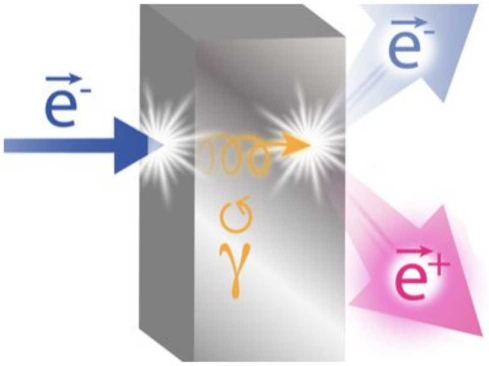
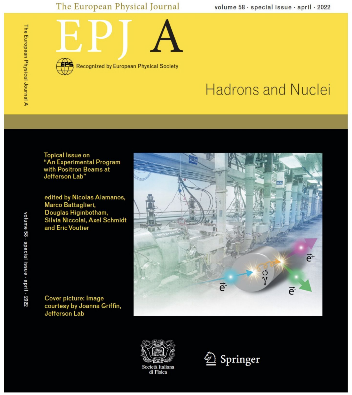
Hall A/C Positron Program

Michael Nycz

Hall A/C Summer Collaboration Meeting

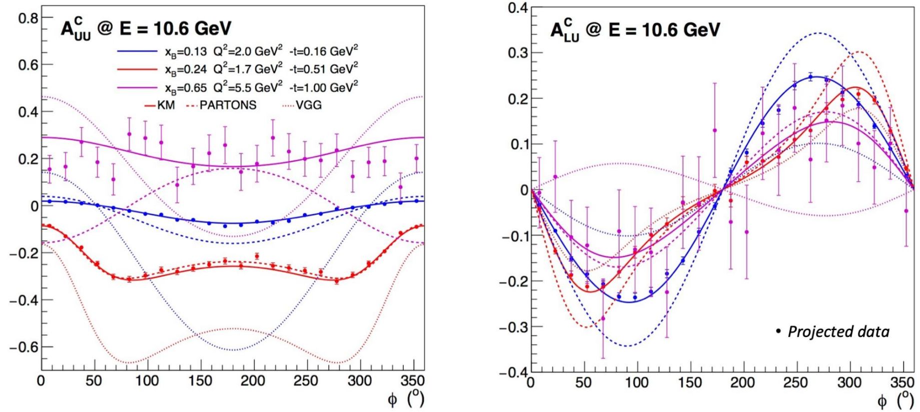
July 15-16 2024



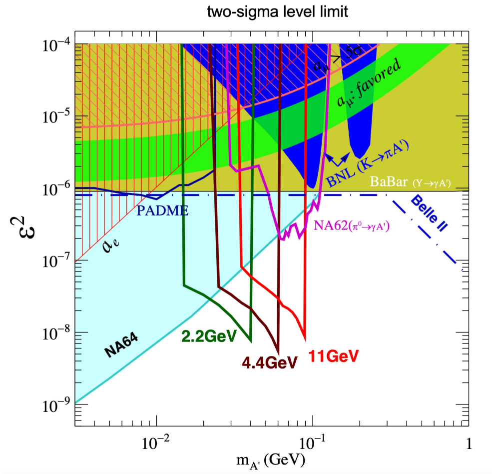


[An Experimental Program with Positron Beams at Jefferson Lab]()

