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Possible $\Sigma(\frac{1}{2}^-)$ under the $\Sigma^*(1385)$ peak in $K\Sigma^*$ photoproduction

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The LEPS collaboration has recently reported a measurement of the reaction $\gamma n \to K^+\Sigma^{*-}(1385)$ with linearly polarized photon beam at resonance region. The observed beam asymmetry is sizably negative at $E_\gamma = 1.8-2.4$GeV, in contrast to the presented theoretical prediction. In this paper, we calculate this process in the framework of the effective Lagrangian approach. By including a newly proposed $\Sigma(J^P = \frac{1}{2}^-)$ state with mass around 1380 MeV, the experimental data for both γn and γp experiments can be well reproduced. It is found that the $\Sigma(\frac{1}{2}^-)$ and/or the contact term may play important role and deserve further investigation.

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I. INTRODUCTION

With the development of accelerator facilities, strangeness production from photon-nucleon scattering has been extensively studied at resonance region [1–9]. These experiments can provide not only more information on the properties and interactions of the known resonances, but also clues for the existence of some new resonances. For $K\Sigma^*(1385)$ photoproduction, high statistic data have been available only recently. The CLAS collaboration has studied the reaction $\gamma + p \to K^+ + \Sigma^{*0}(1385)$ with unpolarized photon beam at energy $E_\gamma = 1.5 - 4$ GeV [2]. The LEPS collaboration has reported the reaction $\gamma + n \to K^+ + \Sigma^{*-}(1385)$, with a linearly polarized photon beam at $E_\gamma = 1.5 - 2.4$ GeV [9]. The high statistic data and the polarized observables provide more information and challenges for theoretical studies.

Theoretical investigations on $K\Sigma^*(1385)$ photoproduction include the work by Lutz and Soyeur [10], which mainly studies the t-channel processes, the work by Döring, Oset and Strottman [11], where the role of $\Delta(1700)$ is addressed, and the work by Oh, Ko, and Nakayama [12], where the roles of N and Δ resonances in s-channel are stressed and compared with the CLAS data [2].

For the approach by Oh, Ko, and Nakayama [12], the total cross section for $\gamma + p \to K^+ + \Sigma^{*0}(1385)$ is calculated in the framework of gauge-invariant effective Lagrangians. The results are in reasonable agreement with the CLAS data [2], showing that the s-channel N and Δ resonances above $K\Sigma^*$ threshold may give important contributions to cross sections. Although this theory can well describe the total cross section of $K\Sigma^*$ photoproduction from CLAS as well as from LEPS experiment [9], the theoretical prediction deviates greatly from the data for linear beam asymmetry measured by LEPS with polarized photon beam. This is an urgent problem for theoretical studies.

From studies of baryon spectroscopy and structures, five quark $qqqq\bar{q}$ components are proposed to play important roles in some baryons [13, 14]. A few years ago, Jaffe and Wilczek have promoted a diquark-diquark-antiquark picture for the pentaquark baryons [15]. Zhang *et al.* then studied the $J^P = \frac{1}{2}^-$ pentaquark baryons based on this picture and predicted a $\Sigma(\frac{1}{2}^-)$ state with mass around 1360 MeV [16]. A more general pentaquark model [13] without introducing explicitly diquark clusters predicts that $\Sigma(\frac{1}{2}^-)$ has a mass similar to $\Lambda(\frac{1}{2}^-)$, which is around 1405 MeV. From these two models, one would expect a $\Sigma(\frac{1}{2}^-)$ state with mass around 1380 MeV. Recent studies on $K^-p \to \Lambda\pi^+\pi^-$ process have shown some evidence for the existence of the $\Sigma(\frac{1}{2}^-)$ near 1380 MeV [17]. In this work, we study the $K\Sigma^*(1385)$ photoproduction processes with the consideration of the case that a portion of $K\Sigma(\frac{1}{2}^-)$ photoproduction is mixed in.

This paper is organized as follows. In section II, the theoretical framework is presented for the $K\Sigma^*$ and $K\Sigma(\frac{1}{2}^-)$ photoproduction from the nucleons. In section III, the numerical results for cross sections and the beam asymmetry are presented and compared with the experimental data, with some discussions. In section IV, we give the summery of this work.

II. THEORETICAL FRAMEWORK

The effective Lagrangian method is an important theoretical approach in describing the various processes at resonance region. We use the effective Lagrangians of Ref. [12] for $K\Sigma^*$ photoproduction, where the contact term is derived from Ref. [18] to keep the amplitude gauge invariant. In the following equations we use Σ^* and Σ denoting the $\Sigma^*(\frac{3}{2}^+)$ at 1385 MeV and the $\Sigma(\frac{1}{2}^-)$ near 1380 MeV, respectively.

A. $K\Sigma^*(\frac{3}{2}^+)$ photoproduction

For the reaction $\gamma N \to K\Sigma^*(\frac{3}{2}^+)$, the Feynman diagrams are shown in Fig. 1, where the incoming momenta are k and p for photon and nucleon, respectively, and the outgoing momenta are q and p' for K meson and the