Experimental Report from EWSB group

E. Barberio,

The University of Melbourne

EWSB session

10 theory talks and 10 experimental talks

Set up so in each session related experimental and theory talks to spark discussions

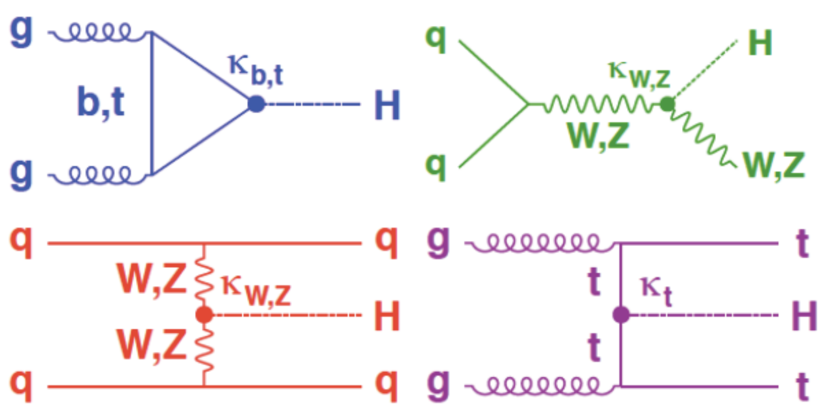
There have been many discussions and questions

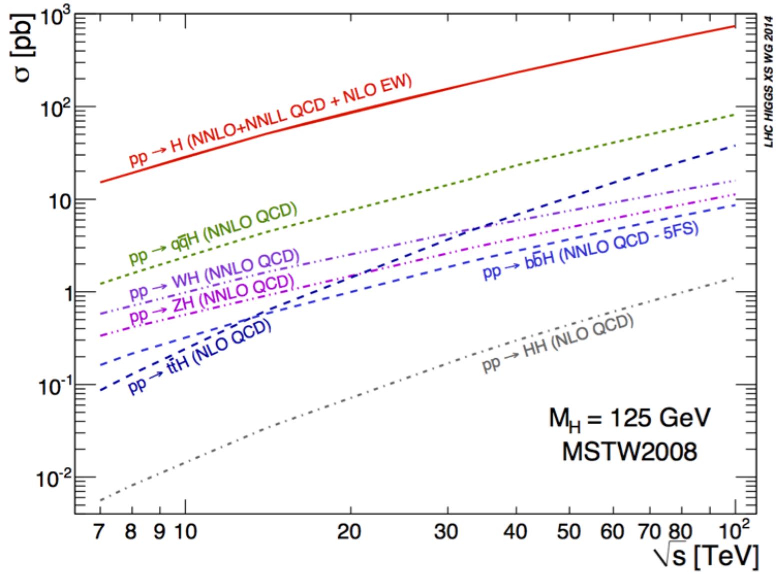
In my summary I will reflect these discussions

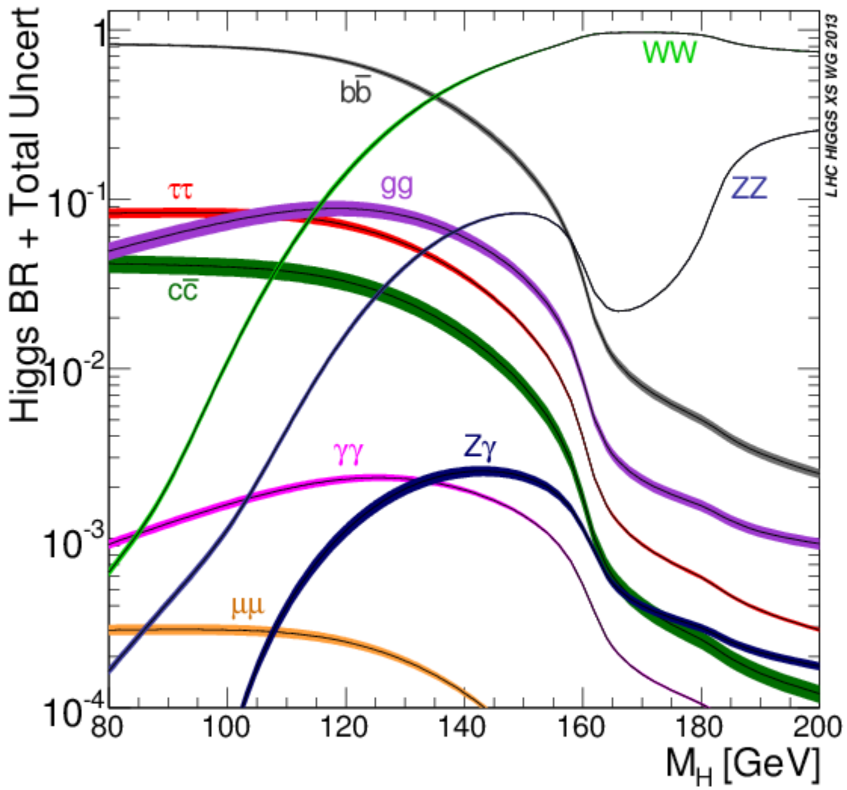
The LHC run at 13 TeV stared, this has influenced this review

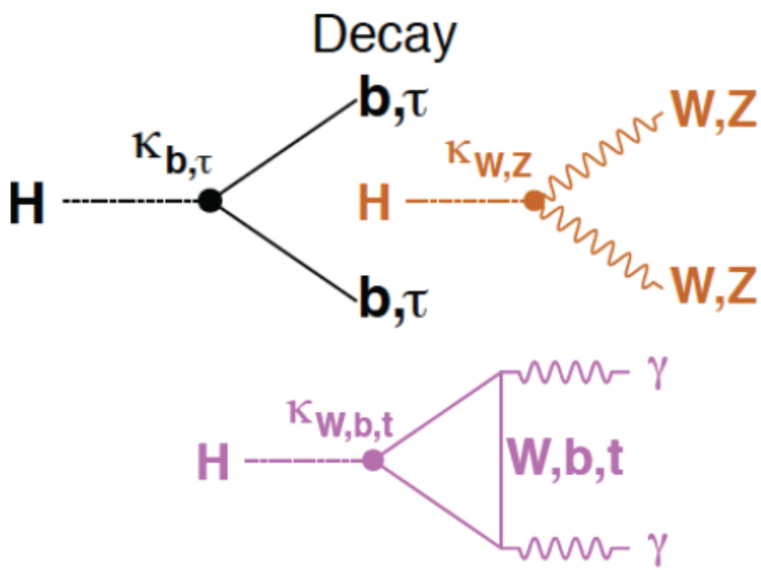
Many thanks to the speakers for their contribution and to the students who assisted during the sessions

Higgs production and decay at the LHC





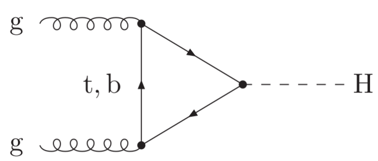
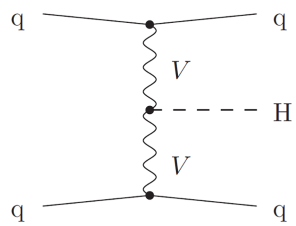
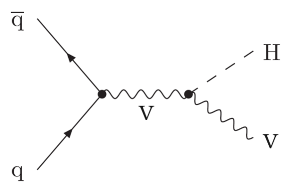
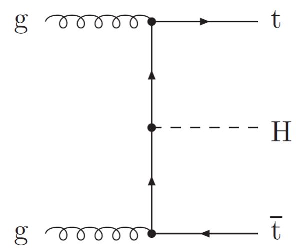




We are measured the boson Higgs decays but still we have no direct evidence of Higgs coupling to fermions

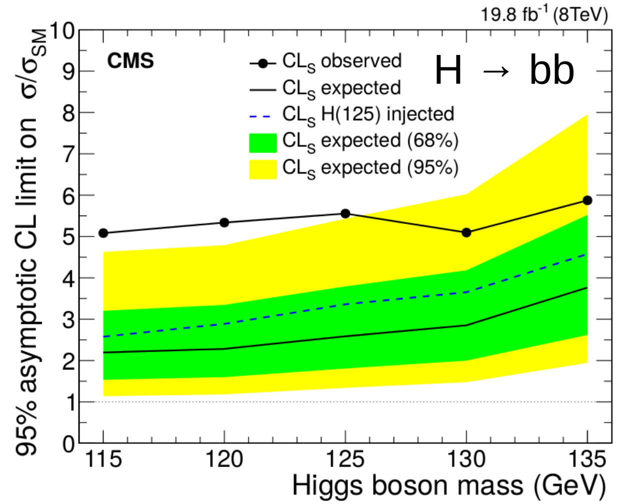
S. Donato

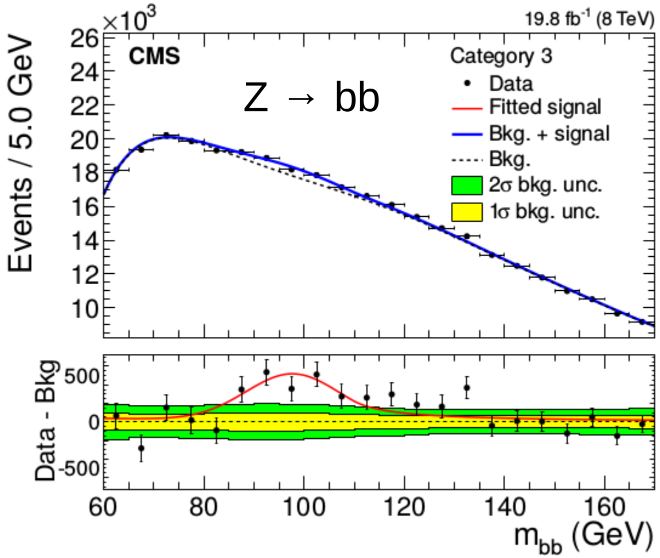
Searches for Higgs boson decaying into fermions

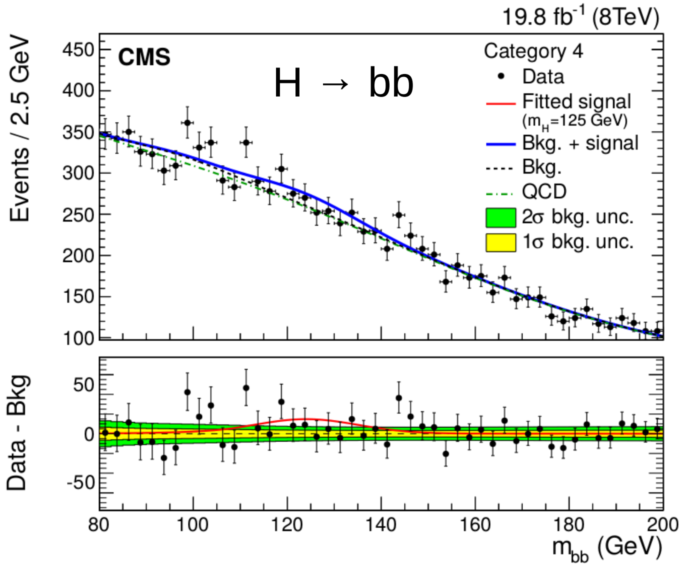
	ggH	VBF	VH	ttH
				
H → bb	(QCD bkg. too large)	Large QCD bkg. Low mass resolut.	Small x-sec∗BR VV, V+jets, tt bkg. Low mass resolution	Small x-sec∗BR tt+jets backgrounds Low mass resolution
H → ττ	Large Z→ττ bkg. Very low mass resol.	Small x-sec∗BR Z→ττ bkg. Low mass resolut.	Small x-sec∗BR Z→ττ bkg. Low mass resolut.	Very small x-sec. Low mass resolution
H → μμ	Small x-sec∗BR. Large Z→μμ bkg. High mass resol.	Very small x-sec∗BR. Small Z→μμ bkg. High mass resol.	Very small x-sec∗BR. Small Z→μμ bkg. High mass resol.	(x-section and BR are too small)

[new!] VBF H $\rightarrow$ bb

- Signal strength: $\boldsymbol{\mu} = \mathbf{2.8}^{+1.6}_{-1.4}$.
- Observed (exp.) 95% CL upper limit: **5.5 (2.5).**
- Observed p-value (exp.): **2.2σ (0.8σ)**.
- Cross-check Z→bb resonance:
  - $\mu_Z = 1.10^{+0.44}_{-0.33}$; p-value$_Z$ 3.6σ (3.3σ).



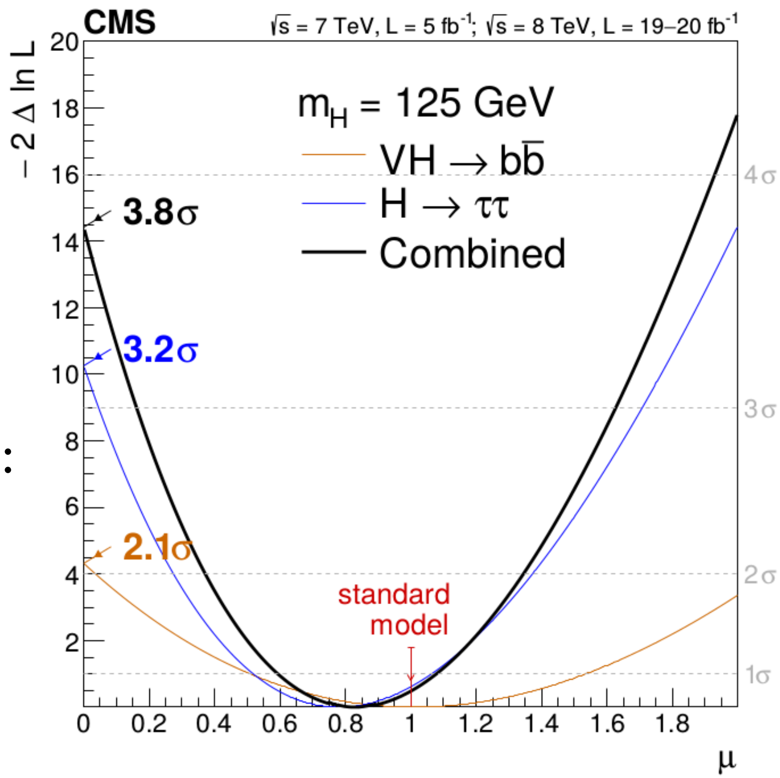




S. Donato

Here where we are:

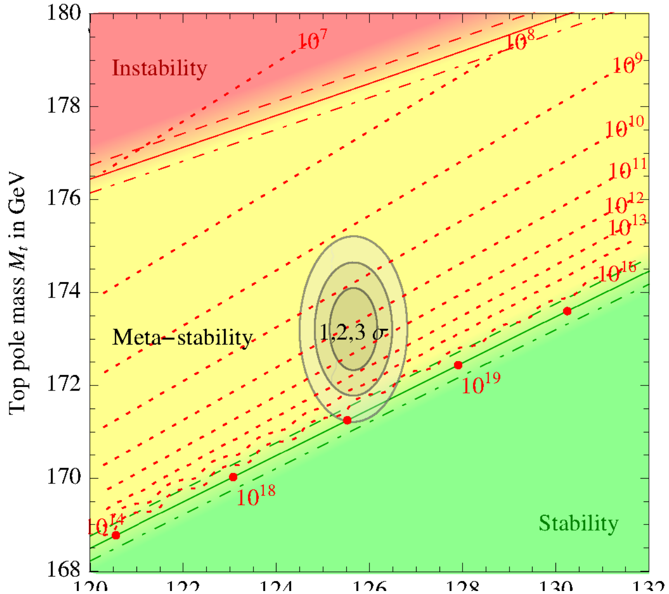
- Combination of all H → bb analysis, signal strength:
  [new!]
  - CMS (VH, VBF, ttH$^{(*)}$): $\boldsymbol{\mu = 1.03^{+0.44}_{-0.42}}$.
  - ATLAS (VH, ttH): $\boldsymbol{\mu = 0.63^{+0.39}_{-0.37}}$.
- Higgs to fermions (H→ττ, VH→bb) p-value:
  - Observed (exp.), CMS: **3.8σ (4.4σ)**.
  - Observed, ATLAS: **~4.5σ**.

