Top associated Higgs production in the ttH to multileptons channel with one hadronic tau in ATLAS

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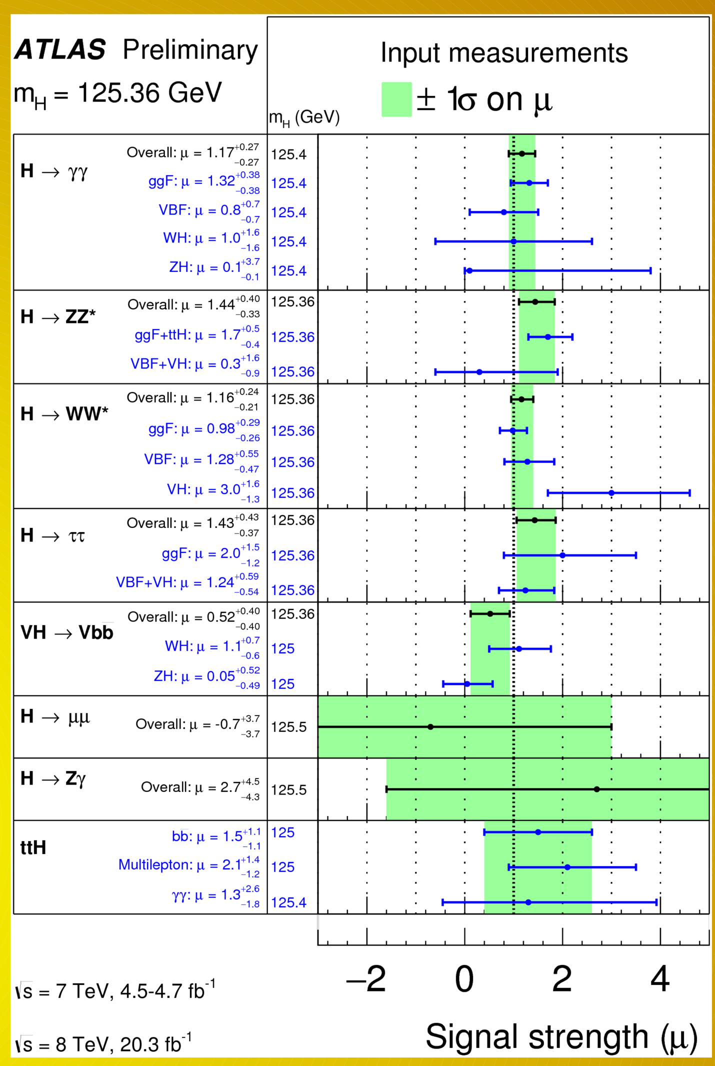
The Higgs boson and ttH

The Higgs boson was discovered in 2012 by its decay channels H → ZZ, H → WW and H → γγ and its mass has been measured to ~ 125 GeV.

Its coupling should be proportional to the mass of the corresponding particle and the Yukawa coupling strengths have been measured in several final states already. However, the top quark one has been accessed only indirectly. This largest Higgs coupling would complete the fermion coupling measurements performed so far and is often called a window to new physics beyond the SM.



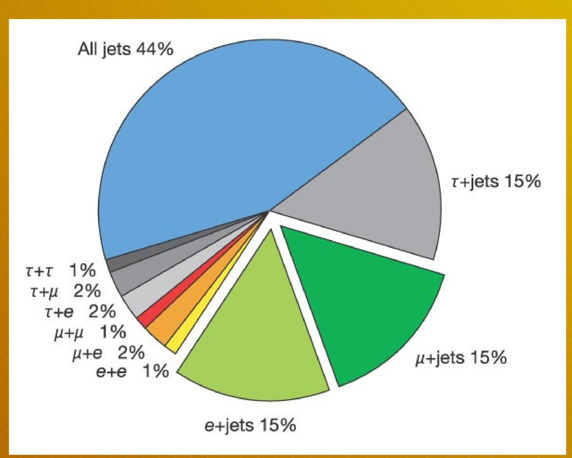
Summary of the signal-strength measurements for a Higgs boson of mass m_H =125.36 GeV, normalised to the SM expectations, for the H→γγ, H→ZZ*, H→WW*, H→ττ, VH→Vbb, H→μμ, H→Zγ, and ttH processes.

The observation of the process in which the Higgs boson is produced in association with a pair of top quarks (ttH) would permit a direct tree-level measurement of the top quark to Higgs boson Yukawa coupling (see Feynman diagram at the lower left), which is otherwise accessible primarily through loop effects.

