The line shape of the open-charm radiative and pionic decays of $Y(4274)$ as a molecular charmonium

Jun He[1,2] and Xiang Liu[1,3*†]
[1]*Research Center for Hadron and CSR Physics, Lanzhou University and Institute of Modern Physics of CAS, Lanzhou 730000, China*
[2]*Institute of Modern Physics of CAS, Lanzhou 730000, China*
[3]*School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China*
(Dated: February 11, 2011)

Under the assignment of the molecular state $D_s\bar{D}_{s0}(2317)$, we investigate the line shapes of the open-charm radiative and pionic decays of $Y(4274)$, which was observed by the CDF Collaboration recently. Our result of the line shape of the photon spectrum of $Y(4274) \to D_s^+ D_s^{*-}\gamma + h.c.$ shows that there exists a very sharp peak near the large end point of photon energy. The line shape of the pion spectrum of $Y(4274) \to D_s^+ D_s^{*-}\pi^0$ is similar to that of the pion spectrum of $Y(4274) \to D_s^+ D_s^{*-}\gamma + h.c.$, where we also find a very sharp peak near the large end point of pion energy. These observations can serve as the crucial test of $Y(4274)$ as a $D_s\bar{D}_{s0}(2317)$ molecular state in future experiment.

PACS numbers: 12.39.-x, 13.75.Lb, 13.20.Jf

I. INTRODUCTION

Very recently the CDF Collaboration announced an explicit enhancement structure with 3.1σ significance in the $J/\psi\phi$ invariant mass spectrum of $B^+ \to K^+ J/\psi\phi$ process, which is of mass $M = 4274.4^{+8.4}_{-6.7}(\text{stat}) \pm 1.9(\text{syst})$ MeV/c^2 and width $\Gamma = 32.3^{+21.9}_{-15.3}(\text{stat}) \pm 7.6(\text{syst})$ MeV/c^2 [1]. In addition, CDF also confirmed the observed $Y(4140)$ previously reported in Ref. [2]. We need to specify that such new results appearing in the $J/\psi\phi$ invariant mass spectrum are based on a sample of $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV with an integrated luminosity of about 6.0 fb^{-1} [1]. In this work, we refer to this new enhancement structure by the name $Y(4274)$.

Before reporting $Y(4274)$ structure, there have been six charmonium-like states observed in B meson decays, which include $X(3872)$ in $B \to \underline{J/\psi\pi^+\pi^-}K$ [3], $Y(3940)$ in $B \to \underline{J/\psi\omega}K$ [4, 5], $Y(4140)$ in $B \to \underline{J/\psi\phi}K$ [2], $Z^+(4430)$ in $B \to \underline{\psi'\pi^+}K$ [6], $Z^+(4015)$ and $Z^+(4248)$ in $B \to \underline{\chi_{c1}\pi^+}K$ [7], where we use the underlines to mark the corresponding decay channels of charmonium-like states observed in experiment. The evidence of $Y(4274)$ revealed by CDF not only makes the spectroscopy of charmonium-like states observed in B meson decays abundant, but also stimulates theorist's interest in revealing its underlying structure. Associated with the observed six charmonium-like states observed in B meson decays, studying $Y(4274)$ will improve our understanding to the essential mechanism resulting in these structures.

The comparison of the existing experimental information of charmonium-like states observed in B meson decays reflects a common property, i.e., these charmonium-like states are near the threshold of charmed meson pair, which provokes the investigation of whether these observed charmonium-like states $X(3872)$, $Z^+(4430)$, $Z^+(4015)/Z^+(4248)$, $Y(3930)$, $Y(4140)$, $Y(4274)$ observed in B meson decay can be explained as the corresponding molecular charmonia [8–17]. To some extent, the molecular assignment to these charmonium-like states is supported by the production mechanism in the weak decays of B meson. The $c\bar{c}$ pair is created from the color-octet mechanism in the weak decays of B meson, then c and $\bar{c}$ respectively capture $\bar{q}$ and q to form charmed meson pair, where a color-octet $q\bar{q}$ pair is popped out by a gluon. Thus, a pair of the charmed mesons with the low momentum easily interact with each other to form the molecular charmonium [17].