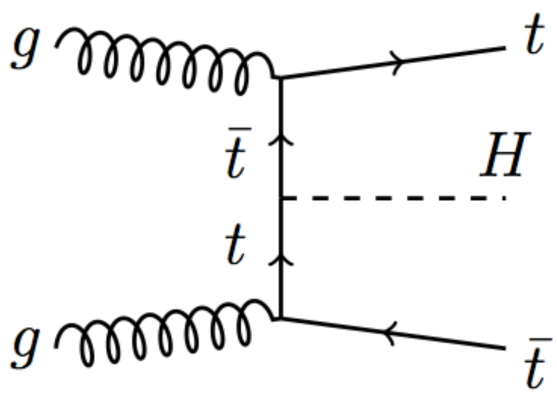


In Run2 these decays will be measured

Top Quarks and Higgs Bosons

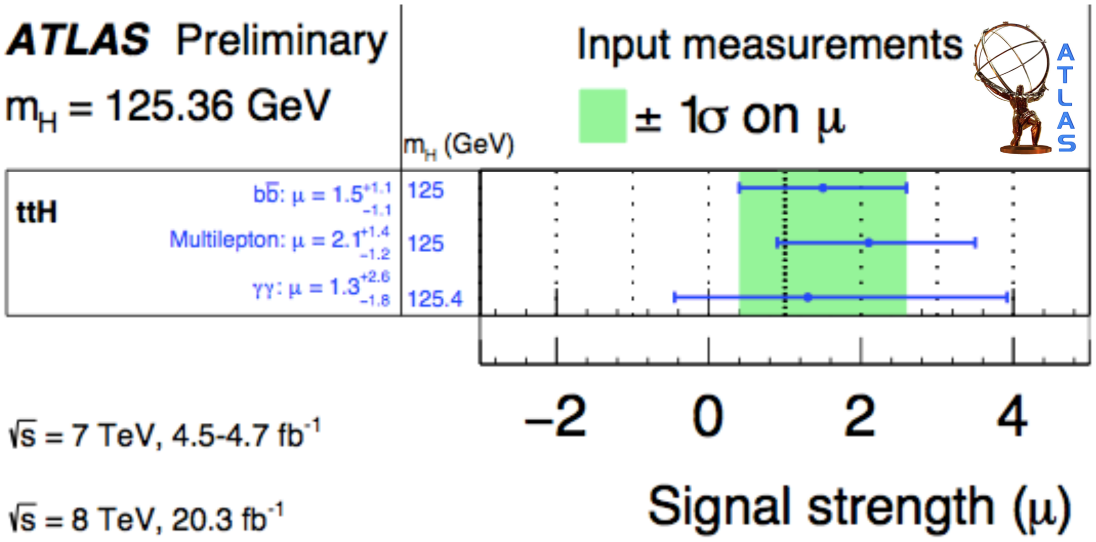
D. Zanzi

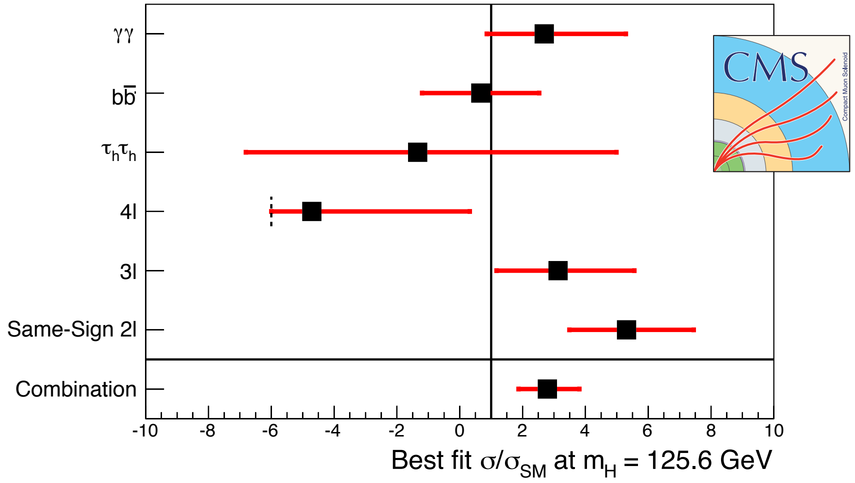




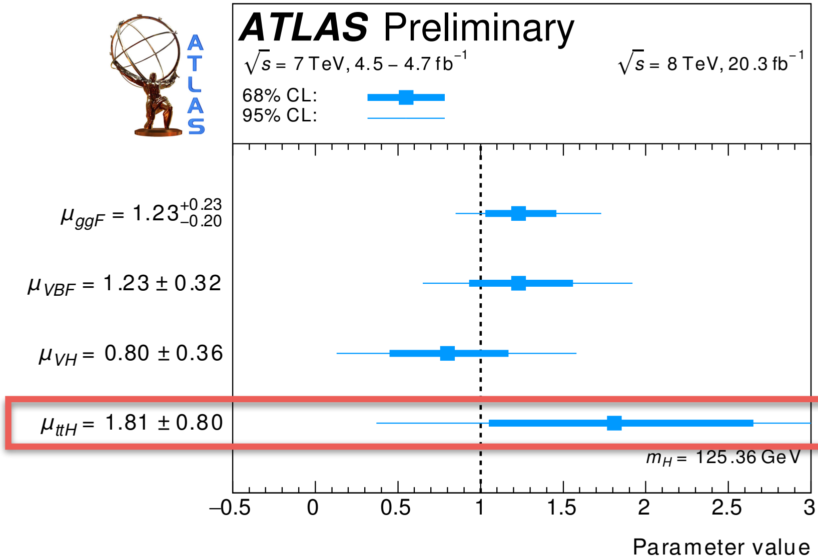
		H→γγ	H→bb	H→WW,ττ	H→ZZ
ttH	ATLAS	Phys Lett B 740 (2015) 222 (7+8TeV)	arXiv:1503.05066 (submitted to EPJC) with MEM (8TeV)	CONF-2015-006 (8TeV)	
	CMS	JHEP09 (2014) 087 (7+8TeV)	arXiv:1502.02485 (submitted to EPJC) with MEM (8TeV) JHEP09 (2014) 087 (w/o MEM)	JHEP09 (2014) 087 (7+8TeV)	
tH	ATLAS	Phys Lett B 740 (2015) 222 (7+8TeV)			
	CMS	HIG-14-001 (8TeV)	HIG-14-015 (8TeV)	HIG-14-026 (8TeV)	

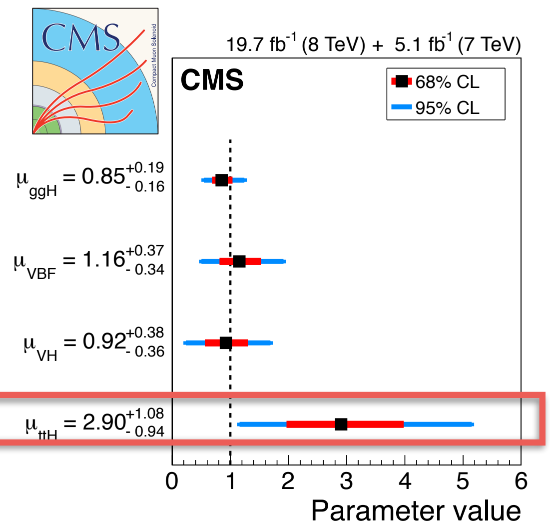
D. Zanzi





Combined result compatible with SM at 2.0σ level



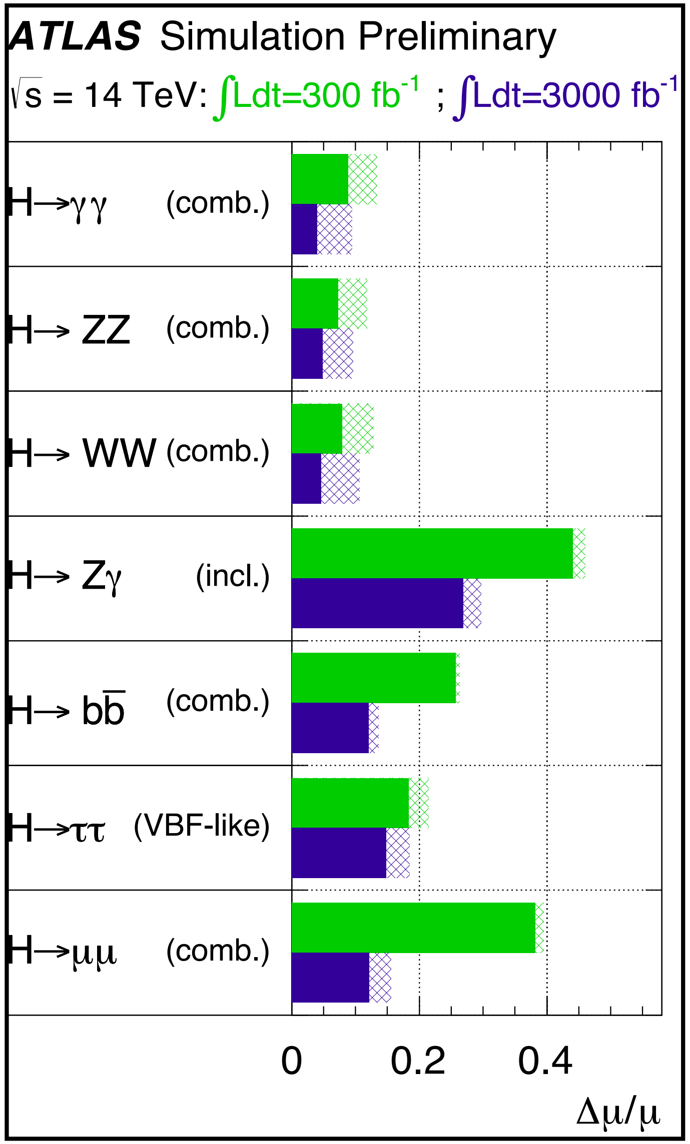


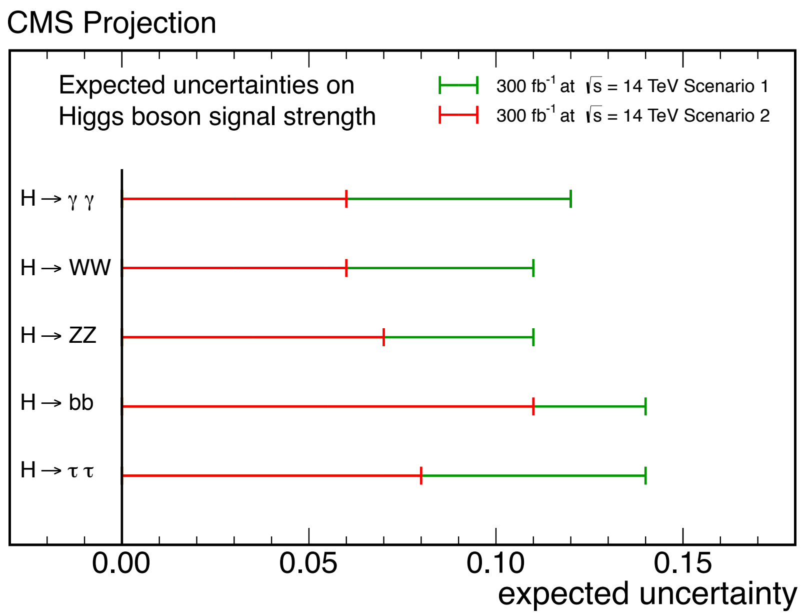
- Full Higgs combination, Higgs decay fractions set to SM values
- ATLAS:
  - μ_{ttH}<3.2(obs), 1.4(exp)
  - $R_{ttH/ggF}$>0 at 2.4σ
- CMS:
  - μ_{ttH}<3.5(obs),1.2(exp)
  - Pull to SM +2.2σ

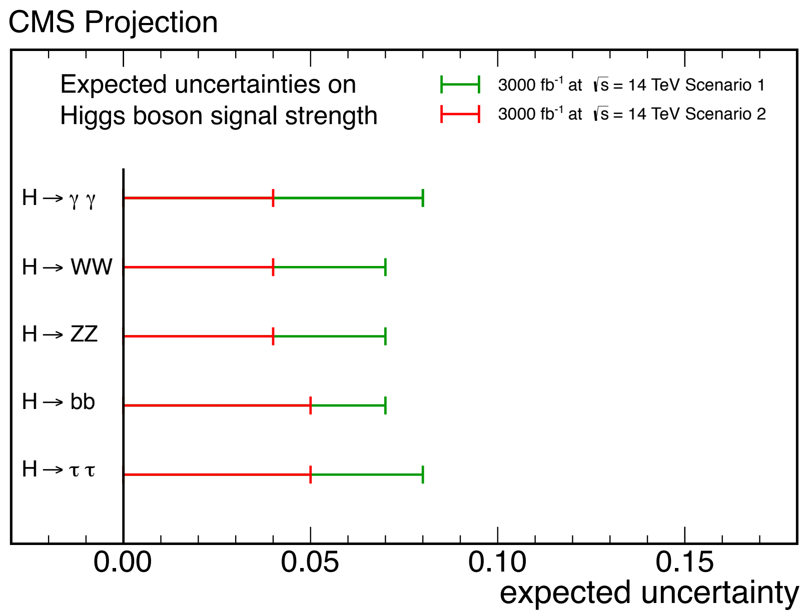
*Here and following, CMS ttH→bb w/o MEM from JHEP09 (2014) 087, tH not included

This is a high priority channel in run2

Run2 prospective



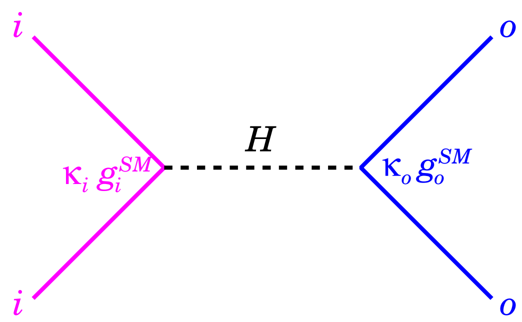




Higgs properties
(my selection)

Reminder: in SM Higgs couplings are $g_f^{SM} = \frac{m_f}{v}$ and $g_V^{SM} = 2\frac{m_V^2}{v}$

M. Fanti



Couplings are accessible through production ($ii \to H$) and decay ($H \to oo$)

Define "couplings modifiers" $\kappa_x = \frac{g_x}{g_x^{SM}}$

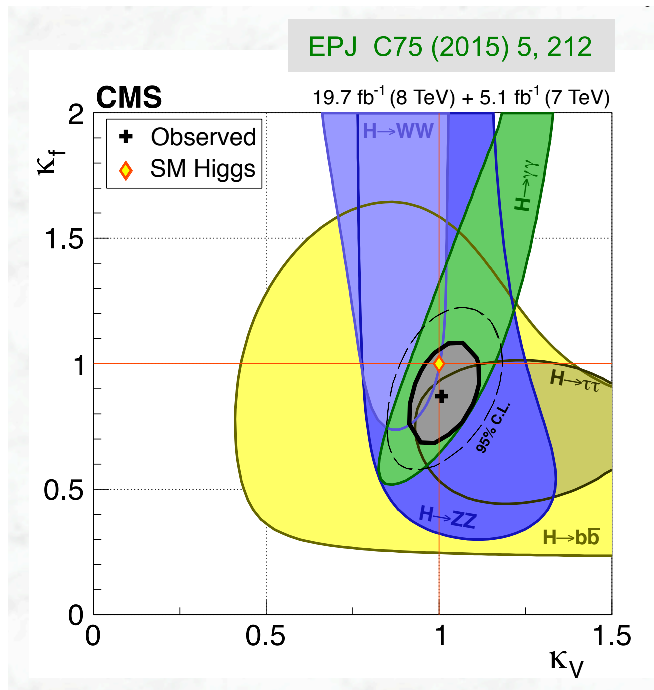
$$\Rightarrow \sigma_{ii \to H \to oo} = \sigma_{ii \to H \to oo}^{SM} \times \frac{\kappa_i^2 \, \kappa_o^2}{\kappa_H^2}$$

$$\left(\kappa_H^2 = \frac{\Gamma_H}{\Gamma_H^{SM}} = \sum_o \kappa_o^2 BR_{H \to oo}^{SM}\right)$$

$\Rightarrow$ Several couplings: $\kappa_W, \ \kappa_Z, \ \kappa_t, \ \kappa_b, \ \kappa_\tau \ \ldots$

Assume weak gauge boson universality: $\kappa_W = \kappa_Z = \kappa_V$ and fermion universality: $\kappa_t = \kappa_b = \kappa_\tau = \kappa_f$

$\Rightarrow$ all measurements compatible with SM prediction ($\kappa_V = 1, \ \kappa_f = 1$)

