First release of Tauola C++ interface: hep-ph/1002.0543 and tauola doxygen web page

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• **(1) τ lepton:** *large mass $\longrightarrow$ large Yukawa coupling $\longrightarrow$ window for new physics*

• **(2) τ lepton:** *decays in detector $\longrightarrow$ its spin state can be measured $\longrightarrow$ window for parity*

• **(3) τ lepton:** *from QCD point of view its mass is intermediate. Decay M.E. has to be taken from models and low energy experiments data.*

• **(4) τ lepton:** *Production and decay are separated perfectly: large lifetime.*

• How to use τ decays **to measure hard proceeses**: *detector response, background-signal separations, many τ decay channels, bremsstrahlung.*

• How to separate into parts entangled things? TAUOLA, PHOTOS, SANC (interfering EW background for new physics), PYTHIA 8.1 for parton shower, hadronization, HepMC for communication.

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Introduction

1. internal τ decay dynamic is of no interest for LHC. It is challenging for low energy precision measurements: see hep-ph/0912.0749. That is why this part of TAUOLA project remain in FORTRAN. LHC may only profit.
2. Extended interface, for user convenience, is now in C++ .
3. Its physics quality is already better than FORTRAN version, but tests are less profound.
4. studies with QCD ME (http://arxiv.org/abs/0802.2182). and parton shower details (http://arxiv.org/abs/0905.1399) needed.

- Web pages of TAUOLA and related C++ projects:

www.ph.unimelb.edu.au/~ndavidson/tauola/doxygen/index.html $\longrightarrow$ TAUOLA C++/HepMC

http://mc-tester.web.cern.ch/MC-TESTER/ $\longrightarrow$ MC-TESTER

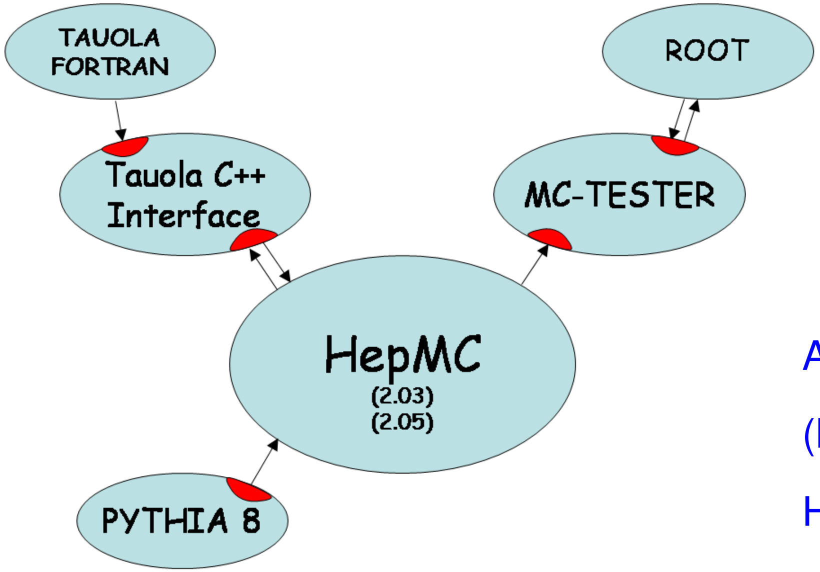
Under development (to be released in early summer):

www.ph.unimelb.edu.au/~ndavidson/photos/doxygen/index.html$\longrightarrow$ PHOTOS C++/HepMC

LHC perspective of τ leptons:

- For LHC phenomenology one can think of τ decay as of part of detector
- how does it ‘respond’ to the particular LHC hard process?
- An event can be constructed from the measured one with hard muons replaced with τ’s or obtained from other Monte Carlo.
- We may want to decay single τ present in event record (HepMC)
- Or look over the whole event and decay all (or just undecayed) τ leptons.
- for calculation of spin effects we may group them in pairs (originating from W’s or Z’s), use information present in event records to calculate spin density matrix or take it from host program.
- **All this affects organization of the program:**

Software organization:



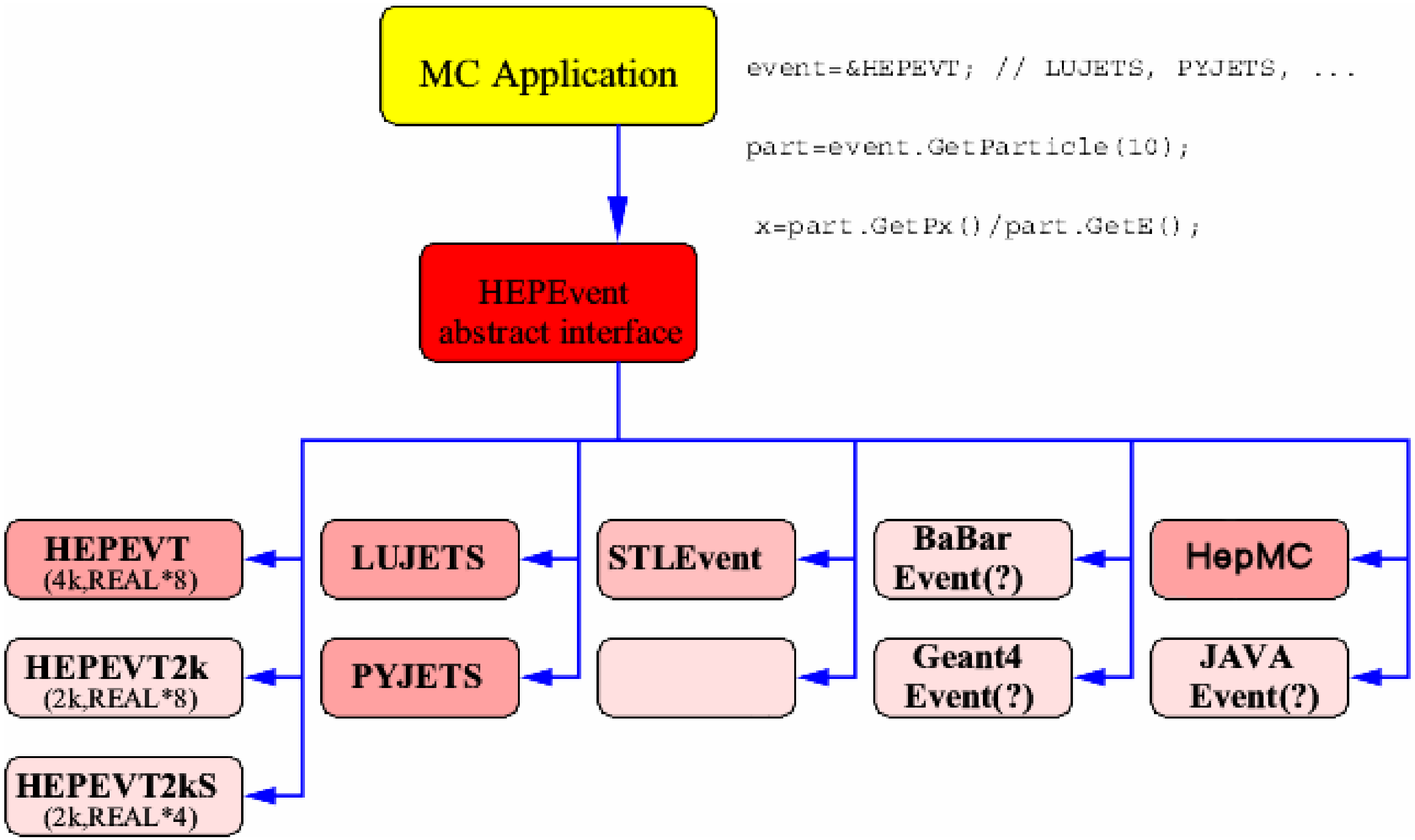
Autoconf scripts are prepared (http://www.gnu.org/software/autoconf/): HepMC and software used in demos/tests (Pythia8, root, MC-Tester) paths are provided. Interface to electroweak corrections through pre defined tables

