Firt Annual Meeting of HiggsTools

Albert-Ludwigs Universität Freiburg
Fakultät für Mathematik und Physik

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TauSpinner in VBF processes

Joined prof. Was group working on Tauola++ and TauSpinner algorithm:

• TauSpinner: a MC algorithm working together with Tauola++ to simulate polarization effects in the final states of tau decays

In future will also manage production matrix elements for $2 \rightarrow 4$

Thus, parity property of the Higgs particle spin state of Z, W or Higgs field can be studied (also options to modify prod M.E.)

Literature on TauSpinner:

i) *"TauSpinner: a tool for simulating CP effects in H to tau tau decays at LHC"*, T. Przedzinski, E. Richter-Was and Z. Was,arXiv:1406.1647, EPJC in print

ii) A. Kaczmarska, J. Piatlicki, T. Przedzinski, E. Richter-Was and Z. Was, *"Application of TauSpinner for studies on tau-lepton polarization and spin correlations in Z, W and H decays at LHC,"*, arXiv:1402.2068, Acta Phys. Polon

iii) *"Ascertaining the spin for new resonances decaying into tau+ tau- at Hadron Colliders"*, S. Banerjee, J. Kalinowski, W. Kotlarski, T. Przedzinski and Z. Was, Eur. Phys. J. C **73**, 2313 (2013)

iv) *"TauSpinner Program for Studies on Spin Effect in tau Production at the LHC"*, Z. Czyczula, T. Przedzinski and Z. Was, Eur. Phys. J. C **72**, 1988 (2012)

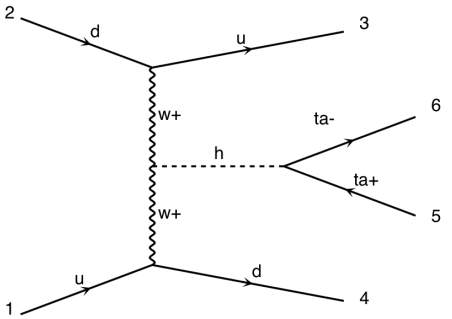
Motivation:

- In 2012 discovery of Higgs-like particle with mass ≈ 125GeV

- Which observables and which convenient channel to choose? (already used in experiment)

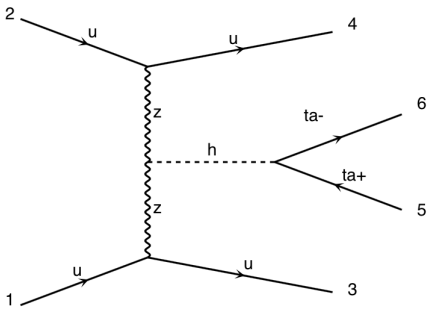
- Question arised in 2014: is the Higgs particle a Scalar or Pseudoscalar?

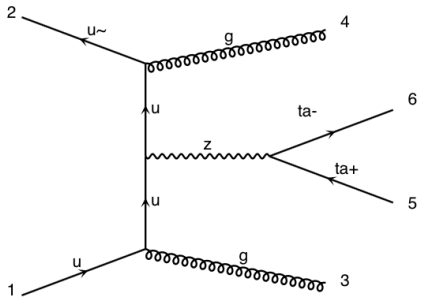
In Year 2015:



- VBF processes (at parton level) $2 \to 4$
- Two jets with large pseudorapidity
- Background from similar signature events:

e.g. Drell-Yan





- Attention for QED FSR, ISR-jets, PDFs

and num. stability

• 2015: Higgs decays into tau-pair useful to ascerting P properties. Higgs properties must be verified for each channel separately.

