IFJPAN-IV-2012-15

Status of TAUOLA and related projects

Z. Wąs[a,b]
[a] *Institute of Nuclear Physics, PAN, Kraków, ul. Radzikowskiego 152, Poland*
[b] *CERN PH-TH, CH-1211 Geneva 23, Switzerland.*

ABSTRACT

Status of new hadronic currents for τ lepton decay Monte Carlo generator `TAUOLA` was reviewed in other talks of the conference. Efforts on comparison with BaBar and Belle collaboration data were carefully discussed. Also use of the program in phenomenology of W decays measured by ATLAS collaboration was presented in these talks as well.

That is why, in my talk, I will concentrate on other aspects of our work necessary for development of τ lepton Monte Carlo programs and their phenomenological use.

Presented results illustrate the status of the projects performed in collaboration with Swagato Banerjee, Zofia Czyczula, Nadia Davidson, Jan Kalinowski, Wojciech Kotlarski Tomasz Przedziński, Olga Shekhovtsova, Elżbieta Richter-Wąs, Pablo Roig, Jakub Zaremba, Qingjun Xu and others.

Presented at International Workshop on Tau Lepton Physics,
TAU12 Nagoya, Japan, September, 2012

IFJPAN-IV-2012-15
December, 2012

1 Introduction

The TAUOLA package [1, 2, 3, 4] for simulation of τ-lepton decays and PHOTOS [5, 6, 7] for simulation of QED radiative corrections in decays, are computing projects with a rather long history. Written and maintained by well-defined (main) 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 presently in use. Those modifications, especially in case of TAUOLA, are valuable from the physics point of view, even though they often did not find the place in the distributed versions of the program. From the algorithmic point of view, versions may differ only in details, but they incorporate many specific results from distinct τ-lepton measurements or phenomenological projects. Such versions were mainly maintained (and will remain so) by the experiments taking precision data on τ leptons. Interesting from the physics point of view changes are still developed in FORTRAN. That is why, for convenience of such partners, part of the TAUOLA should remain in FORTRAN for a few forthcoming years.

Many new applications were developed in C++, often requiring a program interface to other packages (e.g., generating events for LHC, LC, Belle or BaBar physics processes). For the manipulation of matrix element, techniques of re-weighting events were further developed. This required attention on numerical stability issues.

The program structure did not change significantly since previous τ conference [8]. Let us concentrate on physics extentions and novel applications. We will only mention work on new hadronic currents based on the Resonance Chiral approach. This topic was covered in other talks of the conference [9, 11, 10]. Important results are already obtained, but sufficiently good agreement with the experimental data is not yet achieved. New currents are not integrated into main distribution tar-balls for FORTRAN and C++ applications. Further work is on-going, weighted event techniques useful for fits are used. Analyses of high precision, high-statistics data from Belle and BaBar are expected to profit from these solutions. Other aspects of the project such as interfaces for applications based on HepMC [12] event record or new tests and weighting algorithms for spin effects in production processes should be mentioned as well. In this context numerical stability of solutions used in re-weighting events stored in datafiles is of importance.

Our presentation is organized as follows: Section 2 is devoted to the discussion of optional weights in TAUOLA and their use for fits to experimental data. In section 3 we concentrate on PHOTOS Monte Carlo for radiative corrections in decays. Section 4 is devoted to new interfaces of TAUOLA and PHOTOS based on HepMC and written in C++. Work on interface to genuine weak corrections, transverse spin effects and new tests and implementation bremsstrahlung kernels will be presented as well. Comments on changes in MC-TESTER; the program designed for semi-automatic comparisons of simulation samples originating from different programs and heavily used in our projects are also given. Section 5 Summary closes the talk.

Because of the limited space of the contribution, some results will not be presented in the proceedings. They find their place in publications, prepared with coauthors listed in the Abstract. For these works, the present paper may serve as an advertisement.

2 Approach of Resonance Chiral lagrangians and TAUOLA Monte Carlo

In other talks [9, 11, 10] of the conference, Resonance Chiral Lagrangian approach was used for calculations of new hadronic currents to be installed TAUOLA. That is why, we do not need to repeat its description here. In Ref. [13] implementation of those currents is documented in a great detail.