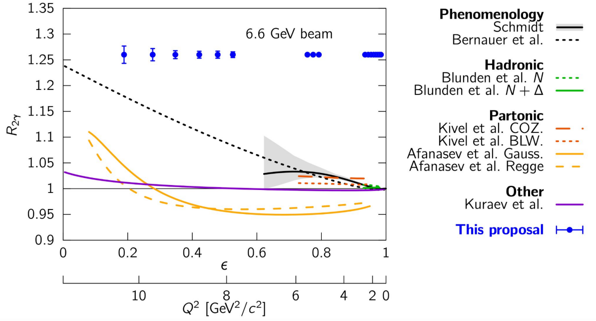
Beam charge asymmetries with CLAS12



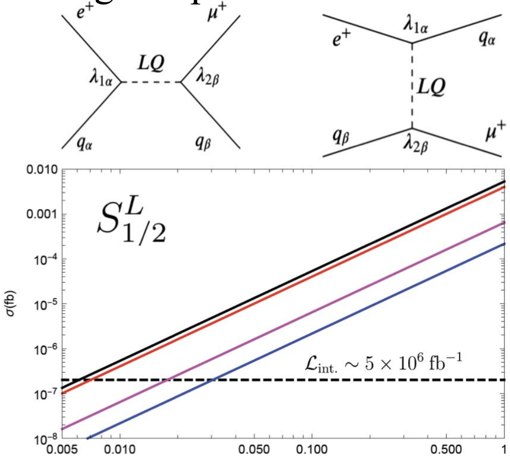
Dark photon search



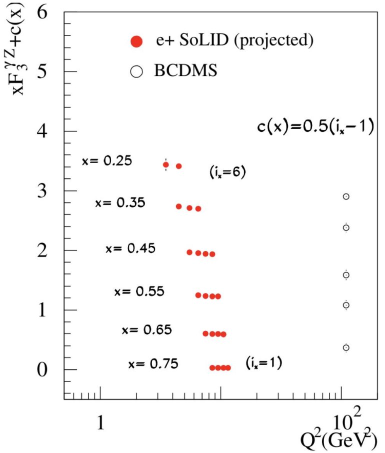
TPE with CLAS12



Charged lepton flavor violation



Electroweak structure function $F_3^{\gamma Z}$



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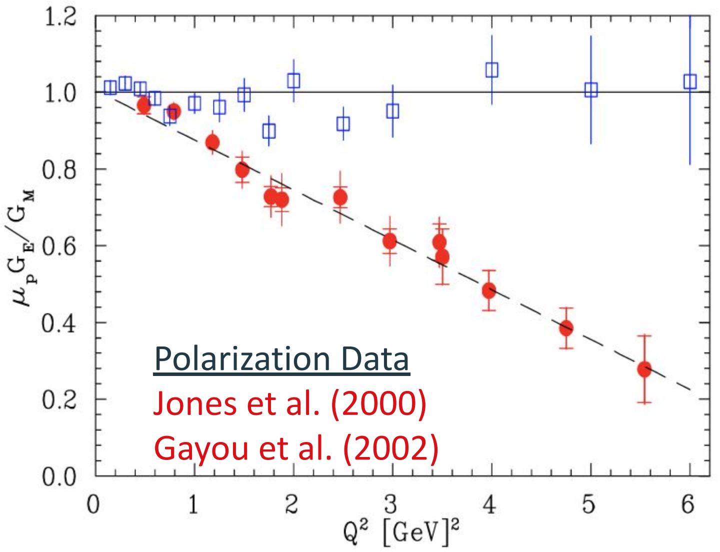
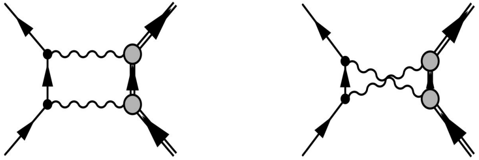
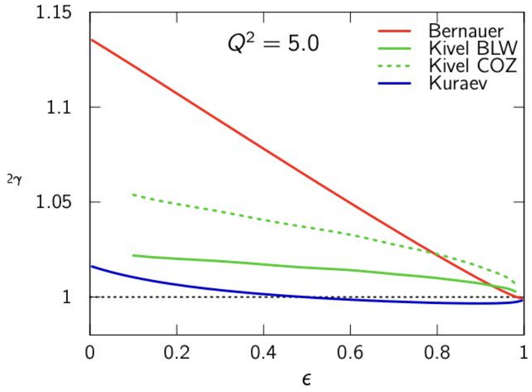
Two-Photon Exchange

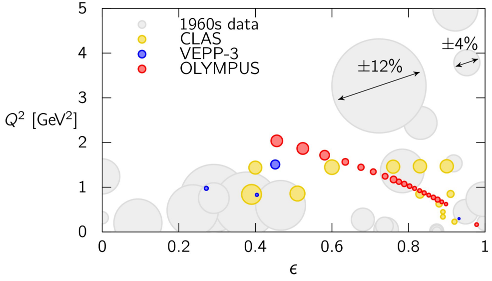
VOLUME 84, NUMBER 7 PHYSICAL REVIEW LETTERS 14 FEBRUARY 2000

G_{E_p}/G_{M_p} Ratio by Polarization Transfer in $\vec{e}p \to e\vec{p}$









Understanding the Two-Photon Exchange with e^+ (and e^-)

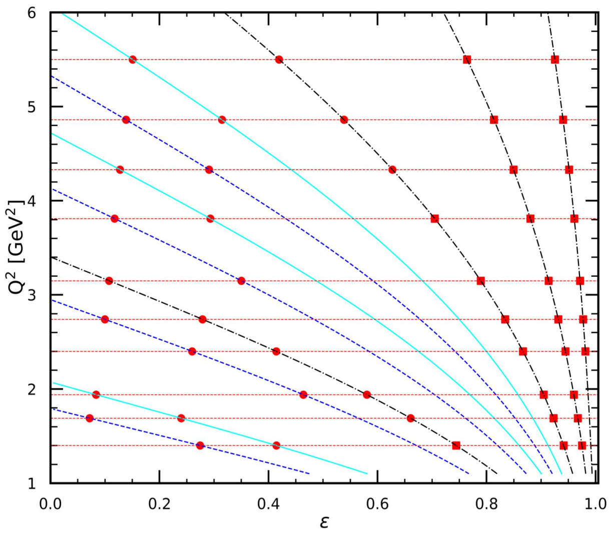
Hall C

A measurement of two-photon exchange in unpolarized elastic positron–proton and electron–proton scattering

