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Semileptonic decays of bottom baryons at LEP

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We study semileptonic Λ_b decays where the Λ_b originates from Z_0 decays into b quarks. The differential decay distributions are calculated using the heavy quark effective theory. We investigate the energy distribution of the decay leptons. In Λ_b decays the lepton energy distribution is sensitive to the standard model parameters via the nontrivial Λ_b polarization. We also discuss a possibility to study b quark fragmentation into baryons using the semileptonic decays.

1. Introduction

Heavy quarks provide a useful tool to look into the standard model and beyond. In particular, the determination of the CKM matrix elements V_{cb} and V_{ub} from b quark decays [#1] and the observation of mixing in the neutral B meson system [2] have been important benchmarks in establishing the standard model.

From the theoretical point of view heavy quark systems may be described systematically within QCD by means of the heavy quark effective theory (HQET) [3,4]. It exploits the fact that the masses of the heavy quarks m are large compared to the scale parameter Λ_{QCD} associated with the light QCD degrees of freedom. In the limit $\Lambda_{\mathrm{QCD}}/m \to 0$ new symmetries arise above those already present in QCD. These lead to considerable simplifications in the description of heavy quark systems. Corrections to the heavy quark limit are of the order Λ_{QCD}/m and $\alpha_s(m)/\pi$. Thus one expects corrections less than ten percent for systems with bottom quarks and about three times larger corrections for the ones involving charm quarks.

There have been many beautiful and important results on the spectroscopy of charmed mesons and baryons and their hadronic and semileptonic decays [5]. In the bottom sector most data so far are on b mesons: In e^+e^- continuum production and in hadroproduction b baryons are very difficult to observe. On the other hand, fixed target experiments as well as e^+e^- resonance production on the $\Upsilon(4s)$ are below the b baryon threshold. Yet, we expect important advances in b baryon physics from LEP, HERA and $p\bar{p}$ colliders. In fact, first evidences for these baryons were already reported by the ALEPH Collaboration [6]. Theortically, the lowest lying b baryon, Λ_b, is particularly challenging since it is here where HQET has its largest predictive power. The light degrees of freedom are in a spin zero state for a Λ_b. Thus the spin of the baryon is the spin of the heavy quark due to the decoupling of the heavy quark spin in HQET.

We shall focus on the exclusive semileptonic decays $\Lambda_b \to \Lambda_c \ell \nu$ and discuss its differential decay distributions. We shall exploit the fact that there are three widely separated mass scales in the problem: $s \gg m \gg \Lambda_{\mathrm{QCD}}$ where $\sqrt{s}$ is the CMS energy of the collider, $s = M_Z^2$ for LEP. Note that we have to calculate the decay distributions in the LEP lab frame rather than in the rest frame of the heavy bottom hadron as it is needed for resonance production of B mesons at the $\Upsilon(4s)$.

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[#1] A review of the present status was given by M. Danilov in ref. [1].

The process which creates the heavy quark is in the present case governed by the large scale s and hence may be treated in a perturbative way. In particular, this provides a definite prediction for the b quark polarization. The subsequent fragmentation of the heavy quark into a heavy hadron involves the light QCD degrees of freedom. Thus it is governed by the small scale $\Lambda \ll m$ and the symmetries of the heavy quark limit are present already in the hadronization process with corrections being of the order of Λ/m. This means in particular that the spin of the heavy quark decouples from the hadronization process and has the interesting consequence that for the heavy ground state baryons (Λ_c and Λ_b) the spin of the baryon is given by the spin direction of the heavy quark. Thus in systems with heavy baryons there is the unique chance to measure the polarization of the quarks created for instance in Z_0 decays at LEP.

In the following we shall argue that the energy distribution of the charged decay lepton depends on the polarization of the b quark and can thus be used to extract the vector and axial vector couplings g_V and g_A for the b quark from such a measurement. The dependence of the decay lepton energy distribution on the b quark polarization is analogous to the τ polarization case $\tau \to \nu_\tau + \ell + \overline{\nu}$.

