# Proton Compton Scattering in the Wide-angle Regime

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Presentation Outline:

- Overview of the physics of Wide-Angle Compton Scattering
- Jefferson Lab WACS programme
- Experimental and analysis techniques
- E99114 cross section and polarisation results
- E07002 preliminary results

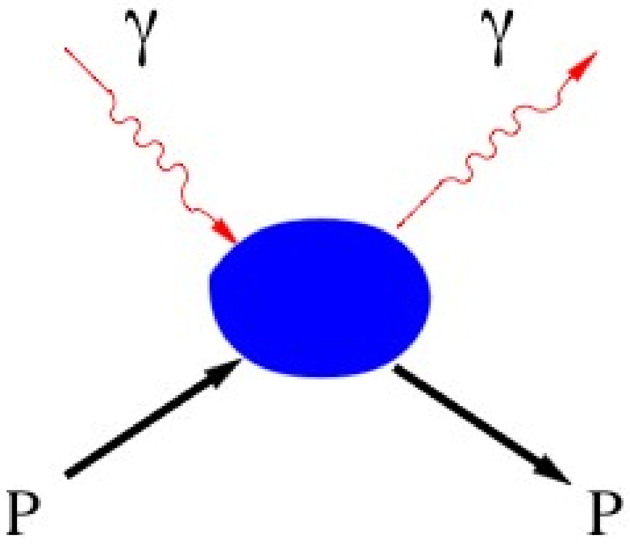
# Why WACS?

Proton Compton scattering in the wide-angle regime ($s, -t, -u >> m^2_{nucleon}$) is a powerful and under-utilised probe of nucleon structure.

Similar physics in play as in elastic ep or DVCS: characterise electromagnetic response of the nucleon without complications from additional hadrons.

Main issues:

- Competing reaction mechanisms
- Interplay between hard and soft processes
- Threshold for onset of asymptotic regime
- Role of hadron helicity flip

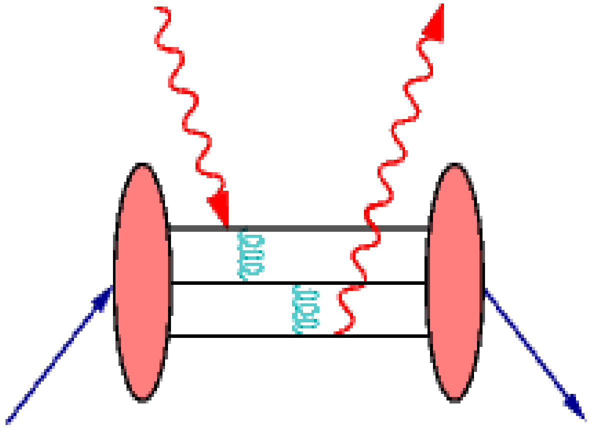


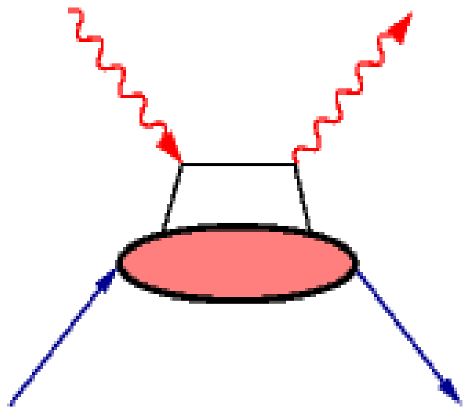
# Test of Reaction Mechanism

A number of reaction mechanisms have been proposed over the years:

- Regge exchange (VMD) - J. M. Laget et al.
- pQCD (two-gluon exchange) – S. Brodsky, P. Guichon, M. Vanderhaeghen
- GPDs (handbag) – A. Radyushkin, P. Kroll et al.
- CQM – G.Miller

Which mechanism is dominant in the few GeV regime?





# GPDs in the Handbag Approach

$$\gamma p \to \gamma p$$

$$R_V(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} H^a(x,0,t),$$

$$R_A(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} \,\mathrm{sign(x)}\, \hat{\mathrm{H}}^a(\mathrm{x},0,\mathrm{t}),$$

