

Extracting GPDs from exclusive photo-production of a gamma-meson pair

DIS 2022

Saad Nabeebaccus

saad.nabeebaccus@ijclab.in2p3.fr



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With S. Wallon, L. Szymanowski, B. Pire, R. Boussarie, G. Duplančić,
K. Passek-Kumerički

Introduction

GPDs: DVCS

DVCS: exclusive process (non forward amplitude)

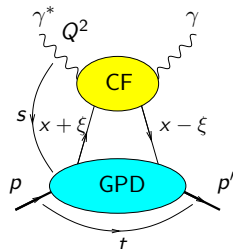
(DVCS: Deep Virtual **Compton** Scattering)

Fourier transf.: $t \leftrightarrow$ impact parameter

$(x, t) \Rightarrow$ 3-dimensional structure

Coefficient Function (hard) \otimes **Generalized Parton Distribution** (soft)

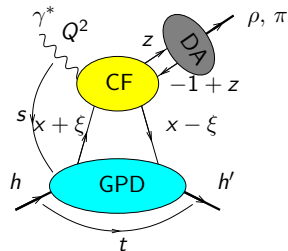
Müller et al. '91 - '94; Radyushkin '96; Ji '97



GPDs: Meson Production

Meson production: γ replaced by ρ, π, \dots

GPD (soft) \otimes CF (hard) \otimes Distribution Amplitude (soft)



Collins, Frankfurt, Strikman '97; Radyushkin '97

proofs valid only for some restricted cases

Introduction

Quark GPDs: twist 2 Chiral-even

Quark GPDs at twist 2

without helicity flip (chiral-even Γ matrices): 4 chiral-even GPDs:
(Note: $\Delta = p' - p$)

$$\begin{aligned} F^q &= \frac{1}{2} \int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' | \bar{q}(-\tfrac{1}{2}z) \gamma^+ q(\tfrac{1}{2}z) | p \rangle \Big|_{z^+=0, z_\perp=0} \\ &= \frac{1}{2P^+} \left[H^q(x, \xi, t) \bar{u}(p') \gamma^+ u(p) + E^q(x, \xi, t) \bar{u}(p') \frac{i \sigma^{+\alpha} \Delta_\alpha}{2m} u(p) \right], \end{aligned}$$

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$$\begin{aligned} \tilde{F}^q &= \frac{1}{2} \int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' | \bar{q}(-\frac{1}{2}z) \gamma^+ \gamma_5 q(\frac{1}{2}z) | p \rangle \Big|_{z^+=0, z_\perp=0} \\ &= \frac{1}{2P^+} \left[\tilde{H}^q(x, \xi, t) \bar{u}(p') \gamma^+ \gamma_5 u(p) + \tilde{E}^q(x, \xi, t) \bar{u}(p') \frac{\gamma_5 \Delta^+}{2m} u(p) \right]. \end{aligned}$$

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$$H^q \xrightarrow{\xi=0, t=0} \text{PDF } q \qquad \tilde{H}^q \xrightarrow{\xi=0, t=0} \text{polarized PDF } \Delta q$$

with helicity flip (chiral-odd Γ matrices): 4 chiral-odd GPDs:

$$\begin{aligned} & \frac{1}{2} \int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p' | \bar{q}(-\tfrac{1}{2}z) i \sigma^{+i} q(\tfrac{1}{2}z) | p \rangle \Big|_{z^+=0, z_\perp=0} \\ &= \frac{1}{2P^+} \bar{u}(p') \left[H_T^q i \sigma^{+i} + \tilde{H}_T^q \frac{P^+ \Delta^i - \Delta^+ P^i}{m^2} \right. \\ & \quad \left. + E_T^q \frac{\gamma^+ \Delta^i - \Delta^+ \gamma^i}{2m} + \tilde{E}_T^q \frac{\gamma^+ P^i - P^+ \gamma^i}{m} \right] u(p), \end{aligned}$$

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$H_T^q \xrightarrow{\xi=0, t=0}$ quark transversity PDFs δq

Note: $\tilde{E}_T^q(x, -\xi, t) = -\tilde{E}_T^q(x, \xi, t)$

Why consider a gamma-meson pair?

Understanding transversity

- Transverse spin content of the proton:

$$\begin{array}{ccc} |\uparrow\rangle_{(x)} & \sim & |\rightarrow\rangle + |\leftarrow\rangle \\ |\downarrow\rangle_{(x)} & \sim & |\rightarrow\rangle - |\leftarrow\rangle \\ \text{spin along } x & & \text{helicity states} \end{array}$$

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- ▶ Transversity GPDs can thus be accessed through **chiral-odd** Γ matrices.
- ▶ Since (in the massless limit) QCD and QED are chiral-even ($\gamma^\mu, \gamma^\mu\gamma^5$), **the chiral-odd quantities** ($1, \gamma^5, [\gamma^\mu, \gamma^\nu]$) **which one wants to measure should appear in pairs.**

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Can we probe transversity GPDs in meson production?

