Hall A Collaboration Meeting
9-10 June 2011

Measurements of the Electron-Helicity Dependent Cross Sections of Deeply Virtual Compton Scattering at 12 GeV in Hall A

E12-06-114

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PAC 30 Report

Proposal: PR12 – 06 - 114

Title: Measurements of the Electron–Helicity Dependent Cross Sections of Deeply Virtual Compton Scattering with CEBAF at 11 GeV.

Spokespersons: Charles E. Hyde – Wright, Bernard Michel, Carlos Munoz Camacho, J. Roche

Motivation: Generalized parton distributions (GPDs) are physical observables which can provide deep insight into the internal structure of the nucleon. They contain the usual parton distributions and elastic form factors as their special limits. In addition, the GPDs allow to probe the quark angular momentum and picture the quark motion in the quantum phase space. Deep Virtual Compton scattering is a very clean way to access the GPDs. Previous experiments have established the reliability of the GPD measurements at the JLAB kinematics. The proposal asks for extension of the current Hall A DVCS experiment E00-110 into higher energy, thus considerably expanding its kinematical coverage and using its successful technique. The strong point of the proposed experiment is that, as E00-110, it would measure the absolute (helicity dependent and helicity independent) cross sections which will permit to extract DVCS observables inaccessible in e.g. measurements of the cross section asymmetries.

100 days

Measurement and Feasibility: The experiment requests 100 days of running in Hall A (88 days of production running and 12 interlaced days for optical curing of the calorimeter; no parasitic use of the beam would be possible during the latter days). Only standard Hall A equipment is requested: 15 cm LH2 target, HRS-L, (expanded) PbF2 calorimeter with necessary upgrades. No technical comments were filed.

Issues: GPD measurements are fundamental for a complete description of nucleons in terms of partons and for our understanding of the QCD. This proposal, together with PR12–06–119 and LOI12–06-108 and LOI12–06-109 define the full programme of the DVCS/GPD measurements at JLAB at 11 GeV. In view of the limited statistics of the future HERMES and COMPASS DVCS data at high x, the planned measurements will be the only ones – and very accurate - in that kinematic region.

Recommendation: Approval

DVCS goals

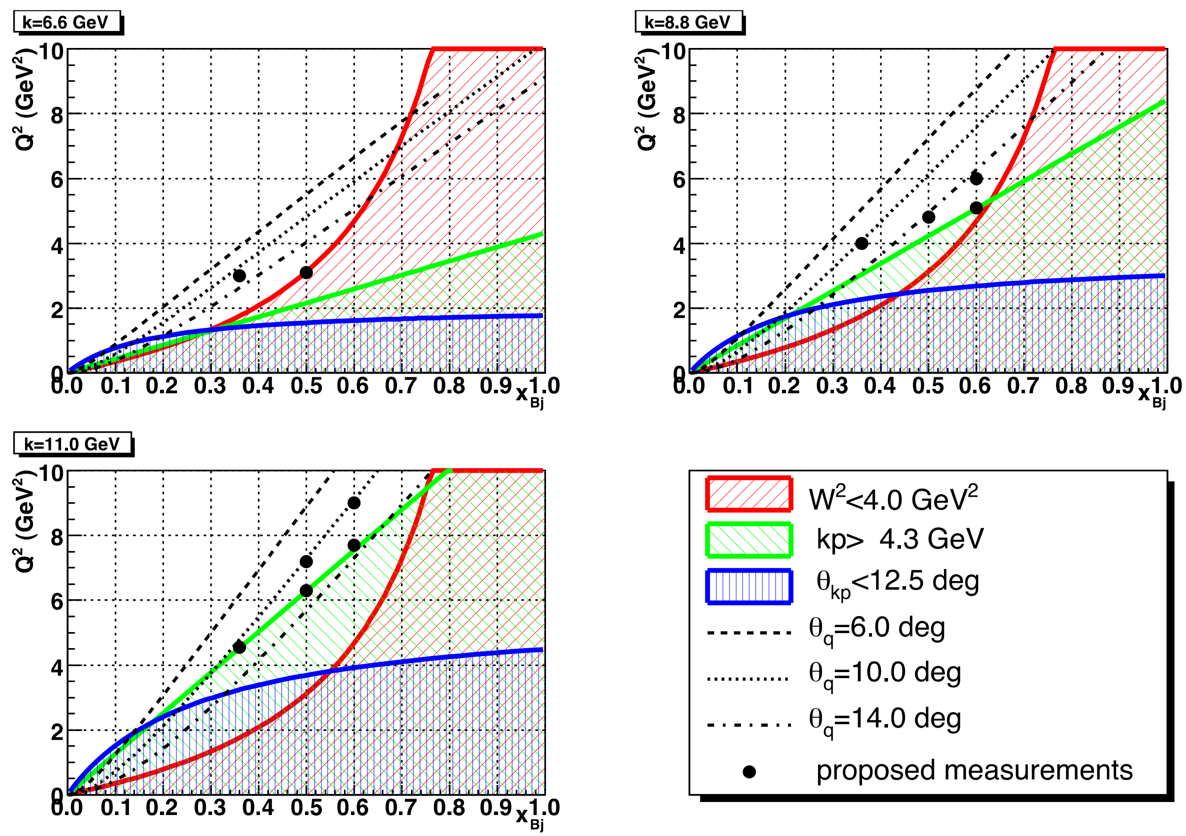
- Precision cross section as a function of Q^2
  - Largest possible range in Q^2
  - Isolate GPD terms from higher twist correlations.
- Widest possible kinematic range compatible with
  - $Q^2 > 2\ GeV^2$
  - $W^2 > 4\ GeV^2$.
- Keep $-\Delta^2 < 1\ GeV^2$.
  - Factorization domain

