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Contribution of N^* and Δ^* resonances in $K^*\Sigma(1190)$ photoproduction

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In this talk, we report theoretical studies on the $K^{*0}\Sigma^+(1190)$ photoproduction in the tree-level Born approximation, employing the effective Lagrangian method. We present the energy and angular dependences of the cross sections. It turns out that the N^* and Δ^* resonance contributions are negligible in the vicinity of the threshold. On the contrary, we observe that the κ and K exchanges in the t channel and $\Delta(1232)$ in the s channel dominate the scattering process, reproducing the experimental data qualitatively well.

Keywords: Photoproduction of $K^*\Sigma$, effective Lagrangian, N^* and Δ^* resonances

I. INTRODUCTION

The strangeness production from various scattering processes plays an important role in understanding the microscopic mechanism of the strong interaction beyond the chiral limit ($m_u \sim m_d \ll m_s$) and extends our knowledge into multi-strangeness particles. In the present talk, we would like to report theoretical studies on the K^* photoproduction off the proton target, i.e. $\gamma p \to K^{*0}\Sigma^+(1190)$. There have been two experimental data from the CLAS collaboration at Jefferson laboratory [1] and the TAPS collaboration at CBELSA [2]. Theoretical studies are also carried out based on the effective Lagrangian method [3] and chiral quark model [4]. In the present work for the $\gamma p \to K^{*0}\Sigma^+(1190)$ process, we employ the effective Lagrangian method at the tree-level Born approximation, including the N^* and Δ^* resonance contributions, such as $F_{15}(2000)$, $D_{13}(2080)$, $G_{17}(2190)$, $D_{15}(2200)$, $F_{35}(2000)$, $G_{37}(2200)$, and $F_{37}(2390)$ [5]. The relevant Feynman diagrams preserving the gauge invariance are given in Fig. 1, in which N, Δ, Σ, and Σ^* indicate the nucleon, $\Delta(1232)$, $\Sigma(1190)$, and $\Sigma^*(1385)$, respectively. The strong coupling constants for the ground-state baryons B, i.e. $g_{K^*\Sigma B}$, are determined by experimental information [5] as well as the Nijmegen soft-core potential model (NSC97a) [6]. As for the strong couplings for the baryon resonances B^*, we make use of the following relation:

$$\Gamma(B^* \to K^*\Sigma) = \sum_{l,s} |G(l,s)|^2, \tag{1}$$

where the amplitude $G(l,s)$ is computed by the SU(6) quark model [7]. For simplicity, we consider only the low-lying resonance states, since we are interested in the vicinity of the threshold. The magnetic transition strengths for the resonances, $\gamma N \to B^*$, are estimated from the experimental and theoretical values for the helicity amplitudes $A(1/2)$ and $A(3/2)$ [5, 8]. The scattering amplitude can be written with the phenomenological form factors that satisfy the Ward-Takahashi identity as follows:

$$\mathcal{M} = [\mathcal{M}_{s(p)} + \mathcal{M}_{u(\Sigma)}]F_c^2 + \mathcal{M}_{t(K)}F_K^2 + \mathcal{M}_{t(\kappa)}F_\kappa^2 + \mathcal{M}_{s(\Delta)}F_\Delta^2 + \mathcal{M}_{u(\Sigma^*)}F_{\Sigma^*}^2 + \mathcal{M}_{s(N^*)}F_{N^*}^2 + \mathcal{M}_{s(\Delta^*)}F_{\Delta^*}^2 \tag{2}$$

and the form factors are defined generically as

$$F_c = F_pF_\Sigma - F_p - F_\Sigma, \qquad F_\Phi = \frac{\Lambda_\Phi^2 - M_\Phi^2}{\Lambda_\Phi^2 - q^2}, \qquad F_B = \frac{\Lambda_B^4}{\Lambda_B^4 + (q^2 - M_B^2)^2}, \tag{3}$$

where q, Λ_Φ and Λ_B stand for the momentum transfer, the cutoff masses for the meson-exchange and baryon-pole diagrams, respectively. For the details of the theoretical framework, readers can refer to [3, 9].

