Target Spin Asymmetry Measurements
for Deeply Virtual Compton Scattering on Polarized Protons

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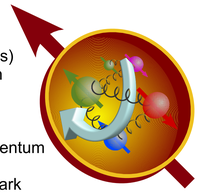
Motivation



Generalized Parton Distributions (GPDs) provide a unified description of nucleon structure

They contain information such as:
- the quark orbital angular momentum contribution to nucleon spin
- wave functions for different quark configurations in a hadron
- transverse parton distributions, etc...

Deeply Virtual Compton Scattering (DVCS) is the simplest process that can be described in terms of GPDs

Measurement of DVCS spin observables allow for extraction of GPDs from experimental data

The CLAS eg1-dvcs experiment measured spin observables:
A_{UL} : Target Spin Asymmetry
A_{LL} : Double Spin Asymmetry
Combined with the CLAS e1-dvcs experiment measured spin observables:
A_{LU} : Beam Spin Asymmetry
σ : Unpolarized cross section
Allows for model independent extraction of GPDs

The **Target Spin Asymmetry** is related to cross section as:

$$A_{UL}=\frac{d\sigma^{\uparrow}-d\sigma^{\downarrow}}{d\sigma^{\uparrow}+d\sigma^{\downarrow}}=\frac{\Delta\sigma}{2\sigma}$$

$\uparrow\downarrow$ are the different target polarization states

Deeply Virtual Compton Scattering (DVCS)

"Deeply Virtual Compton Scattering", in this context, involves a virtual photon exchange between an incident electron and proton target and an emission of a real photon by the scattered proton. This process is shown in Figure (a).

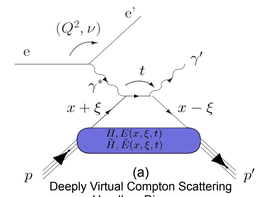
In the QCD leading twist and leading order approximation, there are four independent GPD's **H**, **E**, $\tilde{\mathbf{H}}$ and $\tilde{\mathbf{E}}$.

GPDs are currently of great interest because they contain new information, including longitudinal momentum – transverse space correlations.

The appearance of GPDs in exclusive processes, like DVCS, is established by factorization theorems[1] .

$$Q^2=(e'-e)^2,$$
$$t=(p-p')^2$$
$$\xi\approx\frac{x_B}{2-x_B},$$
$$x_B=\frac{Q^2}{2m\nu},$$
$$\nu=E_{e'}-E_e,$$
$$\underbrace{x+\xi, x-\xi}$$

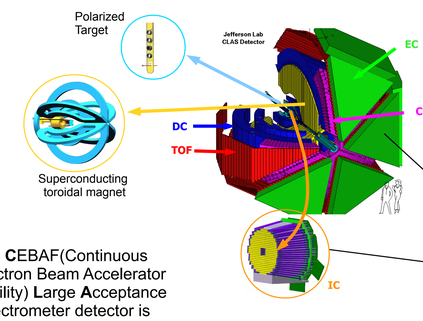
Longitudinal momentum fractions of the initial and final quark (antiquark) respectively



(a)
Deeply Virtual Compton Scattering Handbag Diagram

[1] J. C. Collins, L. Frankfurt and M. Strikman, Phys. Rev. D **56** (1997) 2982; J. C. Collins and A. Freund, Phys. Rev. D **59** (1999) 074009.

CLAS Detector



Charged-particle angle	$15° \le \theta \le 45°$
Charged-particle momentum	$p \ge 0.3$ GeV/c
Photon Angle (EC)	$15° \le \theta \le 45°$
Photon Angle (IC)	$3° \le \theta \le 15°$
Photon Energy	$E_\gamma \ge 0.1$ GeV/c

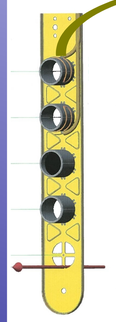
Lab angle coverage of photons using CLAS and IC

The **C**EBAF(Continuous Electron Beam Accelerator Facility) **L**arge **A**cceptance **S**pectrometer detector is built around a six-coil toroidal magnet which defines 6 sectors.
Each sector is equipped with 4 different detectors:

- **Drift Chambers (DC)** – determine the path of charged particles
- **Cherenkov Counters (CC)** – distinguish electrons from pions
- **Time of Flight Counters (TOF)**– position and time of charged particles
- **Electromagnetic Calorimeters (EC)** – very accurate energy measurement, used as event trigger

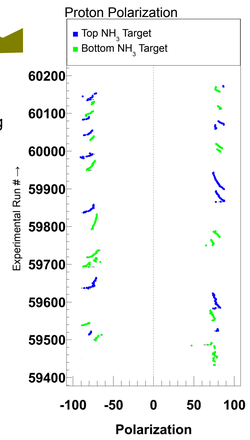
For improved angular photon coverage, an **Inner Calorimeter (IC)** was installed in the center of CLAS for the eg1-dvcs experiment.

