Use of tau leptons at LHC

– practical perspective

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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.*

- How to work with: τ decays, hard proceeses, detector response, background-signal separation

- What are the necessary tools and how to separate into parts entangled things?

- How to share expertise?

Too many entangled subjects ...

1. Experimental user goal: measure physically interesting quantity
2. First design observable capable to do so. Simple assumptions: theory – Born level, experiment – ideal detector (even parton level)
3. Next step: switch on all detector and theoretical effects.
4. If necessary and possible adopt observable definition.
5. For remaining unwanted effects, design methods to subtract.
6. Finally estimate systematic errors.

- Theoretical calculations and Monte Carlo programs should be helpful in that quest, thus subordinate to the challenges of that points.

Web pages of my projects:

http://wasm.home.cern.ch/wasm/goodies.html ⟶ F77

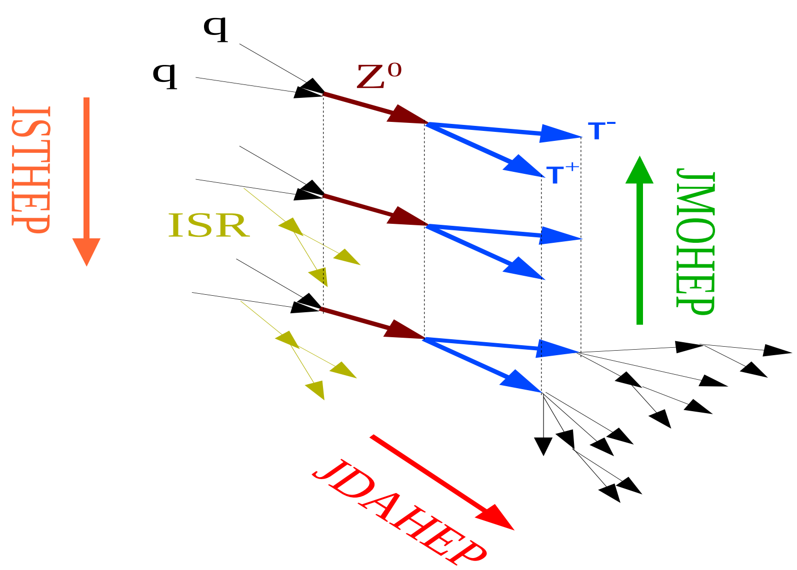
http://www.ph.unimelb.edu.au/ñdavidson/tauola/doxygen/index.html ⟶ TAUOLA C++/HepMC

http://www.ph.unimelb.edu.au/ñdavidson/photos/doxygen/index.html⟶ PHOTOS C++/HepMC

http://mc-tester.web.cern.ch/MC-TESTER/ ⟶ MC-TESTER

Too many entangled subjects ...

Problems With Event Record



1. Hard process (start of generation also result of data analysis)
2. with shower
3. after hadronization
4. Event record overloaded with physics beyond design $\longrightarrow$ gramar problems.
5. That is potential problem for PHOTOS, TAUOLA, MC-TESTER. Note ...

.. from data sample one can get only lowest tree (often incomplete)

Problems are due to physics not computer language

This Is Physics Not F77: we need to go through variants for C++ solutions.

Example of pythia 8.1 $Z \to \tau^+\tau^-\gamma$ event

```
                      Barcode   PDG ID   ( Px,      Py,       Pz,      E )                 Stat  DecayVt
            .
            .
            GenVertex:        -11       ID:   0 (X,cT):0
Z→ Z         I: 1          8        23  -1.80e-03,+2.96e-02,-8.11e+01,+1.19e+02        -44    -1
             O: 1         12        23  -1.36e-03,+2.77e-02,-8.11e+01,+1.19e+02        -44    -1
            .
            .
            GenVertex:        -13       ID:   0 (X,cT):0
Z→τ+τ-       I: 1         12        23  -1.36e-03,+2.77e-02,-8.11e+01,+1.19e+02        -44    -1
             O: 2         15        15  -1.97e+01,-3.85e+01,-3.68e+01,+5.69e+01        -23    -1
                          16       -15  +1.97e+01,+3.86e+01,-4.43e+01,+6.20e+01        -23    -1
            GenVertex:        -14       ID:   0 (X,cT):0
τ+→τ+ γ      I: 1         16       -15  +1.97e+01,+3.86e+01,-4.43e+01,+6.20e+01        -23    -1
             O: 2         17       -15  +1.71e+01,+3.53e+01,-3.93e+01,+5.56e+01         1
                          18        22  +2.59e+00,+3.15e+00,-5.06e+00,+6.50e+00         1
            GenVertex:        -15       ID:   0 (X,cT):0
τ-→τ-        I: 1         15        15  -1.97e+01,-3.85e+01,-3.68e+01,+5.69e+01        -23    -1
             O: 1         19        15  -1.97e+01,-3.85e+01,-3.67e+01,+5.68e+01         1
```

vertex with decay to self
& energy-momentum
not conserved!

placement of photon
in event record

H produced at LHC from $b\bar{b}H$ Yukawa coupling

In case of MSSM and Higgs boson $m_H = 100 - 200 GeV$, it is the key signature.

I will recall some results from the following papers:

- E. Richter-Was, T. Szymocha and Z. Was, "Why do we need higher order fully exclusive Monte Carlo generator for Higgs boson production from heavy quark fusion at LHC?," arXiv:hep-ph/0402159, Phys.Lett.B589:125-134,2004.
- E. Richter-Was, T. Szymocha, "The light Higgs decay into τ-lepton pair: reconstruction in different production processes", ATL-COM-PHYS-2004.

Theoretical foundations well understood:

- Cross section for the process $b\bar{b} \longrightarrow H$ was calculated at NNLO by R. V. Harlander and W. B. Kilgore within, so called, variable flavour number scheme (VFS).
- It was also calculated at the NLO for the parton level process $gg(q\bar{q}) \longrightarrow b\bar{b}H$ within fixed flavour scheme (FFS), eg.by Spira
- Willenbrock et al. choose to start from $gb \longrightarrow bH$.
- Results obtained in these schemes for inclusive cross sections seem to become compatible with each other.
- Nonetheless, just to be on the safe side, let us look at how the experimental signatures may look like.

example from LHC, but most details missing

- For simulation PYTHIA, TAUOLA combined with its universal interface F77.
- None of the production processes implemented in PYTHIA was expected to be modelled sufficiently well. We will use the standard options corresponding to different regions of phase space.
- Born level was taken as $gg \to b\bar{b}H$, $gb \to bH$, $b\bar{b} \to H$ initial jets were simulated by Pythia. For the inclusive analytic results to be unquestionably valid we would like to have acceptance for the 3 cases to be comparable.
- Detector effects are simulated with the help of AcerDET (hep-ph/0207355) by B. Kersevan and E. Richter-Was.
- Selection cut-offs etc. are not defined by me but by the collaborations. Some of them may be changed easily some other not ... This would be different talk.

