Future DVCS experiments in Hall A/Jefferson Lab

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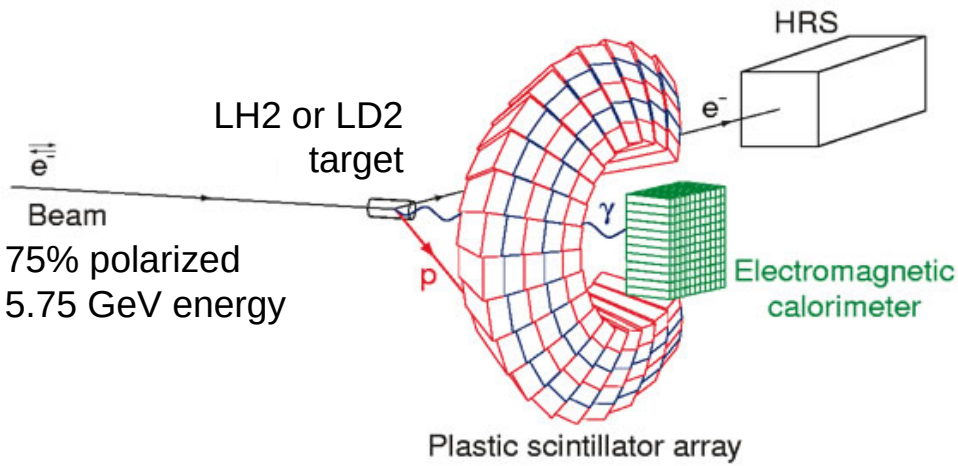
For the DVCS/Hall A collaboration

Measuring $\vec{e}p \to ep\gamma$ and $ep \to ep\pi^0$ cross-sections

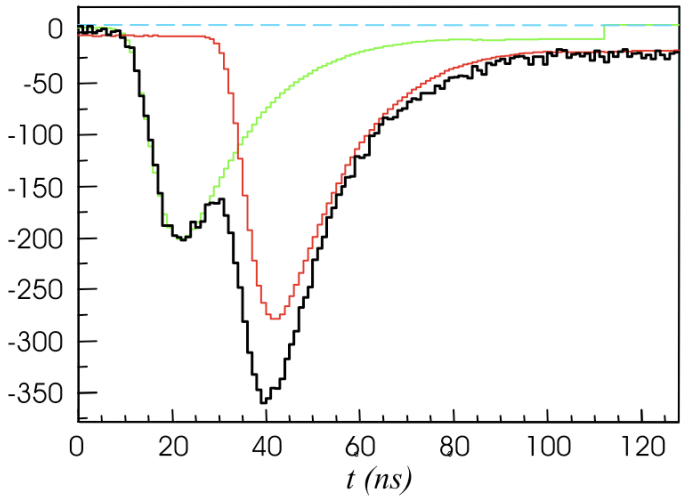
- E07-007: to completely separate (amplitude) observables

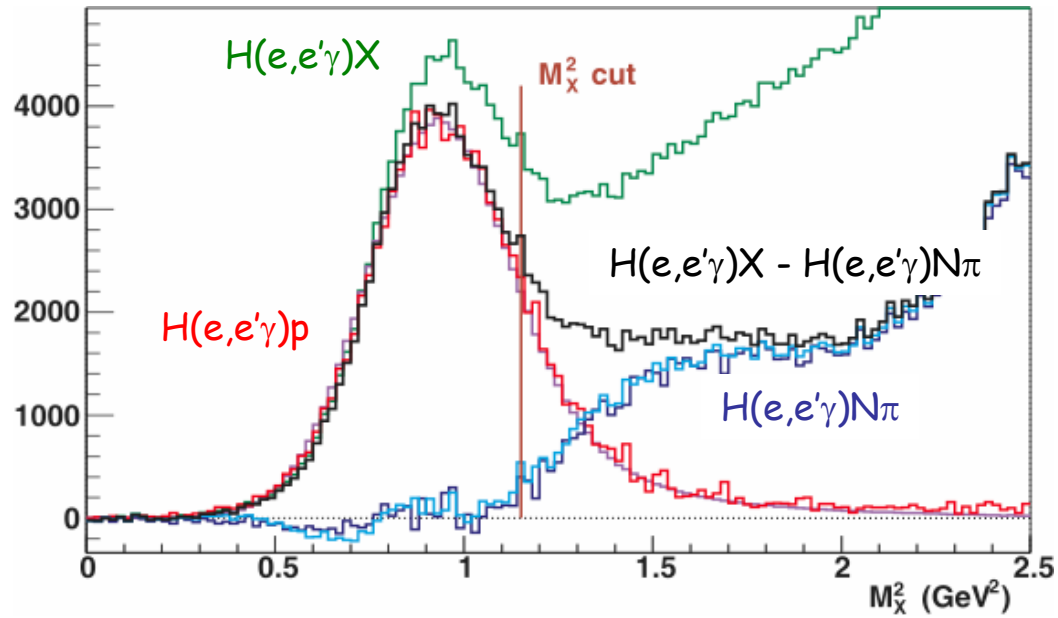
- E12-06-114: large x_{Bj}, Q^2 and t coverage taking advantage of the CEBAF 11 GeV beam

DVCS experiments in Hall A so far: E00-110 and E03-106



Analog Ring Samplers digitalize the calorimeter and proton array signals at 1 GHz





Simple and compact assembly: good control of the solid angle

Critical assessment of E00-110

✓ The ARS are efficient to identify signals at high luminosity.

