ISOBAR MODEL FOR PHOTOPRODUCTION OF $K^+\Sigma^0$ AND $K^0\Sigma^+$ ON THE PROTON.

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Kaon photoproductions on the proton $\gamma p \rightarrow K^+\Sigma^0$ and $\gamma p \rightarrow K^0\Sigma^+$ have been simultaneously analyzed by using isobar models and new SAPHIR data. The result shows that isobar models such as KAON MAID require more resonances in order to explain the data.

1. Introduction

It has been widely known that pion nucleon scattering provides an excellent tool for investigation of nucleon resonances. Indeed, this process has become a longstanding source of information on nucleon resonances properties, such as their masses, decay widths, electromagnetic and hadronic coupling constants, as well as their spins. However, the exclusive use of pion nucleon scattering would bias the information on the existence of certain resonances. Modern quark model studies predict a much richer resonance spectrum than has been observed in $\pi N \rightarrow \pi N$ scattering experiments. Where have all these resonances gone? The answer also comes from these quark models. They have suggested that those “missing” resonances may couple strongly to other channels, such as the $K\Lambda$ and $K\Sigma$ channels or other final states involving vector mesons. Since performing kaon-nucleon or hyperon-nucleon scattering experiments is a daunting task, kaon photoproduction on the nucleon appears as the best solution.

The new generation of electron and photon facilities have paved the way to kaon photoproduction experiments of unprecedented accuracies. Such experiments have been performed at ELSA in Bonn, JLab in Newport News, SPring8 in Osaka, and ESRF in Grenoble. In this paper we will only focus on the newly published data by SAPHIR collaboration of ELSA, for the $\gamma p \rightarrow K^+\Sigma^0$ and $\gamma p \rightarrow K^0\Sigma^+$ channels. These data could be very interesting, since they indicate that isobar models (e.g., KAON MAID) require more resonances in order to reproduce them.

2. Isobar Model

We start with the KAON MAID model. The model consists of the standard Born terms, along with the $K^+$ and $K_1$ exchanges as the background part, while the resonance part includes the isospin 1/2 nucleon resonances $S_{11}(1650)$, $P_{11}(1710)$,
Table 1. Masses and widths of resonances from the three models.

| Resonance | Mass or Width | Original value | Model 1 | Model 2 |
|-----------|---------------|----------------|---------|---------|
| S\(_{11}\)(1650) | M 1650 | 2167 | 1795 |
|           | \(\Gamma\) 150 | 186 | 158 |
| P\(_{13}\)(1710) | M 1710 | 1690 | 1680 |
|           | \(\Gamma\) 100 | 100 | 100 |
| P\(_{13}\)(1720) | M 1720 | 2133 | 2141 |
|           | \(\Gamma\) 150 | 256 | 279 |
| S\(_{31}\)(1900) | M 1900 | 1920 | 1900 |
|           | \(\Gamma\) 200 | 355 | 329 |
| P\(_{31}\)(1910) | M 1910 | 1936 | 1800 |
|           | \(\Gamma\) 250 | 399 | 400 |

\(\chi^2/N\) 4.14 2.44 1.76

and \(P_{13}(1720)\), as well as the isospin 3/2 deltas \(S_{31}(1900)\) and \(P_{31}(1910)\). A brief discussion of the model can be found in Refs. 8, 9.

3. Result and Discussion

As shown by the two panels of Fig. 1, KAON MAID obviously cannot reproduce the new data, especially in the \(K^0\Sigma^+\) channel. This shortcoming is understandable, since KAON MAID was fitted to previous SAPHIR data. From this figure it is also clear that the new data do not exhibit a certain resonance structure and, therefore, an arbitrarily inclusion of new resonances in the model is not advocated. However, a close inspection to the \(K^+\Sigma^0\) total cross section reveals that a significant discrepancy between the prediction of KAON MAID and new data exists at \(W \simeq 2.1\) GeV. This discrepancy originates from the previous data, where no indication of resonances required by the model at this energy as well as due to the large error-bars.

To investigate this phenomenon we refit the original KAON MAID coupling constants by including only new data in our database. The obtained \(\chi^2\) per degrees of freedom is shown in the third column of Table 1 which is clearly far from satisfactory. In the second step, we allow the masses and widths of nucleon resonances to be determined by the fit. As shown by the fourth column of Table 1, the result is quite interesting. Besides significantly reducing \(\chi^2\), the fit shifts both \(S_{11}\) and \(P_{13}\) masses to higher values (2167 MeV and 2133 MeV, respectively), while other resonances seem to be more stable. From the experience in the multipoles study of kaon photoproduction\[13\], we suspect that such behavior could be an indication for the existence of similar resonances, but with relatively different masses. Therefore, in the next step we put two \(S_{11}\) resonances and leave their masses and widths to be determined by the fit. As shown by the fifth column of the same Table, we obtain
Figure 1. Total cross section for $\gamma p \rightarrow K^+ \Sigma^0$ and the $\gamma p \rightarrow K^0 \Sigma^+$ channels. Experimental data are taken from Refs. 4, 10, 11, 12.

two $S_{11}$ with masses 1795 MeV and 2112 MeV, which is seemingly to support the finding of Ref. 13. The result clearly indicates that more resonances are required to explain kaon photoproduction process, a point which should be addressed in future studies.

In the $K^+ \Sigma^0$ channel the difference between the last two models does not clearly show up, but this is not the case of the $K^0 \Sigma^+$ channel. As shown by Fig. 1, it is obvious that Model 1 cannot reproduce the $K^0 \Sigma^+$ total cross section data at energies below 1900 MeV due to the lack of resonances with $M \approx 1800$ MeV. In Model 2 the fitted mass of the first $S_{11}$ and that of the $P_{31}$ are in this region. We also note that in the case of KAON-MAID the divergent behavior of the total cross section at high energies is attributed to the large value of the hadronic form factor cut-off ($0.82$ GeV). At this region a slight increment in total cross section is also observed in Model 1, but not in Model 2.

Figure 2 shows differential cross sections obtained from all models compared with experimental $K^+ \Sigma^0$ data. In this case, similar to the case of the total cross section, only KAON-MAID substantially deviates from experimental data.

Figure 3 compares the differential cross sections for the $K^0 \Sigma^+$ channel. It is evident from this figure that KAON-MAID is unable to reproduce the shape as well as the magnitude of differential cross sections. In contrast to this, both Model 1 and Model 2 can fairly describe these new data up to some structures shown, e.g., at low energies and backward angles. The main difference from these models can be seen at forward directions, where Model 1 tends to produce more forward peaking cross sections at high energies.
Figure 2. Differential cross section for the $\gamma p \rightarrow K^+ \Sigma^0$ channel. Experimental data are taken from Ref. 12. Some older measurements are also shown for comparison.
4. Conclusion

We have shown that new SAPHIR data provide a stringent constrain to isobar models such as KAON MAID. New resonances are required by the models in order to explain the data. Whether or not they are “missing resonances” should be checked in the future by the coupled channels studies.

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