CERN-TH-5855/90

KORALB version 2.1

An upgrade with TAUOLA library of τ decays.

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ABSTRACT

An upgrade of the Monte Carlo program for τ pair production including τ mass, spin and QED $\mathcal{O}(\alpha)$ effects is presented. Its main feature is the interface to the new τ decay Monte Carlo library TAUOLA.

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NEW VERSION SUMMARY

Title of the program: KORALB, version: 2.1

Reference to original program: Comp. Phys. Comm. **36** (1985) 191.

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

Computer: IBM 3090; *Installation:* CERN

Operating system: VM/CMS

Programing language used: FORTRAN 77

High speed storage required: 45000 words

No. of bits in a word: 32

Peripherals used: Line printer

No. of cards in combined program and test deck including TAUOLA library: 5607

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

Comparison with the previous version, and reasons for the new version: The powerful τ decay library [2] is now available. The physics content of the τ production part of the program remains the same. The additional routine `KORALB` is added to make program more user friendly.

Typical running time: 130 events per (IBM 3090) sec., in case of Inclusive τ decays and no beam polarization.

Unusual features of the manual: This is not an independent document. Only the differences with Refs. [1,2] are documented

References:

[1] S. Jadach, Z. Wąs, Comp. Phys. Comm. **36** (1985) 191.

[2] S. Jadach, J. H. Kühn, Z. Wąs, TAUOLA - A library of Monte Carlo programs to simulate decays of polarized τ leptons, submitted to Comp. Phys. Comm.

UPDATE DESCRIPTION

1. Introduction

Since the original version of the KORALB program was published [1], there were no major corrections introduced to the program. All the physical content, (treatment of QED, Z-exchange, spin) remained the same. It is still the most complete and sophisticated Monte Carlo generator for τ pair production process at low energies, $\sqrt{s} < 30$ GeV. In the meantime the other Monte Carlo program KORAZ [4] was developed for higher energies (LEP). In the course of its development a new τ-decay M.C. library has been constructed.

The low energy e^+e^- experiments are still collecting τ-pair data (ARGUS, CLEO) and the new high luminosity experiments are planned (so called τ-charm factories). It is therefore of the urgent need to combine KORALB τ-production program with TAUOLA τ-decay library. In this paper we present new version of KORALB interfaced to TAUOLA. This will be an excellent M.C. tool for future τ-pair production experiments at low energies.

The presented new version of KORALB is almost identical with the old one. Minor modifications include correcting the error described in Ref. [2]. This and other (cosmetic) corrections are marked with strings: "`C;;`" or "`*$`". The old, primitive τ-decay routines are removed and replaced by the τ-decay library TAUOLA [3].

To make the program more user friendly we have introduced a new main routine named `KORALB` which controls flow of input and output information in a transparent way. Let us also note that it is possible to run present versions of the KORALB and KORALZ programs with the same input data set.

In the following, we shall describe how to run the new program, and we list modifications in certain routines and common blocks.

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 routine KORALB. For example a complete sequence of calls which generates 1000 M.C. events may look like

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

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, widths in τ decays from TAUOLA etc. Generally, the input parameters are transferred as KORALB parameters and the output results (momenta, flavors) are encoded in common blocks documented, if necessary, later in this Section.

Let us explain now in a 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).

2.1. Initialization mode

In the initialization mode (MODE=-1) the meaning of the parameters in
KORALB(MODE,KFB,PB1,E1,-KFB,PB2,E2,XPR,MPR)
is the following: REAL*4 PB1(4), PB2(4) are four-momenta of the first and second beam (with PB1(4) and PB2(4) being the energy). Both momenta are necessarily along a third axis in the laboratory system (CMS) and PB1 is required to have a positive third component. INTEGER*4 KFB is a flavor identifier of the first beam (i.e. associated with PB1). KFB=7,-7 denotes electron and positron respectively in the notation of the Lund version 6.3 [5]. 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=-7, E1=(0.0,0.0,1.0), E2=(0.0,0.0,1.0), means that the user asks for

the first beam being a right-handed positron and the second being 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 MPR(40).