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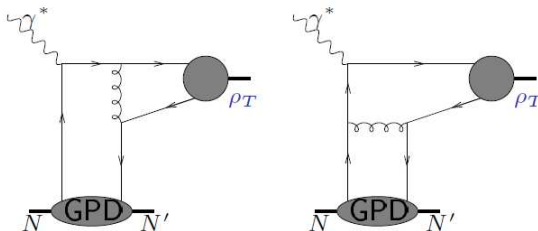
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- ▶ unfortunately $\gamma^* N^\uparrow \rightarrow \rho_T N' = 0$, since such a process would require a helicity transfer of 2 from a photon. [Diehl, Gousset, Pire], [Collins, Diehl]
- ▶ lowest order diagrammatic argument:



$$\gamma^\alpha [\gamma^\mu, \gamma^\nu] \gamma_\alpha = 0$$

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Go to higher twist?

- ▶ This vanishing only occurs at twist 2
- ▶ At twist 3 this process does not vanish [Ahmad, Goldstein, Liuti], [Goloskokov, Kroll]

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- ▶ This vanishing only occurs at twist 2
- ▶ At twist 3 this process does not vanish [Ahmad, Goldstein, Liuti], [Goloskokov, Kroll]
- ▶ However processes involving twist 3 DAs may face problems with factorization (end-point singularities)
can be made safe in the high-energy k_T -factorization approach
[Anikin, Ivanov, Pire, Szymanowski, Wallon]

Why consider a gamma-meson pair?

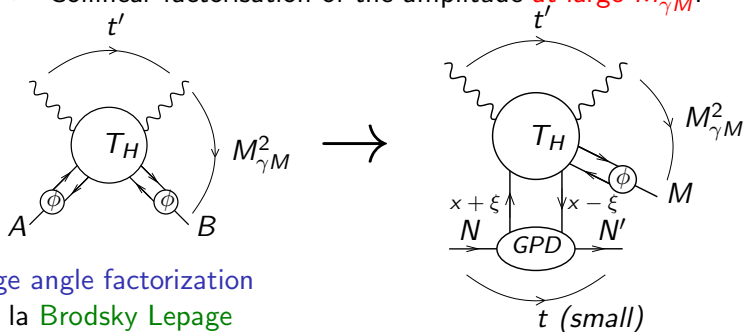
A convenient alternative solution

- ▶ Circumvent this using 3-body final states [Ivanov, Pire, Szymanowski, Teryaev], [Enberg, Pire, Szymanowski], [El Beiyad, Pire, Segond, Szymanowski, Wallon]
- ▶ Consider the process $\gamma N \rightarrow \gamma M N'$, $M = \text{meson}$.

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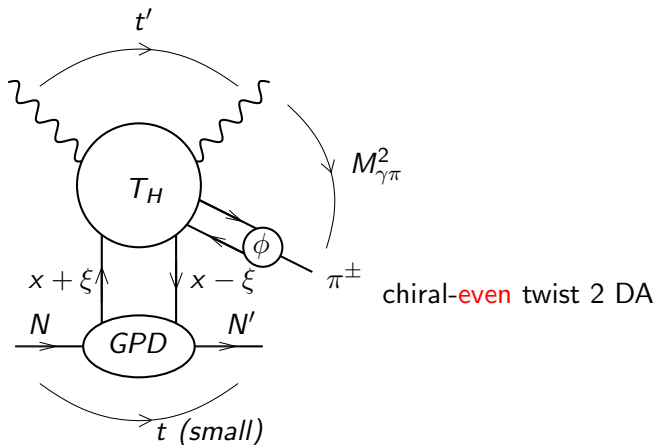
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- ▶ Consider the process $\gamma N \rightarrow \gamma M N'$, $M = \text{meson}$.
- ▶ Collinear factorisation of the amplitude at large $M_{\gamma M}^2$.



large angle factorization
à la Brodsky Lepage

Why consider a gamma-meson pair?

Chiral-even GPDs using $\pi^\pm \gamma$ production

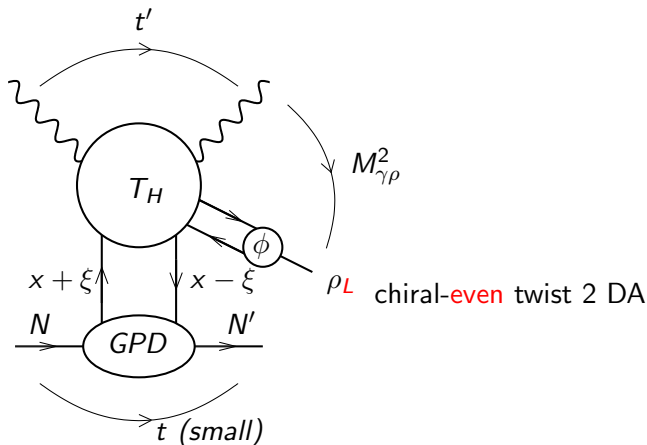


chiral-even twist 2 GPD

[G. Duplanić, K. Passek-Kumerić, B. Pire, L. Szymanowski, S. Wallon]

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Chiral-even GPDs using $\rho_L \gamma$ production

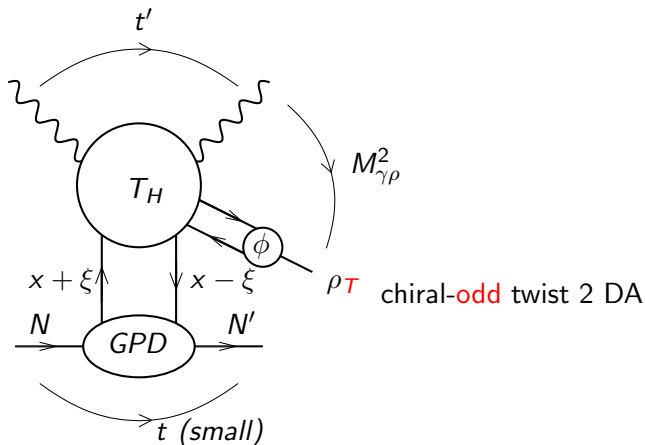


chiral-even twist 2 GPD

[R. Boussarie, B. Pire, L. Szymanowski, S. Wallon]

Why consider a gamma-meson pair?

