Introduction to TauSpinner and its developements

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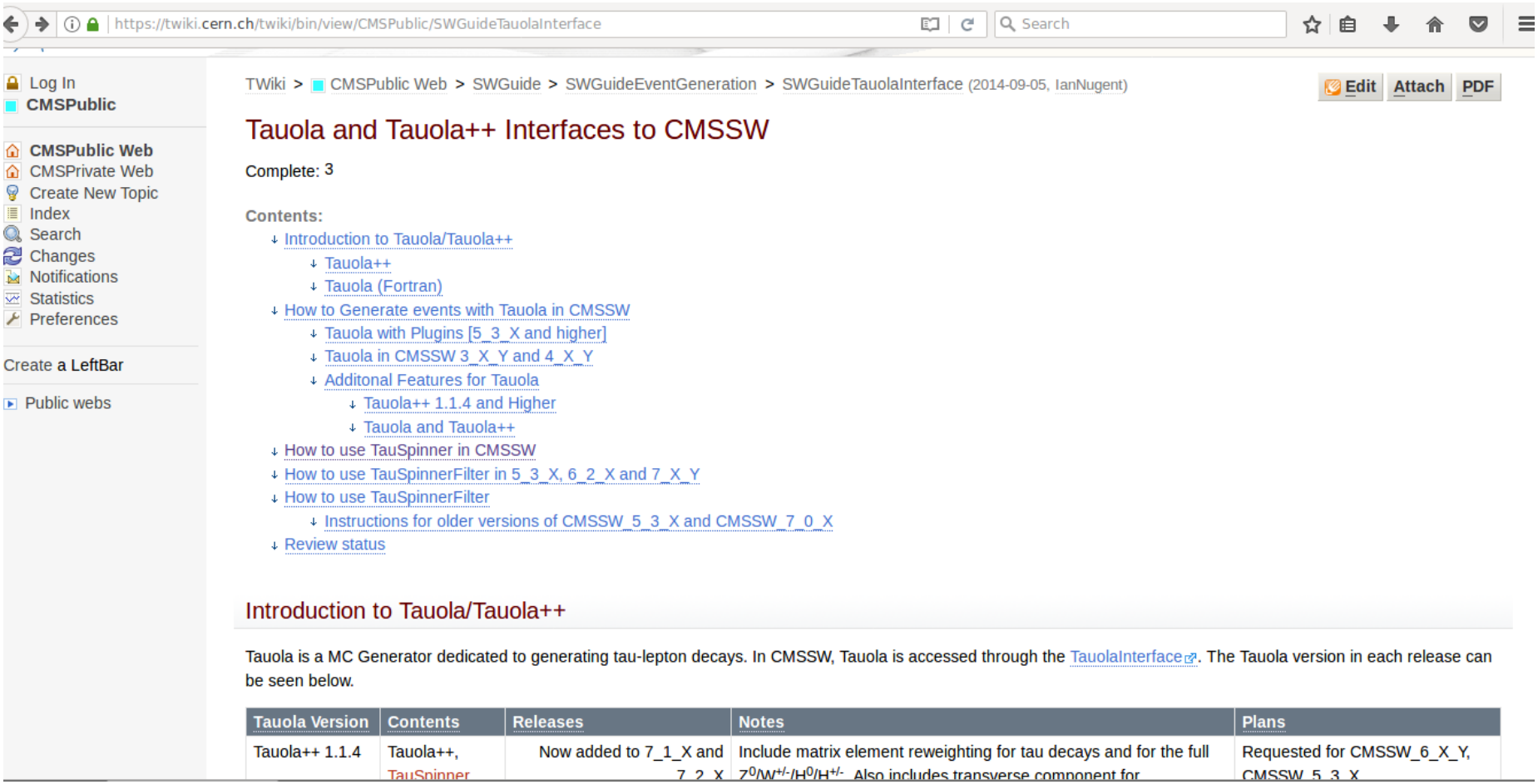
Outline

1. Introduction
2. TauSpinner
3. TauSpinner development
   - Matrix Element implementation (2→4) processes for Non-SM
   - Test of re-weighting
4. Further Information

