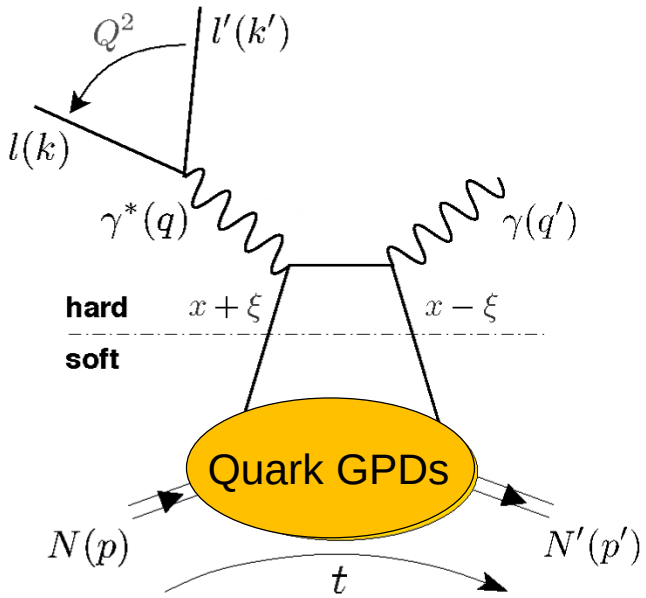
« Studies of DVCS with polarized beams and targets »
AKA
Status and prospectives for GPDs

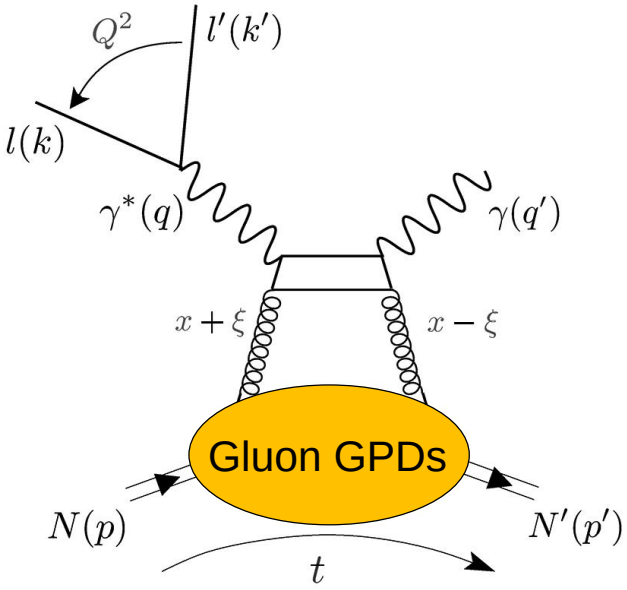
GPDs & experiments: where do we stand
What's missing from the GPD picture
Plans for DVCS with polarized positrons beam
Plans for DDVCS with high-lumi µCLAS12
Perspectives for DVCS@CLAS20+
Conclusions: what should we point on to be « competitive » to the EIC

Silvia Niccolai, IJCLab Orsay
Opportunities with JLab energy and luminosity upgrade
Trento (Italy), 29/9/2022

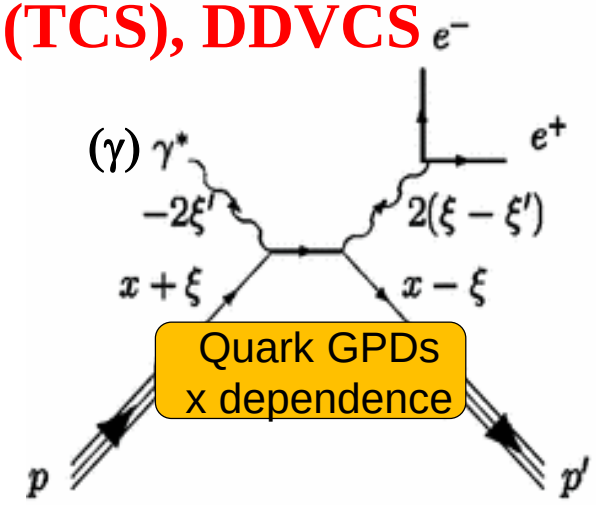
Exclusive reactions giving access to GPDs

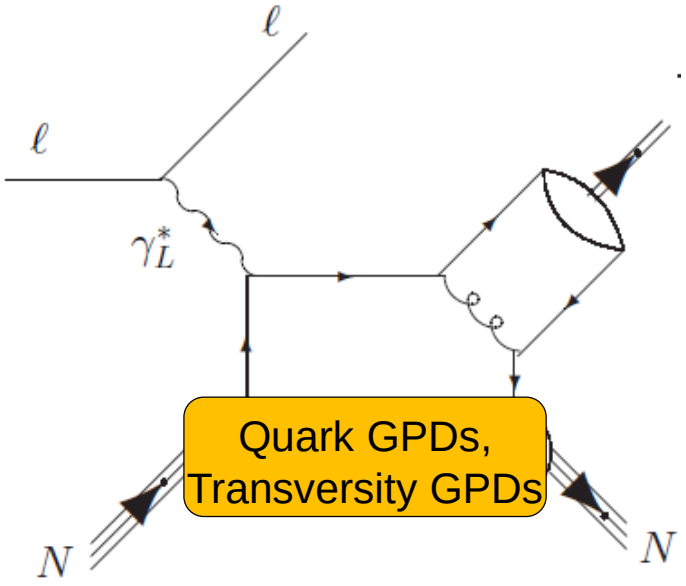


DVCS

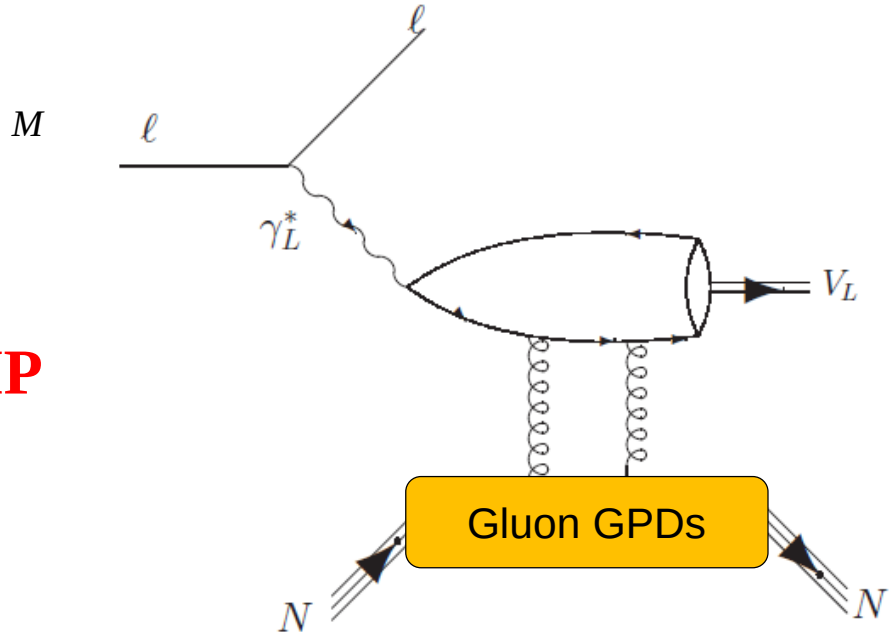


(TCS), DDVCS

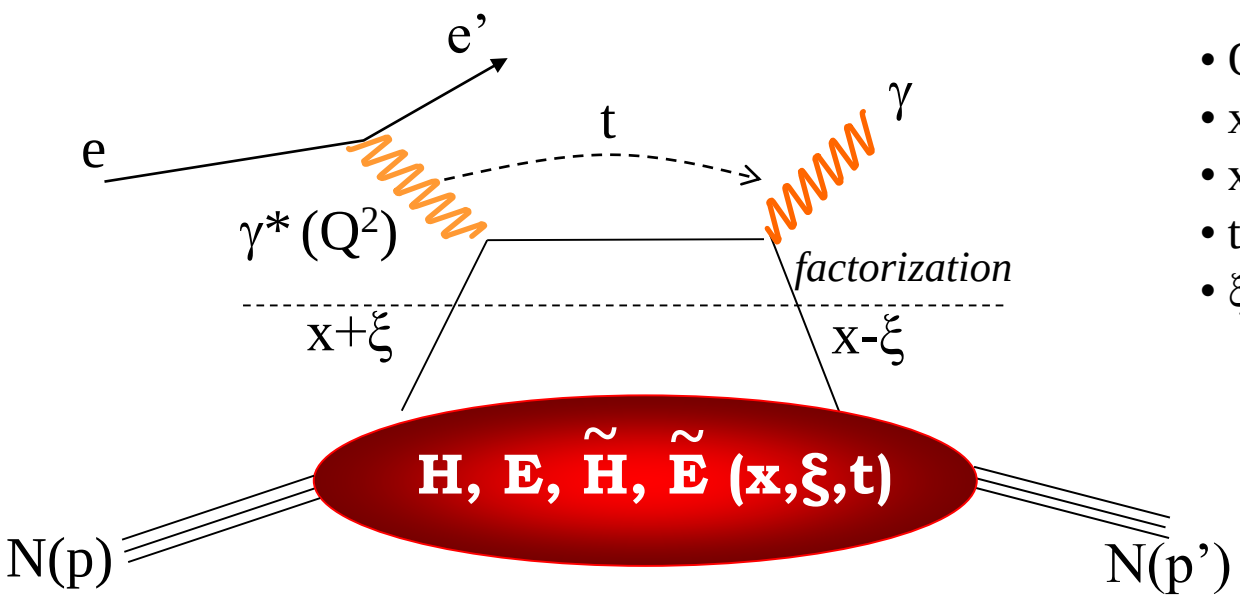




DVMP



Deeply Virtual Compton Scattering and GPDs



- $Q^2 = -(e-e')^2$
- $x_B = Q^2/2M\nu \quad \nu = E_e - E_{e'}$
- $x+\xi$, $x-\xi$ longitudinal momentum fractions
- $t = \Delta^2 = (p-p')^2$
- $\xi \cong x_B/(2-x_B)$

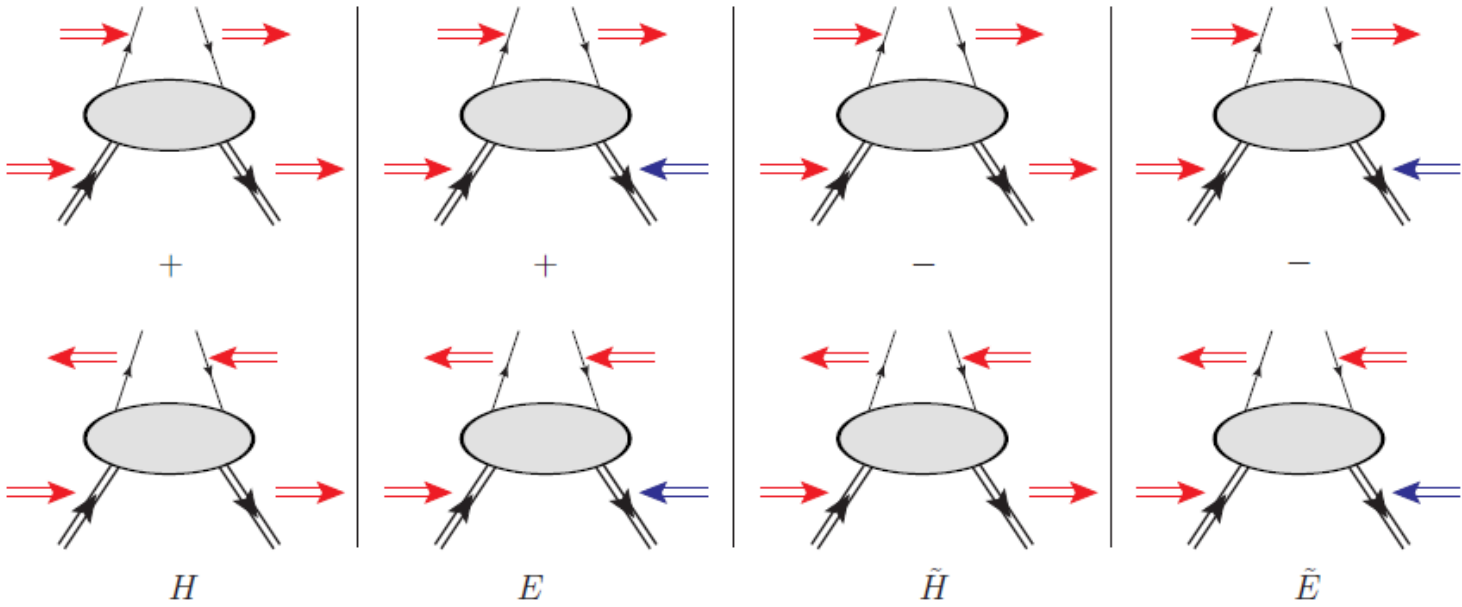
« **Handbag** » factorization, valid in the **Bjorken regime** (**high Q^2** and **ν**, fixed x_B), **$t \ll Q^2$**

*GPDs: Fourier transforms of **non-local**, **non-diagonal** QCD operators*

4 GPDs for each quark flavor
(leading-order, leading twist, quark-helicity conservation)

conserve nucleon spin

flip nucleon spin



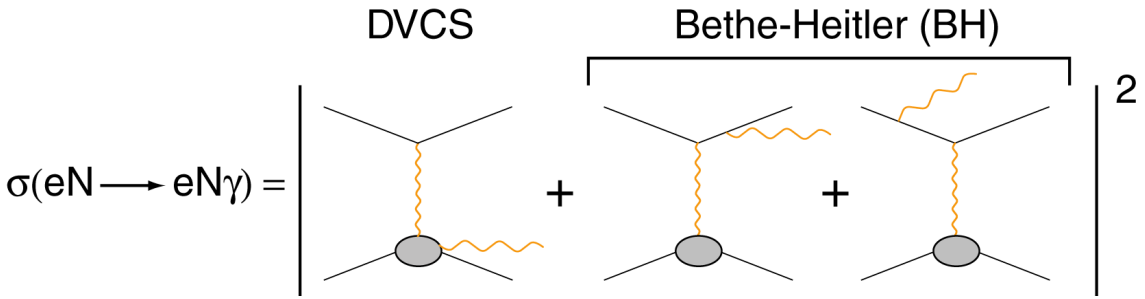
Vector **Tensor** **Axial-vector** **Ps.scalar**

Accessing GPDs through DVCS

$$T^{DVCS} \sim P\int_{-1}^{+1} \frac{GPDs(x,\xi,t)}{x \pm \xi} dx \pm i\pi GPDs(\pm\xi,\xi,t) + \ldots$$

$$Re\mathcal{H}_q = e_q^2 P\int_0^{+1} \left(H^q(x,\xi,t) - H^q(-x,\xi,t)\right)\left[\frac{1}{\xi - x} + \frac{1}{\xi + x}\right] dx$$

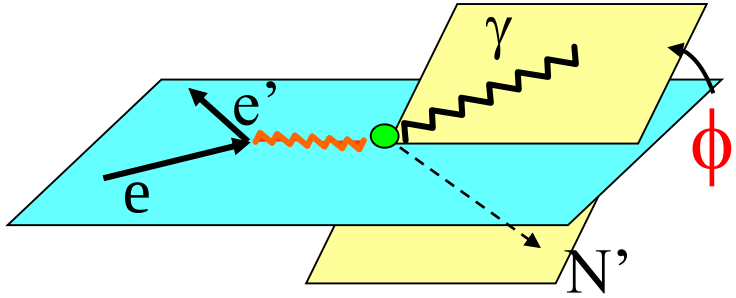
$$Im\mathcal{H}_q = \pi e_q^2 \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right]$$



