Higgs Bosons Decaying to Fermions in ATLAS and CMS

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on behalf of the ATLAS Collaboration
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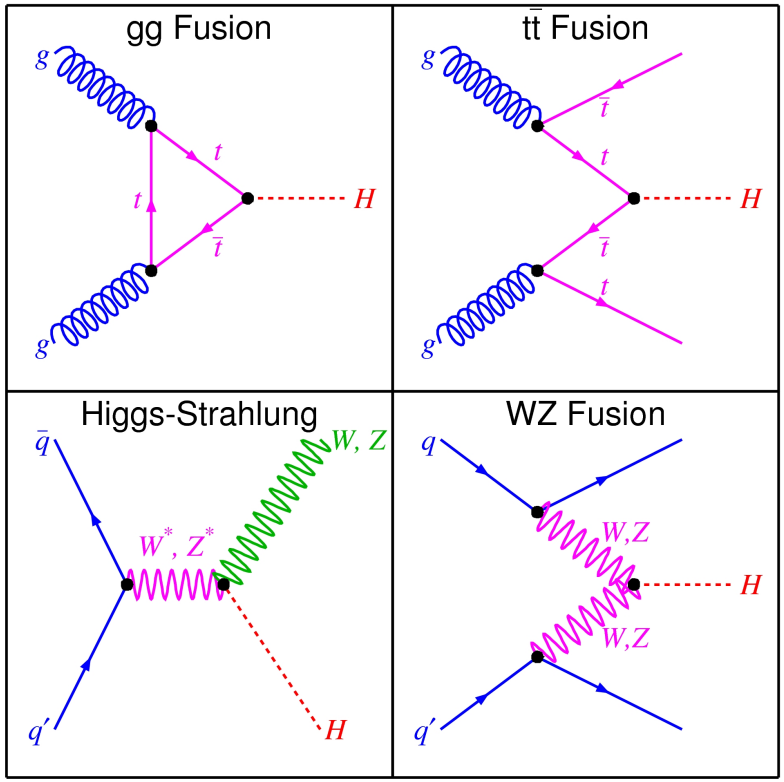
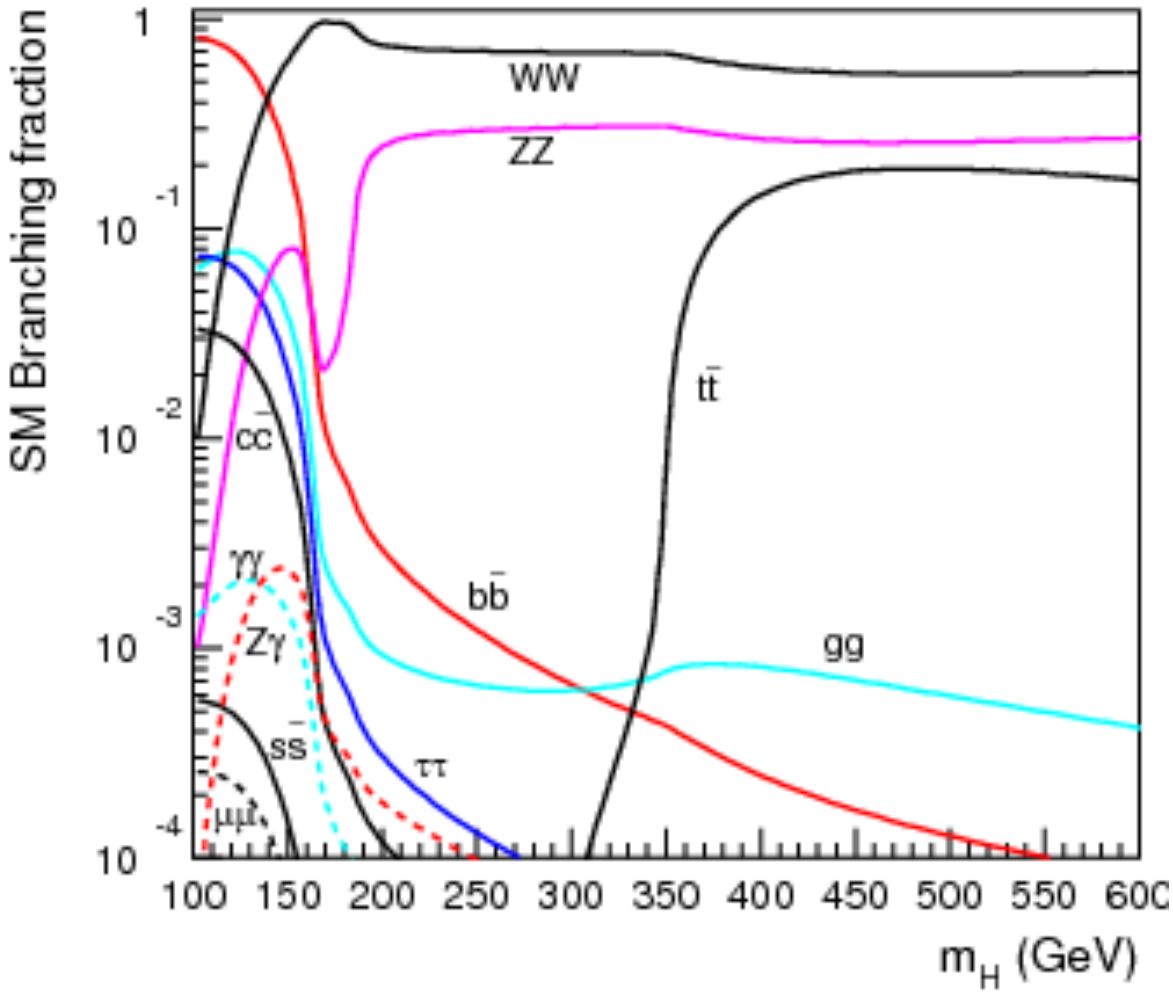
Introduction

