Physics with Polarized Positrons

e^+ @ JLab 12 GeV *e^+ @ eRHIC*

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

and the JLab Positron Working Group

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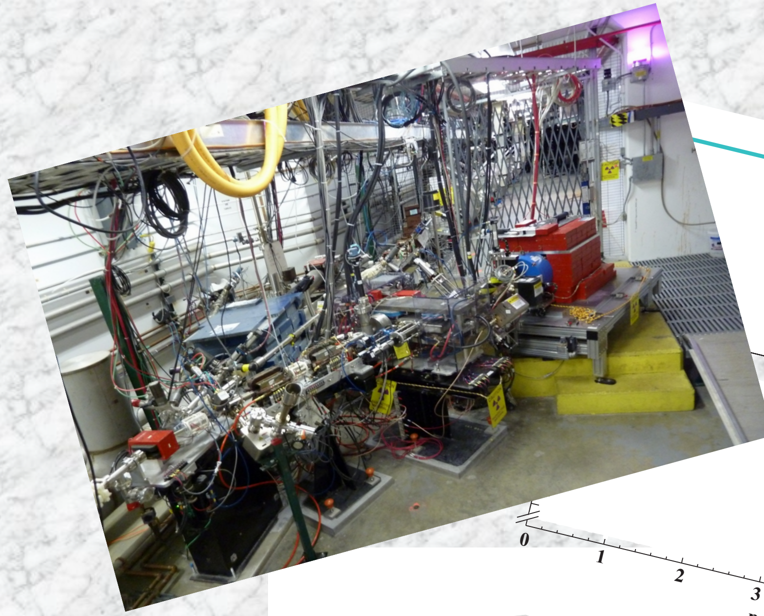
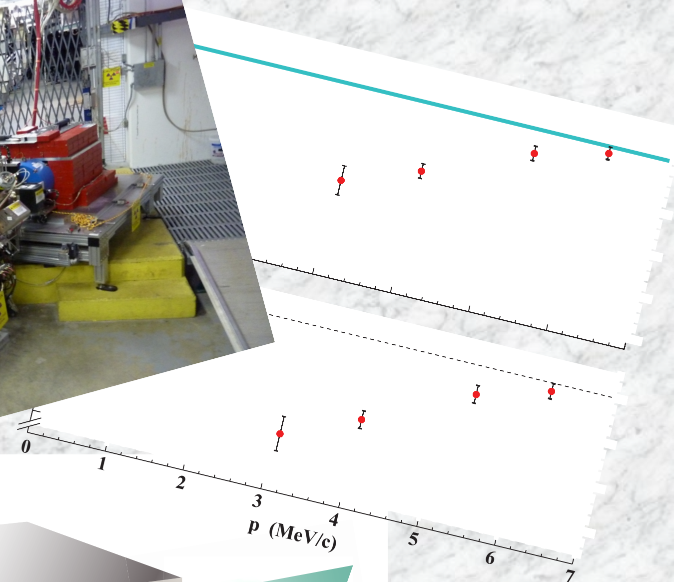
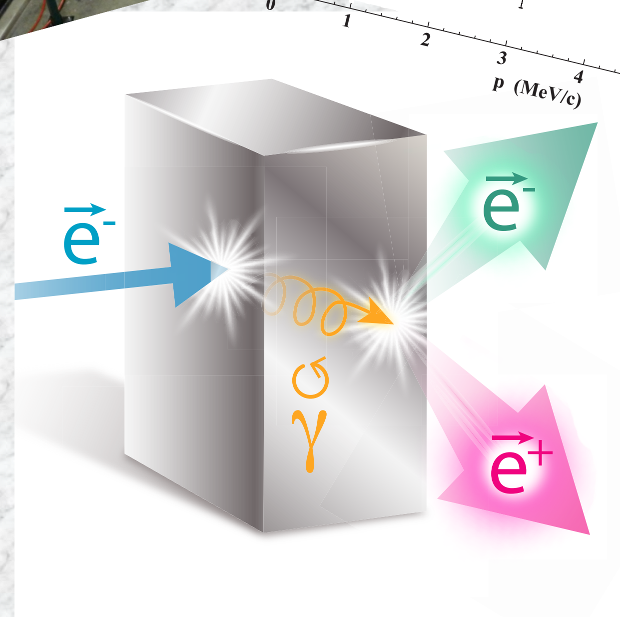
[2]*Laboratoire de Physique des 2 Infinis Irène Joliot-Curie, Orsay, France*
[3]*Stony Brook University, Stony Brook, NY, USA*
[4]*The George Washington University, Washington, DC, USA*
[5]*Istituto Nazionale di Fisica Nucleare, Genova, Italia*
[6]*Università di Genova, Genova, Italia*
[7]*Argonne National Laboratory, Argonne, IL, USA*
[8]*University of Connecticut, CT, USA*
[9]*University of North Georgia, Dahlonega, GA, USA*
…







(i) Physics motivations

(ii) Interference physics

(iii) Structure functions

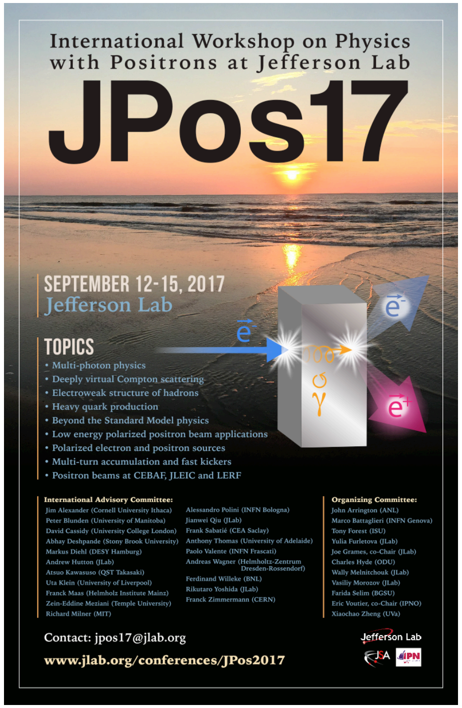
(iv) Sandard Model tests

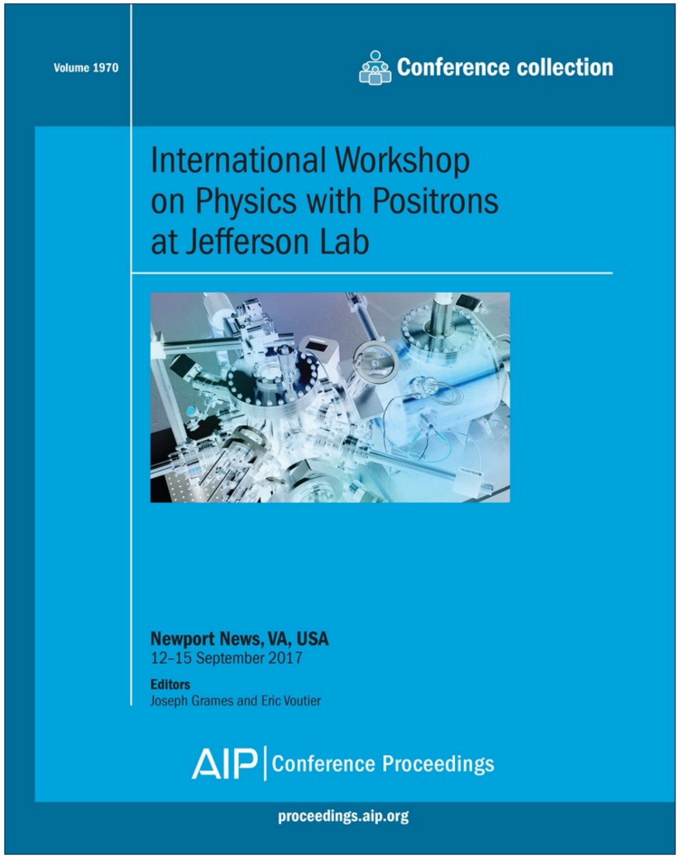
(v) Polarized positrons

(vi) Summary

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)