L_{LD2} (per nucleon): 4 10^{37} $cm^{-2}s^{-1}$ at 1 m from the target

✓ The proton array is not necessary (see missing mass spectra)

- Can reach smaller t
- The cross section increases as t decreases

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o Poor π^0 statistic at low Q^2

the pion energy decreases as Q^2decreases

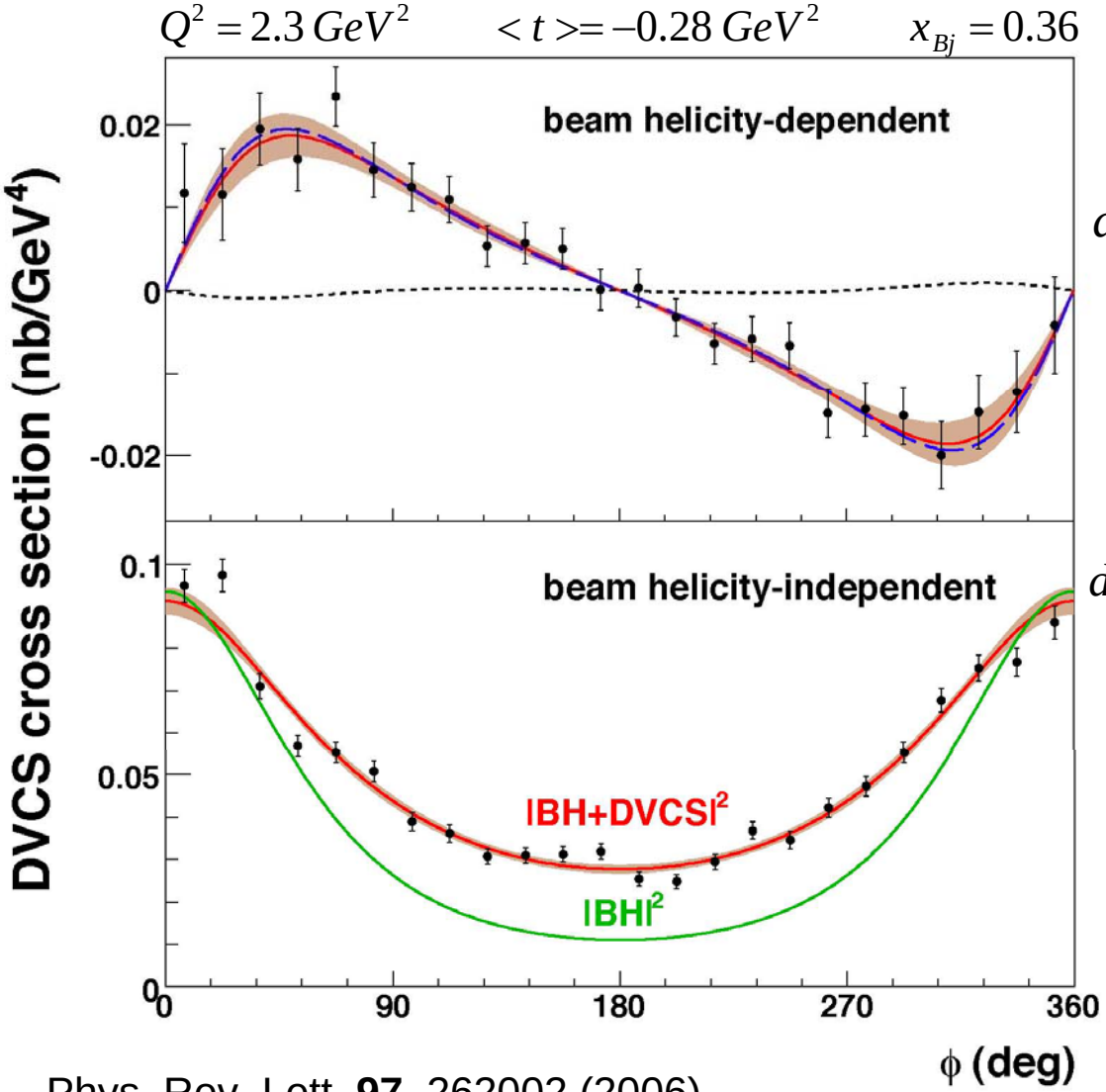
- Lower the threshold for trigger
- Improve live time and bandwidth for the DAQ

o Transmission through the calorimeter blocks degrades with radiation

to perform longer experiments needs to "reset" blocks regularly

- Implement a near UV curing method a la PVA4-MAMI

DVCS cross-sections from E00-110



$$d^4\Sigma = \frac{1}{2}\frac{d^4\vec{\sigma} - d^4\overleftarrow{\sigma}}{dx_{Bj}dQ^2dtd\phi}$$

$$\propto BH \bullet \Im(DVCS) + \Im(DVCS^2)$$

$$d^4\sigma = \frac{1}{2}\frac{d^4\vec{\sigma} + d^4\overleftarrow{\sigma}}{dx_{Bj}dQ^2dtd\phi}$$

$$\propto \left|BH + DVCS\right|^2$$

$$\propto \left|BH\right|^2 + BH \bullet \Re(DVCS) + \Re(DVCS^2)$$

$$\left|BH + DVCS\right|^2 \approx 2\left|BH\right|^2$$

$$\Rightarrow \Re\left(DVCS^2\right) negligible?$$

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E07-007: Complete separation of the (amplitude) observables.

