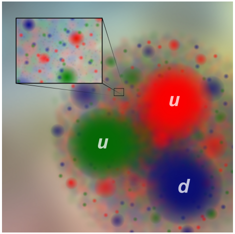
Tomografia protonu w procesie ekskluzywnej produkcji par fotonów z dużą masą inwariantną



Narodowe Centrum Badań Jądrowych
Zakład Fizyki Teoretycznej

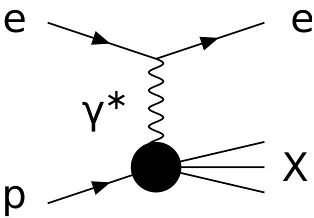
Warszawa, 9 stycznia 2018

Proton spin budget

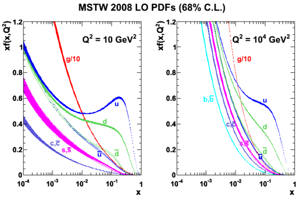
- It is still unknown how the proton spin is built out of quark and gluons polarizations $\Delta\Sigma$ and ΔG and their orbital angular momentum L:

$$\frac{1}{2} = \Delta\Sigma + \Delta G + L$$

- Most important information comes from Deep Inelastic Scattering (DIS):



(a) DIS

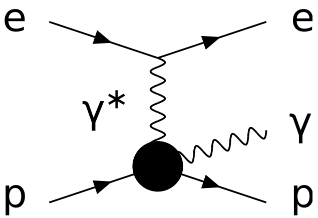


(b) PDFs

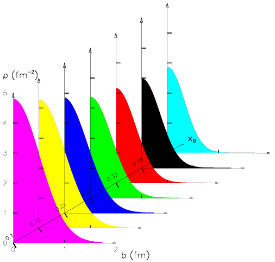
- But inclusive processes give information only about $\Delta\Sigma$ and ΔG.

Exclusive processes

- Exclusive processes described by Generalized Parton Distributions (GPDs), provides information about orbital angular momentum L
- Allow for nuclear tomography - probabilities of finding a parton with longitudinal momentum fraction x at a given $\mathbf{b}_\perp$.



(c) DVCS

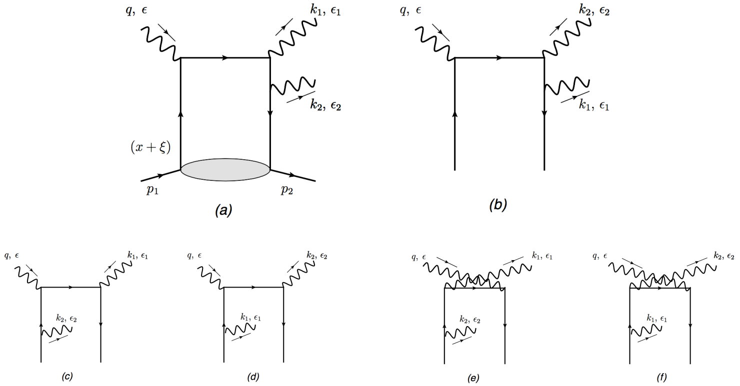


(d) nucleon tomography

Hard photoproduction of a diphoton with a large invariant mass

A. Pedrak, B. Pire, L. Szymanowski, JW, **PRD 96**

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



Rysunek: Feynman diagrams contributing to the coefficient function of the process $\gamma N \to \gamma\gamma N'$

Hard photoproduction of a diphoton with a large invariant mass

- Purely electromagnetic process at Born order - as are deep inelastic scattering (DIS), deeply virtual Compton scattering (DVCS) and timelike Compton scattering (TCS).
- Insensitive to gluon GPDs.
- No contribution from the badly known chiral-odd quark distributions.
- This study enlarges the range of $2 \to 3$ reactions analyzed in the framework of collinear QCD factorization. Simplest - great tool to study factorization.

The scattering amplitude is written in terms of generalized Compton form factors $\mathcal{H}^q(\xi)$, $\mathcal{E}^q(\xi)$, $\tilde{\mathcal{H}}^q(\xi)$ and $\tilde{\mathcal{E}}^q(\xi)$ as

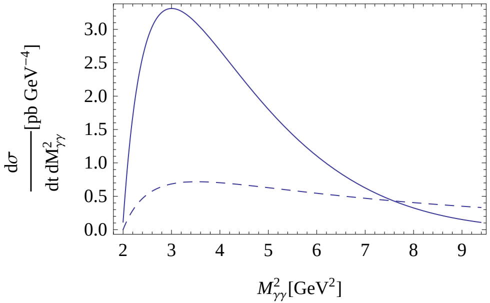
$$\mathcal{T} = \frac{1}{2s}\Bigg[\left(\mathcal{H}(\xi)\bar{U}(p_2)\, \not{n} U(p_1) + \mathcal{E}(\xi)\bar{U}(p_2)\frac{i\sigma^{\mu\nu}\Delta_\nu n_\mu}{2M}U(p_1)\right) + \left(\tilde{\mathcal{H}}(\xi)\bar{U}(p_2)\, \not{n}\gamma^5 U(p_1) + \tilde{\mathcal{E}}(\xi)\bar{U}(p_2)\frac{i\gamma_5(\Delta\cdot n)}{2M}U(p_1)\right)\Bigg]$$

