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KORALB – An upgrade to version 2.4

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ABSTRACT

An upgrade of the Monte Carlo program for τ pair production including τ mass, spin and QED O(α) effects is presented. Its main feature is the interface to the new τ decay Monte Carlo library TAUOLA, new coding of the final states and implementation of the Z exchange at the Born level.

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NEW VERSION SUMMARY

Title of the program: KORALB, version: 2.4

Reference to original program: Comput. Phys. Commun. **36** (1985) 191.

Authors of original program: S. Jadach and Z. Wąs

Computer: HP 715

Operating system: UNIX

Programing language used: FORTRAN 77

High speed storage required: $<$ 1MB

No. of bits in a word: 32

Peripherals used: Line printer

No. of lines in combined program and test deck including TAUOLA and PHOTOS libraries: about 12615.

Keywords: radiative corrections, heavy lepton τ, Monte Carlo simulation, quantum electrodynamics, spin polarization, electroweak effects

Comparison with the previous version, and reasons for the new version: The τ decay library [2] is now updated. The physics content of the τ production part of the program is enriched. Convenient for certain tests, the possibility to use the program at the Born level including Z exchange is introduced.

Typical running time: 1 to 300 events per (HP 715/33) sec, depending on the τ decay modes chosen and no beam polarization.

Unusual features of the manual: This is not an independent document. Only the differences with Ref. [1] are documented.

References:

[1] S. Jadach and Z. Wąs, Comput. Phys. Commun. **36** (1985) 191., ibid. **64** (1991) 261

[2] R. Decker, S. Jadach, M. Jeżabek, J. H. Kühn and Z. Wąs, Comput. Phys. Commun. **64** (1991) 275, ibid. **70** (1992) 69, ibid. **76** (1993) 361.

UPDATE DESCRIPTION

1 Introduction

Since the original version of the KORALB program was published [1], no major improvements has been introduced to the code generating τ-pair production and spin effects. However, it is still the most complete and sophisticated Monte Carlo generator for the τ-pair production process at low energies, $\sqrt{s} < 30$ GeV. Its use is now quite widespread and, as the low-energy e^+e^- experiments are still collecting τ-pair data (CLEO) and the new high-luminosity experiments are planned (on τ-charm or b factories), there is therefore an urgent need to develop KORALB as well as to study its uncertainties.

In this paper we present the new version of KORALB. All the physical content of the program (treatment of QED, Z exchange, spin) remains very similar. The main improvement is the inclusion of possibility of switching off transverse spin correlations and running the program at the peak of the Z (with the Born level Z exchange spin amplitude in the small τ-mass approximation). Modifications to the program include automatized choice of the maximal spin weight allowing easy implementation of the extra amplitudes (such as Z exchange). We include in the program the updated version of the τ-decay library TAUOLA [2] with new QED bremsstrahlung corrections in the τ decays where in the semileptonic τ-decays approximate algorithm of the PHOTOS [3] is now used.

In the last five years we have developed another τ Monte Carlo program KORALZ [4], suitable for higher energies (LEP). With the increasing experimental precision it is becoming important to provide a platform in which results of the two programs can be easily compared. With the present update of KORALB the two programs KORALB and KORALZ can be used to study [6] the systematic errors related to certain terms missing in their matrix elements[1]. On one hand, we are now able to estimate easily the missing transverse spin effects in KORALZ and on the other hand we can check how important are missing higher order QED effects in KORALB. The main principle of these tests/improvements in the predictions consists of calculating the numerical size of the corrections missing in one of the program with the help of the other one. This hybrid Monte Carlo tool enables calculation of above effects in the presence of the detector acceptance, with various choices of cuts etc. We have already successfully applied such a method in our high-precision calculation of the luminosity cross section at LEP [7].

In the following, we shall describe how to run the program, and we list the most important modifications to the code.

[1]Similar comparisons can be performed with the results of a program [5] constructed specially for the study of non-standard couplings of the Z to τ.

