On Deeply Virtual Compton Scattering at Next to Leading Order

H. Moutarde

Irfu/SPhN, CEA-Saclay

Light Cone 2013

In collaboration with : P. Kroll, B. Pire, F. Sabatié, L. Szymanowski and J. Wagner.

Definition.

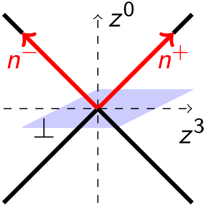
Matrix elements of twist-2 bilocal operators.

$$F^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' \left| \bar{q}\left(-\frac{z}{2}\right)\gamma^+ q\left(\frac{z}{2}\right)\right| p\rangle_{z^+=0, z_\perp=0}$$

$$= \frac{1}{2P^+}\left[H^q \bar{u}(p')\gamma^+ u(p) + E^q \bar{u}(p')\frac{i\sigma^{+\alpha}\Delta_\alpha}{2M}u(p)\right]$$

$$\tilde{F}^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' \left| \bar{q}\left(-\frac{z}{2}\right)\gamma^+\gamma_5 q\left(\frac{z}{2}\right)\right| p\rangle_{z^+=0, z_\perp=0}$$

$$= \frac{1}{2P^+}\left[\tilde{H}^q \bar{u}(p')\gamma^+\gamma_5 u(p) + \tilde{E}^q \bar{u}(p')\frac{\gamma^5\Delta^+}{2M}u(p)\right]$$



References

Müller *et al.*, Fortschr. Phys. **42** (1994) 101
Ji, Phys. Rev. Lett. **78** (1997) 610
Radyushkin, Phys. Lett. B **380** (1996) 417

Definition.

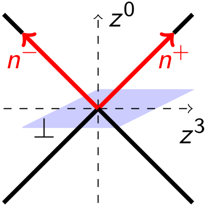
Matrix elements of twist-2 bilocal operators.

$$F^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' \left| \bar{q}\left(-\frac{z}{2}\right)\gamma^+ q\left(\frac{z}{2}\right)\right| p\rangle_{z^+=0, z_\perp=0}$$

$$= \frac{1}{2P^+}\left[H^q \bar{u}(p')\gamma^+ u(p) + E^q \bar{u}(p')\frac{i\sigma^{+\alpha}\Delta_\alpha}{2M}u(p)\right]$$

$$\tilde{F}^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' \left| \bar{q}\left(-\frac{z}{2}\right)\gamma^+\gamma_5 q\left(\frac{z}{2}\right)\right| p\rangle_{z^+=0, z_\perp=0}$$

$$= \frac{1}{2P^+}\left[\tilde{H}^q \bar{u}(p')\gamma^+\gamma_5 u(p) + \tilde{E}^q \bar{u}(p')\frac{\gamma^5\Delta^+}{2M}u(p)\right]$$



See D. Müller's lecture next thursday!

- Partons with a **light-like** separation.
- **Quarks** and **gluon** GPDs.
- $\mathrm{GPD}^{q,g} = \mathrm{GPD}^{q,g}(x, \xi, t)$.

Motivations.

3D imaging of nucleon's partonic content but also. . .

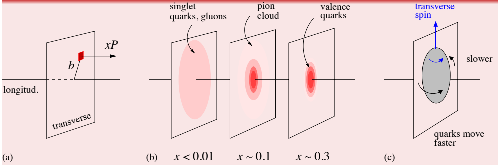
- Correlation of the **longitudinal momentum** and the **transverse position** of a parton in the nucleon.
- Insights on:
    - **Spin** structure,
    - **Energy-momentum** structure.
- **Probabilistic interpretation** of Fourier transform of GPD$(x, \xi = 0, t)$ in **transverse plane**.

Motivations.

3D imaging of nucleon's partonic content but also. . .

- Correlation of the **longitudinal momentum** and the **transverse position** of a parton in the nucleon.
- Insights on:
  - **Spin** structure,
  - **Energy-momentum** structure.
- **Probabilistic interpretation** of Fourier transform of GPD$(x, \xi = 0, t)$ in **transverse plane**.

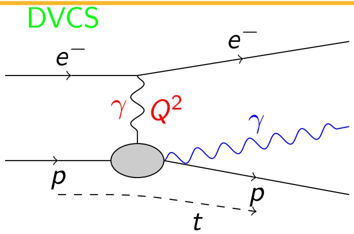
Obtain this 3d picture from exclusive measurements ?



Weiss, AIP Conf. Proc. 1149, 150 (2009)

Timelike and spacelike Compton Scattering.

Scattering amplitudes and their partonic interpretation.

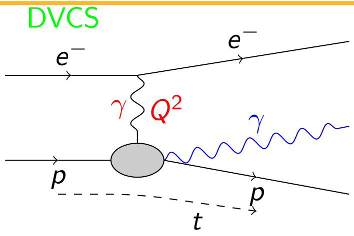


Compton Form Factors

- Parametrize amplitudes.

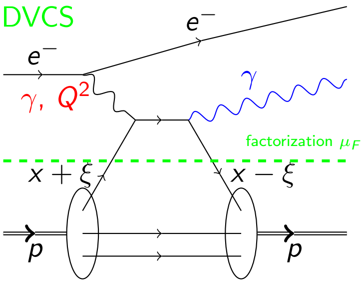
Timelike and spacelike Compton Scattering.