Experimental Constraints

- Hall A: k_e=6.6, 8.8, 11.0 GeV
- HRS-L Central momentum:
  - $k' \leq 4.3$ GeV
  - $\theta \geq 12.5^\circ$
- Central angle of γ-Calorimeter ≥ 11 deg
  - Background rises rapidly below 9 deg.
- Why HRS?
  - 2-3% systematic precision on $d\sigma$
  - Precision determination of **q**-vector
    - Minimize systematic errors in definition of Δ^2 and $\phi_{\gamma\gamma}$.
    - Small binning in Δ^2 and $\phi_{\gamma\gamma}$

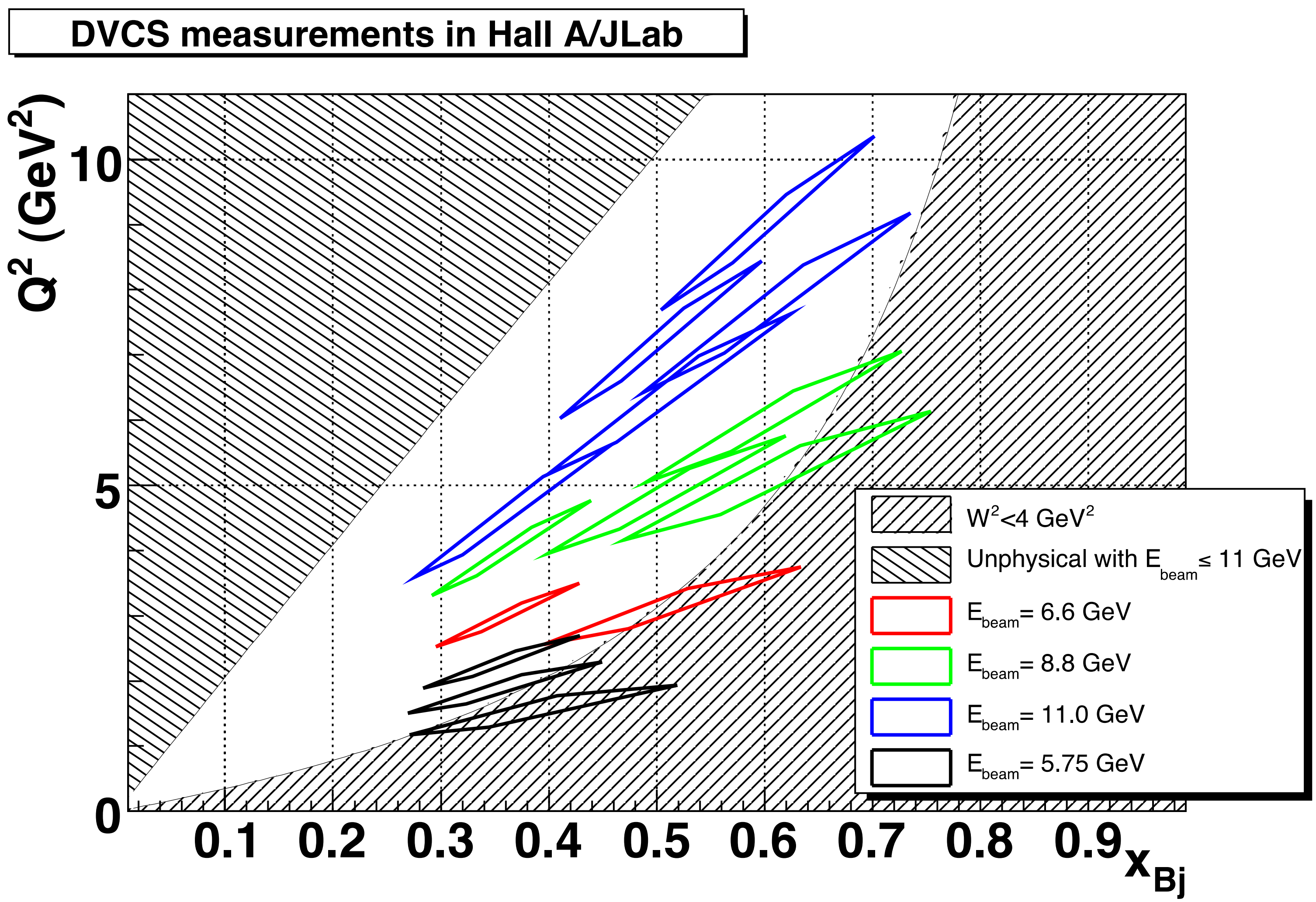
Kinematic Constraints

- θ_q squeezes from above.
- *k'*(HRS) squeezes from below (mostly at 11 GeV)



