Recent results from Higgs physics at the LHC

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On behalf of the ATLAS and CMS collaboration

ICHEP
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Introduction

- The first extended running period of the LHC at $\sqrt{s}$ 7 and 8 TeV brought the anticipated discovery of the Higgs boson by the CMS and ATLAS collaborations, the culmination of a decades-long effort

- With these data ATLAS and CMS have measured nearly all its accessible properties — its production and decay rates, its mass, its couplings to most other SM particles — and set constraints on others

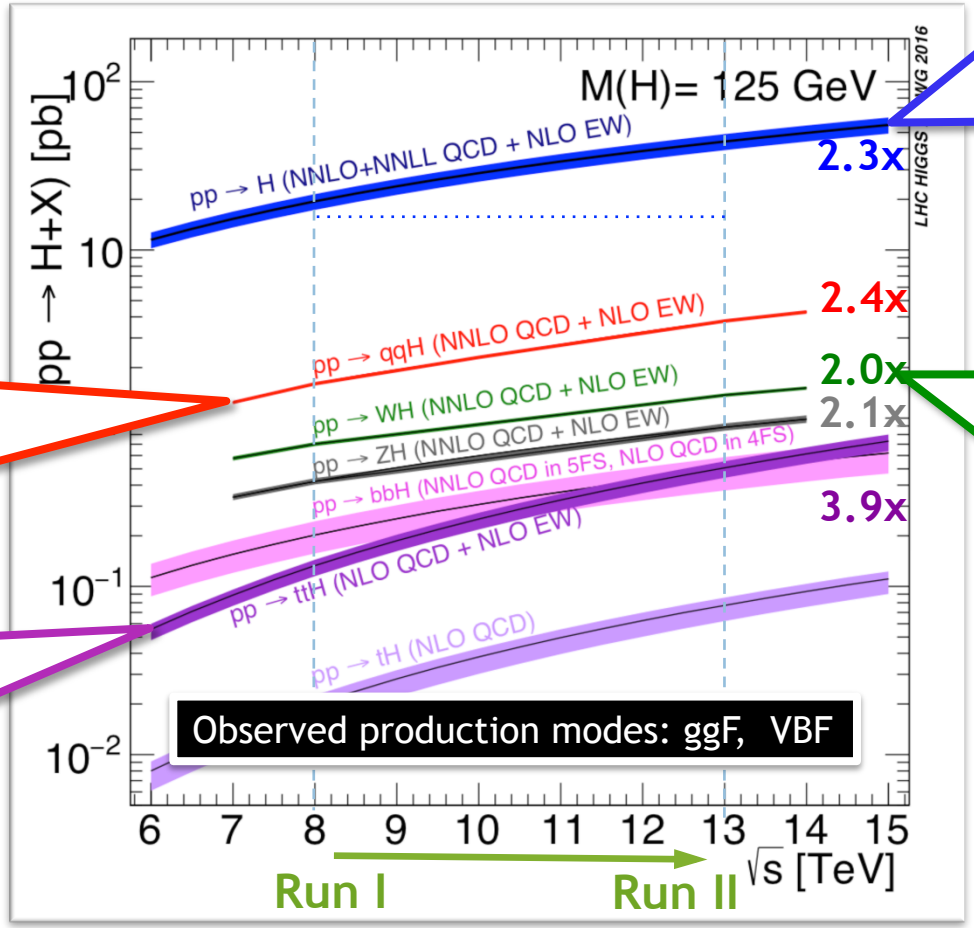
Introduction

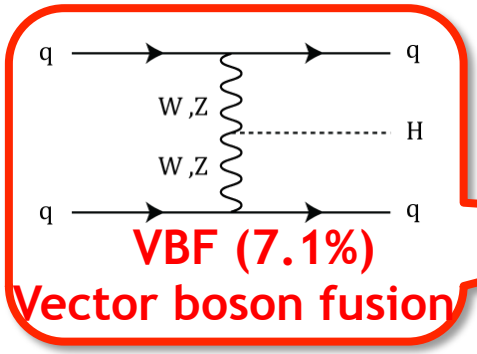
- Run II of the LHC at $\sqrt{s}$ = 13 TeV is now making an even larger sample of Higgs boson events available for analysis

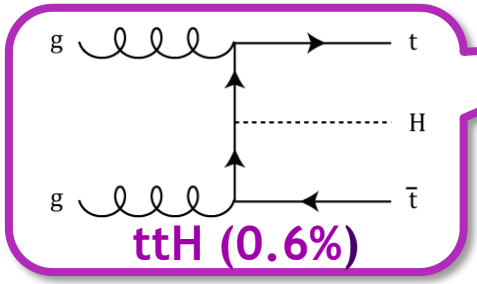
- These data is increasing in precision and opening up new channels to study the interactions of Higgs bosons and SM particles

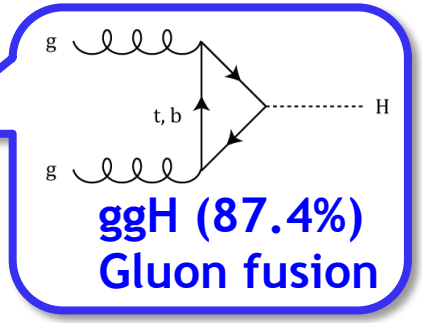
- Higher collision energies is allowing us to direct probe for BSM physics by searching for additional Higgs bosons and for anomalous decays of the Higgs(125) boson

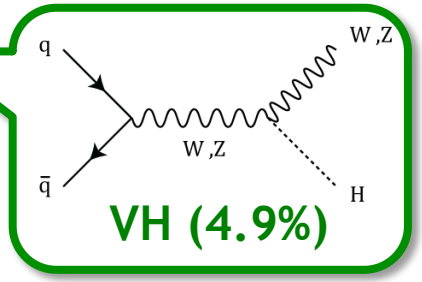
Higgs Boson Production at 125 GeV











7/8 TeV (2011/2012) 13 TeV (>2015)

Higgs Boson Decays at 125 GeV

Observed decay modes:
γγ, ZZ, WW, ττ

Missing bb,cc, μμ, Zγ

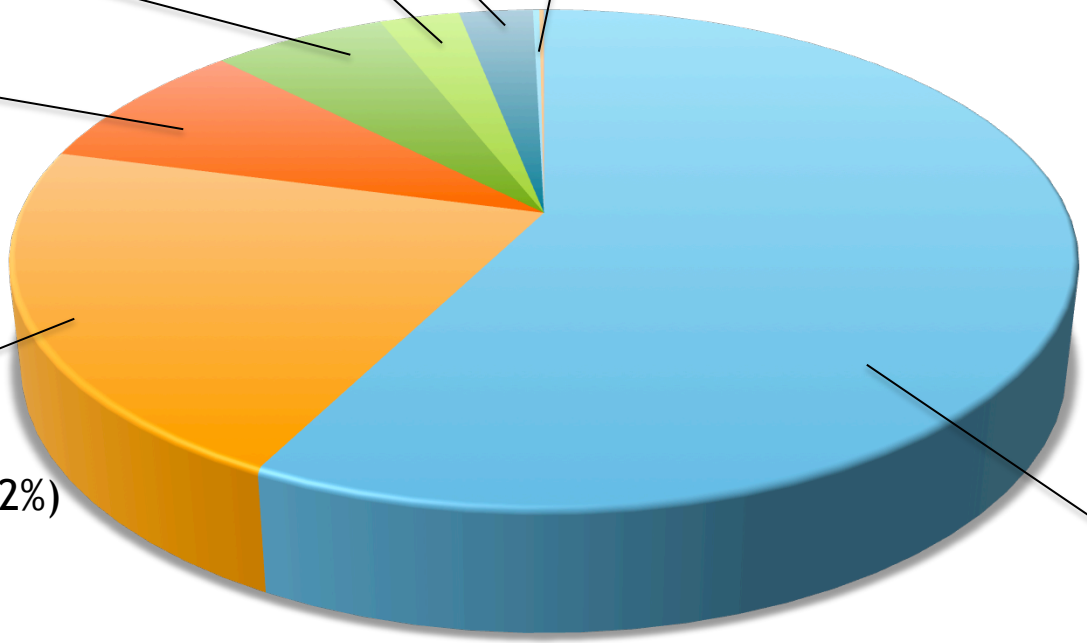
H→ττ
Abundant (6%)
S/B<1
ΔM/M ~ 10-20%

H→ZZ*→4l
Rare (3%)
S/B>>1
ΔM/M ~ 1-2%

H→γγ
Very rare (0.2%)
S/B<1
ΔM/M ~ 1-2%

H→cc (2.9%)

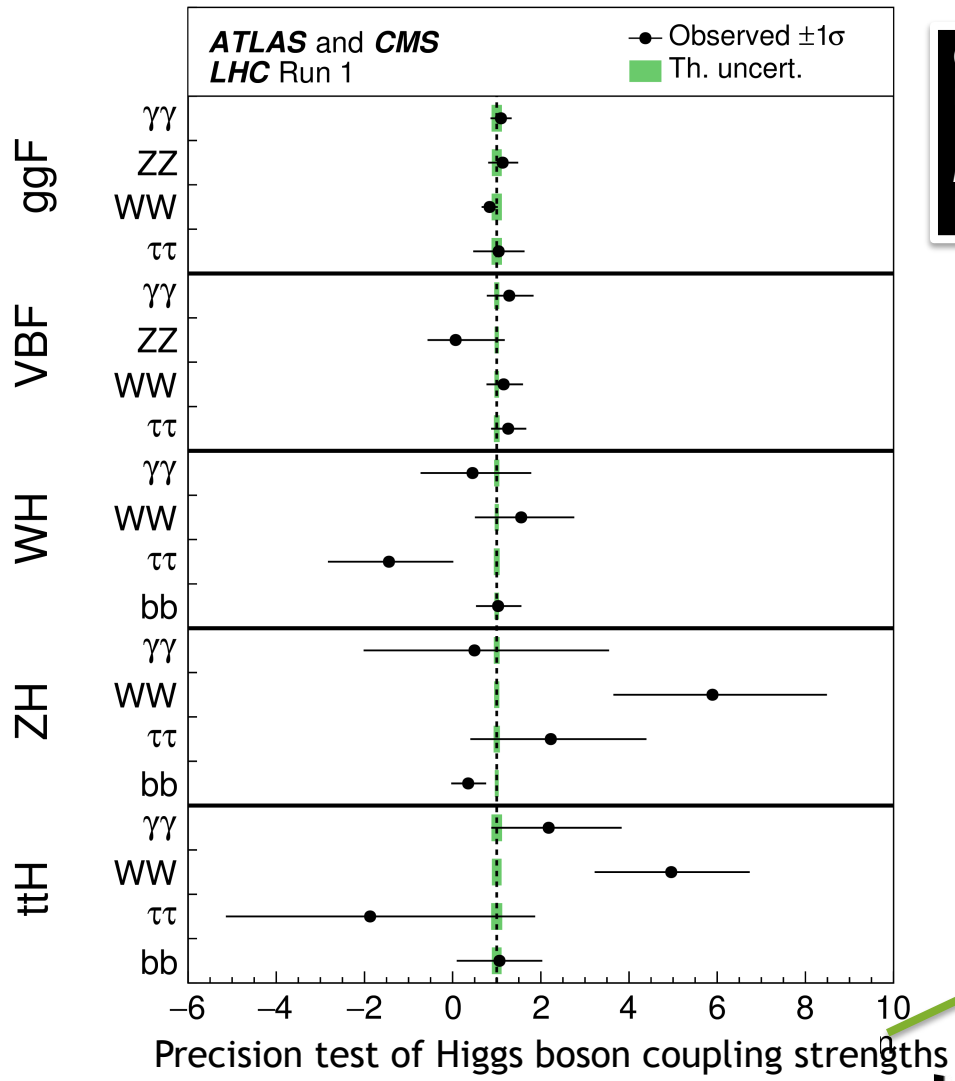
H→gg (8.5%)



H→WW*→2l2ν
Very Abundant (22%)
S/B<1
ΔM/M ~ 30%

H→bb
Abundant (58%)
S/B<<1
ΔM/M ~ 10-20%

Higgs Profile in Run 1



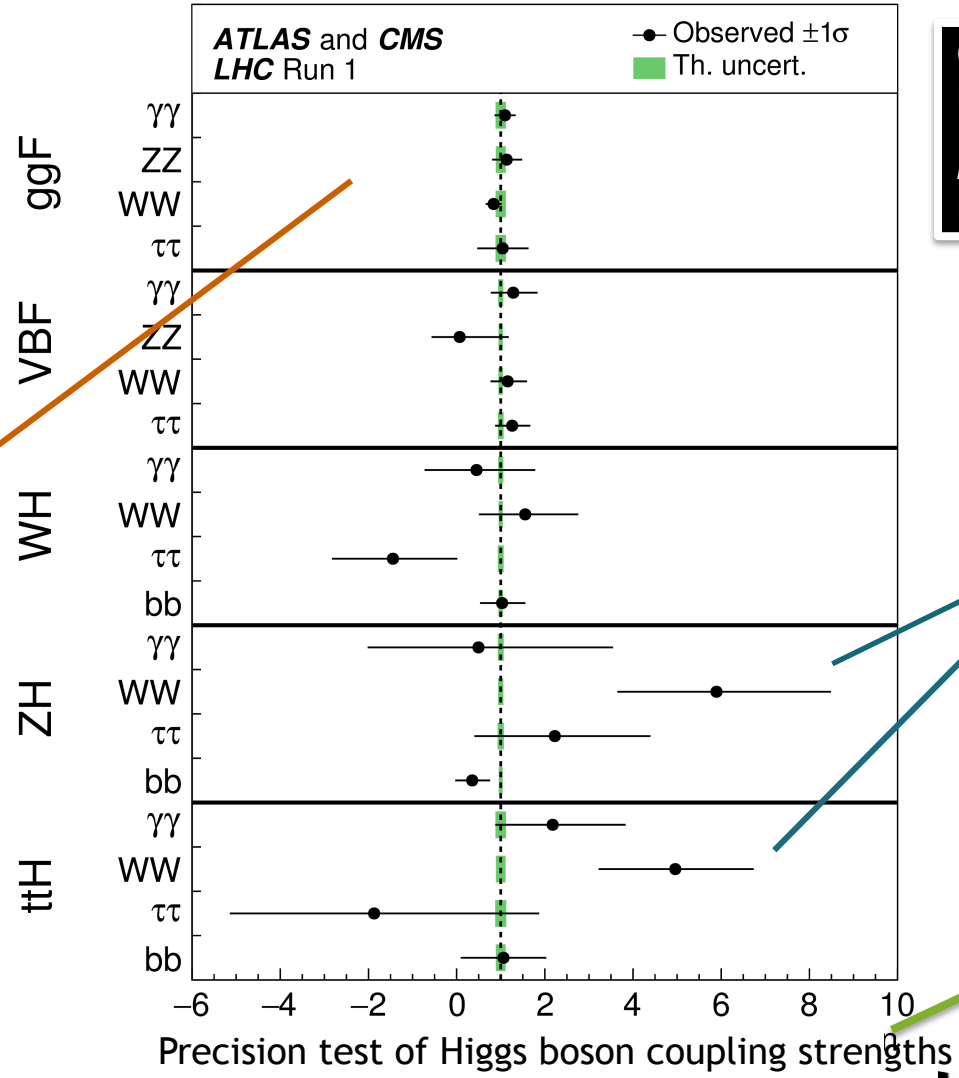
CMS and ATLAS combined 7 and 8 TeV results Run 1 legacy papers:

Mass: Phys. Rev. Lett. 114, 191803
Rates and couplings: arXiv:1606.02266

Coupling strengths

$$\mu = \frac{\sigma}{\sigma_{SM}}$$

Higgs Profile in Run 1



CMS and ATLAS combined 7 and 8 TeV results Run 1 legacy papers:

Mass: Phys. Rev. Lett. 114, 191803
Rates and couplings: arXiv:1606.02266

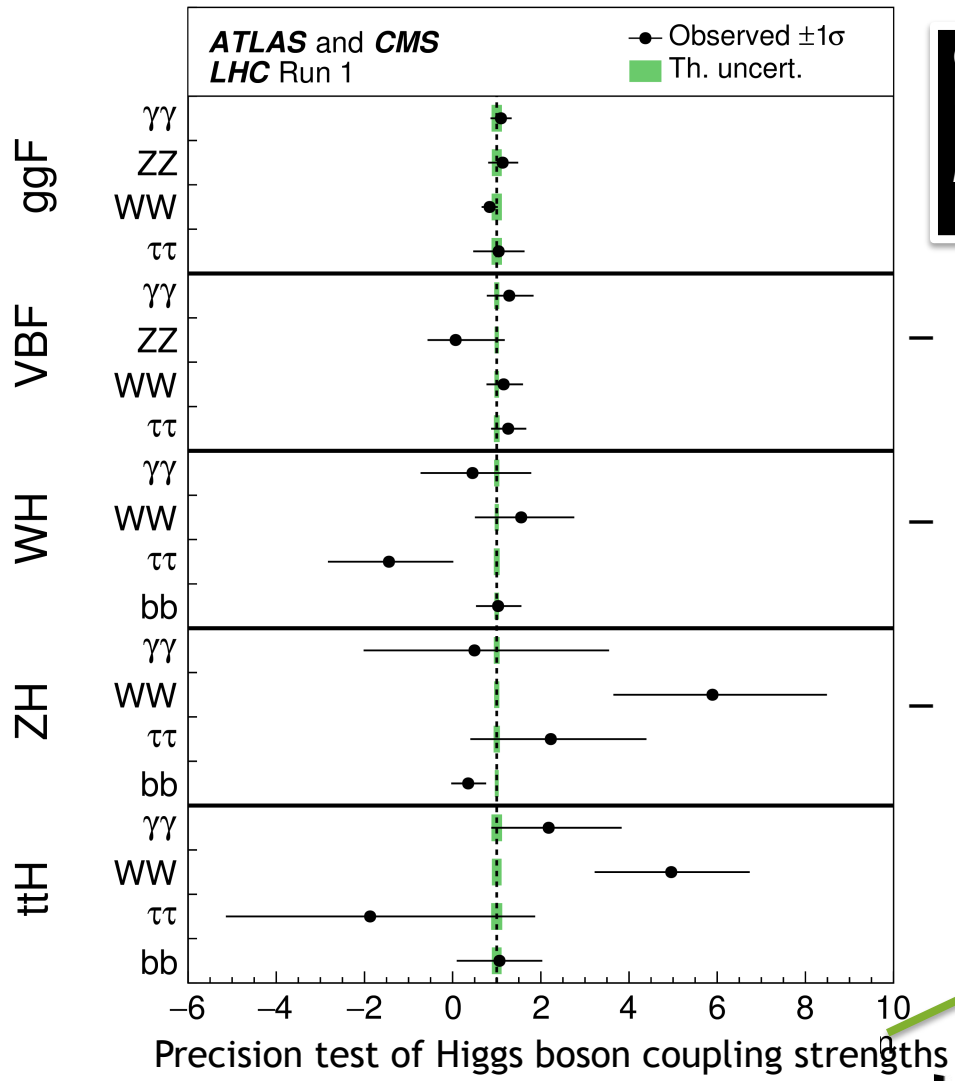
Gluon fusion measurements, starting to approach SM theory uncertainties: **15%**