$$\mathcal{H}(\xi) = \sum_q \int_{-1}^{1} dx\, CF_q^V(x,\xi) H^q(x,\xi), \quad \tilde{\mathcal{H}}(\xi) = \sum_q \int_{-1}^{1} dx\, CF_q^A(x,\xi)\tilde{H}^q(x,\xi),$$

$$\begin{aligned}
\mathrm{Re}\,\mathcal{H}(\xi) &\sim \sum_q e_q^3 P.V. \int_{-1}^{1} dx \frac{H^q(x,\xi) + H^q(-x,\xi)}{x-\xi} \\
\mathrm{Im}\,\mathcal{H}(\xi) &\sim \sum_q e_q^3 \left[H^q(\xi,\xi) + H^q(-\xi,\xi)\right] \\
\mathrm{Re}\,\tilde{\mathcal{H}}(\xi) &\sim 0 \\
\mathrm{Im}\,\tilde{\mathcal{H}}(\xi) &\sim \sum_q e_q^3 \left[\tilde{H}^q(\xi,\xi) - \tilde{H}^q(-\xi,\xi)\right]
\end{aligned}$$

Choosing as independent kinematical variables $\{t, u', M^2_{\gamma\gamma}\}$, the fully unpolarized differential cross section reads

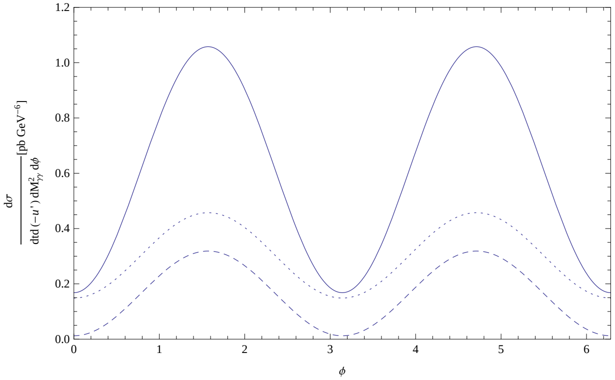
$$\frac{d\sigma}{dM^2_{\gamma\gamma}dtd(-u')} = \frac{1}{2}\frac{1}{(2\pi)^3 32 S^2_{\gamma N} M^2_{\gamma\gamma}} \sum_{\lambda,\lambda_1\lambda_2,s_1,s_2} \frac{|\mathcal{T}|^2}{4}$$



Rysunek: the $M^2_{\gamma\gamma}$ dependence of the unpolarized differential cross section on a proton at $t = t_{min}$ and $S_{\gamma N} = 20 GeV^2$ (full curves) and $S_{\gamma N} = 100 GeV^2$ (dashed curve). The bounds in u' are chosen so that both $-u'$ and $-t'$ are larger than 1 GeV^2.

Azimuthal dependence

Linear initial photon polarization defines the x axis and hence the azimuthal angle ϕ between the initial photon polarization and one of the final photon momentum in the transverse plane.



Rysunek: The azimuthal dependence of the differential cross section $\frac{d\sigma}{dM^2_{\gamma\gamma}dtdu'd\phi}$ at various kinamtical points relevant for JLab.

Summary - diphoton photoproduction

- Purely electromagnetic process at Born order
- Insensitive to gluon GPDs
- Cross section of the order of TCS which is measurable at JLAB
- Strong azimuthal dependence for linearly polarized photon beam

To be done:

- The $O(\alpha_s)$ corrections to the amplitude need to be calculated.They are particularly interesting since they open the way to a perturbative proof of factorization.
- Importance of the timelike vs spacelike nature of the probe with respect to the size of the NLO corrections; since the hard scales at work in our process are both the timelike one $M^2_{\gamma\gamma}$ and the spacelike one u', we are facing an intermediate case between timelike Compton scattering (TCS) and spacelike DVCS.
- Leptoproduction needs to be complemented by the analysis of the Bethe Heitler processes where one or two photons are emitted from the lepton line. Probably dominating and leading to interesting interference effects.

Other news from QCD group

- Tolga Altinoluk: joined this year, Stypendium dla wybitnych młodych naukowców MNiSzW
- Aleksandra Pędrak: joined at the end of last year,
- Lech Szymanowski: 9 publications in the top journals (1 Few Body Systems, 7 Physical Review D, 1 Physical Review Letters)
- PARTONS - P.Sznajder (BP3), J.Wagner: software framework dedicated to the description of exclusive processes: phenomenology, fits, etc. - in collaboration with CEA Saclay, IPN Orsay, ...

All of this theory activity connected to ongoing and planned experiments: LHC, Compass, JLab, RHIC, EIC!