Let us now show numerical results

Caption for the table on the next transparency

1. Let us look at the case when one of the τ's decays hadronically and second leptonically, then the final signature is $(\ell\ \tau\text{-jet}\ E_T^{miss})$.
2. The cumulative acceptances for the selection criteria and for different approaches of modelling production process will be shown
3. For each subsequent line effect of the additional cut off is added.
4. Particle level results are given in blue
5. Results when detector effects are included are shown in red
6. There is small technical point. Tau-leptons are not observed directly neutrino momenta have to be reconstructed from kinematical fit.
7. Small tau-mass limit is used and condition of momentum conservation in transverse plane, that is: $p_T^{mis} = p_T^{\nu_\tau} + p_T^{\bar{\nu}_\tau} + p_T^{\ell}$

example from LHC, but most details missing

Selection	$b\bar{b} \to H$	$gb \to bH$	$gg \to b\bar{b}H$	$gg \to H$	$--$
1 iso ℓ, $p_T^\ell > 20$ GeV 1 τ-jet, $p_T^{\tau-jet} > 30$ GeV	$19.5 \cdot 10^{-2}$	$19.3 \cdot 10^{-2}$	$19.7 \cdot 10^{-2}$	$19.5 \cdot 10^{-2}$	
PARTICLE level					
resolved neutrinos	$16.6 \cdot 10^{-2}$	$16.6 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	$16.9 \cdot 10^{-2}$	**A**
$\|sin(\Delta\phi_{\ell\ \tau-jet})\| > 0.2$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	$9.4 \cdot 10^{-2}$	$10.4 \cdot 10^{-2}$	
$m_T^{\ell,miss} < 50$ GeV	$8.9 \cdot 10^{-2}$	$9.7 \cdot 10^{-2}$	$8.9 \cdot 10^{-2}$	$9.8 \cdot 10^{-2}$	
Additional selection					
$p_T^{miss} > 30$ GeV	$1.3 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	
$cos(\Delta\phi_{\ell\ \tau-jet}) > -0.9$	$8.5 \cdot 10^{-3}$	$2.2 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$3.1 \cdot 10^{-2}$	
$R_{\ell\ \tau-jet} < 2.8$	$6.1 \cdot 10^{-3}$	$1.9 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	**B**
DETECTOR level					
resolved neutrinos	$11.0 \cdot 10^{-2}$	$11.6 \cdot 10^{-2}$	$11.1 \cdot 10^{-2}$	$12.5 \cdot 10^{-2}$	**C**
$\|sin(\Delta\phi_{\ell\ \tau-jet})\| > 0.2$	$5.9 \cdot 10^{-2}$	$7.1 \cdot 10^{-2}$	$6.5 \cdot 10^{-2}$	$8.2 \cdot 10^{-2}$	
$m_T^{\ell,miss} < 50$ GeV	$5.5 \cdot 10^{-2}$	$6.6 \cdot 10^{-2}$	$6.2 \cdot 10^{-2}$	$7.6 \cdot 10^{-2}$	
Additional selection					
$p_T^{miss} > 30$ GeV	$9.1 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$1.4 \cdot 10^{-2}$	$3.0 \cdot 10^{-2}$	
$cos(\Delta\phi_{\ell\ \tau-jet}) > -0.9$	$6.5 \cdot 10^{-3}$	$1.8 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$2.7 \cdot 10^{-2}$	
$R_{\ell\ \tau-jet} < 2.8$	$4.9 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$	$9.3 \cdot 10^{-3}$	$2.3 \cdot 10^{-2}$	**D**

Warning from this example

- *At Particle Level (A) all look like confirmation of assumptions for inclusive calculations. Acceptance an overall factorizing correction. Nice thing.*
- *At Particle Level (B) we get slightly sharper higgs mass peaks, thanks to additional selection cuts.*
- *Acceptance correction become less universal and may be the problem for inclusive calculation. Additional selection cuts look like unnecessary nuisance.*
- *At Detector Level (C) acceptances are independent of the hard process used in PYTHIA. Unfortunately Higgs resonance peak disapear. No signal over background.*
- *At Detector Level (D) we get peaks back, because of additional selection, but acceptance becomes hard process dependent factor of 4 !!!*
- *Solution?* $\longrightarrow$ *better theoretical calculation, better observables or both.*

Mini Conclusions

- Assumptions of theoretical calculation need to be revisited with every step of refinements of experimental analysis
- Whenever possible calculations should be separated into segments
- Experimental users should be able to play with such segments and use interfaces to the benefit of studies of systematics and for optimization of observable construction.
- At present, FORTRAN is less and less known. The interfaces to be used that way have to be in C++ and based on HepMC.
- In the following let me explain status of τ decay library and its universal interface from that perspective.
  1. Separation into τ production and decay
  2. τ decay as low energy physics project
  3. Hard process and programme interface
- Other module PHOTOS for bremsstrahlung in decays will not be discussed this time.

why τ decays can be separated?

Formalism for $\tau^+\tau^-$

- Because narrow τ width approximation can be obviously used for phase space , cross section for the process $f\bar{f} \to \tau^+\tau^- Y; \tau^+ \to X^+\bar{\nu}; \tau^- \to \nu\nu$ reads:

$$d\sigma = \sum_{spin} |\mathcal{M}|^2 d\Omega = \sum_{spin} |\mathcal{M}|^2 d\Omega_{prod}\; d\Omega_{\tau^+}\; d\Omega_{\tau^-}$$

- This formalism is fine, but because of over 20 τ decay channels we have over 400 distinct processes. Also picture of production and decay are mixed.

- but (only τ spin indices are explicitly written):

$$\mathcal{M} = \sum_{\lambda_1\lambda_2=1}^{2} \mathcal{M}^{prod}_{\lambda_1\lambda_2}\, \mathcal{M}^{\tau^+}_{\lambda_1} \mathcal{M}^{\tau^-}_{\lambda_2} BW(\tau^+) BW(\tau^-)$$

- Formula for the cross section can be re-written

$$d\sigma = \Big(\sum_{spin} |\mathcal{M}^{prod}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^+}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^-}|^2\Big) wt\; d\Omega_{prod}\; d\Omega_{\tau^+}\; d\Omega_{\tau^-}$$

why τ decays can be separated?

