Beam-helicity asymmetry arising from deeply virtual Compton scattering measured with kinematically complete event reconstruction

The Hermes Collaboration

Popular Summary

The scattering of electrons off protons is a clean tool to study the structure of protons, which are known to be complex objects made out of quarks and gluons. In the case of deep-inelastic scattering, the energy of the electron is so large that, when impinging on the proton, the strong ties between the quarks inside the proton are broken up. The proton fragments into other sub-atomic particles. These particles, and their subsequent decay products, escape the interaction point, and their energies and angles can be registered by macroscopic particle detectors. Sometimes, however, the proton does not break up; it is quickly shaken and thereby only the velocity of one of its quarks is altered. The information on this intrinsic kinematic change is carried away by a photon or a meson. Since more than a decade, theoretical physicists have been proposing to measure such so-called hard exclusive processes because they promise to deliver information about a 3-dimensional view of the nucleon, in a similar way that nuclear tomography in medicine allows to create sliced pictures of, for example, the human body.

In case the proton stays intact and there is a photon produced, one speaks of Deeply Virtual Compton Scattering (DVCS). This process has been measured in the past couple of years at the Hermes experiment at the Deutsches Elektronen Synchrotron (Desy) in Hamburg, Germany, and at other experiments in Europe and the United States. There is, however, the following complication: it can happen that the proton mutates into its heavier brother, called the Delta+ particle. In the past, only the scattered electron and the DVCS photon could be detected at Hermes. Because the experimental resolution was not sufficient, the "proton case" could not be distinguished from the "Delta+ case", the latter amounting to 12%. However, a pure "proton case" would be desirable to establish a "proton tomography" before looking at other (and likely more complicated) cases such as the Delta+.

For the purpose of studying the pure "proton case", the Hermes apparatus was upgraded in the winter of 2005/2006 with a recoil detector. The detector surrounded the proton target that the electrons were scattered off, allowing for the detection of the intact recoil target protons emerging under steep angles and with low momenta. A diagram of the recoil detector is shown in figure 1. For this publication, data are analyzed that have been collected during the years 2006 and 2007. Many DVCS events (about 17,000) could be recorded for which all three particles were detected at the same time: electron, photon, and proton. In order to select only true DVCS events, i.e. where the proton does not mutate into a Delta+, the angles and momenta of all three registered particles are treated in a common fit and only those events are kept for which the result of the fit is in agreement with the assumption of the pure "proton case". The experimental situation is simulated by Monte Carlo data and it can be shown that with the analysis methods applied, the "Delta+ case" is suppressed to a level below 0.2%.

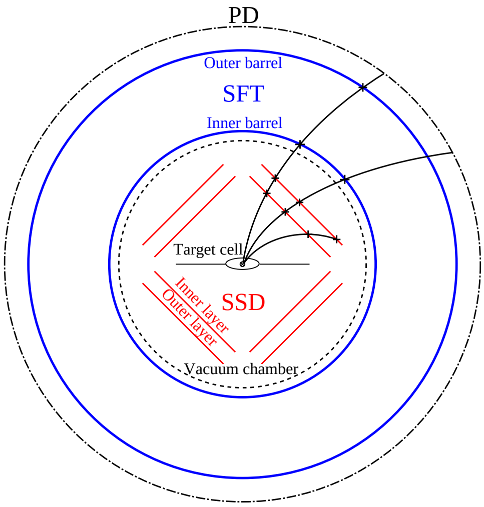

Figure 1: Schematic diagram of the HERMES recoil detector (cross-section view). The impinging electron beam is perpendicular to the paper plane. The cross section of the target cell is shown as ellipse. The curved lines denote reconstructed protons (tracks). The tracking layers are indicated, from inside to outside: Silicon Strip Detector (SSD, in diamond shape; one side of the diamond is about 10 cm long) and Scintillating Fiber Tracker (SFT, circles).

The sample of selected events is treated in the following way: first, the data are split into two parts: one part for which most of the electrons have their spin (intrinsic angular momentum) oriented into the direction of their movement, and the other part for which most of the electrons have their spin oriented opposite to the direction of their movement. In the next step, a so-called beam-helicity asymmetry is computed, which means that the resulting count rates are compared with each other and properly normalized. This is done in various kinematic regions, namely in bins of $-t$, Q^2, and x_{B}. Here, t is the square of the four-momentum transfer to the target proton, $-Q^2$ is the square of the four-momentum transfer by the electron, and x_{B} is a measure of the inelasticity of the process.

Lastly, this asymmetry is subject to a harmonic analysis with respect to the azimuthal angle ϕ between the plane spanned by the incoming and scattered electrons, and the plane spanned by the photon and the outgoing proton. The leading two odd components of the Fourier series are extracted. Figure 2 shows the results for the $\sin\phi$ and $\sin(2\phi)$ Fourier coefficients of the beam-helicity asymmetry (red circles). The statistical uncertainties are indicated by the vertical lines attached to each data point, and the systematic uncertainties are represented by the filled bands. The results are presented in the kinematic binning mentioned above and also (in the very left column, "overall") without splitting the data into kinematic portions. The important (leading) $\sin\phi$ Fourier coefficient is negative and has a magnitude of about 1/3. The sub-leading coefficient is compatible with zero within the experimental uncertainties.

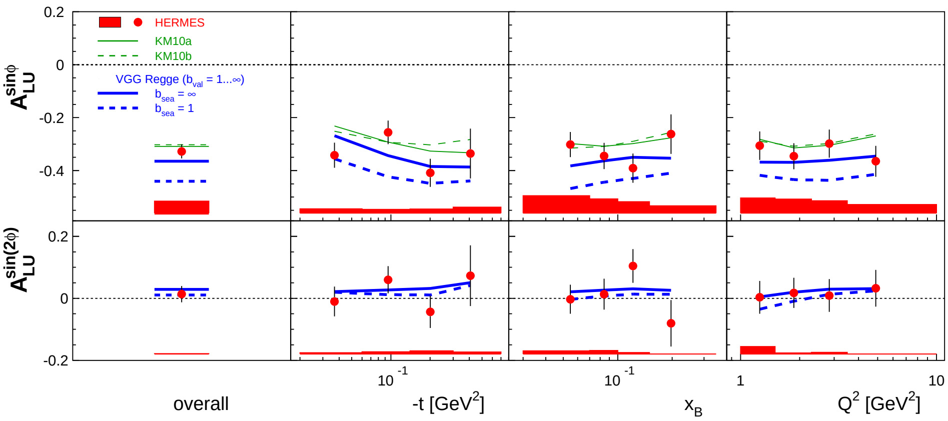

Figure 2: Fourier coefficients of the beam-helicity asymmetry extracted from data with pure "proton case". Also shown are theoretical model curves.

The figure also contains results from theoretical model calculations, displayed as blue bands. One of the model variants describes the new HERMES data fairly well, even though slightly overshooting them in magnitude. The green curves are results from a global fit to previous measurements in DVCS, taking into account various experiments and also including (older) HERMES data. The results from the present publication will serve as another valuable input for future global fits.