Positron Beams and Physics at Jefferson Lab

e^+ @ JLab 12 GeV

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

and the JLab Positron Working Group

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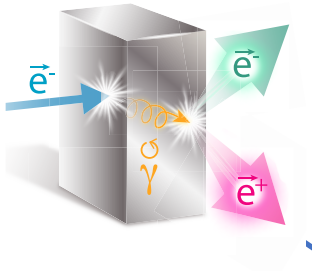
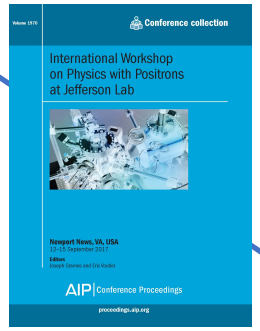
CNRS/IN2P3, Laboratoire de Physique des 2 Infinis Irène Joliot-Curie (IJCLab)
Orsay, France

Thanks to Y. Furletova, S. Mantry, L. Marsicano, A. Schmidt, X. Zheng
for help with this presentation

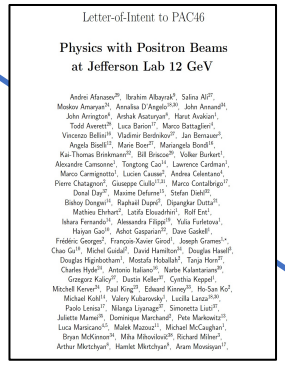


The PWG was created in 2017 after JPos17 (International Workshop on Physics with Positrons at Jefferson Lab) to promote the physics case of positron beams at JLab. It now gathers about 250 physicists from 70 institutions supporting an ambitious experimental program.

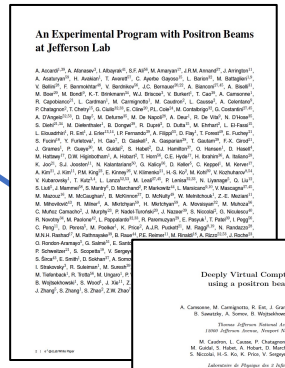
2017

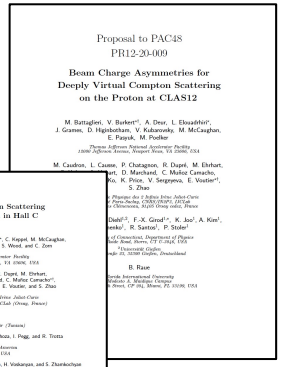


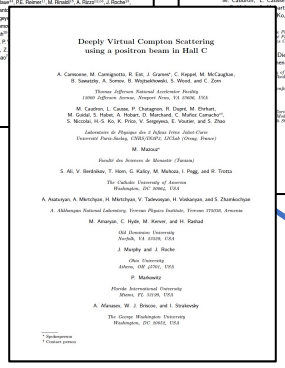
2018



2020







2021…

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

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

More proposals to come…

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

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

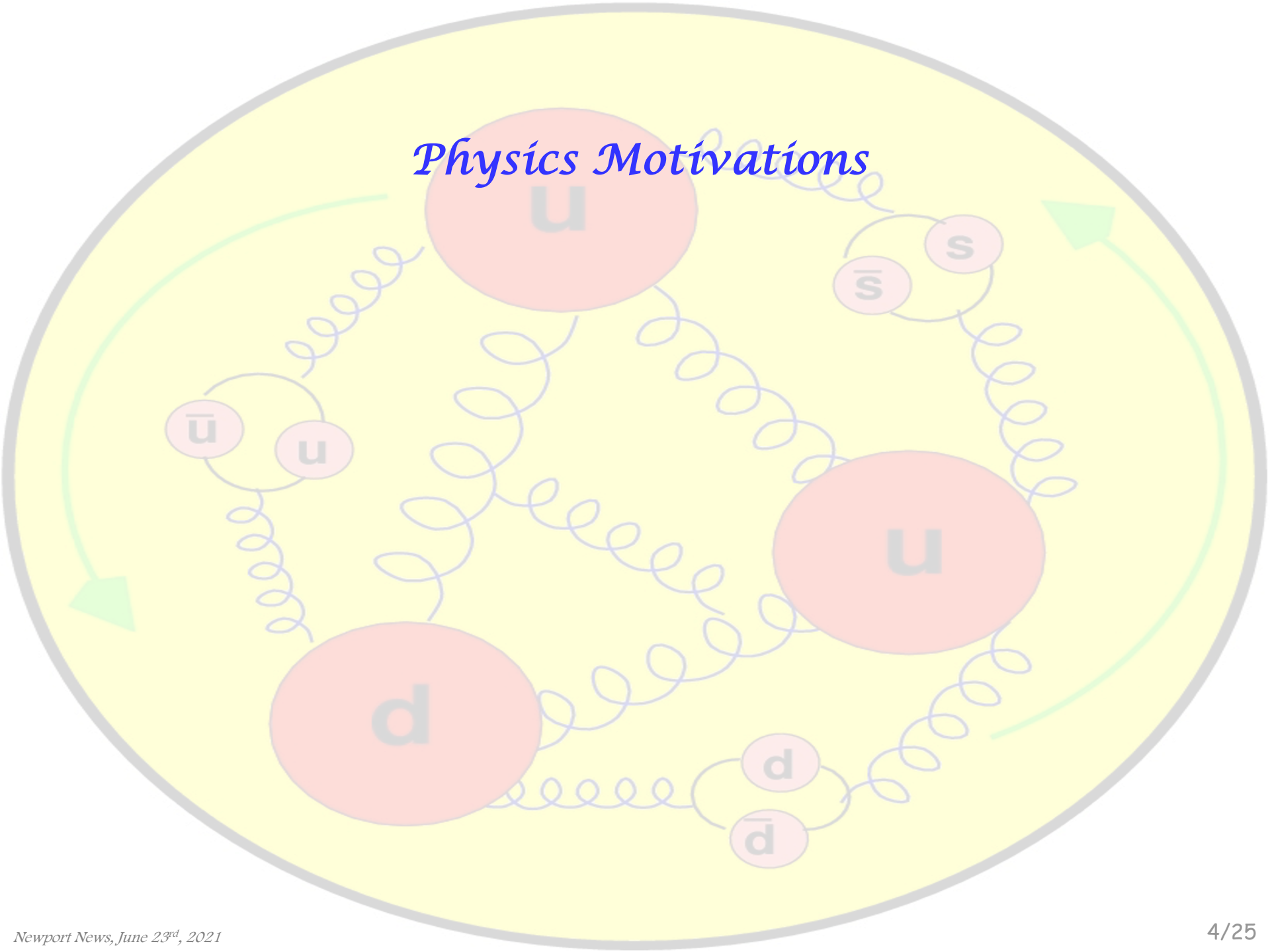
- *Submitted*
- ❖ *Approved*

Contributions are currently peer reviewed.

Publication is in progress and should be completed by september.