As observed in Refs. [13, 17], the mass of $Y(4274)$ is near the threshold of $D_s\bar{D}_{s0}(2317)$ similar to the situation of $Y(4140)$ or $Y(3930)$, which is assigned as molecular of $D^*_{(s)}\bar{D}^*_{(s)}$ [17]. It is natural to assign $Y(4274)$ as an $D_s\bar{D}_{s0}(2317)$ molecular charmonium with the flavor wave function

$$|Y(4274)\rangle = \frac{1}{\sqrt{2}}\Big[|D_s^+ D_{s0}^-\rangle + |D_s^- D_{s0}^+\rangle\Big]. \qquad (1)$$

The dynamical calculation of the mass supports $Y(4274)$ as an S-wave $D_s\bar{D}_{s0}(2317)$ molecular state with $J^P = 0^-$ [13, 17].

Carrying out the dynamical calculation of the mass spectrum of $Y(4274)$ [13, 17] is seen as an important approach to reflect whether $Y(4274)$ is a $D_s\bar{D}_{s0}(2317)$ molecular state. Besides, we also need to perform the study of the decay behavior of $Y(4274)$ under the assignment of the $D_s\bar{D}_{s0}(2317)$ molecular state, which will provide crucial information to future experiment to test the molecular assignment to $Y(4274)$.

Just considering the above reasons and the present theoretical research status of $Y(4274)$, in this work we investigate the open-charm radiative and pionic decays of

*Corresponding author
†Electronic address: xiangliu@lzu.edu.cn

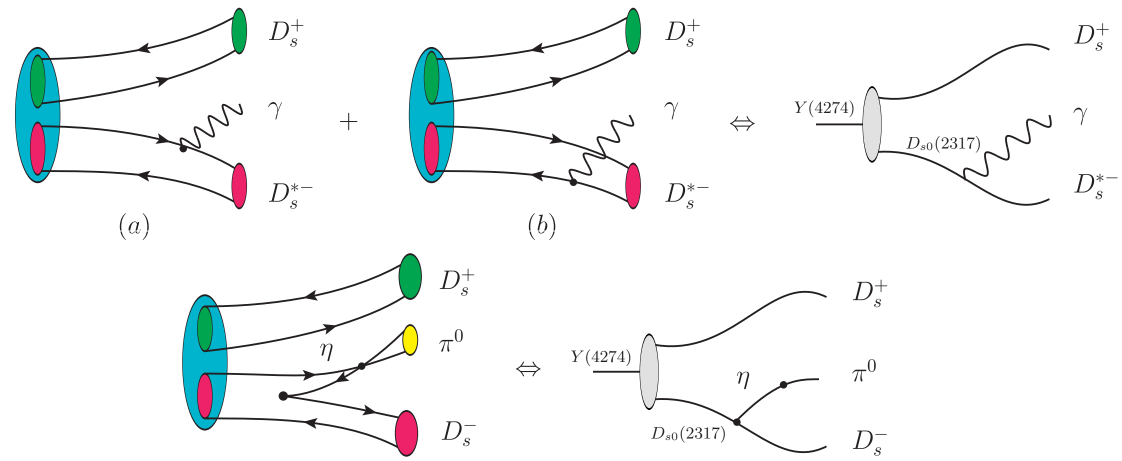

FIG. 1: The quark-level and hadron-level depictions of the open-charm radiative and pionic decays of $Y(4274)$.

$Y(4274)$, especially focusing on the line shape of the corresponding decays.

This work is organized as follows. After the introduction, we illustrate the calculation detail of the open-charm radiative and pionic decays of $Y(4274)$ under the assignment of molecular charmonium. In Sec. III, the numerical result will be presented. This paper ends with a discussion and a short summary.

II. RADIATIVE AND PIONIC DECAYS OF $Y(4274)$

Under the molecular assignment to $Y(4274)$, it is interesting to investigate the radiative and pionic decays of $Y(4274)$. Especially, the photon and pion emitted respectively from the radiative and pionic decays of $Y(4274)$ can be easily detected in experiment. Thus, studying the line shapes of the photon and pion spectra of the corresponding decays is a realistic research topic, which can also provide important information to reflect the internal structure of $Y(4274)$.

