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η-MESON PRODUCTION IN THE COUPLED-CHANNEL EFFECTIVE LAGRANGIAN APPROACH

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Abstract

Pion- and photon-induced reactions are analyzed within the coupled-channel effective Lagrangian Giessen model for the baryon resonance analysis. Last results for the eta-meson productions both in pion and photon induced reactions are presented.

1 Introduction

The properties of most resonances have been obtained from pion-nucleon elastic scattering. Despite of extensive efforts made in the past two main problems are still encountered by any baryon resonance analyses. First, the parameters of many well established states remain uncertain. The second problem is related to 'missing' or 'unresolved' states which are supposed to exist on the basis of quark model calculations but are weakly coupled to the pion-nucleon channel.

The solution of the these problems requires a coupled-channel treatment of the scattering process. First, the inclusion of as many experimental data as possible into each channel constrains free parameters and other ambiguities of the model, helping to draw a solid conclusion on the resonance parameters. Secondly, a multi-channel treatment allows to link different reaction channels as required by unitarity. Keeping that in mind we have developed an unitary coupled-channel effective Lagrangian model [1–3] for a study of pion- and photon-induced reactions in the nucleon resonance energy region. The properties of nucleon resonances are constrained by a direct comparison to the experimental data. In this contribution we report on our last results on the study of the eta-meson production mechanisms both in the pion- and photon-nucleon scattering.

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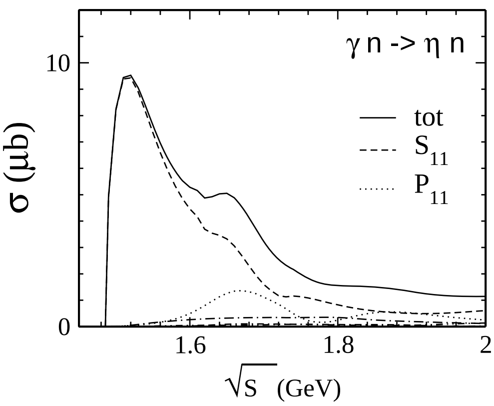

Figure 1: $\gamma n \to \eta n$ total and partial wave cross sections.

2 Results and discussion

The details of the Giessen Model can be found in [2, 3]. Here we briefly outline the main ingredients relevant for the present discussion. The Bethe-Salpeter equation (BSE) is solved in the ladder approximation to obtain a scattering amplitude. The interaction potential $[V]_{ij}$ is built up as a sum of tree-level Feynman diagrams and generally contains resonance and background terms (s- and u-, t-channels correspondingly). The contributions from the corresponding diagrams are calculated using effective interaction Lagrangians [2,3]. Performing a partial wave decomposition and using a K-matrix approximation the Bether-Salpeter equation can be reduced to a set of algebraic equations for the scattering partial wave amplitudes. Such a formulation of the problem allows to include as many open channels as possible. In previous works, $(\pi/\gamma)N \to \gamma N$, πN, $2\pi N$, ηN, ωN, $K\Lambda$, $K\Sigma$ reactions were analysed. The obtained resonance parameters are summarized in [3,4].

Recently, an experimental program on studies of eta-photoproduction on neutron target has been started. The first preliminary data from V. Kuznetsov et al. reveal an excess in the differential cross section of eta-neutron photoproduction at c.m. energies around 1.67 GeV [5]. A similar effect has been also found by the CB-ELSA collaboration. These obervations rise questions about the reaction mechanisms which might be responsible for the observed phenomena. Besides prediction of a narrow state more 'conventional' effects coming from excitations of $S_{11}(1650)$ and $P_{11}(1710)$ must be explored as an alternative scenario.