Physics of τ lepton decays requires sophisticated strategies for the confrontation of phenomenological models with experimental data. On one hand, high-statistics experimental samples are collected, and the obtained precision is high, on the other hand, there is a significant cross-contamination between distinct τ decay channels. Starting from a certain precision level all channels need to be analyzed simultaneously. Change of parameterization for one channel contributing to the background to another one may be important for the fit of its currents. This situation leads to a complex configuration where a multitude of parameters (and models) needs to be simultaneously confronted with a multitude of observables. One has to keep in mind that the models used to obtain distributions in the fits may require refinements or even substantial rebuilds as a consequence of comparison with the data. The topic was covered in detail in the τ Section of Ref. [14]. At present our comparison with the data still do not require such refined methods.

We enable calculation for each generated event (separately for decay of τ^+ and/or τ^-) alternative weights; the ratios of the matrix element squared obtained with new currents, and the one actually used in generation. Then, the vector of weights can be obtained and used in fits. We have checked that such a solution not only can be easily installed into TAUOLA as a stand-alone generator, but it can also be incorporated into the simulation frameworks of Belle and BaBar collaborations. The weights can be calculated after the simulation of detector response is completed. Only then choice of parameters for the hadronic currents has to be performed and the fits completed. This idea was also behind TauSpinner for LHC applications, described in Section 4.

3 PHOTOS Monte Carlo for bremsstrahlung and its systematic uncertainties

Thanks to exponentiation properties and factorization, the bulk of the final state QED bremsstrahlung can be described in a universal way. However, the kinematic configurations caused by QED bremsstrahlung are affecting in an important way signal/background separation. It may affect selection criteria and background contaminations in quite complex and unexpected ways. In many applications, not only in τ decays, such bremsstrahlung corrections are generated with the help of the PHOTOS Monte Carlo. That is why it is of importance to review the precision of this program as documented in Refs. [5, 6, 7]. For the C++ applications, the version of the program is available now. It is documented in Ref. [15].

In C++ applications, the complete first-order matrix elements for the two-body decays of the Z [16] and W [17] decays into a lepton pair are now available. Kernels with complete matrix elements, for the decays of scalar B mesons into a pair of scalars [18] are available for the C++ users as well. For $K \to l\nu\pi$ and for $\gamma^* \to \pi^+\pi^-$ decays [17, 19] matrix element based kernels are still available for tests only. Properly oriented reference frames are needed in those cases. It will be rather easy to integrate those NLO kernels into the main version of the program, because of better control of the decay particle rest frame than in the FORTRAN interface.

In all of these cases the universal kernel of PHOTOS is replaced with the one matching an exact first-order matrix element. In this way terms necessary for the NLO/NLL precision level are implemented[1]. A discussion relevant for control of program systematic uncertainty in $\tau \to \pi\nu$ decay can be found in Ref. [21].

The algorithm covers the full multiphoton phase-space and becomes exact in the soft limit. This is rather unusual for NLL compatible algorithms. One should not forget that PHOTOS generates weight-one events, and does not exploit any phase space ordering. There is a full phase space overlap between the one where a hard matrix element is used and the one for iterated photon emission. All interference effects (between consecutive emissions and emissions from distinct charged lines) are implemented with the help of internal weights.

The results of all tests of PHOTOS with a NLO kernel confirm sub-permille precision level. This is very encouraging, and points to the possible extension of the approach outside of QED (scalar QED). In particular, to the domain of QCD or to QED when phenomenological form factors for interactions of photons need to be used. For that work to be completed, spin amplitudes need to be studied. Let us point to Ref. [22] as an example.

New tests of PHOTOS are available from Ref. [23]. In those tests, in particular, results from the second-order matrix element calculations embedded in KKMC [31] Monte Carlo are used in case of Z decay. For W decays comparisons with electroweak calculations of Refs. [24, 25] are shown.

4 TAUOLA universal interface and PHOTOS interface in C++

In the development of packages such as TAUOLA or PHOTOS, questions of tests and appropriate relations to users' applications are essential for their usefulness. In fact, user applications may be much larger in size and human efforts than the programs discussed here. Good example of such 'user applications' are complete environments to simulate

[1]Note that here the LL (NLL) denotes collinear logarithms (or in case of differential predictions terms integrating into such logarithms). The logarithms of soft singularities are taken into account to all orders. This is resulting from mechanisms of exclusive exponentiation [20] of QED. The algorithm used in PHOTOS Monte Carlo is compatible with exclusive exponentiation. Note that our LL/NLL precision level would even read as respectively NLL/NNNLL level in some naming conventions of QCD.

