KAON PHOTOPRODUCTION: BACKGROUND CONTRIBUTIONS AND MISSING RESONANCES

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Kaon photoproduction off the proton is studied in an effective Lagrangian approach. The dominant resonance contributions in the reaction dynamics are identified, including a search for signals of "missing" resonances. Special attention is paid to the issue of the elusive role played by background contributions.

1 Formalism

Since long, it has been known that pion production and pion induced reactions may be too restrictive to explore the complexity of the nucleon spectrum. Therefore, the study of other meson production reactions is essential to gain access to excited nucleon states which remain unobserved in pionic reactions but which are predicted by (constituent) quark-model calculations. Reactions of this type are the strangeness production processes $p(\gamma, K)Y$, where $Y \equiv \Lambda$ or Σ.

Here, we present results of $p(\gamma, K)Y$ calculations which adopt an effective Lagrangian approach starting from hadronic degrees-of-freedom[1]. The effective Lagrangians provide the mathematical structure of the interaction vertices and the propagators of the intermediate fields. In order to account for the short-range physics of the inter-baryon interaction, form factors are introduced at the hadronic vertices. The cutoff mass of those hadronic form factors sets the typical length scale of the hidden short-range dynamics.

The reaction amplitude contains the usual Born terms and the exchange of the vector meson K^* in the t-channel (also the K_1 is taken into account in the case of $K^+\Lambda$ production). Apart from the "background" contributions, there is common agreement[2] that the three nucleon resonances $S_{11}(1650)$, $P_{11}(1710)$ and $P_{13}(1720)$ play a substantial role in the $p(\gamma, K)Y$ reaction dynamics. Due to isospin considerations, contributions of the $I = \frac{3}{2}$ Δ^* resonances are excluded in the $K^+\Lambda$ channel. For the $K\Sigma$ processes, we have identified the $S_{31}(1900)$ and $P_{31}(1910)$ resonances as likely candidates for intermediate Δ^* states. Finally, we have implemented predicted "missing" resonances and investigated whether their inclusion considerably improved the overall description of the data.

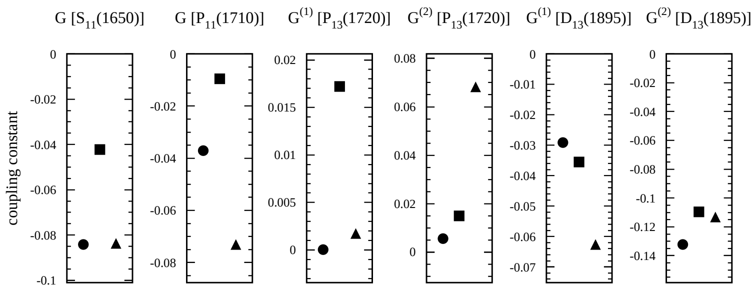

Figure 1. The extracted coupling constants for the $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$ and $D_{13}(1895)$ s-channel resonances in the $p(\gamma, K^+)\Lambda$ process, using three different models for dealing with the background terms. The circles are for model A, the squares for model B and the triangles for model C.

2 Background Contributions

Assuming a moderate breaking of SU(3)-flavor symmetry, one can put forward some ranges for the $g_{K^+\Lambda p}$ and $g_{K^+\Sigma^0 p}$ coupling constants starting from the value of $g_{\pi NN}$. Adopting a realistic breaking of SU(3)-flavor symmetry at the 20% level, though, one finds that the predicted contribution from the Born terms largely overshoots the measured $p(\gamma, K)Y$ cross sections. This observation clearly illustrates that the treatment of the background diagrams poses a serious difficulty when modeling open strangeness photoproduction reactions. We have suggested three schemes which accomplish to reduce the Born strength to realistic levels. In model A, soft hadronic form factors with a cutoff value of the order of the kaon mass ($\simeq 0.5$ GeV) are introduced. Despite our reservations against the use of soft hadronic form factors, it emerges that they are absolutely necessary in order to reduce the Born strength to an acceptable level when no other ingredients are introduced in the model. Alternatively, we showed that the introduction of u-channel hyperon resonances is able to reduce the Born strength through the mechanism of destructive interferences[1]. This method is adopted in model B. Finally, in model C the constraints imposed by a moderate breaking of SU(3) symmetry are simply ignored and $g_{K^+\Lambda p}$ and $g_{K^+\Sigma^0 p}$ are treated as free parameters. In such an approach, the optimum values for the two coupling constants correspond with a completely broken SU(3)-flavor symmetry.

