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Radiative decay of the $\Delta^*(1700)$

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Abstract

Electromagnetic properties provide information about the structure of strongly interacting systems and allow for independent tests of hadronic models. The radiative decay of the $\Delta^*(1700)$ is studied, which appears dynamically generated in a coupled channel approach from the rescattering of the $(3/2^+)$ decuplet of baryons with the (0^-) octet of pseudoscalar mesons. The radiative decay is predicted from the well-known couplings of the photon to the mesons and baryons which constitute this resonance in the dynamical picture.

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1. Introduction

The unitary extensions of chiral perturbation theory ($U\chi PT$) have brought new light to the meson–baryon interaction, showing that some well-known resonances qualify as being dynamically generated. In this picture the Bethe–Salpeter resummation of elementary interactions, derived from chiral Lagrangians, guarantees unitarity and leads at the same time to genuine non-perturbative phenomena such as poles of the scattering amplitude in the complex plane of the invariant scattering energy $\sqrt{s}$, which can be identified with resonances. Coupled channel dynamics plays an essential role in this scheme, with the chiral Lagrangians providing the corresponding transitions of the multiplets; even physically closed channels contribute as intermediate virtual states.

After earlier studies in this direction explaining the $\Lambda(1405)$ and the $N^*(1535)$ as meson–baryon (MB) quasibound states [1–6] from the interaction of the meson octet of the pion (M)

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with the baryon octet of the nucleon (B), new efforts have been undertaken [7,8] to investigate the low lying $3/2^-$ baryonic resonances which decay in s-wave into 0^- mesons (M) and $3/2^+$ baryons (B^*) of the decuplet. The leading interaction of these hadrons, given by the isovector term from Ref. [9], is unitarized by the use of the Bethe–Salpeter equation (BSE) in the on-shell reduction scheme from [8] which allows for a factorization of vertices and the intermediate loop function, thus reducing the BSE to an algebraic matrix equation in coupled channels. The unitarized amplitude develops poles in different isospin and strangeness channels in the complex plane of $\sqrt{s}$, which have been identified with resonances from the PDB [10] such as the $\Lambda^*(1520)$, $\Sigma^*(1670)$, $\Delta^*(1700)$, etc. [8].

In isospin 3/2, strangeness 0, which are the quantum numbers of the $\Delta^*(1700)$, the coupled channels in s-wave are given by $\Delta(1232)\pi$, $\Sigma^*(1385)K$, and $\Delta(1232)\eta$. The $\Delta^*(1700)$, together with a series of other production mechanisms, has been included in Ref. [11] in the study of the $\gamma p \to \pi^0 \eta p$ and $\gamma p \to \pi^0 K^0 \Sigma^+$ photoproduction reactions, currently measured at ELSA/Bonn. In the detailed work of [11] the $\Delta^*(1700)$, together with its strong couplings to $\Delta(1232)\eta$ and $\Sigma^*(1385)K$, turned out to provide the dominant contribution. The branching ratios into these two channels are predicted from the scheme of dynamical generation and differ from a simple $SU(3)$ extrapolation of the $\Delta\pi$ channel by up to a factor of 30 [12].

The predictions for both reactions are in good agreement with preliminary data [13]. Recently, new measurements at low photon energies have been published [14] which also agree well with [11]. This has motivated another study [12] of altogether nine additional pion- and photon-induced reactions. From considerations of quantum numbers and the experimentally established s-wave dominance of the Σ^* production close to threshold, the $\Delta^*(1700)$ channel is expected to play a major, in some reactions dominant, role. Indeed, good global agreement has been found for the studied reactions that span nearly two orders of magnitude in their respective cross sections.

Thus, evidence from quite different experiments has been accumulated that the strong $\Delta^*(1700) \to \Sigma^* K$, $\Delta\eta$ couplings, predicted by the coupled channel model, are realistic. This gives support to the scheme of dynamical generation of this resonance. However, in all the photon-induced reactions from [11,12] the initial $\gamma p \to \Delta^*(1700)$ transition has been taken from the experimental [10] helicity amplitudes $A_{1/2}$ and $A_{3/2}$ [15]: In Ref. [16] the electromagnetic form factors G_1', G_2', and G_3', which appear in the scalar and vector part of the $\gamma p \to \Delta^*(1700)$ transition, have been expressed in terms of the experimentally known $A_{1/2}$ and $A_{3/2}$ [10]; this provides the transition on which we rely in all the photoproduction reactions via $\Delta^*(1700)$ in [11,12].

Such a semi-phenomenological ansatz is well justified: the photon coupling and the width of the $\Delta^*(1700)$ is taken from phenomenology, whereas the strong decays of the $\Delta^*(1700)$ into hadronic channels are predictions from the unitary coupled channel model; the strengths of these strong transitions are responsible for the good agreement with experiment found in [11,12]. It is, however, straightforward to improve at this point, and this is the aim of this study.

Electromagnetic properties provide additional information about the structure of strongly interacting systems and allow for an independent test of hadronic models, in this case the hypothesis that the $\Delta^*(1700)$ is dynamically generated. A virtue of the present model is that one can make predictions for the radiative decay, or equivalently, the inverse process of photoproduction; the components of the $\Delta^*(1700)$ in the meson–baryon base are all what matters, together with the well-known coupling of the photon to these constituents. A similar study has been carried out for the radiative decay of the $\Lambda^*(1520)$ in Ref. [17] that has been described recently as a dynamically generated resonance [18]. For the $\Lambda^*(1520) \to \Sigma^0\gamma$ decay, where the dominant