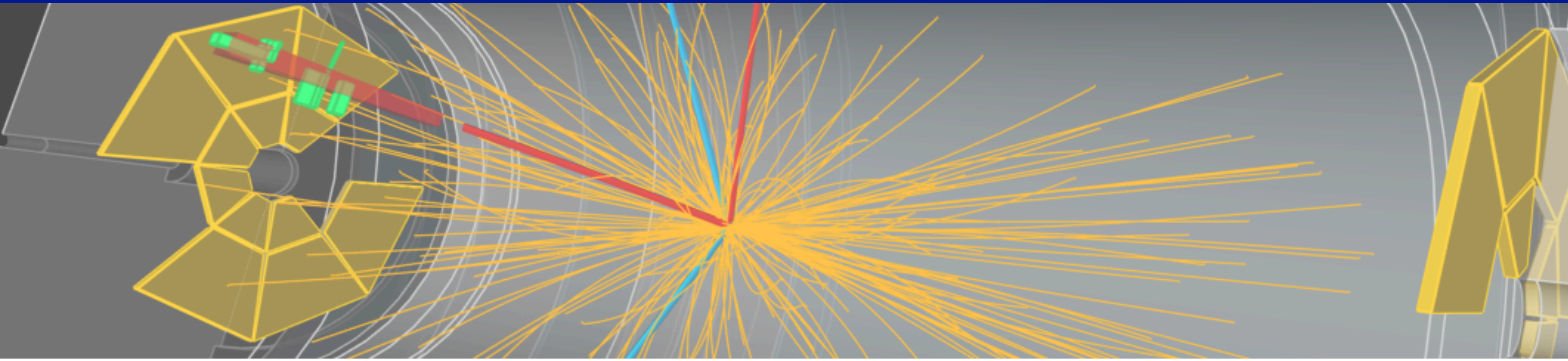


Recent Higgs results from *ATLAS*

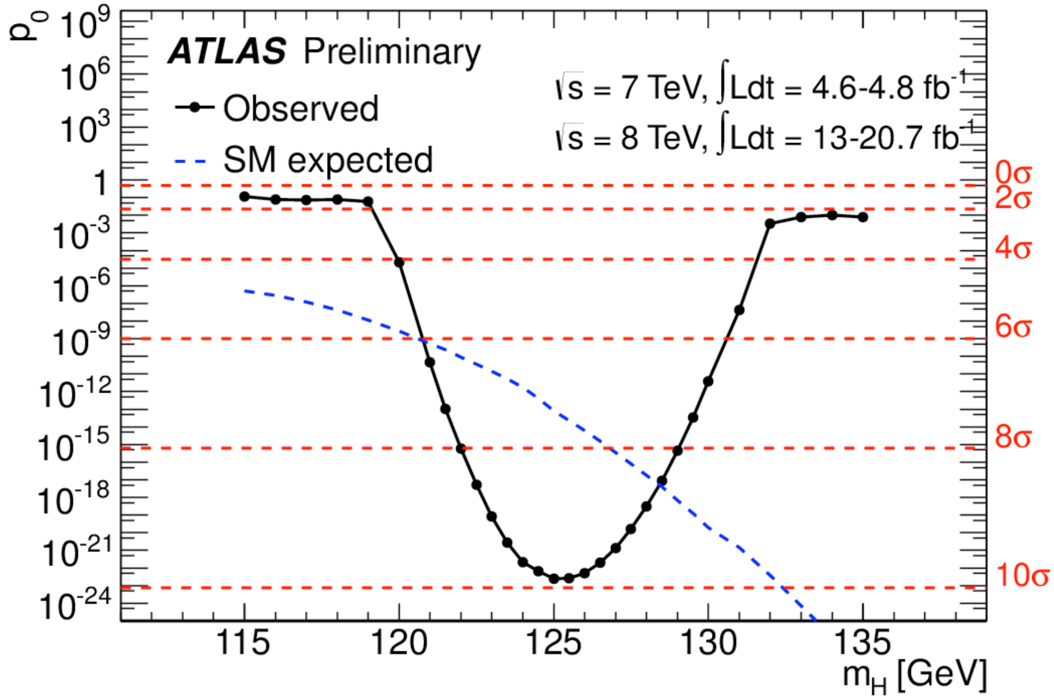
Krisztian Peters
CERN

On behalf of the *ATLAS* Collaboration

CERN Seminar, 15th April 2013

Introduction

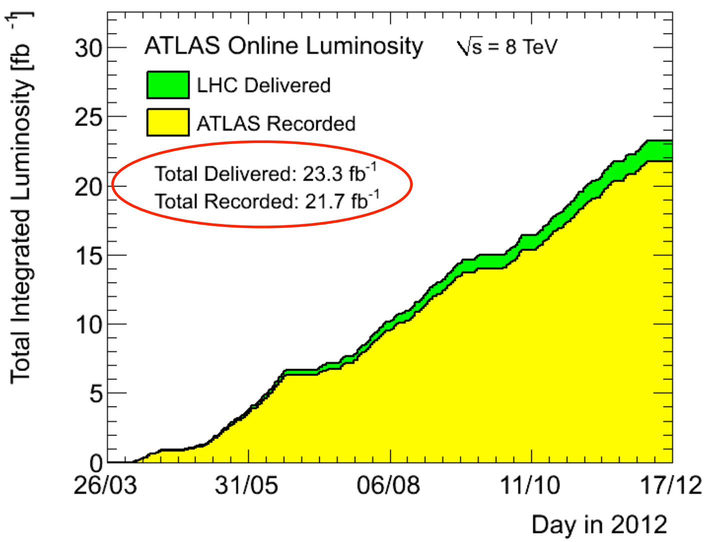
ATLAS combined Higgs signal significance (Moriond 2013)

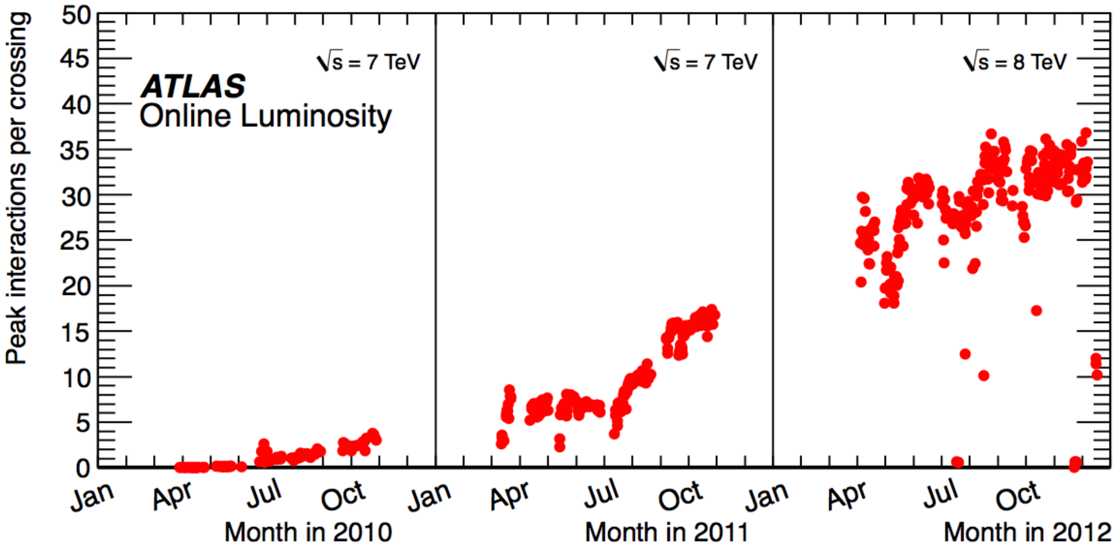


Already at the next chapter of LHC Higgs physics:

- Property measurements of the boson at ~125 GeV
- Search for additional Higgs-like resonances

Run I dataset





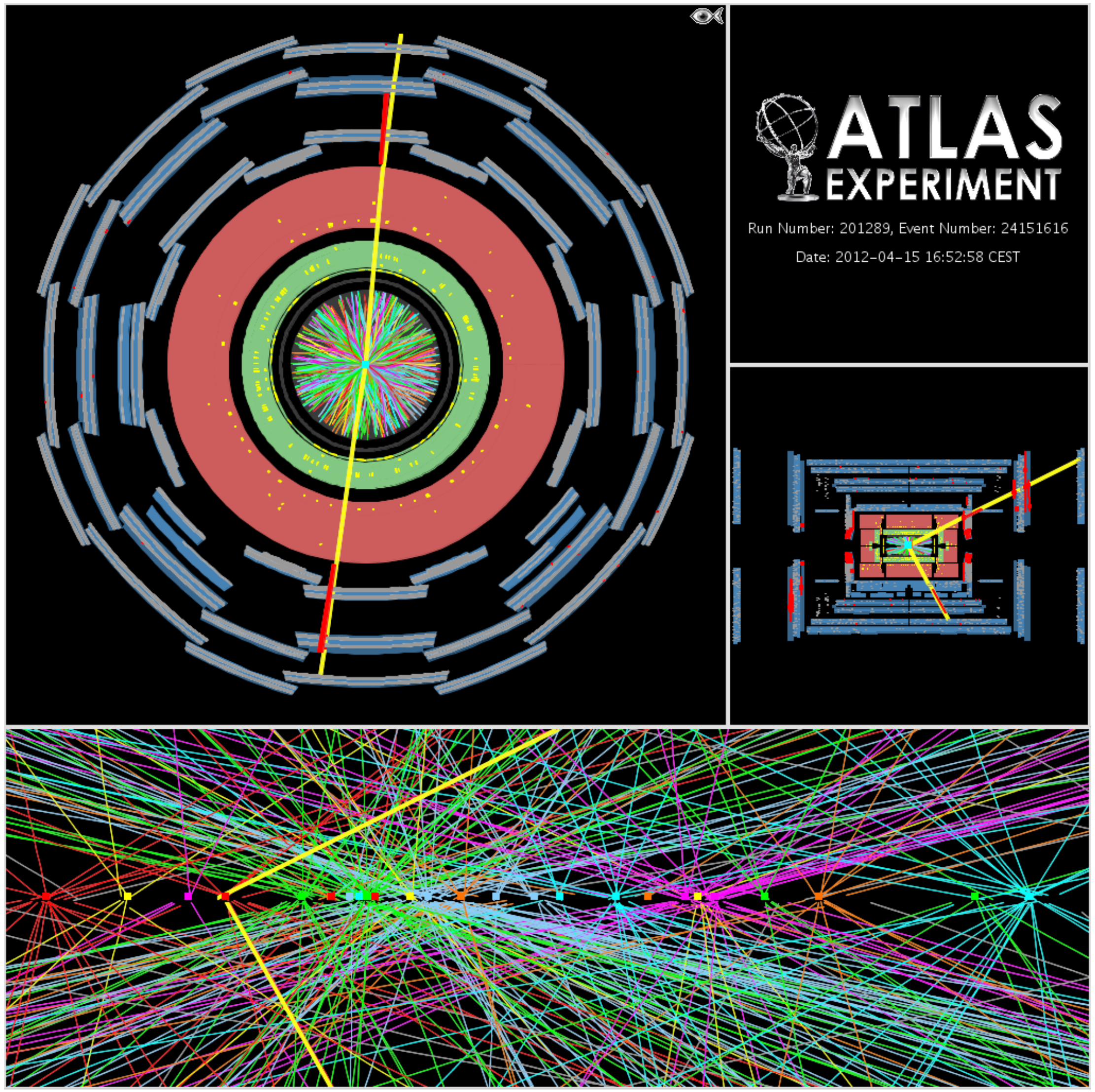
Average data taking efficiency: ~94%

Total efficiency (delivered → physics): ~90%

Available dataset for physics analysis in Run I ~25 fb^{-1}

More data, with higher instantaneous luminosities

Pileup

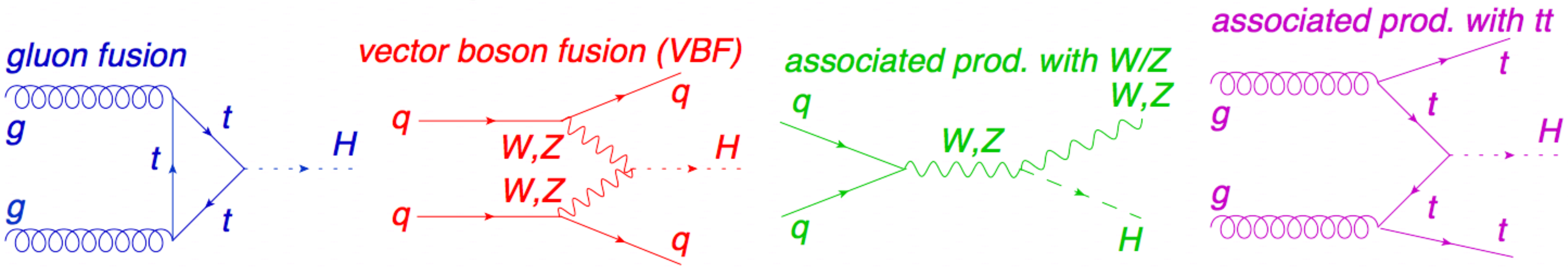


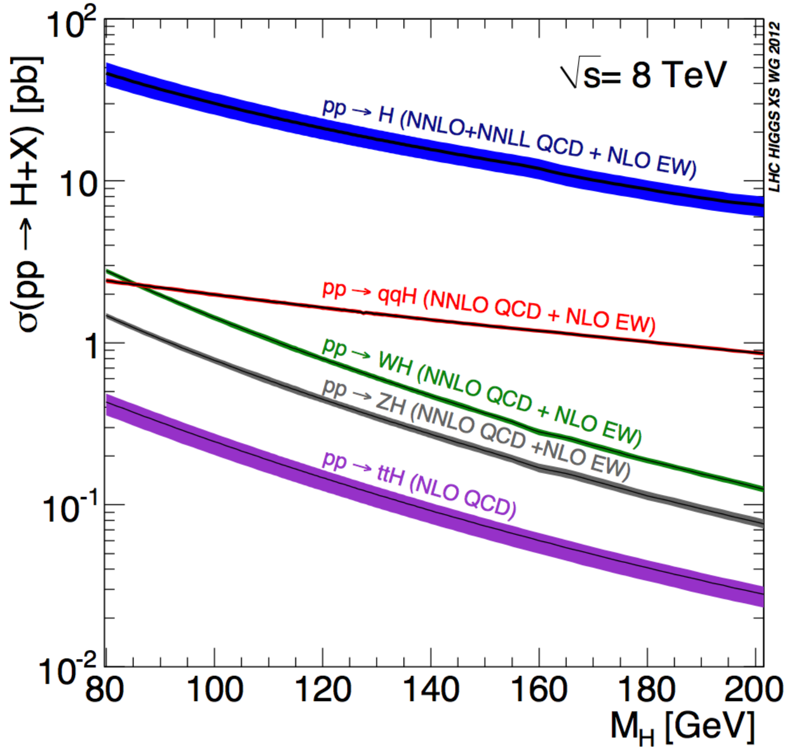
Continuously improve triggering, reconstruction and identification algorithms to cope with this challenging environment

Main impact on jets, missing E_T and tau reconstruction (as well as on trigger rates and computing)

$Z \rightarrow \mu\mu$ event with 25 reconstructed vertices

Higgs production

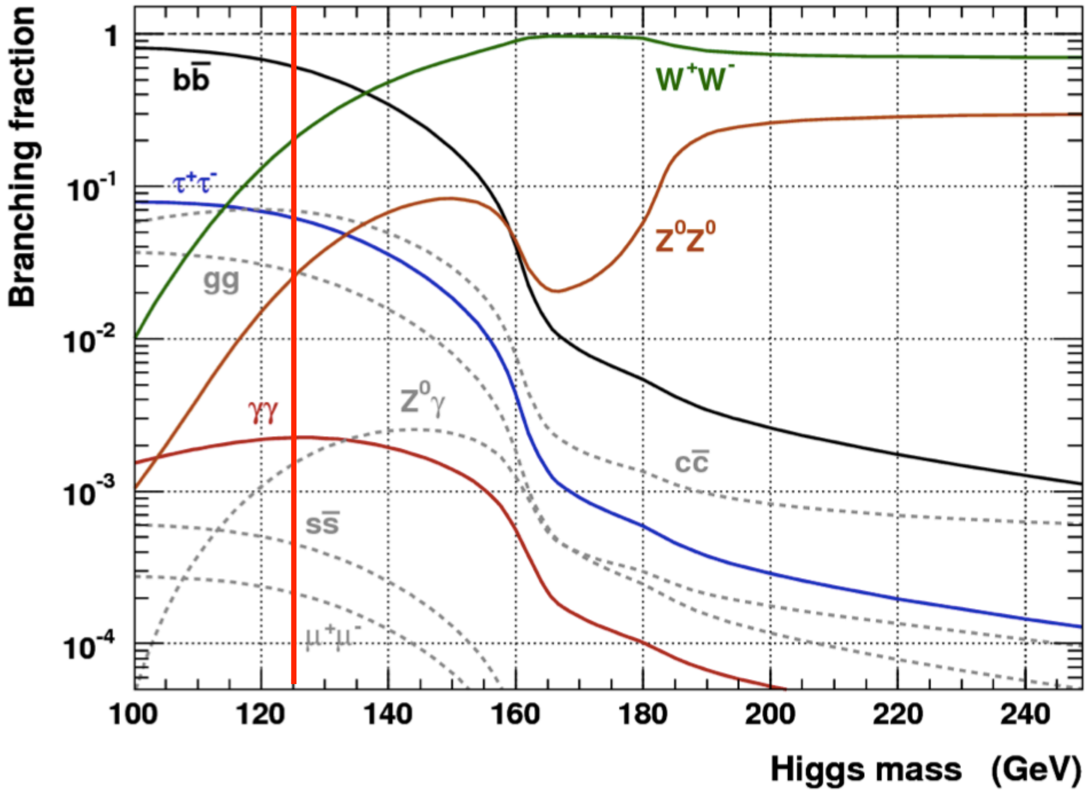




Main production mode via loops. Theory uncertainty *O*(10%)

Access to top-quark, W and Z couplings via production cross section

Higgs decays



Γ_H = 4 MeV not directly measurable at LHC

Best experimental mass resolution for $\gamma\gamma$ and 4ℓ decays

Tree level couplings → decay ττ/bb (fermions) WW/ZZ (bosons)

Loop couplings γγ → sensitive to BSM

Overall experimental strategy

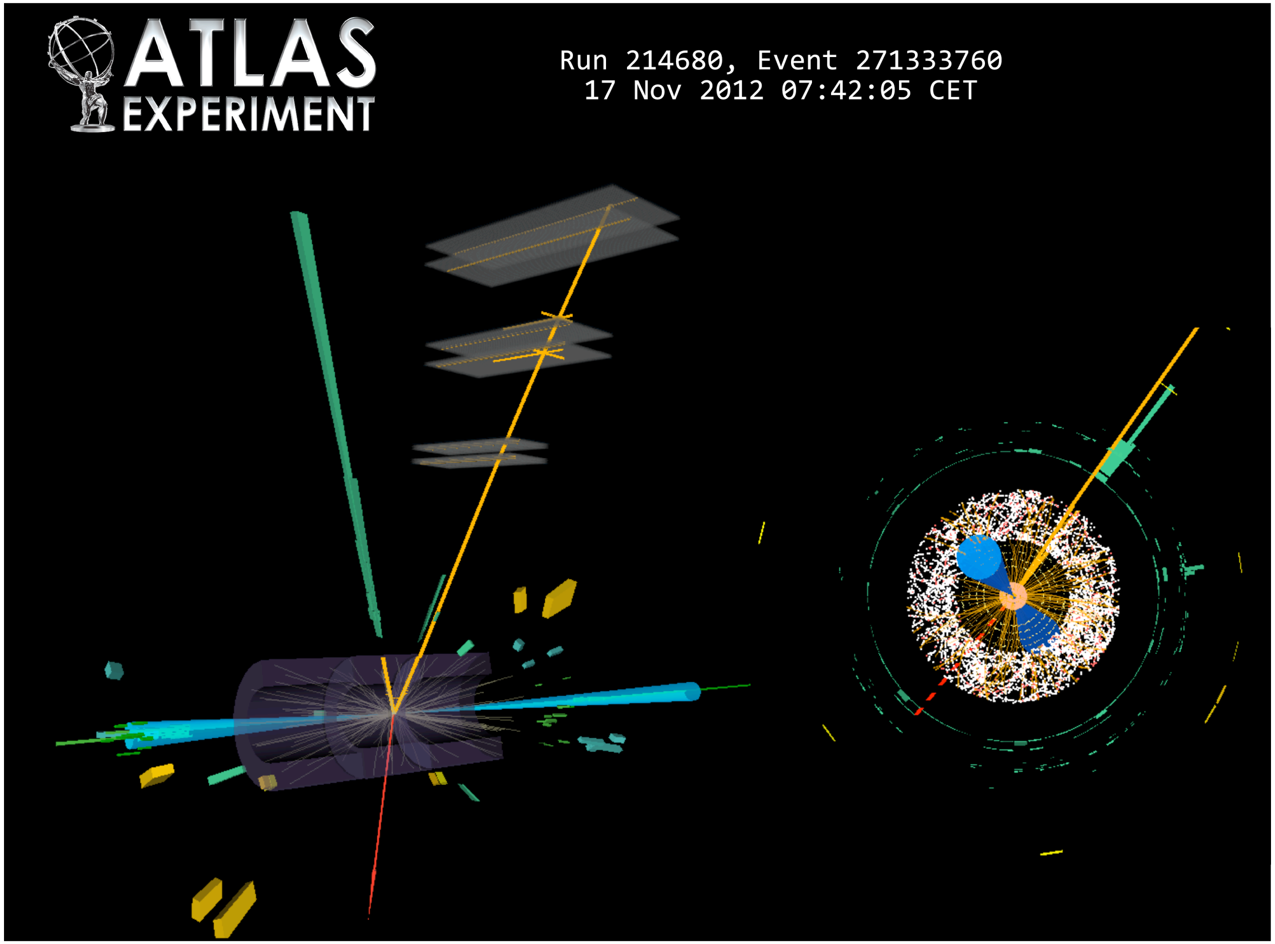
Investigate a large number of final states, with sub-channels to separate different production mechanisms (and to increase overall significance)