Three linac settings; 11 beam energies

Ten Q^2 points: 1.4 - 5.5 GeV^2

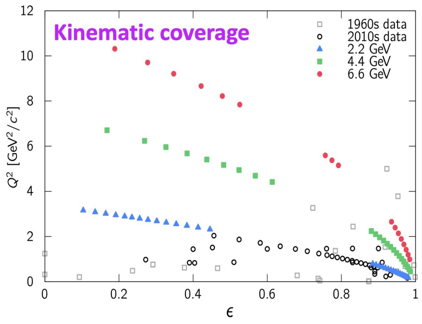
Four or five ε points at each Q^2

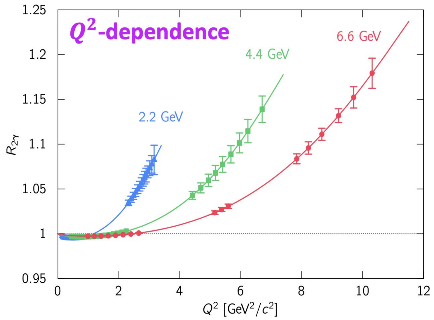


Hall B

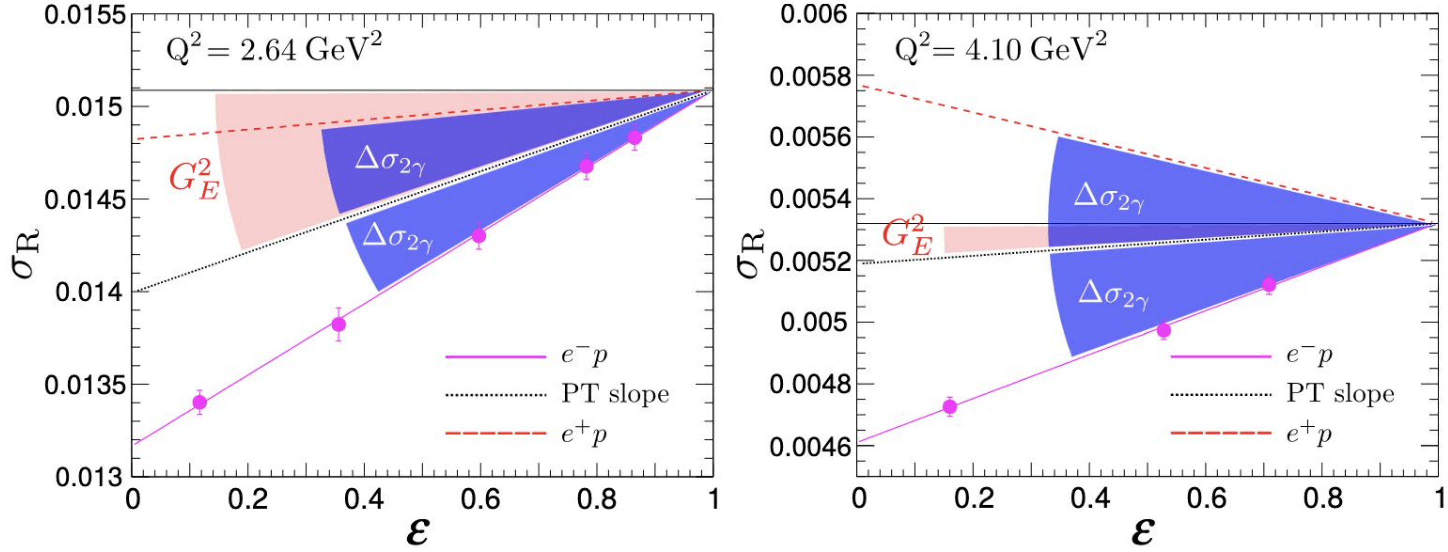
A Direct Measurement of Hard Two-Photon Exchange with Electrons and Positrons at CLAS12 (A. Schmidt, et. al)

$$R \equiv \frac{\sigma^+ p}{\sigma^- p} = \frac{|M_{1\gamma} + M_{2\gamma}|^2}{|M_{1\gamma} - M_{2\gamma}|^2} \rightarrow R_{2\gamma} = 1 - 2\delta_{2\gamma}$$





Two-Photon Exchange: Super Rosenbluth



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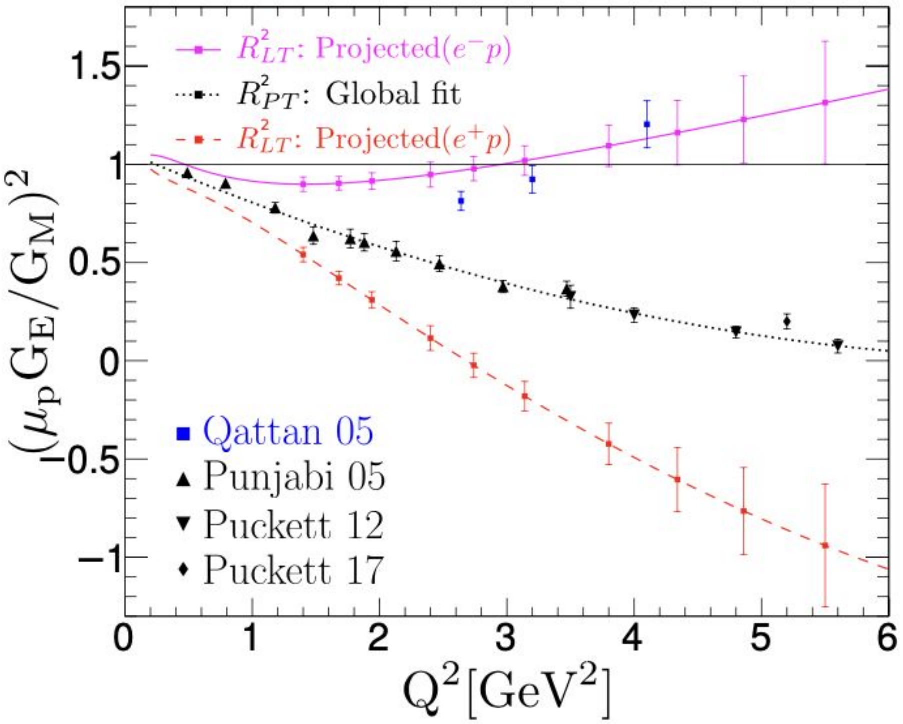
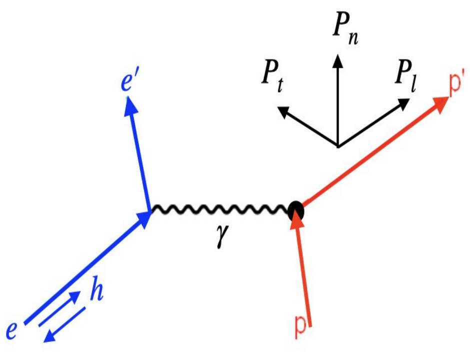
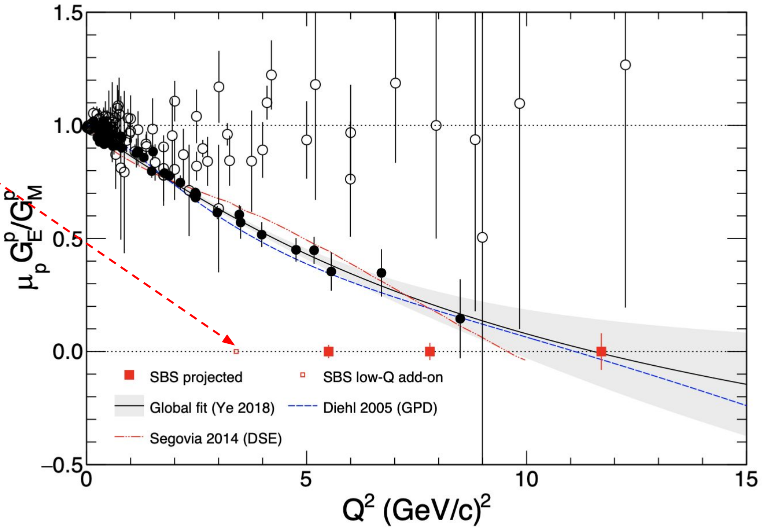