Highlighting **7 mini-LOI's**
Supported by **127 members** **39 institutions**

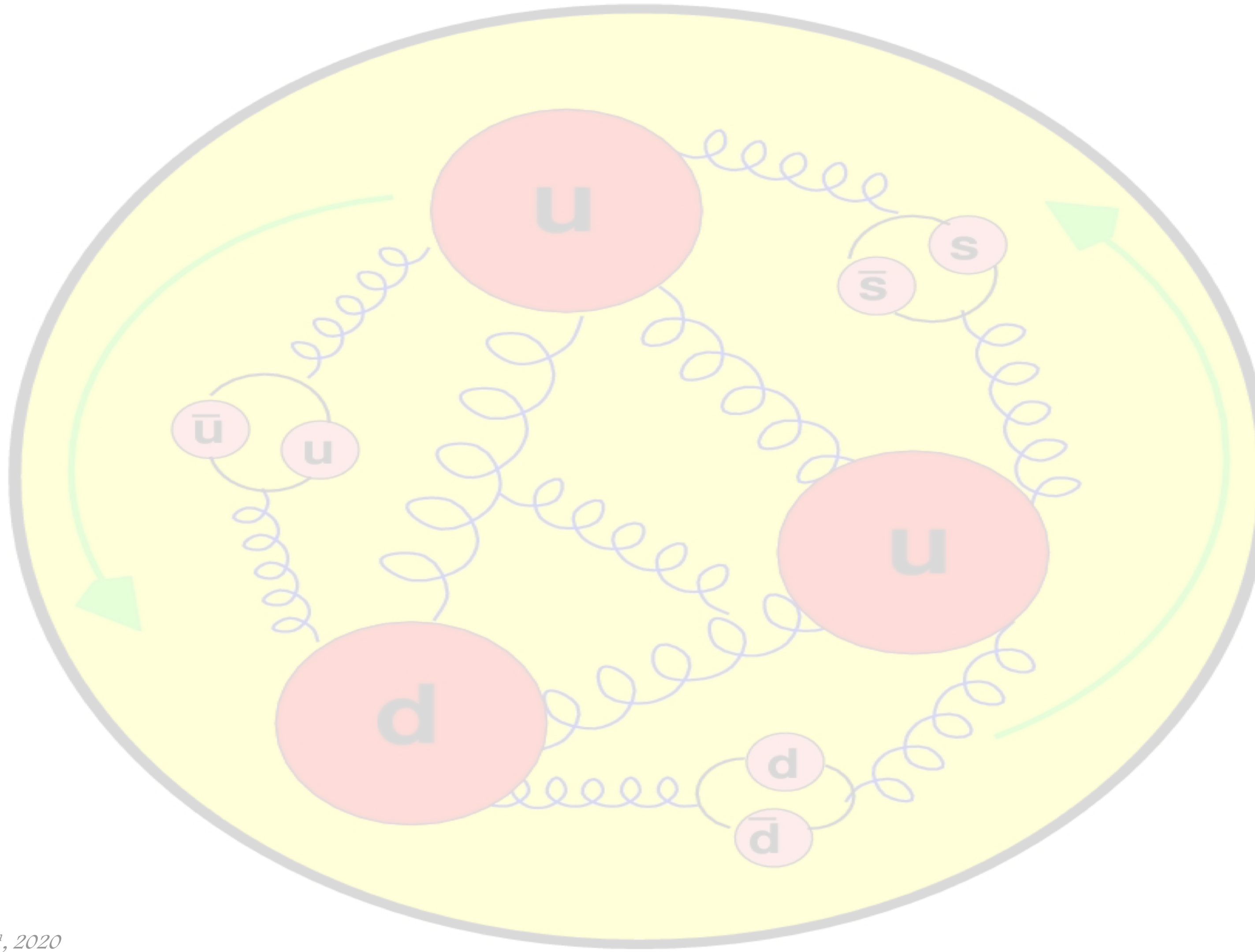
	I (nA) e^-	I (nA) e^+	Beam Polarization	Time (d)
Two-photon exchange				
TPE @ CLAS12	60	60	No	53
TPE @ SupRos	-	1000	No	18
TPE @ SBS	40000	100	Yes	55
Generalized Parton Distributions				
p-DVCS @ CLAS12	75	15	Yes	83
n-DVCS @ CLAS12	60	60	Yes	80
p-DVCS @ Hall C	-	5000	No	56
Test of the Standard Model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

Eric Voutier

Positron Physics



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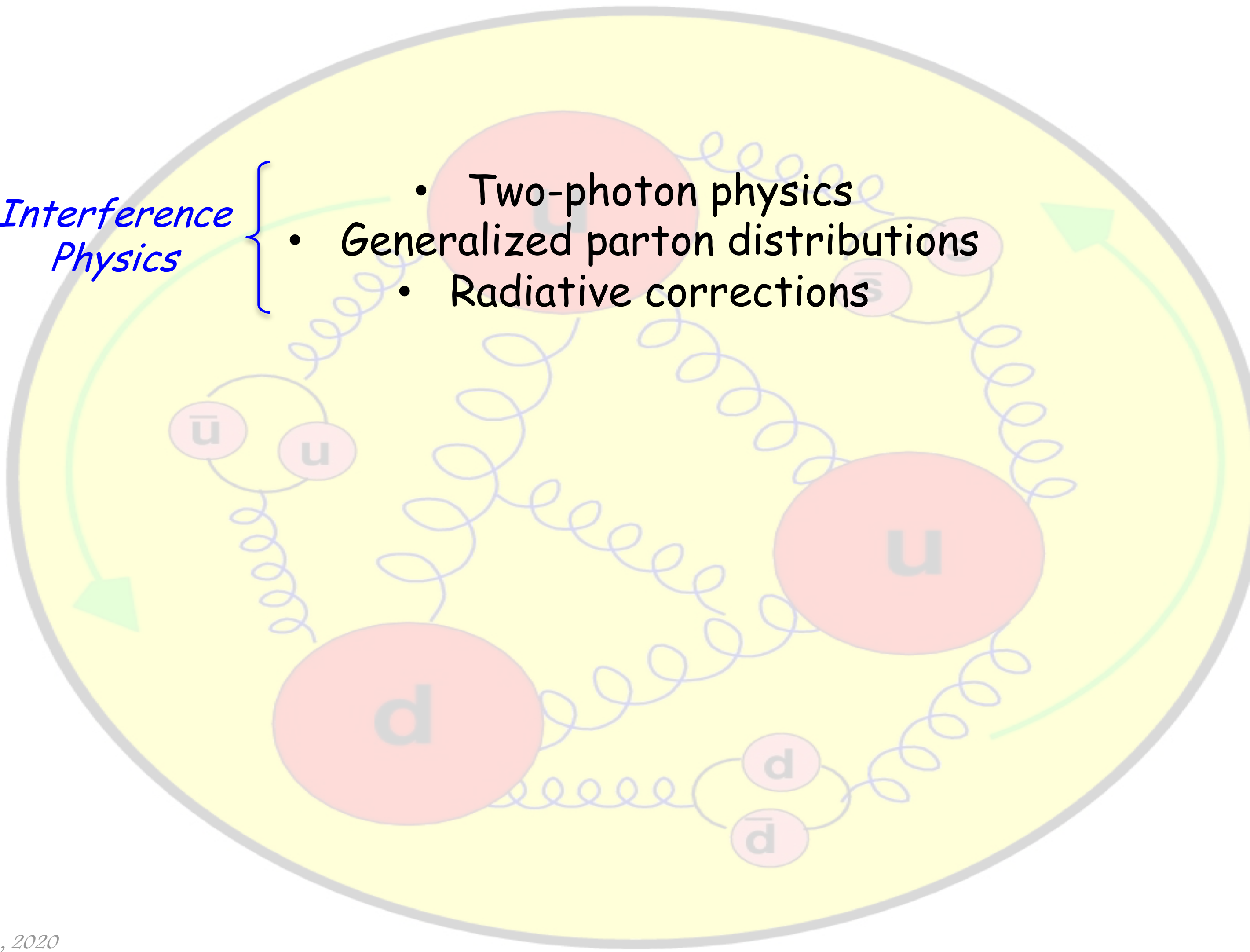
IJCLab Irène Joliot-Curie

Positron Physics



Interference Physics
- Two-photon physics
- Generalized parton distributions
- Radiative corrections

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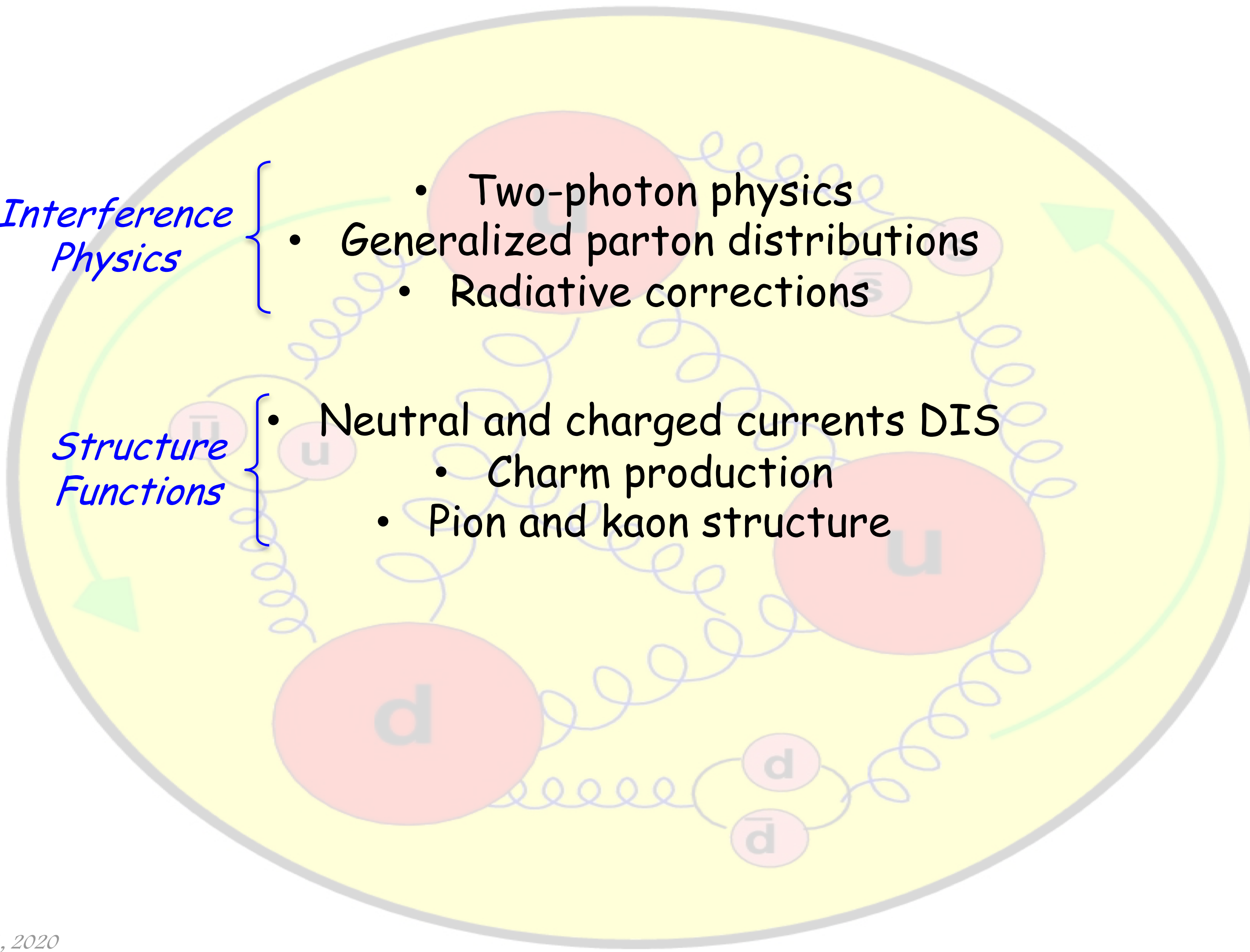
Positron Physics



