

Photo-production of tensor mesons

Ju-Jun Xie^{1,*}, Li-Sheng Geng², and Eulogio Oset³

¹*Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China*

²*School of Physics and Nuclear Energy Engineering and International Research Center for Nuclei and Particles in the Cosmos, Beihang University, Beijing 100191, China*

³*Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC Institutos de Investigación de Paterna, Aptdo. 22085, 46071 Valencia, Spain*

Abstract. Assuming that the $f_2(1270)$, $f_2'(1525)$, $a_2(1320)$, and $K_2^*(1430)$ resonances are dynamically generated states from the vector meson-vector meson interactions in $L = 0$ and spin 2, we study the $\gamma p \rightarrow f_2(1270)[f_2'(1525)]p$, $\gamma p \rightarrow a_2^0(1320)p$, and $\gamma p \rightarrow K_2^*(1430)\Lambda(\Sigma)$ reactions. For the $\gamma p \rightarrow f_2(1270)p$ reaction, we find that the theoretical results for the differential cross sections are in good agreement with the experimental measurements and provide support for the molecular picture of the $f_2(1270)$ in the first baryonic reaction where it has been tested. Furthermore, we predict also the total and differential cross sections for other reactions. The results can be tested in future experiments and therefore offer new clues on the nature of these tensor states.

1 Introduction

Within quark models, mesons are made of quark-antiquark pairs and baryons are composed of three quarks in the low energy region. However, recent observations of the new baryonic P_c states [1] and the mesonic XYZ states [2–5] by various collaborations have challenged this conventional wisdom. There are many different explanations for the nature of these new observed states, but none of them has been accepted unanimously.

It seems clear that Nature is richer than it is preferred to be. Many low-lying states, even those long believed to be conventional $q\bar{q}$ (or qqq) states, may have large components of other nature. Indeed, it has been shown that many of the low-lying mesonic states can be understood not as of $q\bar{q}$ states but as meson-meson molecules, dynamically generated in the so-called unitary approaches. In Refs. [6–8], the $f_2(1270)$, $f_2'(1525)$, $a_2(1320)$, and $K_2^*(1430)$ are found dynamically generated from the vector meson - vector meson (VV) interaction. The molecular nature of these tensor states has been extensively tested in a large number of processes: the two-photon decay of the $f_2(1270)$ [9], the two-photon and one photon-one vector decays of the $f_2(1270)$, $f_2'(1525)$ and $K_2^*(1430)$ [10], the $J/\psi \rightarrow \phi(\omega)f_2(1270)$, $f_2'(1525)$ and $J/\psi \rightarrow K^{*0}(892)\bar{K}_2^{*0}(1430)$ decays [11], the radiative decay of J/ψ into $f_2(1270)$ and $f_2'(1525)$ [12], the $\psi(2S)$ decays into $\omega(\phi)f_2(1270)$, $\omega(\phi)f_2'(1525)$, $K^{*0}(892)\bar{K}_2^{*0}(1430)$ and the radiative decays of $\Upsilon(1S)$, $\Upsilon(2S)$, $\psi(2S)$ into $\gamma f_2(1270)$, $\gamma f_2'(1525)$, $\gamma f_0(1370)$, and $\gamma f_0(1710)$ [13, 14], and the ratio of the decay widths of $\bar{B}_s^0 \rightarrow J/\psi f_2(1270)$ to $\bar{B}_s^0 \rightarrow J/\psi f_2'(1525)$ [15]. The

*e-mail: xiejujun@impcas.ac.cn

agreement with experimental data turns out to be quite good, providing support to the underlying assumption that these states contain large meson-meson components.

Along this line, we study the photo-production of those tensor mesons, assuming that the $f_2(1270)$, $f'_2(1525)$, $a_2(1320)$, and $K_2^*(1430)$ are dynamically generated states from the VV interaction.

2 Formalism and ingredients

From the perspective that the $f_2(1270)$, $f'_2(1525)$, $a_2(1320)$, and $K_2^*(1430)$ are dynamically generated from the VV interaction, the photoproduction of those tensor mesons proceeds via the creation of two vector mesons by the γp initial state in a primary step and the following interaction of the two vector mesons, thus generating the resonance. The corresponding Feynman diagrams are shown in Fig. 1.

