Probing the Higgs false vacuum at the LHC

Measurement of the top Yukawa coupling in the tH production channel with ATLAS

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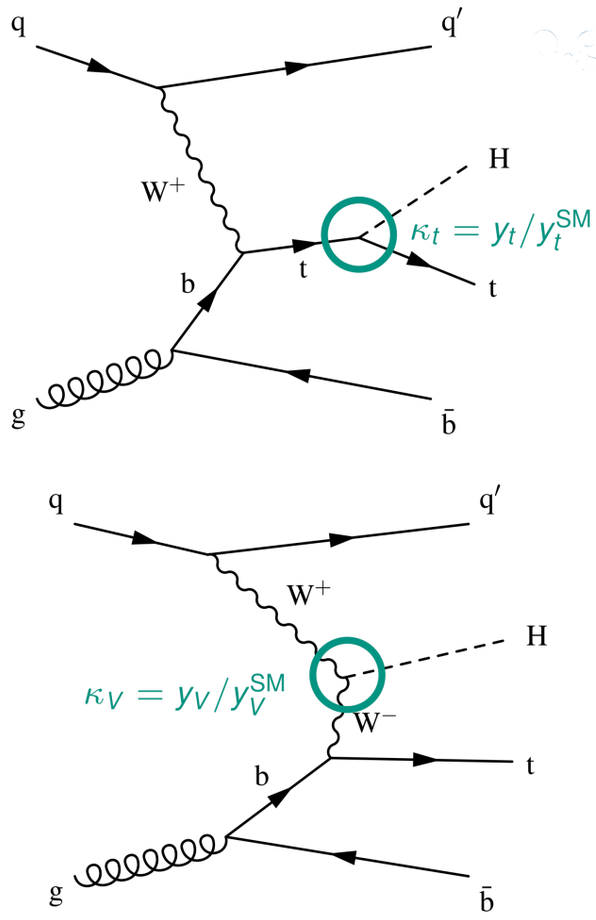
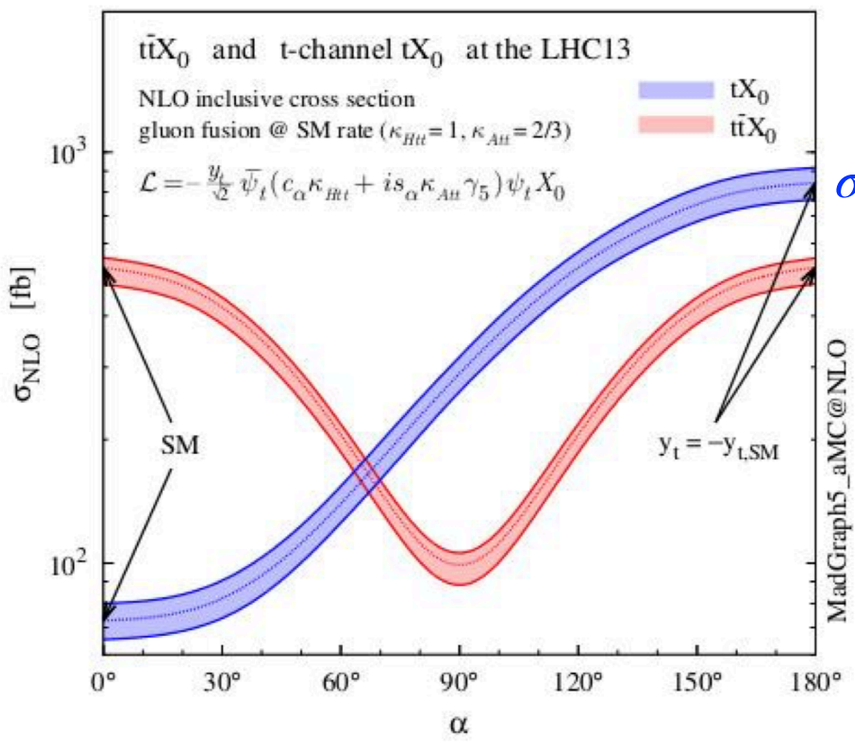
Top quark Yukawa coupling





