E07-002 Update: Wide-Angle Compton Scattering

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Hall C Users Meeting

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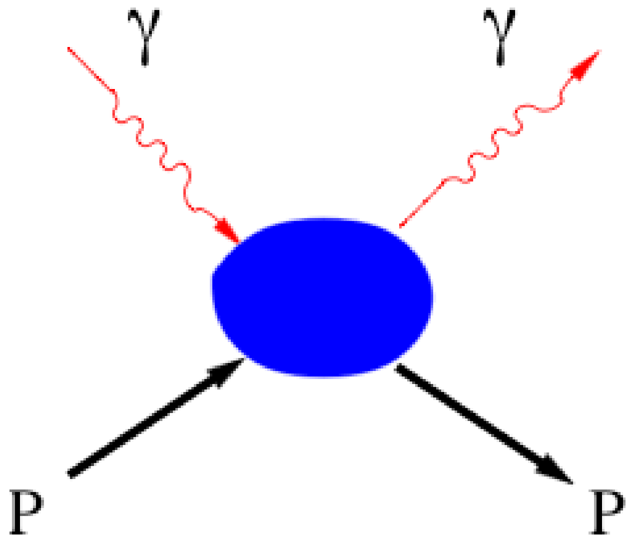
Presentation Outline:

- Brief overview of the physics of Wide-Angle Compton Scattering
- Jefferson Lab WACS programme and previous results
- Experimental techniques
- Analysis update
- Preliminary results

Relevance of WACS

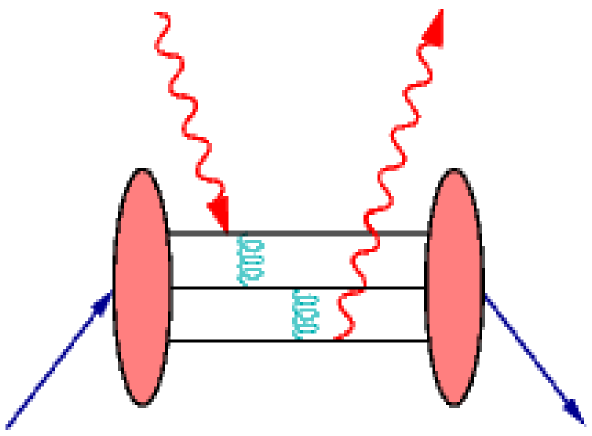
- Proton Compton scattering in the wide-angle regime ($s, -t, -u >> m^2_{nucleon}$) is a powerful and under-utilised probe of nucleon structure.
- It is an elegantly simple reactions, involving only a real photon and ground-state nucleon in both initial and final states.
- The physics in play is similar to that in elastic ep scattering or DVCS: characterise electromagnetic response of the nucleon without complications from additional hadrons.
- It is, however, one of the least understood of the fundamental reactions in the several GeV regime.



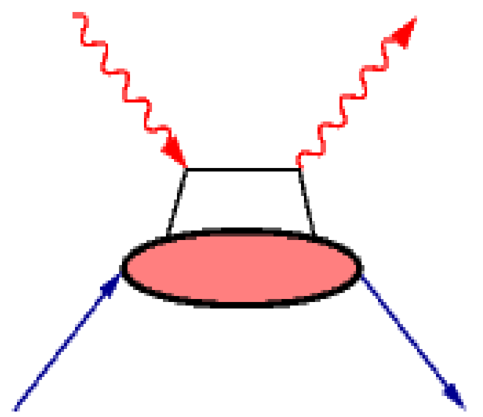
A Test of Reaction Mechanism

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

- pQCD (two-gluon exchange)
- GPDs (handbag)
- rCQM (handbag)
- Regge exchange (VMD)



Does large -t ensure short-distance coupling of the photon and proton? Is factorisation valid?



Which mechanism is dominant in the few GeV regime?