Proposed H(e,e'γ)p Kinematics

- Factor of 2 range in Q^2 at each x_B
- Existing equipment
- Ready for any beam energy
- *Extensions?*
  - *$x_B = 0.2$, $Q^2 = 2.0$ GeV^2 single point also?*
  - *$x_B = 0.7$, $Q^2 = 9$—11 GeV^2*

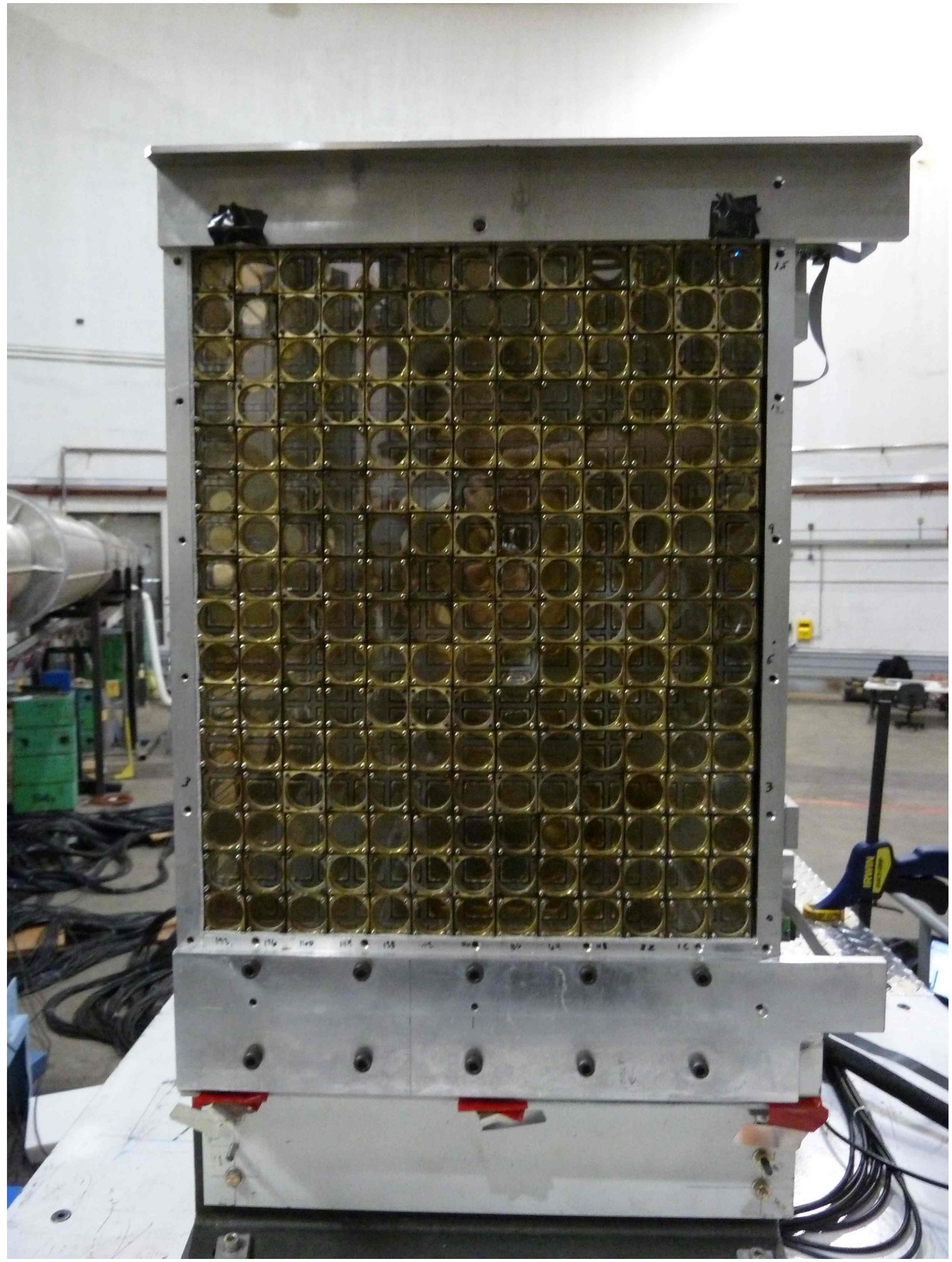


DAQ

- New ARS motherboard for higher throughput
  - VME320
  - Buffering
- New Trigger
  - DVCS trigger fully functional at end of E07-007 run.
  - Thanks to M. Magne, LPC and D. Abbott and Ben Raydo, JLab!