This work is mainly involved in two groups of decay channels of $Y(4274)$, i.e., the radiative and pionic open-charm decays. The radiative open-charm decays of $Y(4274)$ are $D_s^+ D_s^{*-}\gamma$ and $D_s^- D_s^{*+}\gamma$, and the pionic open-charm decays include $D_s^+ D_s^- \pi^0$. In the following, we take the decays $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$ as example. $Y(4274)$ with the assignment of the $D_s \bar{D}_{s0}(2317)$ molecular state firstly dissociates into D_s and $\bar{D}_{s0}(2317)$. Then, transitions $\bar{D}_{s0}(2317) \to \bar{D}_s^*\gamma$ and $\bar{D}_{s0}(2317) \to \bar{D}_s\pi^0$ result in the radiative decay $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and strong decay $Y(4274) \to D_s^+ \bar{D}_s^- \pi^0$ respectively, where $\bar{D}_{s0}(2317)$ decay into $\bar{D}_s \pi^0$ occurs via $\eta - \pi^0$ mixing mechanism [19, 20], which is main decay channel of the observed $D_{s0}(2317)$ [21]. The quark-level and hadron-level descriptions of $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$ are shown in Fig. 1.

In the processes considered in this work, the intermediate state $D_{s0}(2317)^-$ plays important role, which is off-shell since $Y(4274)$ is of negative binding energy under molecular state assignment. Just because of $D_{s0}(2317)^-$ being off-shell, there is no real Breit-Wigner peak corresponding to intermediate $D_{s0}(2317)^-$ in the invariant mass spectrum of $D_s^{*-}\gamma/D_s^-\pi^0$ of $Y(4274) \to D_s^+ D_s^{*-}\gamma/Y(4274) \to D_s^+ D_s^- \pi^0$ process. However, the distribution of the invariant mass spectrum of $D_s^{*-}\gamma$ or $D_s^-\pi^0$ is affected by the intermediate $D_{s0}(2317)^-$ since $D_{s0}(2317)^-$ is near the threshold of $D_s^{*-}\gamma$ or $D_s^-\pi^0$, where to some extent there exists an enhancement in the invariant mass spectrum of $D_s^{*-}\gamma$ or $D_s^-\pi^0$ corresponding to the energy range close to the mass of $D_{s0}(2317)^-$. For the three-body decays $Y(4274) \to D_s^+ D_s^- \pi^0$ and $Y(4274) \to D_s^+ D_s^{*-}\gamma$ discussed in this work, the maximum of the invariant mass of final state $D_s^-\pi^0$ or $D_s^{*-}\gamma$ is $M_Y - M_{D_s}$. The mass gap between $M_Y - M_{D_s}$ and the mass of $D_{s0}(2317)^-$ is $M_Y - M_{D_s} - M_{D_{s0}(2317)}$, which is just the binding energy for $Y(4274)$. Since the binding energy of $Y(4274)$ under the assumption of $D_s\bar{D}_s(2317)$ molecular state is only about -10 MeV, it is reasonable to expect an obvious enhancement in the region where the invariant mass of final state $D_s^-\pi^0$ or $D_s^{*-}\gamma$ is closed to the mass of $D_{s0}(2317)^-$.

In the following, we will be dedicated to study the line-shapes of the photon spectrum in $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and the pion spectrum in $Y(4274) \to D_s^+ D_s^- \pi^0$, which directly reflect on the underlying structure of $Y(4274)$ just mentioned above.

The general expressions of transition matrix elements for $Y(4274)$ sequential decays can be written as

$$
\begin{aligned}
&\mathcal{M}[Y(4274) \to D_s^+ D_s^{*-}\gamma] \\
&= \langle D_s^{*-}\gamma|\mathcal{H}_\gamma|D_{s0}(2317)^-\rangle\langle D_{s0}(2317)^- D_s^+|\mathcal{H}_1|Y\rangle,
\end{aligned}
\tag{2}
$$

$$
\mathcal{M}[Y(4274) \to D_s^+ D_s^- \pi^0]
$$

$$= \langle D_s^- \pi^0 | \mathcal{H}_\pi | D_{s0}(2317)^- \rangle \langle D_{s0}(2317)^- D_s^+ | \mathcal{H}_1 | Y \rangle, \tag{3}$$

