DVCS on a photon
&
generalized parton distributions in the photon

Samuel Friot

Departament Estructura i Constituents de la Materia
Universitat de Barcelona

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The photon structure functions F_2^γ and F_L^γ

High energies ⇒ photon's point-like component dominates its hadronic-like component ⇒ F_2^γ and F_L^γ are perturbatively computable

They have unique features:

- Scaling violation already in the PM for F_2^γ Walsh and Zerwas 1973, Kingsley 1973

$$F_2^\gamma(x,Q^2) = F_2^\gamma(x)\ln\frac{Q^2}{\Lambda^2} + \ldots \qquad F_2^\gamma(x) = \frac{1}{16\pi^2}\sum_i e_i^4 x(1-2x+2x^2)$$

- PM gives wrong scaling violation magnitude and shape Witten 1977

What about generalized parton distributions?

DIS → inclusive → cross-section → imaginary part

DVCS → exclusive → amplitude → imaginary part + real part

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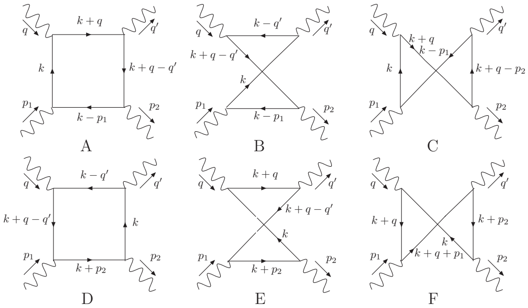

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From now on we put $\Delta_T = 0$

Aim: extract PM analytical expressions for the GPDs from the typical integral representation of the amplitude $\int_{-1}^{1} dx\, f(x, \xi, Q^2) \frac{1}{x - \xi + i\epsilon}$

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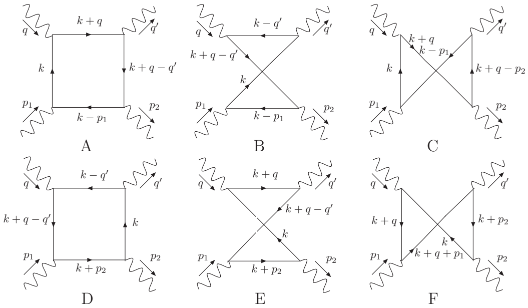

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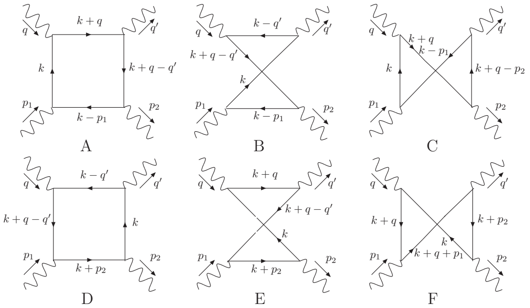

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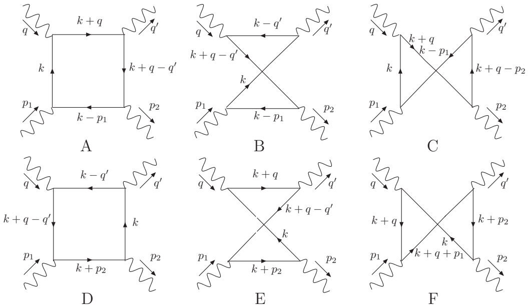

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$$A \doteq \epsilon_\mu \epsilon'^*_\nu \epsilon_{1\alpha} \epsilon^*_{2\beta} T^{\mu\nu\alpha\beta},$$

where $\epsilon(q)$, $\epsilon'^*(q')$, $\epsilon_1(p_1)$ and $\epsilon^*_2(p_2)$ are transverse and

$$T^{\mu\nu\alpha\beta}(\Delta_T = 0) = \frac{1}{4} g_T^{\mu\nu} g_T^{\alpha\beta} W_1 + \frac{1}{8}\left(g_T^{\mu\alpha} g_T^{\nu\beta} + g_T^{\nu\alpha} g_T^{\mu\beta} - g_T^{\mu\nu} g_T^{\alpha\beta}\right) W_2$$

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The loop momentum is $k = (x+\xi)p + \beta n + k_T$
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$$d^4k = \frac{s}{2} dx d\beta d^2 k_T = \frac{\pi s}{2} dx d\beta d\mathbf{k}^2$$

