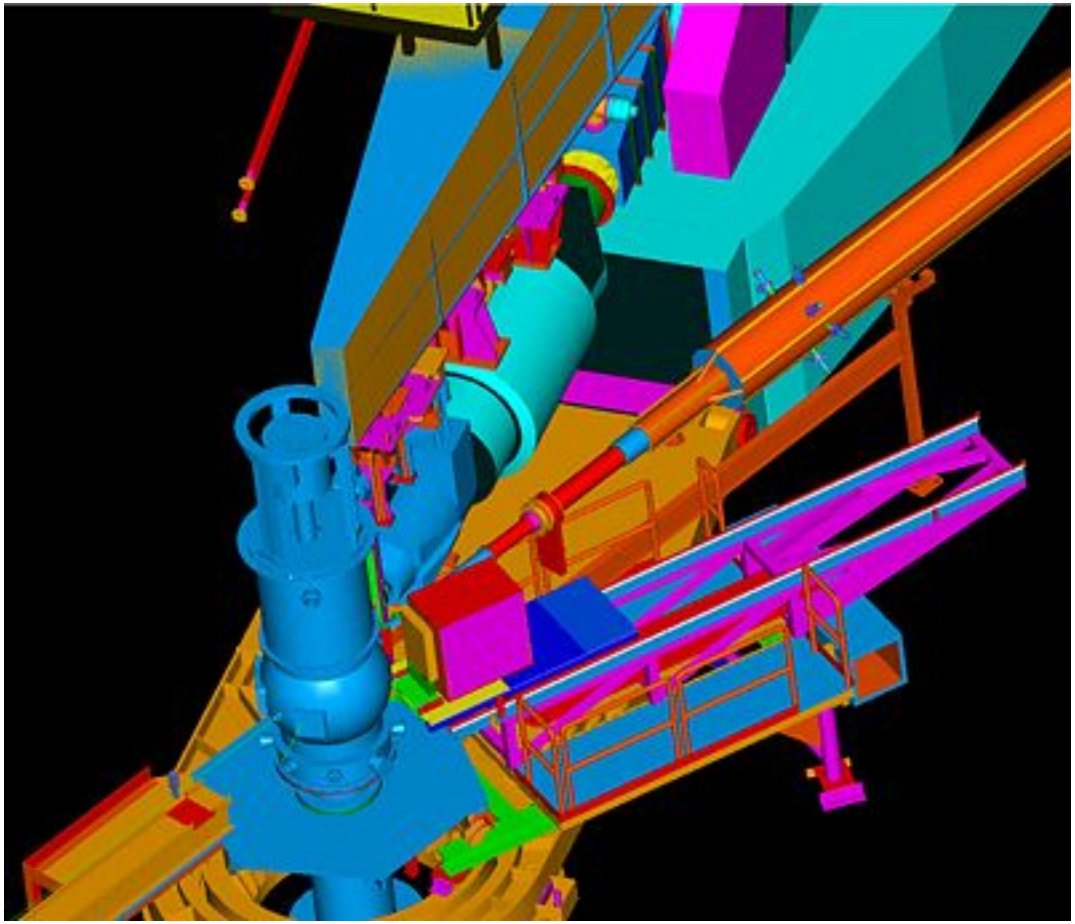
Hall A Collaboration Meeting
7–8 June 2012

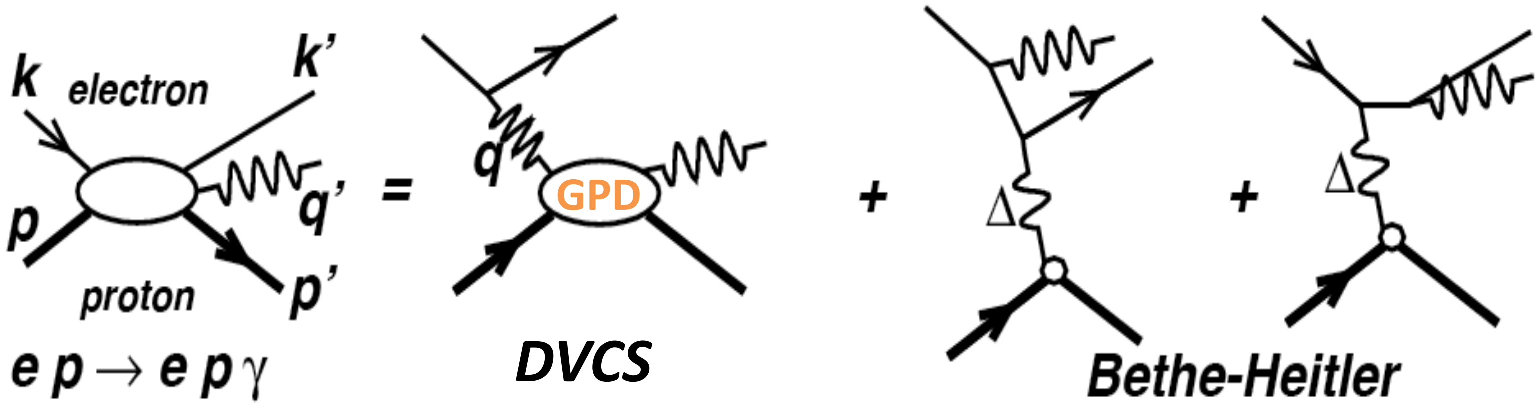
DVCS Experiments

E07-007: H(e,e'γ)p
E08-024: D(e,e'γ)pn
E12-06-114:H(e,e'γ)p



Charles Hyde
Old Dominion University,
for the Hall A DVCS Collaboration
A.Camsonne, C.H., M.Mazouz, C.Munoz, J.Roche
co-spokespersons.