Belitsky, Mueller, Kirchner, Nucl. Phys. B629,323(2002)

Known from FF |DVCS|² (twist-2)

$$d^4\sigma = d^4\sigma\left(\left|BH\right|^2\right) + \Gamma\,\eta C^{DVCS}$$

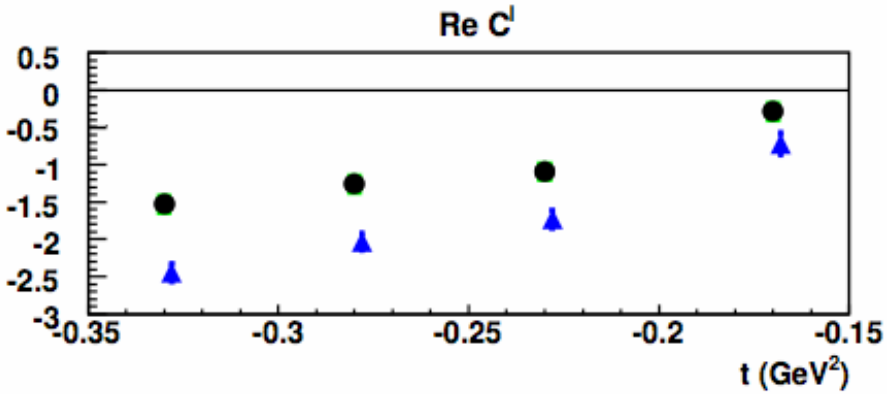
$$+ \underbrace{\frac{\left(\Gamma_0^{\Re} - \cos\phi\right)\Re e\left(C^I\right) + \Gamma_{0,\Delta}^{\Re}\,\Re e\left(C^I + \Delta C^I\right) + \cos 2\phi\,\Gamma_2^{\Re}\,\Re e\left(C_{eff}^I\right)}{1 + \cos\phi + \cos 2\phi}}_{\text{Interference BH-DVCS}}$$

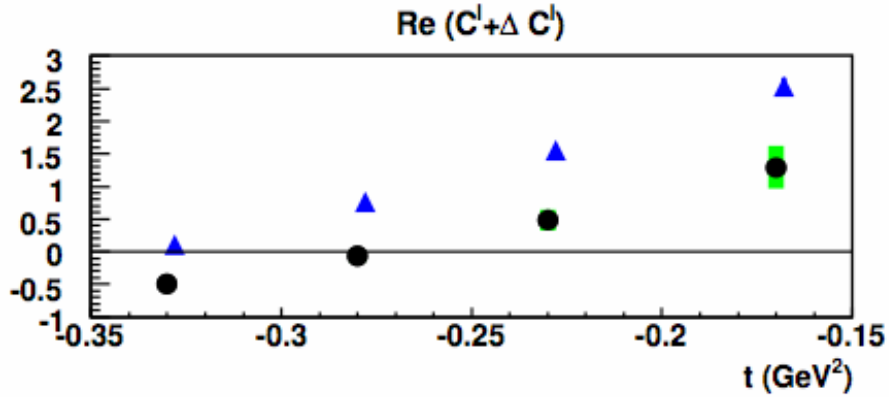
- $\Re e\left(C^I\right)$ and $\Re e\left(C^I + \Delta C^I\right)$ MIX with C^{DVCS} in the azimuthal analysis
- Kinematic coefficients depend on the beam energy which allows a Rosenbluth-like separation of the BH-DVCS and DVCS²

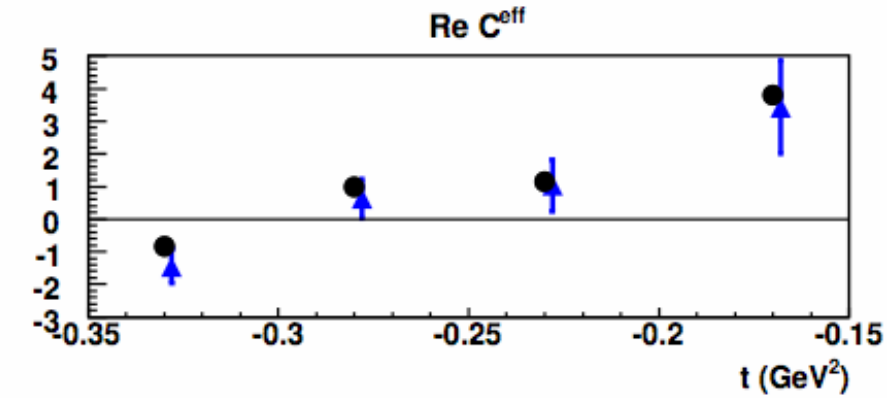
- Goal 1: measure the total cross section $d^4\sigma$ using two beam energies to separate C^{DVCS} from $Re(C^i)$ and $Re(C^i+\Delta C^i)$ at fixed x_{Bj}=0.36 for three Q^2=2.3, 1.9 and 1.5 GeV². E_{beam} ranging from 3.5 to 6 GeV

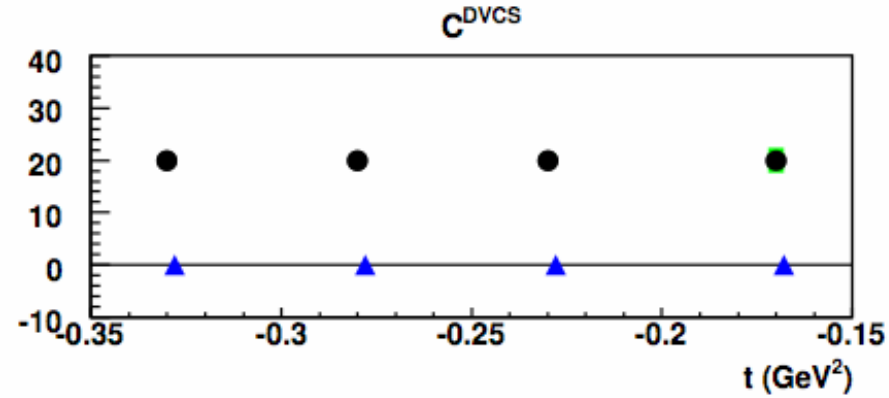
E07-007: projected results for the DVCS^2 and interference separation

Projected results at Q^2=1.5 GeV^2 using simulated cross sections at 2 beam energies









