

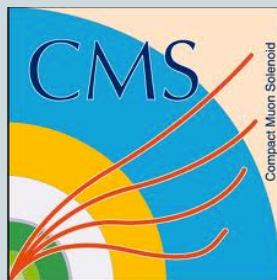
# Search for $H \rightarrow bb$ in association with single top quark as a test of Higgs boson couplings

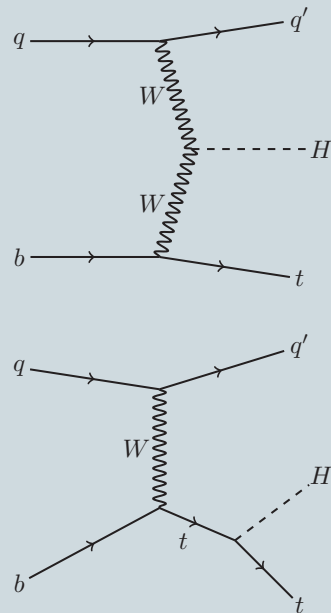
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November 14, 2014 USLUA - Argonne

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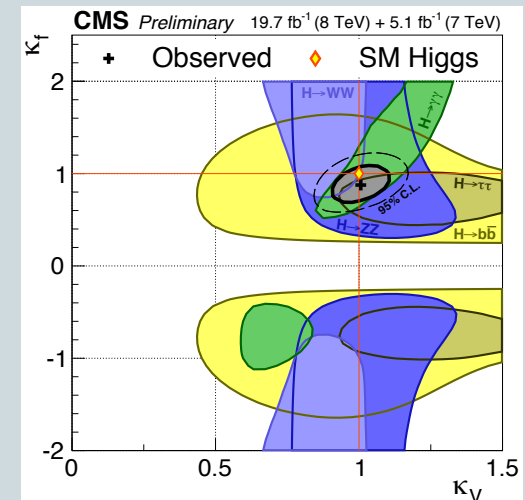
On behalf of the tH(bb) Group



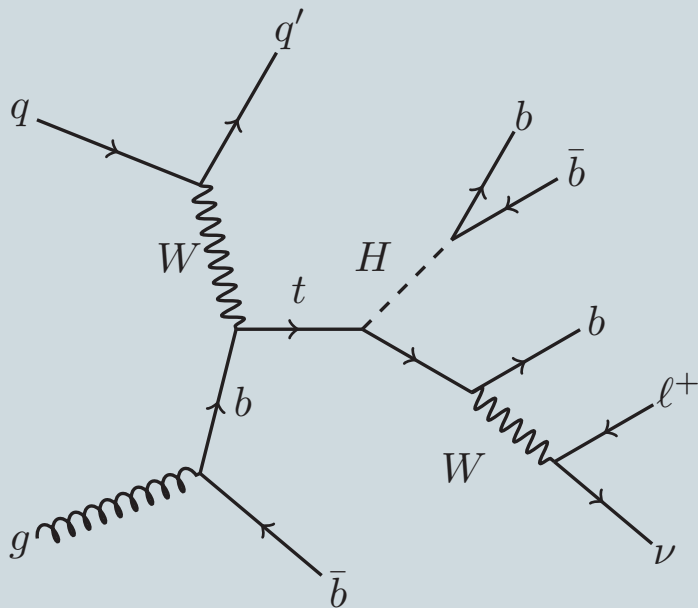


- Core process is single top t-channel
- Two dominate diagrams where the Higgs couples to the W or top quark
  - Destructive interference in SM,  $\sigma \approx 18.3$  fb
  - With an inverted sign of the top Yukawa,  $y_t = -1$ , constructive interference,  $\sigma \approx 234$  fb
  - $\sim 13$  times enhancement

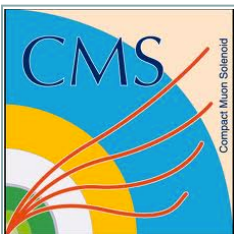
- Original interest arose from the presence of two allowed regions in the  $\kappa_f/\kappa_V$  plane
  - $H \rightarrow \gamma\gamma$  only one sensitive to sign of  $\kappa_f$
  - Updated results show  $\kappa_f = -1$  is disfavored



- Analysis is optimized for  $y_t = -1$  case
- Top decaying leptonically,  $t \rightarrow b l \nu$  ( $l = e, \mu$ )
- Higgs decay to a pair of b quarks,  $H \rightarrow b \bar{b}$
- Use the full 2012 / 8TeV dataset,  $\sim 20/\text{fb}$



