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

PR12-20-009

V. Burkert[1], L. Elouadrhiri[1], F.-X. Girod[3], S. Niccolai[2], E. Voutier[2]
and the CLAS Collaboration

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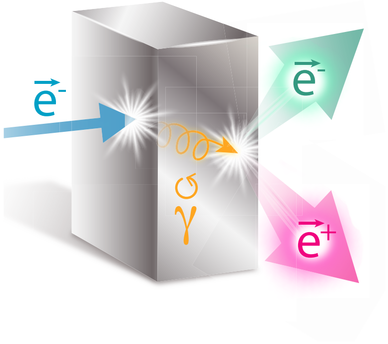
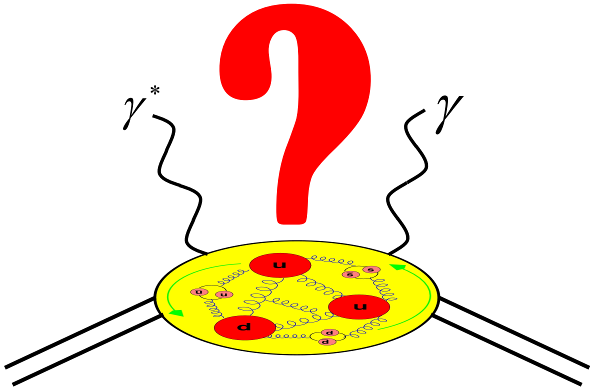
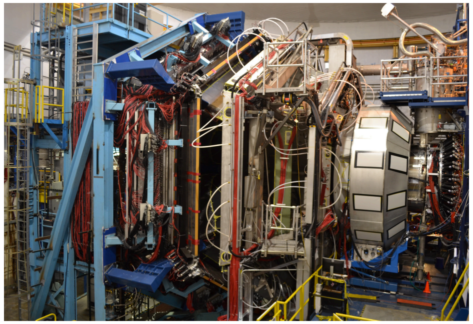
Laboratoire de Physique des 2 Infinis Irène Joliot-Curie (IJCLab), Orsay, France
[3]University of Connecticut, Storrs, CT, USA







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

« We propose to measure the unpolarized and polarized Beam Charge Asymmetries (**BCAs**) of the $\vec{e}^{\pm}p \to e^{\pm}p\gamma$ process on unpolarized Hydrogen with **CLAS12**, using **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 **2400 hours** run with a luminosity of **0.6×10^{35} cm^{-2}·s^{-1}**. »

☛ This proposal follows the Letter-of-Intent LOI12-18-004 discussing the perspectives of an experimental program with positron beams at JLab.

"These measurements all have significant physics interest. The proposers should carefully evaluate feasibility and present the best case possible in a future proposal."

PR12-20-009 ***PR12-20-012*** ***e$^+$@JLab White Paper***

Outline

(i) Generalized parton distributions

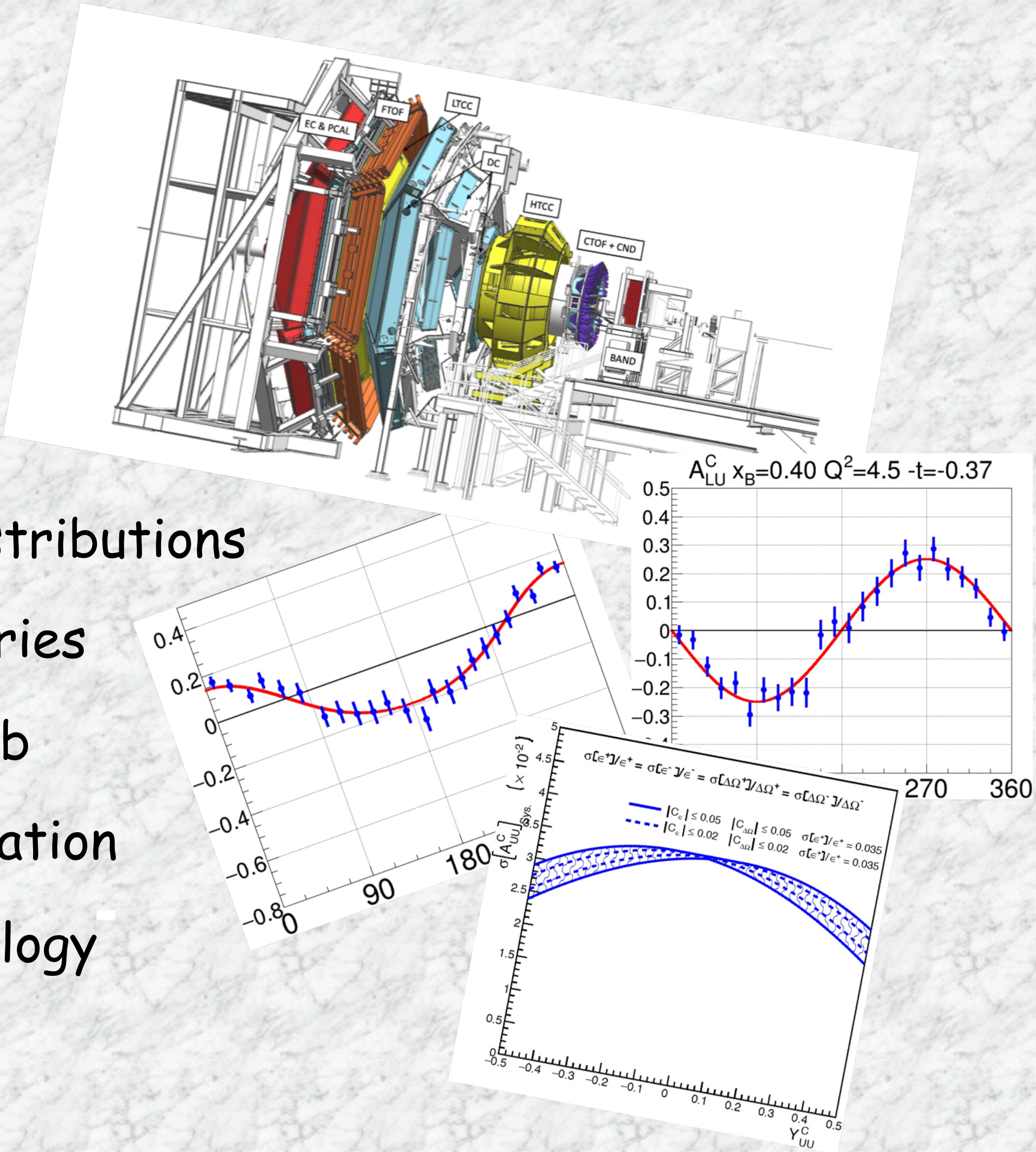
(ii) Beam charge asymmetries

(iii) Positron beams at JLab

(iv) Experimental configuration

(v) Experimental methodology

(vi) Summary

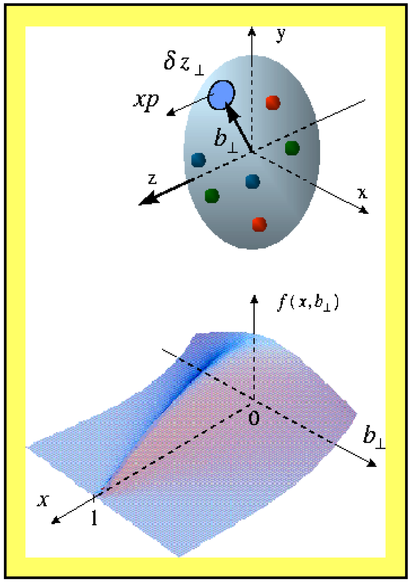


This project has received funding from the European Union’s Horizon 2020 research and innovation program under agreement No 824093.

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

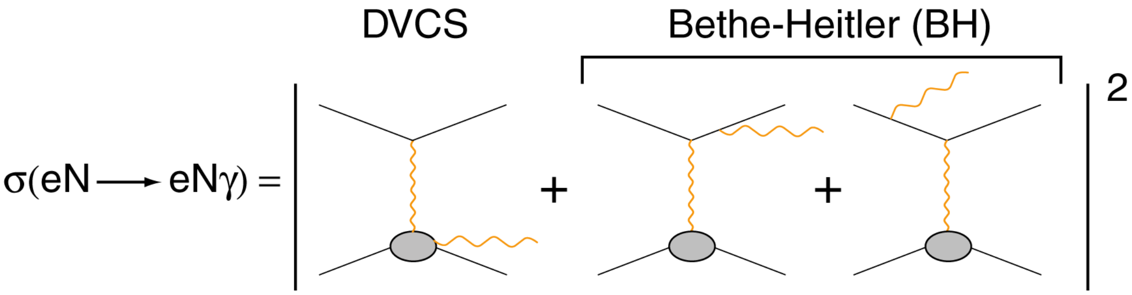
GPDs encode the **correlations between partons** and contain information about the dynamics of the system like the **angular momentum** or the **distribution of the strong forces** experienced by quarks and gluons inside hadrons.

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

A new light on hadron structure

N(e,e'γN) Differential Cross Section

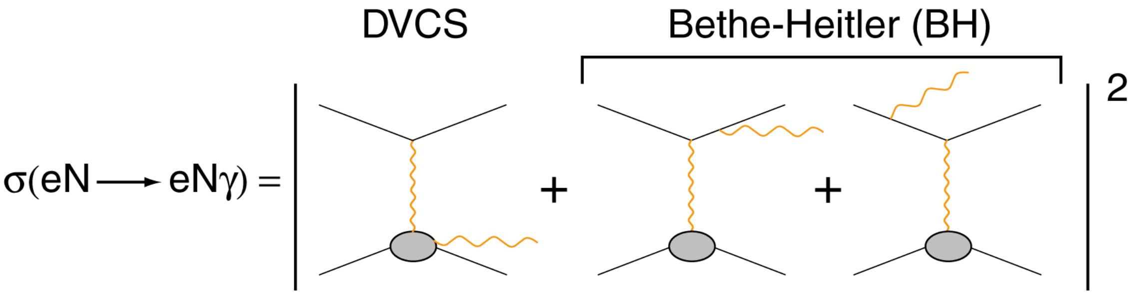
M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009



$$\sigma^{e}_{P0} = \sigma_{BH} + \sigma_{DVCS} + P_1 \tilde{\sigma}_{DVCS} + e_1 \left(\sigma_{INT} + P_1 \tilde{\sigma}_{INT}\right)$$

N(e,e'γN) Differential Cross Section

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



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

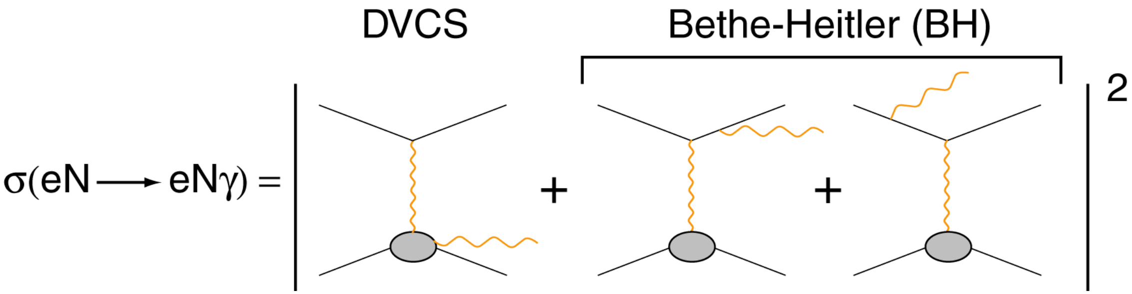
Electron observables

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

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

N(e,e'γN) Differential Cross Section

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



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

Electron & positron observables

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

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

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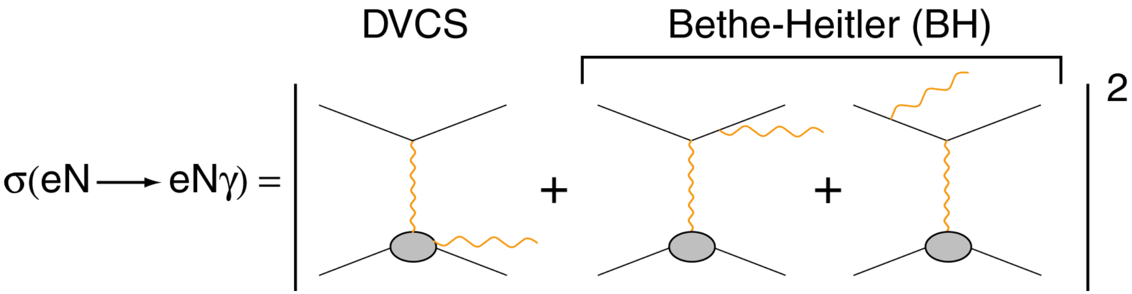

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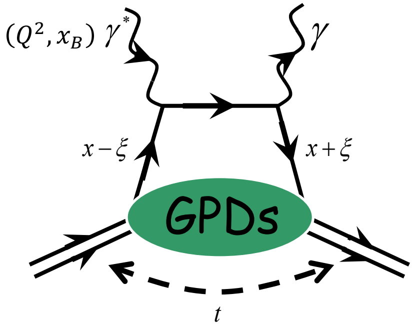
Polarized electrons and positrons allow to **separate** the **unknown amplitudes** of the cross section for electro-production of photons.

