DVCS cross section measurements at JLab

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Hard Exclusive Processes at JLab 12 GeV and a Future EIC
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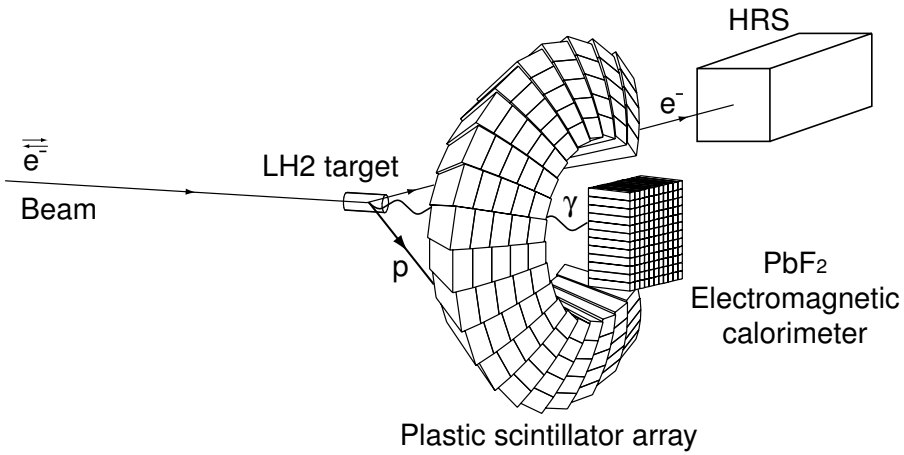
E00-110 kinematics



Kin	Q^2 (GeV^2)	x_B	θ_{γ^*} (deg.)	s (GeV^2)
1	**1.5**	0.36	**22.3**	3.5
2	**1.9**	0.36	**18.3**	4.2
3	**2.3**	0.36	**14.8**	4.9

- Measurement of **both** helicity-dependent and helicity-independent DVCS cross sections independently
- Q^2-dependence of helicity-dependent cross section

Goal:

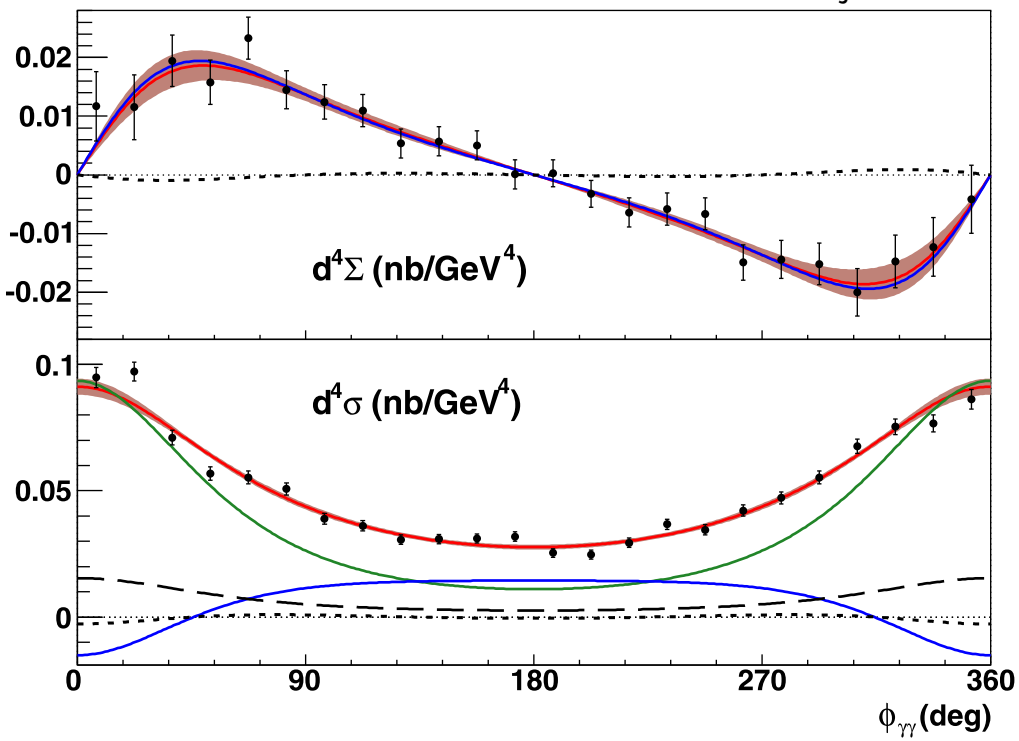
Test **twist-2 dominance** of DVCS at moderate $Q^2 \sim 2$ GeV^2.

. . . and if so, access combinations of **GPDs**.

