New Measurement of Beam Asymmetry from Pion Photoproduction off a Neutron.

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and the CLAS collaboration

Search for nucleon resonances

Despite decades of study our knowledge of the fundamental resonance spectrum of the nucleon is still incomplete. Predictions are heavily reliant on phenomenological models, experimental differentiation between which has not been conclusively resolved. This is as a result of insufficient accuracy and quantity of observables obtained, and leaves many questions in baryon spectrometry open, such as the problem of “missing” resonances [1]. Have they not yet been observed -- or are they simply not there?

Polarisation observables

Photoproduction of pseudo scalar mesons can be described in terms of four complex reaction amplitudes. Experimentally, these combine to yield 16 observables:

$\partial\sigma/\partial\Omega$ and 3 single polarisation observables :

- **Beam Asymmetry**, Σ
- Target asymmetry, T
- Recoil polarisation, P

&

12 double-polarisation observables from polarised combinations of beam-target, beam-recoil and target-recoil.

Beam Asymmetry, *Σ,* from linearly polarised photons is a crucial observable to constrain Partial Wave Analyses (PWA), which are used to extract resonances from experimental data.

$$\frac{d\sigma}{d\Omega} = \sigma_0 \left(1 - P_{lin} \Sigma \cos 2\varphi\right)$$

where P_{lin} is the beam polarisation, σ_0 is the unpolarised cross-section and φ is the angle of the transverse polarisation direction to the reaction plane.

Pion photoproduction from the neutron

Many wide, overlapping resonances are expected to couple to the **pion decay channel**.

Full analysis of the pion channel requires data on both the proton and the **neutron** in order to separate the isoscalar and isovector contributions of EM current in the multipole amplitudes. The world data-set on the neutron, however, is extremely sparse, consisting of only three fixed-angle experiments in a limited energy range [2][3][4] (Fig. 1).

A new, high-statistics photoproduction experiment, g13, using a linearly polarised photon beam at six energy settings (1.1 – 2.3 GeV) with two orthogonal polarisation orientations and a liquid deuterium target has been carried out at Jefferson Laboratory, Virginia, USA, in spring 2007. We present a preliminary measurement of *Σ* from the analysis of the channel:

$$\gamma + n \rightarrow \pi^- + p$$

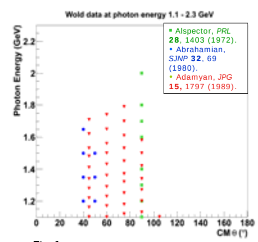

Fig. 1

Jefferson Lab

The g13 experiment was conducted in Hall B of Jefferson Laboratory, an electron accelerator operating at energies up to 6 GeV. It is equipped with a **coherent bremsstrahlung** facility and tagger for the production and measurement of polarised photon beams and houses **CLAS** – the CEBAF Large Acceptance Spectrometer, which, covering almost 4π in solid angle and combined with a toroidal magnetic field, offers excellent sensitivity to charged particles.

Identifying the *n(γ, π)p* channel

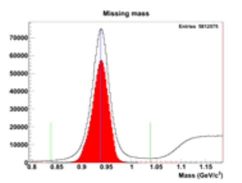

Fig. 2 Missing mass cut between green lines, peak at mass of proton spectator, red area shows missing mass after all cuts.

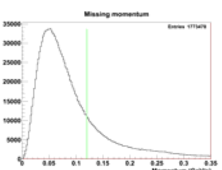

Fig. 3 Missing momentum cut below 0.12 GeV

Need to identify the quasi-free reaction with a spectator proton

$$\gamma + d \rightarrow \pi^- + p + (p_{spectator})$$

- ❖ Momentum-dependent **mass cut** on two particle events selecting π^- and p in the final state.
- ❖ Cut on “missing mass” in the reaction for the **spectator proton** (Fig. 2).
- ❖ Selection of events where **quasi-free** contribution dominates, those with low “missing momentum” – below 0.12 GeV (Fig. 3).
- ❖ Cut on proton and pion being back-to-back in centre-of-mass system (CMS) (Fig.4).

The exact photon was identified (and its energy measured) through timing coincidence with the tagger. This is made possible by the bunched nature of the beam which arrives at 2 ns intervals (Fig. 5).

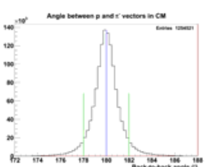

Fig. 4

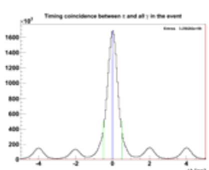

Fig. 5.

Preliminary results

A very preliminary evaluation of a fraction of the data indicates a tiny statistical uncertainty in the final result. The results for a selection of invariant mass bins are shown in Fig 7, where the error bars are purely statistical and degree of polarisation is assumed to be 1. It is our goal to reduce systematics, which are currently very large, to ~5%.

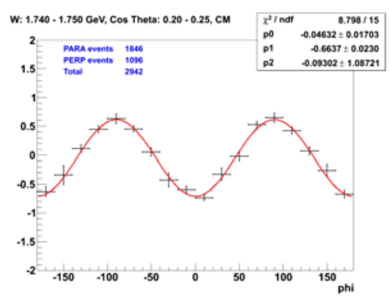

Fig. 6. $\frac{N_{\parallel} - N_{\perp}}{N_{\parallel} + N_{\perp}}$ of pion cross-sections vs. azimuthal angle, fitted with $A + B\cos 2(\varphi + c)$.

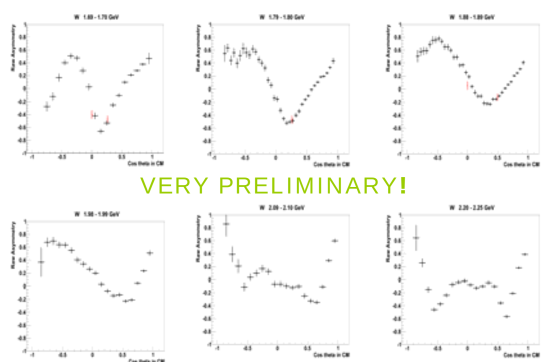

Fig. 7. Very preliminary measurement of Σ.

Extracting Beam Asymmetry

The beam asymmetry can then be extracted from a *cos2φ* fit to the *φ*-distribution of pions in centre-of-mass frame. In order to reduce systematics, the polarisation plane was rotated between two orthogonal directions during the experiment, simplifying the expression (Fig. 6):

$$N_{\parallel} = N_{\theta}(1 - P\Sigma\cos 2\varphi)$$

$$N_{\perp} = N_{\theta}(1 + P\Sigma\cos 2\varphi)$$

$$\Sigma P \cos 2\varphi = \frac{N_{\parallel} - N_{\perp}}{N_{\parallel} + N_{\perp}}$$

In conclusion…

Early extraction of the Beam Asymmetry, *Σ*, from pion photoproduction off the neutron shows that the data quality is good, statistical uncertainty is tiny and a sizeable asymmetry can be observed. The measurement promises to greatly expand the sparse world data-set on the neutron and aid in constraining amplitudes of PWA’s, shedding light on the nucleon excitation spectrum.

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