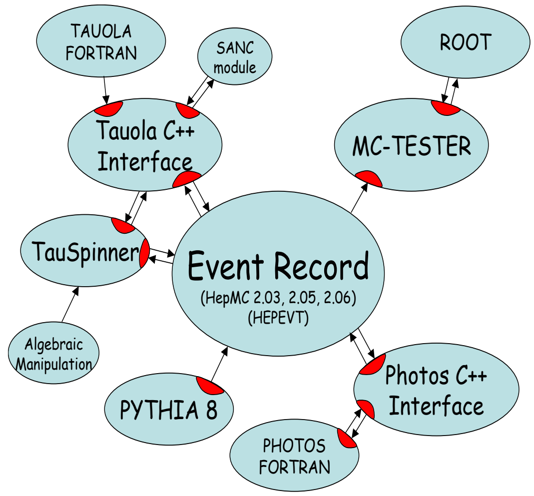

Figure 1: *Scheme of Monte Carlo simulation system with communication based on event record. Each segment feature contribution from different people, may be coded in distinct programinng language and/or be developped with the help of algebraic manipulation systems.*

physics process and control detector response at the same time. Distributions of final state particles are not always of direct interest. Often properties of intermediate states, such as a spin state of τ-lepton, coupling constants or masses of intermediate heavy particles are of prime interest. As a consequence, it is useful that such intermediate state properties are under direct control of the experimental user and can be manipulated to understand detector responses. Our programs worked well with `FORTRAN` applications where `HEPEVT` event record is used. For the `C++ HepMC` [12] case, interfaces were rewritten, both for `TAUOLA` [26] and for `PHOTOS` [15]. The interfaces and as a consequence the programs themselves were enriched; for `PHOTOS` new Matrix element kernels are available; for `TAUOLA` interface, a complete (not longitudinal only) spin correlations are available for Z/γ^* decay. Electroweak corrections taken from Refs. [24, 25] are also used. For the scheme of programs communications see Fig. 1. In this spirit an algorithm of `TauSpinner` [27] to study detector response to spin effects in Z, W and H decays, was developed. Recently `TauSpinner` was enriched [28] with the option to study effects of New Physics, such as effects of spin-2 states in $\tau^+\tau^-$ pairs produced at LHC. Modular organization opens ways for further efficient algorithms to understand detector systematics, but at the same time responsibility to control software precision must be shared by the user. Automated tests of `MC-TESTER` were prepared [29]. New functionalities were introduced into the testing package [30]. In particular, it works now with the `HepMC` event record, the standard of `C++` programs, spectrum of available tests is enriched and events stored on datafiles are easier to test.

The program is available through the LHC Computing Grid (`LCG`) Project. See `GENSER` webpage, Ref. [32], for details. This is the case for `TAUOLA C++` and for `PHOTOS C++` as well. The `FORTRAN` predecessors are available in this way too.

5 Summary and future possibilities

Versions of the hadronic currents available for the TAUOLA library until now, are all based on old models and experimental data of 90's. The implementation of new currents, based on the Resonance Chiral Lagrangian approach is now prepared and tested from the technical side. Methods for efficient confrontation with the experimental data are prepared as well. Once comparison with Belle and BaBar data is successfully completed, new parameterizations will be straightforward for use in a spectrum of applications in FORTRAN or C++ environments.

The status of associated projects: TAUOLA universal interface and MC-TESTER was reviewed. Also the high-precision version of PHOTOS for radiative corrections in decays, was presented. All these programs are available now for C++ applications thanks to the HepMC interfaces.

New results for PHOTOS were mentioned. For the leptonic Z and W decays the complete next-to-leading collinear logarithms effects can now be simulated in C++ applications. However, in most cases these effects are not important, leaving the standard version sufficient. Thanks to this work the path for fits to the data of electromagnetic form factors is opened [19], e.g. in the case of K_{l3} decays.

The presentation of the TAUOLA general-purpose interface in C++ was given. It is more refined than the FORTRAN predecessor. Electroweak corrections can be used in calculation of complete spin correlations in Z/γ^* mediated processes. An algorithm for study of detector responses to spin effects in Z, W and H decays was shown.

The present version of MC-TESTER is stable now. It works with C++ event record HepMC and enables user defined tests in experiments' software environments. We used the tool regularly in our projects.

6 Acknowledgement

This research was supported in part by the funds of Polish National Science Centre under decision DEC-2012/04/M/ST2/00240 and DEC-2011/03/B/ST2/00107 and by the Polish Government grant NN202127937 (years 2009-2011).

References

[1] S. Jadach, J. H. Kuhn, and Z. Was, *Comput. Phys. Commun.* **64** (1990) 275.

[2] M. Jezabek, Z. Was, S. Jadach, and J. H. Kuhn, *Comput. Phys. Commun.* **70** (1992) 69.