$\sigma_{t(\bar{t})H} \propto a|y_t|^2 - by_t$, with $a, b > 0$

$\sigma_{t\bar{t}H} \propto |y_t|^2$

tH vertex sensitive to magnitude and sign of Higgs-top-Yukawa coupling, y_t

- **direct probe of the sign of y_t** (thanks to ttH/WWH interference term)

Standard Model (SM): $y_t = 1$ ⇾ destructive interference ⇾ $\sigma_{SM} \sim 70$ fb

Inverted coupling hypothesis: $y_t = -1$ ⇾ constructive interference ⇾ $\sigma \sim 10 \times \sigma_{SM}$

Test SM accuracy and presence of new physics

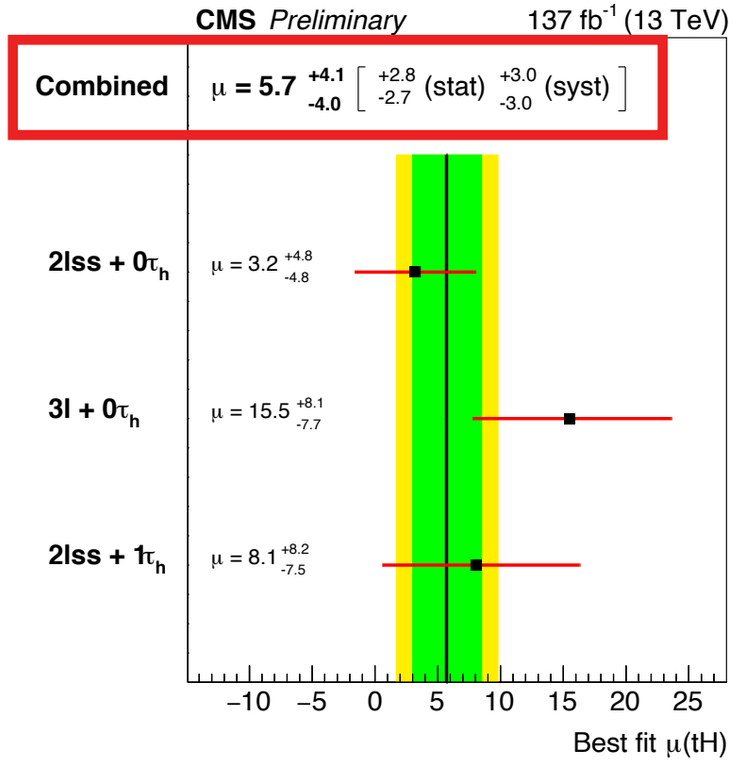
Benchmark & goals

Last public result presented by CMS last Summer

- ttH+tH ML - **CMS-PAS-HIG-19-008**
- $-0.9<y_t<-0.7$ or $0.7<y_t<1.1$ @95%CLs

Last result on tH 1L and combination

- **HIG-18-009-PAS** (with partial Run II data)



Scenario	Channel	Obs. Limit (pb)	Exp. Limit (pb)
$\kappa_t/\kappa_V = 1$ (SM-like)	$b\bar{b}$	8.29	$3.83^{+1.97}_{-1.22}$
	$\gamma\gamma$	5.17	$3.59^{+1.46}_{-0.91}$
	$\mu\mu + e\mu + \ell\ell\ell$	1.40	$1.26^{+0.57}_{-0.37}$
	Combined	**2.04**	$\mathbf{1.04}^{+0.43}_{-0.29}$

→ **μ_{tH}<40**

→ **μ_{tH}<14**

Benchmarks

Project Goals

- first tH measurement with full Run II dataset of LHC
- exclusion of Inverted Top Coupling (ITC) hypothesis

