Discovery potential for the neutral charmoniumlike $Z^0(4200)$ by $\bar{p}p$ annihilation

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Inspired by the observation of charmoniumlike $Z(4200)$, we explore the discovery potential of the neutral $Z^0(4200)$ production by antiproton-proton annihilation with an effective Lagrangian approach. By investigating the $\bar{p}p \to J/\psi\pi^0$ process including the $Z^0(4200)$ signal and background contributions, it is found that the center of mass energy $E_{\text{c.m.}} \simeq 4.0 - 4.5$ GeV is the best energy window for searching the neutral $Z^0(4200)$, where the signal can be clearly distinguished from background. The relevant calculations is not only helpful to search for the neutral $Z^0(4200)$ in the future experiment, but also will promote the understanding the nature and production mechanism of neutral $Z^0(4200)$ better.

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I. INTRODUCTION

In the conventional constituent quark model (CQM), all mesons can be described as quark-antiquark ($q\bar{q}$) states. Such as the charmonium state $J/\psi$, it is composed of a $c\bar{c}$ quark pair. However, a series of charmoniumlike states (including $X(3872)$, $Y(4260)$, $Y(4200)$, $Z(3900)$, $Z(4025)$, $Z(4050)$, $Z(4250)$, $Z(4430)$ and $Z(4200)$ etc.) have been observed in experiments [1-3], many of which do not fit into the $q\bar{q}$ meson spectrum in the classical CQM. In particular, some charged charmonium-like $Z$ states are interpreted as a tetraquark, a hadron molecule or just a cusp effect, and so on [1-3,7,11]. In addition, a series of hidden charm baryons also have been investigated in Refs. [12-14], which were considered as the pentaquark candidates and composed of $[c\bar{c}qqq]$. On the one hand, these studies enriched the picture of exotic states. On the other hand, it should be noted that our understanding of these exotic states is far from being sufficient. Thus, more theoretical and experimental works are needed.

Recently, a new charged charmonium-like $Z^+(4200)$ decaying to $J/\psi\pi^+$ has been observed by the Belle Collaboration with a significance of 6.2$\sigma$ [3]. The relevant experiment results show that the spin-parity quantum number of $Z^+(4200)$ favors $1^+$. Furthermore, its mass and width are measured to be $3^+$

\[
M = 4196^{+31+17}_{-29-13} \text{ MeV/c}^2,
\]
\[
\Gamma = 370^{+70+70}_{-70-132} \text{ MeV}.
\]

It is notice that the $Z^+(4200)$ has the largest width among those charmonium-like $Z$ states which have been observed in experiment. In Ref. [3], by analyzing all the available experimental information about charmonium-like states within the framework of the color-magnetic interaction, the $Z(4200)$ was supposed to be a very promising candidate of the lowest axial-vector hidden-charm tetraquark state and its dominant decay should be $J/\psi\pi$. In Ref. [8-10], the relevant results also support the tetraquark interpretation of $Z(4200)$ in the frame of QCD sum rule. Moreover, with QCD sum rule approach, the $Z(4200)$ was described as the molecule-like state in Ref. [11]. These experimental and theoretical results indicate that the $Z(4200)$ is an ideal candidate for investigating and understanding the nature of exotic charmonium-like states.

As of now, the charmonium-like states are only observed in four ways including the $\gamma\gamma$ fusion process, $e^+e^-$ annihilation, $B$ meson decay and hidden-charm dipion decays of higher charmonia or charmonium-like states. Obviously, it is an important topic to study the production of the charmonium-like state in different processes. As mentioned above, $Z(4200)$ was only observed in the $B$ meson decay. It is natural to ask whether $Z(4200)$ can be found in other processes.

In addition, we note that searching for the neutral partner of the charmonium-like or bottomoniumlike state also aroused the great interest both in experiment and theory. The first observation of neutral Zc(3900) has been reported by CLEO-c [15]. Later, the neutral bottomoniumlike $Z_b^0(10610)$ and charmonium-like $Z_c^0(4020)$ have been observed by Belle and BESIII [14,17], respectively. In theory, the production of the neutral $Z_c^0(4430)$ in $pp \to \psi'(2S)\pi^0$ reaction was investigated in our previous work [18]. These studies not only help in confirming these charmonium-like state, but also opens a window to investigate the nature and production mechanism of exotic state beyond the conventional $q\bar{q}$ states.

