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ON A FEASIBILITY OF MEASURING EXCLUSIVE SEMITAUONIC B^0 DECAYS AT B-FACTORIES*

Maria Różańska and Krzysztof Rybicki

for BELLE Collaboration

Institute of Nuclear Physics
Kawiory 26A, 30-055 Cracow, Poland
e-mail: Maria.Rozanska@ifj.edu.pl
e-mail: Krzysztof.Rybicki@ifj.edu.pl

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The advent of B-factories, rich sources of pure $B-\overline{B}$ pairs, increased an interest in the rare B decays. The B decay channels involving the τ lepton are very interesting both as a stringent test of the Standard Model and as a possible window for a new physics. These decays are difficult experimentally because of the presence of two neutrinos. We have performed extensive simulations of exclusive decays $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ and $\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}$ with a subsequent $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ decay in the BELLE detector at the KEK B-factory. It is possible to reconstruct kinematics of these decays provided we measure momentum of $\overline{B^0}$ and the τ^- decay vertex. Thus obtained τ^- energy and direction are not far from the generated values. The main problem is the background from the inclusive $\overline{B^0}$ decays. For 10^8 $B-\overline{B}$ pairs (one year of full-luminosity KEK-B running) we expect about 35 reconstructed $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ events and the same number of $\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}$ decays. The corresponding numbers of the background events from inclusive B decays are 35 and 15.

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1. Introduction

The B meson decays involving the τ lepton are of great interest. They can give important constraints on both the Standard Model and on new physics. Relatively large mass of the τ lepton has many interesting consequences. First it can enhance some effects of non-SM processes, like those

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with charged scalar fields. Secondly the decays in question are sensitive to certain form-factors which are inaccessible in decays to massless leptons. For the same reason the τ lepton polarization effects are no more suppressed. Also due to big τ mass the $B \to \tau$ decays are expected to be practically saturated by D and D^* channels without additional pions thus avoiding complications with poorly known D^{**} states. Finally the large τ mass results in a big variety of τ decays. Therefore these channels offer many experimental observables, which allow for independent measurements and tests of the SM and of its extensions.

This, potentially very interesting field, is experimentally only weakly explored. So far only inclusive branching fractions has been measured in LEP experiments [1] to be $(2.7 \pm 0.4)\%$. It should be noted that these measurements refer to a $B^-/B^0/B_s^0/b-baryon$ admixture. Such a small branching fraction and at least two neutrinos in the decay chain make measurements of these decays to be very difficult.

The increased interest in studying these decays during the last few years has been partially triggered by the forthcoming experiments devoted to study CP violation in B decays. These are two B-factories at KEK [2] and SLAC [3] as well as hadronic experiments like HERA-B [4]. In particular the B-factories will be rich sources of pure $B\bar{B}$ pairs. In this paper we investigate a possibility of identification and a full kinematical reconstruction of the exclusive decays: $\overline{B}^0 \to D^+\tau^-\overline{\nu}_\tau$ and $\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau$ [1] at the asymmetric B-factory. This is done for a particular case of the BELLE detector [5] at KEK-B factory. Our aim is to evaluate available statistics, signal/noise ratio and measurement accuracy of relevant observables.

In the next section we briefly review physics motivation and interesting quantities to be measured in semitauonic B-decays. Then we present a method of full reconstruction of exclusive $B \to \tau$ decays. Finally we show and discuss our results.

2. Physics interest in semileptonic B decays

Semileptonic decays of hadrons containing a single heavy quark are reasonably well described by the effective heavy quark theory (HQET) and the QCD perturbative corrections. This makes comparison between theory and experiment for these processes to be particularly important. Decays with the heavy τ lepton play a special role in this field. As it was mentioned above, the relatively large masses of the fermions involved in the $B \to \tau$ decays cause that some effects of non SM physics, like presence of

[1] Hereafter any particle symbol will stand for an antiparticle as well, thus *e.g.* $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ denotes simultaneously the charge-conjugated channel *i.e.* $B^0 \to D^-\tau^+\nu_\tau$.

