E12-17-008: Polarization Observables in Wide-Angle Compton Scattering

ERR: What needs to be done?

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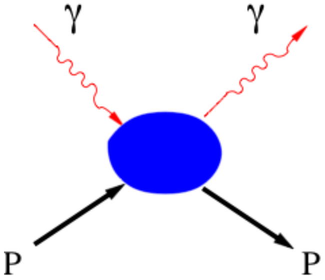
WACS: An Introduction

- Hard exclusive nucleon Compton scattering can be investigated in two complementary kinematic regimes:
    - Deeply-virtual: large Q^2; $\left(\frac{-t}{Q^2}\right) \ll 1$
    - Wide-angle: large $-t$, $-u$; $\left(\frac{Q^2}{-t}\right) \ll 1$
- WACS is a powerful yet under-utilised probe of transverse nucleon structure, similar to high-Q^2 elastic electron scattering.
- However, unlike elastic eN experiments WACS is sensitive to the nucleon's axial structure and therefore related to high-Q^2 neutrino scattering experiments.
- Its theoretical description has strong overlaps with other wide-angle processes in both the space-like and time-like domains.



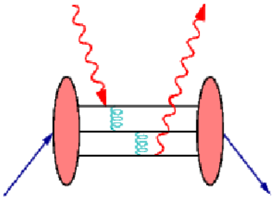
It is one of the least explored of the fundamental reactions in the several GeV regime.

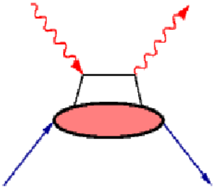
Factorization and the WACS Reaction Mechanism

- A number of theoretical approaches have been proposed over the years:
    - pQCD (two hard gluon exchange)
    - Regge exchange and VMD models

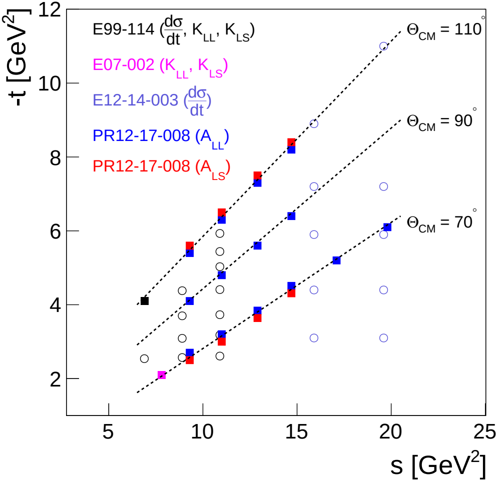
    - GPD-based soft overlap mechanism
    - Soft collinear effective theory (SCET)
    - Relativistic constituent quark model

    - Dyson-Schwinger equations
- How does the reaction mechanism factorize?
- Having established the dominant factorization scheme, what new insights on the non-perturbative structure of the proton are accessible?

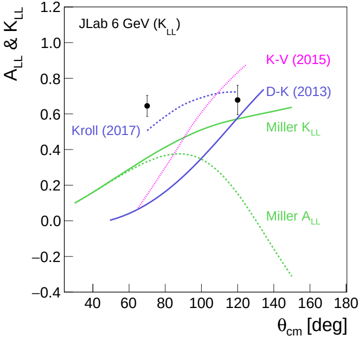


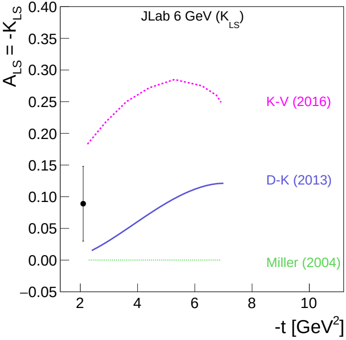


- Two experiments during the 6 GeV era:
  - E99-114 in Hall A with HRS
  - E07-002 in Hall C with HMS
- Cross section experiment approved by PAC42 (A-) for running at 12 GeV:
  - E12-14-003 in Hall C with HMS
- This proposal:
  - PR12-17-008 – measurement of A_{LL} and A_{LS} in Hall C with BigBite.



