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The τ leptons theory and experimental data: Monte Carlo, fits, software and systematic errors.

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Abstract

Status of τ lepton decay Monte Carlo generator TAUOLA is reviewed. Recent efforts on development of new hadronic currents are presented. Multitude new channels for anomalous τ decay modes and parameterization based on defaults used by BaBar collaboration are introduced. Also parameterization based on theoretical considerations are presented as an alternative. Lesson from comparison and fits to the BaBar and Belle data is recalled. It was found that as in the past, in particular at a time of comparisons with CLEO and ALEPH data, proper fitting, to as detailed as possible representation of the experimental data, is essential for appropriate developments of models of τ decays.

In the later part of the presentation, use of the TAUOLA program for phenomenology of W, Z, H decays at LHC is adressed. Some new results, relevant for QED bremsstrahlung in such decays are presented as well.

Keywords: Tau physics, Monte Carlo generator, TAUOLA, QED radiative corrections

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.

The program structure did not change significantly since previous τ conference [8], nowadays however, the C++ implementation become dominant for many aspects of the project. In the following, we will concentrate on physics extensions and novel applications. We will stress importance of the three aspects of the work: (i) construction and implementation of hadronic currents for τ decay currents obtained from models (evaluated from QCD) (ii) presentation of experimental data in a form suitable to fits (iii) preparations of algorithms and definition of distributions useful for fits.

We have prepared two new set of currents, the first based mainly on theoretical consideration, the second on an effort of BaBar collaboration. They are ready

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to be integrated into main distribution tar-balls for FORTRAN and C++ applications. Further work in evaluation if such parameterizations are better suitable for physics purposes is on-going. Weighted event techniques useful for fits were studied as well. Analyses of high precision, high-statistics data from Belle and BaBar may find them useful, similar as LHC experiments.

Our presentation is organized as follows: Section 2 is devoted to presentation of optional initialization for TAUOLA which is based on the program version evolving in BaBar starting from a variant presented on τ conference of 2004 [9]. This version is supplemented with multitude of anomalous τ decay modes as well as with parameterization of our theoretical works of the last decay (of different level of theoretical sophistication depending on decay channel). Possibility to replace hadronic currents or matrix elements with the user provided C++ code is introduced. In Section 3 we concentrate on PHOTOS Monte Carlo for radiative corrections in decays. The new version of the program is now 100 % in C++. Section 4 is for the 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 is presented as well. Next, the algorithm of TauSpinner is presented. It calculates weights to manipulate properties of the event sample accordingly to changed assumptions for the hard process dynamic, or due to changed level of implementation of spin effects. Summary Section 5, closes the presentation.

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 References. For these works, the present paper may serve as an advertisement.

2. New currents in TAUOLA Monte Carlo

In other talks [10, 11] of the conference, it was shown how Resonance Chiral Lagrangian approach was used for calculations of hadronic currents to be installed in TAUOLA. We do not need to repeat it here. In [10] it was stressed that details, such as additional resonances, more specifically the $f_2(1270)$, $f_0(1370)$ and $a_1(1640)$, observed by CLEO long time ago [12] can not be introduced if fits to one-dimensional invariant mass spectra of two- and three-pions systems are only used. In Ref. [12] as an input for parameterization of TAUOLA currents (cleo parameterization [13]), two-dimensional mass scattergrams were used. This should be considered as a minimum for the comparisons with the present day data as well. In fact, already CLEO used more detailed representation of the data in [14]. It may be of interest to repeat such data analysis, with the help of observables, as the ones presented in [15], but adopted to the case of relativistic tau-pair production of Belle or BaBar experiments.

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 rebuildings as a consequence of comparison with the data. The topic was covered in detail in the τ Section of Ref. [16]. At present our comparison with the data still does not profit from such methods.

Let us give some details. We may want to calculate 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. For practical reasons use of semi analytical distributions is much easier. It enables much faster calculation of errors for fit parameters including correlations, but experimental distributions must be available in unfolded form. This was an important ingredient of our work for fits of 3π currents obtained in [17]. We have found that modifications of the currents were necessary to obtain results given in [18]. It is not clear, if such fitting, without additional help of observables as in [15] can be used for the $KK\pi\nu_\tau$ and $K\pi\pi\nu_\tau$ τ decay channel, even if two-dimensional scattergams are available. One has to keep in mind that if experimental data are available as one or at most two dimensional histograms then resulting currents rely on the models. With the present day precision