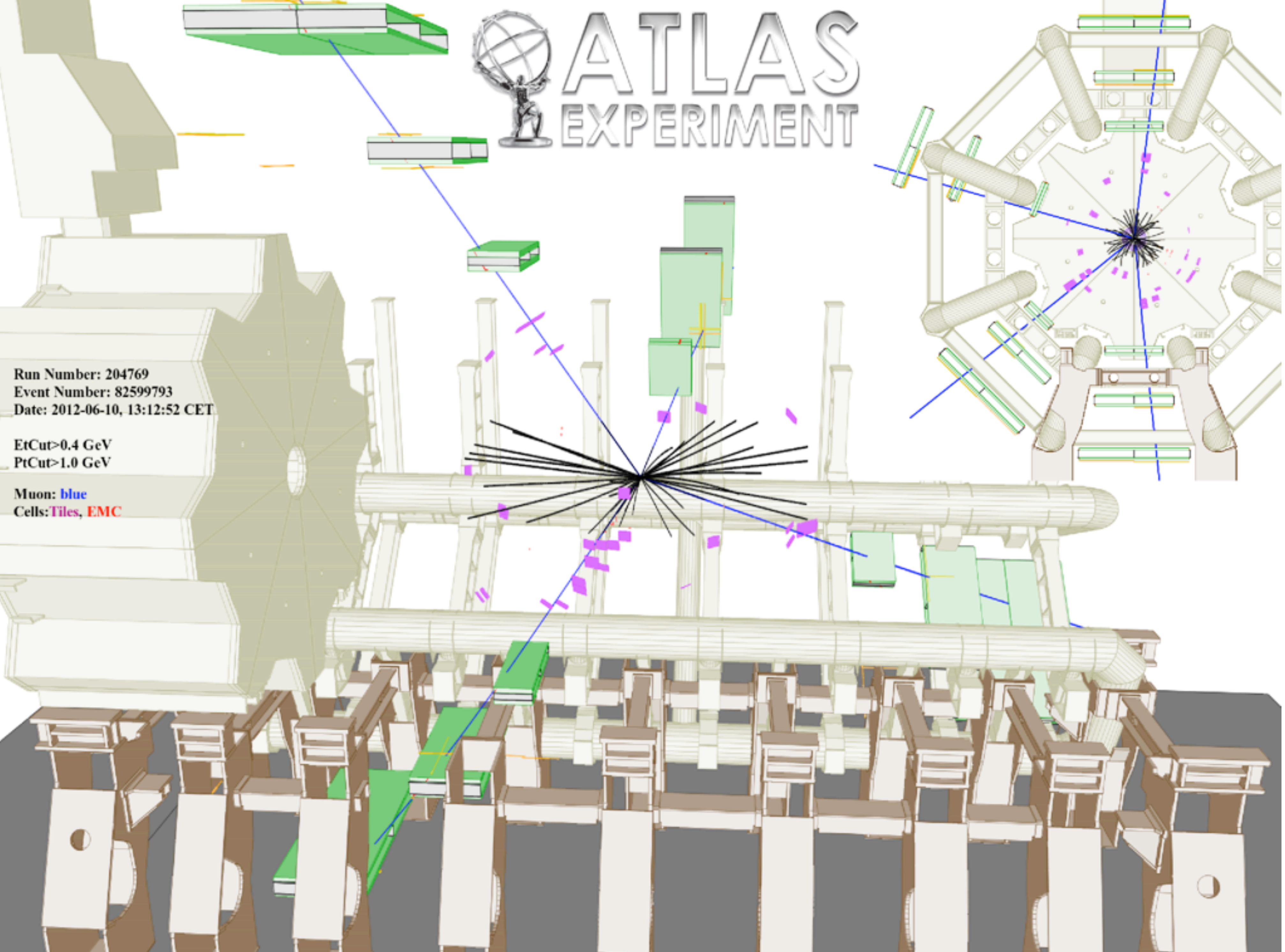

A short overview of ATLAS Higgs Sector Studies

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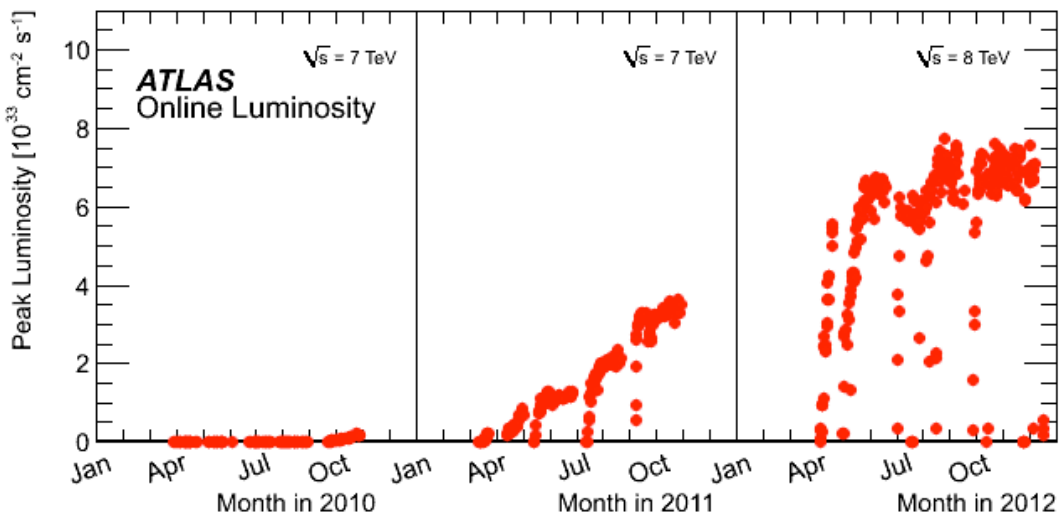
UNIVERSITY OF BIRMINGHAM

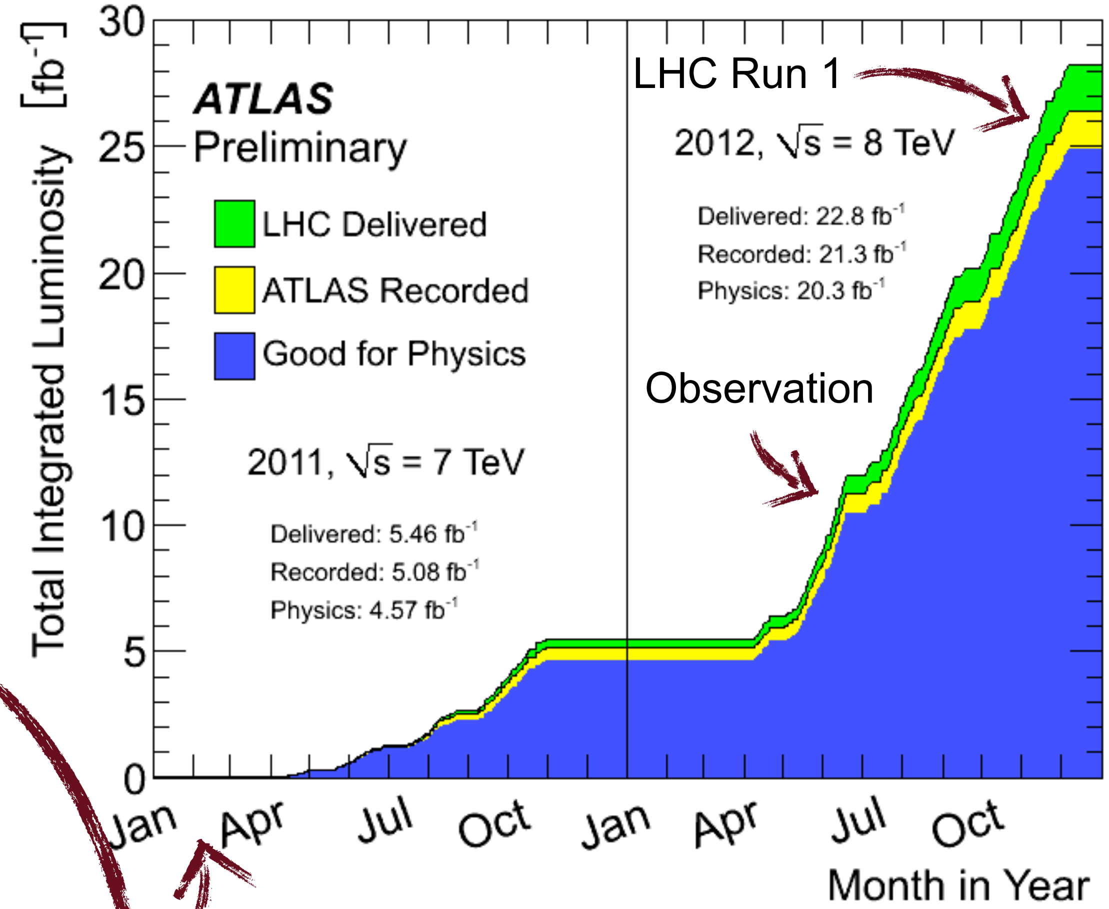
Recent Developments in HEP and Cosmology
9th May 2014, Naxos, Greece

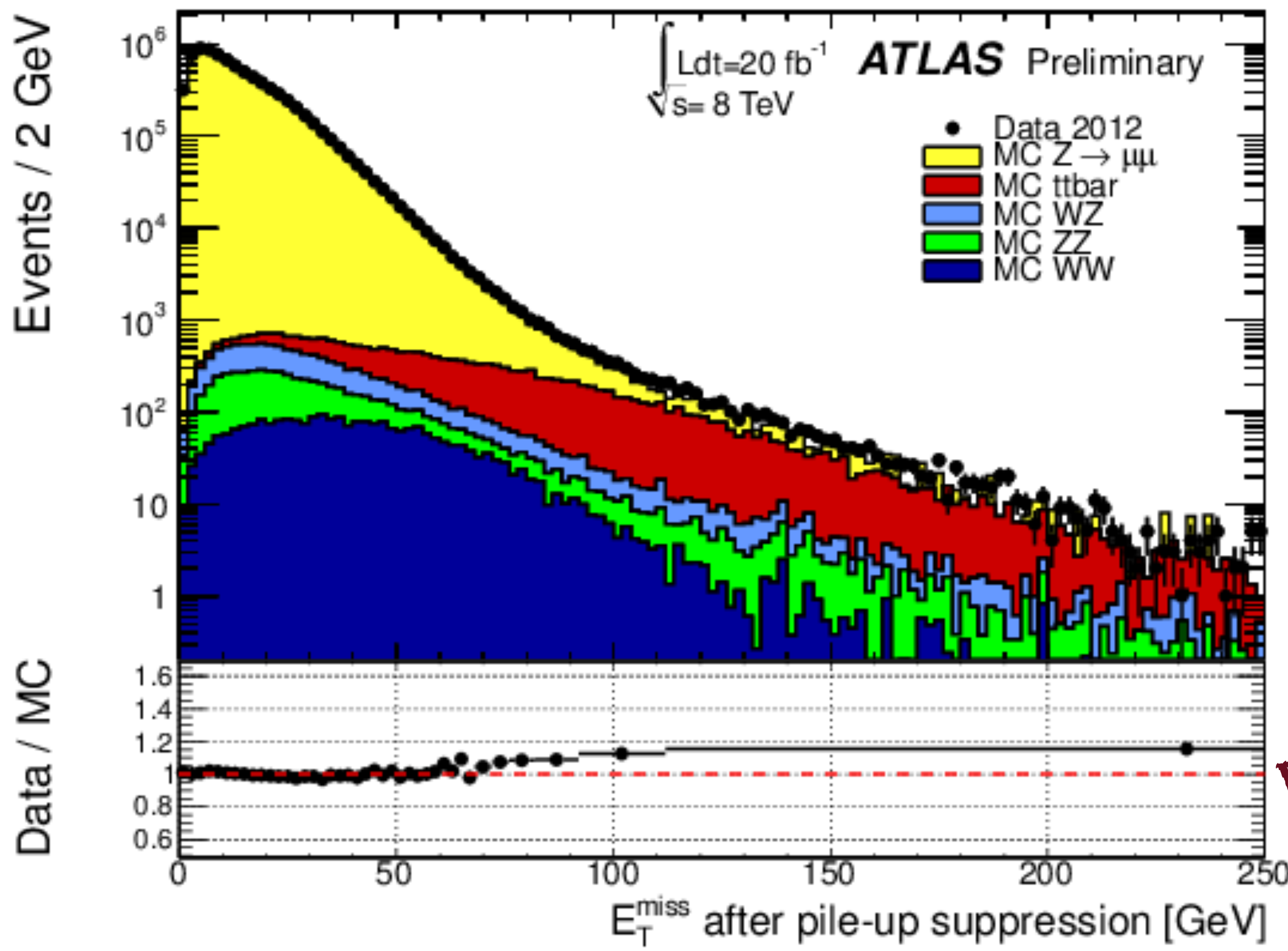
LHC/ATLAS and all that...

Peak Luminosity [$cm^{-2}s^{-1}$]

2.07×10^{32} 3.65×10^{33} 7.73×10^{33} $cm^{-2}s^{-1}$







Excellent LHC/ATLAS operations
Overall efficiencyency 90%

Excellent understanding of the detector performance!

Overview of Higgs studies

Higgs Sector

Minimal

Extended

Properties

Production and Decays

Neutral and Charged

"Model Independent"

Mass

Differential Cross-Sections

Couplings

Spin/CP

Rare

Anomalous

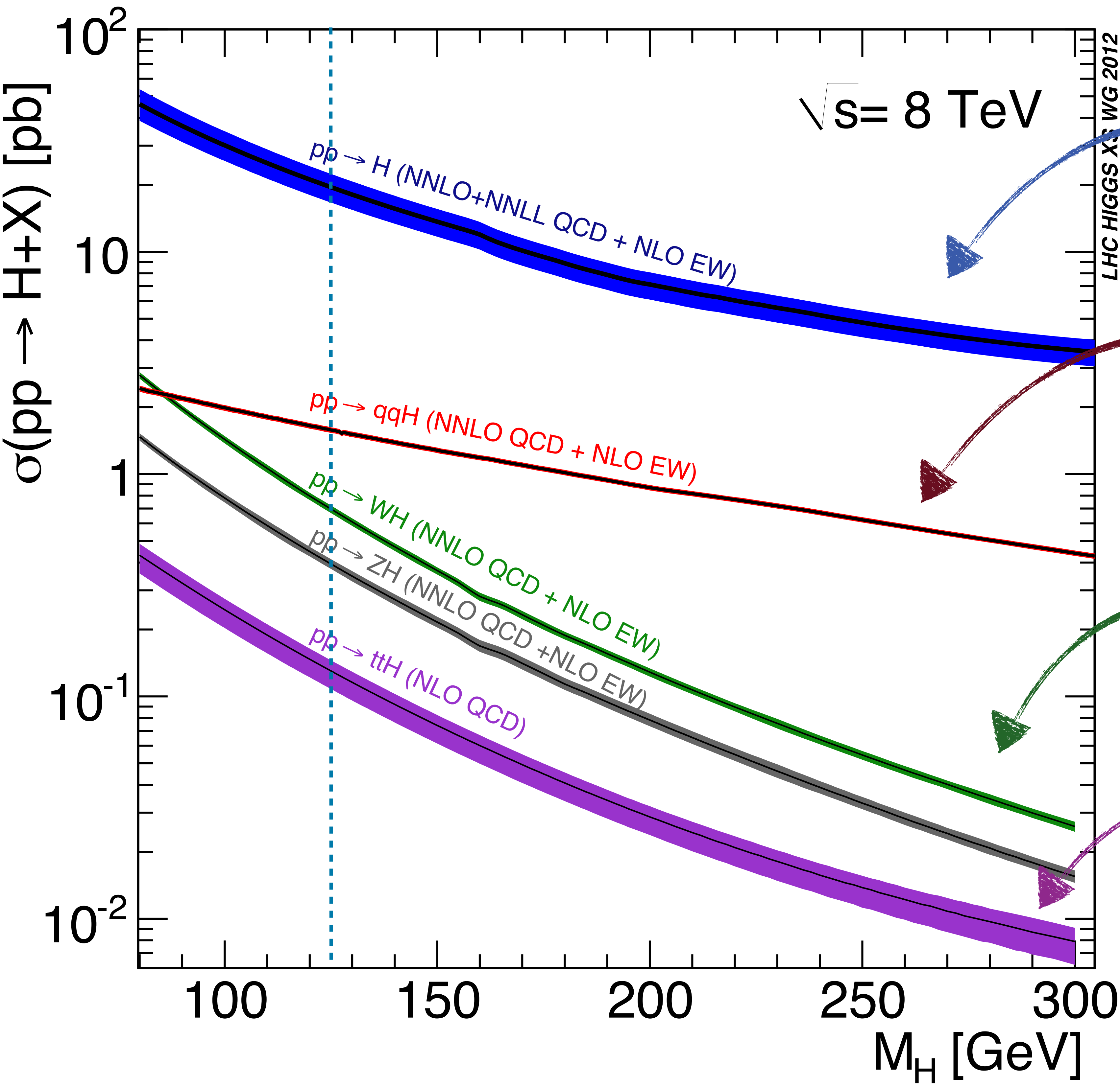
2HDM

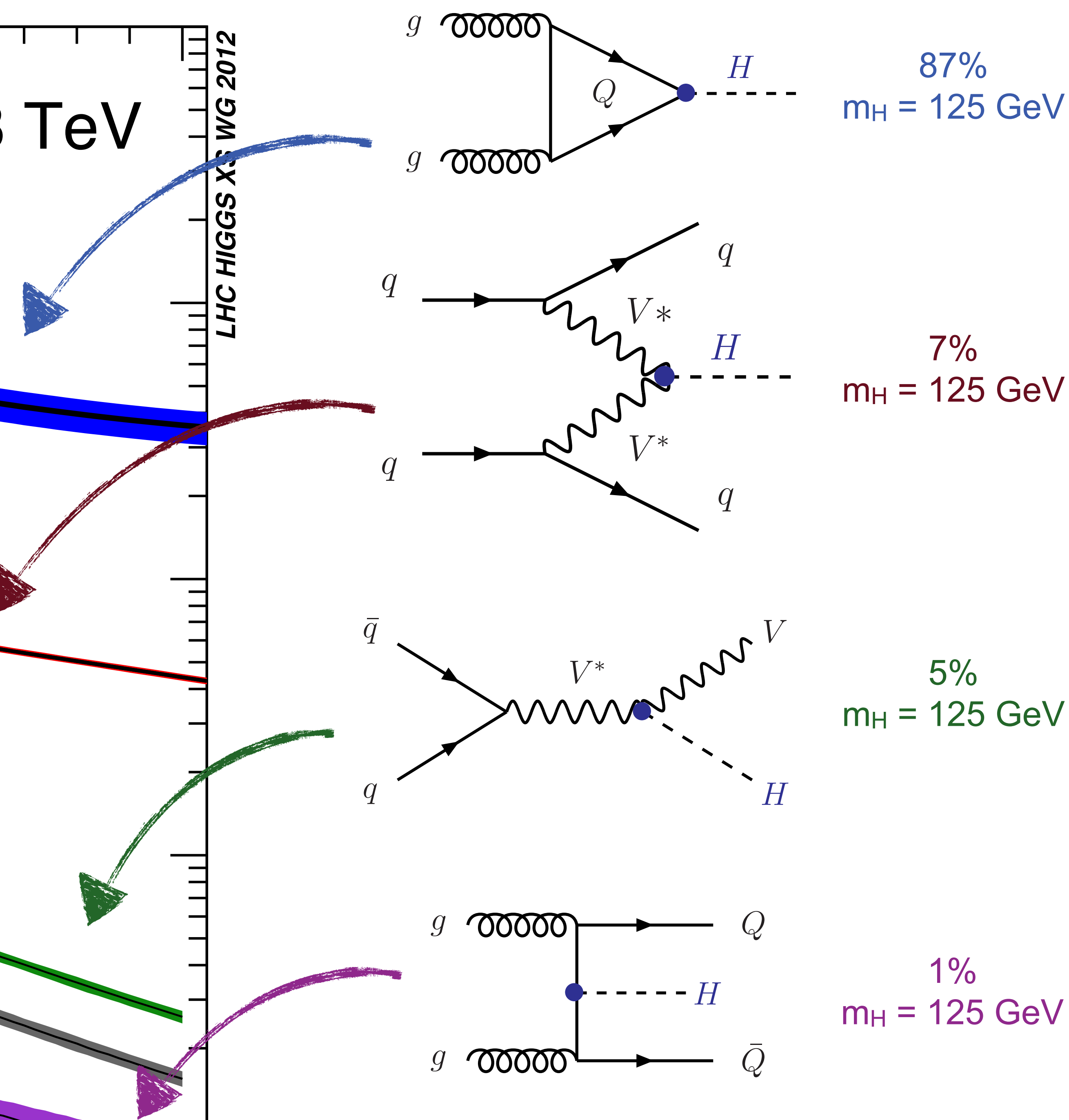
SuSy

[MSSM, pMSSM, NMSSM]

...

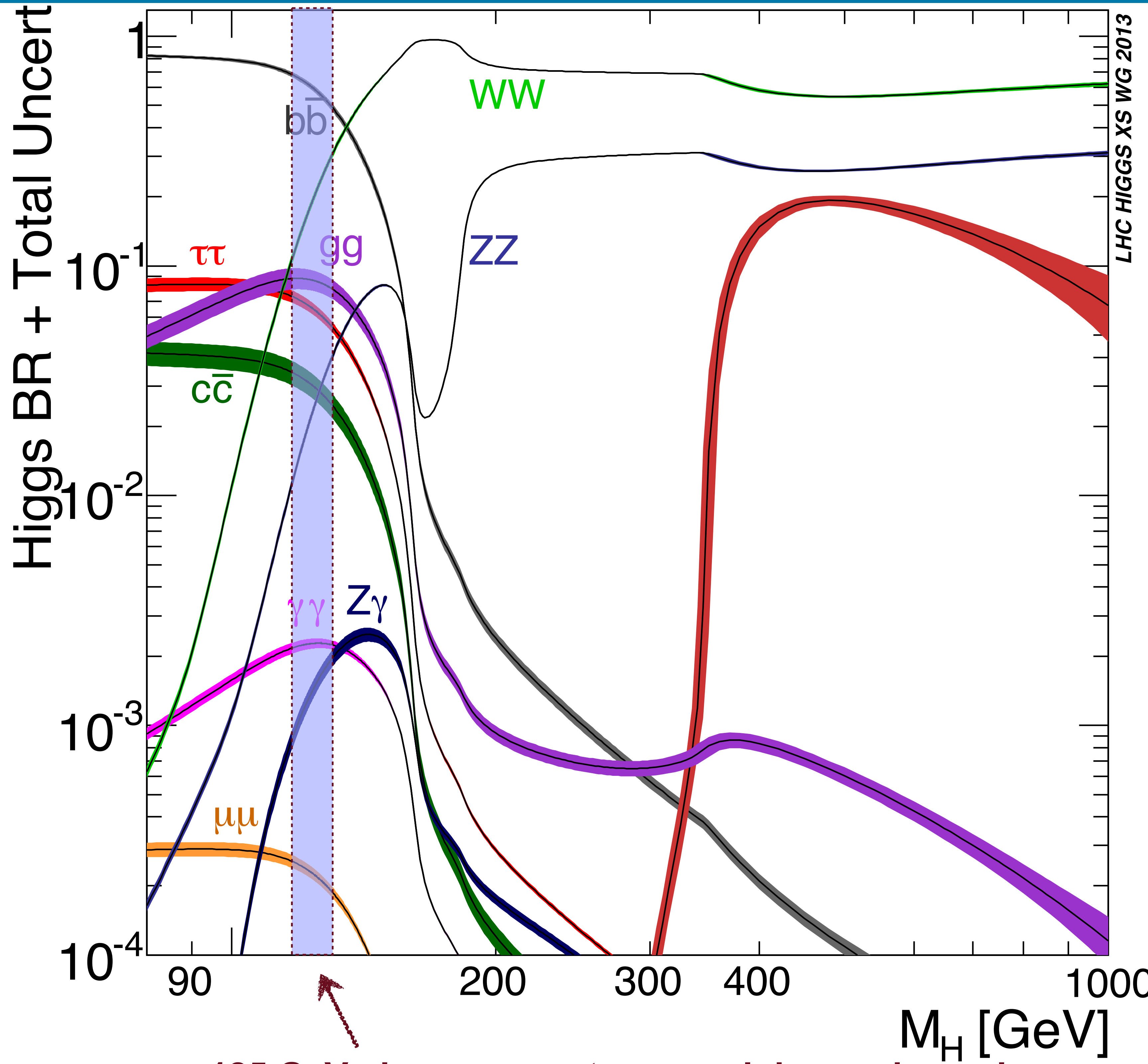
SM Higgs boson production at the LHC



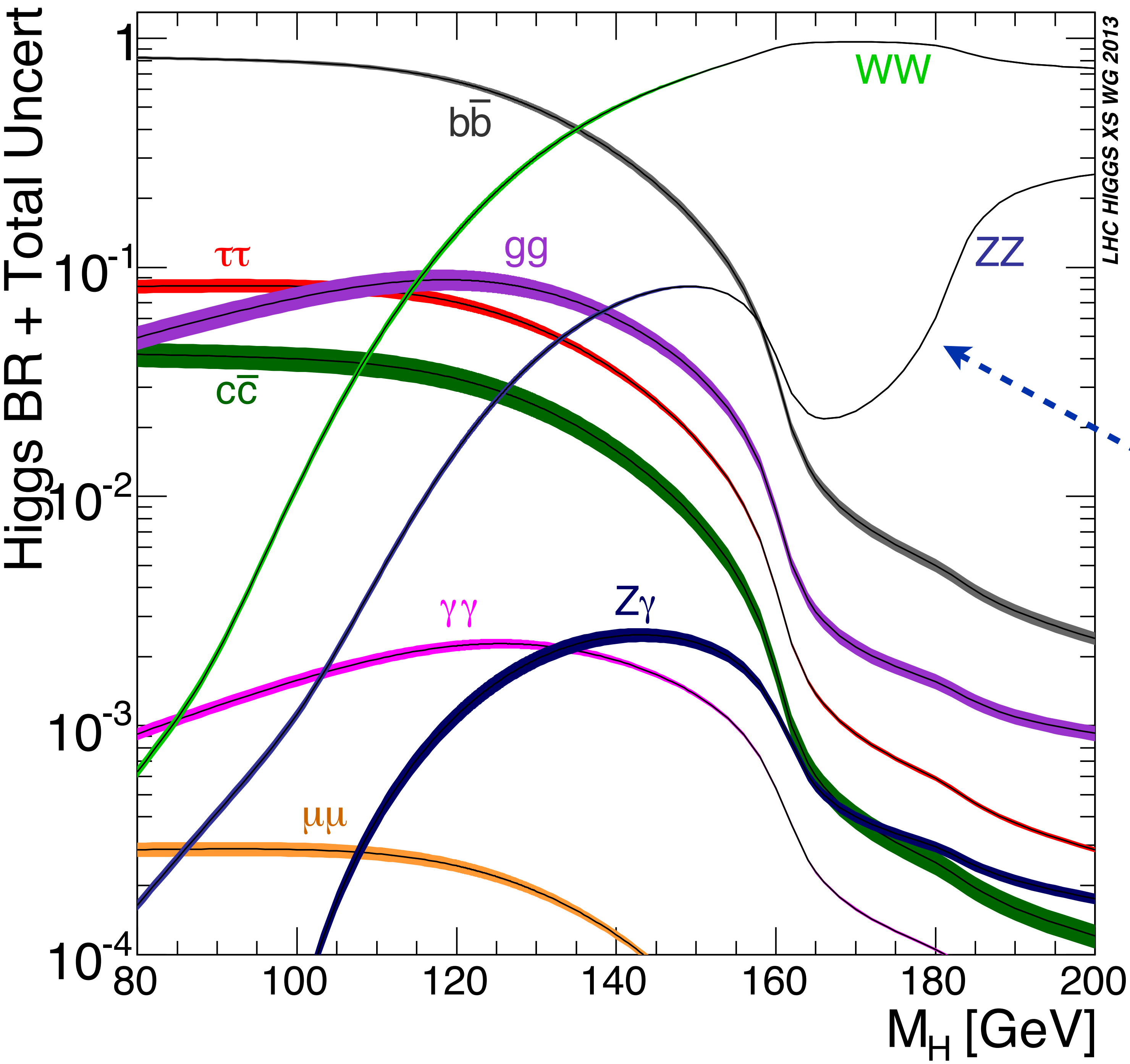


Production cross section
(m_H=125 GeV)
17.4 pb @ 7 TeV
22.1 pb @ 8 TeV
57.02 pb @ 14 TeV

SM Higgs boson decays



m_H~125 GeV gives access to several decay channels
Gauge bosons: γγ, ZZ*, WW*, Zγ
Fermions: bb, ττ, μμ

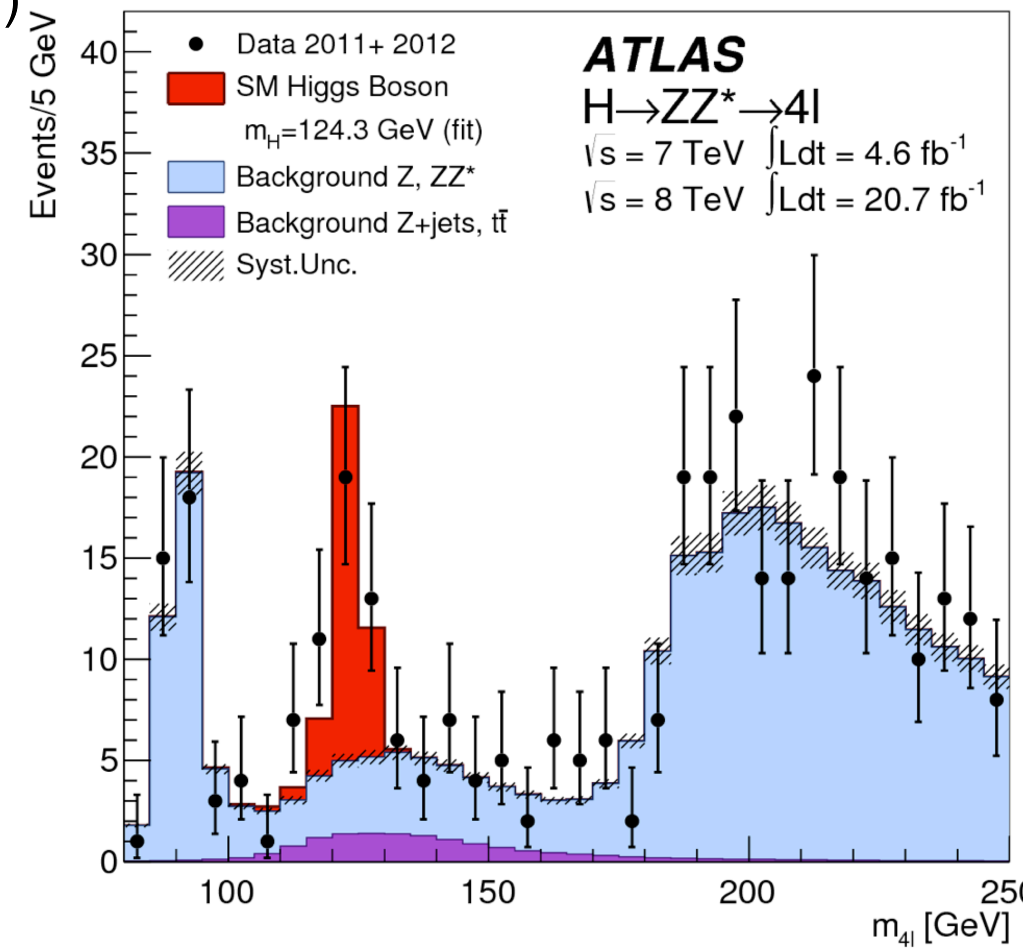


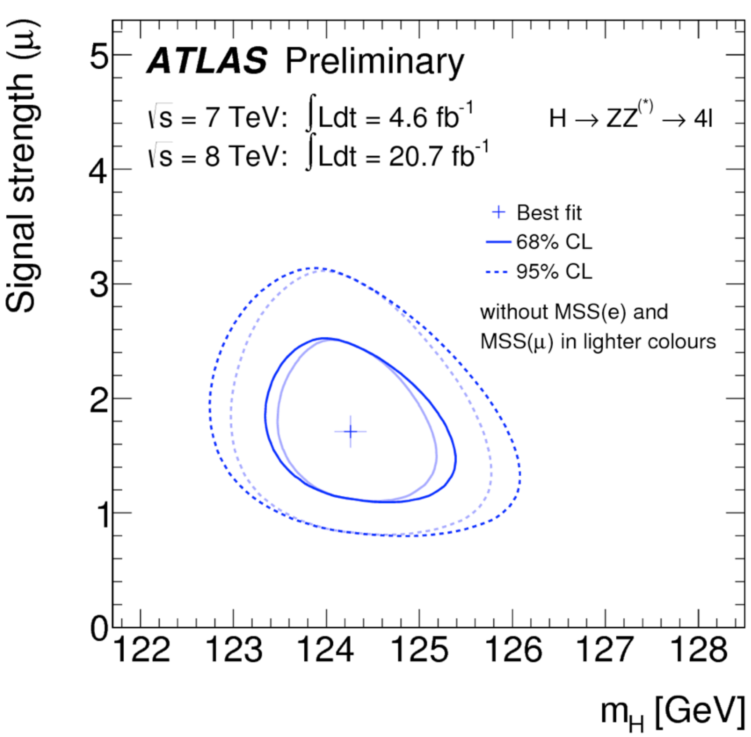
H→ZZ→4l

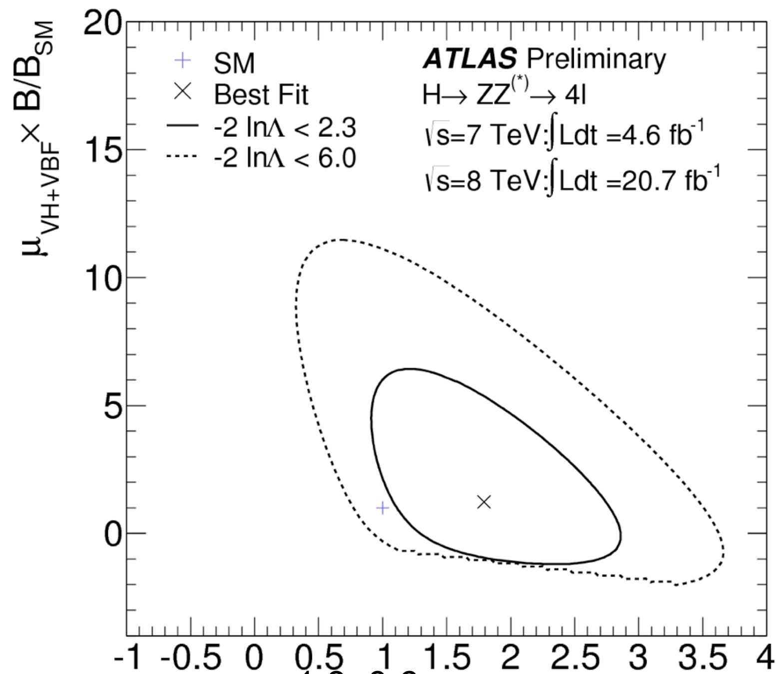
Phys. Lett. B726 (2013) 88/Phys. Lett. B726 (2013) 120/
ATLAS-CONF-2013-013

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

- Narrow peak in m_{4l} spectrum (S/B~1.0-1.9, m_{4l} resolution~1.9 GeV)
- Main Backgrounds (mixture of data-driven/simulation):
  - Mostly $ZZ^{(*)}$ followed by Z+jets (Z+light jets/Zbb) and tt
- Mass
  - Local significance: 6.6σ (4.4σ) at m_H=124.3GeV
  - Mass: $124.3^{+0.6}_{-0.5}(stat)^{+0.5}_{-0.3}(syst)$ GeV
    - Main systematic: e/μ E/P scale
  - Rate with respect to SM: $1.7^{+0.5}_{-0.4}$
    - 1.5 ± 0.4 @ m_H=125.5 GeV
- Couplings
  - Event categorization [VBF-/VH-/ggF-like]
- Spin/CP
  - Discriminants: 5 angles and 2 m_{ll} [no rate information used]
  - Two approaches: BDT / MatrixElement
  - Test 0^+ against $0^-/1^{+/-}/2^+$
    - in all cases alternative hypothesis disfavored

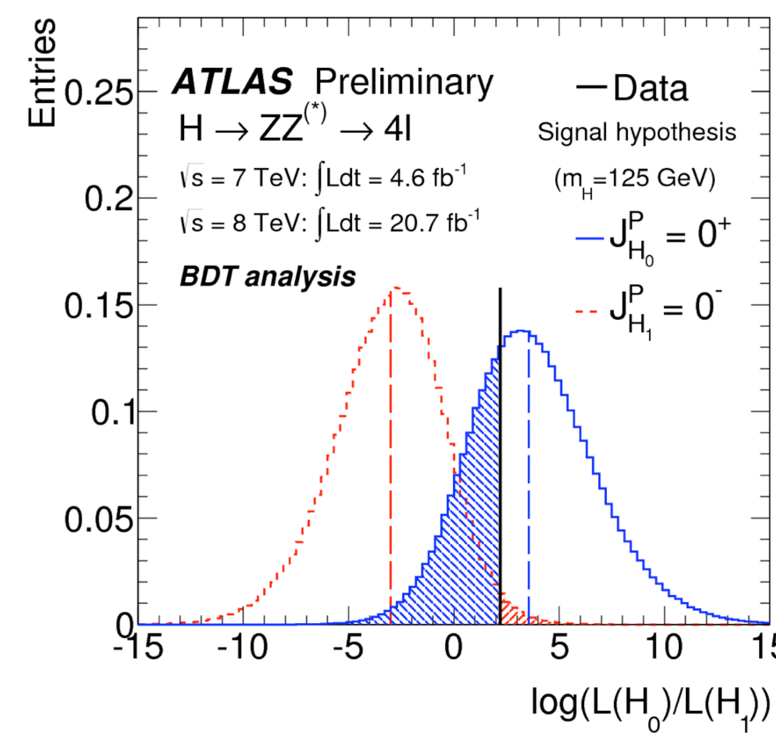


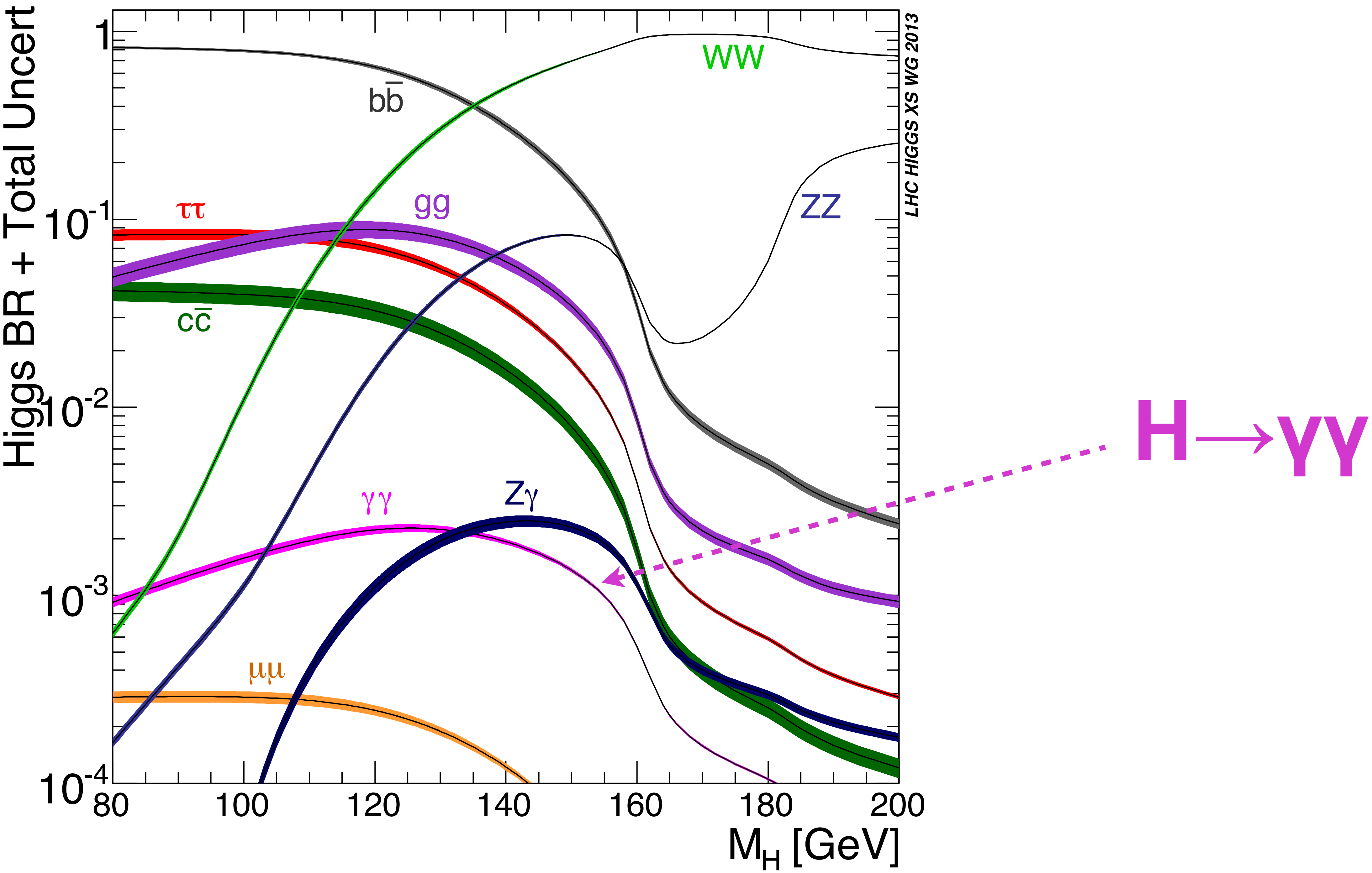




$\mu_{ggF+ttH}$ = 1.8±0.6

$\mu_{VBF+VH} = 1.2^{+3.0}_{-1.7}$

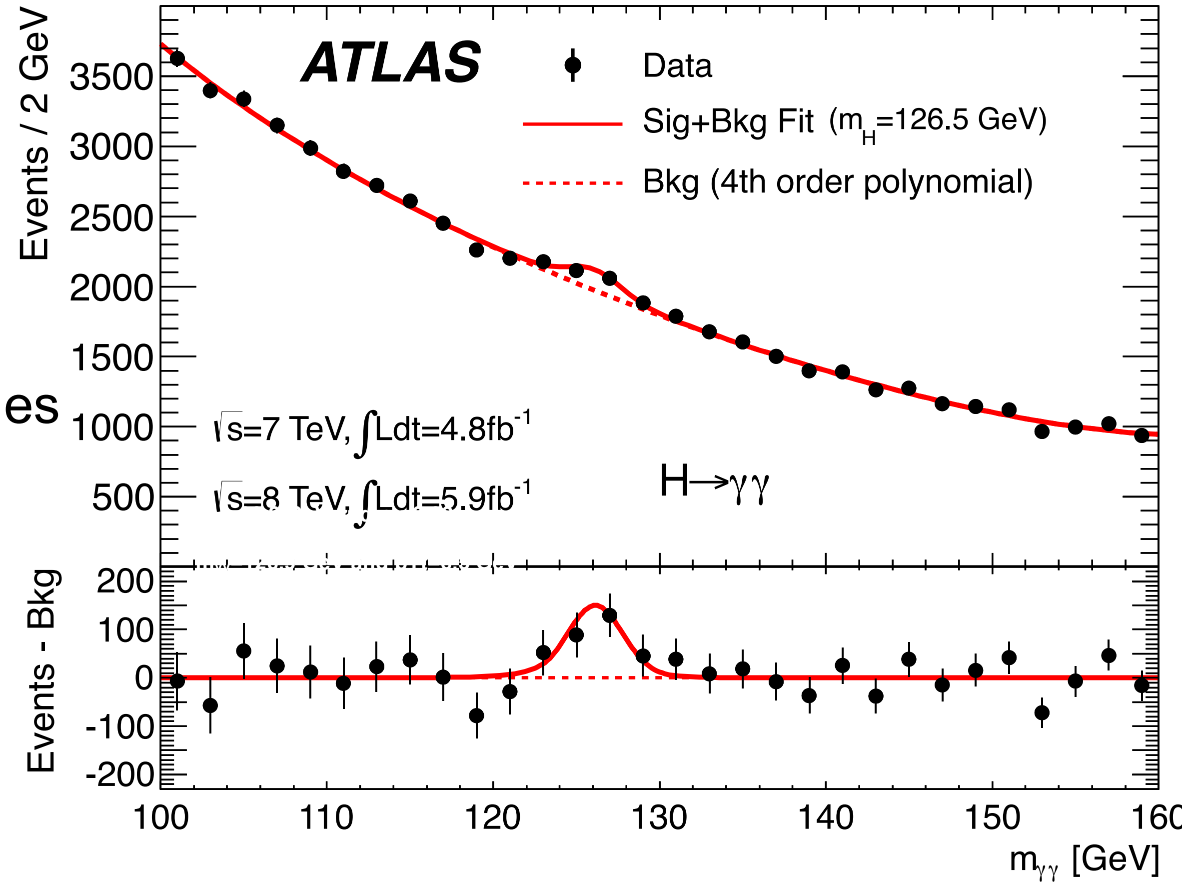


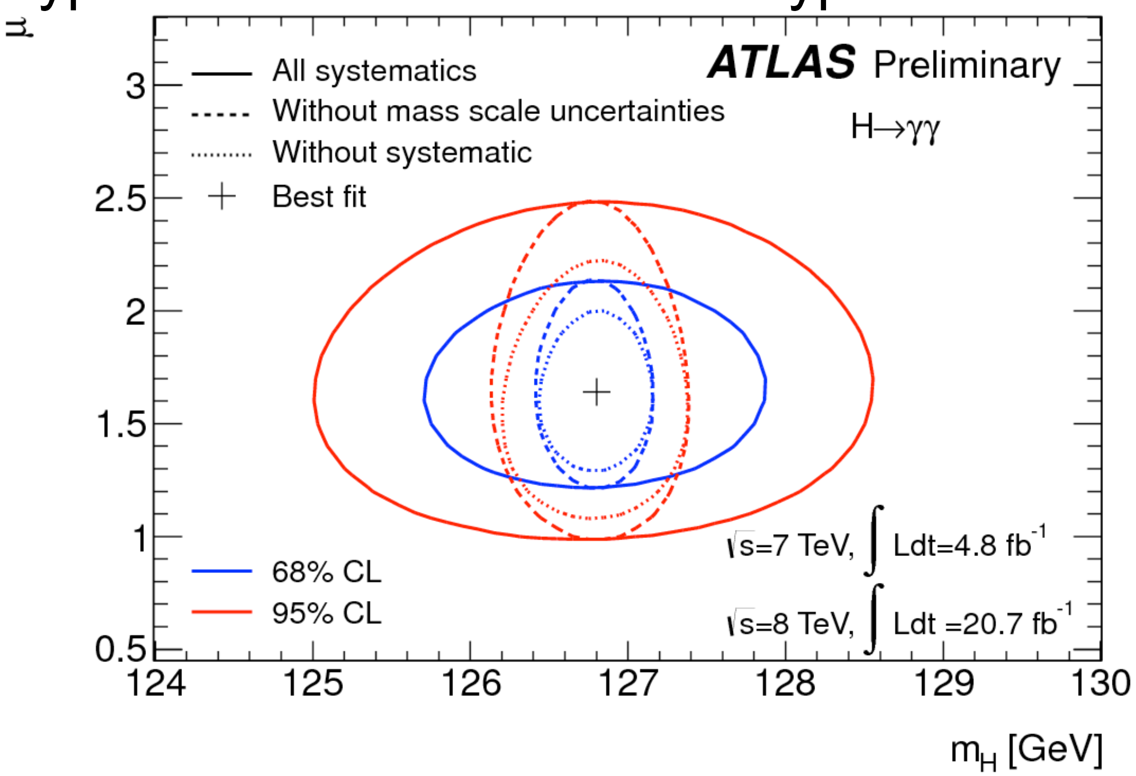


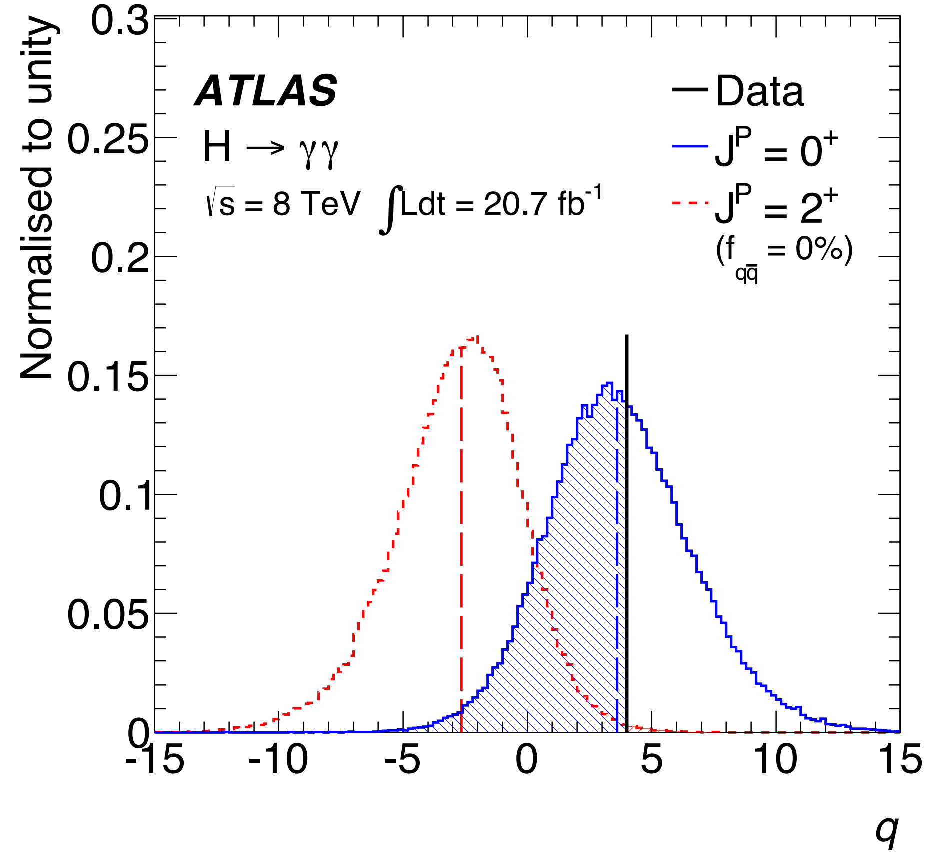
Phys. Lett. B726 (2013) 88/Phys. Lett. B726 (2013) 120/
ATLAS-CONF-2013-012/ATLAS-CONF-2013-029

$H \rightarrow \gamma\gamma$

- Narrow peak in $m_{\gamma\gamma}$ spectrum (inclusive S/B ~ 3%)
- Main Backgrounds (directly from data side-bands)
  ~75% di-photon → $m_{\gamma\gamma}$ resolution [~1.8 GeV]
  ~25% mostly γj and some jj → photon-ID
- Mass/Couplings
  - Two isolated photons (|η|<2.47) with E_T>40/30 GeV
  - 14 exclusive categories: Improve S/B, probe production modes
  - **7.4σ** (4.1σ expected) local for m_H =126.5 GeV
    - Inclusive 6.1σ/2.9σ for inclusive
  - **m_H = 126.8 ± 0.2 (stat) ± 0.7 (syst) GeV**
  - **$\mu = 1.65 \pm 0.24\ (\text{stat})^{+0.25}_{-0.18}\ (\text{syst})$** [2.3σ from SM]
- Spin
  - Selection similar but pT requirements relative to $m_{\gamma\gamma}$
  - Discriminant: polar angle of γ wrt z-axis
  - Simultaneous fit for $m_{\gamma\gamma}$ and |cosθ*|
  - 2^+ hypothesis disfavored wrt 0^+ hypothesis.



