Resonances in $K\Lambda$ production

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1. Introduction

Nucleon resonances play a significant role in the meson production processes. In the case of the pion and eta-meson productions, $P_{33}(1232)$ and $S_{11}(1535)$, respectively, are the dominant resonance contributions, while in the case of the associated production ($K\Lambda$, $K\Sigma$), there is no dominant resonance contribution. Thus, a large number of resonances may couple to this channel. Since the threshold for the $K\Lambda$ production is 1.61 GeV, therefore, this process gives important information about the higher mass resonances, lying in the third and higher resonance regions, which do not contribute in π and η productions. Motivated by these arguments, in this work, we have studied the effect of the different nucleon resonances on the $K\Lambda$ production from the proton target induced by the real photons, *viz.*

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

where the four momenta of the corresponding particles are written in the parentheses. In the present work, we have included only those nucleon resonances which are present in the PDG having spin $\leq 3/2$, mass in the range $1.6-1.9$ GeV and branching ratio in $K\Lambda$. In Sect. 2, we give a brief overview of the model used to study the effect of the nucleon resonances in the $K\Lambda$ production [1]. Sect. 3 presents the results and the findings are concluded in Sect. 4.

2. Formalism

The matrix element for the reaction given in Eq. (1), is expressed as

$$\mathcal{M} = e\epsilon_\mu^r(q) \left\langle \Lambda(p')K^+(p_k)\right| J^\mu \left|p\right\rangle, \tag{2}$$

where $\epsilon_\mu^{(r)}$ is the photon polarization vector, with 'r' being the photon's polarization state.

We are studying the scattering of unpolarized photon with the proton, thus, the summation over the polarization states yields

$$\overline{\sum_{r=\pm1}} \epsilon_\mu^{*(r)}\epsilon_\nu^{(r)} \longrightarrow -g_{\mu\nu}. \tag{3}$$

The hadronic tensor $\mathcal{J}^{\mu\nu}$ is written as

$$\mathcal{J}^{\mu\nu} = \overline{\sum}\sum J^{\mu\dagger}J^\nu, \tag{4}$$

which receives the contribution from the Born as well as the resonance terms. The differential scattering cross section $d\sigma/d\Omega$ in the center of mass (CM) frame is obtained as

$$\left.\frac{d\sigma}{d\Omega}\right|_{CM} = \frac{1}{64\pi^2 s}\frac{|\vec{p}\,'|}{|\vec{p}|}\overline{\sum}\sum|\mathcal{M}|^2, \tag{5}$$

where $s = W^2 = (q+p)^2$ is the CM energy squared and $\overline{\sum}\sum|\mathcal{M}|^2$ is obtained using Eqs. (3) and (4) in Eq. (2).

In the present work, six resonances viz. $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $P_{11}(1880)$, $S_{11}(1895)$ and $P_{13}(1900)$ are considered. The form factors at the electromagnetic vertex are determined in terms of the helicity amplitudes and the $K\Lambda R$ couplings at the strong vertex are determined by the partial decay width of the resonance decaying to $K\Lambda$. We have also taken into account the contribution from the non-resonant terms *viz.* the Born terms and the contact term. The expressions for the hadronic currents of the Born and resonance terms are given in Ref. [1], which are added coherently to obtain the results of the full model.

3. Results and discussion

In Fig. 1, we have shown the contributions of the various nucleon resonances on the total scattering cross section σ as a function of CM energy W, for the process $\gamma + p \to K^+ + \Lambda$. The experimental data from SAPHIR 1998 [2], SAPHIR 2004 [3] and CLAS 2006 [4], along

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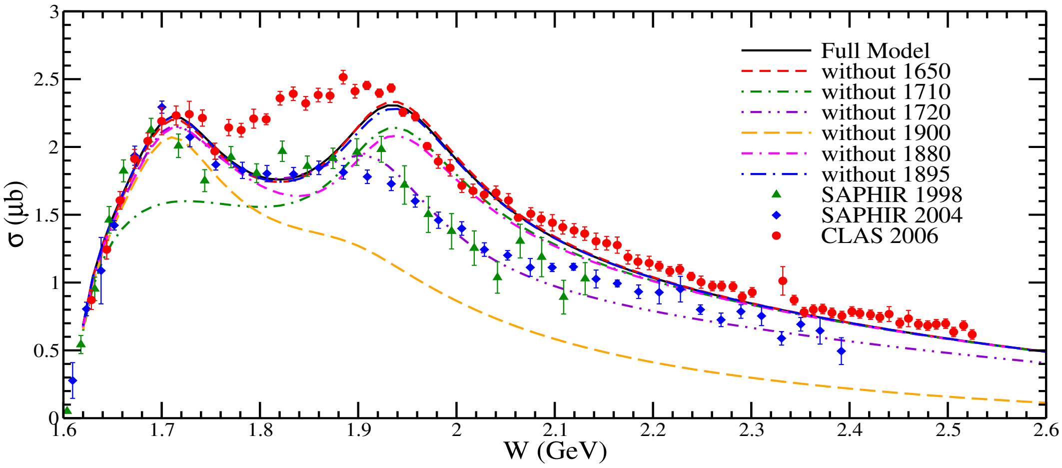

FIG. 1: σ as a function of CM energy W for the process $\gamma + p \to K^+ + \Lambda$. The experimental data is taken from SAPHIR 1998 [2] (open triangle), SAPHIR 2004 [3] (open diamond) and CLAS 2006 [4] (open circle). Solid line represents the results of the full model of the present work, short dashed line, short dashed-dotted line, double-dotted-dashed line, double-dotted-dashed line, long dashed line, double-dashed-dotted line and long dashed-dotted line represents the results of the full model when $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $P_{11}(1880)$, $S_{11}(1895)$ and $P_{13}(1900)$ resonance, respectively, is not taken into account.

with the results of the full model are presented for comparison. Though the contribution from the individual resonances to σ is not significant while we find that the contributions from the non-resonant terms are significant in the threshold region. Therefore, the interference of the resonance term with the background terms is significant. In the region of the CM energy considered here, we have presented the results when a particular resonance is switched off from the full model. The comparison of the results of the full model with the result when a particular resonance is switched off shows the significance of that resonance. One may observe from the figure that the two S_{11} resonances, *viz.* $S_{11}(1650)$ and $S_{11}(1895)$, have a very small effect on the total scattering cross section. The absence of $P_{11}(1710)$ in the hadronic current reduces the first peak by 38% while the second peak is reduced by $\sim$ 7%. The effect of $P_{11}(1880)$ is lesser than the effect of $P_{11}(1710)$ but is still considerable. It must be noted that the results when $P_{13}(1720)$ is excluded are in a very good agreement with the SAPHIR data. Although the first peak is not much affected by the absence of $P_{13}(1720)$, but the second peak is suppressed by 20% as well as it is shifted from $W = 1.94$ GeV to $W = 1.9$ GeV. $P_{13}(1900)$ plays a very significant role even at high $W > 2.2$ GeV as the second peak vanishes when we switch off this resonance.

4. Conclusion

The nucleon resonances contribute significantly in the $K\Lambda$ production at all values of W. The contribution of $P_{11}(1710)$ is found to be significant, although it is not considered in most of the models available in the literature. $P_{13}(1720)$ resonance makes a significant contribution to the cross section for $W \gtrsim 1.85$ GeV and our results are in good agreement with the CLAS data. Furthermore, $P_{13}(1900)$ plays very important role even at high W.

References

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