Measuring Deeply Virtual Compton Scattering



At leading twist:

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

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

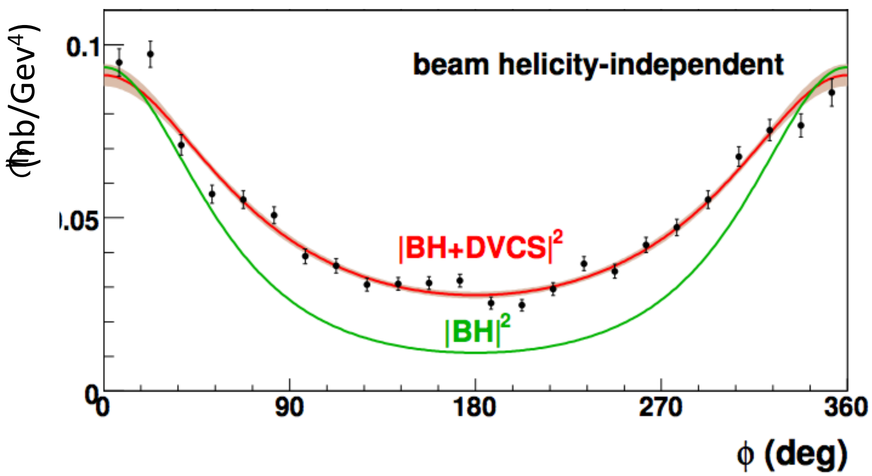
If absolute cross sections cannot be measured
(eg solid angle difficult to evaluate):

$$A = \frac{d^5\overrightarrow{\sigma} - d^5\overleftarrow{\sigma}}{d^5\overrightarrow{\sigma} + d^5\overleftarrow{\sigma}} = \frac{\Delta\sigma}{2\sigma}$$

Second generation experiments (data taken in 2010)

Motivated by the first generation result

$$d^5\sigma = |BH|^2 + (BH \bullet DVCS) + |DVCS|^2$$



Statistics Collected by Kinematics

Kinematics	PAC Hours	% Completed
Proton Data		
Q^2=1.50 GeV^2 / E=5.5 GeV	20	100%
Q^2=1.50 GeV^2 / E=3.3 GeV	60	100%
Q^2=1.75 GeV^2 / E=5.5 GeV	30	100%
Q^2=1.75 GeV^2 / E=4.4 GeV	90	100%
Q^2=2.00 GeV^2 / E=5.5 GeV	50	100%
Q^2=2.00 GeV^2 / E=4.4 GeV	150	82%
Neutron Data		
Q^2=1.75 GeV^2 / E=5.5 GeV	200	60%
Q^2=1.75 GeV^2 / E=4.4 GeV	200	70%

Goal of E07-007 and E08-025:

To separate the BH.DVCS interference contribution from the DVCS^2 contribution.

Also L/T separation of the deeply virtual π^0 production

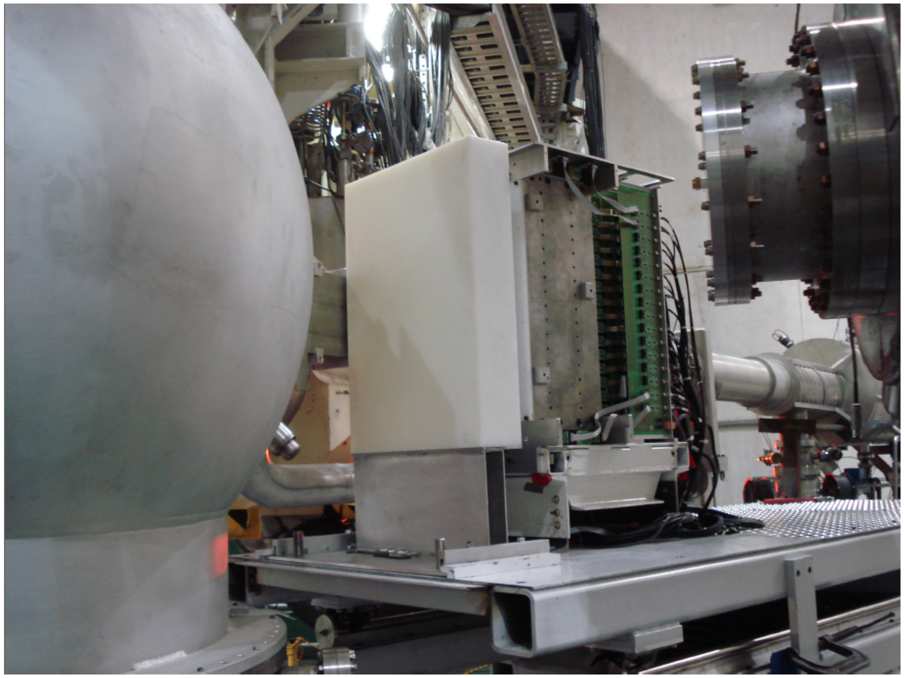
Method:

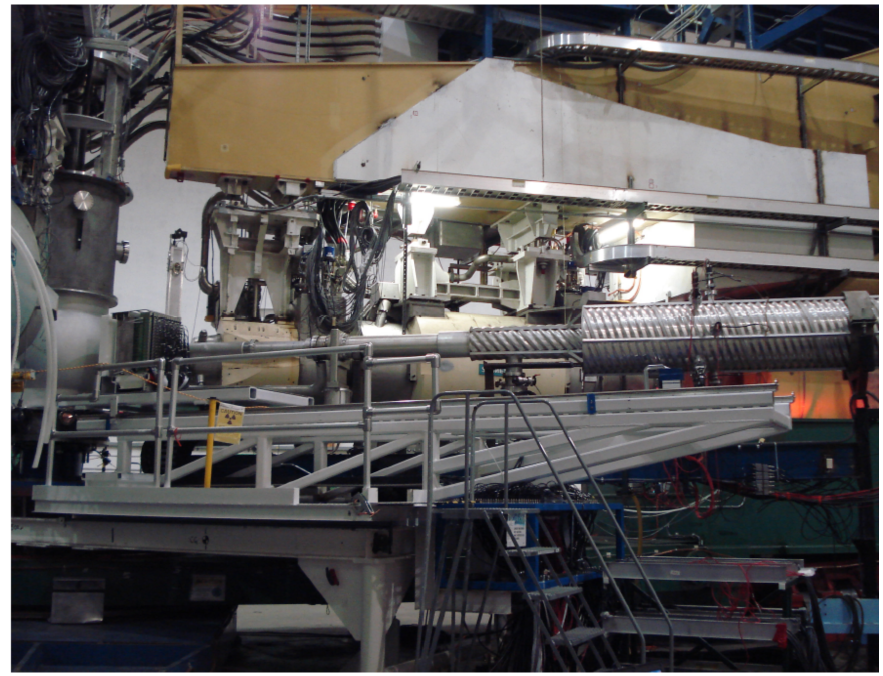
- Measure each Q^2 point at two different beam energies.

    Re[DVCS*BH] and $|DVCS|^2$ scale differently with incident energy

- For LH2 measure three Q^2 while for LD2 measure only one Q^2.

