First data on Deeply Virtual Compton Scattering with CLAS12 at 10.6 GeV Electron Beam

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Tomography of the nucleon

Generalized Parton Distributions
(Fourier transformed)

3 dimensional

Longitudinal momentum
\[ k^+ = x P^+ \]

Transverse position

A. Bacchetta
Tomography of the nucleon

\[ \rho(x, \vec{r}_\perp) = \int \frac{d^2 \Delta_\perp}{(2\pi)^2} e^{-i \Delta_\perp \cdot \vec{r}_\perp} H(x, \xi = 0, t = -\Delta_\perp^2) \]

- \( t = \Delta^2 \): momentum transfer to the target
- Skewness: \( \xi = -\Delta^+ / (2P^+) \)
- Fourier transformation gives us the distribution in \( r_\perp \) and \( x \)

GPDs give access to parton total angular momentum

Ji’s sum rule:

\[ J^q = \frac{1}{2} \int_{-1}^{+1} dx \ x (H^q(x, \xi, 0) + E^q(x, \xi, 0)) \]

Also: mechanical properties and gravitational form factors

Deeply Virtual Compton Scattering

- DVCS amplitude gives access to GPDs through Compton Form Factors

\[ \mathcal{H} = \int_{-1}^{1} H(x, \xi, t) \left( \frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon} \right) dx \]

- Experimentally, one measures exclusive lepto-production of a photon.
- Two competing processes:
  - DVCS
  - Bethe-Heitler (BH)

\[ \sigma(e + p \rightarrow e + p + \gamma) = |DVCS|^2 + |BH|^2 + \text{Interference} \]
DVCS: beam spin asymmetry

- Extraction of GPDs from DVCS with polarized lepton beam and unpolarized target
- Beam spin asymmetry:
  \[ A_{LU} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \]
- At leading order:
  \[ A_{LU} \approx \frac{A \sin(\phi_{Trento})}{1 + B \cos(\phi_{Trento})} \]
  where:
  \[ A = \frac{s_1'}{k c_0^{BH} + c_0'}, \quad B = \frac{k c_1^{BH} + c_1'}{k c_0^{BH} + c_0'} \]
  and \( s_1', c_0', c_1' \) are combinations of Compton Form Factors
  \( \phi_{Trento} \): angle between lepton and proton-\( \gamma \) planes
CLAS12 at Jefferson Lab

CEBAF at Jefferson Lab.
- Upgraded to 12GeV electron beam energy
- High longitudinal polarization, > 80%
- High currents

New large acceptance spectrometer in Hall B: **CLAS12**
- Data taking started in 2018
- Electron energy: 10.6 GeV
• CLAS12 is a package of two complementary spectrometers
• The central detectors in a solenoid field up to 5 Tesla
• The forward detectors around a toroidal field up to 3.6 Tesla

Forward Detector (FD):
• TORUS magnet
• Drift chamber system
• HT Cherenkov Counter
• LT Cherenkov Counter
• Forward ToF System
• Preshower calorimeter
• E.M. calorimeter
• RICH detector

Central Detector (CD):
• SOLENOID magnet
• Barrel Silicon Tracker
• Micromegas tracker
• Central Time-of-Flight
• Central Neutron detector

Forward Tagger (FT):
• Calorimeter at very small angles (< 5°)
CLAS12 extends kinematic coverage at high-x high $Q^2$

Focus here on unpolarized proton target data with $E_e = 10.6\,\text{GeV}$

Electron polarization higher than 85%
DVCS in CLAS12

- Electron: measured in the Forward Detector or in the Forward Calorimeter
- Photon: in the FT (or FD) calorimeter
- Proton: most often in the Central Detector
DVCS in CLAS12: kinematics and particle selection

- Well identified final states
- Electron: $E_e > 2\text{GeV}$
- High energy photon: $E_\gamma > 3\text{GeV}$
- Kinematic cuts:
  - Virtuality: $Q^2 > 1\text{GeV}^2$
  - Inv. mass of hadronic final state: $W^2 > 4\text{GeV}^2$
DVCS in CLAS12: exclusivity

Exclusivity cuts chosen:

- **Missing mass** $ep \to ep\gamma X$
  
  $-0.06 < MM^2 < 0.04 \text{GeV}^2$

- **Missing energy**: $[-1, 2] \text{GeV}^2$

- **Cone angle**: angle between the photon and the photon direction expected from the electron and proton
DVCS in CLAS12: first look at BSA

Beam spin asymmetry

\[ A_{LU} = \frac{1}{P} \frac{N^+(\phi_{Trento}) - N^-(\phi_{Trento})}{N^+(\phi_{Trento}) + N^-(\phi_{Trento})} \]

- \( P \): electron polarization
- \( N^+(-) \): number of photon electroproduction candidates with beam helicity +(-)
- Analysis based on 2% of approved beam time
- Residual background not subtracted (main source \( ep \to ep\pi^0 \))
- Only statistical uncertainty showed
- Integrated over the full kinematic domain
Outlook

- First running with unpolarized proton target is completed
- CLAS12 collected about 40% of the total approved beam current
- Preliminary first look at DVCS beam-spin asymmetry
- Preliminary based on 2% of approved beam time
- Analysis ongoing, optimize $\pi^0$ subtraction and systematics evaluation
- Outlook: extraction of Compton Form Factors with global fits