Form Factors and GPDs

$$\gamma p \rightarrow \gamma p$$

$$
\begin{aligned}
R_V(t) &= \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} H^a(x,0,t), \\
R_A(t) &= \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} \mathrm{sign(x)}\, \hat{\mathrm{H}}^{\mathrm{a}}(\mathrm{x},0,\mathrm{t}), \\
R_T(t) &= \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} E^a(x,0,t),
\end{aligned}
$$

$$ep \rightarrow ep$$

$$
\begin{aligned}
F_1(t) &= \sum_a e_a \int_{-1}^{1} dx\, H^a(x,0,t), \\
G_A(t) &= \sum_a \int_{-1}^{1} dx\, \mathrm{sign(x)}\, \hat{\mathrm{H}}^{\mathrm{a}}(\mathrm{x},0,\mathrm{t}), \\
F_2(t) &= \sum_a e_a \int_{-1}^{1} dx\, E^a(x,0,t),
\end{aligned}
$$

$$\frac{d\sigma}{dt} = \frac{d\sigma}{dt}_{KN} \left\{ \frac{1}{2}\left[R_V^2 + \frac{-t}{4m^2} R_T^2 + R_A^2 \right] - \frac{us}{s^2+u^2}\left[R_V^2 + \frac{-t}{4m^2} R_T^2 - R_A^2 \right] \right\}$$

Studying WACS can lead to constraints on GPDs at large -t and x which differ from electromagnetic form factors due to 1/x and e_a^2 factors.

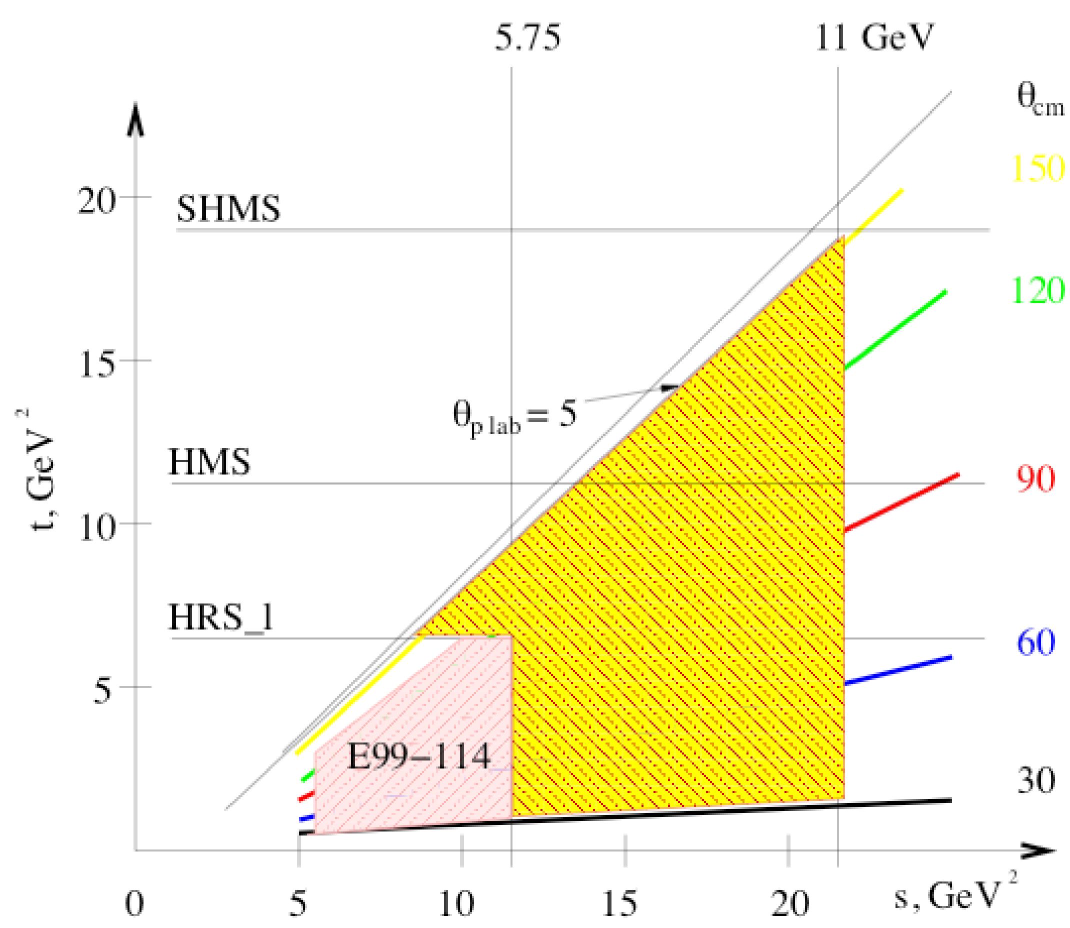
The Jlab WACS Programme

Jlab Experiment E99-114 (Hall A, 2002)

