Determination of the $b \to c$ handedness using nonleptonic Λ_c decays

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We consider possibilities to determine the handedness of $b \to c$ current transitions using semileptonic baryonic $\Lambda_b \to \Lambda_c$ transitions. We propose to analyze the longitudinal polarization of the daughter baryon Λ_c by using momentum-spin correlation measurements in the form of forward-backward (FB) asymmetry measures involving its nonleptonic decay products. We use an explicit form factor model to determine the longitudinal polarization of Λ_c in the semileptonic decay $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$. The mean longitudinal polarization of Λ_c is negative (positive) for left-chiral (right-chiral) $b \to c$ current transitions. The frame-dependent longitudinal polarization of Λ_c is large ($\cong 80\%$) in the Λ_b rest frame and somewhat smaller (30%–40%) in the lab frame when the Λ_b's are produced on the Z^0 peak. We suggest to use nonleptonic decay modes of Λ_c to analyze its polarization and thereby to determine the chirality of the $b \to c$ transition. Since Λ_b's produced on the Z^0 are expected to be polarized we discuss issues of the polarization transfer in $\Lambda_b \to \Lambda_c$ transitions. We also investigate the $p_\perp$- and p-cut sensitivity of our predictions for the polarization of Λ_c.

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In the standard model the charged current transition $b \to c$ is predicted to be left chiral; i.e., the Dirac structure of the transition is given by $\bar{b}\gamma_\mu(1-\gamma_5)c$. This prediction of the standard model has recently been confirmed by a determination of the sign of the lepton's forward-backward (FB) asymmetry in the $(l^-\bar{\nu}_l)$ rest system in the semileptonic decay[1] $\bar{B} \to D^* + l^- + \bar{\nu}_l$ [1,2]. In this analysis one uses the standard model left handedness of the lepton current as input. However, if one leaves the realm of the standard model, the same FB asymmetry would arise if both quark and lepton currents were taken to be right chiral, i.e., if one would switch from an $H_{\mu\nu}(V-A)L^{\mu\nu}(V-A)$ coupling to an $H_{\mu\nu}(V+A)L^{\mu\nu}(V+A)$ coupling.[2]

The FB asymmetry measure alluded to above constitutes a momentum-momentum correlation measure $\langle \mathbf{l}\cdot\mathbf{p} \rangle$ which clearly is not a truly parity-violating measure.[3] What is needed to distinguish between the two above options is to define truly parity-violating spin-momentum correlation measures of the type $\langle \sigma\cdot\mathbf{p} \rangle$.

Some such possible parity-violating measures that have been discussed recently exploit the fact that bottom quarks produced on the Z^0 resonance acquire a $\cong 94\%$ negative longitudinal polarization. In the case that the bottom quark hadronizes into the Λ_b bottom baryon there is a 100% polarization transfer, at least in the heavy-quark limit [5]. One can then define spin-momentum correlations with respect to the longitudinal spin direction of the decaying Λ_b using the momenta of the decay products of the Λ_b. For the semileptonic decays $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$ this has been done using the lepton momentum [5,6] and the Λ_c momentum [6,7]. The sign of these correlations or the sign of the correspondingly defined FB asymmetries allows one to differentiate the above two options which remain after the analysis of the mesonic experiments [1,2]: i.e., the $H_{\mu\nu}(V-A)L^{\mu\nu}(V-A)$ or the $H_{\mu\nu}(V+A)L^{\mu\nu}(V+A)$ option. A drawback of the suggested analyses is that they require the reconstruction of the Λ_b rest frame which will be a difficult experimental task.[4]

Alternatively one can consider the shape of the lepton spectrum directly in the laboratory system [8]. The spin-lepton-momentum correlation effects referred to above have the effect that the emitted leptons in the semileptonic decay $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$ (or $b \to c + l^- + \bar{\nu}_l$) tend to counteralign and align with the polarization of the b for $H_{\mu\nu}(V-A)L^{\mu\nu}(V-A)$ and $H_{\mu\nu}(V+A)L^{\mu\nu}(V+A)$ interactions, respectively, leading to harder and softer lep-

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[1] For a discussion of theoretical background see [3].

[2] A viable model involving a right-handed W_R that is consistent with all present data has recently been proposed [4].

