

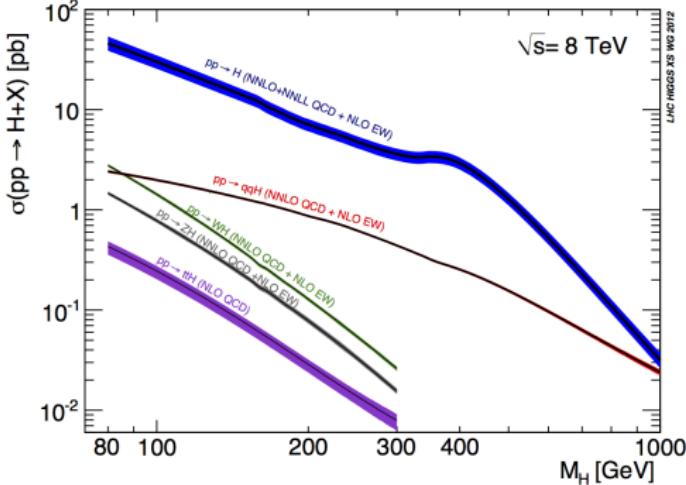
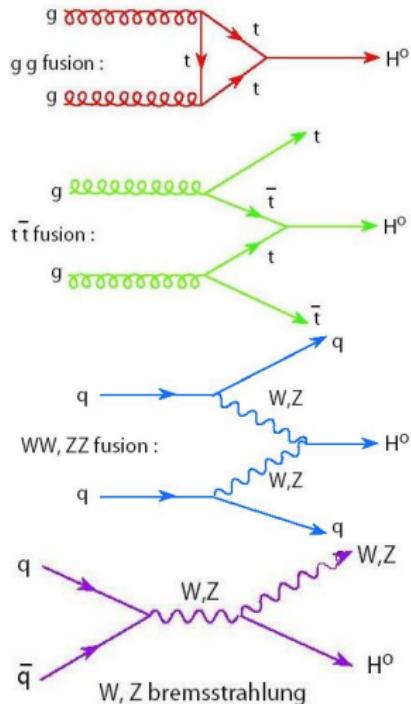
Search for the Higgs boson produced in association with top quarks and decaying into $b\bar{b}$ with the ATLAS detector at LHC

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HASCO - Georg-August-Universität Göttingen
(ATLAS-CONF-2012-135)

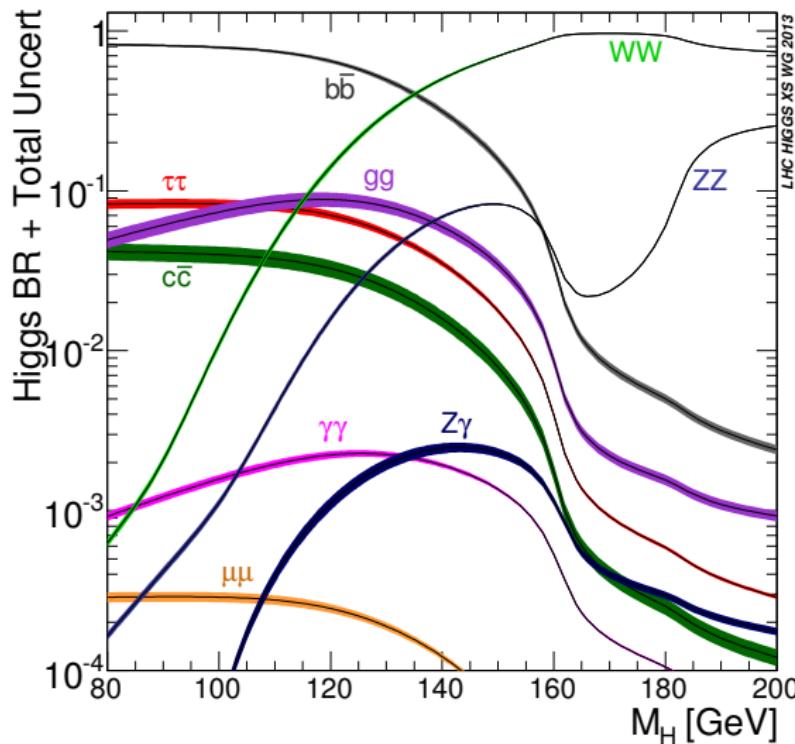
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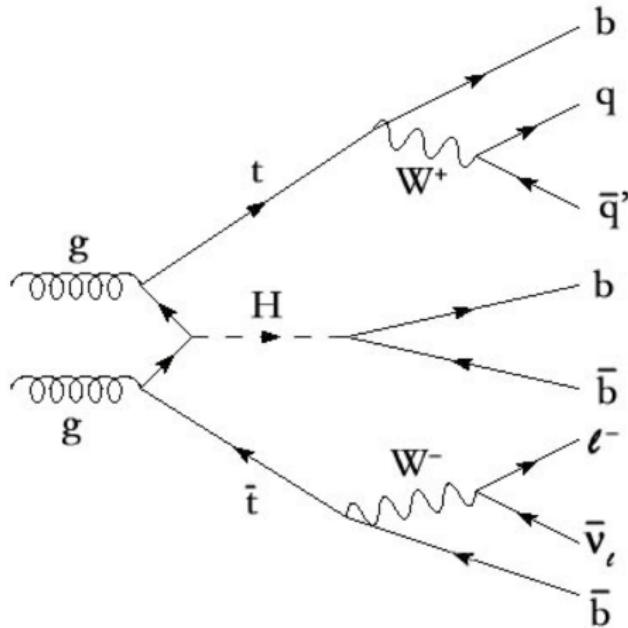
Why search $t\bar{t}H$?