Chiral-odd GPDs using $\rho_T \gamma$ production



chiral-odd twist 2 DA

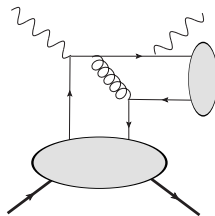
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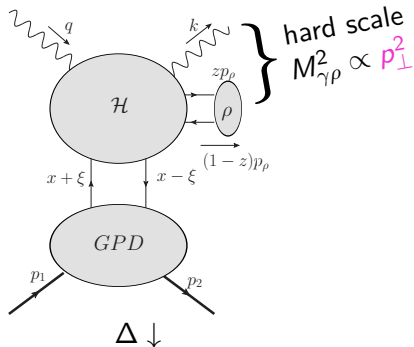
How does it work?



Typical non-zero diagram for a **transverse** ρ meson

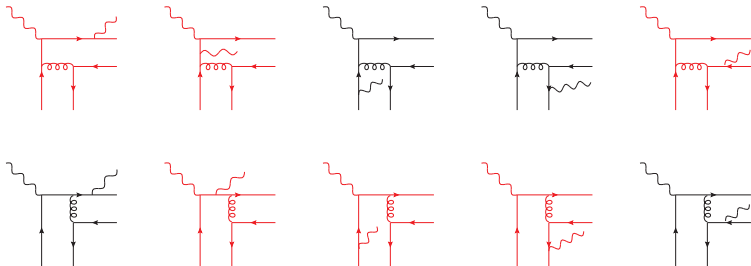
the σ matrices (from either the DA or the GPD) do not kill it anymore!

$$\gamma^{(*)}(q) + N(p_1) \rightarrow \gamma(k) + \rho^0(p_\rho, \varepsilon_\rho) + N'(p_2)$$



Useful Mandelstam variables: $t = (p_2 - p_1)^2$, $u' = (p_\rho - q)^2$

A total of 20 diagrams to compute



- ▶ The other half can be deduced by $q \leftrightarrow \bar{q}$ (anti)symmetry depending on C -parity in t -channel
- ▶ Red diagrams cancel in the chiral-odd case

Details on the parametrisation of GPDs: Backup slides.

\Rightarrow *Radyushkin-type parametrisation in terms of double distributions*

Details on the parametrisation of GPDs: Backup slides.

⇒ *Radyushkin-type parametrisation in terms of double distributions*

For **polarized** PDFs (and hence **transversity** PDFs), two scenarios are proposed for the parameterization:

- ▶ “**standard**” scenario, with flavor-symmetric light sea quark and antiquark distributions.
- ▶ “**valence**” scenario with a completely flavor-asymmetric light sea quark densities.

- We take the simplistic **asymptotic** form of the DAs

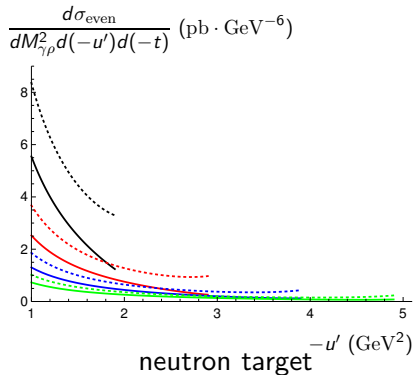
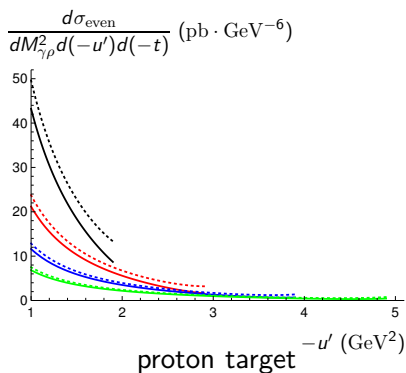
$$\phi_{\pi}(z) = \phi_{\rho\parallel}(z) = \phi_{\rho\perp}(z) = 6z(1-z).$$

- A **non asymptotical** wave function can be also investigated (preliminary):

$$\phi_{sing}(z) = \frac{8}{\pi} \sqrt{z(1-z)}.$$

Results

Fully-differential cross-sections: ρ_L (Chiral even)



$$S_{\gamma N} = 20 \text{ GeV}^2, \text{ at } -t = (-t)_{\min}$$

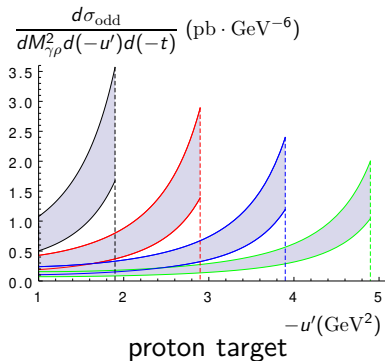
$$M_{\gamma\rho}^2 = 3, 4, 5, 6 \text{ GeV}^2$$

dotted: "standard" model

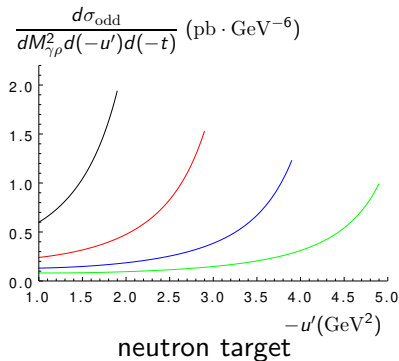
solid: "valence" model

Results

Fully-differential cross-sections: ρ_T (Chiral odd)



