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The tauola-photos-F environment for the TAUOLA and PHOTOS packages†, *release II*

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Abstract

We present the system for versioning two packages: the `TAUOLA` of τ-lepton decay and `PHOTOS` for radiative corrections in decays. The following features can be chosen in an automatic or semi-automatic way: (1) format of the common block `HEPEVT`; (2) version of the physics input (for `TAUOLA`): as published, as initialized by the CLEO collaboration, as initialized by the ALEPH collaboration (it is suggested to use this version only with the help of the collaboration advice), new optional parametrizations of matrix elements in 4π decay channels; (3) type of application: stand-alone, universal interface based on the information stored in the `HEPEVT` common block including longitudinal spin effects in the elementary $Z/\gamma^* \to \tau^+\tau^-$ process, extended version of the standard universal interface including full spin effects in the $H/A \to \tau^+\tau^-$ decay, interface for `KKMC` Monte Carlo, (4) random number generators; (5) compiler options.

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PROGRAM SUMMARY

Title of the environment: `tauola-photos-F`, release II.
Computer: PC running GNU/Linux operating system
Programming languages and tools used: `CPP`: standard C-language preprocessor, `GNU Make` builder tool, also `FORTRAN-77` compiler.
Size of the package: 10 MB uncompressed,
2 MB packed for distribution into `tar.gz` archive.
Keywords:
particle physics, Monte Carlo methods, tau decays, TAUOLA [1], PHOTOS [2]
Nature of the physical problem:
The code of Monte Carlo generators often has to be tuned to the needs of large HEP Collaborations and experiments. Usually, these modifications do not introduce important changes in the algorithm, but rather modify the initialization and form of the hadronic current in τ decays. The format of the event record (`HEPEVT` common block) used to exchange information between building blocks of Monte Carlo systems often needs modification. Thus, there is a need to maintain various, slightly modified versions of the same code. The package presented here allows the production of ready-to-compile versions of `TAUOLA` [1] and `PHOTOS` [2] Monte Carlo generators with appropriate demonstration programs.

The new algorithm, universal interface of `TAUOLA` to work with the `HEPEVT` common block is also documented here. Finally minor technical improvements of `TAUOLA` and `PHOTOS` are also listed.
Method of solution:
The standard `UNIX` tool: the C-language preprocessor is used to produce a ready-to-distribute version of `TAUOLA` [1] and `PHOTOS` [2] code. The final version of `FORTAN77` code is produced from the library of 'pre-code' that is included in the package.
Typical running time:
Depends on the speed of the computer used and the demonstration program chosen. Typically a few seconds.
Accessibility:
web page: `http://cern.ch/wasm/goodies.html`

References:

- 'The tau decay library TAUOLA: Version 2.4' [1]
- 'PHOTOS: A Universal Monte Carlo for QED radiative corrections. Version 2.0" [2]

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1 Introduction

The TAUOLA [3, 4, 1] and PHOTOS [5, 2] programs are computing projects that have a rather long history. Written and maintained by well defined authors, they nonetheless migrated into a wide range of applications where they became ingredients of complicated simulation chains. As a consequence, a large number of different versions are currently in use. From the algorithmic point of view, they often differ only in a few small details, but incorporate substantial amount of specific results from the distinct τ-lepton measurements. The difference in the versions of the programs used is often due to the specific requirements of the interfaces to other packages in the simulation chain (for instance, the format of the event record has to be adjusted).

The present utility for constructing specific versions of TAUOLA and PHOTOS is prepared for software librarians and advanced users. The idea was to create a repository which allows them to include and keep main options of TAUOLA developed for different purposes. At the same time, the repository can provide the standard FORTRAN files, which can be handled later in the same way as the published versions of the packages. The other, relatively new project, which we will call `TAUOLA universal interface`, is also discussed here.

Our present document is not aimed to be the manual of the PHOTOS and TAUOLA packages. It is assumed that the user is familiar with the programs themselves and their documentation, see Refs. [3, 4, 1, 5, 2]. The purpose of the paper is to document how all parts of the code, including different versions and options, are combined into one distribution package. Minor improvements in the codes, since the time of publication, are also listed here. The paper is an extended and enlarged version of the earlier documentation [6] and supersedes it.

Motivations for versioning:

1. PHOTOS: Diferent versions of the Fortran code are necessary according to the different versions of the HEPEVT common block being in use in the HEP libraries (single/double precisions, dimension of matrices).

2. TAUOLA: Different versions of Fortran code are motivated by: (A) different versions of initialization of physics parameters; (B) interfaces with different Monte Carlo generators for the production of τ lepton(s); and (C) different versions of the HEPEVT common block:

   - (A) Different physics initializations:
     (1) As published in [1], with improvements from Ref. [7];
     (2) As initialized by ALEPH collaboration [8] (it is suggested to use this version only after asking the collaboration for advice);
     (3) As initialized by CLEO collaboration [9] (see printout of this version for details);
     (4) New parallel 4π channels of τ decay based on Novosibirsk data [10].
     (5) New parallel 4π channels of τ decay based on Refs. [11, 7].
   - (B) Different interfaces with MC generators:
     (1) Old demo program as in published version [1];

(2) Interface to KKMC [12];
(3) New universal interface using HEPEVT common block including spin effects in the elementary $Z/\gamma^* \to \tau^+\tau^-$ process [13].
(4) The extended version of the standard universal interface including transverse spin effects in the $H/A \to \tau^+\tau^-$ decay [14, 15, 16, 17].

- (C) Different versions of the HEPEVT common block.

3. TAUOLA and PHOTOS: different versions of random number generators.

4. TAUOLA and PHOTOS: makefile's with different compiler flags.

The aim is to provide full backward compatibility at the level of the Fortran source with the various versions being at present in use. Standard Unix tools and infrastructure are used in the discussed setup: cpp the C-language preprocessor; its #if, #elif and #include directives, as well as symbolic links and cat command. It is expected that the user will employ this setup to create her/his version of TAUOLA and PHOTOS libraries (subdirectories tauola/ and photos/) and that other subdirectories of the setup will be erased/stored separately.

2 Organization of the directory tree

Once unpacked, the main directory TAUOLA is created.
It contains README file and:

subdirectories including Fortran precode

1. photos-F/: Main directory containing PHOTOS precode with options.

2. tauola-F/: Main directory containing TAUOLA precode with options.

3. tauola-factory/: Directory containing the glue program, which prepares the non-standard directory tauola-F/.

4. demo-factory/: Directory for updating the input in demo files. For specialized use only, see Section 2.3.

5. randg/: Directory containing random number generators, which are kept separately from the rest of TAUOLA and PHOTOS source code. This should facilitate the replacement with the versions of random number generators favoured by the user. Random number generators are kept in Fortran subroutines placed in files photos-random.h and tauola-random.h.

6. include/: Directory containing the HEPEVT-xxx.h files for different versions of the HEPEVT common block. The symbolic link HEPEVT.h to the one actually used will be placed in this directory at the time of initialization. The phyfix.xxx files with versions of Fortran subroutine PHYFIX used only by TAUOLA universal interface are also stored there. The version to be used needs to be copied into phyfix.h; for more details, see README-phyfix.

subdirectories necessary to run demo and to install packages on different platforms

1. `glibk/`: Directory containing histogramming package, used by demos only.
2. `jetset/`: Directory containing `JETSET` MC package, used by demos only.
3. `jetset2/`: Directory containing `PYTHIA` MC package, used by demos only.
4. `eli/`: Directory containing files necessary to construct demo to be run with `PYTHIA` MC package.
5. `platform/`: Directory containing system-dependent versions of `make.inc` files for supported platforms.
6. `make.inc`: Symbolic link to the chosen `make-xxxx.inc` located in subdirectory `platform/`. The `make-xxxx.inc` files define machine-dependent flags for compilers etc. to be used by all `makefiles`.