Helicity-dependent and helicity-independent cross sections

Accurate determination of $\phi_{\gamma\gamma}$ dependence of $d\Sigma = \frac{\sigma^{\rightarrow} - \sigma^{\leftarrow}}{2}$ and $d\sigma = \frac{\sigma^{\rightarrow} + \sigma^{\leftarrow}}{2}$

$Q^2 = 2.3\,\mathrm{GeV}^2$, $\langle t \rangle = -0.28\,\mathrm{GeV}^2$, $x_{\mathrm{Bj}} = 0.36$



— $\Im\mathrm{m}\,\mathcal{C}^{\mathcal{I},\mathrm{exp}}(\mathcal{F})$
..... $\Im\mathrm{m}\,\mathcal{C}^{\mathcal{I}}(\mathcal{F}^{\mathrm{eff}})$
— Total fit

} 1 *free parameter each*

— $\Re\mathrm{e}\,\mathcal{C}^{\mathcal{I},\mathrm{exp}}(\mathcal{F})$
- - - $\Re\mathrm{e}\,[\mathcal{C}^{\mathcal{I}} + \Delta\mathcal{C}^{\mathcal{I}}]^{\mathrm{exp}}(\mathcal{F})$
..... $\Re\mathrm{e}\,\mathcal{C}^{\mathcal{I}}(\mathcal{F}^{\mathrm{eff}})$

} 1 *free parameter each*

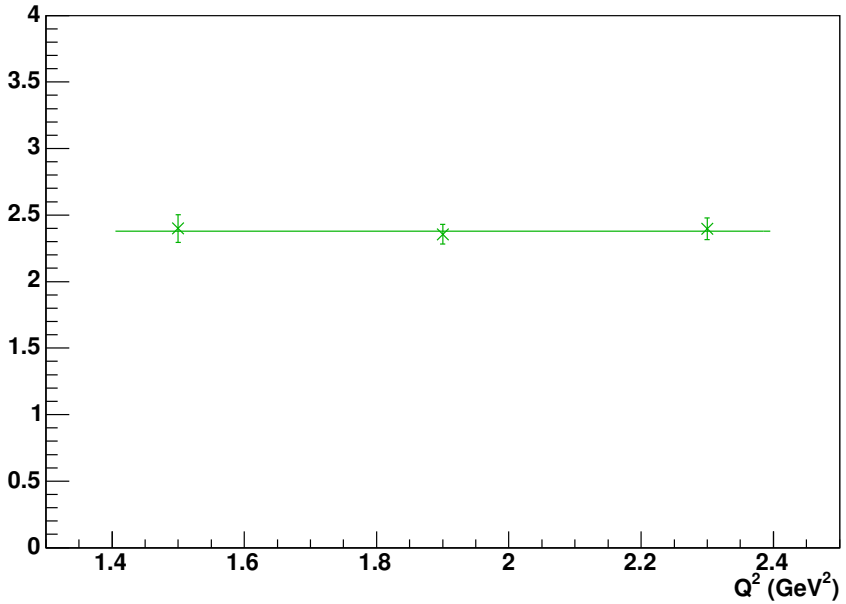
— Bethe-Heitler *fixed*
— Total fit

$d\sigma$: - rich and complex $\phi_{\gamma\gamma}$ structure beyond BH
- interesting & complementary GPD information (real part)