$$R_T(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} E^a(x,0,t),$$

$$ep \to ep$$

$$F_1(t) = \sum_a e_a \int_{-1}^{1} dx\, H^a(x,0,t),$$

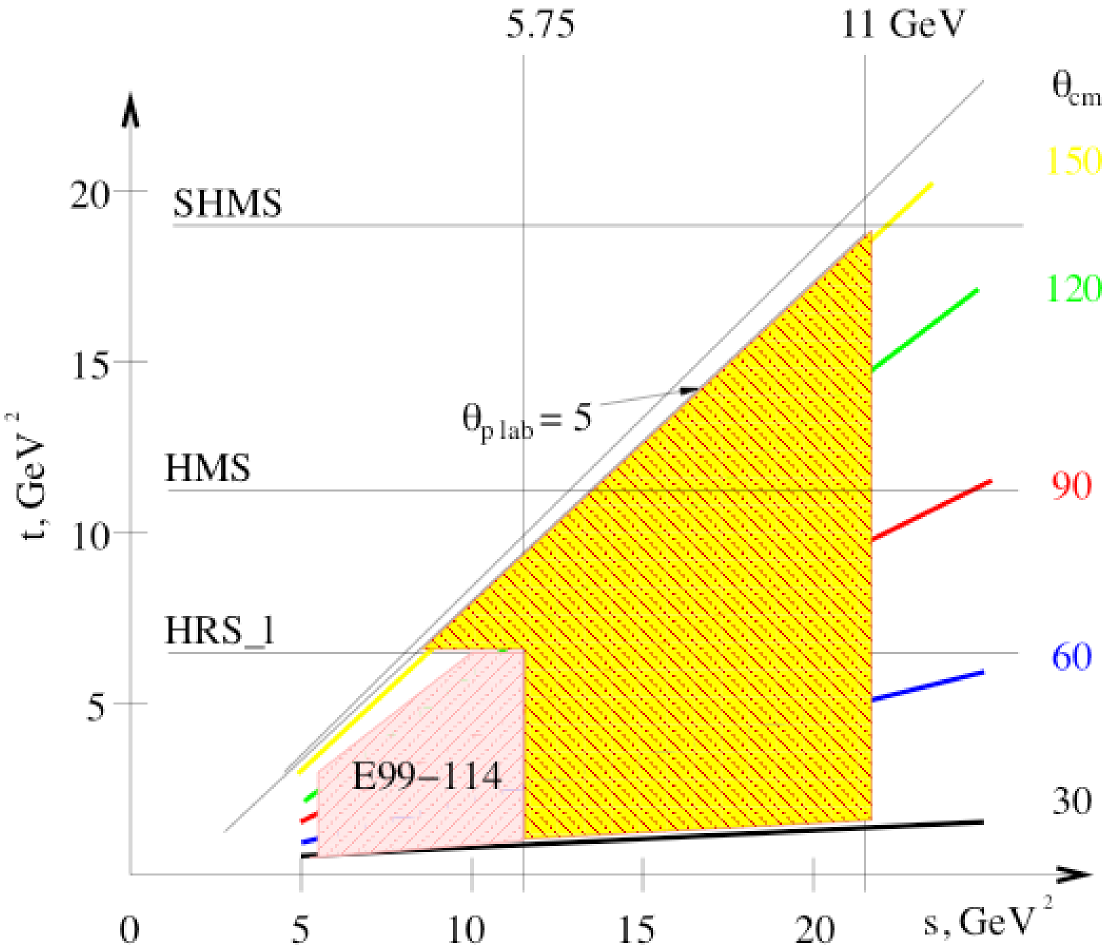
$$G_A(t) = \sum_a \int_{-1}^{1} dx \,\mathrm{sign(x)}\, \hat{\mathrm{H}}^a(\mathrm{x},0,\mathrm{t}),$$

