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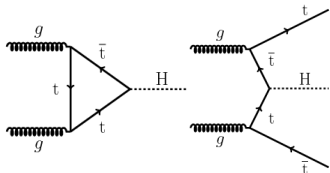
**SERGIO SÁNCHEZ CRUZ**

2<sup>nd</sup> Red LHC workshop

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# **SEARCH FOR TTH PRODUCTION IN MULTILEPTON CHANNELS**

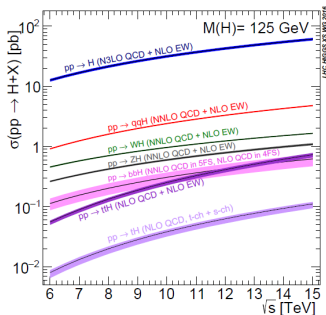
# INTRODUCTION



- ▶ Challenging process to study at the LHC
- ▶ Very rich **experimental signatures** in the different decays of the Higgs
- ▶  $\sigma_{ttH} = 510 \text{ fb}$  at 13 TeV
- ▶ Run 2 provides a **unique opportunity for observation**

## Top-Higgs Yukawa coupling at the LHC

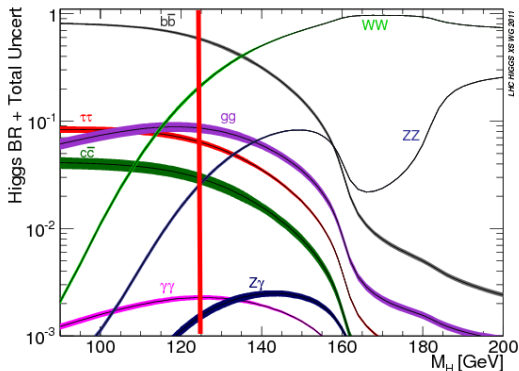
- ▶ Indirect probe through gluon fusion
- ▶ Direct sensitivity from  **$ttH$  production**



## EXPERIMENTAL SIGNATURES

Several topologies depending on the decay mode of the Higgs

- ▶  $H \rightarrow b\bar{b}$ : large branching ratio but large irreducible  $t\bar{t} + b\bar{b}$
- ▶  $H \rightarrow \gamma\gamma$ : very clear final state, but tiny branching ratio
- ▶  $H \rightarrow WW^*, ZZ^*, \tau\tau$ : lower BR, small backgrounds

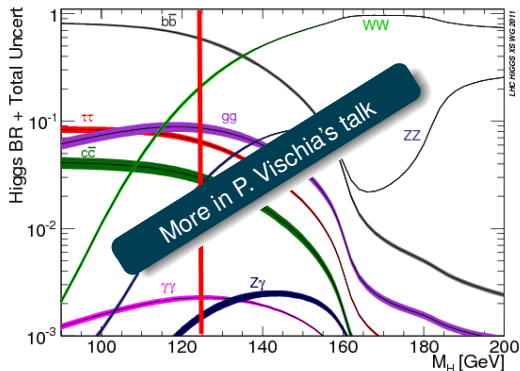


- ▶  $t\bar{t}H$  multileptons: [CMS-PAS-HIG-17-004](#)
- ▶ Combination  $\tau_h$  categories: [arXiv:1803.05485](#)

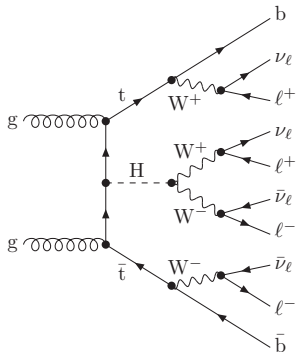
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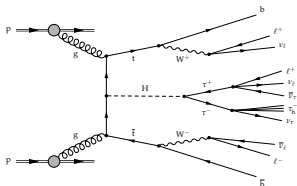
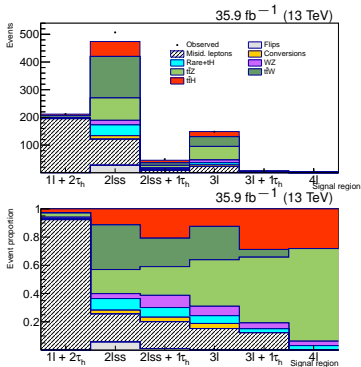
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- ▶  $H \rightarrow WW^*, ZZ^*, \tau\tau$  : lower BR, small backgrounds  $\Leftarrow$  covered in this talk



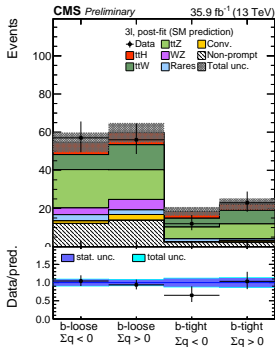
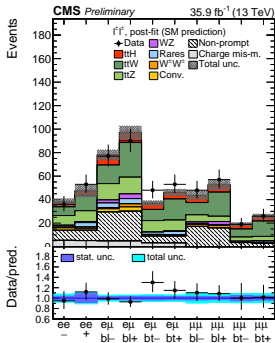
- ▶ ttH multileptons: [CMS-PAS-HIG-17-004](#)
- ▶ Combination  $\tau_h$  categories: [arXiv:1803.05485](#)



- ▶ Several categories depending on number of light leptons and hadronic taus
- ▶ High jet and  $b$ -jet multiplicity

