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

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

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1 Introduction

The B_c meson was first observed in the 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 data agree with the theoretical predictions [3, 13]. Its mass and the spectrum of the binding system can be computed by the 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, 9–11]. According to the estimates, the lifetime is $\tau_{B_c} \simeq 0.4$ ps, a typical one for weak interaction via the virtual W boson. Further detailed experimental studies can be performed at B factories (KEK, SLAC) and the CERN Large Hadron Collider (LHC). Especially, at LHC with the luminosity $\mathcal{L} = 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ 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 the 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 the 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 a 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. c-quark decay with the b-quark being a spectator,
2. 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 three aforementioned types, and it can only occur via the OZI processes. As we know that the OZI rule [15] plays an important role in processes which occur via the strong interaction, and in general at the parton level the calculations concerned are carried out in the framework of the perturbative QCD (PQCD).

The first investigation of the OZI-forbidden annihilation decays $B_c^- \to \eta' \ell^- \bar{\nu}$ in QCD was carried out in 1999 [16]. In this work of Sugamoto and Yang, 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 $g_a^* g_b^* \to \eta'$ coupling [16, 17], which was obtained in the NRQM approximation. The valence quark q and the anti-quark $\bar{q}$ in the light meson were assumed to possess equal momenta and to be on their mass shells, i.e., $p_q = p_{\bar{q}}$ and $p_q^2 = m_q^2$. The branching ratio is estimated to be $\mathrm{Br}(B_c \to \eta' \ell \bar{\nu}) = 1.6 \times 10^{-4}$ for $\ell = \mu, e$, which is accessible at CERN LHC.

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

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

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2 Calculations

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

$$\begin{aligned}
&\mathcal{M}\left(b\bar{c} \to g_a^* g_b^* l^- \nu\right) = \frac{G_F}{\sqrt{2}} V_{cb} g_s^2 \mathrm{Tr}[T_a T_b] \bar{v}_c(p_c) \\
&\times \left[\gamma_\mu(1-\gamma_5) \frac{\mathrm{i}}{\not{p}_b - \not{K} - m_b} \gamma_\beta \frac{\mathrm{i}}{\not{p}_b - \not{k}_1 - m_b} \gamma_\alpha \right. \\
&+ \gamma_\alpha \frac{\mathrm{i}}{\not{k}_1 - \not{p}_c - m_c} \gamma_\beta \frac{\mathrm{i}}{\not{K} - \not{p}_c - m_c} \gamma_\mu (1-\gamma_5) \\
&\left. + \gamma_\beta \frac{\mathrm{i}}{-\not{p}_c + \not{k}_2 - m_c} \gamma_\mu (1-\gamma_5) \frac{\mathrm{i}}{\not{p}_b - \not{k}_1 - m_b} \gamma_\alpha \right] u_b(p_b) \\
&\times \bar{l} \gamma^\mu (1-\gamma_5) \nu_l + (\alpha \leftrightarrow \beta, k_1 \leftrightarrow k_2) \,. \qquad (1)
\end{aligned}$$

Using the Dirac equation and the identities for Dirac matrices, after long but straightforward calculations for the effective Lagrangian $\mathcal{L}_{\text{eff}}$ we get [16]

$$\begin{aligned}
\mathcal{L}_{\text{eff}} = &\frac{G_F}{\sqrt{2}} V_{cb} g_s^2 \mathrm{Tr}[T_a T_b] \bar{c} \gamma_\delta (1-\gamma_5) b \\
&\times \bar{l} \gamma_\mu (1-\gamma_5) \nu_l \mathcal{F}^{\delta\mu\alpha\beta} \frac{1}{k_1^2} \frac{1}{k_2^2} \langle g_{a\alpha}^* g_{b\beta}^* \mid \eta' \rangle \,, \qquad (2)
\end{aligned}$$

where $K = k_1 + k_2$ is the momentum of η', and $\mathcal{F}^{\delta\mu\alpha\beta}$ represents the combination of the 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 $\mathcal{L}_{\text{eff}}$ between the annihilated meson state $|B_c^-\rangle$ and the created non-meson state $\langle 0|$ by using the definition

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

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

$$\langle g_a^*\ g_b^* \mid \eta' \rangle = g_s^2 \delta_{ab} \frac{A_{\eta'}}{k_1 \cdot k_2} \epsilon_{\alpha\beta mn} k_1^m k_2^n \,, \qquad (4)$$

which has widely been used in η' and pseudoscalar productions in heavy quarkonium decays and in high energy collidors [17].

