NLO description of the photoproduction of a diphoton with a large invariant mass

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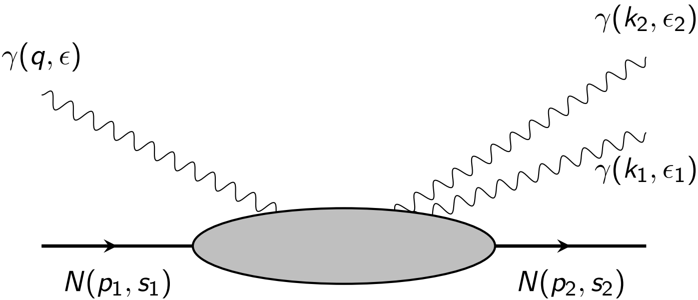
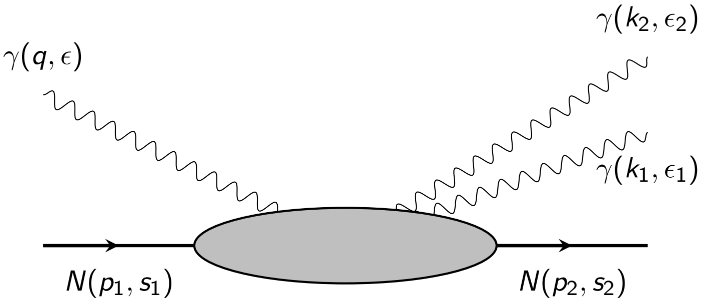
in collaboration with B. Pire, P. Sznajder, L. Szymanowski and J. Wagner

April 14, 2021

Kinematics


$\gamma(q, \epsilon)$
$\gamma(k_2, \epsilon_2)$
$\gamma(k_1, \epsilon_1)$
$N(p_1, s_1)$
$N(p_2, s_2)$

Kinematics



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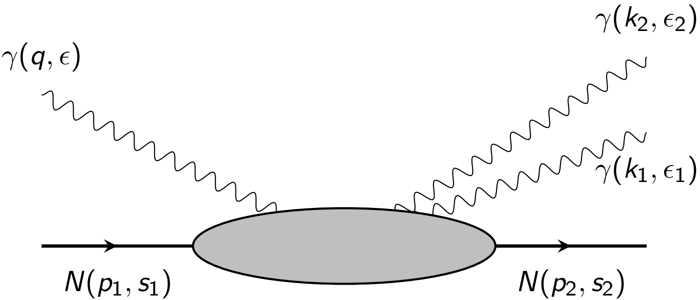

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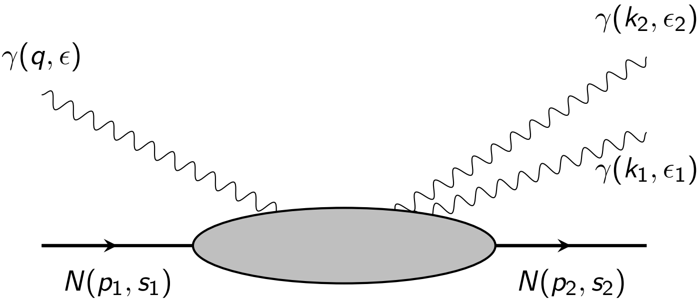

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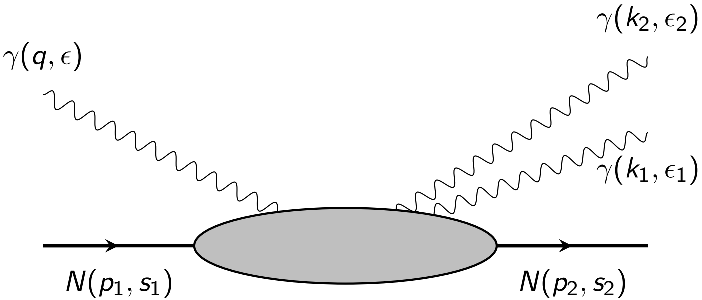

$$S_{\gamma N} = (p+q)^2, \qquad t = (p_1 - p_2)^2,$$
$$M_{\gamma\gamma}^2 = (k_1 + k_2)^2, \qquad u' = (k_2 - q)^2.$$

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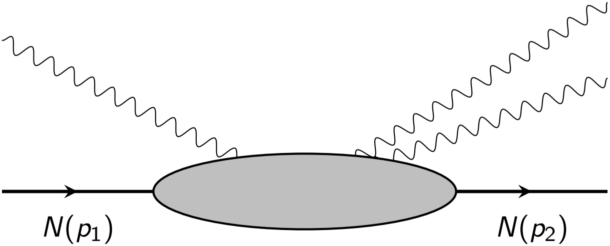
- No contribution from the badly known chiral-odd quark GPDs at leading twist.