Interference Physics

- Two-photon physics
- Generalized parton distributions
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Structure Functions

- Neutral and charged currents DIS
- Charm production
- Pion and kaon structure

Positron Physics

Interference Physics
- Two-photon physics
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Structure Functions
- Neutral and charged currents DIS
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Tests of the Standard Model
- Charge conjugation violation
- Right-handed W-bosons
- Dark photon search
- Leptoquarks, leptogluons

Interference Physics

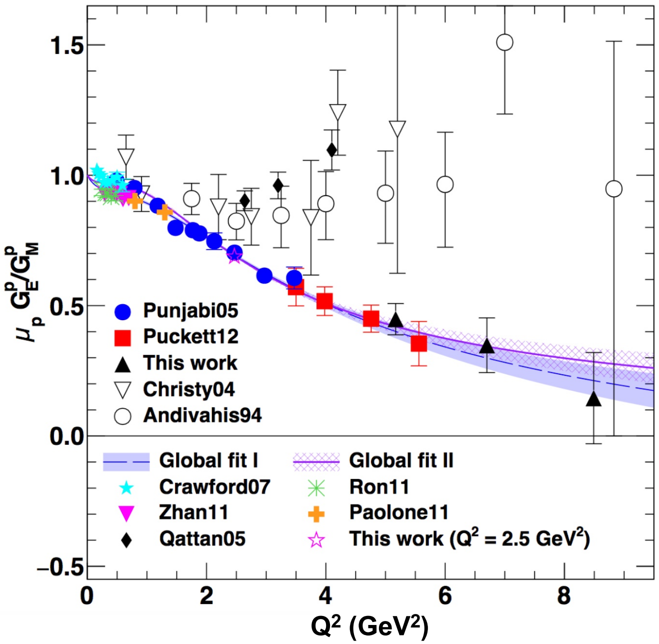
- Two-photon physics
- Generalized parton distributions
- Radiative corrections

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** of the electromagnetic interaction.

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



Within the **2γ exchange hypothesis**, the electromagnetic structure of the nucleon may be parametrized by 3 generalized form factors, corresponding to **8 unknow quantities**.

$$\widetilde{G}_M = G_M(Q^2) + e_l\, \delta\widetilde{G}_M(Q^2,\varepsilon)$$
$$\widetilde{G}_E = G_E(Q^2) + e_l\, \delta\widetilde{G}_E(Q^2,\varepsilon)$$
$$\widetilde{F}_3 = e_l\, \delta\widetilde{F}_3(Q^2,\varepsilon)$$

Experimental Observables

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

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

Cross Section

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

Polarization Transfert

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

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

5 unknown contributions for 6 independent observables

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5 unknown contributions for 6 independent observables

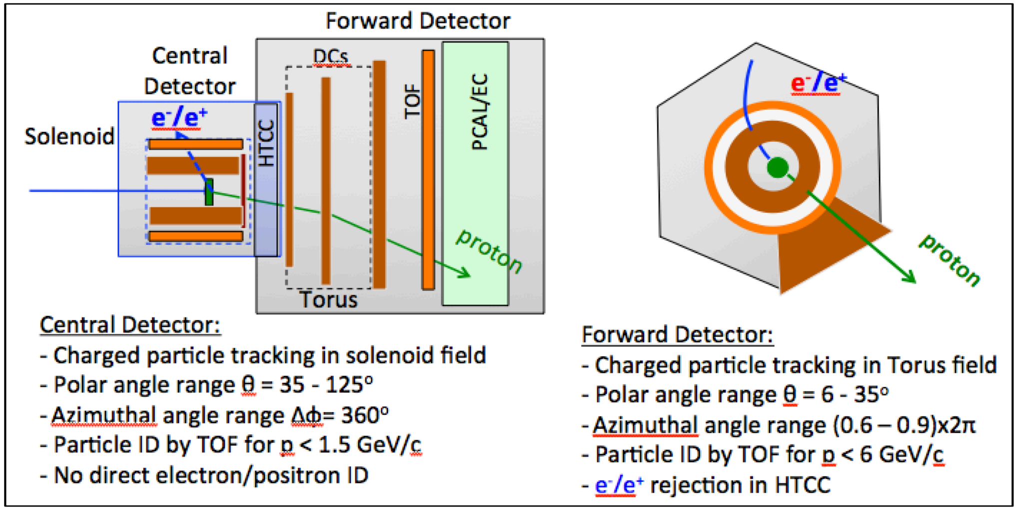
Combining **polarized electrons and positrons** allows a **model independent separation** of the electromagnetic form factors of the nucleon.

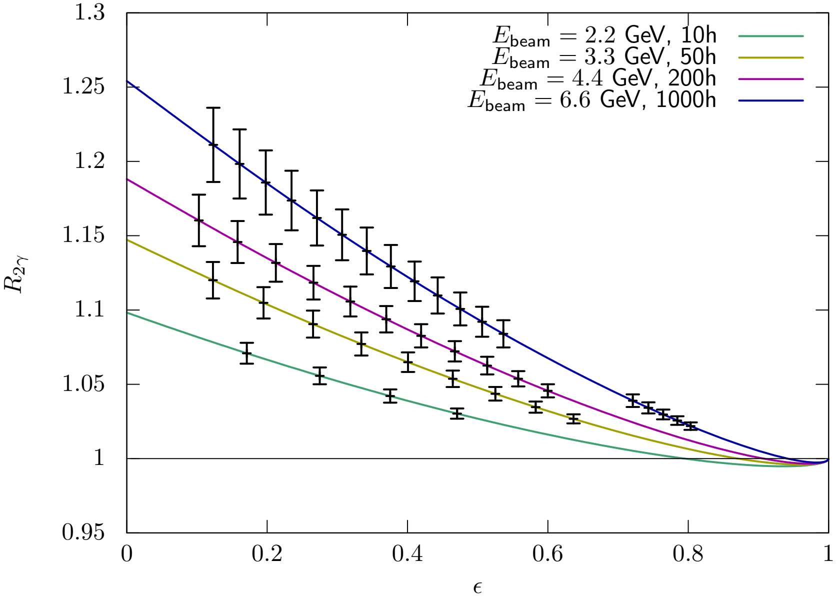
LOI12-18-004

J. Arrington, J. Bernauer, V. Burkert, A. Schmidt et al.

➢ A **modified CLAS12** hosting an electromagnetic calorimeter in place of the Central Neutron Detector would allow to **map out** the **2γ-effects** in the **(Q^2,ε)** space, providing a **conclusive answer about** the relevance of **2γ-effects**.

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

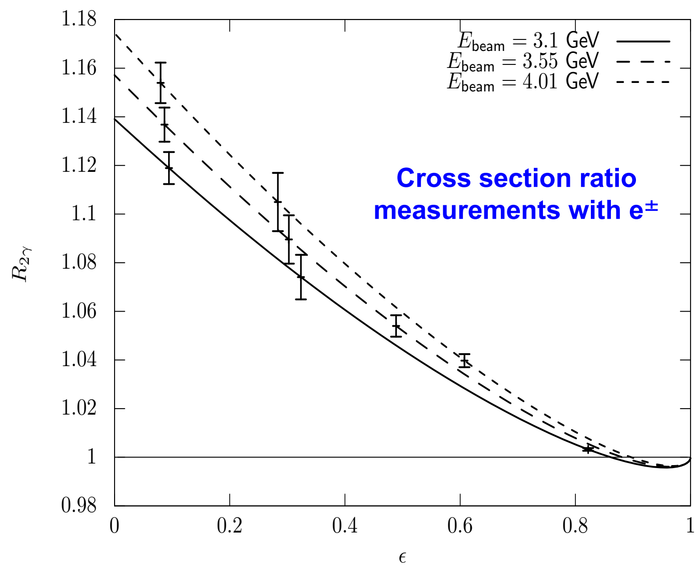




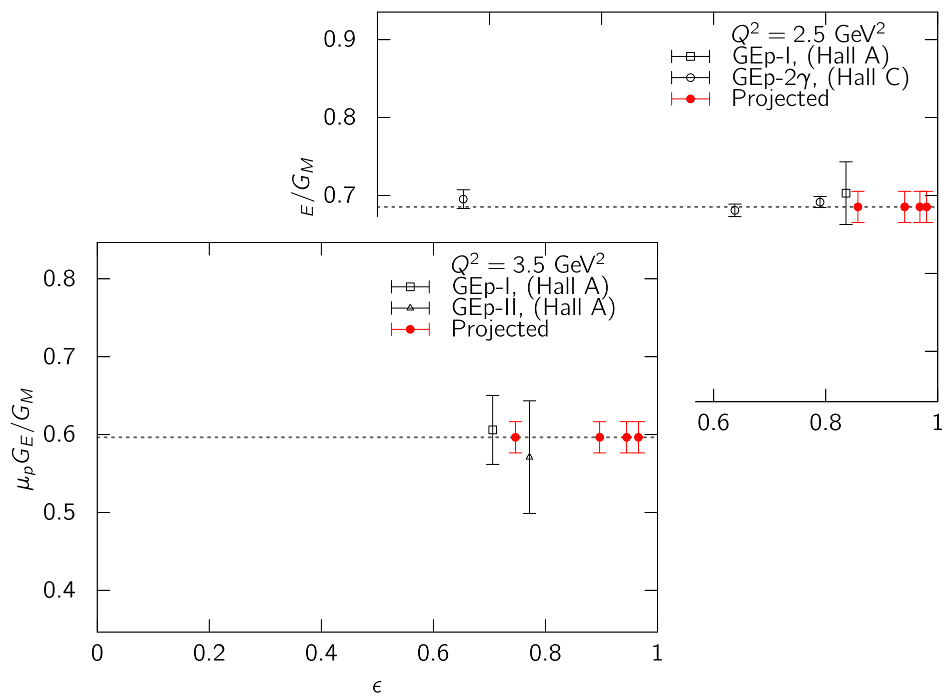
LOI12-18-004

J. Arrington, J. Bernauer, A. Puckett, A. Schmidt et al.

- **High impact** measurements are also feasible in **Hall A & C** to **sign the existence** of 2γ-effects, better **control systematics** with the Super-Rosenbluth technique, and to **provide** unique **polarization transfer** data.



