PROCEEDINGS OF SCIENCE

DVCS on a polarised proton target at CLAS12

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Measuring Deeply Virtual Compton Scattering (DVCS) is crucial to the study of Generalised Parton Distributions (GPDs). GPDs provide a description in 3D of the position and momentum of quarks and gluons inside the nucleon, which is essential to understand how its global properties emerge. The extraction of GPDs necessitates high precision measurements of multiple observables on a wide kinematic range. The CLAS12 experiment at JLab uses the upgraded 10.5 GeV polarised electron beam, allowing for the exploration of a broad kinematic range in the valence region with high statistics. This work presents preliminary analysis of DVCS spin asymmetry observables from the first longitudinally polarised proton target experiment at CLAS12.

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1. Introduction

Generalised Parton Distributions (GPDs) encode the 3D structure of the nucleon in terms of its constituents, quarks and gluons. They describe the correlation between longitudinal momentum distribution and transverse position of partons in the nucleon, thus linking parton distribution functions (PDFs) and nucleon form factors. They are a valuable tool to understand how global properties of the nucleon such as its mass and spin can emerge from the underlying quarks and gluons. At leading order and leading twist, there are four GPDs required to describe the nucleon; two unpolarised (H, E), and two spin dependant ones ($\tilde{H}$, $\tilde{E}$).

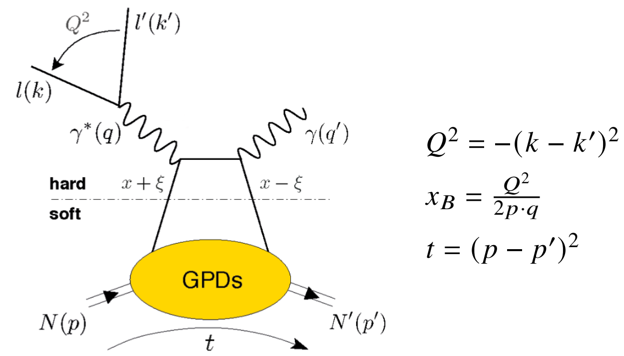

Figure 1: Handbag diagram for the DVCS process.

GPDs can be accessed in hard scattering experiments via exclusive processes such as the Deeply Virtual Compton Scattering (DVCS) process $eN \to e'N'\gamma$ [1], where a virtual photon is exchanged between the electron and a quark in the nucleon, a real photon is emitted, and the nucleon remains intact. In the Bjorken regime (large virtual photon momentum and small momentum transferred to the nucleon), DVCS can be factorised into a hard scattering part, computed in perturbative QCD, and a soft part that is described by GPDs see Fig. 1. The DVCS process is undistinguishable from Bethe-Heitler (BH) process, where the real photon is emitted by the incoming or the scattered electron. Therefore, the exclusive photon electroproduction amplitude is the sum of the squared DVCS and BH amplitudes plus an interference term. The interference term gives rise to spin asymmetries that can be expressed in terms of Compton Form Factors (CFFs), which are convolutions of GPDs with the hard kernel. A wide experimental program is ongoing to measure DVCS observables with high precision on a large kinematic range, which is essential to the extraction of GPDs [2].
The beam spin asymmetry (A_{LU}) and target spin asymmetry (A_{UL}) on a proton target give access to the imaginary part of H and $\tilde{H}$ CFFs in different linear combinations, by measuring both the two contributions can be separated. The work presented here aims at measuring the asymmetries in the valence region, expanding the kinematic range of previous measurements [3] to the upgraded Jefferson Lab kinematics.

2. CLAS12 polarised target experiment at Jefferson Lab

The data presented in this work was collected at Jefferson Lab with the CEBAF 12 GeV electron beam, which is able to achieve beam polarisations of 85% [4]. The experiment was carried out

with the CLAS12 detector located in Hall B [5]. The large acceptance of CLAS12 allows for the detection of all three outgoing particle in the DVCS process simultaneously.
The experiment took data from June 2022 to March 2023 with the first longitudinally polarised target at CLAS12. A new target called APOLLO (Ammonia POLarized LOngitunally) [6] was specifically designed for the experiment. It is a cryogenic solid target able to dynamically polarise hydrogen or deuterium in an ammonia sample, and it was able to provide an average proton polarisation of around 80%. However, only the free protons in the NH_3 molecules are polarised, therefore the nitrogen constitutes a source of unpolarised background that needs to be accounted for in the analysis. To estimate it, the target is also able to hold a carbon and a polyethylene target that are designed to mimic the aerial density of the NH_3 samples. The data presented here is from the summer 2022 run, which totals about half of the expected DVCS statistics collected on the polarised proton target.