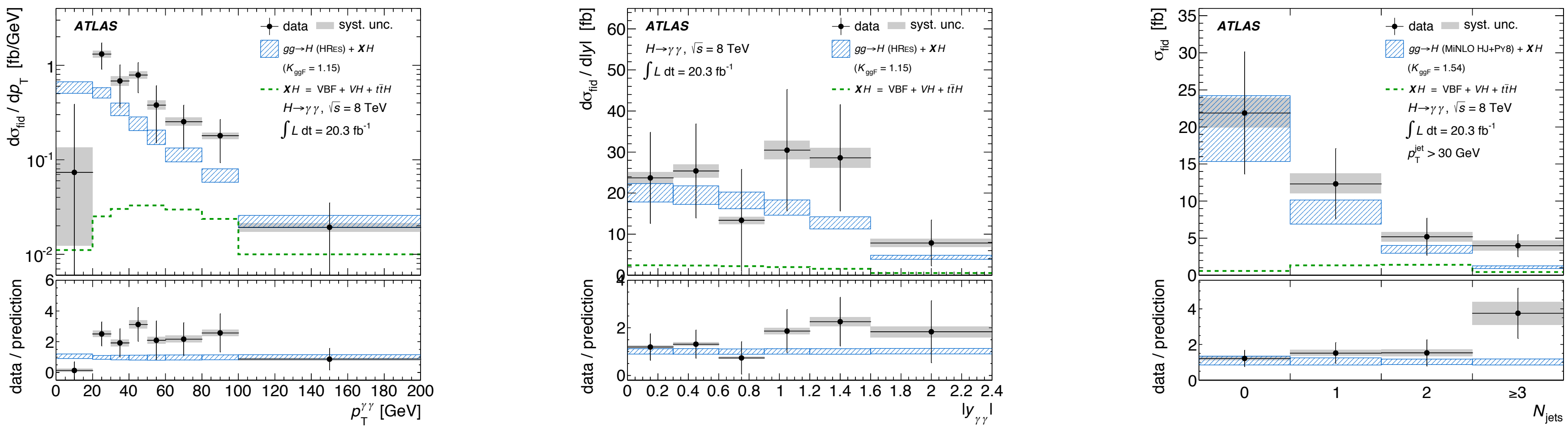


In Run2 we will exploit also those to measure the coupling

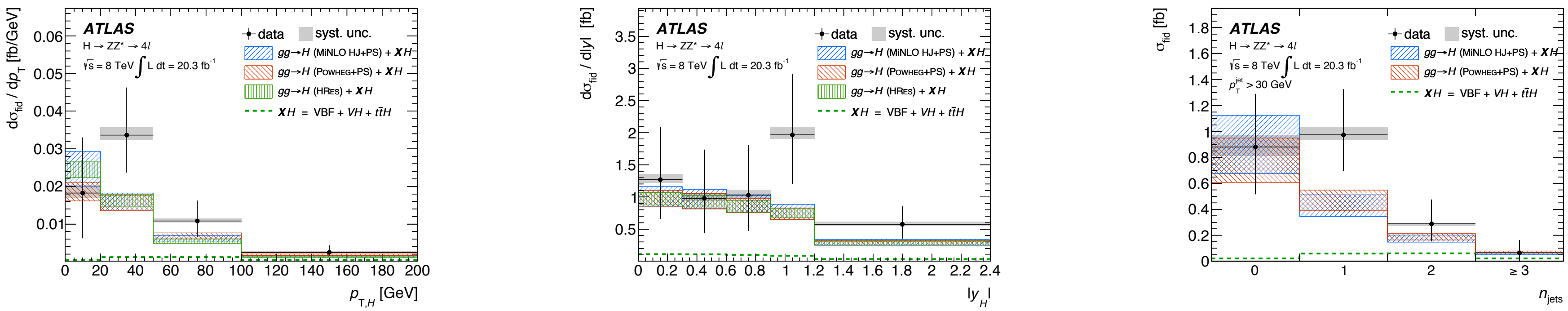
Differential cross-sections

M. Fanti

$H \to \gamma\gamma$



$H \to ZZ^* \to 4\ell$



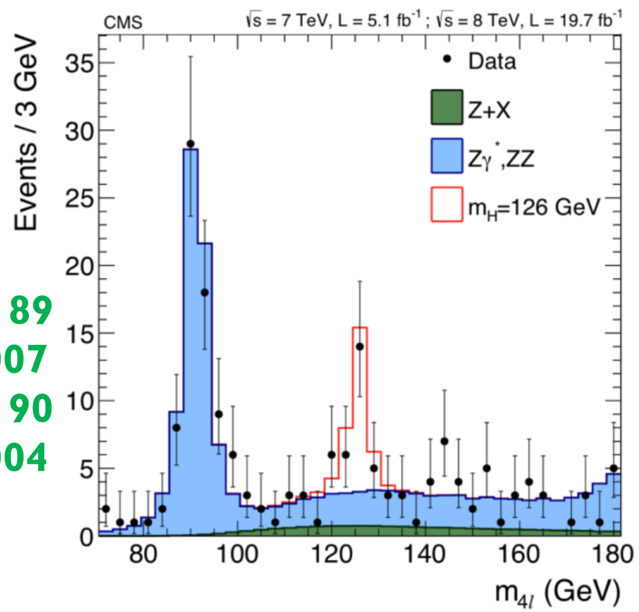
R. Covarelli

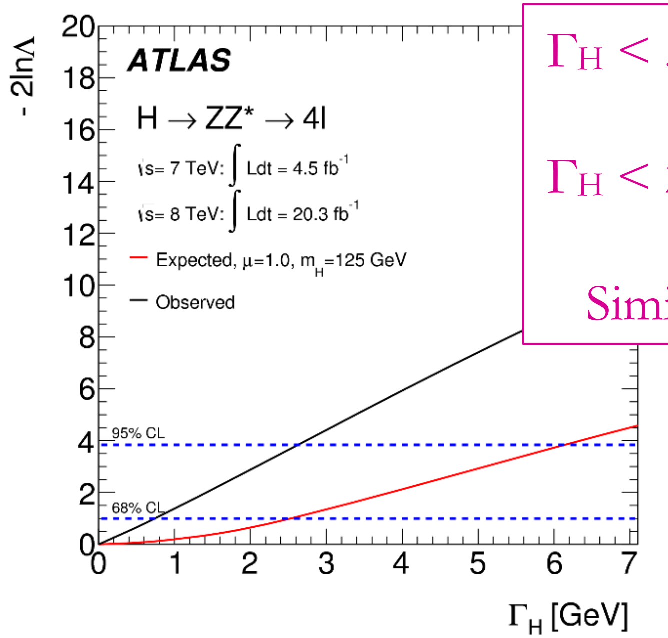
The Higgs width at the LHC

- Direct decay width measurements at the peak limited by experimental resolution:
  - $f(m) \sim BW(m,\Gamma) \otimes R(m,\sigma)$
  - If $\Gamma \ll \sigma$, not possible to disentangle natural width
    - SM Higgs width at m_H = 125 GeV is Γ_H = 4.07 MeV
    - Experimental resolution is $\sigma \sim$ 1-3 GeV for $H \rightarrow ZZ^* \rightarrow 4l$

The Standard Model Higgs width is expected to be small

Phys. Rev. D 89 (2014) 092007
Phys. Rev. D 90 (2014) 052004



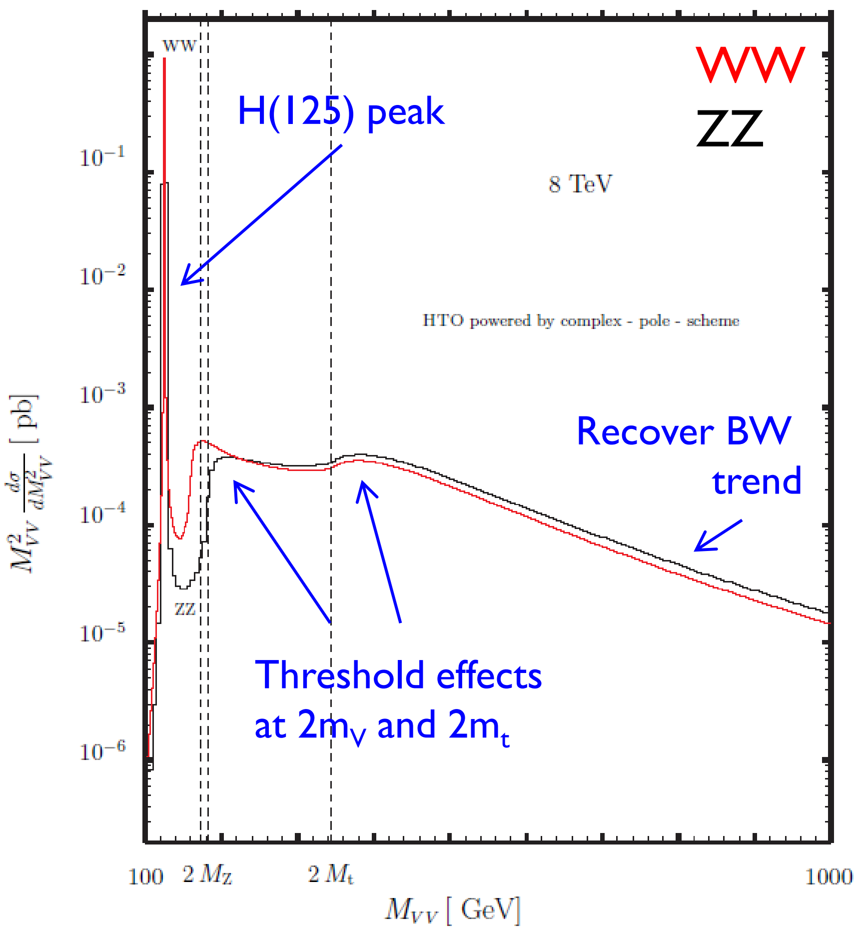


Γ_H < 3.4 GeV @ 95% CL (CMS)
Γ_H < 2.6 GeV @ 95% CL (ATLAS)
Similar results from $\gamma\gamma$

The idea

N. Kauer and G. Passarino (JHEP 08 (2012) 116)

gluon-gluon fusion production



- Off-shell $H^* \to VV$ ($V = W, Z$)
  - Peculiar cancellation between BW trend and decay amplitude creates an enhancement of H(125) cross-section at high m_{VV}

$$\frac{d\sigma_{gg\to H\to ZZ}}{dm^2_{ZZ}} \propto g_{ggH}\,g_{HZZ}\,\frac{F(m_{ZZ})}{(m^2_{ZZ}-m^2_H)^2+m^2_H\Gamma^2_H}$$

(Analogously for WW)

  - About 7.6% of total cross-section in the ZZ final state, but can be enhanced by experimental cuts

	Tot[pb]	$M_{ZZ} > 2\,M_Z$[pb]	R[%]
$gg \to H \to$ all	19.146	0.1525	0.8
$gg \to H \to ZZ$	0.5462	0.0416	7.6

$\mu_{\text{off-shell}}$ and width

F. Caola, K. Melnikov (Phys. Rev. D88 (2013) 054024)
J. Campbell et al. (arXiv:1311.3589)

$$\frac{d\sigma_{gg\to H\to ZZ}}{dm^2_{ZZ}} \propto g_{ggH}\, g_{HZZ} \frac{F(m_{ZZ})}{(m^2_{ZZ} - m^2_H)^2 + m^2_H \Gamma^2_H}$$

(Analogously for WW)

Can it be used to set a constraint on the total Higgs width?

$$\sigma^{\text{on-peak}}_{gg\to H\to ZZ} = \frac{\kappa^2_g \kappa^2_Z}{r} (\sigma \cdot \text{BR})_{\text{SM}} \equiv \mu (\sigma \cdot \text{BR})_{\text{SM}}$$

$$\frac{d\sigma^{\text{off-peak}}_{gg\to H\to ZZ}}{dm_{ZZ}} = \kappa^2_g \kappa^2_Z \frac{d\sigma^{\text{off-peak,SM}}_{gg\to H\to ZZ}}{dm_{ZZ}} = \mu r \frac{d\sigma^{\text{off-peak,SM}}_{gg\to H\to ZZ}}{dm_{ZZ}}$$

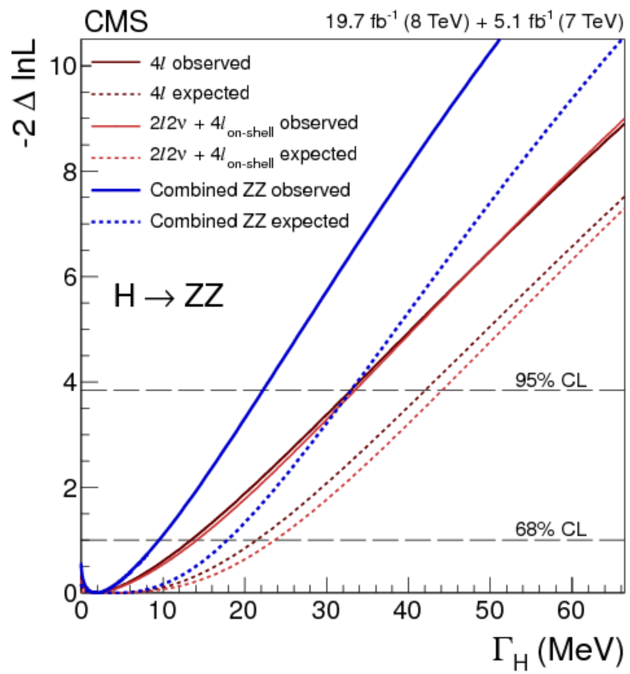
$$\kappa_g = g_{ggH} / g^{\text{SM}}_{ggH}$$
$$\kappa_Z = g_{HZZ} / g^{\text{SM}}_{HZZ},$$
$$r = \Gamma_H / \Gamma^{\text{SM}}_H$$

- Couplings can scale by arbitrary values as a function of m_{VV} (generic New Physics assumption)
  - A new signal strength $\mu_{\text{off}} = \kappa_g^2 \kappa_Z^2$ is extracted from off-shell data
- On-shell and off-shell couplings scale by the same amounts
  - Fitting simultaneously the on-shell and off-shell regions yields a determination of Γ

$r = \Gamma_H / \Gamma_H^{SM}$ Limits on the width

Observed (expected) 95% CL limit:
$r < 5.4$ (8.0)
p-value = 0.25

$\Gamma < 22$ (33) MeV
$\Gamma = 1.8^{+7.7}_{-1.8}$ MeV

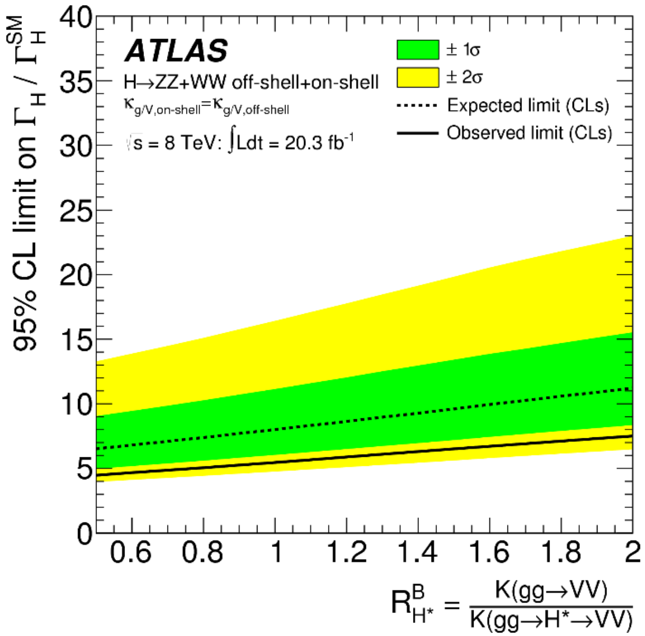


Assuming same on-shell and off-shell couplings

Observed (expected) 95% CL limit: $r < 5.5$ (8.0)

Variations with gg → VV k-factor: $r <$ [4.5, 7.5]

$\Gamma < 23$ (33) MeV
$\Gamma <$ [18, 31] MeV

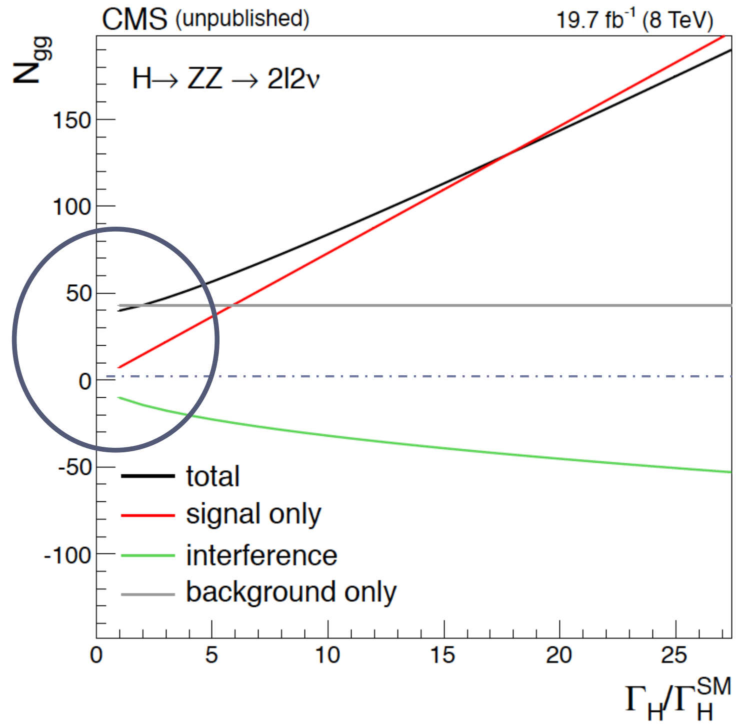


Perspectives for Run2 (I)

- σ(13 TeV)/σ(8TeV) from theory:
  - gg → VV signal (S) ~ 3 at LO (~ 2.2 at NNLO)
  - gg → VV continuum (C) ~ 2.5
  - gg → VV S+C+interference ~ 2.7
  - $q\bar{q}$ → VV background ~ 2

Significant increase of yield per fb^{-1} in Run2

- Caveat:
  - When coming close to r = 1 interference plays a role → effective number of off-shell signal events S+I (at constant μ) does not scale anymore with r



Higgs and BSM

Introduction

- Supersymmetric Higgs signatures may be a diverse topic
  - Here I will focus mostly on “standard” SUSY Higgs

MSSM Higgs searches:

◊ h/H/A → ττ

◊ H+ → τν and tb

◊ A → Zh

NMSSM motivated searches for a light Higgs:

◊ a → μμ

◊ H → aa

◊ NMSSM inspired cascades

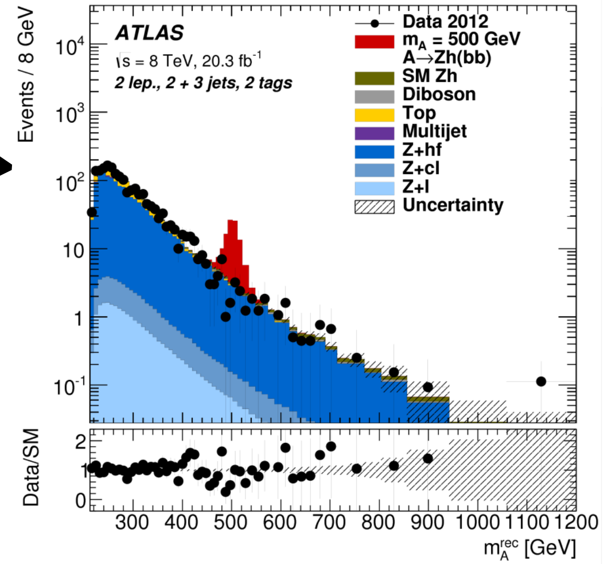
- For more exotic signatures, e.g. H → $\chi^0\chi^0$, see other experimental talks and in particular the talk by James Beacham tomorrow

M. Mozer

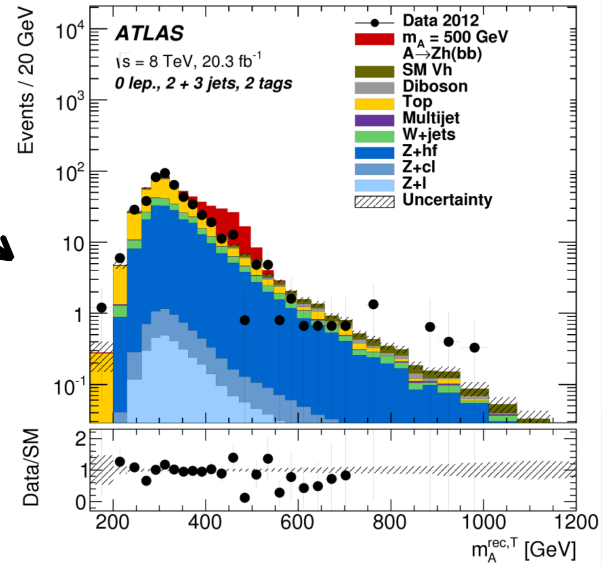
2HDM: Bosonic Decays

- A → Zh → ll bb
  ll ττ
  νν bb
- Parallel analysis to maximize accessible Branching fraction
- Not sensitive when 2HDM parameters conspire

