Monte Carlo program KORALW version 1.03 for W-pair production at LEP2/NLC energies with Yennie-Frautschi-Suura exponentiation[†]

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EXTRACT FROM PROGRAM SUMMARY
Programming language used: FORTRAN 77
Nature of the physical problem:

The W pair production and decay will be used as an important data point for precise tests of the standard electroweak theory at LEP2 and higher energies. The effects due to QED bremsstrahlung and apparatus efficiency have to be subtracted from the data. The program includes not only QED effects in the initial state but also in leptonic decays of W and secondary decays, i.e. in the τ lepton decays. Hadronization of quarks is also performed. The effects of spin are included in combined W-pair production and decay. The τ polarization is also taken into account in its decays. Any experimental cut and apparatus efficiency may be introduced easily by rejecting some of the generated events.
Typical running time: Efficiency is about 30 CPU sec. of HP-9000/735/99 per 1000 unweighted events (including hadronization), for the parameter setting as in the program manual.

From version 1.02 to 1.03

In this note we recall main properties of the generator KORALW. We do not intend to present the program. It was published recently [1]. The present version 1.03 features all properties of the previous version 1.02 that is:

- Matrix element for W-pair production and W-pair decay into four fermions (quarks and/or leptons) with proper W spin treatment and finite W width,
- All decay channels of W into pairs of leptons or quarks,
- Initial-state multi-photon emission within full photon phase space (i.e. with finite transverse photon momenta),
- Simmulation of the decay of polarized heavy τ lepton (decay product of W) in all possible channels, taking into account spin polarization and QED bremsstrahlung,
- Photon emission by leptons, the decay products of W, up to a double bremsstrahlung,
- Arrangement of quarks (decay products of W) into coloured strings and fragmentation into hadrons according to the LUND model using JETSET,
- Massive kinematics with the exact four momentum conservation for the entire W^-W^+ production and decay process.

Since publicaton of the program in July 1995 the following two major improvements were introduced:

- Coulomb correction is introduced in a form useful close to the WW threshold,
- KORALW now includes the interface to the external library calculating the correction-weight due to a more complete matrix element (so called background processes). At present interface to the GRACE library [2] calculating multi-diagram matrix elements is available.

Still remaining important limitations of the program are:

- Simplified matrix element for the QED photon emission,
- Lack of electroweak non-QED corrections[1],
- Simplified "colour arrangement" for four quark jets.

The above and other shortcomings of the program will be systematically addressed in the forthcoming versions of the program.

As detailed description of the KORALW program and its input parameters can be found in ref. [1] and the basics tests are presented in ref [3], let us concentrate here on how to use the recent extensions.

Upgrade documentation – adendum to reference [1]

Coulomb correction is taken from ref. [4] and it can be activated in straightforward way, as explained in the program documentation. Starting from the present KORALW version 1.03, the `KeyCul` component of the program input parameter `NPAR(1)` is thus *not* dummy anymore.

We expect that during the program use, one may need to replace the matrix element. This can happen for example if somebody would be interested to see in his studies an effect of the particular choice of anomalous coupling. Due to the modular structure of KORALW and, in particular, due to full factorizability of the approximate QED matrix element into Born matrix element and the QED part, it is straightforward to replace the existing Born-level matrix element with any other one, provided that the external library is able to calculate the corresponding matrix elements out of the externally generated four-momenta. To this end the external program calculating ratio of the matrix element squared of the particular choice to the basic matrix element squared of the program has to be provided by the user.

Pre-defined inteface, now included in KORALW, will activate those routines with the help of `Key4f` component of KORALW input parameter `NPAR(4)= 10*Key4f +KeyMix`. For `Key4f=0` no external matrix element is included and for `Key4f=1` it

[1]Most probably these corrections are small in comparison with the experimental precision and it is not necessary to include them in the Monte Carlo program – it is enough if they are in the auxiliary semi-analytical program.

is active. The new position of the weigt switch KeyWgt=NPAR(3) is also introduced. For KeyWgt=2 program works as for the old and not modified KeyWgt=0 setting, but the external weights are calculated and transmitted to the common block wgtall.

In our distribution directory (see section 4 of program documentation) the additional fortran file mxlib.f is introduced in the directory interfaces. On the user side, his own directory has to replace the directory ampli4f. The following two routines have to be provided: AMPINI(XPAR,NPAR) which should initialize the external matrix element library. Standard KORALW input parameter matrices XPAR and NPAR can be used there for the initialization purposes. The routine

```
SUBROUTINE AMP4F( Q1,IFLBM1, Q2,IFLBM2,
P1,IFLAV1, P2,IFLAV2, P3,IFLAV3, P4,IFLAV4, WTMOD4F,WT4F)
```

should calculate ratio WTMOD4F, of the new matrix element squared, and the one of the standard KORALW. The Q1,IFLBM1, Q2,IFLBM2, P1,IFLAV1, P2,IFLAV2, P3,IFLAV3, P4,IFLAV4 denote respectively four momenta and identifiers (accordingly to the PDG conventions [5]) of initial state effective beams and the final state fermion states before final state bremsstrahlung generation. The additional vector weight WT4F(I), I=1,9 may optionally be filled by routine AMP4F. It is not used in the program but only transmitted to the KORALW optional weights common block wgtall as wtset(40+I). The WTMOD4F is set into wtset(40).

An example of the interfaced external matrix-element, based on the GRACE code [2], can be obtained upon request ¿from the authors of KORALW. In the distribution version we include dummy ampli4f library. It sets external weight to 1 and prints warning message.

We found it useful to introduce the KeyWu switch which controls the level of sophistication of the W width implementation. Like for the Z (KeyZet) case KeyWu=0,1,2 denotes respectively $(s/M_W)\Gamma_W$, constant and zero W width. Note that NPAR(2)= 100000*KeyWu +10000*KeyRed +1000*KeySpn+100*KeyZet +10*KeyMas +KeyBra.

The semianalytical part of the program KORWAN was enlarged with two functions s1wan(s1) and s1s2wan(s1,s2) for the one and two dimensional distribution of the single or double W invariant masses. These functions require standard initialization of the KORWAN routine with the input parameters as explained in KORALW manual. Optionally, if the KORWAN input parameter keymod is increased by 10000 the calculations in KORWAN are not executed and the initialization is performed only.

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