Probe Lagrangian structure. Measure mass, spin and CP properties

Continue to search for additional Higgs bosons

Channel	ggF	VBF	VH	ttH	Mass	Spin	Dataset
$\gamma\gamma$	✓	✓	✓		✓	✓	25 fb^{-1}
$Z \to 4\ell$	✓	✓	✓		✓	✓	25 fb^{-1}
$WW \to \ell\ell + 2\nu$	✓	✓				✓	25 fb^{-1}
$\tau\tau$	✓	✓	✓				18 fb^{-1}
bb			✓	✓			18 fb^{-1}
$\mu\mu$	✓						21 fb^{-1}
$Z\gamma$	✓						25 fb^{-1}
2HDM (WW)	✓	✓					13 fb^{-1}
Invisible			✓				18 fb^{-1}

$H \rightarrow WW^* \rightarrow \ell\ell + 2\nu$



Main improvements:
(Since HCP result)

Category targeting VBF

Reanalysis of 2011 data

Same flavour added

Optimisation of control regions

Further separation of signal regions

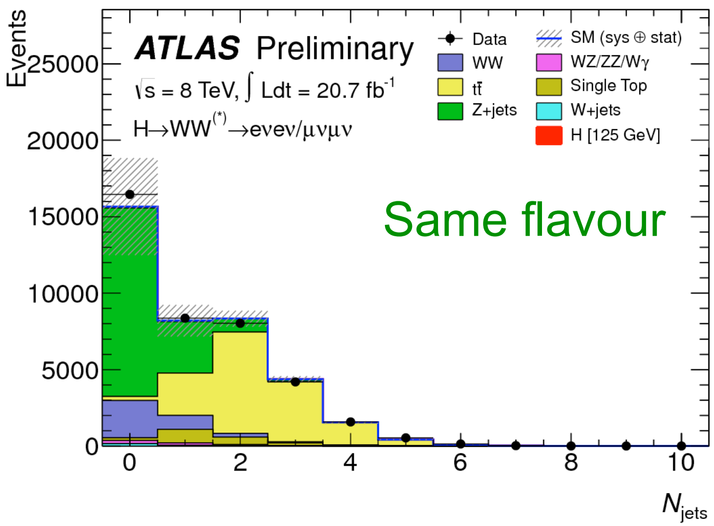
Dataset	Production modes	Exp. signal yield	S/B
25/fb	ggF, VBF	~200	~15%

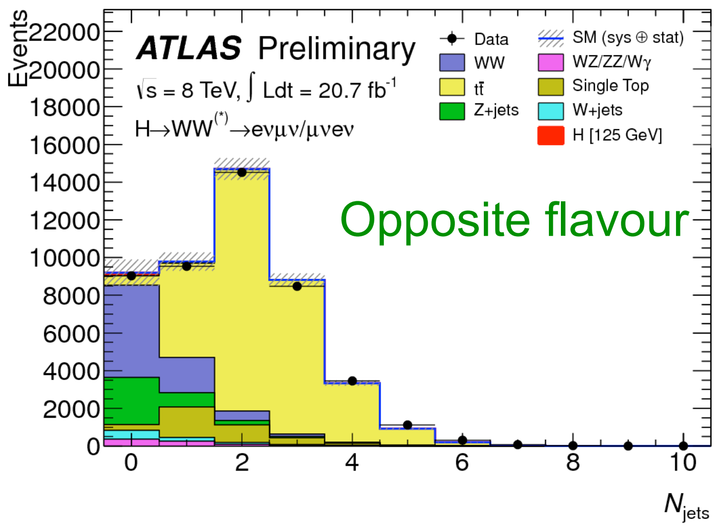
Analysis strategy

Two high pT isolated leptons, split by jet-multiplicity and lepton flavour

Various missing E_T related cuts to remove main DY contribution

Topological cuts for further bkgr. reduction (low m_{ll}, small $\Delta\phi$) / VBF selection

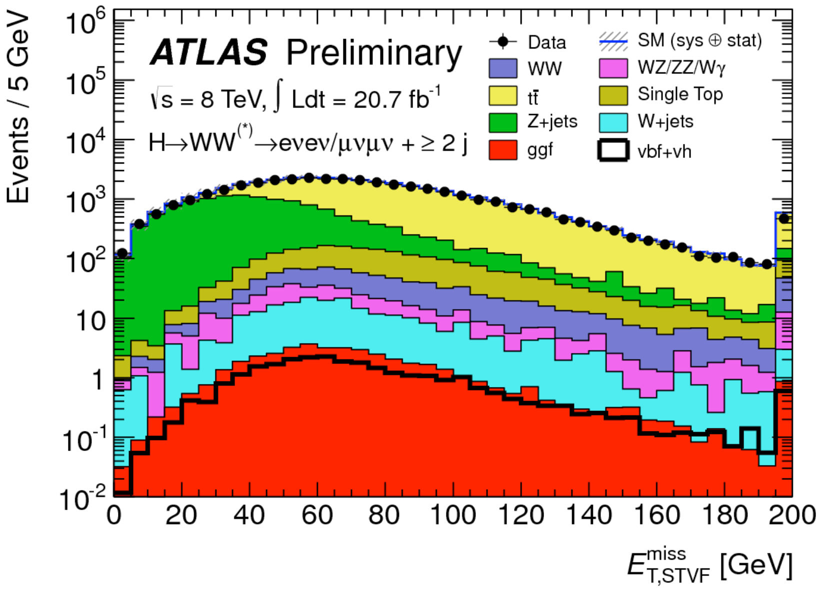




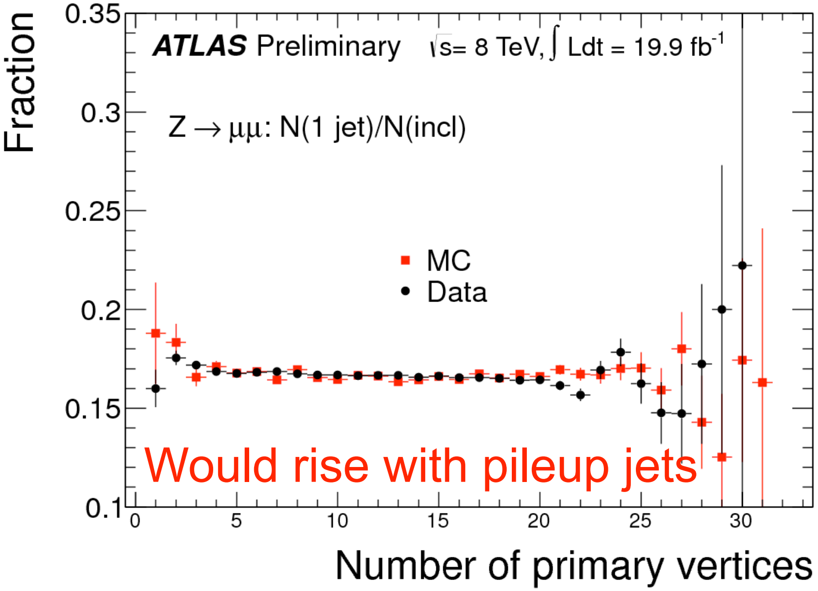
Plots after missing E_T cuts

Jets and missing E_T

Missing E_T soft-term vertex correction



Z → μμ: N(1 jet) / N(incl.)

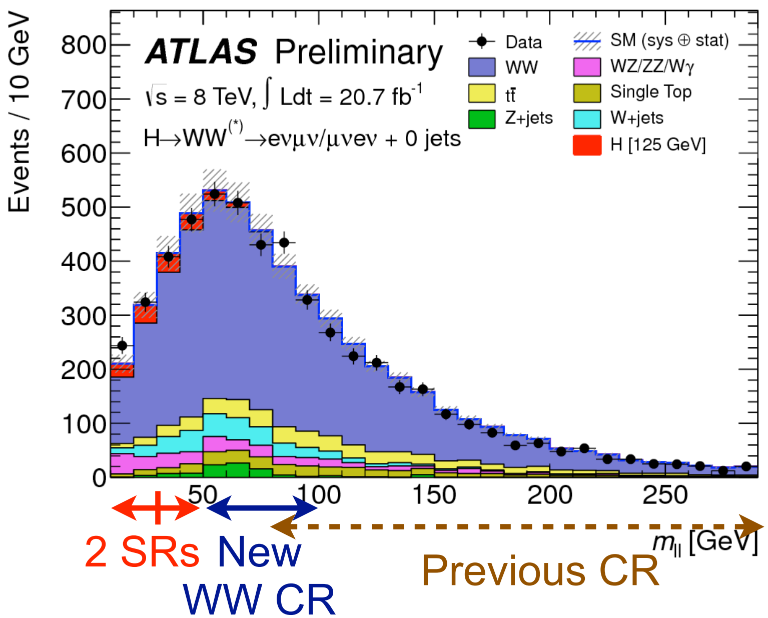


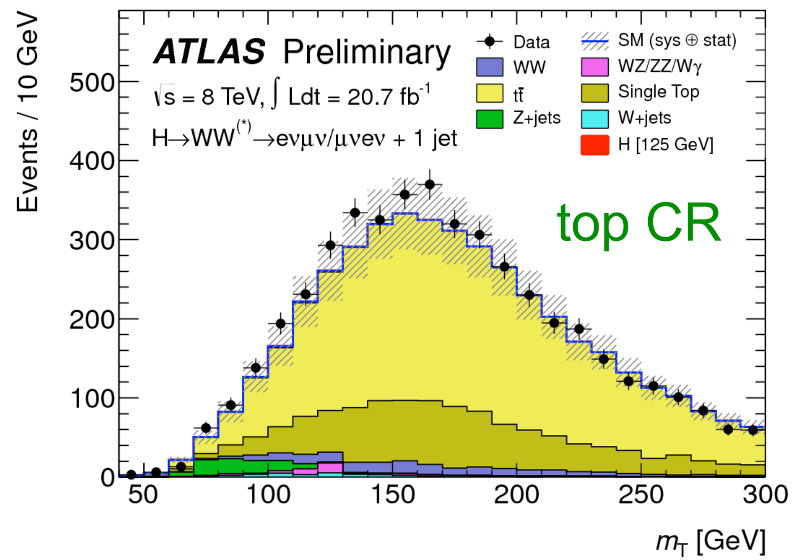
Including tracking information helps to mitigate effects from pileup interaction

Background estimate

Need good understanding of all the high-energy SM processes occurring at a hadron collider (no background be neglected)

Main backgrounds normalised to data in control samples, extrapolate to signal region with simulation or taken directly from data

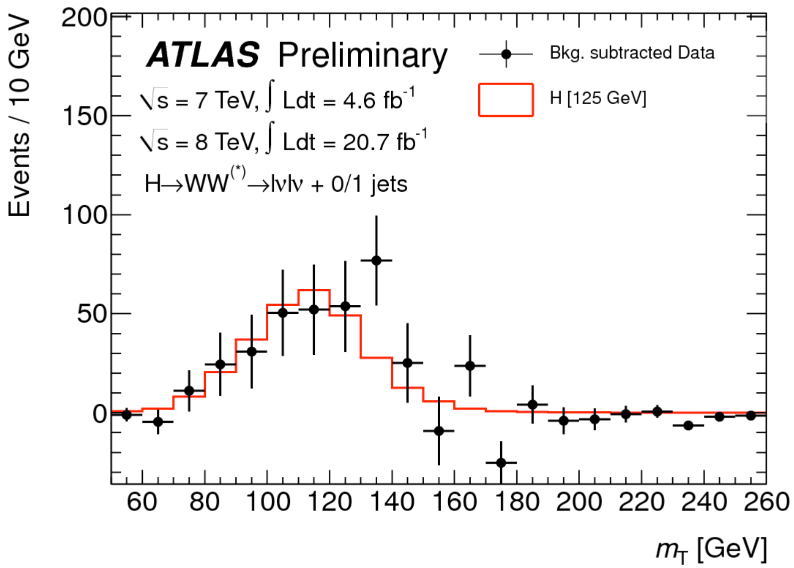


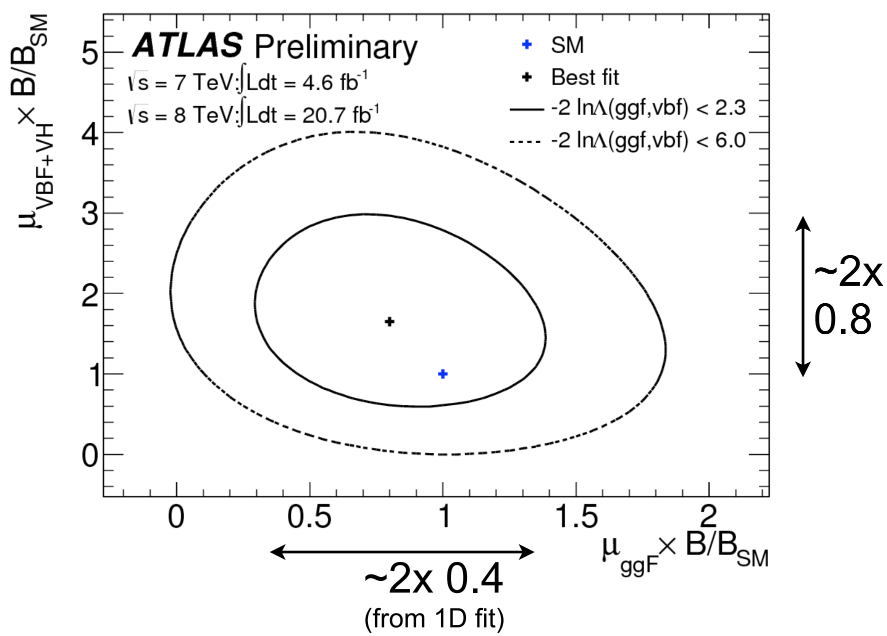


WW extrapolation systematic uncertainties reduced from 7% to 2%

$H \rightarrow WW^* \rightarrow \ell\ell + 2\nu$ results

Final discrimination from m_T shape





Observed significance (125 GeV) 3.8σ (3.7σ expected)

Signal strength at 125 GeV $\mu = 1.01 \pm 0.31$

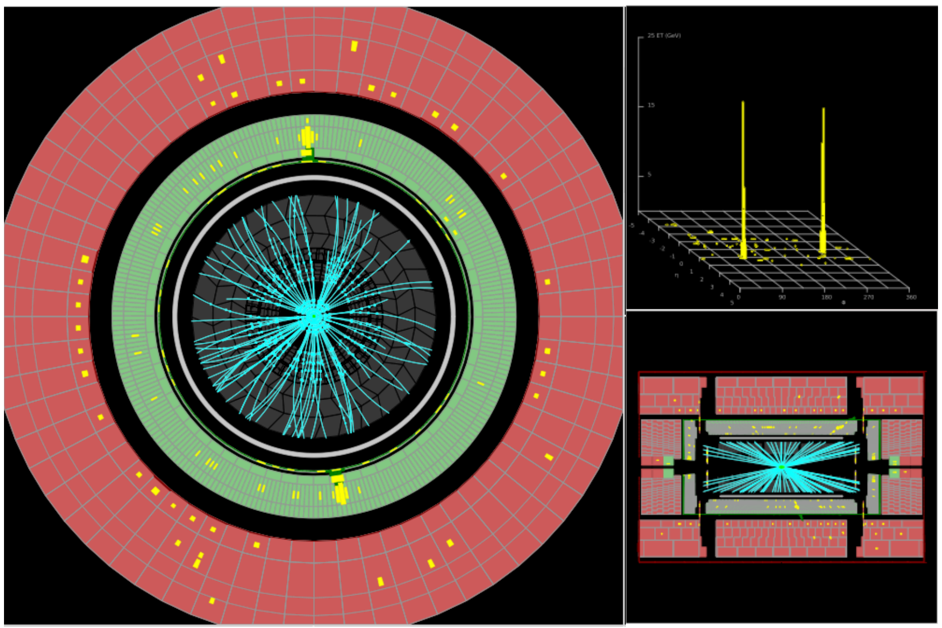
0.21(stat) ± 0.19(theo) ± 0.12(exp) ± 0.04(lumi)

H → γγ

Select events with two isolated high pT photons (40/30 GeV)

Separate events into categories with different S/B, resolutions and different relative contributions of signal production modes

Quantify excess in steeply falling diphoton mass spectrum



Main improvements:
(Since December result)

New / improved categories for VBF and VH signal

Fiducial cross section

Reduced systematic uncertainties

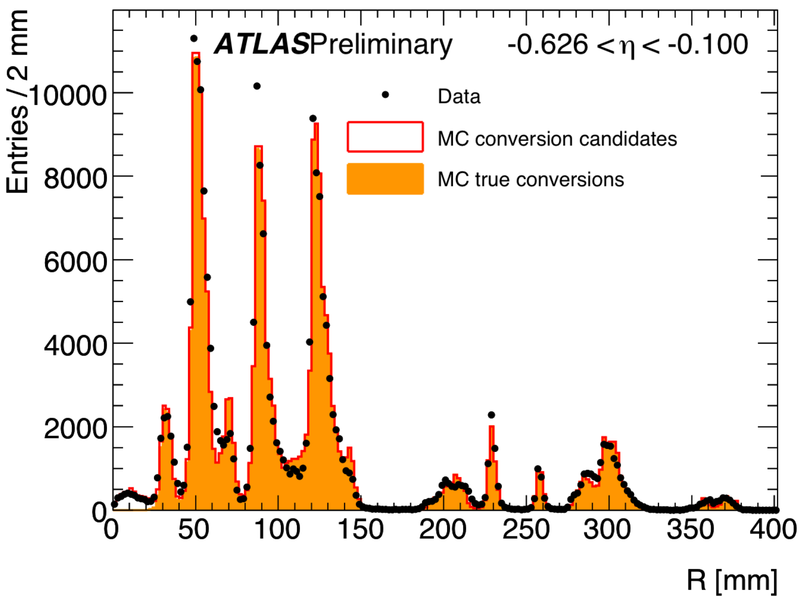
Dataset	Production modes	Exp. signal yield	S/B
25/fb	ggF, VH, VBF	~450	~3%

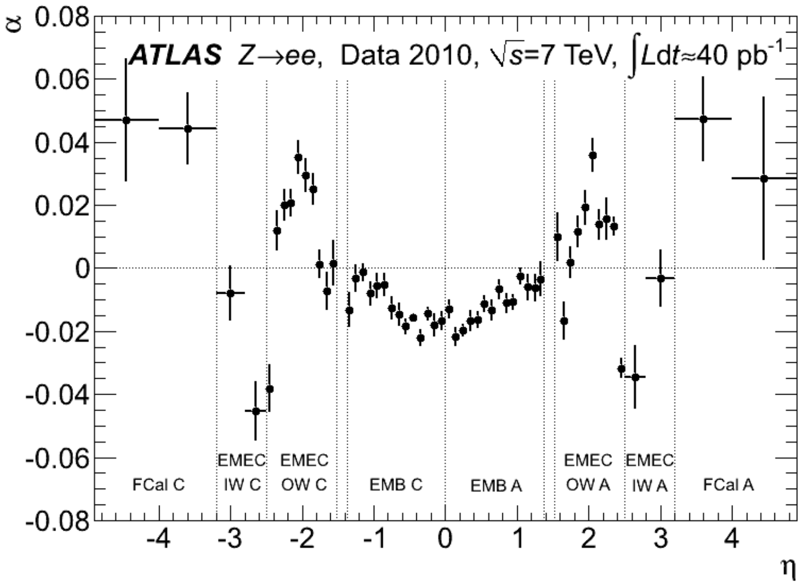
Photon energy calibration

MC based calibration at cluster level tuned in test beam

Need accurate material description for $e \to \gamma$ extrapolation
(Cross checked with EM shower shapes, photon conversions, hadronic interactions and E/p, …)

Energy scale corrections from Z decay to electrons. Cross checked at the lower energy spectrum with radiative Z decays

