

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

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# 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

M Polyakov, B-D Sun, arXiv:1903.02738

Talk O. Teryaev WG7

- 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)

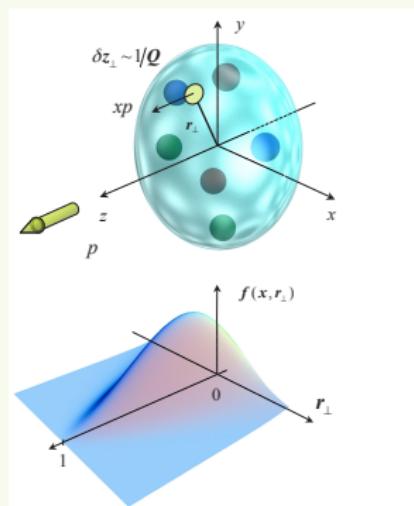
- GPDs are Lorentz scalars parametrizing the off-forward matrix elements of parton correlators in hadrons (non-perturbative QCD)  
[Ji, Radyushkin, ...]

$$\begin{aligned} P &= \frac{p+p'}{2} \\ \Delta &= p' - p \\ t &= \Delta^2, \xi = -\frac{(\Delta n)}{2(Pn)} \end{aligned}$$

- Depend on momentum transfer:  
longitudinal  $\xi$ , 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)

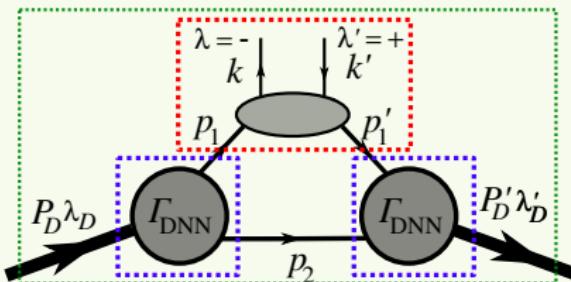
- Interpretation as **3D parton densities** (longitudinal momentum + transverse coordinate) [Burkhardt, Diehl,...]
- Moments** of GPDs are related to generalized form factors
- Certain moments of GPDs can be related to the gravitational form factors (parametrizing the energy-momentum tensor)  
→ GPDs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

# 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  $\xi$
- **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**  $A_{\lambda'+;\lambda-}$  through linear set of equations

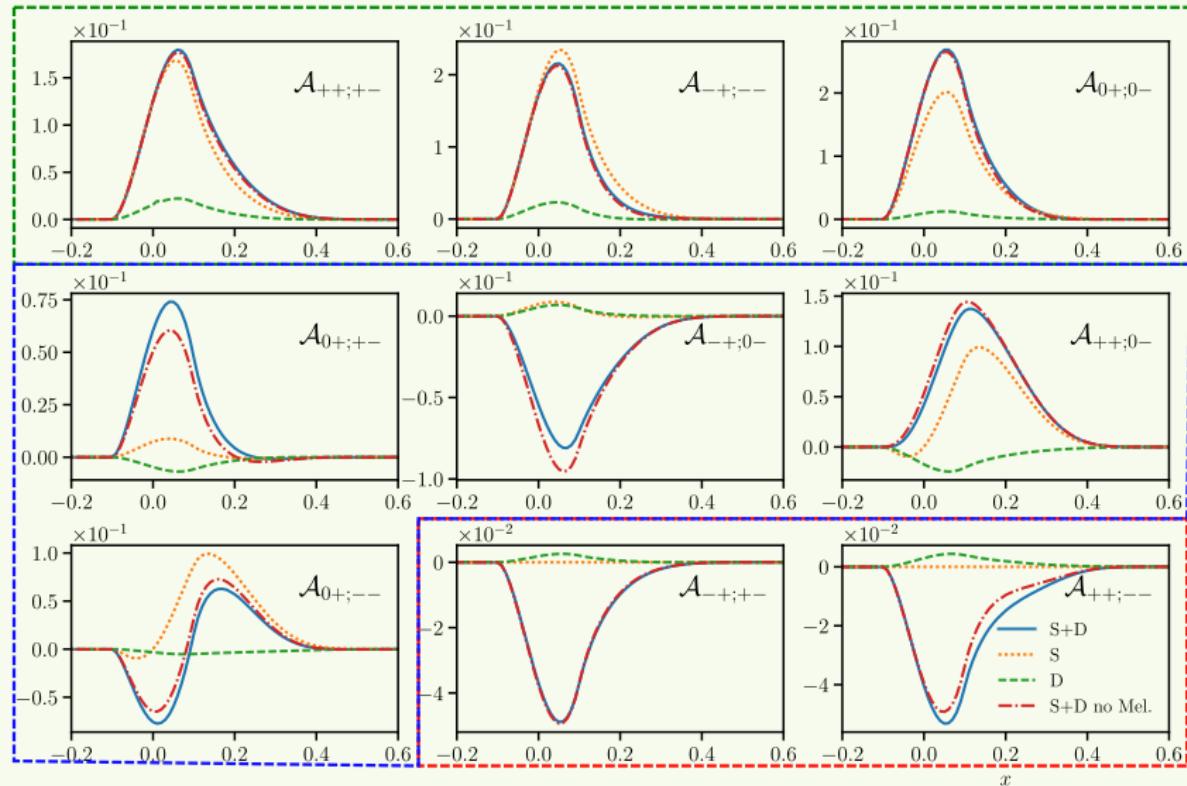
# Deuteron quark GPDs: convolution calculation