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 $J/\Psi \to \eta' \gamma$.

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

$$\begin{aligned}
\mathcal{M} = &\frac{G_F}{\sqrt{2}} V_{cb} g_s^4 \mathrm{Tr}[T_a\ T_b] \delta_{ab} 4 A_{\eta'} \mathrm{i} f_{B_c} \frac{\mathrm{i}}{16\pi^2} \\
&\times (P_\mu f_1 + K_\mu f_2)\, \bar{l} \gamma^\mu (1-\gamma_5) \nu_l \,, \qquad (5)
\end{aligned}$$

where P_μ and K_μ are the momenta of B_c and η', respectively. With f_1, f_2 defined by

$$\begin{aligned}
f_1 = &-4C_{11}(K, p_b - K, 0, 0, m_b) + 4C_{12}(K, p_b - K, 0, 0, m_b) \\
&- 2C_{11}\left(\frac{K}{2}, \frac{K}{2} - p_b, 0, \frac{m_{\eta'}}{2}, m_b\right) \\
&- 2C_{12}\left(\frac{K}{2}, \frac{K}{2} - p_b, 0, \frac{m_{\eta'}}{2}, m_b\right) \\
&- 4C_{11}(K, p_c - K, 0, 0, m_c) \\
&+ 4C_{12}(K, p_c - K, 0, 0, m_c) \\
&+ 2C_{11}\left(\frac{K}{2}, \frac{K}{2} - p_c, 0, \frac{m_{\eta'}}{2}, m_c\right) \\
&+ 2C_{12}\left(\frac{K}{2}, \frac{K}{2} - p_c, 0, \frac{m_{\eta'}}{2}, m_c\right) \\
&+ \frac{2m_b}{m_c} C_{12}\left(\frac{K}{2}, p_b - K, 0, \frac{m_{\eta'}}{2}, m_b\right) \\
&- \frac{2m_c}{m_b} C_{12}\left(\frac{K}{2}, p_c - K, 0, \frac{m_{\eta'}}{2}, m_c\right) \\
&- \frac{2M(m_b - m_c)}{m_b m_c}\left(C_{12}\left(\frac{K}{2} - p_c, P - K, \frac{m_{\eta'}}{2}, m_c, m_b\right)\right. \\
&\left. - \frac{m_c}{M} C_{11}\left(\frac{K}{2} - p_c, P - K, \frac{m_{\eta'}}{2}, m_c, m_b\right)\right) \,, \qquad (6)
\end{aligned}$$