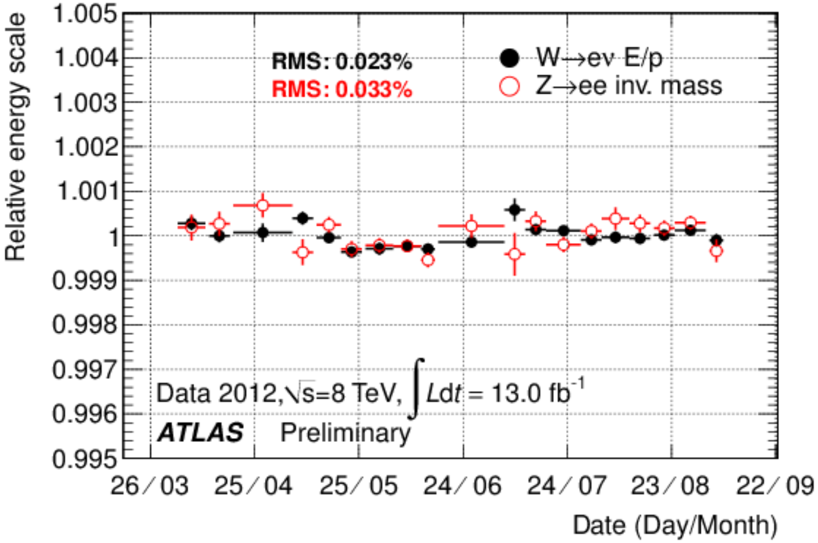


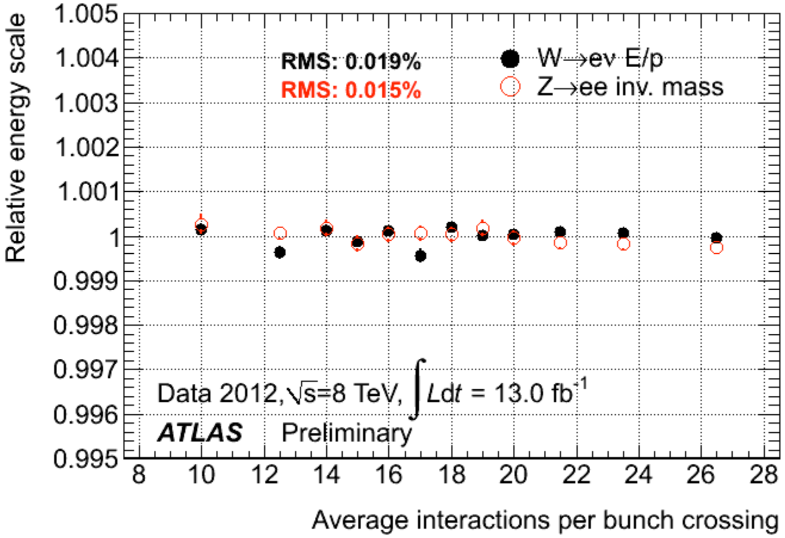


Calibration checks

In-situ energy calibration results and their stability checked with different methods (E/p with $W \to e\nu$, $J/\psi \to ee$)

Stability of EM calorimeter response vs time/pile-up better than 0.1%





Uncertainty on the diphoton mass scale 0.6%, largest contributions:

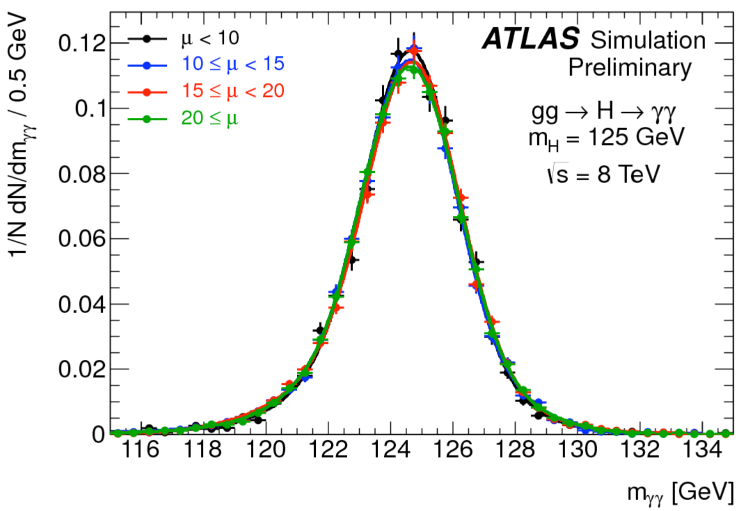
- Material effects (separately for volumes before and after $|\eta| = 1.8$)
- Uncertainty on the in-situ calibration method

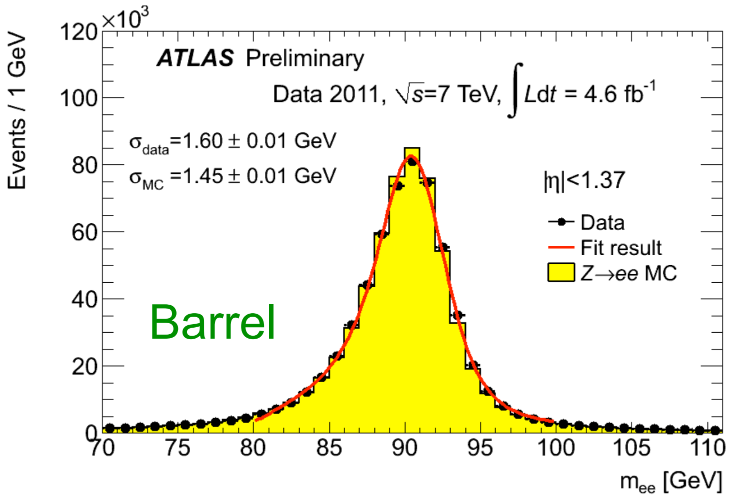
Di-photon mass resolution

Improved and pileup stable mass resolution by relying on calorimeter pointing for the photon direction measurement

Calorimeter resolution corrections derived from Z decay to electrons

- Add effective constant term to perfect MC resolutions through smearing
- 1% in barrel, 1.5 − 2.5% in endcap

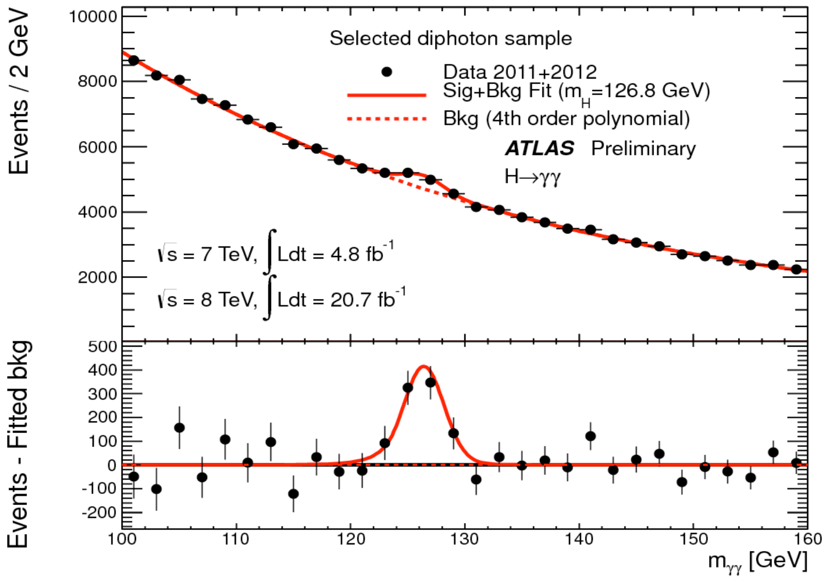


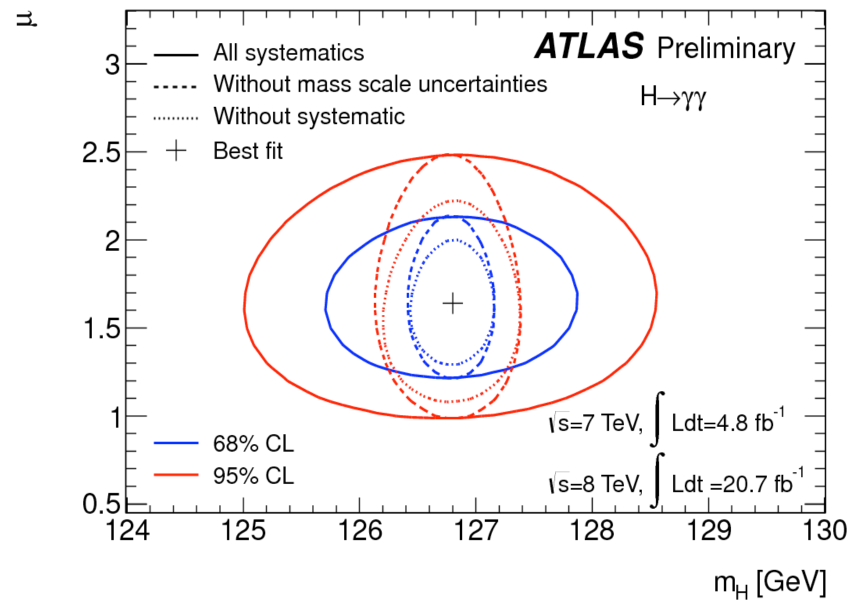


Uncertainty on photon energy resolution (14 − 23%):

Sampling term (from test-beam), 'effective' constant term and $e \rightarrow \gamma$ extrapolation (material upstream calorimeter)

Signal strength





Observed significance 7.4σ (expected 4.1σ), consistent result w/o categories

Mass: m_H =126.8 ± 0.2(stat) ± 0.7(syst) GeV

Signal strength: μ = 1.65 ± 0.24(stat) ± 0.22(syst) [2.3σ compatibility with SM]

Fit prefers narrower than nominal mass resolution by 1.8σ. This is better than with a perfectly uniform calorimeter, likely due to background fluctuation

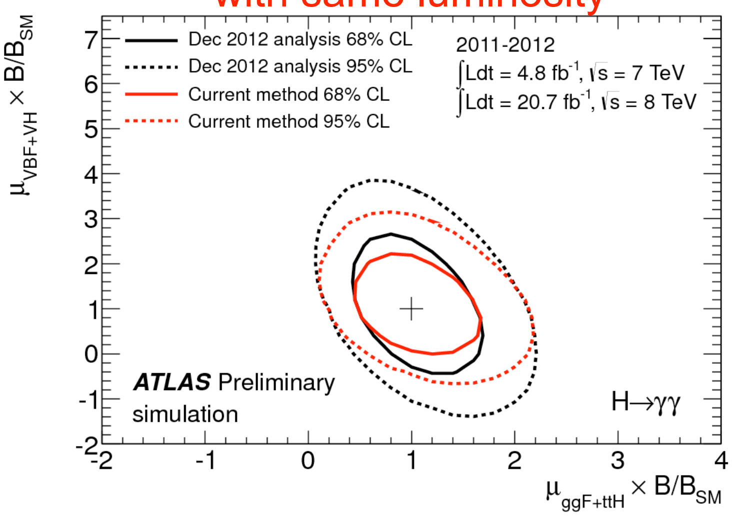
Fitting without resolution constraint gives a ~10% lower signal strength

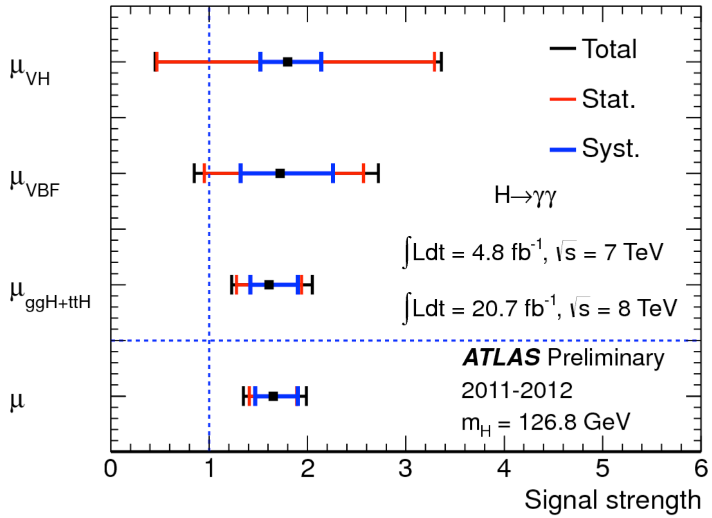
Separate production modes

New and improved VBF and VH categories:

- VBF: two MVA based VBF categories (with different purities)
- VH: improved lepton and dijet-tag category, new MET-tag category

Expected improvement
with same luminosity

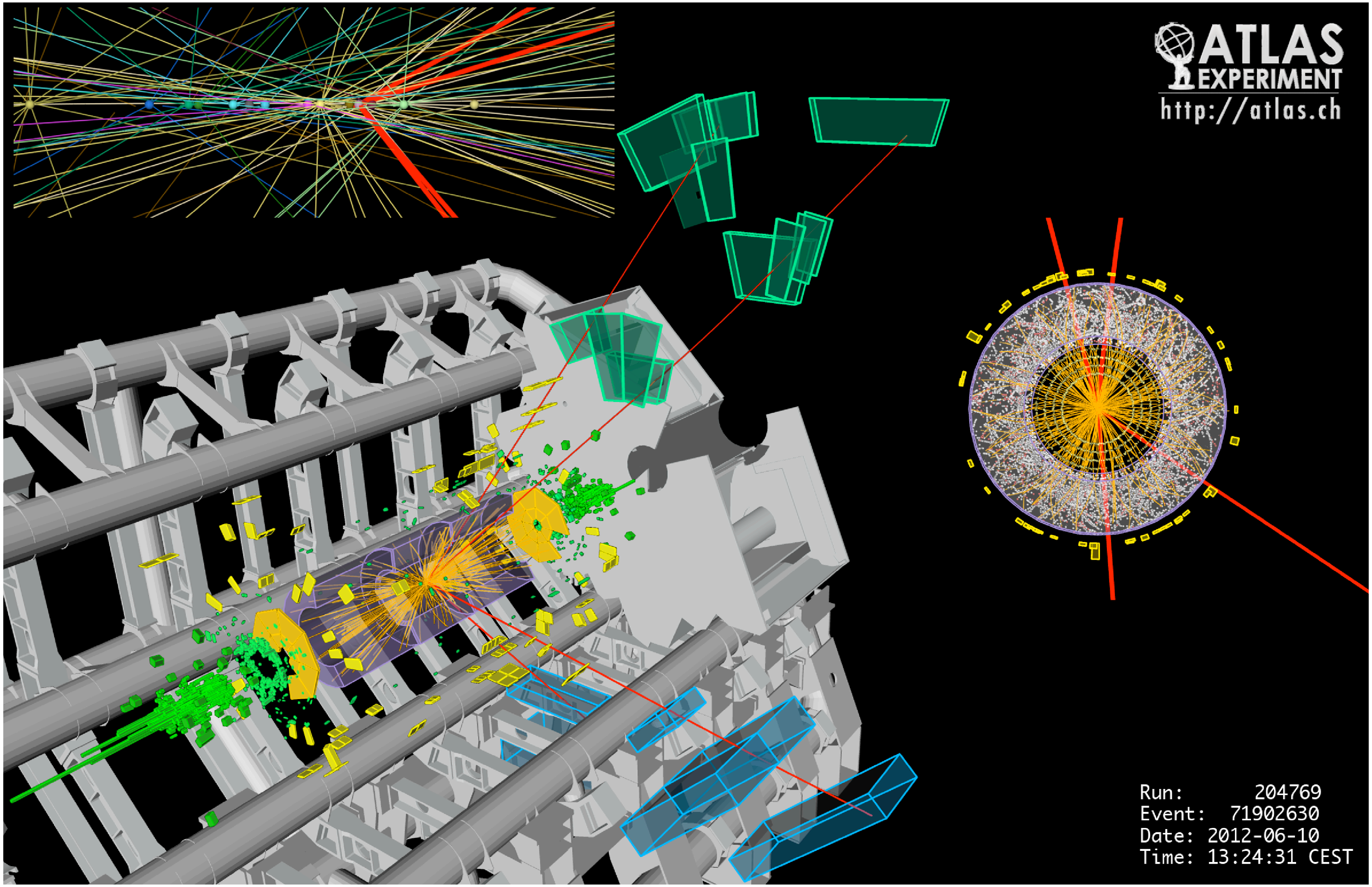




New: fiducial cross section measurement

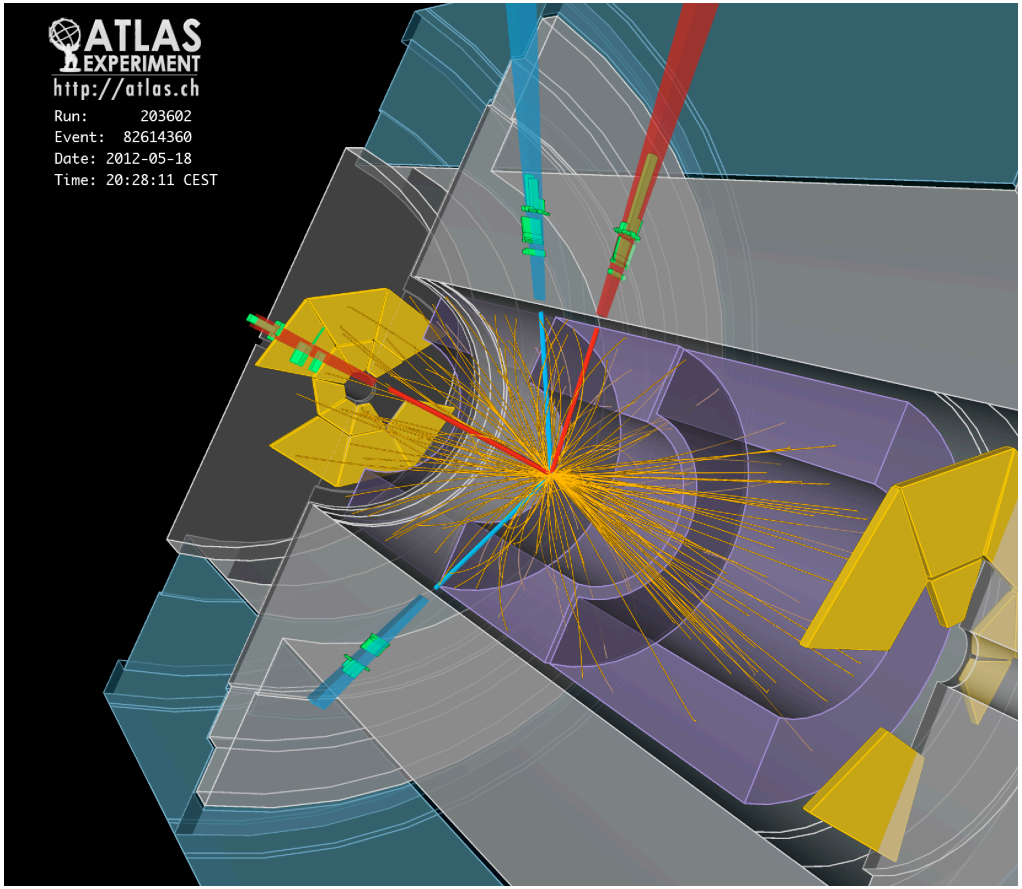
- Inclusive 8 TeV analysis, particle level cuts: $|\eta| < 2.37$, $p_{T\gamma} > 40/30$ GeV
- σ_{fid} x BR = 56.2 ± 12.5 fb   [±10.5(stat) ± 6.5(syst) ± 2.0(lumi)]

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



2 same flavour, opposite charge lepton pairs (one) consistent with Z mass

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



Main improvements:
(Since December result)