2 How to use the program

A Monte Carlo event, i.e. a complete set of final state momenta and flavors, is generated by a single call to the routine KORALB. For example a complete sequence of calls, which generates 1000 Monte Carlo events may look like

```
      REAL*4 PB1(4),PB2(4),E1(3),E2(3),XPR(40)
      INTEGER*4 NPR(40)
      CALL KORALB(-1,KFB,PB1,E1,-KFB,PB2,E2,XPR,NPR)
      DO 300 IEV=1,1000
      CALL KORALB(0,KFB,PB1,E1,-KFB,PB2,E2,XPR,NPR)
300   filling histograms
      CALL KORALB(1,KFB,PB1,E1,-KFB,PB2,E2,XPR,NPR)
```

Here, the first obligatory call on KORALB defines $e^{\pm}$ beam momenta and transfers other input parameters (so far no event generation). The other calls on KORALB in the loop generate M.C. events, and the final optional call terminates the generation by printing some useful output. The final output includes the total cross section, the widths in τ decays from TAUOLA, etc. Generally, the input parameters are transferred as KORALB parameters and the output results (momenta, flavours) are encoded in common blocks documented, if necessary, later in this Section.

Let us explain now in more detail the parameters of KORALB. As is obvious from the above example the first parameter MODE in KORALB(MODE,...) is defining whether KORALB is called in initialization mode (MODE=-1), generation mode (MODE=0), or post-generation mode (MODE=1).

3 Initialization mode

In the initialization mode (`MODE=-1`) the meaning of the parameters in
`KORALB(MODE,KFB,PB1,E1,-KFB,PB2,E2,XPR,NPR)`
is the following: `REAL*4 PB1(4), PB2(4)` are four-momenta of the first and second beam (where `PB1(4)` and `PB2(4)` are energies). Both momenta are necessarily along a third axis in the laboratory system and `PB1` is required to have a positive third component. Having in mind asymmetric b-factories we have introduced a possibility of asymmetric beam energies, and the laboratory system is thus not necessarily identical to the center of mass system (CMS). The two are related by a simple boost along the third axis at the end of the kinematics chain. `INTEGER*4 KFB` is a flavor identifier of the first beam (i.e. associated with `PB1`). `KFB=11,-11` denotes electron and positron, respectively, in the notation of [8]. Two four-vectors `REAL*4 E1(4), E2(4)` are spin polarization vectors of the first and second beam in the $e^{\pm}$ rest frames. For the first beam (`PB1,E1`), the corresponding rest frame used to define its spin polarization vector `E1` has its third axis directed along its line of flight, i.e. it is a standard helicity axis. For `E2`, the direction of the corresponding third axis is opposite to its line of flight, i.e. opposite to its helicity axis. For example `KFB=-11, E1=(0.0,0.0,1.0), E2=(0.0,0.0,1.0)`, means that the user asks for the first beam to be a right-handed positron and the second a left-handed electron. Transverse and partial polarizations are allowed, e.g. `E2=(0.0,0.0,0.5)` would represent a 50% polarized second beam. The other input parameters are transferred through matrices `REAL*4 XPR(40)` and `INTEGER NPR(40)`.

In this table, we give a short summary of all input parameters.

Parameter	Meaning
`KFB`	Flavor identifier of the first beam, KFB$= 11, -11$ denotes electron and positron respectively (PDG notation).
`PB1`	Four-momentum of the first beam. PB1(3)>0 is required.
`E1`	Spin polarization vector of the first beam. E1(3)=helicity.
`PB2`	Four-momentum of the second beam.
`E2`	Spin polarization vector of the second beam. E2(3)=$-$helicity.
`NPR(1)=ISPIN`	Switch for spin effects in τ decay. The user normally sets ISPIN=1 to have all spin effects included and may set ISPIN=0 to neglect them.
`NPR(2)=INRAN`	Integer constant, INRAN$\geq$1, is used to initialize a random number generator in the τ pair production part of M.C.
`NPR(3)=KEYGSW`	Implementation level of the GSW standard electroweak model. For KEYGSW=0 there is no Z exchange at all. For KEYGSW=1 the interference between γ and Z exchange is included.
`NPR(4)=KEYRAD`	Switch for the QED bremsstrahlung. KEYRAD=0 means no QED bremsstrahlung. KEYRAD=1 denotes single bremsstrahlung.
`NPR(5)=JAK1`	The variable JAK1=1,2,3,... defines the decay channel of τ^+ as being $\bar{\nu}e^+\nu$, $\bar{\nu}\mu^+\nu$, $\bar{\nu}\pi^+$, ... according to the order defined in TAUOLA. Furthermore, setting JAK1=0 causes the τ^+ to decay into all channels inclusively according to predefined branching ratios (see routine JAKER), and setting JAK1=$-$1 inhibits the decay completely.
`NPR(6)=JAK2`	The assignments of JAK2, for τ^-, are the same as those of JAK1.

