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The Belle Collaboration

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# Search for $CP$ violation in $\tau$ semi-leptonic decay $\tau^{\pm} \rightarrow \pi^{\pm}\pi^{0}\nu_{\tau}$

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## Abstract

We report results on the first search for direct $CP$ violation in the $\tau$ semi-leptonic decay $\tau^{\pm} \rightarrow \pi^{\pm}\pi^{0}\nu_{\tau}$. A difference of $\tau^{+}$ and $\tau^{-}$ decay angular distribution is examined using a data sample of 2.3fb$^{-1}$ recorded with the Belle detector at the KEKB $e^{+}e^{-}$ collider. No $CP$ violation is observed. An upper limit at the 1% level is set on the $CP$ asymmetry.

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# 1. Introduction

In the Kobayashi-Maskawa model $CP$ violation is restricted to the quark sector and can not occur in lepton decays [1]. It can, however, occur in extensions of the standard model (SM) such as the multi-Higgs-doublet model (MHD) [5]. It has been argued that there is insufficient $CP$ violation in the SM to generate the apparent matter-antimatter asymmetry of the universe [2]. This motivates an experimental search for new $CP$ violating interactions, for instance $CP$ violation effects in semi-leptonic $\tau$ decays.

Observation of $CP$ violation in $\tau$ decays requires not only the existence of a $CP$-odd phase($\theta_{CP}$) but the interference of processes with $CP$-odd and $CP$-even amplitudes as well [3,4]. The $CP$-odd phase($\theta_{CP}$) can appear in the charged-scalar-exchange diagram in models beyond the SM such as MHD. On the other hand, the $CP$-even phase comes from the amplitude of the SM W-exchange diagrams, where $CP$-even strong phases exist in the hadron form factors if there are at least two mesons in the final state. For the $\tau$ lepton decay into two mesons $\tau(l,s) \to \nu(l',s) + h_1(q_1,m_1) + h_2(q_2,m_2)$, there are two form factors of the vector ($F_v$) and scalar ($F_s$) type, in general. The effect of the $CP$ violating charged-scalar-exchange contribution can be taken into account by replacing the SM scalar form factor $F_s$ by

$$F_s \to \tilde{F}_s = F_s + \frac{\eta_s}{m_\tau} F_H, \tag{1}$$

where $F_H$ is a form factor of exotic scalar-exchange and the complex parameter $\eta_s = |\eta_s| e^{i\theta_{CP}}$ parameterizes a possible $CP$ violation effect [3] *. By taking the $CP$ conjugate (i.e. $\tau^- \to \tau^+$), the sign of $\theta_{CP}$ changes: $\theta_{CP} \to -\theta_{CP}$, while the strong phases keep the same sign. The interference between the vector and scalar parts can thus exhibit a characteristic difference in the decay angle distribution of $\tau^+$ and $\tau^-$ leptons which is forbidden if $CP$ is conserved.

In order to investigate this effect, one can define an experimentally measurable asymmetry $A_{CP}(\cos\beta\cos\Psi)$ in terms of the number of events from the $\tau^\pm$ decay, $N^\pm(\cos\beta\cos\Psi)$, in a particular interval of $\cos\beta\cos\Psi$:

$$A_{CP}(\cos\beta\cos\Psi) = \frac{N^+(\cos\beta\cos\Psi) - N^-(\cos\beta\cos\Psi)}{N^+(\cos\beta\cos\Psi) + N^-(\cos\beta\cos\Psi)} \tag{2}$$

$$\propto \frac{1}{m_\tau} Im(F_v F_H^*) |\eta_s| \sin(\theta_{CP}) \cdot \cos\beta \cdot \cos\Psi, \tag{3}$$

where the decay angles $\beta$, $\Psi$ are defined in the hadron ($h_1 + h_2$) rest-frame. The angle $\beta$ denotes the angle between the direction of $h_1$ and the direction ($\hat{n}$) of the $e^+e^-$ c.m.s system in the hadron rest-frame. The angle $\Psi$ is the angle of the $\tau$ lepton direction with respect to $\hat{n}$ (see Fig.1). The cosine of the angle $\Psi$ ($\cos\Psi$) can be reconstructed kinematically from the energy of the observed mesons without knowing the $\tau$ direction itself. The explicit formulae for the evaluation of $\cos\Psi$ are given in Ref. [3].