Project roadmap

FELLINI meeting

Secondment

	2019	2020		2021		2022
General area	***Semester 2***	***Semester 1***	***Semester 2***	***Semester 1***	***Semester 2***	***Semester 1***
Analysis framework						
Optimisation & observables definition						
Precise background estimate						
Rare backgrounds / MC samples						
Data/MC checks, fit setup, etc.						
INT note and publication drafting						

2020 milestones

Last year report (**FELLINI Meeting 24-25.02.2020**)

1. Improvement of Monte Carlo simulation with dedicated filters
- expertise gained in MC generation with latest generators

2. Development of flexible coding infrastructure
- e.g., Multivariate (MVA) and statistical tools used within ATLAS Colalboration

3. Update to the most precise experimental calibrations

4. Definition of the analysis strategies for different channels

Disclaimer!
- many details omitted (still ATLAS Internal results, susceptible to re-tuning)
- will focus on general approach, bottle-necks and prospects!

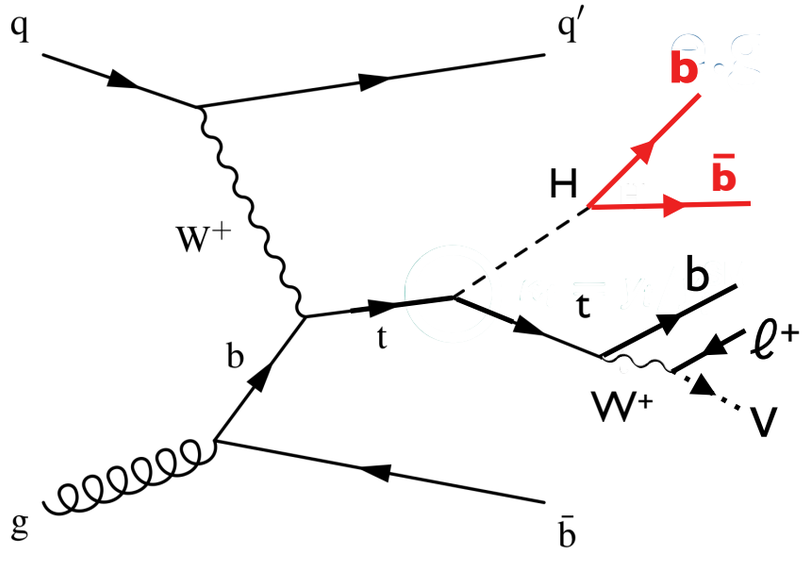
Analysis workflow

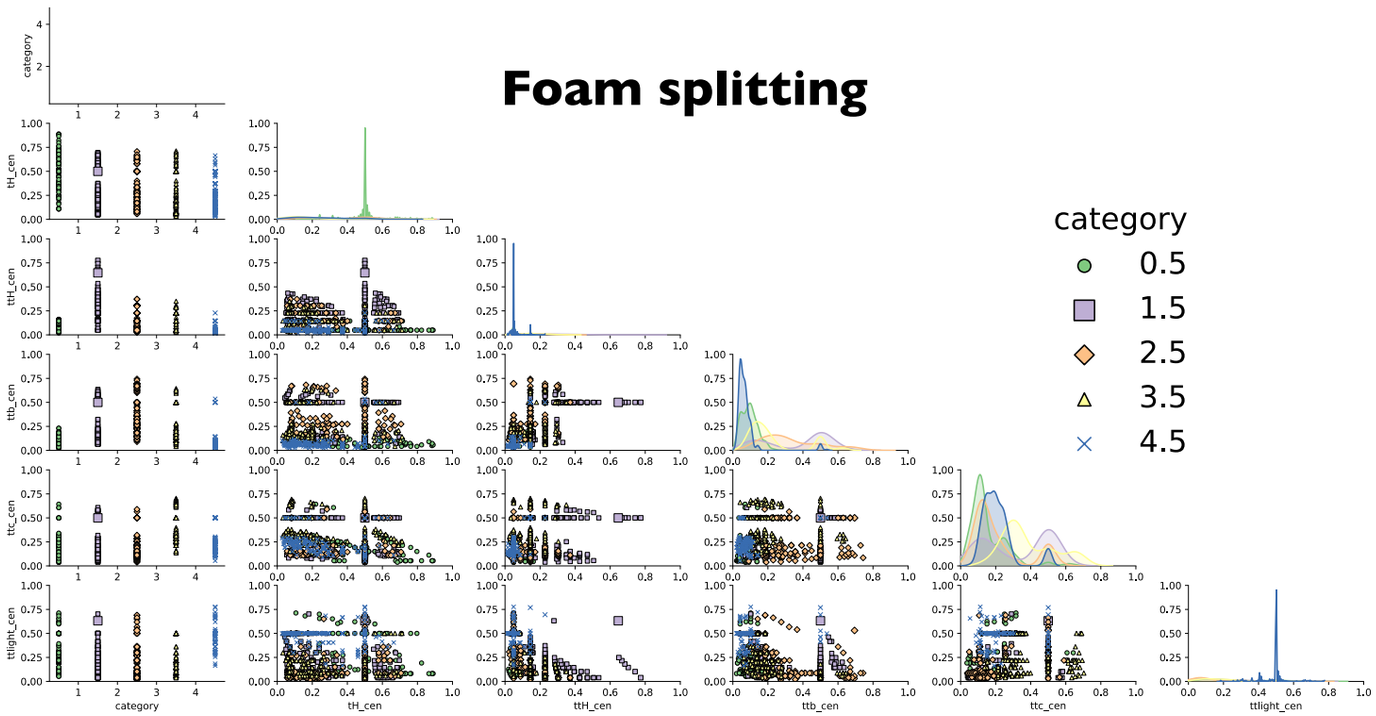
1. Pre-MVA region definition