Pilot users in Atlas and CMS

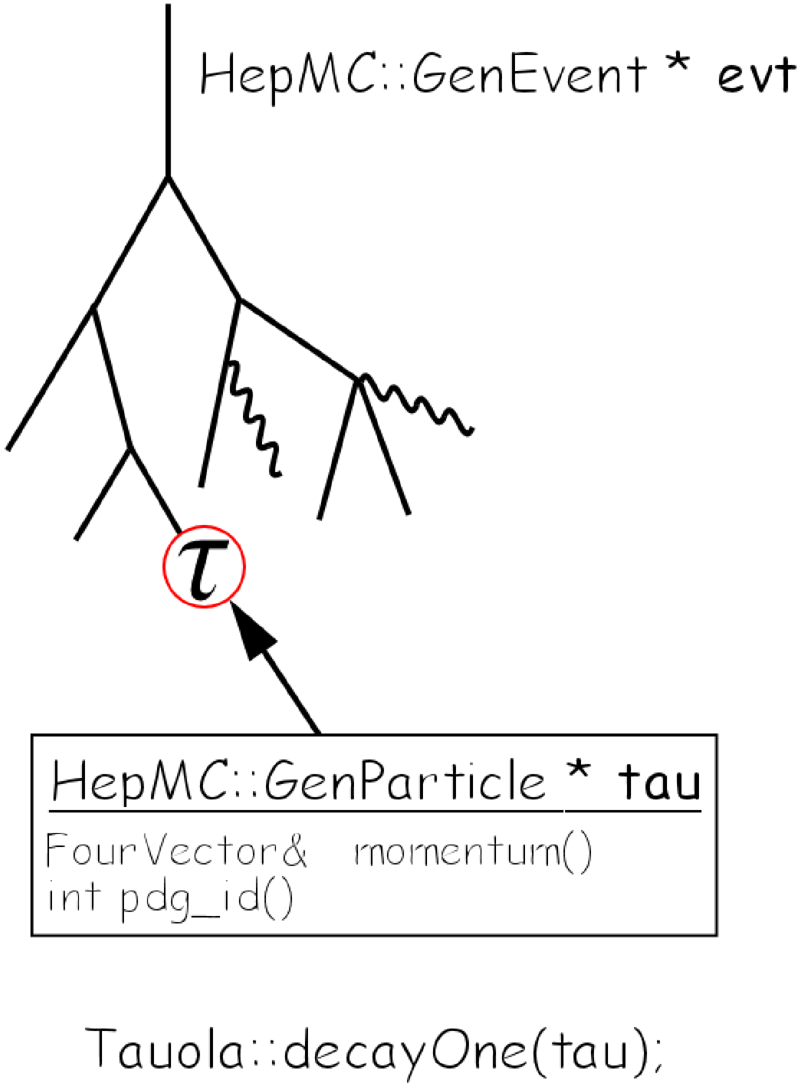
under checks by Genser people; main issues of benchmarking code.

Software organization:

TAUOLA, MC-TESTER and PHOTOS analyze/modify event records such as HEPEVT of F77 or HepMC of C++: robust, if evt. r. content not far from tree-like

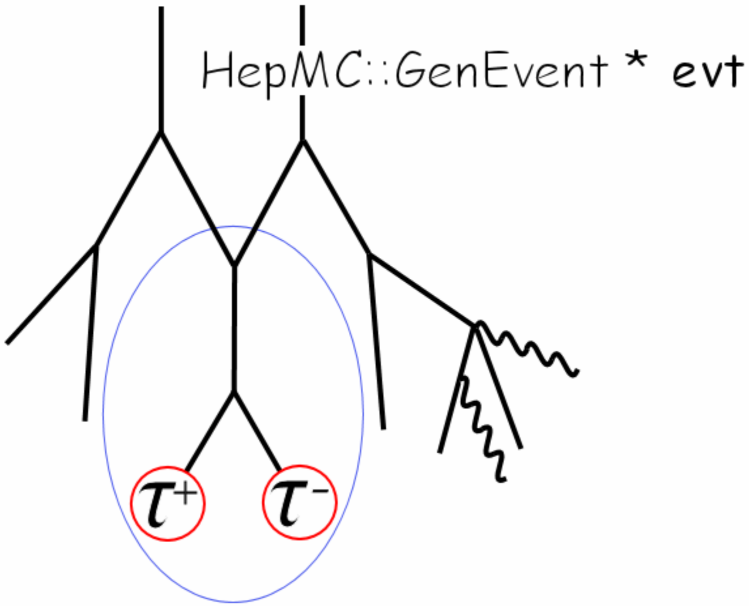


Single tau decay $\longrightarrow$ **NEW**



- For the individual τ decay method `Tauola::decayOne()` is provided
- Pointer `tau` to τ in `HepMC` must be known.
- Unpolarized τ decay will be peformed, decay products will be transferred to lab. frame using τ 4-momentum. Event record will be updated.
- Tau polarization vector, flag to re-decay already decayed τ and pointer to user defined method for boosting from τ rest-frame to lab frame can be passed as well.
- **Interface is prepared for use in user applications when exact spin effects are required (like in EvtGen** if TAUOLA needed there).

Decay of $\tau^+\tau^-$ $(\tau^\pm\nu_\tau)$ pair.

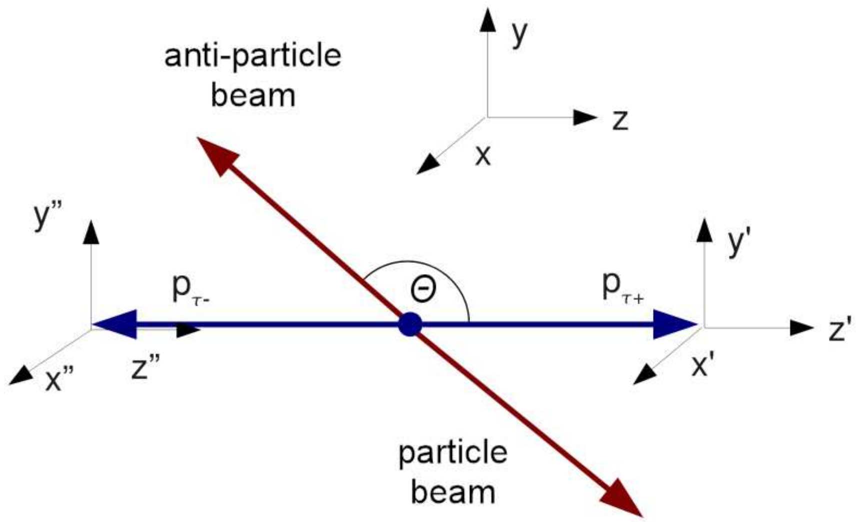


//Create object
TauolaHepMCEvent t_evt(evt);
//Decay taus
t_evt.decayTaus();