“valence” and “standard” models,
each of them with $\pm 2\sigma$ [S. Melis]



“valence” model only

$$S_{\gamma N} = 20 \text{ GeV}^2 \text{ at } -t = (-t)_{\min}$$

$$M_{\gamma\rho}^2 = 3, 4, 5, 6 \text{ GeV}^2$$

Results

Phase space integration

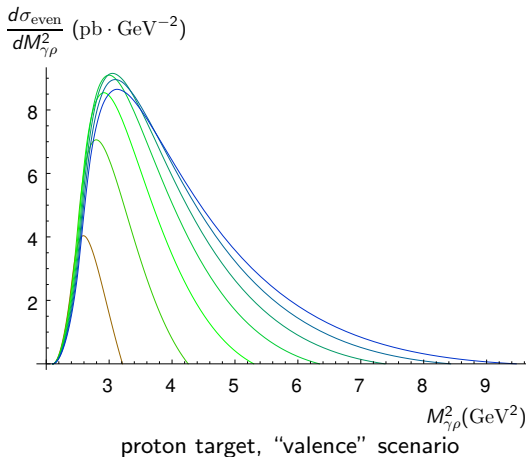
large angle scattering: $M_{\gamma\rho}^2 \sim -u' \sim -t'$

$\Rightarrow -u' > 1 \text{ GeV}^2$ and $-t' > 1 \text{ GeV}^2$ and $(-t)_{\min} \leq -t \leq .5 \text{ GeV}^2$

See backup slides for more details, including information on the phase space evolution in the $(-t, -u')$ plane.

Results

Single differential cross-section: ρ_L (Chiral even)

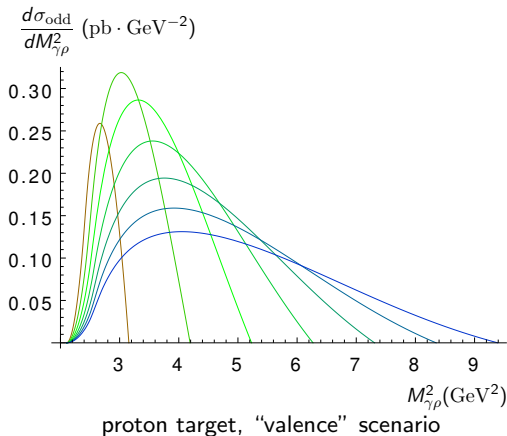


$$S_{\gamma N} = 8, 10, 12, 14, 16, 18, 20 \text{ GeV}^2$$

typical JLab kinematics

Results

Single differential cross-section: ρ_T (Chiral odd)

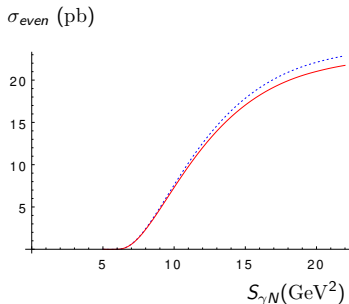


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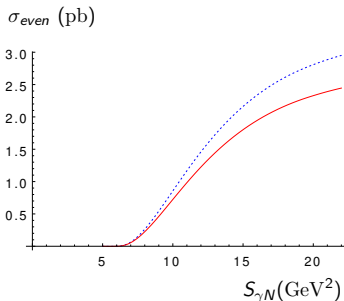
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Integrated cross-section: Valence vs Standard: ρ_L (Chiral even)



proton target



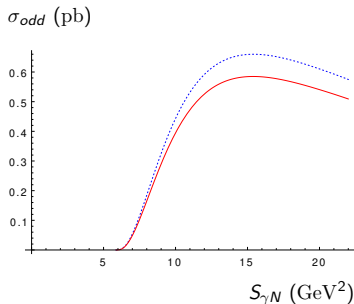
neutron target

solid red: "valence" scenario

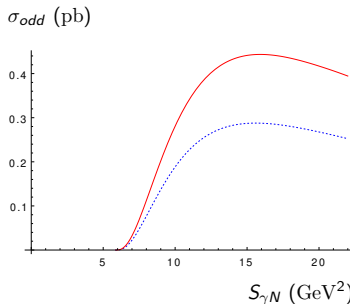
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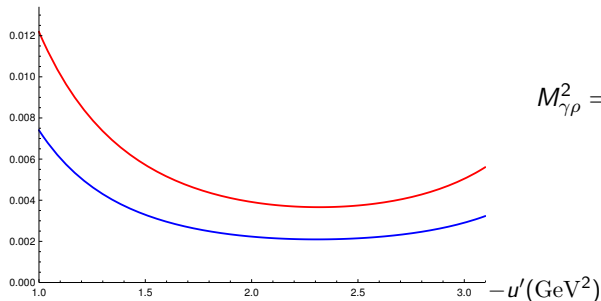
Results (Preliminary)

Fully differential cross-section: Singular DA: ρ_L^+ , Chiral-even

comparing singular DA ($\propto \sqrt{z(1-z)}$)
vs asymptotical DA ($\propto z(1-z)$).

