Photon induced associated production near threshold

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1. Introduction

In this work, we have studied the associated particle production from the proton target using the photon beam, in the threshold region. The hadronic current receives contribution from the background terms as well as from the resonance excitations and their subsequent decay in KY ($Y = \Lambda, \Sigma$). The background terms consists of the Born terms and the kaon and hyperon resonances as their pole do not lie in the physical region of W, while the nucleon resonances constitute the resonant terms. The Born terms are constructed using the non-linear sigma model, which demands the $K\Lambda N$ coupling to be pseudovector that resulted in an additional term, along with the s-, t- and u-channel Born terms, known in the literature as the contact term to preserve the gauge invariance. Since the kaon and hyperon resonances are not well studied experimentally, therefore, their strong and electromagnetic couplings are fitted to the experimental data while the strong and electromagnetic couplings of the nucleon resonances are determined by the helicity amplitudes and decay widths, respectively. In Sect. 2, the formalism for the $K\Lambda$ production has been presented [1] focusing on the threshold region. Sect. 3 presents the results along with their discussions and Sect. 4 concludes the findings of the present work.

2. Formalism

The differential scattering cross section $\frac{d\sigma}{d\Omega}$ for the process

$$\gamma(q) + p(p) \longrightarrow K^+(p_k) + \Lambda(p'), \qquad (1)$$

in the center of mass (CM) frame is expressed as

$$\left.\frac{d\sigma}{d\Omega}\right|_{CM} = \frac{1}{64\pi^2 s}\frac{|\vec{p}'|}{|\vec{p}|}\overline{\sum}\sum|\mathcal{M}|^2, \quad (2)$$

where $s = W^2 = (p+q)^2$ is the square of the CM energy. In Eq. (1), the quantities in the parentheses represent the four momenta of the corresponding particles. The transition matrix element squared is expressed as

$$\overline{\sum}\sum|\mathcal{M}|^2 = -\frac{1}{4}g_{\mu\nu}\mathcal{J}^{\mu\nu}. \qquad (3)$$

The hadronic tensor $\mathcal{J}^{\mu\nu}$ is given by

$$\mathcal{J}^{\mu\nu} = \mathrm{Tr}\left[(\not{p} + M)\tilde{J}^{\mu}(\not{p}' + M_\Lambda)J^{\nu}\right], \quad (4)$$

where J^μ is the hadronic current, with $\tilde{J}^\mu = \gamma_0(J^\mu)^\dagger\gamma_0$. Feynman diagram for the Born terms and the contact term are shown in Fig. 1(a)–(d). The expressions of the hadronic current for the different Born and resonance terms are given in Ref. [1].

3. Results and discussion

In Fig. 2, we have presented the results for the different scattering cross section $d\sigma/d\cos\theta_K^{CM}$ as a function of $\cos\theta_K^{CM}$ at four different values of CM energy W viz. $W = 1.625$, 1.655, 1.675 and 1.685 GeV for the $K\Lambda$ photoproduction process. We have compared our results with the experimental data available from the SAPHIR 1998 [2], SAPHIR 2004 [3], CLAS 2006 [4] and CLAS 2010 [5]. In the region of the present interest, i.e., in the range $W = 1.62 - 1.72$ GeV, our results are in a good agreement with the available experimental data.

In Fig. 3, we have presented the results for the total scattering cross section σ as a function of W for the process $\gamma + p \to K^+ + \Lambda$. We have compared our results with the experimental data taken from SAPHIR 1998 [2],

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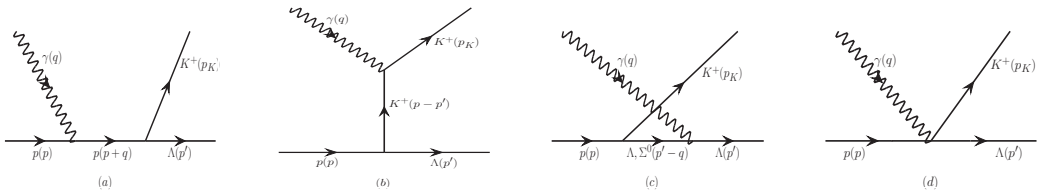

FIG. 1: Feynman diagram for the process $\gamma + p \to K^+ + \Lambda$ showing the contribution from the various Born terms *viz.* (a) s-channel, (b) t-channel, (c) u-channel and (d) contact term.

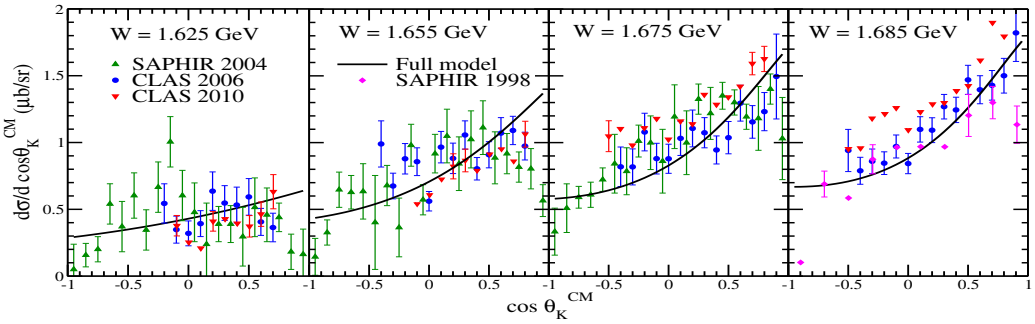

FIG. 2: $d\sigma/d\cos\theta_K^{CM}$ vs $\cos\theta_K^{CM}$ at fixed W viz. W = 1.625, 1.655, 1.675 and 1.685 GeV, for the process $\gamma + p \to K^+ + \Lambda$. Solid line represents the results of the full model of the present work and the experimental data has been taken from SAPHIR 1998 [2] (solid diamond), SAPHIR 2004 [3] (solid up triangle), CLAS 2006 [4] (solid circle) and CLAS 2010 [5] (solid down triangle).

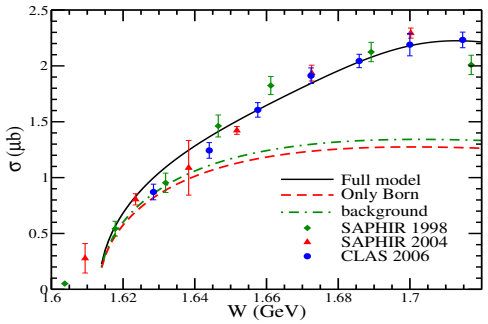

FIG. 3: σ vs. W for the process $\gamma + p \to K^+ + \Lambda$. Lines and points have the same meaning as in Fig. 2. Dashed (dashed-dotted) line represent the results when only Born (background) terms are considered.

SAPHIR 2004 [3] and CLAS 2006 [4]. From the figure, it may be observed that in the low energy region near the threshold i.e. in the range $W = 1.62 - 1.72$ GeV, the results of the present work are in a very good agreement with the CLAS as well as the SAPHIR data.

4. Conclusion

Our results explain very well the threshold region and the role of Born terms are quite significant up to $W \sim 1.65$ GeV. The results of the full model for the total as well as the differential scattering cross section are in a good agreement with the experimental data of SAPHIR and CLAS experiments, near the threshold region.

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