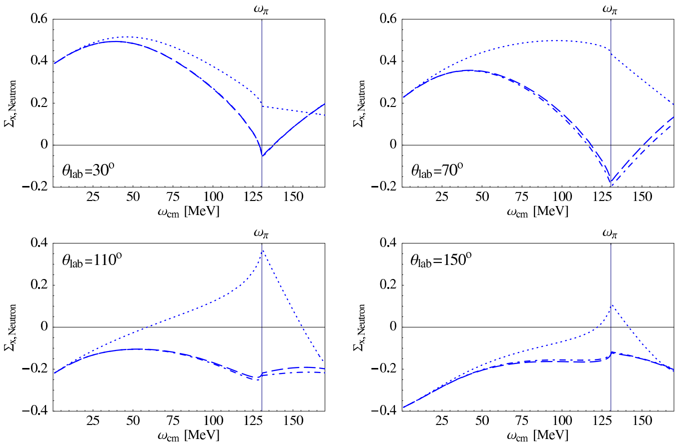

Figure 2: Neutron asymmetry Σ_x^n; for notation see Fig.1.

References

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