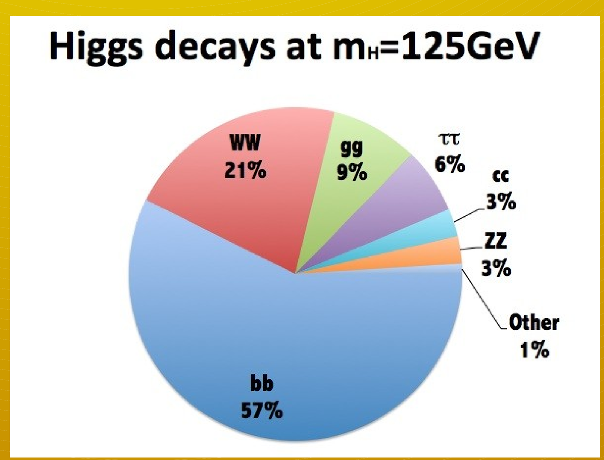
Having both tree- and loop-level measurements would allow disambiguation of new physics effects which could affect the two differently, such as dimension-six operators contributing to the ggH vertex.

The ttH → multileptons channel

The final state in ttH production is defined by the decay products of the top-antitop system as well as those of the Higgs boson.

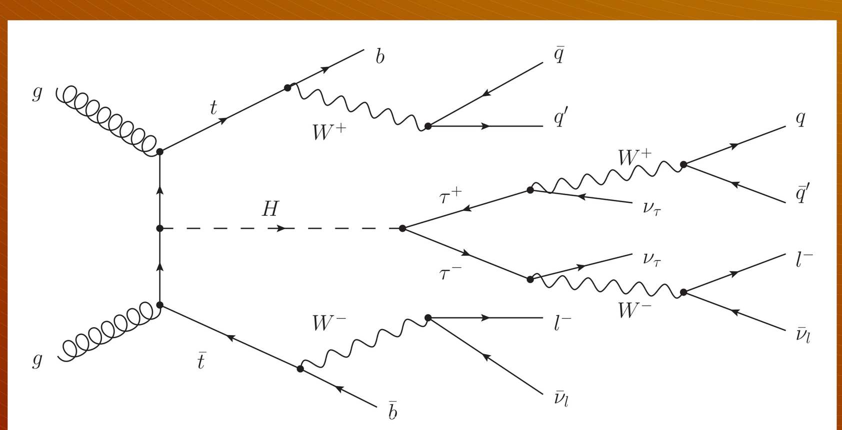


Top-antitop branching fraction ←



Higgs boson branching fraction ←

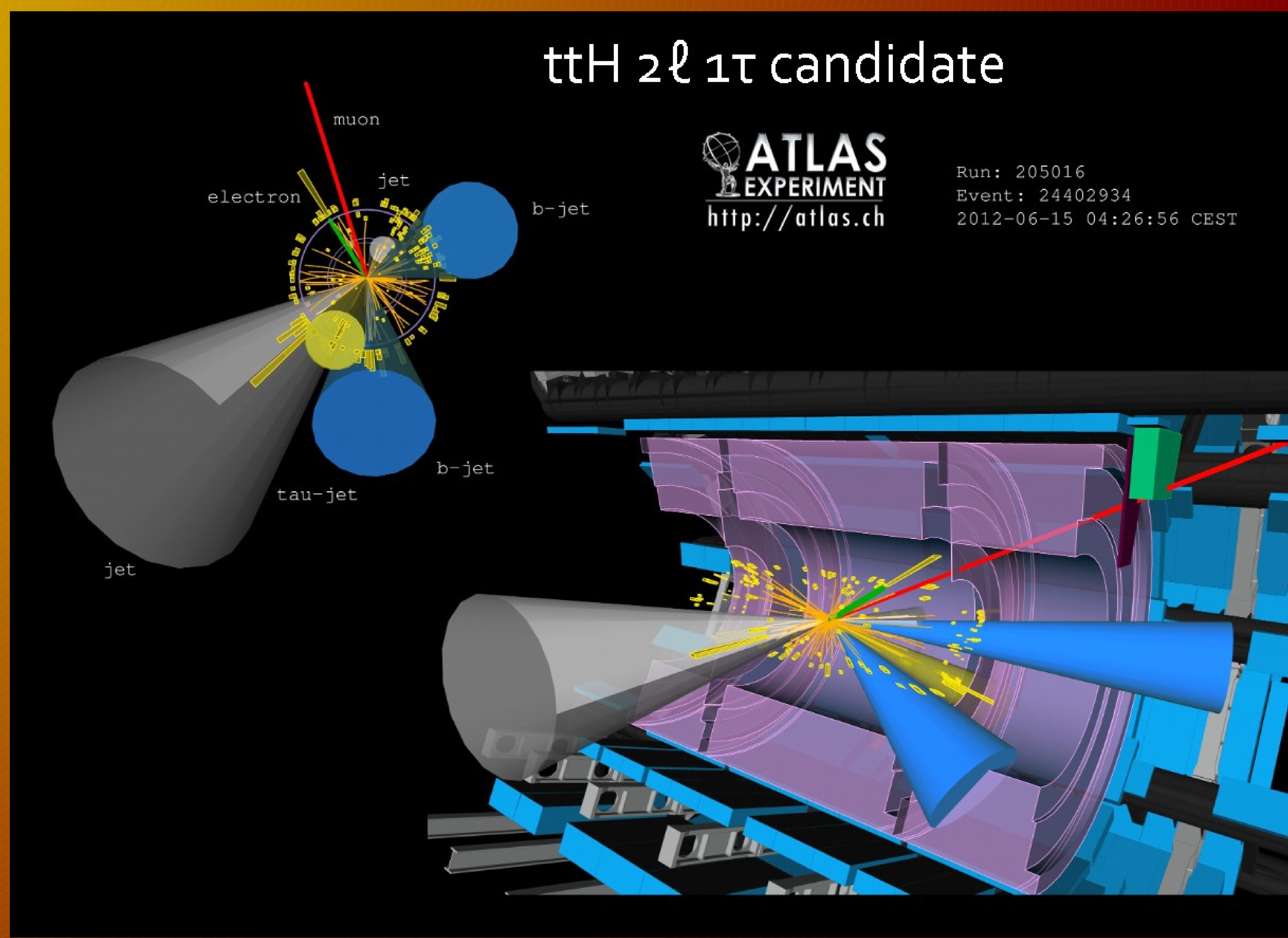
Here we aim for the final state with one top-quark decaying leptonically, the other top decaying hadronically and the Higgs decaying into two tau leptons, one decaying leptonically and one hadronically. This process can be seen in the Feynman diagram below. ↓