There are two reasons to focus on the semileptonic decays $\Lambda_b \to \Lambda_c \ell \nu$ and $\Lambda_b \to X_c \ell \nu$ with $\ell = e, \mu$. The first reason is that we expect them to constitute a substantial fraction of the total decay rate of the bottom baryons, namely to be close to the one given by the free b quark decay which yields branching fractions of about 12%. Furthermore, we shall argue that the inclusive decay is dominated by the channel $\Lambda_b \to \Lambda_c e \nu$. With these estimates one can obtain some information on the fragmentation process of b quarks in particular on the number of baryons created per number of fragmenting b quarks.

The second reason is that the semileptonic decays are relatively easy to reconstruct, in particular the energy distribution of the charged lepton is accessible. As is well known from the polarization analysis of $Z_0 \to \tau^+\tau^- \to \nu_\tau \overline{\nu_e} e^- X$, the polarization of the τ lepton may be inferred from the energy spectrum of the electron in the lab frame. In the present paper we give the corresponding formulae for a polarization analysis of Λ_b baryons created from a Z_0 decay. Similarly to the τ case the lepton energy spectrum in the lab frame contains the information on the baryon polarization, although matters become more complicated, since care has to be taken of the hadronic matrix element for which we shall apply HQET.

2. Exclusive semileptonic decay: $\Lambda_b \to \Lambda_c e \nu$

We first discuss the exclusive decay $\Lambda_b \to \Lambda_c \ell \nu$ where the decaying Λ_b is assumed to be polarized. We give the energy distribution in the laboratory frame in which the Λ_b has a momentum large compared to its mass. The dependence of the energy distribution on the polarization of the Λ_b is studied and the possibility to extract g_A and g_V for the b quark from this polarization measurement is discussed.

We employ the heavy quark limit [3] to write down the current for the weak transition from Λ_b to Λ_c. This current is in general given in terms of six independent form factors [4]:

$$\begin{aligned}
&\langle \Lambda_c(v_c, s_c) | \bar{c}\gamma_\mu(1-\gamma_5) b | \Lambda_b(v_b, s_b) \rangle \\
&\quad = \overline{u}_{\Lambda_c}(v_c, s_c)[F_1(v_b \cdot v_c)\gamma_\mu + F_2(v_b \cdot v_c) v_{b\mu} \\
&\quad + F_3(v_b \cdot v_c) v_{c\mu}] u_{\Lambda_b}(v_b, s_b) \\
&\quad - \overline{u}_{\Lambda_c}(v_c, s_c)[G_1(v_b \cdot v_c)\gamma_\mu + G_2(v_b \cdot v_c) v_{b\mu} \\
&\quad + G_3(v_b \cdot v_c) v_{c\mu}]\gamma_5 u_{\Lambda_b}(v_b, s_b),
\end{aligned} \tag{1}$$

where v_c, v_b are the velocities of the heavy baryons which are related to the momenta p_c, p_b by $p_c = m_c v_c$, $p_b = m_b v_b$ and s_b, s_c denote the spin vectors of the two baryons.

In leading order of HQET these six form factors reduce to only one independent form factor F:

$$F(v_b \cdot v_c) = F_1(v_b \cdot v_c) = G_1(v_b \cdot v_c) \tag{2}$$

$$\begin{aligned}
&F_2(v_b \cdot v_c) = F_3(v_b \cdot v_c) = G_2(v_b \cdot v_c) \\
&\quad = G_3(v_b \cdot v_c) = 0.
\end{aligned} \tag{3}$$