- Final state objects
  - Forward jet,  $q'$ , from t-channel process
  - Two b-jets from Higgs decay
  - 1 isolated lepton, MET, and a b-jet from top decay
  - Additional b-jet from initial state gluon splitting (acceptance)



# Event Selection



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- Standard CMS jet and lepton selection applied
- Single lepton triggers used
- Signal regions include events with 3 or 4 b-tagged jets
- ttbar control region has 2 b-tag jets

1 tight lepton $\mu/e$
3 or 4 b-tagged jets
$\geq 1$ jet fails b-tag
$\geq 4$ jets with $p_T > 30$ GeV/c
MET $> 35/45$ GeV ( $\mu/e$ )

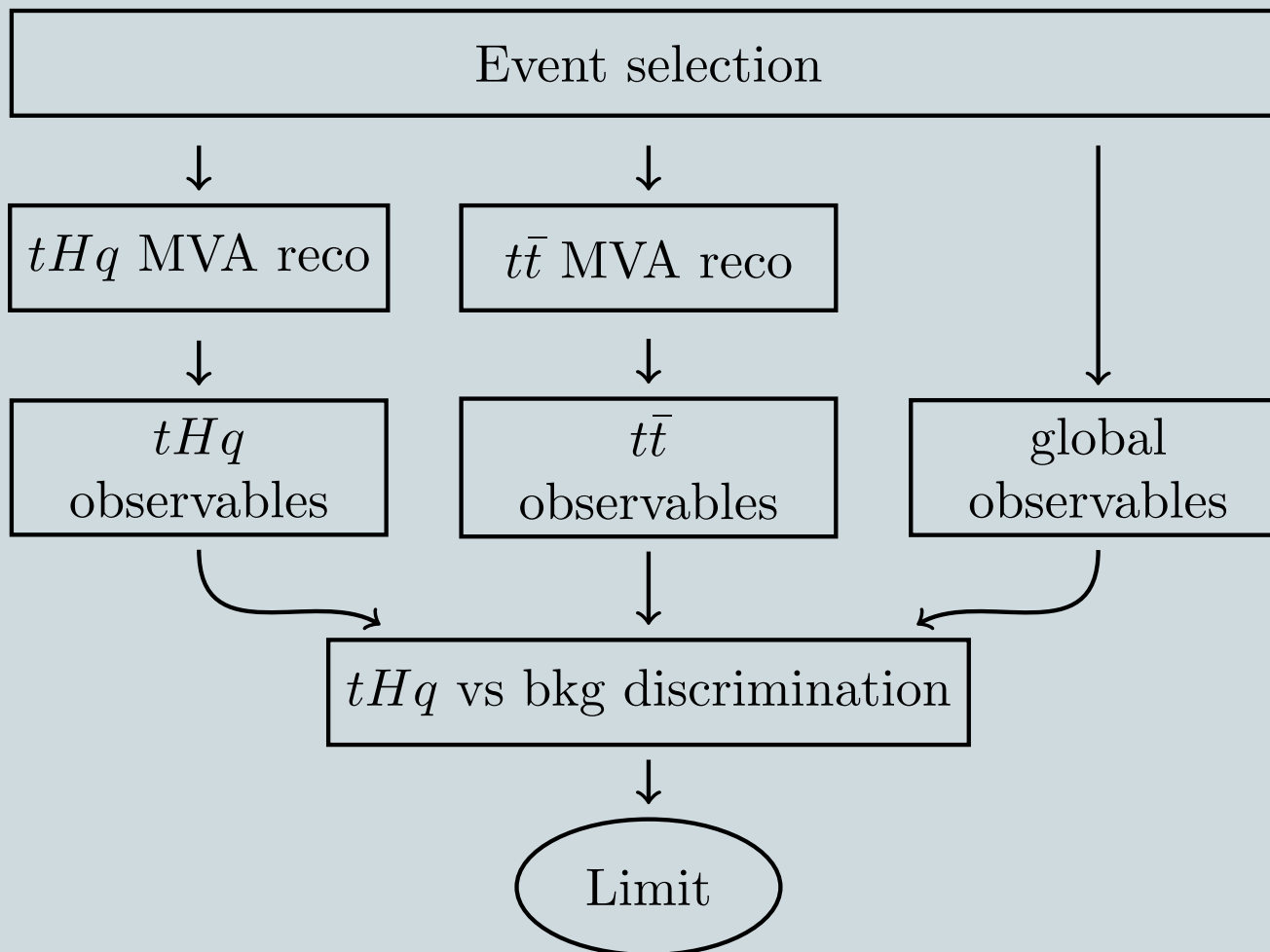
## Pre-selection expected yields

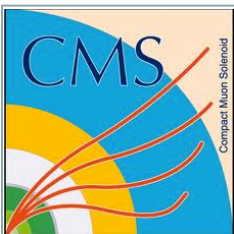
### 3-tag signal region

Process	Muon channel	Electron channel
$t\bar{t}$	$1058 \pm 5$	$718 \pm 4$
Single top	$39 \pm 3$	$27 \pm 3$
Electroweak	$17^{+7}_{-5}$	$11 \pm 7$
$t\bar{t}H$	$12.87 \pm 0.17$	$9.35 \pm 0.15$
Total background	$1128 \pm 9$	$767 \pm 10$
$tHq, y_t = -1$	$7.54 \pm 0.03$	$5.15 \pm 0.02$
S/B ratio	0.7%	0.7%

### 4-tag signal region

Process	Muon channel	Electron channel
$t\bar{t}$	$29.1 \pm 0.8$	$19.8 \pm 0.7$
Single top	$1.1^{+0.8}_{-0.6}$	$1.2 \pm 1.0$
Electroweak	$4^{+6}_{-4}$	$5^{+6}_{-4}$
$t\bar{t}H$	$1.72 \pm 0.06$	$1.43 \pm 0.05$