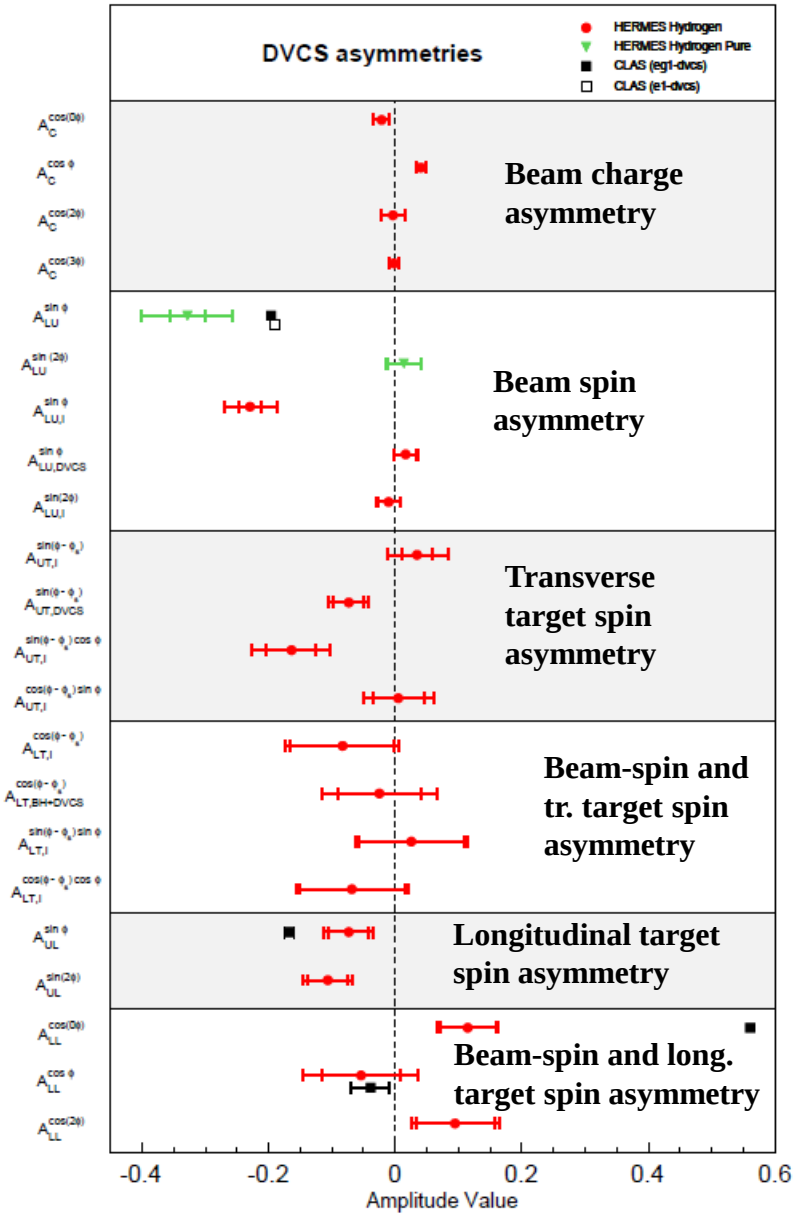
	Proton	Neutron
Polarized beam, unpolarized target: $\Delta\sigma_{LU} \sim \sin\phi\, Im\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E} + \ldots\}$	$Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p, \mathcal{E}_p\}$	$Im\{\mathcal{H}_n, \tilde{\mathcal{H}}_n, \mathcal{E}_n\}$
Unpolarized beam, longitudinal target: $\Delta\sigma_{UL} \sim \sin\phi\, Im\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)(\mathcal{H} + x_B/2\mathcal{E}) - \xi kF_2\tilde{\mathcal{E}}\}$	$Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$	$Im\{\mathcal{H}_n, \mathcal{E}_n\}$
Polarized beam, longitudinal target: $\Delta\sigma_{LL} \sim (A + B\cos\phi) Re\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)(\mathcal{H} + x_B/2\mathcal{E}) + \ldots\}$	$Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$	$Re\{\mathcal{H}_n, \mathcal{E}_n\}$
Unpolarized beam, transverse target: $\Delta\sigma_{UT} \sim \cos\phi \sin(\phi_s - \phi) Im\{k(F_2\mathcal{H} - F_1\mathcal{E}) + \ldots\}$	$Im\{\mathcal{H}_p, \mathcal{E}_p\}$	$Im\{\mathcal{H}_n\}$
Unpolarized beam and target, different lepton charges: $\Delta\sigma_C \sim \cos\phi\, Re\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E} + \ldots\}$	$Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p, \mathcal{E}_p\}$	$Re\{\mathcal{H}_n, \tilde{\mathcal{H}}_n, \mathcal{E}_n\}$

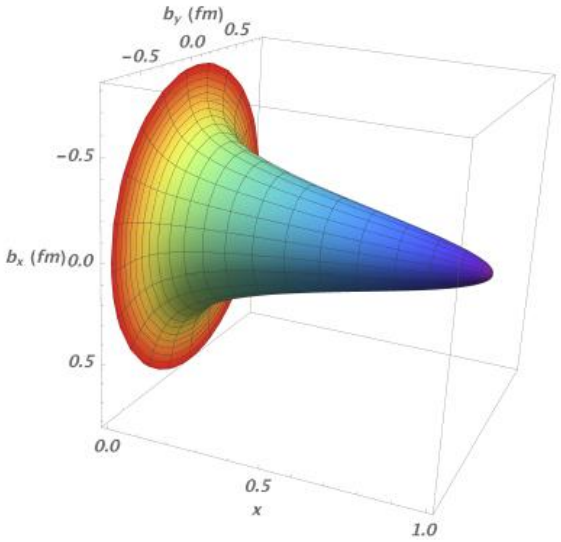
$$\sigma \sim \left|T^{DVCS} + T^{BH}\right|^2$$

$$\Delta\sigma = \sigma^+ - \sigma^- \propto I\left(DVCS \cdot BH\right)$$



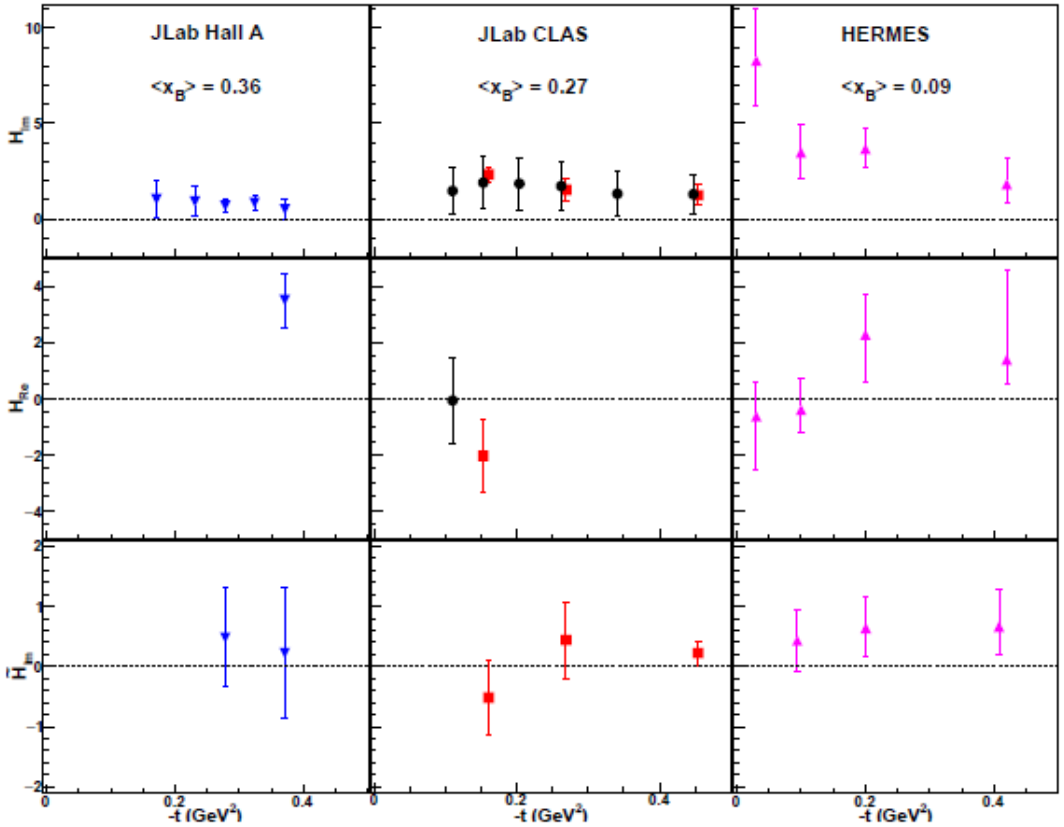
Measured p-DVCS observables and constraints on GPDs





Proton tomography obtained from local fits to HERMES, CLAS, and Hall-A data (Im$\mathcal{H}$ + model dependent assumptions for x dependence)

R. Dupré, M. Guidal, M.Vanderhaeghen, PRD95, 011501 (2017)



Hall A (2015)

CLAS C.S.

CLAS C.S. +TSA+DSA

HERMES

Beam Charge Asymmetry: strong constraint for H_{Re}

N. d'Hose, S.N., A. Rostomyan, EPJA 52, 151 (2016)

Distribution of forces in the proton

$$\int xH(x,\xi,t)\mathrm{d}x = M_2(t) + \frac{4}{5}\xi^2 d_1(t)$$

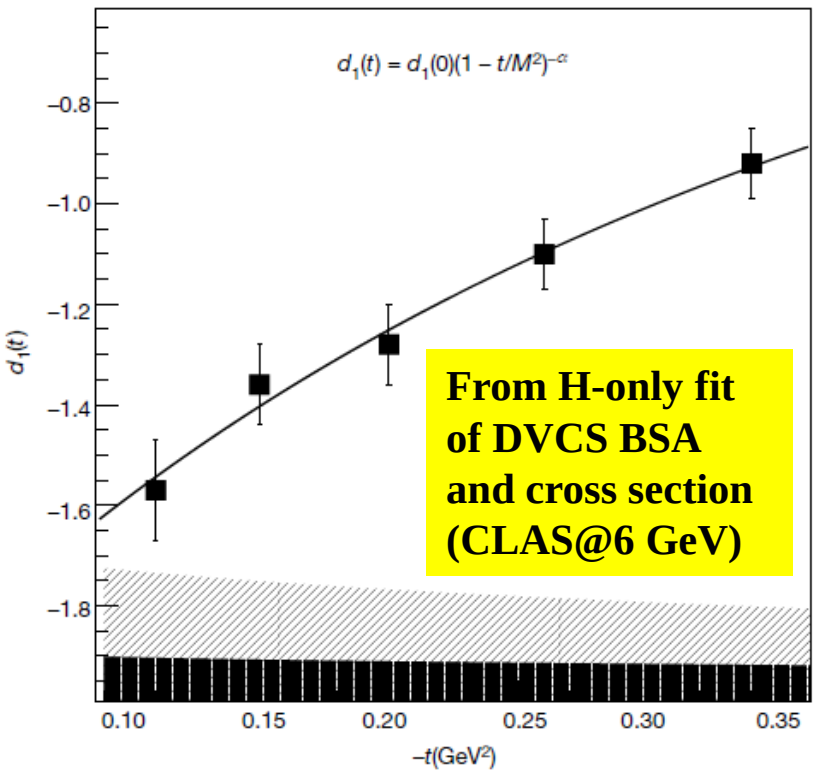
Second Mellin moment of H in x: **Gravitational form factor** → shear forces and pressure

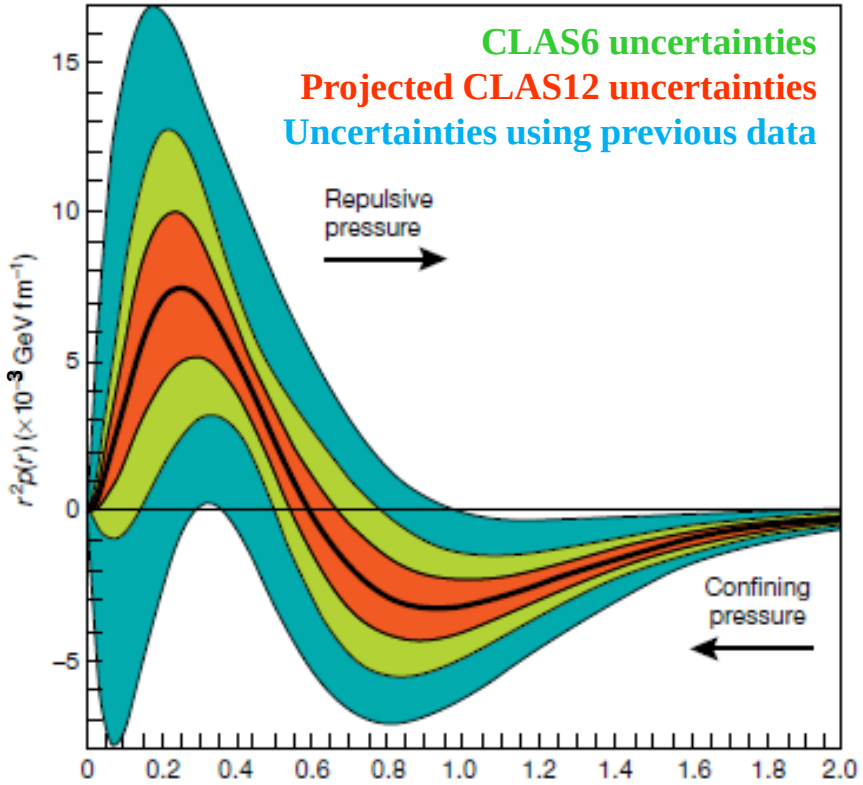
$$\mathrm{Re}\mathcal{H}(\xi,t) + i\mathrm{Im}\mathcal{H}(\xi,t) = \int_{-1}^{1}\mathrm{d}x\left(\frac{1}{\xi-x-i\epsilon} - \frac{1}{\xi+x-i\epsilon}\right)H(x,\xi,t) \quad (1)$$

$$\mathrm{Re}\mathcal{H}(\xi,t) \overset{\mathrm{lo}}{=} D(t) + \mathcal{P}\int_{-1}^{1}\mathrm{d}x\left(\frac{1}{\xi-x} - \frac{1}{\xi+x}\right)\mathrm{Im}\mathcal{H}(x,t)$$

$$D(t) = \frac{1}{2}\int_{-1}^{1}\frac{D(z,t)}{1-z}\mathrm{d}z \qquad D(z,t) = (1-z^2)[d_1(t)C_1^{3/2}(z) + \cdots]$$

$$d_1(t) \propto \int \frac{j_0(r\sqrt{-t})}{2t}p(r)\mathrm{d}^3r$$



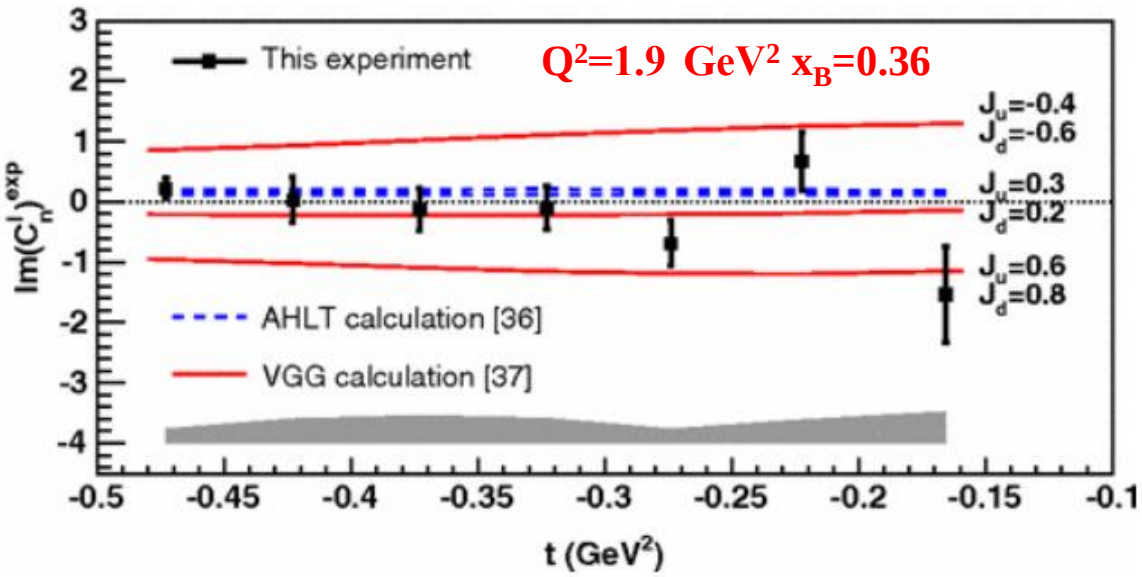


V. Burkert, L. Elouadrhiri, F.X. Girod, Nature 557, 396-399 (2018)

$\vec{e}d \to e\gamma(np)$

Interest of DVCS on the neutron: Hall A at 6 GeV

$$\Delta\sigma_{LU} \sim \sin\phi \; \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E}\}$$