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



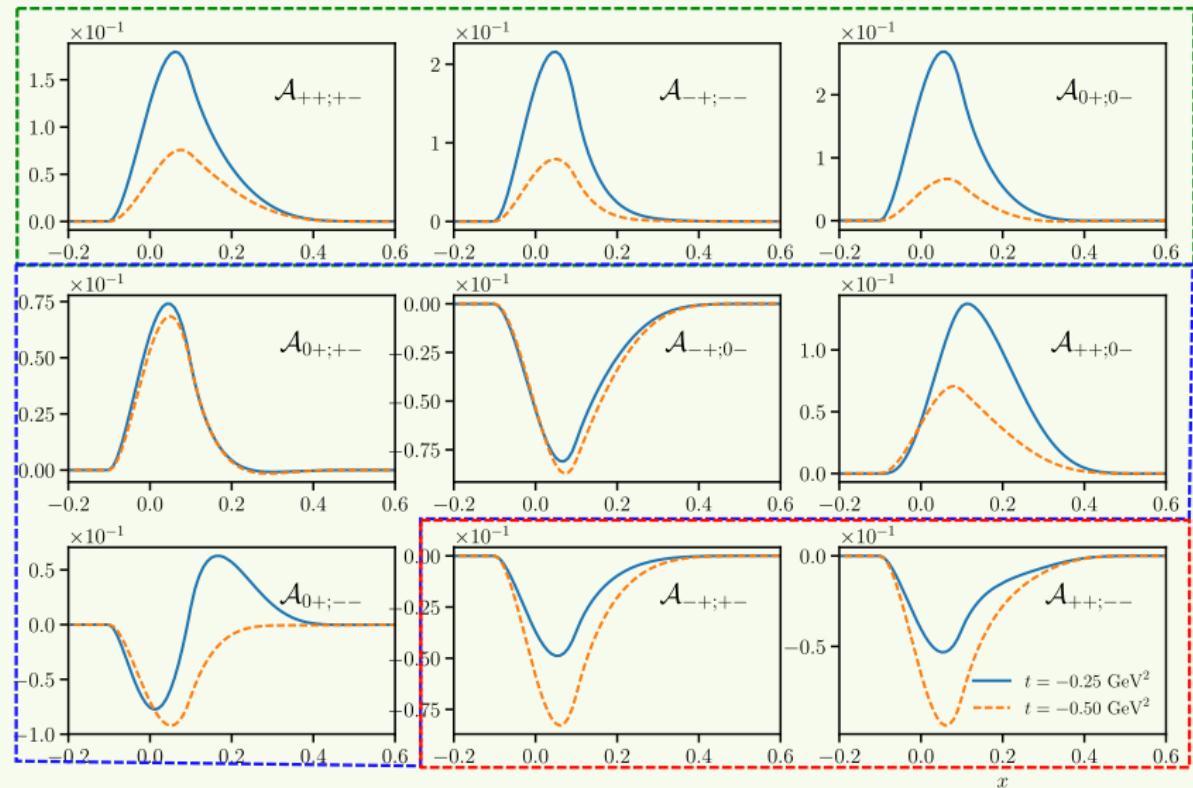
- **Deuteron helicity amplitudes** written as convolution of **nucleon helicity amplitudes**  $\otimes$  **deuteron LF wave function**
- Nucleon chiral even/odd helicity amplitudes  $\rightarrow$  nucleon chiral even/odd GPDs
  - ▶ even: linked to PARTONS: B. Berthou et al., EPJC78 '18; MMS13 PRD88 014001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