3. Event selection

The first step in the analysis is to select events with an electron, a proton and at least a photon reconstructed. Then all particles must pass particle identification and fiducial cuts to ensure that they were reconstructed in areas of the detector with optimal resolution and efficiency. DVCS events are then selected by taking advantage of the fact that the detector is able to measure all particles in the final state to build exclusivity variables. For instance, the total missing mass of the process is defined as the invariant mass of the difference between all the initial and final state particles. In an exclusive event, if no particle is missing and all particles are properly reconstructed it should be consistent with zero. We define six such variables and require them to be within a certain range to select DVCS events. The distribution of each variable on the NH_3 target is compared to the distribution obtained on the carbon target that mimics the contribution from the nitrogen nuclear background. The ranges are then chosen to reject the nuclear background as much as possible. The distributions for some exclusivity variables are shown in Fig. 2.

The remaining nuclear background is accounted for by scaling the target spin asymmetry by a dilution factor D_f. It measures the fraction of all DVCS events that are coming from the polarised free protons in the NH_3 target. It is defined as :

$$D_f = 1 - \frac{N_C}{N_{NH3}}$$

where N_C and N_{NH3} are the yields on the Carbon and NH_3 targets respectively, normalised by the beam charge accumulated on each. Here we assume that the two different target types have the same effective shape and density, which may not be exactly the case. Further studies are ongoing to measure a more accurate dilution factor and evaluate the systematic uncertainty associated.
The dilution factor is found to be stable as a function of the different relevant kinematic variables, therefore a single value $D_f = 89 \pm 1\%$ is used for all the bins.

4. π^0 Background subtraction

Once the exclusivity cuts are applied, the main background remaining comes from $\pi^0 \to \gamma\gamma$ decays. When one of the two photons is energetic enough, it can pass the DVCS event selection to

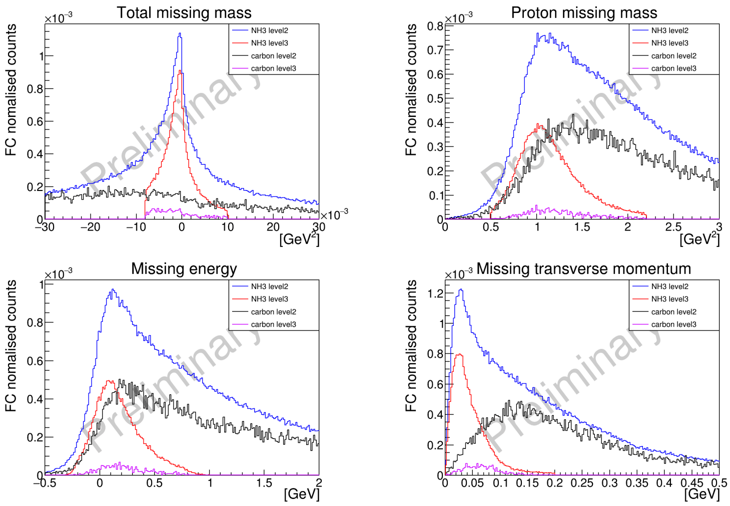

Figure 2: Distributions of some exclusivity variables used for event selection, on both NH_3 and Carbon targets. The two datasets are normalised by the beam charge accumulated on each. The level2 cuts refer to wide preliminary cuts applied to make the peaks more visible. The level3 cuts are the final cuts used to select DVCS events.

become a DVCS candidate. Depending on the decay angle, one photon can carry a large fraction of the momentum after the Lorentz boost, making the event appear exclusive within the detector resolution and therefore able to pass the exclusivity cuts. Since the π^0 production cross-section is higher than the DVCS cross-section in some region of the phase space, this background represents a significant fraction of the DVCS sample.