Improved dedicated equipment: expanded calorimeter and ancillary electronics





Expanded calorimeter (from 132 to 208 blocks)

- less radiation damage than previously (selection of blocks and better shielding)

1 GHz sampling electronic (ARS) with better transfer speed

- used VME320 protocol (16 times faster) and buffering of the FIFO

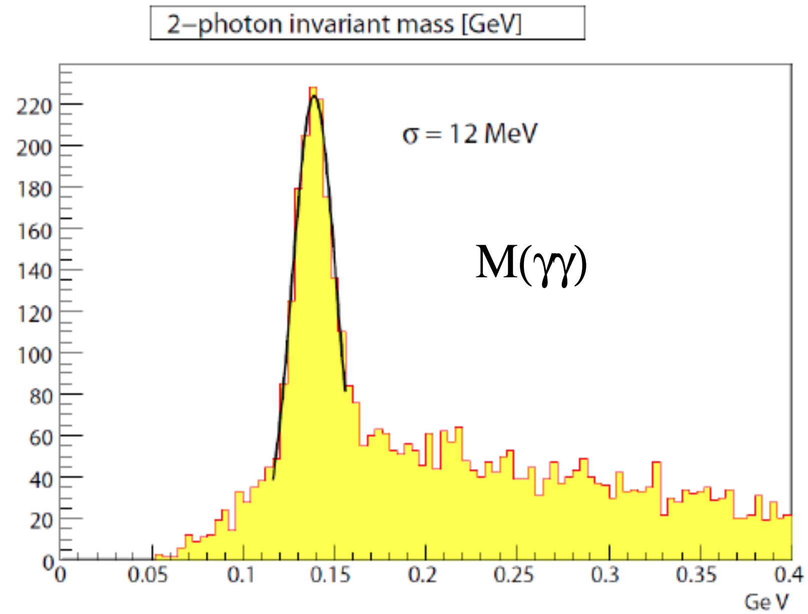
New coincidence trigger module

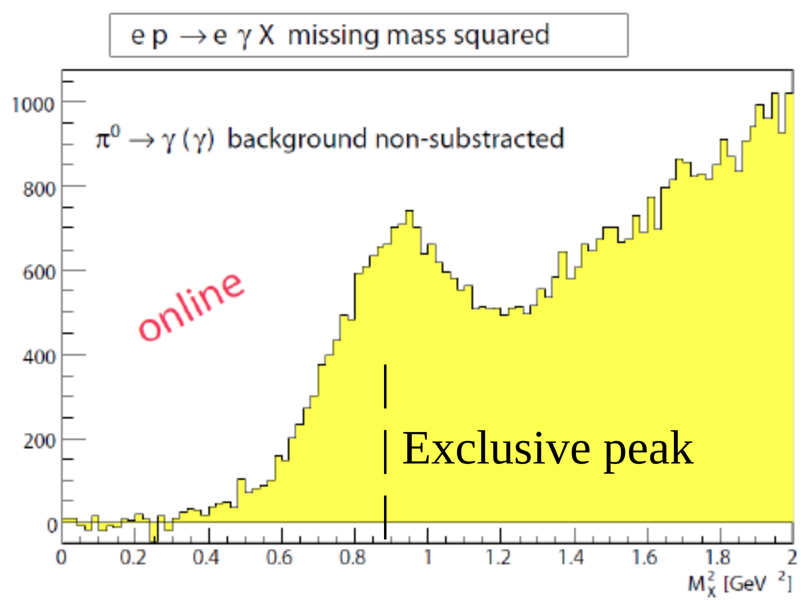
- reduces data rate by selecting clusters above a threshold in the calorimeter
- ran successfully during the last 8 days of the experiment

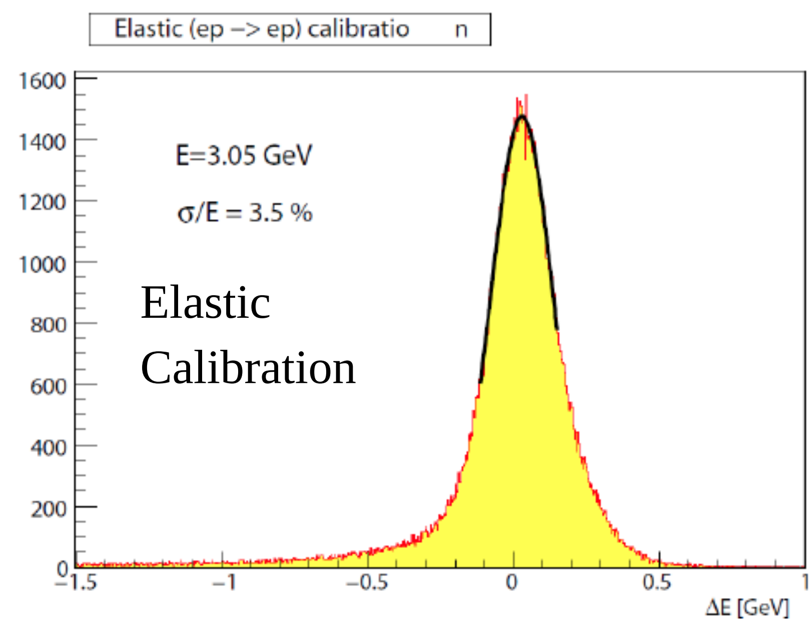
Second generation: Online Data quality

Preliminary analysis demonstrates that the experiment was running well:

- 2-γ invariant mass reproduces the π^0
- ep $\rightarrow$eγx has the desired peak at the nucleon mass, and
- the ep $\rightarrow$ ep elastic calibration reproduces the expected energy resolution







