Spin-3/2 Nucleon Resonances in Kaon Photoproduction

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We have investigated two different formulations of propagators and vertex factors of spin-3/2 nucleon resonances by means of the isobar model for kaon photoproduction $\gamma p \to K^+\Lambda$. The results obtained from both formulations are fitted to experimental data by allowing the coupling constants to vary as free parameters. It is found that the gauge invariant formulation of the interaction vertex leads to a better agreement with the experimental data.

KEYWORDS: kaon photoproduction, spin 3/2, isobar model

1. Introduction

It is widely known that kaon photoproduction provides an essential tool for studies of strange hadrons. Although it has been investigated for more than six decades, a perfect formulation of kaon photoproduction has not yet been achieved. At present, abundant data are available to provide a stringent constraint to the theoretical model. In spite of this fact, the formulation of spin-3/2 or higher-spin nucleon resonances is still plagued by the problem of consistency. In the present work, we aim to investigate two different formulations of spin-3/2 nucleon resonances by means of the isobar model.

2. Models

To calculate the scattering amplitude of kaon photoproduction on the proton

$$\gamma(k) + p(p) \to K^+(q) + \Lambda(p_\Lambda), \tag{1}$$

we use the appropriate Feynman diagrams. The amplitudes consist of the background and resonance terms. In the latter, all nucleon resonances with the status of at least two-star rating and a spin up to 3/2 listed by PDG are taken into account. For the spin-3/2 nucleon resonances, two different formulations of propagators and vertex factors (Models A and B) are considered. In Model A, the scattering amplitude with parity ±1 is given by [1]

$$\begin{aligned}\mathcal{M}^{3/2}_{\rm res.} &= \mp\bar{u}_\Lambda\gamma_5\, p^\mu_\Lambda(\not{p}+\not{k}\mp\sqrt{s})\Big\{g_{\mu\nu}+\gamma_\nu\gamma_\mu-\frac{2}{s}\,q_\mu q_\nu \pm \frac{1}{\sqrt{s}}\big(\gamma_\mu q_\nu-\gamma_\nu q_\mu\big)\Big\}\Big[\mathcal{G}_1\Big\{(k^2\epsilon^\nu - k\cdot\epsilon\, k^\nu)\\ &\quad \pm c_\pm(k^2\not{\epsilon} - k\cdot\epsilon\not{k})\,k^\nu\Big\} + \mathcal{G}_2\,(p\cdot\epsilon\, k^\nu - p\cdot k\epsilon^\nu) + \mathcal{G}_3(k\cdot\epsilon k^\nu - k^2\epsilon^\nu)\Big]\,u_p\,, \end{aligned}\tag{2}$$

Model B is adopted from Ref. [2], which is constructed in a more gauge-invariant fashion and reads

$$\begin{aligned}\mathcal{M}^{3/2}_{\rm res.} &= \bar{u}_\Lambda\gamma_5(\not{p}_\Lambda q^\mu - \not{q}p^\mu_\Lambda)(\not{p}+\not{k}\mp m_{N^*})\Big(3{\rm P}_{\mu\nu}+\gamma^\rho\gamma^\sigma{\rm P}_{\mu\rho}{\rm P}_{\nu\sigma}\Big)\Big\{G^{(1)}(\epsilon^\nu\not{k}-k^\nu\not{\epsilon})\not{p}\\ &\quad +G^{(2)}(k^\nu p\cdot\epsilon - \epsilon^\nu p\cdot k) + G^{(3)}p^\nu(\not{\epsilon}\not{k}-\not{k}\not{\epsilon})\Big\}\,u_p\,. \end{aligned}\tag{3}$$

A comprehensive definition of the notation used in both models can be found in Ref. [3].