and

$$\begin{aligned}
f_2 = &\frac{-4Mm_b}{K^2 - 2p_b \cdot K}\left(2C_{11}(K, p_b - K, 0, 0, m_b)\right. \\
&- C_{12}(K, p_b - K, 0, 0, m_b) \\
&\left. + C_{11}\left(\frac{K}{2}, \frac{K}{2} - p_b, 0, \frac{m_{\eta'}}{2}, m_b\right)\right) \\
&+ \frac{4Mm_c}{K^2 - 2p_c \cdot K}\left(2C_{11}(K, p_c - K, 0, 0, m_c)\right. \\
&- C_{12}(K, p_c - K, 0, 0, m_c) \\
&\left. + C_{11}\left(\frac{K}{2}, \frac{K}{2} - p_c, 0, \frac{m_{\eta'}}{2}, m_c\right)\right) \\
&+ \frac{M}{m_c}\left(C_{11}\left(\frac{K}{2}, p_b - K, \frac{m_{\eta'}}{2}, 0, m_b\right)\right. \\
&- 2C_{12}\left(\frac{K}{2}, p_b - K, \frac{m_{\eta'}}{2}, 0, m_b\right) \\
&\left. + C_0\left(\frac{K}{2}, p_b - K, \frac{m_{\eta'}}{2}, 0, m_b\right)\right) \\
&- \frac{M}{m_b}\left(C_{11}\left(\frac{K}{2}, p_c - K, \frac{m_{\eta'}}{2}, 0, m_c\right)\right. \\
&- 2C_{12}\left(\frac{K}{2}, p_c - K, \frac{m_{\eta'}}{2}, 0, m_c\right) \\
&\left. + C_0\left(\frac{K}{2}, p_c - K, \frac{m_{\eta'}}{2}, 0, m_c\right)\right) \\
&- \frac{M(m_b - m_c)}{m_b m_c}\left(C_{11}\left(\frac{K}{2} - p_c, P - K, \frac{m_{\eta'}}{2}, m_c, m_b\right)\right. \\
&- 2C_{12}\left(\frac{K}{2} - p_c, P - K, \frac{m_{\eta'}}{2}, m_c, m_b\right) \\
&\left. + C_0\left(\frac{K}{2} - p_c, P - K, \frac{m_{\eta'}}{2}, m_c, m_b\right)\right) \,. \qquad (7)
\end{aligned}$$

The three point loop functions and their definitions are as follows [18]:

$$C_0; C_\mu(p,k,m_1,m_2,m_3) = \frac{1}{\mathrm{i}\pi} \times \int \mathrm{d}^n q \frac{1; q_\mu}{(q^2-m_1^2)\left((q+p)^2-m_2^2\right)\left((q+p+k)^2-m_3^2\right)}, \quad (8)$$

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 the Feynman parameters as

$$C_0 = \int_0^1 \int_0^{1-x} \frac{-1}{L(x,y)} \mathrm{d}x\mathrm{d}y\,,$$
$$C_{11} = \int_0^1 \int_0^{1-x} \frac{1-x}{L(x,y)} \mathrm{d}x\mathrm{d}y\,,$$
$$C_{12} = \int_0^1 \int_0^{1-x} \frac{y}{L(x,y)} \mathrm{d}x\mathrm{d}y\,, \quad (9)$$

where

$$L = m_2^2 + \left(m_1^2 - m_2^2\right) x - p^2 x + p^2 x^2 - m_2^2 y + m_3^2 y - k^2 y + k^2 y^2 - 2xyp\cdot k\,. \quad (10)$$

For the heavy b and c quarks, it is reasonable to neglect the relative momentum of the quark constituents and their binding energy relative to their masses. In this nonrelativistic limit, the constituents are on mass shell and move together with the same velocity. It implies the following equations to a good accuracy:

$$M(B_c) = m_c + m_b\,, \qquad p_{\bar{c}} = \frac{m_c}{M} P\,, \qquad p_b = \frac{m_b}{M} P\,. \quad (11)$$

Now let us calculate the decay width of the process $B_c^- \to \eta' \ell^- \bar{\nu}$ taking into account the lepton polarization. The four components of the spin vector of lepton s_μ in terms of $\boldsymbol{\eta}$, the unit vector along the ℓ lepton spin in its rest frame, are given by

$$s_0 = \frac{\mathbf{p}_\ell \cdot \boldsymbol{\eta}}{m_\ell}\,, \quad \mathbf{s} = \boldsymbol{\eta} + \frac{s_0}{E_\ell + m_\ell} \mathbf{p}_\ell\,. \quad (12)$$