https://epja.epj.org/component/toc/?task=topic&id=1430

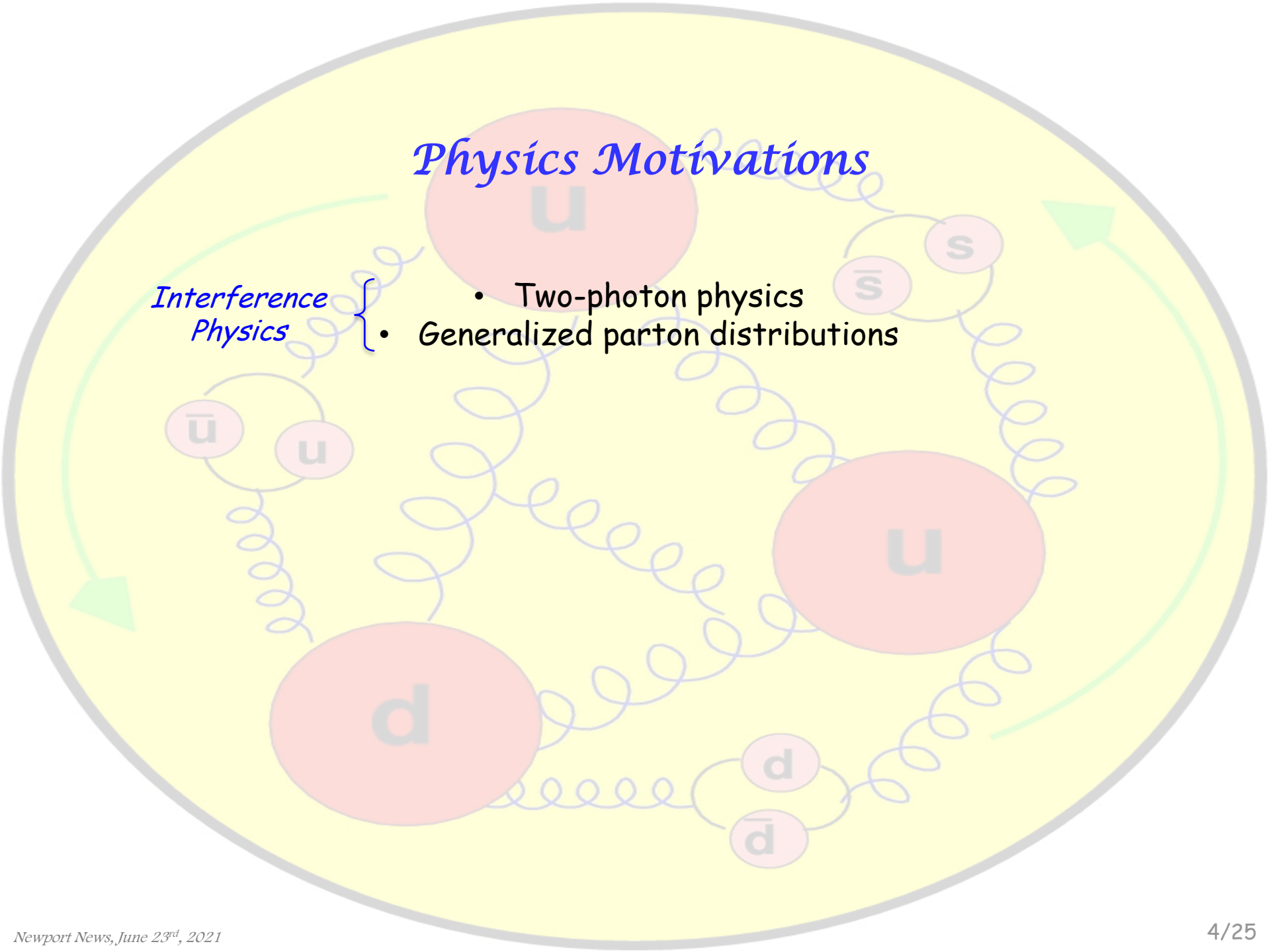
Physics Motivations



Physics Motivations

Interference Physics

- Two-photon physics
- Generalized parton distributions



Physics Motivations

Interference Physics

- Two-photon physics
- Generalized parton distributions

Structure Functions

- Neutral and charged current DIS
- Charm production
- …

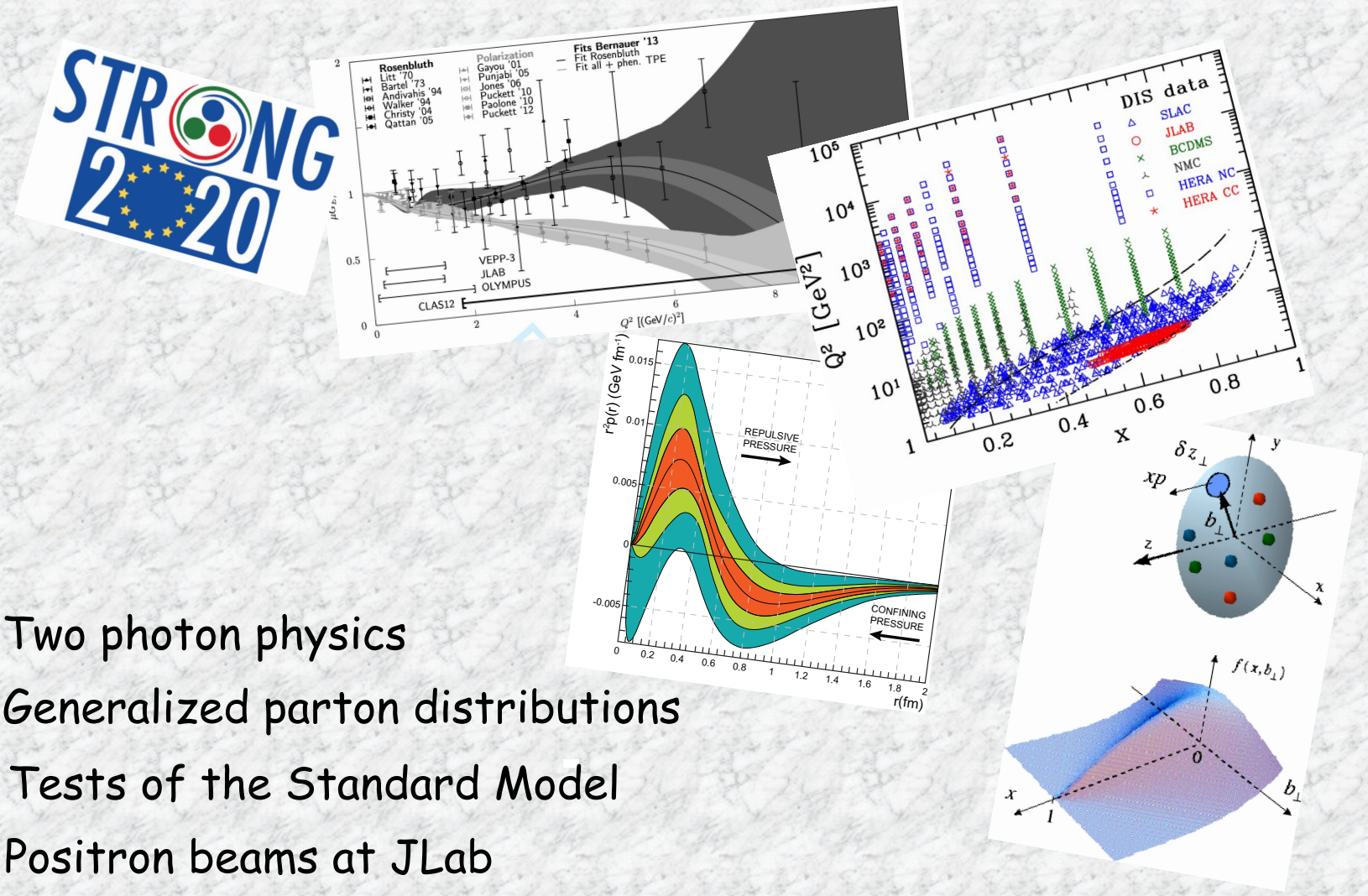
Physics Motivations

Interference Physics
- Two-photon physics
- Generalized parton distributions

Structure Functions
- Neutral and charged current DIS
- Charm production
- …

Standard Model Tests
- Neutral electroweak coupling
- Light Dark Matter search
- Charged Lepton Flavor Violation

Outline



(i) Two photon physics

(ii) Generalized parton distributions

(iii) Tests of the Standard Model

(iv) Positron beams at JLab

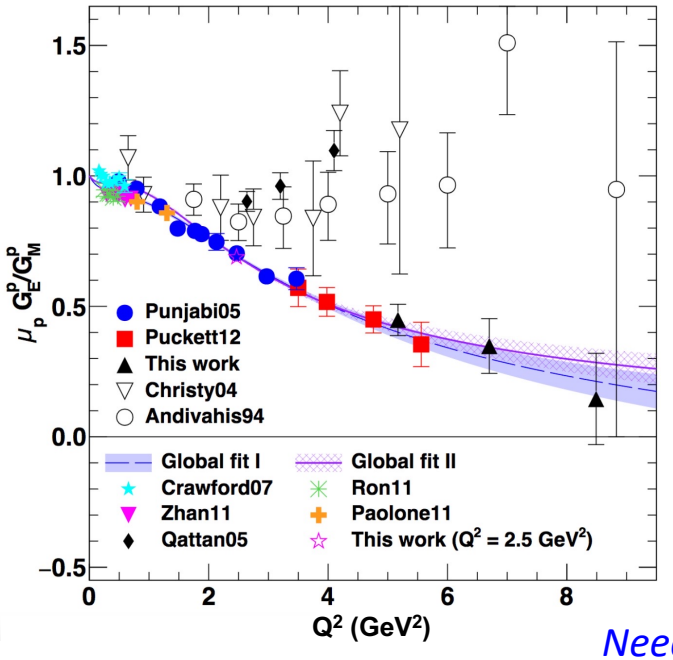
This project has received funding from the European Union's Horizon 2020 research and innovation program under agreement No 824093.

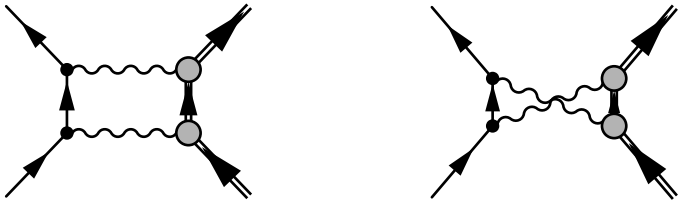
Electromagnetic Form Factors

P.A.M. Guichon, M. Vanderhaeghen, PRL 91 (2003) 142303 P.G. Blunden, W. Melnitchouk, J.A. Tjon, PRL 91 (2003) 142304

➢ Measurements of polarization transfer observables in electron elastic scattering off protons question the validity of the 1γ exchange approximation (OPE) of the electromagnetic interaction.

A.J.R. Puckett et al. PRC 96 (2017) 055203





Hard two-photon exchange (TPE) may be the cause of the form factor discrepancy at high Q^2.

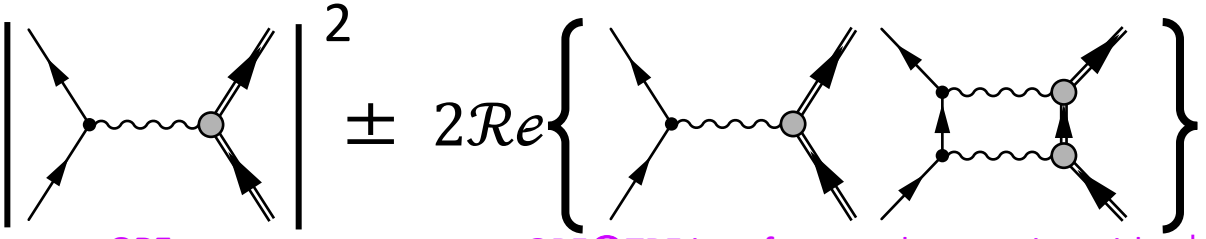
- If the TPE hypothesis is valid, the electromagnetic structure of the nucleon would be parameterized by 3 generalized form factors i.e. 8 unknow quantities.
- TPE can only be calculated within model-dependent approaches.

*Need for a large enough set of **independent** and **sensitive observables**.*

Experimental Observables

M.P. Rekalo, E. Tomasi Gustafsson, NPA 742 (2004) 322 C. Carlson, M. Vanderhaeghen, ARNPS 57 (2007) 171

$$\frac{d\sigma}{d\Omega} \sim |\mathcal{M}|^2 = \left| \right|^2 \pm 2\mathcal{R}e\left\{ \right\} + \ldots$$



OPE

OPE⊗TPE interference changes sign with $e^{\pm}$

➢ Unpolarized $e^{\pm}$ elastic scattering and polarization transfert observables off the nucleon involve up to 5 unknown quantities.

