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

V. Burkert[1*], L. Elouadrhiri[1*], F.-X. Girod[3*], J. Grames[1], S. Niccolai[2*], E. Pasyuk[1],
B. Raue[4], E. Voutier[2*] ...

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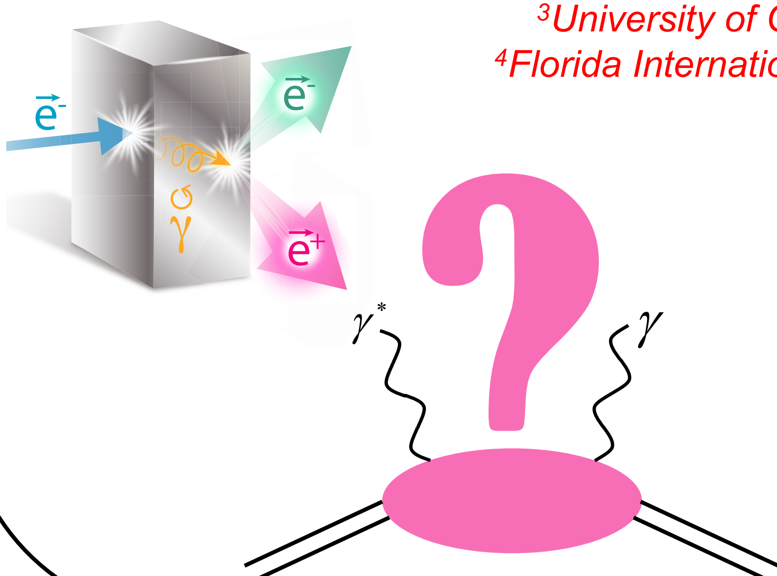
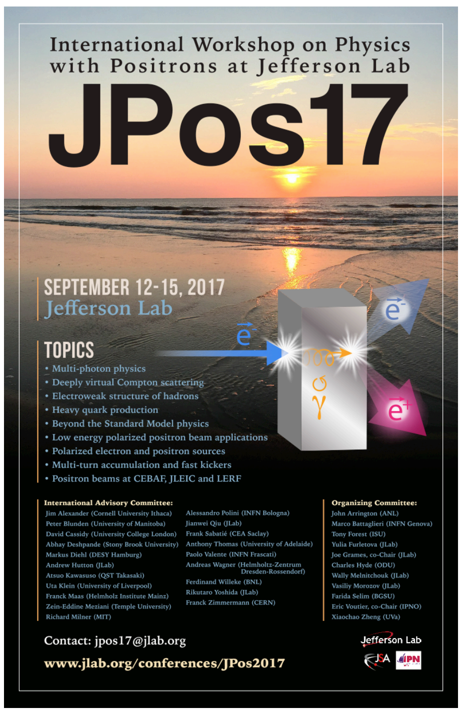
[2]Université Paris Saclay, IJCLab, Orsay, France
[3]University of Connecticut, Storrs, CT, USA
[4]Florida International University, Miami, FL, USA
...

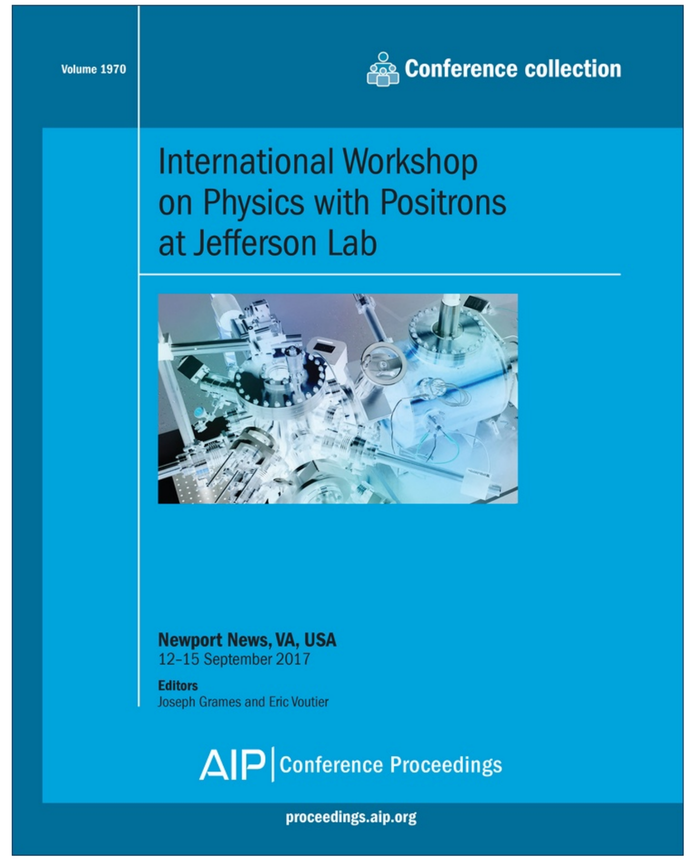


(i) Physics motivations
(ii) Proposed measurements
(iii) Polarized positron beam production
(iv) Positron beam in Hall B
(v) Control of systematics
(vi) Beam time request
(vii) e^+@JLab White Paper

