Status of the Standard Model Higgs boson searches with the ATLAS detector

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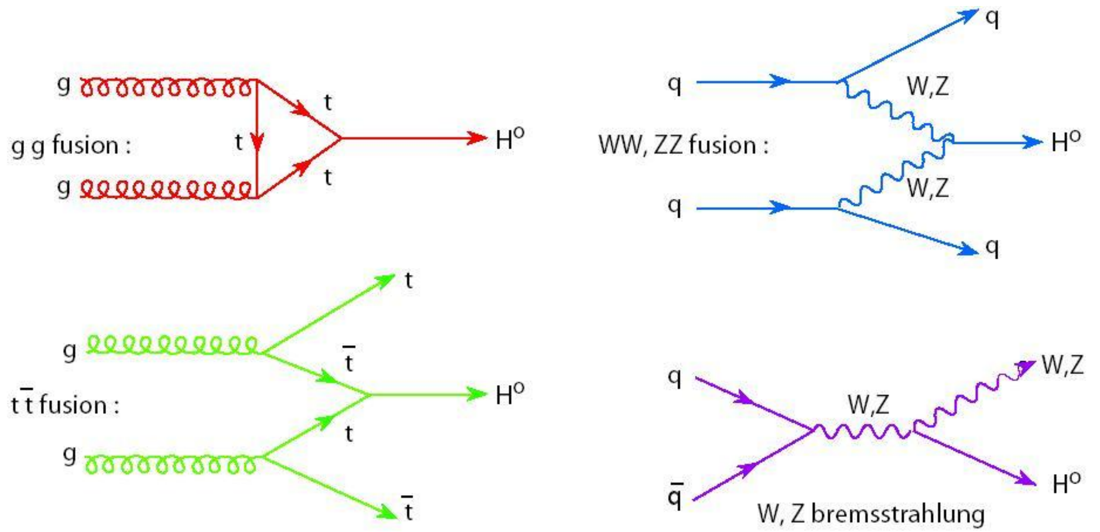
Winter Institute LNF-2013-1, *Frascati 22-24 January 2013*

Outline

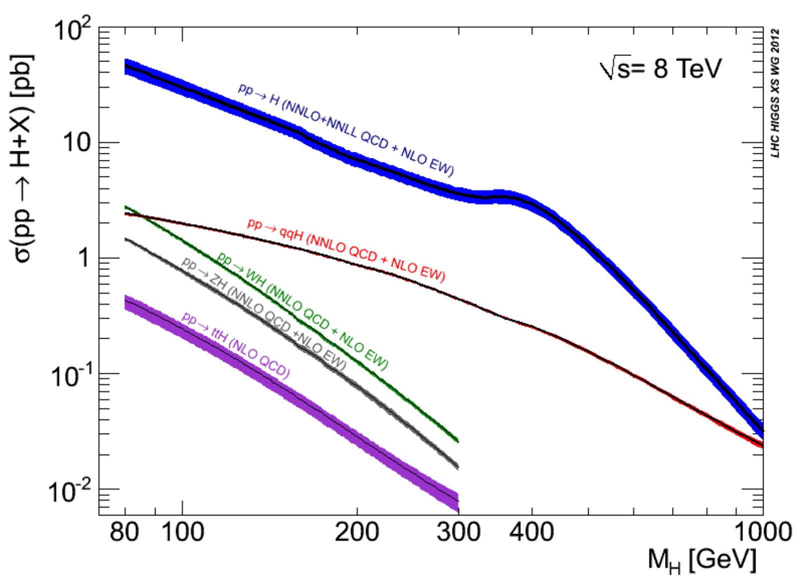
- ✓ Higgs @ LHC;
- ✓ LHC and ATLAS detector;
- ✓ Higgs discovery;
- ✓ Latest results;
- ✓ Higgs properties:
    - Mass;
    - Couplings;
    - J^P;
- ✓ Conclusions.

Higgs @ LHC



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

- gluon-gluon Fusion (ggF):
  19.52 pb (uncertainty 15-20%);
- Vector Boson Fusion (VBF):
  1.58 pb (uncertainty 5%);
- Associated production with W/Z (VH):
  0.7/0.4 pb (uncertainty 5%);
- Associated production with ttbar (ttH):
  0.13 pb (uncertainty 15%).



Higgs @ LHC

Standard Model Higgs decays:

High mass resolution

- H → γγ:

  low mass, high bkg and mass resolution;

- H → $ZZ^{(*)}$ → 4l:

  full mass range, low BR, high purity

  and mass resolution;

High Branching Ratio

- H → $WW^{(*)}$ → lν lν:

  full mass range, small mass resolution,

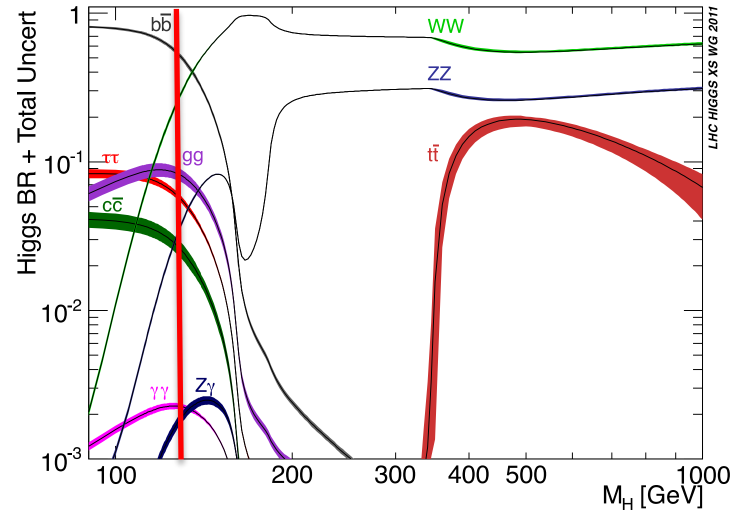
  high rate;

- H → ττ:

  low mass;

- VH → V + bb:

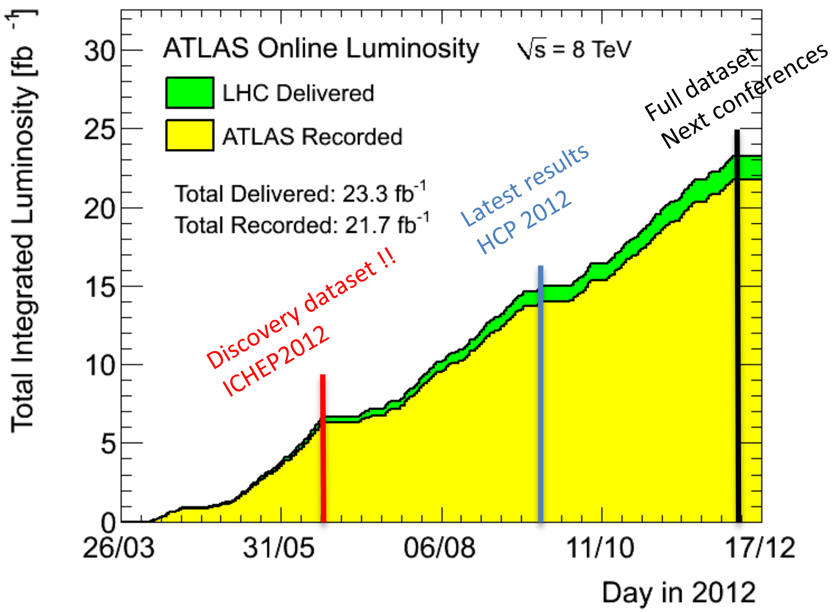
  associated production VH, V= Z or W.



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

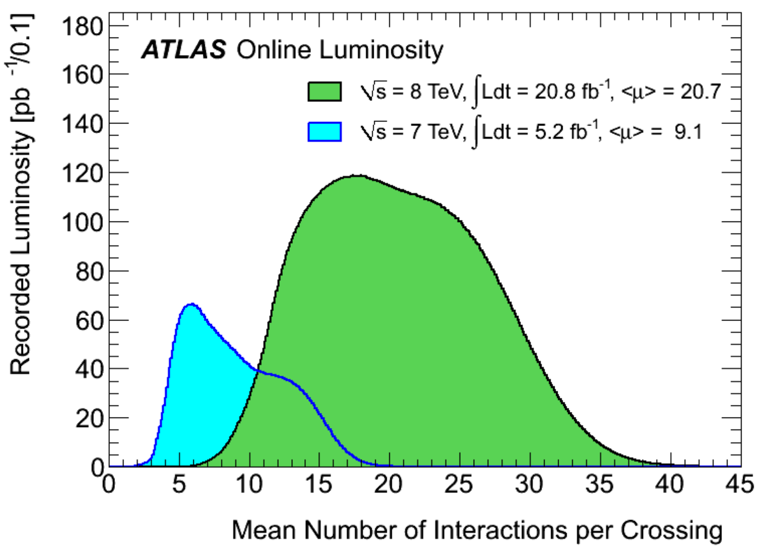
	125	300
γγ	53	-
ZZ	2.9	5.6
WW	59	32
ττ	1500	-
bb **Only VH**	600 **Only VH**	-

Large Hadron Collider

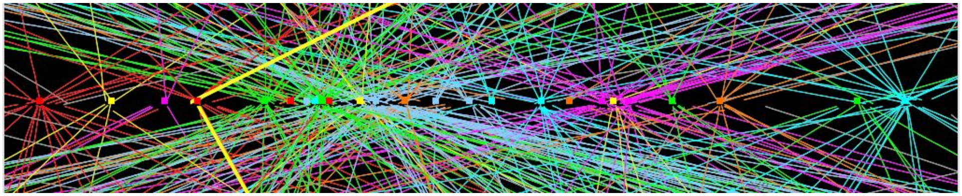


Performance of LHC:

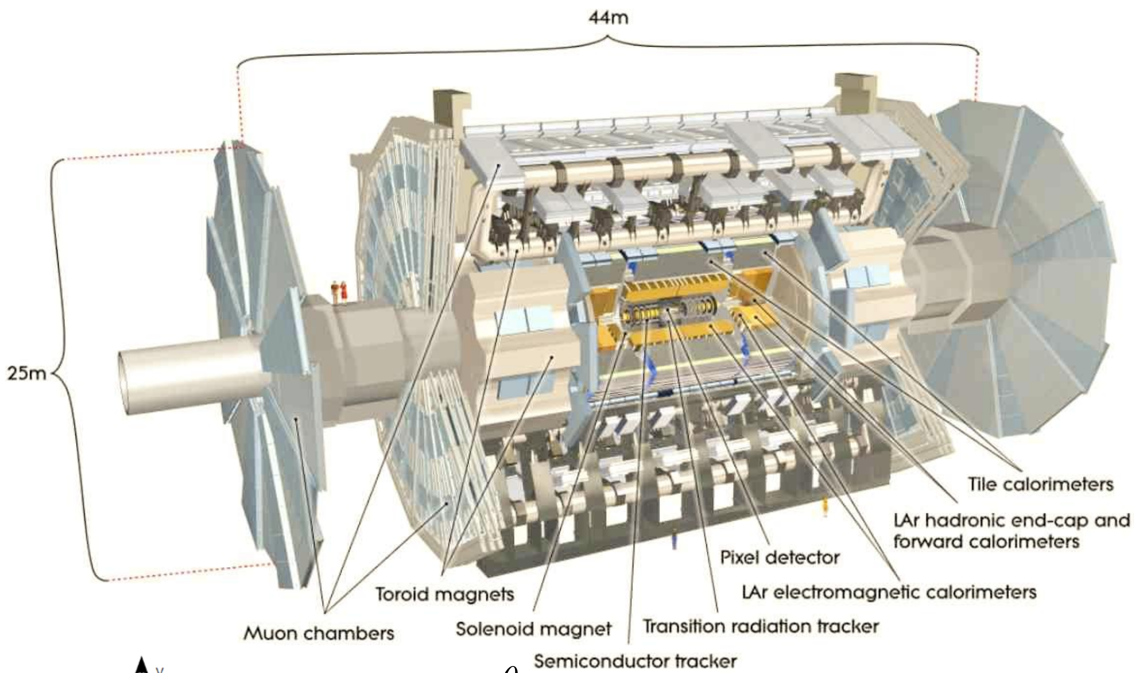
- Proton-proton collider @ $\sqrt{s}$ = 7 (2011) and 8 (2012) TeV;
- Peak luminosity 7.7 10^{33} cm^{-2} s^{-1};
- Integrated lumi delivered: ~ 23 fb^{-1} at 8 TeV and ~ 5 fb^{-1} at 7 TeV;
- Bunch crossing 50 ns.

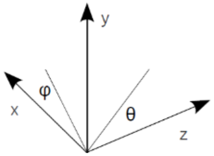


A candidate Z boson event in the dimuon decay with **25 reconstructed vertices**:



A Toroidal Lhc ApparatuS





$$\eta = -\ln \tan \frac{\theta}{2}$$

Inner detector:

- ✓ Silicon;
- ✓ Transition radiation Tracker;
- ✓ Solenoid (2 T).

EM calorimeter:

- ✓ Sampling LAr.

HAD calorimiter:

- ✓ Plastic scintillator (barrel);
- ✓ LAr technology (endcap).

Muon system:

- ✓ 3 air-core toroids;
- ✓ Reco and trigger chambers.

ATLAS p-p run: April-Sept. 2012

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2

All good for physics: 93.7%

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and September 17th (in %) – corresponding to 14.0 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

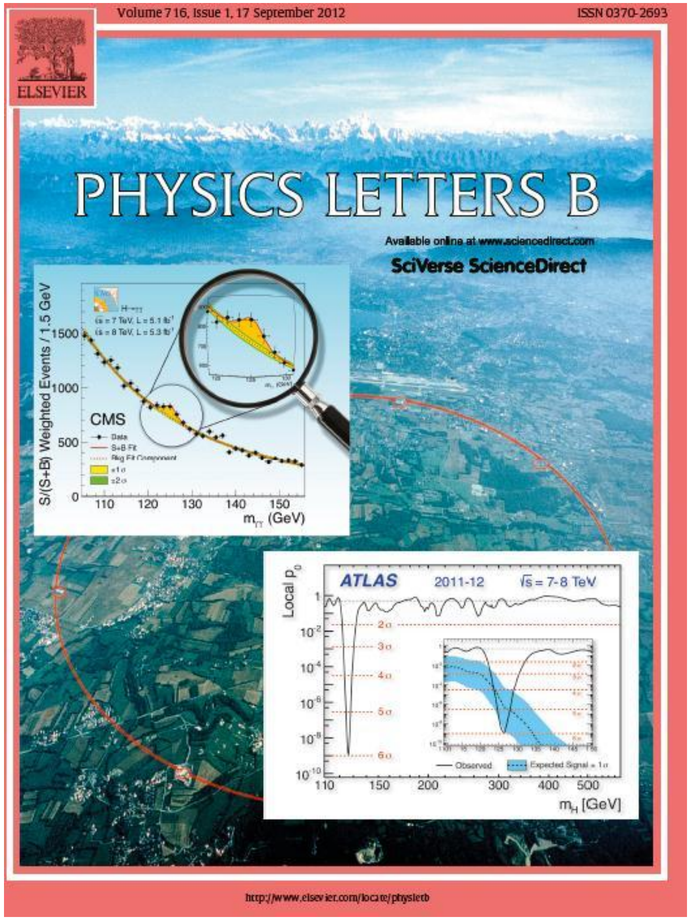
Higgs discovery

4th July 2012, ATLAS [1] and CMS [2] collaborations announced the observation of a new particle.

ATLAS channels 7 + 8 TeV

(4.8 fb^{-1} 7 TeV and 5.8 fb^{-1} 8 TeV) :

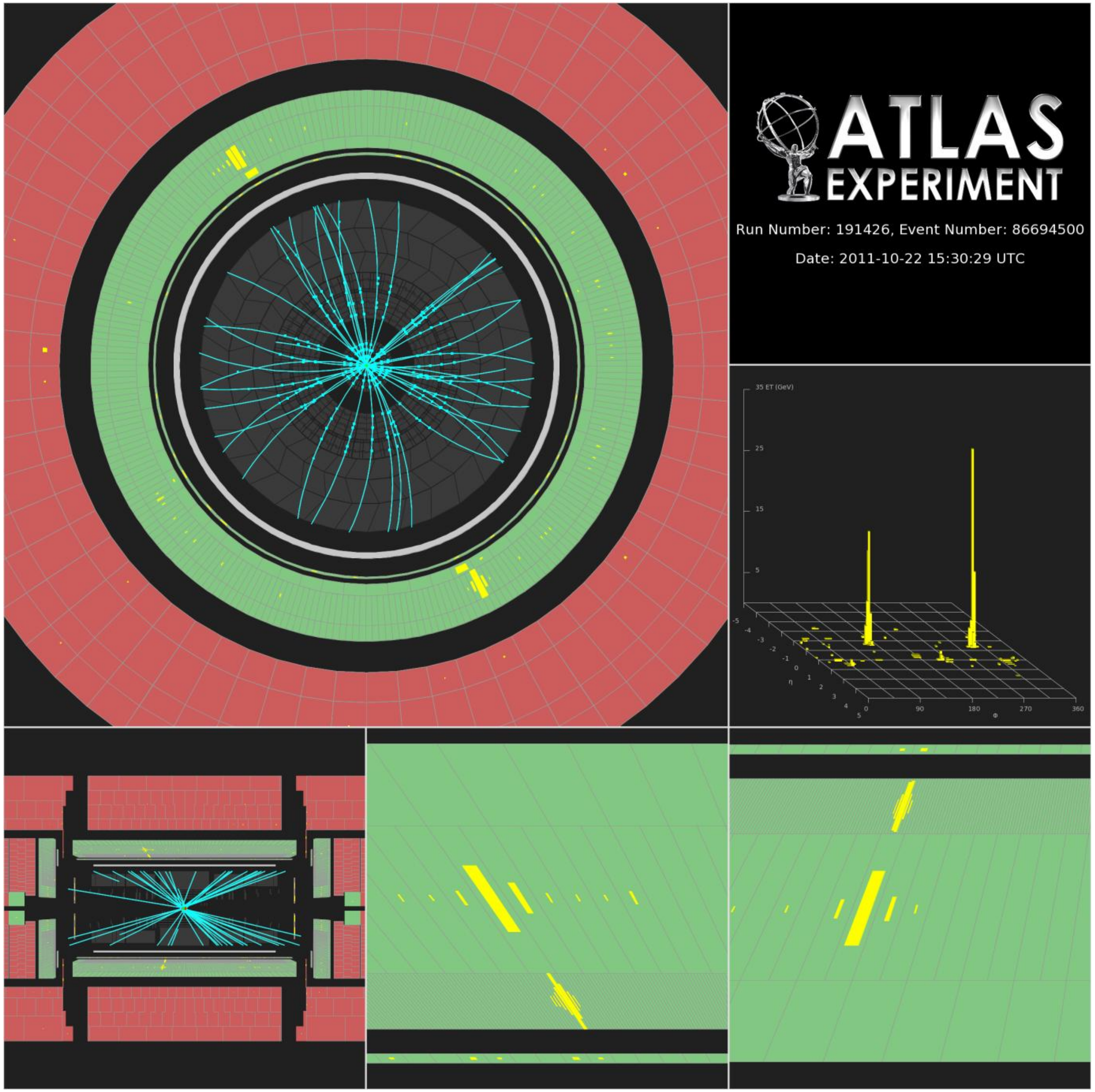
- $H \rightarrow \gamma\gamma$;
- $H \rightarrow ZZ \rightarrow 4l$;
- $H \rightarrow WW \rightarrow l\nu\ l\nu$.



[1] ATLAS Collaboration, Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Phys. Lett. B 716 (2012) 1–29, arXiv:1207.7214 [hep-ex].

[2] CMS Collaboration, Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, Phys. Lett. B 716 (2012) 30–61, arXiv:1207.7235 [hep-ex].

H → γγ

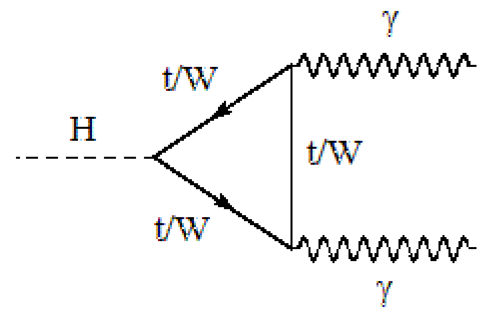

ATLAS
EXPERIMENT
Run Number: 191426, Event Number: 86694500
Date: 2011-10-22 15:30:29 UTC

$H \rightarrow \gamma\gamma$

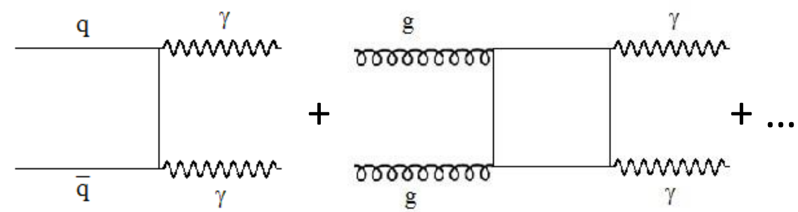
Higgs to gamma gamma:

- BR: ~ 10^{-3} (@ m_H = 125 GeV c^{-2});
- Bkg: γγ, γ+jets, jet-jet;
- Ten exclusive categories (to increase sensitivity):
  - γ converted (unconverted);
  - γ pseudorapidity;
  - P_T trust γγ;
  - VBF selection;
- Signal purity (S/B) ~ 2%-20%;
- Strong jet rejection is needed;
- Lumi 4.8 fb^{-1} @ 7 TeV and 5.8 fb^{-1} @ 8 TeV (4th July 2012).

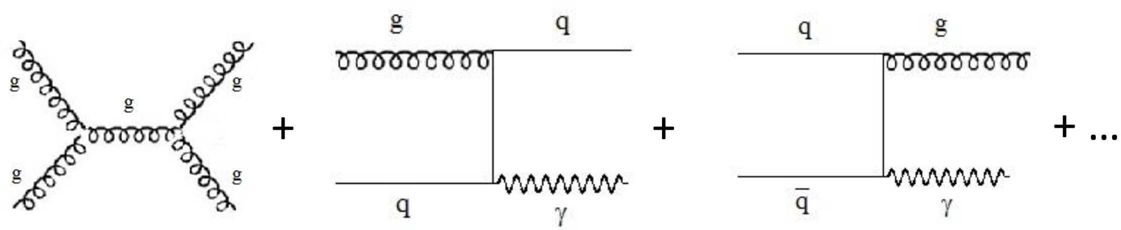
Signal:



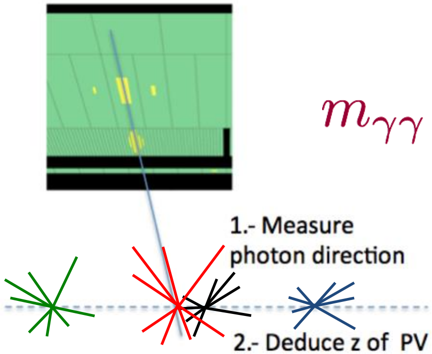
Irreducible bkg: pp→ γγ+ X (~ 75% total bkg)
Normalization and shape from MC + control region:



Reducible bkg: pp→ γj, jj, D-Y
Normalization and shape from MC + control region :



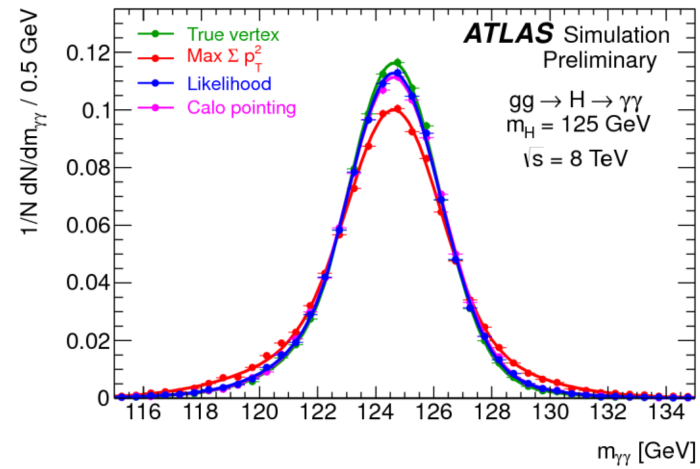
$H \rightarrow \gamma\gamma$



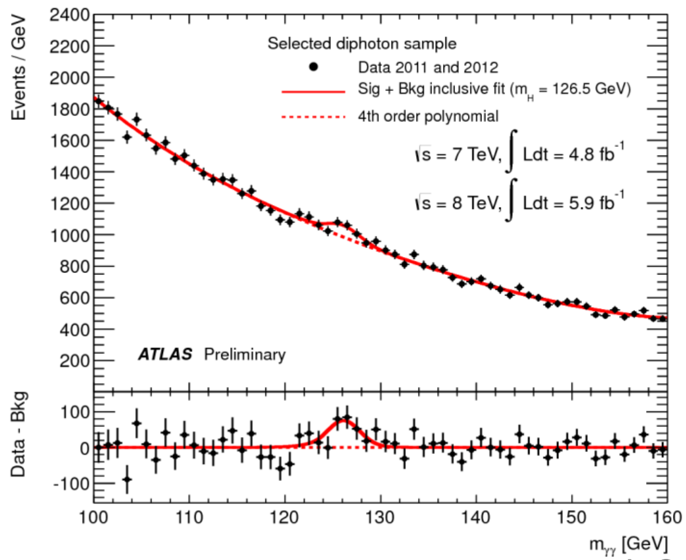
$$m_{\gamma\gamma} = 2E_1E_2(1 - cos\theta)$$

Tracking calorimeter:
measure the photon direction and the position of the primary vertex (small pileup dependence).

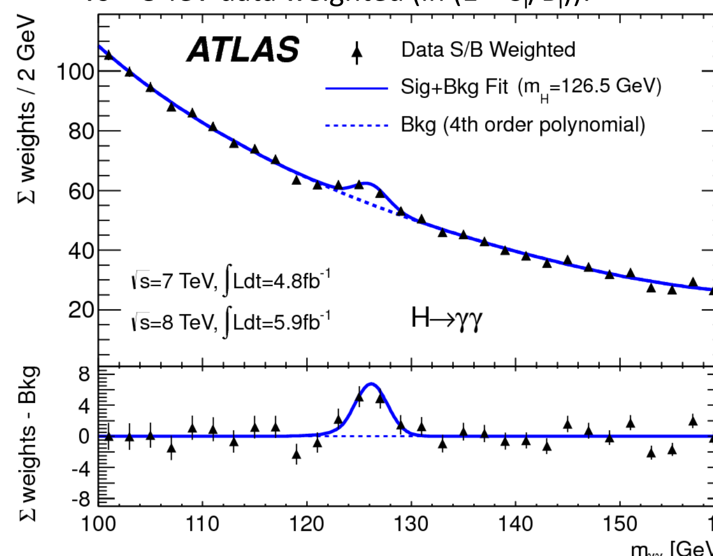
Distribution of expected $m_{\gamma\gamma}$ for different algorithm used to determine the longitudinal vertex position:



$m_{\gamma\gamma}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data:

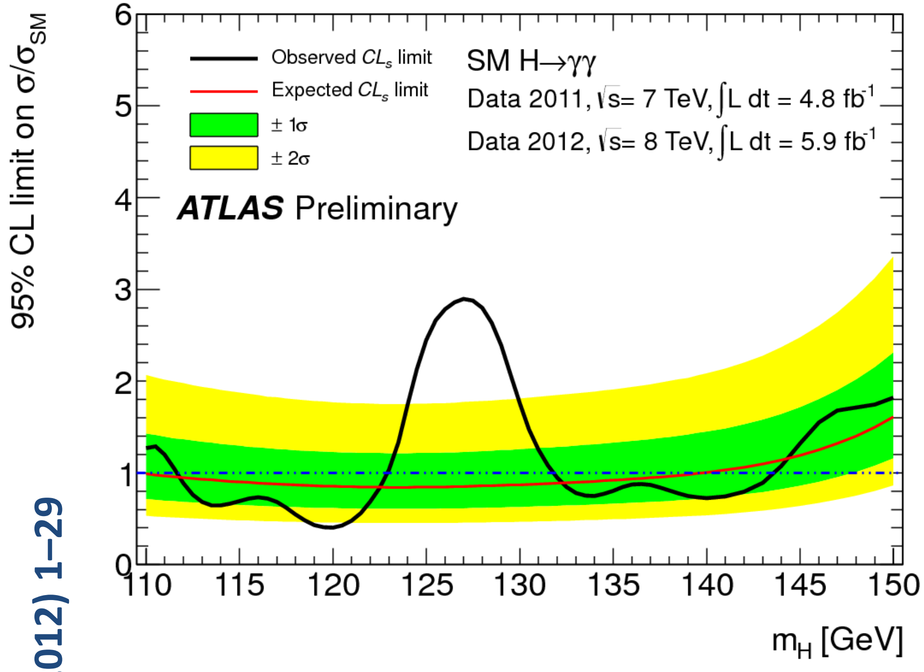


$m_{\gamma\gamma}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data weighted (ln $(1 + S_i/B_i)$):

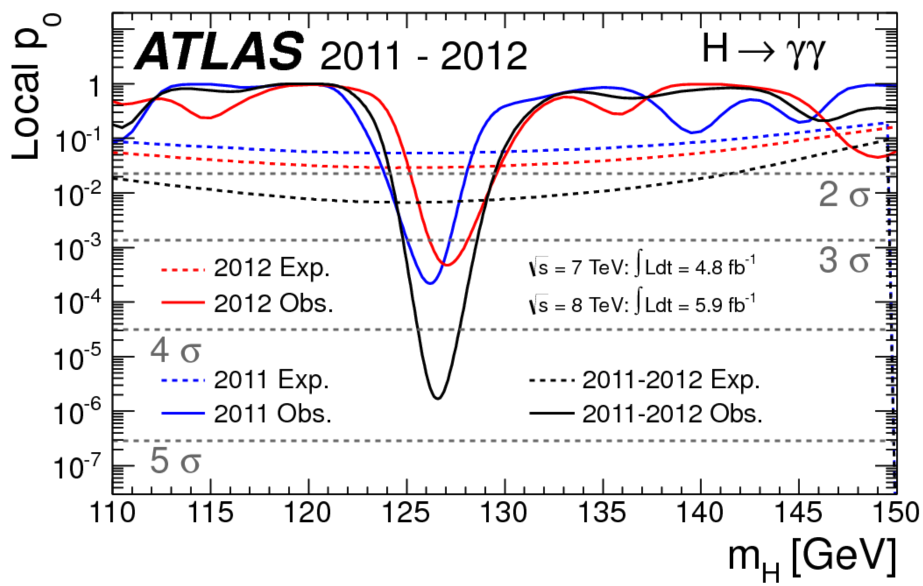


$H \rightarrow \gamma\gamma$

Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



p-value = "*probability*" that result is as or less compatible with the background only hypothesis

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Higgs to gamma gamma (4th July 2012):

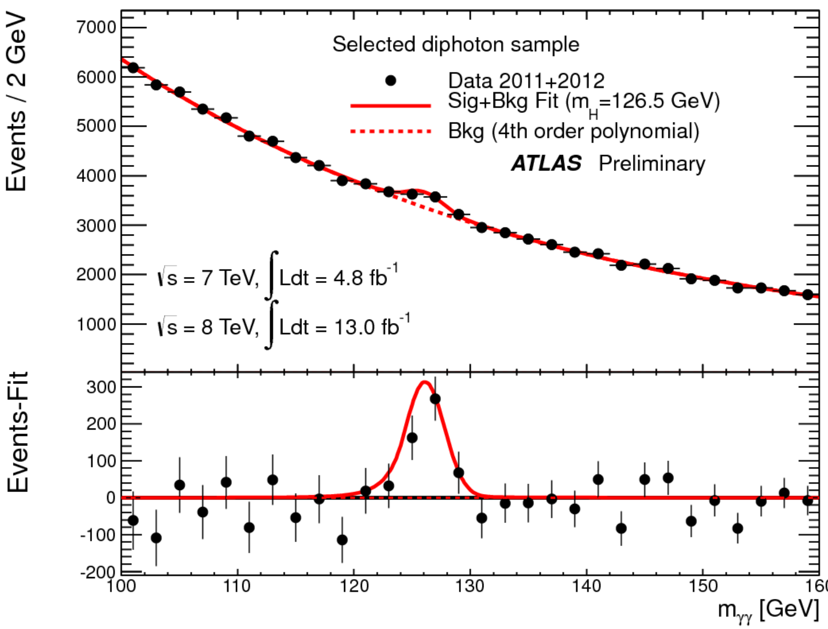
- The SM Higgs boson is excluded at 95% CL: 112-122.5 and 132-143 GeV c^{-2} (exp. 110-139.5 GeV c^{-2});
- Observed p_0 ~ 4.5 standard deviation (exp 2.5) @ m_H = 126.5 GeV c^{-2};
- Signal strength μ = 1.9 +/- 0.5.

H → γγ: latest results

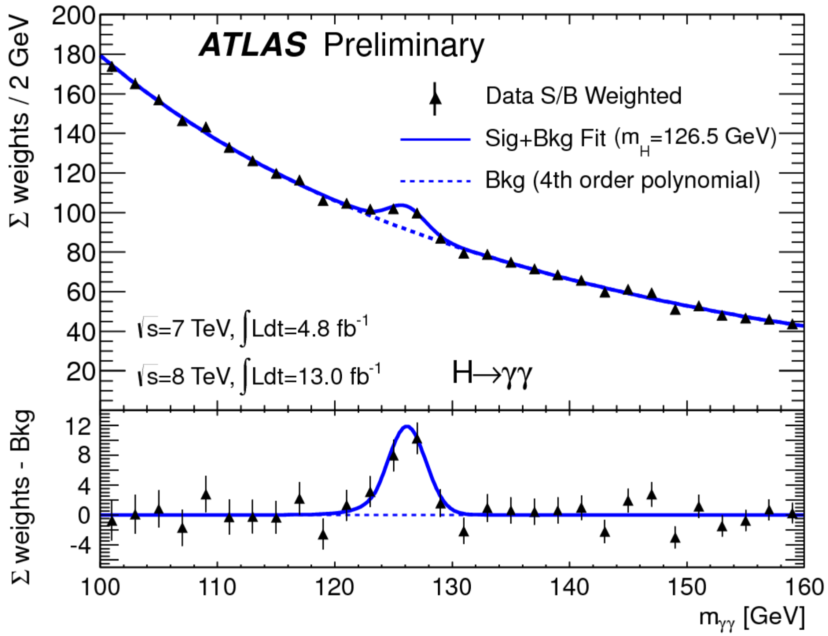
Higgs to gamma gamma update:

- Lumi 4.8 fb^{-1} @ 7 TeV and 13 fb^{-1} @ 8 TeV (Council December 2012);
- Analysis has been re-optimized;
- Added two new categories for the VH production.

