Combination of the Higgs Boson Properties Measurements using the ATLAS detector

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on behalf of the ATLAS Collaboration

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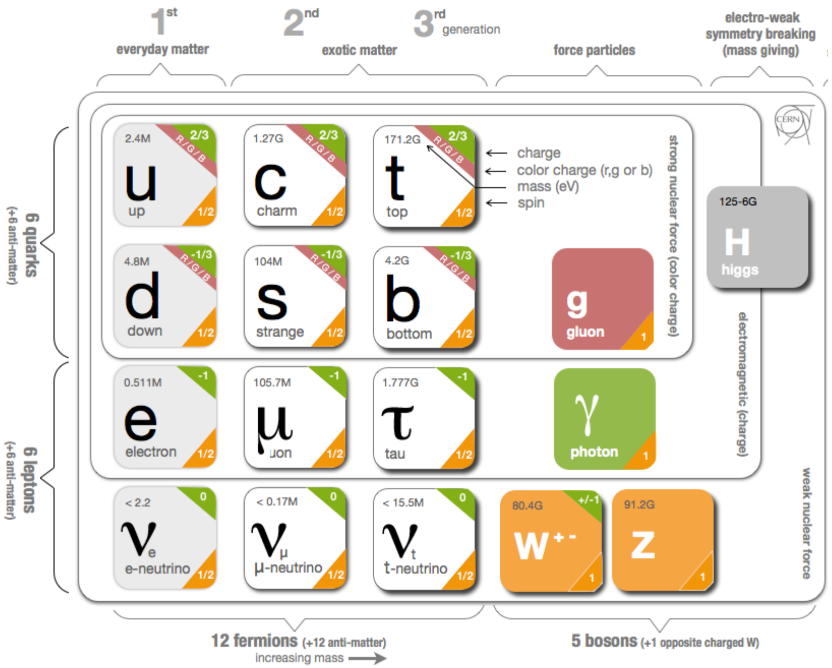
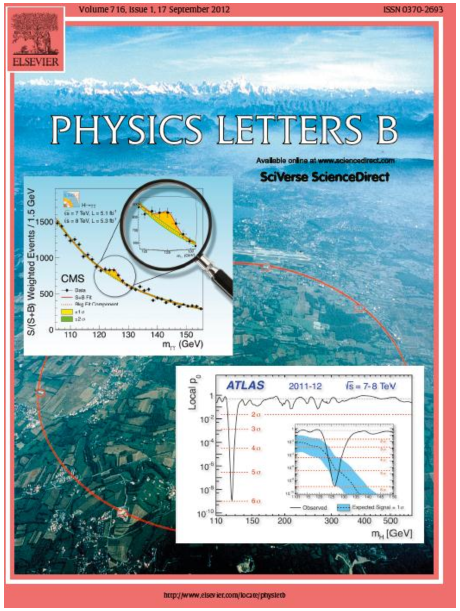
4th July 2012, ATLAS [1] and CMS [2] collaborations announced the observation of a new particle. [1] Phys. Lett. B 716 (2012) 1–29, [2] Phys. Lett. B 716 (2012) 30–61.





Started the "era of the measurement of the Higgs boson properties": TWO NEW PAPERS:

arXiv:1307.1427 [hep-ph] http://arxiv.org/pdf/1307.1427v1

arXiv:1307.1432 [hep-ph] http://arxiv.org/pdf/1307.1432v1

Outline

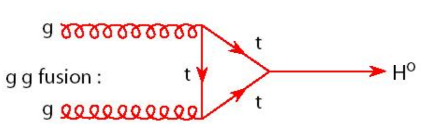
The following results are reported:

- ✓ Higgs mass;
- ✓ Signal strength;
- ✓ Couplings fit;
- ✓ J^P analyses.

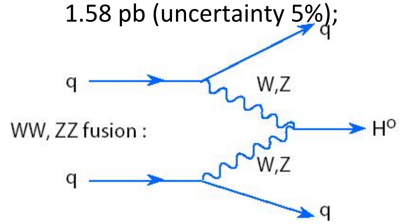
Higgs @ LHC

SM Higgs production (m_H = 125 GeV c^{-2} @ 8 TeV)

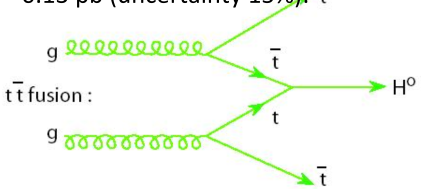
19.52 pb (uncertainty 15-20%);