Compton Form Factors

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



$\xi \cong x_B/(2-x_B)$

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

- 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 $\{\mathcal{H}, \tilde{\mathcal{H}}, \mathcal{E}, \tilde{\mathcal{E}}\}$.

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

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

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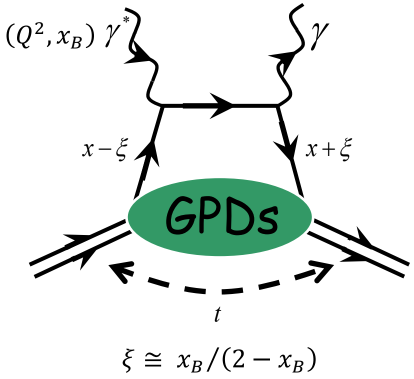

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$$\mathcal{C}^{DVCS} = 4(1-x_B)\left[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right] - x_B^2\left[\mathcal{H}\mathcal{E}^* + \mathcal{E}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}^*\right]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

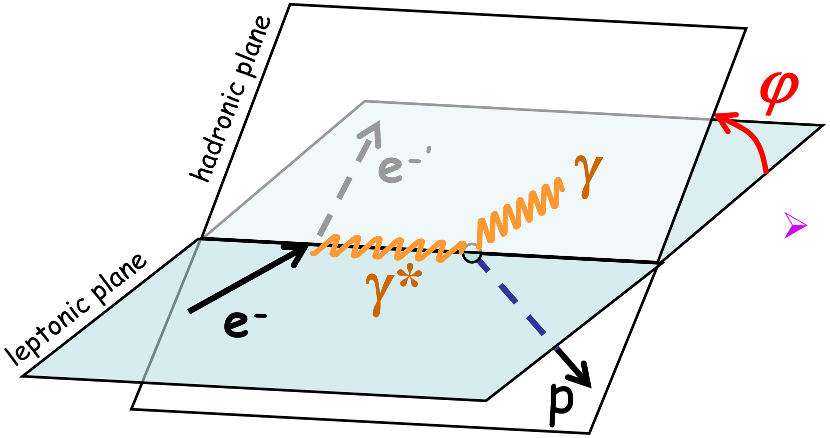
$$\boxed{\mathcal{C}^{INT} = F_1\mathcal{H} - \xi[F_1 + F_2]\widetilde{\mathcal{H}} - \frac{t}{4M^2}\mathcal{E}}$$

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)

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



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

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

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

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

$$\sigma_{DVCS} = c_0^{DVCS}\,\Re e[\mathcal{C}^{DVCS}]$$

$$\tilde{\sigma}_{DVCS} = 0$$

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

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

Gravitational Form Factors

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

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

The 2nd **Mellin moment** of GPDs allows to access the pressure distribution inside hadrons through the **skewness dependency** of GPDs.

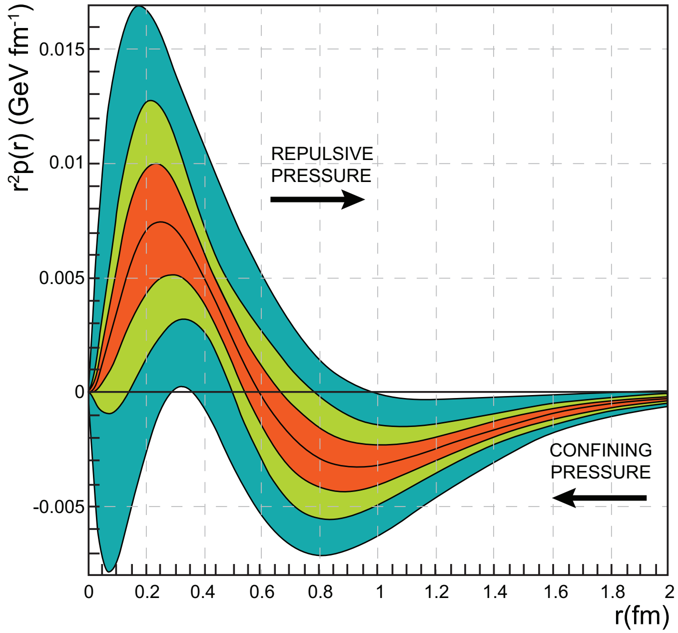
CFF

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

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

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

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



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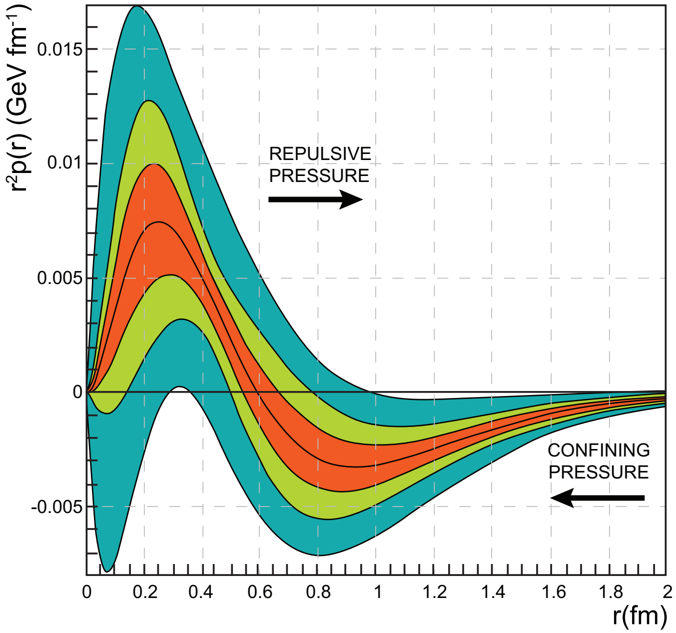

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⇒

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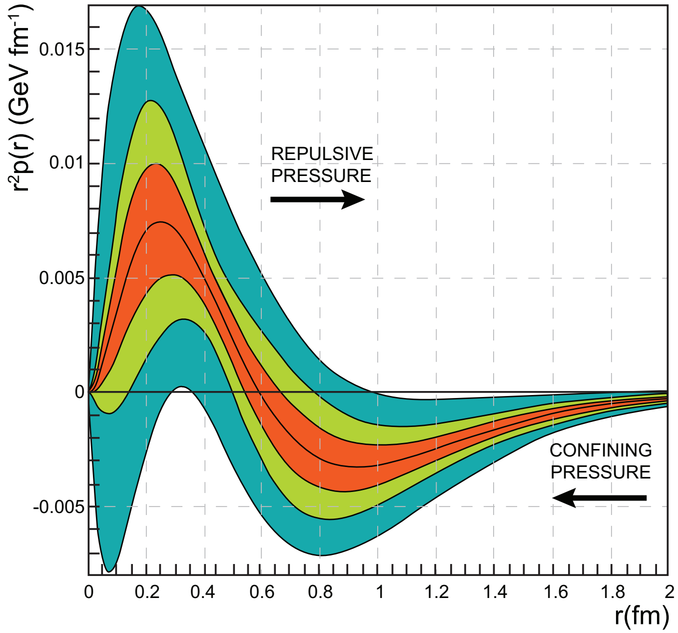


Real part of Compton form factors (σ_{INT})

Beam Charge Asymmetries

Proposed Measurements

Using polarized electron and positron beams, we are proposing to measure

- 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

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

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

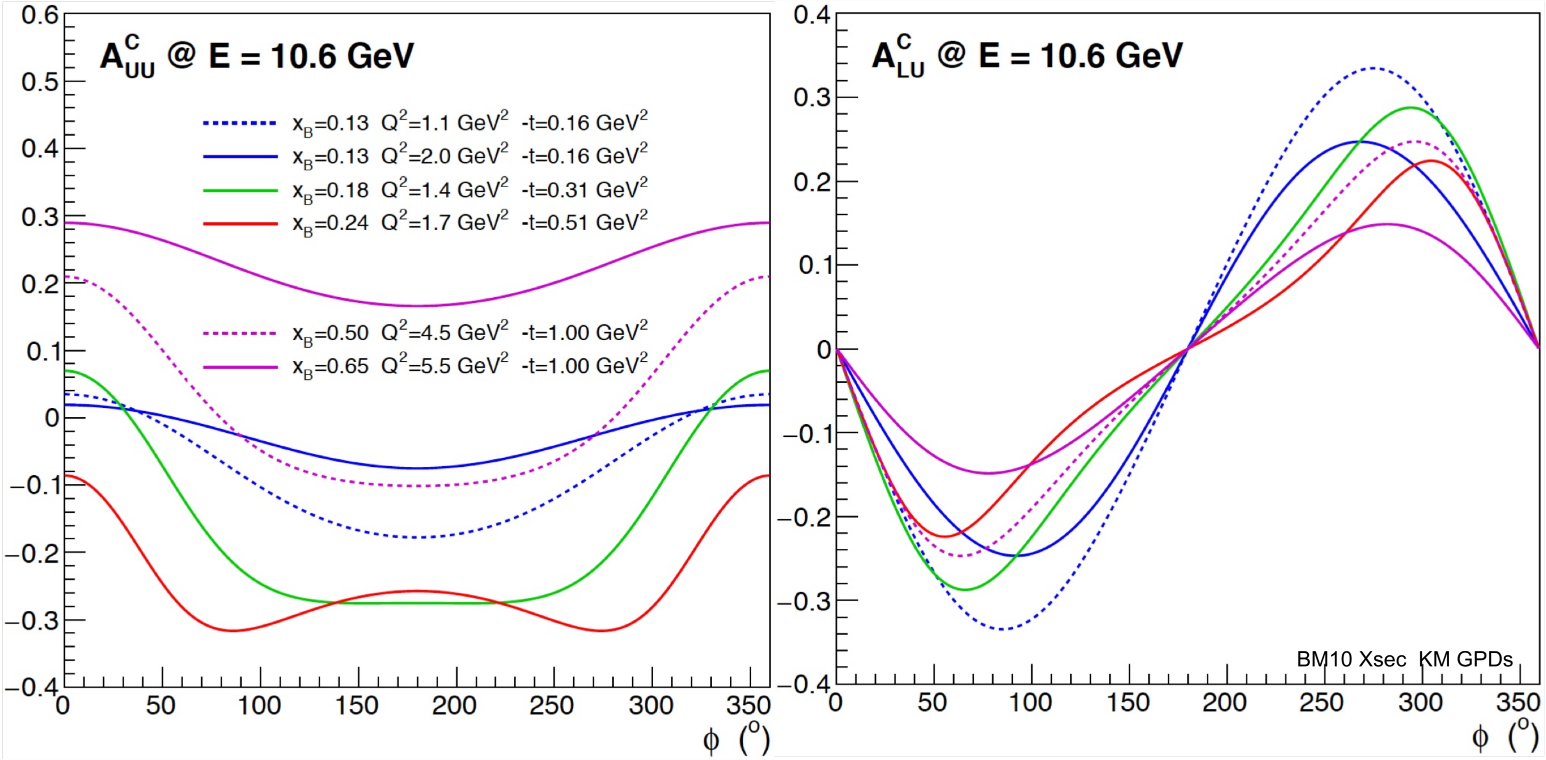
$$A_{LU}^{0} = \frac{(Y_+^+ + Y_+^-) - (Y_-^+ + Y_-^-)}{Y_+^+ + Y_-^+ + Y_+^- + Y_-^-} = \frac{\tilde{\sigma}_{DVCS}}{\sigma_{BH} + \sigma_{DVCS}}$$