charged scalar fields, can be enhanced. In particular semitauonic B decays can give important constraints on the charged Higgs sector. This subject has been extensively studied in many papers [6–15]. The most frequently quoted quantities relevant for these studies are the branching fractions and longitudinal τ polarization both in inclusive $\overline{B} \to \tau\overline{\nu_\tau}X$ [6, 8–11] and in exclusive $\overline{B} \to D^{(*)}\tau\overline{\nu_\tau}$ [7, 12, 15] decays. In particular the longitudinal τ polarization is quite free from theoretical uncertainties and from bound state effects [6, 10, 12].

Another very interesting observable is the transverse τ polarization $P_\tau^\perp$. This quantity is T-odd and receives negligible contribution from the Standard Model. Therefore it can unravel non-SM sources of CP violation [16–21]. As compared to the semileptonic kaon decays ($K_{\mu 3}$), it is advantageous that B mesons can decay both to the pseudoscalar (D) and vector (D*) mesons because they receive contributions from effective scalar and pseudoscalar interactions, respectively [21]. It has been shown that measurements of $P_\tau^\perp$ in exclusive B decays can be used to distinguish between different non-SM sources of CP-violation like multi Higgs-doublet models, squark mixing or leptoquarks [21].

On the other hand, even in the absence of exotic phenomena, the semitauonic B-decays are interesting for the SM studies [22–27]. They are useful in constraining the parameters of the Standard Model, like quark masses m_b, m_c and the strong coupling constant α_s at relatively low energy scale. The most useful quantities for this purpose are the integrated and differential decay rates and the longitudinal τ polarization in inclusive $B \to \tau$ channels. In particular, it has been shown that the moments of charged lepton energy distributions and the longitudinal τ polarization in these decays only weekly depend on the α_s (see *e.g.* [25, 27]) and therefore these observables are particularly suitable for evaluation of heavy quark masses.

Many of the above measurements require the reconstruction of the τ momentum. In addition, various predictions refer to various reference systems, *e.g.* the $\overline{B}^0$ rest frame, the τ^- frame or the $\tau^-\overline{\nu_\tau}$ system. Therefore in this paper we attempt to determine the τ energy and direction thus allowing a full kinematical, although not exact, reconstruction of the semitauonic B decay chains.

3. Reconstruction of decay chains involving two neutrinos

3.1. Principles of reconstruction

The $B \to \tau$ decays involve at least two tauonic neutrinos, the first one from the B decay and the second one from the τ decay. If τ decays leptonically there is additionally a third neutrino associated with the light lepton. Therefore we will restrict our discussion to $B \to \tau$ decays followed by semileptonic τ decays. There are several ways of reconstruction of such decay chains, depending on which quantities are measured. We discuss here four possible model independent methods. The only (and quite natural) assumption, which we make here, is that on the zero mass of the ν_τ.

The simplest situation occurs if the τ direction is known from its production and decay vertices. Then the τ momentum can be reconstructed from energy-momentum conservation either in the $\bar{B}$ decay vertex or in the τ decay vertex. In the first case (method I) the τ momentum is calculated from the missing mass carried by the $\tau - \overline{\nu_\tau}$ system. This can be done if one knows the momentum of decaying $\bar{B}$-meson as well as the four-momenta of all hadrons from its decay. In the second case (method II) four-momenta of all hadrons from semileptonic τ decay have to be measured and the τ momentum is calculated from zero missing mass condition.

If the τ direction cannot be measured there are another two possibilities of kinematical reconstruction. In both cases the measurement of four-momenta of all hadrons from both $\bar{B}$ and τ decays and the knowledge of $\bar{B}$ momentum are required. Additionally the $\bar{B}$ decay vertex and flight line of hadronic system from τ decay (Method III) or decay vertex of τ and flight direction of hadrons from $\bar{B}$ decay (*e.g.* D/D*) have to be measured (Method IV). In both cases the vertex and flight direction of hadrons define a plane containing the τ vector. This, together with conservation laws in $\bar{B}$ and τ decays allows us to reconstruct the τ energy and its direction [2]. General considerations on such reconstruction were presented by Kuno [17]. A procedure, similar to ours, has been sketched by Tanaka in [12].

