ttH status report

Marco Zaro, on behalf of the ttH conveners
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Introduction

- Dominant source of uncertainties in present/future ttH analyses is systematics

- Need to understand and reduce dominant sources of theoretical systematics in signal and backgrounds

- This includes (but does not reduce to) higher-order computations

  - NLO QCD+EW is the current standard (NLOQCD+EW+PS desirable)

  - Next frontier NNLO: approximate results exist for the signal (parallel talk by C. Savoini, Catani et al, 2210.07846), approach likely to be extended to some backgrounds (ttW/ttZ)

  - Parton-shower, matching/merging effects can be important (ttbb, ttW)

  - Off-shell effects: full off-shell calculation vs incoherent sum of double (tt+X) and single (tWX) resonant contribution. Effects are being studied
    Bevilacqua et al, 2005.09427, 2105.08404, 2205.9983, …; Denner et al, 2007.12089, 2102.03246

- Given the broadness of the topics, collaboration with other WGs (Top) must be sought, encouraged and fostered

Recent experimental results

- ATLAS

  - ttH, H→bb, ATLAS-CONF-2022-016
    Probing the CP nature of the top-Higgs Yukawa coupling in ttH and tH events
    with H → bb using the ATLAS detector at the LHC

  - H→γγ, all channels, arXiv:2207.00348
    Measurement of the properties of Higgs boson production at √s=13 TeV in
    the H→γγ channel using 139 fb^{-1} of pp collision data with the ATLAS
    experiment

- CMS

  - ttH, multilepton/CP arXiv:2208.02686
    Search for CP violation in ttH and tH production in multilepton channels in
    proton-proton collisions at √s=13 TeV

  - ttW measurement, arXiv:2208.06485
    Measurement of the cross section of top quark-antiquark pair production in
    association with a W boson in proton-proton collisions at √s=13 TeV
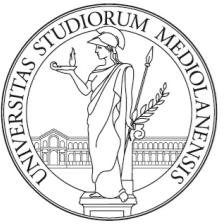
WG activities (I)

- Signal: provide new reference cross sections, including all relevant theory progress. For the moment, we will aim at the restricted (energy, mass) range

  - ttH: NNLO QCD + NNLL soft + complete NLO EW. First individual results expected shortly (end 2022)
    Broggio et al, 1907.04343; Kulesza et al, 2001.030301; Catani et al, 2210.07846

  - tH (various channels) NLO QCD, with FS-uncertainties for t-channel (YR4). EW corrections are known (~-3%, Pagani et al, 2006.10086), but cannot be broken down in t/s/tW channel. Numbers ready (reduced set of mass/energies) except for tW

New tH cross sections

t-ch

√s	mH		σ[pb]	Δμ-	Δμ+	PDF	αs	PDF+αs
13.0	124.60	TOT.	7.617e-02	+6.5	-15.0	1.8	1.2	2.1
13.0	124.60	top	5.003e-02	+6.5	-14.7	1.5	1.2	1.9
13.0	124.60	atop	2.614e-02	+6.4	-15.7	3.1	1.3	3.3
13.0	125.00	TOT.	7.604e-02	+6.4	-15.9	1.8	1.2	2.1
13.0	125.00	top	4.991e-02	+6.5	-15.2	1.5	1.2	1.9
13.0	125.00	atop	2.613e-02	+6.4	-17.1	3.1	1.3	3.3
13.0	125.09	TOT.	7.599e-02	+6.4	-16.1	1.8	1.2	2.1
13.0	125.09	top	4.989e-02	+6.5	-15.3	1.5	1.2	1.9
13.0	125.09	atop	2.610e-02	+6.4	-17.6	3.1	1.3	3.3
13.0	125.38	TOT.	7.579e-02	+6.4	-15.1	1.8	1.2	2.2
13.0	125.38	top	4.974e-02	+6.4	-14.5	1.5	1.2	1.9
13.0	125.38	atop	2.605e-02	+6.4	-16.3	3.1	1.3	3.3
13.0	125.60	TOT.	7.567e-02	+6.4	-15.8	1.8	1.2	2.1
13.0	125.60	top	4.966e-02	+6.4	-15.6	1.5	1.2	1.9
13.0	125.60	atop	2.601e-02	+6.3	-16.1	3.1	1.3	3.3
13.0	126.00	TOT.	7.553e-02	+6.4	-15.5	1.8	1.2	2.1
13.0	126.00	top	4.962e-02	+6.4	-15.1	1.5	1.2	1.9
13.0	126.00	atop	2.591e-02	+6.4	-16.4	3.1	1.3	3.3
13.6	124.60	TOT.	8.579e-02	+6.4	-16.4	1.7	1.2	2.1
13.6	124.60	top	5.614e-02	+6.4	-15.8	1.5	1.2	1.9
13.6	124.60	atop	2.965e-02	+6.3	-17.5	3.0	1.2	3.2
13.6	125.00	TOT.	8.538e-02	+6.4	-15.5	1.7	1.2	2.1
13.6	125.00	top	5.600e-02	+6.4	-15.2	1.5	1.2	1.9