TauolaParticlePair - **get** mothers/grandmothers

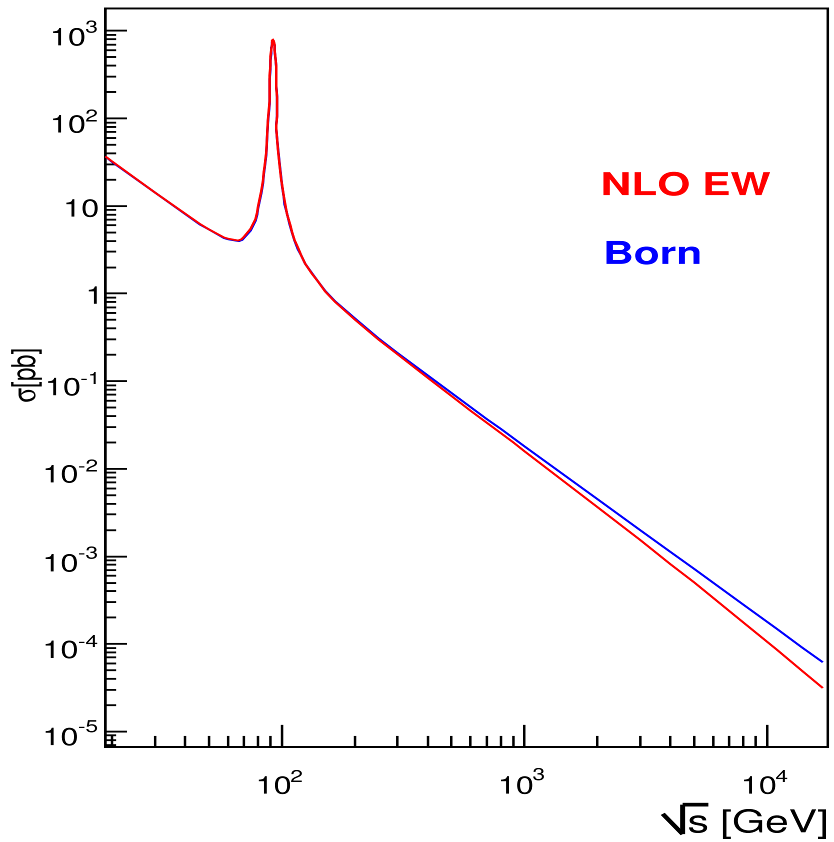
- Create object `t_evt` of class `TauolaHepMCEvent` which inherit from abstract class `TauolaEvent` and use `evt` of `HepMC::GenEvent` class as parameter. Then apply `t_evt.decayTaus()`
- For method `.decayTaus()` event record is searched for elementary processes like $1 \to 2$ (decays) or $2 \to 2$ or $2 \to 1 \to 2$ the s-channel production. For pairs found algorithm of next page is invoked.
- Interface was checked to work well with main processes as produced by PYTHIA 8.1.
- Further testing means checking correctness of HepMC trees, we will come to this point later.

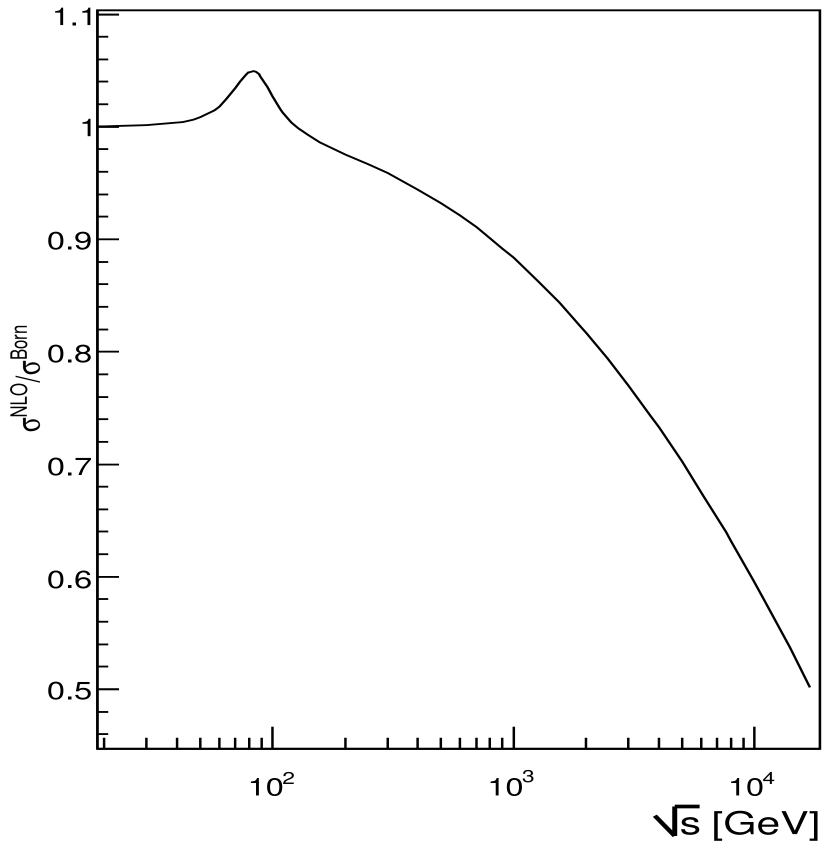
Decay of $\tau^+\tau^-$ ($\tau^\pm\nu_\tau$) pair.



- Configuration of hard process: flavors and 4-momenta of incoming quarks and outgoing τ's (ν_τ)
- **NEW:** algorithm for spin correlations has no approximation.
- However, method to calculate density matrix from that input usually will impose approximations.
- **NEW:** Density matrix including EW corrections is an option. This arrangement can be used to add Z' or to play with spin correlation component by component.
- **NEW:** Helicity states are provided (extra approximation used); Eric Torrence encouragements. Useful to exploit spin in LEP style analyzes.

Numerical results, tests.