Calorimeter

- 208 PbF_2 crystals
  - Spatial resolution 3 mm
  - Energy resolution 3% at 3 GeV
- <10% attenuation from radiation damage in E07-007 and E08-025
- Background strongly peaked in first 3 columns
  - Dominated by beam on target, not secondaries.



Calorimeter acceptance, resolution, placement

- Acceptance $0 < \Delta_T \leq 0.6$ GeV/c
  - Angular size required shrinks as Δ_T / q'
- $\pi^0 \rightarrow \gamma\gamma$ two cluster separation angle $\geq 2m_\pi / q'$
  - Two cluster separation distance ≈ 9 cm
  - Distance D from target to calorimeter
    - $D \geq (9\text{cm})\, q' / (2m_\pi)$
    - D ranges up to 3.0 m at k = 11 GeV.
- Luminosity is limited by radiation dose and pile-up in calorimeter.
  - Both scale as $1/D^2$ at fixed calo angle
  - Suggest $L = (1 \bullet 10^{37}/\text{cm}^2/\text{s})(D/1\text{m})^2$ for $\theta_q < 14°$
    - Higher luminosity possible when calorimeter is at larger angles

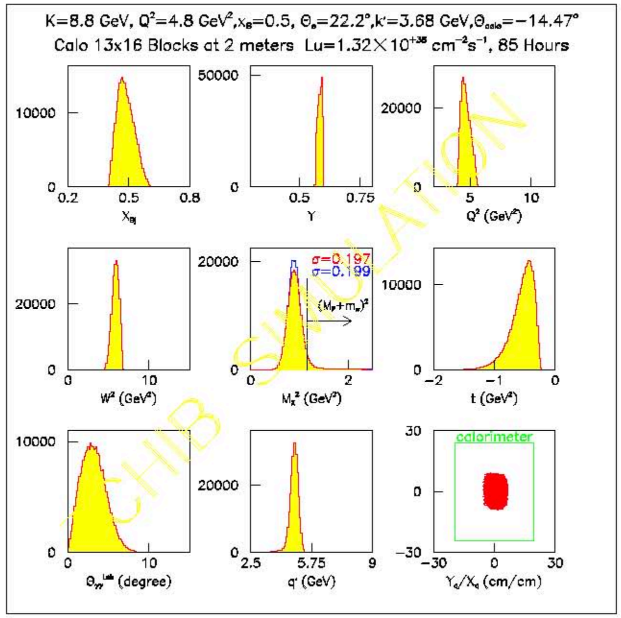
Kinematics and Count Rates

Q^2 (GeV^2)	k (GeV)	$x_{\rm Bj}$	$q'(0^\circ)$ (GeV)	D (m)	θ_q (deg)	θ_{calo}^{min} (deg)	t_{min} (GeV^2)	t_{max} (GeV^2)	$\sigma(M_X^2)$ (GeV^2)	$\mathcal{L}/10^{38}$ (cm^{-2}/s)	HRS (Hz)	DVCS (Hz)	Time (days)
3.0	6.6	0.36	4.35	1.5	11.7	7.1	-0.16	-0.42	0.23	0.75	479	1.16	3
4.0	8.8	0.36	5.83	2.0	10.3	7.0	-0.17	-0.42	0.26	1.3	842	1.74	2
4.55	11.0	0.36	6.65	2.5	10.8	7.0	-0.17	-0.42	0.27	2	2460	4.63	1
3.1	6.6	0.5	3.11	1.5	18.5	11.0	-0.37	-0.64	0.17	0.75	873	0.77	5
4.8	8.8	0.5	4.91	2.0	14.5	8.9	-0.39	-0.70	0.20	1.3	716	0.82	4
6.3	11.0	0.5	6.50	2.5	12.4	7.9	-0.40	-0.72	0.20	2.	778	0.99	4
7.2	11.0	0.5	7.46	2.5	10.2	7.0	-0.40	-0.75	0.25	2.	331	0.53	7
5.1	8.8	0.6	4.18	1.5	17.8	10.4	-0.65	-1.06	0.16	0.75	338	0.27	13
6.0	8.8	0.6	4.97	2.0	14.8	9.2	-0.67	-1.05	0.18	1.3	227	0.22	16
7.7	11.0	0.6	6.47	2.5	13.1	8.6	-0.69	-1.10	0.20	2.	274	0.28	13
9.0	11.0	0.6	7.62	3.0	10.2	7.3	-0.71	-1.14	0.22	3.	117	0.17	20

- Luminosity projected at 4•10^{37} $(D/1.1\text{m})^2$
- Beam time for 250K DVCS events per (Q^2, x_B, Δ^2) bin.
- Reduce luminosity by factor of 4 for settings with q<13 deg.
- Overall reduction in statistics of 1/2-1/4.