Introduction

- Explore final states with τ lepton
- High mass of $\tau \rightarrow$ provide a sensitive window to physics beyond SM
- τ lepton signature can provide a powerful tool in many areas $\rightarrow$
  1- Studies of hard process characteristics
  2- Measurements of properties of Higgs boson
  3- **In a search for new physics**.
- `TauSpinner` algorithm provides a powerful tool for investigation of characteristics of final states with τ lepton

TauSpinner



https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideTauolaInterface

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TWiki > CMSPublic Web > SWGuide > SWGuideEventGeneration > SWGuideTauolaInterface (2014-09-05, IanNugent)

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Tauola and Tauola++ Interfaces to CMSSW

Complete: 3

Contents:

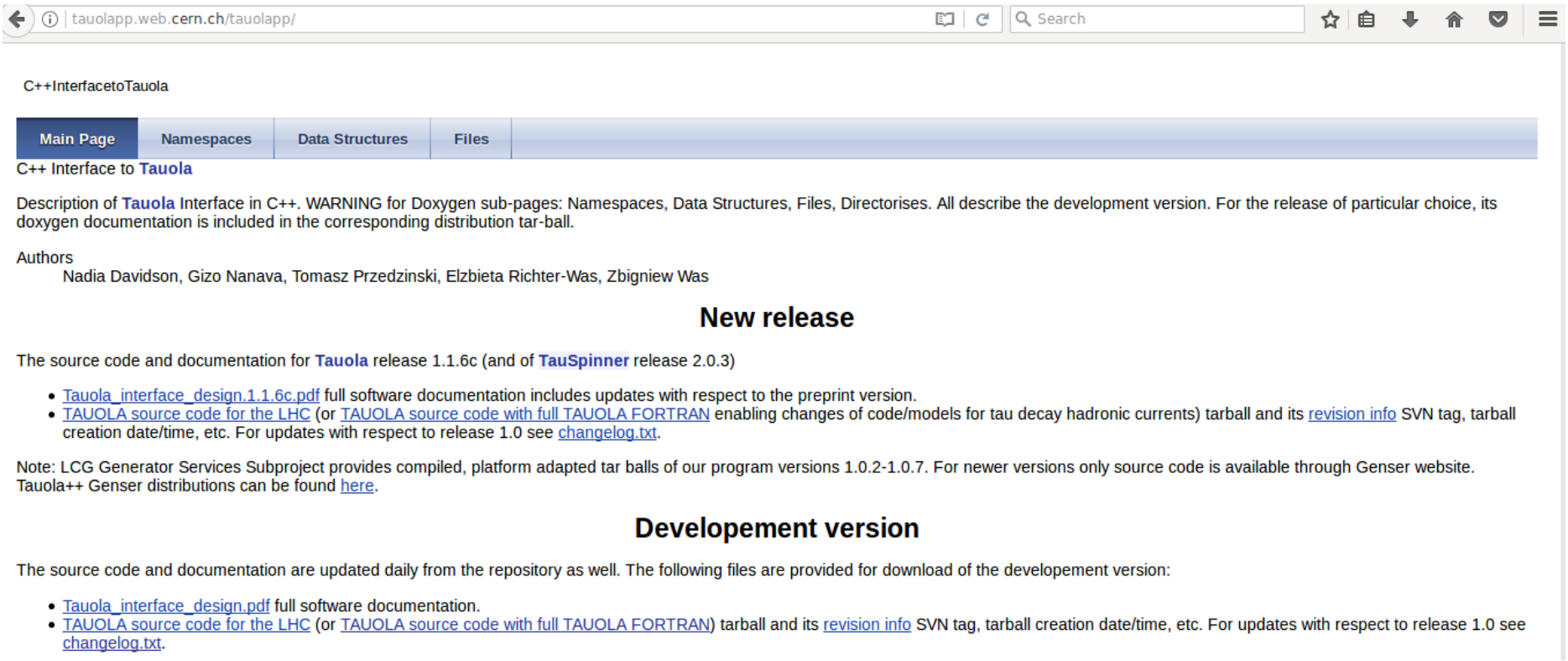
- Introduction to Tauola/Tauola++
  - Tauola++
  - Tauola (Fortran)
- How to Generate events with Tauola in CMSSW
  - Tauola with Plugins [5_3_X and higher]
  - Tauola in CMSSW 3_X_Y and 4_X_Y
  - Additonal Features for Tauola
    - Tauola++ 1.1.4 and Higher
    - Tauola and Tauola++
- How to use TauSpinner in CMSSW
- How to use TauSpinnerFilter in 5_3_X, 6_2_X and 7_X_Y
- How to use TauSpinnerFilter
  - Instructions for older versions of CMSSW_5_3_X and CMSSW_7_0_X
- Review status

Introduction to Tauola/Tauola++

Tauola is a MC Generator dedicated to generating tau-lepton decays. In CMSSW, Tauola is accessed through the TauolaInterface. The Tauola version in each release can be seen below.

