Polarisation Observables from $K^+\Sigma$ Photoproduction on g9a

CLAS Collaboration Meeting

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CEBAF Large Acceptance Spectrometer

Outline

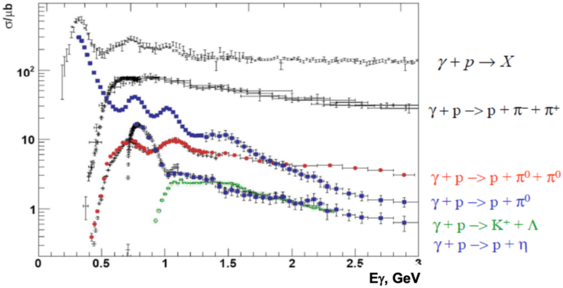
1 Introduction
- A World of Polarisation (Observables)
- JLab, CLAS and FROST

2 Analysis
- Event Selection
- Observable Extraction
- Results

3 Conclusions and Outlook

Motivation

- Baryon Spectroscopy is the study of excited nucleon states
- Finding some states can be difficult in a simple "bump hunt"; many are wide and overlap
- Use alternative means; coupling strength to a reaction channel, manifestation in experimental observables, etc. to aid searches



R. Beck and U. Thoma, EPJ Web Conf 134, 04003 (2017)

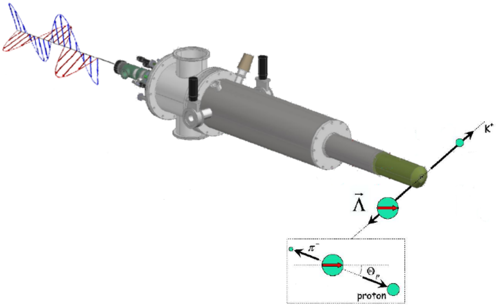
A World of Polarisation (Observables)

- Looking for polarisation observables on strangeness photoproduction
- Many possible channels, here we focus on $K^+\Sigma$

$$\gamma p \to K^+\Sigma \to K^+\Lambda\gamma \to K^+ p\pi^-\gamma$$

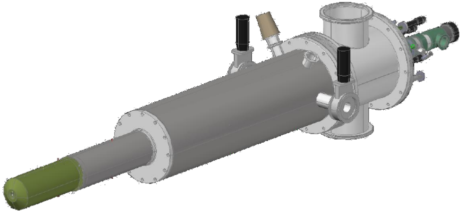
- 16 observables for single meson photoproduction, arising from the scattering amplitudes of the interaction and the particles which carry polarisation

- "Single": σ, Σ, P, T
- Beam-Target: E, F, G, H
- Beam-Recoil: O_X, O_Z, C_X, C_Z
- Target-Recoil: T_X, T_Z, L_X, L_Z



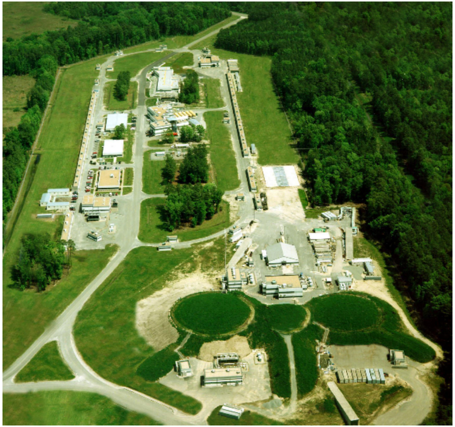
PARA/PERP, Target too

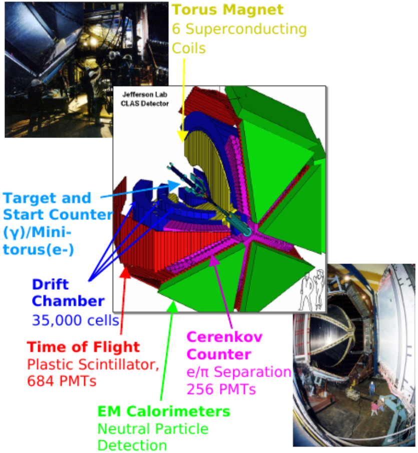
- With a polarised beam and target, can access the single and beam-target double observables
  - Single: σ, Σ, P, T
  - Beam-Target: E, F, G, H
- And more with recoil (i.e. with a self-analysing hyperon)



- Previous work on $K^+\Lambda$ verified the beam asymmetry, Σ and provided first measurements in this channel of G
- Now we show the same observables on $K^+\Sigma$