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

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

Experimental Signal

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

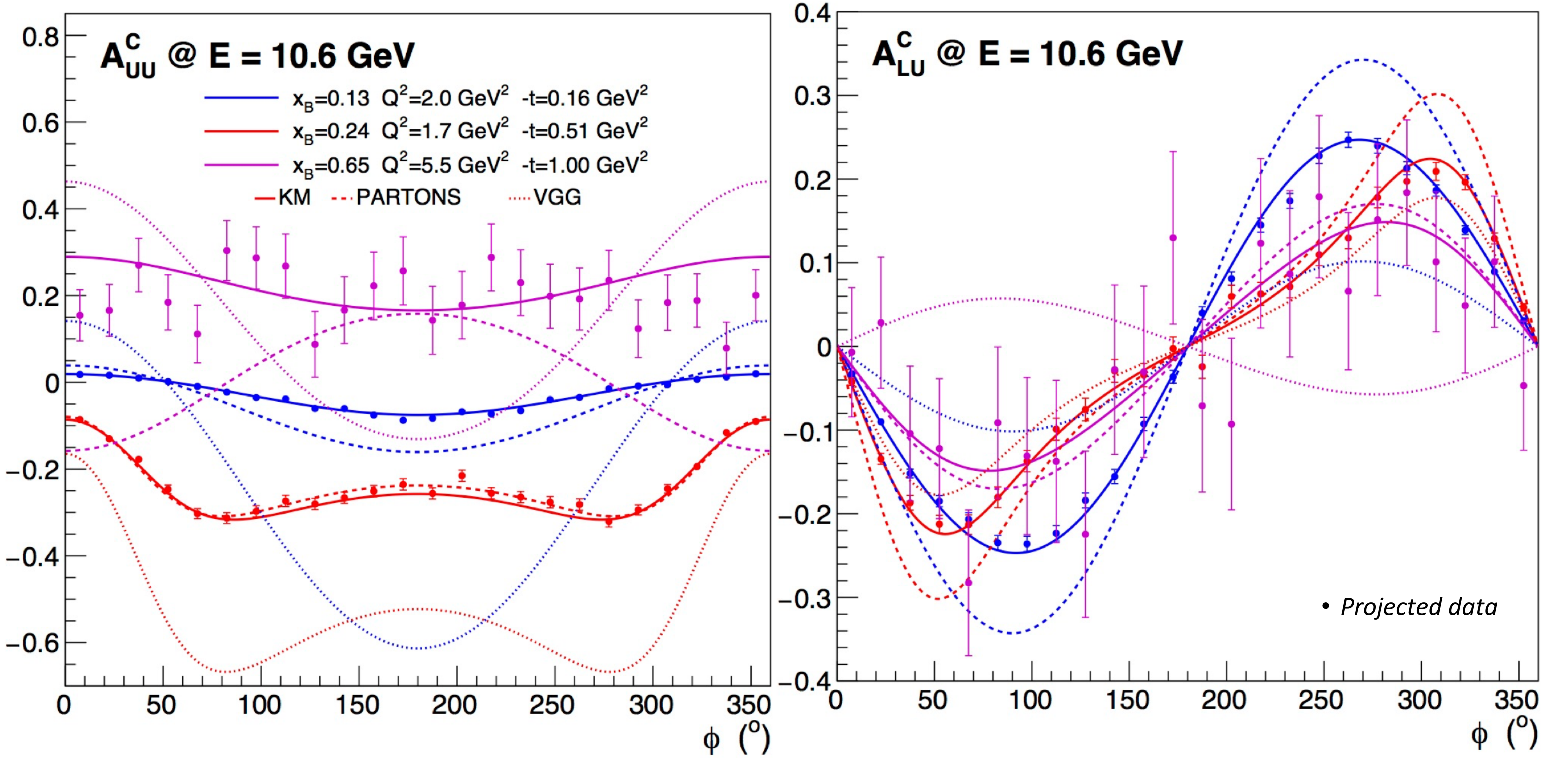


- The **magnitude** of unpolarized and polarized BCAs is **sizeable** and **kinematics dependent**.

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.

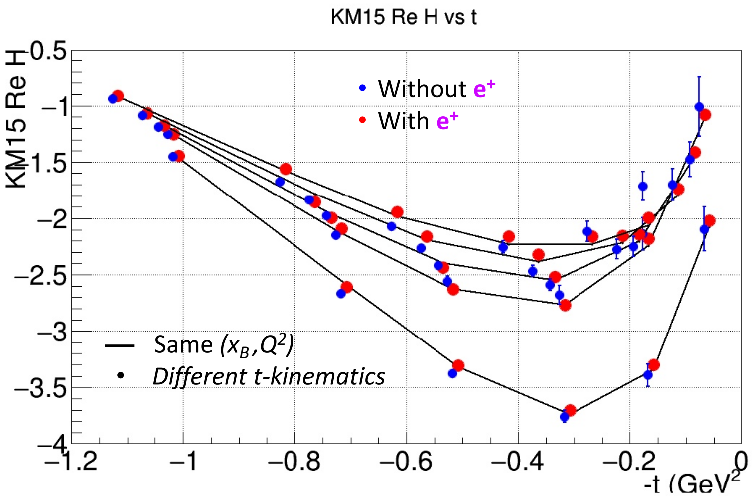
Impact of Positron Measurements

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

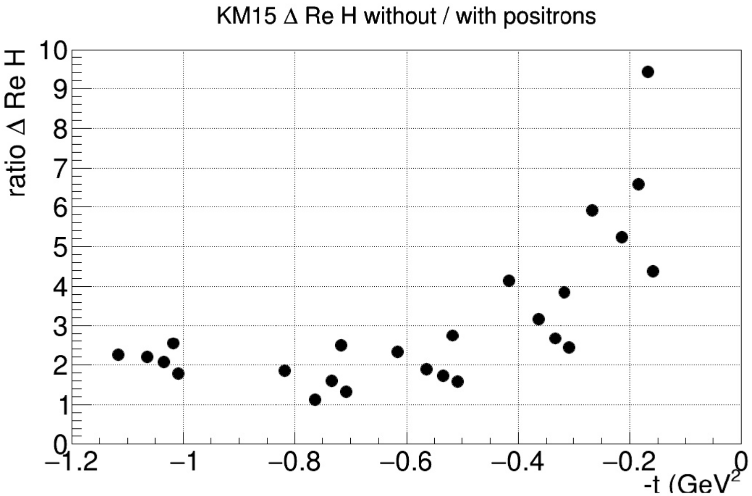
- The importance of positron beams for the determination of CFFs can be quantified in a model-dependent way depending on : the cross section model, the GPDs model, and the hypotheses of the fitting approach.

Observable	σ_{UU}	A_{LU}	A_{UL}	A_{LL}	A^C_{UU}	A^C_{LU}
Sytematics (%)	5	3	3	3⊕3	3	3

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



Purity of e⁺ observables



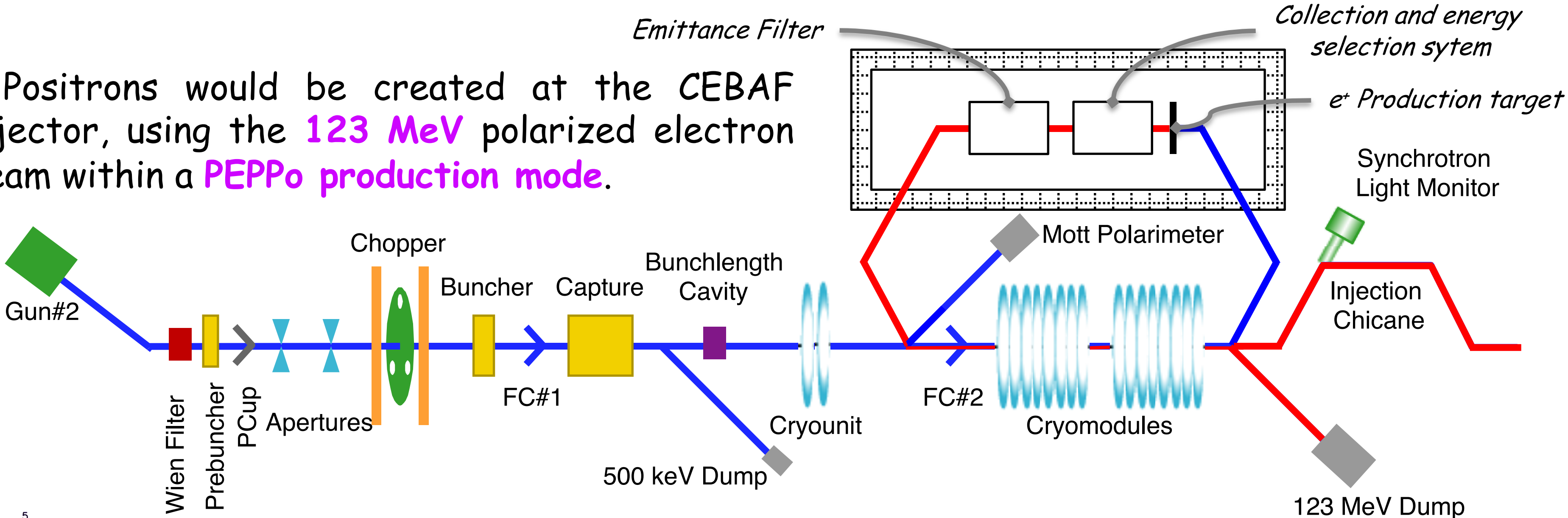
Reduction of CFF correlations

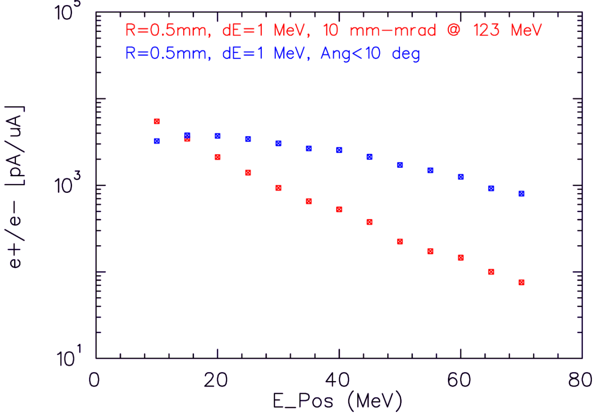
○ Improvement of the **statistical** and **systematical** error of $\mathfrak{Re}[\mathcal{H}]$.

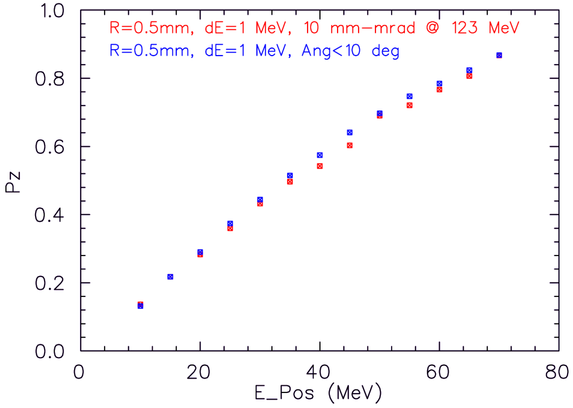
Positron Beam Concept

(PEPPo Collaboration) D. Abbott et al. , PRL 116 (2016) 214801   L. Cardman et al. (JPos17) AIP CP 1970 (2018) 050001

- Positrons would be created at the CEBAF injector, using the **123 MeV** polarized electron beam within a **PEPPo production mode**.