$$F_2(t) = \sum_a e_a \int_{-1}^{1} dx\, E^a(x,0,t),$$

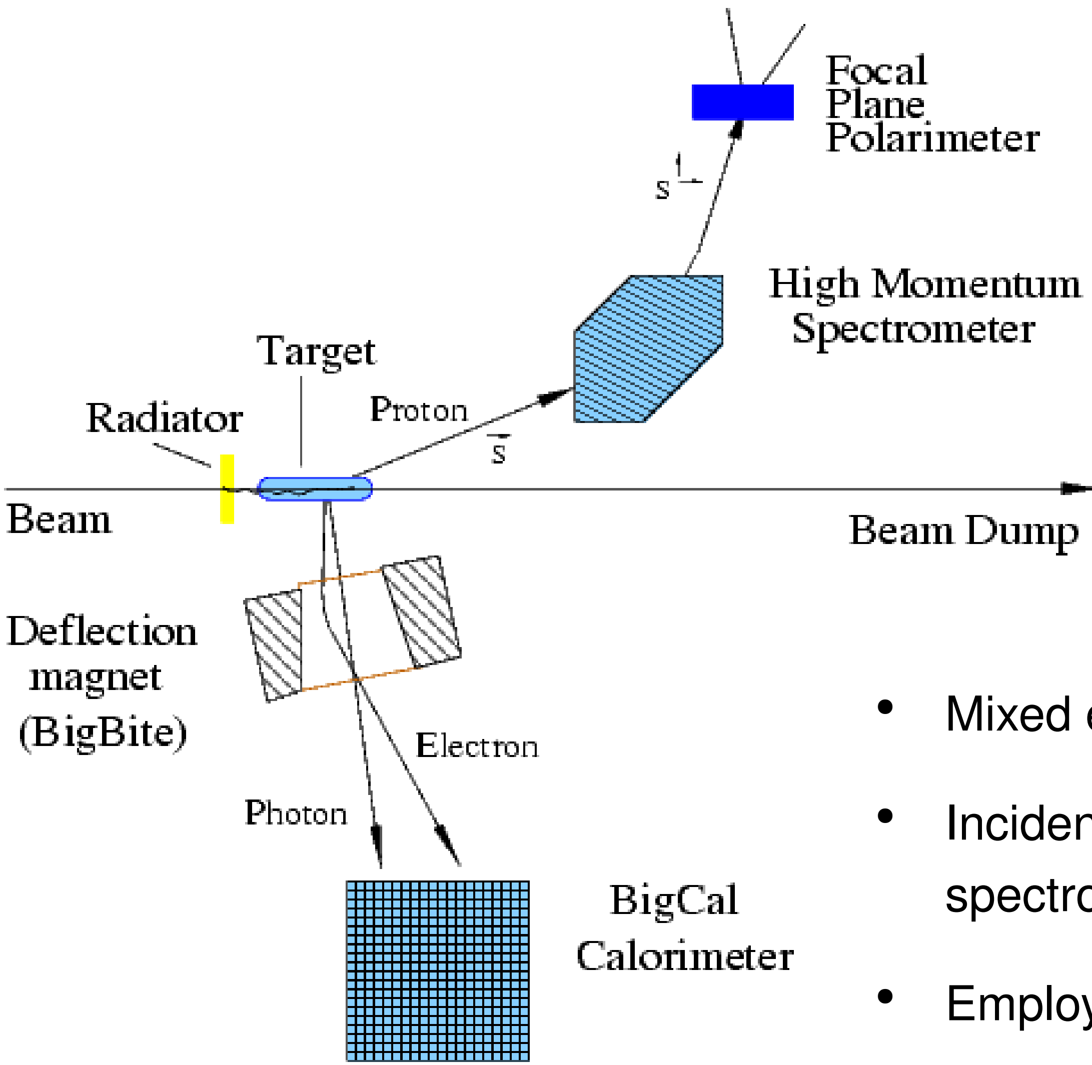
| GPD | $x^{-1}$ moment | $x^0$ moment | $t = 0$ limit |
|---|---|---|---|
| $H^a(x,0,t)$ | $R_V(t)$ | $F_1(t)$ | $q(x)$ |
| $\hat{H}^a(x,0,t)$ | $R_A(t)$ | $G_A(t)$ | $\Delta q(x)$ |
| $E^a(x,0,t)$ | $R_T(t)$ | $F_2(t)$ | $2J(x)/x - q(x)$ |

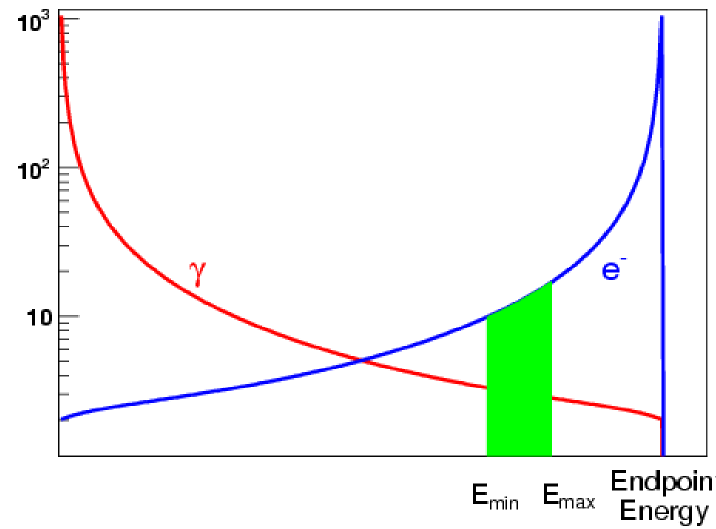
# The Jlab WACS Programme

- There have been two Jlab experiments on WACS.
- E99114 in Hall A involved measurements of cross section over a broad kinematic range and polarisation observables at a single kinematic point.
- E07002 in Hall C provided an additional measurement of polarisation observables.