- where

$$wt = \Big(\sum_{i,j=0,3} R_{ij} h^i h^j \Big)$$

$$R_{00} = 1, \quad < wt >= 1, \quad 0 \leq wt \leq 4.$$

R_{ij} can be calculated from $\mathcal{M}_{\lambda_1 \lambda_2}$
and h^i, h^j respectively from $\mathcal{M}^{\tau^+}$ and $\mathcal{M}^{\tau^-}$.

- Bell inequalities tell us that it is impossible to re-write wt in the following form

$$wt \neq \Big(\sum_{i,j=0,3} R^A_i h^i \Big) \Big(\sum_{i,j=0,3} R^B_j h^j \Big)$$

that means it is impossible to generate first τ^+ and τ^- first in some given ‘quantum state’ and later perform separatelly decays of τ^+ and τ^-

- It can be done only if approximations are used. May be often reasonable, but nonetheless approximations.

- Helicity attributed now to spin exact events. It will carry approximated information. But new feature, available in C++, useful for observable builders.

why τ decays can be separated?

Another simulation segment which can be played with, by the user is bremsstrahlung in decays.

PHOTOS Monte Carlo can be used for that purpose. Its C++ version based on HepMC exist, but requires further work and tests.

Pilot version is available from
http://www.ph.unimelb.edu.au/ñdavidson/photos/doxygen/index.html

At present it is still not recomended for serious use. But we would value feed back.

Precision of the package (C++ and FORTRAN) is better than 0.1 %. Program generation cover full multiphoton phase space. For many processes tests (or additional internal weights) based on exact matrix elements are available.

Also in this case I target possibility of correlated samples; with and without bremstrahlung.

For details on physics, see my last week talk at NIKHEF
http://cern.ch/ wasm/public/NIKHEF.pdf

τ decays as low energy project

Leptonic and semileptonic decays.

- Complete first order QED corrections can be swithced on/off in $\tau \to e(\mu)\nu_\tau \nu$.
- For multiphoton bremsstrahlung PHOTOS can be used instead. In semileptonic channels, PHOTOS is the only option.
- In semileptonic modes, for up to 5 final state scalars, any current can be easily installed/remodelled. Proper treatment of the rest (phase space, spin, leptonic $\tau - \nu_\tau - W$ current) is assured. Thus many versions !
- For 6 pions or more, flat space is used at present.
- In total, well over 20 distinct τ decay modes installed.
- Such organization of the code is OK if non-factorizable electroweak corrrections of order $\frac{\alpha}{\pi}$ can be neglected.
- 3 more or less complete versions of formfactors in authors hands: CLEO 1998 ALEPH (LEP1) and published CPC plus additional single channel special cases!

τ decays as low energy project

- The differential partial width for each tau decay channel reads

$$d\Gamma_X = G^2 \frac{v^2+a^2}{4M} d\mathrm{Lips}(P; q_i, N)(\omega + \hat{\omega} + (H_\mu + \hat{H}_\mu)s^\mu)$$

- The phase space distribution is given by the following expression and independent module of the program accordingly to classical parametrization: $q_5 = N$ and $q_i^2 = m_i^2$ is used

$$d\mathrm{Lips}(P; q_1, q_2, q_3, q_4, q_5) = \frac{1}{2^{23}\pi^{11}} \int_{Q^2_{min}}^{Q^2_{max}} dQ^2 \int_{Q^2_{3,min}}^{Q^2_{3,max}} dQ_3^2$$

$$\int_{Q^2_{2,min}}^{Q^2_{2,max}} dQ_2^2 \quad \times \quad \int d\Omega_5 \frac{\sqrt{\lambda(M^2, Q^2, m_5^2)}}{M^2} \int d\Omega_4 \frac{\sqrt{\lambda(Q^2, Q_3^2, m_4^2)}}{Q^2}$$

$$\times \quad \int d\Omega_3 \frac{\sqrt{\lambda(Q_3^2, Q_2^2, m_3^2)}}{Q_3^2} \int d\Omega_2 \frac{\sqrt{\lambda(Q_2^2, m_2^2, m_1^2)}}{Q_2^2}$$

$$Q^2 = (q_1 + q_2 + q_3 + q_4)^2, \quad Q_3^2 = (q_1 + q_2 + q_3)^2, \quad Q_2^2 = (q_1 + q_2)^2$$

$$Q_{min} = m_1 + m_2 + m_3 + m_4, \quad Q_{max} = M - m_5$$

$$Q_{3,min} = m_1 + m_2 + m_3, \qquad Q_{3,max} = Q - m_4 \; Q_{2,min} = m_1 + m_2, \qquad Q_{2,max} = Q_3 - m_3$$

- Matrix element used in TAUOLA for semileptonic decay

$$\tau(P,s) \to \nu_\tau(N)X$$
$$\mathcal{M} = \frac{G}{\sqrt{2}}\bar{u}(N)\gamma^\mu(v+a\gamma_5)u(P)J_\mu$$

- J_μ the current depends on the momenta of all hadrons

$$|\mathcal{M}|^2 = G^2\frac{v^2+a^2}{2}(\omega + H_\mu s^\mu)$$
$$\omega = P^\mu(\Pi_\mu - \gamma_{va}\Pi^5_\mu)$$
$$H_\mu = \frac{1}{M}(M^2\delta^\nu_\mu - P_\mu P^\nu)(\Pi^5_\nu - \gamma_{va}\Pi_\nu)$$
$$\Pi_\mu = 2[(J^*\cdot N)J_\mu + (J\cdot N)J^*_\mu - (J^*\cdot J)N_\mu]$$
$$\Pi^{5\mu} = 2\,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma}J^*_\nu J_\rho N_\sigma$$
$$\gamma_{va} = -\frac{2va}{v^2+a^2}$$

- If a more general coupling $v+a\gamma_5$ for the τ current and ν_τ mass $m_\nu \neq 0$ are expected to be used, one has to add the following terms to ω and H_μ

$$\hat{\omega} = 2\frac{v^2-a^2}{v^2+a^2}m_\nu M(J^*\cdot J)$$
$$\hat{H}^\mu = -2\frac{v^2-a^2}{v^2+a^2}m_\nu\,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma}J^*_\nu J_\rho P_\sigma$$

τ decays as low energy project

1. At present parametrizations of τ hadronic currents as developped in late 90's is in use.
2. In fact it is also used in HERWIG and SHERPA.
3. It is not enough to look into PDG booklet and update code.
4. Discussion of low energy experimental errors need to be done at this step.
5. That is highly non-trivial, because of cross-contamination of different τ decay modes.
6. I will show now some examples, taken from:
7. S. Eidelman, Z. Was et al. "Precision Monte Carlo simulation for tau decays and low/medium energy experiments" to be published as a chapter of "Quest for precision in hadronic physics at low energies: Monte Carlo tools vs. experimental data" eds. H. Czyz, G. Montagna and G. Venanzoni, LNF-09/10(P) September 14, 2009.

