$B_c^- \rightarrow \eta' \ell^- \bar{\nu}$ decay and lepton polarization asymmetry

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Abstract

In this paper we study the lepton polarization asymmetry for the simileptonic OZI-forbidden annihilation $B_c^- \rightarrow \eta' \ell^- \bar{\nu}$ decay where $l = \mu, \tau$. Our results show that the branching ratio turn out to be of order $10^{-4}$. Beside, we find that longitudinal, transversal and normal components of lepton polarizations can be measured for both $\mu$ and $\tau$ decay modes in the future experiments at the LHC.

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1 Introduction

The $B_c$ meson was first observed in CDF\[1, 2\] detector at the Fermilab Tevatron in 1.8 TeV $p\bar{p}$ collisions. It was measured to have a mass $M_{B_c} = 6.40 \pm 0.39 \pm 0.13 GeV$ and lifetime $\tau_{B_c} = 0.46^{+0.18}_{-0.16} \pm 0.03 ps$, which agree with the theoretical predictions\[3, 13\]. Its mass and the spectrum of the binding system can be computed by potential model\[5, 6\], PNRQCD\[6, 7\] and lattice QCD\[8\] etc. The results are in the region, $m_{B_c} \simeq 6.2 \sim 6.4 GeV$. Its lifetime was estimated in terms of the effective theory of weak interaction and by applying the effective Lagrangian to the inclusive processes of $B_c$ decays\[6, 9, 10, 11\]. According to the estimates, the lifetime is $\tau_{B_c} \simeq 0.4 ps$, a typical one for weak interaction via virtual $W$ boson. Further detailed experimental studies can be performed at B factories (KEK, SLAC) and CERN large Hadron Collider (LHC). Especially, at LHC with the luminosity $L = 10^{34} cm^{-2}s^{-1}$ and $\sqrt{s} = 14 TeV$, the number of $B_c^\pm$ events is expected to be about $10^8 \sim 10^{10}$ per year \[14\], so there seems to exist a real possibility to study not only some $B_c$ rare decays, but also CP violation, T violation and polarization asymmetries. The studies of CP violation, T violation and polarization asymmetries are specially interesting since they can serve as good tools to test the predictions of SM or to reveal the new physics effects beyond the SM.

The study of $B_c$ meson, the ground state of the heavy-flavored binding system $(\bar{c}b)$, the bottom and the charm, constitute a very rich laboratory since this meson is also a suitable object for studying the predictions of QCD. As $B_c$ meson has many decay channels because of its sufficiently large mass predictions of QCD are more reliable. The $B_c$ meson decays provide windows for reliable determination of the CKM matrix element $V_{cb}$ and can shed light on new physics beyond the standard model.

In the framework of the SM its decays can occur via three mechanisms: (1) the c-quark decay with the b-quark being a spectator, (2) the b-quark decay with the c-quark being a spectator, (3) b-quark and c-quark annihilation. The first two mechanisms are expected to contribute about 90% of the total width, and the remaining 10% is owed to the annihilation process.

There is another decay mode which does not belong to the aforementioned types, and it can only occur via the OZI processes. As we know that the OZI rule\[15\] plays an important role in the processes which occur via strong interaction and in general at the parton level the concerned calculations are carried out in the framework of the perturbative QCD (PQCD).

The first investigation of the OZI-forbidden annihilation decays $B^- \rightarrow \eta \ell \bar{\nu}$ in QCD was carried out in 1999 \[16\]. In their work, an effective Lagrangian was adopted to avoid introducing the $B_c$ meson wave function, meanwhile they dealt with the light meson by using an effective $g^*_a g^*_b \rightarrow \eta'$ coupling \[17\]\[18\], which was obtained in the NRQM approximation. The valence quark $q$ and anti-quark $\bar{q}$ in the light meson were assumed to possess equal momenta and be on their mass shells, i.e., $p_q = p_{\bar{q}}$ and $p_q^2 = m_q^2$. The branching ratio estimated to be $Br(B_c \rightarrow \eta \ell \bar{\nu}) = 1.6 \times 10^{-4}$ for $l = \mu, e$, which is accessible at CERN LHC.

In this paper, we investigate lepton polarization asymmetries in semileptonic annihilation decay
$B_c^- \rightarrow \eta' \ell^- \bar{\nu}$.

The paper is organized as follows. In section 2, we give the details of the calculation of the amplitude and polarization asymmetries. Section 3 is devoted to numerical results and discussions.