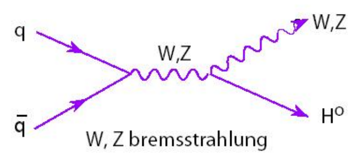
1.58 pb (uncertainty 5%);



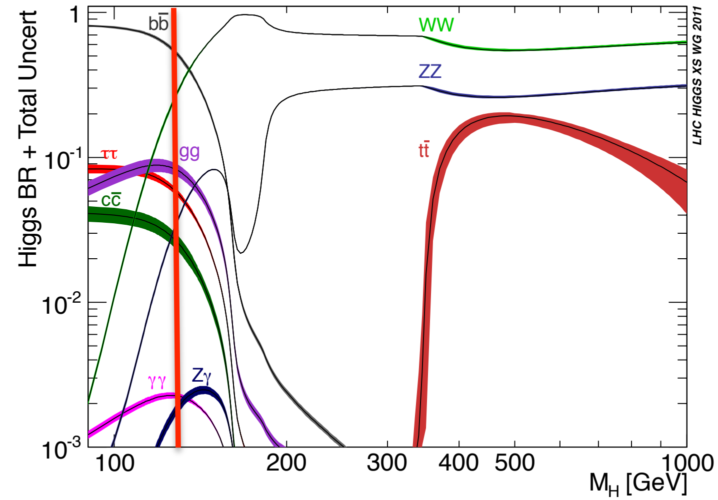
0.13 pb (uncertainty 15%);



0.7/0.4 pb (uncertainty 5%);



SM Higgs Branching Ratio



Main standard Model Higgs decays:

High mass resolution

- $H \rightarrow \gamma\gamma$:
  low S/B and high mass resolution;
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$:
  full mass range, low BR, high purity and mass resolution;

High BR, low mass resolution

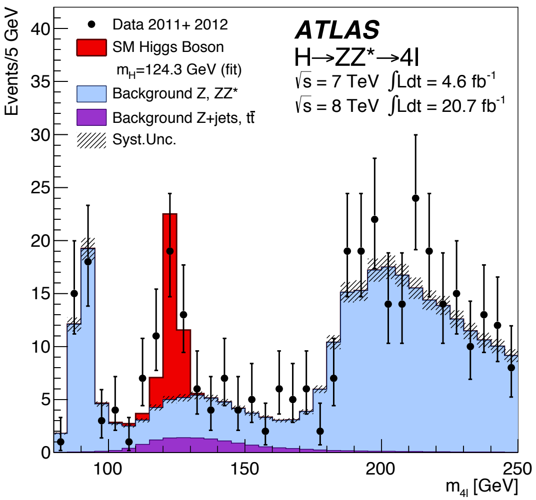
- $H \rightarrow WW^{(*)} \rightarrow l\nu\ l\nu$:
  full mass range, high rate;
- $H \rightarrow \tau\tau$:
  low mass range;
- $VH \rightarrow V + bb$:
  associated production VH, V= Z or W.

Expected events per fb^{-1}, BEFORE the selection:

	125	300
γγ	53	-
ZZ	2.9	5.6
WW	59	32
ττ	1500	-
bb Only VH	600 Only VH	-

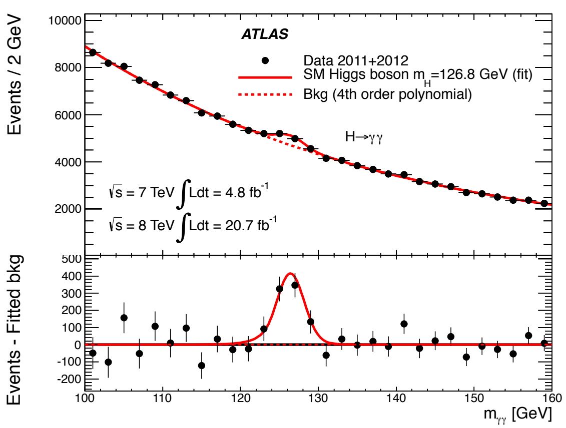
Higgs mass

arXiv:1307.1427 [hep-ph]



