Beam Charge Asymmetries for Deeply Virtual Compton Scattering on the proton at CLAS12

p-DVCS-BCA @ CLAS12 *PR12+23-002*

E. Voutier[1], V. Burkert[2], S. Niccolai[1], R. Paremuzyan[2]
and **the CLAS Collaboration**
and the **Jefferson Lab Positron Working Group**

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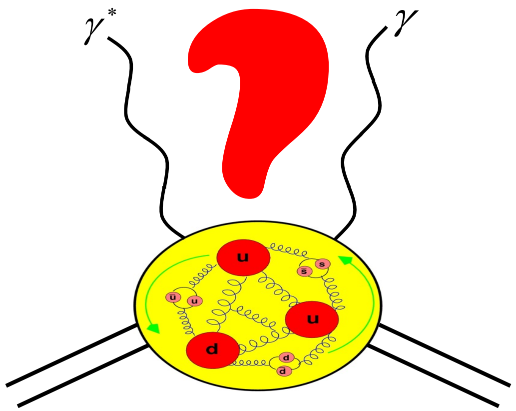
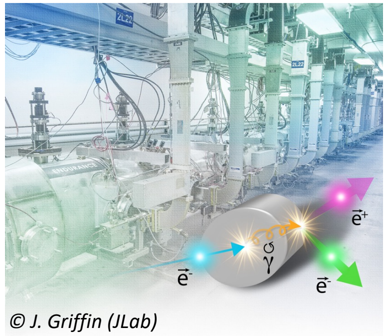
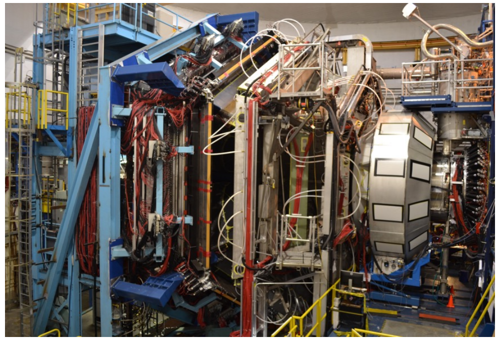






This project has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement Nº 824093.

PR12+23-002

E. Voutier, V. Burkert, S. Niccolai, R. Paremuzyan et al.

V. Burkert et al. EPJ A 57 (2021) 186

« We propose to measure the unpolarized and polarized Beam Charge Asymmetries (**BCAs**) of the $\vec{e}^{\pm}p \rightarrow e^{\pm} p\gamma$ process on an unpolarized Hydrogen target with **CLAS12**, using **50 nA** and **60% polarized positron** and **electron beams** at 10.6 GeV.

The **azimuthal** and ***t*-dependences** of the unpolarized and polarized BCAs will be measured over a **large (x_B,Q^2) phase space** using a **100 days** run at a luminosity of **0.66×10^{35} cm$^{-2}\cdot$s^{-1}**. »

☛ This proposal follows the Letter-of-Intent LOI12-18-004 discussing the perspectives of an experimental program with positron beams at JLab, and the proposal PR12-20-009 conditionnally approved C2.

"These measurements all have significant physics interest. The proposers should carefully evaluate feasibility and present the best case possible in a future proposal. The justification must be very strong to enable the significant changes needed in the accelerator, both in equipment and in schedule. Any proposal should have a section on the linkage between a realistic plan for beam and the way the measurement is made."

"The PAC recognizes the strong science case of positron beams for the GPD program at JLab. However, it feels that more rigorous simulations are needed to highlight the unique potential of the proposed experiment for constraining Compton Form Factors and eventually GPDs. Moreover, the amount of required beam time with secondary electron beams needs to be justified in a more quantitative way."

(Jefferson Lab Positron Working Group) A. Accardi et al. EPJ A 57 (2021) 261

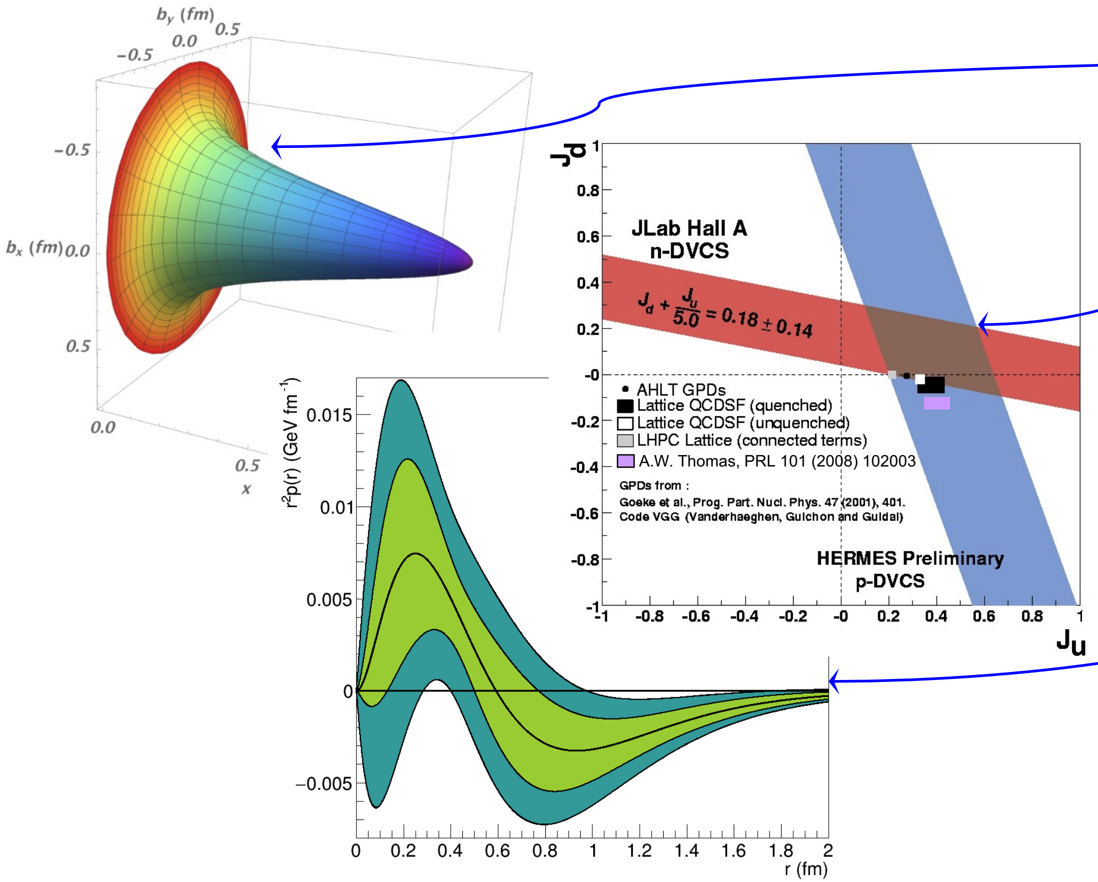
X. Ji, PRL 78 (1997) 610   M. Polyakov, PLB 555 (2003) 57   M.V. Polyakov, P. Schweitzer, IJMP A 33 (2018) 1830025

- Generalized Parton Distributions (GPDs) encode the **correlations between partons** and contain information about the **internal dynamics of hadrons** which express in properties like the **angular momentum** or the **distribution of the forces** experienced by quarks and gluons inside hadrons.

$$\rho^q_H(x,\boldsymbol{b}_\perp) = \int \frac{d^2\boldsymbol{\Delta}_\perp}{(2\pi)^2}\, e^{i\boldsymbol{b}_\perp\cdot\boldsymbol{\Delta}_\perp}\left[H^q(x,0,-\Delta_\perp^2) + H^q(-x,0,-\Delta_\perp^2)\right]$$

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

$$\int_{-1}^{1} x \sum_q H^q(x,\xi,t)\;dx = M_2(t) + \frac{4}{5}\xi^2 d_1(t)$$



M. Mazouz et. al. PRL 9 (2007) 242501   A. Airapetian et al. JHEP 06 (2008) 066   R. Dupré, M. Guidal, M. Vanderhaeghen, PRD 95 (2017) 011501
V. Burkert, L. Elouadrhiri, F.-X. Girod, Nat. 557 (2018) 396

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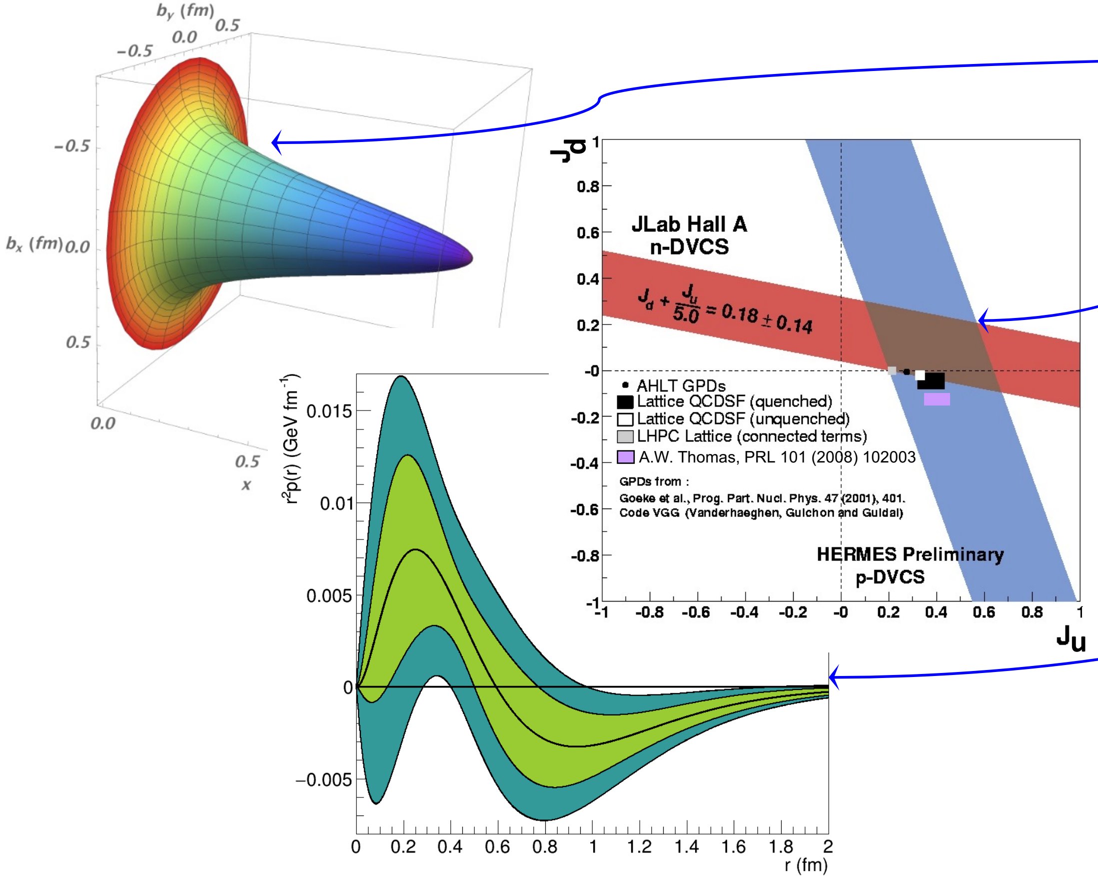

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$$\int_{-1}^{1} x \sum_q H^q(x,\xi,t)\,dx = M_2(t) + \frac{4}{5}\xi^2 d_1(t)$$

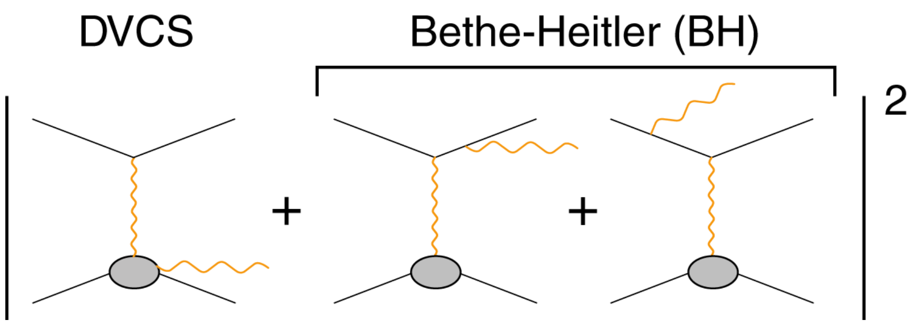
- **Unpolarized e$^+$ combined with unpolarized e$^-$** access the **real part** of the Compton Form Factors (CFFs).
- **Polarized e$^+$ combined with polarized e$^-$** access the **imaginary part** of CFFs and **higher twist effects**.