One can deduce two important features from Eq.(3):

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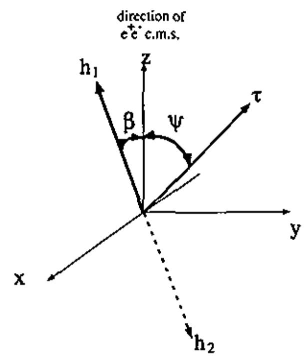
*The parameter $\eta_s$ is the coupling constant of the exotic charged-scalar to quarks measured in the unit of $G_F/\sqrt{2}$. The form factor $F_H$ has a dimension of mass while other form-factors $F_v, F_s$ are dimensionless.




h₁h₂ rest frame

FIG. 1. Definition of the angles $\beta$ and $\Psi$ in two meson decay $\tau^{\pm} \to h_1 h_2 \nu_\tau$.

1. The asymmetry is linear in $\cos\beta\cos\Psi$ and we do not expect an overall rate asymmetry. This feature will be quite important to discriminate the 'true' $CP$-asymmetry and 'fake' asymmetry which might be caused by the possible difference of the reconstruction efficiency in the detector for positive and negative charged tracks.
2. Only the exotic scalar-exchange term $F_H$ contributes to the asymmetry whereas the $F_s$ term does not contribute to $A_{CP}$ since its contribution is common to $\tau^-$ and $\tau^+$.

The first search for a $CP$ asymmetry in the $\tau$-decay was carried out by the CLEO collaboration using the decay mode $\tau^{\pm} \to K_s\pi^{\pm}\nu$ [6] and it is the only measurement so far.

In this paper we report on the first search for $CP$ violation in the decay $\tau^{\pm} \to \pi^{\pm}\pi^0\nu_\nu$. This mode has a merit of high statistics since the $\pi\pi^0$ decay has the largest branching fraction among the various $\tau$ decay modes [†].

## 2. Data and Event selection

The data sample used in this analysis has been collected from $e^+e^-$ collisions at a center of mass energy ($\sqrt{s}$) of 10.6 GeV with the Belle detector at the KEK asymmetric energy $e^+e^-$ collider (KEKB). In KEKB, 8 GeV electrons collide with 3.5 GeV positrons with a finite crossing angle of 22 mrad. In this analysis, we use the data taken from October 1999 to May 2000, which is the first data sample taken by the Belle experiment. The total integrated luminosity accumulated during this period is 2.3 fb$^{-1}$, corresponding to $2.1\times10^6$ produced $\tau^+\tau^-$ events.

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[†]This is a merit of the $\pi\pi^0$ mode compared to the $K\pi$ decay, although the expected asymmetry of the latter is bigger than the former in the charged Higgs exchange model since the quark masses ($u/d$ or $s$ quarks) might enter the Higgs coupling. The latter decay mode will be analyzed in near future.



