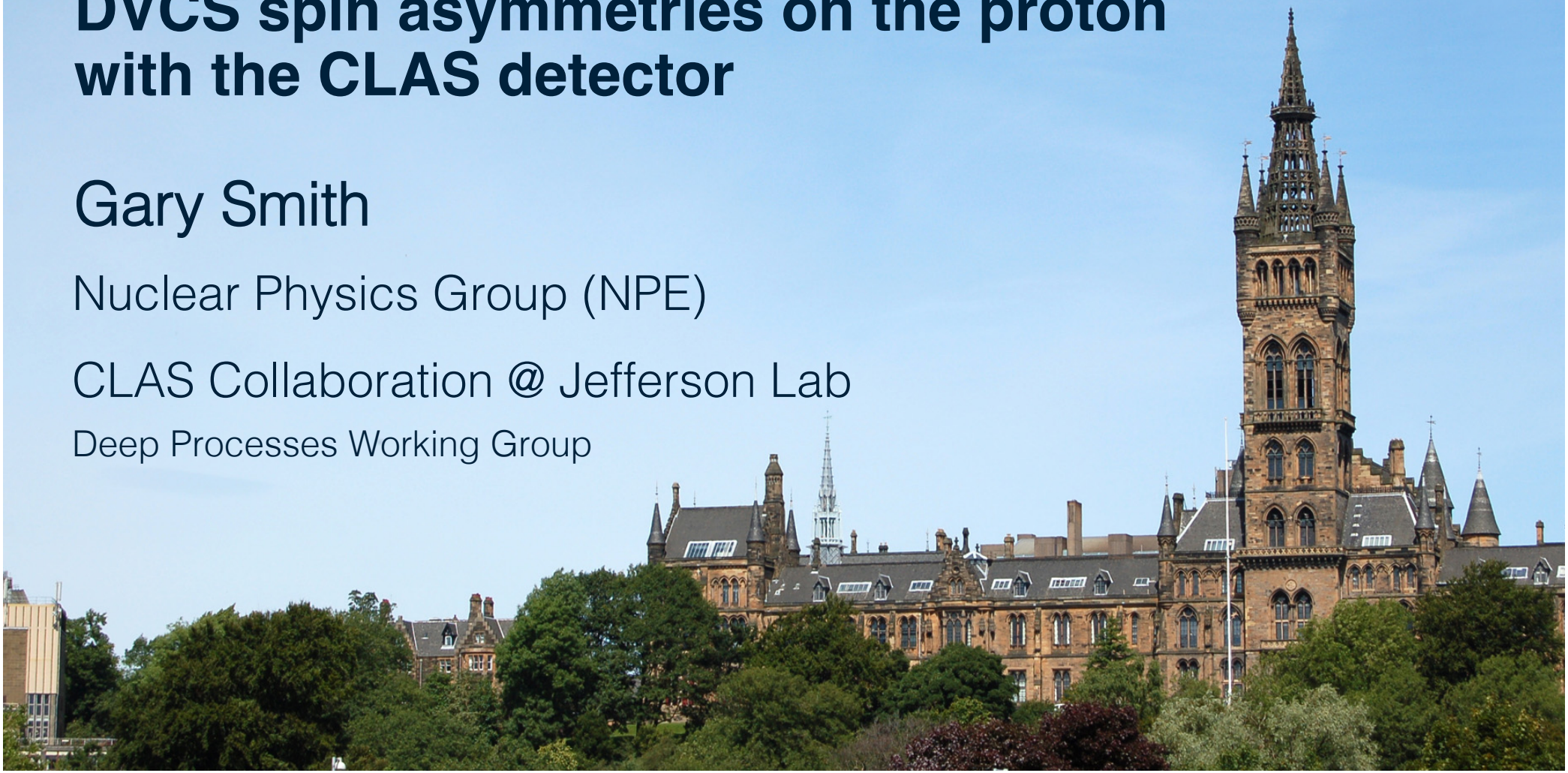
DVCS spin asymmetries on the proton with the CLAS detector

Gary Smith

Nuclear Physics Group (NPE)

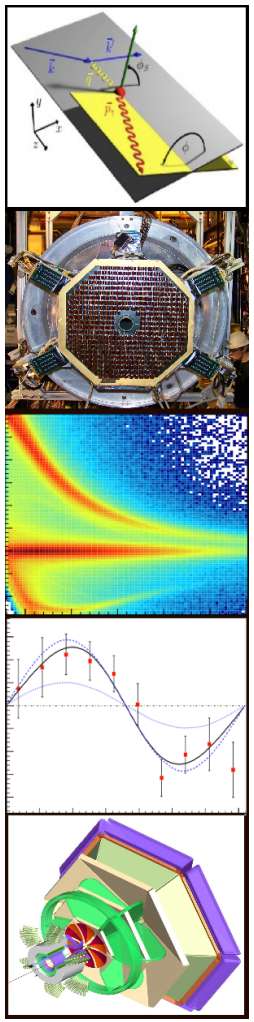
CLAS Collaboration @ Jefferson Lab

Deep Processes Working Group



Introduction

Motivation	DVCS and GPDs - nucleon structure
Experiment	CEBAF@Jefferson Lab, CLAS (Hall B) Inner Calorimeter (IC), polarised target
Analysis	particle ID & data cuts, asymmetries maximum likelihood fitting method
Results	previous, preliminary
Future	Eg1dvcs, CLAS12