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

$$\mathrm{d}\Gamma = \frac{1}{(2\pi)^3} \frac{1}{8M_{B_c}} \mid M \mid^2 \mathrm{d}E_{\eta'} \mathrm{d}E_\ell\,, \quad (13)$$

where

$$|\mathcal{M}|^2 = A_0(x,y) + (A_\mathrm{L}\mathbf{e}_\mathrm{L} + A_\mathrm{N}\mathbf{e}_\mathrm{N} + A_\mathrm{T}\mathbf{e}_\mathrm{T}) \cdot \boldsymbol{\eta}\,, \quad (14)$$

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

$$\mathbf{e}_\mathrm{L} = \frac{\mathbf{p}_\ell}{|\mathbf{p}_\ell|},$$
$$\mathbf{e}_\mathrm{T} = \frac{\mathbf{p}_\ell \times (\mathbf{q} \times \mathbf{p}_\ell)}{|\mathbf{p}_\ell \times (\mathbf{q} \times \mathbf{p}_\ell)|},$$
$$\mathbf{e}_\mathrm{N} = \frac{\mathbf{q} \times \mathbf{p}_\ell}{|\mathbf{q} \times \mathbf{p}_\ell|}\,, \quad (15)$$

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

$$A_0(t,s) = 4M_B^4 \Big\{ -|f_1|^2 [r_{\eta'} + r_\ell + (-1+t)(-1+t+s)] + |f_2|^2 [r_2(-1+r_\ell) - (1+r_\ell-t)(1+r_\ell-t-s)] - 2\,\mathrm{Re}\,[f_1 f_2^*]\,[r_2 - (1+r_\ell-t)(-1+s+t)] \Big\}\,, \quad (16)$$

$$A_\mathrm{L}(t,s) = 2M_B^4 \Big\{ -|f_1|^2 \Big[(-2+s+2t)\sqrt{-4r_\ell+t^2} + \sqrt{-4r_{\eta'}+s^2}\, t\cos(z) \Big] + |f_2|^2 \Big[(-2r_{\eta'} + s(1+r_\ell-t))\sqrt{-4r_\ell+t^2} + \sqrt{-4r_{\eta'}+s^2}\, t(-1-r_\ell+t)\cos(z) \Big] + \mathrm{Re}\,[f_1 f_2^*]\,[(2-2r_{\eta'}+2r_\ell-(2+s)t\sqrt{-4r_\ell+t^2} + \sqrt{-4r_{\eta'}+s^2}(-2+t)t\cos(z)\Big] \Big\}\,, \quad (17)$$

$$A_\mathrm{N}(t,s) = -4M_B^4 \sqrt{r_\ell}\sqrt{-4r_\ell+t^2}\sqrt{-4r_{\eta'}+s^2} \times \sin(z)\mathrm{Im}\,[f_1 f_2^*]\,, \quad (18)$$

$$A_\mathrm{T}(t,s) = -4M_B^4 \sqrt{r_\ell}\sqrt{-4r_{\eta'}+s^2}\sin(z) \times \Big\{ |f_1|^2 + |f_2|^2(1+r_\ell-t) - \mathrm{Re}\,[f_1 f_2^*]\,(-2+t) \Big\}\,, \quad (19)$$

where $r_{\eta'} = \frac{M_B^2}{m_{\eta'}^2}$, $r_\ell = \frac{M_B^2}{m_\ell^2}$, $t = \frac{2E_\ell}{M_B}$, $s = \frac{2E_{\eta'}}{M_B}$ are the normalized energies of the lepton and η', respectively. $\cos(z)$ is given by

$$\cos(z) = \frac{2(1+r_2+r_\ell-s)+(-2+s)t}{\sqrt{(-4r_\ell+t^2)(-4r_{\eta'}+s^2)}}\,. \quad (20)$$

Here z is the angle between the final lepton (ℓ) and the η' particles.

