Extraction of GPDs from Exclusive Dilepton Photoproduction

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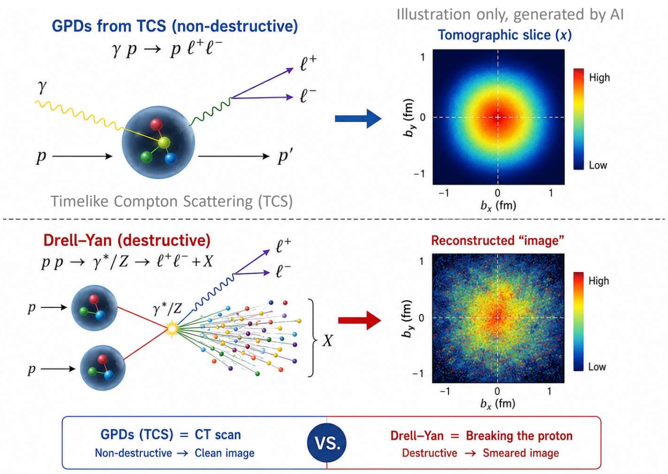
SCanning, not smashing



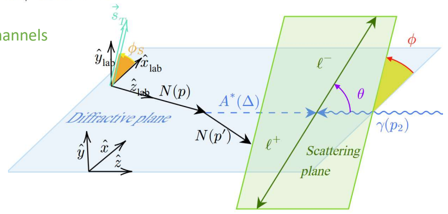
❖ Physics does not depend on frames ⟶ Better frame helps calculations & even better for GPD extractions

❖ SDHEP frame as the optimal frame ⟶ Kinematics ***fully disentangles*** from dynamics & ***angular modulations*** to distinguish GPDs

$$\mathcal{M}(\hat{s},\theta,\phi) \sim \sum_{A^*} e^{i(\lambda_{A^*}-\lambda_\gamma)\phi} F_{A^*} \otimes C_{A^*\gamma\to\ell^-\ell^+}(\hat{s},\theta)$$

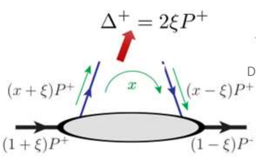
Interference between different channels

$$\cos[\delta(\lambda_{A^*}-\lambda_\gamma)\phi] \quad \text{and/or} \quad \sin[\delta(\lambda_{A^*}-\lambda_\gamma)\phi]$$



$$\frac{d\sigma}{d|t|\,d\xi\,d\phi_S\,d\cos\theta\,d\phi} = \frac{1}{(2\pi)^2}\frac{d\sigma^{\text{unpol}}}{d|t|\,d\xi\,d\cos\theta}\cdot\Big[1+\lambda_N\lambda_\gamma A_{LL}^{\text{LP}} + s_T\lambda_\gamma A_{TL}^{\text{LP}}\cos\phi_S + \zeta_\gamma A_{UT}^{\text{LP}}\cos 4(\phi-\phi_\gamma/2)$$
$$+\left(A_{UU}^{\text{NLP}}+\lambda_N\lambda_\gamma A_{LL}^{\text{NLP}}\right)\cos\phi + \left(\lambda_N A_{LU}^{\text{NLP}}+\lambda_\gamma A_{UL}^{\text{NLP}}\right)\sin\phi$$
$$+\zeta_\gamma A_{UT}^{\text{NLP}}\cos(3\phi-2\phi_\gamma) + \lambda_N\zeta_\gamma A_{LT}^{\text{NLP}}\sin(3\phi-2\phi_\gamma)$$
$$+s_T\left(A_{TU,1}^{\text{NLP}}\cos\phi_S\sin\phi + A_{TU,2}^{\text{NLP}}\sin\phi_S\cos\phi\right) + s_T\lambda_\gamma\left(A_{TL,1}^{\text{NLP}}\cos\phi_S\cos\phi + A_{TL,2}^{\text{NLP}}\sin\phi_S\sin\phi\right)$$
$$+s_T\zeta_\gamma\left(A_{TT,1}^{\text{NLP}}\cos\phi_S\sin(3\phi-2\phi_\gamma) + A_{TT,2}^{\text{NLP}}\sin\phi_S\cos(3\phi-2\phi_\gamma)\right)\Big],$$

DIfficulties, amplitude nature



$$F^q(x,\xi,t) = \int \frac{dz^-}{4\pi} e^{-ixP^+z^-} \langle p'|\bar{q}(z^-/2)\gamma^+ q(-z^-/2)|p\rangle$$

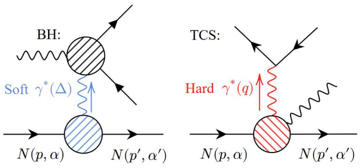
D. Müller, D. Robaschik, B. Geyer, F.-M. Dittes, J. Hořejši, Fortsch. Phys. 42 (1994) 101

$$\widetilde{F}^q(x,\xi,t) = \int \frac{dz^-}{4\pi} e^{-ixP^+z^-} \langle p'|\bar{q}(z^-/2)\gamma^+\gamma_5 q(-z^-/2)|p\rangle$$

❖ Real GPDs enters through ***complex convolutions*** ⟶ Inverse problem & not isolated