The Belle detector consists of Silicon Vertex Detector, Central Drift Chamber(CDC), Electromagnetic Calorimeter, Silica Aerogel Čerenkov Counter, Time of Flight Counter, $\mu/K_L$ detector and Extreme Forward Calorimeter. The full description of the detector is given in Refs. [7,8]. Here we briefly describe relevant apparatus used in this analysis. The charged tracks are measured in 1.5 Tesla magnetic field by the CDC, which consists of 52 cylindrical layers of the drift cells organized into 11 super-layers for $z$ coordinate measurement. $He - C_6H_6$(50/50%) gas is used to minimize the multiple-Coulomb scattering and nuclear interactions. It covers the $17° < \theta < 150°$ angular region. Tracks are fit using an incremental Kalman filtering technique, where individual measurements found by the CDC pattern recognition algorithm are added successively to update the track's parameters at each measurement surface. This approach minimizes the multiple Coulomb scattering on the determination of the track parameters. The momentum resolution is measured to be $\sigma_{p_t}/p_t = (0.36 \oplus 0.28p_t)\%$, where $p_t$ is the transverse momentum in GeV. The energy of the photons are measured by the Electromagnetic Calorimeter which uses 8736 Cesium Iodide(CsI(Tl)) crystals. All of crystals are 30 cm (16.1 $X_0$) long. The calorimeter covers the polar angle($\theta$) from 12° to 155° in laboratory frame. The energy resolution for electromagnetic shower is $\sigma_E/E = [(0.07/E) \oplus (0.8/E^{1/4}) \oplus 1.3]\%$, ( $E$ in GeV).

Events are selected with two charged tracks and zero net charge. Each track is required to have a momentum transverse to the beam axis $p_T \geq 0.1$GeV, extrapolate well to the interaction point to within ±1 cm transversely and ±5 cm along the beam. The maximum $p_T$ among the tracks is required to be $\geq 0.5$ GeV in order to satisfy the trigger conditions. The beam induced background is rejected by requiring the position of the reconstructed event vertex be less than 0.5 cm in the transverse direction and ± 3 cm along the beam. Background from two-photon interactions is rejected by requiring two following conditions: (i) the polar angle ($\theta_{miss}$) of the missing momentum must be $5° < \theta_{miss} < 175°$. (ii) the sum of the absolute value of the momentum of charged tracks and the energy of $\gamma$ clusters in the c.m.s system ($E_{rec}$) must be greater than 3.0 GeV or $p_T^{max}$ greater than 1.0 GeV. Clusters in the CsI calorimeter to which no tracks are associated are regarded as $\gamma$ (or *unmatched*) clusters.

Bhabha events ($e^+e^- \to e^+e^-\gamma$) must be treated with care because of the large cross section for the process and its steep angular distribution. Clean Bhabha events are rejected by requiring the sum of the cluster energy ($E_{sum}$) in c.m.s be less than 9 GeV. To reject the remaining radiative Bhabha events, the sum $E_{rec} + |P|_{miss}$ is required to be less than 9 GeV. Here $|P|_{miss}$ is the absolute value of the missing momentum vector in c.m.s. This cut takes into account the energy carried away by a radiative photon which is emitted along the beam line or the boundary between the barrel and endcap calorimeter. In addition, if both the electrons are scattered to the endcap region, the sum of the c.m.s energy of the *matched* clusters is required to be less than 5.3 GeV. Finally, events of the process $e^+e^- \to \mu^+\mu^-(\gamma)$ are rejected by requiring the sum of the momenta of two leading tracks be less than 9 GeV.

The event is divided into two hemispheres in the $e^+e^-$ c.m.s. with respect to the leading particle. The opening angle of two particles is required to be larger than 90°. The polar angle ($\theta_{axis}$) of the leading particle is limited to the fiducial region $35° < \theta_{axis} < 145°$ in c.m.s. In one hemisphere (tag-side hemisphere) we require only one charged track and no photons with the energy greater than 100 MeV provided such a cluster is well isolated from the nearest track projection (by at least 20 cm).

The $\pi^{\pm}\pi^0$ decay is reconstructed in the other hemisphere by requiring that the charged track not be identified either as an electron or a muon, and there is only one $\pi^0$ with a momentum greater than 100 MeV.

