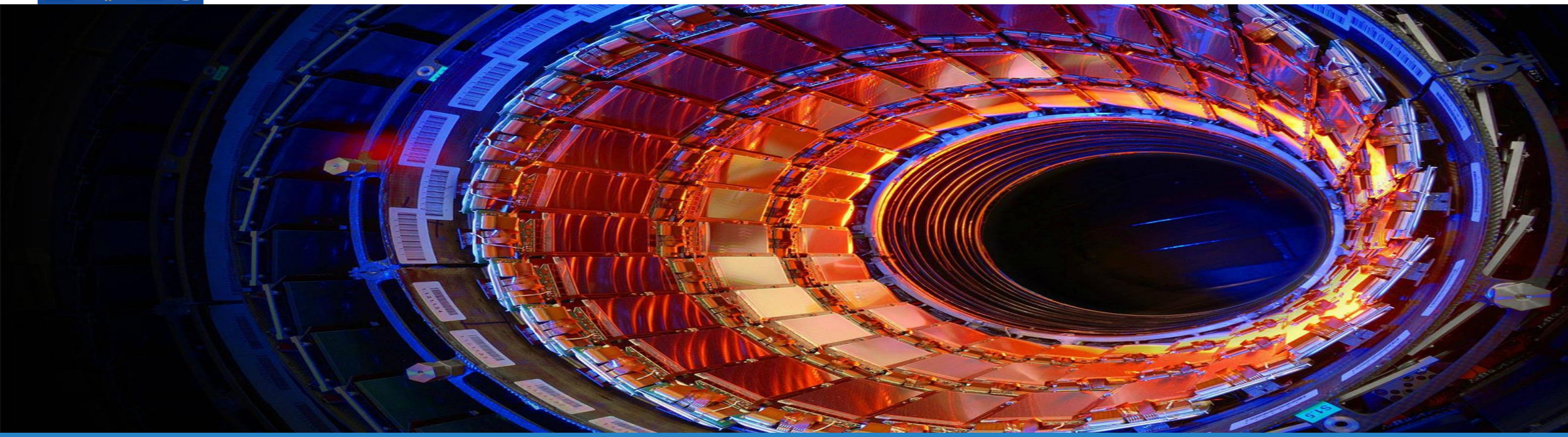

WP 23 – JRA 5 GPD-ACT: Generalized Parton Distributions

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STRONG 2020 Annual Meeting

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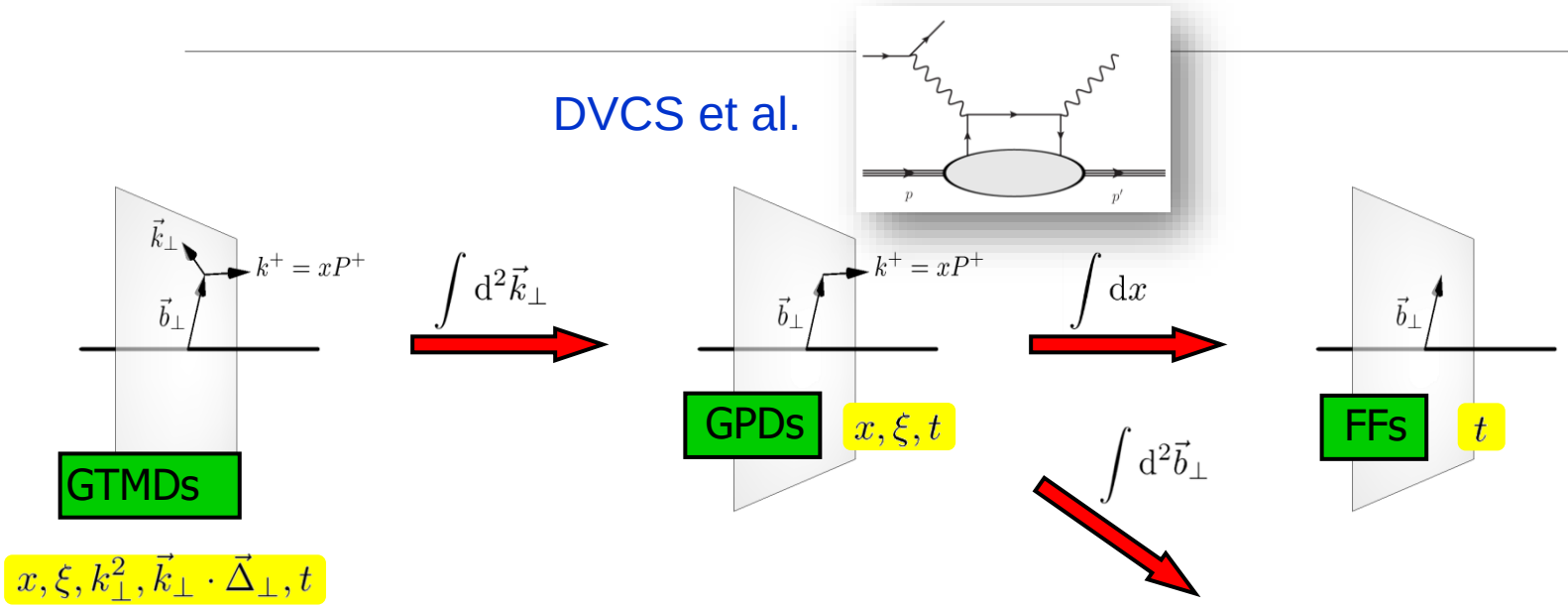
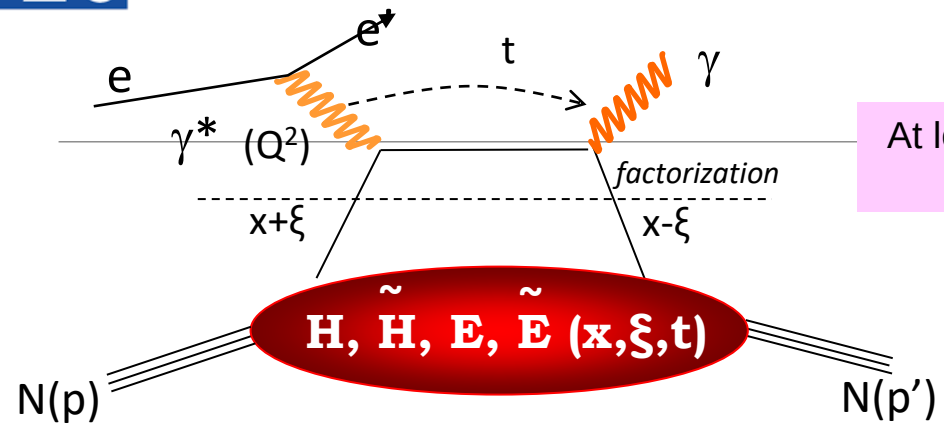
Objective: Generalized Parton Distributions



