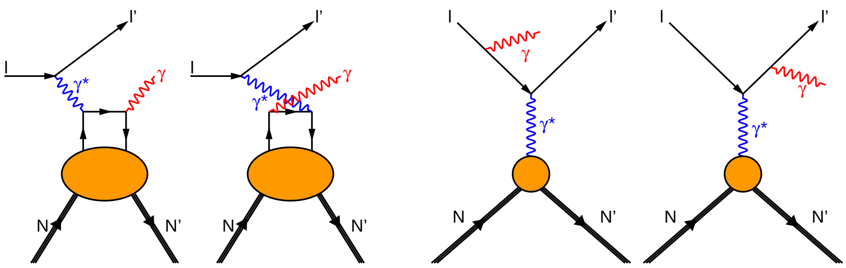
Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on a longitudinally polarized deuterium target

(The HERMES collaboration)

The HERMES experiment located at the HERA storage ring at the research center DESY in Hamburg used a lepton beam with a momentum of 27.6 GeV to scatter off various gaseous targets. The major aim of the experiment was to learn about the structure of the nucleon(s) inside the target, with a special focus on the spin structure of the nucleon.

The large momentum of the point-like beam leptons resulted in a transverse spatial resolution substantially better than 1 fm, which is known to be approximately the size of a nucleon. The spin of the nucleons can be studied by polarizing either the incident beam and/or the target particle. For this measurement, longitudinally polarized electron and positron beams were scattered off a longitudinally polarized deuterium target.

A rich variety of scattering processes can be examined at HERMES. The Deeply Virtual Compton Scattering (DVCS) process is depicted in figure 1(a). It is a simple process where the hadronic states remain unchanged. Instead, the incoming lepton interacts via a virtual photon with a quark of the nuclear system, which radiates a real photon.



(a) (b)

Figure 1: The left two diagrams show the leading contributions to the DVCS process and the right two diagrams to the BH process. In the figure "l" labels a lepton, "$\gamma^{(\star)}$" a (virtual) photon and "N" a nuclei.

The Bethe-Heitler (BH) process, in which the real photon in the final state is emitted by the incident or outgoing lepton, is a competing process (see figure 1(b)). The two processes are experimentally indistinguishable and therefore interfere, leading to an additional interference term in the process amplitude.

At HERMES energies the BH contribution dominates the cross section. Both DVCS and interference amplitudes can be extracted from the data via the concept of asymmetries, which are normalized differences of count rates with respect to a certain property of the experiment. Asymmetries with respect to beam helicity, beam charge and target polarization or a combination thereof were extracted for the discussed data set. The various available spin states of the spin-1 deuteron target allowed an analysis of a tensor contribution in the cross section.

In the case of a nuclear target like deuterium the scattering occurs on either the full deuterium nucleus or on one of the nucleons inside it, the former case is called coherent and the latter incoherent scattering. The probability for incoherent scattering increases with increasing momentum transfer t to the target.

In total, seven different asymmetries were studied in the present work, providing rare access to both the interference term and DVCS amplitude in the cross section. A Fourier decomposition of these asymmetries with respect to the azimuthal angle ϕ between the lepton scattering and the photon production plane was performed. Two of the resulting Fourier amplitudes are shown in figure 2.

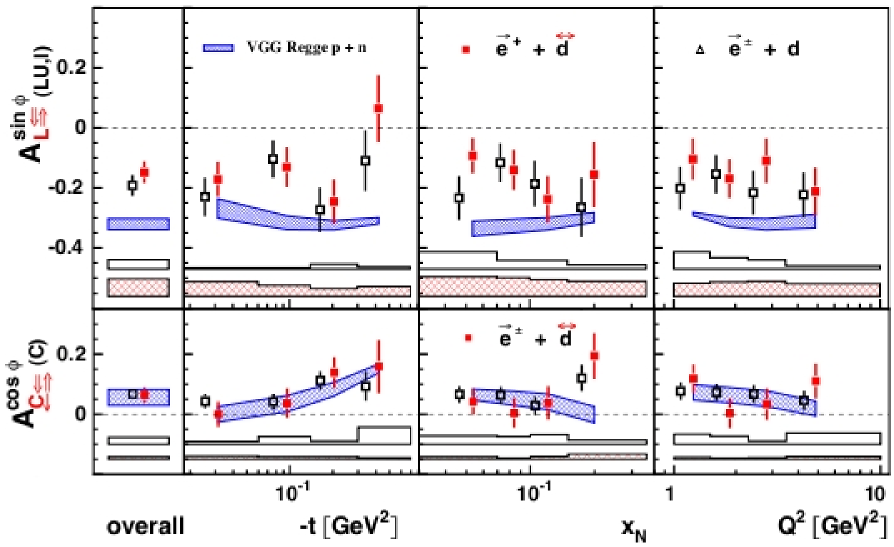


Figure 2: Two examples for the obtained Fourier amplitudes that have been calculated from two different asymmetry extractions. The red filled squares denote the results on a longitudinally polarized deuterium target, while the black open squares show results on comparable observables extracted from an unpolarized deuterium target.

The figure is subdivided into four columns, the first illustrates the result obtained in the whole HERMES acceptance, while the other three show results in bins of three kinematic variables: t, x_N and Q^2. As the scaling variable x_N is strongly related to the squared momentum transfer mediated by the virtual photon Q^2, asymmetries are expected to depend on these two variables in a similar way. The overall results for the two amplitudes shown in figure 2 are found to be significantly non-zero and nicely agreeing with the results obtained from an unpolarized deuterium target on a comparable Fourier amplitude. Even in the lowest t-bin, where the contribution from coherent scattering is as large as 40 % no differences are observed.

The Fourier amplitudes of the measured asymmetry with respect to a tensor polarized target are not shown, but were found to be compatible with zero. In addition, the Fourier amplitudes obtained using longitudinally polarized deuterium and hydrogen targets were found to be compatible for both unpolarized and polarized lepton beams.

In conclusion, no evidence was found for a strong effect from coherent scattering on the deuterium nucleus, onto the Fourier amplitudes of the extracted asymmetries, not even in the lowest t-bins. Nevertheless, a rich variety of asymmetries was measured for the first time and will provide valuable input in further understanding the (spin) structure of the nucleon.