JPos17

Proc. of the International Workshop on Physics with Positrons at Jefferson Lab, J. Grames and E. Voutier Edts. AIP Conf. Proc. 1970 (2018)





https://aip.scitation.org/toc/apc/1970/1?size=all&expanded=1970

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

Letter of Intent submitted to JLab PAC46 (July 2018)

Supported by ***127 members*** from ***39 institutions***

J. Arrington[8], M. Battaglieri[1,6], J. Bernauer[3], V. Burkert[1], A. Celentano[6], L. Elouadrhiri[1], F.-X. Girod[4], J. Grames[1], L. Marsicano[6,7], C. Muñoz Camacho[2], S. Niccolai[2], A. Puckett[9], A. Schmidt[5], E. Voutier[2], …

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[8]*Argonne National Laboratory, Argonne, IL, USA*
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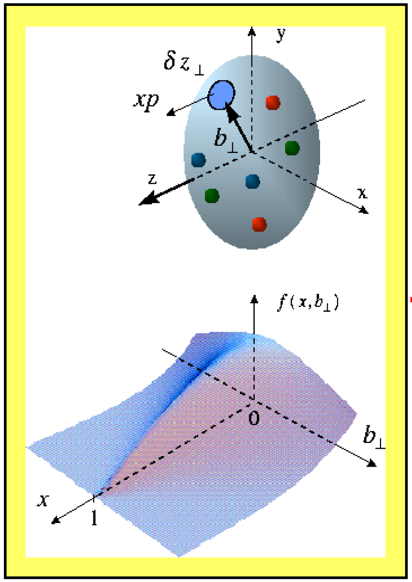
…

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

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.



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

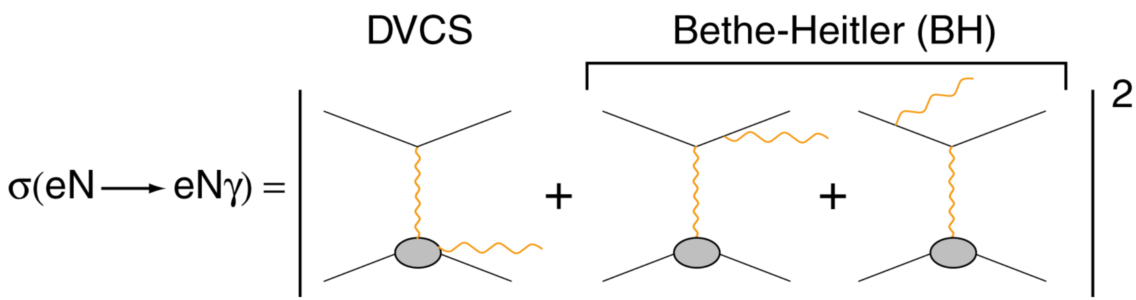
M. Burkardt, PRD 62 (2000) 071503 M.Diehl, EPJC 25 (2002) 223

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

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



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

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

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

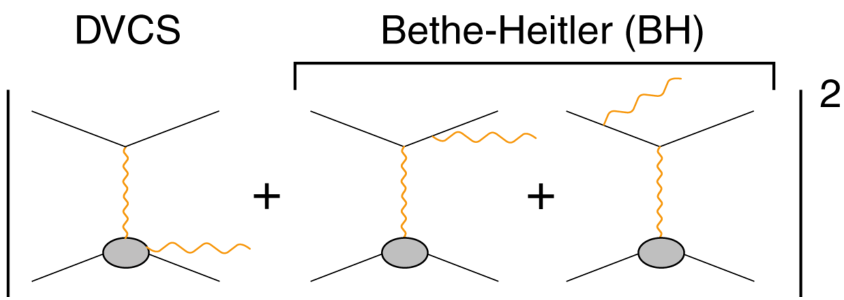
$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\,\tilde{\sigma}_{INT}$$

