

**PHOTO-EXCITATION OF HYPERONS AND EXOTIC
BARYON IN $\gamma N \rightarrow K\bar{K}N$ ***

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We investigate the reaction of $\gamma N \rightarrow K\bar{K}N$ focusing on the photoproduction of $\Lambda(1520)$ and putative exotic $\Theta(1540)$. We consider various background production mechanisms including the production of vector mesons, tensor mesons, and other Λ and Σ hyperons. We discuss the angular distribution of $\Lambda(1520)$ photoproduction cross section and the radiative decays of $\Lambda(1520)$. We also discuss what we expect for the invariant mass distributions if the $\Theta(1540)$ is formed in the reaction, with the parameters studied so far. We find that the peak in the KN invariant mass distribution, if confirmed, can hardly come from the kinematic reflections, especially, due to the tensor meson backgrounds.

Recent experimental activities searching for exotic pentaquark states^{1,2} renewed the interests in double kaon photoproduction, i.e., $\gamma N \rightarrow K\bar{K}N$, motivating recent theoretical investigations on its production mechanisms³⁻⁶. Investigating various physical quantities of this reaction allows the study of hadron resonances that are formed during the reaction. For example, from its $K\bar{K}$ channel, we can study the photoproduction of mesons, which decay mostly into $K\bar{K}$, and the $\bar{K}N$ channel is directly related to the $S = -1$ hyperon production, where S is the strangeness. Furthermore, the KN channel of this reaction gives a tool of searching for the hypothetical $S = +1$ exotic baryons. In fact, this is the reaction used by LEPS Collaboration¹ to observe the exotic Θ , which caused a lot of theoretical and experimental investigations⁶. However, the signals for $\Theta(1540)$

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could not be confirmed by other experiments, which lead to a doubt on its existence.

Another motivation of this work is the radiative decays of hyperon resonances. As stated above, double kaon photoproduction is used to study the production of hyperon resonances. Close inspection of the kinematic region of this reaction at low energies shows that the ϕ meson production is dominant in the $K\bar{K}$ channel and $\Lambda(1520)$ is in the $\bar{K}N$ channel. Therefore, this reaction may be used for studying the production mechanisms of $\Lambda(1520)$, which contain the radiative decays of $\Lambda(1520)$. Theoretical predictions on the radiative decays of $\Lambda(1520)$ are strongly model-dependent and their experimental data are very limited and uncertain⁷. There are recent measurements for $\Gamma(\Lambda(1520) \rightarrow \Lambda\gamma)$ by SPHINX Collaboration and CLAS Collaboration^{8,9}, of which results are consistent to each other. But the decay width of $\Lambda(1520) \rightarrow \Sigma\gamma$ has not been reported so far. (Note that the decay width of $\Lambda(1520) \rightarrow \Sigma\gamma$ in PDG⁷ is not from a direct measurement, but from that of $\Lambda(1520) \rightarrow \Lambda\gamma$ by using some SU(3) relations.)

In this work, we consider the photoproduction of $\Lambda(1520)$ and that of $\Theta(1540)$. As background production mechanisms of the latter, we consider vector meson production, tensor meson production, and the t -channel (tree) Drell diagrams, as well as the production of other Σ and Λ hyperons. We also include the form factors and constrain the cutoff parameter by the total cross section data for $\gamma p \rightarrow K^+K^-p$. The details on the diagrams, effective Lagrangians used in this calculation, and the method to restore the charge conservation condition can be found in Ref. 6. The models for vector meson production can be found in Ref. 10.

Shown in Fig. 1 are the results for the double differential cross sections for $\gamma p \rightarrow K^+\Lambda(1520) \rightarrow K^+K^-p$, where θ is the angle of K^+ in the c.m. frame. In this calculation we use the value of CLAS Collaboration for the $\Lambda(1520) \rightarrow \Lambda\gamma$ decay⁹, ≈ 167 keV. For the decay of $\Lambda(1520)$ into $\Sigma\gamma$ we take two model predictions: the nonrelativistic quark model prediction of Ref. 11, ≈ 55 keV, and that of the relativistic quark model of Ref. 12, ≈ 293 keV. The result shows that the double differential cross section at large scattering angles depends on the decay width of $\Lambda(1520) \rightarrow \Sigma\gamma$.