Mild excess in ttH and ZH production modes

Coupling strengths

$$\mu = \frac{\sigma}{\sigma_{SM}}$$

Higgs Profile in Run 1



CMS and ATLAS combined 7 and 8 TeV results Run 1 legacy papers:

Mass: Phys. Rev. Lett. 114, 191803
Rates and couplings: arXiv:1606.02266

- Mass has been measured to 0.2% precision m_H=125.09±0.24 GeV
- Angular distributions consistent with spin 0 and even parity
- All couplings are consistent with SM within 2.5σ

Coupling strengths

$$\mu = \frac{\sigma}{\sigma_{SM}}$$

Higgs Boson in Run 2

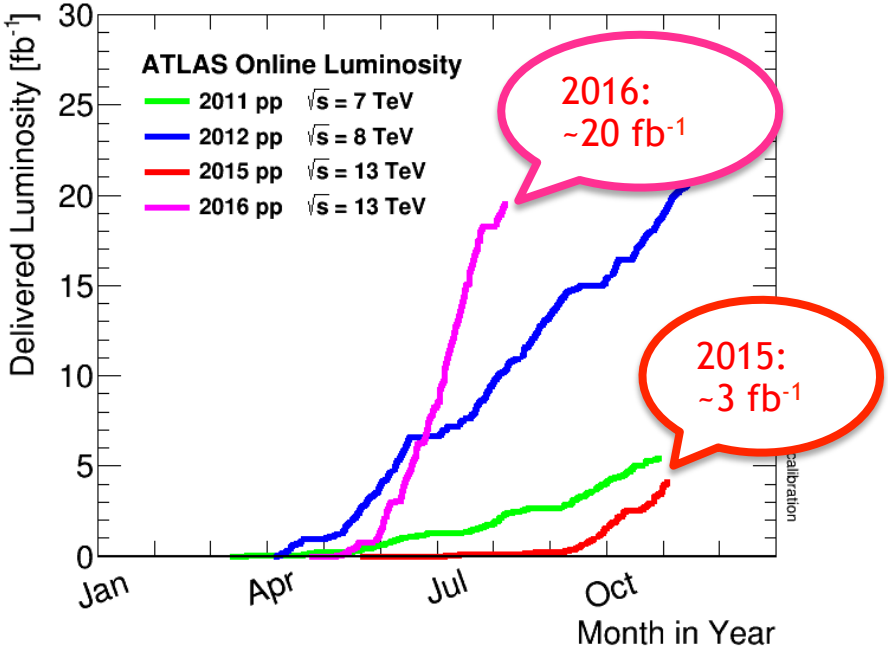
- LHC restarted in 2015 with a collision energy of 13 TeV

- Run 2 dataset per experiment as of **ICHEP2016:**
  - 2015: ~3 fb^{-1}
  - 2016: ~13 fb^{-1}

  Already produced more Higgs bosons than in Run 1!

- Most analyses in Run 2 follow closely methods and strategies developed during Run 1

- In this talk:
  - Only results with 13 TeV
  - Different luminosity per analysis




L. Aperio Bella


M. Cepeda

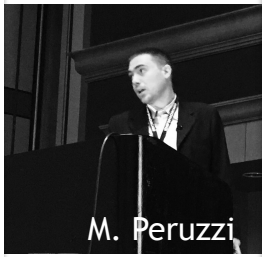
M. Trovatelli

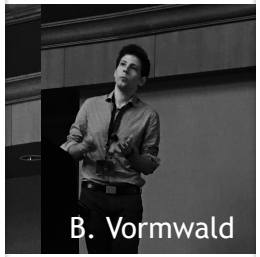

T. Varol


T. Vickey


V. Tavolaro

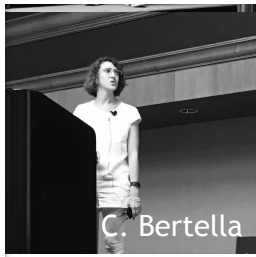

D. Gebaudo


M. Peruzzi


B. Vormwald

K. Köneke


J. Keller


C. Bertella


C. Palmer


G. Marchiori


A. Pilkington


L. Zivkovic


C. Grefe


P. Conde Muino


P. Saxena

N. Wardle

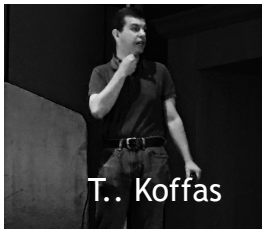

B. Laforge


A. Massironi


U. Sarica

G. Ortona


A. Mertens


T.. Koffas

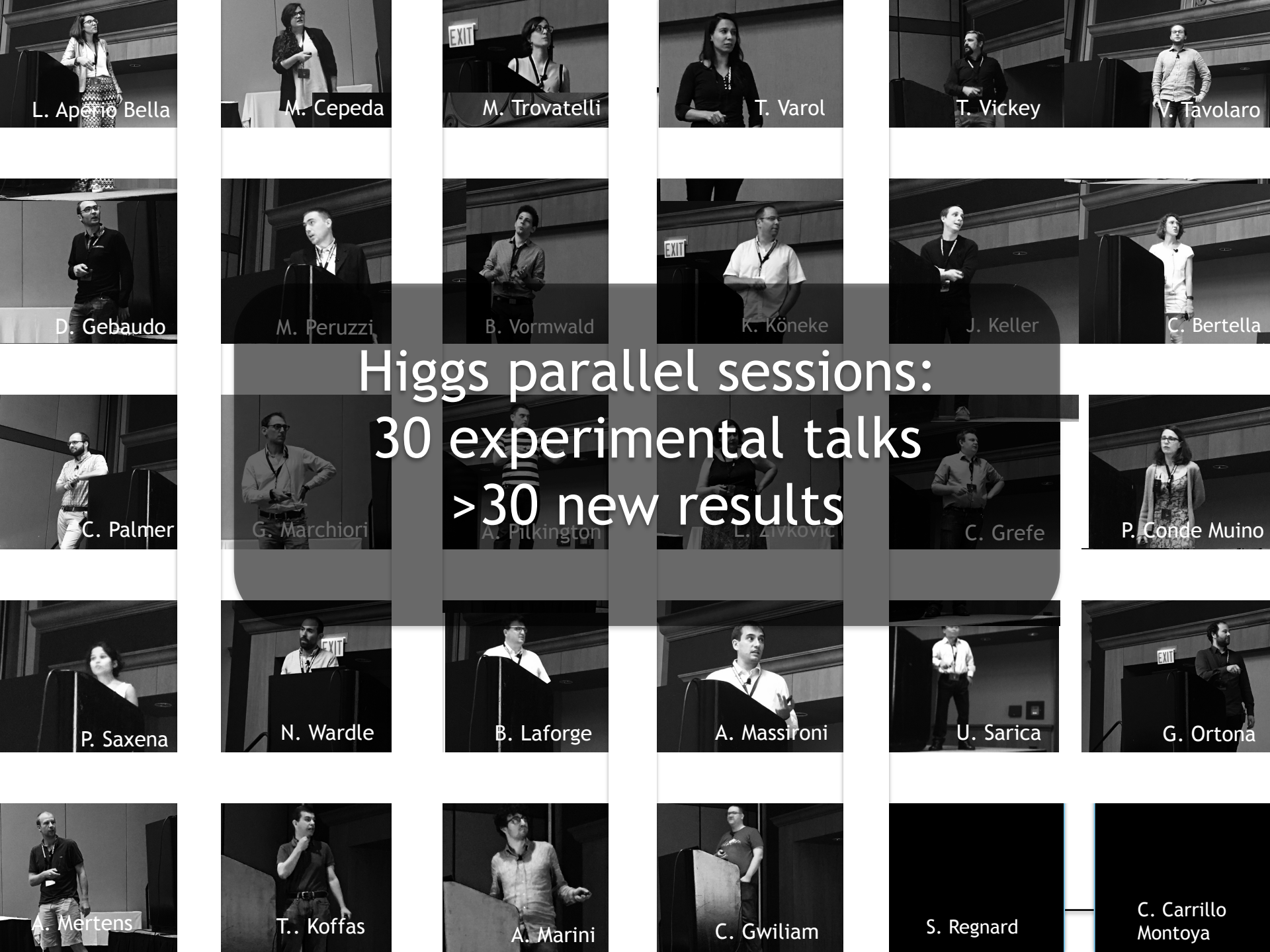

A. Marini


C. Gwiliam

S. Regnard

C. Carrillo Montoya

Higgs parallel sessions:
30 experimental talks
>30 new results



Higgs→γγ

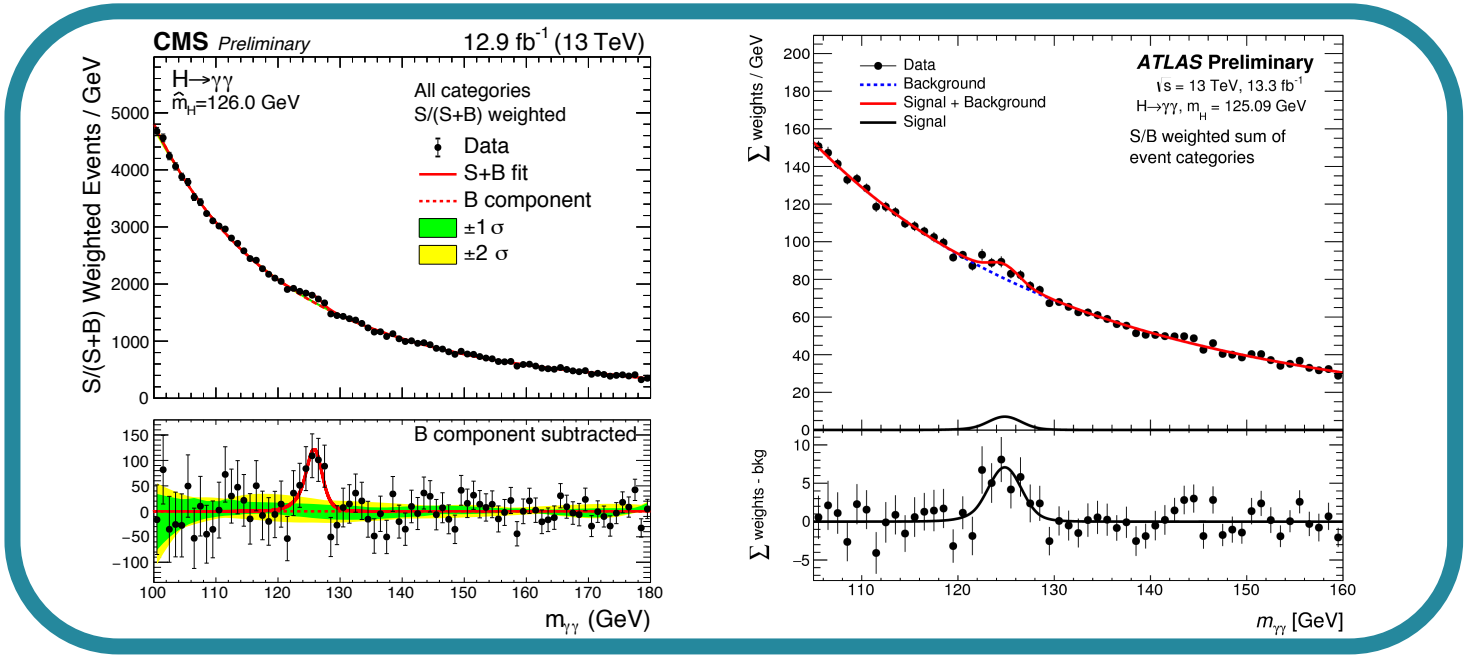
ATLAS -CONF-2016-067

CMS-PAS-HIG-16-020

- *Narrow peak over falling background*

- **Signature:** 2 isolated photons
  - All production modes targeted ggF, VBF, VH (only ATLAS), ttH events

- Signal extracted through fit of $\mathbf{m_{\gamma\gamma}}$ in different event categories
  - Main backgrounds: γγ and γ-jet production



- **Dominant systematic uncertainty:** photon energy scale and resolution and background choice bias (smaller than statistical uncertainties)

Higgs→γγ

ATLAS -CONF-2016-067

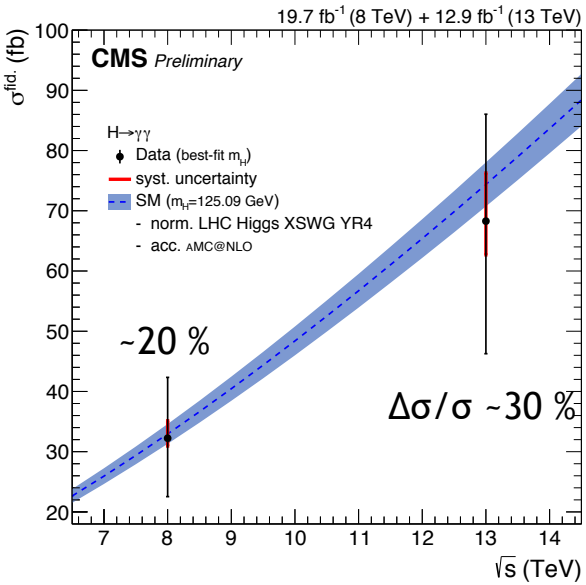
CMS-PAS-HIG-16-020

- **Measurements of fiducial cross section**

13 TeV	Fiducial σ (fb)	SM prediction (fb)
ATLAS (13.3 fb^{-1})	43.2±14.9(stat)±4.9(syst)	$62.8^{+3.4}_{-4.4}$ (N^3LO+XH)
CMS (12.9 fb^{-1})	69^{+16}_{-22}(stat)$^{+8}_{-6}$(syst)	73.8±3.8

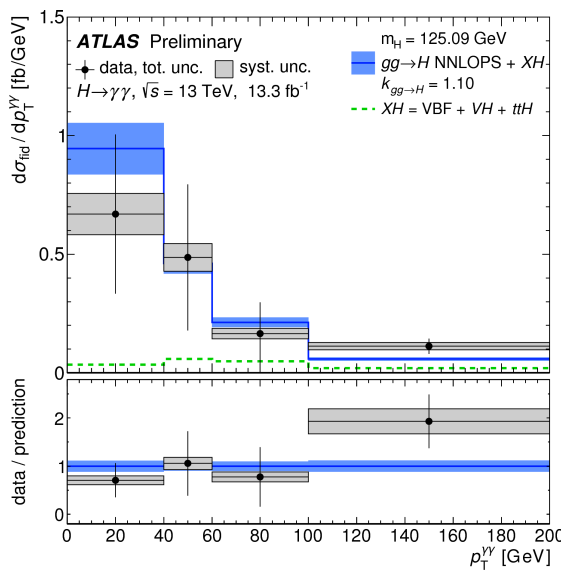
Fiducial σ:
Event yields corrected for detector inefficiency and resolution for minimal theoretical modeling

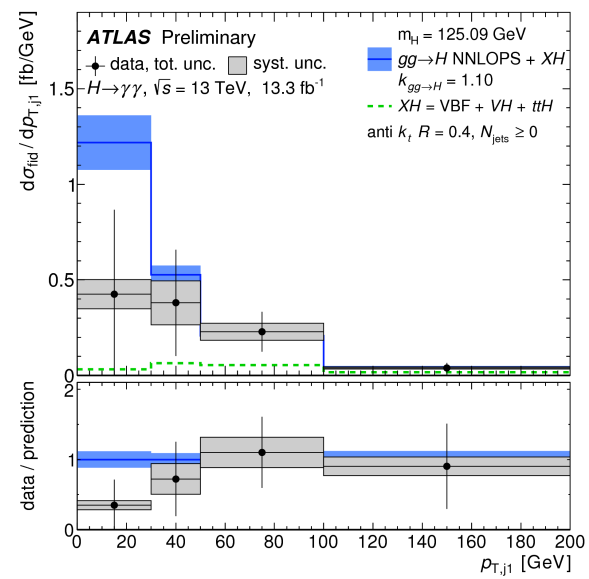
$$\sigma_i = \frac{\nu_i^{sig}}{c_i \int L\,dt}$$



Important to improve MC generators and calculations ➔ reduce systematic uncertainties