Eric Voutier
IJCLab Irène Joliot-Curie

N(e,e'γN) Differential Cross Section

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

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



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

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

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

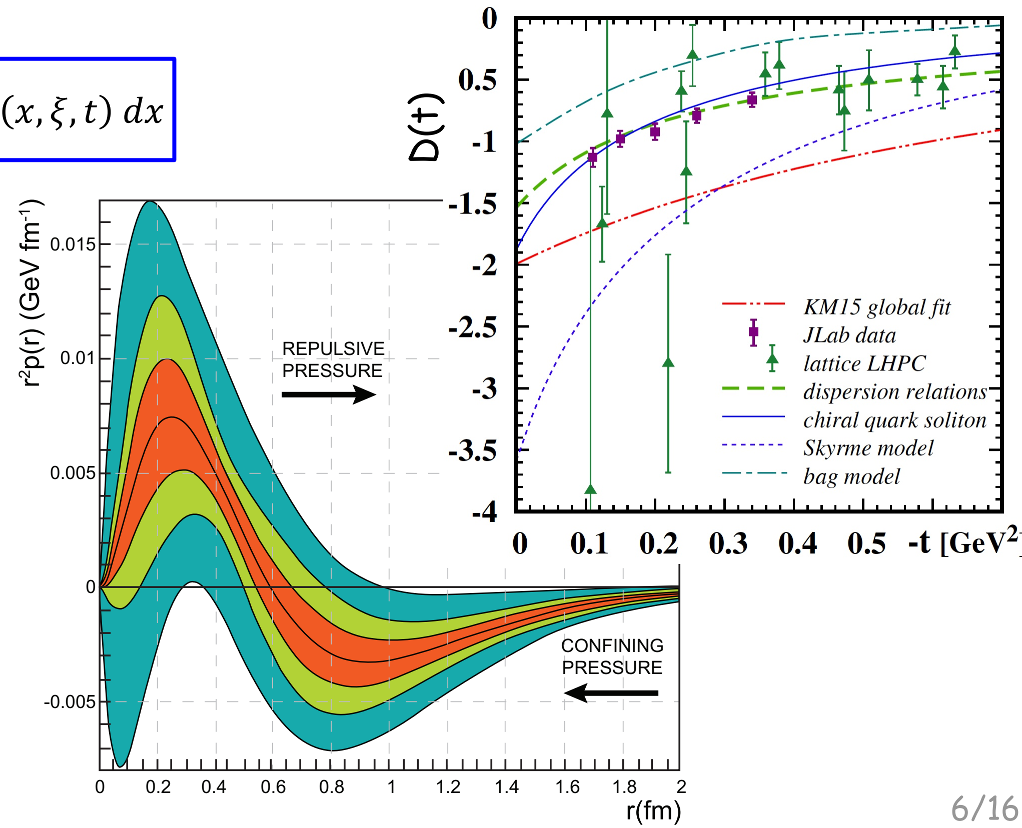
⇒ The 2nd order **Mellin moment** of GPDs allow to access the pressure distribution inside hadrons through the **skewness dependency** of GPDs… (**DDVCS**).

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

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

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

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



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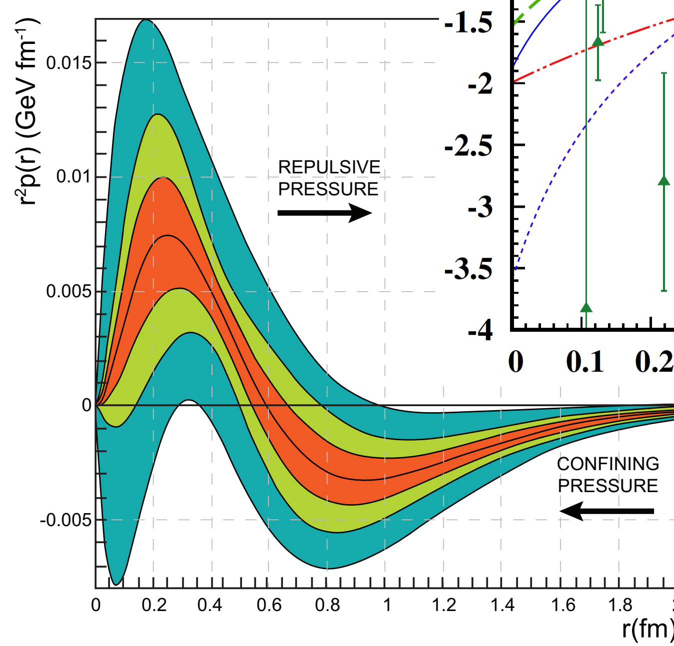
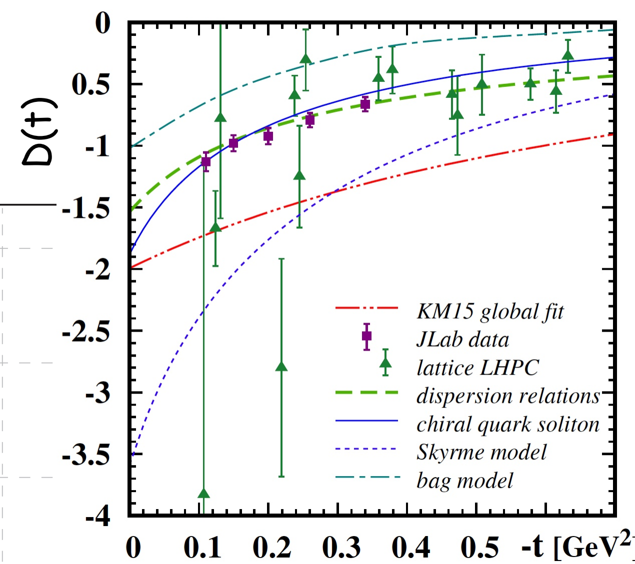
Real part of Compton form factors (σ_{INT})





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Beam Charge Asymmetries

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 charge averaged beam spin asymmetry A_{LU}^{0}, which is sensitive to **higher twist effects**