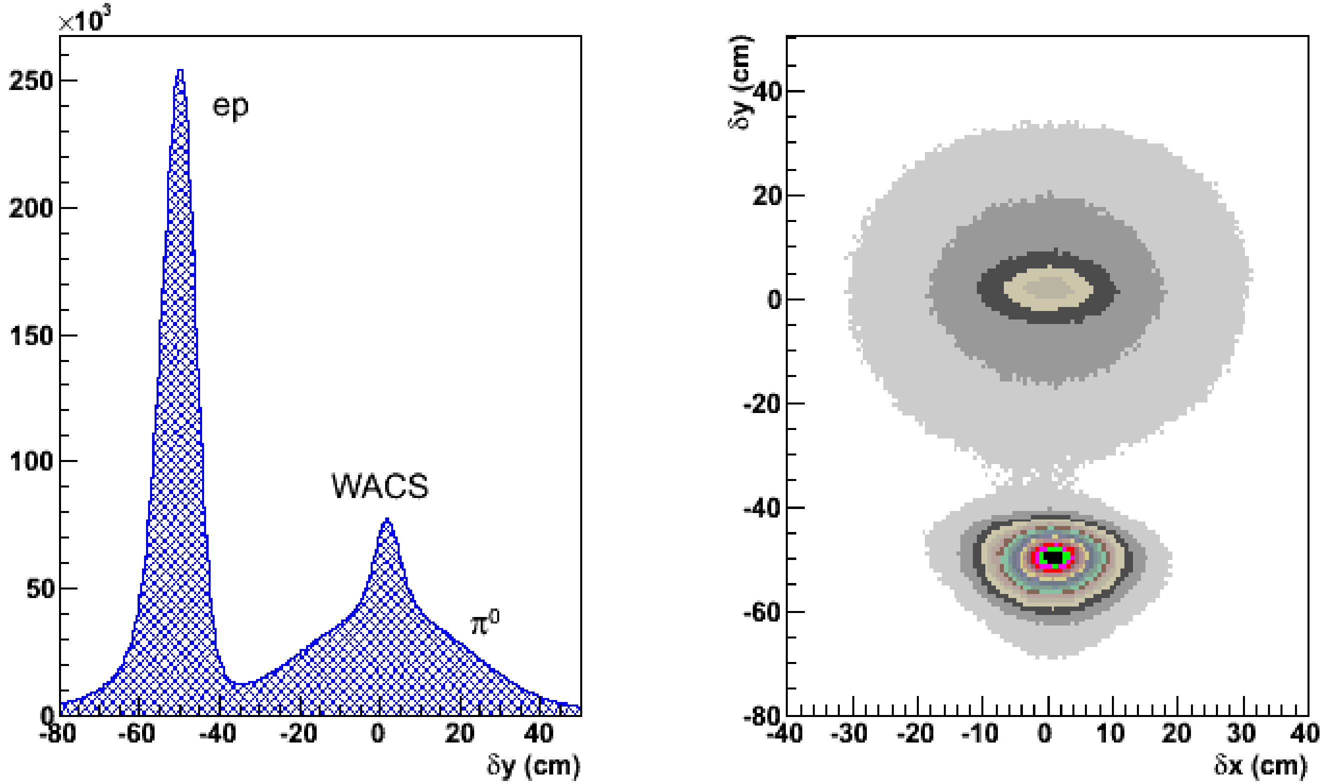
# Experimental Technique



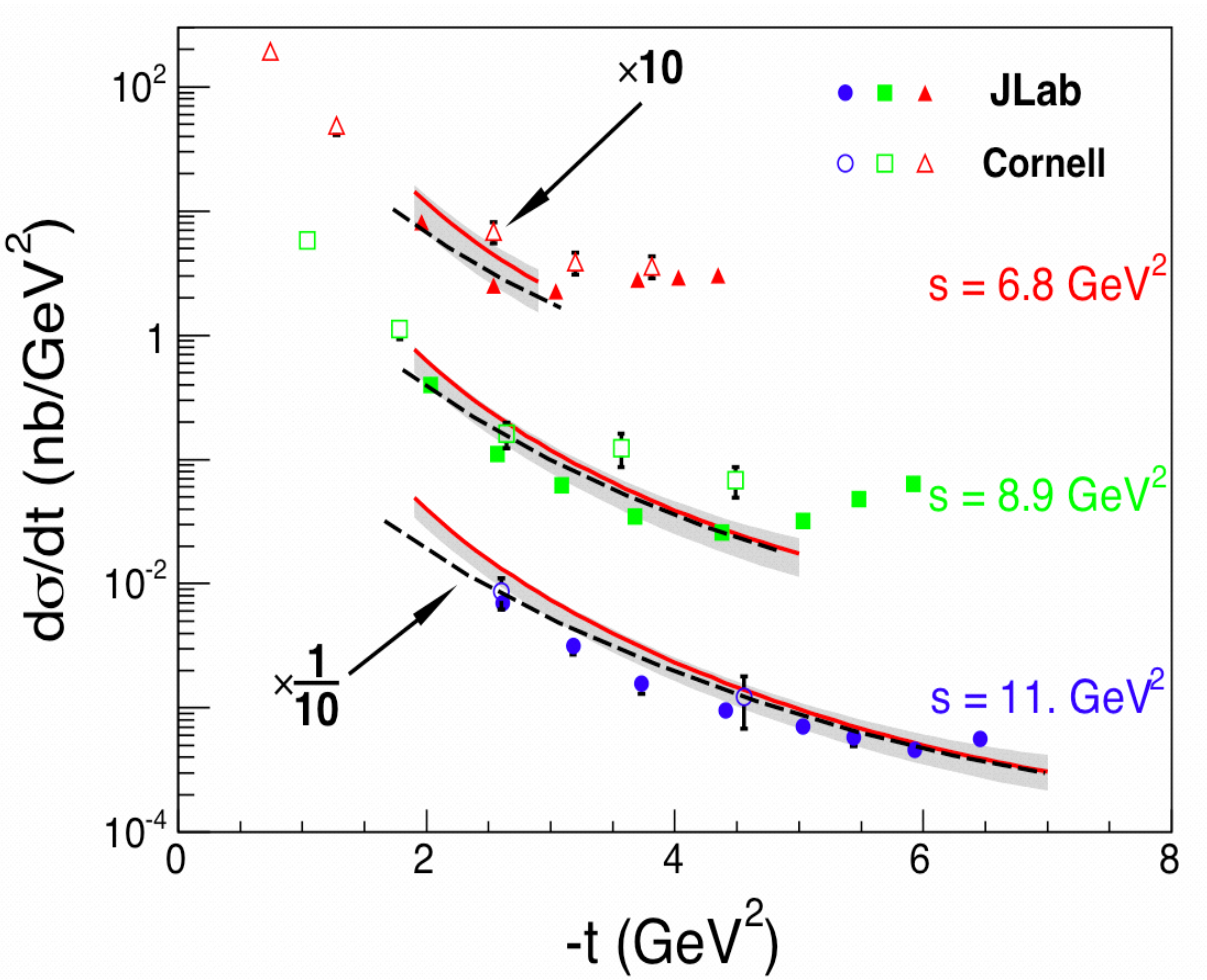

- Mixed electron/photon beam on target.
- Incident photon energy range defined by spectrometer acceptance.
- Employ magnet for electron deflection.