Tauola Version	Contents	Releases	Notes	Plans
Tauola++ 1.1.4	Tauola++, TauSpinner	Now added to 7_1_X and 7_2_X	Include matrix element reweighting for tau decays and for the full $Z^0/W^{+/-}/H^0/H^{+/-}$. Also includes transverse component for	Requested for CMSSW_6_X_Y, CMSSW_5_3_X

TauSpinner webpage



tauolapp.web.cern.ch/tauolapp/

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C++InterfacetoTauola

Main Page | Namespaces | Data Structures | Files

C++ Interface to **Tauola**

Description of **Tauola** Interface in C++. WARNING for Doxygen sub-pages: Namespaces, Data Structures, Files, Directorises. All describe the development version. For the release of particular choice, its doxygen documentation is included in the corresponding distribution tar-ball.

Authors

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

New release

The source code and documentation for **Tauola** release 1.1.6c (and of **TauSpinner** release 2.0.3)

- Tauola_interface_design.1.1.6c.pdf full software documentation includes updates with respect to the preprint version.
- TAUOLA source code for the LHC (or TAUOLA source code with full TAUOLA FORTRAN enabling changes of code/models for tau decay hadronic currents) tarball and its revision info SVN tag, tarball creation date/time, etc. For updates with respect to release 1.0 see changelog.txt.

Note: LCG Generator Services Subproject provides compiled, platform adapted tar balls of our program versions 1.0.2-1.0.7. For newer versions only source code is available through Genser website. Tauola++ Genser distributions can be found here.

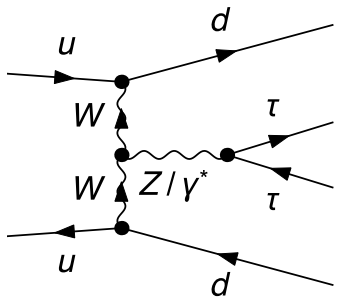
Developement version

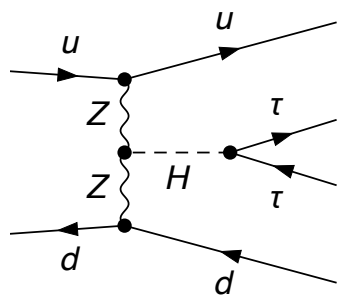
The source code and documentation are updated daily from the repository as well. The following files are provided for download of the developement version:

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

TauSpinner

- TauSpinner is a tool that allows to modify the physics model of the Monte Carlo generated samples due to the changed assumptions of event production dynamics, but without the need of re-generating events.





- The only information used is the kinematics of final state, therefore it can be used both for Data and MC simulations
- TauSpinner calculate weight from input , Weights are ratios of matrix elements calculated for New and OLd assumptions.

New development: Non-SM implementation

- implementation of Beyond SM processes.
- The algorithm is supposed to work for any modification of SM predictions (for production of 2 τs and 2 jets)
- how this model used for spin amplitudes calculation.
- Test of re-weighting

Incorporating MadGraph generated code for Non-SM into TauSpinner: Spin2 case

$$\mathcal{L} \ni \frac{1}{F} X_{\mu\nu} \left(g_{XBB}\ B^{\mu\rho} B_{\rho}{}^{\nu} + g_{XWW} W_i^{\mu\rho} W_{\rho}{}^{\nu} + g_{Xgg} G^{\mu\rho} G_{\rho}{}^{\nu} \right). \quad (1)$$