Parameter	Meaning
`NPR(7)=ITFIN`	This switch key allows the generation of final state fermion pairs other than τ pairs. The τ pairs are produced with ITFIN=1, μ pairs with ITFIN=2. The mass of τ and μ is taken from the common block of TAUOLA. A quark pair may be produced with ITFIN=501-506. In this case the quark mass is defined through XPR(14) (see below). For ITFIN > 1 the τ decay is automatically suppressed.
`NPR(8)=ITDKRC`	Switch for bremsstrahlung in the τ decay.
`NPR(9)=ITRANS`	Switch for transverse spin correlations.
`NPR(11)=IFZET`	Switch for full implementation of Z. At present it can be used only for KEYRAD=0.
`XPR(1)=AMZ`	Mass of the Z.
`XPR(1)=GAMZ`	Width of the Z.
`XPR(4)=GV`	Vector coupling constant g_V and
`XPR(5)=AV`	axial coupling constant g_A of the τ to the W in the τ decay. Note that $g_V = 1$, $g_A = -1$ represent the standard $V - A$ assignment.
`XPR(6)=SINW2`	$\sin^2\theta_W$. It has to be assigned for KEYGSW= 1.
`XPR(8)=AMNUTA`	Mass of the ν_τ. To avoid rounding machine errors it has to be assigned a non-zero value.
`XPR(11)=XK0`	k_0, soft/hard photon cut-off for the QED bremsstrahlung. The recommended value is $k_0 \simeq 0.005$.
`XPR(14)=AMFIN`	Mass of the final state quarks. Dummy parameter for ITFIN=1 or ITFIN=2.
`XPR(13)=XKMAX`	Maximum photon energy to be generated (in $\sqrt{S/4}$ units).
`XPR(i),NPR(i)`	All other entries in the XPR and NPR matrices are dummy.

4 Generation/production mode

In this mode all parameters of KORALB, except for MODE=0, are ignored. The produced Monte Carlo event is stored in the common block

```
C--  HEPEVT                         Standard high-energy physics (HEP)
C--                                 common definitions
      INTEGER NMXHEP
      PARAMETER (NMXHEP=2000)
      INTEGER IDHEP,ISTHEP,JDAHEP,JMOHEP,NEVHEP,NHEP
      REAL  PHEP,VHEP
      COMMON/HEPEVT/NEVHEP,NHEP,ISTHEP(NMXHEP),IDHEP(NMXHEP),
     1JMOHEP(2,NMXHEP),JDAHEP(2,NMXHEP),PHEP(5,NMXHEP),VHEP(4,NMXHEP)
```

The common block HEPEVT contains a complete set of all initial and final state flavors and four-momenta encoded in the standard conventions [8]. This common block contains information on the $e^{\pm}$ beams, on the $\tau^{+}, \tau^{-}, \gamma$, and finally on all the $\tau^{\pm}$ decay products including neutrinos. Conservation of total energy and momentum is explicitly obeyed. Intermediate particles like $W^{\pm}$ and $\rho^{\pm}$ are kept in the record, wherever possible.

In addition the final state momenta for the production process may be found in COMMON / UTIL4 / QP(4),QM(4),PH(4) where REAL*4 QP,QM are four-momenta of τ^{+}, and τ^{-} respectively, and REAL*4 PH is the momentum of the bremsstrahlung photon (in GeV units).

5 Postgeneration mode

A call on KORALB in this mode (MODE=1) may be optionally used in order to obtain information on the value of the integrated cross section and the list of the partial τ decay widths. They are obtained with a finite statistical error depending on the number of generated M.C. events and they correspond strictly to the production and decay matrix elements used in the actual M.C. generation[2]. All this information is printed in the output, and some of it is also provided to the user through parameter matrices XPR and NPR, as in the following table.

Parameter	Meaning
NPR(10)	Number of generated τ pairs.
XPR(10)	Total cross section in cm^2.

[2]For the generation, however, the probabilities of various decay modes are determined using values of the branching ratios from the common block TAUBRA. They have to be initialized by the user, see Long-Write-Up of TAUOLA.