$m_{\gamma\gamma}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data:

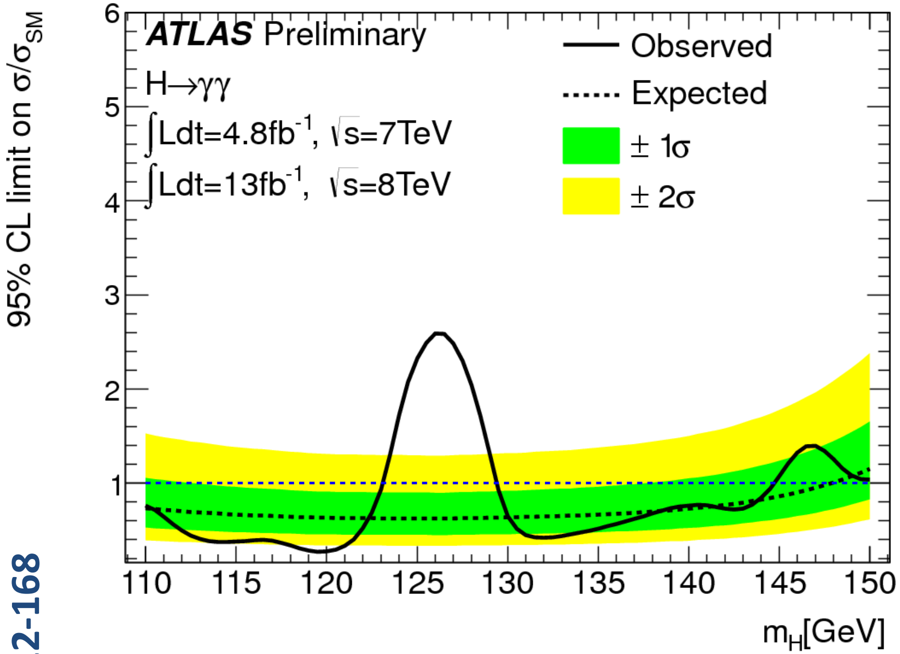


$m_{\gamma\gamma}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data weighted (ln (1 + S_i/B_i)):

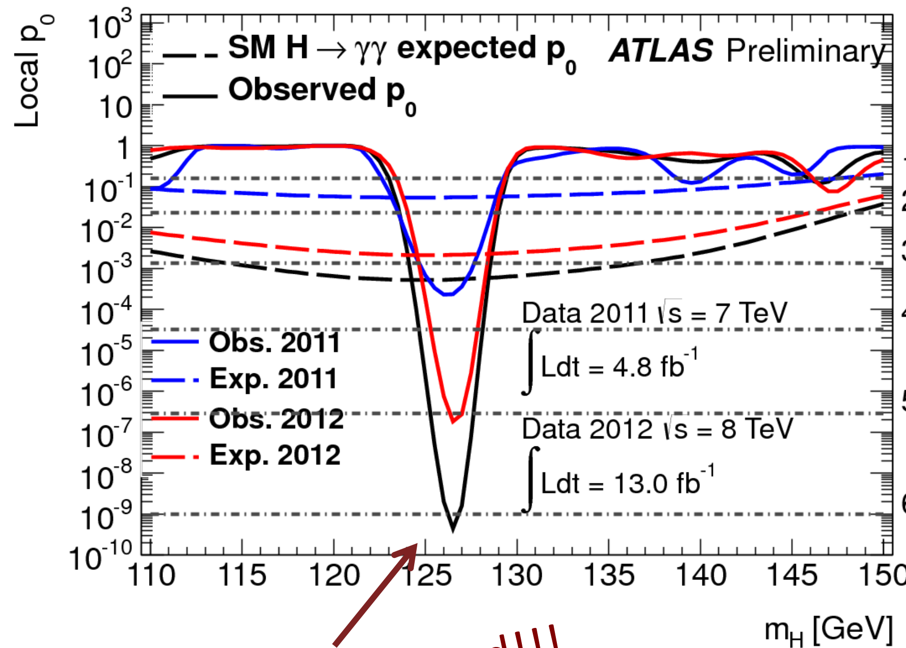


H → γγ: latest results

Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



Signal is confirmed!!!

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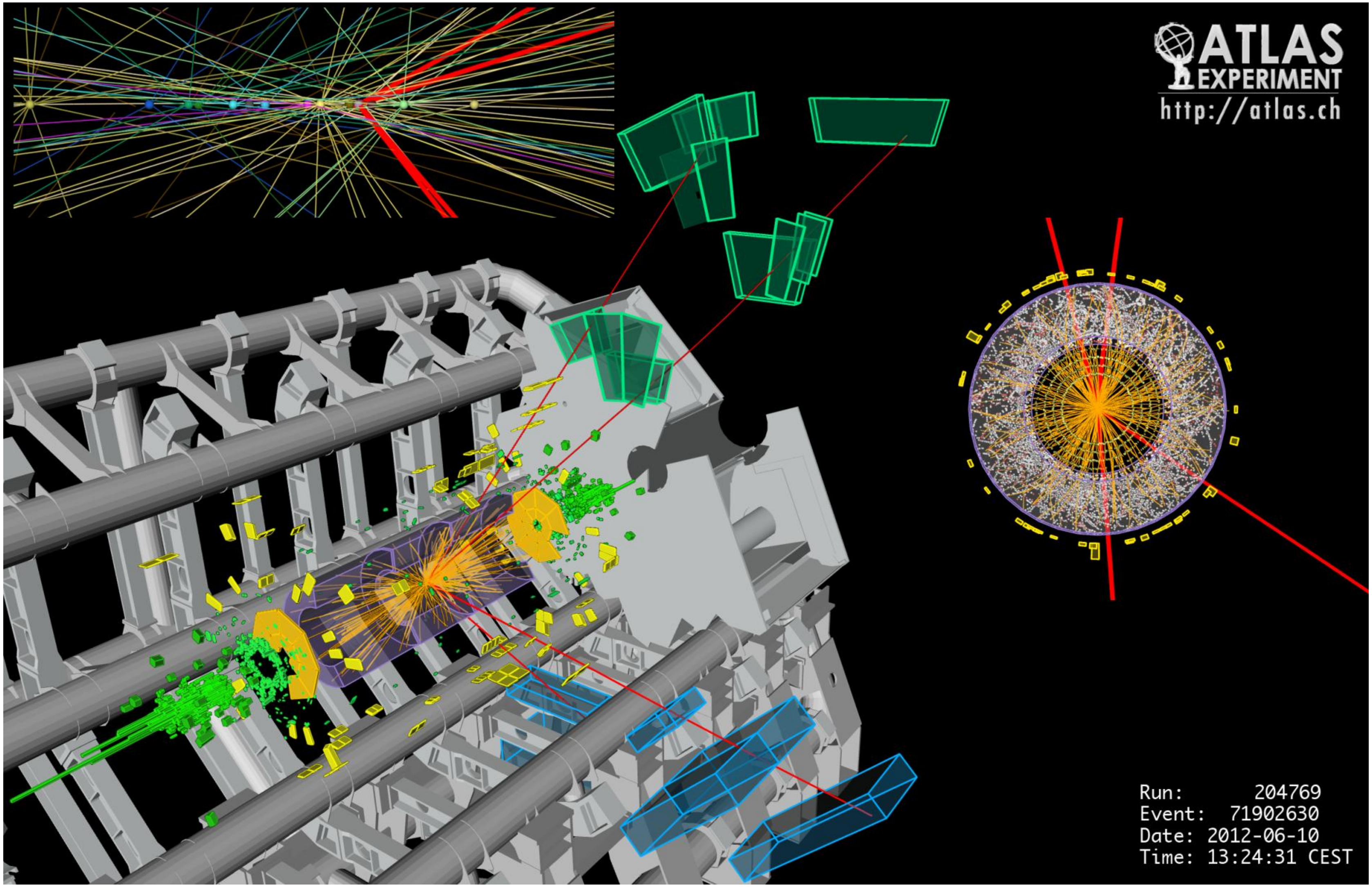
Higgs to gamma gamma (Council 2012):

- The SM Higgs boson is excluded at 95% CL: 110-122.5 and 129.5-144.5 GeV c^{-2} (exp. 110-139.5 GeV c^{-2});
- Observed p_0 ~ 6.1 standard deviation (exp 4.1) @ m_H = 126.6 GeV c^{-2};
- Signal strength $\hat{\mu} = 1.8 \pm 0.3(stat)^{+0.29}_{-0.21}(syst)$

The compatibility with the SM prediction is estimated to be at the 2.4 σ level

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

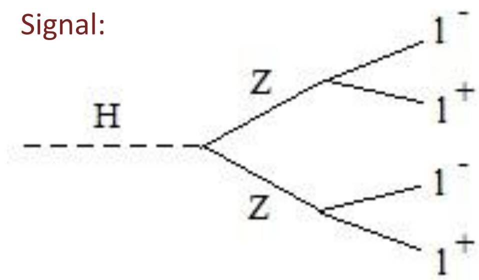


$H \rightarrow ZZ^{(*)} \rightarrow 4l$

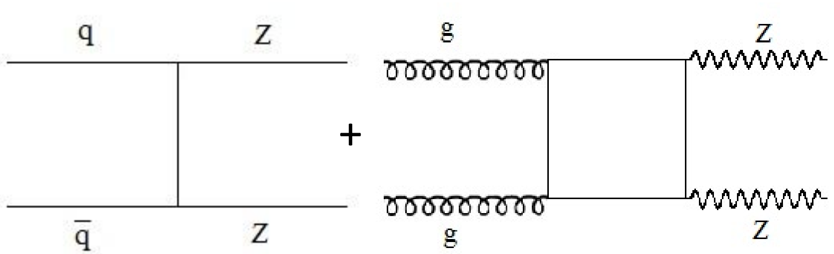
Higgs to four leptons ("golden channel"):

- BR: ~ 10^{-4} (@ m_H = 125 GeV c^{-2});
- Bkg: ZZ, Z+jets, top;
- Signal purity (S/B) ~ 1;
- Lumi 4.8 fb^{-1} @ 7 TeV and 5.8 fb^{-1} @ 8 TeV (4th July 2012).

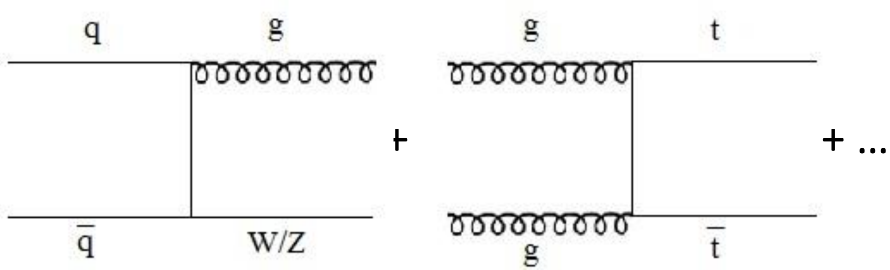
Signal:



Irreducible bkg: pp→ ZZ (~ 70 % total bkg)
rejection: kinematic cuts e.g. m_{12} and m_{34}
Shape and normalization from MC:

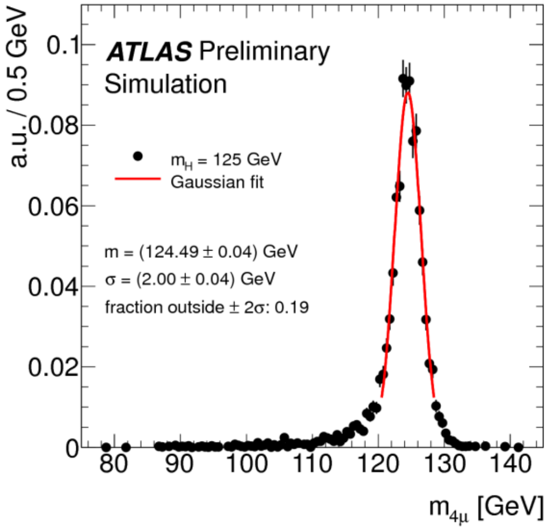


Reducible bkg: pp→ Z+jet, tt… rejection: isolation of leptons, …
Z+jet from control region, Zbb shape from MC and normalization from data:

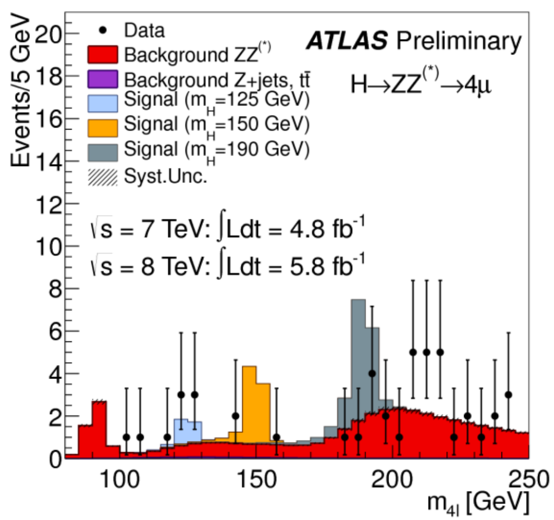


$H \to ZZ^{(*)} \to 4l$

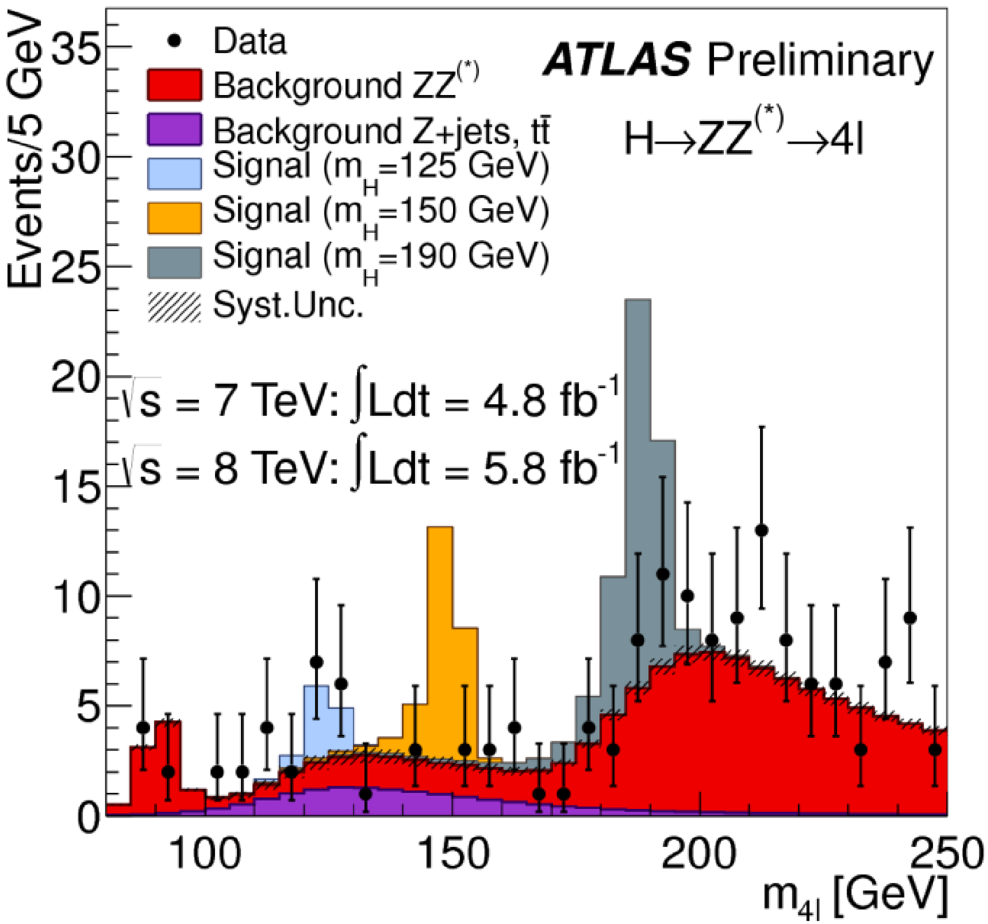
Invariant mass distribution for simulated $H \to ZZ^{(*)} \to 4\mu$:



$m_{4\mu}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data:



m_{4l} distribution for the combined √s = 7 TeV and √s = 8 TeV data:



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

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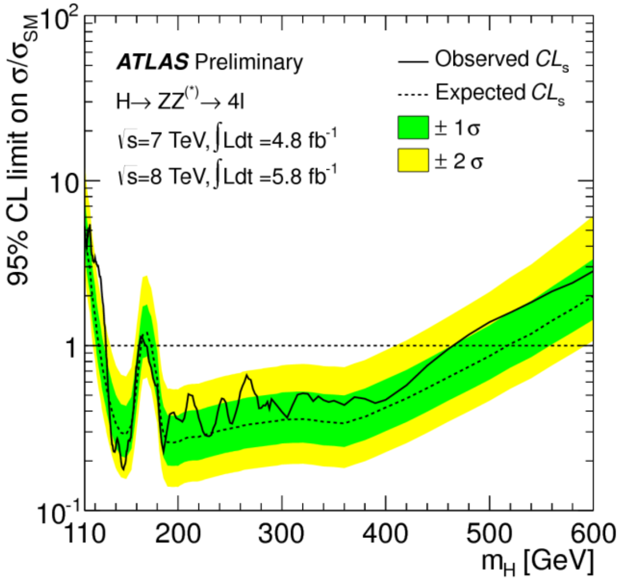
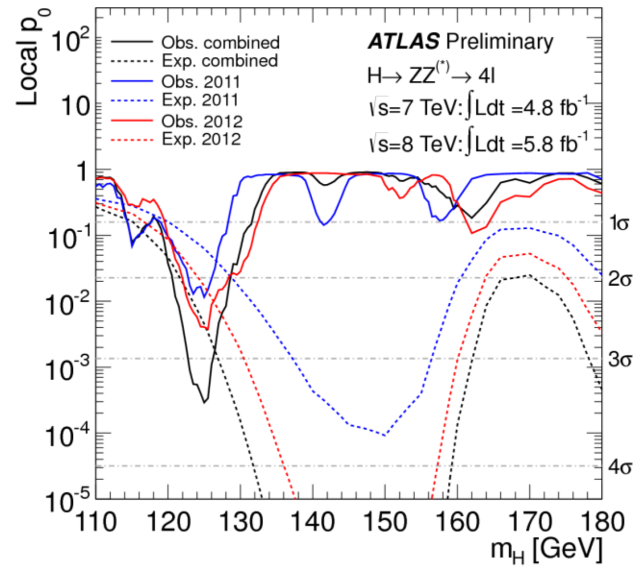
Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



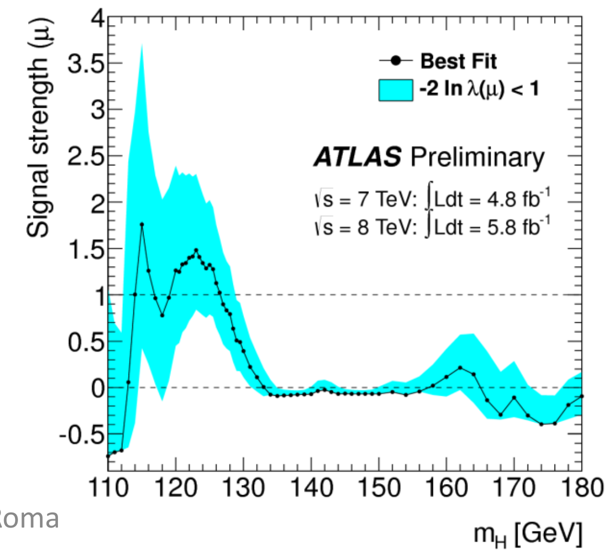
Observed and expected p-value vs Higgs mass:



Higgs to four leptons (4th July 2012):

- The SM Higgs boson is excluded at 95% CL: 131-162 and 170-460 GeV c^{-2} (exp. 124-164 and 176-500 GeV c^{-2});
- Observed p_0 ~ 3.6 standard deviation (exp 2.7) @ m_H = 125 GeV c^{-2};
- Signal strength μ = 1.2 +/- 0.6.

Fitted signal strength parameter vs m_H:

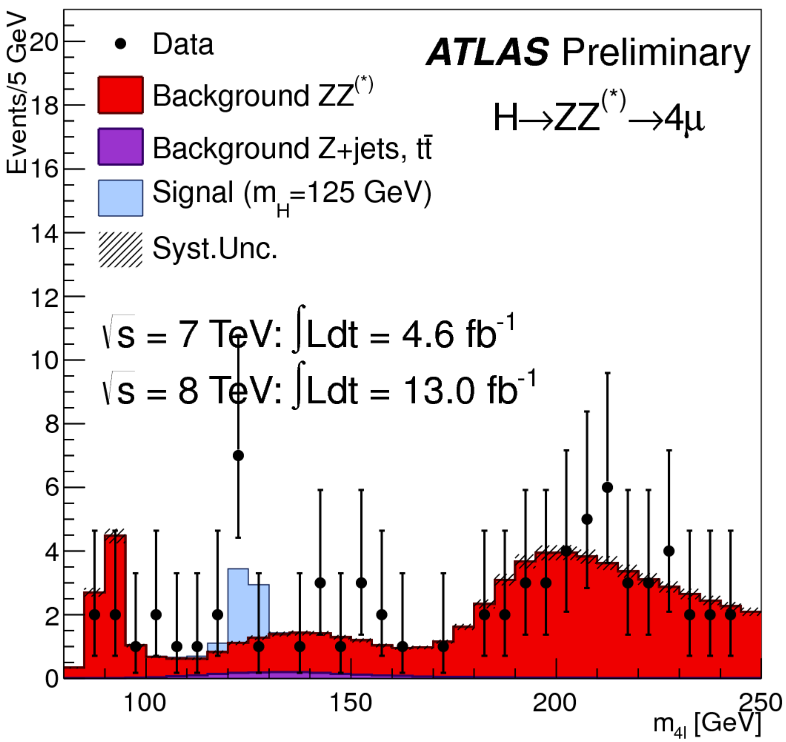


$H \to ZZ^{(*)} \to 4l$: latest results

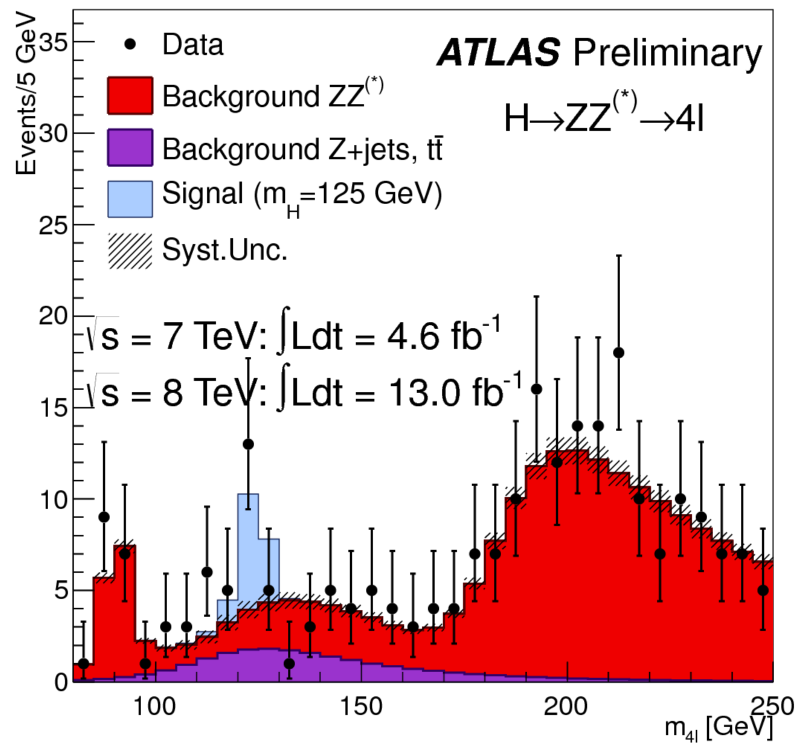
Higgs to four leptons update:

- Lumi 4.8 fb^{-1} @ 7 TeV and 13 fb^{-1} @ 8 TeV (Council December 2012);
- Analysis has been re-optimized.

$m_{4\mu}$ distribution for the combined √s = 7 TeV and √s = 8 TeV data:

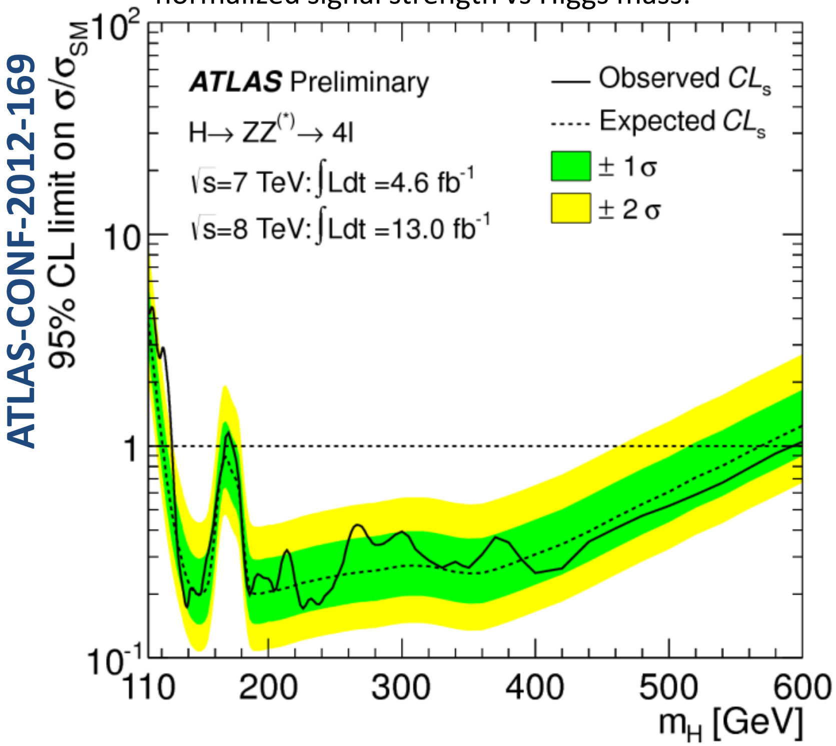


m_{4l} distribution for the combined √s = 7 TeV and √s = 8 TeV data:

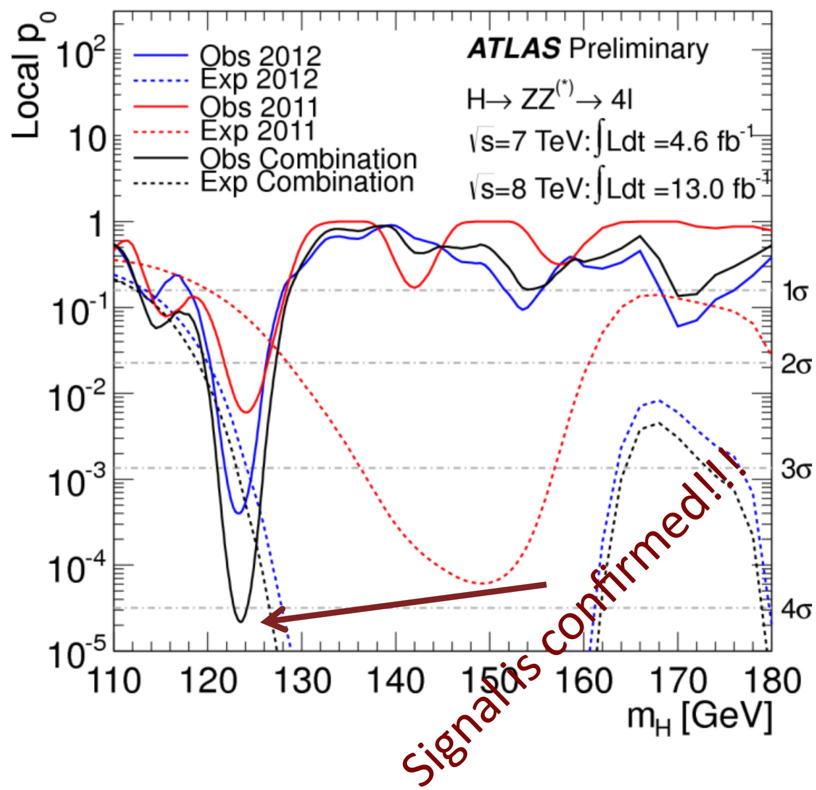


$H \to ZZ^{(*)} \to 4l$: latest results

Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



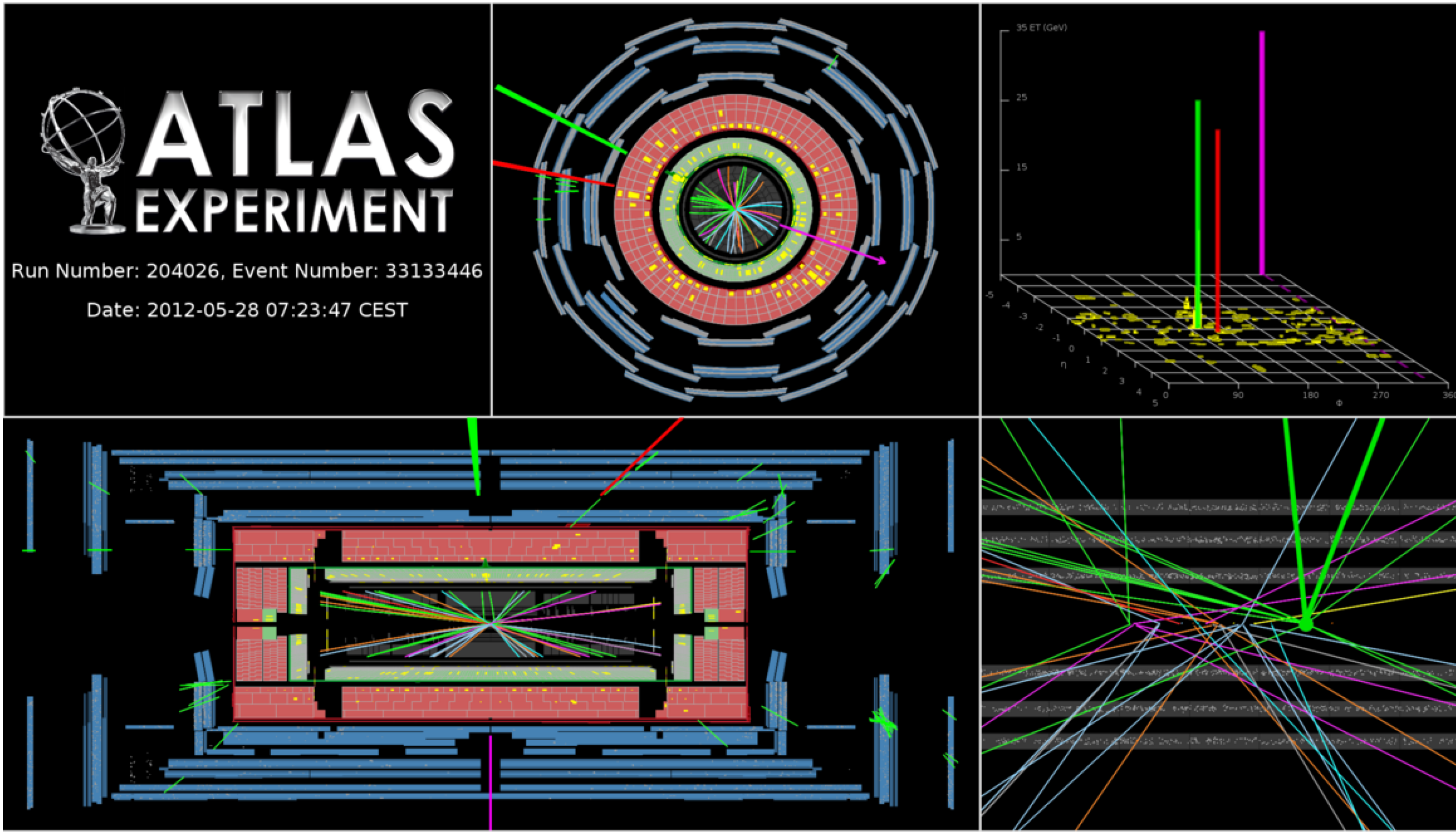
Observed and expected p-value vs Higgs mass:



Higgs to four leptons (Council 2012):

- The SM Higgs boson is excluded at 95% CL: 127.7-166 and 174-600 GeV c^{-2} (exp. 120-580 GeV c^{-2});
- Observed p_0 ~ 4.1 standard deviation (exp 3.1) @ m_H = 123.5 GeV c^{-2};
- Signal strength $\hat{\mu} = 1.3 \pm 0.4$

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

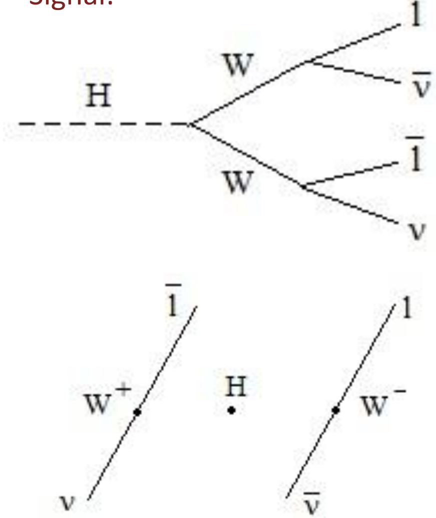


$H \rightarrow WW^{(*)} \rightarrow l\nu \, l\nu$

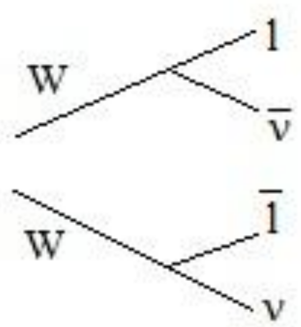
Higgs to WW:

- BR: ~ 2.5×10^{-3} (@ m_H = 125 GeV c^{-2});
- Bkg: WW, W+jets, jet-jet, top;
- Different-flavour e/μ (D-Y rejection);
- Signal purity (S/B) ~ 10%;
- Discriminant variables: m_{ll}, $\Delta\phi_{ll}$, m_T;
- Lumi 4.8 fb^{-1} @ 7 TeV and 13 fb^{-1} @ 8 TeV (HCP 2012).

