G Asymmetry for KΛ Photoproduction using the Frozen Spin Target at CLAS

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Abstract

The FROST experiment at Jefferson Lab, the Thomas Jefferson National Accelerator Facility, in Newport News, Virginia, utilises a frozen spin target in photonuclear experiments with the CLAS detector in Hall B. When combined with linearly and circularly polarised photon beams, use of such a target enables the measurement of beam-target double polarisation observables, potentially allowing "missing" baryon resonances, predicted by SU(6) $\times$ O(3) symmetric quark models but not observed in previous experiments, to be found. Observing these resonances has important implications for our knowledge of the excited states of nucleons, and the models that predict the quark interactions within them.

Motivation

Experimental searches in Hall B at Jefferson Lab for so called "missing" baryon resonances, excited states predicted by quark models but so far unobserved by experiment, focus upon the analysis of photoproduction reactions, where a photon interacts with a nucleon, producing an excited state which decays. To study these reactions, and infer the presence of previously unseen resonances, measurements of quantities known as polarisation observables are required.

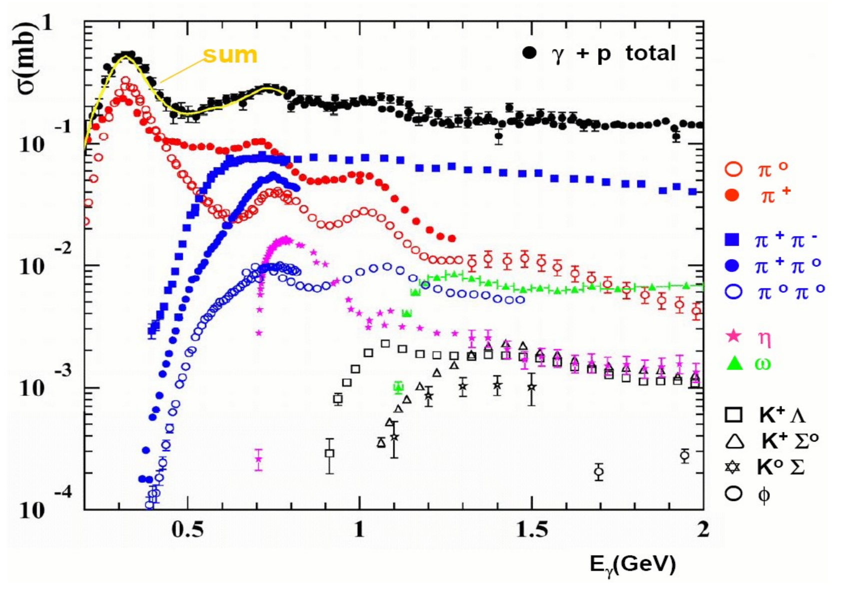

Fig 1: Resonance spectrum for meson photoproduction on the proton. Note that some resonant states are wide and overlapping, making them difficult to isolate from cross-section measurements alone

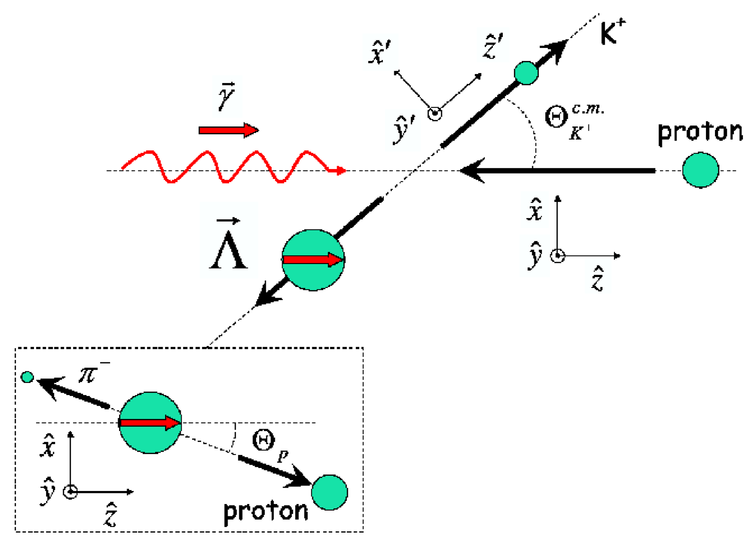

Fig 2: KΛ photoproduction reaction from a proton target

Polarisation observables arise from particles in the reaction that carry polarisation; in Kaon-Lamba photoproduction reactions, these are the photon, the target nucleon, and the recoiling Lamba hyperon. There are 16 polarisation observables in total, and to adequately analyse a reaction, seven of these need to be measured. Using a combination of polarised beam and target; the eight observables shown in green in table 1 (below) can be measured.