[3] For example, it is well known that in e^+e^- annihilation the two-photon exchange contribution also gives rise to nonvanishing FB asymmetries despite the fact that QED is parity conserving.

[4] There is some hope, though, that such a reconstruction can be done with the newly installed vertex detectors in the experiments at the CERN e^+e^- collider LEP (A. Putzer, private communication).

ton spectra in the laboratory system relative to unpolarized decay allowing one to distinguish between the two options in principle. However, as emphasized in [5], a lack of knowledge of the precise form of the $b \to \Lambda_b$ fragmentation function precludes a decision whether the lepton spectrum is harder or softer than that of unpolarized decay, in particular, since there is no unpolarized decay sample to compare with.

Another possibility to distinguish between the $H_{\mu\nu}(V-A)L^{\mu\nu}(V-A)$ and $H_{\mu\nu}(V+A)L^{\mu\nu}(V+A)$ options via a parity-violating measure is to determine the polarization of the lepton in the semileptonic decays $B \to D(D^*)+l^- + \bar{\nu}_l$ [9] or $\Lambda_b \to \Lambda_c + l^- + \nu_l$ [10]. This will be a difficult experiment but may be feasible in the not too distant future for semileptonic decays involving the τ lepton.

In this paper we propose yet a fourth variant of a truly parity-violating spin-momentum correlation measure in $b \to c$ decays. We propose to look at the decay cascade $\Lambda_b \to \Lambda_c(\to a_1 + a_2 + \cdots) + l^- + \bar{\nu}_l$ to determine the chirality of $b \to c$ decays where $\Lambda_c \to a_1 + a_2 + \cdots$ are nonleptonic decays of the Λ_c. The weak nonleptonic decays of the Λ_c serve to analyze the polarization of the Λ_c through the correlation of their momenta with the polarization of the decaying Λ_c. Ideal in this regard are the nonleptonic decays $\Lambda_c \to \Lambda\pi$ and $\Lambda_c \to \Sigma\pi$ the analyzing power of which has recently been determined [11–13]. As a further analyzing channel we discuss the decay modes $\Lambda_c^+ \to p\bar{K}^{*0}$ and $\Lambda_c^+ \to \Delta^{++}K^-$ which could make up a large fraction of the dominant decay mode $\Lambda_c \to pK^-\pi^+$. The analyzing power of these channels has not yet been determined experimentally but can be estimated using the theoretical quark model ansatz of [14].

Consider first the semileptonic decay of an unpolarized Λ_b. Possible polarization effects due to polarized Λ_b decays average out if one integrates over all possible momentum directions of the Λ_c in the decay $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$. Possible Λ_b polarization effects due to incomplete averaging because of experimental cut biases will be discussed later on. We define heliticity form factors for the $\Lambda_b \to \Lambda_c$ transition in the Λ_b rest system by writing

$$H_{\lambda_2\lambda_W} = \langle \Lambda_2;\lambda_2 | V_\mu - \xi A_\mu | \Lambda_1;\lambda_1 \rangle \epsilon^\mu(\lambda_W) , \tag{1}$$

where we have switched to a more generic notation and identify the labels b and c with 1 and 2, respectively. We have introduced a chirality parameter ξ which takes the value $\xi = 1$ and -1 for left-chiral and right-chiral current transitions, respectively. λ_i and λ_W denote the helicities of the Λ_i ($i=1,2$) and the off-shell W boson where $\lambda_1 = \lambda_2 - \lambda_W$ [7,15]. The longitudinal polarization P_L of the Λ_c along the momentum direction of the Λ_c in the Λ_b *rest system* is given by[5] [7,15] (the polarization of the Λ_c in the laboratory frame will be discussed later on)

$$P_L = \frac{|H_{1/2\,1}|^2 - |H_{-1/2\,-1}|^2 + |H_{1/2\,0}|^2 - |H_{-1/2\,0}|^2}{|H_{1/2\,1}|^2 + |H_{-1/2\,-1}|^2 + |H_{1/2\,0}|^2 + |H_{-1/2\,0}|^2} . \tag{2}$$

[5]In Ref. [7] the longitudinal polarization was denoted by α.