New GPD Observables

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

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

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

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

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

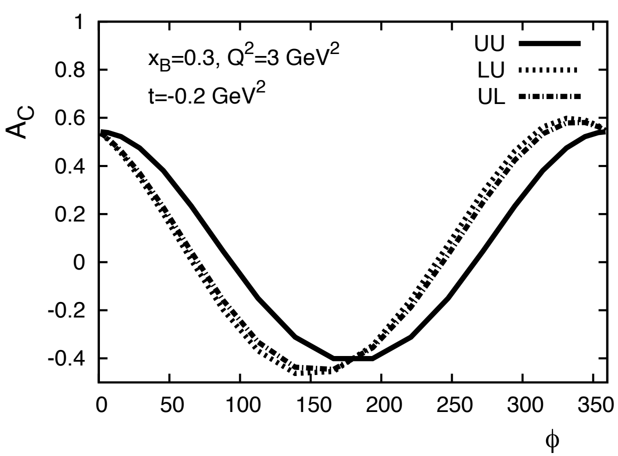
Experimental Observables

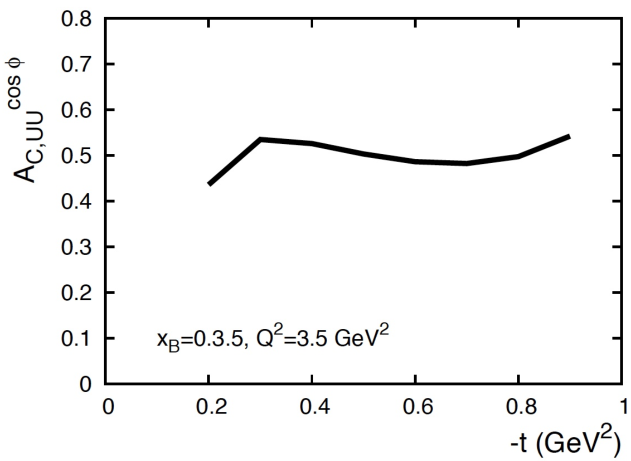
H. Avakian, V. Burkert, V. Guzey, JPos09, AIP 1160 (2009) 43

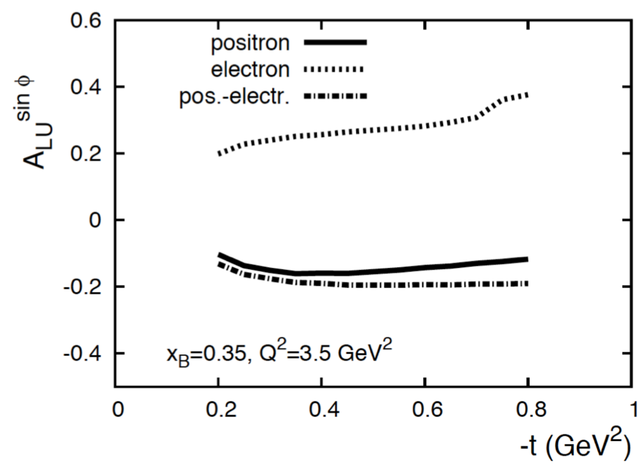
$$CFF \propto F_1\mathcal{H} + \frac{x_B}{2-x_B}(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}$$

Dominant contribution at twist-2 approximation

- Experimental observables are evaluated assuming GPD **H** and **E** dominance, within a **dual parameterization** approach.







Beam charge asymmetries with large amplitudes are predicted.

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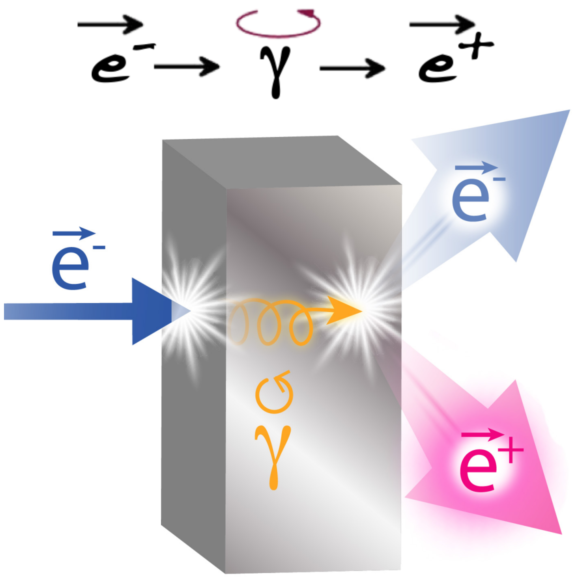
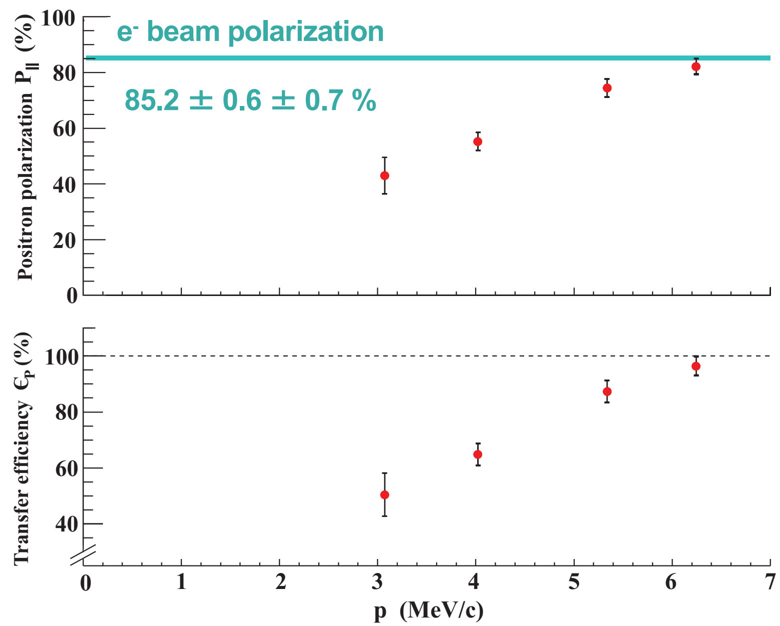
Polarized Electrons for Polarized Positrons

