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Direct vs. final state tensor meson photoproduction - amplitude analysis

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Abstract. Tensor meson photoproduction is described as either a direct production process or a consequence of the final state $\pi\pi$ interactions. We calculate the mass distributions for selected partial waves and confront our predictions with the measurements of the CLAS experiment. We also point out the structures in the photoproduction amplitudes which may result in observable effects able to indicate the dominant tensor meson photoproduction mechanism.

1 Introduction

Spin 2 resonances, in particular the $f_2(1270)$, are important components of the photoproduced $\pi\pi$ and $K\overline{K}$ spectra for effective masses above 1 GeV. Thus any comprehensible partial wave analysis in this kinematic region requires the knowledge of the tensor meson photoproduction amplitudes. They are also important for analyses of the tensor glueball photoproduction as the tensor glueball mixes with conventional isocalar tensor mesons.

2 Structure of the amplitudes

We consider two models for the amplitudes of the tensor meson photoproduction: the direct photoproduction model, where the resonance is produced in the direct channel in the compact spatial region (Fig.1) and the final state interaction (FSI) model (Fig. 2). The resonance photoproduction is usually

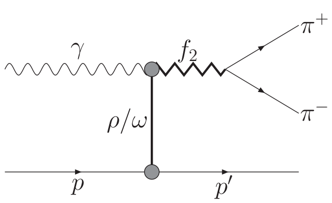

Figure 1. Direct photoproduction diagram.

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studied through the analysis of decay product correlations. Thus we split the direct photoproduction amplitude into two parts, the resonance photoproduction amplitude

$$A_p(\lambda_f, \lambda_\gamma, \sigma_1, \sigma_2) = \epsilon^{\mu\nu *}(\lambda_f) M_{\mu\nu;\rho}(\sigma_1, \sigma_2)\epsilon^{\rho}(\lambda_\gamma) \quad (1)$$

and decay amplitude

$$A_d(\lambda_f) = \frac{G_{f\pi\pi}}{M_f}\epsilon^{\rho\sigma}(\lambda_f)(k_1 - k_2)_\rho (k_1 - k_2)_\sigma \quad (2)$$

where $\lambda_f, \lambda_\gamma, \sigma_1, \sigma_2$ - tensor meson, photon, initial and final nucleon helicities respectively, $\epsilon^{\mu\nu}(\lambda_f)$-polarization tensor of the tensor meson, $\epsilon^{\rho}(\lambda_\gamma)$- photon polarization vector, $G_{f\pi\pi}$ - $f_2\pi\pi$ coupling constant, M_f - $f_2(1270)$ mass and k_1, k_2 - 4-momenta of the π^+ and π^-.

The hadron current $M_{\mu\nu;\rho}(\sigma_1, \sigma_2)$ is defined as

$$M_{\mu\nu;\rho}(\sigma_1, \sigma_2) = \bar{u}(p_2, \sigma_2)\Gamma^{\alpha} u(p_1, \sigma_1) G_{\alpha\beta}(t) A_{\mu\nu;\beta\rho} N_{VNN}(t) N_{\gamma VT}(t) \quad (3)$$

where $N_{VNN}(t)$ and $N_{\gamma VT}(t)$-form-factors, Γ^{α}-NNV vertex function, $G_{\alpha\beta}$ - propagator of the intermediate vector (ρ or ω) meson and $A_{\mu\nu;\beta\rho}$-γTV vertex function which after application of the vector meson and tensor meson dominance [1] is determined by 1 coupling constant. The V and T in the above formulae denote ρ or ω exchanged in the direct photoproduction and f_2 respectively.

In the final state interaction mechanism initially 2 pions are produced from the diffuse spatial region. This reaction is described in terms of the D-wave projected Born amplitude. Pions then undergo final state interactions which may result in the $D-$wave resonance production [2], (Fig. 2).

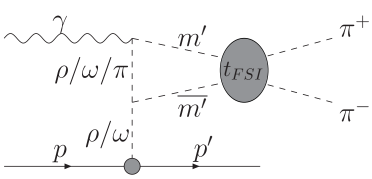

Figure 2. FSI photoproduction diagram.

