Photoproduction of Λ* Resonances at CLAS

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Abstract

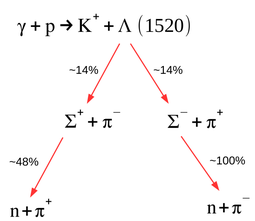
Much is known about the photoproduction of the hyperon resonances Λ(1405)1/2⁻ and Λ(1520)3/2⁻, but little is known about photoproduction to the higher-mass resonances Λ(1670)1/2⁻ and Λ(1690)3/2⁻. Both pairs of resonances are spin-orbit partners and are rated as 4-star (well-known) by the Particle Data Group. In the quark model, the Λ(1405) and Λ(1520) resonances are assigned to the SU(3) singlet, where the Λ(1670) and Λ(1690) are assigned to the excited L=1 octet. In this poster, we present differential cross-sections for Λ(1520)3/2⁻ using photoproduction data from the CLAS detector at Jefferson Lab.

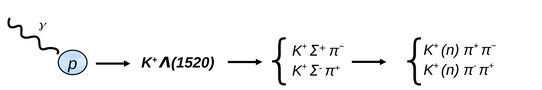
Background

- When a given quantity of energy is added to the nucleon, it can produce an excitation of the valence quarks inside the nucleons, known as resonances. These resonances an decay to lower energy configuration by emitting a quark-antiquark pair, essentially releasing part of the energy as mass. Hadron spectroscopy searches for ground and excited state baryons (qqq) and its emitted mesons ($q\bar{q}$).
- Hyperons are baryons with one or more strange quarks. The Λ's are hyperons with one strange quark and isospin 0. PDG status for the Λ* resonances are shown [1].

Particle	J^P	PDG rating	Status as seen in $N\bar{K}$	$\Lambda\pi$	$\Sigma\pi$	Other Channels
Λ(1405)	1/2-	****	****	Forbidden	****	$\Lambda\pi\pi$, $\Lambda\gamma$
Λ(1520)	3/2-	****	****		****	$\Lambda\eta$
Λ(1670)	1/2-	****	****		****	$\Lambda\pi\pi$, $\Sigma\pi\pi$
Λ(1690)	3/2-	****	****		****	

- Baryon spectra studies have been crucial to understanding QCD, partly through relations between the mass of the quarks and the effective degrees of freedom describing the hadron spectra. Recent studies have shown the importance of three-body final states in order to study higher mass resonances [2].
- Photoproduction off a proton can create K⁺ -meson and a Λ*. The Λ* can decay by a Σπ channel, $\Sigma^+\pi^-$, $\Sigma^-\pi^+$ and $\Sigma^0\pi^0$. For charged decay channels, the Σ± gives off a neutron and a π±.

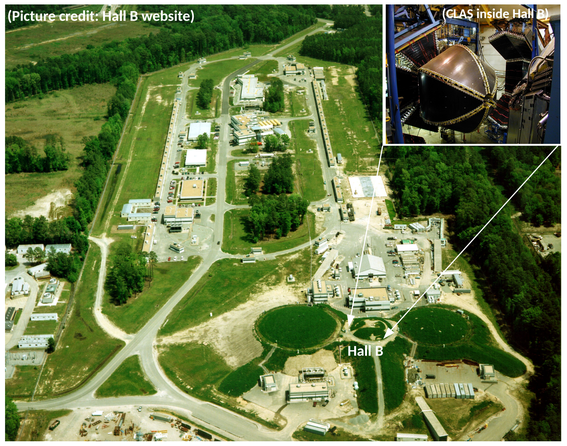




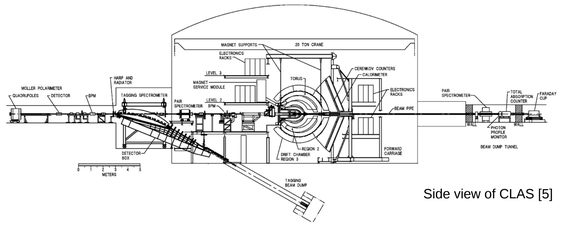
- Recent photoproduction study on Λ(1520) by Kei Moriya *et al.* (CLAS collaboration) [3] has been successful when compared with model predictions by Nam *et al.* [4].
- This study will extend the cross sections to higher photon energies using the g12 experiment at CLAS, where the current theoretical models of Regge exchange are expected to be more accurate. This study of the Λ* resonances, Λ(1520), Λ(1670) and Λ(1690), will provide insight into how baryons evolve into higher-mass excited resonance states.