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The box diagram and W_1

REAL PART

$\mathcal{R}e\, W_1^{box}$ is proportional to the real part of

$$\int \frac{dx\, d\beta\, d\mathbf{k}^2 \quad TrA_1}{[(k+q)^2 - m^2 + i\eta][(k-p_1)^2 - m^2 + i\eta](k^2 - m^2 + i\eta)[(k+\Delta)^2 - m^2 + i\eta]}$$

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- Integration over $\beta \Rightarrow$ DGLAP ($\xi < x < 1$) and ERBL ($-\xi < x < \xi$) integrals.
- Integration over $\mathbf{k}^2 \Rightarrow$ UV divergent

This leads to

$$\mathcal{R}e\, W_1^{box} \sim \int_{\xi}^{1} dx \frac{2(x^2 + (1-x)^2 - \xi^2)}{\pi\, s\, (1-\xi^2)(\xi - x)} \log\frac{m^2}{Q^2} + \int_{-\xi}^{\xi} dx \frac{(x+\xi)(\xi - 2x + 1)}{\pi\, s\, \xi(1+\xi)(x-\xi)} \log\frac{m^2}{Q^2} + div\,.$$

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IMAGINARY PART

By Cutkosky rules, we get

$$Disc\, W_1^{box} = \frac{i}{\pi} e_q^4 N_C \int_{\xi+\frac{m^2}{Q^2}}^{1-\frac{m^2}{Q^2}} \frac{dx}{x-\xi} \frac{(x^2+\bar{x}^2-\xi^2)}{1-\xi^2}$$

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Total PM result

• No contributions to the imaginary part from other diagrams

• All diagrams contribute to cancell UV divergence in the real part but collinear factorization is not in conflict with Gauge invariance requirement: cat-ears diagrams have a divergent real contribution but no log $\frac{m^2}{Q^2}$
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$$\frac{1}{x \pm \xi \mp i\eta} = P\,\frac{1}{(x \pm \xi)} \mp i\pi\delta(x \pm \xi)$$

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QCD factorization of the DVCS amplitude on the photon

Let us consider (from OPE)

$$F^q = \int \frac{dz}{2\pi} e^{ixz} \langle \gamma(p') | \bar{q}(-\frac{z}{2}N) \gamma.N q(\frac{z}{2}N) | \gamma(p) \rangle$$

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where $N = n/n.p$ and $F^{N\mu} = N_\nu F^{\nu\mu}$.
To zeroth order in α_s,

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The renormalization scale is identified with a factorization scale M_F.

Choosing that for $M_F = m$ we have $F^q = 0$, then

$$F_R^q = \frac{N_C e_q^2}{4\pi^2} g_T^{\mu\nu} \epsilon_\mu(p_1)\epsilon_\nu(p_2) \log \frac{m^2}{M_F^2} F(x,\xi)$$

We can define the generalized quark distributions of the photon $H_i^q(x,\xi,0)$ as

$$F_R^q = -g_T^{\mu\nu} \epsilon_\mu(p_1)\epsilon_\nu^*(p_2) H_1^q(x,\xi,0) \,, \quad \tilde{F}_R^q = i\epsilon^{\mu\nu pN} \epsilon_\mu(p_1)\epsilon_\nu^*(p_2) H_3^q(x,\xi,0)$$

because with this definition

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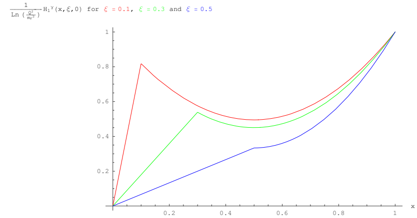
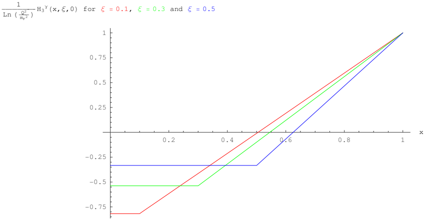
The ln $\frac{M_F^2}{Q^2}$ contribution corresponds to the "photon content of the photon"

One can choose $M_F^2 = Q^2$ to eliminate it $\Rightarrow$ partonic interpretation of DVCS amplitude (at LO)





Conclusion

- One has been able to define the anomalous GPDs of the photon at LO in the PM
- These GPDs can in principle be measured

To go beyond this analysis, one can

- keep Δ_T non-zero
- get QCD corrections from evolution equations with an inhomogeneous term (scaling violation term) DeWitt et al. 1979