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Role of the hadron molecule $\Lambda_c(2940)$ in the $p\bar{p} \to pD^0\bar{\Lambda}_c(2286)$ annihilation reaction

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The annihilation process $p\bar{p} \to pD^0\bar{\Lambda}_c(2286)$ is studied taking into account t-channel D^0, D^{*0} meson exchange and the resonance contribution of $\Lambda_c(2286)$ and $\Lambda_c(2940)$ baryons. We assume that the $\Lambda_c(2940)$ baryon is a pD^{*0} molecular state with spin-parity $\frac{1}{2}^+$ and $\frac{1}{2}^-$. Our results show that near the threshold of $p\bar{p} \to \Lambda_c(2286)\bar{\Lambda}_c(2286)$ the contribution from the intermediate state $\Lambda_c(2940)$ is also sizeable and can be observed at the $\bar{P}$ANDA experiment. Another conclusion is that the spin-parity assignment $\frac{1}{2}^-$ for $\Lambda_c(2940)$ gives enhancement for the cross section in comparison with a choice $\frac{1}{2}^+$.

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I. INTRODUCTION

Studies of the nucleon, nucleon excitations and other baryon resonances with heavy quarks are of great interest in exploring the structure of hadrons. Many related experiments with the aim to investigate baryon resonances have been carried out at facilities like JLab, BEPC, *BABAR* and Belle etc., by using lepton probes as well as e^+e^- scattering techniques. The experiments based on the $p\bar{p}$ annihilation process provide another way to produce heavy baryon resonances which are detected in various decay channels. Forthcoming experiments at $\bar{P}$ANDA, with the $\bar{p}$ momentum in the range from 1 to 15 GeV/c, which corresponds to total center-of-mass energies in the antiproton-proton system between 2.25 and 5.5 GeV, can give rich contributions to these investigations [1]. For example, $p\bar{p}$ annihilation reactions are expected to provide substantial information on the charm baryon $\Lambda_c(2286)$ as well as the baryon resonance $\Lambda_c(2940)$ recently observed by the *BABAR* Collaboration [2] and confirmed by the Belle Collaboration [3].

Theoretical studies on the $\Lambda_c(2940)$ state have been done assuming different assignments for its spin-parity $J^P = \frac{1}{2}^\pm, \frac{3}{2}^\pm, \frac{5}{2}^\pm$ and within different approaches [4–16] (for an overview see Ref. [16]). In Ref. [14] it was discussed the production rate of $\Lambda_c(2940)$ at the forthcoming $\bar{P}$ANDA experiment based the different assignments for the $\Lambda_c(2940)$ spin-parity. It is a first calculation for the total cross section but for example initial state interaction and the contribution of D^* meson exchange are not considered.

In this work we study the resonance $\Lambda_c(2940)$ as a (pD^*) hadronic molecular state with the help of a phenomenological Lagrangian approach. In our previous analysis [16] of the strong two-body decays of the $\Lambda_c(2940)$ we showed that its spin-parity assignment $J^P = \frac{1}{2}^+$ is favored. This ansatz for the $\Lambda_c(2940)$ has been proved to be also reasonable for the observed modes in three-body and radiative decays [16]. Here for completeness we also consider the $J^P = \frac{1}{2}^-$ assignment. The technique for describing and treating composite hadron systems was for example already shown in Refs. [16–18]. Here we aim for a quantitative determination of a production mode of the $\Lambda_c(2940)$, we determine cross sections for the annihilation process $p\bar{p} \to \Lambda_c(2940) \to pD^0\bar{\Lambda}_c(2286)$. It is expected that in experiments of $\bar{P}$ANDA these quantities can possibly be measured. Our predictions together with the structure assumption can provide additional information on the nature of this new resonance.

The paper is organized as follows. In Sec. II, we will briefly discuss the effective Lagrangian approach for the couplings of $\Lambda_c(2286) \to pD^0$ and $\Lambda_c(2940) \to pD^{*0}$. Then we introduce the relevant theory elements to describe the transition $p\bar{p} \to \Lambda_c(2940)\bar{\Lambda}_c(2286) \to pD^0\bar{\Lambda}_c(2286)$. Section III is devoted to the numerical results for the differential and total cross section of $p\bar{p} \to \Lambda_c(2940)\bar{\Lambda}_c(2286) \to pD^0\bar{\Lambda}_c(2286)$. In the calculation we take initial state interaction as well as the D and D^* meson exchange t-channel contributions into account. Finally, we briefly summarize our results.

