DVCS spin asymmetries on the proton with the CLAS detector

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# Introduction

**Motivation**  
DVCS and GPDs - nucleon structure

**Experiment**  
CEBAF@Jefferson Lab, CLAS (Hall B)  
Inner Calorimeter (IC), polarised target

**Analysis**  
particle ID & data cuts, asymmetries  
maximum likelihood fitting method

**Results**  
previous, preliminary

**Future**  
Eg1dvcs, CLAS12
Motivation

DVCS provides a means to access GPDs

- Deeply Virtual Compton Scattering (DVCS) is the hard exclusive leptoproduction of photons.

\[ lN \rightarrow l'N'\gamma \]

- Generalised Parton Distributions (GPDs) describe nucleon structure in terms of correlated momentum and position distributions of partons.
Motivation

Deeply Virtual Compton Scattering

$Q^2$ large, fixed $x$

Bjorken scaling regime: “handbag approximation”

- Lepton interacts with a single quark in the nucleon through the exchange of a virtual photon.

- Factorisation: hard scattering + parameterisation
  (calculable) (measured)
Motivation

Generalised Parton Distributions

**Form Factors**
- Spatial distributions of currents and charges

**Elastic Scattering**

**Parton Distribution Functions**
- Momentum distributions of quarks and gluons

**Deep Inelastic Scattering**

**Generalised Parton Distributions**
- Correlated position and momentum distributions of quarks and gluons

Image adapted from Belitsky, Mueller 2002
Nuclear hologram with exclusive leptoproduction
Experiment

Jefferson Lab - US department of energy funded nuclear research facility

CEBAF Large Acceptance Spectrometer (CLAS) in experimental Hall B
Motivation o Experiment
o Analysis
Results o Future
Experiment

Electromagnetic Calorimeters for primary electron triggering, pion rejection & neutral particle detection

Longitudinally polarised electron beam (~80%) with energies up to 6 GeV

Drift Chambers for track reconstruction and particle ID

Cherenkov Counters for electron ID

Scintillation Counters (TOF)
**Experiment**

- **EG1DVCS** data acquired  
  14 02 09 - 16 03 09 A  
  23 04 09 - 15 06 09 B  
  21 08 09 - 21 09 09 C

- **NH$_3$** and **ND$_3$** longitudinally polarised targets  
  proton polarisation ~%80  
  10% $^{12}$C for background studies

- Inner Calorimeter added to the CLAS detector system to accommodate photon detection at smaller angles
Experiment

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![Target cells](Image from S.Chen CLAS thesis 2006)

![DVCS photon scattering angle from MC simulation](Image from S.Chen CLAS thesis 2006)
Analysis

Particle ID and data cuts - electrons

- Momentum
  Drift Chambers (DCs) $\delta p/p \sim 1\%$
  low momentum particle events rejected

- $\pi^-$ rejection
  Cherenkov Counter - minimum number of photoelectrons
  Electromagnetic Calorimeter - minimum energy, $0.2 < E/p < 0.4$

- Fiducial Cuts
  Hits in low efficiency regions are removed (EC,DCs)
Analysis

Particle ID and data cuts - protons

- $\pi^+, d^+, \ldots$ rejection

\[
\Delta \beta = \frac{d_{TOF}}{c t_{TOF}} - \frac{p}{\sqrt{p^2 + m^2}}
\]

\[
\Delta t = \frac{d_{TOF} \sqrt{p^2 + m^2}}{c p} - t_{TOF}
\]

- Fiducial Cuts
  Hits in low efficiency regions are removed (DCs)
Analysis

Particle ID and data cuts - photons

- neutron rejection in EC
  \( \beta \) calculated using EC time of flight

- Fiducial Cuts
  Hits in low efficiency regions are removed (EC, IC)
Analysis

Particle ID and data cuts - exclusivity

- select region of phase-space where DVCS contribution is large compared with background processes: Bethe-Heitler, reactions on Nitrogen, $\pi^0$ production

$$E_{\gamma}^{\text{min}} \approx 2.5 \text{ GeV}$$

$$\Delta \phi^{\text{max}} = \phi_{p'} - \phi_{\gamma} \approx 2^\circ$$

$$|MM_{X}^{e}p'\rightarrow e'p'\gamma|^2 \approx 0.2 \text{ GeV/c}^2$$

$$\theta_{\gamma\gamma'}^{\text{max}} \approx 1^\circ$$
Analysis

Asymmetries

Longitudinal Target Spin Asymmetry

\[ A_{UL} = \frac{d\sigma^{\Rightarrow} - d\sigma^{\Leftarrow}}{d\sigma^{\Rightarrow} + d\sigma^{\Leftarrow}} \propto \left[ s_{1,LP}^{DVCS} + s_{1,LP}^{I} \right] \sin\phi + \left[ s_{2,LP}^{DVCS} + s_{2,LP}^{I} \right] \sin 2\phi \]

- asymmetries formed from different combinations of beam and target polarisations are sensitive to different GPDs (via Compton Form Factors).

- easier to measure than cross-sections since some systematic uncertainties cancel in the ratio and the opposite coupling of BH terms to the polarisation causes DVCS and interference terms only to remain.
Analysis

Data fitting methods

Least squares fitting method
• minimise chi-squared

Extended Maximum Likelihood
• \( \frac{\partial (\ln L)}{\partial \theta} = 0 \)

\[
\chi^2 = \frac{1}{n} \sum_{i=0}^{n} \left[ \frac{y - f(x_i | \theta)}{\sigma_i} \right]^2
\]

\[
L = \frac{\mu^n e^{-\mu}}{n!} \prod_{i=1}^{n} p(x_i | \theta)
\]

- \( \mu = \mu(\theta) \): expectation value

No binning in \( \phi \)
Simultaneous \( A_{UL}, A_{LL} \) extraction
Cross-check with least-squares
- one less systematic error
- correlated errors
- independence of fitting procedure
Results

Previous

Target Spin Asymmetry EG1B group (S. Chen thesis 2006)

\[ p_0 \sin \phi + p_1 \sin 2\phi \]

\[ p_0 = 0.252 \pm 0.041 \]
\[ p_1 = -0.022 \pm 0.045 \]

MRST02 model prediction

same as above with \( H = 0 \)

Preliminary
Future

Eg1dvcs
- Pass 1 cooking: in progress.
- Maximum Likelihood fit to asymmetries.
- Simulation to determine background contribution.
- 10x increase in statistics will allow study of DVCS variable dependencies of Asymmetries and reduced statistical errors.

CLAS12
- Upgrade of CLAS to coincide with CEBAF electron beam upgrade to 12 GeV
  - first experiments in 2015
- Larger $Q^2$ for DVCS and DVMP
- Neutron DVCS with Central Neutron Detector
DVCS spin asymmetries on
the proton with the CLAS
detector

Thanks
Backup Slide

Correlation Matrix

- Size of box represents size of correlation.

- Filled (open) squares are positive (negative) values.