## 2 Calculations

The effective Lagrangian responsible for $(b \bar{c}) \rightarrow g_a^* g_b^* l \bar{\nu}$ decay is [16]

$$
\mathcal{M}(b \bar{c} \rightarrow g_a^* g_b^* l \bar{\nu}) = \frac{G_F}{\sqrt{2}} V_{cb} g_s^2 T r[T_a T_b] \bar{v}_c(p_c) \left[ \gamma_\mu (1 - \gamma_5) \gamma_\beta \gamma_\alpha \delta_{\mu \alpha} \frac{i}{p_b - \not{F} - m_b} + \frac{i}{\not{P} - m_c - \not{c}} \gamma_\mu (1 - \gamma_5) \gamma_\beta \gamma_\alpha \delta_{\mu \alpha} \frac{i}{p_b - \not{F} - m_b} \right] u_b(p_b) \times \bar{l} \gamma^\mu (1 - \gamma_5) \nu_l + (\alpha \leftrightarrow \beta, k_1 \leftrightarrow k_2). \tag{1}
$$

Using the Dirac equation and identity for Dirac matrices, after long but straightforward calculations for an effective Lagrangian $L_{\text{eff}}$ we get[16]:

$$
L_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{cb} g_s^2 T r[T_a T_b] \bar{c} \gamma_\delta (1 - \gamma_5) b \bar{\gamma}_\mu (1 - \gamma_5) \nu_l \mathcal{F}^{\delta \mu \alpha \beta} \frac{1}{k_1^2 k_2^2} \langle g_a^* g_b^* | \eta' \rangle. \tag{2}
$$

where $K = k_1 + k_2$ is the momentum of $\eta'$, $\mathcal{F}^{\delta \mu \alpha \beta}$ represents the combination of momenta and contains loop integrations, which is explicitly shown in [16].

Having obtained the effective Lagrangian, the total amplitude can be obtained by sandwiching the $L_{\text{eff}}$ between annihilated meson state $|B_c^-\rangle$ and created non-meson state $\langle 0 |$ by using the definition

$$
\langle 0 | \bar{c} \gamma_\mu (1 - \gamma_5) b | B_c(P) \rangle = i f_{B_c} P_\mu \tag{3}
$$

and the $g_a^* g_b^* \rightarrow \eta'$ coupling

$$
\langle g_a^* g_b^* | \eta' \rangle = g_s^2 \delta_{ab} \frac{A_{\eta'}}{k_1 \cdot k_2} \epsilon_{\alpha \beta \gamma \delta} k_1^m k_2^n \tag{4}
$$

which has been widely used in $\eta'$ and pseudoscalar productions in heavy quarkonium decays and in high energy colliders[18].

Here the parameter $A_{\eta'}$ is understood as a combination of SU(3) mixing angles and nonperturbative objects, and can be extracted from the decay $J/\Psi \rightarrow \eta' \gamma$.

Using the definitions mentioned above and performing the loop integrations via Dimensional Regularization, the amplitude is found as follows:

$$
\mathcal{M} = \frac{G_F}{\sqrt{2}} V_{cb} g_s^2 T r[T_a T_b] \delta_{ab} 4 A_{\eta'} i f_{B_c} \frac{i}{16 \pi^2} (P_\mu f_1 + K_\mu f_2) \bar{l} \gamma^\mu (1 - \gamma_5) \nu_l \tag{5}
$$
Where $P_\mu$ and $K_\mu$ are the momentums of $B_c$ and $q'$, respectively. With $f_1$, $f_2$ defined by

$$
f_1 = -4C_{11}(K, p_b - K, 0, 0, m_b) + 4C_{12}(K, p_b - K, 0, 0, m_b)$$
$$-2C_{11}\left(\frac{K}{2}, \frac{K}{2}, p_b, 0, \frac{m_{q'}}{2}, m_b\right) - 2C_{12}\left(\frac{K}{2}, \frac{K}{2}, p_b, 0, \frac{m_{q'}}{2}, m_b\right)$$
$$-4C_{11}(K, p_c - K, 0, 0, m_c) + 4C_{12}(K, p_c - K, 0, 0, m_c)$$
$$+2C_{11}\left(\frac{K}{2}, \frac{K}{2}, p_c, 0, \frac{m_{q'}}{2}, m_c\right) + 2C_{12}\left(\frac{K}{2}, \frac{K}{2}, p_c, 0, \frac{m_{q'}}{2}, m_c\right)$$
$$+\frac{2m_c}{m_c}C_{12}\left(\frac{K}{2}, p_b - K, 0, \frac{m_{q'}}{2}, m_b\right) - \frac{2m_c}{m_b}C_{12}\left(\frac{K}{2}, p_c - K, 0, \frac{m_{q'}}{2}, m_c\right)$$
$$-\frac{2M(m_b - m_c)}{m_b m_c}\left(C_{12}\left(\frac{K}{2} - p_c, P - K, \frac{m_{q'}}{2}, m_c, m_b\right)ight)$$
$$-\frac{m_c}{M}C_{11}\left(\frac{K}{2} - p_c, P - K, \frac{m_{q'}}{2}, m_c, m_b\right),$$