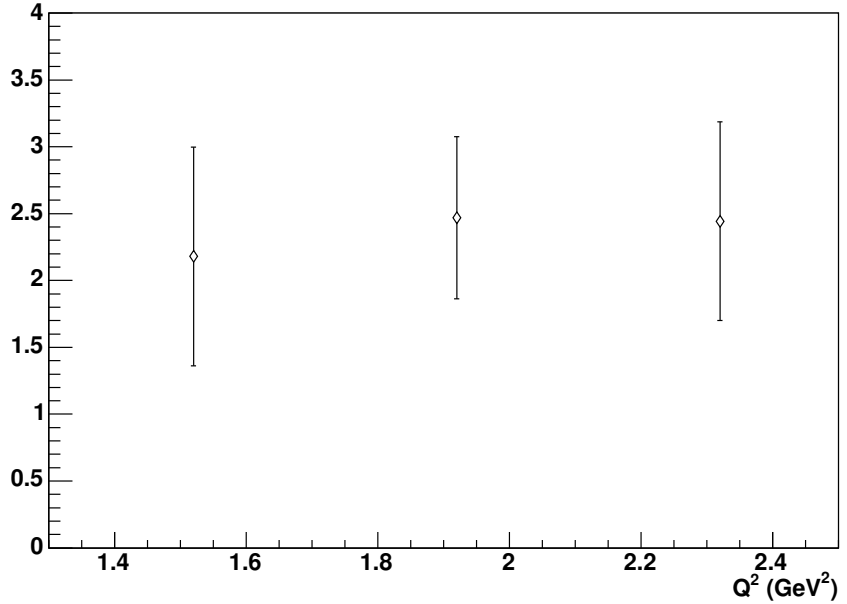
Q^2-dependence: twist-2 dominance

$$0.4 < -t < 0.12 \ (\mathrm{GeV}^2)$$

$\Im\mathrm{m}\,\mathcal{C}^{\mathcal{I}}(\mathcal{F})$

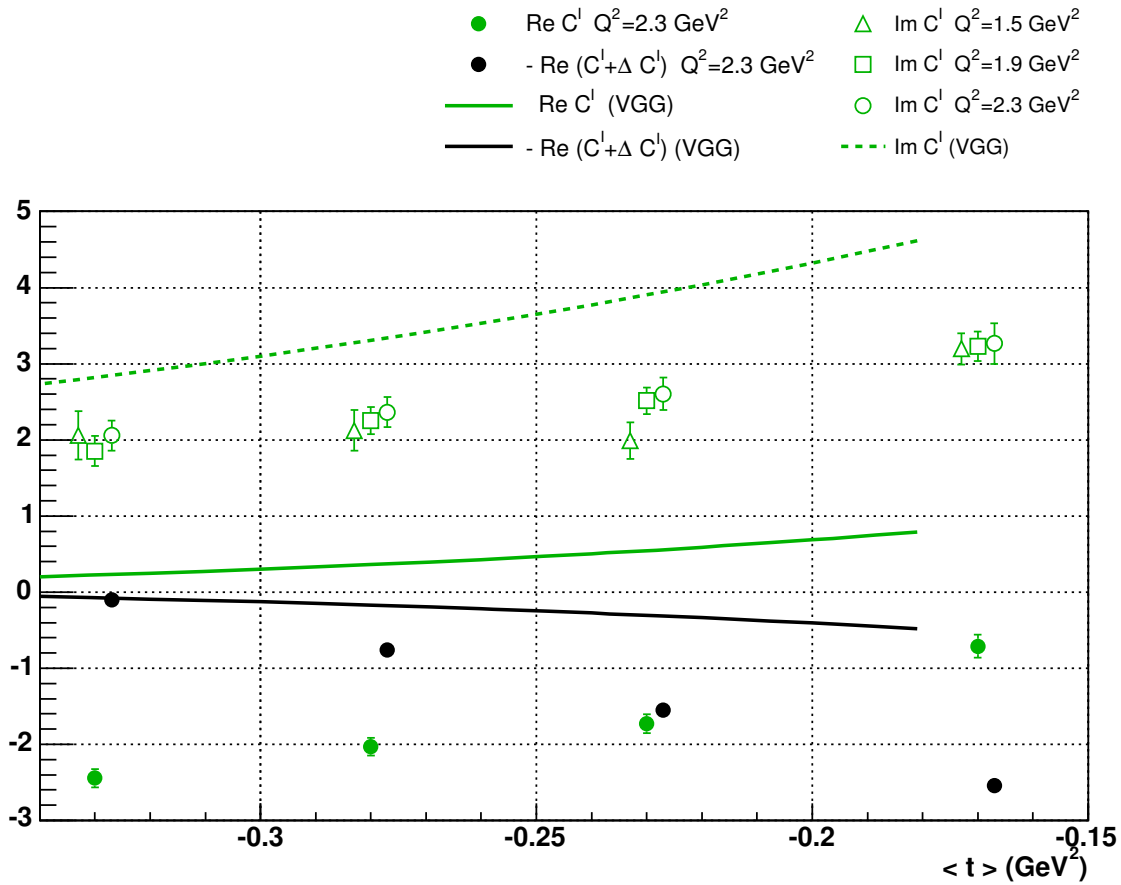


$\Im\mathrm{m}\,\mathcal{C}^{\mathcal{I}}(\mathcal{F}^{\mathrm{eff}})$



- No Q^2-dependence in $\Im\mathrm{m}\,\mathcal{C}^{\mathcal{I}}(\mathcal{F})$ within 3% statistical error bars
- Sets an upper limit for twist-4 and higher $\leq 10\%$

GPD linear combinations and integrals



- Possible (likely) contribution of DVCS^2 terms in these interference results

DVCS^2 contribution

1.- Helicity-correlated cross section: $\Im$maginary part

$$\frac{d^5\Sigma}{d^5\Phi} = \frac{1}{2}\left[\frac{d^5\sigma^+}{d^5\Phi} - \frac{d^5\sigma^-}{d^5\Phi}\right] =$$

$$\underbrace{\sin(\phi_{\gamma\gamma})\Gamma_1^{\Im}\,\Im\mathrm{m}\left[\mathcal{C}^I(\mathcal{F})\right] - \sin(2\phi_{\gamma\gamma})\Gamma_2^{\Im}\,\Im\mathrm{m}\left[\mathcal{C}^I(\mathcal{F}^{\mathrm{eff}})\right]}_{\text{Interference BH-DVCS}} + \underbrace{\sin(\phi_{\gamma\gamma})\Gamma_1^{\Im}\eta_{s1}\,\Im\mathrm{m}\left[\mathcal{C}^{\mathrm{DVCS}}(\mathcal{F}^{\mathrm{eff}},\mathcal{F}^*)\right]}_{|\mathrm{DVCS}|^2\ \text{(twist-3)}}$$

- Different $\phi_{\gamma\gamma}$ dependence of Twist-2 & Twist-3 interference terms:
  $\Rightarrow$ *independent determination*
- $\sin\phi_{\gamma\gamma}\Gamma_1^{\Im}$ term determines observable $\Im\mathrm{m}\left[\mathcal{C}^{I,\mathrm{exp}}(\mathcal{F})\right]$:

$$\Im\mathrm{m}\left[\mathcal{C}^{I,\mathrm{exp}}(\mathcal{F})\right] = \Im\mathrm{m}\left[\mathcal{C}^{I}(\mathcal{F})\right] + \langle\eta_{s1}\rangle\,\Im\mathrm{m}\left[\mathcal{C}^{\mathrm{DVCS}}(\mathcal{F}^{\mathrm{eff}},\mathcal{F}^*)\right] \qquad |\langle\eta_{s1}\rangle|_{E00-110} < 0.01$$