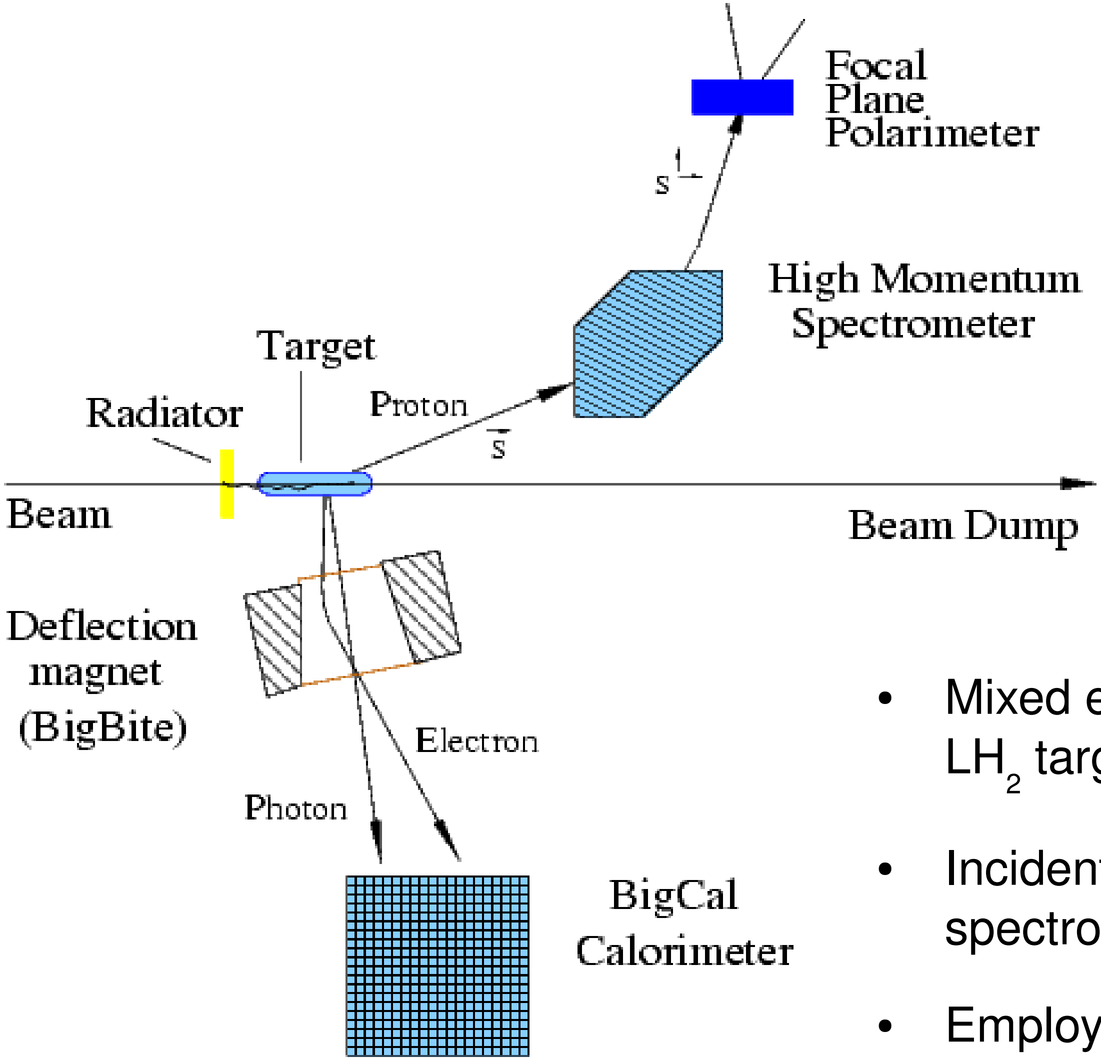
Measurments of spin averaged cross section over broad kinematic range ($6.8 < s < 11\ GeV^2$, $2 < -t < 7\ GeV^2$) and polarisation transfer K_{LL} and K_{LT} at a single point ($s = 6.9\ GeV^2$, $-t = 4\ GeV^2$).

