$t\bar{t}H/tH$ Subgroup: Report and Plans

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Contributors to YR4: Broggio, Casolino, Demartin, Denner, Feger, Ferroglia, Frederix, Frixione, Garzelli, Gieseke, Harrendorf, Hartanto, Hirschi, Höche, Honeywell, Jäger, Juste, Kardos, Kulesza, Lindert, Moreno Llacer, Mantoani, Mawatari, Moretti, Motyka, Pagani, Pecjak, Plätzer, Podskubka, Reuschle, Shabalina, Shao, Schönherr, Siegert, Signer, Stebel, Theeuwes, Trocsanyi, Tsinikos, Wackeroth, Yang, Zaro.

YR4: goals

The aim of the $t\bar{t}H/tH$ section of YR4 has been twofold

- To collect all the new theoretical developments since YR3 and present them in a coherent format that could serve as a useful reference for Run II studies,
  - ▷ NLO EW corrections to $t\bar{t}H$ cross section
  - ▷ off-shell effects in $t\bar{t}H$ production
  - ▷ beyond NLO QCD: soft resummation for $t\bar{t}H$ cross section
  - ▷ NLO QCD corrections to tH cross section
  - ▷ QCD+EW NLO corrections to $t\bar{t}V$ $(V = Z, W^{\pm})$ cross section
- To thoroughly compare NLO QCD+ Parton-Shower event generators and validate their use in experimental analyses,
  - ▷ `OpenLoops` +`SHERPA`, $(t\bar{t}H,\, t\bar{t}b\bar{b})$
  - ▷ `MG5_aMC@NLO` +`PYTHIA8`, $(t\bar{t}H,\, t\bar{t}b\bar{b})$
  - ▷ `PowHel`+`PYTHIA8`, $(t\bar{t}H,\, t\bar{t}b\bar{b})$
  - ▷ `POWHEG BOX` +`PYTHIA8`, $(t\bar{t}H)$
  - ▷ `HERWIG7` using `OpenLoops`+`HERWIG`. $(t\bar{t}H)$

  for both signal (ex: $t\bar{t}H, H \to b\bar{b}$) and background (ex: $t\bar{t}b\bar{b}$).

YR4: activity of the $t\bar{t}H/tH$ working group

Series of topical meetings aimed at updating the theory and experimental communities on mutual problems/needs/progress,

- signal modeling in $t\bar{t}H$, tHq
- backgrounds and uncertainties in $t\bar{t}H$, $H \to b\bar{b}, \gamma\gamma$, multileptons
- $t\bar{t}H$ combination: systematics and correlations

out of which came the **action items** for YR4:

- need better estimate of theoretical uncertainty in the complex framework of $t\bar{t}H$ analyses,
- tool comparison for $t\bar{t}H$ and $t\bar{t} + b$ jets,
- recommendations for $t\bar{t}V$, ...

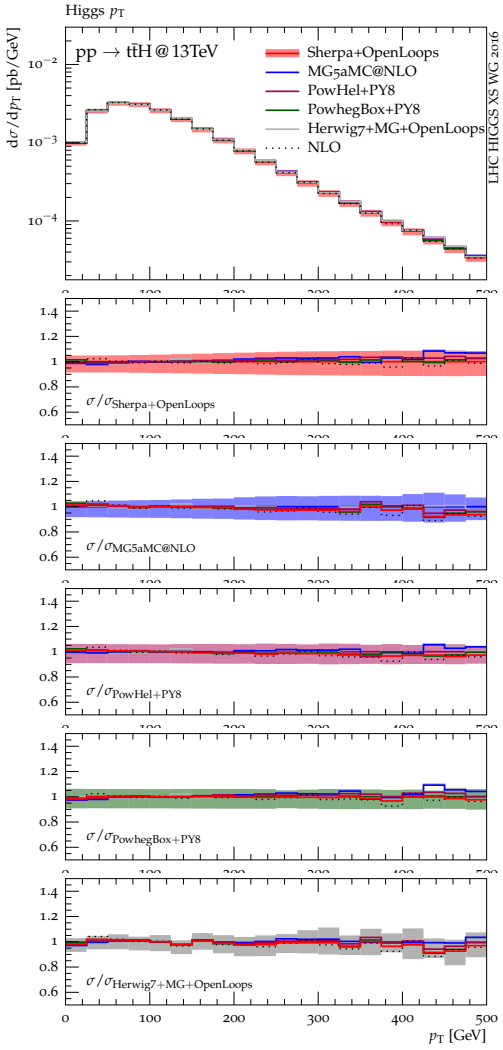
The progress towards YR4 was documented through a series of talks during this series of Workshops:

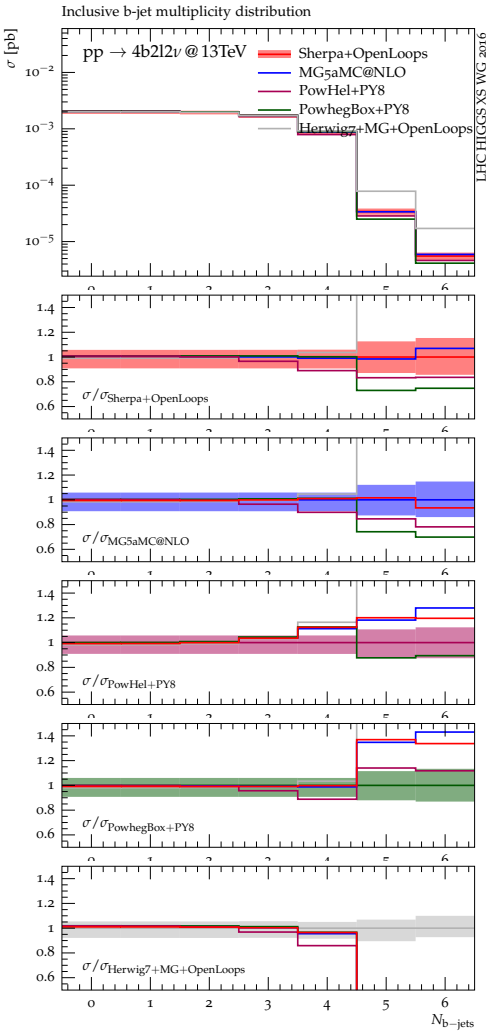
- 10^{th} Workshop, July 2015 (L. R and S. Guindon) $\to$ motivations and plan
- 11^{th} Workshop, January 2016 (S. Pozzorini) $\to$ preliminary results
- Preparatory Meeting, July 2016 (C. Neu) $\to$ final results, now in YR4

