Power Corrections in DVCS

V. M. Braun

University of Regensburg

INT, Seattle, 10/01/2018
We will need very high theory accuracy to access 3D structure on a quantitative level

— Power corrections are part of systematic errors
— Quark-gluon correlations are interesting on their own

• M. Defurne et al., Nature Commun. 8, no. 1, 1408 (2017)
— Why Wandzura-Wilczek much too large for helicity flip?

• M. Hattawy et al. [CLAS Collaboration], Phys. Rev. Lett. 119, no. 20, 202004 (2017)
— Why large nucleus mass does not spoil factorization?

• Higher twist and soft corrections beyond "kinematic" ones?
Ambiguity of the leading twist description

- Planar vs. non-planar kinematics

Define \( (p, q) \) as longitudinal plane:

\[
\begin{align*}
    p &= (p_0, \vec{0}_\perp, p_z) \\
    q &= (q_0, \vec{0}_\perp, q_z)
\end{align*}
\]

\( \Rightarrow \) parton fraction = Bjorken \( x \)

Many choices possible:

\[
\begin{align*}
    p &= (p_0, \vec{0}_\perp, p_z), & q &= (q_0, \vec{0}_\perp, q_z) \\
    p + p' &= (P_0, \vec{0}_\perp, P_z), & q &= (q_0, \vec{0}_\perp, q_z)
\end{align*}
\]

\( \Rightarrow \) parton fraction \( 2\xi = x_B[1 + \mathcal{O}\left(\frac{t}{Q^2}\right)] \), & redefinition of helicity amplitudes

- Ambiguity is resolved by adding “kinematic” power corrections \( t/Q^2, m^2/Q^2 \)
- Why “kinematic”: do not involve new nonperturbative input apart from usual GPDs
helicity amplitudes in the "photon" frame

Braun, Manashov, Pirnay: PRD 86 (2012) 014003

\[ A_{\mu\nu}(q, q', p) = i \int d^4 x e^{-i(z_1 q - z_2 q') x} \langle p', s' | T\{ J_\mu(z_1 x) J_\nu(z_2 x) \} | p, s \rangle \]

\[ = \varepsilon_\mu^+ \varepsilon_\nu^- A^{++} + \varepsilon_\mu^- \varepsilon_\nu^+ A^{--} + \varepsilon_\mu^0 \varepsilon_\nu^- A^{0+} + \varepsilon_\mu^- \varepsilon_\nu^0 A^{0-} + \varepsilon_\mu^0 \varepsilon_\nu^+ A^{+-} + \varepsilon_\mu^- \varepsilon_\nu^+ A^{-+} + q'_\nu A^{(3)} \]

for the calculation to the twist-4 accuracy one needs

- \( A^{++}, A^{--} \): \[ 1 + \frac{1}{Q^2} \]
- \( A^{0+}, A^{0-} \): \[ \frac{1}{Q} \] ← agree with existing results
- \( A^{-+}, A^{+-} \): \[ \frac{1}{Q^2} \] ← straightforward
Main features:

- **Complete results available to** $t/Q^2$, $m^2/Q^2$ **accuracy**
  - translation and gauge invariance restored
  - factorization valid
  - correct threshold behavior $t \to t_{\text{min}}$, $\xi \to 1$
  - correct dispersion relations

- **Two expansion parameters**

  \[
  \frac{t}{Q^2}, \quad \frac{t - t_{\text{min}}}{Q^2}
  \]

- **Most of mass corrections absorbed in** $t_{\text{min}} = -4m^2\xi^2/(1 - \xi^2)$; always overcompensated by finite-$t$ corrections in the physical region

- **Some extra** $m^2/Q^2$ **corrections for nucleon due to spinor algebra; disappear in certain CFF combinations and for scalar targets**
Large effects for the total cross section

M. Defurne et al., Nature Commun. 8, no. 1, 1408 (2017)

- $A^{0\pm}$ too large?
- Flaw in the analysis? Twist-5? Genuine twist-3?
  — a pressing issue
- Twist-4 corrections generally on a 10% level
Coherent DVCS on nuclei

- Target mass corrections

\[
\xi = \frac{2x}{1 + \sqrt{1 + 4x^2m^2/Q^2}}
\]

On a nucleus

\[
m \mapsto Am \quad x \mapsto x/A
\]

⇒ TMC unaffected

- Extend to all twists?
- TMC and finite-\( t \) corrections are intertwined

Braun, Manashov, Pirnay: PRD 86 (2012) 014003

All twist-4 TMC are absorbed in

\[
t_{\text{min}} = -4m^2\xi^2/(1 - \xi^2)
\]

On a nucleus

\[
m \mapsto Am \quad \xi \mapsto \xi/A
\]

⇒ TMC unaffected
Soft corrections

- Example: \( \pi \gamma^* \gamma \)


- Estimates possible:
  - photon wave functions
  - dispersion relations and duality (LCSR)

- Expect a small correction thanks to strong suppression of GPDs at \( x \rightarrow 1 \)
"Genuine" higher twists (quark-gluon correlations)

- Twist-3 GPDS, "genuine" twist-3 corrections
  - Potentially interesting, but want to see $g_2(x, Q^2)$

- Twist-4 GPDS, "genuine" twist-4 corrections
  - No reason to bother:
    - Factorization broken
    - $\frac{|t|}{Q^2} \gg \frac{\Lambda_{QCD}^2}{Q^2}$

- Soft corrections and vector meson electroproduction