The resulting rich final state is selected by those main requirements:

- 2 light, isolated leptons of same charge
- 1 hadronically decaying tau lepton with opposite charge to the light leptons
- at least 4 calorimeter jets
- at least 1 b-tagged jet

ttH → 2l+1τ_{had} candidate in ATLAS collisions

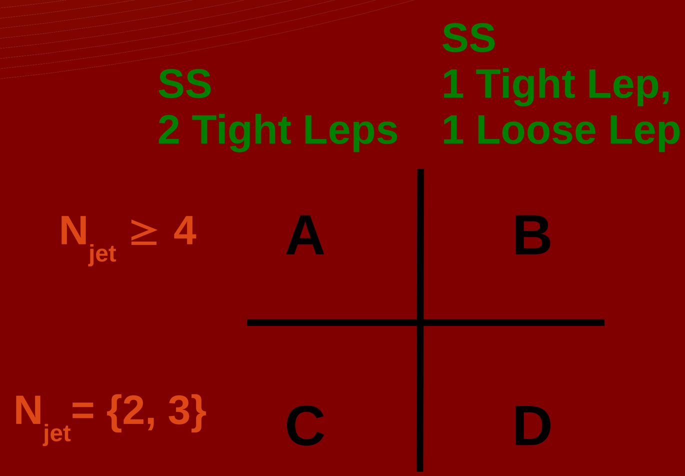


The selected data event of the 2l+1τ_{had} analysis channel. ↑
Visible are the 2 b-jets, 2 light-jets, the electron, the muon and the hadronically decaying tau candidate.

Background estimation

The main reducible (non-prompt) background to the signal selection is direct production of a top-antitop pair ($t\bar{t}$). As the top quarks and thus the W bosons and their leptons as decay products are oppositely charged, the $t\bar{t}$ process cannot produce 2 real, isolated leptons of same charge. We have shown that the second light lepton in $t\bar{t}$ originates from a B-meson decay in more than 95% of the cases.