Let us briefly discuss the relative merits of the four methods.

TABLE I

Parameters to be measured in each reconstruction method

Parameter	Meth. I	Meth. II	Meth. III	Meth. IV
$\bar{B}$ four-momentum	x	–	x	x
four-momenta of hadronic $\bar{B}$ decay products	x	–	x	x
four-momenta of hadronic τ decay products	–	x	x	x
τ decay vertex	x	x	–	x
D decay vertex	–	–	–	x
$\bar{B}$ decay vertex	x	x	x	–

[2] In each case one obtains a quadratic equation on τ energy. In general the twofold ambiguity can be solved only with some additional information.

Table I lists measurements needed in each method. As it can be seen, only the method II does not require four-momenta of hadronic products of $\bar{B}$ decay. Therefore it can be applied also to inclusive $\bar{B} \to \tau X$ decays. The remaining methods can be used only in exclusive $\bar{B}$ decays. The determination of the D/D^* four-momenta is possible only for fully reconstructed D decays. This obviously eliminates the semileptonic D decays. Reconstruction of hadronic D decays depends on specific experimental situation, in particular on neutral particle detection and/or on K/π separation. In addition, these methods require the knowledge of $\bar{B}$ momentum which is difficult at hadronic machines. At B-factories the $\bar{B}$ four momentum can be determined, provided the second B is fully reconstructed. This demand reduces however the event sample by nearly two orders of magnitude, depending on detector features.

The method I allows for undetected hadrons in τ decay, while in the remaining three the requirement of detecting all hadrons from τ limits their applicability only to few τ decay channels.

The measurement of τ decay vertex is possible for decays into three or more charged hadrons (about 15% of decays). The determination of D decay vertex is possible for channels with at least two charged decay products. This brings another reduction factor, but apart from that there are no principal difficulties in reconstructing both the τ and D decay vertices.

On the contrary, it seems difficult to reconstruct the B decay vertex in semitauonic decays. In exclusive $\bar{B} \to D\tau\overline{\nu_\tau}$ channels there is no measurable charged track coming directly from $\bar{B}$. In the decays $\bar{B} \to D^*\tau\overline{\nu_\tau}$ the vertex can be reconstructed from π^+ track and D^0 direction but with rather poor accuracy, because the D^0 and π^+ from D^* are nearly parallel. Let us remind that these two channels probably dominate the $B \to \tau$ decays, thus the channels with additional charged hadrons (which could help in vertexing) occur with much smaller branching fraction. In case of B-factories, if the $B-\overline{B}$ plane is measured, the $\bar{B}$ decay vertex can be determined from intercept of D and/or π direction with this plane, but also with a poor accuracy. In addition, due to the short τ life time and relatively small boost at B-factories, the two vertices in the most cases will not be separated well enough to allow for a meaningful τ direction reconstruction. Thus both methods relying on the τ direction are in practice not applicable at B-factories. From the above discussion, we conclude that the method IV looks most promising for experiments on B-factories and in further analysis we use solely this one. In an extensive simulation (see Section 4) we have tried to answer the following questions:

— do we have enough events left after all the cuts needed for the background suppression,
— what is the signal/noise ratio,
— what is the accuracy of the τ energy and direction determined using the method,
— can one measure the τ polarization.

3.2. Decay channels used in the simulation

The choice of the decay channels is closely connected with the features of the apparatus. The BELLE detector (see Ref. [5] for a detailed description) consists of the following components

— silicon vertex detector

— central drift chamber for tracking and for dE/dx measurement,

— aerogel Čerenkov counters and time of flight counters for charged particle identification,

— electromagnetic CsI calorimeter for an identification and energy measurement of photons and electrons,

— simple calorimeter for K_L^0 detection and muon identification.