# Analysis: Event Selection



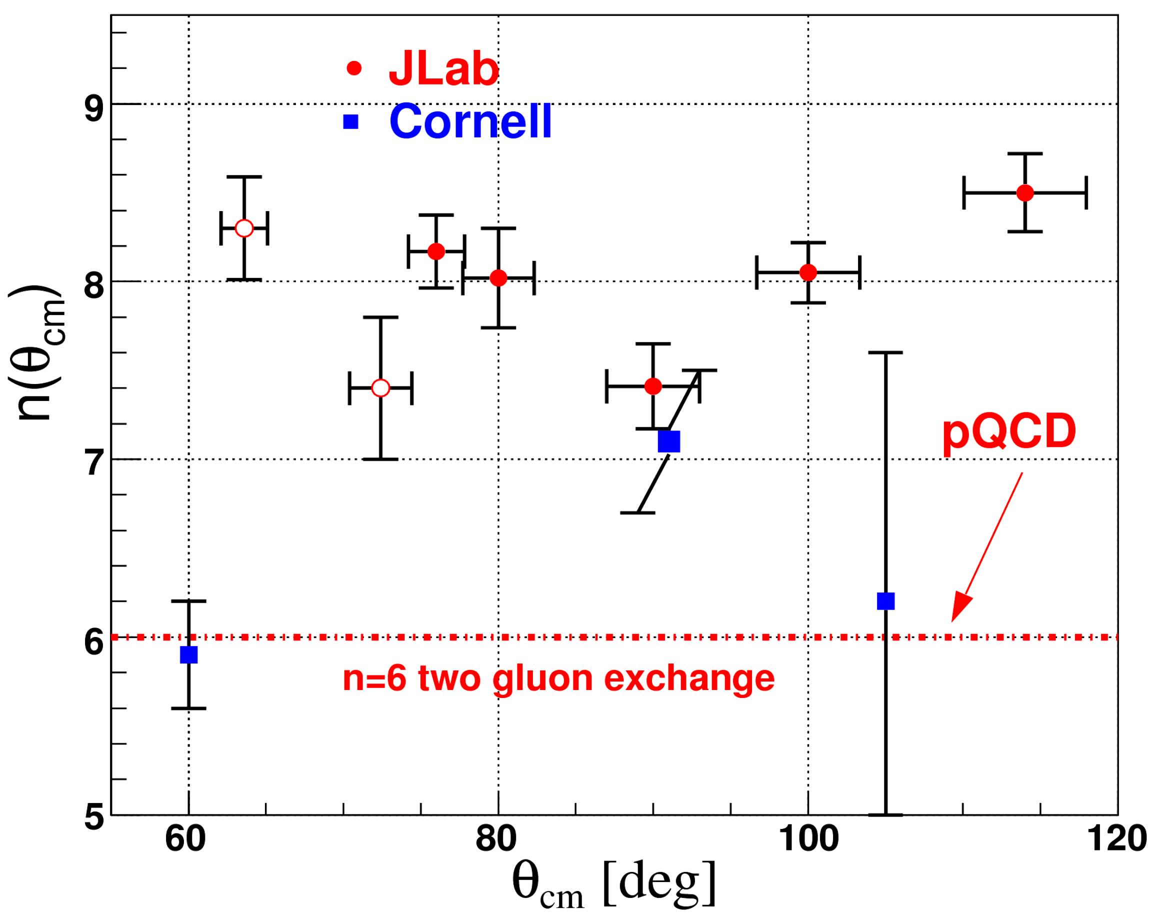

- Use two-body kinematic correlation to separate WACS and $\pi^0$ background.
- Depends critically upon combined spectrometer-calorimeter angular resolution.

# Differential Cross Section



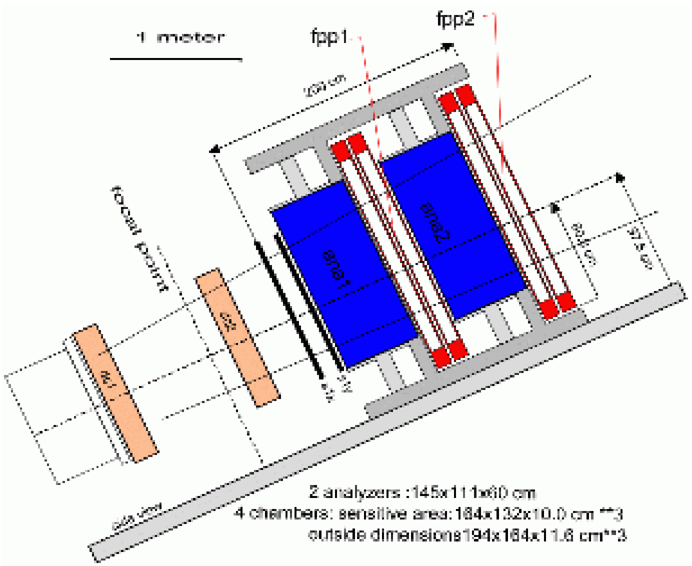

- Jlab results are in agreement with previous results from Cornell (1979).
