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] *et al.*
and the CLAS Collaboration

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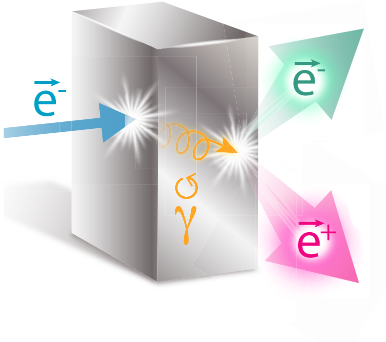
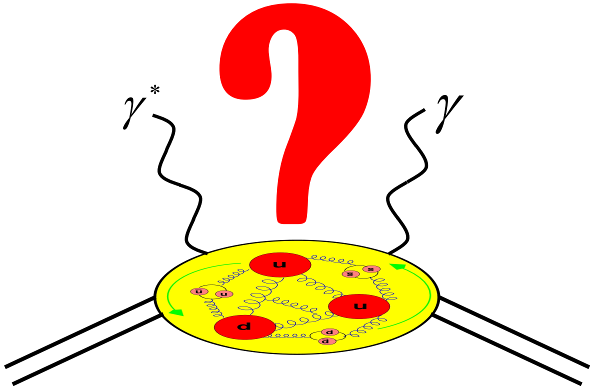
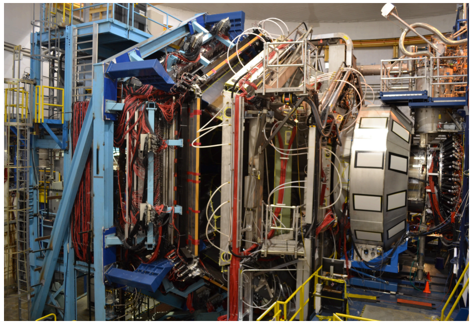






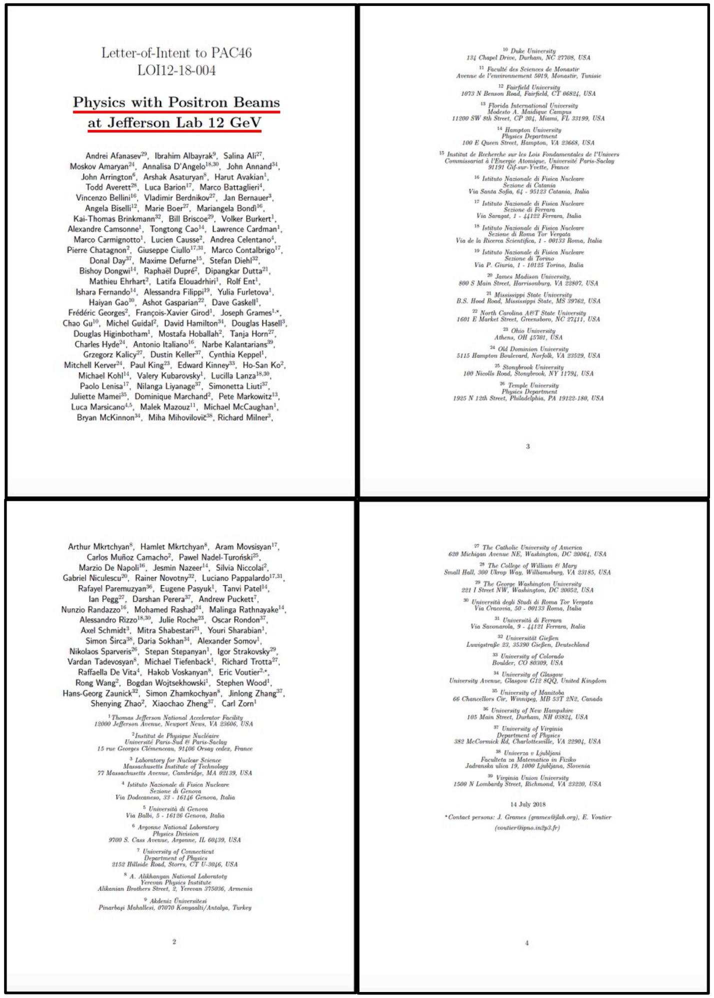
CLAS Collaboration Meeting

July 24th, 2020

Preample

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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Kai-Thomas Brinkmann[32], Bill Briscoe[29], Volker Burkert[1],
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Charles Hyde[24], Antonio Italiano[16], Narbe Kalantarians[39],
Grzegorz Kalicy[27], Dustin Keller[37], Cynthia Keppel[1],
Mitchell Kerver[24], Paul King[23], Edward Kinney[33], Ho-San Ko[2],
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Arthur Mkrtchyan[8], Hamlet Mkrtchyan[8], Aram Movsisyan[17],
Carlos Muñoz Camacho[2], Pawel Nadel-Turoński[25],
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Ian Pegg[27], Darshan Perera[37], Andrew Puckett[7],
Nunzio Randazzo[16], Mohamed Rashad[24], Malinga Rathnayake[14],
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Nikolaos Sparveris[26], Stepan Stepanyan[1], Igor Strakovsky[29],
Vardan Tadevosyan[8], Michael Tiefenback[1], Richard Trotta[27],
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14 July 2018

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4

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

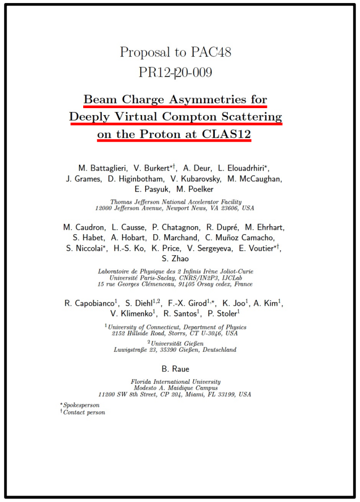
"These measurements all have significant physics interest. The proposers should carefully evaluate feasibility and present the best case possible in a future proposal."

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

Preample

PR12-20-009

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



Proposal to PAC48
PR12-20-009

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

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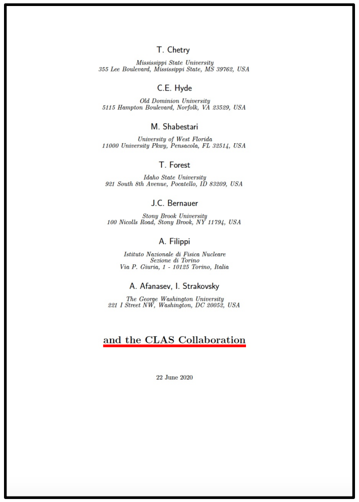

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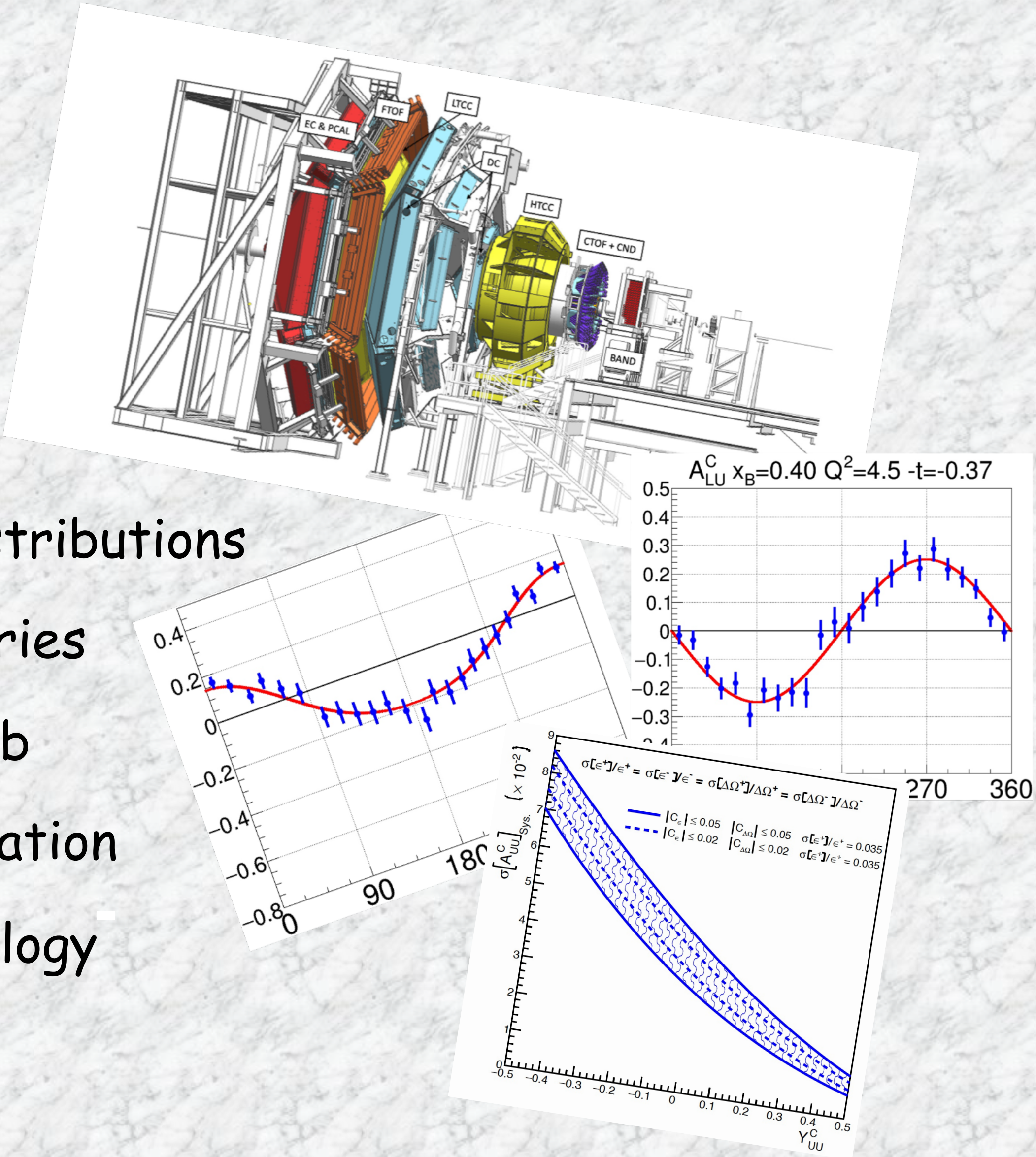
22 June 2020

« 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 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$^{-2}\cdot$s^{-1}**. »

Outline



(i) Generalized parton distributions

(ii) Beam charge asymmetries

(iii) Positron beams at JLab

(iv) Experimental configuration

(v) Experimental methodology

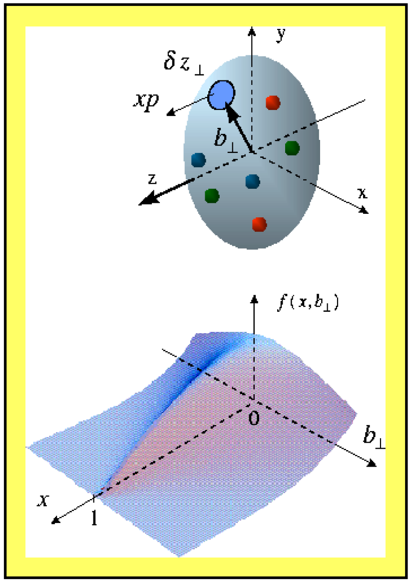
(vi) Summary

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 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.