DVCS^2 contribution

2.- Helicity-independent cross section: $\Re$eal part

$$\frac{d^5\sigma}{d^5\Phi} = \frac{1}{2}\left[\frac{d^5\sigma^+}{d^5\Phi} + \frac{d^5\sigma^-}{d^5\Phi}\right] = \underbrace{\frac{d^5\sigma(|BH|^2)}{d^5\Phi}}_{\text{Known from FF}} + \underbrace{\Gamma\,\eta\,\mathcal{C}^{\text{DVCS}}(\mathcal{F},\mathcal{F}^*)}_{|\text{DVCS}|^2\ \text{(twist-2)}} +$$

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

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

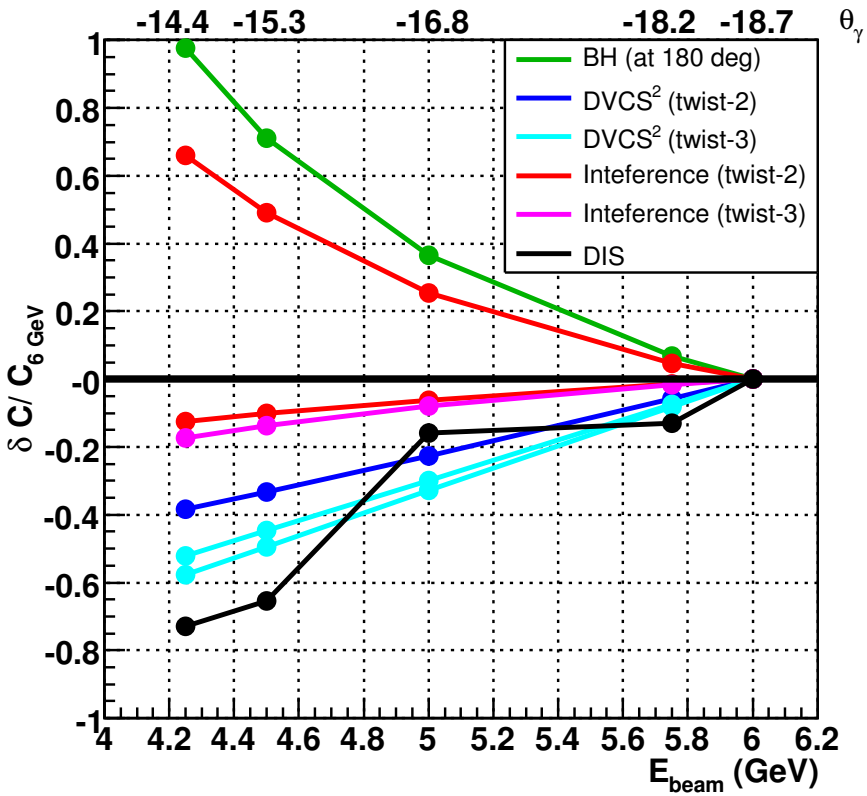
$$|\langle\eta_{0,c1}\rangle|_{E00-110} < 0.05$$

η_{c1} and η_0 depend on beam energy ! $\Longrightarrow$

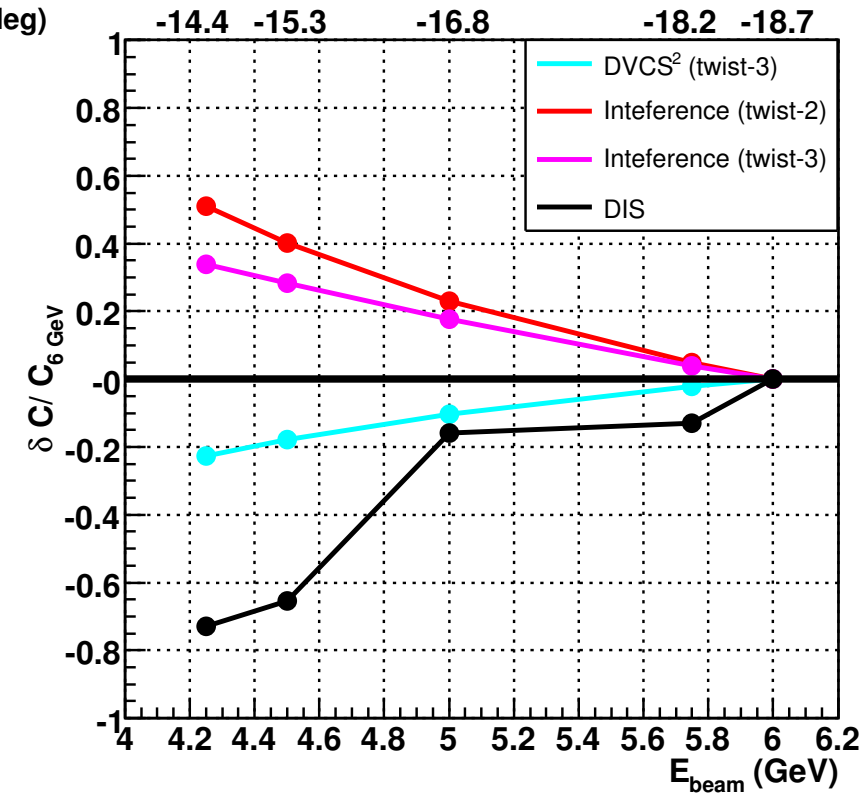
DVCS^2: proposed separation (with JLab 6 GeV!)