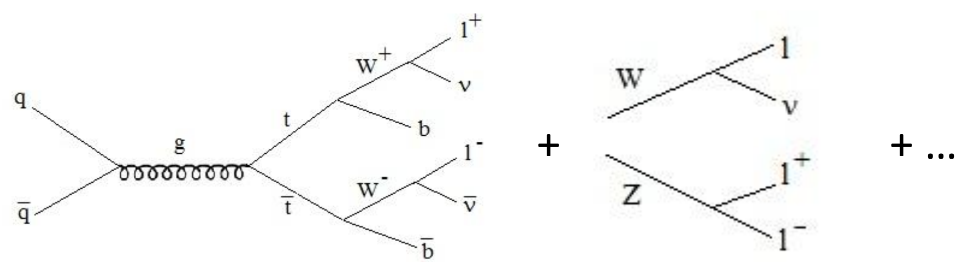
Signal:



Irreducible bkg: pp→ WW, rejection: $\Delta\phi_{ll}$ H has spin 0, WW bkg from simulation + control region:

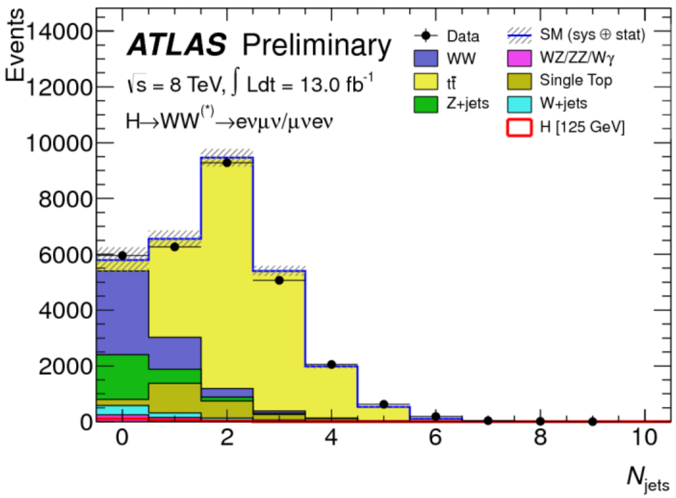


Reducible bkg: pp→ WZ, Z/W+jet, tt. rejection: isolation of leptons , …, W+jets from data, other simulation + control region:

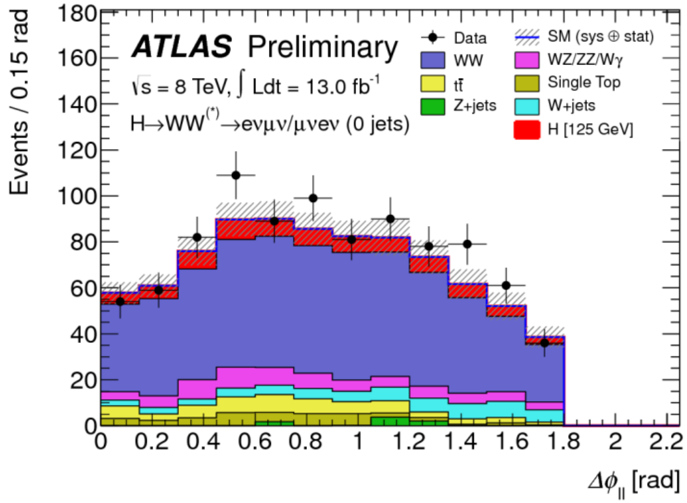


$H \rightarrow WW^{(*)} \rightarrow l\nu\, l\nu$

multiplicity of jets for events satisfying the dilepton and $E_T^{miss}{}_{rel}$ selection:

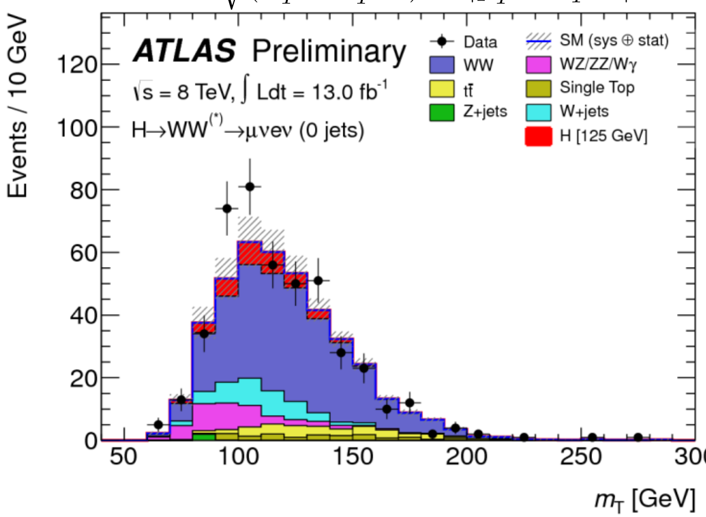


Δφ$_{ll}$ distribution after full event selection:

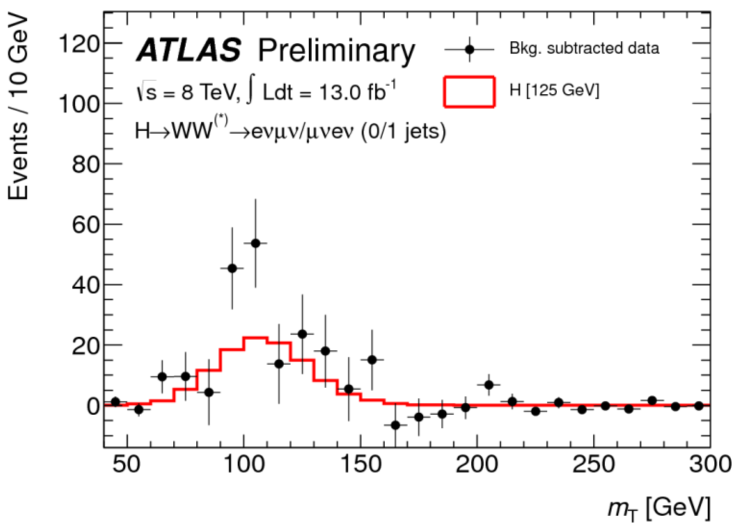


m_T distribution for events satisfying all criteria:

$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - |\mathbf{p}_T^{ll} + \mathbf{E}_T^{miss}|^2}$$



m_T distribution in data with the estimated background subtracted with the predicted signal:



$H \to WW^{(*)} \to l\nu\, l\nu$: latest results

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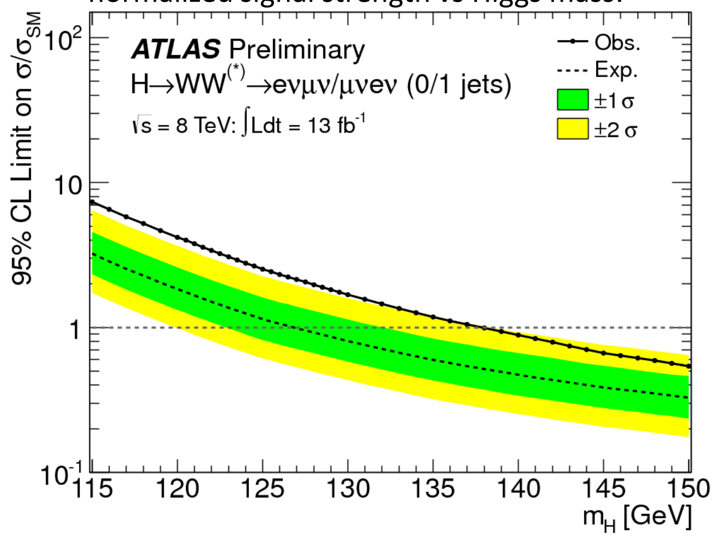
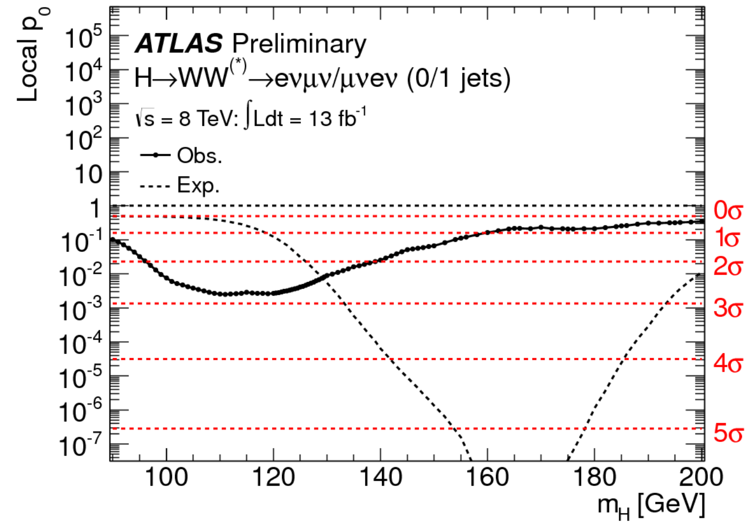
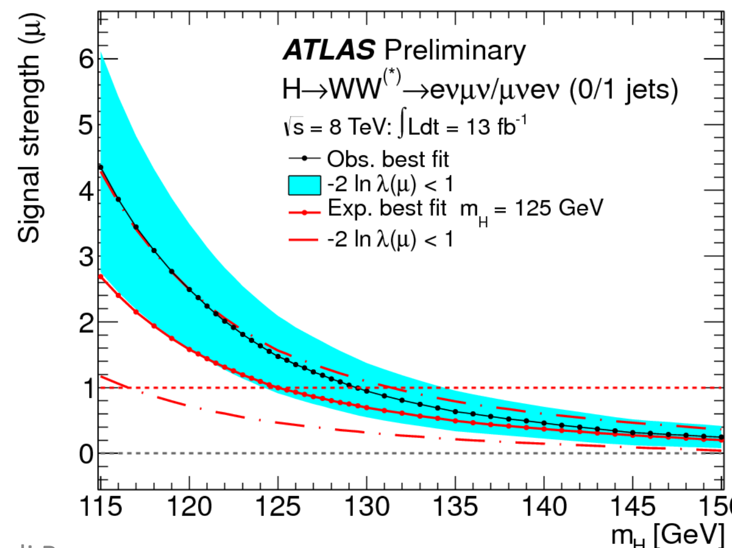
Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



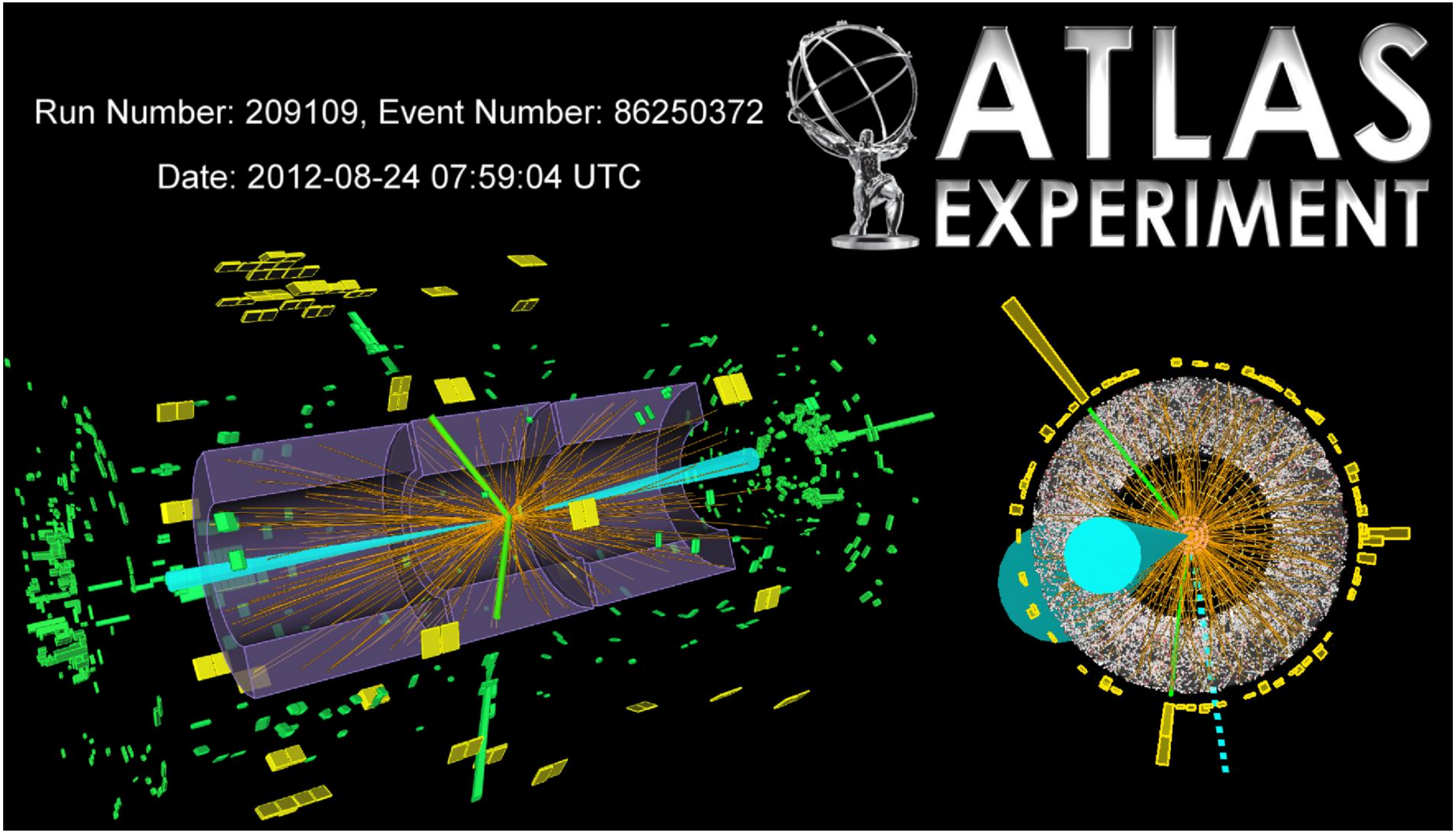
Fitted signal strength parameter vs m_H:



Higgs to WW (HCP 2012):

- Only Different-flavour e/μ updated (higher sensitivity);
- Observed p_0 ~ 2.8 standard deviation (exp 3.1) @ m_H = 125 GeV c^{-2};
- Signal strength μ = 1.5 +/- 0.6.

H → ττ



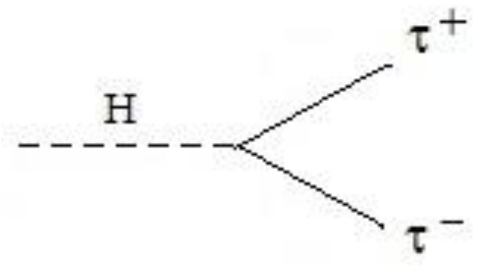
Run Number: 209109, Event Number: 86250372
Date: 2012-08-24 07:59:04 UTC
ATLAS
EXPERIMENT

$H \rightarrow \tau\tau$

Higgs to $\tau\tau$:

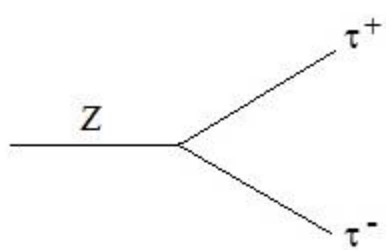
- BR: ~ 6×10^{-2} (@ m_H = 125 GeV c^{-2});
- Bkg: Z, Z+jets, top;
- Signal purity (S/B) ~ 0.3%-30%;
- Many exclusive categories
  τ_{lep}, τ_{had}: boosted, 0-1-2 jets (2 jets for VBF)…
  to increase sensitivity;
- Lumi 4.8 fb^{-1} @ 7 TeV and 13 fb^{-1} @ 8 TeV
  (HCP 2012).

Signal:

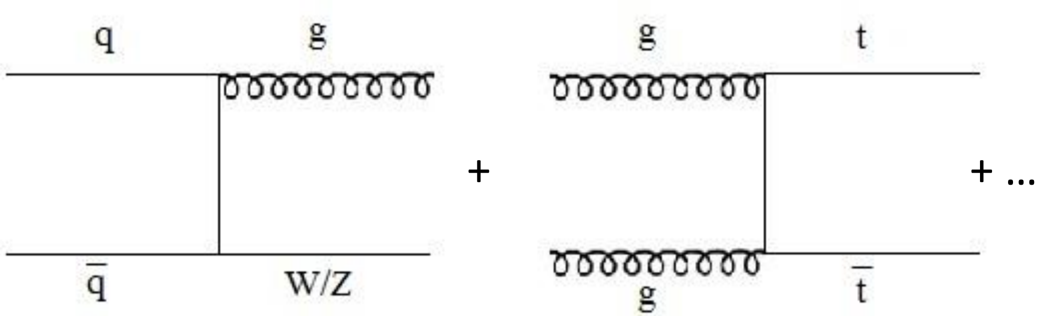


$\tau_{lep}\tau_{lep}$	$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$
12%	46%	42%

Z→ττ from embedding: Start from real Z→μμ events, replace muons with fully-simulated taus with proper polarization and spin correlations:

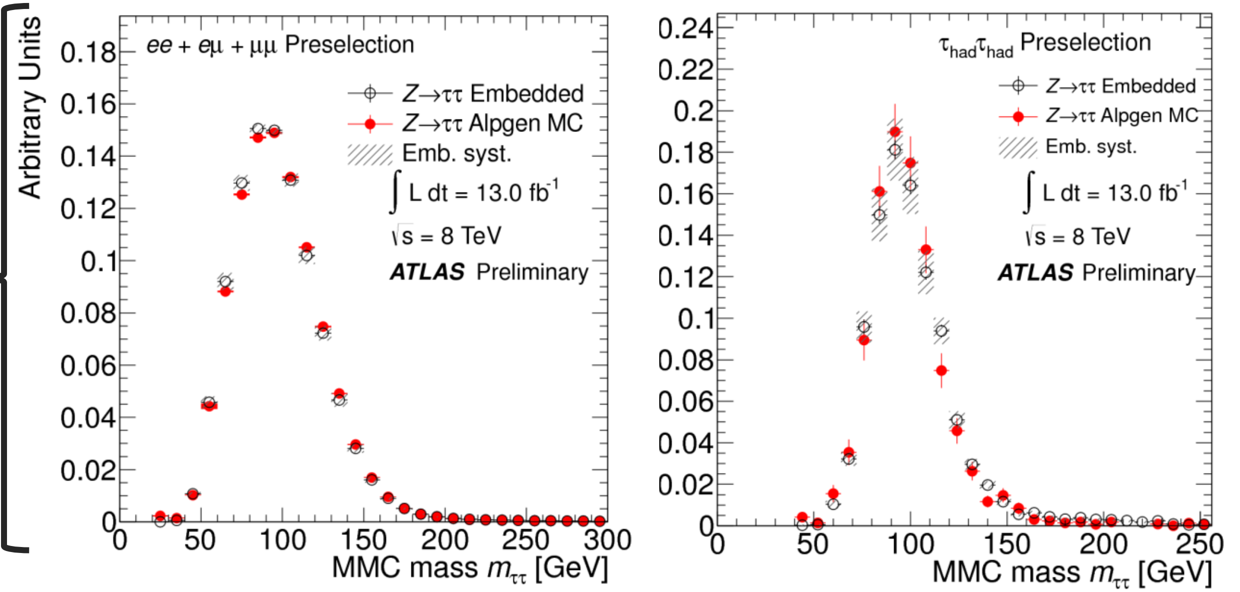


Other backgrounds: W/Z + jet, WW, ZZ, tt… from simulation:

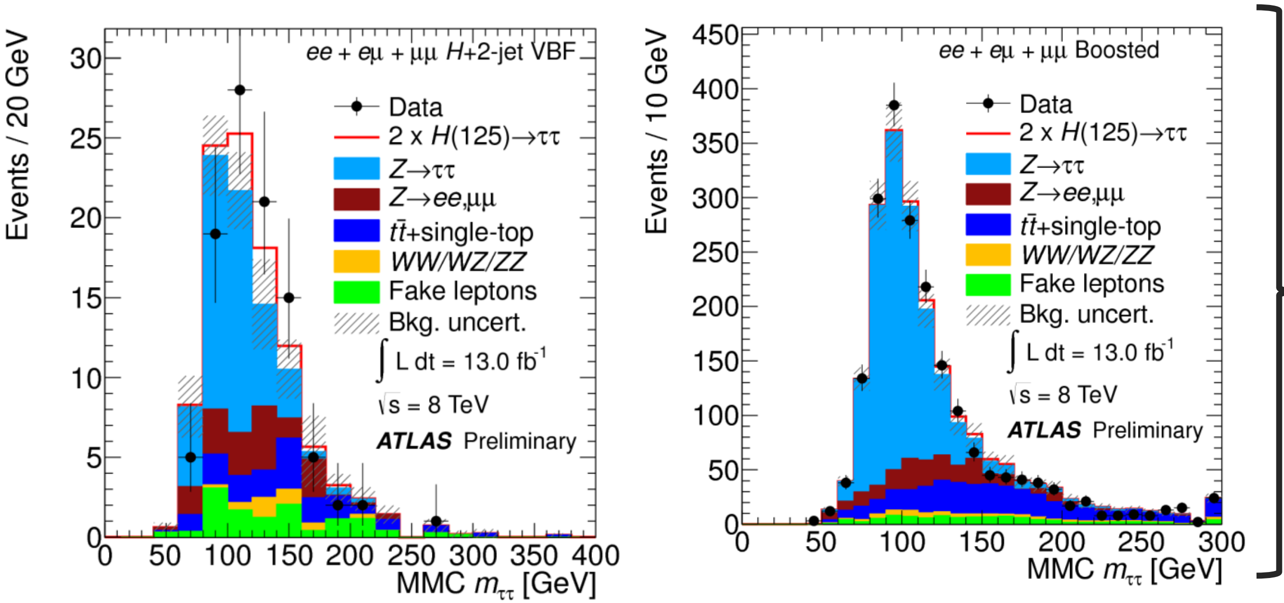


H → ττ

MMC mass distributions for the τ-embedded Z→μμ data and simulated Z→ττ events:



MMC mass distributions of the selected events:



$H \rightarrow \tau\tau$

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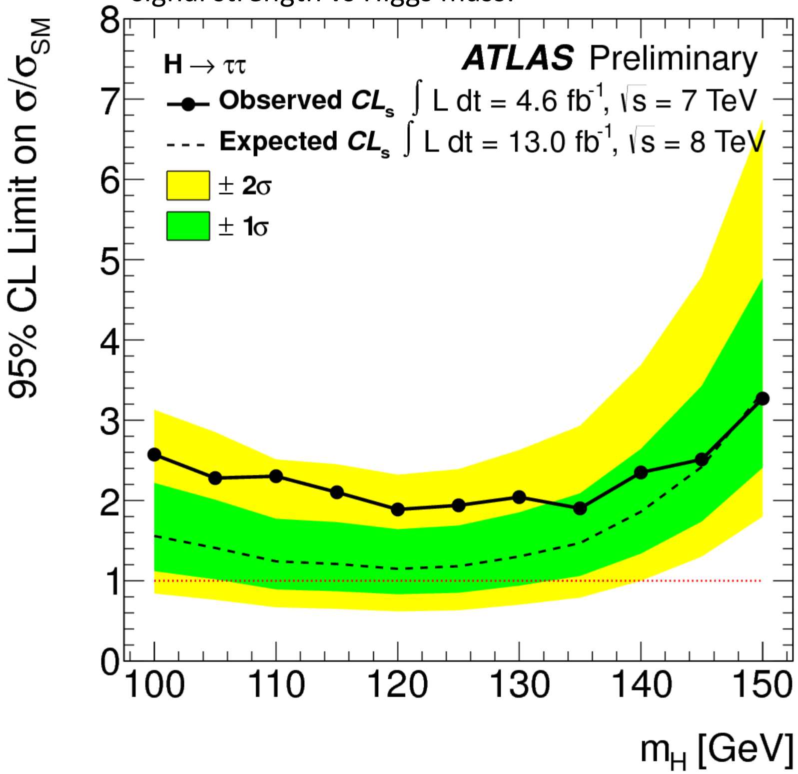
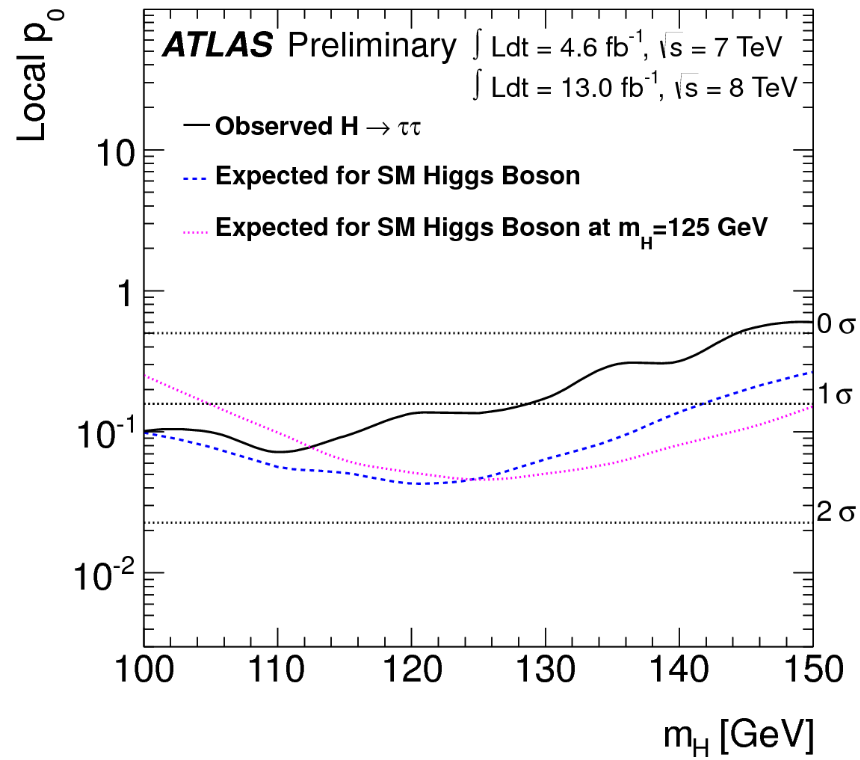
Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



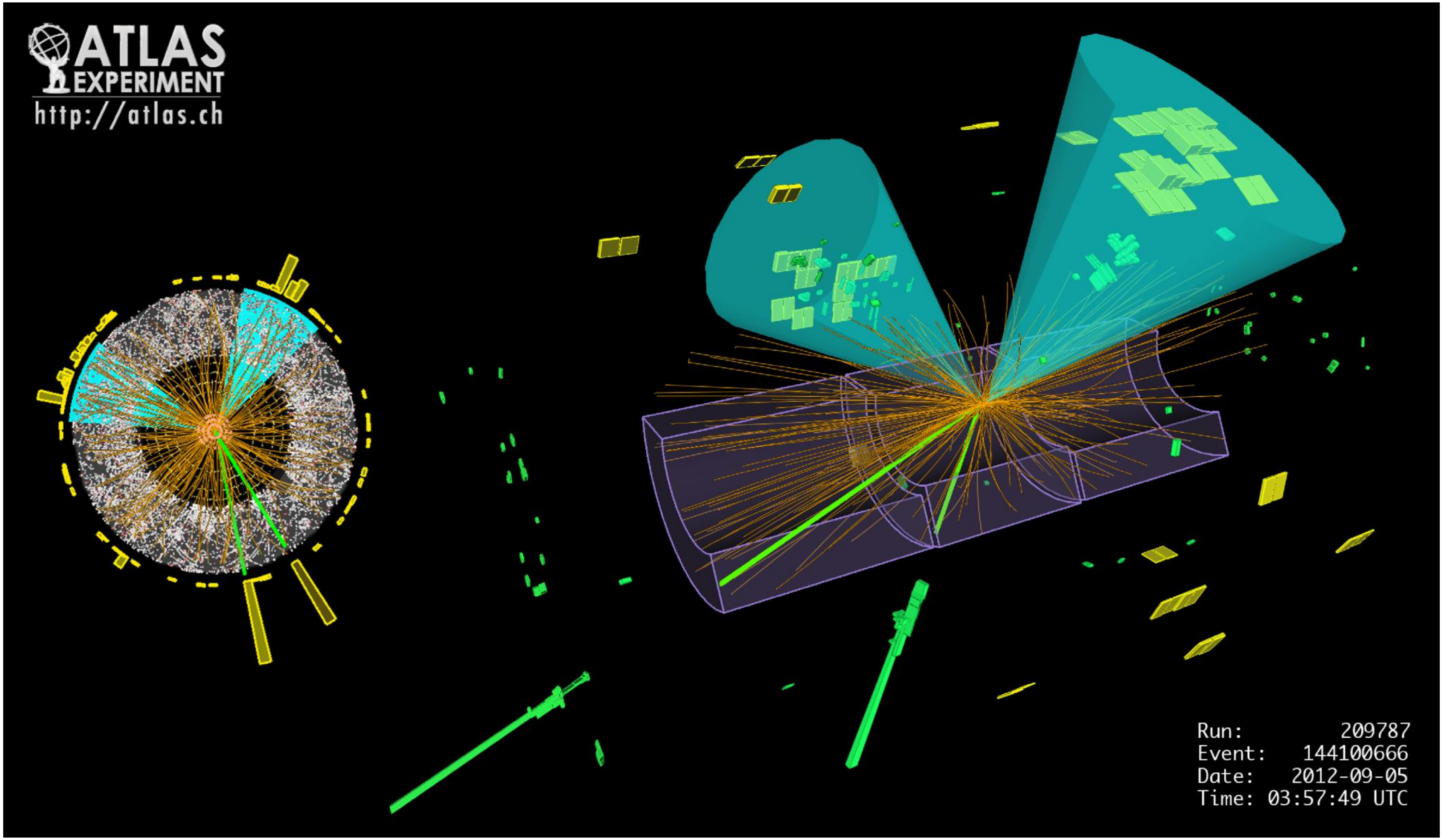
Observed and expected p-value vs Higgs mass:



Higgs to τ τ (HCP 2012):

- 2-3 times SM Higgs boson is excluded at 95% CL: ~ 100-150 GeV c^{-2};
- Observed p_0 ~ 1.1 standard deviation @ m_H = 125 GeV c^{-2};
- Signal strength μ = 0.7 +/- 0.7.

VH → V+bb

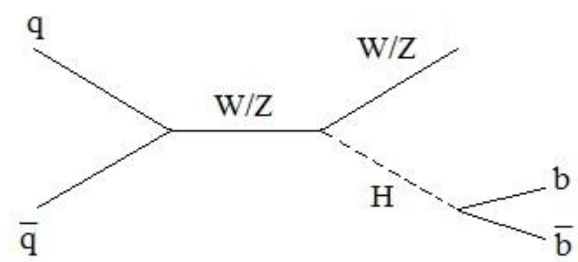

ATLAS
EXPERIMENT
http://atlas.ch
Run: 209787
Event: 144100666
Date: 2012-09-05
Time: 03:57:49 UTC

VH → V+bb

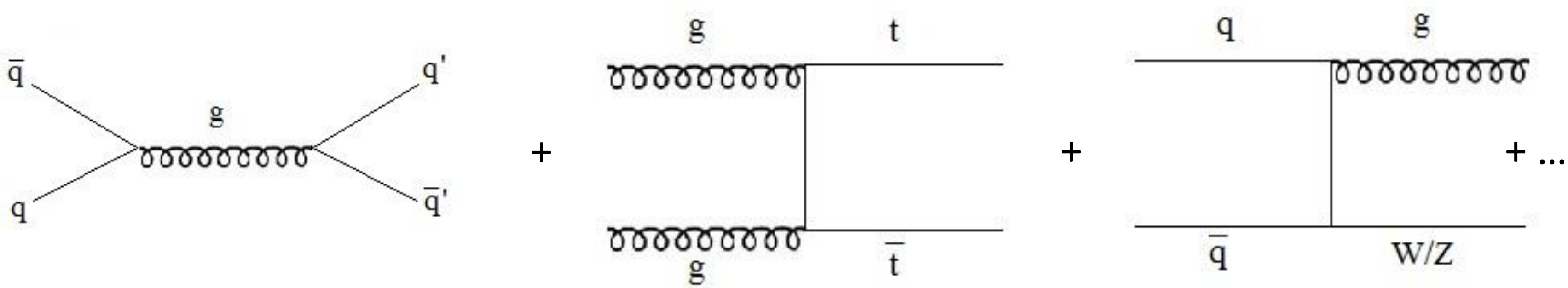
Higgs to bb:

- BR: ~ 0.6 (@ m_H = 125 GeV c^{-2});
- Production: VH;
- Bkg: Zbb, Wbb, top…;
- Three channels:
  - 0 leptons: Z → ν ν + H → bb;
  - 1 lepton: W → l ν + H → bb;
  - 2 leptons: Z → l l + H → bb;
- Signal purity (S/B) ~ 1%-10%;
- Discriminant variables: lep, E_t^{miss}, m_{jj}…;
- Lumi 4.8 fb^{-1} @ 7 TeV and 13 fb^{-1} @ 8 TeV (HCP 2012).