In addition, due to heavy quark symmetries this single form factor is normalized at maximum momentum transfer, i.e. at $v_b \cdot v_c = 1$, to

$$F(v_b \cdot v_c = 1) = 1. \tag{4}$$

The $v_b \cdot v_c$ dependence of the form factor contains nonperturbative informations on the matrix element and may not be calculated from first principles. For the numerical estimates we shall use the simple form

$$F(w) = \frac{w_0^2}{w_0^2 - 2 + 2w}. \tag{5}$$

We shall take the value $w_0 = 0.89$ which was obtained from fitting the lepton spectrum of exclusive semileptonic B decays [7]. In paper of Mannel et al. [7] several different parametrizations were fitted to the lepton spectrum. It turns out that the results for the semileptonic $B \to D$ or $B \to D^*$ decays do not strongly depend on the specific parametrization. This is mainly due to the fact, that the normalization of the form factor at the point $v_b \cdot v_c = 1$ is known and extrapolation off this point is not critical, since $v_b \cdot v_c$ ranges only between 1 and 1.6. We expect that the parametrization (5) is of similar quality for the baryonic decays discussed here.

From this form of the hadronic current we obtain the rate for the exclusive semileptonic decay

$$\begin{aligned}&\Lambda_b(p_b = m_b v_b, s_b)\\ &\quad \to \Lambda_c(p_c = m_c v_c, s_c) + \ell(p_\ell, s_\ell) + \bar{\nu}_\ell(p_\nu, s_\nu),\end{aligned} \tag{6}$$

summed over the spins of the final state particles

$$\begin{aligned}\mathrm{d}\Gamma &= 64 G_F^2 \frac{1}{2E_b} \widetilde{\mathrm{d}p_\nu}\, \widetilde{\mathrm{d}p_\ell}\, \widetilde{\mathrm{d}p_c} (2\pi)^4\\ &\quad \times \delta(p_b - p_c - p_\ell - p_\nu) |F(v_b \cdot v_c)|^2\\ &\quad \times (p_c \cdot p_\ell)[(p_\nu \cdot p_b) - m_b (s_b \cdot p_\nu)].\end{aligned} \tag{7}$$

Here $E_b = p_{b0}$ is the energy of the decaying Λ_b and $\widetilde{\mathrm{d}p} = \mathrm{d}^3\boldsymbol{p}/[2E(2\pi)^3]$. We shall express the rate doubly differential in the momentum transfer to the leptonic system $q^2 = (p_\ell + p_\nu)^2 = 2(p_\ell \cdot p_\nu)$ and the energy of the lepton $E_\ell = p_{\ell 0}$ in the laboratory frame. Note that $v_b \cdot v_c = (m_b^2 + m_c^2 - q^2)/(2 m_b m_c)$.

The phase space integration may be performed by standard methods to yield the doubly differential rate $\mathrm{d}^2\Gamma/(\mathrm{d}q^2\,\mathrm{d}x)$, where $x = E_\ell/E_b$ is the scaled lepton energy. We first give the result for the unpolarized piece Γ_u. It may be expressed in terms of the function

$$f(s) = (\Delta + q^2)s - \tfrac{1}{2}s^2 - q^2 \Delta \ln s, \tag{8}$$

where we have defined $\Delta = m_b^2 - m_c^2 + q^2$. The unpolarized doubly differential rate is then given by

$$\begin{aligned}\frac{\mathrm{d}^2\Gamma_u}{\mathrm{d}q^2\,\mathrm{d}x} &= \frac{G_F^2}{16\pi^3} \frac{1}{E_b \beta} |F(v_b \cdot v_c)|^2\\ &\quad \times [f(s_{\max}) - f(s_{\min})],\end{aligned} \tag{9}$$

where the integration limits $s_{\max}$ and $s_{\min}$ are functions of q^2 and x:

$$s_{\max} = \min\left(\tfrac{1}{2}(\Delta + \sqrt{\Delta - 4m_b^2 q^2}), \frac{2x m_b^2}{1-\beta}\right), \tag{10}$$

$$s_{\min} = \max\left(\tfrac{1}{2}(\Delta - \sqrt{\Delta - 4m_b^2 q^2}), \frac{2x m_b^2}{1+\beta}\right), \tag{11}$$

and $\beta = |\boldsymbol{p}_b|/E_b$.