The following directories are created once the actions of the setup are completed:

1. `photos/`: Standard directory with Fortran code of `PHOTOS` library and its demo.
2. `tauola/`: Standard directory with Fortran code of `TAUOLA` library, its demos and example outputs.
   (a) `tauola/demo-standalone`: Demo program for `TAUOLA` executed in a standalone mode.
   (b) `tauola/demo-jetset`: Demo program for `TAUOLA` executed with `universal interface` and physics event generators using the `HEPEVT` common block. In this demo `HEPEVT` is filled by `JETSET74` [18] Monte Carlo event generator.
   (c) `tauola/demo-pythia`: Optionally, a demo program for `TAUOLA` executed with `universal interface` and `HEPEVT` common block filled by `PYTHIA` [18] Monte Carlo event generator can be created as well.
   (d) `tauola/demo-KK-face`: Interface to KK Monte Carlo [12].

2.1 Options for PHOTOS Monte Carlo

The different options of `PHOTOS` that can be created, correspond solely to the different versions of the `HEPEVT` common block. The possible options are:

1. `KK-all` – for KK Monte Carlo, older versions
2. `2kD-all` – arrays dimension 2000, double precision
3. `4kD-all` – arrays dimension 4000, double precision

4. `2kR-all` – arrays dimension 2000, single precision

5. `10kD-all` – arrays dimension 10000, double precision

The action of preparing the required version of the library is performed with the help of `cpp` preprocessor. It creates a file `photos.f` from precode stored in `photos.F`. Once this is done, the symbolic link to the required version of the `HEPEVT` common block is defined. This link is used in the construction of the `tauola` library, see next section.

2.2 Options for TAUOLA Monte Carlo

Basic options for physics initializations are: `cpc`; `cleo`; `aleph`. As results of the action performed by the package:

1. The `tauola/` subdirectory is erased;

2. The directory structure of `tauola/` is rebuilt;

   - the `tauola/` directory is filled with the Fortran code, libraries and makefiles;
   - `tauola/demo-xx` are filled with the Fortran code of demos;

The three possible versions of created `tauola.f` correspond to formfactors and branching ratios defined respectively as in: (`cpc`) published version of TAUOLA [1,7]; (`aleph`) as adopted by ALEPH collaboration [8], (`cleo`) as adopted by CLEO collaboration [9].

Remarks:

• The `makefile` files are prepared to run `TAUOLA` within the environment of the distribution `TAUOLA` directory; however the templates for makefiles are compatible with those of the `KK` Monte Carlo. Thus if the `tauola` directory is copied into its respective place in the `KKMC` distribution tree, and `make makflag` of `KK/ffbench/` is executed, it overwrites the `makefile` file in `tauola/`. The new ones are produced from `makefile.templ` and match the `KKMC` structure.

• Additional parametrizations for formfactors, which can be useful in some applications, are stored in the directory `TAUOLA/tauola-F/suppl`. They are not ready to use and some cross-checks are mandatory. At present, the code used in Refs. [19] and [20] is stored there.

2.3 How to change the setting of TAUOLA input parameters

It is often necessary to change some of the `TAUOLA` input parameters, such as branching ratios, mass of the τ-lepton, etc. It is convenient to have it done once for all applications, i.e. `demo-KK-face`, `demo-jetset` and `demo-standalone`. The purpose of the `demo-factory` directory is exactly that. Here one can create the `.F` files for the interfaces, by the set of 'Paste' commands embodied in the script `klej`, out of the blocks of Fortran code. More precisely the following files can be re-created:

- For `demo-KK-face`: `./prod/Tauface.F`
- For `demo-jetset`: `./prod/tauola_photos_ini.F`
- For `demo-standalone`: `./prod/taumain.F`

For details of the intialization routines, which are semi-identical in the three cases, see Refs. [3, 4, 1]. This requires special care from the physics point of view. In many cases, the input parameters are inter-related with the actual choice of form factors. The changes should thus be performed consistently.

How to proceed:

1. Some of the routines in directory `./source` have to be updated by hand first. They are stored in individual files. The ones that usually should not be modified are write-protected.
2. Later execution of the script `klej` will create the following files from the pieces stored in the directory `./source` simply by pasting them together:
   - `./prod/Tauface.F`,
   - `./prod/tauola_photos_ini.F`,
   - `./prod/taumain.F`.

   Automatic check (using `diff`) with the archive versions stored in the directory `./back` will also be executed.
3. Finally the following commands copy the files into the appropriate places:
   (a) `cp prod/Tauface.F ../tauola-F/tauface-KK-F/Tauface.F`
   (b) `cp prod/tauola_photos_ini.F ../tauola-F/jetset-F/tauola_photos_ini.F`
   (c) `cp prod/taumain.F ../tauola-F/standalone-F/taumain.F`

2.4 Random number generators

- `PHOTOS` and `TAUOLA` have their own copies of the random number generators. They are contained in the `include` files placed in the directory `randg`.
- The user who wants to implement her/his own generators, e.g. compatible with the ones used by the collaboration, should replace the files:
  - `./photos-random.h`,
  - `./tauola-random.h`

  by those including the appropriate wrappers of his/her own random generators (or empty files if the generators of the same name reside elsewhere).

2.5 Compiler flags, etc.

Platform-dependent parts of the `makefiles` are stored in the directory `platform/`. At present options are available for various distributions of the Linux platform only, but it is rather straightforward to extend them to the new ones.

3 Universal interface with HEPEVT common block

In the present section, we shall document for the first time, how to install and use the `TAUOLA universal interface` with 'any' production generator, to include spin effects in e.g. the $Z/\gamma^* \to \tau^+\tau^-$ process [13,14]. The approximate spin correlations are calculated from the information stored in the `HEPEVT` common block [21] filled by 'any' τ production program. As a demonstration example it is interfaced with the `JETSET` generator; however, it works in the same manner with `PYTHIA, HERWIG` and should work with the `ISAJET` generator as well. In fact, such an interface can be considered as a separate software project, to some degree independent from both the specific problem of τ production and its decay. The aim of this interface is not to replace the matrix element calculations, but rather to provide a method of calculating/estimating spin effects in cases when these would not be taken into account at all.

3.1 HEPEVT common block and HEPEVT event record

The question of adapting the universal interface[1] to different versions of an `HEPEVT` event record goes beyond the technicalities discussed in Section 2.1. In fact it is quite involved, as it depends on specific needs due to the way the `HEPEVT event record` is actually coded into the `HEPEVT common block`. It varies from application to application according to the physics requirement. During the `MC4LHC` Workshop [22] these issues were discussed and it was found, thanks to interaction with the users, that the `TAUOLA universal interface` works with all 3 basic options for `HEPEVT` filled by `PYTHIA` 6.2 (`MSTP(128)=0,1,2`), as well as with `HERWIG` (6.150) [23]. In our example we keep only the working interface with `PYTHIA` version 5.7, the working example with other installations can be found e.g. in [24].