(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**.



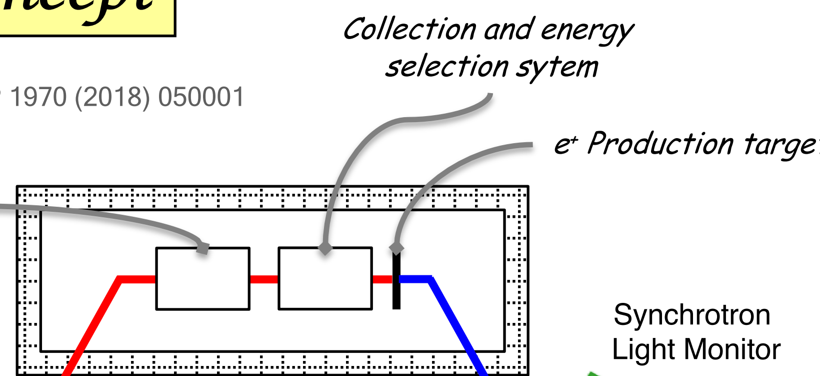


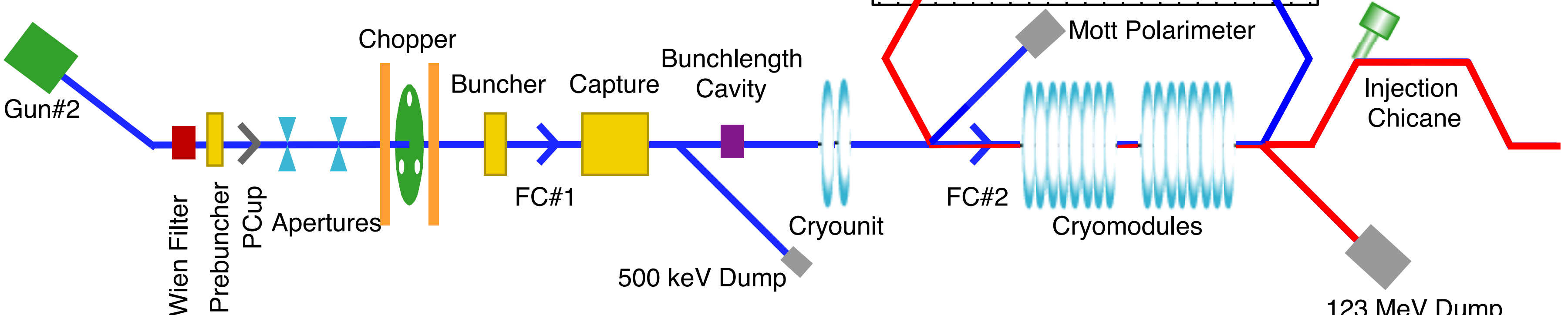
The PEPPo technique can achieve up to 100% transfer of the electron.

