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New results from $Y(4260)$ decays at BESIII

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A series study of $Y(4260)$ are performed with the world's largest data sample around $\sqrt{s} = 4.26$ GeV at BESIII, similar structures around 4.22 GeV, denoted as $Y(4220)$, are observed in the cross section distributions for $e^+e^- \to \pi^+\pi^- J\psi$, $\pi^+\pi^- h_c$, $\pi^+\pi^-\psi(3686)$ and $\pi^+ D^0 D^{*-}$. The parameters are consist with each other within errors. Enhancements around similar positions are observed for $e^+e^- \to K^+K^- J\psi$, ηh_c and $\gamma\eta_c$. Several light hadrons decay channels are investigated to search for $Y(4220)$ and no clear signal is observed.

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1. Introduction

The famous $Y(4260)$ was first observed by BaBar collaboration [1] in the initial-state-radiation (ISR) process $e^+e^- \to \gamma_{\rm ISR}\pi^+\pi^- J\psi$ with a mass around 4.26 GeV/c^2. It was confirmed by CLEO [2] and Belle [3] subsequently using same process. Lately with more statistics [4, 5], the signal of $Y(4260)$ becomes more clear and the mass is tend to be less than 4.26 GeV/c^2.

While being above the open-charm threshold, the $Y(4260)$ is only observed in the hidden-charm decay channels, not like other conventional vector charmonium. From both the cross section measurements of total hadronic [6] and open-charm [7] processes, there is no enhancement around the peak of $Y(4260)$. While for the cross section measurements of other hidden-charm channels at BESIII, such as πZ_c [8], $\gamma X(3872)$ [9] and $\omega\chi_{c0}$ [10], the enhancement is very clear, which indicate that these channels could come from $Y(4260)$ decay. From previous cross section measurements of $e^+e^- \to \pi^+\pi^- J/\psi$, the line shape of $Y(4260)$ is not exactly a symmetric Breit-Wigner (BW). With more data at BESIII, we can measure the cross sections for some hidden and open-charm channels precisely to see if there is any fine structure.

2. Data at BESIII

Up to now, BESIII has accumulated about 12 fb^{-1} data above 4.0 GeV. We have several large data samples (XYZ sample) before to study the XYZ states and about 100 sub-samples (R-scan data) with luminosity about 7 pb^{-1} for each of them. In additional, 9 data samples (blue dots) have been taken recently for the future study of $Y(4260)$. Since the only known produced way of $Y(4260)$ is e^+e^- annihilation, the BESIII is the ideal place to study the $Y(4260)$.

Recently we performed some analyses to measure the cross sections of some hadronic and radiation hidden-charm transitions, open-charm channels, and some light hadrons channels.

3. Hadronic transition

3.1 Cross section measurements of $e^+e^- \to \pi^+\pi^- J\psi$

With more data at BESIII, we measured the cross section of $e^+e^- \to \pi^+\pi^- J\psi$ with significantly improved precision [12]. The results are shown in Fig. 1. The cross section is defined as:

$$\sigma(\sqrt{s}) = \frac{N^{\rm sig}}{\mathscr{L}_{\rm int}(1+\delta)\varepsilon\mathscr{B}}, \tag{3.1}$$

where $N^{\rm sig}$ and $\mathscr{L}_{\rm int}$ are the number of signal events and integrated luminosity, respectively, $(1+\delta)$ is the ISR correction factor and obtained by iterations, ε and $\mathscr{B}$ are the detection efficiency and branching ratio for J/ψ to lepton pairs.

From Fig. 1, a shoulder around 4.3 GeV is observed, which indicate that the structure known as $Y(4260)$ is not caused by one resonance but two. We use three coherent BW with the three body phase space, two for the structure around 4.26 GeV and one for the possible $Y(4008)$, and an incoherent $\psi(3770)$ to parameterize the line shape of $\pi^+\pi^- J\psi$. The fit shows good consistent with data, and the $Y(4260)$ peak can be explained by two resonance, one with mass $4222.0 \pm 3.1 \pm 1.4$ MeV/c^2 and width $44.1 \pm 4.3 \pm 2.0$ MeV, another one with mass $4320.0 \pm 10.4 \pm 7.0$ Mev/C^2 and