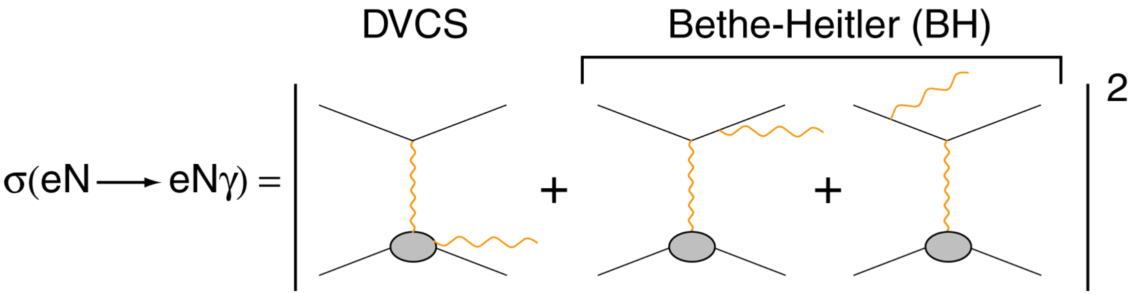
X. Ji, PRL 78 (1997) 610 M. Polyakov, PL B555 (2003) 57

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

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



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

N(e,e'γN) Differential Cross Section

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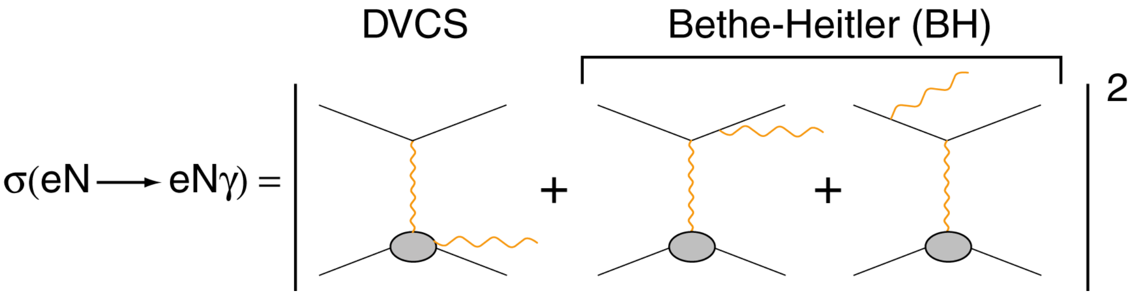


$$\sigma^{e}_{P0} = \sigma_{BH} + \sigma_{DVCS} + P_1\,\tilde{\sigma}_{DVCS} + e_1\left(\sigma_{INT} + P_1\,\tilde{\sigma}_{INT}\right)$$

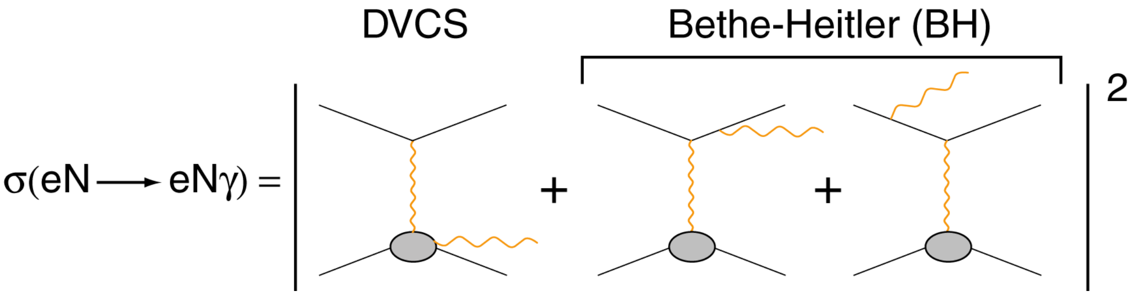
Electron observables

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

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

N(e,e'γN) Differential Cross Section

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



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

Electron observables

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

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

Electron & positron observables

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

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

N(e,e'γN) Differential Cross Section

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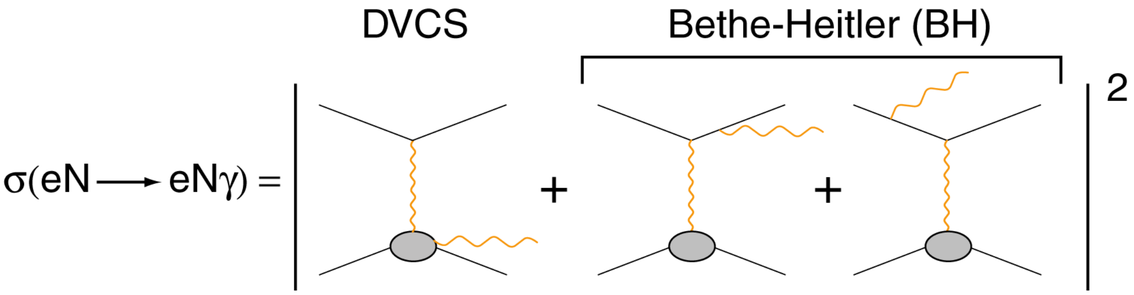

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$$\sigma^{-}_{00} = \sigma_{BH} + \sigma_{DVCS} - \sigma_{INT}$$

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Electron & positron observables

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

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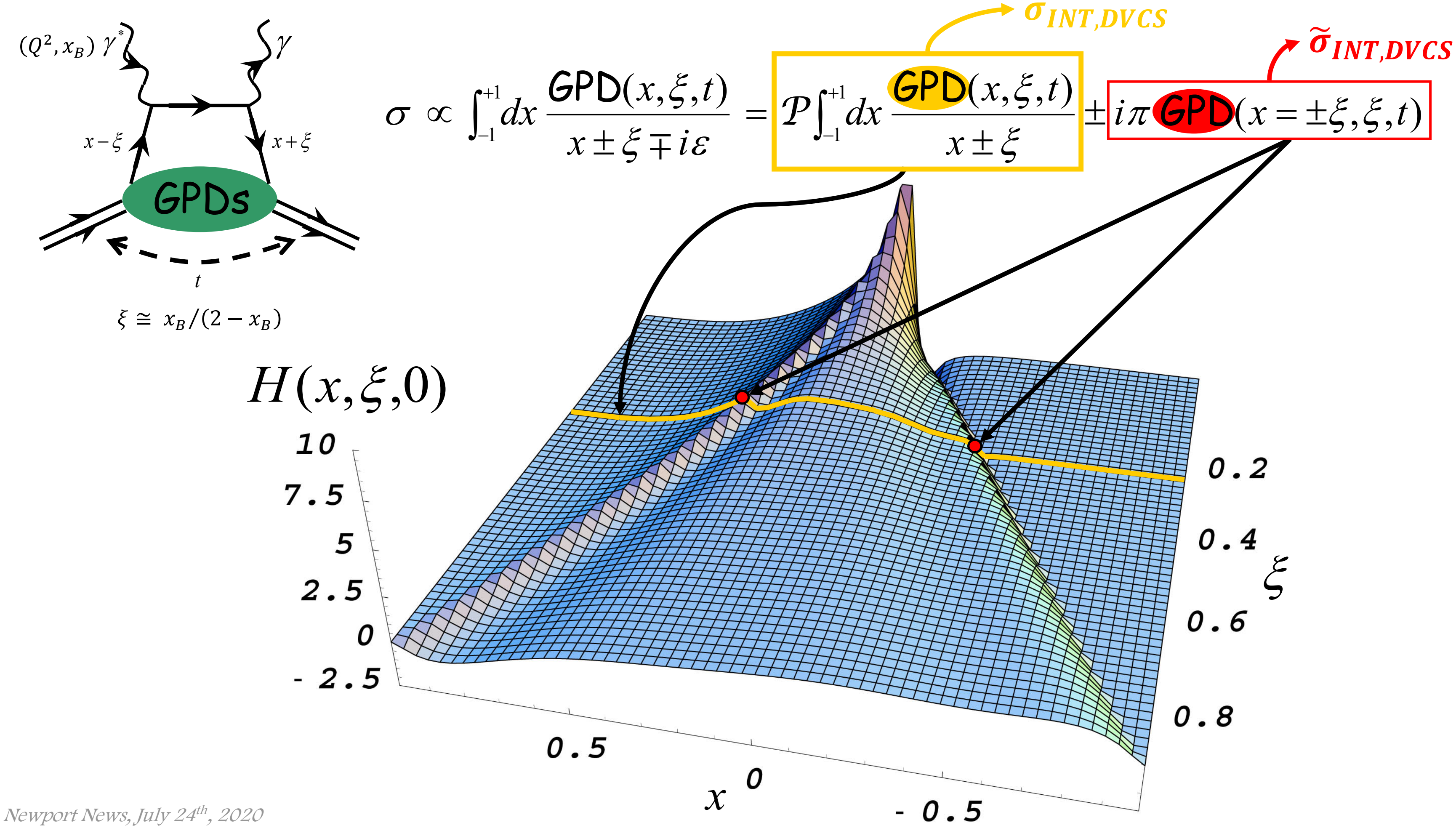
Polarized electrons and positrons allow to **separate** the **unknown amplitudes** of the cross section for electro-production of photons.