M. Mazouz et al., PRL 99 (2007) 242501

E03-106: First-time measurement of $\Delta\sigma_{LU}$ for nDVCS, model-dependent extraction of J_u, J_d

$$D(e,e'\gamma)X - H(e,e'\gamma)X = n(e,e'\gamma)n + d(e,e'\gamma)d + \ldots$$

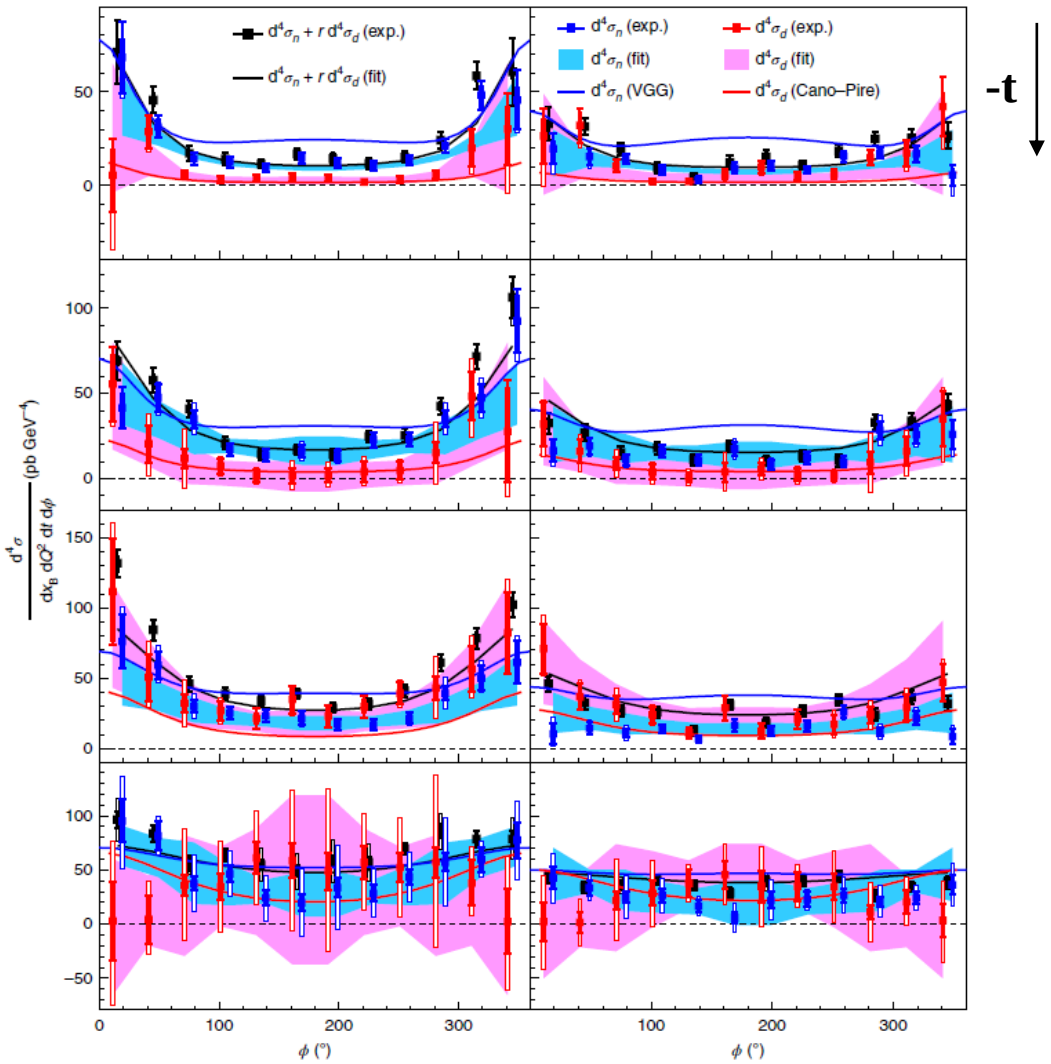
nDVCS and coherent **dDVCS** separated through MM^2_X shift:

- large correlations at low –t
- good separation at larger -t

Hall-A experiment E08-025 (2010)

- Two beam-energies: « Rosenbluth » separation of nDVCS CS
- First observation of non-zero nDVCS CS

M. Benali et al., Nature Physics 16 (2020)

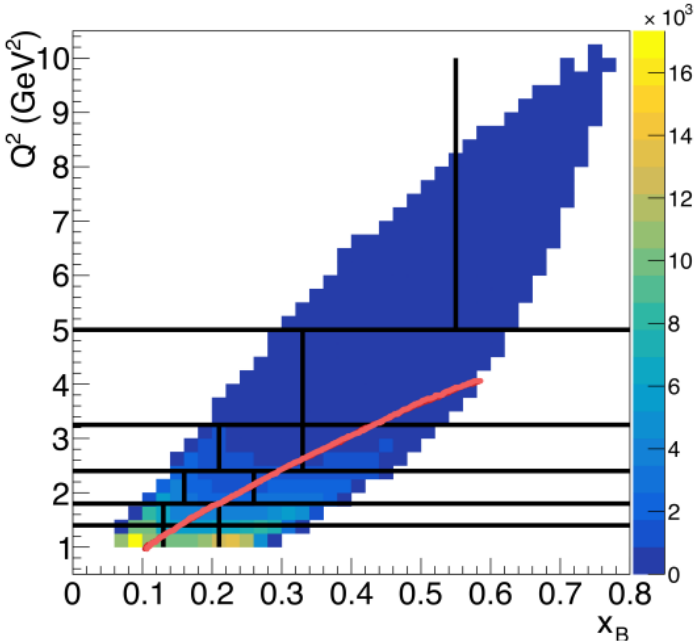


JLab@12 GeV DVCS program

Observable (target)	12-GeV experiments	CFF sensitivity	Status
σ, $\Delta\sigma_{beam}(p)$	Hall A CLAS12 Hall C	Re$\mathcal{H}$(p), Im$\mathcal{H}$(p)	Hall A: data taken in 2016; Phys. Rev. Lett. 128 (2022) 25, 252002 CLAS12: data taken in 2018-2019: CS analysis in progress Hall C: experiment planned for 2023
BSA(p)	CLAS12	Im$\mathcal{H}$(p)	BSA publication at Ad Hoc review stage
lTSA(p), lDSA(p)	CLAS12	Im$\tilde{\mathcal{H}}$(p), Im$\mathcal{H}$(p), Re$\tilde{\mathcal{H}}$(p), Im$\mathcal{H}$(p)	Experiment running until March 2023
tTSA(p)	CLAS12	Im$\mathcal{H}$(p), Im$\mathcal{E}$(p)	Experiment foreseen for ~2025
BSA(n)	CLAS12	Im$\mathcal{E}$(n)	Data taken in 2019-2020, BSA analysis being finalized
lTSA(n), lDSA(n)	CLAS12	Im$\mathcal{H}$(n), Re$\mathcal{H}$(n)	Experiment running until March 2023

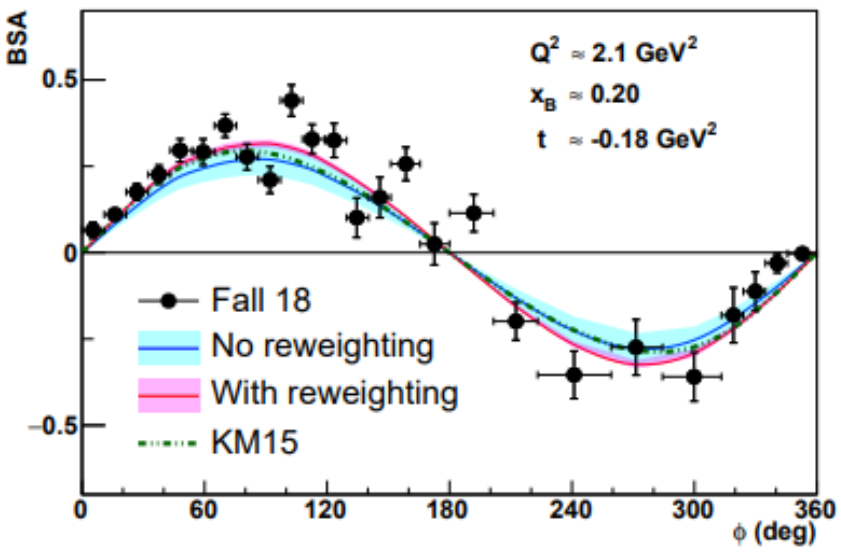
Hall A/C: high luminosity → precision, small kinematic coverage, eγ topology
CLAS12: lower luminosity, large kinematic coverage, fully exclusive final state

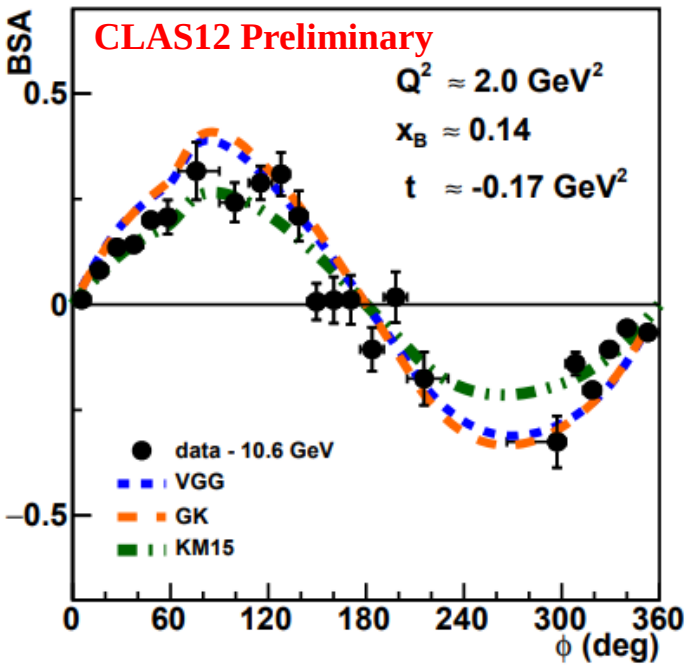
CLAS12: preliminary beam spin asymmetry for DVCS on the proton

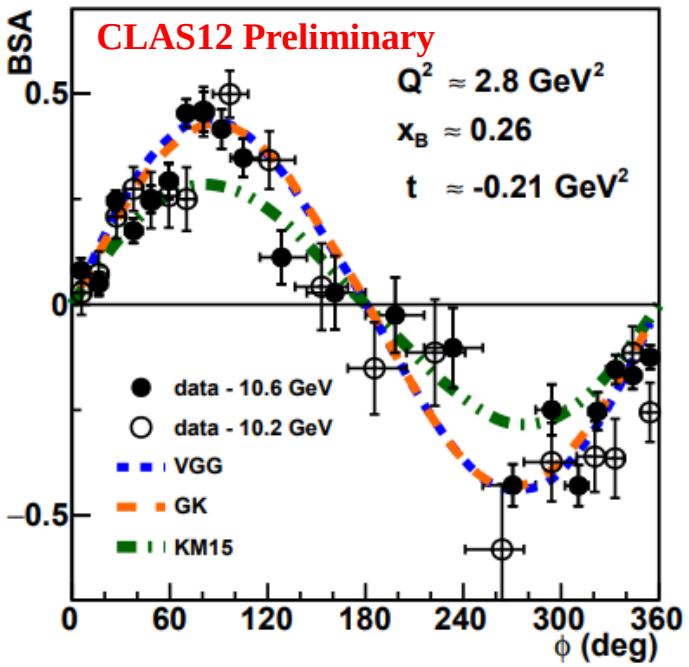


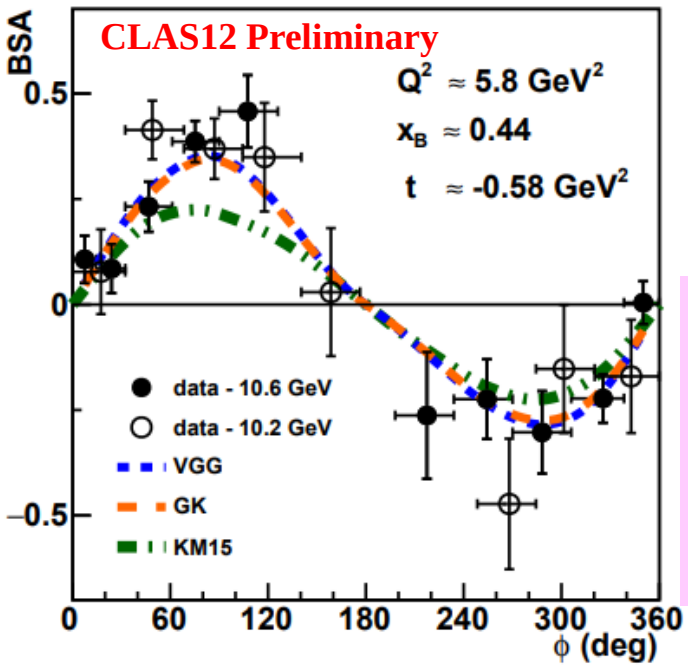
- Data taken in 2018
- Polarized beam (86%) with energy 10.6 GeV; unpolarized LH2 target
- 64 kinematical bins (Q^2, x_B, -t)
- Many kinematics never covered before
- In previously measured kinematics, the new data are shown to be in good agreement with existing data and improve the precision of GPD fits

$\vec{e}p \rightarrow ep\gamma$









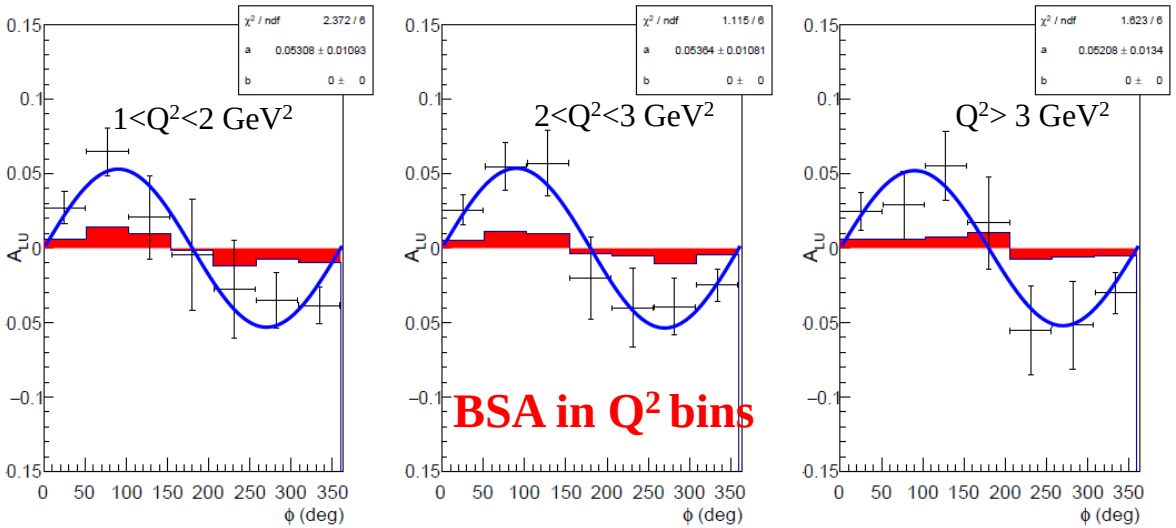
Examples of kinematics only accessible with ~10.6-GeV beam

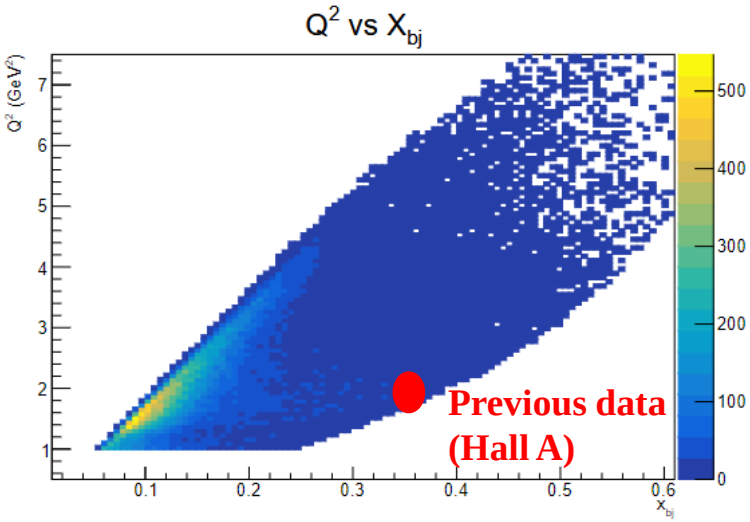
Submission for publication in late October (final stage of Collaboration review)

Preliminary beam spin asymmetry for neutron DVCS (CLAS12)

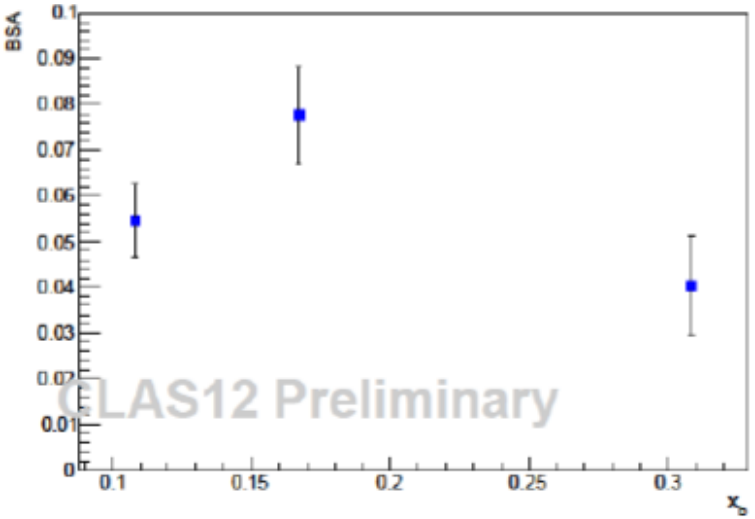
$\Delta\sigma_{LU} \sim \sin\phi\ \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E}\}$

