Positron Beams for Nuclear Femtography

e^+ @ JLab 12 GeV

A. Afanasev, J. Arrington, M. Battaglieri, J.C. Bernauer, V. Bertone, P. Blunden, M. Bondì, A. Camsonne, A. Celentano, E. Cline, L. Darmé, M. De Napoli, H. Dutrieux, L. Elouadrhiri, J. Erler, S. Fucini, Y. Furletova, F.-X. Girod, J. Grames, G.N. Grauvogel, M. Hattawy, D. Hinginbotham, C. Hyde, A. Ilyichev, G. Krnjaic, T. Kutz, Q. Liu, S. Mantry, L. Marsicano, M. Mazouz, W. Melnitchouk, C. Muñoz Camacho, H. Moutarde, E. Nardi, S. Niccolai, J. Owens, B. Pasquini, A.J.R. Puckett, M. Raggi, M. Rinaldi, A. Schmidt, S. Scopetta, H. Spiesberger, P. Sznajder, P. Valente, M. Vanderhaeghen, E. Voutier[1], M. Yurov, S. Zhao, Z.W. Zhao, X. Zheng + …

and the JLab Positron Working Group

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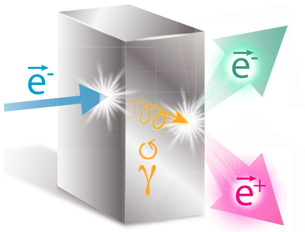
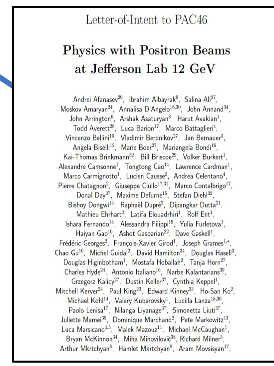
CNRS/IN2P3, Laboratoire de Physique des 2 Infinis Irène Joliot-Curie (IJCLab)
Orsay, France



The PWG was created in 2017 after JPos17 (International Workshop on Physics with Positrons at Jefferson Lab) to promote the physics case of positron beams at JLab. It now gathers about 250 physicists from 70 institutions supporting an ambitious experimental program.

2017

2018



2020

2021…

Topical EPJ A Issue about e⁺@JLab
e⁺ proposals to PAC49

The Letter-of-Intent to PAC46 was followed in FY20 by the e⁺@JLab White Paper (arXiv:2007.15081), and two DVCS proposals to PAC48 (*conditionally approved - C2*).

More proposals to come…

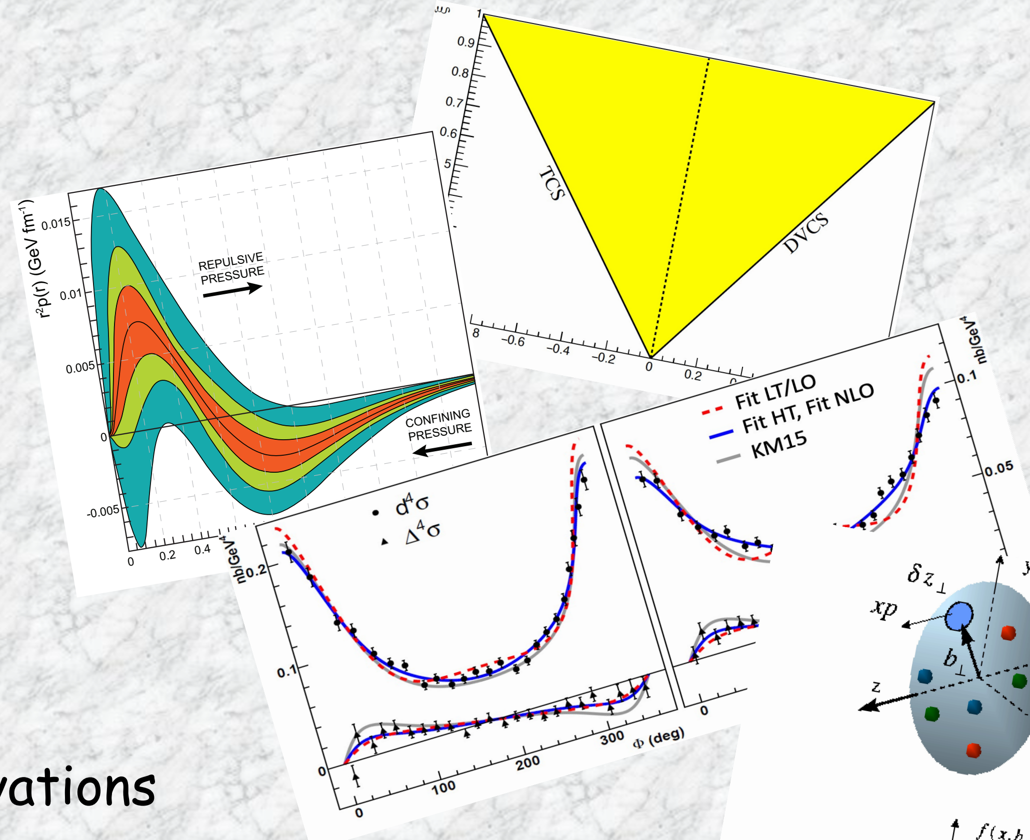
An extended e^+@JLab White Paper constitutes the EPJ A Topical Issue about e+@JLab. It will gather 20 contributions illustrating the benefit of positrons for different physics cases:

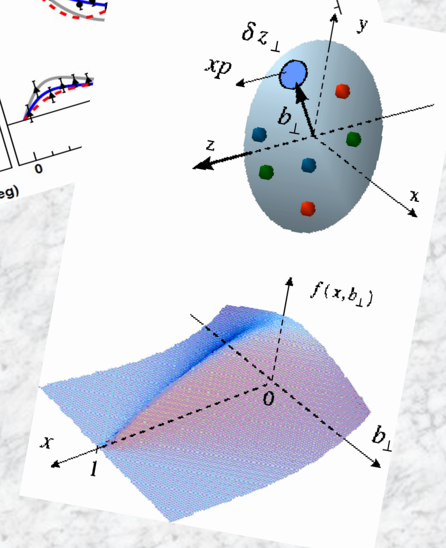
- • Positron beam and physics at Jefferson Lab, 2007.15081
- ❖ Proton charge radius, 2102.11449
- ❖ TPE in cross-section ratio, EPJ A 57 (2021) 144
- • TPE at low ε, 2103.06301
- • TPE in Super-Rosenbluth measurements, 210303752
- ❖ TPE in polarization transfer, EPJ A 57 (2021) 188
- ❖ TPE in target-normal spin asymmetries, 2103.05205
- • TPE in nuclear elastic scattering, 2104.11779
- • Radiative corrections in elastic scattering
- • Generalized polarizabilities of the nucleon, 2106.05683
- • DIS with positron beams
- • p-DVCS cross section, 2105.06540
- ❖ p-DVCS charge asymmetry, EPJ A 57 (2021) 186
- • n-DVCS charge asymmetry, 2104.09158
- • p-DDVCS cross sections and asymmetries, 2103.12773
- • DVCS on the nucleus, 2105.00435
- • Extraction of GPDs from experimental data, 2105.09245
- ❖ Dark photon search, 2105.04540
- ❖ Electroweak couplings, EPJ A 57 (2021) 173
- • Charged lepton flavor violation, JLAB-PHY-21-3419

- • *Submitted*
- ❖ *Approved*

Contributions are currently peer reviewed.

Publication is in progress and should be completed by september.





(i) Positron beam motivations

(ii) Deeply virtual Compton scattering

(iii) Double deeply virtual Compton scattering

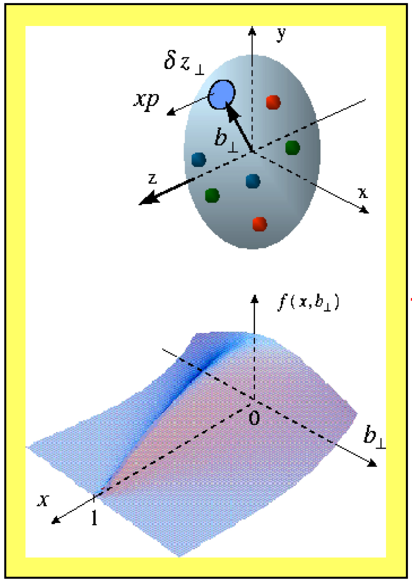
(iv) Impact of positron beam measurements

This project has received funding from the European Union's Horizon 2020 research and innovation program under agreement No 824093.

Parton Imaging

D. Müller, D. Robaschik, B. Geyer, F.M. Dittes, J. Horejsi, FP 42 (1994) 101 X. Ji, PRD 55 (1997) 7114 A. Radyushkin, PRD 56 (1997) 5524

- GPDs parameterize the partonic structure of hadrons and offer the unprecedented possibility to access the spatial distribution of partons.



M. Burkardt, PRD 62 (2000) 071503 M.Diehl, EPJC 25 (2002) 223

GPDs encode the correlations between partons and contain information about the dynamics of the system like the angular momentum or the distribution of the strong forces experienced by quarks and gluons inside hadrons.

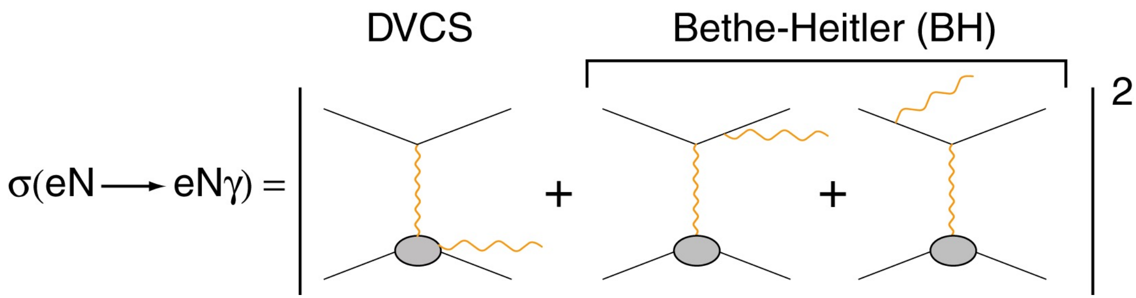
X. Ji, PRL 78 (1997) 610 M. Polyakov, PL B555 (2003) 57

A new light on hadron structure

GPDs can be interpreted as a distribution in the transverse plane of partons carrying some fraction of the longitudinal momentum of the nucleon.

