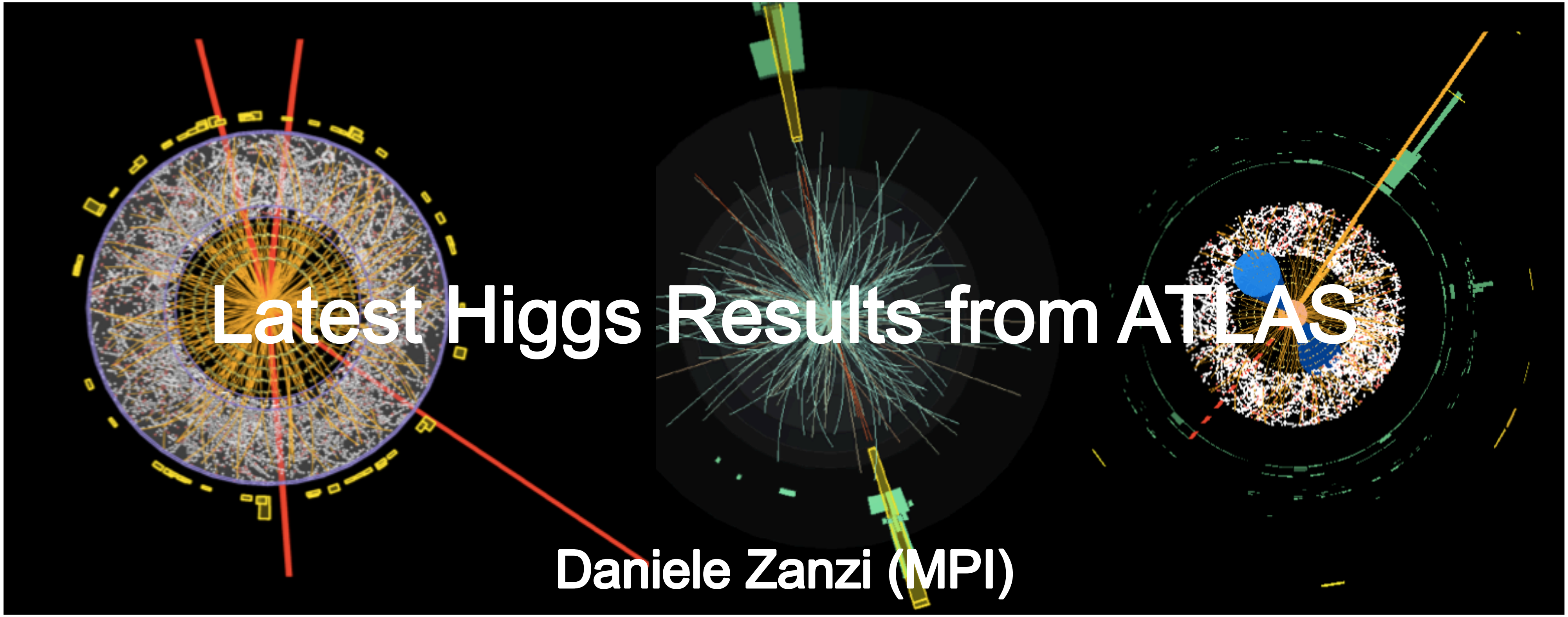

Latest Higgs Results from ATLAS

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PPSMC, 17.05.13

FSP 101 ATLAS

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(Werner-Heisenberg-Institut)

Introduction

Since the discovery of a new resonance on July 2012:

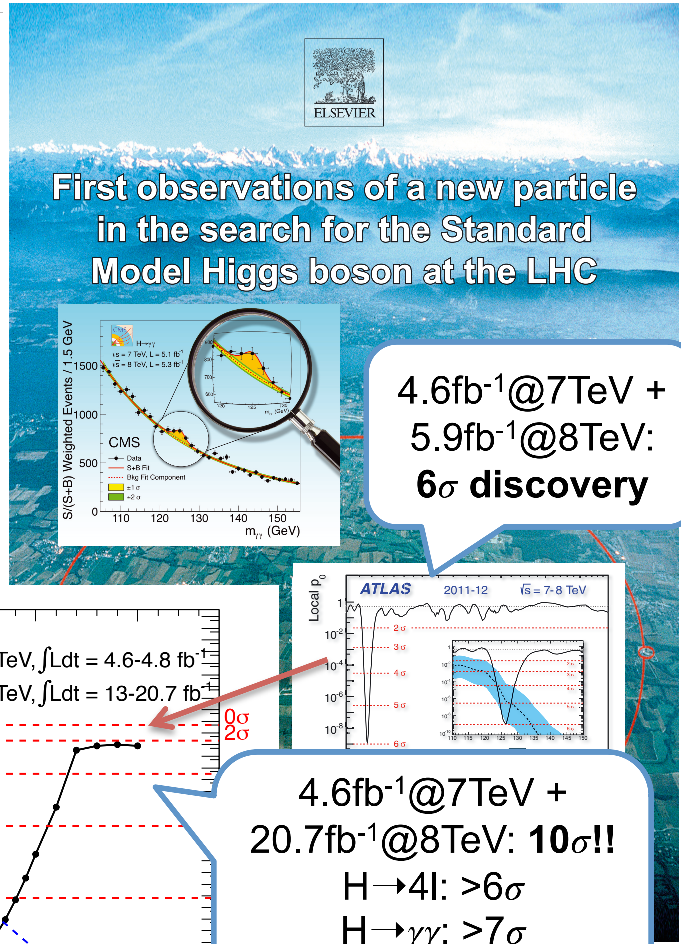
1. Updates with full 2012 dataset
2. Property measurements:
   - mass
   - couplings
   - spin and CP-parity

This talk covers the latest results in:

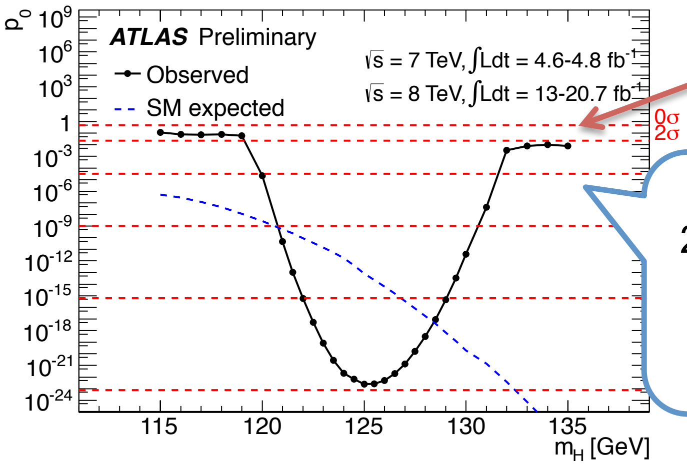
1. H→$\gamma\gamma$
2. H→ZZ
3. H→WW
4. Combination

is this the SM Higgs Boson??