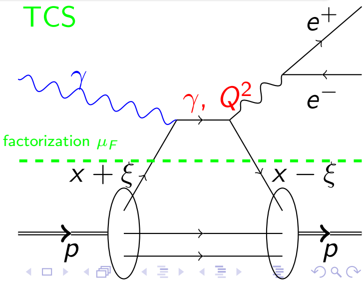
Scattering amplitudes and their partonic interpretation.



Compton Form Factors

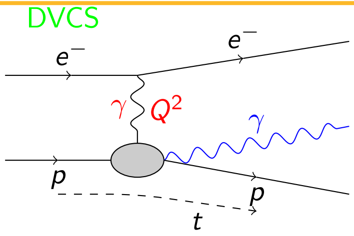
- Parametrize amplitudes.
- Evaluation at LO.





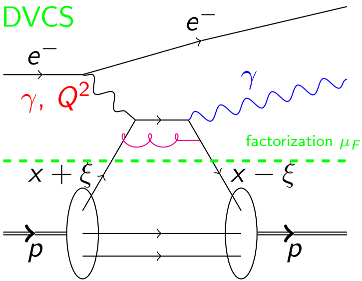
Timelike and spacelike Compton Scattering.

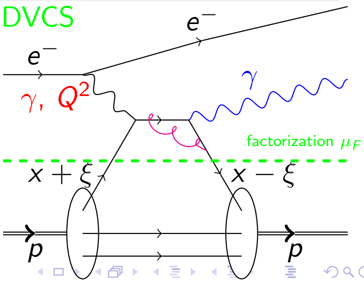
Scattering amplitudes and their partonic interpretation.



Compton Form Factors

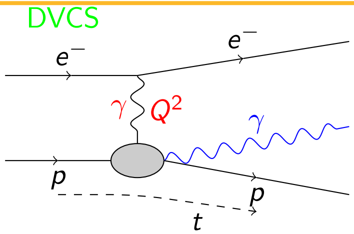
- Parametrize amplitudes.
- Evaluation at LO.
- Evaluation at NLO.





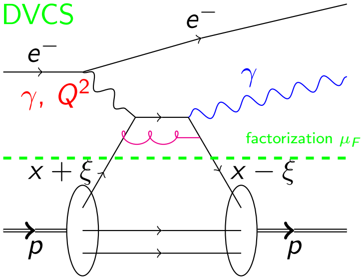
Timelike and spacelike Compton Scattering.

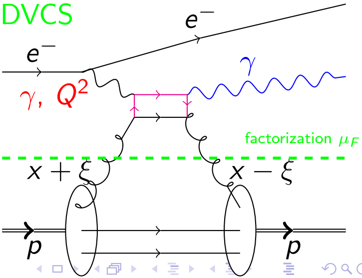
Scattering amplitudes and their partonic interpretation.



Compton Form Factors

- Parametrize amplitudes.
- Evaluation at LO.
- Evaluation at NLO.
- Other diagrams at NLO, including gluon GPDs.





Explicit expressions of Compton Form Factors.

Quark and gluon contributions to the CFF $\mathcal{H}$ at LO and NLO (at fixed t).

- Convolution of singlet GPD $H_q^+(x) \equiv H_q(x) - H_q(-x)$:

$$\mathcal{H}_q(\xi, Q^2) = \int_{-1}^{+1} dx\, H_q^+(x, \xi, \mu_F)\ T_q\left(x, \xi, \alpha_S(\mu_F), \frac{Q}{\mu_F}\right) + \int_{-1}^{+1} dx\, H_g(x, \xi, \mu_F)\ T_g\left(x, \xi, \alpha_S(\mu_F), \frac{Q}{\mu_F}\right)$$

Belistky and Müller, Phys. Lett. **B417**, 129 (1998)
Pire *et al*, Phys. Rev. **D83**, 034009 (2011)

Explicit expressions of Compton Form Factors.

Quark and gluon contributions to the CFF $\mathcal{H}$ at LO and NLO (at fixed t).

- Convolution of singlet GPD $H_q^+(x) \equiv H_q(x) - H_q(-x)$:

$$\mathcal{H}_q(\xi, Q^2) \stackrel{\text{LO}}{=} \int_{-1}^{+1} dx\, H_q^+(x, \xi, \mu_F)\ C_0^q(x, \xi) + \int_{-1}^{+1} dx\, H_g(x, \xi, \mu_F)\ 0$$

Belistky and Müller, Phys. Lett. **B417**, 129 (1998)
Pire *et al*, Phys. Rev. **D83**, 034009 (2011)

- Integration yields **imaginary** parts to $\mathcal{H}$:

$$Im\mathcal{H}_q(\xi, Q^2) \stackrel{\text{LO}}{=} \pi H_q^+(\xi, \xi, \mu_F)$$

Explicit expressions of Compton Form Factors.

Quark and gluon contributions to the CFF $\mathcal{H}$ at LO and NLO (at fixed t).

- Convolution of singlet GPD $H_q^+(x) \equiv H_q(x) - H_q(-x)$:

$$\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \int_{-1}^{+1} dx\, H_q^+(x, \xi, \mu_F) \left[C_0^q + C_1^q + \frac{1}{2} \ln \frac{|Q^2|}{\mu_F^2} C_{\text{Coll}}^q \right] + \int_{-1}^{+1} dx\, H_g(x, \xi, \mu_F) \left(0 + C_1^g + \frac{1}{2} \ln \frac{|Q^2|}{\mu_F^2} C_{\text{Coll}}^g \right)$$

Belistky and Müller, Phys. Lett. **B417**, 129 (1998)
Pire *et al*, Phys. Rev. **D83**, 034009 (2011)

- Integration yields **imaginary** parts to $\mathcal{H}$:

$$Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) + \text{gluon contributions.}$$

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x)\Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F)\Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):

CEA - Saclay

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$
\begin{aligned}
Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} & \; \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) \\
& + \int_{-1}^{+1} dx \, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) \\
& + \text{gluon contributions.}
\end{aligned}
$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):
  - Multiplicative factor $\mathcal{I}$ depends on ξ.