In [6] the coupled-channel Giessen Model was applied to study the effect

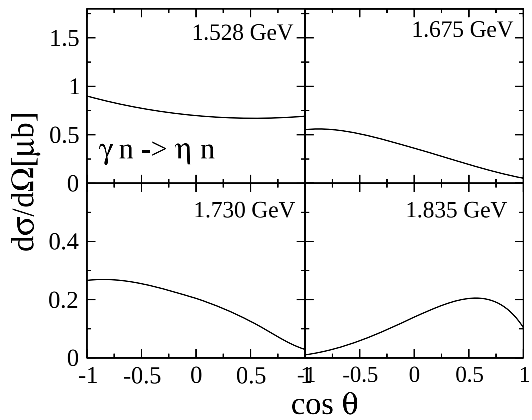

Figure 2: $\gamma n \to \eta n$ differential cross section.

of these two state in $\gamma n \to \eta n$ reaction. The obtained properties of $S_{11}(1535)$ and $S_{11}(1650)$ are very close to the average PDG values [7]. The third resonance $P_{11}(1710)$ is rated three stars by PDG and its parameters are still under debate. We obtain a rather strong coupling of $P_{11}(1710)$ to the final eta-nucleon channel which is close to the upper bound given by PDG.

The calculated total and partial wave cross sections are presented in Fig. 1. We find a positive interference pattern between $S_{11}(1535)$ and $S_{11}(1650)$ states which indeed leads to an enhancement in the S_{11} partial wave cross section at 1.67 GeV. Note, that the above effect is not a result of a simple interference between two S_{11} resonance like it might be thought in terms of Breit-Wigner parameterization. Due to unitarization the scattering amplitude depends strongly on rescattering effects in a number of channels like πN, $2\pi N$, ηN and the decomposition into individual resonance contributions is not straightforward. Hence, the observed interference is a higher order effect coming from the resummation of the perturbation series within the ladder approximation to the BSE. A similar effect is found in the P_{11} partial wave where an excitation of $P_{11}(1710)$ also leads to an increase in the corresponding cross section at 1.67 GeV.

In Fig. 2 the predicted differential cross sections of the eta photoproduction on the neutron are shown. The contribution from the S_{11} partial wave dominates the $\gamma n \to \eta n$ reaction up to 1.6 GeV, resulting in a smooth angular dependence of the differential cross section. At 1.66 GeV the $S_{11}(1650)$ and $P_{11}(1710)$ resonances start to play a role producing an enhancement in the differential cross section at backward angles. At higher energies $\sqrt{s} \geq 1.8$ GeV the effect from these states vanishes and the calculated angular distributions become very similar to that of $\gamma p \to \eta p$. We conclude that the resonance-like structure observed in $\gamma n \to \eta n$ reaction around 1.67 GeV can be explained by the excitation of the $S_{11}(1650)$ and $P_{11}(1710)$ resonance alone, without further need for a new resonance. We emphasize that these states contribute indirectly through higher-order interference effects as discussed above.

3 Summary

Coupled-channel calculations of pion- and photon-induced reactions have been used to constrain properties of nucleon resonances. The latest results on the eta-meson production in the nucleon resonance energy region are presented.

We have shown that the enhancement observed in the experimental data for the $\gamma n \to \eta n$ differential cross section can be explained in terms of interference effects in S_{11} and P_{11} partial waves coming from $S_{11}(1650)$ and $P_{11}(1710)$ resonance contributions respectively. At the 1.67 GeV c.m. energy the predicted differential cross section has a pronounced maximum at backward angles. Note, that experimental data on the $\gamma n \to \eta n$ cross section are usually extracted from photon-deuteron scattering data. Hence, an extended analysis taking into account the deuteron wave function explicitly is necessary for the comparison with the experimental data.

References

[1] T. Feuster and U. Mosel, Phys. Rev. **C58**, 457 (1998), nucl-th/9708051.

[2] G. Penner and U. Mosel, Phys. Rev. **C66**, 055211 (2002), nucl-th/0207066.

[3] V. Shklyar, H. Lenske, U. Mosel, and G. Penner, Phys. Rev. **C71**, 055206 (2005), nucl-th/0412029.

[4] V. Shklyar, H. Lenske, and U. Mosel, Phys. Rev. **C72**, 015210 (2005), nucl-th/0505010.

[5] GRAAL, V. Kuznetsov, Phys. Lett. **B647**, 23 (2007), hep-ex/0606065.

[6] V. Shklyar, H. Lenske, and U. Mosel, Phys. Lett. **B650**, 172 (2007), nucl-th/0611036.

[7] Particle Data Group, K. Hagiwara *et al.*, Phys. Rev. **D66**, 010001 (2002).