e± polarization transfer measurements with SBS

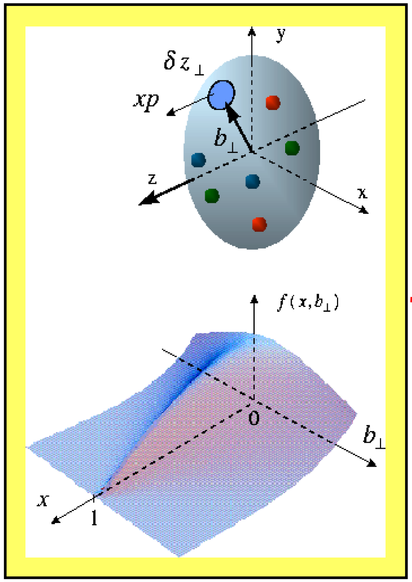


Eric Voutier IJCLab Irène Joliot-Curie

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.

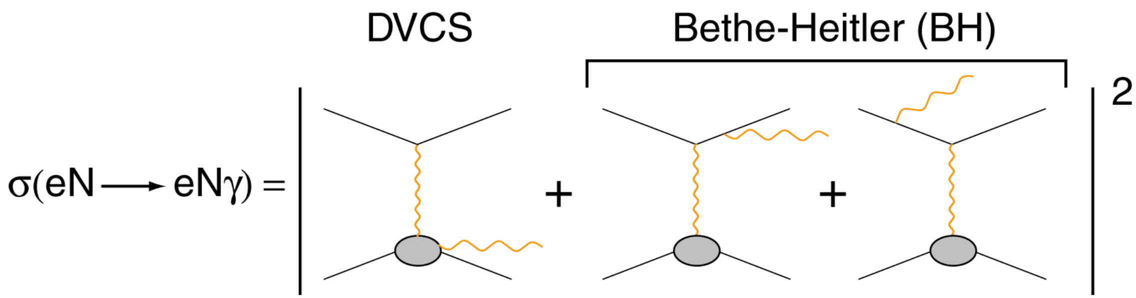
X. Ji, PRL 78 (1997) 610 M. Polyakov, PL B555 (2003) 57

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



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

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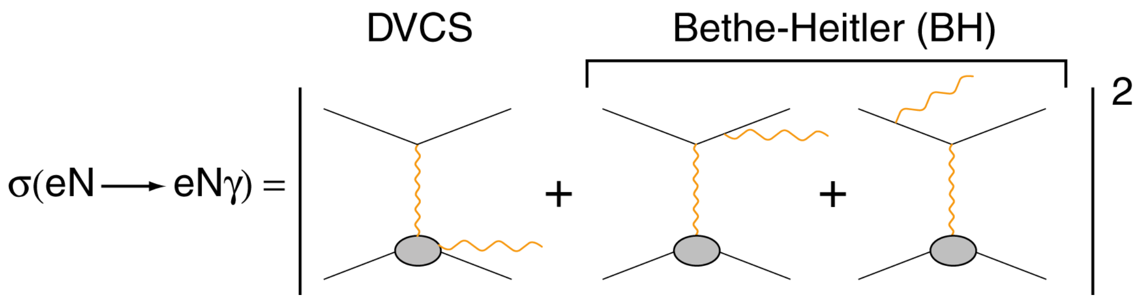

$$\sigma^{e}_{P0} = \sigma_{BH} + \sigma_{DVCS} + P_l\,\tilde{\sigma}_{DVCS} + e_l\left(\sigma_{INT} + P_l\,\tilde{\sigma}_{INT}\right)$$

Electron observables

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

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

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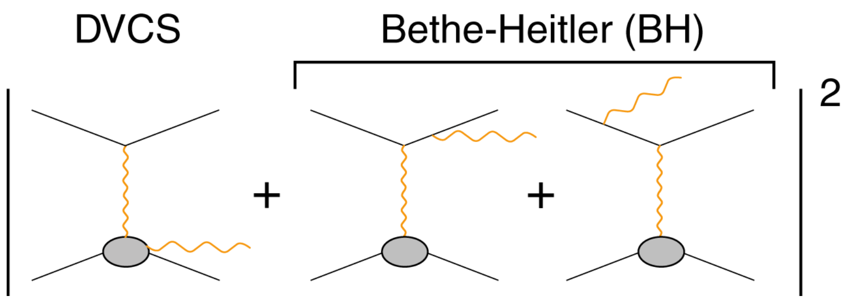
$\sigma(eN \longrightarrow eN\gamma) =$



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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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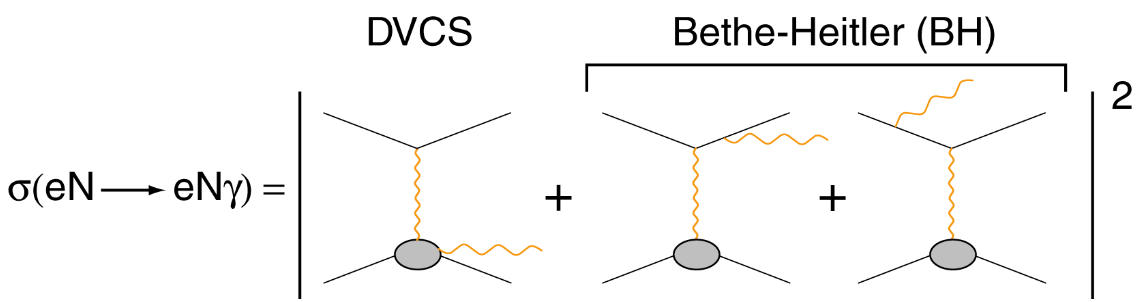

$$\sigma^{e}_{PS} = \sigma^{e}_{P0} + S\left[P_1\,\Delta\sigma_{BH} + \left(\Delta\tilde{\sigma}_{DVCS} + P_1\,\Delta\sigma_{DVCS}\right) + e_1\left(\Delta\tilde{\sigma}_{INT} + P_1\,\Delta\sigma_{INT}\right)\right]$$

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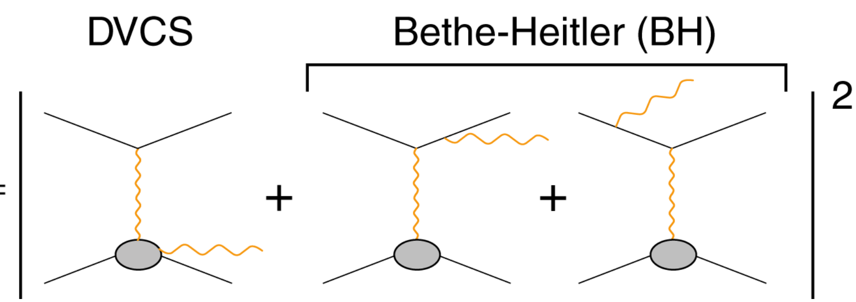

$$\sigma^{e}_{PS} = \sigma^{e}_{P0} + S\left[P_l\, \Delta\sigma_{BH} + \left(\Delta\tilde{\sigma}_{DVCS} + P_l\, \Delta\sigma_{DVCS}\right) + e_l \left(\Delta\tilde{\sigma}_{INT} + P_l\, \Delta\sigma_{INT}\right)\right]$$

Additional observables

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

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

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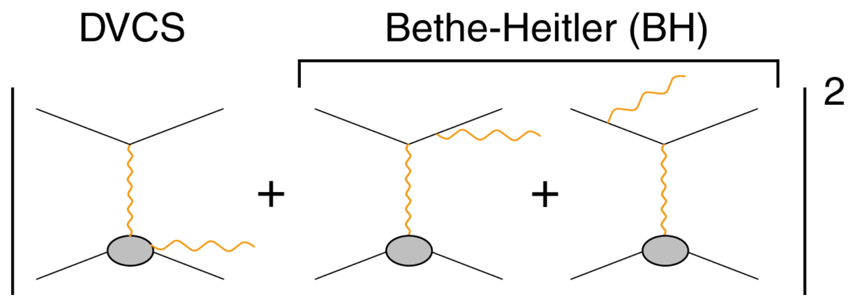
N(e,e'γN) Differential Cross Section

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

$$\sigma(eN \longrightarrow eN\gamma) = \Big|\ \cdots\ \Big|^2$$



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

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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

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

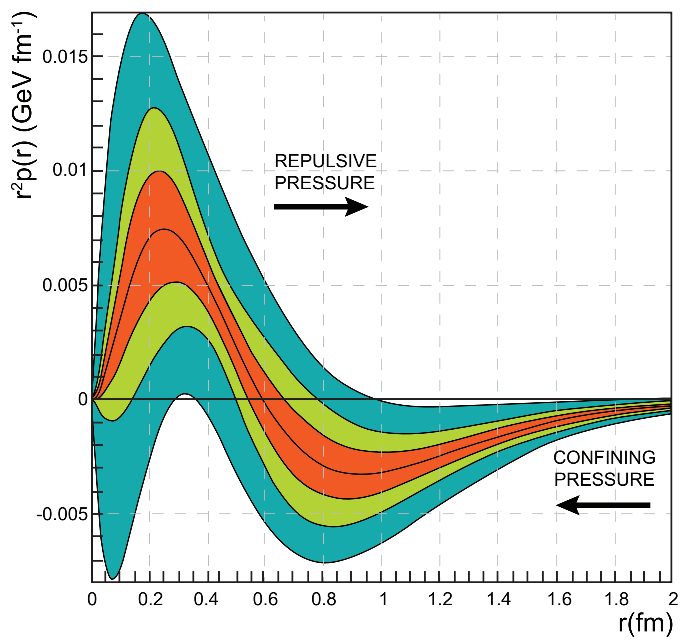
The 2nd order **Mellin moment** of GPDs allow to access the pressure distribution inside hadrons through the **skewness dependency** of GPDs… (**DDVCS**).

