Longitudinal Target-Spin Asymmetries for Deeply Virtual Compton Scattering
E. Seder *et al.* *(CLAS Collaboration)*, **Phys. Rev. Lett. 114, 032001 (2015)**

The Generalized Parton Distributions (GPDs) have emerged two decades ago as a universal tool to describe hadrons, and nucleons in particular, in terms of their elementary constituents, quarks and gluons. The GPDs combine and generalize the features of the form factors measured in elastic scattering and of the parton distribution functions obtained via deep inelastic scattering. They provide a correlation between the longitudinal momentum and the transverse position of partons in a given helicity state, and they can also give access to the contribution to the nucleon spin from the orbital angular momentum of the quarks.

Deeply virtual Compton scattering (DVCS) ($ep \to e'p'\gamma$, Fig. 1) is the simplest process to access the GPDs of the proton. In the appropriate kinematic regime ($Q^2 << M$, $-t << Q^2$), depending on the DVCS observable extracted, different sensitivities to the four GPDs (H, E, $\widetilde{H}$, $\widetilde{E}$) can be realized. For instance, the target-spin asymmetry for a longitudinally polarized proton target, $A_{\rm UL}$, is sensitive to a combination of $\widetilde{H}$ and H. Conversely, the beam-spin asymmetry measured using a polarized beam is dominated by H. While H is connected to the distribution of the electric charge in the nucleon, $\widetilde{H}$ is related to the nucleon axial charge, which expresses the probability that an axial particle (such as W, Z, a_1,...) couples to the nucleon, providing a bridge between the strong and the weak interactions.

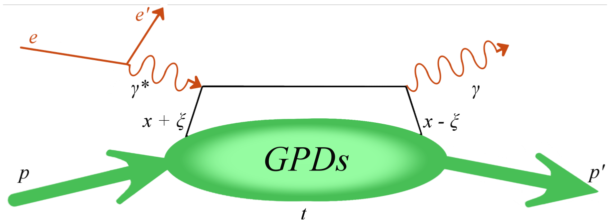

FIG. 1: The "handbag" diagram for the DVCS process on the proton $ep \to e'p'\gamma$. $t = (p - p')^2$ is the squared four-momentum transfer between the initial and final protons. ξ is proportional to the Bjorken variable x_B ($\xi \simeq \frac{x_B}{2 - x_B}$, where $x_B = \frac{Q^2}{2M\nu}$, M is the proton mass and $\nu = E_e - E_{e'}$).

This paper presents results of $ep \to ep\gamma$ longitudinal target-spin asymmetries obtained, for the first time, over a large phase space and in four-dimensional bins in Q^2, x_B, t, and ϕ, the angle formed by the leptonic and hadronic planes. The data were taken in Hall B at Jefferson Lab in 2009, using a polarized electron beam with an average energy of 5.932 GeV that impinged on a solid, dynamically-polarized 1.5-cm-long ammonia target. The scattered electron, the recoil proton, and the photon were detected in the CEBAF Large Acceptance Spectrometer (CLAS).

$A_{\rm UL}$ was measured for 166 bins in Q^2, x_B, $-t$ and ϕ, with an average statistical precision of $\sim$ 25%, which largely dominates the systematic uncertainties. The ϕ dependence of the obtained asymmetries was studied. Interpreting this result in the GPD framework, the dominance of the handbag mechanism can be observed via the prevalence of the $\sin\phi$ term, especially at low t and high Q^2. The t slope of the asymmetry (Fig. 2), shallower with respect to that of the beam-spin asymmetry in the same kinematic range, suggests that the axial charge is more focused in the center of the proton than the electric charge. Predictions of four GPD-based models are in qualitative agreement at low Q^2-x_B and $-t$ with the data, but fail to predict the correct t dependence of the data in the other kinematics, proving the importance of our results to improve the parametrizations of the GPD $\widetilde{H}$. These data, combined with the beam-spin asymmetry results from CLAS and with the double-spin asymmetry obtained using this same data set, will bring strong constraints for model-independent extractions of GPDs.

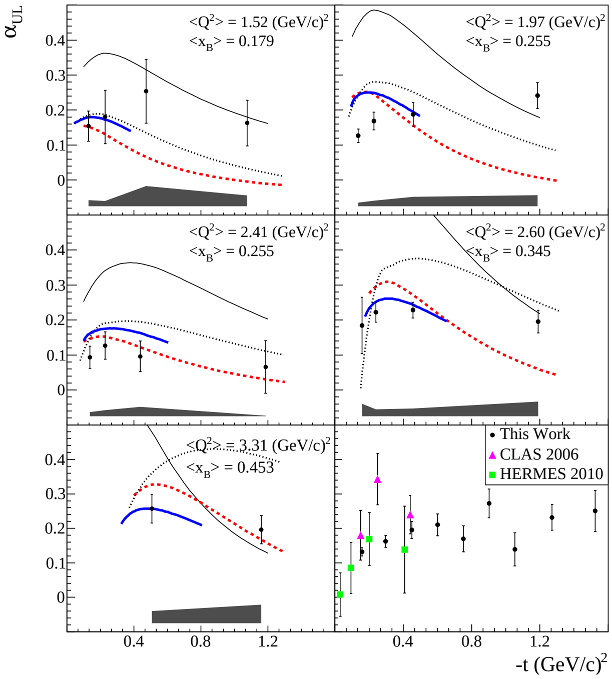

FIG. 2: First five plots: $-t$ dependence of the $\sin\phi$ amplitude of $A_{\rm UL}$ for each Q^2-x_B bin. The shaded bands represent the systematic uncertainties. The curves show the predictions of four GPD models: i) VGG (red-dashed), ii) GK (black-dotted), KMM12 (blue-thick solid), GGL (black-solid). Bottom right plot: comparison of the $\sin\phi$ amplitude of $A_{\rm UL}$ as a function of $-t$ for the results of this work (black dots) integrated over all Q^2 and x_B values ($\langle Q^2\rangle = 2.4$ (GeV/c)^2, $\langle x_B\rangle = 0.31$), the HERMES results (green squares) at $\langle Q^2\rangle = 2.459$ (GeV/c)^2, $\langle x_B\rangle = 0.096$, and the previously published CLAS results (pink triangles), at $\langle Q^2\rangle = 1.82$ (GeV/c)^2, $\langle x_B\rangle = 0.28$.