- In this work we focus on the coupling of X to EW gauge bosons and coupling to gluons would be studied better in Drell-Yan-Like configuration.
- This extension of the SM by a spin 2 field, including its coupling to quarks and tau leptons, is encoded into FeynRules model(FeynRules 2.0 - A complete toolbox for tree-level phenomenology, 1310.1921)
- The FeynRules model file, together with its UFO output(1108.2040)
- The UFO model is used to generate squared matrix elements using MadGraph5 the spin 2 has the support of the HELAS library

Incorporating MadGraph generated code for Non-SM into TauSpinner: Spin2 case

Implementation of new ME needs following steps:

- Generate spin2 process by Madgraph

(a) `import model spin2_w_CKM_UFO`

(b) by default, "multiparticles" containers include all massless partons

```
p = g u c d s u~ c~ d~ s~
j = g u c d s u~ c~ d~ s~
```

(c) generate spin 2 matrix elements

```
generate p p > j j x QED<=99 QCD<=99 NPgg<=99 NPqq<=99
NPVV<=99, x > ta+ ta-
```

(d) write the output to disk in MadGraph's standalone mode using `output standalone "directory name"` command

Incorporating MadGraph generated code for Non-SM into TauSpinner: Spin2 case

- The generated codes for the individual sub-processes are grouped in to subroutines, the proper changed applied:

(a) Depending on the flavor of initial state partons named properly `SUBROUTINE DCX_S2(P,I3,I4,H1,H2,ANS)`

(b) Parameter H1 and H2 introduced as helicities of τs

(c) The subroutines and internal functions generated by MadGraph have the same names for all sub-processes `SMATRIX(P,ANS)`$\rightarrow$ be unique for each sub-process. $u\bar{d} \rightarrow c\bar{d}\,x$, $x \rightarrow \tau^+\tau^-$ name is changed to `UDX_CDX_S2(P,H1,H2,ANS)`

Incorporating MadGraph generated code for Non-SM into TauSpinner: Spin2 case

- Apply the combinatorial and CP symmetries that allow us to reduce the number of parton subprocesses

(a) Check if Matrix Element can be set to zero

(b) Charge conservation imposes that for processes

(c) all necessary transformations (flipping the position of partons or invoking the CP transformation)

Test of matrix elements using fixed kinematical configuration

- For a point in phase space

```
P[0,i]=     500.0000000000      0.0000000000      0.0000000000    500.0000000000
P[1,i]=     500.0000000000      0.0000000000      0.0000000000   -500.0000000000
P[2,i]=      88.5500900000    -22.1003800000     40.0797900000    -75.8043700000
P[3,i]=     328.3248000000   -103.8482000000   -301.9295000000     76.4938500000
P[4,i]=     152.3663000000   -105.8795000000    -97.7082700000     49.5476900000
P[5,i]=     430.7588000000    231.8280000000    359.5580000000    -50.2371700000
```