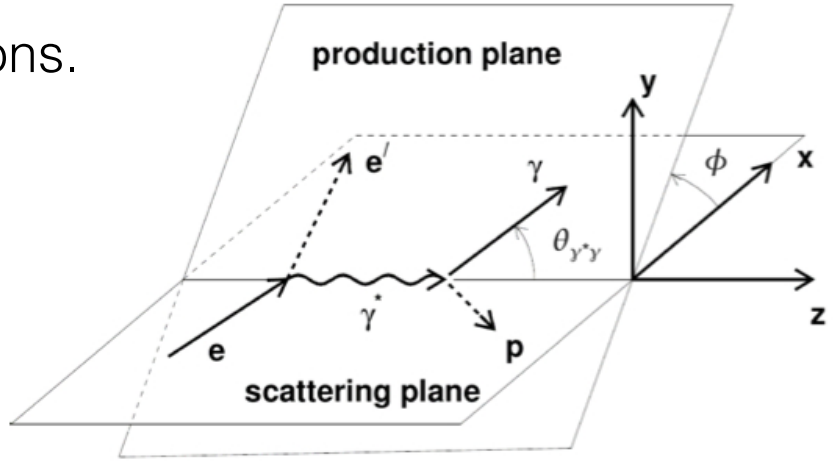
Motivation

DVCS provides a means to access GPDs

- Deeply Virtual Compton Scattering (DVCS) is the hard exclusive leptoproduction of photons.

$$lN \rightarrow l'N'\gamma$$

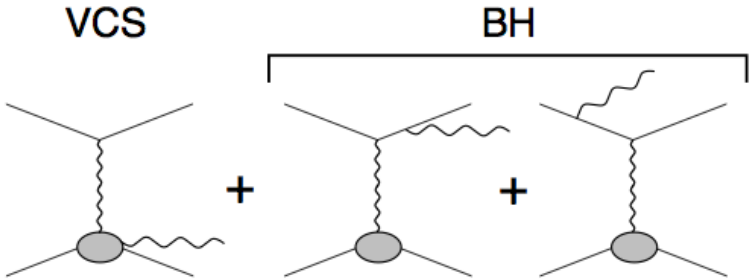
Image from D.Mahon HERMES thesis 2010
DVCS off longitudinally polarised protons at HERMES



- Generalised Parton Distributions (GPDs) describe *nucleon structure* in terms of correlated momentum and position distributions of partons.

Motivation

Image from from S.Chen CLAS thesis 2006
First measurement of DVCS with a polarised proton target



Deeply Virtual Compton Scattering

Q^2 large, fixed x

Bjorken scaling regime: "handbag approximation"

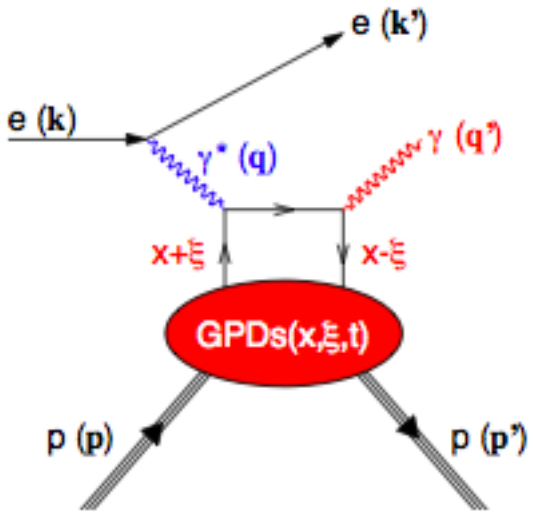


Image from D.Mahon HERMES thesis 2010
DVCS off longitudinally polarised protons at HERMES

• Lepton interacts with a single quark in the nucleon through the exchange of a virtual photon.

• Factorisation: hard scattering + parameterisation
(calculable) (measured)

Motivation

Generalised Parton Distributions

Form Factors - spatial distributions of
Elastic Scattering currents and charges

Parton Distribution Functions - momentum distributions of quarks and gluons
Deep Inelastic Scattering

Generalised Parton Distributions - correlated position and momentum distributions of quarks and gluons
DVCS, DVMP,..