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):
  - Multiplicative factor $\mathcal{I}$ depends on ξ.
  - Integral with **off-diagonal terms**.

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \stackrel{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):
  - Multiplicative factor $\mathcal{I}$ depends on ξ.
  - Integral with **off-diagonal terms**.
  - $Im\mathcal{H}_q$ **contains** gluon contributions.

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \overset{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x)\Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F)\Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):
  - Multiplicative factor $\mathcal{I}$ depends on ξ.
  - Integral with **off-diagonal terms**.
  - $Im\mathcal{H}_q$ **contains** gluon contributions.
- **No more direct link** to H_q even in valence region where $H_q(-\xi, \xi)$ is expected to be small.

Explicit expressions of Compton Form Factors.

Compton Scattering at NLO.

Imaginary part of Compton Form Factor $\mathcal{H}_q$ at NLO:

$$Im\mathcal{H}_q(\xi, Q^2) \stackrel{\text{NLO}}{=} \mathcal{I}(\xi) H_q^+(\xi, \xi, \mu_F) + \int_{-1}^{+1} dx\, \mathcal{T}^q(x) \Big(H_q^+(x, \xi, \mu_F) - H_q^+(\xi, \xi, \mu_F) \Big) + \text{gluon contributions.}$$

Due to $\mathcal{O}(\alpha_S(\mu_F))$ corrections:

- $Im\mathcal{H}_q$ is **no more equal** to $\pi H_q^+(x = \xi, \xi)$ (LO):
  - Multiplicative factor $\mathcal{I}$ depends on ξ.
  - Integral with **off-diagonal terms**.
  - $Im\mathcal{H}_q$ **contains** gluon contributions.
- **No more direct link** to H_q even in valence region where $H_q(-\xi, \xi)$ is expected to be small.

Question: What is the size of these $\mathcal{O}(\alpha_S(\mu_F))$ corrections?

Double Distribution models of the GPD H.

Kroll - Goloskokov model.

- **Factorized Ansatz**. For $i = g$, sea or val :

$$
\begin{aligned}
H_i(x, \xi, t) &= \int_{|\alpha|+|\beta|\leq 1} d\beta d\alpha\, \delta(\beta + \xi\alpha - x) f_i(\beta, \alpha, t) \\
f_i(\beta, \alpha, t) &= e^{b_i t} \frac{1}{|\beta|^{\alpha' t}} h_i(\beta) \pi_{n_i}(\beta, \alpha) \\
\pi_{n_i}(\beta, \alpha) &= \frac{\Gamma(2n_i + 2)}{2^{2n_i+1}\Gamma^2(n_i + 1)} \frac{(1 - |\beta|)^2 - \alpha^2]^{n_i}}{(1 - |\beta|)^{2n_i+1}}
\end{aligned}
$$

- Expressions for h_i and n_i :

$$
\begin{aligned}
h_g(\beta) &= |\beta| g(|\beta|) & n_g &= 2 \\
h^q_{\mathrm{sea}}(\beta) &= q_{\mathrm{sea}}(|\beta|)\mathrm{sign}(\beta) & n_{\mathrm{sea}} &= 2 \\
h^q_{\mathrm{val}}(\beta) &= q_{\mathrm{val}}(\beta)\Theta(\beta) & n_{\mathrm{val}} &= 1
\end{aligned}
$$

Goloskokov and Kroll, Eur. Phys. J. **C42**, 281 (2005)

- Comparison to **existing DVCS measurements** at LO.

Kroll *et al.*, Eur. Phys. J. **C73**, 2278 (2013)

Double Distribution models of the GPD H.

MSTW08 based model with classical Radyushkin's factorized Ansatz.

- Use MSTW08 Parton Distribution Functions.

  Martin *et al.*, Eur. Phys. J. C. **63** (2009) 189.

- Assume factorized t-dependence:

$$H(x, \xi, t) = \int_{|\alpha|+|\beta|\leq 1} d\beta d\alpha \, \delta(\beta + \xi\alpha - x)\pi(\beta, \alpha)f(\beta, t)$$

  - u and d quarks:

$$\begin{aligned} f_u(\beta, \alpha, t) &= \frac{1}{2}F_1^u(t)u(\beta)\pi(\beta, \alpha) \\ f_d(\beta, \alpha, t) &= F_1^d(t)d(\beta)\pi(\beta, \alpha) \end{aligned}$$

    with F_1^u and F_1^d the u and d quark contributions to the proton form factor F_1.
  - s quark and gluons: dipole Ansatz.

- Add D-term from Chiral Quark Soliton Model.

  Goeke *et al.*, Prog.Part.Nucl.Phys. 47 (2001) 401

Definition of DVCS observables (1/3).

Single and double asymmetries.