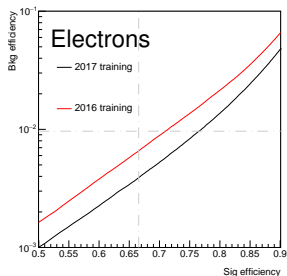
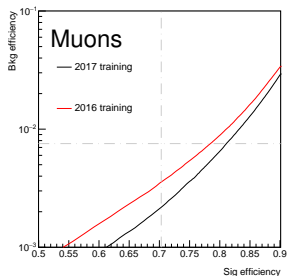


- ▶  $ttV$  production from simulated events
- ▶ non-prompt leptons obtained from data-driven methods



- ▶ Further categorization in  $2l$ ss and  $3l$  categories
  - ▶ Event categorization in **lepton flavor**, **charge** and **b-jet multiplicity**
- ▶ Signal regions still dominated by background
  - ▶ Targeted **multivariate discriminants** for background rejection

# MULTIVARIATE LEPTON IDENTIFICATION

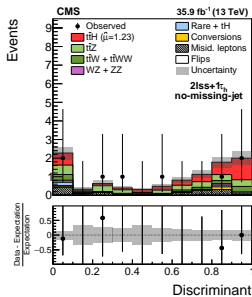
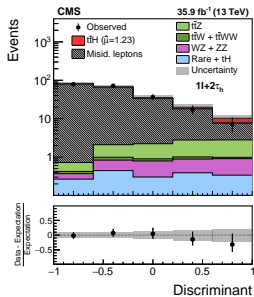
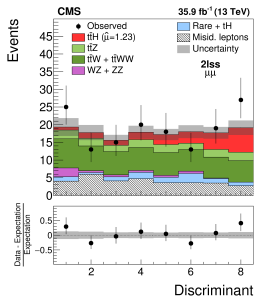


- ▶ Multivariate discriminant to distinguish
  - ▶ Prompt leptons produced in W or Z decays
  - ▶ Leptons produced in other sources (b decays and misid. jets)
- ▶ Very efficient in discriminating main sources of background

- ▶ Improvements in the lepton identification discriminants
- ▶ Adapted to the current detector conditions
- ▶ Redefinition of isolation and jet variables
  - ▶ Sizable gain with respect to the currently published discriminant
  - ▶ Gain is more significant for electrons and low  $p_T$

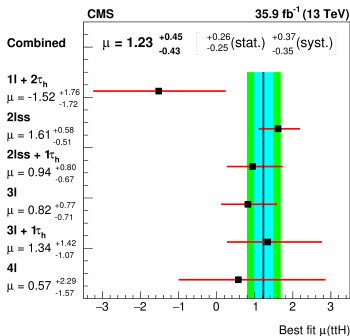
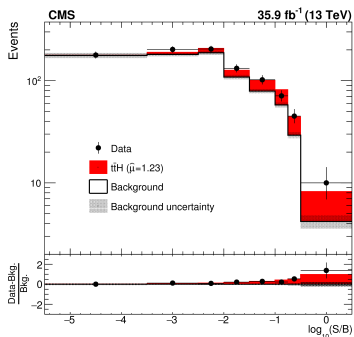
**Work in progress**

- ▶ Event-by-event background discrimination based on
  - ▶ Multivariate hadronic top decay and Higgs decay taggers
  - ▶ Matrix element techniques
  - ▶ Other kinematic variables
- ▶ BDT discriminants trained against  $t\bar{t}$  and  $t\bar{t}V$ 
  - ▶ Discriminators combined into a single variable using a likelihood discriminant
  - ▶ Optimal choice of bin multiplicity with a recursive application of the  $k$ -means algorithm



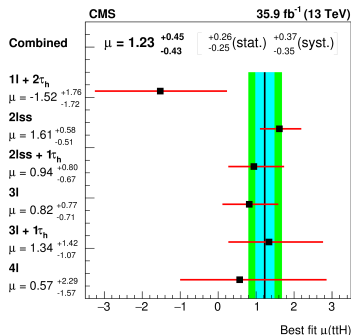


# RESULTS



- ▶ Evidence for ttH production 3.2  $\sigma$  (2.8  $\sigma$  expected)
- ▶ Main uncertainties: theoretical uncertainties (12%), reducible background estimate (11%), lepton identification (11%)

# CONCLUSIONS



- ▶ We have obtained evidence for ttH production in the multilepton channel
- ▶ Measurement dominated by systematic uncertainties
- ▶ Still room for improvement in **lepton identification** and **reducible background estimation and rejection**

- ▶ Looking forward for an observation of ttH in this channel
- ▶ Keep tuned for more results!

# Back-up

## LIMIT PER CATEGORY

Category	Observed limit on $\mu$	Expected limit on $\mu$
$1\ell + 2\tau_h$	2.7	$4.1^{+1.7}_{-1.4}$
$2l_{ss}$	2.8	$1.0^{+0.4}_{-0.2}$
$2l_{ss} + 1\tau_h$	2.5	$1.4^{+0.7}_{-0.3}$
$3\ell$	2.7	$1.6^{+0.8}_{-0.4}$
$3\ell + 1\tau_h$	4.4	$2.8^{+1.3}_{-0.6}$
$4\ell$	6.5	$4.9^{+2.8}_{-1.1}$
Combined	2.1	$0.8^{+0.3}_{-0.2}$