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



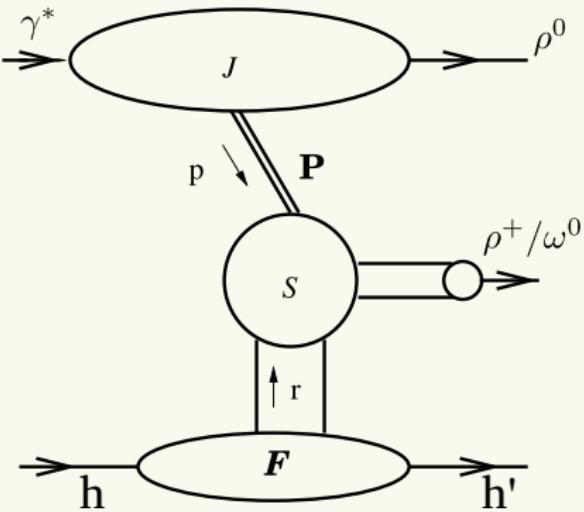
deuteron helicity units flip

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



deuteron helicity units flip

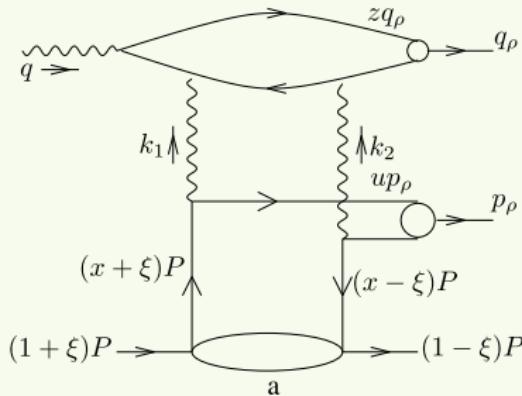
# Diffractive electroproduction of two vector mesons



- Two vector mesons are separated by large rapidity gap
- Ordering of scales: invariant mass of two vector mesons  $s_1 \ggg$  hadron- $(\rho^+/\omega)$  invariant mass  $s_2 \sim p^2 \ggg \Lambda_{\text{QCD}}$
- 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

# Calculation of the hard part

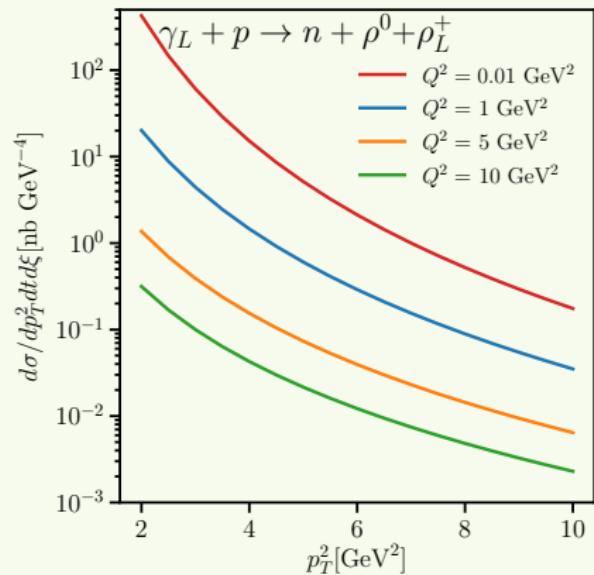
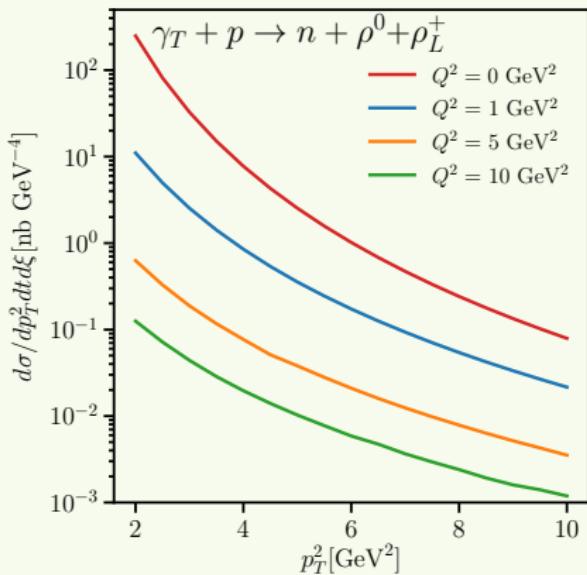