- Analyzing the data without extracting C^{DVCS}

- Analyzing the data and supposing C^{DVCS}=0

E07-007: other physics reaches

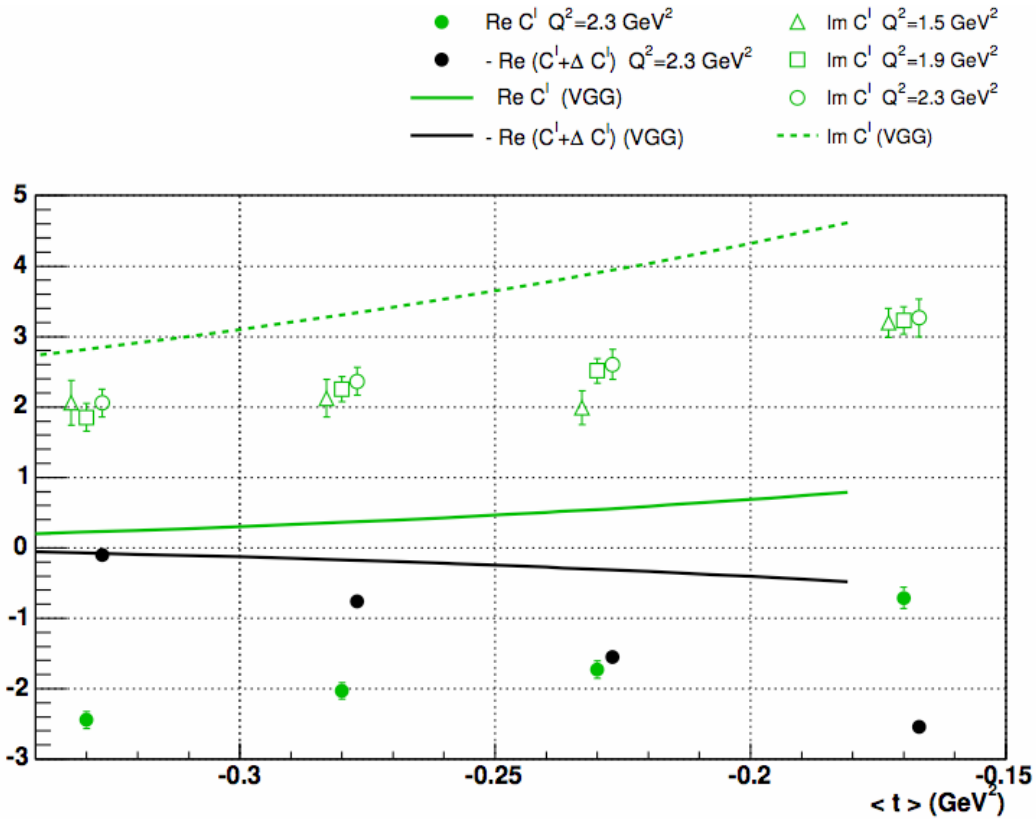
- Measure the ep->epγ cross-section ($d^4\sigma$) at Q^2=2.3, 1.9, 1.5 GeV^2
  - Need to improve the π^0 subtraction scheme
  - Will provide a test of the scaling with unpolarized cross-section

  (E00-110 provided (strong) evidence for scaling with polarized cross-section)

- Measure the 5 response functions of deep ep->epπ^0 at Q^2=2.3, 1.9, 1.5 GeV^2
  - Separate σ_{LT}, σ_{TT} , $\sigma_{LT'}$ from $\sigma_L+\varepsilon\,\sigma_T$ by azimuthal variation and σ_L from σ_T by Rosenbluth method
  - First test of factorization in this deep meson production channel
  - If scaling is observed can extract flavor information on GPDs

Experiment approved by the JLab PAC in January 2007
to receive polarized beam at E_{beam}>5.75GeV

E00-110 results in term of GPDs linear combinations



- for this analysis, $|DVCS|^2$ is neglected
- t-distribution at one x_{Bj}=0.36
- Q^2 dependence only for the Im. part

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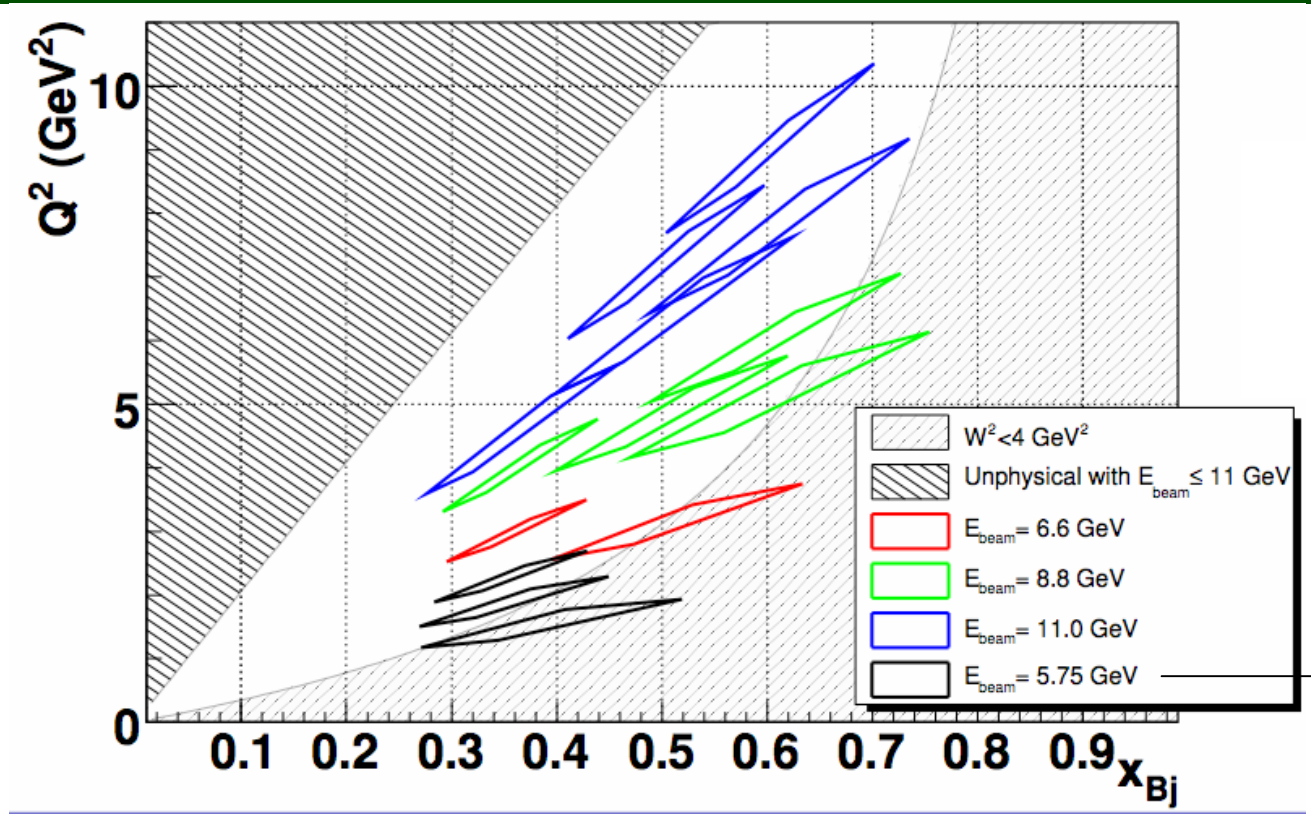
Post 12 GeV upgrade to Cebaf