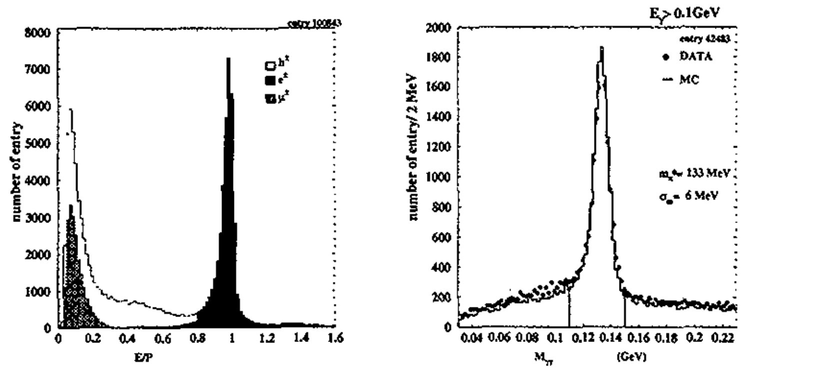


FIG. 2. Left: A typical E/p distribution for the selected $\tau$-pair sample. The hatched area around E/p$\sim$ 1 corresponds to particles identified as electrons, while the hatched one at E/p $\sim$ 0.1 contains muons identified using the information from the muon/$K_L$ detector. Right: A typical $\gamma\gamma$ invariant mass distribution for the tagged $\tau$-pair sample. Data (points) are compared to the Monte-Carlo simulation (histogram). Combinatorial background comes mainly from the multi-$\pi^0$ decays of the $\tau$ lepton.

The left part of Fig. 2 shows the E/p distribution for all charged tracks in the selected $\tau^+\tau^-$ sample; thus demonstrates how well the electron signal is separated from charged hadrons. A charged track is identified as an electron if either E/p is greater than 0.8 or the electron probability determined from the shower shape and dE/dX in the central chamber is greater than 0.7 for E/p > 0.4. A muon is identified by using the information from the muon/$K_L$ detector located outside the calorimeter.

The right part of Fig. 2 shows the $\gamma\gamma$ invariant mass distribution for the tagged $\tau^+\tau^-$ sample, where clusters are considered as candidates for photons from the $\pi^0$ decay if they have the energy greater than 50 MeV (100 MeV in the endcaps) and are not matched to any charged track. The rms resolution of the $\pi^0$ signal varies from 4.8 MeV to 7 MeV, depending on the $\pi^0$ momentum. Pairs of photons in the mass region between 110 and 150 MeV are considered as $\pi^0$ candidates.

In this analysis the kaon tracks are not identified. Thus, the $\pi\pi^0$ sample contains a small admixture of $K\pi$ decays.

## 3. Analysis

The final sample of $\tau^{\pm} \to \pi^{\pm}\pi^0\nu_\tau$ contains $8.3 \times 10^4$ events as shown in Table-I. The sample is dominated by the $\tau \to \rho\nu_\tau$ signal as can be seen from the $\pi^{\pm}\pi^0$ invariant mass distribution shown in Fig. 3.



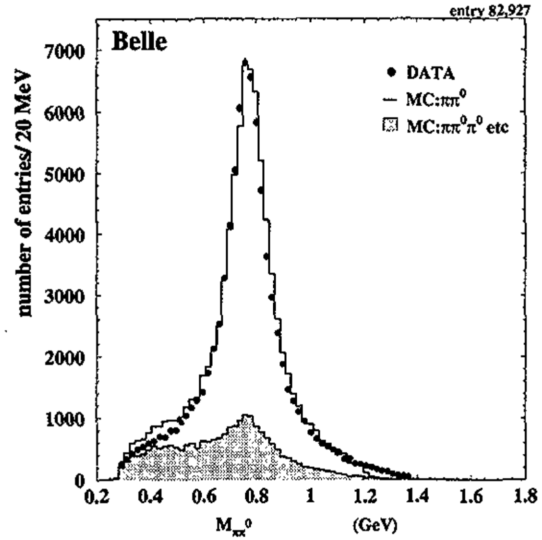


FIG. 3. The $\pi^{\pm}\pi^0$ invariant mass distribution for data (closed circles) and Monte Carlo (histogram) after all selection criteria. The hatched histogram is the 'feed across' from other $\tau$ decays among which the $\tau^{\pm} \to \pi^{\pm}\pi^0\pi^0\nu$ decay mode dominates.