Sample kinematics

- k= 8.8 GeV
- Q^2 = 4.8 GeV^2
- x_B = 0.5



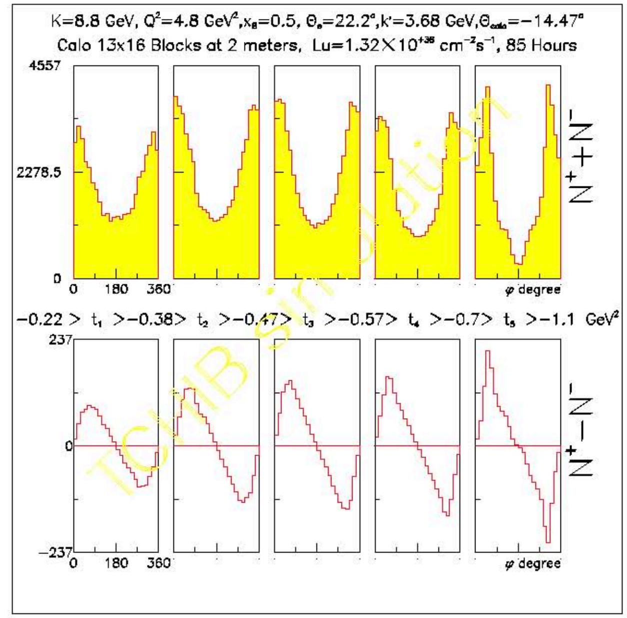
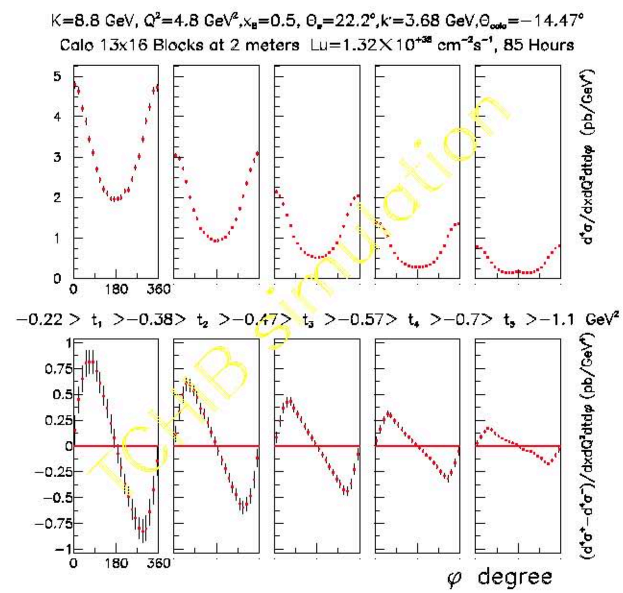


Figure 8: DVCS Distributions for setting $k = 8.8$ GeV, $Q^2 = 4.8$ GeV^2, $x_{\rm Bj} = 0.5$.

Top Left: Cross section weighted acceptance distributions.

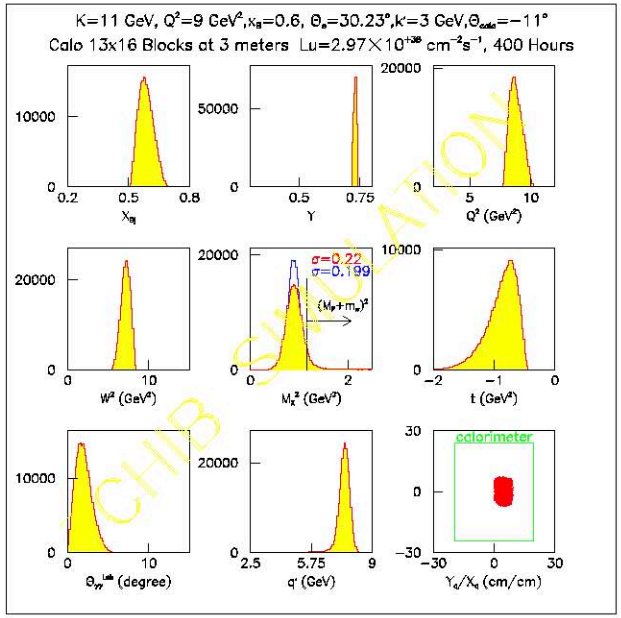
Top Right: Helicity sum and helicity difference projected counts as a function of $\phi_{\gamma\gamma}$ in five bins in t.