and

$$
f_2 = \frac{-4M m_b}{K^2 - 2p_b K}\left(2C_{11}(K, p_b - K, 0, 0, m_b) - C_{12}(K, p_b - K, 0, 0, m_b) + C_{11}\left(\frac{K}{2}, \frac{K}{2}, p_b, 0, \frac{m_{q'}}{2}, m_b\right)\right)$$
$$+\frac{4M m_c}{K^2 - 2p_c K}\left(2C_{11}(K, p_c - K, 0, 0, m_c) - C_{12}(K, p_c - K, 0, 0, m_c) + C_{11}\left(\frac{K}{2}, \frac{K}{2}, p_c, 0, \frac{m_{q'}}{2}, m_c\right)\right)$$
$$+\frac{M}{m_c}\left(C_{11}\left(\frac{K}{2}, p_b - K, \frac{m_{q'}}{2}, 0, m_b\right) - 2C_{12}\left(\frac{K}{2}, p_b - K, \frac{m_{q'}}{2}, 0, m_b\right) + C_{0}\left(\frac{K}{2}, p_b - K, \frac{m_{q'}}{2}, 0, m_b\right)\right)$$
$$-\frac{M}{m_b}\left(C_{11}\left(\frac{K}{2}, p_c - K, \frac{m_{q'}}{2}, 0, m_c\right) - 2C_{12}\left(\frac{K}{2}, p_c - K, \frac{m_{q'}}{2}, 0, m_c\right) + C_{0}\left(\frac{K}{2}, p_c - K, \frac{m_{q'}}{2}, 0, m_c\right)\right)$$
$$-\frac{M(m_b - m_c)}{m_b m_c}\left(C_{11}\left(\frac{K}{2} - p_c, P - K, \frac{m_{q'}}{2}, m_c, m_b\right) - 2C_{12}\left(\frac{K}{2} - p_c, P - K, \frac{m_{q'}}{2}, m_c, m_b\right)\right)$$
$$+C_{0}\left(\frac{K}{2} - p_c, P - K, \frac{m_{q'}}{2}, m_c, m_b\right)\right)$$

The three points loop functions and their definitions are as follows [19]:

$$C_0; C_\mu(p, k, m_1, m_2, m_3) = \frac{1}{i\pi} \int d^n q \frac{1}{(q^2 - m_1^2)((q + p)^2 - m_2^2)((q + p + k)^2 - m_3^2)},$$

where $C_\mu = p_\mu C_{11} + k_\mu C_{12}$. Using the Feynman parametrization we obtain the explicit forms of $C_0, C_{11}$ and $C_{12}$ in terms of Feynman parameters as

$$C_0 = \int_0^1 \int_0^{1-x} \frac{1}{L(x, y)} dx dy$$
$$C_{11} = \int_0^1 \int_0^{1-x} \frac{1 - x}{L(x, y)} dx dy, \quad C_{12} = \int_0^1 \int_0^{1-x} \frac{y}{L(x, y)} dx dy,$$

where

$$L = m_2^2 + (m_1^2 - m_2^2)x - p^2 x + p^2 x^2 - m_2^2 y + m_2^2 y - k^2 y + k^2 y^2 - 2xy p k.$$
are on mass shell and move together with the same velocity. It implies the following equations to a good accuracy

\[ M(B_c) = m_c + m_b, \quad p_c = \frac{m_c}{M} P, \quad p_b = \frac{m_b}{M} P. \] (11)