- Newly discovered Higgs boson must be studied
- Has a mass (approx. 126 GeV) that decays in many channels
- Discovered in the $\gamma\gamma$ and heavy vector boson channels
- Large BR to bb
- $\tau\tau$ also in the picture
- $\mu\mu$ rounds out the SM fermionic channels

Production Channels



Branching Fractions



$H \to \tau\tau$ Motivation

- Direct coupling to lepton sector
- 4th channel for observation, after vector bosons and $\gamma\gamma$
- 6.3% branching ratio at m_H=125 GeV

$\tau_{lep}\tau_{had}$ $\tau_{lep}\tau_{lep}$ $\tau_{had}\tau_{had}$

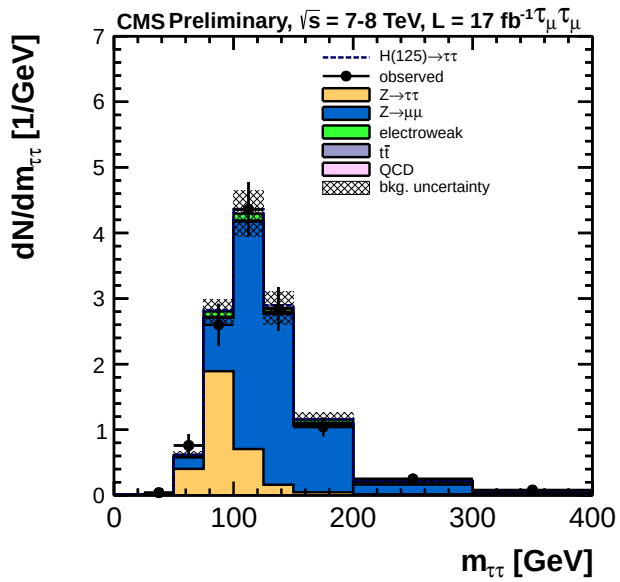
$H \to \tau\tau$: Overview of Analyses

	VBF	Boosted	VH	1-jet	ttH	0-jet*
$\mu\tau_{had}$						
$e\tau_{had}$						
μe						
$\mu\mu$						
ee						
$\tau_{had}\tau_{had}$						

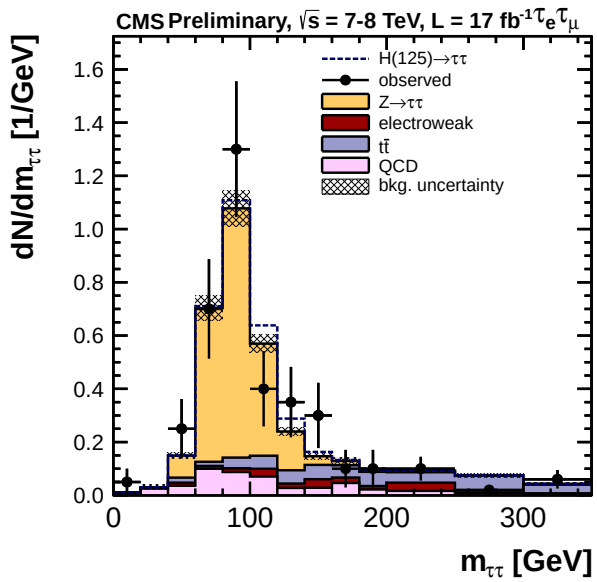
* ATLAS: 7 TeV only; CMS: control region only