τ decays as low energy project

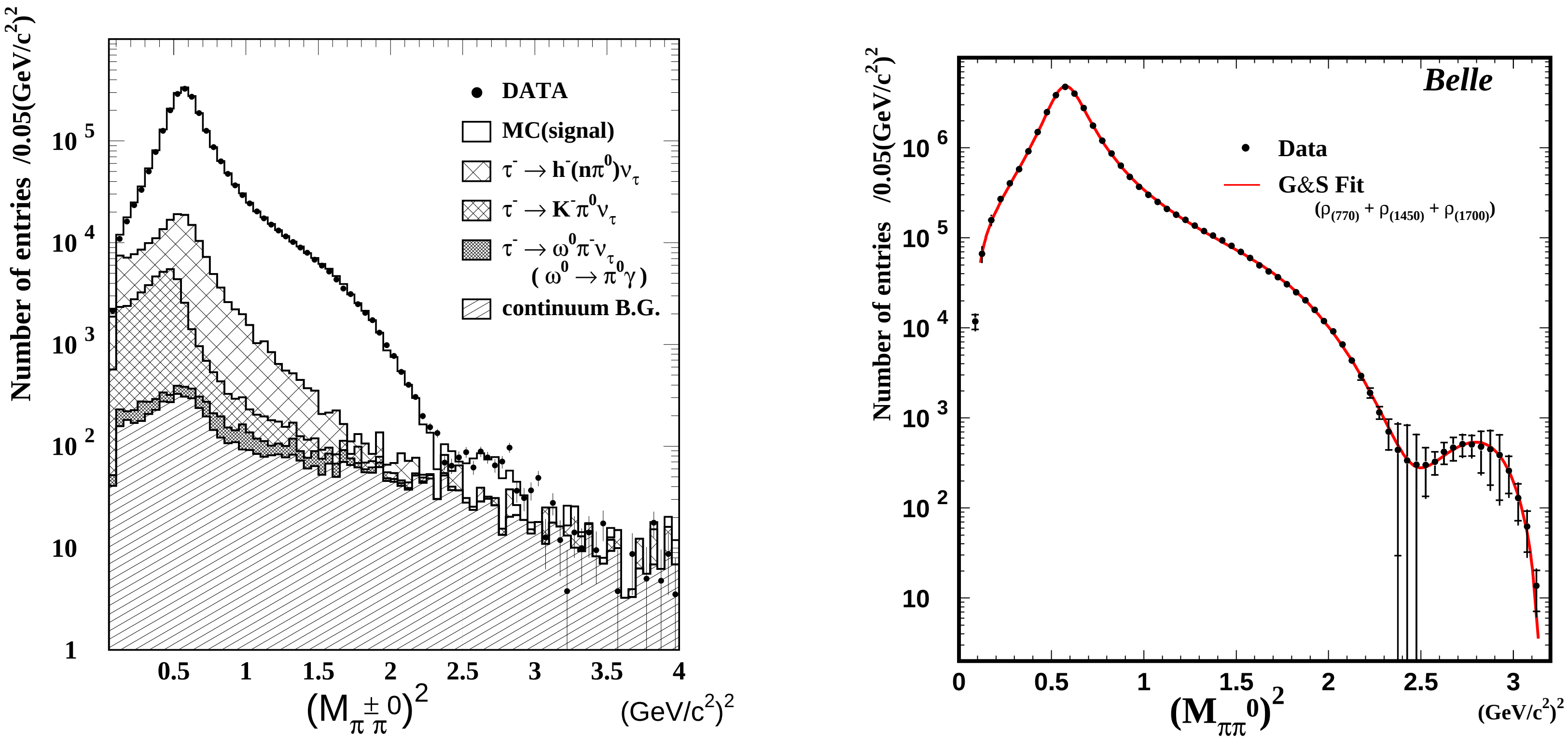
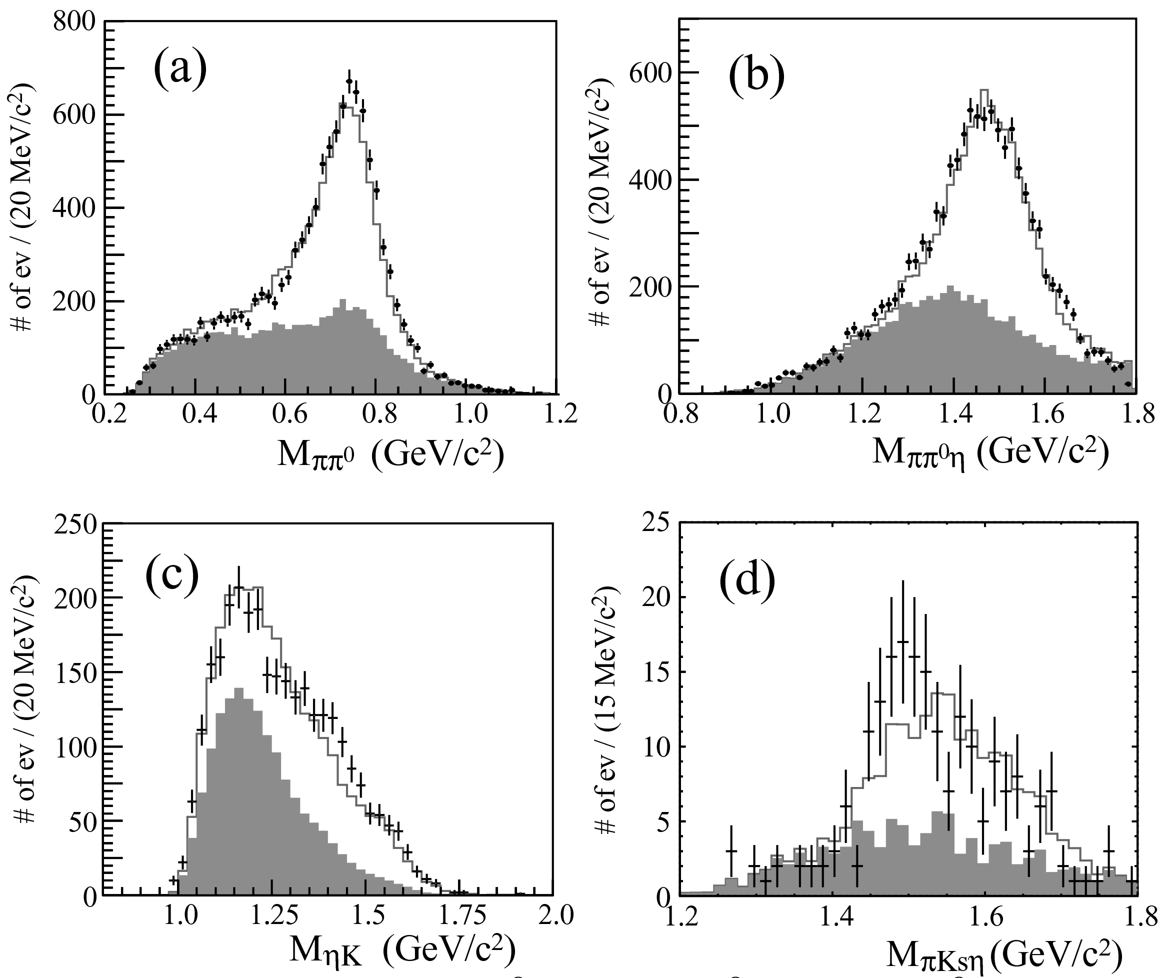