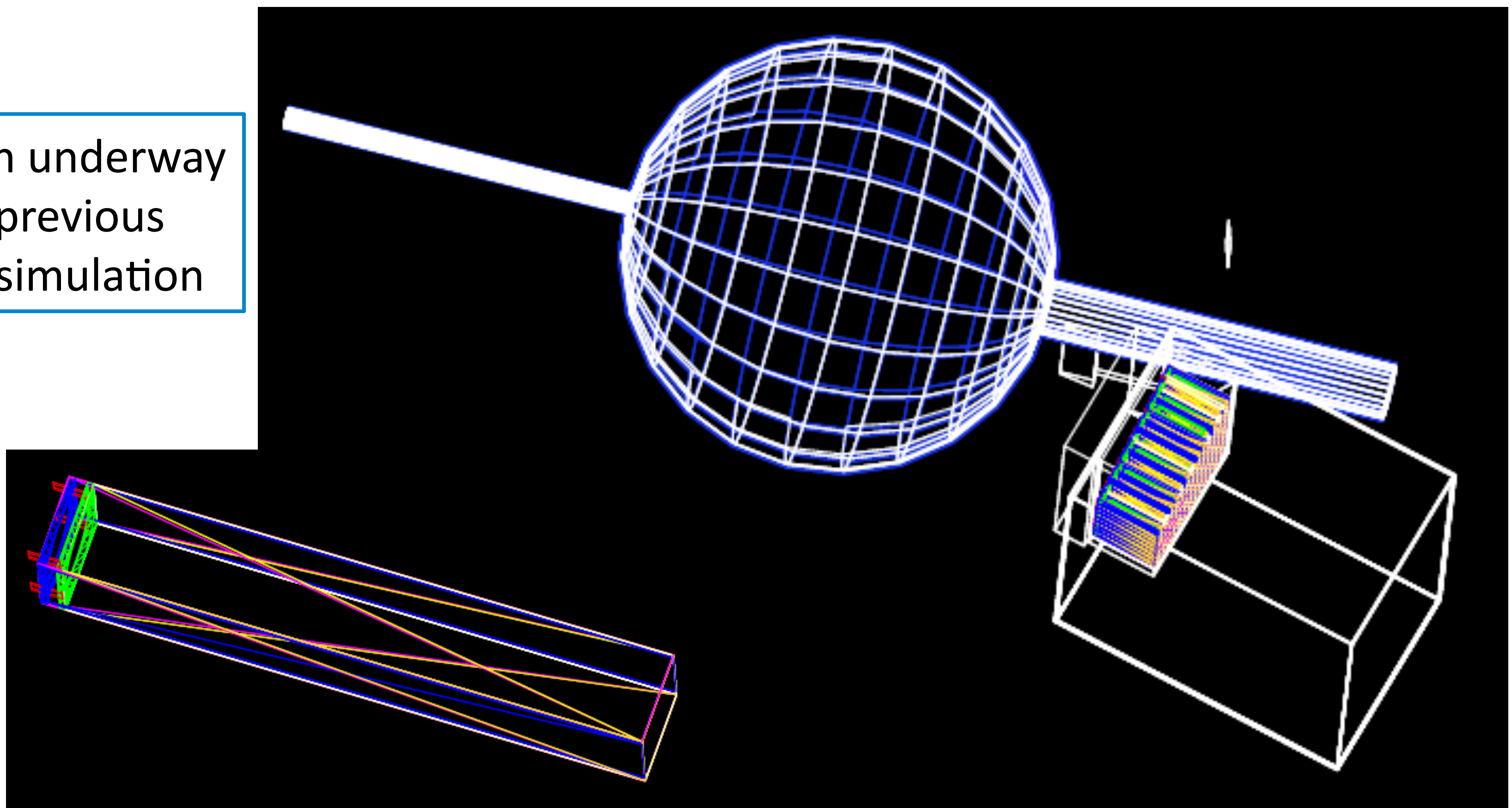
Analysis Update

- Initial Waveform analysis of all PbF_2 data. 40 TB
  - Extraction of γ-cluster energies and positions.
  - Completed at CNRS/IN^2P^3 "Centre de Calcul" Lyon
  - Transfer of condensed data files back to JLab (6 TB) encountered administrative roadblocks. (6 weeks)
- 2^{nd} pass Waveform analysis in progress
  - Correct some errors in initial pass.

GEANT4 Monte Carlo simulation

- Full geometry implemented:
  - Target and scattering chamber
  - Calorimeter blocks with wrapping and PMT holders, shims, and surveyed positions
  - Calorimeter and beam pipe shielding
- Coupled to C++ DVCS event generator, including External & Internal Radiation
- Using same C++ reconstruction software as DVCS data

Validation underway using previous Geant3 simulation



Analysis Manpower

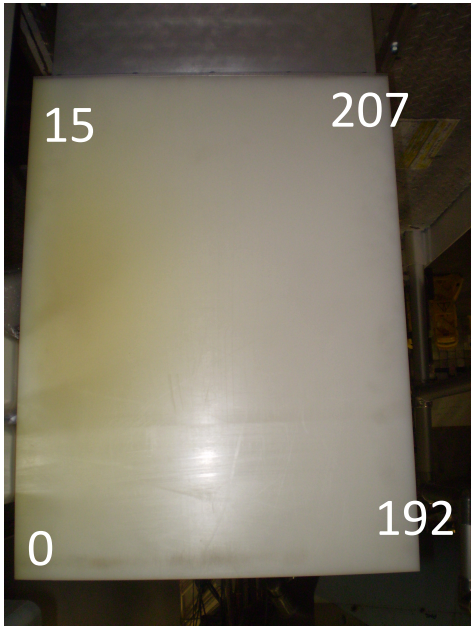
Students
- Alejandro Marti (IPN-Orsay/U. Valencia): 1st year PhD on E07-007 DVCS
- Maxime Defurne (CEA-Saclay): PhD starting 11/01/12 on E07-007 π^0
- Camille Desnault (IPN-Orsay): PhD starting 10/01/12 on E08-025
- Hashir Rashad (ODU): 1st year PhD (post Qual) on E07-007 DVCS