Single Polarisation Observables	
σ, Σ, P, T	
Double Polarisation Observables	
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

Table 1: Polarisation observables. Using polarised beams and targets, eight polarisation observables can be measured; four single polarisation observables and four beam-target double polarisation observables

Jefferson Lab Hall B

Hall B at Jefferson Lab is home to the CEBAF Large Acceptance Spectrometer (CLAS), a layered arrangement of particle detectors, roughly 10 metres in diameter, which surrounds a target, detecting products of the reaction between beam and target with almost full angular coverage. CLAS is used for photon and electron beam experiments, with the FROST experiment using a photon beam. Photonuclear experiments using CLAS have a similar set up; linearly or circularly polarised photons are produced from the JLab accelerator electron beam via a radiator, and pass through a device called a tagging spectrometer, which determines the energy of the photons in the beam by measuring the electron energy. The tagged photon beam then hits a target, positioned in the centre of CLAS.

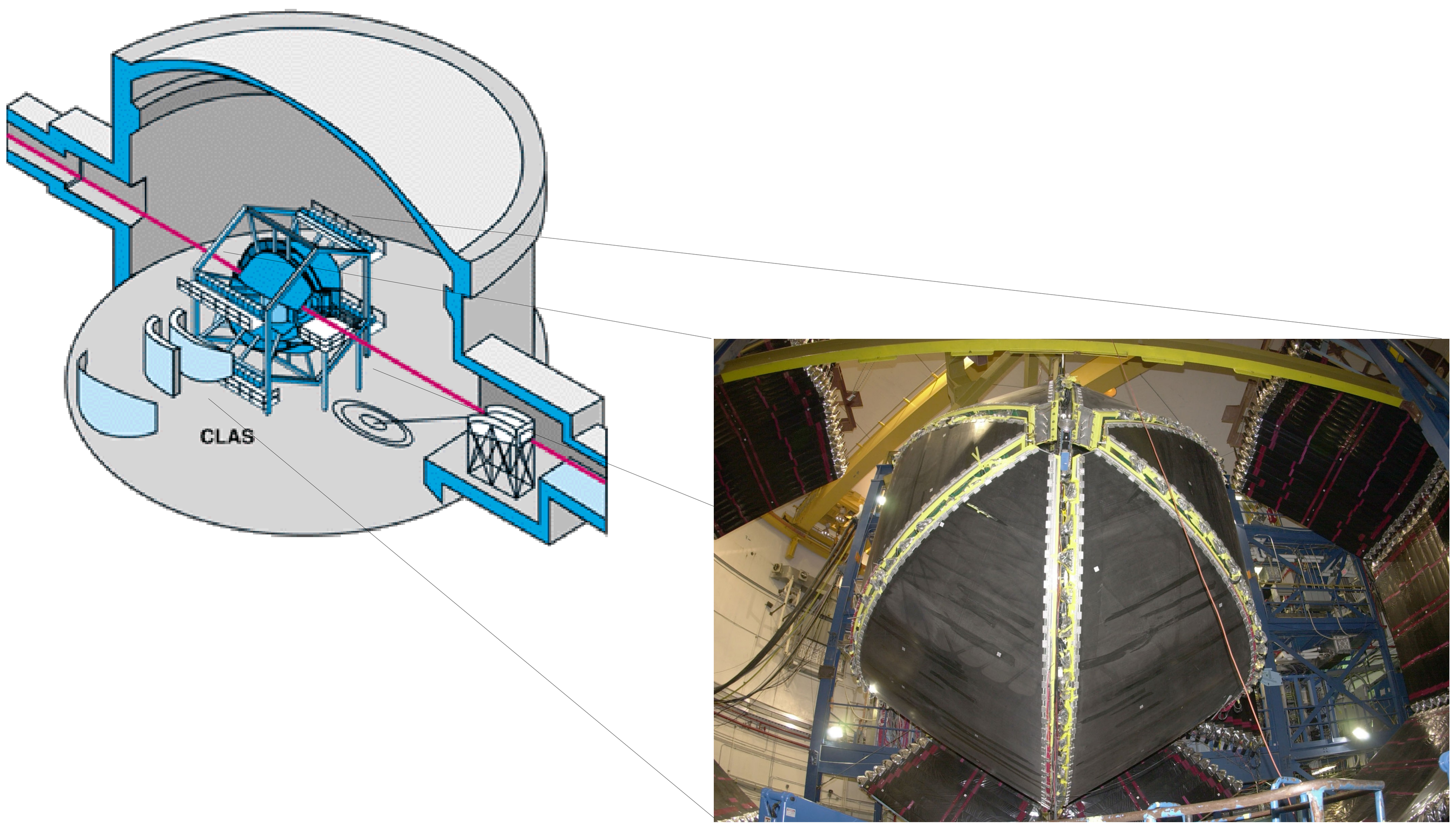

Fig 3: The layout of Hall B, showing the CLAS detector and the photon tagging spectrometer, with a close-up of the CLAS detector