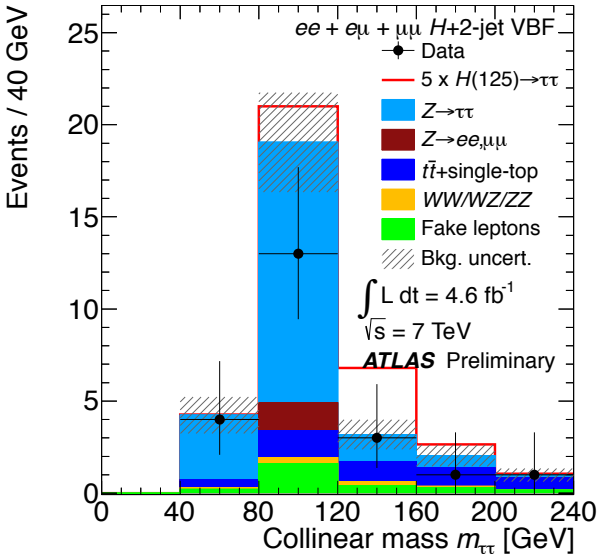
NB: Analysis definitions not identical between collaborations! See notes for more detail

$H \to \tau\tau$: $\tau_{lep}\tau_{lep}$ VBF

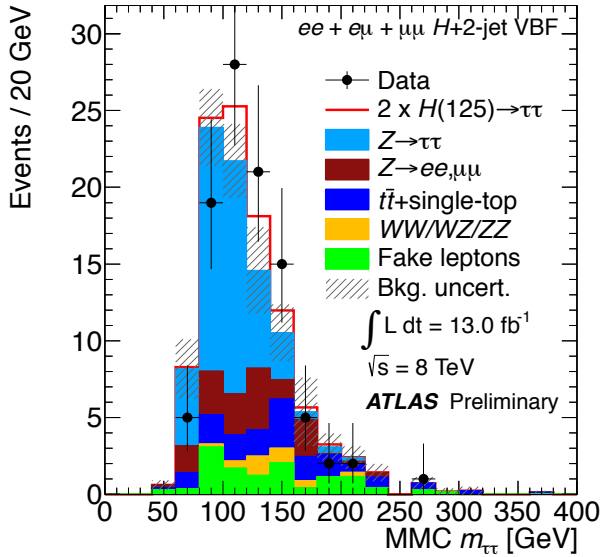


CMS breaks down results by final state of τ's ($\mu\mu$ vs. $e\mu$)
7 TeV and 8 TeV data combined