The discussion of the related problems go beyond this document; we refer the reader to Section 8 for more details. We are also convinced that the problems, because they originate from physics, will appear in event records in other programming languages such as C++.

3.2 Longitudinal spin effects

Let us start with the simpler case, when only longitudinal spin degrees are included. Then the interface acts in the following way:

- The user has to verify if the τ lepton is forced to be stable in the package performing generation of the τ production.

[1] The question is even more serious in the case of `PHOTOS`.

- The contents of the HEPEVT common block is searched for all τ leptons and τ neutrinos.

- It is checked if there are τ flavour pairs (two τ leptons or a τ lepton and a τ neutrino) originating from the same mother(s).

- The decays of the τ flavour pairs are performed with the subroutine TAUOLA. Longitudinal spin correlations are generated in the case of the τ produced from the decay of: $W \to \tau\nu$, $Z/\gamma^* \to \tau\tau$, and the charged Higgs boson $H^{\pm} \to \tau\nu$ (for the neutral Higgs boson the full spin correlations are used, see Section 3.4). Parallel or antiparallel spin configurations are generated, before calling on the τ decay, and then the decays of 100% polarized τ's are executed.

- In the case of the Higgs boson (for the spin correlations to be generated) the identifier of the τ mother must be that of the Higgs boson. The particle code convention as that used by the PYTHIA 5.7 [25] Monte Carlo is adopted, but it can be changed by the user, as explained later in this section.

- In the case of the W and Z/γ^*, this is not necessary, because the interface assumes these production mechanisms as defaults, even if the W or Z/γ^* bosons are not explicitly present in the event record. For example if from the same mother as that of the τ, a ν_τ is also produced, the W (of the momentum equal to the sum of τ and ν_τ) will be taken as the true mother of the τ. Similarly, if another τ with opposite charge is produced from the same mother, the Z/γ^* is assumed to be the mother of the τ pair.

- The spin effects in the states of τ^+, τ^- produced from explicit or implicit Z/γ^* states are upgraded up to nearly KORALZ standards [26,27]. If bremsstrahlung protons are present in the event record (as sisters of Z), then they have to be mergerd either with beams or with τ's, accordingly to approximation explained in [13]. Photon radiation in the decay is performed with PHOTOS package [5,2].

Let us note that the calculation of the τ polarization created from the Z and/or virtual γ^* (as a function of the direction) represents a rather non-trivial extension if high precision is required. Generally, the dedicated study of the production matrix elements of the host generator is necessary in every individual case. The method applied here is based on approximations [13,14].

3.3 Organization of the interface

The TAUOLA interface is organized in a modular form to be used conveniently in 'any environment'.

Initialization

Initialization is performed with the `CALL TAUOLA(MODE,KEYSPIN)`, `MODE=-1`. All necessary input is directly coded in the subroutine TAUOLA placed in a file `tauface-jetset.f`.

The following input parameters are set at this call. We omit those, which are standard input for TAUOLA as defined in its documentation. They are hard-coded in the subroutine.

Parameter	Meaning
POL	Internal switch for spin effects in τ decays and only for the longitudinal case. Normally the user should set POL=1.0, and when POL=0.0 spin polarization effects are absent.
KFHIGGS(3)	(KF=25, 35, 36) Flavour code for h, H and A
KFHIGCH	(KF=37) Flavour code for H^+
KFZ0	(KF=23) Flavour code for Z^0
KFGAM	(KF=22) Flavour code for γ
KFTAU	(KF=15) Flavour code for τ^-
KFNUE	(KF=16) Flavour code for ν_τ
xmtau	τ-lepton mass, used only for KFHIGGS(3), see Section 3.4
xmh	Higgs boson mass, used only for KFHIGGS(3)
psi	Mixing scalar–pseudoscalar angle, this angle is used only for Higgs boson with flavour code equal KFHIGGS(3)

Event generation

For every event generated by the production generator, all τ leptons will decay with the single CALL TAUOLA(0,KEYSPIN) (KEYSPIN=1/0 denotes spin effects switched on/off). In its execution, all τ leptons will be first localized, their positions stored in internal common block TAUPOS, and the information necessary for calculating the τ spin state will be read from HEPEVT common block. The spin state for the given τ (or τ pair) will be generated later, and finally the decay of the polarized τ will be performed with the standard TAUOLA action. In particular, the decay products of τ will be boosted to the laboratory frame and added to the complete event configuration stored in the HEPEVT common block.

Calculation of the τ spin state

Once CALL TAUOLA(0,KEYSPIN) is executed and τ leptons are found, the spin states

have to be calculated.

First, we look in HEPEVT for the position of τ's mothers and store them in matrix IMOTHER(20). Each mother giving τ lepton(s) is stored only once, independently of the number of produced τ's. Later, for every IMOTHER(i) we execute the following steps:

1. The daughters, which are either τ leptons or ν_τ, are searched for.

2. The daughters are combined in pairs, and the case of more than 1 pair is not expected to be important; ad hoc pairing is then performed.

3. The two main cases are thus (τ τ) or (τ ν_τ).

4. The default choices in these two main cases are, respectively, Z/γ^* or W, unless the identifier of IMOTHER(i) is different and explicitly defined, e.g. as a neutral (or charged) Higgs boson.

5. Calculation of the spin parameters is independent from kinematic variables and straightforward in all cases except Z/γ^* (see [13]).

6. For Z/γ^*, the polarization function P_Z [13] is calculated with the help of the function PLZAPX(HOPE,IMO,NP1,NP2). The HOPE is the logical parameter defined in subroutine TAUOLA placed in the file tauface-jetset.f. It tells whether spin effects can be calculated or not. If available information is incomplete, HOPE is set to .false.. Then PLZAPX(HOPE,IMO,NP1,NP2) returns 0.5. The IMO denotes the position of the τ mother in HEPEVT common block, the NP1 denotes the position of τ^+ and the NP2 denotes the position of τ^-.

7. To calculate the reduced $2 \to 2$ body kinematical variables s and $\cos\theta$, the subroutine ANGULU(PD1,PD2,Q1,Q2,COSTHE) is used. Four-momenta of the incoming effective beams and outgoing τ^+ and τ^- are denoted by PD1, PD2, Q1, Q2, respectively. The variables s and $\cos\theta$ are then used in the function P_Z.

Run summary

After the series of events is generated the optional CALL TAUOLA(1,KEYSPIN) can be executed. The information on the whole sample, such as the number of generated τ decays, branching ratios calculated from matrix elements, etc. will be printed.