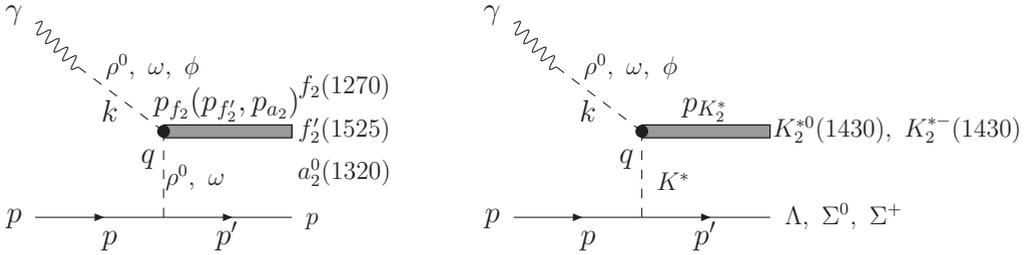


Figure 1. Diagrammatic representation of the photoproduction of tensor mesons.

To evaluate the Feynman amplitudes for the diagrams shown in Fig. 1, we need the coupling of the tensor meson to the respective vector mesons, g_T^{VV} , the γ - V coupling and the VNN coupling. The values for g_T^{VV} are taken from Refs. [7, 18] and shown in Table 1.

Table 1. The coupling constants of tensor mesons to VV .

| Resonance | Channel | g_T^{VV} (MeV) |
|---------------|----------------|------------------|
| $f_2(1270)$ | $\rho\rho$ | (10889, -i99) |
| | $\omega\omega$ | (-440, i7) |
| | $\phi\omega$ | (777, -i13) |
| $f'_2(1525)$ | $\rho\rho$ | (-2443, i649) |
| | $\omega\omega$ | (-2709, i8) |
| | $\phi\omega$ | (5016, -i17) |
| $K_2^*(1430)$ | ρK^* | (10901, -i71) |
| | ωK^* | (2267, -i13) |
| | ϕK^* | (-2898, i17) |
| $a_2(1320)$ | $\rho\omega$ | (0, -i8402) |
| | $\rho\phi$ | (0, -i1912) |

The γ - V conversion vertex can be obtained from the local hidden gauge Lagrangian, and the vector-nucleon-nucleon vertex is obtained from the $SU(3)$ baryon-baryon-vector interaction Lagrangian (see more details in Refs. [16, 17]). Then one can easily calculate the scattering amplitude

T and $\bar{\Sigma} \Sigma |T|^2$. Here we give explicitly the case of $\gamma p \rightarrow f'_2(1525)p$ reaction, as an example,

$$T = e \left(-\frac{g_{f'_2}^{\rho\rho}}{\sqrt{6}} + \frac{g_{f'_2}^{\omega\omega}}{\sqrt{2}} - \frac{g_{f'_2}^{\phi\omega}}{\sqrt{2}} \right) \frac{1}{q^2 - m_V^2} \left[\frac{1}{2} \epsilon_i(\gamma) (-g_{j\mu} + \frac{q_j q_\mu}{m_V^2}) + \frac{1}{2} \epsilon_j(\gamma) (-g_{i\mu} + \frac{q_i q_\mu}{m_V^2}) - \frac{1}{3} \epsilon_m(\gamma) \delta_{ij} (-g_{m\mu} + \frac{q_m q_\mu}{m_V^2}) \right] < p(M') | \gamma^\mu | p(M) >, \quad (1)$$

with M and M' the third spin component of the initial and final proton. The V stands for the exchanged ρ^0 or ω . Following the same procedure, we can obtain the transition amplitudes for $f_2(1270)$, $a_2(1320)$, and $K_2^*(1430)$ productions as in Refs. [16, 17].