Cross Section

$$\sigma_R = G_M^2 + \frac{\varepsilon}{\tau} G_E^2 \pm 2 G_M \Re\left[f_0\left(\delta\tilde{G}_M, \delta\tilde{F}_3\right)\right] \pm 2\frac{\varepsilon}{\tau} G_E \Re\left[f_1\left(\delta\tilde{G}_E, \delta\tilde{F}_3\right)\right]$$

Polarization Transfert

$$\sigma_R P_t = -\sqrt{\frac{2\varepsilon(1-\varepsilon)}{\tau}} \left(G_E G_M \pm G_E \Re\left[\delta\tilde{G}_M\right] \pm G_M \Re\left[f_1\left(\delta\tilde{G}_E, \delta\tilde{F}_3\right)\right]\right)$$

$$\sigma_R P_l = \sqrt{1-\varepsilon^2} \left(G_M^2 \pm 2 G_M \Re\left[f_2\left(\delta\tilde{G}_M, \delta\tilde{F}_3\right)\right]\right)$$

5 unknown contributions for 6 independent observables

LoI12-18-004

Jefferson Lab Positron Working Group

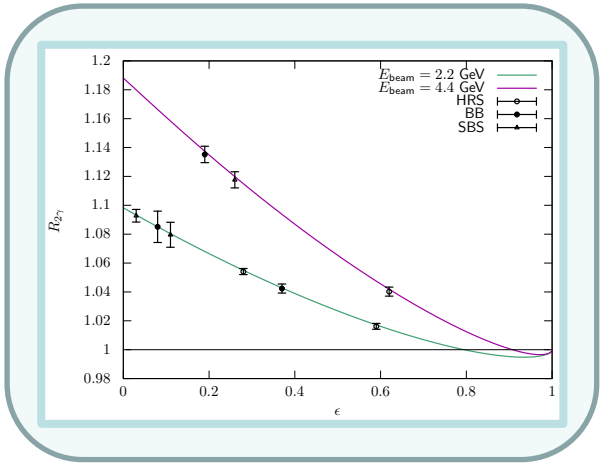
(Jefferson Lab Positron Working Group) A. Afanasev et al. arXiv:1906.09419 (2019)

➢ An unpolarized positron beam at CEBAF would **rapidly** and **decisively** test the TPE hypothesis, **mapping out** the **2γ-effects** in the **(Q^2,ε)** space.

$$R_{2\gamma} = \frac{\sigma_{e^+}}{\sigma_{e^-}} \approx 1 + \delta_{2\gamma}$$

Hall A

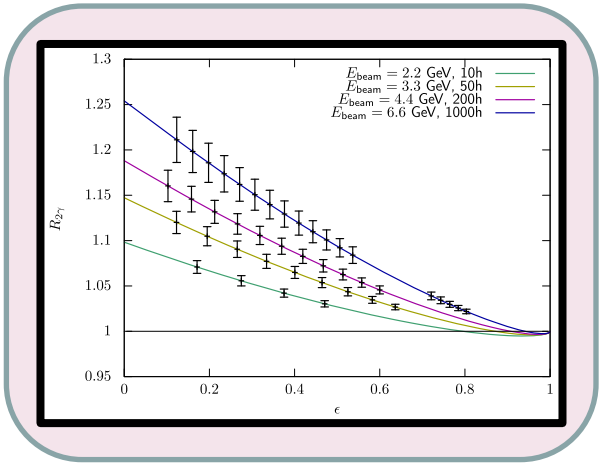
SBS can quickly test high-impact low-ε kinematics.



E. Cline et al. arXiv:2103.06301

Hall B

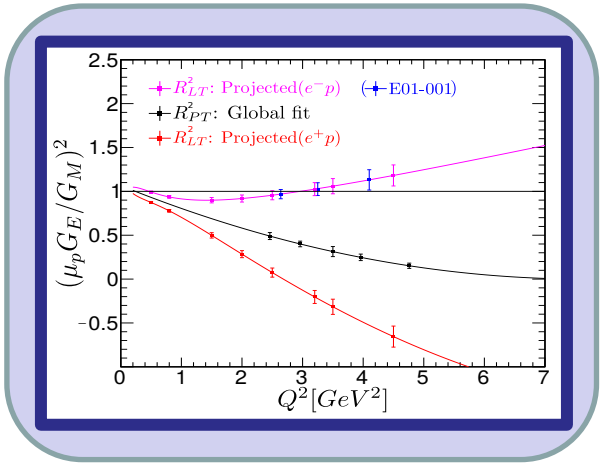
A modified CLAS12 detector will provide a kinematic mapping.



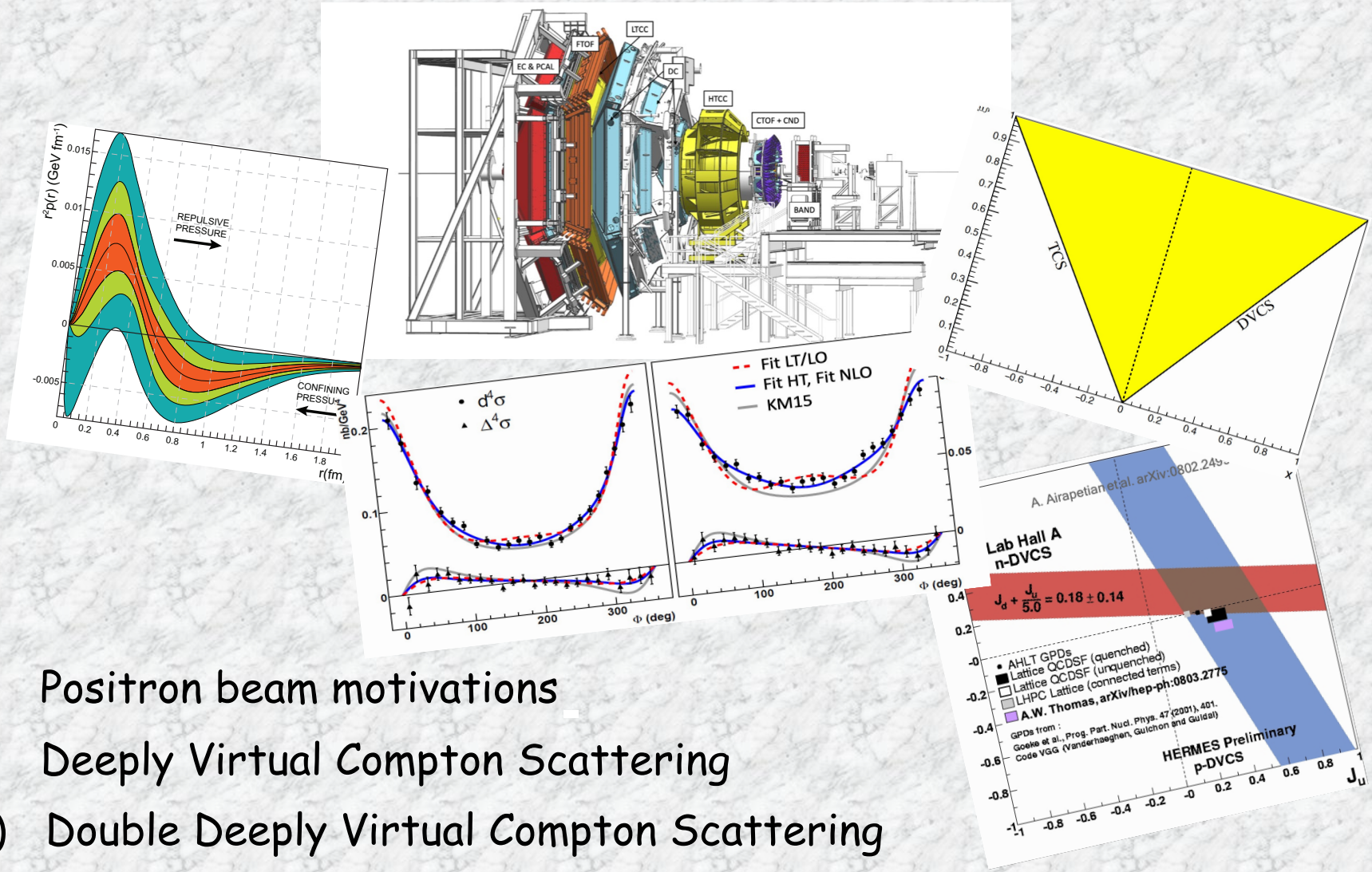
J. C. Bernauer et al., EPJA 57 144 (2021)

Hall C

e^+ Super-Rosenbluth measurements to compare with previous e^- ones.