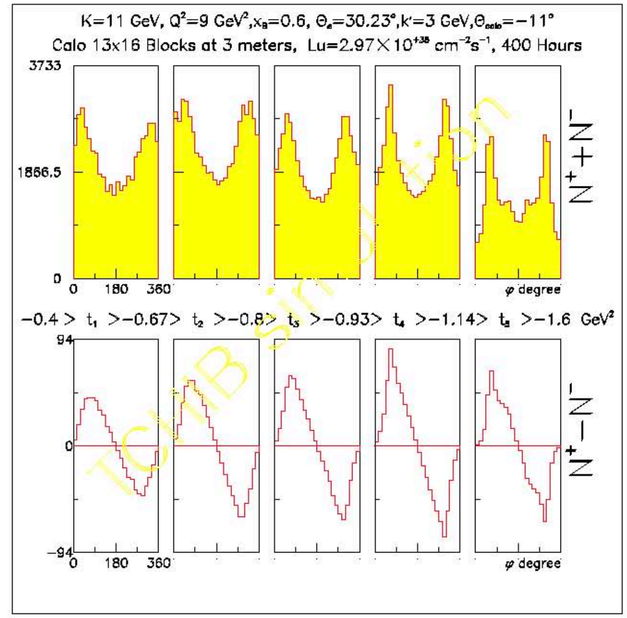
Bottom Right: Helicity sum and helicity difference projected cross sections, with statistical uncertainties, as functions of $\phi_{\gamma\gamma}$ in the same bins in t.



Sample kinematics

- k= 11 GeV
- Q^2 = 9.0 GeV^2
- x_B = 0.6





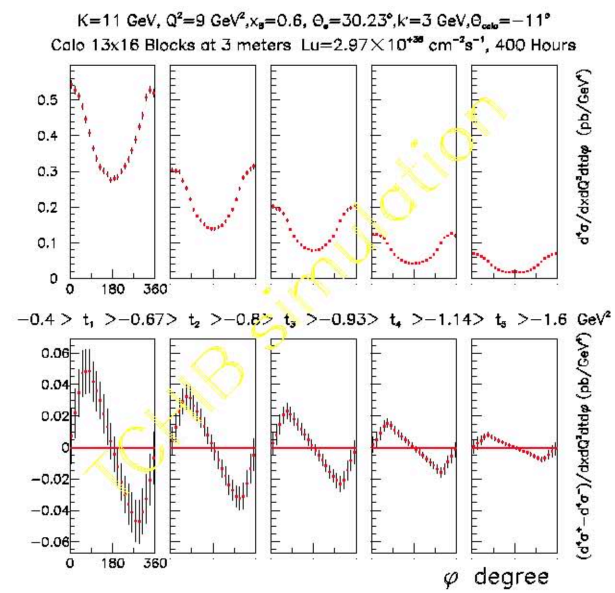


Figure 7: DVCS Distributions for setting $k = 11$ GeV, $Q^2 = 9$ GeV^2, $x_{\rm Bj} = 0.6$.

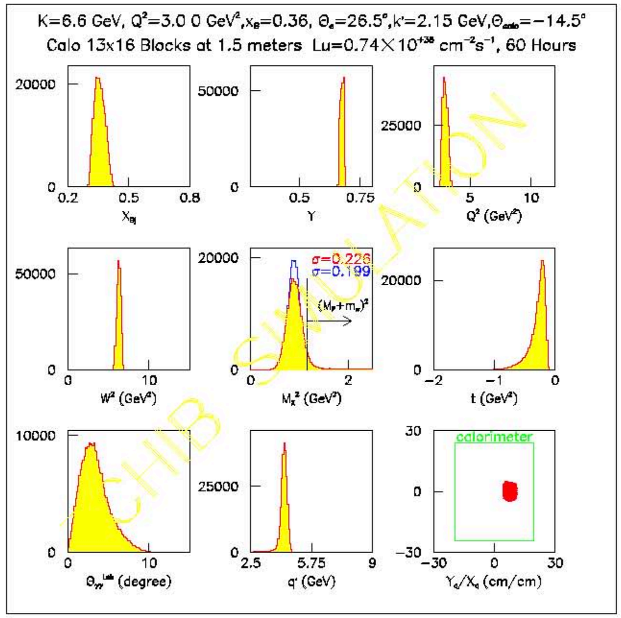
Top Left: Cross section weighted acceptance distributions.

Top Right: Helicity sum and helicity difference projected counts as a function of $\phi_{\gamma\gamma}$ in five bins in t.

Bottom Right: Helicity sum and helicity difference projected cross sections, with statistical uncertainties, as functions of $\phi_{\gamma\gamma}$ in the same bins in t.

