The Beam–Charge Azimuthal Asymmetry and Deeply Virtual Compton Scattering

Three–dimensional pictures of macroscopic objects like, e.g., an apple, are taken by a procedure known as holography, as shown in the left panel of Fig. 1. Light is emitted by a laser and is split into two beams. Both beams are recorded on the holographic plate, but only one is reflected off the apple and thus "carries" the picture of the apple. The other beam is only reflected by mirrors or focused by lenses, i.e., it arrives at the holographic plate in a very well known state and thus acts as a reference beam.

Most people have seen an apple since our eyes are good detectors for "normal" light, which is usually emitted from the sun or from a light bulb and is afterwards reflected from the apple into our eyes. Investigating the world around us by eye is possible as long as the object we look at is bigger than the wavelength of light. If the object is smaller, we need a beam with shorter wavelength and correspondingly we need to change the detector since our eye can only detect the visible light. An example is the use of electron microscopy where the beam of light is replaced by a beam of electrons. For the smallest objects, which are the building blocks of the matter surrounding us, the three–dimensional structure is largely unknown. The objects under investigation are the spatial and momentum distributions of the quarks and gluons inside of protons and neutrons (nucleons), which make up the core of the atoms. An attempt for such a study is shown in the right panel of Fig. 1 and is called nucleon holography. The beam that "carries" the picture of the quarks or gluons (partons) inside the nucleons consists of highly energetic gamma rays (photons). At the HERA collider at DESY these photons are produced after the 27 GeV lepton beam is scattered off a gas target. The produced photon in this so-called **D**eeply **V**irtual **C**ompton

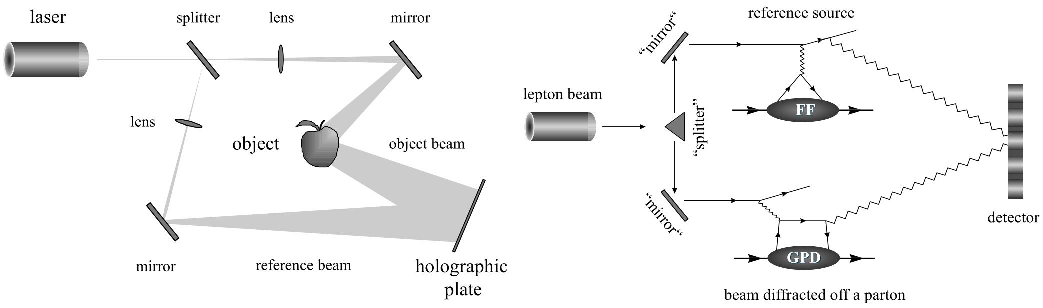

Figure 1: Left panel: Conventional holography. Right panel: "Nucleon holography" via the interference of the deeply virtual Compton scattering (lower graph) and the Bethe–Heitler process (upper graph). Figure taken from: Belitsky/Müller, Nucl. Phys. A711 (2002) 118.

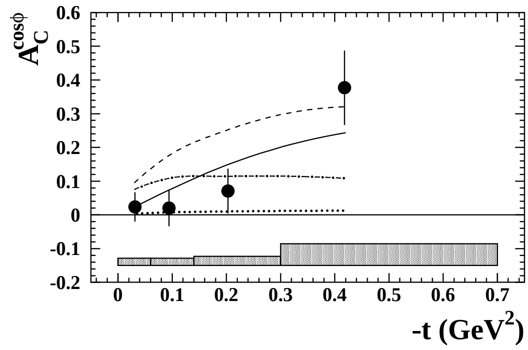

Figure 2: The $\cos\phi$ amplitude of the beam–charge asymmetry as a function of $-t$. The error bars (band) represent(s) the statistical (systematic) uncertainties. The calculations are based on GPD models.

Scattering (DVCS) process is then observed in the detector of the HERMES experiment. The reference beam in this case is a process that will as well result in a high–energy photon. This photon is directly emitted by the lepton and thus does not "see" the inner structure of the nucleon, i.e., the partons. It is called **B**ethe–**H**eitler (BH) process, which is well known and exactly calculable. Since both processes have the same final state they are subject to interference. The interference part of the cross section is the one most interesting to measure, since the building blocks of the underlying mathematical framework, the so-called **G**eneralized **P**arton **D**istributions (GPDs) are most directly accessible through this interference term. A consequence of the interference is a beam-charge azimuthal asymmetry, i.e., the azimuthal distribution of the detected photons, with respect to the plane of the incoming and outgoing lepton, depends on the charge of the lepton. The azimuthal angle is denoted as ϕ, and the asymmetry is expected to predominantly show a cosine behavior as a function of ϕ.

With the electron and positron beams provided by HERA, the first measurement of this $\cos\phi$ amplitude of the beam–charge asymmetry has been performed. The result as a function of the momentum transfer t between the proton in its initial and final state is shown in Fig 2. The model curves are predictions based on various models for GPDs. It is apparent that the sensitivity of the experiment to discriminate between different models is quite good and that the model showing the largest amplitude is already disfavored. The hope is that with more accumulated data the certain GPD models can be decisively constrained. By measuring also other asymmetries in which the proton or the lepton are polarized, the medium term goal is to determine a specific part of the three–dimensional structure of the nucleon, namely the orbital angular momentum of quarks inside the nucleon. The latter is one of the most interesting, yet unknown, observables in nucleon structure.