Next, we consider the production of exotic $\Theta(1540)$. For this calculation, we assume that the Θ belongs to $\bar{\mathbf{10}}$, and it has $J^P = \frac{1}{2}^+$ and a decay width of 1 MeV⁷. The SU(3) effective Lagrangian for the interaction of $\bar{\mathbf{10}}$ with the normal baryon and meson octet can be found, e.g., in Ref. 13. In Fig. 2, we present the results for the invariant mass distributions of various channels in the $\gamma n \rightarrow K^+K^-n$ reaction. Apparently, the peak coming from

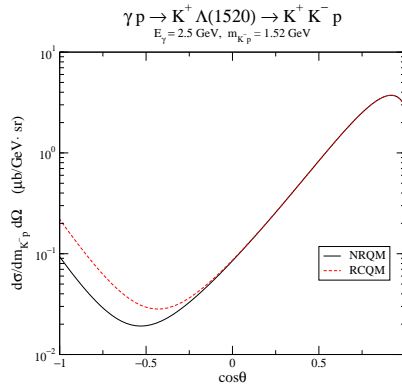


Figure 1. Differential cross section for $\gamma p \rightarrow K^+ \Lambda(1520) \rightarrow K^+ K^- p$. The solid and dashed lines are obtained by using the nonrelativistic quark model¹¹ and relativistic quark model¹² predictions for the $\Lambda(1520) \rightarrow \Sigma \gamma$ decay.

the $\Theta(1540)$ formation depends on the cross section of Θ photoproduction. In this work, we used the model of Ref. 14 for $\gamma N \rightarrow \bar{K} \Theta$. (See, e.g., Ref. 15 for the general properties of this reaction.)

One interesting question about this reaction is whether the peak in the KN channel could come from the other backgrounds, especially from tensor meson production⁴. This was motivated by an old experiment¹⁶ on $\pi^- p \rightarrow K^- X$, where the observed peaks in the exotic channel were ascribed to the background, especially higher-spin meson, production mechanisms, since the peak positions moved by changing the beam energy. Therefore, it is crucial to test whether this can explain the peak in the KN channel of double kaon photoproduction. In this work, we include $a_2^0(1320)$ and $f_2(1275)$ tensor meson production as backgrounds. We found that (i) the tensor meson production alone gives a very broad peak not a sharp peak, although we confirmed that the peak position moved depending on the beam energy, and (ii) the tensor meson production part is suppressed very much compared with the other reaction mechanisms, and its contribution is hard to be seen even after removing the ϕ and $\Lambda(1520)$ production part from the backgrounds. Therefore, any sharp peak, if confirmed, can be hardly explained by kinematic reflections. In addition, a very sharp peak is expected in the KN invariant mass distribution if the exotic Θ is formed in the reaction. (We note that the most recent CLAS experiment¹⁸ shows no evidence of $\Theta(1540)$, but its existence is still controversial^{19,20}.)

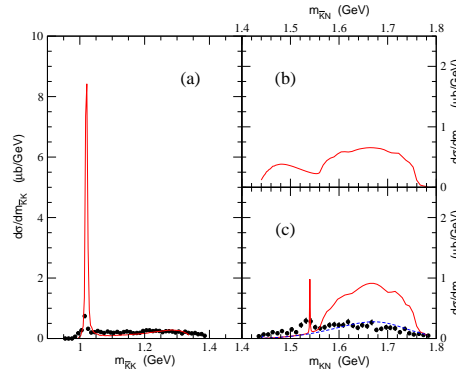


Figure 2. (a) K^+K^- , (b) K^+N , and (c) K^-N invariant mass distributions for $\gamma n \rightarrow K^+K^-n$ at $E_\gamma = 2.3$ GeV. The data are from Ref. 2. The dashed line in (c) is obtained without the ϕ and Θ contributions.

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