s-ch

√s	mH		σ[pb]	Δμ-	Δμ+	PDF	αs	PDF+αs
13.0	124.60	TOT.	2.948e-03	+2.4	-1.9	2.4	0.2	2.4
13.0	124.60	top	1.932e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	124.60	atop	1.016e-03	+2.5	-1.9	2.6	0.2	2.6
13.0	125.00	TOT.	2.927e-03	+2.4	-1.9	2.4	0.2	2.4
13.0	125.00	top	1.919e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	125.00	atop	1.009e-03	+2.5	-1.9	2.6	0.2	2.6
13.0	125.09	TOT.	2.917e-03	+2.4	-1.8	2.4	0.2	2.4
13.0	125.09	top	1.913e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	125.09	atop	1.004e-03	+2.5	-1.8	2.6	0.2	2.6
13.0	125.38	TOT.	2.904e-03	+2.4	-1.9	2.4	0.2	2.4
13.0	125.38	top	1.905e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	125.38	atop	9.996e-04	+2.5	-1.9	2.6	0.2	2.6
13.0	125.60	TOT.	2.893e-03	+2.4	-1.8	2.4	0.2	2.4
13.0	125.60	top	1.896e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	125.60	atop	9.963e-04	+2.4	-1.8	2.6	0.2	2.6
13.0	126.00	TOT.	2.872e-03	+2.5	-1.9	2.4	0.2	2.4
13.0	126.00	top	1.885e-03	+2.4	-1.8	2.5	0.2	2.5
13.0	126.00	atop	9.872e-04	+2.5	-1.9	2.6	0.2	2.6
13.6	124.60	TOT.	3.178e-03	+2.4	-1.8	2.3	0.2	2.3
13.6	124.60	top	2.073e-03	+2.4	-1.8	2.4	0.3	2.5
13.6	124.60	atop	1.104e-03	+2.4	-1.8	2.5	0.2	2.5
13.6	125.00	TOT.	3.151e-03	+2.4	-1.8	2.3	0.2	2.3
13.6	125.00	top	2.059e-03	+2.4	-1.8	2.5	0.3	2.5

WG activities (II)

- Backgrounds: understand and reduce theory systematics, with focus on the PS-related ones

    - ttbb: on-line meeting in June https://indico.cern.ch/event/1165637/ , restarted activities to study PS systematics (with Pozzorini/Jezo/Lindert/Siegert)

    - ttW: upcoming meeting (Dec 9th afternoon), joint with LHC Top WG https://indico.cern.ch/event/1219500/