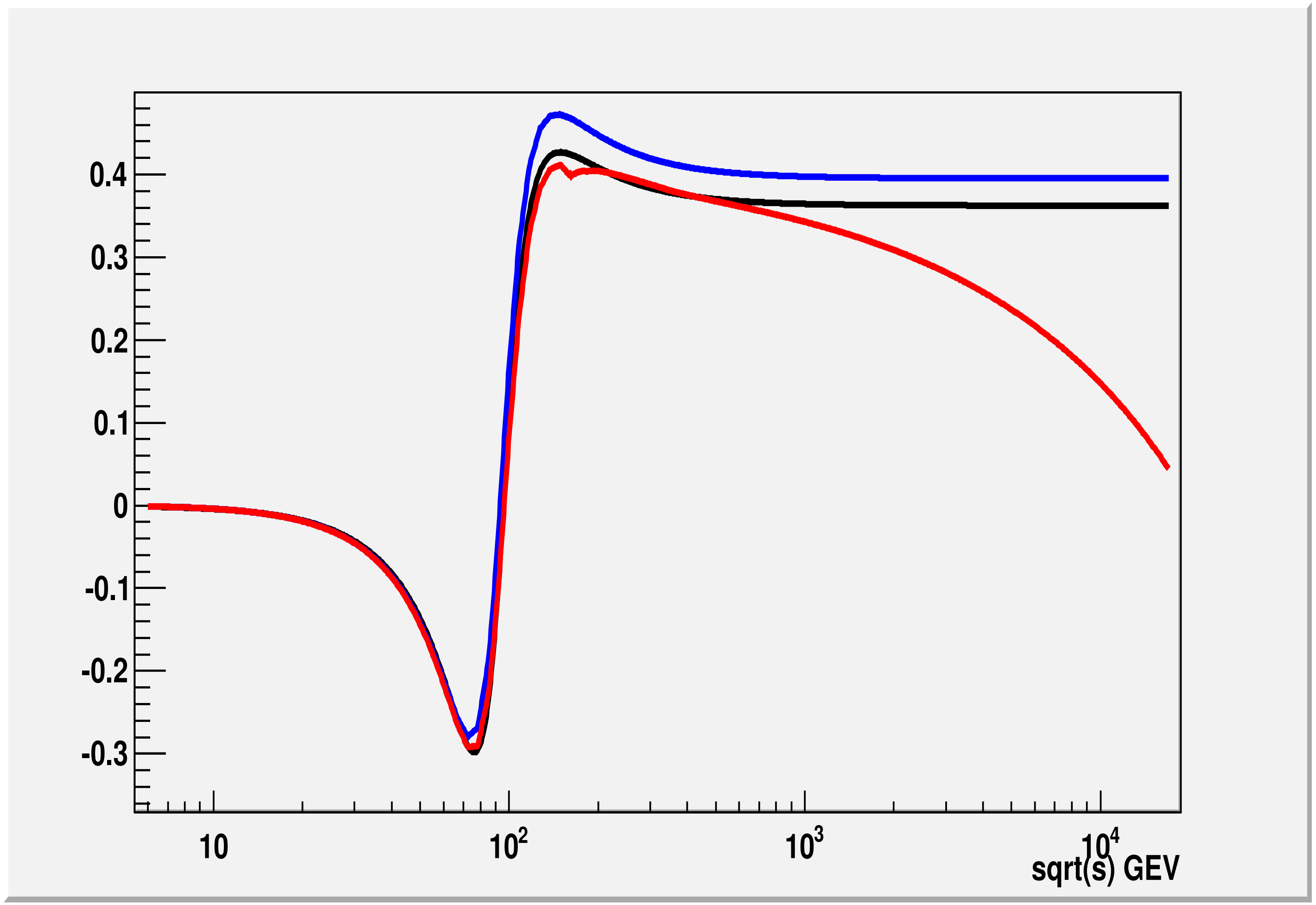




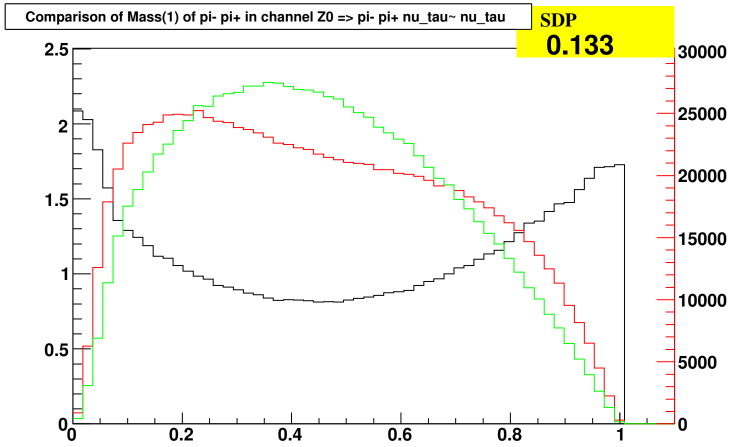
Effect of electroweak corrections on τ-pair production, up quarks, alpha scheme.

Q: What Born parameters are used in PYTHIA?

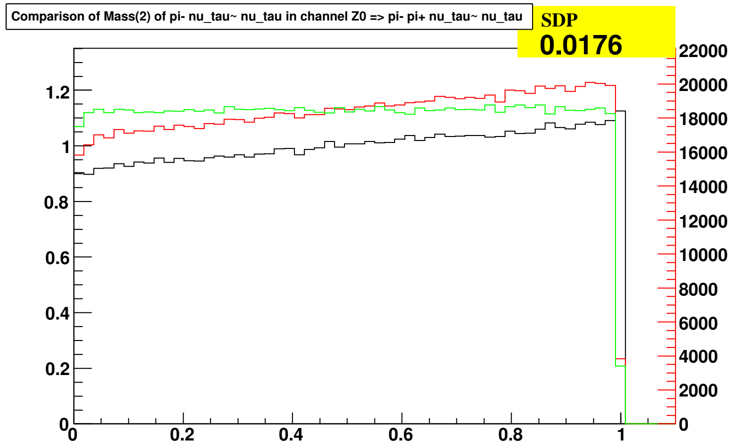
Numerical results, tests.



Effect of electroweak corrections on τ*-polarization, up quarks. Red line includes electroweak corrections, Black is TAUOLA standard and blue is Born, alpha scheme. Scattering angle* $\cos\theta = -0.2$



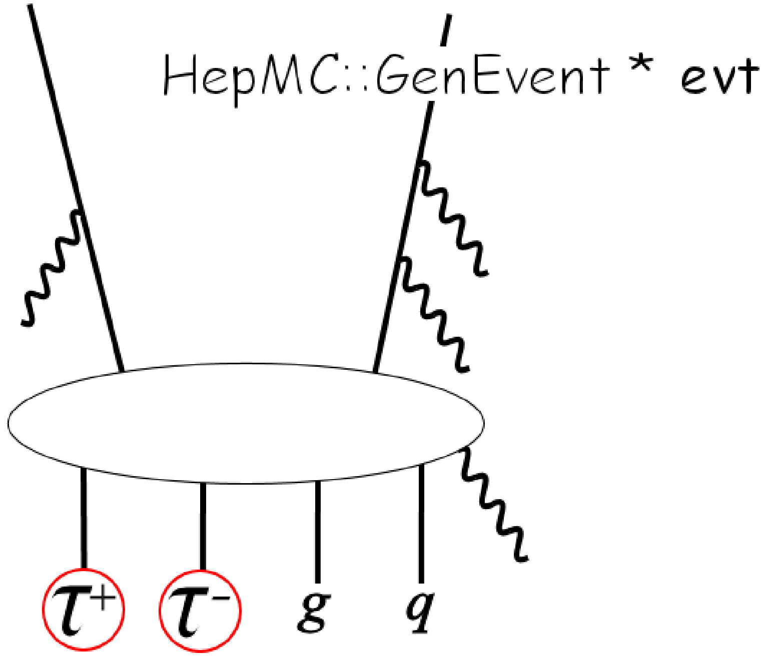
(a) $M_{\pi^+\pi^-}$



(b) $1 - 2\frac{E_{\pi^+}}{M_Z}$

Figure 1: Longitudinal spin observables for the Z boson. Distributions are shown for spin effects switched on (red), spin effects switched off (green) and the ratio between spin on and off (black). Left plot show effect of correlation between τ^+ and τ^- decays, right one is for polarization. Figures are obtained with the help of MC-TESTER.