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

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

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

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



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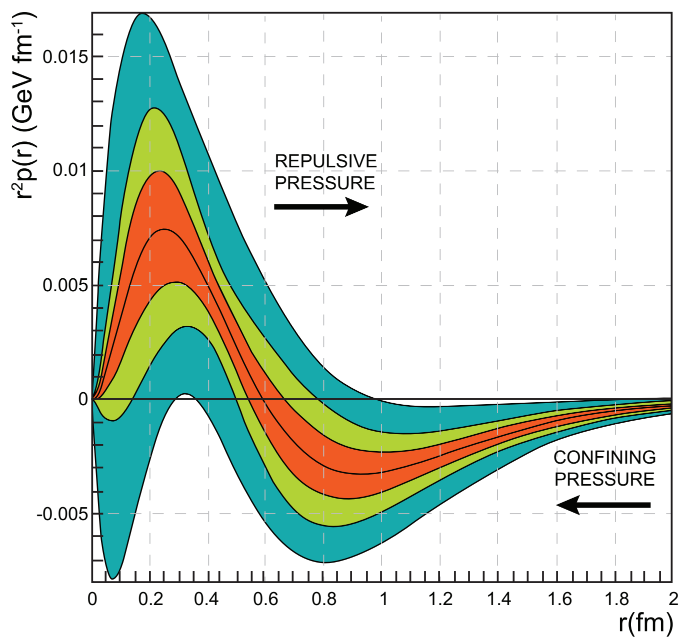


Real part of Compton form factors (σ_{INT})

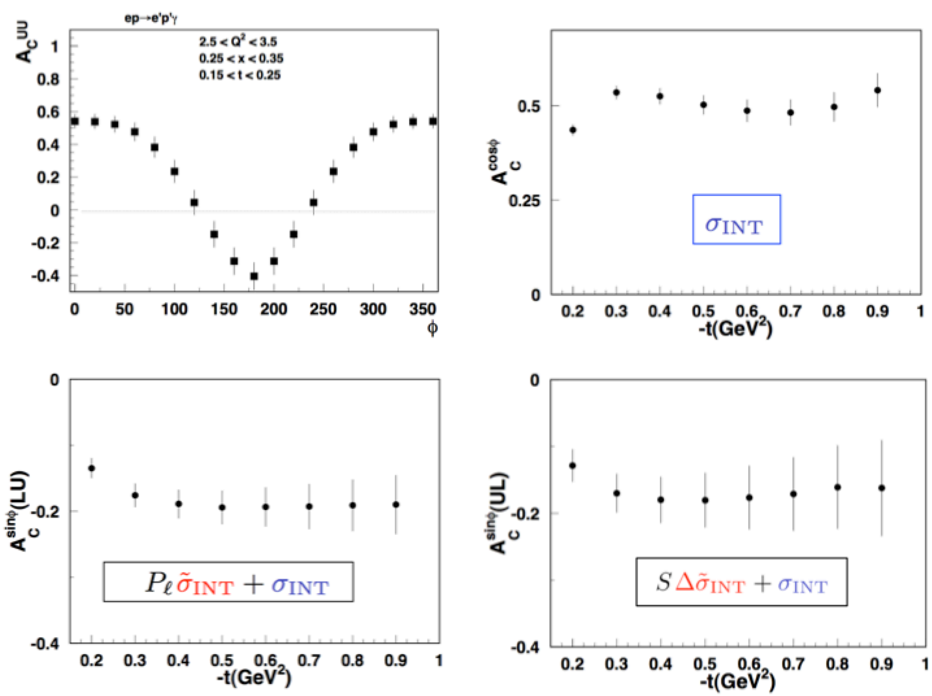
*Also accessible in **TCS** testing GPDs **universality**.*

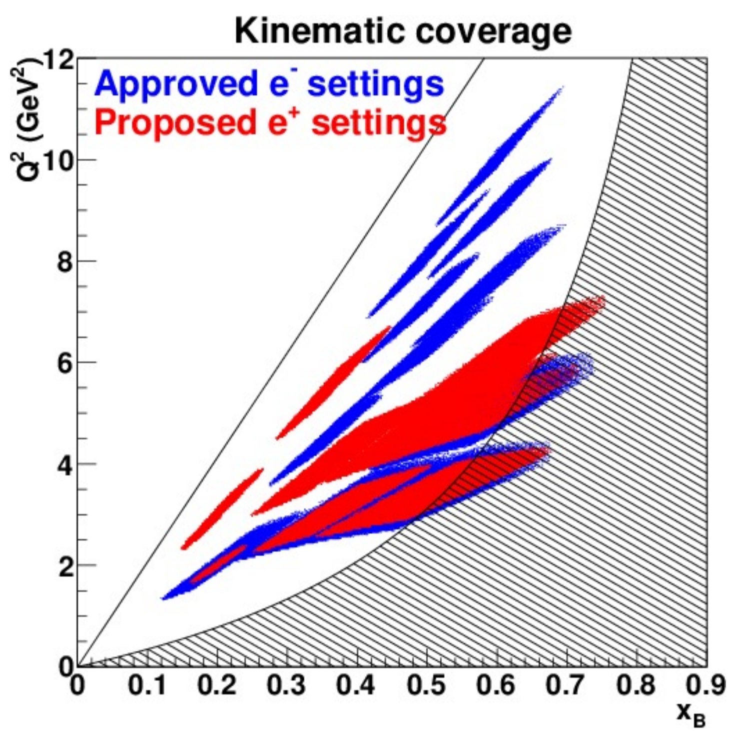
LOI12-18-004

V. Burkert, L. Elouadrhiri, F.-X. Girod, C. Muñoz Camacho et al.

➢ It is proposed to measure **polarized** and **unpolarized** beam **charge asymmetries** off **protons** and **neutrons** (CLAS12), and **unpolarized p-DVCS cross section** with positrons (HMS+NPS).

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



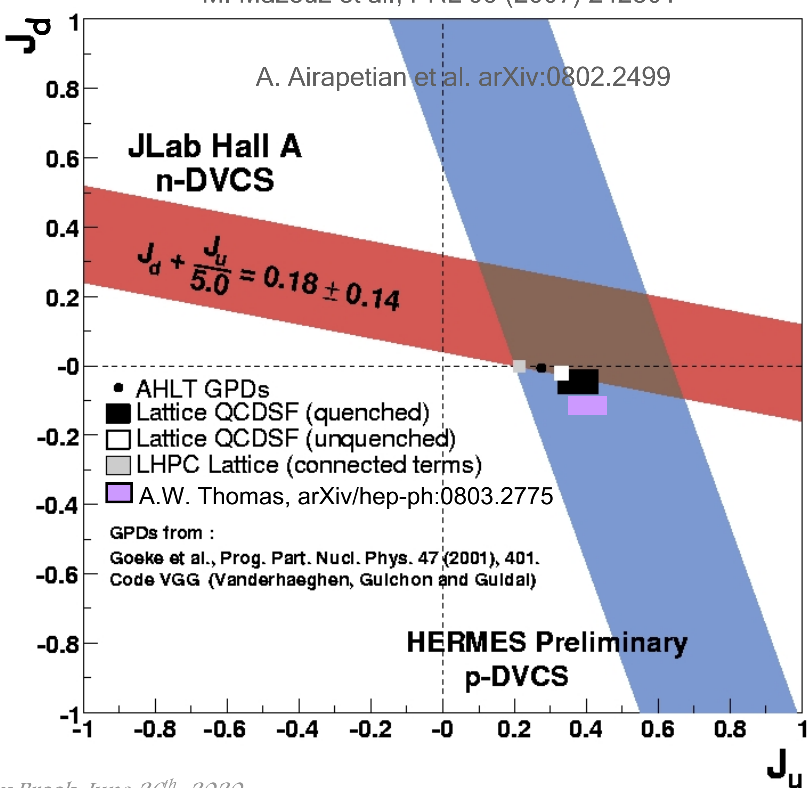


LOI12-18-004

S. Niccolai, E. Voutier et al.

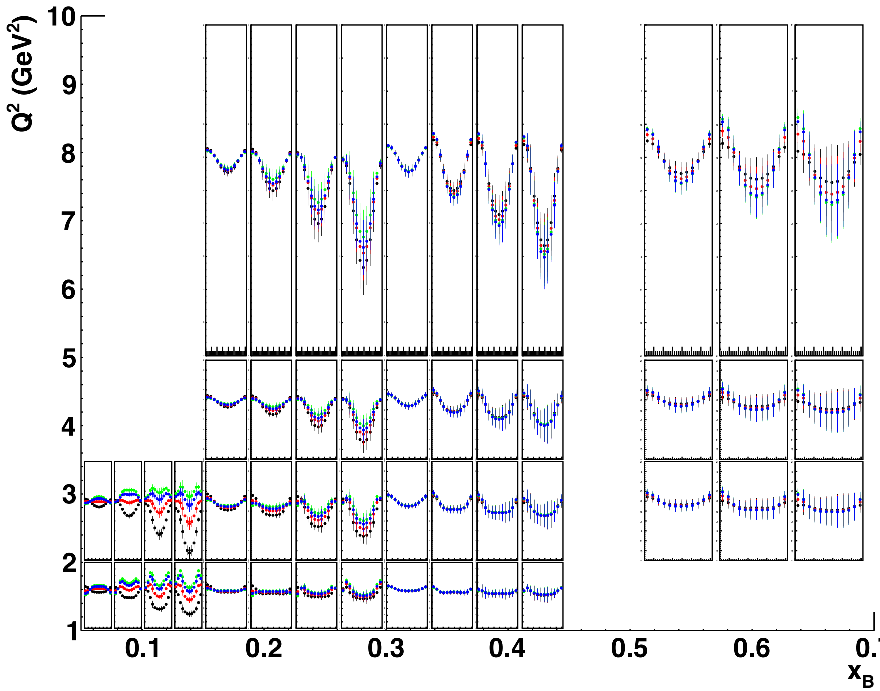
➢ Contrary to **H**, the GPD **E flips the spin of the nucleon** and is consequently not constrained by Deep Inelastic Scattering data.