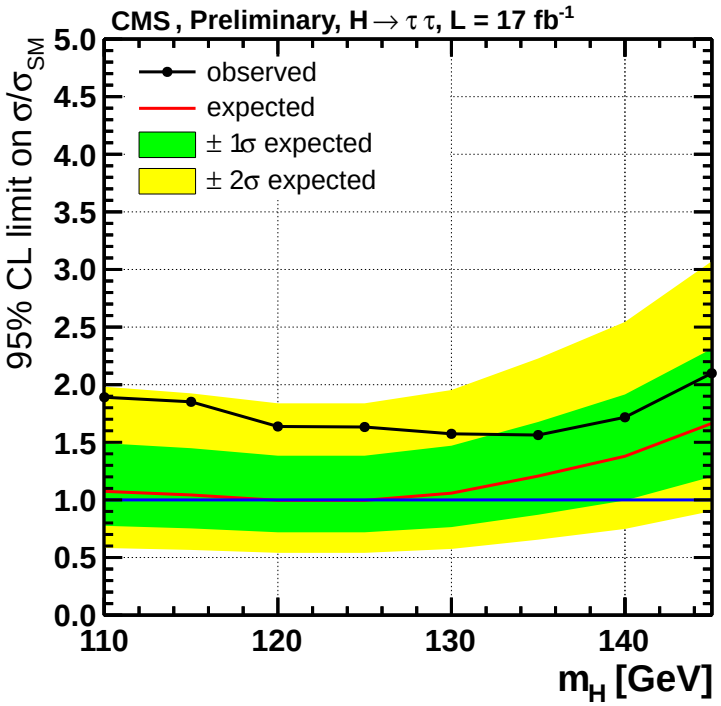




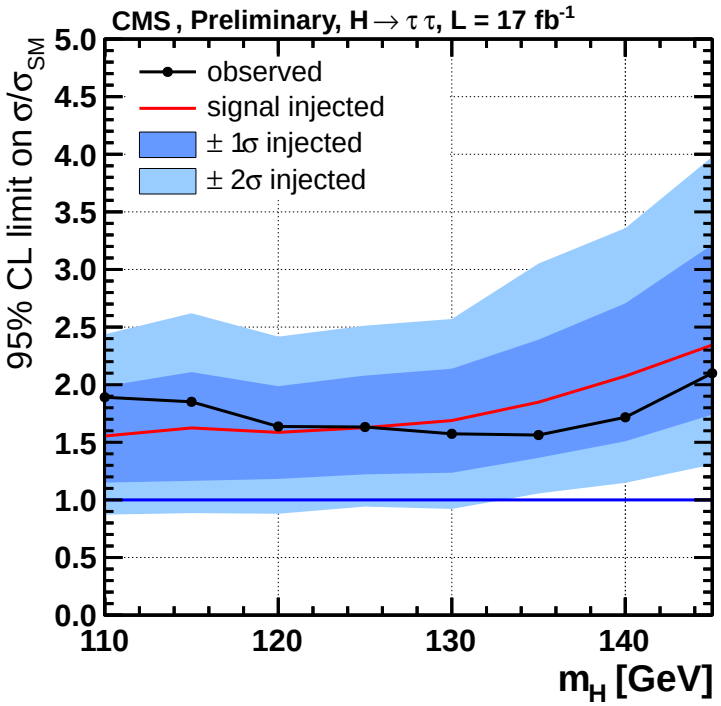
ATLAS breaks down results by energy (7 TeV vs. 8 TeV)
τ final states combined (ee, $e\mu$, $\mu\mu$)



$H \to \tau\tau$: CMS Sensitivity

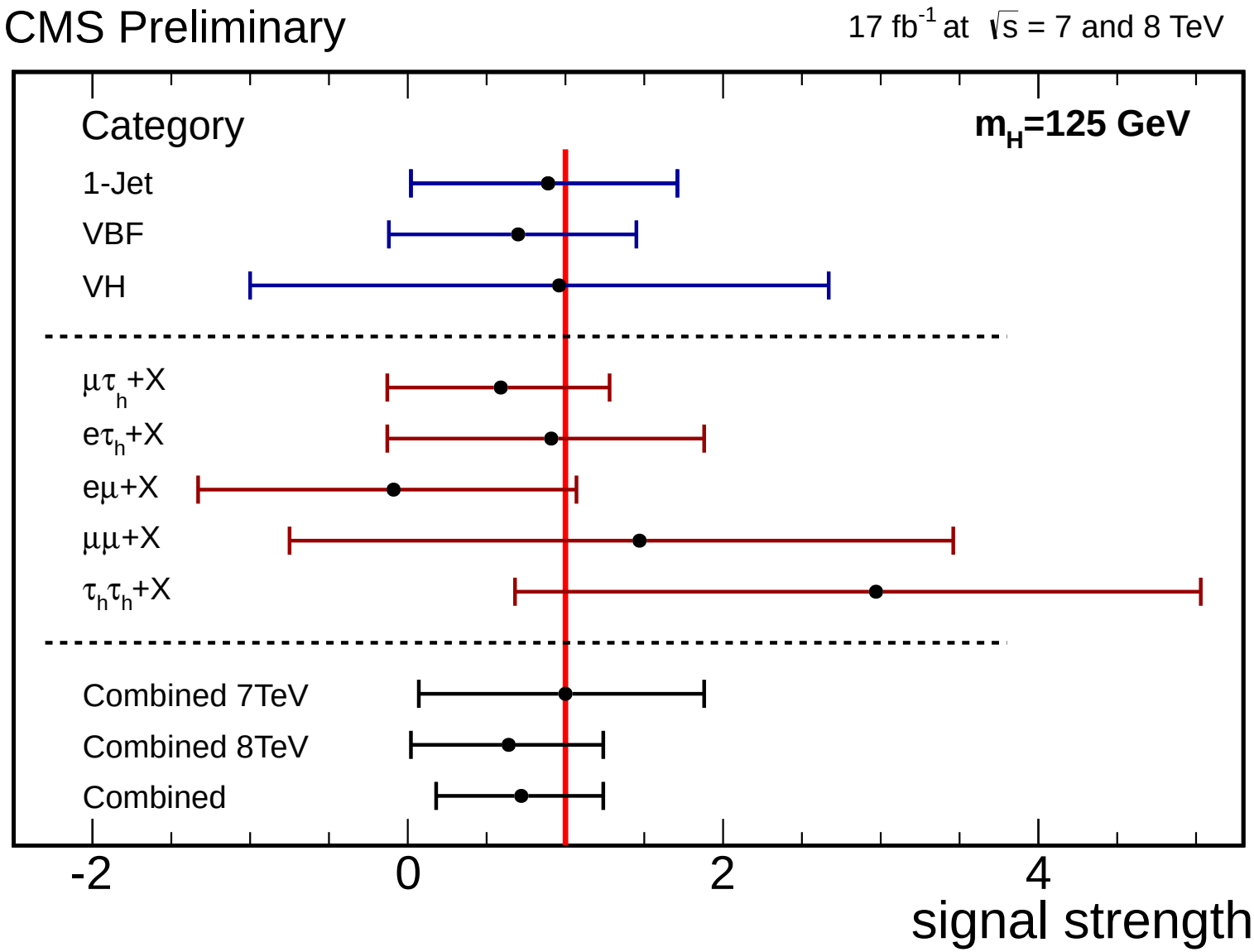


At m_H=125 GeV, observed (expected) 95% CL upper limits on cross section to 1.0 (1.63) $\times$ SM (background-only hypothesis)

