

Probing transversity GPDs through diffractive photo- and electroproduction on the proton and deuteron at an EIC

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arXiv 1907.08662



Recent spin 1 activity (non-exhaustive list)

■ Leading twist transversity GPDs

WC, B. Pire, PRD98 '18

■ Polynomiality sum rules

WC, A. Freese, B. Pire, arXiv:1812.01511

■ Energy-Momentum tensor

WC, S. Cotogno, A. Freese, C. Lorcé, arXiv:1903.00408 → talk C. Lorcé
M Polyakov, B-D Sun, arXiv:1903.02738

■ Lattice calculations: grav. FF, nuclear gluonometry

W. Detmold, D. Pefkou, P. Shanahan, PRD95 '17
W. Detmold, P. Shanahan, PRD94 '16

■ NJL calculation of grav. FF

A. Freese, I Cloët, arXiv:1903.09222

■ Tensor polarized DY

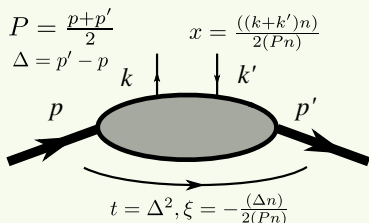
S. Kumano, Q-T Song, PRD94 '16

■ Spin-1 TMDs

Y. Ninomiya, W. Bentz, I. Cloët, PRC96 '17
S. Cotogno, T. Van Daal, P. Mulders, JHEP1711
D. Boer, et al. JHEP1610

Generalized Parton Distributions (GPDs)

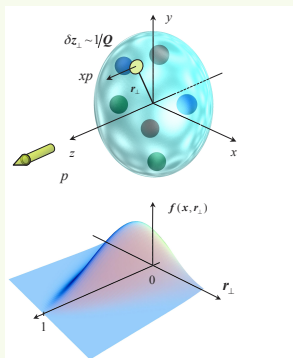
- GPDs are Lorentz scalars parametrizing the off-forward matrix elements of parton correlators in hadrons (non-perturbative QCD) [Ji, Radyushkin, ...]



- Depend on momentum transfer: longitudinal ξ , total t , average parton momentum fraction x
- Appear in Deeply Virtual Compton Scattering (DVCS) and DV meson production amplitudes \rightarrow QCD factorisation
- Forward limit: collinear pdfs
First moment: form factors

Generalized Parton Distributions (GPDs)

- GPDs are Lorentz scalars parametrizing the off-forward matrix elements of parton correlators in hadrons (non-perturbative QCD) [Ji, Radyushkin, ...]



from Belitsky, Radyushkin,
Phys.Rept.418 ('05)

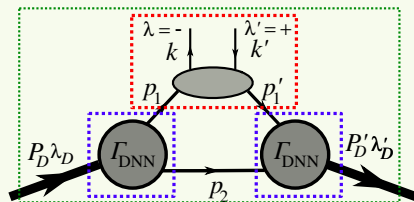
- Interpretation as **3D parton densities** (longitudinal momentum + transverse coordinate) [Burkhardt, Diehl, ...]
- **Moments** of GPDs are related to generalized form factors
- Certain moments of GPDs can be related to the gravitational form factors (parametrizing the energy-momentum tensor)
→ GPDs provide information on **mass, spin, pressure, D-term** in hadrons [Ji, Polyakov, Schweitzer, ...] → talk P. Schweitzer

Properties of spin 1 transversity GPDs

- Quark transversity GPDs are chiral odd (quark helicity flip), do not appear in DVCS at leading twist
- Both for the quark and gluon sector there are **9** transversity GPDs
WC, B. Pire, PRD98 074020 ('18)
- Complex conjugation and P, T symmetries
→ all are **real**, even/oddness [2,3,8] in ξ
- **Forward limit** gives connections with collinear pdfs
 - ▶ $H_{q1}^T(x, 0, 0) = h_1(x)$,
 - ▶ $H_{g5}^T(x, 0, 0) = x\Delta(x)$ [unique to spin 1]
- **Sum rules** for first moments, several are zero due to Lorentz invariance.
- Can be linked to 9 parton-hadron **helicity amplitudes** $\mathcal{A}_{\lambda'+;\lambda-}$ through linear set of equations

