KAON PHOTO AND ELECTROPRODUCTION

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An isobar analysis of the $p(\gamma, K^+)\Lambda$ and $p(e, e'K^+)\Lambda$ reactions in the resonance region is presented. The model parameters are determined on the basis of the real photoproduction data. The electroproduction data are observed to be selective with respect to the parameterization of the background contributions. Model calculations for the Q^2 and W dependence of the separated $p(e, e'K^+)\Lambda$ structure functions are presented.

A theoretical study of the strangeness production reactions $p(\gamma, K^+)\Lambda$ and $p(e, e'K^+)\Lambda$ for $W \leq 2.15$ GeV is reported. An effective Lagrangian approach with hadronic degrees of freedom is adopted. It is believed that a completely well-founded theoretical extraction of information about the nucleon resonance spectrum from photo-meson production results, can only be achieved in a full-blown coupled-channel analysis. As a starting point, however, single-channel calculations can provide essential information, for example regarding the relative importance of the resonant and background diagrams. The background terms turn out to be of the utmost importance when modeling the $p(\gamma, K^+)\Lambda$ reaction and great care must be exercised when parameterizing them[1].

For the presented numerical calculations, the tree-level Feynman diagrams are computed starting from effective interaction Lagrangians. In order to account for finite extension, a hadronic form factor gets introduced at each meson-baryon vertex. The background consists of the usual Born terms and the t-channel $K^*(892)$ and $K_1(1270)$ exchange diagrams. In a particular scheme, which will be presented below, two hyperon resonances ($S_{01}(1800)$ and $P_{01}(1810)$) will be introduced in the u-channel. Further, the four nucleon resonances $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$ and $D_{13}(1895)$ contribute to the s-channel. Those states are recognized in multiple works[2,3] as dominant intermediate N^* resonances in the $K^+\Lambda$ photoproduction reaction. In the process of quantifying the background diagrams, a number of questions have to be addressed. First, the impact of the hadronic form factors on the results can be tuned by varying the cutoff masses. Second, one has to decide upon allowable ranges for the value of the $g_{K^+\Lambda p}$ coupling constant, which amounts to defining the degree to which SU(3) flavor symmetry can be broken. Third, one is left with the choice whether or not to include hyperon u-channel resonances. In Ref. 1 we have shown that three plausible but fundamentally different schemes to deal with the background all lead to a comparable agreement with the $p(\gamma, K^+)\Lambda$ data. This becomes apparent from Fig. 1 where all three model calculations for the total cross section give a reasonable description of the photon energy dependence of the total cross section, measured by the SAPHIR Collaboration[5] in Bonn.

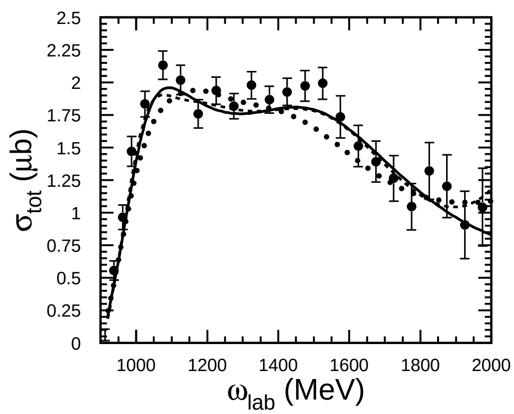

Figure 1. Model predictions for the photon energy dependence of the total $p(\gamma, K^+)\Lambda$ cross section. The curves result from the three different background schemes. The data are from Ref. 5.

Those three models can be used to compute the observables of the corresponding electroproduction $p(e, e'K^+)\Lambda$ process. Thereby, for each of the three models we have taken the coupling constants as determined by optimizing the agreement with the $p(\gamma, K^+)\Lambda$ data. The electromagnetic interaction Lagrangians are modified by means of introducing Q^2 dependent electromagnetic form factors. Our model choices for those form factors are based on predictions of the relativistic constituent quark-model calculations by the Bonn group[10]. The details of this procedure are explained in Ref. 4. Accordingly, no extra free parameters enter our calculations for the electroproduction process. Fig. 2 displays predictions for the longitudinal and transverse response functions and the sum of both, for each of the three proposed background models. The separated response functions and the total virtual cross section are defined in the standard manner:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_T}{d\Omega} + \epsilon\frac{d\sigma_L}{d\Omega} + \epsilon\frac{d\sigma_{TT}}{d\Omega}\cos(2\phi) + \sqrt{\epsilon(\epsilon+1)}\frac{d\sigma_{TL}}{d\Omega}\cos(\phi) \ . \qquad (1)$$