PLB 716(2012) 1

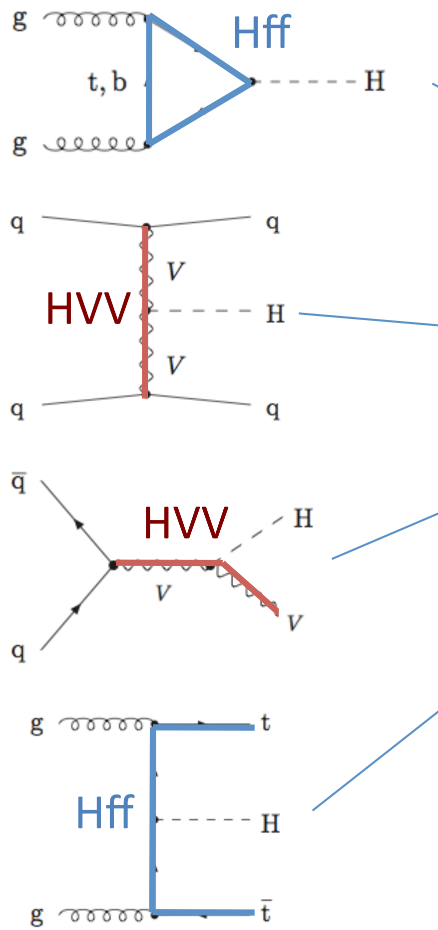


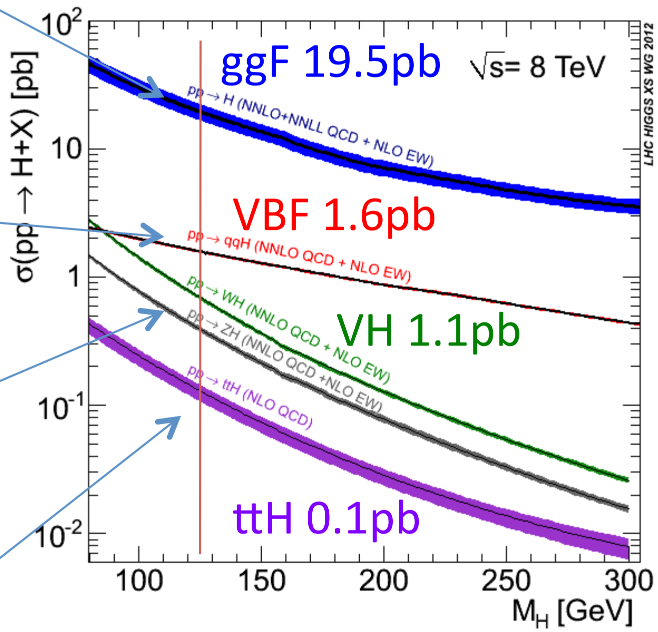
4.6fb^{-1}@7TeV + 5.9fb^{-1}@8TeV: **6σ discovery**

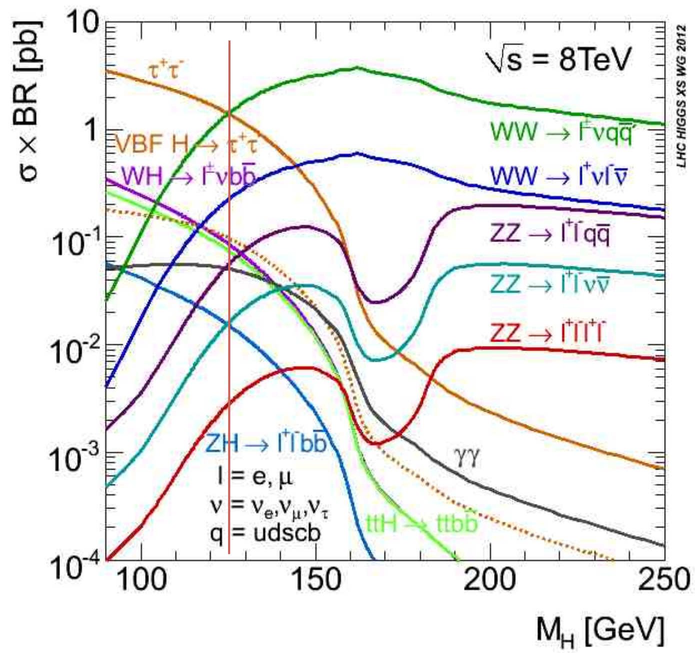


4.6fb^{-1}@7TeV + 20.7fb^{-1}@8TeV: **10σ!!**
H→4l: >6σ
H→$\gamma\gamma$: >7σ
H→WW: 3.8σ

SM Higgs boson @LHC







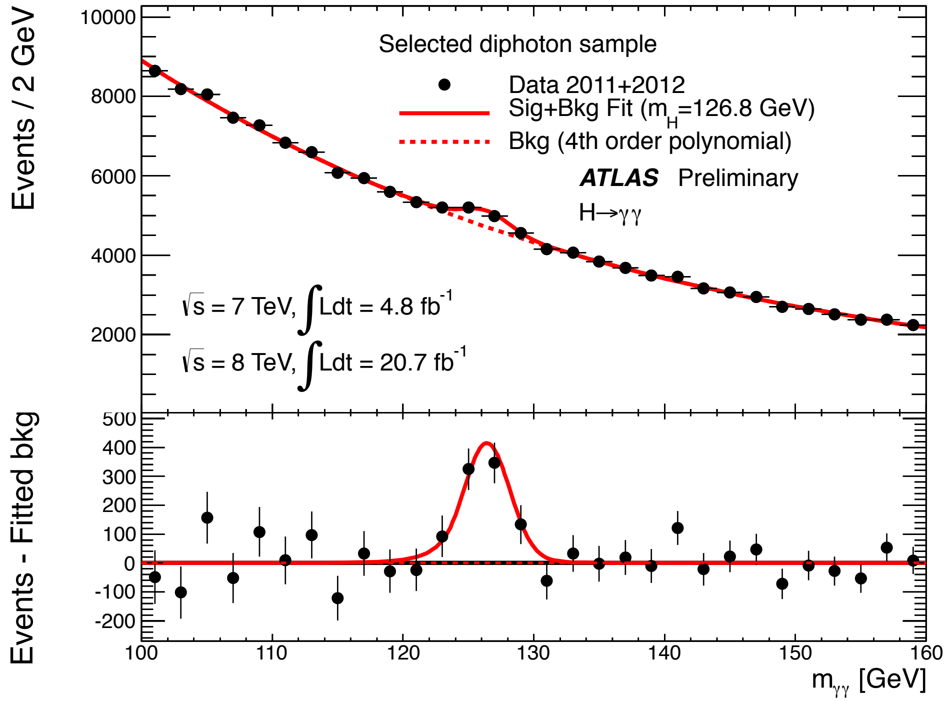
Searches span most of the final states and are optimized for single production modes in order to fully characterize the new boson

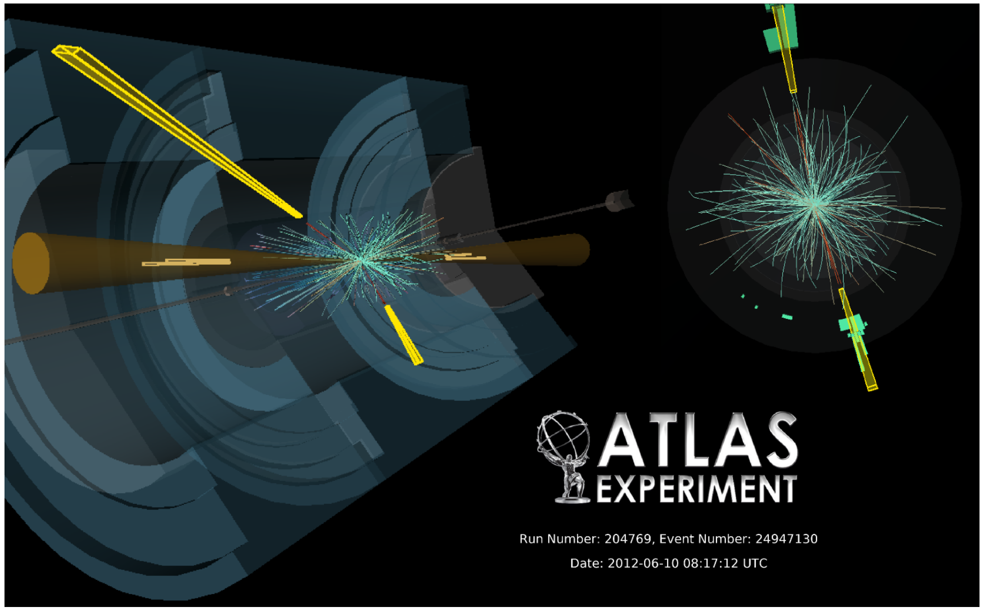
$H \rightarrow \gamma\gamma$

ATLAS-CONF-2013-012

BR(125GeV)=0.2%

1. 2 isolated high-p_T photons (E_T>40,30 GeV)
2. Background extrapolated from side-bands in data ($\gamma\gamma$ 75%, γj 22%, jj 3%)
3. Mass resolution ~1.7GeV at 126 GeV
4. Events categorized in several VBF/VH/ggF-dominated regions