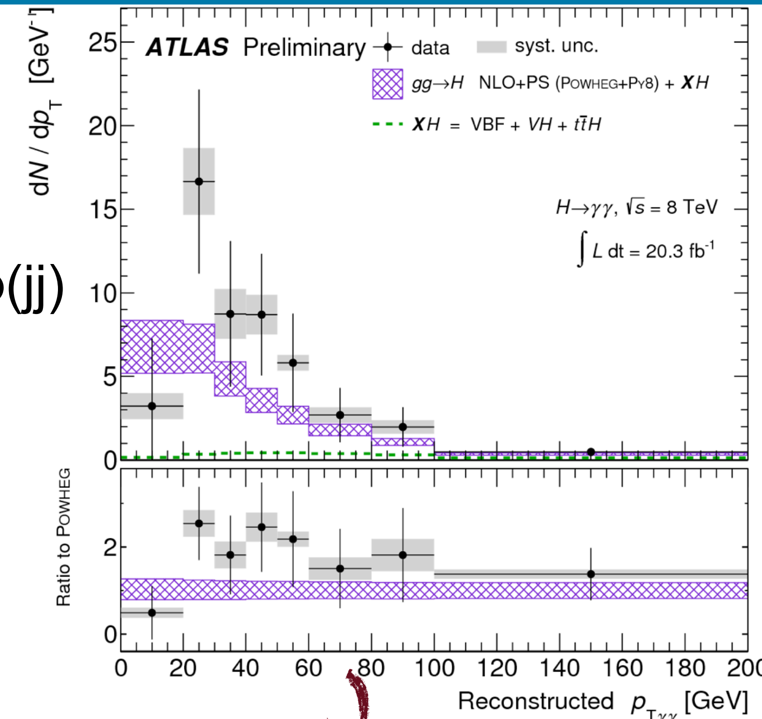


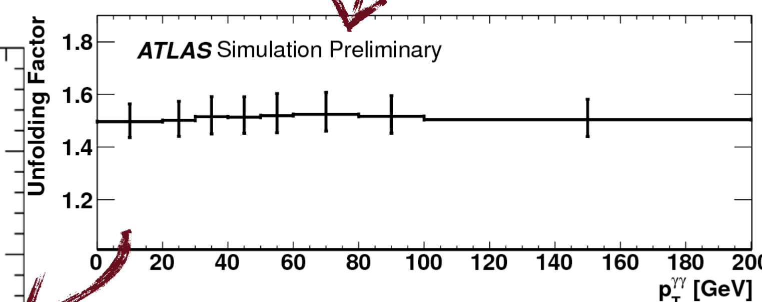


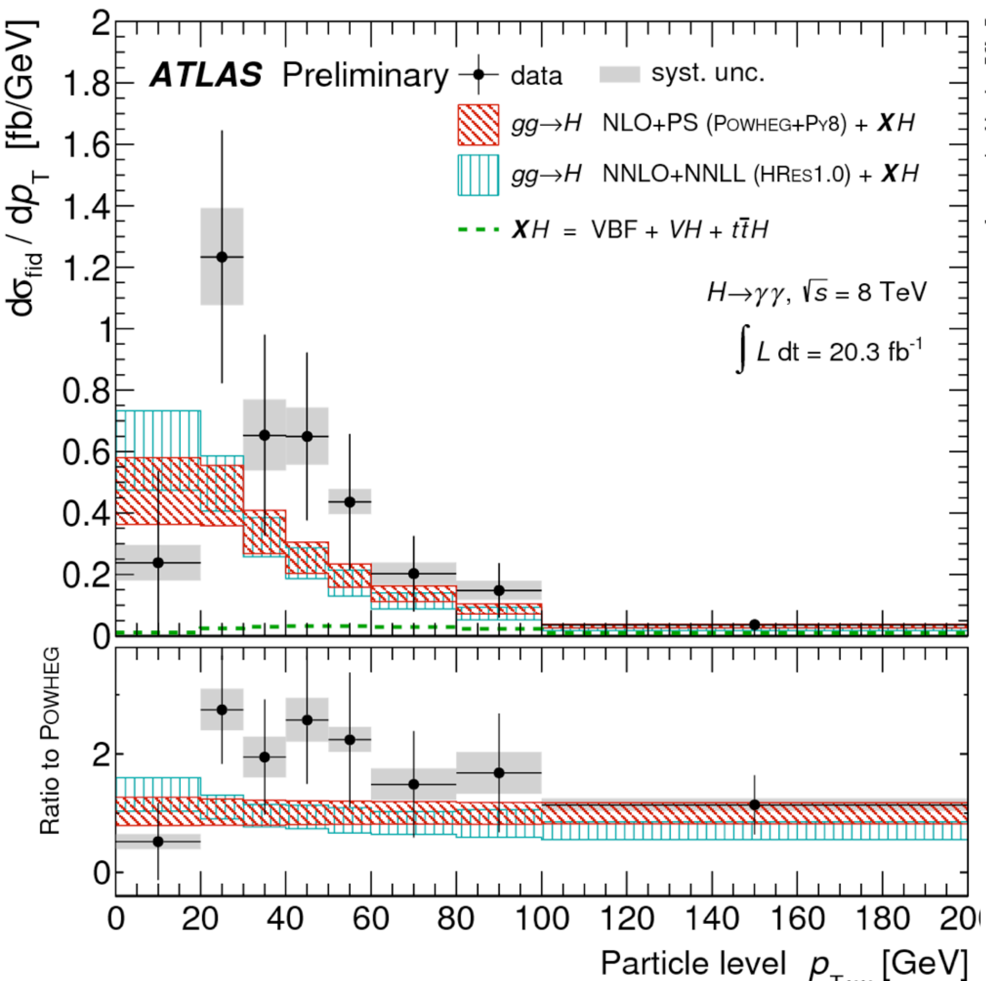
Differential cross section measurements

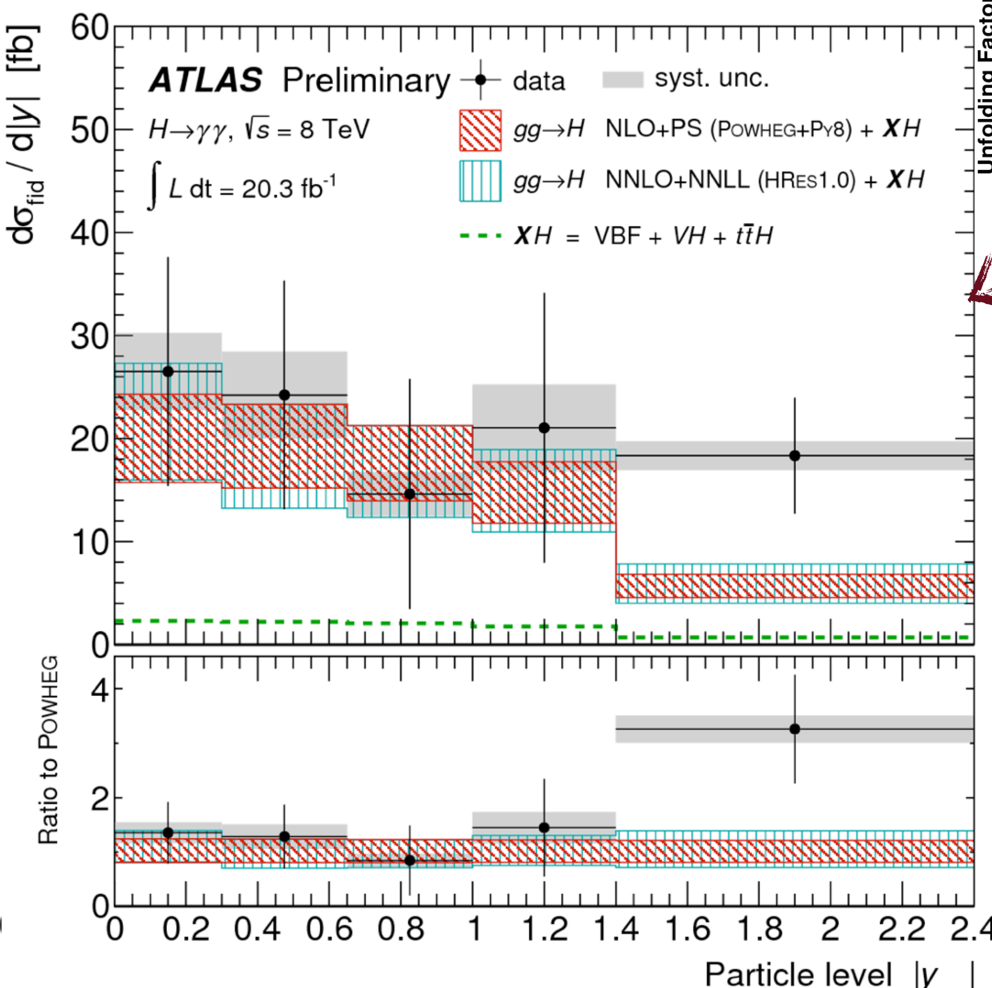
ATLAS-CONF-2013-072

- Currently only extracted from H→γγ
  - First set of differential cross section measurements
- 7 variables: pT(H), y(H), cosθ*, N_{jets}, jet veto fractions, leading jet pT, pT(Hjj), Δφ(jj)
- Extraction procedure
  - γγ dataset binned in variable of interest
  - Simultaneous unbinned maximum likelihood fit of $m_{\gamma\gamma}$ in the pre-defined bins
  - Bin-by-bin acceptance, efficiency and resolution correction(“unfolding”)



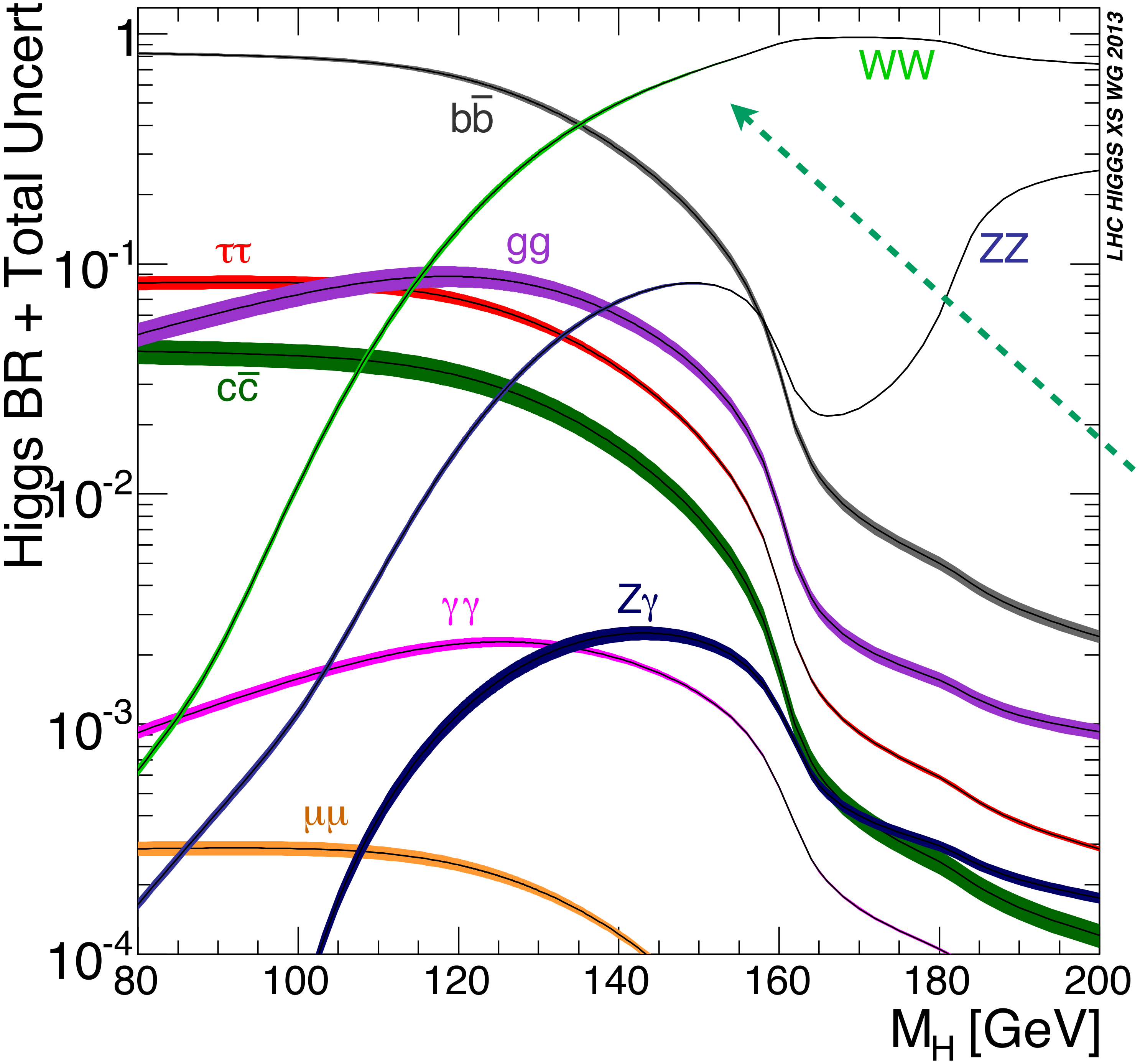






Comparison of the “unfolded” differential cross sections with
- NLO Powheg
- MINLO H+1j
- NNLO+NNLL HRes

Within current experimental and theory uncertainties, no significant deviation from SM is observed



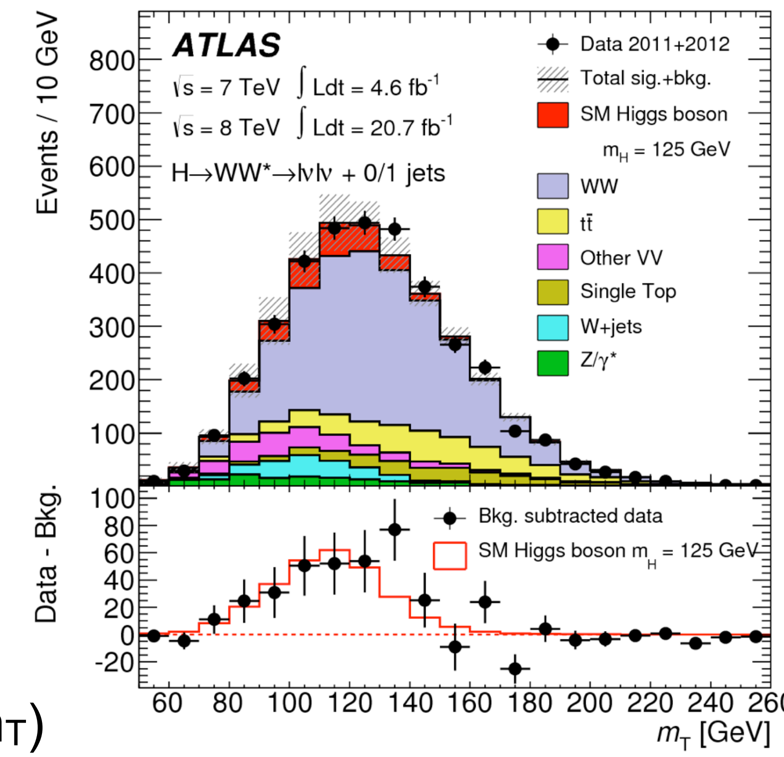
$H \rightarrow WW \rightarrow l\nu l\nu$

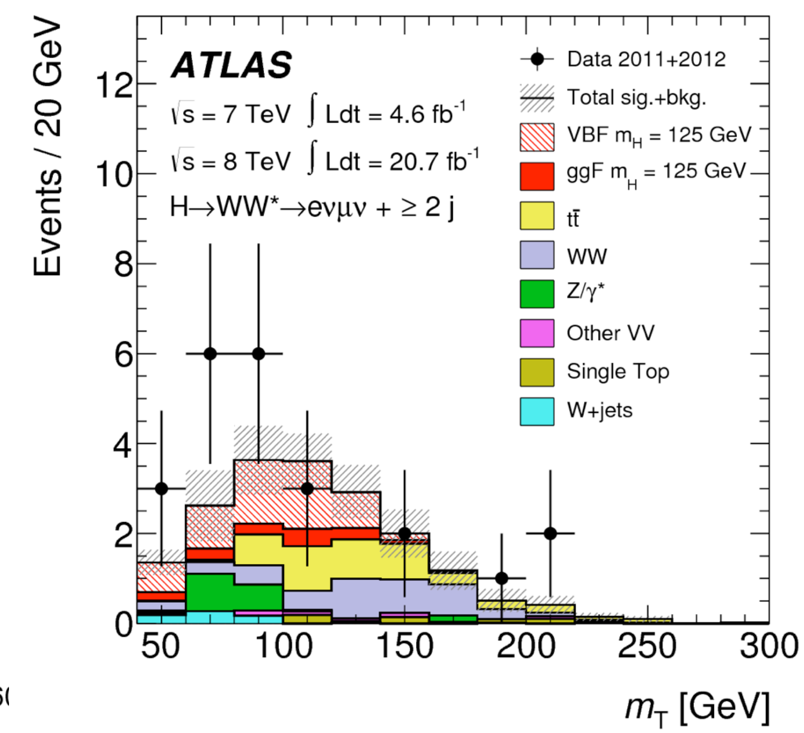
Phys. Lett. B726 (2013) 88/Phys. Lett. B726 (2013) 120/ATLAS-CONF-2013-030 /ATLAS-CONF-2013-031

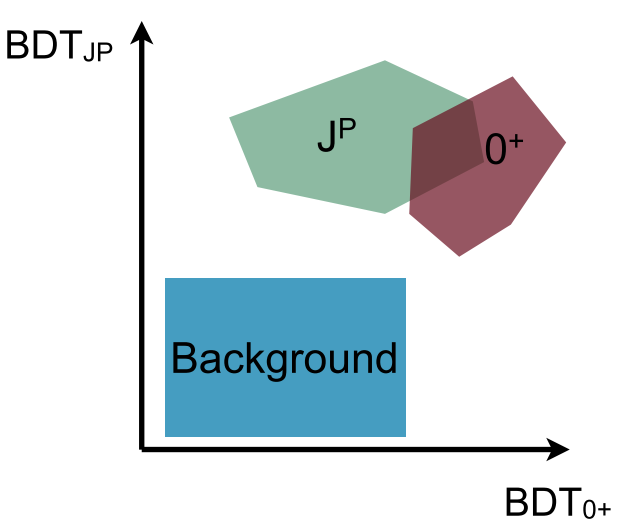
$H\to WW^{(*)}\to l\nu l\nu$

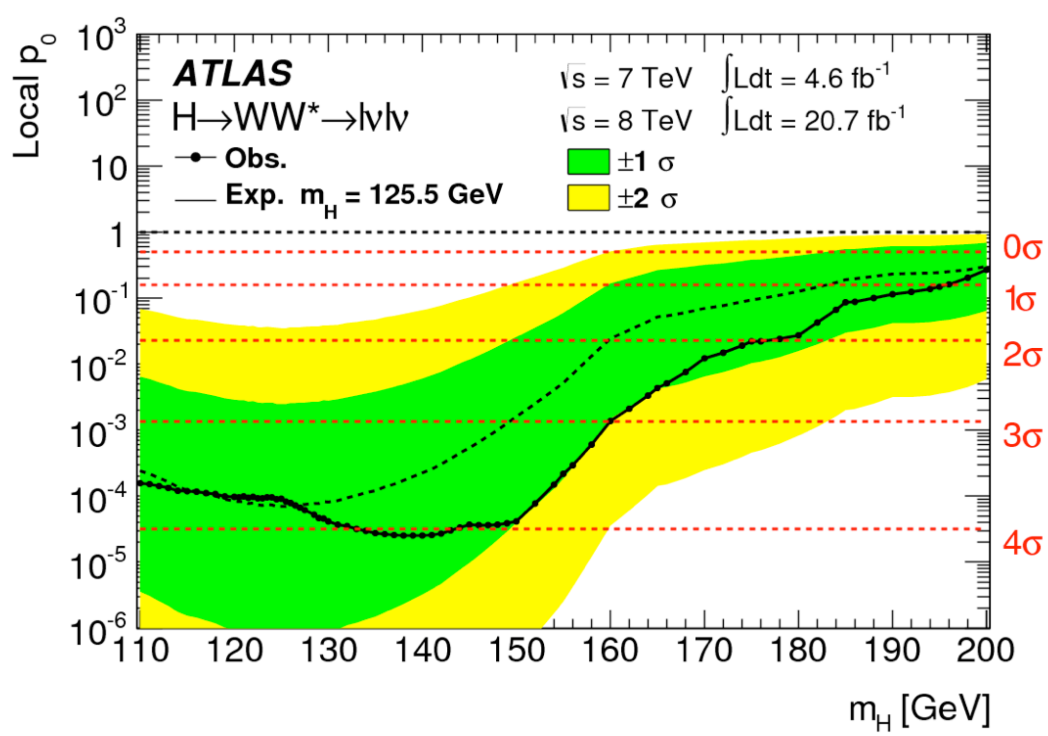
- l^+l^- + MET ⇛ Complex final state/no mass peak
- Observable: $m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$
- Backgrounds: WW, top, W/Z+jets
- Couplings
  - Separate final states:
    - lepton flavors: μe, eμ, μμ, ee
    - jet multiplicities: 0, 1, ≥2
    - dilepton mass: m_{ll}
- m_H=125GeV: μ=1.01 ± 0.31
  - Local significance: 3.8σ (3.7σ)
- Spin/CP (eμ+0j only)
  - Relaxed spin-sensitive requirements
  - 2D-fit of two BDT classifiers (m_{ll}, $\Delta\varphi_{ll}$, p_{Tll}, m_T)
    - BDT_{0+}: SM Higgs against sum of bkg
    - BDT_{JP}: J^P signal against sum of bkg
  - Test 0^+ against $1^{+/-}/2^+$

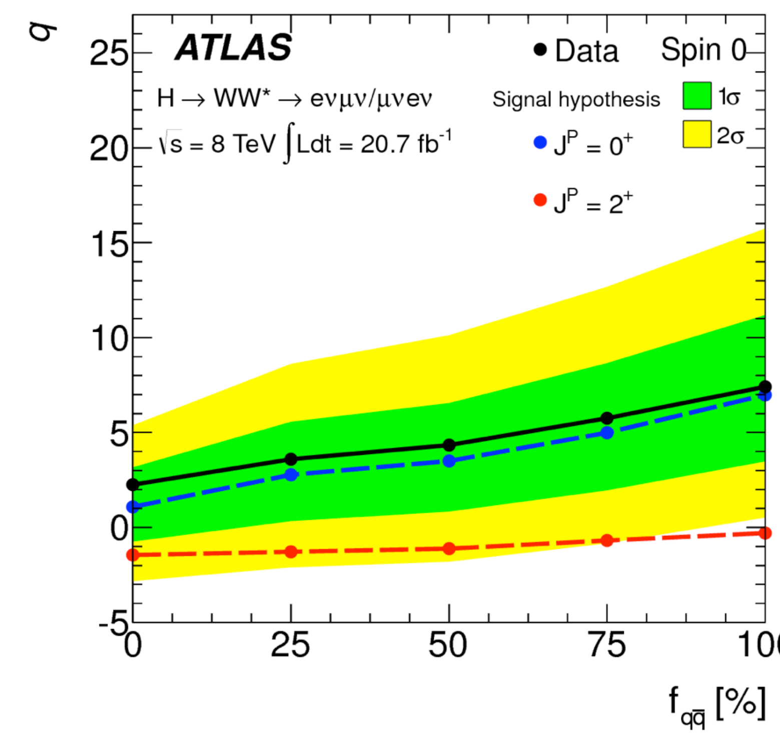
  alternative hypotheses disfavored











Mass

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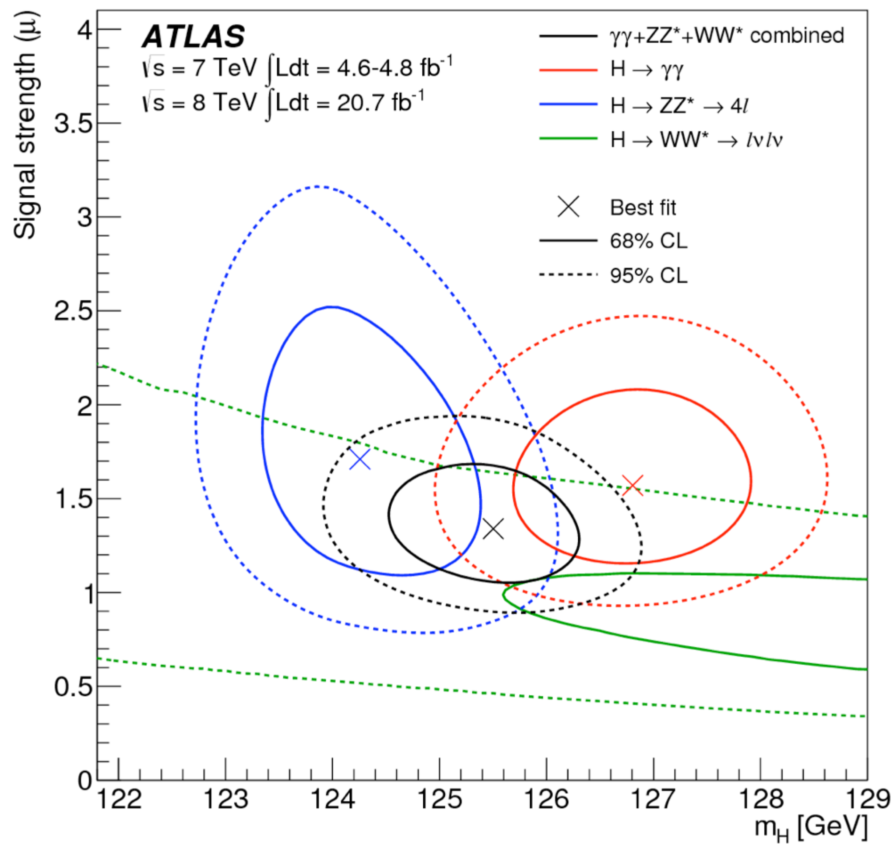
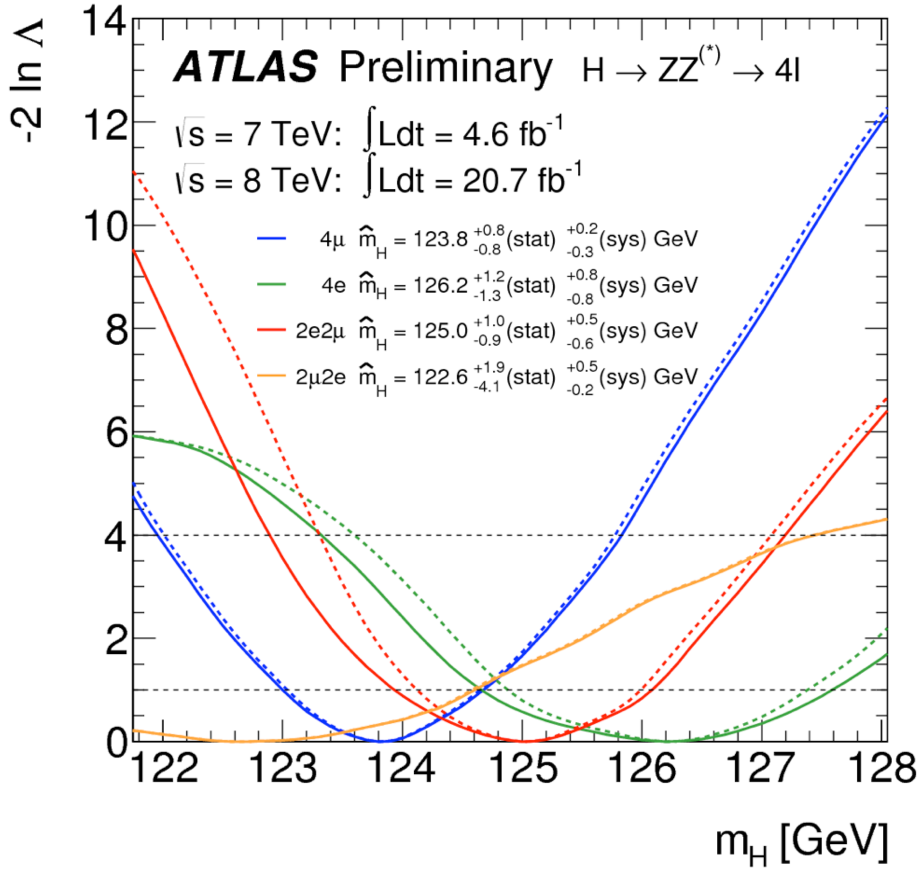
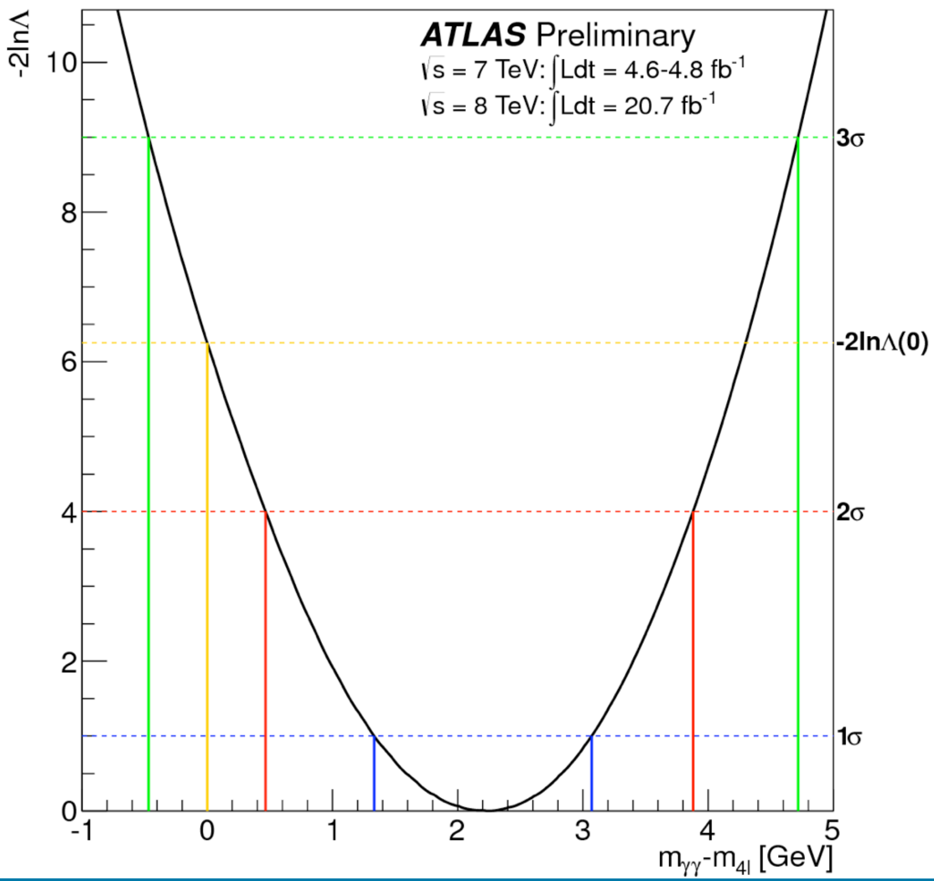






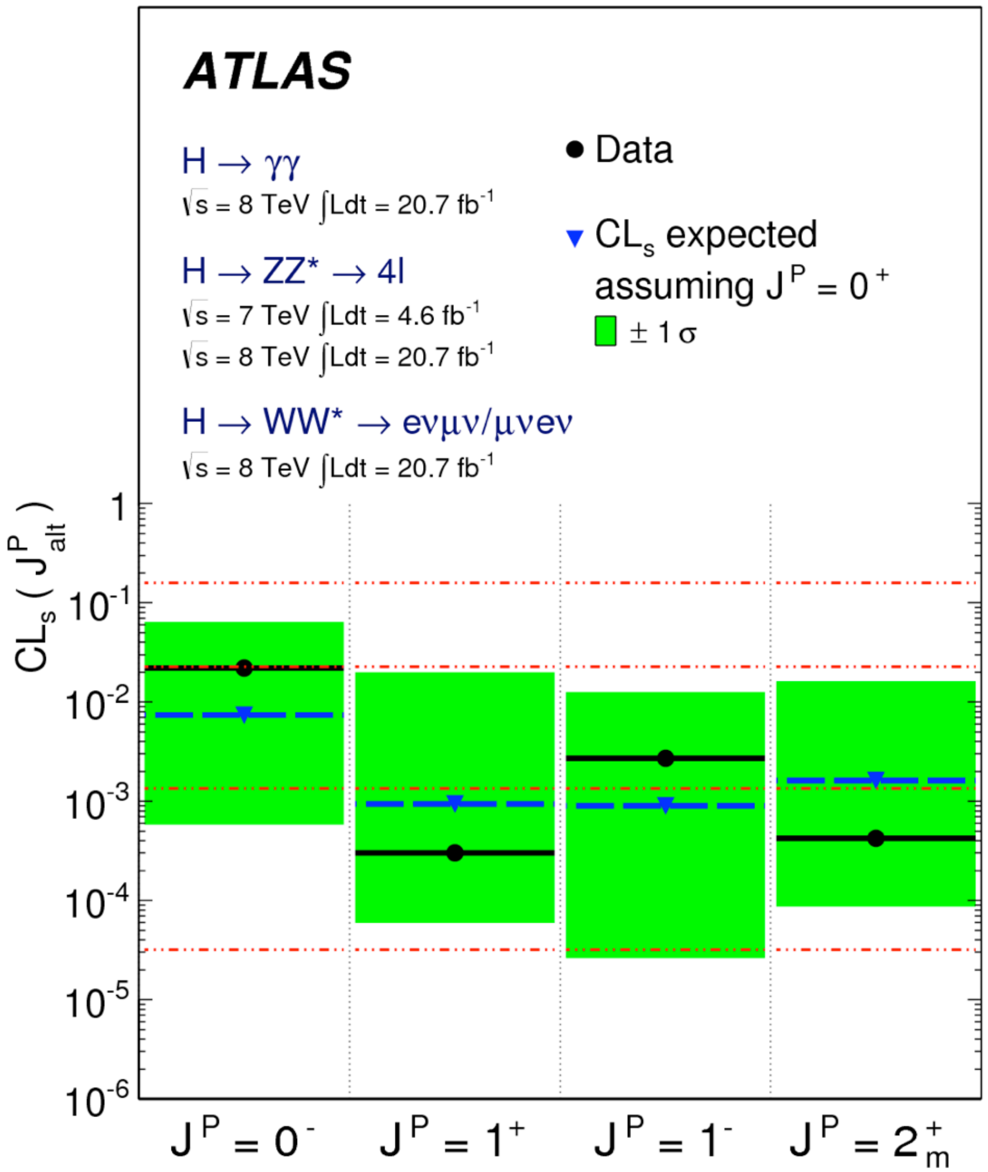
Higgs boson mass measurement using:
- $H \to \gamma\gamma$: **126.8 ± 0.2 (stat) ± 0.7 (syst) GeV**
- $H \to ZZ \to 4l$: **$124.3^{+0.6}_{-0.5}$(stat)$^{+0.5}_{-0.3}$(syst) GeV**

Combined m_H:**125.5 ± 0.2 (stat)$^{+0.5}_{-0.6}$ (syst) GeV**
- single particle to give as much/more discrepant result 1.5% (2.4σ)
- rates independent free parameters in the fit
- by moving ±1σ the main systematics (calibration, upstream material, pre-samples energy scale) consistency increases up to 8%
- $H \to 4l$ consistency leads to -0.8σ adjustment of e/γ energy scale
  - shift -350 MeV for $H \to \gamma\gamma$ mass

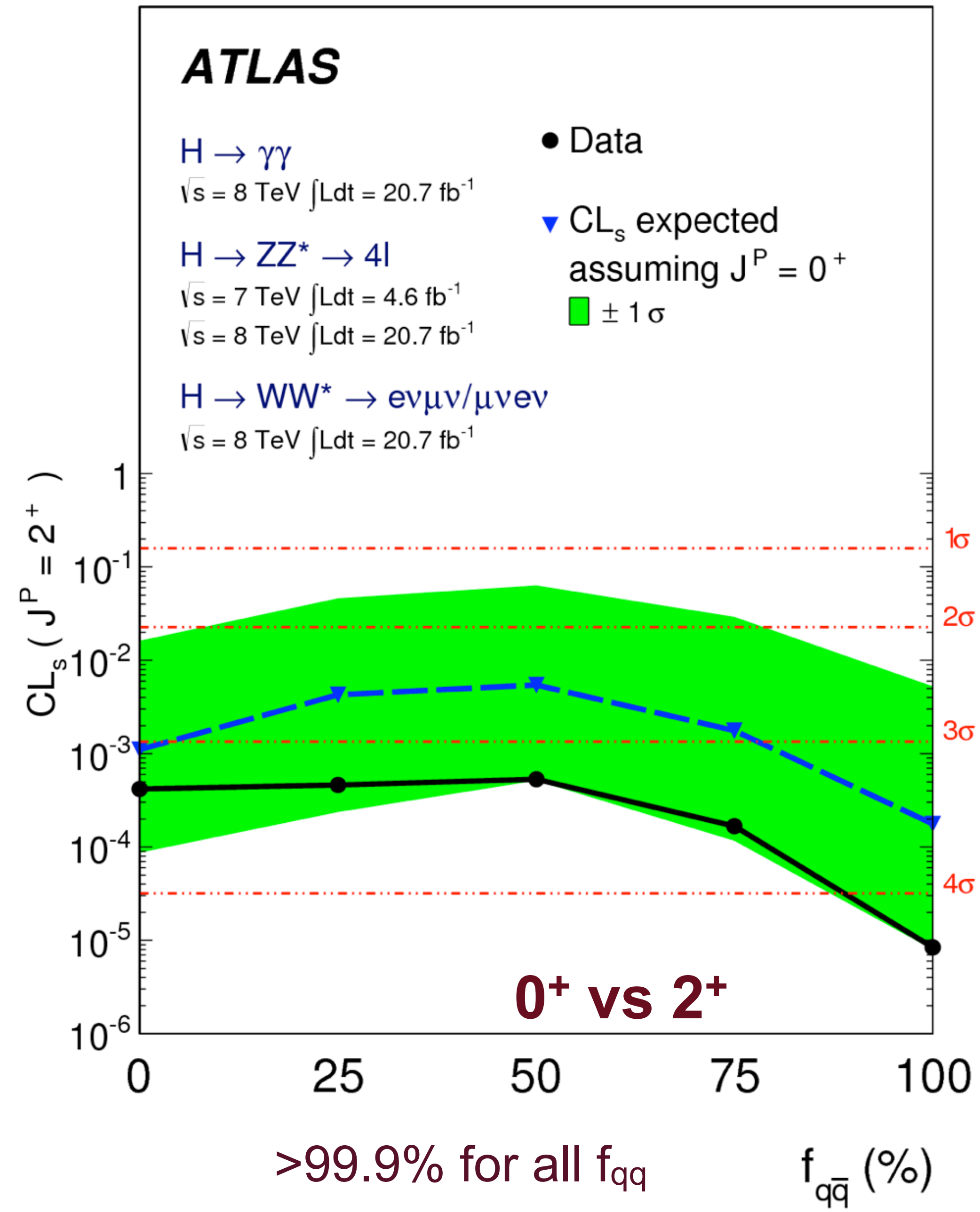
Spin/CP

Phys. Lett. B726 (2013) 120/ ATLAS-CONF-2013-040

Channel	$H \to ZZ^{(*)} \to 4\ell$	$H \to WW^{(*)} \to \ell\nu\ell\nu$	$H \to \gamma\gamma$
Dataset	20.7 fb^{-1} @ 8 TeV 4.8 fb^{-1} @ 7 TeV	20.7 fb^{-1} @ 8 TeV	20.7 fb^{-1} @ 8 TeV
Reference	ATLAS-CONF-2013-013	ATLAS-CONF-2013-031	ATLAS-CONF-2013-029
0^-	✓	-	-
1^+	✓	✓	-
1^-	✓	✓	-
2^+	✓	✓	✓

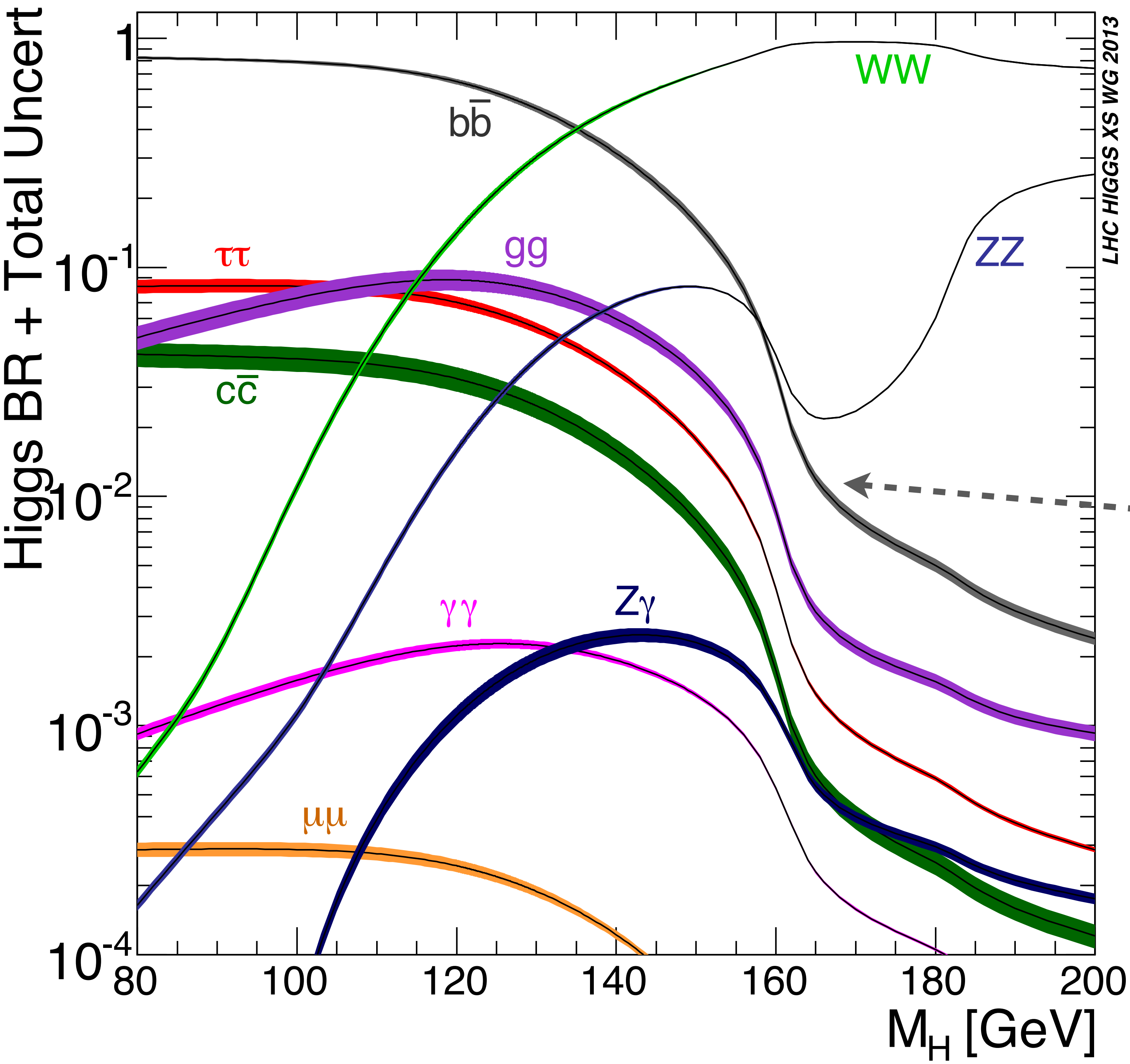


0^+ vs 0^- 97.8% **0^+ vs 1^+** >99.9% **0^+ vs 1^-** 99.7%



>99.9% for all f_{qq}

All studied alternative hypotheses are strongly disfavored with respect to the 0^+ hypothesis.

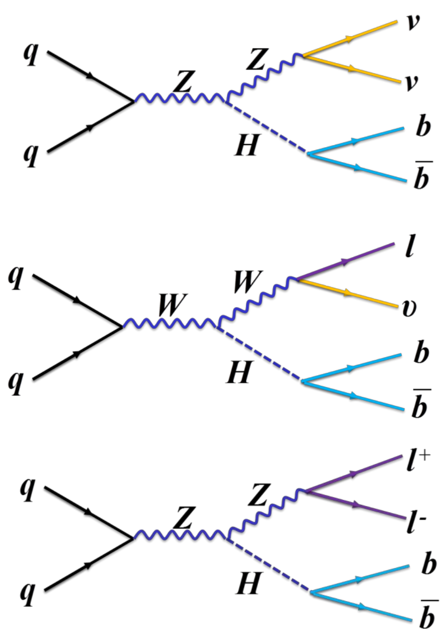


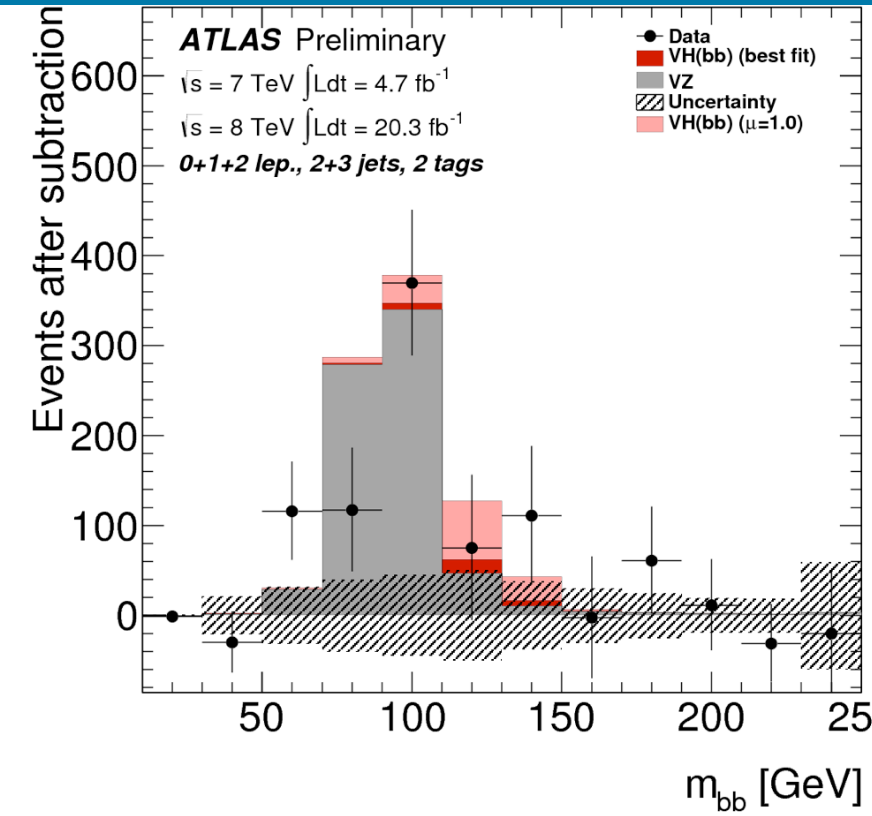
H→bb

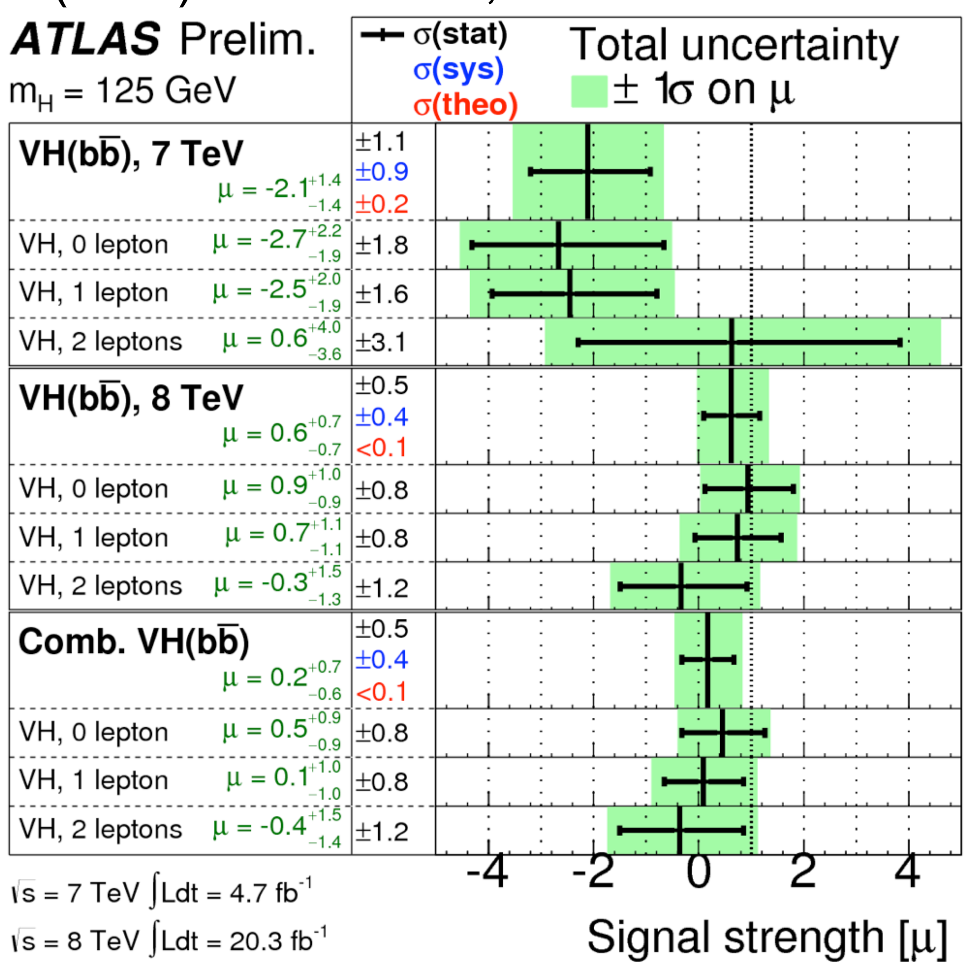
ATLAS-CONF-2013-079

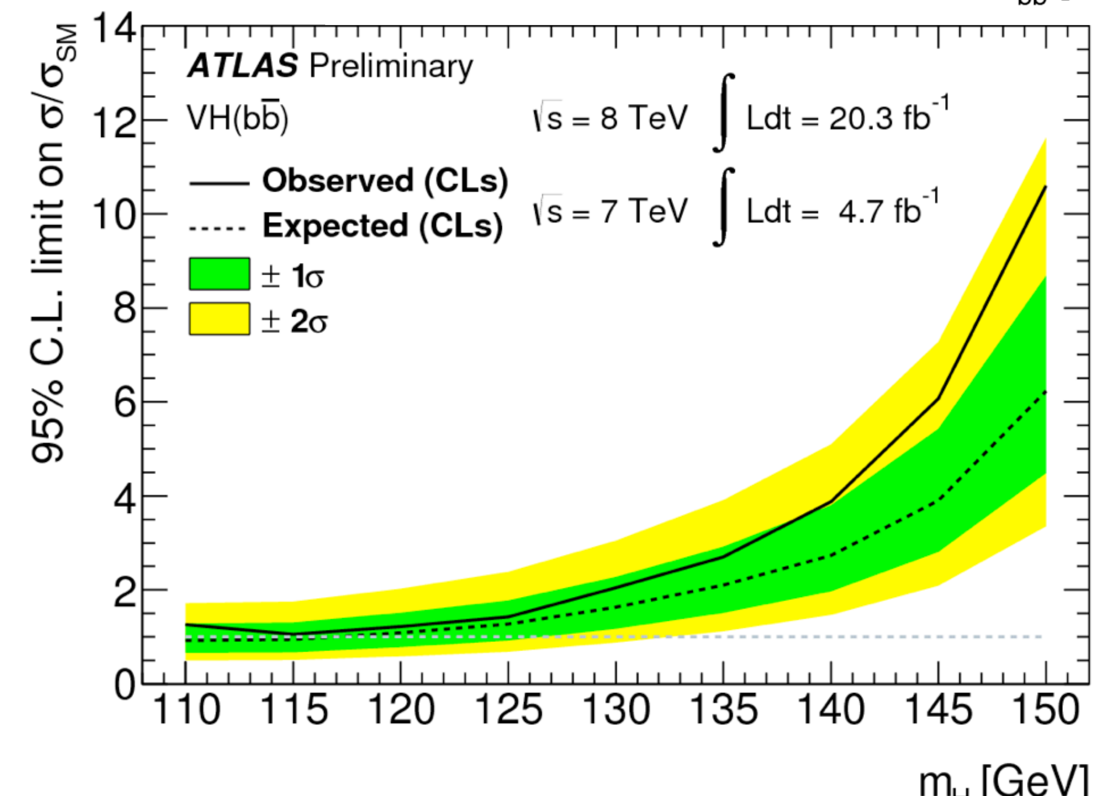
H→bb

- Largest BR (58%@m_H=125 GeV) but large QCD background
- Use associated production with W/Z
  - Final states with leptons, MET and b-jets
- Backgrounds: W/Z+jets and top
- Final discriminant m_{bb}
- Separate final states:
  - lepton multiplicity: 0, 1, 2
  - $P_T(V)$ or MET
  - jet multiplicity
  - 26 signal bins in total [+ 27 control regions]
- Validate analysis with VZ(→bb) production
  - 4.8σ (5.1σ) observation, rate 0.9±0.2 wrt SM expectation

