

Study of $\phi(2170)$ at BESIII

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Abstract. After the first observation of $\phi(2170)$ in the process $e^+e^- \rightarrow \gamma_{ISR}\phi f_0(980)$, several theoretical interpretations have been proposed to explain the nature of $\phi(2170)$. Aspects of $\phi(2170)$ are still not fully understood until now. Large J/ψ events and energy scan data samples collected by the BESIII detector provide the opportunity to perform the further study to $\phi(2170)$. In this presentation, $J/\psi \rightarrow \eta\phi(2170)$ and $e^+e^- \rightarrow \eta\phi(2170)$ are studied to improve the measurements of mass and width of $\phi(2170)$. $e^+e^- \rightarrow K^+K^-$, ϕK^+K^- and $K^+K^-K^+K^-$ are investigated to search for the new decay mode of $\phi(2170)$. Those studies would be useful for improving the understanding of the nature of $\phi(2170)$.

1 Introduction

The $\phi(2170)$, also denoted as $Y(2175)$ with $J^{PC} = 1^{--}$ in Particle Data Group (PDG) [1], is first observed in the initial-state-radiation (ISR) process $e^+e^- \rightarrow \gamma_{ISR}\phi f_0(980)$ by BABAR [2] collaboration. It is later confirmed in the same ISR process by Belle [3] collaboration and in $J/\psi \rightarrow \eta\phi f_0(980)$ process by BESII [4] collaboration.

Theoretically, several interpretations have been proposed to interpret the nature of $\phi(2170)$ with predicated masses, widths and decay modes. These include an $s\bar{s}g$ hybrid meson [5]; a conventional $s\bar{s}$ meson [6]; a $s\bar{s}s\bar{s}$ tetraquark state [7, 8]; a $\Lambda\bar{\Lambda}$ bound state [9, 10]; a three body system ϕKK [11]; and a $\phi f_0(980)$ resonance with final state interaction [12]. The decay $\phi(2170) \rightarrow K^{*0}\bar{K}^{*0}$ is forbidden if $\phi(2170)$ is a hybrid state but allowed if it is a quarkonium state [5, 6]. BESII collaboration investigates the decay $\phi(2170) \rightarrow K^{*0}\bar{K}^{*0}$ in $J/\psi \rightarrow \eta\phi(2170)$ process and no obvious enhancement near 2.175 GeV/ c^2 is observed [13]. The $\phi\eta$, $\phi\eta'$ decay mode of $\phi(2170)$ is preferred by the $s\bar{s}s\bar{s}$ tetraquark state [14]. The $2^3D_1s\bar{s}$ suggests a considerable branching fraction of decay $\phi(2170) \rightarrow K^+K^-$, while this decay mode is forbidden by interpretations of $s\bar{s}g$ hybrid meson and $3^3S_1s\bar{s}$ state [6]. The invariant mass of ϕK^+K^- is favored by three body system interpretation [11].

The aspect of $\phi(2170)$ still remain mystery. Large J/ψ events and energy scan data samples collected by the BESIII detector provide the opportunity to perform the further study to $\phi(2170)$. A more precise measurement of mass and width and investigation in the decay mode to $\phi(2170)$ would be useful for improving the understanding of the nature of $\phi(2170)$.

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2 $\phi(2170)$ study at BESIII

2.1 $J/\psi \rightarrow \eta\phi(2170) \rightarrow \eta\phi f_0(980)$

BESII collaboration confirms the $\phi(2170)$ with 58×10^6 J/ψ events using the process $J/\psi \rightarrow \eta\phi(2170) \rightarrow \eta\phi f_0(980)$ [4]. With highly improved statistics of 225×10^6 J/ψ events collected at BESIII detector, this process is performed again to clarify the nature of $\phi(2170)$ [15].

The $\phi(2170)$ is observed in $\phi f_0(980)$ mass spectrum with a statistical significance greater than 10σ , as shown in Fig. 1 (a). The mass and width are measured to be $M = (2200 \pm 6 \pm 5)$ MeV/ c^2 and $\Gamma = (104 \pm 15 \pm 15)$ MeV, respectively. This measurement is consistent with the previous results and improves the precision of mass and width.

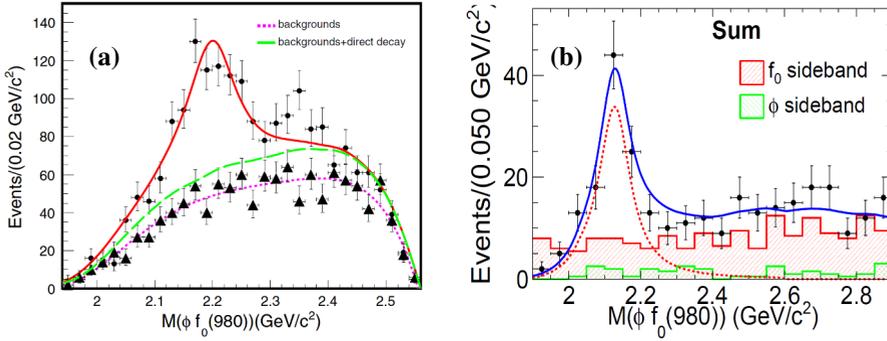


Figure 1. (a) Fit to the $\phi f_0(980)$ invariant mass distribution. The circular dots with error bars show the distribution in the signal region; the triangular dots with error bars show the backgrounds estimated using sideband regions. (b) Fit to the $\phi f_0(980)$ invariant mass distribution.