Differential cross section measurements





Higgs→γγ

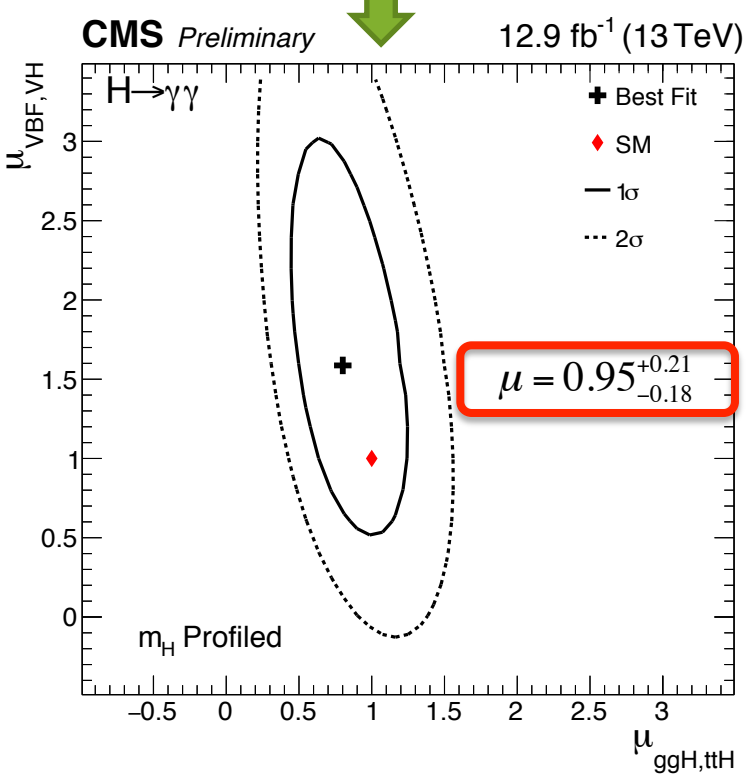
ATLAS -CONF-2016-067

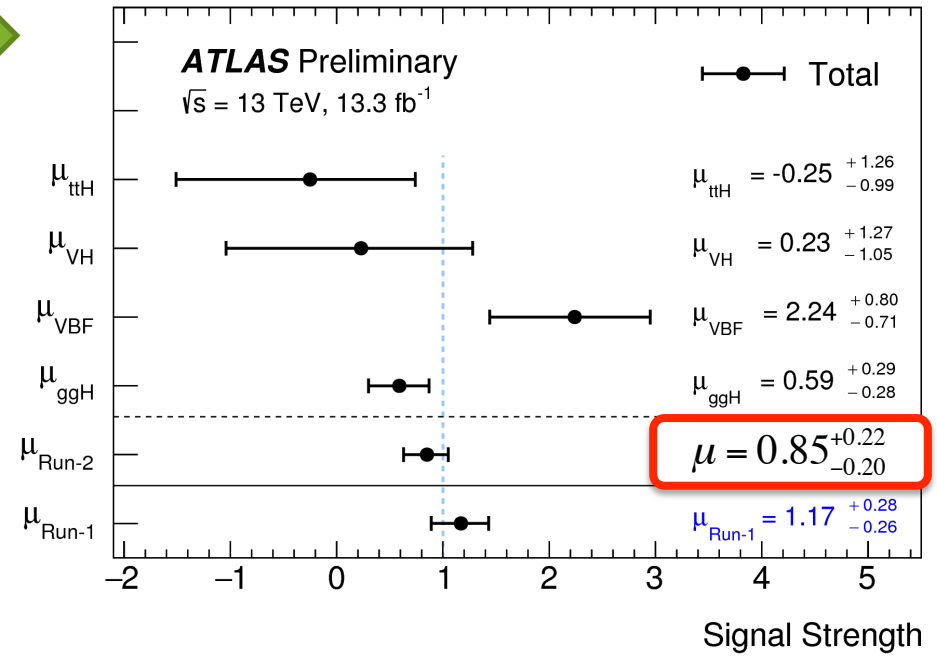
CMS-PAS-HIG-16-020

Production cross section and signal strength

- Events are split into orthogonal categories that exploit topological differences between production mechanisms

Extract strength of production processes in a 2-parameter fit





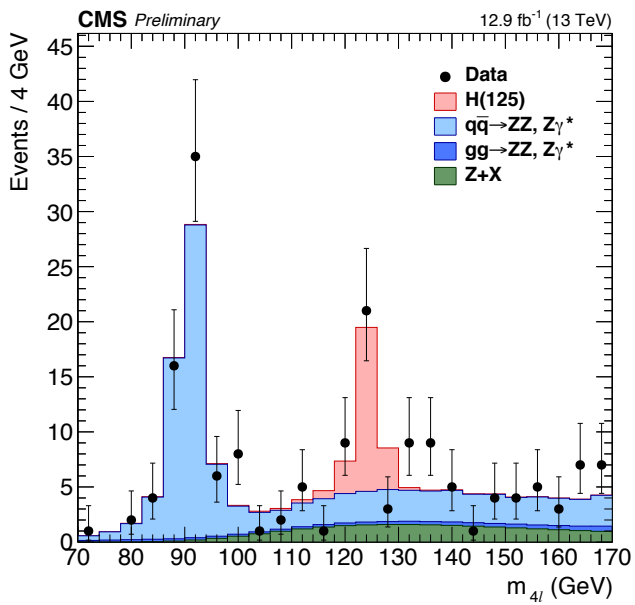
- Achieved similar precision to Run 1
- Measurements compatible with SM
- Results still dominated by statistical uncertainty

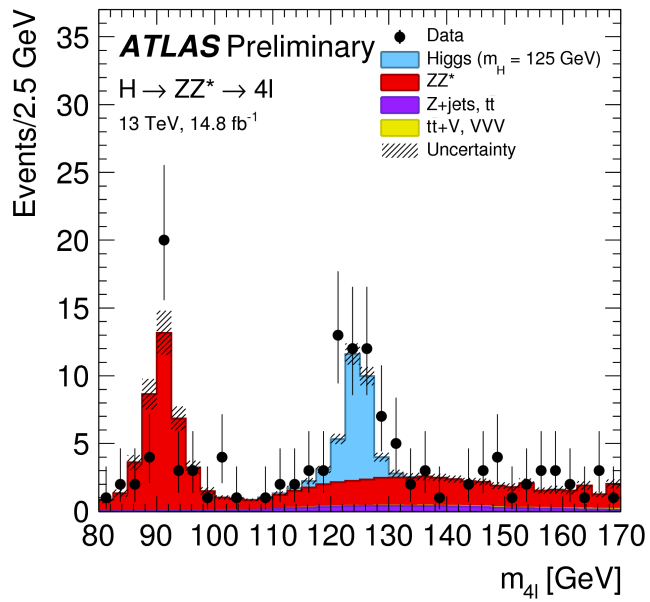
Higgs→ZZ*

ATLAS-CONF-1206-079

CMS-PAS-HIG-16-033

- *Narrow peak over a flat background*
- **Signature:** two pairs of same flavor, opposite sign, isolated leptons
  - All production modes targeted ggF, VBF, VH, ttH events
- Extraction of signal through fit of m_{4l}
  - Also uses kinematic discriminant (e.g. M_{Z1}, M_{Z2}, 5 angles from decay chain, matrix element) used to enhance the signal purity of different production modes
- **Dominant systematic uncertainty:** luminosity and lepton SF (smaller than statistical uncertainty)





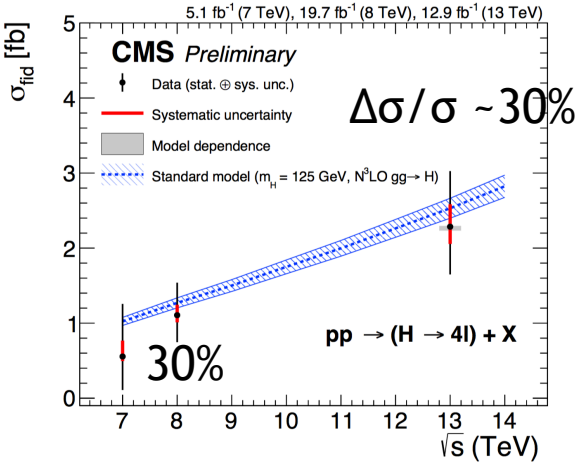
Higgs→ZZ*

ATLAS-CONF-1206-079

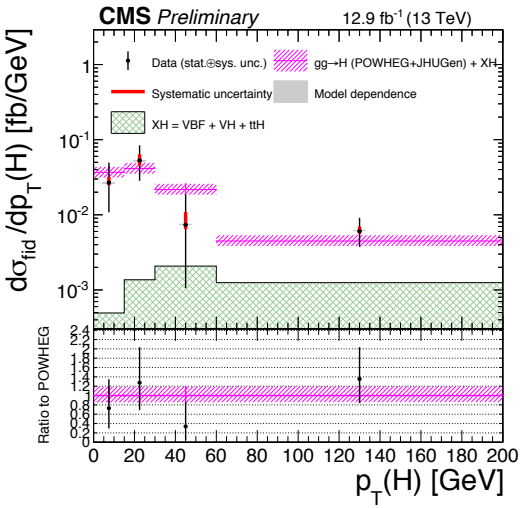
CMS-PAS-HIG-16-033

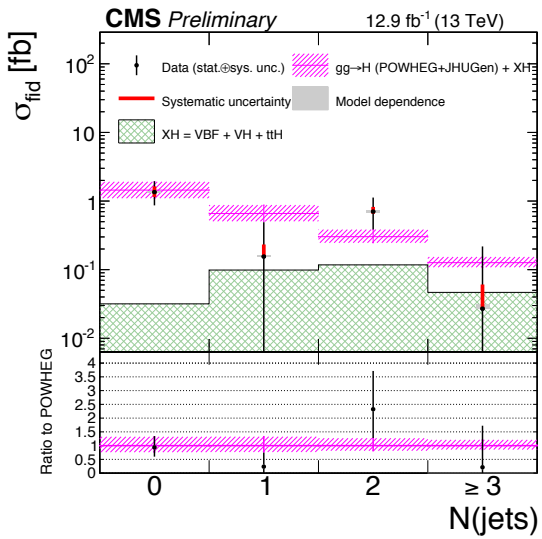
Measurements of fiducial cross section

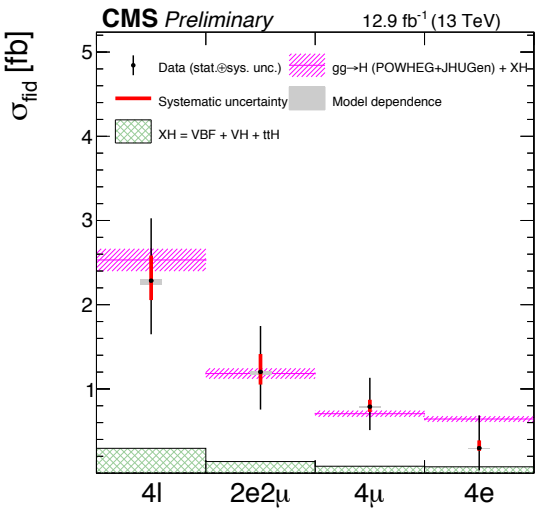
13 TeV	Fiducial σ (fb)	SM prediction (fb)
ATLAS (14.8 fb^{-1})	$4.54^{+1.02}_{-0.90}$	$3.07^{+0.21}_{-0.25}$
CMS (12.9 fb^{-1})	$2.29^{+0.74}_{-0.64}(stat)^{+0.30}_{-0.23}(syst)$	2.53±0.13



Differential cross section measurements





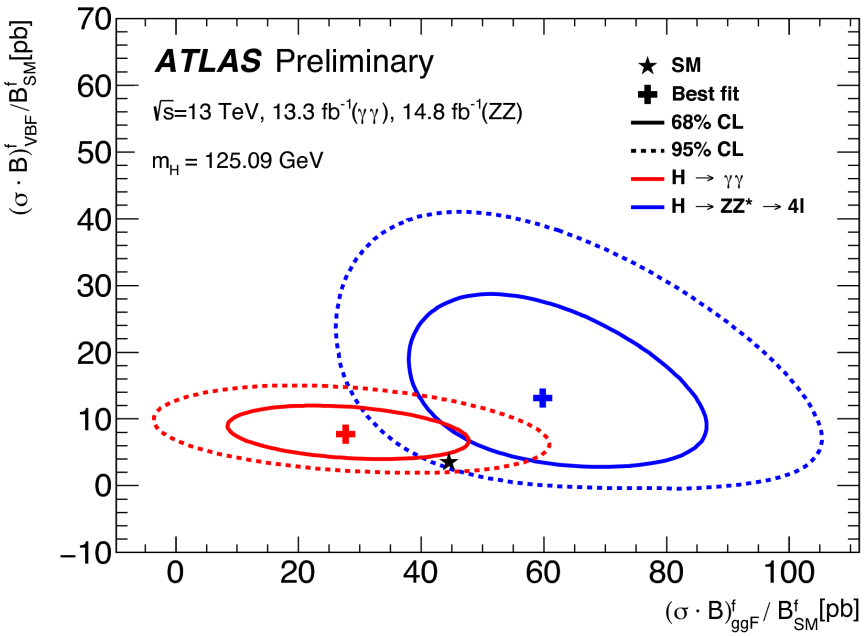


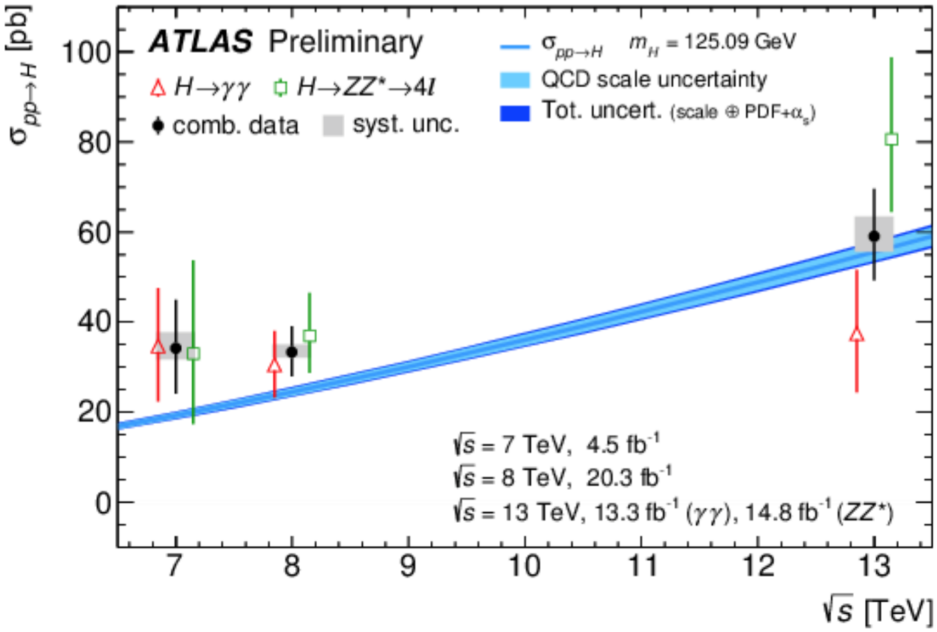
Combination of H→γγ and H→ZZ*

ATLAS-CONF-2016-081

- Combine H→γγ and H→Z→4l inclusive samples, with no categorization
- Higgs production is observed with 10σ significance (8.6σ expected) with 13 TeV data in agreement with SM expectations

	Measurement at 13 TeV	SM prediction at 13 TeV
σ (pb)	$59.0^{+9.7}_{-9.2}(\text{stat})^{+4.4}_{-3.5}(\text{syst})$	$55.5^{+2.4}_{-3.4}$
μ	$1.13^{+0.18}_{-0.17}$	1

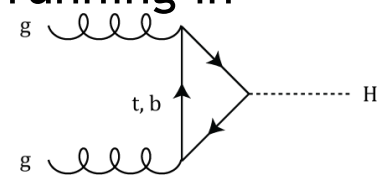


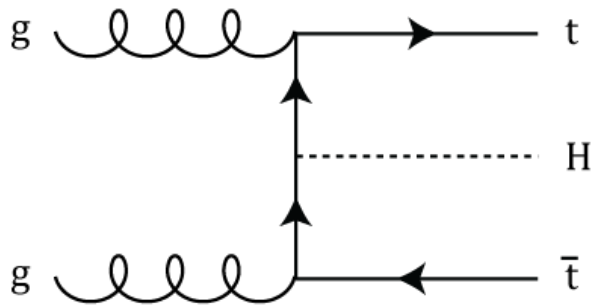


Comparable precision to Run 1

Towards Discovery - ttH

- Probing the Yukawa coupling between **top and Higgs** at LHC:
  - via gluon fusion cross section, assumes no BSM particles running in the loop
  - **directly at tree level, via associated production:**





ttH(→bb): Uses H→bb with one or two W bosons decaying to e or μ (and ttH (hadronic) with both W bosons decaying hadronically)

ttH(multileptons): targets H→ WW, ZZ, ττ (τ decaying leptonically and hadronically), and additional leptons from top quark decays

ttH(γγ): included in H→γγ analyses

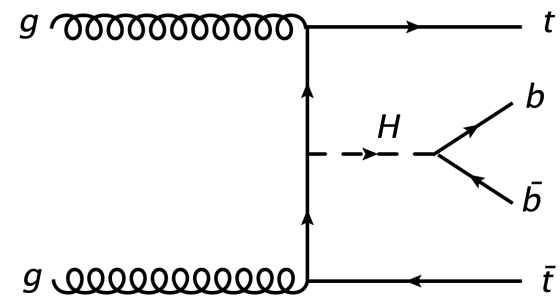
Higgs decay mode	BR (%)
H→bb	58.1
H→WW	21.5
H→ττ	6.3
H→ZZ	2.6
H→γγ	0.23

ttH(→bb)

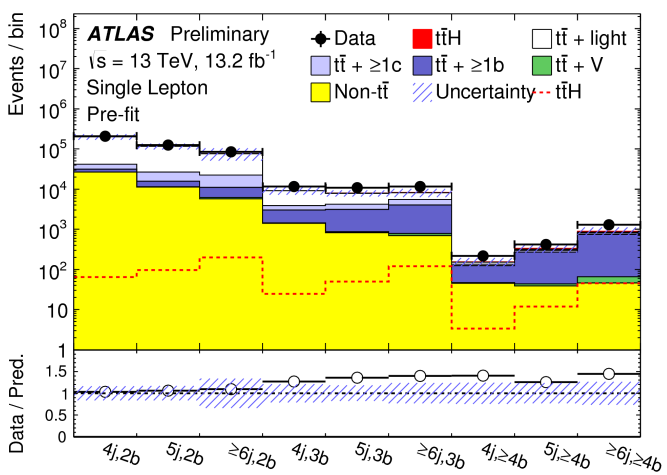
CMS-PAS-HIG-16-004

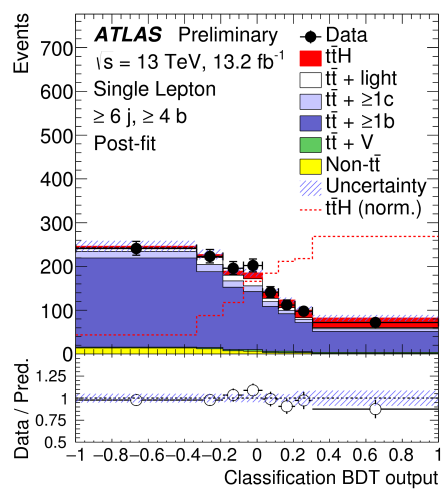
ATLAS -CONF-2016-080

- Largest branching ratio and large background, also offers sensitivity to the Higgs-Bottom Yukawa coupling
- **Analysis strategy:** categorize events according to amount of leptons, jets, b-jets
  - Main background tt+heavy flavour production: very challenging theoretical description
- **Dominant systematic uncertainty:** signal and background modeling and normalization (larger than statistical uncertainty)