[3] S. Jadach, Z. Was, R. Decker, and J. H. Kuhn, *Comput. Phys. Commun.* **76** (1993) 361–380.

[4] P. Golonka *et al.*, *Comput. Phys. Commun.* **174** (2006) 818–835, hep-ph/0312240.

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

[6] E. Barberio and Z. Was, *Comput. Phys. Commun.* **79** (1994) 291–308.

[7] P. Golonka and Z. Was, *Eur. Phys. J.* **C45** (2006) 97–107, `hep-ph/0506026`.

[8] Z. Was, Nucl. Phys. Proc. Suppl. **218**, 249 (2011) [arXiv:1101.1652 [hep-ph]].

[9] O. Shekhovtsova talk at International Workshop on Tau Lepton Physics, TAU12 Nagoya, Japan, September, 2012.

[10] I. Nugent talk at International Workshop on Tau Lepton Physics, TAU12 Nagoya, Japan, September, 2012.

[11] P. Roig talk at International Workshop on Tau Lepton Physics, TAU12 Nagoya, Japan, September, 2012.

[12] M. Dobbs and J. B. Hansen, *Comput. Phys. Commun.* **134** (2001) 41–46, https://savannah.cern.ch/projects/hepmc/.

[13] O. Shekhovtsova, T. Przedzinski, P. Roig and Z. Was. "Resonance chiral Lagrangian currents and tau decay Monte Carlo," `1203.3955` , Phys. Rev. D in print. also http://annapurna.ifj.edu.pl/~wasm/RChL/RChL.htm

[14] S. Actis *et al.*, *Eur. Phys. J.* **C66** (2010) 585–686, `0912.0749`.

[15] N. Davidson, T. Przedzinski, and Z. Was, `1011.0937`.

[16] P. Golonka and Z. Was, *Eur. Phys. J.* **C50** (2007) 53–62, `hep-ph/0604232`.

[17] G. Nanava, Q. Xu, and Z. Was, *Eur. Phys. J.* **C70** (2010) 673–688, `0906.4052`.

[18] G. Nanava and Z. Was, *Eur. Phys. J.* **C51** (2007) 569–583, `hep-ph/0607019`.

[19] Q. Xu and Z. Was, Eur. Phys. J. C **72**, 2158 (2012) [arXiv:1201.0189 [hep-ph]].

[20] S. Jadach, B. F. L. Ward, and Z. Was, *Phys. Rev.* **D63** (2001) 113009, `hep-ph/0006359`.

[21] Z. -H. Guo and P. Roig, Nucl. Phys. Proc. Suppl. **218**, 122 (2011) [arXiv:1010.2838 [hep-ph]].

[22] A. van Hameren and Z. Was, `0802.2182`.

[23] P. Golonka, G. Nanava, and Z. Was, Tests of PHOTOS Hard Bremsstrahlung, http://mc-tester.web.cern.ch/MC-TESTER/PHOTOS-MCTESTER/ and A. Arbuzov, T. Przedzinski, R. Sadykov, Z. Was http://annapurna.ifj.edu.pl/~wasm/phNLO.htm, also A. Arbuzov, T. Przedzinski, R. Sadykov, Z. Was CERN-PH-TH/2012-354

[24] A. Andonov *et al.*, `0812.4207`.

[25] A. Andonov *et al.*, *Comput. Phys. Commun.* **174** (2006) 481–517, `hep-ph/0411186`.

[26] N. Davidson, G. Nanava, T. Przedzinski, E. Richter-Was and Z. Was, Comput. Phys. Commun. **183**, 821 (2012) [arXiv:1002.0543 [hep-ph]].

[27] Z. Czyczula, T. Przedzinski and Z. Was, Eur. Phys. J. C **72**, 1988 (2012) [arXiv:1201.0117 [hep-ph]].

[28] S. Banerjee, J. Kalinowski, W. Kotlarski, T. Przedzinski and Z. Was, arXiv:1212.2873 [hep-ph].

[29] P. Golonka, T. Pierzchala, and Z. Was, *Comput. Phys. Commun.* **157** (2004) 39–62, `hep-ph/0210252`.

[30] N. Davidson, P. Golonka, T. Przedzinski and Z. Was, Comput. Phys. Commun. **182**, 779 (2011) [arXiv:0812.3215 [hep-ph]].

[31] S. Jadach, B. Ward, and Z. Was, *Comput.Phys.Commun.* **130** (2000) 260–325, `hep-ph/9912214`.

[32] M. Kirsanov, A. Ribon, and O. Zenin, *PoS* **ACAT08** (2008) 114.