Two new categories targeting VBF/VH production

- Loose VBF selection
- 5th lepton for VH category

Improved lepton pairing and selection

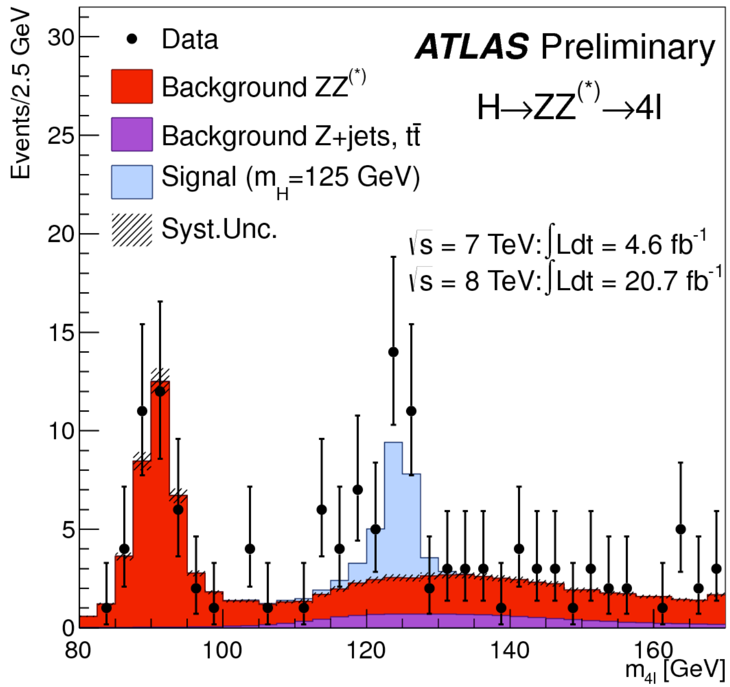
Z mass constraint and FSR correction

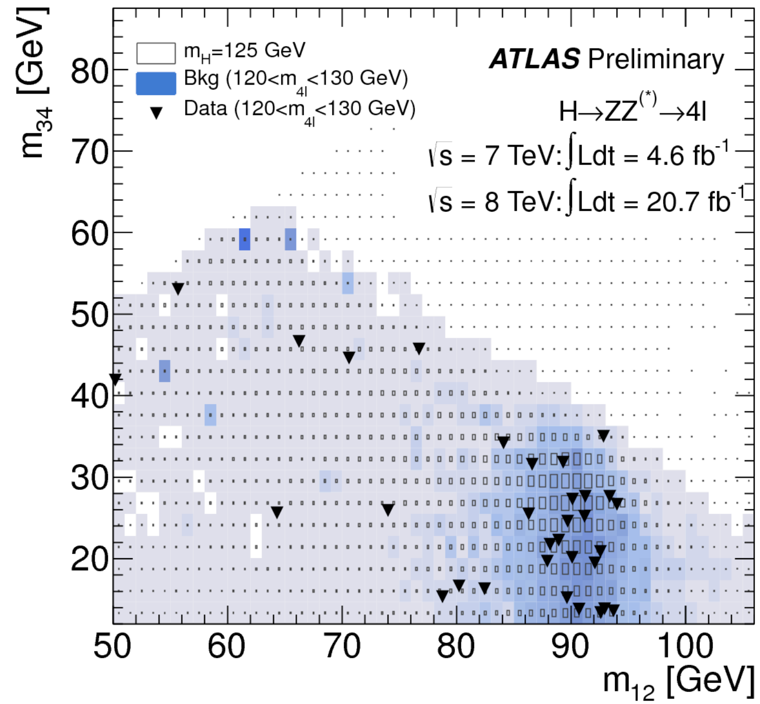
Extended search range to higher mass states

Dataset	Production modes	Exp. signal yield	S/B
25/fb	ggF, (VBF, VH)	~16	~1.4

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

Look for a clustering of events in the 4-lepton invariant mass distribution





Main backgrounds:

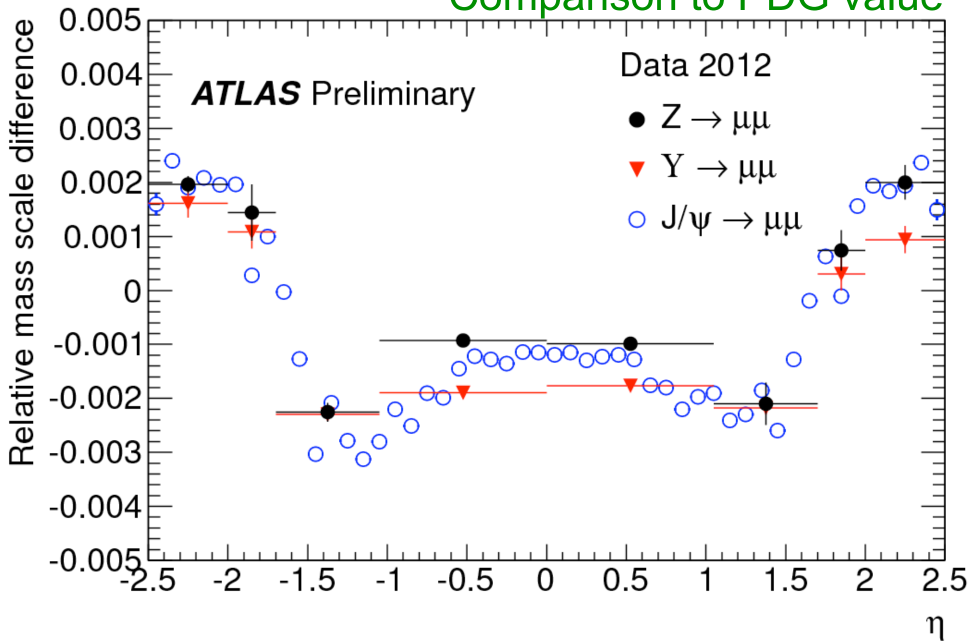
- SM *ZZ** production, irreducible (estimated from MC)
- Top, *Z*+bb, *Z*+jj (data driven estimation)
  - Minimise with isolation and small impact parameter requirements

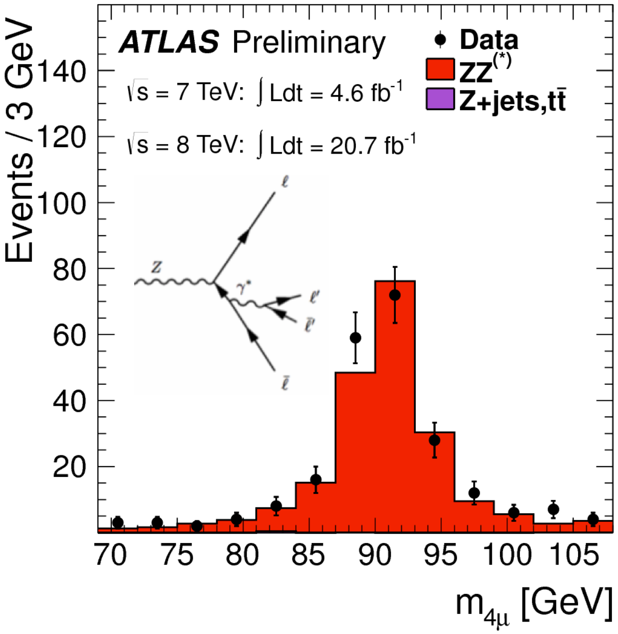
Energy scale and resolution

Muon energy scale (and resolution) corrections and systematic uncertainties determined from from large Z, J/psi (20M) and Υ samples

- Resolution corrections (0.2 -1.3%), scale corrections (<0.1%)
- Independent measurements from the muon system and inner detector
- Probe global and local scale biases, overall uncertainty on 4μ scale 0.2%

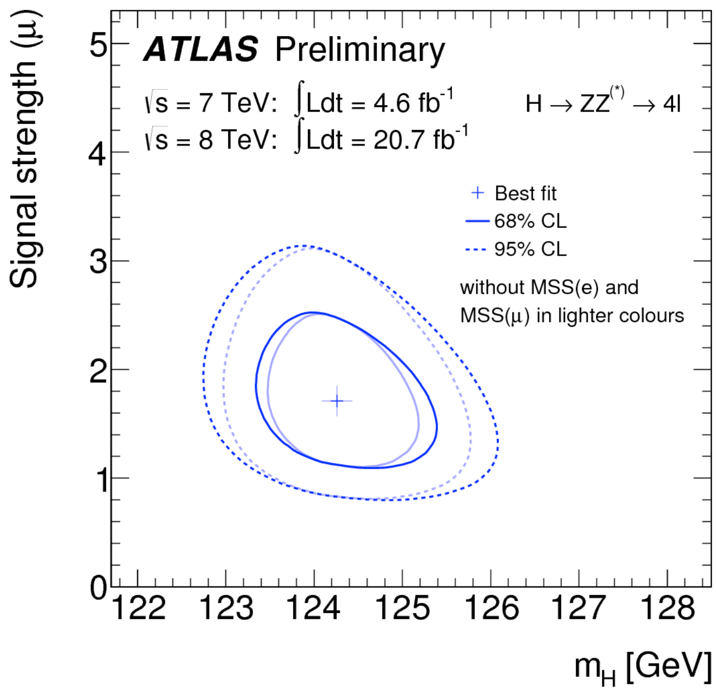
Comparison to PDG value

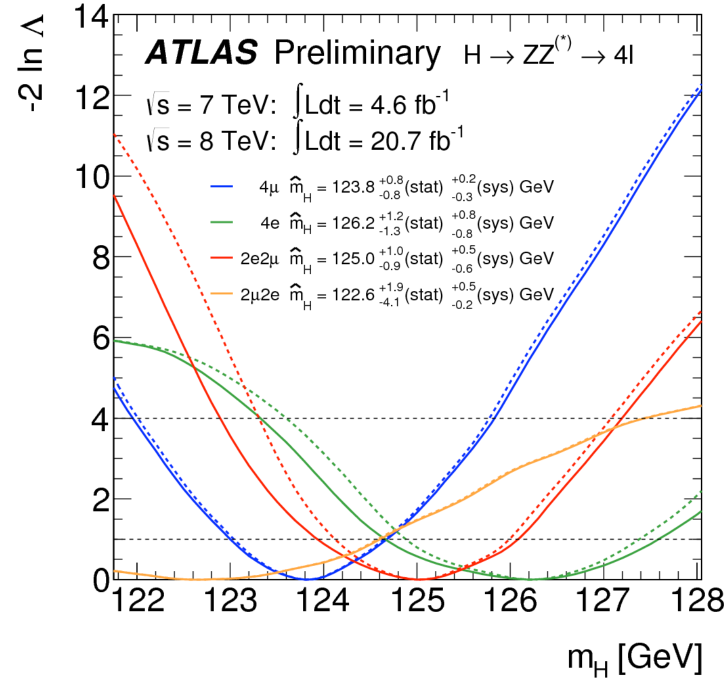




Good control of single resonant process from relaxed analysis selection

Signal strength and mass



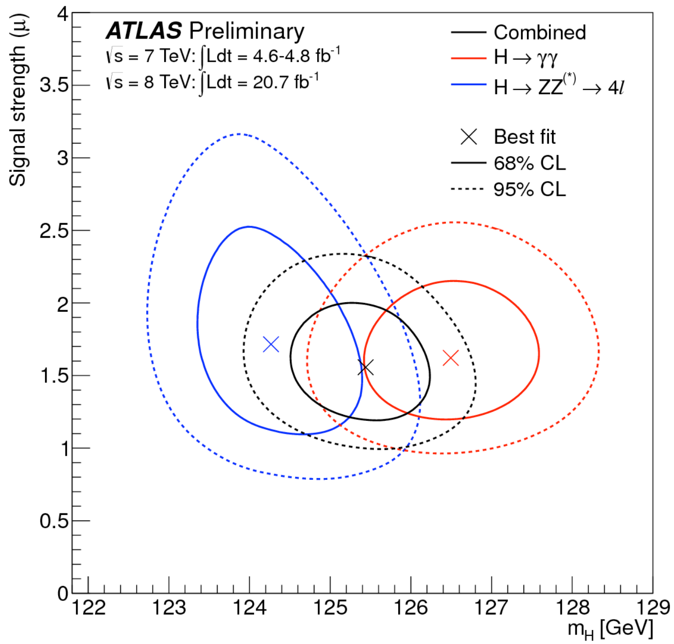


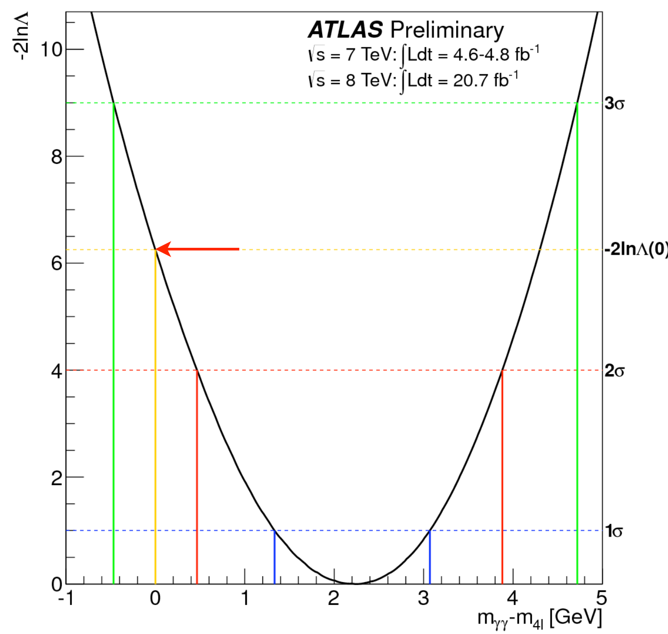
Observed significance 6.6σ (expected from SM Higgs 4.4σ)

m_H = 124.3 ± 0.6 (stat) ± 0.4 (syst) GeV   μ (124.3 GeV) = 1.7 ± 0.4

800 MeV shift from previous result due to increased dataset and updated set of candidates due to optimised analysis

H → γγ and H → 4ℓ mass combination





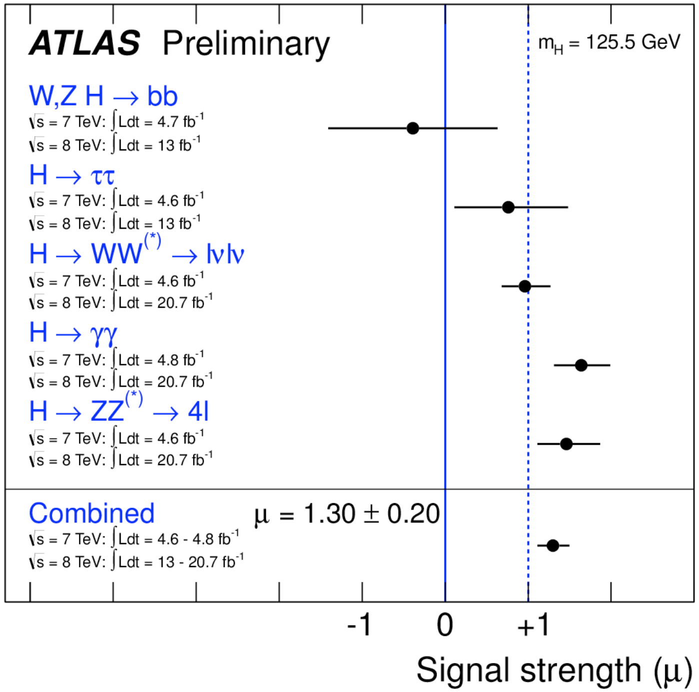
Combined mass measurement m_H = 125.5 ± 0.2 (stat) ± 0.6 (syst) GeV

The mass difference is reduced by 700 MeV compared to the December result

Taking mass scale systematic uncertainties and their correlations into account the compatibility of the two measurements is at the 1.5% (2.4σ level)

With an alternative treatment of systematic uncertainties this increases to 8%

Combination of channels



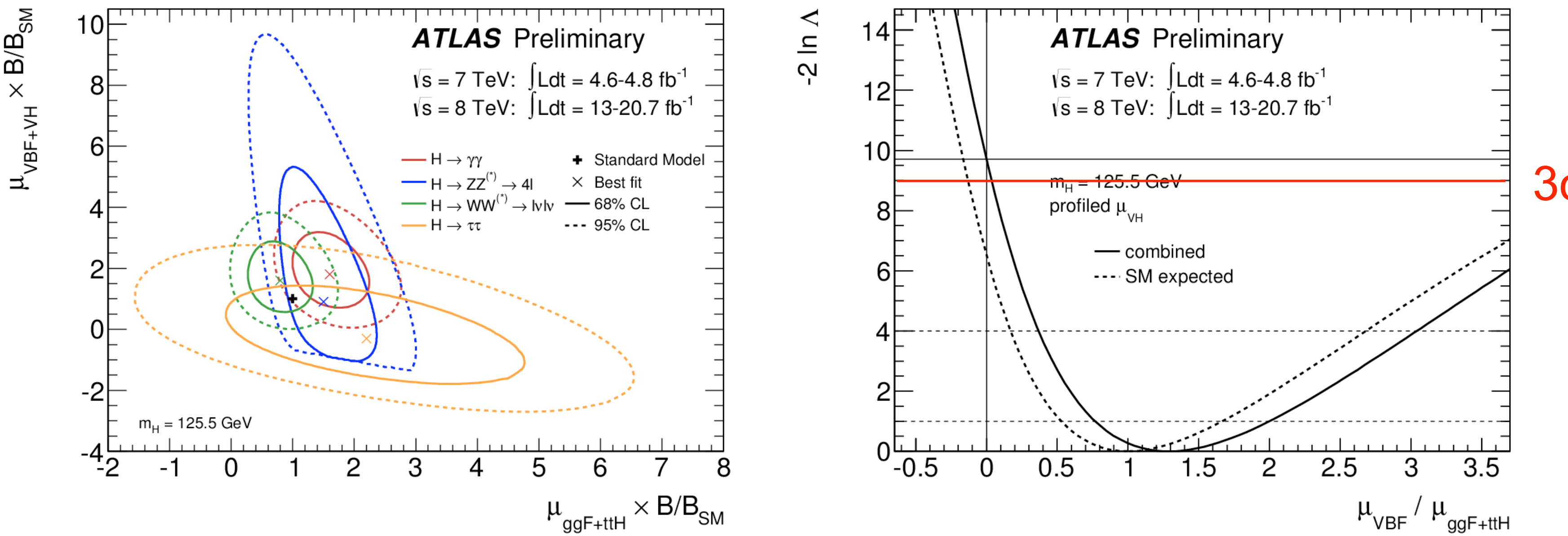
Higgs Boson Decay	μ (m_H=125.5 GeV)
$VH \to Vbb$	-0.4 ± 1.0
$H \to \tau\tau$	0.8 ± 0.7
$H \to WW^{(*)}$	1.0 ± 0.3
$H \to \gamma\gamma$	1.6 ± 0.3
$H \to ZZ^{(*)}$	1.5 ± 0.4
Combined	1.30 ± 0.20

Combined signal strength μ =1.30 ± 0.13 (stat) ± 0.14 (syst)

Global compatibility between the 5 channels and the SM expectation is 8%

Dependence of the combined μ on the mass is weak
(4% for 124.5 - 126.5 GeV)

Evidence for VBF production



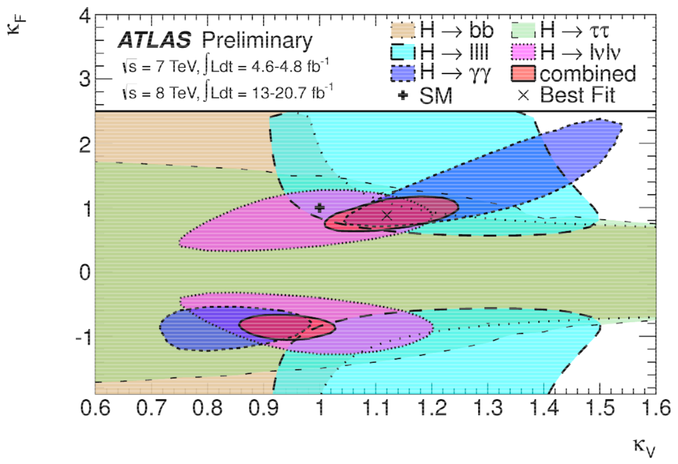
Comparison of different channels in the 2D production mode likelihood contour

Use the ratio of production modes to eliminate the *B/B_{SM}* dependence

Profile μ_{VH} to test VBF alone:

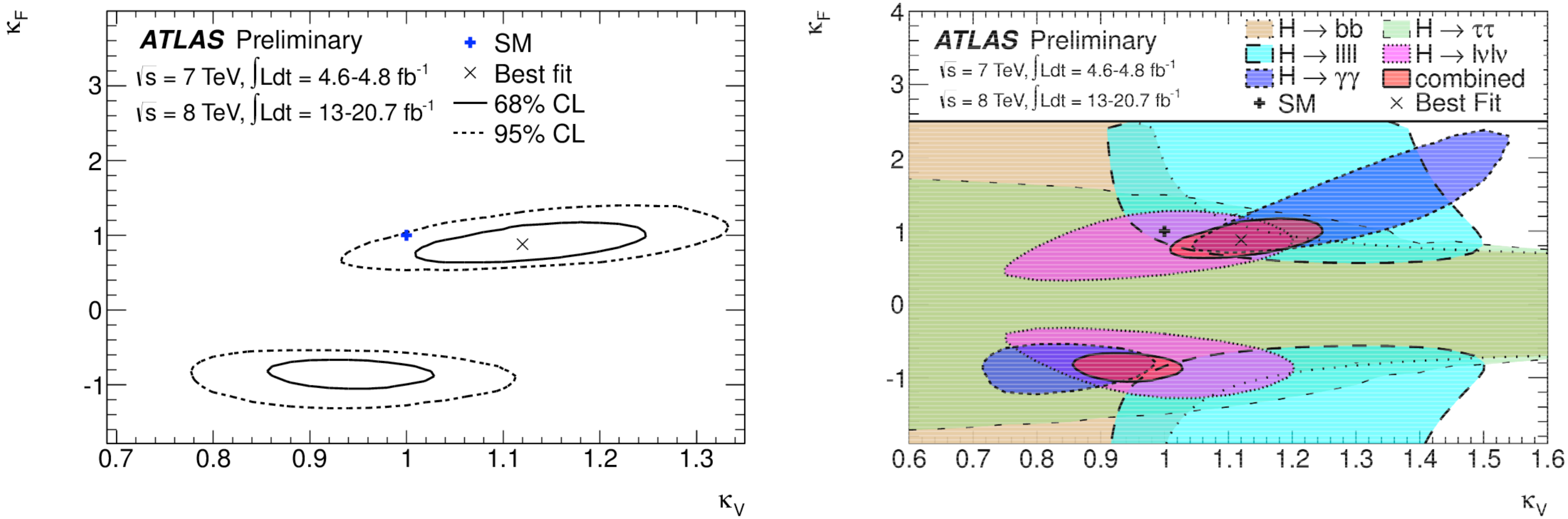
$\mu_{VBF} / \mu_{ggF}+\mu_{ttH} = 1.2^{+0.7}_{-0.5}$ → 3.1σ evidence for VBF production