Generalized Parton Distributions (GPDs):

- fully correlated parton distributions in both **transversal coordinate** and **longitudinal momentum** space
- accessible in **hard exclusive** reactions (DVCS, DVMP, TCS,…)

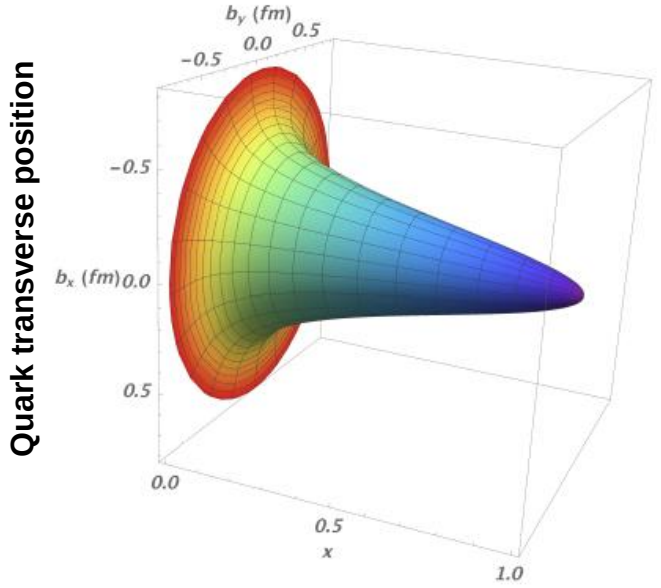


At leading order QCD, twist 2, chiral-even, quark sector
→ **4 GPDs for each quark flavor**

Nucleon tomography

$$q(x,\mathrm{b}_\perp)=\int_0^\infty \frac{d^2\Delta_\perp}{(2\pi)^2}e^{i\Delta_\perp \mathrm{b}_\perp}H(x,0,-\Delta_\perp^2)$$

$$\Delta q(x,\mathrm{b}_\perp)=\int_0^\infty \frac{d^2\Delta_\perp}{(2\pi)^2}e^{i\Delta_\perp \mathrm{b}_\perp}\tilde{H}(x,0,-\Delta_\perp^2)$$



Quark longitudinal momentum

Quark angular momentum (Ji's sum rule)

$$\frac{1}{2}\int_{-1}^{1} x\,dx\,(H(x,\xi,t=0)+E(x,\xi,t=0))=J=\frac{1}{2}\Delta\Sigma+\Delta L$$

PRD95, 011501 (2017);
EPJA 53, 171 (2017) (we want to improve on that!)