Two-Photon Exchange: Polarization Observables



$$\frac{G_E}{G_M} = -\frac{P_t}{P_l}\frac{(E+E')}{2M}tan(\theta_e/2)$$

Low Q^2 e^- point measured with SBS approved at PAC 52



$$\frac{P_t}{P_l} = -\sqrt{\frac{2\epsilon}{\tau(1+\epsilon)}}\frac{G_E}{G_M} \times \left[1 \pm \mathrm{Re}\left(\frac{\delta\widetilde{G}_M}{G_M}\right) \pm \frac{1}{G_E}\mathrm{Re}\left(\delta\widetilde{G}_E + \frac{\nu}{M^2}\widetilde{F}_3\right) \mp \frac{2}{G_M}\mathrm{Re}\left(\delta\widetilde{G}_M + \frac{\epsilon\nu}{(1+\epsilon)M^2}\widetilde{F}_3\right) + \mathcal{O}(\alpha^2)\right],$$

- e^- data will be collected with SBS G_E^p Experiment (E12-07-109):
- Future e^+ proposal

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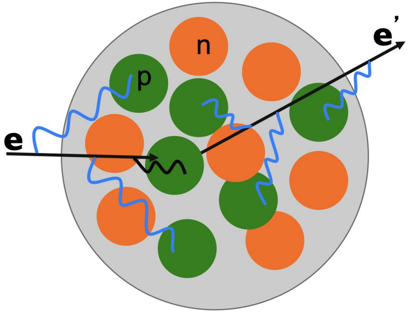
Constraining the Impact of Coulomb Corrections in DIS

1. Leptons can be accelerated / decelerated in Coulomb field of nuclei



From D. Gaskell
PAC Presentation

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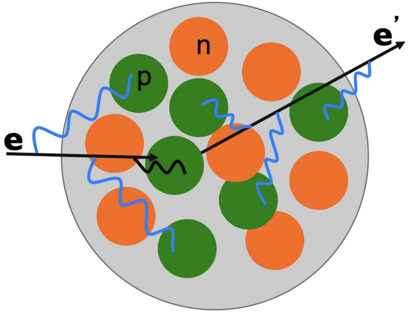
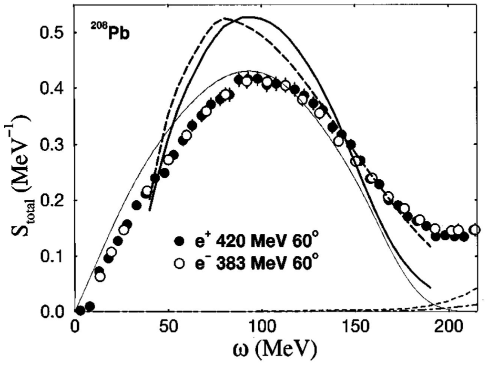


From D. Gaskell PAC Presentation

2. Quasielastic scattering:
   a. Effective Momentum Approximation (EMA)

$$E_e \rightarrow E_e + \bar{V}$$
$$E'_e \rightarrow E'_e + \bar{V}$$



P. Gueye et al., *Phys. Rev. C*, 1999

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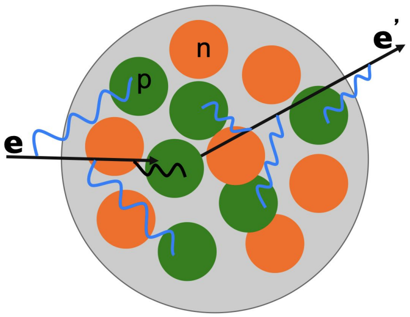

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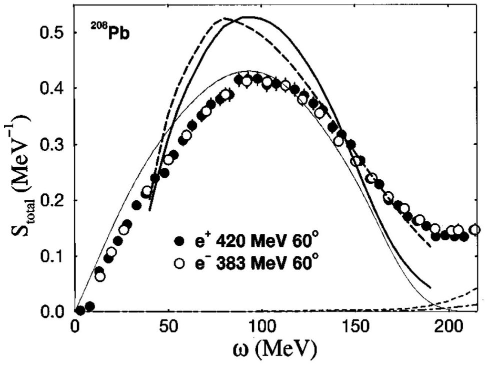
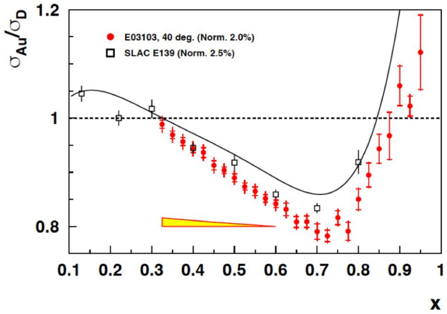
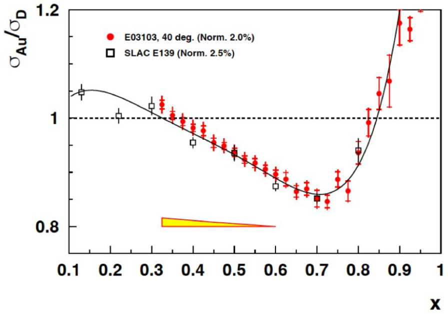