Polarized Proton Target



NMR Measurement

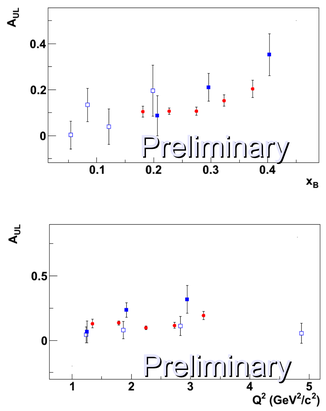
- $^{14}NH_3$ target material
- Cooled to ~ 1 Kelvin using evaporative cooling on LHe
- Surrounded by a 5 Tesla superconducting magnet
- Continuously polarized using Dynamic Nuclear Polarization (DNP)
- Polarization during the experiment was monitored by Nuclear Magnetic Resonance (NMR) measurement →

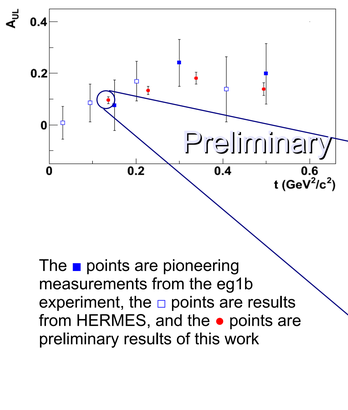


- The target insert (shown above left) held 4 targets for use in the eg1-dvcs experiment: 2 polarized NH_3 targets, 1 carbon target, and 1 empty target cup.
- Average achieved proton polarization ~ 85%.

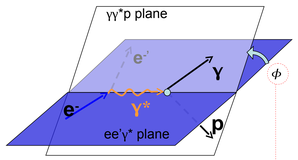
DVCS Target Spin Asymmetry Measurements

The plots below show preliminary results of the Deeply Virtual Compton Scattering (DVCS) Spin Asymmetry $\mathbf{A_{UL}}$'s t , x_B, Q^2, and ϕ dependence.

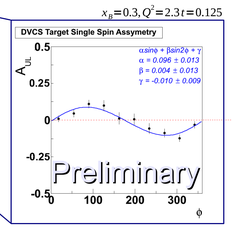




The ■ points are pioneering measurements from the eg1b experiment, the □ points are results from HERMES, and the ● points are preliminary results of this work



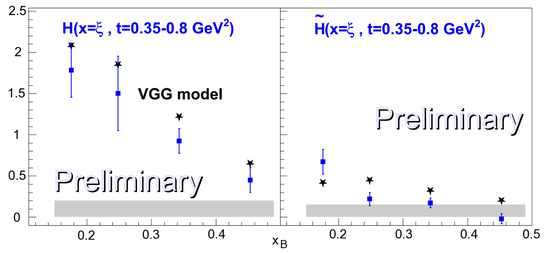
DVCS reaction frame



Φ dependance of A_{UL} for 1 bin in t

Model Independent GPD Extraction

For the plot shown below, the blue ■ points are the The Vanderhaeghen, Guichon and Guidal (VGG) GPD preliminary **H** and $\tilde{\mathbf{H}}$ results using extracted Compton Form Factors (CFFs) $\mathcal{H}_{Im}$, and $\tilde{\mathcal{H}}_{im}$ produced using the eg1-dvcs preliminary spin asymmetries shown above, combined with the e1-dvcs results.



The VGG program extracts Compton Form Factors by simultaneously fitting the CLAS DVCS observables, $\mathbf{A_{UL}}$, A_{LL}, A_{LU} , and σ

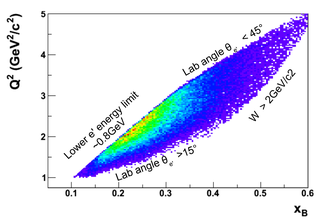
From these CFFs one can recover GPDs for a given kinematic regime, as shown on the above plot.

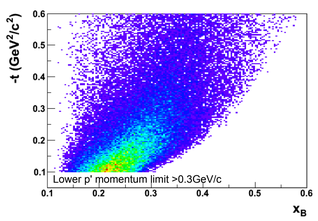
The black ★ points on the plot are from the VGG model prediction of GPD **H** and $\tilde{\mathbf{H}}$, produced using a next to leading order QCD analysis of inclusive polarized deep-inelastic lepton-nucleon scattering [2]

[2] M. Vanderhaeghen, P. A. M. Guichon, and M. Guidal, Phys. Rev. D 60, 094017 (1999)

Kinematic Coverage

Pictured to the right are the available kinematic coverages of CLAS at 6 GeV. Binning in these variables allows for the extraction of their dependence within the target single spin asymmetry.





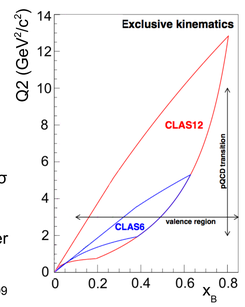
- **Q^2** - Squared momentum transfer at the electron vertex.
- **x_B** - Bjorken scaling variable: Fraction of the proton momentum carried by the struck parton.
- **t** - Squared momentum transfer at the proton vertex.

Outlook

Results of A_{UL} shown are preliminary, further studies are underway, including:
- π^0 contamination
- Simulation
- Systematic error

Model independent GPD extraction from spin observables A_{UL}, A_{LL}, A_{LU} , and σ from eg1-dvcs and e1-dvcs experiments is on the way

The CLAS12 upgrade will allow for DVCS measurements over a much greater range of kinematics →



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