M. Mazouz et. al. PRL 9 (2007) 242501 A. Airapetian et al. JHEP 06 (2008) 066 R. Dupré, M. Guidal, M. Vanderhaeghen, PRD 95 (2017) 011501
V. Burkert, L. Elouadrhiri, F.-X. Girod, Nat. 557 (2018) 396

Deeply Virtual Compton Scattering

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

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



∝ to the **real part** of a **CFF linear combination**

$$d^5\sigma^{e}_{P0} = d^5\sigma_{BH} + d^5\sigma_{DVCS} + P\, d^5\tilde{\sigma}_{DVCS} + e\,[d^5\sigma_{INT} + P\, d^5\tilde{\sigma}_{INT}]$$

∝ to the **real part** of a **CFF bilinear combination**

$$d^5\sigma^{\pm}_{00} = d^5\sigma_{BH} + d^5\sigma_{DVCS} \pm d^5\sigma_{INT}$$

Polarized positron and electron beams allow to **separate** the unknown amplitudes of the cross section for electro-production of photons.

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IJCLab Irène Joliot-Curie

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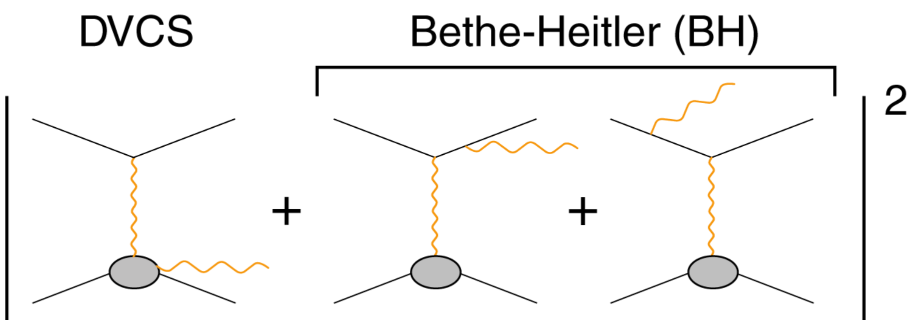

$\propto$ to the **real part** of a **CFF linear combination**

$\propto$ to the **imaginary part** of a **CFF linear combination**

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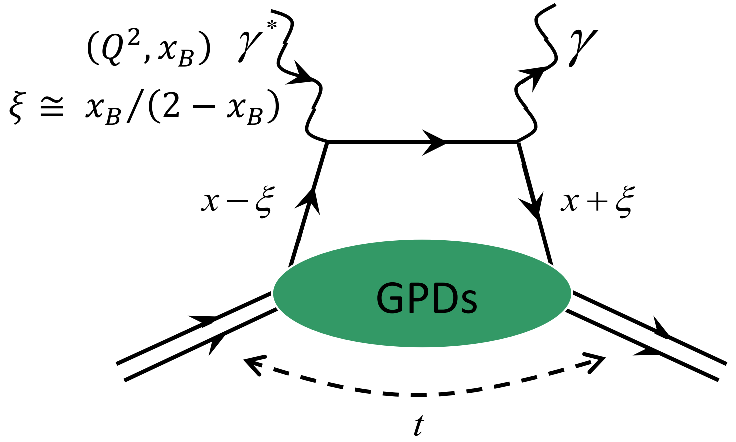
$\propto$ to the **imaginary part** of a **CFF bilinear combination**

$$d^5\sigma^{\pm}_{00} = d^5\sigma_{BH} + d^5\sigma_{DVCS} \pm d^5\sigma_{INT}$$

$$d^5\sigma^{\pm}_{+0} - d^5\sigma^{\pm}_{-0} = 2\,[d^5\tilde{\sigma}_{DVCS} \pm d^5\tilde{\sigma}_{INT}]$$

Polarized positron and electron beams allow to **separate** the **unknown amplitudes** of the cross section for electro-production of photons.

Compton Form Factors



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

$$d^5\sigma \propto \int_{-1}^{+1} dx \, \frac{\mathbf{GPD}(x,\xi,t)}{x \pm \xi \mp i\epsilon} = \mathcal{P} \int_{-1}^{+1} dx \, \frac{\mathbf{GPD}(x,\xi,t)}{x \pm \xi} \pm i\pi \, \mathbf{GPD}(x = \pm\xi, \xi, t)$$

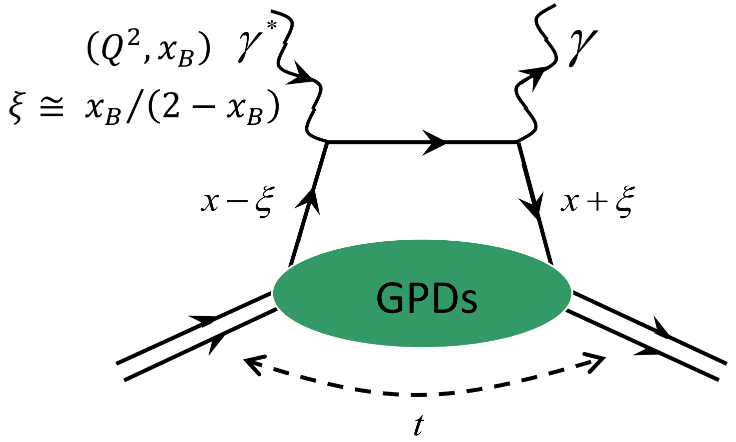
$\sigma_{INT,DVCS}$ $\tilde{\sigma}_{INT,DVCS}$

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

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

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

Compton Form Factors



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$\boldsymbol{\sigma_{INT,DVCS}}$ (principal value term) $\qquad \boldsymbol{\tilde{\sigma}_{INT,DVCS}}$ (imaginary term)

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

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

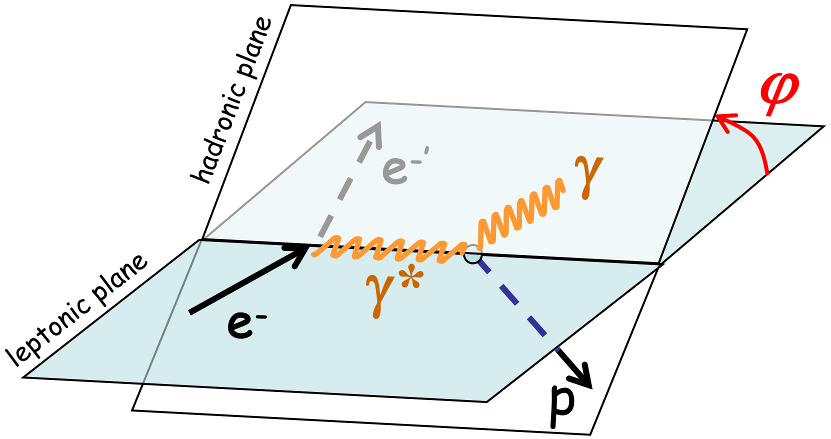
$$\mathcal{C}^{INT} = F_1\mathcal{H} - \xi[F_1 + F_2]\widetilde{\mathcal{H}} - \frac{t}{4M^2}\mathcal{E}$$

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

Experimental Method

A.V. Belitsky, D. Müller, A. Kirchner, NPB 629 (2002)

$$d^5\sigma_{P0}^{e} = d^5\sigma_{BH} + d^5\sigma_{DVCS} + P\, d^5\tilde{\sigma}_{DVCS} + e\, [d^5\sigma_{INT} + P\, d^5\tilde{\sigma}_{INT}]$$



$$d^5\sigma_X \equiv \frac{d^5\sigma_X}{dQ^2\, dx_B\, dt\, d\phi_e\, d\varphi}$$

- The BH differential cross section is exactly calculable from the proton form factors (F_1,F_2) known at small t.

$$d^5\sigma_{BH} = \frac{1}{P_1(\varphi)P_2(\varphi)} \sum_{n=0}^{2} c_n^{BH} \cos(\varphi)$$

➢ At twist-2 and leading α_{QCD}-order, the cross section components exhibit specific azimuthal dependences.

$$d^5\sigma_{DVCS} = c_0^{DVCS}\, \mathfrak{Re}[\mathcal{C}^{DVCS}]$$

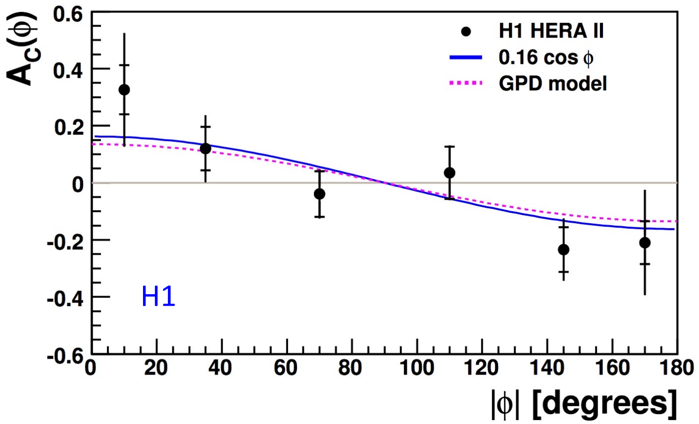
$$d^5\tilde{\sigma}_{DVCS} = 0$$

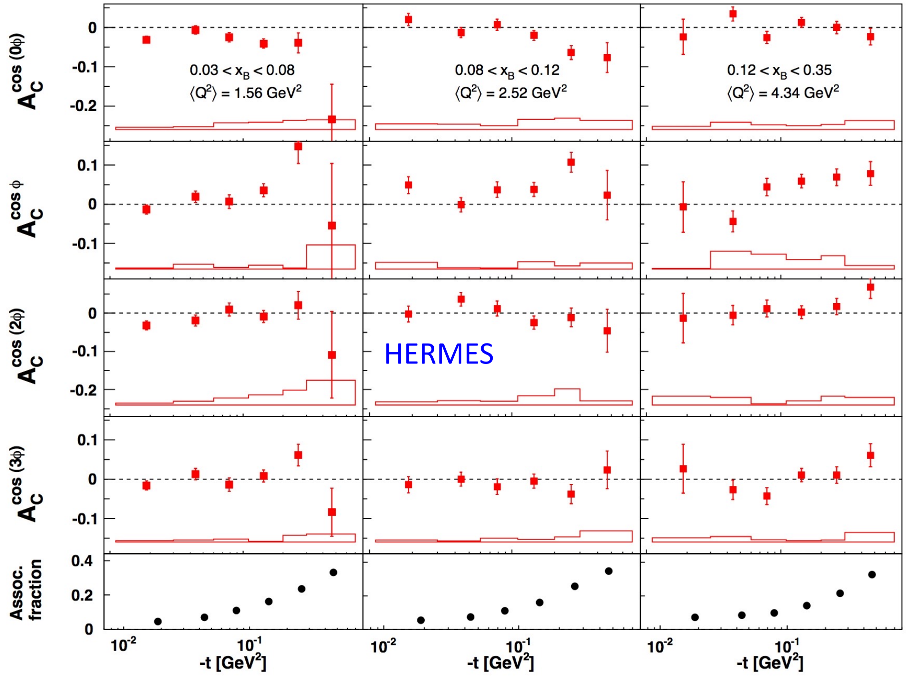
$$d^5\sigma_{INT} = \frac{c_0^{INT} + c_1^{INT}\cos(\varphi)}{P_1(\varphi)P_2(\varphi)}\, \mathfrak{Re}[\mathcal{C}^{INT}]$$

$$d^5\tilde{\sigma}_{INT} = \frac{s_1^{INT}\sin(\varphi)}{P_1(\varphi)P_2(\varphi)}\, \mathfrak{Im}[\mathcal{C}^{INT}]$$

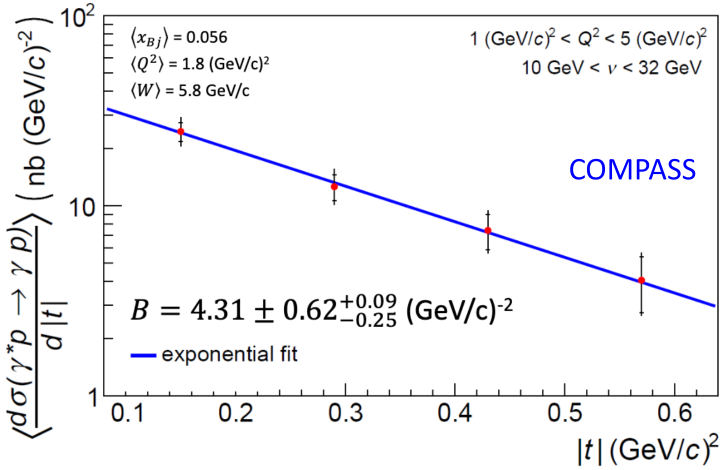
Current Knowledge

- Pioneering comparisons of DVCS with **electron** and **positron** beams at **H1** and **HERMES demonstrated** the existence of a **BCA-signal**.
- Because of the $\overleftrightarrow{\mu}^{\pm}$ beam nature, the **COMPASS** experiment cannot combine beam charge and polarization independently.





$$\Sigma\sigma_{\mp 0}^{\pm} = 2(d\sigma_{BH} + d\sigma_{DVCS} - P d\tilde{\sigma}_{INT})$$



(H1 Collaboration) F.D. Aaron et al. PLB 681 (2009) 391 (HERMES Collaboration) A. Airapetian et al. JHEP 06 (2008) 066 – 11(2009) 083 – 07 (2012) 032
(COMPASS Collaboration) R. Akhunzyanov et al. PLB 793 (2019) 188

Proposed Measurements

V. Burkert et al. EPJ A 57 (2021) 186

- Using polarized positron and electron beams we propose to measure a full set of new GPD observables :
  - the **unpolarized beam charge asymmetry** A^C_{UU}, sensitive to the CFF real part;
  - the **polarized beam charge asymmetry** A^C_{LU}, sensitive to the CFF imaginary part;
  - the **charge averaged beam spin asymmetry** A^0_{LU}, signature of higher twist effects.

