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Is $X(3915)$ accessible at meson photoproduction experiment?

Xiao-Hua Yuan[1,3,a], Qing-Yong Lin[1,3], and Xiang Liu[2,3]

[1] *Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China*
[2] *School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China*
[3] *Research Center for Hadron and CSR Physics, Lanzhou University and Institute of Modern Physics of CAS, Lanzhou 730000, China*

Abstract. In this paper, we introduce our study on the discovery potential of charmonium-like state $X(3915)$ via meson photoproduction. By considering the signal and background contribution to $\gamma p \to J/\psi\omega p$ process, we obtain the total cross sections for $\gamma p \to J/\psi\omega p$, which provide important information to further experimental exploration of $X(3915)$. Especially, we also emphasize that the discovery potential of charmonium-like state $X(3915)$ is determined by the coupling constant of $X(3915) \to J/\psi\omega$, which is a crucial parameter of reflecting the inner structure of $X(3915)$. Thus, studying $X(3915)$ via meson photoproduction is helpful in revealing the underlying property of $X(3915)$.

1 Introduction

In the past decade, more and more charmonium-like states, which are also named as XYZ states, were announced by experiment. At present, the observed XYZ are from B meson decays, e^+e^- annihilation, the double charm production, $\gamma\gamma$ fusion process, and the hidden-charm/bottom dipion and open-charm/bottom decays of higher charmonia/bottomonia and charmonium-like/bottomonium-like states. The study of XYZ states is helpful to improve our understanding of the non-perturbative behavior of QCD [1].

Among these studies of XYZ states, exploring XYZ states via other production processes different from observed processes mentioned above is an interesting research topic. In this paper, we introduce our progress on the investigation of charmonium-like state $X(3915)$ [2] via meson photoproduction.

2 The meson photoproduction of $X(3915)$

As a charmonium-like state, $X(3915)$ was first observed in the $J/\psi\omega$ invariant mass spectrum of $\gamma\gamma \to J/\psi\omega$ with mass $m = (3915 \pm 3 \pm 2)$ MeV and width $(17 \pm 10 \pm 3)$ MeV [2]. Later, BaBar confirmed $X(3915)$ [3], where the spin-parity analysis of $X(3915)$ indicates that $X(3915)$ has $J^P = 0^+$ quantum number as good candidate of P-wave charmonium $\chi'_{c0}(2P)$ [4]. In Ref. [5], we explore the discovery potential of $X(3915)$ through meson photoproduction.

a. e-mail: x.yuan@impcas.ac.cn

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Due to the vector meson dominance (VMD), we give the signal contribution depicting the $\gamma p \to X(3915)p \to J/\psi\omega p$ (see Fig. 1), while the background contribution is from the Pomeron exchange. We obtain the square of the total invariant transition amplitude

$$|\mathcal{M}|^2 = \sum \left| T_{fi}^{Signal} + T_{fi\,(a)}^{Pomeron} + T_{fi(\,b)}^{Pomeron} \right|^2 . \quad (1)$$

the total cross section of the process $\gamma p \to J/\psi\omega p$ reads as

$$d\sigma = \frac{m_N^2}{|k_1 \cdot p_1|} \frac{|\mathcal{M}|^2}{4} (2\pi)^4 d\Phi_3(k_1 + p_1; p_2, k_2, k_3), \quad (2)$$

where $d\Phi_3(k_1 + p_1; p_2, k_2, k_3)$ is the 3-body phase space. Adopting the effective Lagrangian approach, we write out the transition amplitudes $\mathcal{T}_{fi}^{Singal}$, $T_{fi\,(a)}^{Pomeron}$ and $T_{fi\,(a)}^{Pomeron}$ (see Ref. [5] for more details of the deduction of amplitudes). For numerically obtaining the total cross section including both signal and background contributions, we adopt the FOWL code.

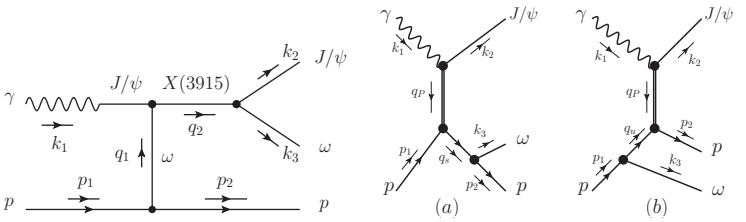

Figure 1. The signal (left panel) and background contributions to $\gamma p \to J/\psi\omega p$. Here, there are two typical diagrams describing the background contribution, which are marked by (a) and (b).