Employing simple helicity arguments, P_L is expected to be negative and positive in most of the phase-space region for left-chiral ($\xi = 1$) and right-chiral ($\xi = -1$) $b \to c$ transitions, respectively. For the mean value of P_L one finds

$$\langle P_L \rangle = \xi \begin{cases} -0.77 & \text{IMF [16]} , \\ -0.81 & \text{FQD} . \end{cases} \tag{3}$$

The two polarization values refer to the heavy-quark effective theory (HQET) improved infinite momentum frame (IMF) model of Ref. [16] and free quark decay (FQD) where we use $m_b = M_{\Lambda_b} = 5.64$ GeV and $m_c = M_{\Lambda_c} = 2.285$ GeV in order to get the phase space right (see, e.g., [16]).[6]

The longitudinal polarization of the Λ_c can be probed by looking at the angular distribution of its subsequent nonleptonic decays. Ideal in this regard are the nonleptonic modes $\Lambda_c \to \Lambda\pi$ and $\Lambda_c \to \Sigma\pi$ since the analyzing power of these decays has recently been determined. For $\Lambda_c \to \Lambda\pi$ one has

$$\alpha_{\Lambda_c \to \Lambda\pi} = \begin{cases} -1.0^{+0.4}_{-0.0} & [11] , \\ -0.96 \pm 0.42 & [12] . \end{cases} \tag{4}$$

For $\Lambda_c \to \Sigma\pi$ we quote the preliminary value [13]

$$\alpha_{\Lambda_c \to \Sigma\pi} = -0.43 \pm 0.23 \pm 0.20 . \tag{5}$$

The decay distribution of the Λ or Σ in the Λ_c rest frame reads [7,15]

$$W(\Theta_\Lambda) = 1 + P_L \alpha_{\Lambda_c} \cos\Theta , \tag{6}$$

where the polar angle Θ is measured with respect to the original flight direction of the Λ_c and α_{Λ_c} stands for either of the asymmetry parameters in (4) and (5). Correspondingly, one can define a forward-backward asymmetry by averaging over the daughter baryons in the respective forward (F) ($0° \le \Theta < 90°$) and backward (B) ($90° \le \Theta < 180°$) hemispheres to obtain

$$A_{\rm FB} = \tfrac{1}{2} P_L \alpha_{\Lambda_c} . \tag{7}$$

Judging from the large numerical values of the mean of P_L, Eq. (3), and of the asymmetry parameters α_{Λ_c}, Eqs. (4) and (5), a measurement of the sign of $A_{\rm FB}$ within reasonable error should allow one to conclude for the sign of ξ and therefore for the chirality of the $b \to c$ transition with a good certainty.

Next we turn to the decay mode $\Lambda_c \to pK^-\pi^+$. This is the darling channel for experimentalists as it is easy to identify experimentally. According to the authors of [17] its branching ratio is approximately five times bigger than $\Lambda_c \to \Lambda\pi$. Note also that this decay mode has been used to reconstruct the Λ_c in semileptonic Λ_b decays pro-

[6]The difference in the two values, Eq. (3), does not imply that $1/m_Q$ effects are large in the IMF model of [16]. The difference is mainly due to form-factor effects which enhance the high-q^2 region in form-factor models where the polarization is smallest.

duced on the Z_0 [18]. However, nothing is known experimentally about the analyzing power of this channel. We therefore have to turn to some theoretical input. One may either concentrate on the resonant substructures $\Lambda_c\to p\bar{K}^{*0}$ and $\Lambda_c\to\Delta^{++}K^-$ present in $\Lambda_c\to pK^-\pi^+$ or treat the decay in a resonance approximation in that one assumes that the decay is dominated by the channels $\Lambda_c\to p\bar{K}^{*0}$ and $\Lambda_c\to\Delta^{++}K^-$. The present experimental evidence for the viability of such a resonance approximation is somewhat inconclusive. The Mark II Collaboration [19] quotes relative branching ratios of $(18\pm10)\%$ and $(17\pm7)\%$ for $\Lambda\to p\bar{K}^{*0}$ and $\Lambda_c\to\Delta^{++}K^-$, respectively, relative to $\Lambda_c\to pK^+\pi^-$, the R415 Collaboration [20] quotes $(42\pm24)\%$ and $(40\pm17)\%$, respectively, for the same two relative branching ratios and, more recently, the ACCMOR Collaboration [21] quotes $(35^{+0.06}_{-0.07}\pm0.03)\%$ and $(12^{+0.04}_{-0.05}\pm0.05)\%$, respectively. One can only hope that future experiments can clarify the situation. At any rate, the channel $\Lambda_c\to p\bar{K}^{*0}$ can be expected to have a substantial branching ratio.