Signal:

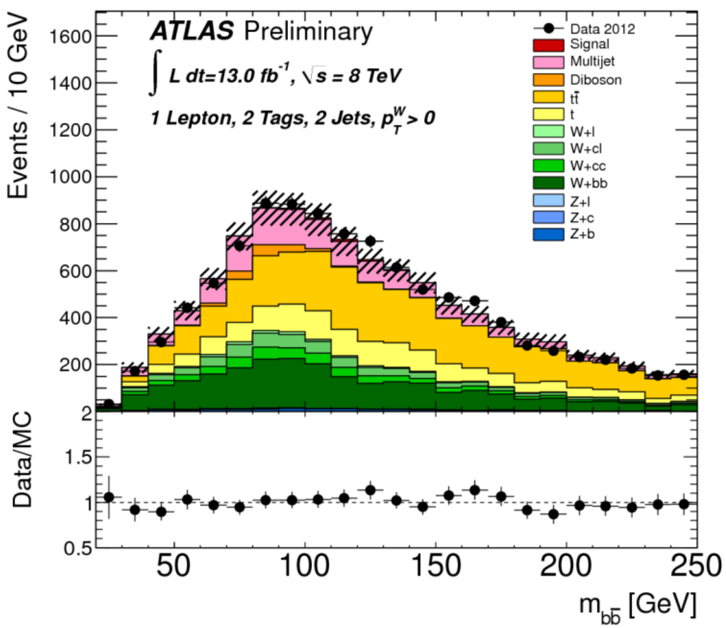


Backgrounds: W/Z + jet, tt… are estimated using a combination of techniques based on the comparison of data and MC predictions. ZZ, WW from simulation and MultiJet only form data:

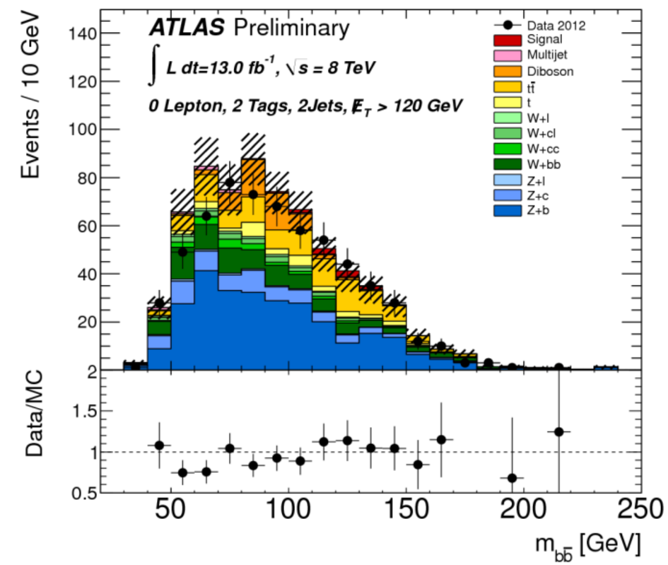


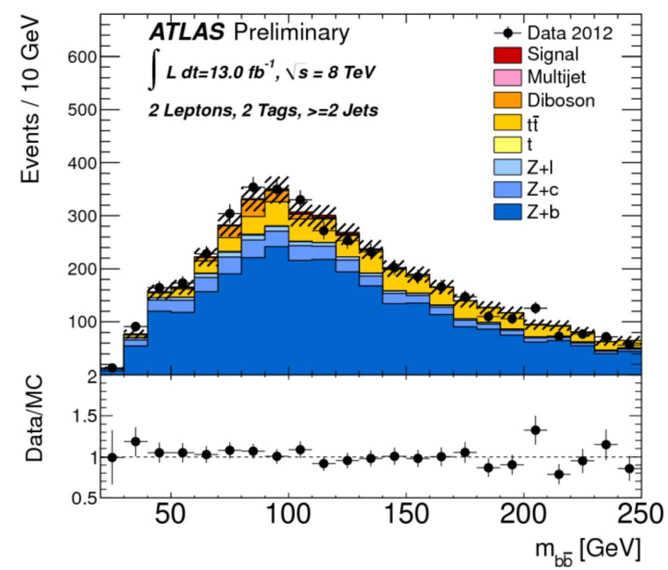
VH → V+bb

m_{bb} distributions after full event selection for 2jets and 0-1-2 leptons.



The normalizations of backgrounds are determined by a maximum likelihood fit to control and signal regions.





VH → V+bb

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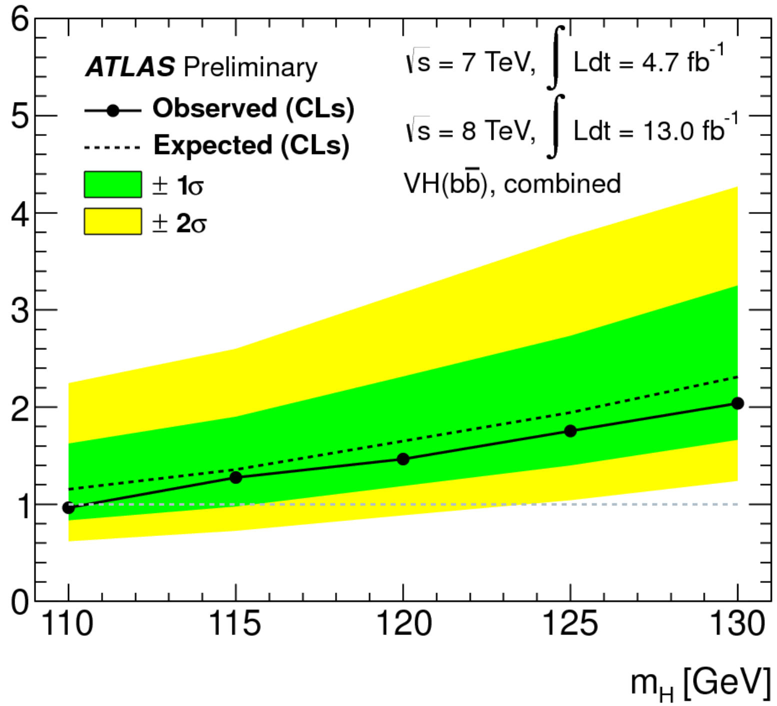
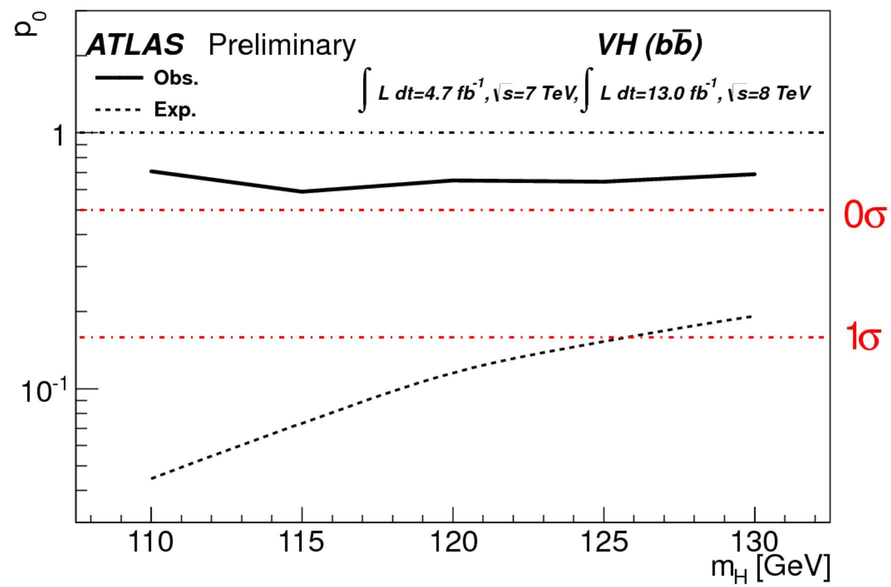
Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



Higgs to bb (HCP2012):

- The SM Higgs boson is excluded @ 95% CL: 110 GeV c^{-2};
- 2 times SM Higgs boson is excluded at 95% CL: ~ 110-130 GeV c^{-2};
- No significant excess is observed.

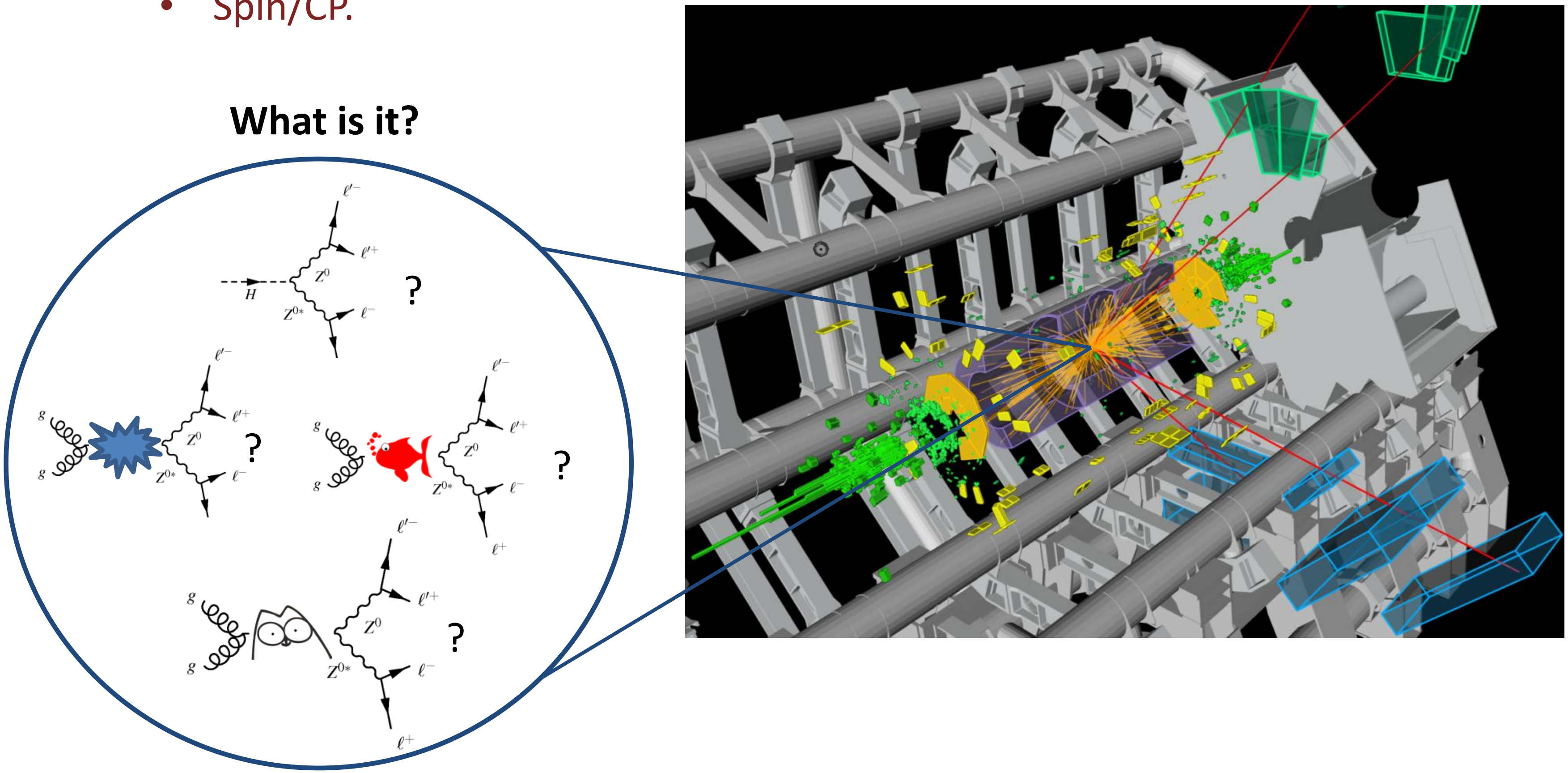
What is it?

Is it really the Standard Model Higgs boson?

Needed study its properties:

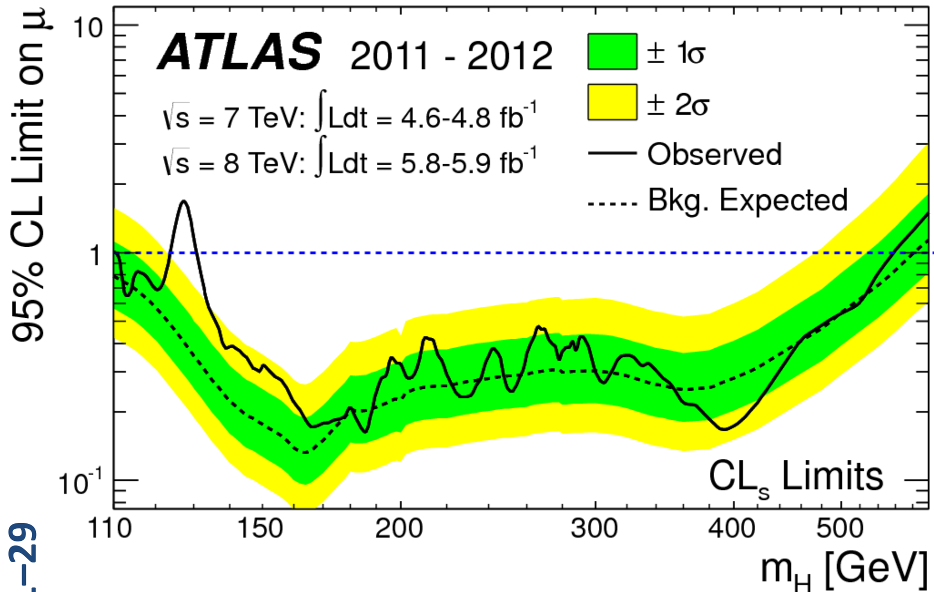
- Mass;
- Couplings;
- Spin/CP.

What is it?

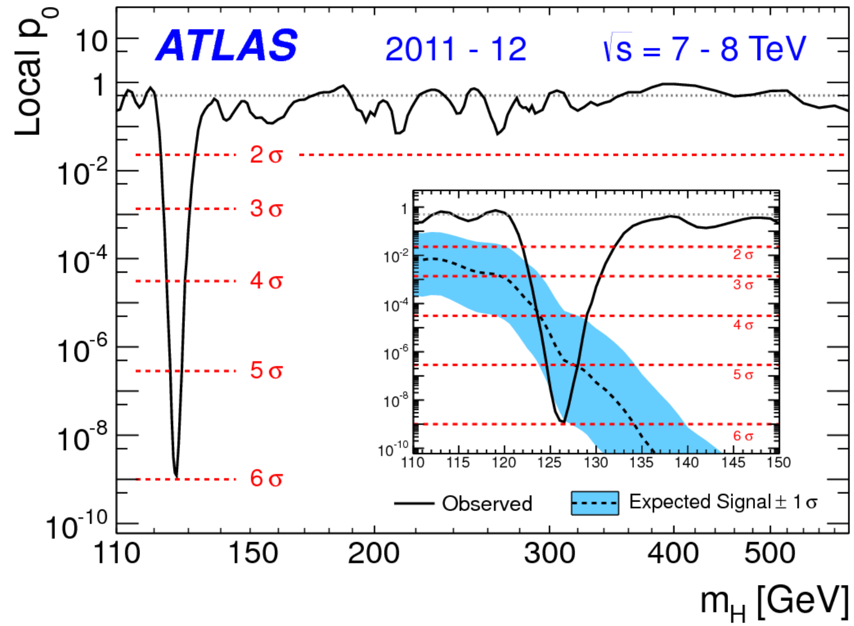


Higgs combination

Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



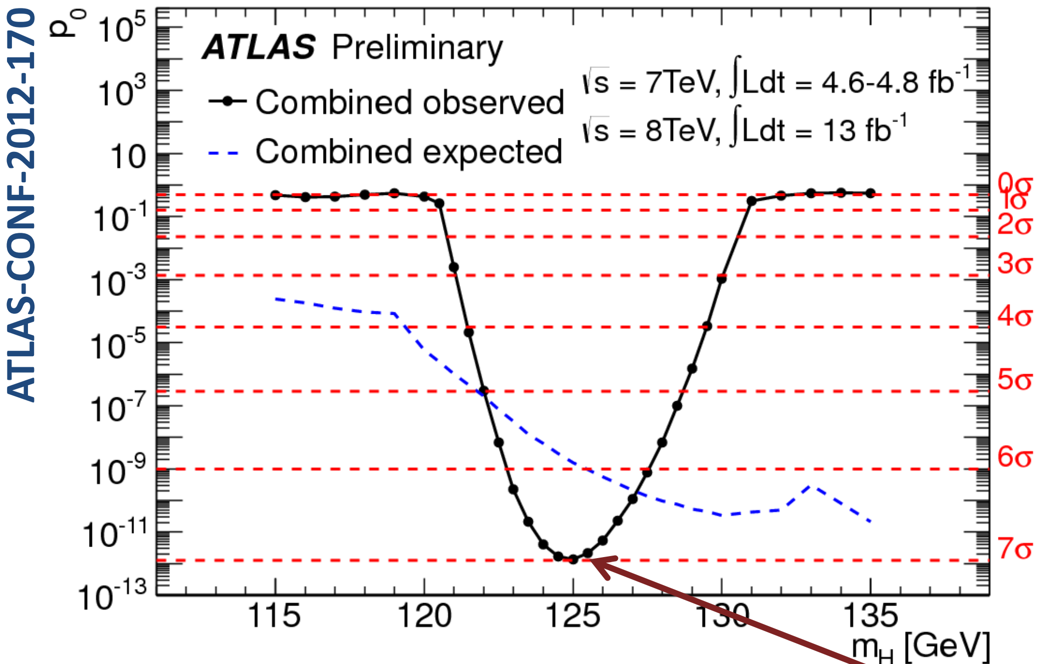
Phys. Lett. B 716 (2012) 1–29

Higgs combination (July 2012):

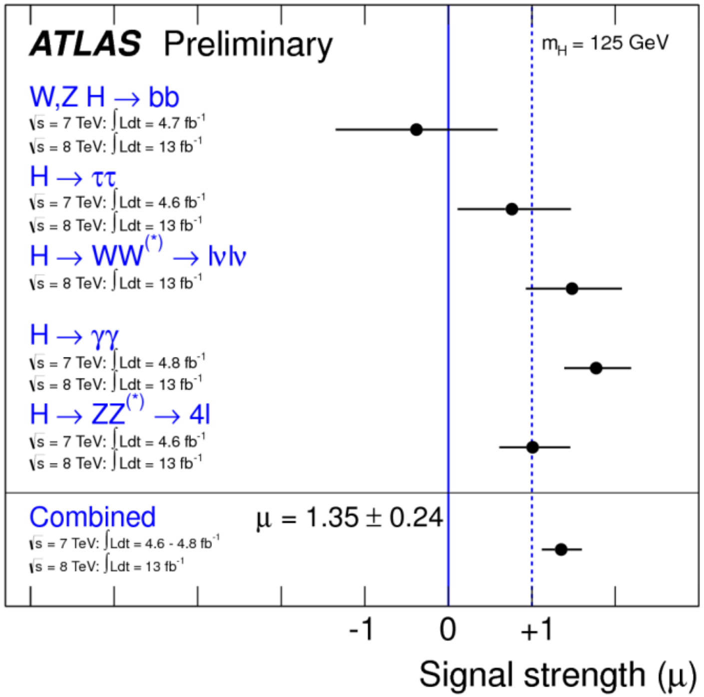
- The SM Higgs boson is excluded at 95% CL: 111-122 and 131-559 GeV c^{-2} (exp 110-582 GeV c^{-2});
- Observed p_0 ~ 6.0 standard deviation (exp 4.9) @ m_H = 126 GeV c^{-2};
- Signal strength μ = 1.4 +/- 0.3.

Higgs combination: latest results

Observed and expected p-value vs Higgs mass:



Signal strength for all channels and combined:



Expected significance : 5.9 σ

Signal is confirmed!!!

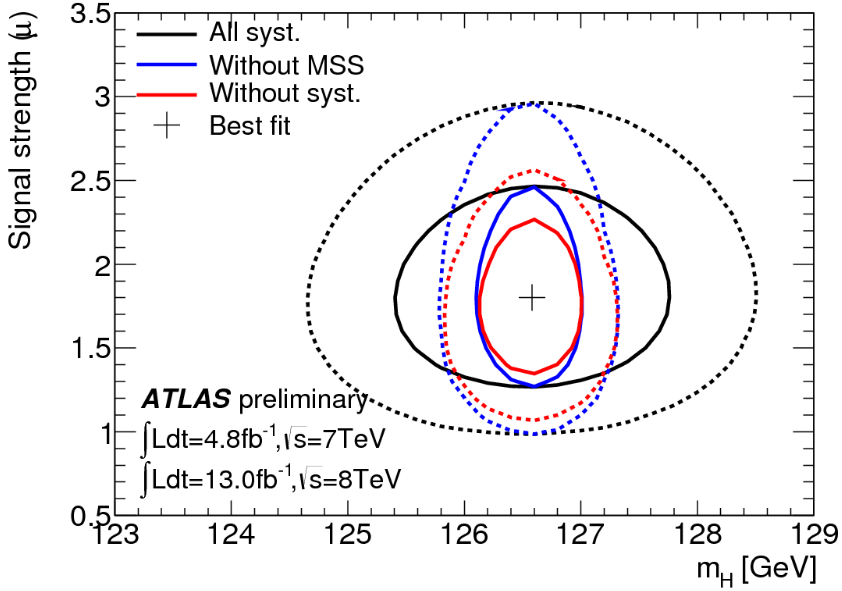
Observed significance: 7.0 σ

Combined signal strength is: $\hat{\mu} = 1.35 \pm 0.19(stat) \pm 0.15(syst)$

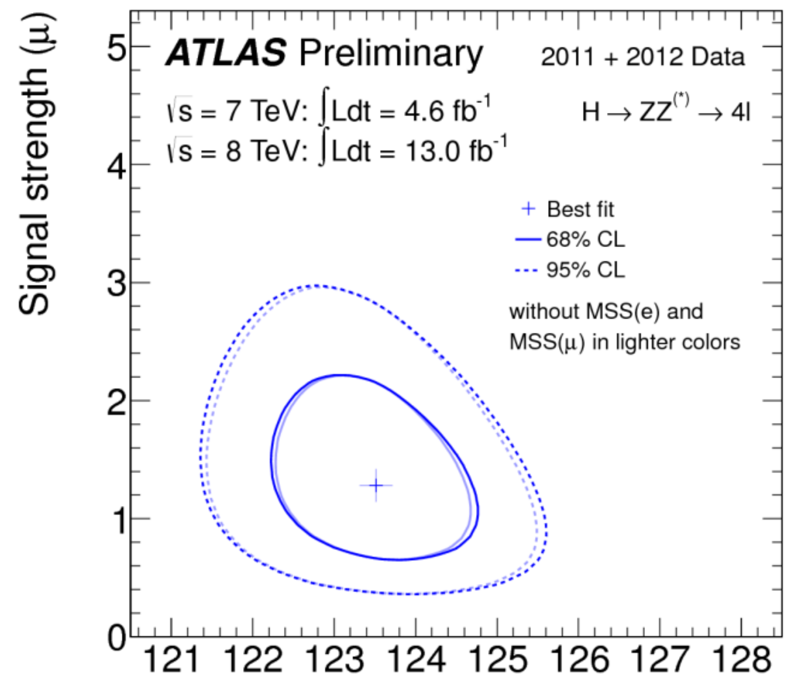
Higgs mass

H → γγ and H → ZZ(*) → 4l best-fit values of m_H and μ, and the corresponding 1-2 σ contours:

H → γγ



H → ZZ(*) → 4l



H → γγ:

Signal strenght $\hat{\mu} = 1.8 \pm 0.3(stat)^{+0.29}_{-0.21}(syst)$

Mass $m_H = 126.6 \pm 0.3(stat) \pm 0.7(syst)\ GeVc^{-2}$

H → $ZZ^{(*)}$ → 4l:

Signal strenght $\hat{\mu} = 1.3 \pm 0.4$

Mass $m_H = 123.5 \pm 0.9(stat)^{+0.4}_{-0.2}\ GeVc^{-2}$

Higgs mass

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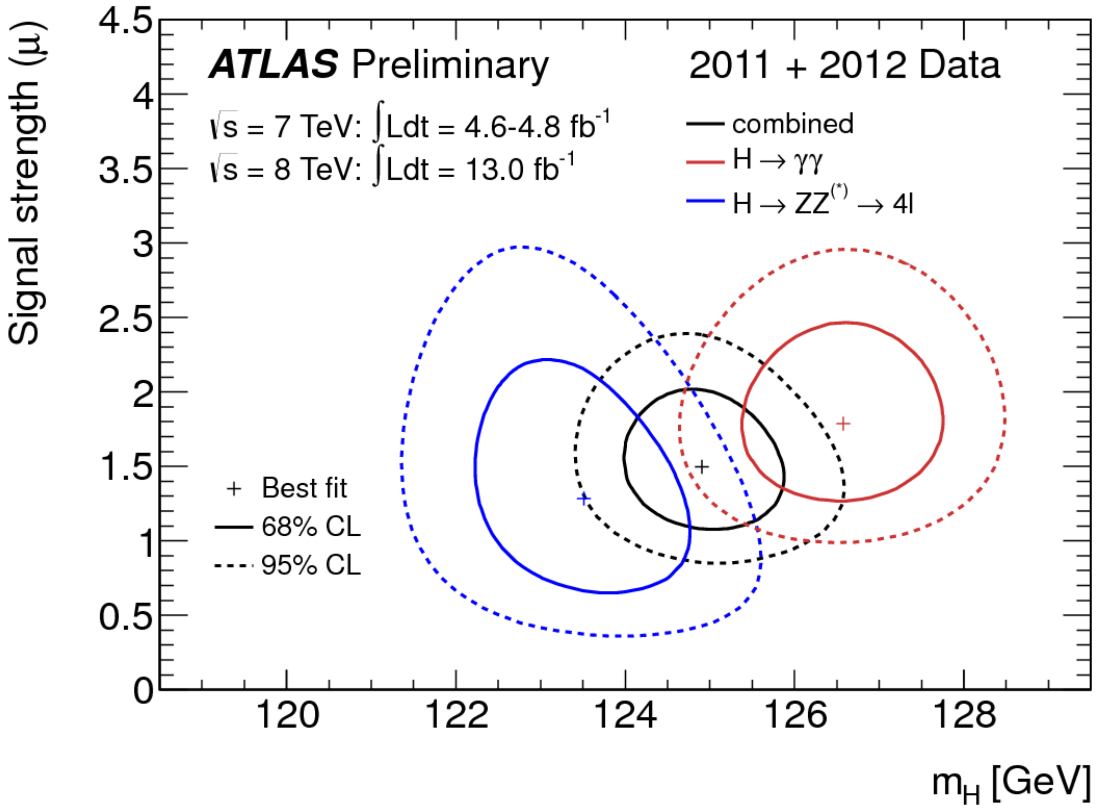


Combined mass measurement is: $m_H = 125.2 \pm 0.3(stat) \pm 0.6(syst)\ GeV c^{-2}$

Combined signal strenght: $\hat{\mu} = 1.5^{+0.33}_{-0.29}$

Taking all systematics into account the two masses, the compatibility of the two masses is estimated to be at the 2.7 σ level (A more conservative treatment of scale systematics (rectangular PDFs) leads to a compatibility of 2.3 σ).

Higgs couplings

arXiv:1209.0040 [hep-ph]

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 as in the SM.
- The signals observed in the different search channels originate from a single narrow resonance;
- The width of the Higgs boson with a mass of 126 GeV is assumed to be negligible.

Strategy:

Choose a model: More accurate with higher order corrections and external constraints;

Test small deviations from the SM predictions.

$$(\sigma \cdot \mathrm{BR})\,(ii \to \mathrm{H} \to f\!f) = \frac{\sigma_{ii} \cdot \Gamma_{f\!f}}{\Gamma_{\mathrm{H}}}$$

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

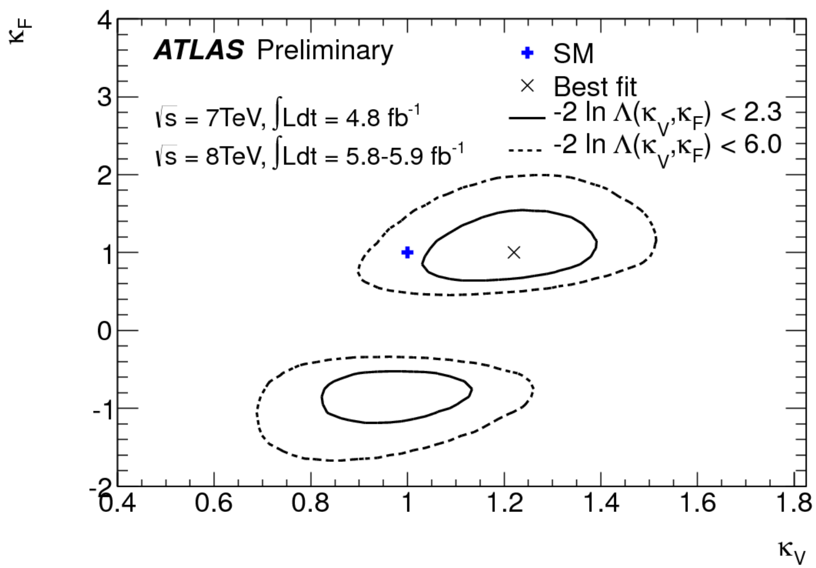
Higgs couplings

Benchmark model k_V-k_F.

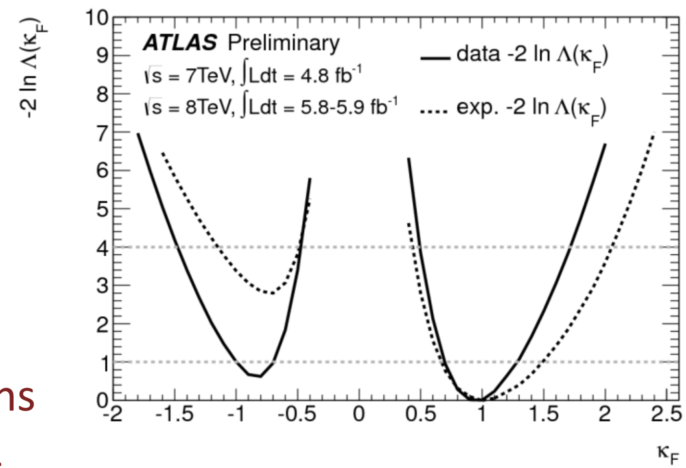
Some sensitivity to the relative sign of k_F gained from the negative interference between W and fermion-loop in H → γγ decay.

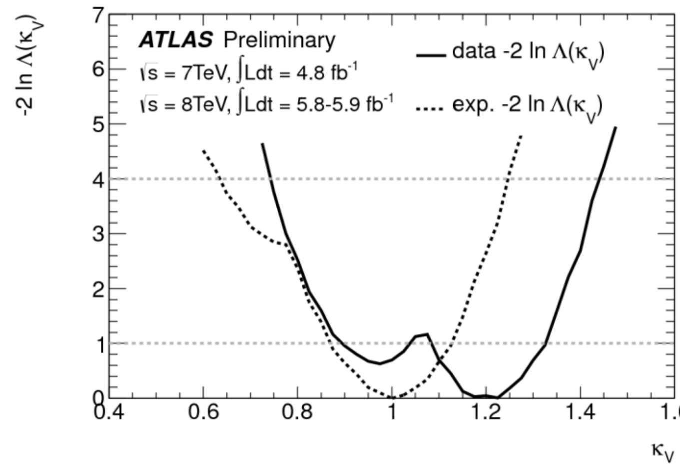
$$\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$$ Scale factor for all fermions

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



ATLAS-CONF-2012-127





$$\kappa_i{}^2 = \frac{\Gamma_{ii}}{\Gamma_{ii}^{SM}}$$

Higgs couplings

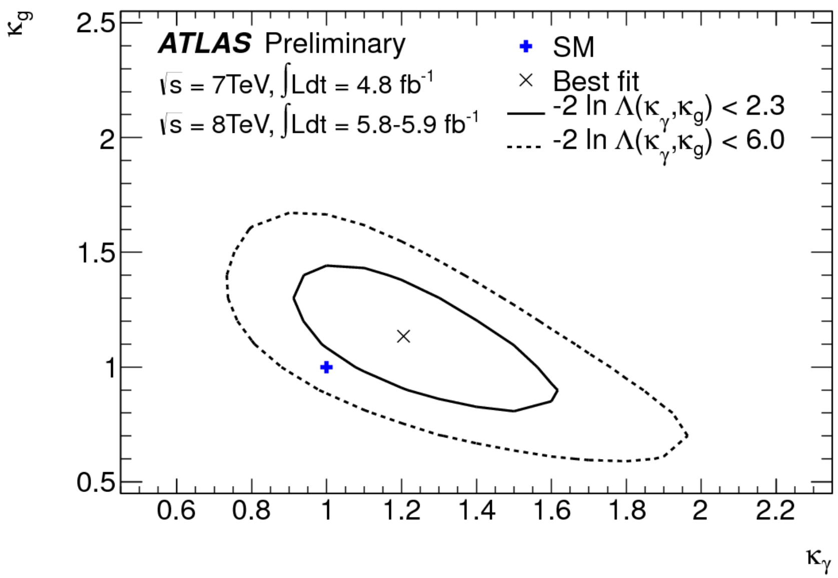
Benchmark model k_g-k_γ.