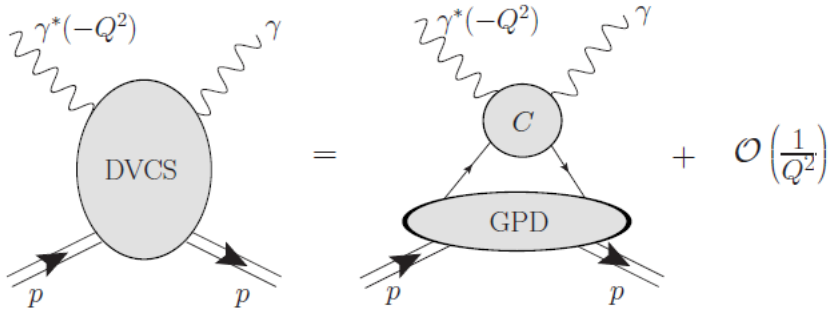
Compton Form Factors vs GPDs

- At leading order DVCS cross-section depends on four complex

Compton form factors (CFFs)

$$\mathcal{H}(\xi, t, Q^2), \quad \mathcal{E}(\xi, t, Q^2), \quad \widetilde{\mathcal{H}}(\xi, t, Q^2), \quad \widetilde{\mathcal{E}}(\xi, t, Q^2)$$

- [Collins et al. '98]



- CFFs are convolution:

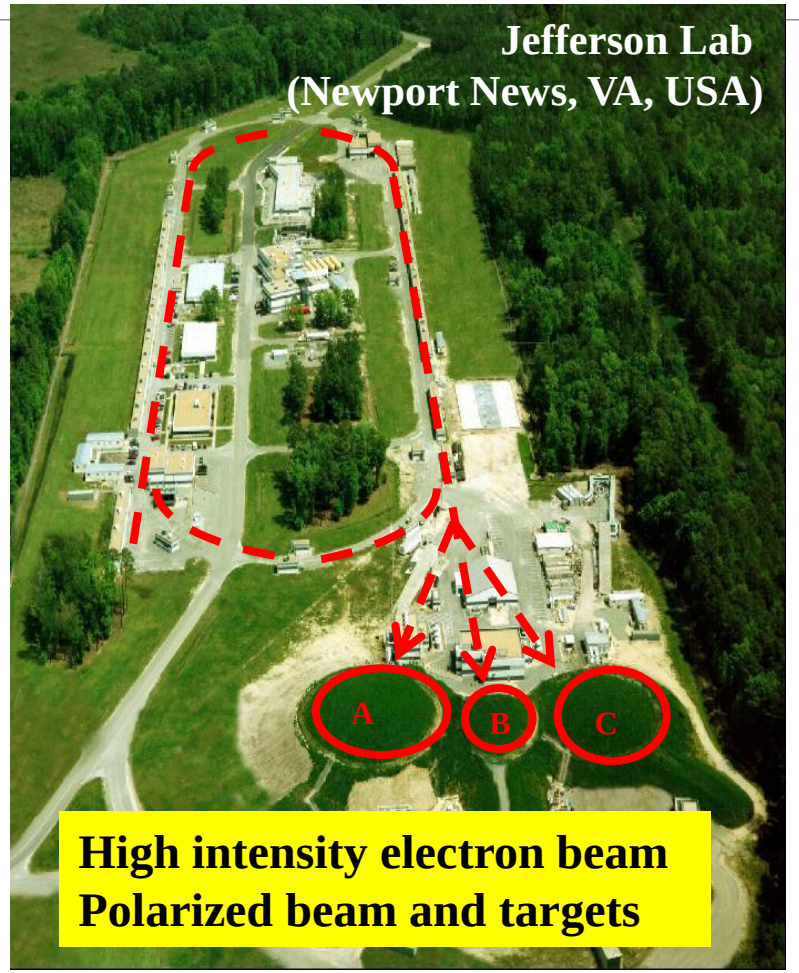
$$^a\mathcal{H}(\xi, t, Q^2) = \int \mathrm{d}x \; C^a(x, \xi, \frac{Q^2}{Q_0^2}) \; H^a(x, \xi, t, Q_0^2) \qquad a=q,G$$

- $H^a(x, \eta, t, Q_0^2)$ — Generalized parton distribution (GPD)

  [Müller '92, et al. '94, Ji, Radyushkin '96]

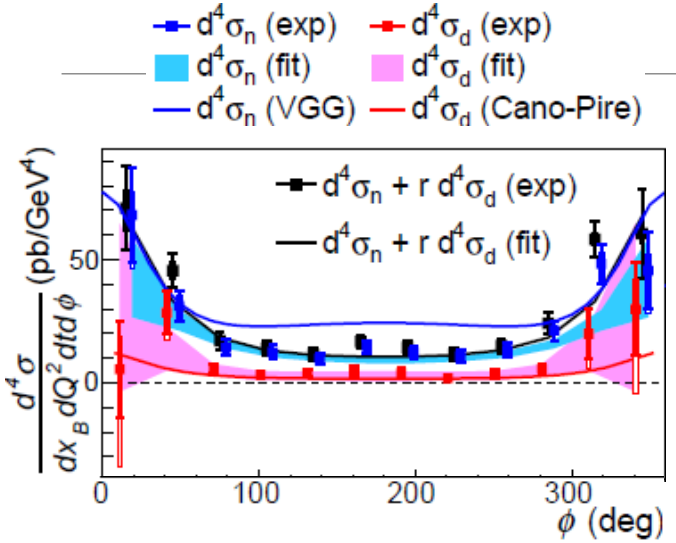
Objectives of JRA5-GPD-ACT

- Analysis of GPD experiments at **JLab@6 GeV** and of DVCS and DVMP with a recoil detector **at COMPASS**
- Preparation, data taking and analysis of new experiments for **JLab@12GeV** (nDVCS, nuclear DVCS, TCS, DDVCS)
- Producing projections for GPD experiments to propose for EIC
- Building models of GPDs (standard twist-2, but also twist-3 and transversity GPDs), using also the constraints obtained by lattice QCD calculations
- Improved theoretical studies, including higher order and higher twist corrections
- Both experimental and theoretical efforts will be combined in **extraction of GPD information by fits to the data**.

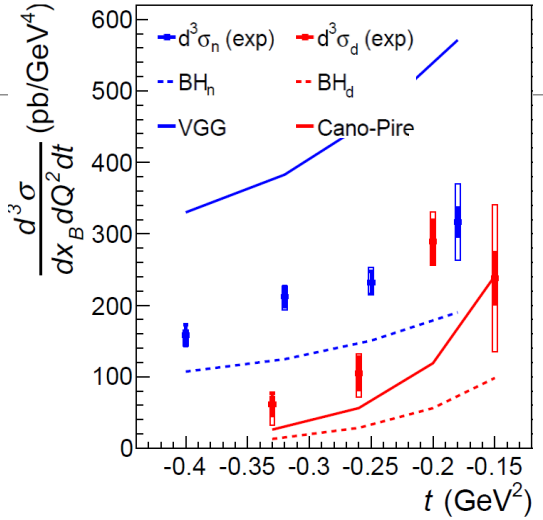


DVCS off the neutron in Hall A @ 6 GeV

Update on progress (Task 1)



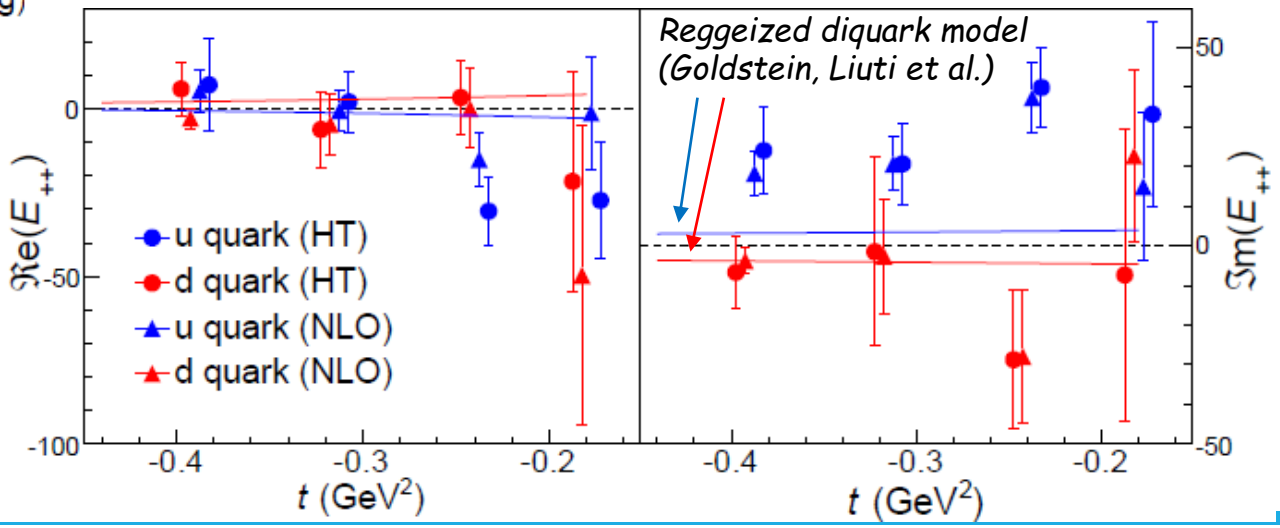
- Coherent deuteron & quasi-free neutron DVCS cross sections off LD_2
- 1st observation of DVCS signal off neutron
- Unique sensitivity to GPD *E*



Flavor separation of CFFs when combined with p-DVCS

NLO and HT analyses performed:

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

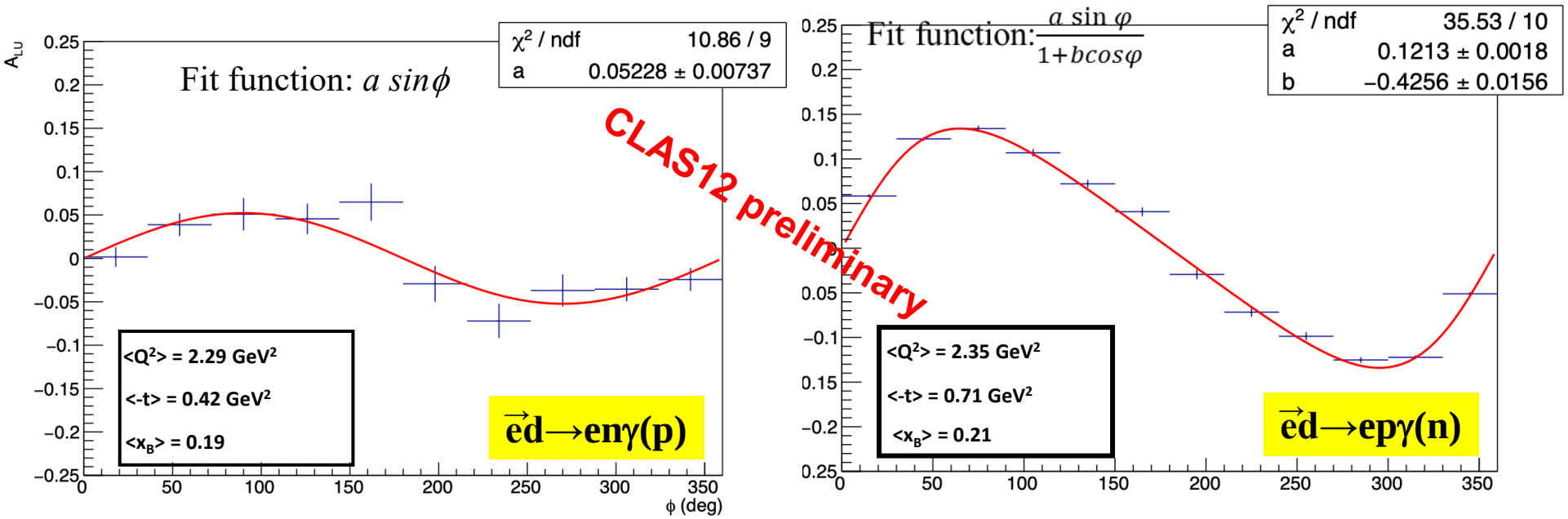


DVCS off the neutron with CLAS12

- **Spring and fall/winter 2019/20**
- **10.6 GeV electron beam, liquid deuterium target**

***ed*→ *e(p)nγ* Fully exclusive final state:**
CLAS12+Forward Tagger+Central Neutron Detector

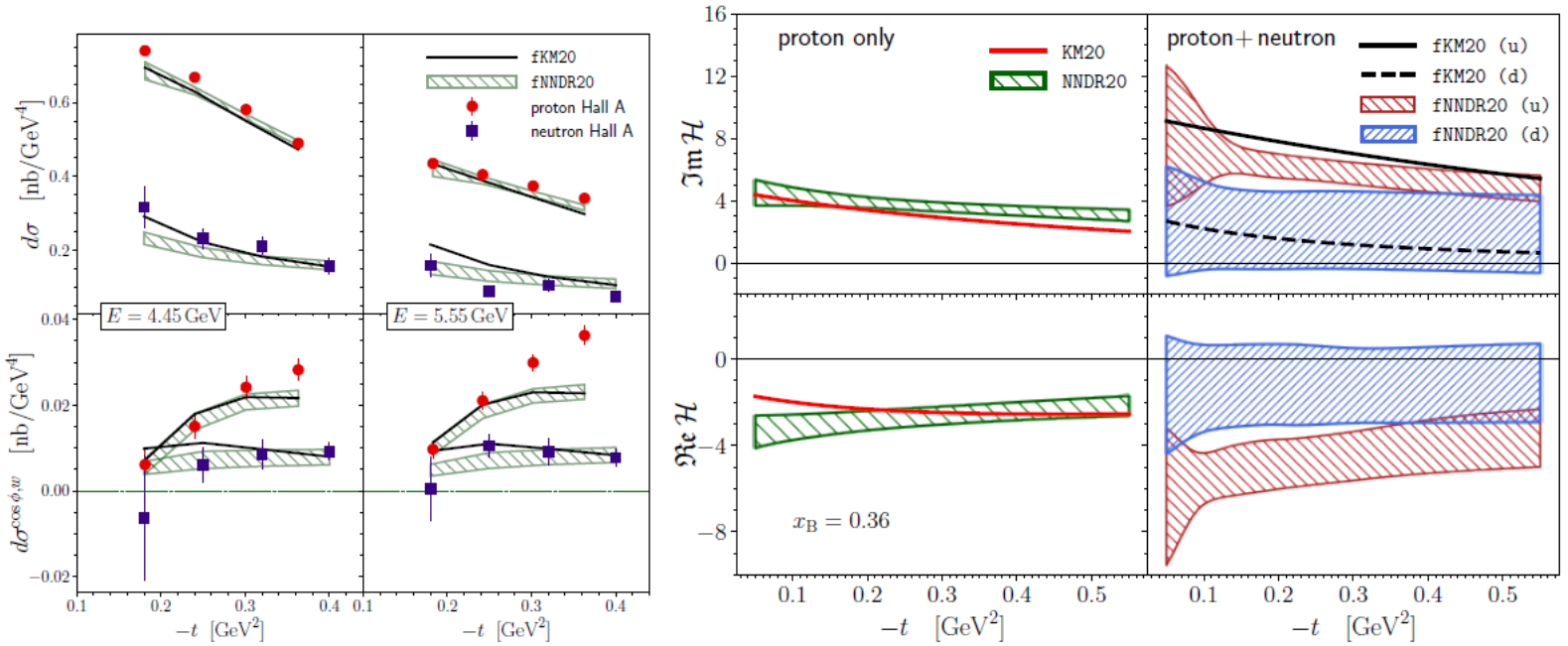
Beam spin asymmetry: the most sensitive observable to the GPD E → Quarks' angular momentum



Work by A. Hobart (IJCLab) – Spring19 data, raw asymmetries, no π^0 subtraction yet

Adding neural nets to the mix …

Update on progress (Task 3)



Clean separation of up and down valence quark distributions using both proton and neutron DVCS data from JLab [M. Čuić et al., 2007.00029]

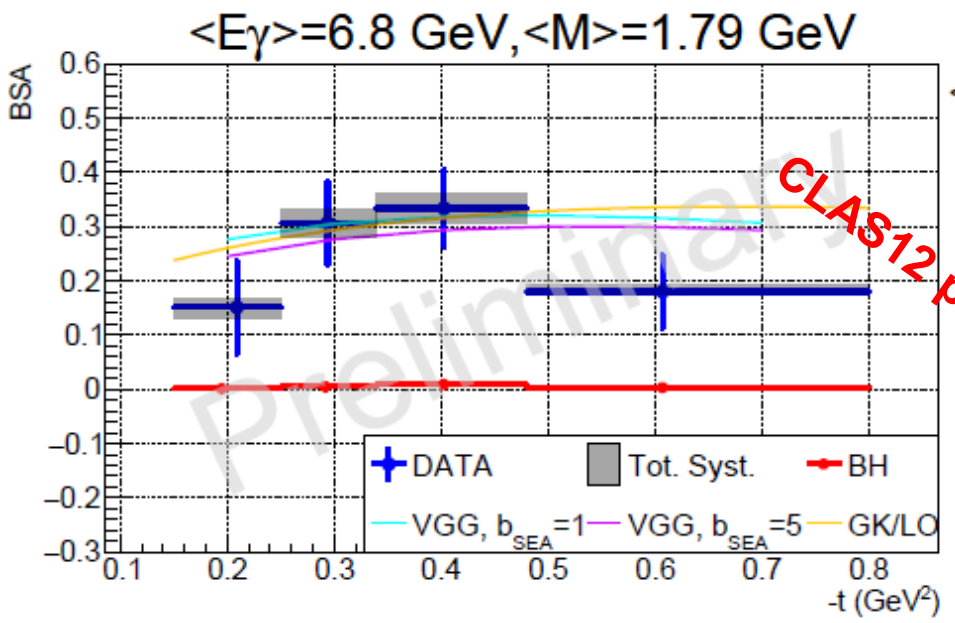
Timelike Compton Scattering with CLAS12

- 1st CLAS12 experiment: spring and fall 2018
- 10.6 GeV electron beam, lyquid hydrogen target

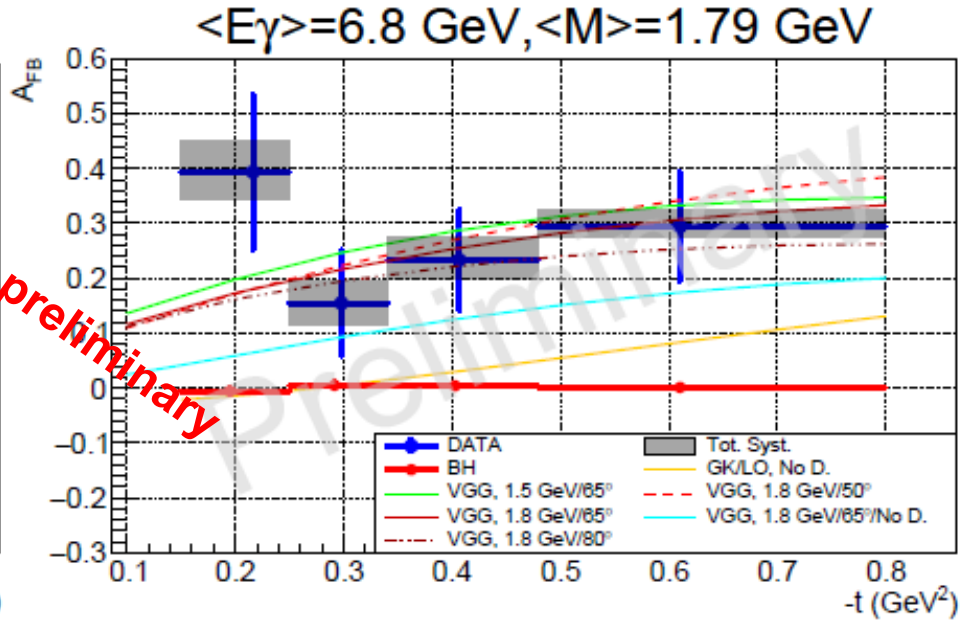
Timelike Compton Scattering: $\gamma p \rightarrow \gamma^* p' \rightarrow e^+e^- p'$

- Time-reversal conjugate reaction of DVCS
- Gives access to real part of CFFs (→GPDs)
- Test of the universality of GPDs

Beam-spin asymmetry (~ Im$\mathcal{H}$)



Forward-backward asymmetry (~ Re$\mathcal{H}$)