Demonstration program

Our main program demo.f is stored in the subdirectory demo-jetset. It reads in the file init.dat, which includes some input parameters for the particular run, such as the number of events to be generated (by JETSET/PYTHIA), or the type of the interaction it should use to produce τ's. We address the reader directly to the code for more details. It is self-explanatory. The printouts at the interface initialization has the form presented in Fig. 1, while that at the end of the execution has the form presented in Fig. 2.

```
*********************************************************************
*                        *****TAUOLA UNIVERSAL INTERFACE: ******     *
*                        *****VERSION 1.10, November 2003 ******     *
*                        **AUTHORS: P. Golonka, B. Kersevan, ***     *
*                        **T. Pierzchala, E. Richter-Was, ******     *
*                        ****** Z. Was, M. Worek ***************     *
*                        **USEFUL DISCUSSIONS, IN PARTICULAR ***     *
*                        *WITH C. Biscarat and S. Slabospitzky**     *
*                        ****** are warmly acknowledged ********     *
*                                                                    *
*                        ********** INITIALIZATION  ************     *
*             1.00000    tau polarization switch must be 1 or 0      *
*             1.57080    Higs scalar/pseudo mix CERN-TH/2003-166     *
*********************************************************************
```

Figure 1: Printout of `TAUOLA universal interface` initialization

```
*********************************************************************
*                        *****TAUOLA UNIVERSAL INTERFACE: ******     *
*                        *****VERSION 1.10, November 2003 ******     *
*                        **AUTHORS: P. Golonka, B. Kersevan, ***     *
*                        **T. Pierzchala, E. Richter-Was, ******     *
*                        ****** Z. Was, M. Worek ***************     *
*                        **USEFUL DISCUSSIONS, IN PARTICULAR ***     *
*                        *WITH C. Biscarat and S. Slabospitzky**     *
*                        ****** are warmly acknowledged ********     *
*                        ****** END OF MODULE OPERATION ********     *
*********************************************************************
```

Figure 2: Printout of `TAUOLA universal interface` end-of-run messages

3.4 Transverse spin effects

The extended version of the standard `universal interface`, of the `TAUOLA` τ-lepton decay library, includes the complete spin effects for τ leptons originating from the spin zero particle, i.e. in $H/A \to \tau^+\tau^-$ decay [14, 15, 16]. As usual, the interface is expected to work with any Monte Carlo generator providing production (and subsequent decay into pair of τ leptons) of the Higgs boson. Since the Higgs boson spin is zero, the spin correlations of its decay products do not depend at all on the mechanism of the Higgs boson production. Technical difficulties related to the choice of τ^+ and τ^- spin quantization frames, present in the case of $e^+e^- \to Z/\gamma^* \to \tau^+\tau^-$ [28, 29] (initial state bremsstrahlung effects included or not), are not present. The analytical form of the density matrix is simple. To calculate the density matrix for the pair of τ-leptons it is thus enough to: know their four-momenta, know that they indeed originate from the Higgs boson, and assume the type of the Yukawa interaction. Such information is stored in the `HEPEVT` common block [21] used by practically all Monte Carlo generators for Higgs boson production.

The interface acts in the following way and according to principles described in [3]:

- The algorithm is organized in two steps. In the first step, the τ lepton pair is generated and the τ leptons decay in their respective rest frames, as if there were no spin effects at all. In the second step, the spin weight is calculated and rejection is performed. If the event is rejected, only the generation of the τ lepton decays is repeated.

- The spin weight for Higgs boson decay into $\tau^+\tau^-$ is given by the following formula

$$wt = \frac{1}{4}\Big(1 + \sum_{i=1}^{3}\sum_{j=1}^{3} R_{ij} h_1^i h_2^j\Big). \tag{1}$$

- The components of the density matrix R_{ij} are equal $R_{33} = -1$, $R_{11} = \pm 1$, $R_{22} = \pm 1$, respectively, for pure scalar and pseudoscalar Higgs boson, and all other components are zero. The h^i and h^j are the polarimetric vectors of the $\tau^\pm$ leptons (they are calculated by `TAUOLA`).

- In general, the Yukawa coupling can be written as $\bar{\tau}(a + ib\gamma_5)\tau$. With our choice of quantization frames, the following non-zero components of R_{ij} are obtained (see Ref. [17]):

$$R_{33} = -1, \qquad R_{11} = R_{22} = \frac{a^2\beta^2 - b^2}{a^2\beta^2 + b^2}, \qquad R_{12} = -R_{21} = \frac{2ab\beta}{a^2\beta^2 + b^2}, \tag{2}$$

  where $\beta = \sqrt{1 - \frac{4m_\tau^2}{m_H^2}}$. With Yukawa coupling written in the form $\bar{\tau}N(\cos\phi + i\sin\phi\gamma_5)\tau$ and with the limit $\beta \to 1$, the expressions reduce to the components of the rotation matrix by an angle -2ϕ:

$$R_{11} = R_{22} = \cos 2\phi, \qquad R_{12} = -R_{21} = \sin 2\phi. \tag{3}$$

The following changes had to be introduced to the algorithm explained in Ref. [13]:

- The quantization frames for the spin states of τ^+ and τ^- need to be properly oriented with respect to each other. In our solution they are simply connected by the boost along the τ lepton momenta as defined in the Higgs boson rest frame. At the technical level this is enforced by the `TRALOR` routine [3], which defines the relation of the $\tau^\pm$ spin quantization frames with the laboratory frame. As an intermediate step this routine uses the Higgs boson rest frame.

- The density matrix for the pure scalar/pseudoscalar case was taken from Ref. [30], and in the most general case in Ref. [31]. We have adapted it to the quantization frames as specified previously. Two cases are implemented: pure scalar Higgs boson and Higgs boson with mixed scalar–pseudoscalar coupling.

- Generation of τ^+ and τ^- decays is implemented in the subroutine `SPINHIGGS` placed in the file `tauface-jetset.f` and performed following the method explained and used in Refs. [3,29].

- The function `wthiggs(IFPSEUDO,HH1,HH2)` is used to calculate the spin weight. The `HH1` and `HH2` are the τ^+ and τ^- polarimetric vectors calculated inside the subroutine `DEKAY` placed in the file `tauola.f`. The `IFPSEUDO` is a logical parameter, defined in the subroutine `TAUOLA` and placed in the file `tauface-jetset.f`. It tells whether spin effects are calculated for the scalar or for the mixed scalar–pseudoscalar Higgs boson. If we have pure scalar Higgs boson it is set to `.false.`. If we have mixed scalar–pseudoscalar case it is set to `.true.`. The pure pseudoscalar case is for $\phi = \frac{\pi}{2}$.

- We have assumed that production generator provides two-body Higgs boson decays to τ leptons. In particular, that it does not provide any bremsstrahlung corrections. Instead, `PHOTOS` [5,2] (see also [32]) can be used for that purpose, once the generation of $\tau^\pm$ decays is completed.

- A more complete inclusion of bremsstrahlung corrections would require a substantial rewriting and extension of the program to the solution presented in Ref. [12] or a similar one.

4 How to use the package

1. Start with `make Clean` from main directory to secure against mismatches.

2. Check platform-dependent `makefiles`.

   - Go to subdirectory `platform/`
   - Determine if `make-xxx.inc` file specific for your computer is present there: for Linux it is `make-linux.inc`; for others it needs to be adapted.
   - Erase the symbolic link `make.inc` which exists in this directory and create a new one, which points at the chosen `make-xxx.inc`:

- `rm make.inc`
- for Linux: `ln -s make-linux.inc make.inc`

Afterwards check whether a link to the `make.inc` is present in the main directory.

3. The settings of `TAUOLA` input parameters can be changed for all implemented applications, see Section 2.3 for details.

4. `PHOTOS` and `TAUOLA` have their own private random generators. If you wish to replace them, you should do it at this point, see Section 2.4.

5. Create required versions of `photos/` and `tauola/` directories. It is mandatory to create `photos/` directory first, *i.e.* before creating `tauola/`.

