Towards extraction of GPDs from DVCS data

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Introduction

Global analysis of DVCS data - “classic” approach

Global analysis of DVCS data - ANN approach

Summary
Deeply Virtual Compton Scattering (DVCS)

Chiral-even GPDs:
(helicity of parton conserved)

\[ H^{q,g}(x, \xi, t) \quad \text{for sum over parton helicities} \]
\[ E^{q,g}(x, \xi, t) \]
\[ \tilde{H}^{q,g}(x, \xi, t) \quad \text{for difference over parton helicities} \]
\[ \tilde{E}^{q,g}(x, \xi, t) \]

nucleon helicity conserved

nucleon helicity changed

factorization for \(|t|/Q^2 \ll 1\)
GPDs accessible in various production channels and observables
→ experimental filters

DVCS
Deeply Virtual Compton Scattering

TCS
Timelike Compton Scattering

HEMP
Hard Exclusive Meson Production

more production channels sensitive to GPDs exist!
GPDs studied in various laboratories
→ need to cover a broad kinematic range

experiments
closed  active  planned
Kinematic cuts used in presented analyses:

\[ Q^2 > 1.5 \text{ GeV}^2 \]

\[ -t/Q^2 < 0.2 \]
Nucleon tomography

- Nucleon tomography

\[
q(x, b_{\perp}) = \int \frac{d^2 \Delta}{4\pi^2} e^{-ib_{\perp} \cdot \Delta} H^q(x, 0, t = -\Delta^2)
\]

- Study of long. polarization with GPD $\tilde{H}$
- Study of distortion in transv. polarized nucleon with GPD $E$

- Impact parameter $b_{\perp}$ defined w.r.t. center of momentum, such as $\sum x b_{\perp} = 0$
Energy momentum tensor

Energy momentum tensor in terms of form factors:

\[
\langle p', s' | \hat{T}^{\mu\nu} | p, s \rangle = \bar{u}(p', s') \left[ \frac{P^\mu P^\nu}{M} A(t) + \frac{\Delta^\mu \Delta^\nu - \eta^{\mu\nu} \Delta^2}{M} C(t) + M \eta^{\mu\nu} \bar{C}(t) + \frac{P^\mu i \sigma^{\nu\lambda} \Delta_{\lambda}}{4M} [A(t) + B(t) + D(t)] + \frac{P^\nu i \sigma^{\mu\lambda} \Delta_{\lambda}}{4M} [A(t) + B(t) - D(t)] \right] u(p, s)
\]

Access to total angular momentum and “mechanical” forces acting on quarks

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

Ji’s sum rule
PARTONS project

- PARTONS - platform to study GPDs
- Come with number of available physics developments implemented
- Addition of new developments as easy as possible
- To support effort of GPD community
- Can be used by both theorists and experimentalists

http://partons.cea.fr
PARTONS project

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H^u @ x_i = 0.2, t = -0.1 GeV^2, \mu_F^2 = 2 GeV^2

GK11
MPSSW13
VGG
Vinnikov
H. Moutarde, P. S., J. Wagner "Border and skewness functions from a leading order fit to DVCS data"  

Goal: global extraction of Compton Form Factors (CFFs) from DVCS data using LO/LT formalism

Analysis done within PARTONS framework
Compton Form Factors

- imaginary part

\[ \text{Im} G_0(\xi, t) = \pi G^{(+)}(\xi, \xi, t) = \pi \sum_q e_q^2 G_q^{(+)}(\xi, \xi, t) \]

\[ G_q^{(+)}(x, \xi, t) = G_q^q(x, \xi, t) \mp G_q^q(-x, \xi, t) \]

\[ G^{(+)}_q(\xi, \xi, t) = G^{val}_q(\xi, \xi, t) + 2G^{sea}_q(\xi, \xi, t) \]

- real part

\[ \text{Re} G(\xi, t) = \text{P.V.} \int_0^1 G^{(+)}(x, \xi, t) \left( \frac{1}{\xi - x} \mp \frac{1}{\xi + x} \right) \, dx \]

\[ \text{Re} G(\xi, t) = \text{P.V.} \int_0^1 G^{(+)}(x, x, t) \left( \frac{1}{\xi - x} \mp \frac{1}{\xi + x} \right) \, dx + C_G(t) \]

\[ C_H(t) = -C_E(t) \quad C_{\tilde{H}}(t) = C_{\tilde{E}}(t) = 0 \]