To subtract this background we choose to apply the method used in the CLAS12 DVCS beam-spin asymmetry measurement with an unpolarised target [7]. The first step is to select a wide sample of $ep \rightarrow e'p'\pi^0$ events, that includes exclusive but also semi-inclusive (SIDIS) events coming both from the polarised protons and from the nuclear background in the target. We then simulate the decay of each π^0 in the sample a thousand times and run the decays through the Geant4 simulation of the detector keeping the detected electron and proton from the data event. The π^0 and DVCS cuts are applied to the output, and we can compute the acceptance ratio of decays reconstructed as DVCS events over decays reconstructed as π^0 events. This allows us to estimate the fraction of false DVCS events in the data sample coming from π^0 decays, we find a contamination of up to 55% in some kinematic bins.

5. Results

The beam spin (A_{LU}) and target spin (A_{UL}) asymmetries can now be computed as :

$$A_{LU} = \frac{1}{P_B}\frac{P_t^-(N^{++}-N^{-+})+P_t^+(N^{+-}-N^{--})}{P_t^-(N^{++}+N^{-+})+P_t^+(N^{+-}+N^{--})}, \qquad A_{UL} = \frac{1}{D_f}\frac{N^{++}+N^{-+}-N^{+-}-N^{--}}{P_t^-(N^{++}+N^{-+})+P_t^+(N^{+-}+N^{--})}$$

where P_B is the beam polarisation, $P_t^\pm$ is the target polarisation, and N^{bt} is the corrected

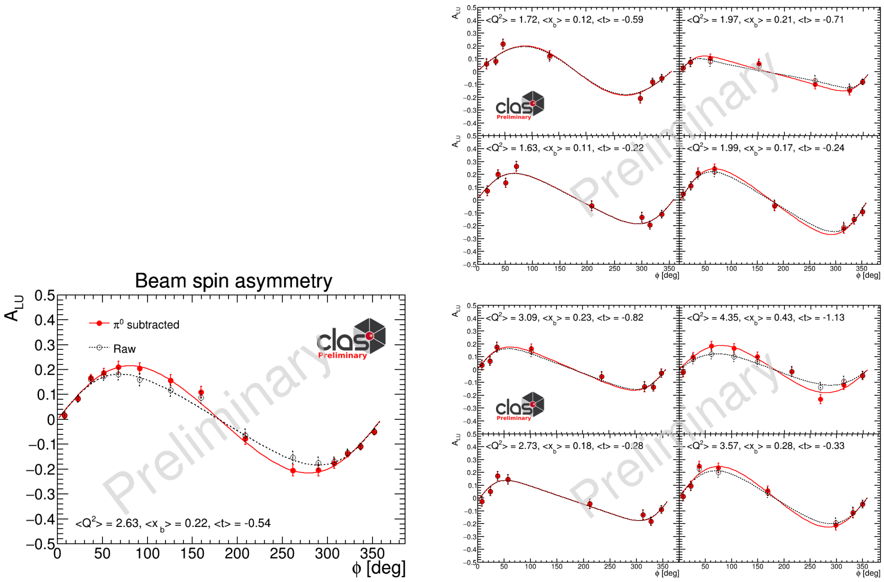

Figure 3: Beam spin asymmetry A_{LU} as a function of ϕ, integrated (left) and binned in Q^2 x_B and t (right), only statistical errors are included. The points are fitted with an approximation of the A_{LU} behaviour at leading order leading twist: $a\sin(\phi)/(1 + b\cos(\phi))$.

number of events with beam polarisation b and target polarisation t, defined as:

$$N^{bt} = \frac{Y^{bt}}{\mathrm{FC}^{bt}}(1 - R^{bt})$$

where Y^{bt} is the raw yield of events, FC^{bt} is the accumulated beam charge sent on the target in that spin configuration and R^{bt} is the π^0 contamination fraction.
The asymmetries are computed in bins of Q^2, x_B and t chosen to have the same number of events. Each bin is then further binned in ϕ, the angle between the leptonic and hadronic plane. The results are shown in Figs. 3 and 4. It is important to note that the results are preliminary and only include statistical uncertainties, therefore no comparison with theory models or with previous measurements has been performed yet.
The asymmetries do display the characteristic sinusoidal shape as a function of ϕ that is expected from the interference between the DVCS and BH amplitudes. Figures 3 and 4, also show the asymmetries before and after π^0 background subtraction. The background clearly dilutes the asymmetries, which is expected because the π^0 asymmetries are small compared to the DVCS ones.