The polarized piece Γ_p, i.e. the piece containing the polarization vector s_b, is given in terms of the function g:

$$\begin{aligned}g(s) &= -\tfrac{1}{4}s^2 + \tfrac{1}{2}s(2m_b^2 x + \Delta + q^2)\\ &\quad - \ln s[m_b^2 x(\Delta + q^2) + \tfrac{1}{2}q^2(2m_b^2 + \Delta)]\\ &\quad - \frac{1}{s}[m_b^2 x q^2 (2m_b^2 + \Delta) + (m_b q^2)^2] + \frac{1}{s^2} x (m_b^2 q^2)^2.\end{aligned} \tag{12}$$

We obtain

$$\begin{aligned}\frac{\mathrm{d}^2\Gamma_p}{\mathrm{d}q^2\,\mathrm{d}x} &= \frac{G_F^2}{8\pi^3} \frac{1}{E_b \beta^2} |F(v_b \cdot v_c)|^2\\ &\quad \times [g(s_{\max}) - g(s_{\min})].\end{aligned} \tag{13}$$

Finally, the rate Γ for the decay of the polarized Λ_b baryons with a degree of polarization

$$\mathcal{P} \equiv \frac{\mathrm{d}\Gamma(+s) - \mathrm{d}\Gamma(-s)}{\mathrm{d}\Gamma(+s) + \mathrm{d}\Gamma(-s)} \tag{14}$$

is given by

$$\frac{\mathrm{d}^2\Gamma}{\mathrm{d}q^2\,\mathrm{d}x} = \frac{\mathrm{d}^2\Gamma_u}{\mathrm{d}q^2\,\mathrm{d}x} + \mathcal{P} \frac{\mathrm{d}^2\Gamma_p}{\mathrm{d}q^2\,\mathrm{d}x}. \tag{15}$$

We note that the Λ_b decay rate depends on $\beta = |\boldsymbol{p}_b|/E_b$. Taking carefully the limits $\beta = 0$ in (9) and (13) and a constant form factor $F(w) = 1$ we recover the well known formula for the semileptonic decay width of a free b quark [8]. Neglecting higher order corrections the energy of the b quark at LEP is half the Z_0 mass. In the heavy quark limit the Λ_b becomes degenerate with the mass of the b quark and we shall take $E_b = E_{\Lambda_b} = \frac{1}{2}M_Z = 45$ GeV $(1 - \beta = 1.2\%)$ for our numerical estimate. This corresponds to a hard fragmentation function for $b \to \Lambda_b$

which is expected to be similarly hard as the one for $b \to B$. We have explicitly checked that the energy distribution is very insensitive to the precise value of E_b as long as $E_b \gg m_b$ and thus we do not expect large effects from the fragmentation function.

We now concentrate on the lepton energy distribution which is arrived at by integrating over q^2. We show in fig. 1 the resulting x shapes for three different cases. (5). The two pieces Γ_u and Γ_p of the rate are plotted separately for $m_b = 5.2$ GeV. The solid line is the case of constant form factor $F(w) = 1$ and $m_c = 0$. In this limit the q^2 integration may be performed analytically. It yields

$$\frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}x} = \tfrac{1}{3}(5 - 9x^2 + 4x^3) - \mathcal{P}\tfrac{1}{3}(1 - 9x^2 + 8x^3). \qquad (16)$$

the well known result for the lepton energy spectrum obtained for the process $Z_0 \to \tau^+\tau^- \to \ell\nu X$ [9].

The dashed curve is the lepton energy spectrum for finite charm quark mass but still $F(w) = 1$. We have taken the value $m_c = 1.8$ GeV. Including the finite charm quark mass has the effect that the variable x has the upper limit $x \leqslant \frac{1}{2}(\beta + 1)(1 - m_c^2/m_b^2) \approx 0.88$. Furthermore, small values of x are enhanced and large values become suppressed in the unpolarized rate. Similarly the polarized piece depends stronger on x than in the case $m_c = 0$.

Finally, the dashed dotted curve includes the form factor as given in (5). For the unpolarized piece this reduces the x dependence compared to the case with constant form factor, while the x dependence of the polarized piece gets strongly enhanced. In particular for small lepton energies the polarized contribution gets enlarged by about a factor of two.