“valence” model for the polarized PDFs

$$\frac{d\sigma_{\text{even}}}{dM_{\gamma\rho}^2 d(-u') d(-t)} \text{ (nb} \cdot \text{GeV}^{-6}\text{)}$$

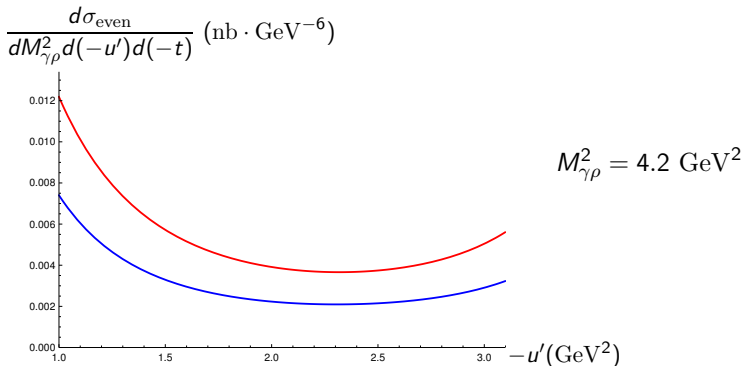


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⇒ sizable effect, larger than the one due to uncertainties on polarized PDFs

Prospects at experiments

Counting rates: JLab

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- ▶ with an expected luminosity of $\mathcal{L} = 100 \text{ nb}^{-1}\text{s}^{-1}$, for 100 days of run:
 - $\rho_L^0 : \approx 7.6 \times 10^4$ (Chiral-even)
 - $\rho_T^0 : \approx 7.5 \times 10^3$ (Chiral-odd)
 - $\pi^+ : \approx 5.8 \times 10^4$ (Chiral-even)
 - $\pi^- : \approx 4.1 \times 10^4$ (Chiral-even)

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- ▶ For data already taken, about 1 order of magnitude less...

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- ▶ **Adjust kinematics** for searches at EIC, LHC at UPC, LHeC and COMPASS. [Ongoing]
- ▶ Add **Bethe-Heitler** component (photon emitted from incoming lepton)
 - zero in chiral-odd case.
 - suppressed in chiral-even case, but could estimate their contributions.

Outlook

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- ▶ Consider **twist-3** contributions.
- ▶ Generalise to **electroproduction** ($Q^2 \neq 0$) (and include Bethe-Heitler contributions).

The END

BACKUP SLIDES

What are GPDs?

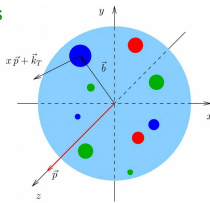
From Wigner distributions to GPDs and PDFs

6D/5D

Wigner distributions
for hadrons

$$W(x, \vec{b}, k_T)$$

Experimentally
inaccessible directly



uPDFs (gluons)

Unintegrated parton
distributions

$$\int d^3 \vec{b}$$

$$\int d^2 k_T \int d b_z$$

$$b_T \leftrightarrow \Delta$$

$$\int d^2 k_T \int \text{Fourier}(\vec{b})$$

$$\xi=0$$

GPDs

$$f(x, b_T)$$

Impact parameter
distributions

$$H(x, 0, t)$$

$$t = -\Delta^2$$

$$H(x, \xi, t)$$

generalised parton
distributions

$$f(x, k_T)$$

Transverse momentum
dependent distributions

PDFs

$$f(x)$$

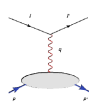
parton distributions



FFs

$$G_{E,M}(t)$$

form factors



GFFs

generalized form factors

lattices

$$\int dx x^{n-1}$$

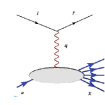
$$\int dx$$

$$t=0$$

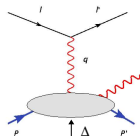
$$\int d^2 b_T$$

$$\int d^2 k_T$$

1D



inclusive and semi-
inclusive processes



exclusive
processes

Computation

Parametrising the GPDs: ρ_L and π case, Chiral-even

$$\int \frac{dz^-}{4\pi} e^{ixP^+z^-} \langle p_2, \lambda_2 | \bar{\psi}_q \left(-\frac{1}{2}z^- \right) \gamma^+ \psi \left(\frac{1}{2}z^- \right) | p_1, \lambda_1 \rangle$$
$$= \frac{1}{2P^+} \bar{u}(p_2, \lambda_2) \left[H^q(x, \xi, t) \gamma^+ + E^q(x, \xi, t) \frac{i\sigma^{\alpha+} \Delta_\alpha}{2m} \right] u(p_1, \lambda_1)$$

$$\int \frac{dz^-}{4\pi} e^{ixP^+z^-} \langle p_2, \lambda_2 | \bar{\psi}_q \left(-\frac{1}{2}z^- \right) \gamma^+ \gamma^5 \psi \left(\frac{1}{2}z^- \right) | p_1, \lambda_1 \rangle$$
$$= \frac{1}{2P^+} \bar{u}(p_2, \lambda_2) \left[\tilde{H}^q(x, \xi, t) \gamma^+ \gamma^5 + \tilde{E}^q(x, \xi, t) \frac{\gamma^5 \Delta^+}{2m} \right] u(p_1, \lambda_1)$$

- Take the limit $\Delta_\perp = 0$.
- In that case and for small ξ , the dominant contributions come from H^q and \tilde{H}^q .