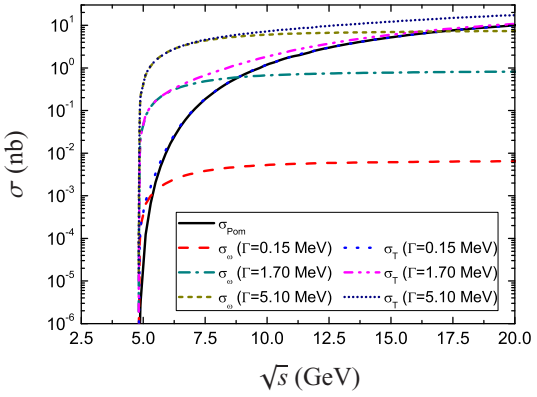

Figure 2. The energy dependence of the total cross sections for $\gamma p \to J/\psi\omega p$. Here, σ_{Pom} and σ_ω are the results only considering the Pomeron exchange and the ω exchange contributions, respectively, while σ_T denotes the total cross section of $\gamma p \to J/\psi\omega p$. We also give the variations of σ_ω and σ_T to $\sqrt{s}$ corresponding to the typical values $\Gamma(X(3915) \to J/\psi\omega) = 0.15$ MeV, $\Gamma(X(3915) \to J/\psi\omega) = 1.7$ MeV and $\Gamma(X(3915) \to J/\psi\omega) = 5.1$ MeV.

In Fig. 2, we show the total cross section of $\gamma p \to J/\psi\omega p$, where we consider the signal and background contributions. The comparison of the typical σ_ω, σ_T and σ_{Pom} indicates: 1) When $\Gamma(X(3915) \to J/\psi\omega) = 0.15$ MeV, the corresponding σ_ω is rather small. However, σ_ω is larger than σ_{Pom} around $\sqrt{s} = 5$ GeV, which is close to the threshold of $\sqrt{s}$ of the $\gamma p \to J/\psi\omega p$ reaction. Since the decay width of $X(3915) \to J/\psi\omega$ determines whether the $X(3915)$ signal is buried by the background, the above analysis makes us obtain the lower limit of $\Gamma(X(3915) \to J/\psi\omega)$ if distinguishing the $X(3915)$ signal from the background. 2) When $\Gamma(X(3915) \to J/\psi\omega) = 1.7$ MeV and 5.1 MeV,

the corresponding σ_T is dominated by the $X(3915)$ signal contribution at $\sqrt{s} \leq 8$ and $\sqrt{s} \leq 15$ GeV, respectively (see Fig. 2 for the detail). It means that the $X(3915)$ signal can be easily observed if taking suitable $\sqrt{s}$ range.

3 Summary

In this paper, we introduce our result of studying charmonium-like state $X(3915)$ via meson photoproduction. $X(3915)$ is a good candidate of $\chi'_{c0}(2P)$ [4], where $X(3915)$ was only reported in the $\gamma\gamma$ fusion process [2, 3]. This study can further shed light on the properties of $X(3915)$. We notice that the final state of the observed $X(3915)$ decay contain two vector mesons. Thus, meson photoproduction process is suitable to study $X(3915)$. For quantitatively answering whether $X(3915)$ can be observed in meson photoproduction process, we study the $\gamma p \to J/\psi\omega p$ process by including the $X(3915)$ signal and background contributions, where the corresponding cross section is obtained, which provide valuable information to the experimental study of $X(3915)$ by meson photoproduction.

Our calculation shows that the experimental measurement of the decay width of $X(3915) \to J/\psi\omega$ is a crucial input in studying the meson photoprodution of $X(3915)$. At present, this value is still missing in experiments. In our work, we have to consider several typical values of $\Gamma(X(3915) \to J/\psi\omega)$ to discuss the discovery potential of $X(3915)$ by meson photoproduction.

Among these running and forthcoming experiments, the COMPASS experiment is a good platform to perform the search for $X(3915)$ via meson photoproduction. We also expect further experimental progresses on $X(3915)$.

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References

[1] X. Liu, Chin. Sci. Bull. **59**, 3815-3830 (2014)
[2] S. Uehara *et al.* (Belle collaboration), Phys. Rev. Lett. **104**, 092001 (2010)
[3] J. P. Lee *et al.*, Phys. Rev. Lett. **86**, 072002 (2012)
[4] X. Liu, Z. G. Luo, and Z. F. Sun, Phys. Rev. Lett. **104**, 122001 (2010)
[5] Q. Y. Lin, X. Liu and H. S. Xu, Phys. Rev. D **89**, 034016 (2014)