where $\mathcal{H}_1$ describes the collapse of S-wave $D_s \bar{D}_{s0}(2317)$ molecular state into D_s^+ and $D_{s0}(2317)^-$. $\mathcal{H}_\gamma$ or $\mathcal{H}_\pi$ denotes the interaction of $D_{s0}(2317)^-$ with $D_s^{*-}\gamma$ or $D_s^- \pi^0$. For describing the decay amplitude, we adopt the same method as that in Refs. [18, 22, 23], where the radiative decay behaviors of $X(3872)$ as a $D\bar{D}^* + h.c.$ molecular state and $Y(4140)/Y(3930)$ as $D_s^* \bar{D}^*/D^* \bar{D}^*$ were studied under the corresponding assignments of molecular states.

The matrix element $\langle D_{s0}(2317)^- D_s^+ | \mathcal{H}_1 | Y \rangle$, describing the collapse of $Y(4274)$ into $D_{s0}(2317)^-$ and D_s^+, can be represented as

$$\langle D_{s0}(2317)^- D_s^+ | \mathcal{H}_1 | Y \rangle = \alpha \Psi(\boldsymbol{q}), \tag{4}$$

where $\alpha = 1/\sqrt{2}$ is the weight factor of the component $|D_{s0}(2317)^- D_s^+\rangle$ in the molecular wave function (see Eq. (1)). The wave function $\Psi(\boldsymbol{q})$ in momentum space, describing S-wave $D_s \bar{D}_{s0}(2317)$ molecular state, is of the form [22, 23]

$$\Psi(\boldsymbol{q}) = \sqrt{8\pi\kappa} \Big(\frac{1}{\boldsymbol{q}^2 + \kappa^2} \Big) \tag{5}$$

with $\kappa = \sqrt{2 m_\tau E}$, where E and m_τ are the binding energy and the reduced mass of $D_s \bar{D}_{s0}(2317)$ molecular system, respectively. $\boldsymbol{q}$ denotes the relative momentum between $\bar{D}_{s0}(2317)$ and D_s in the molecular system.

We adopt the effective Lagrangians

$$\begin{aligned} &\mathcal{L}_{D_{s0}(2317) D_s^* \gamma} \\ &= g_\gamma \, (\partial^\mu \gamma^\nu \partial^\mu \Psi^\nu_{D_s^*} - \partial^\nu \gamma^\mu \partial^\mu \Psi^\nu_{D_s^*}) \Psi_{D_{s0}}, \quad (6) \\ &\mathcal{L}_{D_{s0}(2317) D_s \pi} = g_\pi \Psi_{D_s} \Psi_\pi \Psi_{D_{s0}} \quad (7) \end{aligned}$$

to depict the interactions of $D_{s0}(2317)$ with $D_s^* \gamma$ and $D_s \pi$ respectively, where g_γ and g_π is the effective coupling constants. Thus, the amplitudes $\langle D_s^{*-} \gamma | \mathcal{H}_\gamma | D_{s0}(2317)^- \rangle$ and $\langle D_s^- \pi^0 | \mathcal{H}_\pi | D_{s0}(2317)^- \rangle$ read as

$$\begin{aligned} &\langle D_s^{*-} \gamma | \mathcal{H}_\gamma | D_{s0}(2317)^- \rangle \\ &= g_\gamma \, \varepsilon_{1\mu} \varepsilon_{2\nu} (g^{\mu\nu} k_1 \cdot k_2 - k_1^\nu k_2^\mu), \quad (8) \\ &\langle D_s^- \pi^0 | \mathcal{H}_\pi | D_{s0}(2317)^- \rangle = g_\pi, \quad (9) \end{aligned}$$

where $k_1(k_2)$ and $\varepsilon_1(\varepsilon_2)$ are momenta and the polarization vectors of photon(D_s^{*-}), respectively.