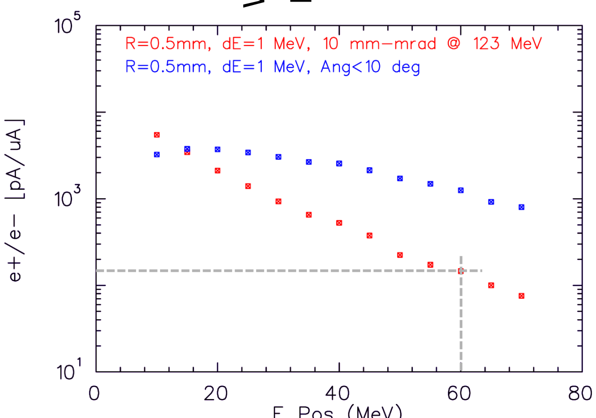
e⁺@JLab Concept

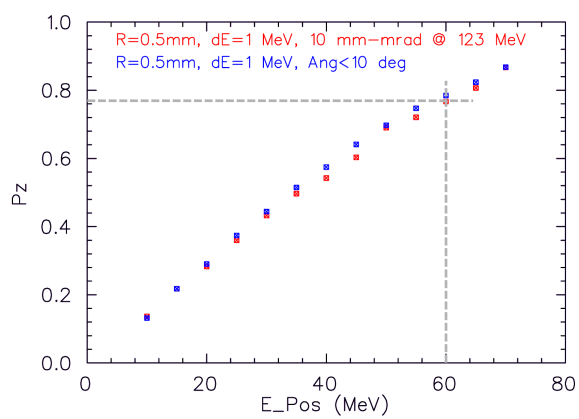
L. Cardman et al. (JPos17) AIP CP 1970 (2018) 050001

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









✓ Selecting **60 MeV** positrons maximizes the FoM
$(P_{e^+} \approx 75\% \, P_{e^-}, \; I \approx 100 \text{ nA})$

✓ Selecting **6 MeV** positrons maximizes the flux
$(I > 1 \, \mu A)$

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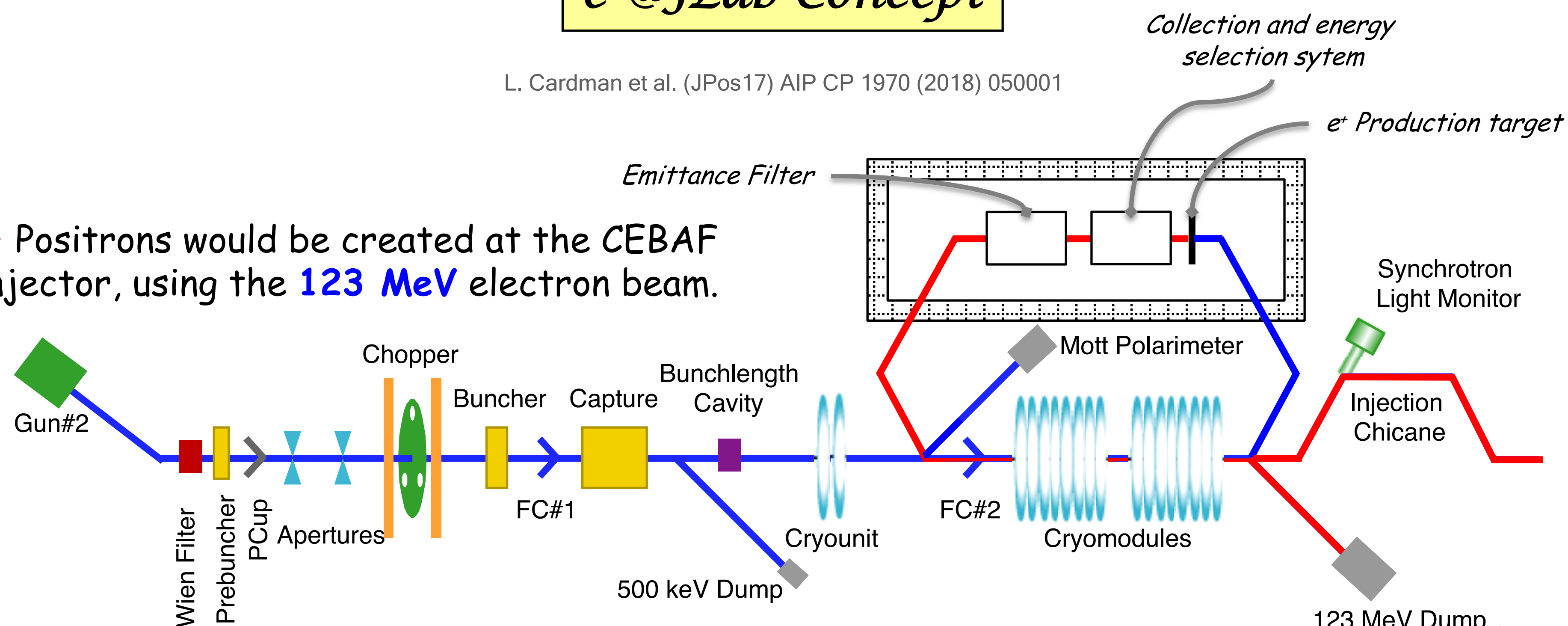
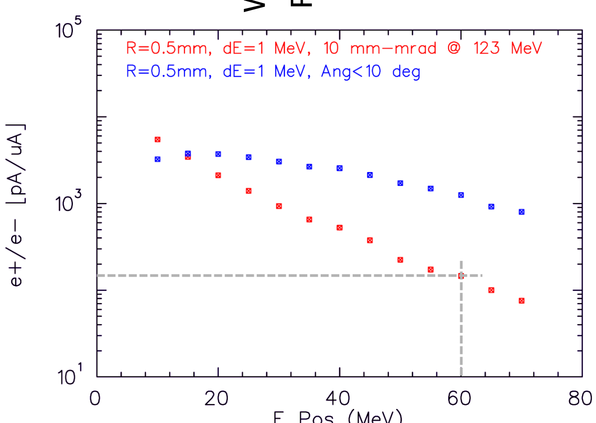
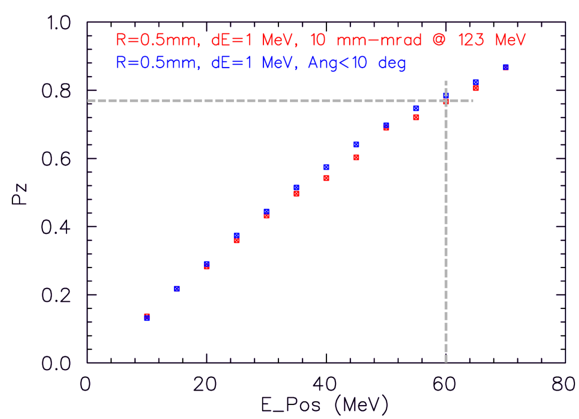
e^+@JLab Concept