$$Q^2 = 1.9\,\text{GeV}^2,\ x_B = 0.36,\ s = 4.9\ \text{GeV}^2$$

Unpolarized cross section



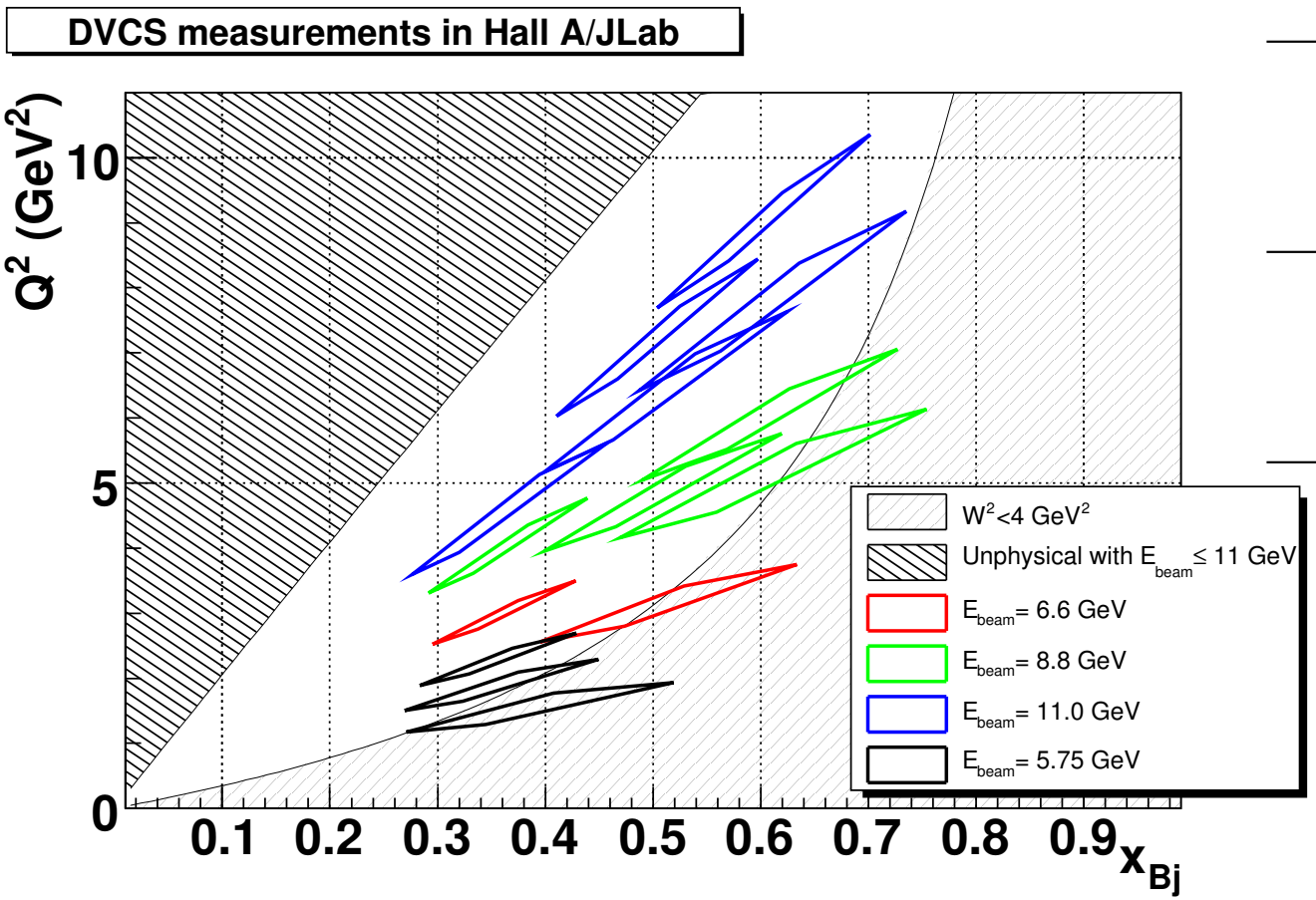
Helicity-dependent cross section



Possible DVCS^2 separation by changing beam energy

Kinematic coverage

JLab12 with 3, 4, 5 pass beam
(6.6, 8.8, 11.0 GeV beam energy)