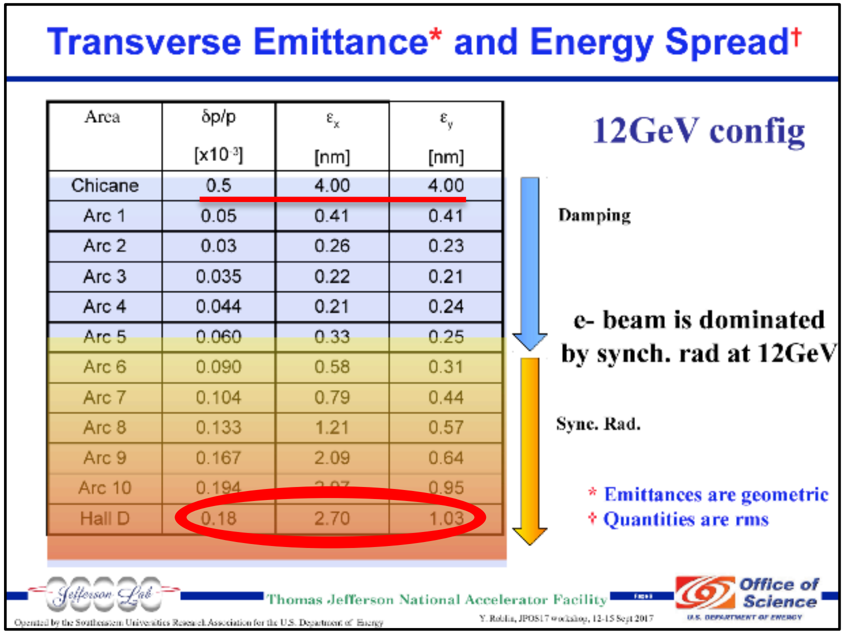
✓ Selecting **60 MeV** positrons maximizes the FoM (**60%**, **100 nA**).

✓ Selecting **6 MeV** positrons maximizes the flux (**0%**, **5 μA**).

Beam Properties

Y. Roblin at the International Workshop on Physics with Positrons at Jefferson Lab, Newport News, September 12-15, 2017

- At the source, the secondary **e^+** beam is much larger momentum dispersion and emittance than the primary **e^-** beam, but has the **same $\delta p/p$** with a spot size **2-3 times larger** at target.



Transverse Emittance* and Energy Spread†

Area	δp/p [x10⁻³]	ε_x [nm]	ε_y [nm]
Chicane	0.5	4.00	4.00
Arc 1	0.05	0.41	0.41
Arc 2	0.03	0.26	0.23
Arc 3	0.035	0.22	0.21
Arc 4	0.044	0.21	0.24
Arc 5	0.060	0.33	0.25
Arc 6	0.090	0.58	0.31
Arc 7	0.104	0.79	0.44
Arc 8	0.133	1.21	0.57
Arc 9	0.167	2.09	0.64
Arc 10	0.194	2.07	0.95
Hall D	0.18	2.70	1.03

12GeV config

Damping

e- beam is dominated by synch. rad at 12GeV

Sync. Rad.

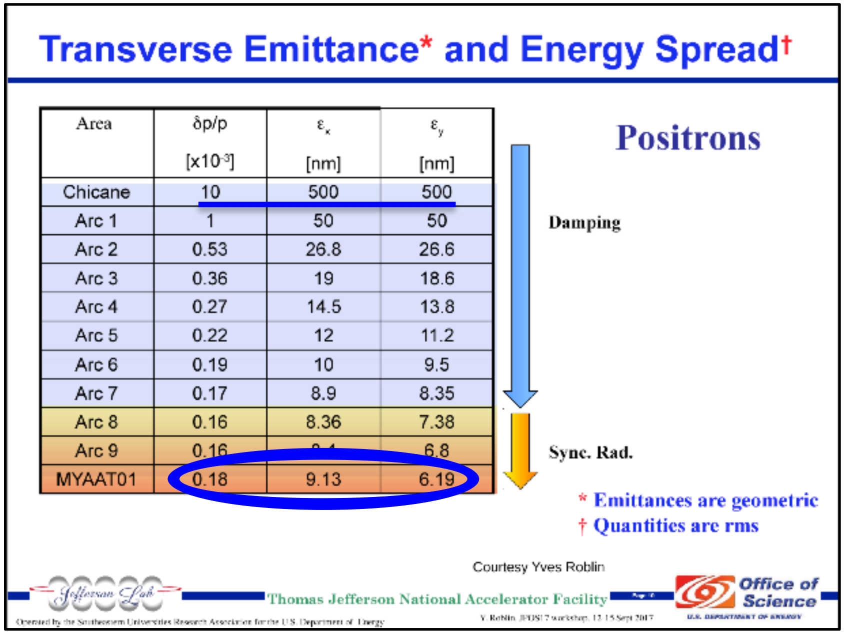
* Emittances are geometric
† Quantities are rms

Thomas Jefferson National Accelerator Facility

Operated by the Southeastern Universities Research Association for the U.S. Department of Energy

Y. Roblin, JPOS17 workshop, 12-15 Sept 2017

Office of Science U.S. DEPARTMENT OF ENERGY



Transverse Emittance* and Energy Spread†

Area	δp/p [x10⁻³]	ε_x [nm]	ε_y [nm]
Chicane	10	500	500
Arc 1	1	50	50
Arc 2	0.53	26.8	26.6
Arc 3	0.36	19	18.6
Arc 4	0.27	14.5	13.8
Arc 5	0.22	12	11.2
Arc 6	0.19	10	9.5
Arc 7	0.17	8.9	8.35
Arc 8	0.16	8.36	7.38
Arc 9	0.16	[illegible]	6.8
MYAAT01	0.18	9.13	6.19

Positrons

Damping

Sync. Rad.

* Emittances are geometric
† Quantities are rms

Courtesy Yves Roblin

Thomas Jefferson National Accelerator Facility

Operated by the Southeastern Universities Research Association for the U.S. Department of Energy

Y. Roblin, JPOS17 workshop, 12-15 Sept 2017

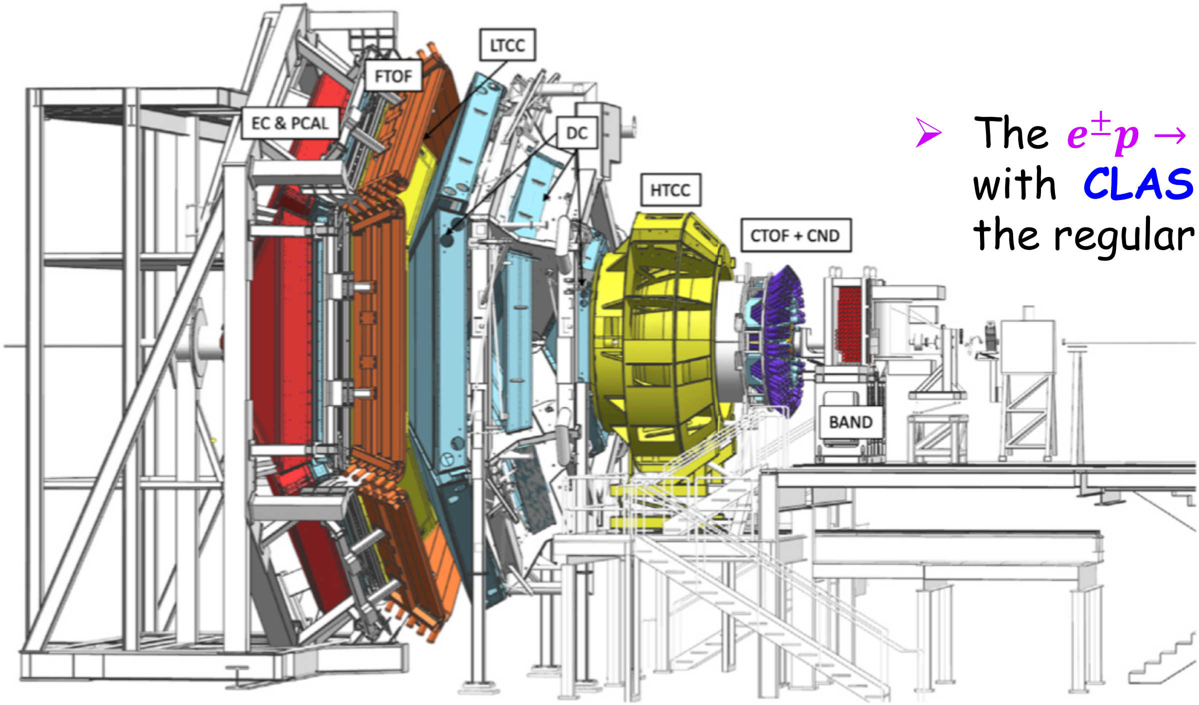
Office of Science U.S. DEPARTMENT OF ENERGY

➡ A **target cell** with **50% larger** (15 mm diameter) entrance and exit **windows** is aniticipated to **avoid** any **interaction** with the target **structure frames**.

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.

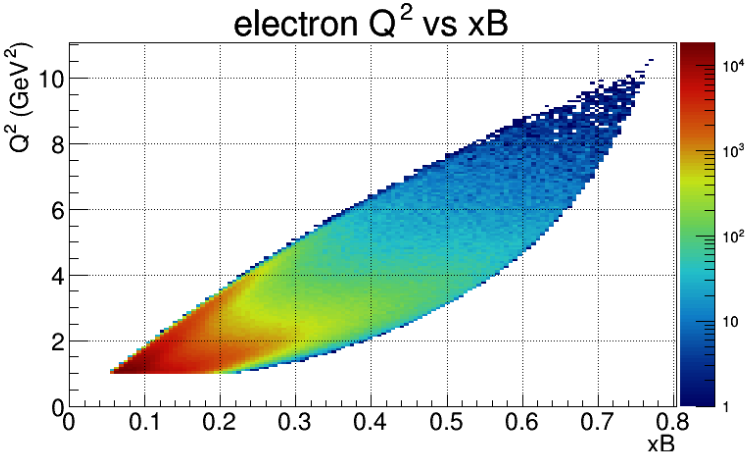
  - $\mathcal{L} = 0.6\times10^{35}\ \mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$
  - New 5 cm LH_2 target cell

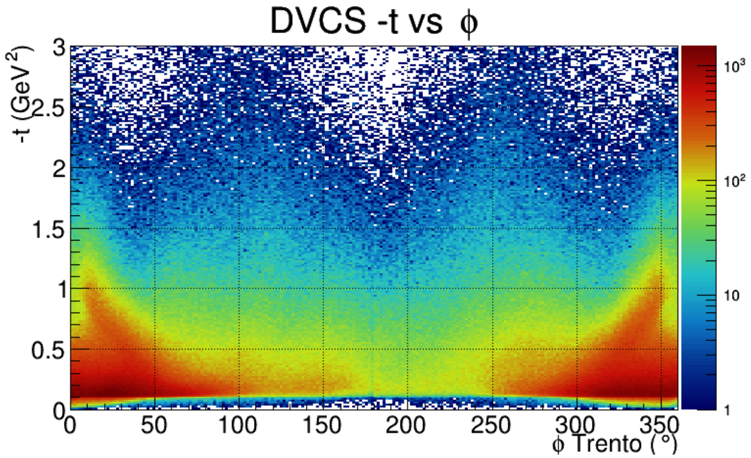
- There is **no difference** bewteen **e⁻** and **e⁺** beam transport in Hall B beam line, nor in beam related detector background.

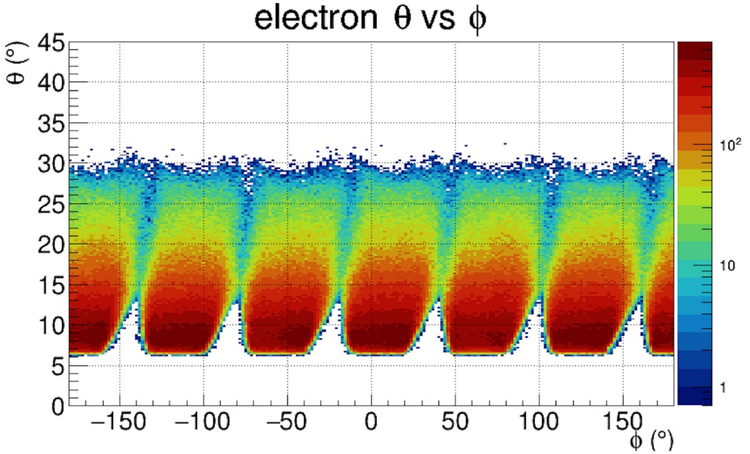
- Beam diagnostics are expected to operate similarly with **e⁻** and **e⁺** beam.