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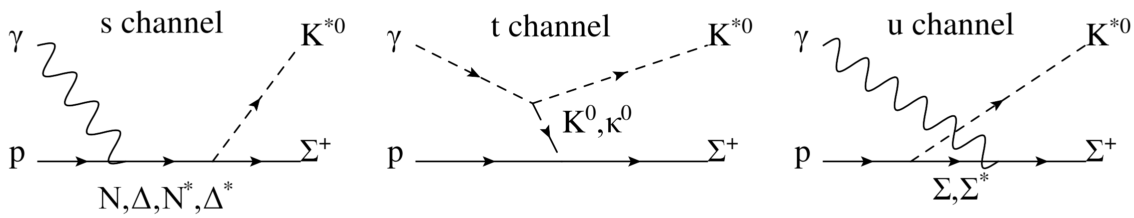

FIG. 1: Relevant Feynman diagrams for $\gamma p \to K^{*0}\Sigma^{+}(1190)$.

II. NUMERICAL RESULTS

In this section, we discuss the numerical results. In Fig. 2, we show them for the differential cross section as functions of $\cos\theta_{K^*}$ for different photon energies $E_\gamma = (1.925 \sim 2.475)$ GeV. The solid and dotted curves indicate the cases with and without the resonance contributions, respectively. The experimental data are taken from the CLAS [1] and TAPS [2]. As shown in Fig. 2, the two experimental data are qualitatively well reproduced and the resonance contributions are almost negligible. We verify that the K and κ exchanges provide strong contribution in the forward scattering region, whereas the backward scattering regions are dominated by the $\Sigma(1190)$ exchange in the u channel.