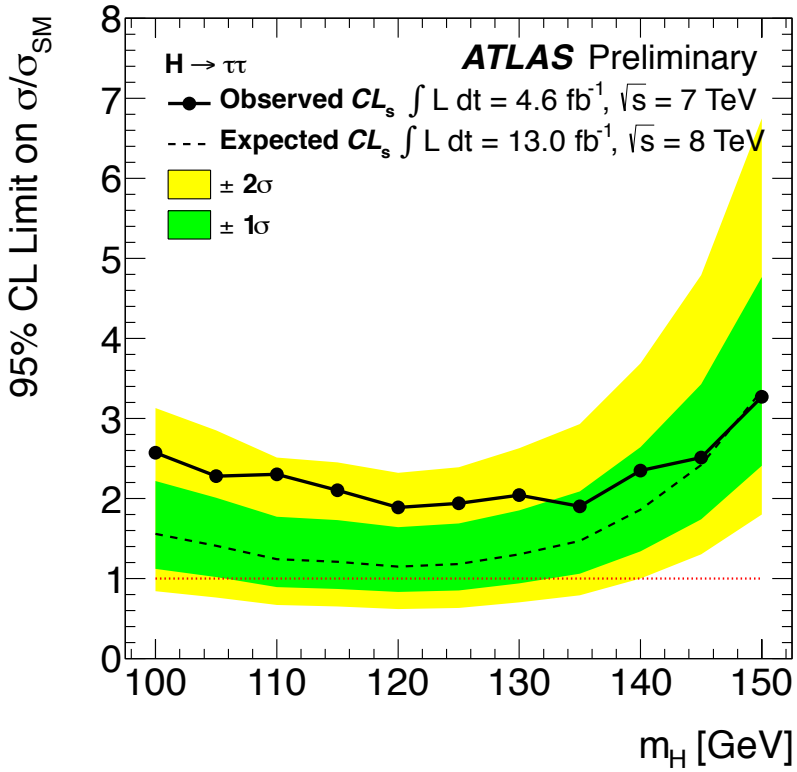


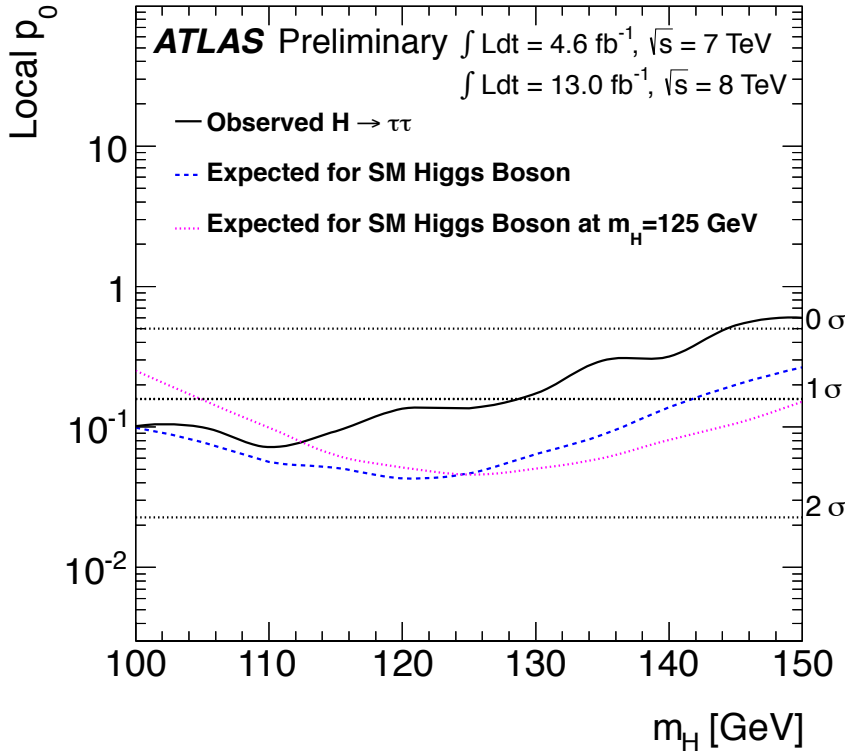
Includes an SM Higgs boson at m_H=125 GeV for the expected result