Complications: parton shower and bremsstrahlung

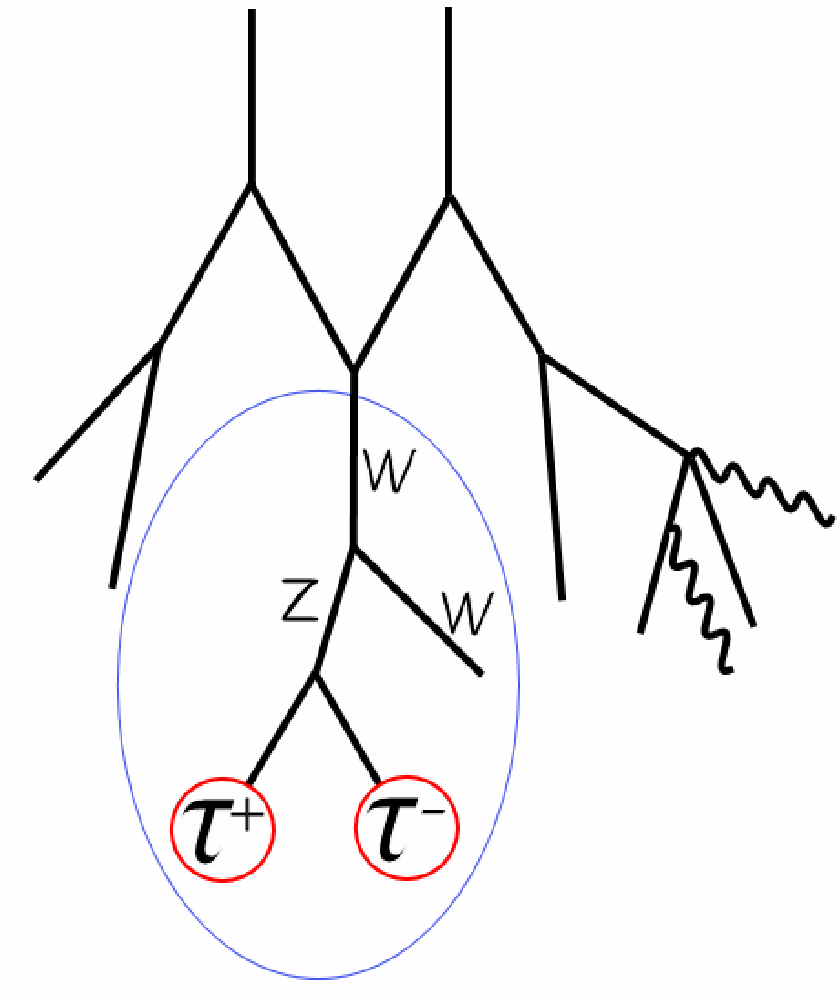


//Create object
TauolaHepMCEvent t_evt(evt);
//Decay taus
t_evt.decayTaus();

TauolaParticlePair - **construct** mothers/grandmothers

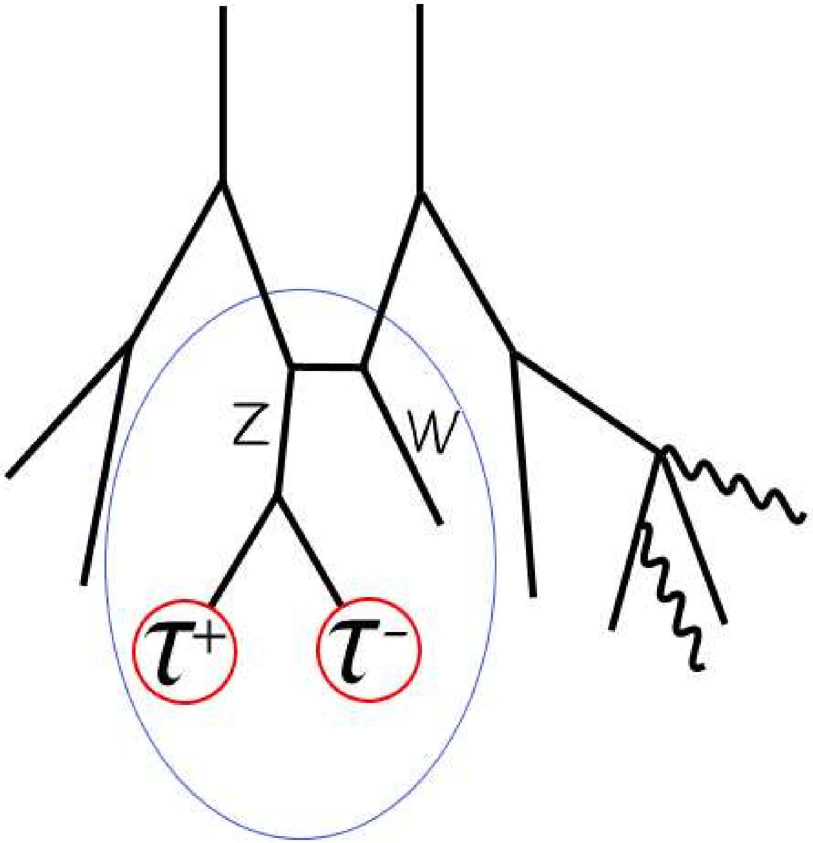
- In general simple branching $2 \to 1 \to 2$ is not to be found.
- The vertex for τ production may look like on the picture.
  Born level process $2 \to 1 \to 2$ must be deciphered: assumptions on QCD must be made (or higher order matrix element available).
- many options many potential traps.
- complete NLO QCD QED for spin is possible.
- but first long tests that in all cases all is OK at QCD LL.

Further steps



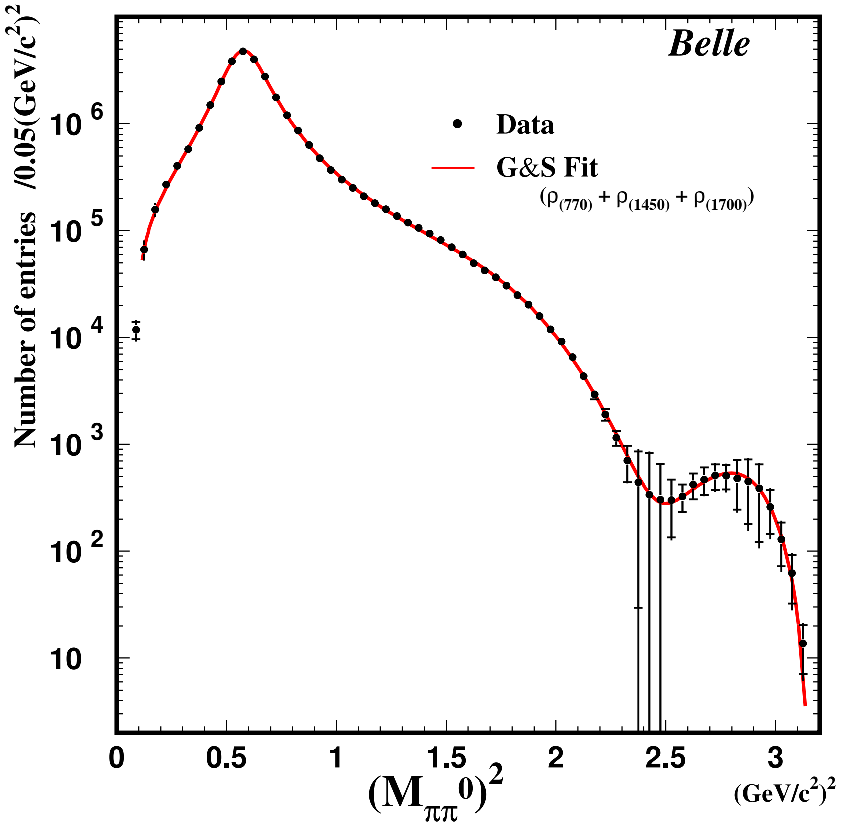
- There is an interest in using τ decays from TAUOLA for more complicated SM processes or the ones of New Physics
- One can think that our universal interface could be useful ...
- This can be done, but approximation on spin can be inadequate.