2. N-hypotheses classification to classify signal and main backgrounds (MVA)

3. Split multi-dimensional space in N regions
   - regions used to study modelling of individual processes and/or measure rate in data

4. Statistical fit in N regions
   - y_t measurement and extraction of 95% C.L.s exclusion limit for different hypothesis of y_t





Current bottlenecks

1. Precise estimate of the $t\bar{t}$+jets process. Currently [JHEP 04 (2019) 046]

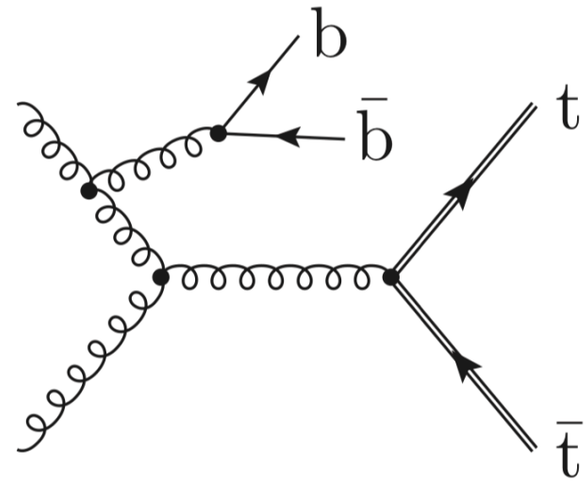
- x-section accuracy: NNLO in p-QCD, including soft-gluon resummation to NNLL
- MC simulation: NLO generators (4/5FS)
  - dedicated filters for best modelling of extra-gluon radiation
- **10-25% mis-modelling in ≥3 b-jets regions** may affect the tH analyses

2. Better simulation for Higgs produced in association with single-top t- and Wt-channels

- NLO not explored by most of the current generators
  - working on the alternatives available on the market
- complication arising in MadGraph (partially solved with new MC@NLO-Δ)
  - "On the reduction of negative weights in MC@NLO-type matching procedures" [JHEP07(2020)238]