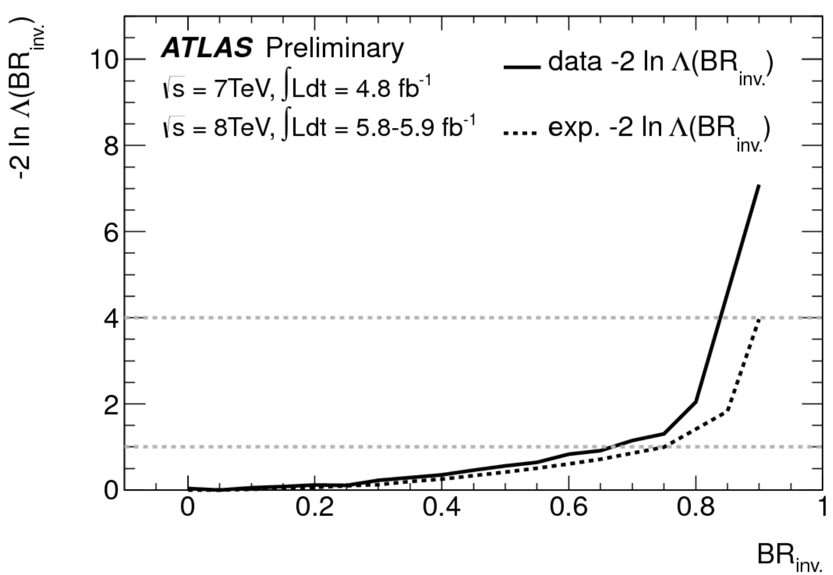
The potential new particles contributing to the H→γγ and gg → H loops, may or may not contribute to the total width of the observed state from direct invisible decays.

$$\kappa_g^2(\kappa_b, \kappa_t, m_H) = \frac{|\kappa_b A_b(m_H) + \kappa_t A_t(m_H)|^2}{|A_b(m_H) + A_t(m_H)|^2}$$ gg → H loop

$$\kappa_\gamma^2(\kappa_b, \kappa_t, \kappa_W, m_H) = \frac{|\kappa_b A'_b(m_H) + \kappa_t A'_t(m_H) + \kappa_W A'_W(m_H)|^2}{|A'_b(m_H) + A'_t(m_H) + A'_W(m_H)|^2}$$ H → γγ loop

ATLAS-CONF-2012-127





Higgs couplings

Simplified benchmark models were used to study the correlations of production and decay modes in different final states, and compare them to the predictions for the SM Higgs boson:

- ✓ Couplings to Fermions and Vector Gauge Bosons (k_V-$k_{F,}$ k_g-k_γ, k_{VV}-λ_{FV});
- ✓ Probing the custodial symmetry of the W and Z coupling (λ_{WZ}, k_{ZZ}, λ_{FZ});
- ✓ Probing the up- and down-type fermion symmetry (λ_{du}, k_{uu}, λ_{Vu});
- ✓ Probing the quark and lepton symmetry(λ_{Vq}, k_{qq}, λ_{lq}).

Within the current statistical uncertainties and assumptions, no significant deviations from the Standard Model couplings are observed.

Higgs J^P : $H \to ZZ^{(*)} \to 4l$

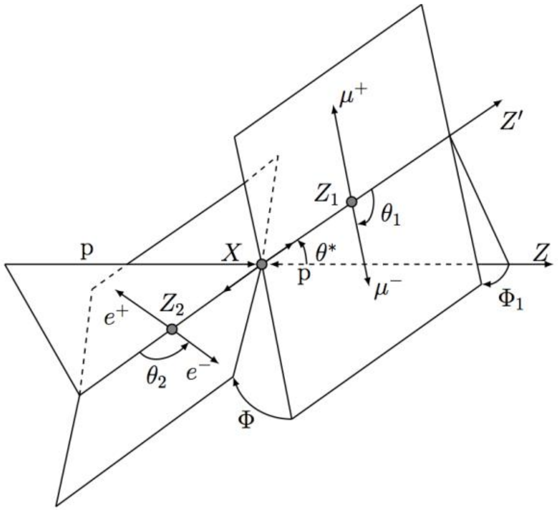
Final state allows measuring J^P:

- 5 angles (production, decay);
- m_{12}, m_{34};

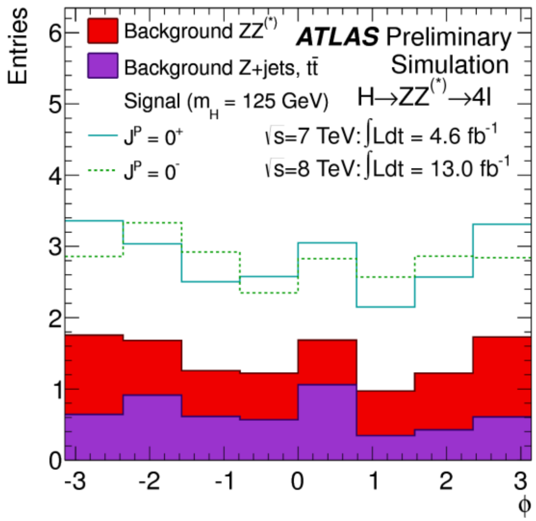
Discriminate 0^+ (SM) hypothesis against: 0^-, 2^+_m (graviton-like tensor with minimal couplings) 2^- (pseudo-tensor).

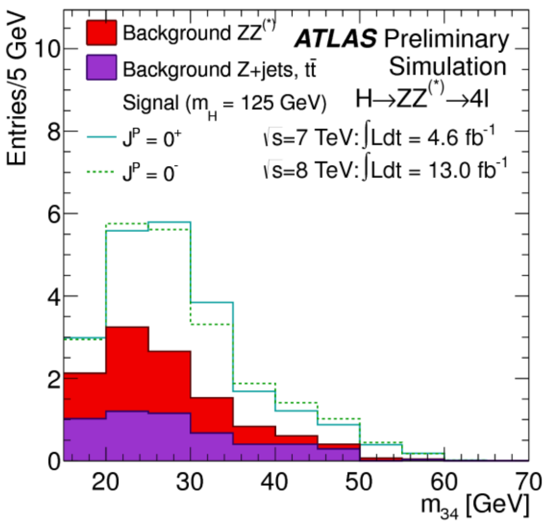
Two Multi-Variate discriminants used:

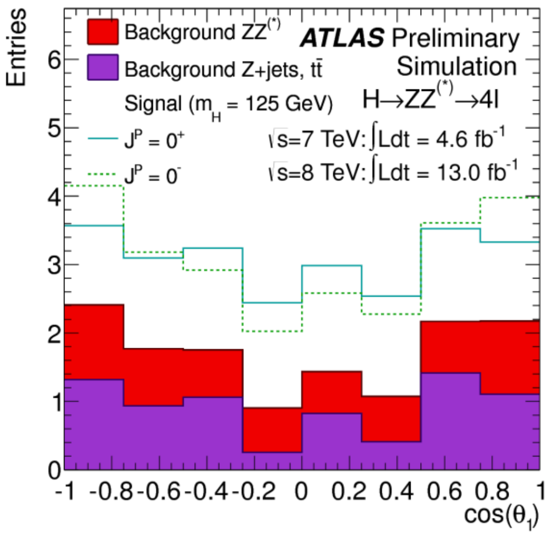
- Boosted Decision Tree (BDT);
- Matrix-Element-Likelihood-Analysis (J^P-MELA).



Expected distributions for 0^+ and 0^- hypothesis of ϕ, $\cos\theta_1$ and m_{34} for the combined $\sqrt{s}$ = 8 TeV and $\sqrt{s}$ = 7 TeV luminosity:



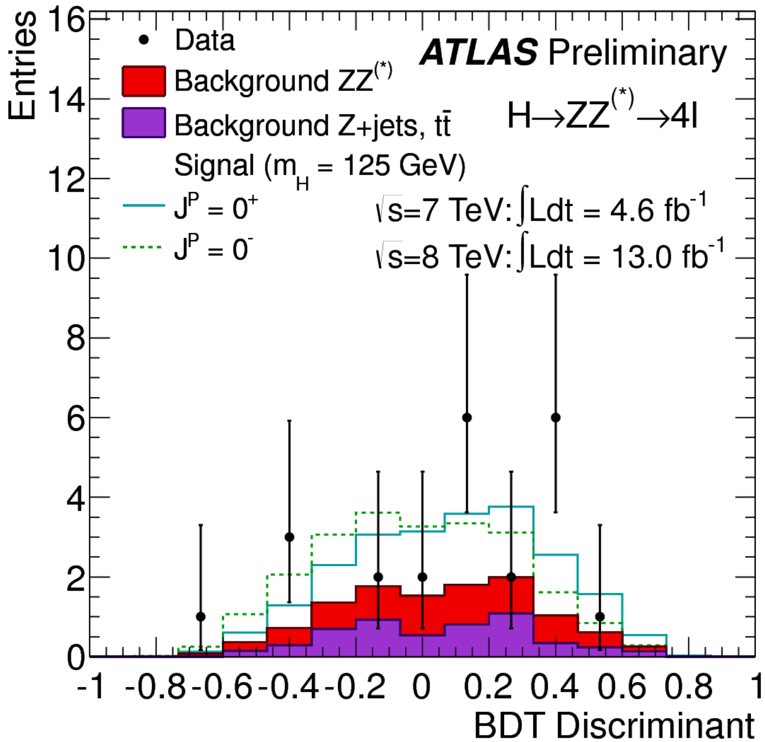


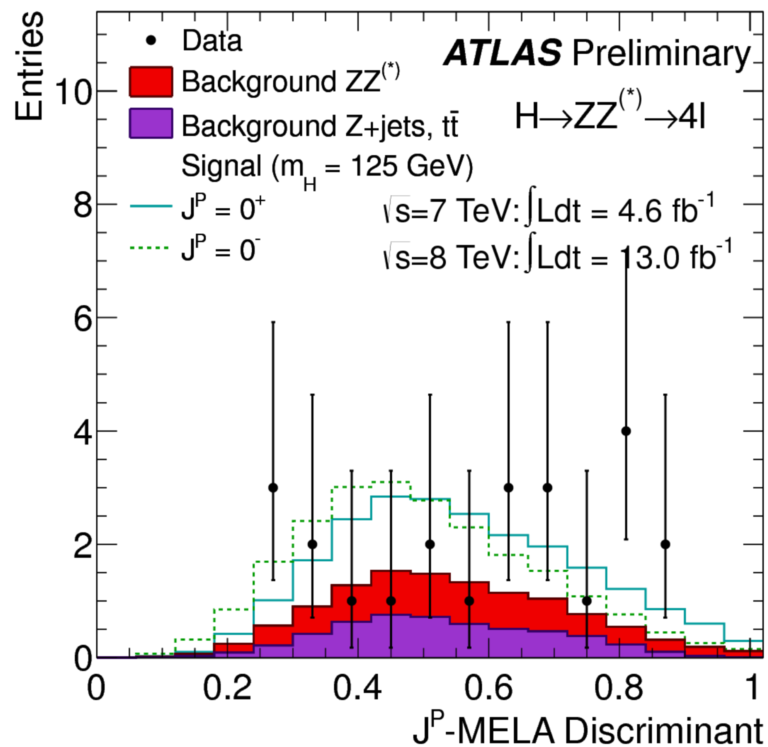


Higgs J^P : $H \rightarrow ZZ^{(*)} \rightarrow 4l$

Distributions of the BDT and J^P-MELA discriminants for data and Monte Carlo expectations for the combined $\sqrt{s}$ = 8 TeV and $\sqrt{s}$ = 7 TeV data sets:

ATLAS-CONF-2012-169



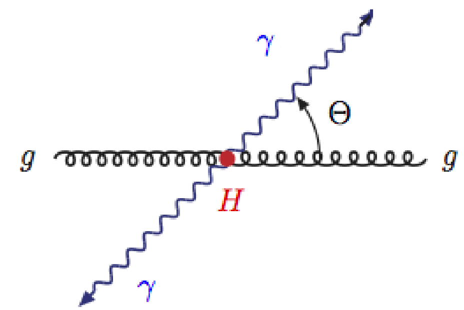


0^+ vs 0^-: 2.3 σ (2.7 σ) observed (1.7 σ, 1.9 σ expected);

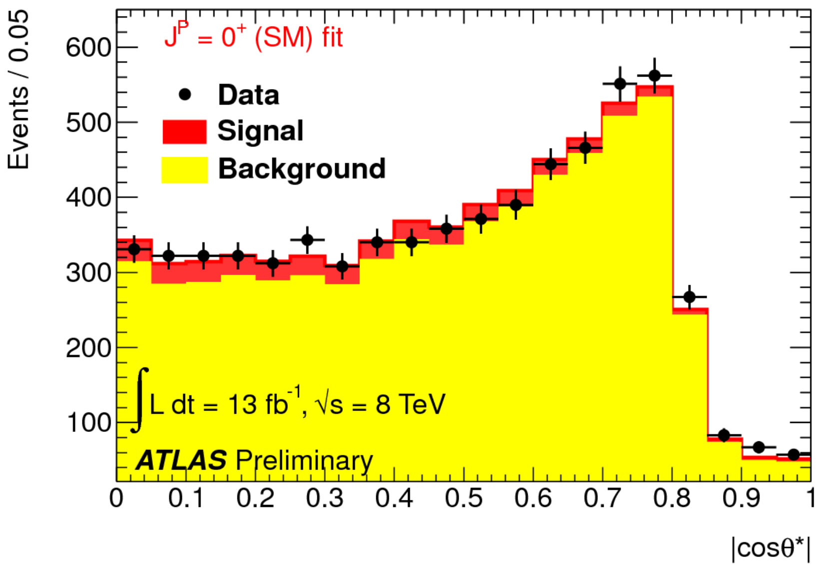
0^+ vs 2^+: excluded @ 85% CL.

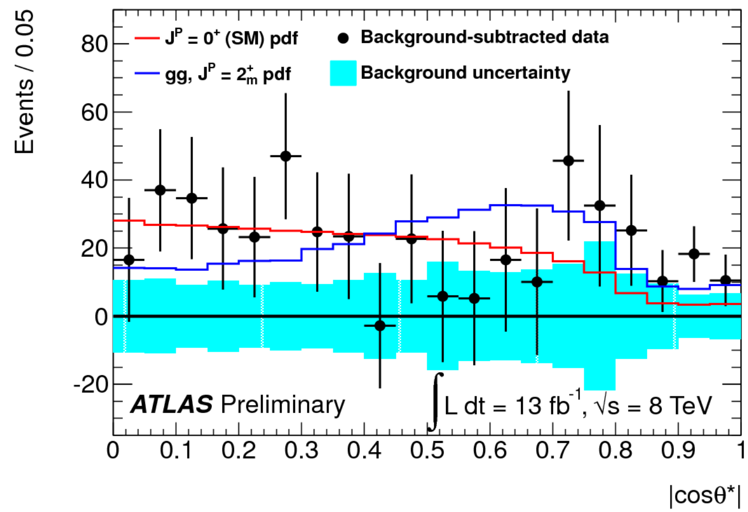
Higgs J^P : $H \to \gamma\gamma$

Sensitive variable is di-photon cos θ* distribution:



ATLAS-CONF-2012-168





Expected sensitivity: exclusion of the spin 2^+ hypothesis @ the 97% CL;
Observed exclusion of spin 2+ hypothesis @the 91% CL.

Conclusions

- ✓ Excellent performance of LHC and of the ATLAS detector allowed to strengthen the observation of the new boson;
- ✓ The discovery is fully confirmed on all the most sensitive channel;
- ✓ First measurements of its coupling properties and its mass;
- ✓ All properties measured until now are consistent with a SM Higgs;
- ✓ The analyses are now moving from searches to measurement: more results to comeusing the full set of ~21 fb^{-1} collected in 2012.

References

Higgs to gamma gamma:

arXiv:1207.7214 [hep-ex], ATLAS-CONF-2012-168

Higgs to four leptons:

arXiv:1207.7214 [hep-ex], ATLAS-CONF-2012-169

Higgs to WW:

arXiv:1207.7214 [hep-ex], ATLAS-CONF-2012-158

Higgs to tautau:

ATLAS-CONF-2012-160

Higgs to bb

ATLAS-CONF-2012-161

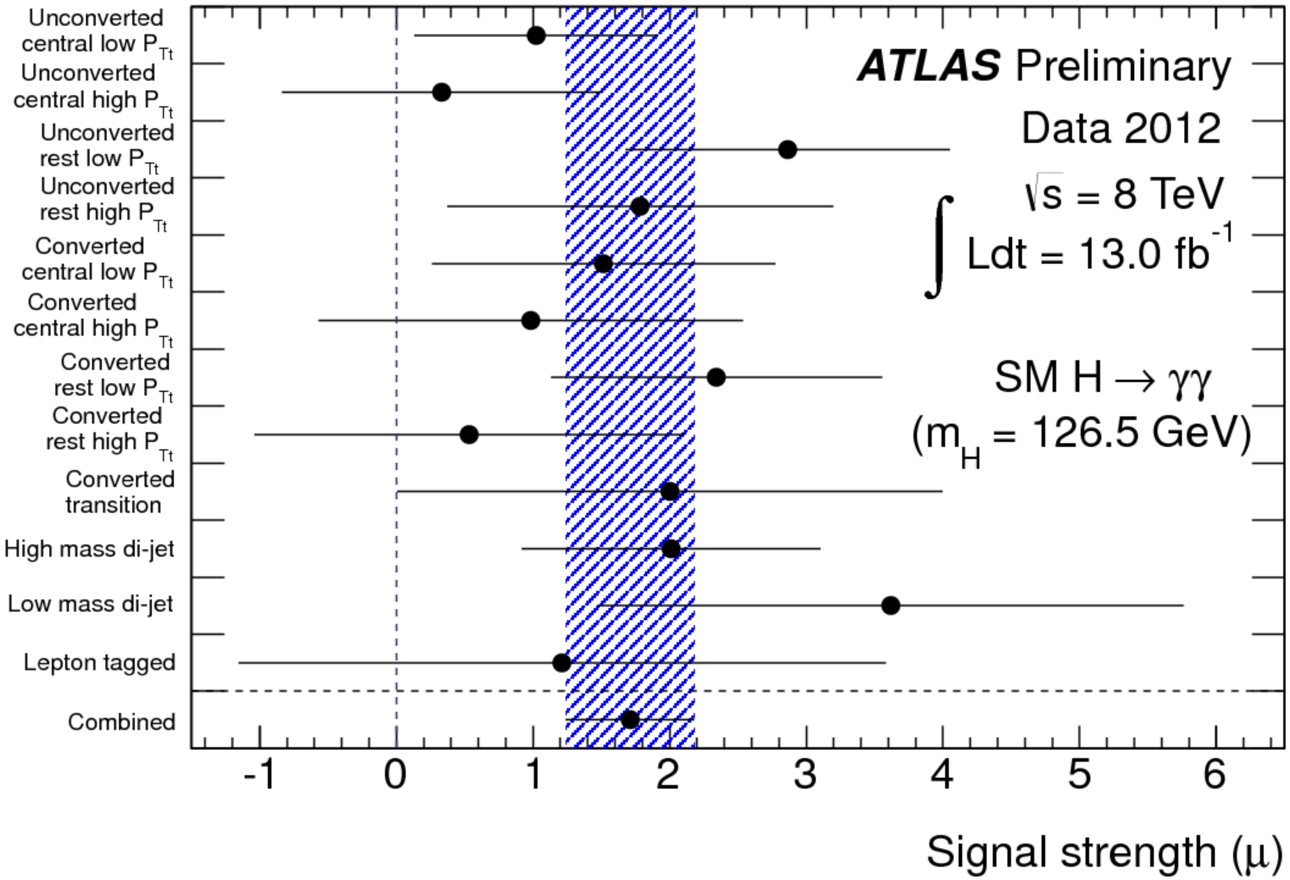
Higgs properties:

arXiv:1207.7214 [hep-ex], ATLAS-CONF-2012-168, ATLAS-CONF-2012-127, ATLAS-CONF-2012-169, ATLAS-CONF-2012-170, arXiv:1209.0040 [hep-ph]

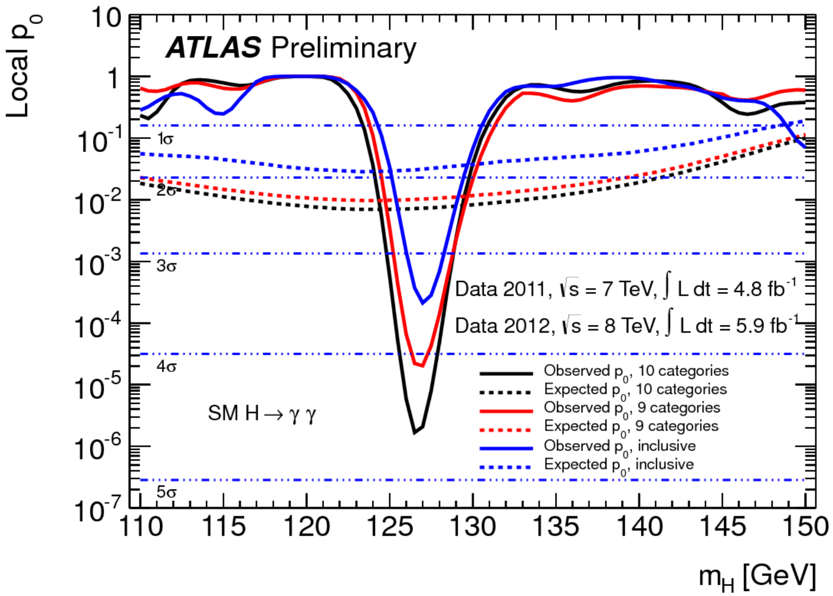
Table 1: Number of events in the data (N_D) and expected number of expected signal events (N_S) for m_H = 126.5 GeV from the $H \rightarrow \gamma\gamma$ analysis, for each category in the mass range 100-160 GeV, based on SM predictions. The mass resolution Full Width at Half Maximum (FWHM) is also given. Numbers for the 7 TeV analysis can be found in Ref. [7]. The statistical uncertainties on N_S and FWHM are less than 1%. The breakdown of expected signal events in the $gg \rightarrow H$, VBF, WH, ZH, ttH processes is detailed. For more details, see the text.

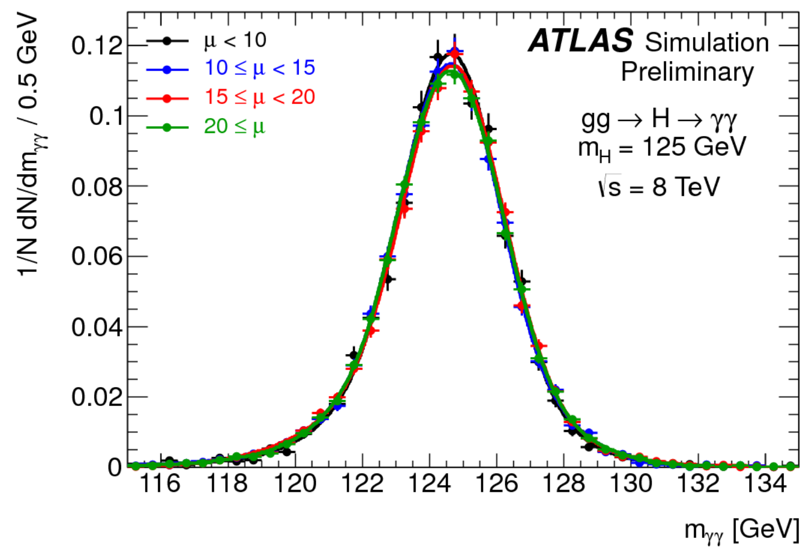
$\sqrt{s}$	8 TeV							
Category	N_D	N_S	$gg \rightarrow H$ [%]	VBF [%]	WH [%]	ZH [%]	ttH [%]	FWHM [GeV]
Unconv. central, low p_{Tt}	6797	32	93	4.2	1.4	0.9	0.2	3.45
Unconv. central, high p_{Tt}	319	4.7	76	15.2	3.9	2.9	1.7	3.22
Unconv. rest, low p_{Tt}	26802	69	93	4.2	1.7	1.1	0.2	3.75
Unconv. rest, high p_{Tt}	1538	9.7	76	15.1	4.5	3.3	1.2	3.59
Conv. central, low p_{Tt}	4480	21	93	4.2	1.4	0.9	0.2	3.86
Conv. central, high p_{Tt}	199	3.1	77	14.5	4.1	2.8	1.7	3.51
Conv. rest, low p_{Tt}	24107	60	93	4.1	1.7	1.1	0.2	4.32
Conv. rest, high p_{Tt}	1324	8.3	75	15.1	4.9	3.4	1.3	4.00
Conv. transition	10891	28	90	5.6	2.3	1.5	0.3	5.57
High Mass two-jet	345	7.6	31	68.2	0.3	0.2	0.1	3.65
Low Mass two-jet	477	4.7	60	5.1	20.7	12.1	1.6	3.45
One-lepton	151	2.0	3.2	0.4	62.5	15.8	18.0	3.85
All categories (inclusive)	77430	249	88	7.4	2.8	1.6	0.5	3.87

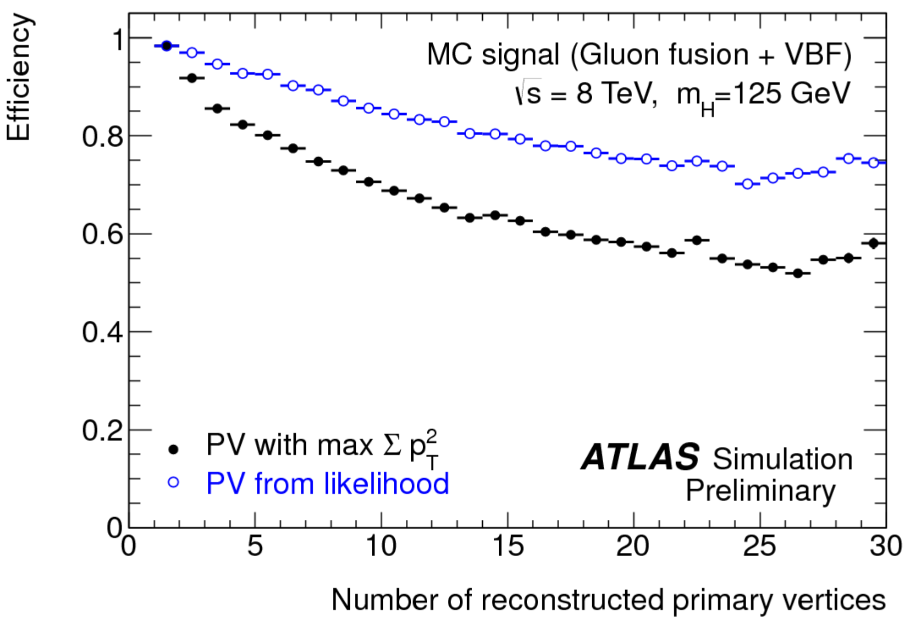
Best fit value for the signal strength in the different categories and combined:



The pTt of the diphoton system is defined as the transverse component of the diphoton momentum, when projected on the axis given by the difference of the photon momenta


ATLAS Preliminary
Local p_0
m_H [GeV]
Data 2011, $\sqrt{s}$ = 7 TeV, $\int L\,dt$ = 4.8 fb^{-1}
Data 2012, $\sqrt{s}$ = 8 TeV, $\int L\,dt$ = 5.9 fb^{-1}
Observed p_0, 10 categories
Expected p_0, 10 categories
Observed p_0, 9 categories
Expected p_0, 9 categories
Observed p_0, inclusive
Expected p_0, inclusive
SM $H \rightarrow \gamma\gamma$
1σ
2σ
3σ
4σ
5σ


ATLAS Simulation
Preliminary
$1/N\ dN/dm_{\gamma\gamma}$ / 0.5 GeV
$m_{\gamma\gamma}$ [GeV]
$\mu < 10$
$10 \leq \mu < 15$
$15 \leq \mu < 20$
$20 \leq \mu$
$gg \rightarrow H \rightarrow \gamma\gamma$
m_H = 125 GeV
$\sqrt{s}$ = 8 TeV


Efficiency
Number of reconstructed primary vertices
MC signal (Gluon fusion + VBF)
$\sqrt{s}$ = 8 TeV, m_H=125 GeV
PV with max Σp_T^2
PV from likelihood
ATLAS Simulation
Preliminary

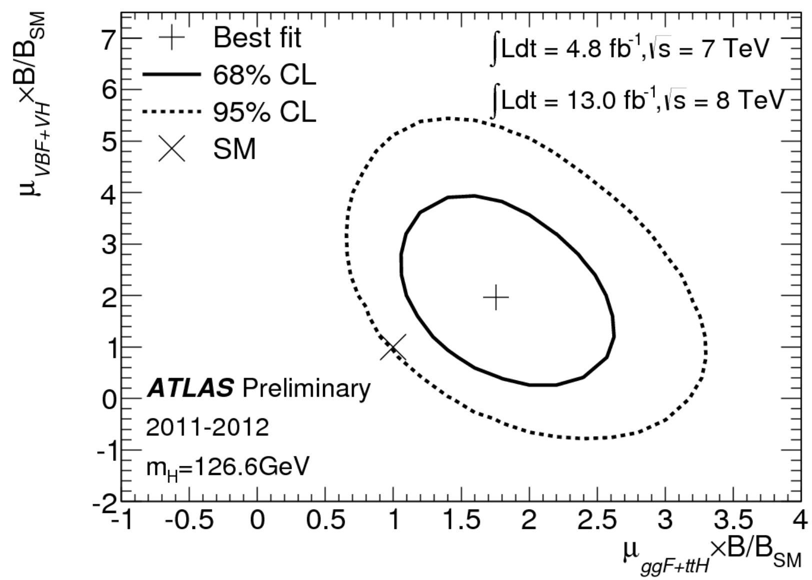
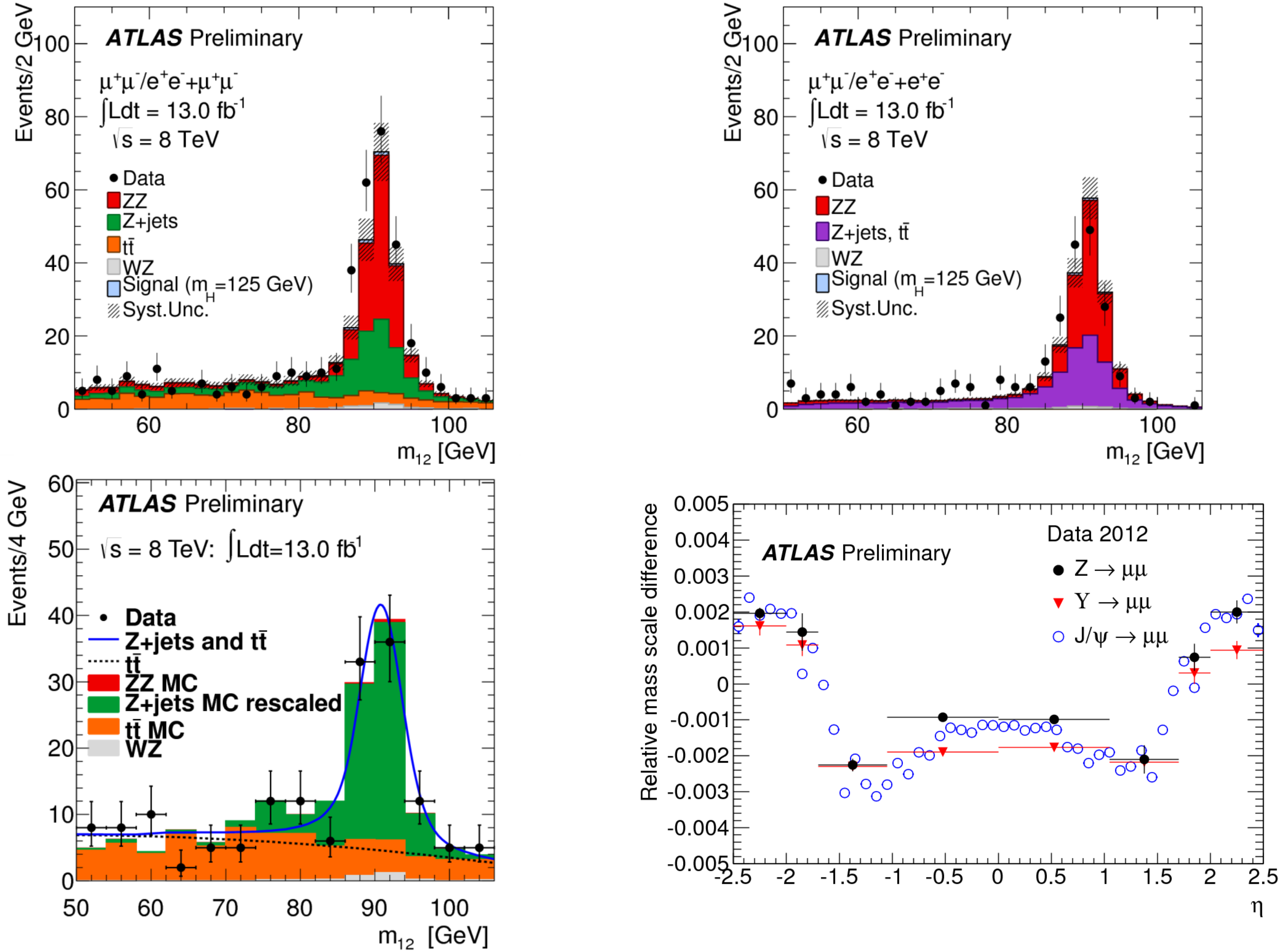

$\mu_{VBF+VH} \times B/B_{SM}$
$\mu_{ggF+ttH} \times B/B_{SM}$
Best fit
68% CL
95% CL
SM
$\int Ldt$ = 4.8 fb^{-1}, $\sqrt{s}$ = 7 TeV
$\int Ldt$ = 13.0 fb^{-1}, $\sqrt{s}$ = 8 TeV
ATLAS Preliminary
2011-2012
m_H=126.6GeV

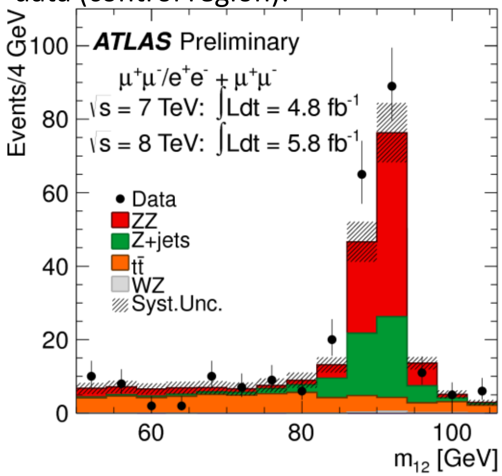
Table 6: The numbers of expected signal and background events together with the number of observed events, in a window of ±5 GeV around 125 GeV for 13.0 fb^{-1} at $\sqrt{s}$ = 8 TeV and 4.6 fb^{-1} at $\sqrt{s}$ = 7 TeV as well as for their combination.