II. APPROACH

We consider two assignments for the spin and parity quantum numbers of the $\Lambda_c(2940)$—$J^{\mathrm{P}} = \frac{1}{2}^+$ and $J^{\mathrm{P}} = \frac{1}{2}^-$.

While the $\frac{1}{2}^+$ assignment is favored in our analysis of the strong decays of the $\Lambda_c(2940)$ here we consider both possibilities for J^{P}. We consider this resonance as a bound state dominated by the molecular pD^{*0} component

$$|\Lambda_c(2940)\rangle = |pD^{*0}\rangle. \tag{1}$$

The annihilation processes $p\bar{p} \to \Lambda_c(2286)\bar{\Lambda}_c(2286) \to pD^0\bar{\Lambda}_c(2286)$ and $p\bar{p} \to \Lambda_c(2940)\bar{\Lambda}_c(2286) \to pD^0\bar{\Lambda}_c(2286)$ are described by t-channel diagrams based on the exchange of D and D^* mesons (see Fig. 1). The evaluation of the Feynman diagrams relies on several elements for the effective interaction of the involved hadrons. In the following we use the following notations in the formulas with $\Lambda_c(2286) \equiv \Lambda_c$ and $\Lambda_c(2940) \equiv \Lambda_c'$.

The couplings g_{BpD}, g_{BpD^*}, defining the BpD and BpD^* interactions (where $B = \Lambda_c$, Λ_c'), enter in the phenomenological interaction Lagrangians involving the $\Lambda_c(2286)$ baryon with

$$\mathcal{L}_{\Lambda_c pD} = g_{\Lambda_c pD}\bar{\Lambda}_c i\gamma_5 pD^0 + \mathrm{H.c.}, \tag{2}$$

$$\mathcal{L}_{\Lambda_c pD^*} = g_{\Lambda_c pD^*}\bar{\Lambda}_c\gamma^\mu pD^{*0}_\mu + \mathrm{H.c.} \tag{3}$$

The ones involving the Λ_c' baryon for the $J^{\mathrm{P}} = \frac{1}{2}^+$ and $J^{\mathrm{P}} = \frac{1}{2}^-$ assignments are set up as

$$\mathcal{L}^{\frac{1}{2}^+}_{\Lambda_c' pD} = g_{\Lambda_c' pD}\bar{\Lambda}_c' i\gamma_5 pD^0 + \mathrm{H.c.}, \tag{4}$$

$$\mathcal{L}^{\frac{1}{2}^+}_{\Lambda_c' pD^*} = g_{\Lambda_c' pD^*}\bar{\Lambda}_c'\gamma^\mu pD^{*0}_\mu + \mathrm{H.c.} \tag{5}$$

and

$$\mathcal{L}^{\frac{1}{2}^-}_{\Lambda_c' pD} = f_{\Lambda_c' pD}\bar{\Lambda}_c' pD^0 + \mathrm{H.c.}, \tag{6}$$

$$\mathcal{L}^{\frac{1}{2}^-}_{\Lambda_c' pD^*} = f_{\Lambda_c' pD^*}\bar{\Lambda}_c'\gamma^\mu\gamma^5 pD^{*0}_\mu + \mathrm{H.c.} \tag{7}$$

The couplings in these Lagrangians have been determined in Ref. [16]. In particular, from $SU(4)$ invariant Lagrangians [16,19] we deduce the couplings

$$g_{\Lambda_c pD} = -\frac{3\sqrt{3}}{5}g_{\pi NN} = -14.97,$$
$$g_{\Lambda_c pD^*} = -\frac{\sqrt{3}}{2}g_{\rho NN} = -5.20 \tag{8}$$

given in terms of the pion-nucleon $g_{\pi NN} = 13.4$ and the vector rho-nucleon $g_{\rho NN} = 6$ coupling constants.