Since the $Z(4200)$ was observed in $J/\psi\pi$ channel [3] and its dominant decay mode is very likely to be $J/\psi\pi$ [3], the neutral $Z^0(4200)$ should has a coupling with $J/\psi\pi^0$. Besides, the tetraquark or molecule-like state can be re-
garding as a general four-quark state $|c\bar{c}d\bar{d}\rangle$, which means that the neutral $Z^0(4200)$ probably is composed by $|c\bar{c}u\bar{u}\rangle$ or $|c\bar{c}d\bar{d}\rangle$. According to the OZI rule [19], one can speculate that the partial decay width of $Z^0(4200)\to\bar{p}p$ may be larger than that of $J/\psi\to\bar{p}p$. Therefore, the $\bar{p}p\to J/\psi\pi^0$ reaction is probably an ideal channel for searching and studying the neutral $Z^0(4200)$.

In this work, with an effective Lagrangian approach, the production of neutral $Z^0(4200)$ in $\bar{p}p\to J/\psi\pi^0$ reaction are investigated for the first time. Furthermore, in light of the situations of PANDA detector at FAIR@GSI [20, 22], the feasibility of searching the neutral $Z^0(4200)$ by $\bar{p}p$ annihilation is discussed, which can provide valuable information to future experimental exploration of neutral $Z^0(4200)$.

This paper is organized as follows. After an introduction, we present the investigation method and formalism for $Z^0(4200)$ production. In Sec. III, the background contributions to the $J/\psi\pi^0$ final states are discussed. The numerical result are given in Sec. IV. Finally, This paper ends with the discussion and conclusion.

II. THE Z0(4200) YIELD BY THE ANTIPROTON-PROTON SCATTERING

It will be difficult to study $Z^0(4200)$ at quark-gluon level in the now energy range. Therefore, the effective Lagrangian method in terms of hadrons will be used in our research.

A. Feynman diagrams and effective interaction 
Lagrangian densities

The basic tree level Feynman diagram for the production of $Z^0(4200)$ in $\bar{p}p\to J/\psi\pi^0$ reaction through s-channel is depicted in Fig. 1. For the $Z(4200)$, its quantum number of spin-parity has been determined by Belle Collaboration to be $J^P = 1^+$ [5]. Therefore, the relevant effective Lagrangian for the vertices of $Z\bar{p}p$ and $Z^0(4200)\to J/\psi\pi^0$ is given in Eq. (1) as used in Refs. [24–26],

$$\mathcal{L}_{Z\bar{p}p} = g_{Z\bar{p}p}\bar{\phi}_p\gamma^\mu\gamma_5\phi_pZ_\mu,$$  \hspace{1cm} (1)

where $Z$, $\psi$, and $\phi$ denote the fields of $Z(4200)$, $J/\psi$ and nucleon, respectively. The $g_{Z\bar{p}p}$ and $g_{Z\psi\pi}$ are the coupling constants. Considering the size of the hadrons, we introduce the general form factor for the intermediate $Z^0(4200)$ as used in Refs. [24–26],

$$F_Z(q^2) = \frac{\Lambda^4_Z}{A_Z^2 + (q^2 - M^2)^2},$$  \hspace{1cm} (3)

where $q$, $M_Z$, and $\Lambda_Z$ are the 4-momentum, mass, and cut-off parameters for the intermediate $Z^0(4200)$, respectively.

B. Coupling constants and the OZI analysis in the process of Z0(4200) → p̅p

With the effective Lagrangians above, the coupling constant $g_{Z\bar{p}p}$ and $g_{Z\psi\pi}$ can be determined by the partial decay widths $\Gamma_{Z^0(4200)\to\bar{p}p}$ and $\Gamma_{Z^0(4200)\to J/\psi\pi^0}$, respectively,

$$\Gamma_{Z^0(4200)\to\bar{p}p} = (g_{Z\bar{p}p})^2 \frac{2}{3\pi M_Z} p_N^* c.m.,$$  \hspace{1cm} (4)

FIG. 2: (Color online) The quark level diagram depicting $J/\psi\to\bar{p}p$ decay [(a)] and $Z^0(4200)\to\bar{p}p$ decay [(b)].