	Signal (m_H=125 GeV)	$ZZ^{(*)}$	Z + jets, $t\bar{t}$	Observed
		$\sqrt{s} = 8$ TeV		
4μ	3.1 ± 0.4	1.55 ± 0.07	0.31 ± 0.09	6
$2\mu 2e$	1.4 ± 0.2	0.56 ± 0.04	0.78 ± 0.16	1
$2e2\mu$	1.9 ± 0.3	0.80 ± 0.04	0.26 ± 0.07	3
$4e$	1.5 ± 0.2	0.77 ± 0.08	1.20 ± 0.19	4
total	7.9 ± 1.1	3.7 ± 0.2	2.6 ± 0.3	14
		$\sqrt{s} = 7$ TeV		
4μ	0.88 ± 0.11	0.48 ± 0.02	0.05 ± 0.02	2
$2\mu 2e$	0.32 ± 0.05	0.14 ± 0.01	0.43 ± 0.09	1
$2e2\mu$	0.48 ± 0.06	0.22 ± 0.01	0.04 ± 0.02	1
$4e$	0.28 ± 0.04	0.17 ± 0.02	0.52 ± 0.13	0
total	2.0 ± 0.3	1.0 ± 0.1	1.0 ± 0.2	4
		$\sqrt{s} = 8$ TeV and $\sqrt{s} = 7$ TeV		
4μ	4.0 ± 0.5	2.03 ± 0.09	0.36 ± 0.09	8
$2\mu 2e$	1.7 ± 0.2	0.70 ± 0.05	1.21 ± 0.18	2
$2e2\mu$	2.4 ± 0.3	1.02 ± 0.05	0.30 ± 0.07	4
$4e$	1.8 ± 0.3	0.94 ± 0.09	1.72 ± 0.23	4
total	9.9 ± 1.3	4.7 ± 0.3	3.6 ± 0.3	18

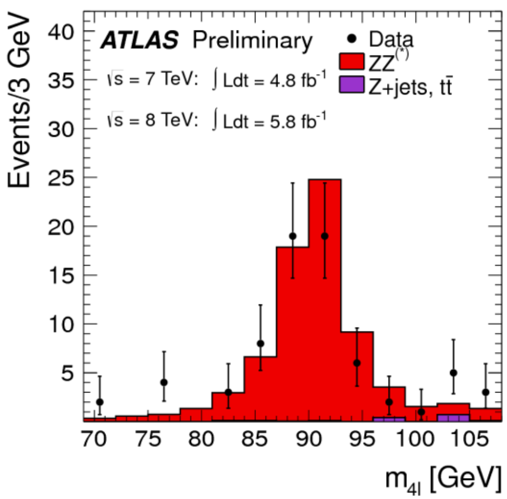


ATLAS Preliminary
μ+μ-/e+e-+μ+μ-
∫Ldt = 13.0 fb-1
√s = 8 TeV
Data
ZZ
Z+jets
tt̄
WZ
Signal (mH=125 GeV)
Syst.Unc.
Events/2 GeV
m12 [GeV]
ATLAS Preliminary
μ+μ-/e+e-+e+e-
∫Ldt = 13.0 fb-1
√s = 8 TeV
Data
ZZ
Z+jets, tt̄
WZ
Signal (mH=125 GeV)
Syst.Unc.
Events/2 GeV
m12 [GeV]
ATLAS Preliminary
√s = 8 TeV: ∫Ldt=13.0 fb-1
Data
Z+jets and tt̄
tt̄
ZZ MC
Z+jets MC rescaled
tt̄ MC
WZ
Events/4 GeV
m12 [GeV]
ATLAS Preliminary
Data 2012
Z → μμ
Υ → μμ
J/ψ → μμ
Relative mass scale difference
η

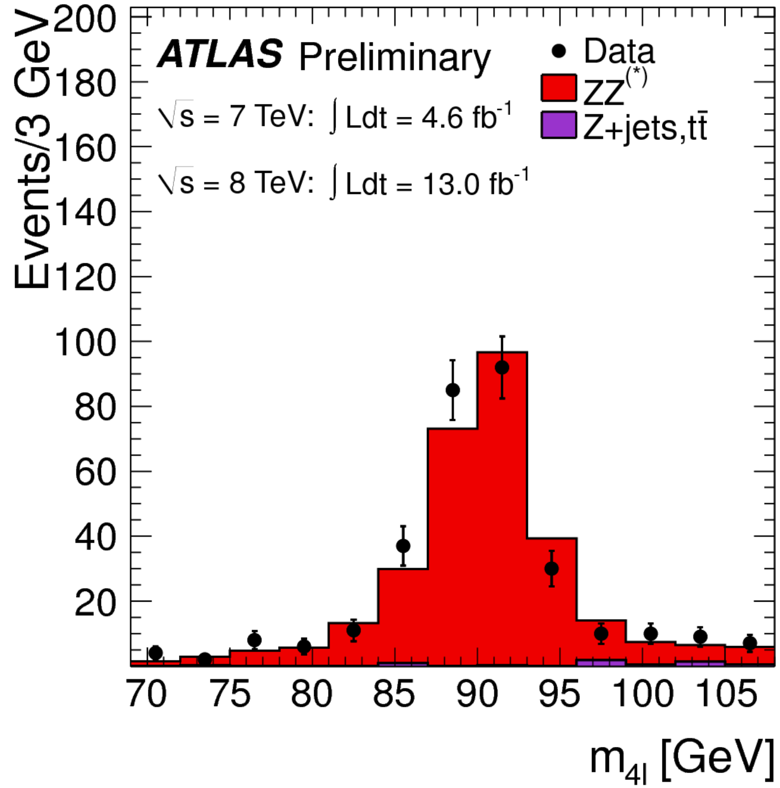
m_{12} distribution for the combined √s = 7 TeV and √s = 8 TeV data (control region):

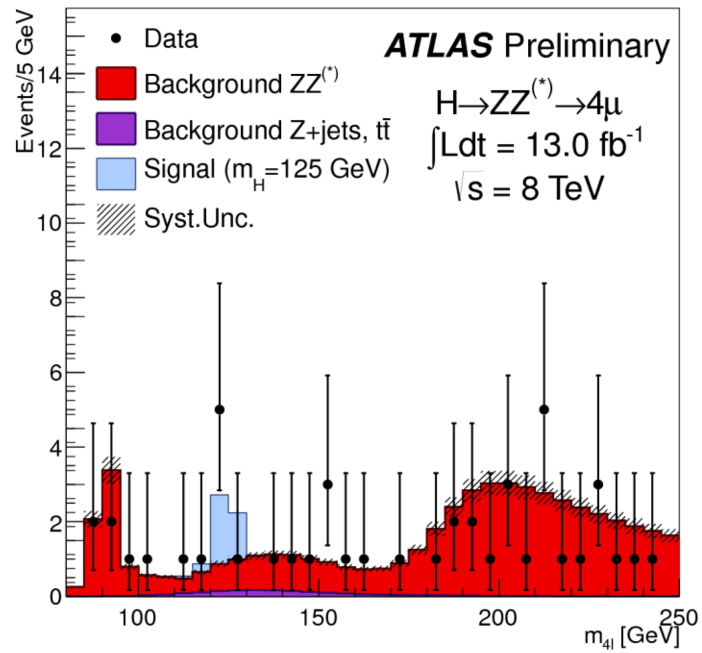


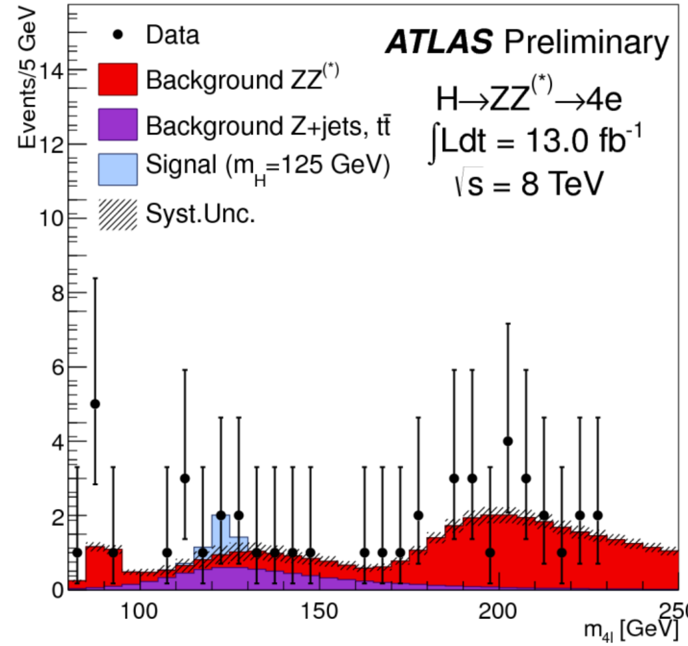
m_{4l} distribution at Z peak for the combined √s = 7 TeV and √s = 8 TeV data (loose selection):

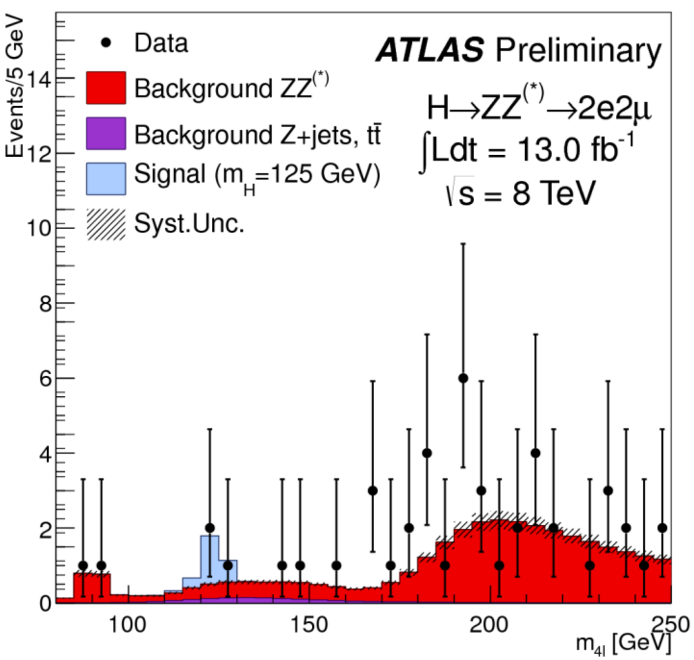


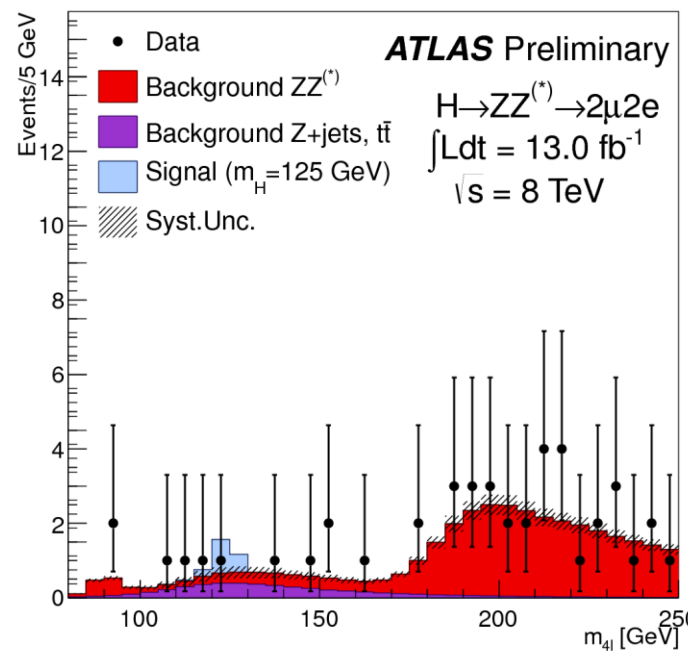
m_{4l} distribution at Z peak for the combined √s = 7 TeV and √s = 8 TeV data (loose selection):

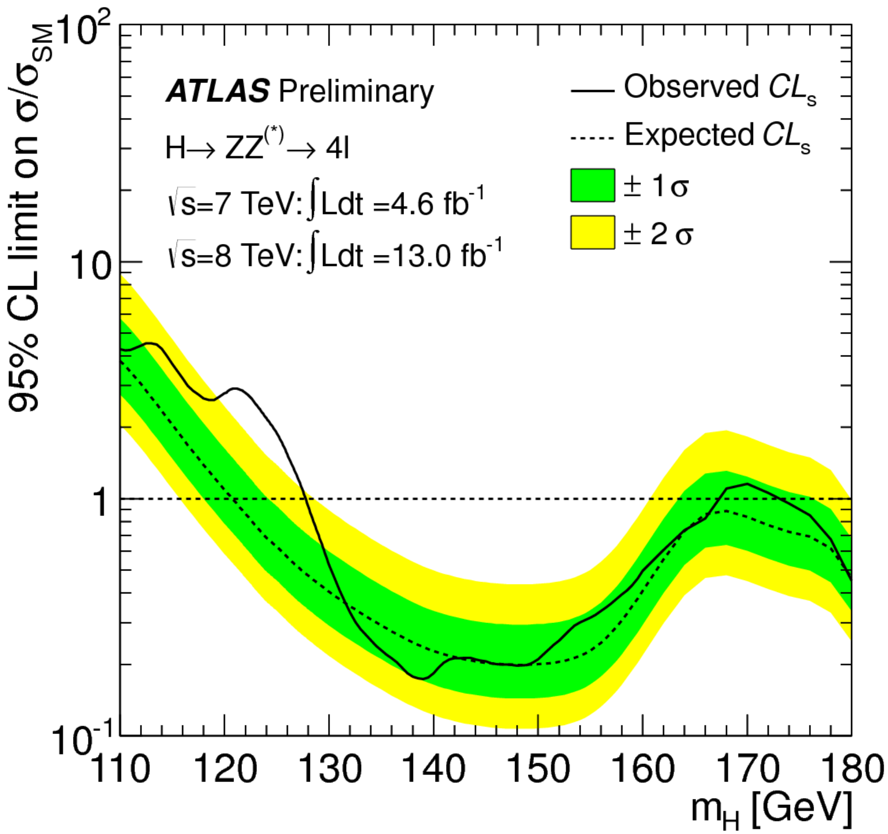



Data
Background ZZ(*)
Background Z+jets, tt̄
Signal (mH=125 GeV)
Syst.Unc.
ATLAS Preliminary
H→ZZ(*)→4μ
∫Ldt = 13.0 fb-1
√s = 8 TeV
Events/5 GeV
m4l [GeV]

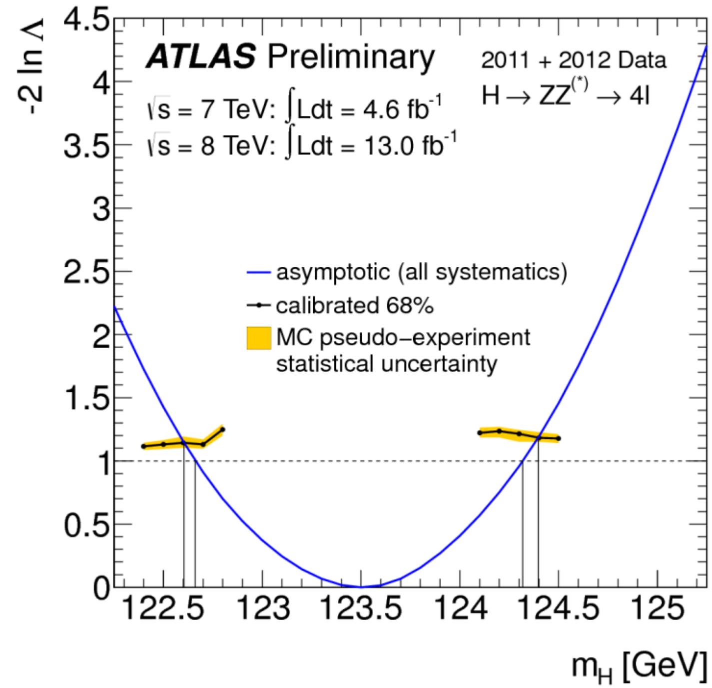

Data
Background ZZ(*)
Background Z+jets, tt̄
Signal (mH=125 GeV)
Syst.Unc.
ATLAS Preliminary
H→ZZ(*)→4e
∫Ldt = 13.0 fb-1
√s = 8 TeV
Events/5 GeV
m4l [GeV]


Data
Background ZZ(*)
Background Z+jets, tt̄
Signal (mH=125 GeV)
Syst.Unc.
ATLAS Preliminary
H→ZZ(*)→2e2μ
∫Ldt = 13.0 fb-1
√s = 8 TeV
Events/5 GeV
m4l [GeV]

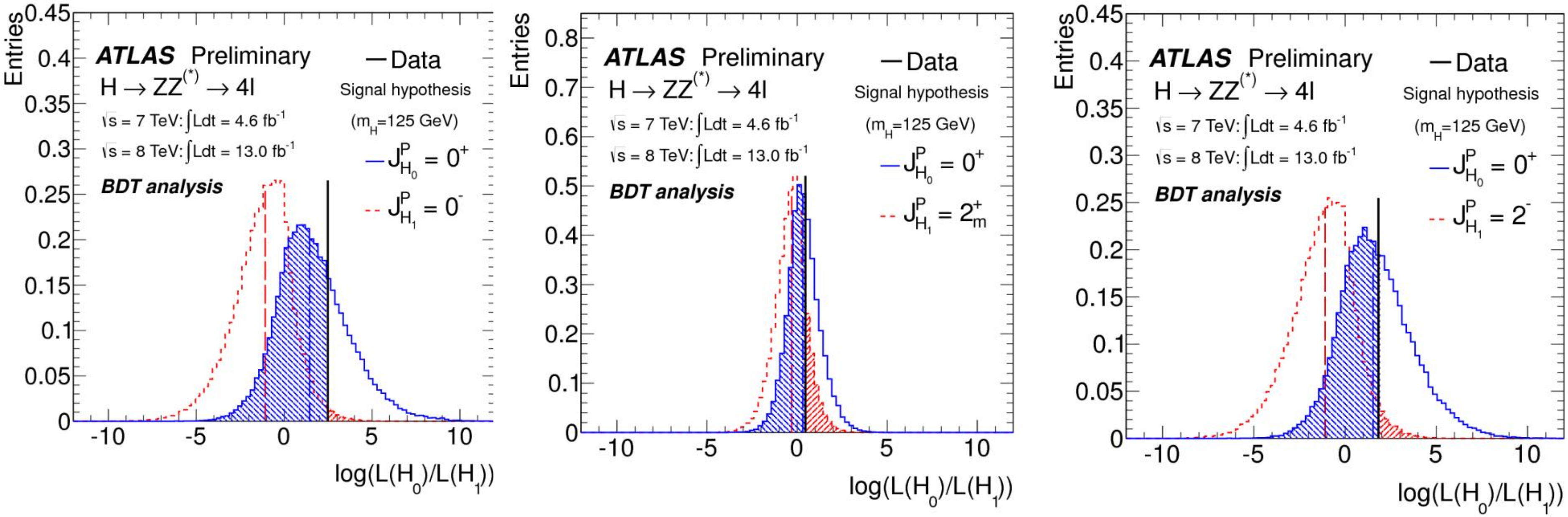

Data
Background ZZ(*)
Background Z+jets, tt̄
Signal (mH=125 GeV)
Syst.Unc.
ATLAS Preliminary
H→ZZ(*)→2μ2e
∫Ldt = 13.0 fb-1
√s = 8 TeV
Events/5 GeV
m4l [GeV]



ATLAS Preliminary
H→ ZZ(*)→ 4l
√s=7 TeV: ∫Ldt =4.6 fb-1
√s=8 TeV: ∫Ldt =13.0 fb-1
Observed CLs
Expected CLs
± 1σ
± 2 σ
95% CL limit on σ/σSM
mH [GeV]



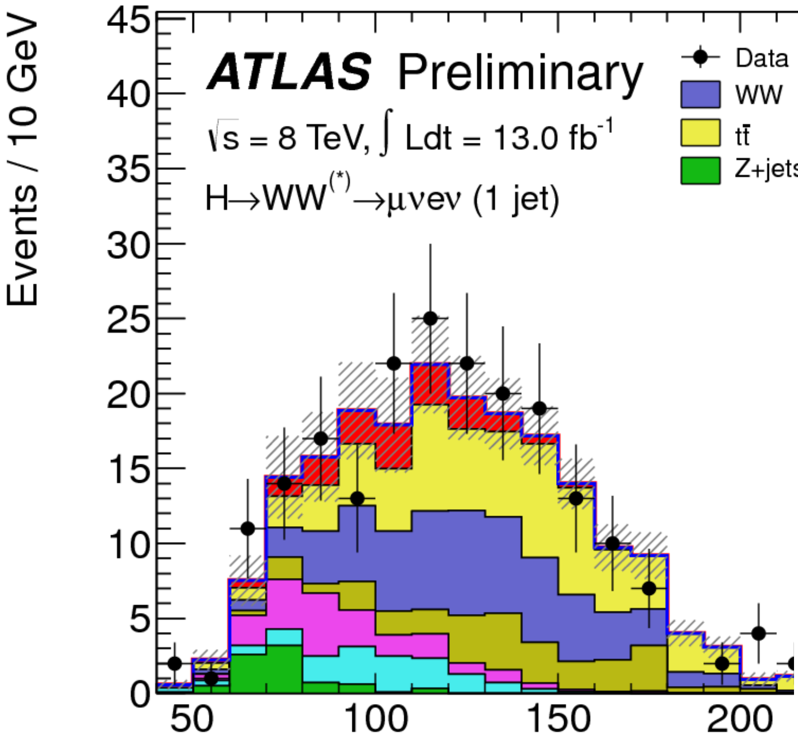
ATLAS Preliminary
2011 + 2012 Data
H → ZZ(*) → 4l
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 13.0 fb-1
asymptotic (all systematics)
calibrated 68%
MC pseudo−experiment statistical uncertainty
-2 ln Λ
mH [GeV]

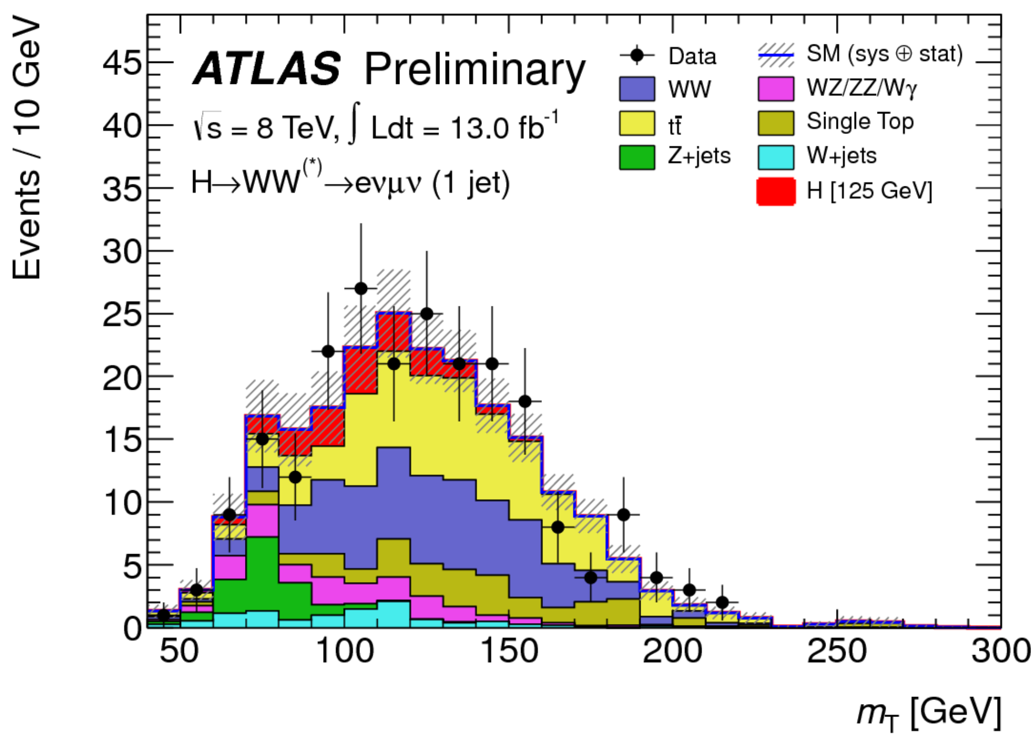


Tested J^P hypotheses for an assumed 0^+									
	0^-			2^+_m			2^-		
	expected	observed	obs 0^+	expected	observed	obs 0^+	expected	observed	obs 0^+
BDT analysis									
p_0-value	0.041	0.011	0.69	0.20	0.16	0.57	0.046	0.029	0.56
σ	1.7	2.3	-0.50	0.84	0.99	-0.18	1.7	1.9	-0.15
J^P-MELA analysis									
p_0-value	0.031	0.0028	0.76	0.18	0.17	0.53	0.04	0.025	0.56
σ	1.9	2.7	-0.72	0.91	0.97	-0.08	1.7	2.0	-0.15

Table 4: The expected numbers of signal and background events after the requirements listed in the first column, as well as the observed numbers of events, are shown for the different signal regions (upper table) and the main control regions (middle table). The signal is shown for $m_H = 125$ GeV. The W+jets background is estimated entirely from data, whereas MC predictions normalised to data in control regions are used for the WW, $t\bar{t}$, $tW/tb/tqb$ and $Z/\gamma^* \to \tau\tau$ processes in all the stages of the selection. Contributions from other diboson background sources are taken entirely from MC predictions. For the middle table, the W+jets contribution is also estimated entirely from data, however no normalisation factors are applied, except that the top normalisation factor is applied for the top background estimate in the WW control regions. The lower table lists the numbers of expected and observed events after the $\Delta\phi_{\ell\ell}$ cut, for both 0-jet and 1-jet events and separately depending on the flavour of the leading lepton. Only statistical uncertainties associated with the numbers of events in the MC samples are shown.

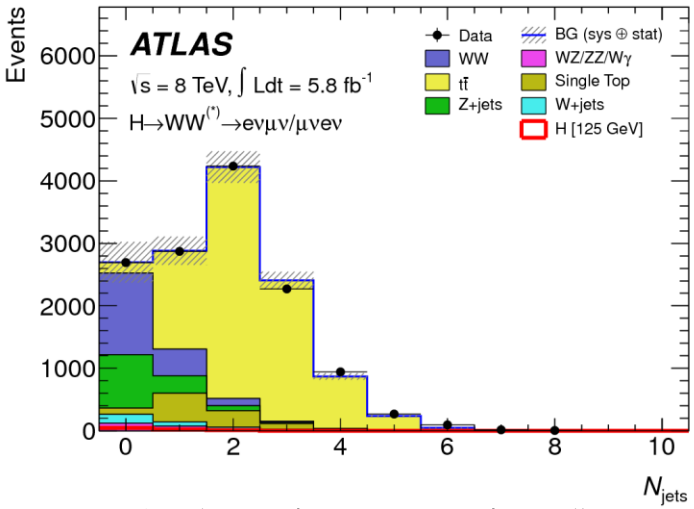
Cutflow evolution in the different signal regions									
H+ 0-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
Jet veto	110 ± 1	3004 ± 12	242 ± 8	387 ± 8	215 ± 8	1575 ± 20	340 ± 5	5762 ± 28	5960
$\Delta\phi_{\ell\ell,E_{\mathrm{T}}^{\mathrm{miss}}} > \pi/2$	108 ± 1	2941 ± 12	232 ± 8	361 ± 8	206 ± 8	1201 ± 21	305 ± 5	5246 ± 28	5230
$p_{\mathrm{T},\ell\ell} > 30$ GeV	99 ± 1	2442 ± 11	188 ± 7	330 ± 7	193 ± 8	57 ± 8	222 ± 3	3433 ± 19	3630
$m_{\ell\ell} < 50$ GeV	78.6 ± 0.8	579 ± 5	69 ± 4	55 ± 3	34 ± 3	11 ± 4	65 ± 2	814 ± 9	947
$\Delta\phi_{\ell\ell} < 1.8$	75.6 ± 0.8	555 ± 5	68 ± 4	54 ± 3	34 ± 3	8 ± 4	56 ± 2	774 ± 9	917
H+ 1-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
One jet	59.5 ± 0.8	850 ± 5	158 ± 7	3451 ± 24	1037 ± 17	505 ± 9	155 ± 5	6155 ± 33	6264
b-jet veto	50.4 ± 0.7	728 ± 5	128 ± 5	862 ± 13	283 ± 10	429 ± 8	126 ± 4	2555 ± 20	2655
$Z \to \tau\tau$ veto	50.1 ± 0.7	708 ± 5	122 ± 5	823 ± 12	268 ± 9	368 ± 8	122 ± 4	2411 ± 19	2511
$m_{\ell\ell} < 50$ GeV	37.7 ± 0.6	130 ± 2	39 ± 2	142 ± 5	55 ± 4	99 ± 3	30 ± 2	495 ± 8	548
$\Delta\phi_{\ell\ell} < 1.8$	34.9 ± 0.6	118 ± 2	35 ± 2	134 ± 5	52 ± 4	22 ± 2	24 ± 1	386 ± 8	433


ATLAS Preliminary
$\sqrt{s}$ = 8 TeV, $\int$ Ldt = 13.0 fb^{-1}
H→WW$^{(*)}$→μνeν (1 jet)
Data
WW
$t\bar{t}$
Z+jets
SM (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
H [125 GeV]
Events / 10 GeV

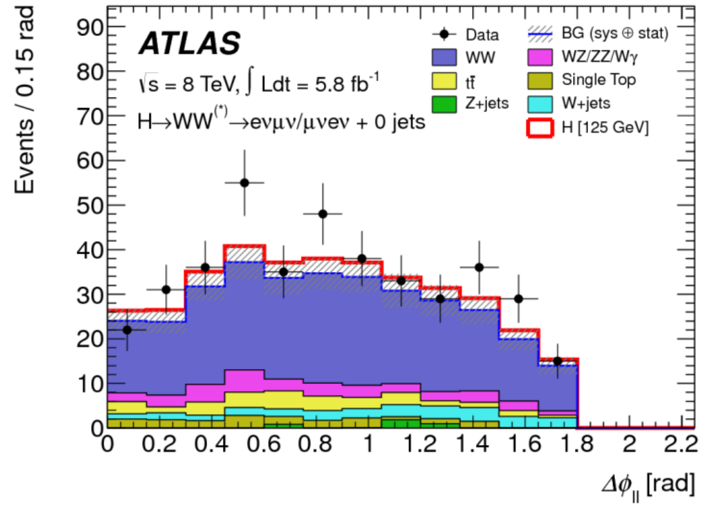

ATLAS Preliminary
$\sqrt{s}$ = 8 TeV, $\int$ Ldt = 13.0 fb^{-1}
H→WW$^{(*)}$→eνμν (1 jet)
Data
WW
$t\bar{t}$
Z+jets
SM (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
H [125 GeV]
Events / 10 GeV
m_T [GeV]

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

multiplicity of jets for events satisfying the dilepton and $E_T^{miss}{}_{rel}$ selection:

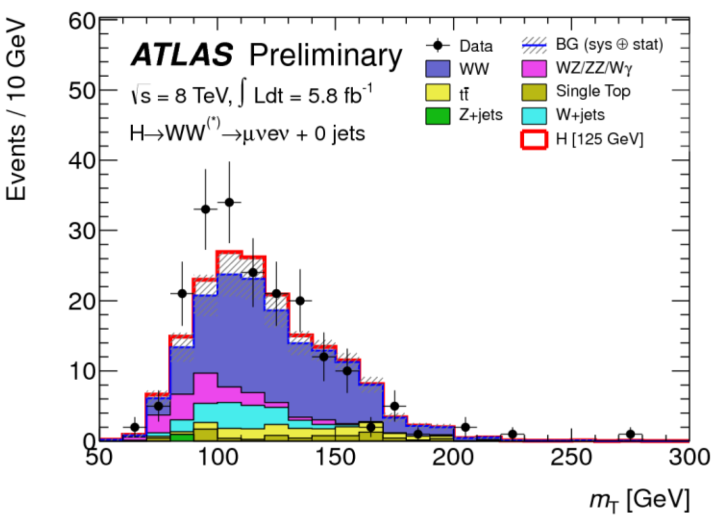


Δφ$_{ll}$ distribution after full event selection:

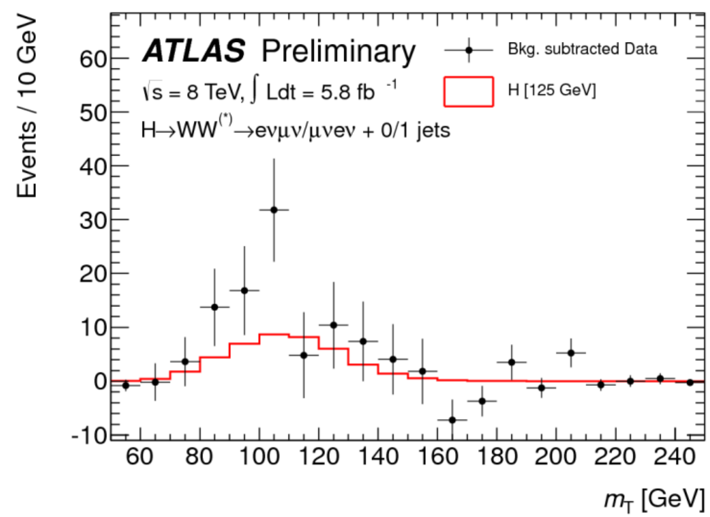


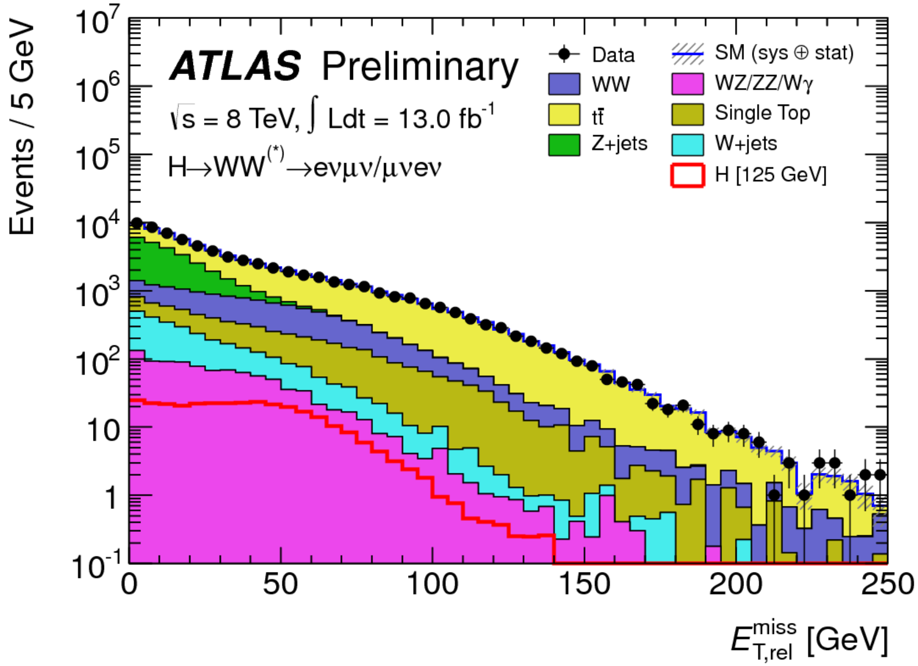
m_T distribution for events satisfying all criteria:

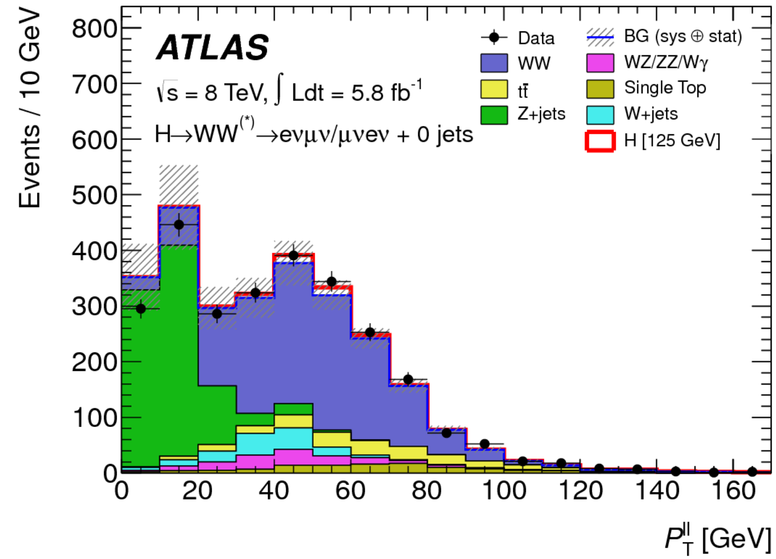
$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - |\mathbf{p}_T^{ll} + \mathbf{E}_T^{miss}|^2}$$

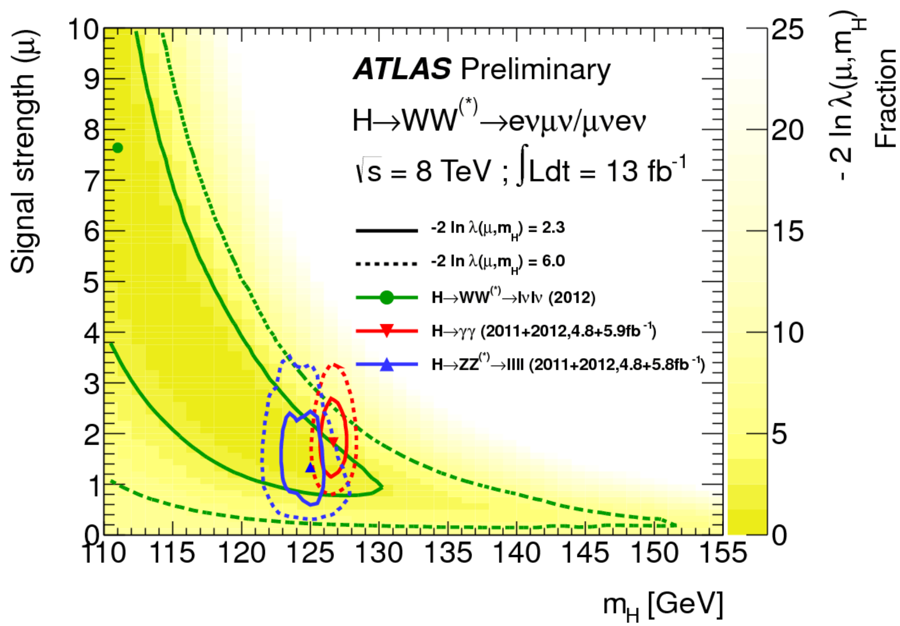


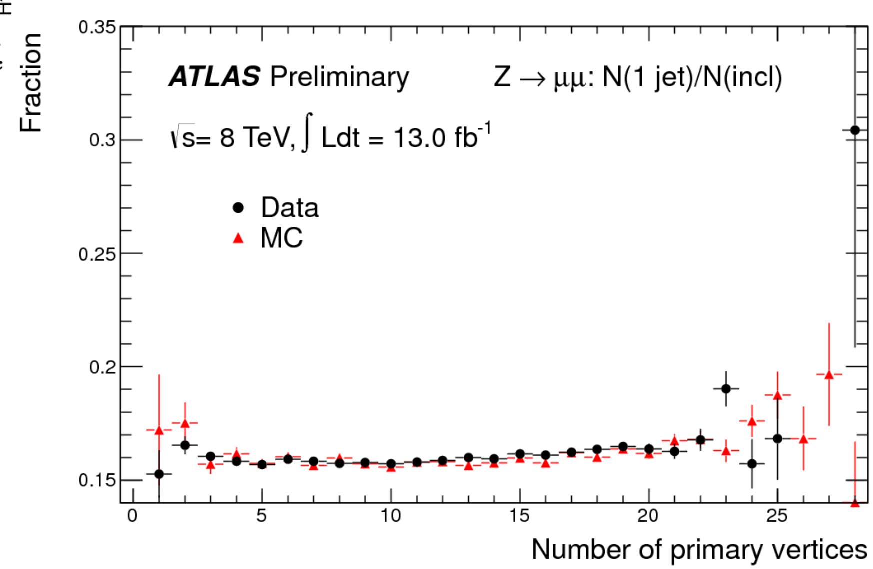
m_T distribution in data with the estimated background subtracted with the predicted signal:




ATLAS Preliminary
√s = 8 TeV, ∫ Ldt = 13.0 fb-1
H→WW(*)→eνμν/μνeν
Data
WW
tt̄
Z+jets
SM (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
H [125 GeV]
Events / 5 GeV
E miss T,rel [GeV]


ATLAS
√s = 8 TeV, ∫ Ldt = 5.8 fb-1
H→WW(*)→eνμν/μνeν + 0 jets
Data
WW
tt̄
Z+jets
BG (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
H [125 GeV]
Events / 10 GeV
P ll T [GeV]


ATLAS Preliminary
H→WW(*)→eνμν/μνeν
√s = 8 TeV ; ∫Ldt = 13 fb-1
-2 ln λ(μ,mH) = 2.3
-2 ln λ(μ,mH) = 6.0
H→WW(*)→lνlν (2012)
H→γγ (2011+2012,4.8+5.9fb-1)
H→ZZ(*)→llll (2011+2012,4.8+5.8fb-1)
Signal strength (μ)
mH [GeV]
- 2 ln λ(μ,mH)


ATLAS Preliminary
Z → μμ: N(1 jet)/N(incl)
√s= 8 TeV, ∫ Ldt = 13.0 fb-1
Data
MC
Fraction
Number of primary vertices

H → WW$^{(*)}$ → lν lν

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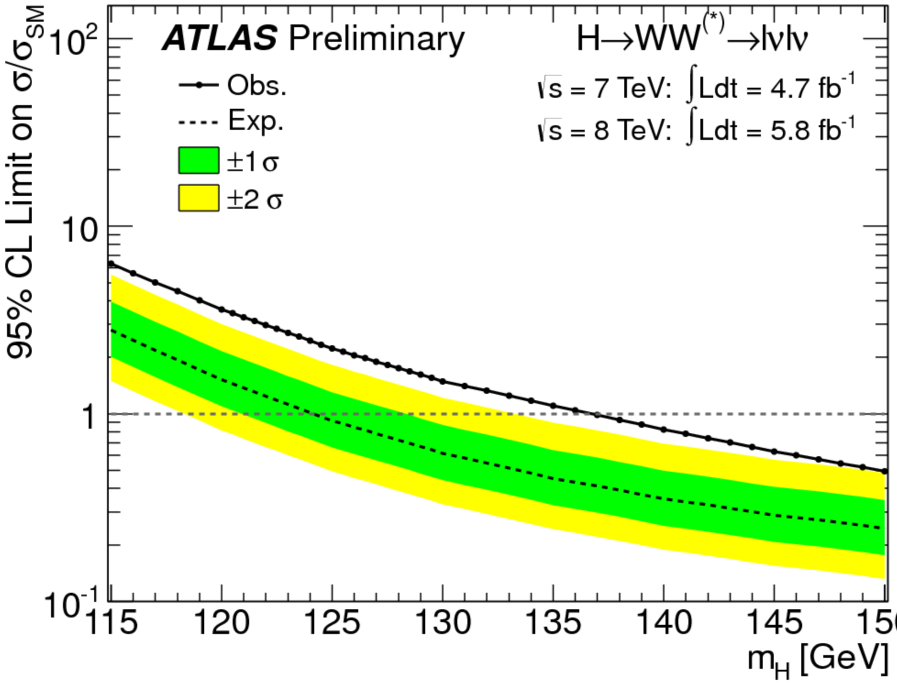
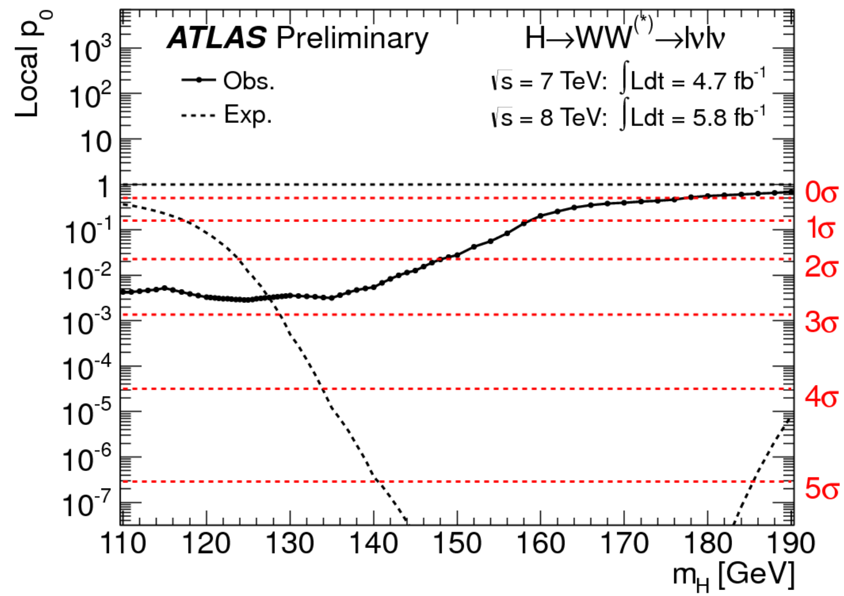
Observed and expected CLs limit on the normalized signal strength vs Higgs mass:



Observed and expected p-value vs Higgs mass:



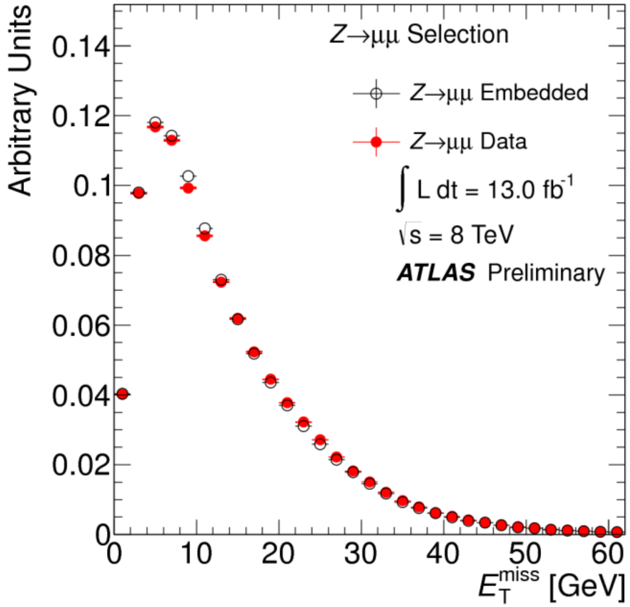
Higgs to WW (July 2012):

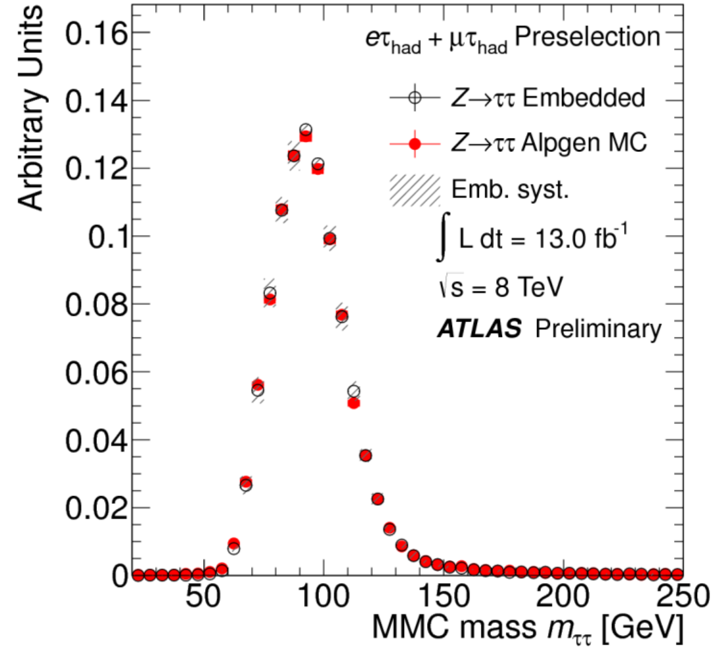
- The SM Higgs boson is excluded at 95% CL: 137-261 GeV c^{-2} (exp 124-233 GeV c^{-2});
- Observed p_0 ~ 2.8 standard deviation (exp 2.3) @ m_H = 125 GeV c^{-2};
- Signal strength μ = 1.3 +/- 0.5.

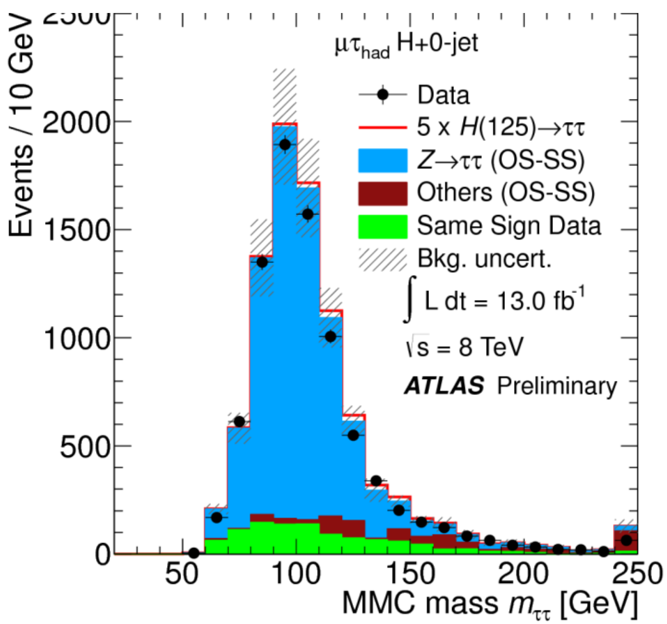
Table 3: Event requirements applied in the different categories of the $H \to \tau_{\rm lep}\tau_{\rm had}$ analysis. Requirements marked with a triangle (▹) are categorization requirements, meaning that if an event fails that requirement it is still considered for the remaining categories. Requirements marked with a bullet (•) are only applied to events passing all categorization requirements in a category; events failing such requirements are discarded.

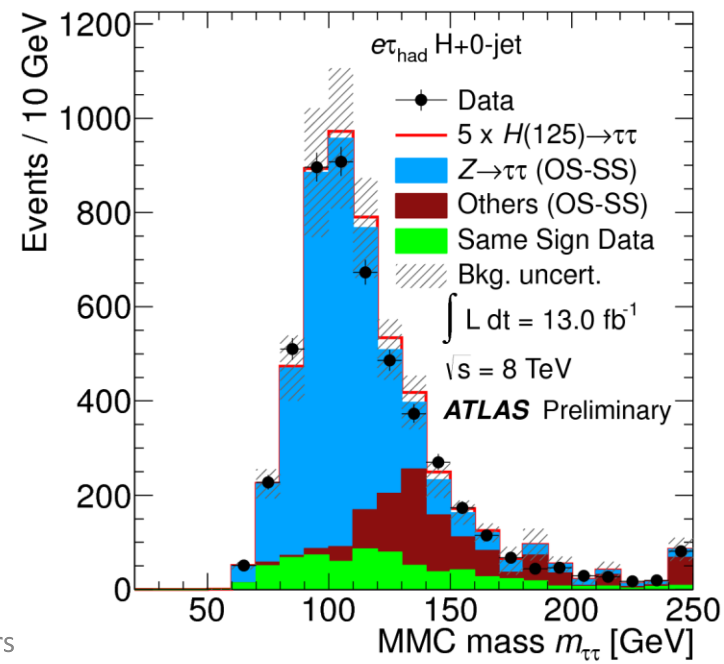
7 TeV		8 TeV	
VBF Category	**Boosted Category**	**VBF Category**	**Boosted Category**
▹ $p_{\rm T}{}^{\tau_{\rm had\text{-}vis}}$ >30 GeV	–	▹ $p_{\rm T}{}^{\tau_{\rm had\text{-}vis}}$ >30 GeV	▹ $p_{\rm T}{}^{\tau_{\rm had\text{-}vis}}$ >30 GeV
▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV
▹ ≥ 2 jets	▹ $p_{\rm T}^{\rm H} > 100$ GeV	▹ ≥ 2 jets	▹ $p_{\rm T}^{\rm H} > 100$ GeV
▹ $p_{\rm T}{}^{j1}, p_{\rm T}{}^{j2} > 40$ GeV	▹ $0 < x_1 < 1$	▹ $p_{\rm T}{}^{j1} > 40$, $p_{\rm T}{}^{j2}$ >30 GeV	▹ $0 < x_1 < 1$
▹ $\Delta\eta_{jj} > 3.0$	▹ $0.2 < x_2 < 1.2$	▹ $\Delta\eta_{jj} > 3.0$	▹ $0.2 < x_2 < 1.2$
▹ $m_{jj} > 500$ GeV	▹ Fails VBF	▹ $m_{jj} > 500$ GeV	▹ Fails VBF
▹ centrality req.	–	▹ centrality req.	–
▹ $\eta_{j1} \times \eta_{j2} < 0$	–	▹ $\eta_{j1} \times \eta_{j2} < 0$	–
▹ $p_{\rm T}{}^{\rm Total} < 40$ GeV	–	▹ $p_{\rm T}{}^{\rm Total} < 30$ GeV	–
–	–	▹ $p_{\rm T}{}^{\ell}$ >26 GeV	–
• $m_{\rm T}$ <50 GeV	• $m_{\rm T}$ <50 GeV	• $m_{\rm T}$ <50 GeV	• $m_{\rm T}$ <50 GeV
• $\Delta(\Delta R) < 0.8$	• $\Delta(\Delta R) < 0.8$	• $\Delta(\Delta R) < 0.8$	• $\Delta(\Delta R) < 0.8$
• $\sum \Delta\phi < 3.5$	• $\sum \Delta\phi < 1.6$	• $\sum \Delta\phi < 2.8$	–
–	–	• b-tagged jet veto	• b-tagged jet veto
1 Jet Category	**0 Jet Category**	**1 Jet Category**	**0 Jet Category**
▹ ≥ 1 jet, $p_{\rm T}$ >25 GeV	▹ 0 jets $p_{\rm T}$ >25 GeV	▹ ≥ 1 jet, $p_{\rm T}$ >30 GeV	▹ 0 jets $p_{\rm T}$ >30 GeV
▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV	▹ $E_{\rm T}^{\rm miss}$ >20 GeV
▹ Fails VBF, Boosted	▹ Fails Boosted	▹ Fails VBF, Boosted	▹ Fails Boosted
• $m_{\rm T}$ <50 GeV	• $m_{\rm T}$ <30 GeV	• $m_{\rm T}$ <50 GeV	• $m_{\rm T}$ <30 GeV
• $\Delta(\Delta R) < 0.6$	• $\Delta(\Delta R) < 0.5$	• $\Delta(\Delta R) < 0.6$	• $\Delta(\Delta R) < 0.5$
• $\sum \Delta\phi < 3.5$	• $\sum \Delta\phi < 3.5$	• $\sum \Delta\phi < 3.5$	• $\sum \Delta\phi < 3.5$
–	• $p_{\rm T}^{\ell} - p_{\rm T}^{\tau} < 0$	–	• $p_{\rm T}^{\ell} - p_{\rm T}^{\tau} < 0$

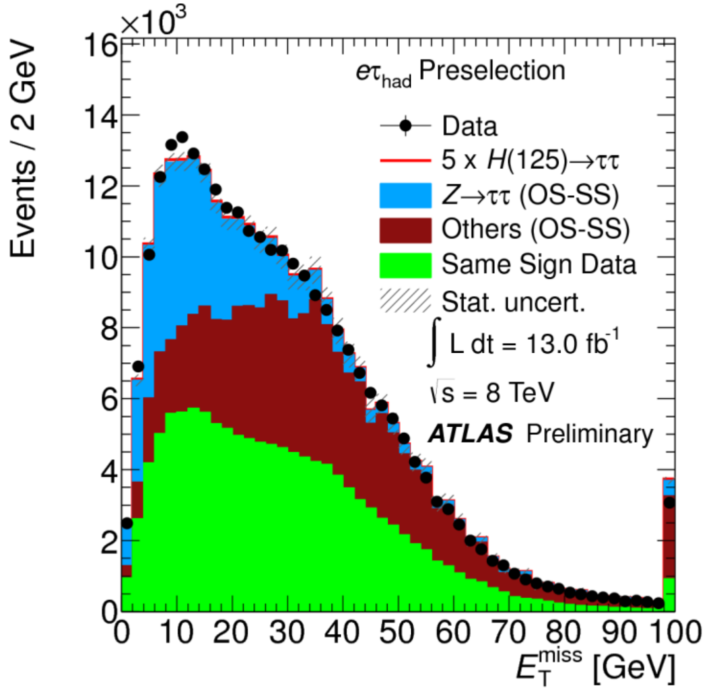
E_T^{miss} distributions for the $Z \rightarrow \mu\mu$ data before and after muon embedding:

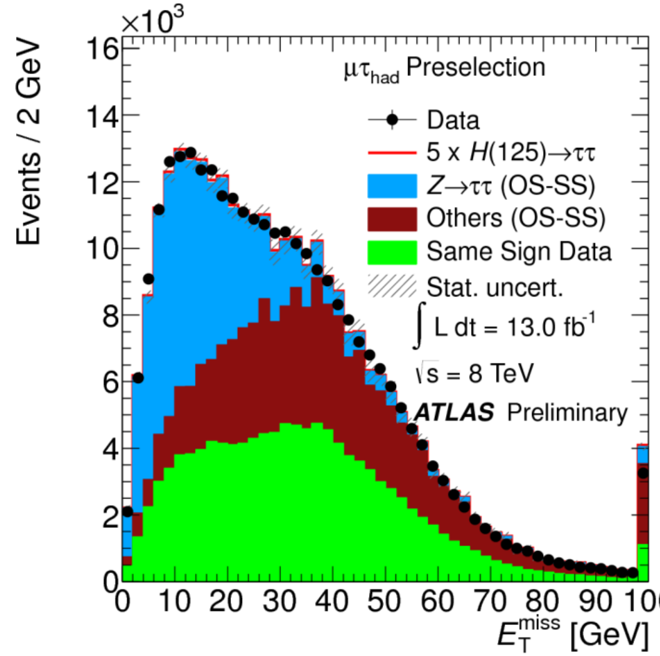









$\times 10^3$
Events / 2 GeV
$e\tau_{had}$ Preselection
Data
5 x $H(125)\to\tau\tau$
$Z\to\tau\tau$ (OS-SS)
Others (OS-SS)
Same Sign Data
Stat. uncert.
$\int L\,dt = 13.0\ fb^{-1}$
$\sqrt{s}$ = 8 TeV
ATLAS Preliminary
E_T^{miss} [GeV]


$\times 10^3$
Events / 2 GeV
$\mu\tau_{had}$ Preselection
Data
5 x $H(125)\to\tau\tau$
$Z\to\tau\tau$ (OS-SS)
Others (OS-SS)
Same Sign Data
Stat. uncert.
$\int L\,dt = 13.0\ fb^{-1}$
$\sqrt{s}$ = 8 TeV
ATLAS Preliminary
E_T^{miss} [GeV]

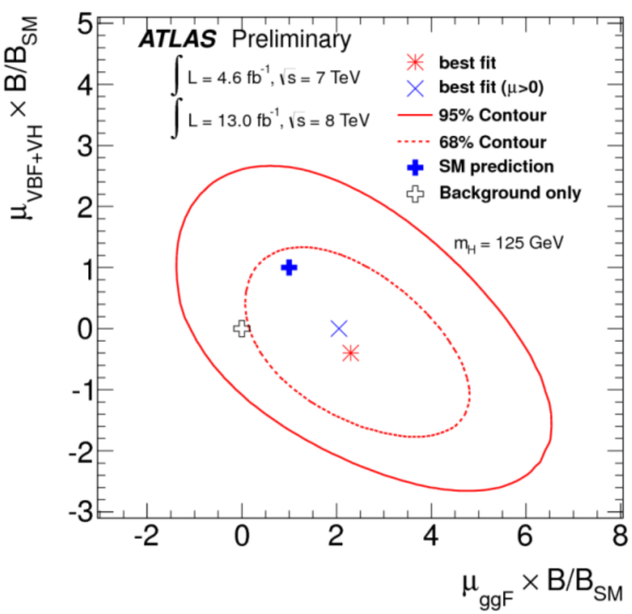
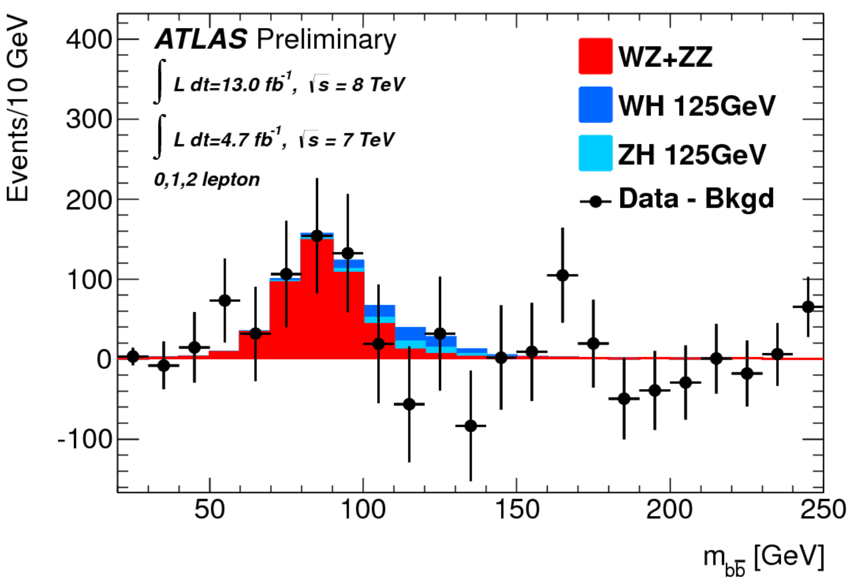
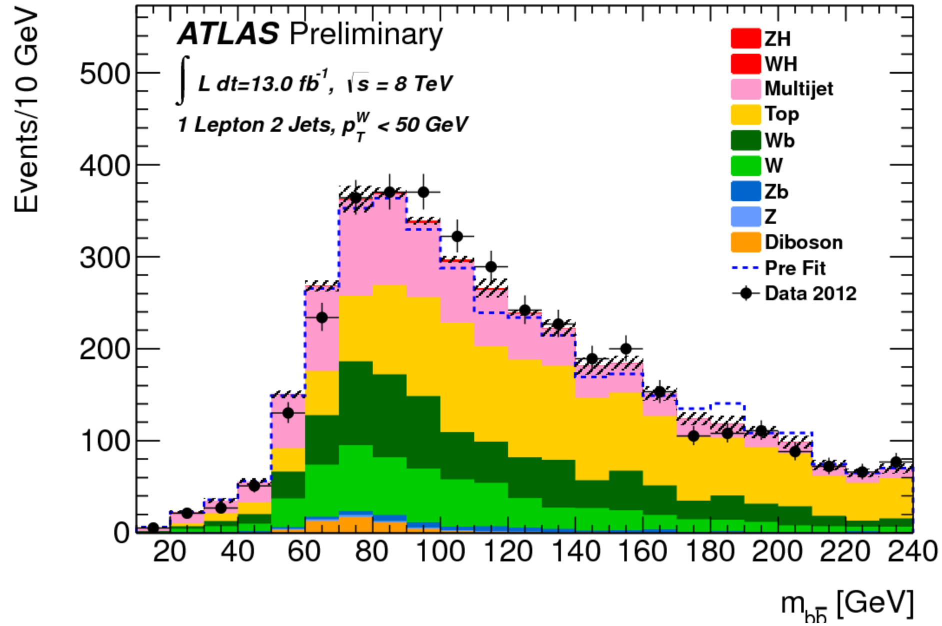
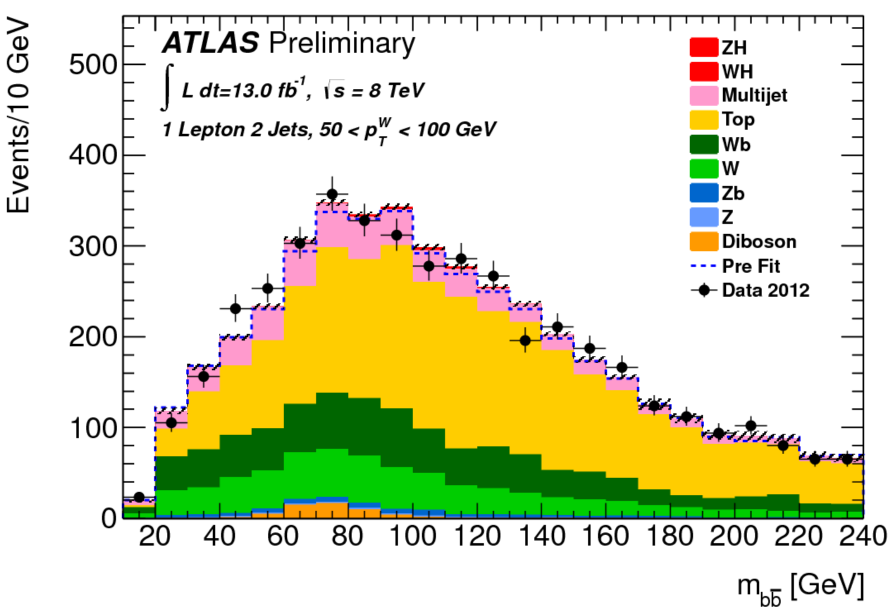

ATLAS Preliminary
$\int L = 4.6\ fb^{-1}$, $\sqrt{s}$ = 7 TeV
$\int L = 13.0\ fb^{-1}$, $\sqrt{s}$ = 8 TeV
best fit
best fit (μ>0)
95% Contour
68% Contour
SM prediction
Background only
m_H = 125 GeV
$\mu_{VBF+VH} \times B/B_{SM}$
$\mu_{ggF} \times B/B_{SM}$

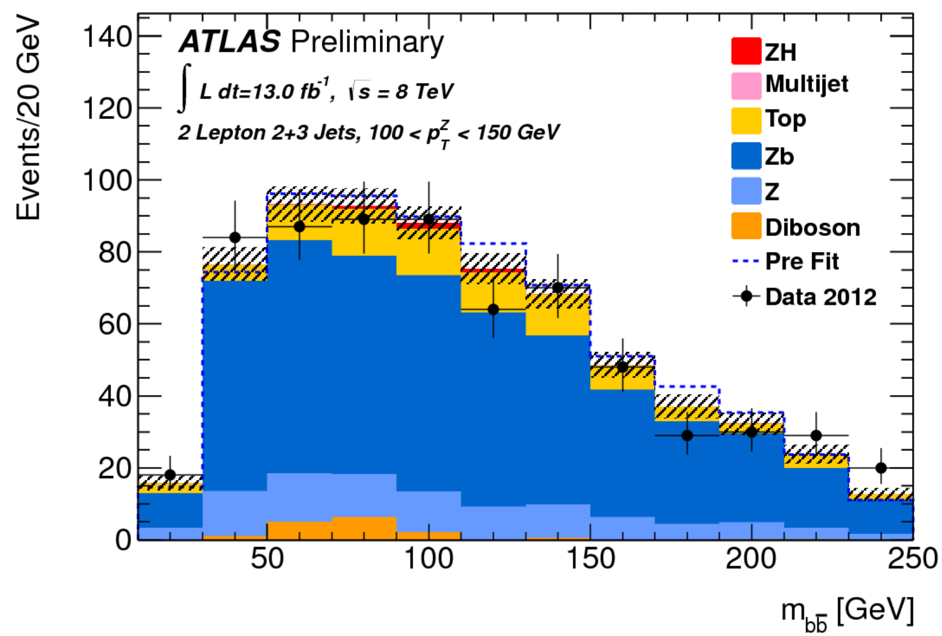
Table 6: The expected numbers of signal and background events for the $\sqrt{s}$ = 8 TeV data after the profile likelihood fit, as well as the observed number of events, are shown. The expected number of signal events are shown for WH and ZH production separately for m_H = 125 GeV. The quoted error on the total background represents one standard deviation of the profiled nuisance parameters incorporating both the systematic and statistical uncertainties.