Figure 1: Two-pion invariant mass distribution for $\tau^- \longrightarrow \pi^-\pi^0\nu_\tau$ decay at Belle. Various background contributions to the dipion mass distribution (left) and underlying dynamics (right) clearly demonstrate a pattern of three interfering resonances: $\rho(770)$, $\rho(1450)$, $\rho(1700)$. From technical point of view this channel is easy: only 1 function of 1 variable need to be fitted.

τ decays as low energy project



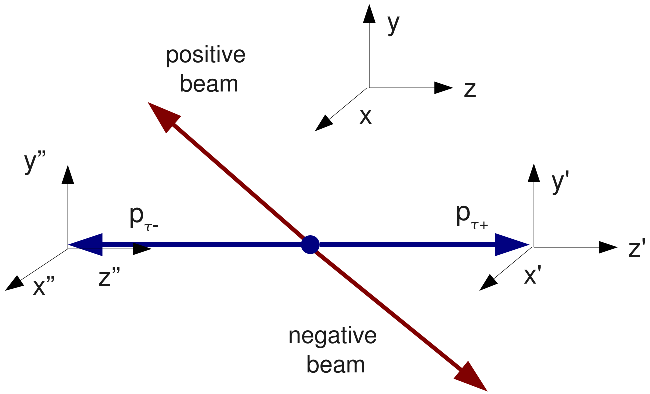
Invariant mass distributions: (a) $\pi\pi^0$ and (b) $\pi\eta\pi^0$ for $\tau \longrightarrow \pi\pi^0\eta\nu_\tau$; (c) ηK for $\tau \longrightarrow K\eta\nu_\tau$ and (d) $\pi K_S^0\eta$ for $\tau \longrightarrow \pi K_S^0\eta\nu_\tau$ at Belle. Figure shows that there is reasonable agreement for $\eta\pi^-\pi^0\nu_\tau$ (a, b) and worse for $\eta K^-\nu_\tau$ (c) and $\eta K^{*-}\nu_\tau$ (d). Note large background. Fits are more complicated too. In principle 4 complex functions of 3 variables contribute and define distribution over 8 dimensions.

Status of TAUOLA formfactors

- At present formfactors available in TAUOLA are based on models and data as of 1998.
- No systematic effort by low energy experiments to systematize wealth of present day data is completed as now.
- There is an ongoing effort in that direction and that is why significant part of TAUOLA remain in FORTRAN till now.
- This is not a big problem for modern software. Such code can be used with C++.
- But do we need at LHC precision τ decays at all?
- For main processes, for rare backgrounds, for precision physics?
- Anyway it can be only a benefit to have more precise module.

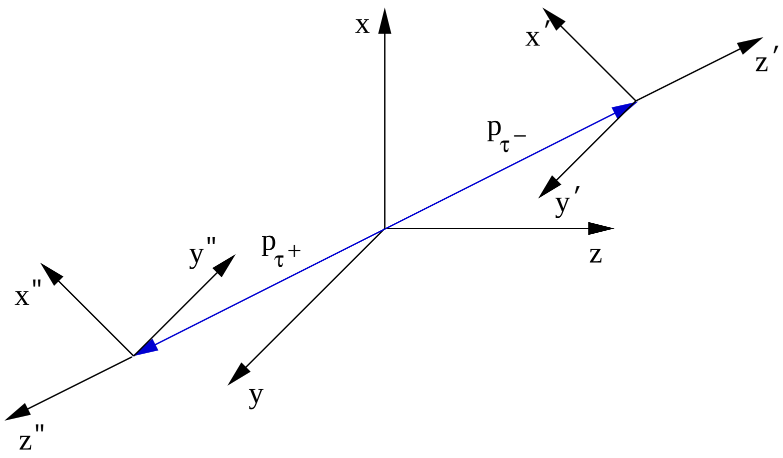
TAUOLA: summary

- Phase space. Matrix element $\longrightarrow$ Electroweak vertex.
- Leptonic decays: $\tau \rightarrow e(\mu)\nu_\tau\nu(\gamma)$. Semileptonic decays: hadronic currents.
- For LHC phenomenology one can think of τ decay as of part of detector
- how does it match the rest of LHC physics process?
- For τ to decay, we need to have τ 4-momentum and density matrix ...
- ...thus we need to decipher hard process, for full spin we need τ rest frame orientation as well.
- How much one can rely on information from production generators?
- We will want to play with detector level lepton universality one day. For that purpose one replace muons with taus in measured events. No history entries in event record etc.
- TAUOLA interface is about toy reconstruction of hard process from data!
- Work of different people at different time. Precision of generators *(and) tests of experimental reconstructions. When it is simultaneously possible ?*



In the Monte Carlo realization it means that:

- We have to find and reconstruct kinematic configuration of hard process and how it relates to lab frame.
- For every possible hard process calculate and later use density matrix
- Optionally use more spohisticated density matrix including EW corrctions or add Z'.
- Once event is ready one may generate helicity states using approximated density matrix. For special use in debugging reconstruction algorithms.
- Exercises on how to get hard process from data.