The couplings $g_{\Lambda_c' pD}$, $g_{\Lambda_c' pD^*}$ and $f_{\Lambda_c' pD}$, $f_{\Lambda_c' pD^*}$ have been evaluated in the hadronic molecular approach [16,17] for the $\Lambda_c(2940)$ baryon state using the compositeness condition [20–22] with

$$g_{\Lambda_c' pD} = -0.54, \qquad g_{\Lambda_c' pD^*} = 6.64,$$
$$f_{\Lambda_c' pD} = -0.97, \qquad f_{\Lambda_c' pD^*} = 3.75. \tag{9}$$

The dressed $M = D$, D^* meson propagators are accompanied by the vertex form factors

$$F_M(t) = \frac{\Lambda_M^2 - M_M^2}{\Lambda_M^2 + t} \tag{10}$$

encoding the off shellness of $D(D^*)$ mesons, where $\Lambda_M = 3$ GeV is the cutoff parameter and t stands for the exchanged momentum squared [23]. When choosing the cutoff parameter as $\Lambda_M = 3$ GeV we follow the argument given in Ref. [24], where such a value was originally used. As was found [24] the cross section for $p\bar{p} \to \Lambda_c(2286)\bar{\Lambda}_c(2286)$ is sensitive to a variation of the parameter Λ_M and reduces by a factor 3 when Λ_M decreases from 3 to 2.5 GeV. It was pointed out [24] that the value of the cutoff parameter Λ_M should be bigger than either one of the masses of the exchanged charmed mesons D and D^*.

Note that we performed a microscopic calculation for $g_{\Lambda_c' pD}$, $g_{\Lambda_c' pD^*}$ and $f_{\Lambda_c' pD}$, $f_{\Lambda_c' pD^*}$ based on the molecular structure of the $\Lambda_c(2940)$ state with a clear dominance (by a factor $\simeq 3$) of the f-couplings corresponding to the $\frac{1}{2}^-$ assignment of the $\Lambda_c(2940)$ state. Note, in Ref. [14] such couplings were fixed from the two-body decay widths of the $\Lambda_c(2940)$ assuming that this widths are the same for all spin-parity assignments. Obviously, this procedure is

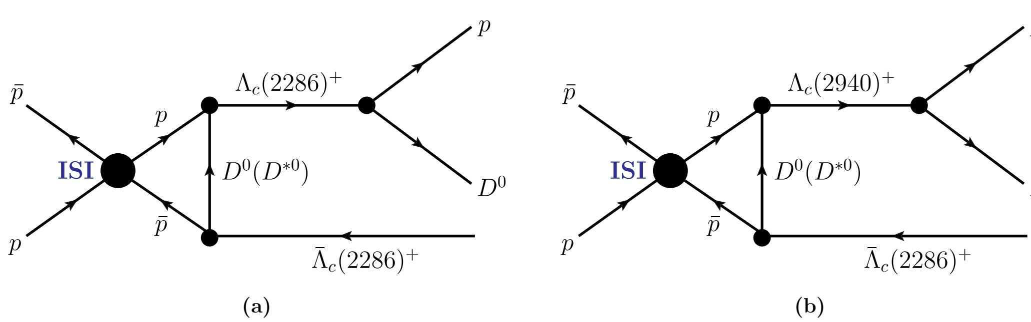

FIG. 1 (color online). D^0 and D^* meson exchange diagrams contributing to the $P\bar{p} \to pD^0\bar{\Lambda}_c$ process: (a) resonance contribution of the $\Lambda_c(2286)$ and (b) of the $\Lambda_c(2940)$ baryon. "ISI" in the figures stands for the initial state interaction.

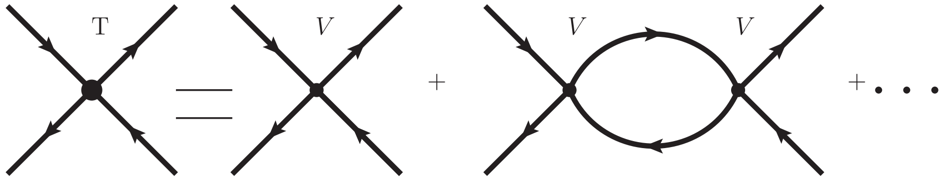

FIG. 2. Lippmann-Schwinger equation for the initial state interaction of the $N\bar{N}$ system.

not quite consistent because of the different spin-parity structures and phase spaces.