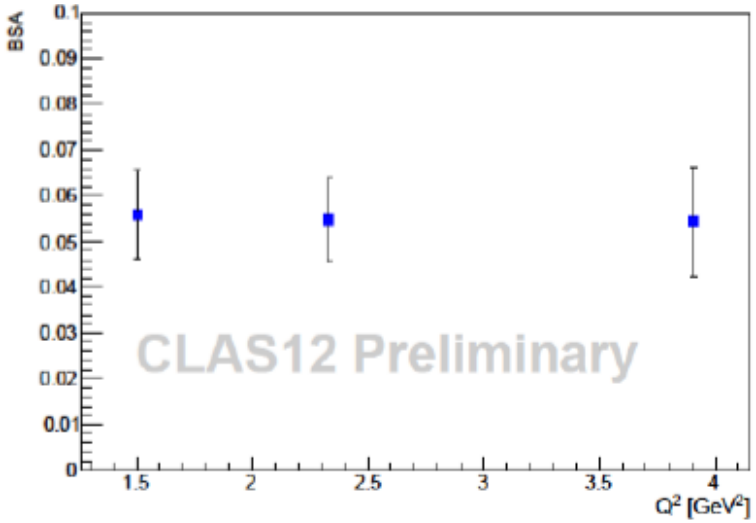
$\vec{e}d \rightarrow en\gamma(p)$

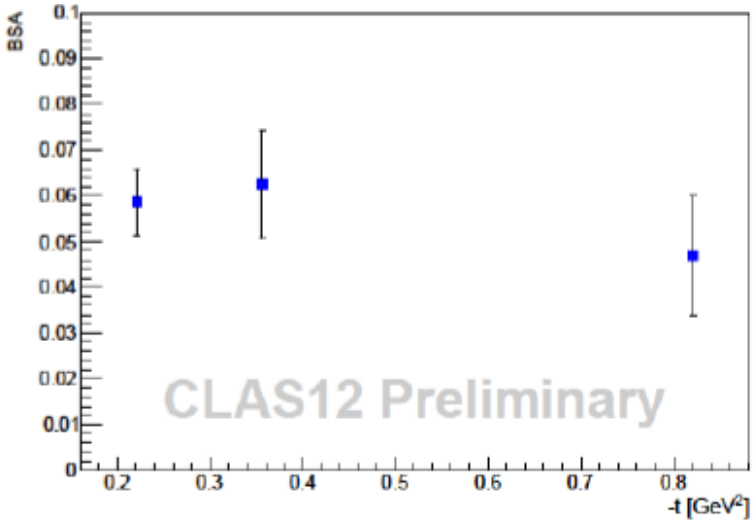




- Data taken in 2019/2020
- LD2 target, ~10.4 GeV beam energy
- Scan of the BSA on a wide phase space
- Reaching the high Q^2-high x_B region
- Exclusivity thanks to **detection of the active neutron** → small systematics
- **Low statistics → higher luminosity necessary**



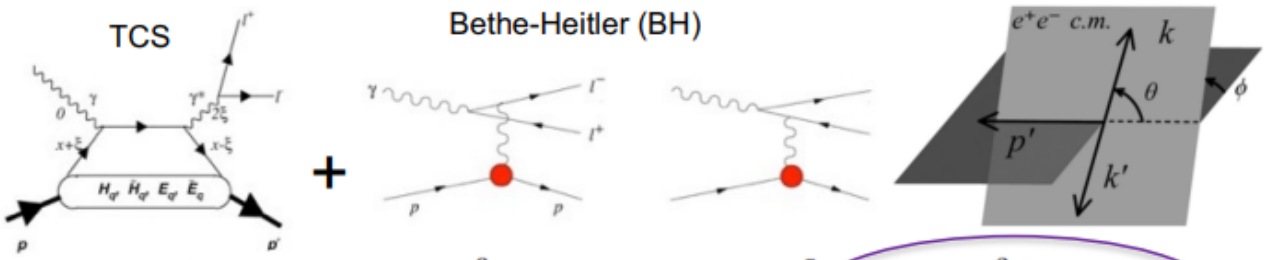




First-ever measurement of Timelike Compton Scattering (CLAS12)

- The beam helicity asymmetry of TCS accesses the imaginary part of the CFF in the same way as in DVCS and probes the universality of GPDs
- The forward-backward asymmetry is sensitive to the real part of the CFF → direct access to the Energy-Momentum Form Factor $D_q(t)$ (linked to the D-term) that relates to the mechanical properties of the nucleon (quark pressure distribution)
- This measurement proves the importance of TCS for GPD physics.
- Limits: very small cross section → **high luminosity is necessary for a precise measurement**

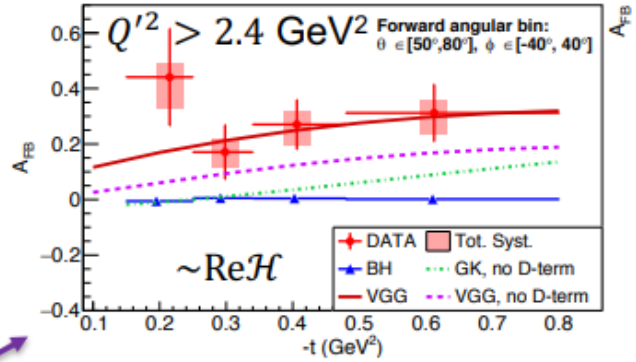
TCS – time-reversal symmetric process to DVCS:
incoming photon is real, and the outgoing photon has large time-like virtuality.

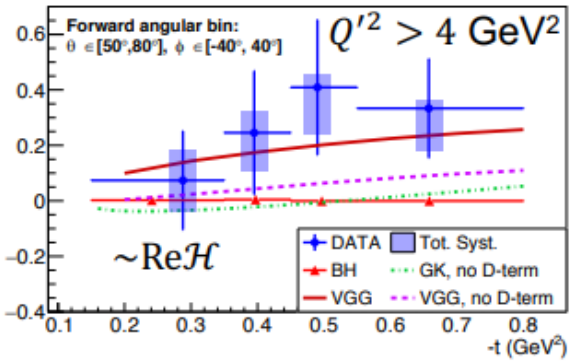


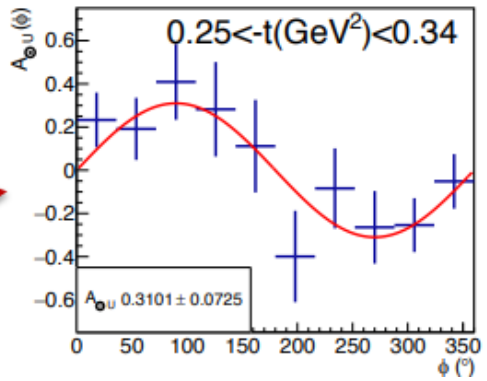
$$\frac{d\sigma_{INT}}{dQ'^2\,dt\,d(\cos\theta)\,d\varphi} = -\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{M}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\Big[\cos\varphi\,\frac{1+\cos^2\theta}{\sin\theta}\,\mathrm{Re}\tilde{M}^{--} - \cos 2\varphi\,\sqrt{2}\cos\theta\,\mathrm{Re}\tilde{M}^{0-} + \cos 3\varphi\,\sin\theta\,\mathrm{Re}\tilde{M}^{+-} + O\Big(\frac{1}{Q'}\Big)\Big]$$

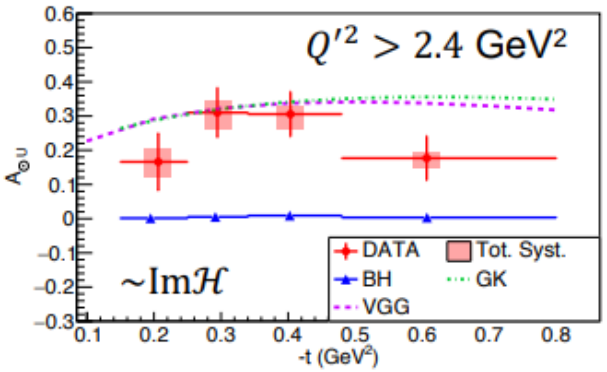
Incoming photon polarization

$$-\lambda\,\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{M}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\Big[\sin\varphi\,\frac{1+\cos^2\theta}{\sin\theta}\,\mathrm{Im}\tilde{M}^{--} - \sin 2\varphi\,\sqrt{2}\cos\theta\,\mathrm{Im}\tilde{M}^{0-} + \sin 3\varphi\,\sin\theta\,\mathrm{Im}\tilde{M}^{+-} + O\Big(\frac{1}{Q'}\Big)\Big].$$









P. Chatagnon et al. (CLAS), Phys. Rev. Lett. 127, 262501 (2021)

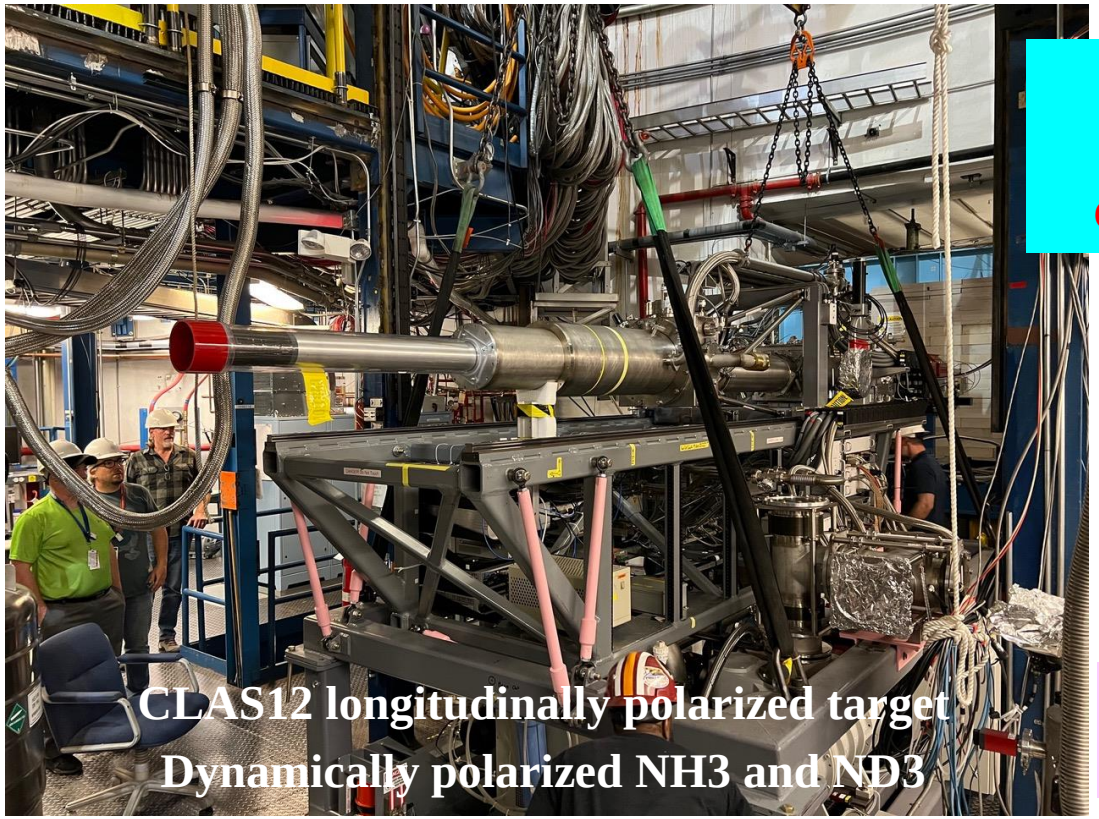
Ongoing at CLAS12: DVCS (p, n) on longitudinally polarized target

First-time measurement of longitidunal target-spin asymmetry and double (beam-target) spin asymmetry for nDVCS

$$\Delta\sigma_{UL} \sim \sin\phi\ \mathrm{Im}\{F_1\tilde{\mathcal{H}}+\xi(F_1+F_2)(\mathcal{H}+x_B/2\mathcal{E})-\xi k F_2\,\tilde{\mathcal{E}}+\ldots\}$$

$$\Delta\sigma_{LL} \sim (A+B\cos\phi)\ \mathrm{Re}\{F_1\tilde{\mathcal{H}}+\xi(F_1+F_2)(\mathcal{H}+x_B/2\mathcal{E})-\xi k F_2\,\tilde{\mathcal{E}}+\ldots\}$$

→ 3 observables (including BSA), constraints on real and imaginary CFFs of various neutron GPDs



$$\vec{e}\vec{p} \rightarrow ep\gamma$$
$$\vec{e}\vec{d} \rightarrow e(p)n\gamma$$

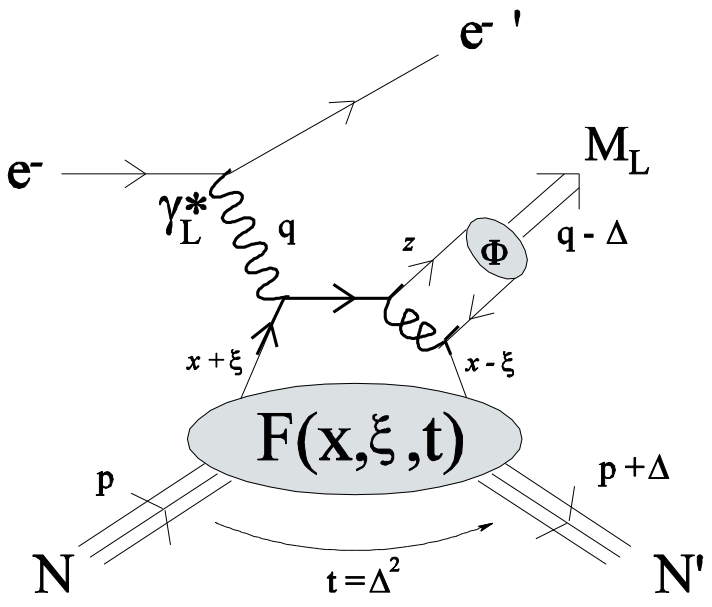
CLAS12 + Longitudinally polarized target + CND

Running from June 2022 to March 2023

Transversely polarized target for CLAS12 in development → experiment ~2026

Ultimate goals: flavor separation of CFFs & Ji's sum rule

Deeply virtual meson production and GPDs



Factorization proven only for **longitudinally polarized** virtual photons

Different mesons → different sensitivity to GPDs

H	$\tilde{H}$
E	$\tilde{E}$
↓	↓
Vector mesons (ρ, ω, ϕ)	**Pseudoscalar** mesons (π, η)

π^0	$2\Delta u+\Delta d$
η	$2\Delta u-\Delta d$

ρ^0	$2u+d$
ω	$2u-d$
ρ^+	$u-d$

quark flavor decomposition accessible via meson production

$$\mathcal{A}_L = -\frac{2ie}{9}\left(\int_0^1 dz \frac{\Phi(z)}{z}\right)\frac{4\pi\alpha_S(Q^2)}{Q}\int_{-1}^{+1} dx \left\{\left[\frac{1}{x-\xi+i\epsilon}+\frac{1}{x+\xi-i\epsilon}\right]F(x,\xi,t)\right\}$$

Complications: effective scale in the hard scattering process, meson distribution amplitude

Deeply virtual meson production at CLAS

Vector mesons: exclusive ρ^0, ω, ϕ and ρ^+ electroproduction on the proton with CLAS