1 For simplicity, we use $Z$ and $\psi$ denote $Z^0(4200)$ and $J/\psi$, respectively.
\[
\Gamma_{Z^0(4200) \to J/\psi\pi^0} = \left( \frac{g_{Z\pi\pi}}{M_Z} \right)^2 \left| \frac{p_{\text{c.m.}}^z}{24\pi M_Z^2} \right|^2 \left( \frac{M_Z^2 - m_{\pi}^2 - m_{Z}^2}{2} + m_{\psi}^2 E_\pi^2 \right),
\]
with
\[
\begin{align*}
|p_{\text{c.m.}}^z| &= \frac{\lambda^{1/2}(M_Z^2, m_\pi^2, m_{\psi}^2)}{2M_Z}, \\
|p^z_{\text{c.m.}}| &= \frac{\lambda^{1/2}(M_Z^2, m_\pi^2, m_{\psi}^2)}{2M_Z}, \\
E_\pi &= \sqrt{|p^z_{\text{c.m.}}|^2 + m_{\pi}^2},
\end{align*}
\]
where \(\lambda\) is the Källen function with \(\lambda(x, y, z) = (x - y - z)^2 - 4yz\).

As of now, no relevant experiment data about \(\Gamma_{Z(4200) \to \bar{p}p}\) and \(\Gamma_{Z(4200) \to J/\psi\pi}\) are available. However, in Refs. [10, 11] the decay width \(\Gamma_{Z(4200) \to J/\psi\pi} = 87.3 \pm 47.1\) MeV or \(\Gamma_{Z(4200) \to J/\psi\pi} = 24.6\) MeV were obtained with QCD sum rule by assuming that the \(Z(4200)\) is a tetraquark state or molecule-like state, respectively. Thus we get the coupling constants \(g_{Z\psi\pi}/M_Z = 1.73, 0.918\) GeV\(^{-1}\), which correspond to the partial decay width \(\Gamma_{Z(4200) \to J/\psi\pi} = 87.3, 24.6\) MeV.

For the partial decay width of \(Z^0(4200) \to \bar{p}p\), we try to obtain it by analyzing and comparing with the QCD 

\[
\text{suppressed process of } J/\psi \to pp \text{. According to constituent quark model, the traditional charmion } J/\psi
\]

is regarded as a pure \(c\bar{c}\) state, while there are only up and down quarks (antiquarks) in the proton (antiproton). Thus the \(J/\psi \to pp\) decay is actually a disconnected process and at least need three gluons to connect it (as shown in Fig. 2(a)). In the frame of the Okubo-Zweig-Iizuka (OZI) rule [19], the incidence of \(J/\psi \to \bar{p}p\) process is greatly suppressed. With the total decay width and branch ratios of \(J/\psi\) listed in PDG [27], one get the partial decay width \(\Gamma_{J/\psi \to \bar{p}p} \simeq 0.2\) keV, which is indeed a small value and consistent with the prediction by OZI rule [19]. Since the neutral \(Z^0(4200)\) may be have minimal quark content of \((c\bar{c}u\bar{u})\) or \((c\bar{c}d\bar{d})\), as seen in Fig. 2(b), the \(Z^0(4200) \to \bar{p}p\) reaction is a connected whole and it is an OZI allowed process [19]. Therefore, in principle, the probability of \(Z^0(4200)\) decay to \(\bar{p}p\) should be higher than \(J/\psi \to \bar{p}p\), which may be part of reason that the total decay width of \(Z^0(4200)\) is 3 order larger than the total width of \(J/\psi\). Accordingly we speculate that the partial width \(\Gamma_{Z^0(4200) \to \bar{p}p}\) may well be at least three magnitude larger than \(\Gamma_{J/\psi \to \bar{p}p}\). Then we get \(g_{Z\bar{p}p} \simeq 0.05\) by taking \(\Gamma_{Z^0(4200) \to \bar{p}p} = 200\) keV.

\[\text{C. Amplitude}\]

Following the Feynman rules and using above Lagrangian densities, we can obtain the invariant amplitude \(\mathcal{M}_{Z\bar{p}p}^{\text{signal}}\) for the \(\bar{p}(p_1)p(p_2) \to J/\psi(p_3)\pi^0(p_4)\) reaction through s-channel as shown in Fig. 1,

\[
\mathcal{M}_{Z\bar{p}p}^{\text{signal}} = g_{\bar{p}pp}g_{Z\psi\pi}F_Z(q^2)\frac{\epsilon^\nu(p_3) \cdot (p_3 \cdot p_4g_{\mu\nu} - p_3\nu p_4\nu)}{M_Z} \times G^{\mu\nu}(p_1)\gamma_\alpha\gamma_5u(p_2),
\]

where \(G^{\mu\nu}(p_1)\) are the propagators of the \(Z^0(4200)\), taking the Breit-Wigner form [28],

\[
G^{\mu\nu}(q) = \frac{i}{q^2 - M_Z^2 + iM_Z\Gamma_Z}.
\]