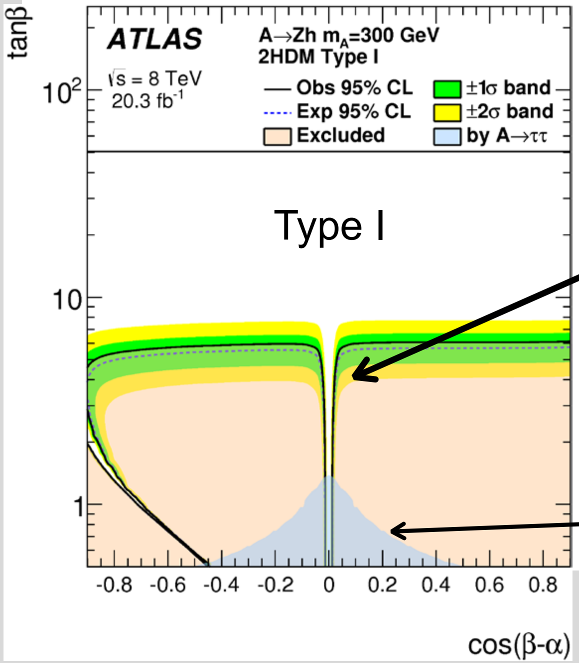
Good resolution
Low background
Low branching ratio



poor resolution
higher background
higher branching ratio

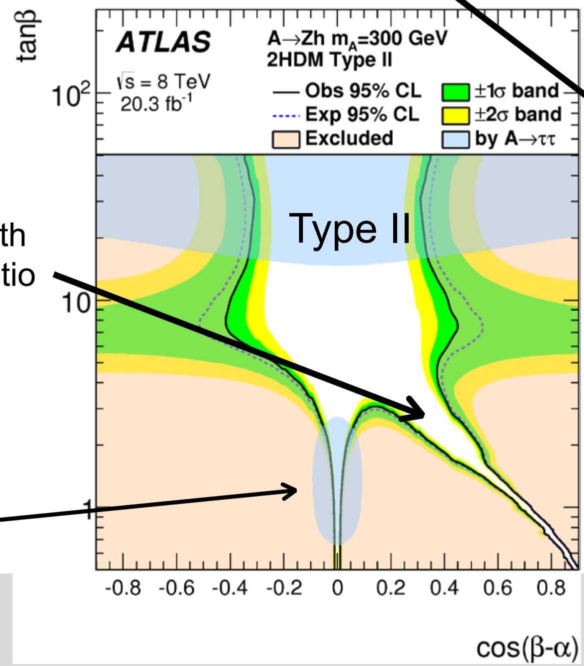


[Phys. Lett. B 744 (2015) 163]



Small regions with low branching ratio h → bb / ττ

X→ττ results

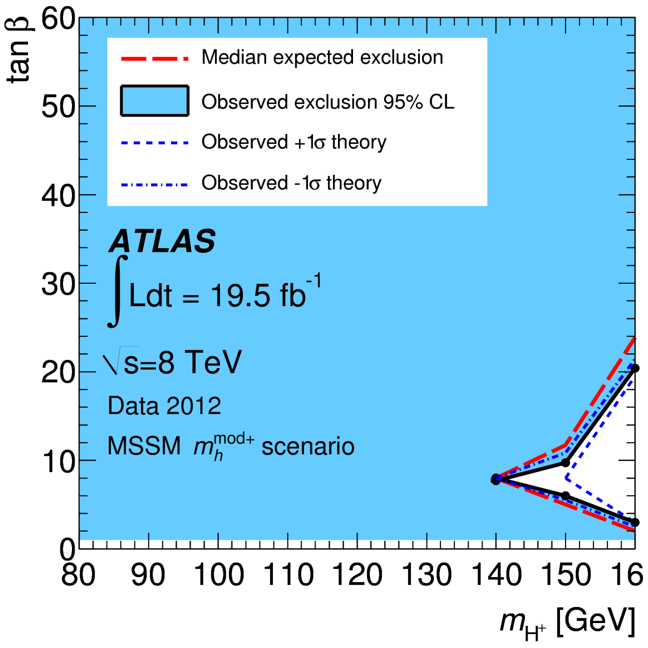


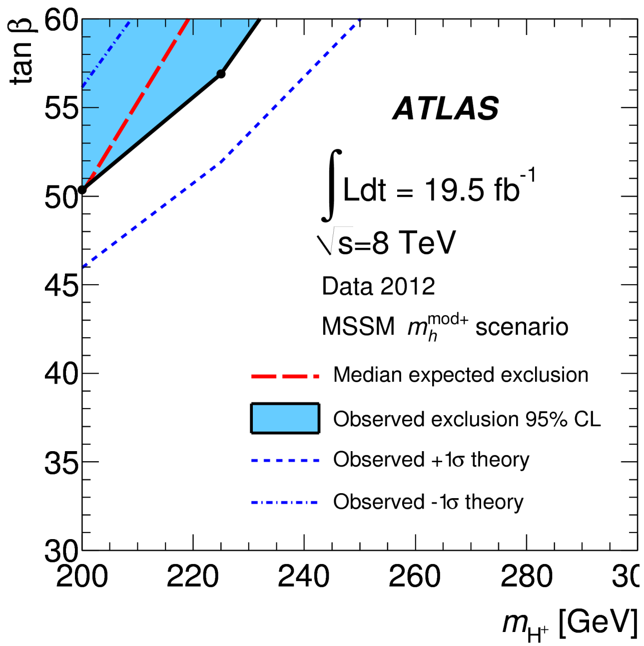
N. Rompotis

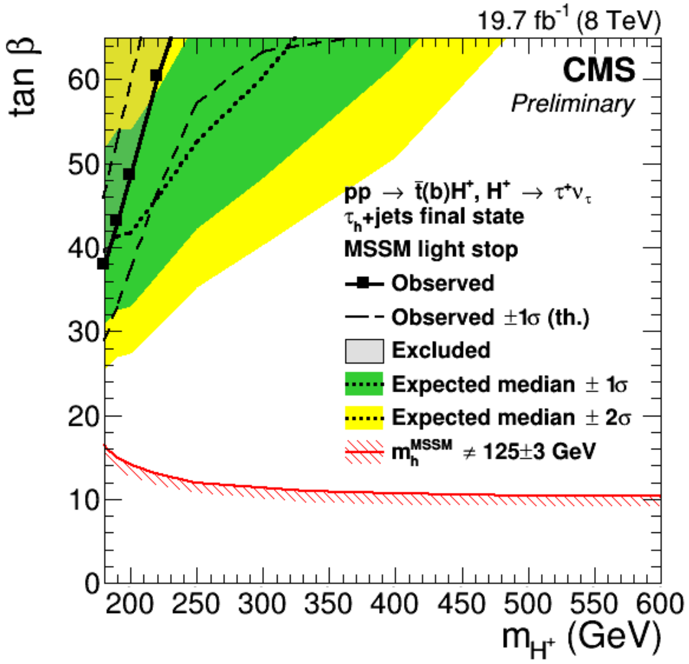
H+ → τν

Limits from flavour physics e.g. b—>s gamma are comparable

- Interpretation of the search in various MSSM scenarios (in addition to the cross section and BR limits)







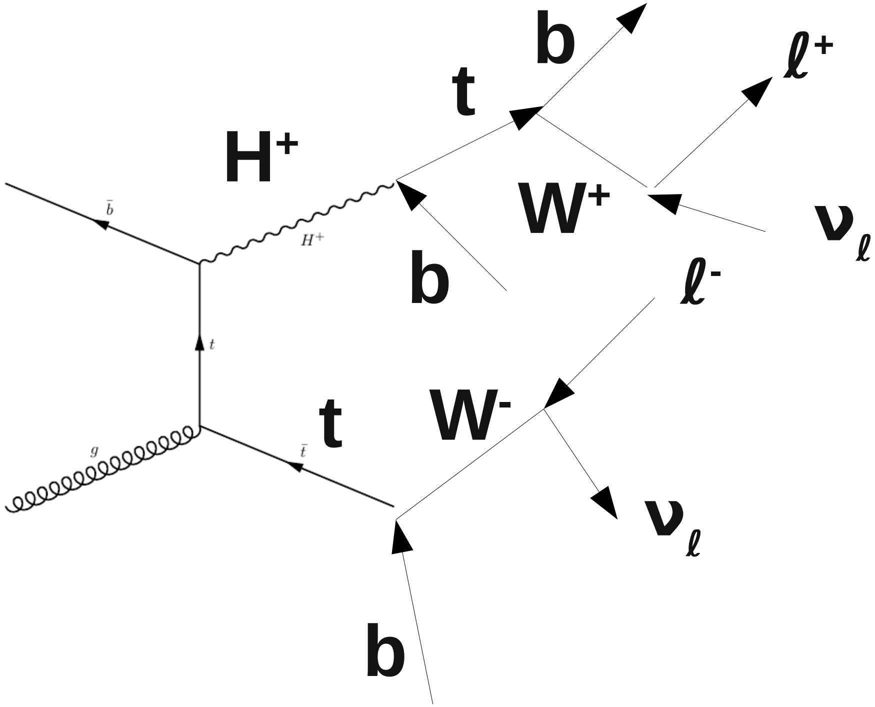
arXiv:1412.6663

CMS-PAS-HIG-13-026

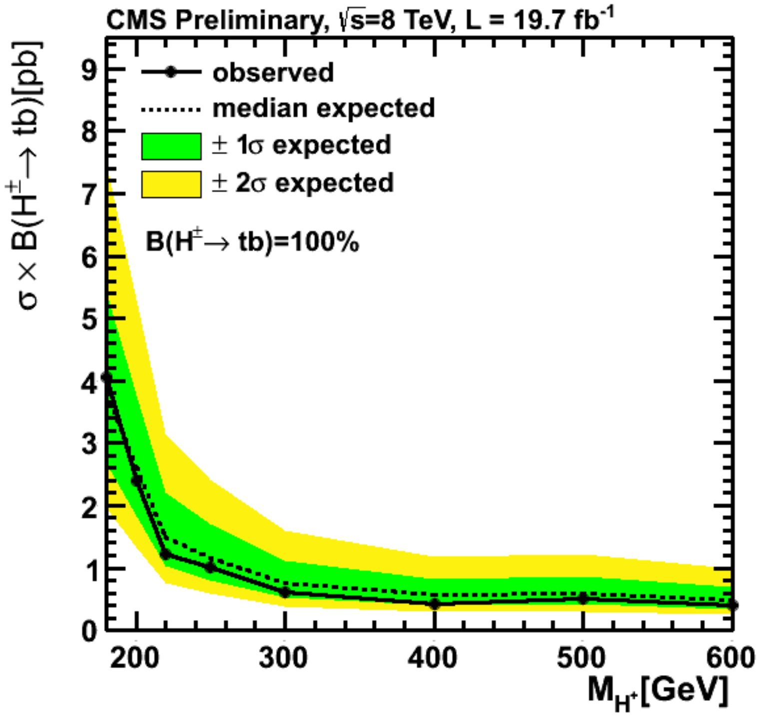
N. Rompotis

$H^+ \to tb$

- This is the most typical decay mode of a high mass Charged Higgs (MSSM or not!)
- The LHC has just started exploring that!



CMS-PAS-HIG-13-026



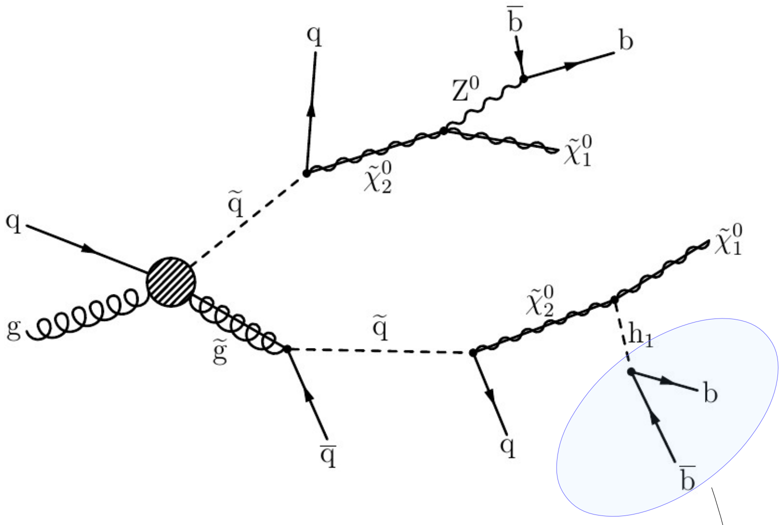
Next-to-MSSM (NMSSM)

- NMSSM: next to minimal supersymmetric Standard Model
  - Addition of a singlet in the Higgs sector
  - 2 more Higgses and one more neutralino with respect to MSSM; more freedom with respect to the MSSM:
    - Higgs sector not necessarily CP conserving at lowest order (although usually CP-conservation is assumed)
    - Tree level MSSM relation “$m_h < m_Z$” is not valid any more
  - Typical signatures involve a light CP-odd Higgs
    - a->μμ, ττ, bb, h->aa, ...

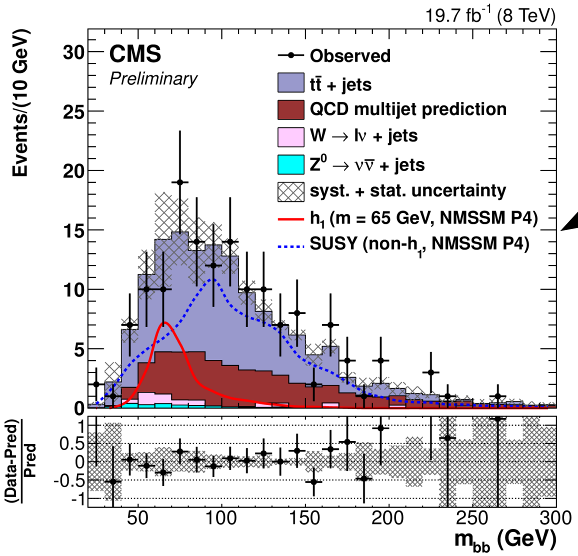
NMSSM signatures may be shared with other new physics, so you will see them in other talks as well.

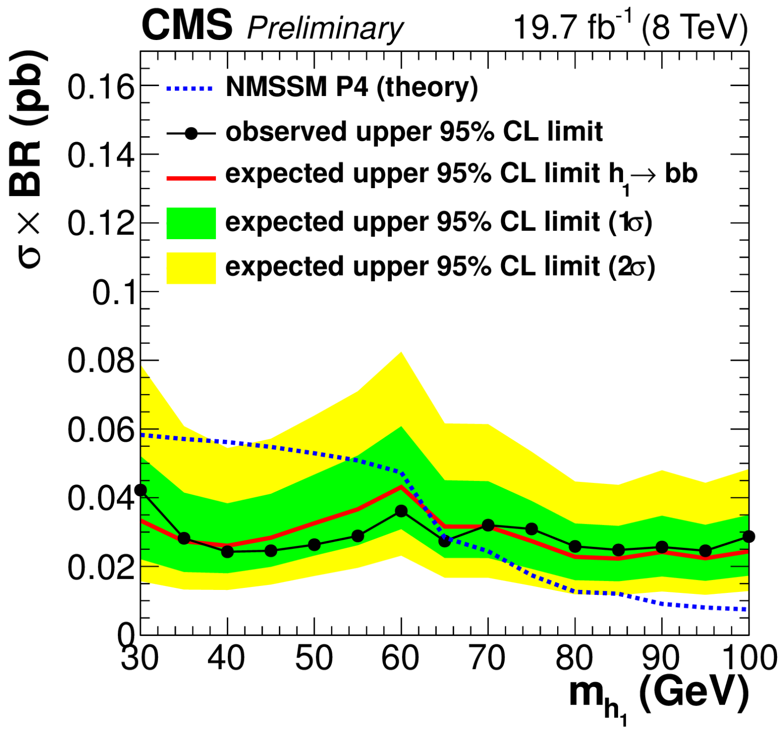
h_1->bb in cascades

CMS-PAS-HIG-14-030



A light higgs boson produced in a SUSY-inspired cascade: hard jets, MET and b-jets from Higgs decay





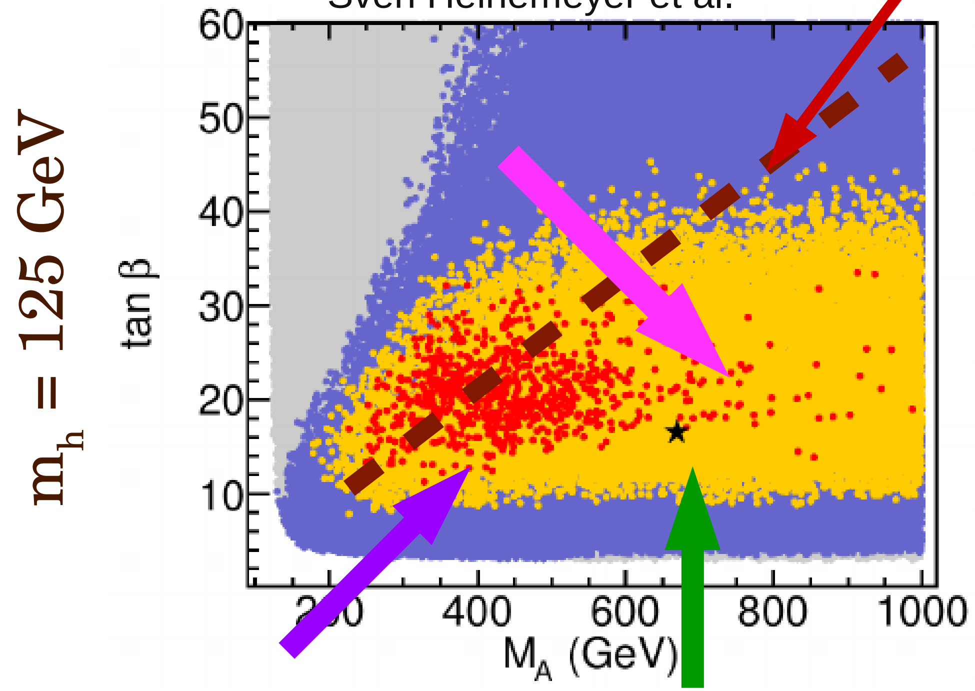
Shown prediction from an NMSSM benchmark taken from arXiv:0801.4321

The future

- The future is bright: there is still a lot of way to cover and the Run-II results will be very interesting

MSSM ττ search constrain (red dashed line)

Eur.Phys.J. C73 (2013) 2354, Sven Heinemeyer et al.