Using (16) we get the following expression for the differential decay rate:

$$\frac{\mathrm{d}\Gamma(s)}{\mathrm{d}s} = \frac{\Delta(s)}{8(2\pi)^3} C^2 M^3\,, \quad (21)$$

where

$$C = \frac{8}{3}\alpha_\mathrm{s}^2 f_{B_c} A_{\eta'} \frac{G_\mathrm{F}}{\sqrt{2}} V_{cb}\,. \quad (22)$$

and the expression for Δ is

$$\Delta = \frac{(1+r_{\eta'}-r_\ell-s)^2\sqrt{-4r_{\eta'}+s^2}}{3(1+r_{\eta'}-s)^3} \times \Big\{2\left(1+r_{\eta'}-s\right)\left(-4r_{\eta'}+s^2\right) \times \left(|f_1|^2+|f_2|^2+2\,\mathrm{Re}[f_1 f_2^*]\right) - 4r_\ell\Big\{|f_1|^2\left(-3+r_{\eta'}+3s-s^2\right)+|f_2|^2 \left(r_{\eta'}-3r_{\eta'}^2+3r_{\eta'}s-s^2\right) + \mathrm{Re}\left[f_1 f_2^*\right]\left(8r_{\eta'}-3-3r_{\eta'}s+s^2\right)\Big\}\Big\}. \quad (23)$$

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 ℓ polarization asymmetries by

$$P_i(s) = \frac{\mathrm{d}\Gamma(\mathbf{e}_i)-\mathrm{d}\Gamma(-\mathbf{e}_i)}{\mathrm{d}\Gamma(\mathbf{e}_i)+\mathrm{d}\Gamma(-\mathbf{e}_i)}\,,\ (i=\mathrm{L},\mathrm{N},\mathrm{T})\,, \quad (24)$$

we find that

$$P_i(s) = \frac{\int A_i(t,s)\mathrm{d}t}{\int A_0(t,s)\mathrm{d}t}\,,\ (i=\mathrm{L},\mathrm{N},\mathrm{T})\,. \quad (25)$$

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 $\tau_{B_c} = 0.46$ ps. The decay constant f_{B_c} probes the strong (nonpertubative) QCD dynamics which bind the b and $\bar{c}$ quarks to form the bound state B_c. In the nonrelativistic limit, f_{B_c} can be related to the value of the B_c wave function at the origin [19]. The leptonic decay constant is estimated by QCD sum rules [20] and using the nonrelativistic potential models

$$f_{B_c} = \begin{cases} 450\ \text{MeV (Buchmüller-type potential [21])}\,, \\ 512\ \text{MeV (power law potential [22])}\,, \\ 479\ \text{MeV (logarithmic potential [23])}\,, \\ 687\ \text{MeV (Cornell potential [24])}\,. \end{cases} \quad (26)$$

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

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

$$t_{\mathrm{Max}} = \frac{(1+r_{\eta'}+r_\ell-s)(2-s)}{2(1+r_{\eta'}-s)} + \frac{|(1+r_{\eta'}-r_\ell-s)|\sqrt{(-4r_{\eta'}+s^2)}}{2(1+r_{\eta'}-s)}\,. \quad (27)$$

The dependence of the branching ratio on the normalized η' momentum for the μ and τ cases are displayed in Figs. 1 and 2. It is seen that the normalized η' 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 the basic scalar functions C_0 and C_{12} and C_{11} in [18], that the normalized η' momentum distribution behaves as

$$\propto \frac{1}{\sqrt{s^2-r_{\eta'}}}\,, \quad (28)$$

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

$$\mathrm{Br}(B_c \to \eta'\mu\bar{\nu}\,) \sim 1.6\times 10^{-4}\,, \quad (29)$$

$$\mathrm{Br}(B_c \to \eta'\tau\bar{\nu}\,) \sim 2.2\times 10^{-4}\,, \quad (30)$$

for μ, e leptons and τ leptons, respectively.