$t\bar{t}+b\bar{b}$ x-section

JHEP 04 (2019) 046



Important for new physics and rare searches

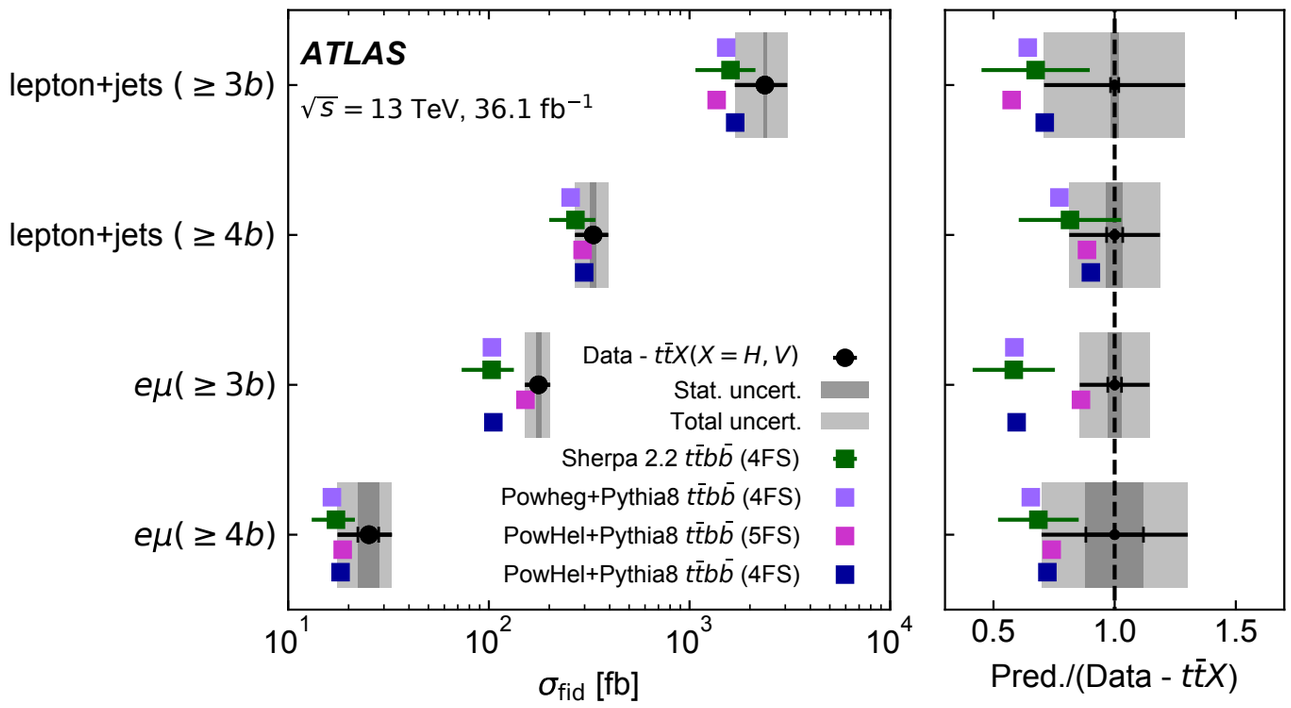
- state-of-the-art NLO predictions suffer from large uncertainty
- experimental input needed to test predictions

Fiducial and differential $t\bar{t}+b\bar{b}$ cross sections in ℓ+jets and dilepton channels using 36 fb^{-1} (@13TeV)

- unfolded to particle level

General excess w.r.t. various NLO predictions

- still compatible within total uncertainties
- **experimental uncertainty smaller than theory one**



Plans & secondment

1. Start first interaction with ATLAS Editoral Board in next months

2. Aim for publications within 1 year

- possibly fast-paper by Winter 2021 and combination paper by Summer 2022

3. Secondment foreseen at CERN, Geneva (Swiss) starting from 07.2021

- analysis consolidation towards publication (approval meetings, faster iterations with Higgs coordination and management, synergy with the analysis team based at CERN)