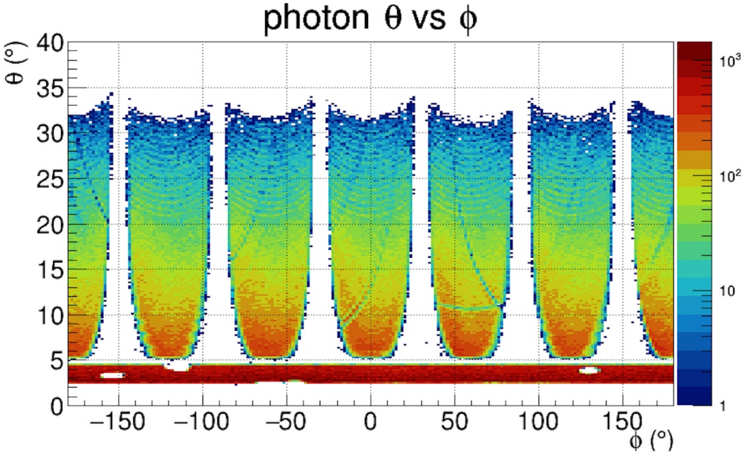
Kinematic Coverage

From a subset of RGA data in OUT-bending mode



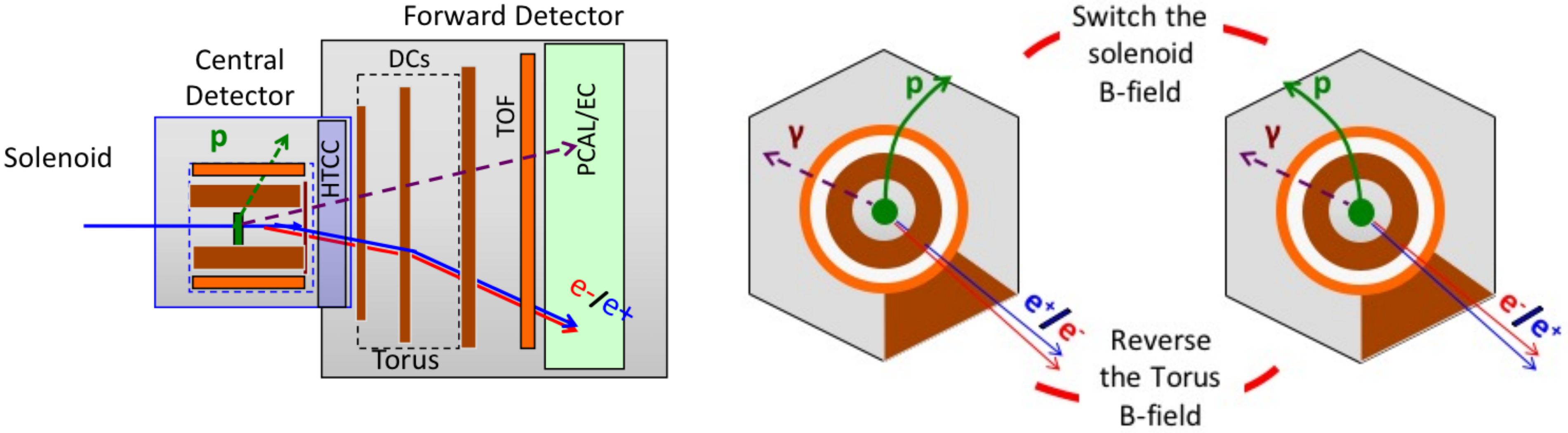






False Asymmetries

- 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 reveals false asymmetries in the Forward Detector, which may creates 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.

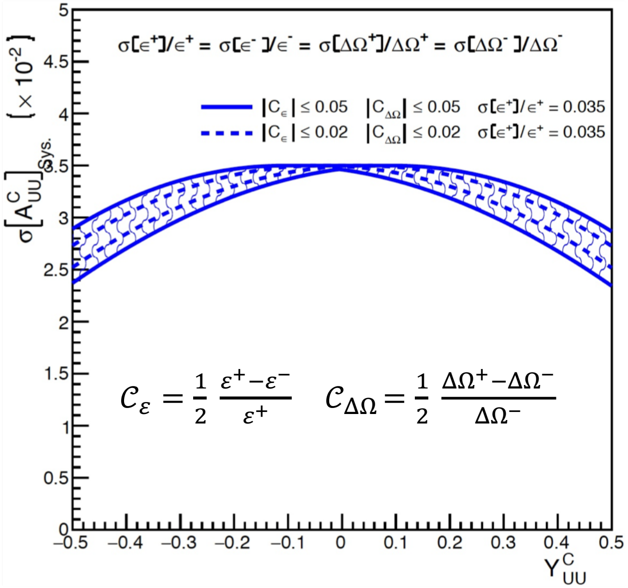
Systematical Effects

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

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)

Systematics projection on A^C_{UU} for **5%** uncertainty on $\varepsilon \cdot \Delta\Omega$.



$$\mathcal{C}_\varepsilon = \frac{1}{2}\,\frac{\varepsilon^+ - \varepsilon^-}{\varepsilon^+} \qquad \mathcal{C}_{\Delta\Omega} = \frac{1}{2}\,\frac{\Delta\Omega^+ - \Delta\Omega^-}{\Delta\Omega^-}$$

Systematical Effects

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

Minizing systematics in e^+/e^- comparison requires:

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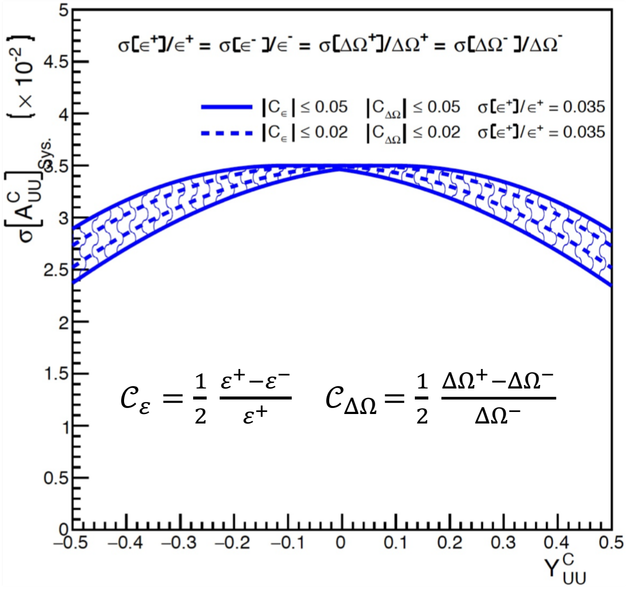
  (accumulated charge, beam polarization)

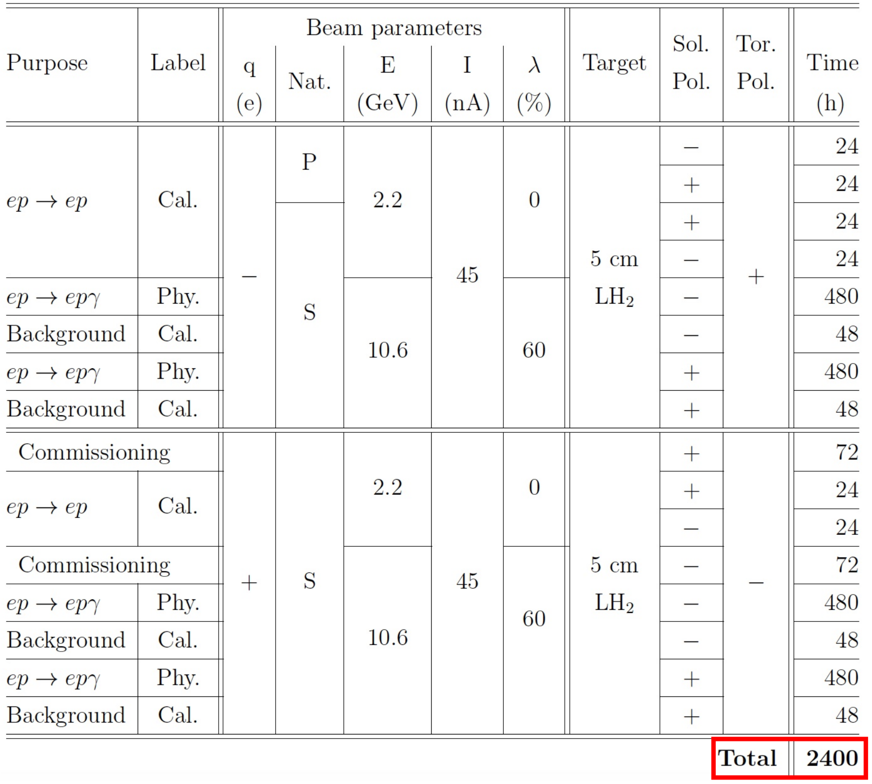
Systematics projection on A_{UU}^{C} for **5%** uncertainty on $\varepsilon \cdot \Delta\Omega$.



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

Beam Time Request

We are asking for a total of **100 days** of beam, operating **CLAS12** with **45 nA e$^-$** and **e$^+$** beams polarized at **60%**, distributed in :



Purpose	Label	Beam parameters					Target	Sol. Pol.	Tor. Pol.	Time (h)
		q (e)	Nat.	E (GeV)	I (nA)	λ (%)				
$ep \to ep$	Cal.	−	P	2.2	45	0	5 cm LH$_2$	−	+	24
								+		24
			S					+		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	45	0	5 cm LH$_2$	+	−	72
$ep \to ep$	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 nature

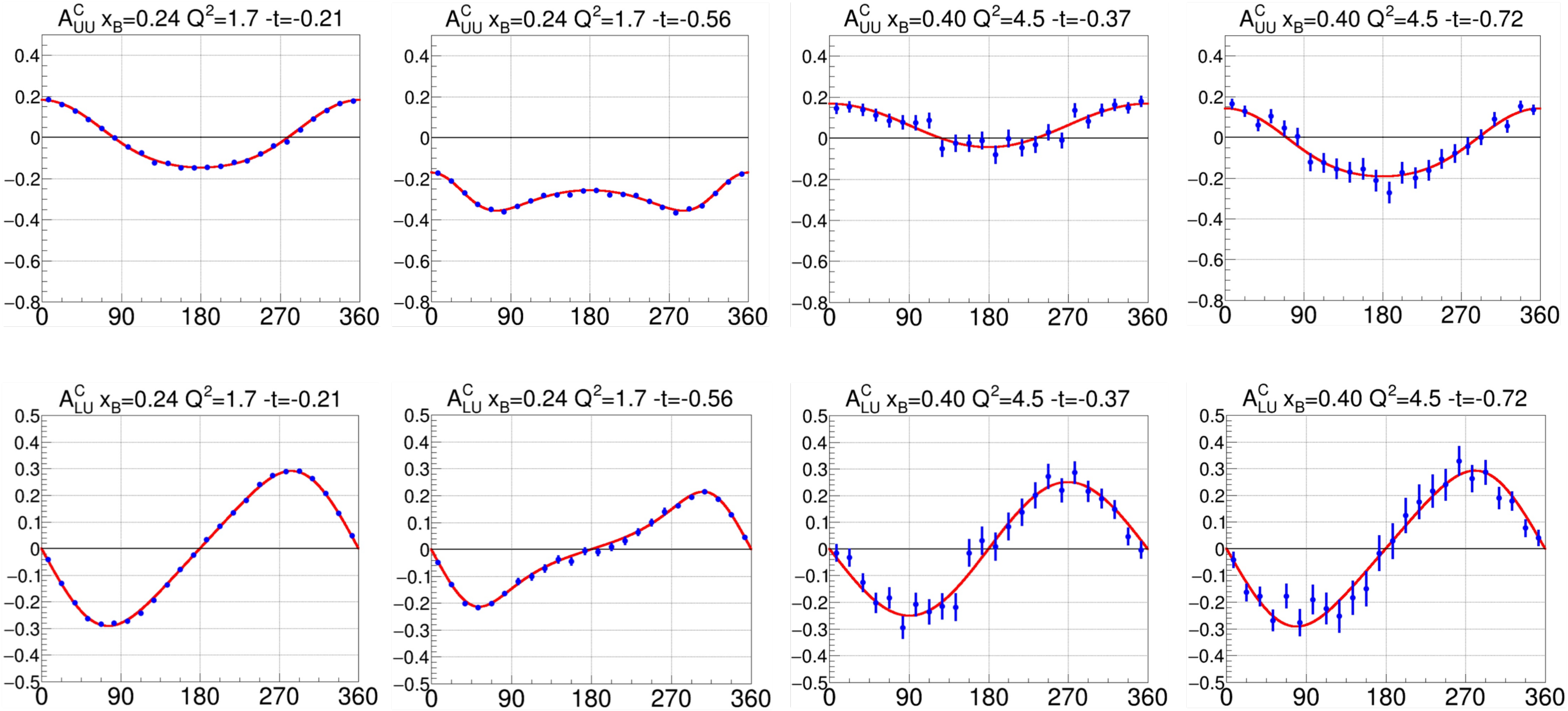
- ○ 2 days with the CEBAF **e$^-$** beam;
- ○ 46 days with the secondary **e$^-$** beam;
- ○ 52 days with the secondary **e$^+$** beam;

and different energies

- ○ 9 days at 2.2 GeV;
- ○ 91 days at 10.6 GeV.