Compton Form Factors

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

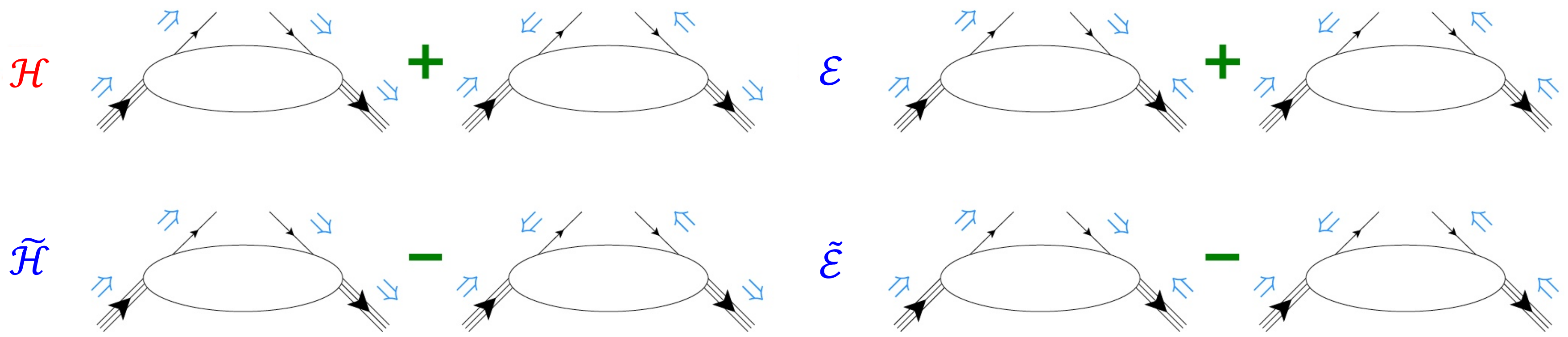


$$\sigma \propto \int_{-1}^{+1} dx \, \frac{\mathrm{GPD}(x,\xi,t)}{x \pm \xi \mp i\varepsilon} = \boxed{\mathcal{P}\int_{-1}^{+1} dx \, \frac{\mathrm{GPD}(x,\xi,t)}{x \pm \xi}} \pm \boxed{i\pi \, \mathrm{GPD}(x=\pm\xi,\xi,t)}$$

Experimental Observables

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

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



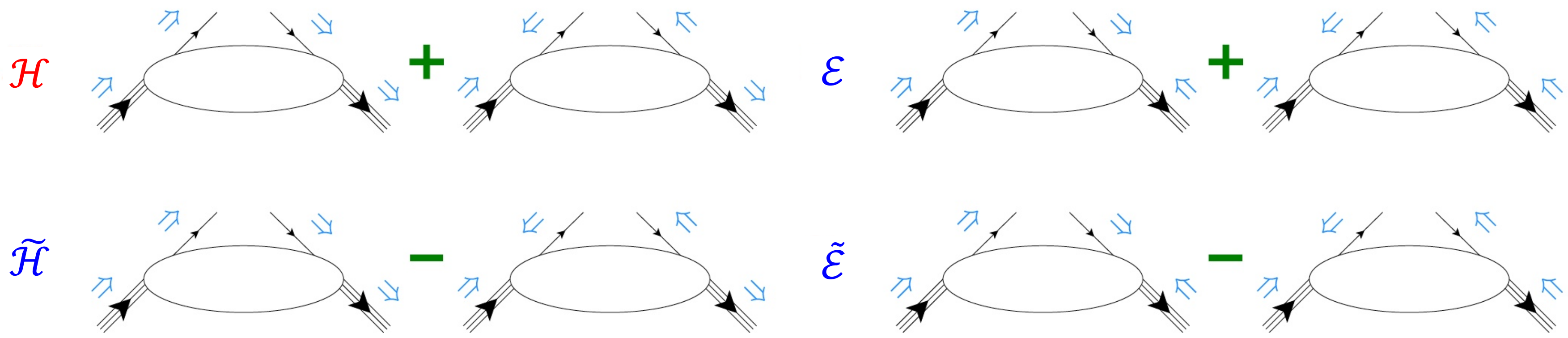
$$\mathcal{C}^{DVCS} = 4(1-x_B)\left[\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right] - x_B^2\left[\mathcal{H}\mathcal{E}^* + \mathcal{E}\mathcal{H}^* + \widetilde{\mathcal{H}}\tilde{\mathcal{E}}^* + \tilde{\mathcal{E}}\widetilde{\mathcal{H}}^*\right] - \left(x_B^2 +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

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

Experimental Observables

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

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



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

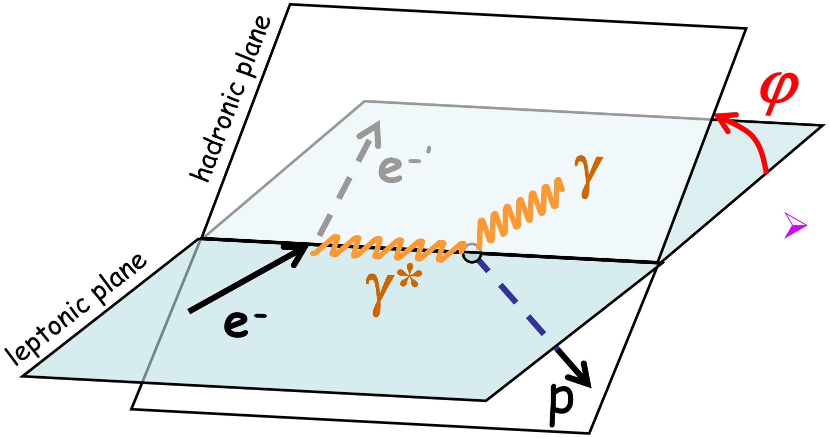
$$\boxed{\mathcal{C}^{INT} = F_1\mathcal{H} - \xi[F_1 + F_2]\widetilde{\mathcal{H}} - \frac{t}{4M^2}\mathcal{E}}$$

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**.

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

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

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

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

Nucleon Internal Pressure

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

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

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

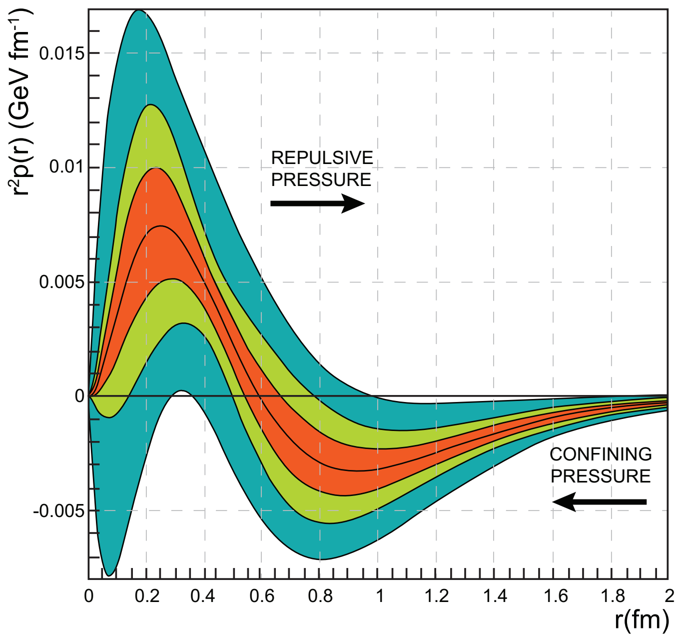
CFF

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

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

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

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



Nucleon Internal Pressure

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

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

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

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

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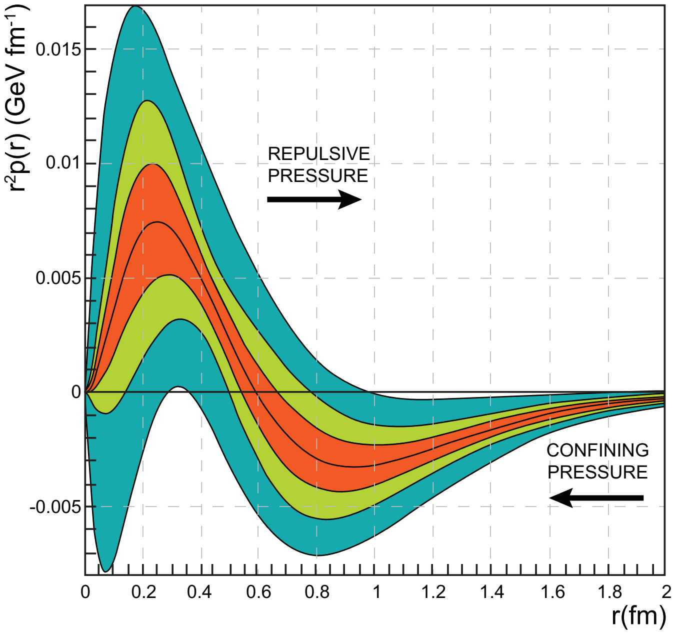
$$D(z,t) = (1-z^2)\left[d_1(t)\,C_1^{3/2}(z) + \ \ldots\right]$$

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



*Also accessible in **TCS** testing GPDs **universality**.*

Proposed Measurements

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

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

New GPD Observables

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

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

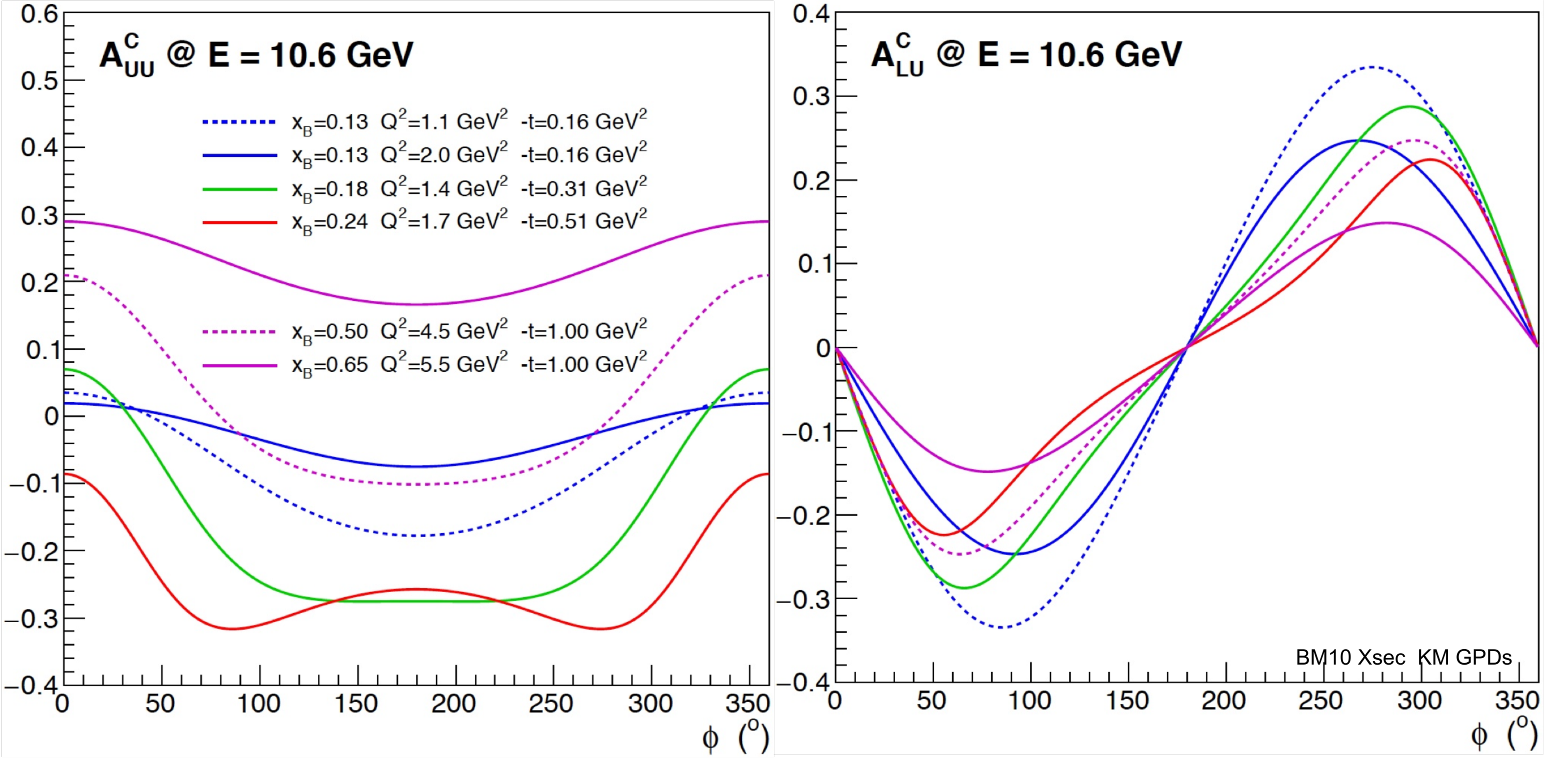
$$A^0_{LU} = \frac{(Y^+_+ + Y^-_+) - (Y^+_- + Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{\tilde{\sigma}_{DVCS}}{\sigma_{BH} + \sigma_{DVCS}}$$