- Combined beam-spin and charge asymmetries :

$$d\sigma^{h_e, Q_e}(\phi) = d\sigma_{\mathrm{UU}}(\phi) \left[1 + h_e A_{\mathrm{LU,DVCS}}(\phi) + Q_e h_e A_{\mathrm{LU,I}}(\phi) + Q_e A_{\mathrm{C}}(\phi)\right]$$

- Single beam-spin asymmetry :

$$A_{\mathrm{LU}}^{Q_e}(\phi) = \frac{d\sigma^{Q_e}_{\rightarrow} - d\sigma^{Q_e}_{\leftarrow}}{d\sigma^{Q_e}_{\rightarrow} + d\sigma^{Q_e}_{\leftarrow}}$$

- Relation between observables :

$$A_{\mathrm{LU}}^{Q_e}(\phi) = \frac{Q_e A_{\mathrm{LU,I}}(\phi) + A_{\mathrm{LU,DVCS}}(\phi)}{1 + Q_e A_{\mathrm{C}}(\phi)}$$

- Compute Fourier coefficients of asymmetries.

Definition of DVCS observables (2/3).

Combined cross sections.

- COMPASS **combined beam-spin and charge** cross sections:

$$\begin{aligned}
\mathcal{S}_{\mathrm{CS,U}} &= d\sigma^{\overset{+}{\rightarrow}} + d\sigma^{\overset{-}{\leftarrow}} &&= 2d\sigma_{UU}(1 - A_{LU,I}) \\
\mathcal{D}_{\mathrm{CS,U}} &= d\sigma^{\overset{+}{\rightarrow}} - d\sigma^{\overset{-}{\leftarrow}} &&= 2d\sigma_{UU}(A_C - A_{LU,DVCS}) \\
\mathcal{A}_{\mathrm{CS,U}} &= \frac{d\sigma^{\overset{+}{\rightarrow}} - d\sigma^{\overset{-}{\leftarrow}}}{d\sigma^{\overset{+}{\rightarrow}} + d\sigma^{\overset{-}{\leftarrow}}} &&= \frac{A_C - A_{LU,DVCS}}{1 - A_{LU,I}}
\end{aligned}$$

- JLab Hall A **beam-polarized** cross sections:

$$\begin{aligned}
\Delta\sigma &= d\sigma^{\overset{-}{\rightarrow}} - d\sigma^{\overset{-}{\leftarrow}} \\
\Sigma\sigma &= d\sigma^{\overset{-}{\rightarrow}} + d\sigma^{\overset{-}{\leftarrow}}
\end{aligned}$$

- Compute Fourier coefficients of cross sections.

Definition of DVCS observables (3/3).

What are the probed combinations of CFFs ?

Typical kinematics

Experiment	Kinematics		
	x_B	Q^2 [GeV^2]	t [GeV^2]
HERA	0.001	8.00	-0.30
COMPASS	0.05	2.00	-0.20
HERMES	0.09	2.50	-0.12
CLAS	0.19	1.25	-0.19
HALL A	0.36	2.30	-0.23

Definition of DVCS observables (3/3).

What are the probed combinations of CFFs ?

Typical kinematics

Experiment	Kinematics			
	x_B	Q^2 [GeV^2]	t [GeV^2]	$-t/Q^2$
HERA	0.001	8.00	-0.30	0.04
COMPASS	0.05	2.00	-0.20	0.10
HERMES	0.09	2.50	-0.12	0.05
CLAS	0.19	1.25	-0.19	0.15
HALL A	0.36	2.30	-0.23	0.10

Definition of DVCS observables (3/3).

What are the probed combinations of CFFs ?

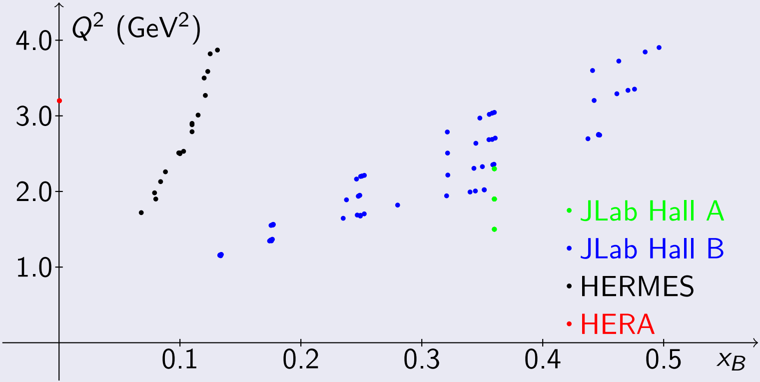
Selection of observables

Experiment	Observable	Normalized CFF dependence
HERMES	$A_{\mathrm{C}}^{\cos 0\phi}$	$\mathrm{Re}\mathcal{H} + 0.06\mathrm{Re}\mathcal{E} + 0.24\mathrm{Re}\widetilde{\mathcal{H}}$
	$A_{\mathrm{C}}^{\cos \phi}$	$\mathrm{Re}\mathcal{H} + 0.05\mathrm{Re}\mathcal{E} + 0.15\mathrm{Re}\widetilde{\mathcal{H}}$
	$A_{\mathrm{LU,I}}^{\sin \phi}$	$\mathrm{Im}\mathcal{H} + 0.05\mathrm{Im}\mathcal{E} + 0.12\mathrm{Im}\widetilde{\mathcal{H}}$
	$A_{\mathrm{UL}}^{+,\sin \phi}$	$\mathrm{Im}\widetilde{\mathcal{H}} + 0.10\mathrm{Im}\mathcal{H} + 0.01\mathrm{Im}\mathcal{E}$
CLAS	$A_{\mathrm{LU}}^{-,\sin \phi}$	$\mathrm{Im}\mathcal{H} + 0.06\mathrm{Im}\mathcal{E} + 0.21\mathrm{Im}\widetilde{\mathcal{H}}$
	$A_{\mathrm{UL}}^{-,\sin \phi}$	$\mathrm{Im}\widetilde{\mathcal{H}} + 0.12\mathrm{Im}\mathcal{H} + 0.04\mathrm{Im}\mathcal{E}$
HALL A	$\sigma^{\cos 0\phi}$	$1 + 0.05\mathrm{Re}\mathcal{H} + 0.007\mathcal{H}\mathcal{H}^*$
	$\sigma^{\cos \phi}$	$1 + 0.12\mathrm{Re}\mathcal{H} + 0.05\mathrm{Re}\widetilde{\mathcal{H}}$

Kinematic region of existing DVCS measurements.