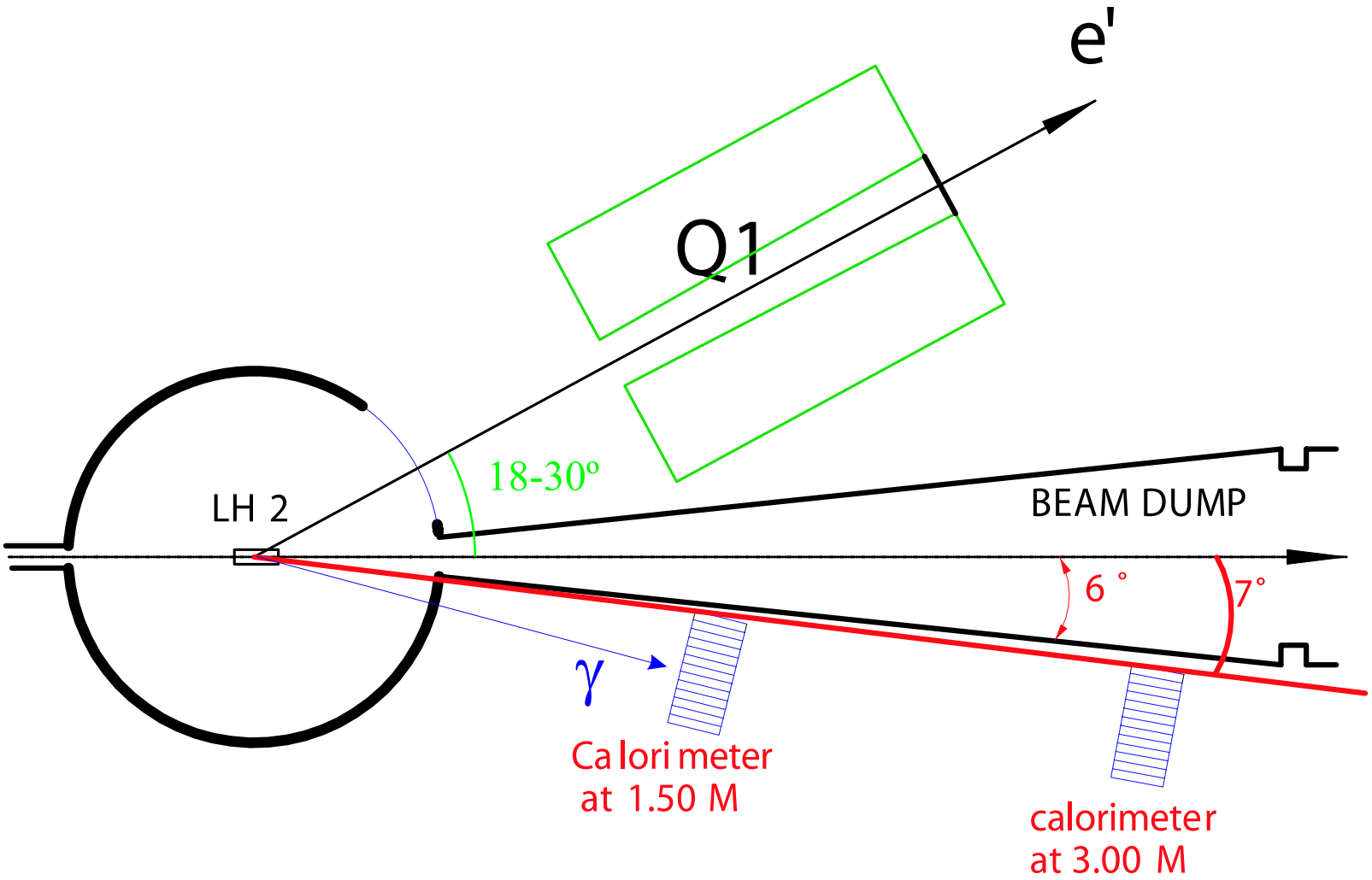


	Beam time (days)		
Q^2 (GeV^2)	$x_{\rm Bj}$ 0.36	0.50	0.60
3.0	3		
4.0	2		
4.55	1		
3.1		5	
4.8		4	
6.3		4	
7.2		7	
5.1			13
6.0			16
7.7			13
9.0			20
Total	6	20	62

1 GeV^2 range in $t_{min} - t$

88 days
250k events/setting

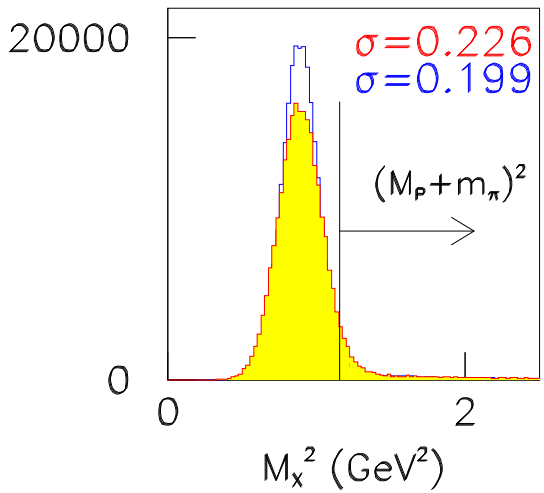
Experimental configuration ($e\,p \rightarrow e\,\gamma\,X$)