Having this apparatus in mind we have selected the following decay chains for our simulations :
$\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$, $\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}$,
followed by
$\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$
and
$D^{*+} \to D^+\pi^0$ or $D^{*+} \to D^0\pi^+$
$D^+ \to K^-\pi^+\pi^+$,
$D^0 \to K^-\pi^+\pi^0$, $D^0 \to K^-\pi^+$ or $D^0 \to K^-\pi^+\pi^+\pi^-$.

We have used only the above charm decays because we need large branching fractions, at least two charged particles (to form a vertex) and at most one π^0 (to have a reasonable detector efficiency). In future one could also consider some channels with a K^0.

The branching fraction for the charmed mesons are well known [1]:
$\mathrm{BF}(D^{*+} \to D^+\pi^0) = (68.3 \pm 1.4)\%$
$\mathrm{BF}(D^{*+} \to D^0\pi^+) = (30.6 \pm 2.5)\%$,
$\mathrm{BF}(D^+ \to K^-\pi^+\pi^+) = (9.1 \pm 0.6)\%$,
$\mathrm{BF}(D^0 \to K^-\pi^+\pi^0\ ) = (13.9 \pm 0.9)\%$,
$\mathrm{BF}(D^0 \to K^-\pi^+) = (3.83 \pm 0.12)\%$,
$\mathrm{BF}(D^0 \to K^-\pi^+\pi^+\pi^-\ ) = (7.5 \pm 0.4)\%$.

The branching fraction for the $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ (this is the largest-branching-fraction channel allowing the vertex reconstruction) has not yet been measured. From the known values [1] for two similar channels, namely:
$\mathrm{BF}(\tau^- \to \pi^+\pi^-\pi^- + neutrals) = (14.1 \pm 0.3)\%$
$\mathrm{BF}(\tau^- \to h^+h^-h^-\overline{\nu_\tau}) = (9.8 \pm 0.1)\%$
we guess (may be somewhat optimistically) $\mathrm{BF}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau) = 10\%$.

The main uncertainty in evaluation of the final sample is due to the branching fractions of the $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ and $\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}$ channels. The value quoted in the Review of Particle Physics [1] *i.e.* $\mathrm{BF}(b \to \tau^+\nu_\tau + anything) = (2.7 \pm 0.4)\%$ comes from the indirect ALEPH and L3 measurement for the $B^\pm/B^0/B^0_s/b{-}baryon$ admixture. The same is true for the recent OPAL and DELPHI [28] results yielding very similar values. We assume the decays in question saturate the inclusive $\overline{B^0} \to \tau^-\nu_\tau$... branching fraction and (may be again somewhat optimistically) we take:
$\mathrm{BF}(\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}\ ) = 1\%$,
$\mathrm{BF}(\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}\ ) = 2\%$.

We used only these combinations of D^* and D decays which produce at most one π^0 in the final state. We have not yet simulated decays of charged B mesons: $B^- \to D^0\tau^-\overline{\nu_\tau}$ and $B^- \to D^{*0}\tau^-\overline{\nu_\tau}$ but we expect roughly similar results.

3.3. Detailed description of the reconstruction

The method IV (see Sec.$\tilde{3}$.1) has been applied in the following steps.

1. First we reconstruct the D^+ or D^{*+} decay using mass and vertex constraint for the D^+ or D^0 and the mass difference for the D^{*+} . This gives us the energy E_D and the space point of the D decay vertex as well as momentum $\vec{p_D}$ of the D^+ or of the D^{*+} .

2. Then we reconstruct B^0 ("another B") accepting any combination of particles with a total effective mass close to that of the B^0 .

3. Knowing the beam energy and momentum as well as those of B^0 we calculate energy E_B and momentum $\vec{p_B}$ of $\overline{B^0}$ ("our B").

4. Now we calculate energy E_M, momentum $\vec{p_M}$ and mass M_M of the $\tau^-\overline{\nu_\tau}$ system as

$$\begin{aligned} E_M &= E_B - E_D\,, \\ \vec{p_M} &= \vec{p_B} - \vec{p_D}\,, \\ M_M &= \sqrt{E_M^2 - p_M^2}\,. \end{aligned}$$

5. Then we reconstruct the $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ decay vertex. This space point together with the decay vertex and the direction of D^+ or D^0 span the $D-\tau$ plane.