   - Go to the directory `photos-F`
   - Type one of the following commands to choose the required version of `HEPEVT`:
     - `make KK-all`
     - `make 2kD-all`
     - `make 4kD-all`
     - `make 2kR-all`
     - `make 10kD-all`
   - Go to directory tauola-F:
   - Type one of the following commands to choose the required version of `TAUOLA` initialization:
     - `make cpc`
     - `make cleo`
     - `make aleph`

     The user can then type
     - `make pythia`

     to construct the additional demo executable with `PYTHIA`. In this demonstration program, old `PYTHIA` version 5.720 [18] is used. The user is anyway expected to attach the package to a new software, up to date at the time of installation. In this example, the matching of the common block dimensions is not automatically assured. The option `make 4kD-all` has to be used.

6. The required version of `PHOTOS` and `TAUOLA` will reside in newly (re)created directories `./photos` and `./tauola`.

7. The following `demos` can be invoked from those directories:

   - Demo for `PHOTOS` resides in `./photos/demo`, and can be invoked by command `make` followed by `make run`.

- Demo for TAUOLA stand-alone resides in ./tauola/demo-standalone, and can be invoked by the command make followed by make run.
- Demo for TAUOLA with JETSET being a host Monte Carlo resides in ./tauola/demo-jetset, and can be invoked by the command make followed by make run.
- Demo for TAUOLA with PYTHIA being a host Monte Carlo resides in ./tauola/demo-pythia, and can be invoked by the command make followed by make run.
- Interface to KKMC resides in ./tauola/KK-face/Tauface.f. It has to be moved to ./KK2f/Tauface.f of distribution directory of KKMC [12]. The rest of the ./tauola directory should replace the original one of the KK Monte Carlo distribution.

Finally, let us remark that most of the TAUOLA tree is not necessary and can be erased at this point. Code and makefiles of the directories ./tauola and ./photos are sufficient. To execute demo programs, the directories ./jetset and ./glibk need to be kept or replaced by the appropriate links. The make.inc symbolic link pointing to the make-xxxx.inc file in the directory ./platform also needs to be kept. The file make-xxxx.inc defines appropriate compiler flags.

5 New hadronic currents for $\tau \to 4\pi$ channels of τ decay

The parametrization of formfactors developed for 4π channels of τ decay and based on Novosibirsk data has been coded in a form suitable for the TAUOLA Monte Carlo package [10]. There exist two 4π final states in τ^- decay (i.e. $\tau^- \to \nu_\tau \pi^- \pi^0 \pi^0 \pi^0$, $\tau^- \to \nu_\tau \pi^- \pi^- \pi^+ \pi^0$). Both are available as parallel decay modes in the cpc, cleo or aleph versions. To get the new 4π channels of τ decay (BINP version) one should act in the following way:

1. Go to directory tauola-factory.
   - There is a glue programme that prepares a Fortran 'precode' of TAUOLA library and places it in the directory ../tauola-F.
   - Type the following command to see the parameters of the glue programme:
     - ./glue
   - Type the following command to choose the BINP version:
     - ./glue binp
   - Type the following command to come back to the standard version:
     - ./glue standard

2. Go to the main directory.

3. Act according to the instructions described in the previous chapter.

4. The required TAUOLA version (cpc, cleo or aleph) with new 4π channels of τ decay (BINP version) will reside in newly (re)created directory ./tauola.

Another parametrization of form factors for 4π channels based on References [11,7] is available as well. It can be installed, similar the case described above. The only difference is that flag binp has to be replaced with Karlsruhe.

6 Universal tool for HEP Monte Carlo generator comparison: MC-TESTER

Within the scope of the TAUOLA-PHOTOS project work, a pilot project of MC-TESTER tool for semi-automatic comparisons of Monte Carlo generators has been deployed. Initially, the project was targeted to be a part of this package: it was intended to be used as a debugging/analysis tool for comparing the results produced by various versions of TAUOLA and PHOTOS code.

We decided however to publish MC-TESTER as an independent project [33]. The scope of its possible use spans far beyond its original use case. We have however preserved the relationship between the two projects: we include two versions of TAUOLA code (that may be produced using TAUOLA-PHOTOS) in the MC-TESTER distribution (versions 1.0 and 1.1) as a test that verifies the correctness of MC-TESTER installation.

More information and the code of MC-TESTER is available from its web page [34].

7 Minor upgrades in TAUOLA and PHOTOS

There is no need to publish the new versions of the programs: since the last publication, the upgrades are minor. Nonetheless let us list here the main improvements collected over the years. The list of fixes for numerically rather insignificant bugs, as well as necessary changes due to the evolution of compilers, will not be given here. For that purpose we refer the reader to the comments in the code, to the README files included in the distribution and to the package web page [35].

7.1 TAUOLA

Apart from the modifications listed in Section 1, no changes were introduced in the cpc and aleph initializations of TAUOLA since the time they became available. In the case of cleo initialization, a change was introduced in the $\tau \to \nu\pi^+\pi^+\pi^-\pi^0$ channel; normalization of the ω current was adjusted to experimental data [36]. To this end, the ω contribution was diminished from 68% down to 40% of the total rate for the $\tau \to \nu\pi^+\pi^+\pi^-\pi^0$ channel. The new version of TAUOLA 2.7, was nonetheless introduced, which is marked in all initialization printouts, to document progress in bug fixing etc. The

creation dates printed in the outputs are retained. They mark the time when the bulk of the work was done.

Since publication [10] a careful analysis of a hadronic current for 4π final states was performed; related extensive studies and comparisons are documented in Ref. [37]. The new parametrization based on Refs. [11, 7] was also installed in `TAUOLA` . Different options of models discussed in Ref. [10] were probed. Let us list changes with respect to [10], which are now installed in the `TAUOLA` code if used with the `binp` option. We will use the opportunity to list misprints found in Ref. [10] as well:

1. In Table 4 of Ref. [10] in all columns of function arguments, $\sqrt{Q^2}$ were listed rather than Q^2, as written in the table header.

2. Formula (20) of [10] should read $g_\sigma(s) = (1 - 4m^2/s)^{1/2}$, rather than $g_\sigma(s) = (s - 4m^2/s)^{1/2}$.

3. All propagators derived from formula (18) of Ref. [10], should be normalized to -1 at $q^2 = 0$; also imaginary part should be set to zero below opening of the appropriate decay channel (i.e. typically for $q^2 < 4m^2$).