Full documentation provided on:

`https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGTTH`

YR4 highlights: Validation of NLO+PS tools, $t\bar{t}H, H \to b\bar{b}$





Comparison with and w/o top decays,
$t \to be^+\nu_e$
$\bar{t} \to \bar{b}\mu^-\nu_\mu$

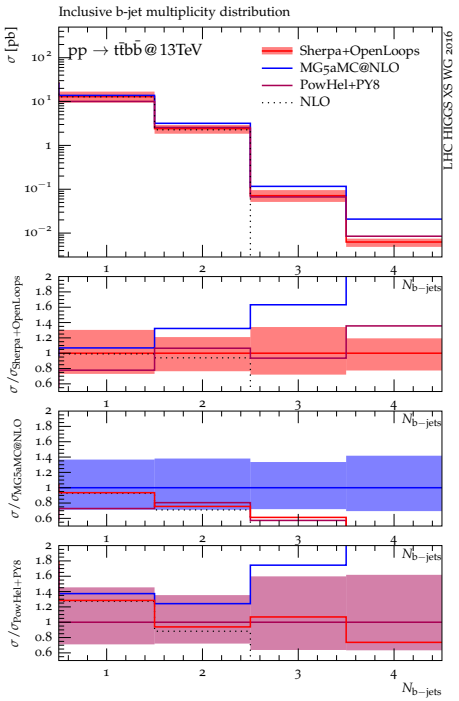
Proved very good compatibility within scale uncertainty

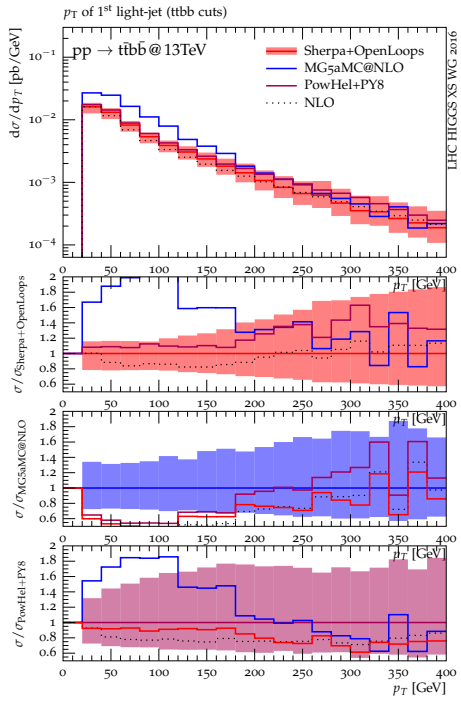
$N_{\text{b-jets}} > 4$

$\hookrightarrow$ shower effects

$\hookrightarrow$ more meaningful to investigate in the context of specific experimental analyses.

YR4 highlights: Validation of NLO+PS tools, $t\bar{t} + b$ jets





↪ switch off top decays, hadronization, UE

↪ To better compare the effect of

- different matchings
- different parton showers
- different flavor scheme

Discrepancies emerge that will have to be understood if we want to resolve the very large systematic uncertainties that affects experimental analyses

↪ **This is becoming a limiting factor**.

Beyond YR4: plans for future work

Given the momentum gained by $t\bar{t}H$ in Run II LHC analyses, we think that, as a WG, **we need to focus on validating existing theoretical tools for background Monte-Carlo simulation**.

We believe that **this is the ideal framework for these kind of studies**, and would like to push them forward (as we started doing in YR4).

We suggest picking very few goals, inspired by the needs of experimental analyses, and organizing a focused activity on those, e.g.

- $t\bar{t} + b$ jets
- $t\bar{t}+$ multileptons
- $t\bar{t} + \gamma$(s)

aiming at identifying, prioritizing, and addressing the specific problems that still induce large systematic effects in experimental analyses,

- use of different matching procedures (`MC@NLO` vs `POWHEG`)
- use of different showers and shower-induced effects (`SHERPA` vs `PYTHIA` vs `HERWIG`)
- more process-specific issues (flavor scheme, multiscale dynamics, etc.)

We need the participation of key people on both the experimental and theoretical side.

Beyond YR4: plans for future work

We would like the $t\bar{t}H$/tH WG to serve three main purposes:

- Foster the refinement of theoretical predictions (higher-orders EW+QCD, off-shell effects, etc.) and serve as a vehicle to bring any new development to fruition;
- Provide the natural framework to validate the tools ultimately used by ATLAS and CMS in Run II analyses.
- Provide recommendations for the application of NLO tools (for signal and backgrounds) and related uncertainties, especially in the complex framework of background-rich $t\bar{t}H$ analyses.

We propose to:

- Call an organizational meeting to suggest and discuss a few focused studies, identifying the people who are interested in actively contribute.
- Promote these studies to official activities of this WG with regular meetings and expected progress in between.
- Monitor the appearance of new (experimental and/or theoretical) results and allow space in the WG to give them resonance.