CLAS@JLab

The g12 experiment took place at Jefferson Lab from March to June 2008 using CLAS spectrometer in Hall B.



The 60-60 nA electron beam of energy 5.715 GeV, delivered by the CEBAF accelerator, produces bremsstrahlung photon beam. The tagging system at Hall B provided a high-luminosity, circularly polarized, high-energy real-photon beam (up to 5.4 GeV) for the g12 run.



Side view of CLAS [5]

The beam is sent to bombard a 40 cm long unpolarized liquid hydrogen target. The detection and tracking by CLAS consists of determining a particle's TOF, momentum, and track information. The final state particles detected of this reaction study are K⁺, π^+ and π^-.

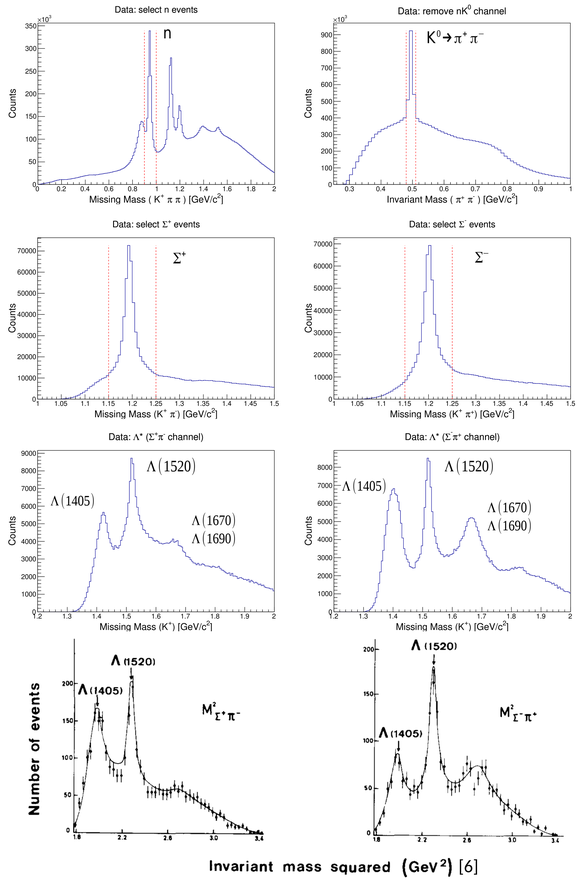
References

[1] M. Tanabashi *et al.*, Phys. Rev. D, 98:030001, Aug 2018.
[2] R. G. Edwards *et al.*, Phys. Rev. D, 87:054506, Mar 2013.
[3] K. Moriya *et al.*, Phys. Rev. C, 88:045201, Oct 2013.
[4] S. Nam *et al.*, Phys. Rev. C, 81:055206, May 2010.
[5] B. A. Mecking et *al.*, NIM, 3, 513–533 (2003).
[6] J. Griselin *et al.*, Nuc. Phys. B, 93(2):189 – 216, 1975.

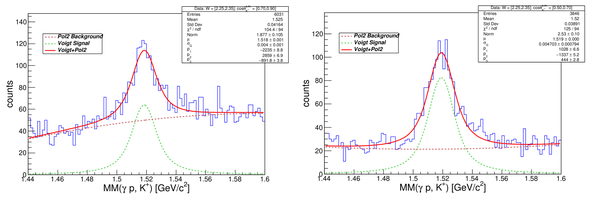
Λ* Resonances

Event selection begins with photon selection, particle identification, accompanied by detector cuts and corrections. A series of missing mass cuts narrow down the search for the Λ* resonances.