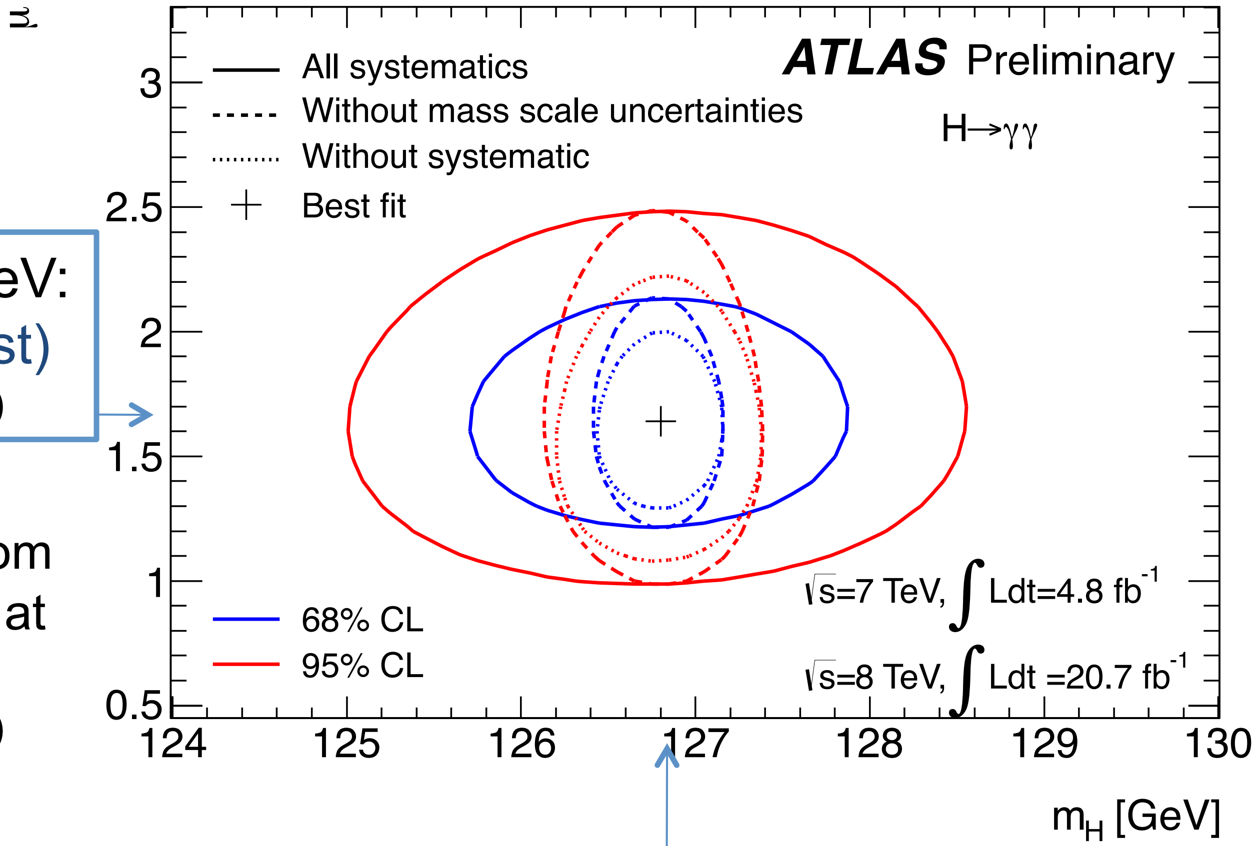


$H \rightarrow \gamma\gamma$: Mass & signal strength

ATLAS-CONF-2013-012

Signal strength at 126.8 GeV:
$1.65 \pm 0.24(\text{stat})^{+0.25}_{-0.18}(\text{syst})$
(2.3σ from the SM hypothesis)

Significance of the excess from background-only hypothesis at 126.8 GeV: 7.4σ
(2σ excess for the VBF signal)

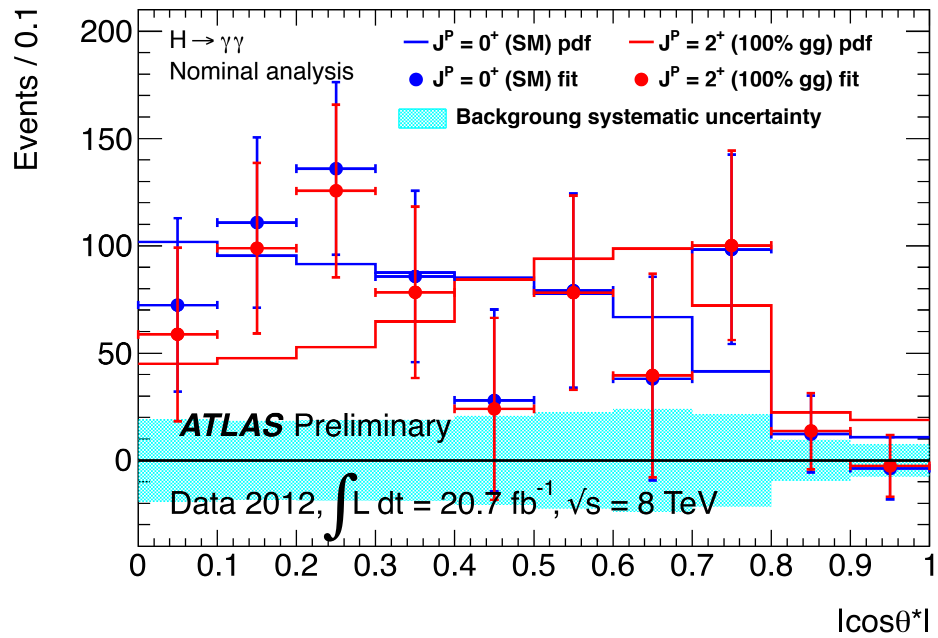


Best-fit mass: $126.8 \pm 0.2(\text{stat}) \pm 0.7(\text{syst})$ GeV
(dominated by photon energy scale uncertainty)

$H \rightarrow \gamma\gamma$: Spin

ATLAS-CONF-2013-012

1. Spin-1 hypothesis disfavoured by Landau-Yang theorem
2. Comparison of the SM 0^+ hypothesis with the 2^+_m "graviton-like" with minimal couplings (produced via gg and qqbar)
3. Discriminating variable: polar angle θ^* in the resonance rest frame
4. 2 independent fit of signal (0^+ or 2^+_m) + background → slightly different background subtraction