J. R. Arrington, M. Yurov., arXiv:2103.03752



(i) Positron beam motivations

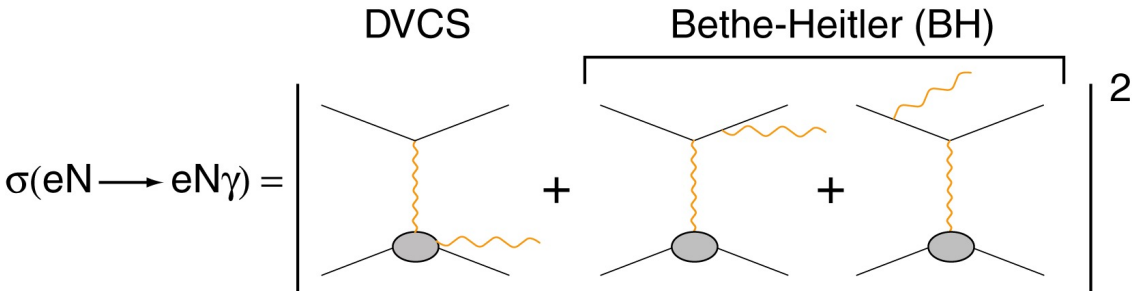
(ii) Deeply Virtual Compton Scattering

(iii) Double Deeply Virtual Compton Scattering

N(e,e'γN) Differential Cross Section

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

DVCS Bethe-Heitler (BH)



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

Electron observables

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

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

Electron & positron observables

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

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

N(e,e'γN) Differential Cross Section

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

DVCS Bethe-Heitler (BH)

$$\sigma(eN \longrightarrow eN\gamma) = \left| \quad + \quad + \quad \right|^2$$

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

Electron observables

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

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

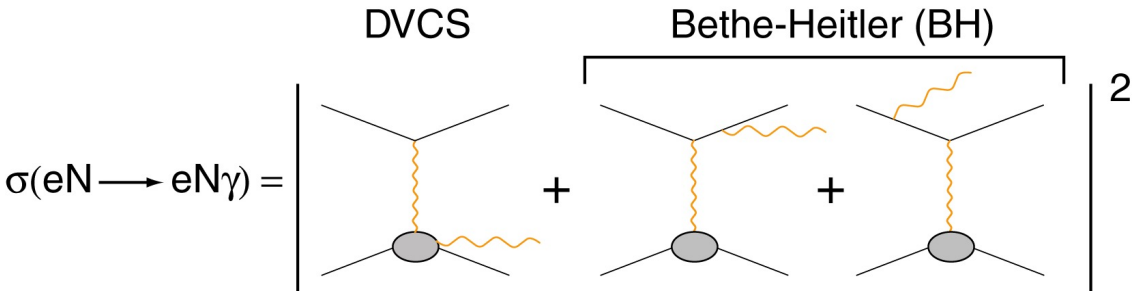
Electron & positron observables

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

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

N(e,e'γN) Differential Cross Section

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

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Electron & positron observables

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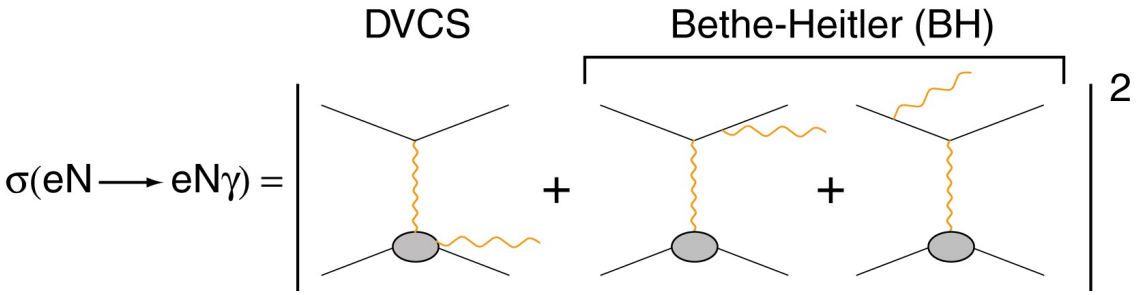
N(e,e'γN) Differential Cross Section

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



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

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

PR12-20-009

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

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

Beam Charge Asymmetries are proposed to be measured at CLAS12:

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

New GPD Observables @ JLab

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

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

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

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

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

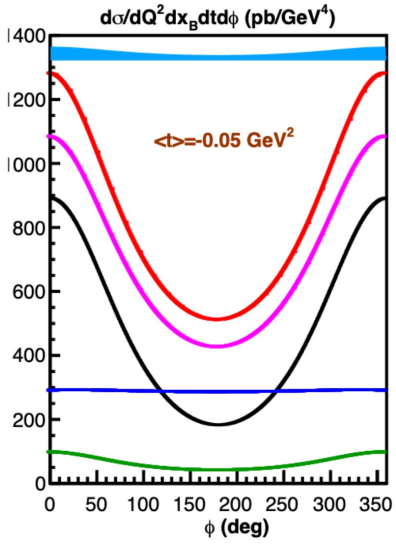
Pr12-20-012

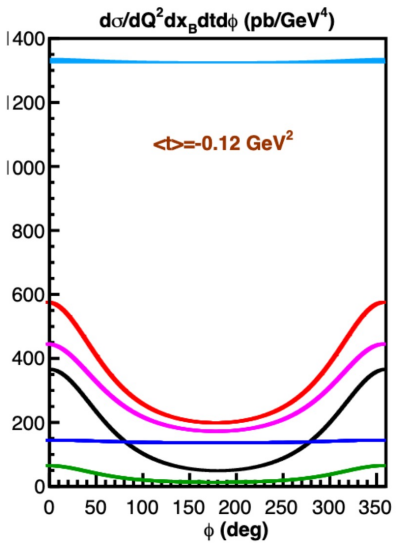
J. Grames, M. Mazouz, C. Muñoz Camacho et al.

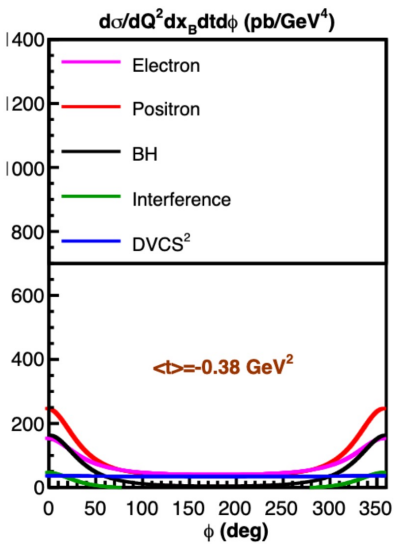
A. Afanasev et al. arXiv:2105.06540 (2021)

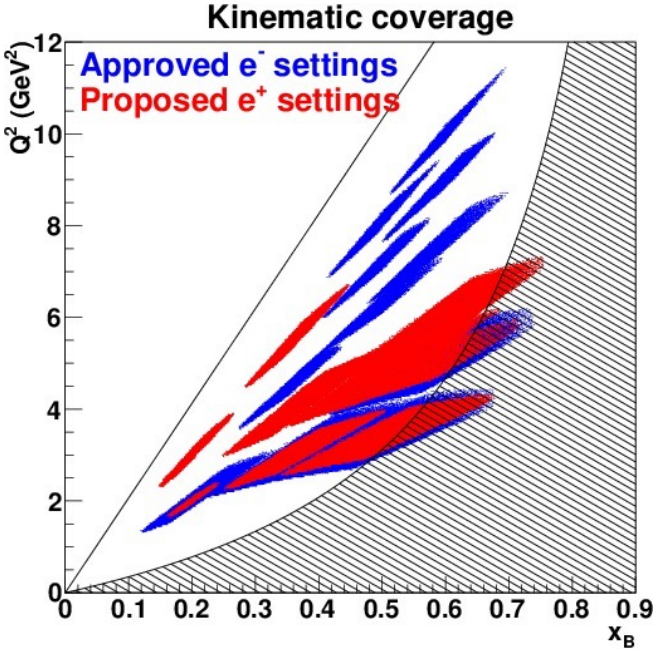
➢ Combining the HMS and the NPS spectrometers, precise cross section measurements with unpolarized positron beam will be performed at selected kinematics where electron beam data will soon be accumulated.

$x_B = 0.5 \quad Q^2 = 3.4\ GeV^2$







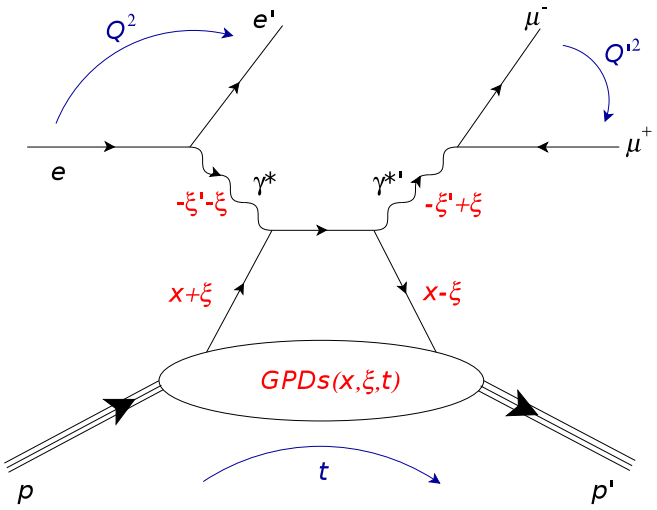


Off-Diagonal Compton Form Factors

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

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

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



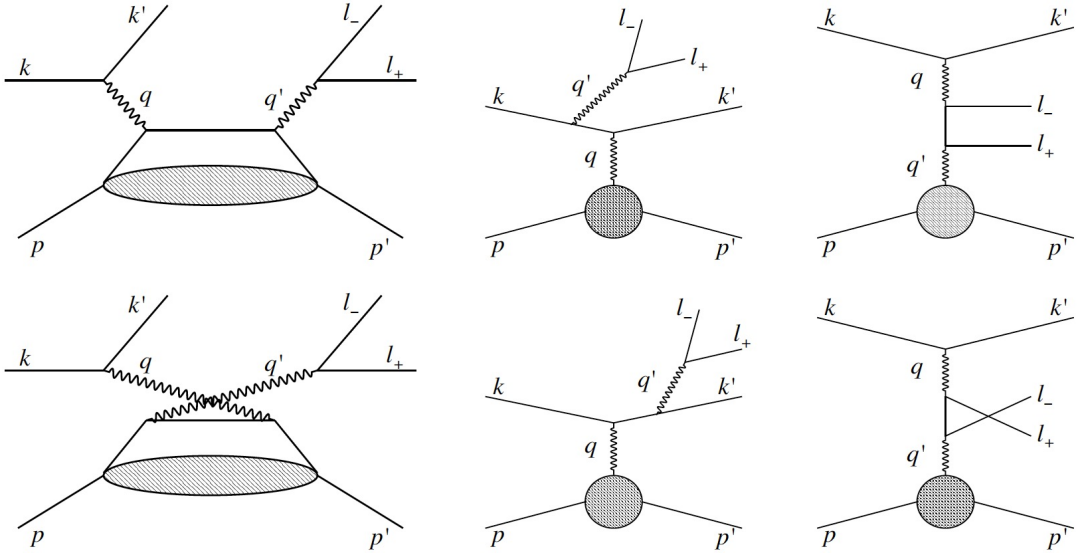
$$F_+(x,\xi,t) = \sum_q \left(\frac{e_q}{e}\right)^2 \left[F^q(x,\xi,t) \mp F^q(-x,\xi,t)\right]$$