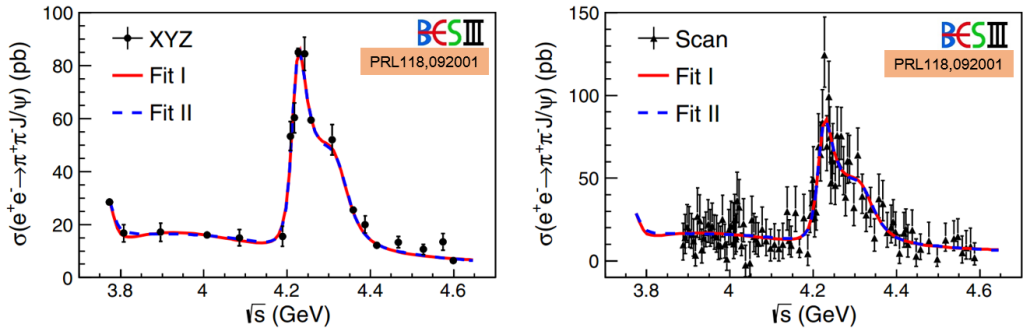

Figure 1: Cross sections of $e^+e^- \to \pi^+\pi^- J\psi$ for XYZ data (left) and R-scan data (right).

width $101.4^{+25.3}_{-19.7} \pm 10.2$ MeV, respectively. The first resonance agrees with the $Y(4260)$ reported by BaBar, CLEO and Belle, but much narrower thanks to more statistics at BESIII. The statistical significance for the second resonance is larger than 7.6σ, and the parameters are similar with the $Y(4360)$. For $Y(4008)$, we can not confirm it.

3.2 Cross section measurements of $e^+e^- \to \pi^+\pi^- h_c$

Like $\pi^+\pi^- J\psi$, we measured the cross section of $e^+e^- \to \pi^+\pi^- h_c$ [13] with same data and the cross section is defined with the same method. For the reconstruction of h_c, we use the E1 transition $\gamma\eta_c$ and use 16 decay channels to tag η_c.

The cross sections are shown in Fig. 2 (left) and obtained by iterations. The cross section goes down at 4.23 and 4.4 GeV, which indicate there should be one structure around 4.23 and one around 4.4 GeV. Two coherent BW with three body phase space are used to get the parameters. The statistical significance of two structures assumption over one is larger than 10σ. The first one has mass $4218.4^{+5.5}_{-4.5} \pm 0.9$ MeV/c^2 and width $66.0^{+12.3}_{-8.3} \pm 0.4$ MeV and consist with the similar structure observed in $\pi^+\pi^- J/\psi$ and $\omega\chi_c 0$, the second one has mass $4391.5^{+6.3}_{-6.8} \pm 1.0$ MeV/c^2 and width $139.5^{+16.2}_{-20.6} \pm 0.6$ MeV.

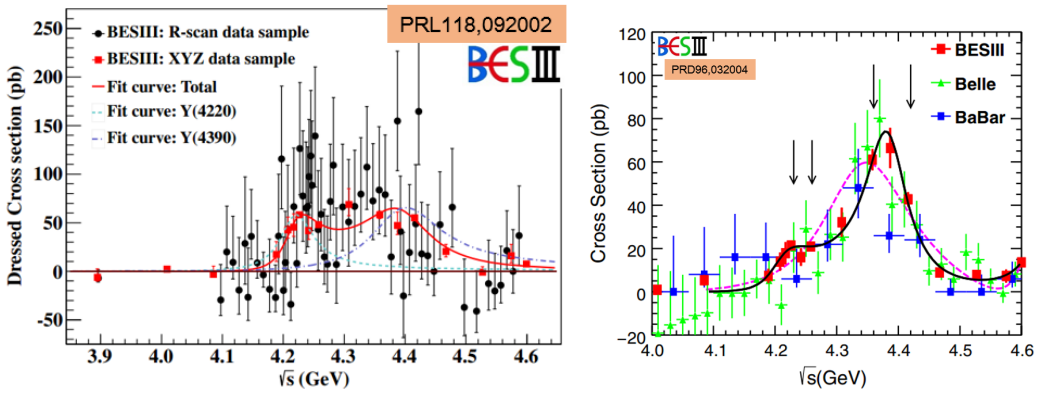

Figure 2: Cross sections of $e^+e^- \to \pi^+\pi^- h_c$ (left) and $\pi^+\pi^-\psi(3686)$ (right)

