DVCS analysis at JLab Hall A

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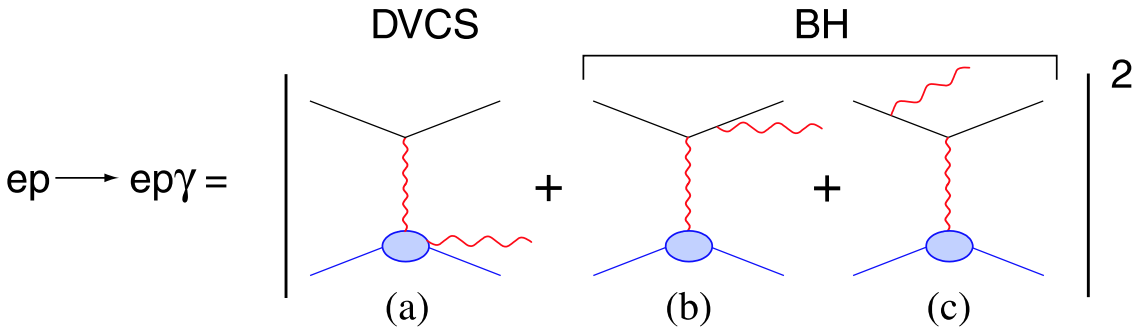
Outline

1. Motivations
2. Hall A DVCS program of measurements
3. 2006–2007 results
4. New 6 GeV experiments (under analysis)
5. 12 GeV program

DVCS experimentally: interference with Bethe-Heitler



At leading twist:

$$d^5\overrightarrow{\sigma} - d^5\overleftarrow{\sigma} = \Im m\left(T^{BH}\cdot T^{DVCS}\right)$$

$$d^5\overrightarrow{\sigma} + d^5\overleftarrow{\sigma} = |BH|^2 + \Re e\left(T^{BH}\cdot T^{DVCS}\right) + |DVCS|^2$$

$$\mathcal{T}^{DVCS} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\epsilon} + \cdots =$$

$$\underbrace{\mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}}_{\text{Access in helicity-independent cross section}} - \underbrace{i\pi\, H(x=\xi,\xi,t)}_{\text{Access in helicity-dependent cross-section}} + \ldots$$

The Hall A DVCS program

1. Accurate cross-section measurements (3–4% uncertainties)
   - Highest sensitivity observable
   - Necessary for disperssion analysis (M. Vanderhaeghen's talk)
2. Q^2–dependence of all observables
   - *Only* way to disentangle higher twists
3. Both proton and neutron (deuteron) targets
   - Flavor sensitivity

The program:

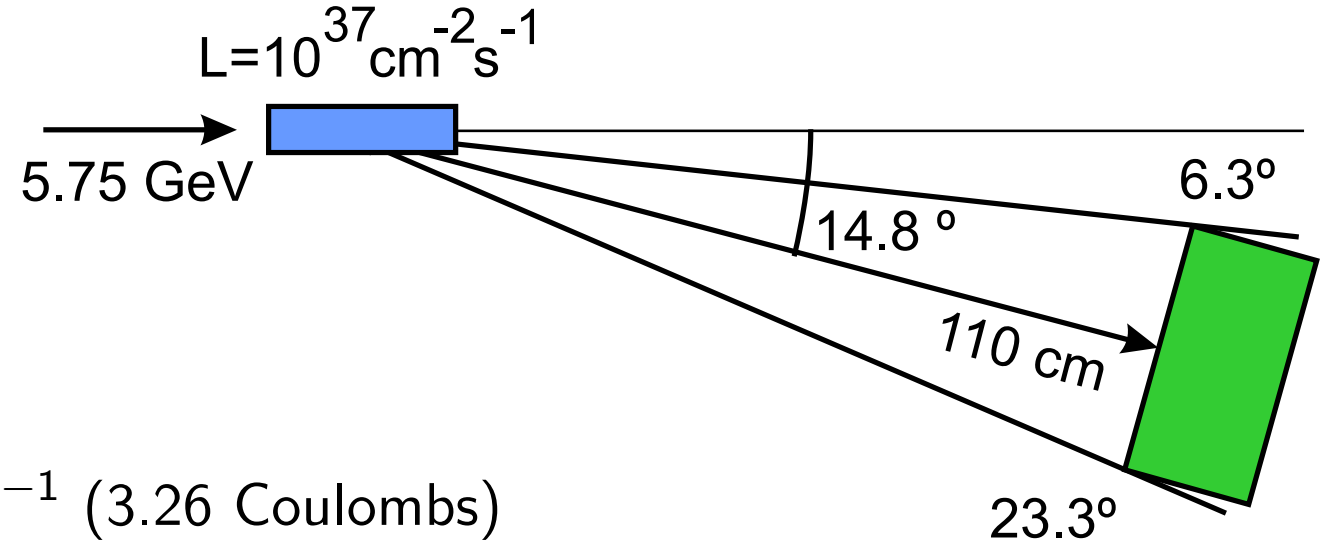
- First round of experiments in 2004 (published in 2006–2007)
- Second round (Rosenbluth separation) in 2010 (under analysis)
- 12 GeV: Extended kinematic coverage in 2015

Complementary program on exclusive π^0's$\rightarrow$ Wednesday's session

E00-110 (2004): goal and kinematics

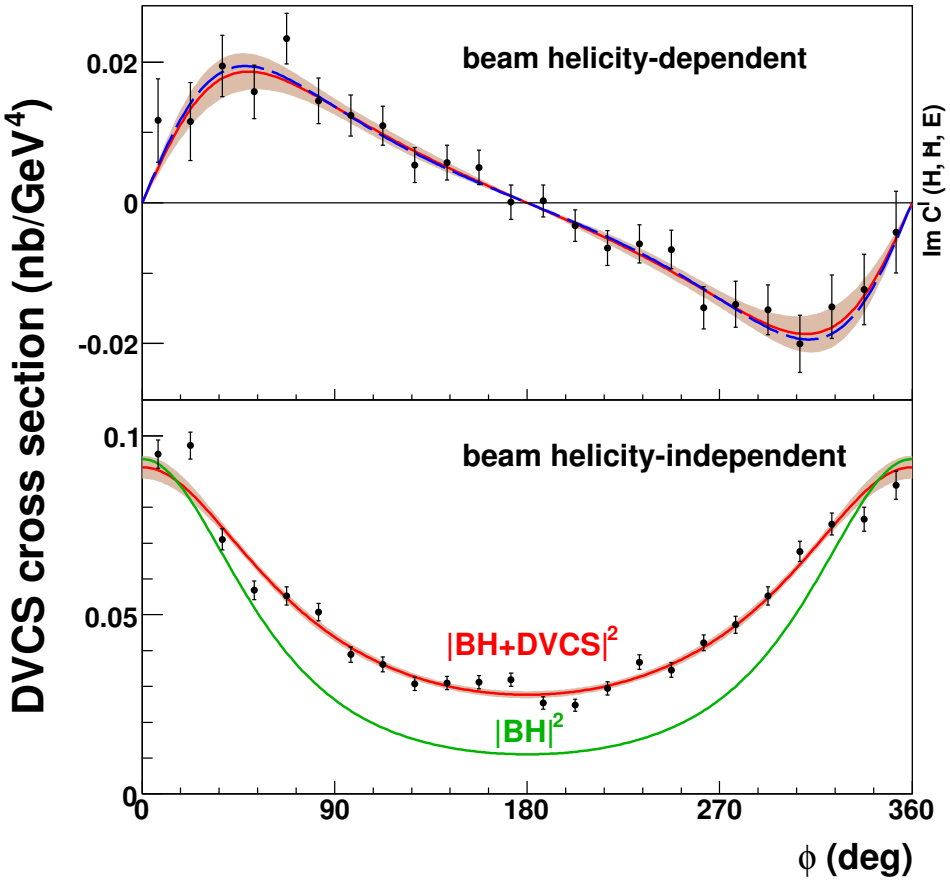
Kin	Q^2 (GeV^2)	x_B	θ_e (deg.)	θ_{γ^*} (deg.)	P_e (GeV)
1	**1.5**	0.36	15.6	**22.3**	3.6
2	**1.9**	0.36	19.3	**18.3**	2.9
3	**2.3**	0.36	23.9	**14.8**	2.3