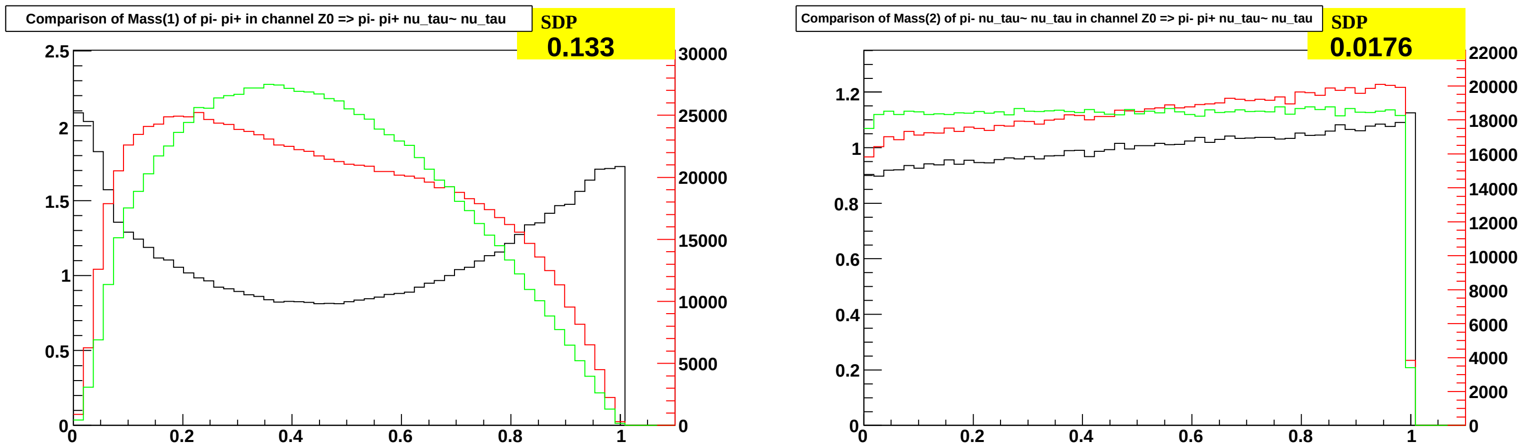
Convention for spinor algebra must be checked too.

Status on hard processes in TAUOLA C++ interface:

- External density matrix is available now only for Z/γ^* intermediate state. It features electroweak corrections of SANC (D. Bardin et al.) and full spin effects.
- Slightly different conventions of frames in SANC. Adjustment (rotations etc) are needed.
- For other processes:
  - H, A
  - $W^\pm$, $H^\pm$

density matrix is like in FORTRAN, but infrastructure for complete spin is ready.

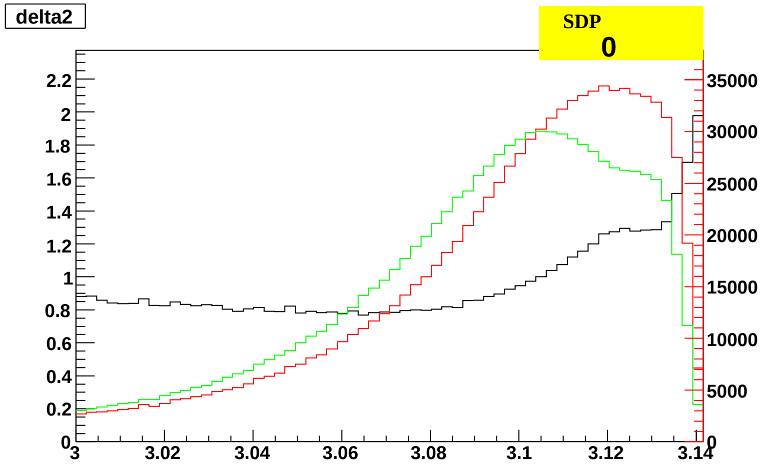
- Program found to work well with main processes as simulated in PYTHIA 8.1 but it is far from the end of testing.
- Testing means studies on reconstruction too.



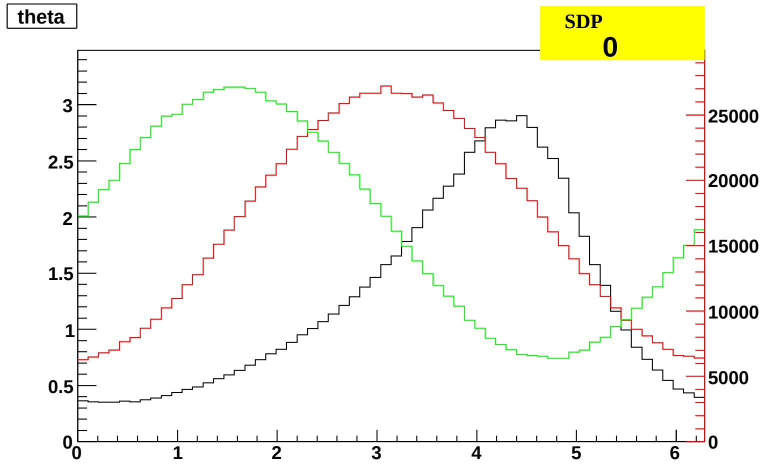
(a) $M_{\pi^+\pi^-}$ (b) $1 - 2\frac{E_{\pi^+}}{M_Z}$

Figure 2: 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. How acceptance would change that?