6 The most important modifications to the program

1. The τ decay library TAUOLA is updated.
2. The algorithm for QED radiative corrections of PHOTOS in the τ decay simulation is introduced.
3. Transverse spin correlation can be switched on and off with the help of `NPR(9)=ITRANS`.
4. Z exchange can be switched on, `NPR(11)=IFZET`. Its mass, width and $\sin^2\theta_W$ are transmitted in through `XPR(1)`, `XPR(2)` and `XPR(6)` respectively. The meaning of these parameters is exactly the same as in KORALZ [4]. At present this option is limited to the case of the Born level.
5. The energies of e^+e^- beams can be different; however, the beam energy spread is not yet introduced. Beam momenta have to be back to back.
6. Certain bugs were removed. The most important one is discussed in the Appendix; fortunately it is numerically insignificant.

The following three new common blocks were introduced:

1. `COMMON / NEWZET/ IFZET,ITRANS`
2. `common / znowy / amz,gamz`
3. `COMMON / CMSLAB/ GAMLAB`

As can be seen, there is still a lot of improvement in the program to be done. The present version of the program, together with KORALZ, forms a definite platform to decide whether a multi-photon Monte Carlo including complete spin treatment is needed or whether the hybrid solution KORALB+KORALZ presented here is still sufficient.

Acknowledgements
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References

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[3] E. Barberio, B. van Eijk and Z. Wąs, Comput. Phys. Commun. **66** (1991) 115; E. Barberio, and Z. Wąs, Comput. Phys. Commun. **79** (1994) 291.

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APPENDIX

In our paper [9] and in all calculations of spin amplitudes we used a different (opposite sign) choice of the scattering angle θ in the part of cross section Born+virtual ($k < k_0$) from that for the real-photon-emission part ($k > k_0$). The above choice is not the problem in itself but for some unknown reasons (blind optimization during the final clean-up before publication?) this fact was not properly reflected in the `TRALOR` routine, already in the first published version [1] of KORALB.

Corrections to our papers. All spin amplitudes expressions for correlation tensors R_{abcd}, numerical results, etc., in Refs. [9, 1] and any other are NOT affected. The bug is present in the long-write-up [1]: In eq. (2.28) in the definition of $L_0(\tau^\pm)$ rotation matrix $R_1(-\theta)$ should be replaced with $R_1(\theta)$. The same change should be made in Fig. 1a. The same change propagates to eqs. (2.2), (3.5) and Fig. 2a in Ref. [10] and to Fig. 1a in Ref. [11]. Note that the TIPTOP program and related papers are not affected because this program, although derived from KORALB, has a different `TRALOR` routine. The same is true for the KORALZ program.

Apologies and remarks on tests of KORALB: We are really very sorry for any inconveniences and/or any other possible consequences of the above bug. We would like to stress (as usual) that the user of any Monte Carlo program should test its basic properties relevant to her/his specific needs. Although it is always our aim that the Monte Carlo program is 100% free of bugs, the user should NEVER assume that this is true. *How well is* KORALB *tested?* Its basic tests are in Ref. [9] and we strongly recommend any user to repeat them before he applies results of the program[3]. We expressed on many occasions our feelings that with present statistics of millions τ's these old tests are NOT sufficient and there is an urgent need for more sophisticated tests – in addition to a repetition of old ones. Note that tests in Ref. [12] are performed on distributions, which are in principle sensitive to the bug; however, numerical size of the effect is small – it is respectively 1% and 3% for the distribution L of Ref. [12] calculated at 10 and 4 GeV center of CMS energy. Such a small effect could not be seen with the tests performed in this paper.

We would like to encourage anybody who finds observables more sensitive to the bug to contact us as soon as possible. The bug can be re-introduced with the flag `IBLAD=1` in routine `TRALOR`. We will immediately redistribute this information to other users of KORALB. So far, we can hope that the bug did not affect any experimental analysis.

Acknowledgement: We would like to thank Dr. Holger Thurn for reporting the bug and for helping us to localize it. His dedicated effort (including one day off his private visit in the Geneva area during Easter 93) was also very helpful in understanding the numerical effects of the bug. We would also like to thank Prof. Charles Nelson for calculating the sensitivity of his plots on the artificial introduction in his formulae a term equivalent to the bug we had in KORALB.