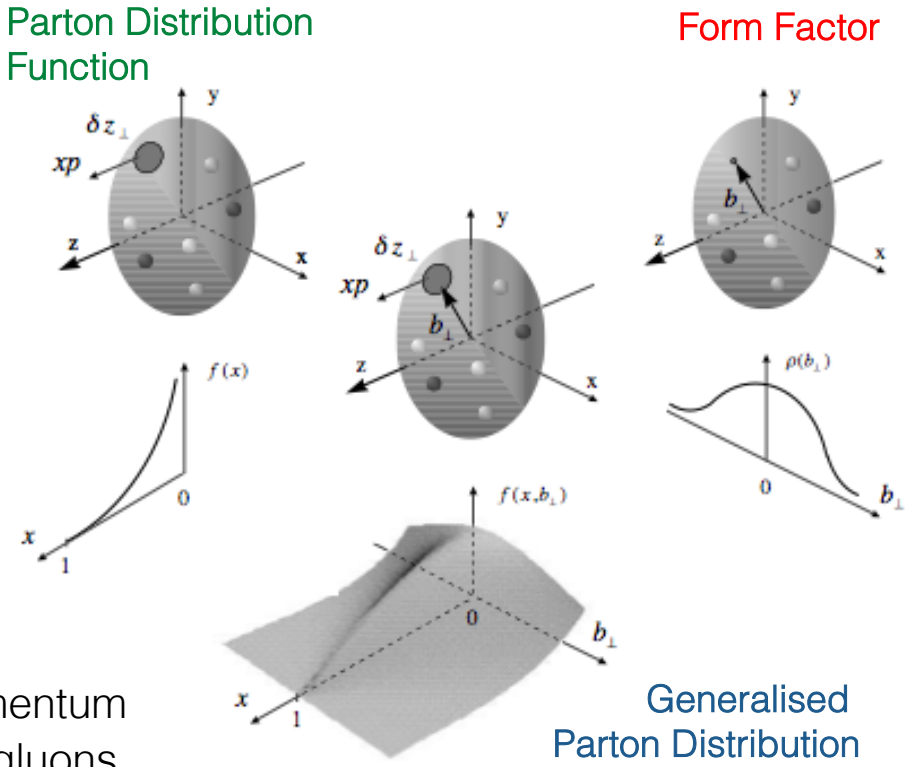
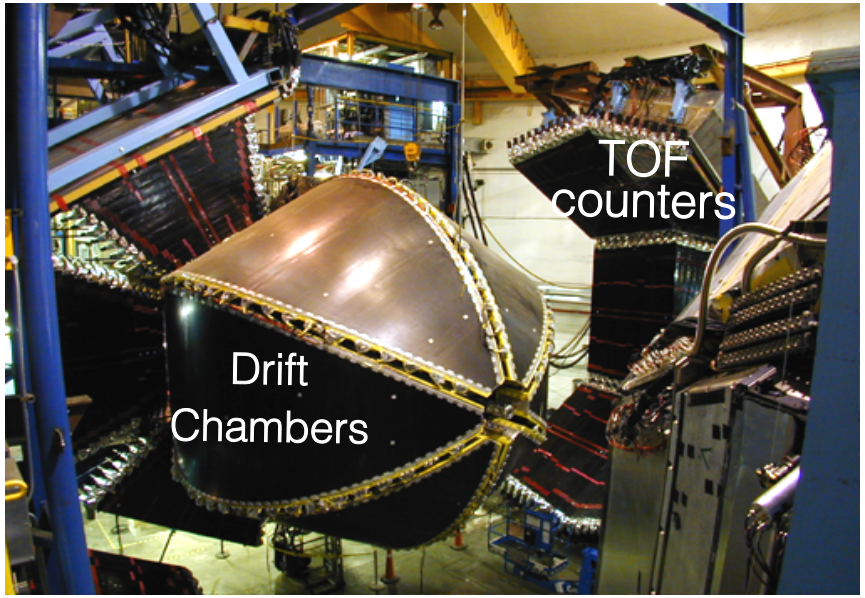


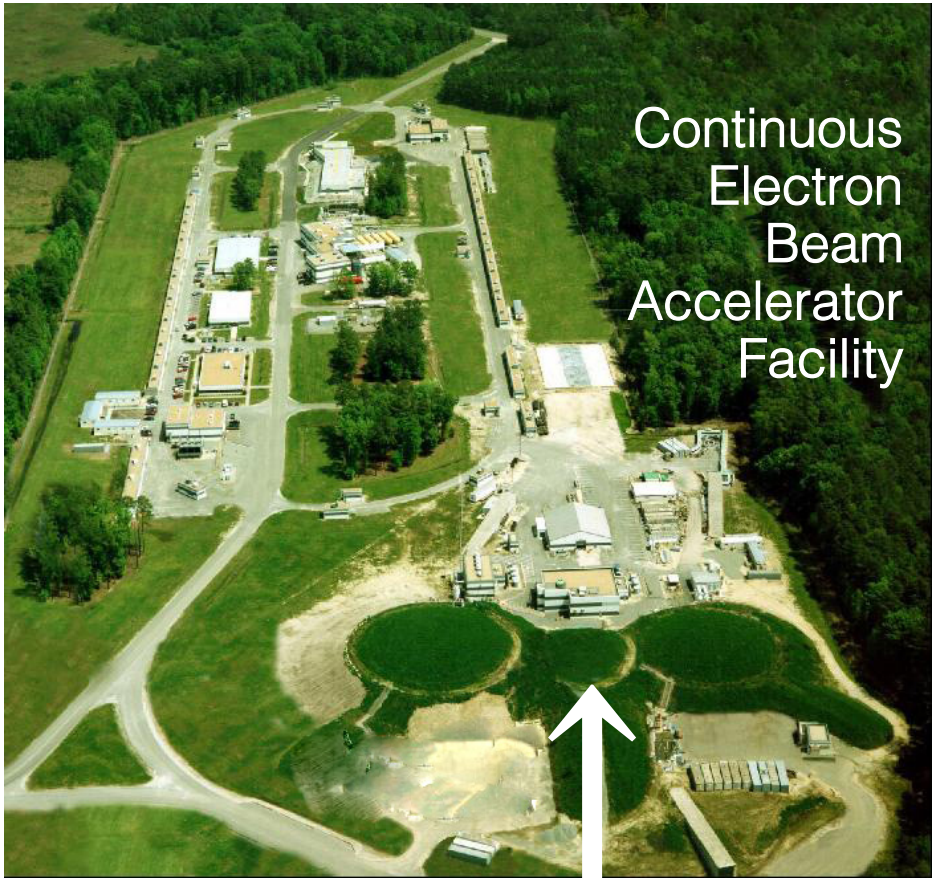
Image adapted from Belitsky, Mueller 2002
Nuclear hologram with exclusive leptoproduction