Higgs decay modes

Study $H \rightarrow b\bar{b}$ decay mode → is the dominant decay mode





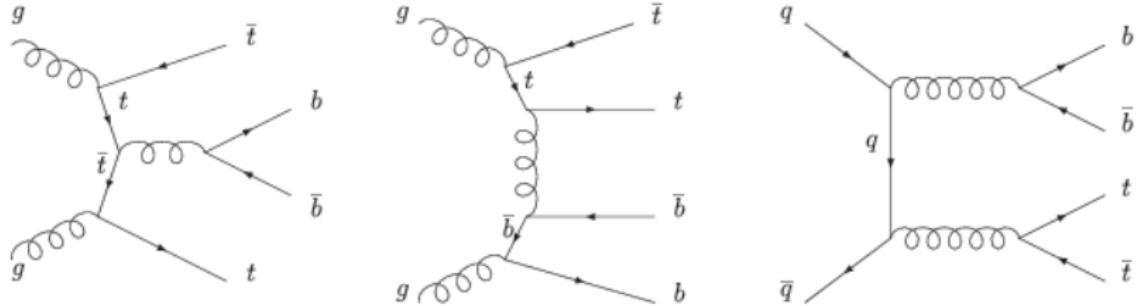
- **Single lepton channel:** signal signature is one lepton, 6 jets of which 4 are b-tagged
- **Dilepton channel:** signal signature is two leptons of opposite charge and 4 jets of which 4 are b-tagged.
- All hadronic channel (not published yet)

Goal: measure the top-Higgs Yukawa coupling $\lambda_{fermion} = \frac{\sqrt{2} \cdot m_{ferm}}{v} \approx 0.992$

Backgrounds

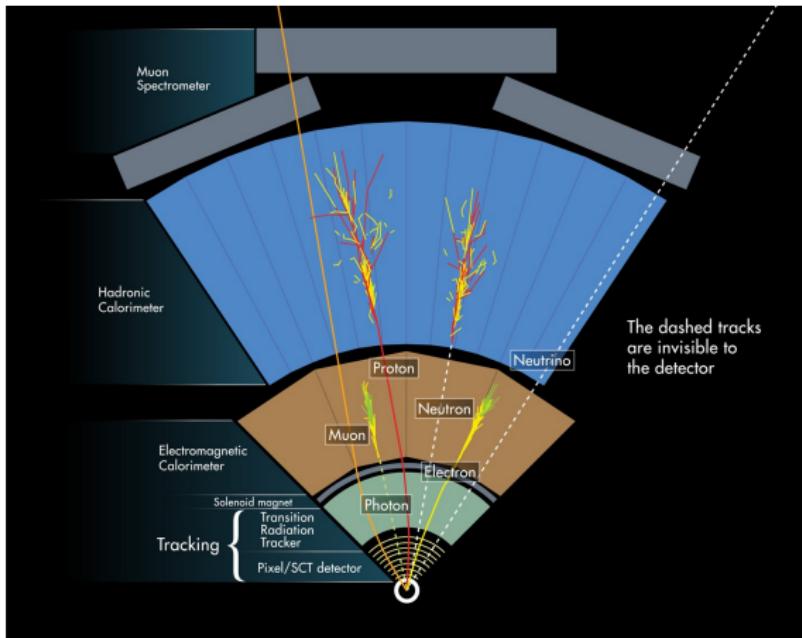
The main source of background to this search comes from $t\bar{t}$ produced in association with at least two extra jets. This source of background has two components:

- $t\bar{t} + b\bar{b} \rightarrow$ same final state signature as the signal (irreducible background)
- $t\bar{t} +$ light jets and $c\bar{c}$



The ATLAS detector

- Data was obtained using the ATLAS-Detector at $\sqrt{s} = 8 \text{ TeV}$ and $\int L dt = 20.3 \text{ fb}^{-1}$ (2012)



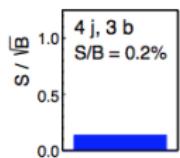
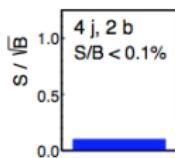
- Especially interested in jet-events → Hadronic Calorimeter

Event selection

Nine independent regions in single lepton channel:

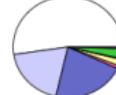
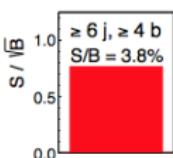
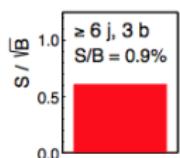
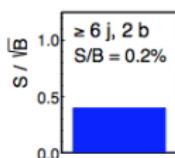
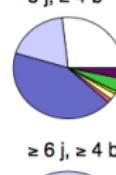
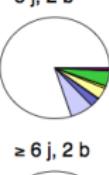
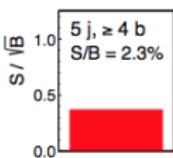
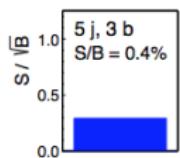
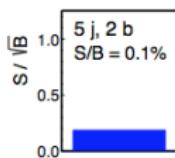
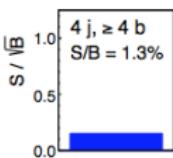
ATLAS Preliminary Simulation

$\sqrt{s} = 8 \text{ TeV}$, $\int L dt = 20.3 \text{ fb}^{-1}$



Single lepton

$m_H = 125 \text{ GeV}$



ATLAS
Preliminary
Simulation
 $m_H = 125 \text{ GeV}$
 $\sqrt{s} = 8 \text{ TeV}$



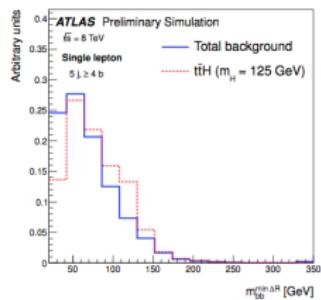
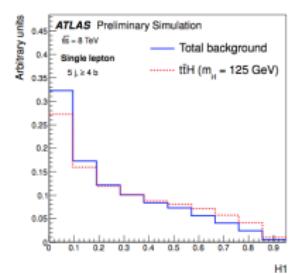
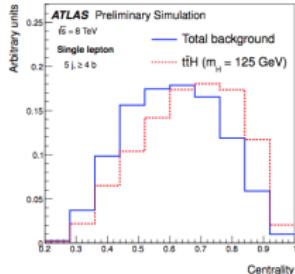
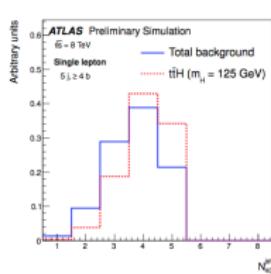
Single lepton

Analysis method: use multivariate analysis (MVA)

Goal: distinguish signal and background

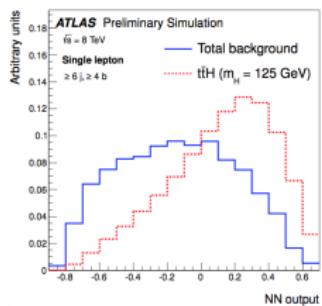
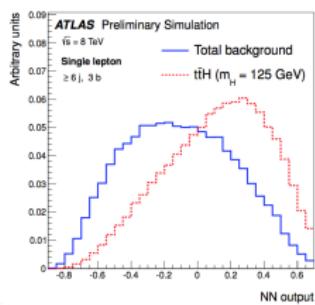
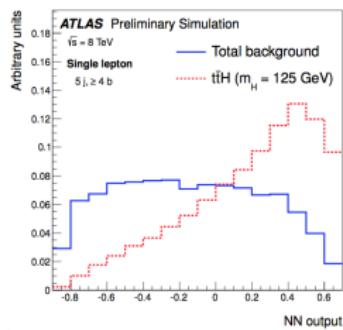
→ **multivariate analysis**: take info from many variables into account

- Choice of the variables: ranking procedure which considers the statistical separation power.
- Considered variables: object kinematics, global event variables, event shape variables and object pair properties.
- All variables used for the multivariate analysis are required to be well described by data in multiple control regions.



