GPDs from present and future measurements

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We report on the access of generalized parton distributions (GPDs) from deeply virtual Compton scattering (DVCS) measurements. We also point out that such measurements at a proposed high-luminosity electron-ion collider (EIC) provide insight in both the transverse distribution of sea quarks and gluons as well as the proton spin decomposition.

1 Introduction

During the last decade the HERA and JLAB collaborations have spent much effort to measure exclusive processes such as electroproduction of photon, vector mesons, and pseudoscalar mesons in the deeply virtual region in which the virtuality $\mathcal{Q}^2 \gtrsim 1\text{GeV}^2$ of the exchanged space-like photon allows to resolve the internal structure of the proton. In such processes one can access GPDs which can be viewed as a non-diagonal overlap of light-cone wave functions. These GPDs are intricate functions $F(x, \eta, t, \mu^2)$ that depend on the momentum fraction x, the skewness η, the t-channel momentum transfer t, and the factorization scale μ^2. Phenomenologically, they are most directly accessible at the crossover line $\eta = x$ (see below). Moreover, GPDs are related to (generalized) form factors and standard parton densities. The GPD framework opens a complementary window to address the partonic content of the nucleon. In particular, it offers the possibility to access the transverse distribution of partons and to address the decomposition of the nucleon spin in terms of quark and gluon degrees of freedom, see reviews [1].

In Sect. 2 we shortly report on the GPD extraction from present DVCS data and in Sect. 3 we study the possible impact of an proposed EIC. Finally, we conclude.

2 GPDs from present DVCS experiments

The DVCS amplitude is mostly dominated by the Compton form factor (CFF) $\mathcal{H}$ and to extract information on the associated GPD H we consider DVCS off an unpolarized proton target. The leading twist-two dominated beam spin $A_{\rm LU}^{\sin\phi}$, beam charge $A_{\rm BC}^{\cos\phi}$ and $A_{\rm BC}^{\cos(0\phi)}$ as well as azimuthal angle $\Sigma_{{\rm UU},w}^{\cos\phi}$ asymmetry data from fixed target experiments together with fit results [5] and model predictions [6] are displayed in Fig. 1. Here, *KM10*... arise from DVCS fits that include also H1/ZEUS collider data and utilize hybrid models where sea quarks and gluons are described by flexible GPD models while the valence quark GPDs are only modeled on the crossover line and dispersion relations are used for the later to evaluate the corresponding real part of the CFFs [5]. It turns out that the unpolarized cross section measurements of Hall A at

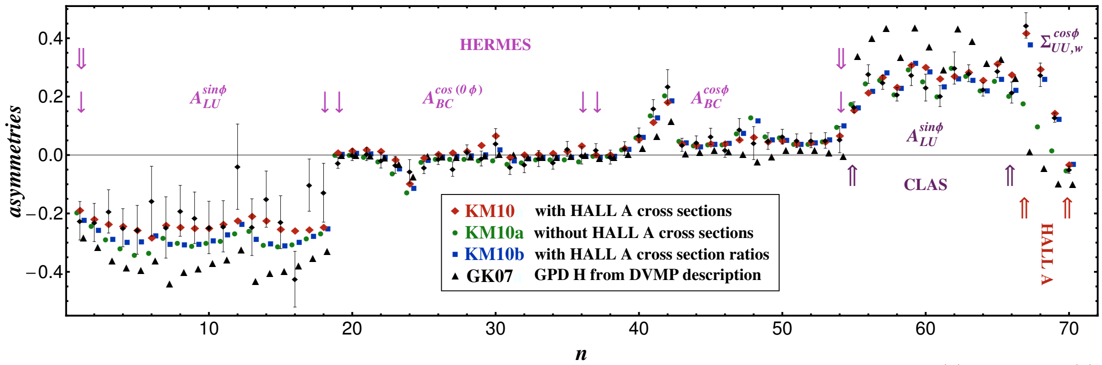

Figure 1: Measurements for fixed target kinematics labeled by data point number n: $A_{\rm LU}^{(1)}$ (1-18), $A_{\rm BC}^{(0)}$ (19-36), $A_{\rm BC}^{(1)}$ (37-54) from [2]; $A_{\rm LU}^{(1)}$ (55-66) and $\Sigma_{\rm LU}^{(1),w}$ (67-70) are derived from Refs. [3] and [4]. Hybrid model fits *KM10a* (circles, slightly shifted to the l.h.s.) *KM10b* (squares, slightly shifted to the r.h.s.) and *KM10* (diamonds) and a model prediction *GK07* (triangles-up, slightly shifted to the r.h.s.) [6].