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 $\tau^\pm \rightarrow \pi^\pm \nu_\tau$. 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

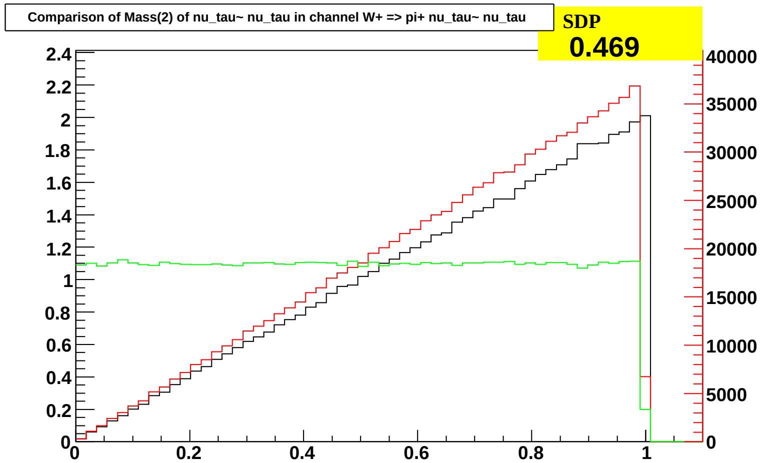


Figure 4: Decay $W^+ \to \nu_\tau \tau^+, \ \tau^+ \to \pi^+ \bar{\nu}_\tau$. Pion energy spectrum in W rest-frame, variable $1 - 2\frac{E_{\pi^+}}{M_{W^+}}$ is used. Spin effects included (red line) and neglected (green line are plotted). From inspection of black line one may conclude that green histogram 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

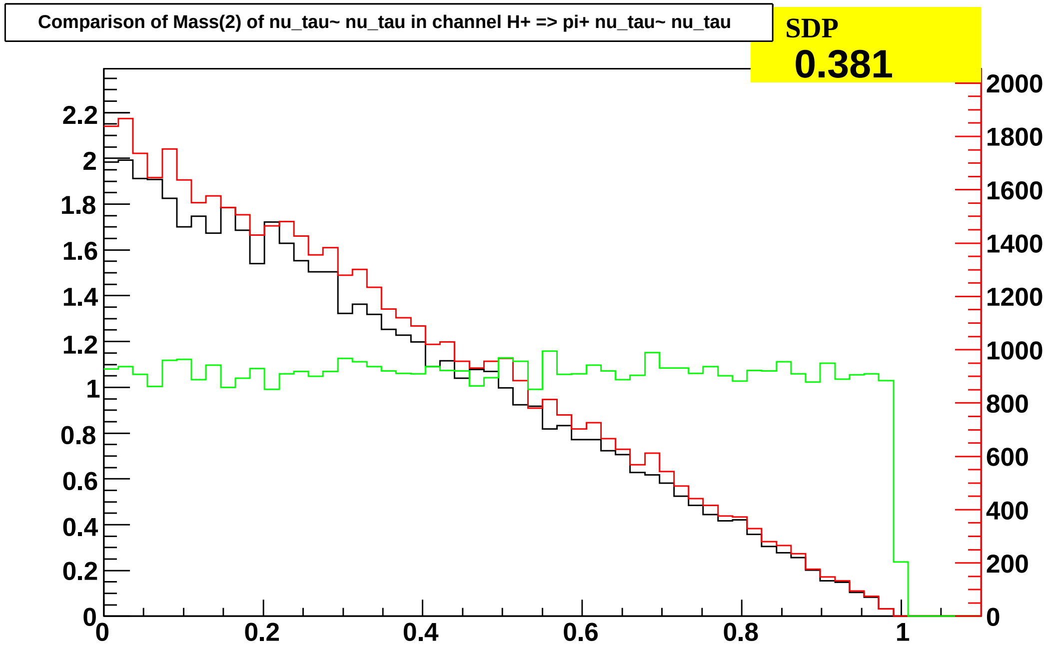
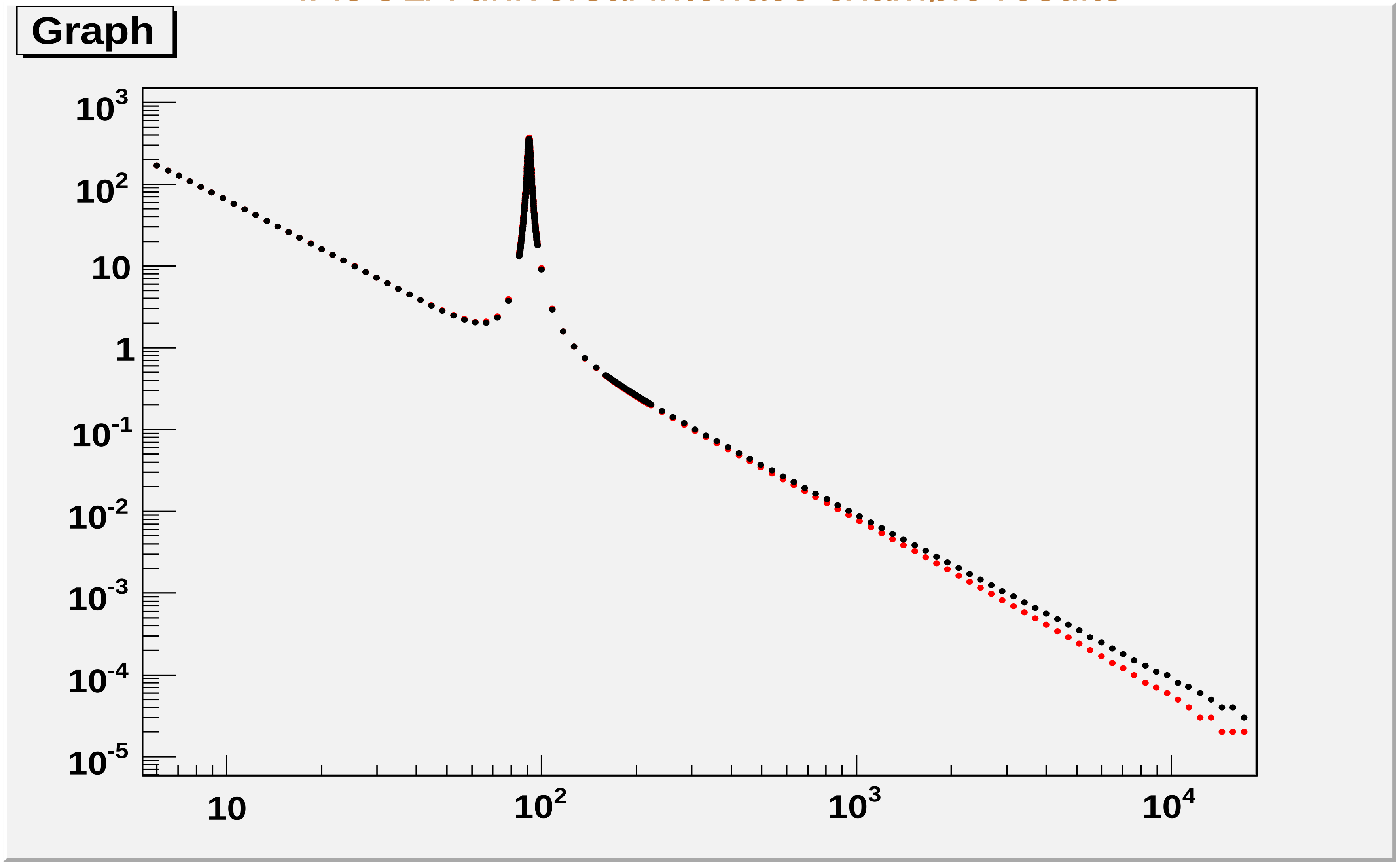
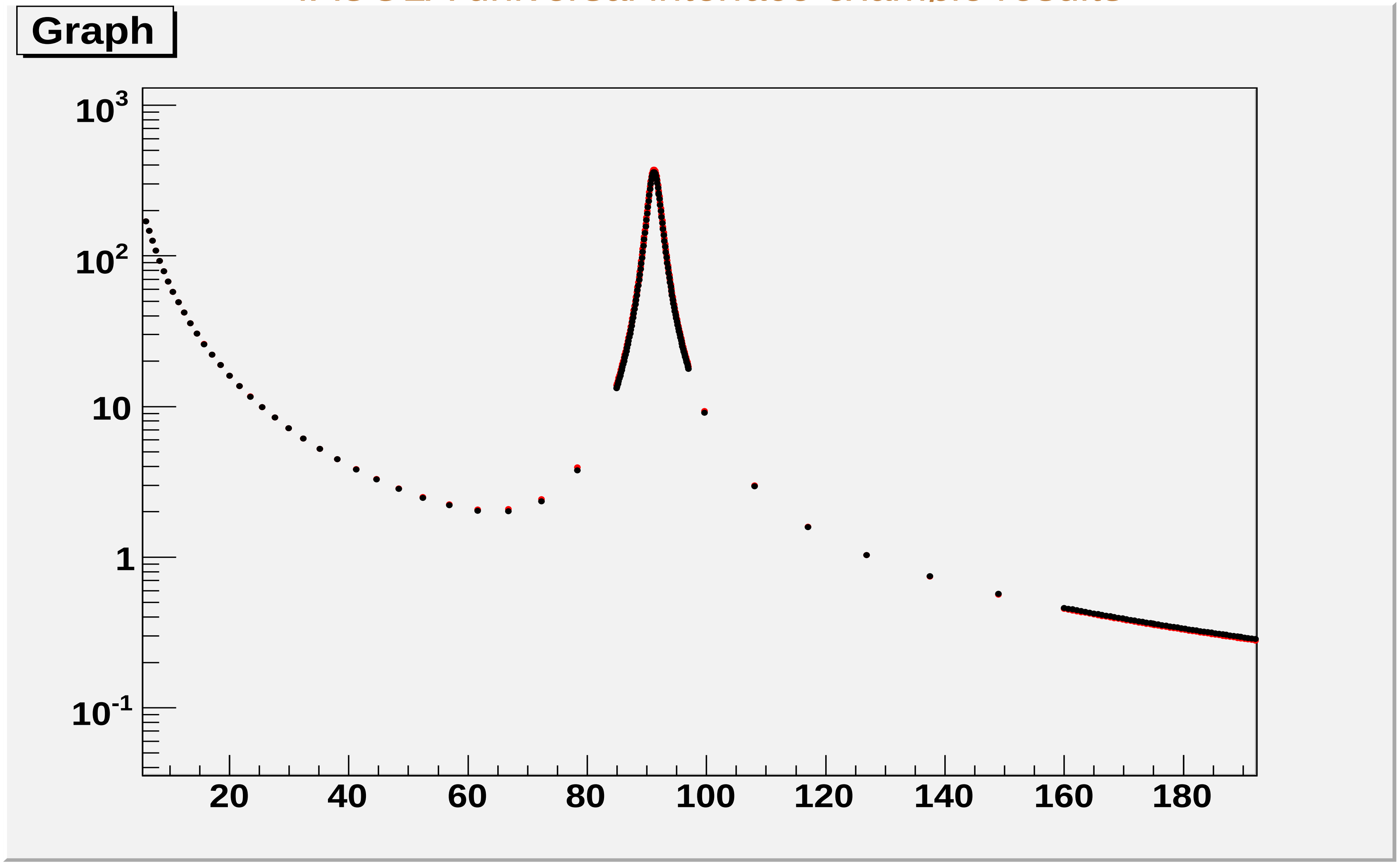