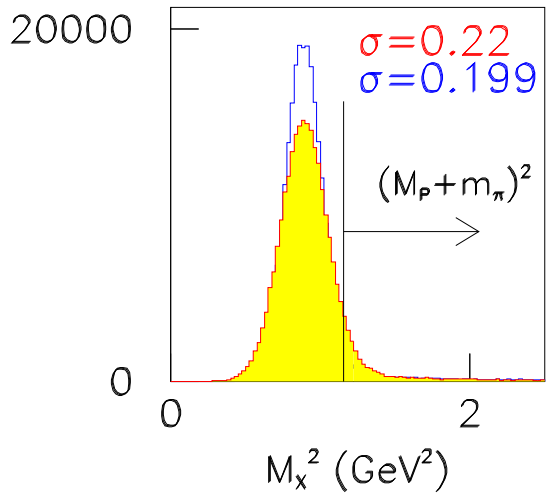
Missing mass resolution

(Cf. Table V for all kinematic settings)

6.6 GeV setting



11 GeV setting



E00-110 **This proposal**

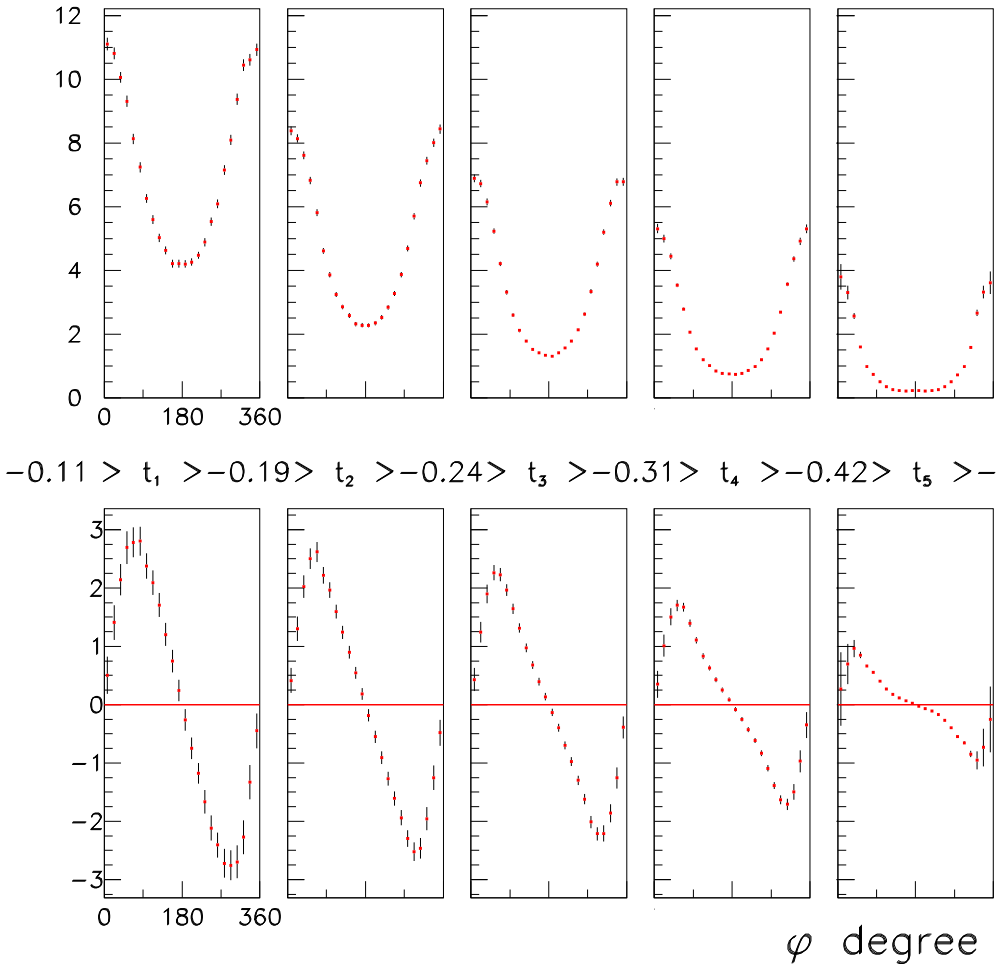
Very similar M_X^2 resolution $\Rightarrow$ same exclusivity with $e\,\gamma$ *detection only*.

Cross sections

- Model by Vanderhaeghen, Guichon & Guidal (VGG), with factorized $t-$dependence
- 250k events/setting or 40k events per $t-$bin
- Similar statistical accuracy as E00-110

Helicity-independent cross sections (pb/GeV^4)

6.6 GeV setting $Q^2 = 3.0\,\mathrm{GeV}^2$, $x_{\mathrm{Bj}} = 0.36$

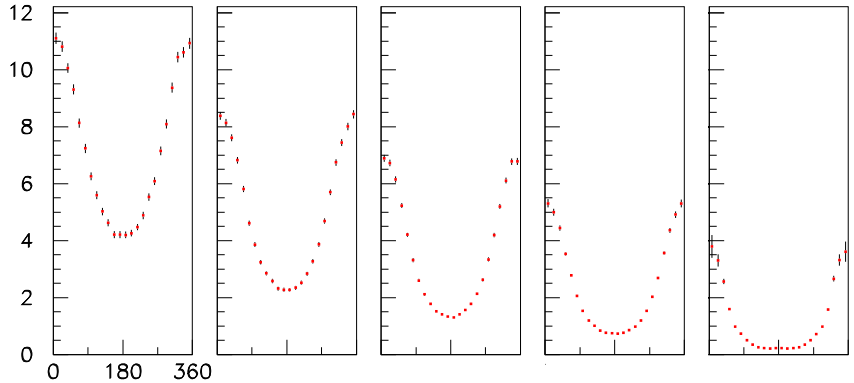


Helicity-dependent cross sections (pb/GeV^4)