The remaining backgrounds from non-$\tau^+\tau^-$ processes are estimated from Monte Carlo. The backgrounds arising from the $e^+e^- \to q\bar{q}$ continuum and two photon processes [10] are 0.7% and 0.5% respectively while others are negligible. The KORALB/TAUOLA [9] Monte Carlo code is used for the generation of events of the $e^+e^- \to \tau^+\tau^-(\gamma)$ processes. After passing the Belle detector simulation, Monte Carlo distributions are compared with data in Fig.3. The data and Monte Carlo agree well for the $\rho$ meson signal shape. The hatched area is the expected feed across from the decays of $\tau$ into multi-$\pi^0$ modes. Since no tight cuts on additional photons in the signal hemisphere is applied, the final sample includes a 10% feed across from multi-$\pi^0$ modes, such as $\pi\pi^0\pi^0$.

The momentum spectra of charged pions ($\pi^{\pm}$) and their polar angle distribution measured in the laboratory system are compared with the Monte Carlo simulation in Fig. 4. Good agreement is observed.

Using this sample, the asymmetry from $\tau^+$ and $\tau^-$ decays has been measured in two intervals of $\cos\beta\cos\Psi$, $A_{cp}(\cos\beta\cos\psi > 0)$ and $A_{cp}(\cos\beta\cos\psi < 0)$, and the results are given in Table. I. The asymmetry is consistent with zero within the statistical error of 0.5%. No systematic difference between the $\tau^+$ and $\tau^-$ is observed in the $\cos\beta\cos\Psi$ distribution shown in Fig. 5. The asymmetry in finer intervals of $\cos\beta\cos\Psi$ is shown in Fig. 6. Since an actual $CP$-asymmetry should be proportional to $\cos\beta\cos\Psi$, we fit the asymmetry $A(\cos\beta\cos\Psi)$ distribution with a straight line-function($a \cdot \cos\beta\cos\Psi + b$) and a function

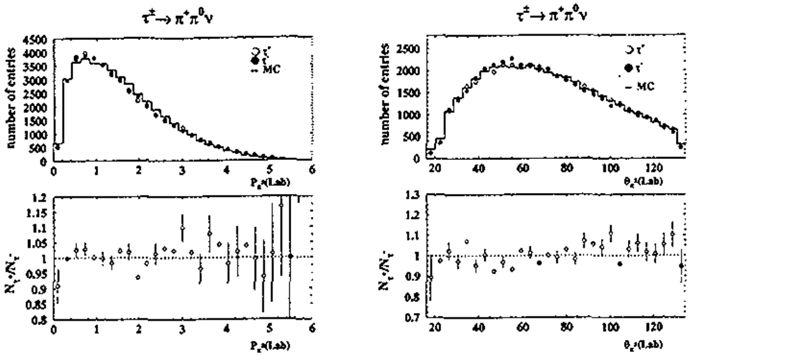


FIG. 4. $\pi^{\pm}$ momentum (left) and polar angle (right) distribution in laboratory system for $\pi^{\pm}$ in the $\tau \to \pi^{\pm}\pi^{0}\nu$ decay. Closed circles show $\tau^{+}$ and open circles - $\tau^{-}$ decays. The Monte-Carlo expectation is shown by the histogram. The bottom figures present the ratio $(N_{\tau^+}/N_{\tau^-})$ of the number of events between $\tau^{+}$ and $\tau^{-}$.

without a slope to check the goodness of the fit. The fit results are summarized in Table II and are shown by the dotted lines in Fig. 6. As can be seen from Table II, the asymmetry distribution can be fitted equally well by the straight line with and without slope, and is *consistent with no CP asymmetry within statistical errors.*