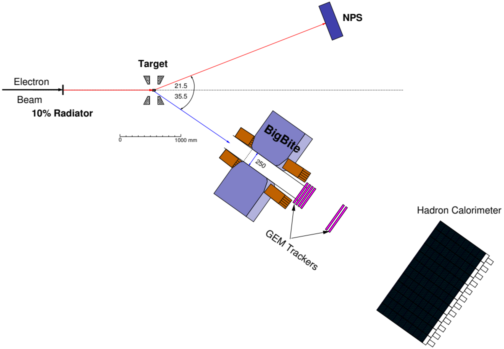
Key Physics Questions





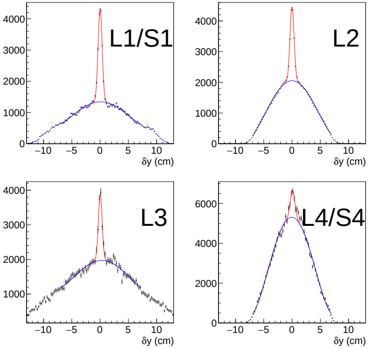
- To what degree is the factorized mechanism dominant and how significant are theoretical corrections?
- What are the constraints on GPD moments and what do they tell us about the proton's axial and tensor structure?
- Is the quark which absorbs and emits photons a constituent or a current quark?
- What does comparison of the SCET and GPD predictions tell us about proton structure and the role of hadron helicity-flip?

1. A 3 μA polarized electron beam incident on a 10 % radiator inside a Compact Photon Source (CPS) produces a high-intensity untagged photon beam.
2. The proton target is the UVA/JLab solid polarized ammonia target.
3. The recoil proton is detected with the BigBite spectrometer equipped with GEM trackers and trigger detectors.
4. The highly-segmented $PbWO_4$ NPS calorimeter is used to detect the scattered photon.



The use of the CPS and BigBite results in a significantly improved figure-of-merit over all previous experiments and opens up a new range of polarized physics opportunities at JLab.

- Data analysis relies on utilization of the kinematic two-body correlation between the scattered photon/electron and the recoil proton.
- The three dominant reaction channels within acceptance are:
  - $\gamma p \rightarrow \gamma p$
  - $\gamma p \rightarrow \pi^0 p$
  - ~~$ep \rightarrow ep$ and ($ep\gamma$)~~
- Robust extraction of the WACS signal requires:
  - Excellent angular and momentum resolution in both the photon and proton spectrometers.
  - Precise determination of π^0 background shape, particularly at large scattering angles.

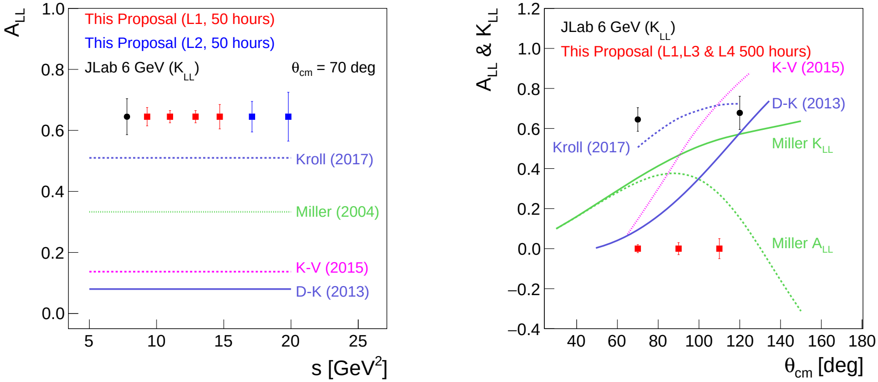


The use of a pure photon beam and large acceptance spectrometers makes the data analysis significantly simpler and reduces overall systematic uncertainty.

Proposed Measurements

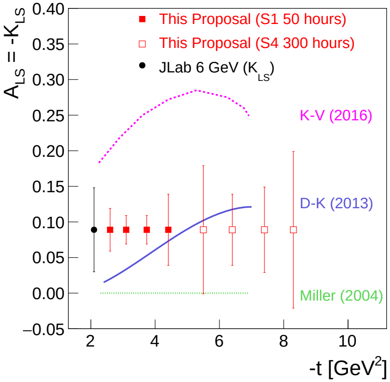
Kin	E_{Beam} [GeV]	E_{in} Range [GeV]	s [GeV^2]	-t [GeV^2]	-u [GeV^2]	θ^{cm} [°]	θ_{γ} [°]	θ_{p} [°]	θ_H^{targ} [°]
L1	8.8	4 - 8	12.1	3.5	6.9	70	21.5	35.5	0
S1	8.8	4 - 8	12.1	3.5	6.9	70	21.5	35.5	-20
L2	11.0	8 - 11	18.7	5.6	11.3	70	17.4	30.5	0
L3	8.8	4 - 8	12.1	5.3	5.2	90	30.2	26.5	0
L4	8.8	4 - 8	12.1	7.0	3.3	110	42.3	19.4	0
S4	8.8	4 - 8	12.1	7.0	3.3	110	42.3	19.4	+80