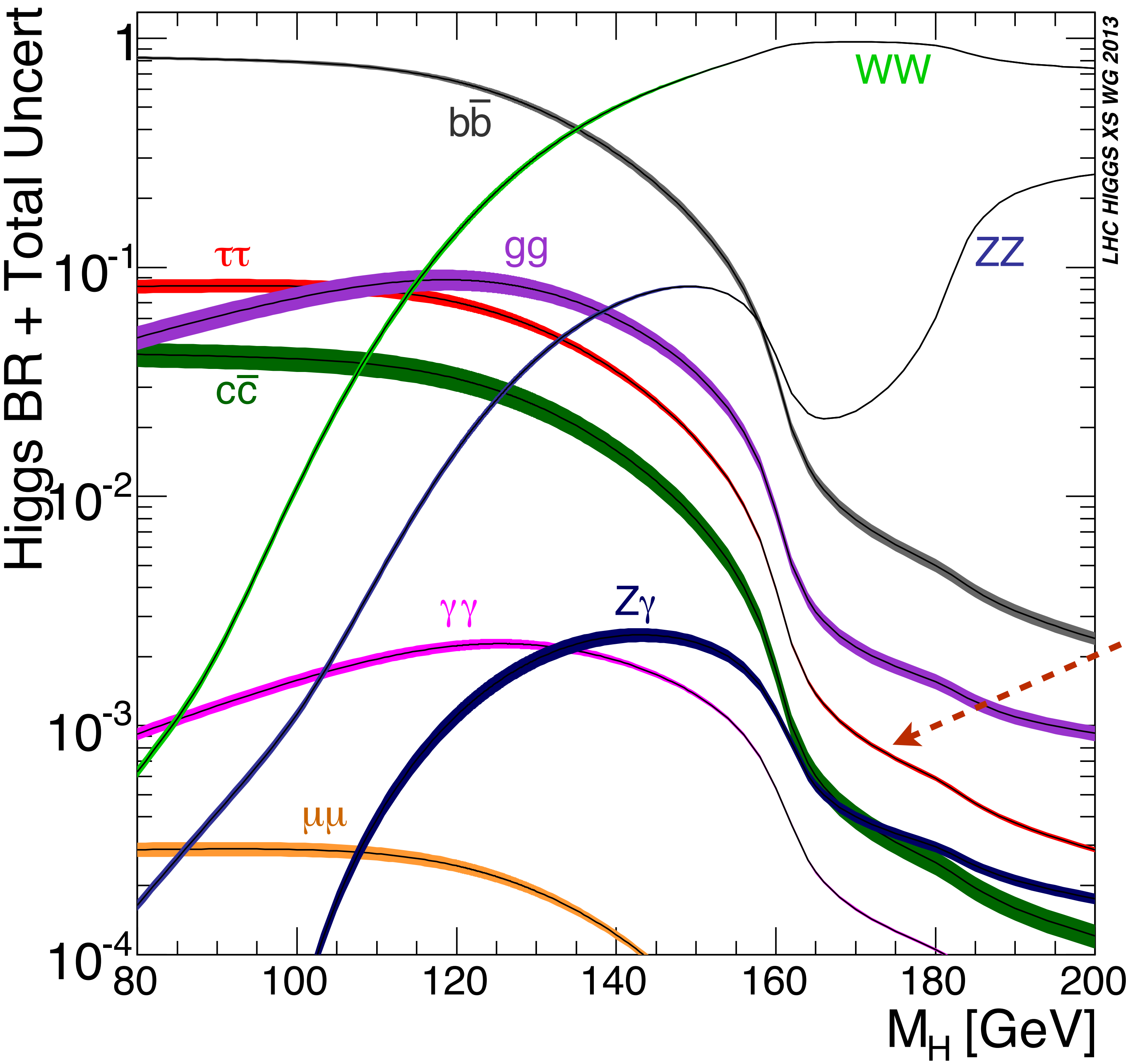








95% CL exclusion limit: 1.4 (1.3) x SM at m_H=125 GeV
$\mu = 0.2 \pm 0.5$ (stat) ± 0.4 (syst)

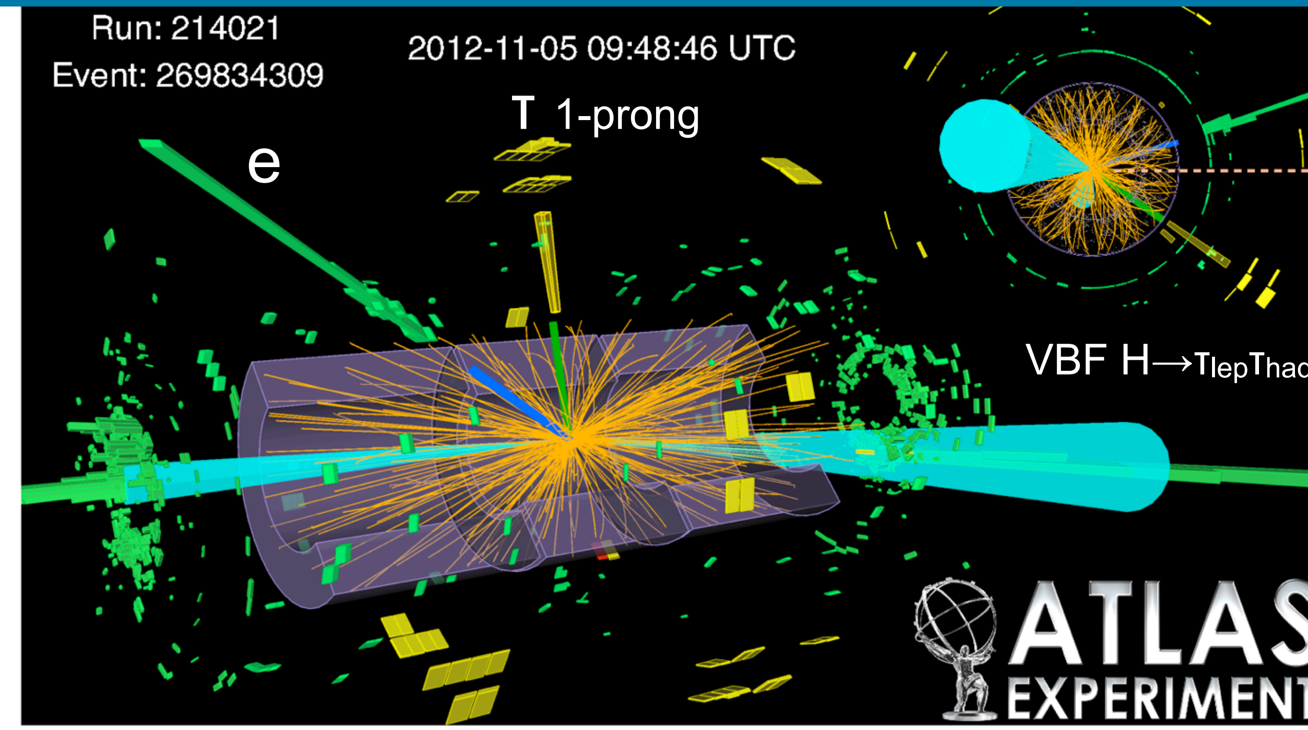


H→ττ

ATLAS-CONF-2013-108

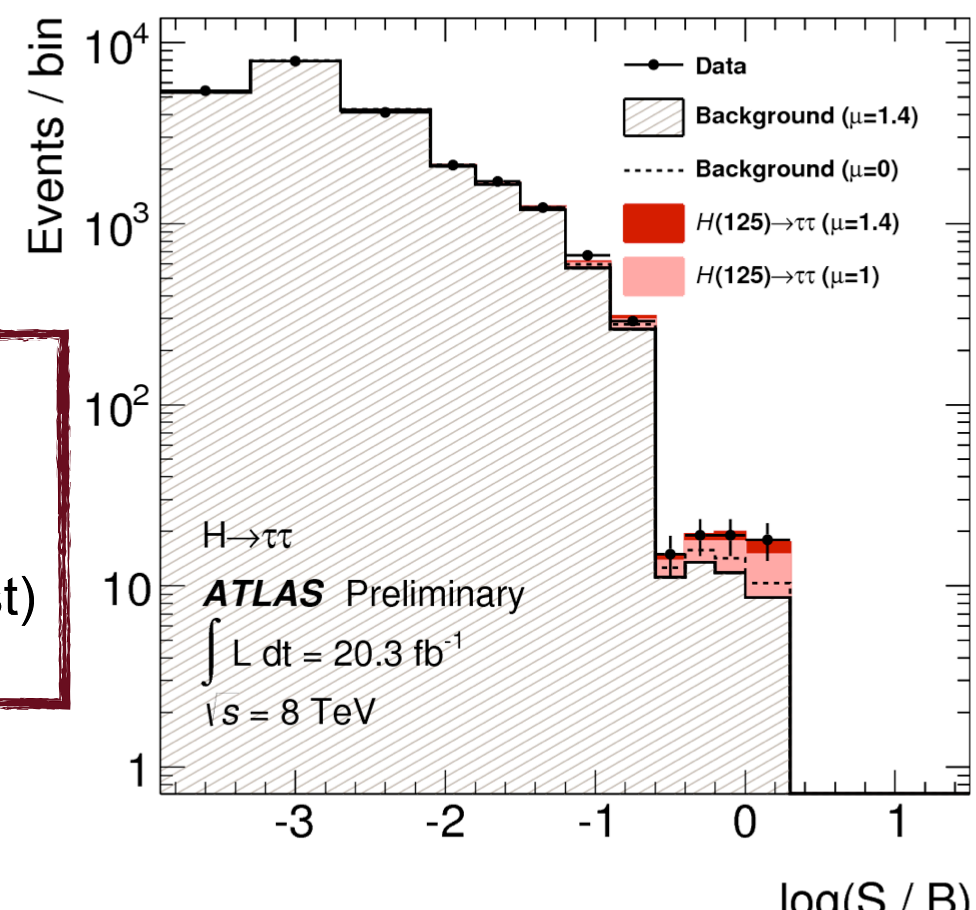
H→ττ

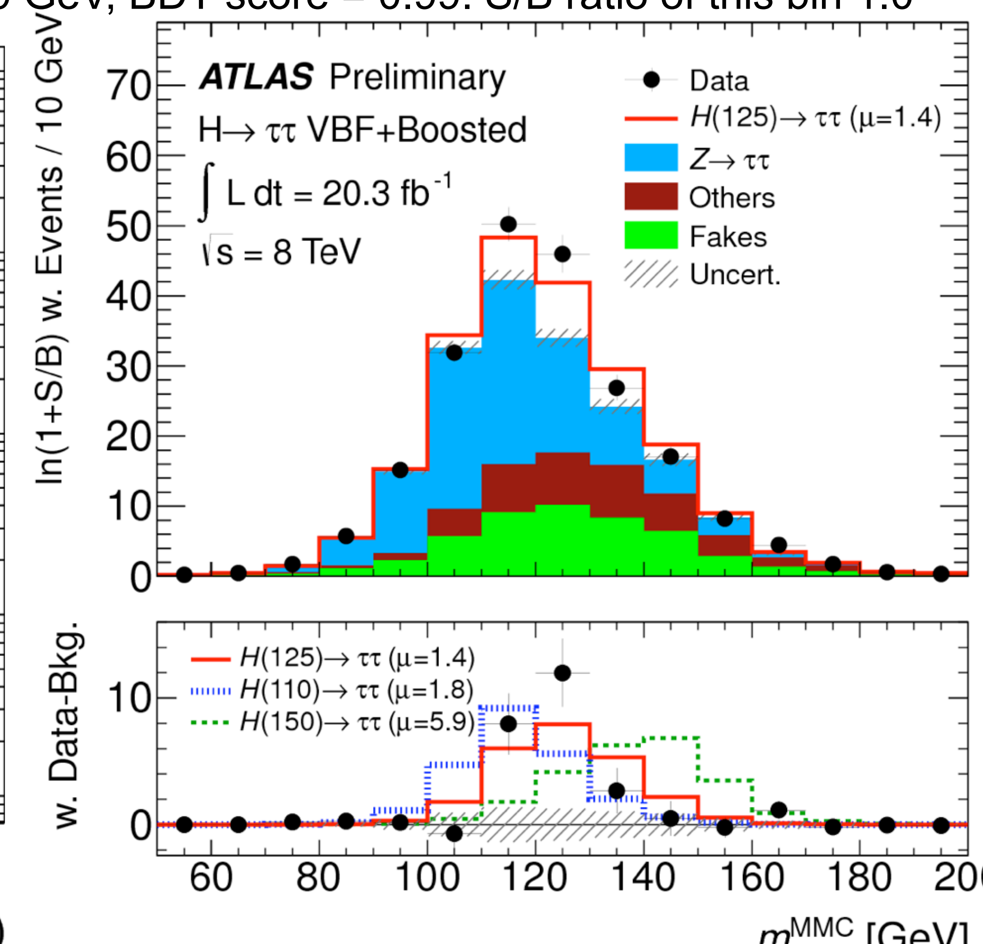
- Most promising for down-type fermion/lepton couplings
- Backgrounds
  - Z → ττ dominant [embedding]
  - "Fakes": Multijet, W+jets, top [data-driven]
  - "Other": Dibosons/H->WW* [MC]
- Three sub-channels: $\tau_{lep}\tau_{lep}$, $\tau_{lep}\tau_{had}$, $\tau_{had}\tau_{had}$
- Two exclusive categories/final state: *VBF* (2 jets with large Δη) and *Boosted* (large di-tau pT)
- Boosted Decision Tree: *di-tau properties* ($m_{\tau\tau}$, $\Delta R_{\tau\tau}$, ...), *jet topology* (m_{jj}, $\Delta\eta_{jj}$, ...), *event activity/topology* (scalar/vector pT sum, object centralities, ...)



e p_T = 56 GeV, τ_{had} p_T = 27 GeV, MET=113 GeV, $m_{j1,j2}$=1.53 TeV, $m_{\tau\tau}^{MMC}$=129 GeV, BDT score = 0.99. S/B ratio of this bin 1.0

Evidence observed for Higgs boson decays to τ-leptons
significance 4.1σ (3.2σ)
$\mu=1.43^{+0.31}_{-0.29}(stat)^{+0.41}_{-0.30}(syst)$
@ m_H=125 GeV



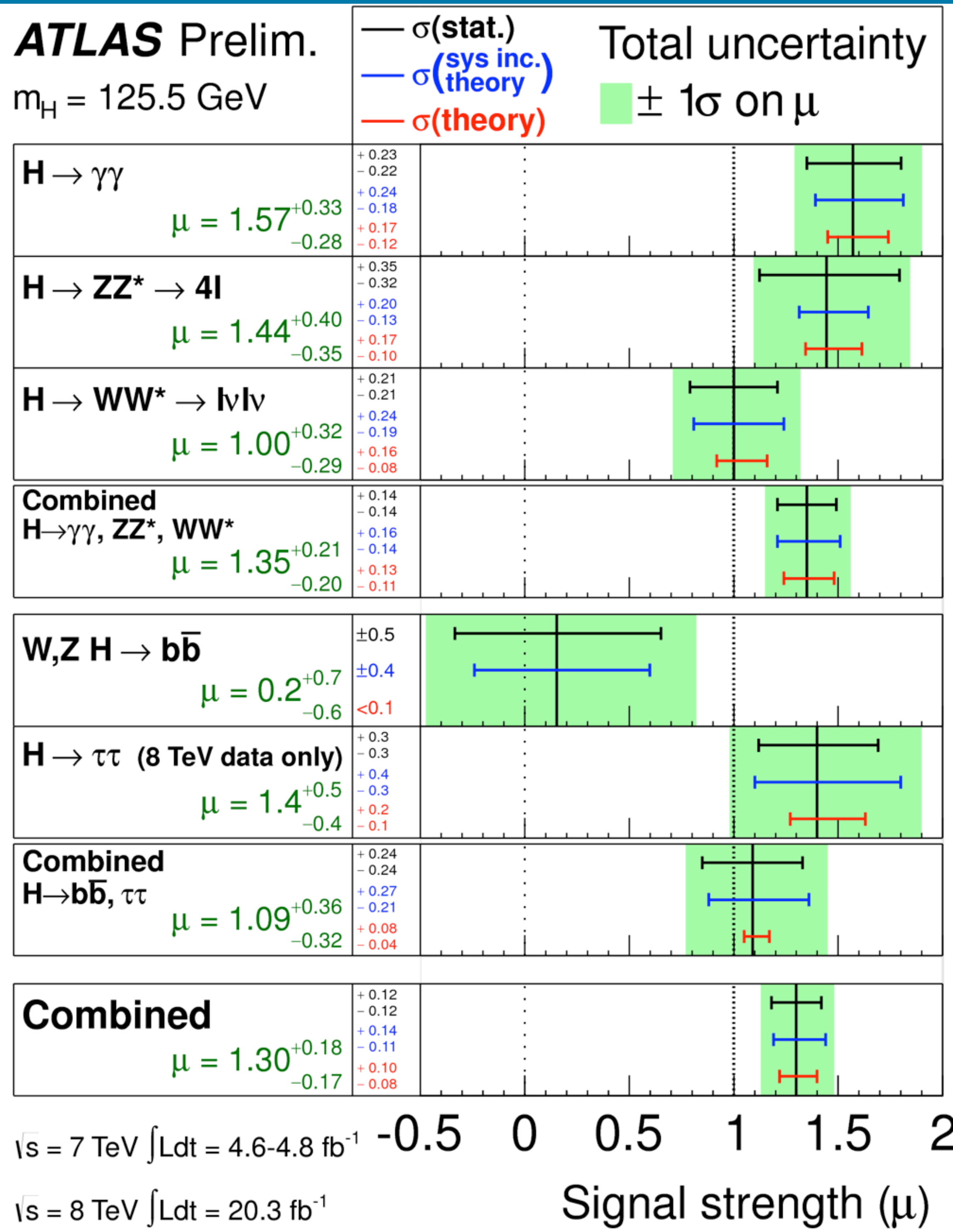


Summary of main SM Higgs channels

ATLAS-CONF-2014-009

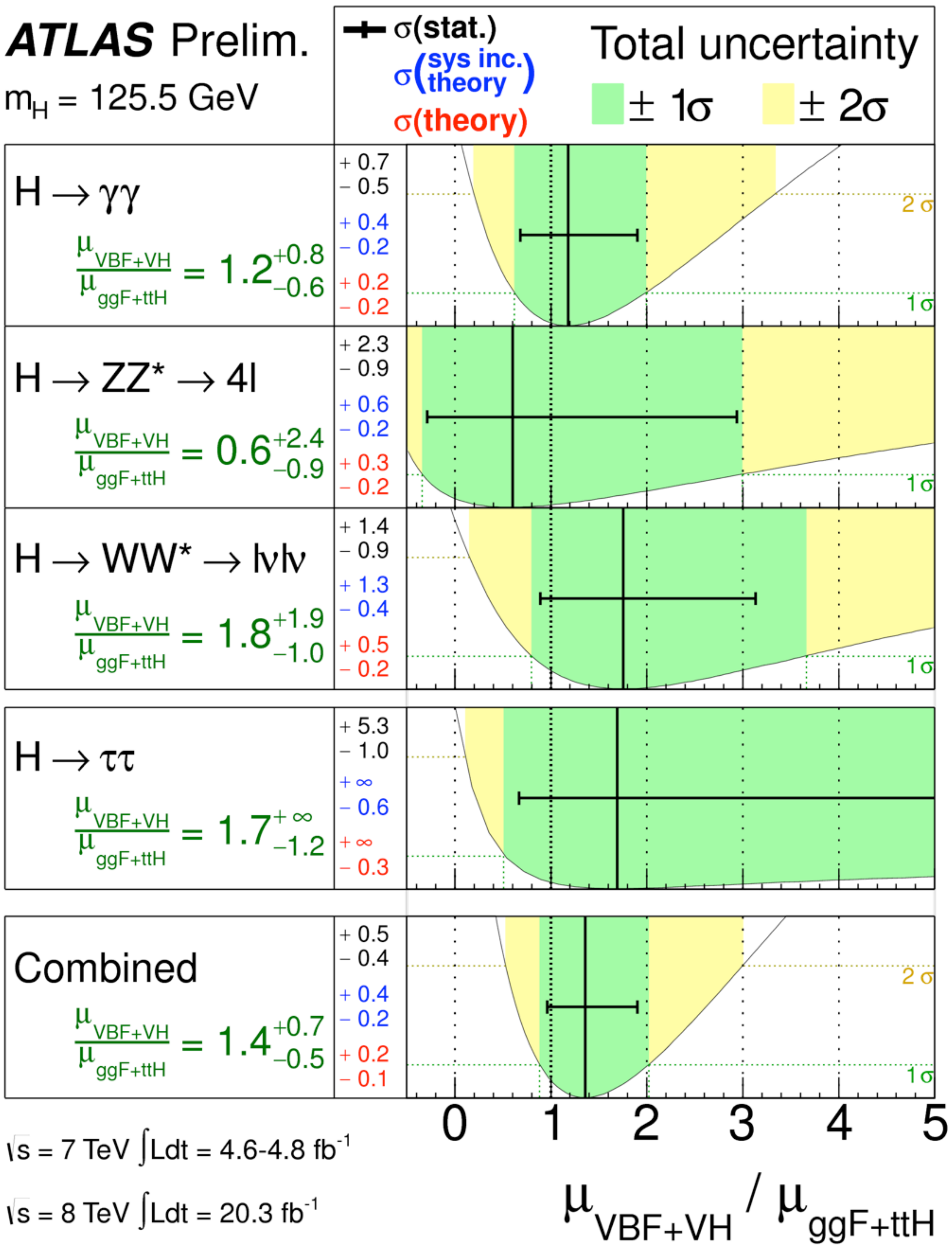
Bosonic Decays

Fermionic Decays



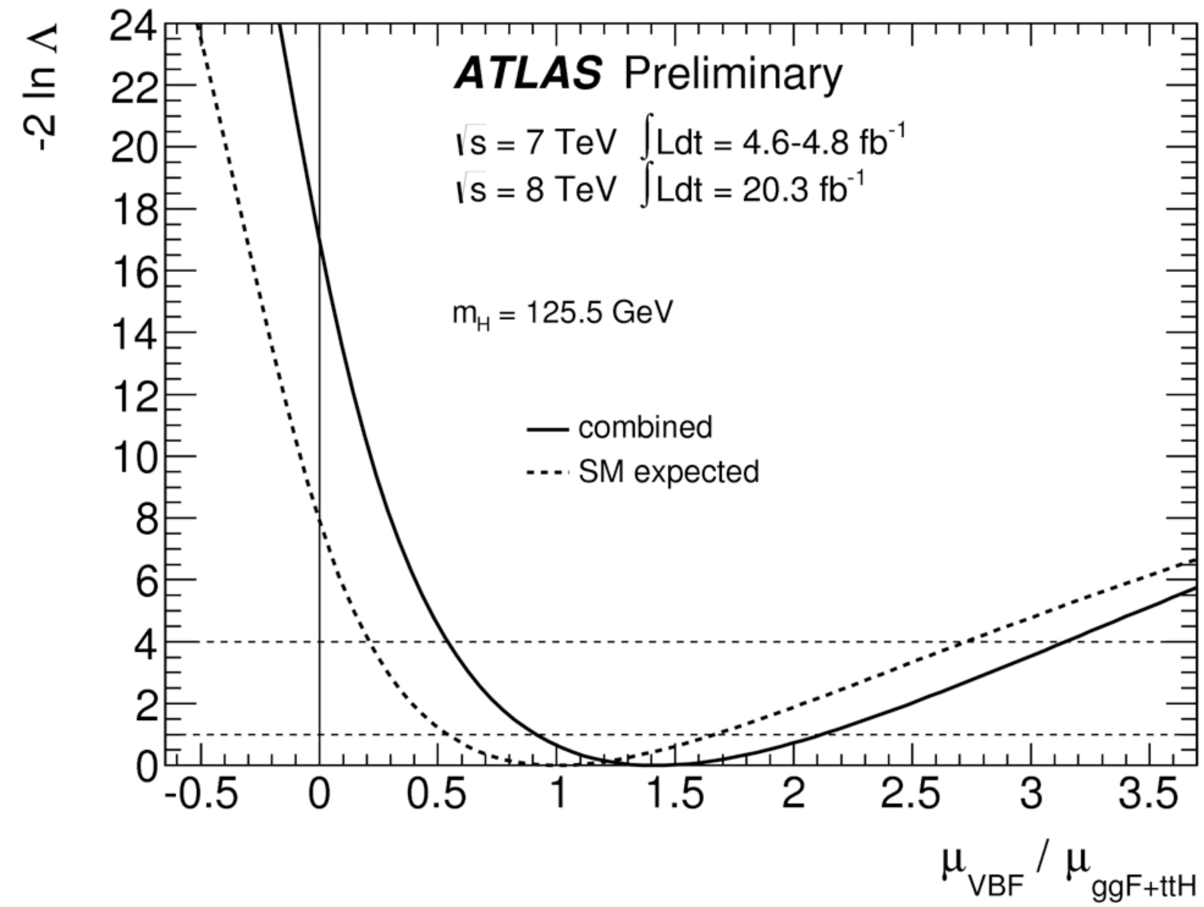
Complete Run 1 dataset analyzed for the five major channels
Significant signal has been observed in: H→γγ, H→ZZ*, H→WW and H→ττ
H→bb now reaching SM sensitivity

Signal strength for production mechanisms



Overall Higgs boson signal strength measurement:
- no information on production mechanisms
- assuming SM ratio of production cross-section

Split vector boson/fermion mediated processes:
- signal strengths μ_{VBF+VH} and $\mu_{ggF+ttH}$
- $\mu_{VBF+VH} / \mu_{ggF+ttH} = 1.4^{+0.5}_{-0.4}(\text{stat})^{+0.4}_{-0.2}$ (sys)
  - model independent (no assumption on branching ratios)
- 4.1σ evidence for VBF Higgs boson production



Higgs boson couplings

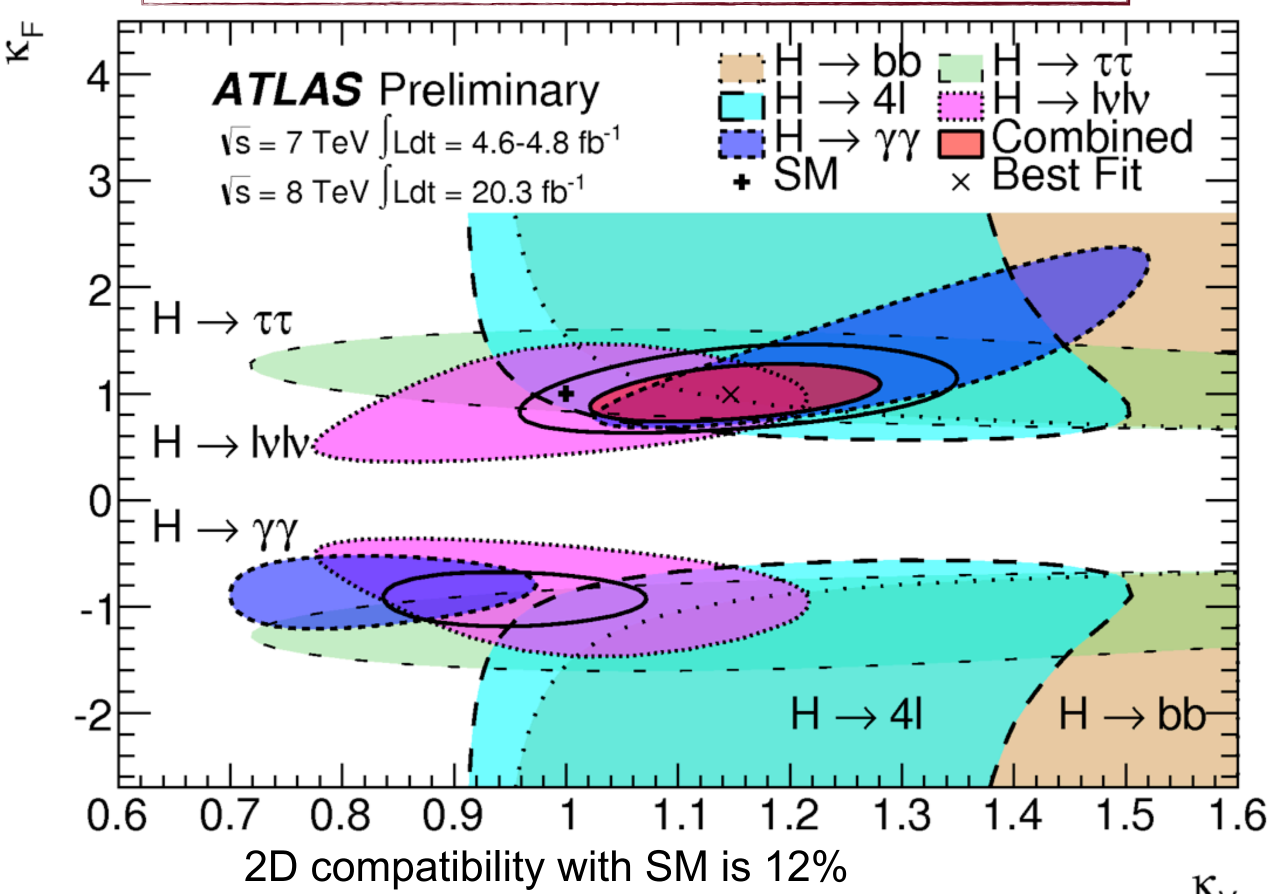
Higgs boson signal strength measurement following formalism of arXiv:1209.0040

- single resonance of 125.5 GeV
- narrow width approximation
- only modifications of the coupling strengths

Table 2: Summary of the coupling benchmark models discussed in this note, where $\lambda_{ij} = \kappa_i/\kappa_j$, $\kappa_{ii} = \kappa_i\kappa_i/\kappa_H$, and the functional dependence assumptions are: $\kappa_V = \kappa_W = \kappa_Z$, $\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$ (and similarly for the other fermions), $\kappa_g = \kappa_g(\kappa_b, \kappa_t)$, $\kappa_\gamma = \kappa_\gamma(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W)$, and $\kappa_H = \kappa_H(\kappa_i)$. The tick marks indicate which assumptions are made in each case. The last column shows, as an example, the relative couplings involved in the $gg \to H \to \gamma\gamma$ process (see Appendix A for more details).

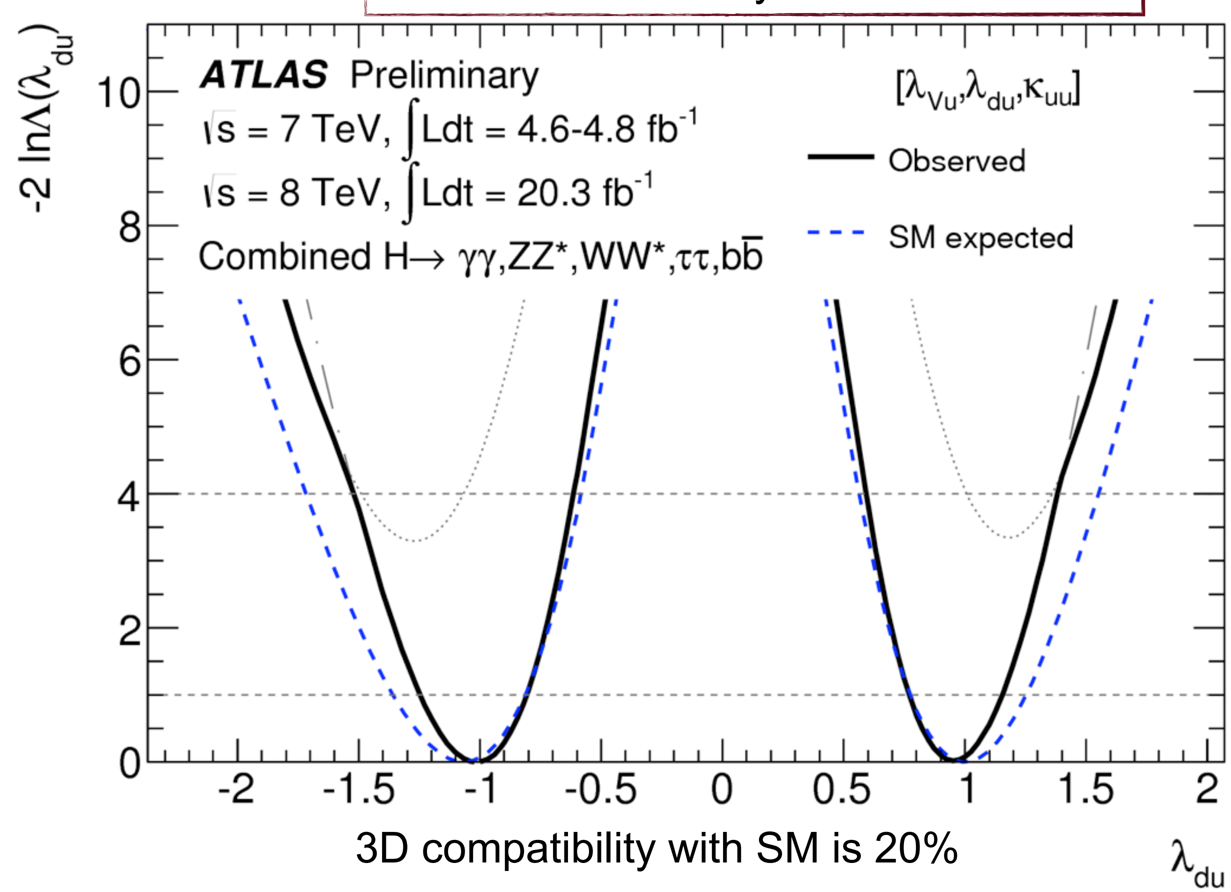
Section	Probed couplings	Parameters of interest	Functional assumptions κ_V	κ_F	κ_g	κ_γ	κ_H	Example: $gg \to H \to \gamma\gamma$
5.2.1	Couplings to fermions and bosons	κ_V, κ_F	√	√	√	√	√	$\kappa_F^2 \cdot \kappa_\gamma^2(\kappa_F, \kappa_V)/\kappa_H^2(\kappa_F, \kappa_V)$
5.2.2		$\lambda_{FV}, \kappa_{VV}$	√	√	√	√	-	$\kappa_{VV}^2 \cdot \lambda_{FV}^2 \cdot \kappa_\gamma^2(\lambda_{FV}, \lambda_{FV}, \lambda_{FV}, 1)$
5.3	Custodial symmetry	$\lambda_{WZ}, \lambda_{FZ}, \kappa_{ZZ}$	-	√	√	√	-	$\kappa_{ZZ}^2 \cdot \lambda_{FZ}^2 \cdot \kappa_\gamma^2(\lambda_{FZ}, \lambda_{FZ}, \lambda_{FZ}, \lambda_{WZ})$
5.4.1	Up-/down-type fermions	$\lambda_{du}, \lambda_{Vu}, \kappa_{uu}$	√	κ_u, κ_d	√	√	-	$\kappa_{uu}^2 \cdot \kappa_g^2(\lambda_{du}, 1) \cdot \kappa_\gamma^2(\lambda_{du}, 1, \lambda_{du}, \lambda_{Vu})$
5.4.2	Leptons/Quarks	$\lambda_{lq}, \lambda_{Vq}, \kappa_{qq}$	√	κ_l, κ_q	√	√	-	$\kappa_{qq}^2 \cdot \kappa_\gamma^2(1, 1, \lambda_{lq}, \lambda_{Vq})$
5.5.1	Vertex loops	κ_g, κ_γ	=1	=1	-	-	√	$\kappa_g^2 \cdot \kappa_\gamma^2/\kappa_H^2(\kappa_g, \kappa_\gamma)$
5.5.2	+ H→inv./undet. decays	$\kappa_g, \kappa_\gamma, BR_{i.,u.}$	=1	=1	-	-	√	$\kappa_g^2 \cdot \kappa_\gamma^2/\kappa_H^2(\kappa_g, \kappa_\gamma) \cdot (1 - BR_{i.,u.})$
5.6.1	Generic models with and without assumptions on vertex loops and Γ_H	$\kappa_W, \kappa_Z, \kappa_t, \kappa_b, \kappa_\tau$	-	-	√	√	√	$\frac{\kappa_g^2(\kappa_b,\kappa_t)\cdot\kappa_\gamma^2(\kappa_b,\kappa_t,\kappa_\tau,\kappa_W)}{\kappa_H^2(\kappa_b,\kappa_t,\kappa_\tau,\kappa_W,\kappa_Z)}$
5.6.2		$\lambda_{WZ}, \lambda_{tg}, \lambda_{bZ}, \lambda_{\tau Z}, \lambda_{gZ}, \lambda_{\gamma Z}, \kappa_{gZ}$	-	-	-	-	-	$\kappa_{gZ}^2 \cdot \lambda_{\gamma Z}^2$

Deviations described by overall scales kF (kV) for fermions (bosons). No BSM contribution



2D compatibility with SM is 12%

Probe Up/Down-type fermion symmetry
Bosons scaled by common factor



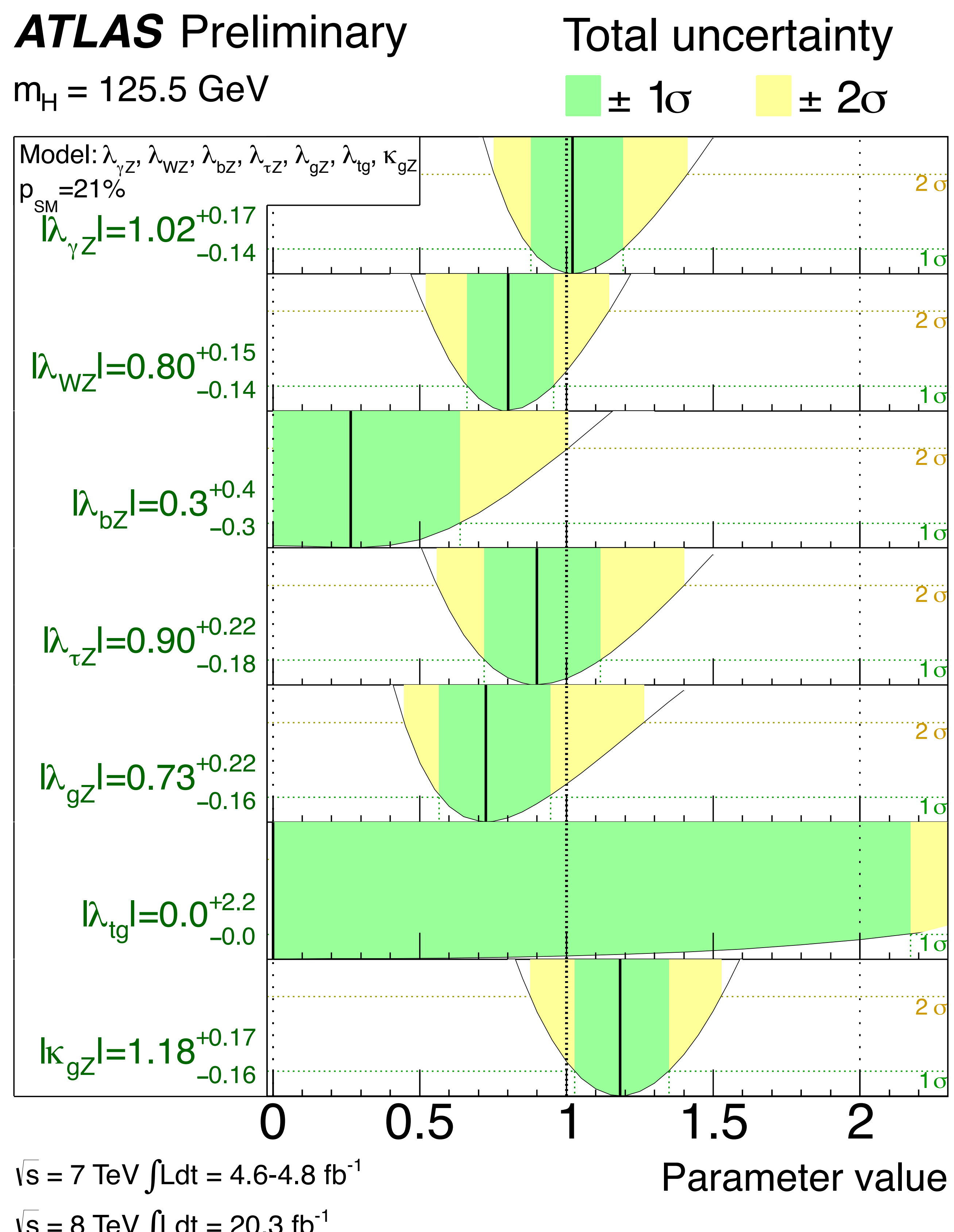
3D compatibility with SM is 20%

Higgs boson couplings (II)

Eventually, the aim is to perform a complete fit to determine the ratios of couplings of the Higgs bosons

No assumptions on BSM contributions (effective coupling scale factors for gg→H and H→γγ)

No assumption on width → ratios of scalings



BSM examples

The properties of the observed Higgs boson already constraint BSM contributions

ATLAS-CONF-2014-010

Additional EW singlet field

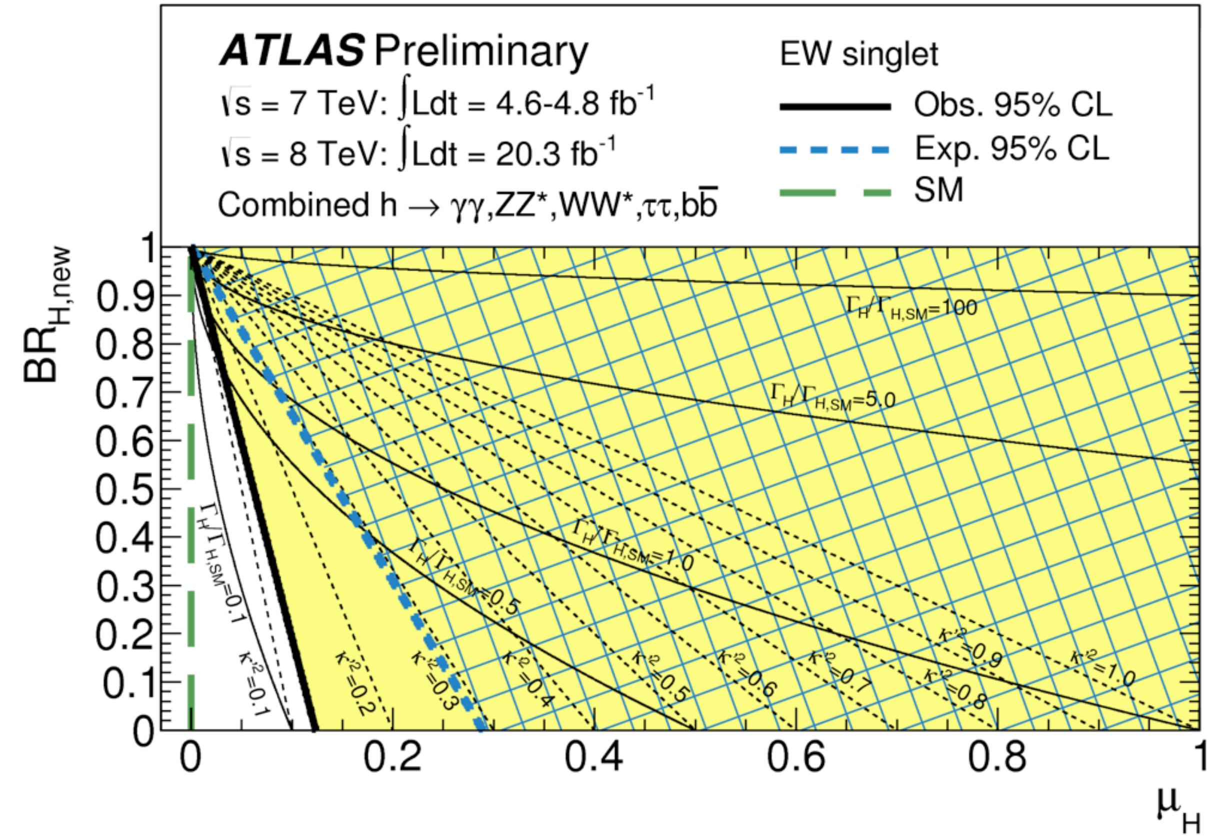
Simplest extension of SM Higgs sector

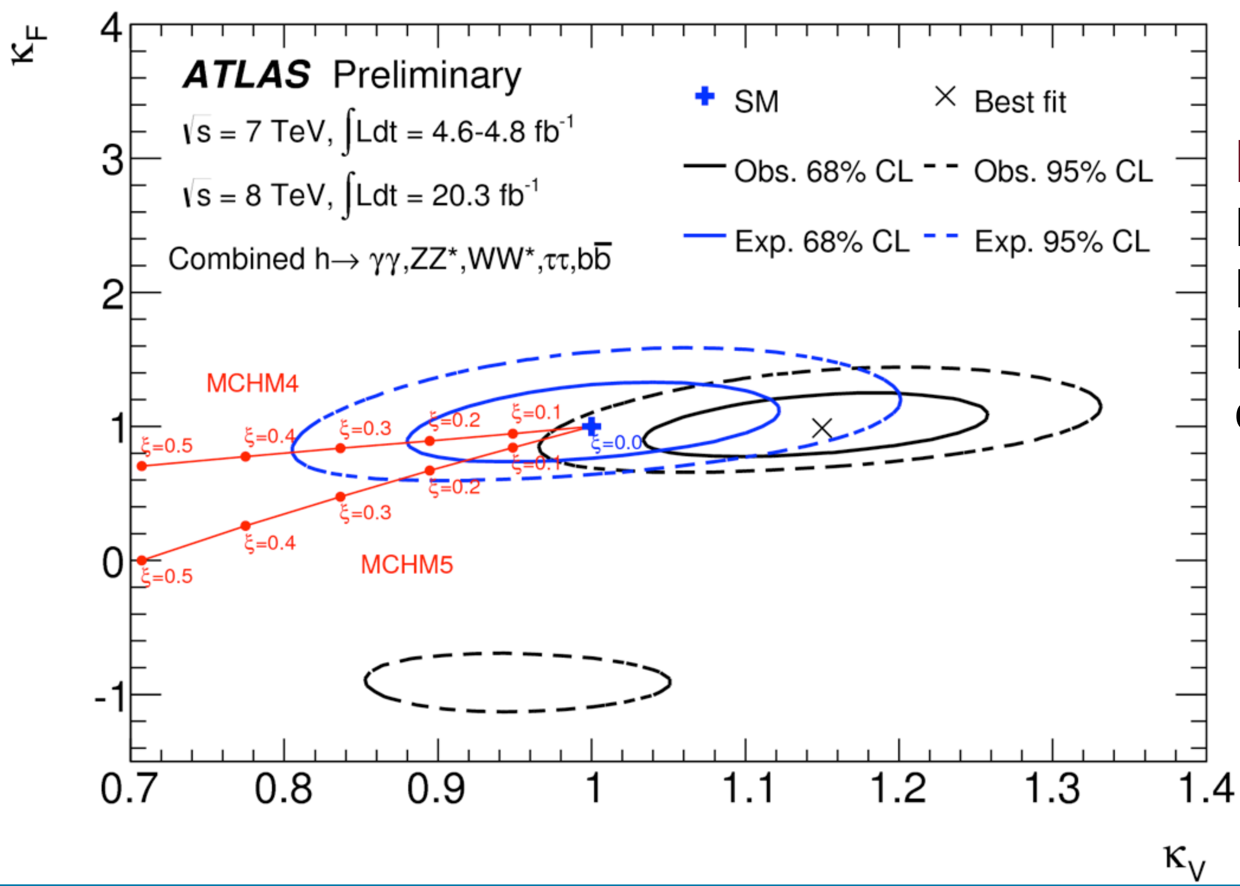
Results in two CP-even Higgs bosons: h, H (assumed non degenerate)

Couplings similar to SM Higgs boson, but each scaled by common factor, denoted as κ (κ') for h(H).
From unitarity: $\kappa^2+\kappa'^2=1$

$$\mu_h = \frac{\sigma_h \times \mathrm{BR}_h}{(\sigma_h \times \mathrm{BR}_h)_{\mathrm{SM}}} = \kappa^2$$

$$\mu_H = \frac{\sigma_H \times \mathrm{BR}_H}{(\sigma_H \times \mathrm{BR}_H)_{\mathrm{SM}}} = \kappa'^2\,(1 - \mathrm{BR}_{H,\mathrm{new}})$$





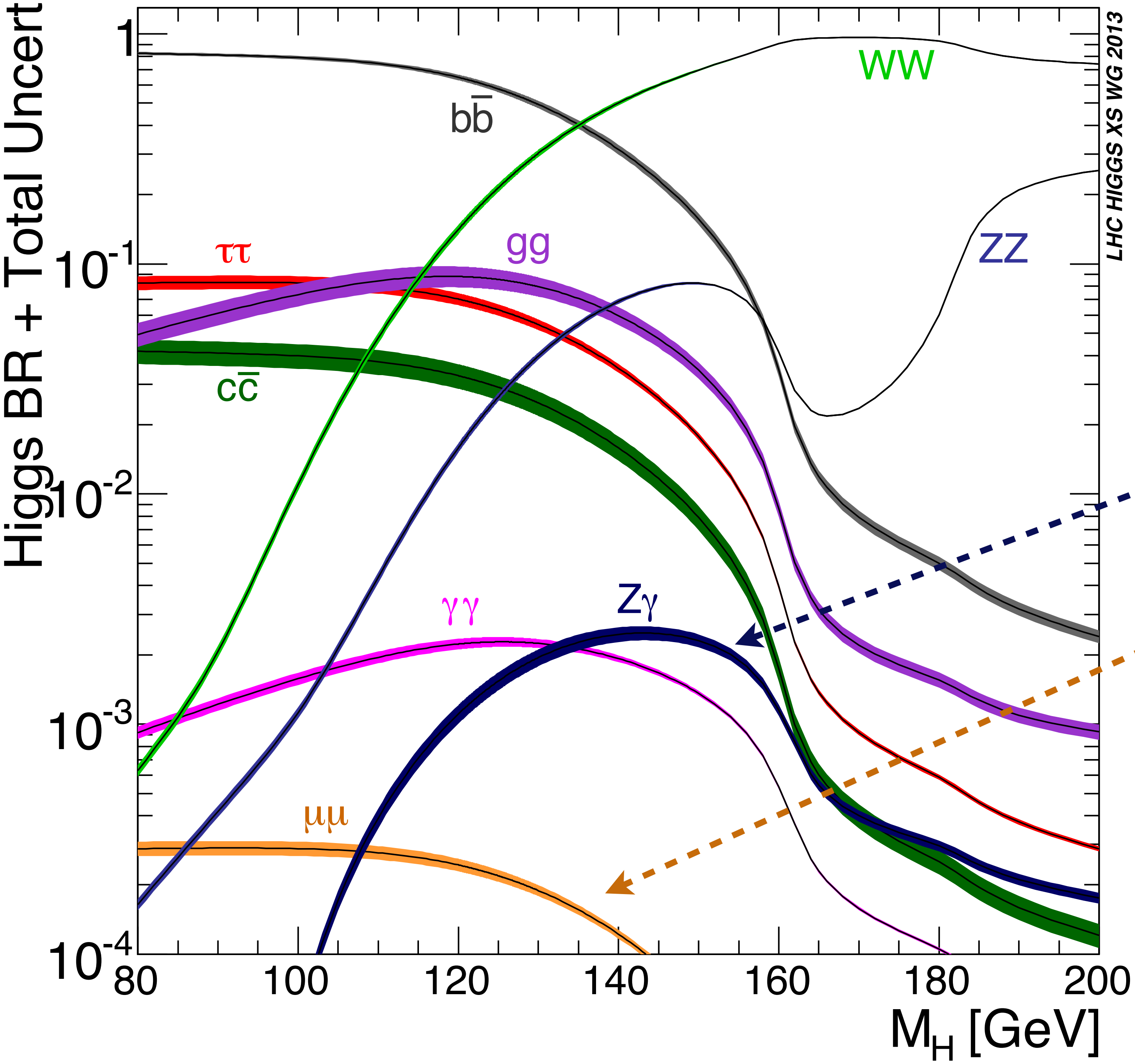
Minimal Composite Higgs Model

Higgs is pseudo Nambu-Goldstone boson

Neglecting contributions from new heavy resonances the Higgs couplings modified wrt SM as a function of compositeness scale: $\xi = v^2/f^2$