## $t\bar{t}b\bar{b}$: impact of off-shell effects   G. Bevilacqua

- For most observables, off-shell effects are very small also *differentially*

2. H_T^{had} and H_T^{vis}:

$$H_T^{had} = \sum_{i=1}^{4} p_T(b_i)$$

$$H_T^{vis} = H_T^{had} + \sum_{i=1}^{2} p_T(\ell_i)$$
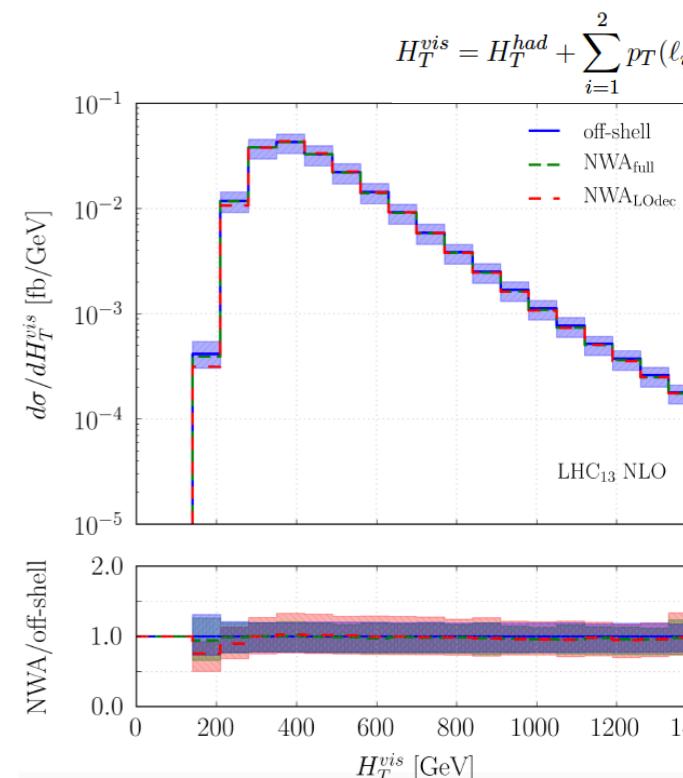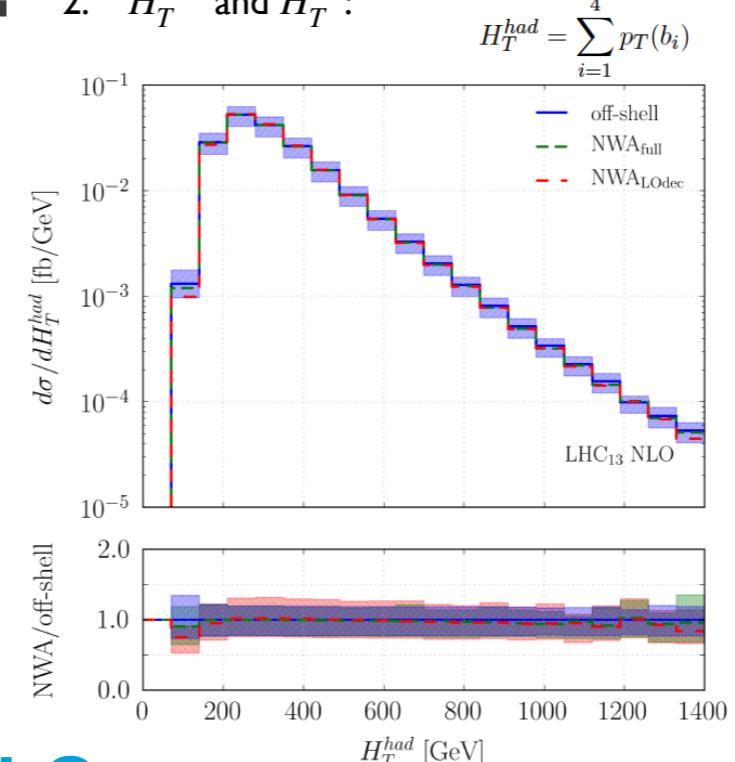