The leading order analysis



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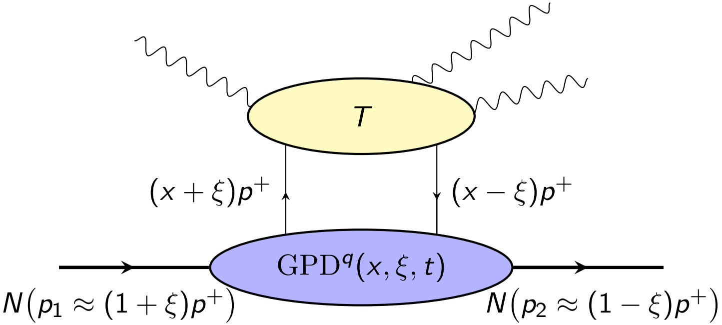

$$\mathcal{A} = \sum_q \int_{-1}^{1} dx\, \mathcal{T}\big(x, S_{\gamma N}, t, u', M^2_{\gamma\gamma}\big)\,\mathrm{GPD}^q(x,\xi,t).$$

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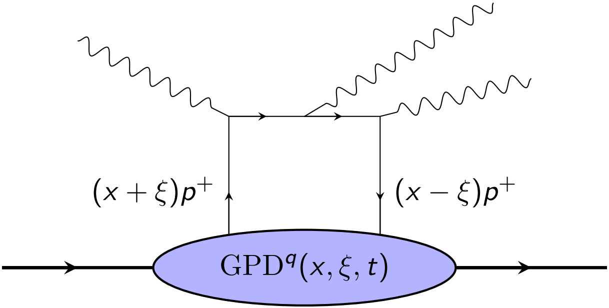

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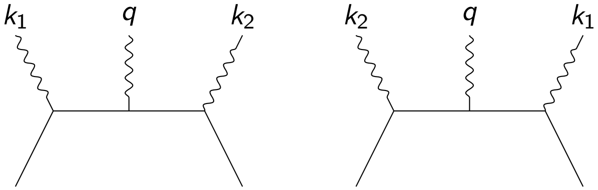

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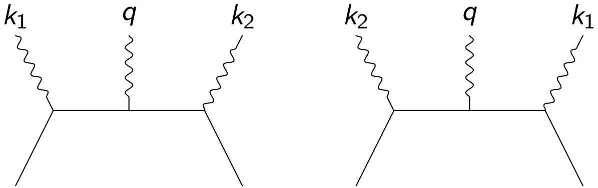


The LO hard part $\propto i\pi\frac{1}{\xi}\Big(\delta(x+\xi)+\delta(x-\xi)\Big)$, so that, at the leading QCD order the result is proportional to $\mathrm{GPD}(\xi,\xi,t)+\mathrm{GPD}(-\xi,\xi,t)$.