Total background	$37^{+6}_{-4}$	$29^{+7}_{-4}$
$tHq, y_t = -1$	$0.835 \pm 0.010$	$0.580 \pm 0.009$
S/B ratio	2.3%	2.0%



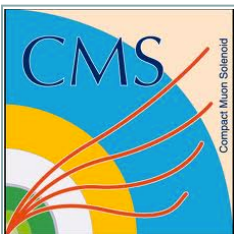


# Event Reconstruction (1)



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- Hypothesize it is a tHq event
  - Higgs candidate
  - Top candidate
  - Forward light jet
- Hypothesize it is a semi-leptonic ttbar event
  - Hadronic top candidate
  - Leptonic top candidate
- This is a multi-jet final state leading to difficulty in assigning jets to each candidate
  - There are many ways to match reconstructed jets in each hypothesis
  - Each possible combination is known as an interpretation
  - An MVA is trained using tHq and semi-lep ttbar MC respectively
    - ✦ If each reconstructed jet matches the generator quark ( $\Delta R < 0.3$ ), then the interpretation is labeled as **correct**
    - ✦ Otherwise, the interpretation is labeled as **wrong**

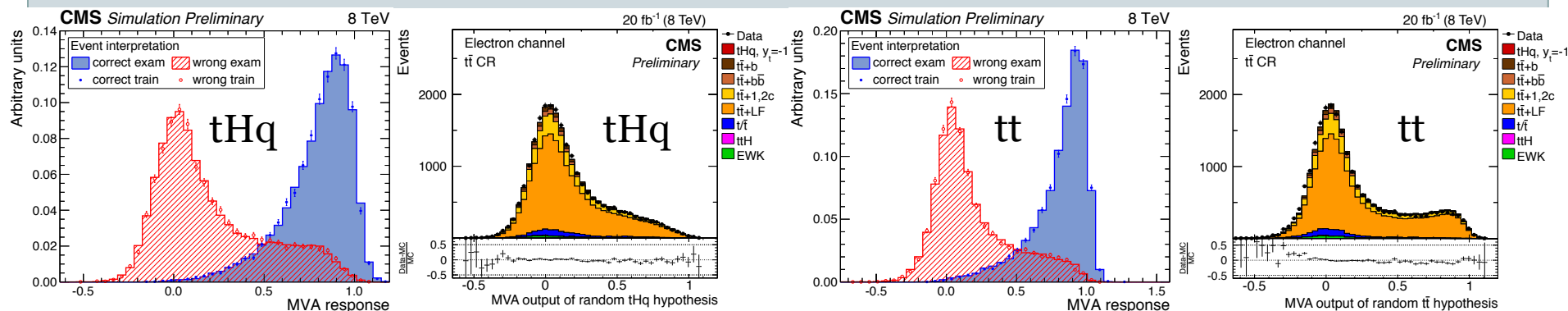


# Event Reconstruction (2)

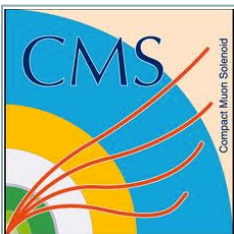


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- The MVA separates **correct** and **wrong** interpretations
- Train “correct” matches vs. randomly picked “wrong” matches
- Events that do not contain a “correct” match (acceptance/inefficiencies) are not used in training