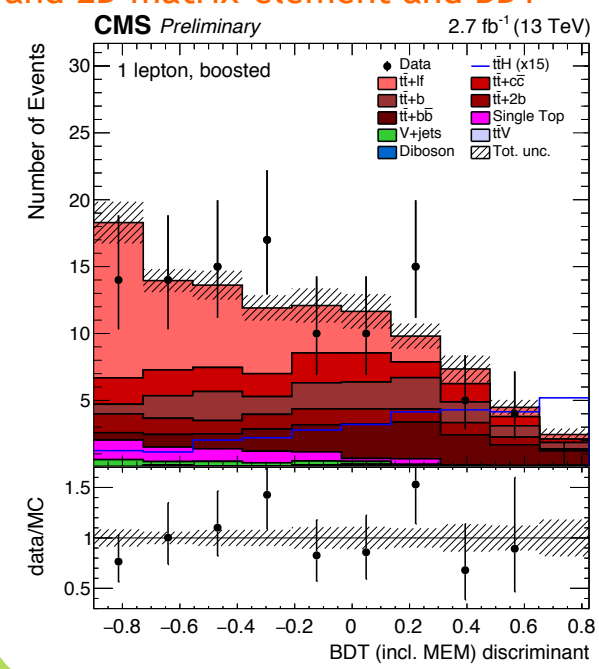


ATLAS uses BDT to reconstruct Higgs and separate signal and background for each category





CMS includes now a boosted category and 2D matrix-element and BDT



ttH(→bb)

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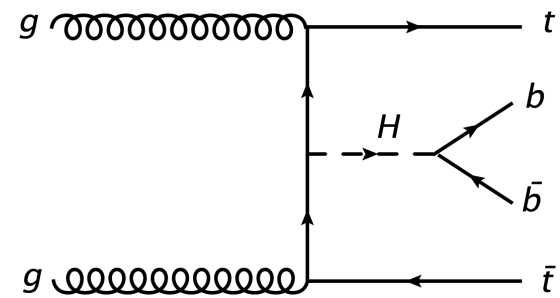
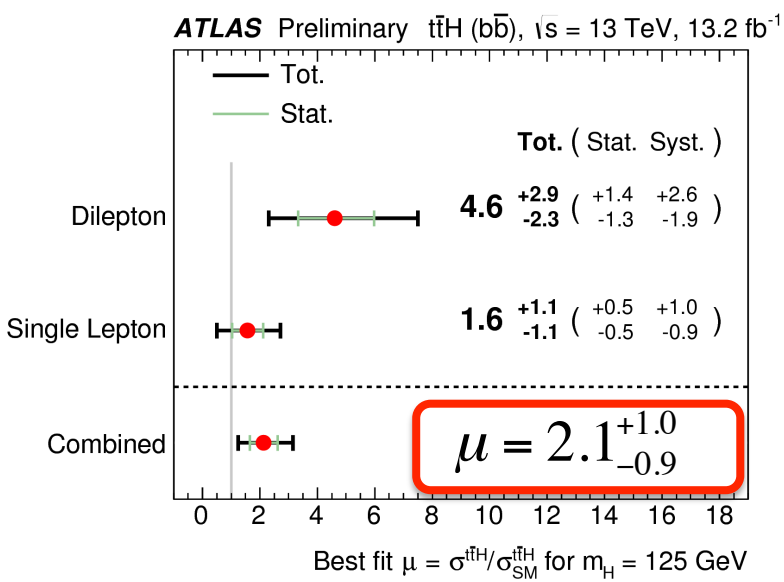
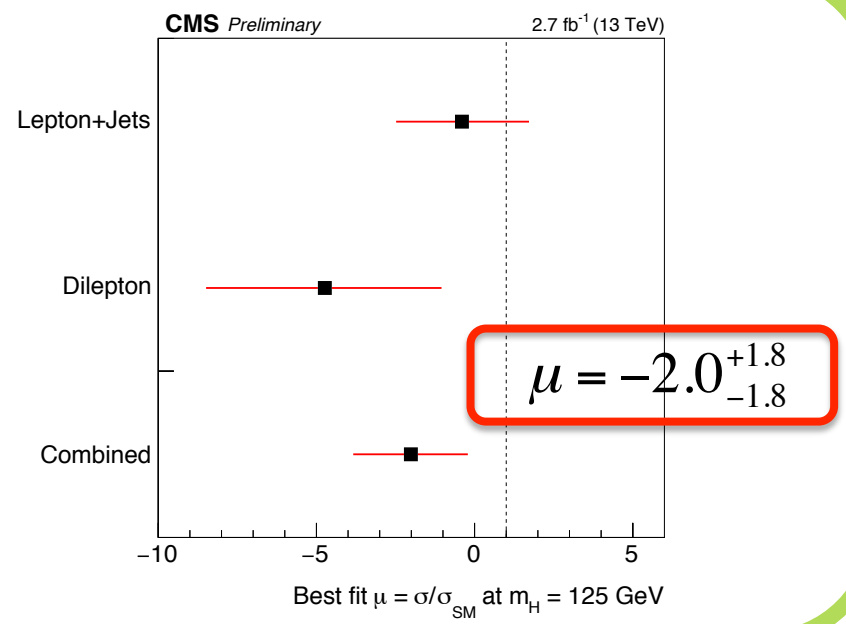




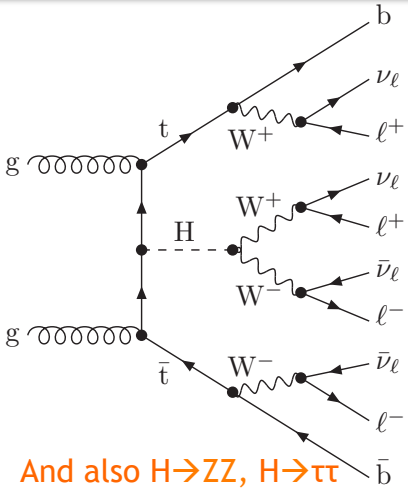


ttH(multileptons)

CMS-PAS-HIG-16-022

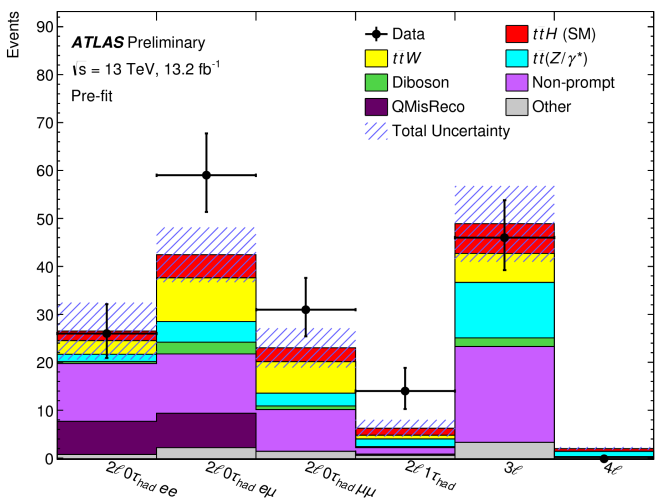
ATLAS-CONF-2016-058

- Targets Higgs decays and focus on final states with clean signatures and low backgrounds
- **Signature:** 2-4 leptons, 2 or more jets, and at least 1 b-tagged jet. Allows at least one τ_{had}
- **Dominant systematic uncertainty:** fake-rate measurements and non-prompt background estimates

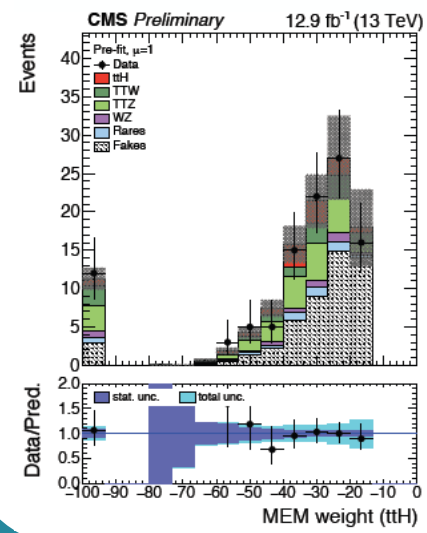


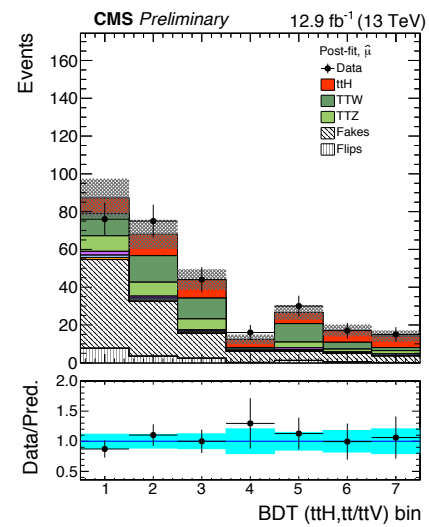
And also H→ZZ, H→ττ

ATLAS cut and count analysis in main different category regions



CMS BDT based discriminants including matrix element weights





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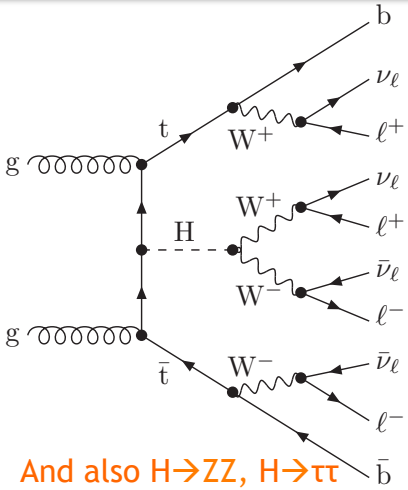
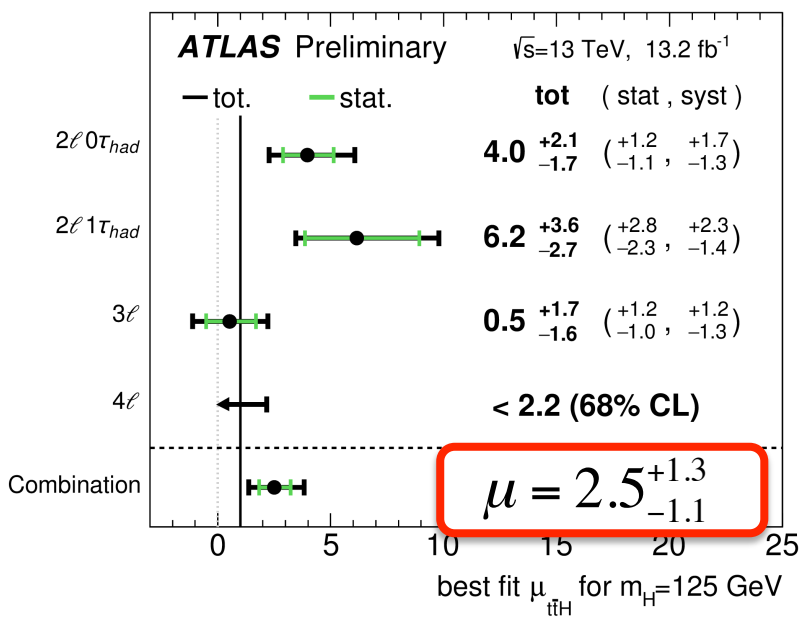
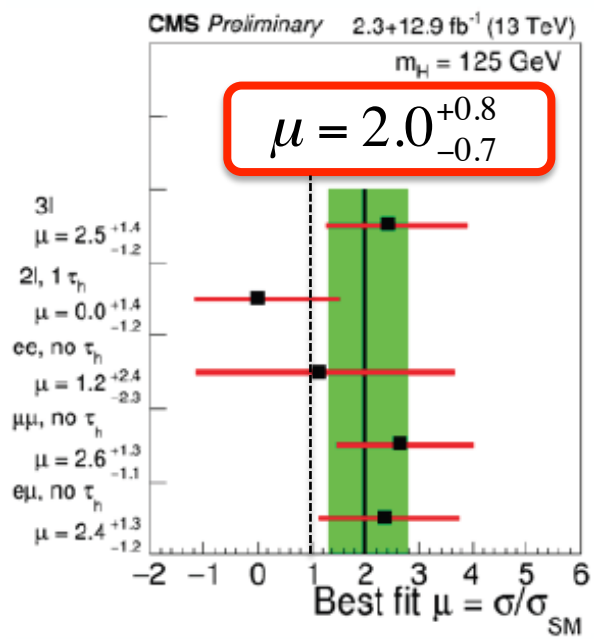
- **Signature:** 2-4 leptons, 2 or more jets, and at least 1 b-tagged jet. Allows at least one τ_{had}
- **Dominant systematic uncertainty:** fake-rate measurements and non-prompt background estimates



And also H→ZZ, H→ττ

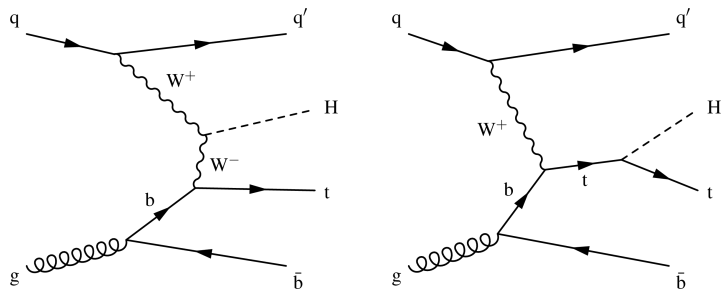


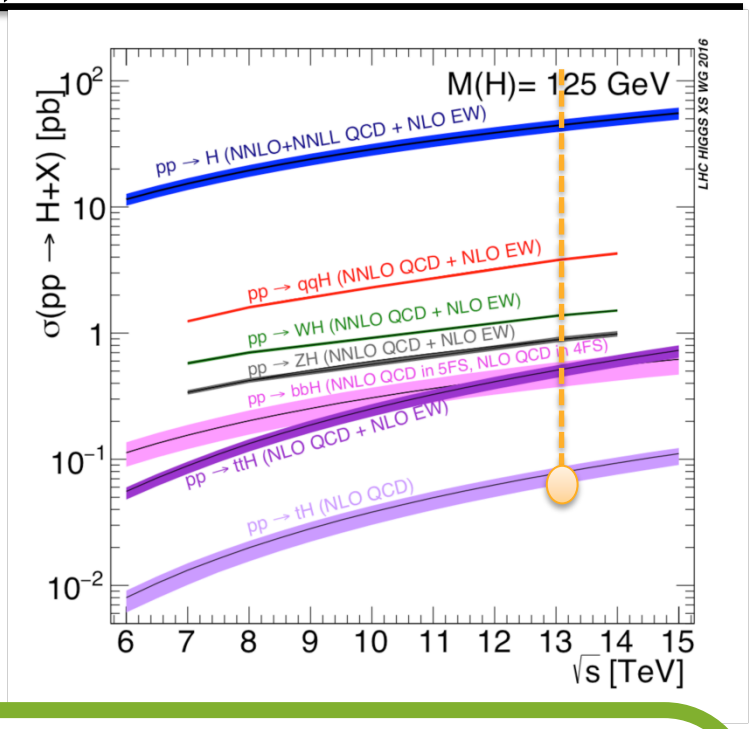


ttH combination $\mu = 1.7^{+0.7}_{-0.8}$ ATLAS-CONF-2016-068

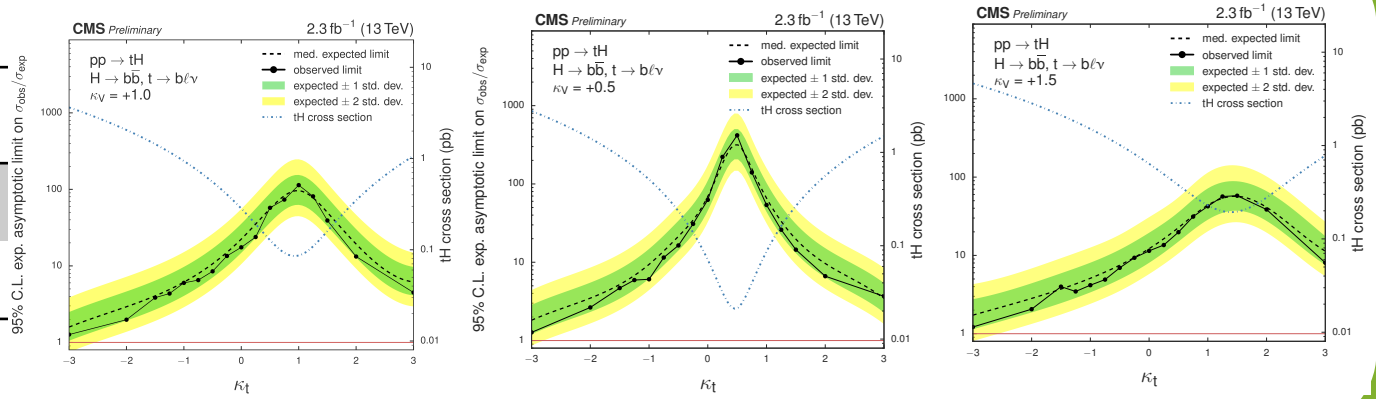
tH(→bb)

- Smallest SM production cross section
  - Diagrams are interfering in SM
  - While it is constructive for inverted top coupling (ITC) κ_{top}=-1



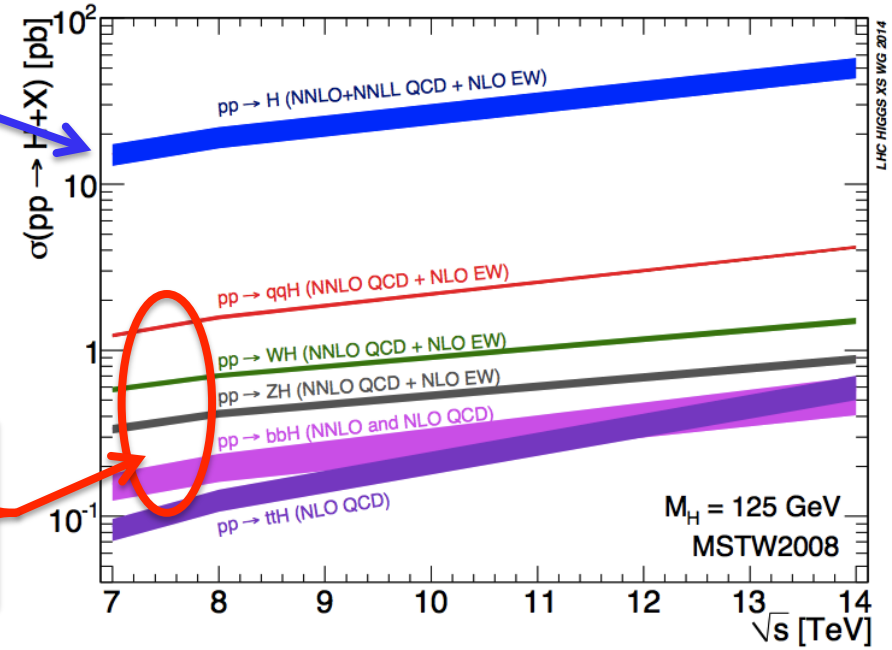


CMS	Upper limit x SM (expected)
SM	113.7 (98.6)
ITC	6.0 (6.4)