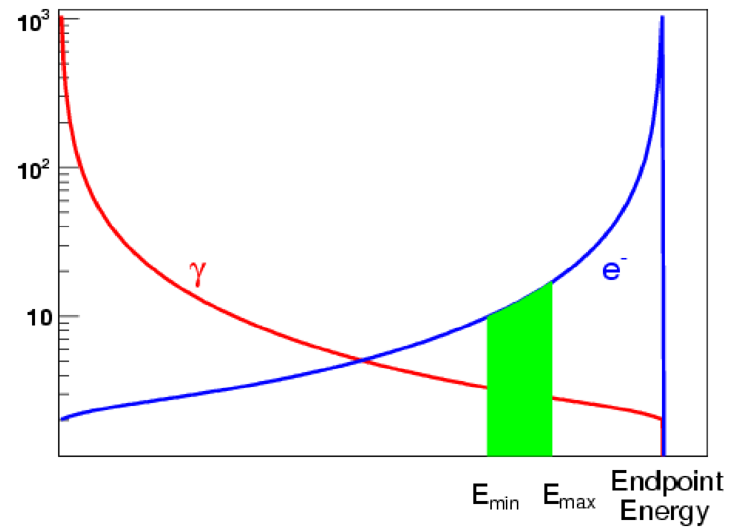
Jlab Experiment E07-002 (Hall C, 2008)

Measurement of polarisation observables K_{LL}, K_{LT}, and P_N at $s = 8.0\ GeV^2$, $-t = 2.1\ GeV^2$.



