Nuclear–mass dependence of azimuthal beam–helicity and beam–charge asymmetries in deeply virtual Compton scattering

The exploration of the inner structure of nucleons (protons or neutrons) - which form the overwhelming majority of all observed matter in the universe - is the core task of experiments performed at DESY with the HERA accelerator.
Most of our knowledge on the inner quark-gluon structure of the nucleon results from scattering point-like particles like electrons off protons or nuclear targets. Such interactions are described by the exchange of a virtual photon between the beam electron and the target. The higher the virtuality of the exchanged photon, the smaller is the space region we explore in the target nucleon. Such *deep inelastic scattering* (DIS) experiments have been successfully interpreted within the QCD parton model introducing parton distribution functions (PDFs). These PDFs contain the information about the number of partons inside the nucleon, the way they share the nucleon's momentum and longitudinal spin.
However, all our knowledge about the inner structure of the nucleon is so far projected into one direction only, the longitudinal one. A full understanding of the nucleon structure requires knowledge about the spatial distribution of partons in the nucleon, their orbital motion and a possible connection between their orbital motion, their spin and the spin of the nucleon.
Such a multi-dimensional space and momentum resolution of the nucleon structure is offered by the so-called Generalised Parton Distributions (GPDs), which include also the ordinary PDFs described before. These new functions allow to study a completely new aspect of nucleon structure: the localization of partons in the plane transverse to the motion of the nucleon. As such GPDs are an excellent tool for *nucleon tomography.* They can be measured in hard exclusive processes where the nucleon stays intact and all scattered and produced particles are observed.
HERMES has measured a variety of exclusive scattering processes. In this paper those of interest are the Deeply Virtual Compton Scattering (DVCS) and Bethe-Heitler (BH) processes. In the former, the incoming lepton interacts via a virtual photon with a quark inside the nucleon, which radiates a real photon. In contrast, in the competing BH process the real photon is directly radiated by the incoming or outgoing lepton, yielding no information about the structure of the target nucleon. As the final states of these processes are experimentally indistinguishable, the two processes interfere. This provides an additional interference term in the process amplitude which is a very powerful tool to access information about GPDs. This interference term can be isolated using polarization observables or different beam charges. Such analyses could be uniquely performed at HERMES using the longitudinally polarized electron or positron beams of the HERA storage ring and/or longitudinally or transversely polarized nucleon targets.
This article presents the first study of DVCS on nuclear targets. Nuclei provide a laboratory where, compared to the free nucleon, additional information can be obtained on GPDs by observing how they become modified in the nuclear environment. Therefore, studies of *nuclear* GPDs offer a new opportunity to investigate the nature of the nuclear environment.

Two processes can be distinguished for both DVCS and BH: if the target nucleus remains in its ground state the process is called coherent, while it is called incoherent if the nucleus is broken up into nucleons. The latter process is expected to be very similar to scattering on free nucleons. In constrast, coherent DVCS on nuclei has been suggested to provide new insights into the origin of nuclear effects already observed in usual inclusive DIS processes.

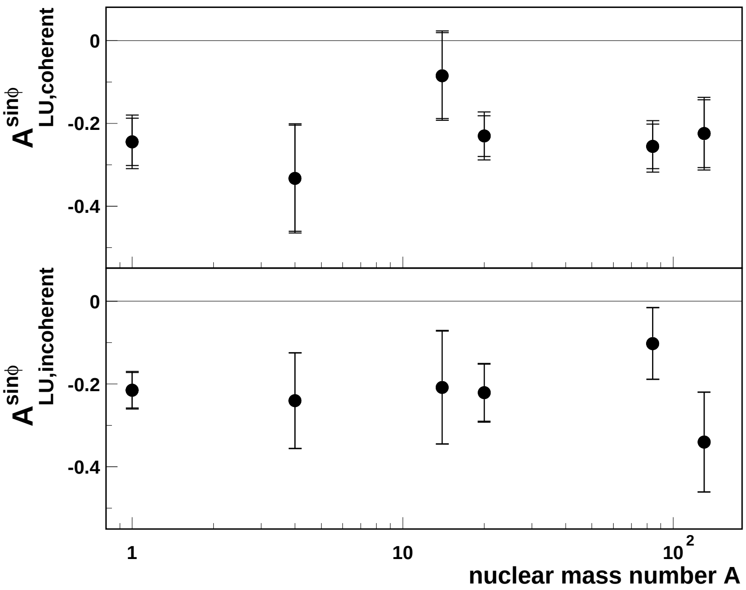

Figure 1: Nuclear mass dependence of the beam-helicity asymmetry for coherent (upper panel) and incoherent (lower panel) scattering on hydrogen, helium, nitrogen, neon, krypton and xenon.

Figure 1 presents such a DVCS observable, the beam-helicity asymmetry, as function of the nuclear mass number for both coherent (top panel) and incoherent (bottom panel) scattering. We indeed observe that incoherent scattering on nuclear targets is very similar to that on a free proton (hydrogen). It is more interesting to look at the coherent scattering process. Here, we do not observe any nuclear-mass dependence of the beam-helicity asymmetry. This is in agreement with predictions based on models which express nuclear GPDs in terms of nucleon GPDs thereby neglecting binding effects. However, the general feature of models that estimate DVCS observables for coherent scattering is the expectation of an enhancement of the nuclear DVCS observable compared to that of a free proton. Our data do not support this anticipated enhancement, indicating that the ansatz for nuclear GPDs and the neglection of binding effects to a large extend are oversimplified.