P. Gueye et al., *Phys. Rev. C*, 1999

3. Inelastic Scattering - Less clear
   a. Important for JLab kinematics
   b. EMA (not yet verified for inelastic)

From D. Gaskell PAC Presentation





PR12+23-003

<u>E12-14-002</u>

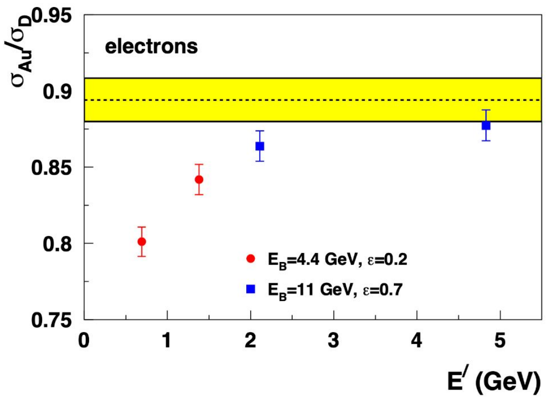
W. Henry, S. Alsalmi,M. Christy,D. Gaskell,T. James Hague,S. Malace,D. Nguyen, P. Solvignon-Slifer

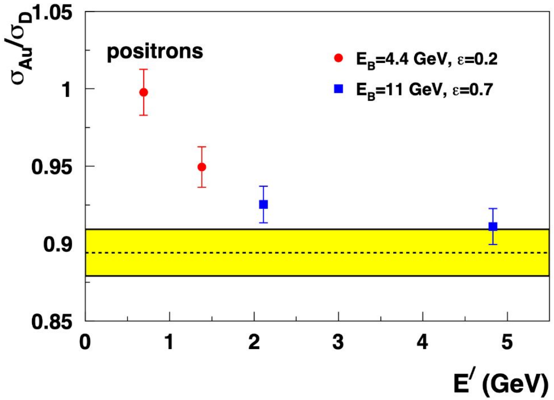
<u>PR12+12-003</u>

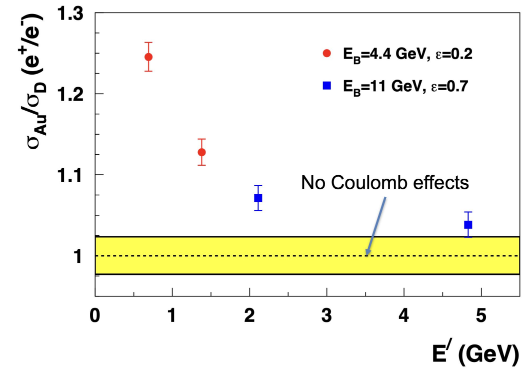
Bill Henry, Dave Gaskell, Nadia Fomin

- E12-14-002
  - e^- measurements
- PR12+23-003
  - Perform CC test using e^+ at same kinematics as E12-14-002
- Allows direct comparison of e^- & e^+
- Target ratios $\left(\frac{\sigma_{Au}}{\sigma_D}\right)$
- Super-ratio for e^+/e^-
  - Cleanest measurement of CC
  - Insensitive to assumptions in electron/positron-only CC test

$$R = \frac{\left(\frac{\sigma_{Au}}{\sigma_D}\right)^{e+}}{\left(\frac{\sigma_{Au}}{\sigma_D}\right)^{e-}}$$







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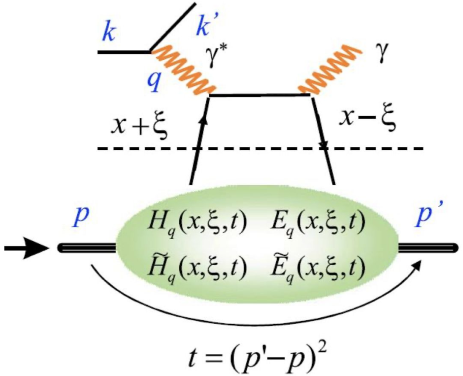
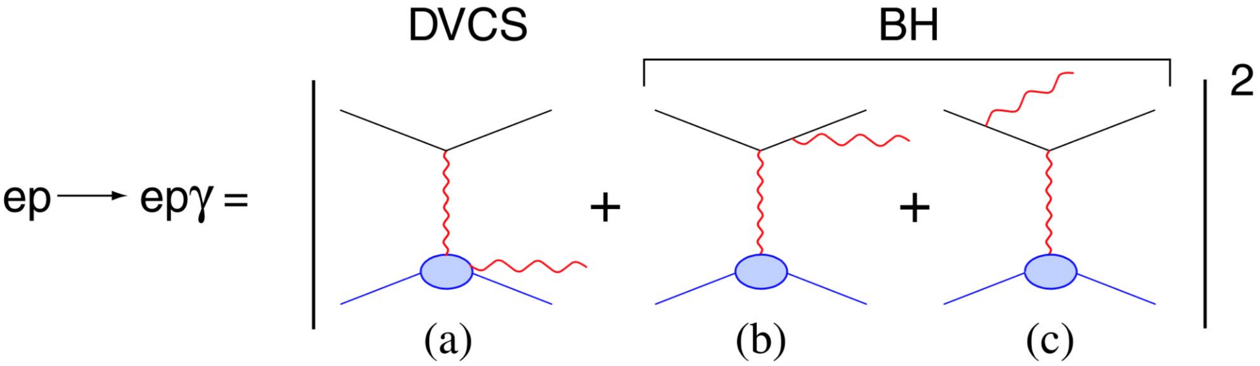
Deeply Virtual Compton Scattering