Experimental Technique

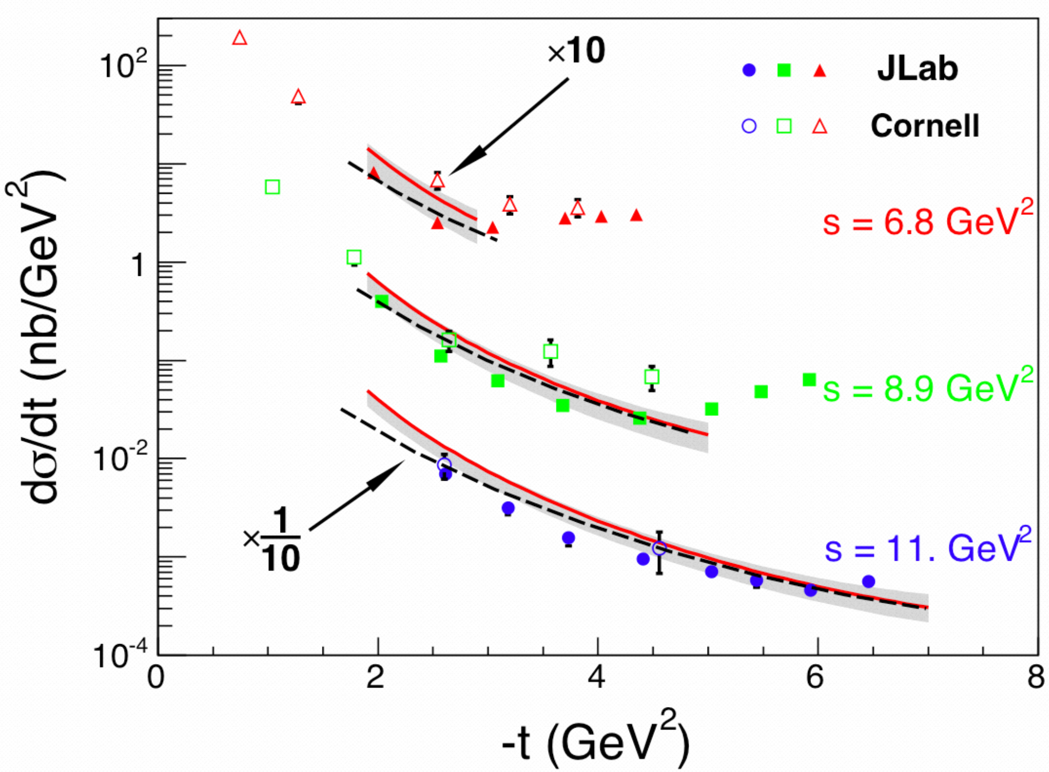




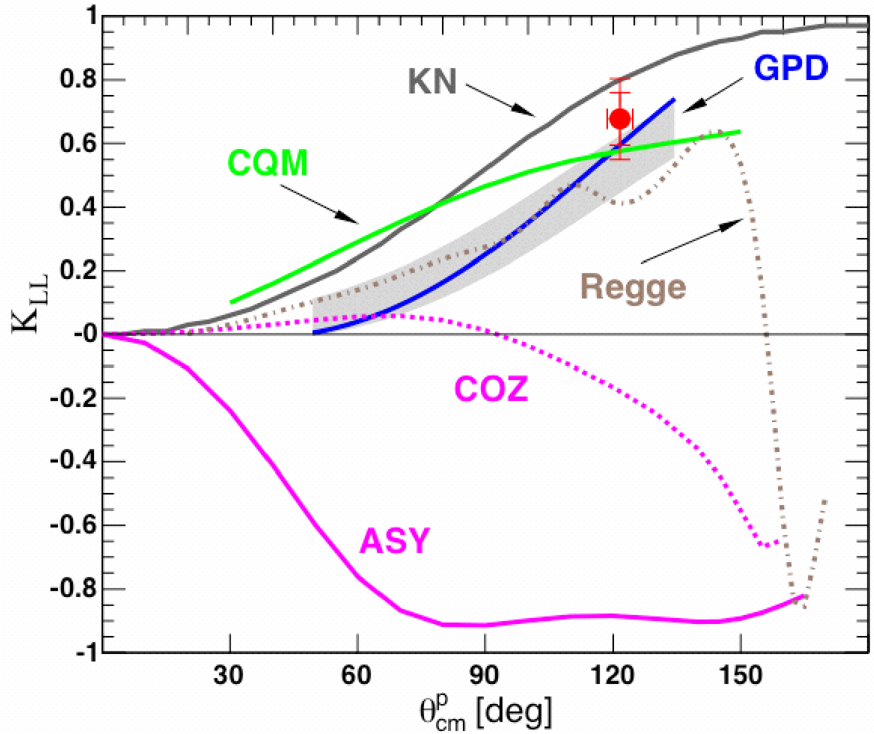
- Mixed electron/photon beam (9% Cu) on 15 cm LH_2 target.
- Incident photon energy range defined by spectrometer acceptance.
- Employ BigBite magnet for electron deflection.

E99-114 Results

Danagoulian et al, PRL 98, 152001



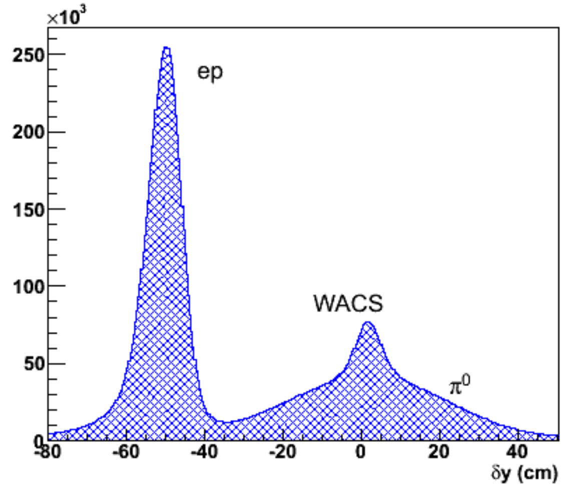
DJH et al, PRL 94, 242001

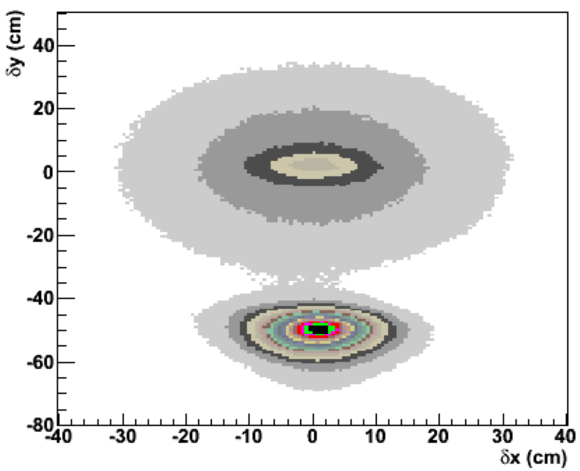


- Disagreement with pQCD predictions **but K_{LL} at low -u.**
- GPD predictions show good agreement.