- Once each event reconstruction is complete, a set of observables are available for use
  - $tHq$ : Higgs  $p_T$ ,  $|\eta|$  forward jet, top mass
  - $t\bar{t}$ : leptonic top mass,  $\Delta R$  between light jets  $W_{had}$
- These variables can then be used for sig./bkg. discrimination

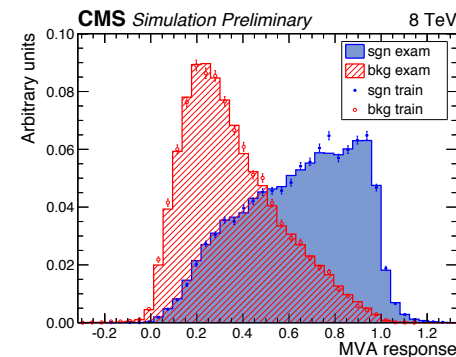
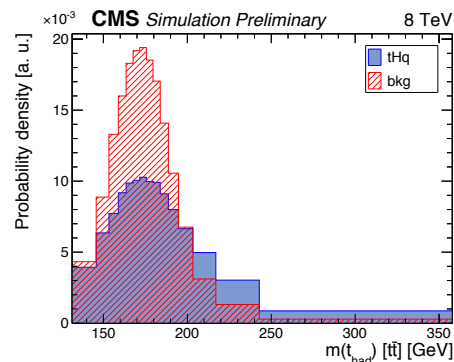
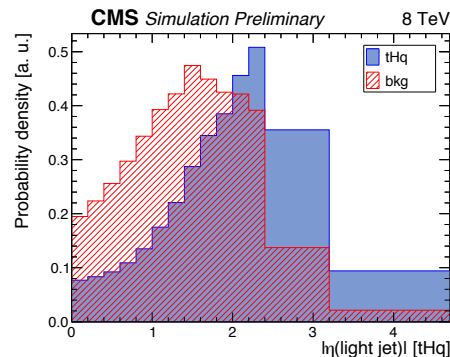
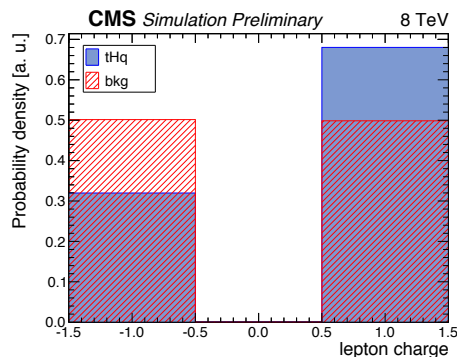


# Signal Extraction



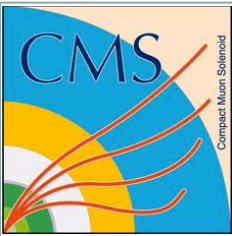
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- The previous MVAs were only used to reconstruct objects and obtain useful variables
- To separate signal and background, a third MVA is trained using select inputs
  - Global observables
  - Variables defined in signal (tHq) interpretation
  - Variables defined in background (ttbar) interpretation



- Signal: tHq ( $y_t = -1$ )
- Background
  - Semi-lep ttbar, di-lep ttbar, and ttH
  - Others not considered in training (statistics limited)