N(e,e'γN) Differential Cross Section

M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009



$$\sigma^{e}_{P0} = \sigma_{BH} + \sigma_{DVCS} + P_l\,\widetilde{\sigma}_{DVCS} + e_l\left(\sigma_{INT} + P_l\,\widetilde{\sigma}_{INT}\right)$$

Electron observables

$$\sigma^{-}_{00} = \sigma_{BH} + \sigma_{DVCS} - \sigma_{INT}$$

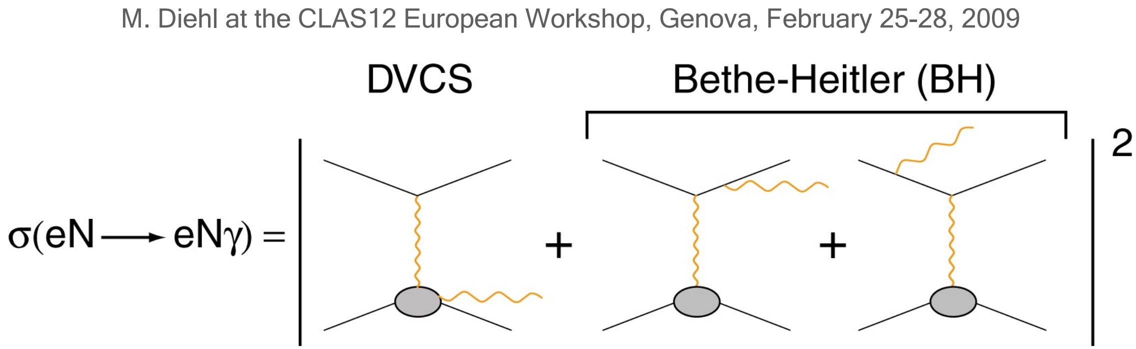
$$\sigma^{-}_{+0} - \sigma^{-}_{-0} = 2\,\widetilde{\sigma}_{DVCS} - 2\,\widetilde{\sigma}_{INT}$$

Electron & positron observables

$$\sigma^{+}_{00} - \sigma^{-}_{00} = 2\,\sigma_{INT}$$

$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\widetilde{\sigma}_{INT}$$

$\mathcal{N}(e,e'\gamma\mathcal{N})$ Differential Cross Section



$$\sigma^{e}_{PS} = \sigma^{e}_{P0} + S\left[P_l\, \Delta\sigma_{BH} + \left(\Delta\widetilde{\sigma}_{DVCS} + P_l\, \Delta\sigma_{DVCS}\right) + e_l\left(\Delta\widetilde{\sigma}_{INT} + P_l\, \Delta\sigma_{INT}\right)\right]$$

Electron observables

$$\sigma^{-}_{00} = \sigma_{BH} + \sigma_{DVCS} - \sigma_{INT}$$

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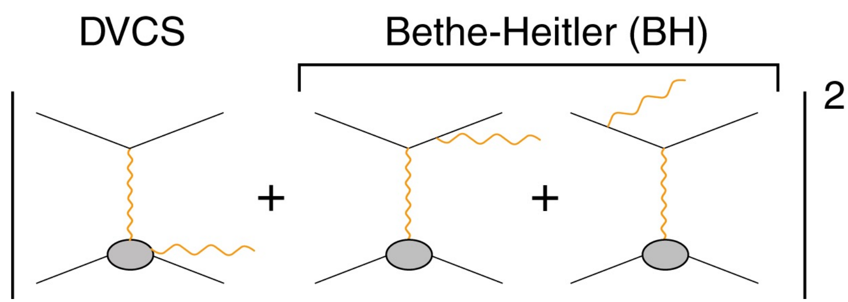
N(e,e'γN) Differential Cross Section

M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009

$$\sigma(eN \longrightarrow eN\gamma) =$$



$$\sigma^{e}_{PS} = \sigma^{e}_{P0} + S\left[P_l\,\Delta\sigma_{BH} + \left(\Delta\widetilde{\sigma}_{DVCS} + P_l\,\Delta\sigma_{DVCS}\right) + e_l\left(\Delta\widetilde{\sigma}_{INT} + P_l\,\Delta\sigma_{INT}\right)\right]$$

Additional observables

$$\sigma^{\pm}_{0+} - \sigma^{\pm}_{0-} = 2\Delta\widetilde{\sigma}_{DVCS} \pm 2\Delta\widetilde{\sigma}_{INT}$$

$$\left[\sigma^{\pm}_{++} - \sigma^{\pm}_{+-}\right] - \left[\sigma^{\pm}_{-+} - \sigma^{\pm}_{--}\right] = 4\,\Delta\sigma_{BH} + 4\,\Delta\sigma_{DVCS} \pm 4\,\Delta\sigma_{INT}$$

Electron observables

$$\sigma^{-}_{00} = \sigma_{BH} + \sigma_{DVCS} - \sigma_{INT}$$

$$\sigma^{-}_{+0} - \sigma^{-}_{-0} = 2\,\widetilde{\sigma}_{DVCS} - 2\,\widetilde{\sigma}_{INT}$$

Electron & positron observables

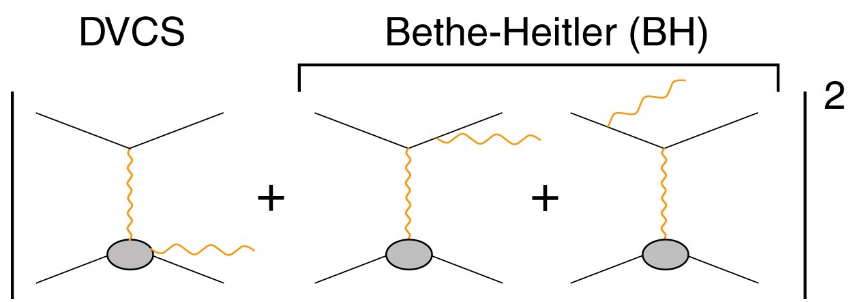
$$\sigma^{+}_{00} - \sigma^{-}_{00} = 2\,\sigma_{INT}$$

$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\widetilde{\sigma}_{INT}$$

N(e,e'γN) Differential Cross Section

M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009

$\sigma(eN \longrightarrow eN\gamma) =$



$$\sigma^e_{PS} = \sigma^e_{P0} + S\left[P_l\, \Delta\sigma_{BH} + \left(\Delta\tilde{\sigma}_{DVCS} + P_l\, \Delta\sigma_{DVCS}\right) + e_l\left(\Delta\tilde{\sigma}_{INT} + P_l\, \Delta\sigma_{INT}\right)\right]$$

Additional observables

$$\sigma^{\pm}_{0+} - \sigma^{\pm}_{0-} = 2\Delta\tilde{\sigma}_{DVCS} \pm 2\Delta\tilde{\sigma}_{INT}$$

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Electron & positron observables

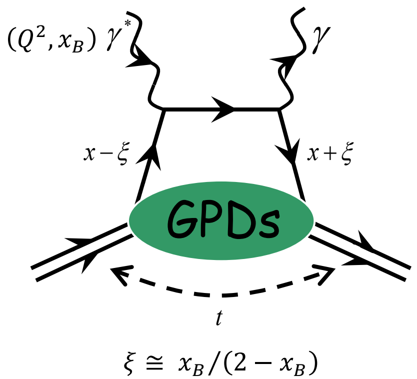
$$\sigma^{+}_{00} - \sigma^{-}_{00} = 2\,\sigma_{INT}$$

$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\tilde{\sigma}_{INT}$$

Polarized electrons and positrons allow to separate the unknown amplitudes of the cross section for electro-production of photons.

Compton Form Factors

- GPDs enter the epγ cross section via Compton Form Factors (CFFs) representing an integral over the intermediate quark longitudinal momentum.



$$\sigma \propto \int_{-1}^{+1} dx \frac{\text{GPD}(x,\xi,t)}{x \pm \xi \mp i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \frac{\text{GPD}(x,\xi,t)}{x \pm \xi} \pm i\pi\,\text{GPD}(x=\pm\xi,\xi,t)$$

$\sigma_{INT,DVCS}$ $\tilde{\sigma}_{INT,DVCS}$

- At twist-2 and leading α_{QCD}-order, the epγ reaction accesses the four chiral even and parton helicity conserving GPDs $\{H, \tilde{H}, E, \tilde{E}\}$ of the proton via the CFFs $\{\mathcal{H}, \tilde{\mathcal{H}}, \mathcal{E}, \tilde{\mathcal{E}}\}$.

$$\mathcal{C}^{DVCS} = 4(1-x_B)\left[\mathcal{H}\mathcal{H}^* + \tilde{\mathcal{H}}\tilde{\mathcal{H}}^*\right] - x_B^2\left[\mathcal{H}\mathcal{E}^* + \mathcal{E}\mathcal{H}^* + \tilde{\mathcal{H}}\tilde{\mathcal{E}}^* + \tilde{\mathcal{E}}\tilde{\mathcal{H}}^*\right] - \left(x_B^2 + (2-x_B)^2\frac{t}{4M^2}\right)\mathcal{E}\mathcal{E}^* - x_B^2\frac{t}{4M^2}\tilde{\mathcal{E}}\tilde{\mathcal{E}}^*$$