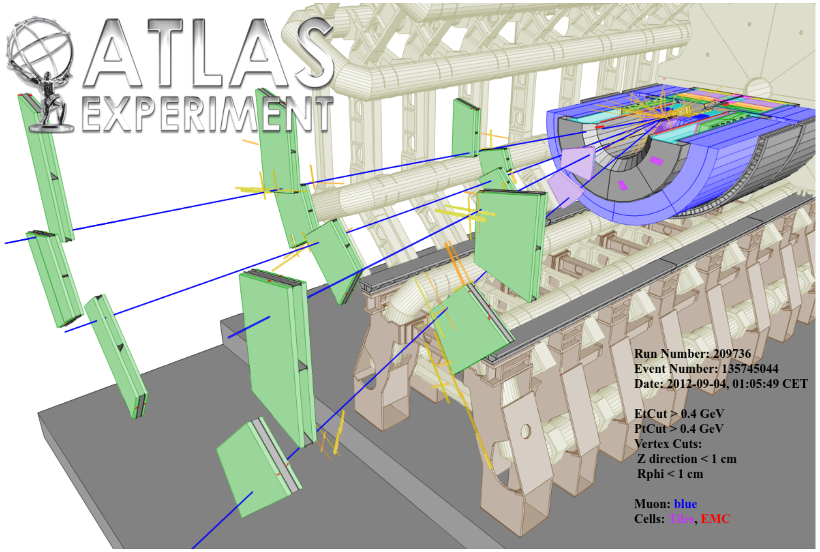
- Data in better agreement with the SM 0^+ hypothesis
- 2^+_m resonance produced via gluon fusion excluded at 99% CL

$H \rightarrow ZZ^{(*)} \rightarrow 4l$

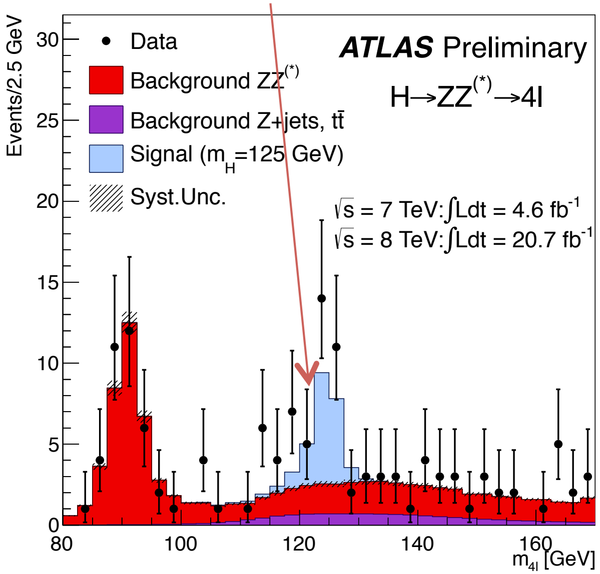
ATLAS-CONF-2013-013

BR(125GeV)=0.01%

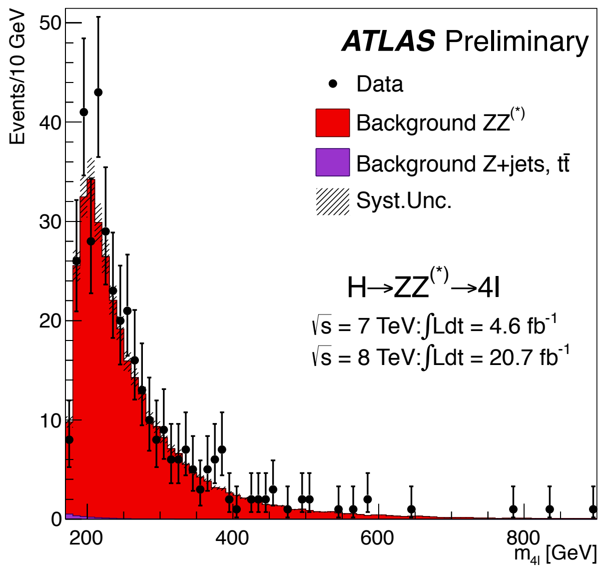
1. 2 OS SF isolated lepton pairs (p_T>20,15, 10, 7(6) GeV)
2. Clean signature, very high S/B, but low statistics
3. Mass resolution ~1.6-2.4 GeV
4. Categorization in VBF/VH/ggF-like events



SM expectation

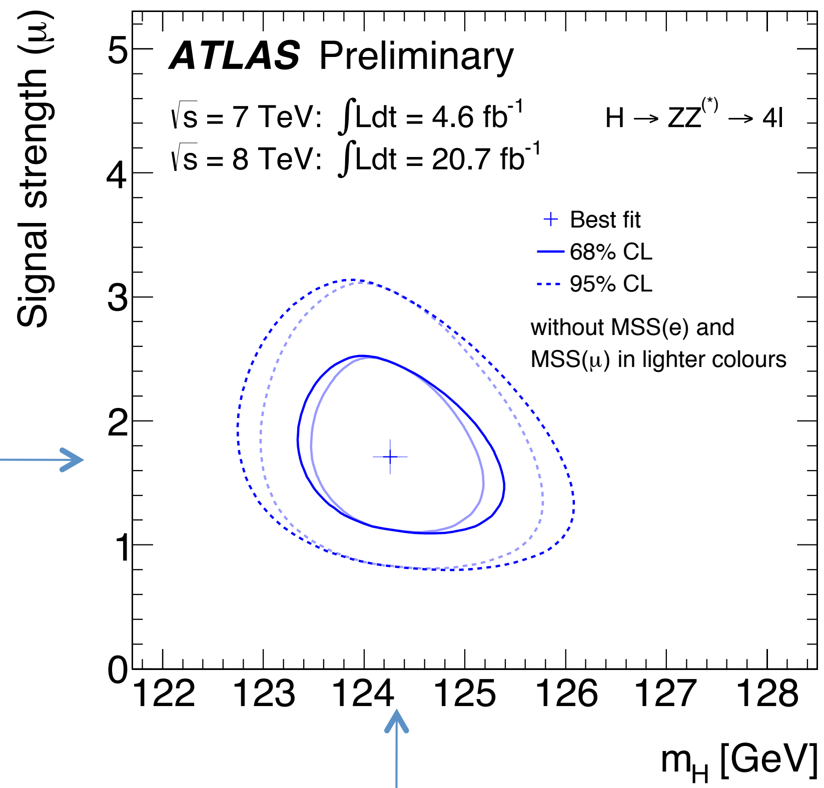


m_{4l} range [GeV]	[120-130]	>160
Observed Events	32	376
Exp. SM signal	15.9±2.1	
Exp. Bkg	11.1±1.3	348±26



H→ZZ(*)→4l: Mass & signal strength

ATLAS-CONF-2013-013



Signal strength at 124.3 GeV: $1.7^{+0.5}_{-0.4}$

Significance of the excess from background-only hypothesis at at 124.3 GeV: 6.6σ

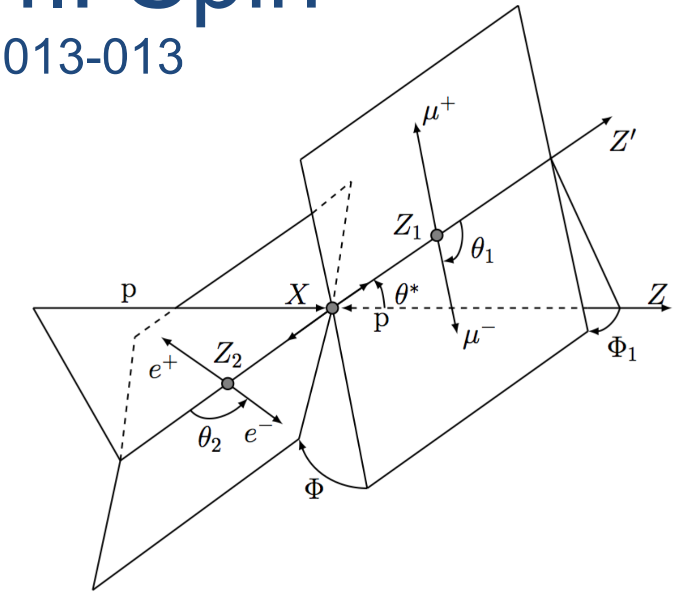
(1 Higgs candidate in VBF region)

Best-fit mass: $124.3^{+0.6}_{-0.5}(\text{stat})^{+0.5}_{-0.3}(\text{syst})$ GeV

(dominated by statistical error, systematic error mainly from energy/momentum scale uncertainties)