6. From the conservation laws in the production and decay of the τ^- (both involving *massless* neutrinos) we obtain the following expressions for the angles[3] $\theta_{M\tau}$ and $\theta_{\tau 3\pi}$ between the (unknown) τ^- direction and those of $\tau^-\overline{\nu_\tau}$ system and 3π system respectively:

$$\cos\theta_{M\tau} = \frac{2E_\tau E_M - (M_M^2 + M_\tau^2)}{2p_\tau p_M},$$
$$\cos\theta_{\tau 3\pi} = \frac{2E_\tau E_{3\pi} - (M_{3\pi}^2 + M_\tau^2)}{2p_\tau p_{3\pi}},$$

   where E_τ and $\vec{p_\tau}$ are the (unknown) energy and momentum of the τ^-, $E_{3\pi}$ and $\vec{p_{3\pi}}$ are the (measured) total energy and momentum of the 3π system coming from the decay of the τ^-.

7. Knowing the $D-\tau$ plane we can eliminate the τ^- direction from the above equations and obtain a quadratic equation for E_τ.

8. Once E_τ is known we can determine the τ direction from the above equations and calculate $\vec{p_\tau}$ as well.

4. Selection criteria and efficiency

The decay chain in question was simulated using the BELLE event generator, based on the code developed by the CLEO-II collaboration [30]. The detector performance was simulated using the BELLE fast simulation program FSIM [31]. We have assumed $\overline{B^0}$ to decay according to "our" decay chain while the B^0 decays are standard ones. We assumed the $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ decay to be completely dominated by the $\tau^- \to a_1^-(1260)\overline{\nu_\tau}$, $a_1^-(1260) \to \rho^0\pi^-$ decay chain since the OPAL collaboration [29] has shown a reasonable consistency of the measured m$(\pi^+\pi^-)$ and m$(\pi^+\pi^-\pi^-)$ distributions with such an assumption. The selection criteria were tuned using also the inclusive sample in which both B's decay according to a standard decay table. The background from the continuum under the $\Upsilon(4S)$ resonance should be much smaller because we demand the reconstruction of the

[3] all angles are defined in the laboratory system if not specified otherwise

B^0. Additionally, this background could be reduced by using various shape variables *e.g.* the Fox–Wolfram moments.

We start from rather weak cuts on multiplicities of charged particles $N_{\rm ch}$ and photons N_γ measured in the detector:

$$N_{\rm ch} \le 16\,, \qquad N_\gamma \le 8\,. \tag{1}$$

While reconstructing the charm decay we demand:

— K^- identification and detection of all decay products

— vertex fit of a weak decay of D^+ or D^0.

The charm reconstruction efficiency ranges from 8% for $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+\pi^0$ to 74% for $D^+ \to K^-\pi^+\pi^+$ decay.

Our simulation shows that in $\approx 3\%$ of cases we reconstruct nearly all B^0 ("another B") decay products. In fact we demand their effective mass in the range $(5.10 \div 5.35)$GeV thus allowing for a loss of a single pion or of a photon.

When calculating the four-momentum of $\overline{B^0}$ ("our B") we introduce special cuts to reduce the $\overline{B^0}$ decays into D^+ or D^{*+} and D_s^- or D_s^{*-}. This is potentially a very dangerous background if the secondary D_s^- decays into three charged pions and some neutrals because:

— the branching fractions are similar or larger than those for our decay chains,

— there is a genuine D^+ or D^{*+},

— the lifetimes of the D_s^- and of the τ^- are very similar,

— the 3π system has similar properties in both cases because the masses of parent particles are rather close.

In order to reduce this background we demand $M_M > 2.3$ GeV and $\overline{p_D} < 1.68$ GeV$/c$, where $\overline{p_D}$ is the D^+ or D^{*+} momentum in the $\overline{B^0}$ rest system (in two-body background decay there are generally higher momenta than in our three-body one).