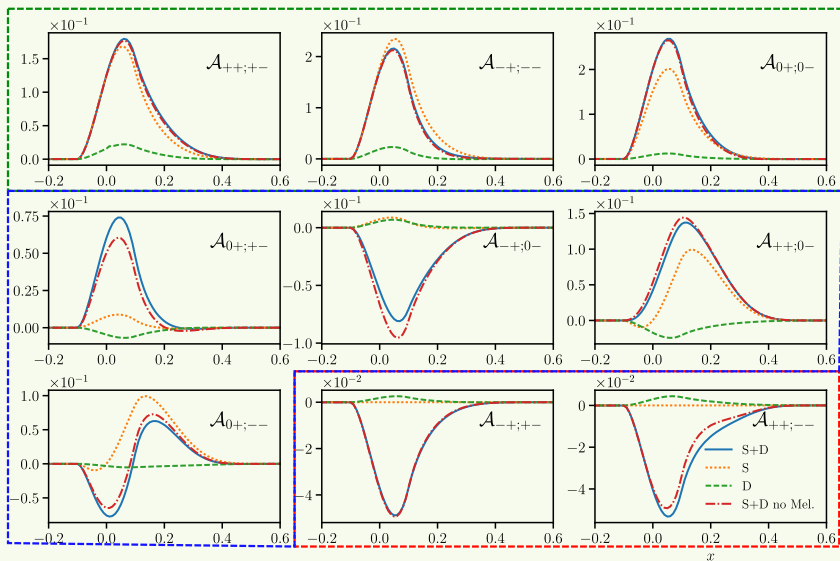
Deuteron quark GPDs: convolution calculation

- Approach based on Cano, Pire, EPJA19 ('04) 423-438



- **Deuteron helicity amplitudes** written as convolution of **nucleon helicity amplitudes** \otimes **deuteron LF wave function**
- Nucleon chiral even/odd helicity amplitudes \rightarrow nucleon chiral even/odd GPDs
 - ▶ even: linked to PARTONS: B. Berthou et al., EPJC78 '18; MMS13 PRD88 014001
 - ▶ odd: parametrization based on Goloskokov, Kroll, EPJA47 112 ('11)
- Deuteron helicity amplitudes \rightarrow deuteron GPDs
- Does **not** obey polynomiality constraints