The FROST Target

The FROST target, designed and built by the Jefferson Lab target group, is a polarised proton target. Solid butanol pellets are used as the target material and are held in a cylindrical target holder, which sits inside CLAS. The target is polarised using a technique called Dynamic Nuclear Polarisation (DNP), where a high magnetic field is employed to polarise free electrons in a material then, by applying microwaves, this polarisation is transferred to the nuclei. Once polarised, the microwaves and high magnetic field are switched off, and using a combination of millikelvin cooling and a weaker holding magnetic field, the polarisation can be maintained for periods of several days. Polarising the target in this way enables data to be taken without the polarising magnet obscuring reaction products from CLAS.

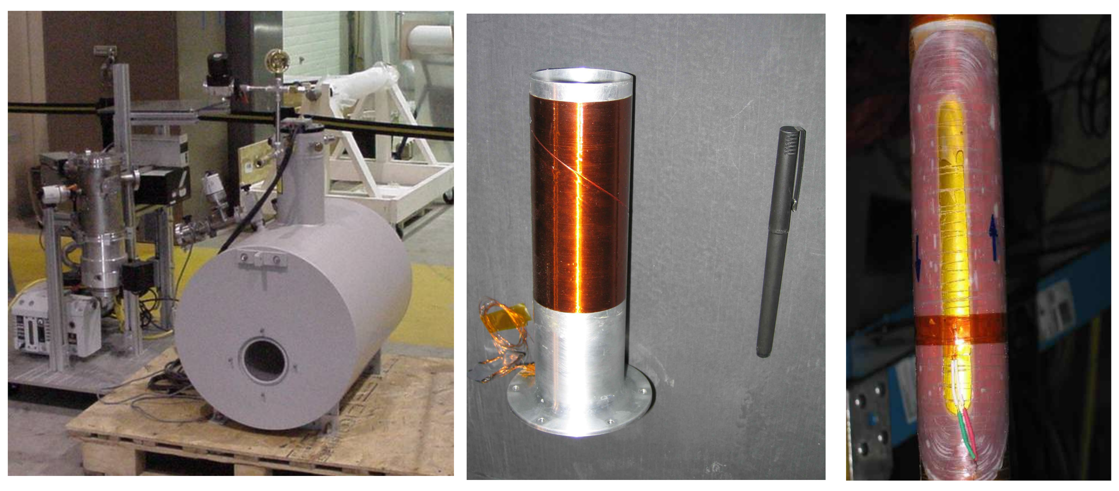

Fig 4: Polarising and holding magnets for the FROST target. (from left) The longitudinal polarising and holding magnets, both used in g9a, and the transverse holding magnet tested in February 2008 for use in the next FROST experiment, g9b, which will run in 2010.

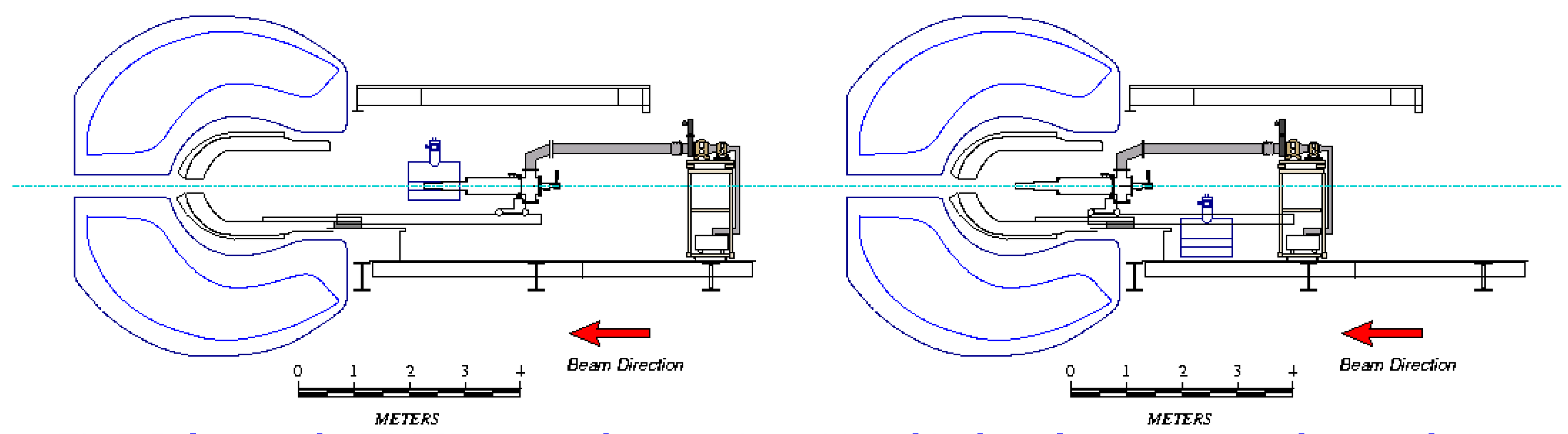

Fig 5: Polarising the FROST target. The target is positioned in the polarising magnet during polarisation (left), and once polarised, is repositioned inside the CLAS detector while data is taken (right)