Looking for the Bjorken regime.

What is large Q^2 ?

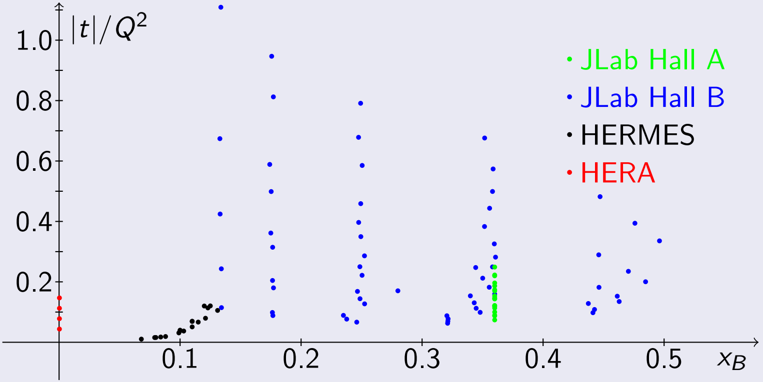


- World data cover **complementary kinematic regions**.

Kinematic region of existing DVCS measurements.

Looking for the Bjorken regime.

What is large Q^2 ?

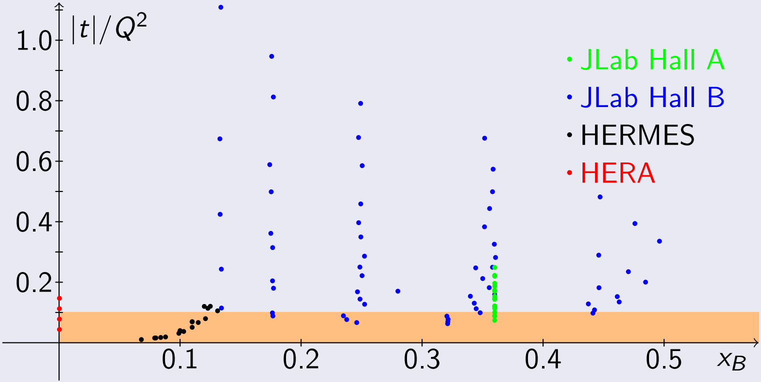


- World data cover **complementary kinematic regions**.
- Q^2 is **not so large** for most of the data.

Kinematic region of existing DVCS measurements.

Looking for the Bjorken regime.

What is large Q^2 ?

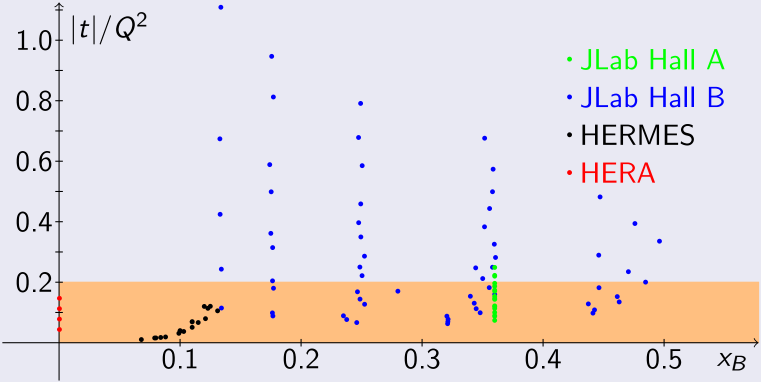


- World data cover **complementary kinematic regions**.
- Q^2 is **not so large** for most of the data.
- Higher twists, finite-t and target mass corrections ?

Kinematic region of existing DVCS measurements.

Looking for the Bjorken regime.

What is large Q^2 ?



- World data cover **complementary kinematic regions**.
- Q^2 is **not so large** for most of the data.
- Higher twists, finite-t and target mass corrections ?

Approximations.

First systematic study of DVCS polarized and unpolarized observables.

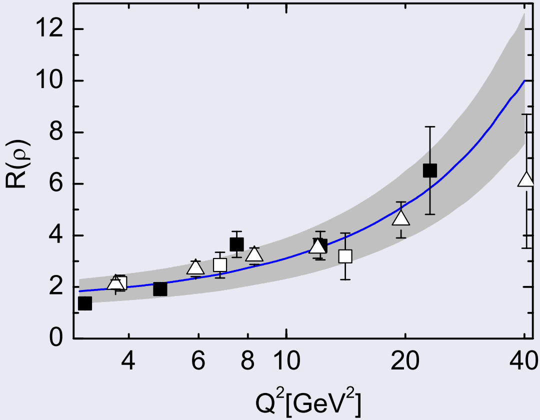
Unless explicitly stated

- Work at twist 2 accuracy.
- Use LO expression of kernel $C(x, \xi)$.
- No finite$-t$ or target mass corrections (higher twist).

Goloskokov-Kroll (GK) model on DVMP.

The GK model **was tuned** to analyse DVMP.