Here

\[
\mathcal{P}^{(1)} = \sum_{\text{spins}} \kappa^\mu \cdot \kappa^\nu = \tilde{g}^{\mu\nu}(q)
\]

\[
= -g^{\mu\nu} + q^\mu q^\nu/q^2
\]

is the projection operator for the state with spin-1.

\[\text{III. THE BACKGROUND ANALYSIS AND CROSS SECTION}\]

Fig. 3 show the \(\bar{p}(p_1)p(p_2) \to J/\psi(p_3)\pi^0(p_4)\) process through t-channel (a) and u-channel (b) by exchanging a proton, which can be regarded as the main background contributions for the production of \(Z^0(4200)\) as described in Fig. 1.

The Lagrangian densities for the vertices of \(\bar{p}p\pi^0\) and \(J/\psi\bar{p}p\) read as

\[
\mathcal{L}_{\bar{p}p\pi^0} = -ig_{\bar{p}pp}\bar{p}\gamma_5\tau \cdot \pi\gamma_5\phi_p, \quad \mathcal{L}_{\bar{p}p\psi} = -ig_{\bar{p}pp}\bar{p}\gamma_5\gamma^\mu\phi_p\psi_\mu,\]

where \(\psi\) and \(\phi\) denote the fields of \(J/\psi\) and nucleon, respectively, while \(\tau\) is Pauli matrix.

The coupling constant \(g_{\bar{p}pp} = 13.5\) is adopted [30], while coupling constant \(g_{\bar{p}pp}\) is determined by partial decay widths:

\[
\Gamma_{\psi \to \bar{p}p} = (g_{\bar{p}pp})^2 \frac{|p_{\text{c.m.}}^z|}{6\pi m_{\psi}^2} (m_{\psi}^2 + 2m_p^2)
\]
with
\[ \vec{p}_{\text{c.m.}} = \sqrt{m_\psi^2 - 4m_p^2} \frac{2}{3}. \] (15)

Thus we get \( g_{\bar{p}p\psi} \simeq 1.6 \times 10^{-3} \), which is calculated by the measured branching fractions and total widths of \( J/\psi \) (\( m_\psi = 3096.916 \text{ MeV} \) and \( \Gamma_\psi = 92.9 \text{ keV} \)) [27].

The monopole form factors for the \( \bar{p}p\pi^0 \) and \( J/\psi\bar{p}p \) vertices are introduced as the same as Bonn potential model [31]:
\[ F(q_i^2) = \frac{\Lambda_N^2 - m_p^2}{\Lambda_N^2 - q_i^2}, \quad i = t, u \] (16)
where \( \Lambda_N, m_p \) and \( q_i (q_t = (p_3 - p_1) \text{ and } q_u = (p_4 - p_1)) \) are the cut-off parameter, mass and four-momentum of the exchanged proton, respectively.

According to the Feynman rules and above equations, the full invariant amplitude \( M_N = M_N^t + M_N^u \) for the background as depicted in Fig. 3 can be obtained,
\[ M_N = M_N^t + M_N^u = g_{\bar{p}p\psi} \bar{g}_{\bar{p}\psi\pi} \gamma_\mu (p_1) \left\{ \gamma^\nu (p_3) \frac{q_t + m_p}{q_t^2 - m_p^2} + \gamma^\nu \frac{q_u + m_p}{q_u^2 - m_p^2} F^2(q_i^2) \right\} \gamma_\mu (p_2). \] (17)

With the amplitudes listed in Eqs. (9) and (17), we get the square of the total invariant amplitude\(^2\)
\[ |M|^2 = \sum |M_Z^{\text{signal}} + M_N|^2. \] (18)

We define \( s = q^2 = (p_1 + p_2)^2 \), then the unpolarized differential cross section for the reaction \( \bar{p}(p_1)p(p_2) \rightarrow J/\psi(p_3)\pi^0(p_4) \) at the center of mass (c.m.) frame is as follows:
\[ \frac{d\sigma}{d\cos \theta} = \frac{1}{32\pi s} |\vec{p}_1^{\text{c.m.}}| \left( \frac{1}{4} \sum \text{spins} |M|^2 \right), \] (19)
where \( \vec{p}_1^{\text{c.m.}} \) and \( \vec{p}_3^{\text{c.m.}} \) are the three-momentum of initial anti-proton and final \( J/\psi \), while \( \theta \) denotes the angle of the outgoing \( J/\psi \) meson relative to the anti-proton beam direction in the c.m. frame. The total cross section can be easily obtained by integrating the above equation.