MCHM4: $\kappa = \kappa_V = \kappa_F = \sqrt{1-\xi}$ f>710 (460) GeV at 95%CL

MCHM5: $\kappa_V = \sqrt{1-\xi}$, $\kappa_F = \frac{1-2\xi}{\sqrt{1-\xi}}$. f>640 (550) GeV at 95%CL



Rare Decays

$H \rightarrow Z\gamma$

$H \rightarrow \mu\mu$

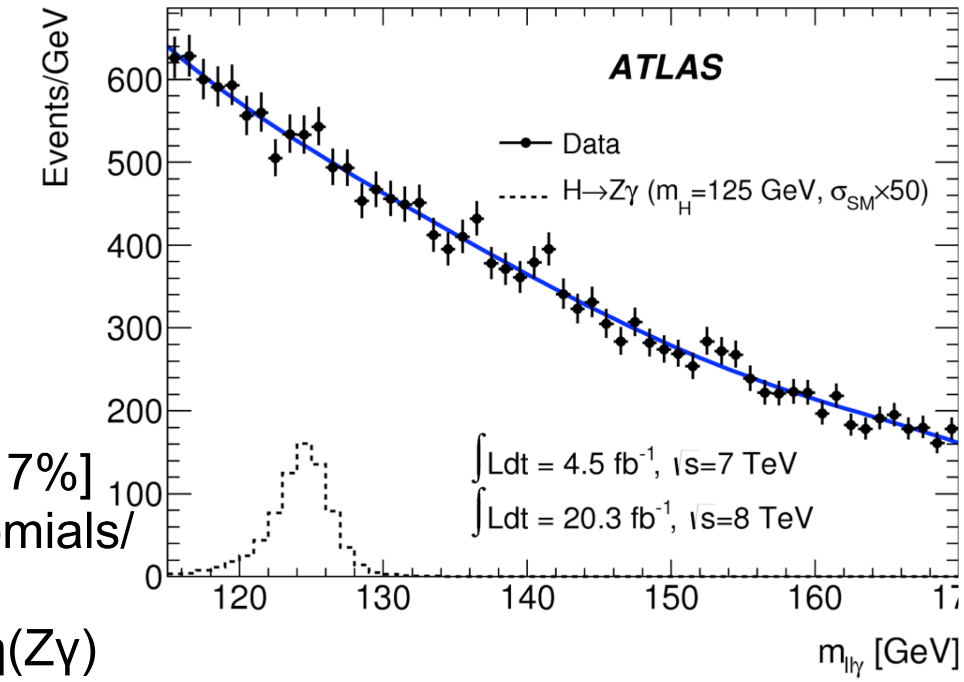
+ Rare Production through ttH

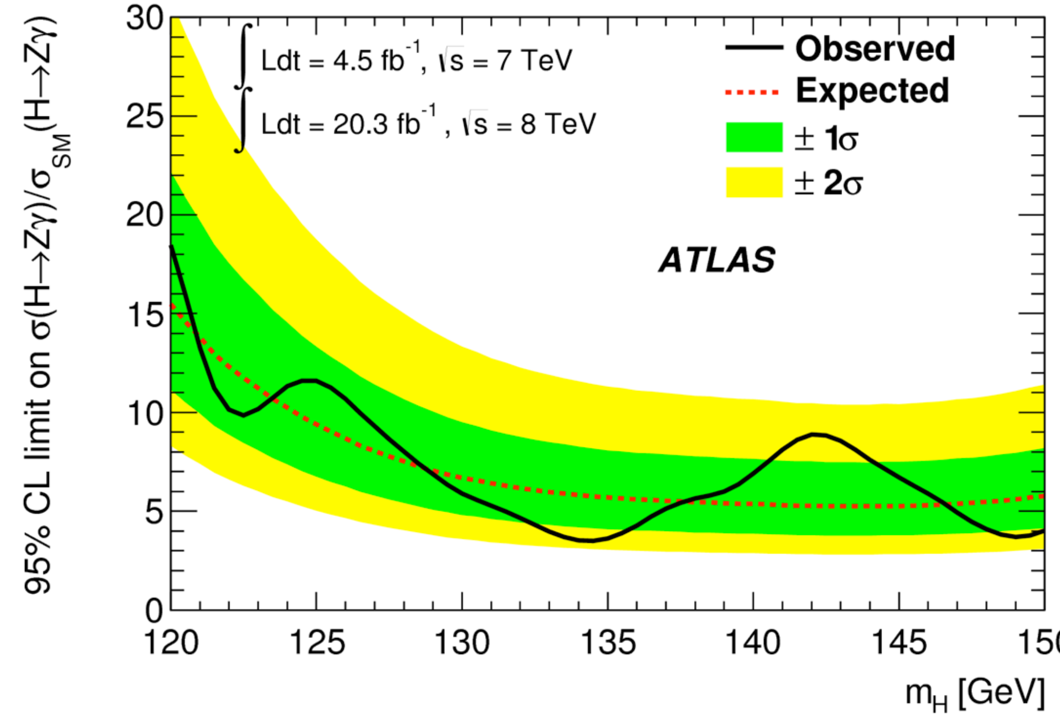
Rare Higgs Decays

H→Zγ

Phys. Lett. B 732(2014),8

- loop induced
  → sensitive to new physics
- Signature: $e^+e^-/\mu^+\mu^- + \gamma$
- BR~10^{-4}(125GeV); S/B~1%
- Background: continuum Z+γ/ radiative Z→llγ [82%], Z+jets [17%]
- Background Modeling: polynomials/ exponentiated polynomials
- Categorization: ee/μμ, pTt, Δη(Zγ)
- 95% CL upper limit @m_H=125.5 GeV: 11 (9) x SM

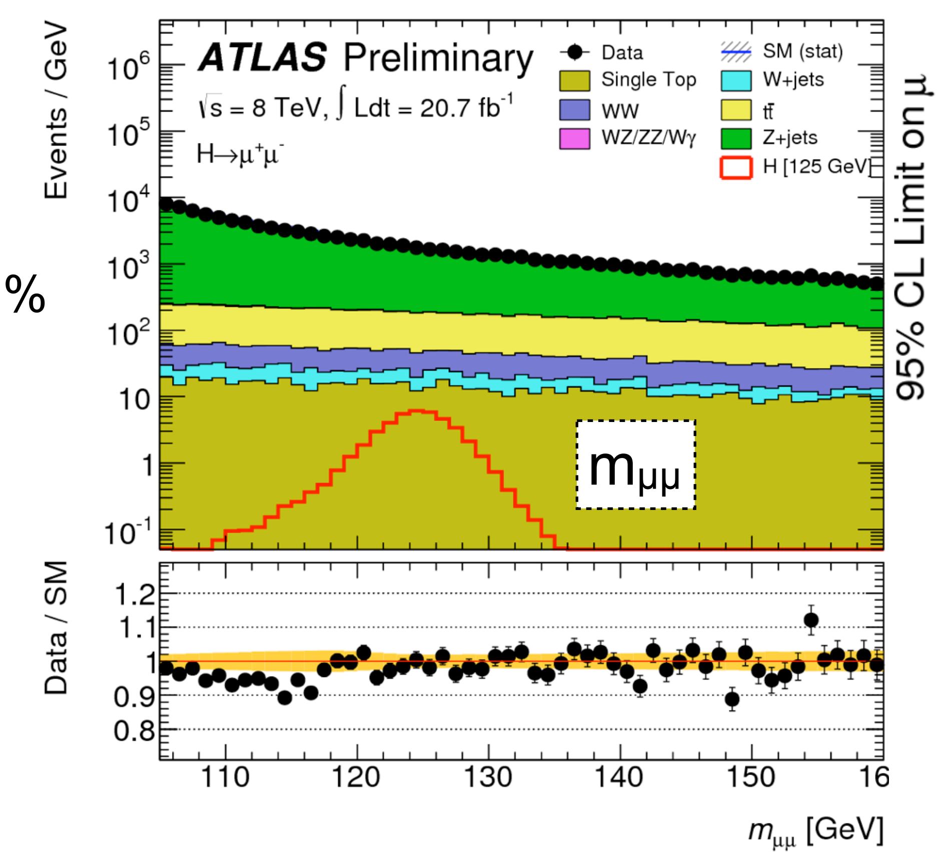


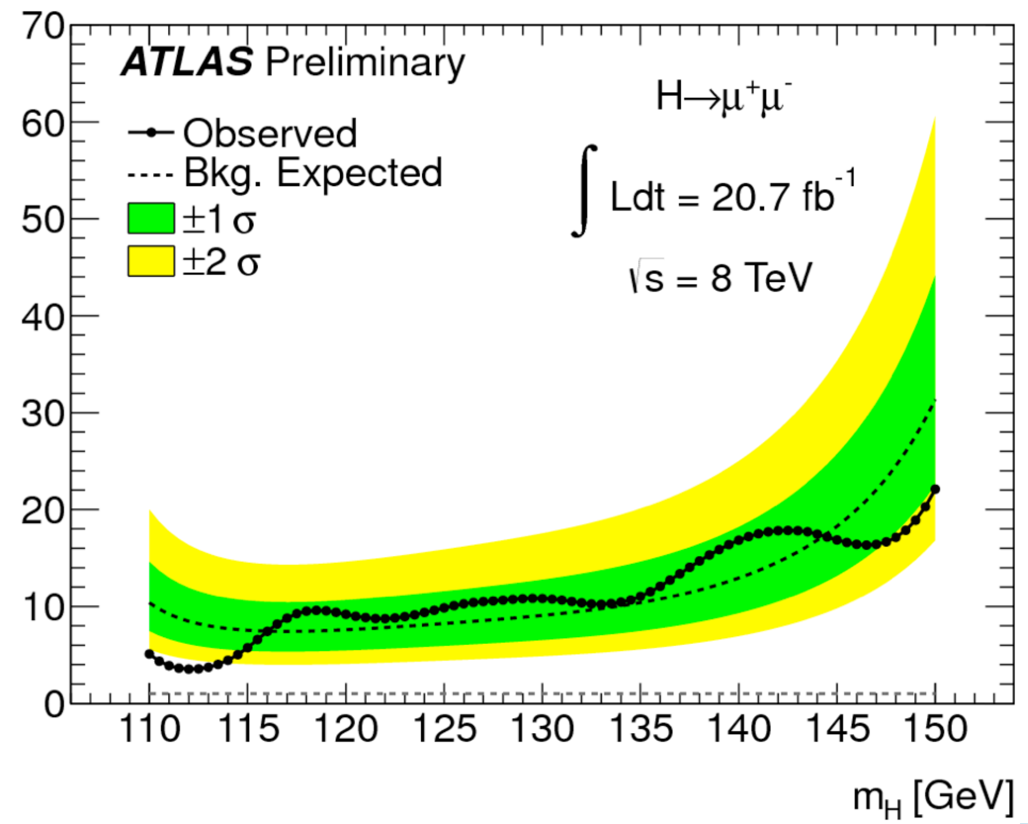


H→μμ

ATLAS-CONF-2013-010

- probe coupling to muons
- BR ~$2 \cdot 10^{-4}$(125GeV);S/B ~0.2%
- two opposite-charge muons (p_T>25,15 GeV, $p_{T\mu\mu}$>15 GeV)
- backgrounds: $Z/\gamma^* \to \mu\mu$, top, dibosons
- Categorization: central muons and non-central
- Background Model: BW+Expo
- 95% CL upper limit @m_H=125 GeV: 9.8 (8.2)xSM





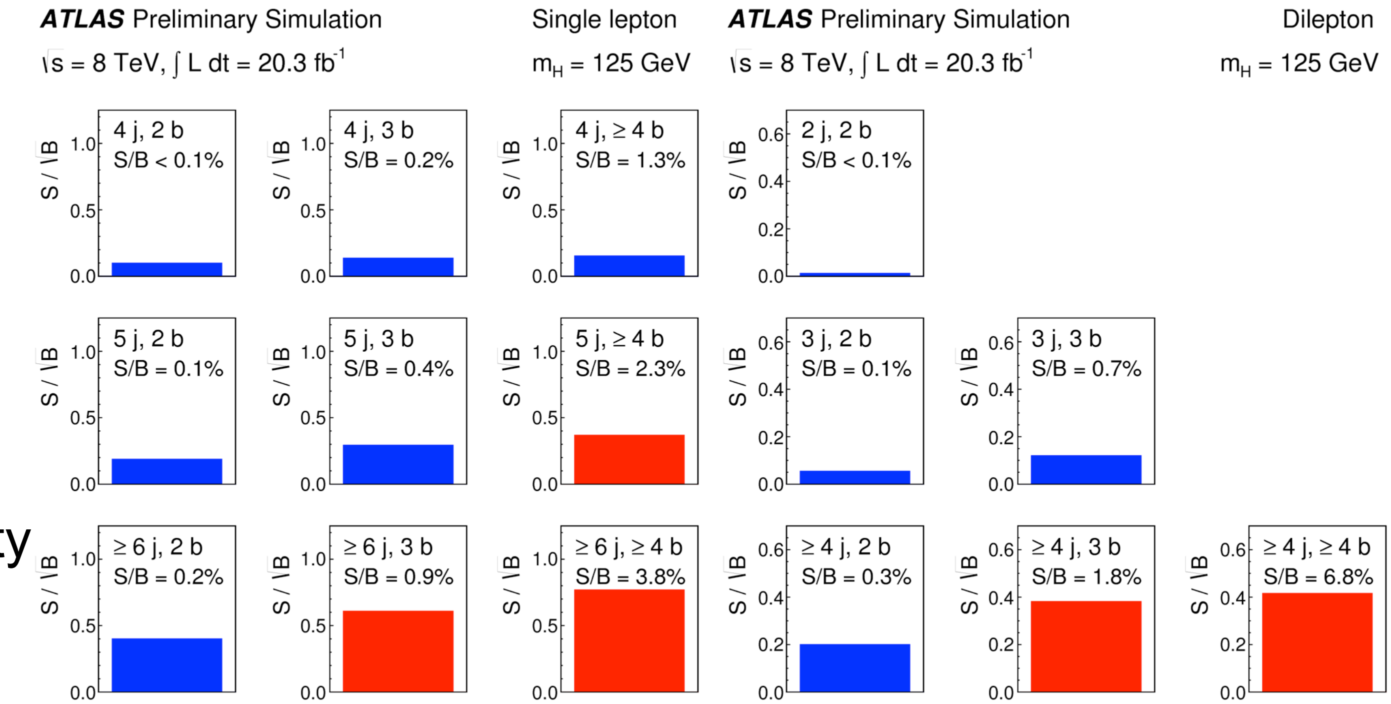
ttH

ATLAS-CONF-2014-011

- Direct sensitivity to top-quark Yukawa coupling
- Two final states explored H→bb and H→γγ

ttH(→bb)

- Two channels
  - Single lepton
    - 1 lepton, ≥4 jets of which ≥2 b-tag
  - Di-lepton
    - 2 opposite-charge leptons, ≥2 b-tag
- Further categorization based on jet and b-tag multiplicity
  - Single lepton: 9 bins
  - Di-lepton: 6 bins
- Fit Strategy
  - Signal Depleted Regions: H_T(had) and H_T
  - l+jets, 5jets,3b-tag: NN tt+bb/cc vs tt+light jets
  - Signal Rich Regions: NN ttH vs tt+jets

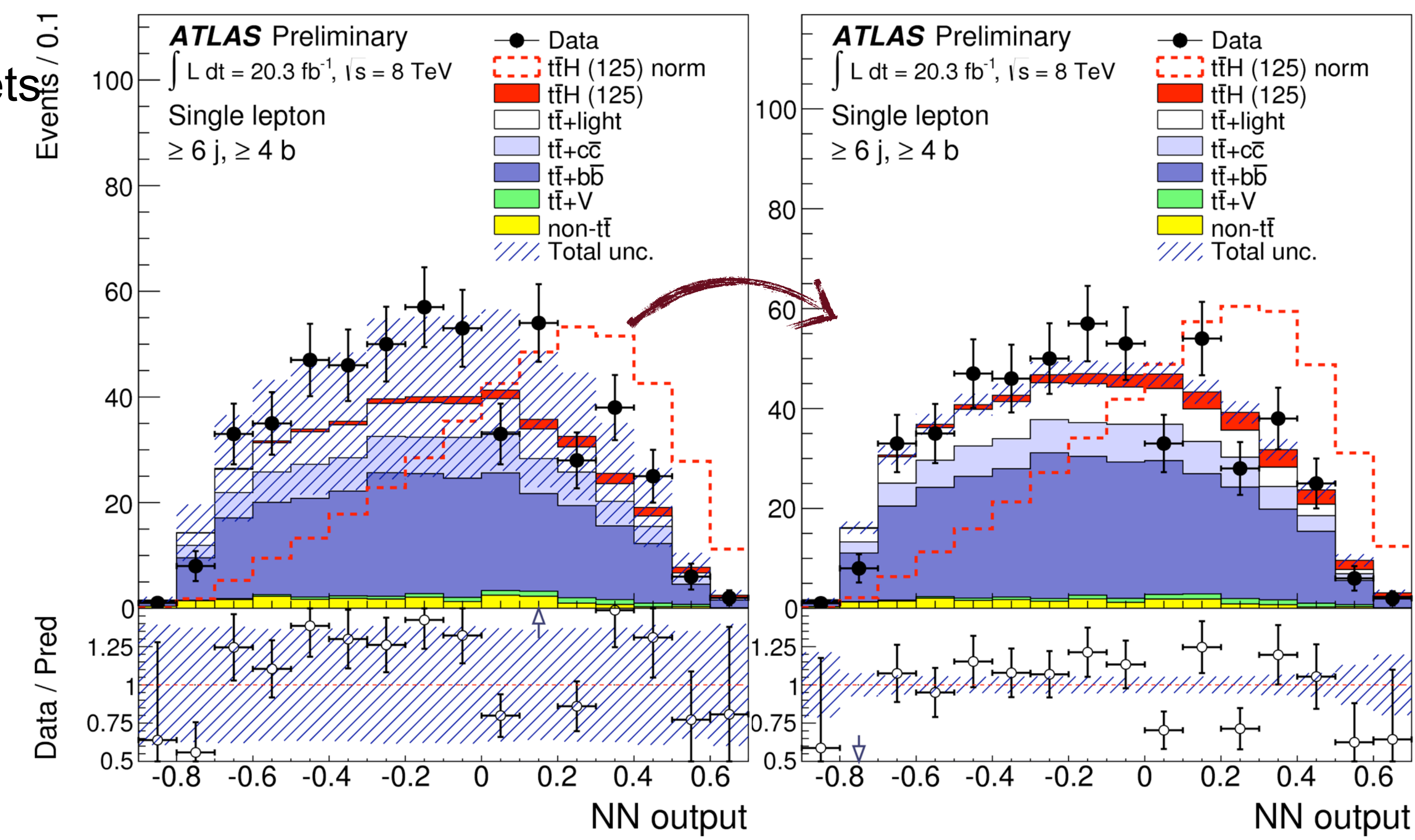


Single Lepton

	2 b-tags	3 b-tags	$\geq$ 4 b-tags
4 jets	H_T^{had}	H_T^{had}	H_T^{had}
5 jets	H_T^{had}	NN	NN
$\geq$ 6 jets	H_T^{had}	NN	NN

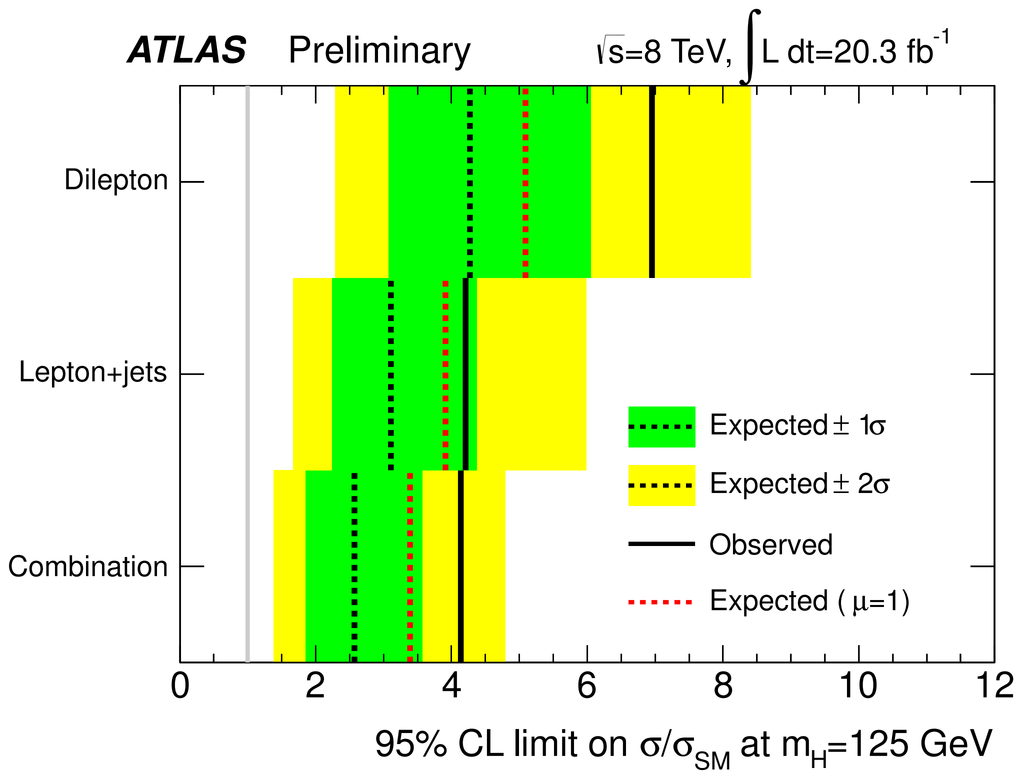
Di-Lepton

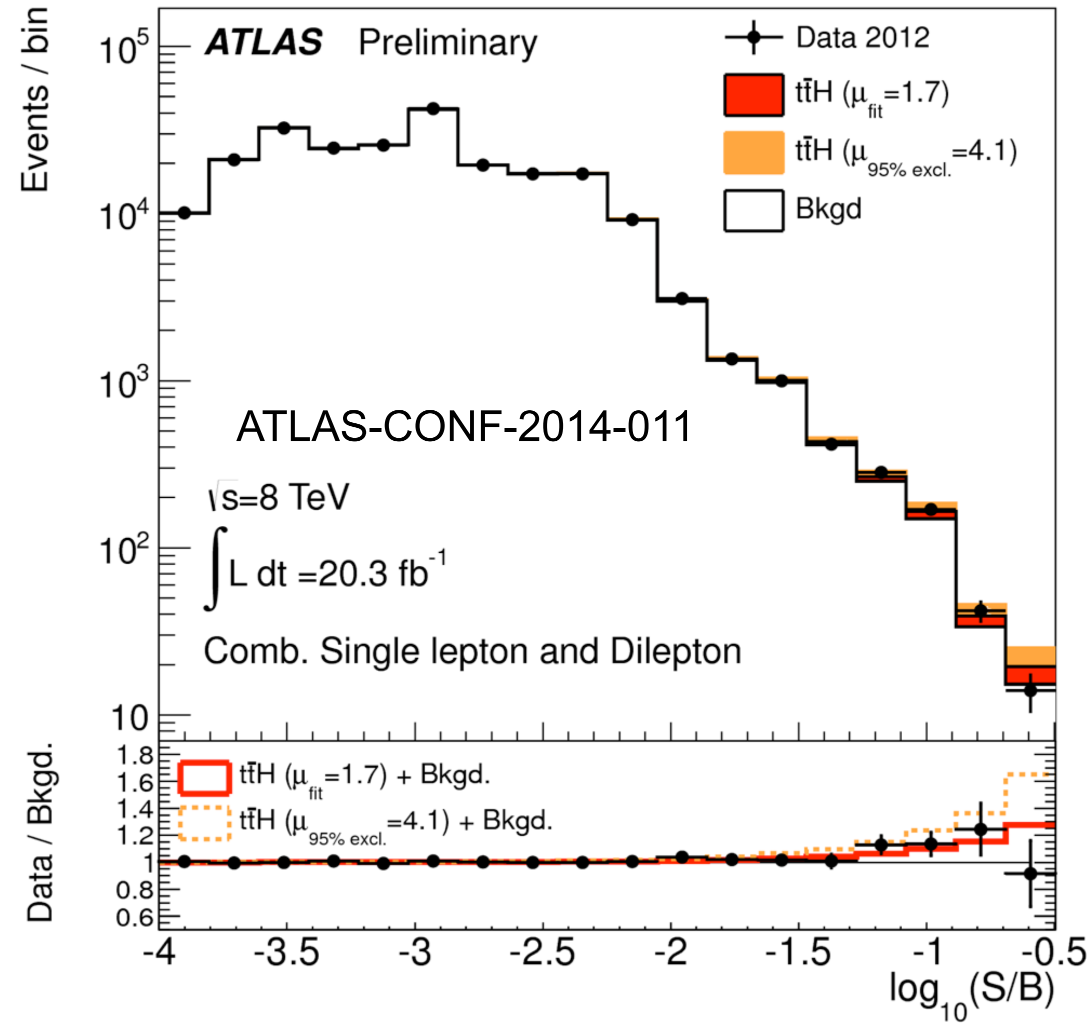
	2 b-tags	3 b-tags	$\geq$ 4 b-tags
2 jets	H_T		
3 jets	H_T	NN	
$\geq$ 4 jets	H_T	NN	NN



ttH

@m_H=125.0 GeV
- 4.1 (2.6) x σ_{SM} 95% CL upper limit
- μ=1.7±1.4

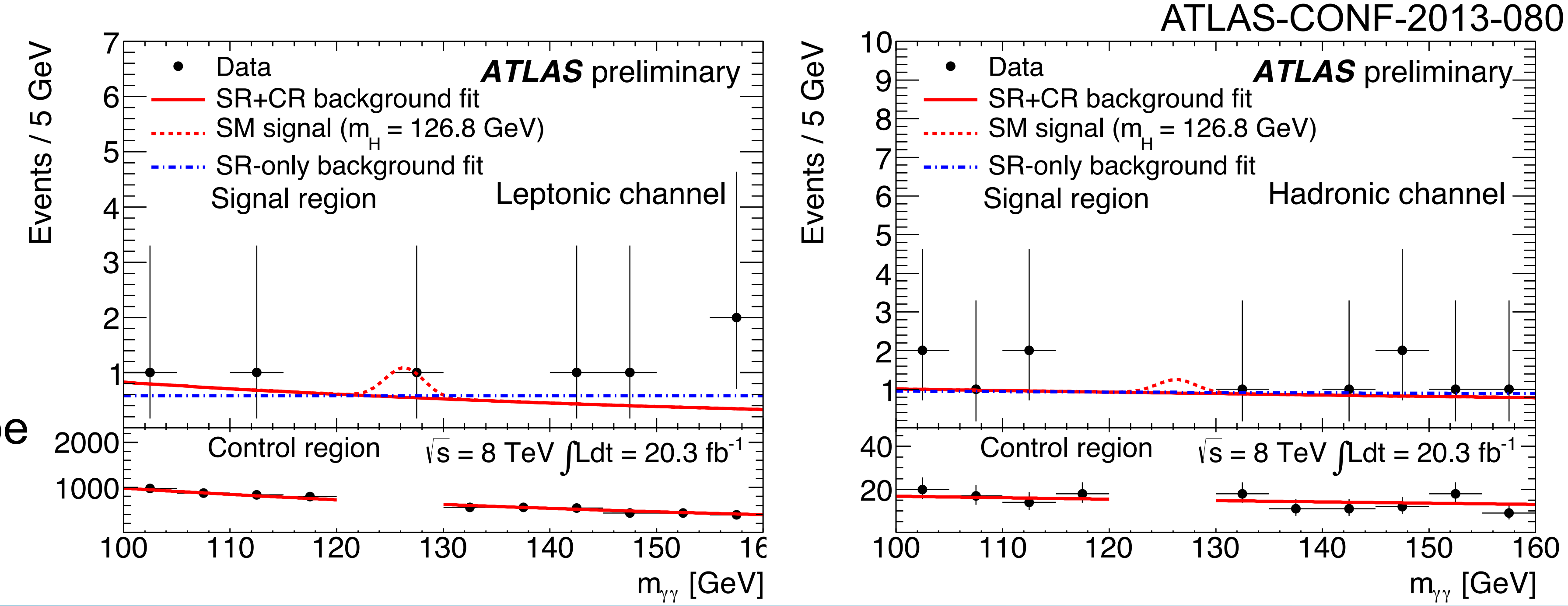


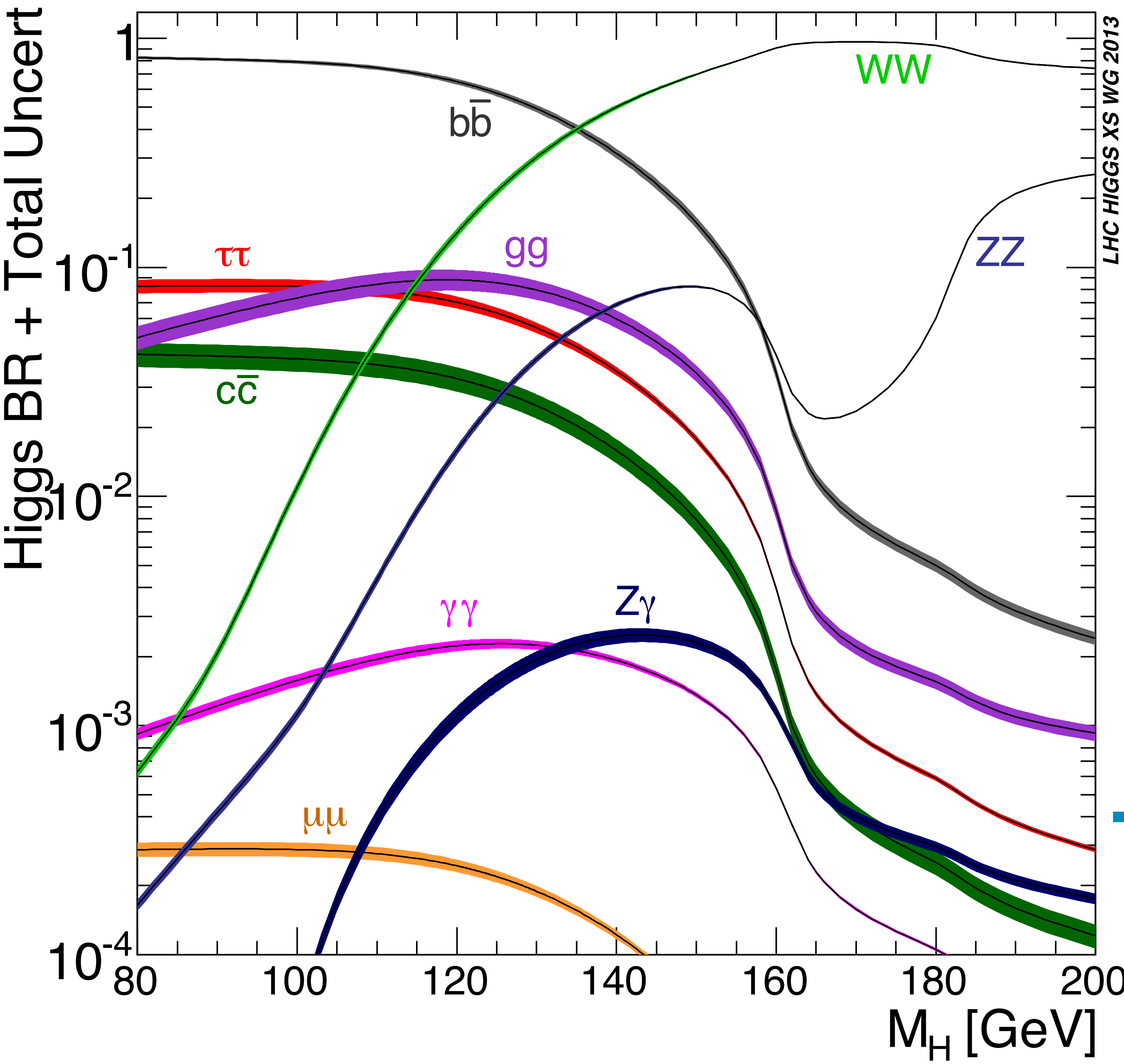


ttH($\rightarrow\gamma\gamma$)

- Leptonic
(≥ 1 lepton, ≥1 b-tag and MET>20)
- Hadronic
(≥ 6 jets, ≥2 b-tags and 0 leptons)
- Analysis similar to H→γγ
  - Include CR to constrain BKG shape
- 95% CL upper limit on $\sigma(ttH)/\sigma(ttH)_{SM}$
  - @m_H=125 GeV: ~4.5 (~6.2)xSM

ATLAS-CONF-2013-080





Anomalous Decays

H→inv

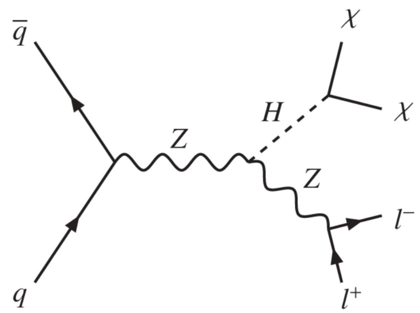
????

+ Anomalous Production

ZH(→inv)

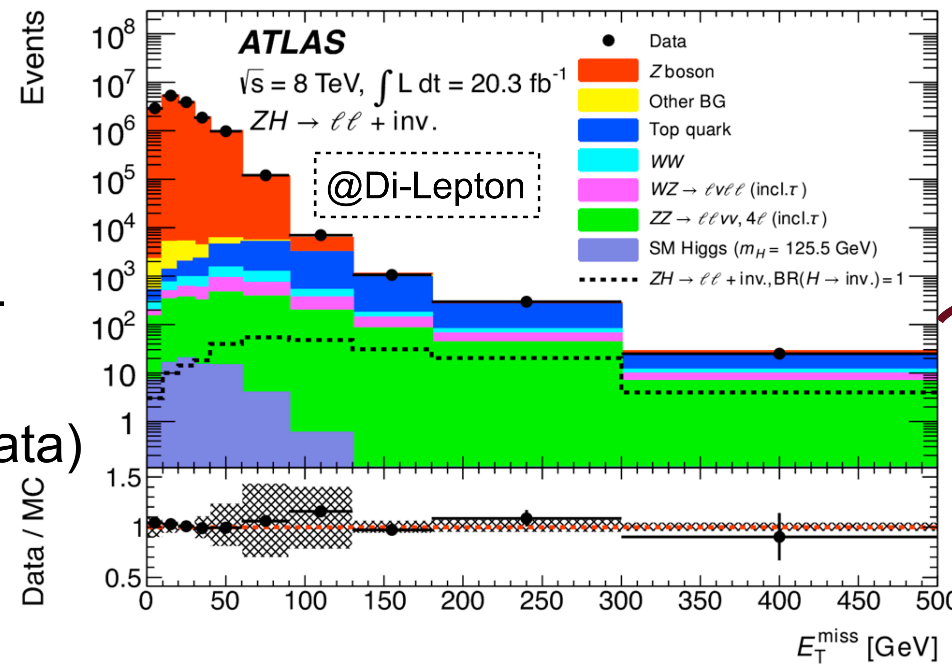
arXiv:1402.324
accepted by PRL

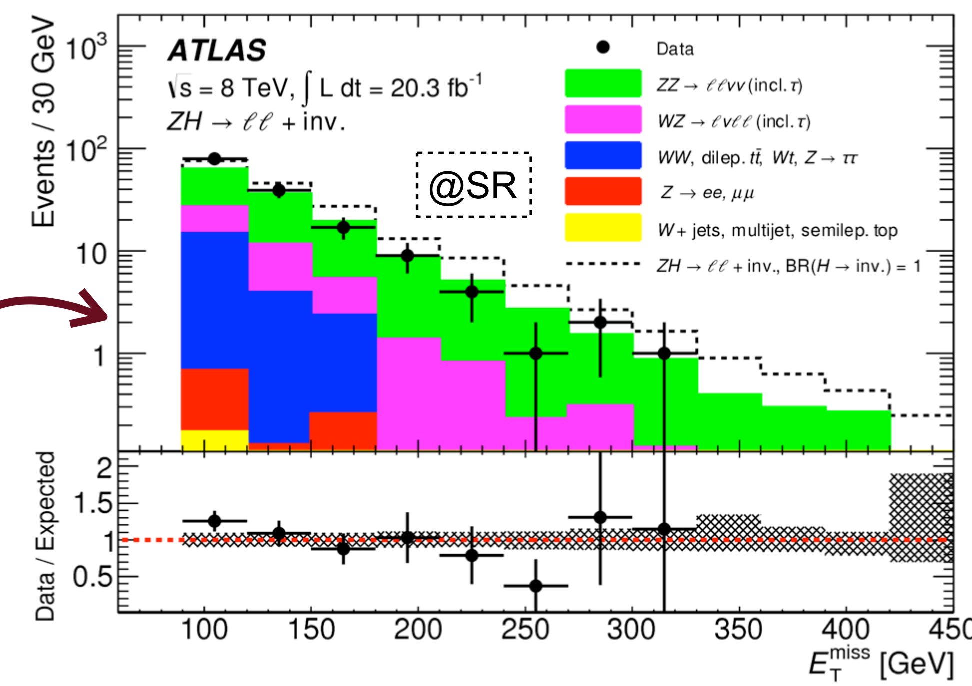
- SM "Invisible" decays suppressed; BR(H→ZZ*→4ν)=$1.2\cdot10^{-3}$
  - Observation means New Physics!

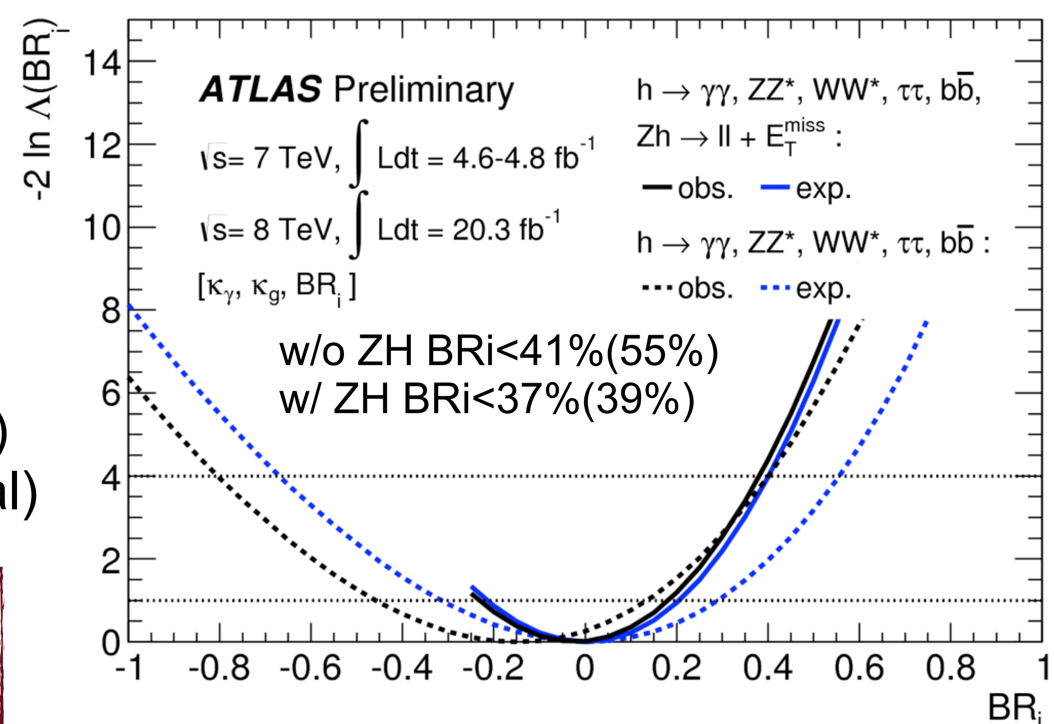


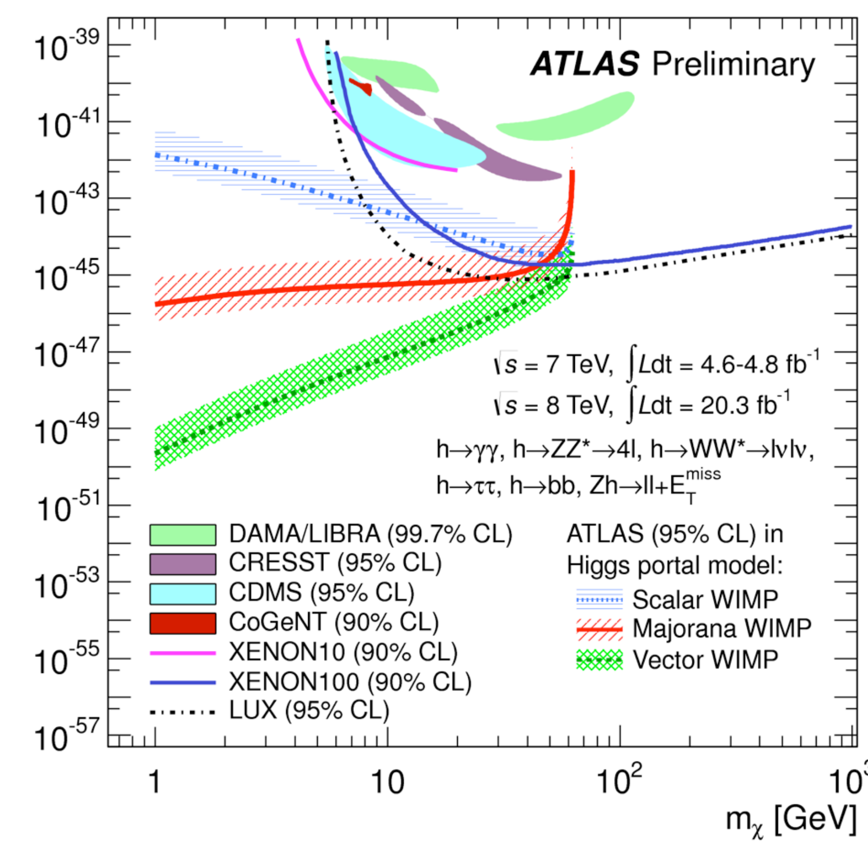
- Signature:Z→ e+e-/μ+μ- + MET
- Backgrounds
  - WW→lνlν, tt,Wt, Z→ττ (eμ-data)
  - Z→ll (double side-bands)
  - W,single-top (lepton quality)
  - ZZ→llνν, WZ→lνll (MC)
- Selection
  - Di-Lepton consistent with Z
  - ETmiss>90 GeV
  - Δφ(ETmiss,pTmiss)<0.2
  - Δφ(pTll,ETmiss)>2.6
  - Δφ(l,l)<1.7
  - |ETmiss-pTll|/pTll<0.2
  - 3rd lepton veto/jet veto
- Direct limits on the BR(H→inv)
- Constrain WIMPs (Higgs-portal)

m_H=125.5 GeV; 95% CL
BR(H→invisible) <75%(<62%)





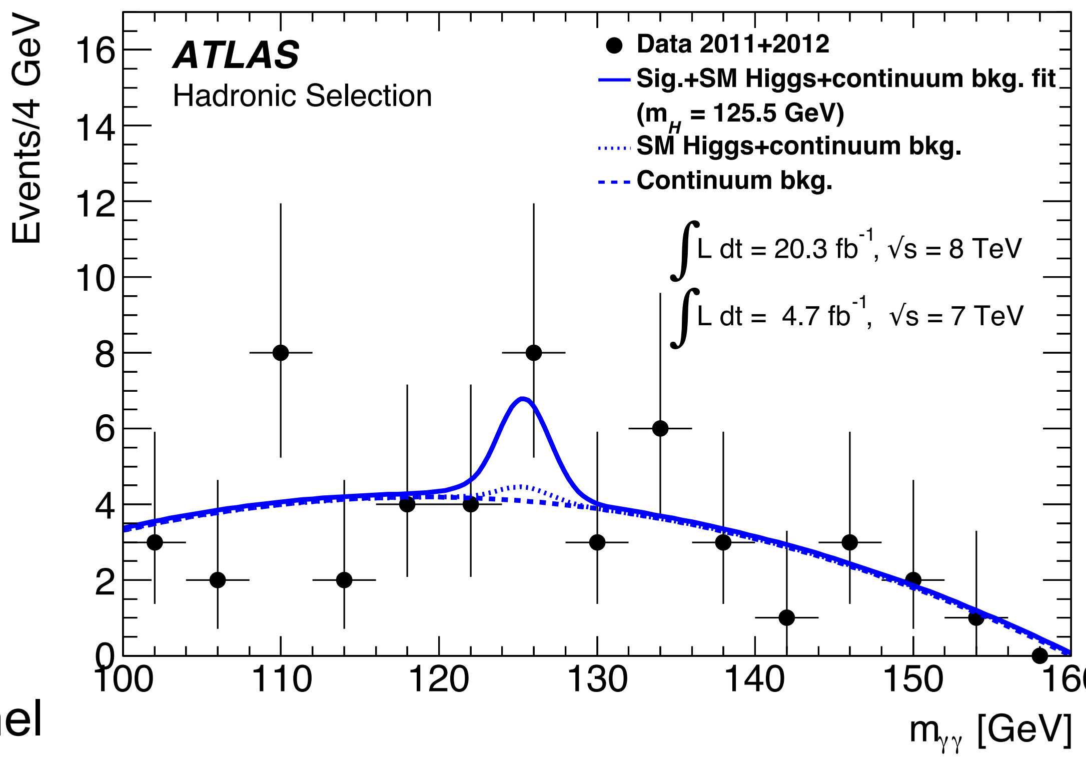




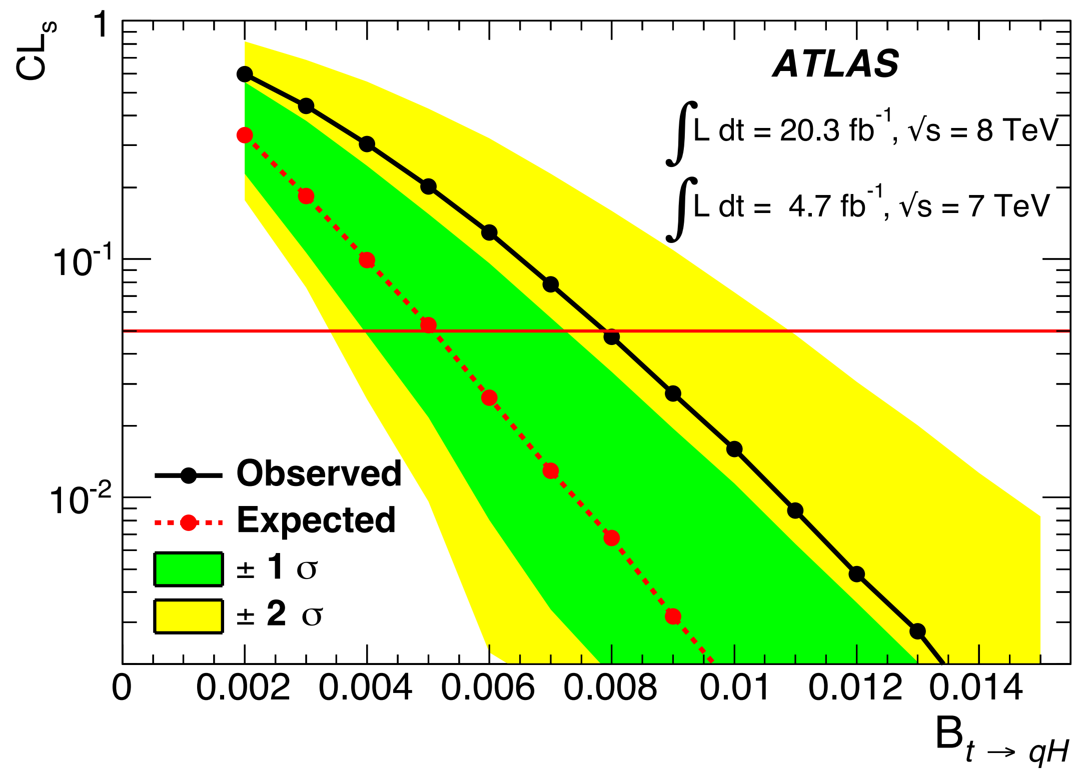
FCNC in t→qH(→γγ)

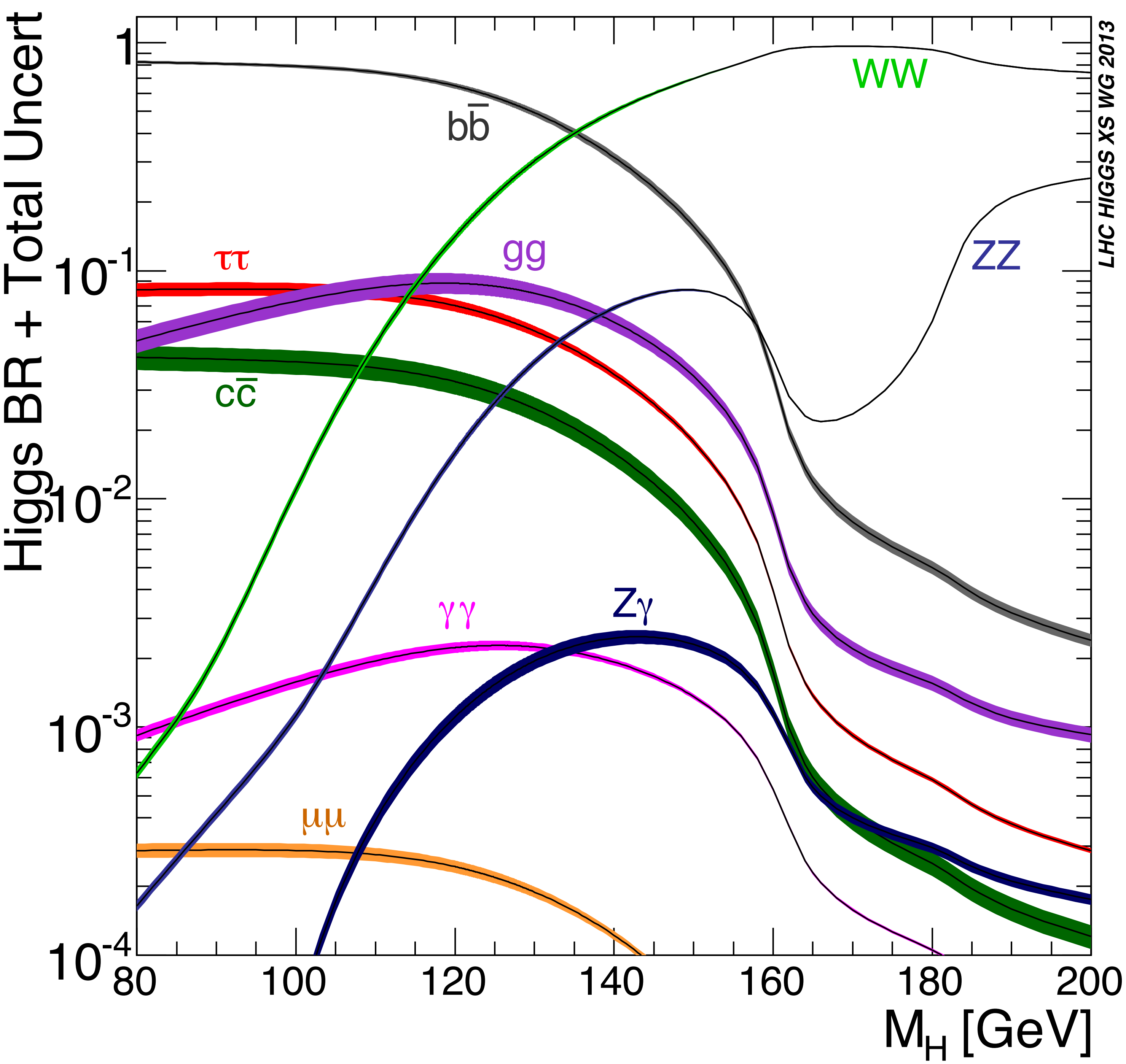
arXiv:1403.6293
accepted by JHEP

- Search in ttbar events for t→qH, where q=(c,u)
- Two channels:
  - Leptonic
    1 lepton, ≥2 jets, ≥1 b-tags, MET
  - Hadronic
    0 lepton, ≥4 jets, ≥1 b-tags
  - Mass cuts for top candidates
- Analysis procedure similar to H→γγ
  - Leptonic :BKG shape from CR
  - Hadronic:BKG shape from MC
  - Background from SM Higgs production in included
- 50 (1) events selected in the Hadronic (Leptonic) channel
- 95% CL upper limit on t→cH BR
@m_H=125.5 GeV: 0.79% (0.51%)