The g9a Run and measuring G

The g9a experiment ran from October 2007 until February 2008, recording just over 10 billion events using a combination of linearly and circularly polarised photon beams. During this run, the target performed well, matching, and exceeding estimates of its performance. Currently, fully calibrated circularly polarised data from g9a is available for analysis, and linearly polarised data will follow in the near future.

The G observable is one of four beam-target polarisation observables, shown in table 1. 'G' arises from a linearly polarised photon beam on a longitudinally polarised target, and is the difference over the sum of cross sections for this set up, as expressed in equation (1).

$$G = \frac{(\sigma(\pi/4, +z, 0) - \sigma(\pi/4, -z, 0))}{(\sigma(\pi/4, +z, 0) + \sigma(\pi/4, -z, 0))} \quad (1)$$

Appropriate data for this observable forms part of the g9a dataset. Now fully calibrated data is becoming available, it is possible to begin particle identification of the data, identifying events which correspond to K-Lambda photoproduction, a first step towards analysis of this reaction channel. Once these events are identified, the reaction can be analysed to extract the G observable.

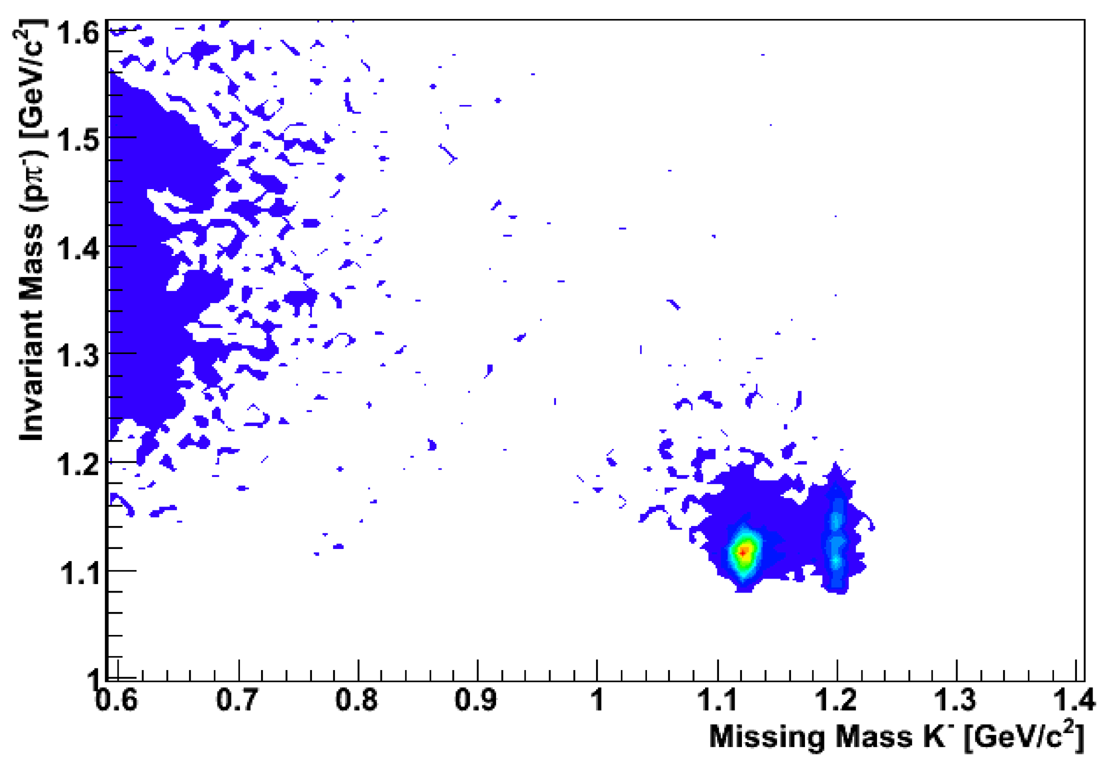

Fig 6: Missing mass of positive charged Kaons identified by CLAS versus invariant mass of Proton and reconstructed Pi minus, from circularly polarised g9a data. Two peaks corresponding to the Lambda and Sigma hyperons are visible between 1.1GeV and 1.2Gev on the x-axis. By applying a cut in the region of the Lambda, Kaon-Lambda events can be extracted from the data.

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