Figures 3 and 4 are displaying the dependency of P_{L} for μ and τ leptons, respectively. We see that the P_{L} for the

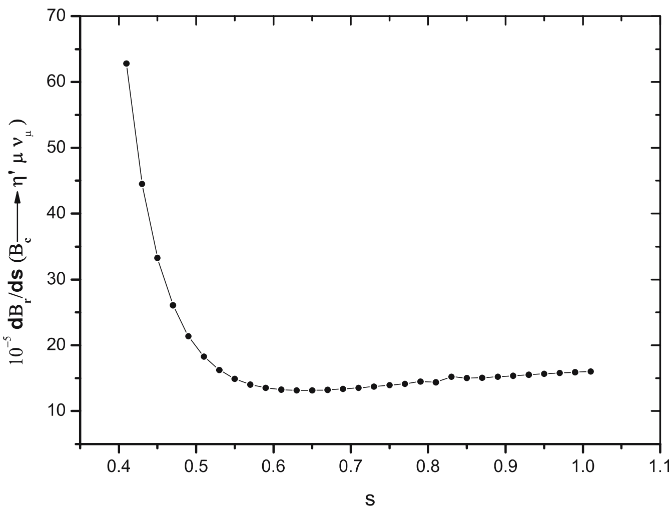

Fig. 1. The distribution of $\mathrm{d}Br/\mathrm{d}s$ as a function of s (normalized energy of η') for the $B_c \to \eta'\mu\nu_\mu$ decay

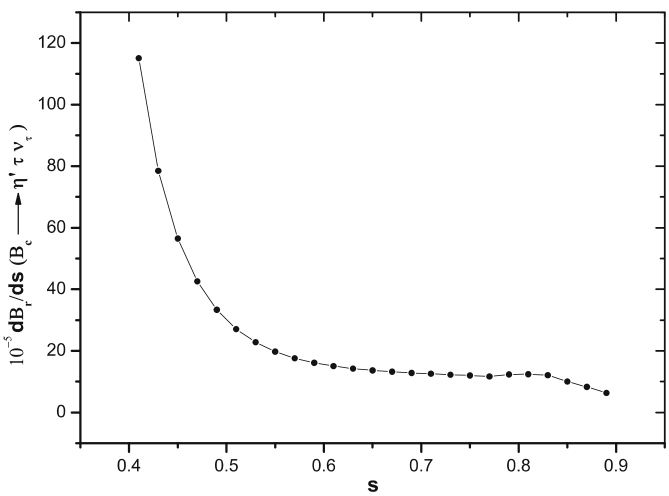

Fig. 2. The same as Fig. 1 but for for the $B_c \to \eta'\tau\nu_\tau$ decay

τ lepton can take both negative and positive values. Precisely, for $s \leq 0.45$ it takes negative values and elsewhere it is positive.

Figures 5 and 6 display the dependency of $P_{\rm N}$ for μ and τ leptons, respectively. We see that for both leptons $P_{\rm N}$ is negative and has a minimum at $s \simeq 0.83$ and $s \simeq 0.75$, respectively.

Figures 7 and 8 display the dependency of $P_{\rm T}$ for μ and τ leptons, respectively. We see that for both leptons $P_{\rm T}$ is negative and has a minimum at $s \simeq 0.95$ and $s \simeq 0.75$, respectively.

Finally, a few words about the detectability 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 μ and τ leptons (see Table 1).

Experimentally, to measure an asymmetry $\langle P_i \rangle$ of a decay with the branching ratio $\mathcal{B}$ at the $n\sigma$ level, the required number of events is given by the formula $N = n^2/(\mathcal{B}\langle P_i \rangle^2)$. It follows from this expression and Table 1 that to observe