MSSM ττ and bb searches will continue digging into the parameter space at the high tanβ region

The low tanβ, high mass region is much more difficult to access experimentally (A/H->tt)

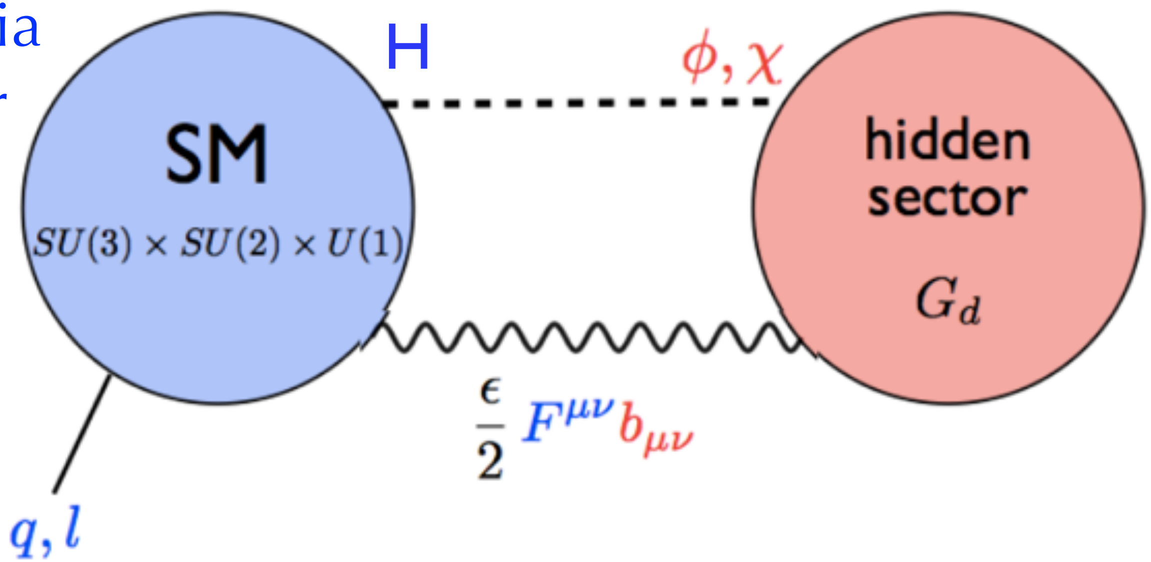
The low tanβ, low mA will continue being constrained via Zh, ττ, hh, ...

The Higgs as a dark/hidden sector portal

Many extensions of the SM postulate new states readily accessible via the SM scalar sector

See *Exotic Decays of the 125 GeV Higgs Boson* for an exhuastive roundup: arXiv:1312.4992

J. Beacham



The small total width of the Higgs (~4 MeV) means that even a small BSM coupling can translate into a detectable signature

- H125 could be our **best** window into a dark sector
- In addition to the generic interest in discovering evidence of a dark sector, most extensions feature a viable dark matter candidate
- Hadron collider results complement DM direct detection experiments

Here highlighting both dedicated searches for invisible Higgs decays (resulting in E_T^{miss}) and searches where the Higgs plays an initial or intermediate role:

H —> invisible

Mono-H

H —> mono-X (+)

H —> hidden valley —> unique exp. objects

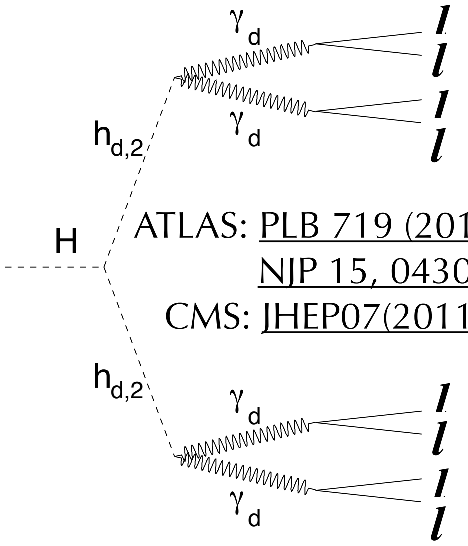
H —> 2X —> 2P2Q, resonant X

H ⟶ lepton-jets (via dark fermions/scalars/photons)

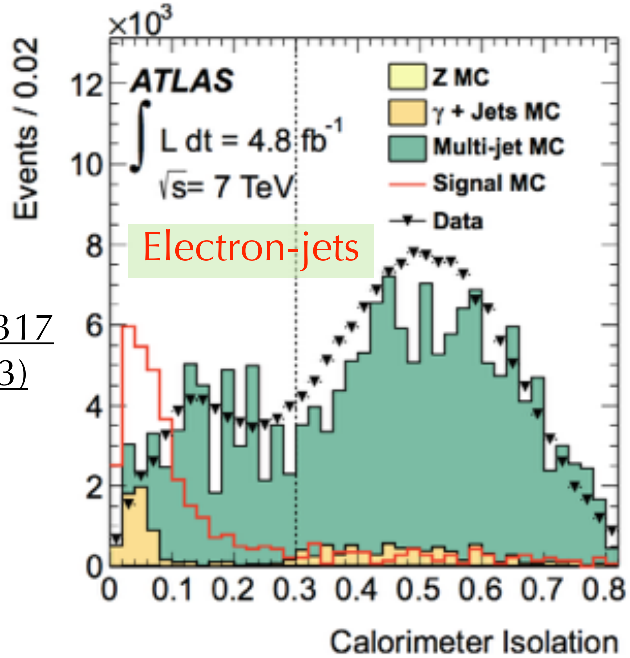
Dark/hidden sector coupled to SM Higgs and leptons via very light dark sector particles

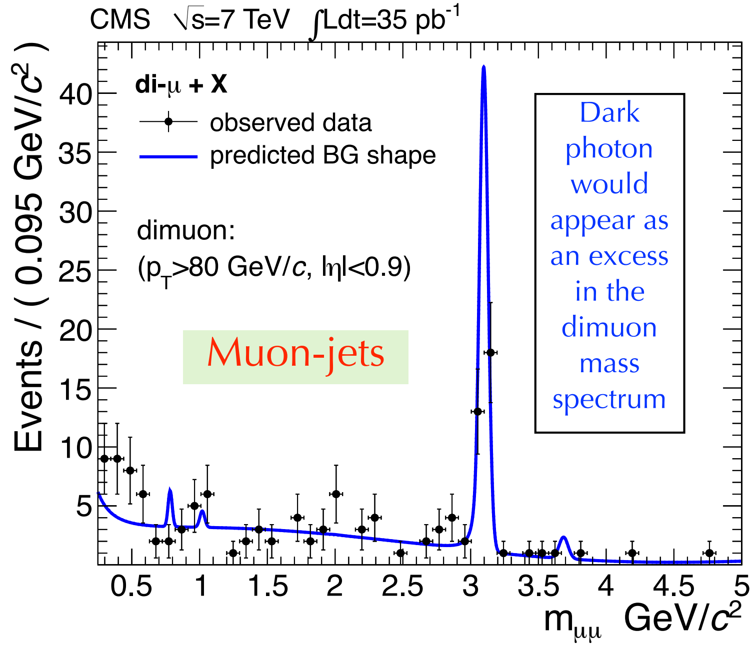
- Highly collimated groupings of leptons: **lepton-jets;** distinct LHC signature

Prompt — 7 TeV



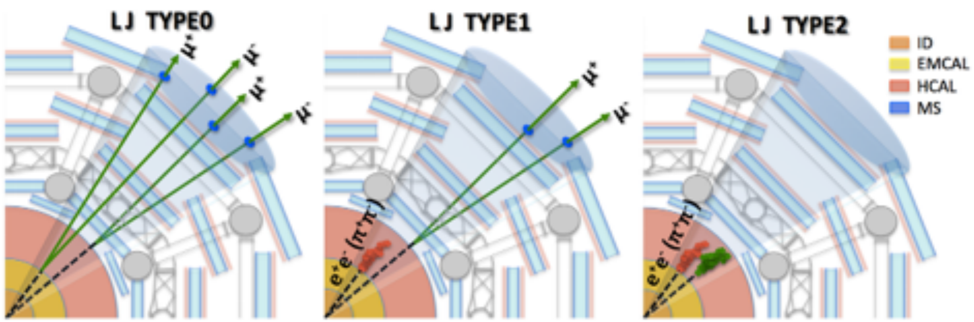
ATLAS: PLB 719 (2013) 299-317
NJP 15, 043009 (2013)
CMS: JHEP07(2011)098





Displaced — 8 TeV

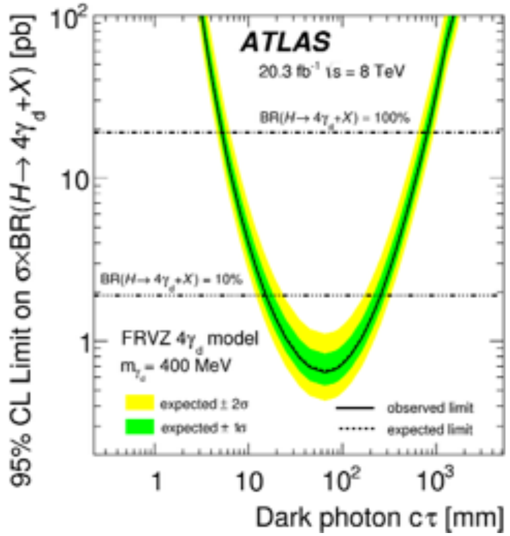
ATLAS: JHEP11(2014)088

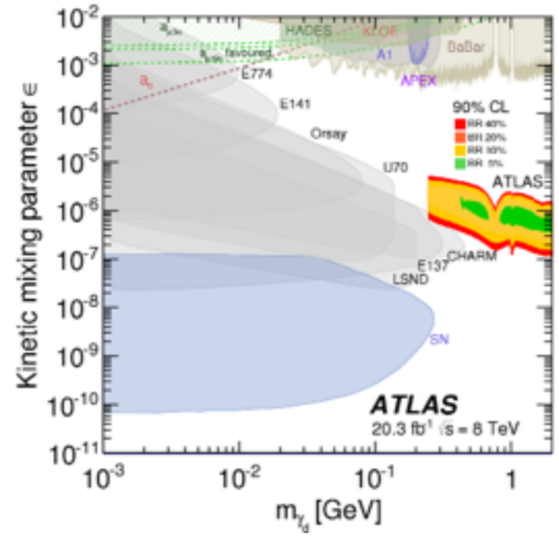


Three separate types of lepton-jet definitions considered

Cosmic backgrounds important here

Weak interaction ==> non-negligible dark photon lifetime



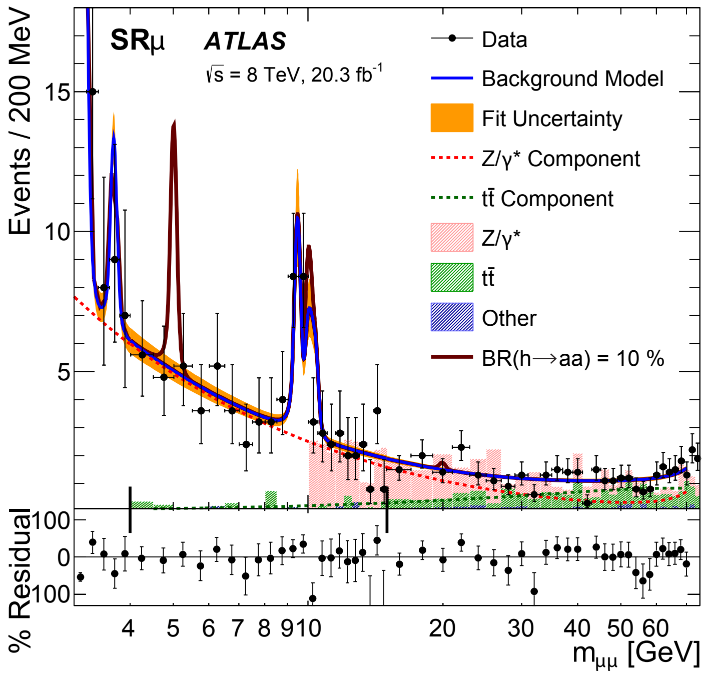


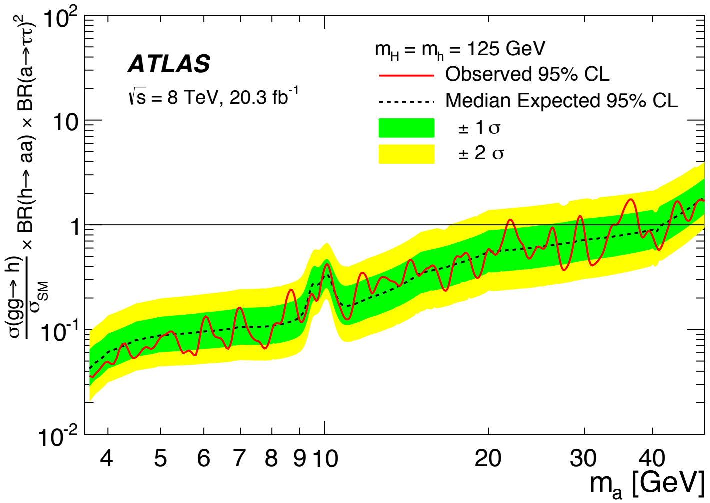
ATLAS: arXiv:1505.01609
Submitted to PRD

H ⟶ aa(ss) ⟶ {2μ2τ or 4μ}

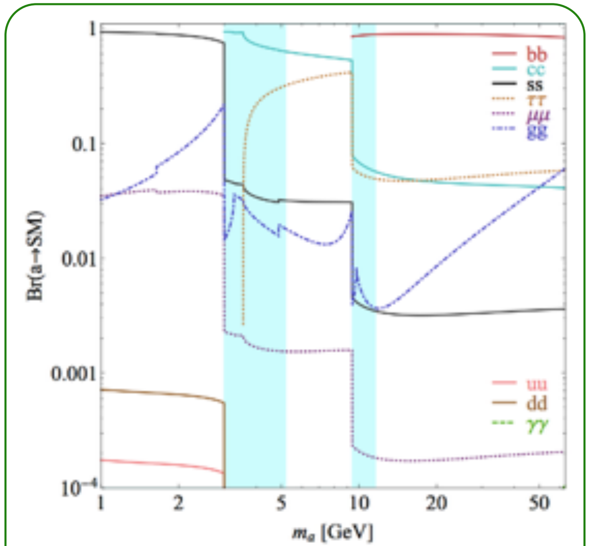
CMS: arXiv:1506.00424
Submitted to PLB

H —> aa —> 2μ2τ



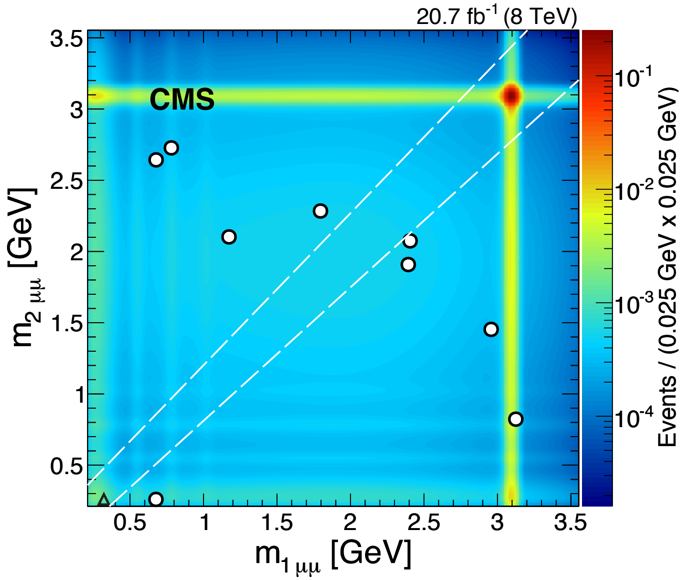


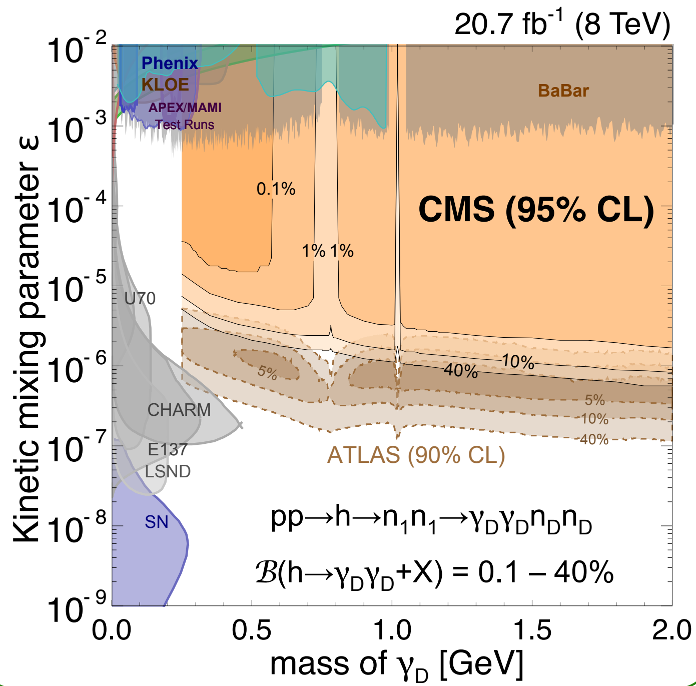
Extended Higgs sectors with relatively light (pseudo)scalars (*a*)*s* from hidden sectors