New GPD Observables @ JLab

$\propto \Re\mathfrak{e}[\mathcal{C}^{INT}]$

$$A^C_{UU} = \frac{(Y^+_+ + Y^+_-) - (Y^-_+ + Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{d^5\sigma_{INT}}{d^5\sigma_{BH} + d^5\sigma_{DVCS}}$$

$\propto \Im\mathfrak{m}[\mathcal{C}^{INT}]$

$$A^C_{LU} = \frac{(Y^+_+ - Y^+_-) - (Y^-_+ - Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{d^5\tilde{\sigma}_{INT}}{d^5\sigma_{BH} + d^5\sigma_{DVCS}}$$

$= 0$

$$A^0_{LU} = \frac{(Y^+_+ + Y^-_+) - (Y^+_- + Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{d^5\tilde{\sigma}_{DVCS}}{d^5\sigma_{BH} + d^5\sigma_{DVCS}}$$

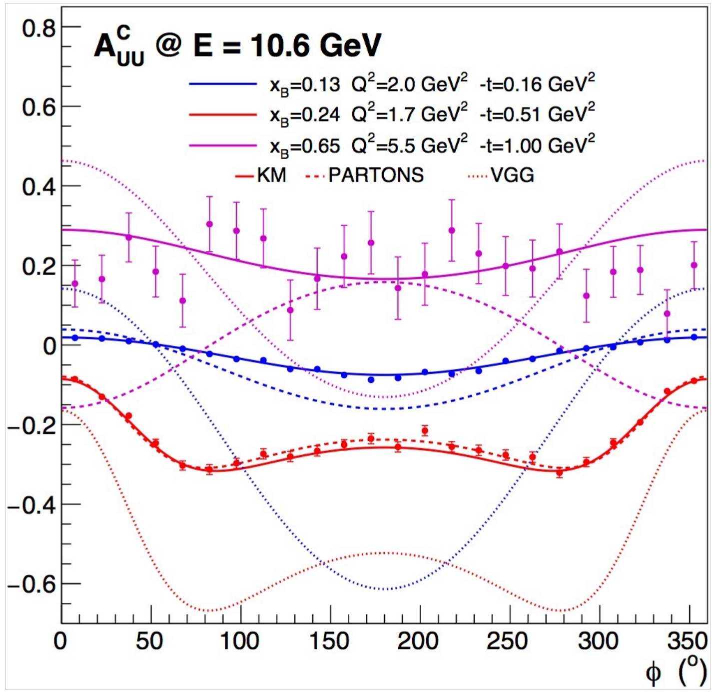
$$Y^{e^\pm}_{\pm P^\pm} = \frac{N^\pm_\pm}{Q^\pm_\pm P^\pm}$$

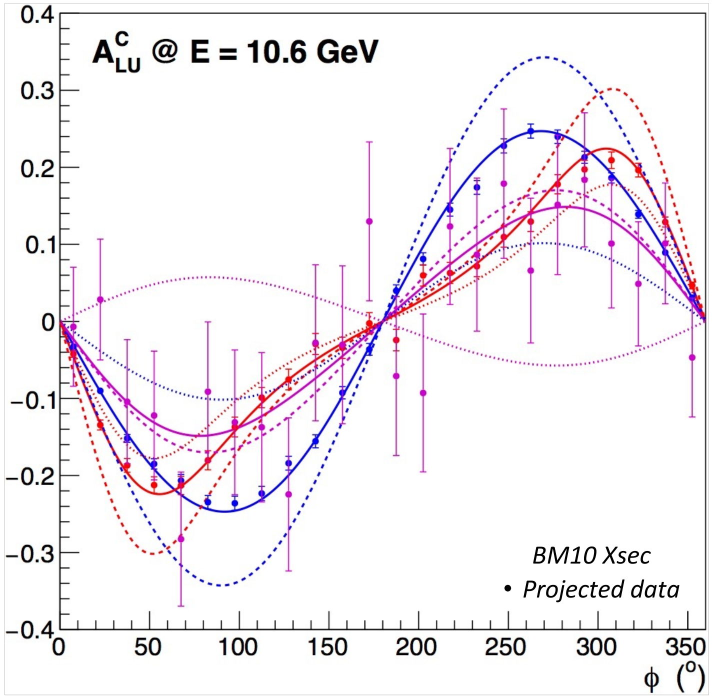
is the beam polarization and accumulated charge normalized yield.

$$A^C_{LU} \neq A^\pm_{LU} = \frac{\pm(d^5\tilde{\sigma}_{INT} \pm d^5\tilde{\sigma}_{DVCS})}{d^5\sigma_{BH} + d^5\sigma_{DVCS} \pm d^5\sigma_{INT}}$$

Experimental Signal

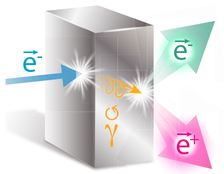
A.V. Belitsky, D. Müller, PRD 82 (2010) 074010 K. Kumerički, D. Müller, NPB 841 (2010) 1
B. Berthou et al. EPJC 78 (2018) 478 M. Vanderhaeghen, P.A.M. Guichon, M. Guidal, PRD 60 (1999) 094017





- The **magnitude** of unpolarized and polarized BCAs is **sizeable** and **kinematics dependent**.
- The **shape** and **magnitude** of unpolarized and polarized BCAs are **sensitive** to the specific **GPD model**.

- Projected data at **small and moderate** (x_B, Q^2, t) are **accurate** and **selective** of the GPD model.
- Statistics at **large** (x_B, Q^2, t) degrades but is still **selective** of the GPD model.



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Impact of Positron Measurements (I)

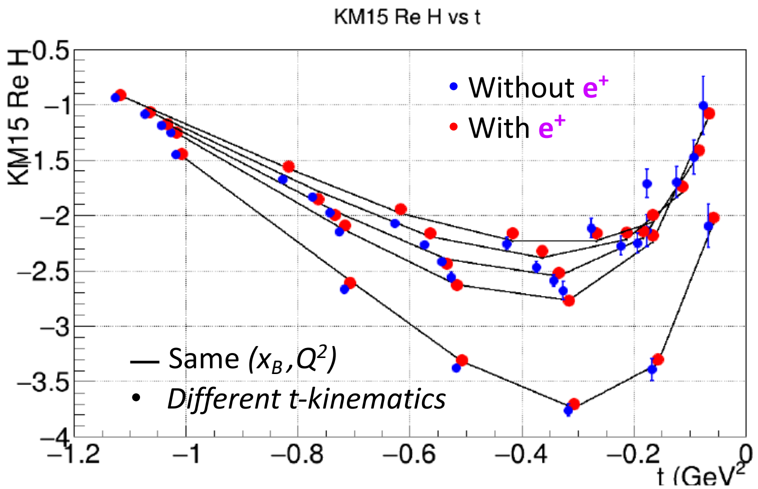
K. Kumerički, D. Müller, NPB 841 (2010) 1

E.C. Aschenauer, S. Fazio, K. Kumerički, D. Müller, JHEP 09 (2013) 093

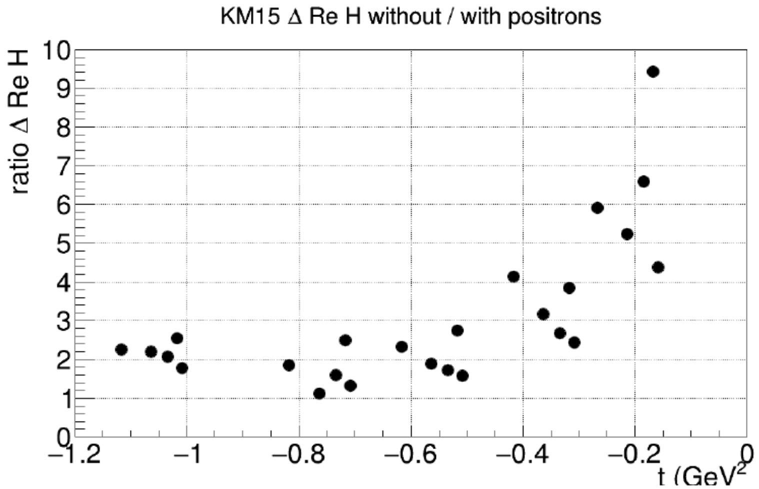
- The importance of positron beams for the determination of CFFs can be quantified in a model-dependent way depending on : the cross section model, the GPDs model, and the hypotheses of the fitting approach.

Observable	σ_{UU}	A_{LU}	A_{UL}	A_{LL}	A^C_{UU}	A^C_{LU}
Time (d)	80	80	100	100	80	80
Systematics (%)	5	3	3	$3\oplus3$	3	3

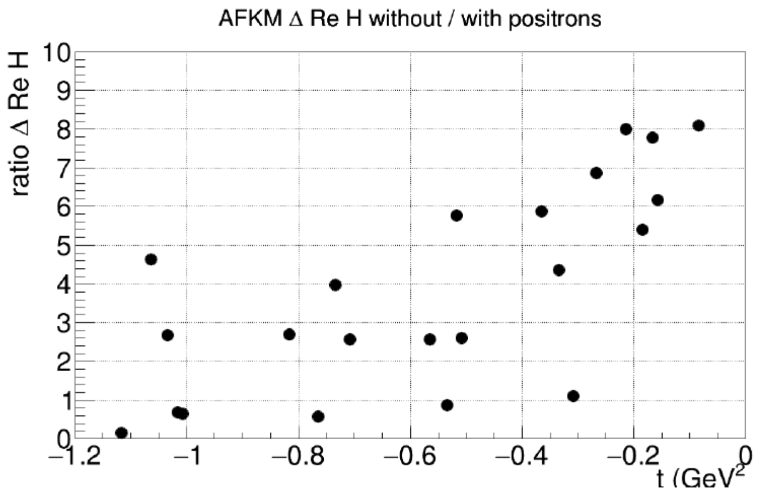
Fitting of $\{\mathcal{H}, \widetilde{\mathcal{H}}\}$ CFFs assuming model values for $\{\mathcal{E}, \widetilde{\mathcal{E}}\}$ CFFs.



Purity of e^+ observables



Reduction of CFF correlations



Reduction of CFF correlations

☛ Improvement of the **determination** of $\Re e[\mathcal{H}]$.