Process	SM	QS	2HDM-III	FC-2HDM	MSSM
$t \to u\gamma$	$3.7 \cdot 10^{-16}$	$7.5 \cdot 10^{-9}$	—	—	$2 \cdot 10^{-6}$
$t \to uZ$	$8 \cdot 10^{-17}$	$1.1 \cdot 10^{-4}$	—	—	$2 \cdot 10^{-6}$
$t \to uH$	$2 \cdot 10^{-17}$	$4.1 \cdot 10^{-5}$	$5.5 \cdot 10^{-6}$	—	10^{-5}
$t \to c\gamma$	$4.6 \cdot 10^{-14}$	$7.5 \cdot 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-9}$	$2 \cdot 10^{-6}$
$t \to cZ$	$1 \cdot 10^{-14}$	$1.1 \cdot 10^{-4}$	$\sim 10^{-7}$	$\sim 10^{-10}$	$2 \cdot 10^{-6}$
$t \to cH$	$3 \cdot 10^{-15}$	$4.1 \cdot 10^{-5}$	$1.5 \cdot 10^{-3}$	$\sim 10^{-5}$	10^{-5}





Extended Sectors

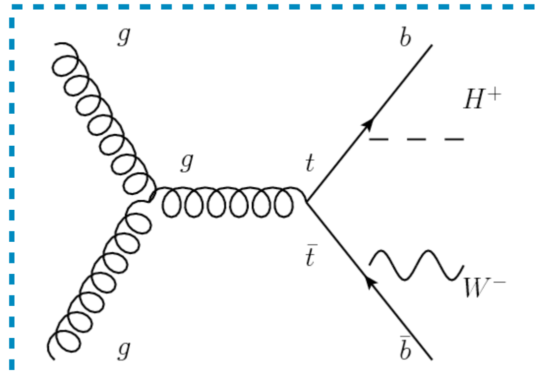
H±→τν

ATLAS-CONF-2013-090

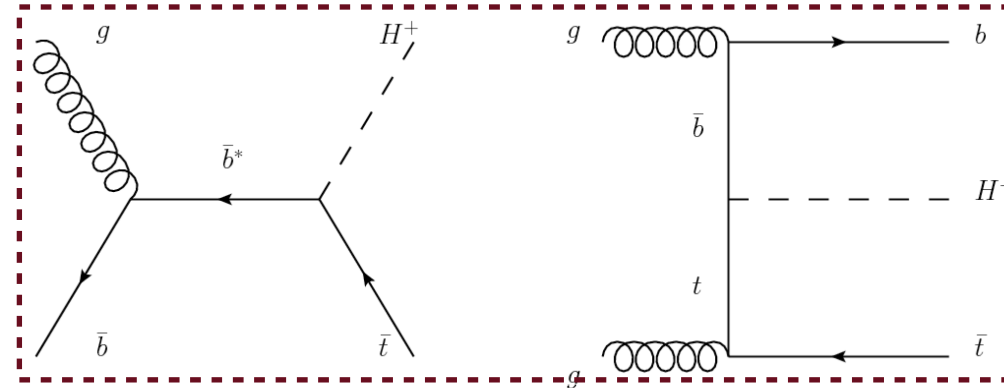
- Search for H±→τν
- Production depends on m_{H+}
  - Observation means New Physics!
- Backgrounds: ttbar, single-top, W/Z+jets,...
- Discriminant variable:

$$m_T = \sqrt{2 p_T^{\tau} E_T^{\text{miss}} (1 - \cos \Delta\phi_{\tau,\text{miss}})}$$

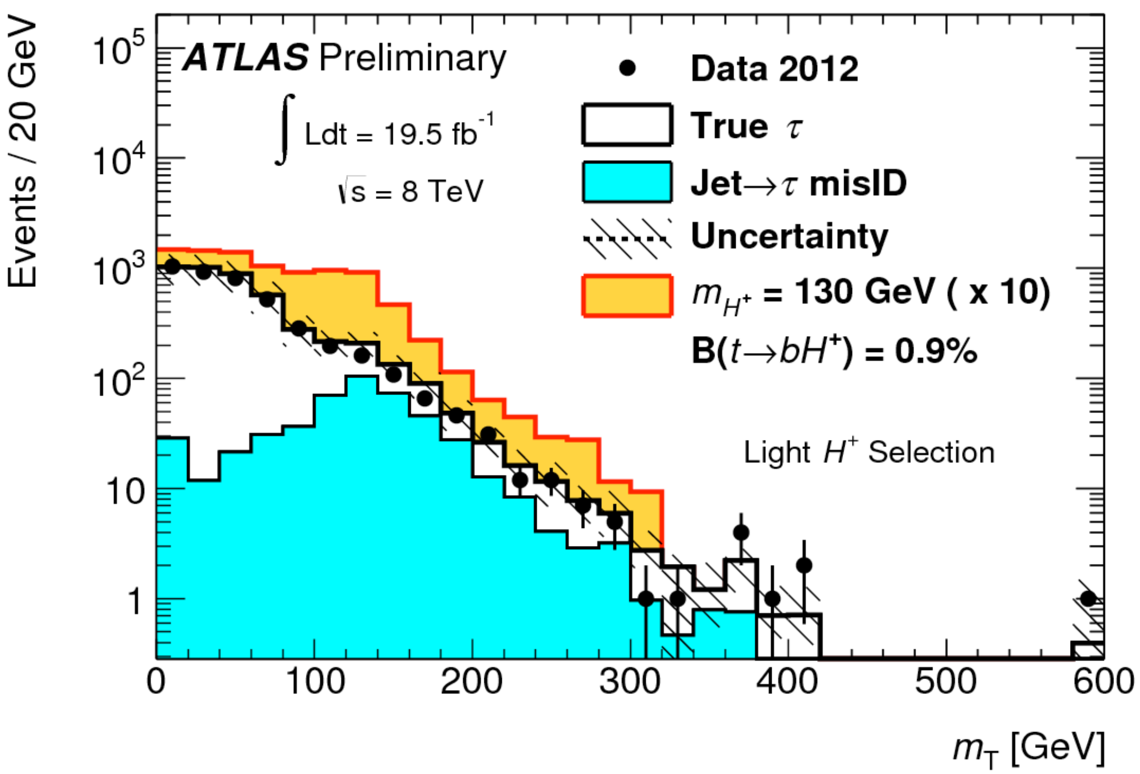
- Backgrounds:
  - Real hadronic τ (MC corrected)
  - Fake hadronic τ (data)

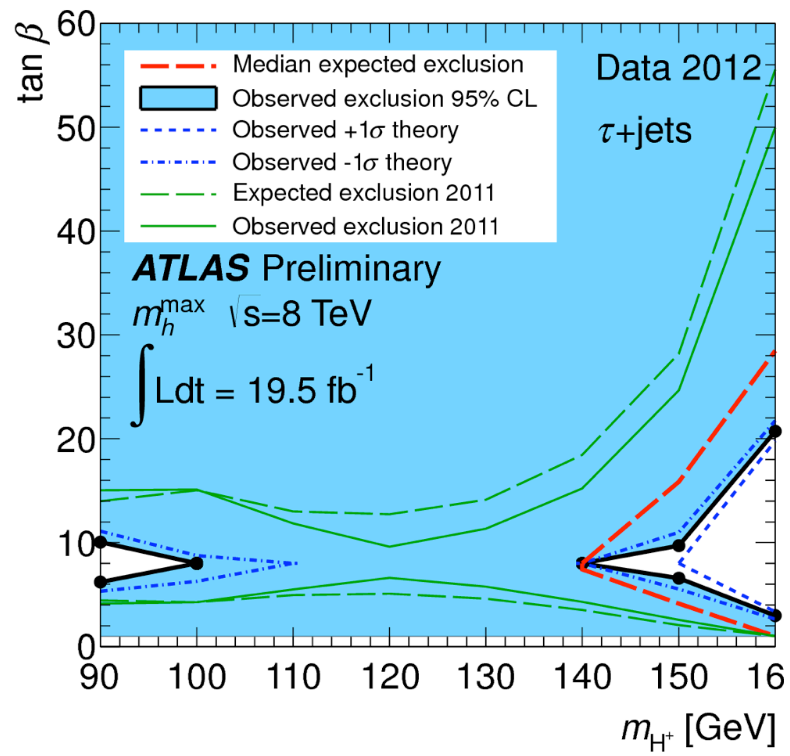


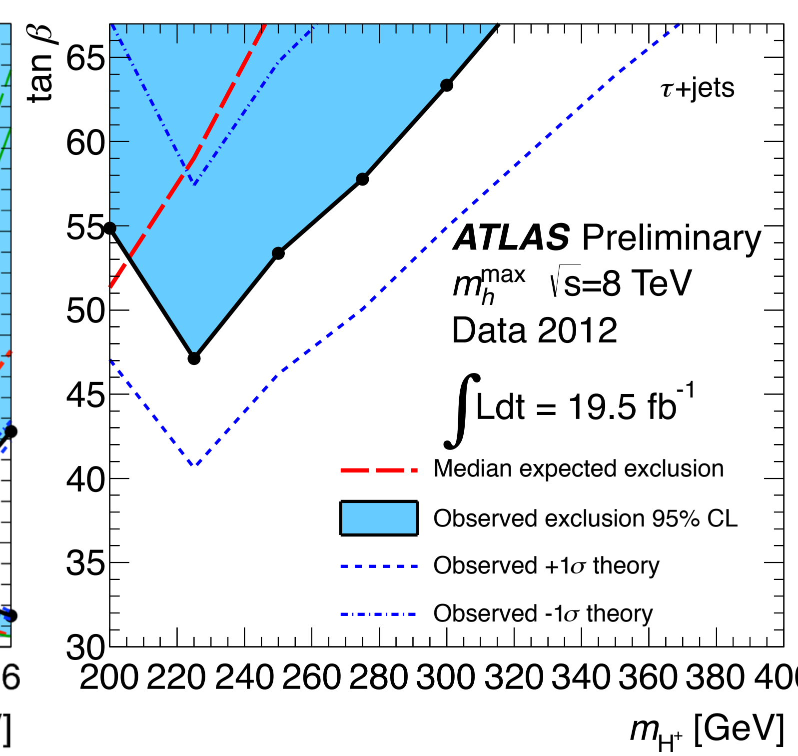
Light H± ($m_{H\pm}<m_t$)



Heavy H± ($m_{H\pm}>m_t$)







Assuming BR(H±→τν)=1

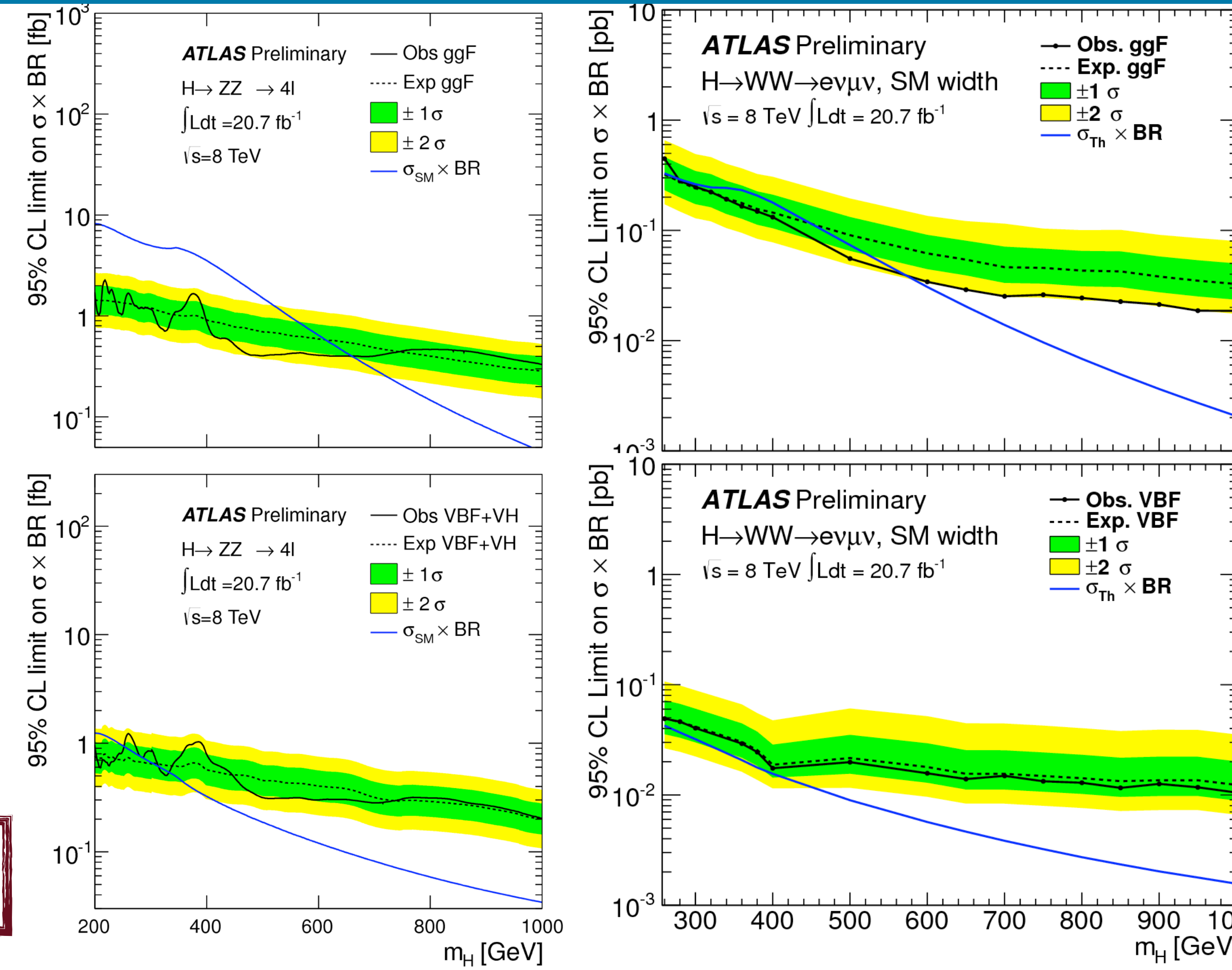
- BR(t→H±b) <0.24-2.1% at 95%CL for 90 GeV< $m_{H\pm}$ <160 GeV
- σ(pp→t(b)H±) <0.017 - 0.90pb 95%CL for 180 GeV< $m_{H\pm}$ <600 GeV

More Searches

High Mass
H→ZZ→4l/H→WW→lνlν

ATLAS-CONF-2013-013
ATLAS-CONF-2013-067

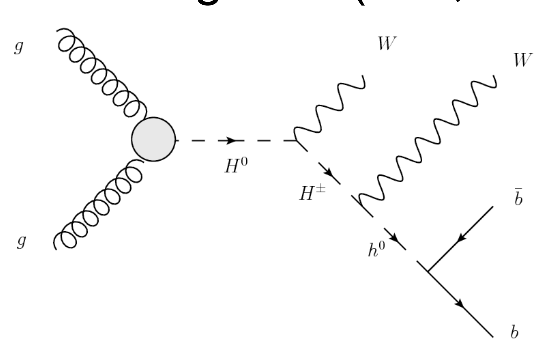
- Complex Pole Scheme used
  - Interference with background considered
- H→ZZ→4l identical to the standard analysis
- H→WW→eνμν considered
  - Also Narrow Width approximation studied
  - Backgrounds: WW, tt, Wt, Z→ττ, W+jets
  - Light Higgs treated as background
  - Categories in jet multiplicities

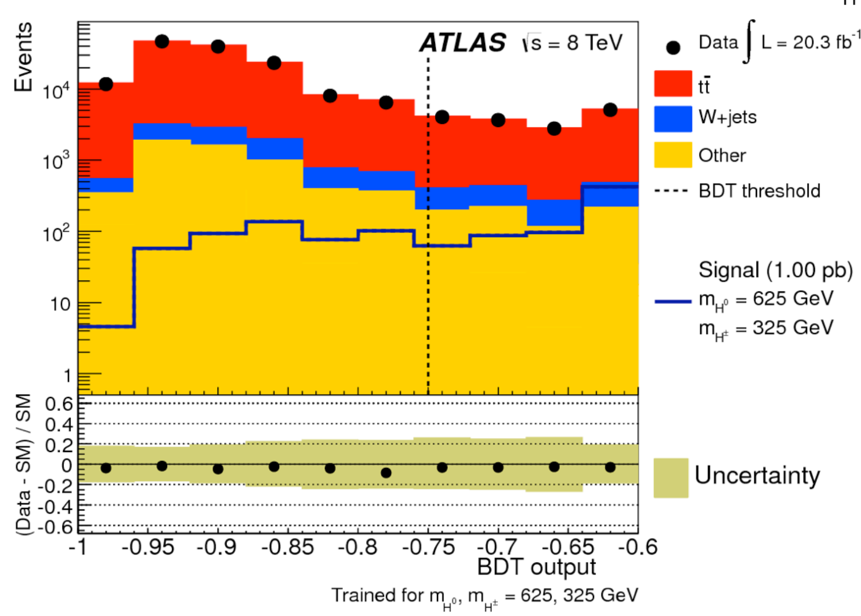


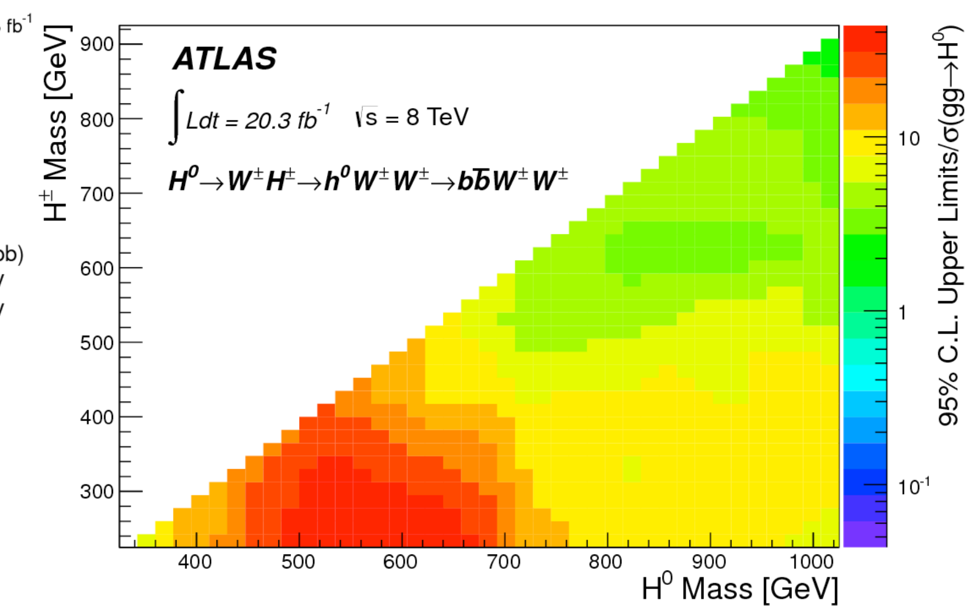
$H^0 \to W^\pm H^\mp \to W^\pm W^\mp h^0 \to W^\pm W^\mp bb$

Phys. Rev. D 89, 032002 (2014)

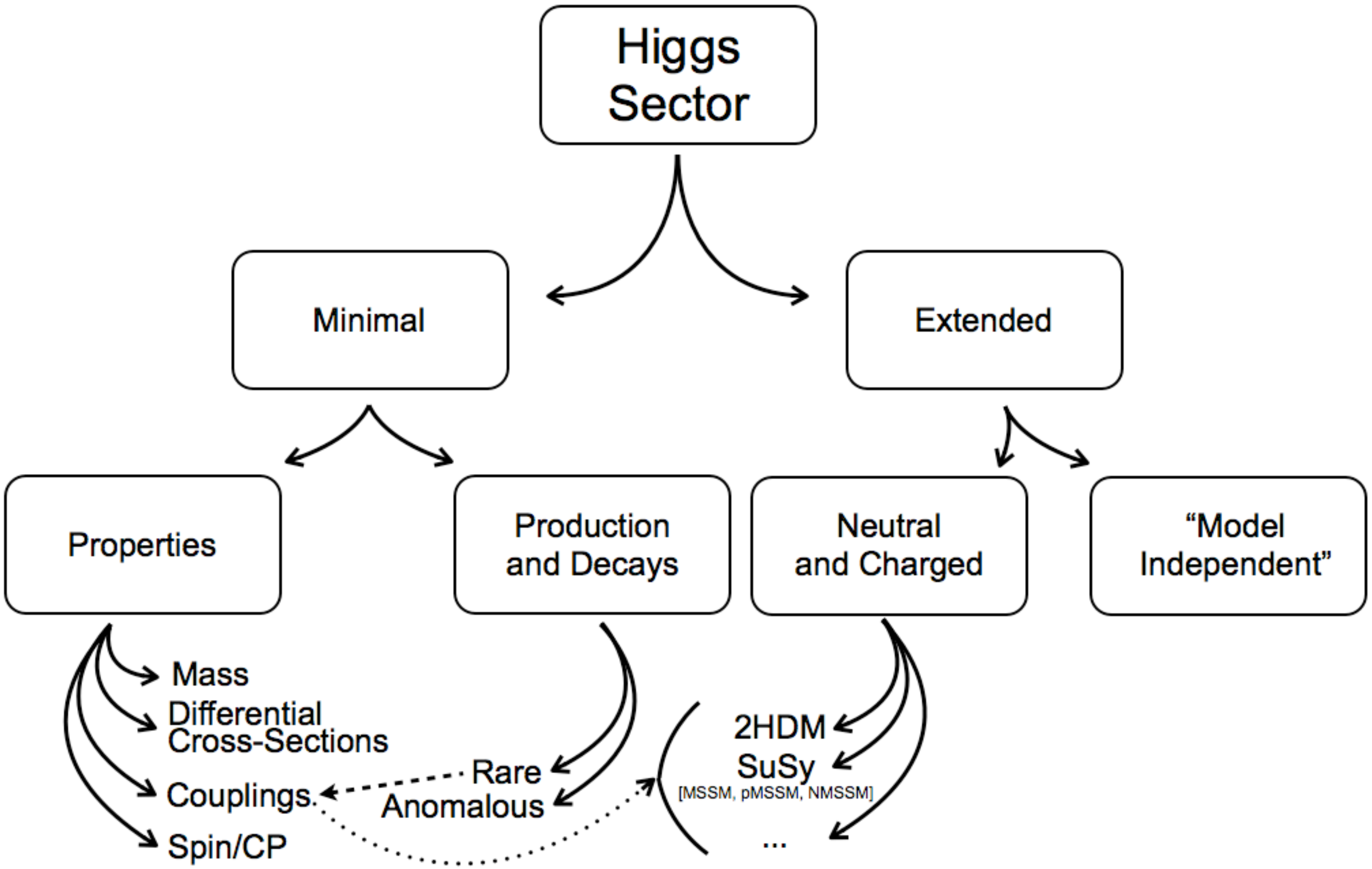
- Search for multi-Higgs boson cascade
- Simplified model approach
- Selection: 1 lepton +MET+ ≥4jets
  - BDT on grid of (m_{H0}, $m_{H\pm}$)

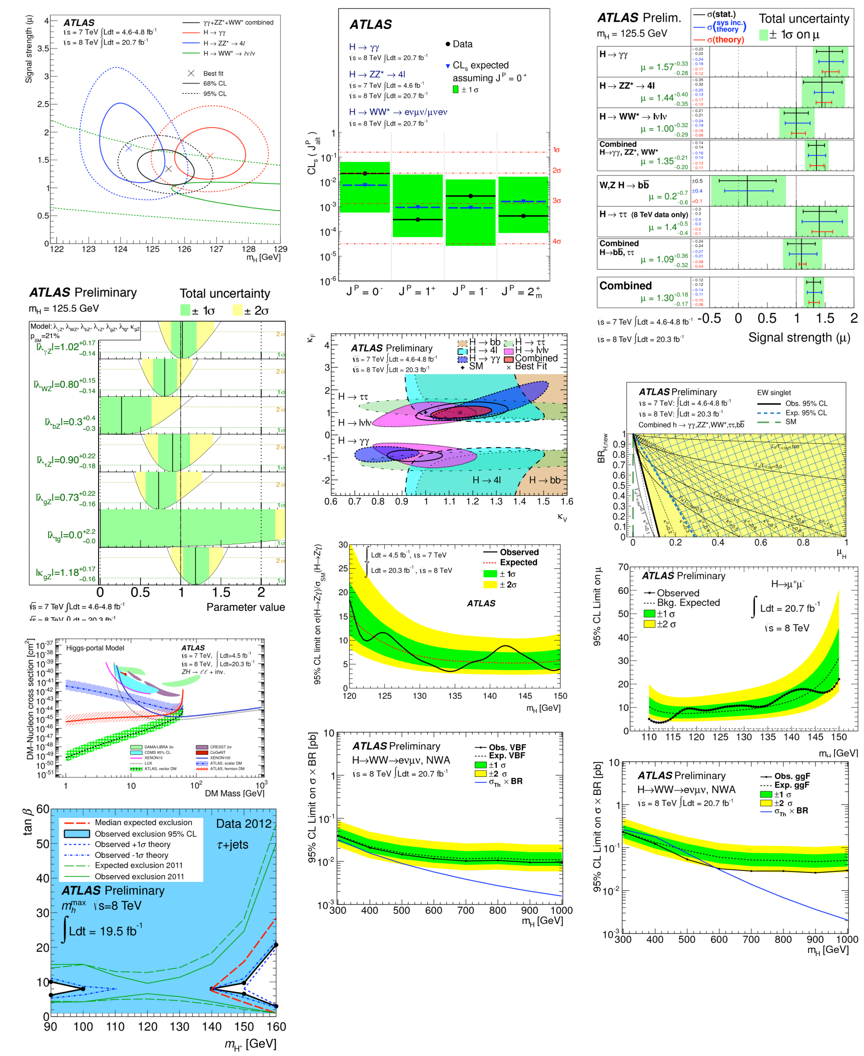






Summary



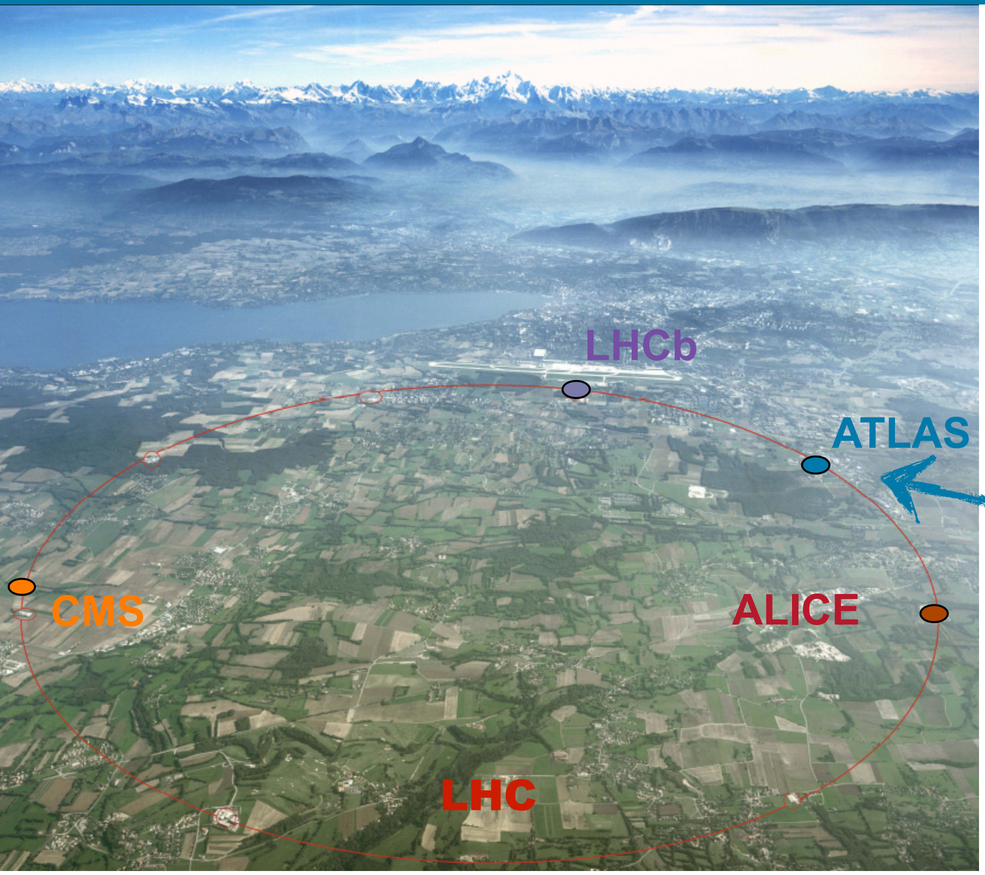


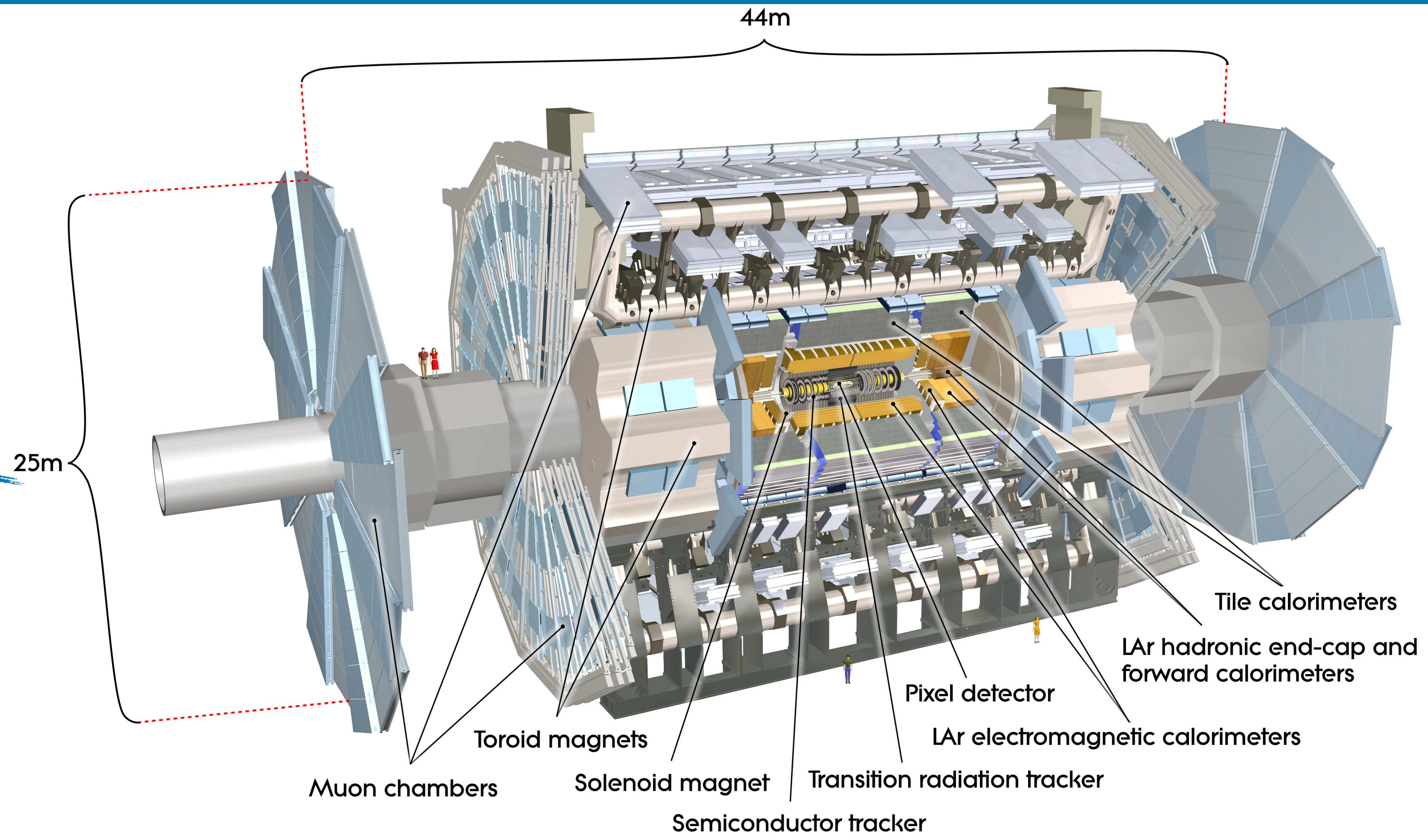
A wealth of new results has appeared over the last year pushing further our understanding of the Higgs sector

Many questions to answer and stones to turn still!
We're already preparing for LHC Run II to take advantage of higher energy and five-fold increase in integrated luminosity!
[and even further...]

Additional Slides

A Toroidal LHC ApparatuS



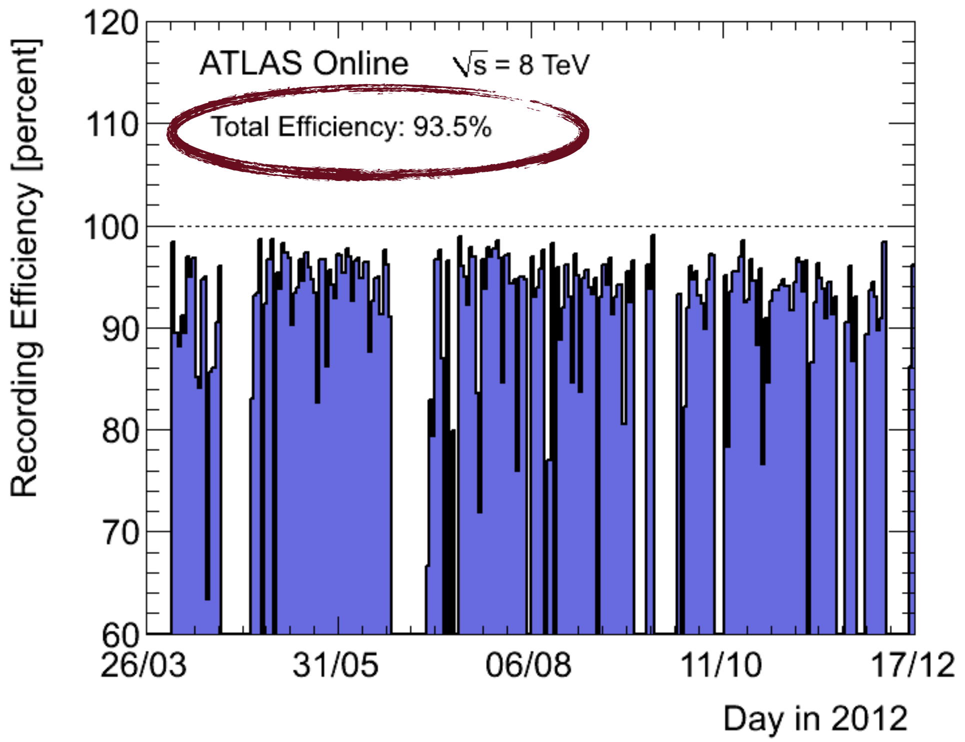


→ Multi-purpose detector designed for the harsh LHC environment

→ High data-taking efficiency and very good data-quality

ATLAS p-p run: April-December 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.4	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5
All good for physics: 95.8%										

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 December 6th (in %) – corresponding to 21.6 fb^{-1} of recorded data.

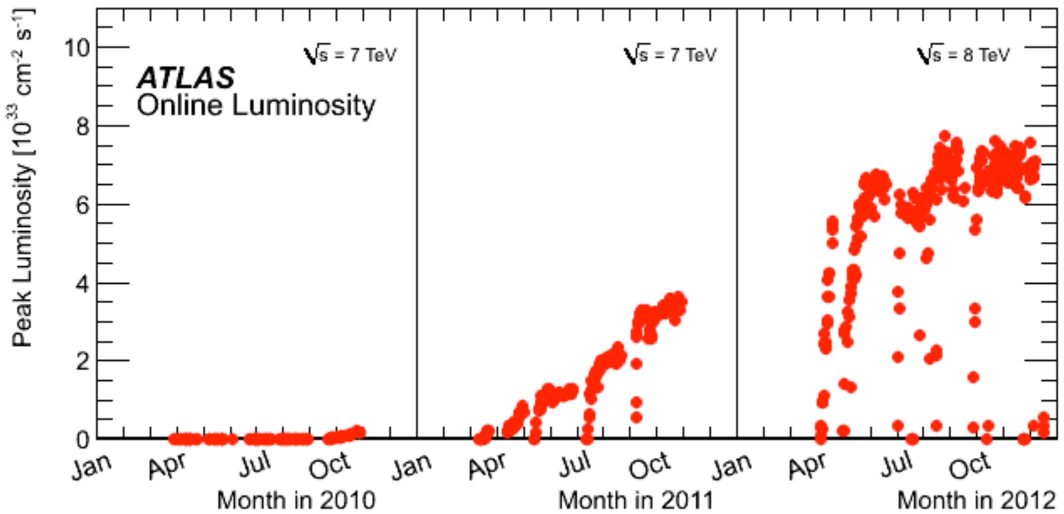


The LHC Run I dataset

Excellent LHC performance during Run I :
4.8 fb^{-1} at 7 TeV and 20.7 fb^{-1} at 8 TeV

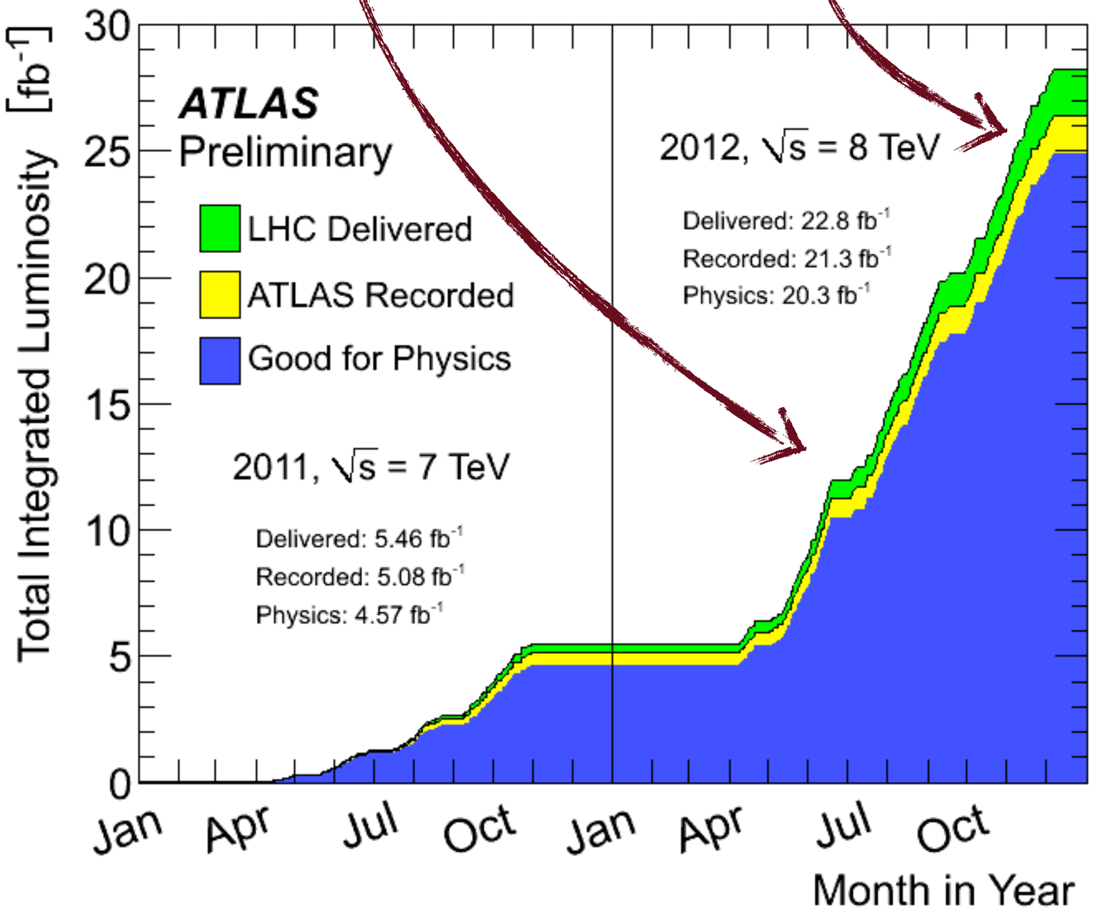
Pile-up exceeding detector design specifications
→ Maintain performance through improved algorithms
→ Proper modeling of experimental conditions essential

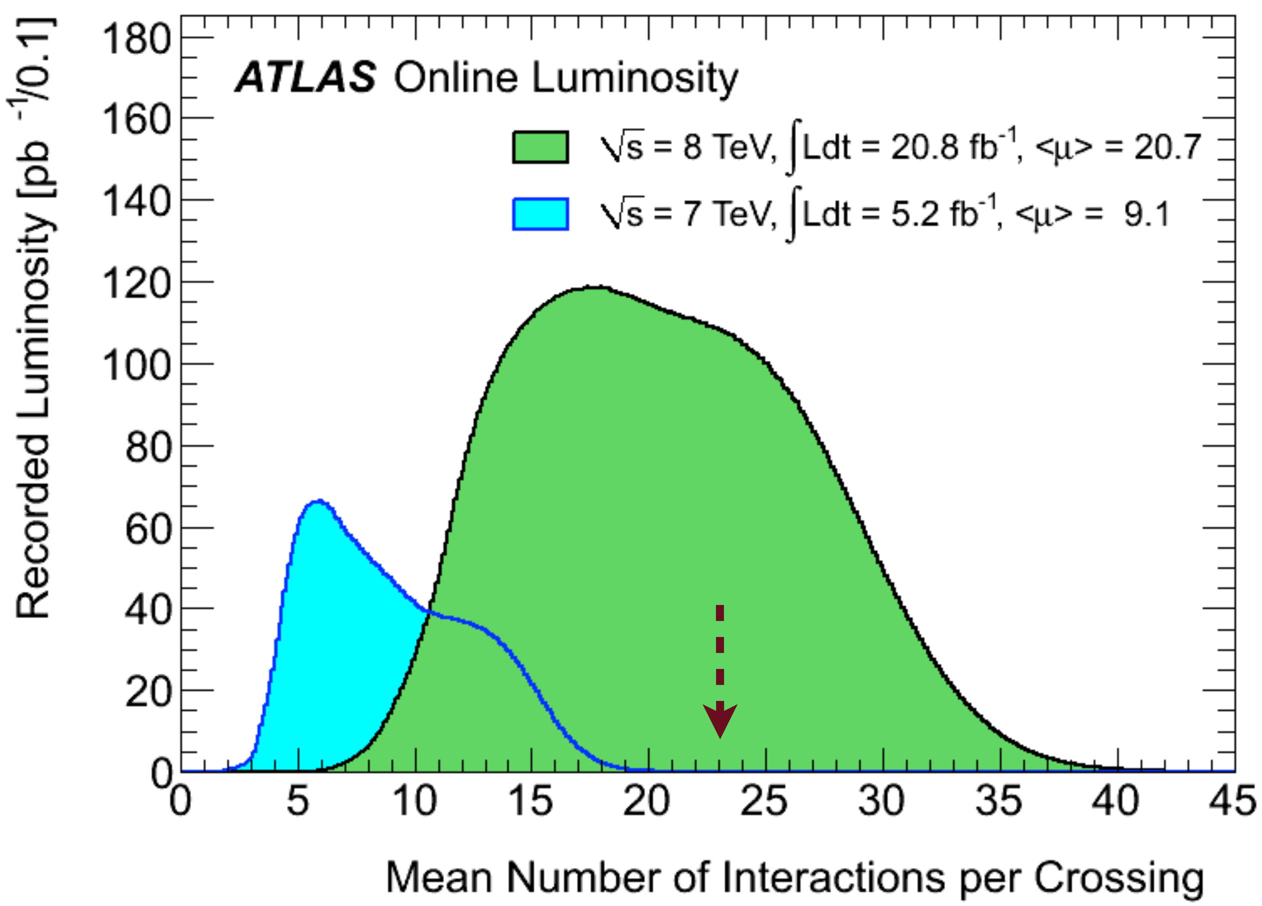
Peak Luminosity [cm^{-2}s^{-1}]
2.07×10^{32} 3.65×10^{33} 7.73×10^{33}cm^{-2}s^{-1}



"Observation" dataset

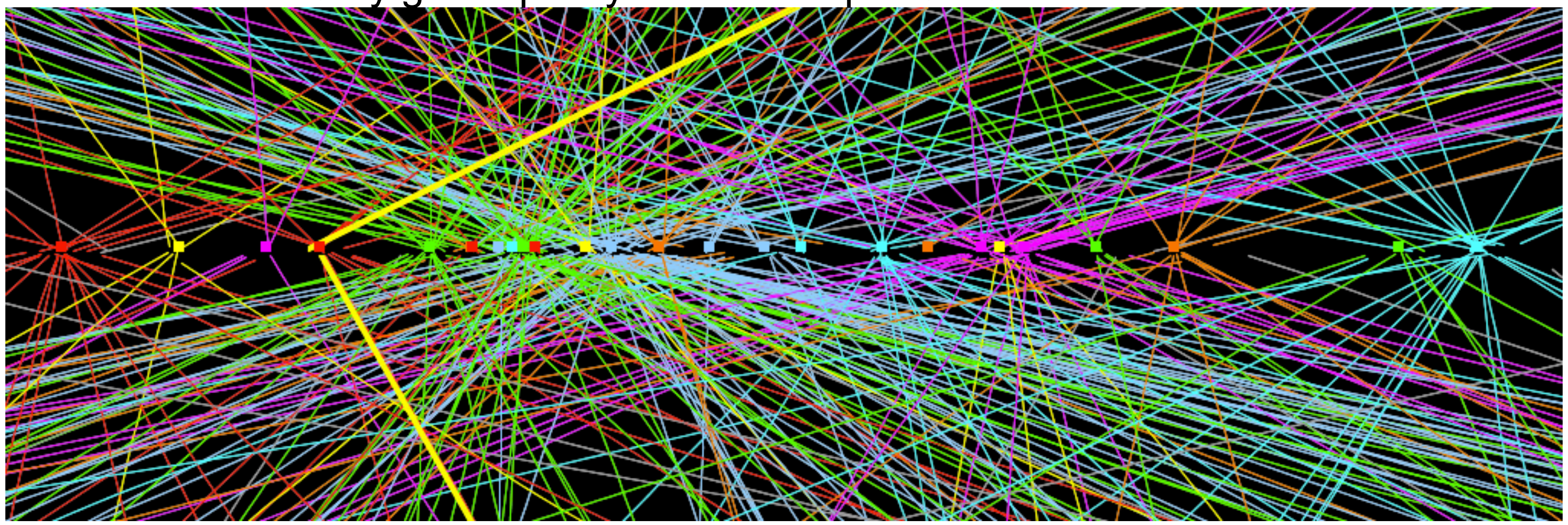
Final LHC Run 1 dataset

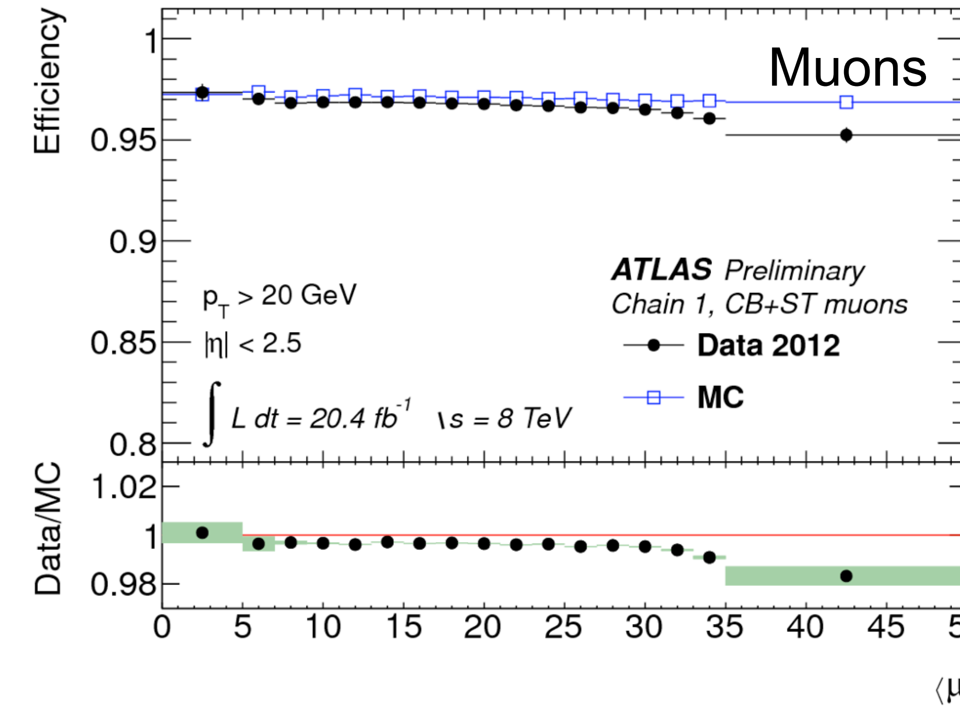


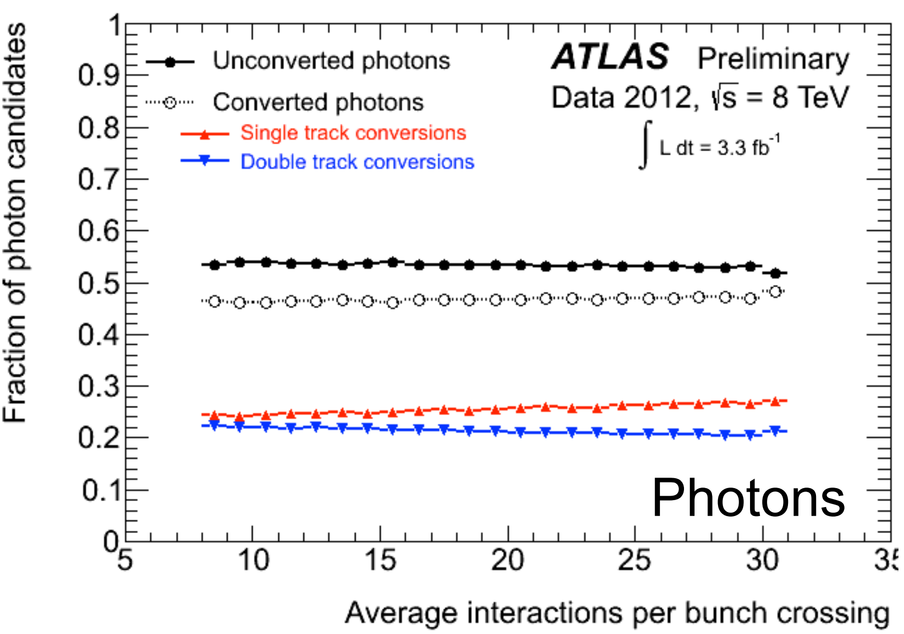


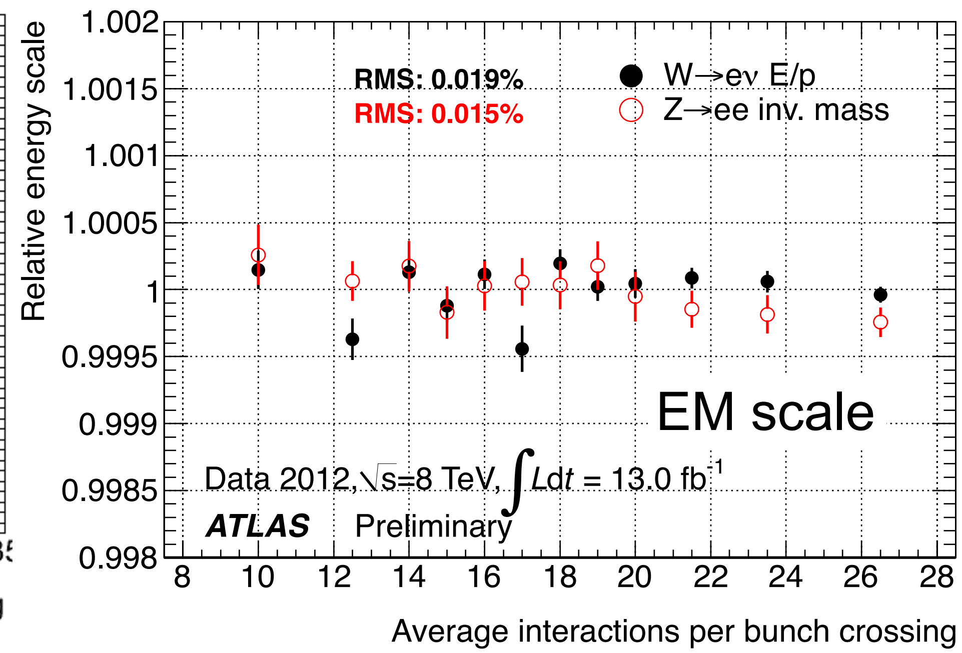
ATLAS Performance: Photons, Electrons and Muons