H→ZZ(*)→4l: Spin

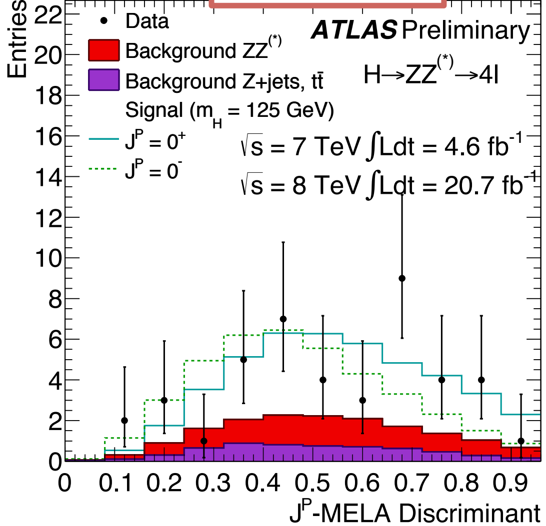
ATLAS-CONF-2013-013



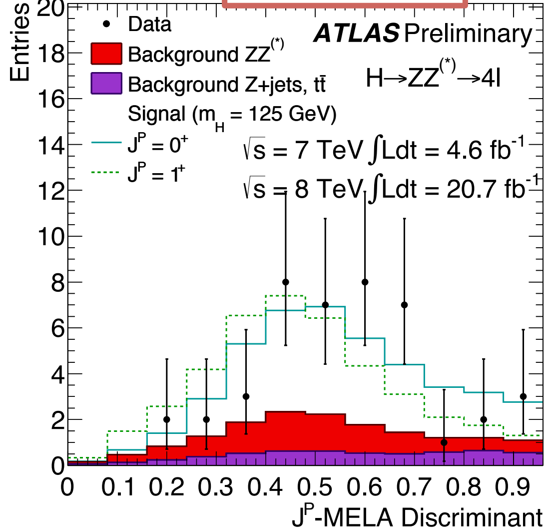
1. Discriminants combining kinematics of production and decay (5 angles and 2 Z masses)
2. SM 0^+ hypothesis tested vs 0^-,$1^\pm$,$2^\pm$
3. 43 events in $115<m_{4l}<130$ used

- Data in better agreement with SM 0^+ hypothesis wrt to all other tested models
- 0^- and 1^+ excluded at >97.8% CL

SM vs 0^-



SM vs 1^+

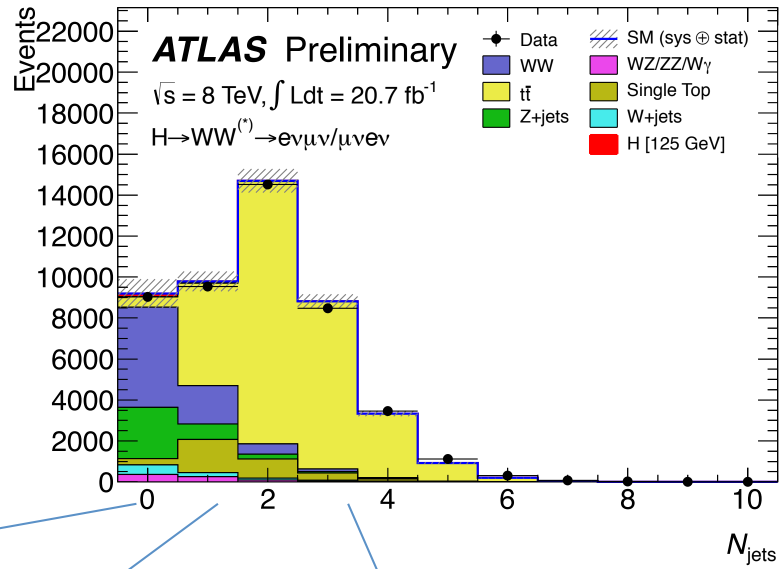


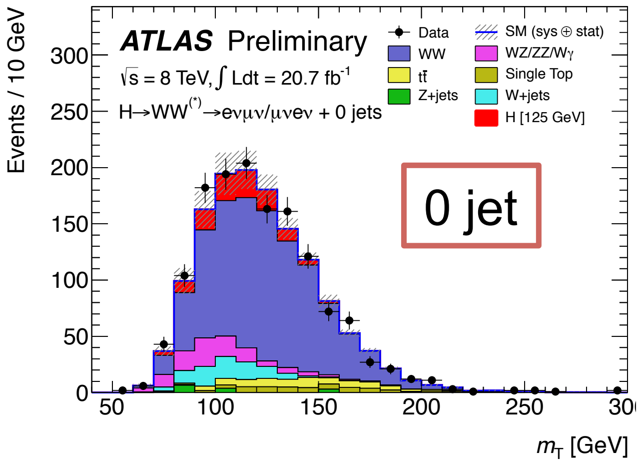
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ ($l=e,\mu$)

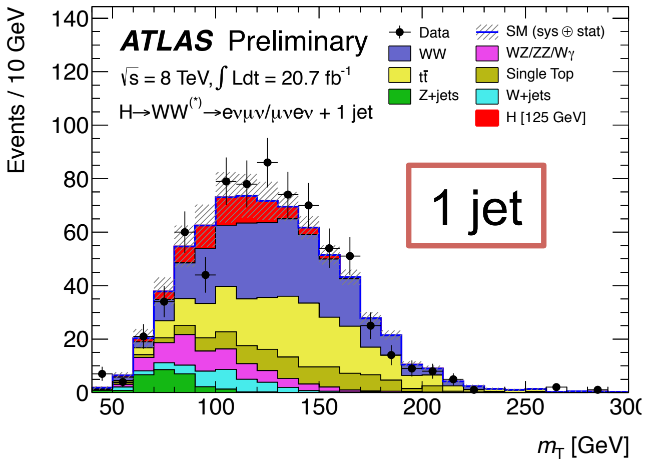
BR(125GeV)=2%

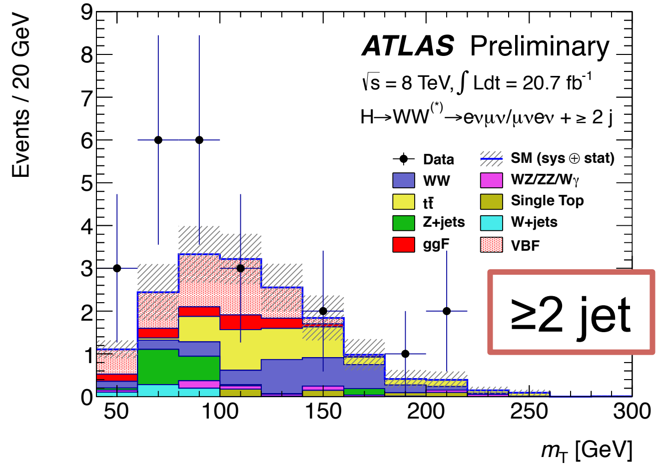
ATLAS-CONF-2013-030

1. 2 OS isolated leptons (p_T>25,15 GeV) and large missing transverse momentum
2. Categorization based on lepton flavour ($e\mu$ +μe or ee+$\mu\mu$) and jet multiplicity (0,1, ≥2)
3. Very different background composition for each category
4. No mass resolution because of the two neutrinos
5. "counting experiment": good background estimation is crucial