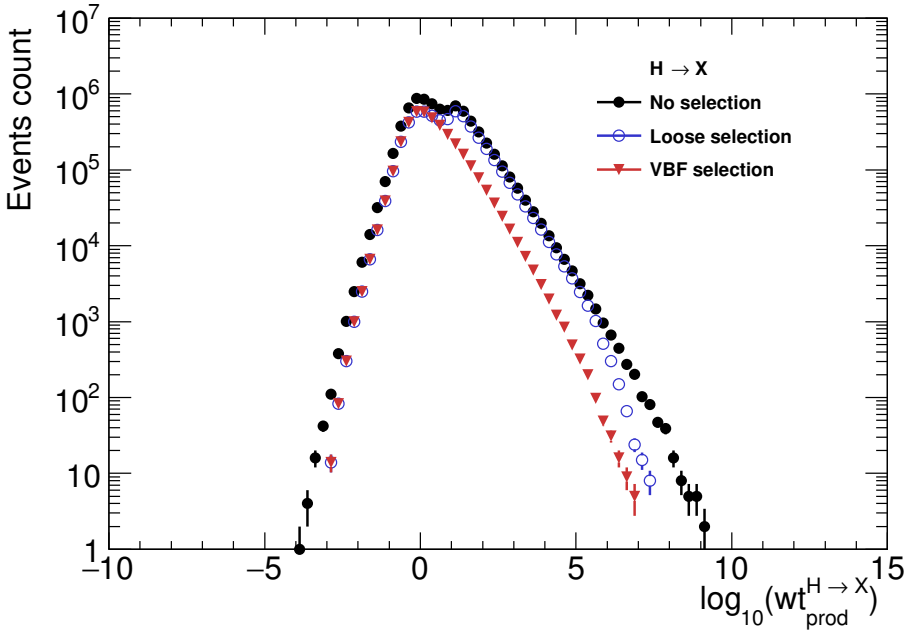
```
ID-s= -4 -4 -4 -4  CP used= 1 ## VALUE:  5.4498795386e-11   ##  Spin contr.:  (+-)=  2.722e-11  (-+)=  2.728e-11  (--)=  2.001e-15  (++)=  2.000e-15
ID-s= -4 -3 -4 -3  CP used= 1 ## VALUE:  2.4550857518e-12   ##  Spin contr.:  (+-)=  1.092e-12  (-+)=  1.363e-12  (--)=  1.970e-17  (++)=  1.540e-17
ID-s= -4 -3 -4 -1  CP used= 1 ## VALUE:  1.7504240128e-14   ##  Spin contr.:  (+-)=  2.714e-15  (-+)=  1.431e-14  (--)=  2.441e-16  (++)=  2.398e-16
ID-s= -4 -3 -3 -4  CP used= 1 ## VALUE:  5.2604665756e-11   ##  Spin contr.:  (+-)=  2.627e-11  (-+)=  2.633e-11  (--)=  1.994e-15  (++)=  1.992e-15
ID-s= -4 -3 -3 -2  CP used= 1 ## VALUE:  3.5660092224e-16   ##  Spin contr.:  (+-)=  9.101e-18  (-+)=  3.421e-16  (--)=  2.661e-18  (++)=  2.706e-18
ID-s= -4 -3 -2 -3  CP used= 1 ## VALUE:  1.8277516190e-14   ##  Spin contr.:  (+-)=  1.373e-15  (-+)=  1.690e-14  (--)=  1.949e-18  (++)=  1.633e-18
ID-s= -4 -3 -2 -1  CP used= 1 ## VALUE:  9.6558861882e-16   ##  Spin contr.:  (+-)=  1.496e-16  (-+)=  7.878e-16  (--)=  1.421e-17  (++)=  1.397e-17
ID-s= -4 -3 -1 -4  CP used= 1 ## VALUE:  1.0030302326e-15   ##  Spin contr.:  (+-)=  1.297e-16  (-+)=  8.731e-16  (--)=  9.599e-20  (++)=  9.985e-20
ID-s= -4 -3 -1 -2  CP used= 1 ## VALUE:  1.8892558599e-17   ##  Spin contr.:  (+-)=  3.852e-19  (-+)=  1.809e-17  (--)=  2.068e-19  (++)=  2.100e-19
ID-s= -4 -2 -4 -2  CP used= 1 ## VALUE:  4.2991410664e-12   ##  Spin contr.:  (+-)=  2.149e-12  (-+)=  2.149e-12  (--)=  4.370e-16  (++)=  4.370e-16
ID-s= -4 -2 -2 -4  CP used= 1 ## VALUE:  5.0256296146e-11   ##  Spin contr.:  (+-)=  2.509e-11  (-+)=  2.516e-11  (--)=  1.937e-15  (++)=  1.936e-15
ID-s= -4 -1 -4 -3  CP used= 1 ## VALUE:  2.0822426627e-14   ##  Spin contr.:  (+-)=  1.833e-15  (-+)=  1.899e-14  (--)=  1.933e-19  (++)=  9.984e-20
ID-s= -4 -1 -4 -1  CP used= 1 ## VALUE:  4.3555086047e-12   ##  Spin contr.:  (+-)=  2.158e-12  (-+)=  2.196e-12  (--)=  5.405e-16  (++)=  5.366e-16
ID-s= -4 -1 -3 -4  CP used= 1 ## VALUE:  7.2679264348e-16   ##  Spin contr.:  (+-)=  3.219e-16  (-+)=  4.037e-16  (--)=  5.923e-19  (++)=  5.705e-19
```