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 the **secondary polarized electron and positron beams** produced at a **PEPPo positron source**, 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.

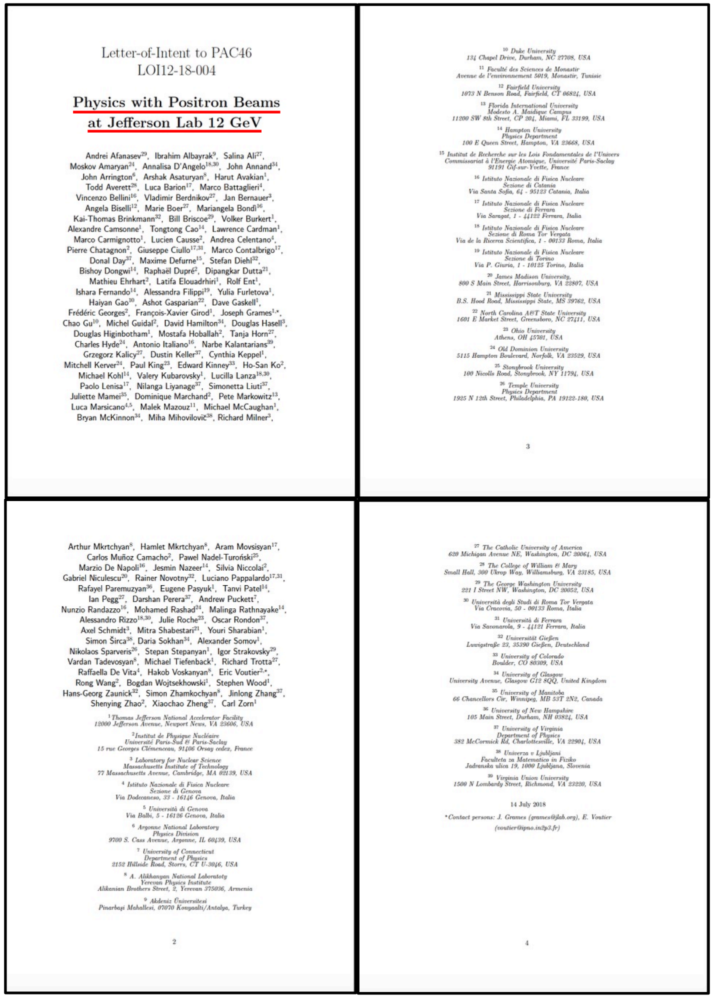
The direct access to the real part of the INT amplitude via positron beams will constitute a major step forward for DVCS studies.

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

Additional Slides …

LOI12-18-004

J. Grames, E. Voutier et al. Jefferson Lab LOI12-18-004 (2018), arXiv:1906.09419



Letter-of-Intent to PAC46
LOI12-18-004

Physics with Positron Beams
at Jefferson Lab 12 GeV

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14 July 2018

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Letter of Intent submitted to JLab PAC46 (July 2018)

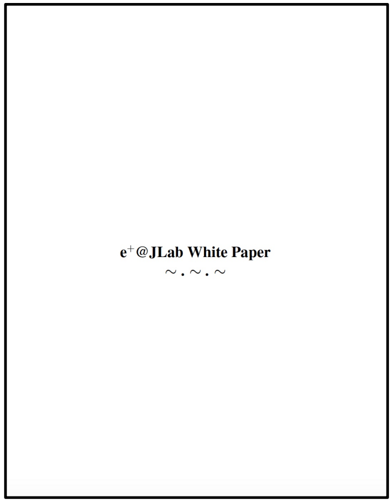
Highlighting **7 mini-LOI's**
Supported by **127 Members** from **39 Institutions**

	I (nA)		Beam	Time
	e^-	e^+	Polarization	(d)
Two-photon exchange				
TPE @ CLAS12	60	60	No	53
TPE @ SupRos	-	1000	No	18
TPE @ SBS	40000	100	Yes	55
Generalized Parton Distributions				
p-DVCS @ CLAS12	75	15	Yes	83
n-DVCS @ CLAS12	60	60	Yes	80
p-DVCS @ Hall C	-	5000	No	56
Test of the Standard Model				
A' search	-	10-100	No	180
			Total Data Taking Time	525

"These measurements all have significant physics interest. The proposers should carefully evaluate feasibility and present the best case possible in a future proposal."

e^+ @ JLab White Paper

A. Accardi et al. JLab-PHY-20-3232, arXiv:2007.15081 (2020)



e^+@JLab White Paper
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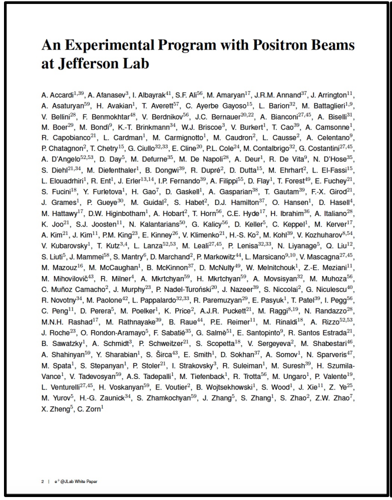

An Experimental Program with Positron Beams at Jefferson Lab

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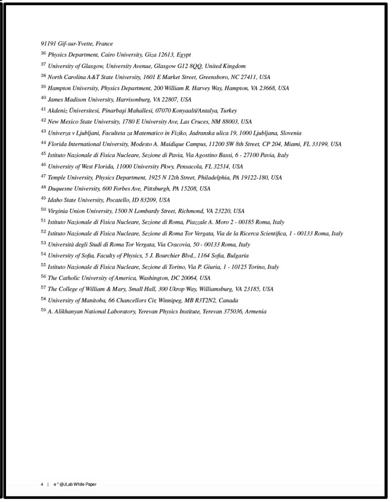

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4 | e^+@JLab White Paper

An experimental program with positron beams at Jefferson Lab

discussing **15** possible **experiments** covering:

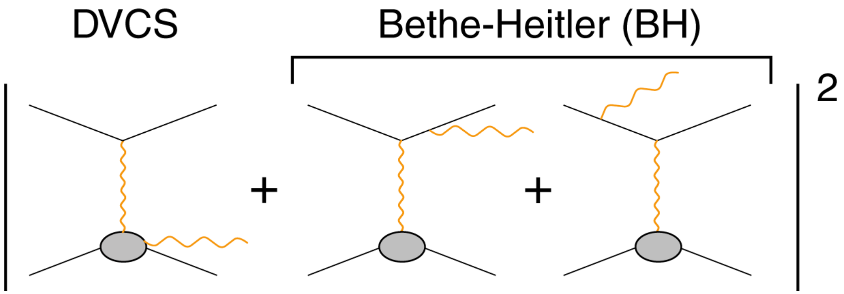
- Generalized Parton Distributions physics,
- Two-Photon Exchange physics,
- Tests of the Standard Model,
- and other specific measurements.

Supported by **197 Members** from **59 Institutions**

N(e,e'γN) Differential Cross Section

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

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



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

Electron observables

Additional observables

Electron & positron observables

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

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

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

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

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

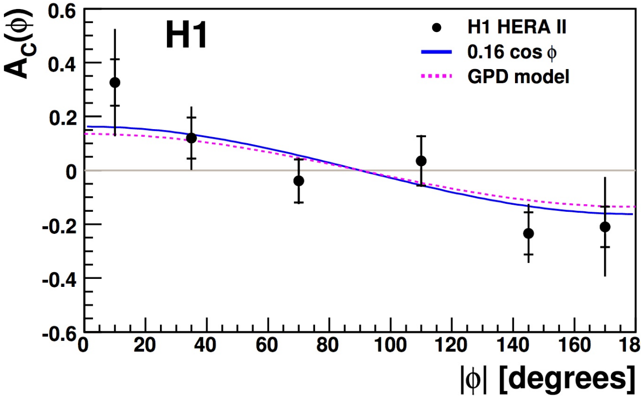
$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\widetilde{\sigma}_{INT}$$

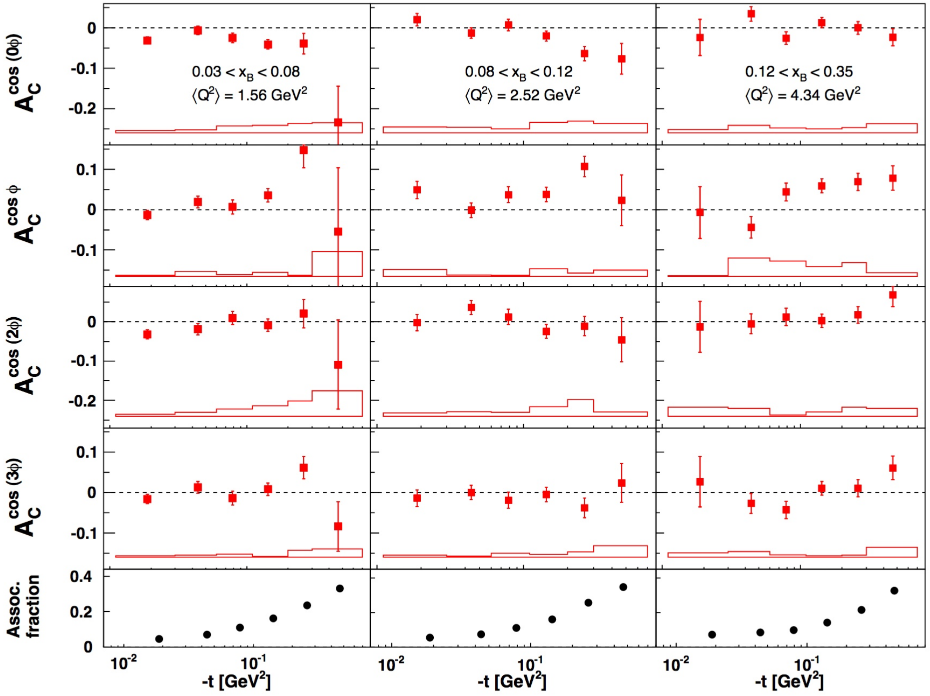
Polarized electrons and positrons allow to **separate** the **unknown amplitudes** of the cross section for electro-production of photons.

Existing Data

(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

- Pioneering measurements of DVCS with electron and positron beams at **HERA demonstrated** the existence of a **BCA-signal**.