2.2 $e^+e^- \rightarrow \eta\phi(2170) \rightarrow \eta\phi f_0(980)$

The observed production mechanisms for $\phi(2170)$ are so far limited to direct e^+e^- annihilation and $J/\psi \rightarrow \eta\phi(2170)$ decay. The production of $\eta\phi(2170)$ are expected in $\psi(3686)$ decay as well as in direct e^+e^- annihilation in the non-resonant energy region, considering the process $J/\psi \rightarrow \eta\phi(2170)$ has been observed.

The state $\phi(2170)$ is observed in the process $e^+e^- \rightarrow \eta\phi(2170)$ at center-of-mass energies between 3.7 and 4.6 GeV with a statistical significance larger than 10σ , as shown in Fig. 1 (b) [16]. The mass and width of $\phi(2170)$ are determined to be $M = (2135 \pm 8 \pm 9)$ MeV/ c^2 and $\Gamma = (104 \pm 24 \pm 12)$ MeV, respectively. No significant signal is observed in process $\psi(3686) \rightarrow \eta\phi(2170)$.

2.3 $e^+e^- \rightarrow K^+K^-$

The decay of $\phi(2170)$ to K^+K^- final state is forbidden in the interpretations of $s\bar{s}g$ hybrid meson and $3^3S_1 s\bar{s}$ state, while the $2^3D_1 s\bar{s}$ state suggests a considerable branching fraction of decay $\phi(2170) \rightarrow K^+K^-$. With the data samples collected at center-of-mass energies between 2.000 and 3.080 GeV, the process of $e^+e^- \rightarrow K^+K^-$ is studied.

The measured cross section of $e^+e^- \rightarrow K^+K^-$, as shown in Fig. 2 (a), is consistent with previous measurements and significantly improves the precision. A Structure around 2.23 GeV is observed with significance greater than 20σ and the measured mass $M = (2230 \pm 5 \pm 17)$ MeV/ c^2 and width $\Gamma = (144 \pm 12 \pm 18)$ MeV are not consistent with that of $\phi(2170)$ from PDG(2016). Interpretation of $\phi(2170)$ as $2^3D_1 s\bar{s}$ state seems unfavored.

2.4 $e^+e^- \rightarrow \phi K^+K^-$ and $K^+K^-K^+K^-$

The $\phi(2170) \rightarrow \phi K^+K^-$ is favored by three body system interpretation. Using the same data sample as that in Sect. 2.3, the process of $e^+e^- \rightarrow K^+K^-$ and $e^+e^- \rightarrow K^+K^-K^+K^-$ are investigated.

The cross section of $e^+e^- \rightarrow \phi K^+K^-$ and $e^+e^- \rightarrow K^+K^-K^+K^-$ are measured at 2.000-3.080 GeV. Possible structure around 2.23 GeV is found in the cross section shapes of $e^+e^- \rightarrow \phi K^+K^-$ and $e^+e^- \rightarrow K^+K^-K^+K^-$, as shown in Fig. 2 (b) and (c). The possible structure is far away from $\phi(2170)$ in PDG(2016).

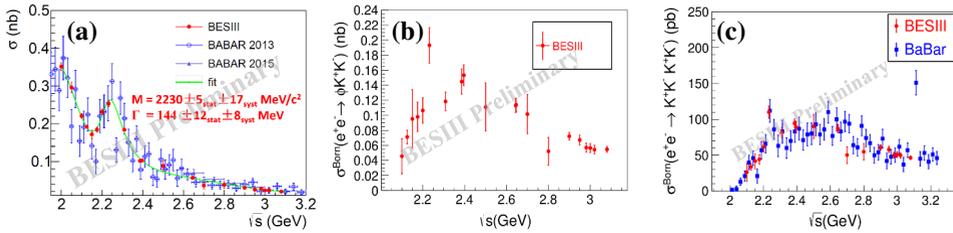


Figure 2. Cross section of $e^+e^- \rightarrow K^+K^-$ (a), $e^+e^- \rightarrow \phi K^+K^-$ (b) and $e^+e^- \rightarrow \phi K^+K^-K^+K^-$ (c).

3 Summary and discussion

In this presentation, using large J/ψ events and energy scan data samples at BESIII, the study to $\phi(2170)$ is performed. The $\phi(2170)$ is observed in the processes of $J/\psi \rightarrow \eta\phi(2170) \rightarrow \eta\phi f_0(980)$ and $e^+e^- \rightarrow \eta\phi(2170) \rightarrow \eta\phi f_0(980)$. The mass and width of $\phi(2170)$ are measured. The cross section of $e^+e^- \rightarrow K^+K^-$, ϕK^+K^- and $K^+K^-K^+K^-$ are measured at 2.000-3.080 GeV and the structure in the cross section line shapes are far away from the $\phi(2170)$ in PDG(2016). Investigations of $\phi\eta$, $\phi\eta'$ and $\omega\eta$ processes are ongoing at BESIII to perform the further study to $\phi(2170)$.

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