In the table below we give a short summary of all input parameters.

Parameter	Meaning
KFB	Flavor identifier of the first beam, KFB=7,-7 denotes electron and positron respectively (Lund notation).
PB1	Four momentum of the first beam. PB1(3)>0 is required.
E1	Spin polarisation vector of the first beam. E1(3)=helicity.
PB2	Four momentum of the second beam.
E2	Spin polarisation vector of the second beam. E2(3)=−helicity.
MPR(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.
MPR(2)=INRAN	Integer constant, INRAN$\geq$1, is used to initialise a random number generator in the τ pair production part of M.C.
MPR(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.
MPR(4)=KEYRAD	Switch for the QED bremsstrahlung. KEYRAD=0 means no QED bremsstrahlung. KEYRAD=1 denotes single bremsstrahlung.

Parameter	Meaning
NPR(5)=JAK1	The variable JAK1=1,2,3,4,5,6,7,8 defines the decay channel of τ^+ as being $\bar{\nu}e^+\nu$, $\bar{\nu}\mu^+\nu$, $\bar{\nu}\pi^+$, $\bar{\nu}\rho^+$, $\bar{\nu}a_1^+$, $\bar{\nu}K^+$, $\bar{\nu}K^{*+}$, $\bar{\nu}(n\pi)^+$, respectively. Furthermore, setting JAK1=0 causes the τ^+ to decay into all four 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 of JAK1.
NPR(7)=ITFIN	This switch key allows to generate final state fermion pairs other than τ pairs. The τ pairs are produced with ITFIN=1, μ pairs with ITFIN=2. Mass of τ and μ is taken from the common block of TAUOLA. Quark pair may be produced with ITFIN=501-506. In this case quark mass is defined through XPR(14) see below. For ITFIN > 1 the τ decay is automatically suppressed.
NPR(8)=ITDKRC	Dummy in the present version of the program. Switch for bremsstrahlung in the τ decay.
XPR(1)=AMZ	Mass 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)=SIN2	$\sin^2\theta_W$. 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 nonzero value.
XPR(11)=XK0	k_0, soft/hard photon cut-off for the QED bremsstrahlung. 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(i),NPR(i)	All other entries in the XPR and NPR matrices are dummy.

2.2. 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

```
COMMON / LUJETS / N,K(2000,2),P(2000,5)
```

The common block LUJETS contains a complete set of all initial and final state flavors and four-momenta encoded in the standard conventions of the Lund program version 6.3, see for more details the original reference [5]. This common block contains information on the $e^\pm$ beams, on the τ^+, τ^-, γ 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, like in the Lund programs. If the user wants π^0's to decay, it can be done by means of calling on LUEXEC. Every event may be edited using LUEDIT and displayed using LULIST. These three routines belong to the Lund package JETSET [5]. In KORALB itself, however, there is no explicit call to any Lund subprogram.

In addition the final state momenta for the production process may only 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).

2.3. 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*. All this information is printed in the output, and some of it is also provided to the user through parameter matrices XPR and NPR, see table below.

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

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

3. The most important modifications of the program.

Modifications of subprograms:

(1) Subroutine **KORALB** is added to the program. It is the user interface routine.

(2) Subroutine **START** is replaced by the **STARB** routine. Its basic function is the same, but the list of parameters is different
CALL STARB(ENE,AMFIN,IDE,IDF,AMZ,SINW2,INRAN,XK0). The parameters denote respectively: beam energy and final state (τ) mass (in GeV), electron beam and final state coupling constants identifiers (ID=2,3,4 denote respectively lepton, up and down type quarks) Z mass (GeV), $sin^2\theta_W$, initialization constant for the random number generator and minimal photon energy (in the beam energy units).