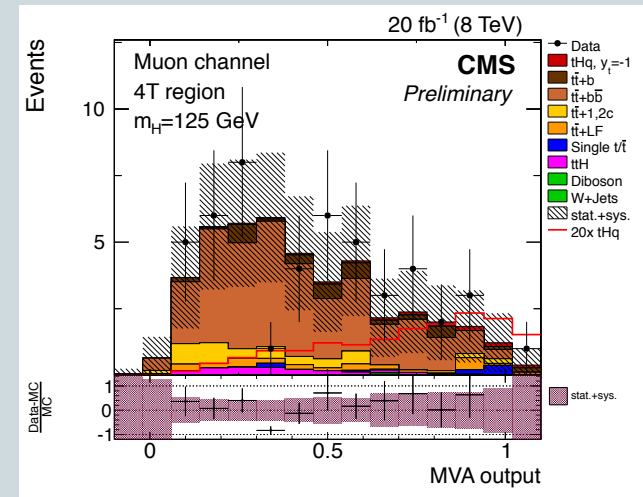
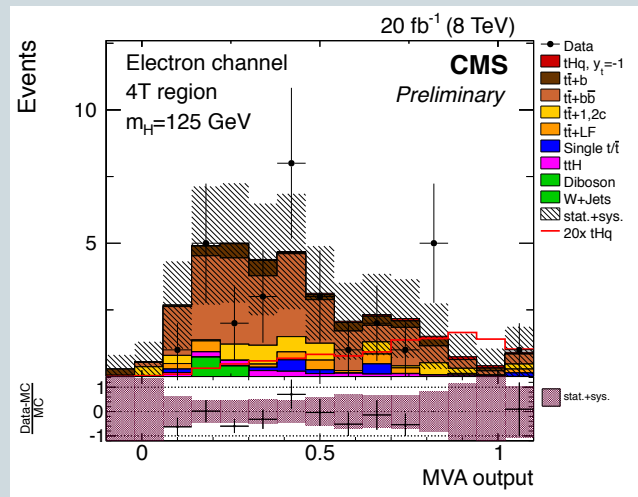
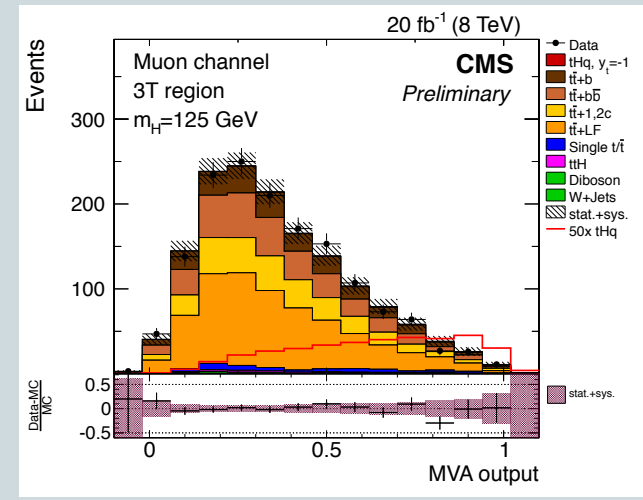
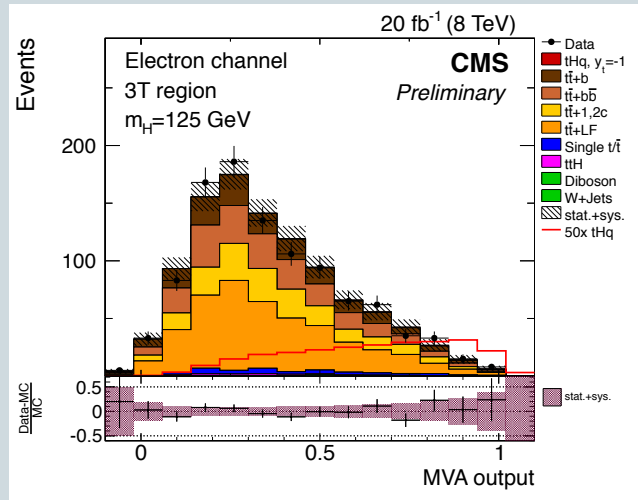


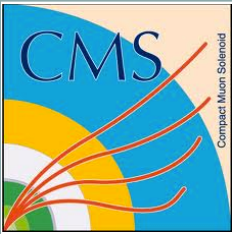


# Post-fit MVA Outputs



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# Result



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- The limit fit to data is performed simultaneously in the MVA output distributions on the previous slide
  - All systematics included as nuisance parameters

CL <sub>s</sub> limit on $\sigma_{95\%} / \sigma_{y_t=-1}$	
Expected	Observed
5.14 <sup>+2.14</sup> <sub>-1.44</sub>	7.57

- Analysis able to exclude at 95% C.L. tHq production ( $y_t=-1$ ) with a cross section  $> 1.8$  pb (1.3 pb expected)
- Cross-check analysis with data-driven ttbar estimation is consistent

- tHq ( $H \rightarrow \gamma\gamma$ ) expected and observed limit of  $\sim 4$  (zero events after unblinding)
- Future combination

Analysis	Status
t( $H \rightarrow bb$ )q	Approved
t( $H \rightarrow \gamma\gamma$ )q	Approved
t( $H \rightarrow WW$ )q	Underway
t( $H \rightarrow \tau\tau$ )q	Underway