Example:
2HDM+S with
Type 1 Yukawa couplings

H —> aa —> 4μ



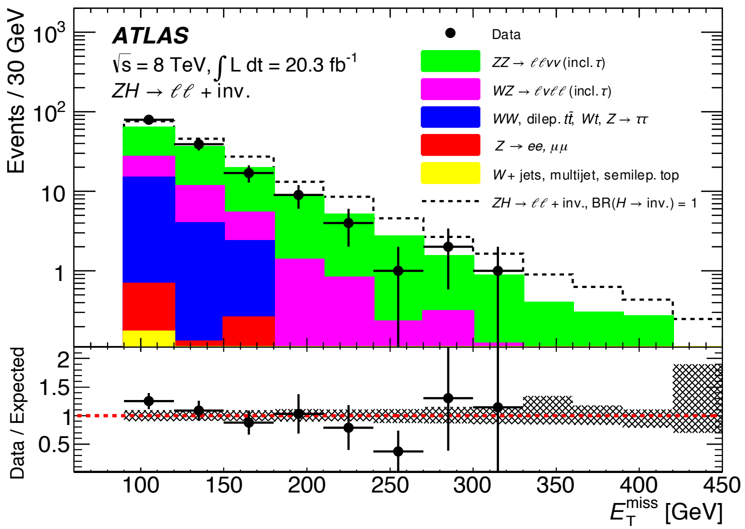


Interpreted in kinetic mixing parameter / dark photon mass plane

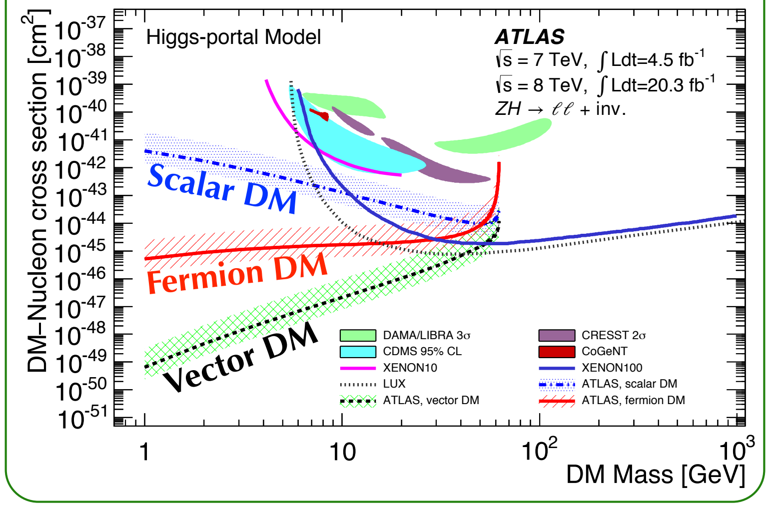
VH ⟶ (ll or jj) + invisible / VBF H ⟶ invisible

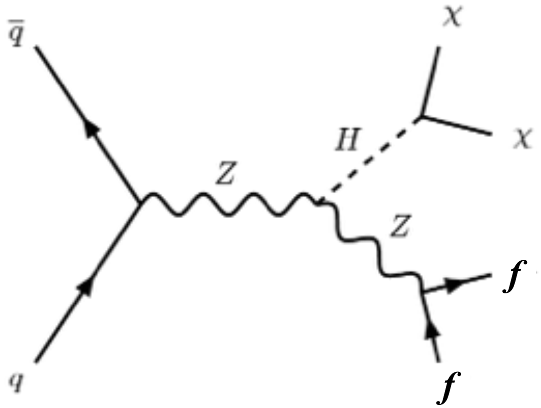
ATLAS: PRL 112.201802
arXiv:1504.04324 (Submitted to EPJC)
ATLAS-CONF-2015-004

Z ⟶ ll (l = e,μ)

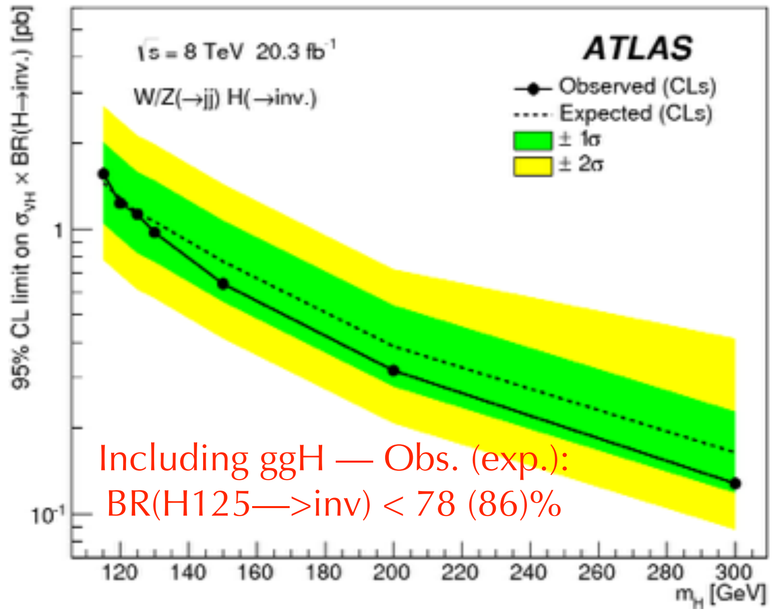


ZH — Obs. (exp.):
BR(H125—>inv) < 75 (62)%

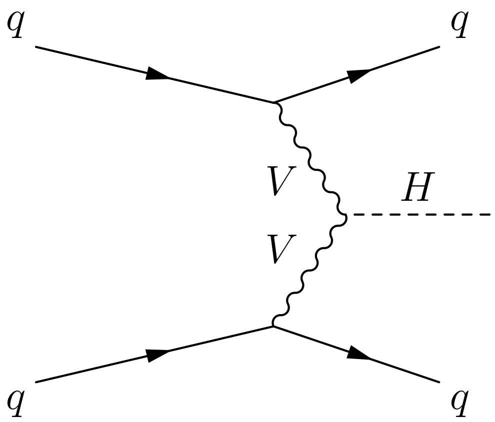




V ⟶ jj

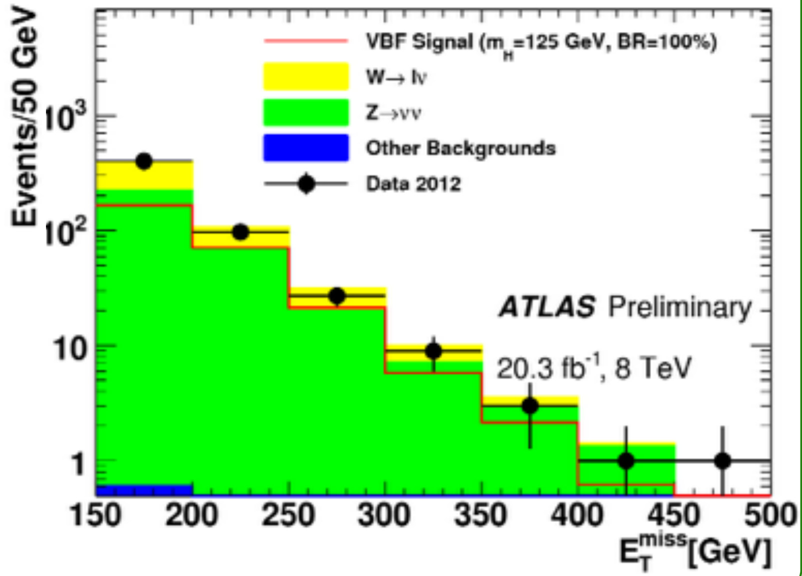


Including ggH — Obs. (exp.):
BR(H125—>inv) < 78 (86)%



Collider results interpreted in model-dependent way to complement dark matter direct-detection experiments

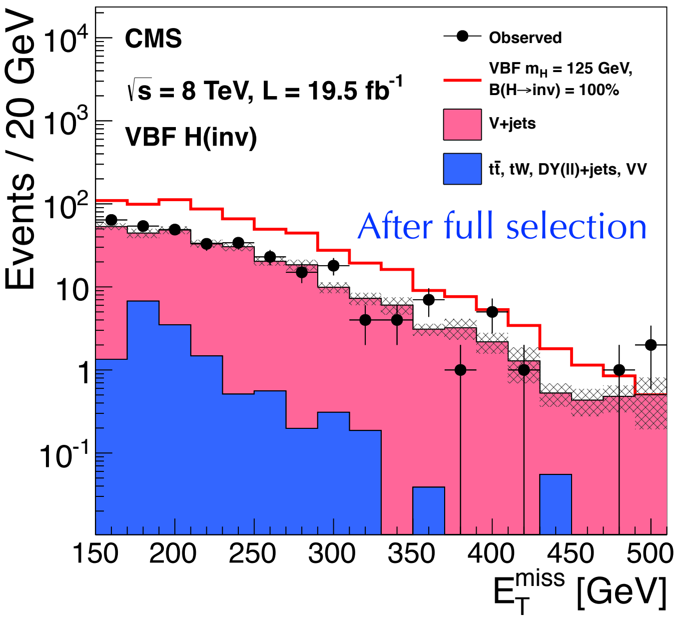
Strongest limit from VBF — Obs. (exp.):
BR(H125—>inv) < 29 (35)%

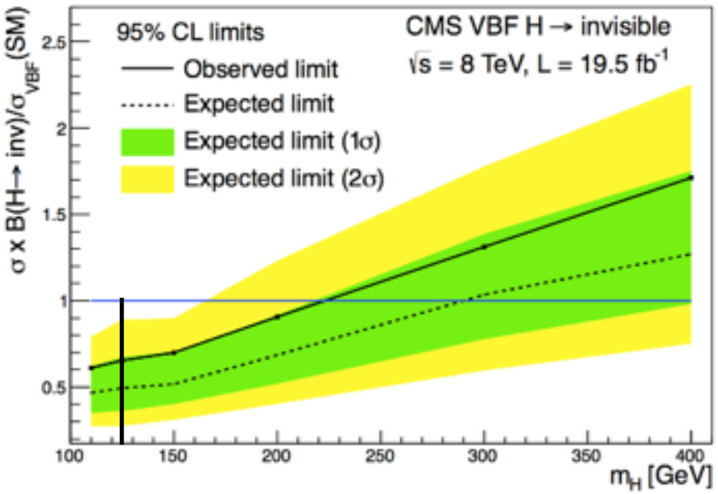


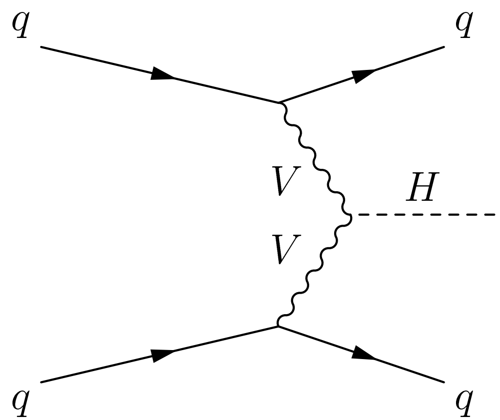
VH ⟶ (ll or jj) + invisible / VBF H ⟶ invisible

CMS: EPJC 74 (2014) 2980

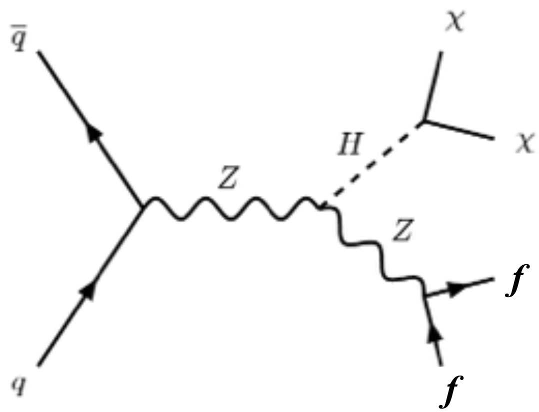
VBF



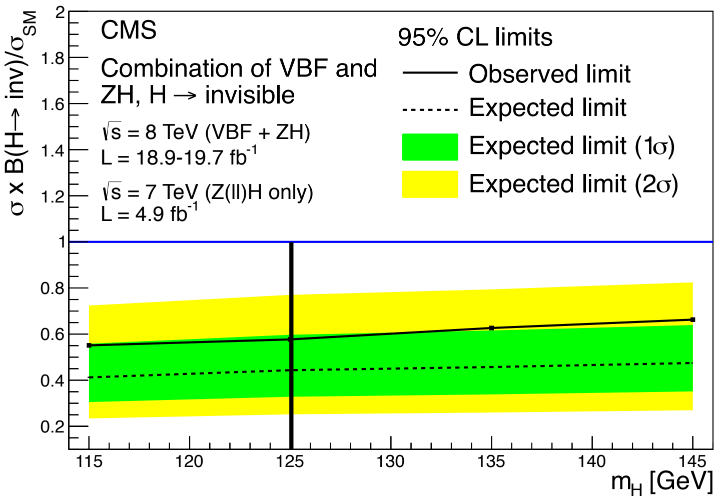


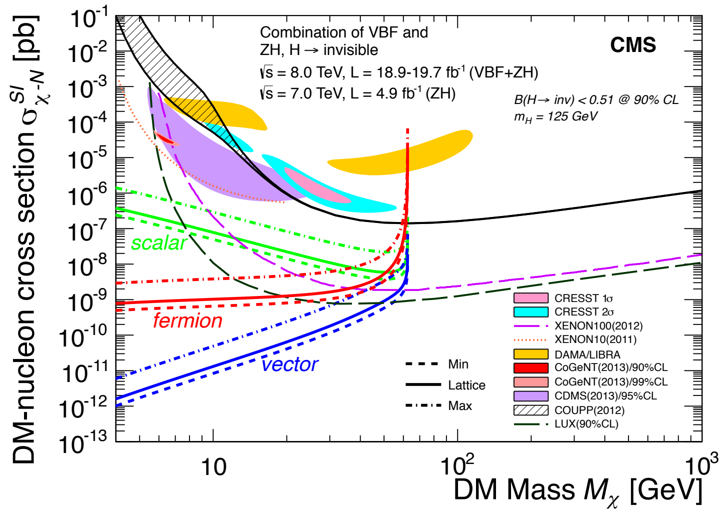


All channels combined
Obs. (exp.):
BR(H125—>inv) < 58 (44)%



Combination VBF and ZH

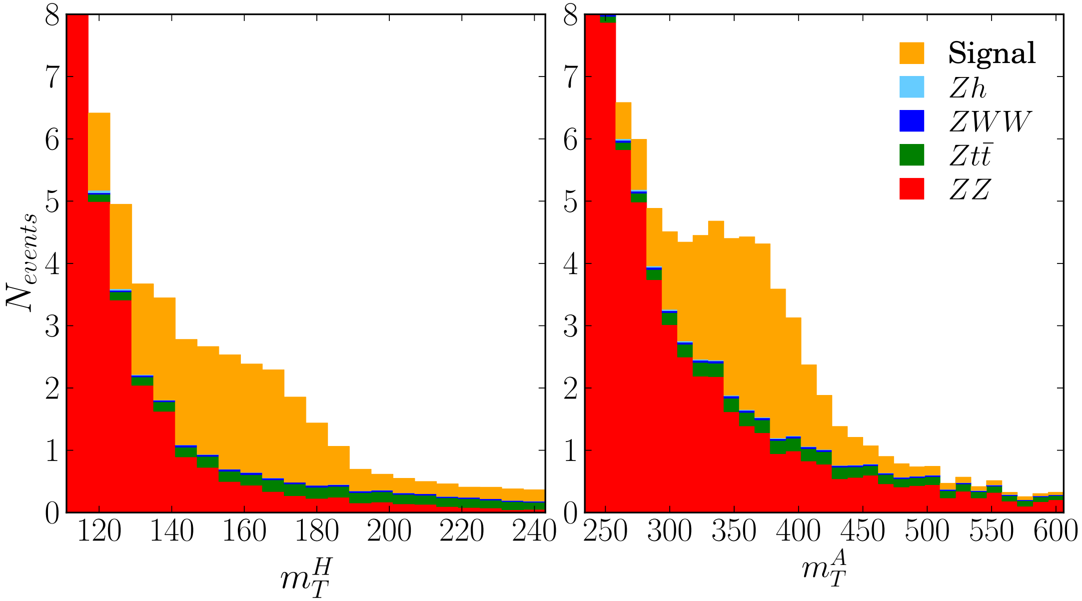




$A_0 \to ZH_0 \to WW\ell\ell$

G. C. Dorsch

- Away from alignment, $b\bar{b}\ell\ell$ is dominated by $A_0 \to Zh_0$ but altogether low due to suppressed $BR_{A_0}(Zh_0)$.
- $WW\ell\ell$ is then the most promising channel.
- Main backgrounds: $ZZ \to 4\ell$, $Zt\bar{t}$, ZWW and Zh.
- Require one lepton pair to reconstruct Z.



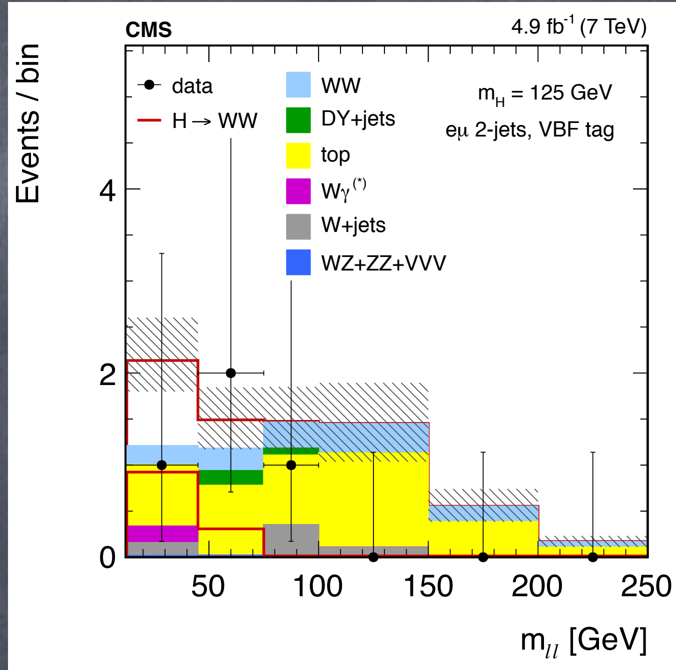
LHC 14 TeV,
$\mathcal{L} = 60$ fb^{-1}

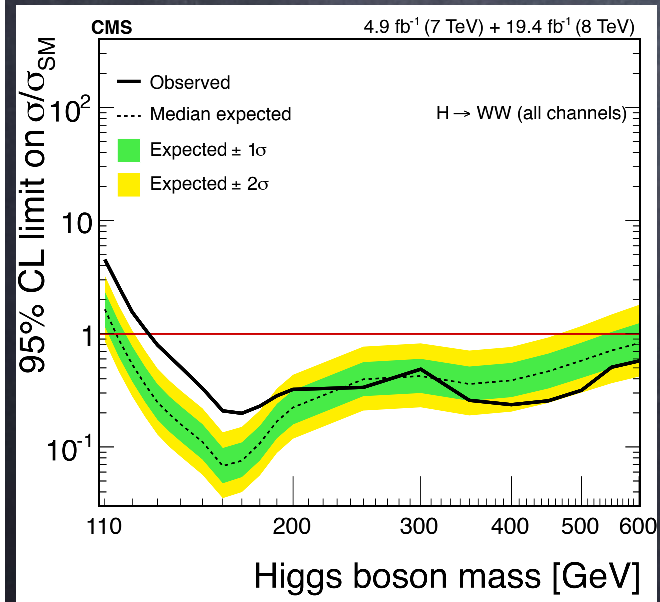
- A single cut on $m_{4\ell} > 260$ GeV allows for signal extraction.
- Significance of 5σ reached for $\mathcal{L} = 60$ fb^{-1} ($\mathcal{L} = 200$ fb^{-1} with 10% background uncertainty).