- Wider range in
  $0.36 < x_{Bj} < 0.6$
  $3 < Q^2 < 9$ GeV²
- High statistic t-dependence at each x_{Bj} and Q^2
- Strong test of factorization at each (x_{Bj},t)

E12-06-114: Hall A/CEBAF 12 GeV experiment



Each bin (x_{Bj}, Q^2, t) get the same statistic than in E00-110

Experiment approved by the JLab PAC in 2006

E12-06-114: physics reach

- Q^2 variation:
  - 2:1 range at each x_{Bj}
  - Accurate measurement of the twist-2 dominance
- x_{Bj} variation (dependence):
  - Precision data on variation of t-dependence with x_{Bj}
  - Study of transverse correlations
- t variation:
  - 5 bins in $0 < t\text{-}t_{min} < 1\ GeV^2$
  - Fourier-conjugate to the spatial distributions of quark as a function of their momentum fraction x_{Bj}
- π^0 electro-production cross section:
  - Dominance of twist 2 (isolation of leading twist)
  - Sensitive to nucleon GPDs $\tilde{H}$ and $\tilde{E}$

The future of the DVCS program in Hall A at Jlab

- Two experiments already approved by the Jlab/PAC
  - Building up on the successful experimental technique of E00-110 and E03-106
  - Will measure absolute cross-sections both helicity independent and helicity dependent
  - Will measure both deep photon and deep pion electro-production
  - E07-007 before the 12 GeV upgrade, E12-06-114 after the upgrade

- Physics reach
  - What is the size to the $DVCS^2$ term with respect to the interference term and the BH^2 term?
  - Does the scaling observed in the Imaginary sector hold on the Real sector for photon electro-production? What about the deep pion electro-production?
  - Extended kinematic range for the Compton Form Factor measurement:

$t-t_{min} < 1 GeV^2$ Q^2: 2 to 9 GeV^2 x_{Bj}: 0.36 to 0.6

Backup

Experimental upgrades from E00-110

- Expanded PbF2 calorimeter: 11∗12 + 76 blocks
  - Higher acceptance in π^0 measurements and subtraction
  - Increase t-acceptance: $\Delta(t_{min}-t)=1\ GeV^2$

- Electronics:
  - Upgraded calorimeter trigger system:
    lower threshold to increase π^0 statistics
  - DAQ upgrade to improve livetime and bandwidth

- No proton detection: calorimeter can handle 4∗E00-110 rates

- Flared beam pipe to minimize secondary background in the calorimeter
  Background dominated by Moeller and π^0 decays from target