Analysis method: use multivariate analysis (MVA)

Final discriminant for the $t\bar{t}H$ signal (red, dotted) and background (blue, solid) for the single lepton channel, in the ($5j, \geq 4b$), ($\geq 6j, 3b$), and ($\geq 6j, \geq 4b$) regions.



Likelihood Analysis

The distributions of the discriminants from each of the channels and regions considered are combined to test for the presence of a signal with $m_H = 125$ GeV → statistical analysis based on a binned likelihood function

$$\mathcal{L}(\mu, \theta) = \prod_{i=1}^M \frac{(\mu \cdot s_i + b_i)^{n_i} e^{-(\mu \cdot s_i + b_i)}}{n_i!}$$

- $\mu = \frac{\sigma}{\sigma_{th}}$ signal strength parameter
- θ = set of nuisance parameters that encode the effect of systematic uncertainties on the signal and background expectations
- M = number of bins
- n_i = number of events in the bin i



Test statistics:

$$q_\mu = -2 \ln \left(\frac{\mathcal{L}(\mu, \hat{\theta}_\mu)}{\mathcal{L}(\hat{\mu}, \hat{\theta}_\mu)} \right)$$

$\hat{\mu}, \hat{\theta}_\mu$ = the best values of the parameters obtained by maximizing \mathcal{L}
 $\hat{\theta}_\mu$ are the values of the nuisance parameters obtained by maximizing \mathcal{L} at μ fixed

Systematic uncertainties

Several sources of systematic uncertainty are considered that can affect the normalisation of signal and background and/or the shape of their corresponding final discriminant distributions.