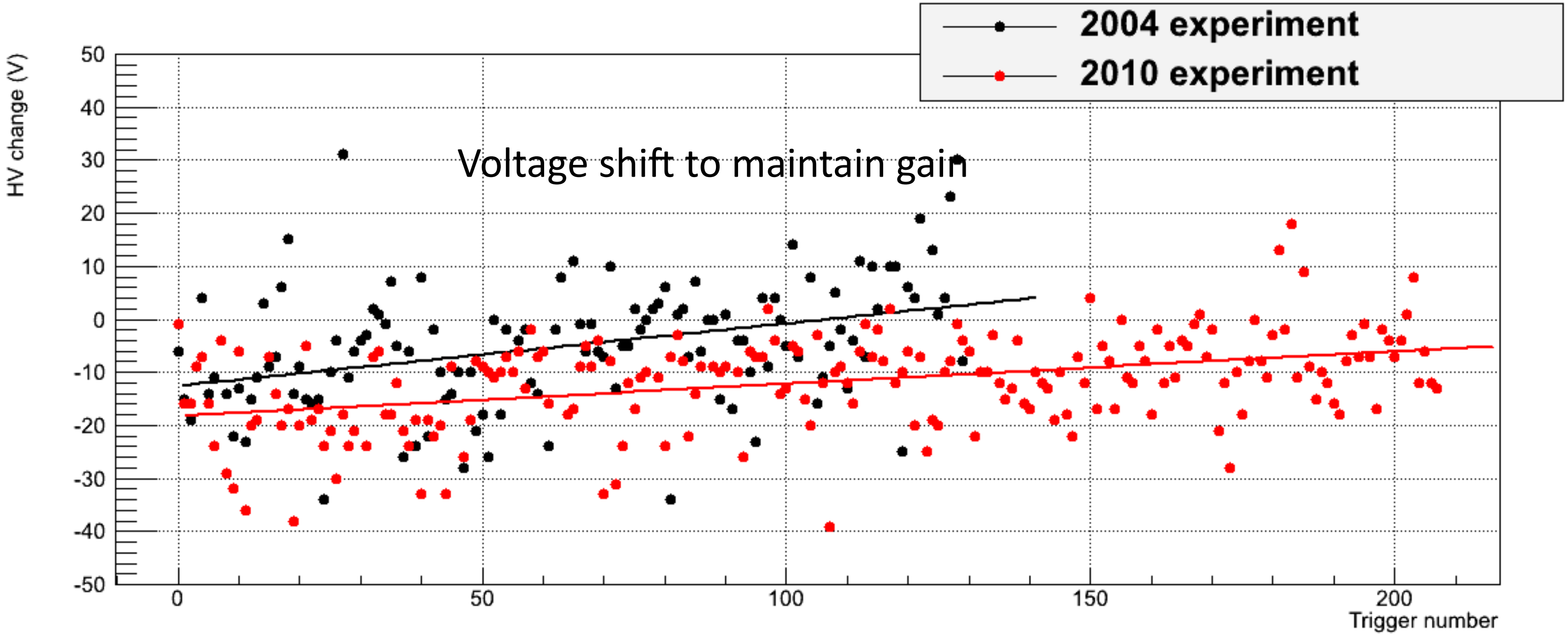
Postdocs
- Rafayel Paremuzyan (IPN-Orsay): Geant4 simulations
- Eric Fuchey (Temple U): Polarimetry Analysis

Other Personnel
- Hisham Albataineh (Texas A&M, Kingsville)
- Alexandre Camsonne (JLab)
- Charles Hyde (ODU)
- Malek Mazouz (Monastir, Tunisia)
- Carlos Munoz Camacho (IPN-Orsay)
- Julie Roche (Ohio U)
- Franck Sabatié (CEA-Saclay)

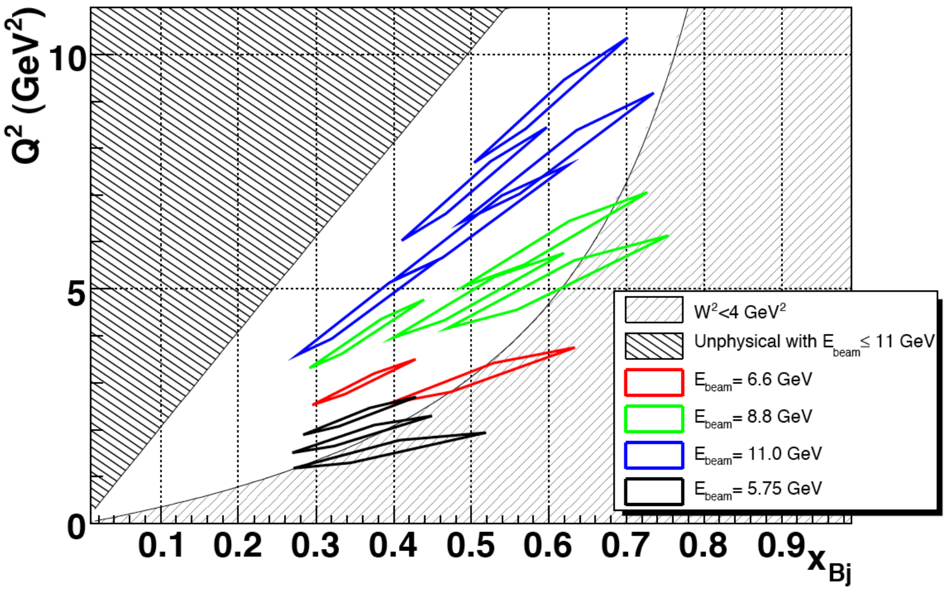
PMT Aging

- All PMTs returned to Clermont-Ferrand for recalibration of gain (ATLAS HCal Test-Stand, M. Crouau).
- Small systematic shifts, no sign of major aging (~20 spares on hand for 12 GeV).





Third generation experiment (JLab 12 GeV era)



The strengths of our method

- Accurate cross-sections
  - -High luminosity 10^{38} $cm^{-2}s^{-1}$
  - -Well understood acceptance
- High angular resolution
  - Small bins necessary to capture the rapidly varying Bethe-Heitler cross-section
- Equal statistic in even bin (even at high Q2)

Goals for E12-06-114 (100 PAC days, A+ rated Jlab experiment):

•To measure precise absolute cross-sections (3-5% stat and 4% sys uncertainties)

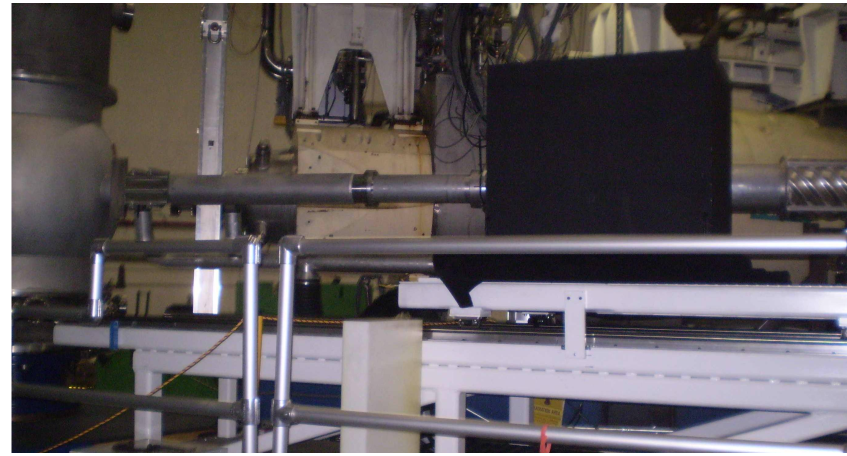
•To test the scaling of the DVCS cross-sections