TABLE I. The number of selected events and observed asymmetry in the positive and negative $\cos\beta\cos\psi$ regions.

| $\cos\beta\cos\psi$ | $N(\pi^+\pi^0)$ | $N(\pi^-\pi^0)$ | $A_{cp}(\cos\beta\cos\psi)$ |
|---|---|---|---|
| $\cos\beta\cos\psi > 0$ | 19,455 | 19,610 | −0.004±0.005 |
| $\cos\beta\cos\psi < 0$ | 22,148 | 21,714 | +0.010±0.005 |
| Total | 41,603 | 41,324 | +0.003±0.003 |

TABLE II. Results of the fit of the asymmetry A($\cos\beta\cos\psi$) distribution by a straight line with and without slope.

| Curve | $a$ | $b$ | $\chi^2/n.d.f.$ |
|---|---|---|---|
| straight line | $-0.015 \pm 0.010$ | $+0.0027 \pm 0.0035$ | $12.1/8 = 1.5$ |
| line without slope | – | $+0.0033 \pm 0.0033$ | $15.2/9 = 1.7$ |

A study of the possible sources of systematic uncertainties and bias in the $A_{CP}$ measurement is in progress. The principal source of the detector asymmetry could come from the



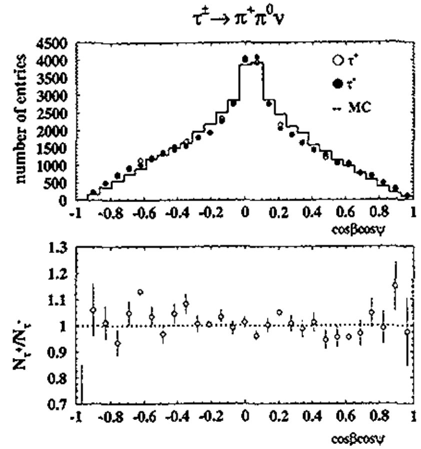


FIG. 5. The $\cos\beta\cos\Psi$ distribution for the decay $\tau^{\pm} \to \pi^{\pm}\pi^{0}\nu$. Closed circles show $\tau^{+}$ and open circles - $\tau^{-}$ decays. The Monte Carlo expectation is shown by the histogram. The bottom figures present the ratio $(N_{\tau^+}/N_{\tau^-})$ of the number of events.

difference of the cross sections for the nuclear interactions of positive and negative charged hadrons. In principle, this could change the tracking efficiency of the charged tracks as well as the calorimeter response, such as the number of fake clusters in a hadronic shower. In this respect a $\gamma$ veto used in the event selection is a potential source of producing the fake asymmetry.

So far we have checked the charge asymmetry as a function of various observables in the signal and $\tau \to (\pi/\mu)\nu$ events. The latter process has the merit of making an independent check of the detector systematics since it has similar topology to the signal but should has no $CP$ asymmetry since there are no strong phases in the final state. Among the distributions we checked, only the momentum distribution shows a visible charge asymmetry for pions with momenta less than about 0.2 GeV( see Fig. 4). Since the reason for this is not yet understood and the statistical significance is not high, we did not apply any correction to the observed $A_{CP}$ at this time.

In summary, we report preliminary results on a search for CP violation in the $\tau^{\pm} \to \pi^{\pm}\pi^{0}\nu$ decay using first data recorded by the Belle experiment at KEKB. No $CP$ violation has been observed. From the larger value of the asymmetry in the $\cos\beta\cos\psi < 0$ region, the upper limit on $|A_{CP}(\cos\beta\cos\psi)|$ is set to be

$$|A_{CP}(\cos\beta\cos\psi)| < 0.016$$

at the 90% confidence level. This limit will be improved with better understanding of the systematics and an increase of the data sample.