- pQCD predictions underestimate the magnitude of the cross section data by an order of magnitude.
- Both GPD (solid red line) and CQM (dashed line) predictions give a good account of the data in the wide-angle regime.

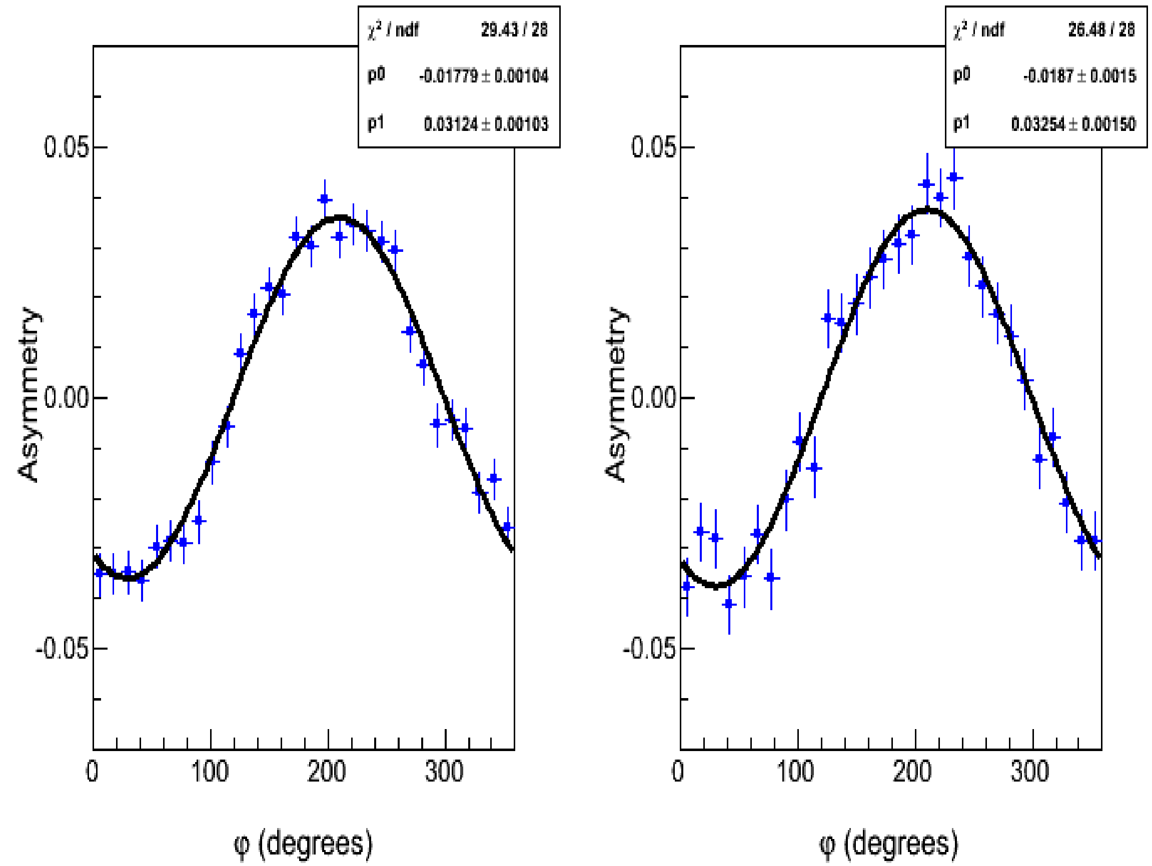
# Cross Section Scaling at Fixed CM Angle