For the decay mode $\Lambda_c^{\uparrow}\to p\bar{K}^{*0}$ one can write down a polar decay distribution in complete analogy with Eq. (6). In the Λ_c rest frame one has

$$W(\Theta_p)=1+P_L\alpha_p\cos\Theta_p\ , \tag{8}$$

where Θ_p is the polar angle of the proton relative to the original direction of flight of the Λ_c. The asymmetry parameter α_p is given by

$$\alpha_p=\frac{-|H_{1/2\,1}|^2+|H_{-1/2\,-1}|^2+|H_{1/2\,0}|^2-|H_{-1/2\,0}|^2}{|H_{1/2\,1}|^2+|H_{-1/2\,-1}|^2+|H_{1/2\,0}|^2+|H_{-1/2\,0}|^2} \tag{9}$$

and the $H_{\lambda_p\lambda_{K^*}}$ are helicity amplitudes defined by (see, e.g., [14])

$$H_{\lambda_p\lambda_{K^*}}=\langle p,\lambda_p;\bar{K}^{*0},\lambda_{K^*}|\mathcal{H}_{\rm nl}|\Lambda_c,\lambda_{\Lambda_c}\rangle \tag{10}$$

with $\lambda_p-\lambda_{K^*}=\lambda_{\Lambda_c}$. We mention that the decay distribution Eq. (8) and the asymmetry parameter α_p (9) can be directly transcribed from the corresponding decay distribution for $(\frac{1}{2}^+)^{\uparrow}\to(\frac{1}{2}^+)+W_{\rm off\ shell}$ written down in [7,15].

Analogous to Eq. (7) one can then define a forward-backward asymmetry averaging over protons in the forward $(0°\le\Theta<90°)$ and backward $(90°\le\Theta<180°)$ hemispheres, where F and B are defined relative to the flight direction of the Λ_c. One obtains

$$A_{\rm FB}=\tfrac{1}{2}P_L\alpha_p\ . \tag{11}$$

The asymmetry parameter α_p can be calculated using the quark model approach of Ref. [14]. The relevant quark line diagrams are drawn in Fig. 1. For the decay $\Lambda_c\to p\bar{K}^{*0}$ there is a factorizing contribution (IIa) and a W-exchange contribution (IIb). The relative amplitude of the two contributions has been determined in [14] through a fit to the available data on nonleptonic Λ_c decays whereas the factorizing contribution can be calculated for particular wave-function models. Using the results

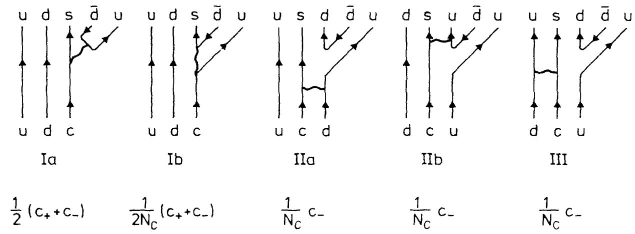

FIG. 1. Flavor diagrams contributing to two-body nonleptonic decays of the Λ_c. For illustrative purposes we have labeled the flavor diagrams according to the decay $\Lambda_c\to\Lambda\pi$.

of [14] one finds

$$\begin{aligned} H_{1/2\,1}&=(2.14-0.40)\times10^{-6}\ ,\\ H_{-1/2\,-1}&=(-3.24-1.58)\times10^{-6}\ ,\\ H_{1/2\,0}&=(-1.46-1.68)\times10^{-6}\ ,\\ H_{-1/2\,0}&=(4.26-2.51)\times10^{-6}\ , \end{aligned} \tag{12}$$

where the two numbers in the parentheses refer to the contributions of diagrams (IIa) and (IIb), respectively. The contributions of the factorizing contribution (IIa) and the W-exchange contribution (IIb) are constructive for the helicity amplitudes $H_{-1/2\,-1}$ and $H_{1/2\,0}$ and destructive for the helicity amplitudes $H_{1/2\,1}$ and $H_{-1/2\,0}$. It is therefore clear that one will have a negative asymmetry value and thereby a negative value for $A_{\rm FB}$ for the left-chiral $b\to c$ currents. Numerically one obtains

$$\alpha_p=0.69 \tag{13}$$

using the model values (12). Note, though, that the predicted value Eq. (13) is quite sensitive to the relative weight and sign of the contributions written down in (12) (factorizing and nonfactorizing) and is thereby subject to some theoretical uncertainty.

Concerning the channel $\Lambda_c\to\Delta^{++}K^-$ one notes that this decay is contributed to only by the W-exchange diagram as drawn in Fig. 1 (III). One has the two helicity amplitudes $H_{\lambda_\Delta\lambda_\pi}$ with $\lambda_\Delta=\pm\frac{1}{2}$. Looking at the helicity configurations of the quark diagrams one finds $H_{1/2\,0}=H_{-1/2\,0}$ because of the symmetric nature of the Δ^{++} quark model wave function. Thus, one finds that the decay $\Lambda_c\to\Delta^{++}K^-$ is a purely parity-conserving p-wave transition [14]. Correspondingly, the asymmetry parameter in this decay is zero.

If one considers the sum of the two above subchannels one finds a diluted asymmetry value for the asymmetry of the proton in the decay $\Lambda_c\to pK^{*0}+\Delta^{++}K^-$. One then has

$$\alpha_p=0.37\text{–}0.46 \tag{14}$$

where the first and second values refer to 88 and 50% ratios of the $\Lambda_c\to\Delta^{++}K^-$ and $\Lambda_c\to p\bar{K}^{*0}$ rates.

Summarizing our results for the two subchannels of $\Lambda_c\to pK^-\pi^+$ considered by us we find that the proton is preferentially emitted backward (forward) for a left-

(right-) chiral $b \to c$ transition. The analyzing power of this nonleptonic decay mode is large, in particular, if one selects the $\Lambda_c \to p\bar{K}^{*0}$ band.

Let us now return to the question of polarization transfer from a polarized Λ_b with longitudinal polarization P ($-1 \le P \le 1$) to a polarized Λ_c with longitudinal polarization P_L ($-1 \le P_L \le 1$). To this end we write down the unnormalized density matrix elements of the Λ_c in the Λ_b rest system [7]:

$$\begin{aligned} \rho_{1/2\,1/2}(\cos\Theta_{\Lambda_c}) &= |H_{1/2\,1}|^2(1-P\cos\Theta_{\Lambda_c}) \\ &\quad + |H_{1/2\,0}|^2(1+P\cos\Theta_{\Lambda_c})\,, \\ \rho_{-1/2\,-1/2}(\cos\Theta_{\Lambda_c}) &= |H_{-1/2\,-1}|^2(1+P\cos\Theta_{\Lambda_c}) \\ &\quad + |H_{-1/2\,0}|^2(1-P\cos\Theta_{\Lambda_c})\,, \end{aligned} \tag{15}$$

where Θ_{Λ_c} is the polar angle of the Λ_c relative to the original flight direction of the Λ_b in the Λ_b rest frame. The $\cos\Theta_{\Lambda_c}$ dependence of the longitudinal polarization P_L of Λ_c can then be calculated from

$$P_L(\cos\Theta_{\Lambda_c}) = \frac{\rho_{1/2\,1/2}(\cos\Theta_{\Lambda_c}) - \rho_{-1/2\,-1/2}(\cos\Theta_{\Lambda_c})}{\rho_{1/2\,1/2}(\cos\Theta_{\Lambda_c}) + \rho_{-1/2\,-1/2}(\cos\Theta_{\Lambda_c})}\,. \tag{16}$$