Deuteron hel. amplitudes: $\xi = 0.1, t = -0.25 \text{ GeV}^2$



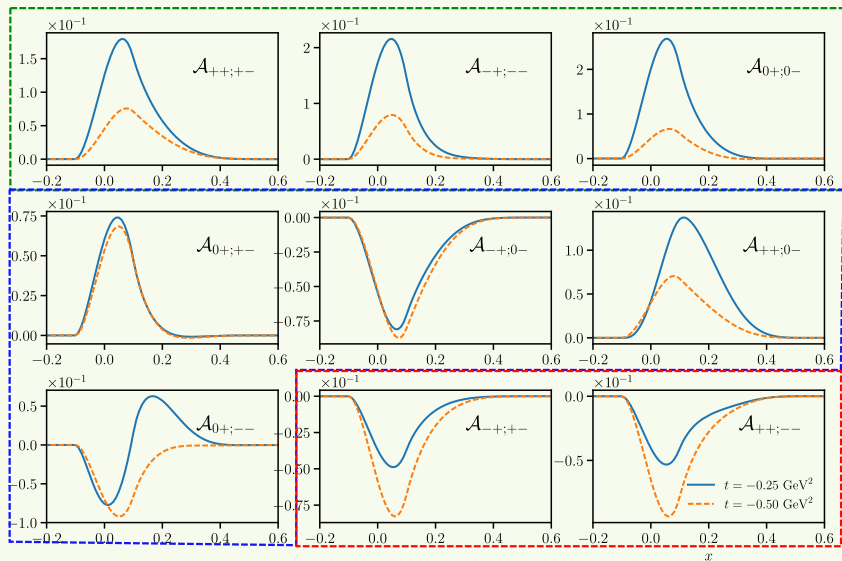
0

1

2

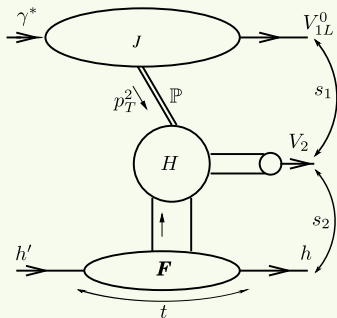
deuteron helicity units flip

Deuteron hel. amplitudes: t -dep, $\xi = 0.1$



deuteron helicity units flip

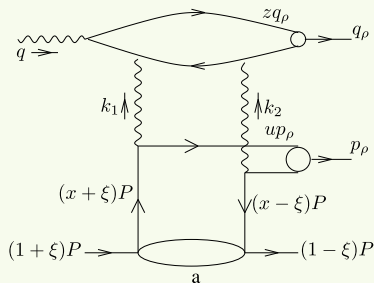
Diffractive electroproduction of two vector mesons



- Two vector mesons are separated by large rapidity gap
- Ordering of scales: invariant mass of two vector mesons $s_1 \gg \gg$ hadron- (ρ^+/ω) invariant mass $s_2 \sim p^2 \gg \gg \Lambda_{\text{QCD}}$
- Pomeron \rightarrow two gluon exchange
- No gluon contribution as Pomeron is C-even

- All the hard work already done for the nucleon in
D.Yu. Ivanov, B. Pire, L. Szymanowski, PLB550 '02
R. Enberg, B. Pire, L. Szymanowski, EPJC47 '06
- Extension for deuteron straightforward: ω and ϕ ($s - \bar{s}$) production

Calculation of the hard part

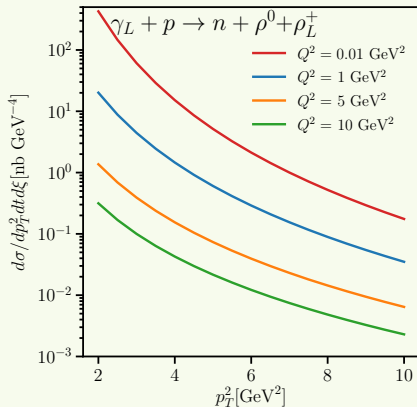
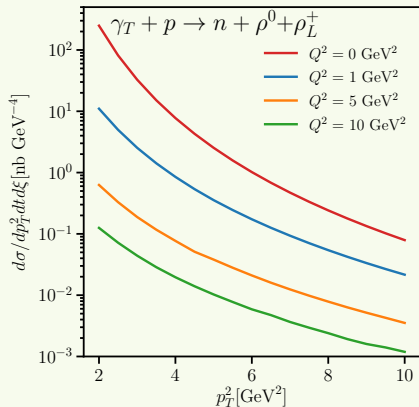


D.Yu. Ivanov, B. Pire, L. Szymanowski, PLB550 '02

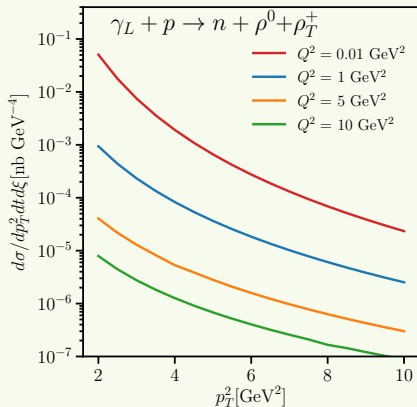
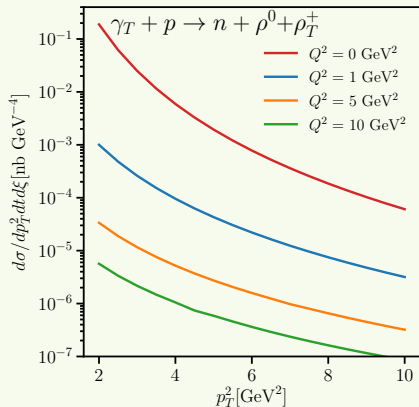
- 6 diagrams contributing at LO
- Collinear approximation and leading twist contributions
- Factorization **OK** for LO, no endpoint singularities
- GPDs probed in the **ERBL** $-\xi < x < \xi$ region
- Asymptotic form for DAs
- Cross section **independent** of s