•To separate the Re and Im part of the DVCS amplitude

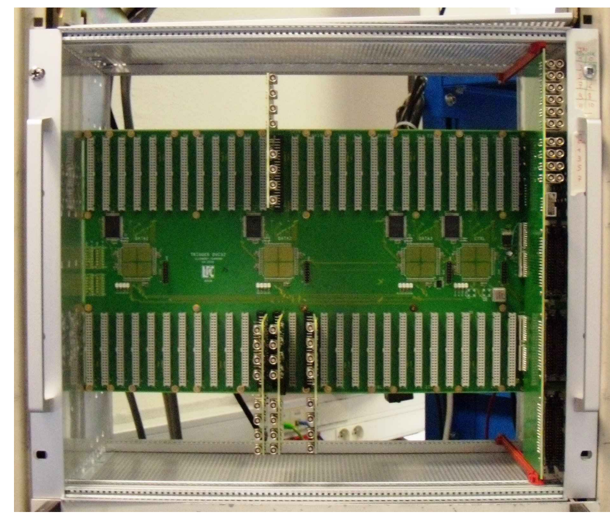
Our equipment is ready:

we will be able to run as soon as the Jlab beam is available

E12-06-114



- 100 days approved on Hydrogen with 'A' rating
  - All major equipment in hand
    - Rebuild previous scattering chamber/beam line
    - Add extension to beamline shielding
  - Will start rebuilding calo and commissioning calo trigger/DAQ in 2013 (~ 1 year needed).



- Will be ready for earliest useful beam
  - Energies from 6.6 to 11.0 GeV
  - Currents 5.0 μA to 20 μA on 15 cm LH_2
    - Maximum Luminosity scales as Distance squared (L^2) to Calo
    - L scales as k (for $\pi^0 \rightarrow \gamma\gamma$ two cluster separation)
      - 1.5 m at 6.6 GeV to 3.0 m at 11 GeV
    - t_{min}-t acceptance roughly invariant

Thank you

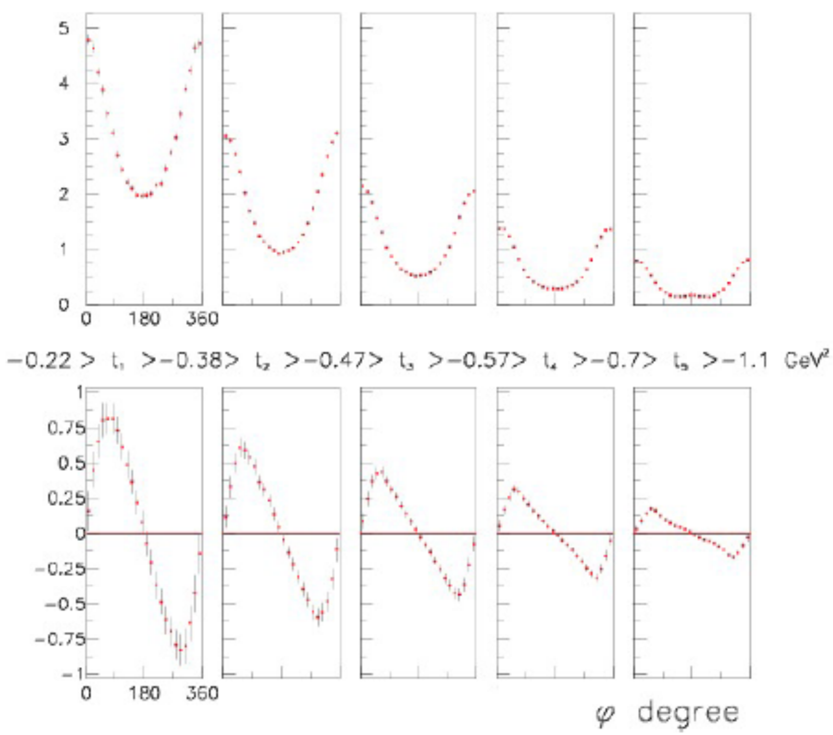
- Collaborators Welcome
- Also working on future extensions to polarized ^3He, NH_3 targets…

E12-06-114: Projections and beamtime request

Luminosity: from $4 \cdot 10^{37}$ to $1 \cdot 10^{38}$ Hz/cm^2

$E_b = 8.8$ GeV, $Q^2 = 4.8$ GeV^2, $x_B = 0.50$

Helicity-independent cross sections (pb/GeV4)



Helicity-dependent cross sections (pb/GeV4)

Statistical uncertainty: from 3 % to 5 %

Beamtime request (days)

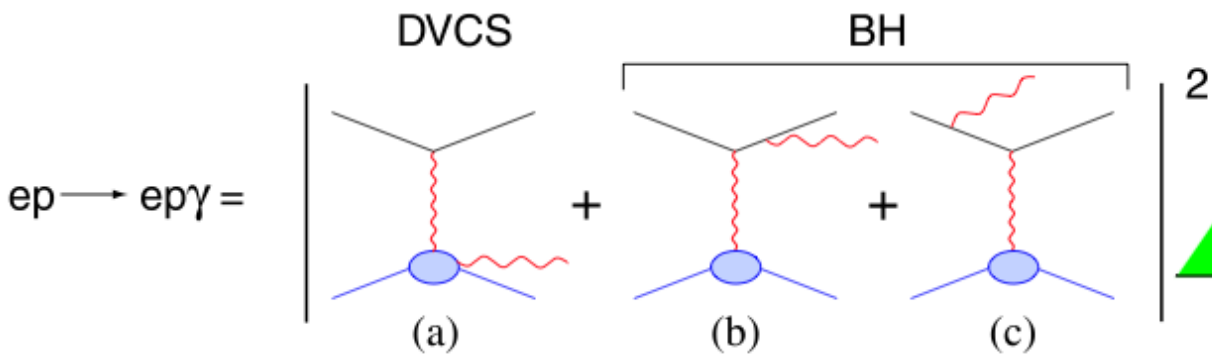
Q^2 (GeV)	$x_B = 0.36$	$x_B = 0.5$	$x_B = 0.6$
3.0	3		
4.0	2		
4.6	1		
3.1		5	
4.8		4	
6.3		4	
7.2		7	
5.1			13
6.0			16
7.7			13
9.0			20

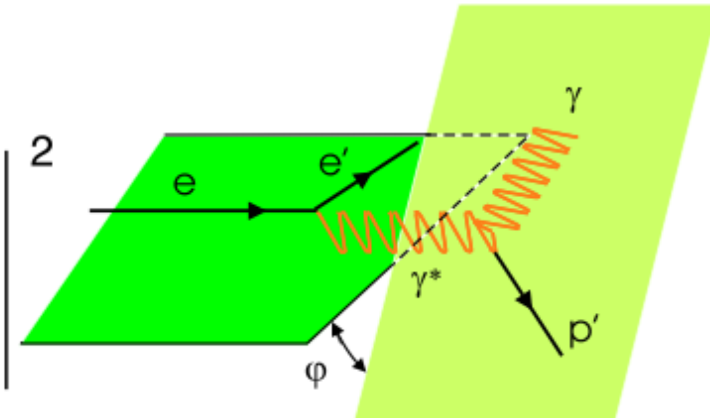
Total: 88 + 12 (overhead) = 100 days

Systematic uncertainty: 4 %

- 2.5% acceptance
- 3% π^0 contamination

E07-007 (Hall A)