- Limited accuracy of Cornell results for scaling of the cross section at fixed CM angle supported $s^{-6}$ prediction of pQCD.
- Jlab results reveal scaling is closer to $s^{-8}$, thus rejecting pQCD dominance in the few GeV regime.

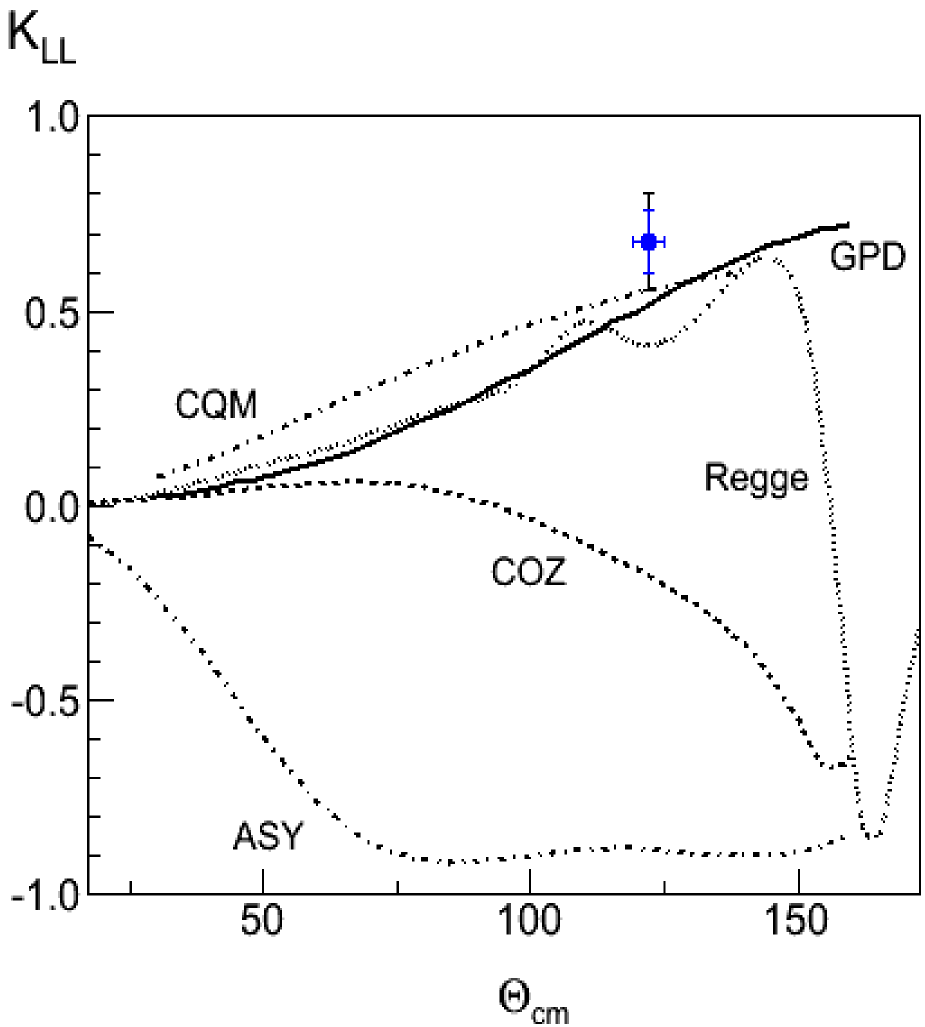
# Analysis: Polarisation Observables




- Double analyser FPP used to extract beam-helicity asymmetries at spectrometer focal plane.