4. In the definition of the ρ propagator in formula (18) of Ref. [10], the term $dm(q^2)$ was neglected. The full ρ propagator should read

$$\begin{aligned} D_\rho(q^2) &= q^2 - M_\rho^2 - M_\rho\Gamma_\rho\ dm(q^2) + iM_\rho\Gamma_\rho\frac{g_\rho(q^2)}{g_\rho(M_\rho^2)} \\ dm(q^2) &= \left(h_\rho(q^2) - h_\rho(M_\rho^2) - (q^2 - M_\rho^2)\frac{dh_\rho(q^2)}{dq^2}\Big|_{q^2=M_\rho^2}\right)/g_\rho(M_\rho^2), \end{aligned} \tag{4}$$

   where

$$h_\rho(q^2) = \begin{cases} \dfrac{\sqrt{1-\frac{4m^2}{q^2}}\ln\left(\frac{1+\sqrt{1-\frac{4m^2}{q^2}}}{1-\sqrt{1-\frac{4m^2}{q^2}}}\right)(q^2-4m^2)}{\pi} & \text{for } q^2 > 4m^2, \\ -8\frac{m^2}{\pi} & \text{for } q^2 = 0 \text{ GeV}^2, \\ 0 & \text{otherwise .} \end{cases} \tag{5}$$

5. The full ω propagator should read (the $\frac{g_\omega(q^2)}{g_\omega(M_\omega^2)}$ was approximated by 1):

$$D_\omega(q^2) = q^2 - M_\omega^2 + iM_\omega\Gamma_\omega\frac{g_\omega(q^2)}{g_\omega(M_\omega^2)} \tag{6}$$

$$\frac{g_\omega(q^2)}{g_\omega(M_\omega^2)} = \begin{cases} \max\left(0\ ,\ \begin{array}{c} 1 + 17.560(\sqrt{q^2} - M_\omega) + 141.110(\sqrt{q^2} - M_\omega)^2 + \\ +894.884(\sqrt{q^2} - M_\omega)^3 + 4977.35(\sqrt{q^2} - M_\omega)^4 + \\ +7610.66(\sqrt{q^2} - M_\omega)^5 - 42524.4(\sqrt{q^2} - M_\omega)^6 \end{array}\right) & \text{for } \sqrt{q^2} < 1.0 \text{ GeV}, \\ -1333.26 + 4860.19\sqrt{q^2} - 6000.81(\sqrt{q^2})^2 + 2504.97(\sqrt{q^2})^3 & \text{otherwise .} \end{cases} \tag{7}$$

Function (7) is involved, because of effects due to three-body phase space, threshold effects of pion masses as well as opening of the resonant ρ channel in ω decay.

6. In formula (16) of Ref. [10] the overall sign was missing.

7. In formula (21) of Ref. [10], the coefficient in front of the second line should include s instead of a.

8. We have recalculated, using two methods, the outcome from formula (21) of [10]. We have found some numerical difference with respect to the one used before. The size of the difference is small, except the region above 1.3 GeV, which is not important anyway (see Ref. [37]).

9. In the comment for formula (21) of Ref. [10] it should be stated that three-vectors and energies are defined in the a_1 (3π) system rather than in the $\tilde{\rho}$ (4π) system.

10. In formula (25) of Ref. [10], the overall coefficient z_{mix} was missing, but it was set in the code to $z_{mix} = 1$ anyway.

11. At the beginning of Section 5 in Ref. [10] the numerical constant $\Lambda^2 = 1.2$ GeV should be defined, rather than Λ alone.

All points from the above list do not change the numerical content of the code, except for point 8, which brings a modification, and consequently leads to numerically small compensating changes of the content of the tables of functions G presented in Ref. [10].

We found, while playing with different versions of the `TAUOLA` code describing the Novosibirsk hadronic current, that we had for some time an overall sign error in the space-like component of the current. For all distributions involving pions only, it was fully compensated by the choice of the fit functions $G(Q^2)$ (formulae (14), (15) and (22–24) of Ref. [10]). Also all figures in Ref. [10] are correct.

However, as a consequence of the bug, the distributions involving ν_τ were affected in `TAUOLA BINP`. The effect was not large enough for comparisons with `TAUOLA CLEO` to hint for the problem. The differences were within the expected systematic errors of the two parametrizations. We have also found an additional misprint in the numerical value for our fit functions: $G_{\pi^+\pi^-\pi^+\pi^0}$, $G^{\omega}_{\pi^+\pi^-\pi^+\pi^0}$ and $G_{\pi^+\pi^0\pi^0\pi^0}$ (see Table 4, Ref. [10]). An overall constant or function was missing. Once corrections are taken together, the values in Table 4 should be multiplied respectively by:

- $$\frac{76.565\sqrt{0.71709 * \sqrt{Q^2} - 0.27505}}{M_\rho^4\sqrt{Q^2}} \quad \text{for the} \quad G_{\pi^+\pi^-\pi^+\pi^0}(Q^2), \tag{8}$$

- $$\frac{886.84\sqrt{0.70983 * \sqrt{Q^2} - 0.26689}}{M_\rho^4\sqrt{Q^2}} \quad \text{for the} \quad G^{\omega}_{\pi^+\pi^-\pi^+\pi^0}(Q^2), \tag{9}$$

- $$\frac{96.867\,|\texttt{z_forma1(Q}^2\texttt{)}|\sqrt{0.70907 * \sqrt{Q^2} - 0.26413}}{M_\rho^4\sqrt{Q^2}} \quad \text{for the } G_{\pi^+\pi^0\pi^0\pi^0}(Q^2) \quad (10)$$

before being used in formulae (14), (15) and (22–24) of Ref. [10]. Numerical values of the $|\texttt{z_forma1(Q}^2\texttt{)}|$ function are tabulated in the new `TAUOLA` function `ZFA1TAB(Q2)`, as was the case with the functions G.

Finally, during the work, as a byproduct, we have switched on the interference between the ω and non-ω parts of this current. This changed the overall rate, mainly because of the interference of small, spread over all phase space tails of the ω Breit-Wigner propagator. The numerical effect is not visible in the differential distribution, but it affects the total rate by 1.017(1). We changed the normalization of $G_{\pi^+\pi^-\pi^+\pi^0}(Q^2)$ and $G^{\omega}_{\pi^+\pi^-\pi^+\pi^0}(Q^2)$ by the same factor, so as to reproduce the total 4π rate as in PDG 2000. Note that the interference of the ω current with the remaining part provides 1.7 % effect on the total rate.

7.2 PHOTOS

The changes we introduced are collected in the following subsections.

7.2.1 Subroutine PHCORK

During the test phase of the `Photos+` [38], a C++ implementation of the `PHOTOS` algorithm, it turned out that the generation becomes unstable for events produced at TeV energies. The use of `PHOTOS` at this energy range was then studied for the first time. The kinematics of events produced by `PYTHIA` 5.7 was often not precise enough, because of rounding errors for (`REAL*4`) floating-point variables.

The particles described by a tree-structured event record (i.e. `HEPEVT` common block used by `PHOTOS`), form decay 'branches' composed of a 'mother' – the decaying particle, and 'daughters' – its decay products. When the kinematics of a branch is not correct (the sum of 4-momentum of decay products does not match the 4-momentum of the mother particle or the particles momenta are off shell), numerical instabilities are encountered. It is not possible to perform boosts of the particles correctly if the boost parameters are large (in certain of the events where errors occurred, we found, for instance, a pion with momentum of order of TeV/c).

A special routine `PHCORK`, which corrects these kinds of inconsistencies, have been developed and inserted to `PHOTOS` code[2].

The routine works in one of four modes, selected at the initialization of `PHOTOS`:

- mode 1: no correction performed,
- mode 2: energy is corrected from mass,

[2] This routine became available in 1999 and can be found in the `CERNLIB` version of `PHOTOS`.

- mode 3: mass is corrected from energy,
- mode 4: energy is corrected from mass for particles up to a mass of 0.4 GeV, for heavier ones: mass is corrected.

In cases, where a branch (sub-cascade starting from certain particles) has two mothers, the first mother's momentum is corrected according to the sum of its children momenta and the momentum of the second mother.

The default mode is 1, which means that no correction is applied, and full compatibility with older implementations is retained.