The intermediate $\Lambda_c(2286)$ and $\Lambda_c(2940)$ baryon resonances are described by a Breit–Wigner form contained in the propagators with a constant width Γ_B in the imaginary part:

$$S_B(p) = \frac{M_B + \not{p}}{M_B^2 - p^2 - iM_B\Gamma_B}, \qquad B = \Lambda_c, \Lambda_c', \tag{11}$$

where $\Gamma_{\Lambda_c} \simeq 3.3 \times 10^{-9}$ MeV and $\Gamma_{\Lambda_c'} = 17^{+8}_{-6}$ MeV are the widths of the $\Lambda_c(2286)$ and $\Lambda_c(2940)$ states, respectively. In our calculation we use the central value of 17 MeV for the width of $\Lambda_c(2940)$.

Following Ref. [24] we also take into account the initial state interaction (ISI) for the $p\bar{p}$ entrance channel. For the T matrix of the $N\bar{N}$ interaction we use the Lippmann-Schwinger equation

$$T(\vec{q}', \vec{q}; E) = V(\vec{q}', \vec{q}; E) + \int \frac{d^3p V(\vec{q}', \vec{p}) T(\vec{p}, \vec{q}; E)}{E(q) - E(p) + i\epsilon}, \tag{12}$$

as illustrated in Fig. 2. In above equation $V_{N\bar{N}}(\vec{q}', \vec{q})$ is a phenomenological nucleon-antinucleon potential given by the sum of a pion exchange $V^{\pi}_{N\bar{N}}(\vec{q}', \vec{q})$ and optical nucleon-antinucleon potential $V^{\rm opt}_{N\bar{N}}(\vec{q}', \vec{q})$

$$V_{N\bar{N}}(\vec{q}', \vec{q}) = V^{\pi}_{N\bar{N}}(\vec{q}', \vec{q}) + V^{\rm opt}_{N\bar{N}}(\vec{q}', \vec{q}). \tag{13}$$

The π-exchange potential is given by [23,24]

$$V^{\pi}_{N\bar{N}}(\vec{q}', \vec{q}) = \frac{g^2_{\pi NN}}{12M_N^2} \frac{\vec{k}_\pi^2}{M_\pi^2 + \vec{k}_\pi^2} \times (\vec{\sigma}_1 \cdot \vec{\sigma}_2 + \hat{S}_{12}(\vec{k}_\pi))\,(\vec{\tau}_1 \cdot \vec{\tau}_2)\, F_\pi^2(\vec{k}_\pi^2), \tag{14}$$

with M_N and M_π being the masses of nucleon and pion, respectively. The potential contains the tensor operator

$$\hat{S}_{12}(\vec{k}_\pi) = 3\vec{\sigma}_N \cdot \hat{\vec{k}}_\pi \vec{\sigma}_{\bar{N}} \cdot \hat{\vec{k}}_\pi - \vec{\sigma}_N \cdot \vec{\sigma}_{\bar{N}}, \tag{15}$$

where $\hat{\vec{k}} = \vec{k}/|\vec{k}|$ and $\vec{k}_\pi = \vec{q} - \vec{q}'$ is the three-momentum of the pion. $F_\pi(\vec{k}_\pi^2)$ is a phenomenological monopole form factor

$$F_\pi(\vec{k}_\pi^2) = \frac{\Lambda_\pi^2 - M_\pi^2}{\Lambda_\pi^2 + \vec{k}_\pi^2}, \tag{16}$$

where $\Lambda_\pi = 1.3$ GeV is the cutoff parameter.

The optical potential for the $N\bar{N}$ scattering state is given by [23,24]

$$V^{\rm opt}_{N\bar{N}}(r) = (u_0 + iw_0) e^{-\vec{r}^2/2r_0^2} \tag{17}$$

where the parameters were fixed as $u_0 = -0.0480$ GeV, $w_0 = 0.5319$ GeV and $r_0 = 0.56$ fm.