$\mathcal{P} = 75.3\%$

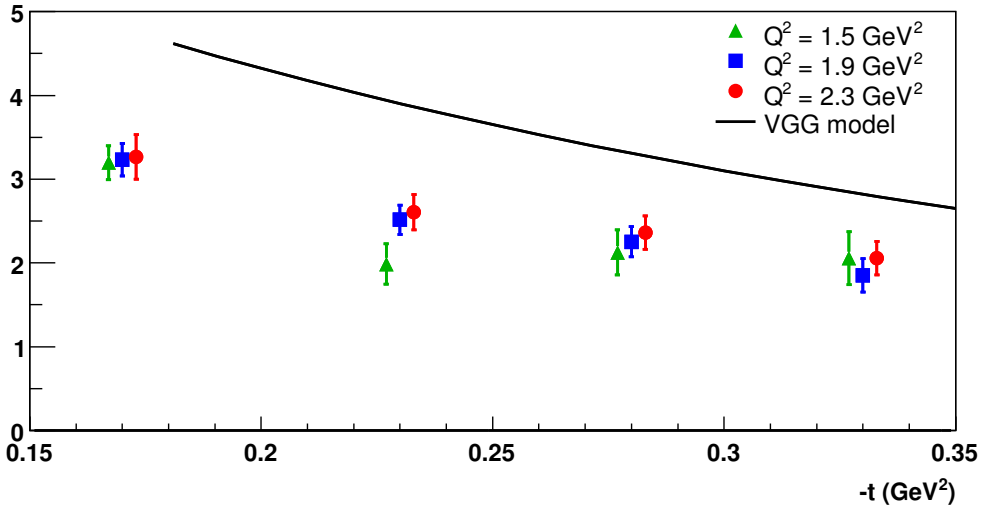


$\int \mathcal{L}\, dt = 13294$ fb^{-1} (3.26 Coulombs)

E00-110 results



Scaling en Q^2



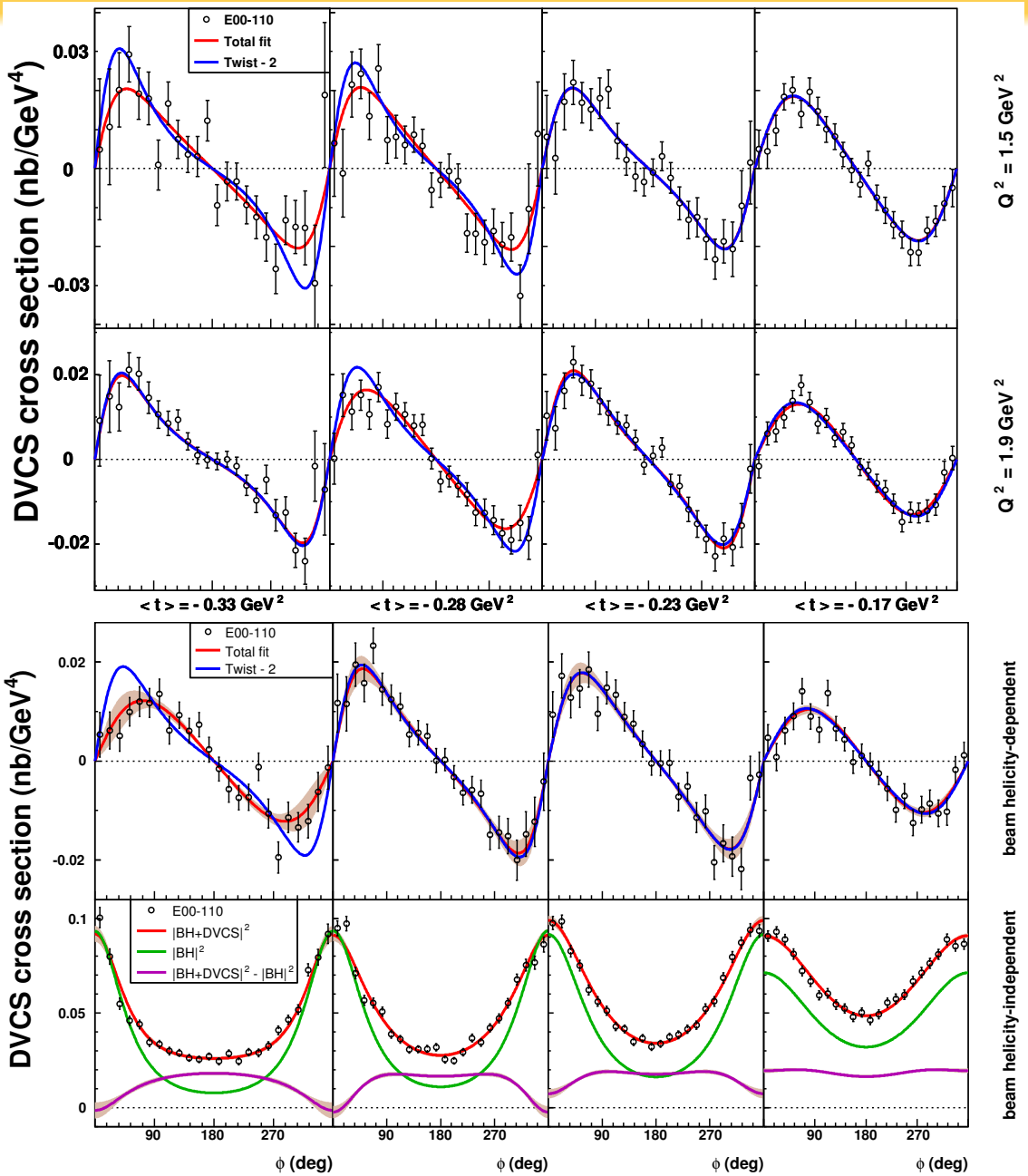
Twist-2: dominant contribution

Contributions from BH^2, $DVCS^2$ and BH-DVCS interference

Phys. Rev. Lett. **97**, 262002 (2006)