0.9 ≤ MM(K⁺πn) ≤ 1.0	Select neutron events
0.48 ≤ IM($\pi^+\pi^-$) ≤ 0.51	Remove nK⁰ channel
1.15 ≤ MM(K⁺π^-) ≤ 1.25 1.15 ≤ MM(K⁺π^+) ≤ 1.25	Select Σ^+ and Σ^- events for exclusive Σπ channels
1.44 ≤ MM(K⁺) ≤ 1.6	Fitting Range
2.05 ≤ W ≤ 2.45 GeV -0.9 ≤ $\cos\theta^{K+}_{cm}$ ≤ 0.9 -2.5 ≤ t ≤ -0.3	Kinematic Ranges $s = (P_\gamma + P_p)^2$ $t = (P_\gamma + P_{K+})^2$



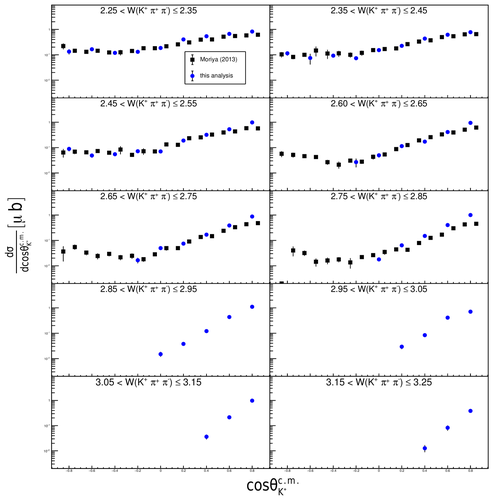
The events were then binned in W energy and K⁺ azimuthal angle ranges. Voigtian Function over a smooth quadratic background was used to extract yield and acceptance.



Λ(1520) Differential Cross-sections

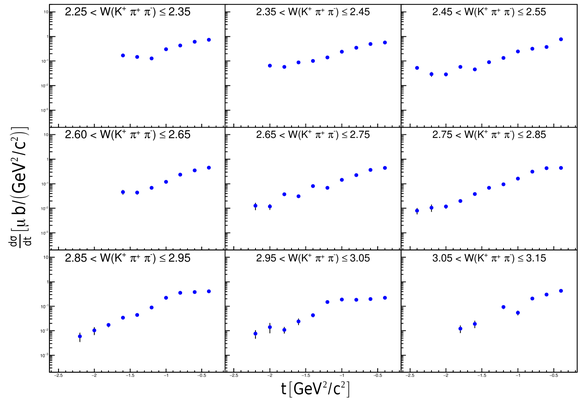
With yield (Y), acceptance (A) and luminosity (L), differential Cross-sections were obtained for both channels. By averaging over the two decay branches, Λ(1520) cross-sections are obtained and then compared with previous CLAS results.

$$\frac{d\sigma}{d\cos\theta^{c.m.}_{K^+}} = \frac{Y(W, \cos\theta^{c.m.}_{K^+})}{\tau(\Delta\cos\theta^{c.m.}_{K^+})\,A(W, \cos\theta^{c.m.}_{K^+})\,L(W)}$$



t-channel analysis was carried out by binning events in different W energy ranges and momentum transfer (t) bins.

$$\frac{d\sigma}{dt} = \frac{Y(W,t)}{\tau(\Delta t)\,A(W,t)\,L(W)}$$



Summary

- Photoproduction is a powerful tool to hunt for missing resonances in hadron spectra.
- Two channels for Λ(1520) are investigated using the same final state particles: K⁺, π^+ and π^-.
- Differential cross sections for Λ(1520) using both decay branches are plotted for s- and t- channels analysis. An analysis note has been submitted for CLAS review.
- Study of the octet higher mass resonances Λ(1670) & Λ(1690) is ongoing with the same final state particles.