Correction is performed in two steps. First, all daughters' energies (or masses, depending on the requested mode of correction) are corrected to fulfil the $E^2 - p^2 = M^2$ constraint.

In the second step, the sum of all daughters' 4-momenta is calculated. The mother's momentum is corrected to this value. In cases where two mothers are present, only the first mother's 4-momentum is corrected to a value:
$P_{mother_1} = (\sum_{daughters} P_{daughter}) - P_{mother_2}$.

7.2.2 Interference correction

In the published version of PHOTOS [2] the interference between photon emission from two sources was available only for two-body decays into particles of opposite charge and equal mass. Since then, the interference correction was extended to work also in the case of decays into particles of distinct masses. On the technical side the interference correction was re-coded to work more efficiently. For example this should prevent the program to stop in case of double bremsstrahlung and interference corrections in the decay of the very heavy $Z/\gamma^* \to e^+e^-$ state.

7.2.3 Enabling flags

For some users, it is convenient to block/enable PHOTOS generation in some cases, for tests or because of unphysical coding of events into the HEPEVT common block. Flags to block/enable PHOTOS generation in $\pi^0 \to e^+e^-\gamma$ and in W decay into quarks were introduced. The flags are initialized in the subroutine PHOINI.

7.2.4 Weight correction in the decay $W \to l\nu_l$

For the leptonic decays of the W boson, PHOTOS predictions were carefully compared with the results from the first order matrix element generator [32]. It was found that even though the leading corrections were properly modelled by PHOTOS, the non-leading missing effects were relatively large. The origin of these discrepancies was understood, and the appropriate correcting weight was introduced into PHOTOS. With these changes the agreement with the matrix element calculation improved sizeably [39], especially in regions of phase space populated with hard non-collinear photons. A new option was introduced, to initialize this correcting weight. It can be switched on/off with the new flag IFW, initialized in subroutine PHOCIN. The method can easily be extended to other

processes where the matrix element is available from QED calculations or from modelling based on experimental data.

7.2.5 PHOTOS 2.07

Once all these modifications are installed, the new version 2.07 of PHOTOS was created.

8 Issues related to distinct event record schemes

Let us note that the packages presented here work with the standard HEPEVT event record, where the tree structure of the event evolution is properly coded into a unique tree structure. Generally this is not the case. However, the programs were shown to work properly with the extension of the standard of the type as originating from PYTHIA [40] with MSTP(128)=0,1,2. Necessary adjustments turned out to be non-trivial and in fact correctness of their action cannot be garanteed in the general case [41]. The case of HERWIG [23] turned out to be even more complex. Even though in this case the HEPEVT common block is used as standard event record, the mother–daugter pointers are nonetheless used in a different way. As a consequence, events generated by HERWIG are far from the design format of the HEPEVT event record. We were able to tune the working of the TAUOLA universal interface to the requirements of operating with HERWIG; however, the interfacing of PHOTOS turned out to be rather more difficult.

The principal issue from which difficulties with the HEPEVT decoding arise is that PYTHIA as well as HERWIG produce a new copy of the participating particles each time a physical effect (e.g. final state radiation) is added; consequently several copies of particle entries are produced, which cannot be consistently put in the HEPEVT structure. In order to circumvent this problem, the JMOHEP and/or JDAHEP entries are *overloaded*, i.e. the information stored in them is used for other purposes than their original one. For example, PYTHIA with MSTP(128)=0 setting uses the JMOHEP entry to point to the copies of a particle (cf. Fig. 3) and HERWIG uses the JMOHEP(2,I) entries to store the colour information of the particle flow. A generic interface thus has to be informed of these possibilities and to correct for them for the TAUOLA and PHOTOS procedures to work properly.

At present a working version of modified PHOTOS routines, which appears to work with HERWIG, can be found in the distribution of AcerMC [24]. However rigorous testing is necessary before these modifications can be included in the official PHOTOS distribution. The original PHOTOS code had to be modified due to the 'overloaded' HEPEVT record, since its requirements for matching mother–daughter pointers were too strict for either PYTHIA or HERWIG. The modification was limited to PHOTOS_MAKE and PHOBOS routines. In addition the tracking of the IDHW array was added to PHOTOS_MAKE to accommodate the HERWIG event record. A further modification was however necessary in the PHOIN routine since in HERWIG the entry JMOHEP(2,I) is not empty but filled with colour flow information, which in turn inhibited PHOTOS radiation off participating particles[3]

[3] PHOTOS expects the non-zero second mother JMOHEP(2,I) entry only for $gg(qq) \to t\bar{t}$ process, which is treated by a set of dedicated routines; this in turn clashes with HERWIG overloaded JMOHEP(2,I) entry.

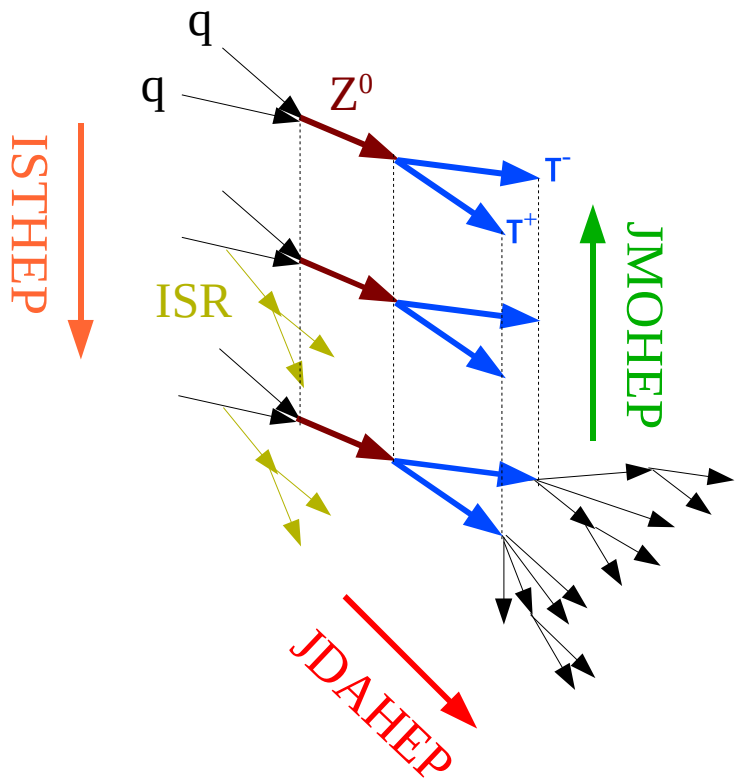

Figure 3: The usage of `JMOHEP` and `JDAHEP` pointers in `PYTHIA` with `MSTP(128)=0` setting. While `PYTHIA` keeps the `JDAHEP` entries to point in the direction of event evolution, the `JMOHEP` is used to point to the copies of a particle produced when perturbative effects, such as initial state radiation(ISR) or τ decays are added; the particle copies at different stages of event simulation are consistently distinguished by the `ISTHEP` tags.

It has to be stressed that implementing the HERWIG interface to PHOTOS is desirable since up to version 6.5 HERWIG did not have any QED radiation implemented in the decays. In the later releases, PHOTOS is installed in decays (and hadronic production) of t-quarks, as well as in W decays. This is done, however, through specifically tailored interfaces embodied within the HERWIG code.