(3) Subroutine **FINISH** is replaced by the **FINISB**. Its basic function is the same, but another output parameter **ERREL** is added. It denotes relative statistical error on the total cross section calculated from the generated sample.

(4) Subroutines **DECAY, DECTAU, RAN2** are removed.

(5) Subroutine **EVENT** is renamed **EVENTB**.

(6) Subroutine **SETWS** is replaced by **SETCUP**, it calculates coupling constants of a given fermion to γ, Z. It does not calculate the Z mass and width anymore.

(7) In subroutine **TRALO4** additional output parameter are added. They denote respectively boosted four-momentum and its invariant mass.

Modifications of common blocks:

(8) Common **DECPP** is removed, instead common **LUJETS** of the LUND program, version 6.3 has to be used.

(9) Common **CONTRL** is modified. Variable **ISPIN** is added. It defines whether the spin correlations between τ^+ and τ^- are included or not (ISPIN=1/0).

(10) Commons **UTIL4, UTIL8** are simply single and double precision copies of the unmodified common **UTIL**.

(11) In the new common block BEAMS the 4-momenta of the positron and electron beams **XPB1(4),XPB2(4)** and their LUND identifiers **KF1,KF2** are stored.

(12) Common JAK is replaced by the common JAKI. The description of common blocks **JAKI, IDFC, DECPAR, PARMAS,TAUBRA** is given in [3]. They contain additional input data necessary to initialize TAUOLA.