\(^2\) In principle, the interference between amplitudes for the signal and the non-resonant background should be considered. Since we do not now have experimental data, we take the relative phase between different amplitudes as zero in the present work. Thus the total cross section for the \( \bar{p}p \rightarrow J/\psi\pi^0 \) process obtained by us is an upper estimate.
values of $\Gamma_i$ cross sections for the process of $\bar{p}p \rightarrow J/\psi \pi^0$ with two typical values of $\Gamma_i$, where $\Gamma_i$ denotes the decay width of $Z(4200) \rightarrow J/\psi$. Here, the $\sigma_{\text{total}}$ and $\sigma_{\text{signal}}$ are the total cross section and the cross section of signal, respectively.

GeV.

One notice that there is a obvious peak structure at center-mass energy $E_{\text{c.m.}} \approx 4.2$ GeV which is near the threshold of $Z(4200)$. Moreover, the cross section of signal increases with the increasing of cut-off parameter $\Lambda_Z$, but at a modest rate. Especially in the range of $4.0 \text{ GeV} \lesssim E_{\text{c.m.}} \lesssim 4.5$ GeV, it is found that the cross sections from signal contributions are not sensitive to the cut-off parameter $\Lambda_Z$. We take typical value $\Lambda_Z = 1.0$ GeV in the following, which can ensure the cross section of signal are limited to a smaller value.

In Fig. 5, we illustrate the proton exchange contributions with different cut-off parameters $\Lambda_N$, which is obvious that the cross sections from background contributions are sensitive to the values of the cutoff $\Lambda_N$. Fortunately, the reaction $\bar{p}p \rightarrow J/\psi \pi^0$ has been measured by the E760 and E835 experiment at low energy [22, 23], which can help us to constrain the cut-off parameter $\Lambda_N$. From Fig. 5 it can be found that the numerical results from the proton exchange contributions are consistent with the E760 and E835 datas by taking $\Lambda_N = 1.9$ and 3.0 GeV, respectively. Based on the consideration of seeking a larger limit for the cross section of background, we take $\Lambda_N = 3.0$ GeV in the next calculation. Besides, we notice that the amplitude estimate of $\bar{p}p \rightarrow J/\psi \pi^0$ is about 0.3 nb at $E_{\text{c.m.}} = 3.5 - 3.6$ GeV in ref. [24]. This value is closer to the E835 data [23] if we consider its uncertainty. Thus we taking $\Lambda_N = 3.0$ GeV in our calculation should be reasonable.

Fig. 6 show the total cross sections for $\bar{p}p \rightarrow J/\psi \pi^0$ reaction including both signal and background contributions by taking $\Lambda_Z = 1.0$ GeV and $\Lambda_N = 3.0$ GeV. We notice that the cross section of $Z^0(4200)$ production goes up very rapidly and has a peak around $E_{\text{c.m.}} \approx 4.2$ GeV. Besides, it is found that the contributions from the signal are dominant in the region of $4.0 \text{ GeV} \lesssim E_{\text{c.m.}} \lesssim 4.5$ GeV. Naturally, we can conclude that $4.0 \text{ GeV} \lesssim E_{\text{c.m.}} \lesssim 4.5$ GeV is the best energy window for searching the neutral charmoniumlike $Z^0(4200)$ in experiment, which the signal can be clearly distinguished from background.

Around the center of mass $E_{\text{c.m.}} \approx 4.2$ GeV, the total cross section from signal and background contributions is on the order of $0.14 \mu b$ and $0.04 \mu b$, which correspond to the decay width $\Gamma_{Z^0(4200)} \rightarrow J/\psi \pi^0 = 87.3$ MeV and $\Gamma_{Z^0(4200)} \rightarrow J/\psi \pi^0 = 24.6$ MeV, respectively.