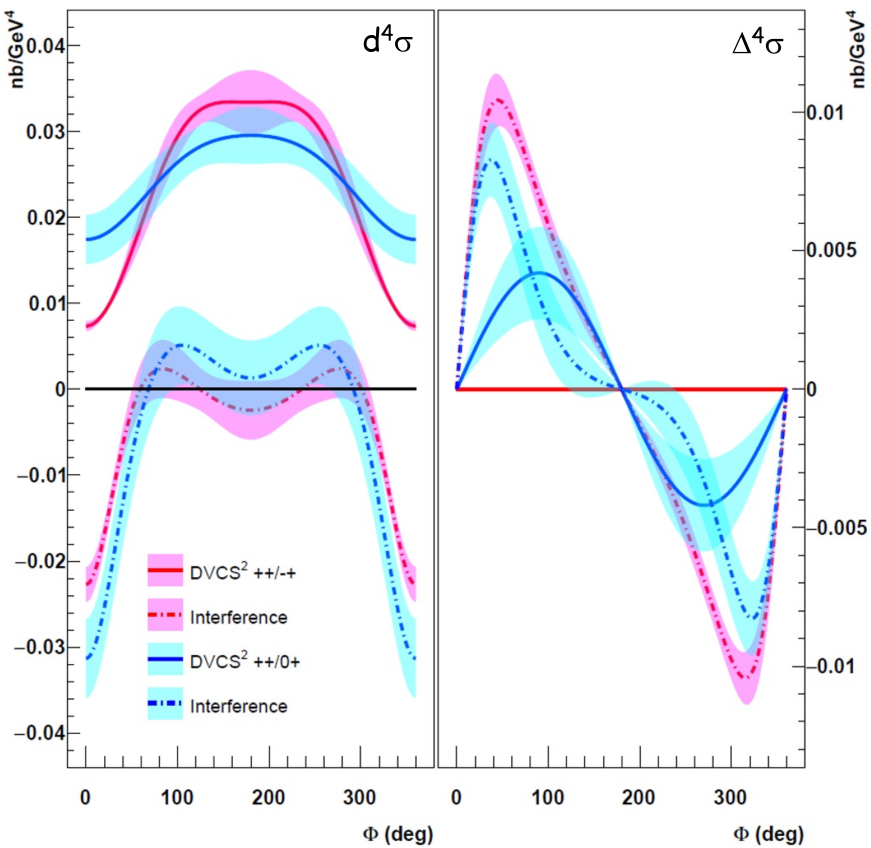
$$\mathcal{C}^{INT} = F_1\mathcal{H} - \xi[F_1 + F_2]\tilde{\mathcal{H}} - \frac{t}{4M^2}\mathcal{E}$$

Importance of the separation of the DVCS and INT reaction amplitudes for the determination of CFFs.

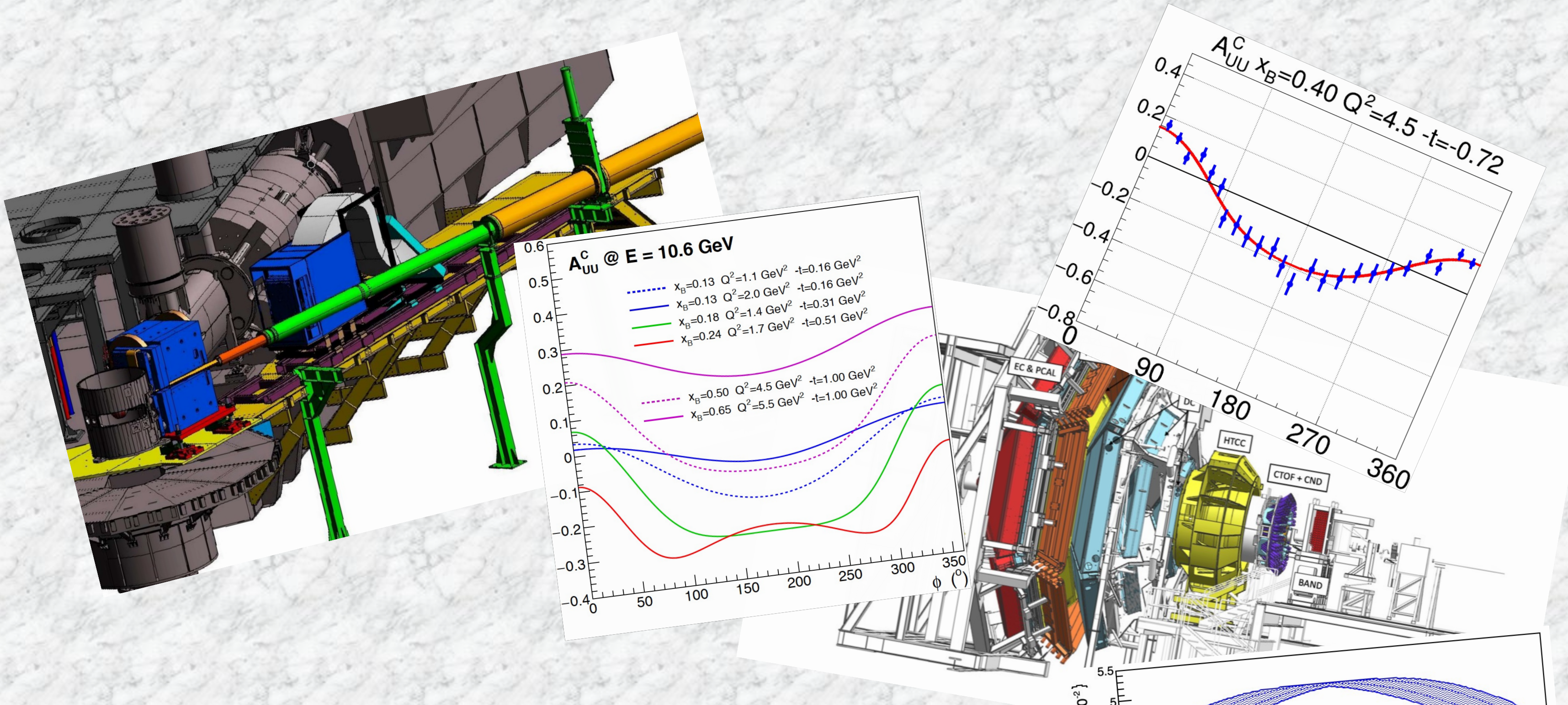
Rosenbluth-Like Separation

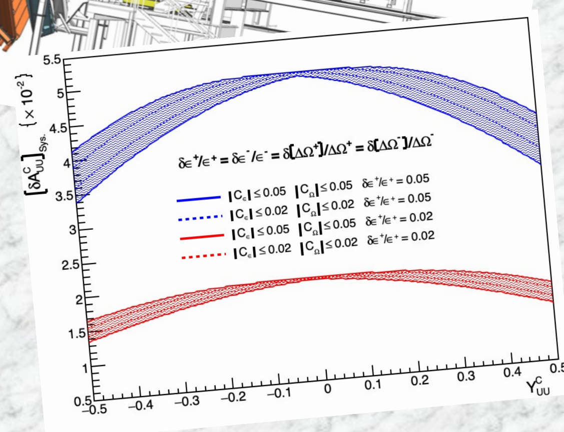
M. Defurne et al. Nat. Com. 8 (2017) 1408

- DVCS and INT contributions can be separated by taking advantage of their different dependence on the beam energy, however at the expense of *some ambiguity*.



- Fitting simultaneously experimental data at different beam energies within a leading-twist and leading-order approach fails.
- A successful fit of experimental data requires **either** single-helicity flip (Higher Twist) or double-helicity flip (Next-to-leading-Order).
- These two scenarios lead however to significantly different DVCS and INT contributions.





(i) Beam charge asymmetries @ CLAS12

(ii) Positron cross sections @ NPS

(iii) Nuclear DVCS

Pr12-20-009

V. Burkert, L. Elouadrhiri, F.-X. Girod, S. Niccolai, E. Voutier et al.

V. Burkert et al. arXiv:2103.12651 (2021)

Beam Charge Asymmetries are proposed to be measured at CLAS12:

- The unpolarized beam charge asymmetry A_{UU}^{C}, which is sensitive to the CFF real part
- The polarized beam charge asymmetry A_{LU}^{C}, which is sensitive to the CFF imaginary part
- The neutral beam spin asymmetry A_{LU}^{0}, which is sensitive to **higher twist effects**

New GPD Observables @ JLab

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

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

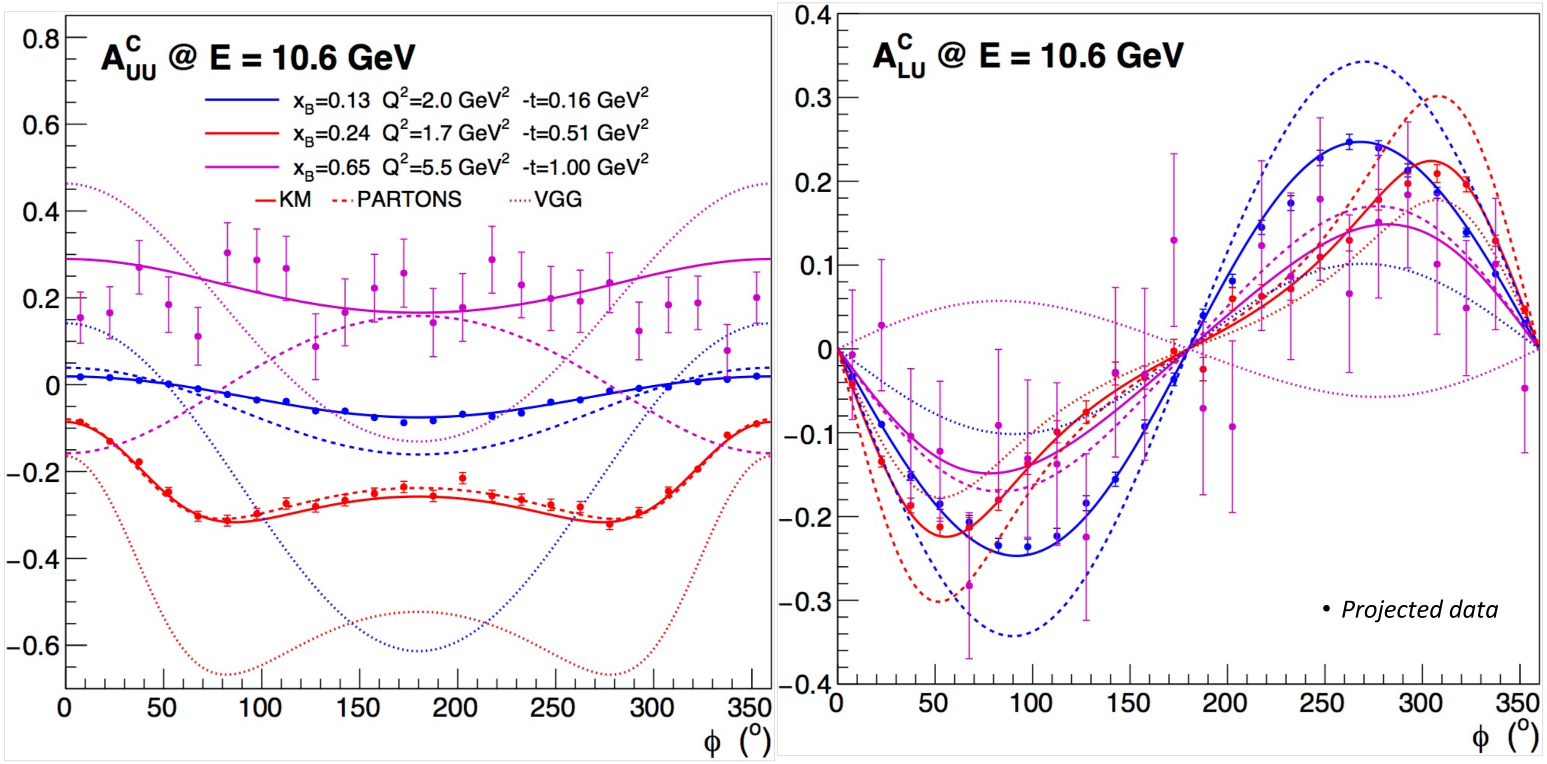
$$A_{LU}^{0} = \frac{(Y_+^+ + Y_+^-) - (Y_-^+ + Y_-^-)}{Y_+^+ + Y_-^+ + Y_+^- + Y_-^-} = \frac{\tilde{\sigma}_{DVCS}}{\sigma_{BH} + \sigma_{DVCS}}$$