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** maximizes th… ($P_{e^+} \approx 75\%$ … 00 nA)
- ✓ S… MeV positrons …mizes the flux ($I > 1\ \mu A$)

4 pC @ 250 MHz
123 kW beam power on a thick target

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e^+ Beam Induced Modifications

Beam transport and characterization

- There is **no difference** bewteen electron and positron beam transport in Hall B beam line
- Beam diagnostic shoud be operated *in principle*
- *Møller to Bhabha polarimeter*

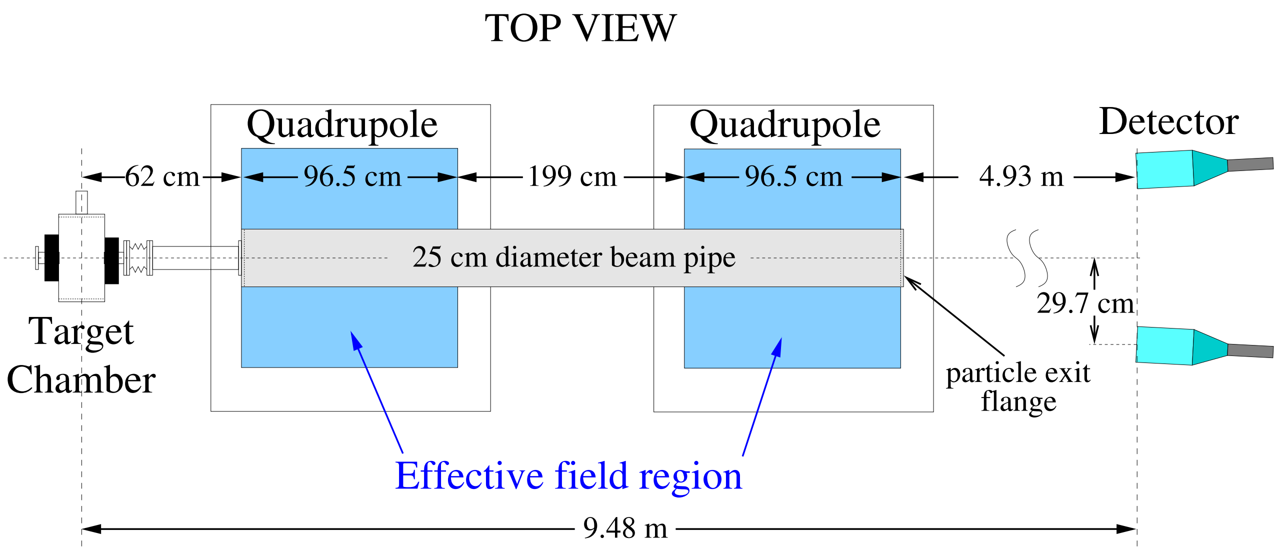
On-going reflexion of experts

Beam related background in CLAS12

- **Bhabha** and **Møller** scattering have different angular distributions: from similar to **much smaller** as c.m. angle increases
- Positron **annihilation** is an additional background process

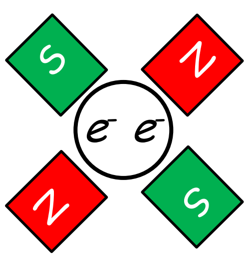
Simulations in progress

Møller to Bhabha Polarimeter



Bhabha asymmetry is **identical** to **Møller**, and **cross sections similar magnitude** at 90°c.m.

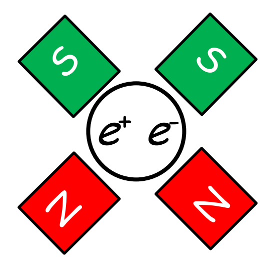
The transition of the Møller polarimeter into a Bhabha polarimeter requires to rewire the quads into dipoles.



view downstream

- Loss of half the coincidences
- Potential background issues from cross-over events

In principle possible…



in bending mode

B. Raue

Beam Related Systematics

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 have the **same $\delta p/p$** at target, with an emittance **2-3 times larger**.