# Comparison of tt@NLO and ttbb@NLO

J. Katzy

MZ
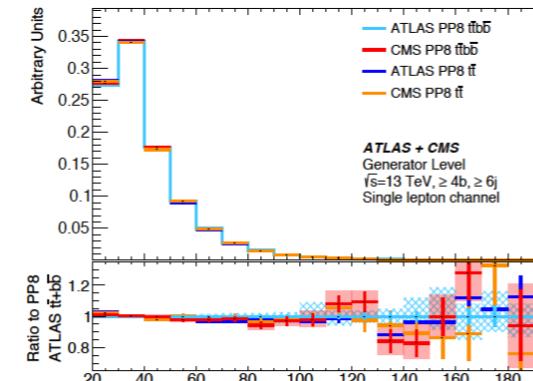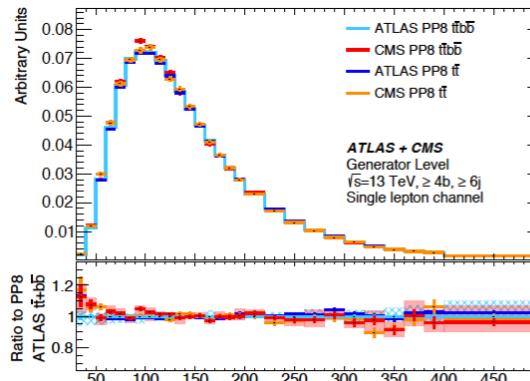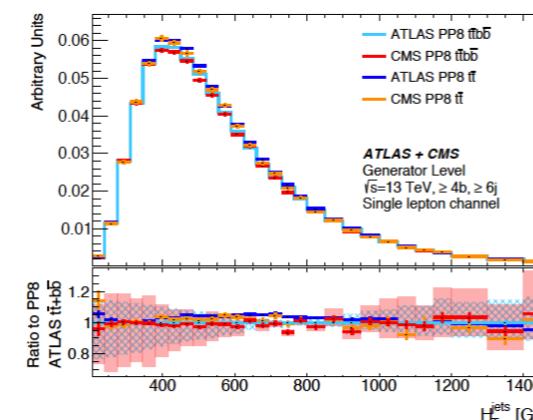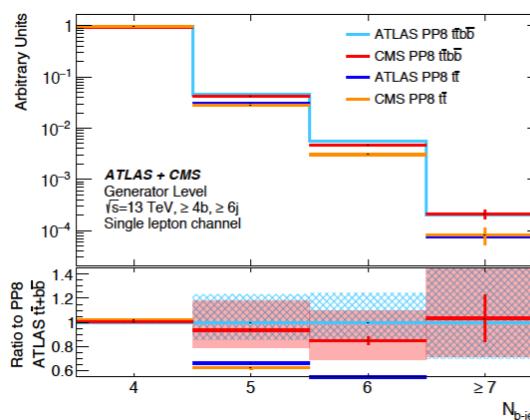
New prescription (2020)

- Reduce the YR4 scales by factor 2: pt(light) improves
- This also reduces the K factor

NLOPS YR4 scales
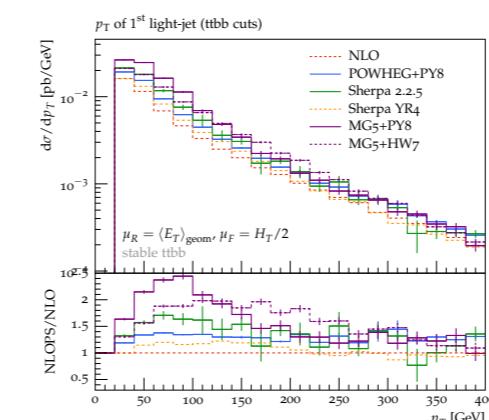
NLOPS 0.5 rescaling
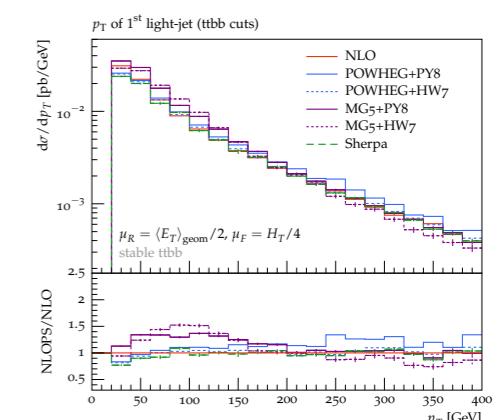
○ scale reduction significantly reduces NLOPS/NLO and MC spread (form 2.5 to 1.5
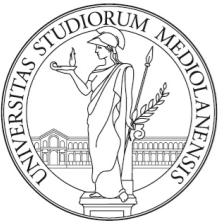
Joint session of LHC Top and Higgs working groups: ttW modeling in light of ttH measurements