As mentioned above, the PANDA detector at FAIR [20, 23] is an ideal platform searching for the $Z^0(4200)$ by $\bar{p}p$ collision. With a $\bar{p}$ beam of 15 GeV/c [20, 23] one has $E_{\text{c.m.}} = 5.47$ GeV, which allows one to observe charmoniumlike $Z^0(4200)$ state in $J/\psi \pi^0$ production up to a mass $M_Z \approx 4.2$ GeV. Assuming the integrated luminosity of PANDA can reach up to $1.5 \text{ fb}^{-1}$ per year [20, 23], taking $\sigma_{\text{total}} \approx 0.04 - 0.14 \mu b$, one can expect about $6 \times 10^7 - 2.1 \times 10^8$ events per year for the production of $J/\psi \pi^0$ at $E_{\text{c.m.}} \approx 4.2$ GeV, which are enough to meet the requirement of the experiment. At present, except for the $Z^0(4200)$, other charmonium-like $Z$ states (such as $Z(3900)$, $Z(4025)$ and $Z(4430)$ etc.) were also observed in the $J/\psi \pi$ invariant mass. Since all of them have probably the identical quantum numbers $J^P = 1^+$, the interference of each other is possible. The above situation indicate that the contributions from other $Z^0$ maybe be significant for the $\bar{p}p \rightarrow J/\psi \pi^0$ process. However, in this work, we focus only on the $Z^0(4200)$ state and do not consider the contributions from other $Z^0$ states.

Fig. 7 show the differential cross section including both signal and background contributions at the center of mass energy $E_{\text{c.m.}} = 4.0, 4.2, 4.5$ and 5 GeV. We notice that the line shape of total differential cross section is less affect by background and almost coincident with the line shape of signal differential cross section at $E_{\text{c.m.}} = 4.0 - 4.5$ GeV, which are consistent with the calculations as presented in Fig. 6. In comparison, it is found that the shapes of total angular distributions is different from the shapes of signal angular distributions at $E_{\text{c.m.}} = 5$ GeV, which due to the background has a strong effect on the total cross section at $E_{\text{c.m.}} = 5$ GeV. These predicitions can be checked by the future experiment.

V. DISCUSSION AND CONCLUSION

In this work, we investigate the neutral $Z^0(4200)$ production in $\bar{p}p \rightarrow J/\psi \pi^0$ reaction with an effective Lagrangian approach. Our numerical result indicate that the $\bar{p}p \rightarrow J/\psi \pi^0$ is very likely an ideal channel to study and search for the neutral hidden charm $Z^0(4200)$. Furthermore, it is found that the center of mass energy $E_{\text{c.m.}} \approx 4.0 - 4.5$ GeV is the best energy window for searching the neutral $Z^0(4200)$, which the signal can be easily distinguished from background. Moreover, According to our estimation, enough $Z^0(4200)$ events near $E_{\text{c.m.}} \approx 4.2$ GeV can be produced at PANDA, which
able to check our predictions on the respective coupling the near future experiments at LHC and BelleII will be

Here, the partial decay width is taken as $\Gamma_Z \approx 87.3$ MeV.

indicate that searching for the neutral $Z^0(4200)$ by $\bar{p}p$ annihilation at PANDA is feasible. Besides, since our calculations are carried out in the premise of assuming that the $Z^0(4200)$ has a coupling with $\bar{p}p$ and $J/\psi\pi^0$, the near future experiments at LHC and BelleII will be able to check our predictions on the respective coupling strengths of the $Z^0(4200)$.

It should be mentioned that the value of coupling constant $g_{Z\bar{p}p}$ is determined by analyzing and comparing the degree of OZI suppressed in the process of $Z^0(4200) \to \bar{p}p$ and $J/\psi\to \bar{p}p$, which is based on the assumption of the neutral $Z^0(4200)$ may be composed by $|ccu\bar{u}\rangle$ or $|ccd\bar{d}\rangle$. According our estimate, even if taking $\Gamma_{Z^0(4200)\to \bar{p}p} = 20$ keV (this value is one order smaller than that we used in the above calculations ) and $\Gamma_{Z^0(4200)\to J/\psi\pi^0} = 24.6$ MeV, the cross section from signal $Z^0(4200)$ contributions by $\bar{p}p$ annihilation at $E_{c.m.} \approx 4.2$ GeV could still reach up to the level of 4 nb which is at least one order higher than that of background. This means that an obvious bump at $E_{c.m.} \approx 4.2$ GeV can be expected to be apparent in the $\bar{p}p \to J/\psi\pi^0$ process. Thus, we strongly suggest the relevant experiment can be carried out, which will not only be conducive to verify the existence of $Z(4200)$ but enable us to have a more comprehensive understanding of the nature of exotic states and OZI rule.

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