Further steps



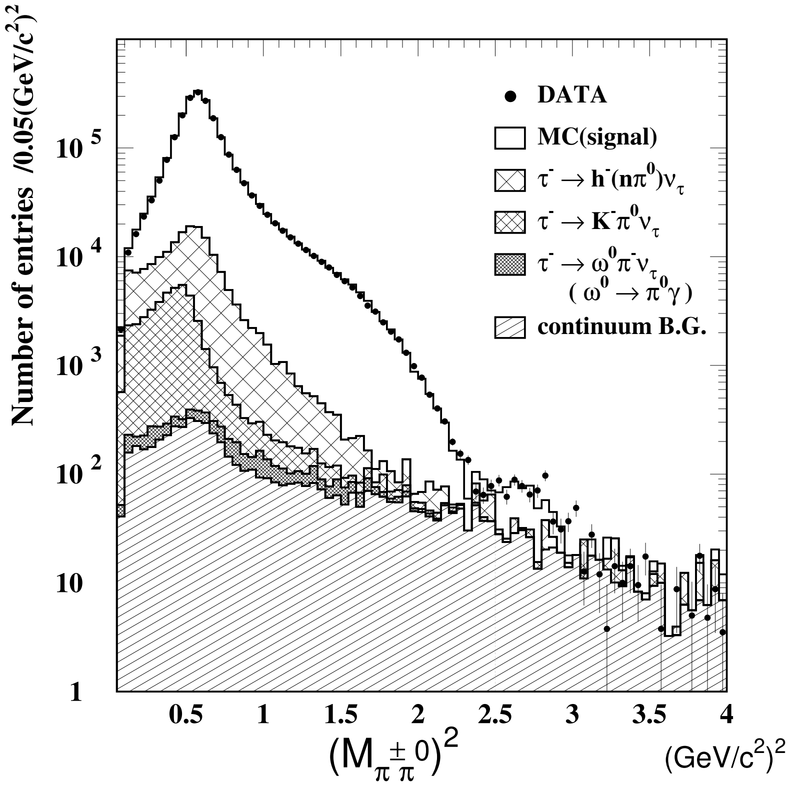
- The same final state as on previous figure can be obtained from the diagram as shown here: full 2$\longrightarrow$ 4 matrix element should be used for spin calculation.
- That is an example where our method `Tauola::decayOne(tau);` with all arguments will be useful.
- But single tree (single diagram) can be still useful as step in designing experimental observable.

from hep-ph/0912.0749



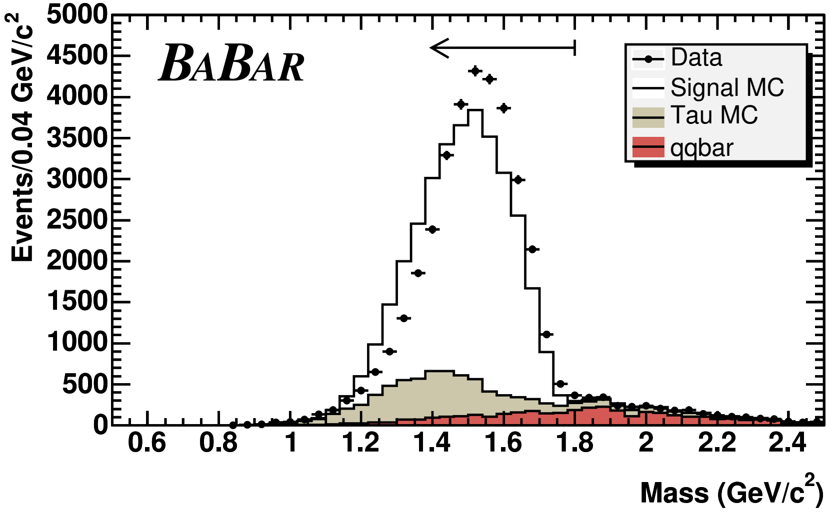
- TAUOLA is used for benchmarking τ decays for MC such as HERWIG, PYTHIA, EVTGEN or SHERPA. We have seen such plots on monday in P. Richardson talk.
- In that talk we could see that publicly available TAUOLA hadronic current is not perfect match of the experimental data.
- Quite in contrary, the internal Belle collaboration parametrization used in TAUOLA is making perfect match for invariant mass of $\pi^+\pi^0$-pair in $\tau \to \pi^+\pi^0\nu$ decay channel.
- Correct simulation of τ decays for LHC applications!
- But, do correction of single channel bring means real progress?

from hep-ph/0912.0749



- Measured distribution in interesting range has to be disentangled from background
- At higher end of the spectrum backround dominates over $\pi^+\pi^0\nu_\tau$.
- The same should be expected from LHC detectors.
- Correct simulation of τ decays for LHC applications!
- But, do it for all channels simultaneously!

from hep-ph/0912.0749



The invariant mass of five charged particles for $\tau^- \rightarrow 3h^-2h^+\nu_\tau$ at BaBar.

- For multi-scalar final states challenge: simultaneous fits of many complex form-factors of many variables into massively multi-dimensional distributions. Theoretical constrains apply (or not)
- I hope that this challenge will be adressed by Belle and BaBar.
- The purpose of our report *Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data*, hep-ph/0912.0749 was to stress the point.
- But it is not going to be easy.
- On the technical side, that is the reason why parts of TAUOLA will remain in FORTRAN until this work is finished.

Summary

- New version of TAUOLA interface (C++/HepMC) released.
- Doxygen web-page, code and spires documentation public.
- Program is stable with main (all?) types of PYTHIA 8.1 events:
  benchmark root files prepared with MC-TESTER, samples of 10^8 events.
- TAUOLA **C++ interface is richer than its FORTRAN predecessor:**
  - Electroweak corrections are available for Z/γ mediated τ pair production.
  - algorithm for single τ decay is available.
  - Special MC methods prepared: optional weights, helicity states info etc.
- parts remain in F77: low energy projects.
- FORTRAN TAUOLA universal interface will be serviced as long as needed.

Extra transparencies

Main Page Data Structures Files Directories

C++ Interface to Tauola

Description of **Tauola** Interface in C++

Authors:
Nadia Davidson, Gizo Nanava, Tomasz Przedzinski, Elzbieta Richter-Was, Zbigniew Was

Downloads

The source code and documentation for the release 1.0. The following files are provided for download:

- arXiv:1002.0543 full software documentation.
- TAUOLA source code tarball.