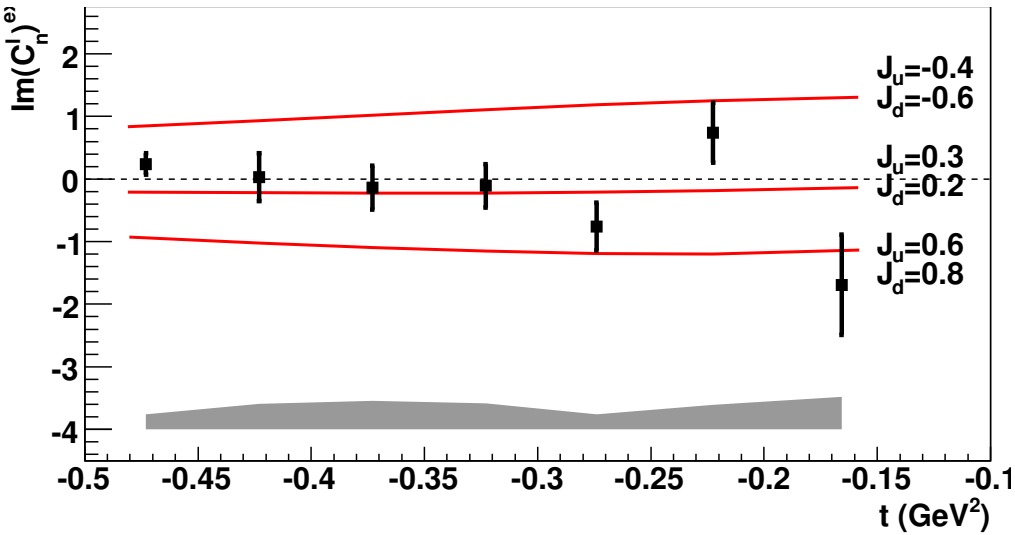
Cross-section results

- 3 values of Q^2: 1.5, 1.9, 2.3 GeV^2
- Fixed $x_B = 0.36$, 4 bins in t
- $\sim$5% syst. uncertainty



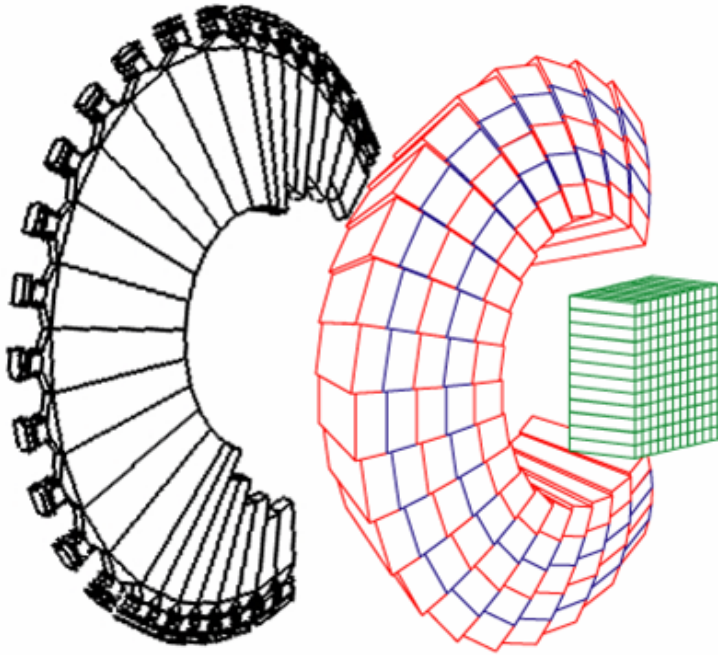
DVCS on the neutron: experiment E03-106 at JLab

LD_2 target ($F_2^n(t) \gg F_1^n(t)$!)



$$\sigma^{\rightarrow} - \sigma^{\leftarrow} = \Gamma(A \sin\varphi + \dots)$$

Charged particle veto
in front of scintillator array



$$A = F_1(t)\mathcal{H} + \frac{x_B}{2 - x_B}[F_1(t) + F_2(t)]\tilde{\mathcal{H}} - \underbrace{\frac{t}{4M^2} \cdot F_2(t) \cdot \mathcal{E}}$$

Main contribution for neutron

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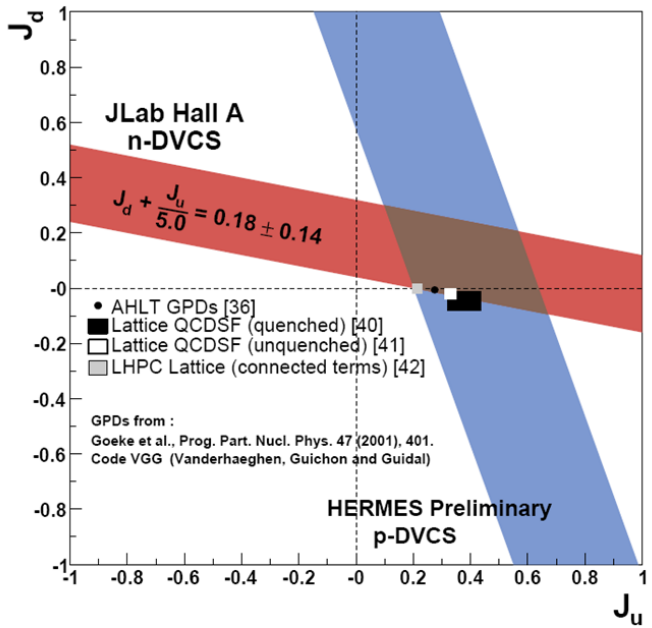

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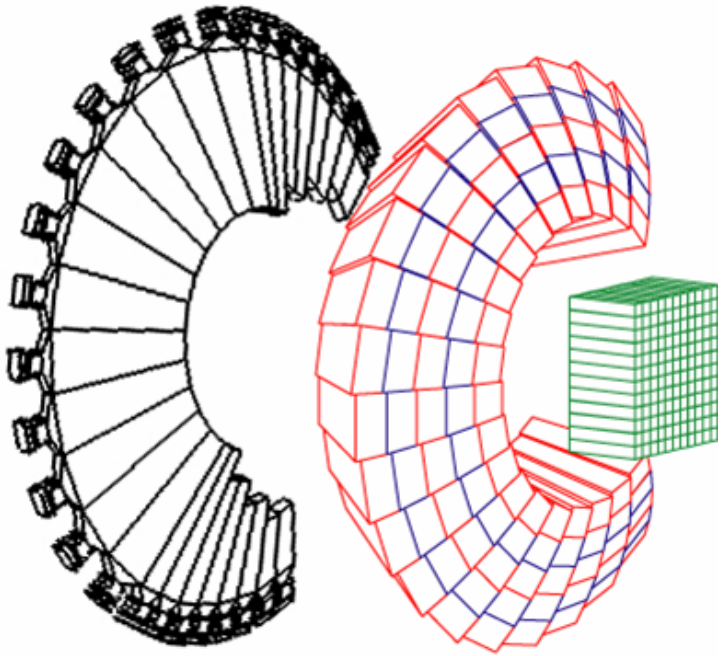