For the calculation of the process in Fig. 1 we assume that the ISI can be factorized out by the dimensionless factor

$$J_0 = \int d^3q' T_{N\bar{N}}(\vec{q}', \vec{q}) \frac{1}{E_{p_1} + E_{P-p_1} - \sqrt{s} + i\epsilon}. \tag{18}$$

In the evaluation of J_0 we use the center-of-momentum frame, where the momenta of incoming $(p_1, p_2 = P - p_1)$ and outgoing $(p_1', P - p_1')$ particles are defined as

$$\begin{aligned} p_1 &= (E_1, \vec{q}), & p_2 &= (E_2, -\vec{q}), \\ p_1' &= (E_1', \vec{q}'), & p_2' &= (E_2', -\vec{q}'), \end{aligned} \tag{19}$$

and $s = (E_1 + E_2)^2$ is the total energy squared.

Finally, the invariant matrix element corresponding to the process $p\bar{p} \to pD^0\bar{\Lambda}(2286)$ is written as

$$\mathcal{M}_{\rm inv} = \mathcal{M}^{(a)}_{\rm inv} + \mathcal{M}^{(b)}_{\rm inv}. \tag{20}$$

$\mathcal{M}^{(a)}_{\rm inv}$ is the contribution of diagram in Fig. 1(a) [contribution of the $\Lambda_c(2286)$ state]

$$\begin{aligned} \mathcal{M}^{(a)}_{\rm inv} = {}& g^{aP}_{\rm eff} \frac{F_M^2(t)}{M_D^2 - t} \bar{u}(q_1) i\gamma_5 \frac{M_{\Lambda_c} + \not{p}_4}{M_{\Lambda_c}^2 - p_4^2 - iM_{\Lambda_c}\Gamma_{\Lambda_c}} i\gamma_5 u(p_1)\, \bar{v}(p_2) i\gamma_5 v(q_2) \\ &+ g^{aV}_{\rm eff} \frac{F_M^2(t)}{M_{D^*}^2 - t} \left(-g^{\mu\nu} + \frac{p_3^\mu p_3^\nu}{M_{D^*}^2}\right) \bar{u}(q_1) i\gamma_5 \frac{M_{\Lambda_c} + \not{p}_4}{M_{\Lambda_c}^2 - p_4^2 - iM_{\Lambda_c}\Gamma_{\Lambda_c}} \gamma_\mu u(p_1)\, \bar{v}(p_2) \gamma_\nu v(q_2). \end{aligned} \tag{21}$$

The amplitude $\mathcal{M}_{\rm inv}^{(b)}$ is the result of the diagram in Fig. 1(b) [contribution of the $\Lambda_c(2940)$ state]. For assignments $\frac{1}{2}^+$ and $\frac{1}{2}^-$ it is given by

$$\text{assignment } J^P = \frac{1}{2}^+$$

$$\mathcal{M}_{\rm inv}^{(b)} = g_{\rm eff}^{bP} \frac{F_M^2(t)}{M_D^2 - t} \bar{u}(q_1) i\gamma_5 \frac{M_{\Lambda_c'} + \not{p}_4}{M_{\Lambda_c'}^2 - p_4^2 - iM_{\Lambda_c'}\Gamma_{\Lambda_c'}} i\gamma_5 u(p_1)\, \bar{v}(p_2) i\gamma_5 v(q_2)$$
$$+ g_{\rm eff}^{bV} \frac{F_M^2(t)}{M_{D^*}^2 - t}\left(-g^{\mu\nu} + \frac{p_3^\mu p_3^\nu}{M_{D^*}^2}\right) \bar{u}(q_1) i\gamma_5 \frac{M_{\Lambda_c'} + \not{p}_4}{M_{\Lambda_c'}^2 - p_4^2 - iM_{\Lambda_c'}\Gamma_{\Lambda_c'}} \gamma_\mu u(p_1)\, \bar{v}(p_2)\gamma_\nu v(q_2) \quad (22)$$