☛ $A^C_{LU} \neq A^\pm_{LU} = \frac{\pm P(\tilde{\sigma}_{INT} \pm \tilde{\sigma}_{DVCS})}{\sigma_{BH} + \sigma_{DVCS} \pm \sigma_{INT}}$ $A^C_{LU} = \frac{A^+_{LU} - A^-_{LU}}{2}$ if BH dominates

$Y^{e^\pm}_{\pm P^\pm} = \frac{N^\pm_\pm}{Q^\pm_\pm P^\pm}$ *is the beam polarization and accumulated charge normalized yield.*

Experimental Signal

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

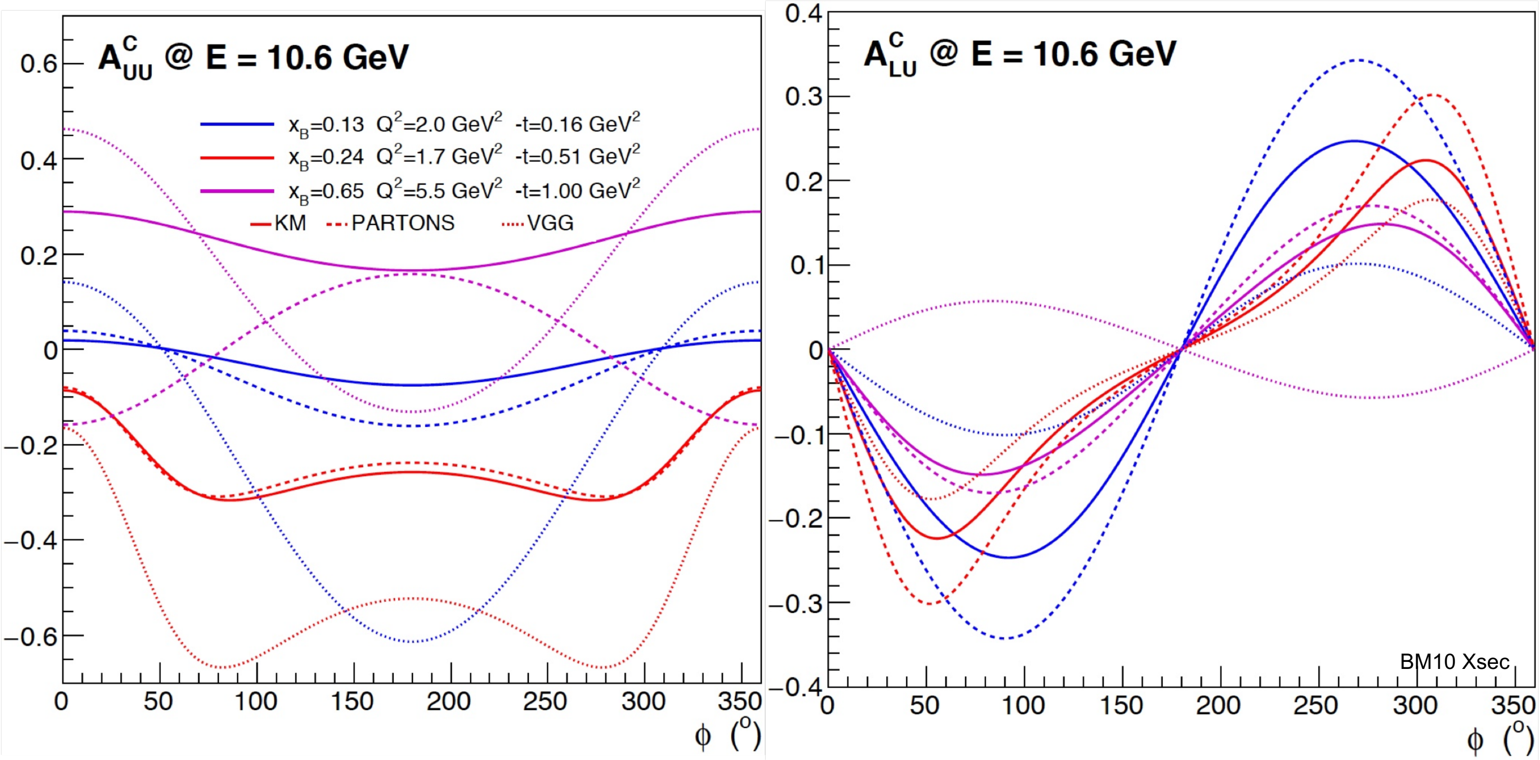


- The **magnitude** of unpolarized and polarized BCAs is **sizeable** and kinematics dependent.

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



- Both the **shape** and **magnitude** of unpolarized and polarized BCAs are **sensitive** to the specific GPD model.

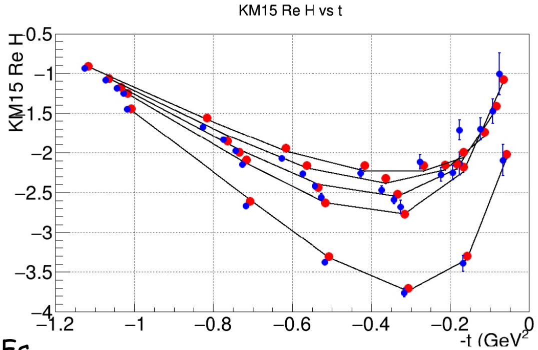
Impact of Positron Measurements

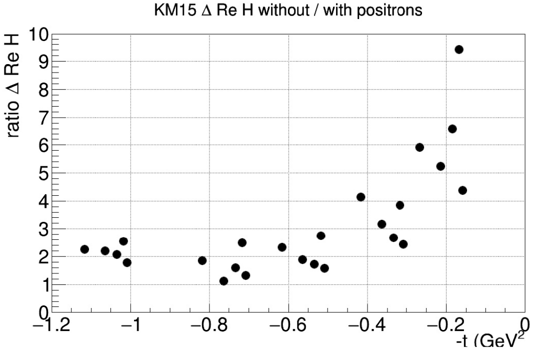
K. Kumerički, D. Müller, NPB 841 (2010) 1   E.C. Aschenauer, S. Fazio, K. Kumerički, D. Müller, JHEP 09 (2013) 093

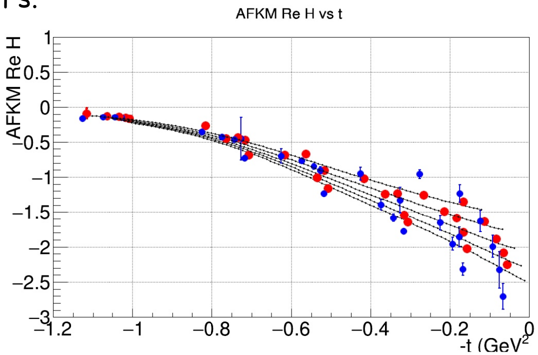
- The importance of positron beams for the determination of CFFs can be quantified in a model-dependent way depending on : the cross section model, the GPDs model, and the hypotheses of the fitting approach.

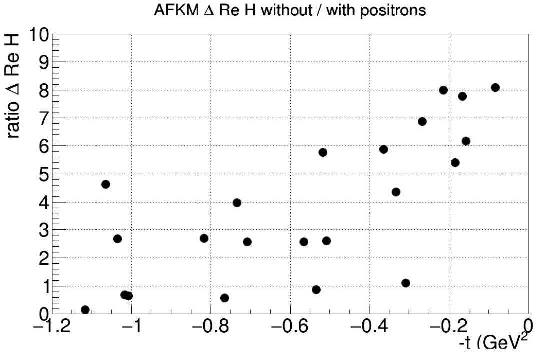
Observable	σ_{UU}	A_{LU}	A_{UL}	A_{LL}	A^C_{UU}	A^C_{LU}
Time (d)	80	80	100	100	80	80
$\mathcal{L}$ ($\times 10^{35}$ cm^{-2}·s^{-1})	0.6	0.6	2	2	0.6	0.6
Packing Fraction	1	1	0.17	0.17	1	1
Sytematics (%)	5	3	3	$3\oplus3$	3	3

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









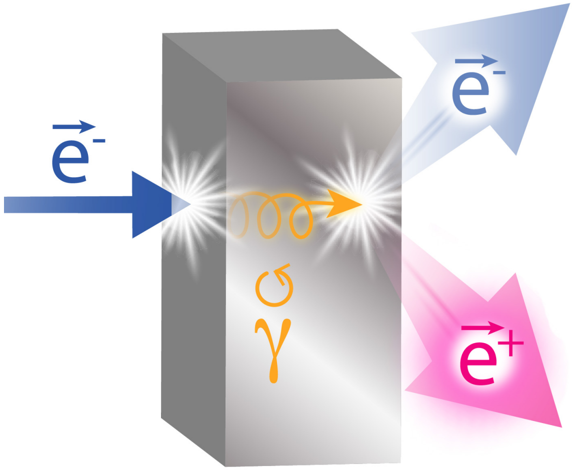
- ○ Improvement of the **statistical** and **systematical** error on $\Re e[\mathcal{H}]$.

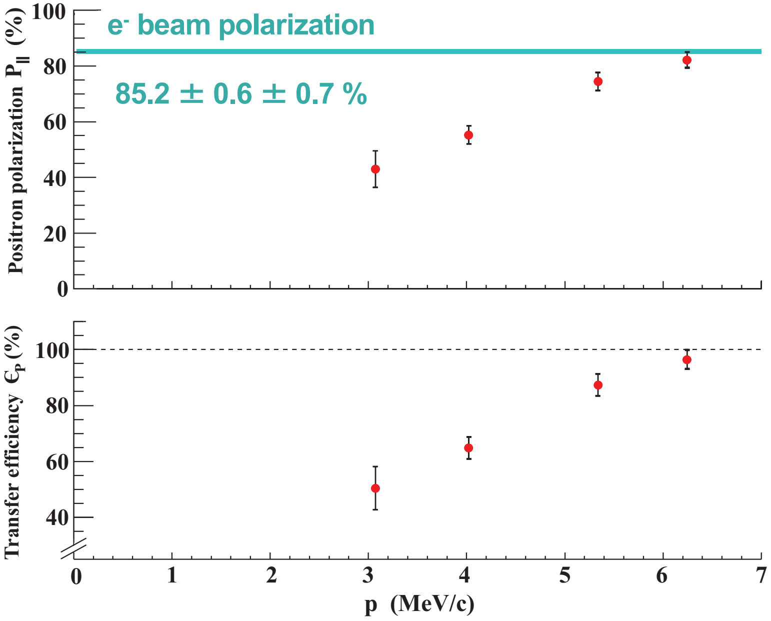
Polarized Electrons for Polarized Positrons

(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**.