Figure 5: Decay $H^+ \to \nu_\tau \tau^+,\ \tau^+ \to \pi^+ \bar{\nu}_\tau$. Pion energy is calculated in the H rest-frame, the variable $1 - 2E_{\pi^+}/M_H^+$ is used. Spin effects included (red line) and neglected (green line) are plotted. As one can see the spectra are reversed compared to the case 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).



Effect of electroweak corrections on τ-pair production. As expected, it is relatively large for virtualities well above W-pair threshold. Plot made from tables available in TAUOLA interface. Note dense pretabulation regions around Z peak and WW threshold.



Effect of electroweak corrections on τ-pair production. Window around Z peak. As expected effects are small.

Summary – general

- I tried to show that phenomenology of τ leptons at LHC is an complex issue
- Decay models and low energy experiments data; their systematic errors etc.
- New physics signatures at LHC using τ leptons.
- Realistic predictions with all theoretical, detector, effects taken in.
- Methods to subtract unwanted physics.
- Theoretical predictions: one building block or interchangeable segments.
- How much of this can be delegated to external people, how much has to be done in experiments.
- Expertise gaining, teaching, programming constraints.

Summary – my tools

- new version of TAUOLA universal interface is ready for tests and pilot installation in ATHENA.
- Draft documentation is available.
- Pre-release but complete code is available (bug fxing monitored with svn).
- part of TAUOLA will remain in FORTRAN for some time (link to low energy experiments). This part is well hidden and does not need control of LHC community.
- PHOTOS (HepMC version) exist too but its testing is less advanced.
- Our plan is to deliver stable C++ TAUOLA interface by X-mas.
- But already now, it is ready for pilot use and features important new options: complete spin effects in Z decay, electroweak corrections in hard process. Interface for new physics add-ups.