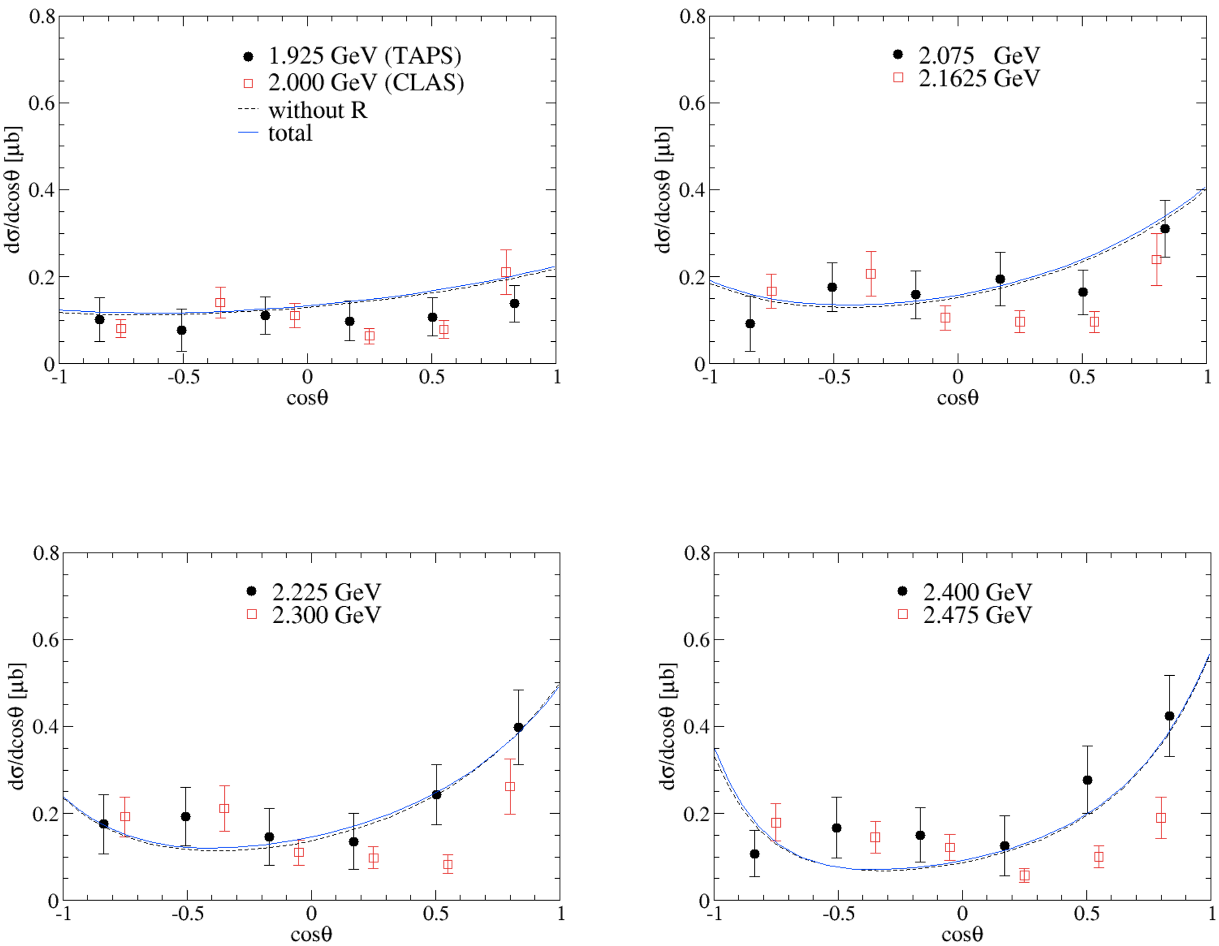

FIG. 2: (Color online) Differential cross section as functions of $\cos\theta$ for different photon energies $E_\gamma = (1.925 \sim 2.475)$ GeV. The experimental data are taken from the TAPS [2] and CLAS [1].

The numerical results for the total cross sections are given in the left panel of Fig. 3 as functions of E_γ. Note that the numerical results are slightly underestimated for $E_\gamma = (2 \sim 2.5)$ GeV in comparison to the data even with the resonance contributions. In the right panel of Fig. 3, we depict each contribution from the s-channel resonances. Although D_{13} and G_{17} provide sizable contributions near the threshold, they are still far smaller than those from the Born contributions. We note that this tendency of the small effects from the resonances are obviously different from the $K^*\Lambda$ [3, 9] and $K\Lambda$ [10] photoproductions. The difference between the Λ and Σ channels can be understood by the much smaller strong couplings for the Σ channel computed by the SU(6) quark model in comparison to those for the Λ channel [7].

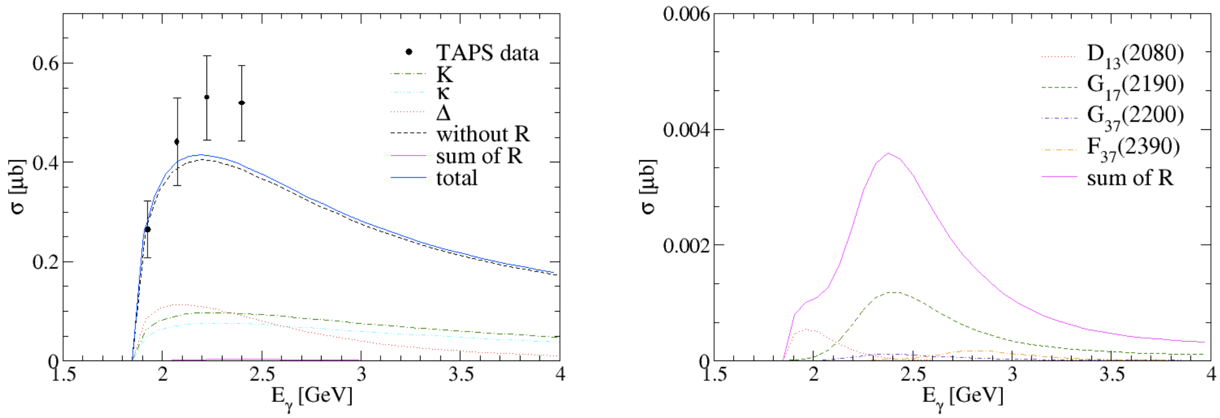

FIG. 3: (Color online) Left: Total cross sections as functions of E_γ. The experimental data are taken from the TAPS [2]. Right: Total cross sections from the resonance contributions in the s channel.

III. SUMMARY

We have investigated the $K^{*0}\Sigma^+(1190)$ photoproduction using the effective Lagrangian method at the tree-level Born approximation. In addition to the Born terms, we also took into account the resonance contributions in the s and u channels. The experimental data were reproduced qualitatively well. It also turns out that the resonance contributions are almost negligible in the energy and angular dependences of the cross sections, being different from the $K\Lambda$ and $K^*\Lambda$ photoproductions. The strange meson (K and κ) exchanges in the t channel and the $\Delta(1232)$ contribution in the s channel are the most dominant in describing the $K^{*0}\Sigma^+(1190)$ photoproduction. More detailed works are under progress and appear elsewhere.

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