Finally, the amplitudes of sequential decays $Y(4274) \to D_s^+ D_s^{*-} \gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$ can be expressed as

$$\Big| \mathcal{M}[Y(4274) \to D_s^+ D_s^{*-} \gamma] \Big|^2 = g_\gamma^2 (k_1 \cdot k_2)^2 \Psi^2(\boldsymbol{q}), \tag{10}$$

$$\Big| \mathcal{M}[Y(4274) \to D_s^+ D_s^- \pi^0] \Big|^2 = \frac{g_\pi^2}{2} \Psi^2(\boldsymbol{q}). \tag{11}$$

The differential decay width is written as

$$\begin{aligned} d\Gamma &= \frac{1}{2E} |\mathcal{M}|^2 (2\pi)^4 \delta^4 (\sum_{i=1}^{3} k_i - P) \\ &\quad \times \frac{d^3 k_1}{(2\pi)^3 2E_1} \frac{d^3 k_2}{(2\pi)^3 2E_2} \frac{d^3 k_3}{(2\pi)^3 2E_3} \end{aligned} \tag{12}$$

where the P and E are the momentum and energy of the initial $Y(4274)$. k_i and E_i with $i = 1, 2, 3$ are the momenta and energies of the particles in final states respectively.

III. NUMERICAL RESULT

With the preparation in Sec. II, we carry out the study of the line shapes of the photon and pion spectra of $Y(4274) \to D_s^+ D_s^{*-} \gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$ processes under the assignment of the $D_s \bar{D}_{s0}(2317)$ molecular state to $Y(4274)$. Different from the previous work in Ref. [18], here we use the CERNLIB program FOWL to produce the Dalitz plots and the line shapes of the photon and pion spectra of $Y(4274) \to D_s^+ D_s^{*-} \gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$. Since we are mainly interested in the corresponding line shapes, the maximum of the line shape of photon/pion energy spectrum is normalized to 1.

The Dalitz plot and photon spectrum for $Y(4274) \to D_s^+ D_s^{*-} \gamma$ are presented in the Fig. 2. Although the photon spectrum of $Y(4140) \to D_s^{*+} D_s^- \gamma$ has been investigated in the literature [18], the corresponding Dalitz plot was not given in their work, where the nonrelativistic approximation was adopted. We also show the result of $Y(4140) \to D_s^{*+} D_s^- \gamma$ in Fig. 2 for easily comparing with the numerical result of $Y(4274) \to D_s^+ D_s^{*-} \gamma$.

For $Y(4274) \to D_s^+ \bar{D}_s^* \gamma$, an accumulation appears in the Dalitz plot with photon energy $E_\gamma \sim 0.19$ GeV and $M_{D_s^* \gamma} \sim 2.3$ GeV. The line shape of the photon spectrum of $Y(4274) \to D_s^+ \bar{D}_s^* \gamma$ indicates that exists a very sharp peak near the large end point of photon energy, which directly corresponds to the accumulation in the Dalitz plot. Comparing the result of $Y(4274) \to D_s^+ \bar{D}_s^* \gamma$ with that of $Y(4140) \to D_s^{*+} D_s^- \gamma$ also shows that the peak relevant to $Y(4274)$ is narrower than that involved in $Y(4140)$, which is due to the smaller binding energy for $Y(4274)$ ($E_{Y(4274)} \approx -10$ MeV) than that for $Y(4140)$ ($E_{Y(4140)} = -80$ MeV).

In Fig. 3, we present the Dalitz plot and the line shape of pion spectrum for $Y(4274) \to D_s^+ D_s^- \pi^0$ process. A steep peak also exists near the large end point of pion energy which is similar to the situation of $Y(4274) \to D_s^+ D_s^{*-} \gamma$.

IV. SUMMARY

Stimulated by the recent evidence of $Y(4274)$ [1] and the $D_s \bar{D}_{s0}(2317)$ molecular charmonium explanation to