M. Mazouz et al., PRL 99 (2007) 242501



X. Ji, PRL 78 (1997) 610

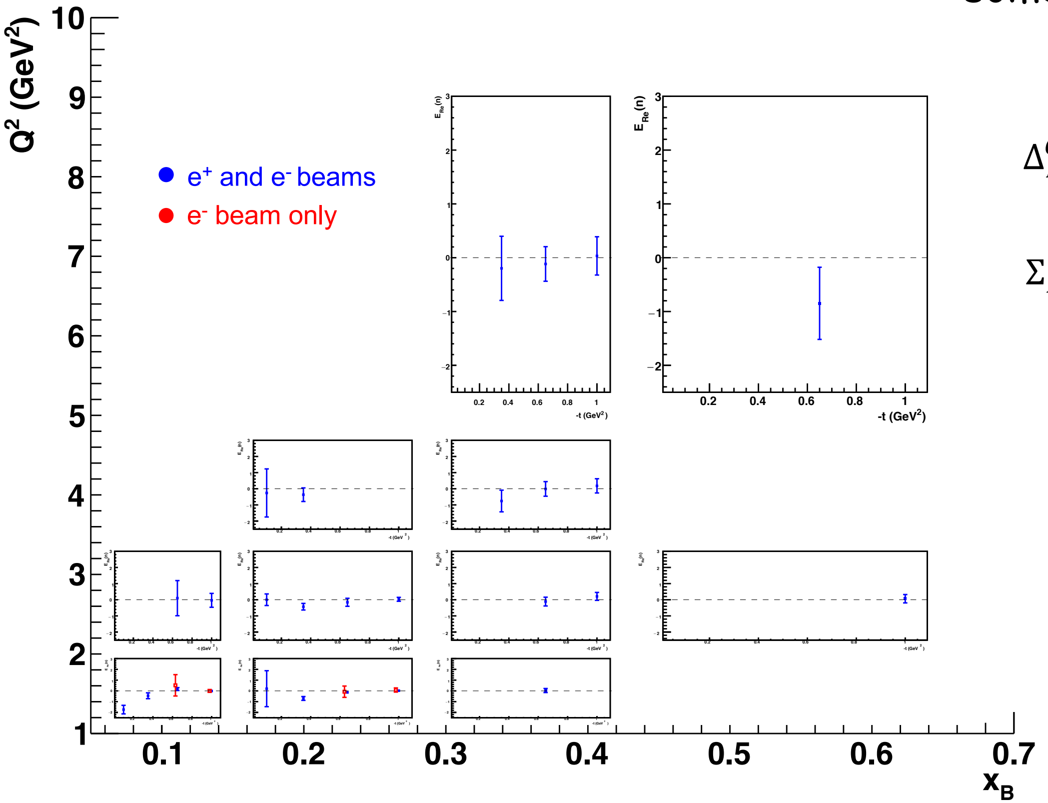
$$\int_{-1}^{1} x\,[H(x,\xi,t\to 0) + E(x,\xi,t\to 0)]\,dx = J$$



LOI12-18-004

S. Niccolai, E. Voutier et al.

$$A_C \propto \frac{1}{F_2} \Re e \left[\xi \widetilde{H}_n - \frac{t}{4M^2} E_n \right]$$



- The **BCA** on the neutron accesses the **real part** of the CFF **E**, and is sensitive to $\tilde{H}$ at some kinematics.

$$\Delta^C_{LU} = \frac{(d^4\sigma^+_{+0} - d^4\sigma^+_{-0}) - (d^4\sigma^-_{+0} - d^4\sigma^-_{-0})}{d^4\sigma^+_{+0} + d^4\sigma^+_{-0} + d^4\sigma^-_{+0} + d^4\sigma^-_{-0}} \quad \propto \widetilde{\sigma}_{INT}$$

$$\Sigma^C_{LU} = \frac{(d^4\sigma^+_{+0} - d^4\sigma^+_{-0}) + (d^4\sigma^-_{+0} - d^4\sigma^-_{-0})}{d^4\sigma^+_{+0} + d^4\sigma^+_{-0} + d^4\sigma^-_{+0} + d^4\sigma^-_{-0}} \quad \propto \widetilde{\sigma}_{DVCS}$$

$$A_{LU} = \frac{\Sigma^C_{LU}}{1 - A_C} - \frac{\Delta^C_{LU}}{1 - A_C}$$

Polarized positron beams provide a different **access** to the **imaginary part**, and **probe** the importance of **higher twists**.

Structure Functions

- Neutral and charged currents DIS
- Charm production
- Pion and kaon structure

Deep Inelastic Scattering

E. Aschenauer, T. Burton, T. Martin, H. Spiesberger, M. Stratman, PRD 88 (2013) 114025

➢ **Charge current** DIS access **quark flavors combination different** from those measured with the **electromagnetic interaction**.

$$\frac{d^2\Delta\sigma^e_{PL}}{dx\,dy} = -\frac{8\pi\alpha^2}{yQ^2}(1+e_1P_1)^2\eta_W\left[Y_+g_5^{W^{e_1}} + e_1Y_-g_1^{W^{e_1}}\right]$$

Leading order

Polarized electron off protons

$$g_1^{W^-} = \Delta u + \Delta\bar{d} + \Delta\bar{s} + \Delta c \qquad g_5^{W^-} = -\Delta u + \Delta\bar{d} + \Delta\bar{s} - \Delta c$$

$$g_1^{W^+} = \Delta\bar{u} + \Delta d + \Delta s + \Delta\bar{c} \qquad g_5^{W^+} = \Delta\bar{u} - \Delta d - \Delta s + \Delta\bar{c}$$

Polarized positron off protons

Direct access to $\Delta\Sigma$

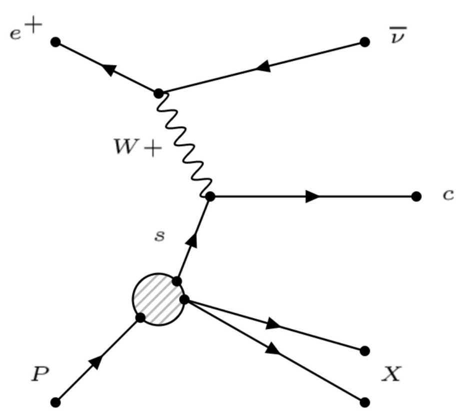
$$g_1^{W^-} + g_1^{W^+} = \Delta\Sigma$$

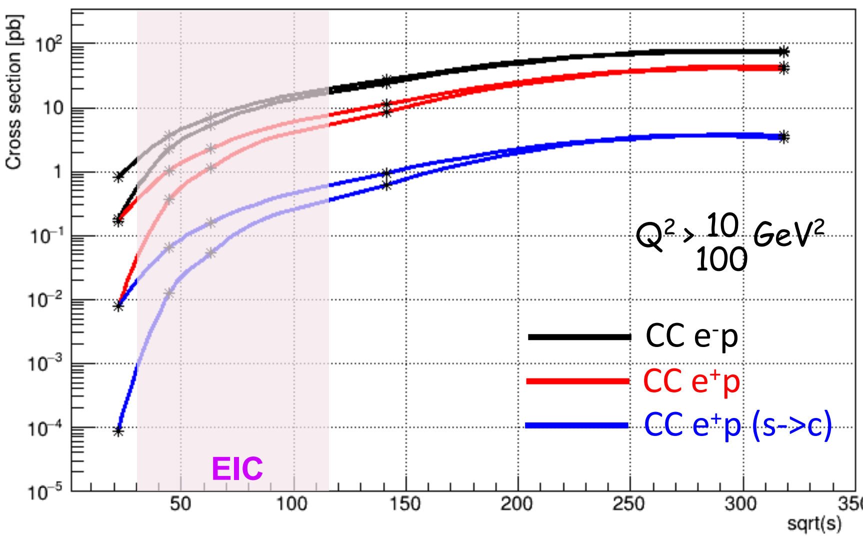
Access to strange polarized PDF free of hadronization ambiguities

$$g_5^{W^-}(p) - g_5^{W^+}(p) + g_5^{W^-}(n) - g_5^{W^+}(n) = 2[\Delta c + \Delta\bar{c}] - 2[\Delta s + \Delta\bar{s}]$$

Strangeness Tagging

- The **modest center-of-mass energy** at the EIC can be **compensated** by the **high luminosity** and **polarization degree** of the lepton beam, to help for **precise measurements** of the small **charge current cross section**.





- **Charm production** via **charged current** exchange preferentially couples to the **strange content** of the nucleon.

$$e^+ + \mathrm{p} \to \overline{\upsilon_e} + c + X$$
$$e^- + \mathrm{p} \to \upsilon_e + \bar{c} + X$$

An integrated luminosity of 10 fb^{-1}/year would provide ~**1500 events/year**.