Higgs couplings



Characterise production cross sections and branching ratios in terms of a few common LO motivated multiplicative factors (κ^2) to the SM Higgs couplings

Fermion vs vector couplings



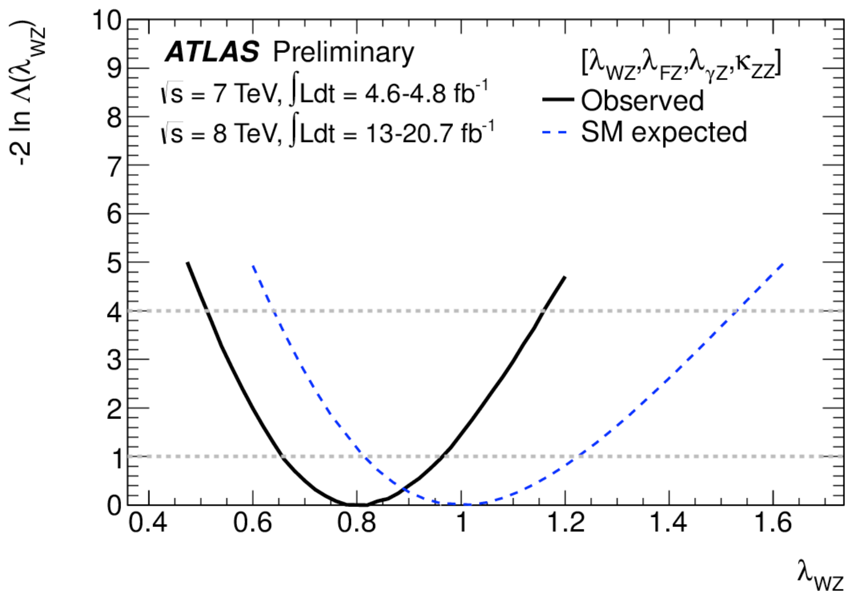
2-parameter benchmark model, group fermion and vector couplings together

- $\kappa_V = \kappa_W = \kappa_Z$; $\kappa_F = \kappa_t = \kappa_b = \kappa_\tau = \kappa_g$
- Here: assume only SM particles contribute to κ_g ($gg \to H$) and κ_γ ($H \to \gamma\gamma$)

One overall not observable sign, choose $\kappa_V > 0$. Some sensitivity to κ_F sign from interference between top and W in $H \to \gamma\gamma$

2D compatibility with the SM: 8%

W vs Z couplings (custodial symmetry)



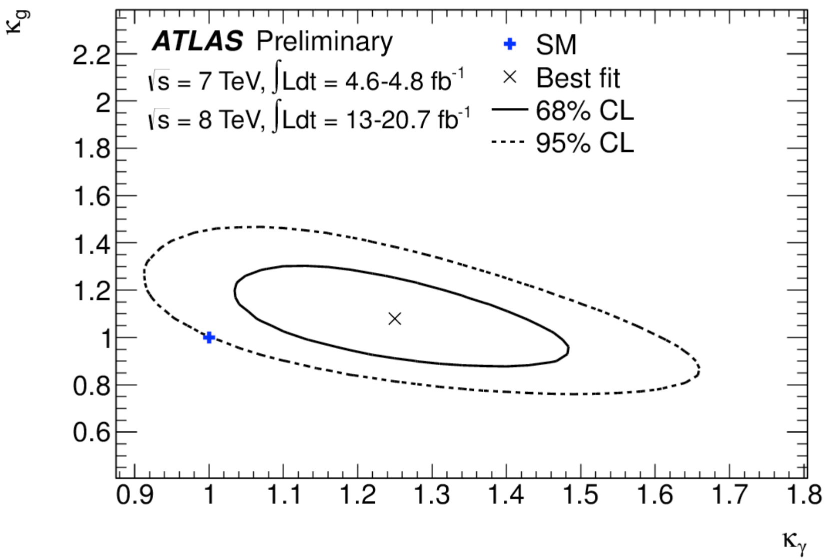
$\lambda_{WZ} = 0.80 \pm 0.15$

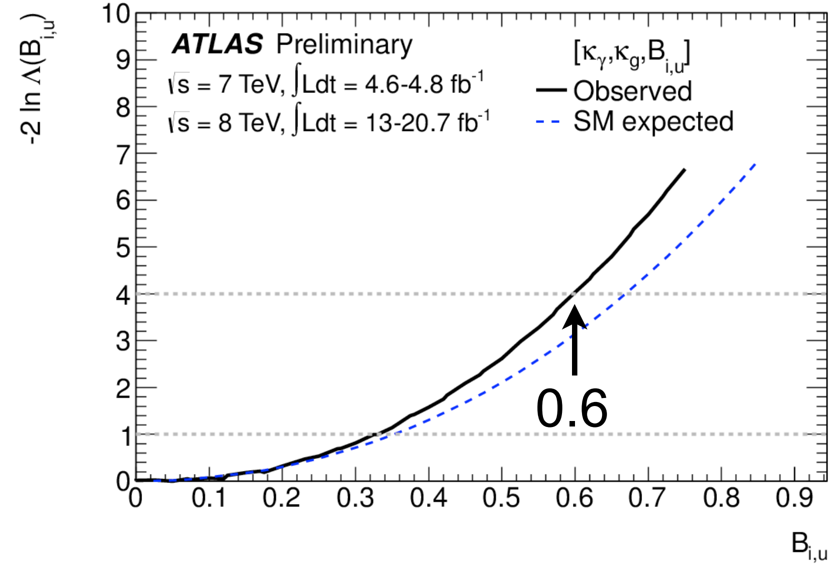
Ratio of W/Z couplings (λ_{WZ}), with:

- Fermion couplings grouped together
- Total width left free
- Extra degree to allow to absorb deviation from the SM in the $H \rightarrow \gamma\gamma$ loop

λ_{WZ} consistent with the SM

Probing beyond SM contributions





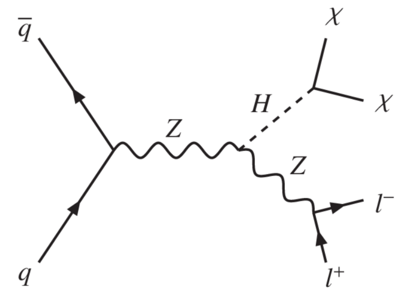
Test for non-SM particle content in $gg\to H$ and $H\to\gamma\gamma$ loops (κ_g and κ_γ)

- All other coupling scale factors as in the SM: $\kappa_i = 1$
- Assume only SM contributions to the total width (no undetected modes)

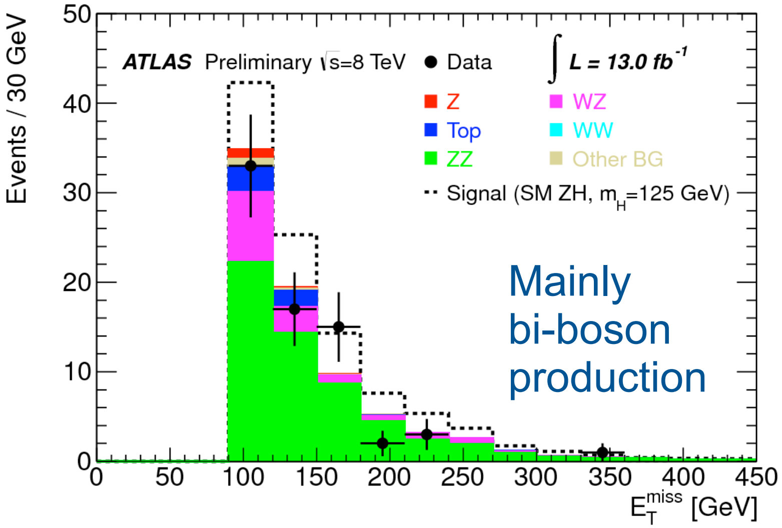
Test for invisible or undetectable non-SM decay modes (profile κ_g and κ_γ)

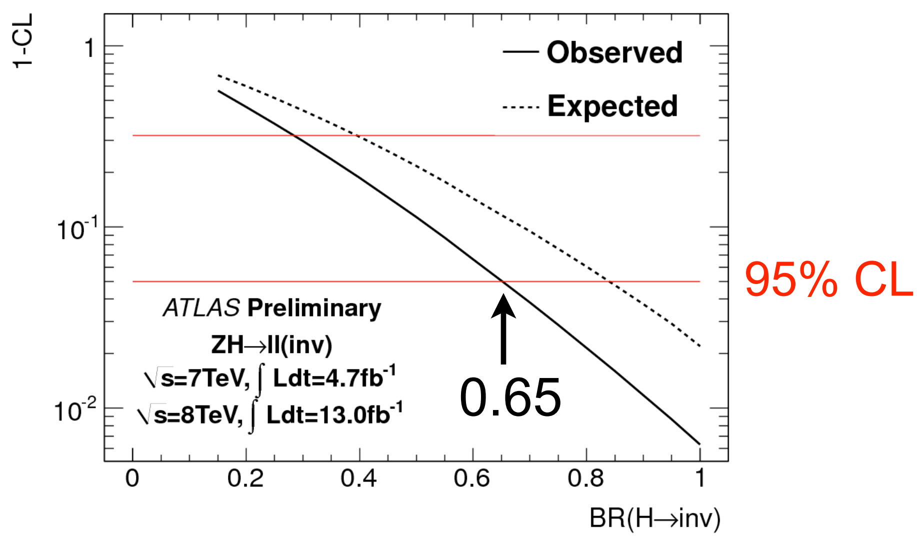
Invisible decay

Dedicated search for ZH→ $\ell\ell$ + invisible



Select events with two exclusive leptons, large missing E_T, recoiling against the Z boson





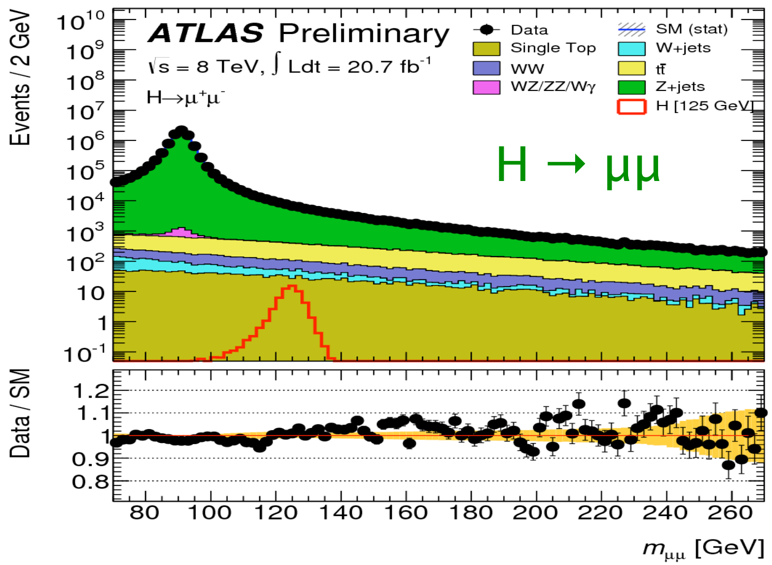
Also, search for ZH production with invisible decaying Higgs. No excess of events is observed over a wider mass range

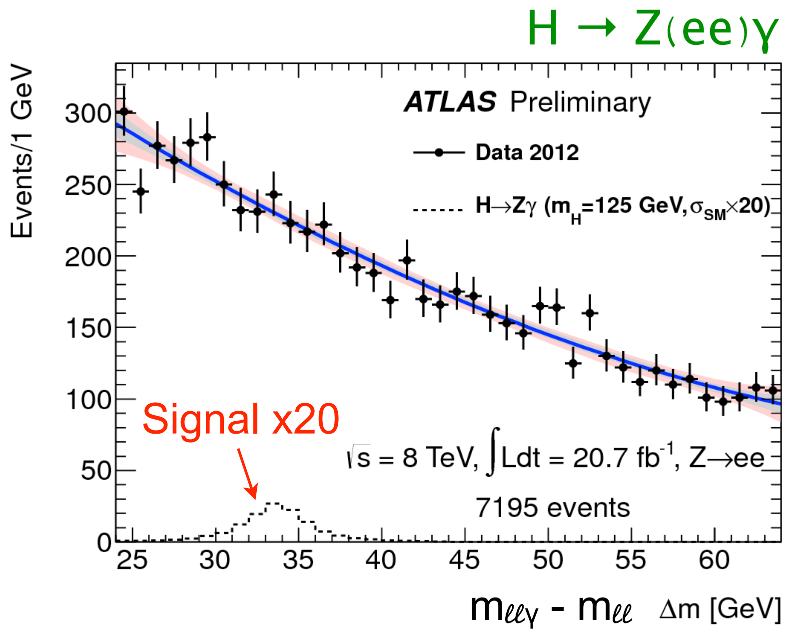
Cross section limits are in the range of ~30 - 10 fb over m_H = 115 − 300 GeV

H → μμ and H → Zγ

Both analyses exploit similar experimental techniques to H → γγ

- Select events with two high pT isolated leptons (and photon for Zγ)
- Main backgrounds (SM Z and Zγ), model with invariant mass sideband fit
- Look for bump in steeply falling mass spectrum

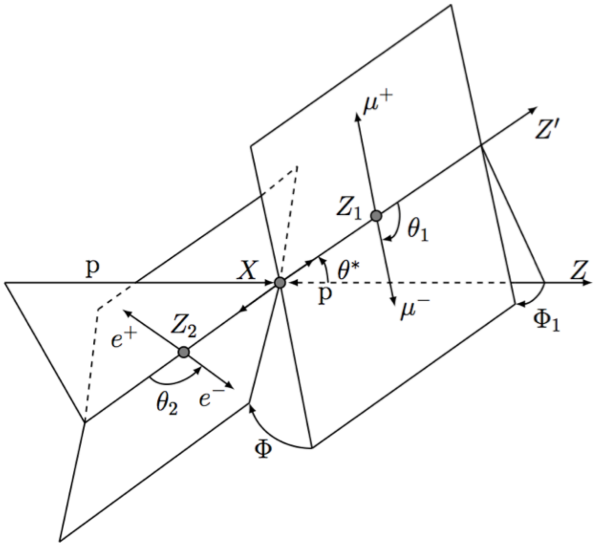




Test (eventually) SM Higgs couplings to second generation fermions, rate enhancements from BSM models (complementary to H → γγ)

No significant excesses observed, limits σ/σ_{SM} ~ 10−15 at m_H = 125 GeV

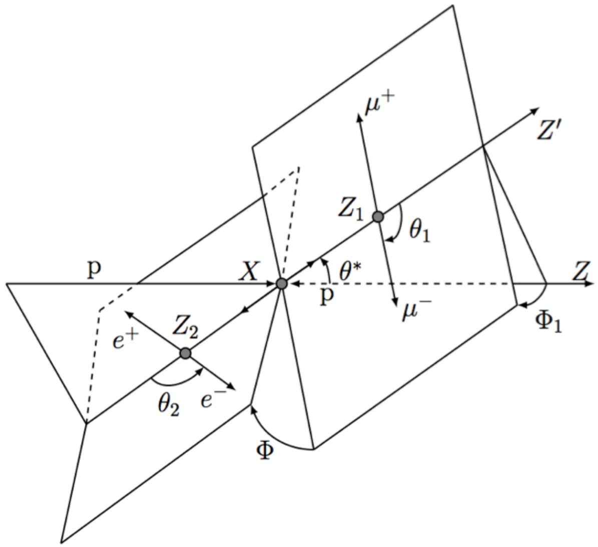
Spin studies



Overview

Spin studies in three different decay modes

- $H \rightarrow \gamma\gamma$: fully reconstructed, however only production angle θ^* available
- $H \rightarrow WW$: direct calculation of decay angles not possible, use other kinematic distributions
- $H \rightarrow ZZ$: fully reconstructed, decay of Z bosons provides information on the Z decay planes



Spin 1 hypothesis strongly disfavoured by Landau-Yang theorem, main interest is to test the SM 0^+ hypothesis against spin 2^+: start with spin 2 tensor with minimal couplings to SM particles (2^+_m)

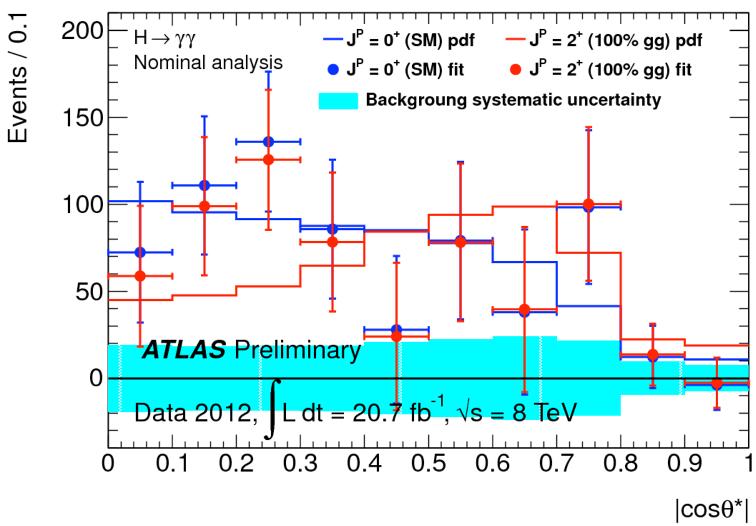
Spin 2^+_m discrimination is tested for possible mixtures of gluon and quark initiated production

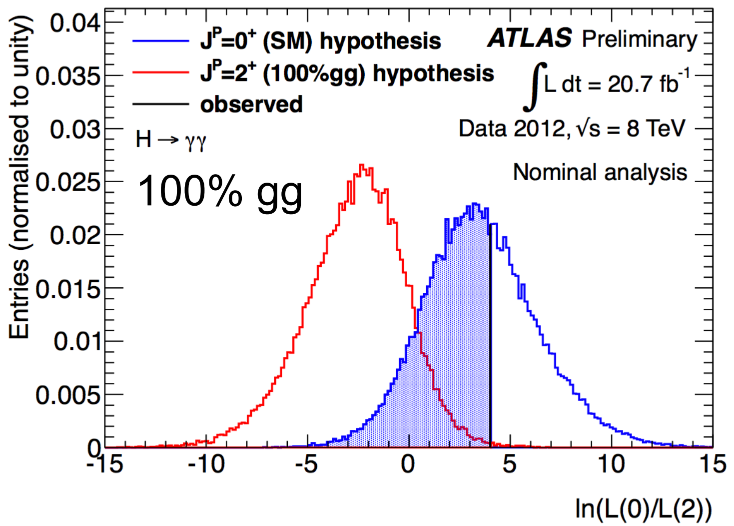
$H \rightarrow ZZ$ analysis is also testing other spin parity states, as 0^+ vs 0^- etc. with gluon-fusion production

H → γγ analysis

Extract spin information only from the cosθ* shape

- Relative photon cuts $p_T/m_{\gamma\gamma}$ to minimise the correlation between $m_{\gamma\gamma}$ and cosθ*
- Obtain background cosθ* pdf from data $m_{\gamma\gamma}$ side-bands
- Final statistical analysis with combined fit to cosθ* and $m_{\gamma\gamma}$