$\vec{e}^- \rightarrow \vec{\gamma} \rightarrow \vec{e}^+$



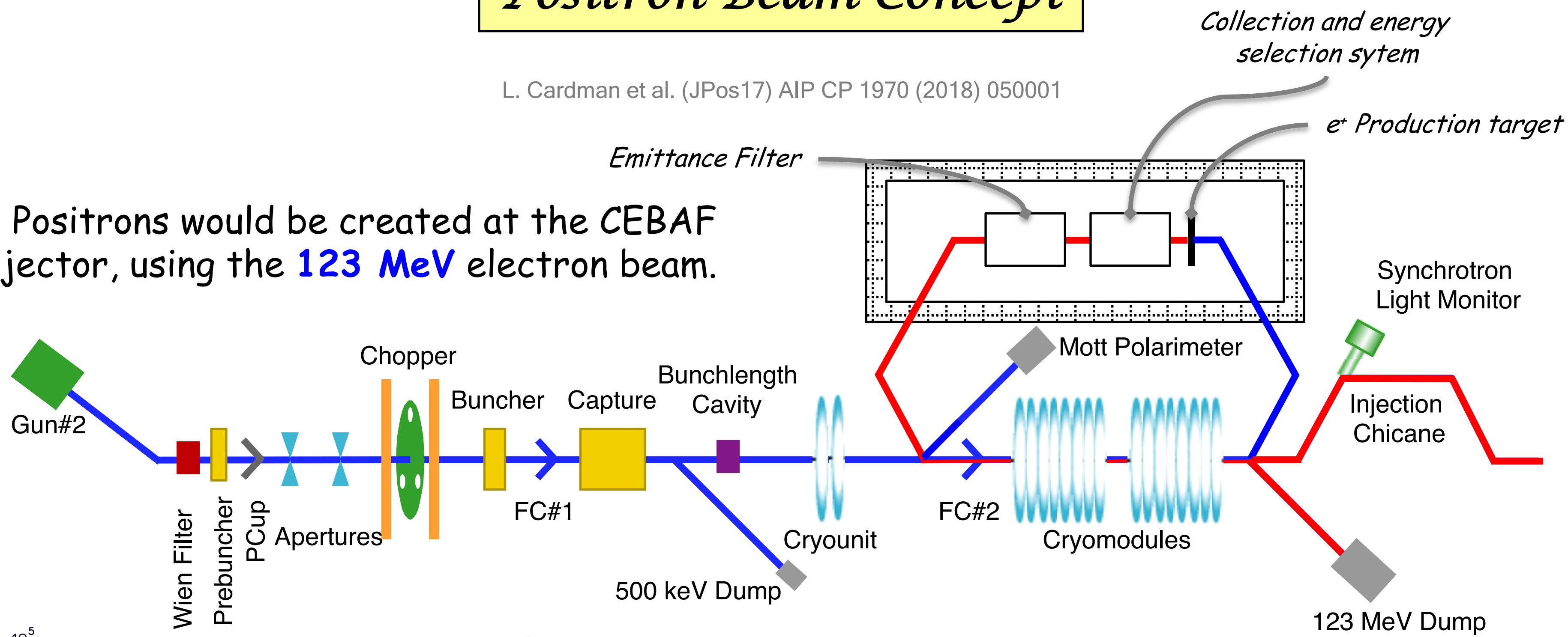


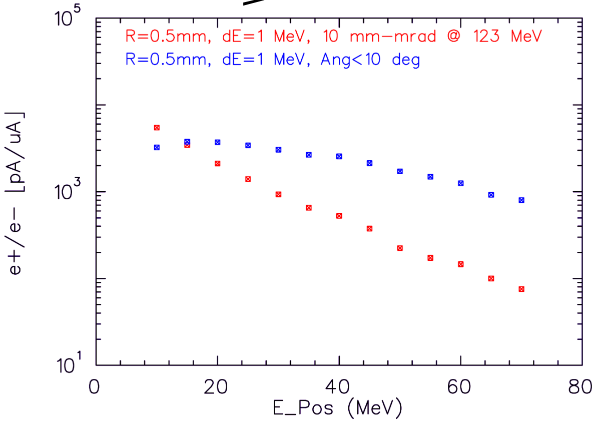
The PEPPo technique can achieve up to 100% transfer of the electron polarization.

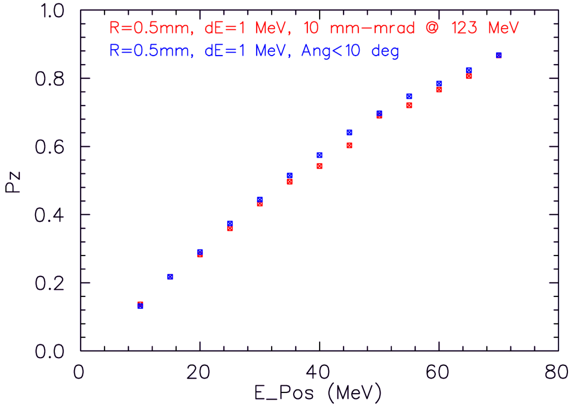
Positron Beam Concept

L. Cardman et al. (JPos17) AIP CP 1970 (2018) 050001

- Positrons would be created at the CEBAF injector, using the **123 MeV** electron beam.







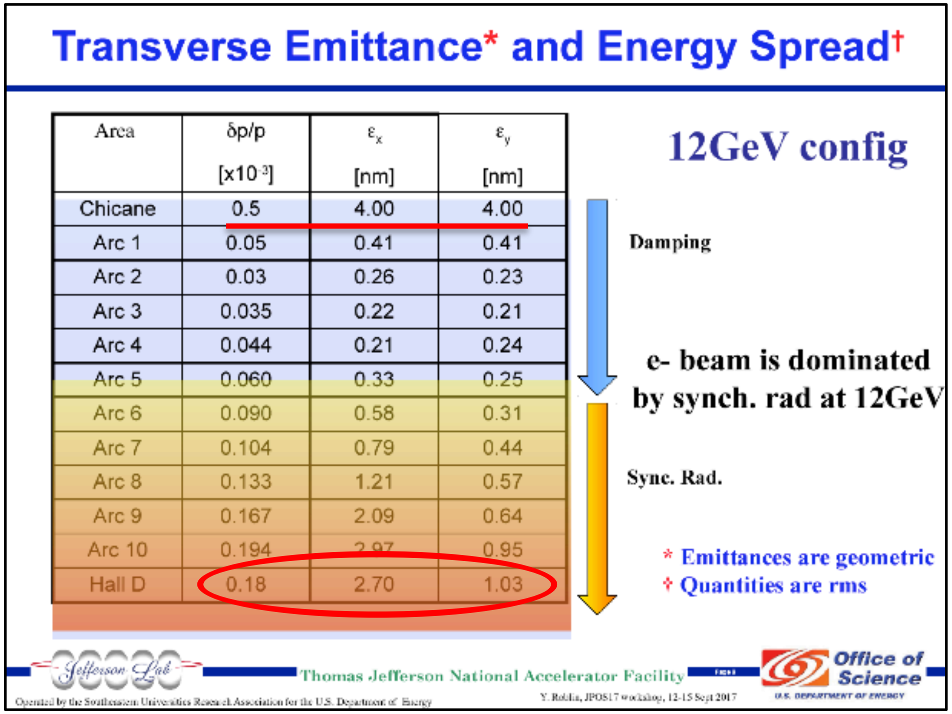
✓ Selecting **60 MeV** positrons maximizes the FoM (**60%**, **100 nA**).

✓ 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

- Despite much larger momentum dispersion and emittance at the source, e^+ and e^- beams at target have the same $\delta p/p$ with a spot size 2-3 times larger for e^+.



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	2.97	0.95
Hall D	0.18	2.70	1.03

12GeV config

Damping

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

Sync. Rad.

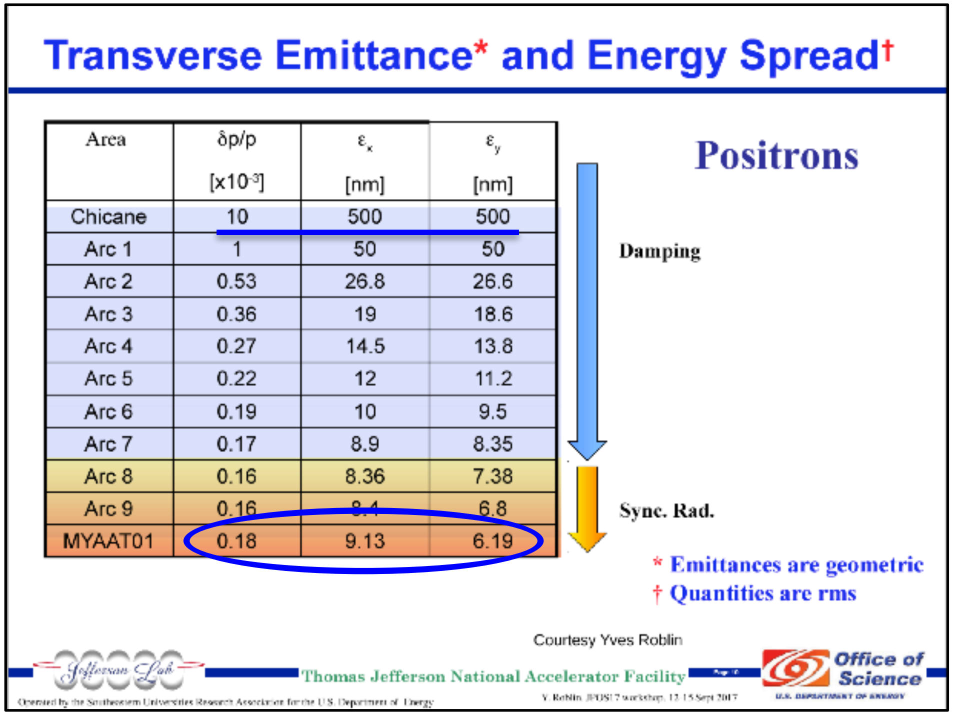
* Emittances are geometric

† 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



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	8.4	6.8
MYAAT01	0.18	9.13	6.19

Positrons

Damping

Sync. Rad.