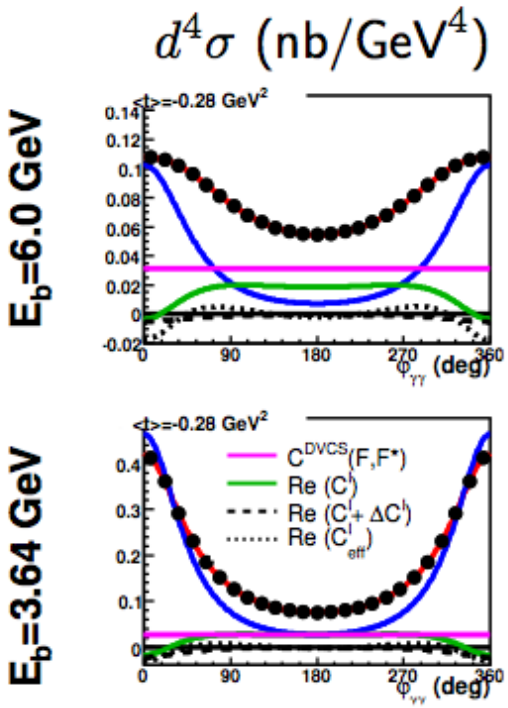
$$\sigma(ep \to ep\gamma) = \underbrace{|BH|^2}_{\text{Known to} \sim 1\%} + \underbrace{\mathcal{I}(BH \cdot DVCS)}_{\text{Linear combination of GPDs}} + \underbrace{|DVCS|^2}_{\text{Bilinear combination of GPDs}}$$

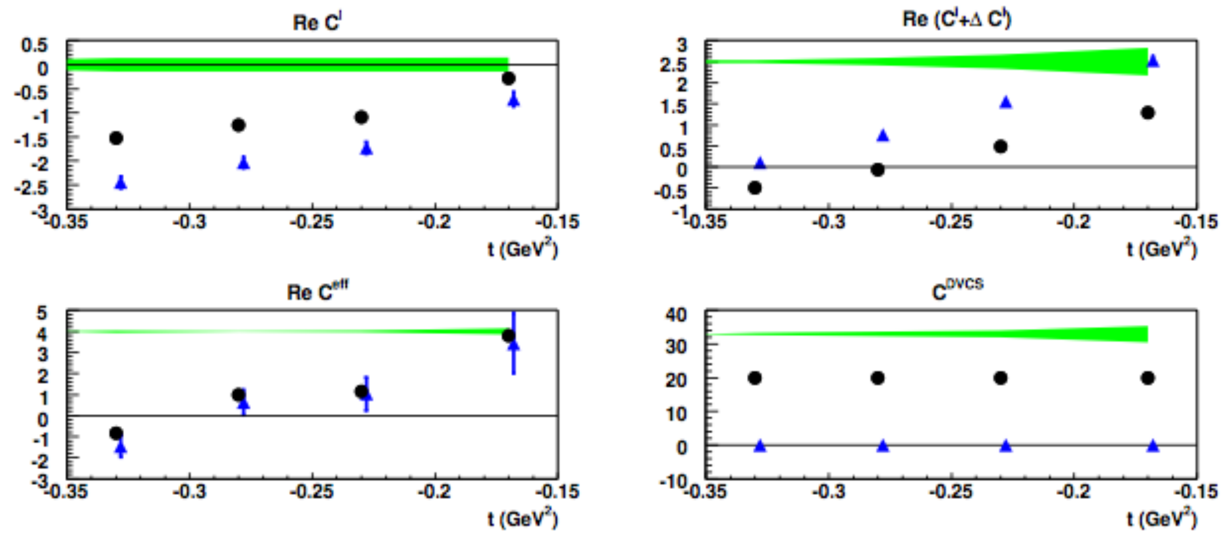
DVCS cross section has a very rich azimuthal structure:

- 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: 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 $ep \to ep\pi^0$