Higgs→bb

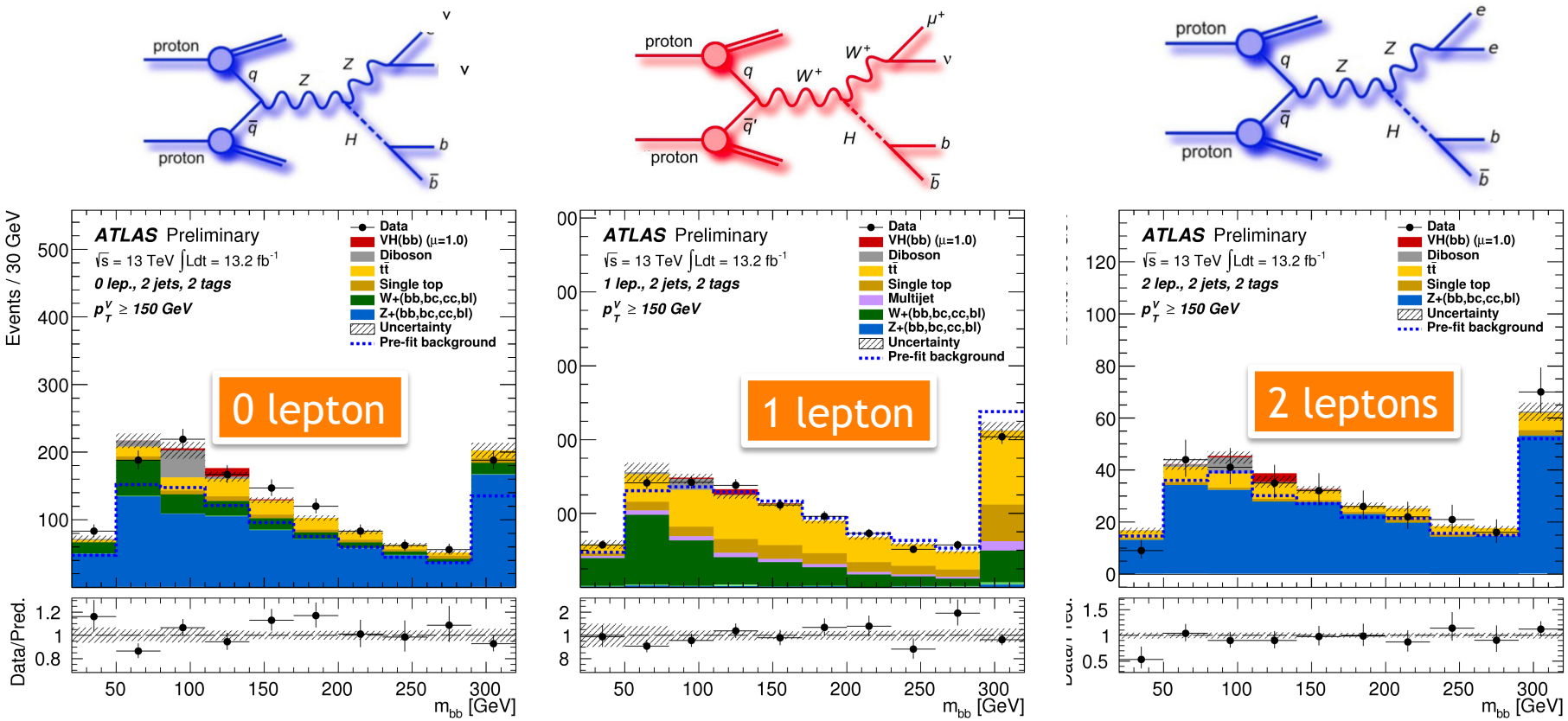
- Important to establish coupling of Higgs to b quarks
  - Inclusive H→bb search extremely challenging: overwhelming background from QCD multi-jet production
- Exploit associated production modes:
  - ttH as previously shown
  - VH with lepton/MET provides clean signature
  - VBF with tagging of forward jets



VH(→bb)

ATLAS-CONF-2016-091

- **Analysis strategy:** utilize leptonic decays of Z/W events
  - Multivariate techniques necessary to achieve good S/B
  - Dominant backgrounds, depend on channel: Z+b, tt
  - Most discrimination from m_{bb} and $\Delta R(b_1,b_2)$
- Systematic and statistical uncertainties of the same size



VH(→bb)

ATLAS-CONF-2016-091

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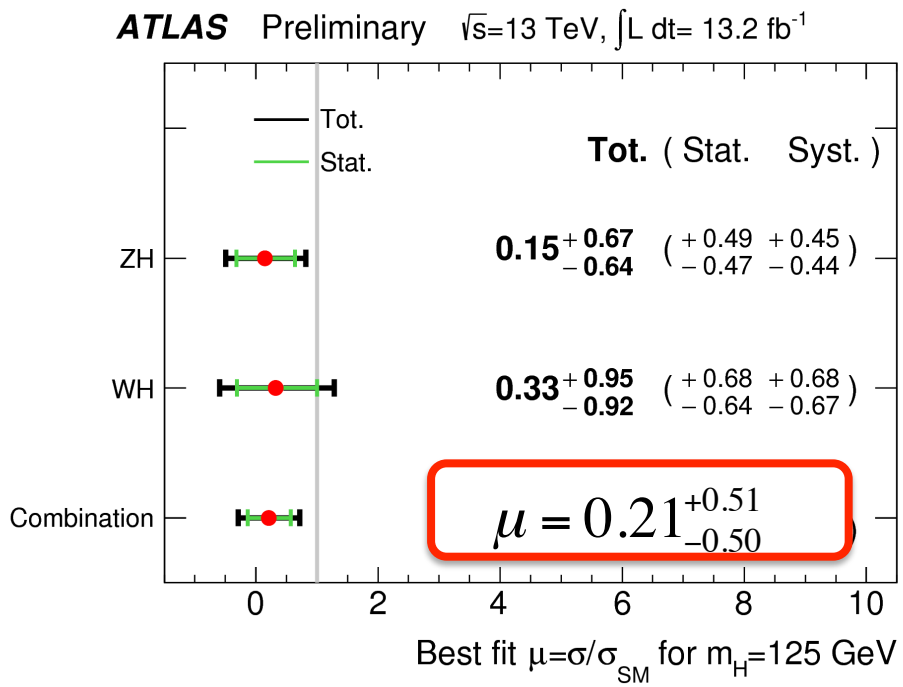


	Significance (expected)
ATLAS (13 TeV)	0.4σ (1.94σ)
ATLAS+CMS (8 TeV)	2.6σ (3.7σ)
Tevatron	2.8σ

Fit tested on SM

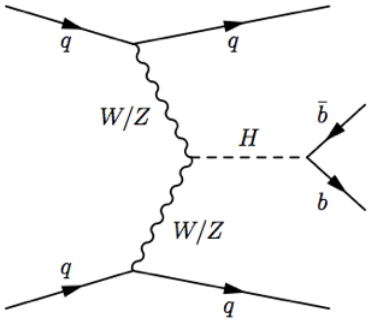
	W(Z)Z(→bb)
Observed μ	0.91±0.17(stat) $^{+0.32}_{-0.27}$(syst)
Significance	3.0σ (expected 3.2σ)

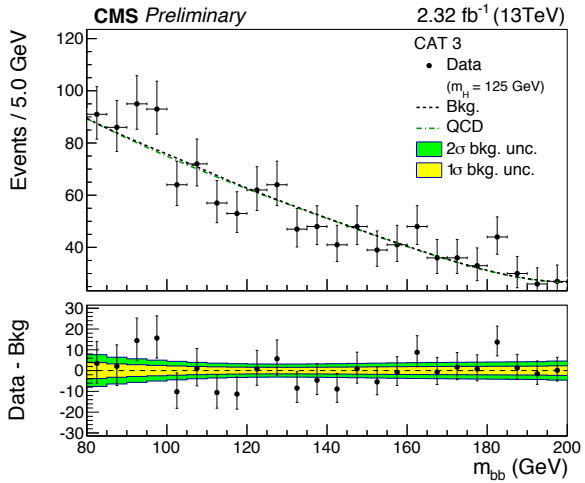
VBF Higgs→bb

CMS-PAS-HIG-16-003

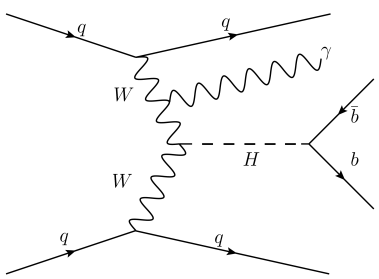
ATLAS-CONF-2016-063

- VBF H→bb more difficult to exploit VBF than VH signature for H→bb but larger production cross-section
  - Forward jets are used to trigger and discriminate against multi-jet background
  - Signal extracted via a fit to the m_{bb} spectrum





CMS	Upper limit x SM (expected)	Signal strength μ
Run 1	5.5 (2.5)	$2.8^{+1.6}_{-1.4}$
Run 2	3.4 (2.3)	$1.3^{+1.2}_{-1.1}$



ATLAS result with 12.6 fb^{-1} requiring a high p_T photon to provide a clean signature for efficient triggering

Fit tested on SM

ATLAS	H(→bb) + γj	Z(→bb) + γj
Upper limit at 95% CL	4 x SM (expected 6 x SM)	2 x SM (expected 1.8 x SM)

Higgs→μμ

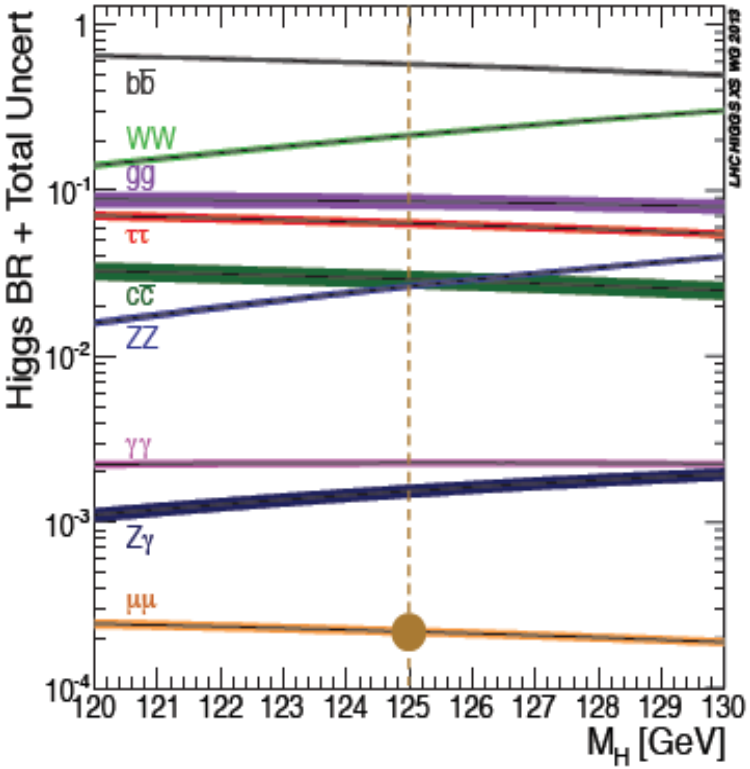
ATLAS-CONF-2016-041

- A very **rare decay** in the SM
  - Probe Yukawa-coupling to 2nd-generation fermions and mass dependence
  - Test of the Higgs coupling to leptons

- **Signature:** Very clean signature from dimuon final state but $Z/\gamma^* \rightarrow \mu\mu$ overwhelming irreducible background

- **Analysis strategy:**

  Search for peak in $m_{\mu\mu}$ spectrum over smoothly falling background
  - Categorize events according to VBF and ggF signature enriched



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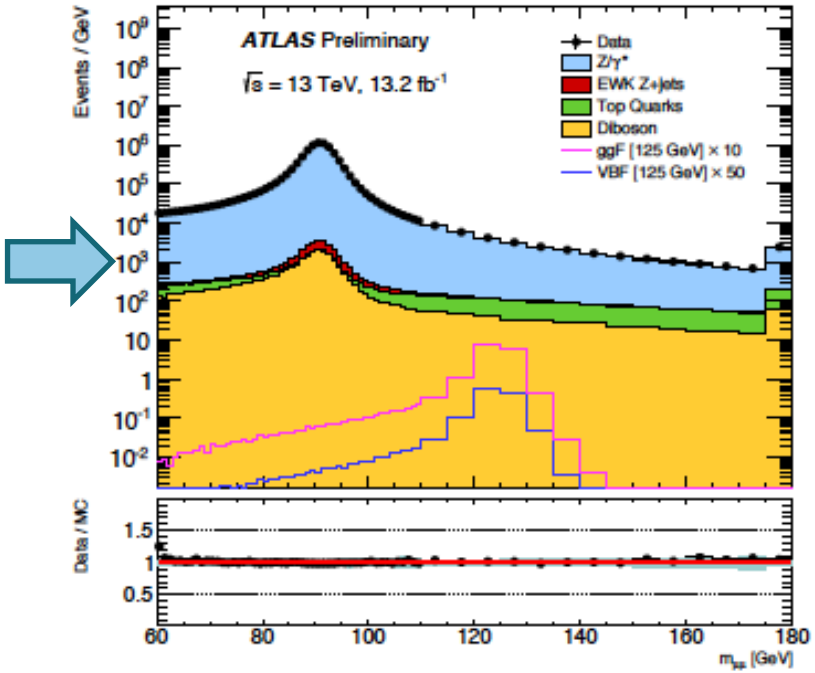

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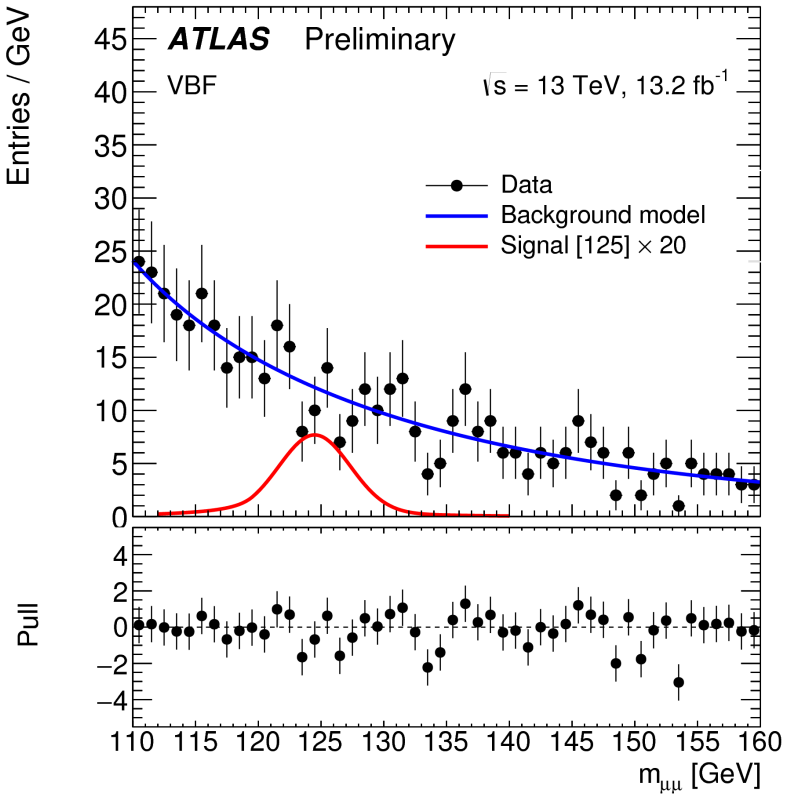


ATLAS	Upper limit x SM (expected)
Run 1	7.1 (7.2)
Run 2	4.4 (5.5)
Combined Run 1 and Run 2	3.5 (4.5)

Beyond the SM

- The 125 GeV Higgs is so far consistent with the SM prediction
- Extensions of the standard model often include an extended Higgs sector
- Numerous models introduce additional Higgses. Many BSM theories require two or more Higgs doublets
  - Heavy Higgs (H),
  - Charged Higgs (H±),
  - Pseudo-scalar Higgs (A)
- And current constraints still allow for Higgs to couple to new particles or new couplings to particle
  - Higgs to invisible
  - Lepton flavour violating decays
  - H(125) decays to pseudo-scalars
- An extensive range of BSM searches are performed at the LHC

Heavy Higgs Searches @ 13 TeV

Some of these in Exotica talk

Higgs to fermions		
H→ττ	2.3 fb^{-1} (CMS-PAS-HIG-16-006)	13.3 fb^{-1} (ATLAS-CONF-2016-085)
H→bb	2.7 fb^{-1} (CMS-PAS-HIG-16-025)	
Higgs to vector bosons		
H→ZZ→4l	12.9 fb^{-1} (CMS-PAS-HIG-16-033)	14.8 fb^{-1} (ATLAS-CONF-2016-079)
H→ZZ→llνν	2.3 fb^{-1} (CMS-PAS-HIG-16-001)	13.3 fb^{-1} (ATLAS-CONF-2016-056)
H→ZZ→llqq	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-082)
H→ZZ→qqνν	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-082)
H→WW→lνlν	2.3 fb^{-1} (CMS-PAS-HIG-16-023)	13.2 fb^{-1} (ATLAS-CONF-2016-074)
H→WW→lνqq	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-062)
H→Zγ		13.3 fb^{-1} (ATLAS-CONF-2016-044)
Higgs to Higgs (diHiggs)		
H→hh→bbbb	2.3 fb^{-1} (CMS-PAS-HIG-16-002)	13.3 fb^{-1} (ATLAS-CONF-2016-049)
H→hh→bbττ	12.9 fb^{-1} (CMS-PAS-HIG-16-029)	
H→hh→bbWW	2.3 fb^{-1}(CMS-PAS-HIG-16-011)	
H→hh→γγWW*		13.3 fb^{-1} (ATLAS-CONF-2016-071)
H→hh→γγbb		13.3 fb^{-1} (ATLAS-CONF-2016-004)