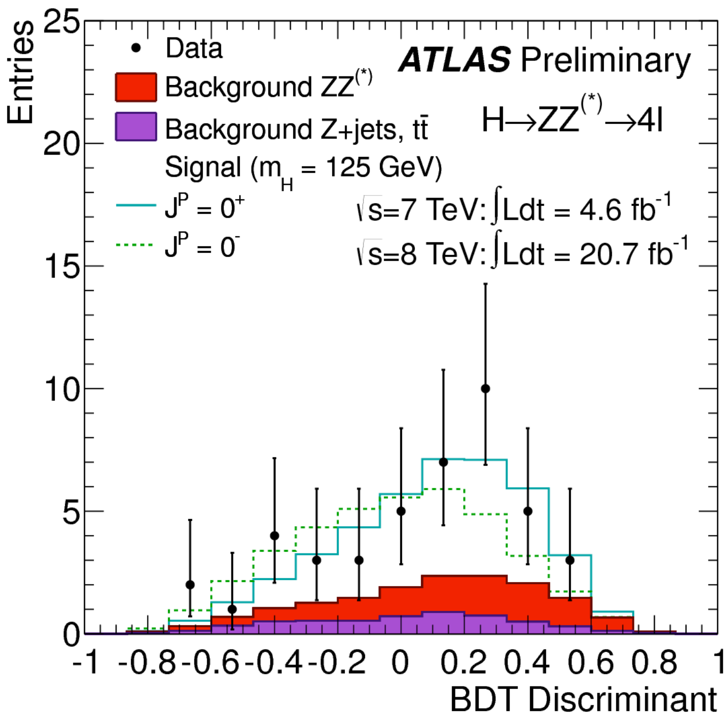




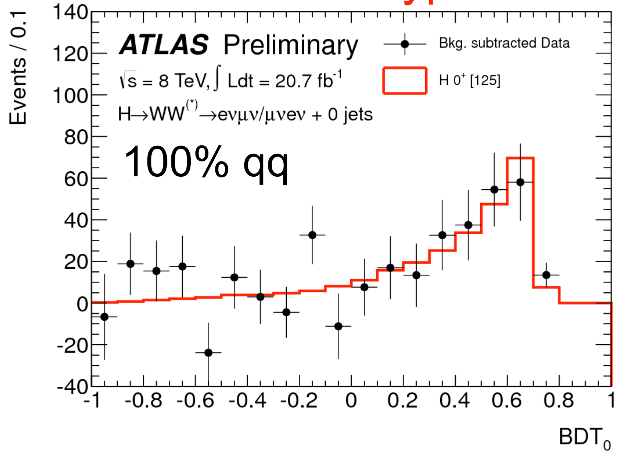
Main uncertainty: modelling of cosθ* for background events

BDT discriminant analyses

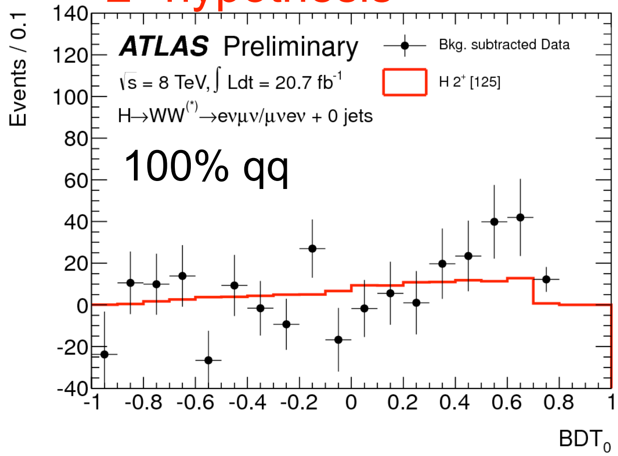
Both, the WW and ZZ analysis is using BDTs with angular and/or other kinematic variables to discriminate different spin (parity) hypotheses



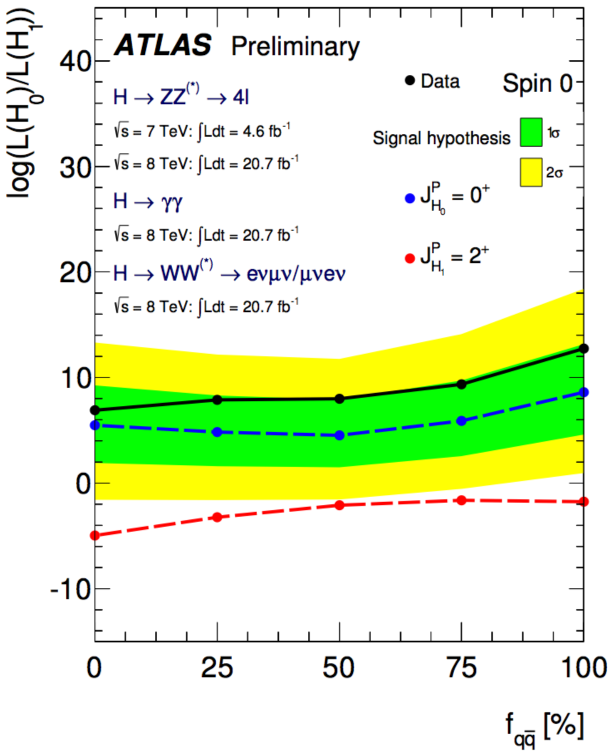
0+ hypothesis

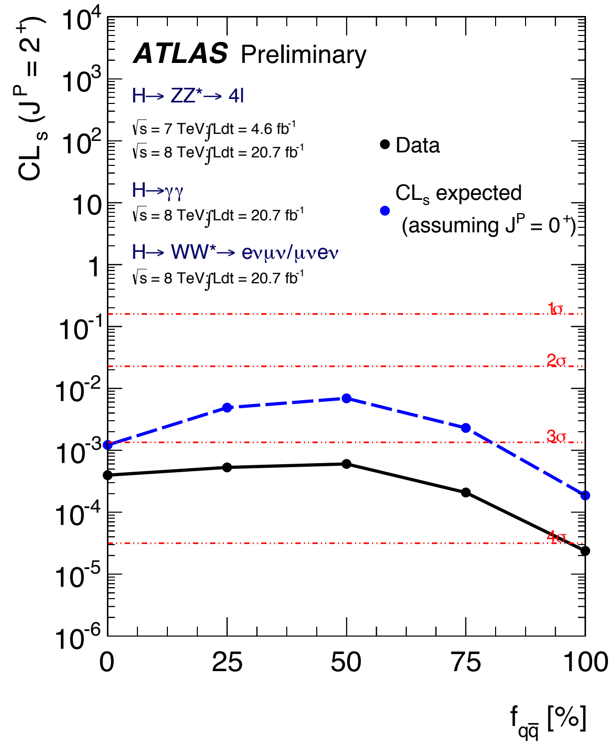


2+ hypothesis



Spin results





New

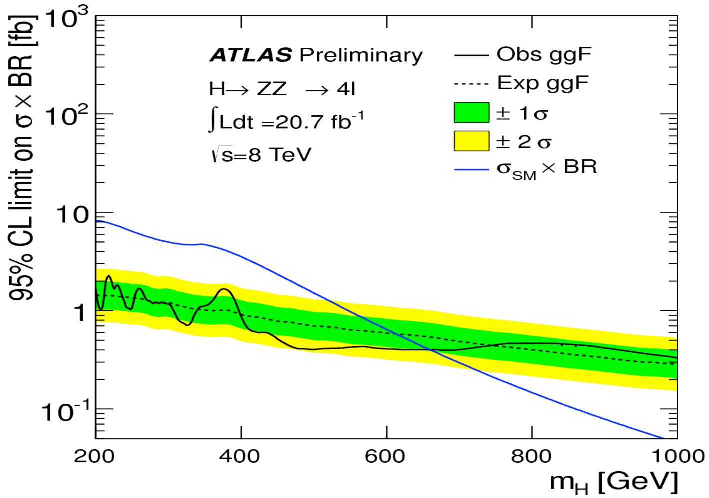
Will appear as: ATLAS-CONF-2013-040

In combination, the 3 channels exclude the 2^+_m model at the 99.9% CL

- Main sensitivity from WW (and γγ for pure ggF production)
- Complementary sensitivity of channels for the different qq production fractions

The ZZ analysis excludes the 0^-, 1^+ and (1^-) hypotheses at the >95% (94%) CL

Search for beyond-SM Higgs



σ x BR limit for an additional gluon-fusion produced Higgs with SM-like width decaying to $ZZ \rightarrow 4\ell$

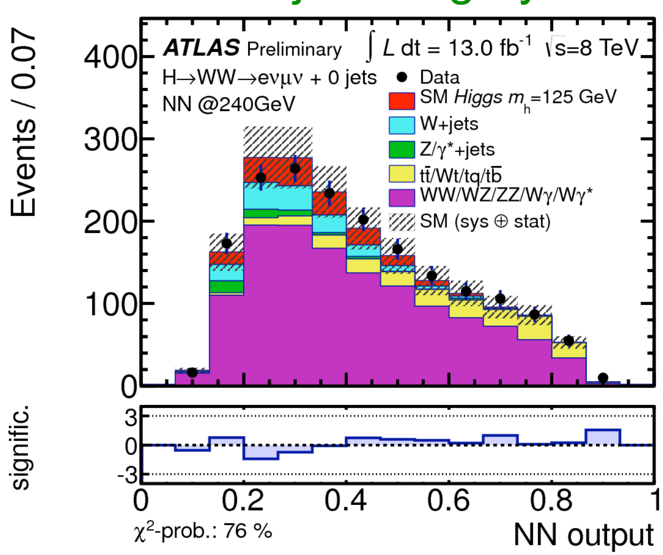
2HDM in WW → eμ + 2ν

Boson at 125 GeV (*h*) could be part of a 2HDM, search for additional CP-even (*H*) contribution

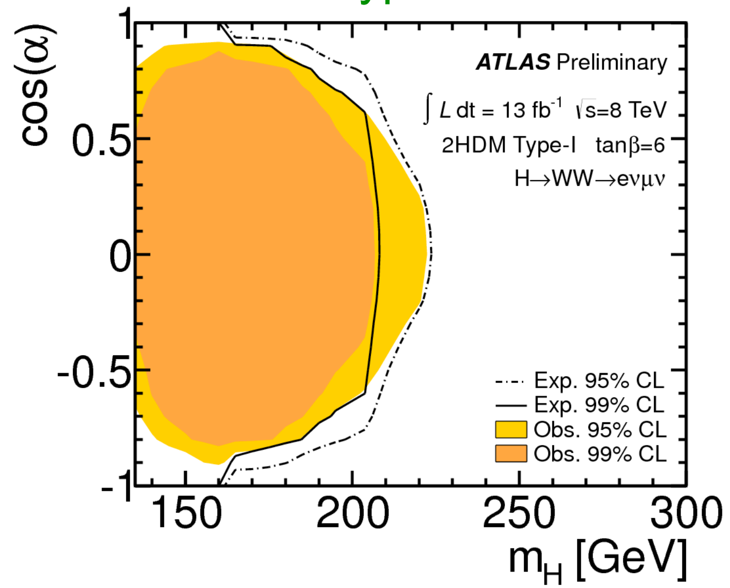
Free parameters: cos α, tan β and m_H, contribution from A and $H^{\pm}$ negligible.
Use high mass SM signal MCs scaled to 2HDM coupling strength

Selection similar to SM H → WW analysis, with two jet-based categories.
Combine several kinematic variables to NN discriminants

0-jet category

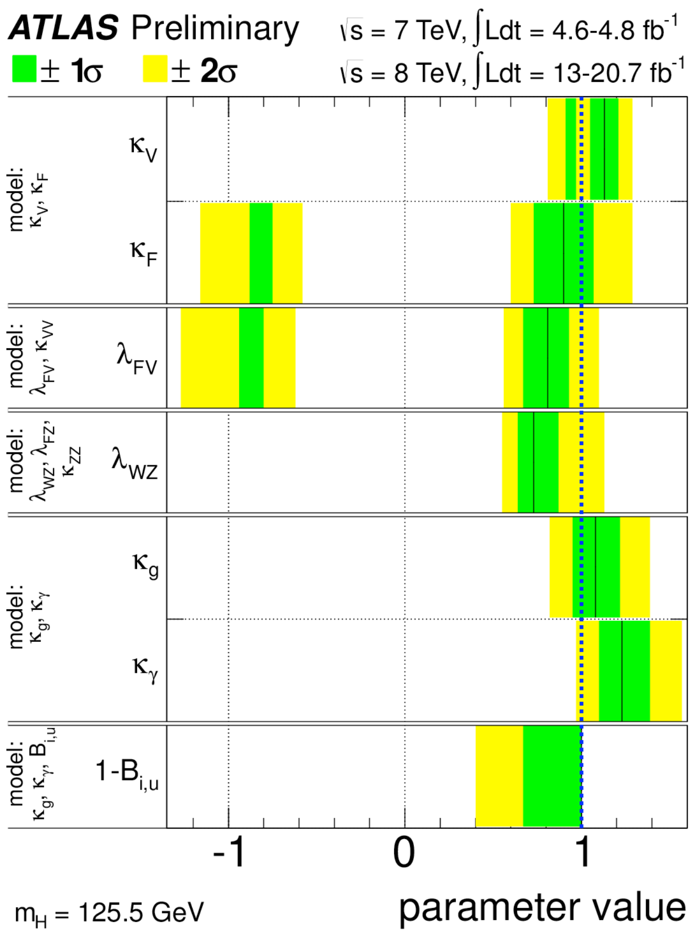


Type-I



Additional plots for Type-II and tan β values 1, 3, 6, 20

Conclusions



Moving towards precision Higgs Physics

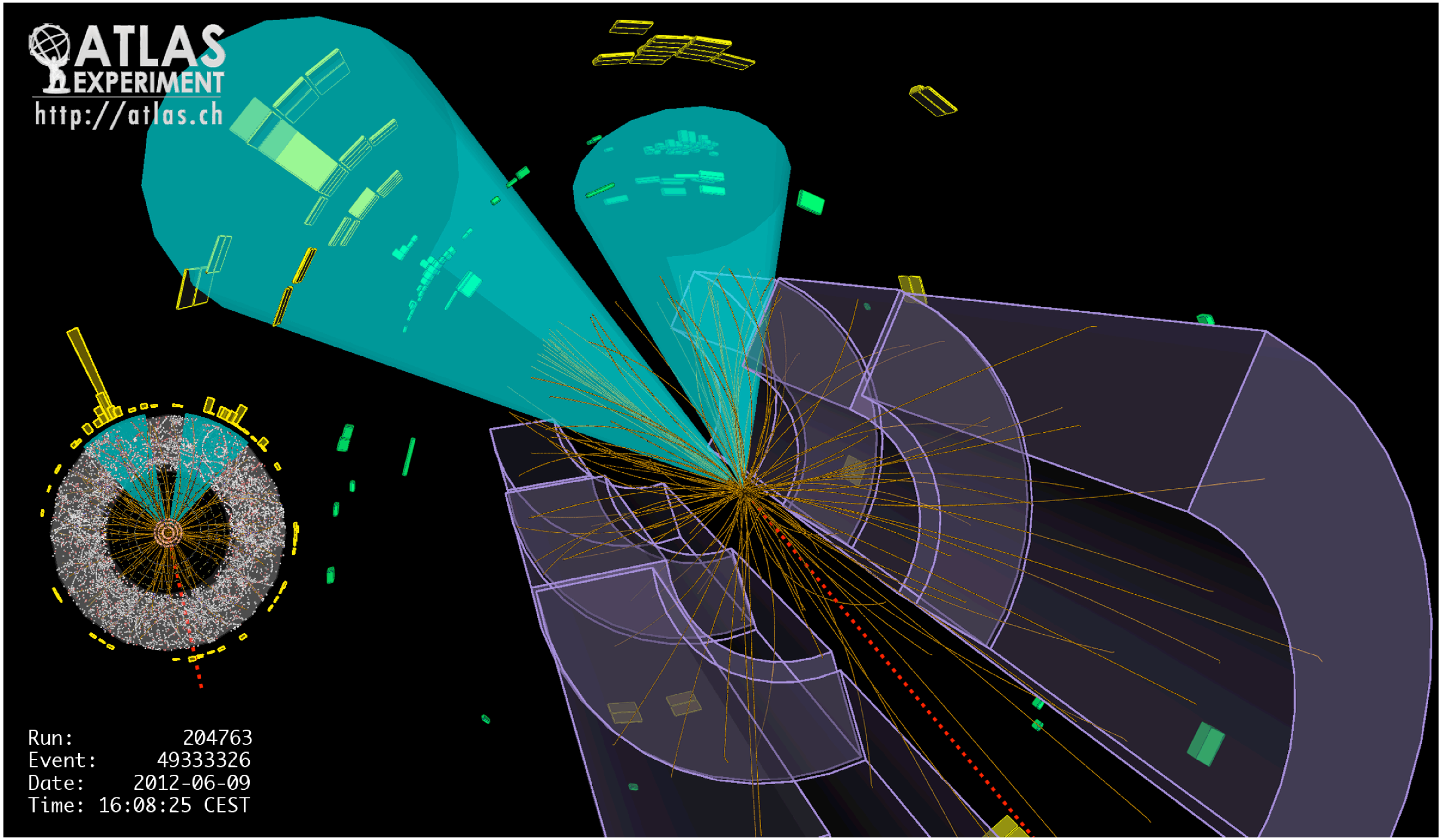
- Evidence for VBF production
- Correct ratio of W/Z couplings
- No strong hints of new physics, neither in the loop, nor in the decay

The observed state is consistent with SM spin/CP

Active search for rare decays and additional states of the EWSB sector

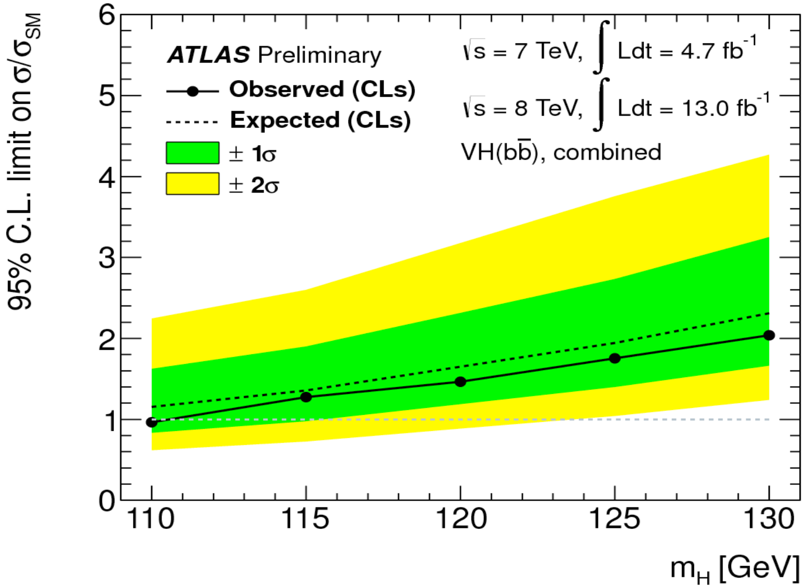
Backup slides

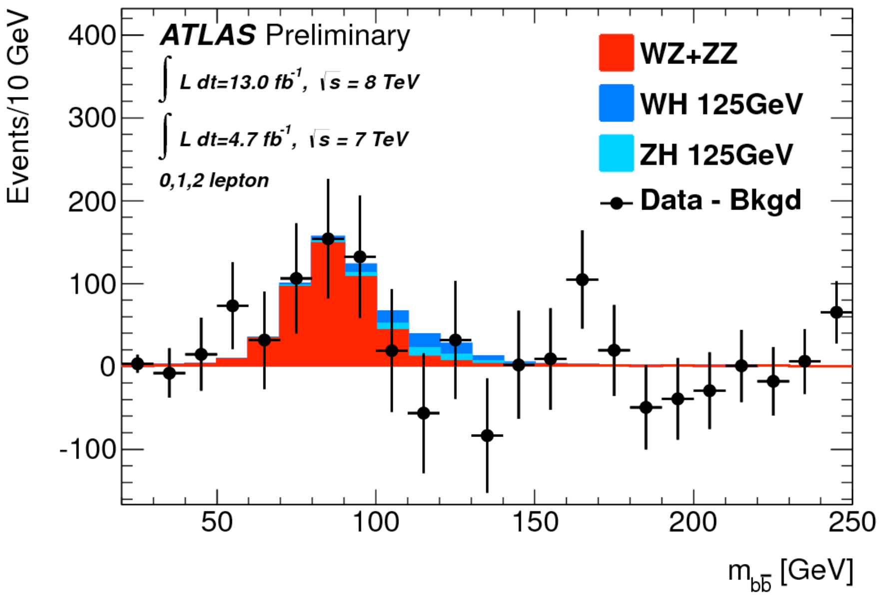
VH production with H → bb



Dataset	Production modes	Exp. signal yield	S/B
18/fb	VH	~50	~1 – 10%

VH production with H → bb





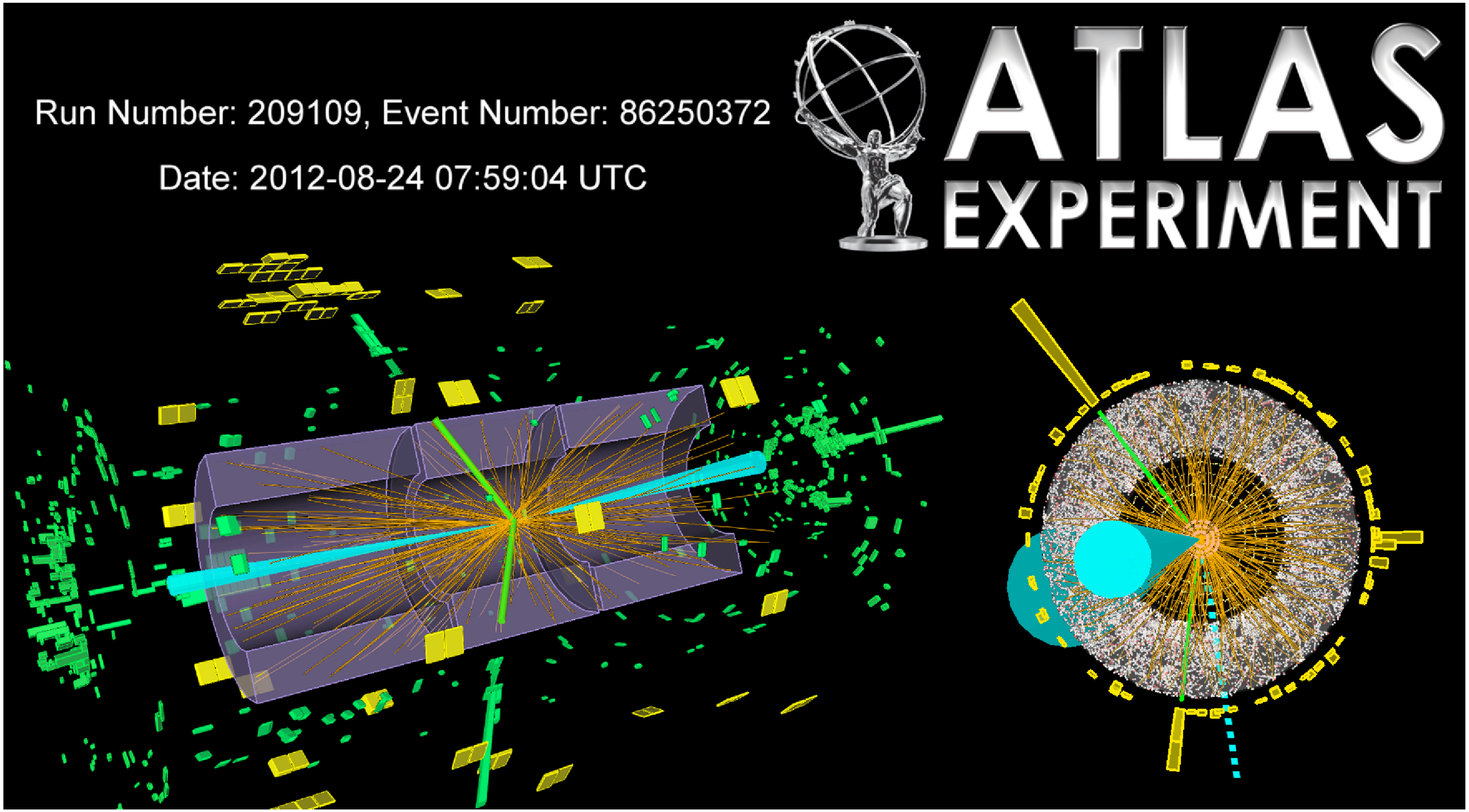
Limits derived from m_{bb} distribution (~16% resolution)

