$t\bar{t}H$ Associated Production: tools and studies for LHC Run II

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$t\bar{t}H$, Signal

- NLO QCD+PS available through: aMC@NLO, PowHel, POWHEG, Sherpa, including top-quark spin correlation effects.
- Add simulation of various Higgs decay channels ($H \to b\bar{b}$, W^+W^-, $\tau^+\tau^-$, $\gamma\gamma$, ...), study related uncertainties.
- Top decays known only in LO+PS approximation: NLO+PS needed?
- First calculation of (electro)weak corrections now available (arXiv:1407.0823, arXiv:1407.1110), matching with PS available through aMC@NLO.
- $t\bar{t}H + j$ available at NLO (parton level) and NLO+PS through aMC@NLO: relevant for $t\bar{t}H$ analysis? If yes it requires NLO merging with $t\bar{t}H + 0j$ (would be a proxy to $t\bar{t}H$ at NNLO, which is probably not feasible in the near future)

$t\bar{t}H$, Background

Theoretical predictions for backgrounds will play a key role for the success of the ttH analyses. (Ex.: $t\bar{t}b\bar{b}$ and $t\bar{t}$+jets backgrounds are crucial for $t\bar{t}H(b\bar{b})$):

- ▷ background predictions should be at least NLO accurate and matched to showers; the need of NLO multi-jet merging techinques should be addressed;
- ▷ we need a solid understanding of theory uncertainties (including shower uncertainties) in the context of matching/merging;
- ▷ we need sound recipes for the estimate of uncertainties of shapes and ratios used in the experimental analyses.

$t\bar{t}H(b\bar{b})$ background

- NLO+PS $t\bar{t}b\bar{b}$ calculations available in the 5F and 4F schemes. We need:
  - ▷ comparison of 4F vs 5F schemes and MC@NLO vs POWHEG matching
  - ▷ uncertainty of $g \to b\bar{b}$ shower splittings
- $t\bar{t}$+jets with NLO multi-jet merging
  - ▷ compare wrt NLO+PS and LO merging
  - ▷ theory uncertainties (also for $t\bar{t}$+HF/$t\bar{t}$+jets ratios, correlations between different jet-multiplicity bins, etc...)

$t\bar{t}H(W^+W^-, \tau^+\tau^-, \gamma\gamma)$ backgrounds

- ▷ We need to identify dominant backgrounds.
- ▷ We need to improve theory predictions and have a reliable estimate of theoretical uncertainties, once specific experimental strategies are established.