$H \to \tau\tau$: CMS Channel Breakdown



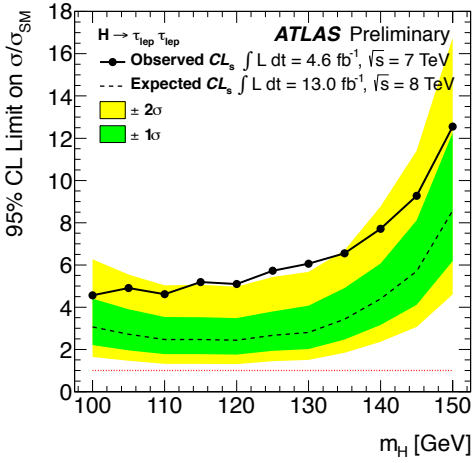
$H \to \tau\tau$: ATLAS Sensitivity



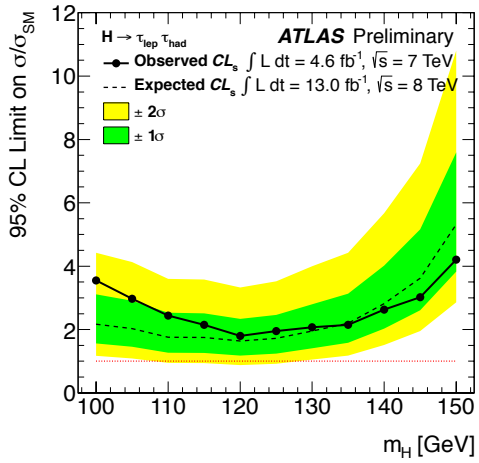


for m_H=125 GeV, local significance of 1.1σ and best fit value μ=0.7$\pm$0.7

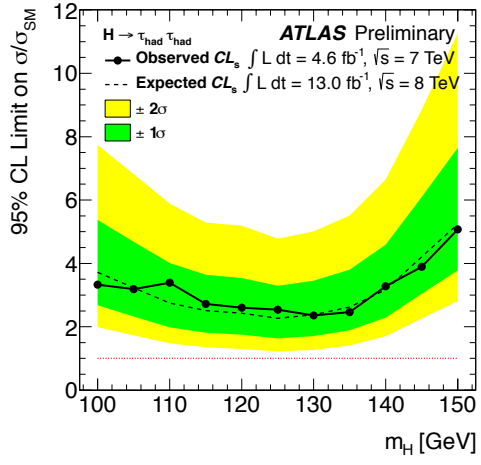
$H \to \tau\tau$: ATLAS Channel Breakdown



$\tau_{lep}\tau_{lep}$



$\tau_{lep}\tau_{had}$



$\tau_{had}\tau_{had}$

VBF channels

non-VBF channels

$H \to bb$ Motivation

- High branching ratio (about 58%) means that observation is crucial
- Direct ggF impossible to observe because of high QCD background
  - VH: associated production
  - ttH: allows us to measure couplings to quarks?
  - VBF: tag the forward jets

Higgs to bb at ATLAS

- VH: sensitivity of 1.8 times SM
- ttH: sensitivity of 13.1 times SM
- VBF: result planned for winter 2015

Higgs to bb at CMS

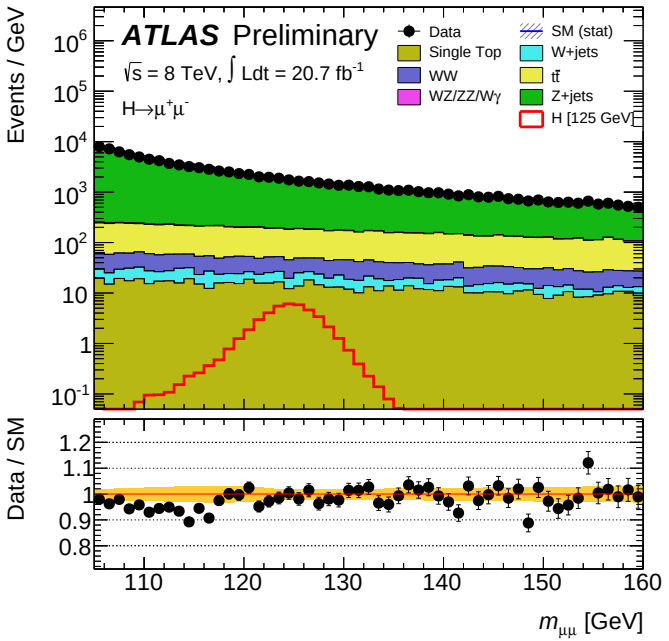
- VH: 2.1 sigma excess observed
- ttH: done in combination with $\tau\tau$
- VBF: sensitivity 3.6 times SM