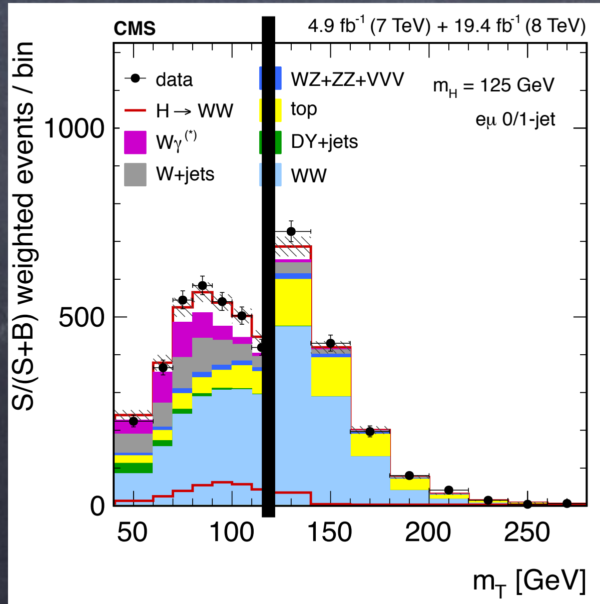
P. K. Mal

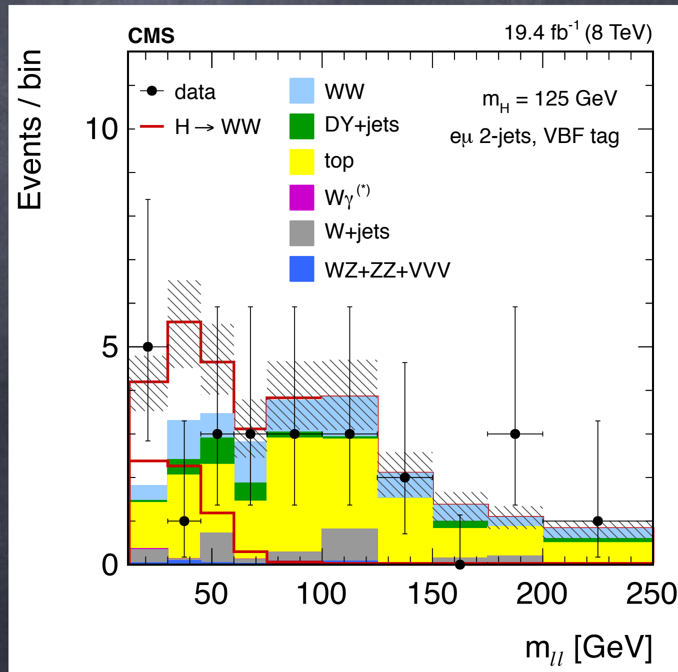
Search for H→WW→lνlν (II)

- CMS analyses are categorized into 2-leptons and 3-leptons final states
  - 2-leptons: 0/1-jet ggF tag, 2-jets VBF tag, 2-jets VH tag
  - 3-leptons: WH→lνlνlν and ZH→lllν+2 jets
- Signal events are extracted either through template fit or counting







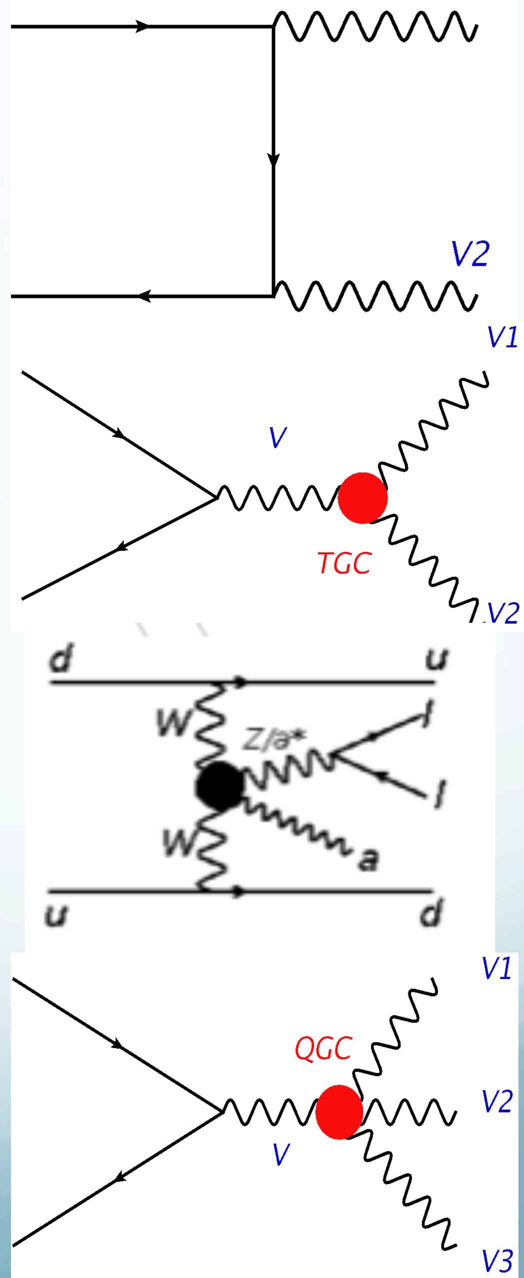


CMS-HIG-13-023/arXiv:1312.1129

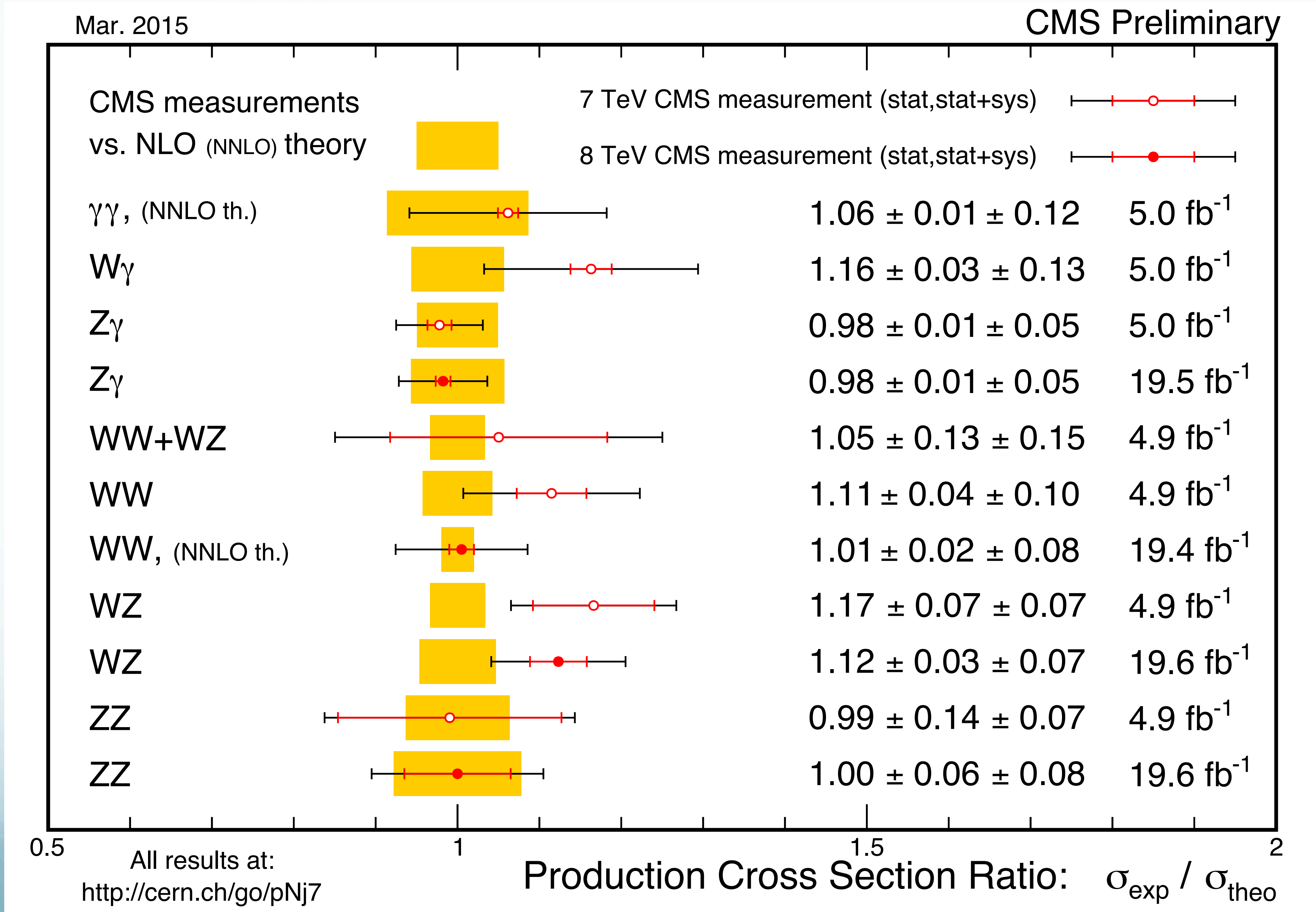
Toward Vector Boson Scattering and the unitarization of the SM

Most of Multi-boson processes have been measured in CMS and ATLAS.

- Multi-boson measurements important test of EWK sector of SM.
- High-tail enhancements: new physics searches
  - Sensitive to anomalous Triple (Quartic) Gauge Couplings
- Vector Boson Scattering: probing unitarization of cross section by Higgs boson
- Important backgrounds to Higgs and new physics



RUN 1



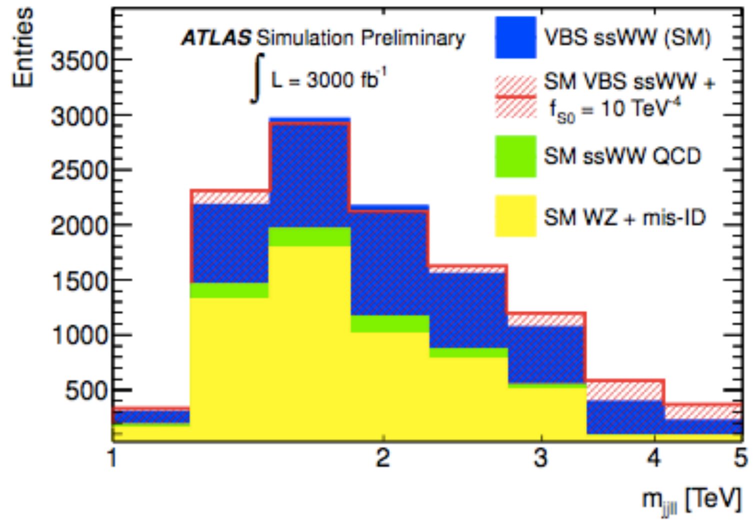
Mar. 2015
CMS Preliminary
CMS measurements
vs. NLO (NNLO) theory
7 TeV CMS measurement (stat,stat+sys)
8 TeV CMS measurement (stat,stat+sys)
γγ, (NNLO th.)
1.06 ± 0.01 ± 0.12
5.0 fb-1
Wγ
1.16 ± 0.03 ± 0.13
5.0 fb-1
Zγ
0.98 ± 0.01 ± 0.05
5.0 fb-1
Zγ
0.98 ± 0.01 ± 0.05
19.5 fb-1
WW+WZ
1.05 ± 0.13 ± 0.15
4.9 fb-1
WW
1.11 ± 0.04 ± 0.10
4.9 fb-1
WW, (NNLO th.)
1.01 ± 0.02 ± 0.08
19.4 fb-1
WZ
1.17 ± 0.07 ± 0.07
4.9 fb-1
WZ
1.12 ± 0.03 ± 0.07
19.6 fb-1
ZZ
0.99 ± 0.14 ± 0.07
4.9 fb-1
ZZ
1.00 ± 0.06 ± 0.08
19.6 fb-1
0.5
1
1.5
2
All results at:
http://cern.ch/go/pNj7
Production Cross Section Ratio: σexp / σtheo

RUN II Prospective

ATLAS-PHYS-PUB-2013-006
arXiv:1309.7452
arXiv:1408.5243

Expected Cross-Sections (WW)

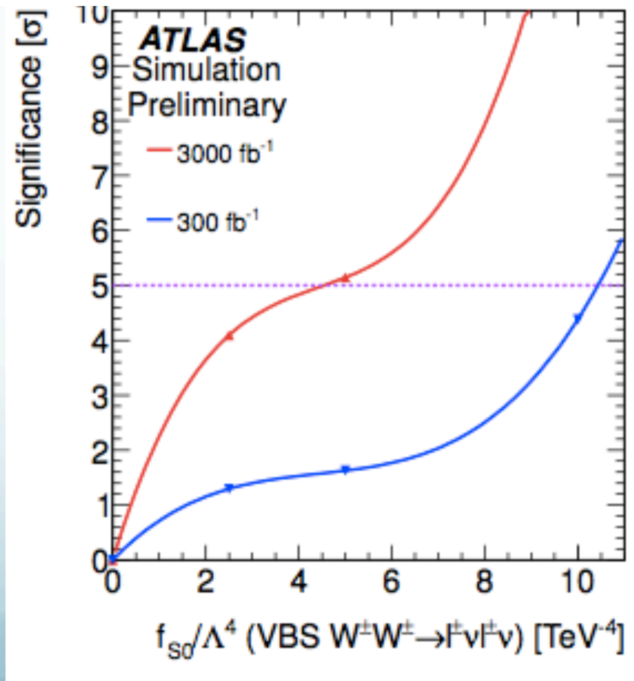
$\frac{\sqrt{s}}{\text{TeV}}$	σ_{LO}	σ_{NLO}	σ_{NNLO}	$\sigma_{gg\to H\to WW^*}$
7	$29.52^{+1.6\%}_{-2.5\%}$	$45.16^{+3.7\%}_{-2.9\%}$	$49.04^{+2.1\%}_{-1.8\%}$	$3.25^{+7.1\%}_{-7.8\%}$
8	$35.50^{+2.4\%}_{-3.5\%}$	$54.77^{+3.7\%}_{-2.9\%}$	$59.84^{+2.2\%}_{-1.9\%}$	$4.14^{+7.2\%}_{-7.8\%}$
13	$67.16^{+5.5\%}_{-6.7\%}$	$106.0^{+4.1\%}_{-3.2\%}$	$118.7^{+2.5\%}_{-2.2\%}$	$9.44^{+7.4\%}_{-7.9\%}$
14	$73.74^{+5.9\%}$ [illegible]	[illegible] $_{-3.3\%}$	$131.3^{+2.6\%}_{-2.2\%}$	$10.64^{+7.5\%}_{-8.0\%}$



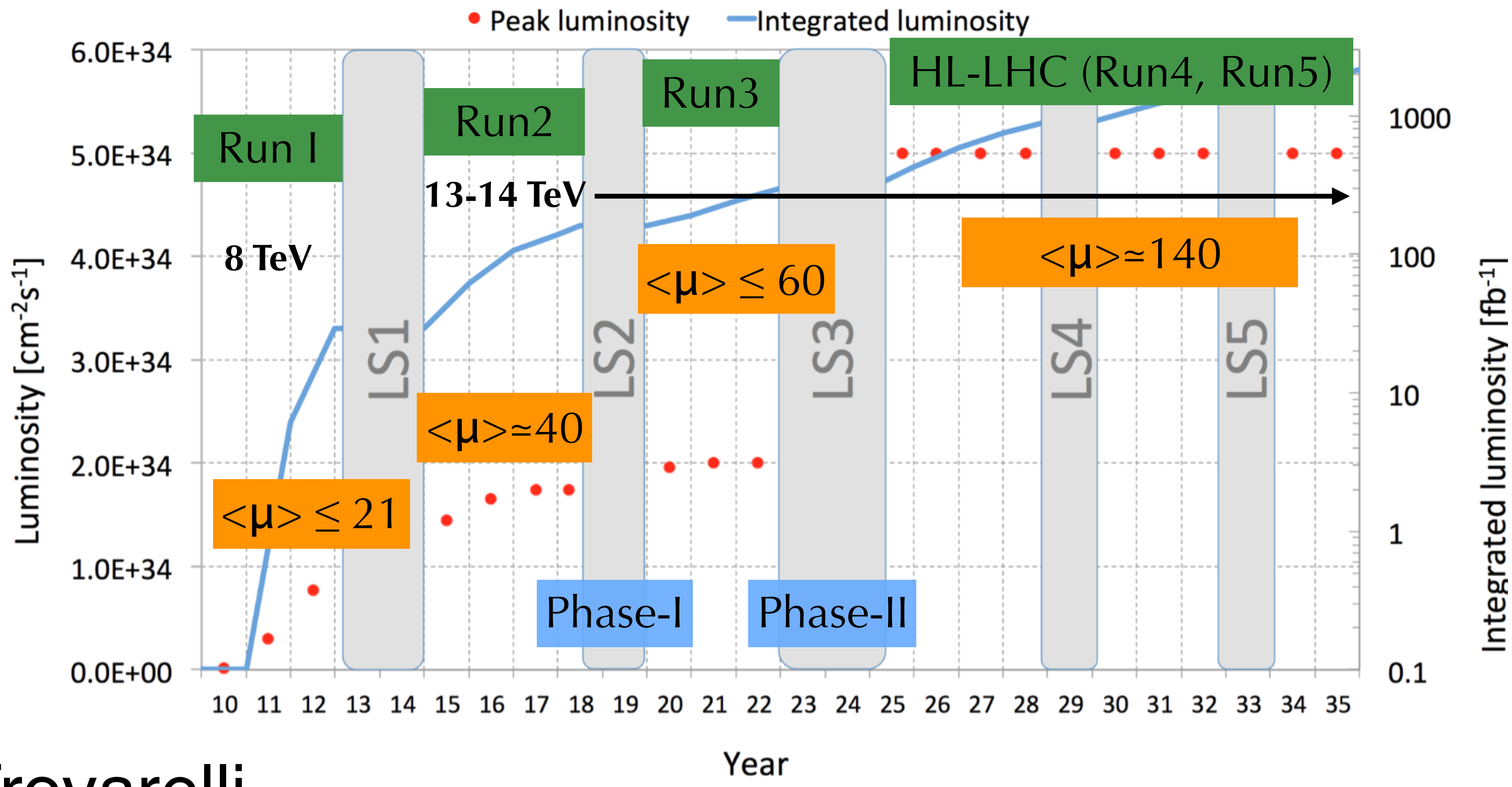
WZ + jj processes, 5 significance discovery values and 95% CL limits (with/without unitarity violation bound)