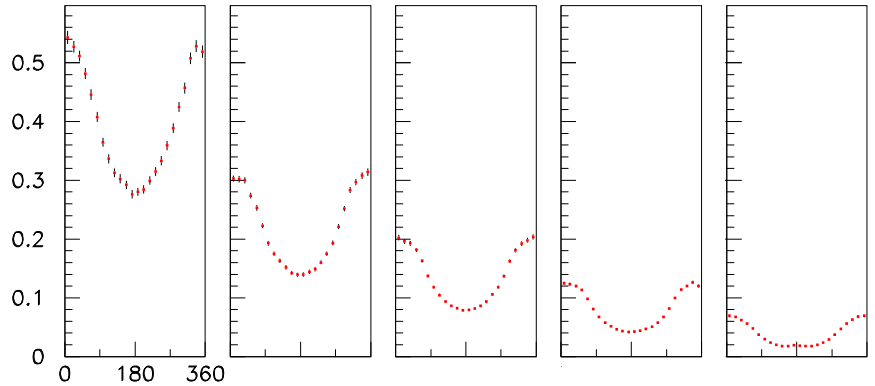
Cross sections

Helicity-independent cross sections (pb/GeV^4)

8.8 GeV setting $Q^2 = 4.8\,\mathrm{GeV}^2$, $x_{\mathrm{Bj}} = 0.50$

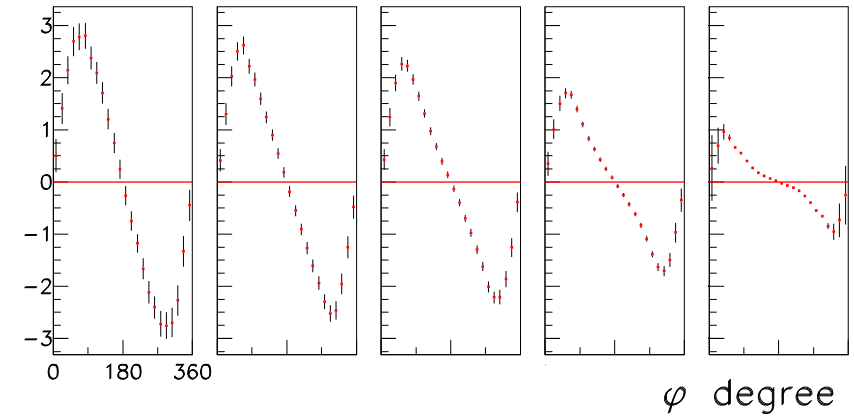


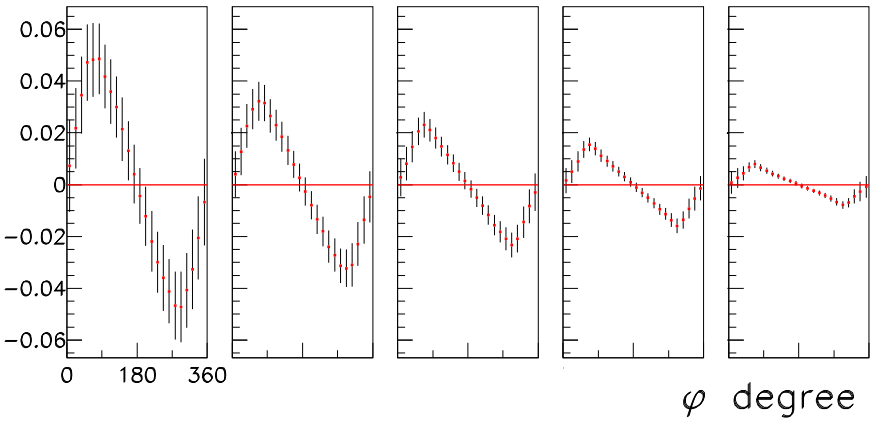
11 GeV setting $Q^2 = 9.0\,\mathrm{GeV}^2$, $x_{\mathrm{Bj}} = 0.60$



$-0.11 > t_1 > -0.19 > t_2 > -0.24 > t_3 > -0.31 > t_4 > -0.42 > t_5 > -1$ GeV^2

$-0.4 > t_1 > -0.67 > t_2 > -0.8 > t_3 > -0.93 > t_4 > -1.14 > t_5 > -1.6$ GeV^2





Helicity-dependent cross sections (pb/GeV^4)

Systematic errors

Type		Relative errors (%)	
		E00-110	proposed
Luminosity	target length and beam charge	1	1
HRS-Calorimeter	Drift chamber multi-tracks	1.5	1
	Acceptance	2	2
	Trigger dead-time	0.1	0.1
DVCS selection	π^0 subtraction	3	1
	e(p,e'γ)πN contamination	2	3
	radiative corrections	2	1
Total cross section sum		4.9	4.1
Beam	Polarization $\Delta P/P$	2	1
Total cross section difference		5.3	4.2