Experiment

Jefferson Lab - US department of energy funded nuclear research facility

CEBAF Large Acceptance Spectrometer (CLAS) in experimental Hall B



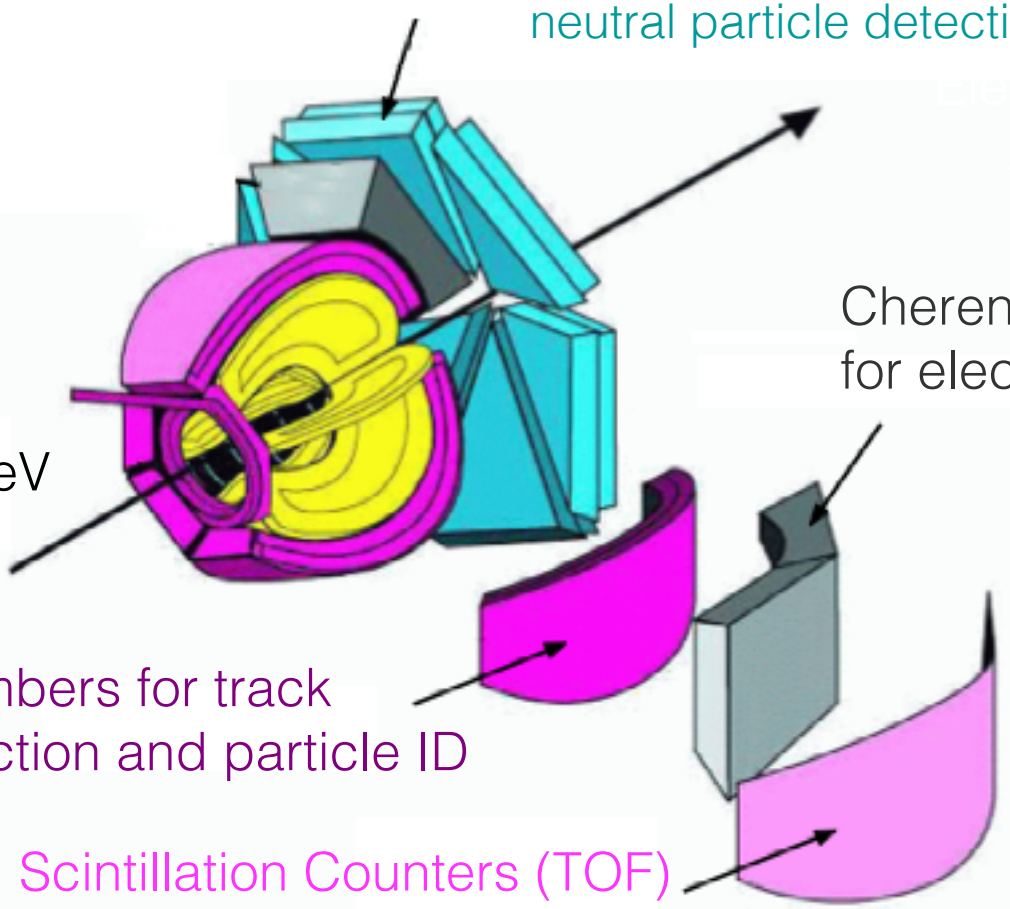


Hall B

Experiment

Electromagnetic Calorimeters for primary electron triggering, pion rejection & neutral particle detection

Longitudinally polarised electron beam (~80%) with energies up to 6 GeV



Cherenkov Counters for electron ID

Drift Chambers for track reconstruction and particle ID

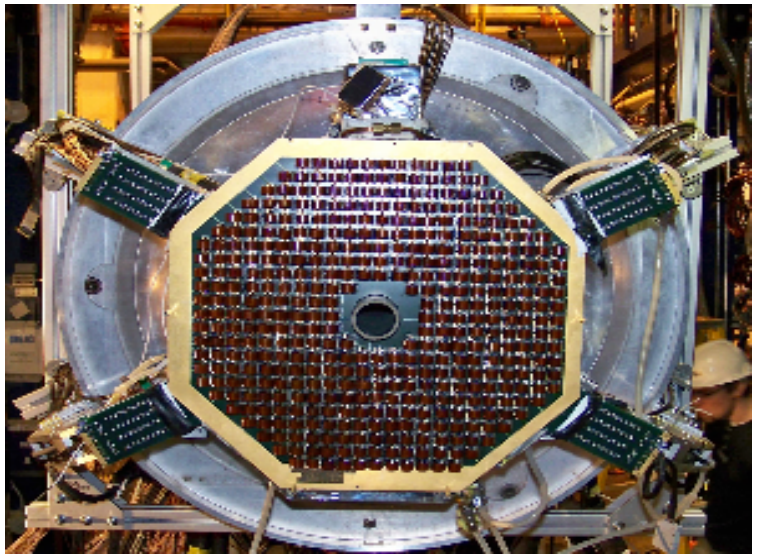
Scintillation Counters (TOF)

Experiment

Target cells

- EG1DVCS data acquired 14 02 09 - 16 03 09 A
  23 04 09 - 15 06 09 B
  21 08 09 - 21 09 09 C
- NH_3 and ND_3 longitudinally polarised targets
  proton polarisation ~%80
  10% ^{12}C for background studies

- Inner Calorimeter added to the CLAS detector system to accommodate photon detection at smaller angles