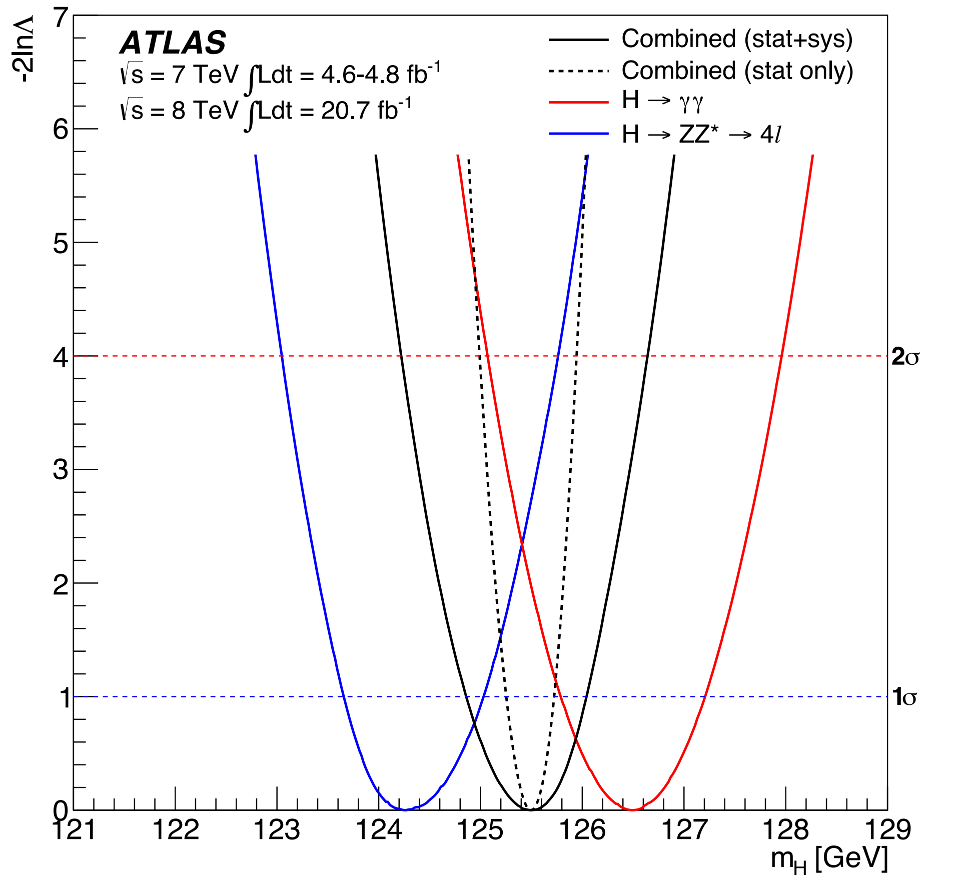
H → ZZ* → 4l

Mass: $m_H = 124.3\ ^{+0.6}_{-0.5}\ (stat)\ ^{+0.5}_{-0.3}\ (sys)\ GeV$



H → γγ

Mass: $m_H = 126.8 \pm 0.2\ (stat)\ \pm 0.7\ (sys)\ GeV$

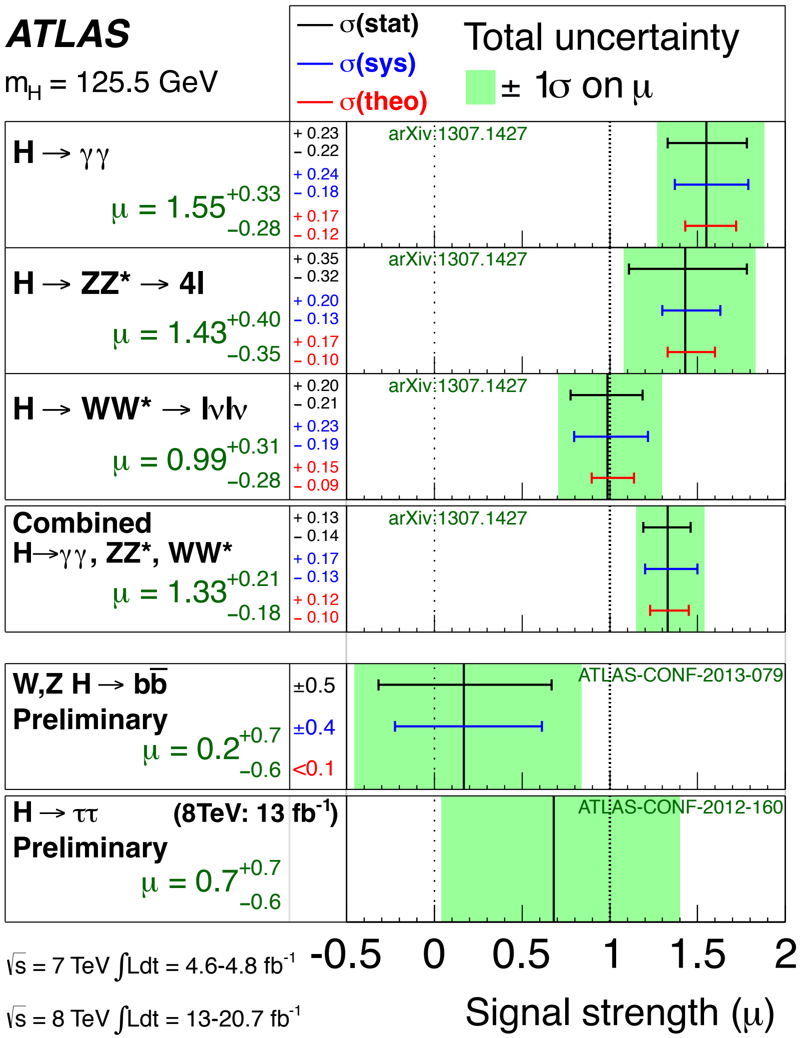


Combined mass: $m_H = 125.5 \pm 0.2\ (stat)\ ^{+0.5}_{-0.6}\ (sys)\ GeV$

Taking all systematics into account, the compatibility of the two masses is estimated to be at the 2.4 σ level.
The main sources of systematic uncertainty are the photon and lepton energy and momentum scales

Signal strength

arXiv:1307.1427 [hep-ph]



- Measure the ratio μ between the observed rate and the SM expectation for σ x BR (the comb. of γγ+ZZ+WW is reported):

$$\mu = 1.33\ ^{+0.21}_{-0.18}$$

- Result consistent with μ=1 (SM);
- Fermionic and “rare” channels to be added (Preliminary results).
- Preliminary combination with fermionic channel:

$$\mu = 1.23\ \pm 0.18$$

Higgs couplings