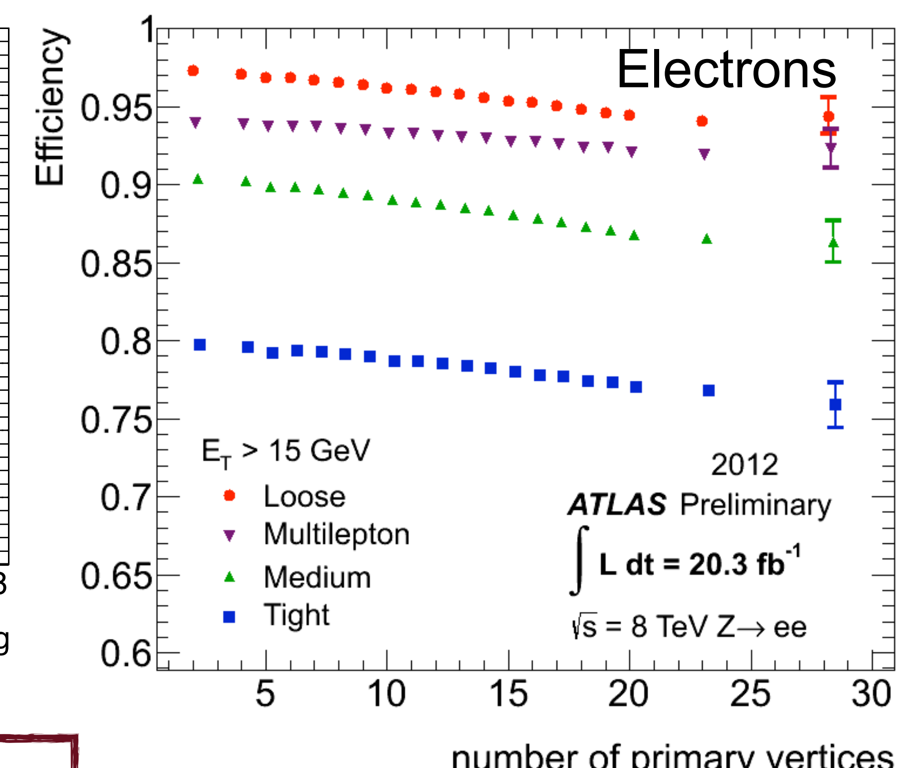
Z→μμ candidate with 25 reconstructed vertices from the 2012 run.
Only good quality tracks with pT>0.4GeV are shown





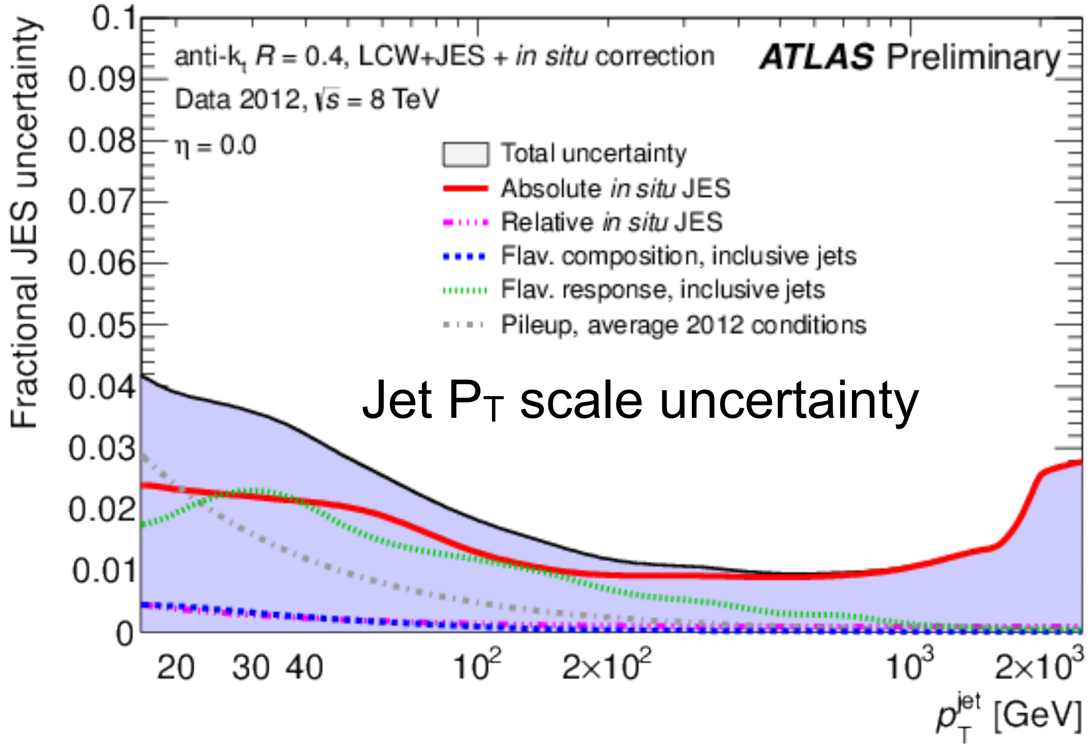




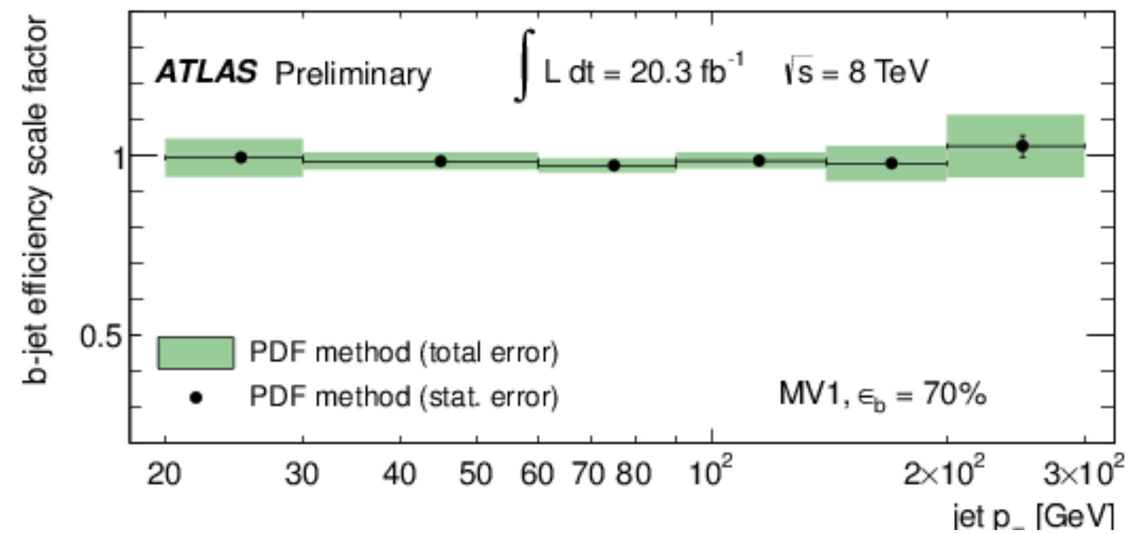


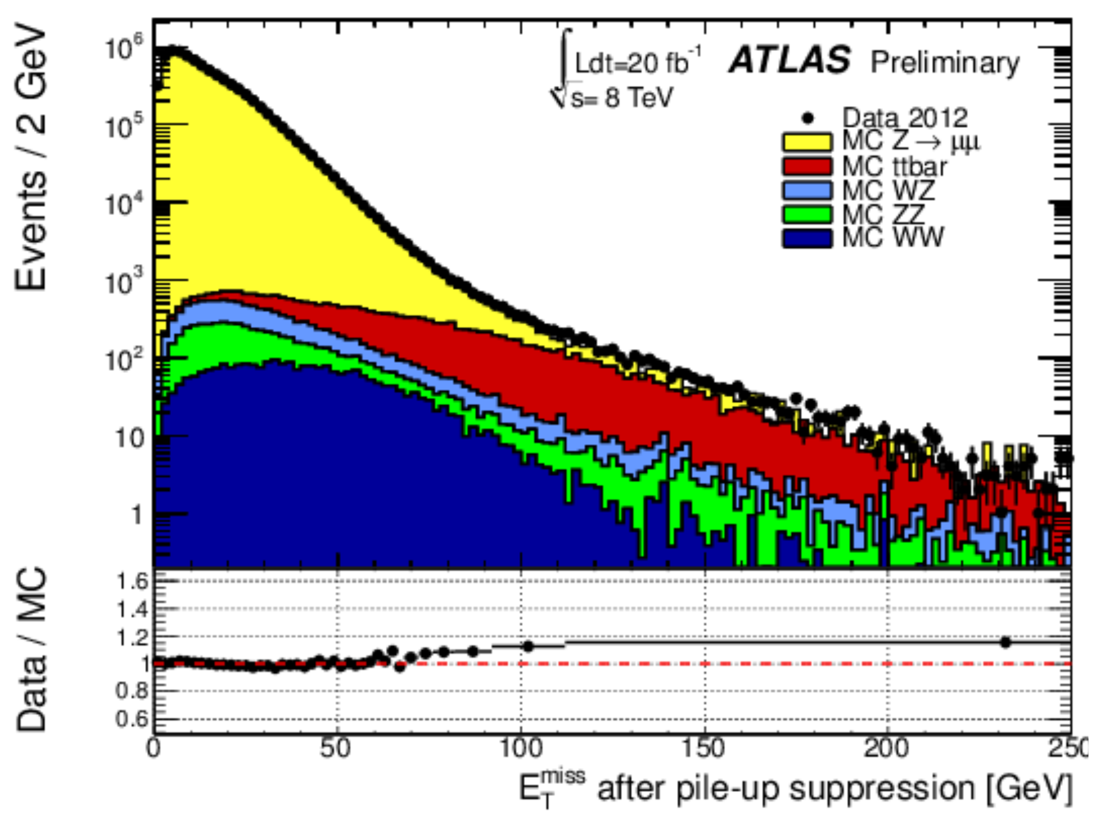
- μ,e and γ reconstruction stable with pile-up
- Excellent stability of EM response!
  - Energy scale@m_Z known to ~0.3%
  - Uniformity ~1% (2.5% for 1.37< |η|<1.8)

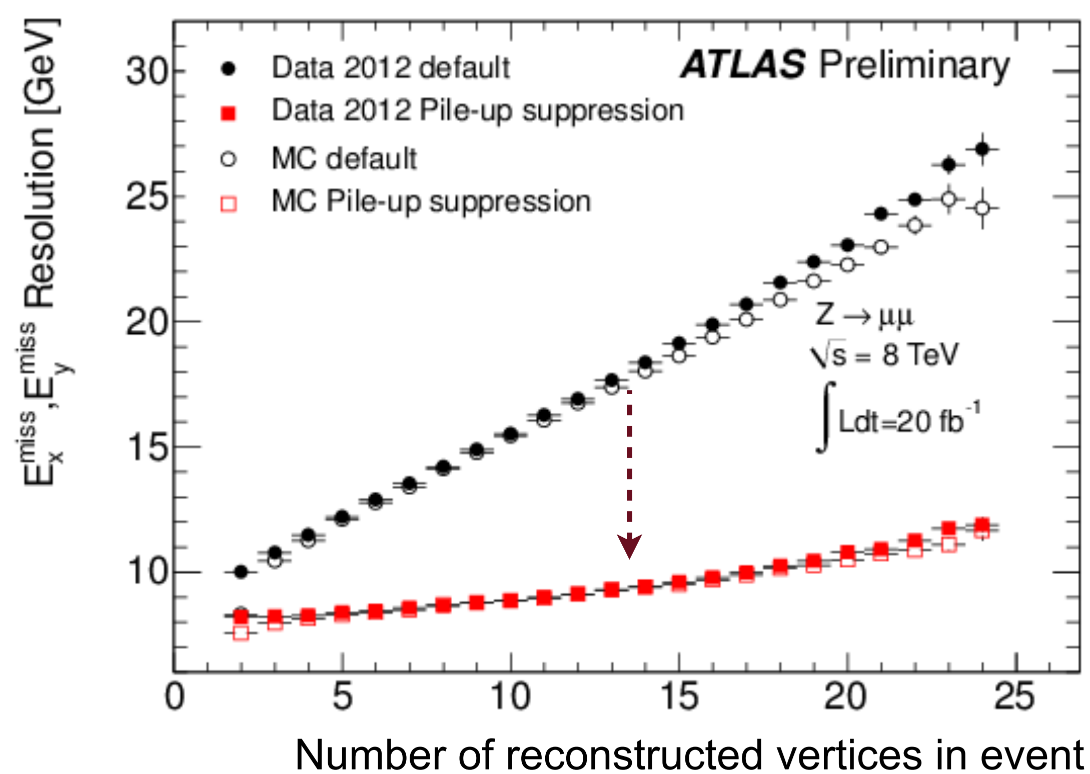
ATLAS Performance: Jets, b-tagging and Missing E_T



JES/b-tagging uncertainties at few % level
MET good performance under pile-up.
Well modeled by simulation







Excellent understanding of the detector performance!

Summary and prospects for the (near) future

Patras 2011

⇒ LHC delivered 45/pb in 2010 → 35-43/pb used depending on final state

⇒ Mostly inclusive searches/cut based/Data-driven background

⇒ H→γγ sensitivity comparable to Tevatron 2010 findings

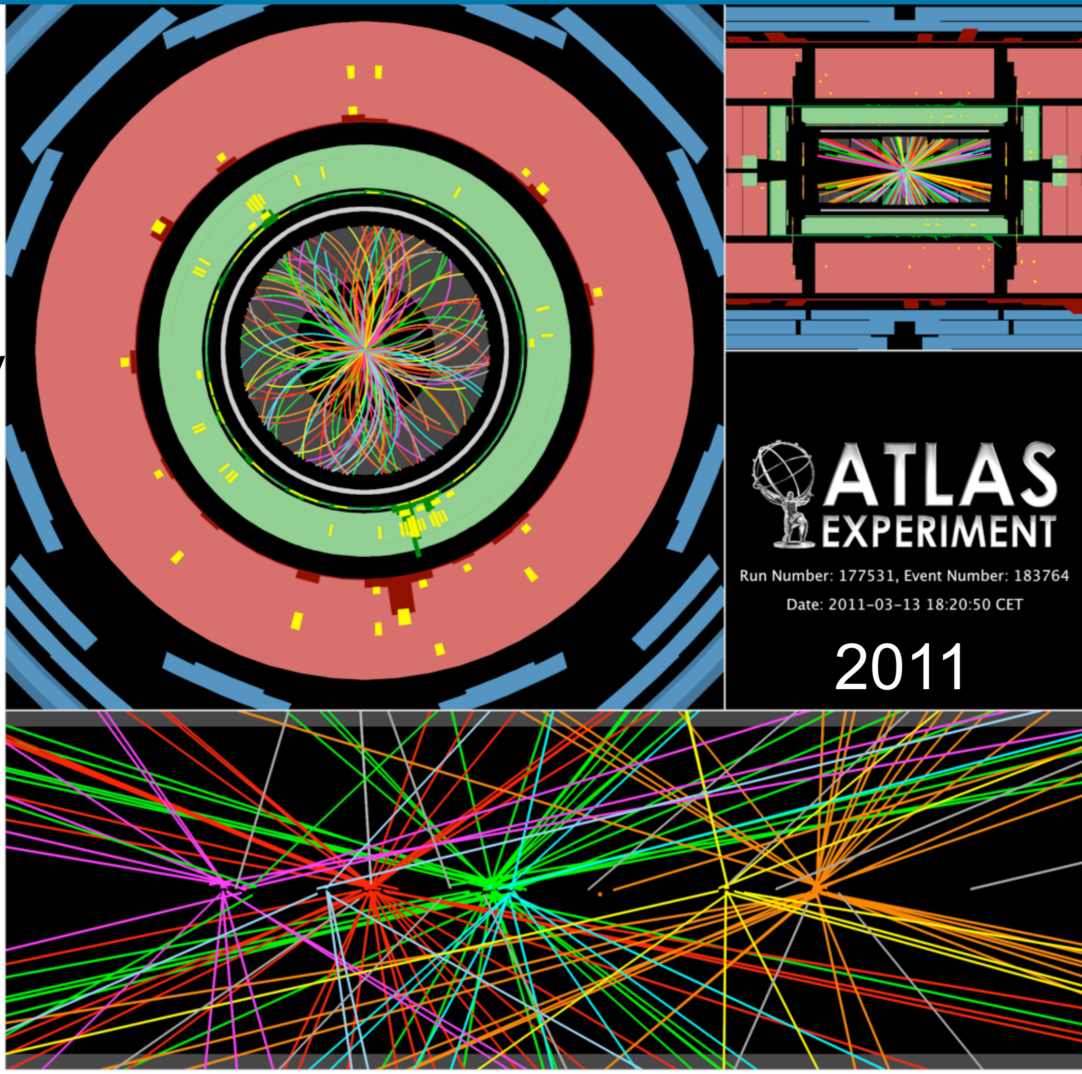
⇒ H→WW→lνlν limit near Standard Model (2.4xσ_{SM} expected @M_H=170GeV)

⇒ H→ZZ→4l no candidates → limit to improve as $1/\mathcal{L}_{int}$

⇒ H→ZZ→llνν/llqq world's best limits between 200 - 400 GeV

⇒ H→WW→lνqq most sensitive single channel for M_H>400GeV

⇒ h/H/A→ττ in MSSM supersedes published Tevatron 2010 results



LHC already started operations for 2011

→ to run through to 2012 @ 7TeV

→ 25/pb already recorded (in a week!)

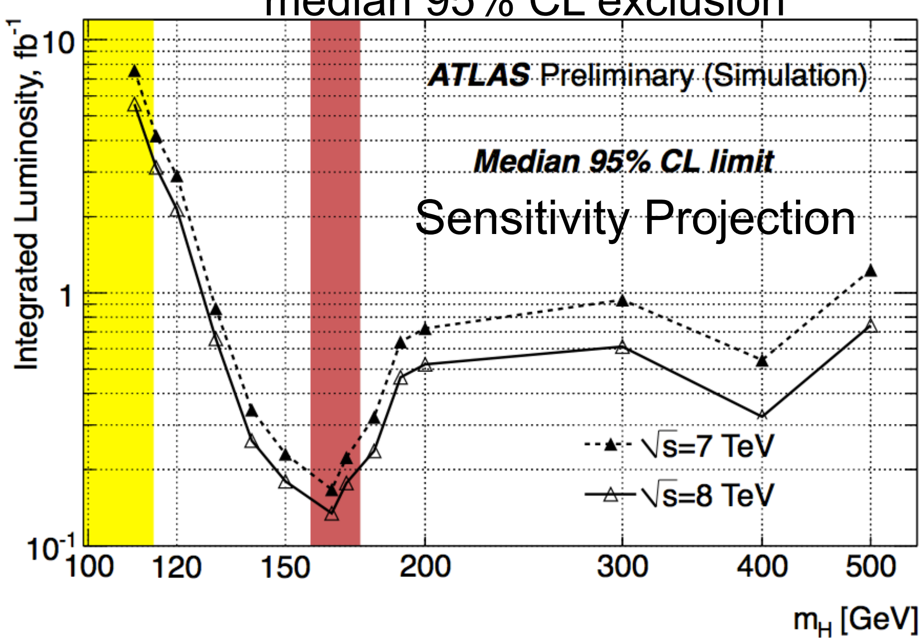
Plan is to run to the end of 2012

→ then shutdown (~18 months)

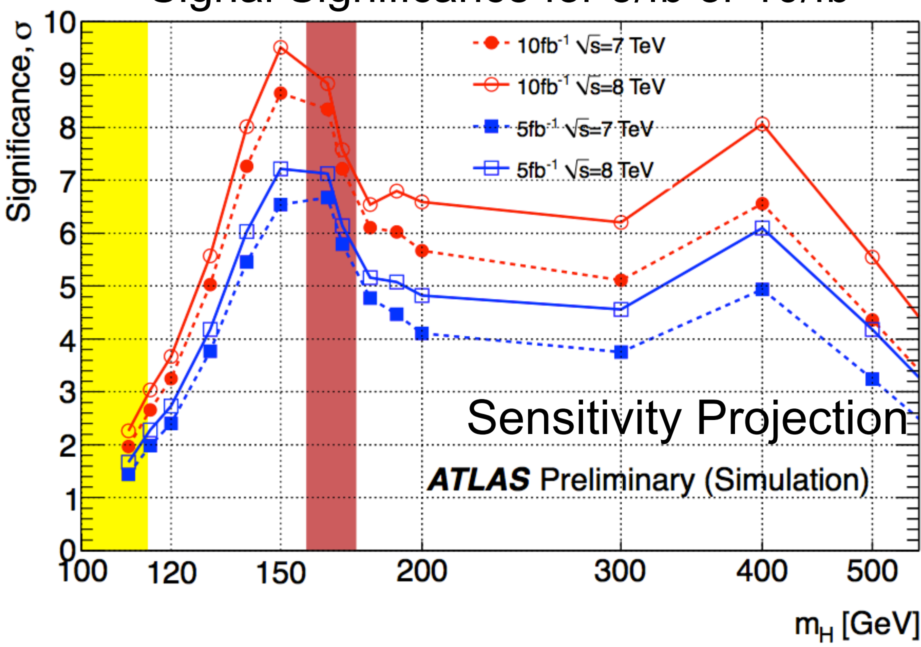
Few fb^{-1}/experiment expected
→ up to 0.5-1 fb^{-1} this summer

Sensitive to SM Higgs boson cross sections this summer!

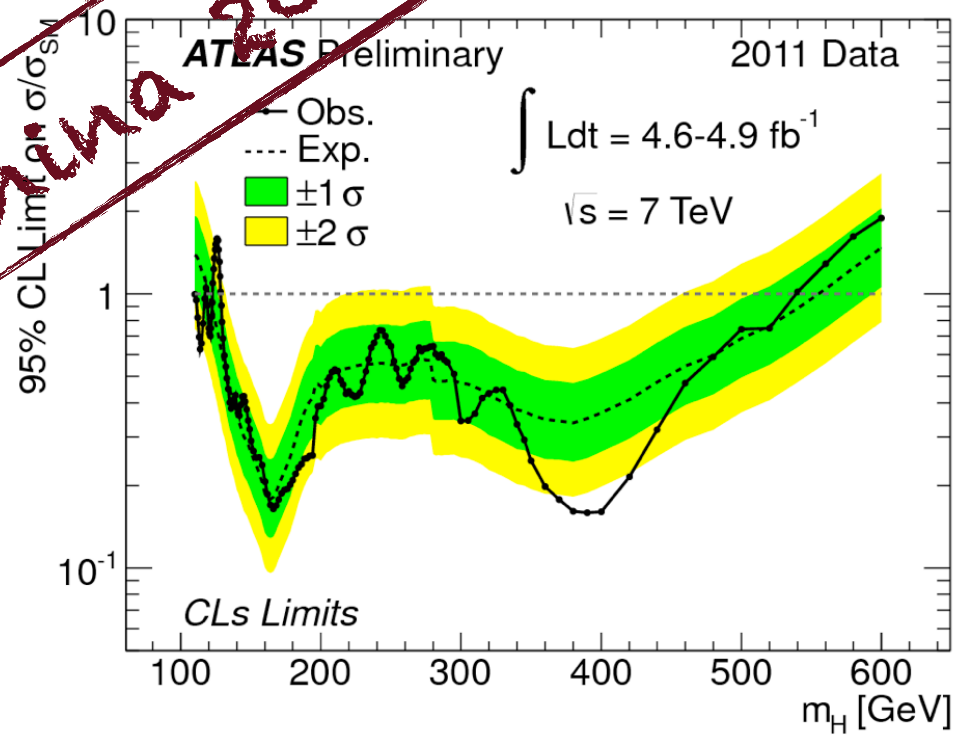
Luminosity needed for median 95% CL exclusion

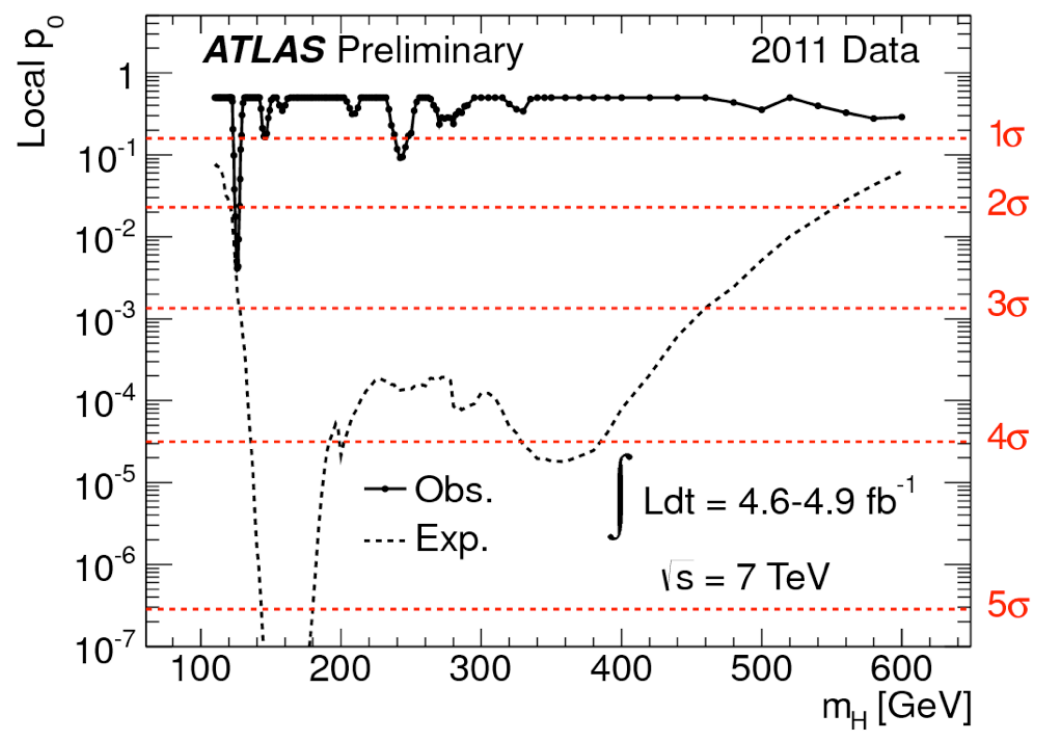


Signal Significance for 5/fb or 10/fb



Summary





Ioannina 2012

⇒ Summary of searches with ×120 integrated luminosity and a year of work wrt HEP2011!

⇒ 8 analyses + combination prepared for Winter Conferences 2012

→ Most of these include multiple final states/sub-channels

⇒ The landscape of Higgs boson searches is very different!

→ Only a small gap of 6.5 GeV not excluded in the region prefered by the Global Electroweak Fit

→ A small but intriguing excess at around ~126 GeV to keep us excited in 2012!

⇒ LHC will run at 8 TeV this year delivering up to 5 fb^{-1} for ICHEP and 15 - 20 fb^{-1} during 2012

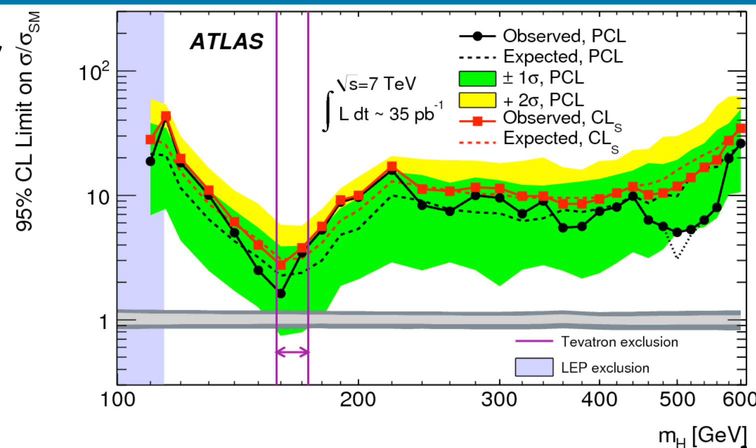
→ by the end of the year we should be able to tell:

Measurement of the properties of the new found particle

or study Electroweak Symmetry Breaking through Vector-Boson-Scattering?

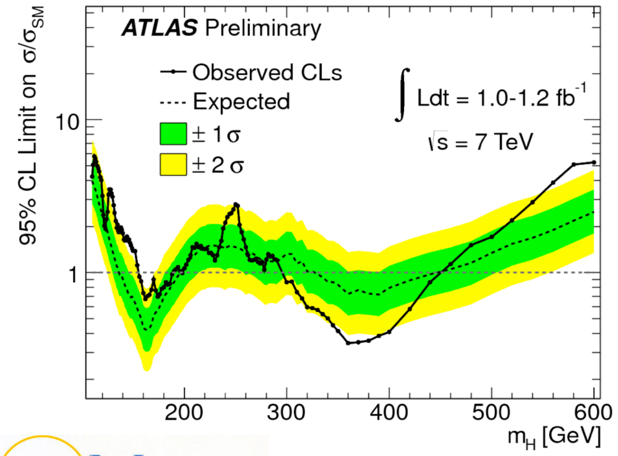
ATLAS Higgs timeline

40 pb^{-1} — Apr

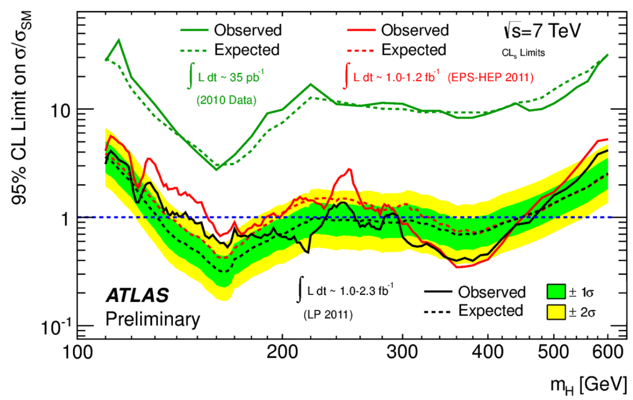


Eur.Phys.J. C71 (2011) 1728

1 fb^{-1} — Jul

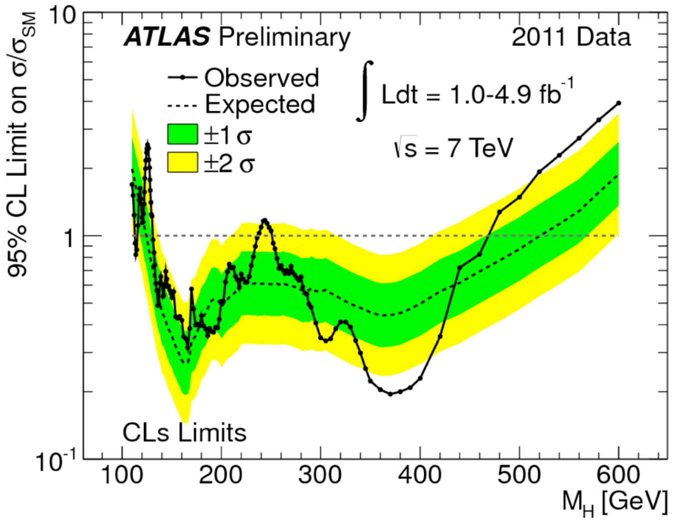


2 fb^{-1} — Aug



LEPTON PHOTON 2011
XXV International Symposium on Lepton and Photon Interactions at High Energies

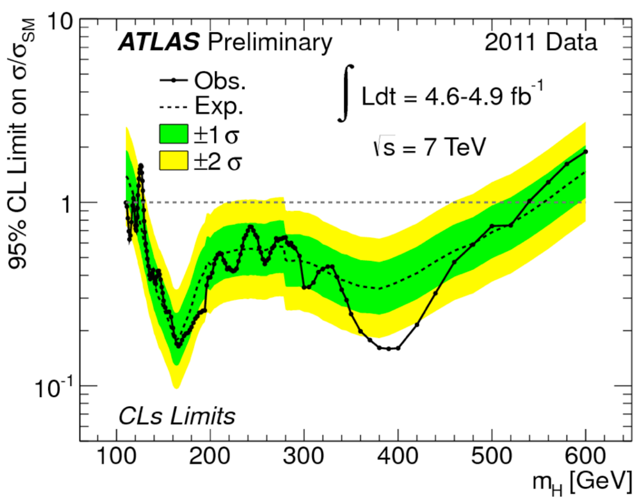
5 fb^{-1} — Dec



2011

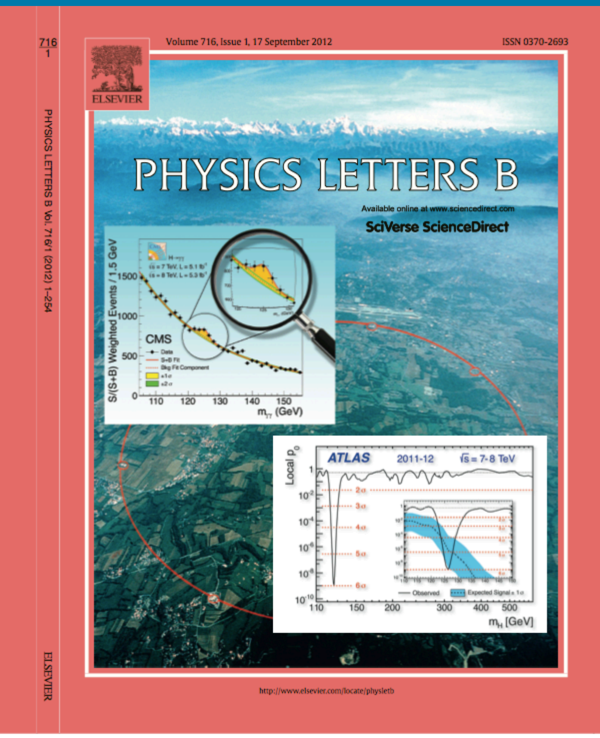
2012

Mar



47TH RENCONTRES DE MORIOND

Observation of a particle and a Nobel Prize



July 4, 2012

Physics Letters B 716 (2012) 1–29

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

ATLAS Collaboration *

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

ARTICLE INFO

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Editor: W.-D. Schlatter

ABSTRACT

A search for the Standard Model Higgs boson in proton–proton collisions with the ATLAS detector at the LHC is presented. The datasets used correspond to integrated luminosities of approximately 4.8 fb^{-1} collected at $\sqrt{s}=7$ TeV in 2011 and 5.8 fb^{-1} at $\sqrt{s}=8$ TeV in 2012. Individual searches in the channels $H \to ZZ^{(*)} \to 4\ell$, $H \to \gamma\gamma$ and $H \to WW^{(*)} \to e\nu\mu\nu$ in the 8 TeV data are combined with previously published results of searches for $H \to ZZ^{(*)}$, $WW^{(*)}$, $b\bar{b}$ and $\tau^+\tau^-$ in the 7 TeV data and results from improved analyses of the $H \to ZZ^{(*)} \to 4\ell$ and $H \to \gamma\gamma$ channels in the 7 TeV data. Clear evidence for the production of a neutral boson with a measured mass of 126.0 ± 0.4 (stat) ± 0.4 (sys) GeV is presented. This observation, which has a significance of 5.9 standard deviations, corresponding to a background fluctuation probability of 1.7×10^{-9}, is compatible with the production and decay of the Standard Model Higgs boson.

Physics Letters B 716 (2012) 30–61

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC ☆

CMS Collaboration *

CERN, Switzerland

This paper is dedicated to the memory of our colleagues who worked on CMS but have since passed away. In recognition of their many contributions to the achievement of this observation.

ARTICLE INFO

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Available online 18 August 2012
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Higgs

ABSTRACT

Results are presented from searches for the standard model Higgs boson in proton–proton collisions at $\sqrt{s}=7$ and 8 TeV in the Compact Muon Solenoid experiment at the LHC, using data samples corresponding to integrated luminosities of up to 5.1 fb^{-1} at 7 TeV and 5.3 fb^{-1} at 8 TeV. The search is performed in five decay modes: $\gamma\gamma$, ZZ, W^+W^-, $\tau^+\tau^-$, and $b\bar{b}$. An excess of events is observed above the expected background, with a local significance of 5.0 standard deviations, at a mass near 125 GeV, signalling the production of a new particle. The expected significance for a standard model Higgs boson of that mass is 5.8 standard deviations. The excess is most significant in the two decay modes with the best mass resolution, $\gamma\gamma$ and ZZ; a fit to these signals gives a mass of 125.3 ± 0.4(stat.) ± 0.5(syst.) GeV. The decay to two photons indicates that the new particle is a boson with spin different from one.

VOLUME 13, NUMBER 9 PHYSICAL REVIEW LETTERS 31 AUGUST 1964

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium

(Received 26 June 1964)

Volume 12, number 2 PHYSICS LETTERS 15 September 1964

BROKEN SYMMETRIES, MASSLESS PARTICLES AND GAUGE FIELDS

P. W. HIGGS
Tait Institute of Mathematical Physics, University of Edinburgh, Scotland

Received 27 July 1964

VOLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1964

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland

(Received 31 August 1964)

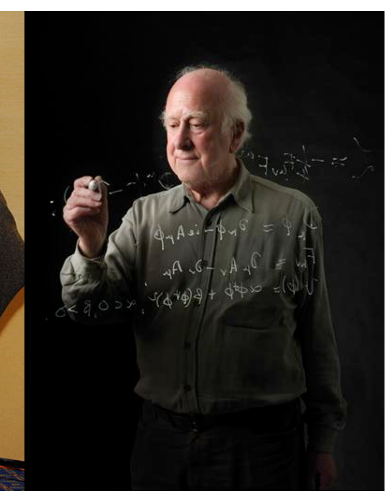
VOLUME 13, NUMBER 20 PHYSICAL REVIEW LETTERS 16 NOVEMBER 1964

GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England

(Received 12 October 1964)

Oct 8, 2013

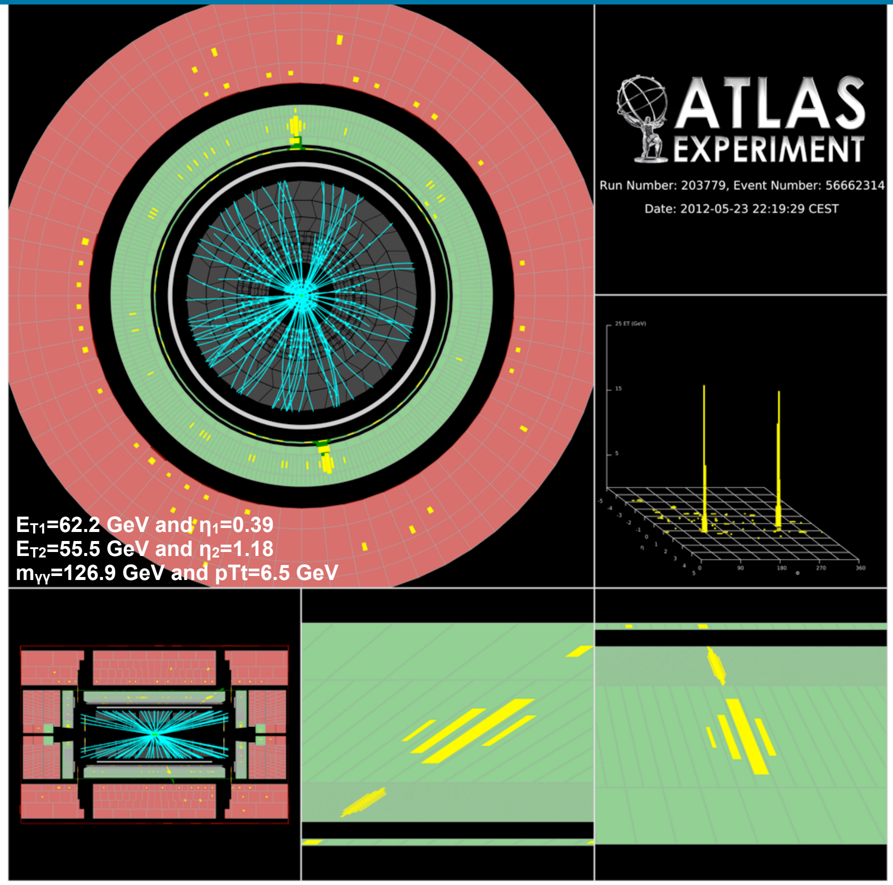


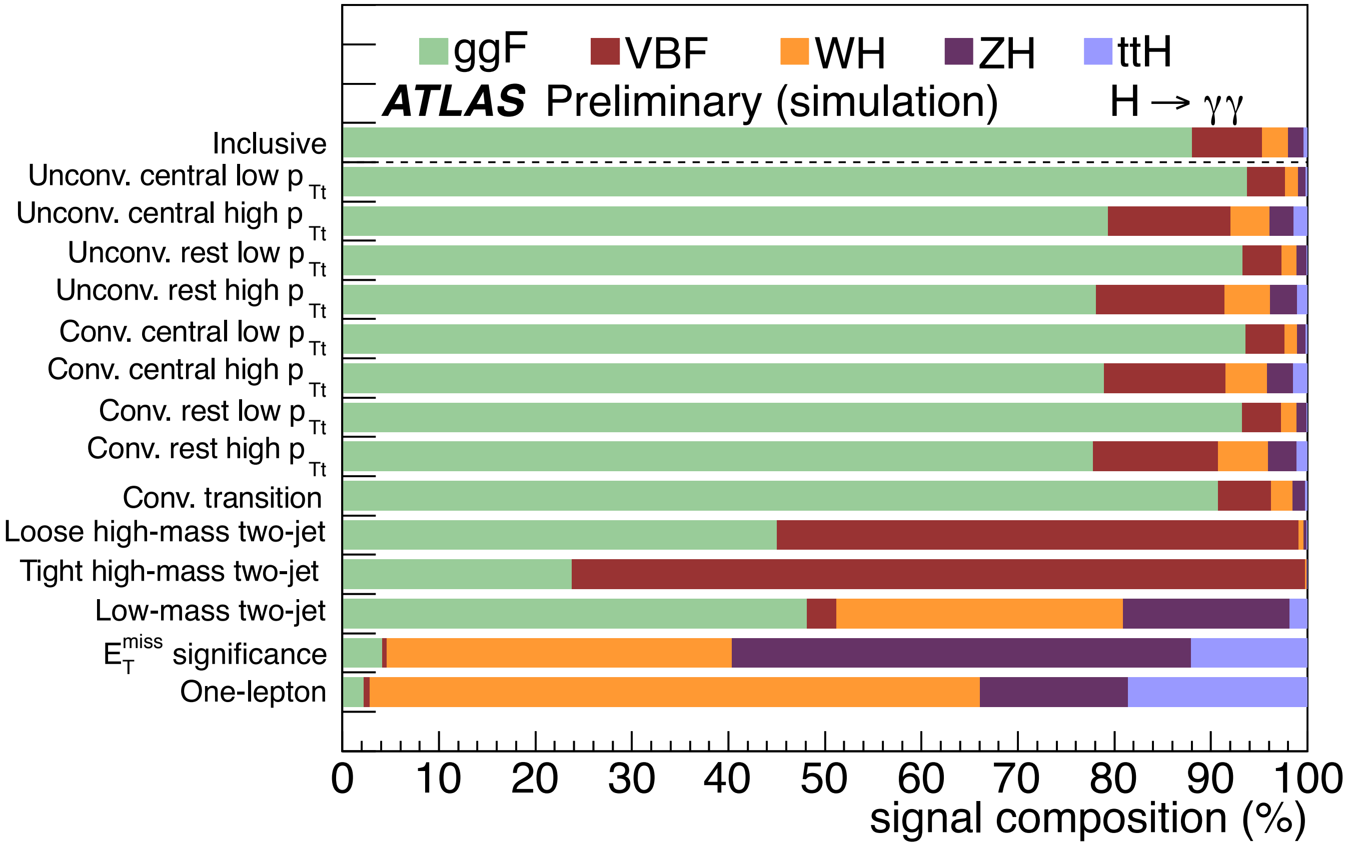
The 2013 Nobel Prize in Physics awarded jointly to F. Englert and P. W. Higgs:

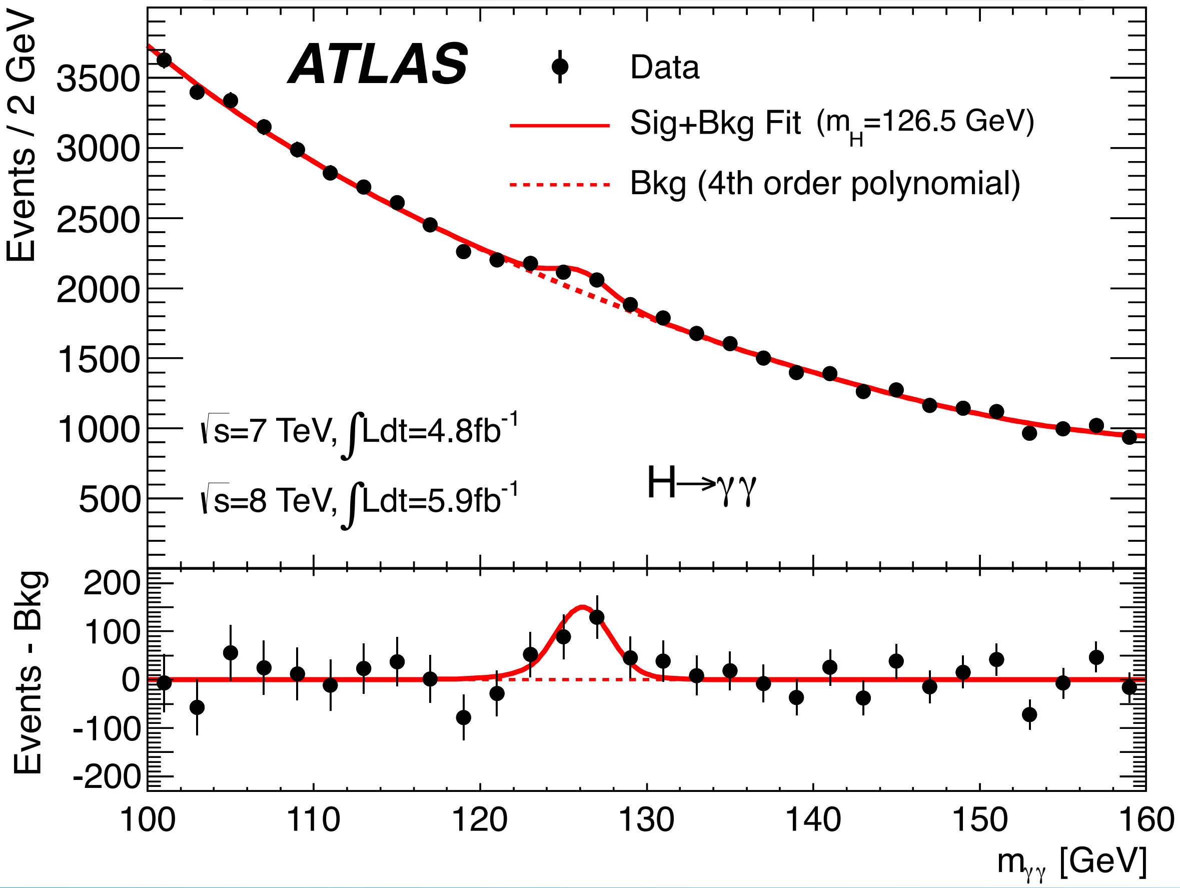
"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, <u>by the ATLAS and CMS experiments at CERN's Large Hadron Collider</u>"

H→γγ

- Narrow peak in $m_{\gamma\gamma}$ spectrum
  - inclusive S/B ~ 3%
- Main Backgrounds:
  - ~75% di-photon → $m_{\gamma\gamma}$ resolution [~1.8 GeV]
  - ~25% mostly γj and some jj → photon-ID
- Background directly from data side-bands
- Event Selection:
  - → Two isolated photons (|η|<2.47) with E_T>40/30 GeV
- Event Categorization
  - → Improve S/B
  - → Enhance particular signal production modes
  - → 14 exclusive categories