In contrast to what happens for the real-photon case of Fig. 1, large dif-

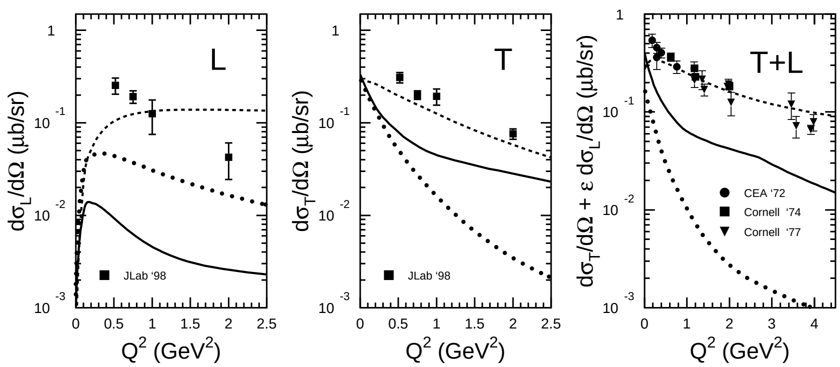

Figure 2. Model predictions for the Q^2 dependence of the longitudinal and transverse $p(e, e'K^+)\Lambda$ response functions at $W = 1.84$ GeV and $\cos\theta = 1$ and the ϕ-averaged $p(e, e'K^+)\Lambda$ cross section $d\sigma_T + \varepsilon d\sigma_L$ at $W = 2.15$ GeV and $\theta = 8°$. The line conventions are as mentioned in the text. The data are from Refs. 6, 7, 8, 9.

ferences emerge between the predictions of the three different background schemes in Fig. 2. Apparently, only one of the three proposed background schemes leads to a reasonable description of the measured electroproduction strengths. Despite the fact that the predicted Q^2 dependence of the $d\sigma_L$ term is more flat than what the data seem to suggest, the model represented by the dashed line is the sole one that can account for the right order of magnitude in both the longitudinal, transverse and total response. The physical input that went into the corresponding background scheme suggests a dominant role for hyperon resonances in the u-channel, a $g_{K^+\Lambda p}$ value compatible with moderately broken SU(3) flavor symmetry and a rather large cutoff mass for the hadronic form factor ($\Lambda_h \geq 1.5$ GeV). For the dotted and solid curves in Fig. 2, no u-channel hyperon resonances were introduced. In the absence of those hyperon resonances, the $p(\gamma, K^+)\Lambda$ data could only be reproduced in our model either after adopting small cutoff masses (solid curves), or by using a value for $g_{K^+\Lambda p}$ that is far beyond the ranges of moderately broken SU(3) flavor symmetry (dotted curves).

After the identification of the superiority of one particular background model, in Fig. 3 we present its predictions for the W and Q^2 dependence of the four integrated response functions, defined as $\sigma_X = \int \frac{d\sigma_X}{d\Omega} d\Omega$. At the real photon point $Q^2 = 0$, the transverse term corresponds with the total $p(\gamma, K^+)\Lambda$ cross section. A striking observation is that the Q^2 dependence of the σ_L response is far softer than for its transverse counterpart. We observed that the predicted Q^2 dependence of σ_L is rather sensitive to the

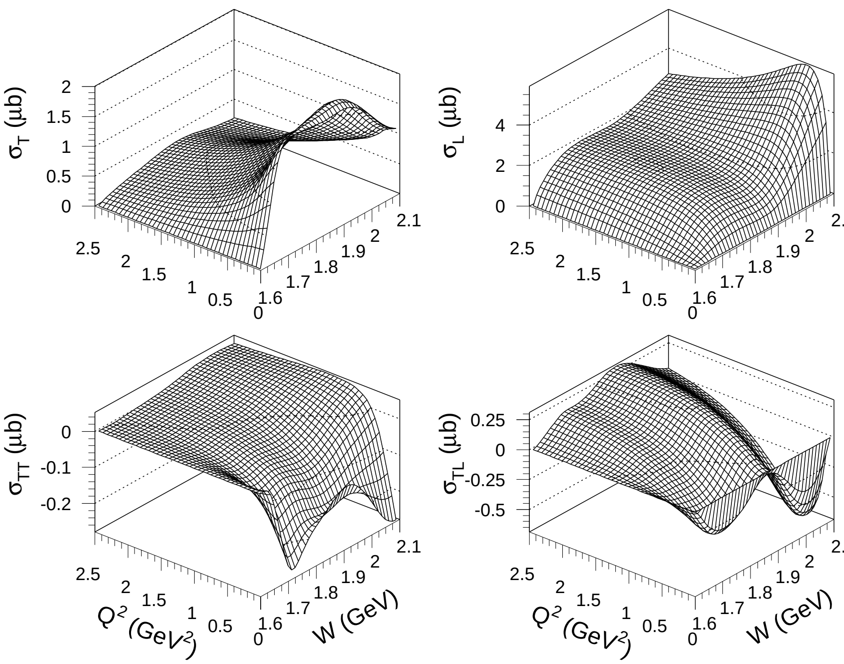

Figure 3. Model calculations for the W and Q^2 dependence of the integrated $p(e, e'K^+)\Lambda$ response functions σ_T, σ_L, σ_{TT} and σ_{TL}. A background model which includes hyperon resonances is adopted.

adopted parameterizations for the meson electromagnetic form factors.

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