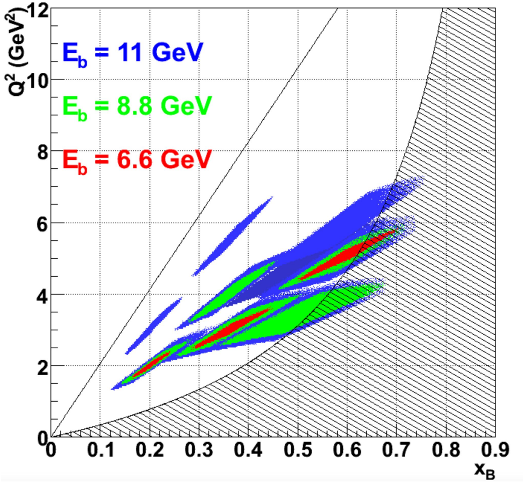


$$|\mathcal{T}(\pm ep \to \pm ep\gamma)|^2 = |\mathcal{T}^{BH}|^2 + |\mathcal{T}^{DVCS}|^2 \mp \mathcal{I}$$

"The simplest hard exclusive process related to Generalized Parton Distributions (GPDs)"

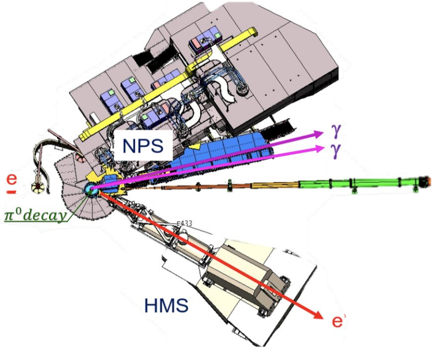
Interference term: opposite sign for e^- and e^+

PR12+23-006 (C. Munoz Camacho and M. Mazouz)



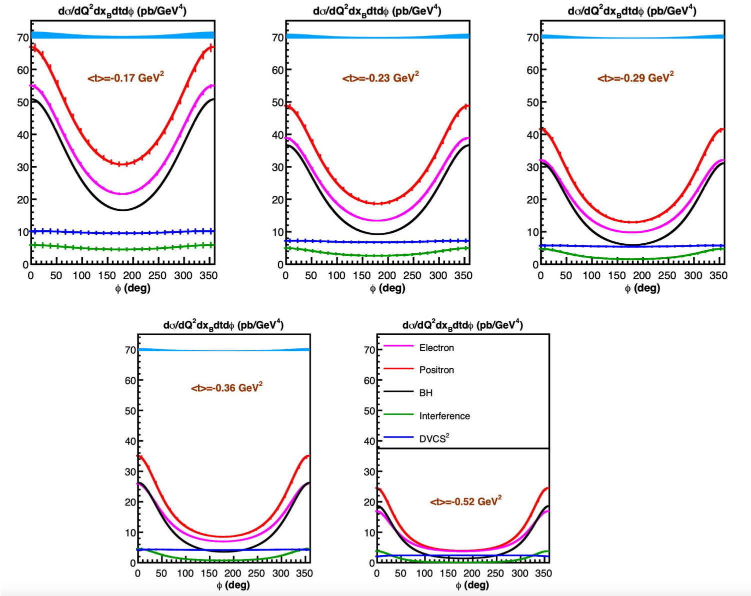
- Precision cross section measurements
  - HMS (e^- or e^+) + NPS (neutral particle spectrometer)
- Clean, model-independent separation of DVCS^2 and DVCS-BH interference
- Combining e^- & e^+ allows for more stringent constraints on Compton Form Factors (CFF)
- Same kinematics as *E12-13-010*

See talk by M. Kerver

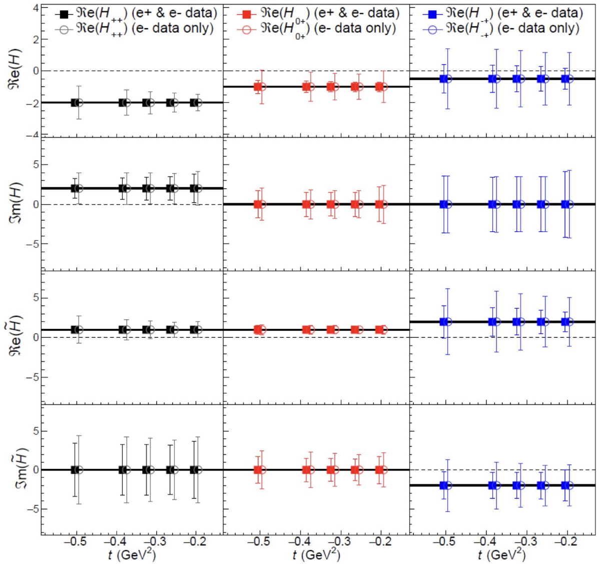


Projections

- Combination of e^- and e^+ cross sections
  - Separation of the DVCS^2 contribution and the DVCS- BH interference