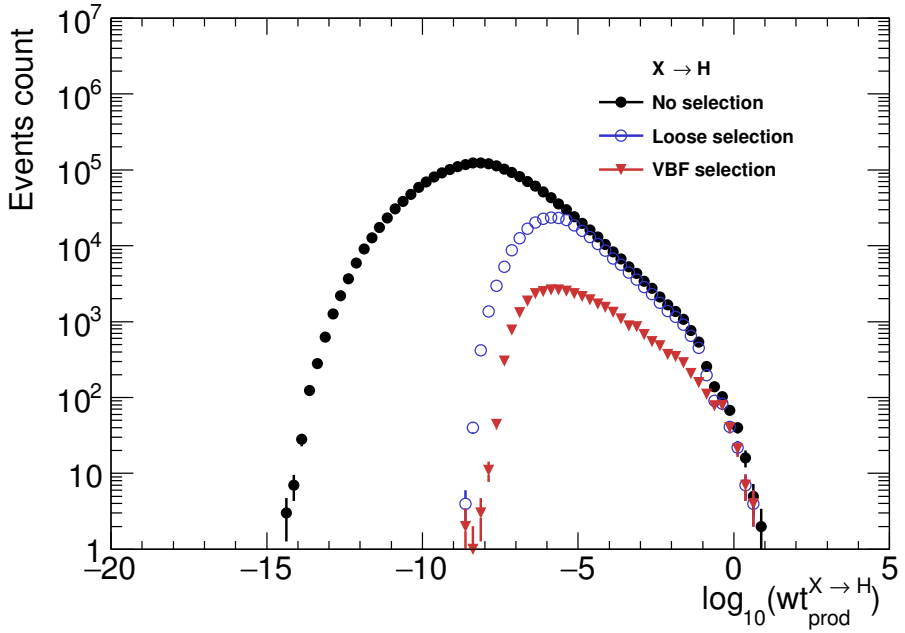
- The agreement of at least 6 significant digit has been confirmed.

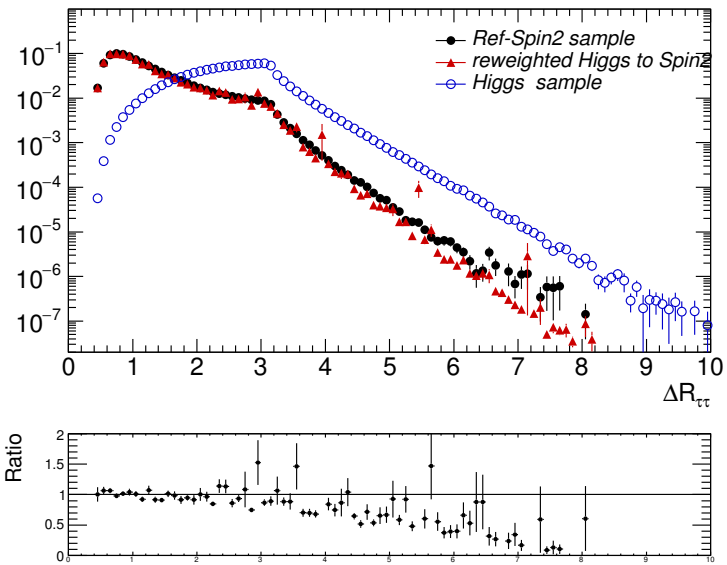
Test of re-weighting

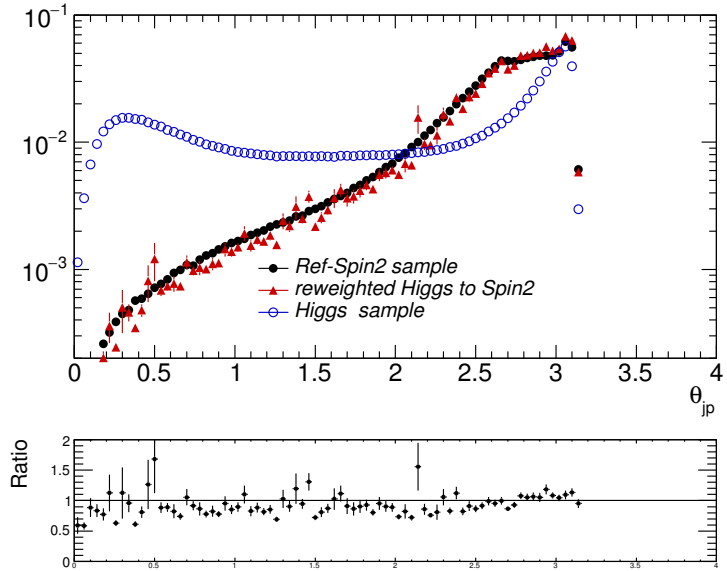
- Samples for Spin2 and Higgs particle by Madgraph were generated (10 M).
- The parameters in TauSpinner initialized in consistent with generated sample.
- The spin weight ratio calculated by TauSpinner by *getWtNonSM* method
- Re-weighting applied on kinematical distribution