Transverse Emittance* and Energy Spread†

12GeV config

Area	$\delta p/p$ [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

Damping

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

Sync. Rad.

* Emittances are geometric
† Quantities are rms

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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†

Positrons

Area	$\delta p/p$ [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

Damping

Sync. Rad.

* Emittances are geometric
† Quantities are rms

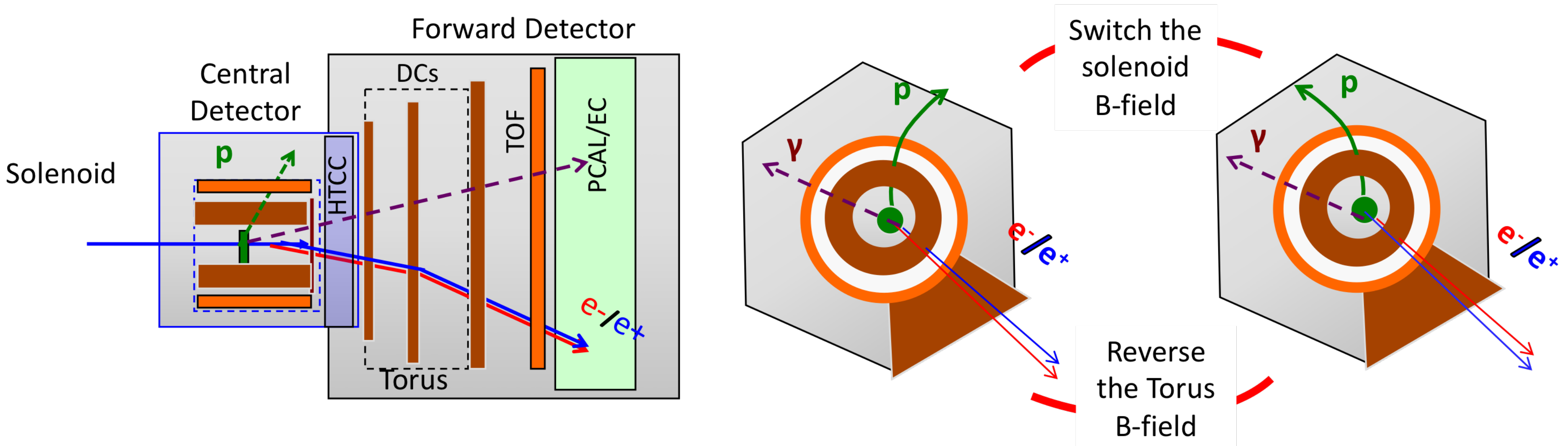
Courtesy Yves Roblin

Thomas Jefferson National Accelerator Facility — Office of Science, U.S. Department of Energy
Operated by the Southeastern Universities Research Association for the U.S. Department of Energy
Y. Roblin, JPOS17 workshop, 12-15 Sept 2017

- **Select** the **electron** from the e^+e^--pair produced at the source to investigate these possible effects or perform the physics measurement.

Detector Related Systematics

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



Two possible remedies

V. Burkert

- Switch the solenoid field to reveals false asymmetries in FD, 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.

Eric Voutier

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BCA @ CLAS12

Purpose	Beam	Energy (GeV)	Polarization (%)	Luminosity ($cm^{-2}.s^{-1}$)	Time (d)
Commissionning / Calibration	e^+/e^-	11	60 (> 40)	10^{35}	4
p-DVCS	e^-				38
	e^+				38
				Total	**80**

➢ We propose to run for **80 days** equally shared between polarized positron and electron beams, including:

commissionning of « new » equipment,

specific systematics calibration measurements,

DVCS physics data taking off the proton.

- *Projections of experimental measurements*
- ***Impact** of positron measurements on **CFF** extraction*
- ***Impact** of positron measurements on **D-term** determination*

Work in progress…

JLab Positron Working Group

https://wiki.jlab.org/pwgwiki/index.php/E%2B_White_Paper_Sub-Group

Full information available here

- The JLab Positron Working Group is developping a White Paper intenting to describe the full extent of a **Physics Program** with **Positron** beams at **JLab**.

Four Physics Sub-Groups

- Deeply Virtual Compton Scattering (Silvia Niccolai, niccolai@ipno.in2p3.fr)
- Two-Photon Exchange Physics (Axel Schmidt, schmidta@jlab.org)
- Physics Beyond the Standard Model (Marco Battaglieri, battagli@jlab.org)
- Other Topics (Douglas Higinbotham, doug@jlab.org)

Revised Time Table

First draft of each contribution: **May 11th**.
Final contribution: **June 1st**.
First draft of the White Paper: June 15th.
Final Positron White Paper: **June 29th**.

Contact the convener of your physics sub-group for any contribution to the **e+@JLab White Paper**

Template files available here

https://ipnshare.in2p3.fr/owncloud/index.php/s/BdDZ2NHS2qSV4jZ/download