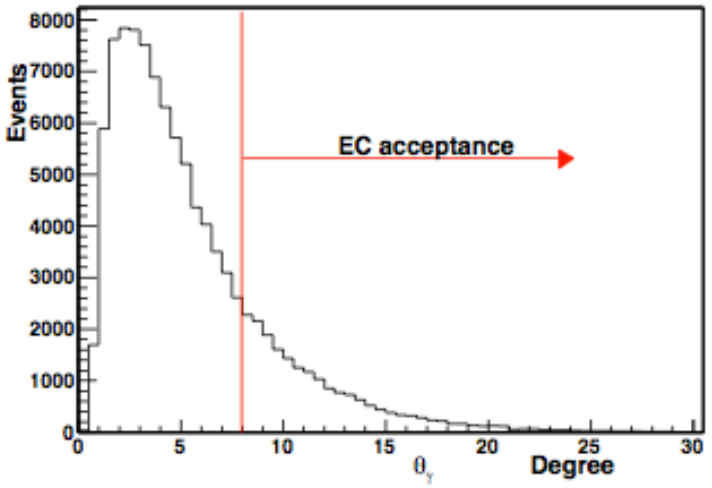

Inner Calorimeter

Experiment

Target cells

- EG1DVCS data acquired 14 02 09 - 16 03 09 A
  23 04 09 - 15 06 09 B
  21 08 09 - 21 09 09 C
- NH_3 and ND_3 longitudinally polarised targets
  proton polarisation ~%80
  10% ^{12}C for background studies

Image from from S.Chen CLAS thesis 2006



DVCS photon scattering angle from MC simulation

- Inner Calorimeter added to the CLAS detector system to accommodate photon detection at smaller angles

Analysis

Particle ID and data cuts - electrons

- Momentum

Drift Chambers (DCs) $\delta p/p \sim 1\%$

low momentum particle events rejected

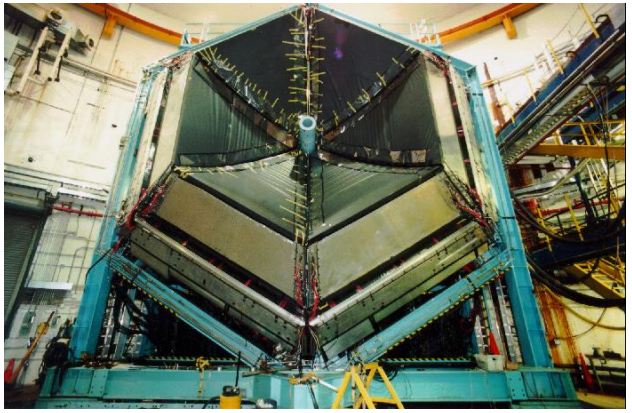
- π^- rejection

Cherenkov Counter - minimum number of photoelectrons

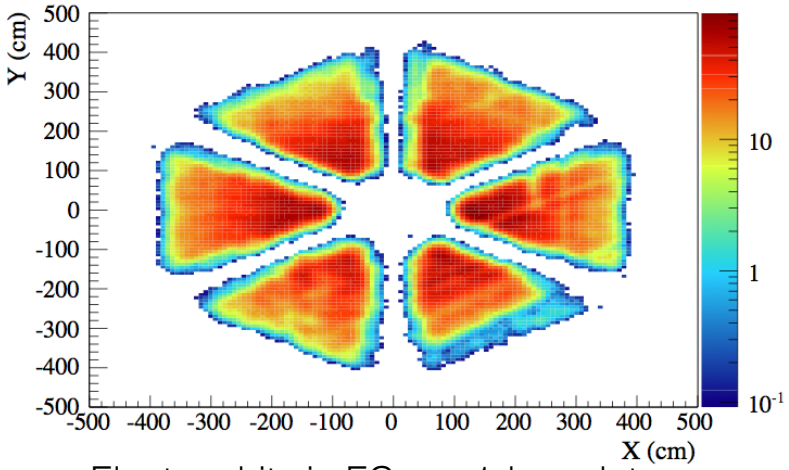
Electromagnetic Calorimeter - minimum energy, $0.2<E/p<0.4$

- Fiducial Cuts

Hits in low efficiency regions are removed (EC,DCs)



Hall B Electromagnetic Calorimeter (EC)