Developement version

The source code and documentation are updated daily from the repository as well. The following files are provided for download of developement version:

- Tauola_interface_design.pdf full software documentation.
- TAUOLA source code tarball and its revision info SVN tag, tarball creation date/time, etc. For updates with respect to release 1.0 see changelog.txt.

Introduction/Status

At prestent (since Feb 2 2010) the C++ interface functionality for TAUOLA is complete. Longitudinal spin correlation are being checked using MC-TESTER now. Transverse spin correlations and full functionality of TAUOLA Universal Interface are coded. Genuine electroweek corrections for proceeses mediated by Z/gamma are implemented as well.

The tar file contains the c++ interface along with the source code for tauola itself (as available from old web page; version Oct 11 2005). The developement version contains the latest source code for the interface from our subversion repository. Note that revision numbers, dates and other info for this development version can be found in revision information file listed above.

At present, the tar ball includes everything that is needed for installation. User is advised to use HepMC 2.04+ libraries as described below.

Requirements

For compilation, and to run simple example, the interface requires:

- HepMC v2.04 or later.

For further examples, one need to install also:

- ROOT v5.18 or later
- PYTHIA 8.1 or later. PYTHIA must be compiled with HepMC 2 so that the PYTHIA library hepmcinterface exists.
- MC-TESTER v1.24 or later. Do not forget to compile the additional HepMC library libHepMCEvent as well.

Configuration and Compilation

In order to compile the TAUOLA C++ interface:

- Execute './configure' with additional command line options:
  - '--with-HepMC=<path> ' provides the path to HepMC installation directory. One can set HEPMCLOCATION variable instead of using this directive. This path is required for interface to compile.
  - '--prefix=<path>' provides the installation path. The 'include' and 'lib' directories will be copied there if 'make install' is executed later. If none has been provided, the default directory for installation is '/usr/local'.
- Execute 'make'
- Optionally, execute 'make install' to copy files to the directory provided during configuration.

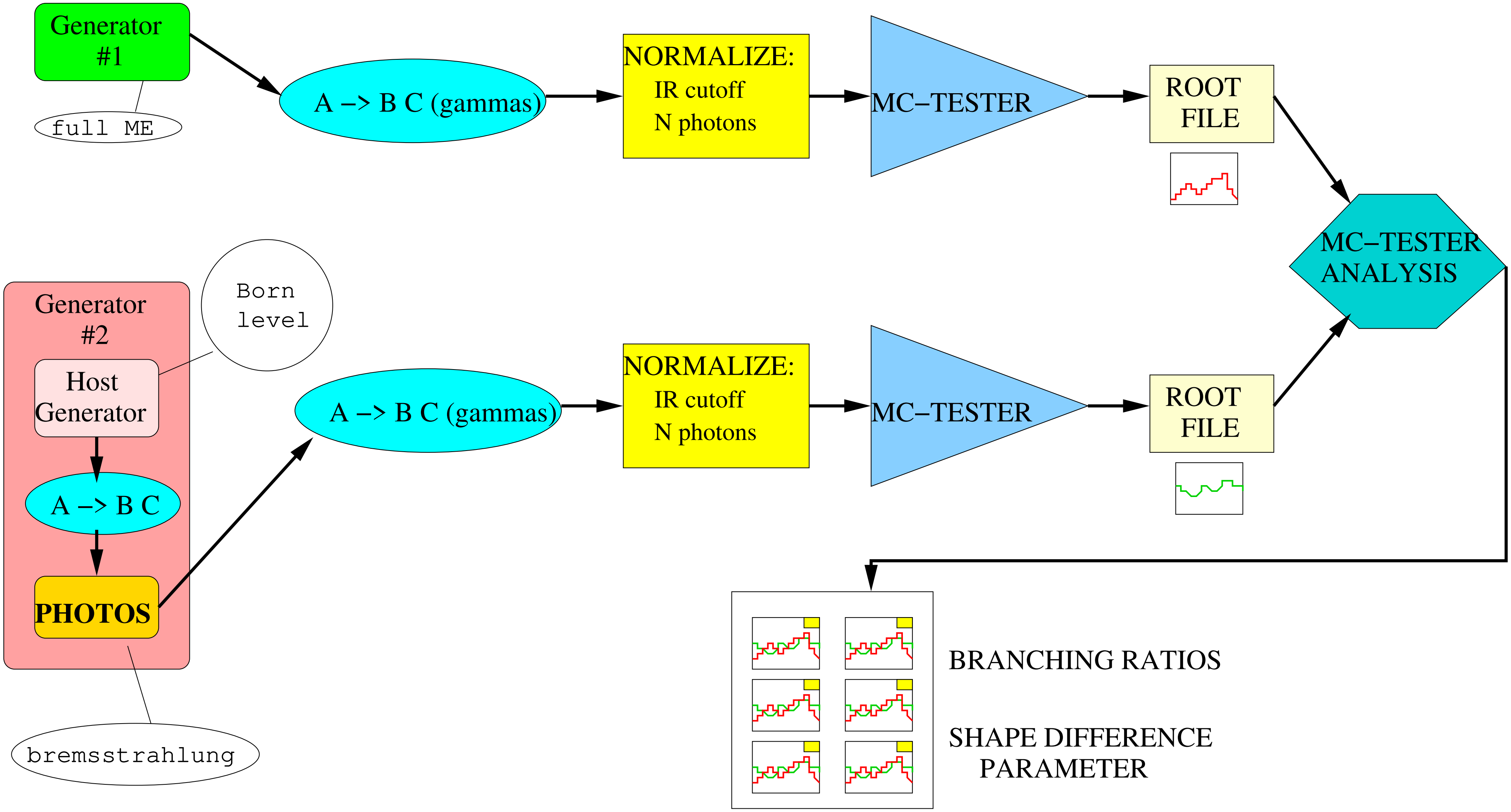
After compiling the 'tauola-fortran' part, the TAUOLA C++ interface will be compiled and the '/lib' and '/include' directories will contain the appropriate library and include files.

In order to compile the examples, enter 'examples' directory, and:

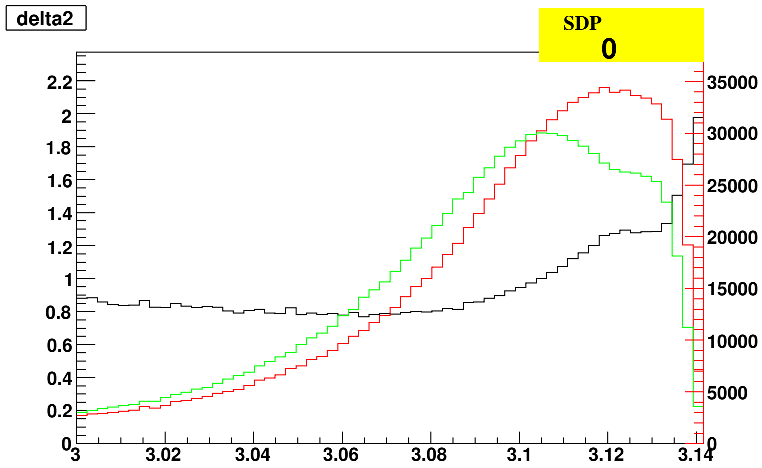
- execute './configure' to determine which examples can be compiled. Additional paths can be provided as command line options:
  - '--with-Pythia8=<path>' provides the path to Pythia8 installation directory. One can set PYTHIALOCATION variable instead of using this directive. This path is required for all additional examples and tests.
  - '--with-MC-Tester=<path>' provides the path to MC-Tester installation directory (the libHepMCEvent must be compiled as well, check MC-Tester documentation for more details). One can set MCTESTERLOCATION variable instead of using this directive. This path is required for all additional examples and tests. It is assumed that using this option also implies that ROOT has already been installed (since it's required by MC-TESTER). The location of its binaries should be listed in PATH variable.
- execute 'make'

Figure 2: First page of the TAUOLA doxygen web page.