M. Arratia, Y. Furletova, T.J. Hobbs, F. Olness, S.J. Sekula, arXiv:2006.12520

Standard Model Tests

- Charge conjugation violation
- Right-handed W-bosons
- Dark photon
- Leptoquarks, leptogluons

Eric Voutier IJCLab Irène Joliot-Curie

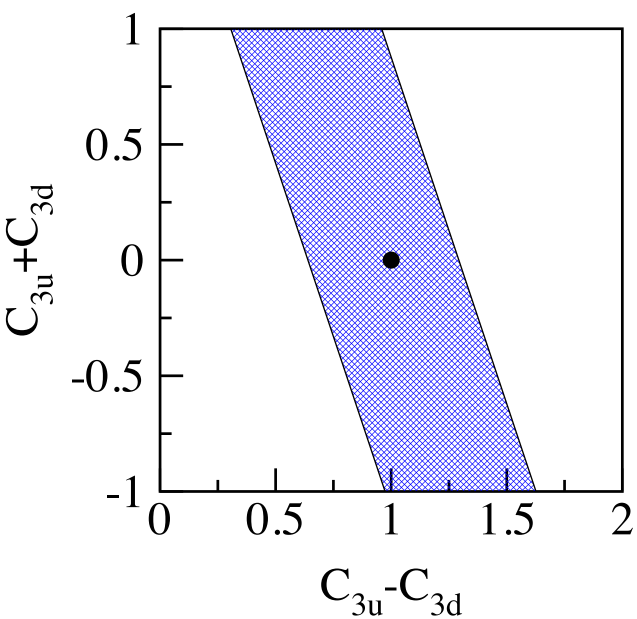
Weak Neutral Current Couplings

S.M. Berman, J.R. Primack , Phys. Rev. D 9 (1974) 2171 X. Zheng, JPos09, Newport News (2009)

- The comparison of **polarized electron** an **polarized positon** scatterings provides access to the **charge conjugation-violation** coupling C_{3q} from the interference between the weak neutral and electromagnetic currents.

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

$C_{3q} \leftarrow g_A^e g_A^q$



The combination of C_{3q} couplings is **poorly known**; have only been measured at CERN using **muon** and **anti-muon** beams on a carbon target.

$$0.81\,(2C_{2u}-C_{2d}) + 2C_{3u}-C_{3d} = 1.53 \pm 0.45$$

D. Wang et al. Phys. Rev. C 91 (2015) 045506

$$2C_{3u} - C_{3d} = 1.65 \pm 0.45$$

C_{3q} are known only within 30%

Weak Neutral Current Couplings

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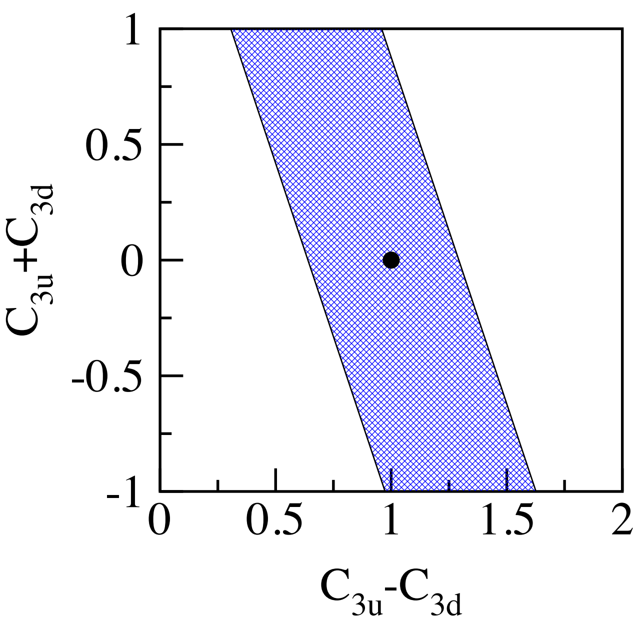
- The comparison of **polarized electron** an **polarized positon** scatterings provides access to the **charge conjugation-violation** coupling C_{3q} from the interference between the weak neutral and electromagnetic currents.

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

$g_A^e g_A^q$



$$A^{e_L^- - e_R^+} = \frac{d\sigma(e_L^- N) - d\sigma(e_R^+ N)}{d\sigma(e_L^- N) + d\sigma(e_R^+ N)}$$

$$A_p^{e_L^- - e_R^+} = \left(\frac{3G_F Q^2}{2\pi\alpha\sqrt{2}}\right) \frac{y(2-y)}{2} \frac{2C_{2u}u_V - C_{2d}d_V + 2C_{3u}u_V - C_{3d}d_V}{4u+d}$$

$$A_d^{e_L^- - e_R^+} = \left(\frac{3G_F Q^2}{2\pi\alpha\sqrt{2}}\right) \frac{y(2-y)}{2} \frac{2C_{2u} - C_{2d} + 2C_{3u} - C_{3d}}{5} \frac{u_V + d_V}{u + \bar{u} + d + \bar{d}}$$

$$A_d^{e_L^- - e_R^+} \approx 108\, \frac{y(2-y)}{2}\, (2C_{3u} - C_{3d})\, Q^2 \text{ ppm}$$

There exists a unique opportunity for a polarized electron and positron beam to improve the C_{3q} knowledge.

Polarized Charged Current Cross Section

Y. Furletova, S. Mantry, (JPos17) AIP CP 1970 (2018) 030005

- The **polarization dependence** of the charge current cross section can be measured to potentially reveal *deviations from the Standard Model prediction*.

$$\frac{d^2\sigma_{SM}^{e^+p}}{dx\,dQ^2} = (1+P_e)\,\frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2\left[\bar{u}+\bar{c}+(1-y^2)(d+s)\right]$$

$$\frac{d^2\sigma_{SM}^{e^-p}}{dx\,dQ^2} = (1-P_e)\,\frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2\left[u+c+(1-y^2)(\bar{d}+\bar{s})\right]$$

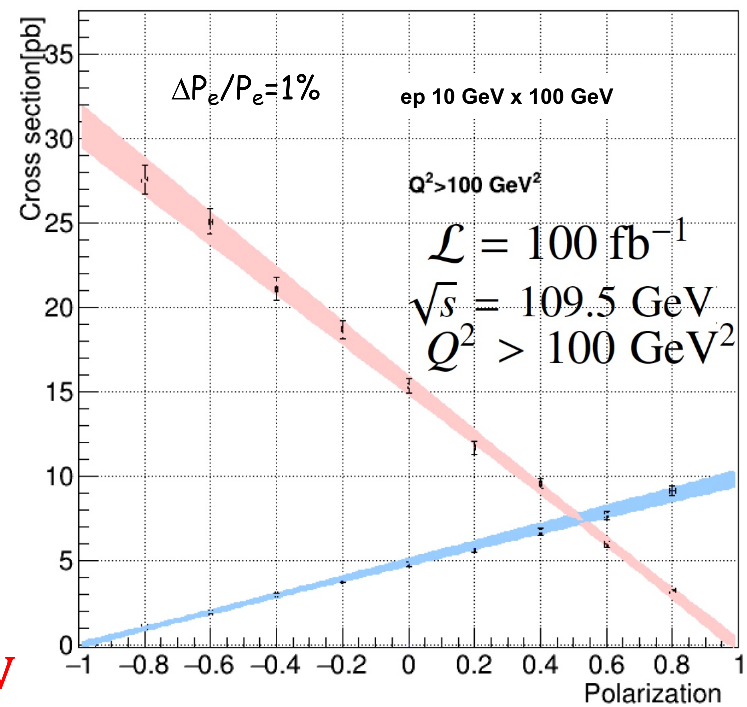
$\sigma^{e^\pm p}\,(P_e = \mp 1) \neq 0 \;\rightarrow$ Limit on the mass of right-handed W-boson

95% confidence level upper bound

$$\sigma^{e^\pm p}\,(P_e = \mp 1) < 0.0776\ \text{pb} \;\rightarrow\; M_R \geq 270\ \text{GeV}$$

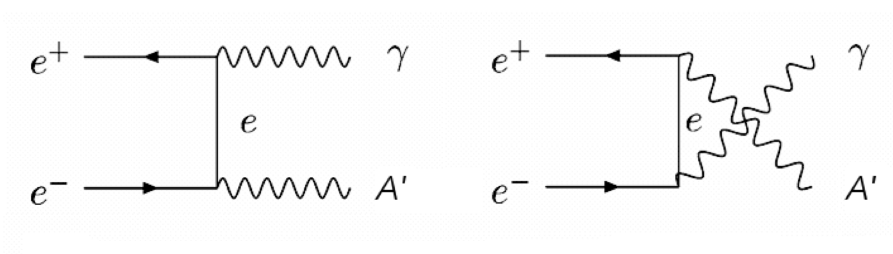
(HERA limit in e^+p is 208 GeV)

EIC projections

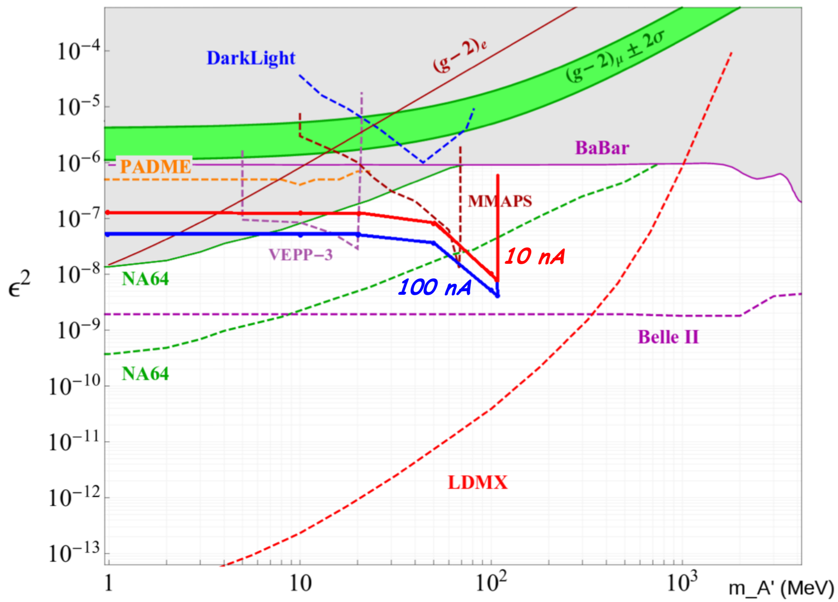


LOI12-18-004

M. Battaglieri, A. Celentano, L. Marsicano et al.



- The e^+e^--annihilation offers an alternative way to probe the existence of a dark photon by measuring the photon spectra in the A' invisible decay chanel.