Further background reduction is done with the demand that after reconstruction of D^+ or D^{*+} and of the B^0 there are *three* charged pions left *and nothing else*. This reduces our sample by about a factor of two.

It should be stressed that we make rather weak cuts on the 3π system *i.e.*

— 0.45 GeV $< \ m_{3\pi} < 1.65$ GeV,

— $E_{3\pi} = (1.05 \div 2.85)$ GeV,

— $p_{3\pi} > 2.4$ GeV

— $m_{bd3\pi} < 2.0$ GeV, where $m_{bd3\pi}$ is the missing mass in the $\overline{B^0} \to D^+/D^{*+}\pi^+\pi^-\pi^-$ decay,

— antiselection of K^0 for any $\pi^+\pi^-$ pair,

— $m_s(\pi^+\pi^-) < 0.9$GeV,

— $m_l(\pi^+\pi^-) < 1.1$GeV ,

where m_s and m_l stand for lower- and higher- mass $\pi^+\pi^-$ combinations.

Finally we reconstruct the $\tau^- \to \pi^+\pi^-\pi^-\nu_\tau$ vertex and solve the quadratic equation for the E_τ. This can be done in about 60% of cases. We have empirically found that the two solutions of the equation are close each other. Therefore instead of selecting one of them we take the average value which is generally close to the generated E_τ.

We further reduce the background by demanding:

$$2.8 < m(D^+/D^{*+} - 3\pi) < 4.65 \text{ GeV},$$

$$\theta(D^+/D^{*+} - \tau^-) > 7^o ,$$

where $m(D^+/D^{*+} - 3\pi)$ and $\theta(D^+/D^{*+} - \tau^-)$ are the mass and the emission angle of the $(D^+/D^{*+} - 3\pi)$ and $(D^+/D^{*+} - \tau^-)$ system respectively. The final efficiencies for all channels are given in Table II. Fig. 1 shows that this efficiency does not depend strongly on E_τ.

TABLE II

Simulation results for various $\overline{B^0}$ decay channels

Decay chain	Efficiency	Signal	Back-ground
$\overline{B^0} \to D^+\tau^-\overline{\nu_\tau},\ D^+ \to K^-\pi^+\pi^+$	3.8×10^{-3}	34	34
$\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau},\ D^{*+} \to D^+\pi^0,\ D^+ \to K^-\pi^+\pi^+$	1.4×10^{-3}	8.0	1.2
$\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau},\ D^{*+} \to D^0\pi^+,\ D^0 \to K^-\pi^+\pi^0$	0.4×10^{-3}	8.1	1.9
$\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau},\ D^{*+} \to D^0\pi^+,\ D^0 \to K^-\pi^+$	1.8×10^{-3}	9.0	6.8
$\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau},\ D^{*+} \to D^0\pi^+,\ D^0 \to K^-\pi^+\pi^+\pi^-$	0.8×10^{-3}	7.1	3.7

5. Discussion of results

For one year of full-luminosity KEK-B running and with expected performance of the BELLE detector we should collect 10^8 $B\overline{B}$ pairs. Table II shows numbers of events expected for such a sample in each channel, both for our effect (using branching fractions from Sec.2) and for background from the inclusive B decays. For the channels involving a D^{*+} the signal

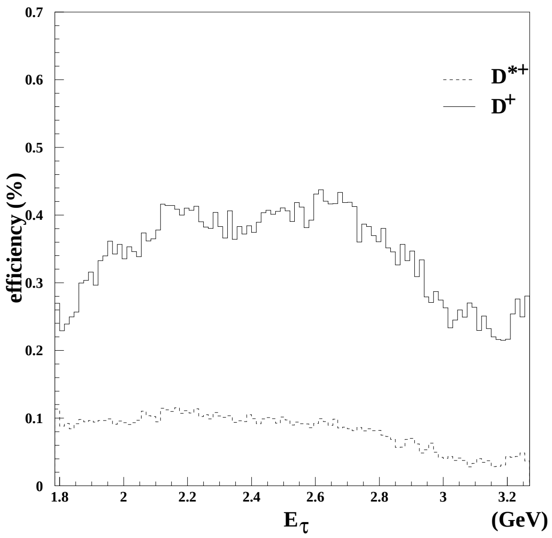

Fig. 1. Reconstruction efficiency versus E_τ (D^{*+} plot is an average of four channels).