K. Lukashin *et al.*, Phys. Rev. C 63, 065205, 2001 **(ϕ@4.2 GeV)**

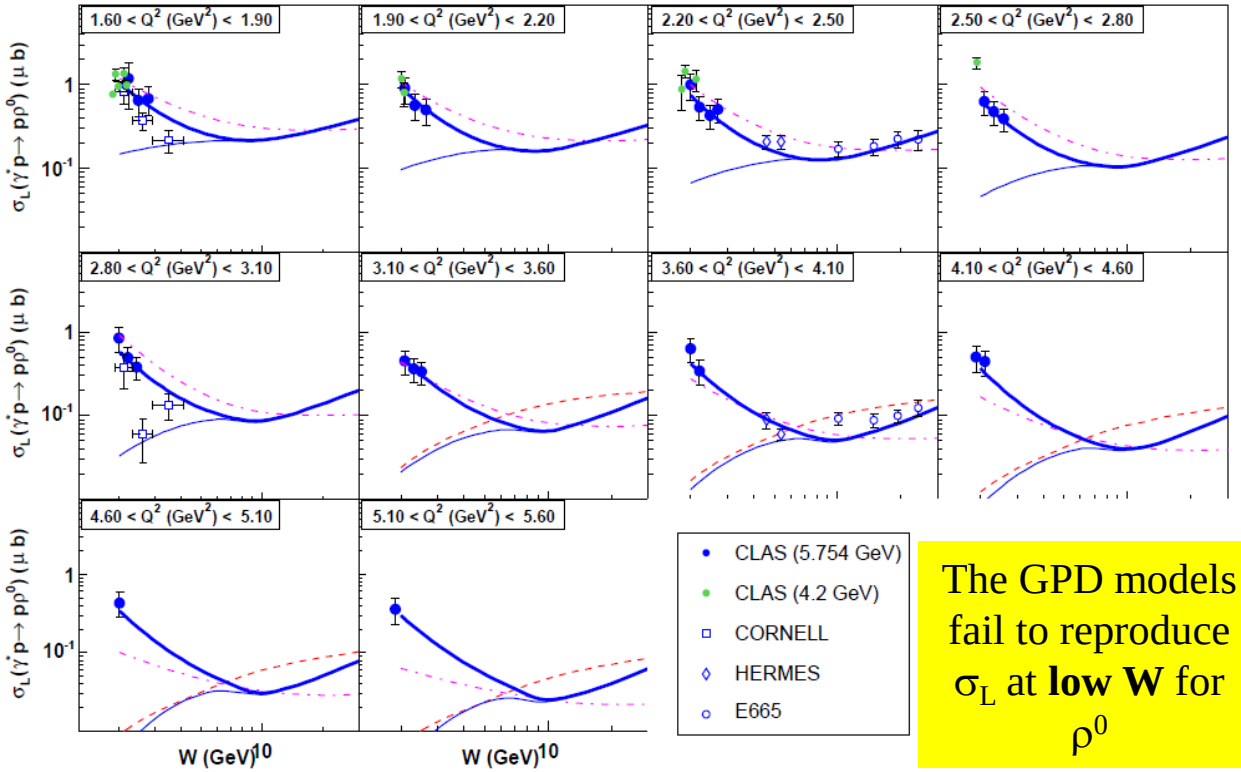
C. Hadjidakis *et al.*, Phys. Lett. B 605, 256-264, 2005 **(ρ^0@4.2 GeV)**

L. Morand *et al.*, Eur. Phys. J. A 24, 445-458, 2005 **(ω@5.75GeV)**

J. Santoro *et al.*, Phys. Rev. C 78, 025210, 2008 **(ϕ@5.75 GeV)**

S. Morrow *et al.*, Eur. Phys. J. A 39, 5-31, 2009 **(ρ^0@5.75GeV)**

A. Fradi, Orsay Univ. PhD thesis **(ρ^+@5.75 GeV) Not published**



The GPD models fail to reproduce σ_L at **low W** for ρ^0

Pseudoscalar mesons: exclusive π^0 and η electroproduction on the proton with CLAS

R. De Masi *et al.*, Phys. Rev. C 77, 042201(R), 2008 **(π^0@5.75GeV)**

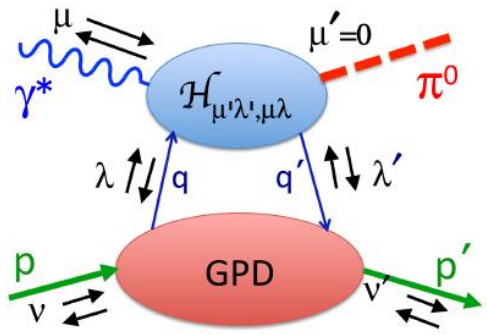
K. Park *et al.*, Phys. Rev. C 77, 015208, 2008 **(π^+@5.75 GeV)**

I. Bedlinskiy *et al.*, Phys. Rev. Lett. 109 (2012) 112001;
Phys. Rev. C 90, 039901 (2014) **(π^0@5.75GeV)**

I. Bedlinskiy *et al.*, Phys. Rev. C 95, 035202 (2017) **(η@5.75GeV)**

The measured pseudo-scalar cross sections show a **strong transverse contribution** and are well described by transversity GPD models:

- Goloskokov-Kroll
- Liuti-Goldstein
- $\sigma_L \ll \sigma_T$



Recap: what have we learned so far

- ImH well constrained, in CLAS (and soon CLAS12) kinematics
- ReH constrained mainly by Hall A measurements in selected kinematics; important for D-term and distribution of forces
- Initial constraints on $\tilde{\mathcal{H}}$ from longitudinally polarized target experiments, more data coming soon
- Potential of TCS for Re$\mathcal{H}$, D-term, universality of GPDs
- Importance of nDVCS for E_n sensitivity and flavor separation, but low statistics
- pDVCS on transverse target is vital to constrain E_p
- Still no information on x dependence of GPDs
- DVMP: only pseudo-scalars had until now a « succesful » GPD interpretation (transversity) → higher Q^2 may be necessary

Perspectives for upgrades at JLab

Polarized positrons beam

Higher luminosity

Double beam energy

DVCS with polarized positrons beam at JLab

The important of beam-charge asymmetry for DVCS was highlighted by the pioneering HERMES experiment
Disposing of a polarized positron/electron beams at JLab → new observables = different sensitivities to GPDs
Beam Charge Asymmetries proposed to be measured at CLAS12:
- The unpolarized beam charge asymmetry A_C^{UU}, which is sensitive to the real part of the CFF → D-term, forces in the proton
- The polarized beam charge asymmetry A_C^{LU}, which is sensitive to the imaginary part of the CFF
- The neutral beam spin asymmetry A_0^{LU}, which is sensitive to higher twist effects

New GPD Observables @ JLab

$$A_{UU}^{C} = \frac{(Y_+^+ + Y_-^+) - (Y_+^- + Y_-^-)}{Y_+^+ + Y_-^+ + Y_+^- + Y_-^-} = \frac{\sigma_{INT}}{\sigma_{BH} + \sigma_{DVCS}}$$

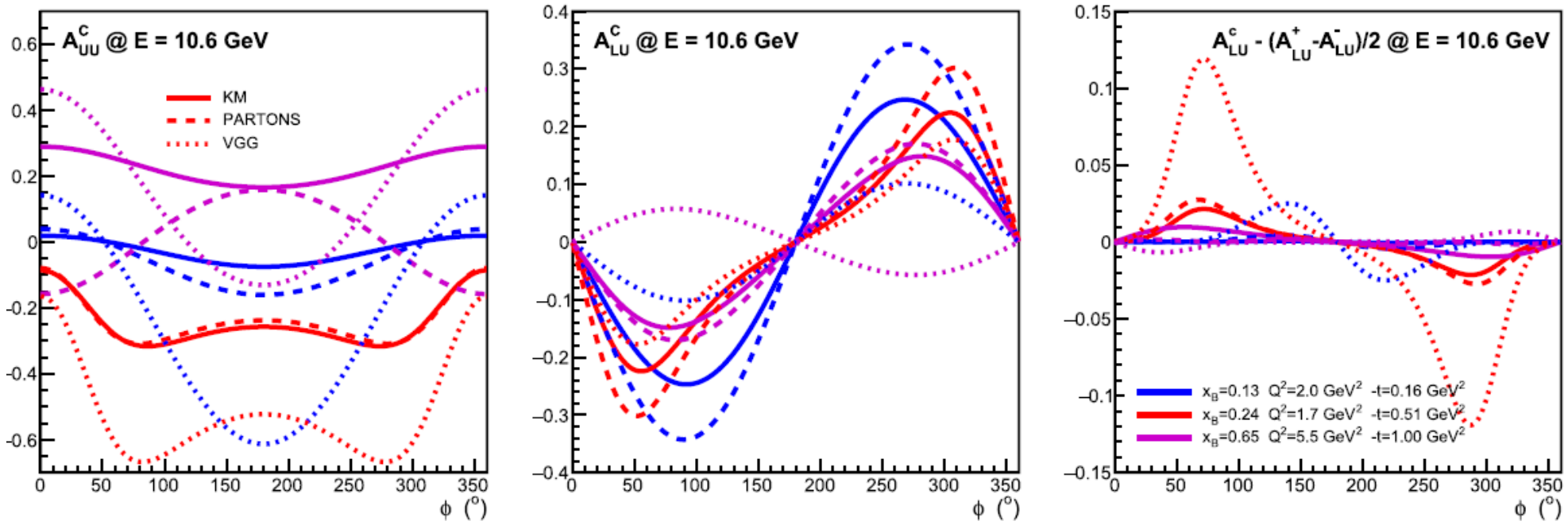
$$A_{LU}^{C} = \frac{(Y_+^+ - Y_-^+) - (Y_+^- - Y_-^-)}{Y_+^+ + Y_-^+ + Y_+^- + Y_-^-} = \frac{\tilde{\sigma}_{INT}}{\sigma_{BH} + \sigma_{DVCS}}$$

$$A_{LU}^{0} = \frac{(Y_+^+ + Y_+^-) - (Y_-^+ + Y_-^-)}{Y_+^+ + Y_-^+ + Y_+^- + Y_-^-} = \frac{\tilde{\sigma}_{DVCS}}{\sigma_{BH} + \sigma_{DVCS}}$$

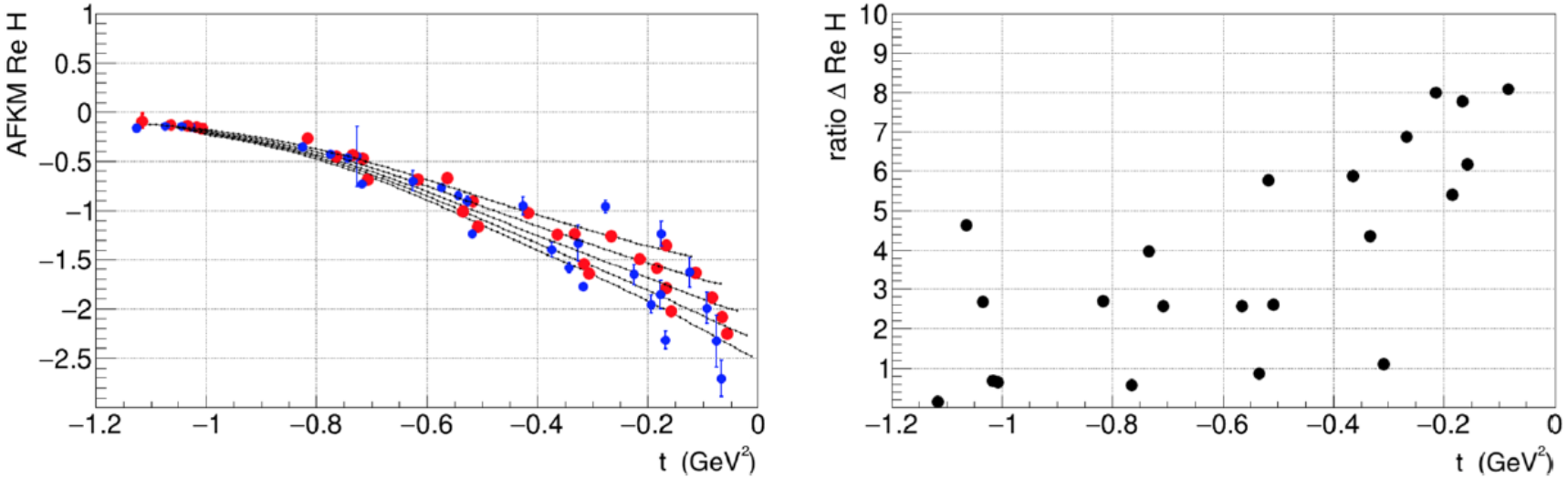
$$A_{LU}^{C} \neq A_{LU}^{\pm} = \frac{\pm(\tilde{\sigma}_{INT} \pm \tilde{\sigma}_{DVCS})}{\sigma_{BH} + \sigma_{DVCS} \pm \sigma_{INT}}$$

pDVCS with polarized positrons beam at CLAS

Model predictions for the three observables

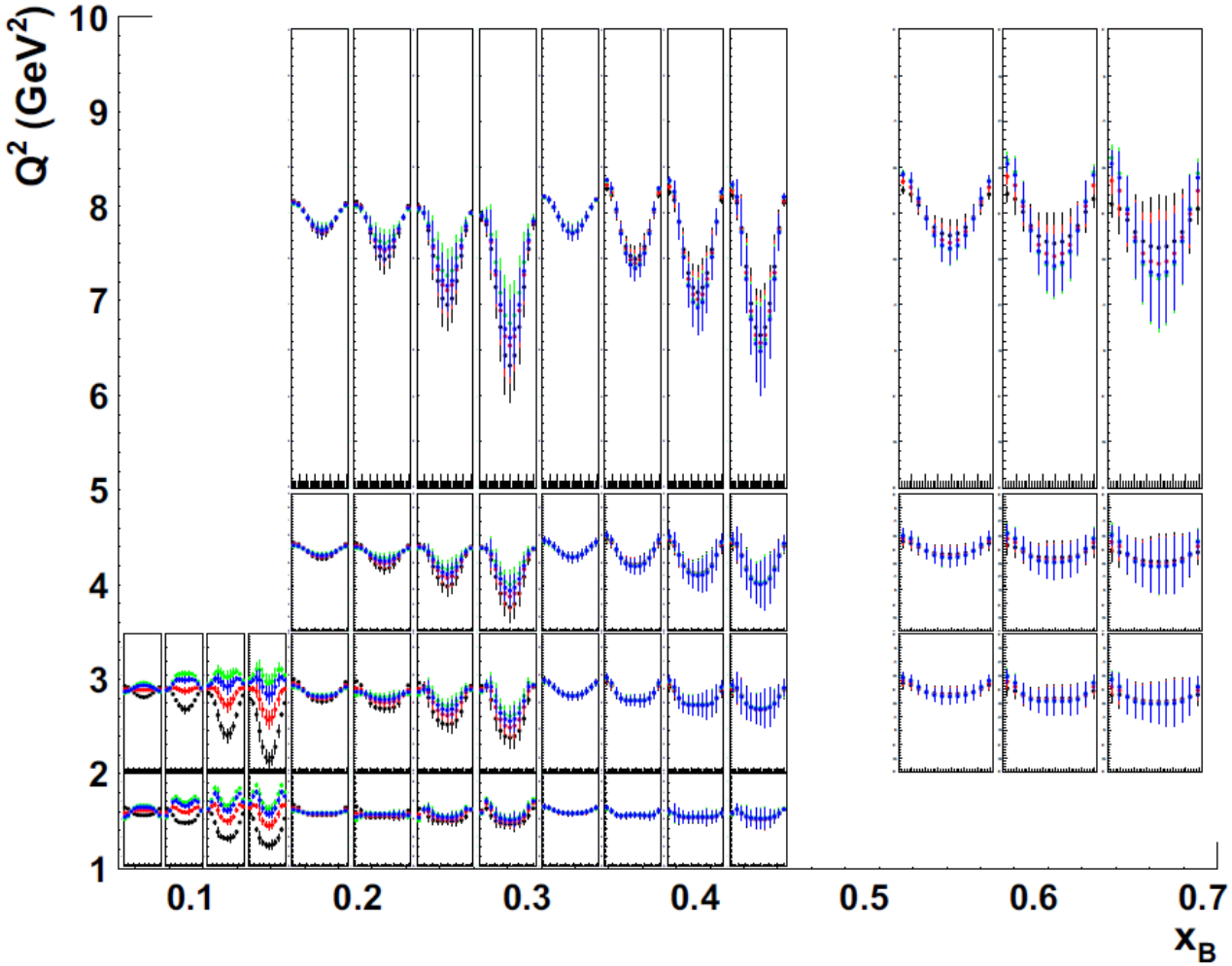


Impact of positron projected data on the extraction of ReH via global fits: major reduction of relative uncertainties, especially at low -t