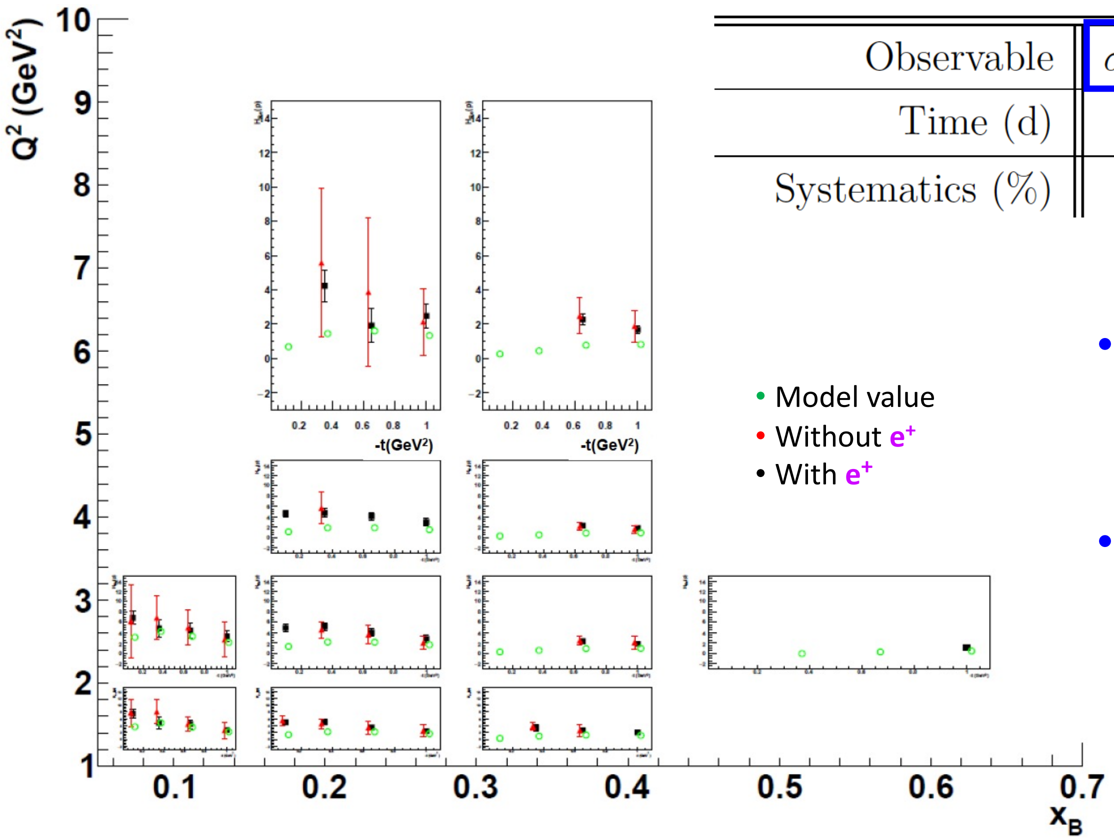
Impact of Positron Measurements (II)

M. Guidal, EPJ A 37 (2008) 319; EPJ A 40 (2009) 119

- 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^C_{UU}	A^C_{LU}
Time (d)	50	50	40	40	80	80
Systematics (%)	10	5	5	$5\oplus5$	5	5

Fitting of $\{\mathcal{H},\widetilde{\mathcal{H}},\mathcal{E},\widetilde{\mathcal{E}}\}$ CFFs assuming $\Im m[\widetilde{\mathcal{E}}] = 0$.



- Model value
- Without e+
- With e+

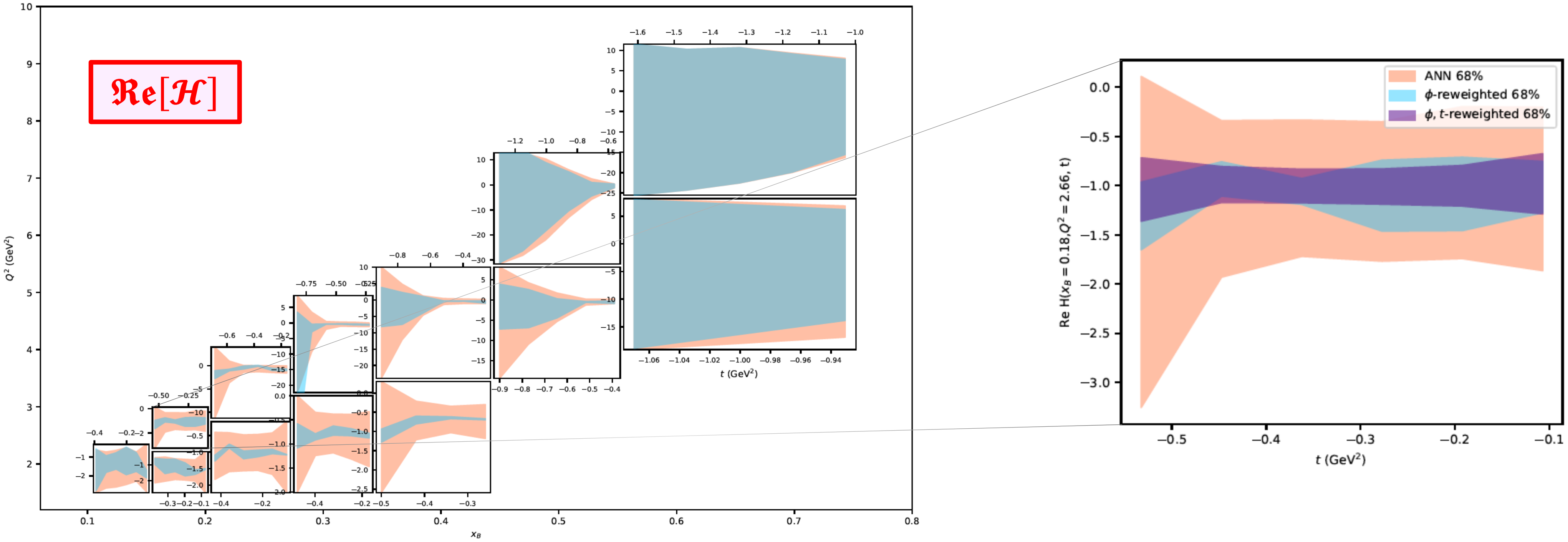
- **Positron beams** permit the determination of $\mathfrak{Re}[\mathcal{H}]$ in a **larger phase space**, at kinematics inaccesible to electron beam data only.
- When electron data are successfull, **positron beams** provide a **strong reduction of the error** on $\mathfrak{Re}[\mathcal{H}]$, far beyond simple increase of statistics.

☛ Improvement of the **determintion** of $\mathfrak{Re}[\mathcal{H}]$.

Impact of Positron Measurements (III)

H. Dutrieux, V. Bertone, H. Moutarde, P. Sznajder, EPJ A 57 (2021) 300

- The **existing DVCS world data set** (H1, ZEUS, HERMES, JLab 6 GeV, COMPASS) is analyzed within a **global fit** based on an Artificial Neural Network procedure within PARTONS to extract CFFs.
- The impact of **projected CLAS12 BCA** data on the proton is evaluated from a **Bayesian reweighting analysis** of CFFs.

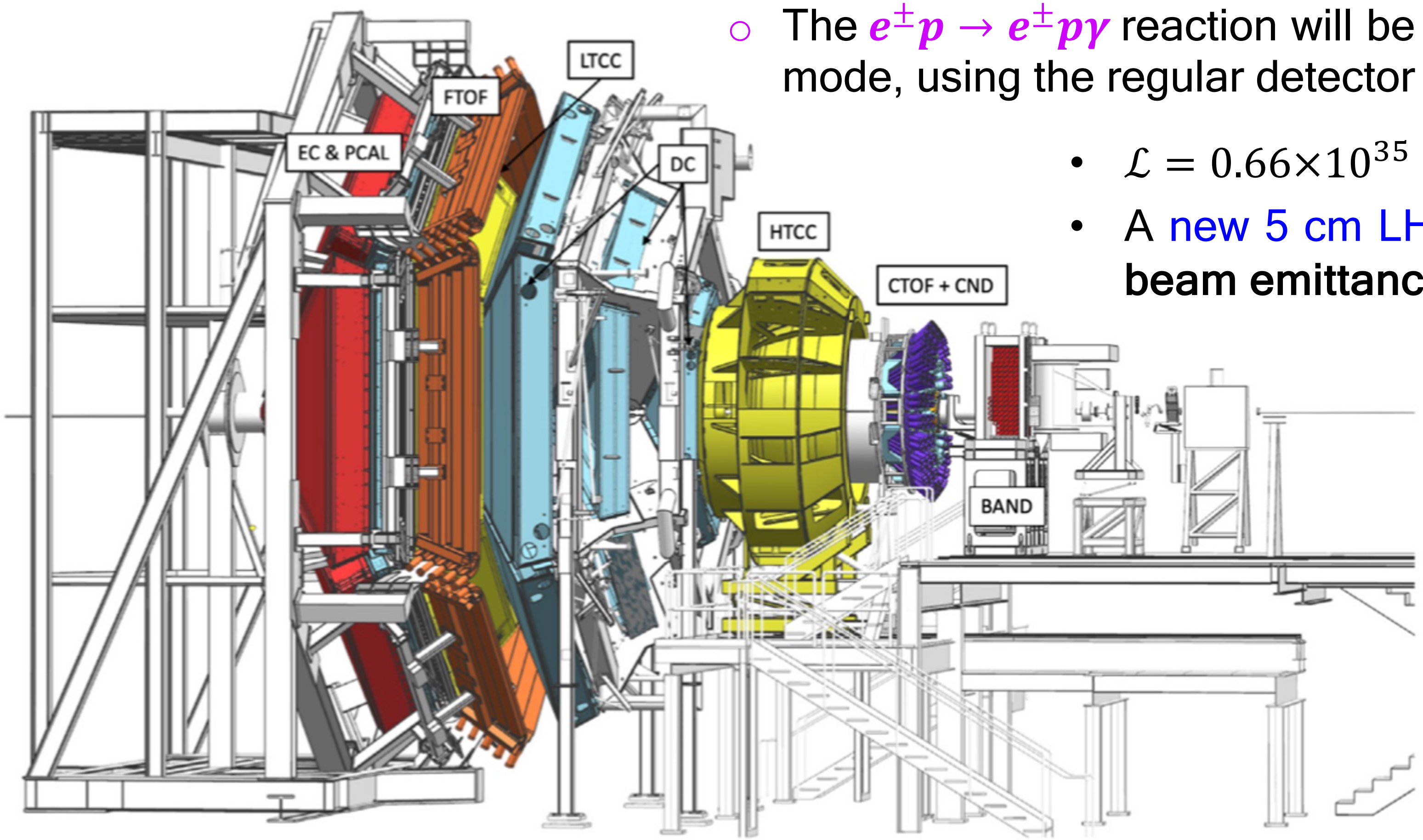


☛ Improvement of the definition of the **determination** of $\mathfrak{Re}[\mathcal{H}]$.

Experimental configuration

CLAS12

V. Burkert et al. NIMA 959 (2020) 163419



- The $e^{\pm}p \to e^{\pm}p\gamma$ reaction will be measured with **CLAS12** in **OUT-bending** mode, using the regular detector arrangement.
  - $\mathcal{L} = 0.66{\times}10^{35}\ \mathrm{cm^{-2}\cdot s^{-1}}$
  - A new 5 cm LH_2 target cell is anticipated to accept **larger beam emittance if** needed.

Beam Line

- There is **no difference** bewteen **e⁻** and **e⁺** beam transport in Hall B beam line, nor in beam related detector background.

- Beam diagnostics are expected to operate similarly with **e⁻** and **e⁺** beam.

- Upgrade of the existing Møller polarimeter into a **Møller**/**Bhabha** polarimeter (*work in progress*).