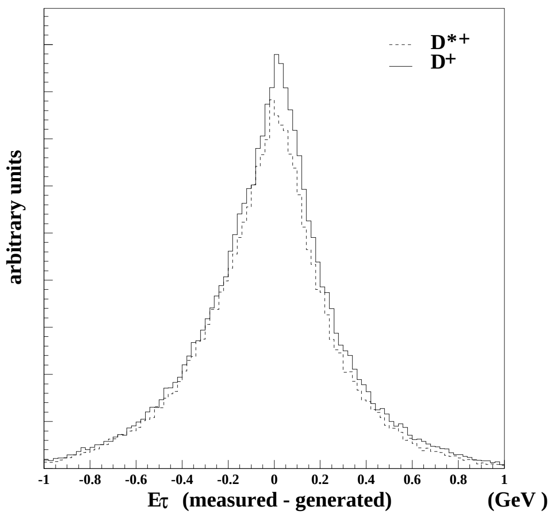

Fig. 2. The difference between measured and generated E_τ.

(total of 34 events) appears to be clearly larger than the background (total of 14 events) even if the branching fractions are somewhat smaller than those quoted in Sec.2. Probably the situation in all channels could be improved by some knowledge about phenomenology of the decay chain under consideration.

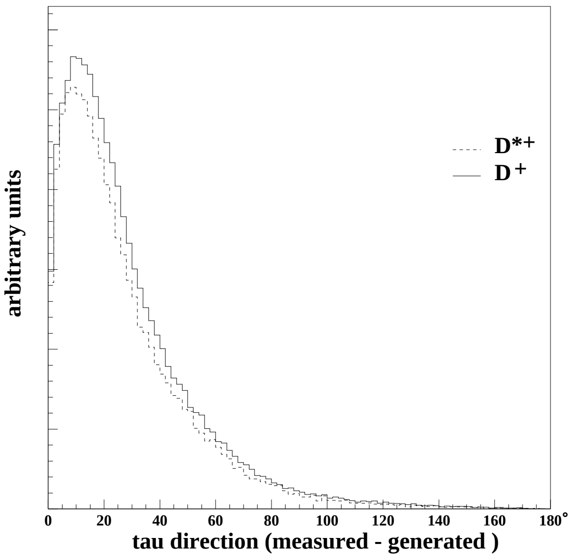

Fig. 3. The difference between measured and generated direction of τ.

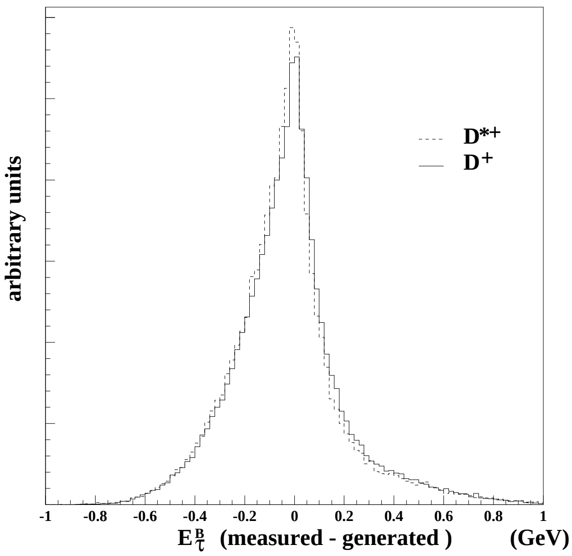

Fig. 4. The difference between measured and generated E_τ^B.