TEST RUN OUTPUT

```
=========================================================================
=========================================================================
=========================================================================
=========================================================================
                         DEMONSTRATION PROGRAM
                        THE MONTE CARLO PROGRAM
                          KORALB- VERSION 2.4
                   PREPRINT CERN-TH 7272, MAY 1994
=========================================================================
=========================================================================
    NEVTES=   2000  NO. OF REQUESTED EVENTS
    ENE   =   5.00  BEAM ENERGY
=========================================================================
=========================================================================
```

[3]In fact the statement in Ref. [9] p. 1155: "spin of the τ-s try to align both in the same direction along the beam axis" cannot be reproduced with a published version of KORALB – this may indicate that bug was introduced just before the submission of the program for publication in Ref. [1].

```
1***************************************************************************
 *                         =KORALB VERSION 2.4 INPUT PARAMETERS ==          *
 *                         ==========MAY  1994===================          *
 *              -11     KF1    =  FIRST BEAM IDENTIFIER                    *
 *               11     KF2    =  SECOND BEAM IDENTIFIER                   *
 *                         ==== FOUR MOMENTA OF THE BEAMS ========          *
 *        7.500000000     PB1(3) =  FIRST BEAM, 3-RD COMPONENT             *
 *        7.500000000     PB1(4) =              0-TH COMPONENT             *
 *       -5.000000000     PB2(3) = SECOND BEAM, 3-RD COMPONENT             *
 *        5.000000000     PB2(4) =              0-TH COMPONENT             *
 *                         ==== SPIN VECTORS OF THE BEAMS ========          *
 *         .000000000     E1(1)  =  FIRST BEAM, 1-ST COMPONENT             *
 *         .000000000     E1(2)  =              2-ND COMPONENT             *
 *         .000000000     E1(3)  =              3-RD COMPONENT             *
 *         .000000000     E2(1)  = SECOND BEAM  1-ST COMPONENT             *
 *         .000000000     E2(2)  =              2-ND COMPONENT             *
 *         .000000000     E2(3)  =              3-RD COMPONENT             *
 *                         ==== INPUT PARAMS IN NPAR =============          *
 *                1     ITFIN  =  TYPE OF THE FINAL STATE                  *
 *                1     ISPIN  =  SPIN EFFECTS SWITCH                      *
 *               17     INRAN  =  RANDOM NUMB. INITIALISATION              *
 *                1     KEYGSW =  GSW IMPLEMENTATION LEVEL                 *
 *                1     KEYRAD =  BREMSSTRAHLUNG   SWITCH                  *
 *                0     JAK1   =  DECAY TYPE TAU+                          *
 *                0     JAK2   =  DECAY TYPE TAU-                          *
 *                1     ITDKRC =  BREM. IN DECAY SWITCH                    *
 *                1     ITRANS =  TRANSVERSE SPIN CORR. SWITCH             *
 *                0     IFZET  =  NEW IMPLEMENT. OF Z SWITCH               *
 *                         ==== INPUT PARAMS IN XPAR =============          *
 *       91.199996948     AMZ   = MASS OF ZO BOSON                         *
 *        2.500000000     GAMZ  = WIDTH OF ZO BOSON                        *
 *         .230000004     SINW2 =  SIN**2(THETAWEINBERG)                   *
 *        1.000000000     GV    = VECTOR COUPLING CONST. IN DECAY          *
 *       -1.000000000     GA    = AXIAL  COUPLING CONST. IN DECAY          *
 *         .010000000     AMNUTA= MASS OF TAU-NEUTRINO  IN DECAY           *
 *         .010000000     XKO   = SOFT/HARD PHOTON CUT OFF                 *
 ***************************************************************************

 ********************************************************************************
 *                                                                              *
 *                         =========================                            *
 *                           PHOTOS, Version:  2. 0                             *
 *                           Released at:  16/11/93                             *
 *                         =========================                            *
 *                                                                              *
 *                  PHOTOS QED Corrections in Particle Decays                   *
 *                                                                              *
 *        Monte Carlo Program - by E. Barberio, B. van Eijk and Z. Was          *
 *        From version 2.0 on - by E.B. and Z.W.                                *