Heavy Higgs Searches @ 13 TeV

Higgs to fermions		
$H \to \tau\tau$	2.3 fb^{-1} (CMS-PAS-HIG-16-006)	13.3 fb^{-1} (ATLAS-CONF-2016-085)
$H \to bb$	2.7 fb^{-1} (CMS-PAS-HIG-16-025)	
Higgs to vector bosons		
$H \to ZZ \to 4l$	12.9 fb^{-1} (CMS-PAS-HIG-16-033)	14.8 fb^{-1} (ATLAS-CONF-2016-079)
$H \to ZZ \to llvv$	2.3 fb^{-1} (CMS-PAS-HIG-16-001)	13.3 fb^{-1} (ATLAS-CONF-2016-056)
$H \to ZZ \to llqq$	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-082)
$H \to ZZ \to qqvv$	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-082)
$H \to WW \to lvlv$	2.3 fb^{-1} (CMS-PAS-HIG-16-023)	13.2 fb^{-1} (ATLAS-CONF-2016-074)
$H \to WW \to lvqq$	included exotica/B2G	13.2 fb^{-1} (ATLAS-CONF-2016-062)
Higgs to Higgs (diHiggs)		
$H \to hh \to bbbb$	2.3 fb^{-1} (CMS-PAS-HIG-16-002)	13.3 fb^{-1} (ATLAS-CONF-2016-049)
$H \to hh \to bb\tau\tau$	12.9 fb^{-1} (CMS-PAS-HIG-16-029)	
$H \to hh \to bbWW$	2.3 fb^{-1}(CMS-PAS-HIG-16-011)	
$H \to hh \to \gamma\gamma WW^*$		13.3 fb^{-1} (ATLAS-CONF-2016-071)
$H \to hh \to \gamma\gamma bb$		13.3 fb^{-1} (ATLAS-CONF-2016-004)

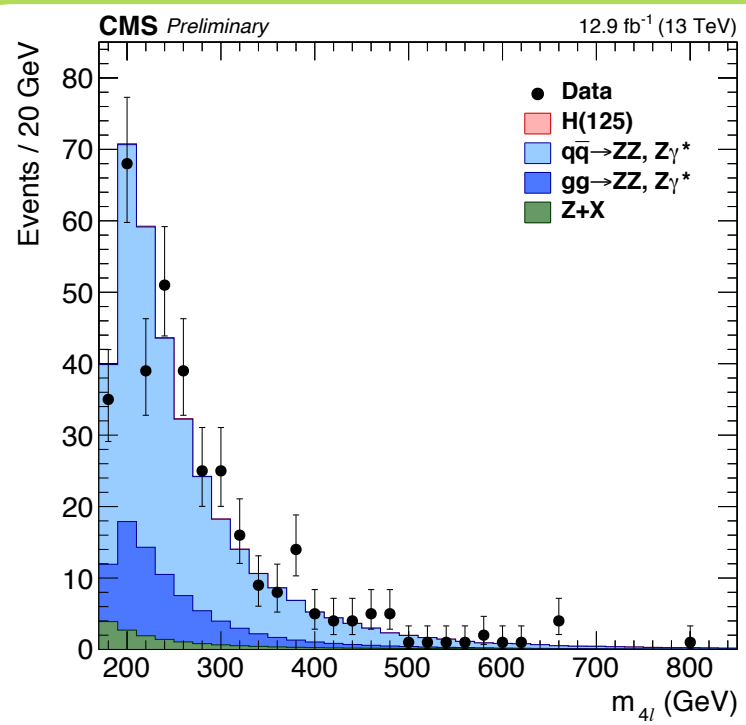
Some of these in Exotica talk

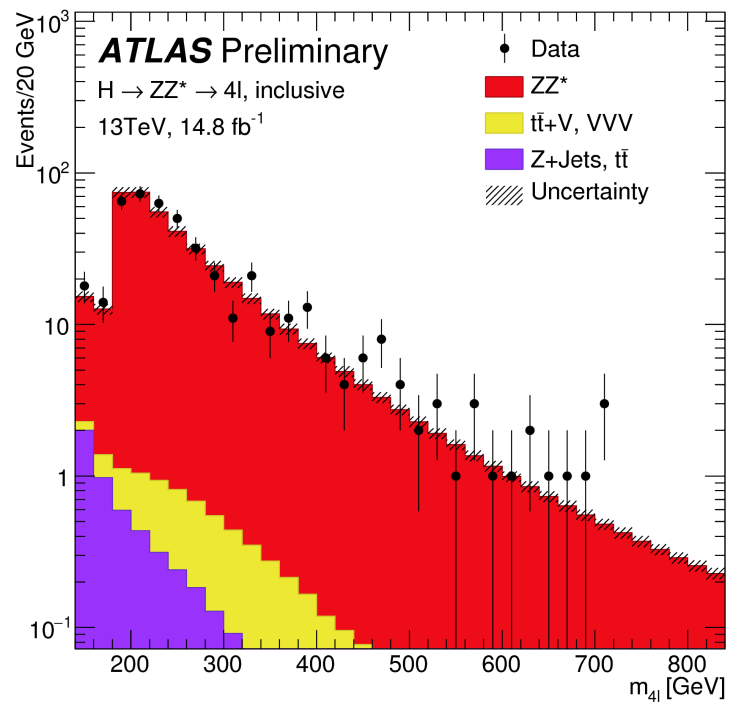
Heavy Higgs→ZZ→4l

CMS-PAS-HIG-16-033

ATLAS -CONF-2016-079

- Search for an additional heavy scalar
  - Assumed to be produced via the ggF and VBF processes
- Extension of the H→ZZ measurement and fits the m_{4l} distribution
- No signal seen we set limits for different decay width Γ_X assumptions



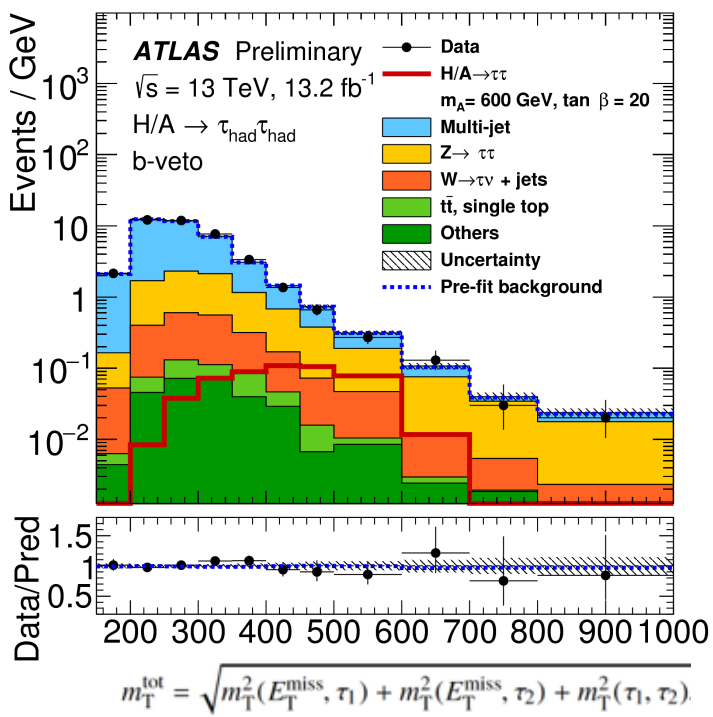


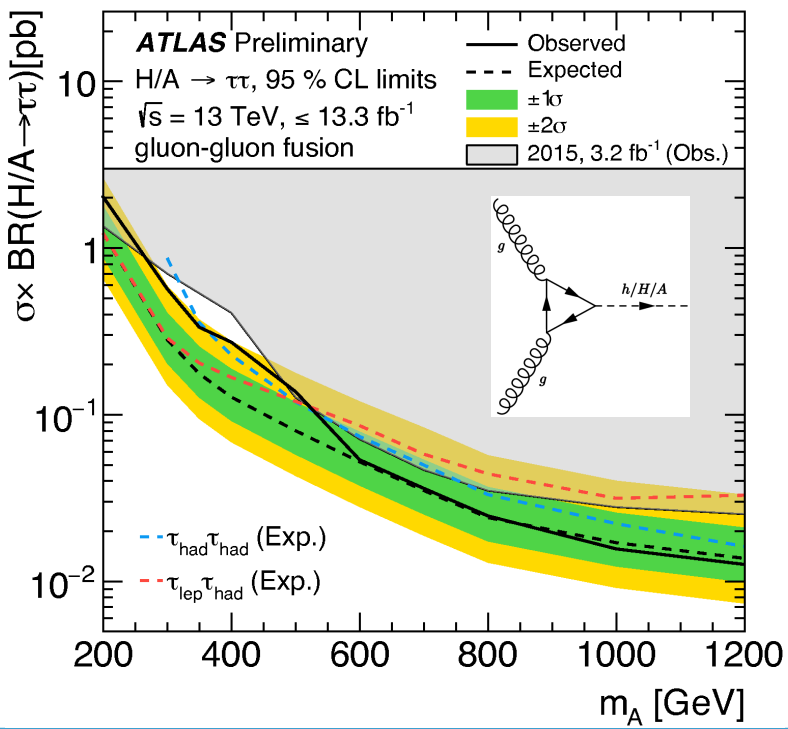
Heavy Higgs→ττ

ATLAS-CONF-2016-041

- In 2HDMs a heavy Higgs boson can have enhanced couplings to down-type fermions
  - Increased heavy Higgs production decaying mainly to b quarks and τ leptons

- New ATLAS analysis includes new triggers and event categories
  - Combine all categories but separate limits for production mechanism





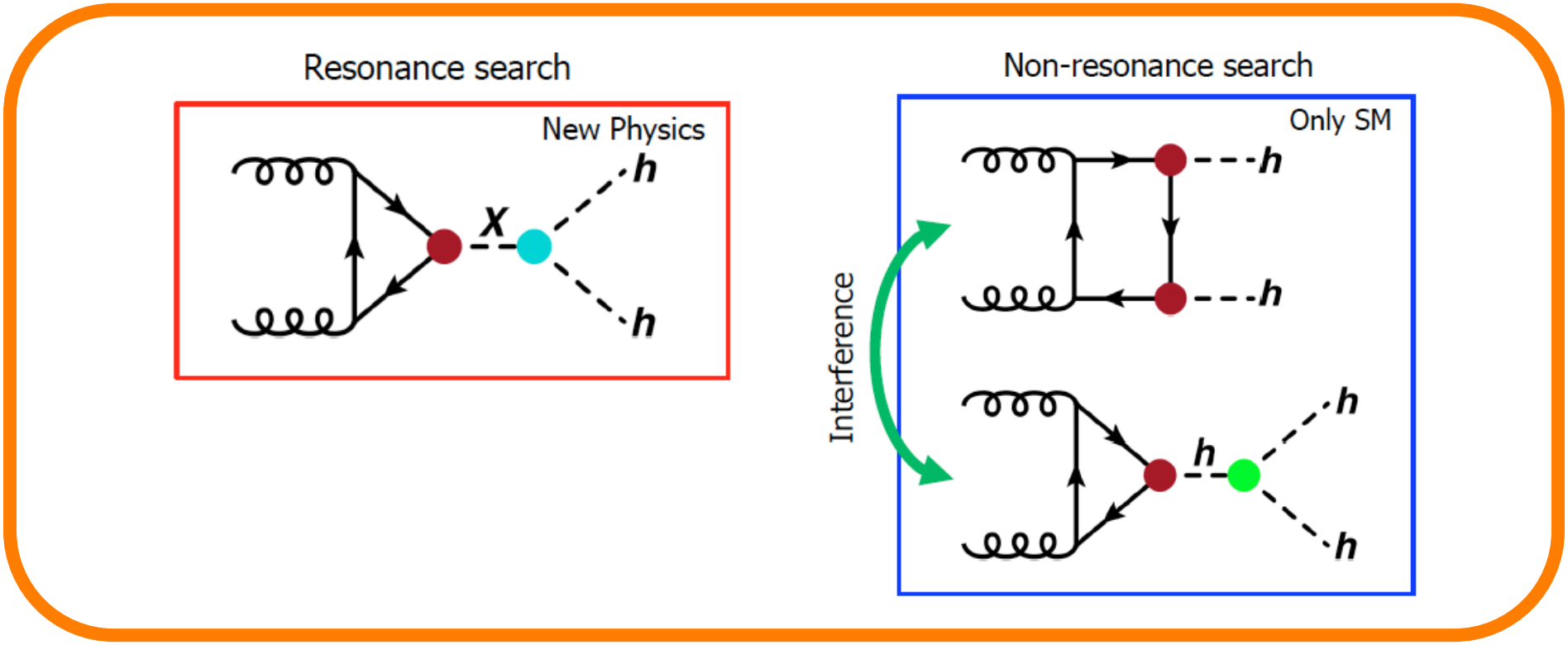
Higgs→hh→bbττ

CMS-PAS-HIG-16-029

CMS-PAS-HIG-16-028

- **Resonance** search
  - generally one h(125)→bb [BR=58%]
  - resonance searches benchmark models: spin-0 (radion) and spin-2 (G)

- **Non-resonance** search
  - BSM can be enhanced by resonance or particle in the loop and can be modeled in EFT adding dim-6 operators to the SM Lagrangian
    - can be described with 5 parameters: λ_{hhh}, y_t, c_2, c_{2g}, c_g



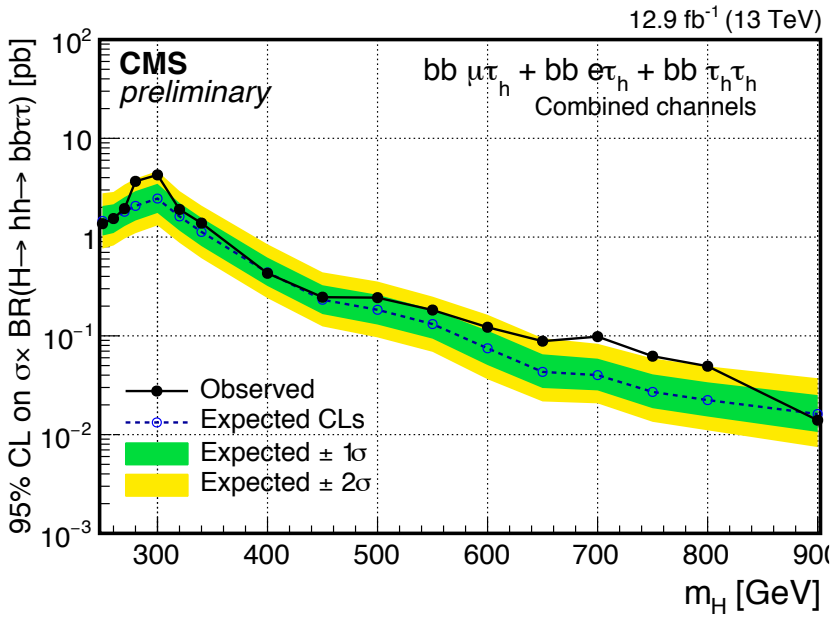
Higgs→hh→bbττ

CMS-PAS-HIG-16-029

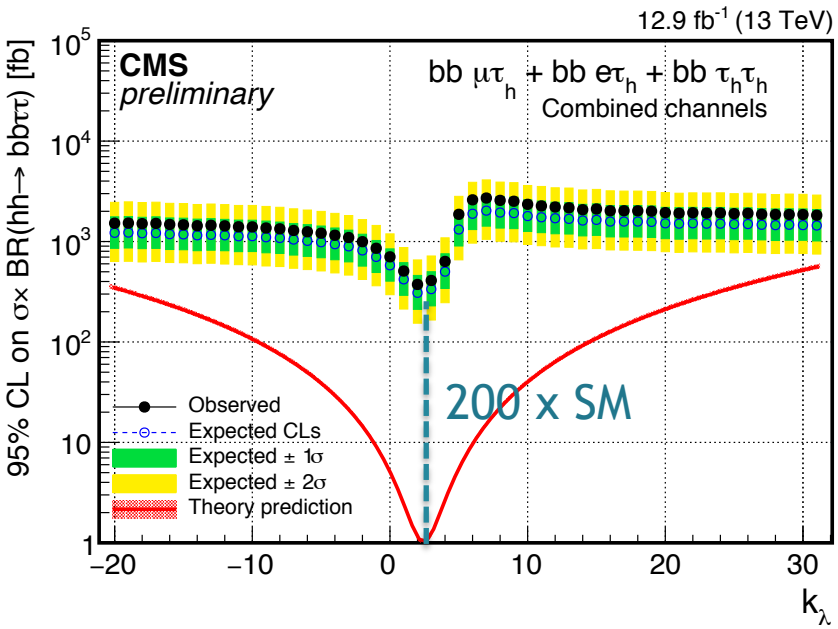
CMS-PAS-HIG-16-028

- **Resonant** search
  - Fit to the invariant mass of ττ and bb
  - At high m_H→boosted regime, uses substructure information for jets, b-tag
- **Non-resonant** search
  - Limits as a function of the ratio of the anomalous trilinear coupling to the SM trilinear coupling ($\kappa_\lambda=\lambda_{hhh}/\lambda^{SM}_{hhh}$)
  - At κ_λ=1 value corresponds to ~200 (170) x SM prediction

Resonant



Non-Resonant



Charged Higgs Searches @ 13 TeV

Charged Higgs		
$H^+ \rightarrow \tau\nu$		14.7 fb^{-1} (ATLAS-CONF-2016-088)
$H^+ \rightarrow tb$		13.2 fb^{-1} (ATLAS-CONF-2016-089)
$H^+ \rightarrow WZ$	15.2 fb^{-1} (CMS-PAS-HIG-16-025)	