The framework makes the following assumptions:

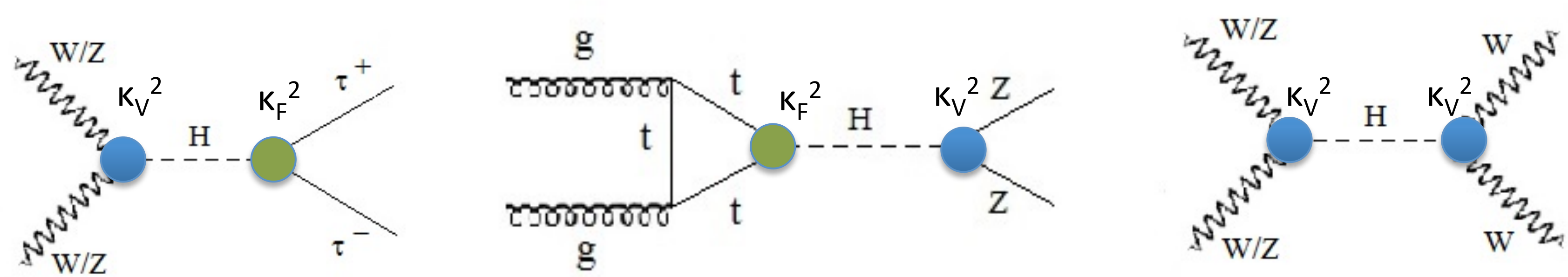
- Only modifications of couplings strengths, i.e. of absolute values of couplings, are taken into account: the observed state is assumed to be a CP-even scalar.
- The signals observed in the different search channels originate from a single narrow resonance;
- The width of the Higgs boson with a mass of 125.5 GeV is assumed to be negligible compare to detector resolution.

arXiv:1307.1427 [hep-ph]

Strategy:

Choose a model: More accurate with higher order corrections and external constraints and test small deviations from the SM predictions.

e.g. κ_V-κ_F: ($g_F = \kappa_F \sqrt{2} m_F / v$, $g_V = \kappa_V\, 2\, m_V^2 / v$)



Following prescriptions of LHC Higgs Cross-section Light Mass Subgroup.

Couplings

arXiv:1307.1427 [hep-ph]

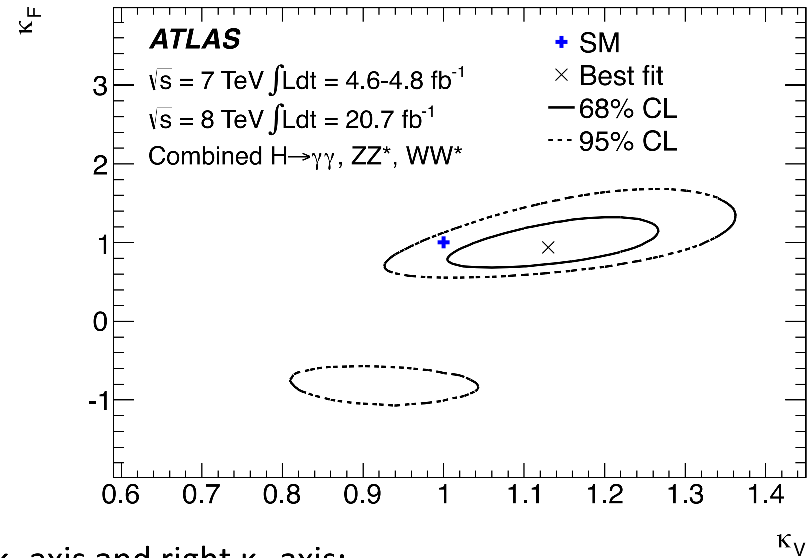
Vector boson and fermion couplings.

