# Analysis of $K^0\Sigma^+$ photoproduction off the proton using CLAS at Jefferson Laboratory

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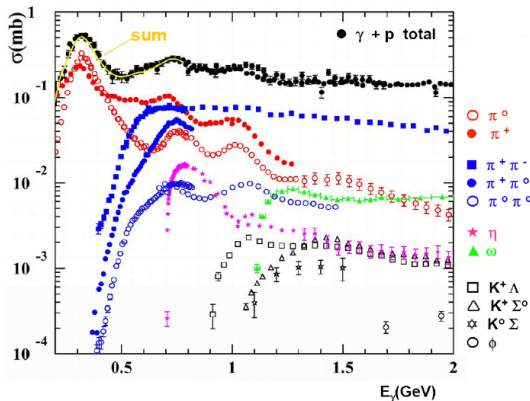
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# Overview

1. Why study this reaction?
2. What is the experiment?
3. How do we perform particle ID and signal / background separation?
4. What can we measure?
5. How do we extract the results?

# Why study this reaction?



- Goal: understanding the baryon excitation spectrum
- Resonances are predicted but many are not yet measured
- Models / Partial Wave Analyses require further constraints beyond cross-section measurements
- Data for the $K^0\Sigma^+$ channel is limited - this study will be a first measurement of 3 observables
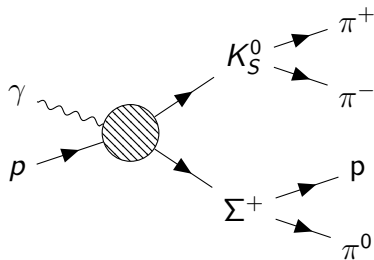
3

# The experiment
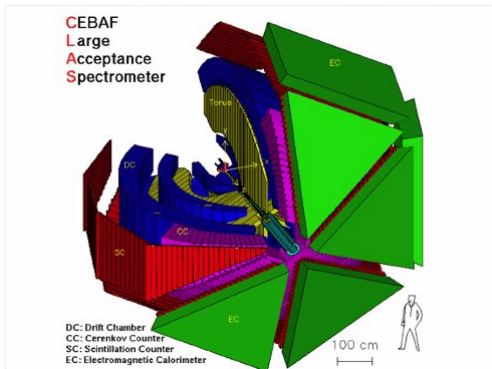


- CLAS at Thomas Jefferson National Accelerator Facility
- 4.5 GeV electron beam
- Linearly polarised photon beam produced from diamond radiator
  - Photon energy 1.1 - 2.1 GeV
  - Centre-of-mass energy 1.7 - 2.2 GeV
- Liquid hydrogen target

# Polarised photon beam
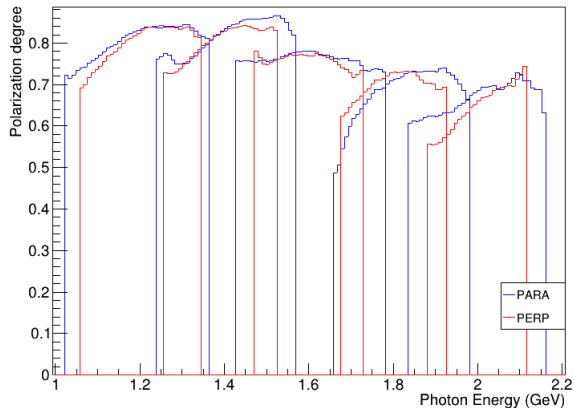


- Mean polarization degree approx 0.7
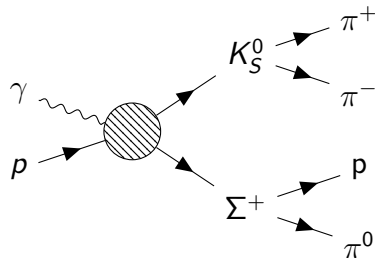- Systematic error  2-6%