and

$$\text{Assignment } J^P = \frac{1}{2}^-$$

$$\mathcal{M}_{\rm inv}^{(b)} = f_{\rm eff}^{bP} \frac{F_M^2(t)}{M_D^2 - t} \bar{u}(q_1) \frac{M_{\Lambda_c'} + \not{p}_4}{M_{\Lambda_c'}^2 - p_4^2 - iM_{\Lambda_c'}\Gamma_{\Lambda_c'}} u(p_1)\, \bar{v}(p_2) i\gamma_5 v(q_2)$$
$$+ f_{\rm eff}^{bV} \frac{F_M^2(t)}{M_{D^*}^2 - t}\left(-g^{\mu\nu} + \frac{p_3^\mu p_3^\nu}{M_{D^*}^2}\right) \bar{u}(q_1) i\gamma_5 \frac{M_{\Lambda_c'} + \not{p}_4}{M_{\Lambda_c'}^2 - p_4^2 - iM_{\Lambda_c'}\Gamma_{\Lambda_c'}} \gamma_\mu\gamma_5 u(p_1)\, \bar{v}(p_2)\gamma_\nu v(q_2). \quad (23)$$

Here we use the following notations: $p_1, p_2, p_3, q_1, q_2, q_3$ are the momenta of initial proton, initial antiproton, the exchanged $D^0 (D^{0*})$ meson, final proton, final $\bar{\Lambda}(2286)$ and final D^0 meson, respectively; $t = p_3^2$; $p_4 = q_1 + q_3 = M_{pD}$ is the momentum of the $\Lambda_c(2286)$ ($\Lambda_c(2940)$) resonance related to the invariant mass of the final proton and D^0 meson; $u(p_1)$, $\bar{v}(p_2)$, $\bar{u}(q_1)$, $v(q_2)$ are the spinors describing initial proton, initial antiproton, final proton and final $\bar{\Lambda}(2286)$, respectively. The couplings $g_{\rm eff}^{ij}$ and $f_{\rm eff}^{ij}$ ($i = a, b$; $j = P, V$) are defined as

$$g_{\rm eff}^{aP} = J_0 g_{\Lambda_c pD}^3, \qquad g_{\rm eff}^{aV} = J_0 g_{\Lambda_c pD} g_{\Lambda_c pD^*}^2,$$
$$g_{\rm eff}^{bP} = J_0 g_{\Lambda_c' pD}^3, \qquad g_{\rm eff}^{bV} = J_0 g_{\Lambda_c' pD} g_{\Lambda_c' pD^*}^2, \quad (24)$$

$$f_{\rm eff}^{bP} = J_0 g_{\Lambda_c' pD} f_{\Lambda_c' pD}^2, \qquad f_{\rm eff}^{bV} = J_0 g_{\Lambda_c' pD} f_{\Lambda_c' pD^*}^2. \quad (25)$$

III. NUMERICAL RESULTS AND DISCUSSION

The differential cross section for the process $p\bar{p} \to pD^0\bar{\Lambda}_c$ is obtained through the expression

$$\frac{d\sigma}{dM_{pD}} = \frac{1}{1024\pi^4} \frac{1}{s\sqrt{s - 4M_N^2}} \times \int d\cos\theta_3\, d\Omega_1^*\, |\vec{q}_1^{\,*}|\, |\vec{q}_2|\, |\mathcal{M}_{\rm inv}|^2 \quad (26)$$

where $\vec{q}_1^{\,*}$ and Ω_1^* are the three-momentum and solid angle of the outgoing proton in the center-of-mass frame of the final pD system; $\vec{q}_2$ and θ_2 are the three-momentum and scattering angle of the final $\bar{\Lambda}_c(2286)$ state. In above equation M_{pD} is the invariant mass of the final pD two-body system. The transition amplitude for $p\bar{p} \to pD^0\bar{\Lambda}_c$ of Fig. 1 is contained in the invariant matrix element $\mathcal{M}_{\rm inv}$. The contributions of D and D^* exchange as well as of the possible intermediate states $\Lambda_c(2286)$ and $\Lambda_c(2940)$ are fully taken into account. Masses of the intermediate baryons and of the exchanged D mesons are taken from the Particle Data Group compilation. The effect of initial state interaction is expressed through the factor J_0 of Eq. (18) is also present in $\mathcal{M}_{\rm inv}$. Neglecting ISI would correspond to $J_0 = 1$. Values for $|J_0|^2$ are displayed in Fig. 3 indicating a sizable suppression of the transition as induced by ISI.