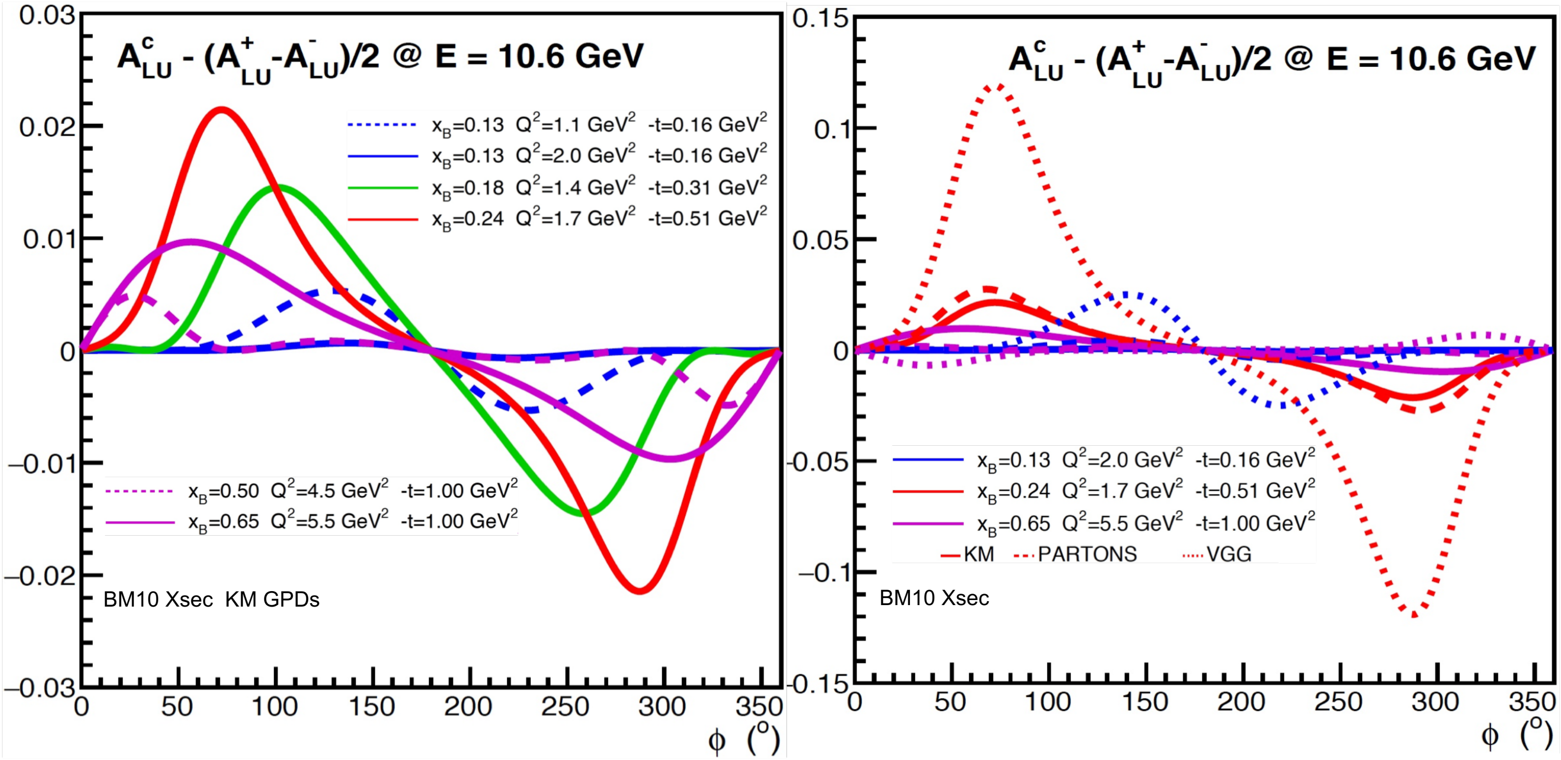




- The **COMPASS** experiment operating high energy $\mu^{\pm}$ beams should release in a near future **BCA data** in the **sea-quark region**.

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

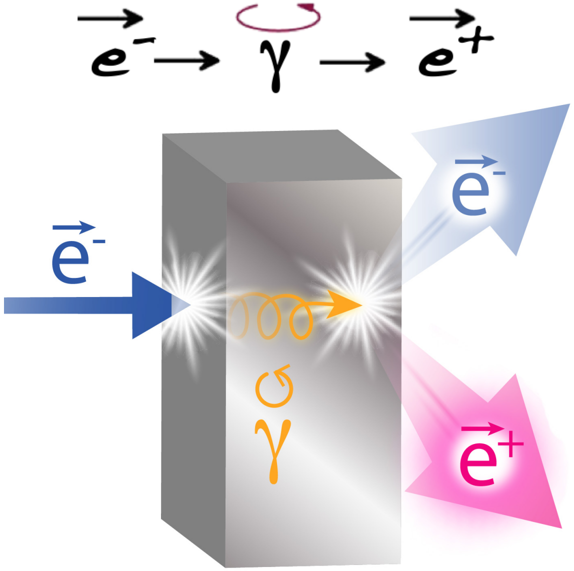


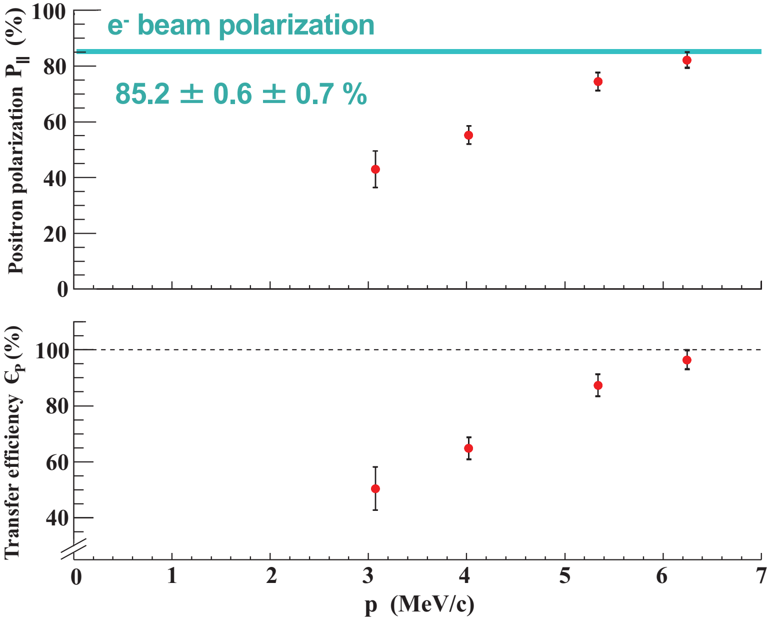
- BH-dominance ≡ $A^C_{LU} - (A^+_{LU} - A^-_{LU})/2 = 0$ is a **kinematics-** and **GPD model-dependent hypothesis** eventually testable at CLAS12.

Polarized Electrons for Polarized Positrons

(PEPPo Collaboration) D. Abbott et al. , PRL 116 (2016) 214801

➢ **PEPPo** demonstrated **efficient polarization transfer** from **8.2 MeV/*c*** **electrons to positrons**, expanding polarized positron capabilities **from GeV to MeV accelerators**.

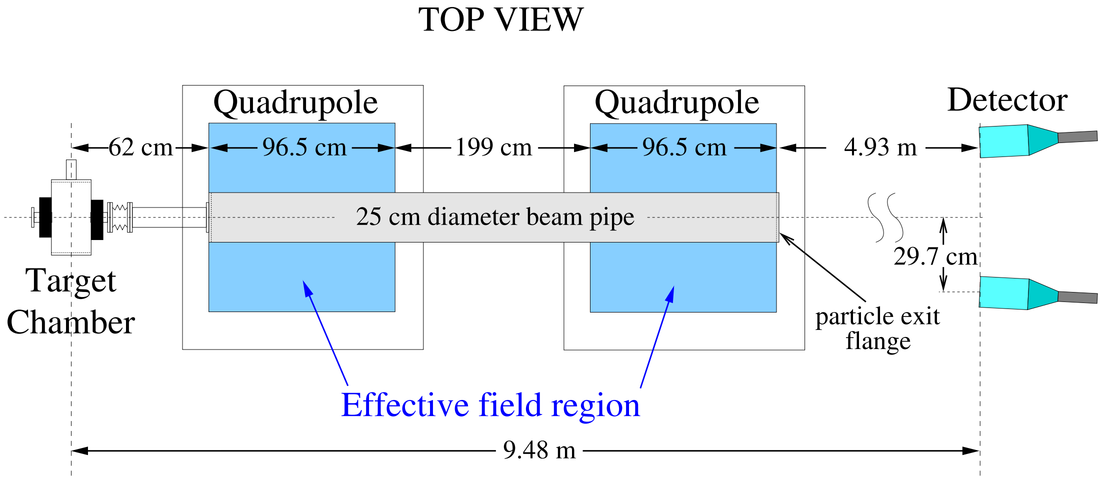




The **PEPPo** technique can achieve up to **100% transfer** of the electron polarization.

Møller to Bhabha Polarimeter

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



- 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.

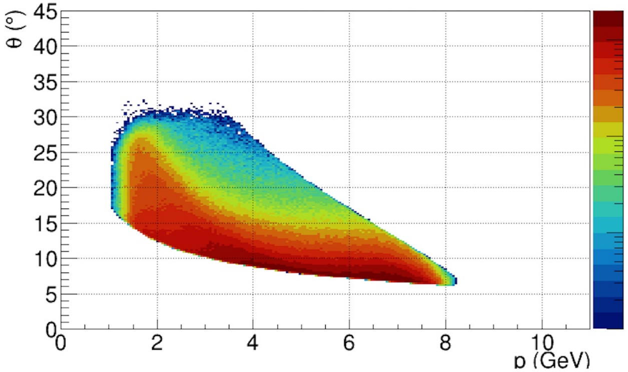
On-going design optimization

Detector Acceptance

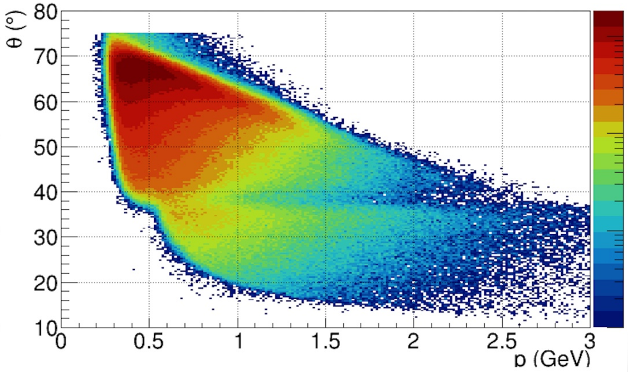
From a subset of out-bending RGA data

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

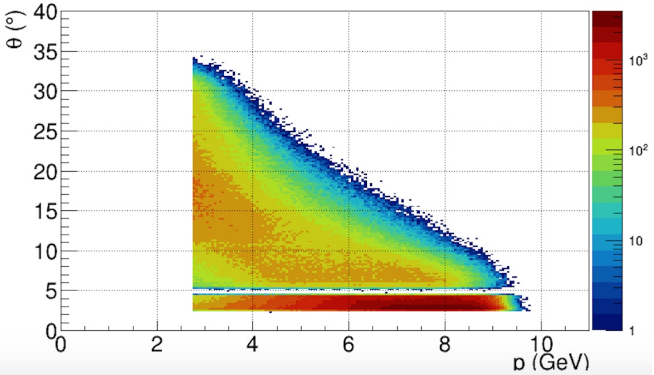
Electron (Positron)



Proton



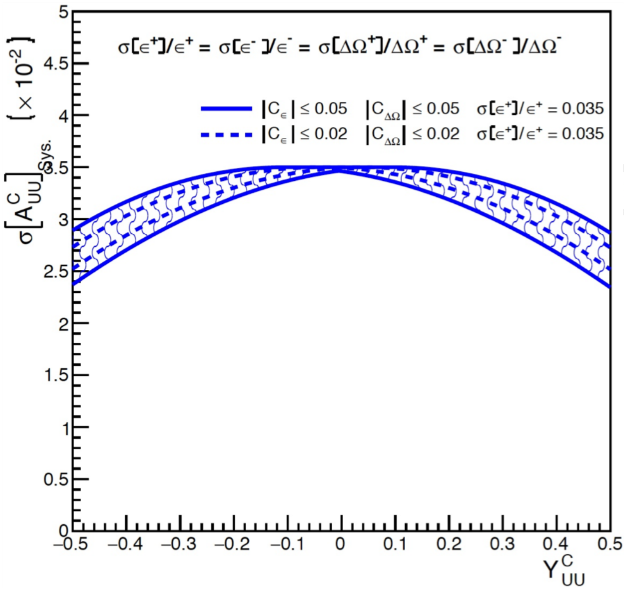
Photon

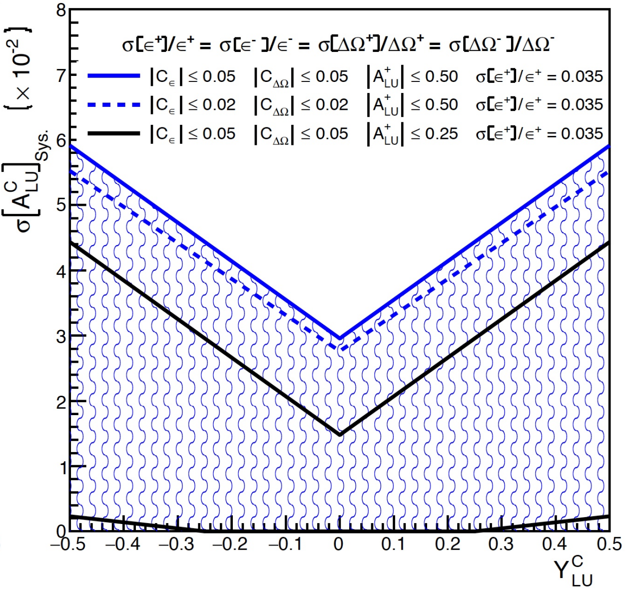


- ○ Scattered electrons (positrons) are detected in the Forward Detector (FD).
- ○ Recoil protons are detected essentially in the Central Detector (CD), but also in the FD at large $-t$.
- ○ Produced photons are measured in the Electromagnetic Calorimeter (Ecal) of the FD and in the Forward Tagger Calorimeter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