6. Conclusion

This work presents preliminary results for the first measurement of DVCS beam and target spin asymmetries with a longitudinally polarised proton target at CLAS12. At this stage the analysis takes into account the nuclear and π^0 backgrounds, and shows promising results with only half of the DVCS statistics collected currently analysed. Further studies are ongoing to measure the impact of the nuclear background more accurately, validate the π^0 background subtraction and estimate systematic uncertainties.

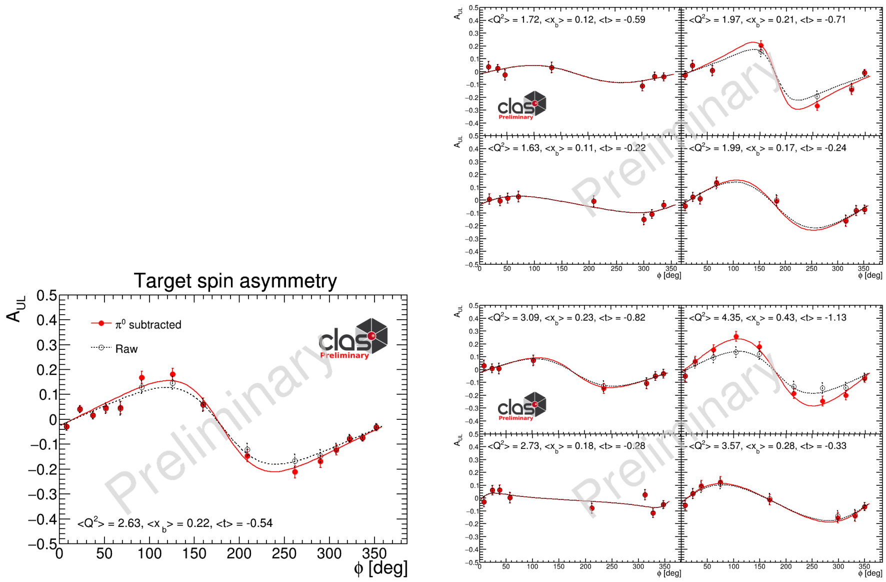

Figure 4: Target spin asymmetry A_{UL} as a function of ϕ, integrated (left) and binned in Q^2 x_B and t (right). Only statistical errors are included.

References

[1] M. Guidal, H. Moutarde and M. Vanderhaeghen, *Generalized parton distributions in the valence region from deeply virtual compton scattering*, *Reports on Progress in Physics* **76** (2013) 066202.

[2] N. D'Hose, S. Niccolai and A. Rostomyan, *Experimental overview of Deeply Virtual Compton Scattering*, *The European physical journal. A, Hadrons and Nuclei* **52** (2016) 151.

[3] S. Pisano, A. Biselli, S. Niccolai et al., *Single and double spin asymmetries for deeply virtual compton scattering measured with clas and a longitudinally polarized proton target*, *Physical Review D* **91** (2015) .

[4] P.A. Adderley, S. Ahmed, T. Allison, R. Bachimanchi, K. Baggett, M. BastaniNejad et al., *The continuous electron beam accelerator facility at 12 gev*, *Phys. Rev. Accel. Beams* **27** (2024) 084802.

[5] V.D. Burkert et al., *The CLAS12 Spectrometer at Jefferson Laboratory*, *Nucl. Instrum. Meth. A* **959** (2020) 163419.

[6] P. Pandey, *Longitudinal Solid Polarized Target for CLAS12 and Study of Spin Structure of Nucleons*, Ph.D. thesis, Old Dominion U. (main), 2024. 10.25777/jmae-c846.

[7] G. Christiaens, M. Defurne, D. Sokhan et al., *First clas12 measurement of deeply virtual compton scattering beam-spin asymmetries in the extended valence region*, *Phys. Rev. Lett.* **130** (2023) 211902.