$s = 6.9\ GeV^2$
$-t = 4.0\ GeV^2$
$-u = 1.13\ GeV^2$

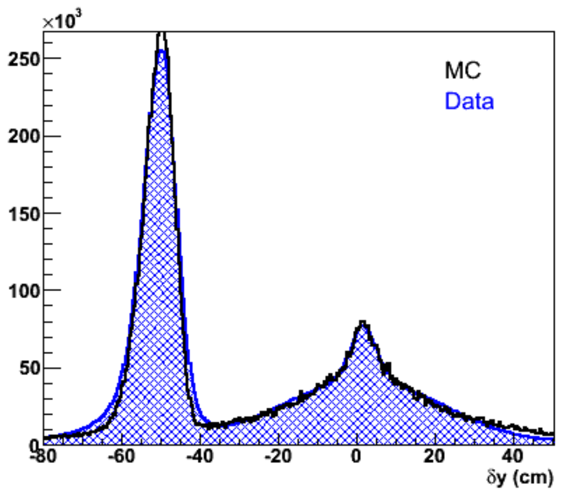
Analysis: Event Selection

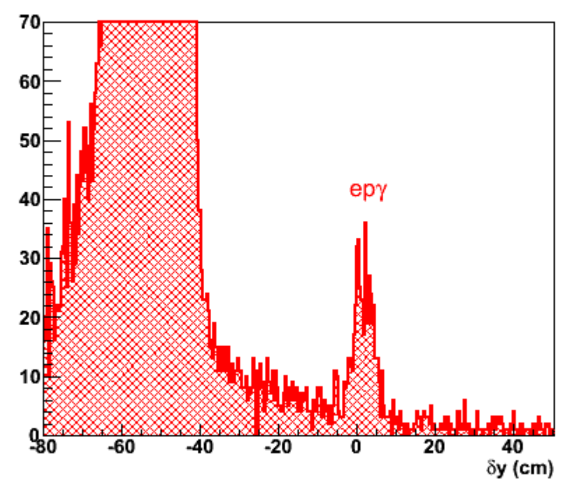




- Utilise two-body kinematic correlation between photon/electron and proton to select WACS events.
- Three main reaction channels:
  - $\gamma p \rightarrow \gamma p$
  - $ep \rightarrow ep$ ($ep \rightarrow ep\gamma$)
  - $\gamma p \rightarrow \pi^0 p \rightarrow \gamma\gamma p$
- Other (> 3 body reactions) such as eta or resonant π^0 production do not contribute.
- Background in the WACS region of interest is therefore exclusively from π^0 decay and $ep\gamma$ events.
- These events dilute the polarisation signal.
- Therefore, a dedicated Monte Carlo has been written to understand these backgrounds and extract dilution factors.