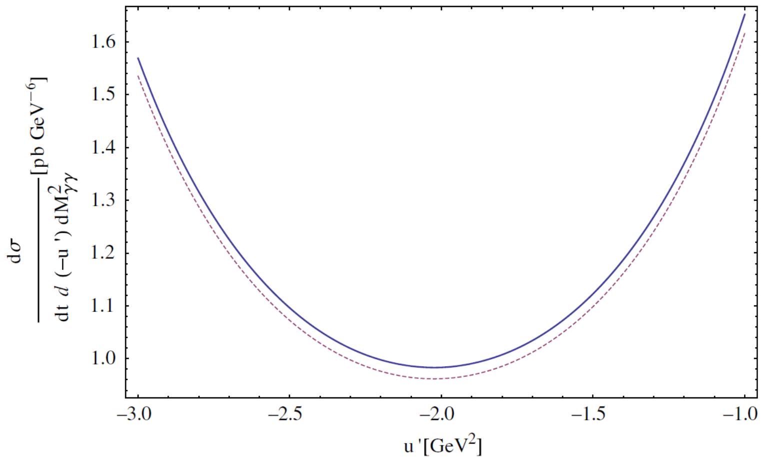
The leading order analysis

Unpolarised differential cross section

$$\frac{d\sigma}{dM^2_{\gamma\gamma}\, dt\, d(-u')}.$$

The LO results, Pedrak et al. Phys. Rev. D 96 (2017) and Phys. Rev. D 101 (2020), show that this process can be studied at intense quasi-real photon beam facilities in JLab or EIC.

The leading order analysis



The u' dependence of the differential cross section for two different models of GPDs. $S_{\gamma N} = 20\,\mathrm{GeV}^2$, $M^2_{\gamma\gamma} = 4\mathrm{GeV}^2$, $t = t_{min}$.

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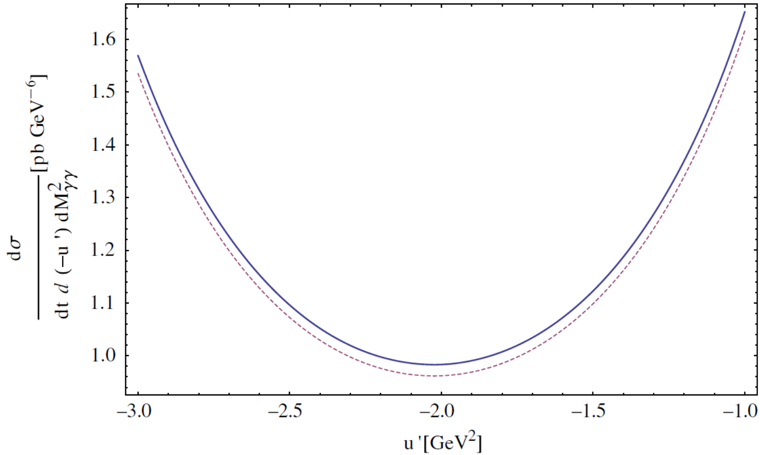

The u' dependence of the differential cross section for two different models of GPDs. $S_{\gamma N} = 20\,\mathrm{GeV}^2$, $M^2_{\gamma\gamma} = 4\mathrm{GeV}^2$, $t = t_{min}$.
The differential cross section is small, but measurable.

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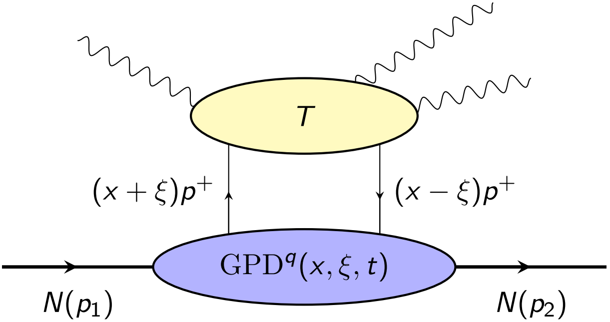
Factorization at NLO



$$\mathcal{A} = \sum_q \int_{-1}^{1} dx\, \mathcal{T}(x, S_{\gamma N}, t, u', M^2_{\gamma\gamma})\, \mathrm{GPD}^q(x, \xi, t).$$

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$$\mathcal{T}^q(x) = \mathcal{C}^q_0 + \frac{\alpha_S}{2\pi} \Big(\frac{M^2_{\gamma\gamma} e^\gamma}{4\pi\mu_R^2} \Big)^{-\varepsilon/2} \Big(\frac{2}{\varepsilon} \mathcal{C}^q_{coll.} + \mathcal{C}^q_1 \Big).$$