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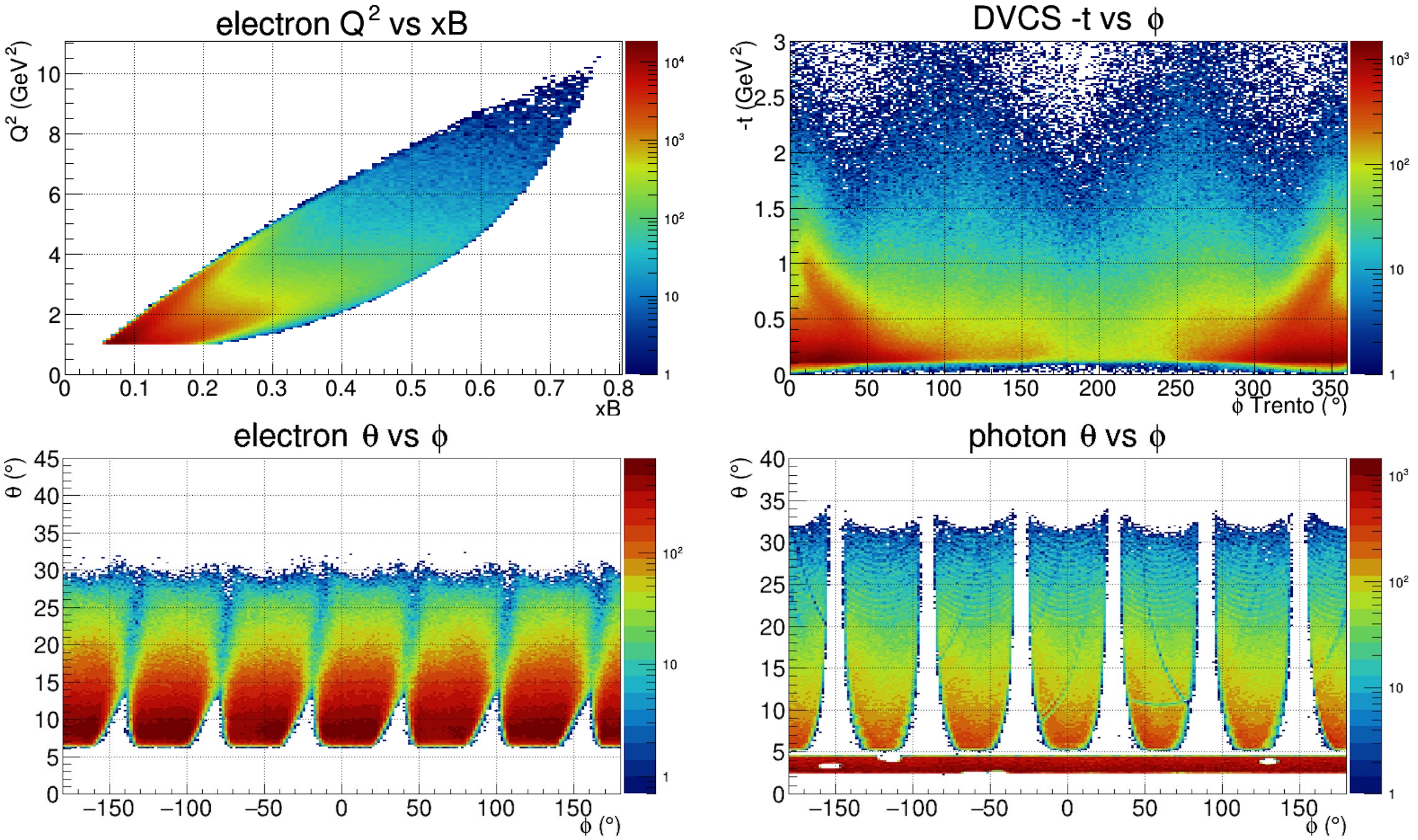
Kinematic Coverage

From a subset of out-bending RGA data



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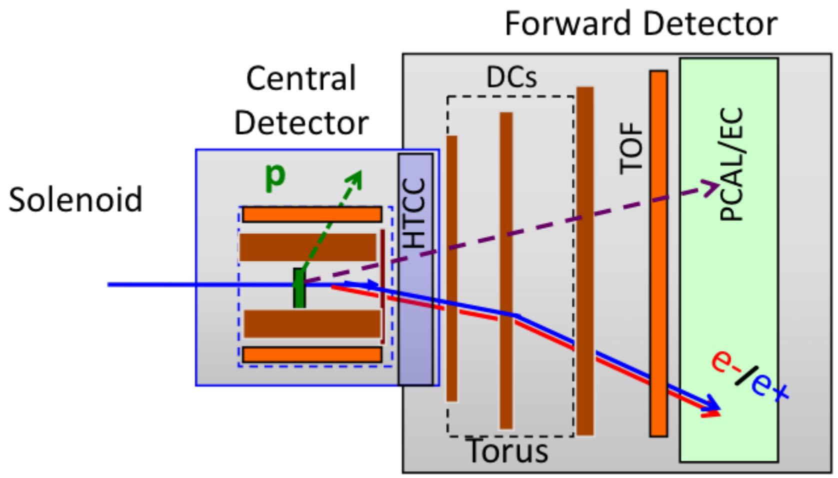
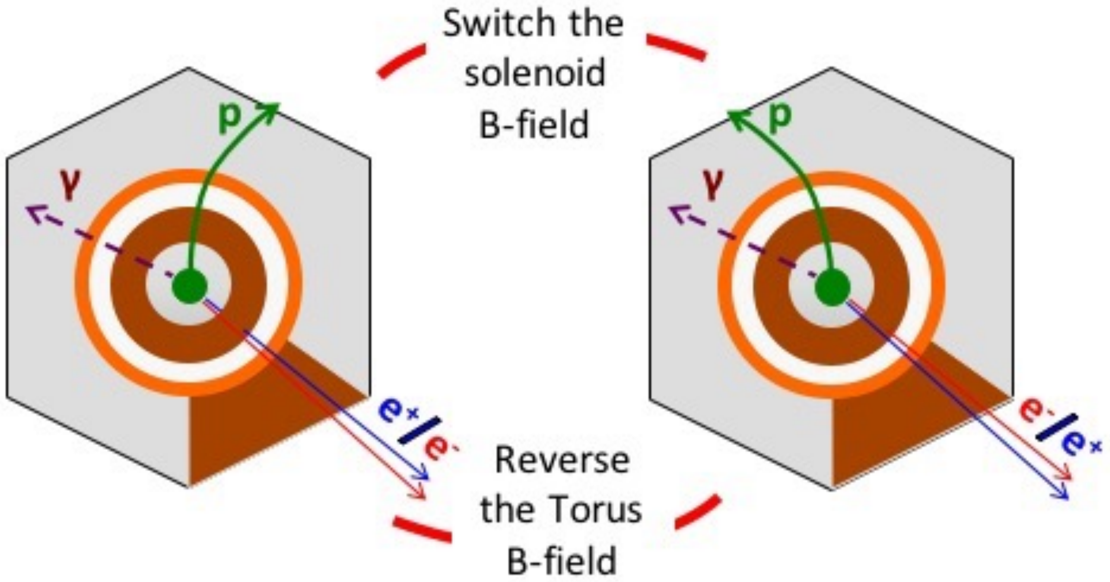
False Asymmetries

- Potential false asymmetries may occur due to e^- and e^+ from same vertex and kinematics passing through different part of the detector shifted in ϕ in a sector.





- **Switch** the **solenoid field** to reveal false asymmetries in the Forward Detector, which may create false asymmetries in proton tracking.

- **Measure**, simultaneously to DVCS, **elastic scattering** cross sections for e^- and e^+ at low-Q^2 where 2γ-effects are small.

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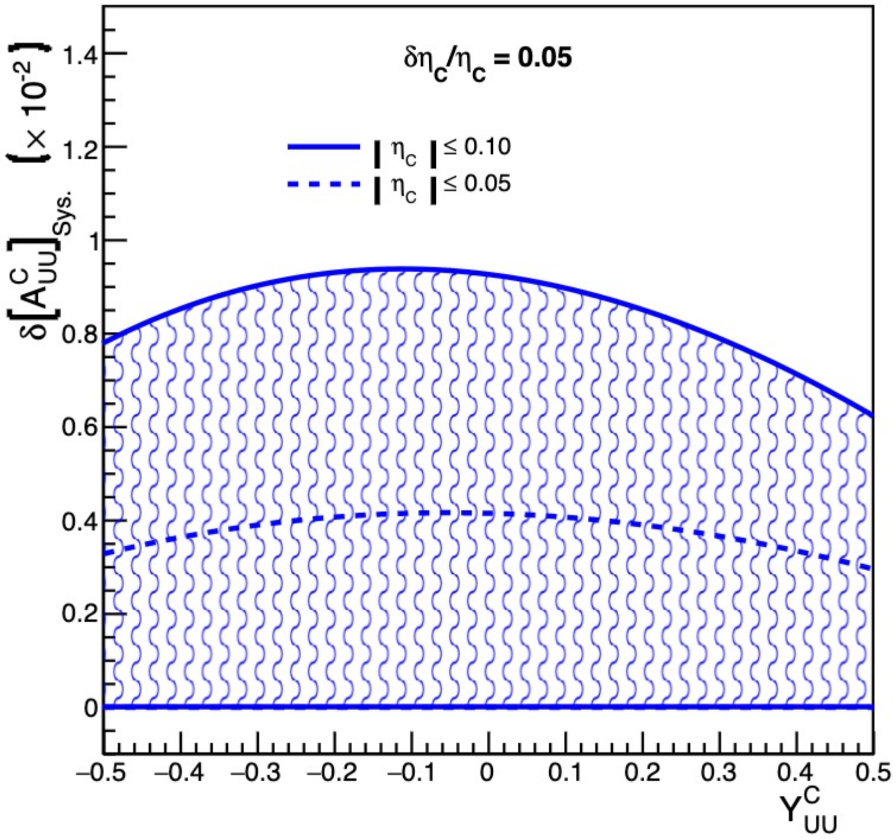
Systematic Effects

- The measurement of **BCAs** is comparable to the measurement of **relative cross sections** where some **systematical effects** cancel out while others ask for carefull control and monitoring.

$$\eta_C = \frac{1}{2}\left(1 - \frac{\varepsilon^+ \Delta\Omega^+}{\varepsilon^- \Delta\Omega^-}\right) \rightarrow A^C_{UU} = \frac{(1+\eta_C)\mathcal{Y}^C_{UU} - \eta_C}{1 + \eta_C - \eta_C \mathcal{Y}^C_{UU}}$$

Minizing systematics in **e⁺/e⁻** comparison requires :

- ↠ Same **beam qualities** (energy, transverse profile, emittance…)
- ↠ Same **detector** (target, efficiency, solid angle…)
- ↠ Same **statistics** (accumulated charge, beam polarization)



- **Take DVCS data** with the **secondary electron** beam *(simultaneously produced at the positron production target)* prior data taking with the **secondary positron** beam.

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Beam Time Request

- We are asking for a total of **100 days** of beam, operating **CLAS12** with **50 nA e^+** and **e^-** beams polarized at **60%**.

Purpose	Label	Beam parameters q (e)	Nat.	E (GeV)	I (nA)	λ (%)	Target	Sol. Pol.	Tor. Pol.	Time (h)
$ep \to ep$	Cal.	−	P	2.2	50	0	5 cm LH_2	−	+	24
								+		24
Commissioning			S					+		24
$ep \to ep$	Cal.							+		24
								−		24
$ep \to ep\gamma$	Phy.			10.6		60		−		480
Background	Cal.							−		48
$ep \to ep\gamma$	Phy.							+		480
Background	Cal.							+		48
Commissioning		+	S	2.2	50	0	5 cm LH_2	+	−	48
$ep \to ep$	Cal.							+		24
								−		24
Commissioning				10.6		60		−		72
$ep \to ep\gamma$	Phy.							−		480
Background	Cal.							−		48
$ep \to ep\gamma$	Phy.							+		480
Background	Cal.							+		48
									Total	2400

- **80** days for **physics** data taking
- **20** days for **commissioning** and **calibration**

using lepton beams of different charge

- 2 days with the CEBAF e^- beam
- 52 days with the secondary e^+ beam
- 46 days with the secondary e^- beam