5

# Reaction channel



$\Sigma^+ \rightarrow p\pi^0$
Branching fraction$=51.6\%$
$\alpha = -0.980$

Final state $p\ \pi^+\ \pi^-\ (\pi^0)$

# Particle Identification



Final state $p\ \pi^+\ \pi^-\ (\pi^0)$

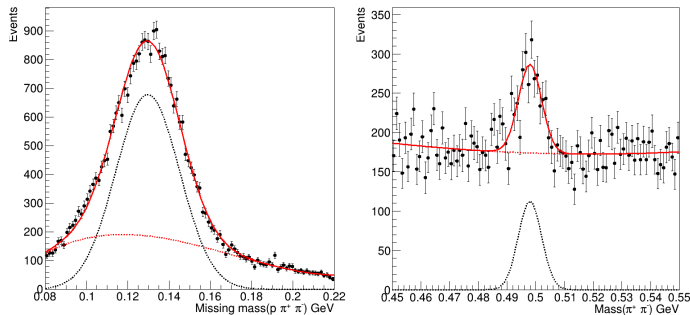| Particle ID cuts |
|---|
| 3 charged particles, 0, 1 or 2 neutral particles in event |
| Mass and charge of particles compatible with $p\ \pi^+\ \pi^-$ |
| Reaction vertex contained within the target |
| Tagged photon identified with absolute time difference $< 1$ ns |
| $E_{setting} - 200 MeV < E_\gamma < E_{setting}$ |

# Reaction Channel Identification



- Use of sPlots technique to separate signal and background
- Model $\pi^0$ and $K^0$ mass as Gaussian peak on polynomial background

# Signal/Background extraction
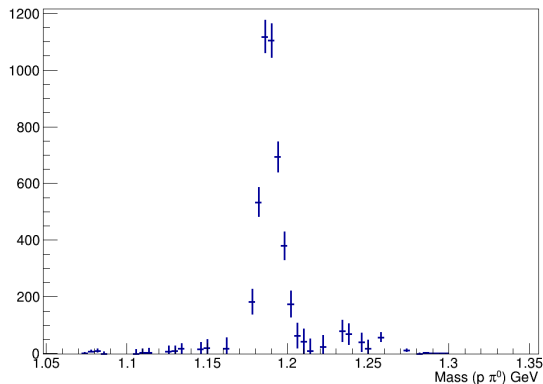


- Mass of reconstructed $\Sigma^+$ with signal weights applied
- PDF mass of $\Sigma^+$ = 1189 MeV

# Angular distribution dependance on polarisation observables

$$\frac{d\sigma}{d\Omega} \equiv \sigma\left(\phi, \cos\theta_x, \cos\theta_y, \cos\theta_z\right) = \sigma_0 \{1 - P^\gamma \Sigma \cos 2\phi$$
$$+\alpha \cos\theta_x P^\gamma O_x \sin 2\phi$$
$$+\alpha \cos\theta_y P - \alpha \cos\theta_y P^\gamma T \cos 2\phi$$
$$+\alpha \cos\theta_z P^\gamma O_z \sin 2\phi\},$$

- $\phi$ = angle of reaction plane wrt polarisation plane
- $\cos\theta_x$, $\cos\theta_y$, $\cos\theta_z$ = direction cosines of proton in the rest frame of the hyperon
    - $y$-axis normal to reaction plan
    - $z$-axis parallel to beam in rest frame of hyperon
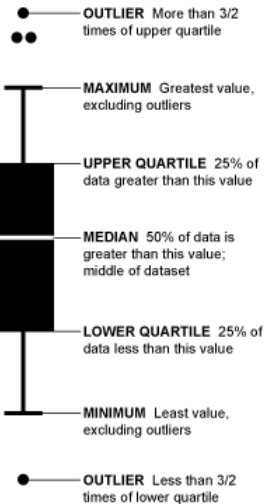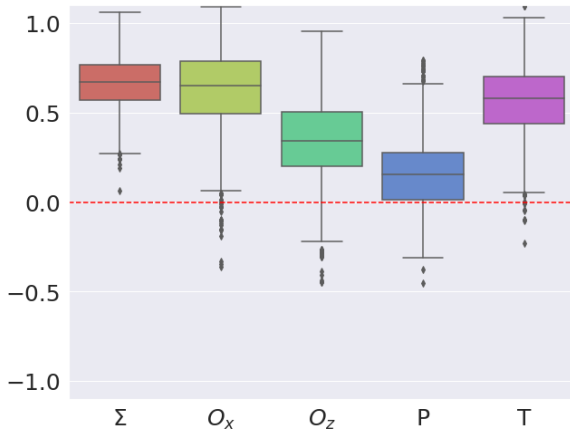- Polarisation observables: $\Sigma, P, T, O_x, O_z$