Computation

Parametrising the GPDs: ρ_T case, Chiral-odd

$$\begin{aligned} & \int \frac{dz^-}{4\pi} e^{ixP^+z^-} \langle p_2, \lambda_2 | \bar{\psi}_q \left(-\frac{1}{2}z^- \right) i\sigma^{+i} \psi \left(\frac{1}{2}z^- \right) | p_1, \lambda_1 \rangle \\ &= \frac{1}{2P^+} \bar{u}(p_2, \lambda_2) \left[H_T^q(x, \xi, t) i\sigma^{+i} + \tilde{H}_T^q(x, \xi, t) \frac{P^+ \Delta^i - \Delta^+ P^i}{M_N^2} \right. \\ &+ \left. E_T^q(x, \xi, t) \frac{\gamma^+ \Delta^i - \Delta^+ \gamma^i}{2M_N} + \tilde{E}_T^q(x, \xi, t) \frac{\gamma^+ P^i - P^+ \gamma^i}{M_N} \right] u(p_1, \lambda_1) \end{aligned}$$

- Take the limit $\Delta_\perp = 0$.
- In that case and for small ξ , the dominant contributions come from H_T^q .

- GPDs can be represented in terms of **Double Distributions**
[Radyushkin]

$$H^q(x, \xi, t = 0) = \int_{-1}^1 d\beta \int_{-1+|\beta|}^{1-|\beta|} d\alpha \delta(\beta + \xi\alpha - x) f^q(\beta, \alpha)$$

- ▶ GPDs can be represented in terms of **Double Distributions** [Radyushkin]

$$H^q(x, \xi, t=0) = \int_{-1}^1 d\beta \int_{-1+|\beta|}^{1-|\beta|} d\alpha \delta(\beta + \xi\alpha - x) f^q(\beta, \alpha)$$

- ▶ ansatz for these Double Distributions [Radyushkin]:

- ▶ chiral-even sector:

$$\begin{aligned} f^q(\beta, \alpha, t=0) &= \Pi(\beta, \alpha) q(\beta) \Theta(\beta) - \Pi(-\beta, \alpha) \bar{q}(-\beta) \Theta(-\beta), \\ \tilde{f}^q(\beta, \alpha, t=0) &= \Pi(\beta, \alpha) \Delta q(\beta) \Theta(\beta) + \Pi(-\beta, \alpha) \Delta \bar{q}(-\beta) \Theta(-\beta). \end{aligned}$$

- ▶ chiral-odd sector:

$$f_T^q(\beta, \alpha, t=0) = \Pi(\beta, \alpha) \delta q(\beta) \Theta(\beta) - \Pi(-\beta, \alpha) \delta \bar{q}(-\beta) \Theta(-\beta).$$

- ▶ GPDs can be represented in terms of **Double Distributions** [Radyushkin]

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- ▶ $\Pi(\beta, \alpha) = \frac{3}{4} \frac{(1-\beta)^2 - \alpha^2}{(1-\beta)^3}$: profile function

- simplistic factorized ansatz for the t -dependence:

$$H^q(x, \xi, t) = H^q(x, \xi, t = 0) \times F_H(t)$$

with $F_H(t) = \frac{C^2}{(t-C)^2}$ a standard **dipole form factor**
($C = 0.71\text{GeV}^2$)

- ▶ $q(x)$: unpolarized PDF [GRV-98]
and [MSTW2008lo, MSTW2008nnlo, ABM11nnlo, CT10nnlo]
- ▶ $\Delta q(x)$ polarized PDF [GRSV-2000]
- ▶ $\delta q(x)$: transversity PDF [Anselmino *et al.*]

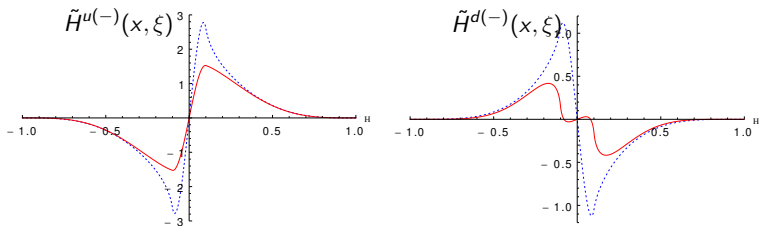
Effects are not significant! But relevant for NLO corrections!