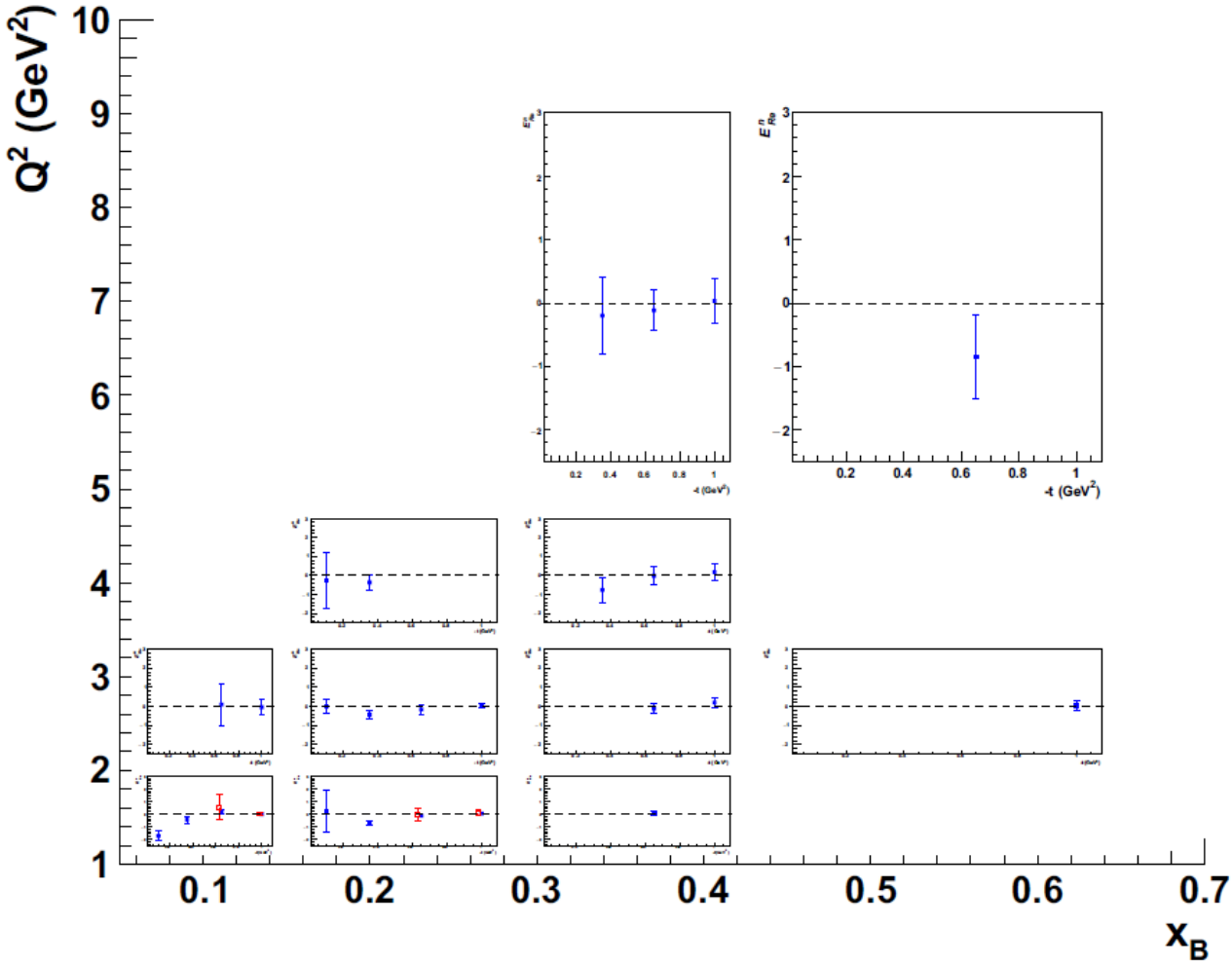
V. Burkert et al., Eur. Phys. J. A (2021) 57:186

nDVCS with polarized positrons beam at CLAS12



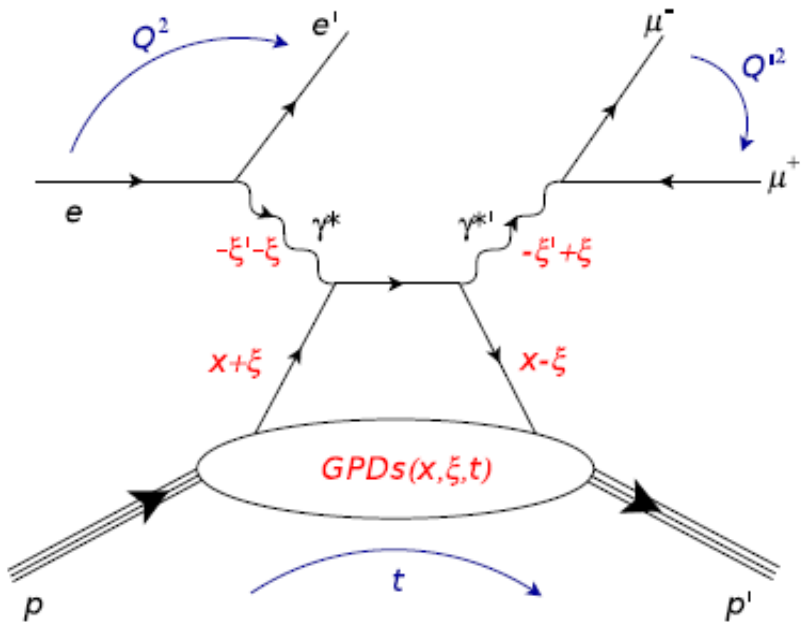
Projections (VGG) for the BCA, for various values of J_u, J_d
0.3, 0.1; 0.2/0.0; 0.1/−0.1; 0.3/−0.1

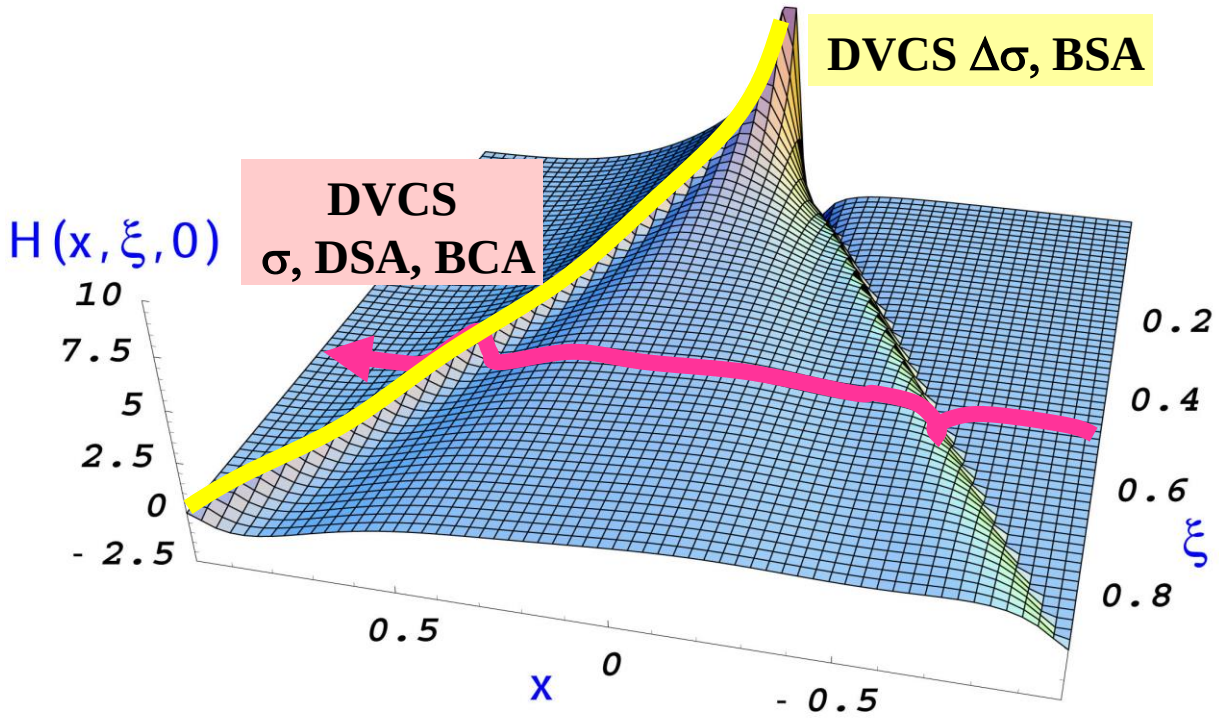
S.N. et al, Eur. Phys. J. A (2021) 57:226



Impact on the extraction of Re$\mathcal{E}$ using local fits, using the projections of approved CLAS12 nDVCS measurements with and without BCA

DDVCS: the gateway to the full kinematic mapping of GPDs





Thanks to the virtuality of the final photon, Q'^{2}, **DDVCS** allows a unique direct access to GPDs at **x ≠ ±ξ**, which is fundamental for their modeling

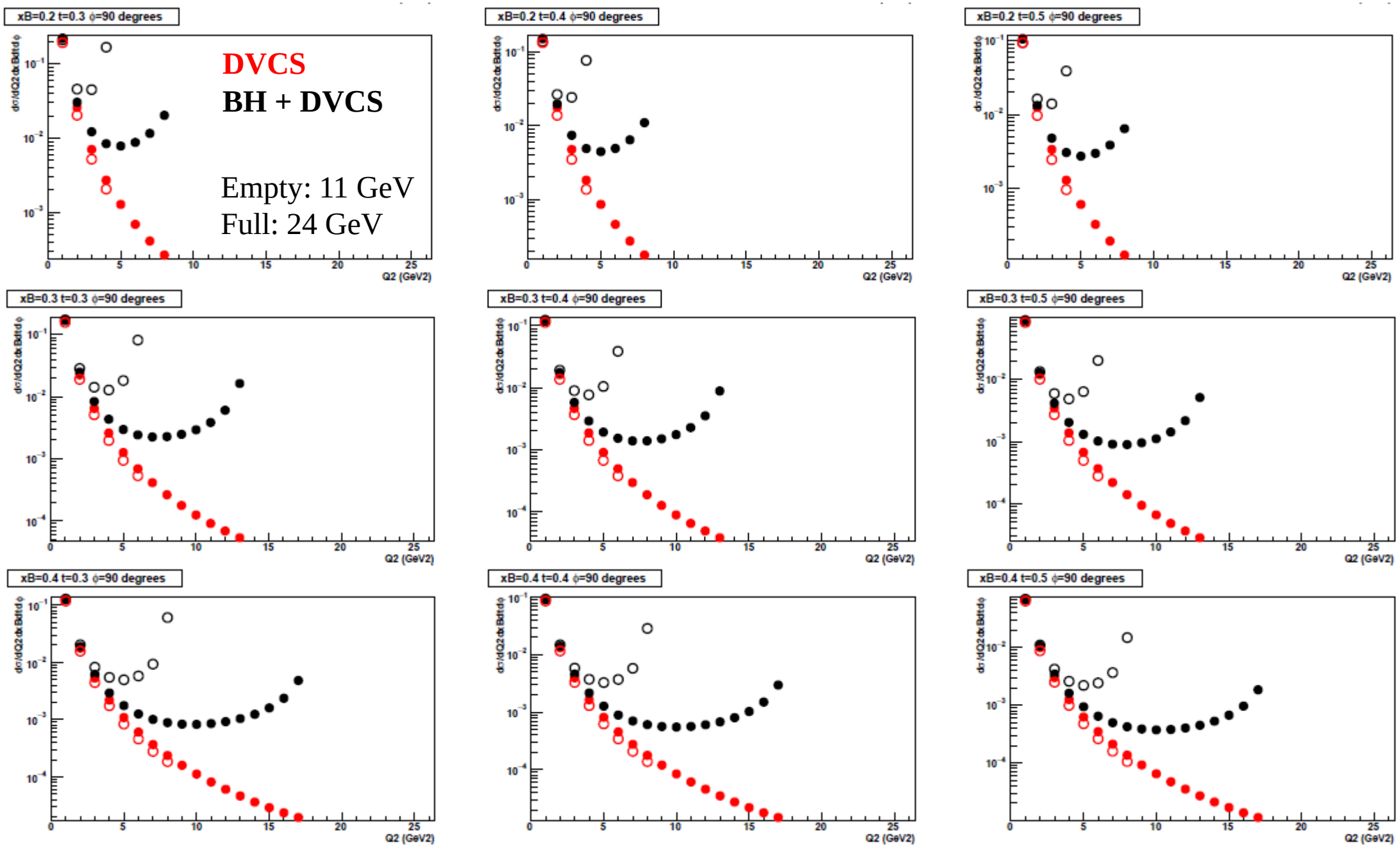
Experimental challenges:

- Small cross section (300 times less than DVCS)
- Need to detect muons

- **Possible CLAS12 upgrade (LOI): "μCLAS12" for DDVCS and J/ψ ep→e'p'μ+μ- at L~10^{37} cm^{-2}s^{-1} New tracker, calorimeter, shielding**

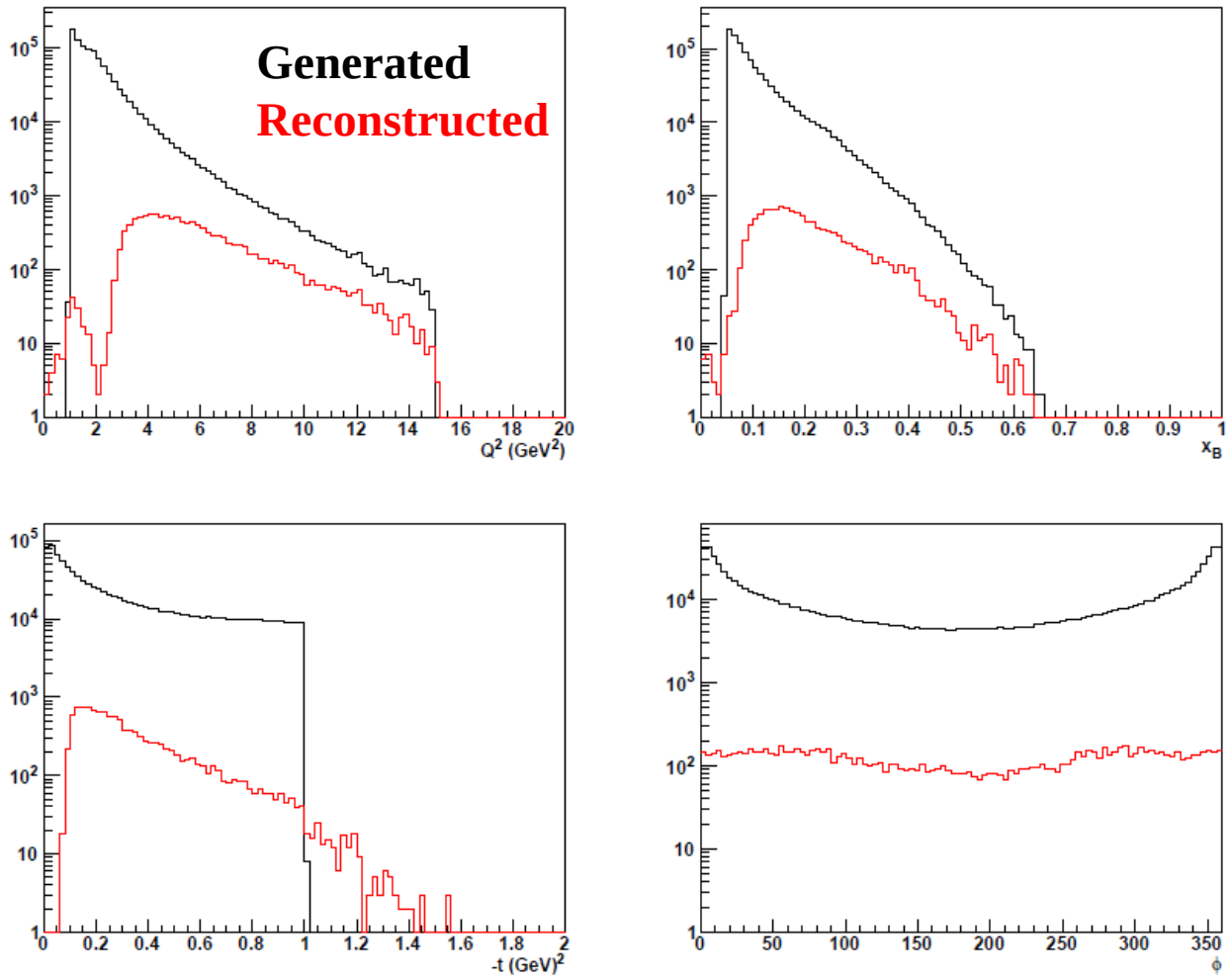
- **Possible DDVCS experiment with SOLID@HallA (LOI)**

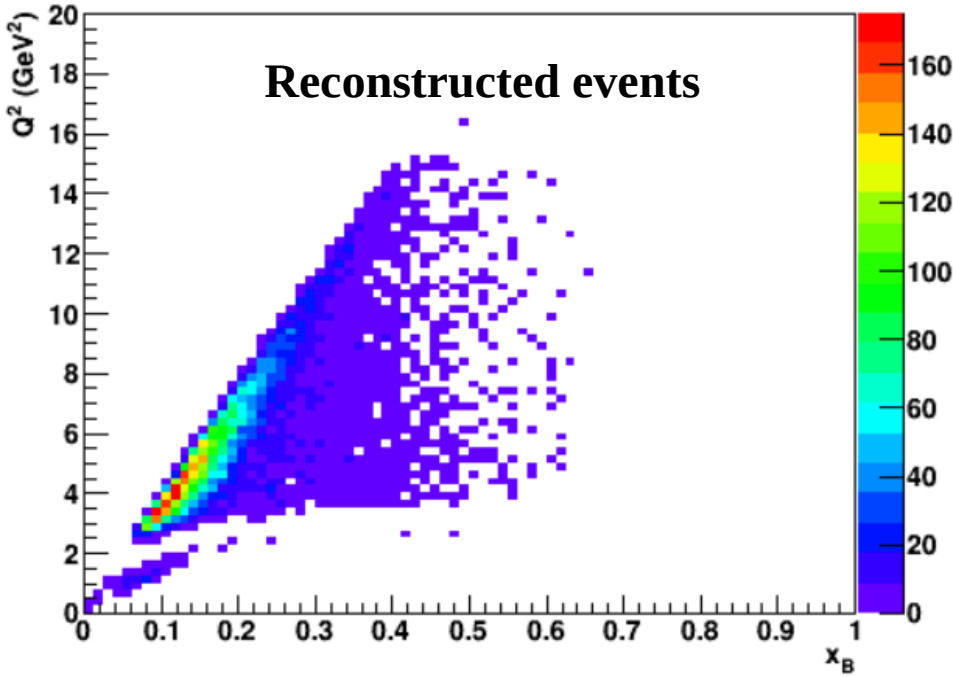
Cross section DVCS @ 24 GeV, VGG predictions