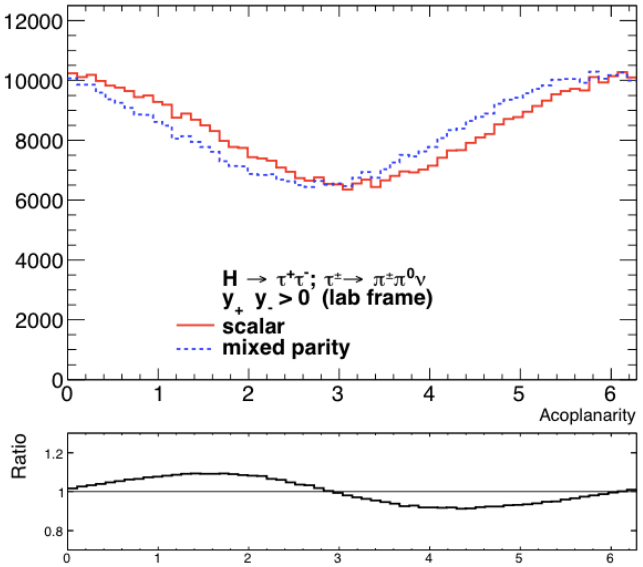
• For the case $H \to \tau^+\tau^-$ promising obsevable:

acoplanarity angle in ϱ-ϱ rest frame

e.g. for the decay
$\tau^\pm \to \rho^\pm \bar{\nu}_\tau(\nu_\tau)$
$\to \pi^\pm \pi^0$
one has:
$\mathbf{n}_\pm = \mathbf{p}_{\pi^\pm} \times \mathbf{p}_{\pi^0}$

$$cos\varphi^* = \frac{\mathbf{n}_+ \cdot \mathbf{n}_-}{|\mathbf{n}_+||\mathbf{n}_-|}$$

$$y_1 = \frac{E_{\pi^+} - E_{\pi^0}}{E_{\pi^+} + E_{\pi^0}}\,; \qquad y_2 = \frac{E_{\pi^-} - E_{\pi^0}}{E_{\pi^-} + E_{\pi^0}}.$$



Technology of TauSpinner:

- TauSpinner can make use both of generated and measured event samples
- calculations are made at parton level:

$$d\sigma = \sum_{flavours} \int dx_1 dx_2 f(x_1,...) f(x_2,...) d\Omega_{prod}^{parton\ level}\ d\Omega_{\tau+}\ d\Omega_{\tau-}$$
$$\left(\sum_{spin} |\mathcal{M}^{prod}|^2\right)\left(\sum_{spin} |\mathcal{M}^{\tau^+}|^2\right)\left(\sum_{spin} |\mathcal{M}^{\tau^-}|^2\right) wt$$

- thus the main systematic error comes from choice of PDFs but also from large transverse momentum in the hard process
- Input: only 4-momenta of tau leptons and decay products
- x_1, x_2 also reconstructed from taus 4-momenta
- Parton level matrix elements and PDFs are used to calculate spin weights and/or weights to modify/compare matrix elements for options of production mechanism. This is useful for signal/background evaluation.

- Reweighting algorithm: it can handle data samples which already include spin effect or not

$$\begin{aligned} WT &= wt_{\sigma_{prod}} wt^{\tau^+}_{\Gamma_{decay}} wt^{\tau^-}_{\Gamma_{decay}} wt_{spin} \\ wt_{spin} &= R_{i,j} h^i_{\tau^+} h^j_{\tau^-}. \end{aligned}$$

- TauSpinner already applied to $W^{\pm} \to \tau^{\pm}\nu, Z \to \tau^+\tau^-$ and $q\bar{q} \to \gamma/Z \to \tau^+\tau^-$ in experimental analysis

- Longitudinal and transverse polarization

Advantages of TauSpinner:

• reconstruction of incoming partons only from the 4-momenta of tau-pair and no need to know flavours of incoming quarks

• top-down approach: events reconstructed from final state: consistent with experiment where intermediate states are not known

• code for VBF can help to evaluate systematic errors for the case when 2 --> 2 processes are used. In particular approximations for high transverse momentum configurations can be checked. Weights are calculated using the matrix elements of the two jets case. Then the difference with 2-->2 will estimate effect of approximation.

Future plans:

i) having matrix elements to account for VBF Higgs productions:
extensisive validating tests needed (presently working on it)

ii) investigate bahaviour of discriminating variables sensitive to spin

iii) quantify sensitivity to the measure of of spin properties of the Higgs-like state

iv) try differnt PDFs

v) extimate systematic errors