 *                                                                              *
 ********************************************************************************
 *                                                                              *
 *                  Internal input parameters:                                  *
 *                                                                              *
 *                  INTERF= T  ISEC= T  IFTOP= T                                *
 *                  ALPHA_QED=  .00730   XPHCUT=  .01000                        *
 *                                                                              *
 *                  option with interference is active                          *
 *                  option with double photons is active                        *
 *                  emision in t tbar production is active                      *
 *                                                                              *
 ********************************************************************************
 *                         ==KORALB-INITIALIZATION THROUGH TAUOLA=          *
 *        1.784199953     AMFIN = MASS OF FINAL STATE FERMION              *
 ***************************************************************************
```

```
                 START PARAMETERS ARE ...
                                              ENERGY        6.1237  GEV
                                              SINW2          .2300
                                              INRAN            17
0
                 MASS OF ELECTROWEAK BOSON ZO IS  (GEV)     91.2000
                 COUPLIG CONSTANTS: CVE, CAE       -.0475    -.5941
                                    CVF, CAF       -.0475    -.5941
0
                 CONTRIBUTIONS TO SOFT CROSS SECT. ARE...
                 BORN + SOFT PHOTON + VERTEX CORR. INIT.      .6953
                 TOTAL CROSS SECTION - APPROXIMATE          1.2578

                 ALL ABOVE CROSS SECTIONS ARE GIVEN IN
                 UNITS OF THE LOWEST ORDER ( POINTLIKE )
                 ONE PHOTON CROSS-SECTION  SIGO WHICH IS
                 EQUAL TO            .57904E-33 CM**2

***************************************************************************
*                         *****TAUOLA LIBRARY: VERSION 2.5 ******         *
*                         ***********DECEMBER 1993***************         *
*                         **AUTHORS: S.JADACH, Z.WAS*************         *
*                         **R. DECKER, M. JEZABEK, J.H.KUEHN*****         *
*                         **AVAILABLE FROM: WASM AT CERNVM ******         *
*                         ***** PUBLISHED IN COMP. PHYS. COMM.***         *
*                         *******CERN-TH-5856 SEPTEMBER 1990*****         *
*                         *******CERN-TH-6195 SEPTEMBER 1991*****         *
*                         *******CERN TH-6793 NOVEMBER  1992*****         *
*                         **5 or more pi dec.: precision limited          *
*                         ****DEKAY ROUTINE: INITIALIZATION******         *
*                  0      JAK1   = DECAY MODE TAU+                        *
*                  0      JAK2   = DECAY MODE TAU-                        *
***************************************************************************
 RANMAR INITIALIZED:   54217137          0         0
***************************************************************************

SPIN: itrans= 1   *****

                 MOMENTA FROM KORAL,     EVENT NO.      1
                                      P(1)         P(2)         P(3)         P(4)         MASS
                 QP               -1.87564      2.88373     -3.58937      5.28213      1.78420
                 QM                1.87564     -2.88373      6.08937      7.21787      1.78420
                 PH                 .00000       .00000       .00000       .00000       .00000
                 SUM                .00000       .00000      2.50000     12.50000

===== EVENT NO.   1 =====

                         Event listing (standard)

                 The Lund Monte Carlo - JETSET version 7.3
                 **  Last date of change:  20 May 1992  **


 I  particle/jet  K(I,1) K(I,2) K(I,3)   K(I,4)    K(I,5)    P(I,1)    P(I,2)    P(I,3)    P(I,4)    P(I,5)

 1  !e+!              21    -11     0         3         4    .00000    .00000   7.50000   7.50000    .00051
 2  !e-!              21     11     0         3         4    .00000    .00000  -5.00000   5.00000    .00051
 3  (tau+)            11    -15     1         5         6  -1.87564   2.88373  -3.58937   5.28213   1.78420
 4  (tau-)            11     15     1        13        14   1.87564  -2.88373   6.08937   7.21787   1.78420
 5  nu_tau~            1    -16     3         0         0   -.25852    .60430   -.62339    .90594    .01000
 6  (W+)              11     24     3         7        12  -1.61712   2.27943  -2.96598   4.37619   1.59471