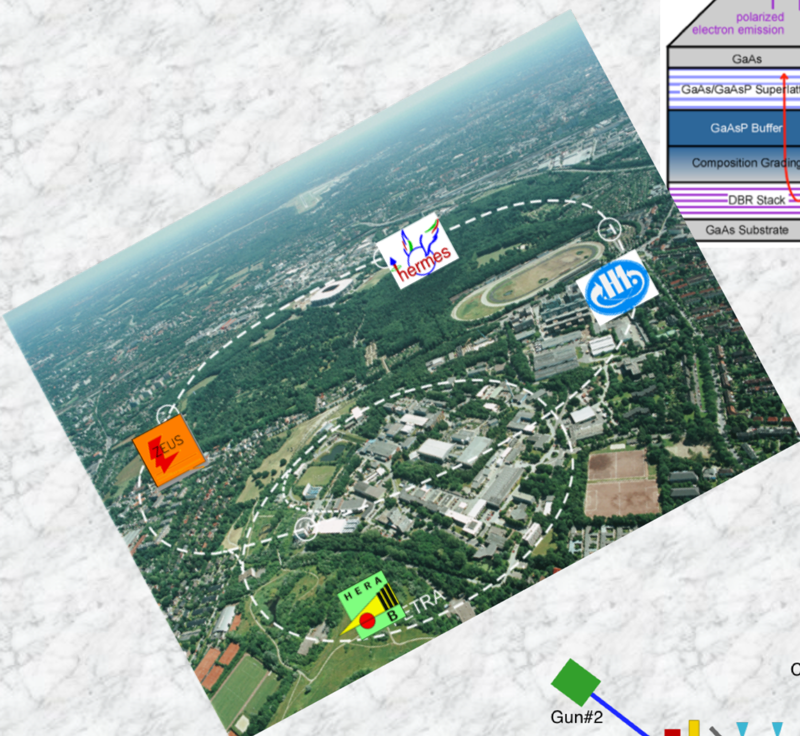


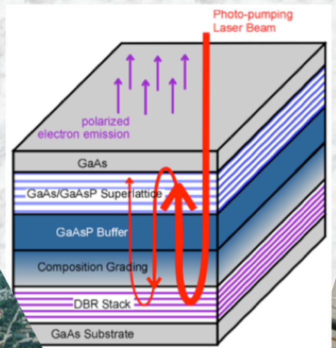
P. Valente, J. Alexander, (JPos17) AIP CP 1970 (2018) 020007
L. Marsicano, (JPos17) AIP CP 1970 (2018) 020008

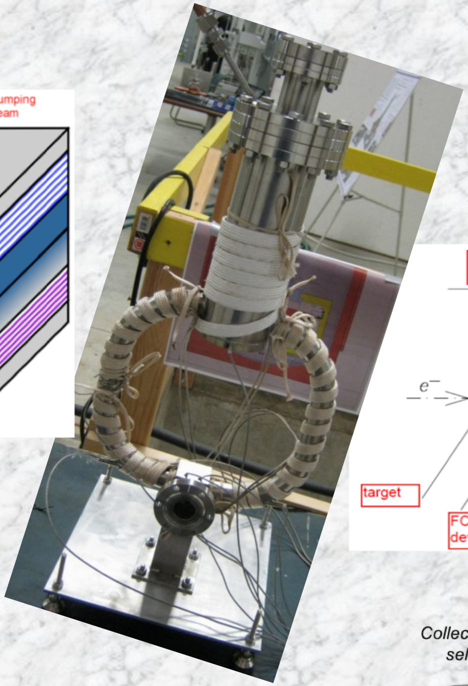
180 days data taking with a high energy positron beam would extend the A' mass reach up to 100 MeV and would improve by a factor 10 the coupling strength sensitivity.

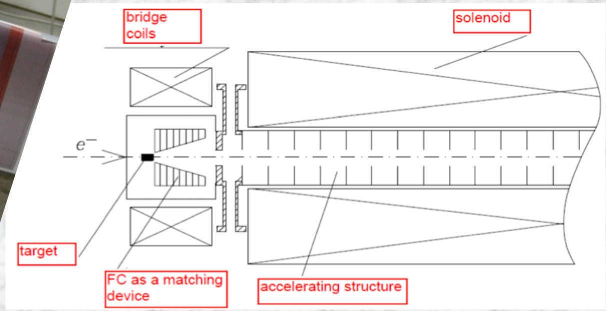
Polarized Positrons

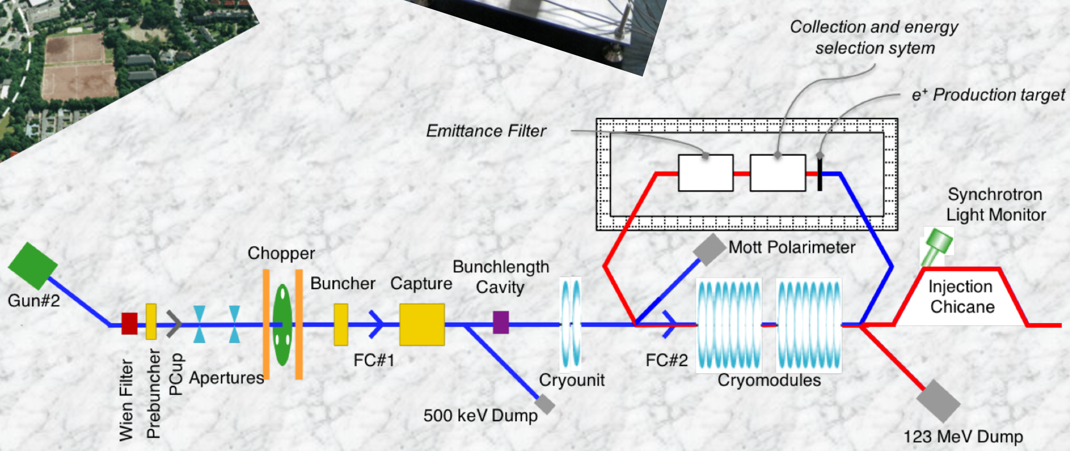
See J. Grames' talk







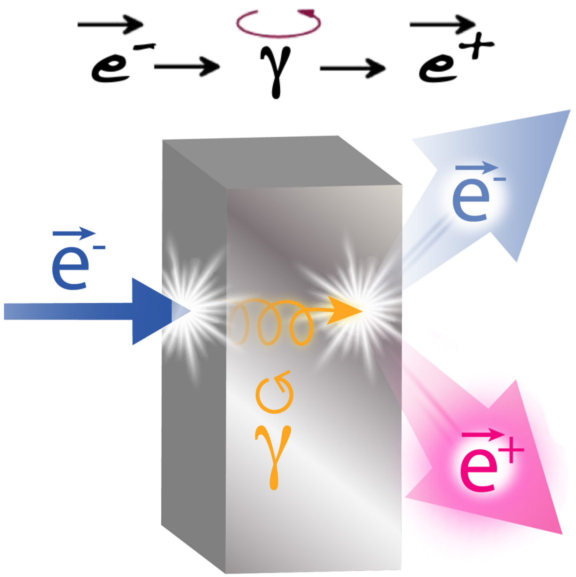


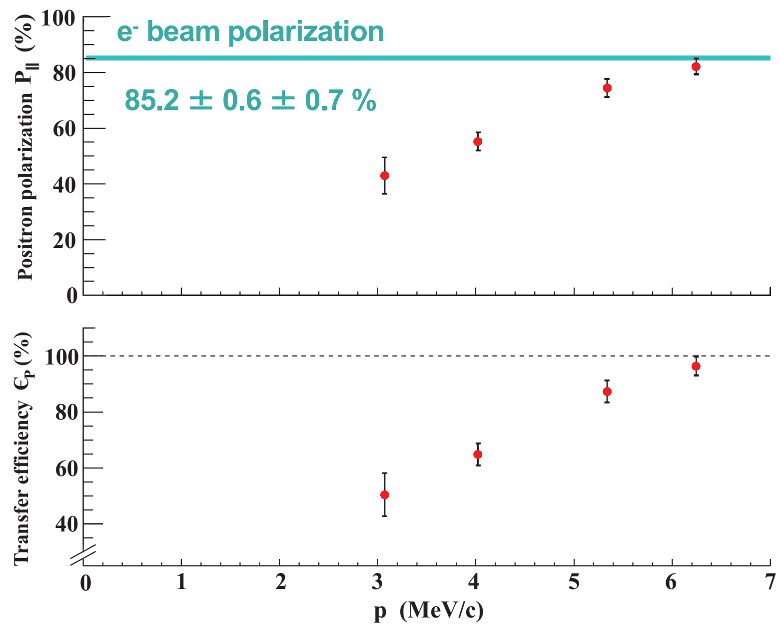


Polarized Electrons for Polarized Positrons

(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.

Eric Voutier
IJCLab Irène Joliot-Curie

e^+@ eRHIC

Unpolarized and **polarized positron beams** provide a unique opportunity to **enhance** the **physics reach** at JLab and eRHIC.

Interferences, neutral and charged currents, test of the Standard Model...

Unpolarized positron beams are determinant for the GPD program.

☛ **Positron** beams would be a **small addition** to eRHIC.

☛ **Unpolarized** beams are **straightforward**, **polarized** beams are challenging but **achievable**.

The e^+@JLab White paper will be soon available.... Stay tuned !!