95%CL limit at 125 GeV: 1.8 xSM (exp 1.9)

μ(125) = -0.4 ± 0.7(stat) ± 0.8(syst)

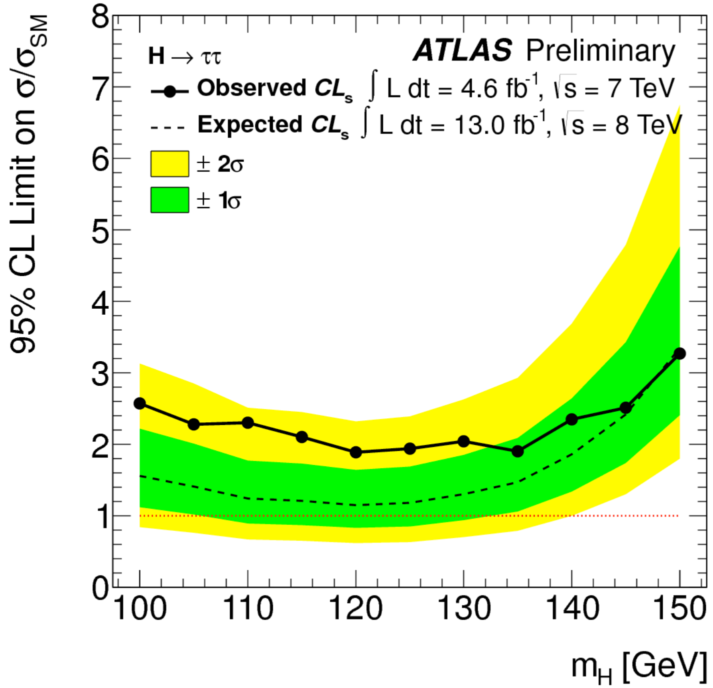
Main benchmark analysis, 4.0σ observation of WZ(bb)/ZZ(bb)

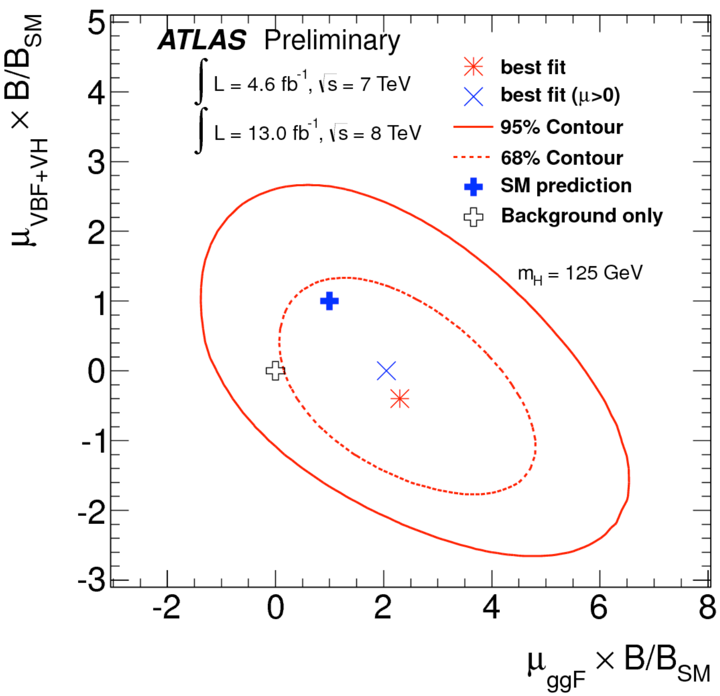
H → ττ



Dataset	Production modes	Exp. signal yield	S/B
18/fb	VBF, ggF, VH	~330	~0.3 – 30%

H → ττ





Search in exclusive categories:

- Tau decays: lep-lep, lep-had, had-had
- Jets: 0, 1 (boosted or not), 2 (VBF, VH) → most powerful channel VBF

95%CL limit at 125 GeV: 1.9 xSM (exp 1.2), μ(125) = 0.7 ± 0.7

No probing evidence yet in H → ττ and H → bb

Higgs couplings

Measure deviations of couplings from the SM prediction (arXiv:1209.0040)

Basic assumptions:

- There is only one underlying state at mH~125 GeV
- It has negligible width
- It is a CP-even scalar (only allow for modification of coupling strengths, no change in the Lorentz structure)

→ Characterise production cross sections and branching ratios in terms of a few common LO motivated multiplicative factors (κ^2) to the SM Higgs couplings

Example:

$$\sigma \times BR(ii \to \mathrm{H} \to ff) = \frac{\sigma_{ii} \cdot \Gamma_{ff}}{\Gamma_{\mathrm{H}}}$$

$$(\sigma \cdot \mathrm{BR})(\mathrm{gg} \to \mathrm{H} \to \gamma\gamma) = \sigma_{\mathrm{SM}}(\mathrm{gg} \to \mathrm{H}) \cdot \mathrm{BR}_{\mathrm{SM}}(\mathrm{H} \to \gamma\gamma) \cdot \frac{\kappa_{\mathrm{g}}^2 \cdot \kappa_{\gamma}^2}{\kappa_{\mathrm{H}}^2}$$

$$\kappa_g = f(\kappa_t, \kappa_b, M_H)$$

$$\kappa_H = f'(\kappa_t, \kappa_b, \kappa_\tau, \kappa_W, \kappa_Z, M_H)$$

$H \rightarrow \gamma\gamma$ and $H \rightarrow 4l$ Mass Scale Systematic Uncertainties

Main Mass Scale systematic uncertainties (considered in also ICHEP studies) :

Source	Relative Mass Scale Effect
Absolute Energy scale calibration from Z	0.3%
Upstream material simulation inaccuracies	0.3%
Pre-Sampler energy scale	0.1%

Further investigation and extensive checks lead to find additional sources of systematic uncertainties :

- LAr Strips relative calibration (0.2%)
- Calibration of the high gain (0.15%)
- Mis-classification due to fake conversions (0.13%)
- Backgound modeling (0.1%)
- Lateral shower development simulation (0.1%)
- Effect of PV choice (0.03%)

Main 4l Mass Scale systematic uncertainties :

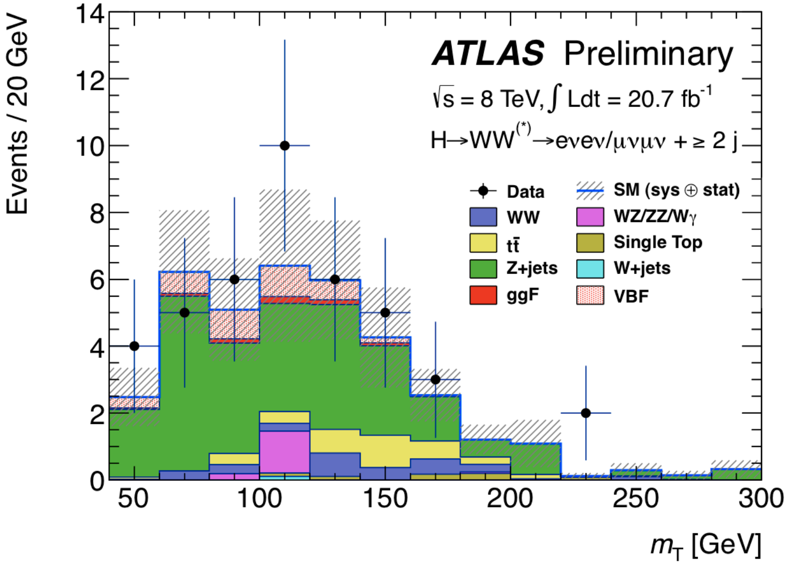
Source	Relative Mass Scale Effect
Absolute Energy scale calibration from Z	0.4%
Low transverse energy electrons	0.2%
Muon momentum scale	0.2%

Further investigation and extensive checks have not lead to additional substantial sources of systematic uncertainty :

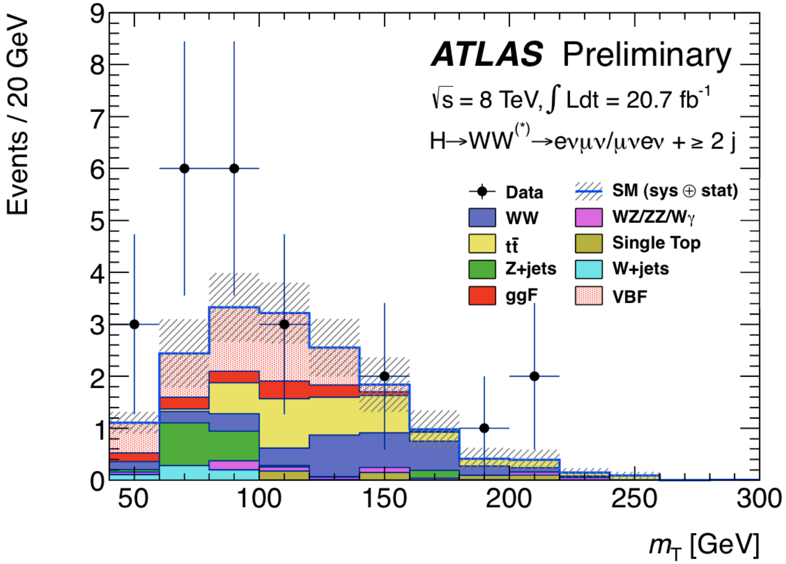
- Measurement with MS and ID alone
- Local detector biases checked event by event
- Local resolution effects checked using event-by-event error;
- kinematic distributions in agreement with expectation
- FSR simulation
- Different mass reconstruction using Z-mass constraint (+400 MeV shift)

1

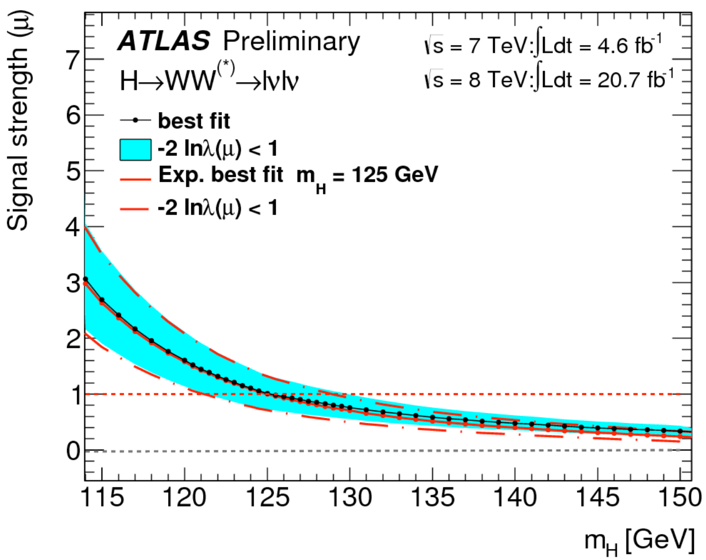
H → WW* → ℓℓ + 2ν



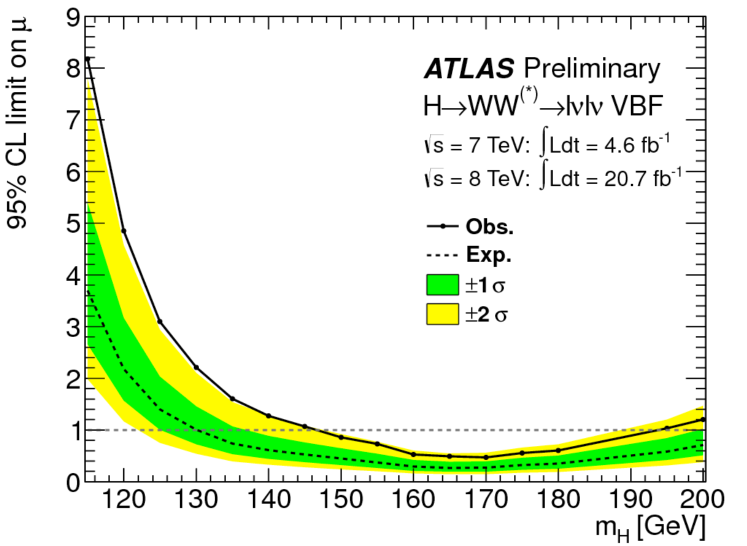
ATLAS Preliminary
√s = 8 TeV, ∫ Ldt = 20.7 fb-1
H→WW(*)→eνeν/μνμν + ≥ 2 j
Data
WW
tt̄
Z+jets
ggF
SM (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
VBF
Events / 20 GeV
mT [GeV]



ATLAS Preliminary
√s = 8 TeV, ∫ Ldt = 20.7 fb-1
H→WW(*)→eνμν/μνeν + ≥ 2 j
Data
WW
tt̄
Z+jets
ggF
SM (sys ⊕ stat)
WZ/ZZ/Wγ
Single Top
W+jets
VBF
Events / 20 GeV
mT [GeV]

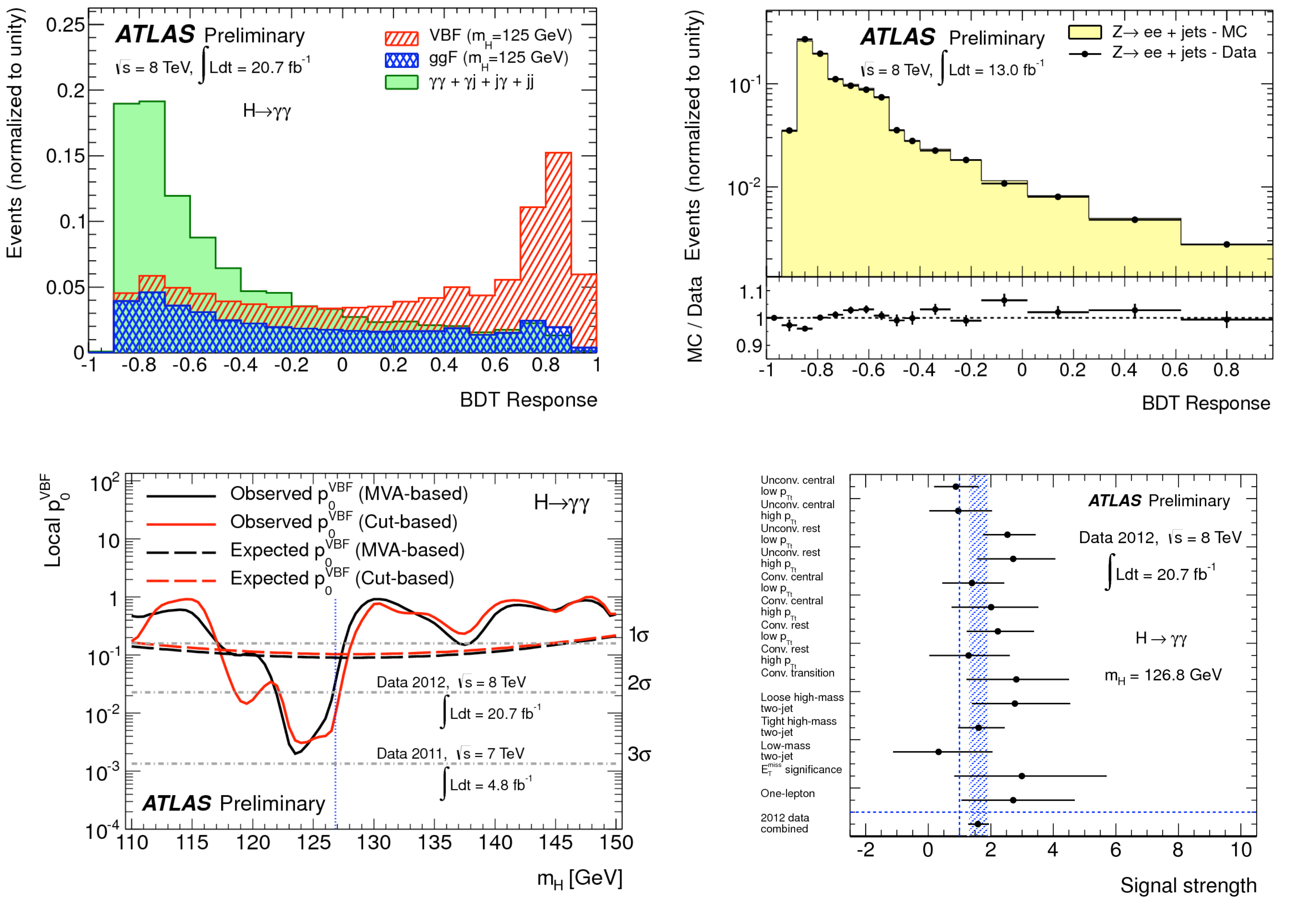


ATLAS Preliminary
H→WW(*)→lνlν
√s = 7 TeV:∫Ldt = 4.6 fb-1
√s = 8 TeV:∫Ldt = 20.7 fb-1
best fit
-2 lnλ(μ) < 1
Exp. best fit mH = 125 GeV
-2 lnλ(μ) < 1
Signal strength (μ)
mH [GeV]



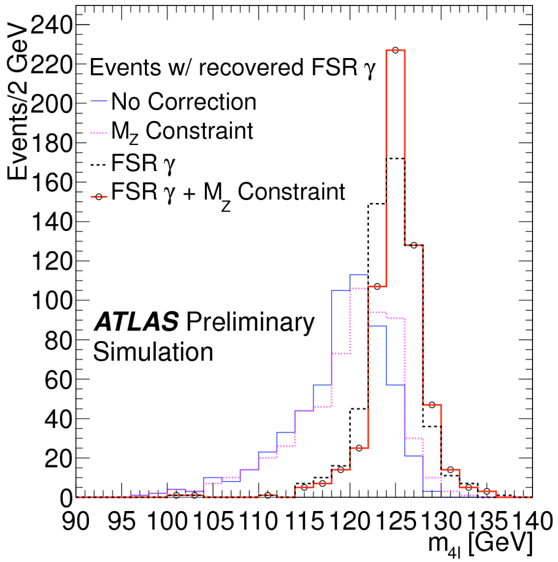
ATLAS Preliminary
H→WW(*)→lνlν VBF
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
Obs.
Exp.
±1 σ
±2 σ
95% CL limit on μ
mH [GeV]