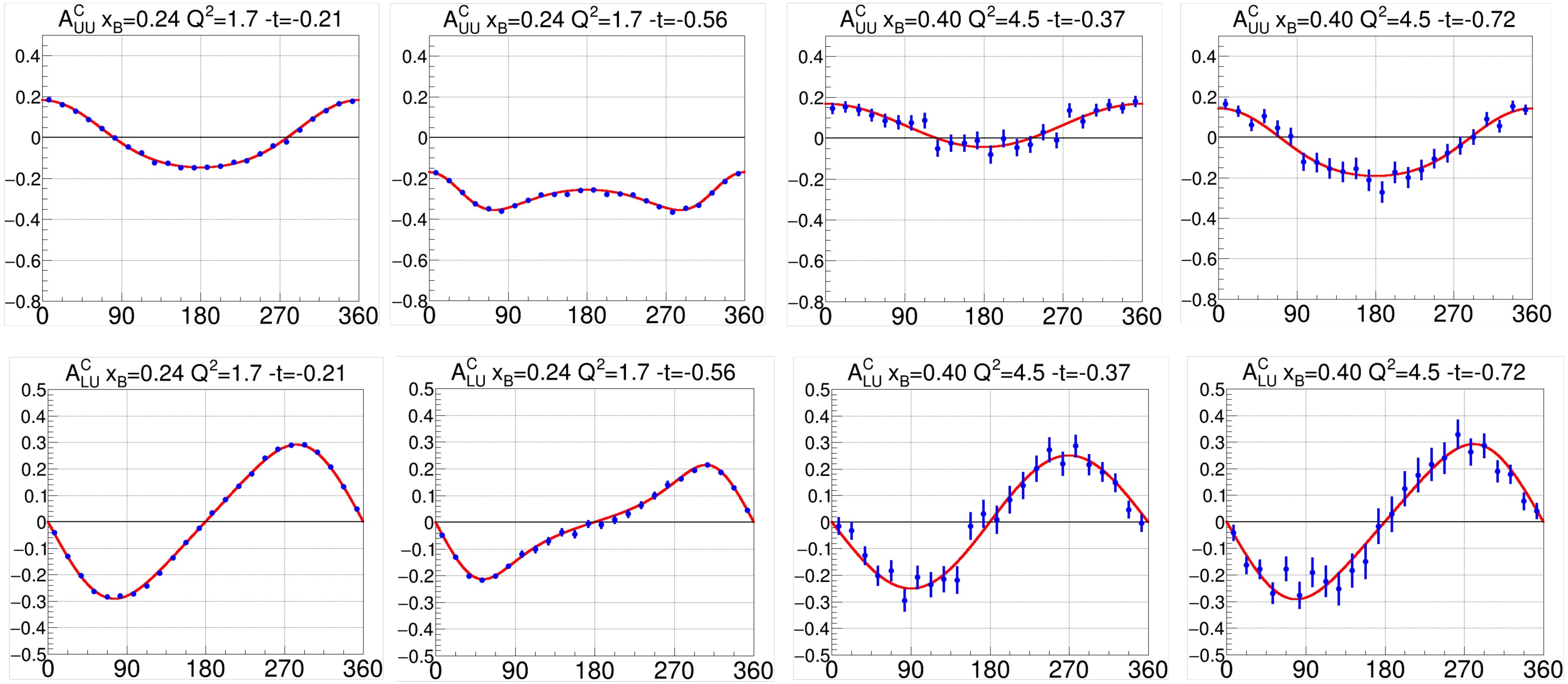
and different beam energies

- 9 days at **2.2** GeV
- 91 days at **10.6** GeV

The experimental strategy assumes 1 Beam Charge Change (BCC), but the experiment would benefit of more frequent changes if BCC can be achieved within an amount of time similar to a beam energy change.

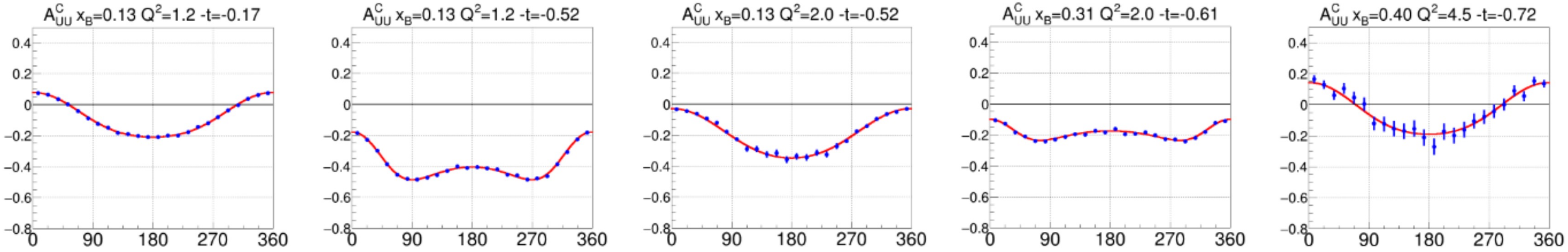
Experimental Projections

- A sample of expected experimental data… 15 bins in (x_B, Q^2) x 6 bins in t = 90 azimuthal dependences per observable (A^C_{UU}, A^C_{LU}).



p-DVCS BCAs @ CLAS12

- We propose to measure **Beam Charge Asymmetries for the DVCS reaction off protons** at 10.6 GeV with **CLAS12** and using **secondary polarized electron and positron beams** over a **100 days** data taking period.
- The **separation** of the **DVCS** and **INT** reaction amplitudes will provide **unambiguous experimental signals** that **uniquely determine CFFs**, particularly $\mathfrak{Re}[\mathcal{H}]$ for the proposed experiment.



The direct access to the real part of the INT amplitude when comparing electron and positron beams constitutes a major step forward for DVCS studies.

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

Additional slides …

PR12+23-002

E. Voutier, V. Burkert, S. Niccolai, R. Paremuzyan et al.

Proposal to PAC51

PR12+23-002

Beam Charge Asymmetries for Deeply Virtual Compton Scattering on the Proton at CLAS12

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a CLAS Collaboration and

Jefferson Lab Positron Working Group

Proposal

22 May 2023

A Collaboration of

76 Physicists
from
21 Institutions

with the support of the

CLAS Collaboration
and the
JLab Positron Working Group

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IJCLab Irène Joliot-Curie

Gravitational Form Factor

V. Burkert, L. Elouadrhiri, F.-X. Girod, Nature 557 (2018) 396
K. Kumerički, Nature 570 (2019) E1
M.V. Polyakov, P. Schweitzer, Int. J. Mod. Phys. A33 (2018) 1830025

$$\int_{-1}^{1} x\, H(x,\xi,t)\, dx = M_2(t) + \frac{4}{5}\xi^2 d_1(t)$$

The 2nd **Mellin moment** of GPDs allows to access the **dynamical content** of hadrons through the **skewness dependency** of GPDs.

CFF

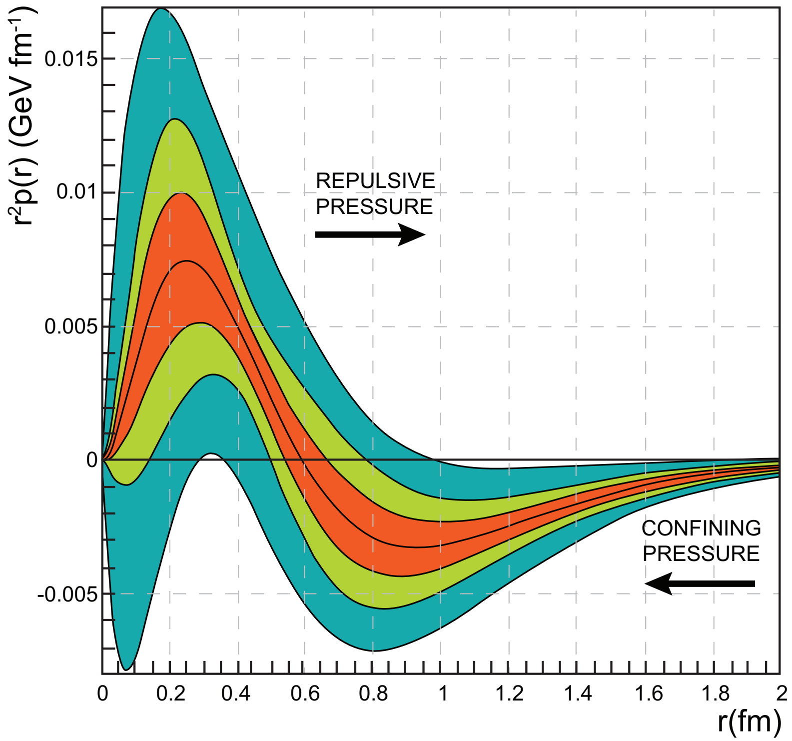
$$\mathcal{H}(\xi,t) = \int_{-1}^{1} \left[\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon} \right] H(x,\xi,t)\, dx$$

$$\mathfrak{Re}[\mathcal{H}(\xi,t)] \overset{\text{LO}}{=} D(t) + \mathcal{P}\left\{ \int_{-1}^{1} \left[\frac{1}{\xi - x} - \frac{1}{\xi + x} \right] \mathfrak{Im}[\mathcal{H}(x,t)]\, dx \right\}$$

$$D(t) = \frac{1}{2} \int_{-1}^{1} \frac{D(z,t)}{1-z}\, dz$$

$$D(z,t) = (1 - z^2)\left[d_1(t)\, C_1^{3/2}(z) + \ldots \right]$$

Real part of Compton form factors (σ_{INT})



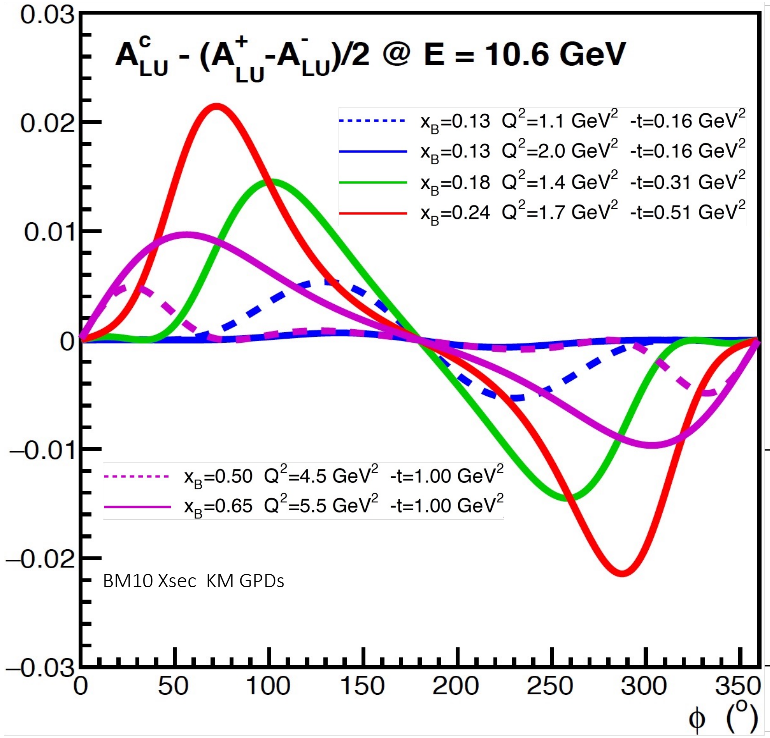
Bethe-Heitler Dominance

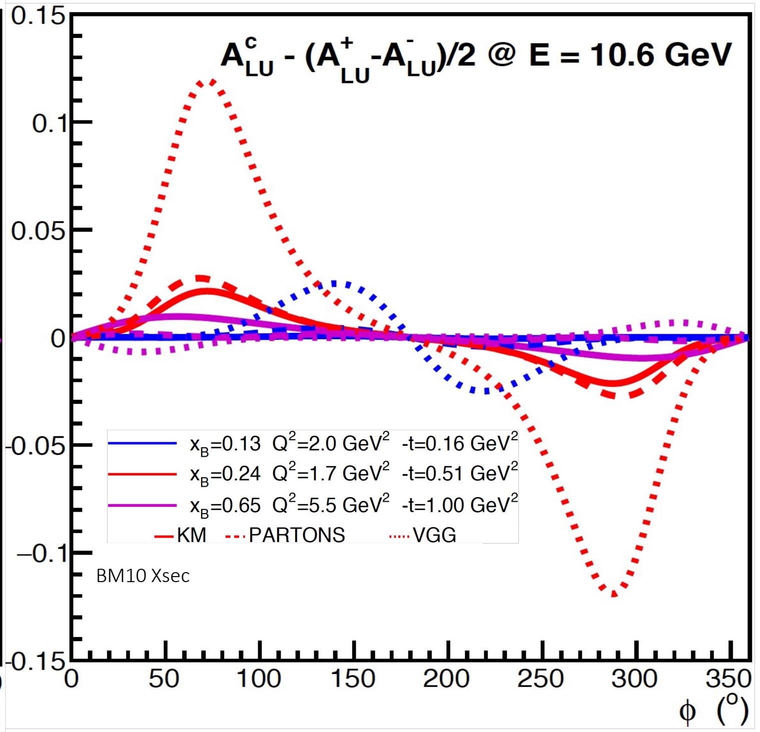
A.V. Belitsky, D. Müller, PRD 82 (2010) 074010 K. Kumerički, D. Müller, NPB 841 (2010) 1

B. Berthou et al. EPJC 78 (2018) 478 M. Vanderhaeghen, P.A.M. Guichon, M. Guidal, PRD 60 (1999) 094017

- If the Bethe-Heitler (**BH**) amplitude dominates the **epγ cross section**, the **polarized BCA** is **linked** to the **positron** and **electron BSA** via the relation

$$A^C_{LU} = (A^+_{LU} - A^-_{LU})/2$$





- BH-dominance is an **hypothesis sensitive** to **GPD-models** which can be investigated at **Ce$^+$BAF** and **CLAS12**.