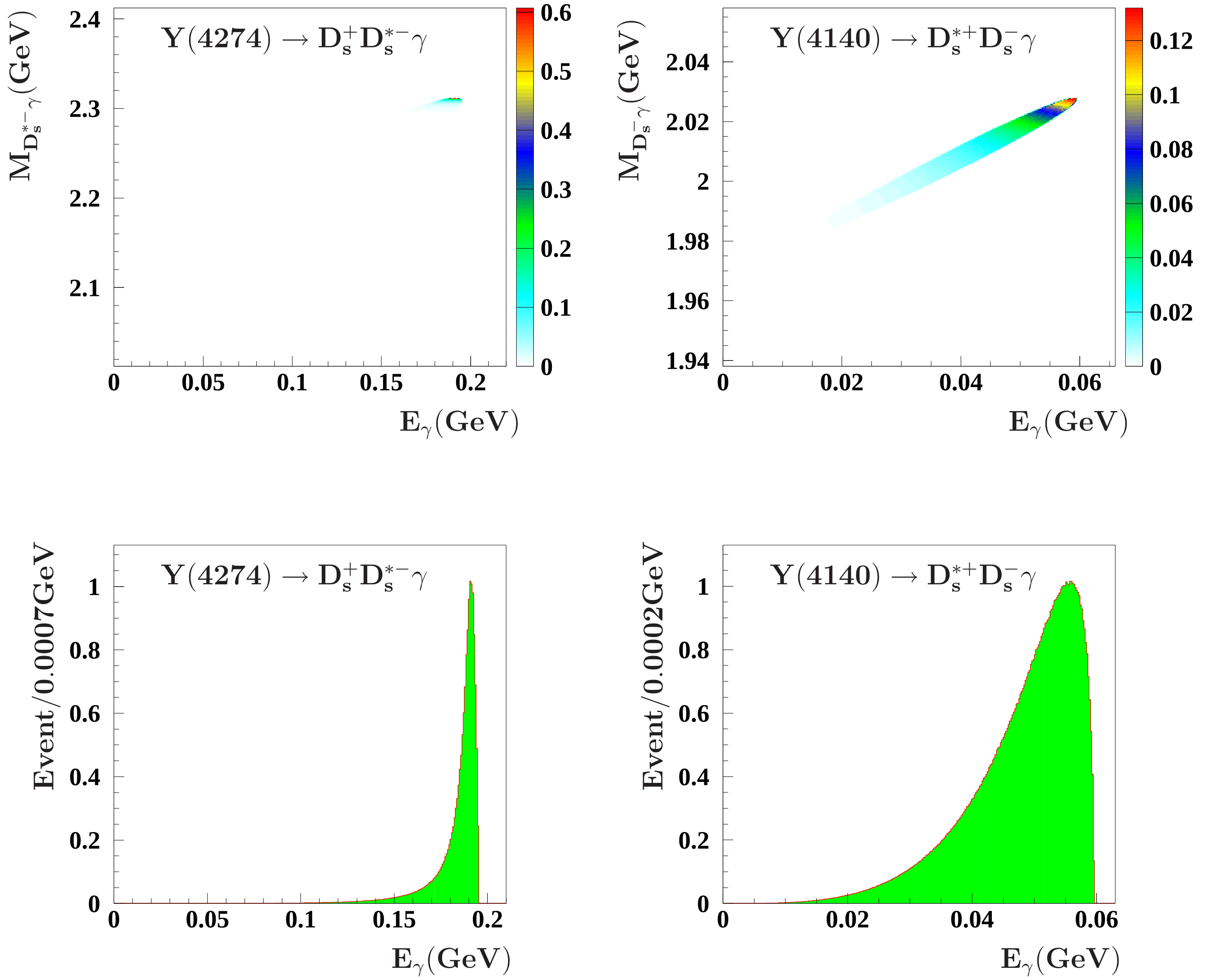

FIG. 2: (Color online) The Dalitz plot and photon spectrum for $Y(4274) \to D_s^+ D_s^{*-}\gamma$ (the first column). Here, we also present the result (the second column) of $Y(4140) \to D_s^{*+} D_s^{-}\gamma$ with the assignment of $D_s^{*+} D_s^{*-}$ molecular state to $Y(4140)$ [18], which is applied to make a comparison with that of $Y(4274)$ (see Ref. [18] for more details).

$Y(4274)$ [17], in this work we study the open-charm radiative and pionic decays $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$, where we not only present the Dalitz plots but also give the line shape of photon and pion spectra of $Y(4274) \to D_s^+ D_s^{*-}\gamma$ and $Y(4274) \to D_s^+ D_s^- \pi^0$ in detailed. These theoretical predictions of the decay behavior of $Y(4274)$ will provide valuable information to further experimental study of $Y(4274)$, especially to test the molecular charmonium assignment to $Y(4274)$.