D.Yu. Ivanov, B. Pire, L.  
Szymanowski, PLB550 '02

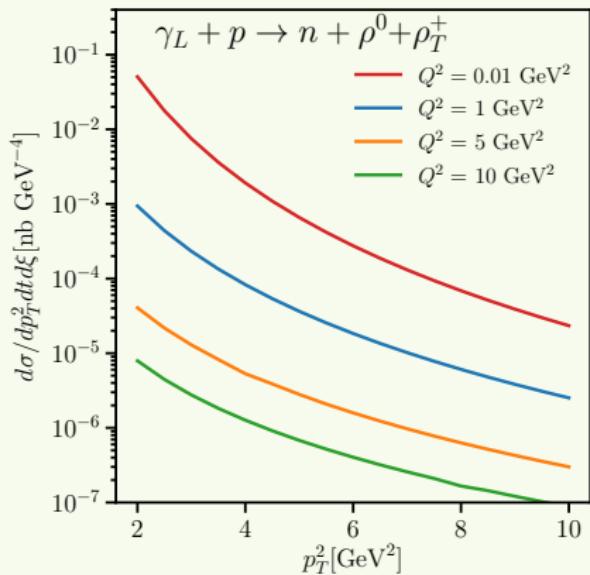
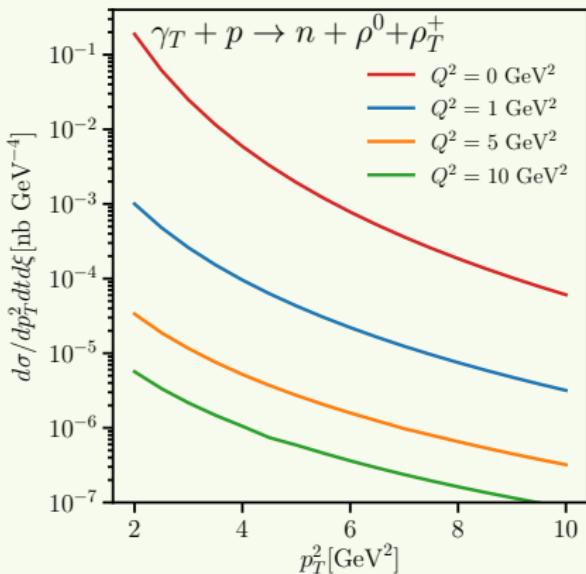
- 6 diagrams contributing at LO
- Collinear approximation and leading twist contributions
- Factorization **OK** for LO, no endpoint singularities
- GPDs probed in the **ERBL**  $-\xi < x < \xi$  region
- Asymptotic form for DAs
- Cross section **independent** of  $s$

- 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)