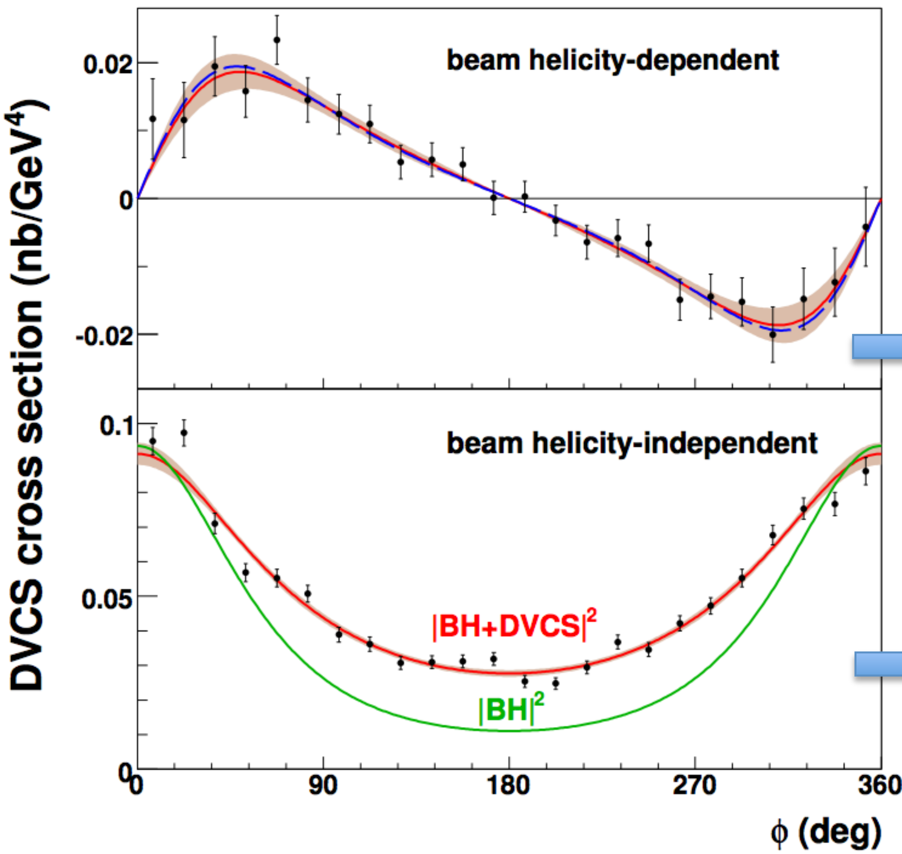


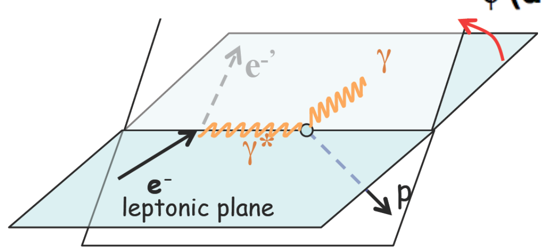
● E07-007 ■ Systematic uncertainty

▲ E00-110: assuming DVCS^2=0

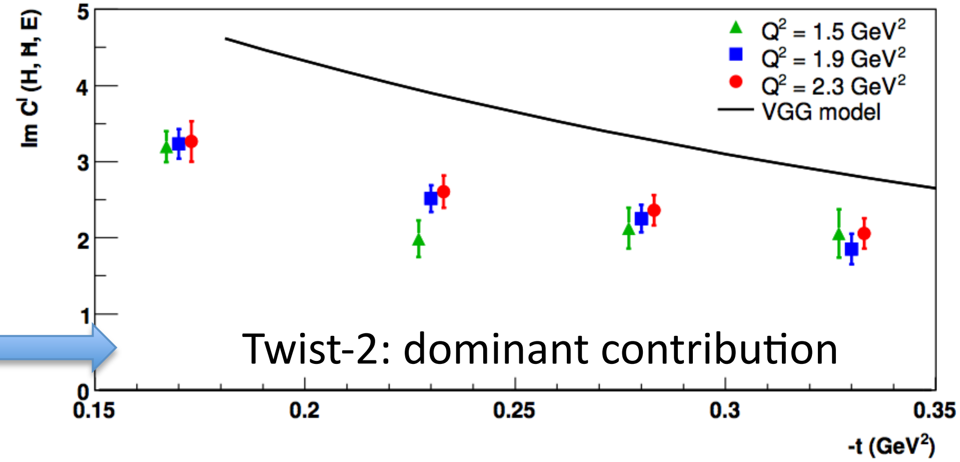
Proton experiment   PRL 97: 262002 (2006)

x=0.36, Q^2=2.3 GeV^2 t=-0.28 GeV^2





$$C^I = F_1\mathcal{H} + \xi(F1+F2)\tilde{\mathcal{H}} + kF_2\mathcal{E}$$



BH^2, DVCS^2 and BH-DVCS interference all contribute to the total cross-section.

Also results on:

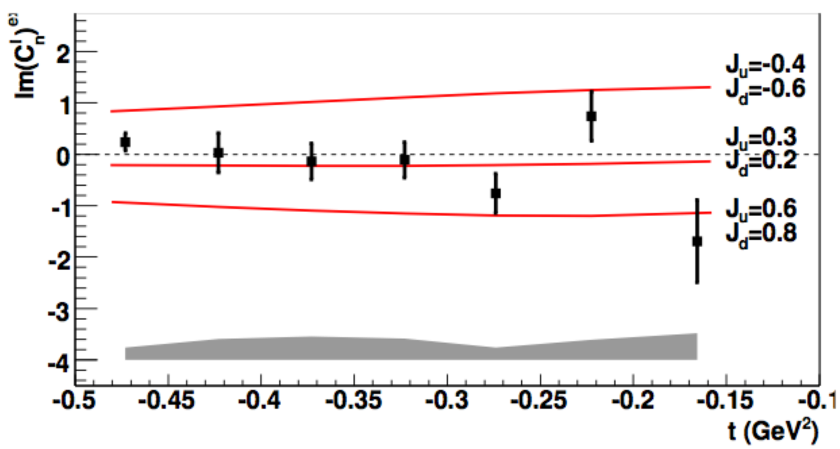
-Neutron: PRL 99: 242501 (2007)

$-\pi^0$ electro-production: PRC 83 (2011) 025201

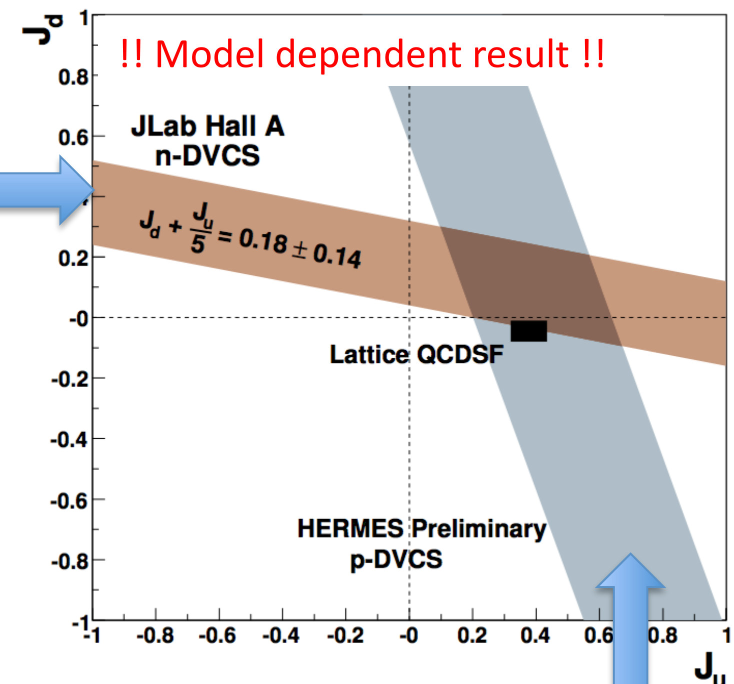
Neutron experiment PRL 99: 242501 (2007)

Ji's sum rule on the fraction of the proton spin carried by quarks:

$$\frac{1}{2} = J_q + J_g \quad \text{and} \quad J_q = \lim_{t \to 0} \int_{-1}^{+1} dx\, x\, [H_q(x,\xi,t) + E_q(x,\xi,t)]$$



VGG model with various parameters defining the GPD E (-> different values of J_u and J_d)



Hermes:
Unpolarized beam, transversly polarized proton target

Ji, PRL 78:610 (97) VGG, Phys Rev D 60: 094017 (99) Lattice, PRL 92:042002 (04) Hermes, Eur Phys J C46:729 (06)