3.3 Cross section measurements of $e^+e^- \to \pi^+\pi^-\psi(3686)$

We studied the $e^+e^- \to \pi^+\pi^-\psi(3686)$ with $\psi(3686)$ to $\pi^+\pi^- J\psi$ and $\pi^0\pi^0(\pi^0\eta\gamma\gamma)J\psi$ [14]. The cross sections are shown in Fig. 2 (right). With more statistics at BESIII, the cross section has much better precision than the results from BaBar [15] and Belle [16]. Besides the $Y(4360)$, there is an enhancement around 4.22 GeV, which maybe caused by $Y(4260)$, and it goes up around 4.6 GeV. Three coherent BW are used to parameterize the line shape. The structure around 4.22 GeV is observed in $\pi^+\pi^-\psi(3686)$ for the first time with a significance of 5.8σ, and has a mass $4209.5 \pm 7.4 \pm 1.4$ MeV/c^2 and width $80.1 \pm 24.6 \pm 2.9$ MeV, which are consist with the structure observed in $\pi^+\pi^- J\psi$ and $\pi^+\pi^- h_c$. The second structure has a mass $4383.8 \pm 4.2 \pm 0.8$ MeV/c^2 and width $84.2 \pm 12.5 \pm 2.1$ MeV and consist with the that in $\pi^+\pi^- h_c$.

3.4 Cross section measurements of $e^+e^- \to KKJ\psi$

The process of $e^+e^- \to KKJ\psi$ is investigated and the Born cross sections after vacuum polarization correction are shown in Fig. 3 for $K^+K^- J\psi$ (left) and $K_SK_S J\psi$ (right). The ratio of cross sections between this two channels are consist with prediction by isospin symmetry, but the ratio between $KKJ\psi$ and $\pi^+\pi^- J\psi$ are not the same along c.m. energy, which indicate more complex structure in $KKJ\psi$

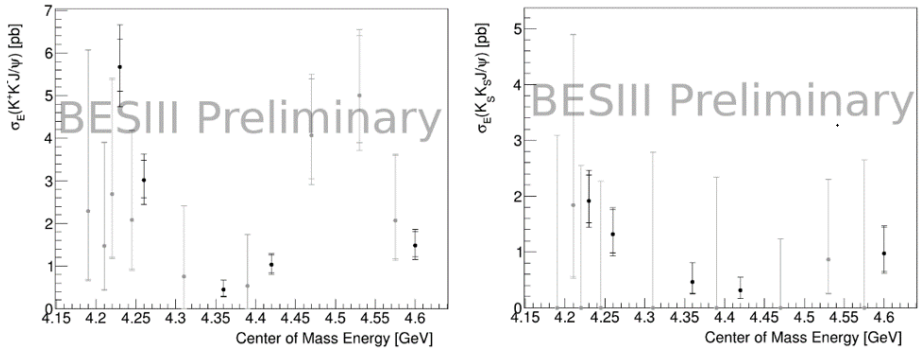

Figure 3: Cross sections of $e^+e^- \to K^+K^- J\psi$ (left) and $K_SK_S J\psi$ (right)

3.5 Cross section measurements of $e^+e^- \to \eta h_c$

We observe the process $e^+e^- \to \eta h_c$ for the first time and the Born cross section are shown in Fig. 4 (right). Clear signal is observed at 4.23 GeV and may come from the same structure in $e^+e^- \to \eta J\psi$ [17]. The ratio between cross section of ηh_c and $\eta J\psi$ is determined to be 0.20 ± 0.07 and 1.79 ± 0.84 at 4.23 and 4.36 GeV, and larger than theoretical predictions of $\psi(4160)$ and $\psi(4415)$ decays.