Sample kinematics

- k= 6.6 GeV
- Q^2 = 3.0 GeV^2
- x_B = 0.36



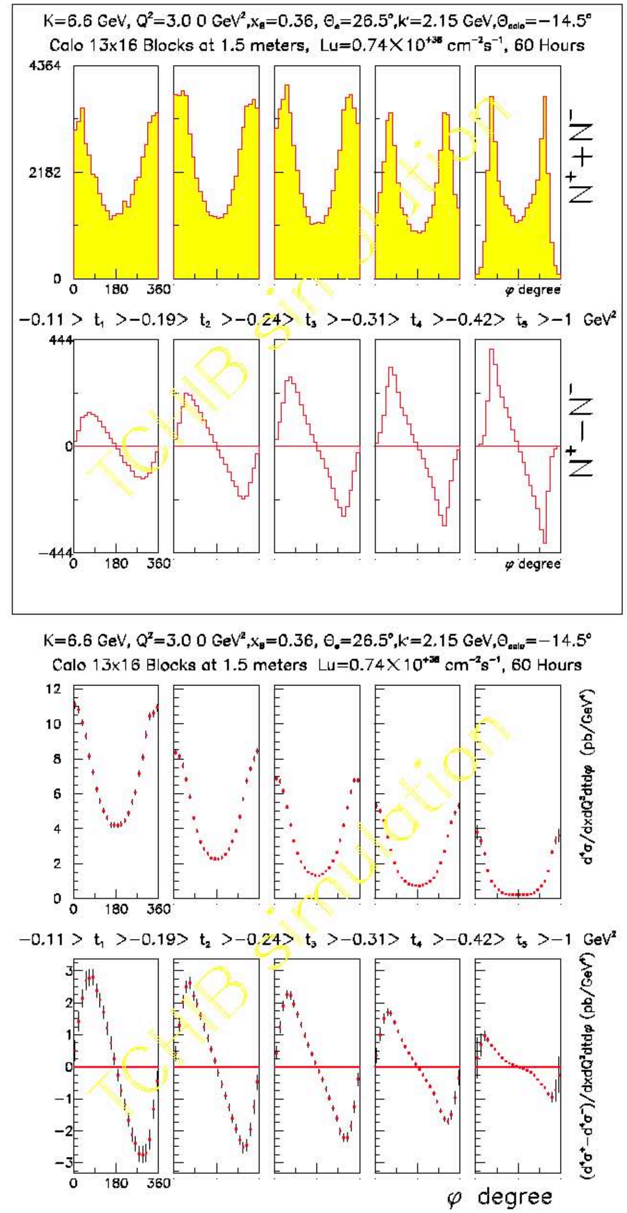


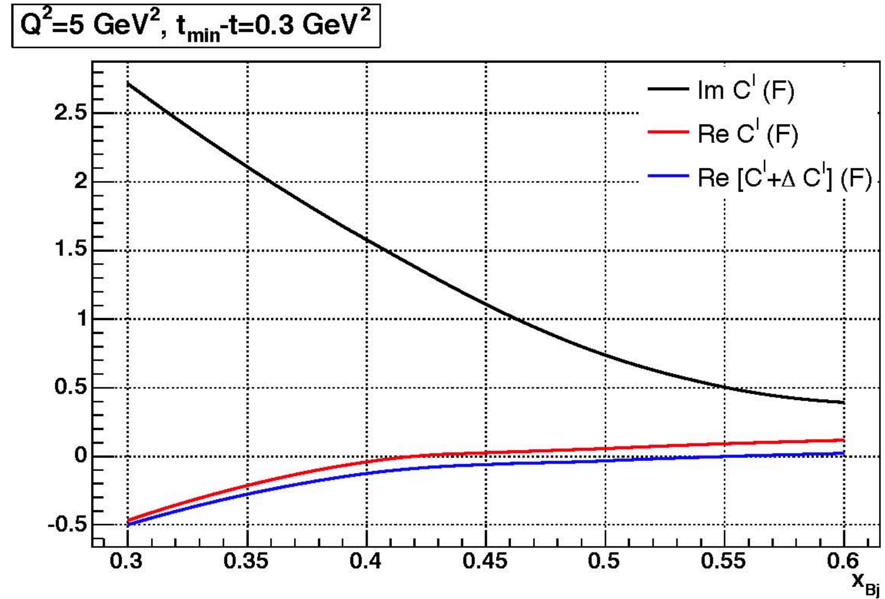
Figure 9: DVCS Distributions for setting $k = 6.6$ GeV, $Q^2 = 3.0$ GeV^2, $x_{Bj} = 0.36$.

Top Left: Cross section weighted acceptance distributions.