Some sensitivity to the relative sign of κ_F gained from the negative interference between W and fermion-loop in H → γγ decay.

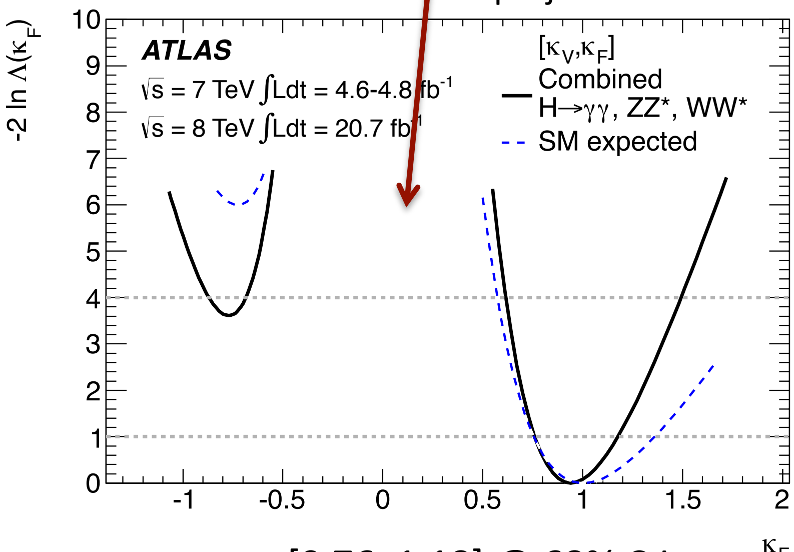
$$\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$$ Scale factor for all fermions

$$\kappa_V = \kappa_W = \kappa_Z$$ Scale factor for all vectors

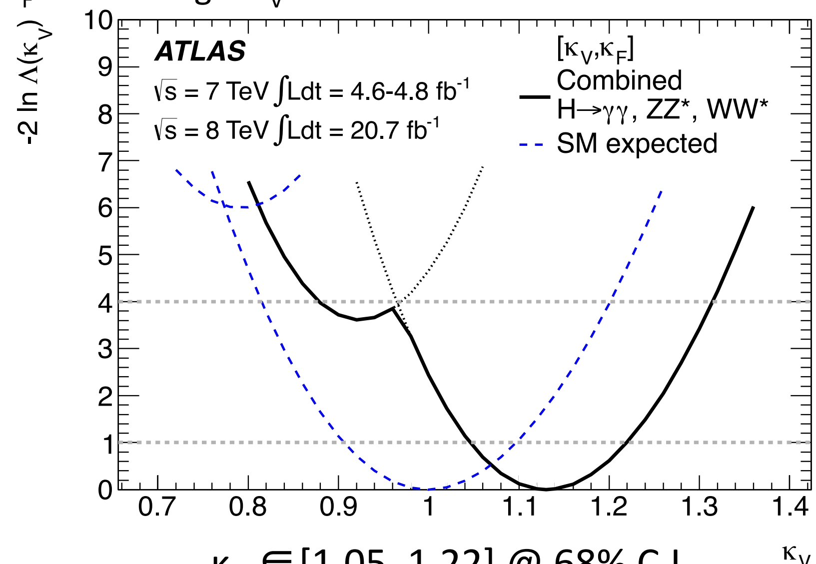
fermion coupling indirectly observed (>5σ rejection of κ_F= 0)



1D projections of 2D NLL, left κ_F axis and right κ_V axis:



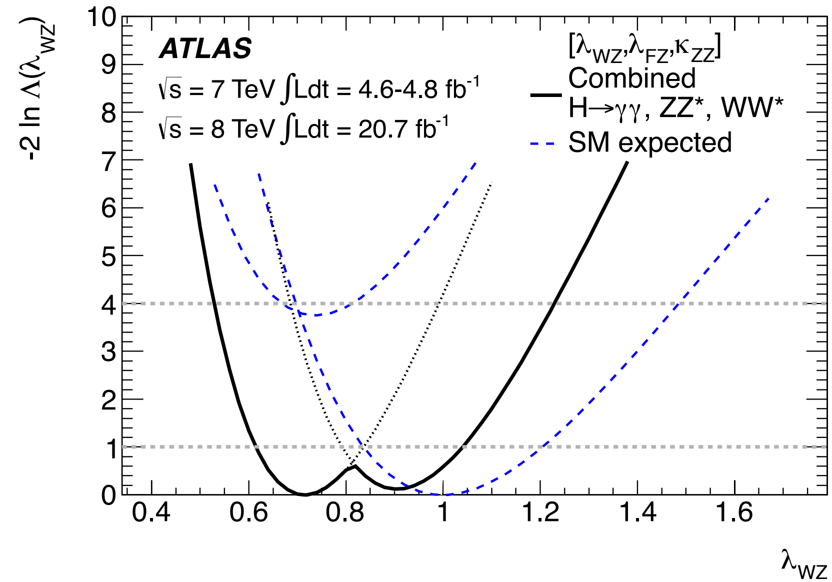
$\kappa_F \in [0.76, 1.18]$ @ 68% C.L.



$\kappa_V \in [1.05, 1.22]$ @ 68% C.L.

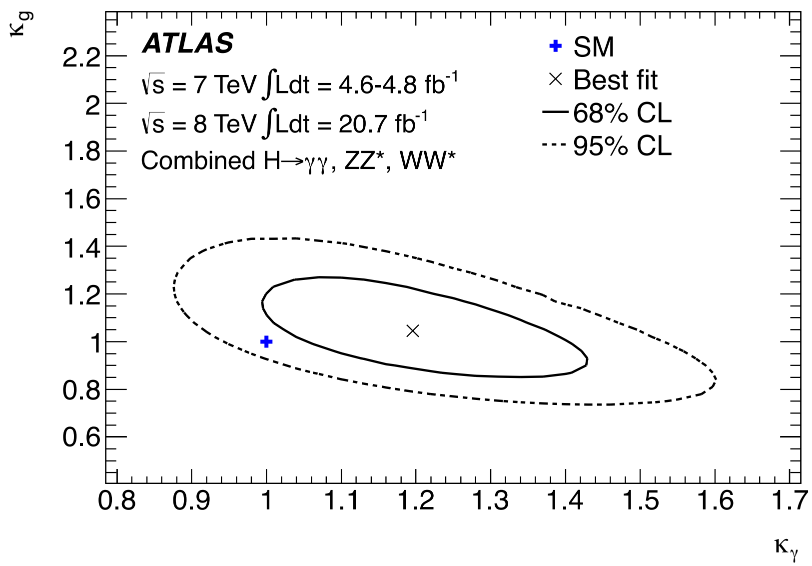
Couplings

arXiv:1307.1427 [hep-ph]

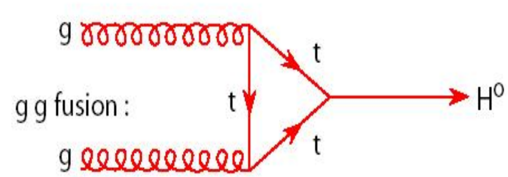


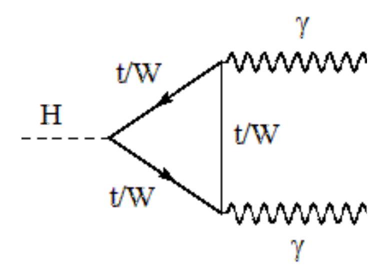
Ratio of couplings to the W and Z bosons.
Custodial symmetry imposes the SM coupling ratio between the W and Z Higgs couplings. Results form the ratio of the couplings are reported.

$$\lambda_{WZ} = \kappa_W/\kappa_Z \in [0.61, 1.04] \text{ @ 68\% C.L.}$$



Loop structure.
The potential new particles contributing to the H → γγ and gg → H loops, may or may not contribute to the total width of the observed state from direct invisible decays.