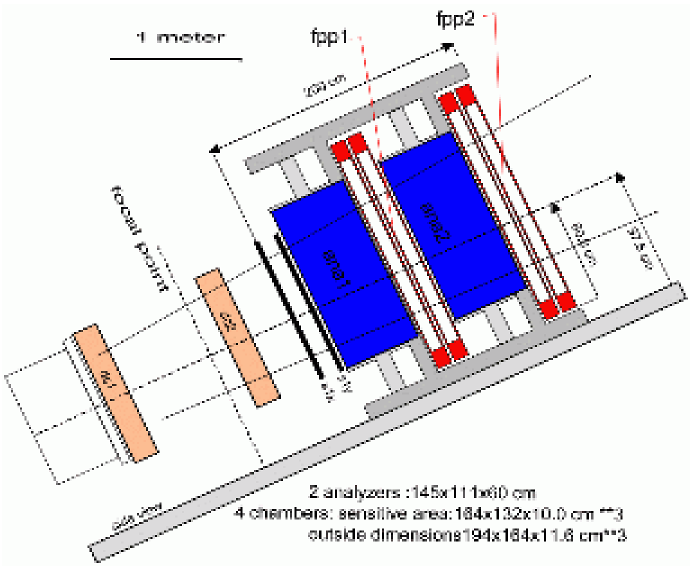
Analysis: MC Background Study

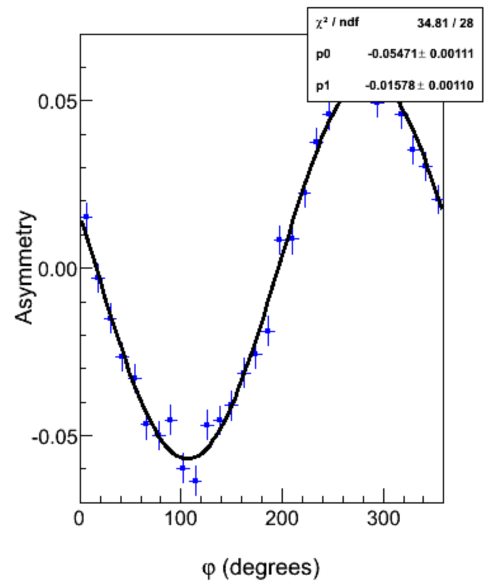


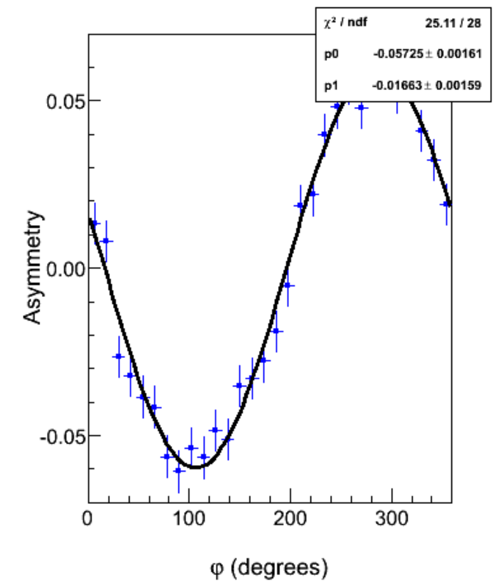


- A Monte Carlo combining a Root-based event generator and Geant4 simulation has been developed.
- Fiducial cuts rather than full HMS acceptance calculation (SIMC) used for now.
- Good agreement with data achieved with known cross sections and detector resolution.
- π^0 shape and BigBite fringe fields need a bit more work.
- By turning off WACS and $p\pi^0$ reactions in event generator, the epγ background can be calculated.
- Ratio epγ/WACS = 10.6 %.
- This number can be compared with data taken specifically for investigating this background.

Analysis: Polarisation Observables

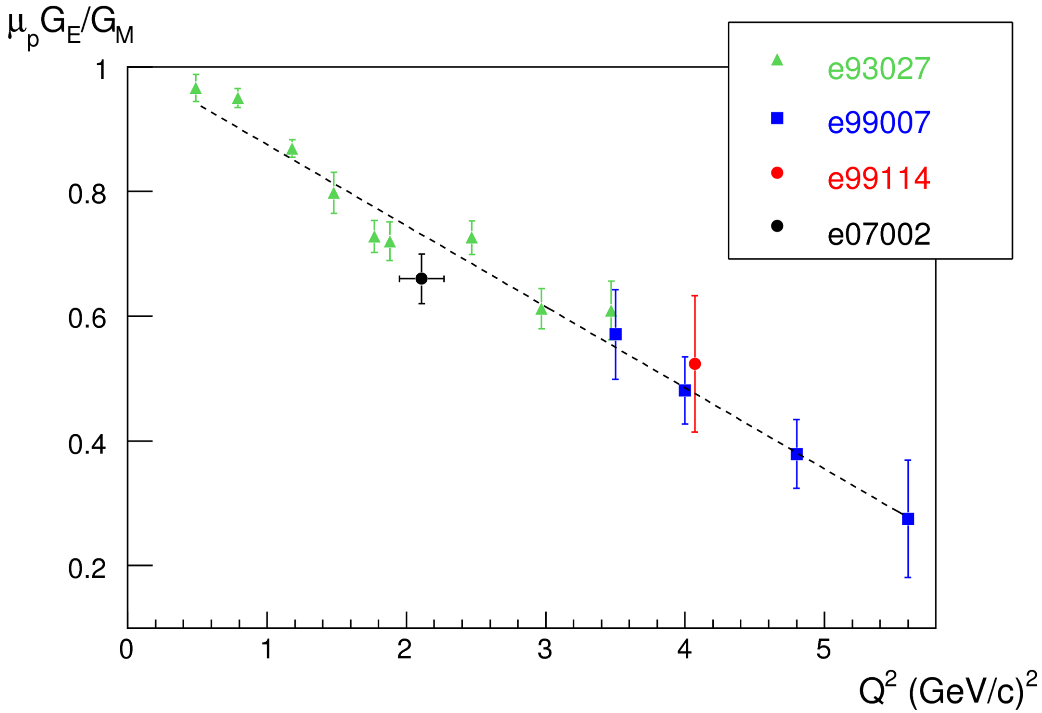






- Double analyser FPP used to extract beam-helicity asymmetries at spectrometer focal plane.
- Simple dipole approximation for spin transport used for now.
- Transformation of polarisation from lab -> CM frame.