Acknowledgements

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2. S. Jadach, Z. Wąs, Erratum, Acta Phys. Polon. **B16** (1985) 483.
3. S. Jadach, J. H. Kühn, Z. Wąs, TAUOLA - A library of Monte Carlo programs to simulate decays of polarized τ leptons, submitted to Comp. Phys. Comm.
4. S. Jadach, R. G. Stuart, Z. Wąs and W. Hollik, The Monte Carlo program KORAL-Z, to be submitted to Comp. Phys. Comm., short description can be found in "Physics at LEP 1", ed. G. Altarelli, R. Kleiss, C. Verzegnassi, CERN 89-08, vol 3. p. 69 (1989).
5. T. Sjöstrand, Comp. Phys. Commun. **27** (1982) 243, and Comp. Phys. Commun. **28** (1983) 229.

```
                        DEMONSTRATION PROGRAM
                      THE MONTE CARLO PROGRAM
                       KORALB- VERSION 2.1

    NEVTES=     25  NO. OF REQUESTED EVENTS
    ENE    =  10.00  BEAM ENERGY

1*****************************************************************
*                    =KORALB VERSION 2.1 INPUT PARAMETERS ==    *
*                    ========AUGUST  1990==================     *
*                -7  KF1    =  FIRST BEAM IDENTIFIER           *
*                 7  KF2    =  SECOND BEAM IDENTIFIER          *
*                    ==== FOUR MOMENTA OF THE BEAMS ========    *
*       10.000000000 PB1(3) =  FIRST BEAM, 3-RD COMPONENT      *
*       10.000000000 PB1(4) =              0-TH COMPONENT      *
*      -10.000000000 PB2(3) =  SECOND BEAM, 3-RD COMPONENT     *
*       10.000000000 PB2(4) =              0-TH COMPONENT      *
*                    ==== SPIN VECTORS OF THE BEAMS =======    *
*        1.000000000 E1(1)  =  FIRST BEAM, 1-ST COMPONENT      *
*        0.000000000 E1(2)  =              2-ND COMPONENT      *
*        0.000000000 E1(3)  =              3-RD COMPONENT      *
*       -1.000000000 E2(1)  =  SECOND BEAM  1-ST COMPONENT     *
*        0.000000000 E2(2)  =              2-ND COMPONENT      *
*        0.000000000 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          *
*                 2  JAK1   =  DECAY TYPE TAU+                  *
*                 3  JAK2   =  DECAY TYPE TAU-                  *
*                 0  ITDKRC =  BREM. IN DECAY SWITCH            *
*                    ==== INPUT PARAMS IN XPAR ==============   *
*       91.199996948 AMZ    = MASS OF Z0 BOSON                 *
*        0.230000019 SINW2  =  SIN**2(THETAWEINBERG)           *
*        1.000000000 GV     = VECTOR COUPLING CONST. IN DECAY  *
*       -1.000000000 GA     = AXIAL  COUPLING CONST. IN DECAY  *
*        0.010000002 AMNUTA= MASS OF TAU-NEUTRINO  IN DECAY    *
*        0.010000002 XK0    = SOFT/HARD PHOTON CUT OFF         *
*****************************************************************

*                    ==KORALB-INITIALIZATION THROUGH TAUOLA=     *
*        1.784196854 AMFIN = MASS OF FINAL STATE FERMION        *
*****************************************************************

0*****************************************************************************************************
                    START PARAMETERS ARE ...
                                                 ENERGY      10.0000  GEV
                                                 SINW2        0.2300
                                                 INRAN            17
                    MASS OF ELECTROWEAK BOSON Z0 IS  (GEV)    91.2000
                    COUPLIG CONSTANTS: CVE, CAE      -0.0475  -0.5941
                                       CVF, CAF      -0.0475  -0.5941
                    CONTRIBUTIONS TO SOFT CROSS SECT. ARE...
                    BORN + SOFT PHOTON + VERTEX CORR. INIT.     0.6713
                    TOTAL CROSS SECTION - APPROXIMATE           1.3397

                    ALL ABOVE CROSS SECTIONS ARE GIVEN IN
                    UNITS OF THE LOWEST ORDER ( POINTLIKE )
                    ONE PHOTON CROSS-SECTION  SIGO WHICH IS
                    EQUAL TO            0.21714E-33 CM**2

*****************************************************************
*                    *****TAUOLA LIBRARY: VERSION 1.5 ******    *
*                    ***********AUGUST 1990***************     *
*                    **AUTHORS: S.JADACH, J.H.KUEHN, Z.WAS**    *
*                    **AVAILABLE FROM: WASM AT CERNVM ******    *
*                    **TO BE PUBLISHED IN COMP. PHYS. COMM.*    *
*                    ****DEKAY ROUTINE: INITIALIZATION******    *
*                 2  JAK1   = DECAY MODE TAU+                   *
*                 3  JAK2   = DECAY MODE TAU-                   *
*****************************************************************
 RANMAR INITIALIZED:   54217137          0         0

*****************************************************************

                    MOMENTA FROM KORAL.     EVENT NO.      1
                                      P(1)        P(2)        P(3)        P(4)        MASS
                    QP              2.25969     -9.14612    -2.83883    10.00000     1.78419