Evaluation of Systematics

- Solid angle and detector efficiency differences between **e⁻** and **e⁺** result in corrections (η_C) to raw normalized yield asymmetries ($\mathcal{Y}^C_{UU}$, $\mathcal{Y}^C_{LU}$), and related systematic uncertainties.





$$\eta_C = \mathcal{C}_{\Delta\Omega} - \mathcal{C}_\varepsilon - 2\mathcal{C}_{\Delta\Omega}\mathcal{C}_\varepsilon$$

$$\mathcal{C}_\varepsilon = \frac{1}{2}\,\frac{\varepsilon^+ - \varepsilon^-}{\varepsilon^+}$$

$$\mathcal{C}_{\Delta\Omega} = \frac{1}{2}\,\frac{\Delta\Omega^+ - \Delta\Omega^-}{\Delta\Omega^-}$$

$$A^C_{UU} = \frac{(1+\eta_C)\mathcal{Y}^C_{UU} - \eta_C}{1 + \eta_C - \eta_C\mathcal{Y}^C_{UU}}$$

$$A^C_{LU} = \left[1 + \eta_C\left(1 + A^C_{UU}\right)\right]\mathcal{Y}^C_{LU} - \eta_C\left(1 + A^C_{UU}\right)A^+_{LU}$$

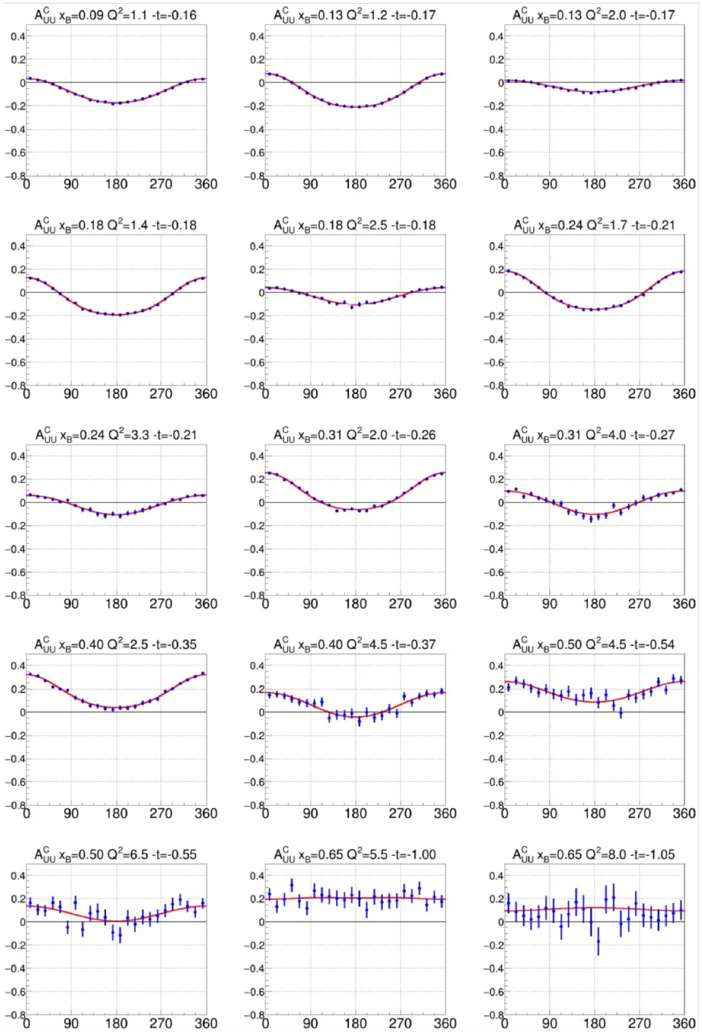
Assuming **5% systematic** uncertainty on ε·ΔΩ and **raw asymmetries** within **[-50%;50%]**:

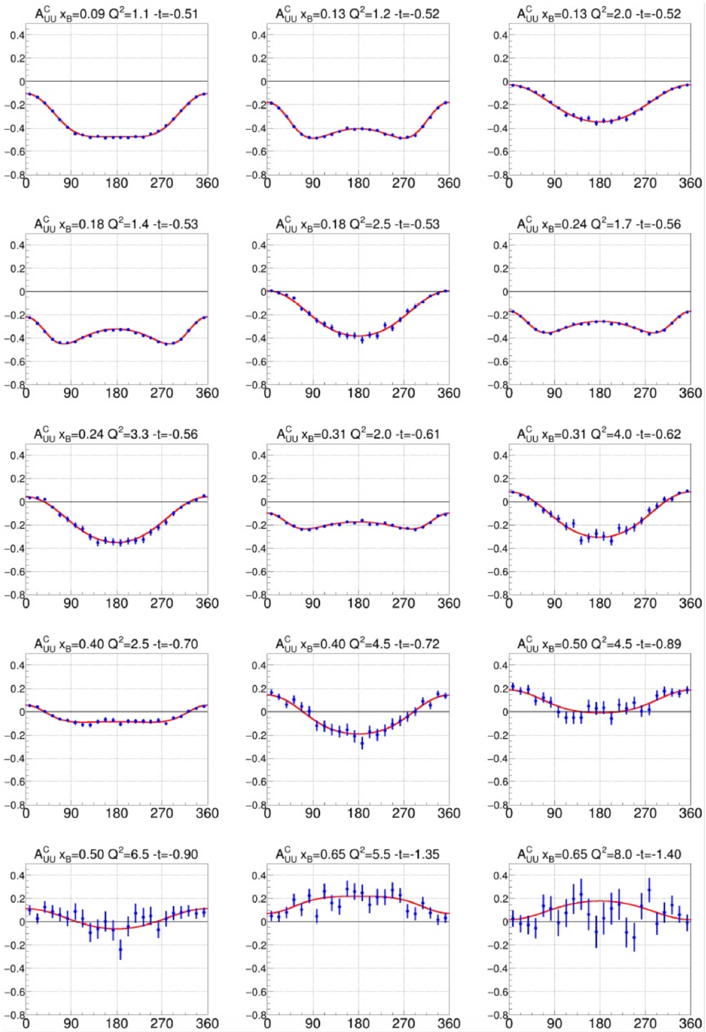
- ○ **Unpolarized BCA** systematics are about **0.03**;
- ○ **Nul polarized BCA** can be measured with a systematic uncertainty about **0.03**.

Experimental methodology

p-DVCS unpolarized BCA @ CLAS12

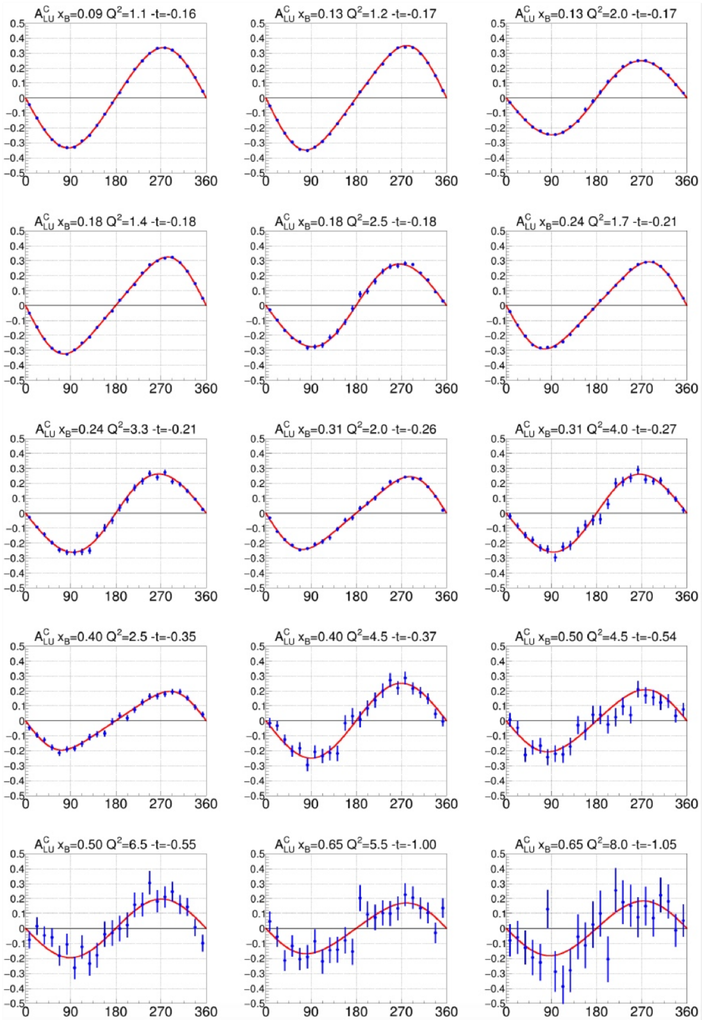
More projected data...

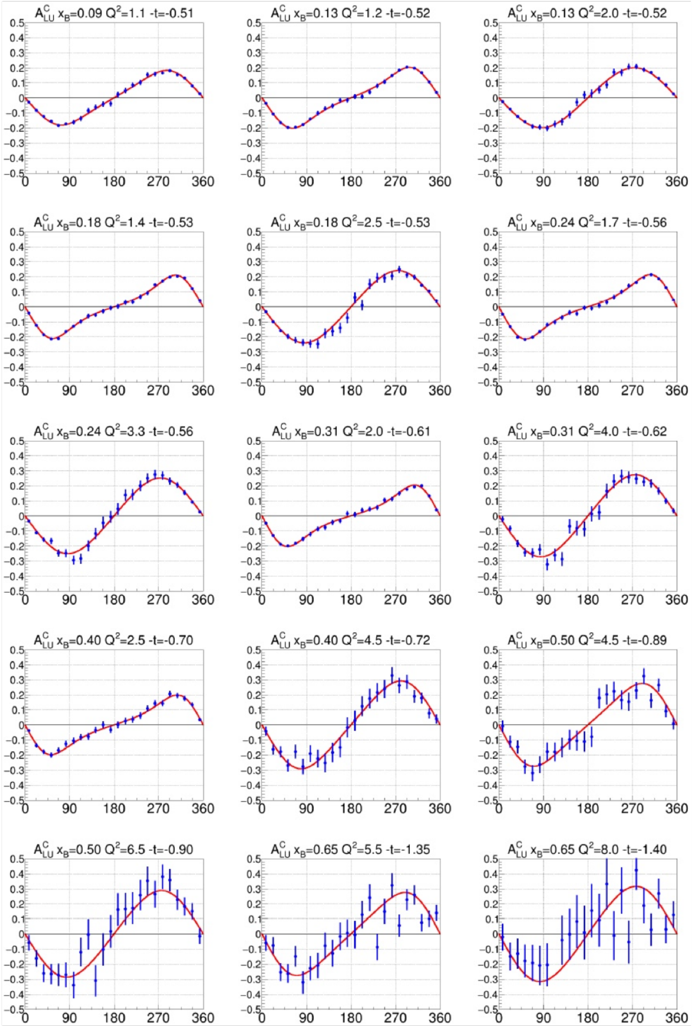




p-DVCS polarized BCA @ CLAS12

More projected data...





p-DVCS positron BSA @ CLAS12

More projected data...