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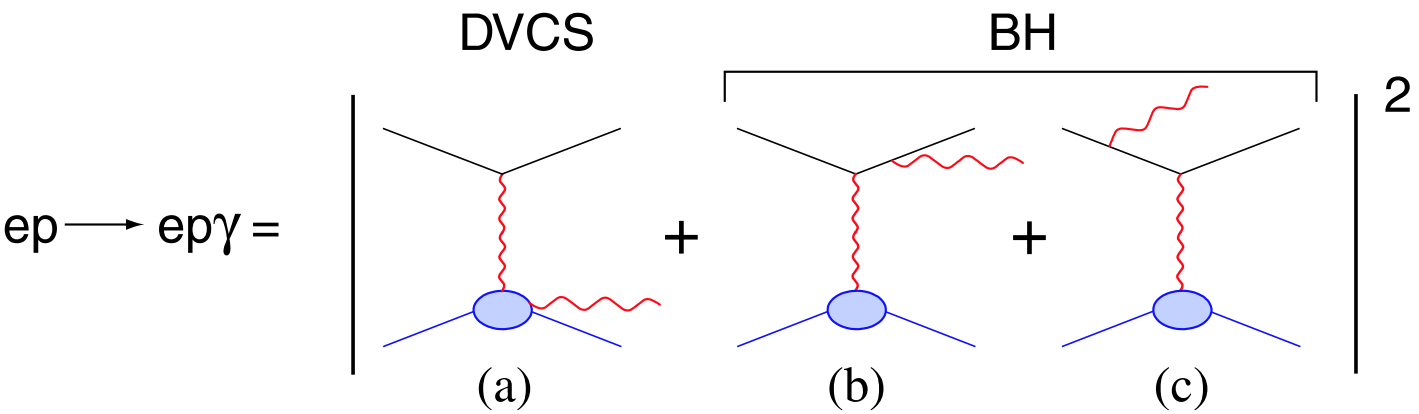
Main contribution for neutron

E07-007

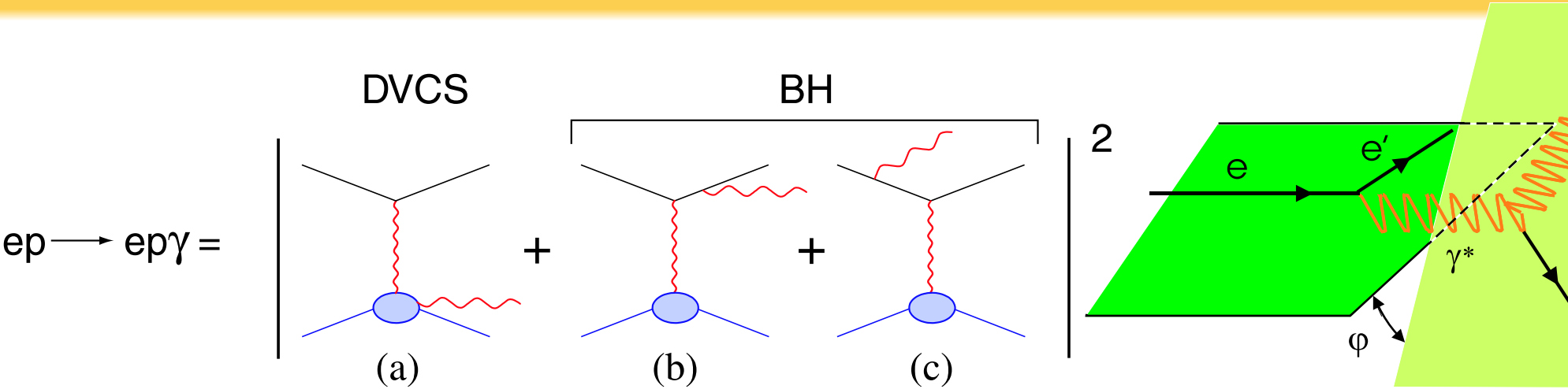


$$\sigma(ep \to ep\gamma) = \underbrace{|BH|^2}_{\text{Known to } \sim 1\%} + \underbrace{\mathcal{I}(BH \cdot DVCS)}_{\text{Linear combination of GPDs}} + \underbrace{|DVCS|^2}_{\text{Bilinear combination of GPDs}}$$

DVCS cross section has a very rich azimuthal structure:

- Azimuthal analysis allows the separation of the different contributions to $\mathcal{I}$ if $DVCS^2$ is negligeble.
- If $DVCS^2$ is important, $\mathcal{I}$ and $DVCS^2$ terms **MIX** in an azimuthal analysis.
- The **different energy dependence** of $\mathcal{I}$ and $DVCS^2$ allow a full separation.

E07-007



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DVCS cross section

$$\frac{d^5\sigma}{d^5\Phi} = \underbrace{\frac{d^5\sigma(|BH|^2)}{d^5\Phi}}_{\text{Known from FF}} + \underbrace{\Gamma\,\eta\,\mathcal{C}^{\text{DVCS}}(\mathcal{F},\mathcal{F}^*)}_{|\text{DVCS}|^2\text{ (twist-2)}} +$$

$$\underbrace{(\Gamma_0^{\Re} - \cos(\phi_{\gamma\gamma})\Gamma_1^{\Re})\Re\text{e}\left[\mathcal{C}^I(\mathcal{F})\right] + \Gamma_{0,\Delta}^{\Re}\Re\text{e}\left[\mathcal{C}^I + \Delta\mathcal{C}^I\right](\mathcal{F}) + \cos(2\phi_{\gamma\gamma})\Gamma_2^{\Re}\Re\text{e}\left[\mathcal{C}^I(\mathcal{F}^{\text{eff}})\right]}_{\text{Interference BH-DVCS}}$$

- $\Re\text{e}\left[\mathcal{C}^{I,\,\text{exp}}(\mathcal{F})\right] = \Re\text{e}\left[\mathcal{C}^I(\mathcal{F})\right] + \langle\eta_{c1}\rangle\,\mathcal{C}^{\text{DVCS}}(\mathcal{F},\mathcal{F}^*)$
- $\Re\text{e}\left[\mathcal{C}^{I,\,\text{exp}} + \Delta\mathcal{C}^{I,\,\text{exp}}\right](\mathcal{F}) = \Re\text{e}\left[\mathcal{C}^I + \Delta\mathcal{C}^I\right](\mathcal{F}) + \langle\eta_0\rangle\,\mathcal{C}^{\text{DVCS}}(\mathcal{F},\mathcal{F}^*)$