4. Radiative transition: $e^+e^- \to \gamma\eta_c$

Besides the hadronic transition, we also use the radiative transition to search for the $Y(4260)$. We observe first evidence for the process $e^+e^- \to \gamma\eta_c$ between 4.01 and 4.60 GeV [18], and the Born cross section are shown in Fig. 4 (right). The cross section is better explained by assuming $\gamma\eta_c$

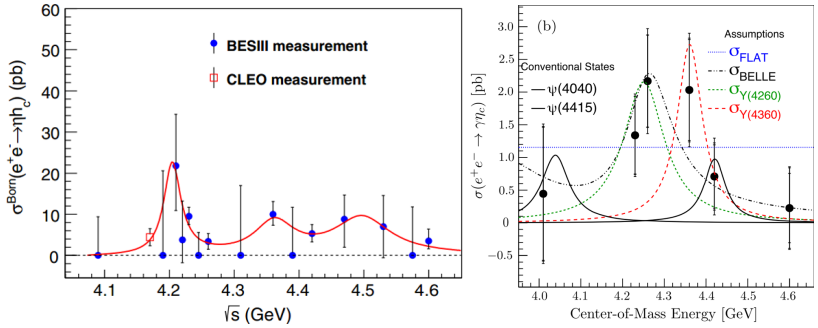

Figure 4: Cross sections of $e^+e^- \to \eta h_c$ (left) and $\gamma\eta_c$ (right)

comes from $Y(4260)$ decays than from conventional charmonium $\psi(4040)$, $\psi(4160)$ and $\psi(4415)$. The enhancement around 4.26 GeV may suggest the existence of a hybrid charmonium state [19].

5. Open-charm: $e^+e^- \to \pi^+D^0D^{*-}$

To understand the $Y(4260)$, we perform a study of a open-charm process $e^+e^- \to \pi^+D^0D^{*-}$ since its production could be strongly enhanced above the $D\bar{D}_1(2420)$ threshold [20]. Fig. 5 (left) shows the distribution of cross sections. We observe a clear enhancement around 4.23 GeV and a broad one around 4.4 GeV. Two coherent BW are used to fit the cross sections. The mass and width for the first structure are $4228.6 \pm 4.1 \pm 5.0$ MeV/c^2 and $77.1 \pm 6.8 \pm 2.7$ MeV, and for the second one are $4404.6 \pm 7.4 \pm 4.8$ MeV/c^2 and $191.7 \pm 13.0 \pm 15.1$ MeV, respectively. The first structure has similar parameters with that in the above processes, and more importantly consist with the prediction of $D\bar{D}_1(2420)$ molecule.

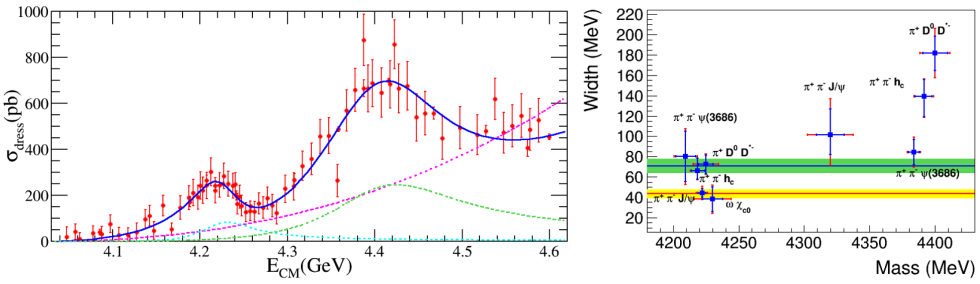

Figure 5: Cross sections of $e^+e^- \to \pi^+D^0D^{*-}$ (left) and parameters for the resonances in this proceeding (right).

6. Light hadron channels

In addition, we performed several analysis to search for the light hadron decays of $Y(4260)$. The Born cross section of $e^+e^- \to \phi\phi\phi, \phi\phi\omega$ [21], $p\bar{p}\pi^0$ [22] and $\eta Y(2175)$ [23] are measured from 4.0 to 4.6 GeV. No obvious $Y(4260)$ signal was observed.

7. Summary and discussion

In summary, we observed a structure with mass around 4220 MeV, denoted as $Y(4220)$, in $e^+e^- \to \pi^+\pi^- J\psi$, $\pi^+\pi^- h_c$, $\pi^+\pi^-\psi(3686)$ and open-charm channel $\pi^+ D^0 D^{*-}$, similar with that in $\omega\chi_{c0}$. Fig. 5 (right) shows the parameters, the masses are consist well between different channels, while the width measurements have larger difference and maybe caused by other effects, e.g. open-charm threshold, three body phase space. For the ηh_c and $\gamma\eta_c$, enhancement around the peak of $Y(4220)$ is observed and we need more data to confirm. No light hadron decays of $Y(4220)$ was observed. With more data at BESIII, we can investigate more channels and the nature of $Y(4220)$ will become more and more clear.

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