N* Experiments with CLAS

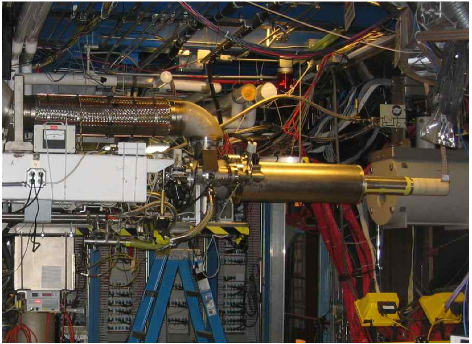




NIM A, 503(3), 2003

g9a/FROST

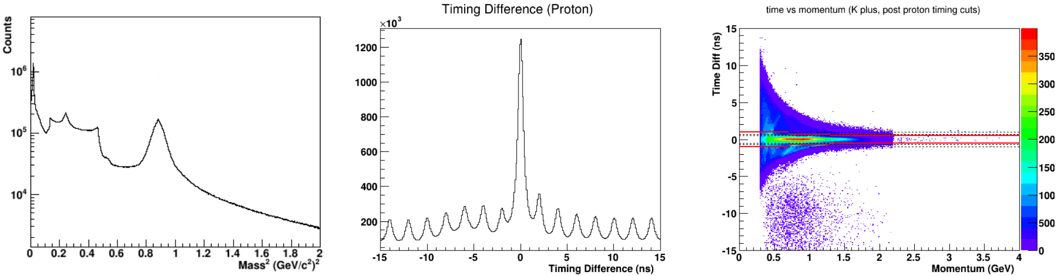
- Data from g9a run period: November 2007 to February 2008
- Linearly and circularly polarised photon beams on a longitudinally polarised target
- Polarisation direction regularly flipped during run
- Nine coherent peak settings in linear polarisation, spanning energy range 0.7 to 2.3 GeV
  - In this case, the reduced cross section can be expressed as:



$$\frac{d\sigma}{d\Omega} = \sigma_0\{1 - P_{lin}\Sigma cos(2\phi) + P_z(P_{lin}Gsin(2\phi))\}$$

Analysis - Particle ID

- Initial particle ID via combination of charge and time-of-flight mass
- Select candidate Protons and Kaons
- Apply photon-to-particle timing difference cuts eliminate misidentification

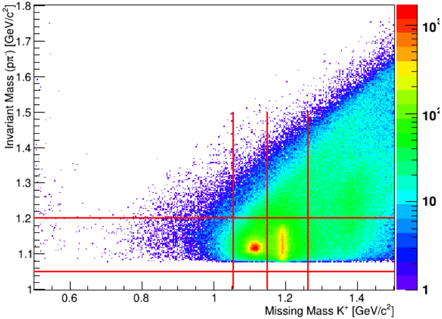


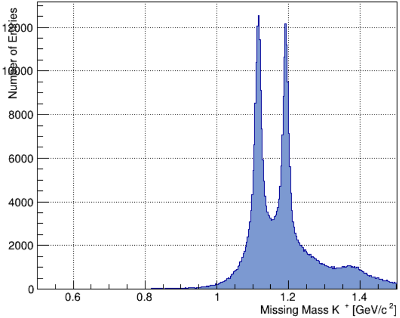
Channel Identification

- Select channel of interest:

$$\gamma p \rightarrow K^+\Sigma \rightarrow K^+\Lambda\gamma \rightarrow K^+p\pi^-\gamma$$

- Non exclusive selection - reconstruct pion from detected proton and kaon
- Hyperons identified via kaon missing mass and proton pion invariant mass



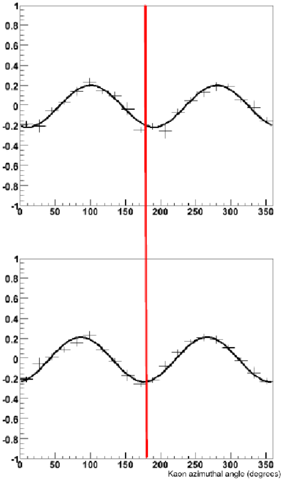


Extracting Observables

- Binned fitting on asymmetries of two states of beam polarisation (PARA and PERP)
- Technique has been extensively employed in the JLab N* program and similar experiments worldwide
- Recall that on a linpol beam and a longitudinally polarised target:

$$\frac{d\sigma}{d\Omega} = \sigma_0\{1 - P_{lin}\Sigma cos(2\phi) + P_z(P_{lin}Gsin(2\phi))\}$$

- A cos(2ϕ) + sin(2ϕ) fit to a PARA/PERP asymmetry can be used to extract Σ and G for each state of target polarisation



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Extracting Observables II

- Binned asymmetry fitting relies on a number of assumptions
- In lower statistics channels, or datasets where PARA and PERP have large variations between them in flux, polarisation, etc., reliable observable extraction is more challenging
- Using a maximum likelihood approach, we can extract observables event-by-event, and better account for variation between polarisation states
- We can define the likelihood function for each event as:

$$L_i = c_i[1 - P_{lin,i}\Sigma cos(2\phi_i) + P_{z,i}(P_{lin,i}Gsin(2\phi_i))]A$$