In Figs. 4–7 we show the differential cross sections $d\sigma/dM_{pD}$ for the total energies $\sqrt{s} = 5.25$ GeV and $\sqrt{s} = 5.5$ GeV. In the calculation we take the $\Lambda_c(2940)$

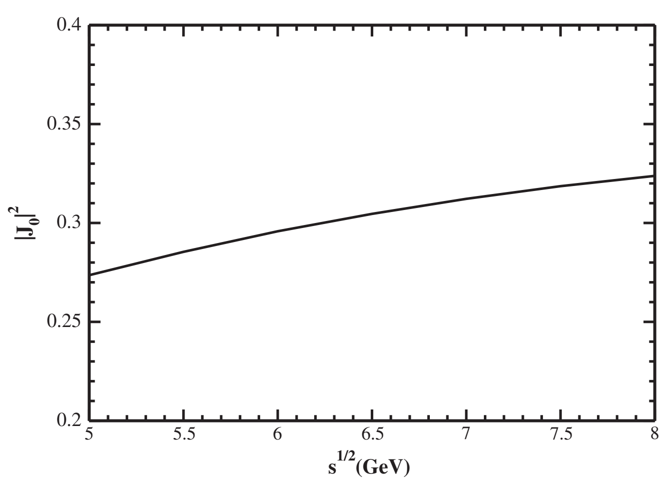

FIG. 3. Initial state interaction factor $|J_0|^2$ in dependence on $s^{1/2}$.

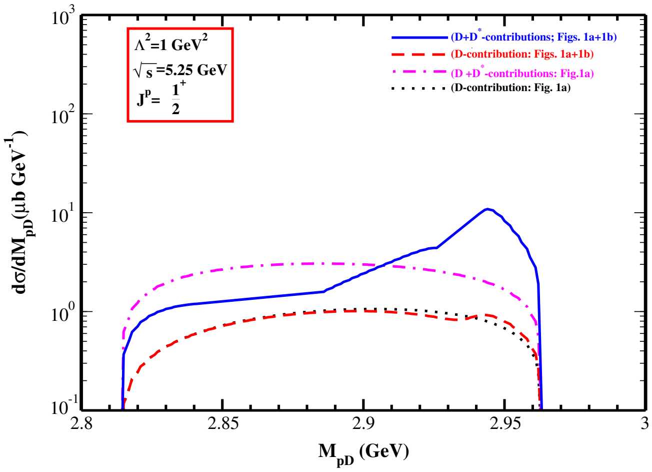

FIG. 4 (color online). Differential cross section $d\sigma/dM_{pD}$ for $s^{1/2} = 5.25$ GeV for $J^P = \frac{1}{2}^+$ of the $\Lambda_c(2940)$.

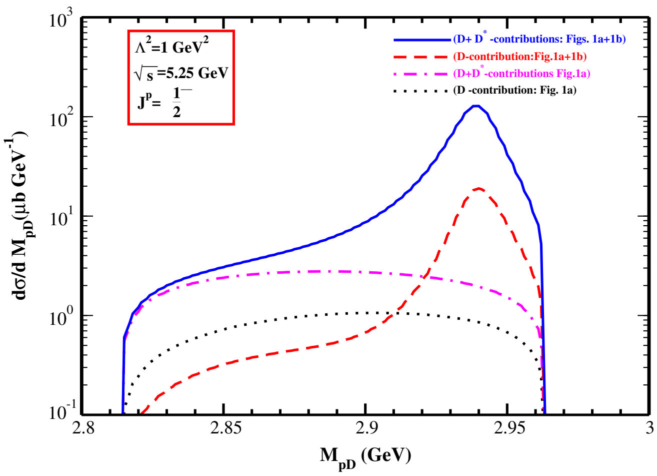

FIG. 5 (color online). Differential cross section $d\sigma/dM_{pD}$ for $s^{1/2} = 5.25$ GeV for $J^P = \frac{1}{2}^-$ of the $\Lambda_c(2940)$.