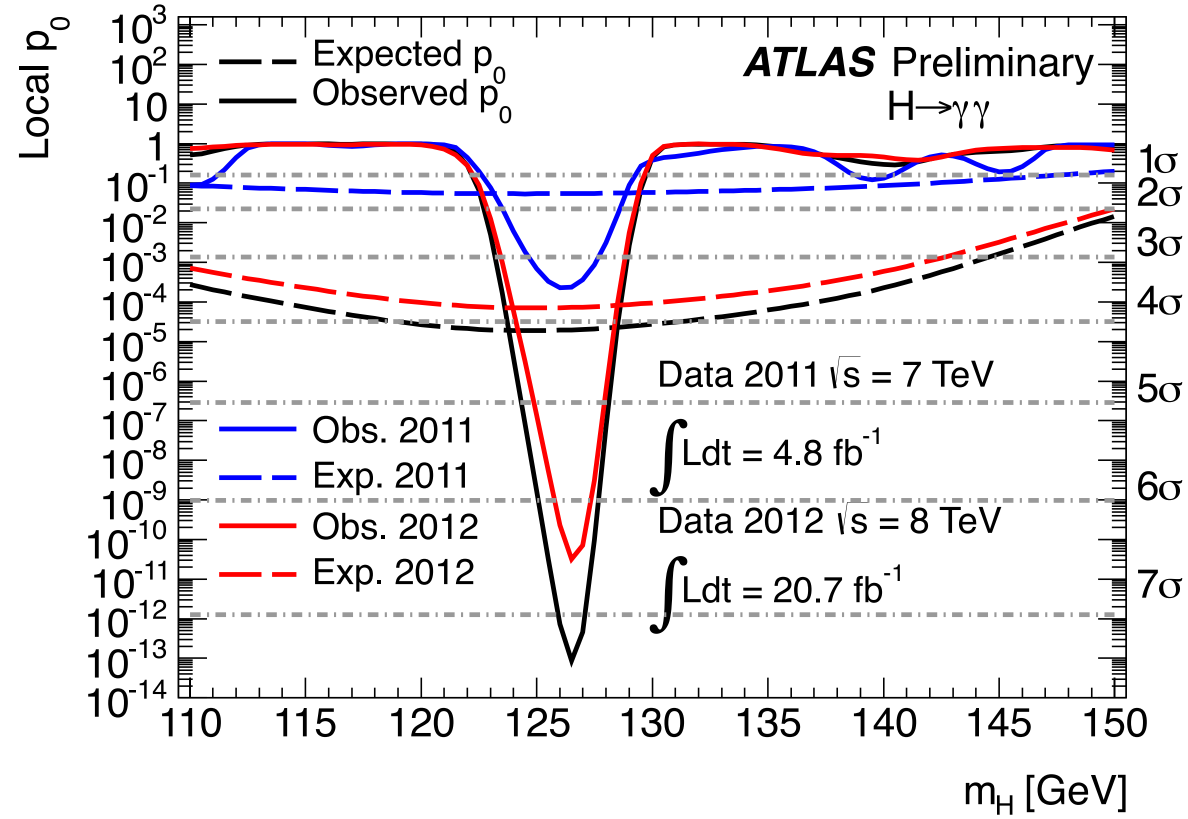


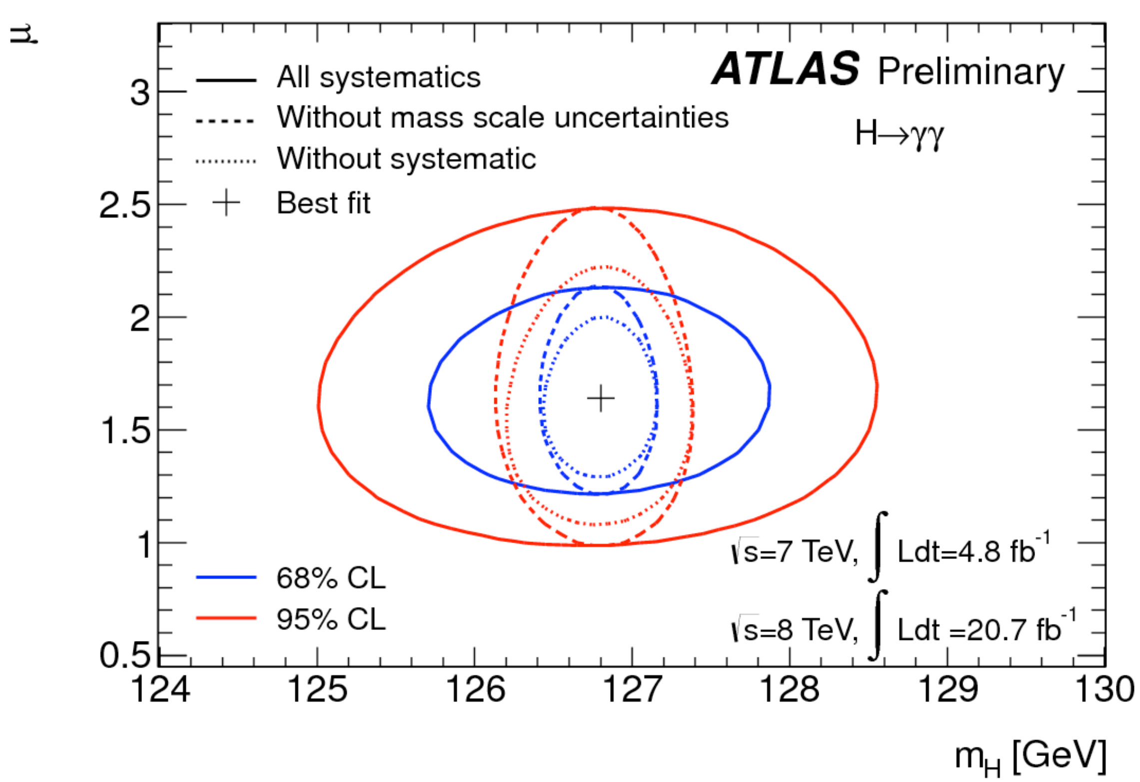


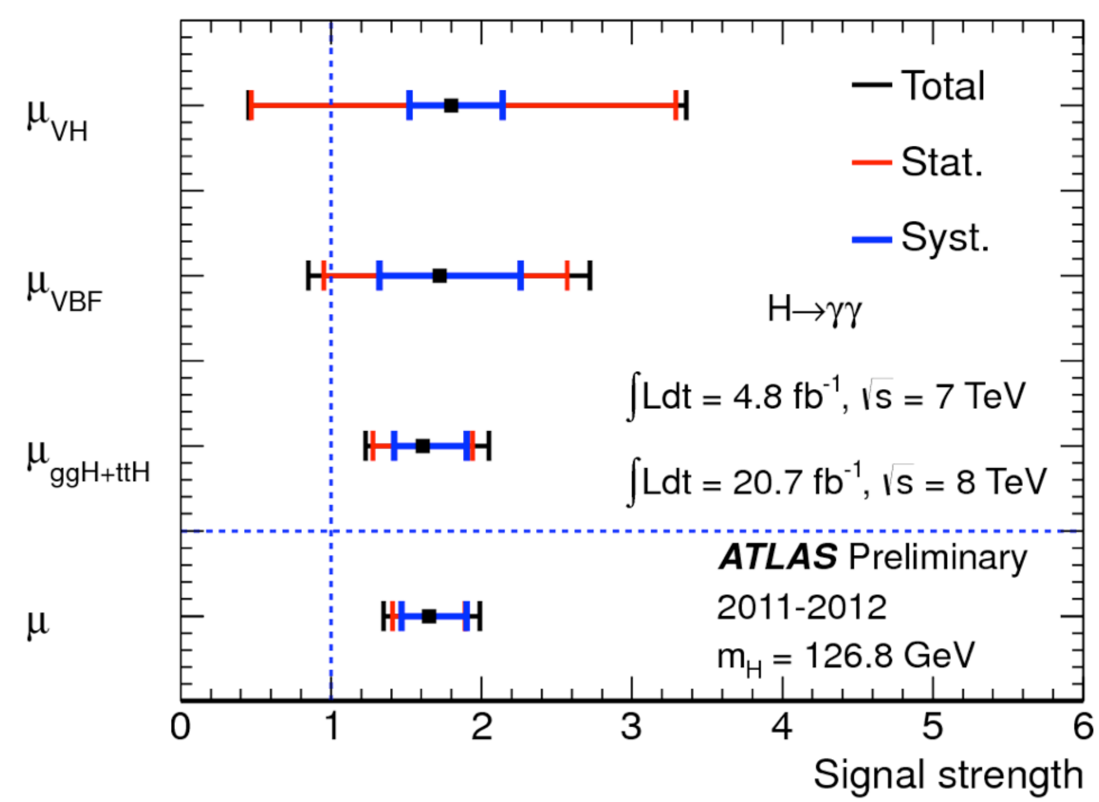
H→γγ: Results

<u>Most significant deviation from B-only hypothesis observed at m_H =126.5 GeV:</u>

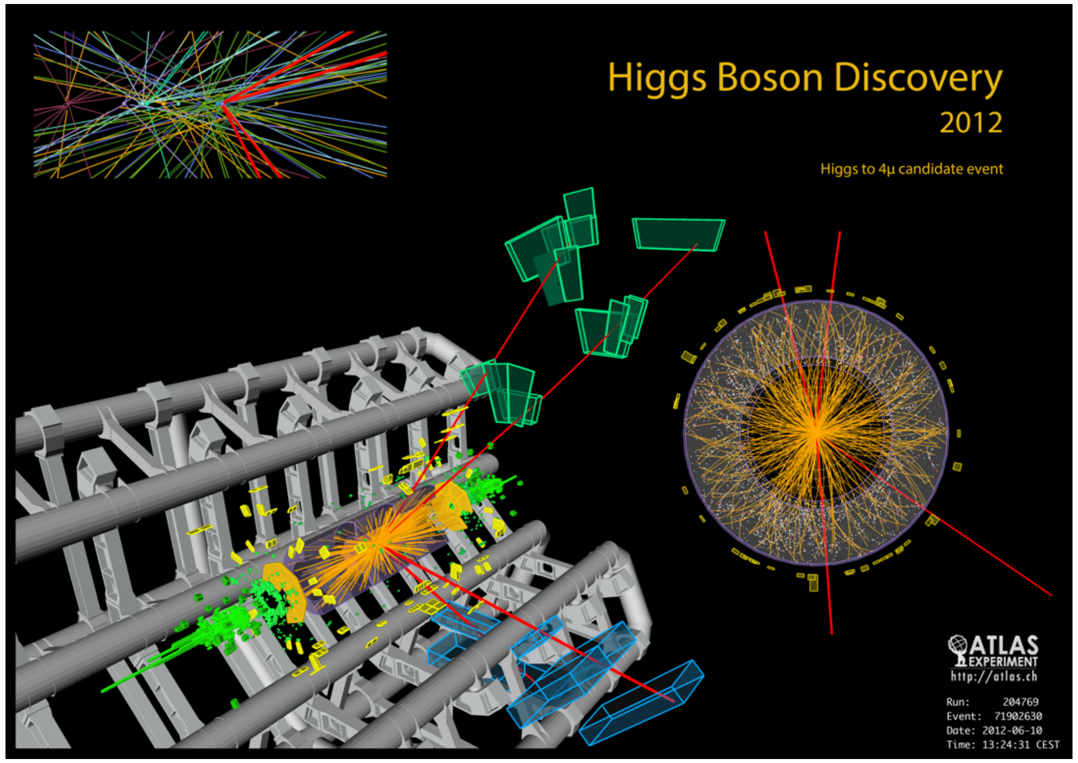
- Local significance: **7.4σ** (4.1σ expected)
  - Inclusive analysis: 6.1σ (2.9σ expected)
- Mass measurement:
  126.8 ± 0.2 (stat) ± 0.7 (syst) GeV
  - Main systematics: γ energy scale (Z→ee), material modeling and pre-sampler energy scale → 0.6 GeV
- Rate with respect to SM:
  $1.65 \pm 0.24\ (\mathrm{stat})^{+0.25}_{-0.18}\ (\mathrm{syst})$
  → 2.3σ deviation from the Standard Model



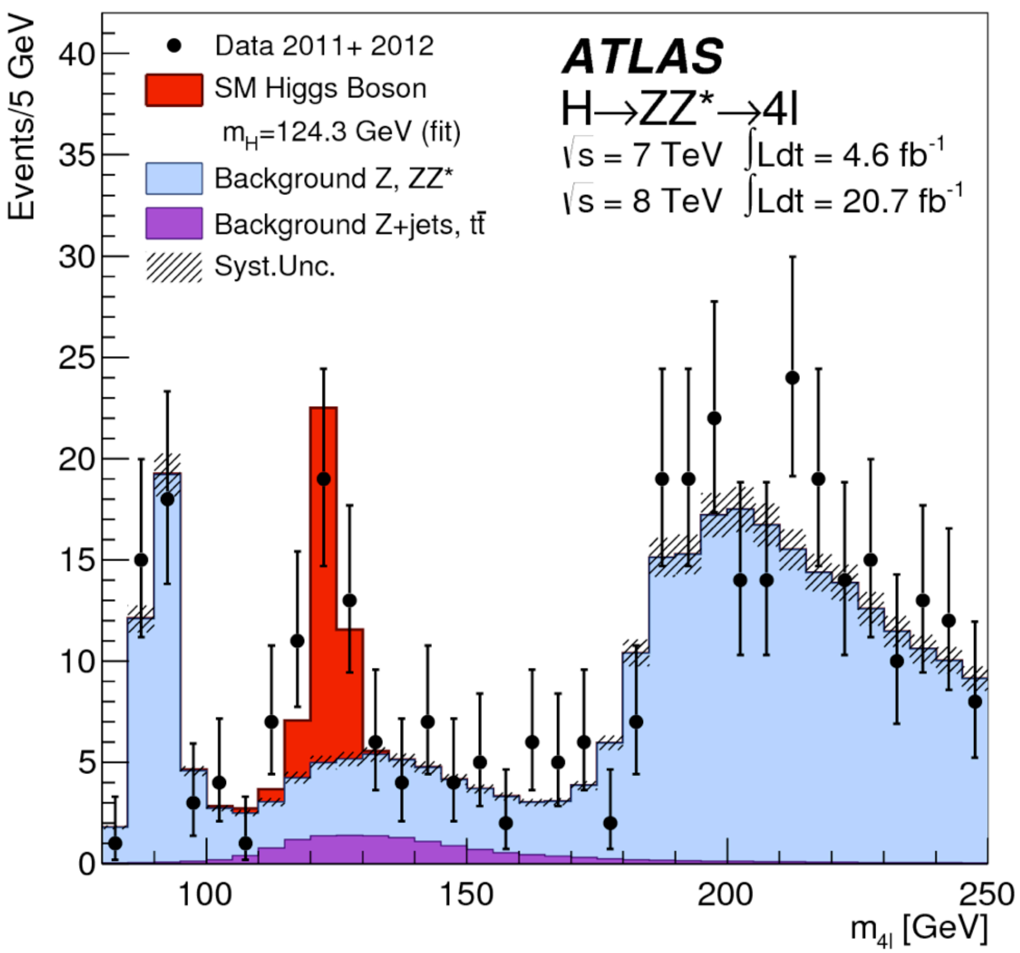




H→ZZ(*)→4l



- Search for peak in m_{4l} spectrum
- “Golden Channel”
  - → S/B ~ 1.0 - 1.9 @ m_H=125 GeV
  - → Mass resolution ~1.9 GeV
- Main Backgrounds:
  - → $ZZ^{(*)}$→4l and for $m_{4l}<2m_Z$
  - → Z+jets (Z+light jets/Zbb) and tt
- Event Selection
  - → Two same-flavor opposite-sign di-leptons (e/μ)
  - → Single lepton and di-lepton triggers
  - → $pT^{1,2,3,4}$ > 20, 15, 10, 7 GeV (6 GeV for μ)
  - → 50 GeV < m_{12} < 106 GeV, 12-50 GeV <m_{34}<115 GeV
  - → Isolation/d_0 significance
  - → all same-flavor opposite-sign pairs m_{ll}>5 GeV
  - → ΔR(l,l′) > 0.10(0.20) for all same(different)-flavor

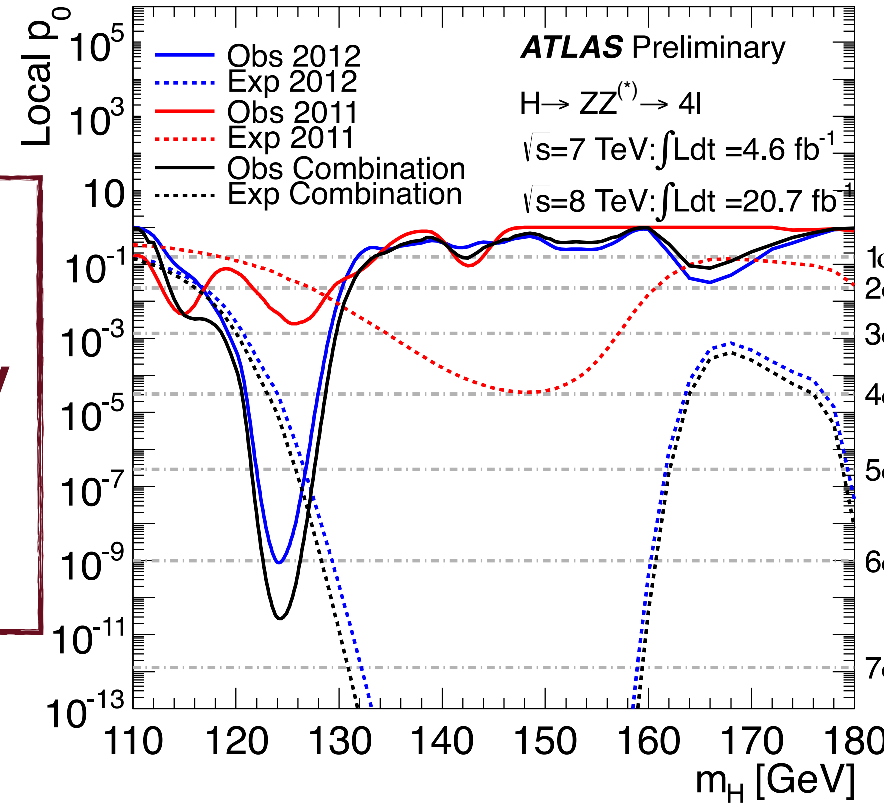


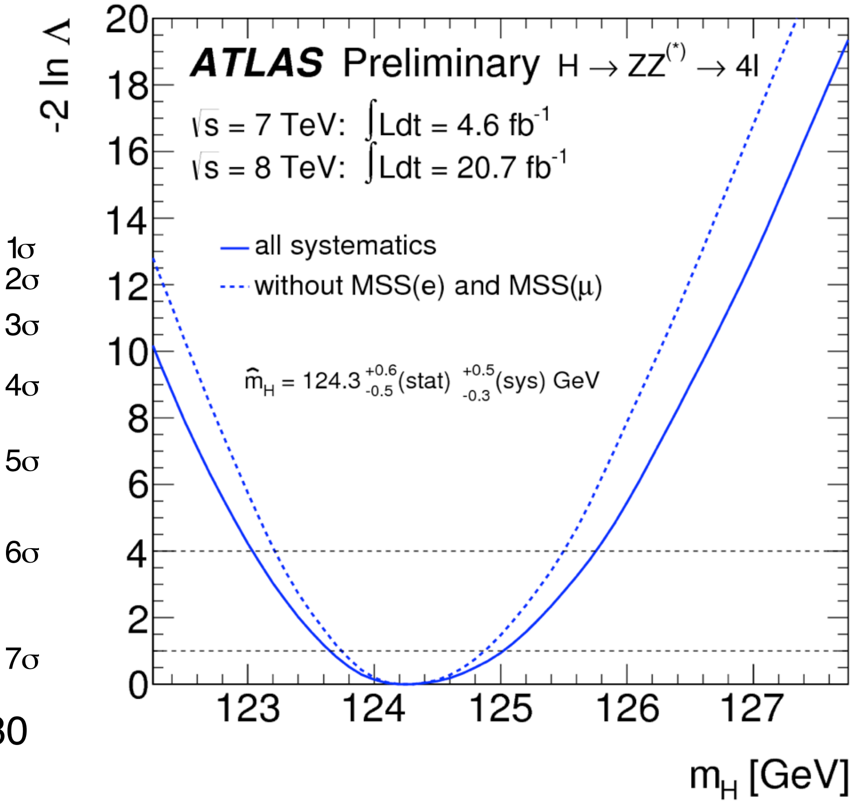
	Signal	$ZZ^{(*)}$	Other Backgrounds	Observed	S/B
4μ	6.3±0.8	2.8±0.1	0.55±0.15	13	~1.9
2μ2e	3.0±0.4	1.4±0.1	1.56±0.33	5	~1.0
2e2μ	4.0±0.5	2.1±0.1	0.55±0.17	7	~1.5
4e	2.6±0.4	1.2±0.1	1.11±0.28	6	~1.1

120-130 GeV

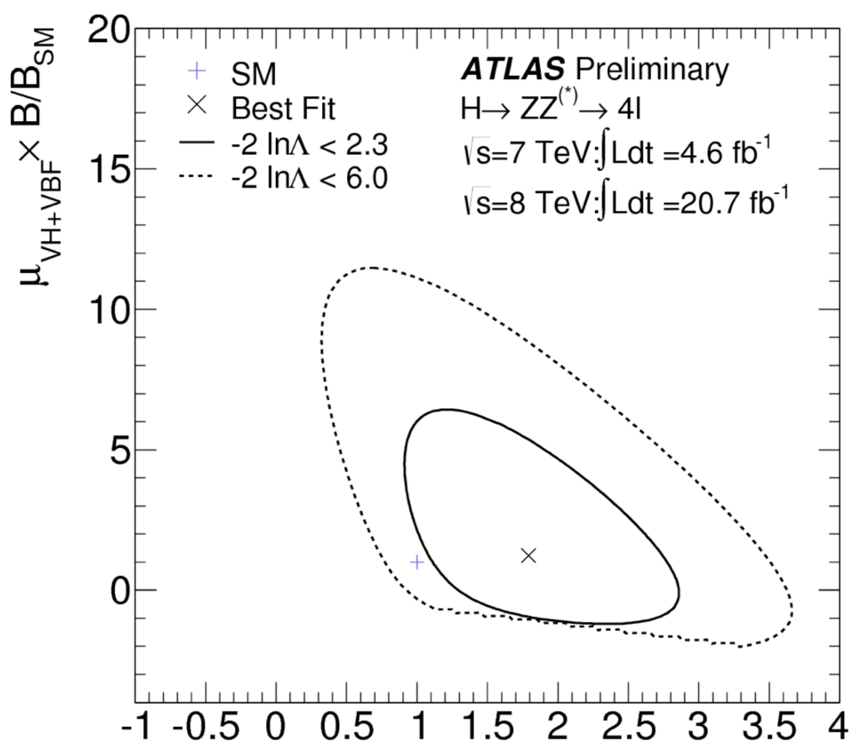
H→ZZ(*)→4l: Results

- Local significance:
  - **6.6σ** (4.4σ) at m_H=124.3GeV
- Mass: **$124.3^{+0.6}_{-0.5}$(stat)$^{+0.5}_{-0.3}$(syst) GeV**
  - Main systematic: e/μ E/P scale
- Rate with respect to SM: $1.7^{+0.5}_{-0.4}$
  - **1.5 ± 0.4 @ m_H=125.5 GeV**



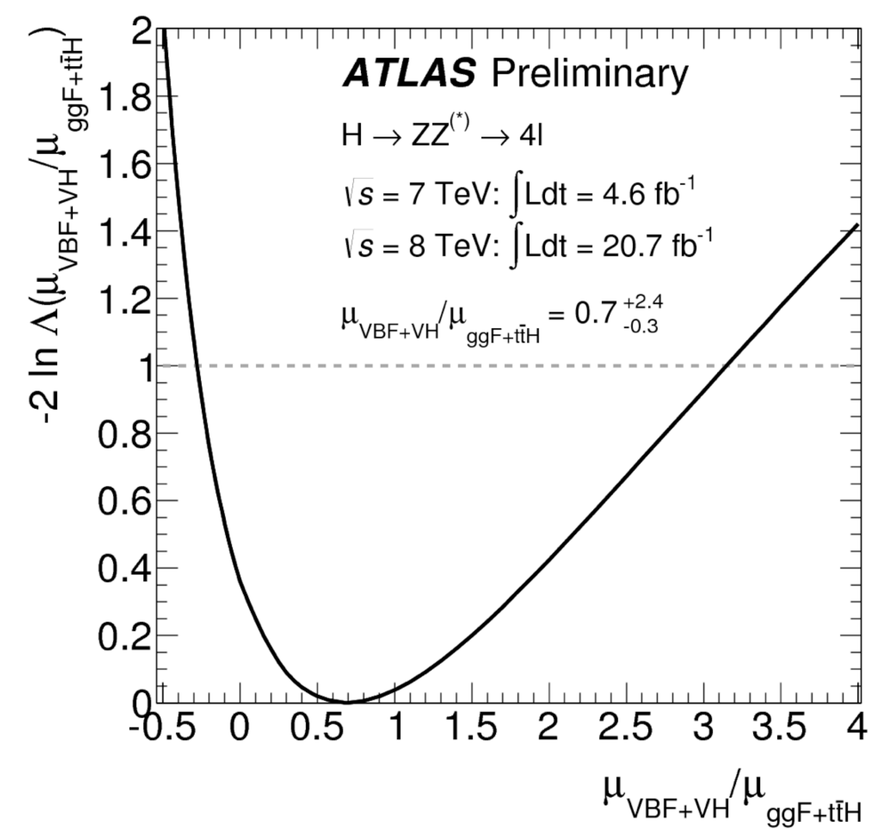


Implement event categorisation to obtain sensitivity to production modes:
- VBF-like (jets in VBF topology)
- VH-like (additional leptons)
- ggF-like (all remaining events)



$\mu_{ggF+ttH}$ = 1.8±0.6

μ_{VBF+VH} = $1.2^{+3.0}_{-1.7}$

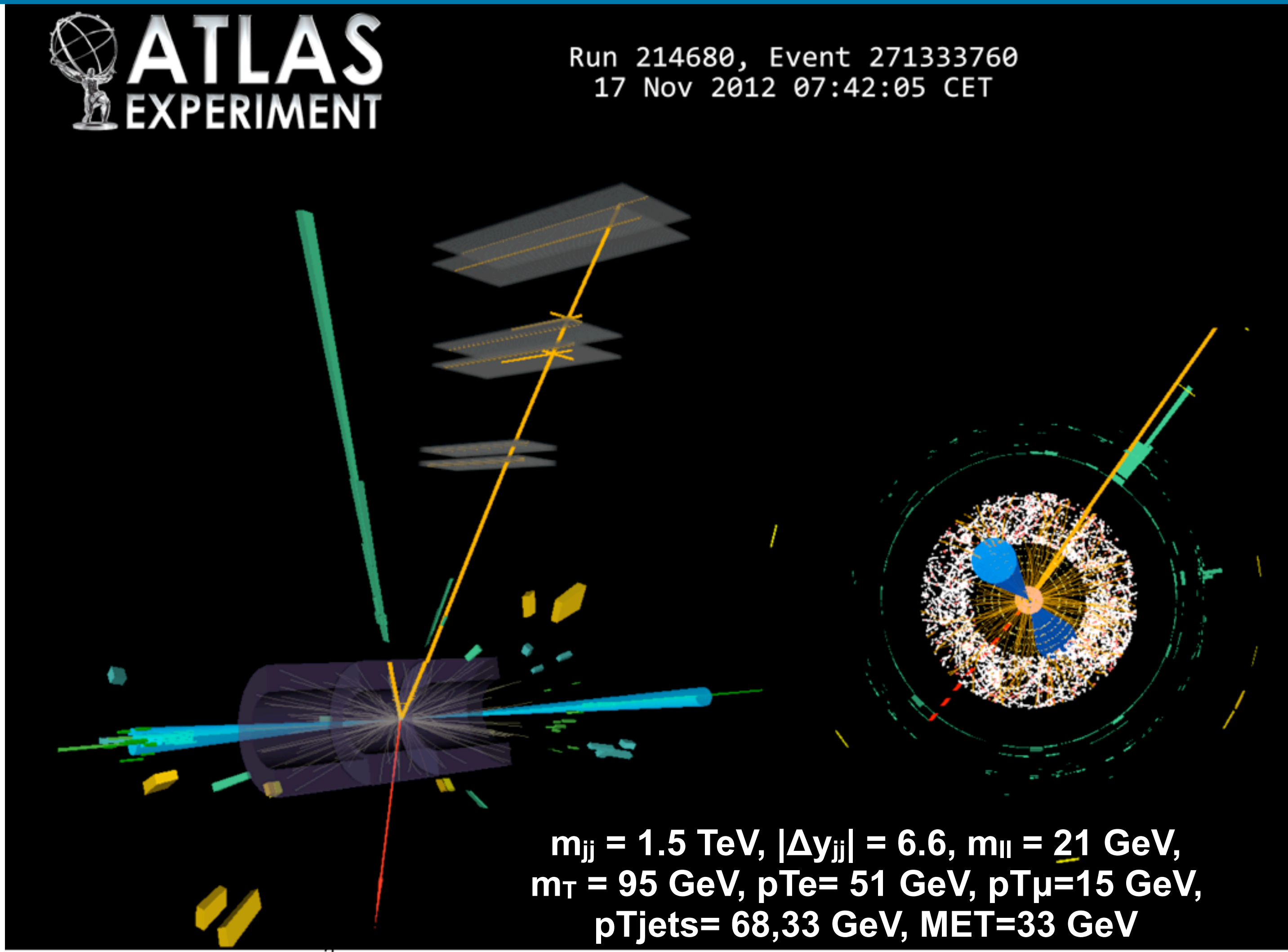


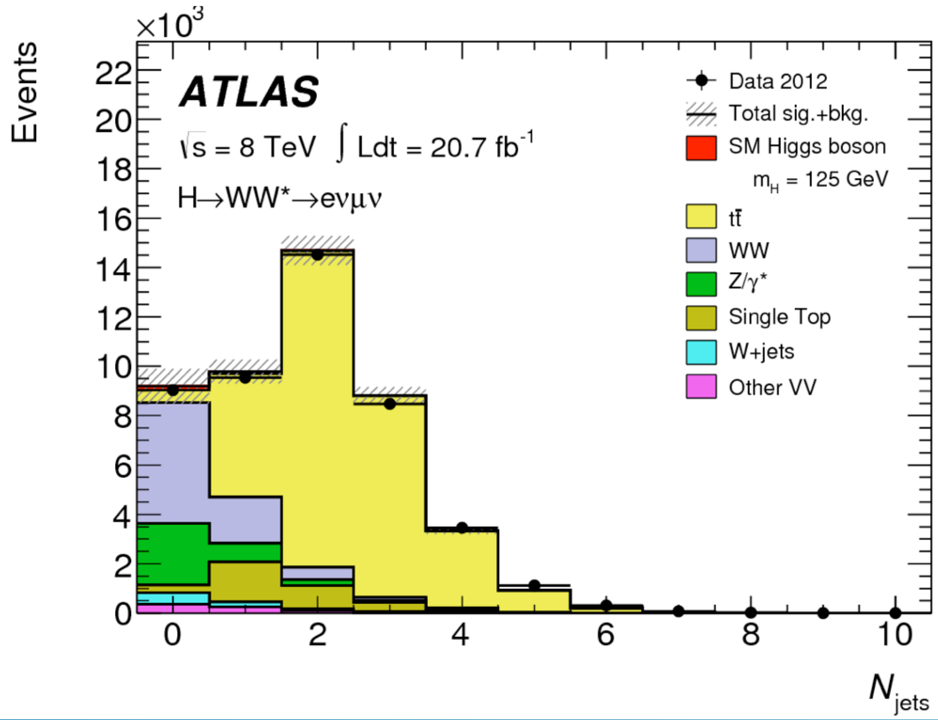
H→WW(*)→lνlν

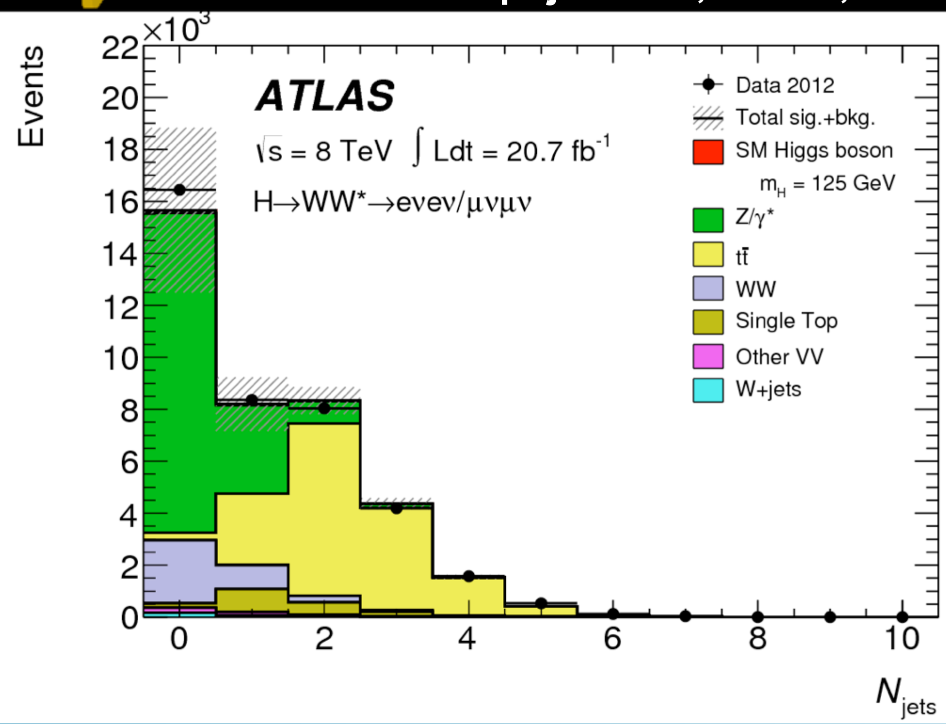
- Sensitive in wide mass range
  - → no mass peak
  - → complex final state
- Signature: l^+l^- + MET
- Observable:

$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$

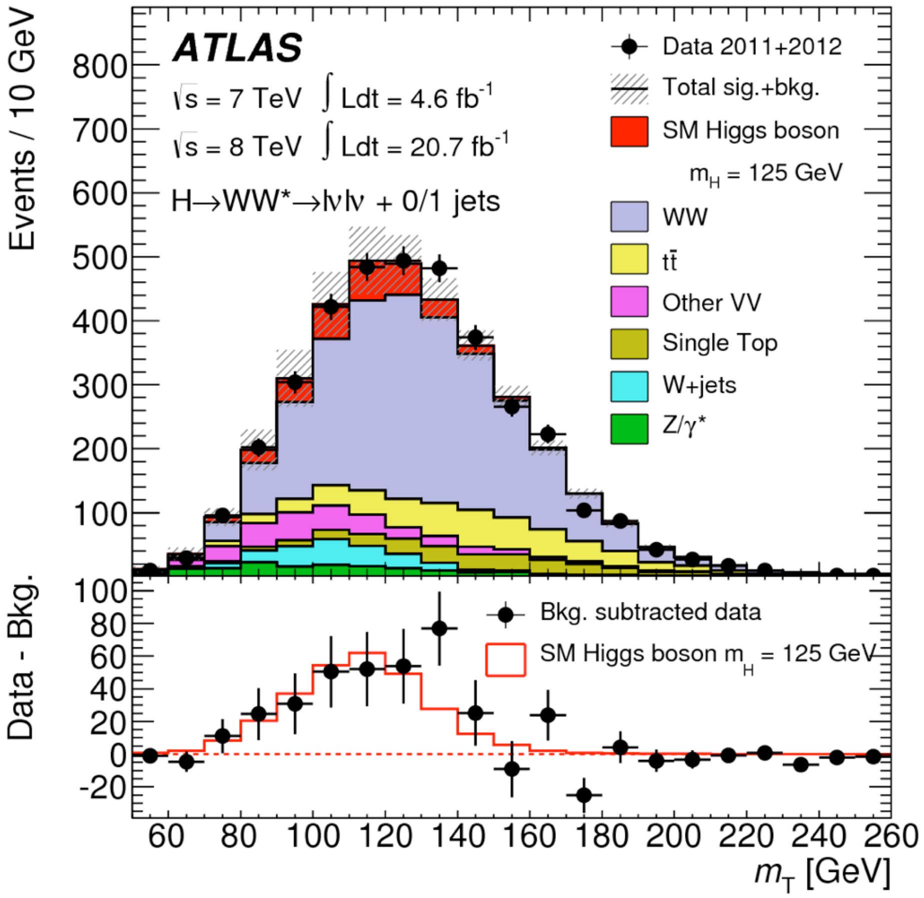
- Backgrounds: WW, top, W/Z+jets
- Separate final states:
  - dilepton mass: m_{ll}
  - lepton flavors: μe, eμ, μμ, ee
  - jet multiplicities: 0, 1, ≥2

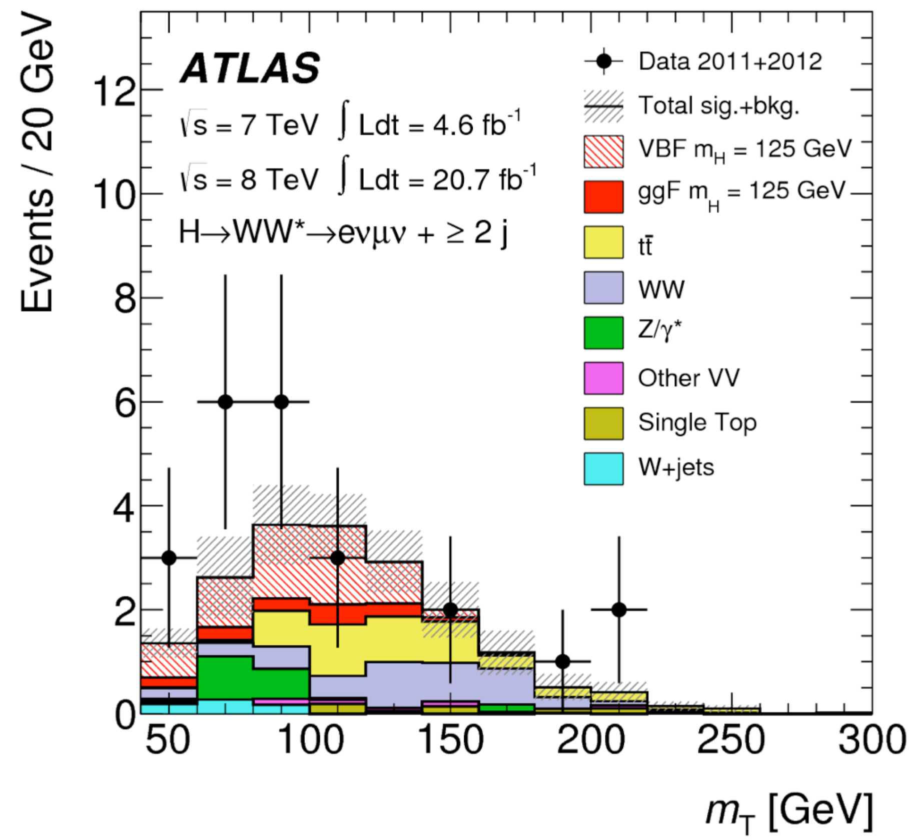






H→WW$^{(*)}$→lνlν: Results 2011+2012



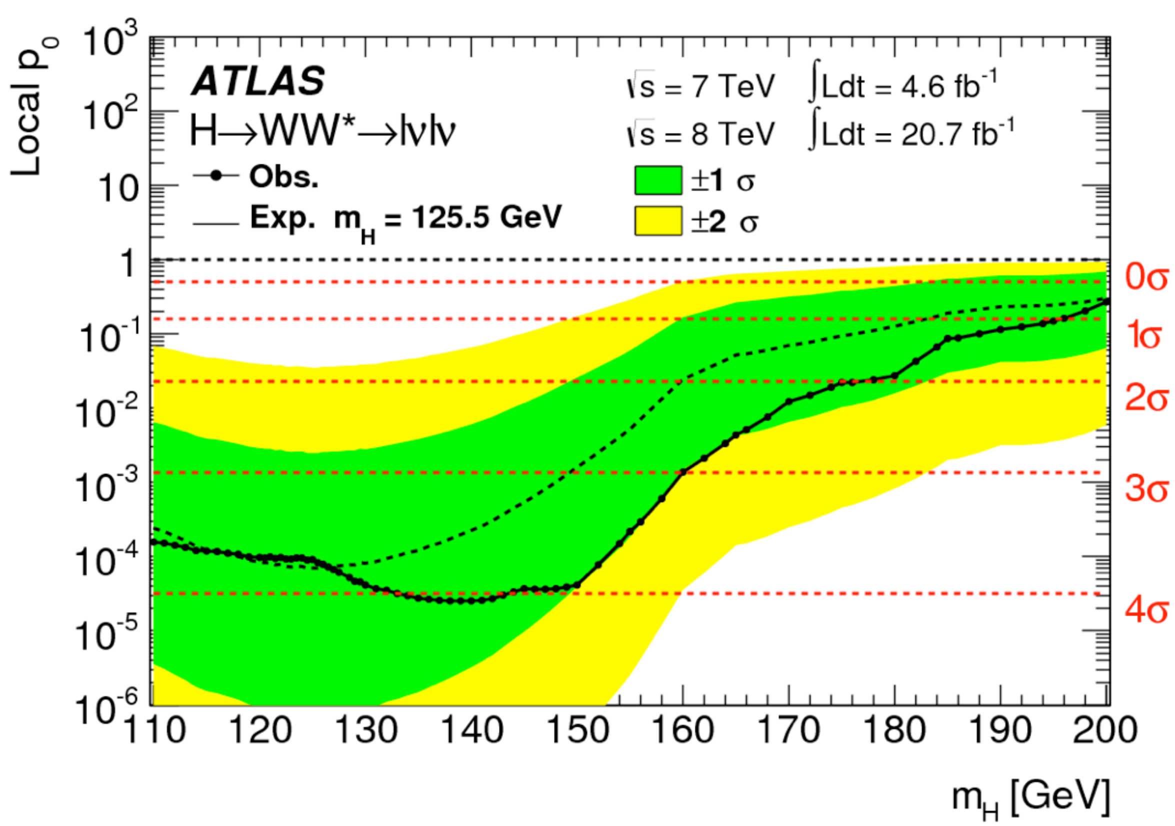


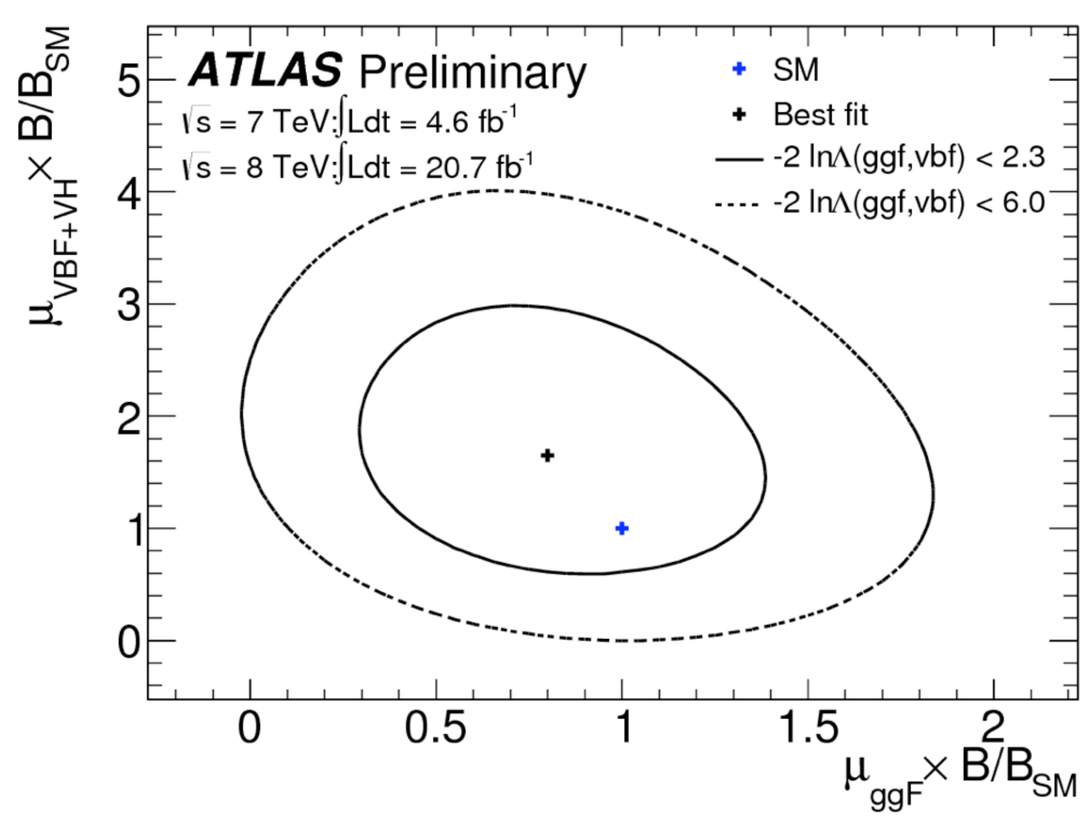
At m_H=125GeV

Local significance: 3.8σ (3.7σ)

Rate with respect to SM:

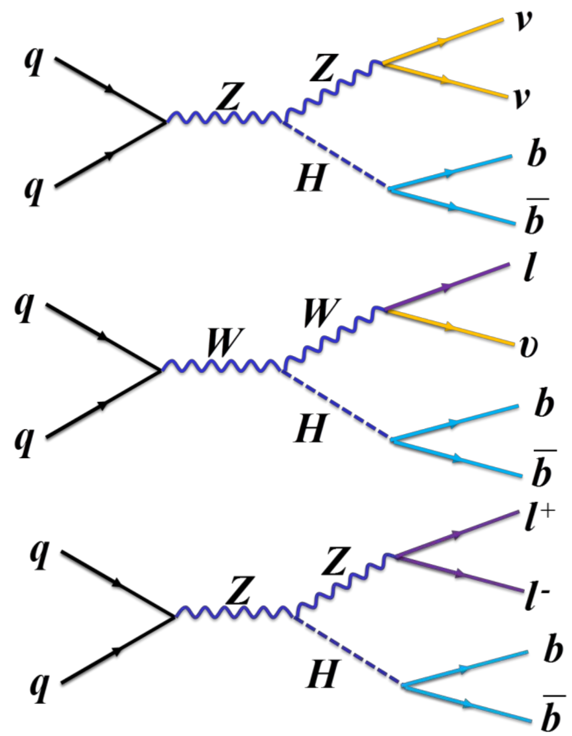
1.01 ± 0.31 @ m_H=125 GeV

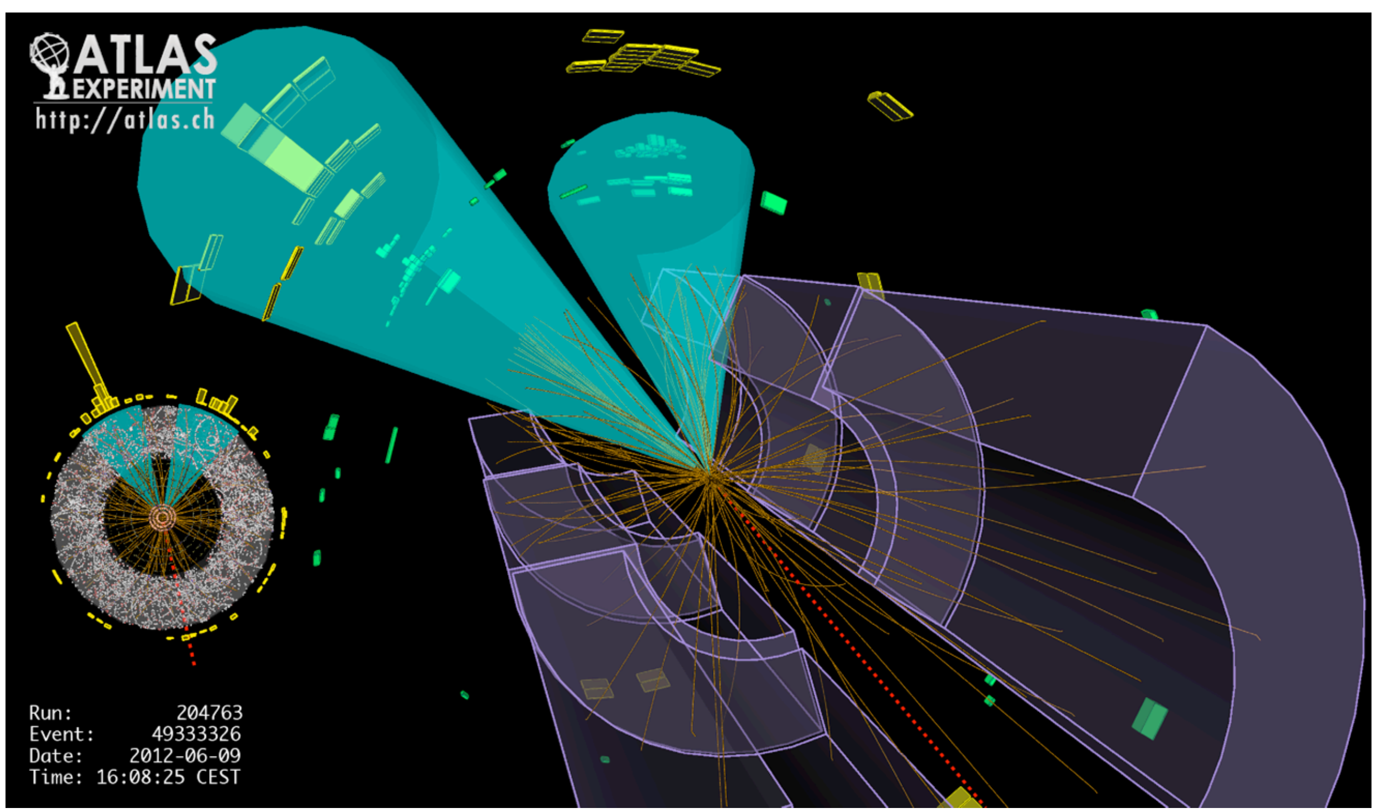




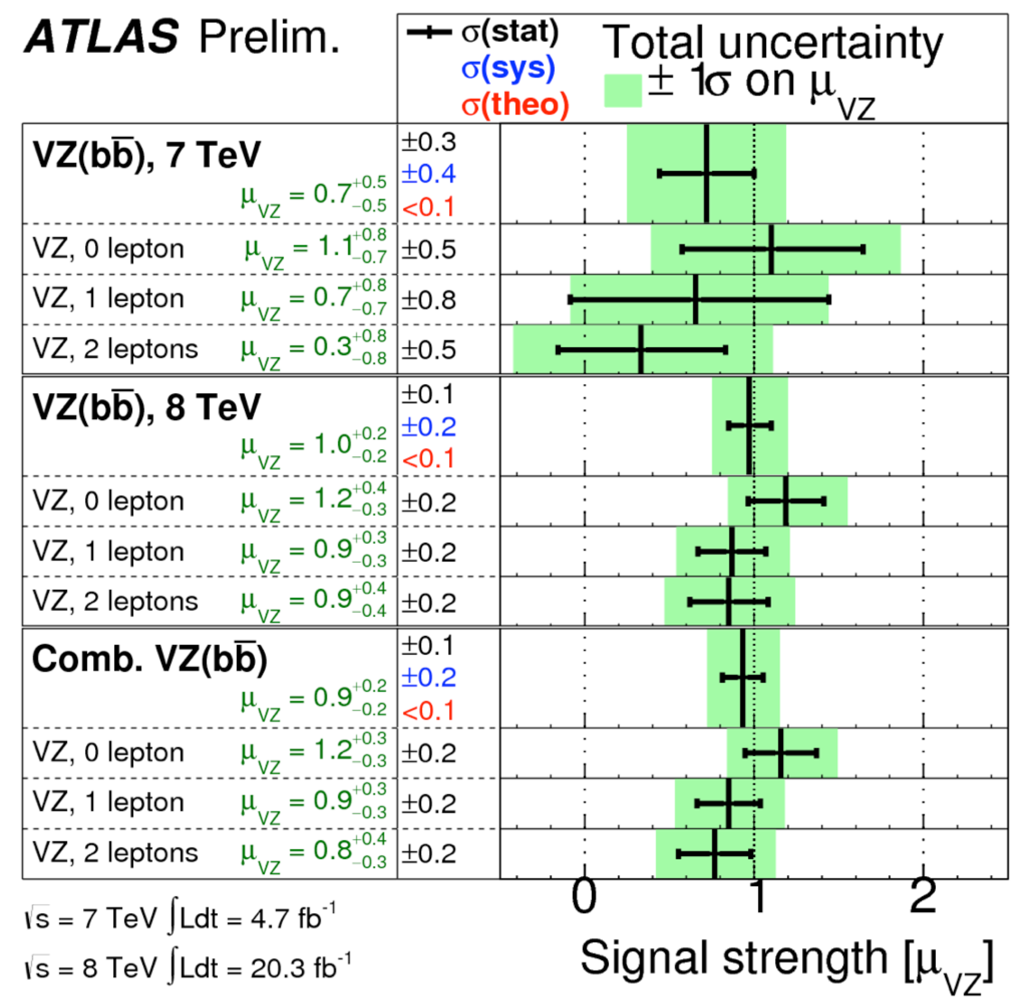
H→bb : Results

- Largest BR (58%@m_H=125 GeV) but large QCD background
- Exploit associated production with W or Z
  - Final states with leptons, MET and b-jets
- Backgrounds: W/Z+jets and top
- Final discriminant m_{bb}
- Separate final states:
  - number of leptons: 0, 1, 2
  - $P_T(V)$ or MET
  - number of jets
  - 26 signal bins in total
  - [+ 27 control regions]