- And extract observables by maximising the log-likelihood function:

$$\log L = b + \sum_i \log[1 - P_{lin,i}\Sigma cos(2\phi_i) + P_{z,i}(P_{lin,i}Gsin(2\phi_i))]$$

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Dilution of Observables

- Parameters extracted from $\cos(2\phi) + \sin(2\phi)$ fits are the free proton value, diluted with a carbon contribution (and beam and target polarisations)
- i.e. for the Σ observable, we actually measure $\Sigma_{Butanol}$, from which we can infer the free proton value

$$\Sigma_{Proton} = \frac{1}{N_{Proton}}(N_{Butanol}\Sigma_{Butanol} - N_{Carbon}\Sigma_{Carbon})$$

- For G, carbon in the target is unpolarised and we measure $G_{Butanol}$, estimating the free proton value via;

$$G_{Proton} = \frac{N_{Butanol}}{N_{Proton}}(N_{Butanol}G_{Butanol})$$

- The 'N' terms represent event yields per bin corresponding to the relevant material
- These must be estimated for Carbon and Proton...

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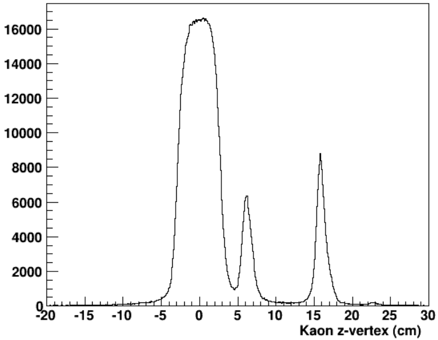
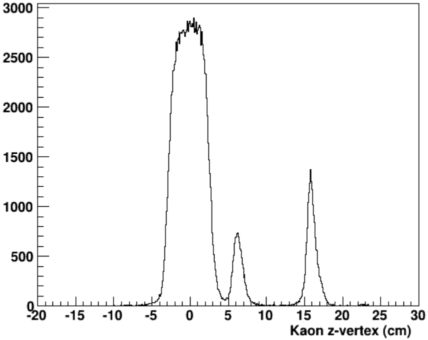
Target Selection

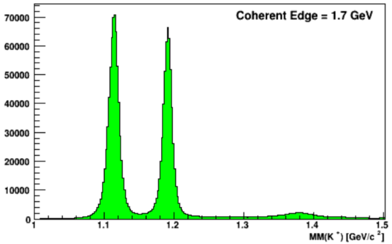
- FROST target contains Butanol (left), Carbon (centre) and Polythene (right)
- Resolvable from Kaon z-vertex after particle and channel identification

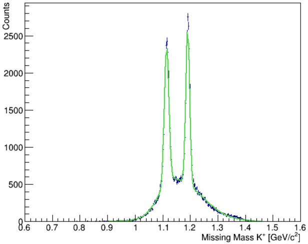




- Only Butanol is polarised, other targets used to account for nuclear backround and dilution effects of unpolarised nuclei in butanol

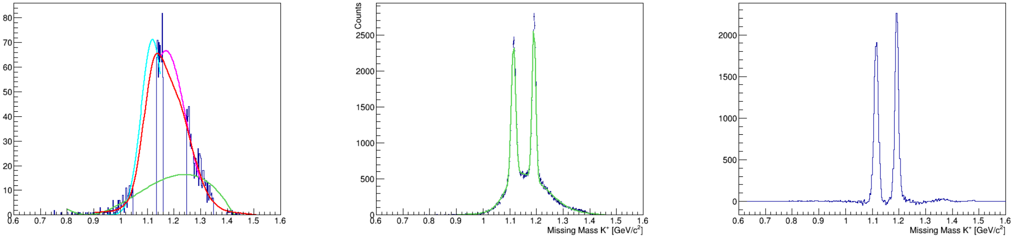
Estimating Carbon





- Contolling systematic uncertainties, particularly on a measurement of G, requires a robust method of accounting for Carbon
- We know from data on proton targets (left) that shape under the hyperon peaks on butanol (right) is almost entirely from bound nucleon effects