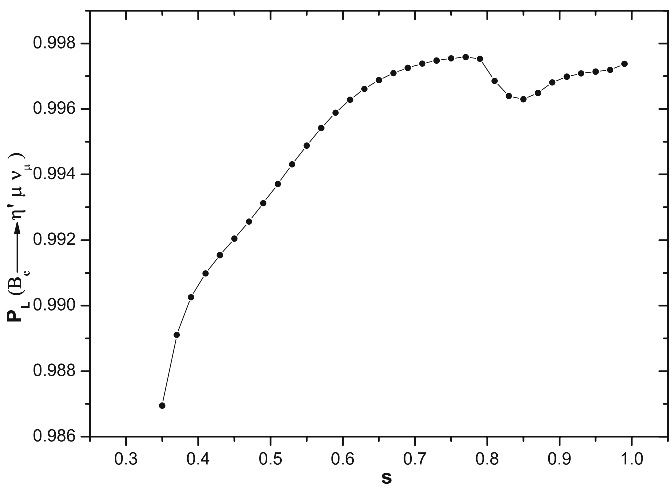

Fig. 3. The dependence of the longitudinal lepton polarization $P_{\rm L}$ on s for the $B_c \to \eta' \mu \nu_\mu$ decay

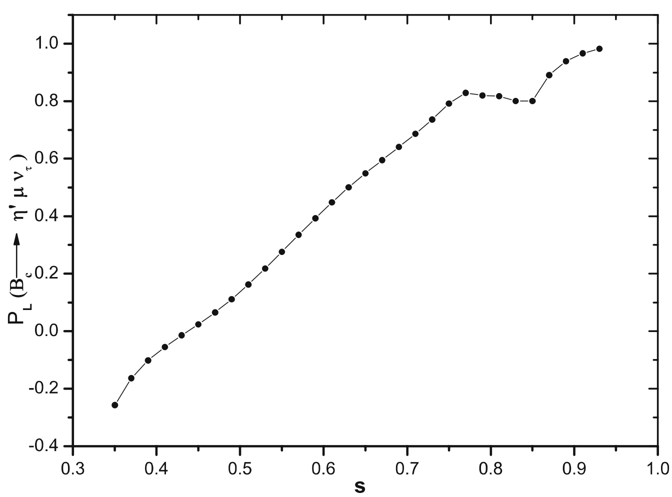

Fig. 4. The same as Fig. 3 but for the $B_c \to \eta' \tau \nu_\tau$ decay

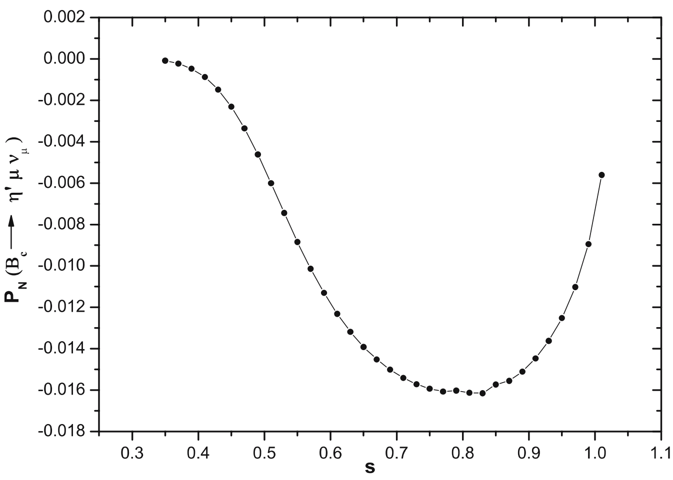

Fig. 5. The dependence of the normal lepton polarization $P_{\rm N}$ on s for the $B_c \to \eta' \mu \nu_\mu$ decay