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

$Y_{\pm}^{e^{\pm}} = \frac{N_{\pm}^{\pm}}{Q_{\pm}^{\pm}}$ *is the yield normalized the accumulated beam charge.*

Partonic Content Sensitivity

A.V. Belitsky, D. Müller, PRD 82 (2010) 074010
K. Kumerički, D. Müller, NPB 841 (2010) 1   B. Berthou et al. EPJC 78 (2018) 478   M. Vanderhaeghen, P.A.M. Guichon, M. Guidal, PRD 60 (1999) 094017



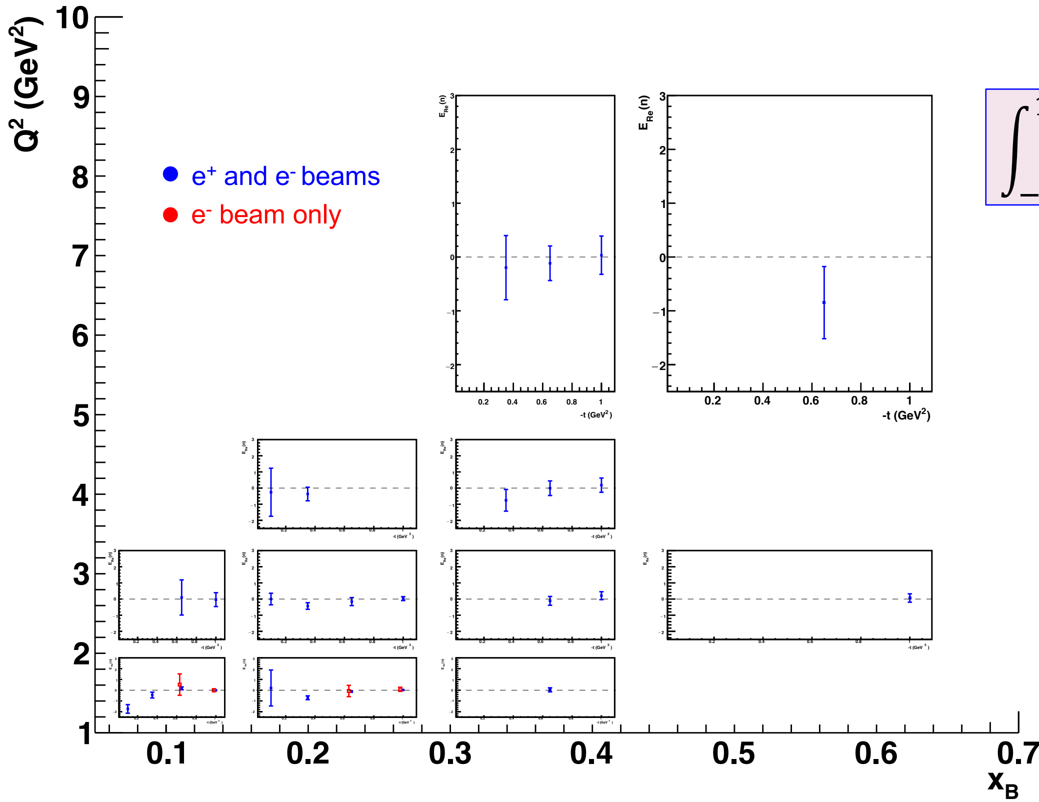
- The **shape** and **magnitude** of BCAs are **sensitive** to the specific **GPD model**.

Eric Voutier
IJCLab Irène Joliot-Curie

LoI12-18-004
Jefferson Lab Positron Working Group

(Jefferson Lab Positron Working Group) A. Afanasev et al. arXiv:1906.09419 (2019)   S. Niccolai et al. arXiv:2104.09158 (2021)

- Contrary to H, the GPD **E flips the spin of the nucleon** and is consequently not constrained by Deep Inelastic Scattering data.



X. Ji, PRL 78 (1997) 610

$$\int_{-1}^{1} x\,[H(x,\xi,t\to 0)+E(x,\xi,t\to 0)]\,dx = J$$

$$A_{UU}^{C} \propto \frac{1}{F_2}\Re\mathrm{e}\left[\xi\widetilde{H}_n - \frac{t}{4M^2}E_n\right]$$

The **BCA** on the neutron accesses the **real part** of the CFF **E**, and is sensitive to $\tilde{H}$ at some kinematics.

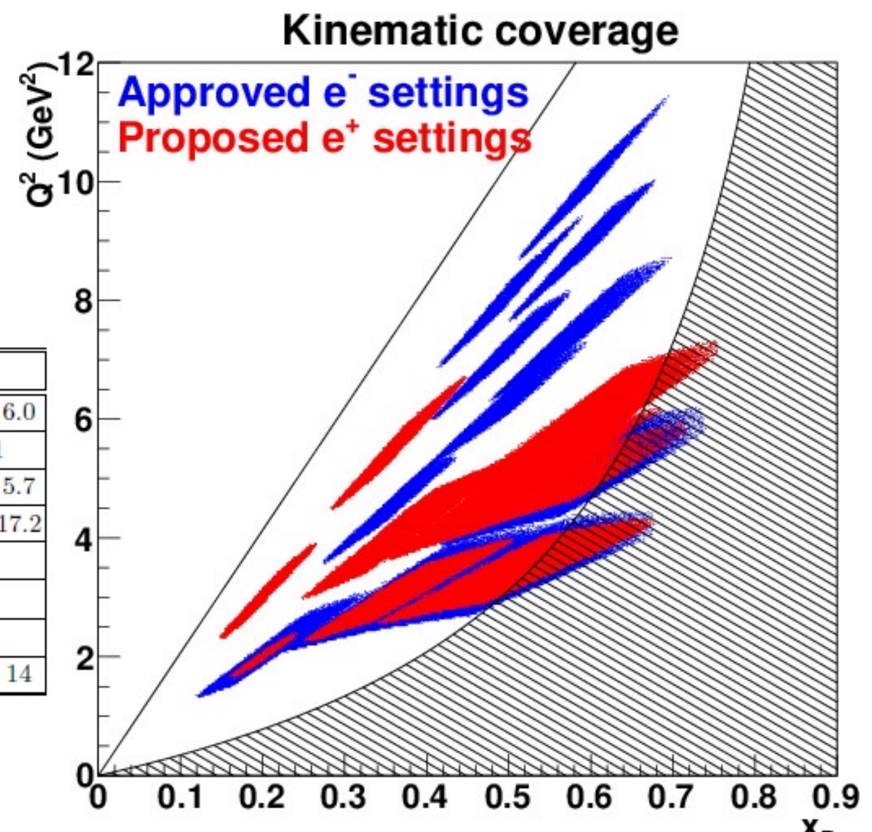
Pr12-20-012

J. Grames, M. Mazouz, C. Muñoz Camacho et al.

➢ Combining the HMS and the NPS spectrometers, precise cross section measurements with unpolarized positron beam will be performed at selected kinematics where electron beam data will soon be accumulated.

Conditionally approved e^+ data corresponds to 25% of the approved e^- statistics.

x_{Bj}	0.2				0.36						0.5			0.6			
Q^2 (GeV)^2	2.0			3.0	3.0			4.0		5.5	3.4		4.8	5.1			6.0
k (GeV)	6.6	8.8	11		6.6	8.8	11	8.8	11		8.8	11		6.6	8.8	11	
k' (GeV)	1.3	3.5	5.7	3.0	2.2	4.4	6.6	2.9	5.1	2.9	5.2	7.4	5.9	2.1	4.3	6.5	5.7
θ_{Calo} (deg)	6.3	9.2	10.6	6.3	11.7	14.7	16.2	10.3	12.4	7.9	20.2	21.7	16.6	13.8	17.8	19.8	17.2
D_{Calo} (m)	6	4		6	3			4	3	4	3						
$\sigma_{M_X^2}$ (GeV^2)	0.17			0.22	0.13		0.12	0.15		0.19	0.09		0.11	0.09			
I_{beam} (μA)	5																
Days	1	1	3	1	2	3	2	3	4	13	4	3	7	7	2	7	14