The differential cross section for those reactions are given by $d\sigma/dt = \frac{m_i^2}{16\pi s |\vec{k}|^2} \bar{\Sigma} \Sigma |T|^2$ with s the invariant mass squared of the γp system, $m_i^2 = m_p^2$ for $\gamma p \rightarrow f_2(1270)$, $[f'_2(1525), a_2^0(1320)]p$ reaction, $m_i^2 = m_p m_\Lambda$ for $\gamma p \rightarrow K_2^{*+}(1430)\Lambda$ reaction, and $m_i^2 = m_p m_\Sigma$ for $\gamma p \rightarrow K_2^*(1430)\Sigma$ reaction. The variable \vec{k} is the three momenta of photon in the center of mass frame, and $t = q^2 = (p - p')^2$.

3 Numerical results

We show the results of $d\sigma/dt$ at $E_\gamma = 3.4$ GeV for the six reactions in Fig. 2 (left), where the experimental data are taken from Ref. [19] for $\gamma p \rightarrow f_2(1270)p$ reaction. It is found that our results are in good agreement with experiment for $f_2(1270)$ production. Besides, we see that the slopes for the six reactions are quite similar.

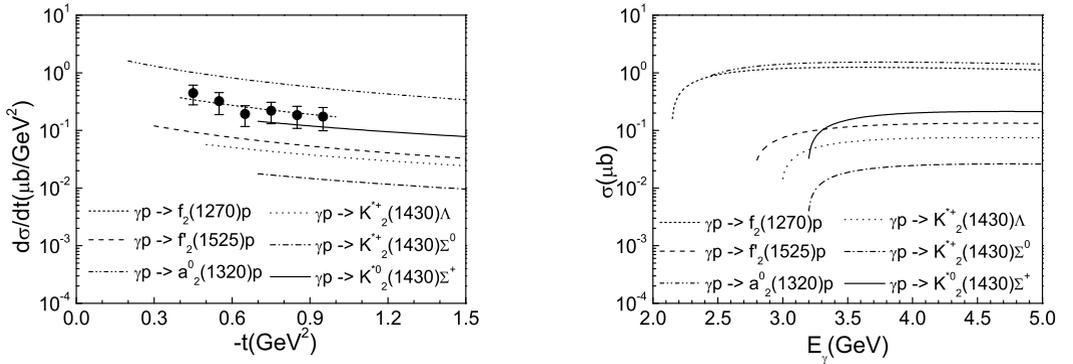


Figure 2. Left: differential cross section $\frac{d\sigma}{dt}$ as a function of t at $E_\gamma = 3.4$ GeV. Right: total cross section for the photo-production of tensor mesons as a function of E_γ .

In addition to the differential cross section, we calculate also the total cross section for the six reactions as a function of the photon beam energy E_γ . The results are shown in Fig. 2 (right). The total cross sections increase rapidly away from threshold and soon become almost constant at higher photon energies. The results for the $f_2(1270)$ and $a_2(1320)$ are larger than for the other productions.

It is worth mentioning that the reaction formalism advocated here involves parameters fixed by previous works, which allow us to make predictions for total cross sections. The differential and total cross sections can be checked in future experiments, such as those at CLAS. In this sense, the reaction mechanism can be easily tested.

4 Conclusions

Recently, it is found that the $f_2(1270)$, $f_2'(1525)$, $a_2(1320)$, and $K_2^*(1430)$ resonances, though long been accepted as ordinary $q\bar{q}$ states, can be dynamically generated from the vector meson-vector meson interaction. Many studies adopting such a scenario have been performed in mesonic reactions and all yield positive results. In this work, we have extended the molecular picture to the γp reaction. The elements needed for the test are very simple, which makes particularly transparent the interpretation of the results. On the one side those tensor mesons couple to VV and the coupling have been fixed before in the unitary approach that generates the $f_2(1270)$, $f_2'(1525)$, $a_2(1320)$, and $K_2^*(1430)$ states as VV molecules based on the local hidden gauge formalism for the interaction of vector mesons. On the other side, with these couplings and the vector meson dominance hypothesis, incorporated in the local hidden gauge approach, the photon gets converted into one of the vector mesons, which interacts with the vector meson emitted by the incoming proton to generate the $f_2(1270)$, $f_2'(1525)$, $a_2(1320)$, and $K_2^*(1430)$ states. With this simple picture we predict both the differential and total cross sections, which could be tested by future experiments, such as those at CLAS.

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