rather large $x_{\rm B} = 0.36$ indicate a larger DVCS amplitude, which is not expected from "standard" GPD models. In the *KM10a* fit we simply neglect this data, in *KM10b* fit we form azimuthal angle asymmetries from these cross sections, and finally in the KM10 model we take these cross sections explicitly into account. All fits have χ^2/d.o.f. ≈ 1 and, especially, we describe with the *KM10* model the Hall A cross sections, where the DVCS amplitude enhancement at large $x_{\rm B}$ arises from an effective contribution that is pragmatically associated with $\widetilde{\mathcal{H}}$ and $\widetilde{\mathcal{E}}$. The results are available as executable code, providing the photon electroproduction cross section off unpolarized proton, on http://calculon.phy.pmf.unizg.hr/gpd/.

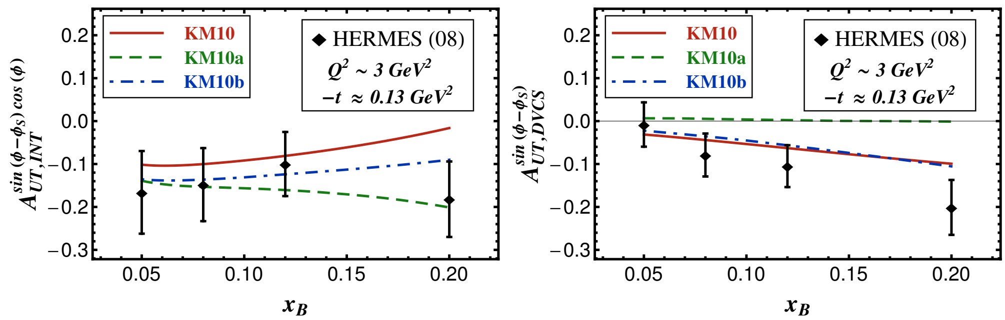

Figure 2: DVCS predictions for the single transverse target spin asymmetries from HERMES [8].

A more detailed model analysis of DVCS data, including measurements on polarized proton, is feasible and should be performed in near future. It has been illustrated in CFF fits [7] that the inclusion of measurements with a longitudinal polarized proton target provide access to the GPD $\widetilde{H}$ and simultaneously reduce the GPD H uncertainties. On the other hand, the target helicity flip GPDs E and $\widetilde{E}$ remain hidden in present measurements. The most promising observable to access GPD E is the single transverse target spin asymmetry. However, although the HERMES collaboration was able to disentangle the interference and DVCS squared terms [8], we might conclude from the fact that these measurements are partially describable with our unpolarized fits, where GPD E enters only in the real part of CFF $\mathcal{E}$, that GPD E extraction from present data suffers strongly from the correlation with the other GPDs, see Fig. 2.