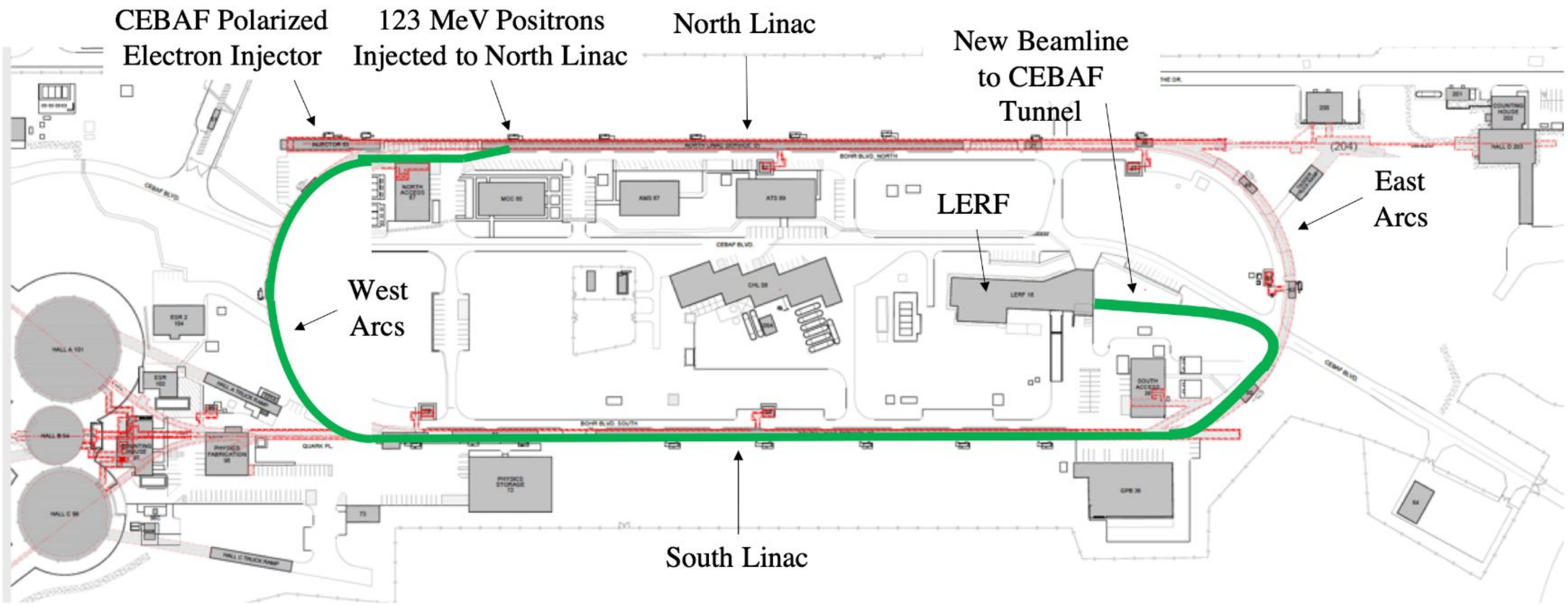
- ~ 4-6 times improvement in CFF



(Possible) Future Proposals

1. PR12-21-006: *Measurement of the Asymmetry A_d^(e+e-)between e^+ – 2H and e^- – 2H Deep Inelastic Scattering Using SoLID and PEPPo at JLab* (X. Zheng)
2. LOI12+23-005: *Amplitude-level Searches for Dark Photons in Bhabha Scattering* (D. Mack)
3. LOI12+23-008: *Polarization transfer in positron-proton elastic scattering* (A. Puckett, J. Bernauer, A. Schmidt)
4. LOI12+23-015: *Energy dependence of dispersive effects in unpolarized inclusive elastic electron/positron-nucleus scattering* (P. Gueye, J. Arrington, P. Giuliani, D. Higinbotham)
5. LOI12+23-002: *The Axial Form Factor of the Nucleon from Weak Capture of Positrons* (D. Dutta)
6. LOI (PAC 52): *Measurement of the Two-Photon Exchange Contribution to the Positron-Neutron Elastic Scattering Cross Section* (E. Fuchey, S. Alsalmi)

Apologies for any recent LOIs I missed!

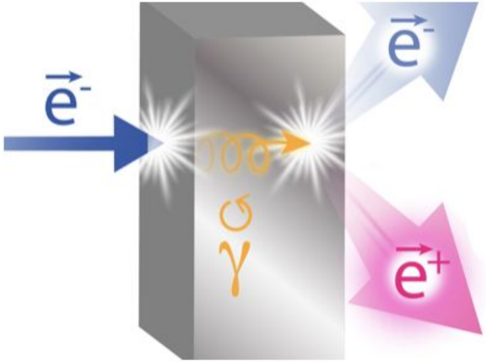


- ➔ Positron upgrade would transform LERF into 123 MeV positron injector
- ➔ A new transport line will transport the beam to CEBAF injection point

Machine Parameters

$$\vec{e}^- \rightarrow \vec{\gamma} \rightarrow \vec{e}^+ \; (+\, \vec{e}^-)$$

When a longitudinally polarized e- beam strikes matter, e+ produced in the shower carrying ***>50% of the e- beam energy*** *are significantly longitudinally* ***spin polarized****…*