A 2-dimensional sideband method was developed to estimate the $t\bar{t}$ background events in signal-region (A) from data events in regions B,C and D. It uses loose lepton definitions with adapted isolation to enrich leptons from B-decays. →



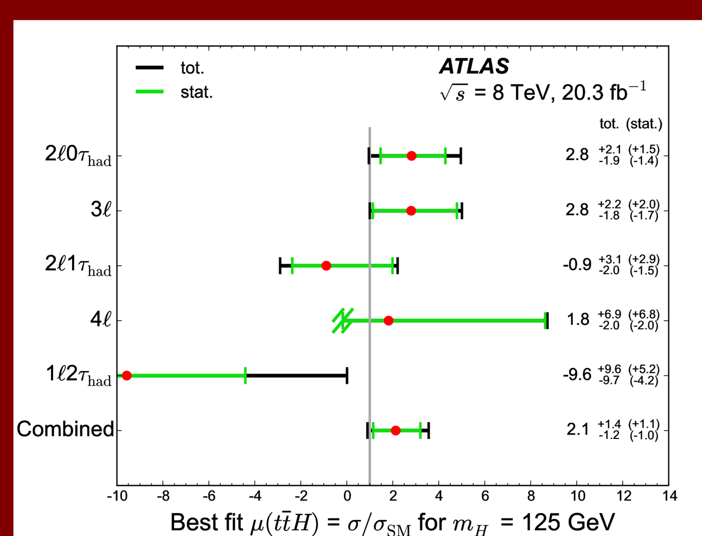
Also the hadronically decaying tau lepton (τ_{had}) can be fake, but is obtained to be real from W decays in about 30% - 50% of the cases in all regions. The fakes are dominantly arising from misidentified light jets. The τ_{had} fakes are included in the background estimation as well and a correction factor is applied to account for small differences in the regions. Possible charge flips of light leptons are covered by this method as such are included in the sideband regions.

Results

Category	q mis-id	Non-prompt	$t\bar{t}W$	$t\bar{t}Z$	Diboson	Expected bkg.	$t\bar{t}H$ ($\mu=1$)	Observed
$ee+\geq 5j$	1.1 ± 0.5	2.3 ± 1.2	1.4 ± 0.4	0.98 ± 0.26	0.47 ± 0.29	6.5 ± 1.8	0.73 ± 0.14	10
$e\mu+\geq 5j$	0.85 ± 0.35	6.7 ± 2.4	4.8 ± 1.2	2.1 ± 0.5	0.38 ± 0.30	15 ± 3	2.13 ± 0.41	22
$\mu\mu+\geq 5j$	–	2.9 ± 1.4	3.8 ± 0.9	0.95 ± 0.25	0.69 ± 0.39	8.6 ± 2.2	1.41 ± 0.28	11
$ee+4j$	1.8 ± 0.7	3.4 ± 1.7	2.0 ± 0.4	0.75 ± 0.20	0.74 ± 0.42	9.1 ± 2.1	0.44 ± 0.06	9
$e\mu+4j$	1.4 ± 0.6	12 ± 4	6.2 ± 1.0	1.5 ± 0.3	1.9 ± 1.0	24 ± 5	1.16 ± 0.14	26
$\mu\mu+4j$	–	6.3 ± 2.6	4.7 ± 0.9	0.80 ± 0.22	0.53 ± 0.30	12.7 ± 2.9	0.74 ± 0.10	20
3ℓ	–	3.2 ± 0.7	2.3 ± 0.7	3.9 ± 0.8	0.86 ± 0.55	11.4 ± 2.3	2.34 ± 0.35	18
$2\ell 1\tau_{had}$	–	$0.4^{+0.6}_{-0.4}$	0.38 ± 0.12	0.37 ± 0.08	0.12 ± 0.11	1.4 ± 0.6	0.47 ± 0.08	1
$1\ell 2\tau_{had}$	–	15 ± 5	0.17 ± 0.06	0.37 ± 0.09	0.41 ± 0.42	16 ± 5	0.68 ± 0.13	10
4ℓ Z-enr.	–	$\lesssim 10^{-3}$	$\lesssim 3 \times 10^{-3}$	0.43 ± 0.12	0.05 ± 0.02	0.55 ± 0.15	0.17 ± 0.02	1
4ℓ Z-dep.	–	$\lesssim 10^{-4}$	$\lesssim 10^{-3}$	0.002 ± 0.002	$\lesssim 2 \times 10^{-5}$	0.007 ± 0.005	0.025 ± 0.003	0

Obtained event yields in all multilep. channels for backgrounds, signal and observation with the one τ_{had} channel highlighted.

The observations are translated into limits and measurements of signal strength μ , also for the other four multilepton channels. The combined measurement is shown at the bottom and is so far in agreement with SM expectations. →



With an increase of signal cross section by a factor of 3.9 from 8 TeV to 13 TeV center-of-mass energy, the ttH channel will *shine* in LHC Run 2.

Reference: The ATLAS Collaboration, *Search for the associated production of the Higgs boson with a top quark pair in multilepton final states with the ATLAS detector*, CERN-PH-EP-2015-109, arXiv:1506.05988v1, sub. to Phys. Lett. B.