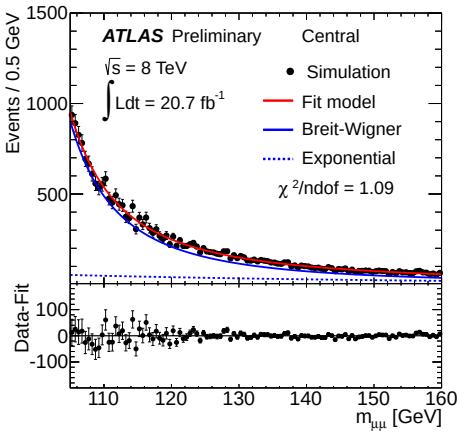
$H \to \mu\mu$ Motivation

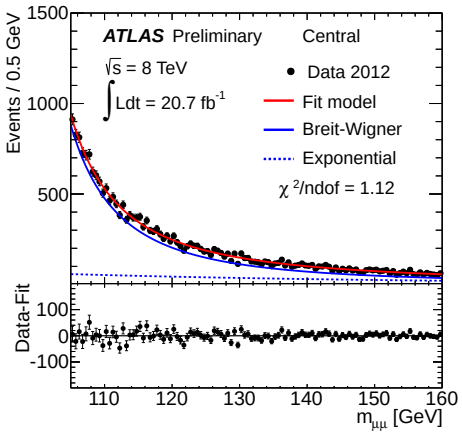
- Small cross section
- Clean final state signature
- Only channel for measuring coupling to second-generation fermions
- Large irreducible background of $Z/\gamma^* \to \mu\mu$
- Can have enhanced BF from non-SM contributions

Higgs to $\mu\mu$ at ATLAS

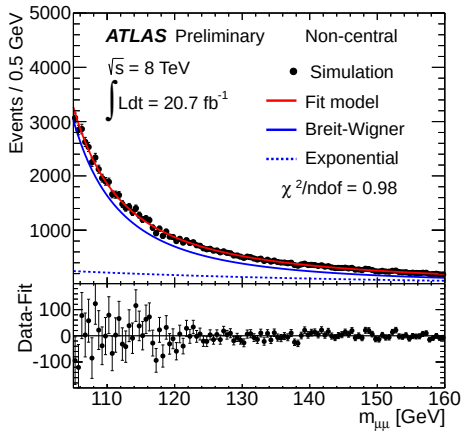
- Reconstruct invariant mass of 2 muons, $p_T^{\mu 1} > 25$ GeV and $p_T^{\mu 2} > 15$ GeV
- Remove 60% of Drell-Yan background events (and keeping 80% of signal) by requiring $p_T^{\mu+\mu-} > 15$ GeV (events failing this cut go into a background control region)
- Search for bump in the invariant mass spectrum, main background is Z+jets
- Background model: exponential plus Breit-Wigner, to capture Z tail

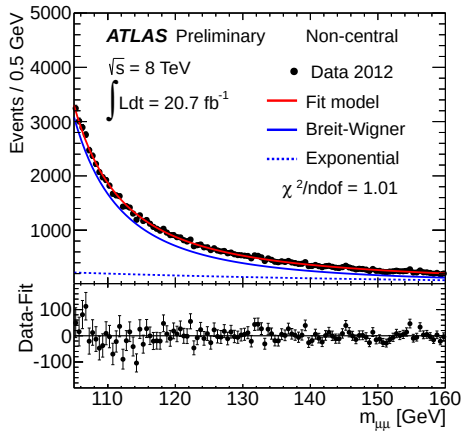






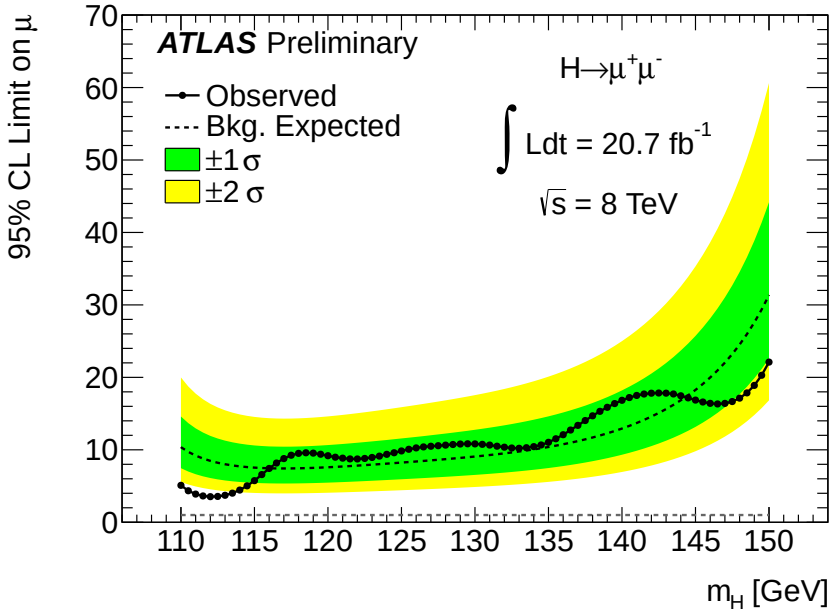
Simulation and data in central region ($|\eta(\mu_{1,2})| < 1.0$), fit with BW + exponential