All three schemes succeed in providing a satisfactory description of the

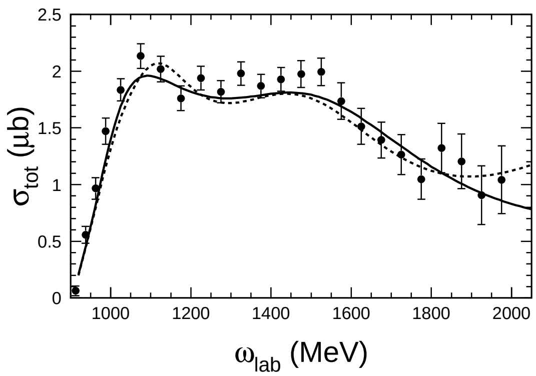

Figure 2. Model calculations for the total $p(\gamma, K^+)\Lambda$ cross section. The solid curve includes the missing D_{13}, the dashed curve includes a P_{13} resonance.

SAPHIR[3,4] data which consists of total and differential cross sections as well as recoil polarization asymmetries. Despite the fair agreement of the three models with the data, it has to be stressed that in some cases a substantial amount of model dependence is introduced in the extracted resonance parameters. This is made clear in Fig. 1 where the extracted coupling constants of the nucleon resonances for the $p(\gamma, K^+)\Lambda$ process are plotted for the three different background models. For the $K\Sigma$ counterpart, the extracted resonance coupling constants are less dramatic affected by the model dependences in the background diagrams. The model dependence in the extracted resonance couplings is rather unfortunate, given that this information can bridge the gap between the $p(\gamma, K)Y$ measurements and the quark-model calculations for baryons. The same variations are also observed in the predictions of the photon beam asymmetry and other polarization observables. Here also, the $K\Sigma$ results seem to be more stable than the $K^+\Lambda$ ones with regard to variations in the parameterization of the background diagrams.

3 Missing Resonances

With the release of the SAPHIR data back in 1998, it became clear that the energy dependence of the total $p(\gamma, K^+)\Lambda$ cross section exhibits a peculiar structure about 1.5 GeV photon lab energy. It was suggested by the George Washington group[2] that this structure could be theoretically accounted for by the inclusion of a "missing" $D_{13}(1895)$ resonance. Such a resonance has never been observed in pionic reactions but its existence was predicted by constituent quark-model calculations[5]. As such, it appears as a good candidate for a "missing" resonance. Our calculations confirm that the description of the $p(\gamma, K^+)\Lambda$ data is significantly improved after the inclusion of this new D_{13} resonance and that the calculations can account for the observed structure in the energy dependence of the total cross section. With respect to the classification of the quantum numbers of this additional resonance, it should be stressed that the data can equally well be described by adding other resonant states. For example, as is made clear in Fig. 2, the inclusion of a "missing" P_{13} resonance can also produce the structure in the energy dependence of the total cross section. In the other isospin channels, $p(\gamma, K^+)\Sigma^0$ and $p(\gamma, K^0)\Sigma^+$, the quality of agreement between the model calculations and the SAPHIR data only marginally improved after the inclusion of the missing resonance.

4 Conclusion

Model calculations for the $p(\gamma, K^+)Y$ observables are presented. Special attention is paid to the issue of the background contributions. It turns out that different schemes for dealing with the background can account for the available data but produce significant model dependences in the extracted resonance parameters and in the predictions for the unmeasured polarization observables. Whereas the energy dependence of the measured $p(\gamma, K^+)\Lambda$ cross section suggests the existence of a previously unobserved resonance, the current data does not enable one to identify unambiguously the quantum numbers of it. Indeed, both a D_{13} and a P_{13} resonance with a mass of about 1.9 GeV are able to improve the description of the $p(\gamma, K^+)\Lambda$ data. There are no convincing signals for a salient role of a such an additional resonance in the $p(\gamma, K)\Sigma$ channels. We are confident, however, that the upcoming data for various polarization observables and electroproduction response functions will allow to further pin down the full reaction dynamics of the strangeness photoproduction processes and remove some of the model dependences which exist to date.

References

1. S. Janssen, J. Ryckebusch, D. Debruyne and T. Van Cauteren, *Phys. Rev.* C **65**, 015201 (2002).
2. T. Mart and C. Bennhold, *Phys. Rev.* C **61**, R0112201 (2001).
3. M.Q. Tran *et al.*, *Phys. Lett.* B **445**, 20 (1998).
4. S. Goers *et al.*, *Phys. Lett.* B **464**, 331 (1999).
5. S. Capstick and W. Roberts, *Phys. Rev.* D **58**, 074011 (1998).