Calorimeter radiation damage

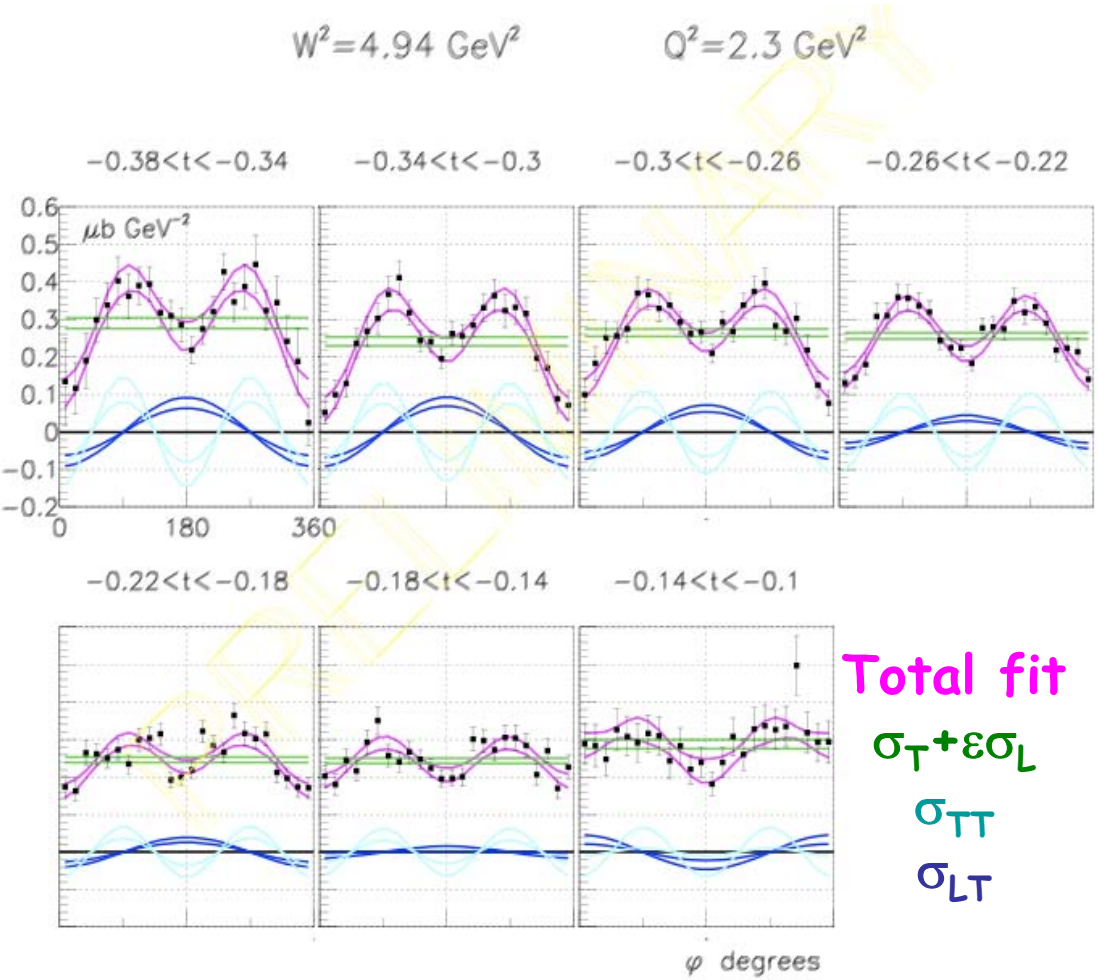
- E00-110 experience
  - Dose estimate by e and π^0 above 15^0 and Moeller below 10^0
  - Dose grows a factor of 5 from 11.5^0 to 7.5^0
  - 20% gain loss without loss in missing mass and energy resolution

- New experiments strategies
  - Minimum angle of the closest block: 7^0
  - Luminosity equal to the peak luminosity in E00-110 taking into account the distance target-calorimeter
  - Blue light curing (MAMI-A4): ~17h to cure a transparency loss of 25%

Curing every ~ 5th day of running at the minimum angle

E00-110: π^0 electroproduction *preliminary* results

$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \varepsilon\frac{d\sigma_L}{dt} + \sqrt{2\varepsilon(1+\varepsilon)}\frac{d\sigma_{LT}}{dt}\cos\phi + \varepsilon\frac{d\sigma_{TT}}{dt}\cos 2\phi + \lambda\sqrt{2\varepsilon(1-\varepsilon)}\frac{d\sigma_{LT'}}{dt}\sin\phi$$