Parameter	Luminosity [fb^{-1}]	14 TeV 5σ	14 TeV 95% CL	33 TeV 5σ	33 TeV 95% CL
$c_{\phi d}/\Lambda^2$ [TeV^{-2}]	3000	15.2 (15.2)	9.1 (9.1)	12.6 (12.7)	7.7 (7.7)
	300	28.5 (28.7)	17.1 (17.1)	23.1 (23.3)	14.1 (14.2)
f_{T1}/Λ^4 [TeV^{-4}]	3000	0.6 (0.9)	0.4 (0.5)	0.3 (0.6)	0.2 (0.3)
	300	1.1 (1.6)	0.7 (1.0)	0.6 (0.9)	0.3 (0.6)

Channel	Parameter	(95% CL limits) 14TeV, 300 fb-1	(95% CL limits) 14TeV, 3000 fb-1
W±W±jj	$f_{S,0}/\Lambda^4$(TeV^{-4})	[−6.8, 6.8]	[−0.8, 0.8]
WZ jj	$f_{T,1}/\Lambda^4$(TeV^{-4})	[−0.7, 0.7]	[−0.3, 0.3]
Zγγ	$f_{T,9}/\Lambda^4$(TeV^{-4})	[−0.9, 0.9]	[−0.3, 0.3]



The High Luminosity-LHC project



M. Trovarelli

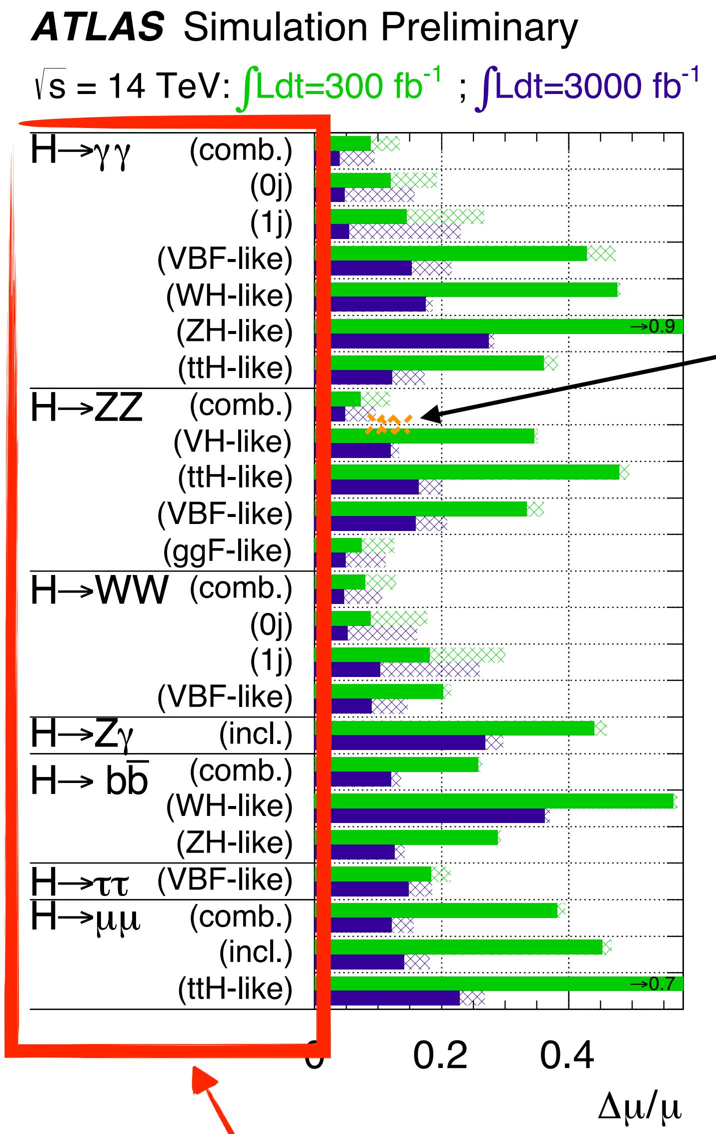
- HL-LHC will start in mid-2025 after ~2.5 years of shutdown
- Levelled luminosity of $5 \cdot 10^{34}$ cm^{-2} s^{-1}
- Average number of pile-up interactions per bunch crossing <μ> ≃ 140
- Expect to collect ~ 300 fb^{-1} with LHC and ~3000 fb^{-1} with the HL-LHC

Experimental Challenges

★ High pile-up ⇒ detector and trigger improvements needed

★ High radiation level ⇒ detector damage

Channels summary

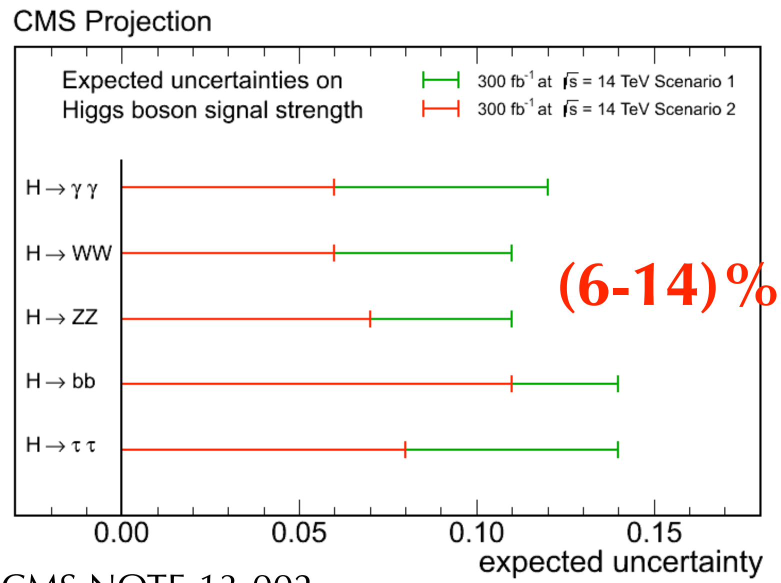


The hashed areas indicates the current theory systematic uncertainties (CERN-2011-002, CERN-2012-002)

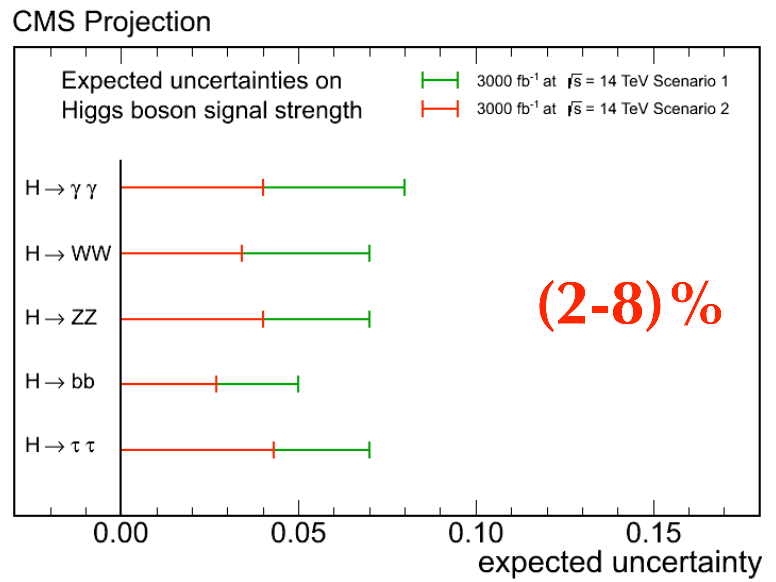
Different experimental categories considered

comb. = all combined

inclu. = only inclusive result shown



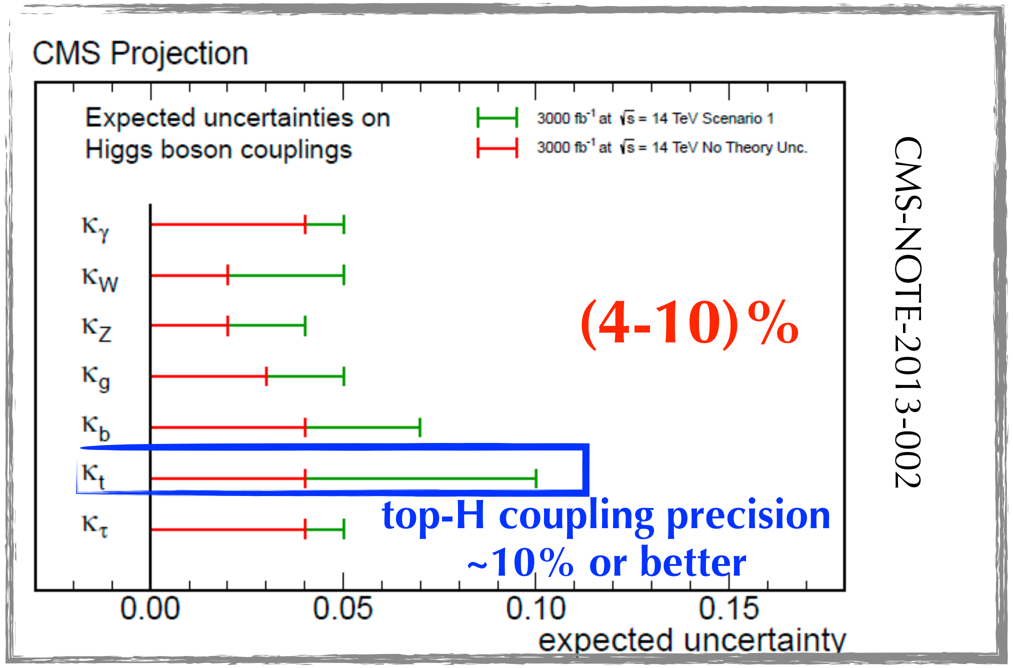
CMS NOTE-13-002



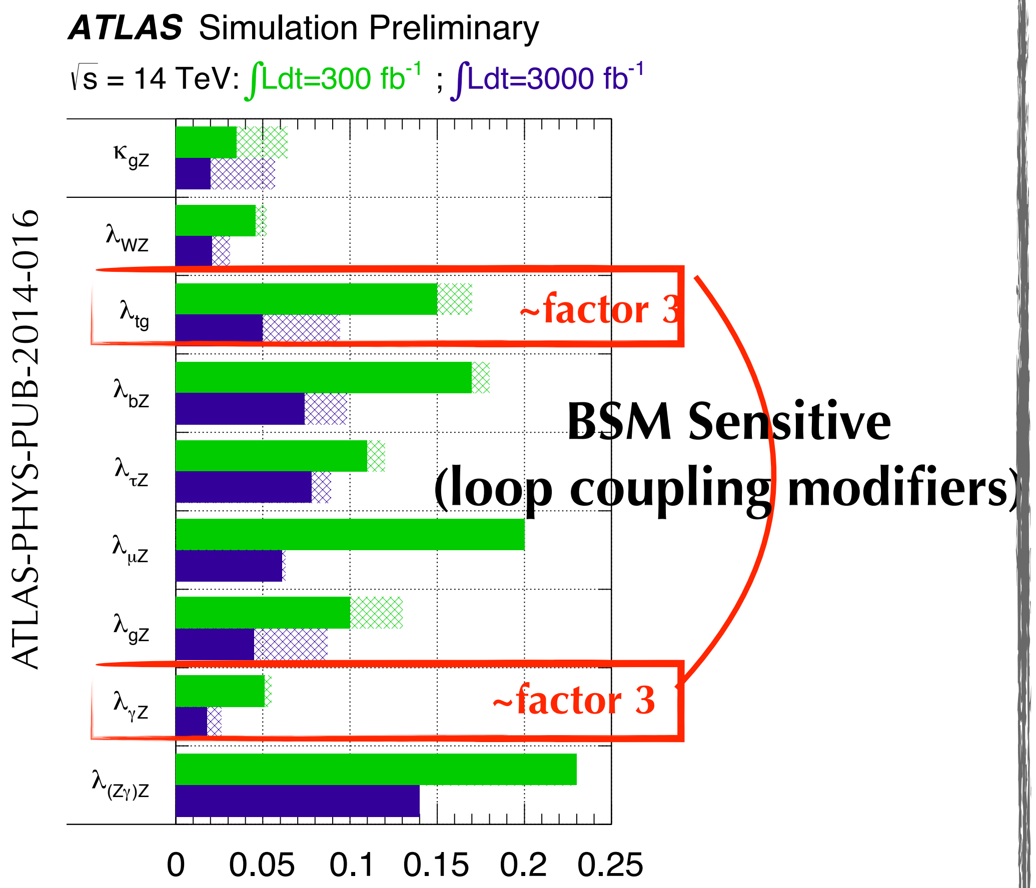
Couplings

$$\frac{\sigma \cdot B(gg \to H \to \gamma\gamma)}{\sigma_{SM}(gg \to H) \cdot B_{SM}(H \to \gamma\gamma)} = \frac{k_g^2 \cdot k_\gamma^2}{k_H^2}$$

(Model dependent)

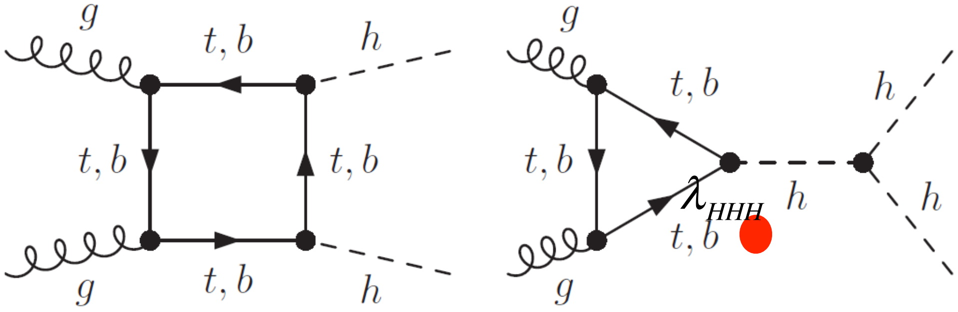


- no BSM particles inside loops $\Gamma_H = \sum_i \Gamma_i$



(Model independent) $\Delta\lambda_{XY} = \Delta(\frac{\kappa_X}{\kappa_Y})$

Higgs pair production



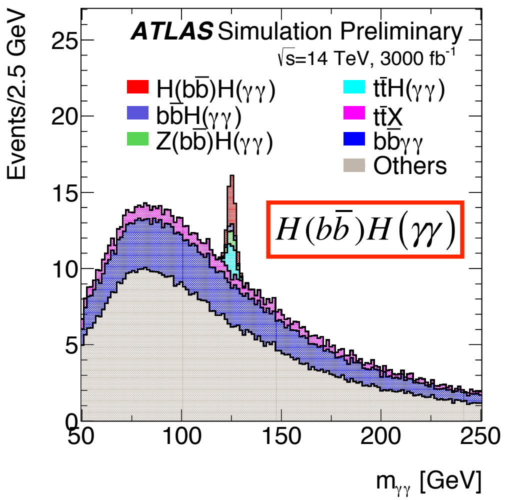
Destructive interference ⇒ SM cross section decrease

$\sigma \simeq 40.8\, fb$ (Phys. Rev. Lett. 111 (2013) 201801)

Decay Channel	Branching Ratio	Total Yield (3000 fb^{-1})
$b\bar{b} + b\bar{b}$	33%	40,000
$bb + W^+W^-$	25%	31,000
$b\bar{b} + \tau^+\tau^-$	7.3%	8,900
$ZZ + b\bar{b}$	3.1%	3,800
$W^+W^- + \tau^+\tau^-$	2.7%	3,300
$ZZ + W^+W^-$	1.1%	1,300
$\gamma\gamma + b\bar{b}$	0.26%	320
$\gamma\gamma + \gamma\gamma$	0.0010%	1.2

ECFA2014

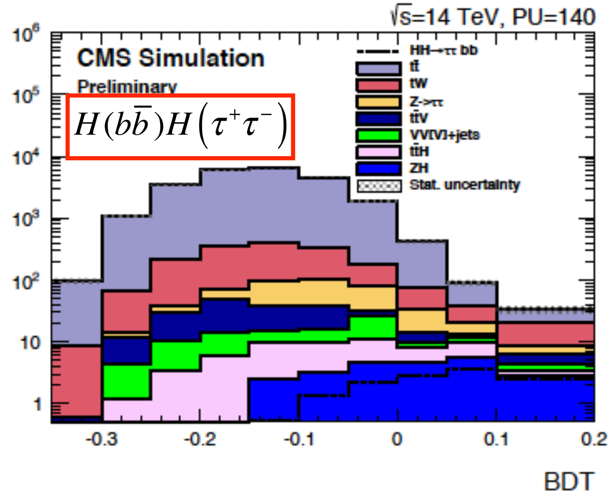
- Small cross section + huge background (top and fakes processes)



ATL-PHYS-PUB-2014-019

ATLAS expects ~ 8 events after selections corresponding to a signal significance of 1.3σ for the SM scenario

Physics at the High-Luminosity LHC (2015)



CMS expects a signal significance of 0.9σ

Outlook

We have a lot of results form Run1

The Higgs properties are being measured and we are using the Higgs as a gate to BSM physics

In Run 2 we will be able to see Higgs to fermions (3^{rd} generation), measure Higgs properties more precisely, and exploiting further the Higgs for BSM searches

Then with HL we hope to check the unitarization of the SM

Final thanks to the local organizers for an impeccable conference