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

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

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

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



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

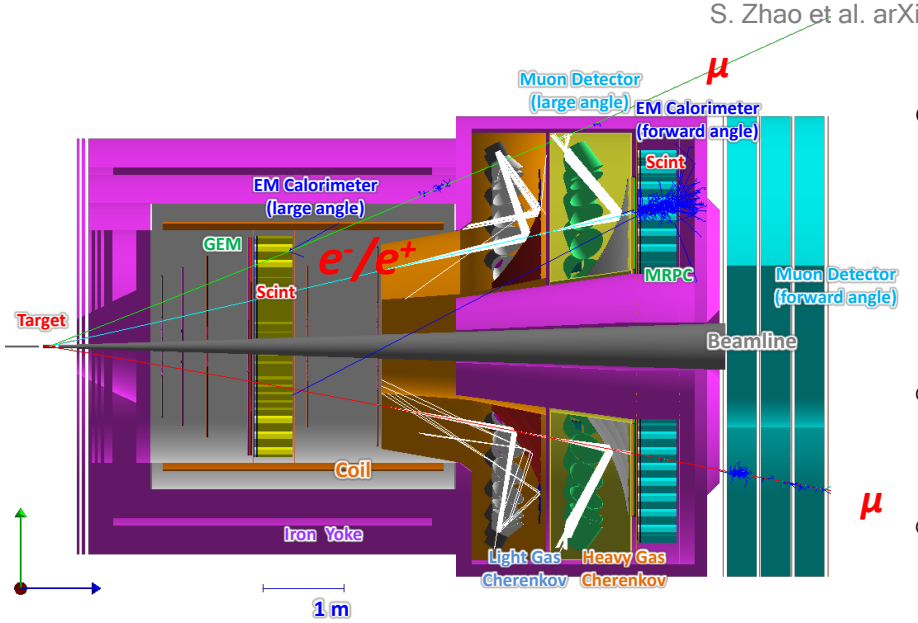
Integration over lepton pair angles

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

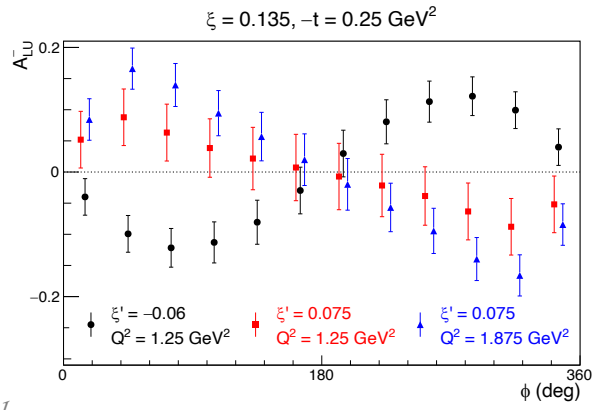
LoI12-15-005

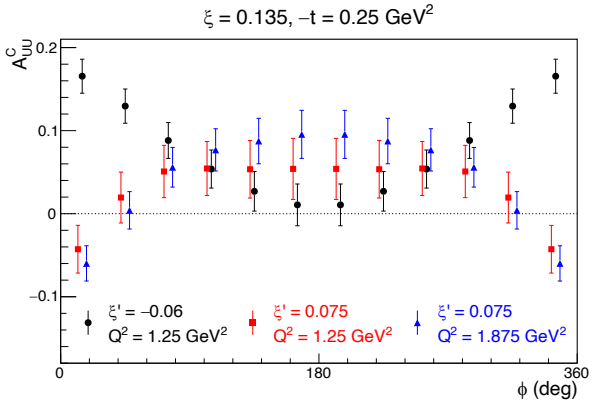
M. Boer, A. Camsonne, K. Gnanvo, E. Voutier, Z. Zhao et al.

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

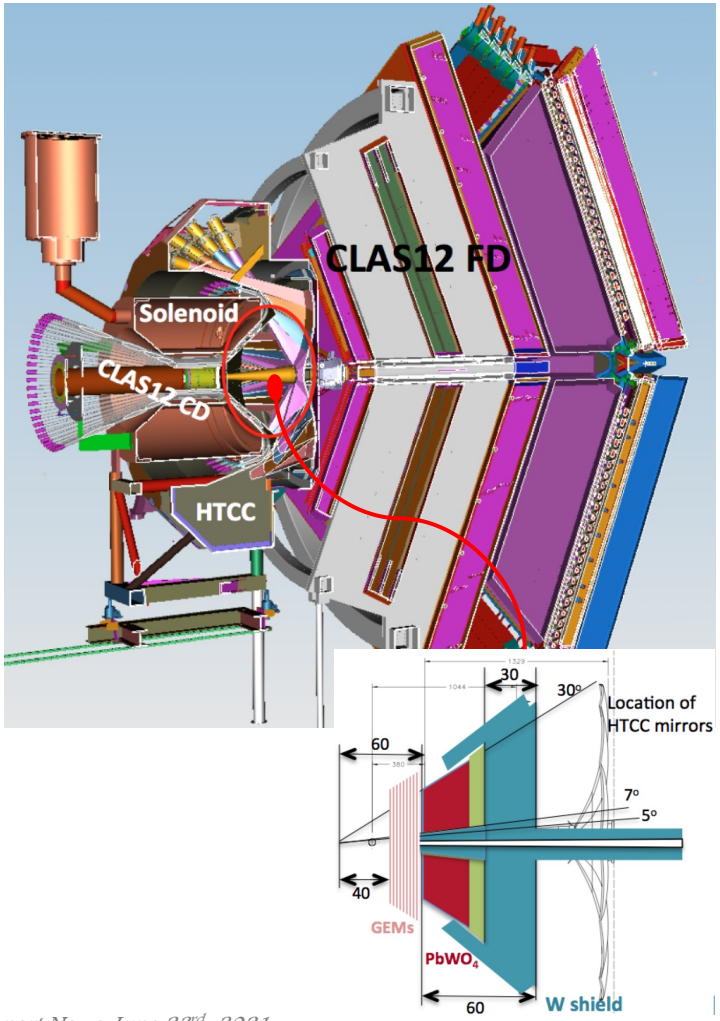


- The SoLID apparatus completed with muon detectors at large and forward angles, would allow DDVCS measurements with both polarized electron and polarized positron beams.
- The initial LoI discussed electron BSA measurements over a 50 days run parasitic to the J/Ψ approved experiment.
- Completing this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

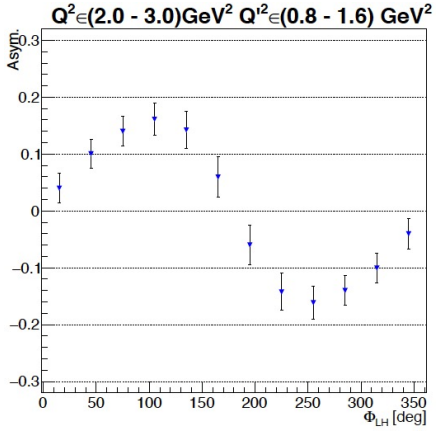


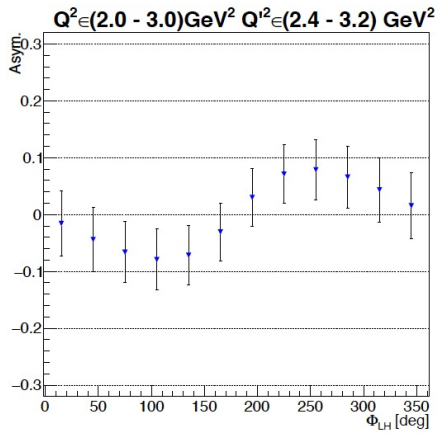


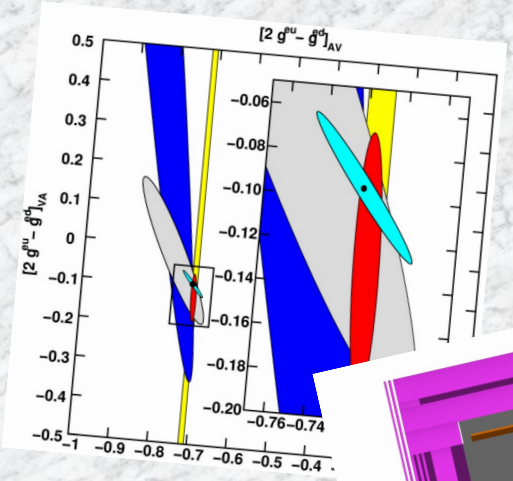
LoI12-16-004
S. Stepanyan et al.