Experimental configuration

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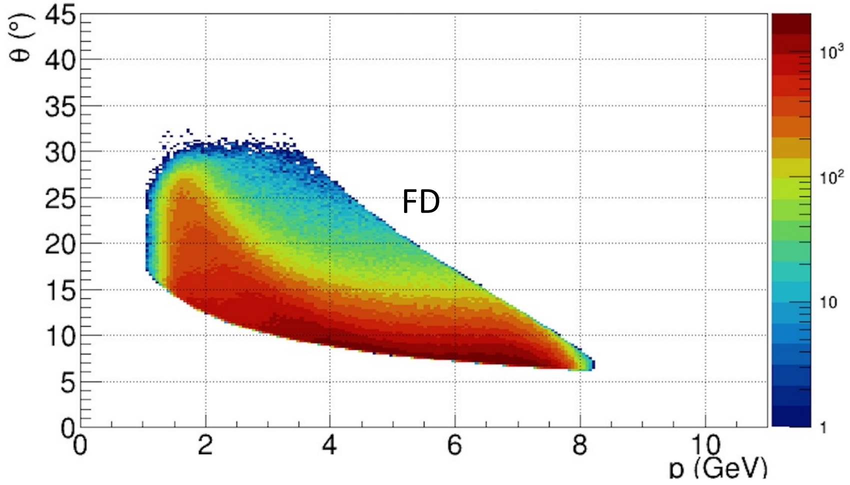
Detector Acceptance

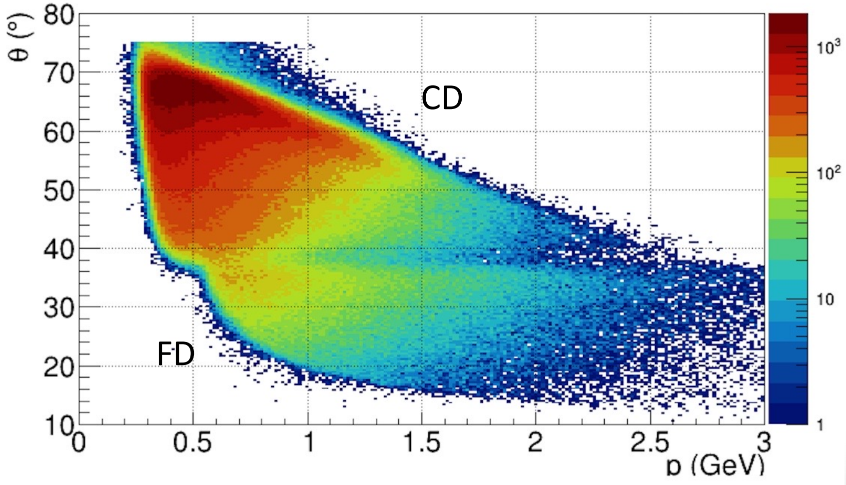
From a subset of out-bending RGA data

- The CLAS12 torus will operate in **OUT-Bending mode**.

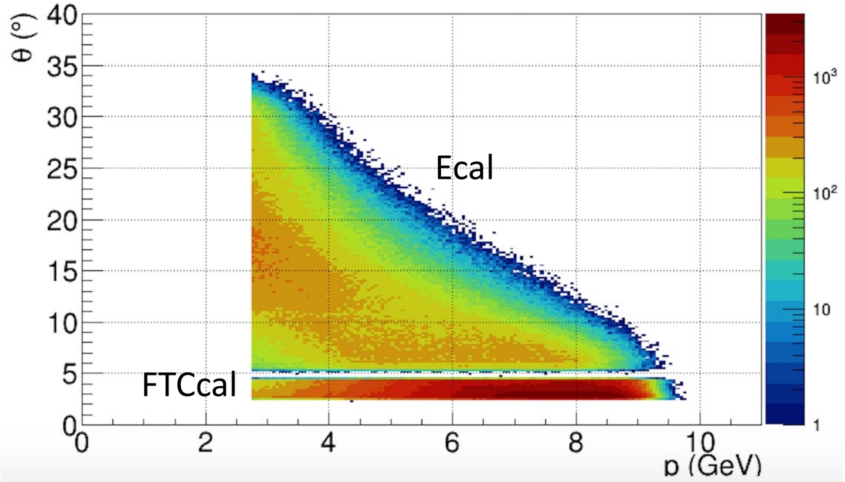
Electron (Positron)



Proton



Photon



- Scattered electrons (positrons) are detected in the Forward Detector (FD).
- Recoil protons are detected essentially in the Central Detector (CD), but also in the FD at large $-t$.
- Produced photons are measured in the Electromagnetic Calorimeter (Ecal) of the FD and in the Forward Tagger Calorimeter (FTCal).

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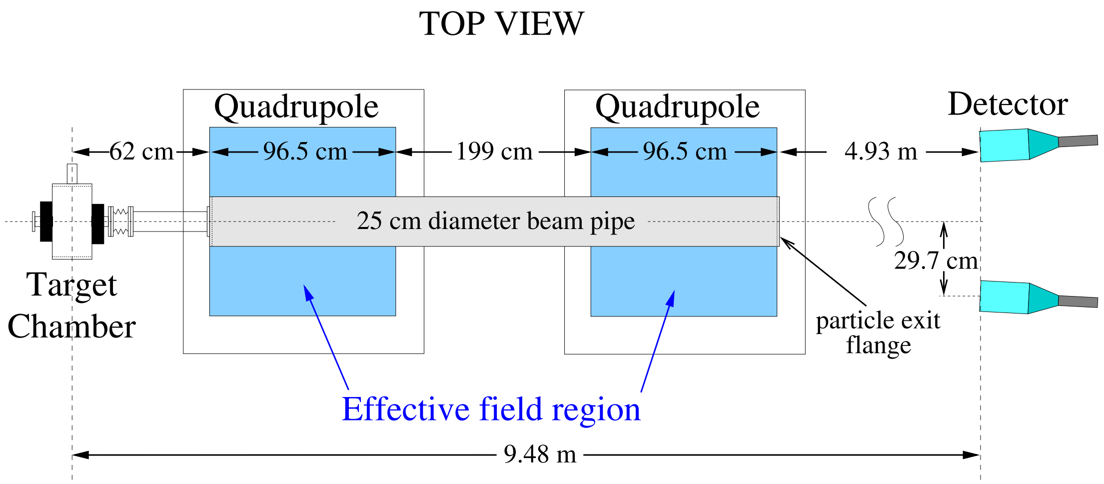
Møller/Bhabha Polarimeter

- **Bhabha asymmetries** are **identical** to **Møller's**, and **cross sections** are **similar magnitude** at 90°c.m.



$$A_{ZZ}(\theta_{cm}) = -\frac{(7+\cos\theta_{cm})\sin^2\theta_{cm}}{(3+\cos^2\theta_{cm})^2}$$

- Tapez une équation ici.The transition of the **Møller** polarimeter into a **Bhabha** polarimeter will be achieved by adaptating the detector configuration to allow for single (**e^+**) and/or coincidence (**e^+e^-**) detection at 90°c.m.

On-going design & optimization…

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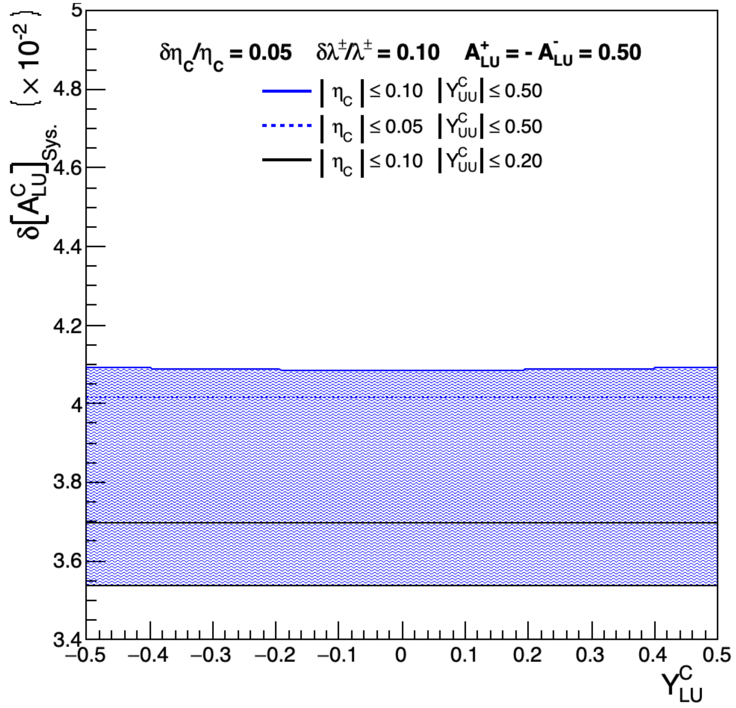
Systematic Effects

- The measurement of polarized **BCAs** is comparable to the measurement of **relative cross sections** where some systematical effects cancel out while others ask for careful control and monitoring.

$$\delta[A^C_{LU}]_{Sys.} = \left[\left(\frac{\mathcal{Y}^C_{LU}\mathcal{Y}^C_{UU} - \mathcal{Y}^0_{LU}}{(1+\eta_C-\eta_C\mathcal{Y}^C_{UU})^2}\,\delta\eta_C \right)^2 + \left(\frac{1}{2}\,\frac{A^+_{LU}(1+\mathcal{Y}^C_{UU})}{1+\eta_C-\eta_C\mathcal{Y}^C_{UU}}\,\frac{\delta\lambda^+}{\lambda^+} \right)^2 + \left(\frac{1+2\eta_C}{2}\,\frac{A^-_{LU}(1-\mathcal{Y}^C_{UU})}{1+\eta_C-\eta_C\mathcal{Y}^C_{UU}}\,\frac{\delta\lambda^-}{\lambda^-} \right)^2 \right]^{1/2}$$

$$\eta_C = \frac{1}{2}\left(1 - \frac{\varepsilon^+\Delta\Omega^+}{\varepsilon^-\Delta\Omega^-}\right) \rightarrow A^C_{LU} = \frac{(1+\eta_C)\mathcal{Y}^C_{UU} - \eta_C\mathcal{Y}^0_{LU}}{1+\eta_C-\eta_C\mathcal{Y}^C_{UU}}$$

- The accuracy of the knowledge of the **beam polarization** combines with detector systematics to lead to a **minimum absolute systematic uncertainty** which depends on the **beam spin asymmetries**, 0.035 in the example shown here.