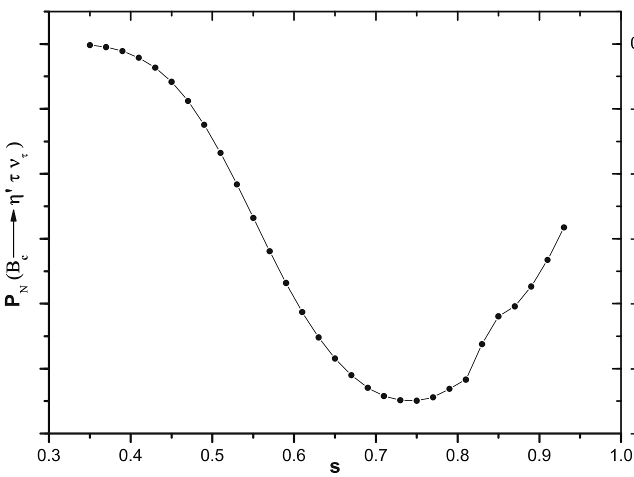

Fig. 6. The same as Fig. 5 but for the $B_c \to \eta' \tau \nu_\tau$ decay

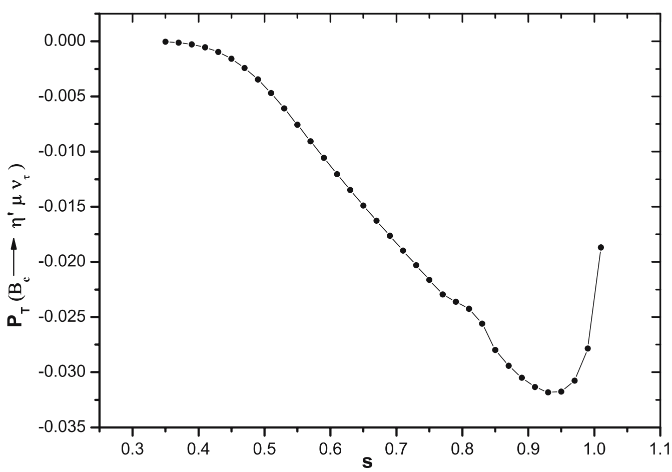

Fig. 7. The dependence of the transversal lepton polarization $P_{\rm T}$ on s for the $B_c \to \eta' \mu \nu_\mu$decay

the lepton polarizations $\langle P_{\rm L} \rangle, \langle P_{\rm N} \rangle$ and $\langle P_{\rm T} \rangle$ in $B_c^- \to \eta' \ell^- \bar{\nu}$ decay at 1σ level, the expected number of events are $N = (1, 3, 10^4) \times 10^7$, respectively. On the other hand,

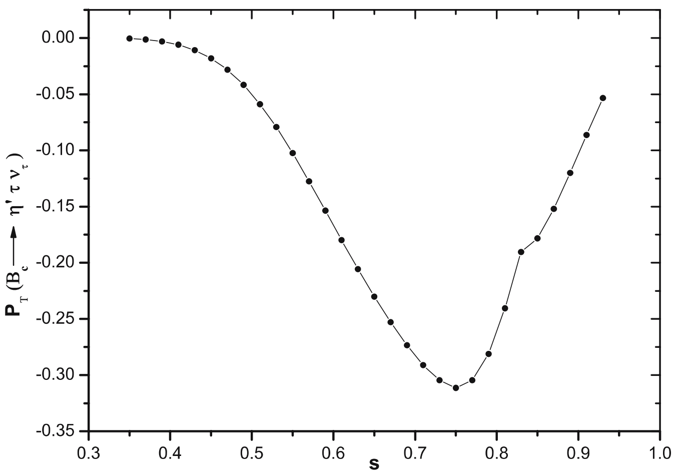

Fig. 8. The same as Fig. 7 but for the $B_c \to \eta' \tau \nu_\tau$ decay

Table 1. The averaged longitudinal, normal and transversal polarization for μ and τ leptons

$\langle P_i \rangle$	$B_c \to \eta' \mu \nu_\mu$	$B_c \to \eta' \tau \nu_\tau$
$\langle P_{\rm L} \rangle$	0.71	0.258
$\langle P_{\rm N} \rangle$	-0.007	-0.1
$\langle P_{\rm T} \rangle$	-0.009	-0.09

the number of $B\overline{B}$ pairs that are expected to be produced at B factories and LHCb will be 10^8 and 10^{12} $B\overline{B}$ pairs, respectively. A comparison of these numbers allows us to conclude that not only the measurements of the longitudinal polarization of the muon and the longitudinal, normal and transversal polarization of the τ lepton, but also the measurements of the normal and transversal polarizations of the μ 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 $B_c^- \to \eta' \ell^- \bar{\nu}$ and lepton polarization asymmetries.

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