# Longitudinal Polarisation Transfer



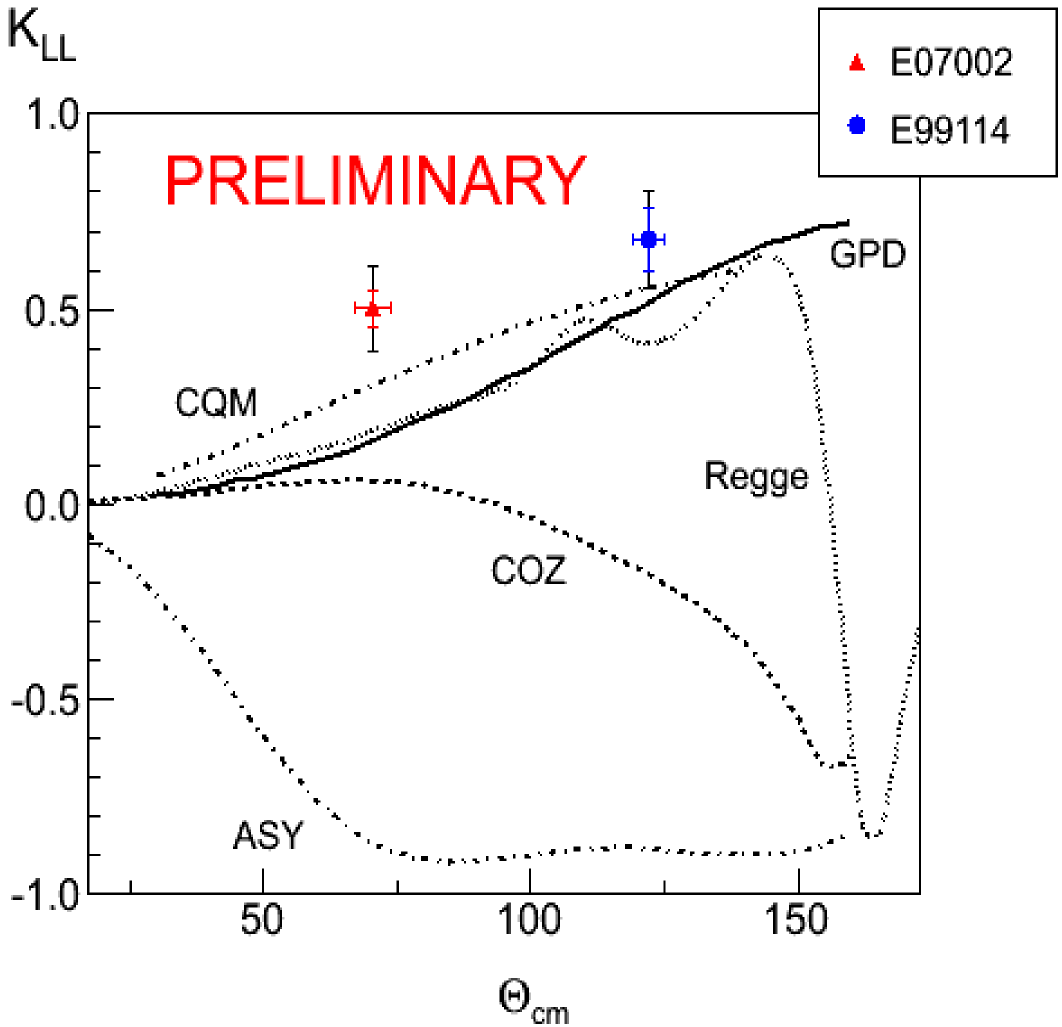

$s = 6.9\ GeV^2$

$-t = 4.0$

$-u = 1.1$

- Disagreement with pQCD predictions but $K_{LL}$ measured at low -u.
- Handbag predictions show good agreement, although limited accuracy prevents further discrimation.
- Further confirmation needed at higher s, -t and -u.

# New Results from E07002




$s = 8.0\ GeV^2$
$-t = 2.1$
$-u = 4.1$

- Systematic uncertainties remain large at this stage; will be reduced by factor 3 – 5.
- Results demonstrate that reaction proceeds through interaction of photon with a singe active quark.
- Result from E07002 highlights importance of orbital moment of active quark.

# Summary

- WACS is a powerful probe of proton structure, which is similar to elastic ep and DVCS and can be described in terms of moments of GPDs.
- Results from two Jlab experiments unambiguously demonstrate the inapplicability of pQCD approaches in the few GeV regime.
- The reaction appears instead to proceed through coupling of the photon to a single active quark in the so-called handbag mechanism.
- Non-perturbative paramterisations of the proton describe the re-absorption of this active quark.
- Recent polarisation results highlight the importance of quark orbital angular momentum in this process.