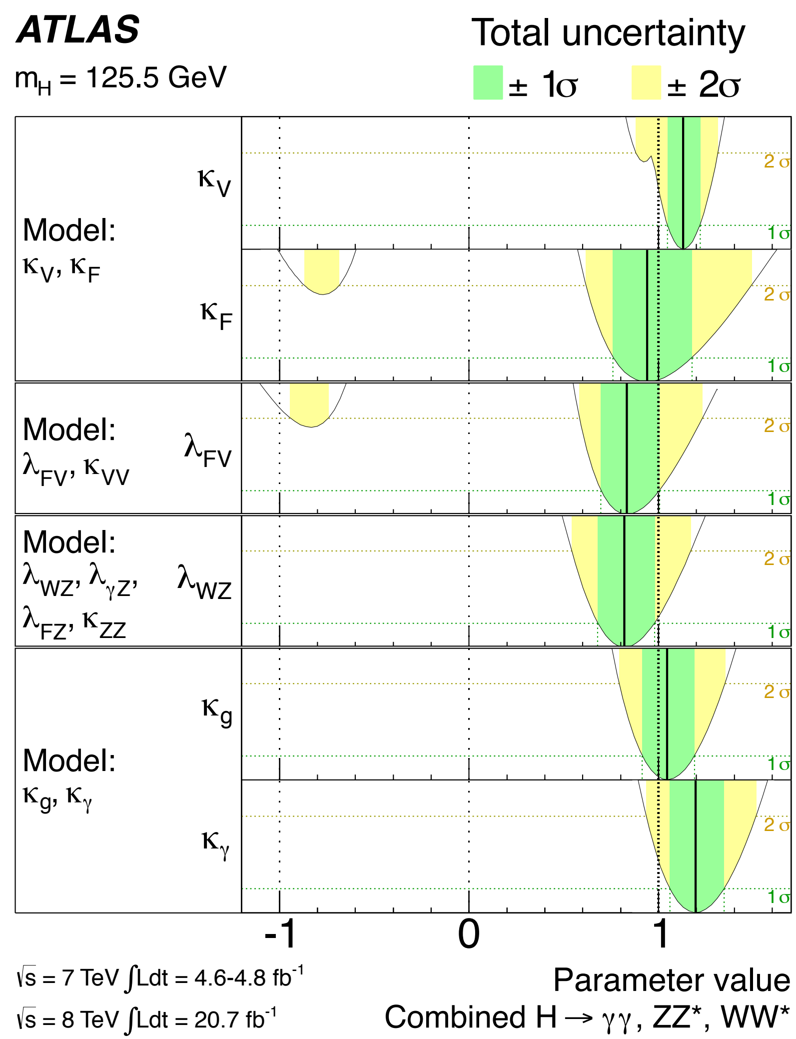
$$\kappa_g = 1.04 \pm 0.14, \; \kappa_\gamma = 1.20 \pm 0.15$$

Couplings

arXiv:1307.1427 [hep-ph]

Summary of couplings fit:

- results consistent with a SM Higgs boson;
- κ_V constrained at ±10% level
- Couplings to fermions indirectly observed;
- κ_W/κ_Z found to be consistent with one;
- No evidence for significant anomalous contributions to the gg → H and H → γγ loops;
- fermion and "rare (μμ, Zγ) " Higgs channels to be added.



Spin

The production and decay of the $J^P = 0^-$ resonance, as well as of the spin–1 and spin–2 resonances with both even and odd parities are modelled using the JHU generator @ LO

- 0^- : ZZ only. Pseudoscalar particle, no CP mixing;
- $1^\pm$: ZZ and WW. The Landau–Yang theorem forbids the direct decay of an on–shell spin-1 particle into a pair of photons;
- 2^+: graviton–inspired tensor with minimal couplings to SM particles. The results are quoted as function of the fraction of qq production mode.

arXiv:1307.1432 [hep-ph]

$H \rightarrow \gamma\gamma$: Spin extracted using $|\cos\vartheta^*|$, (of the photons with respect to the *z*-axis) distribution in Collins-Soper frame;