Analysis: FPP Calibration

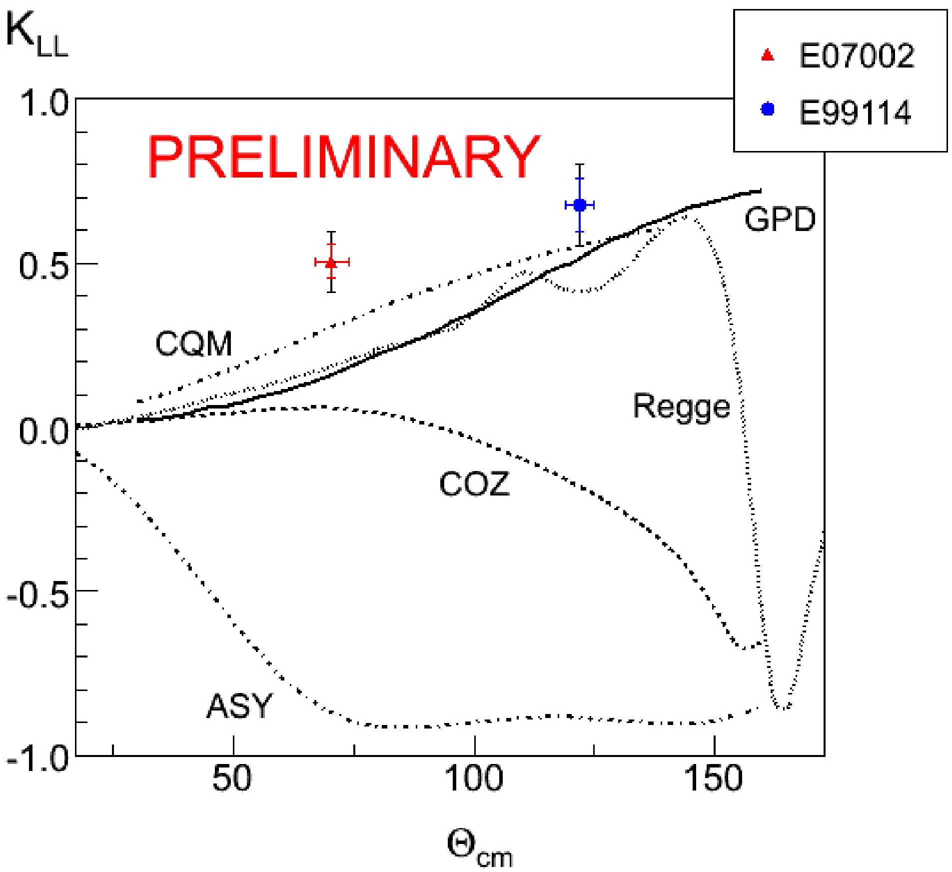


- Off-endpoint elastic ep data used for FPP analysing power calibration.
- Value obtained (0.148 +/- 0.002) and Gep/GMp are consistent with expectations.
- However, how significant will radiative corrections be to this data?

Outstanding Analysis Issues

- Full HMS spin transport calculation required, rather than simple dipole approx.
- Parametrisation of FPP analysing power in θ (and maybe Tp?).
- Study of FPP false asymmetries for extraction of P_n.
- Study of improved BigCal energy calibration utilising photons from π^0 decay.

Preliminary Results



s = 8.0 GeV², -t = 2.1 GeV², -u = 4.1 GeV²

- K_{LL} = 0.506 +/- 0.052 (+/- 0.04)
  K_{LT} = 0.063 +/- 0.052 (+/- 0.04)
- K_{LL} can be related to the form factor ratio R_A/R_V.
- K_{LT}/K_{LL} is related to the ratio R_T/R_V.
- Systematic uncertainties will be reduced further.
- Further definitive evidence that WACS proceeds through interaction of a photon and a single quark.

Summary

- WACS is a powerful probe of proton structure, which is similar to elastic ep scattering and DVCS and can be described in terms of moments of GPDs.
- A preliminary analysis of E07002 data has reinforced the conclusion from previous Hall A results that pQCD models are not yet applicable.
- Further insights relating to the short-range spin structure of the proton can be extracted within the GPD approach.
- With MC tools in place for understanding the necessary background corrections, a careful and detailed final analysis can now be undertaken.
- With no obvious stumbling blocks in sight, preparation of a draft publication can hopefully begin early summer.