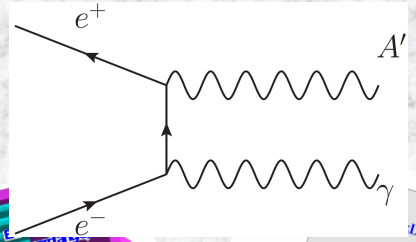


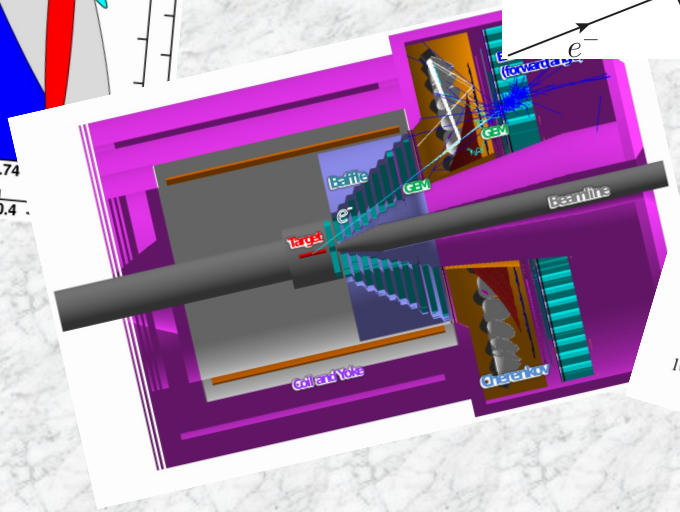
- A modified CLAS12 spectrometer with a new tracker, a new calorimeter and a tungsten shield in the HTCC working volume would allow to increase CLAS12 luminosity up to $10^{37}cm^{-2}\cdot s^{-1}$.
- The new detection system will serve electron identification.
- The CLAS12 forward detector will act as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

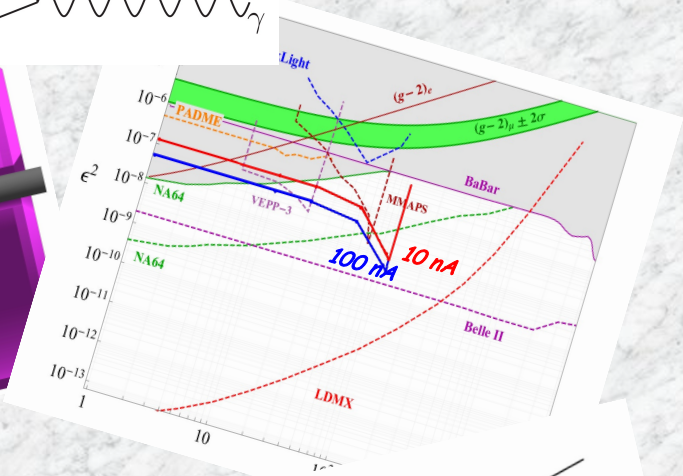


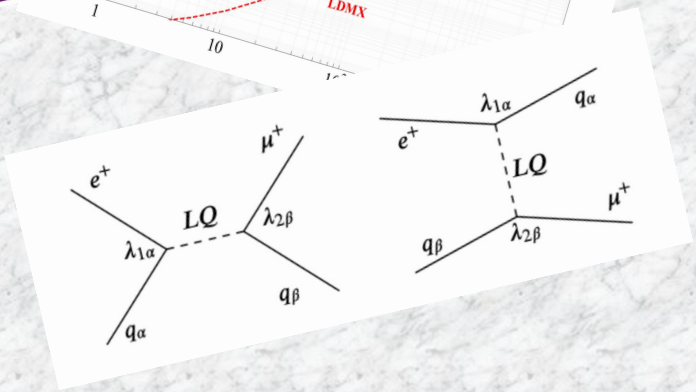












(i) Neutral electroweak coupling

(ii) Light Dark Matter search

(iii) Charged Lepton Flavor Violation

PR12-21-006
(SoLID and Hall A Collaborations) X. Zheng et al.

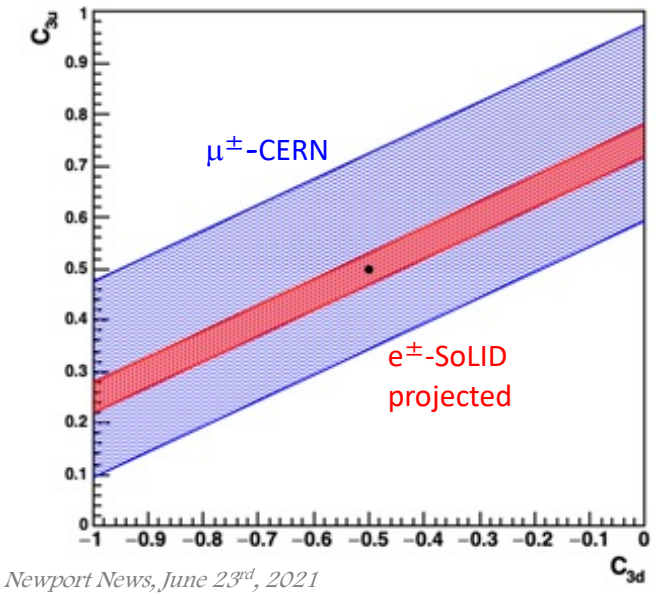
X. Zheng, JPos09, Newport News (2009) X. Zheng, J. Erler, Q. Liu, H. Spiesberger, EPJA 57 (2021) 5

- Comparing **unpolarized electron** and **positon** DIS scatterings accesses the C_{3q} axial-axial neutral current coupling, and the $F_3^{\gamma Z}$ structure function.

$$\mathcal{L} = \frac{G_F}{\sqrt{2}} \sum_q \left[C_{1q}\, \bar{\ell}\gamma^\mu\gamma_5\ell\bar{q}\gamma_\mu q + C_{2q}\, \bar{\ell}\gamma^\mu\ell\bar{q}\gamma_\mu\gamma_5 q + C_{3q}\, \bar{\ell}\gamma^\mu\gamma_5\ell\bar{q}\gamma_\mu\gamma_5 q \right]$$

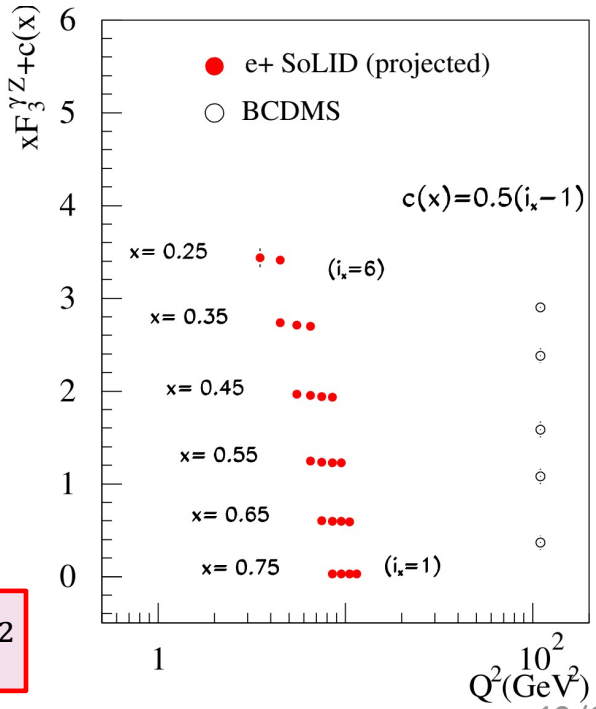
$$C_{3\substack{u\\d}} = -2\, g_A^e g_A^q = \pm\frac{1}{2}$$

$$A_d^{e^+e^-} \approx -108\, Y(y)\, R_q(x)(2C_{3u} - C_{3d})\, Q^2 \text{ ppm/GeV}^2$$



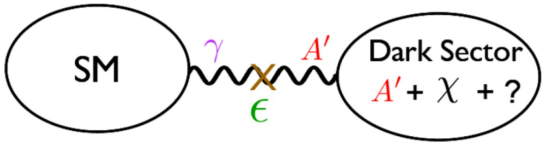
$$A_d^{e^+e^-} = \frac{d\sigma(e^+d) - d\sigma(e^-d)}{d\sigma(e^+d) - d\sigma(e^-d)}$$

$$A_d^{e^+e^-} = \frac{G_F}{2\sqrt{2}\,\pi\alpha} \frac{g_A^e}{2} Y_3 \frac{F_3^{\gamma Z}}{F_1^{\gamma}} Q^2$$

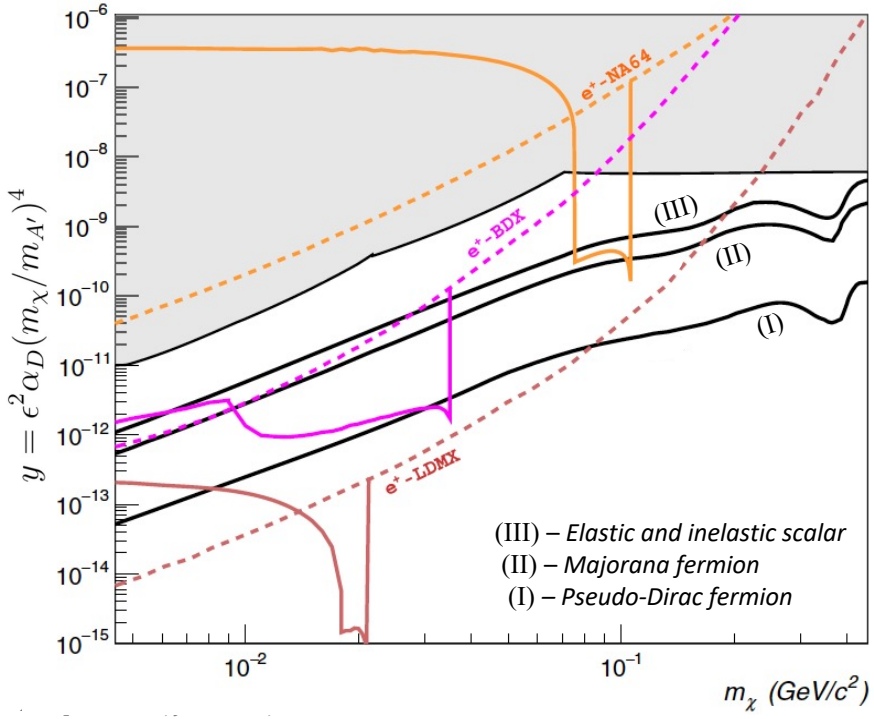


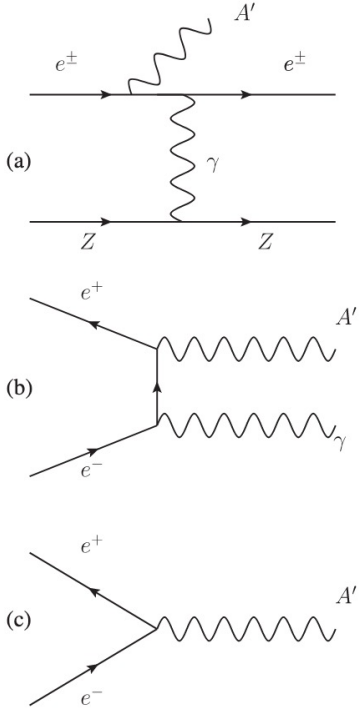
Positron Beam Scenarios

B. Wojtsekhowski AIP Conf. Proc. 1160 (2009) 149 L. Marsicano et al. PRL 121 (2018) 041802



- The **light dark matter** hypothesis can explain the gravitationally observed relic abundance provided a **new interaction between SM and dark sector** exists.