Friday 9 Dec 2022, 14:00 → 18:00 Europe/Zurich

Virtual meeting

Fabio Maltoni (Universite Catholique de Louvain (UCL) (BE) and Università di Bologna) , Josh McFayden (University of Sussex) , Malgorzata Maria Worek (Rheinisch Westfaelische Tech. Hoch. (DE)) , Marco Zaro (Università degli Studi e INFN Milano (IT)) , Maria Aldaya Martin (DESY) , Sergio Sanchez Cruz (Universitaet Zuerich (CH)) , Wolfgang Wagner (Bergische Universitaet Wuppertal (DE))

| Registration | You are registered for this event. | 👤 29 | Check details |

Participants
A Aman Desai   B Brendon Bullard   D Daniel Stremmer   E Efe Yazgan   G Giovanni Pelliccioli
G Giuseppe Bevilacqua   I Ibrahim Mirza   J Jasmina Nasufi   J Jonathan Hermann

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14:00 → 14:20 **Issues in multilepton final states in ttW production** 🕐 20m

Speakers: Didar Dobur (Ghent University (BE)) , Elizaveta Shabalina (Georg August Universitaet Goettingen (DE))

14:25 → 14:45 **Reference cross-sections and methods used in analyses at ATLAS and CMS for ttW production** 🕐 20m

Speakers: Clara Ramon Alvarez (Universidad de Oviedo (ES)) , Tamara Vazquez Schroeder (CERN)

14:50 → 15:10 **NLO QCD and EW corrections to off-shell ttW production** 🕐 20m

Speakers: Giovanni Pelliccioli (Max-Planck-Institut für Physik) , Giovanni Pelliccioli (Würzburg University)

15:15 → 15:35 **Modelling uncertainties of ttW multilepton signatures** 🕐 20m

Speaker: Laura Reina (Florida State University (US))

15:40 → 16:10 **Coffee break** 🕐 30m

16:10 → 16:30 **Improving NLO merging for ttW production** 🕐 20m

Speaker: Rikkert Frederix (Lund University)

16:35 → 16:55 **NLO multi-jet merging for ttW production including electroweak corrections in Sherpa** 🕐 20m

Speakers: Enrico Bothmann (University of Göttingen) , Enrico Bothmann

Marco Zaro

17:00 → 18:00 **Open discussion** 🕐 1h

Some considerations on the theory/experiment collaboration

These considerations have been drafted as it appeared to us that the th-exp communication broke down in some cases, leading to misunderstandings and a non-optimal outcome

- Most of the studies we do in the LHCHWG require close th-exp interaction, specially those on theory systematics

- Collaboration should start from the beginning of a specific analysis, in order to get proper advice on input parameters, state-of-the-art tools and possible advantages/disadvantages of a given strategy (e.g. cuts, see Salam et al, 2106.08329), and should continue on a regular basis throughout the analysis

- Also, collaboration with other WGs (top, DM, EFT) should be fostered, with small groups of th. people interacting on specific topics with the experiments

- It would be advisable that relevant conveners be informed on the existence of such groups

Thank you!