Electron hits in EC - eg1dvcs data

Analysis

Particle ID and data cuts - protons

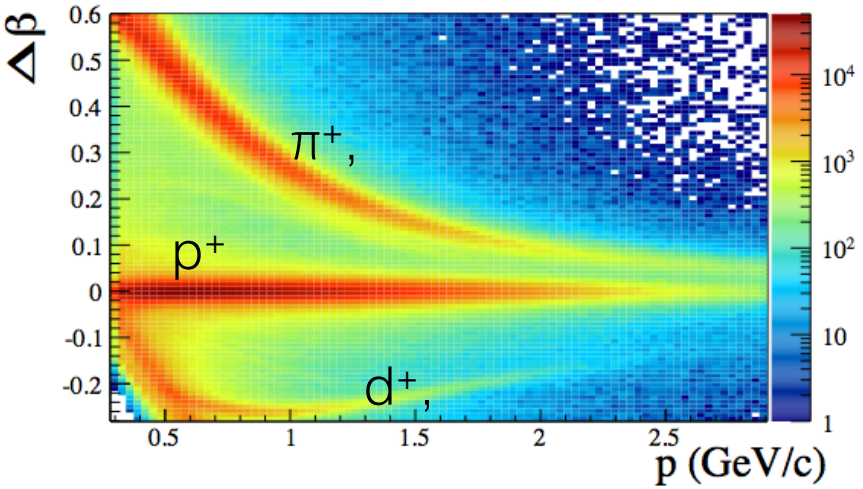
- π^+,d^+,… rejection

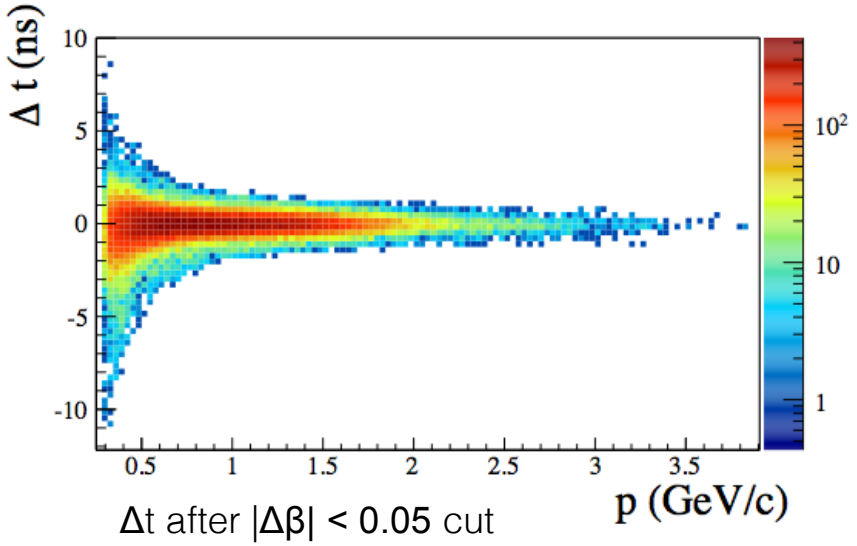
$$\Delta\beta = \frac{d_{TOF}}{ct_{TOF}} - \frac{p}{\sqrt{p^2+m^2}}$$

$$\Delta t = \frac{d_{TOF}\sqrt{p^2+m^2}}{cp} - t_{TOF}$$

- Fiducial Cuts

Hits in low efficiency regions are removed (DCs)





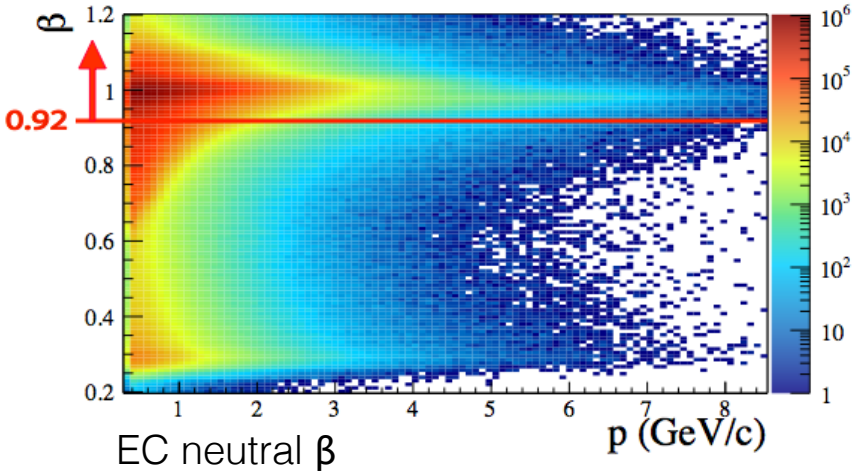
Δt after |Δβ| < 0.05 cut

Analysis

Particle ID and data cuts - photons

- neutron rejection in EC

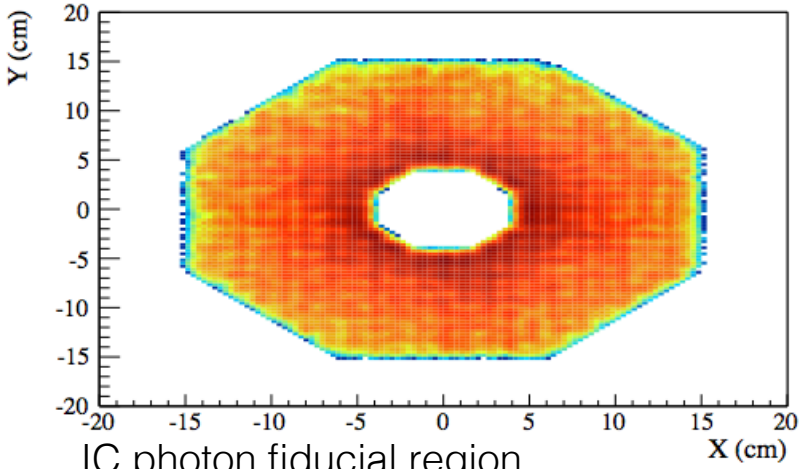
β calculated using EC time of flight



EC neutral β

- Fiducial Cuts

Hits in low efficiency regions are removed (EC, IC)



IC photon fiducial region

Analysis

Particle ID and data cuts - exclusivity

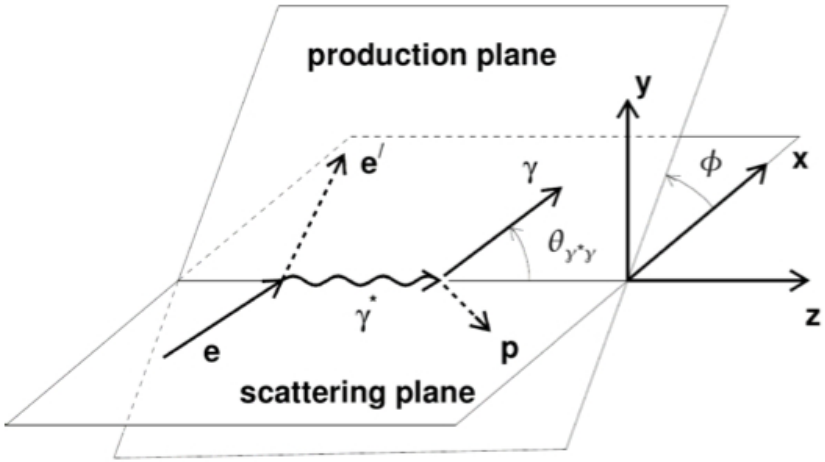
- select region of phase-space where DVCS contribution is large compared with background processes: Bethe-Heitler, reactions on Nitrogen, π^0 production

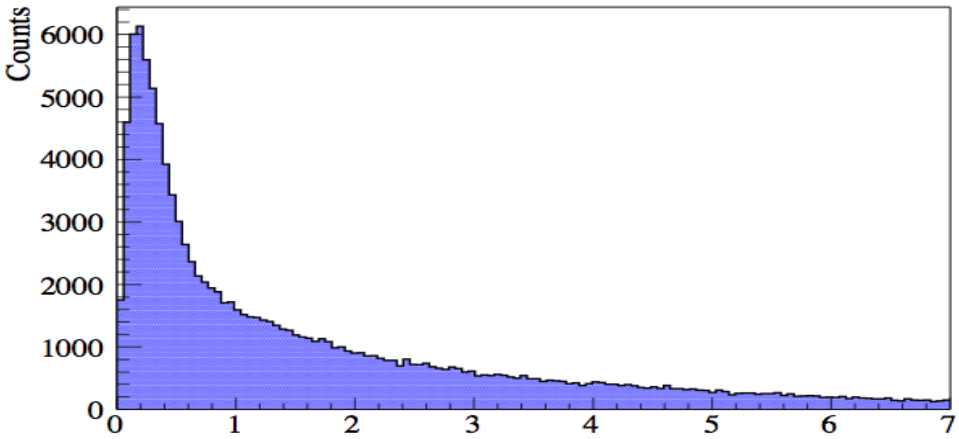
$$E_{\gamma}^{min} \simeq 2.5\ GeV$$

$$\Delta\phi^{max} = \phi_{p'} - \phi_{\gamma} \simeq 2^{\circ}$$

$$|MM_X^{ep \to e'p'\gamma}|^2 \simeq 0.2\ GeV/c^2$$

$$\theta_{\gamma\gamma'}^{max} \simeq 1^{\circ}$$





Cone angle between detected and reconstructed Photon (IC only) after $|MM_X|^2<0.2$, $Q^2>1$ GeV^2, $W>2$ GeV, $|\Delta\Phi|<2^o$, $E_g>2.5$ GeV cuts.

Analysis

Asymmetries

Longitudinal Target Spin Asymmetry

$$A_{UL} = \frac{d\sigma^{\Rightarrow} - d\sigma^{\Leftarrow}}{d\sigma^{\Rightarrow} + d\sigma^{\Leftarrow}} \propto [s_{1,LP}^{DVCS} + s_{1,LP}^{\mathcal{I}}]sin\phi + [s_{2,LP}^{DVCS} + s_{2,LP}^{\mathcal{I}}]sin2\phi$$

- asymmetries formed from different combinations of beam and target polarisations are sensitive to different GPDs (via Compton Form Factors).

- easier to measure than cross-sections since some systematic uncertainties cancel in the ratio and the opposite coupling of BH terms to the polarisation causes DVCS and interference terms only to remain.

Analysis Data fitting methods

Least squares fitting method
- minimise chi-squared

$$\chi^2 = \frac{1}{n}\sum_{i=0}^{n}\left[\frac{y - f(x_i|\theta)}{\sigma_i}\right]^2$$

Extended Maximum Likelihood

- $\frac{\partial(lnL)}{\partial\theta} = 0$

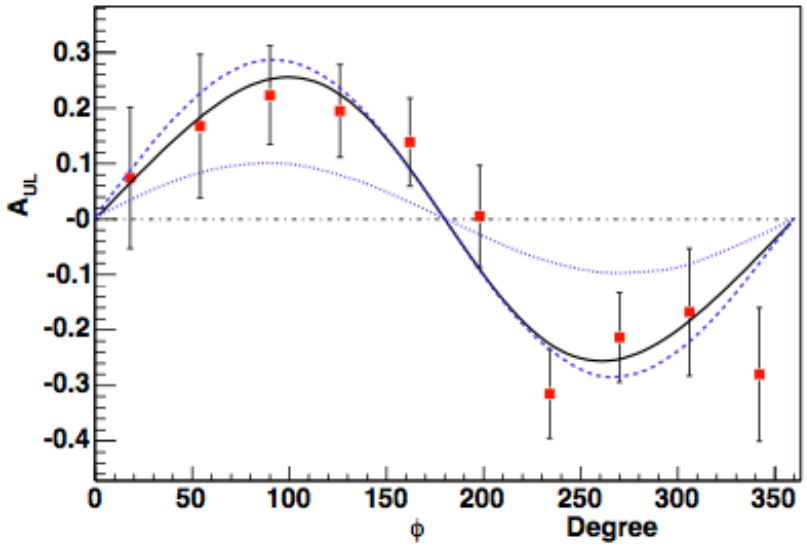
$$L = \frac{\mu^n e^{-\mu}}{n!}\prod_{i=1}^{n} p(x_i|\theta)$$