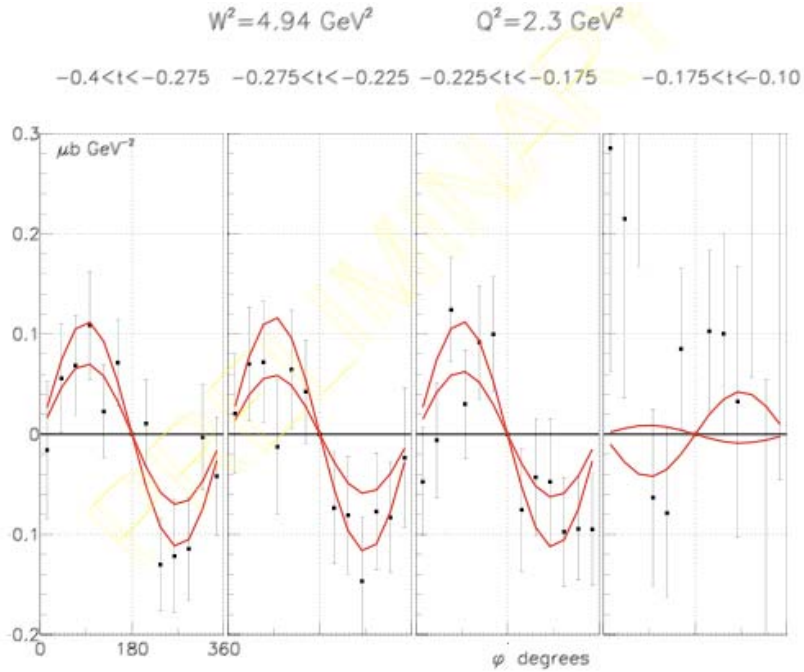


Total fit

$\sigma_T+\varepsilon\sigma_L$

σ_{TT}

σ_{LT}



$\sigma_{LT'}$

E00-110: π^0 electroproduction *preliminary* results

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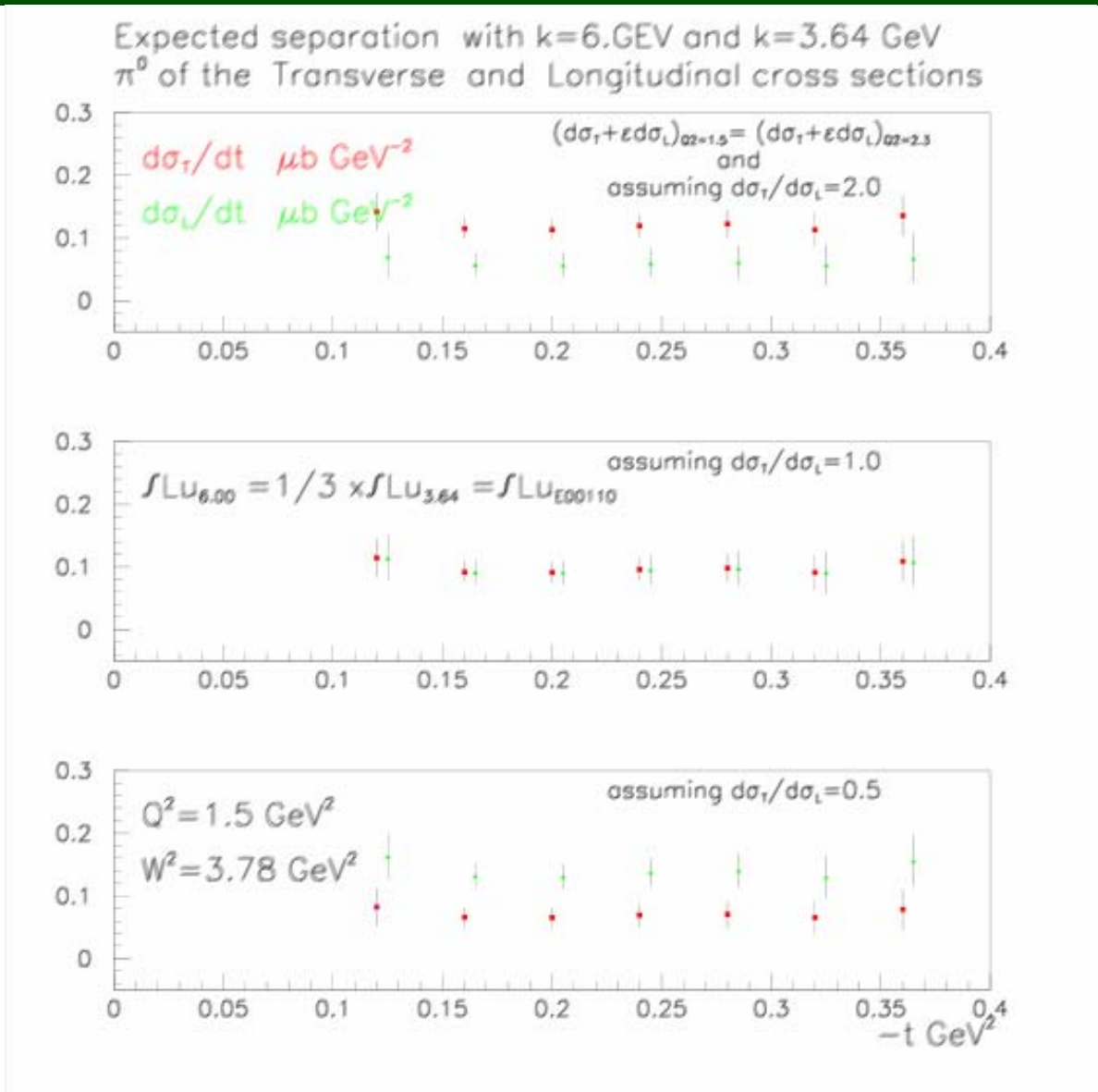
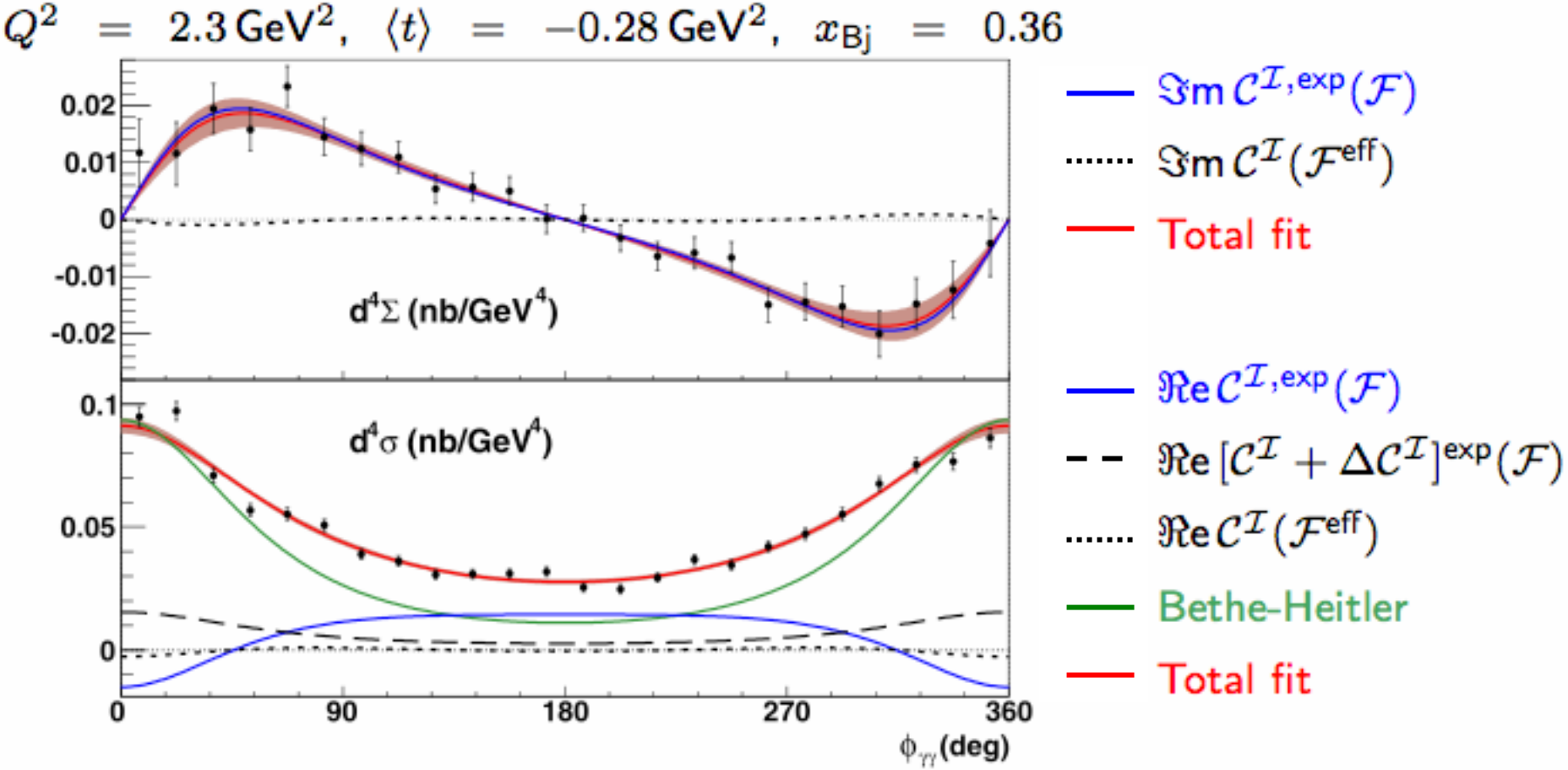
π^0: Expected σ_L Rosenbluth separation at Q^2=1.5 GeV^2