	0-lepton, 2 jet			0-lepton, 3 jet			1-lepton					2-lepton				
Bin	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]						p_{T}^{W}[GeV]					p_{T}^{Z}[GeV]				
	120-160	160-200	>200	120-160	160-200	>200	0-50	50-100	100-150	150-200	> 200	0-50	50-100	100-150	150-200	>200
ZH	2.9	2.1	2.6	0.8	0.8	1.1	0.3	0.4	0.1	0.0	0.0	4.7	6.8	4.0	1.5	1.4
WH	0.8	0.4	0.4	0.2	0.2	0.2	10.6	12.9	7.5	3.6	3.6	0.0	0.0	0.0	0.0	0.0
Top	89	25	8	92	25	10	1440	2276	1120	147	43	230	310	84	3	0
$W + c$,light	30	10	5	9	3	2	580	585	209	36	17	0	0	0	0	0
$W + b$	35	13	13	8	3	2	770	778	288	77	64	0	0	0	0	0
$Z + c$,light	35	14	14	8	5	8	17	17	4	1	0	201	230	91	12	15
$Z + b$	144	51	43	41	22	16	50	63	13	5	1	1010	1180	469	75	51
Diboson	23	11	10	4	4	3	53	59	23	13	7	37	39	16	6	4
Multijet	3	1	1	1	1	0	890	522	68	14	3	12	3	0	0	0
Total Bkg.	361 ± 29	127 ± 11	98 ± 12	164 ± 13	63 ± 8	42 ± 5	3810 ± 150	4310 ± 86	1730 ± 90	297 ± 27	138 ± 14	1500 ± 90	1770 ± 110	665 ± 47	97 ± 12	72 ± 12
Data	342	131	90	175	65	32	3821	4301	1697	297	132	1485	1773	657	100	69


ATLAS Preliminary
∫ L dt=13.0 fb-1, √s = 8 TeV
∫ L dt=4.7 fb-1, √s = 7 TeV
0,1,2 lepton
WZ+ZZ
WH 125GeV
ZH 125GeV
Data - Bkgd
Events/10 GeV
m_bb̄ [GeV]


ATLAS Preliminary
∫ L dt=13.0 fb-1, √s = 8 TeV
1 Lepton 2 Jets, p_T^W < 50 GeV
ZH
WH
Multijet
Top
Wb
W
Zb
Z
Diboson
Pre Fit
Data 2012
Events/10 GeV
m_bb̄ [GeV]


ATLAS Preliminary
∫ L dt=13.0 fb-1, √s = 8 TeV
1 Lepton 2 Jets, 50 < p_T^W < 100 GeV
ZH
WH
Multijet
Top
Wb
W
Zb
Z
Diboson
Pre Fit
Data 2012
Events/10 GeV
m_bb̄ [GeV]


ATLAS Preliminary
∫ L dt=13.0 fb-1, √s = 8 TeV
2 Lepton 2+3 Jets, 100 < p_T^Z < 150 GeV
ZH
Multijet
Top
Zb
Z
Diboson
Pre Fit
Data 2012
Events/20 GeV
m_bb̄ [GeV]

H→γγ and H→ZZ*→4l masses

Mass scale and resolution uncertainties cross checked in great detail for both channels (more details in the backup)

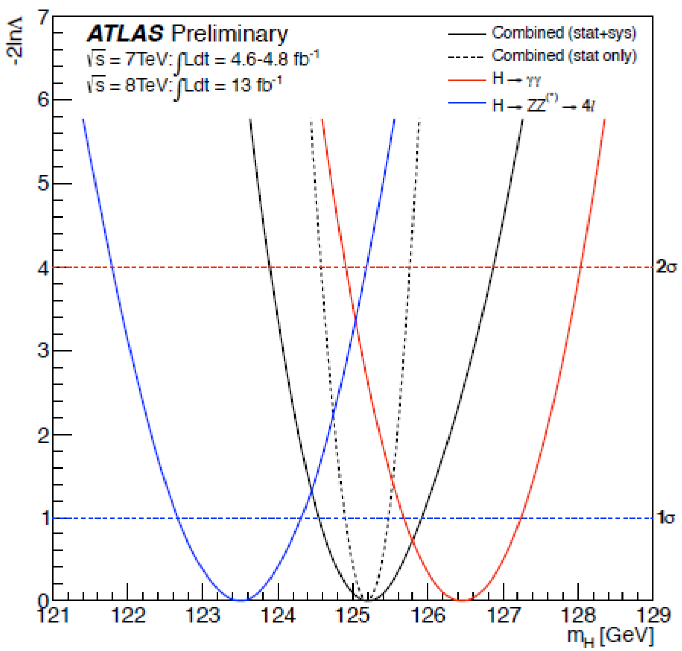
- γγ error dominated by systematics, mainly photon energy scale (total syst. 0.5%, stat error is 0.3%)

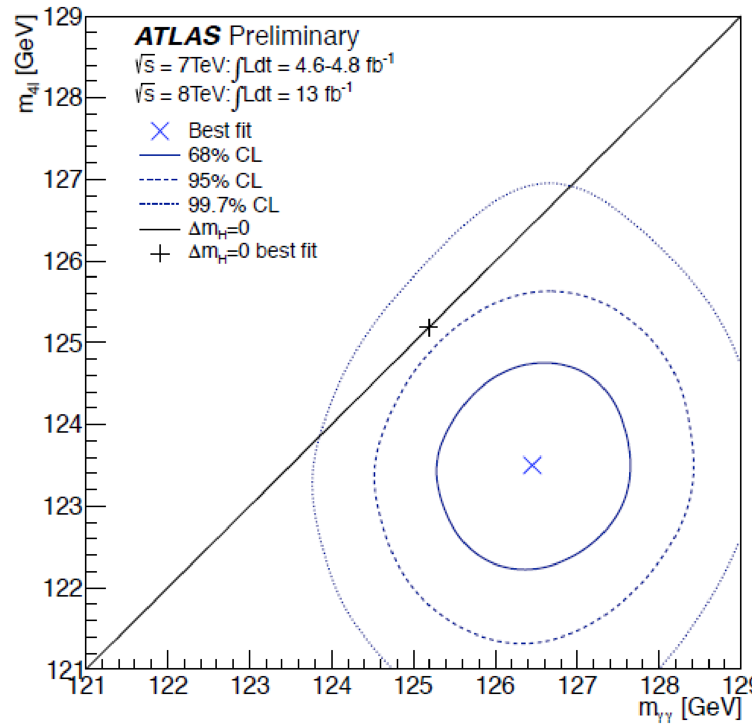
- H→ZZ*→4l: error dominated by statistics, most of the sensitivity is coming from the 4μ channel (total syst is 0.3%, stat error is 0.7%)

Measurements consistency is evaluated via a likelihood function of the mass difference, when fitting a common mass

The difference corresponds to 2.7 σ

A more conservative treatment of scale systematics (rectangular PDFs) leads to 2.3 σ





H→γγ mass systematic uncertainties

Absolute energy scale	0.3%
Uncertainties on upstream material simulation	0.3%
Pre-sampler energy scale	0.1%
Non-linearity of EM calo electronics	0.15%
Conversion fraction	0.1%
Relative calibration of first and second sampling	0.2%
Lateral leakage corrections	0.1%
Resolution	0.15%

+other smaller effects
Total systematic error is 0.55%   (0.7 GeV)

4l mass measurement
dominated by the 4μ channel

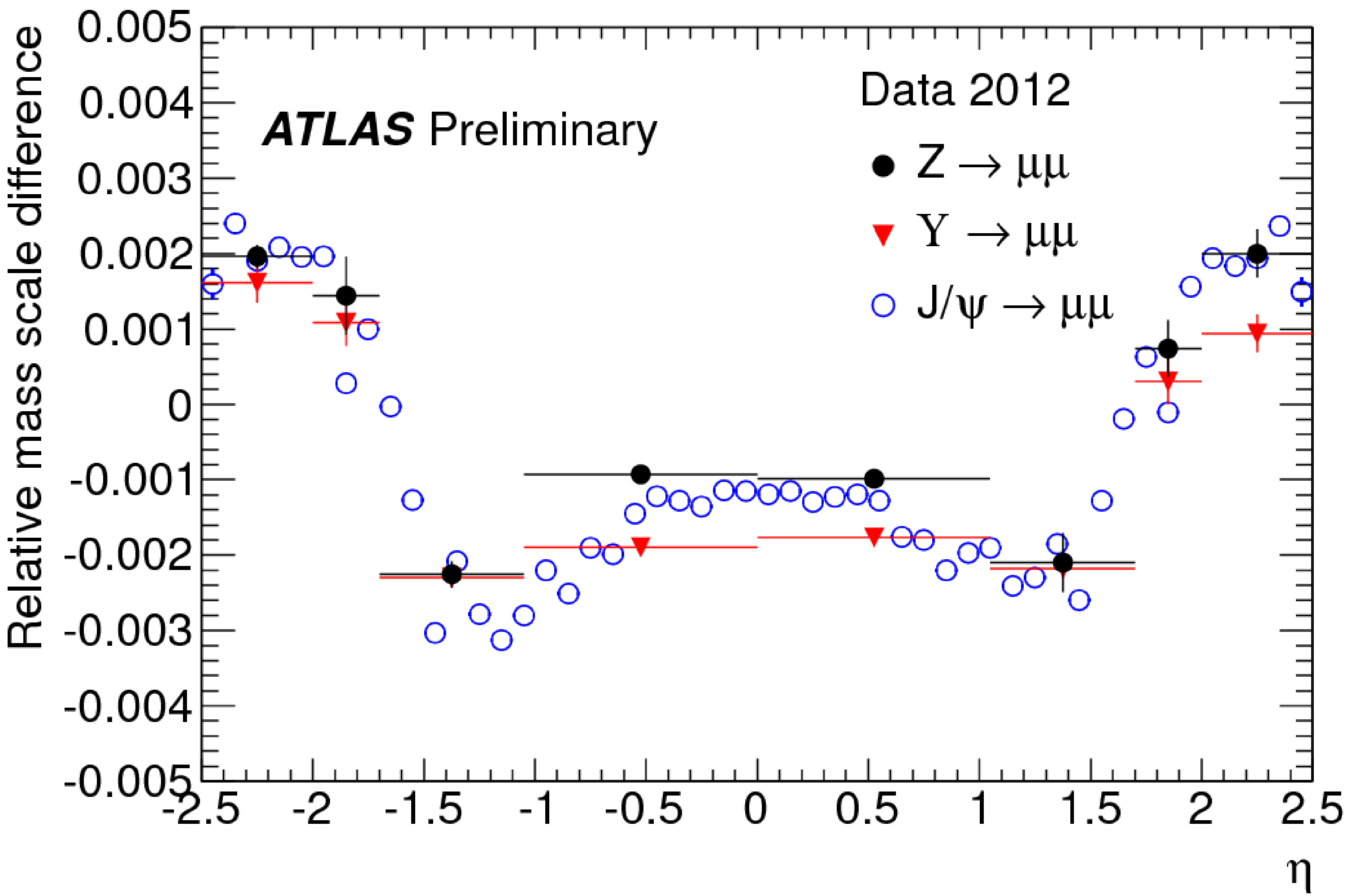
Muon momentum scale	0.2%
Electron energy scale (4e)	0.4%
Low E_T electrons	0.1%

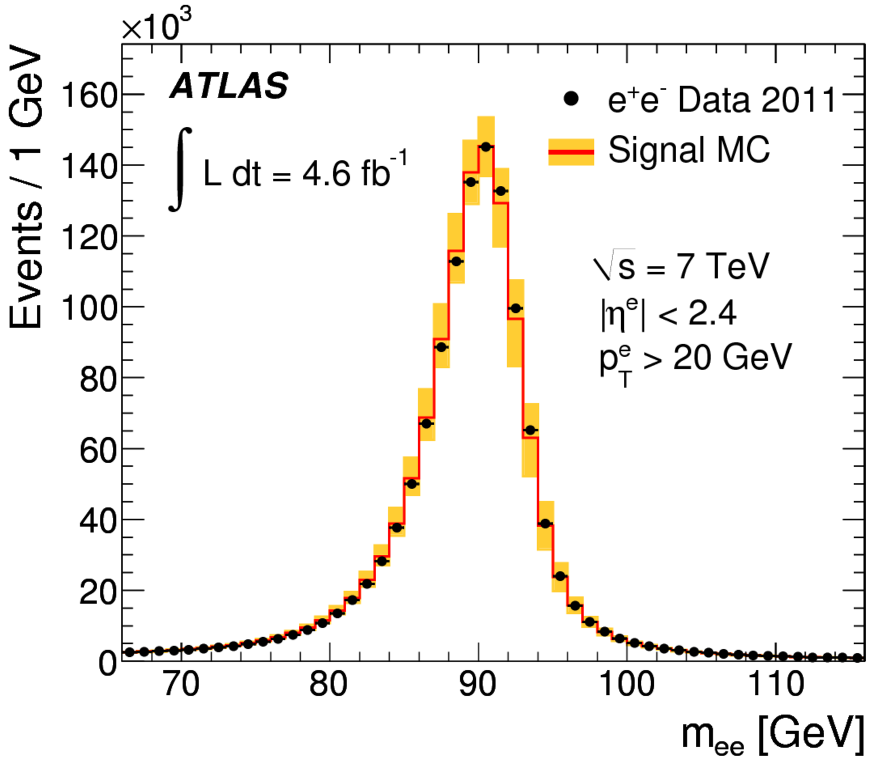
Possible local detector biases checked event by event

FSR contribution negligible

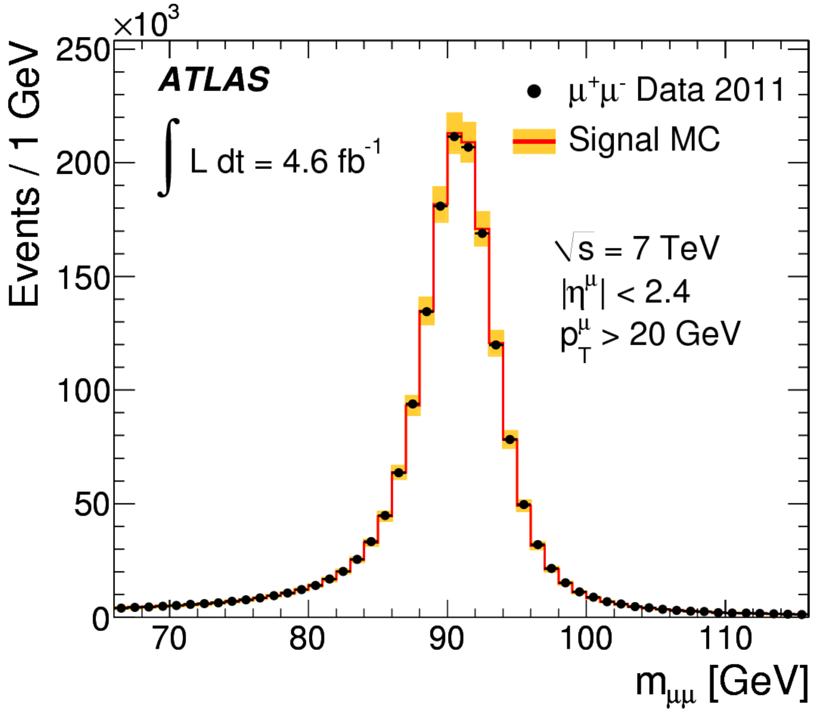
ID and MS measurements also checked separately

Relative global mass scale difference between the measured resonance mass and the PDG value





$\times 10^3$
Events / 1 GeV
ATLAS
$\int L\,dt = 4.6\ fb^{-1}$
e^+e^- Data 2011
Signal MC
$\sqrt{s} = 7$ TeV
$|\eta^e| < 2.4$
$p_T^e > 20$ GeV
0
20
40
60
80
100
120
140
160
70
80
90
100
110
m_{ee} [GeV]



$\times 10^3$
Events / 1 GeV
ATLAS
$\int L\,dt = 4.6\ fb^{-1}$
$\mu^+\mu^-$ Data 2011
Signal MC
$\sqrt{s} = 7$ TeV
$|\eta^\mu| < 2.4$
$p_T^\mu > 20$ GeV
0
50
100
150
200
250
70
80
90
100
110
$m_{\mu\mu}$ [GeV]

Production modes

$$\frac{\sigma_{ggH}}{\sigma_{ggH}^{SM}} = \begin{cases} \kappa_g^2(\kappa_b, \kappa_t, m_H) \\ \kappa_g^2 \end{cases} \quad (3)$$

$$\frac{\sigma_{VBF}}{\sigma_{VBF}^{SM}} = \kappa_{VBF}^2(\kappa_W, \kappa_Z, m_H) \quad (4)$$

$$\frac{\sigma_{WH}}{\sigma_{WH}^{SM}} = \kappa_W^2 \quad (5)$$

$$\frac{\sigma_{ZH}}{\sigma_{ZH}^{SM}} = \kappa_Z^2 \quad (6)$$

$$\frac{\sigma_{t\bar{t}H}}{\sigma_{t\bar{t}H}^{SM}} = \kappa_t^2 \quad (7)$$

Detectable decay modes

$$\frac{\Gamma_{WW^{(*)}}}{\Gamma_{WW^{(*)}}^{SM}} = \kappa_W^2$$

$$\frac{\Gamma_{ZZ^{(*)}}}{\Gamma_{ZZ^{(*)}}^{SM}} = \kappa_Z^2$$

$$\frac{\Gamma_{b\bar{b}}}{\Gamma_{b\bar{b}}^{SM}} = \kappa_b^2$$

$$\frac{\Gamma_{\tau^-\tau^+}}{\Gamma_{\tau^-\tau^+}^{SM}} = \kappa_\tau^2$$

$$\frac{\Gamma_{\gamma\gamma}}{\Gamma_{\gamma\gamma}^{SM}} = \begin{cases} \kappa_\gamma^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_\gamma^2 \end{cases}$$

$$\frac{\Gamma_{Z\gamma}}{\Gamma_{Z\gamma}^{SM}} = \begin{cases} \kappa_{(Z\gamma)}^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_{(Z\gamma)}^2 \end{cases}$$

Currently undetectable decay modes

$$\frac{\Gamma_{t\bar{t}}}{\Gamma_{t\bar{t}}^{SM}} = \kappa_t^2$$

$$\frac{\Gamma_{gg}}{\Gamma_{gg}^{SM}} \; : \; \text{see Section 3.1.2}$$

$$\frac{\Gamma_{c\bar{c}}}{\Gamma_{c\bar{c}}^{SM}} = \kappa_t^2$$

$$\frac{\Gamma_{s\bar{s}}}{\Gamma_{s\bar{s}}^{SM}} = \kappa_b^2$$

$$\frac{\Gamma_{\mu^-\mu^+}}{\Gamma_{\mu^-\mu^+}^{SM}} = \kappa_\tau^2$$

Total width

$$\frac{\Gamma_H}{\Gamma_H^{SM}} = \begin{cases} \kappa_H^2(\kappa_i, m_H) \\ \kappa_H^2 \end{cases}$$

Boson and fermion scaling assuming no invisible or undetectable widths

Free parameters: $\kappa_V(=\kappa_W=\kappa_Z), \kappa_f(=\kappa_t=\kappa_b=\kappa_\tau)$.

	$H\to\gamma\gamma$	$H\to ZZ^{(*)}$	$H\to WW^{(*)}$	$H\to b\bar{b}$	$H\to\tau^-\tau^+$
ggH, $t\bar{t}H$	$\frac{\kappa_f^2\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_f^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_f^2\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	
VBF, WH, ZH	$\frac{\kappa_V^2\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_V^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_V^2\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	

Boson and fermion scaling without assumptions on the total width

Free parameters: $\kappa_{VV}(=\kappa_V\cdot\kappa_V/\kappa_H), \lambda_{fV}(=\kappa_f/\kappa_V)$.

	$H\to\gamma\gamma$	$H\to ZZ^{(*)}$	$H\to WW^{(*)}$	$H\to b\bar{b}$	$H\to\tau^-\tau^+$
ggH, $t\bar{t}H$	$\kappa_{VV}^2\cdot\lambda_{fV}^2\cdot\kappa_\gamma^2(\lambda_{fV},\lambda_{fV},\lambda_{fV},1)$	$\kappa_{VV}^2\cdot\lambda_{fV}^2$		$\kappa_{VV}^2\cdot\lambda_{fV}^2\cdot\lambda_{fV}^2$	
VBF, WH, ZH	$\kappa_{VV}^2\cdot\kappa_\gamma^2(\lambda_{fV},\lambda_{fV},\lambda_{fV},1)$	κ_{VV}^2		$\kappa_{VV}^2\cdot\lambda_{fV}^2$	

$$\kappa_i^2=\Gamma_{ii}/\Gamma_{ii}^{SM}$$

Probing custodial symmetry assuming no invisible or undetectable widths

Free parameters: $\kappa_Z, \lambda_{WZ}(=\kappa_W/\kappa_Z), \kappa_f(=\kappa_t=\kappa_b=\kappa_\tau)$.

	$H\to\gamma\gamma$	$H\to ZZ^{(*)}$	$H\to WW^{(*)}$	$H\to b\bar{b}$	$H\to\tau^-\tau^+$
ggH, $t\bar{t}H$	$\frac{\kappa_f^2\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_Z\lambda_{WZ})}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_f^2\cdot\kappa_Z^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_f^2\cdot(\kappa_Z\lambda_{WZ})^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_f^2\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	
VBF	$\frac{\kappa_{VBF}^2(\kappa_Z,\kappa_Z\lambda_{WZ})\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_Z\lambda_{WZ})}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_{VBF}^2(\kappa_Z,\kappa_Z\lambda_{WZ})\cdot\kappa_Z^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_{VBF}^2(\kappa_Z,\kappa_Z\lambda_{WZ})\cdot(\kappa_Z\lambda_{WZ})^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_{VBF}^2(\kappa_Z,\kappa_Z\lambda_{WZ})\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	
WH	$\frac{(\kappa_Z\lambda_{WZ})^2\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_Z\lambda_{WZ})}{\kappa_H^2(\kappa_i)}$	$\frac{(\kappa_Z\lambda_{WZ})^2\cdot\kappa_Z^2}{\kappa_H^2(\kappa_i)}$	$\frac{(\kappa_Z\lambda_{WZ})^2\cdot(\kappa_Z\lambda_{WZ})^2}{\kappa_H^2(\kappa_i)}$	$\frac{(\kappa_Z\lambda_{WZ})^2\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	
ZH	$\frac{\kappa_Z^2\cdot\kappa_\gamma^2(\kappa_f,\kappa_f,\kappa_f,\kappa_Z\lambda_{WZ})}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_Z^2\cdot\kappa_Z^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_Z^2\cdot(\kappa_Z\lambda_{WZ})^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_Z^2\cdot\kappa_f^2}{\kappa_H^2(\kappa_i)}$	

Probing custodial symmetry without assumptions on the total width

Free parameters: $\kappa_{ZZ}(=\kappa_Z\cdot\kappa_Z/\kappa_H), \lambda_{WZ}(=\kappa_W/\kappa_Z), \lambda_{FZ}(=\kappa_f/\kappa_Z)$.

	$H\to\gamma\gamma$	$H\to ZZ^{(*)}$	$H\to WW^{(*)}$	$H\to b\bar{b}$	$H\to\tau^-\tau^+$
ggH, $t\bar{t}H$	$\kappa_{ZZ}^2\lambda_{FZ}^2\cdot\kappa_\gamma^2(\lambda_{FZ},\lambda_{FZ},\lambda_{FZ},\lambda_{WZ})$	$\kappa_{ZZ}^2\lambda_{FZ}^2$	$\kappa_{ZZ}^2\lambda_{FZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{ZZ}^2\lambda_{FZ}^2\cdot\lambda_{FZ}^2$	
VBF	$\kappa_{ZZ}^2\kappa_{VBF}^2(1,\lambda_{WZ}^2)\cdot\kappa_\gamma^2(\lambda_{FZ},\lambda_{FZ},\lambda_{FZ},\lambda_{WZ})$	$\kappa_{ZZ}^2\kappa_{VBF}^2(1,\lambda_{WZ}^2)$	$\kappa_{ZZ}^2\kappa_{VBF}^2(1,\lambda_{WZ}^2)\cdot\lambda_{WZ}^2$	$\kappa_{ZZ}^2\kappa_{VBF}^2(1,\lambda_{WZ}^2)\cdot\lambda_{FZ}^2$	
WH	$\kappa_{ZZ}^2\lambda_{WZ}^2\cdot\kappa_\gamma^2(\lambda_{FZ},\lambda_{FZ},\lambda_{FZ},\lambda_{WZ})$	$\kappa_{ZZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{ZZ}^2\lambda_{WZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{ZZ}^2\lambda_{WZ}^2\cdot\lambda_{FZ}^2$	
ZH	$\kappa_{ZZ}^2\cdot\kappa_\gamma^2(\lambda_{FZ},\lambda_{FZ},\lambda_{FZ},\lambda_{WZ})$	κ_{ZZ}^2	$\kappa_{ZZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{ZZ}^2\cdot\lambda_{FZ}^2$	

$$\kappa_i^2=\Gamma_{ii}/\Gamma_{ii}^{SM}$$

Table 5: A benchmark parametrization where custodial symmetry is probed through the λ_{WZ} parameter.

Probing up-type and down-type fermion symmetry assuming no invisible or undetectable widths

Free parameters: $\kappa_V (= \kappa_Z = \kappa_W), \lambda_{du} (= \kappa_d/\kappa_u), \kappa_u (= \kappa_t)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\frac{\kappa_g^2(\kappa_u\lambda_{du},\kappa_u)\cdot\kappa_\gamma^2(\kappa_u\lambda_{du},\kappa_u,\kappa_u\lambda_{du},\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_g^2(\kappa_u\lambda_{du},\kappa_u)\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_g^2(\kappa_u\lambda_{du},\kappa_u)\cdot(\kappa_u\lambda_{du})^2}{\kappa_H^2(\kappa_i)}$	
$t\bar{t}H$	$\frac{\kappa_u^2\cdot\kappa_\gamma^2(\kappa_u\lambda_{du},\kappa_u,\kappa_u\lambda_{du},\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_u^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_u^2\cdot(\kappa_u\lambda_{du})^2}{\kappa_H^2(\kappa_i)}$	
VBF WH ZH	$\frac{\kappa_V^2\cdot\kappa_\gamma^2(\kappa_u\lambda_{du},\kappa_u,\kappa_u\lambda_{du},\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_V^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_V^2\cdot(\kappa_u\lambda_{du})^2}{\kappa_H^2(\kappa_i)}$	

Probing up-type and down-type fermion symmetry without assumptions on the total width

Free parameters: $\kappa_{uu} (= \kappa_u \cdot \kappa_u/\kappa_H), \lambda_{du} (= \kappa_d/\kappa_u), \lambda_{Vu} (= \kappa_V/\kappa_u)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\kappa_{uu}^2\kappa_g^2(\lambda_{du},1)\cdot\kappa_\gamma^2(\lambda_{du},1,\lambda_{du},\lambda_{Vu})$	$\kappa_{uu}^2\kappa_g^2(\lambda_{du},1)\cdot\lambda_{Vu}^2$		$\kappa_{uu}^2\kappa_g^2(\lambda_{du},1)\cdot\lambda_{du}^2$	
$t\bar{t}H$	$\kappa_{uu}^2\cdot\kappa_\gamma^2(\lambda_{du},1,\lambda_{du},\lambda_{Vu})$	$\kappa_{uu}^2\cdot\lambda_{Vu}^2$		$\kappa_{uu}^2\cdot\lambda_{du}^2$	
VBF WH ZH	$\kappa_{uu}^2\lambda_{Vu}^2\cdot\kappa_\gamma^2(\lambda_{du},1,\lambda_{du},\lambda_{Vu})$	$\kappa_{uu}^2\lambda_{Vu}^2\cdot\lambda_{Vu}^2$		$\kappa_{uu}^2\lambda_{Vu}^2\cdot\lambda_{du}^2$	

$\kappa_i^2 = \Gamma_{ii}/\Gamma_{ii}^{SM}, \kappa_d = \kappa_b = \kappa_\tau$

Table 6: A benchmark parametrization where the up-type and down-type symmetry of fermions is probed through the λ_{du} parameter.

Probing quark and lepton fermion symmetry assuming no invisible or undetectable widths

Free parameters: $\kappa_V (= \kappa_Z = \kappa_W), \lambda_{lq} (= \kappa_l/\kappa_q), \kappa_q (= \kappa_t = \kappa_b)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH $t\bar{t}H$	$\frac{\kappa_q^2\cdot\kappa_\gamma^2(\kappa_q,\kappa_q,\kappa_q\lambda_{lq},\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_q^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_q^2\cdot\kappa_q^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_q^2\cdot(\kappa_q\lambda_{lq})^2}{\kappa_H^2(\kappa_i)}$
VBF WH ZH	$\frac{\kappa_V^2\cdot\kappa_\gamma^2(\kappa_q,\kappa_q,\kappa_q\lambda_{lq},\kappa_V)}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_V^2\cdot\kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_V^2\cdot\kappa_q^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_V^2\cdot(\kappa_q\lambda_{lq})^2}{\kappa_H^2(\kappa_i)}$

Probing quark and lepton fermion symmetry without assumptions on the total width

Free parameters: $\kappa_{qq} (= \kappa_q \cdot \kappa_q/\kappa_H), \lambda_{lq} (= \kappa_l/\kappa_q), \lambda_{Vq} (= \kappa_V/\kappa_q)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH $t\bar{t}H$	$\kappa_{qq}^2\cdot\kappa_\gamma^2(1,1,\lambda_{lq},\lambda_{Vq})$	$\kappa_{qq}^2\cdot\lambda_{Vq}^2$		κ_{qq}^2	$\kappa_{qq}^2\cdot\lambda_{lq}^2$
VBF WH ZH	$\kappa_{qq}^2\lambda_{Vq}^2\cdot\kappa_\gamma^2(1,1,\lambda_{lq},\lambda_{Vq})$	$\kappa_{qq}^2\lambda_{Vq}^2\cdot\lambda_{Vq}^2$		$\kappa_{qq}^2\cdot\lambda_{Vq}^2$	$\kappa_{qq}^2\lambda_{Vq}^2\cdot\lambda_{lq}^2$

$\kappa_i^2 = \Gamma_{ii}/\Gamma_{ii}^{SM}, \kappa_l = \kappa_\tau$

Table 7: A benchmark parametrization where the quark and lepton symmetry of fermions is probed through the λ_{lq} parameter.

Probing loop structure assuming no invisible or undetectable widths

Free parameters: κ_g, κ_γ.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_g^2}{\kappa_H^2(\kappa_i)}$			
$t\bar{t}H$ VBF WH ZH	$\frac{\kappa_\gamma^2}{\kappa_H^2(\kappa_i)}$	$\frac{1}{\kappa_H^2(\kappa_i)}$			

Probing loop structure allowing for invisible or undetectable widths

Free parameters: $\kappa_g, \kappa_\gamma, BR_{inv.,undet.}$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2(\kappa_i)/(1-BR_{inv.,undet.})}$	$\frac{\kappa_g^2}{\kappa_H^2(\kappa_i)/(1-BR_{inv.,undet.})}$			
$t\bar{t}H$ VBF WH ZH	$\frac{\kappa_\gamma^2}{\kappa_H^2(\kappa_i)/(1-BR_{inv.,undet.})}$	$\frac{1}{\kappa_H^2(\kappa_i)/(1-BR_{inv.,undet.})}$			

$$\kappa_i^2 = \Gamma_{ii}/\Gamma_{ii}^{SM}$$

Table 8: A benchmark parametrization where effective vertex couplings are allowed to float through the κ_g and κ_γ parameters. Instead of absorbing κ_H, explicit allowance is made for a contribution from invisible or undetectable widths via the $BR_{inv.,undet.}$ parameter.

Probing loops while allowing other couplings to float assuming no invisible or undetectable widths

Free parameters: $\kappa_g, \kappa_\gamma, \kappa_V (= \kappa_W = \kappa_Z), \kappa_f (= \kappa_t = \kappa_b = \kappa_\tau)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_g^2 \cdot \kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_g^2 \cdot \kappa_f^2}{\kappa_H^2(\kappa_i)}$	
$t\bar{t}H$	$\frac{\kappa_f^2 \cdot \kappa_\gamma^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_f^2 \cdot \kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_f^2 \cdot \kappa_f^2}{\kappa_H^2(\kappa_i)}$	
VBF WH ZH	$\frac{\kappa_V^2 \cdot \kappa_\gamma^2}{\kappa_H^2(\kappa_i)}$	$\frac{\kappa_V^2 \cdot \kappa_V^2}{\kappa_H^2(\kappa_i)}$		$\frac{\kappa_V^2 \cdot \kappa_f^2}{\kappa_H^2(\kappa_i)}$	

Probing loops while allowing other couplings to float allowing for invisible or undetectable widths

Free parameters: $\kappa_{gV} (= \kappa_g \cdot \kappa_V/\kappa_H), \lambda_{Vg} (= \kappa_V/\kappa_g), \lambda_{\gamma V} (= \kappa_\gamma/\kappa_V), \lambda_{fV} (= \kappa_f/\kappa_V)$.

	$H \to \gamma\gamma$	$H \to ZZ^{(*)}$	$H \to WW^{(*)}$	$H \to b\bar{b}$	$H \to \tau^-\tau^+$
ggH	$\kappa_{gV}^2 \cdot \lambda_{\gamma V}^2$	κ_{gV}^2		$\kappa_{gV}^2 \cdot \lambda_{fV}^2$	
$t\bar{t}H$	$\kappa_{gV}^2 \lambda_{Vg}^2 \lambda_{fV}^2 \cdot \lambda_{\gamma V}^2$	$\kappa_{gV}^2 \lambda_{Vg}^2 \lambda_{fV}^2$		$\kappa_{gV}^2 \lambda_{Vg}^2 \lambda_{fV}^2 \cdot \lambda_{fV}^2$	
VBF WH ZH	$\kappa_{gV}^2 \lambda_{Vg}^2 \cdot \lambda_{\gamma V}^2$	$\kappa_{gV}^2 \lambda_{Vg}^2$		$\kappa_{gV}^2 \lambda_{Vg}^2 \cdot \lambda_{fV}^2$	

$$\kappa_i^2 = \Gamma_{ii}/\Gamma_{ii}^{SM}, \kappa_V = \kappa_W = \kappa_Z, \kappa_f = \kappa_t = \kappa_b = \kappa_\tau$$

Table 9: A benchmark parametrization where effective vertex couplings are allowed to float through the κ_g and κ_γ parameters and the gauge and fermion couplings through the unified parameters κ_V and κ_f.