Now let us calculate the decay width of the process \( B_c^- \rightarrow \eta' \ell^- \bar{\nu} \) taking into account the lepton polarization. Four components of spin vector of lepton \( s_\mu \) in terms of \( \vec{\eta} \), the unit vector along the \( \ell \) lepton spin in its rest frame are given by

\[ s_0 = \frac{\vec{p}_\ell \cdot \vec{\eta}}{m_\ell}, \quad \vec{s} = \vec{\eta} + \frac{s_0}{E_\ell + m_\ell} \vec{p}_\ell. \] (12)

In the \( B_c^+ \) rest frame, the partial decay rate is found to be

\[ d\Gamma = \frac{1}{(2\pi)^3} \frac{1}{8M_{B_c}} |M|^2 dE_{\eta'} dE_\ell, \] (13)

where

\[ |M|^2 = A_0(x, y) + (A_L \vec{e}_L + A_N \vec{e}_N + A_T \vec{e}_T) \cdot \vec{\eta}, \] (14)

where \( \vec{e}_i \) \((i = L, N, T)\) is the unit vector along the longitudinal, normal and transversal components of the lepton polarization, defined as:

\[
\begin{align*}
\vec{e}_L &= \frac{\vec{p}_\ell}{|\vec{p}_\ell|}, \\
\vec{e}_T &= \frac{\vec{p}_\ell \times (\vec{q} \times \vec{p}_\ell)}{|\vec{p}_\ell \times (\vec{q} \times \vec{p}_\ell)|}, \\
\vec{e}_N &= \frac{\vec{q} \times \vec{p}_\ell}{|\vec{q} \times \vec{p}_\ell|},
\end{align*}
\] (15)

respectively. The quantities \( A_0, A_L, A_N, A_T \) can be calculated directly and are given by

\[
\begin{align*}
A_0(t, s) &= 4M_B^2 \{-|f_1|^2[r_{\eta'} + r_\ell] + (-1 + t)(-1 + t + s) \\
&+ |f_2|^2[r_2(-1 + r_\ell) - (1 + r_\ell - t)(1 + r_\ell - t - s)] \\
&- 2Re[f_1f_2^\dagger][r_2 - (1 + r_\ell - t)(-1 + s + t)]\}, \tag{16}
\end{align*}
\]

\[
\begin{align*}
A_L(t, s) &= 2M_B^2 \{-|f_1|^2[(-2 + s + 2t)\sqrt{-4r_\ell + t^2} + \sqrt{-4r_{\eta'} + s^2} t \cos(z)] \\
&+ |f_2|^2[-2r_{\eta'} + s(1 + r_\ell - t)]\sqrt{-4r_\ell + t^2} + \sqrt{-4r_{\eta'} + s^2} t(-1 - r_\ell + t) \cos(z)] \\
&+ Re[f_1f_2^\dagger][(-2 - 2r_{\eta'} + 2r_\ell - (2 + s)t)\sqrt{-4r_\ell + t^2} + \sqrt{-4r_{\eta'} + s^2}(-2 + t) t \cos(z)]\}, \tag{17}
\end{align*}
\]

\[
\begin{align*}
A_N(t, s) &= -4M_B^2 \sqrt{r_\ell}\sqrt{-4r_\ell + t^2} \sqrt{-4r_{\eta'} + s^2} \sin(z) Im[f_1f_2^*] \tag{18}
\end{align*}
\]

\[
\begin{align*}
A_T(t, s) &= -4M_B^2 \sqrt{r_\ell}\sqrt{-4r_{\eta'} + s^2} \sin(z)\{|f_1|^2 + |f_2|^2(1 + r_\ell - t) - Re[f_1f_2^*](-2 + t)\} \tag{19}
\end{align*}
\]
where \( r_{\eta'} = \frac{M^2_{\tau}}{m^2_{\eta'}} \), \( r_\ell = \frac{M^2_{\tau}}{m^2_\ell} \), \( t = \frac{2E_\ell}{M_B} \), \( s = \frac{2E_{\eta'}}{M_B} \) are normalized energies of the lepton and \( \eta' \), respectively. \( \cos(z) \) is given by:

\[
\cos(z) = \frac{2(1 + r_\ell + r_{\eta'} - s + (-2 + s)t)}{\sqrt{(-4r_\ell + t^2)(-4r_{\eta'} + s^2)}}
\]