Computation

Valence vs Standard scenarios in \tilde{H} (Chiral-even, Axial)

Typical kinematic point: $\xi = .1 \leftrightarrow S_{\gamma N} = 20 \text{ GeV}^2$ and $M_{\gamma\rho}^2 = 3.5 \text{ GeV}^2$

$$\tilde{H}^{q(-)}(x, \xi, t) = \tilde{H}^q(x, \xi, t) - \tilde{H}^q(-x, \xi, t) \quad [C = -1]$$



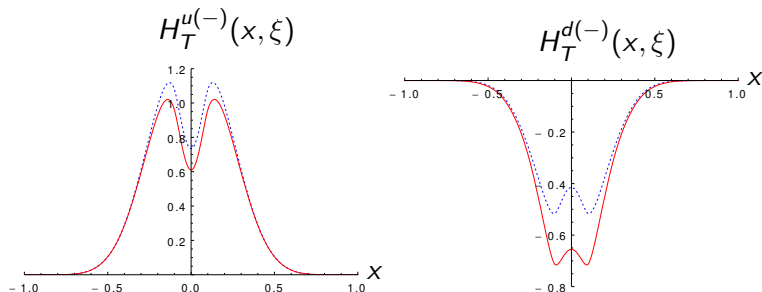
“valence” and “standard”: two GRSV Ansätze for $\Delta q(x)$

Computation

Valence vs Standard scenarios in H_T (Chiral-odd)

Typical Kinematic Point: $\xi = .1 \leftrightarrow S_{\gamma N} = 20 \text{ GeV}^2$ and $M_{\gamma\rho}^2 = 3.5 \text{ GeV}^2$

$$H_T^{q(-)}(x, \xi, t) = H_T^q(x, \xi, t) + H_T^q(-x, \xi, t) \quad [C = -1]$$



“valence” and “standard”: two GRSV Ansätze for $\Delta q(x)$

\Rightarrow two Ansätze for $\delta q(x)$

- Helicity conserving (vector) DA at twist 2: ρ_L

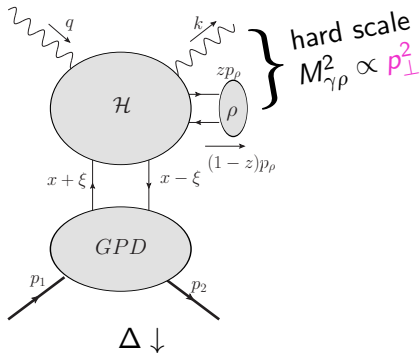
$$\langle 0 | \bar{u}(0) \gamma^\mu u(x) | \rho^0(p, s) \rangle = \frac{p^\mu}{\sqrt{2}} f_\rho \int_0^1 du e^{-iup \cdot x} \phi_{\parallel}(u)$$

- ρ_T DA at twist 2:

$$\langle 0 | \bar{u}(0) \sigma^{\mu\nu} u(x) | \rho^0(p, s) \rangle = \frac{i}{\sqrt{2}} (\epsilon_\rho^\mu p^\nu - \epsilon_\rho^\nu p^\mu) f_\rho^\perp \int_0^1 du e^{-iup \cdot x} \phi_\perp(u)$$

► Work in the limit of:

- $\Delta_{\perp} \ll p_{\perp}$
- $M^2, m_{\rho}^2 \ll M_{\gamma\rho}^2$



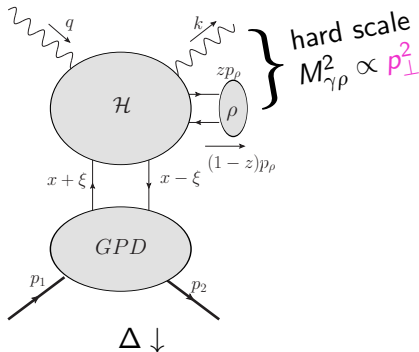
► Work in the limit of:

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► initial state particle momenta:

$$q^{\mu} = n^{\mu},$$

$$p_1^{\mu} = (1 + \xi) p^{\mu} + \frac{M^2}{s(1+\xi)} n^{\mu}$$



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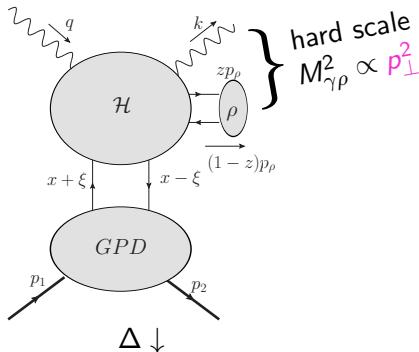
$$p_1^{\mu} = (1 + \xi) p^{\mu} + \frac{M^2}{s(1+\xi)} n^{\mu}$$

- final state particle momenta:

$$p_2^{\mu} = (1 - \xi) p^{\mu} + \frac{M^2 + \vec{p}_t^2}{s(1 - \xi)} n^{\mu} + \Delta_{\perp}^{\mu}$$

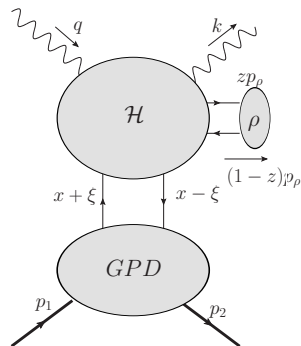
$$k^{\mu} = \alpha n^{\mu} + \frac{(\vec{p}_t - \vec{\Delta}_t/2)^2}{\alpha s} p^{\mu} + p_{\perp}^{\mu} - \frac{\Delta_{\perp}^{\mu}}{2},$$

$$p_{\rho}^{\mu} = \alpha_{\rho} n^{\mu} + \frac{(\vec{p}_t + \vec{\Delta}_t/2)^2 + m_{\rho}^2}{\alpha_{\rho} s} p^{\mu} - p_{\perp}^{\mu} - \frac{\Delta_{\perp}^{\mu}}{2},$$



$$\mathcal{A} \propto \int_{-1}^1 dx \int_0^1 dz \textcolor{red}{T}(x, \xi, z) \textcolor{blue}{H}(x, \xi, t) \Phi_\rho(z)$$

- z integration performed **analytically** using an asymptotic DA $\propto z(1-z)$
- GPD models plugged into expression for amplitude and the integral performed w.r.t. x **numerically**.