10

# Preliminary results
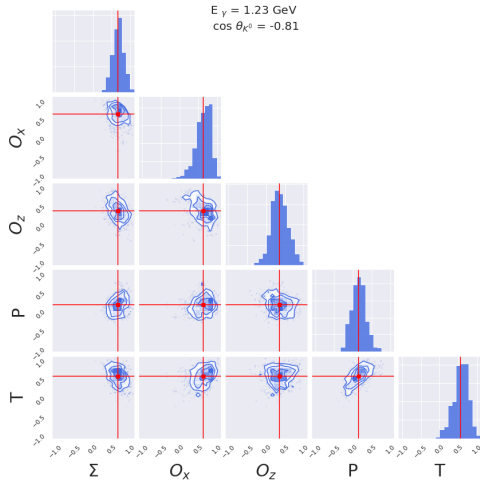


- Likelihood sampling using Markov Chain Monte Carlo
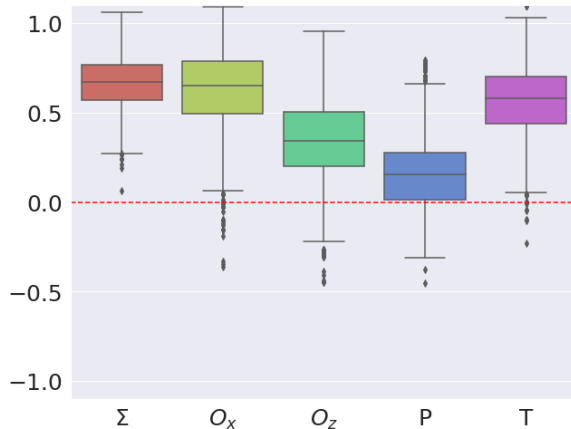- Obtain posterior and correlation for each of the 5 observables

# Preliminary results



$E_\gamma = 1.23$ GeV $\cos\theta_{K^0} = -0.81$

# Preliminary results



$E_\gamma = 1.23$ GeV $\cos\theta_{K^0} = -0.81$

- Example results for one bin
- Measurements for 21 kinematic bins in $E_\gamma$ and $cos(\theta_{K^0})$ will be extracted
- Finalised results will provide new data for theorists to implement in their fits

13

# Summary

- The study of baryon resonances is an important tool for investigating QCD in the non-perturbative region
- Phenomenological models explaining the behaviour observed in hadronic processes are constrained by the "polarization observables" associated with these resonances
- The preliminary results shown are a first measurement for three of the five observables extracted and will add to the world-data available for constraining resonance models of the proton
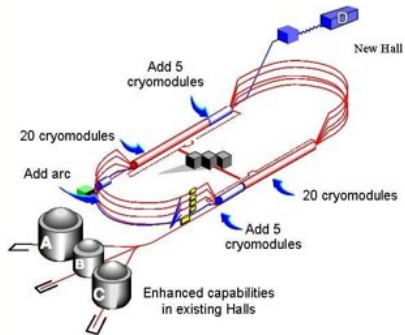
Thanks for your attention

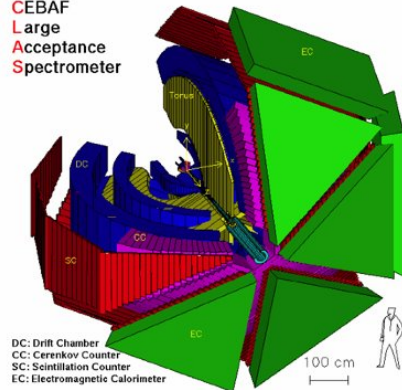Louise Clark
University of Glasgow

Supplementary material

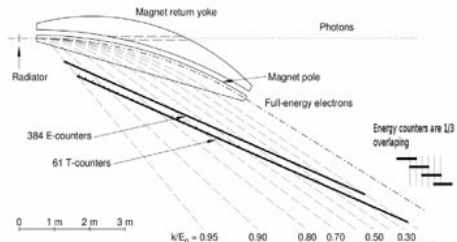Louise Clark
University of Glasgow

# CLAS detector at JLab

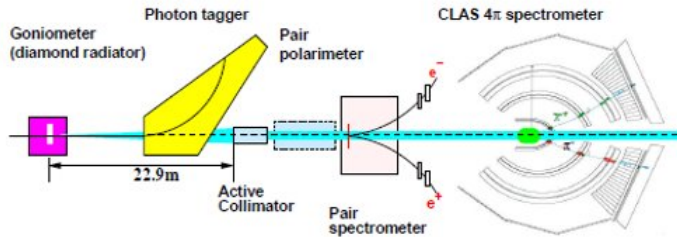# CLAS detector at JLab

# Markov Chain Monte Carlo