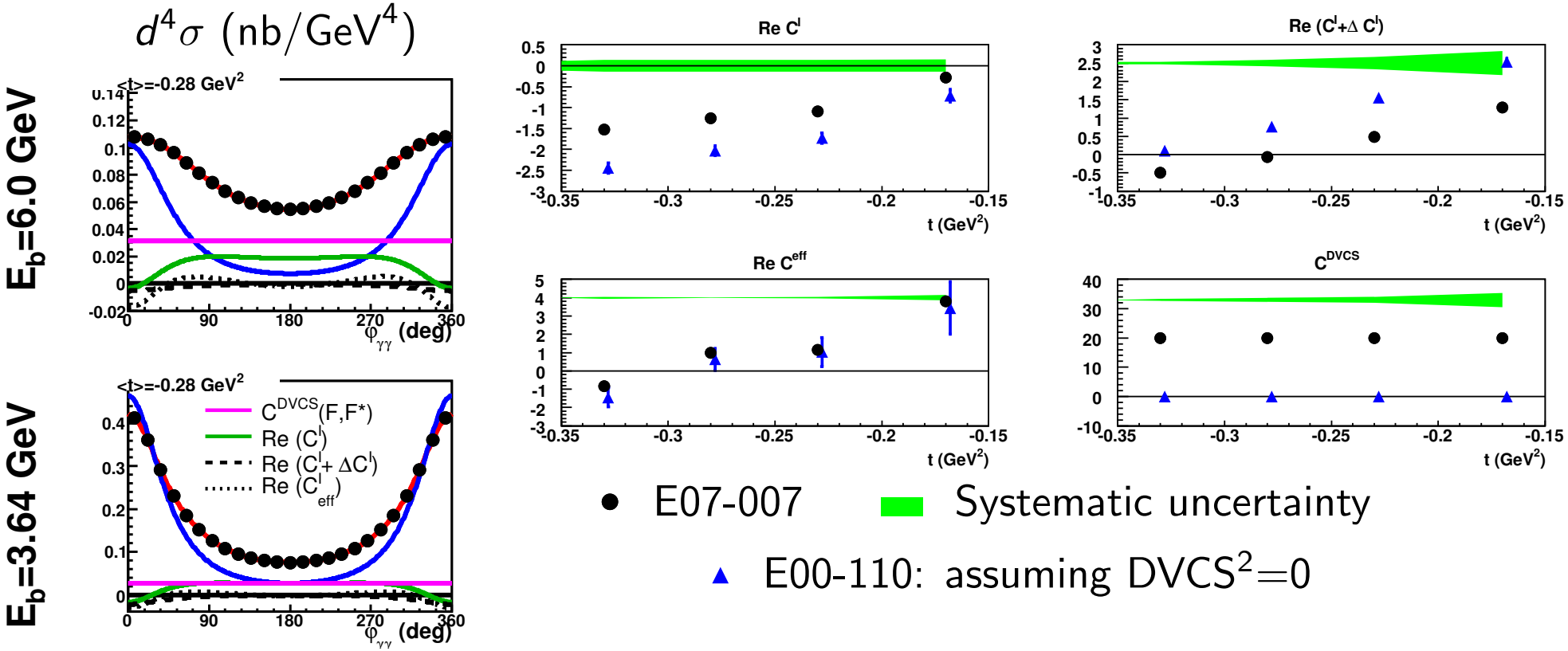
$$|\langle\eta_{0,c1}\rangle|_{E00-110} < 0.05$$

However...

$\langle\eta_{0,c1}\rangle$ depends on the *beam energy*,
which allows a Rosenbluth-like separation of BH·DVCS and DVCS^2

E07-007: Rosenbluth-like DVCS^2–$\mathcal{I}$ separation in Hall A

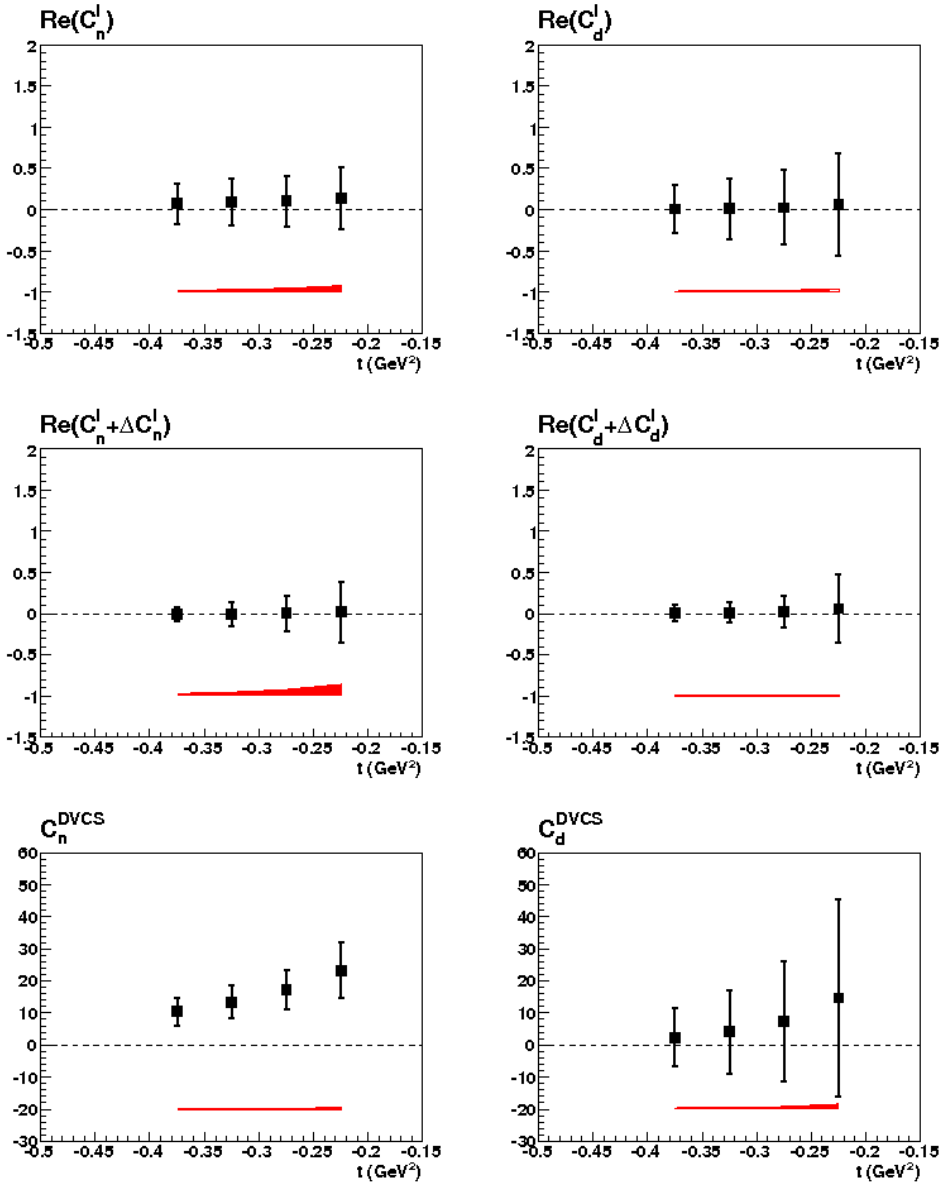
- Clean separation of BH-DVCS intereference term from pure DVCS^2
- Scaling test on the real part of the DVCS amplitude
- Rosenbluth separation of σ_L/σ_T for $ep \to ep\pi^0$