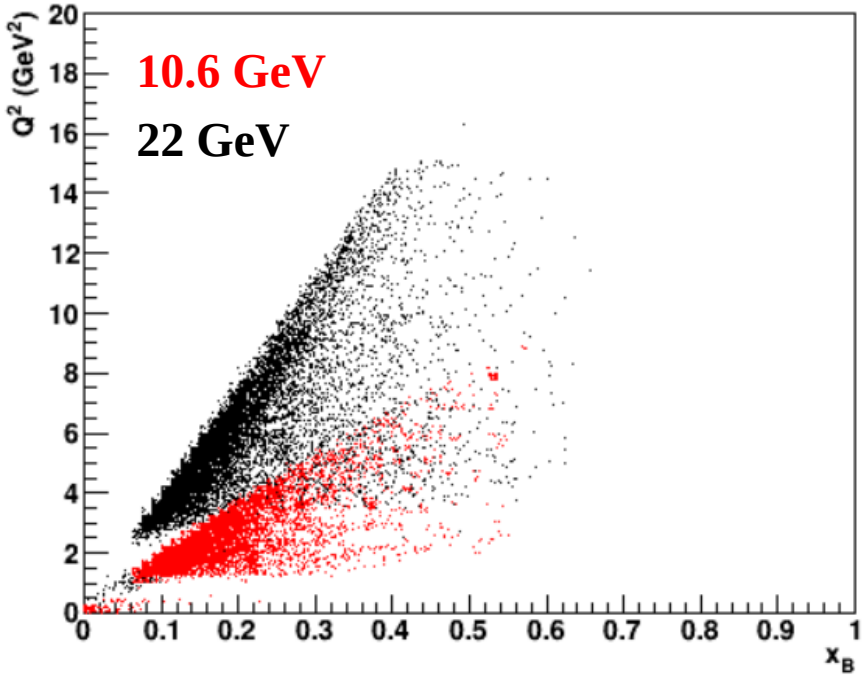


pDVCS with 22-GeV beam (current CLAS12)

Simulated pDVCS events at 22 GeV (H. Avakian), passed through GEMC (current CLAS12) and standard CLAS12 reconstruction (R. De Vita)







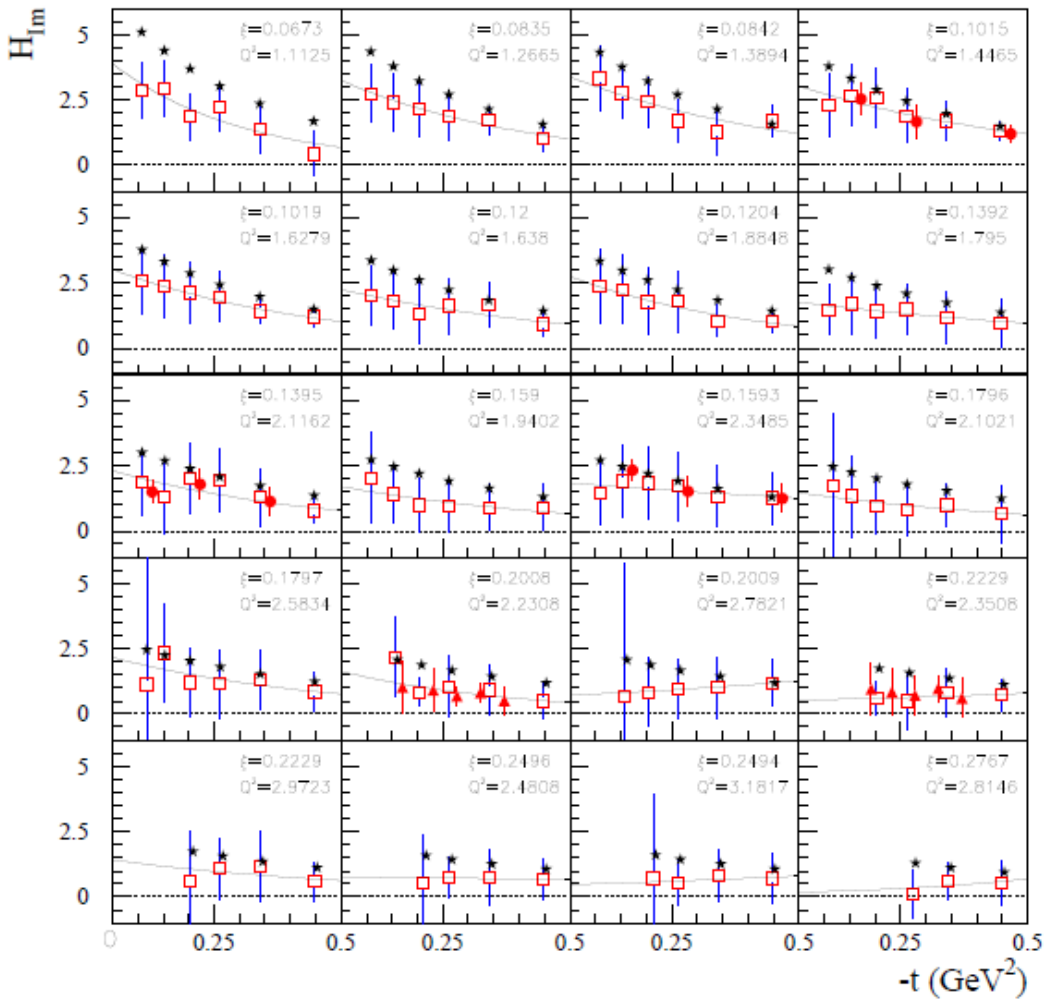
With the current CLAS12 acceptance ~1%, mainly all new kinematics
PID? Backgrounds? Further studies are needed

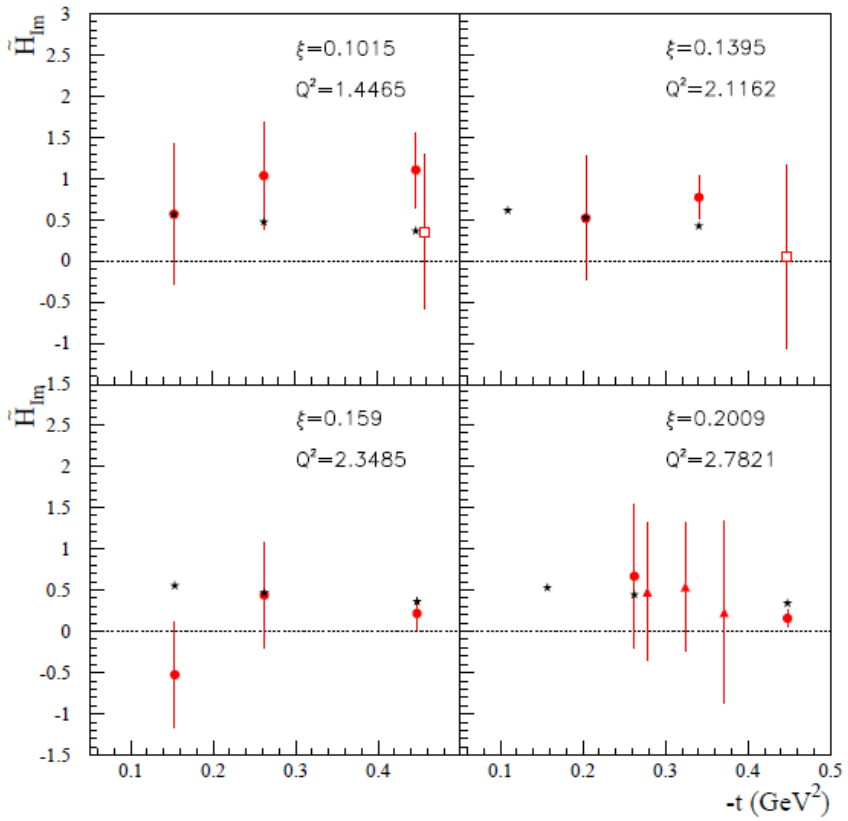
Conclusions (and my personal opinions)

- Exclusive reaction can provide a **wealth of information on nucleon structure**, via the measurement of **GPDs**: nucleon tomography, quark angular momentum, distribution of forces in the nucleon
- **pDVCS** has been and is being **extensively measured**, aside from **beam-charge and transverse-target observables**
- **nDVCS** measurements are ongoing, **cross sections and asymmetries are very small → higher luminosity** would be welcome, as well as measurements of **BCA**
- **TCS & DDVCS** are the **golden channels** that should be explored in the future to go beyond DVCS: universality of GPDs, real part of CFFs, x dependence of GPDs
- **Higher beam energy** will increase the **phase space for DVCS**, but also **lower cross sections** (strong BH dominance?); PID and backgrounds need to be studied; likely beneficial for **DVMP** measurements, but **let's have a look first at 11-GeV data**
- To have an **upgraded JLab** (CLAS12) **coexisting and competing with the EIC**, we should prove that it allows **UNIQUE physics**, not only **complementary kinematics**: pointing towards the measurements of **small-cross-section and unmeasured reactions/observables requiring high luminosity and/or polarized positrons beam can be a good strategy**; higher energy alone (without positrons and/or DDVCS) doesn't seem to me to lead to a strong enough physics case, at least in the GPDs field
- **Ideally, we should aim for high-lumi, energy, and positrons** ☺

Back-up slides

Results for H_{Im} and $\tilde{H}_{Im}$ from the fits of JLab 2015 data

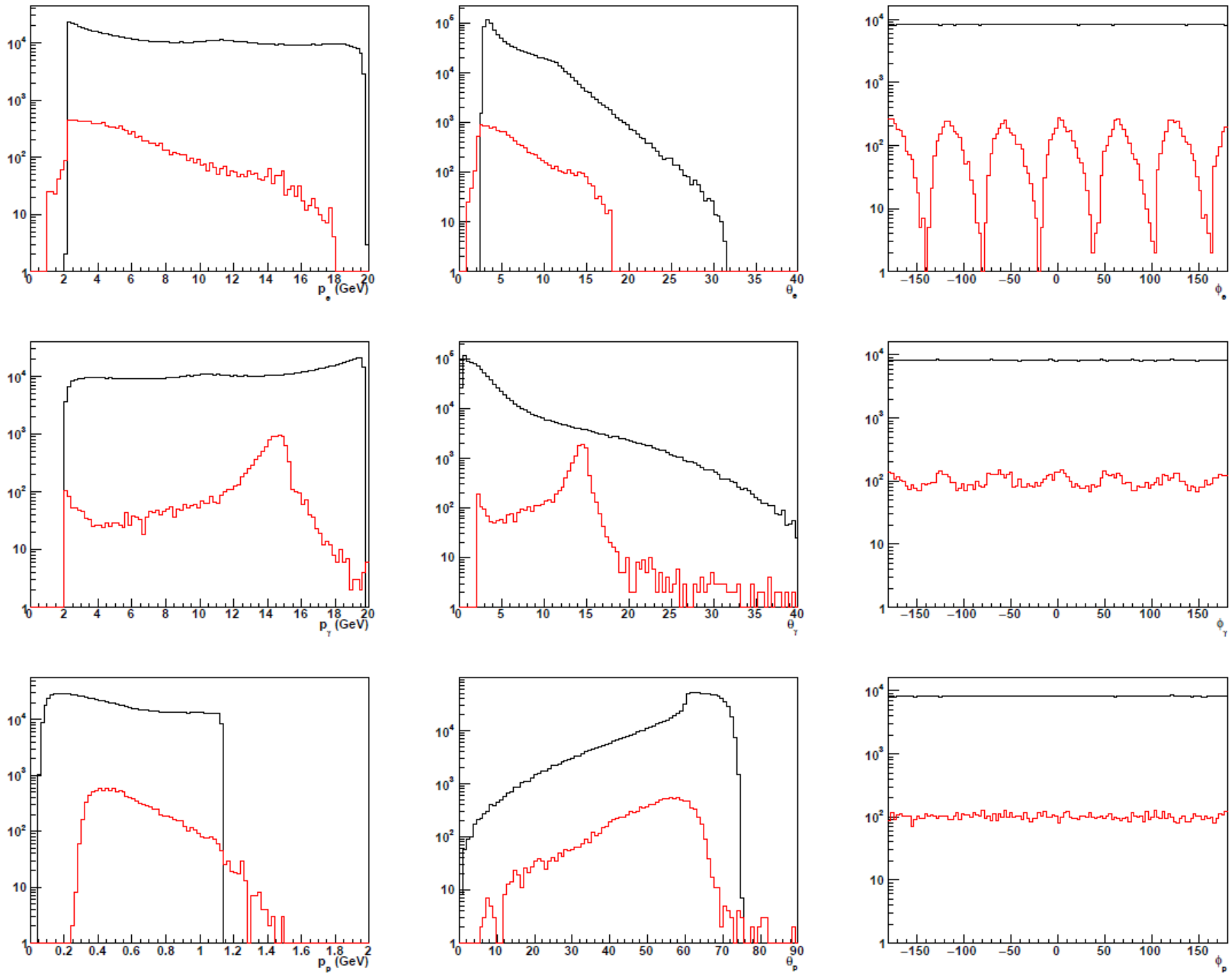




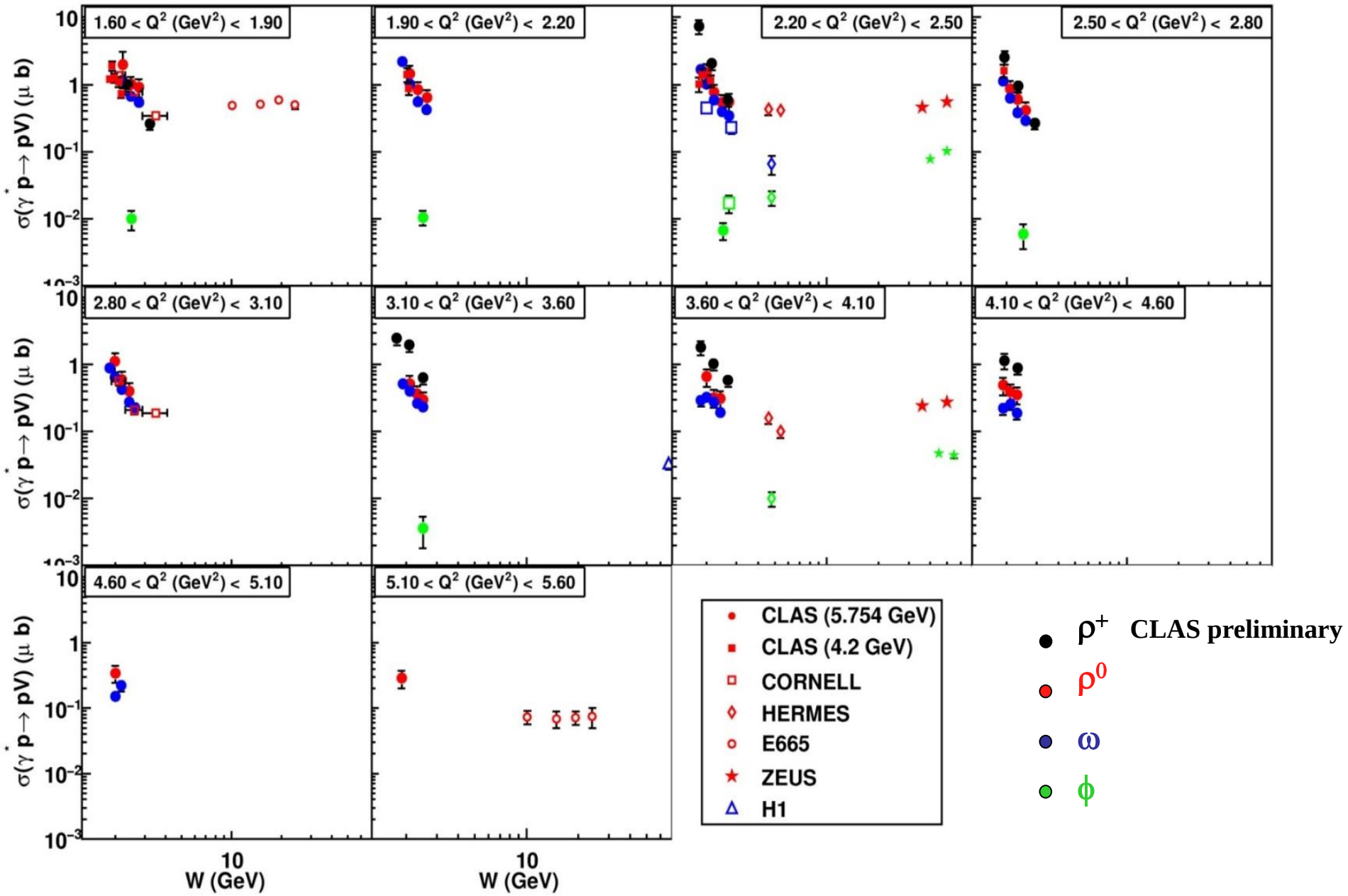
- □ Fit to CLAS c.s. and beam pol. c.s.
- ● Fit to CLAS c.s., beam pol. c.s., lTSA, DSA
- ▲ Fit to Hall A c.s. and beam pol. c.s.
- ★ VGG model