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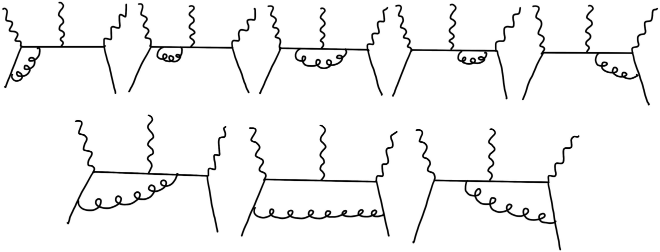
If that is true, then

$$\mathcal{A} = \sum_q \int_{-1}^{1} dx \mathrm{GPD}^q_R(x;\mu_F)\left(\mathcal{C}^q_0(x)+\frac{\alpha_S}{2\pi}\left[\mathcal{C}^q_1(x)+\ln\left(\frac{\mu_F^2}{M^2_{\gamma\gamma}}\right)\mathcal{C}^q_{coll.}(x)\right]\right).$$

One loop corrections



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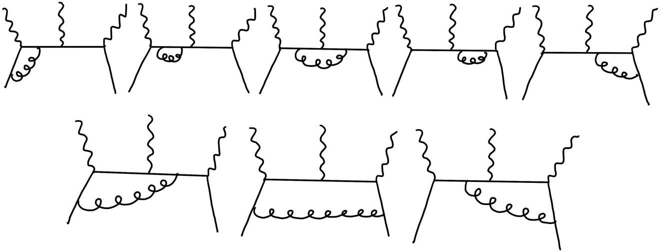

There are 48 diagrams at NLO; considering permutations over photons we reduce this number to 8.

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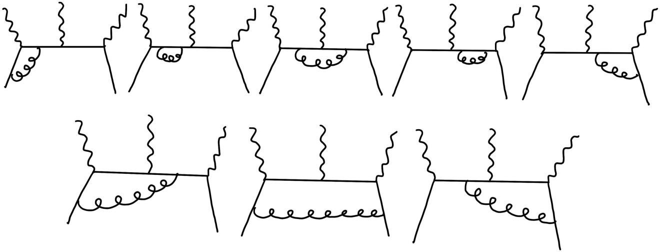

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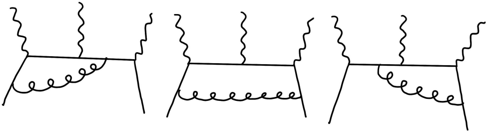
Rememeber, that there are no contributions from gluon-initiated processes.

One loop corrections – 4- and 5- point diagrams



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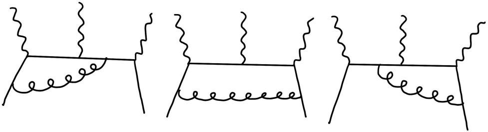

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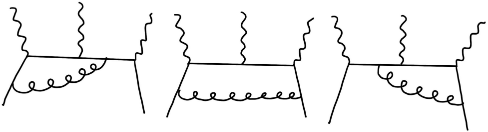

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All particles are massless $\Longrightarrow$ using the appropriate substitution we can factorize the resulting 3-dimensional integral using redefined Feynman parameters $\{u_i\}$:

$$\int_0^1 du_3\, u_3^n (1-u_3)^m \int_0^1 du_2 \int_0^1 du_1\, \Delta(u_1, u_2).$$

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The second part is finite and expressible in terms of log and dilog functions.

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$$\mathcal{C}^q_{coll.} = iC_F \times \mathrm{C} \times \mathrm{Im}\Bigg[\frac{3}{(x-\xi+i0^+)(x+\xi-i0^+)} + \\ + \frac{1}{\xi}\frac{\log\left(\frac{x-\xi+i0^+}{-2\xi}\right)}{x-\xi+i0^+} - \frac{1}{\xi}\frac{\log\left(\frac{x+\xi-i0^+}{2\xi}\right)}{x+\xi-i0^+}\Bigg].$$

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To check the cancelation of discussed divergences, it is easier to use the following form of the LO part:

$$\mathcal{C}_0^q(x) = i \times \mathrm{C} \times \mathrm{Im}\Big(\frac{1}{(x+\xi-i0^+)(x-\xi+i0^+)}\Big).$$

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Indeed,

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- The full form of the NLO amplitude has been obtained. At this order, there are non-vanishing contributions to the real part of the amplitude.
- Phenomenological analysis is in progress – currently we are working on implementation of results in the PARTONS framework.