Estimating Carbon

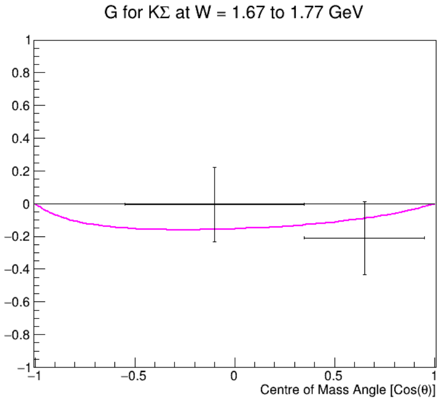


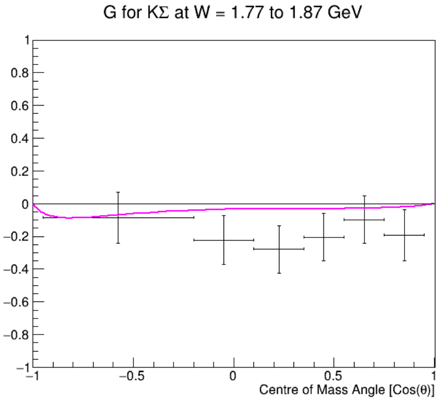
- Parameterise, using carbon data to initialise a fit
- Refit to Butanol and determine proportion of Carbon events in each bin

Initial Results

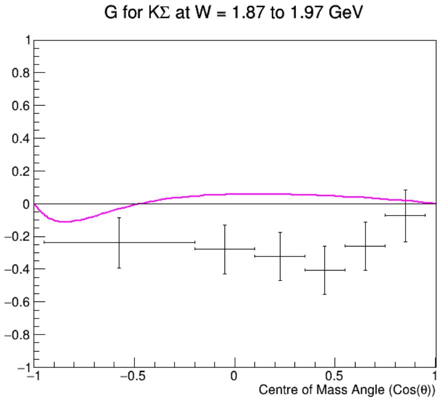
- Initial results from the maximum likelihood technique for the G observable on $K^+\Sigma$
- Comparison to Kaon-MAID (pink line), actively seeking other models and updated fits

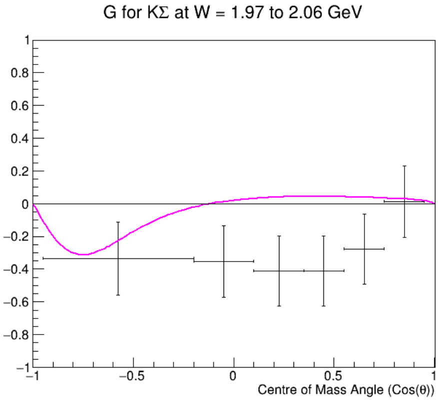
G on $K^+\Sigma$


G for KΣ at W = 1.67 to 1.77 GeV
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1
−0.5
0
0.5
1
Centre of Mass Angle [Cos(θ)]

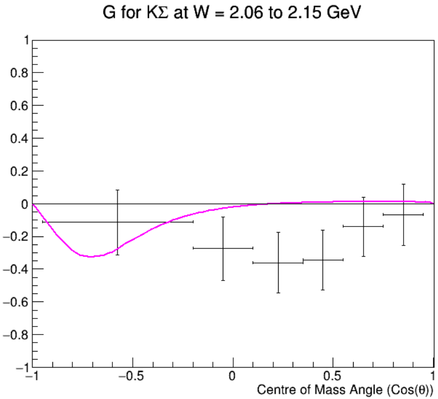

G for KΣ at W = 1.77 to 1.87 GeV
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1
−0.5
0
0.5
1
Centre of Mass Angle [Cos(θ)]

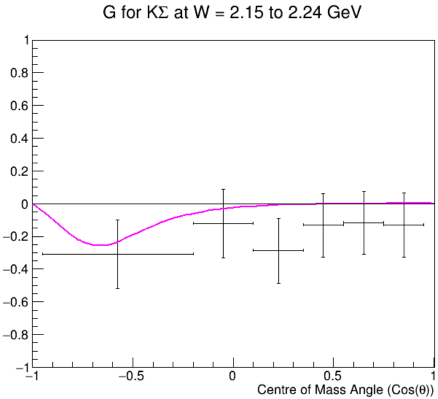
G on $K^+\Sigma$


G for KΣ at W = 1.87 to 1.97 GeV
Centre of Mass Angle (Cos(θ))


G for KΣ at W = 1.97 to 2.06 GeV
Centre of Mass Angle (Cos(θ))

G on $K^+\Sigma$


G for KΣ at W = 2.06 to 2.15 GeV
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1
−0.5
0
0.5
1
Centre of Mass Angle (Cos(θ))


G for KΣ at W = 2.15 to 2.24 GeV
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1
−0.5
0
0.5
1
Centre of Mass Angle (Cos(θ))

Outlook and Plans

- First measurement of the G observable for $K^+\Sigma$ photoproduction using maximum likelihood technique on this data
- Analysis note prepared and ready to submit
- $K^+\Lambda$ analysis already approved, paper draft in progress
- Measuring target-recoil observables may be feasible using this method