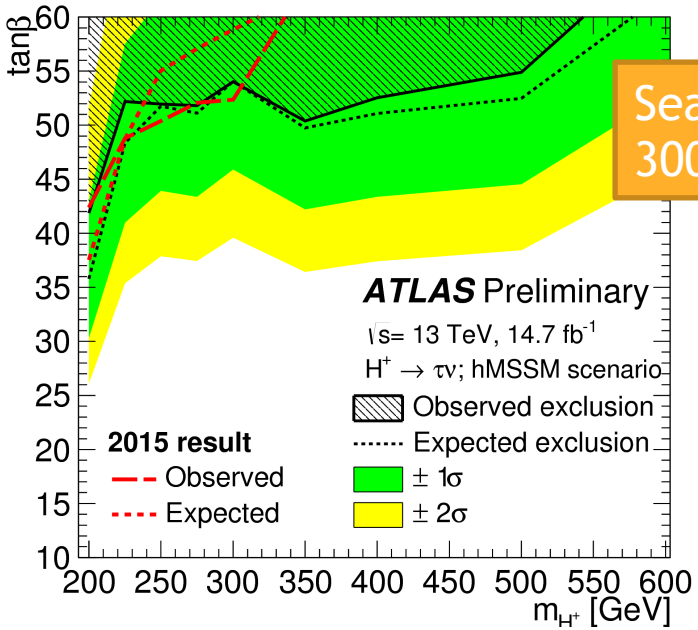
Charged Higgs

CMS-PAS-HIG-16-025

ATLAS-CONF-2016-089

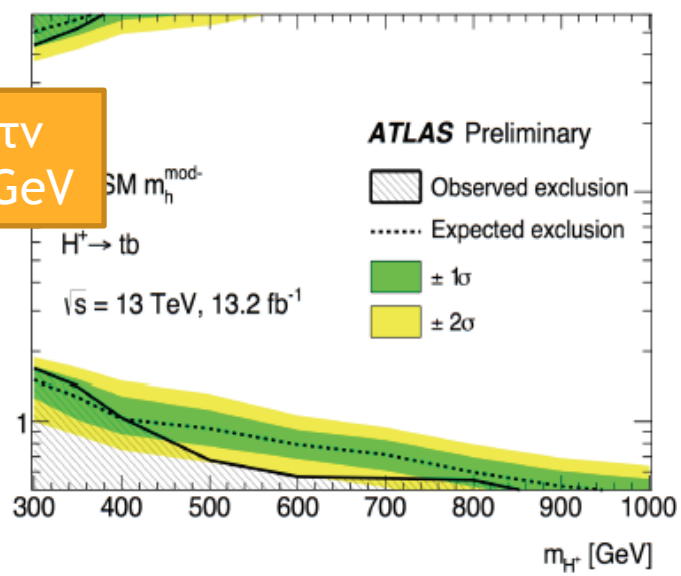
ATLAS-CONF-2016-088

Charged Higgs bosons appear in many extensions of the SM

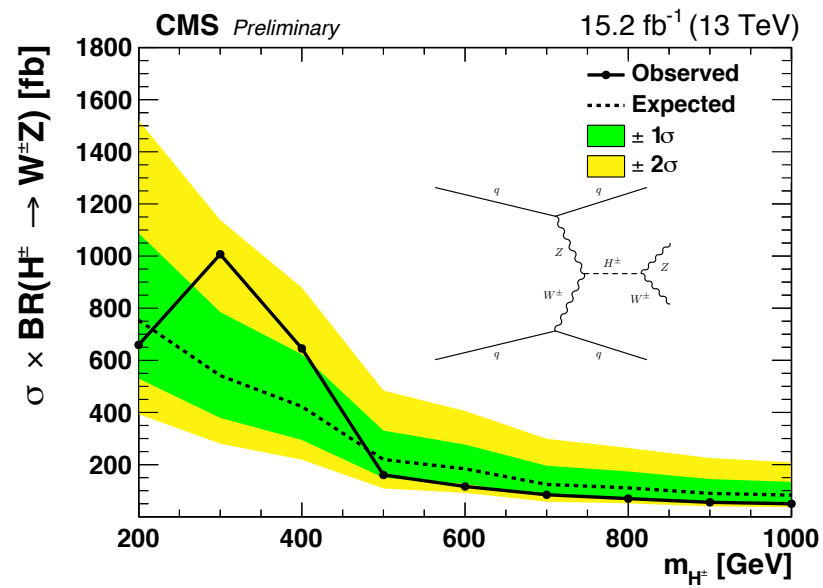


Search for $H^{\pm} \rightarrow tb$
$300 < m_{H^{\pm}} < 1000$ GeV

Search for $H^{\pm} \rightarrow \tau\nu$
$200 < m_{H^{\pm}} < 2000$ GeV

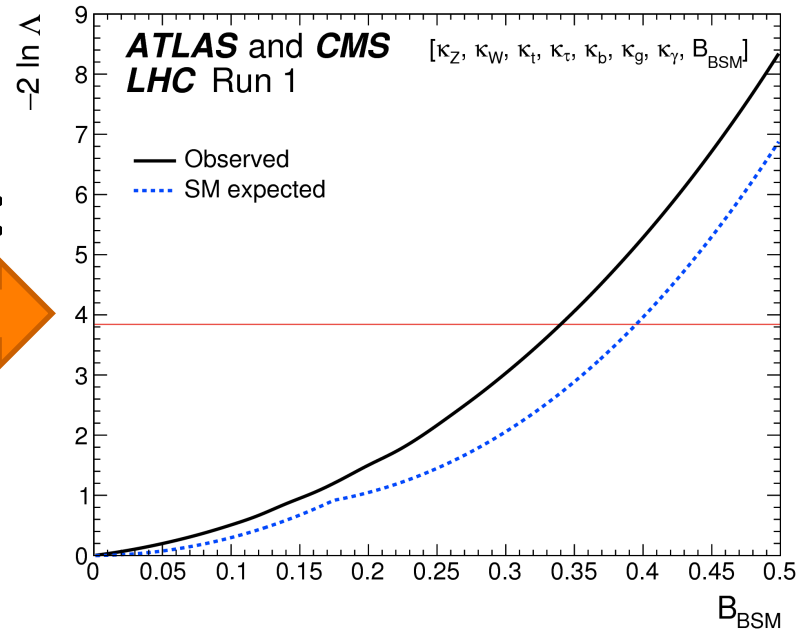


Search for $H^{\pm}WZ$



Exotic decays of the Higgs boson

- Fit of Run-1 SM Higgs measurements/searches provides indirect constraint:
  - B(H→BSM)<34% at 95% CL



- Search for BSM decays directly, e.g.
  - H→ invisible
  - LFV decays, e.g. eμ, μτ, eτ
  - H→aa in nMSSM

Exotic decays at 13 TeV

Higgs to invisible		
ggF + VH	12.9 fb^{-1} (CMS-PAS-HIG-16-037)	
combination	Run 1 + Run 2 (2.3 fb^{-1}) (CMS-PAS-HIG-16-016)	
ZH	12.9 fb^{-1} (CMS-PAS-HIG-16-038)	13.3 fb^{-1} (ATLAS-CONF-2016-056)
Lepton Flavor Violating Decays		
$H \rightarrow \mu\tau$	2.3 fb^{-1} (CMS-PAS-HIG-16-005)	
h(125) to pseudo-scalars		
$h \rightarrow aa \rightarrow 2\mu 2b$	Run I full dataset summary of results (CMS-PAS-HIG-16-007)	
$h \rightarrow aa \rightarrow 4\mu$		
$h \rightarrow aa \rightarrow 2\mu 2\tau$		
$h \rightarrow aa \rightarrow 4\tau$		
$W(h \rightarrow aa \rightarrow b\tau)$		3.2 fb^{-1} (arXiv:1606.08391)
Rare decays		
$H/Z \rightarrow \varphi\gamma$		2.7 fb^{-1} (arXiv:1607.03400)

Exotic decays at 13 TeV

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ggF + VH	12.9 fb^{-1} (CMS-PAS-HIG-16-037)	
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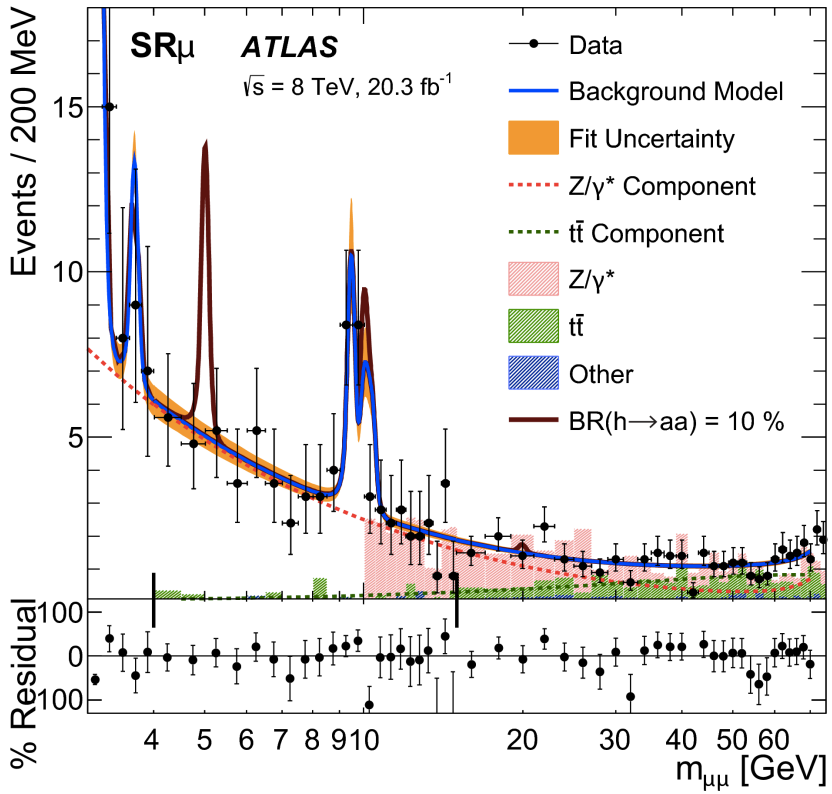
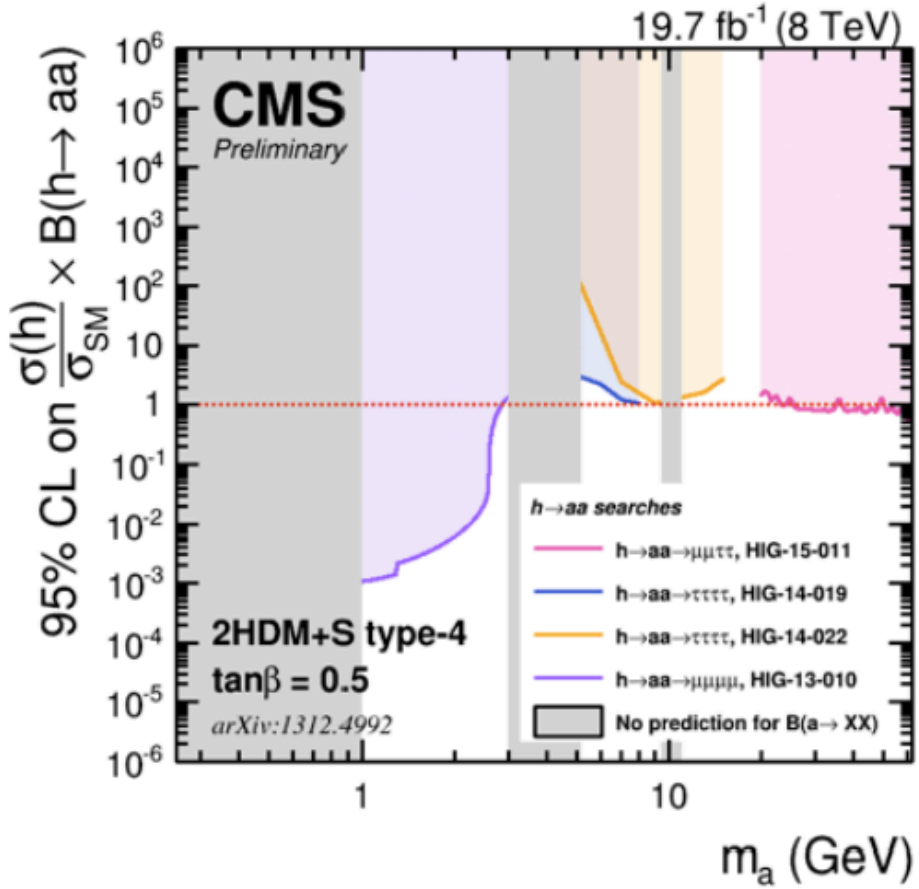
Higgs→aa

CMS-PAS-HIG-16-007



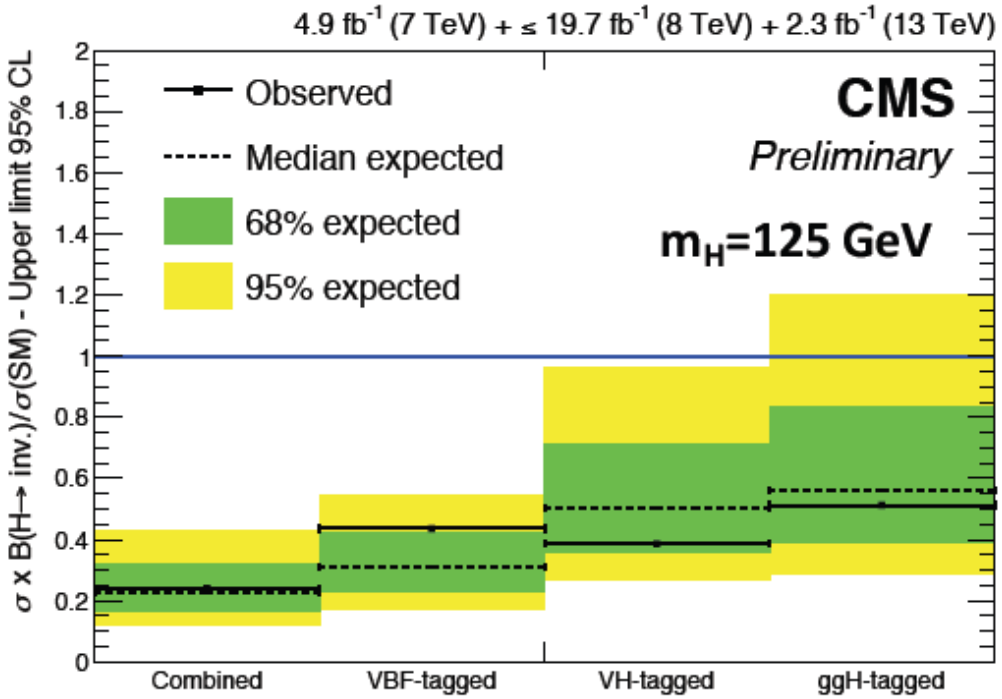


- Many final states explored by ATLAS and CMS
  - Many searches depending on m(a) and decay, e.g. a->γγ,μμ,ττ,bb
  - No significant deviation from SM expectation in any search
  - BR limits range from 0.1% to 100% depending on m(a)

Higgs→invisible

CMS-PAS-HIG-16-037

- Search for invisible Higgs boson decays in several production modes, with different cross-sections and S/B ratios
- Assume SM values for ratios of production cross sections



VH includes Z(ll), Z(bb), and V(jj)H channels

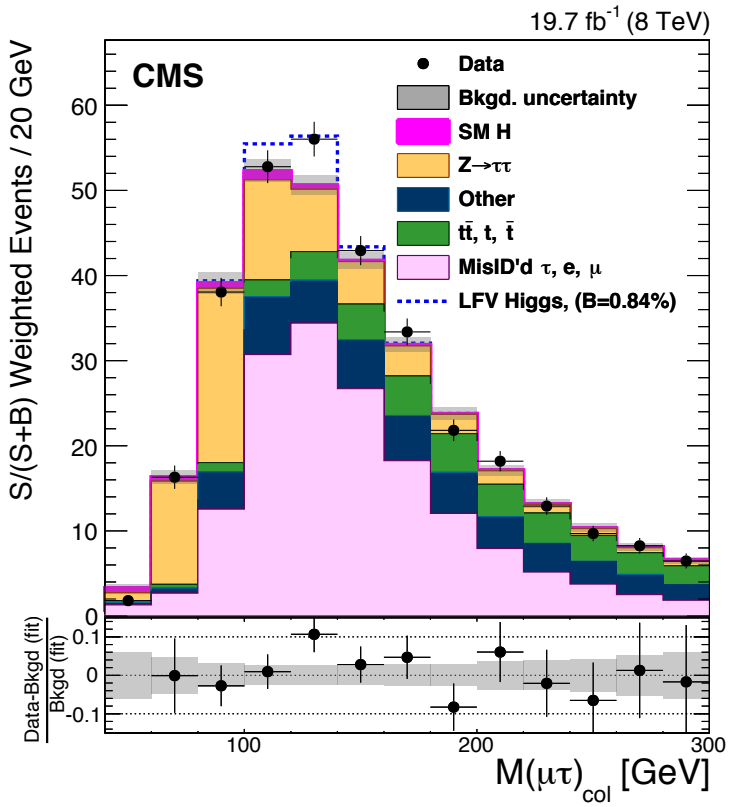
Expected sensitivity dominated by vector-boson fusion channel

σxB(H→invisible) < 24% (23% expected)

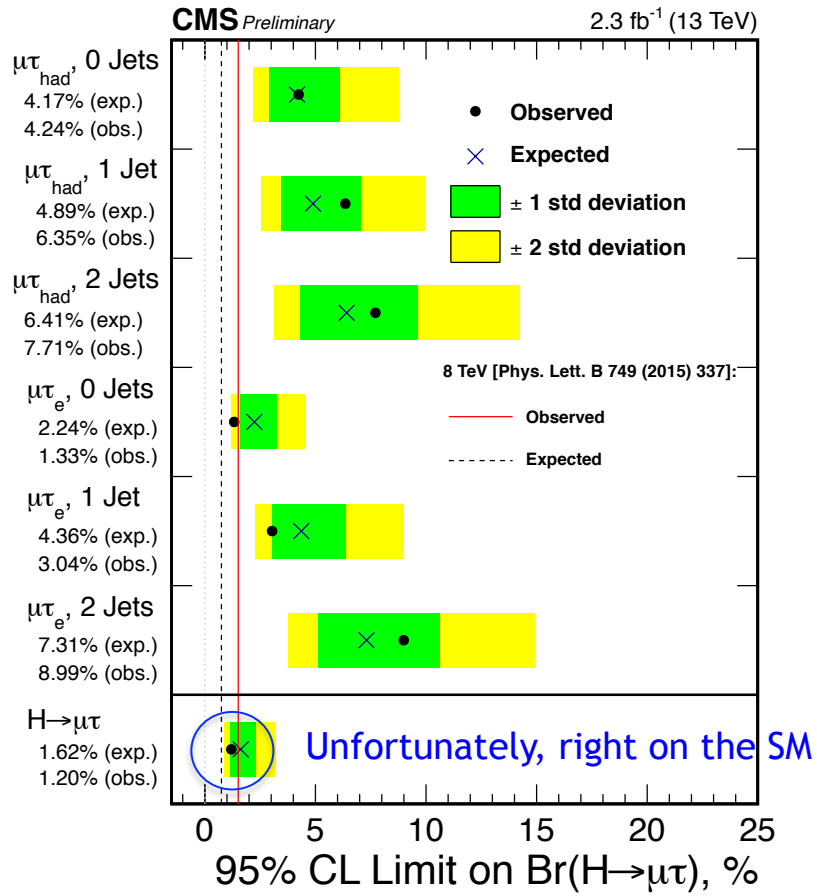
Lepton Flavor Violating Higgs

CMS-PAS-HIG-16-005

- In the 8 TeV data, CMS found a small excess searching for lepton-flavor violating Higgs couplings in H→μτ



With 13 TeV. we searched again :



Summary

- Run II of the LHC at $\sqrt{s}$ = 13 TeV is now making an even larger sample of Higgs boson events available for analysis
  - Higgs physics is moving at full speed
- These data are increasing in precision and opening up new channels to study the interactions of Higgs bosons and SM particles
  - Run 2 is surpassing Run 1 precision
- Higher collision energies is allowing us to direct probe for BSM physics by searching for additional Higgs bosons and for anomalous decays of the Higgs(125) boson
  - Many BSM searches presented, more to come soon !