σ_L/σ_T for ρ^0 at W = 90 GeV

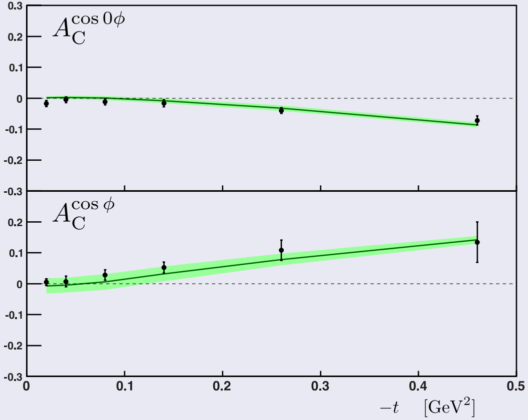


Goloskokov and Kroll, Eur. Phys. J. C**53** (2005) 281

Goloskokov-Kroll (GK) model on DVCS.

No parameter of the GK model **was tuned** to analyse DVCS.

Beam Charge Asymmetry, HERMES

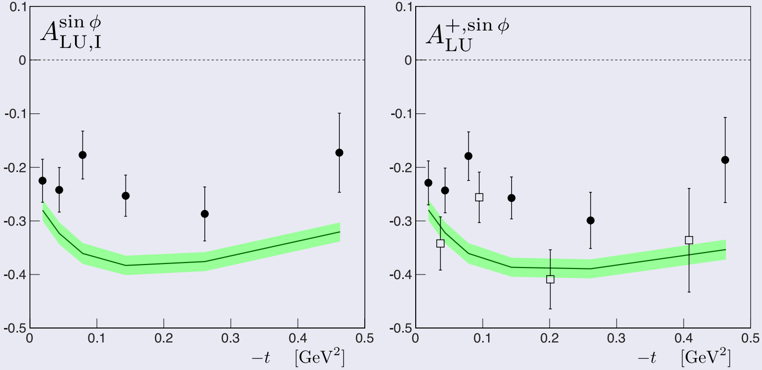


Kroll *et al.*, Eur. Phys. J C**73** (2013) 2278

Goloskokov-Kroll (GK) model on DVCS.

No parameter of the GK model **was tuned** to analyse DVCS.

Beam Spin Asymmetry, HERMES

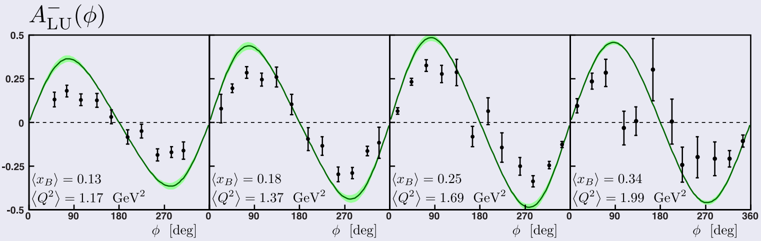


Kroll *et al.*, Eur. Phys. J C**73** (2013) 2278

Goloskokov-Kroll (GK) model on DVCS.

No parameter of the GK model **was tuned** to analyse DVCS.

Beam Spin Asymmetry, CLAS

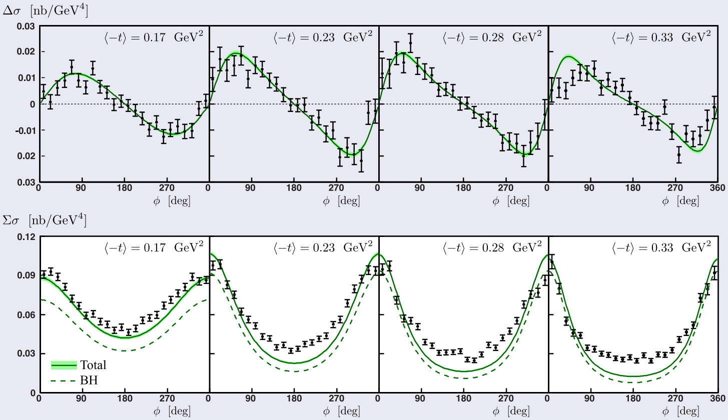


Kroll *et al.*, Eur. Phys. J C**73** (2013) 2278

Goloskokov-Kroll (GK) model on DVCS.

No parameter of the GK model **was tuned** to analyse DVCS.

Helicity-dependent and independent cross sections, JLab Hall A



Kroll *et al.*, Eur. Phys. J C**73** (2013) 2278

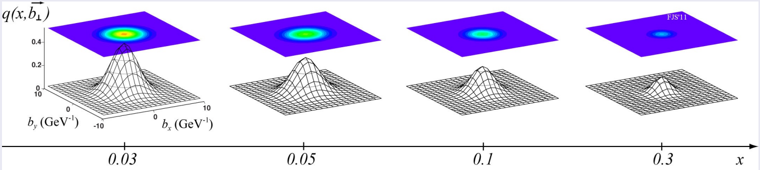
Goloskokov-Kroll (GK) model on DVCS.

No parameter of the GK model **was tuned** to analyse DVCS.

