# Spin and Parity Measurement of $\Lambda(1405)$ Baryon - Review of a CLAS Publication

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FSU Weekly Group Meeting

Weekly Group Meeting

08/18/2014

# Outline

# Introduction

Paper reference - K. Moriya *et al.*, PRL 112, 082004 (2014).
Note : selected as a PRL "Editor's Suggestion"

**The** $\Lambda(1405)$ **baryon -**

- The first excited state of the family of $\Lambda$ hyerons (baryons with 1 s quark.)
- Elusive nature - 3 quark state or hybrid ?
- Theories that predict the nature of this hyperon assume that it has $J^P = \frac{1}{2}^-$, based on quark model. But at least one model predicts "$+$" parity.
- Spin and parity of this hyperon have never been studied in the past due to experimental challenges like hard to create it(since mass < $N\overline{K}$), and it must be produced spin polarized.

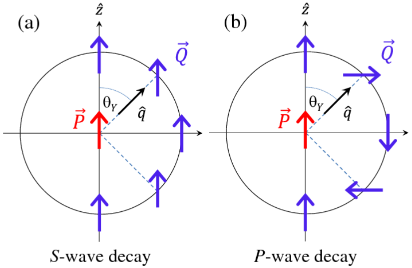
# Outline

# Determining Spin (J) and Parity (P)

$\gamma p \to K^+\Lambda, \Lambda \to \Sigma^+\pi^- \to p\pi^0\pi^-$

**Spin determination-**

- The decay angular distribution of $\Sigma^+\pi^-$ is solely dependent on J.
- For spin $\frac{1}{2}$, the decay will be isotropic. But it can also be isotropic if $\Lambda$ is unpolarized. Hence, polarization of $\Lambda$ is essential.




**Parity determination-**

- If J=$\frac{1}{2}$ then,for unpol. beam-target, pol. $\vec{P}$ of $\Lambda$ is restricted to be out of the production plane.
- The polarization transferred ($\vec{Q}$) from $\Lambda$ to $\Sigma^+$ determines the angular momentum of $\Lambda$'s decay. That determines its parity.

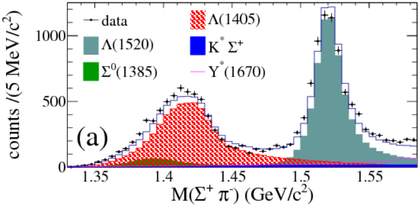
# Outline

# Experimental Setup and Analysis

Run group - CLAS run g11a with unpolarized photon beam, target at JLab.

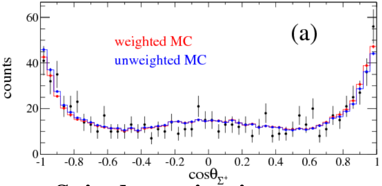
Kinematic range chosen for dominant $\Sigma^+\pi^-$ decay:
$2.55 < W < 2.85$ GeV, 0.6< $cos(\theta)_{c.m.}{}^{K^+}$ <0.9

$\overrightarrow{Q}$ determined from weak decay asymmetry in the decay $\Sigma^+ \rightarrow p\pi^0$




No event-based background separation. Applied a $\Sigma^+\pi^-$ mass cut of 1.30 - 1.45 GeV, where the spectrum is dominated by $\Lambda(1405)$. Estimated background $\sim 16\%$

# Analysis

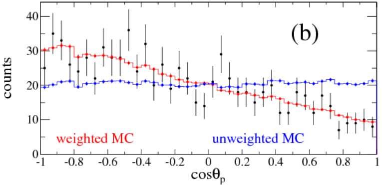



Here, $\cos(\theta_{\Sigma^+})$ is the polar angle of $\Sigma^+$ in the $\Lambda$ rest frame. Z axis - normal to the production plane.

**Spin determination-**

- For J = $\frac{1}{2}$, the above angular distribution should be isotropic, given $\Lambda$ was polarized.
- For higher J, the distribution will be anisotropic.
- To account for angular variation due to CLAS acceptance, the data was fitted with Monte Carlo which also included the angular distribution for various spin hypothesis.
- Unweighted MC - polarization of $\Sigma^+$ not considered.
- Result - good agreement between data and MC for J=$\frac{1}{2}$

# Analysis

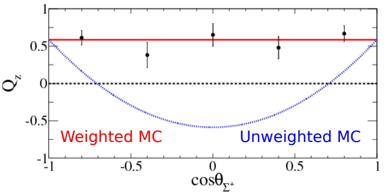


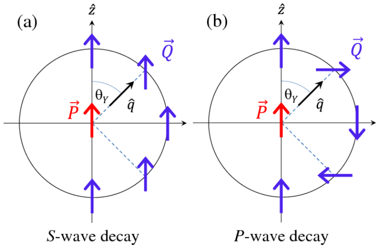

Here, $\cos(\theta_p)$ is the polar angle of $p$ in the $\Sigma^+$ rest frame. Z axis - direction of $\Lambda$'s polarization.

**Parity determination-**

- $I(\theta_p) \propto (1 + Q_z cos(\theta_p))$.
- So, fitting the data with unweighted MC (i.e. not weighting it with $Q_z$)didn't work well.
- Fitting the data with weighted MC gave us $Q_z$ for each $cos(\theta_{\Sigma^+})$ bin.

# Analysis




**Parity determination(continued ..)-**

- $Q_z$ turned out to be independent of the decay polar angle $\theta_{\Sigma+}$
- Result: P = -1. $J^P = \frac{1}{2}^+$ and $\frac{3}{2}^-$ were excluded.

# Outline

# Result

**$J^P$ of $\Lambda(1405)$ = $\frac{1}{2}^-$ was confirmed.**

A by-product of this analysis was getting the $\Lambda$ polarization, since P = $Q_z$ for $J^P = \frac{1}{2}$. It came out to be $45\%$.