As remarked already before, the heavy quark spin decouples in the heavy quark limit and the spin of the heavy baryon is the spin of the bound b quark. The hadronization process is soft and thus HQET predicts that the polarization of the heavy baryon is the polarization of the heavy quark as it was produced in the Z_0 decay. The polarization of the b quark is given by the vector and axial vector couplings g_V and g_A of the b quark to the Z_0. Thus a measurement of the polarization of the Λ_b gives a possibility to measure g_A and g_V for the b quark. The standard model prediction for the polarization $\mathcal{P}$ of a Λ_b or, equivalently, of a b quark from a Z_0 decay is quite large:

$$\mathcal{P} = \frac{2g_A g_V}{g_A^2 + g_V^2} = 0.94. \qquad (17)$$

In order to investigate the sensitivity of the lepton spectrum to the polarization $\mathcal{P}$ we plot in fig. 2 the x distribution $\mathrm{d}\Gamma/\mathrm{d}x = \mathrm{d}\Gamma_u/\mathrm{d}x + \mathcal{P}\,\mathrm{d}\Gamma_p/\mathrm{d}x$ for the case of an unpolarized Λ_b (dashed curve) and for a polarized Λ_b (solid curve) with a polarization as given in (17). The shapes of the two curves are quite different. In particular for small values of x the sensitivity to the polarization (and thus to g_A and g_V) is very large, since in the region $0 \leqslant x \leqslant 0.3$ the

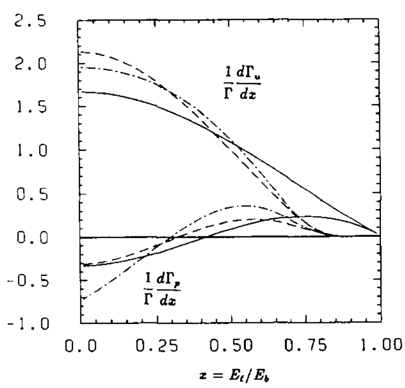

Fig. 1. The energy distribution of the lepton in the laboratory frame split into the polarized and unpolarized piece. solid curves: constant form factor and $m_c = 0$, dashed curves: constant form factor and $m_c = 1.8$ GeV, dashed dotted curves: form factor as in (5) and $m_c = 1.8$ GeV.

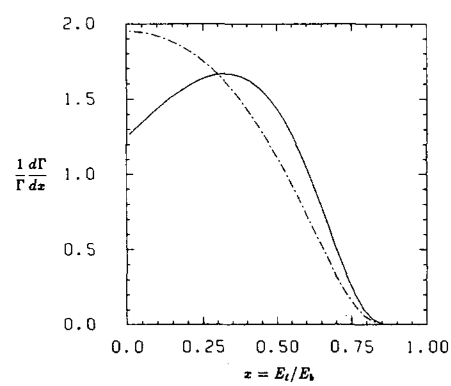

Fig. 2. The energy distribution of the lepton in the laboratory frame for unpolarized Λ_b decay (dashed curve) and the standard model prediction (solid curve).

spectrum is a monotonically increasing function of x while the unpolarized one decreases.

3. Inclusive decay: $\Lambda_b \to X_c \ell \nu$

Heavy quark methods are not directly applicable to inclusive processes. On the other hand it is known from the semileptonic B meson decays that the major contribution to the total semileptonic branching fraction comes from the two lowest lying D meson states; the D and the D^* meson saturate the inclusive semileptonic rate to a large extent.

This saturation is expected in the heavy quark picture: At the point of maximum momentum transfer $v_b \cdot v_c = 1$ the only possible final states are the lowest spin symmetry doublett, namely the D and the D^*, since in the heavy quark limit the light degrees of freedom do not change in the weak transition of the heavy quark. As remarked before, in a $B \to D$ or $B \to D^*$ transition the maximum value of $v_b \cdot v_c$ is about 1.6 and thus there is no strong change in the light degrees of freedom over the whole kinmatically allowed range.