H_{Im} has steeper t-slope than $\tilde{H}_{Im}$: the axial charge (~Δu-Δd) is more "concentrated" than the electric charge

R. Dupré, M. Guidal, S.N. , M. Vanderhaegen, EPJA 53, 171 (2017)


p_e (GeV)
θ_e
φ_e
p_γ (GeV)
θ_γ
φ_γ
p_p (GeV)
θ_p
φ_p

Comparison between vector mesons (σ)



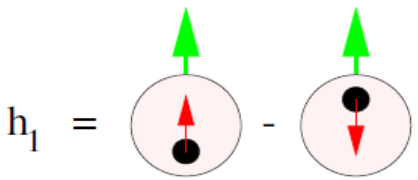
Chiral-odd GPDs

- 4 chiral-odd GPDs (parton helicity flip)
- Difficult to access (helicity flip processes are **suppressed**)
- Chiral-odd GPDs are very **little constrained**
- Anomalous tensor magnetic moment:

$$\kappa_T = \int_{-1}^{+1} dx\, \bar{E}_T(x,\xi,t=0) \qquad \bar{E}_T = 2\tilde{H}_T + E_T$$

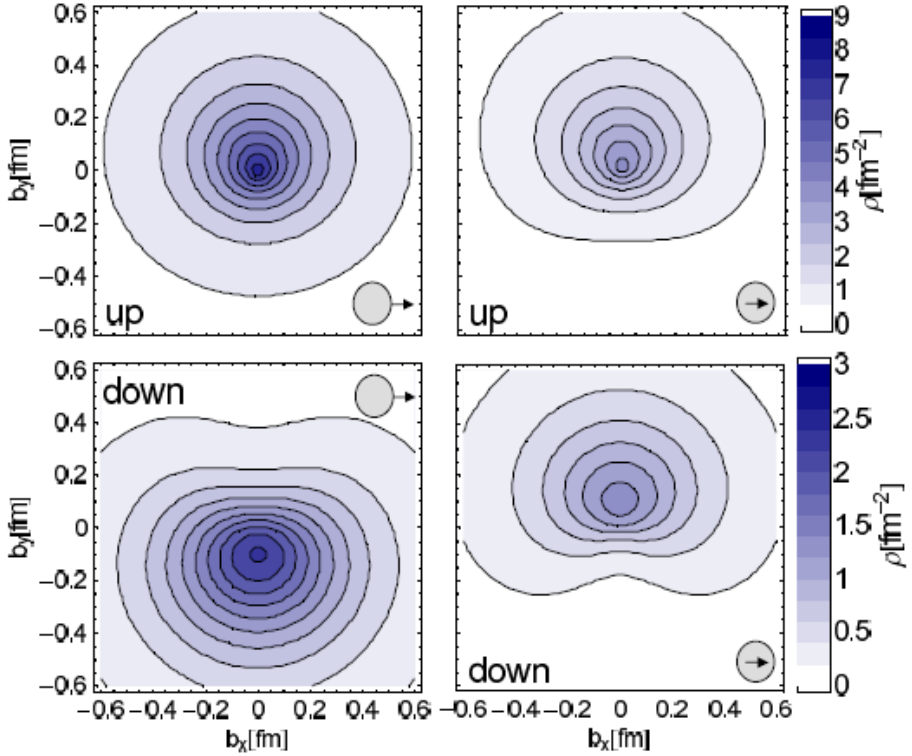
- Link to the **transversity** distribution: $H_T^q(x,0,0) = h_1^q(x)$

$$H_T, \tilde{H}_T, E_T, \tilde{E}_T$$



Transverse Densities for u and d quarks in the nucleon

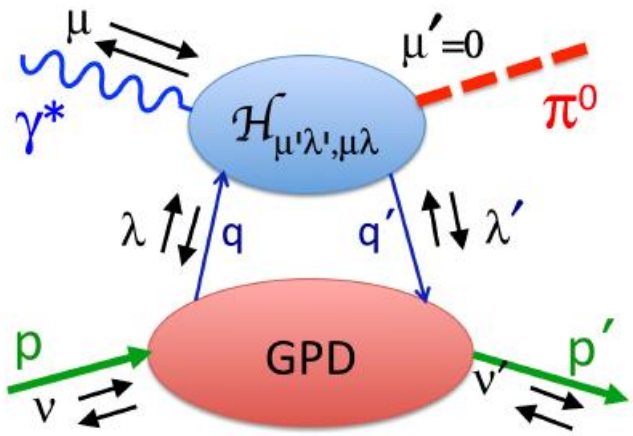
Distributions of unpolarized quarks in a transversely polarized nucleon, **linked to E**

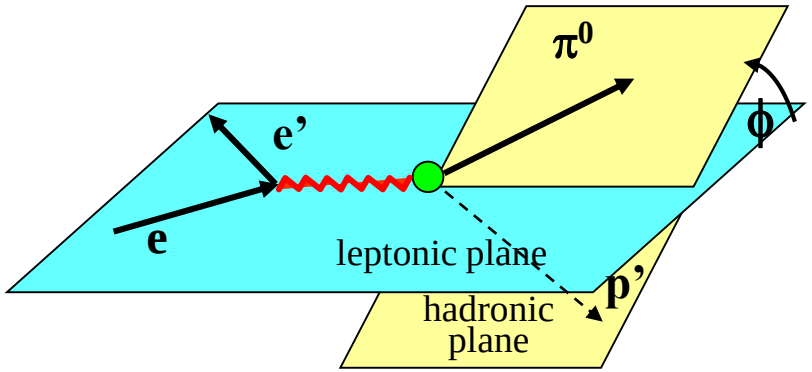


Distribution of transversely polarized quarks in an unpolarized nucleon, **linked to $\bar{E}_T$**

Gockeler et al, Phys. Rev. Lett. 98, 222001 (2007), lattice calculation

Exclusive π^0 electroproduction





$$\frac{d\sigma}{dQ^2 dx_B\, d\phi dt} = \Gamma(Q^2, x_B)\,\frac{1}{2\pi}\left(\sigma_T + \varepsilon\sigma_L + \varepsilon cos2\phi\sigma_{TT} + \sqrt{2\varepsilon(1+\varepsilon)}cos\phi\sigma_{LT}\right)$$

Leading twist: $\sigma_L = \frac{4\pi\alpha_e}{k'Q^6}\left[(1-\xi^2)|<\tilde{H}>|^2 - 2\xi^2\,\mathrm{Re}\left(<\tilde{H}>^*<\tilde{E}>\right) - \frac{t'}{4m^2}\xi^2|<\tilde{E}>|^2\right]$

σ_L is suppressed: $\tilde{H}^\pi = \frac{1}{3\sqrt{2}}\left[2\tilde{H}^u + \tilde{H}^d\right]$

Generalized Compton Form Factors

$$<\tilde{H}> = \sum_\lambda \int_{-1}^{1} dx\, M(x,\xi,Q^2,\lambda)\tilde{H}(x,\xi,t)$$

$$\sigma_T = \frac{4\pi\alpha_e}{2\kappa}\frac{\mu_\pi^2}{Q^4}\left[(1-\xi^2)|<HT>|^2 - \frac{t'}{8m^2}|<\overline{E_T}>|^2\right]$$

$$\sigma_{TT} = \frac{4\pi\alpha_e}{2\kappa}\frac{\mu_\pi^2}{Q^4}\frac{t'}{8m^2}|<\overline{E_T}>|^2$$

Transversity GPD models:

- Goloskokov-Kroll
- Liuti-Goldstein
- $\sigma_L << \sigma_T$

CLAS results

I. Bedlinskiy et al., Phys. Rev. Lett. 109 (2012) 112001; Phys. Rev. C 90, 039901 (2014)

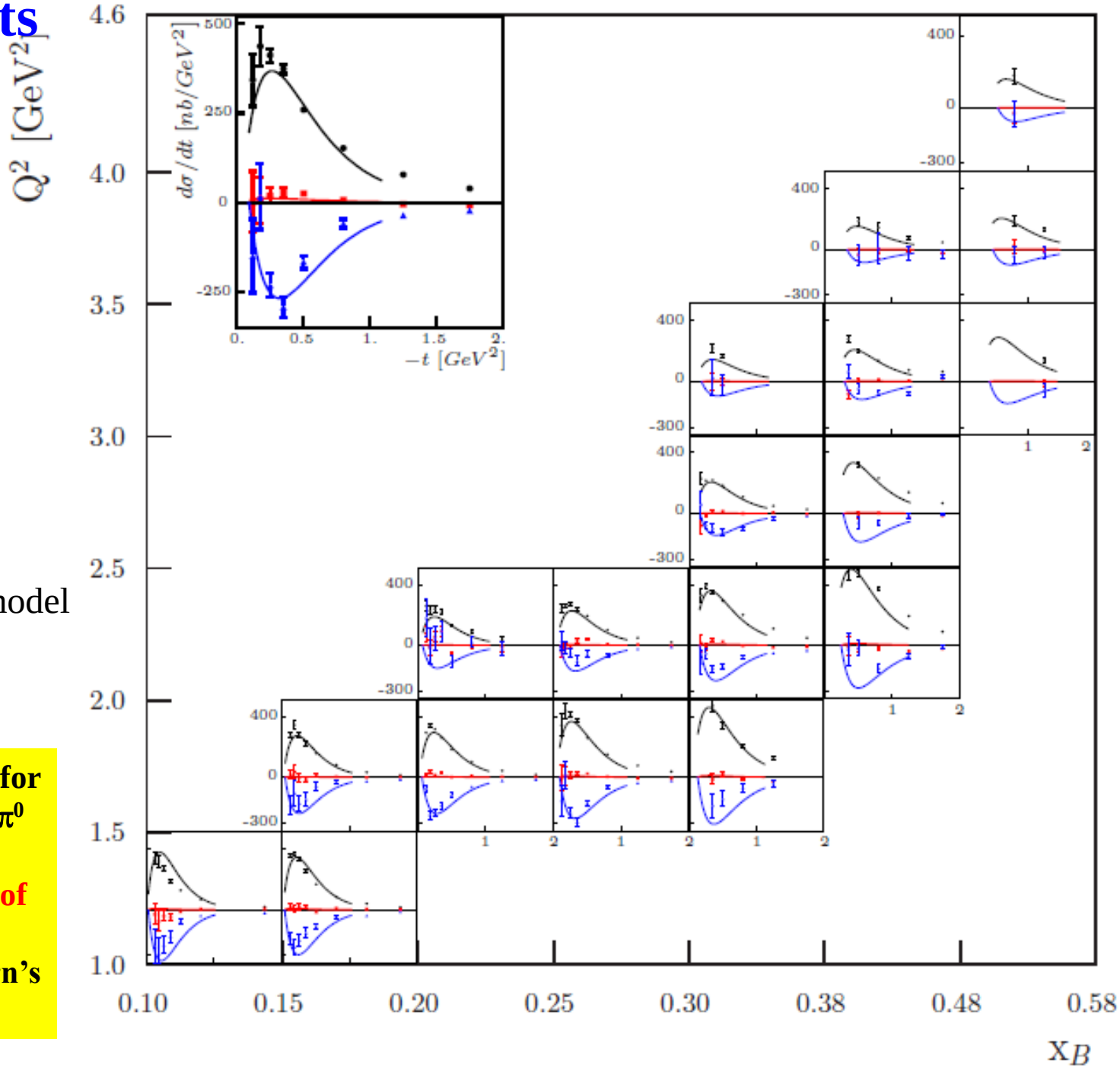
$\sigma_T+\varepsilon\sigma_L$

σ_{LT}

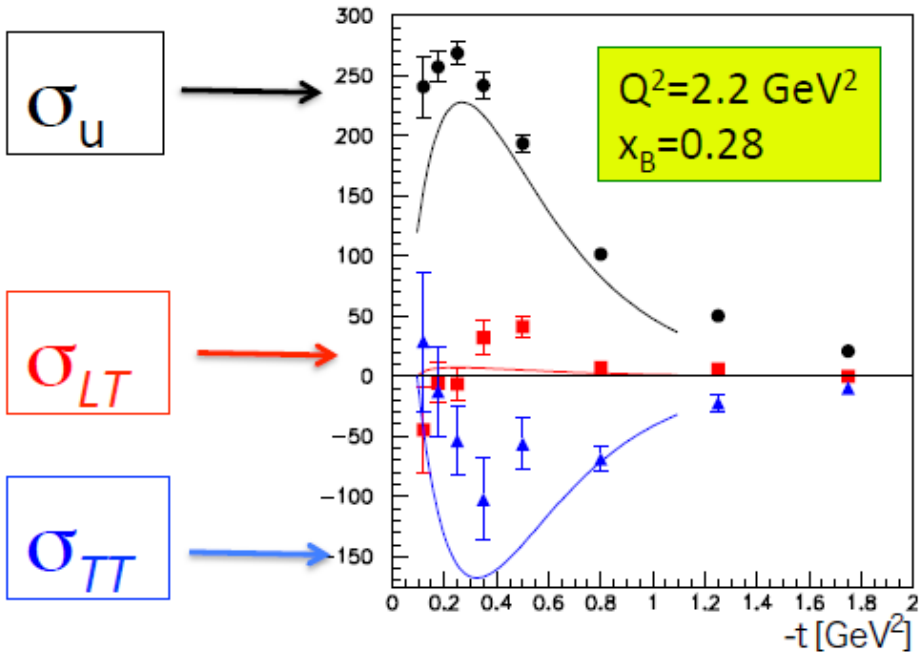
σ_{TT}

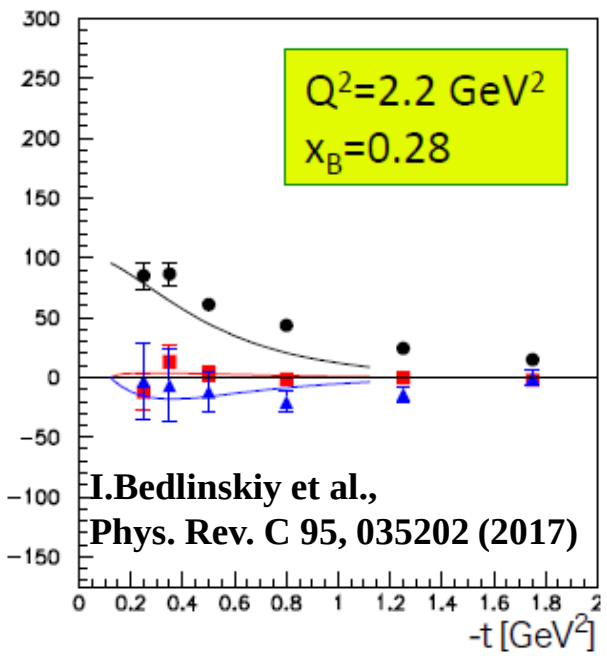
Goloskokov-Kroll model
Transversity GPDs

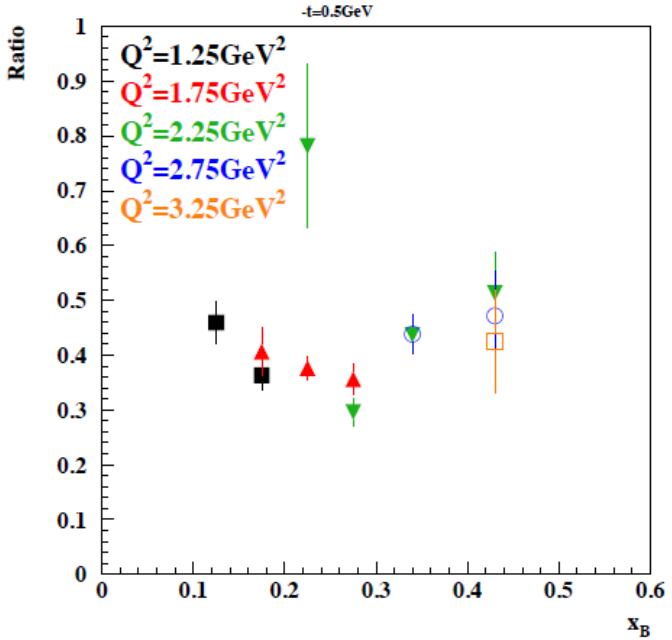
Recent Hall A results for proton and neutron π^0 electroproduction
→ flavor separation of transversity GPDs
(M. Defurne's, T. Horn's talks)



Comparison π^0/η







- Very little dependence on x_B and Q^2
- Chiral-odd GPD models predict this ratio to be **~1/3** at CLAS kinematics
- Chiral-even GPD models predict this ratio to be around 1 (at low –t)

Potentially one can perform **flavor separation of transversity GPDs** combining π^0 and η