Measurement of Azimuthal Asymmetries with respect to both Beam–Charge and transverse Target–Polarization in Exclusive Electroproduction of Real Photons

The distribution of partons (quarks and gluons) in the nucleon is usually parametrized in the so-called **P**arton **D**istribution **F**unctions (PDFs). These functions depend on a resolution scale Q^2 and on x_B, which can be interpreted as the fraction of the nucleon momentum carried by a parton in the nucleon. In particular, the scattering experiments carried out at DESY led to a very precise determination of the PDFs. The lepton (electron or positron) beams of HERA were scattered off protons, whereby their energy was high enough to penetrate the proton and thus probe its quark-gluon substructure in the direction of motion of the beam. No information about the transverse distribution of quarks and gluons is encoded in the PDFs. This is different for the so-called **G**eneralized **P**arton **D**istributions (GPDs), in which the usual PDFs have been subsumed. While PDFs are measured in *inclusive* deep inelastic scattering where the proton does not stay intact, GPDs can be accessed in *exclusive* reactions in which the proton usually stays intact after the lepton-parton interaction. The difference in the momentum of the proton before and after the scattering took place is the so-called Mandelstam variable t, known from simple two-body kinematics. It accounts for the momentum difference in both the direction of the beam as well as transverse to it. GPDs also depend on the variable t and encode the proton substructure in longitudinal momentum space and in transverse position space. The ability to describe longitudinal momentum distributions as a function of transverse localization is a prerequisite for the so-called Ji-relation, which gives the relation between the low $-t$ limit of a certain combination of GPDs and the total angular momentum of a given quark species in the nucleon. The latter is unknown so far, and this in fact is the only quantitative way known today to access this quantity.

In practice, the 27 GeV leptons provided by HERA at DESY are scattered off a transversely polarized hydrogen gas target. Events are of interest in which the scattered lepton and a produced photon are observed in the HERMES detector,

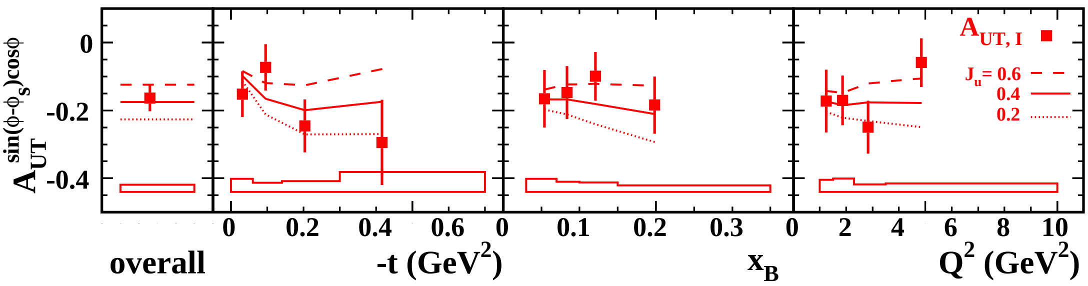

Figure 1: Azimuthal amplitude describing the $\sin(\phi - \phi_s)\cos\phi$ dependence of the interference term on the transverse target polarization. The curves are predictions based on a certain GPD model, with three different values for the u-quark total angular momentum J_u and fixed d-quark total angular momentum $J_d = 0$.

whereby special care is taken to ensure that the sample mostly contains the exclusive events in which the proton stays intact. This sample will then mostly contain events from the so-called **D**eeply-**V**irtual **C**ompton **S**cattering (DVCS) process in which the photon originates from the lepton-parton interaction, and from the **B**ethe–**H**eitler (BH) process, in which the photon is directly emitted by the lepton and thus does not contain information about the inner structure of the nucleon. Since both processes have the same final state they are subject to quantum mechanical interference. The interference part of the cross section is the one most interesting to measure, since the GPDs are most directly accessible through this interference term.

A consequence of the interference is a transverse target–spin azimuthal asymmetry (TTSA), i.e., the azimuthal distribution of the detected photons depends on the target polarization direction. The relevant azimuthal angles describing the event topology are denoted as ϕ and ϕ_s. An example for an asymmetry expected to predominantly show a $\sin(\phi - \phi_s) \times \cos\phi$ behavior is shown in Fig. 1 as a function of $-t$, x_B and Q^2. This asymmetry is sensitive to J_u, the total angular momentum of u-quarks in the nucleon, as can be seen by the comparison of the data to the curves for various values of J_u. The latter are based on calculations using a certain GPD model. A more quantitative comparison of this and other asymmetries to this and another GPD model leads to constraints in the J_u versus J_d plane shown as bands in Fig. 2. The two models give very different results, showing that the model

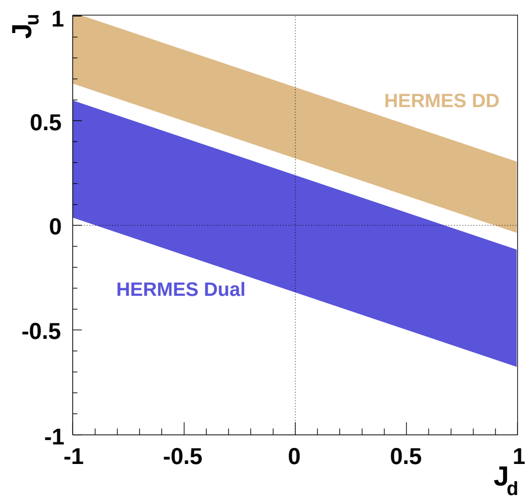

Figure 2: Model-dependent constraints on u-quark total angular momentum J_u versus d-quark total angular momentum J_d, obtained by comparing DVCS TTSA data and theoretical calculations based on two different GPD models.

uncertainty is very large as of today. However, once these and future models are tested against the results of other measurements that probe different combinations of GPDs, the data presented in this paper will contribute significantly to determine the total quark angular momentum.