- The e^+e^--annihilation offers an alternative way to probe the existence of a dark photon.

(a) A′-strahlung in scattering.

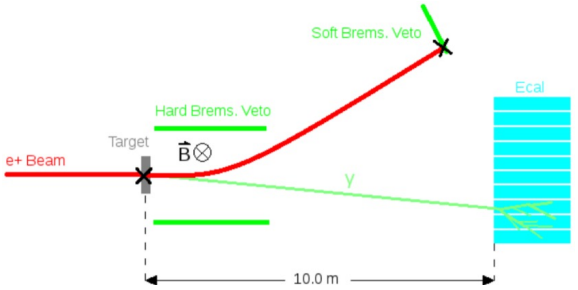
(b) A′-strahlung in annihilation.

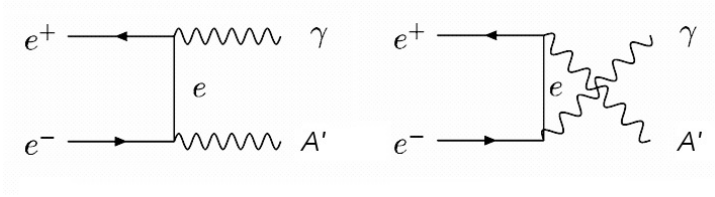
(c) A′-resonnant production.

Thin Target Configuration

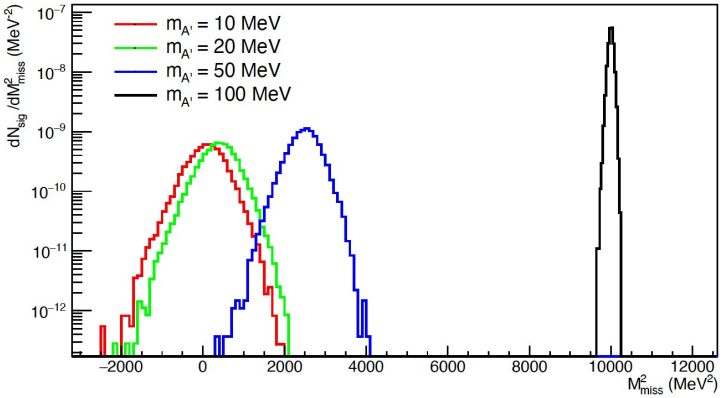
P. Valente, J. Alexander, (JPos17) AIP CP 1970 (2018) 020007 L. Marsicano, (JPos17) AIP CP 1970 (2018) 020008
(Jefferson Lab Positron Working Group) A. Afanasev et al. arXiv:1906.09419 (2019) M. Battaglieri et al. arxiv:2105.04540 (2021)

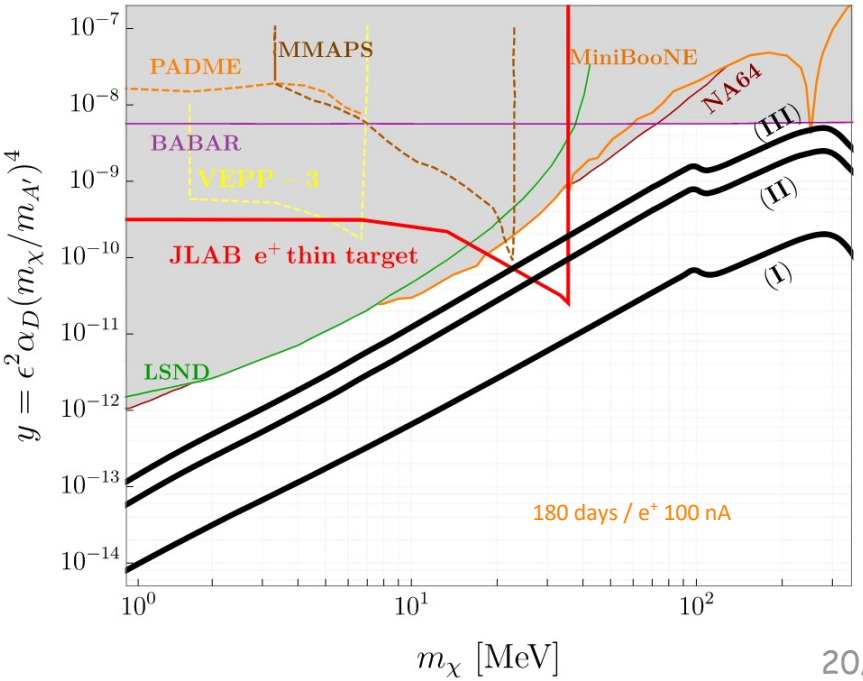
- A PADME like experiment using a 100 nA e^+ beam interacting with a 100 μm ^{12}C would extend the A' mass reach.





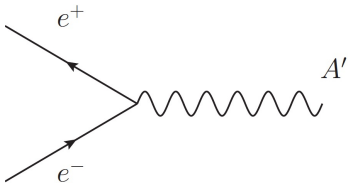
$$M^2_{miss} = \left(P_{beam} + P_{target} - P_\gamma\right)^2$$



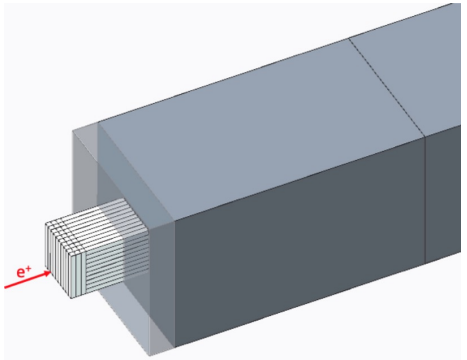


Thick Target Configuration

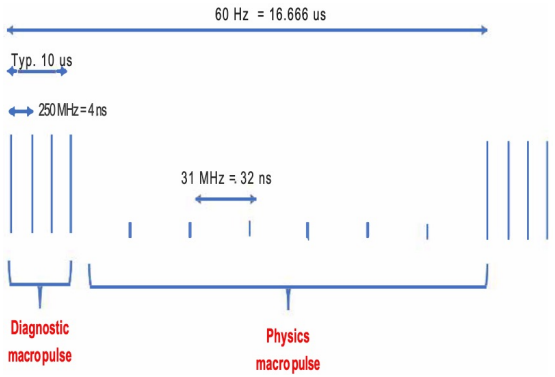
M. Battaglieri et al. arxiv:2105.04540 (2021)



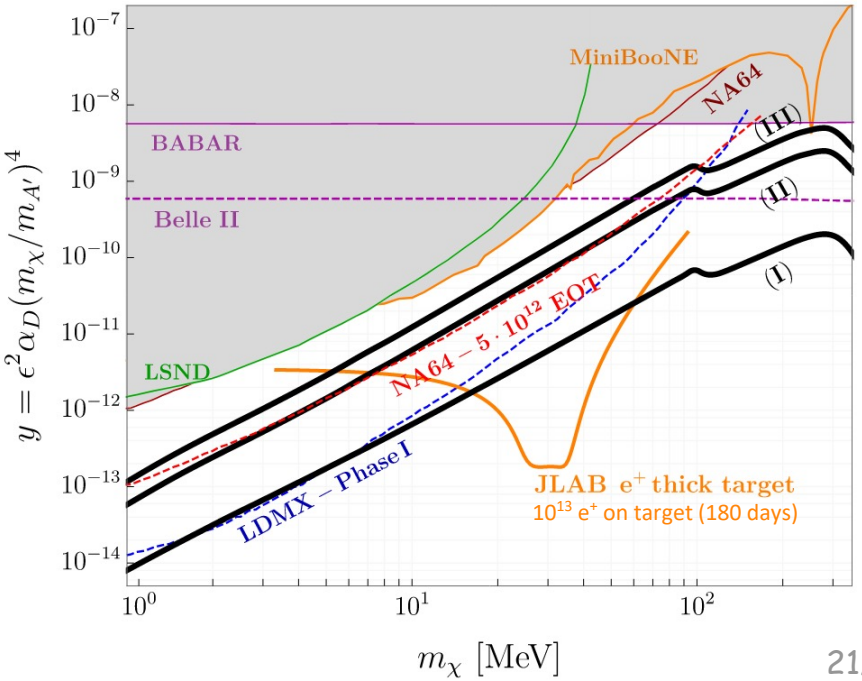
➢ Missing energy experiment with a **11 GeV e⁺** beam interacting with an **active thick target** (ECAL) completed with an hadronic calorimeter (HCAL).



$$E_{miss} = E_{beam} - E_{CAL} \qquad m_{A'} = \sqrt{2 m_e E_{miss}}$$



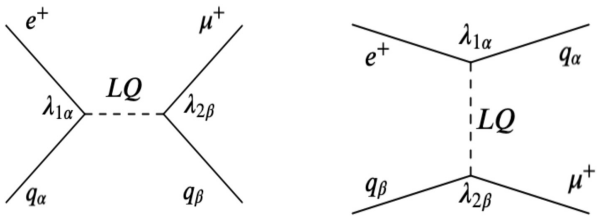
A non-trivial time structure of the beam is required to avoid e⁺ beam pile-up in the detector.