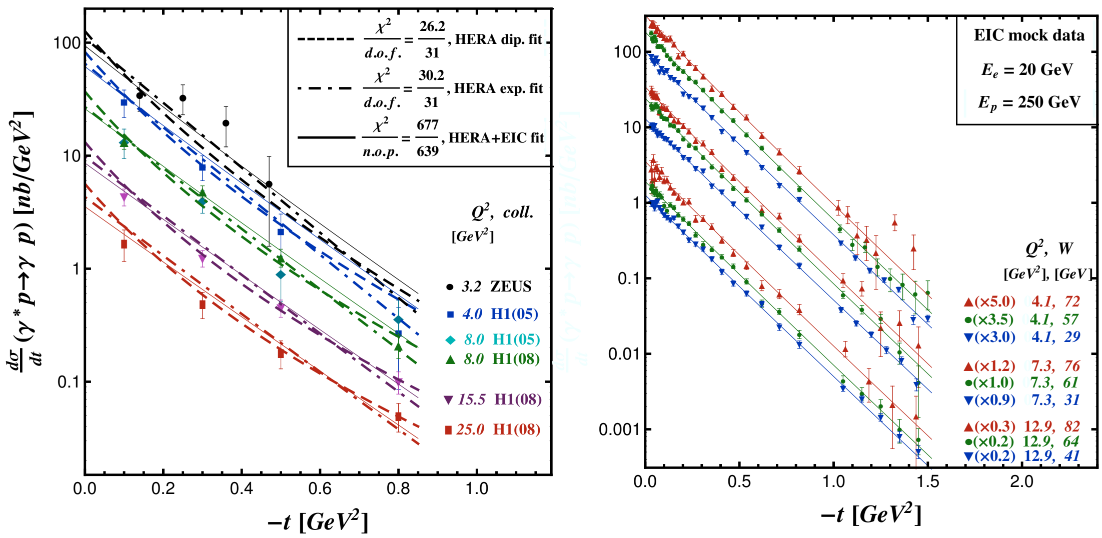

Figure 3: DVCS measurements from H1 [9] and ZEUS [10] (left) and EIC pseudo data (right).

3 Impact of planned and proposed DVCS experiments

In nearest future it is expected that new DVCS measurements will be released: beam spin asymmetry from HERMES, taken with a recoil detector, longitudinal target spin asymmetries from CLAS, and cross sections from CLAS and Hall A, see the contributions of M. Murray and D. Sokhan in these proceedings. These results will provide more constraints in a global GPD analysis; however, they will not give a full solution of the decomposition problem. Certainly, the planned high luminosity experiments at JLAB@12 GeV will help to access GPDs in the valence region. The planned COMPASS II experiments will improve the knowledge of GPD H in the region where sea quarks and gluons are getting dominant, and, hopefully, measurements on a polarized target might give insight in the small x-behavior of other twist-two GPDs. Thereby, the interesting point is whether GPD E possesses a "pomeron"-like behavior.

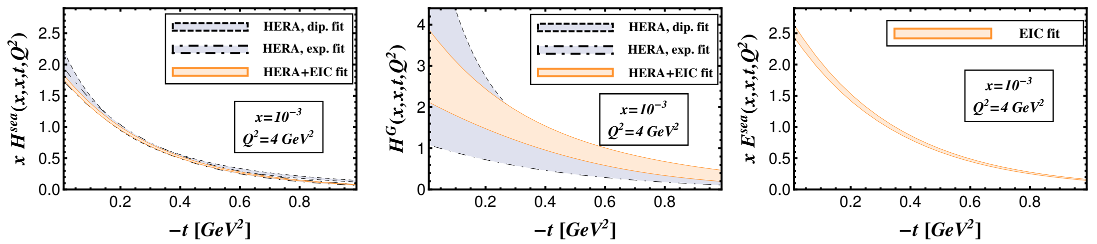

Figure 4: Fit results to H1/ZEUS (dashed and dash-dotted surrounded areas) and EIC pseudo (solid surrounded areas) DVCS cross sections, shown in Fig. 3.

In Fig. 3 we display DVCS cross section data from H1/ZEUS (left) and EIC pseudo data for an electron and proton beam energy of $E_e = 20\,GeV$ and $E_p = 250\,GeV$, respectively (right). The cross section is obtained by subtracting the BH contribution, where the interference term is negligibly small. Due to the exponential t-dependence of the CFFs, the subtraction errors are rather large at $1\,GeV^2 \lesssim -t$. For more details on data simulation, see the contributions of E. Aschenhauer and S. Fazio in these proceedings. In Fig. 4 we display the outcome of our

H1/ZEUS (dashed and dash-dotted surrounded areas) and simultaneous H1/ZEUS/EIC (solid surrounded areas) fits with flexible GPD models. Thereby, we also took EIC pseudo data for the transverse polarized target spin asymmetry $A_{\rm UT}^{\sin(\phi-\phi_S)}(\phi)$, which allows for a decomposition of GPD H and E contributions. As explained in the proceedings contribution of M. Diehl, such measurements allow for a 2D imaging of the partonic content at small x of the unpolarized and transverse polarized proton. We add that an access of GPD E in this region will provide a qualitative estimate of the angular momentum carried by sea quarks.

4 Conclusions

The first generation of hard exclusive experiments at HERA and JLAB provided us insight into the GPD description of DVCS, where GPD H could be accessed with some uncertainty. The biggest portion of these uncertainties is related to the fact that measurements on unpolarized proton do not allow for a GPD decomposition. In future GPD analyses this problem might be partially overcome, however, we expect that it cannot be fully solved. Planned and proposed experiments will have a big impact to reveal GPDs from measurements. Especially, a high-luminosity EIC offers the possibility to resolve the transverse distribution of quarks and to give a qualitative insight into the angular momentum of sea quarks.

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