❖ Simple as TCS, still ***two subprocesses***

⟶ Bethe-Heitler (non-GPDs) & Timelike Compton Scattering



❖ Exclusive process + photon beam ⟶ ***Limited Statistics***

HArmonics, dedicated to GPDs

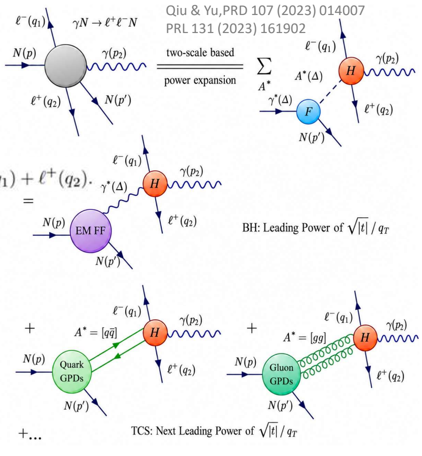
Two-scale nature of TCS enables a natural factorization and power expansion

$$q_T \sim q_{1T} \sim q_{2T} \sim Q \gg \sqrt{|t|} = \sqrt{\Delta^2}$$

Qiu & Yu, PRD 107 (2023) 014007
PRL 131 (2023) 161902

Two-staged description:

$$N(p) \to A^*(\Delta = p - p') + N(p'),$$
$$\hookrightarrow A^*(\Delta) + \gamma(p_2) \to \ell^-(q_1) + \ell^+(q_2).$$



- $A^*(\Delta)$ has a typical lifetime of $\frac{1}{\sqrt{|t|}} \gg \frac{1}{Q} \to$ ***long-lived*** quasi state.
- $A^*(\Delta)$ contains all the info about GPDs
- A natural expansion in powers of $\sqrt{|t|}/Q$
- An expansion of **different twist** GPDs

EXtraction, made clean

CLAS, PRL 127 (2021) 262501

Proposed measurement:

$$A_{\odot U} = \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-}$$

Conventional almost no simplifications:

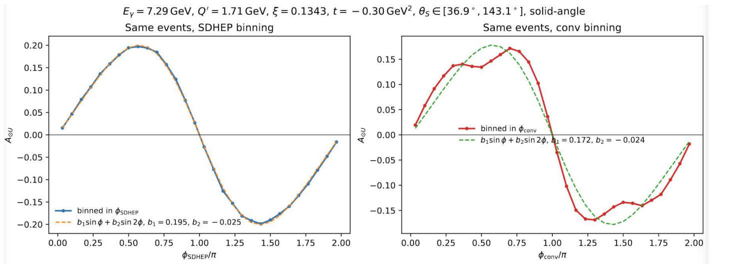
Berger, Diehl, Pire (2002)

$$A_{\odot U}(\phi_{\text{conv}},\theta_{\text{conv}}) = \frac{\frac{1}{s^2}\frac{M}{Q'}\frac{L_0}{\sqrt{1-\tau}}\sin\phi_{\text{conv}}\frac{1+\cos^2\theta_{\text{conv}}}{\sin\theta_{\text{conv}}}\operatorname{Im}\widetilde{M}^{--}}{\frac{1}{(s-M^2)^2}\left[\left(F_1^2-\frac{t}{4M^2}F_2^2\right)\frac{A}{-t}+(F_1+F_2)^2\frac{B}{2}\right]-\frac{1}{s^2}\frac{M}{Q'}\frac{L_0}{\sqrt{1-\tau}}\cos\phi_{\text{conv}}\frac{1+\cos^2\theta_{\text{conv}}}{\sin\theta_{\text{conv}}}\operatorname{Re}\widetilde{M}^{--}}$$

SDHEP much simplified expression:

$$A_{\odot U}(\theta_{\text{SDHEP}},\phi_{\text{SDHEP}}) = \frac{A_{UL}^{NLP}\sin\phi_{\text{SDHEP}}}{1-A_{UU}^{NLP}\cos\phi_{\text{SDHEP}}} \qquad A_{\odot U}(\phi_{\text{SDHEP}}) = \frac{\int d\theta_{\text{SDHEP}}\,A_{\odot U}(\theta_{\text{SDHEP}},\phi_{\text{SDHEP}})}{\int d\theta_{\text{SDHEP}}\,A_{\odot U}(\theta_{\text{SDHEP}},\phi_{\text{SDHEP}})} = \frac{\overline{A}\sin\phi_{\text{SDHEP}}}{1-\overline{B}\cos\phi_{\text{SDHEP}}}$$

Simple two-parameter fit



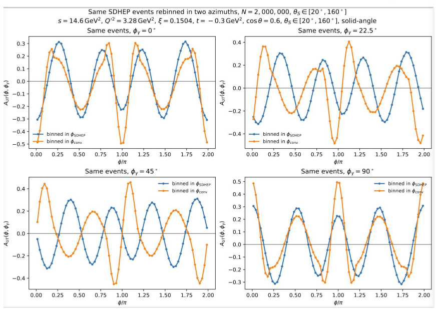
Simple shape in SDHEP framework and complex shape in conventional one as expected; worsened by ***limited statistics***.

POlarization, new handles

❖ All polarizations could be accessed ⟶ A potential linear polarization application

$$\Sigma_{UT}(\phi,\phi_\gamma;\theta) \equiv \frac{1}{\zeta_\gamma}\frac{d\sigma(\phi_\gamma)-d\sigma\left(\phi_\gamma+\frac{\pi}{2}\right)}{d\sigma(\phi_\gamma)+d\sigma\left(\phi_\gamma+\frac{\pi}{2}\right)} = \frac{A_{UT}^{\text{LP}}\cos(4\phi-2\phi_\gamma)+A_{UT}^{\text{NLP}}\cos(3\phi-2\phi_\gamma)}{1+A_{UU}^{\text{NLP}}\cos\phi}$$

$$\longrightarrow \quad \Sigma_{UT}(\phi,\phi_\gamma) = \frac{\overline{A}_{\text{LP}}\cos(4\phi-2\phi_\gamma)+\overline{A}_{\text{NLP}}\cos(3\phi-2\phi_\gamma)}{1-\overline{B}\cos\phi}$$



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