We expect a similar behaviour for the Λ_b. Since the two polarization directions of the Λ_c are the lowest baryonic spin symmetry doublett with a charm quark the decay $\Lambda_b \to \Lambda_c e\nu$ alone should saturate the inclusive rate $\Lambda_B \to X_c e\nu$ to the same extend like $B \to De\nu$ and $B \to D^* e\nu$ saturate $B \to X_c e\nu$.

The dominance of the lowest spin symmetry doublett is in fact seen in the B meson decays. Taking the values from ref. [10] we have a saturation of $(95^{+5}_{-25}\%$ of the inclusive semileptonic rate from these two channels. Although recent CLEO data indicate, that the value of [10] for $B \to D^* e\nu$ could be a factor of two too large [11], the dominance of these two channels is still at a level of 70%. However, even such a low saturation percentage will not invalidate any of our arguments.

In addition, $\Lambda_b \to \Sigma_c e\nu$ transitions are suppressed by at least one power of $\Lambda_{\mathrm{QCD}}/m_c$ [4] and thus we expect that the above lepton spectrum should also be a reasonable approximation to the inclusive lepton spectrum. This is of some importance since at the present stage the semileptonic Λ_b decays are not fully reconstructed and thus only the inclusive rate is accessible [12].

4. Fragmentation of a b quark into baryons

Baryon production at colliders is usually described as a two step process, the production of a heavy quark occurring at a short time scale $\sim 1/Q$ where Q is of the order of the heavy quark mass, and a subsequent fragmentation occurring at much smaller scale, of the order of Λ_{QCD}. While heavy quark production can reliably be calculated in perturbation theory, quark fragmentation into mesons and baryons can so far only be modelled and is thus subjected to rather large uncertainties. In the LUND string model [13], for example, it is assumed that antidiquark–diquark (colour triplet–antitriplet) pairs are produced in the chromoelectric field in a way similar to the production of quark antiquark pairs. The production can be treated as a tunneling phenomenon and its probability is therfore proportional to $\exp(-\pi m^2/\kappa)$ where $\kappa \approx 0.2\,\mathrm{GeV}^2$. Thus the relative probability for diquark to quark production is about qq : q = 0.09 : 1 which corresponds to a nonstrange diquark mass of about 420 MeV. This assumption also implies that strange diquarks will be much suppressed compared to nonstrange diquarks. Furthermore, spin 1 diquarks will have about the same probability since the relative heavier mass compared to the spin 0 diquarks is (roughly) compensated by an extra factor of 3 from counting the different spin states.

Although the s quark is certainly not heavy we expect from comparison with the strange baryons that the spin $\frac{3}{2}$ b baryons will decay strongly into either Λ_b or Σ_b. The neutral Σ_b^0 will decay electromagnetically into a Λ_b; this leaves us with the Λ_b and the charged $\Sigma_b^\pm$ as possible candidates for weak decays. In the strange baryon systems the phase space is not sufficient to allow for the strong decay $\Sigma^\pm \to \Lambda\pi^\pm$ and hence the charged Σ hyperons decay weakly. Since one expects that the Σ–Λ mass splitting does not scale with the heavy quark mass one may argue that one should expect a similarly small splitting in the b baryon system. Thus one would conclude that the charged $\Sigma_b^\pm$ will decay weakly.

However, one may as well argue that the charged Σ_b decays strongly. In the corresponding systems involving charm quarks the phase space is just sufficient for the strong decay $\Sigma_c \to \Lambda_c\pi$. In addition, quark model calculations for b baryons [14] yield a Σ_b–Λ_b mass difference between 140 and 330 MeV, which is sufficient for a strong decay.

We shall not try to settle this issue in the present paper but rather assume that only the Λ_b will decay weakly. From this assumption we expect that the electron spectrum from the semileptonic b baryon decays is given by the one for the Λ_b decays. If this assumption were wrong the spectrum would look different due to the different x shape of the semileptonic $\Sigma_b^{\pm}$ decays.