Here the \( z \) is a angle between the final lepton(\( \ell \)) and \( \eta' \) particles. Using Eq.(16) we get the following expression for differential decay rate:

\[
\frac{d\Gamma(s)}{ds} = \frac{\Delta(s)}{8(2\pi)^3}C^2M^3,
\]

where

\[
C = \frac{8}{3}\alpha_s^2f_{Bc}A_{\eta'}G_FV_{cb}.
\]

and the expression for \( \Delta \) is as:

\[
\Delta = \frac{(1 + r_{\eta'} - r_\ell - s)^2\sqrt{-4r_{\eta'} + s^2}}{3(1 + r_{\eta'} - s)^3}\left\{ 2(1 + r_{\eta'} - s)(-4r_{\eta'} + s^2)(|f_1|^2 + |f_2|^2 + 2Re[f_1f_2^*])
- 4r_\ell(|f_1|^2(-3 + r_{\eta'} + 3s - s^2) + |f_2|^2(r_{\eta'} - 3r_{\eta'}^2 + 3r_{\eta'}s - s^2)
+ Re[f_1f_2^*](8r_{\eta'} - 3 - 3r_{\eta'}s + s^2) \right\}
\]

It should be mentioned that if one neglects the lepton mass(\( r_\ell = 0 \)), the results in [16] are obtained. If we define the longitudinal, normal and transversal \( \ell \) polarization asymmetries by

\[
P_i(s) = \frac{d\Gamma(\vec{e}_i) - d\Gamma(-\vec{e}_i)}{d\Gamma(\vec{e}_i) + d\Gamma(-\vec{e}_i)}, \quad (i = L, N, T),
\]

we find that

\[
P_i(s) = \int \frac{A_i(t,s)dt}{\int A_0(t,s)dt}, \quad (i = L, N, T).
\]

3 Numerical Results and Discussions

In this section the numerical analysis is done not only for the differential decay width but also for the polarization asymmetries(\( P_i \)). For numerical results, we take \( \alpha_s = \alpha_s(M_{B_c}) = 0.2 \), \( V_{cb} = 0.04 \), \( A_{\eta'} = 0.2 \) and \( \tau_{B_c} = 0.46ps \). The decay constant \( f_{B_c} \) probes the strong(nonpertubative) QCD dynamics which bind \( b \) and \( \bar{c} \) quarks to form the bound state \( B_c \). In nonrelativistic limit, \( f_{B_c} \) can be related to the value of the \( B_c \) wave function at origin[20]. Leptonic decay constant is estimated by QCD sum rules[21] and using the nonrelativistic potential models

\[
f_{B_c} = \begin{cases}
450MeV & \text{(Buchmüller-Tye potential[22])} \\
512MeV & \text{(power law potential[23])} \\
479MeV & \text{(logarithmic potential[24])} \\
687MeV & \text{(cornell potential[25])}
\end{cases}
\]

For numerical illustrations, we take $f_{B_c} = 0.5 \text{ GeV}$. We also do numerical integration in eq. (25) for $s$ values in the interval $s \in [2\sqrt{r_{\eta'}} , 1 + r_{\eta'} - r_{\ell}]$ with respect to $t$ ranging from $t_{Min}$ to $t_{Max}$ which are given as:

$$

t_{Min} = \frac{(1 + r_{\eta'} + r_{\ell} - s) (2 - s)}{2(1 + r_{\eta'} - s)} - \frac{|(1 + r_{\eta'} - r_{\ell} - s)| \sqrt{(-4 r_{\eta'} + s^2)}}{2(1 + r_{\eta'} - s)} \\

t_{Max} = \frac{(1 + r_{\eta'} + r_{\ell} - s) (2 - s)}{2(1 + r_{\eta'} - s)} + \frac{|(1 + r_{\eta'} - r_{\ell} - s)| \sqrt{(-4 r_{\eta'} + s^2)}}{2(1 + r_{\eta'} - s)}
$$

(27)

The dependence of the branching ratio on normalized $\eta'$ momentum for $\mu$ and $\tau$ cases are displayed in Fig.1 and Fig. 2. It is seen that the normalized $\eta'$ momentum distribution is peaked at small values of $s$. In fact, it is reasonable if we consider the expressions of $f_1$ and $f_2$ in terms of basic scalar functions $C_0$ and $C_{12}$ and $C_{11}$ in [19], the normalized $\eta'$ momentum distribution behaves as

$$
\propto \frac{1}{\sqrt{s^2 - r_{\eta'}}},
$$

(28)

when $s$ is small. Therefore, there is a singularity at the starting point of the distribution, but it is integrable and give finite decay width. The branching ratio is estimated to be

$$
Br(B_c \to \eta' \mu \bar{\nu}) \sim 1.6 \times 10^{-4},
$$

(29)

$$
Br(B_c \to \eta' \tau \bar{\nu}) \sim 2.2 \times 10^{-4},
$$

(30)

for $\mu, \tau$ leptons, respectively.