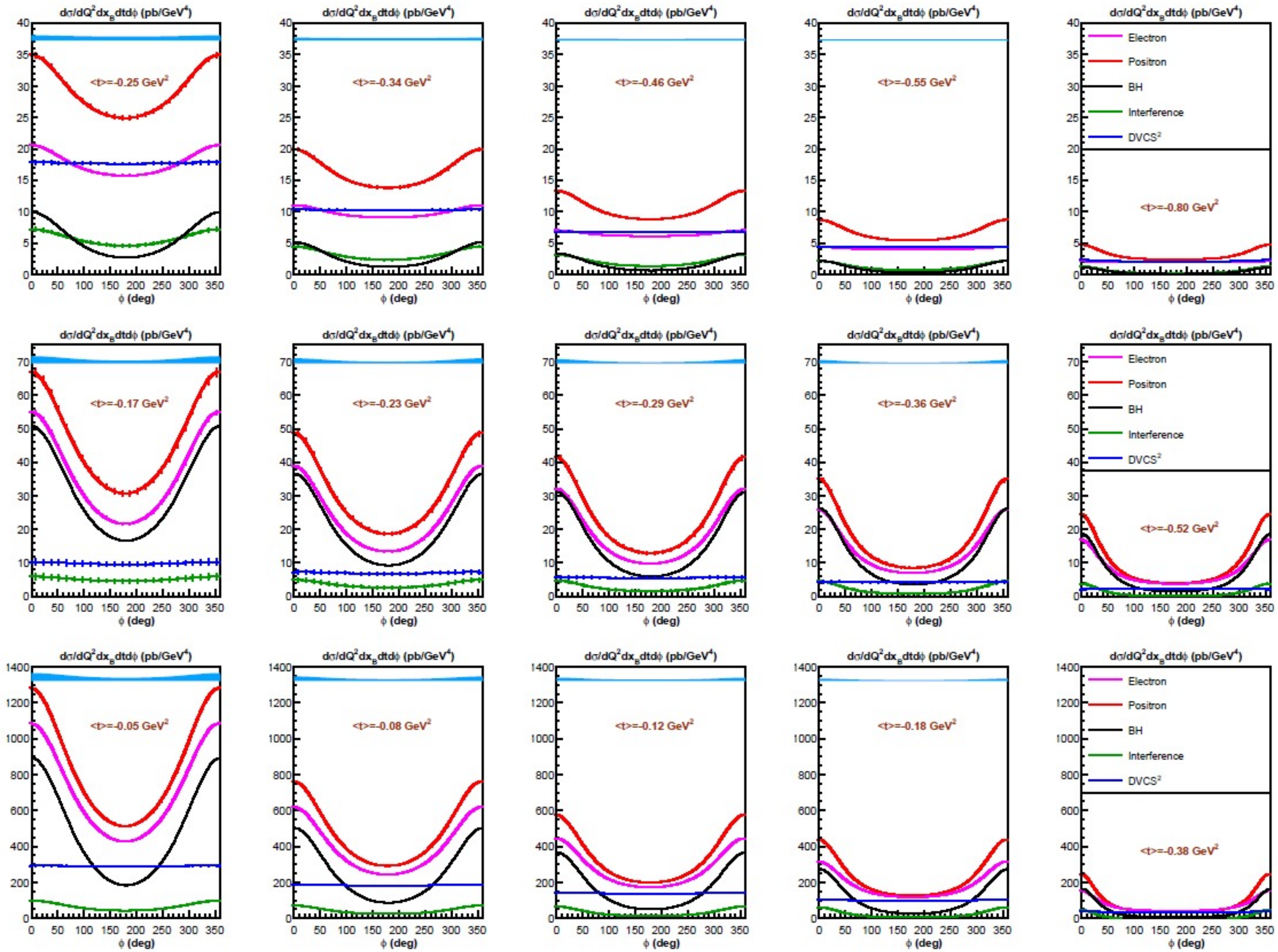
Projected Data

K. Kumerički, D. Müller, NPB 841 (2010) 1   C. Muñoz Camacho et al. to appear in EPJ A

DVCS dominance — $x_B = 0.2$, $Q^2 = 2.0\ GeV^2$

BH dominance — $x_B = 0.3$, $Q^2 = 4.0\ GeV^2$

Shared DVCS and BH — $x_B = 0.5$, $Q^2 = 3.4\ GeV^2$

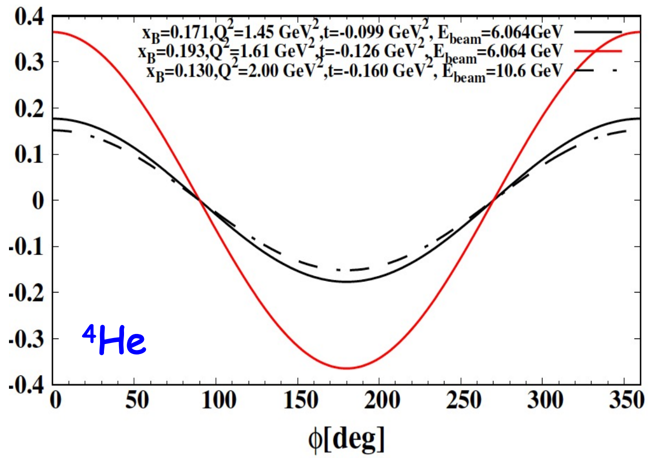


Coherent He-DVCS

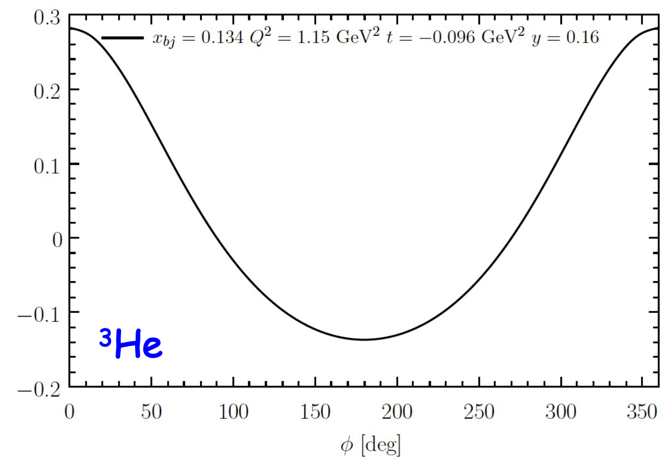
M. Rinaldi, S. Scopetta, PRC 85 (2012) 062201; PRC 87 (2013) 035208   S. Fucini, M. Hattawy, M. Rinaldi, S. Scopetta, arxiv:2105.00435

➢ The association of the ALERT recoil detector and the CLAS12 spectrometer with high-energy electron and positron beams offer a new tool for the investigation of the nuclear force.

$$\Re e[\mathcal{H}_A(\xi,t)] = \mathcal{P}\int_0^1 \left[\frac{1}{\xi+x}+\frac{1}{x-\xi}\right] H_A(x,\xi,t)\,dx = \frac{1}{\pi}\mathcal{P}\int_0^1 \left[\frac{1}{\xi+x}+\frac{1}{x-\xi}\right]\Im m[H_A(x,x,t)]\,dx - \delta(t)$$

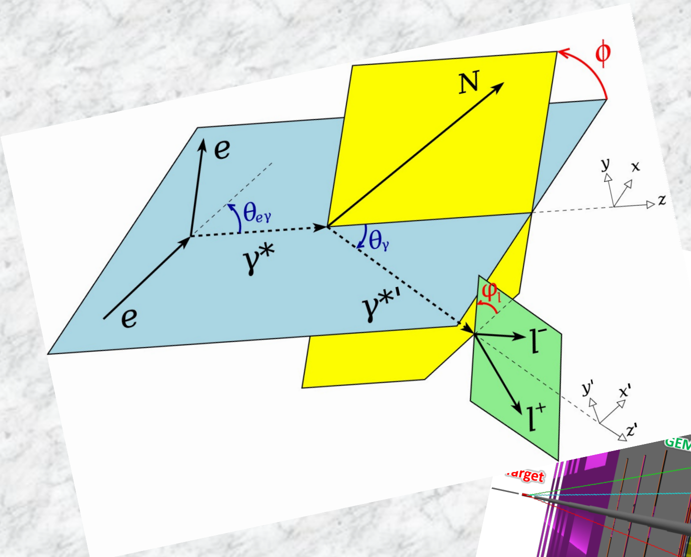


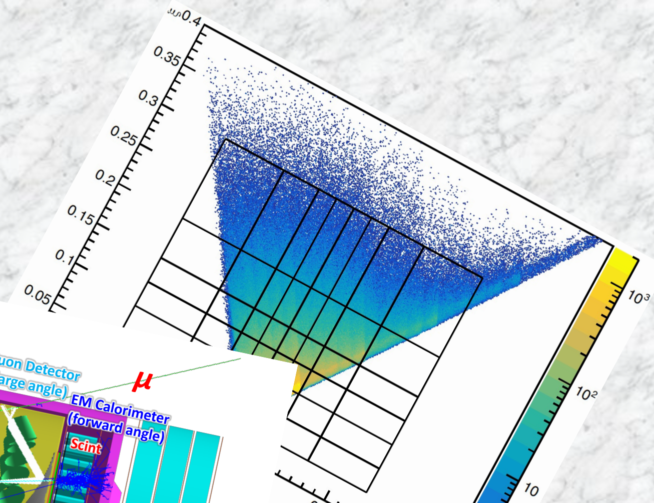
Testing ground of higher twist effects.

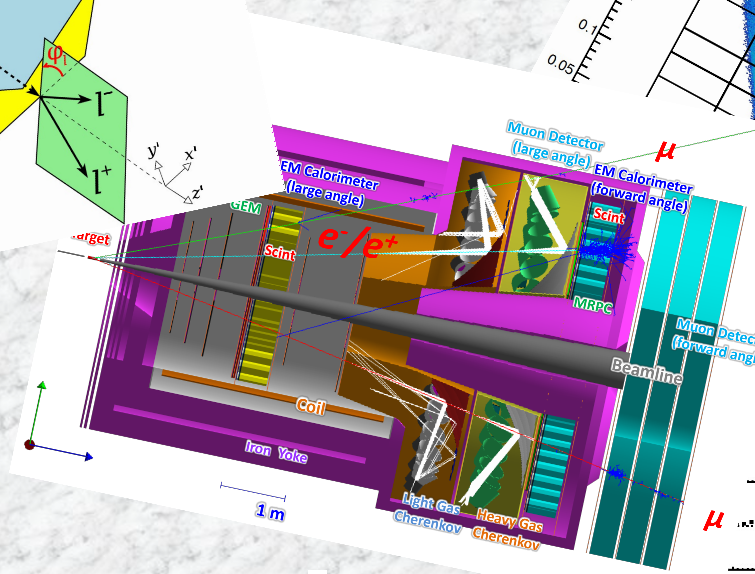


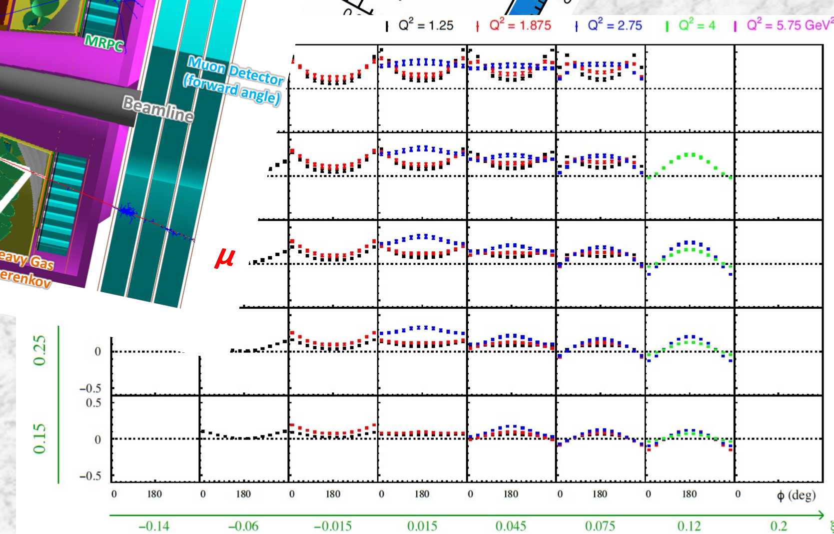
Sensitivity to neutron GPDs.

S. Zhao, Doctorate Thesis, Université Paris-Saclay, 2020UPASS147 (2020)









(i) p-DDVCS @ SoLID

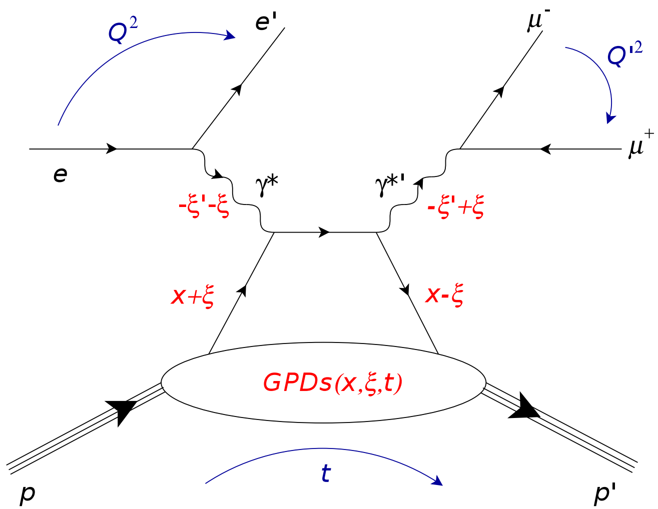
(ii) p-DDVCS @ CLAS12

Off-Diagonal Compton Form Factors

M. Guidal, M. Vanderhaeghen, PRL 90 (2003) 012001   A.V. Belitsky, D. Müller PRL 90 (2003) 022001; PRD 68 (2003) 116005

- Because of the virtuality of the final photon, **DDVCS** allows a direct access to GPDs at $x \neq \pm\xi$, of importance for their modeling and for the investigation of nuclear dynamics through sum rules.

$$\mathcal{F}(\xi',\xi,t) = \mathcal{P}\int_{-1}^{1} dx\, F_{+}(x,\xi,t)\left[\frac{1}{x-\xi'} \pm \frac{1}{x+\xi'}\right] - \mathrm{i}\pi F_{+}(\xi',\xi,t)$$



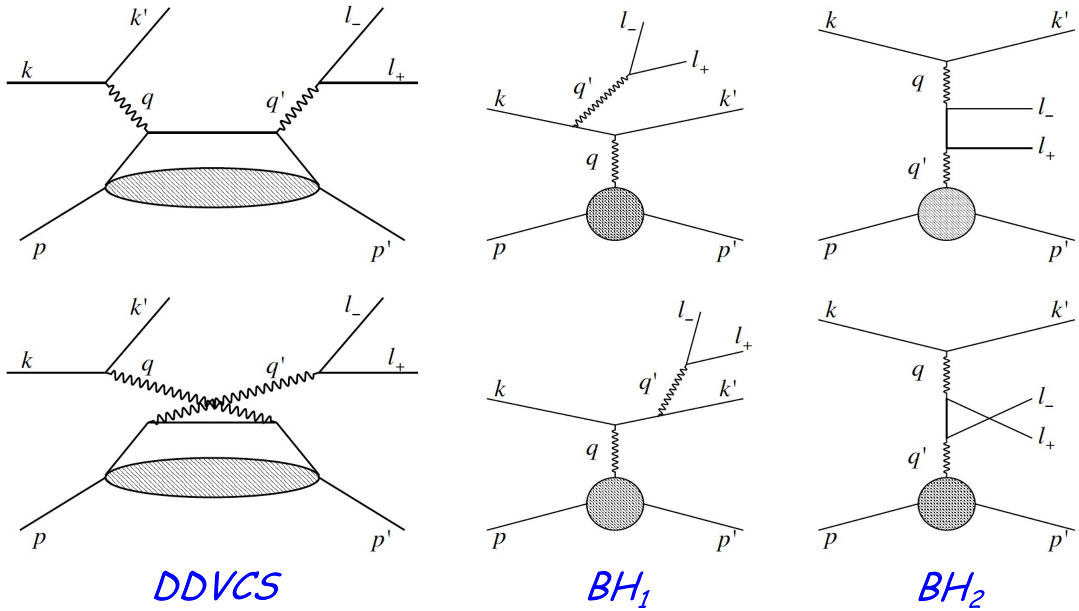
$$F_{+}(x,\xi,t) = \sum_{q}\left(\frac{e_q}{e}\right)^2 \left[F^q(x,\xi,t) \mp F^q(-x,\xi,t)\right]$$

$$\xi' = \frac{Q^2 - Q'^2 + t/2}{2Q^2/x_B - Q^2 - Q'^2 + t} \qquad \xi = \frac{Q^2 + Q'^2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$

- Following the sign change of ξ' around Q^2=Q^2, the CFF $\mathcal{H}$ and $\mathcal{E}$ are also **changing sign**, which provides a testing ground of **GPD universality**.

N(e,e'l⁺l⁻N) Differential Cross Section

- The lepto-production of a lepton-pair off the nucleon involves one **additional Bethe-Heitler** like mechanism. Integrating over the lepton-pair angles provides a beam charge and polarization dependence similar to DVCS.



$$d^7\sigma_P^e = d^7\sigma_{BH_1} + d^7\sigma_{BH_2} + d^7\sigma_{DDVCS} + P\, d^7\tilde{\sigma}_{DDVCS} - e\left[d^7\sigma_{BH_{12}} + d^7\sigma_{INT_1} + P\, d^7\tilde{\sigma}_{INT_1}\right] + d^7\sigma_{INT_2} + P\, d^7\tilde{\sigma}_{INT_2}$$

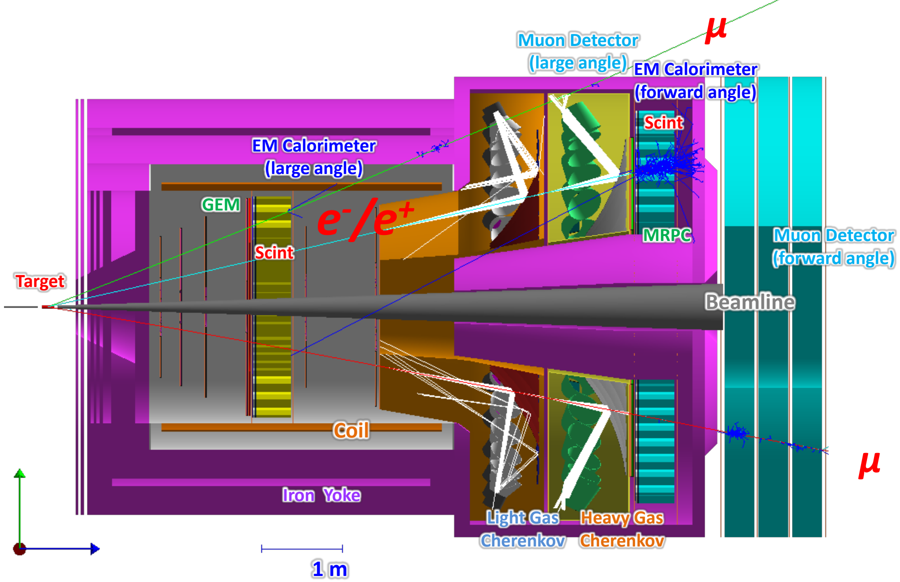
Integration over lepton pair angles

$$d^5\sigma_P^e = d^5\sigma_{BH_1} + d^5\sigma_{BH_2} + d^5\sigma_{DDVCS} + P\, d^5\tilde{\sigma}_{DDVCS} - e\left[d^5\sigma_{INT_1} + P\, d^5\tilde{\sigma}_{INT_1}\right]$$

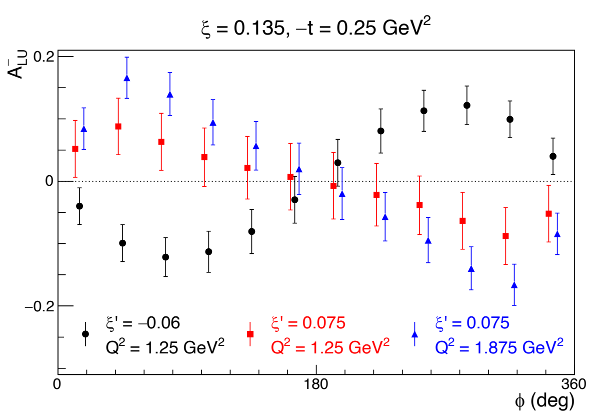
LoI12-15-005

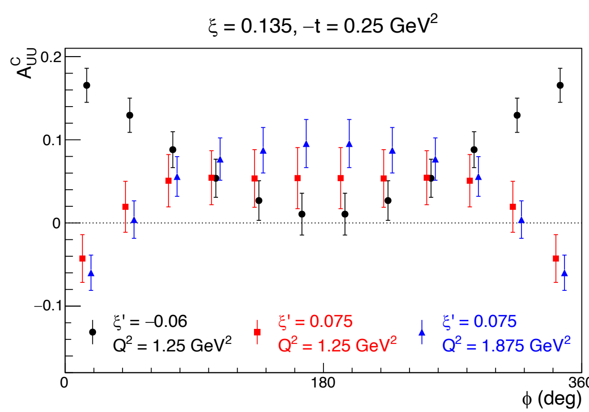
M. Boer, A. Camsonne, K. Gnanvo, E. Voutier, Z. Zhao et al.

S. Zhao et al. arXiv:2103.12773 (2021)

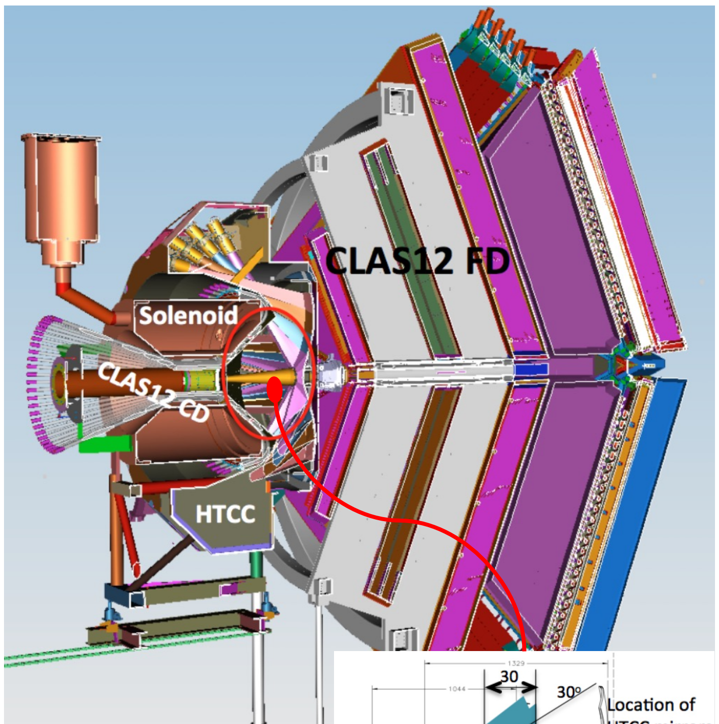


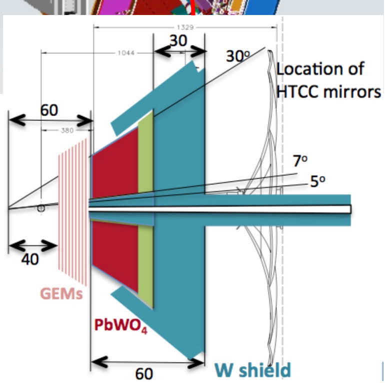
- The **SoLID** apparatus completed with **muon detectors** at large and forward angles, would allow DDVCS measurements with both polarized electron and polarized positron beams.
- The initial LoI discussed **electron BSA** measurements over a 50 days run parasitic to the J/Ψ approved experiment.
- Completing this program with a 50 days positron beam run would provide **unpolarized BCA** data.



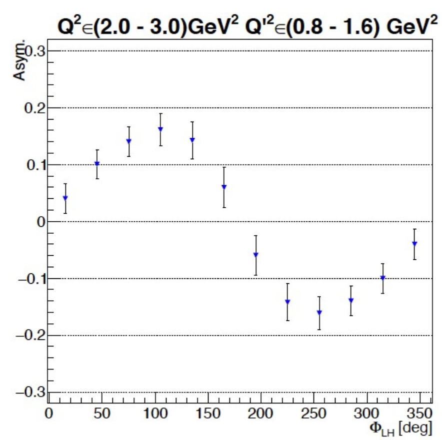


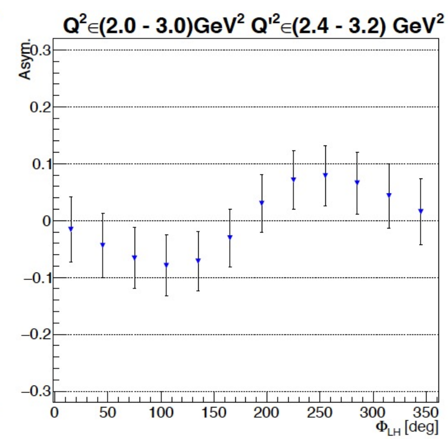
LoI12-16-004
S. Stepanyan et al.

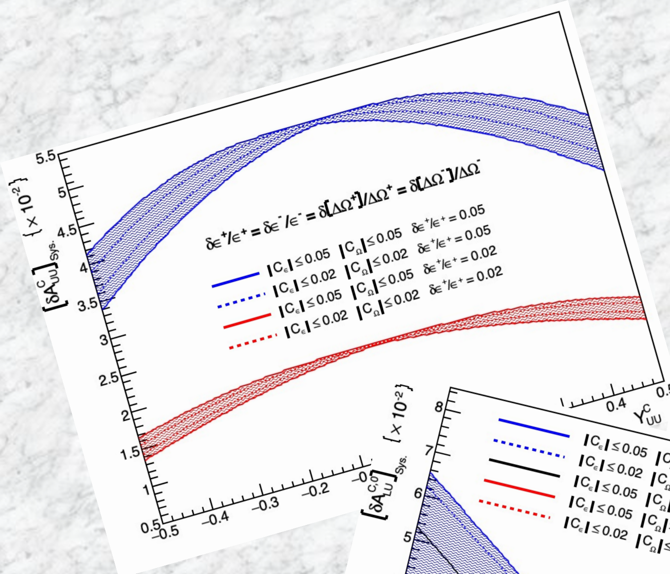


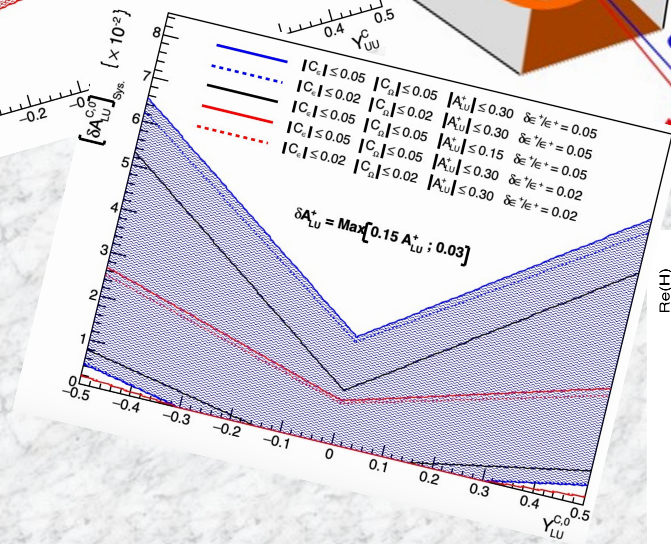


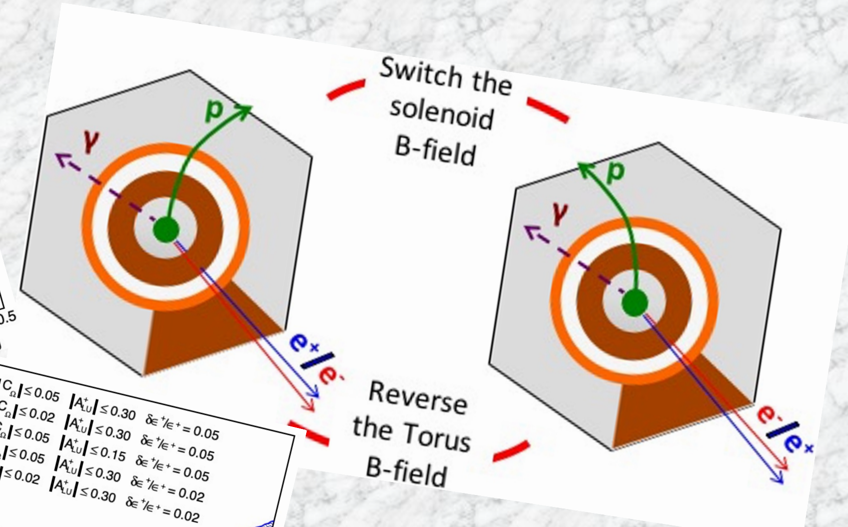
- A modified CLAS12 spectrometer with a new tracker, a new calorimeter and a tungsten shield in the HTCC working volume would allow to increase CLAS12 luminosity up to $10^{37}cm^{-2}\cdot s^{-1}$.
- The new detection system will serve electron identification.
- The CLAS12 forward detector will act as a muon detector.
- This reconfigured CLAS12 spectrometer would measure DDVCS and J/Ψ electroproduction over a 100 days run.

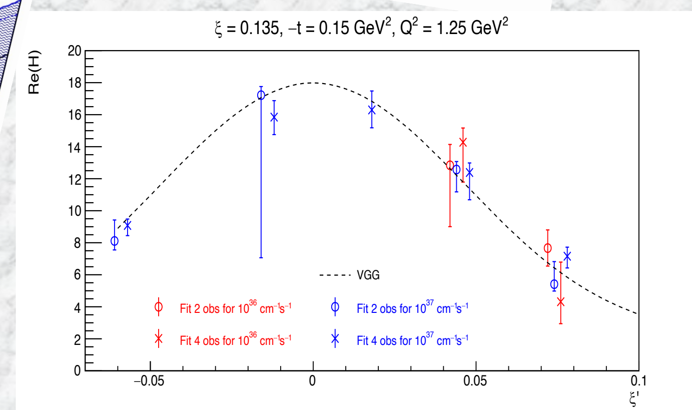












(i) p-DVCS @ CLAS12

(ii) p-DVCS @ NPS

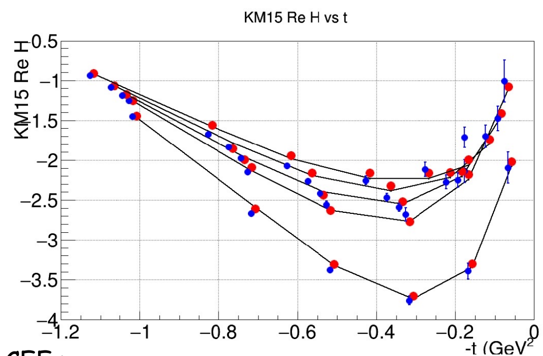
p-DVCS BCA
Local Fit

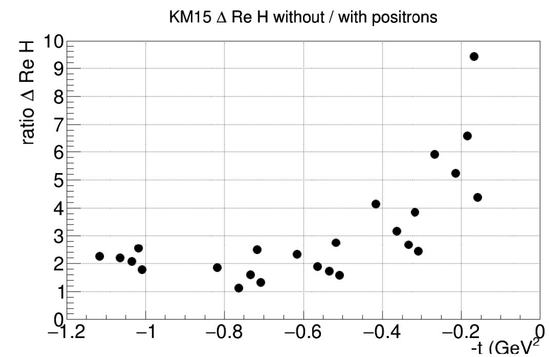
K. Kumerički, D. Müller, NPB 841 (2010) 1   E.C. Aschenauer, S. Fazio, K. Kumerički, D. Müller, JHEP 09 (2013) 093
V. Burkert et al. arXiv:2103.12651 (2021)

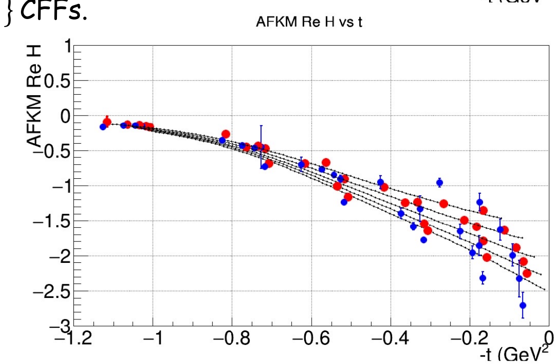
- The importance of positron beams for the determination of CFFs can be quantified in a model-dependent way depending on : the cross section model, the GPDs model, and the hypotheses of the fitting approach.

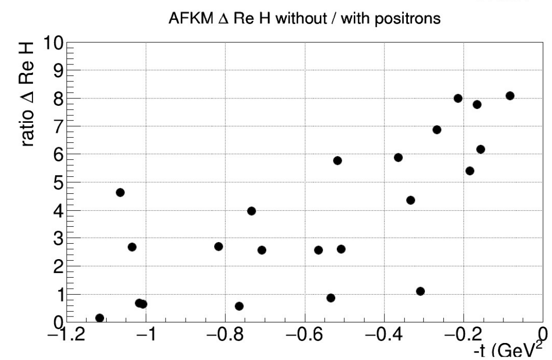
Observable	σ_{UU}	A_{LU}	A_{UL}	A_{LL}	A_{UU}^{C}	A_{LU}^{C}
Time (d)	80	80	100	100	80	80
$\mathcal{L}$ ($\times 10^{35}$ cm^{-2}$\cdot$s^{-1})	0.6	0.6	2	2	0.6	0.6
Packing Fraction	1	1	0.17	0.17	1	1
Sytematics (%)	5	3	3	$3 \oplus 3$	3	3

Fitting of $\{\mathcal{H}, \tilde{\mathcal{H}}\}$ CFFs assuming model values for $\{\mathcal{E}, \tilde{\mathcal{E}}\}$ CFFs.







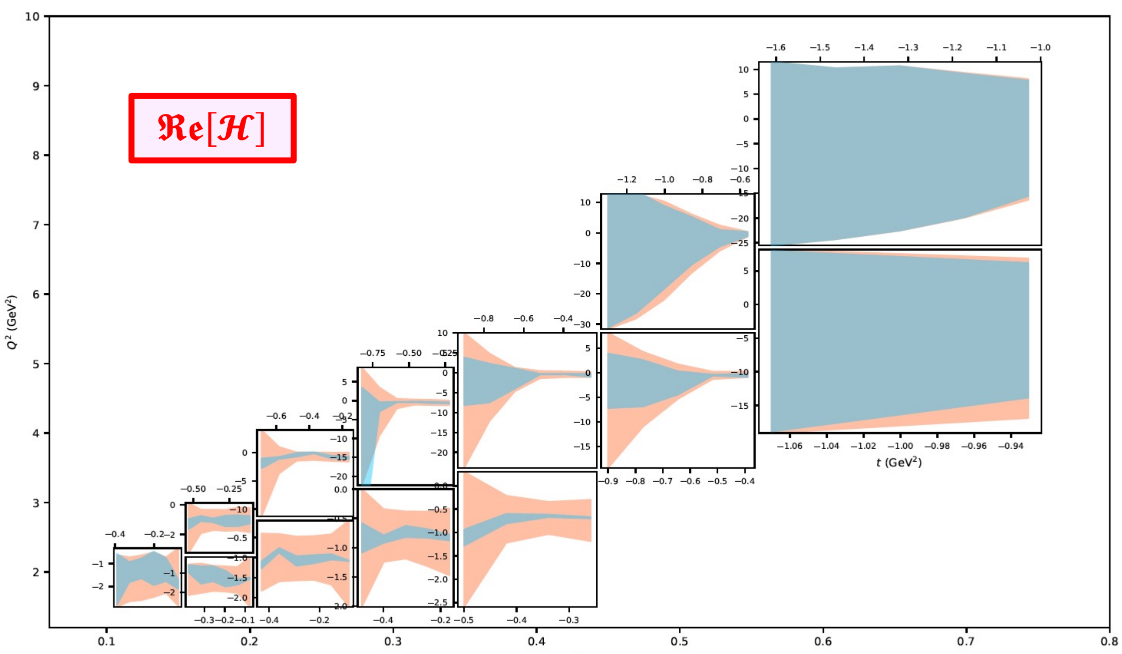


- Improvement of the statistical and systematical error on $\Re e[\mathcal{H}]$.

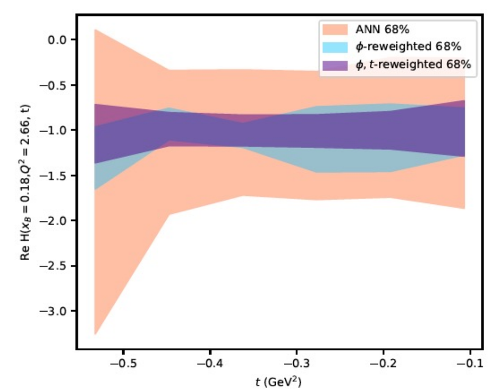
p-DVCS BCA
Global Fit

H. Dutrieux, V. Bertone, H. Moutarde, P. Sznajder, arxiv:2105.09245

- The **existing DVCS world data set** is analyzed within a **global fit** based on an Artificial Neural Network procedure to extract CFFs.
- The impact of **projected CLAS12 BCA** data on the proton is evaluated from a **Bayesian reweighting analysis** of CFFs.



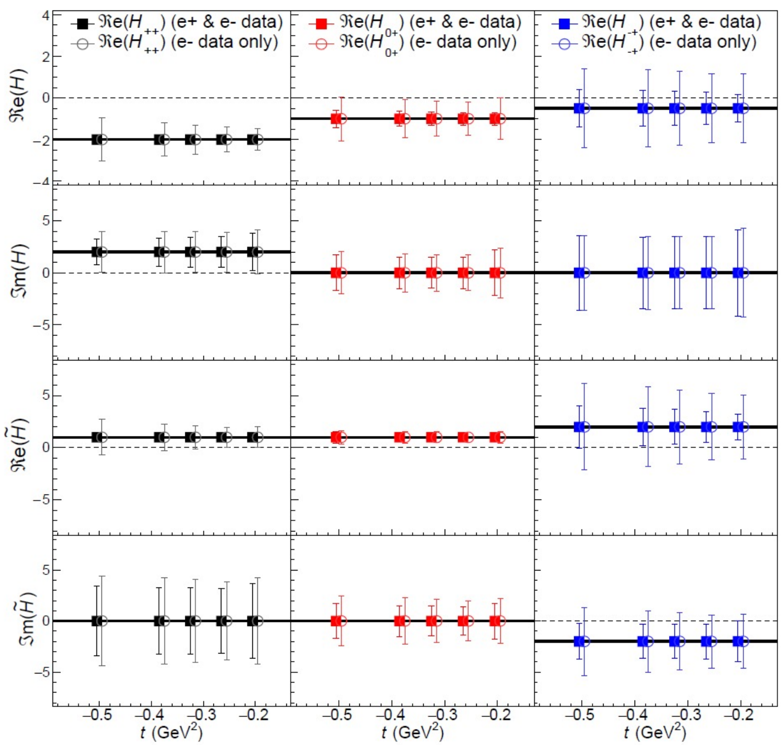
- Improvement of the definition of the **68% confidence region** for $\Re e[\mathcal{H}]$.



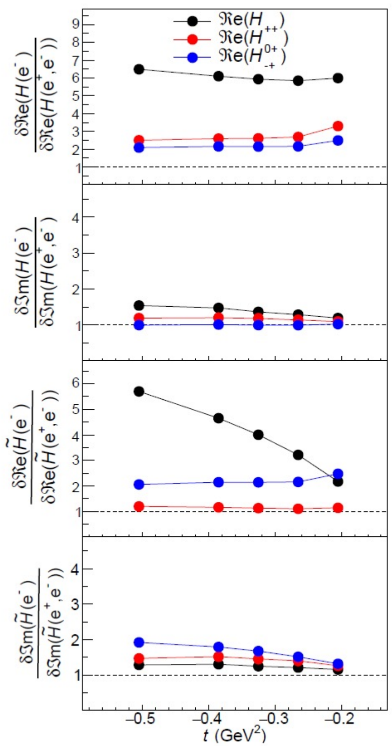
p-DVCS cross section

K. Kumerički, D. Müller, NPB 841 (2010) 1   V.M. Braun, A.N. Manashov, D. Müller, B.M. Pirnay PRD 89 (2014) 074022

- CFFs $\mathcal{H}$ and $\widetilde{\mathcal{H}}$ are determined from electron and positron pseudo data within a higher-twist (HT) and next-to-leading-order (NLO) modeling of the polarized (e^-) and unpolarized cross sections (e^- e^+).



Fitting $\{++, 0+, -+\}$ for $\{\mathcal{H}, \widetilde{\mathcal{H}}\}$ CFFs



- Improvement of the **statistical** error on $\Re e[\mathcal{H}]$ and $\Re e[\widetilde{\mathcal{H}}]$ by a factor **4-6**.
- Improvement about a factor **2** on HT and NLO CFFs.

Positron beams **reduce the correlations** between CFFs.

Eric Voutier
IJCLab Irène Joliot-Curie

e^+ @ JLab

A rich and high impact experimental program has been developed, asking for polarized positron beams at JLab.

e+@JLab Topical Issue of EPJ A in preparation

In the DVCS and DDVCS channels, e^+ beams enable:

- an undisputable **separation** of the **INT** amplitudes;
- a **direct access** to the **real part** of CFFs;
- a **window** of study of HT and NLO effects.

« … A program of both electron and positron scattering with CEBAF at Jefferson Lab (and the future Electron Ion Collider) would have much greater impact than simply a quantitative change of GPD uncertainties. Direct access to the real part of the Compton Form Factors would be a qualitative shift for 3-D imaging of nucleons and nuclei. The measurement of DVCS with a positron beam is a key factor for the completion of the ambitious scientific program for the understanding of the 3-D structure and dynamics of hadronic matter… »

This project has received funding from the European Union's Horizon 2020 research and innovation program under agreement No 824093.