* Emittances are geometric

† Quantities are rms

Courtesy Yves Roblin

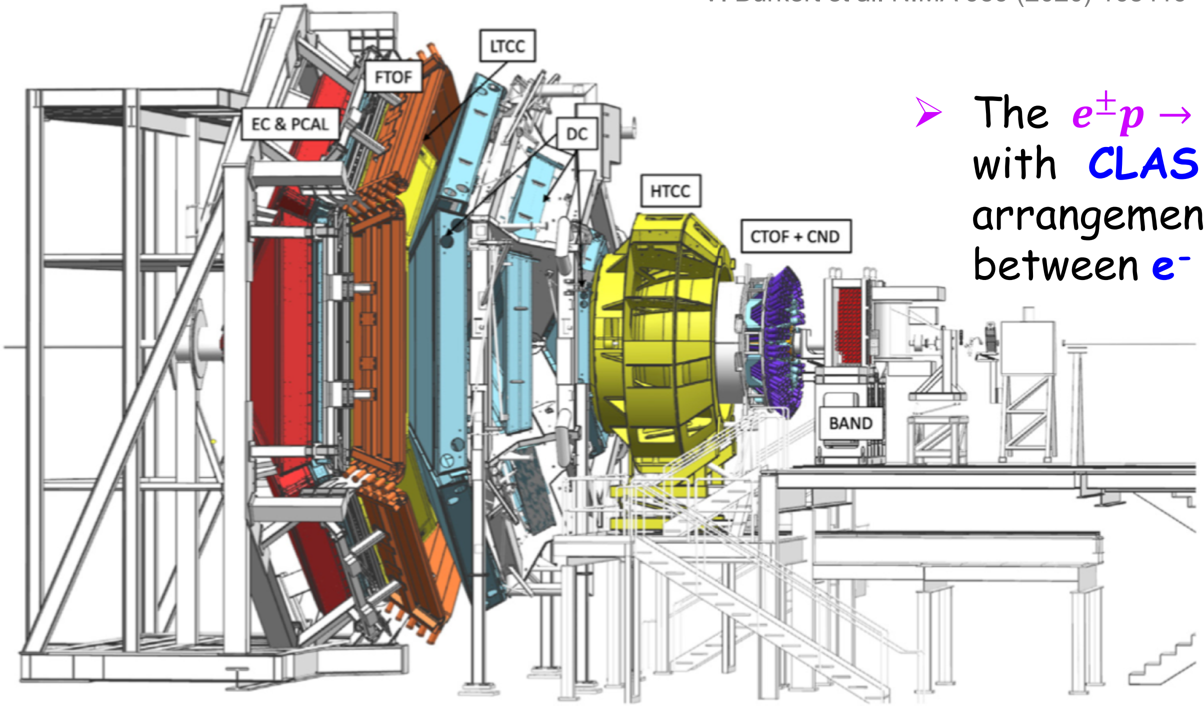
Thomas Jefferson National Accelerator Facility

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

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

This motivates a change of the target cell with a 50% larger diameter (15mm).

CLAS12



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

- The $e^{\pm}p \rightarrow e^{\pm}p$ reaction will be measured with **CLAS12**, using the regular detector arrangement and reversing magnet polarities between **e⁻** and **e⁺** data.
  - ○ $\mathcal{L} = 0.6{\times}10^{35}\ \mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$
  - ○ New 5 cm long target cell featuring **entrance** and **exit windows** with larger diameter.

- 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.

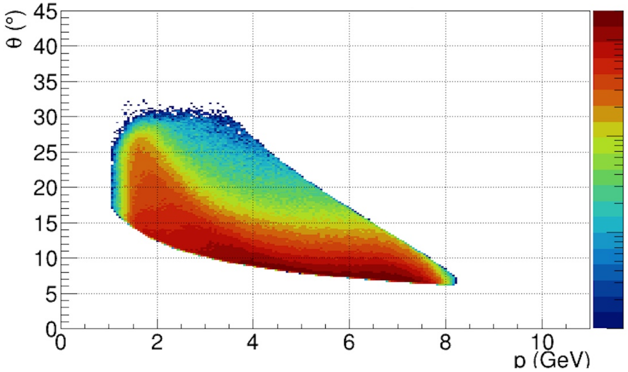
- The **Møller** polarimeter needs adaptations to operate in **Bhabha** mode: **change** of the **detector configuration** to allow for single and coincidence detection operation.

Detector Acceptance

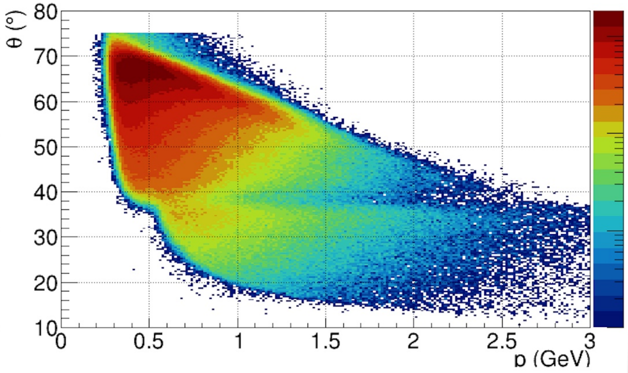
From a subset of out-bending RGA data

- ➢ The CLAS12 torus will operate in **OUT-Bending mode** for both e$^-$ and e$^+$.

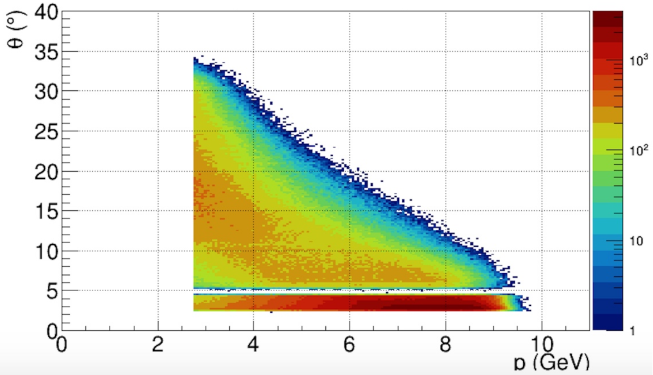
Electron (Positron)



Proton



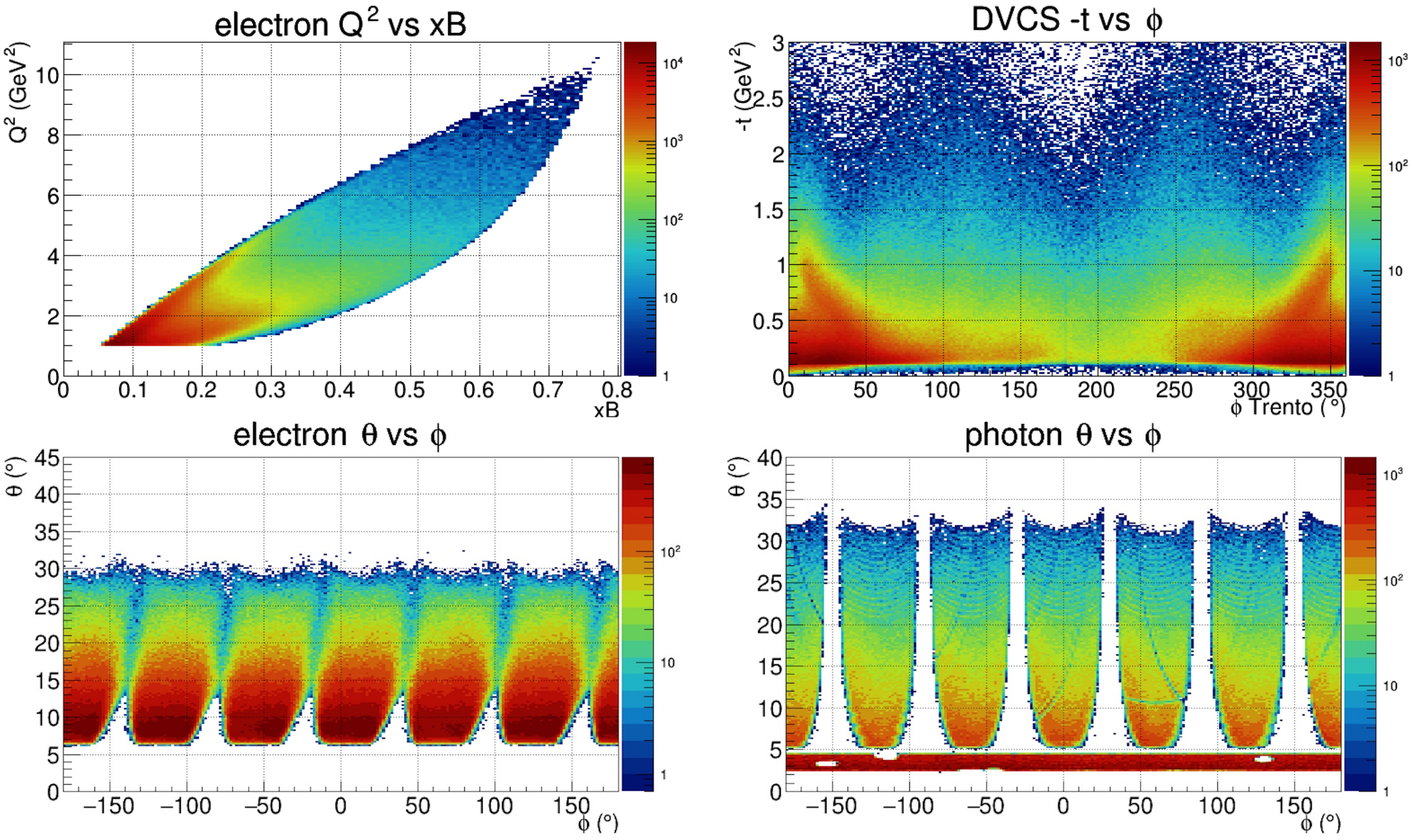
Photon



- ○ 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).

Kinematic Coverage

From a subset of out-bending RGA data



Beam Related Systematics

- 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.