μ = μ(θ): expectation value

No binning in ϕ - one less systematic error
Simultaneous A_{UL}, A_{LL} extraction - correlated errors
Cross-check with least-squares - independence of fitting procedure

Results

Previous



Target Spin Asymmetry EG1B group
(S.Chen thesis 2006)

_____ fit to data
$p_0 \sin\phi + p_1 \sin 2\phi$
$p_0 = 0.252 \pm 0.041$
$p_1 = -0.022 \pm 0.045$

---------- MRST02 model prediction

..... same as above with $\tilde{H} = 0$

Preliminary

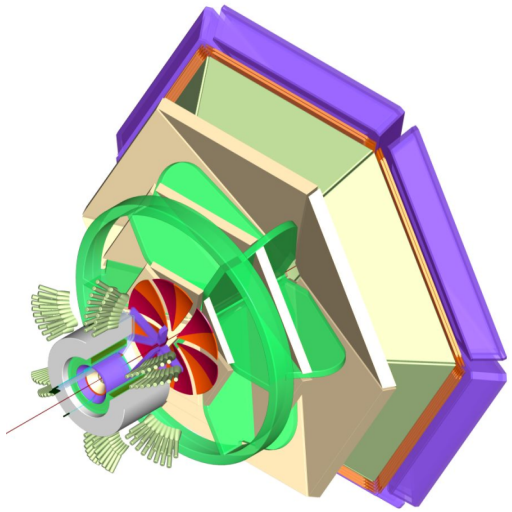
Future

Eg1dvcs

- Pass 1 cooking: in progress.
- Maximum Likelihood fit to asymmetries.
- Simulation to determine background contribution.
- 10x increase in statistics will allow study of DVCS variable dependencies of Asymmetries and reduced statistical errors.

CLAS12

- Upgrade of CLAS to coincide with CEBAF electron beam upgrade to 12 GeV
  - first experiments in 2015
- Larger Q^2 for DVCS and DVMP
- Neutron DVCS with Central Neutron Detector



Thanks

KYUNGPOOK NATIONAL UNIVERSITY 경북대학교

Fairfield UNIVERSITY

UNIVERSITÉ PARIS-SUD 11

WILLIAM & MARY

University of Connecticut

UNIVERSITY of VIRGINIA

INFN Istituto Nazionale di Fisica Nucleare

OLD DOMINION UNIVERSITY

UNIVERSITE JOSEPH FOURIER SCIENCES. TECHNOLOGIE. SANTÉ

NPE Glasgow

Jefferson Lab

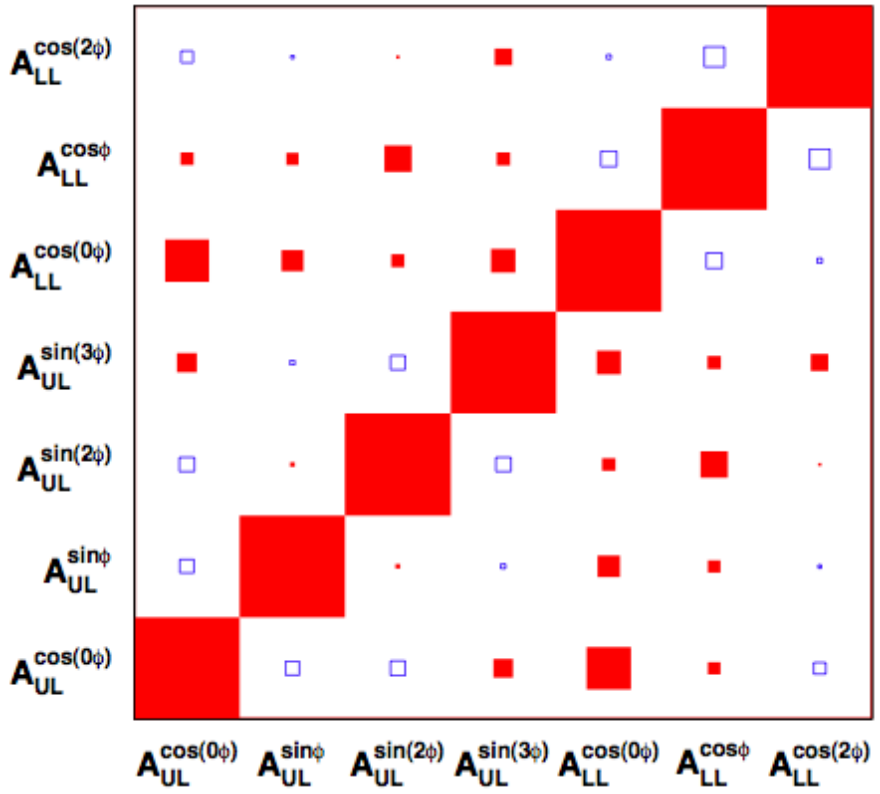
Science & Technology Facilities Council

IOP Institute of Physics

Backup Slide

Correlation Matrix

- Size of box represents size of correlation.

- Filled (open) squares are positive (negative) values.

D.Mahon PhD thesis 2010 - HERMES