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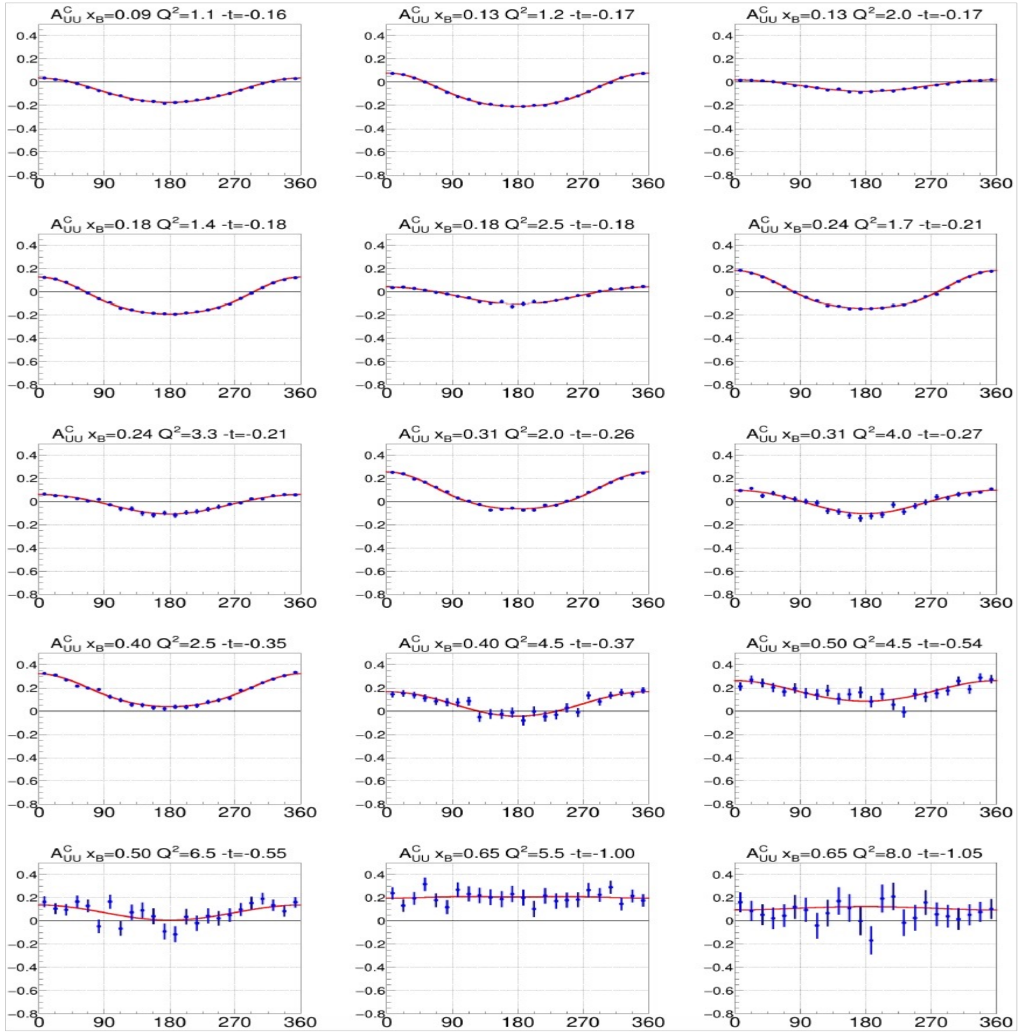
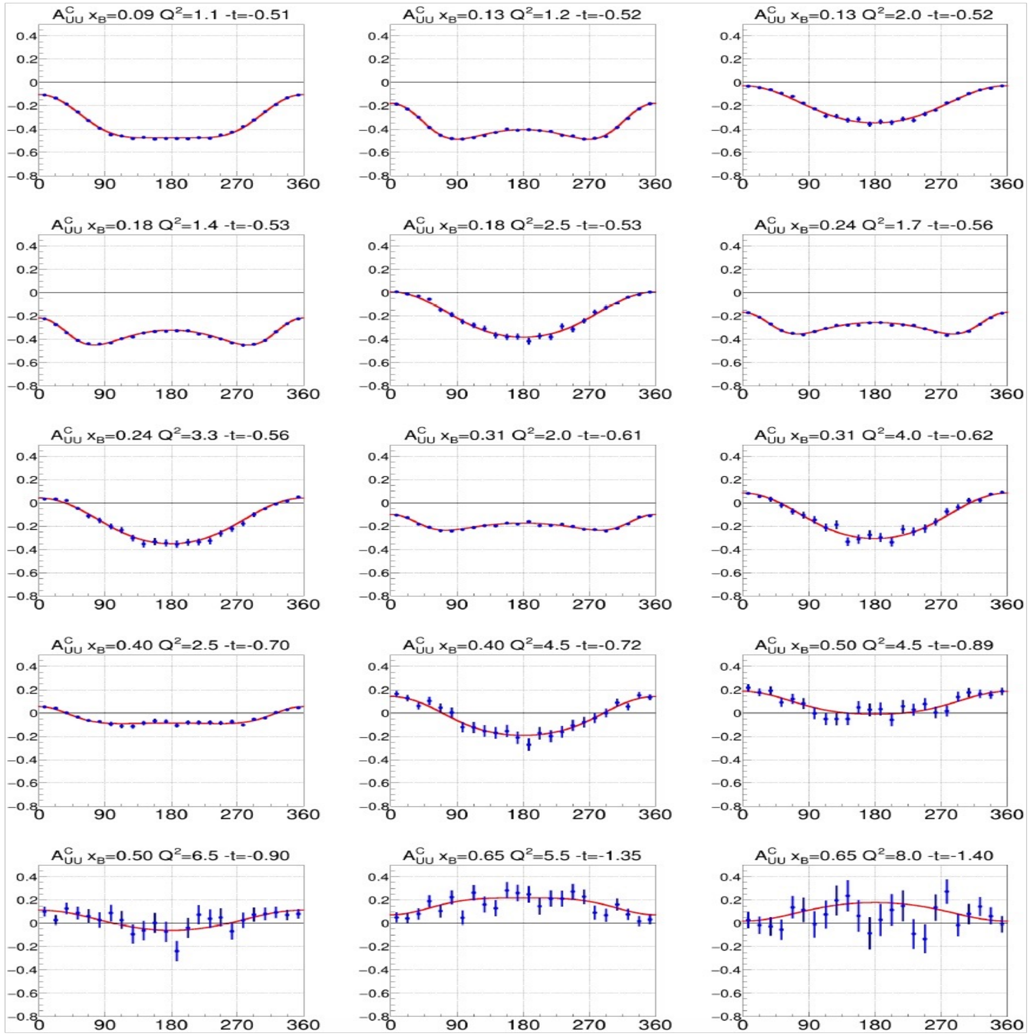
p-DVCS unpolarized BCA @ CLAS12

More projected data…





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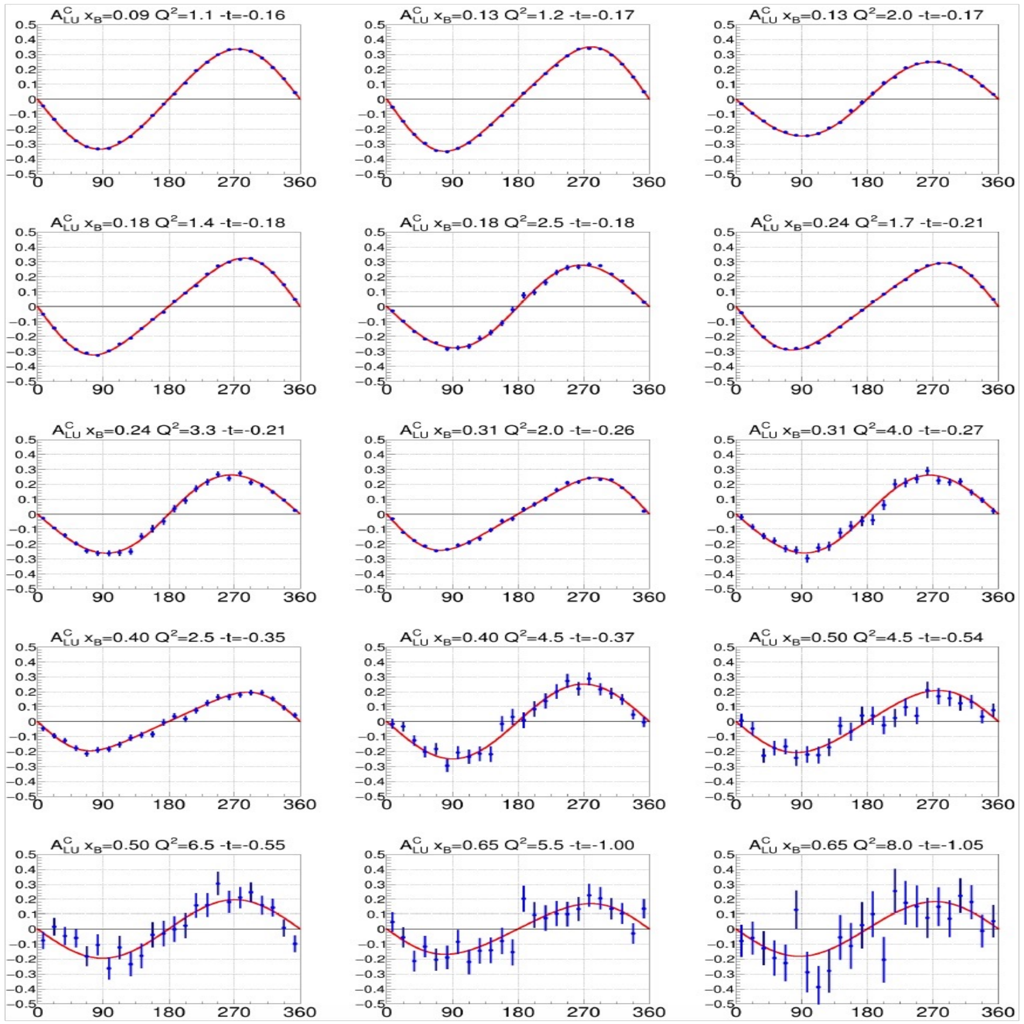
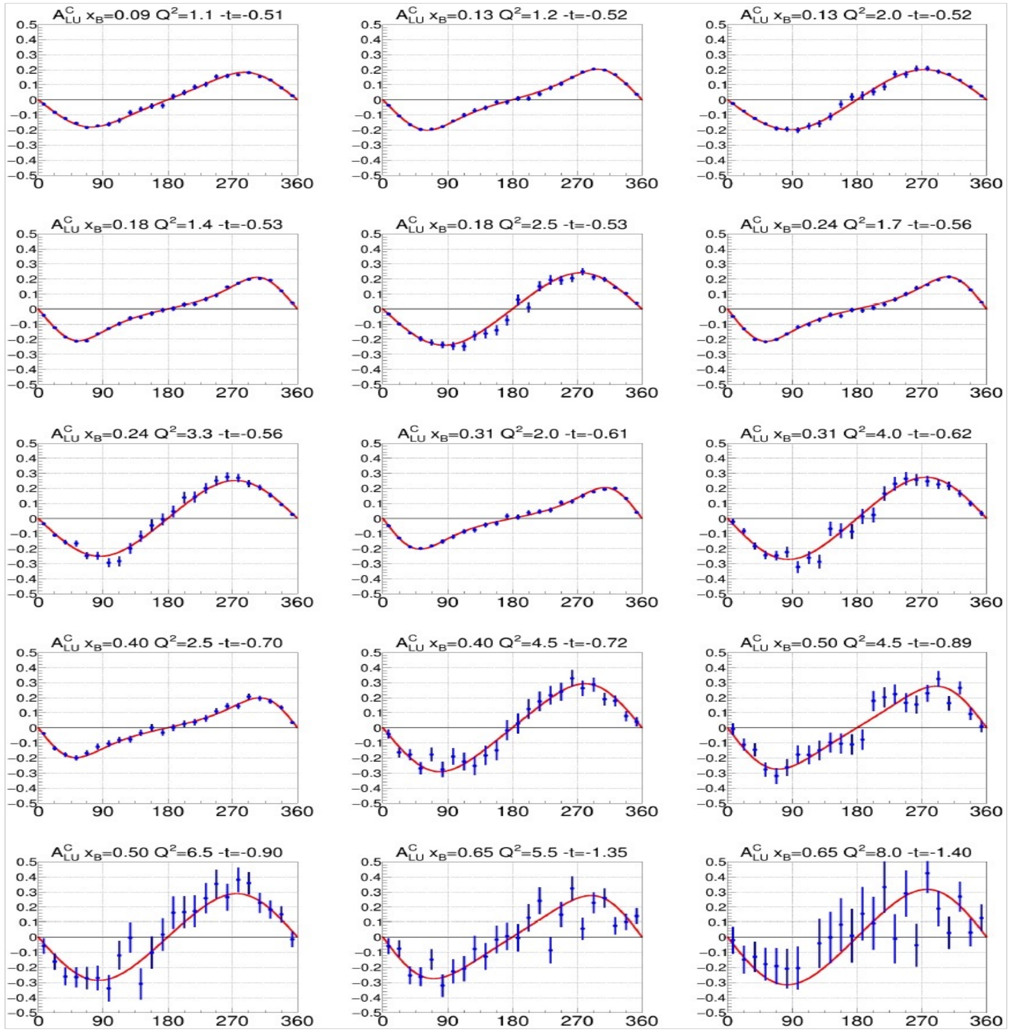
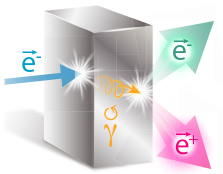
Irène Joliot-Curie

p-DVCS polarized BCA @ CLAS12

More projected data…







Experimental method

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p-DVCS positron BSA @ CLAS12

More projected data…