Fig.3 and Fig.4 are displaying the dependency of $P_L$ for $\mu$ and $\tau$ leptons, respectively. We see that the $P_L$ for $\tau$ lepton can take both negative and positive values. Precisely, for $s \leq 0.45$ it takes negative values and elsewhere it is positive.

Fig.5 and Fig.6 are displaying the dependency of $P_N$ for $\mu$ and $\tau$ leptons, respectively. We see that for both leptons $P_N$ is negative and has minimum at $s \simeq 0.83$ and $s \simeq 0.75$, respectively.

Fig.7 and Fig.8 are displaying the dependency of $P_T$ for $\mu$ and $\tau$ leptons, respectively. We see that for both leptons $P_T$ is negative and has minimum at $s \simeq 0.95$ and $s \simeq 0.75$, respectively.

Finally, a few words about the detectibility of the lepton polarization asymmetries at $B$ factories or future hadron colliders, are in order. As an estimation, we choose the averaged values of the longitudinal, transversal and normal polarizations for both $\mu$ and $\tau$ leptons (see TABLE 1).

| $\langle P_i \rangle$ | $B_c \to \eta' \mu \bar{\nu}$ | $B_c \to \eta' \tau \bar{\nu}$ |
|----------------------|-------------------------------|-------------------------------|
| $\langle P_L \rangle$ | 0.71                          | 0.258                         |
| $\langle P_N \rangle$ | -0.007                        | -0.1                          |
| $\langle P_T \rangle$ | -0.009                        | -0.09                         |

TABLE 1. The averaged Longitudinal, Normal and Transversal polarization for $\mu$ and $\tau$ leptons.
Experimentally, to measure an asymmetry $\langle P_i \rangle$ of a decay with the branching ratio $B$ at the $n\sigma$ level, the required number of events is given by the formula $N = n^2/(B\langle P_i \rangle^2)$. It follows from this expression and TABLE 1 that to observe the lepton polarizations $\langle P_L \rangle$, $\langle P_N \rangle$ and $\langle P_T \rangle$ in $B_c^- \rightarrow \eta' \ell^- \bar{\nu}$ decay at $1\sigma$ level, the expected number of events are $N = (1, 3, 10^4) \times 10^7$, respectively. On the other hand, the number of $B\bar{B}$ pairs that are expected to be produced at B factories and LHCb will be $10^8$ and $10^{12}B\bar{B}$ pairs, respectively. A comparison of these numbers allows us to conclude that not only the measurements of the longitudinal polarization of muon and longitudinal, normal and transversal polarization of $\tau$ lepton, but also the measurements of the normal and transversal polarizations of the $\mu$ lepton with the order of $\approx \%1$ (see TABLE 1) could be accessible at $B$ factories.

In conclusion, we carried out a study on the semileptonic annihilation decays $B_c^- \rightarrow \eta' \ell^- \bar{\nu}$ and lepton polarization asymmetries.

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Figure Captions

Figure 1: The distribution of $dBr/ds$ as a function of $s$ (normalized energy of $\eta'$) for the $B_c \rightarrow \eta' \mu \nu_{\mu}$ decay.
Figure 2: The same as Figure 1 but for the $B_c \rightarrow \eta' \tau \nu_{\tau}$ decay.
Figure 3: The dependence of the longitudinal lepton polarization $P_L$ on $s$ for the $B_c \rightarrow \eta' \mu \nu_{\mu}$ decay.
Figure 4: The same as Figure 3 but for the $B_c \rightarrow \eta' \tau \nu_{\tau}$ decay.
Figure 5: The dependence of the normal lepton polarization $P_N$ on $s$ for the $B_c \rightarrow \eta' \mu \nu_{\mu}$ decay.
Figure 6: The same as Figure 5 but for the $B_c \rightarrow \eta' \tau \nu_{\tau}$ decay.
Figure 7: The dependence of the transversal lepton polarization $P_T$ on $s$ for the $B_c \rightarrow \eta' \mu \nu_{\mu}$ decay.
Figure 8: The same as Figure 7 but for the $B_c \rightarrow \eta' \tau \nu_{\tau}$ decay.
Figure 7:

Figure 8:
