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On Testing V-A in Λ_b Decays*

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ABSTRACT

We comment on a recent suggestion by Amundson, Rosner, Worah and Wise to test the chirality of the b-quark decay coupling via polarized Λ_b baryons produced in $e^+e^- \to Z \to \Lambda_b + X$. We study the effect of contributions from an amplitude in which a right-handed b to c current couples to a V-A lepton current.

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b-quark decays are known to be governed by very weak couplings, which in the Standard Model are given by the two tiny mixing angles θ_{23}, θ_{13} [1]. These decays are therefore very sensitive to new kinds of interactions, and in particular to right-handed couplings [2]. Recently we described a viable $SU(2)_L \times SU(2)_R \times U(1)$ model, in which b-quarks decay purely right-handedly [3]. We pointed out that measurement of the lepton asymmetry in $B \to D^* \ell \nu$ [4] cannot distinguish our model from the Standard Model, since in this process the lepton current in our model is dominantly V+A [5]. A nice test, which may distinguish between the exchange of left- and right-handed gauge bosons in b decays was suggested by Amundson, Rosner, Worah and Wise [6]. These authors noted that the electron spectrum from highly polarized Λ_b's produced in $e^+e^- \to Z \to \Lambda_b + X$ is significantly harder for V-A than for V+A quark and lepton currents. Thus, ongoing experiments at LEP, in which leptons from Λ_b decay were already observed [7], may offer an early test of the model.

In this brief note we wish to study the effect of $W_L - W_R$ mixing, which exists in our model in addition to W_R exchange [3], to see how much it can affect the electron spectrum calculated in [6]. Also, as a model-independent study and to demonstrate another version of right-handed b to c couplings, we will first calculate the electron spectrum for a V+A quark coupling, assuming that the lepton current is purely left-handed. Such a possibility is outside the parameter range of the model of [3], since it corresponds to decays due to $W_L - W_R$ mixing alone. This case, which seems to be one's first guess of what right-handed b couplings might be, was recently excluded by the $B \to D^* \ell \nu$ data [4]. Our purpose of including a discussion of this case is to show that also in the case of Λ_b decays it can be most easily distinguished from other cases studied here.

We use the physics of the heavy quark symmetry presented in [6,8] and the notations of[6] to describe the lepton spectrum in terms of the free-quark decay $b \to c e^- \overline{\nu}_e$. For a V+A b to c coupling and a V-A lepton current the normalized electron decay distribution in the b rest frame is given by[9] :

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{dxd(\cos\psi)} = \frac{6x^2(1-\zeta)^2}{f(m_c^2/m_b^2)}(1-x)(1-P\cos\psi) \ , \tag{1}$$

$$x \equiv 2E^*/m_b \ , \qquad \zeta \equiv m_c^2/[m_b^2(1-x)] \ .$$

$f(y)$ is a well-known phase-space function, and E^*, ψ are the energy of the electron and its angle with respect to the b-quark polarization. The polarization is almost complete, $P = -0.93$. The boost from the b rest-frame to the Z frame, in which $Z \to b\overline{b}$ occurs, is described in[6] . For $P = -1$ we find from Eq.(1) the electron energy spectrum shown in Fig. 1(c). We used the values of $m_b = 5$ GeV, $m_c = 1.66$ GeV, $E_b = 45$ GeV from[6] , and chose a minimum electron transverse momentum of $p_T^{min} = 0.8$ GeV/c. This spectrum should be compared with the two spectra of[6] using the same momentum cut, shown in Fig.1(a), Fig.1(b), which describe the cases of V-A and V+A quark and lepton currents, respectively. The difference is striking. The distribution of Fig.1(c) peaks at a considerably higher energy (14 GeV instead of $7-9$ GeV) and involves many fewer low energy electrons than the two other distributions.

The possibility of a V+A b to c current coupled to a V-A lepton current was recently excluded by measurement of the forward-backward asymmetry in $B \to D^* \ell \nu$[4] . This measurement favors the two cases in which both quark and lepton currents are either V-A or V+A[5] . The first case corresponds to the Standard Model, while the second one describes the dominant W_R exchange contribution in model[3] . For both cases the measured lepton angular distribution sets 95% C.L.

upper limits on the allowed rates coming from amplitudes in which the quarks and leptons couple with opposite chiralities. The form-factor-dependent limits on the ratio of rates of opposite and equal chiralities are at the level of 30%. The implication of these limits on the model[3] is a bound on the $W_L - W_R$ mixing parameter, ζ_g:

$$(\frac{\zeta_g}{\beta_g})^2 < 0.30 \; , \qquad \beta_g \equiv \frac{g_R^2}{g_L^2}\frac{M_L^2}{M_R^2} \; . \tag{2}$$

We use this constraint to study within model[3] the effect of $W_L - W_R$ mixing on the lepton energy spectrum of Λ_b decay. Fig.1(d) describes the spectrum corresponding to $(\zeta_g/\beta_g)^2 = 0.29$, which is just below the limit (2). The peak of this distribution lies between the peaks of the V-A and V+A distributions, Fig.1(a) and Fig.1(b), respectively. That is, the effect of $W_L - W_R$ mixing is to diminish the difference between the distributions of our model and the Standard Model. Nevertheless, the feature of a considerably lower high-energy electron tail persists in our model. An observation of a higher tail, as in Fig.1(a), would clearly favor the Standard Model.

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REFERENCES

1. Particle Data Group, Phys. Lett. **B239**, 1 (1990).
2. M. Gronau, talk at the Conference on B Factories: The State of the Art in Accelerators, Detectors and Physics, Stanford, CA, April 6-10, 1992, ed. D. Hitlin, to be published.
3. M. Gronau and S. Wakaizumi, Phys. Rev. Lett. **68**, 1814 (1992); M. Gronau and S. Wakaizumi, in B Decays, ed. S. Stone, (World Scientific, Singapore, 1992) p. 479; M. Gronau, Phys. Lett. **B288**, 90 (1992).
4. CLEO Collaboration, S. Sanghera *et al.*, The CLEO Collaboration, Cornell University Report No. CNLS 92/1156 (1992), to be published.
5. M.Gronau and S. Wakaizumi, Phys. Lett. **B280**, 79 (1992).
6. J.F. Amundson, J.L. Rosner, M. Worah and M.B. Wise, University of Chicago Report No. EFI 92-38-Rev, 1992, to be published.
7. ALEPH Collaboration, D. Decamp *et al.*, Phys. Lett. **B278**, 209 (1992); OPAL Collaboration, P.D. Acton *et al.*, Phys. Lett. **B281**, 394 (1992).
8. See also J.G. Koerner and M. Kraemer, Phys. Lett. **B275**, 475 (1992); T. Mannel and G.A. Schuler, Phys. Lett. **B279**, 194 (1992).
9. Y.S. Tsai, Phys. Rev. **D19**, 2809 (1979).

FIGURE CAPTION

FIG.1. Distributions in electron laboratory energy for inclusive semileptonic Λ_b decays from $e^+e^- \rightarrow Z \rightarrow \Lambda_b + X$, with $p_T^{min} = 0.8$ GeV/c. (a) Standard Model[6] , (b) W_R exchange[6] , (c) V+A quark coupling and V-A lepton coupling, (d) Model[3] with $(\zeta_g/\beta_g)^2 = 0.29$.

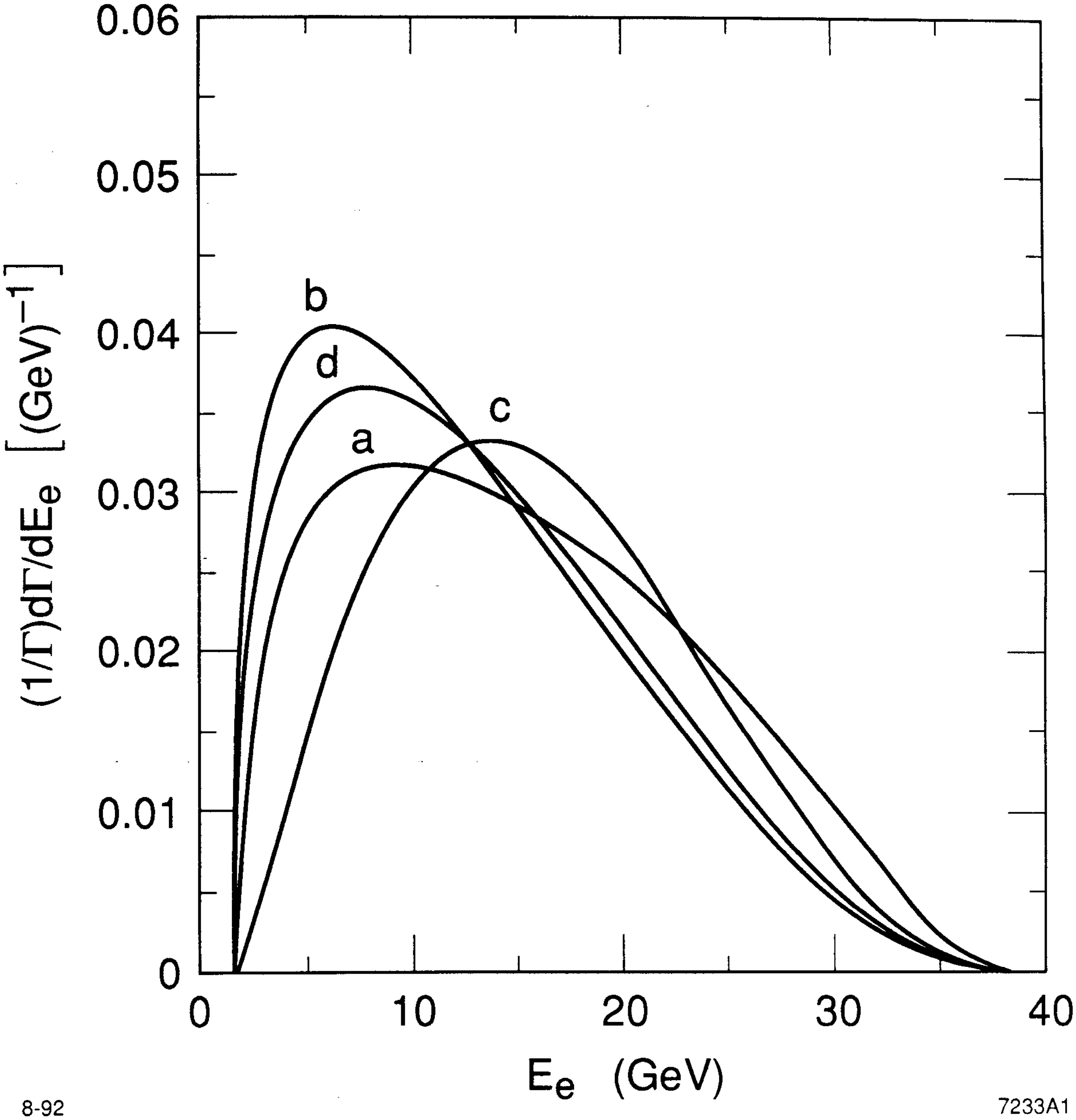
0.06
0.05
0.04
0.03
0.02
0.01
0
0
10
20
30
40
$(1/\Gamma)d\Gamma/dE_e$ $[(\mathrm{GeV})^{-1}]$
E_e (GeV)
a
b
c
d
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Fig. 1