Kaon photoproduction on the nucleon: overview of some applications

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Some applications of the elementary kaon photoproduction process are discussed: the investigation of missing resonances in the $p(\gamma, K^+)^\Lambda$ channel, the role of the $P_{13}(1720)$ state in the $p(\gamma, K^0)^\Sigma^+$ channel, and the calculation of the Gerasimov-Drell-Hearn sum rule. For the latter, we present an extension of our previous study to higher energies.

1. INTRODUCTION

The electromagnetic production of kaons provides an important source of information on hadronic physics with strangeness. Due to the rather weak coupling at the electromagnetic vertex, the reaction operator is quite simple and, therefore, the use of single channel analysis may be quite sufficient to describe the process. This process can be used to simultaneously study kaon-hyperon-nucleon coupling constants, isospin symmetry, hadronic form factors, baryon and meson resonances, and contributions of kaon-hyperon final states to the magnetic moment of the nucleon. In this report we will focus only on the two last topics.

2. THE ELEMENTARY PROCESS WITH SOME APPLICATIONS

For a detailed discussion of the elementary operator we refer to Ref. \cite{1}. The background part of the operator consists of the standard Born terms along with the $K^*(892)$ and $K_1(1270)$ vector meson poles in the $t$-channel. The resonance part of the $K\Lambda$ operator includes the $S_{11}(1650)$, $P_{11}(1710)$, and $P_{13}(1720)$ resonances. We also include hadronic form factors in hadronic vertices by employing the gauge method of Haberzettl \cite{2} which leads to an excellent agreement between experimental data and model calculations.

2.1. Investigation of Nucleon Resonances

A brief inspection of the Particle Data Table reveals that less than 40\% of the nucleon resonances predicted by constituent quark models are observed in $\pi N \to \pi N$ scattering experiments. Quark model studies have suggested that those "missing" resonances may couple to other channels, such as the $K\Lambda$ and $K\Sigma$ channels. Stimulated by the new $p(\gamma, K^+)^\Lambda$ SAPHIR total cross section data \cite{3}, which suggest a structure around $W = 1900$
MeV, we start the investigation by using our isobar model. As shown in Fig.1, our previous model cannot reproduce the total cross section. The constituent quark model of Capstick and Roberts predicts many new states around 1900 MeV. However, only a few of them have been calculated to have a significant $K\Lambda$ decay width. We have performed fits for each of the possible states, allowing the fit to determine the mass, width and coupling constants of the resonance. We found that only in the case of the $D_{13}(1895)$ state couplings are obtained that are in remarkable agreement with recent quark model predictions. The result is shown in Fig.1, where without this resonance the model shows only one peak near threshold, while inclusion of the new resonance leads to a second peak at $W$ slightly below 1900 MeV, in accordance with the new SAPHIR data.

In the case of $K^0\Sigma^+$ photoproduction we find that a better agreement with experimental data can be achieved by including the $P_{13}(1720)$ resonance. As shown in Fig.2 the inclusion of this state does not influence the $K^+\Sigma^0$ channel appreciably, in contrast to the other three $K\Sigma$ channels, where the prominent effect is found in the $K^0\Sigma^+$ channel. This is due both to the isospin coefficient which enhances the $P_{13}(1720) \rightarrow K^0\Sigma^+$ decay over the $P_{13}(1720) \rightarrow K^+\Sigma^0$ coupling and the very different structure of the Born terms in $K^0$ photoproduction. The extracted fractional decay width is found to be consistent with the prediction of the quark model, whose magnitude is almost one order smaller than the value given by Particle Data Group.

2.2. Gerasimov-Drell-Hearn Sum Rule

The Gerasimov-Drell-Hearn (GDH) sum rule relates the anomalous magnetic moment of the nucleon $\kappa_N$ to its excitation spectrum in the resonance region by an integral. Previous analyses on pion photoproduction multipole amplitudes show a discrepancy between theoretical prediction and indirect experimental investigations of the GDH sum rule.
Here we calculate the contribution of kaon photoproduction processes to the GDH sum rule by using our isobar model.

In our previous calculation \([11]\), we have fixed the upper limit of integration at 2.2 GeV. Exact formulation was obtained by integrating the structure function \(\sigma_{TT'}\), and an approximation of the upper bound of integral is achieved by calculating total cross section \(\sigma_T\). We obtained a value of \(\kappa_p^2(K) = -0.063\) and \(\kappa_n^2(K) = 0.031\). Note that although this is relatively small, the result is consistent with the Karliner’s work \([10]\).

In order to improve our GDH calculation we increase the upper limit of integration to higher energies. For the present, we use the Regge model given in Ref. \([12]\) to calculate the cross sections in the energy region between 5 and 15 GeV. The result is shown in Fig. 3, where it is clear that contributions from higher energies are very small. Nevertheless, the important message here is the convergence of \(\sigma_{TT'}\), which indicates the convergence of the integral in the case of kaon. In the future, we will improve our model by reggeizing the \(t\)-channel intermediate state. Some preliminary results have been reported in Ref. \([13]\).

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