Secondary Positron Beam properties ≠ **Primary** CEBAF **Electron** Beam properties

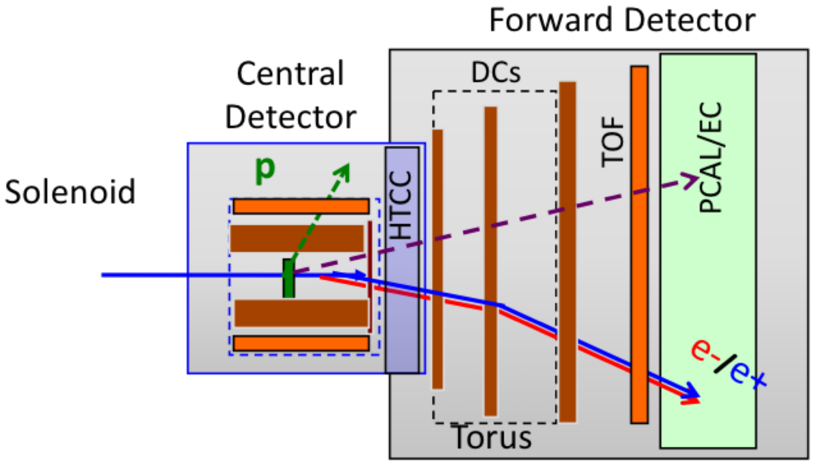
- ○ **Different transverse profile** → different target cells
- ○ **Different emittance** → different background conditions

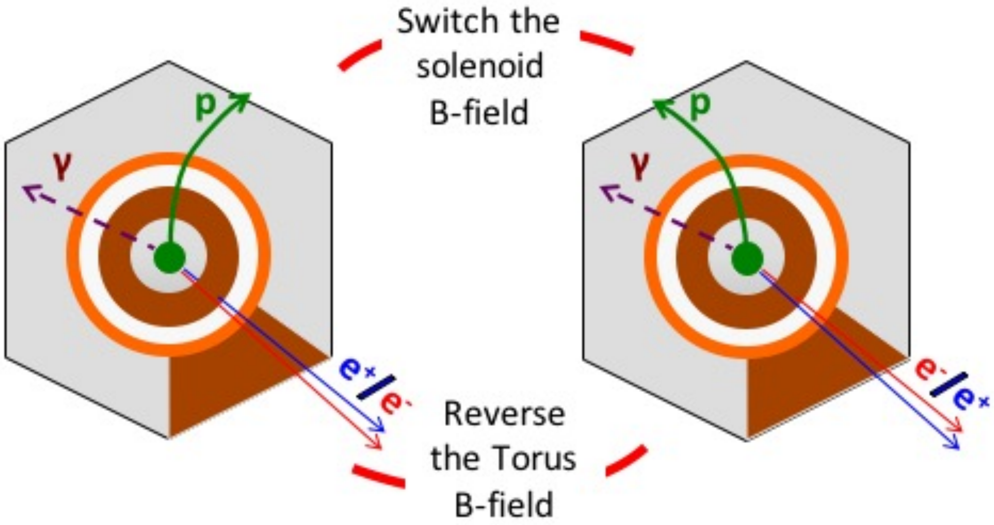
- ○ Different target cells → no compensation of **target related systematics**
- ○ Different background conditions → **additional systematic effects**

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

Detector Related Systematics

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



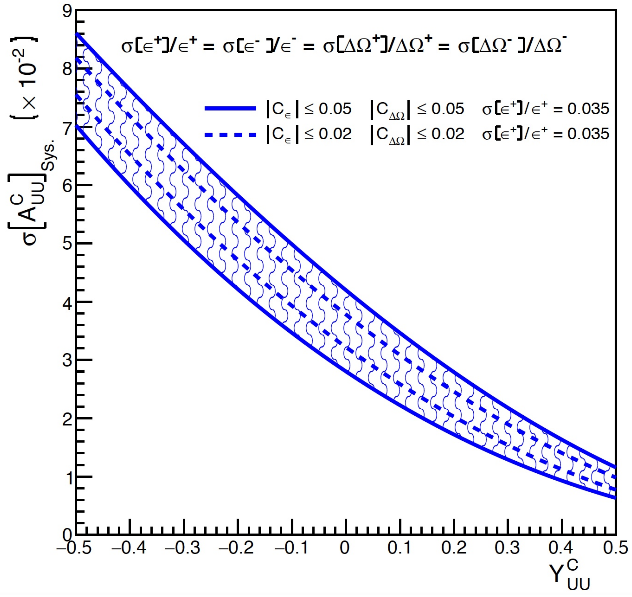


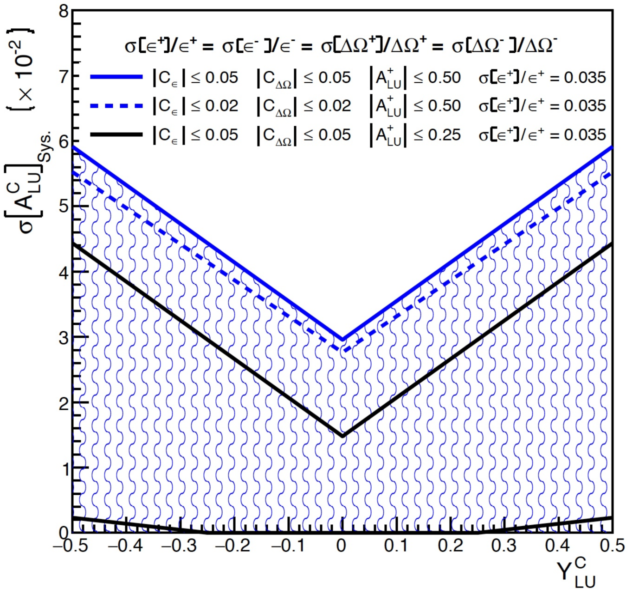
- **Switch** the **solenoid field** to reveal false asymmetries in FD, which may create false asymmetries in proton tracking.

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

Evaluation of Systematics

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





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

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

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

$$A_{UU}^C = \frac{(1+\eta_C)\mathcal{Y}_{UU}^C - \eta_C}{1 + \eta_C - \eta_C\mathcal{Y}_{UU}^C}$$

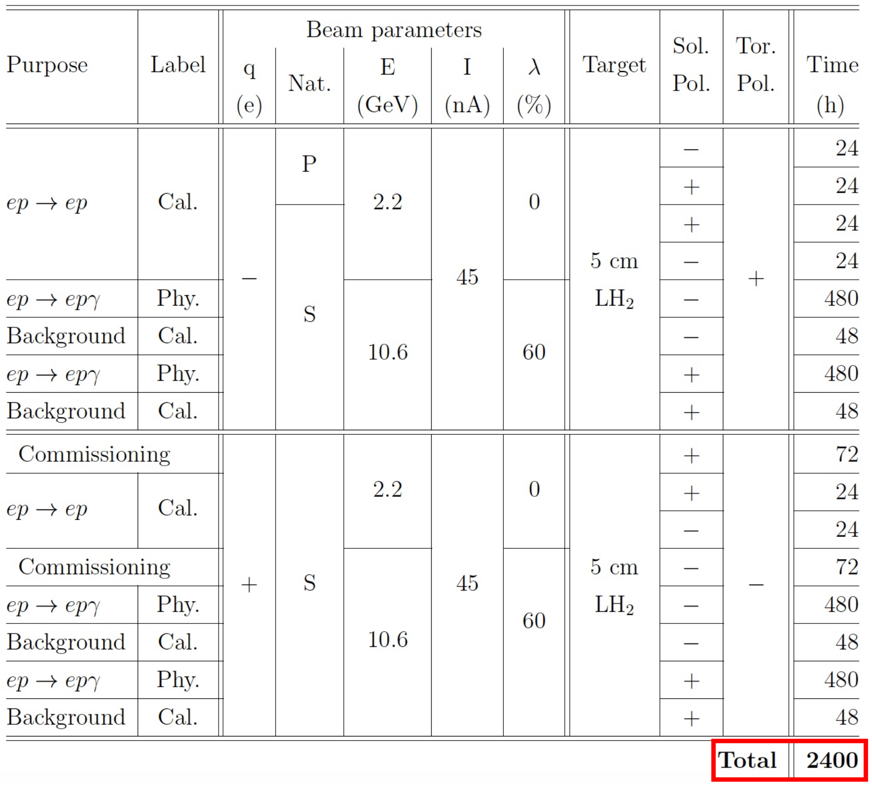
$$A_{LU}^C = \left[1 + \eta_C\left(1 + A_{UU}^C\right)\right]\mathcal{Y}_{LU}^C \\ - \eta_C\left(1 + A_{UU}^C\right)A_{LU}^+$$

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

- ○ **Unpolarized BCA** systematics are contained < **0.09**;
- ○ **Nul polarized BCA** can be measured within a systematic uncertainty about **0.03**.

Beam Time Request

We are asking for a total of **100 days** of beam, operating **CLAS12** with a modified **5 cm** long **LH$_2$ target** under **45 nA e$^-$** and **e$^+$** beam exposure 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;**

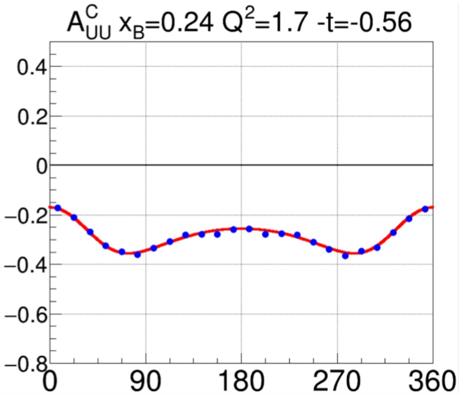
using lepton beams of different nature

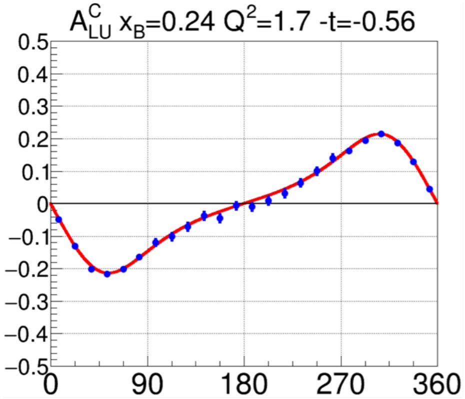
- 2 days with the CEBAF **e$^-$** beam;
- 46 days with the secondary **e$^-$** beam;
- 52 days with the secondary **e$^+$** beam;

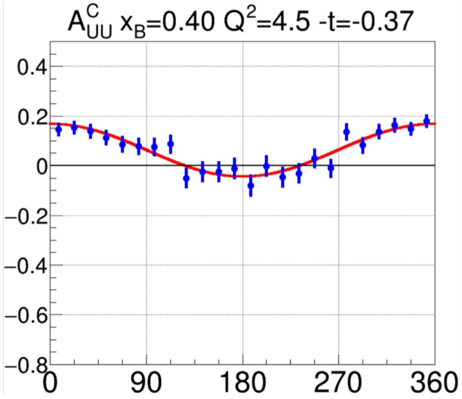
and different energies

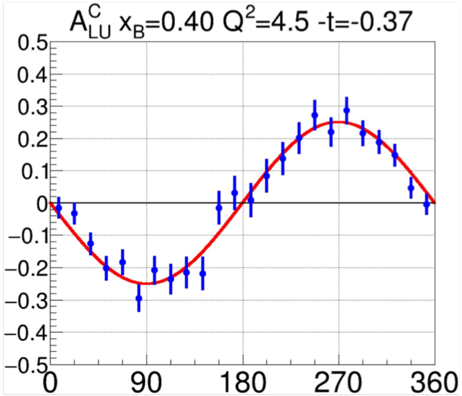
- 9 days at 2.2 GeV;
- 91 days at 10.6 GeV.

p-DVCS BCAs @ CLAS12





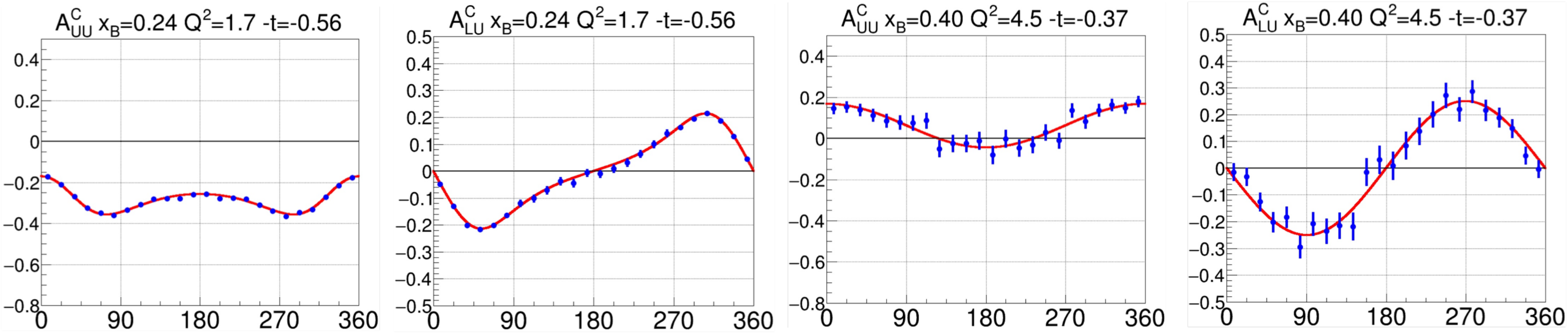




This project has received funding from the European Union's Horizon 2020 research and innovation program under agreement No 824093.