Machine parameter table now more comprehensive

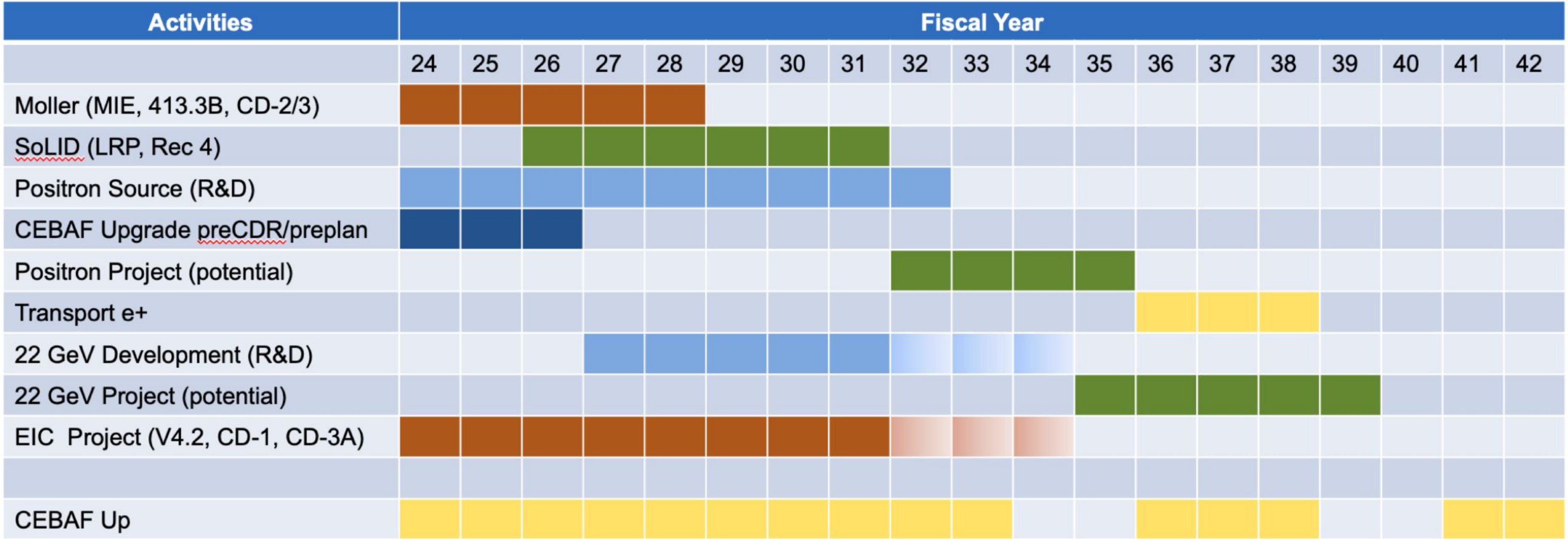
Machine Parameter	CEBAF e-	Ce+BAF		
		e+	Degraded e-	e-
Multiplicity	4	1 or 2		
Max. Energy (ABC/D)	11/12 GeV	11/12 GeV		
Beam Repetition	250/499 MHz	250/499 MHz		
Duty Factor	100% cw	100% cw		
Unpolarized Intensity	170 μA**	> 1 μA	>> 1 uA	170 μA**
Polarized Intensity	170 μA**	> 50 nA	>> 1uA	170 μA**
Beam Polarization	> 85%	> 60%	>85% ?	>85%

** Total beam power at Jefferson Lab is limited to 1.1 MW with a max. of 0.9 MW to individual high power dumps.

Yves Roblin JLUO 2024

See talk by Andriy Ushakov
Concept of a Positron Source at Ce+BAF

Timeline Scenarios (highly speculative)



Summary and Outlook

- Future JLab positron program will address long standing questions along with opening up new observables
- Currently 6 C1 approved experiments
  - PAC 51 - 5 approved experiments
  - PAC 52 - 1 approved experiment (+ additional e^- portion of polarization transfer)
  - ~400 PAC days (halls B & C)
- Experiments and proposals touch upon
  - TPE, DVCS, dark photon, electroweak couplings, etc…
- JLab positron program continues to grow
  - New LOI at PAC 52
- Look forward to new proposals at PAC 53
- Sign up to the Positron Working Group mailing list pwg@jlab.org
- Hadron Physics 2030 Workshop
  - October 21, 2024 to November 8, 2024 at Institut Pascal

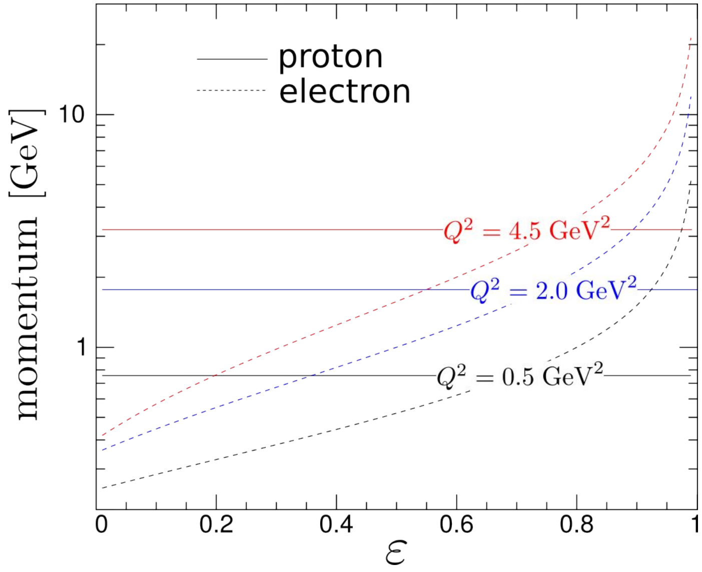
Advantages of Super-Rosenbluth: *Momentum*

ε dependence of momentum:

Proton momentum fixed at fixed Q^2

Momentum dependent corrections

No ε dependence



Advantages of Super-Rosenbluth: *Cross Section*

ε dependence of momentum:

Proton momentum fixed at fixed Q^2

Momentum dependent corrections

No ε dependence

ε dependence of cross section:

Higher statistical precision at low ε

Minimal ε dependence

Rate dependent corrections & uncertainties