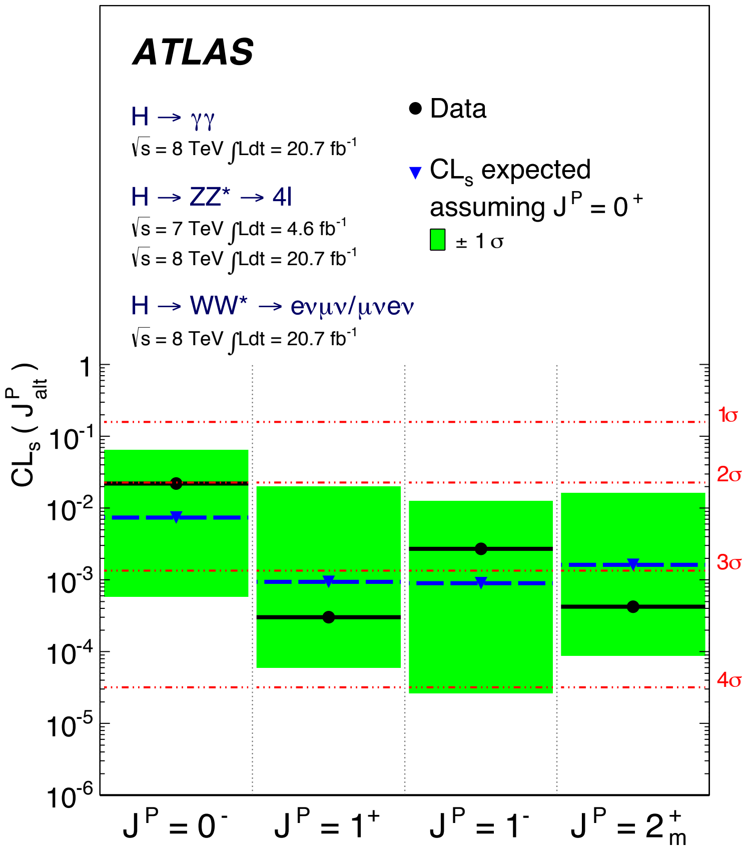
$H \rightarrow ZZ^* \rightarrow 4l$: Multivariate discriminant based on a Boosted Decision Tree (BDT) is used to distinguish between pairs of spin and parity hypothesis (five angles and two Z masses);

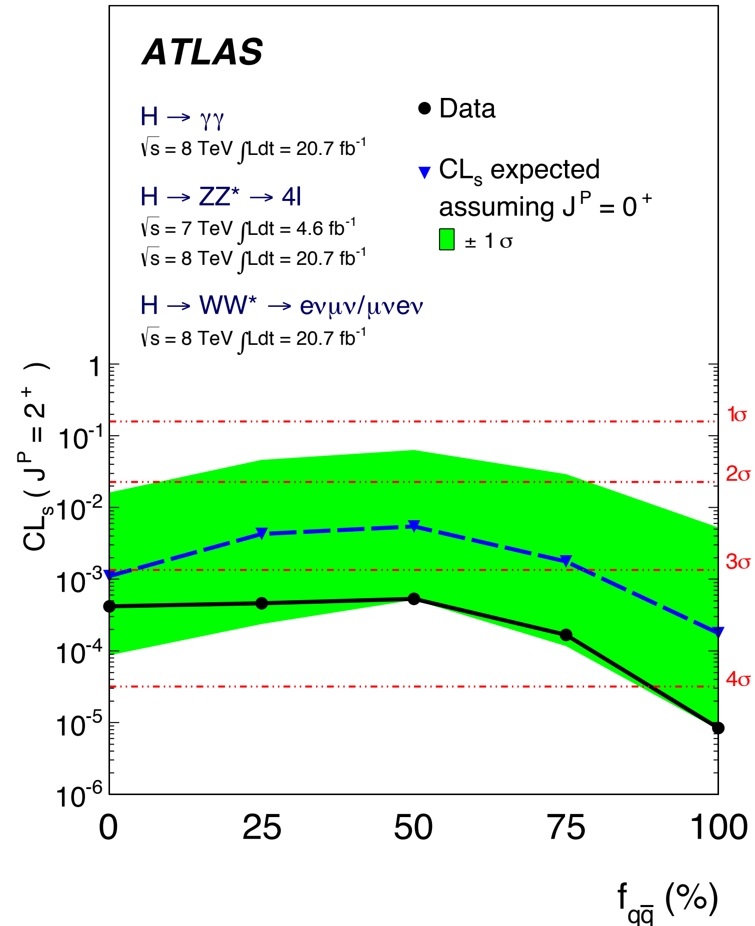
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$: The analysis is restricted to events containing two leptons of different flavors;
A BDT algorithm is used to distinguish between the spin hypotheses (m_{ll}, $\Delta\phi_{ll}$, p_T^{ll}, m_T);

Spin

arXiv:1307.1432 [hep-ph]

Expected (blue triangles/dashed line) and observed (black circles/solid line) confidence level CL_s for alternative spin–parity hypotheses assuming a $J^P = 0^+$ signal. The green bands represent the 68% expected exclusion range for a signal with assumed $J^P = 0^+$.





Conclusions

- ✓ Excellent performance of LHC and of the ATLAS detector allowed to measure properties of new boson discovered last year;
- ✓ H->γγ and H->4l are able to claim the discovery by themselves;

- ✓ All properties, spin and couplings, measured until now are consistent with a SM Higgs:
  - Mass measured to be approximately 125.5 GeV;
  - Spin-1 and spin-2 hypotheses excluded at >95% CL;
  - CP-odd hypotheses excluded at approximately 2 σ;
  - Couplings to fermions, vector bosons, and through loops are compatible with SM expectations.