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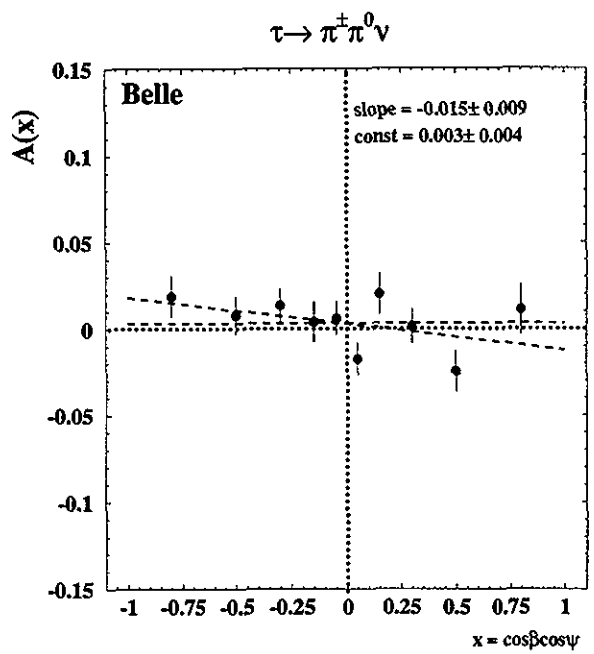


FIG. 6. Asymmetry $A(\cos\beta\cos\Psi)$ as a function of $\cos\beta\cos\Psi$. The dashed lines are fits with a straight line or a straight line without a slope. See text for details.


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## REFERENCES


[1] M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49** (1973) 652.

[2] P. Huet, E. Sather, Phys. Rev. **D51** (1995) 279; M.B. Gavela *et al.*, Nucl. Phys. **B430** (1994) 345; P. Huet, A.E. Nelson, Phys. Rev. **D53** (1996) 4578.

[3] J.H.Kühn and E. Mirkes, Phys. Lett. **B398** (1997) 407; Y.S. Tsai, Nucl. Phys. B(Proc. Suppl.)**55C** (1997) 293.

[4] S.Y. Choi, J. Lee and J. Song, Phys. Lett. **B437** (1998) 191.

[5] Y. Grossman, Nucl. Phys. **B426** (1994) 355, and references therein.

[6] S. Anderson *et al.* (CLEO collab.), Phys. Rev. Lett. **81** (1998) 3823.

[7] KEKB B-Factory Design Report, KEK Report 95-7 (1995).

[8] Central Chamber: H. Hirano *et al.*, KEK Preprint 2000-2, submitted to Nucl. Instr. Meth.; M. Akatsu *et al.*, DPNU-00-06, submitted to Nucl. Inst. Meth.
CsI: H. Ikeda *et al.*,Nucl. Instr. Meth. **441** (2000) 401.
SVD: H. Aihara *et al.*, KEK Preprint 2000-34.
ACC: T. Iijima *et al.*, *Proceeding of the 7th International Conference on Instrumentation for Colliding Beam Physics, Hamamatsu, Japan, Nov. 15-19,1999.*
TOF: H. Kichimi *et al.*, submitted to Nucl. Instr. Meth.
Muon/$K_L$: A. Abashian *et al.*, Nucl. Instr. Meth. **449** (2000) 112.
Trigger: Y. Ushiroda *et al.*, Nucl. Instr. Meth. **A438** (1999) 460.

[9] KORALB(v.2.4)/TAUOLA(v.2.6): S. Jadach and Z. Was, Comp. Phys. Commun. **85** (1995) 453 and *ibid*, **64** (1991) 267, *ibid*, **36** (1985) 191; S. Jadach, Z. Was, R. Decker and J.H. Kühn, Comp. Phys. Commun. **64** (1991) 275, *ibid*, **70** (1992) 69, *ibid*, **76** (1993) 361.

[10] F. A. Berends, P. H. Daverveldt, R. Kleiss, Comp. Phys. Commun. **40** (1986) 285.