"-" for \( G \in \{ H, E \} \)

"+" for \( G \in \{ \tilde{H}, \tilde{E} \} \)

connected to EMT FF
Ansatz

\[ C^q_G(t) = 2 \int_{0}^{1} \left( G^{q(+)}(x, x, t) - G^{q(+)}(x, 0, t) \right) \frac{1}{x} \, dx \]

- subtraction constant as analytic continuation of Mellin moments to \( j = -1 \)

\[ G^q(x, 0, t) = \text{pdf}^q_G(x) \, \exp(f^q_G(x)t) \quad \quad f^q_G(x) = A^q_G \log(1/x) + B^q_G (1-x)^2 + C^q_G (1-x)x \]

- reduction to PDFs and correspondence to EFFs
- modify "classical" \( \log(1/x) \) term by \( B^q_G (1-x)^2 \) in low-\( x \) and by \( C^q_G (1-x)x \) in high-\( x \) regions
- polynomials found in analysis of EFF data \( \rightarrow \) good description of data
- allow to use the analytic regularisation prescription
- finite proton size at \( x \rightarrow 1 \)

\[ G^q(x, x, t) = G^q(x, 0, t) \, g^q_G(x, x, t) \quad g^q_G(x, x, t) = \frac{a^q_G}{(1-x^2)^2} \left( 1 + t(1-x)(b^q_G + c^q_G \log(1+x)) \right) \]

- at \( x \rightarrow 0 \) constant skewness effect
- at \( x \rightarrow 1 \) reproduce power behaviour predicted for GPDs in Phys. Rev. D69, 051501 (2004)
- \( t \)-dependence similar to DD-models with \( 1-x \) to avoid any \( t \)-depen. at \( x = 1 \)
1. Analysis of PDF parameterisations

\[ \text{pdf}(x, Q^2) = x^{-g(\delta_p, \delta_q, Q^2)}(1 - x)^\alpha \]
\[ \times \sum_{i=0}^{4} g(p_i, q_i, Q^2)x^i \]
\[ g(p, q, Q^2) = p + q \log \frac{Q^2}{Q_0^2} \]

2. Analysis of Elastic Form Factor data

\[ \chi^2/\text{ndf} = 129.6/(178 - 9) \approx 0.77 \]

3. Analysis of DVCS data

\[ \chi^2/\text{ndf} = 2346.3/(2600 - 13) \approx 0.91 \]
\[ Q^2 = 2 \text{ GeV}^2 \]
Results

Nucleon tomography:

\[ Q^2 = 2 \text{ GeV}^2 \]

no uncertainties!
Results

Nucleon tomography:

\[
\langle b^2 \rangle_q (x) = \frac{\int d^2b_\perp \, b^2 q(x, b_\perp)}{\int d^2b_\perp \, q(x, b_\perp)}
\]

\[Q^2 = 2 \text{ GeV}^2\]
H. Moutarde, P. S., J. Wagner “Unbiased determination of Compton Form Factors” preliminary results

Goal: global extraction of Compton Form Factors (CFFs) from DVCS data using ANN technique

Analysis done within PARTONS framework
Quality of fit:

\[ \frac{\chi^2}{n\text{Points}} = \frac{2243.5}{2624} \approx 0.85 \]

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@ $t = -0.3 \text{ GeV}^2$, $Q^2 = 2 \text{ GeV}^2$
Subtraction constant

- Direct extraction of subtraction constant → encouraging precision
- As expected, no \( \xi \) behaviour observed → consistency check
- Strong, model independent constraints on extraction of pressure information
■ Parameterizations of border and skewness functions
  → basic properties of GPD as building blocks
  → small number of parameters
  → encoded access to nucleon tomography and subtraction constant

■ Neural network parameterization of CFFs
  → model independent extraction (also true for subtraction constant)
  → powerful tool to study GPDs / reduction of model uncertainties
  → perfect to study impact of future experiments