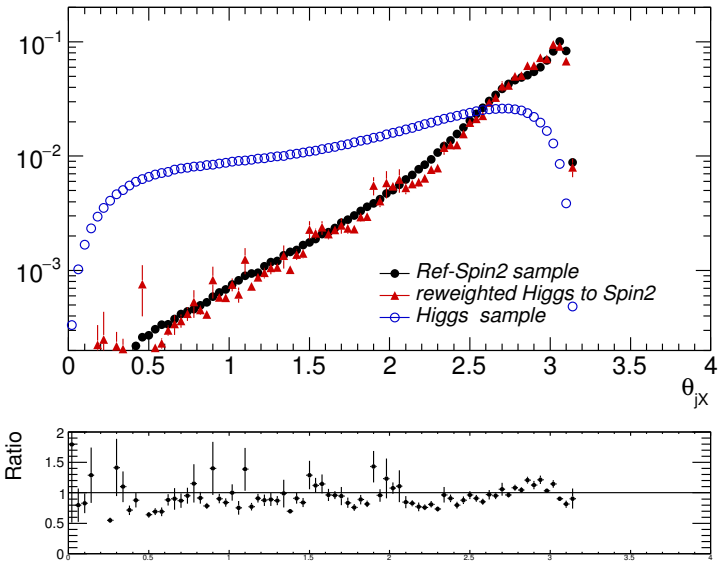
Distribution of weight

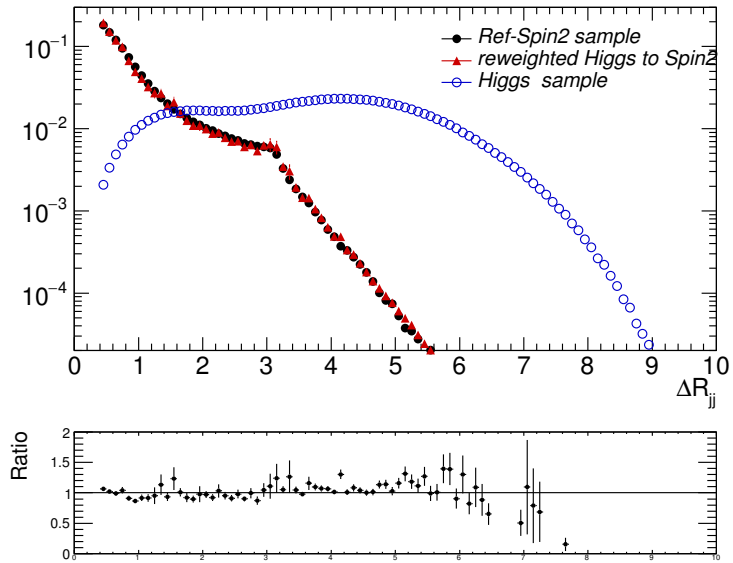





Ref-Spin2 sample
reweighted Higgs to Spin2
Higgs sample
$\Delta R_{\tau\tau}$
Ratio


Ref-Spin2 sample
reweighted Higgs to Spin2
Higgs sample
θ_{jp}
Ratio


Ref-Spin2 sample
reweighted Higgs to Spin2
Higgs sample
θ_{jX}
Ratio


Ref-Spin2 sample
reweighted Higgs to Spin2
Higgs sample
ΔR_{jj}
Ratio

Further Information

- https://arxiv.org/pdf/1604.00964.pdf
- Systematic of `TauSpinner` for τ pairs with two hard jets and its recent development: http://www.actaphys.uj.edu.pl/fulltext?series=Reg&vol=48&page=903
- tauolapp.web.cern.ch/tauolapp/resources/TAUOLA.development.version