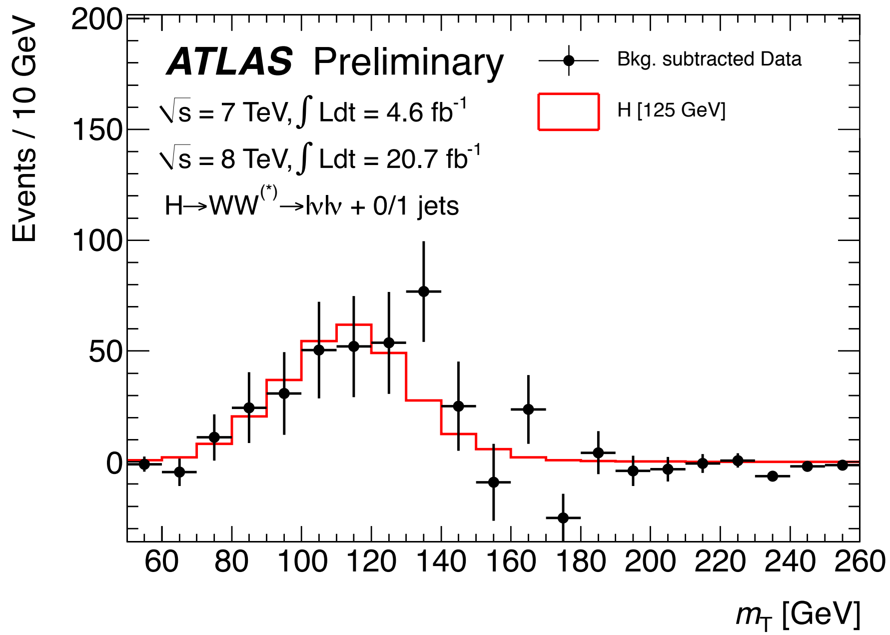






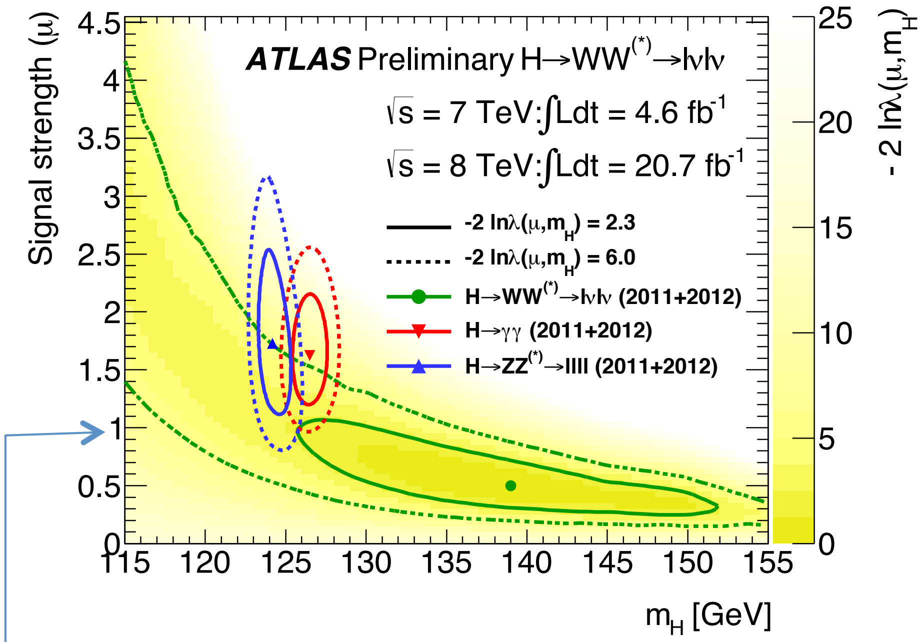
H→WW(*)→lνlν: Signal strength

ATLAS-CONF-2013-030



Significance of the excess from background-only hypothesis at 125 GeV: 3.7σ

(2.5σ for VBF signal)



No mass measurement

Signal strength at 125 GeV: 1.01±0.31

[±0.21(stat)±0.19(theory)±0.12(exp.syst)]

SPIN: 2^+_m hypothesis excluded at 95-99% CL_S

SM Higgs combination

ATLAS-CONF-2013-034

Higgs Boson Decay	Subsequent Decay	Sub-Channels	$\int L\,dt$ [fb^{-1}]	Ref.
		2011 $\sqrt{s}$ =7 TeV		
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu$, 2-jet VBF, ℓ-tag$\}$	4.6	[8]
$H \to \gamma\gamma$	–	10 categories $\{p_{Tt} \otimes \eta_\gamma \otimes$ conversion$\} \oplus \{$2-jet VBF$\}$	4.8	[7]
$H \to WW^{(*)}$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu e, \mu\mu\} \otimes \{$0-jet, 1-jet, 2-jet VBF$\}$	4.6	[9]
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	$\{e\mu\} \otimes \{$0-jet$\} \oplus \{\ell\ell\} \otimes \{$1-jet, 2-jet, $p_{T,\tau\tau} > 100$ GeV, $VH\}$	4.6	[10]
	$\tau_{lep}\tau_{had}$	$\{e, \mu\} \otimes \{$0-jet, 1-jet, $p_{T,\tau\tau} > 100$ GeV, 2-jet$\}$	4.6	
	$\tau_{had}\tau_{had}$	$\{$1-jet, 2-jet$\}$	4.6	
$VH \to Vbb$	$Z \to \nu\nu$	$E_T^{miss} \in \{120-160, 160-200, \geq 200$ GeV$\} \otimes \{$2-jet, 3-jet$\}$	4.6	[11]
	$W \to \ell\nu$	$p_T^W \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	4.7	
	$Z \to \ell\ell$	$p_T^Z \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	4.7	
		2012 $\sqrt{s}$ =8 TeV		
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu$, 2-jet VBF, ℓ-tag$\}\}$	20.7	[8]
$H \to \gamma\gamma$	–	14 categories $\{p_{Tt} \otimes \eta_\gamma \otimes$ conversion$\} \oplus \{$2-jet VBF$\} \oplus \{\ell$-tag, E_T^{miss}-tag, 2-jet VH$\}$	20.7	[7]
$H \to WW^{(*)}$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu e, \mu\mu\} \otimes \{$0-jet, 1-jet, 2-jet VBF$\}$	20.7	[9]
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	$\{\ell\ell\} \otimes \{$1-jet, 2-jet, $p_{T,\tau\tau} > 100$ GeV, $VH\}$	13	[10]
	$\tau_{lep}\tau_{had}$	$\{e, \mu\} \otimes \{$0-jet, 1-jet, $p_{T,\tau\tau} > 100$ GeV, 2-jet$\}$	13	
	$\tau_{had}\tau_{had}$	$\{$1-jet, 2-jet$\}$	13	
$VH \to Vbb$	$Z \to \nu\nu$	$E_T^{miss} \in \{120-160, 160-200, \geq 200$ GeV$\} \otimes \{$2-jet, 3-jet$\}$	13	[11]
	$W \to \ell\nu$	$p_T^W \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	13	
	$Z \to \ell\ell$	$p_T^Z \in \{< 50, 50-100, 100-150, 150-200, \geq 200$ GeV$\}$	13	

Mass measurement

ATLAS-CONF-2013-014, ATLAS-CONF-2013-034

High resolution channels:

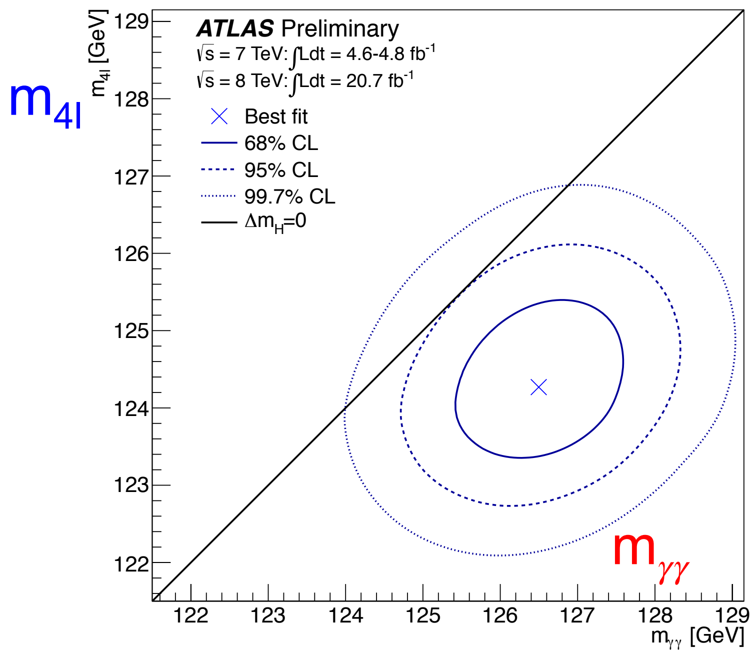
1. $H \to ZZ^* \to 4l$:

- $m_H = 124.3^{+0.6}_{-0.5}(stat)\ ^{+0.5}_{-0.3}(syst)$ GeV
- $4\mu(4e)$-event momentum resolution ±0.2%(0.4%),

2. $H \to \gamma\gamma$:

- $m_H = 126.8 \pm 0.2(stat) \pm 0.7(syst)$ GeV
- systematic error dominated by systematic uncert on photon energy scale

Combination:
$125.5 \pm 0.2(stat)^{+0.5}_{-0.6}(syst)$ GeV

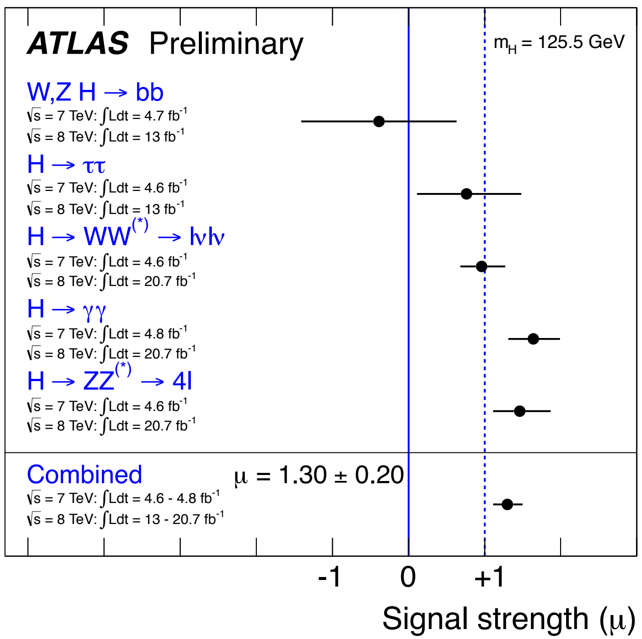


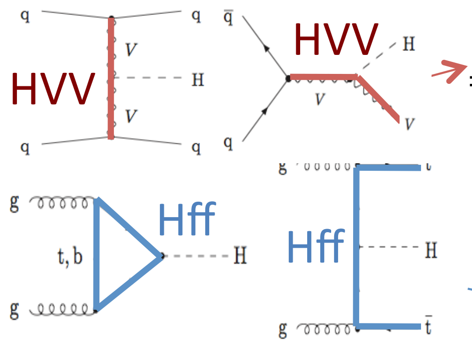
$\Delta m = 2.3^{+0.6}_{-0.7}(stat) \pm 0.6(syst)$ GeV
(2.4σ from $\Delta m=0$)

Signal Strengths

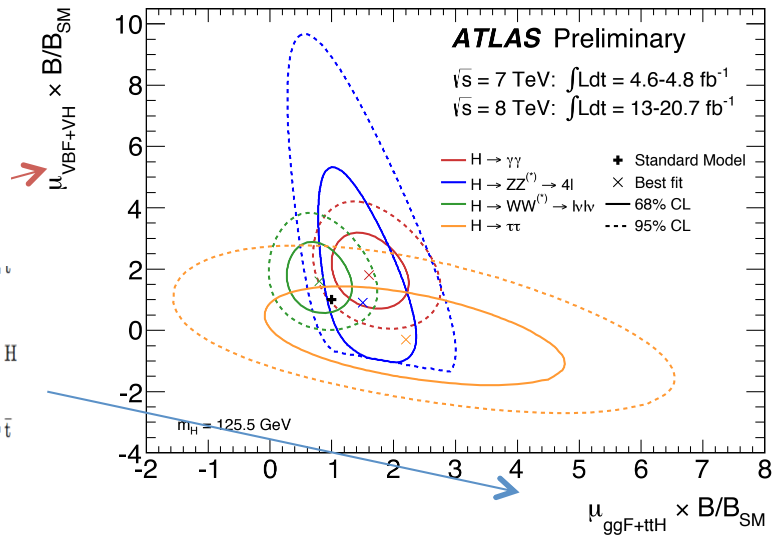
ATLAS-CONF-2013-034

Signal strength for individual channels





Signal strength for production modes



$\mu = 1.30 \pm 0.13(stat) \pm 0.14(syst)$

9% compatibility with SM

(weak dependence on assumed Higgs mass)

$\mu_{VBF+VH}/\mu_{ggF+ttH} = 1.2^{+0.7}_{-0.5}$

Compatible with SM expectation of unity

3.1σ from $\mu_{VBF}/\mu_{ggF+ttH}=0$ hypothesis

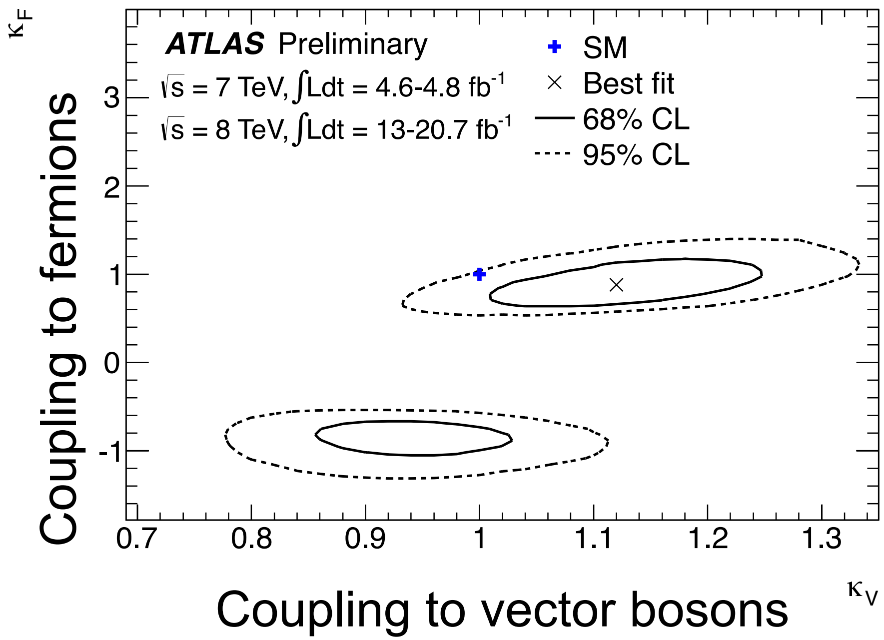
Fermion vs Vector Coupling

ATLAS-CONF-2013-034

Assumptions:

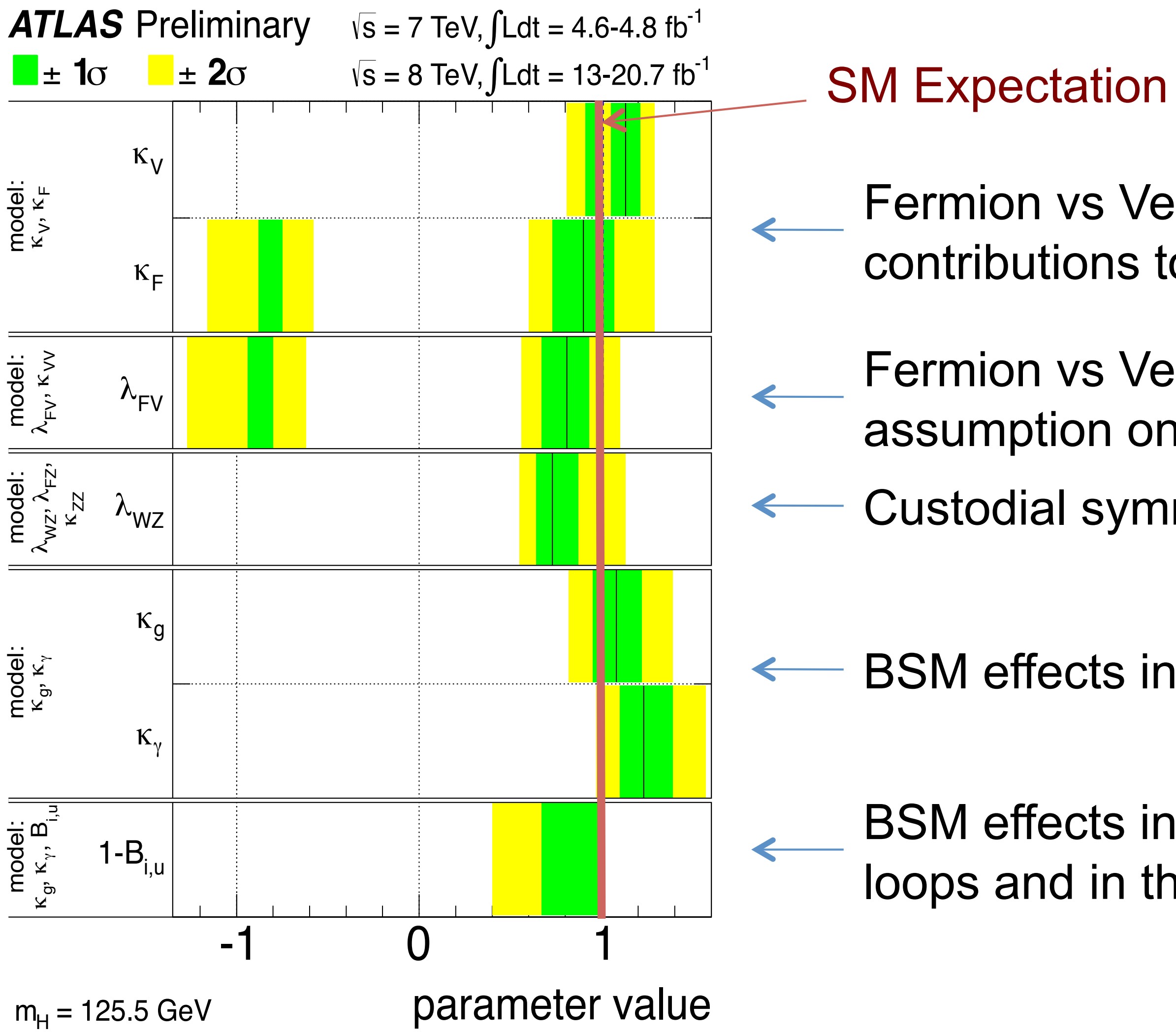
- Signals observed in different channels originate from **single narrow** resonance with $\mathbf{m_H}$**=125.5 GeV**
- Zero-width approximation: σxBR(ii→H→ff) = $\sigma_{ii} \cdot \Gamma_{ff} / \Gamma_H$
- Tensor structure of the couplings assumed to be SM, only coupling strengths are modified with scale factors k

1. Consistent treatment of couplings in Higgs production and decay
2. Vector coupling scale factor $k_V = k_W = k_Z$
3. Fermion coupling scale factor $k_F = k_t = k_b = k_\tau = k_g$
4. Only SM contributions in H→$\gamma\gamma$ and gg→H loops and in Higgs decays
5. 8% compatibility with SM hypothesis
6. Vector coupling k_V directly and indirectly constrained
7. Fermion coupling k_F still not directly constrained, but only indirectly from ggF-dominated channels



Coupling Fits

ATLAS-CONF-2013-034



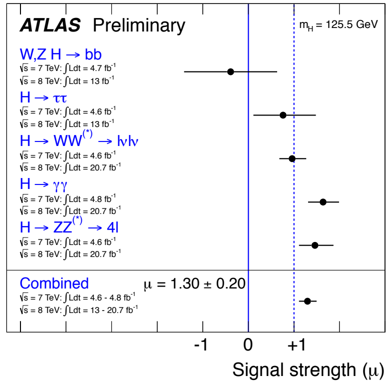
- Fermion vs Vector coupling (only SM contributions to total width)
- Fermion vs Vector coupling (no assumption on total width)
- Custodial symmetry of W and Z coupling
- BSM effects in the ggF and $H \rightarrow \gamma\gamma$ loops
- BSM effects in the ggF and $H \rightarrow \gamma\gamma$ loops and in the Higgs decay

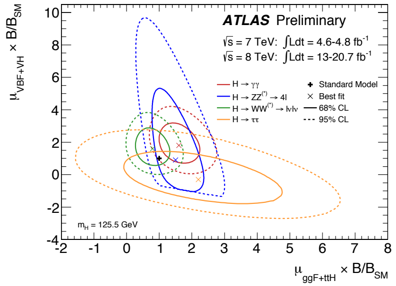
Summary

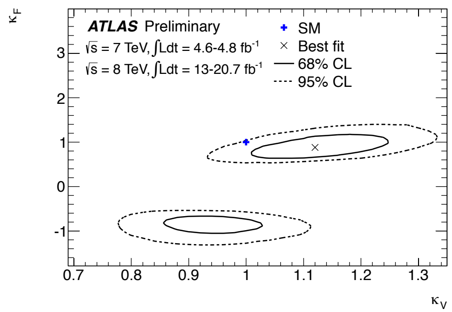
1. Preliminary results based on full 2012 datasets in $H \rightarrow \gamma\gamma$, $H \rightarrow ZZ^* \rightarrow 4l$ and $H \rightarrow WW^* \rightarrow l\nu l\nu$
2. Independent observations in all three channels
3. $m_H = 125.5 \pm 0.2(\text{stat})^{+0.5}_{-0.6}(\text{syst})$ GeV
4. $\mu = 1.30 \pm 0.13(\text{stat}) \pm 0.14(\text{syst})$
5. $\mu_{VBF+VH}/\mu_{ggF+ttH} = 1.2^{+0.7}_{-0.5}$
6. 3.1σ evidence of VBF production
7. Higgs couplings consistent with SM within 2σ
8. SM 0^+ hypothesis preferred against $0^-, 1^\pm$ and $2^\pm$

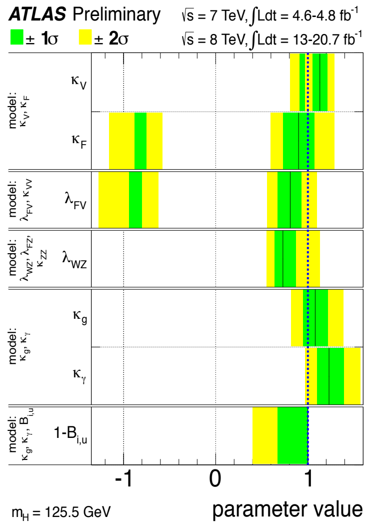
$\Rightarrow$ VERY SM-like…

is this the SM Higgs Boson??









Summary

Summary


WE HAVE IT*!
(*) “IT” means A Higgs boson, responsible for the Higgs mechanism
Next question: is this THE SM Higgs boson? are there others??