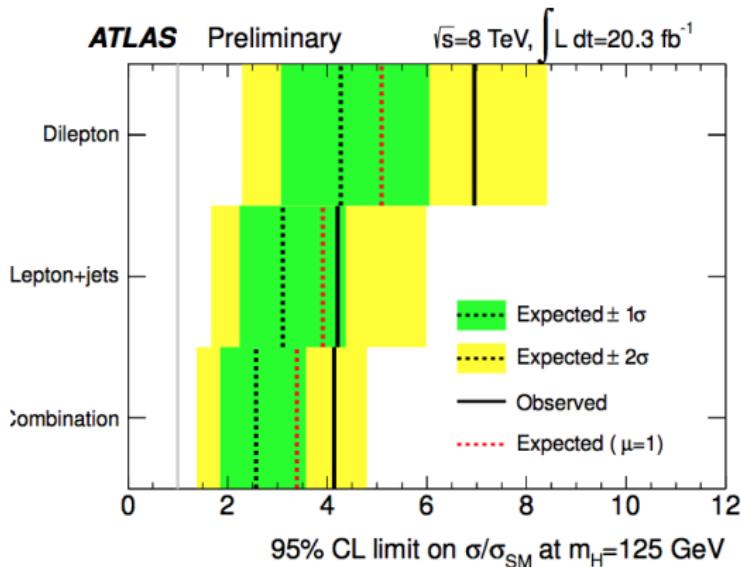
Main systematic uncertainties

- tagging efficiency
- JES
- $t\bar{t}$ heavy-flavour

Results I

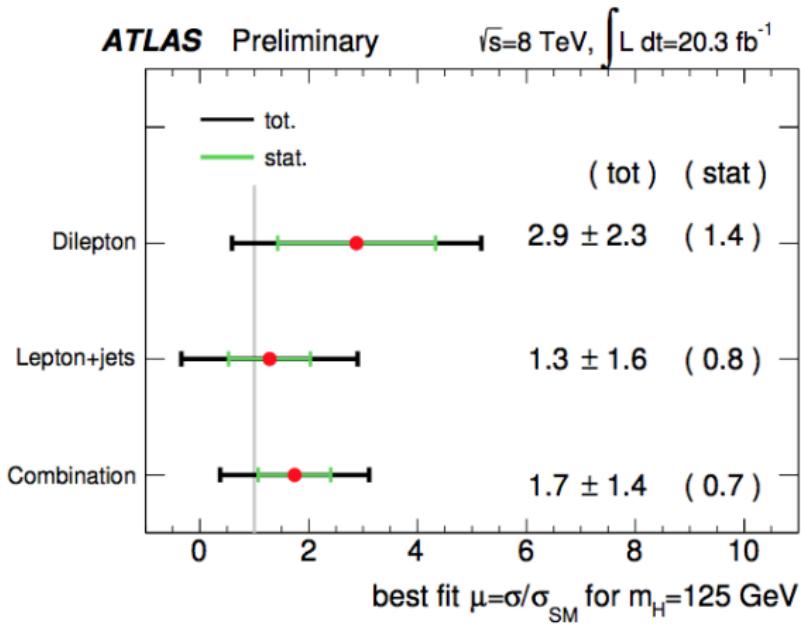
Test statistic used to:

- measure the compatibility of the observed data with the background-only hypothesis ($\mu = 0$)
- make statistical inferences about $\mu \rightarrow$ study upper limits with the CLs method

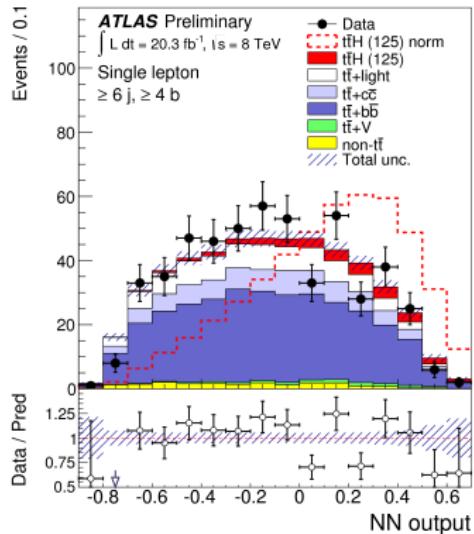


Results II

Fitted value of the signal strength and its uncertainty for the individual channels and their combination, assuming $m_H = 125 \text{ GeV}$



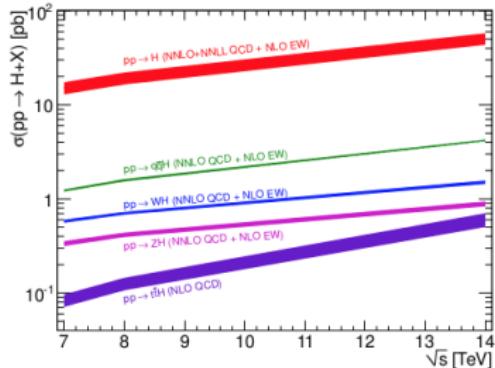
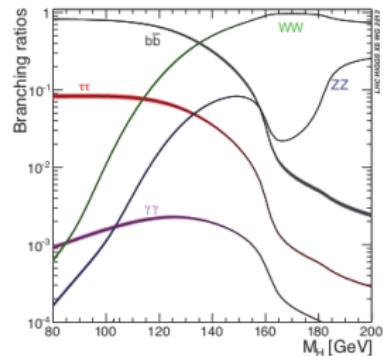
Conclusions



- No significant excess of events above the background expectation is found
- An observed (expected) 95% confidence-level limit of 4.1 (2.6) times the Standard Model cross section is obtained
- By performing a fit under the signal plus background hypothesis, the ratio of the measured signal strength to the Standard Model expectation is found to be $\mu = 1.7 \pm 1.4 \rightarrow$ consistent with the Standard Model one

Future prospects

- ttH analyses not sensitive yet
- higher \sqrt{s} will lead to higher ttH cross-section
- ttbar xsec does not increase by the same amount



Process	$\sigma(8 \text{ TeV})$	$\sigma(14 \text{ TeV})$	$\frac{\sigma(14 \text{ TeV})}{\sigma(8 \text{ TeV})}$
ttH	0.1302 pb	0.6113 pb	4.7
ttbar	234 pb	920 pb	3.9

Back-up Slides

Analysis method

- Neural Network: analysis tool used to discriminate signal from background in the regions with significant expected $t\bar{t}H$ signal contribution.
- In each analysis region of interest a 3-layer feed-forward network is constructed with N_I input nodes in the first layer, $N_I + 2$ nodes in the second layer, and 1 output node in the third and final layer. N_I = the number of variables being considered.