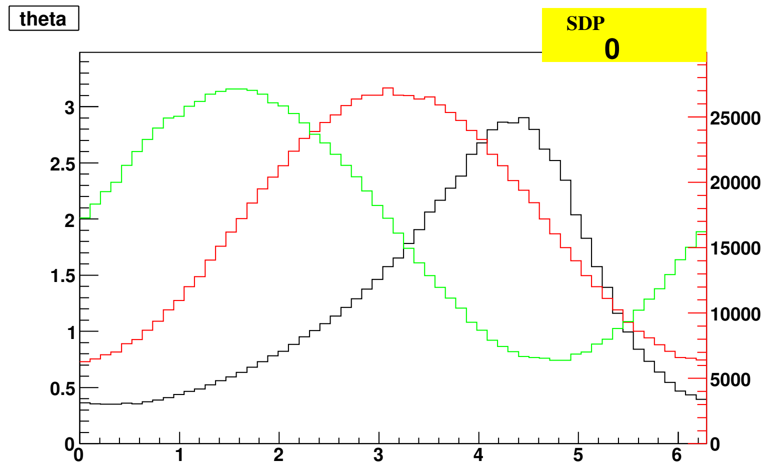
MC-TESTER to test PHOTOS/TAUOLA



Distribution for Higgs parity



(a) $\pi^+\pi^-$ acollinearity distribution ($\approx \pi$))



(b) $\pi^+\pi^-$ acoplanarity distribution

Figure 3: Transverse spin observables for the H boson for $\tau^\pm \to \pi^\pm \nu_\tau$. Distributions are shown for scalar higgs (red), scalar-pseudoscalar higgs with mixing angle $\frac{\pi}{4}$ (green) and the ratio between the two (black). What is ultimate frontier in ρ reconstruction in LHC detectors?

W

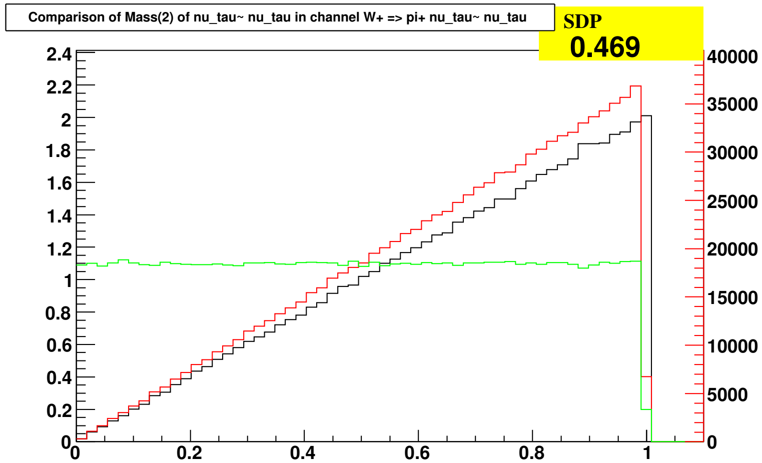


Figure 4: Decay $W^+ \to \nu_\tau \tau^+,\ \tau^+ \to \pi^+ \bar{\nu}_\tau$. Pion energy spectrum in W rest-frame, variable $1 - 2\frac{E_{\pi^+}}{M_{W^+}}$ is used. Spin effects included (red line) and neglected (green line are plotted). From inspection of black line one may conclude that green histogram is more populous at lower values. Such impression come from comparison of black and red lines. This is however consequence of different scales (right side one is used for red and green lines, left one for their ratio: that is black line). First test of transverse spin in C++ interface.

charged Higgs

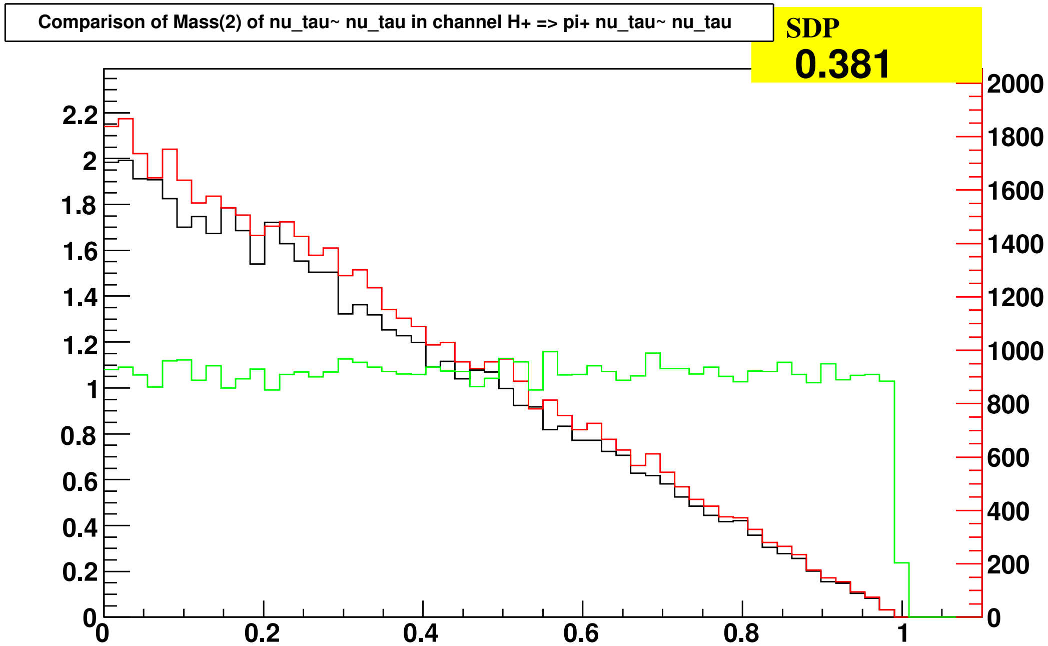


Figure 5: Decay $H^+ \to \nu_\tau \tau^+$, $\tau^+ \to \pi^+ \bar{\nu}_\tau$. Pion energy is calculated in the H rest-frame, the variable $1 - 2E_{\pi^+}/M_H^+$ is used. Spin effects included (red line) and neglected (green line) are plotted. As one can see the spectra are reversed compared to the case of W decay. From inspection of the black line one may conclude that green histogram is more populous at lower values. Such conclusion come from comparison of black and red lines. This is however conseuence of different scales (right side one is used for red and green lines, left one for their ratio: black line).