Spin structure with GK model (quoted at 4 GeV^2)

- $J^u \simeq 0.250$, $J^d \simeq 0.020$, $J^s \simeq 0.015$, $J^g \simeq 0.214$
- $\sum_{q,g} J^{q,g} \simeq 1/2$

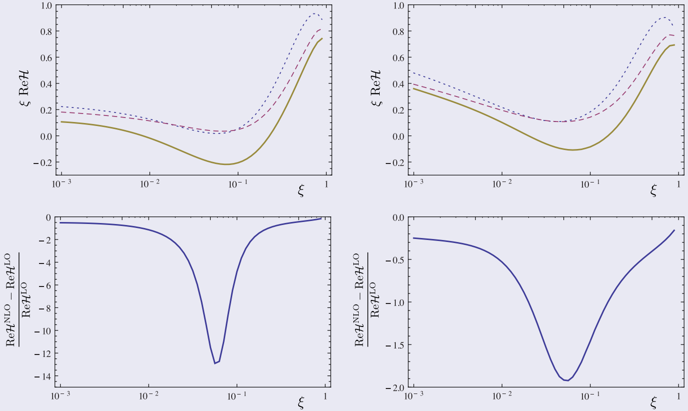
3d nucleon structure with GK model



Spacelike Compton Form Factors.

Large NLO corrections, mostly due to gluons, maximum in the kinematic region of HERMES and COMPASS.

$Re\mathcal{H}$ at LO and NLO



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

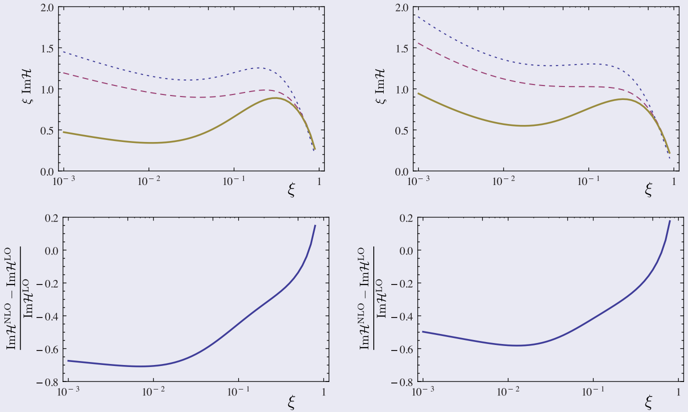
dotted: LO dashed: NLO quark corrections solid: full NLO

Left: KG model Right: MSTW08-based model

Spacelike Compton Form Factors.

Large NLO corrections, mostly due to gluons, maximum in the kinematic region of HERMES and COMPASS.

$Im\mathcal{H}$ at LO and NLO



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

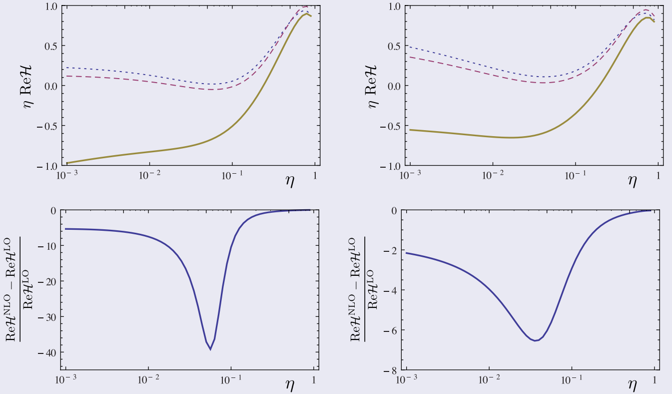
dotted: LO dashed: NLO quark corrections solid: full NLO

Left: KG model Right: MSTW08-based model

Timelike Compton Form Factors.

Large NLO corrections, mostly due to gluons, maximum in the kinematic region of HERMES and COMPASS.

$Re\mathcal{H}$ at LO and NLO



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

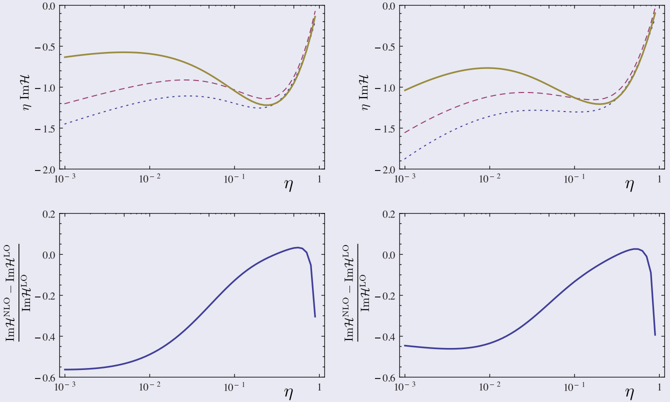
dotted: LO   dashed: NLO quark corrections   solid: full NLO

Left: KG model   Right: MSTW08-based model

Timelike Compton Form Factors.

Large NLO corrections, mostly due to gluons, maximum in the kinematic region of HERMES and COMPASS.

$Im\mathcal{H}$ at LO and NLO



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

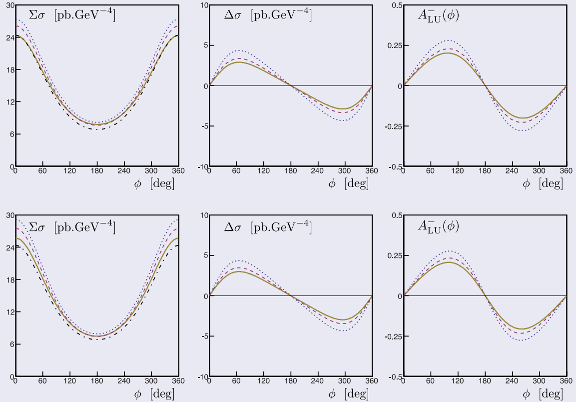
dotted: LO   dashed: NLO quark corrections   solid: full NLO

Left: KG model   Right: MSTW08-based model

Projections: CLAS12 kinematics, DVCS channel.