- E07-007 — Systematic uncertainty
- E00-110: assuming DVCS^2=0

Analysis underway. . .

E08-025: DVCS/π^0 Rosenbluth separation on the n/d



E08-025 experiment:

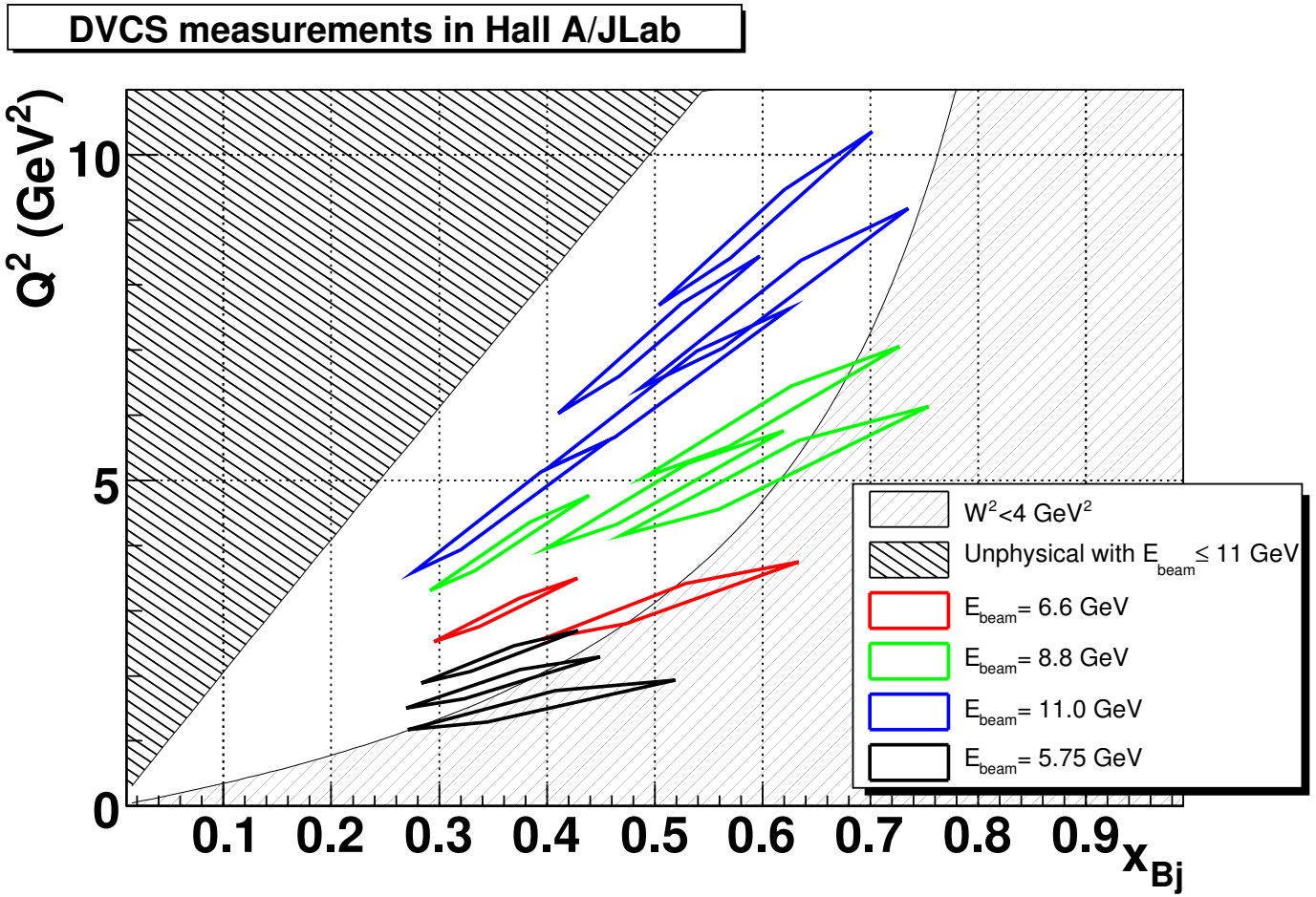
- Unpolarized cross section
- Rosenbluth separation

Ran simultaneously with E07-007 in Fall 2010

E12-06-114: JLab Hall A at 11 GeV

JLab12 with 3, 4, 5 pass beam

(6.6, 8.8, 11.0 GeV beam energy)