We need to emphasize that $Y(4274) \to D_s^+ D_s^- \pi^0$ is peculiar to $Y(4274)$ under the assignment of $D_s \bar{D}_{s0}(2317)$ molecular state since such decay reflects the internal structure $Y(4274)$. $Y(4274) \to D_s^+ D_s^- \pi^0$ occurs via the interaction of $D_{s0}(2317)^-$ with $D_s^- \pi^0$ after the collapse of $Y(4274)$ into D_s^+ and $D_{s0}(2317)^-$, where $D_{s0}(2317)^- \to D_s^- \pi^0$ is a special decay channel observed by experiment [21]. Thus, the experimental search to $Y(4274) \to D_s^+ D_s^- \pi^0$ channel and the measurement to the line shape of pion spectrum of $Y(4274) \to D_s^+ D_s^- \pi^0$ will be as effective approach to check molecular charmonium assignment to $Y(4274)$.

In summary, more and more observations of charmonium-like states X, Y, Z in B meson decays provide us good platform to deeply study what is the internal mechanism for producing these charmonium-like

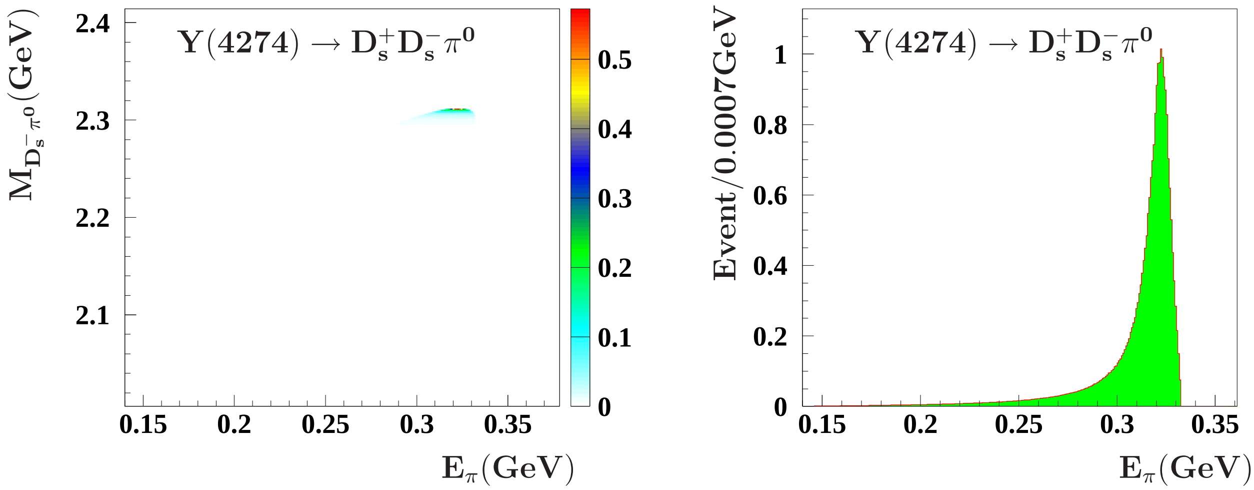

FIG. 3: (Color online) The Dalitz plot and pion spectrum for $Y(4274) \to D_s^+ D_s^- \pi^0$.

states, which is one of the most important research topics full of challenges and opportunities in charm physics [24]. Besides carrying out the dynamical calculation of mass spectra to judge whether the corresponding molecular charmonium assignments can be applied to explain the observed charmonium-like states, the decay behavior can also reflect important information of these observed charmonium-like states. Just considering such reasons, in this work we investigate the decay behavior of the open-charm radiative and pionic decays of $Y(4274)$ assuming $Y(4274)$ as the candidate of $D_s\bar{D}_{s0}(2317)$ molecular charmonium [17]. We expect future experiment to study $Y(4274)$, which will give definite answer of whether $D_s\bar{D}_{s0}(2317)$ molecular charmonium is suitable to explain $Y(4274)$ by comparing with our predictions presented in this work.