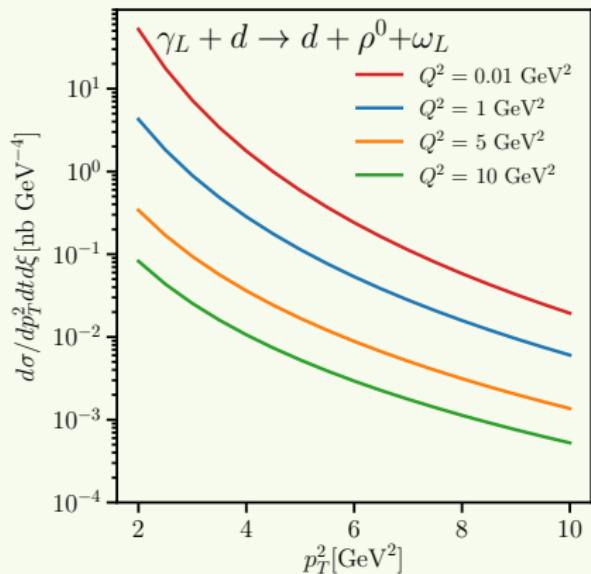
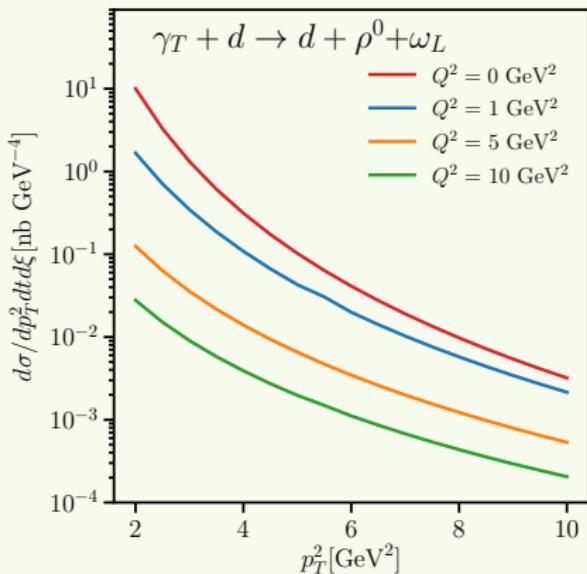
- Chiral even nucleon GPD
- Calculation at  $\xi = 0.3, t = t_{\min}$



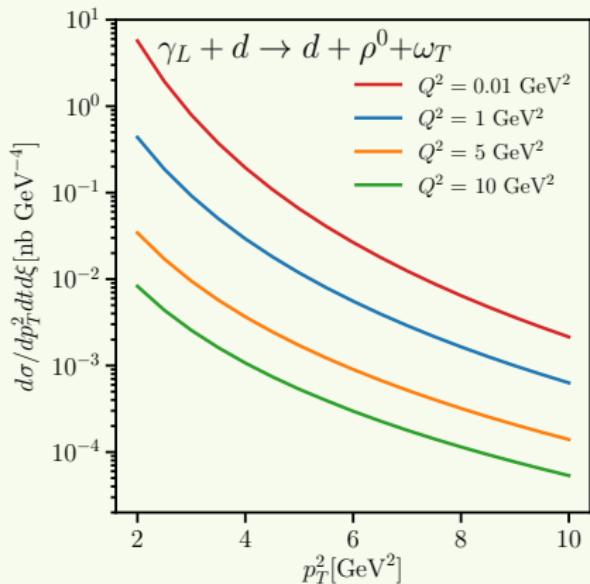
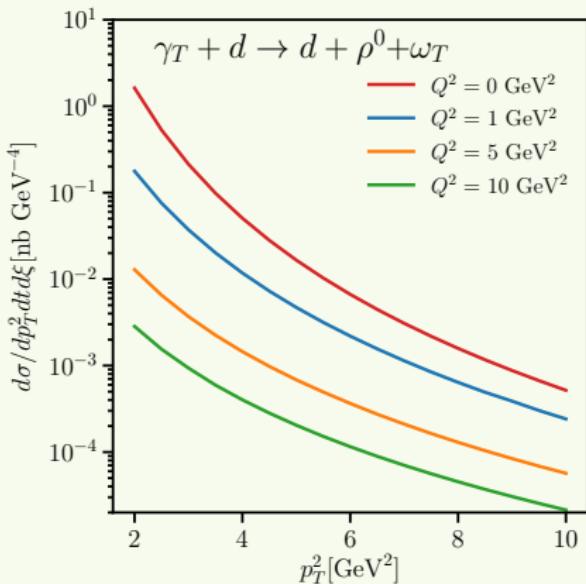
- Chiral odd nucleon GPD
- Calculation at  $\xi = 0.3, t = t_{\min}$



- Chiral even deuteron GPD
- Calculation at  $\xi = 0.1, t \approx t_{\min}$



- Chiral odd deuteron GPD
- Calculation at  $\xi = 0.1, t \approx t_{\min}$



# 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 for EIC measurements
- 
- Improved convolution that respects polynomiality constraints
  - $\phi$  production
  - Calculations at  $t \neq t_{\min} \rightarrow$  more GPDs contributing