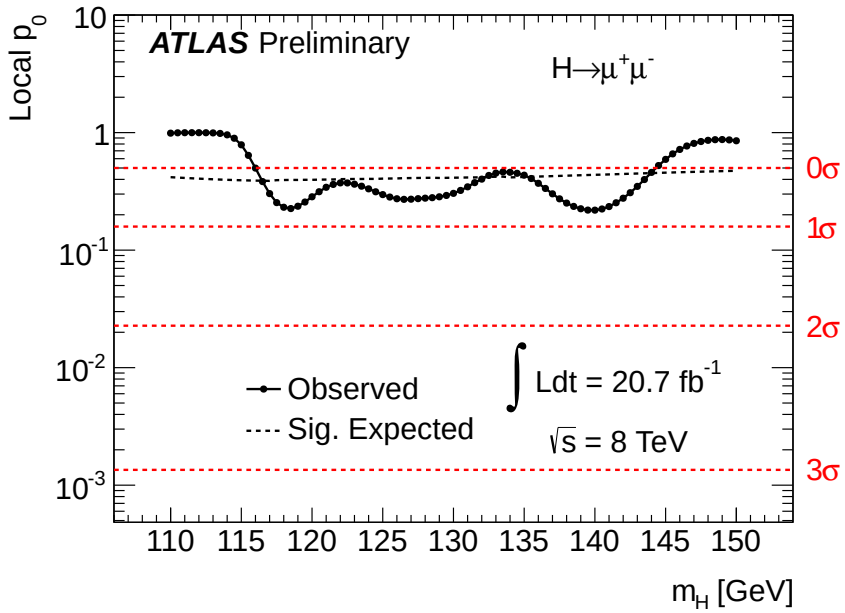




Simulation and data in non-central region ($|\eta(\mu_{1,2})| > 1.0$), fit with BW + exponential

$H \to \mu\mu$ Results at ATLAS





m_H	observed limits	exp. median	exp. + 2σ	exp. $+1\sigma$	exp. -1σ	exp. -2σ
110	5.1	10.4	20.0	14.6	7.5	5.6
115	5.7	7.5	14.5	10.6	5.4	4.0
120	9.2	7.6	14.6	10.7	5.5	4.1
125	9.8	8.2	15.9	11.6	5.9	4.4
130	10.8	9.1	17.5	12.8	6.5	4.9
135	11.0	10.4	20.1	14.6	7.5	5.6
140	16.8	12.9	25.0	18.2	9.3	6.9
145	16.9	18.3	35.3	25.7	13.2	9.8
150	22.1	31.3	60.6	44.2	22.6	16.8

$H \to \mu\mu$ Results at CMS

to be included if approved

Prospects for 2015 and beyond

References

- ATLAS, *Search for the bb decay of the Standard Model Higgs boson in associated (W/Z)H production with the ATLAS detector*, 19 July 2013
- ATLAS, *Search for the Standard Model Higgs boson produced in association with top quarks in proton-proton collisions at $\sqrt{s}$=7 TeV using the ATLAS detector*, 15 September 2012
- CMS, *Search for the SM Higgs boson produced in association with W or Z bosons, and decaying to bottom quarks*, 14 May 2013
- CMS, *Search for Higgs Boson Production in association with a top-quark pair and decaying to bottom quarks or tau leptons*, 26 July 2013
- ATLAS, *Search for the Standard Model Higgs boson in H to tau tau decays in proton-proton collisions with the ATLAS detector*, 13 November 2012
- CMS, *Search for the standard model Higgs boson decaying to tau pairs in proton-proton collisions at $\sqrt{s}$=7 and 8 TeV*, 15 March 2013
- CMS, *Search for the standard model Higgs boson decaying to tau pairs produced in association with a W or Z boson with the CMS experiment in pp collisions at $\sqrt{s}$ = 7 and 8 TeV*
- ATLAS, *Search for the SM Higgs boson in H to mu mu decays with the ATLAS detector*, 5 March 2013
- LHC Higgs Cross Section Working Group, *http://arxiv.org/abs/1101.0593*, 20 May 2011
- LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs Cross Sections: 2. Differential Distributions*