In Fig. 2, we show the $\cos\Theta_{\Lambda_c}$ dependence of $\langle P_L \rangle$ of Λ_c again for the HQET improved IMF model of [16] and the FQD model. For definiteness we have taken $P = -0.94$. This refers to the case of Λ_b's produced on the Z_0. As mentioned earlier b quarks produced on Z_0 are expected to be negatively polarized with a 94% degree of polarization. Here we assume that the polarization transfer in the fragmentation $b \to \Lambda_b$ is 100%, as predicted in the heavy-quark limit [5]. For smaller values of P the asymmetry in the polarization transfer plot, Fig. 2, would be reduced. At 90° there clearly is no polarization transfer and one recovers the values of Eq. (3). The polarization transfer in Fig. 2 has been calculated for left-chiral ($\xi = 1$) $b \to c$ transitions. The right-chiral case ($\xi = -1$) is obtained from Fig. 2 by the replacement $P_L \to -P_L$ and $\Theta_{\Lambda_c} \to \pi - \Theta_{\Lambda_c}$, i.e., reflections on both zero axes. As emphasized above the dependence of P_L on P drops out when one integrates over $\cos\Theta_{\Lambda_c}$.

What has been said up to now requires the reconstruction of the Λ_b rest system. This will not be an easy task for the energetic Λ_b bottom baryons produced on Z^0 where the analysis suggested in this paper is most likely to be done first. There is some hope, though, that such a reconstruction can be done with the newly installed vertex detectors in the CERN detectors, as mentioned before. Nevertheless, we shall in the following discuss the more realistic situation present in the LEP environment of energetic longitudinally polarized Λ_b's whose rest frames cannot be reconstructed. The polarization of the Λ_c's in the semileptonic decays takes a more complicated form in the laboratory frame than in the Λ_b rest frame as given by Eqs. (2) and (16). In particular, negatively polarized Λ_c's emerging backward in the Λ_b rest frame will turn into positively polarized Λ_c's in the laboratory frame because of the momentum reversal due to the requisite Lorentz boost. Also, because of experimental cuts and/or biases the Λ_c's polarization dependence on the polarization of Λ_b may no longer average out; i.e., one has to address the question of polarization transfer under realistic experimental conditions.

In order to study all these issues we have written a Monte Carlo program that generates semileptonic decay events of polarized Λ_b into polarized Λ_c. It is then a simple matter to adapt our calculation to the experimental conditions present in the LEP environment including longitudinal and transversal lepton momentum cuts.

In Fig. 3, the dependence of $\langle P_L \rangle$ on the energy of Λ_b in the laboratory frame is shown for the FQD model with $m_b = m_{\Lambda_b} = 5.64$ GeV and $m_c = m_{\Lambda_c} = 2.285$ GeV, where $E_{\Lambda_b} = zM_Z/2$. At $z_{\min} = 2m_{\Lambda_b}/M_Z$ corresponding to a Λ_b being produced at rest we have $\langle P_L \rangle = -0.81$ as given in Eq. (3). For $z_{\min} < z \lesssim 0.3$ the mean polarization $\langle P_L \rangle$ quickly increases and shows almost no z dependence for $z \gtrsim 0.3$. The reason that the mean polarization of the Λ_c saturates so fast is clear: the average energy

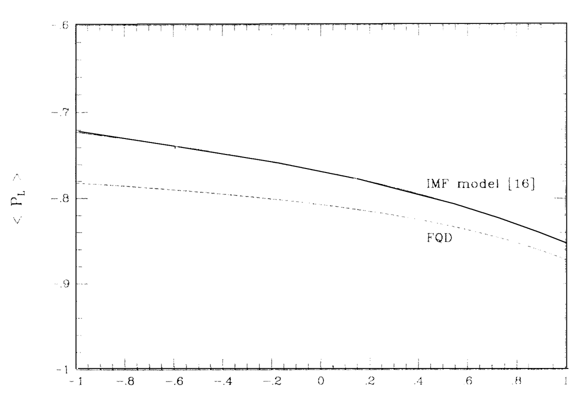

FIG. 2. Polarization transfer from a 94% (negatively) longitudinally polarized Λ_c in semileptonic decays $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$ as a function of the angle Θ_{Λ_c} between the Λ_c and the Λ_b.