Another two issues are related to the double counting. If there is no information passed from the host program and the common block PHOQED of PHOTOS is not appropriately filled, then there is no way for PHOTOS to know that in some decays it should not generate bremsstrahlung (again) and thus 'double counting' will appear. While the question is not relevant for HERWIG, since no photon bremsstrahlung is implemented, it can become an issue in PYTHIA, for some specific processes. Indeed, one can generally switch off the photon radiation off leptons (by setting a high limit on PARJ(90), cf. [40]); however, one cannot do it on the basis of specific processes and/or decays.

The issue is not shared in the TAUOLA universal interface, since the decayed τ leptons are not decayed again and the original decay will remain.

9 Summary and future possibilities

We have presented the system for creating the required version of PHOTOS and TAUOLA packages from their master versions. The master versions are structured in a relatively compact form without code duplications etc. The minor modifications of the programs, introduced since their publication, were also explained.

The creation of the system was the first step towards future attempts to develop packages without loss of their present physics contents. Some experience, already collected in that direction, is summarized in [38]. We find the question of the language translation for the fixed program version relatively easy. On the contrary, the question of project continuity into further upgrades motivated by the physics needs to be thought over carefully. Matching the programming styles of the C++ experts with the strategies of testing numerical correctness of consecutive versions is a rather crucial issue, which has to be addressed. Tools and methods embodied in Fortran code survive such translation with difficulty.

At a certain moment, the necessary strategy may thus require fluency in the Fortran, Object-Orientated languages and physics content of the project by the same person. Platform-independent tools for mixing code in Fortran and OO languages might be of great help.

In this paper we have also documented for the first time technical side of the universal interface for the TAUOLA package. From now on, its version number 1.10 is printed in the output.

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References

[1] S. Jadach, Z. Wąs, R. Decker, and J. H. Kühn, *Comput. Phys. Commun.* **76** (1993) 361.

[2] E. Barberio and Z. Wąs, *Comput. Phys. Commun.* **79** (1994) 291.

[3] S. Jadach, J. H. Kühn, and Z. Wąs, *Comput. Phys. Commun.* **64** (1990) 275.

[4] M. Jeżabek, Z. Wąs, S. Jadach, and J. H. Kühn, *Comput. Phys. Commun.* **70** (1992) 69.

[5] E. Barberio, B. van Eijk, and Z. Wąs, *Comput. Phys. Commun.* **66** (1991) 115.

[6] P. Golonka, E. Richter-Wąs, and Z. Wąs, `hep-ph/0009302`.

[7] R. Decker, M. Finkemeier, P. Heiliger, and H. H. Jonsson, *Z. Phys.* **C70** (1996) 247–254, `hep-ph/9410260`.

[8] ALEPH Collaboration, B. Bloch, to contact send a mail to `Brigitte.Bloch-Devaux@cern.ch`.

[9] CLEO Collaboration, A. Weinstein, see `http://www.cithep.caltech.edu/~ajw/korb_doc.html#files`.

[10] A. E. Bondar *et al.*, *Comput. Phys. Commun.* **146** (2002) 139–153, `hep-ph/0201149`.

[11] H. Czyż and J. H. Kühn, "*Four pion final states with tagged photons at electron positron colliders*", *Eur. Phys. J.* **C 18** (2001) 497.

[12] S. Jadach, B. F. L. Ward, and Z. Was, *Comput. Phys. Commun.* **130** (2000) 260, `hep-ph/9912214`.

[13] T. Pierzchała, E. Richter-Wąs, Z. Wąs, and M. Worek, *Acta Phys. Polon.* **B32** (2001) 1277, `hep-ph/0101311`.

[14] Z. Wąs and M. Worek, *Acta Phys. Polon.* **B33** (2002) 1875, `hep-ph/0202007`.

[15] G. R. Bower, T. Pierzchała, Z. Wąs, and M. Worek, *Phys. Lett.* **B543** (2002) 227, `hep-ph/0204292`.

[16] K. Desch, Z. Wąs, and M. Worek, *Eur. Phys. J.* **C29** (2003) 491, `hep-ph/0302046`.

[17] K. Desch, A. Imhof, Z. Was, and M. Worek, *Phys. Lett.* **B579** (2004) 157, `hep-ph/0307331`.

[18] T. Sjöstrand and M. Bengtsson.

[19] OPAL Collaboration, G. Abbiendi *et al.*, *Eur. Phys. J.* **C13** (2000) 197, hep-ex/9908013.

[20] DELPHI Collaboration, P. Abreu *et al.*, *Phys. Lett.* **B426** (1998) 411.

[21] Particle Data Group Collaboration, C. Caso *et al.*, *Eur. Phys. J.* **C3** (1998) 1.

[22] Chair W. Pokorski, N. Brook, session on decay packages of *"CERN Workshop on Monte Carlo tools for the LHC"* , July 7 - Aug 1 2003, CERN Geneva, http://agenda.cern.ch/fullAgenda.php?ida=a031540.

[23] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber, *JHEP* **0101** (2001) 010, hep-ph/0011363.

[24] B. Kersevan and E. Richter-Wąs, *Comp. Phys. Commun.* **149** (2003) 142, Available at http://cern.ch/Borut.Kersevan/AcerMC.Welcome.html.

[25] T. Sjöstrand, *Comput. Phys. Commun.* **82** (1994) 74.

[26] S. Jadach, B. F. L. Ward, and Z. Wąs, *Comput. Phys. Commun.* **79** (1994) 503.

[27] S. Jadach, B. F. L. Ward, and Z. Wąs, hep-ph/9905205.

[28] S. Jadach, B. F. L. Ward, and Z. Was, *Eur. Phys. J.* **C22** (2001) 423, hep-ph/9905452.

[29] S. Jadach and Z. Was, *Acta Phys. Polon.* **B15** (1984) 1151.

[30] M. Kramer, J. H. Kühn, M. L. Stong, and P. M. Zerwas, *Z. Phys.* **C64** (1994) 21, hep-ph/9404280.

[31] B. Grządkowski and J. F. Gunion, *Phys. Lett.* **B350** (1995) 218, hep-ph/9501339.

[32] A. Andonov, S. Jadach, G. Nanava, and Z. Wąs, *Acta Phys. Polon.* **B34** (2003) 2665, hep-ph/0212209.

[33] P. Golonka, T. Pierzchała, and Z. Wąs, hep-ph/0210252.

[34] http://cern.ch/Piotr.Golonka/MC/MC-TESTER.

[35] http://www.cern.ch/wasm/goodies.html.

[36] Particle Data Group Collaboration, K. Hagiwara *et al.*, *Phys. Rev.* **D66** (2002) 010001.

[37] T. Pierzchala, "The extension of TAUOLA Monte Carlo library, simulating τ lepton decays", PhD Thesis, Silesian University 2004, see home page at http://hpjmiady.ifj.edu.pl/~pierzchala.

[38] P. Golonka, MSc Thesis written under the supervision of Z. Wąs, see home page at http://cern.ch/Piotr.Golonka/MC/photos.

[39] G. Nanava and Z. Wąs, hep-ph/0303260.

[40] T. Sjöstrand *et al.*, *Comput. Phys. Commun.* **135** (2001) 238, hep-ph/0010017.

[41] Talks by B. Kersevan and M. Worek, presented at the *'Workshop on Monte Carlo tools for the LHC'*, CERN, July 2003.