as a hadronic molecule as of Eq. (1). The size parameter of the correlation function is selected as $\Lambda^2 = 1$ GeV^2 [16] in the hadron molecule scenario. We explicitly display the contributions—of the diagram in Fig. 1(a) with D^0 exchange only (dotted line), of the diagram in Fig. 1(a) with D^0 and D^{*0} exchange (dot-dashed line), of the diagrams in Figs. 1(a) and 1(b) with D^0 exchange only (dashed line) and the full contribution of the diagrams in Figs. 1(a) and 1(b), including both D^0 and D^{*0} exchange (solid line). A change of the spin-parity assignment from $\frac{1}{2}^+$ to $\frac{1}{2}^-$ leads to an enhancement of the cross section by a factor 10. Also, the $\Lambda_c(2940)$ resonance gives a sizable contribution, which can be checked at the $\bar{P}$ANDA experiment.

To summarize, we have estimated the differential and total cross sections of $p\bar{p} \to pD^0\bar{\Lambda}_c$ in an energy range relevant for $\bar{P}$ANDA. In our calculations we include initial

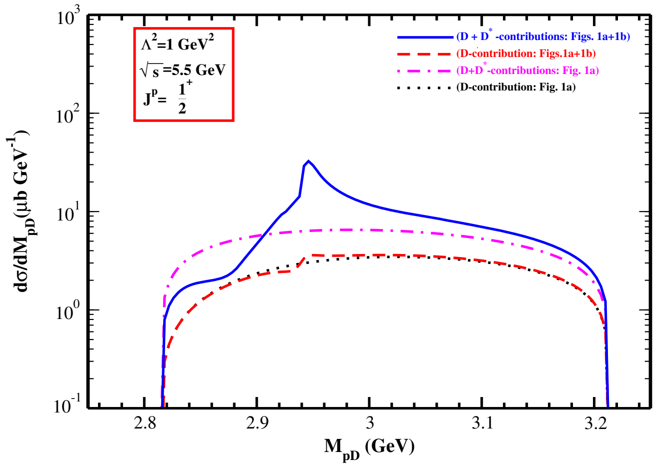

FIG. 6 (color online). Differential cross section $d\sigma/dM_{pD}$ for $s^{1/2} = 5.5$ GeV for $J^P = \frac{1}{2}^+$ of the $\Lambda_c(2940)$.

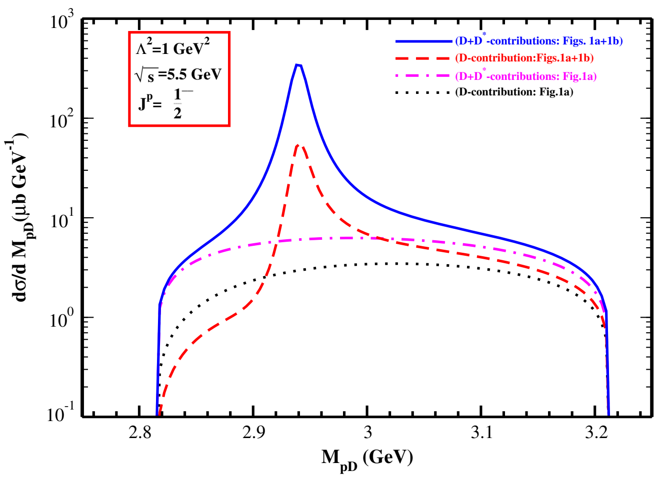

FIG. 7 (color online). Differential cross section $d\sigma/dM_{pD}$ for $s^{1/2} = 5.5$ GeV for $J^P = \frac{1}{2}^-$ of the $\Lambda_c(2940)$.

state interaction as well as the D and D^* exchange dynamics. The inclusion of ISI leads to a suppression, D exchange dominates the transition dynamics. We include the resonance $\Lambda_c(2940)$ which is treated as a $\frac{1}{2}^+$ or as a $\frac{1}{2}^-$ molecular pD^{*0} state. In our analysis we work out and discuss the role of the $\Lambda_c(2940)$ in comparison to the background effect including the $\Lambda_c(2286)$. We hope and expect that future experiments at $\bar{P}$ANDA will provide a test to our model calculations especially because the two spin-parity assignments can be clearly distinguished.

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