CLAS12 preliminary

Work by Pierre Chatagnon (IJCLab) – PRL in preparation

Exclusive processes studied at COMPASS (task 2 update)

Preliminary analyses of the DVCS data taken in 2016-17 already presented last year

Since this time:

Many progres in the data analysis and in the MC chain

- ✓ deep improvement of calibrations of the 3 Electromagnetic Calorimeters,
- ✓ deep improvement of calibrations of the Recoil Proton Detectors
- ✓ determination of 2D efficiencies of the muon trigger hodoscopes,
- ✓ determination of 2D efficiencies of all the trackers

Publiction of paper in PLB:

Measurement of the cross section for hard exclusive π^0 leptoproduction PLB 805 (2020) 135454

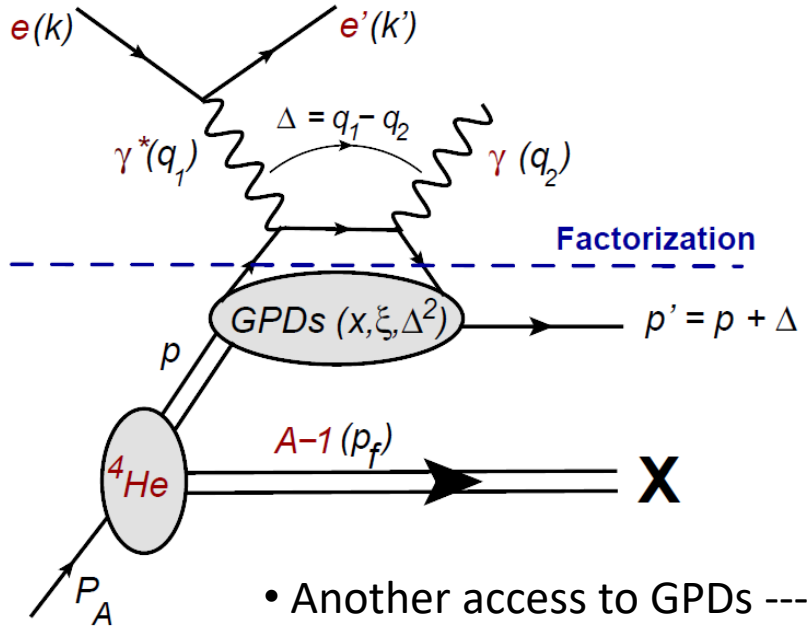
Submission of paper to EPJC:

Spin Density Matrix Elements in Exclusive ω Meson Muoproduction hep-ex/2009.03271

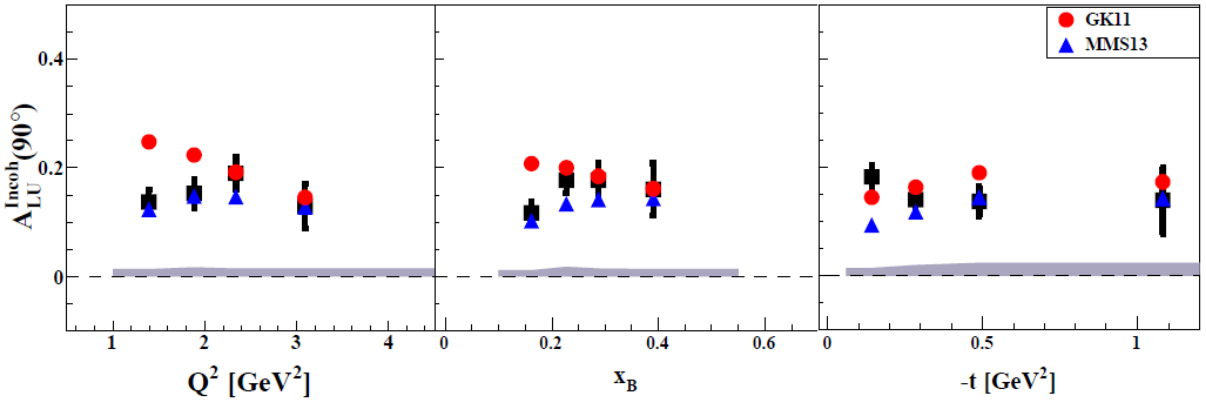
Many other relevant processes studied

- **Diffractive two-meson electroproduction** with a nucleon and deuteron target, W. Cosyn (Florida Intl. U. and Gent U.), B. Pire (Ecole Polytechnique, CPHT), L. Szymanowski (NCBJ, Warsaw), e-Print: 2007.01923 Published in: Phys.Rev.D 102 (2020) 5, 054003.
- **Electroproduction of a large invariant mass photon pair**, A. Pedrak (NCBJ, Warsaw), B. Pire (Ecole Polytechnique, CPHT), L. Szymanowski (NCBJ, Warsaw), J. Wagner (NCBJ, Warsaw), e-Print: 2003.03263, Published in: Phys.Rev.D 101 (2020) 11, 114027.
- **Diffractive deeply virtual Compton scattering**, Bernard Pire (Ecole Polytechnique, CPHT), Lech Szymanowski (NCBJ, Warsaw), Samuel Wallon (Orsay, LPT), e-Print: 1912.10353, Published in: Phys.Rev.D 101 (2020) 7, 074005
- Data-driven study of **timelike Compton scattering**, O. Grocholski (Warsaw U.), H. Moutarde (IRFU, Saclay), B. Pire (Ecole Polytechnique, CPHT), P. Sznajder (NCBJ, Warsaw), J. Wagner (NCBJ, Warsaw), e-Print: 1912.09853, Published in: Eur.Phys.J.C 80 (2020) 2, 171.
- **Backward-angle Exclusive π^0 Production** above the Resonance Region, W.B. Li, G.M. Huber, J.R. Stevens, K. Semenov-Tian-Shansky, L. Szymanowski, B. Pire et al., e-Print: 2008.10768