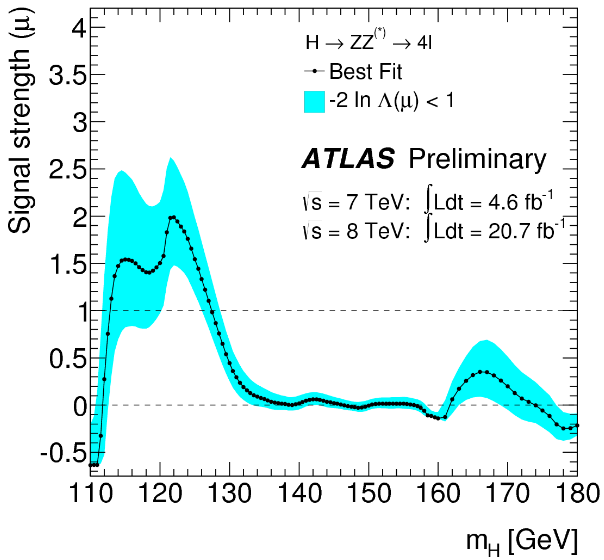
H → γγ

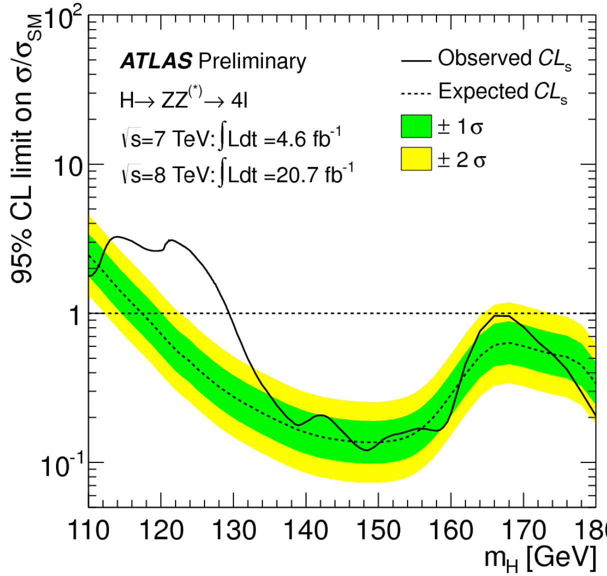


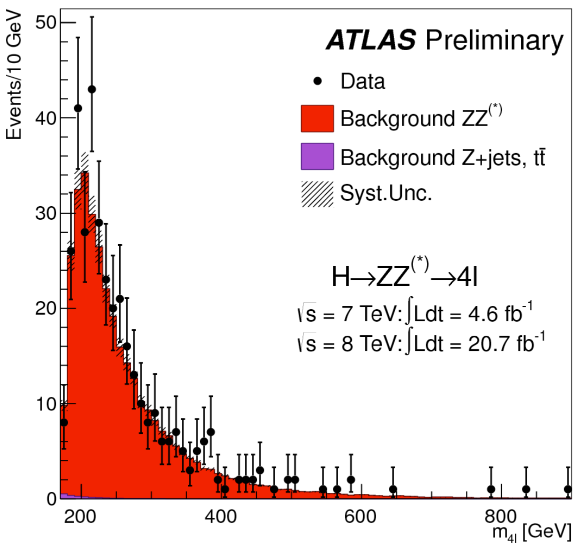
ATLAS Preliminary
√s = 8 TeV, ∫Ldt = 20.7 fb⁻¹
H→γγ
VBF (m_H=125 GeV)
ggF (m_H=125 GeV)
γγ + γj + jγ + jj
Events (normalized to unity)
BDT Response
ATLAS Preliminary
√s = 8 TeV, ∫Ldt = 13.0 fb⁻¹
Z→ ee + jets - MC
Z→ ee + jets - Data
MC / Data
Local p0^VBF
Observed p0^VBF (MVA-based)
Observed p0^VBF (Cut-based)
Expected p0^VBF (MVA-based)
Expected p0^VBF (Cut-based)
Data 2012, √s = 8 TeV ∫Ldt = 20.7 fb⁻¹
Data 2011, √s = 7 TeV ∫Ldt = 4.8 fb⁻¹
1σ
2σ
3σ
m_H [GeV]
Unconv. central low pTt
Unconv. central high pTt
Unconv. rest low pTt
Unconv. rest high pTt
Conv. central low pTt
Conv. central high pTt
Conv. rest low pTt
Conv. rest high pTt
Conv. transition
Loose high-mass two-jet
Tight high-mass two-jet
Low-mass two-jet
ET miss significance
One-lepton
2012 data combined
m_H = 126.8 GeV
Signal strength

H → ZZ* → 4ℓ

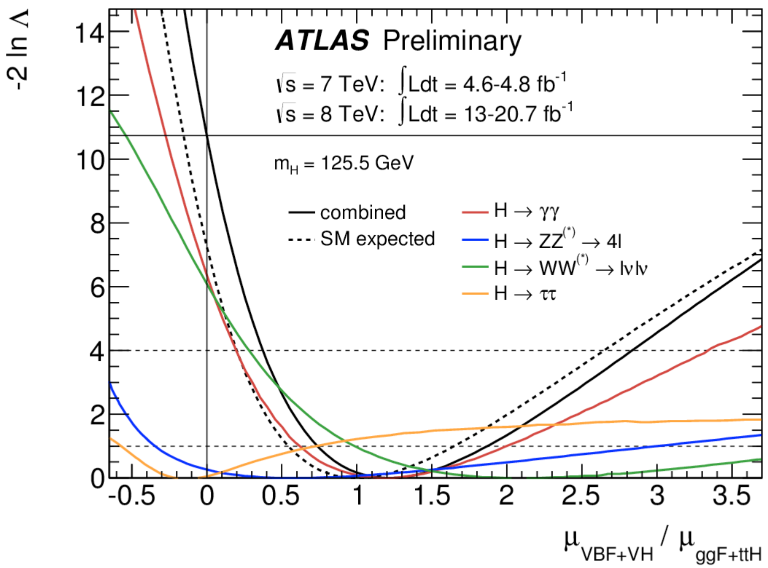

Events/2 GeV
Events w/ recovered FSR γ
No Correction
M_Z Constraint
FSR γ
FSR γ + M_Z Constraint
ATLAS Preliminary
Simulation
m_4l [GeV]

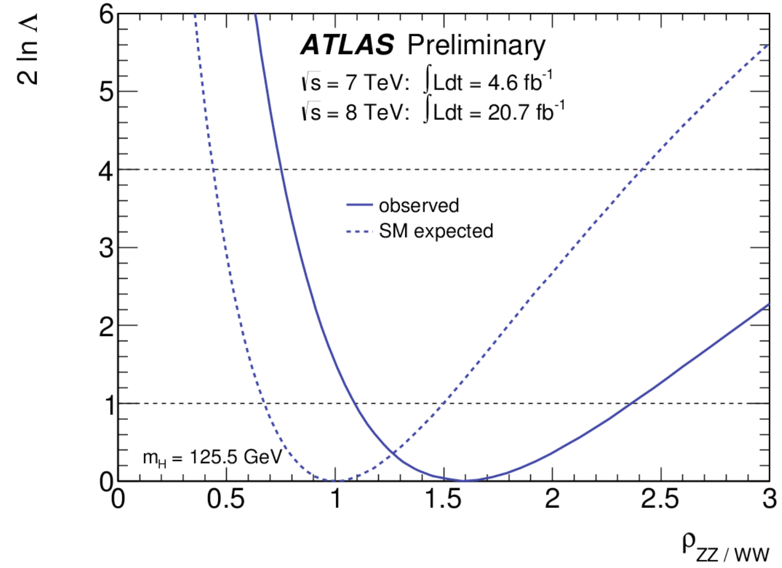

Signal strength (μ)
H → ZZ(*) → 4l
Best Fit
-2 ln Λ(μ) < 1
ATLAS Preliminary
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
m_H [GeV]

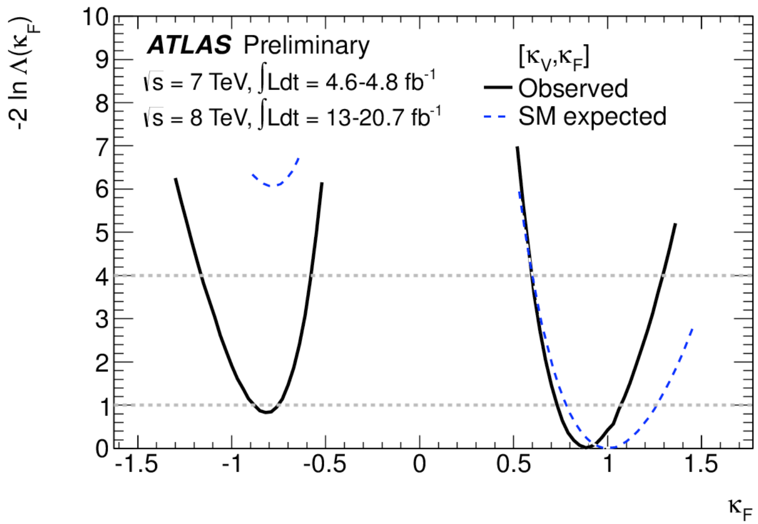

95% CL limit on σ/σ_SM
ATLAS Preliminary
H→ ZZ(*)→ 4l
√s=7 TeV: ∫Ldt =4.6 fb-1
√s=8 TeV: ∫Ldt =20.7 fb-1
Observed CLs
Expected CLs
± 1σ
± 2 σ
m_H [GeV]

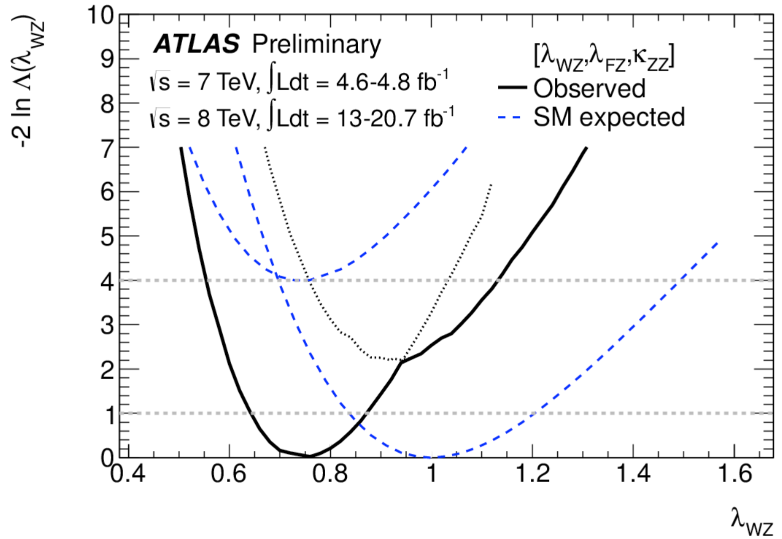

Events/10 GeV
ATLAS Preliminary
Data
Background ZZ(*)
Background Z+jets, tt̄
Syst.Unc.
H→ZZ(*)→4l
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
m_4l [GeV]

Couplings


ATLAS Preliminary
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb-1
√s = 8 TeV: ∫Ldt = 13-20.7 fb-1
mH = 125.5 GeV
combined
SM expected
H → γγ
H → ZZ(*) → 4l
H → WW(*) → lνlν
H → ττ
-2 ln Λ
μVBF+VH / μggF+ttH

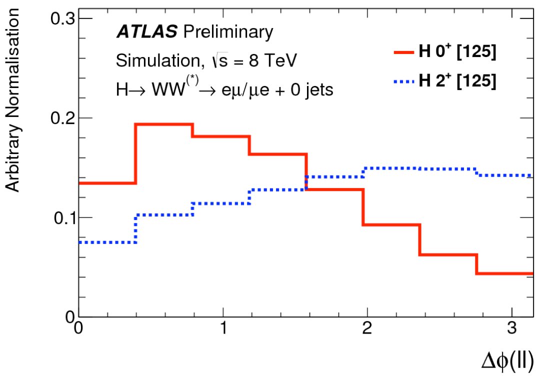

ATLAS Preliminary
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
observed
SM expected
mH = 125.5 GeV
2 ln Λ
ρZZ / WW

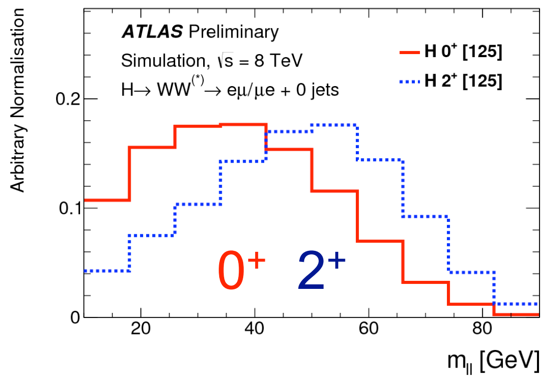

ATLAS Preliminary
√s = 7 TeV, ∫Ldt = 4.6-4.8 fb-1
√s = 8 TeV, ∫Ldt = 13-20.7 fb-1
[κV,κF]
Observed
SM expected
-2 ln Λ(κF)
κF

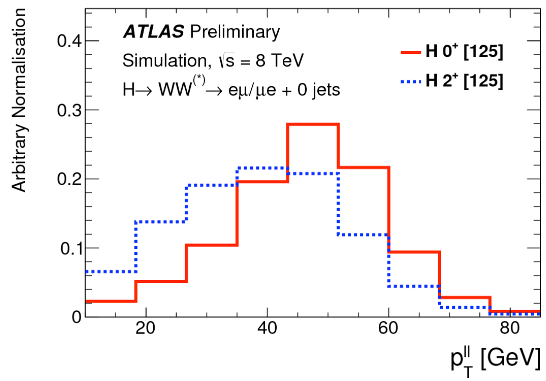

ATLAS Preliminary
√s = 7 TeV, ∫Ldt = 4.6-4.8 fb-1
√s = 8 TeV, ∫Ldt = 13-20.7 fb-1
[λWZ,λFZ,κZZ]
Observed
SM expected
-2 ln Λ(λWZ)
λWZ

Spin WW

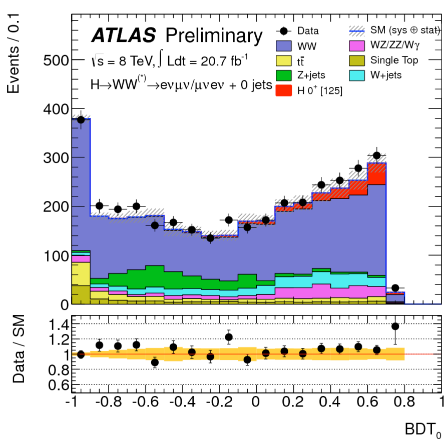
Input variables:



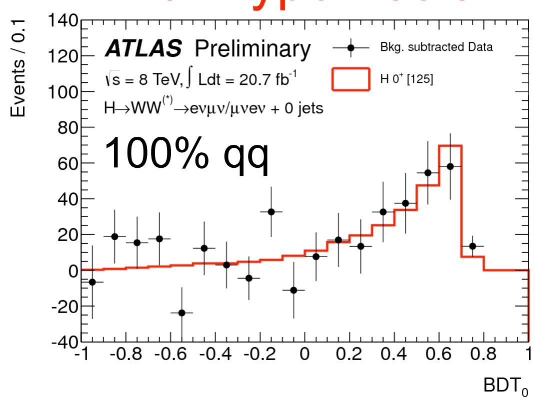




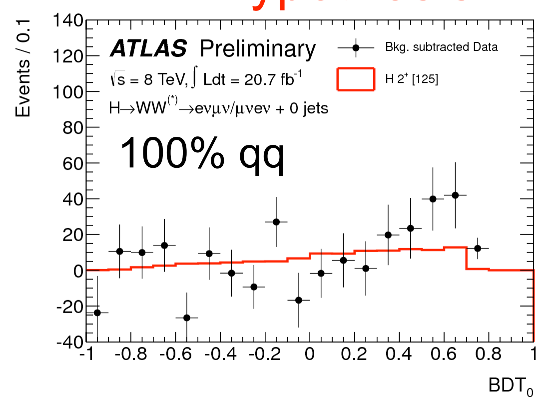
BDT discrimination:



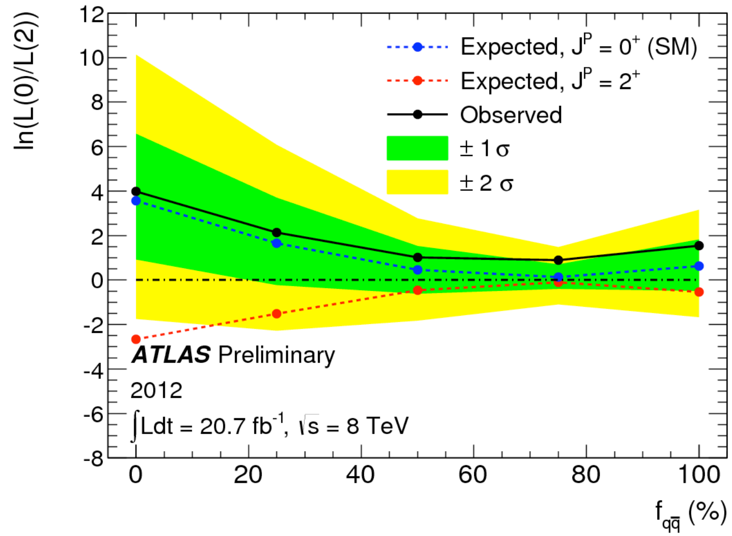
0^+ hypothesis

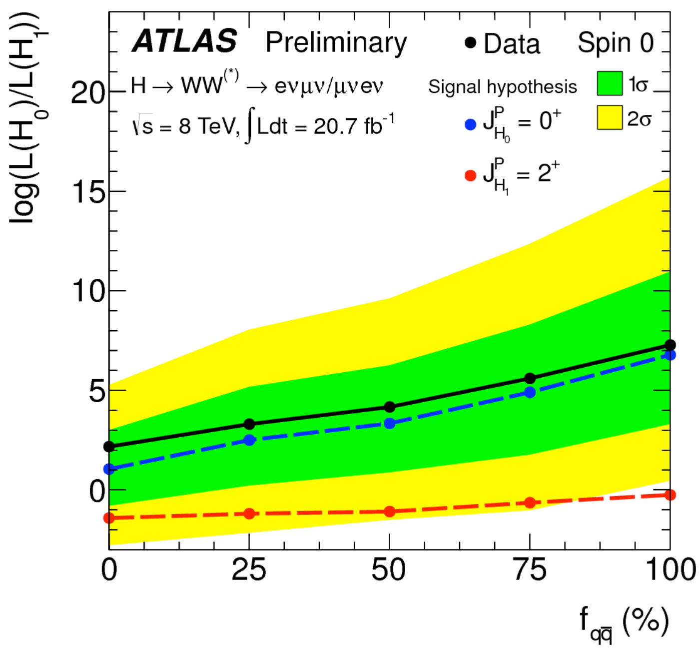


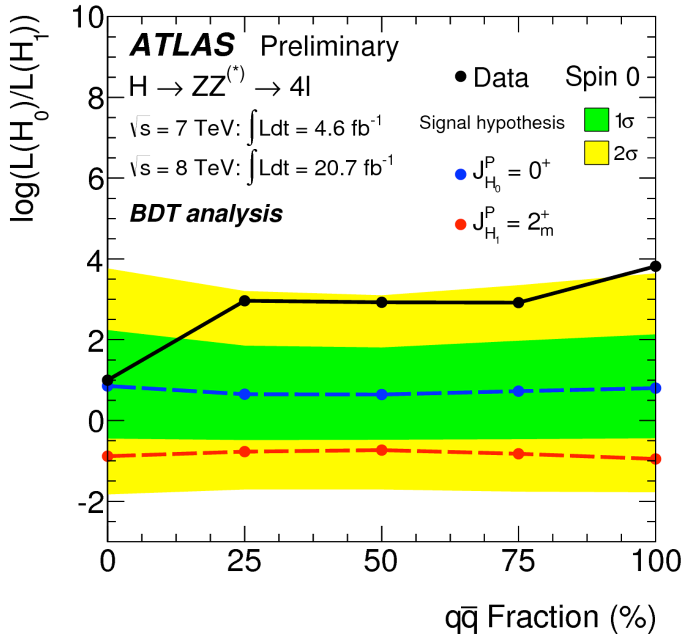
2^+ hypothesis



Spin


ATLAS Preliminary
2012
∫Ldt = 20.7 fb-1, √s = 8 TeV
Expected, JP = 0+ (SM)
Expected, JP = 2+
Observed
± 1 σ
± 2 σ
ln(L(0)/L(2))
fqq̄ (%)


ATLAS Preliminary
Data
Spin 0
H → WW(*) → eνμν/μνeν
√s = 8 TeV, ∫Ldt = 20.7 fb-1
Signal hypothesis
1σ
2σ
JP H0 = 0+
JP H1 = 2+
log(L(H0)/L(H1))
fqq̄ (%)


ATLAS Preliminary
H → ZZ(*) → 4l
√s = 7 TeV: ∫Ldt = 4.6 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
BDT analysis
Data
Spin 0
Signal hypothesis
1σ
2σ
JP H0 = 0+
JP H1 = 2+m
log(L(H0)/L(H1))
qq̄ Fraction (%)