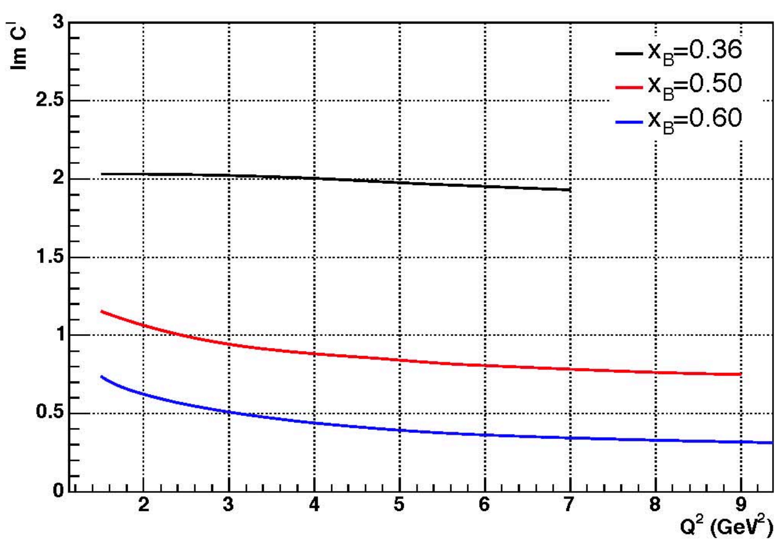
Top Right: Helicity sum and helicity difference projected counts as a function of $\phi_{\gamma\gamma}$ in five bins in t.

Bottom Right: Helicity sum and helicity difference projected cross sections, with statistical uncertainties, as functions of $\phi_{\gamma\gamma}$ in the same bins in t.

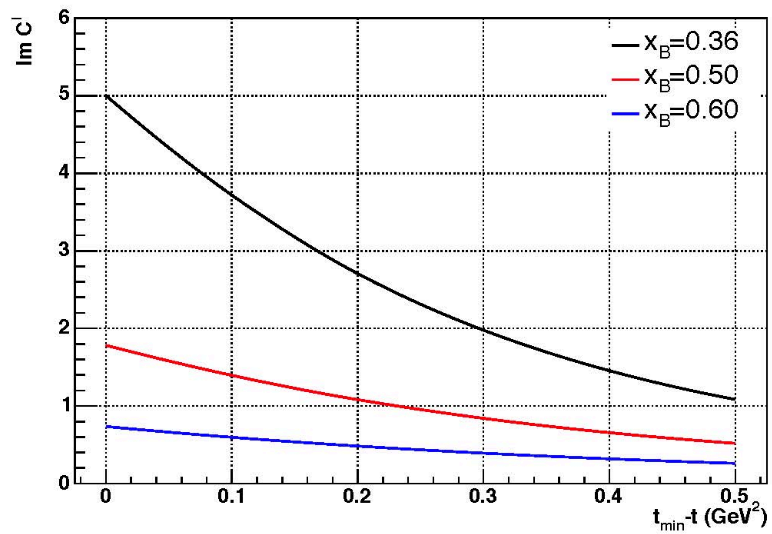
Sample Physics



x_B-dependence of observables in VGG model



Q^2 evolution (*H* only)



Δ^2-dependence of $\Im$m[C^I] in VGG model

Ready for Beam

- Staging area for 1 year
- Six weeks installation
- Compton quality beam
- Any energy greater than 6 GeV
- Join us !!

Future Extensions

- x_B=0.7, $Q^2 \leq 11$ GeV^2
- D target
- Energy overlap?
  - |DVCS|^2, Re[DVCS•BH] separations
  - Lowering Q^2 at fixed x_B requires increasing *k'*
    - *SBS or Hall C*
  - Reducing x_B at fixed k, Q^2 forces Calorimeter to smaller angles.
- Polarized ^{3}He Target
  - If L = 10^{37}/cm^2/s
  - Full separation of all GPDs in 1 month of data for one Q^2, x_B bin
- H($e,e'p\ \phi$) LOI to PAC36 for HRS×SBS
- SoLID?

Detailed Kinematics

Table III: Detailed DVCS Kinematics. The first line is from E00-110, and is included for comparison purposes. The angle θ_q is the central angle of the virtual photon direction $q = (k - k')$.

Q^2 (GeV^2)	x_{Bj}	k (GeV)	k' (GeV)	θ_e (°)	θ_q (°)	$q'(0°)$ (GeV)	W^2 (GeV^2)
1.90	0.36	5.75	2.94	19.3	18.1	2.73	4.2
3.00	0.36	6.60	2.15	26.5	11.7	4.35	6.2
4.00	0.36	8.80	2.88	22.9	10.3	5.83	8.0
4.55	0.36	11.00	4.26	17.9	10.8	6.65	9.0
3.10	0.50	6.60	3.20	22.5	18.5	3.11	4.1
4.80	0.50	8.80	3.68	22.2	14.5	4.91	5.7
6.30	0.50	11.00	4.29	21.1	12.4	6.50	7.2
7.20	0.50	11.00	3.32	25.6	10.2	7.46	8.1
5.10	0.60	8.80	4.27	21.2	17.8	4.18	4.3
6.00	0.60	8.80	3.47	25.6	14.1	4.97	4.9
7.70	0.60	11.00	4.16	23.6	13.1	6.47	6.0
9.00	0.60	11.00	3.00	30.2	10.2	7.62	6.9