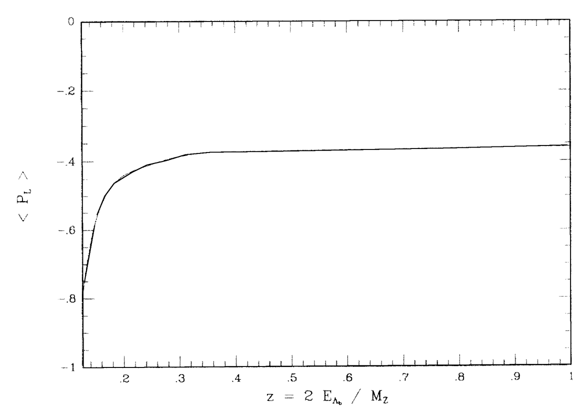

FIG. 3. Mean longitudinal polarization of laboratory frame Λ_c's from Λ_b's produced on the Z^0 as a function of Λ_b's fractional energy.

released in $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$ is quite small on the scale of the Z^0 mass. In particular, the sign of the longitudinal polarization does not change over the whole z range. The same behavior is true for the IMF quark model calculation of [16].

It is obvious from Fig. 3 that our results are practically not affected by the details of fragmentation: the fragmentation function $b \to \Lambda_b$ is expected to be strongly peaked in the high-z region where the saturation of $\langle P_L \rangle$ has set in. This is born out by the so-called Peterson fragmentation function [23]. Further we conclude that our predictions for $\langle P_L \rangle_{\rm lab}$ will only be marginally affected by the folding in of any realistic fragmentation function.

The last point we want to discuss is the cut dependence of our predictions for Λ_c's polarization. The cut dependence comes in because of experimental trigger requirements: one triggers on high $p_\perp$ and high p leptons in order to select on semileptonic Λ_b decays [18,22]. Again we use a polarization of $P = -0.94$ for the b quark and for Λ_b. As can be judged from the numbers in Table I, the effects of such cuts have little effect on our prediction for the polarization of the Λ_c in the laboratory frame. There is a small effect in that the cuts tend to enhance the longitudinal polarization in the laboratory frame.

Table I summarizes our results on the calculation of $\langle P_L \rangle$. We find a large longitudinal polarization of the Λ_c in the Λ_b rest frame leading to large forward-backward asymmetries in subsequent nonleptonic decays of the Λ_c. The absolute value of the longitudinal polarization (and thereby the forward-backward asymmetry) is reduced by about a factor of 2 when the analysis has to be performed in the LEP laboratory frame. Our predictions are practically not affected by fragmentation and possible experimental cuts.

In summary we have used an explicit form-factor model and the free quark decay model to determine the longitudinal polarization of the Λ_c in the semileptonic decays $\Lambda_b \to \Lambda_c + l^- + \bar{\nu}_l$. The mean longitudinal polarization of the Λ_c is negative (positive) for the left-chiral (right-chiral) $b \to c$ current transitions. The mean longitudinal polarization of Λ_c turns out to be large ($\cong 80\%$) in the Λ_b rest frame and somewhat smaller (30–40 %) in the laboratory frame when Λ_b's are produced on the Z^0 peak. We have suggested using nonleptonic decay modes of the Λ_c to analyze its polarization. Most useful in this regard are the decay modes $\Lambda_c \to \Lambda\pi$ and $\Lambda_c \to \Sigma\pi$ since the decay asymmetry parameters in these modes have recently been measured. We have also discussed the modes $\Lambda_c \to p\bar{K}^{*0}$ and $\Lambda_c \to \Delta^{++}K^-$ for which we have provided theoretical model-dependent decay asymmetry parameters. We believe that the issue whether the $b \to c$ transitions are left or right chiral can be settled in the near future using the analysis suggested in this paper.

TABLE I. Values for the mean longitudinal polarization $\langle P_L \rangle$ of the Λ_c in the Λ_b rest frame and in the laboratory frame from Z_0 decays with and without cuts. The energy of the Λ_b in the laboratory frame is taken to be 40 GeV corresponding to a mean value of $\langle z \rangle \approx 0.88$ (cf. [23]). We use $p_\perp^{\rm cut} = 1$ GeV and $p^{\rm cut} = 3$ GeV [18,22].

$\langle P_L \rangle$	FQD model	Quark model [16]
Λ_b rest frame	−0.81	−0.77
Laboratory frame; no cuts	−0.36	−0.26
Laboratory frame; cut on $p_\perp$	−0.41	−0.32
Laboratory frame; cut on $p_\perp$ and p	−0.40	−0.31

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