The general form of the FSI amplitude is:

$$A_{\pi^+\pi^-}(\lambda_f, \lambda_\gamma, \sigma_1, \sigma_2) = V_{\pi^+\pi^-}(\lambda_f, \lambda_\gamma, \sigma_1, \sigma_2) + \\ 4\pi \sum_{m'\overline{m}'} \int_0^{\infty} \frac{\kappa'^2 d\kappa'}{(2\pi)^3} F(\kappa, \kappa')\langle \pi^+\pi^- | \hat{t}_{FSI} | m'\overline{m}' \rangle G_{m'\overline{m}'}(\kappa') V_{m'\overline{m}}(\lambda_f, \lambda_\gamma, \sigma_1, \sigma_2) \quad (4)$$

where $V_{m'\overline{m}}$ - Born amplitude, $\hat{t}_{FSI}$ - final state scattering amplitude [3], $G_{m'\overline{m}'}(\kappa')$ - propagator of the intermediate meson pair, $F(\kappa, \kappa')$ - form-factor regularizing the meson loop. In our calculations the kinematical variables are defined in the s channel helicity frame.

Direct photoproduction amplitude can be expressed in terms of the nucleon spin matrices

$$A(\sigma'\sigma) \sim a\vec{\epsilon}\cdot\vec{\Gamma}_{\sigma'\sigma}\left[(\vec{q}\cdot\vec{k})^2 - \frac{1}{3}\vec{k}^2\vec{q}^2\right] + b(q\cdot\Gamma_{\sigma'\sigma})(\vec{\epsilon}\cdot\vec{k})(\vec{q}\cdot\vec{k}) + c\left[(\vec{\epsilon}\cdot\vec{k})(\vec{\Gamma}_{\sigma'\sigma}\cdot\vec{k}) - \frac{1}{3}\vec{k}^2(\vec{\epsilon}\cdot\vec{\Gamma}_{\sigma'\sigma})\right] \quad (5)$$

where q, k - photon and outgoing pion 4-momenta, $\Gamma_{\sigma'\sigma}$ - spin matrix of the nucleon vertex. Important observation concerning the spin structure of this amplitude is that the third term of Eq. 5 is responsible for spin correlation between the tensor meson and the proton which can be detected provided the polarization of the proton is measured. There are no terms of that kind in the FSI model.

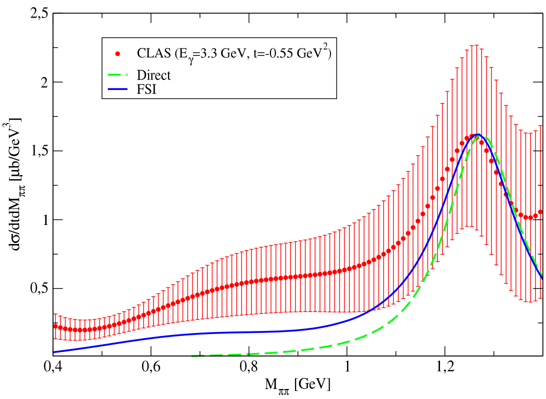

Figure 3. The *D*-wave mass distribution predicted by the direct and FSI photoproduction models compared to CLAS data.

3 Summary

We compared the predictions of both models with the $f_2(1270)$ photoproduction data on the mass distribution and helicity projected mass distributions from the CLAS experiment [4]. The models predict similar ratios of the helicity projected mass distributions but the direct photoproduction model requires the background amplitudes to be added in order to describe the mass distribution.

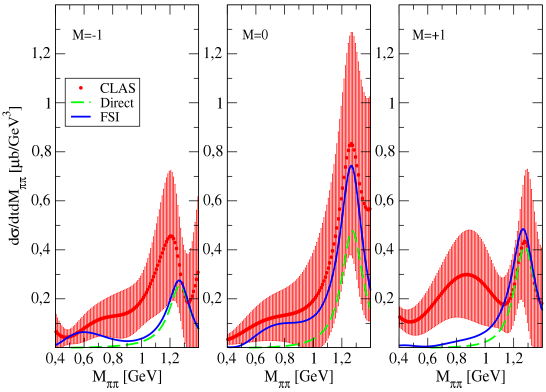

Figure 4. Predictions of both models compared with mass distributions projected on -1, 0 and +1 partial waves measured by CLAS.

Both models agree that the $f_2(1270)$ photoproduction is dominated by the λ_f=0 partial wave. The measurement of spin correlations between the final tensor meson and the proton may be used to indicate the dominant mechanism of the tensor meson photoproduction.

Acknowledgements

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