L. Aperio Bella


M. Cepeda

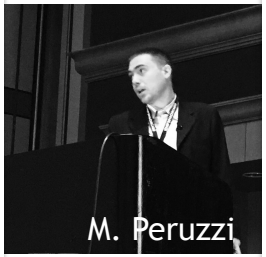
M. Trovatelli

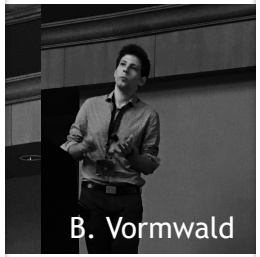

T. Varol


T. Vickey


V. Tavolaro

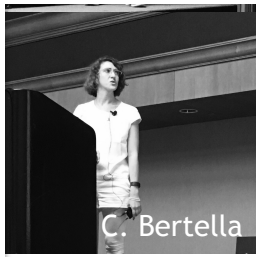

D. Gebaudo


M. Peruzzi


B. Vormwald

K. Köneke


J. Keller


C. Bertella


C. Palmer


G. Marchiori


A. Pilkington


L. Zivkovic


C. Grefe


P. Conde Muino


P. Saxena

N. Wardle

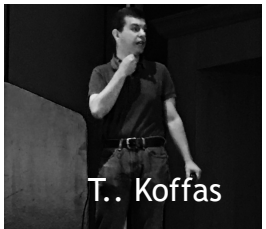

B. Laforge


A. Massironi


U. Sarica

G. Ortona


A. Mertens


T.. Koffas


A. Marini


C. Gwiliam

S. Regnard

C. Carrillo Montoya

EXTRA MATERIAL

Fiducial Cross Sections

- Differences in the fiducial selections for H→ZZ and H→γγ

- Taken from the links :
  - ATLAS H→ZZ http://cds.cern.ch/record/2206253/files/ATLAS-CONF-2016-079.pdf
  - CMS H→ZZ http://cds.cern.ch/record/2204926/files/HIG-16-033-pas.pdf
  - ATLAS H→γγ http://cds.cern.ch/record/2206210/files/ATLAS-CONF-2016-067.pdf
  - CMS H→γγ http://cds.cern.ch/record/2205275/files/HIG-16-020-pas.pdf

- γγ differences in fiducial selection :
  - CMS : both photons $|\eta| < 2.5$, excluding $1.44 < |\eta| < 1.57$, 1st $p_T > 30$ GeV, 2nd $p_T > 20$ GeV
  - ATLAS : both photons $|\eta| < 2.37$ (excluding $1.37 < |\eta| < 1.52$), both with $E_T > 25$ GeV and

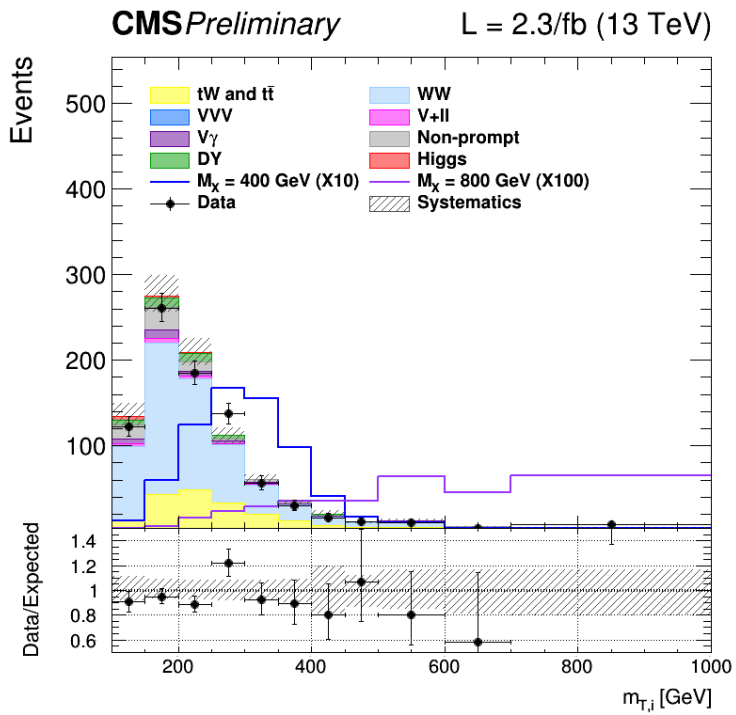
- ZZ differences in fiducial selection :
  - CMS : 1st lepton $P_T > 20$ GeV, 2nd $P_T > 10$ GeV, other mu $P_T > 5$, ele $P_T > 7$ GeV
  - ATLAS : 1st $P_T > 20$ GeV, 2nd $P_T > 15$, 3rd $P_T > 10$ GeV, 4th mu $P_T > 5$, 4th ele $P_T > 7$ GeV
  - Z_1 and Z_2 mass cuts also slightly different between experiments

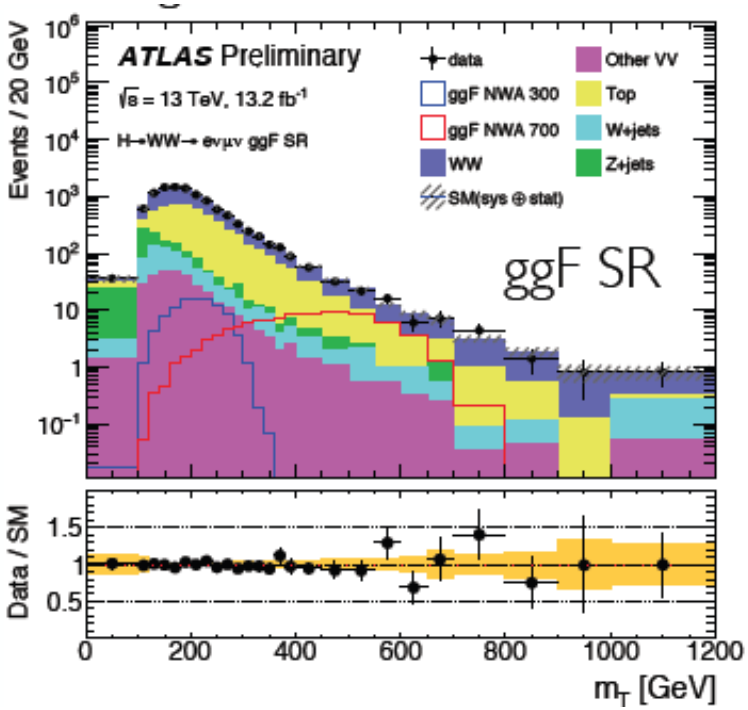
- For both, additional cuts to remove various backgrounds - too hard to tabulate
- Additional cuts on jets, b-jets, leptons to enrich ttH, VH, VBF categories

Heavy Higgs→WW→lvlv

- Extraction of signal done via a fit to the M_T of the 2 leptons and MET
  - Events are categorized according to the jet multiplicity
  - Divided in ggF and VBF

- Limits set for different hypothesis of the signal width
  - ATLAS: low mass limits than previously combined limits





Heavy Higgs→WW→lvlv

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  - Events are categorized according to the jet multiplicity
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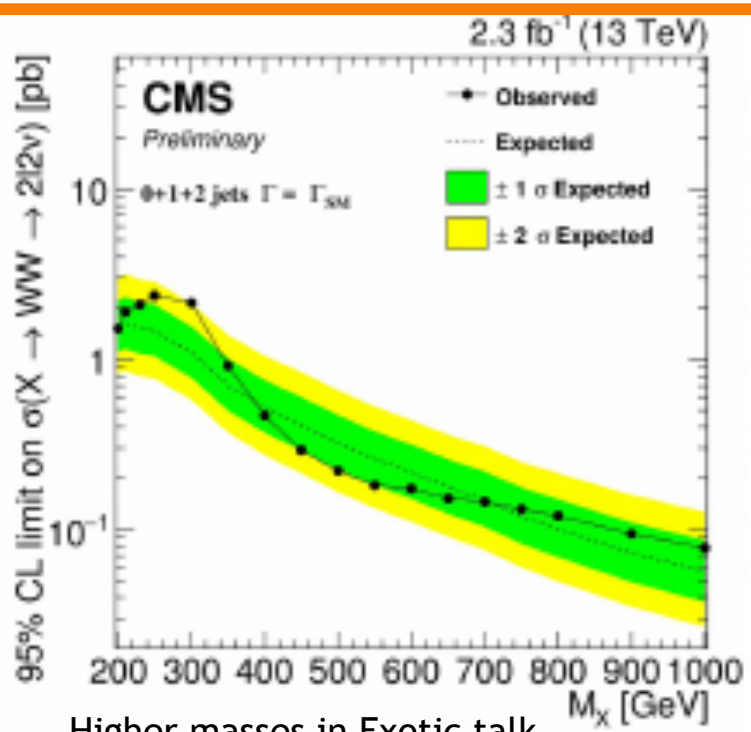
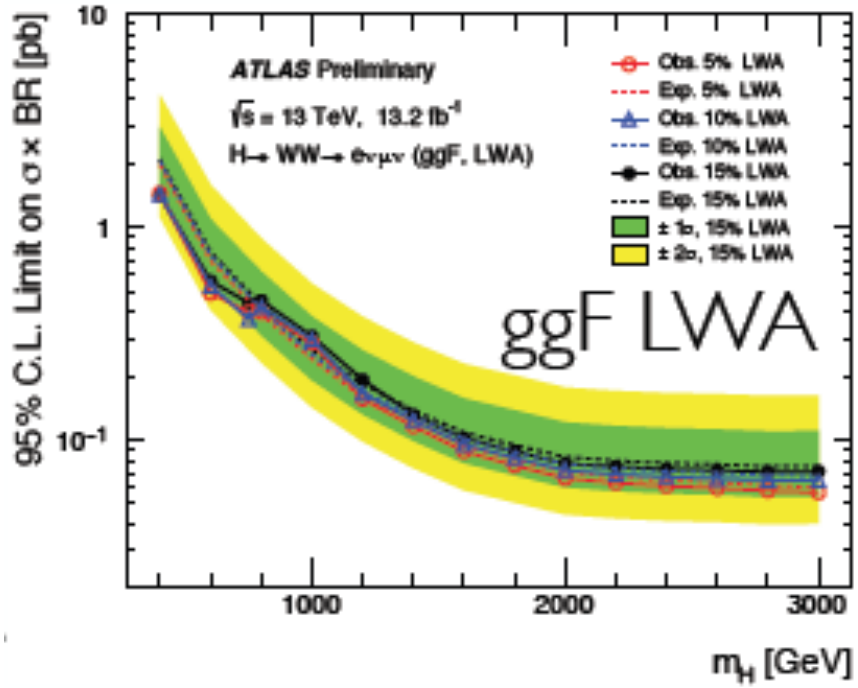


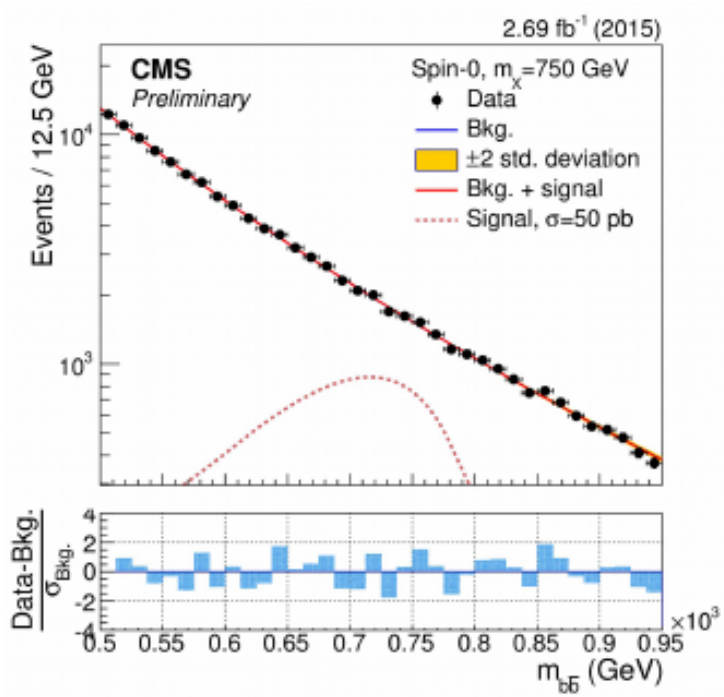


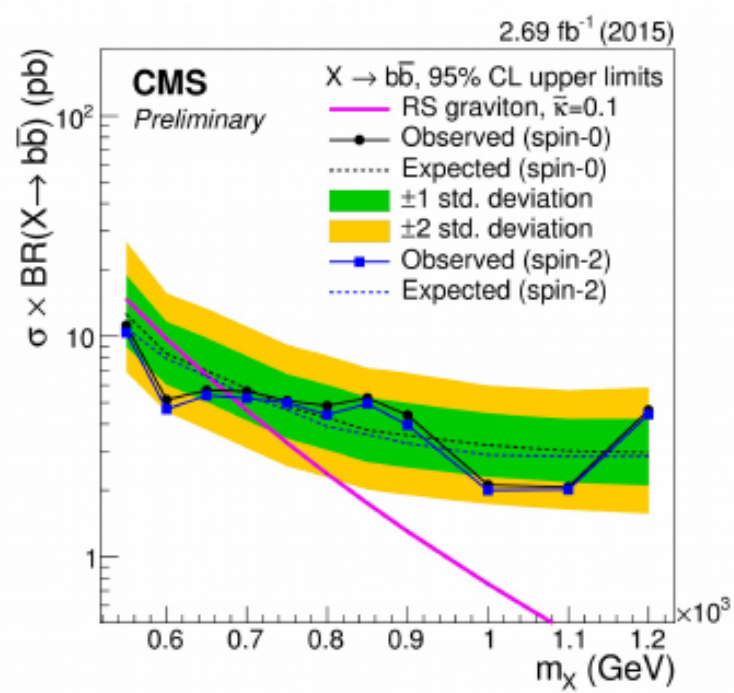
Higher masses in Exotic talk

Heavy Higgs→bb

- Narrow heavy neutral boson resonance decaying to b quarks
  - Motivated by excess of data in diphoton (750 GeV)
  - Two benchmark scenarios: a spin-0 resonance produced in gluon-gluon fusion, and a spin-2 Randall-Sundrum graviton, both with a negligible width-over-mass ratio

- Peak in dijet mass spectrum to smoothly falling background





Higgs→bb

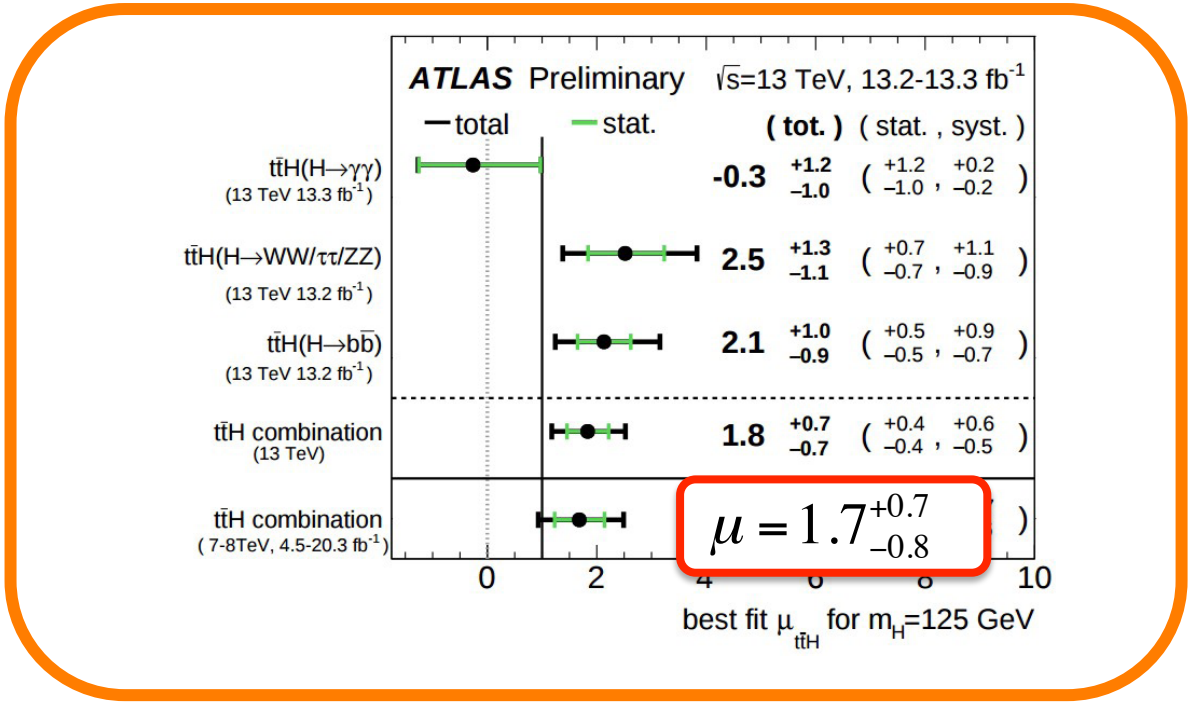
VBF	
8 TeV	**Upper limit x SM (expected)**
ATLAS	4.4 (5.4)
CMS	5.5 (2.5)

VH	
8 TeV	**Observed (expected) significance**
ATLAS	1.4σ (2.6σ)
CMS	2.1σ (2.1σ)
ATLAS+CMS	2.6σ (3.7σ)
Tevatron	2.8σ

ttH(combination)

ATLAS-CONF-2016-068

- ttH(→bb), tt(multileptons), and ttH(γγ) combined



$$\mu = 1.7^{+0.7}_{-0.8}$$

- Observed significance with respect to background only hypothesis 2.8σ (1.8σ expected)

Heavy Higgs→ZZ→4l

CMS-PAS-HIG-16-033

ATLAS -CONF-2016-079

- Search for an additional heavy scalar
  - Assumed to be produced via the ggF and VBF processes
- Extension of the H→ZZ measurement and fits the m_{4l} distribution
- Decay width Γ_X free parameter in the limit, different assumptions considered