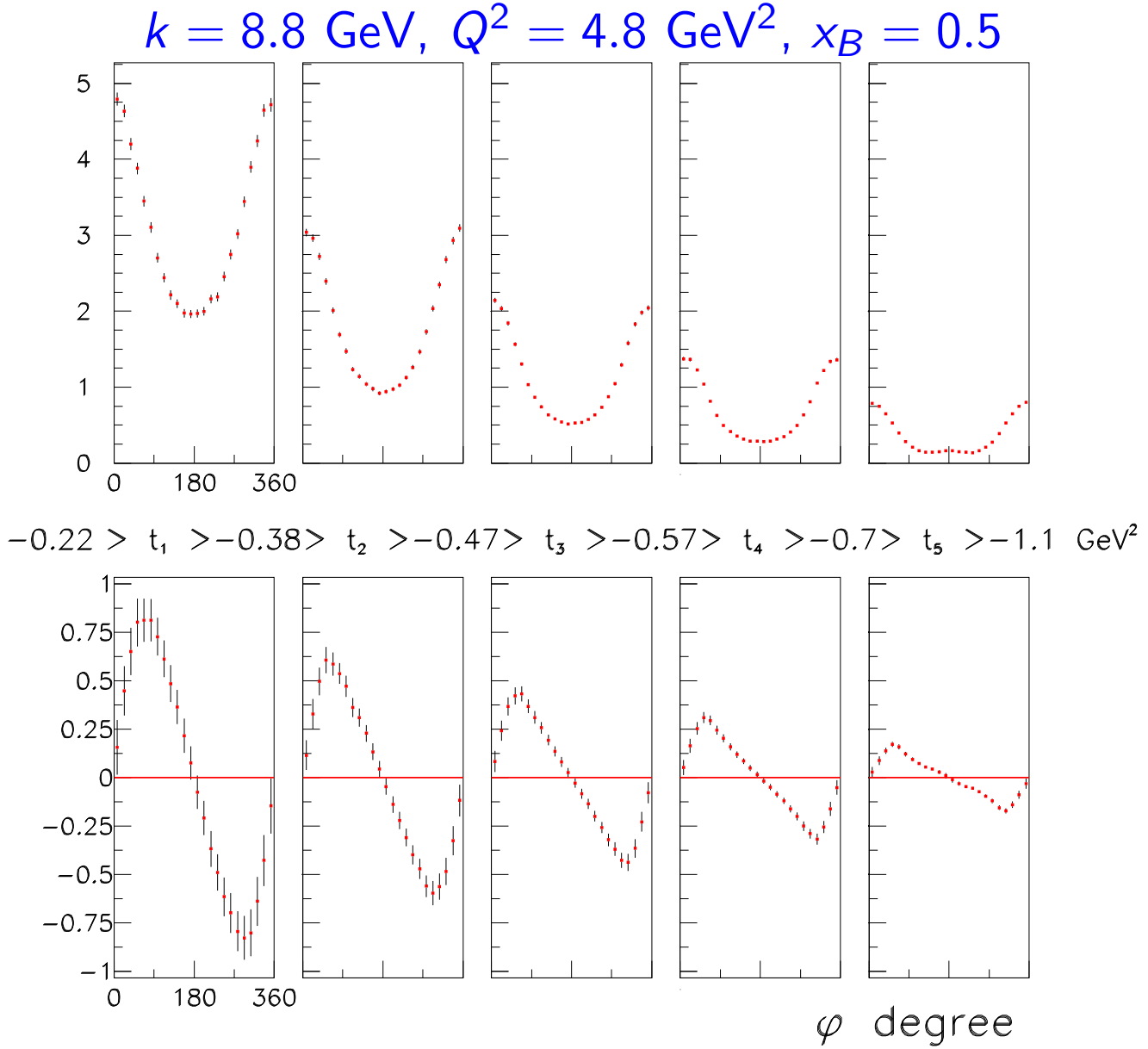
88 days

250k events/setting

1 year of operations in JLab/Hall A

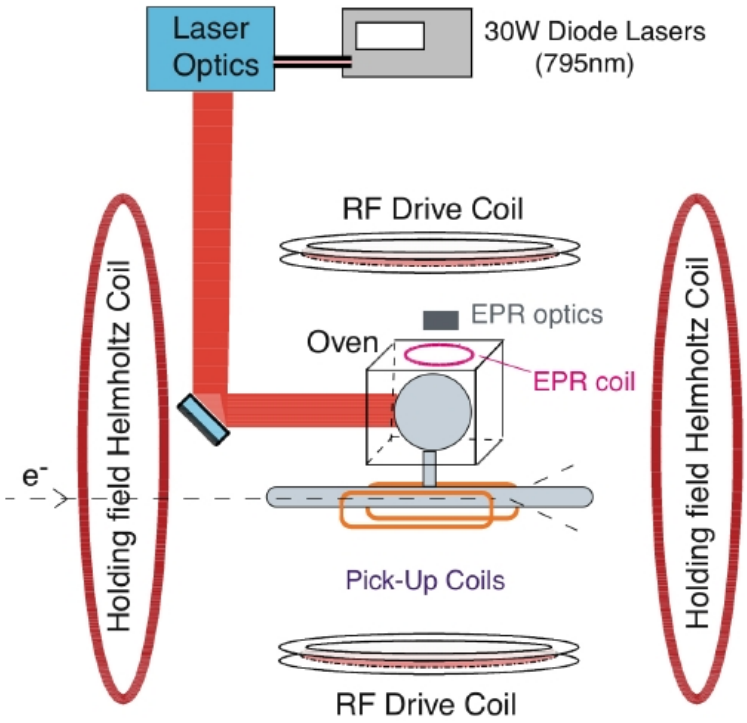
E12-06-114: projections

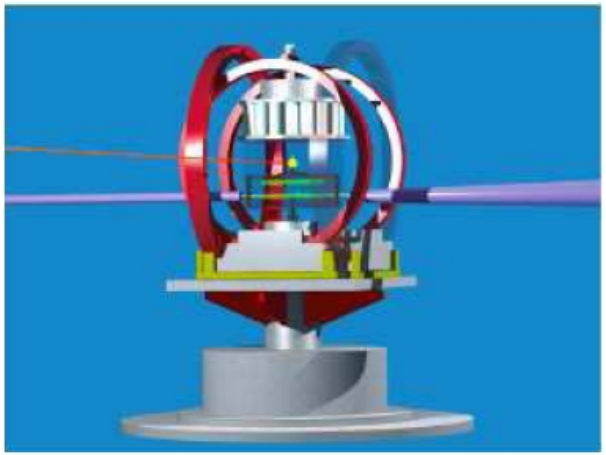
- Helicity-dependent & helicity-independent cross sections (pb/GeV^4)
- 4% systematic uncertainty
- Similar statistical precision depending on kinematics



Polarized ^3He target

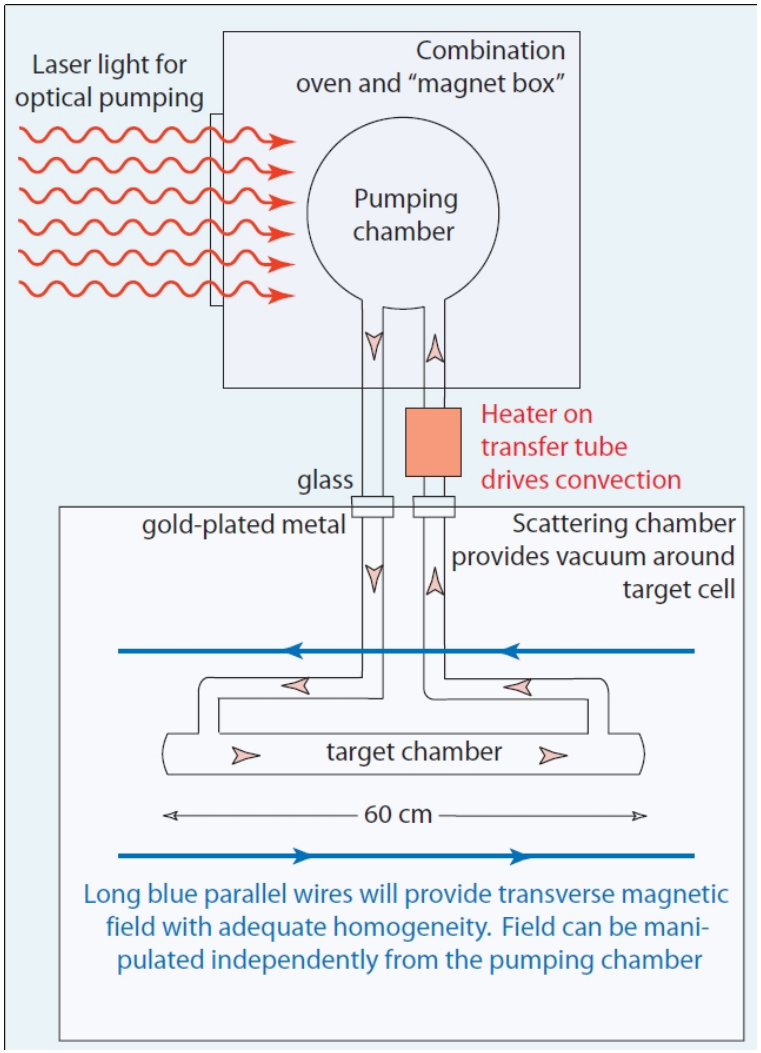
- n lum. of $10^{36}/cm^2/s$ (14 atm$\times$40 cm)
- Background luminosity:
  - p in ^3He + entrance/exit windows
  - $10^{37}/cm^2$ total luminosity
- Polarization: 50%
  - Nuclear physics dilution factor 0.86 (d-state)
  - -2.8% p polarization
  - Long. & Trans.