Acknowledgement

This project is supported by the National Natural Science Foundation of China under Grants No. 10705001, No. 10905077, No. 11005129, No. 11035006, the Ministry of Education of China (FANEDD under Grant No. 200924, DPFIHE under Grants No. 20090211120029, NCET under Grant No. NCET-10-0442, the Fundamental Research Funds for the Central Universities, the project sponsored by SRF for ROCS, SEM under Grant No. HGJO90402) and Chinese Academy of Sciences (the Special Foundation of President under Grant No. YZ080425).

[1] T. Aaltonen *et al.* [CDF Collaboration], arXiv:1101.6058 [hep-ex].

[2] T. Aaltonen *et al.* [CDF Collaboration], Phys. Rev. Lett. **102**, 242002 (2009) [arXiv:0903.2229 [hep-ex]].

[3] S. K. Choi *et al.* [Belle Collaboration], Phys. Rev. Lett. **91**, 262001 (2003) [arXiv:hep-ex/0309032].

[4] K. Abe *et al.* [Belle Collaboration], Phys. Rev. Lett. **94**, 182002 (2005) [arXiv:hep-ex/0408126].

[5] B. Aubert *et al.* [BaBar Collaboration], Phys. Rev. Lett. **101**, 082001 (2008) [arXiv:0711.2047 [hep-ex]].

[6] S. K. Choi *et al.* [BELLE Collaboration], Phys. Rev. Lett. **100**, 142001 (2008) [arXiv:0708.1790 [hep-ex]].

[7] R. Mizuk *et al.* [Belle Collaboration], Phys. Rev. D **78**, 072004 (2008) [arXiv:0806.4098 [hep-ex]].

[8] E. S. Swanson, Phys. Lett. B **588**, 189 (2004) [arXiv:hep-ph/0311229].

[9] Y. R. Liu, X. Liu, W. Z. Deng and S. L. Zhu, Eur. Phys. J. C **56**, 63 (2008) [arXiv:0801.3540 [hep-ph]].

[10] X. Liu, Z. G. Luo, Y. R. Liu and S. L. Zhu, Eur. Phys. J. C **61**, 411 (2009) [arXiv:0808.0073 [hep-ph]].

[11] X. Liu, Y. R. Liu, W. Z. Deng and S. L. Zhu, Phys. Rev. D **77**, 034003 (2008) [arXiv:0711.0494 [hep-ph]].

[12] X. Liu, Y. R. Liu, W. Z. Deng and S. L. Zhu, Phys. Rev. D **77**, 094015 (2008) [arXiv:0803.1295 [hep-ph]].

[13] L. L. Shen, X. L. Chen, Z. G. Luo, P. Z. Huang, S. L. Zhu, P. F. Yu and X. Liu, Eur. Phys. J. C **70**, 183 (2010) [arXiv:1005.0994 [hep-ph]].

[14] G. J. Ding, Phys. Rev. D **79**, 014001 (2009) [arXiv:0809.4818 [hep-ph]].

[15] G. J. Ding, Phys. Rev. D **80**, 034005 (2009) [arXiv:0905.1188 [hep-ph]].

[16] X. Liu and S. L. Zhu, Phys. Rev. D **80**, 017502 (2009)

[arXiv:0903.2529 [hep-ph]].
[17] X. Liu, Z. G. Luo and S. L. Zhu, arXiv:1011.1045 [hep-ph].
[18] X. Liu and H. W. Ke, Phys. Rev. D **80**, 034009 (2009) [arXiv:0907.1349 [hep-ph]].
[19] W. Wei, P. Z. Huang and S. L. Zhu, Phys. Rev. D **73**, 034004 (2006) [arXiv:hep-ph/0510039].
[20] X. Liu, Y. M. Yu, S. M. Zhao and X. Q. Li, Eur. Phys. J. C **47**, 445 (2006) [arXiv:hep-ph/0601017].
[21] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **90**, 242001 (2003) [arXiv:hep-ex/0304021].
[22] M. B. Voloshin, Phys. Lett. B **579**, 316 (2004) [arXiv:hep-ph/0309307].
[23] M. B. Voloshin, Int. J. Mod. Phys. A **21**, 1239 (2006) [arXiv:hep-ph/0509192].
[24] X. Q. Li, X. Liu and Z. T. Wei, Front. Phys. China **4**, 49 (2009) [arXiv:0808.2587 [hep-ph]].