- Total amplitude can be written as a convolution of **impact factor** ($\gamma_{L/T} \rightarrow \rho_L^0$) \otimes $\rho_{L/T}^+$; $\omega_{L/T}$ **DA** \otimes **GPD** factor (chiral **even/odd**)

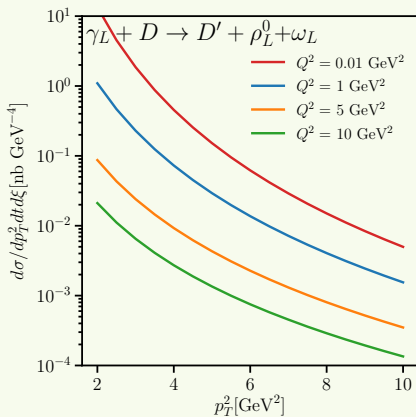
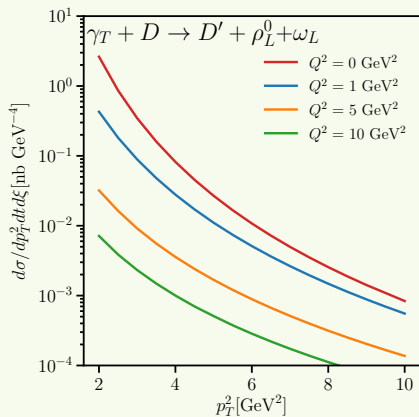
- Chiral even nucleon GPD
- Calculation at $\xi_N = 0.3, t = t_{\min} = -0.33 \text{ GeV}^2$



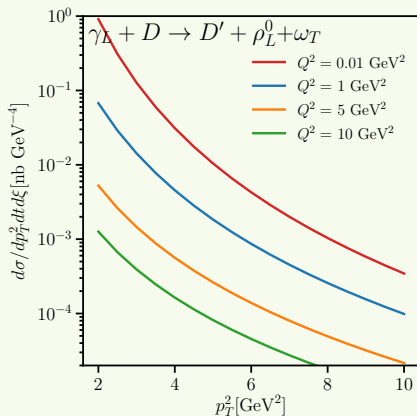
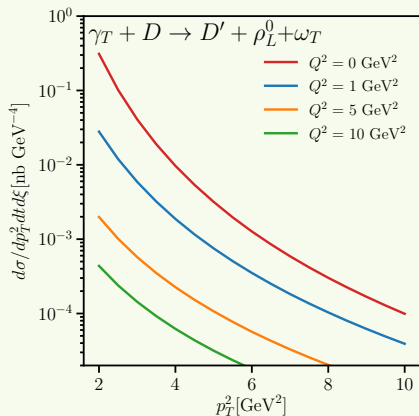
- Chiral odd nucleon GPD
- Calculation at $\xi_N = 0.3, t = t_{\min} = -0.33 \text{ GeV}^2$



- Chiral even deuteron GPD
- Calculation at $\xi_D = 0.15, t \approx t_{\min} = -0.33 \text{ GeV}^2$



- Chiral odd deuteron GPD
- Calculation at $\xi_D = 0.15$, $t \approx t_{\min} = -0.33 \text{ GeV}^2$



Conclusion and Outlook

- Theory and phenomenology activity on spin-1 hadron structure
- 9 transversity GPDs for both quark and gluons in spin 1 hadron at leading twist
- Deuteron quark GPDs in convolution picture
- Diffractive electroproduction of two vector mesons can probe chiral even/odd GPDs of nucleon and deuteron
- Cross sections look feasible at EIC with forward detectors

- Improved convolution that respects polynomiality constraints
- ϕ production ($s - \bar{s}$)
- Calculations at $t \neq t_{\min} \rightarrow$ more GPDs contributing