^{3}He target upgrade

- R&D ongoing for an upgraded target
- Neutron luminosity of $10^{37}/\mathrm{cm}^2/\mathrm{s}$
  - Proton luminosity $2 \cdot 10^{37}/\mathrm{cm}^2/\mathrm{s}$
  - Endcaps $\leq 10^{37}/\mathrm{cm}^2/\mathrm{s}$
- Target polarization: $0.5 \cdot (0.86n - 0.028p)$

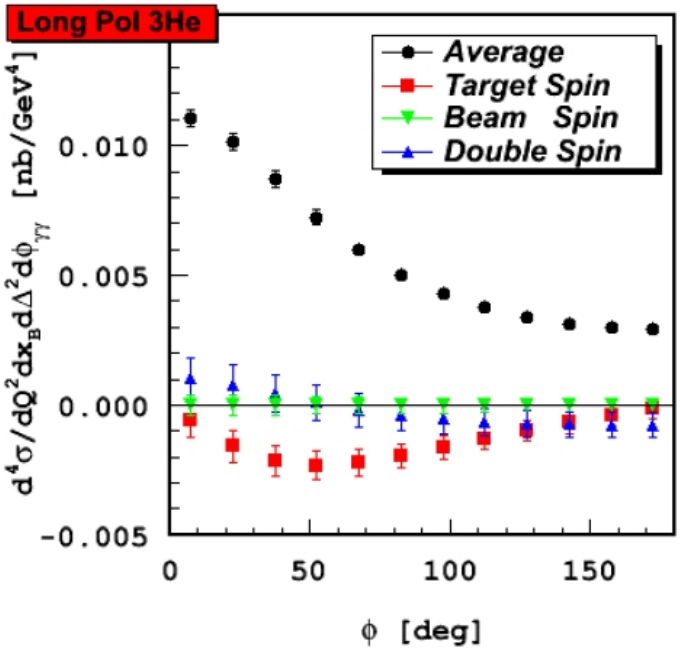


Cross section projections (at 10^{37} cm^{-2}s^{-1})

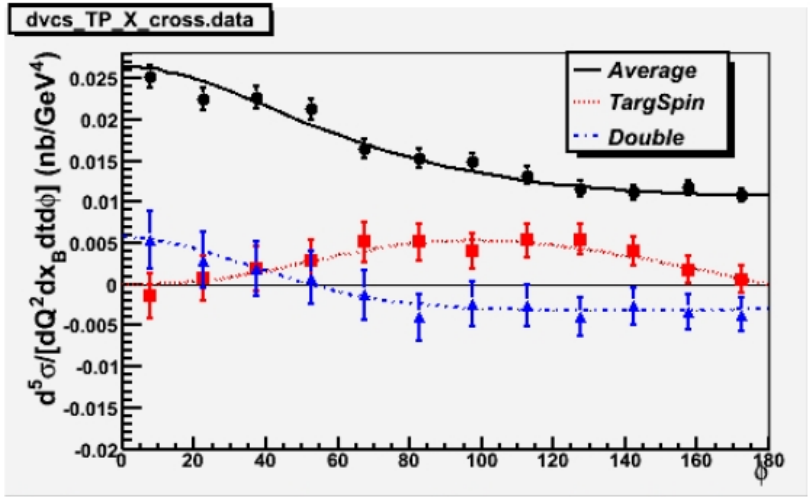
$Q^2 = 2.3$ GeV^2, $x_B = 0.36$, $k = 8.8$ GeV, $t = -0.26$ GeV^2, 10 days

$Q^2 = 4$ GeV^2, $x_B = 0.36$, $k = 8.8$ GeV,

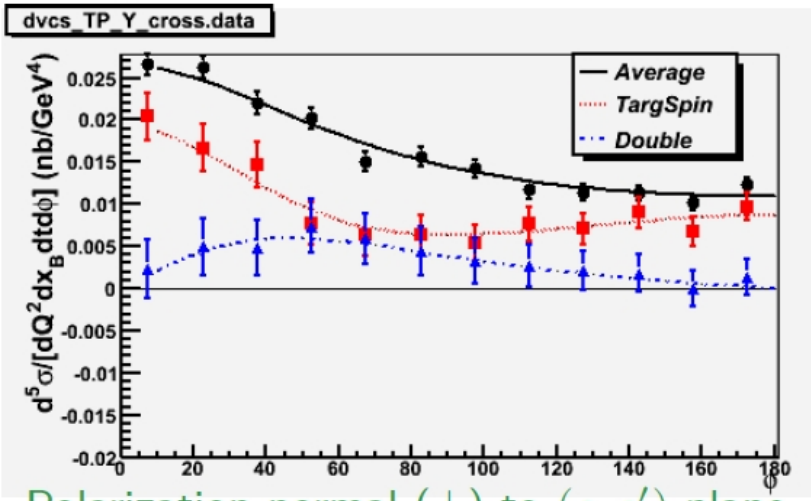
$t_{min} - t = 0.15$ GeV^2, 20 days



- 50%×80% polarization



Polarization sideways ($\|$) to (e, e') plane



Polarization normal ($\perp$) to (e, e') plane

Figures by C. Hyde

Summary and outlook

- Wide program of accurate DVCS cross-section measurements
- Full (Rosenbluth) separation of all terms in the cross-section
- Q^2 dependence of each term ($\rightarrow$ higher twists)

- Ambitious program approved for 12 GeV
- Posibilities of polarized target observables (long. & trans.) with polarized ^{3}He target