Summary

p-DVCS BCAs @ CLAS12



We are proposing 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**.

The **separation** of the **DVCS** and **INT** reaction amplitudes will provide **unambiguous experimental signals** and will benefit **CFFs** and **GPDs determination**, particularly $\Re\mathrm{e}[\mathcal{H}]$.

The direct access to the real part of the INT amplitude via positron beams will constitute a real qualitative shift 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 …

Preample

e+ @ JLab White Paper

A. Accardi et al. arXiv:2007.##### (2020)

e+@JLab White Paper
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An Experimental Program with Positron Beams at Jefferson Lab

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2 | e+@JLab White Paper

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An experimental program with positron beams at Jefferson Lab

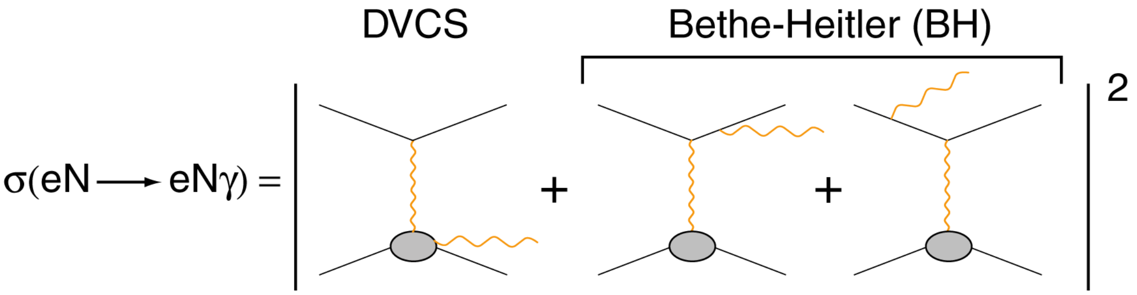
discussing **15** possible **experiments** covering:

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

Supported by **196 Members** from **59 Institutions**

N(e,e'γN) Differential Cross Section

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



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

Additional observables

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

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

Electron observables

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

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

Electron & positron observables

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

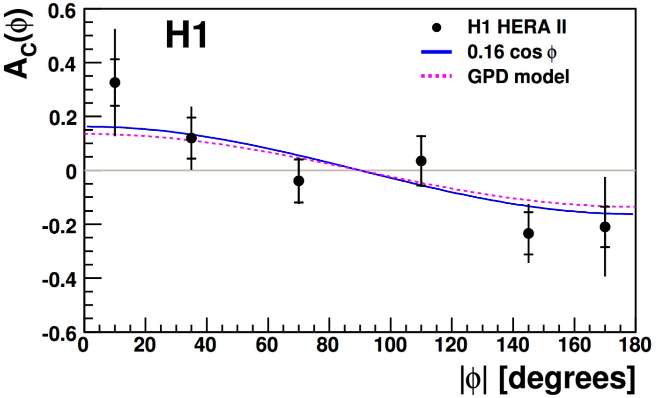
$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\tilde{\sigma}_{INT}$$

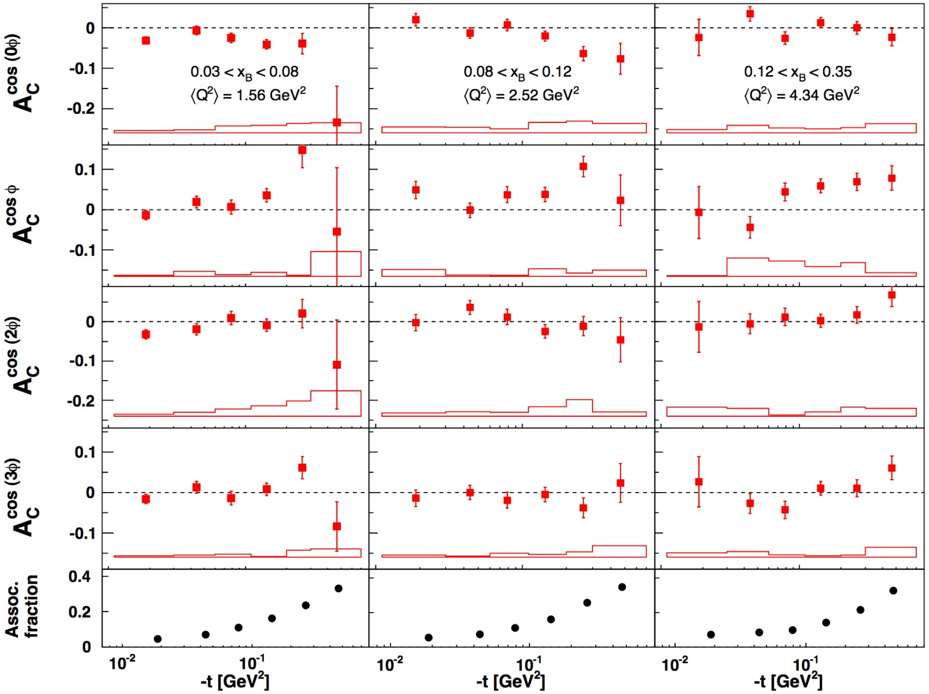
Polarized electrons and positrons allow to **separate** the **unknown amplitudes** of the cross section for electro-production of photons.

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**.



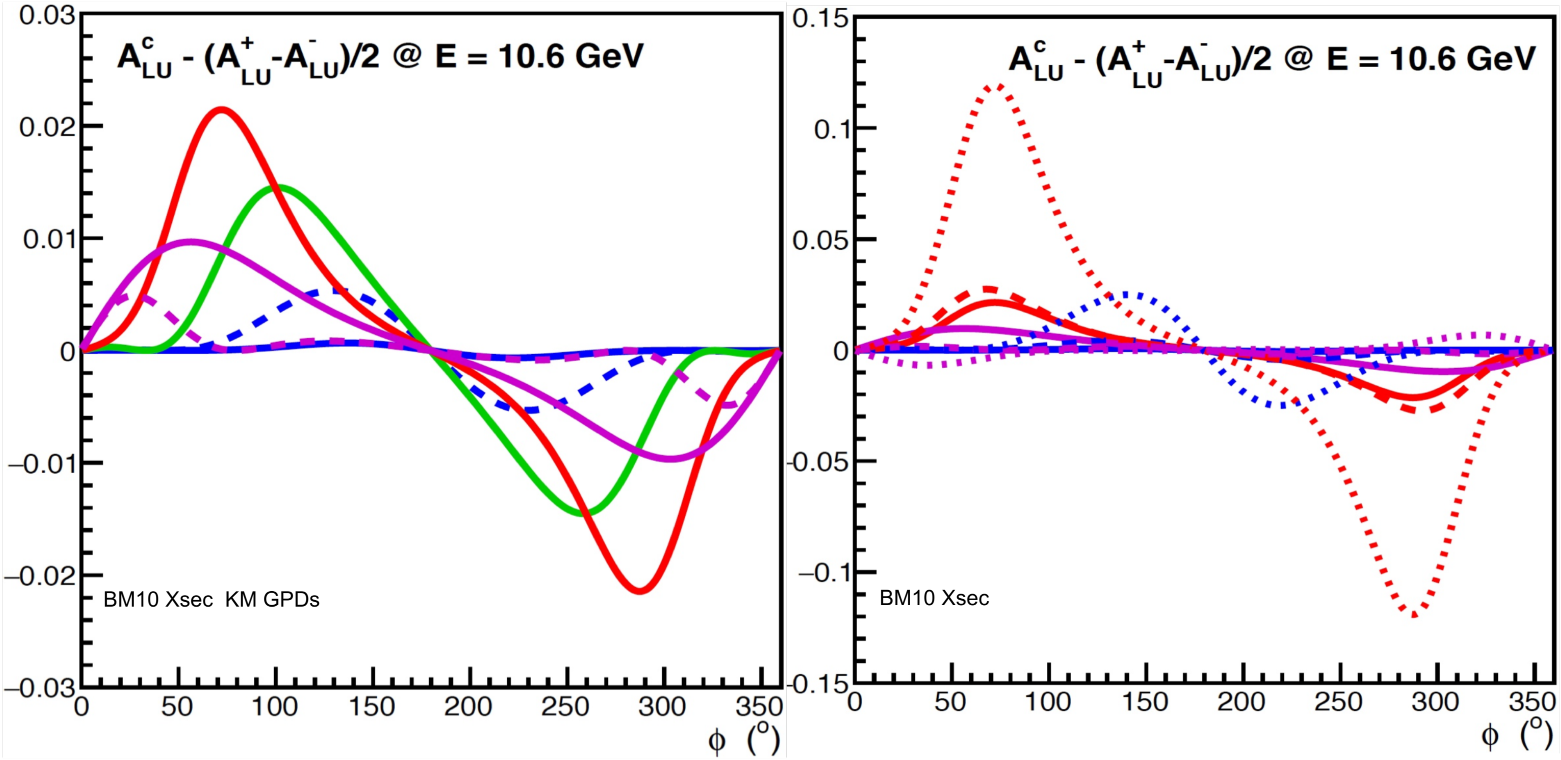


○ The **COMPASS** experiment operating high energy $\mu^\pm$ beams should release in a near future **BCA data** in the **sea-quark region**.

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 is a **kinematics-** and **GPD model-dependent hypothesis** eventually testable at CLAS12.

Experimental Projections

- *A sample of expected experimental data…*