Fig. 2 shows a comparison of the measured and generated E_τ. The solid line refers to the $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ decay channel, the dashed one to a sum of four decay chains involving the D^{*+}.

Fig. 3 shows a comparison of the measured and generated τ^- direction. This is a difference between two directions in space, therefore there are only positive values. It is seen that the accuracy is nearly identical in both channels, which is not surprising. The slow pion from the D^{*+} decay, representing the only difference between measurements of the two channels, contributes but little to the charm momentum. It should be stressed that we have also tried to determine the τ^- direction from its production and decay vertices. The first one was an intercept of the D^+ or D^0 direction (always hooked at the relevant D decay vertex) with the $B^0 - \overline{B^0}$ plane. The accuracy of this intercept is very poor. One could hope for the bachelor π^+ from the D^{*+} decay to help, unfortunately this hardly improves the result because this pion is very slow. Consequently the τ^- direction determined in such a way is generally further from the generated value than the one determined above. The knowledge of the τ^- direction is very important for the study of the polarization, but the situation could be hardly improved even with much better vertexing.

Fig. 4 shows the difference between the measured and generated τ energy E_τ^B in the $\overline{B^0}$ rest system. The distribution is distinctly narrower than the one in Fig. 2 which is due to partial cancellation of various measurement errors involved.

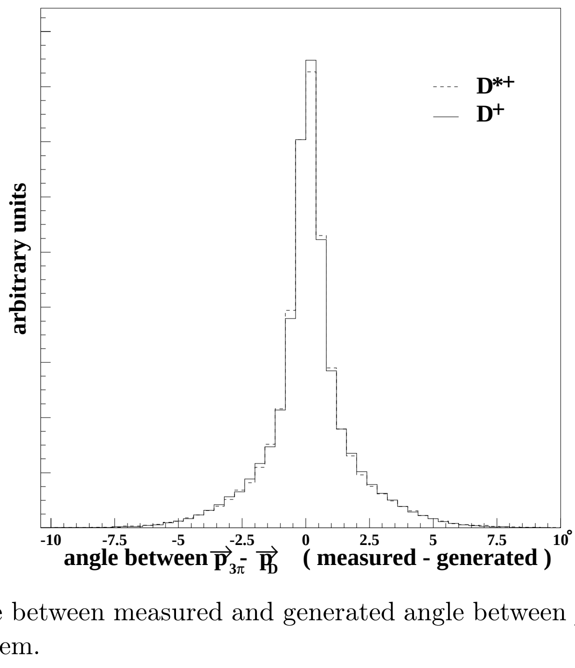

Fig. 5. Difference between measured and generated angle between $\vec{p_{3\pi}}$ and $-\vec{p_D}$ in the $\overline{B^0}$ rest system.

Finally Fig. 5 shows the polarization variable, which is independent of the τ^- direction, namely the angle between the total momentum of the 3π and the D^+/D^{*+} direction in the $\overline{B^0}$ rest system (more exactly the direction opposite to that of the D^+/D^{*+}; this is the direction of virtual W^-). The narrow distribution indicates a possibility of the measurement of polarization using this quantization axis. Since the τ vertex reconstruction is not needed here, one could in principle use one-prong τ decay channels, some of which (*e.g.* $\tau^- \to \pi^-\overline{\nu_\tau}$) have better analyzing power.

In general our results are much less optimistic than those of Kuno [17]. The difference is due to our considering of background and taking realistic vertex accuracy.

6. Conclusions

We have demonstrated that the kinematical reconstruction of the $\overline{B^0} \to D^+\tau^-\overline{\nu_\tau}$ and $\overline{B^0} \to D^{*+}\tau^-\overline{\nu_\tau}$ is possible at B-factories. However the branching fractions of the relevant decay channels and the selection criteria needed for background suppression reduce the sample to the limit of the experimental possibilities. The statistics could by significantly increased by improving detection efficiency of neutral particles. The accuracy of measured quantities is severely limited by vertexing because of the very short lifetime of the τ. Nevertheless, at least for the second decay it seems possible to overcome the background problem and to measure some physically interesting quantities.

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