From our above discussion of semileptonic decays we propose a measurement of the fragmentation $b \to \Lambda_b$ in e^+e^- annihilation at LEP. The method is based on the decay chain

$$\Lambda_b \to \Lambda_c + \ell^- + \overline{\nu}_\ell + X \to \Lambda + \ell^- + X \qquad (18)$$

and the experimental ability to distinguish between Λ and $\overline{\Lambda}$ [6]. Consider first the inclusive semileptonic decay $\Lambda_b \to X_c + \ell^- + \overline{\nu}_\ell$. Since the free quark decay formula works reasonably well in the B and the D system we shall take this branching ratio equal to the one for a free b quark decay. The same argument holds for the B mesons and we expect that the inclusive semileptonic brancing fraction of Λ_b should be very close to the one for the inclusive semileptonic B meson decays. Thus we expect

$$\mathrm{Br}(\Lambda_b \to X_c \ell \nu) = (10\text{–}13)\%. \qquad (19)$$

Consider now $X_c \to \Lambda + X$. Since $V_{bc} \gg V_{bu}$ we may neglect possible $b \to u$ transitions. Furthermore, as argued in the last section we expect the exclusive decay $\Lambda_b \to \Lambda_c e\nu$ to saturate the inclusive semileptonic rate to about 90 %.

Thus we have $\mathrm{Br}(\Lambda_b \to \Lambda_c X \ell \nu) \geqslant 90\% \cdot \mathrm{Br}(\Lambda_b \to X_c \ell \nu)$, where X may be empty and we may take this branching fraction to be one for the estimates presented here. The decay $\Lambda_c \to \Lambda X$ is known to have a branching fraction of $27 \pm 9\%$ and may be used to identify the Λ_c through the $\Lambda \ell^-$ combination.

5. Conclusions

Heavy flavor physics at colliders is an interesting way to obtain information on those heavy hadrons which may not be investigated at e^+e^- machines running on the $\Upsilon(4s)$ resonance. In particular bottom baryons may be accessible only in this way in the near future.

Theoretically heavy hadrons may be consistently described by HQET, which is a systematic expansion of QCD in powers of Λ_{QCD}/m. This framework has been sucessfully used to describe heavy flavor decays in an environment of an e^+e^- machine running on the $\Upsilon(4s)$ resonance.

Aside from the mass scales involved in HQET Λ_{QCD} and m_{H} a third scale is involved at a collider, namely the cms energy of the collider $\sqrt{s}$. Since $s \gg m_{\mathrm{H}} \gg \Lambda_{\mathrm{QCD}}$, the creation of the heavy quarks may be treated in perturbative QCD from which also a prediction for the heavy quark polarization is obtained. The fragmentation of the heavy quarks into hadrons is governed by a small scale of the order of Λ_{QCD} and thus heavy quark symmetries are present already in the hadronization process. From this and from the predictions for the decays of the heavy hadrons from HQET one may extract additional information from heavy quark decays at colliders.

In the present note we have presented a detailed analysis of how to extract information on standard model parameters from the semileptonic Λ_b decays at an e^+e^- collider. Our results may be easlily transferred to other types of colliders, since only the energy spectrum of the b quarks enters the analysis. We pointed out that one can do polarization measurements of the heavy quarks created in Z_0 decays, since the heavy quark spin decouples from the soft hadronization process and the polarization of the Λ_b baryons is the same as for the bottom quarks. The polarization of the Λ_b baryon may be measured from the energy distribution of the lepton in the laboratory frame and yields direct access to the vector and axial vector couplings of the bottom quark. Since the exclusive decay $\Lambda_b \to \Lambda_c e\nu$ is expected to saturate a large fraction of the inclusive semileptonic rate of the Λ_b it will be possible to obtain some information from the inclusive lepton spectra.

Finally we discussed a way to obtain some information on the fragmentation process of a b quark into bottom baryons. From the analysis we have presented it should be possible to measure the number of Λ_b baryons created per fragmenting b quark in the near future.

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