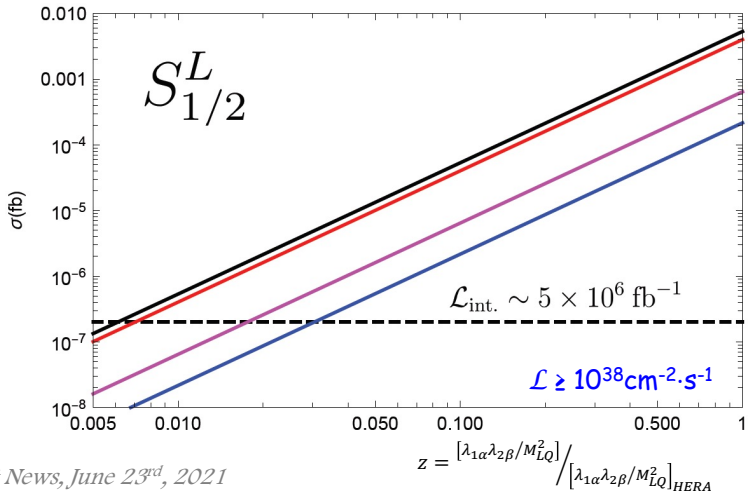
Lepto-Quark Scenario

W. Buchmuller, R. Ruckl, D. Wyler, PLB 191 (1987) 442 Y. Furletova, S. Mantry, (JPos17) AIP CP 1970 (2018) 030005

- In spite of the small c.m. energy, the high luminosity ($\lesssim 10^{39}$cm^{-2}.s^{-1}) at JLab enables **testing** Charged Lepton Flavor Violation (**CLFV**), and will allow for **substantial improvement** over HERA limits.



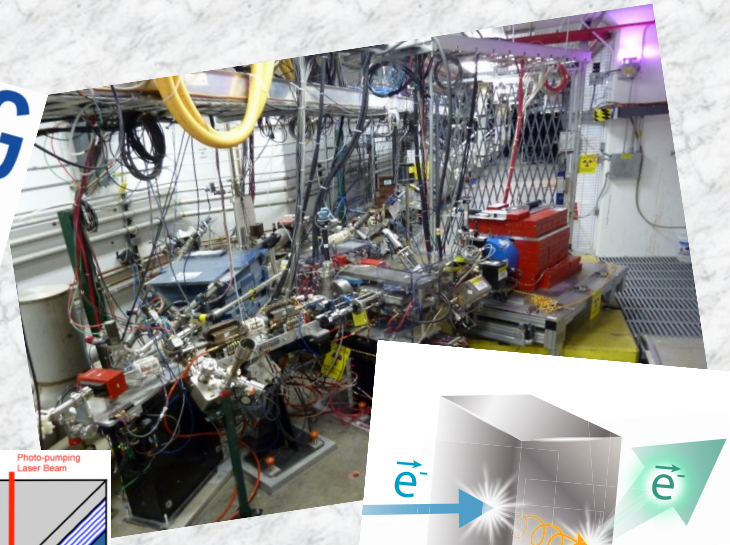
$$e^\pm + N \longrightarrow \mu^\pm + X$$

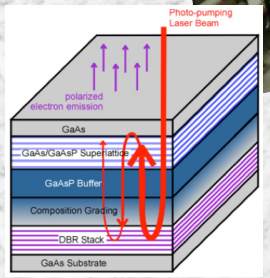


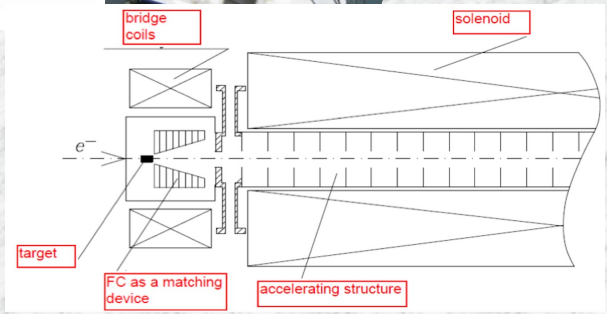
In the Lepto-Quark (LQ) scenario, up to 14 different LQs may mediate transitions between quarks and leptons.

Type	J	F	Q	ep dominant process	Type	J	F	Q	ep dominant process
S_0^L	0	2	$-1/3$	$e_L^- u_L \to \begin{cases} \ell^- u \\ \nu_\ell d \end{cases}$	V_0^L	1	0	$+2/3$	$e_R^+ d_L \to \begin{cases} \ell^+ d \\ \bar{\nu}_\ell u \end{cases}$
S_0^R	0	2	$-1/3$	$e_R^- u_R \to \ell^- u$	V_0^R	1	0	$+2/3$	$e_L^+ d_R \to \ell^+ d$
$\tilde{S}_0^R$	0	2	$-4/3$	$e_R^- d_R \to \ell^- d$	$\tilde{V}_0^R$	1	0	$+5/3$	$e_L^+ u_R \to \ell^+ u$
S_1^L	0	2	$-1/3$	$e_L^- u_L \to \begin{cases} \ell^- u \\ \nu_\ell d \end{cases}$	V_1^L	1	0	$+2/3$	$e_R^+ d_L \to \begin{cases} \ell^+ d \\ \bar{\nu}_\ell u \end{cases}$
			$-4/3$	$e_L^- d_L \to \ell^- d$				$+5/3$	$e_R^+ u_L \to \ell^+ u$
$V_{1/2}^L$	1	2	$-4/3$	$e_L^- d_R \to \ell^- d$	$S_{1/2}^L$	0	0	$+5/3$	$e_R^+ u_R \to \ell^+ u$
$V_{1/2}^R$	1	2	$-1/3$	$e_R^- u_L \to \ell^- u$	$S_{1/2}^R$	0	0	$+2/3$	$e_L^+ d_L \to \ell^+ d$
			$-4/3$	$e_R^- d_L \to \ell^- d$				$+5/3$	$e_L^+ u_L \to \ell^+ u$
$\tilde{V}_{1/2}^L$	1	2	$-1/3$	$e_L^- u_R \to \ell^- u$	$\tilde{S}_{1/2}^L$	0	0	$+2/3$	$e_R^+ d_R \to \ell^+ d$

- Electron and **positron** beams have **different sensitivity** to LQs.
- Beam **polarization** would distinguish between **left-** and **right-handed** LQs.



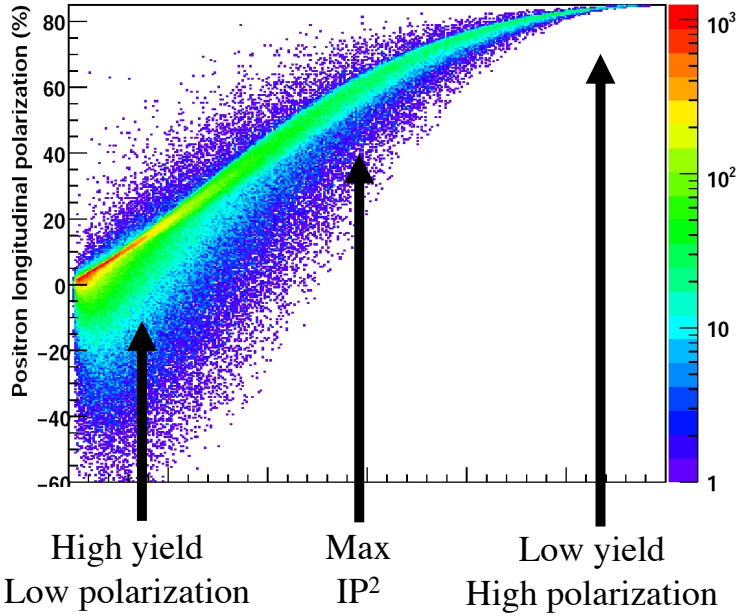


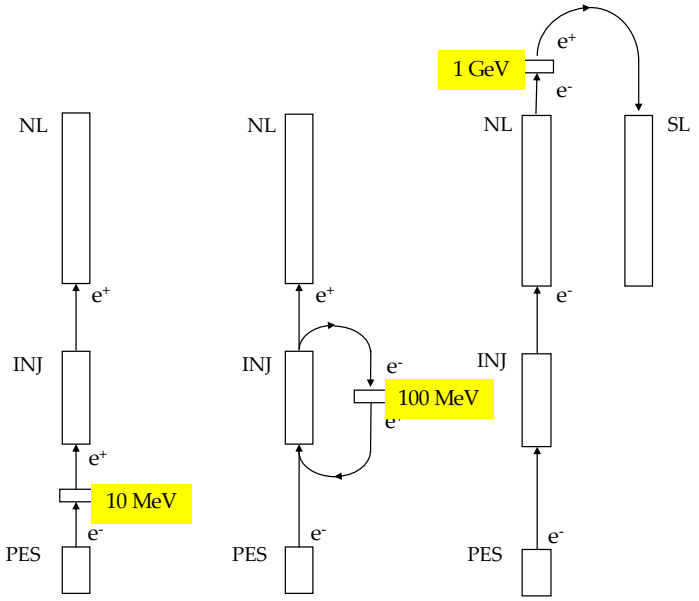


(i) PEPPo concept at JLab

Positron Source & Beam

- It is the goal of the **current R&D** to identify the most appropriate implementation of **PEPPo at CEBAF**, taking into account the many constraints and technological challenges (**target heating**, **collection system**, **emittance filter**, **injection into CEBAF**, **radiation environment**, **civil construction**, **cost**…) towards the development of a **prototype** and a **CDR**.





Towards a Conceptual Design Report for end of 2022…

e^+ @ JLab

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

e+@JLab Topical Issue of EPJ A in preparation

- In the elastic channel, e^+ beams definitely resolve the TPE issue.

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

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

- Polarized/unpolarized e^+ beams also offer new paths to test the Standard Model.

The list not exhaustive: VCS, DIS, polarized targets…

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