Incoherent DVCS off ^{4}He



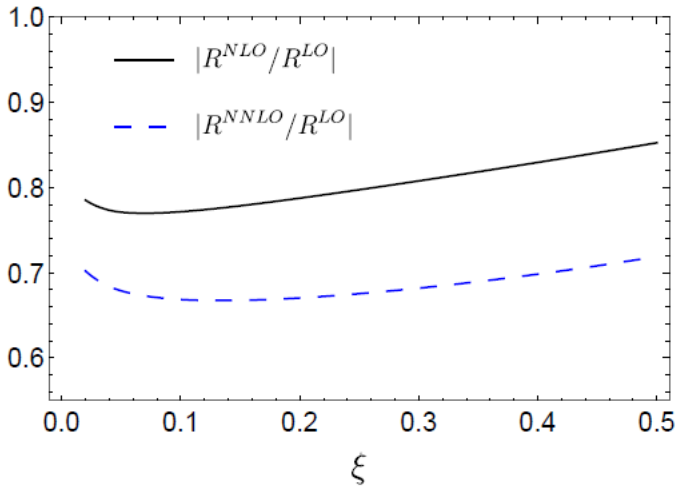
S. Fucini et al., 2008.11437

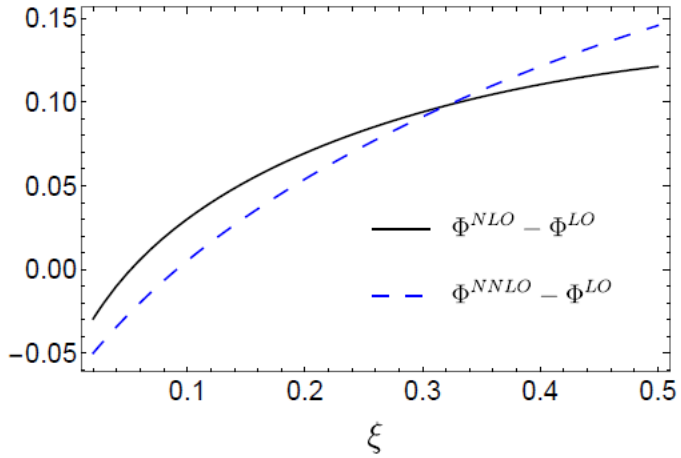


- Another access to GPDs --- of the **bound** proton
- Theory developed and confronted with recent data from JLab
- Perspectives for EIC
- The cross sections for coherent DVCS off ^{4}He calculated by the INFN-Perugia are being used to develop an event generator for JLab12 and EIC

Advances on the theoretical side

• Vector contributions to two loop coefficient functions for DVCS calculated (V. M. Braun et al., arXiv:2007.06348, published in JHEP)





• Double parton distributions in the pion in the Nambu–Jona-Lasinio model, A. Courtoy, S. Noguera, S. Scopetta, arXiv: 1909.09530, published in JHEP

Deliverables and milestones

LIST OF DELIVERABLES (TABLE 3.1c)

Deliverable number	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
WPno.1	Publication of JLab@12GeV results	23	IPN Orsay	R	PU	36
WPno.2	Publication of COMPASS results	23	CEA-Saclay	R	PU	48
WPno.3	Public software serving GPD fit results	23	Uni Zagreb	OTHER	PU	46

- There are **no deliverables or milestones due** for Reporting Period 1

Milestones

LIST OF MILESTONES (TABLE 3.2a)

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
WPGPD.1	Completion of JLab Hall-A DVCS, and Hall-B TCS and nDVCS analyses		12/24/36	Arxiv publication/ Conference presentation and/or analysis note
WPGPD.2	Publication of COMPASS t dependence for DVCS and π^0 cross sections		24	Published paper
WPGPD.3	Construction of the ALERT, NPS, and FT-hodoscope electronics		24/48	TDR/prototype (DEM)
WPGPD.4	Lattice moments of GPDs and global GPD fits		28	Presented at conference or published paper
WPGPD.5	Models for several classes of GPDs and published study of GPD-related observables	QCDSoft	36	Published papers

Status

- Most of the funding (66%) went for hiring **postdocs** (we hired 3 – CNRS, CEA, INFN; and they are doing excellent work)
- Rest of the funding (33%) is for **travel** – severely restricted due to the COVID-19 pandemic
- Deliverables seem not to be in danger

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