DVCS cross-sections from E00-110

Accurate determination of $\phi_{\gamma\gamma}$ dependence of $d^4\Sigma = \frac{1}{2}\frac{d^4\vec{\sigma} - d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\phi_{\gamma\gamma}}$ and $d^4\sigma = \frac{1}{2}\frac{d^4\vec{\sigma} + d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\phi_{\gamma\gamma}}$



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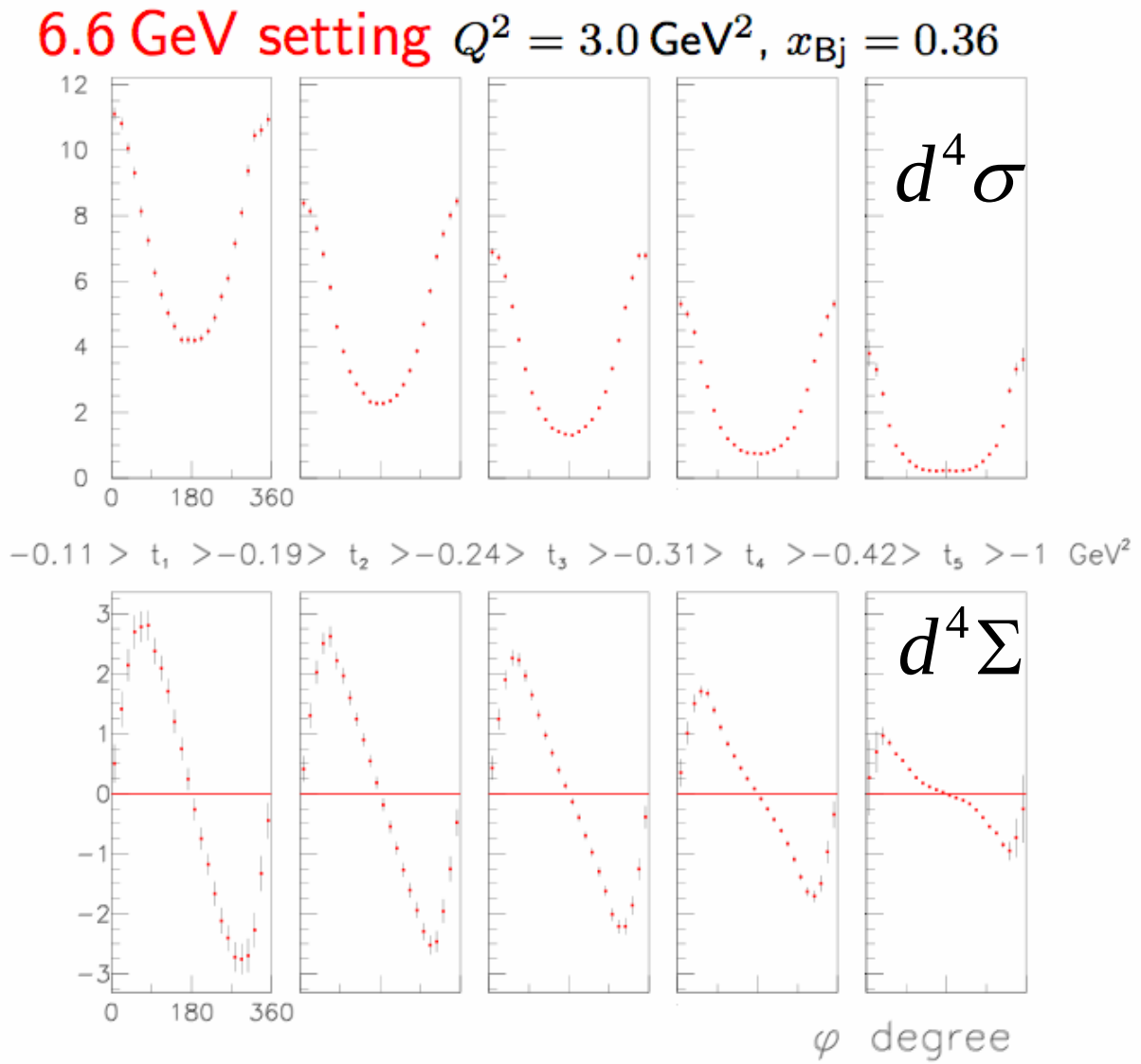
Projected cross-section precision for E12-06-114

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



Systematic uncertainties in cross-sections (E12-06-114)

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