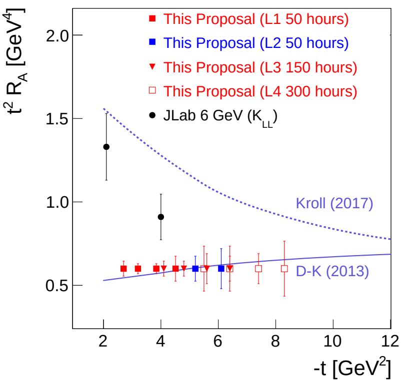
- Beam-time estimates are based on the requirement of ± 0.1 or better statistical uncertainty in at least one *s*-*t* bin.
- The overall systematic uncertainty is estimated to be around 6 - 7 % and is dominated by contributions from the pion background subtraction, the target packing fraction and the target polarization.
- 200 hours is expected for experimental overheads, such as calibration data-taking, beam polarimetry, target annealing and kinematic changes.



- Make an explicit, model-independent test of factorization by measuring the s-dependence of the polarization observables at fixed θ_p^{cm}, and verify that target mass corrections and higher twist effects are small.
- Measurement of A_{LL} at large CM scattering angle will allow for a singular test of whether current or constituent quarks are the relevant degree of freedom in hard exclusive reactions at these sub-asymptotic energies.

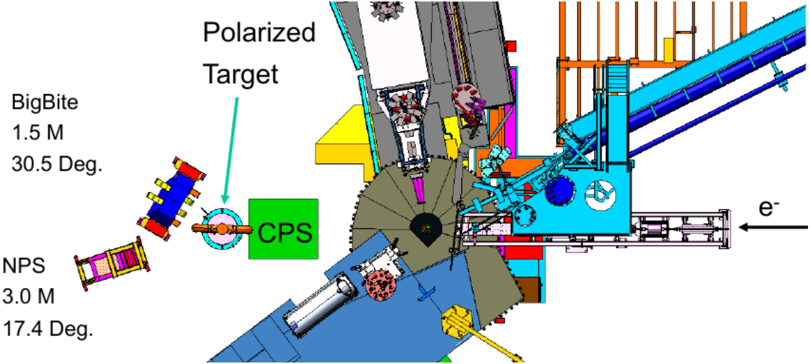
Expected Results – Proton Structure





- Systematically improve our knowledge of the non-perturbative matrix elements of the handbag mechanism in the GPD and SCET approaches.
- Constrain the GPDs $\tilde{H}$ and E at high $-t$ and compare with the Axial and Pauli form factors, which will have a significant and broad impact in the fields of electron and neutrino scattering.

ERR Key Questions – Hardware



All hardware components will have been used in production running at JLab – apart from the CPS.

(Figure from Steve Woods' Hall C presentation last week)

ERR Key Questions – Detectors

- Re-check background, trigger and dose rates (g4sbs).
- What will be needed for the move of the BB GEMs to Hall C?
- What trigger detectors to use for Bigbite (BigHAND vs HCAL vs ...)?
- BB power supply?
- Platforms for BB and NPS?
- ...

ERR Key Questions – Target

- What needs to be considered given the target is going to be downstream of the pivot?
- The small coil opening angle in the transverse configuration makes the S4 kinematic problematic.
- A final scheme is needed for target raster/motion.
- ...

ERR Key Questions – CPS

- Timeframe?
- Budget?
- ...

ERR Key Questions – DAQ, Software, Slow Controls

- Incorporate SBS GEM analysis code in Hall C software.
- DAQ?
- Slow controls?
- ...

Next Steps

- When ready, request ERR for E12-17-008.
- Think about a draft agenda (based on these slides/discussion).
- Draft documents (COO, ESAD, RSAD, ERG, OSPs)

What are our milestones before formal ERR request?