 7  pi+                1    211     6         0         0   -.65293    .44957   -.44716    .92079    .13957
 8  pi+                1    211     6         0         0   -.43892    .53231   -.45426    .83776    .13957
 9  pi-                1   -211     6         0         0    .00161    .34322   -.38606    .53509    .13957
```

```
10  pi0              1    111    6        0        0  -.26154   .56536  -.91306  1.11352   .13496
11  pi0              1    111    6        0        0  -.04032   .21164  -.47769   .54113   .13496
12  pi0              1    111    6        0        0  -.22502   .17733  -.28774   .42789   .13496
13  nu_tau           1     16    4        0        0  1.66804 -1.72233  2.78665  3.67618   .01000
14  K-               1   -321    4        0        0   .20760 -1.16140  3.30271  3.54169   .49367
           sum charge:   .00   sum mom. and inv. mass:    .00000   .00000  2.50000 12.50000 12.24745
0****************************************************************************************************
 FINISB

                     NO. OF CRUDE EVENTS      AVERAGE WEIGHT      PERCENT ERRORS
          HARD BREMSS. WEIGHT       2413             .889922       .17
          SPIN WEIGHT               4589            1.009561       .48
          TOTAL EXACT CROSS SECT. IN SIGO UNITS     1.207301       .55

 ***************************************************************************
 *                        *****TAUOLA LIBRARY: VERSION 2.5 ******          *
 *                        ***********DECEMBER 1993***************          *
 *                        **AUTHORS: S.JADACH, Z.WAS*************          *
 *                        **R. DECKER, M. JEZABEK, J.H.KUEHN*****          *
 *                        **AVAILABLE FROM: WASM AT CERNVM ******          *
 *                        ***** PUBLISHED IN COMP. PHYS. COMM.***          *
 *                        *******CERN-TH-5856 SEPTEMBER 1990*****          *
 *                        *******CERN-TH-6195 SEPTEMBER 1991*****          *
 *                        *******CERN TH-6793 NOVEMBER  1992*****          *
 *                        *****DEKAY ROUTINE: FINAL REPORT*******          *
 *               2000     NEV1   = NO. OF TAU+ DECS. ACCEPTED              *
 *               2000     NEV2   = NO. OF TAU- DECS. ACCEPTED              *
 *              10178     NEVTOT = SUM                                     *
 *    NOEVTS  PART.WIDTH     ERROR       ROUTINE    DECAY MODE             *
 *       185    .9877298    .0231463     DADMEL     ELECTRON               *
 *       195    .9988754    .0234156     DADMMU     MUON                   *
 *       178    .6058310    .0000000     DADMPI     PION                   *
 *       171   1.3090163    .0155149     DADMRO     RHO (->2PI)            *
 *       184    .7080593    .0158554     DADMAA     A1  (->3PI)            *
 *       199    .0397533    .0000000     DADMKK     KAON                   *
 *       198    .0704854    .0131909     DADMKS     K*                     *
 *       162    .0838137    .0202910  TAU-  --> 2PI-,  PI0,  PI+           *
 *       198    .0166806    .0192922  TAU-  --> 3PI0,        PI-           *
 *       185    .0624964    .0254668  TAU-  --> 2PI-,  PI+, 2PI0           *
 *       187    .0299522    .0253486  TAU-  --> 3PI-, 2PI+,                *
 *       186    .0042098    .0282325  TAU-  --> 3PI-, 2PI+,  PI0           *
 *       171    .0042849    .0300143  TAU-  --> 2PI-,  PI+, 3PI0           *
 *       180    .0059910    .0214980  TAU-  -->  K-, PI-,  K+              *
 *       177    .0058121    .0227550  TAU-  -->  K0, PI-, K0B              *
 *       195    .0005070    .0202095  TAU-  -->  K-,  K0, PI0              *
 *       180    .0062184    .0151180  TAU-  --> PI0, PI0,  K-              *
 *       138    .0309523    .0212613  TAU-  -->  K-, PI-, PI+              *
 *       178    .0313717    .0209280  TAU-  --> PI-, K0B, PI0              *
 *       193    .0110985    .0236187  TAU-  --> ETA, PI-, PI0              *
 *       174    .0031587    .0174919  TAU-  --> PI-, PI0, GAM              *
 *       186    .0188184    .0229825  TAU-  -->  K-,  K0                   *
 *                   THE ERROR IS RELATIVE AND  PART.WIDTH                 *
 *                   IN UNITS GFERMI**2*MASS**5/192/PI**3                  *
 ***************************************************************************

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 *                        ==KORALB VERSION 2.4 FINAL REPORT======          *
 *                        =========== MAY 1994==================           *
 *               2000     NUMBER OF THE GENERATED EVENTS                   *
 *          .69907E-33    TOTAL CROSS SECTION   CM**2                      *
 *          .004873007    RELATIVE ERROR                                   *
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