Strong supression for the $\Theta^+(1540, J^P = 3/2^-)$ photoproduction from the proton target

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In the present work, we study the photoproduction of Θ^+ for the two possible quantum numbers, i.e. $J^P = 3/2^-$ and $1/2^+$. We use the Born approximation with the effective Lagrangians. The Rarita-Schwinger formalism is utilized for describing spin–3/2 Θ^+ relativistically. The gauge-invariant, Lorentz-invariant and crossing-symmetric four dimensional form factor is employed with the cutoff fixed to the data of the $\Lambda(1520)$ photoproduction [1]. Several unknown parameters are determined by the quark model and phenomenological consideration.

From above considerations, we are able to find the following consequences: The null result of the CLAS experiment [2] for the Θ^+ photoproduction from the proton target can be understood, if Θ^+ is assumed to have the quantum numbers $J^P = 3/2^-$. Furthermore, the strong suppression for $\Theta^+(3/2^-)$ is rather stable for the choice of the value of $g_{K^*N\Theta}$. The main reason for this strong suppression can be explained by the dominant contribution from the contact term, which is also the case of the $\Lambda(1520)$ photoproduction. For completeness and comparison, we also present the total and differential cross section for $\Theta^+(1/2^+)$. Though we find the strong suppression for the proton target when K^* is absent, the difference between the two targets, i.e. the neutron and proton ones is not large at all, if we consider the contribution of K^*–exchange. We summarize our results in Table. I, where we also consider K^*–exchange for $\Theta^+(1/2^+)$.

J^P	$3/2^-$		$1/2^+$	
$\Gamma_{\Theta\to KN}$	0.1 MeV (1.0 MeV)		1.0 MeV	
$g_{K^*N\Theta}$	±4		±1.73	
Reaction	$\gamma n \to K^-\Theta^+$	$\gamma p \to K^0\Theta^+$	$\gamma n \to K^-\Theta^+$	$\gamma p \to K^0\Theta^+$
σ	$\sim 30nb\,(\sim 250nb)$	$\sim 7nb\,(\sim 7nb)$	$\sim 1.5nb$	$\sim 1.5nb$
$d\sigma/d(\cos\theta)$	Forward peak	Bump at $\sim 50^\circ$	Bump at $\sim 45^\circ$	Bump at $\sim 45^\circ$

TABLE I: The main results of the Θ^+ photoproduction

Consequently, if K^*–exchange plays an important role in describing the Θ^+ photoproduction as argued in Ref. [3], the Θ^+ with $J^P = 3/2^-$ can explain the newest CLAS null results of the existence of the Θ^+ from the proton target naturally, if Θ^+ does exist. However, we note that our model calculation still contains some ambiguous physical quantities such as κ_Θ and $g_{K^*N\Theta}$. When these numbers can be determined adequately, the predictive power of our calculation will be enhanced. If the forthcoming CLAS experiment of the Θ^+ photoproduction from the neutron target [2] observes the evidence of the Θ^+ baryon, the present investigation on the $\Theta^+(3/2^-)$ photoproduction will shed light on the physics of the pentaquark baryon Θ^+.

If our suggestion Θ^+ with $J^P = 3/2^-$ turns out to be true, the analysis of the Θ^+ decay in the helicity t–channel frame is quite useful to determine the spin and main contribution to the Θ^+ production as done for the $\Lambda(1520)$ electroproduction [4] and photoproduction [5].

[1] S. I. Nam, A. Hosaka and H. -Ch. Kim, arXiv:hep-ph/0503149.
[2] R. De Vita *et al.* [Clas Collaboration], talk given at APS april meeting (2005).
[3] T. Mart, A. Salam, K. Miyagawa and C. Bennhold, arXiv:nucl-th/0412095.
[4] S. P. Barrow *et al.* [Clas Collaboration], Phys. Rev. C **64**, 044601 (2001).
[5] D. P. Barber *et al.*, Z. Phys. C **7**, 17 (1980).