Sizeable NLO corrections and gluon contributions.

$E_e = 11$ GeV, $x_B = 0.36$, $Q^2 = 4$ GeV^2, $t = -0.2$ GeV^2



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

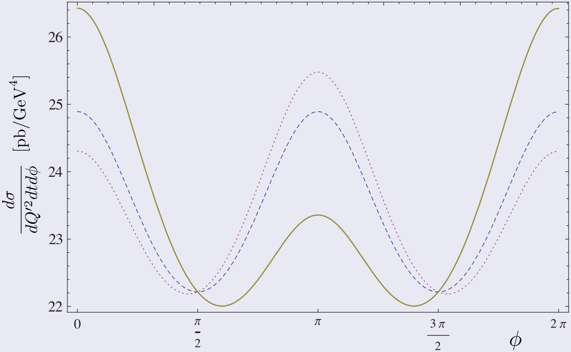
dotted: LO dashed: NLO quark corrections solid: full NLO

Upper line: KG model Lower line: MSTW08-based model

Projections: CLAS12 kinematics, TCS channel.

Sizeable NLO corrections and gluon contributions.

$E_\gamma = 10$ GeV ($\eta \simeq 0.11$), $Q^2 = 4$ GeV^2, $t = -0.1$ GeV^2



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

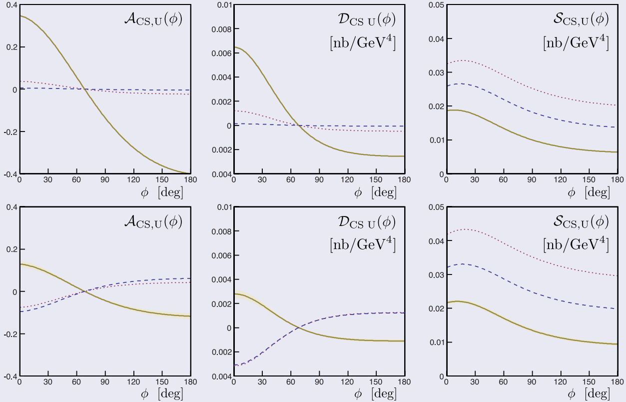
dashed: pure BH — dotted: BH + LO Interference — solid: BH + NLO Interference

KG model — Cross section integrated over $\theta \in \left(\frac{\pi}{4}, \frac{3\pi}{4}\right)$

Projections: COMPASS kinematics, DVCS channel.

Sizeable NLO corrections and gluon contributions.

$E_\mu = 160$ GeV, $x_B = 0.1$, $Q^2 = 4$ GeV^2, $t = -0.2$ GeV^2



Moutarde *et al.*, Phys. Rev. **D87**, 054029 (2013)

dotted: LO dashed: NLO quark corrections solid: full NLO

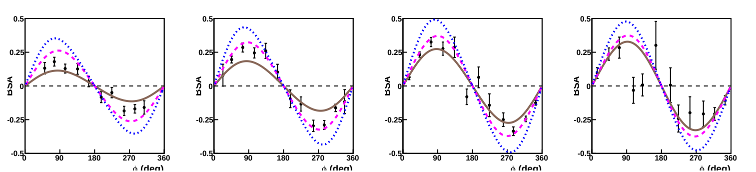
Upper line: KG model Lower line: MSTW08-based model

CLAS beam spin asymmetries, DVCS channel.

Distinction between LO and NLO already relevant for 6 GeV data.

From left to right: $x_B = 0.13, 0.18, 0.25$ and 0.34
$Q^2 = 1.17, 1.37, 1.69$ and $1.99\ \text{GeV}^2$
$t \simeq -0.3\ \text{GeV}^2$

Preliminary result



dotted: LO dashed: NLO quark corrections solid: full NLO

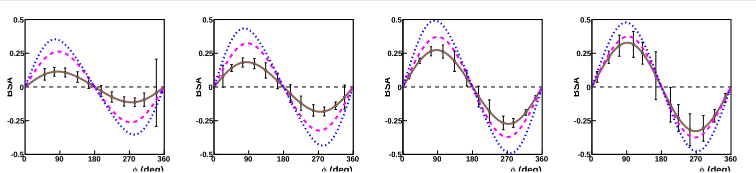
- Comparison with KG model.

CLAS beam spin asymmetries, DVCS channel.

Distinction between LO and NLO already relevant for 6 GeV data.

From left to right: $x_B = 0.13, 0.18, 0.25 \text{ and } 0.34$
$Q^2 = 1.17, 1.37, 1.69 \text{ and } 1.99 \text{ GeV}^2$
$t \simeq -0.3 \text{ GeV}^2$

Preliminary result



dotted: LO dashed: NLO quark corrections solid: full NLO

- Comparison with KG model.
- Compare differences between LO and NLO computations to **experimental statistical uncertainty** considering full NLO computation as nominal result.

CEA - Saclay

Conclusions.

Constraining gluon GPDs even from data in the valence region?

- **Large NLO "corrections"** to DVCS amplitude.
- Need resummed expressions!

Altinoluk *et al.*, JHEP **1210**, 049 (2012)
Altinoluk *et al.*, arXiv:1206.3115 [hep-ph]

- Sensitivity to **gluon GPDs** even in the **valence region**.
- Direct impact on **extraction** of CFFs from experimental data and their **interpretation**.
- Need global GPD fits to **separate quarks and gluon** contributions and allow an **accurate** interpretation of extracted data.
- **COMPASS and JLab12 DVCS experiments may provide a way to constrain gluon GPDs!**