                    QM             -2.25969      9.14612     2.83883    10.00000     1.78419
                    PH              0.00000      0.00000     0.00000     0.00000     0.00000
                    SUM             0.00000      0.00000     0.00000    19.99998

                    EVENT LISTING (EXTENDED)
    I  K(I,1)  K(I,2)   PART/JET       P(I,1)      P(I,2)      P(I,3)      P(I,4)      P(I,5)
    1   40000      -7   E    B+ B      0.00000     0.00000    10.00000    10.00000     0.00051
    2   40000       7   E    -  B      0.00000     0.00000   -10.00000    10.00000     0.00051
    3   20000     -11   TAU B+ D      2.25969     -9.14612    -2.83883    10.00000     1.78419
    4   20000      11   TAU -  D     -2.25969      9.14612     2.83883    10.00000     1.78419
    5       3     -12   NUTAB         1.48908     -5.16256    -2.12815     5.77914     0.01001
    6   20003       3   W   +  D      0.77061     -3.98355    -0.71068     4.22085     0.92086
    7       6      -9   MU  B+       -0.15264     -0.58932     0.05702     0.62049     0.10566
    8       6      10   NUMUO         0.92325     -3.39423    -0.76770     3.60036     0.00043
    9       4      12   NUTAO         0.09909      2.43807     1.11073     2.68101     0.00998
   10       4     -17   PI  B-       -2.35878      6.70804     1.72810     7.31898     0.13957
              SUM:        0.00000     0.00000     0.00000    19.99998    19.99998
0*****************************************************************************************************
 FINISB
                    NO. OF CRUDE EVENTS      AVERAGE WEIGHT      PERCENT ERRORS
          HARD BREMSS. WEIGHT        99           0.894894        0.62
          SPIN WEIGHT               188           0.938750        5.91
          TOTAL EXACT CROSS SECT. IN SIGO UNITS   1.191721        6.20

*****************************************************************
*                    ******** DADMMU FINAL REPORT  ********     *
*                649  NEVRAW = NO. OF MU  DECAYS TOTAL          *
*                188  NEVACC = NO. OF MU  DECS. ACCEPTED        *
*                  0  NEVOVR = NO. OF OVERWEIGHTED EVENTS       *
*        0.49051E-12  PARTIAL WIDTH (MU  DECAY) IN GEV UNITS    *
*        0.969351292  IN UNITS GFERMI**2*MASS**5/192/PI**3      *
*        0.031781018  RELATIVE ERROR OF PARTIAL WIDTH           *
*****************************************************************

*****************************************************************
*                    ******** DADMPI FINAL REPORT  ********     *
*                188  NEVTOT = NO. OF PI  DECAYS TOTAL          *
*        0.25031E-12  PARTIAL WIDTH ( PI DECAY) IN GEV UNITS    *
*        0.605811236  IN UNITS GFERMI**2*MASS**5/192/PI**3      *
*         0.00000000  RELATIVE ERROR OF PARTIAL WIDTH (STAT.)   *
*****************************************************************

*****************************************************************
*                    *****TAUOLA LIBRARY: VERSION 1.5 ******    *
*                    ***********AUGUST 1990***************     *
*                    **AUTHORS: S.JADACH, J.H.KUEHN, Z.WAS**    *
*                    **AVAILABLE FROM: WASM AT CERNVM ******    *
*                    **TO BE PUBLISHED IN COMP. PHYS. COMM.*    *
*                    *****DEKAY ROUTINE: FINAL REPORT*******    *
*                 25  NEV1   = NO. OF TAU+ DECS. ACCEPTED      *
*                 25  NEV2   = NO. OF TAU- DECS. ACCEPTED      *
*                376  NEVTOT = SUM                              *
*    NOEVTS  PART.WIDTH     ERROR       ROUTINE    DECAY MODE  *
*         0   0.0000000  0.0000000      DADMEL     ELECTRON    *
*        25   0.9693513  0.0317810      DADMMU     MUON        *
*        25   0.6058112  0.0000000      DADMPI     PION        *
*         0   0.0000000  0.0000000      DADMRO     RHO (->2PI) *
*         0   0.0000000  0.0000000      DADMAA     A1  (->3PI) *
*         0   0.0000000  0.0000000      DADMKK     KAON        *
*         0   0.0000000  0.0000000      DADMKS     K*          *
*         0   0.0000000  0.0000000      DADNPI     PI- 2PI+ PI0*
*         0   0.0000000  0.0000000      DADNPI     PI- 3PI0    *
*         0   0.0000000  0.0000000      DADNPI     3PI- 2PI+   *
*         0   0.0000000  0.0000000      DADNPI     3PI- 2PI+ PI0*
*                THE ERROR IS RELATIVE AND  PART.WIDTH          *
*                IN UNITS GFERMI**2*MASS**5/192/PI**3           *
*****************************************************************

*****************************************************************
*                    ==KORALB VERSION 2.1 FINAL REPORT======    *
*                    ========AUGUST  1990==================     *
*                 25  NUMBER OF THE GENERATED EVENTS            *
*        0.25877E-33  TOTAL CROSS SECTION   CM**2               *
*        0.070678529  RELATIVE ERROR                            *
*****************************************************************
```