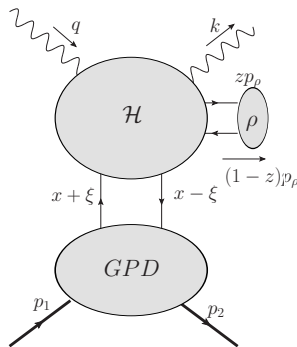


$$\mathcal{A} \propto \int_{-1}^1 dx \int_0^1 dz \textcolor{red}{T}(x, \xi, z) \textcolor{blue}{H}(x, \xi, t) \Phi_\rho(z)$$

- ▶ z integration performed **analytically** using an asymptotic DA $\propto z(1-z)$
- ▶ GPD models plugged into expression for amplitude and the integral performed w.r.t. x **numerically**.
- ▶ Differential cross section:

$$\left. \frac{d\sigma}{dt du' dM_{\gamma\rho}^2} \right|_{-t=(-t)_{min}} = \frac{|\overline{\mathcal{A}}|^2}{32 S_{\gamma N}^2 M_{\gamma\rho}^2 (2\pi)^3} \cdot$$

- ▶ Kinematic parameters: $S_{\gamma N}$, $M_{\gamma\rho}^2$ and $-u'$
Recall: $u' = (p_\rho - q)^2$, $t = (p_2 - p_1)^2$



Results

Phase space integration: Evolution in $(-t, -u')$ plane

large angle scattering: $M_{\gamma\rho}^2 \sim -u' \sim -t'$

$\Rightarrow -u' > 1 \text{ GeV}^2$ and $-t' > 1 \text{ GeV}^2$ and $(-t)_{\min} \leq -t \leq .5 \text{ GeV}^2$

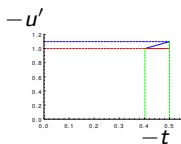
Results

Phase space integration: Evolution in $(-t, -u')$ plane

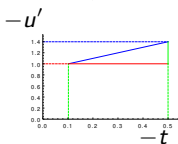
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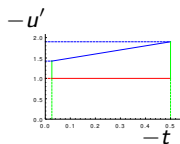
example: $S_{\gamma N} = 20 \text{ GeV}^2$



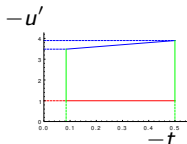
$M_{\gamma\rho} = 2.2 \text{ GeV}^2$



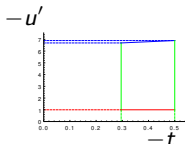
$M_{\gamma\rho} = 2.5 \text{ GeV}^2$



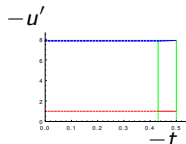
$M_{\gamma\rho} = 3 \text{ GeV}^2$



$M_{\gamma\rho} = 5 \text{ GeV}^2$



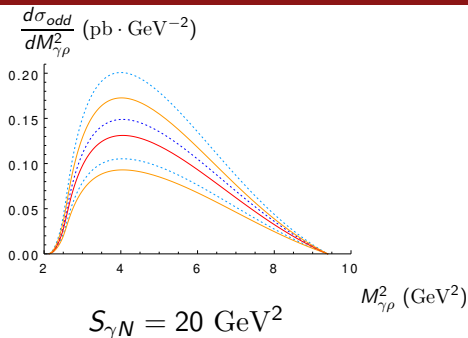
$M_{\gamma\rho} = 8 \text{ GeV}^2$



$M_{\gamma\rho} = 9 \text{ GeV}^2$

Results

Single differential cross-section: Valence vs Standard: ρ_T (Chiral odd)



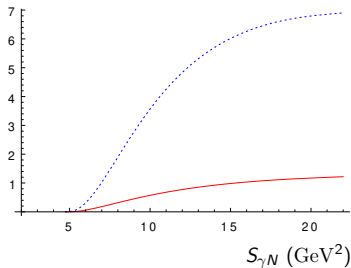
Various ansätze for the PDFs Δq used to build the GPD H_T :

- ▶ *dotted curves*: “standard” scenario
- ▶ *solid curves*: “valence” scenario
- ▶ *deep-blue* and *red* curves: central values
- ▶ *light-blue* and *orange*: results with $\pm 2\sigma$.

Results

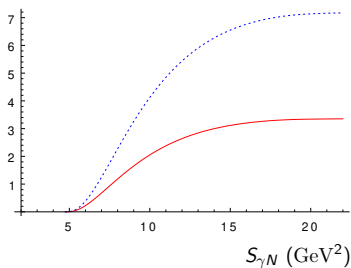
Integrated cross-section: Valence vs Standard: π^\pm (Chiral even)

$\sigma_{\gamma\pi^+}$ (pb)



proton target

$\sigma_{\gamma\pi^-}$ (pb)



neutron target

solid red: "valence" scenario

dashed blue: "standard" one