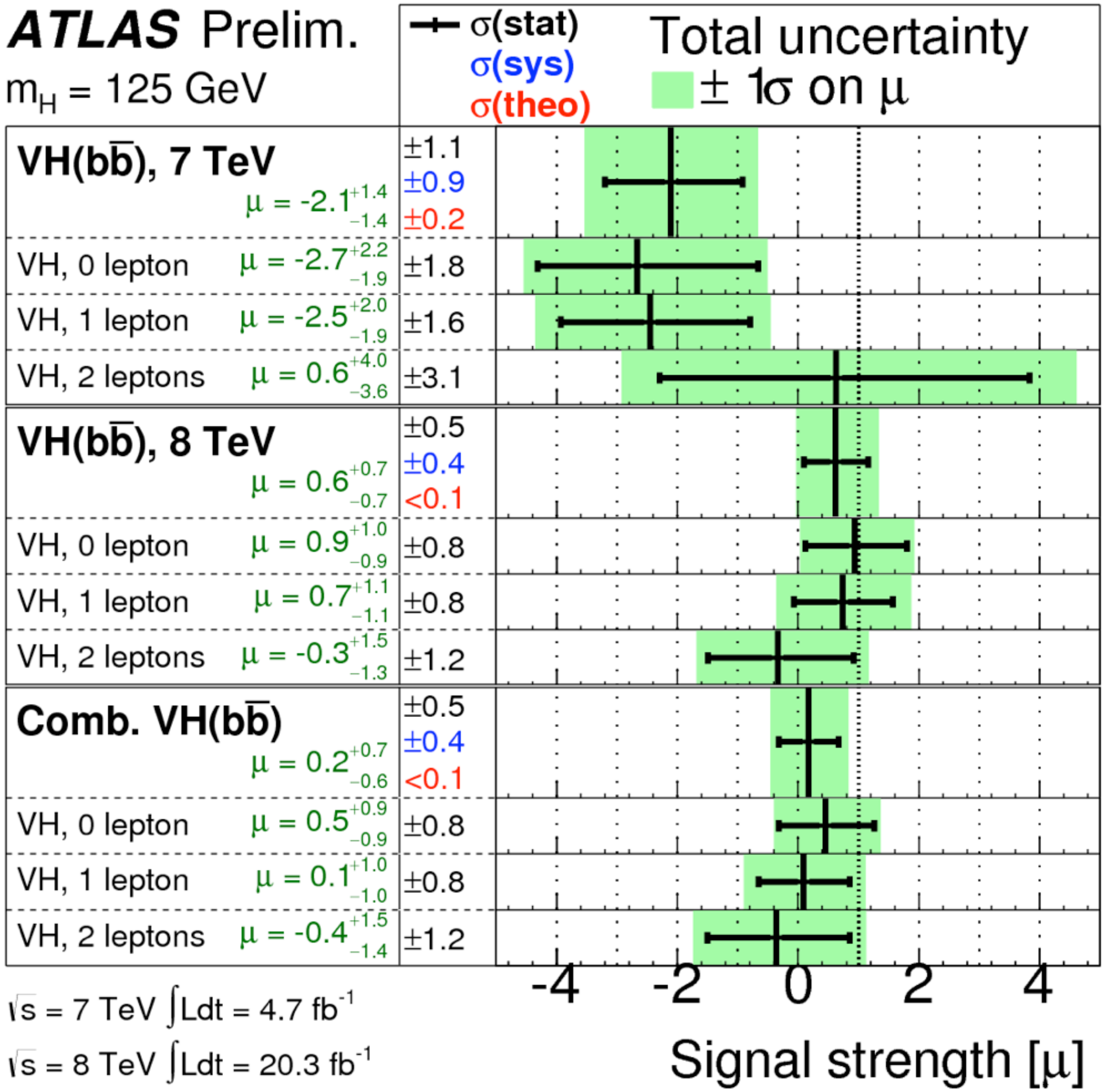


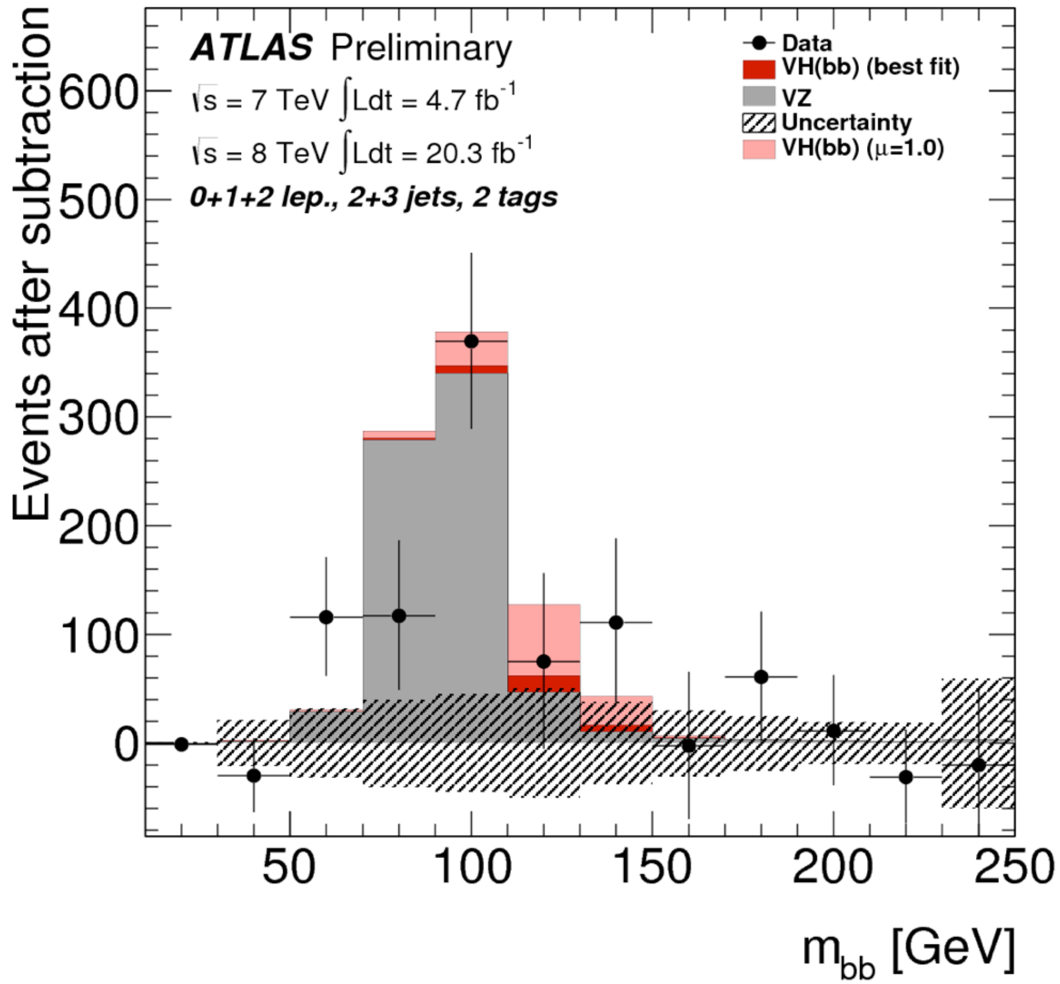


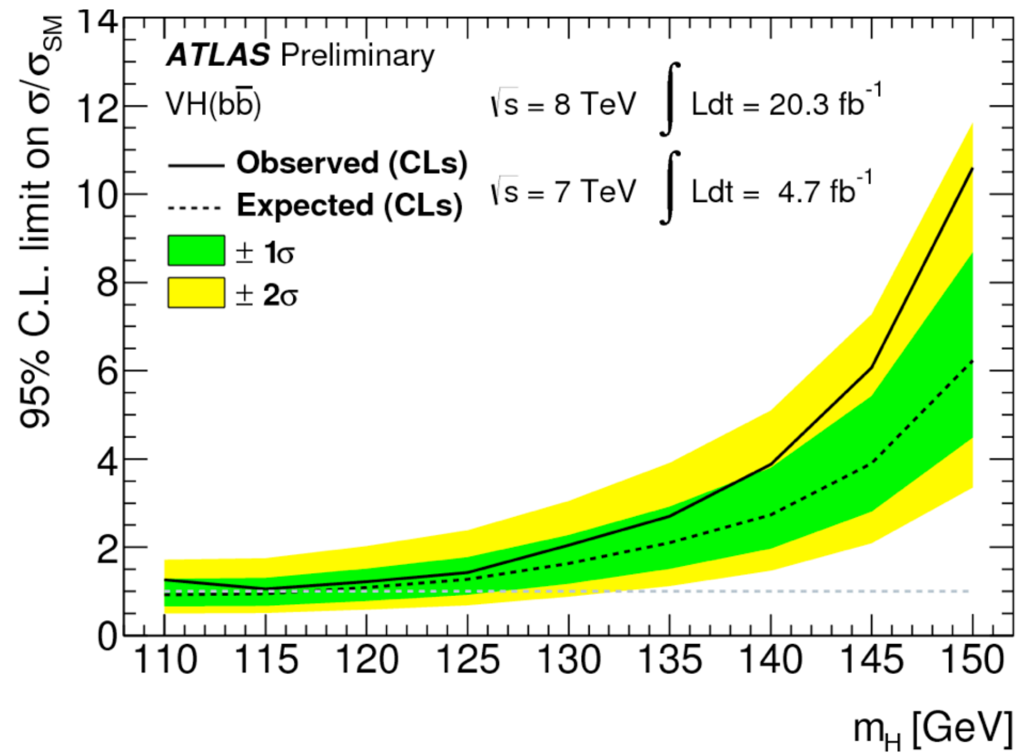
Validate analysis with VZ(→bb) production
- Observation at 4.8σ (5.1σ)
- Rate in agreement with SM expectation



H→bb



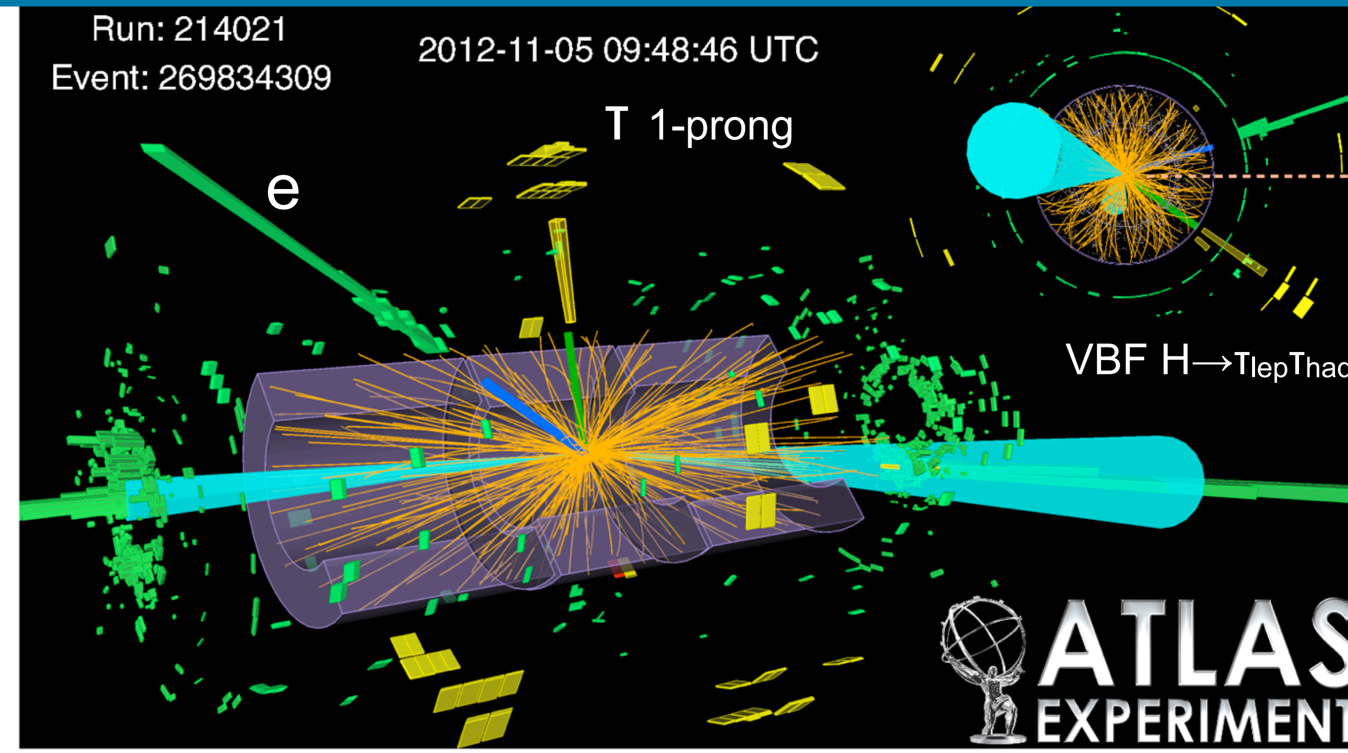




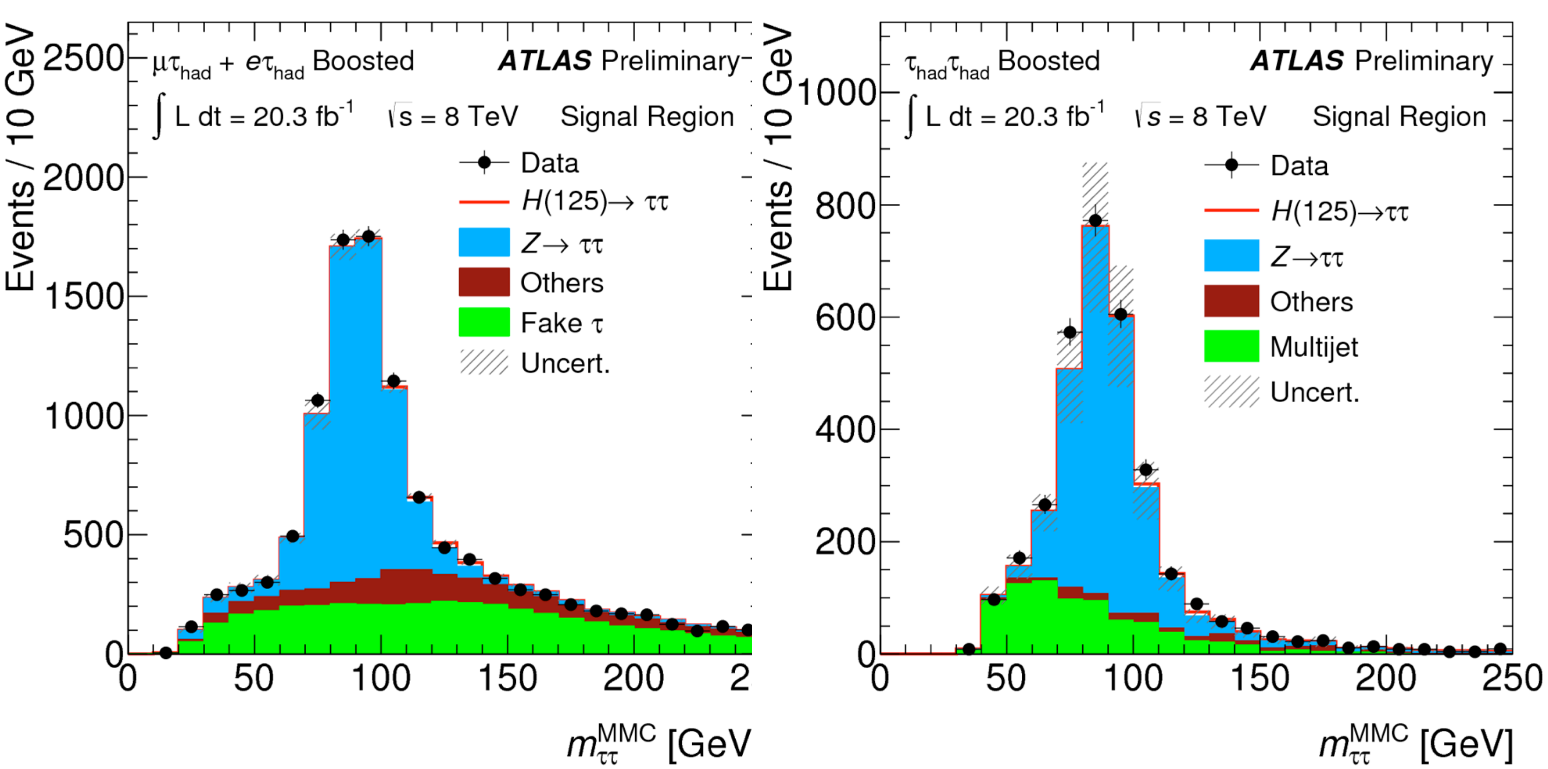
m_H=125 GeV
95% CL exclusion limit 1.4 (1.3) x SM
μ = 0.2 ± 0.5 (stat) ± 0.4 (syst)

H→ττ

- Most promising channel for direct evidence of lepton Yukawa couplings
- Search in three sub-channels
  - $\tau_{lep}\tau_{lep}$ BR~12% → 2 leptons
  - $\tau_{lep}\tau_{had}$ BR ~46% → 1 lepton
  - $\tau_{had}\tau_{had}$ BR~42% → 0 lepton
- Backgrounds
  - Z → ττ dominant estimated from data using the embedding technique
  - “Fakes”: Multijet, W+jets, top from dta
  - “Other”: Diboson produciton and H->WW* from MC



ep_T = 56 GeV, τ_{had} p_T = 27 GeV, MET=113 GeV, $m_{j1,j2}$=1.53 TeV, $m_{\tau\tau}^{MMC}$=129 GeV, BDT score = 0.99. S/B ratio of this bin 1.0



- MVA with Boosted Decision Trees
- Variables include:
  - properties of the di-tau system
    $m_{\tau\tau}$, $\Delta R_{\tau\tau}$, ...
  - jet topology,
    m_{jj}, $\Delta\eta_{jj}$, ...
  - event activity/topoly
    scalar and vector pT sum, object centralities, ...

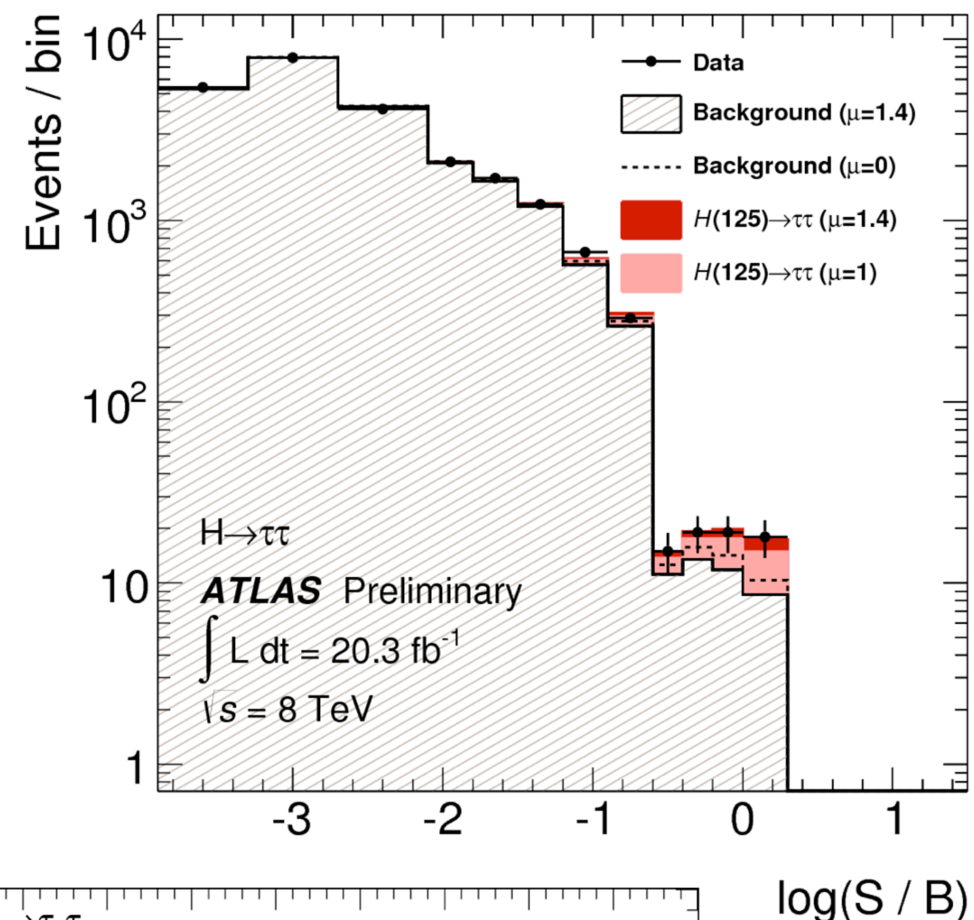
Two categories for each final state:
- VBF : 2 jets with large Δη
- Boosted: events failing the VBF category, but with large di-tau pT

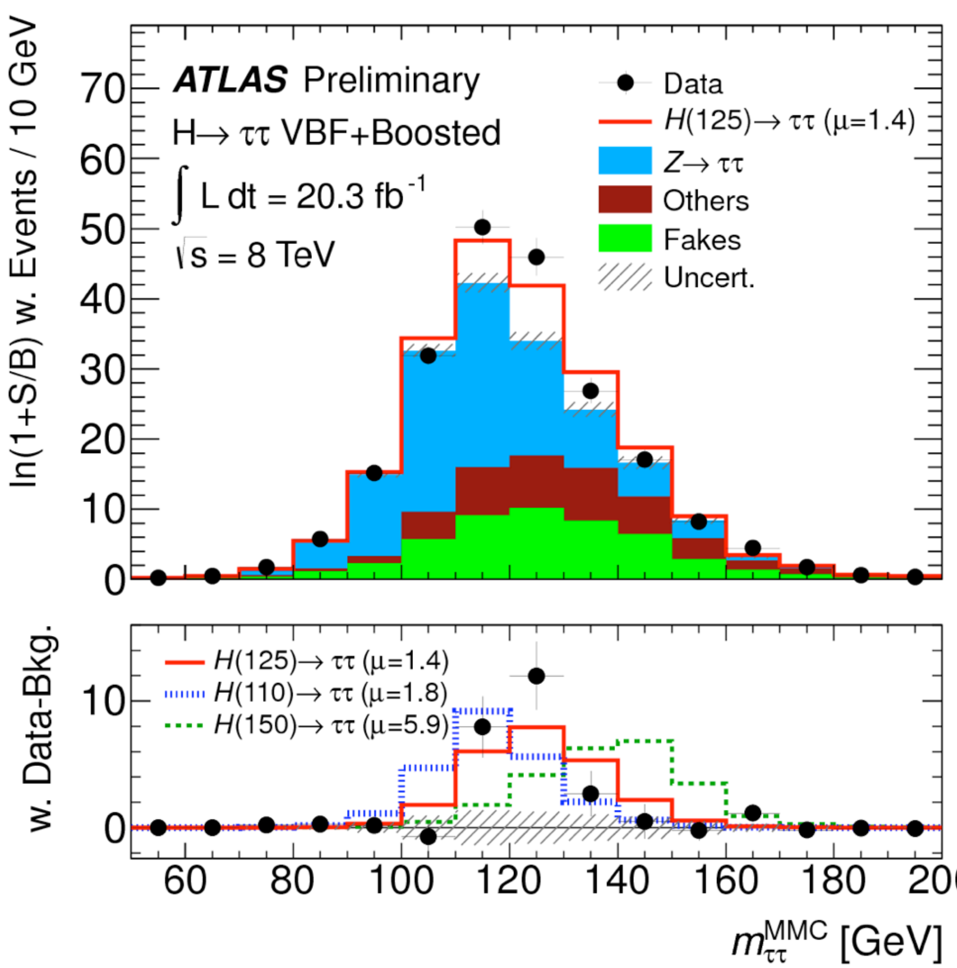
Evidence observed for Higgs boson decays to τ-leptons with significance of 4.1σ (3.2σ)

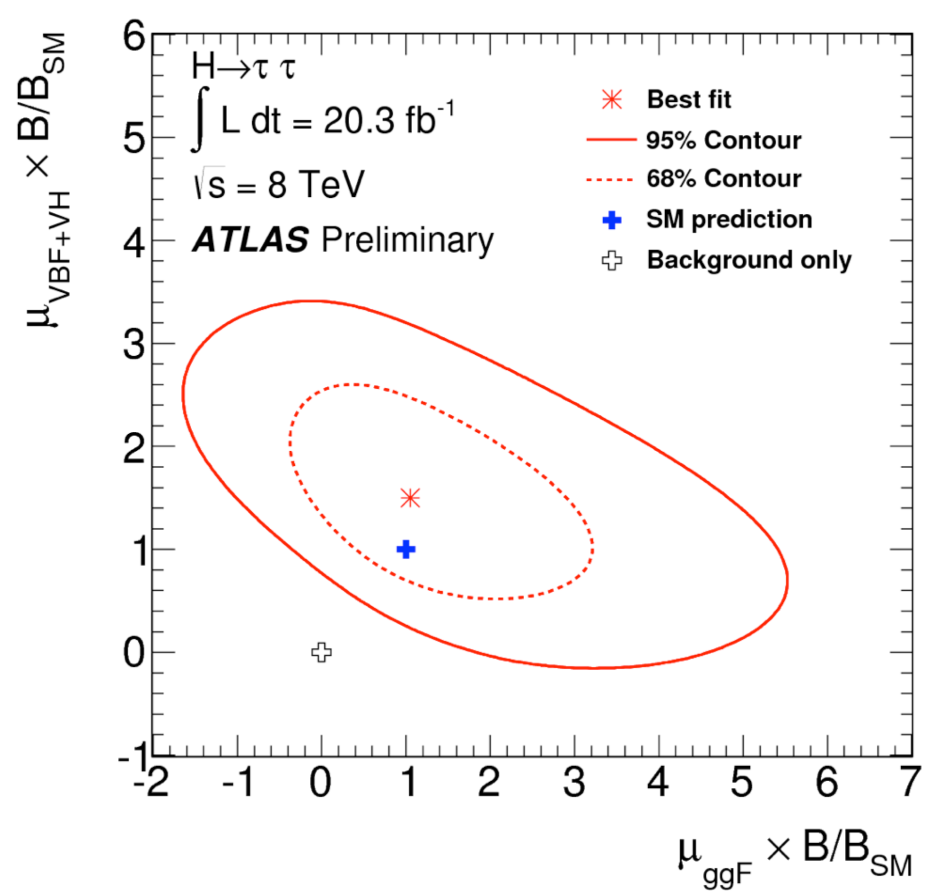
- Signal Strength (m_H=125 GeV):

  $$\mu = 1.43^{+0.31}_{-0.29}(\mathrm{stat})^{+0.41}_{-0.30}(\mathrm{syst})$$

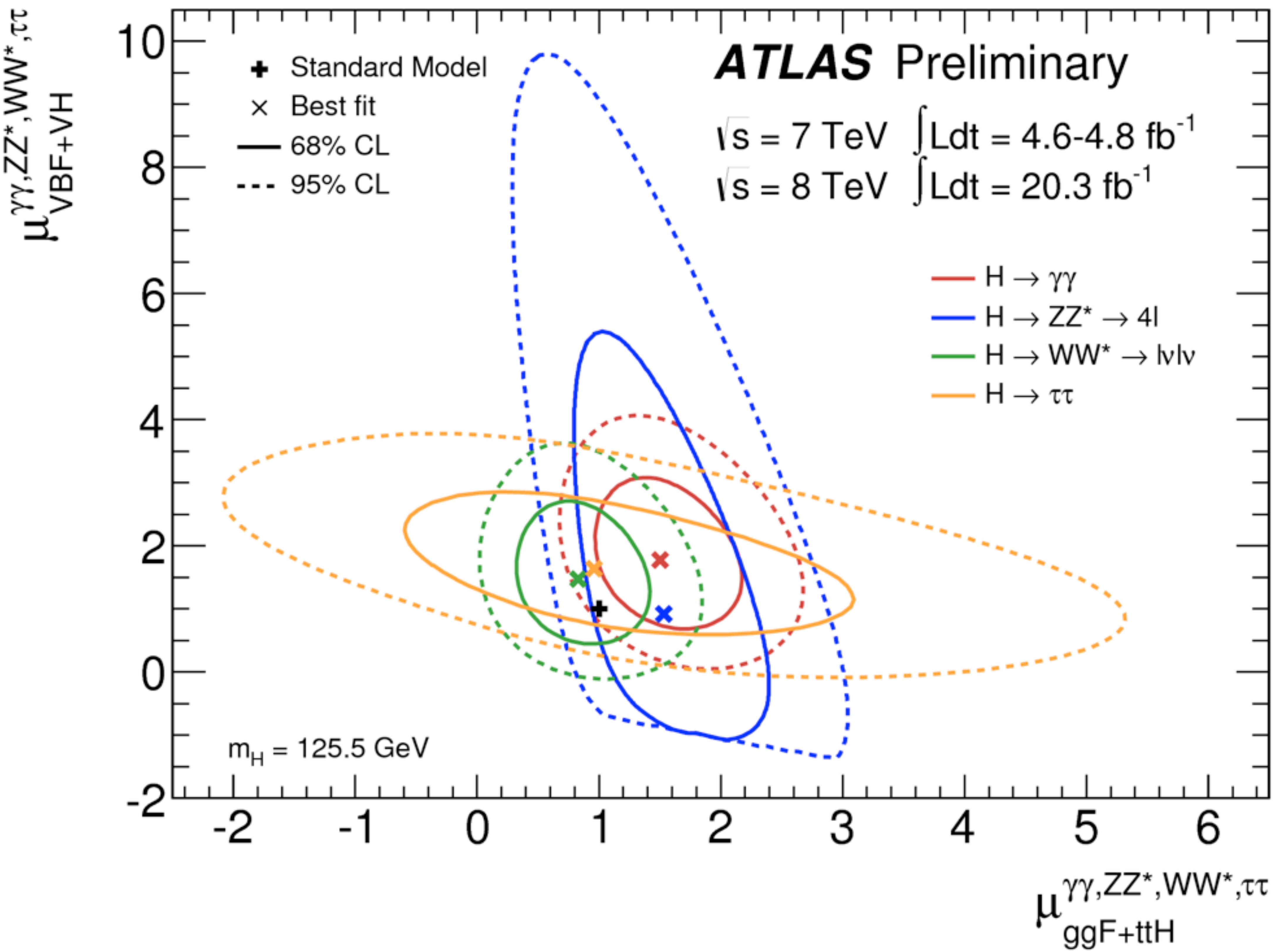
- in agreement with SM expectation



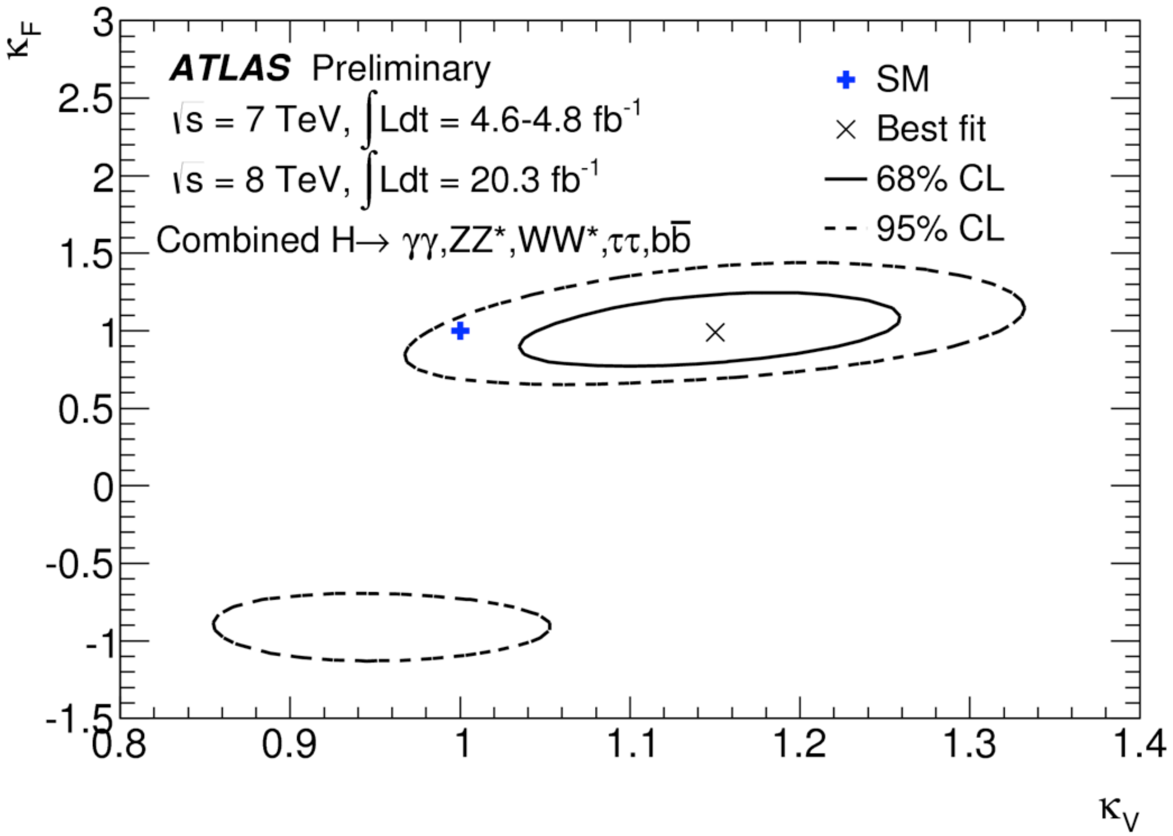


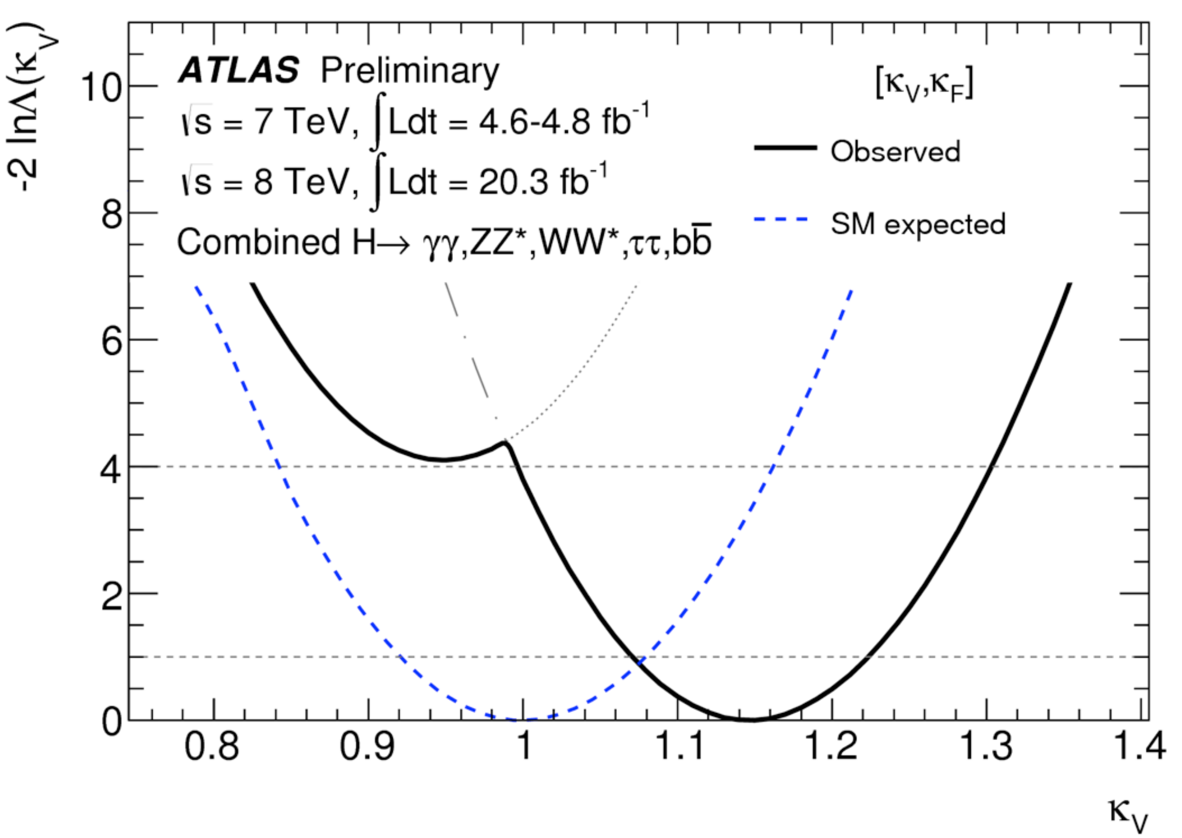


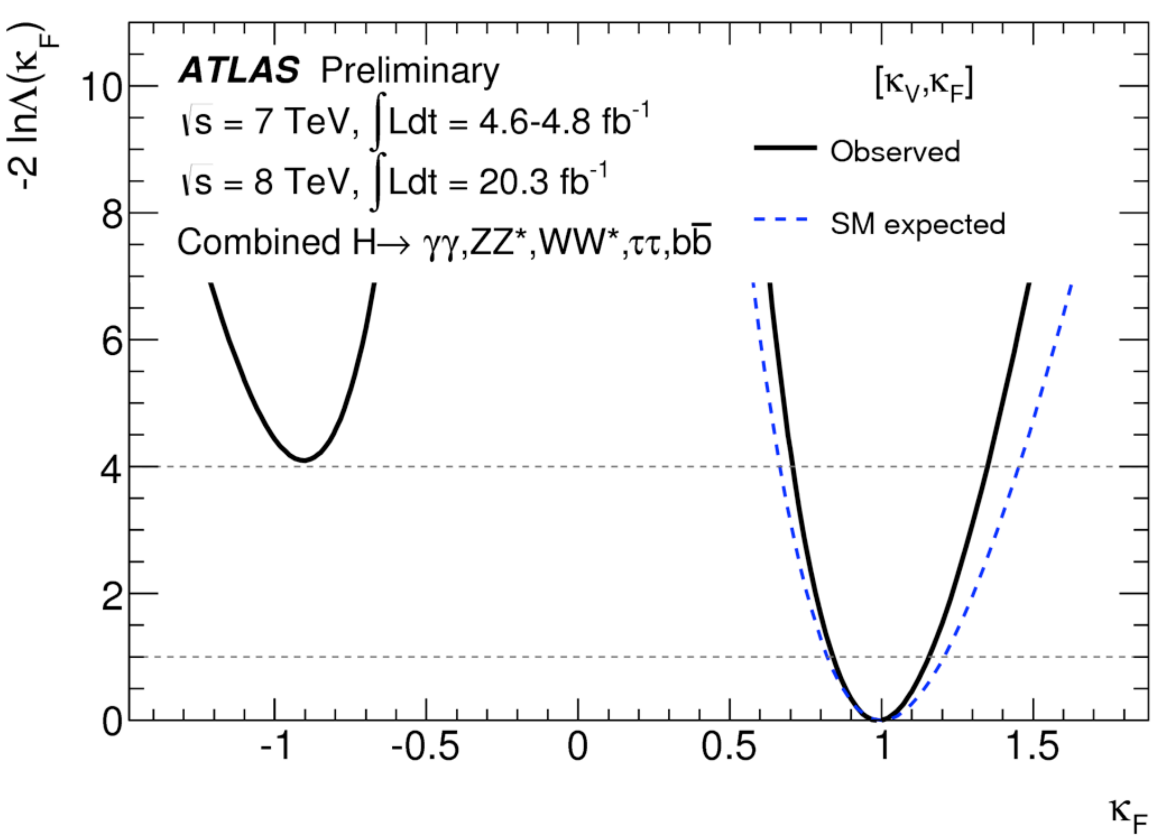
Production Mechanisms



Higgs boson couplings







Spin/CP

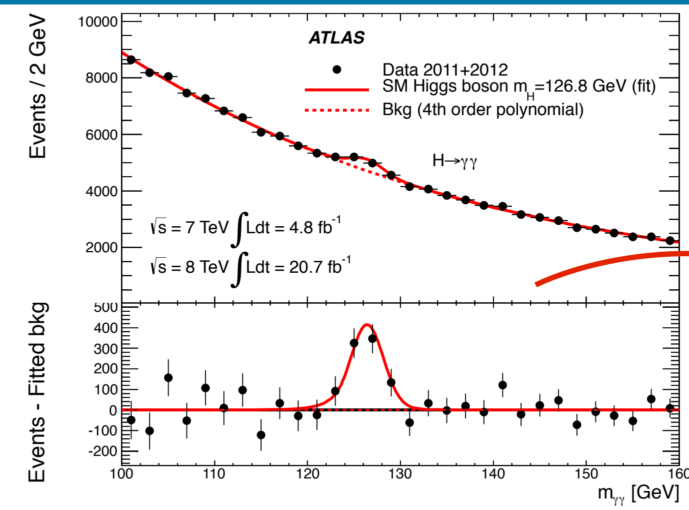
Find observables sensitive to spin and parity, build discriminants and separate between pure spin/CP hypotheses.
For hypothesis testing, only kinematics used. No rate information.

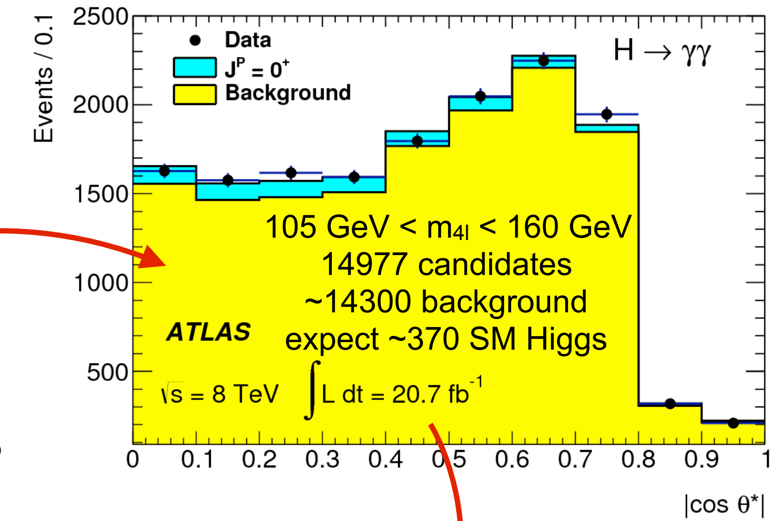
Channel	$H \to ZZ^{(*)} \to 4\ell$	$H \to WW^{(*)} \to \ell\nu\ell\nu$	$H \to \gamma\gamma$
Dataset	$20.7\ \mathrm{fb}^{-1}$ @ 8 TeV $4.8\ \mathrm{fb}^{-1}$ @ 7 TeV	$20.7\ \mathrm{fb}^{-1}$ @ 8 TeV	$20.7\ \mathrm{fb}^{-1}$ @ 8 TeV
Reference	ATLAS-CONF-2013-013	ATLAS-CONF-2013-031	ATLAS-CONF-2013-029
0^-	✓	-	-
1^+	✓	✓	-
1^-	✓	✓	-
2^+	✓	✓	✓

- Spin Combination: ZZ+WW+γγ
  - ATLAS-CONF-2013-040
  - Phys. Lett. B 726 (2013), pp. 120-144

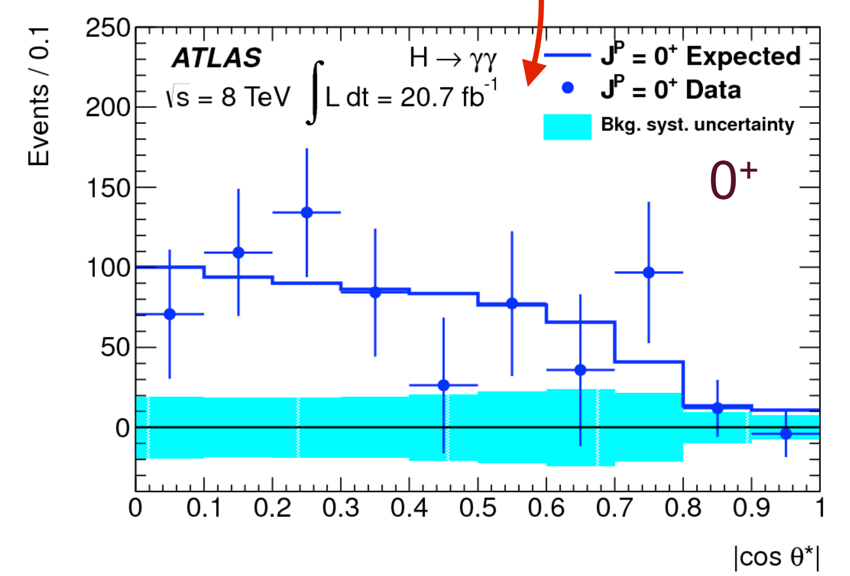
H→γγ Spin

- Discriminating variable:
polar angle of γ wrt z-axis of the Collins-Soper frame (minimize effect of ISR)
- Analysis similar to "rate/mass" analysis
    - $p_{T\gamma 1} > 0.35\ m_{\gamma\gamma}$ and $p_{T\gamma 2} > 0.25\ m_{\gamma\gamma}$
    [Minimize $m_{\gamma\gamma}$ and cosθ* correlations for background]
- H→γγ is a low S/B final state (inclusive ~3%)
    - Simultaneous fit
        $m_{\gamma\gamma}$ and |cosθ*| in signal region
        $m_{\gamma\gamma}$ in side-bands

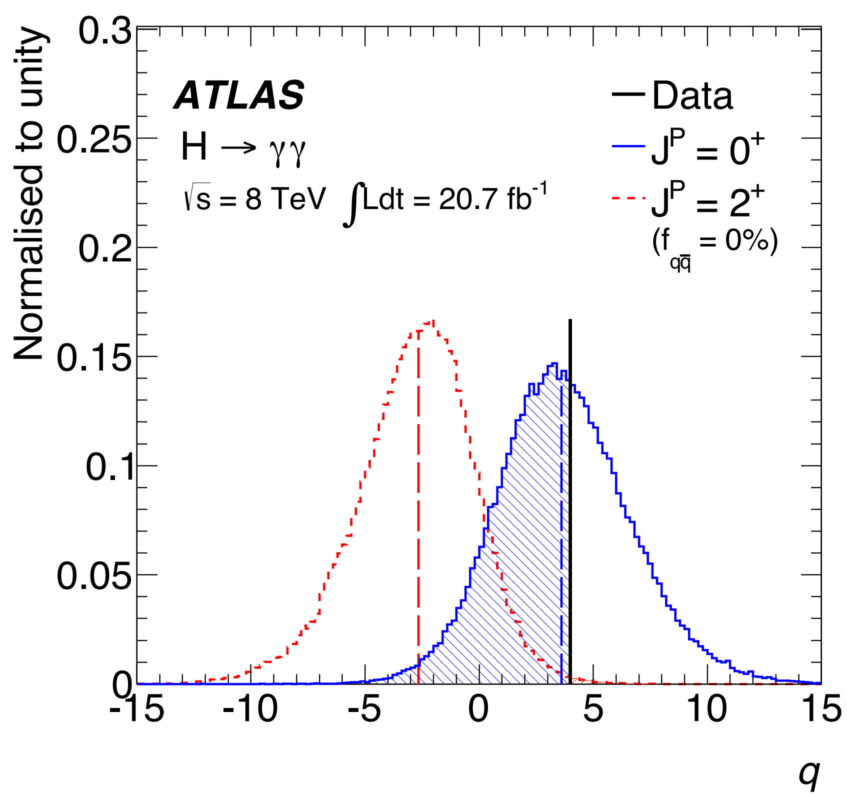


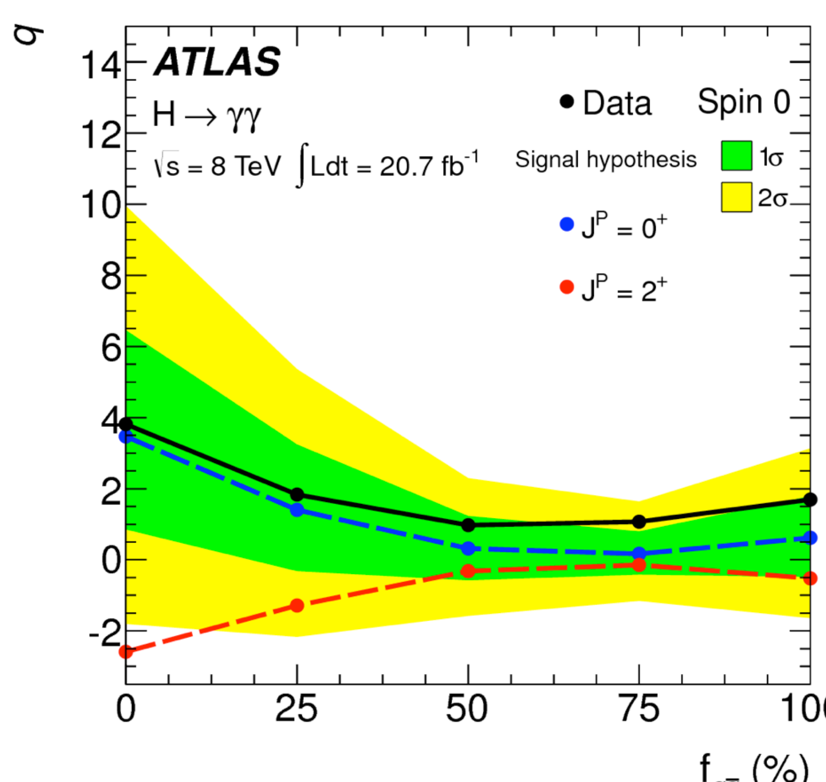


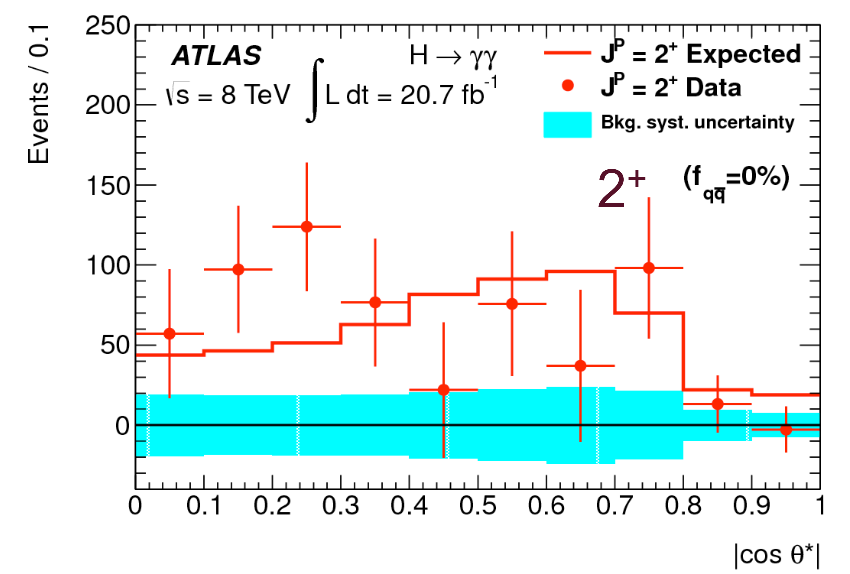
$$|\cos\theta^*| = \frac{|\sinh(\Delta\eta^{\gamma\gamma})|}{\sqrt{1+(p_T^{\gamma\gamma}/m_{\gamma\gamma})^2}} \frac{2p_T^{\gamma 1}p_T^{\gamma 2}}{m_{\gamma\gamma}^2}$$



The 2^+ hypothesis is disfavored with respect to the 0^+ hypothesis.

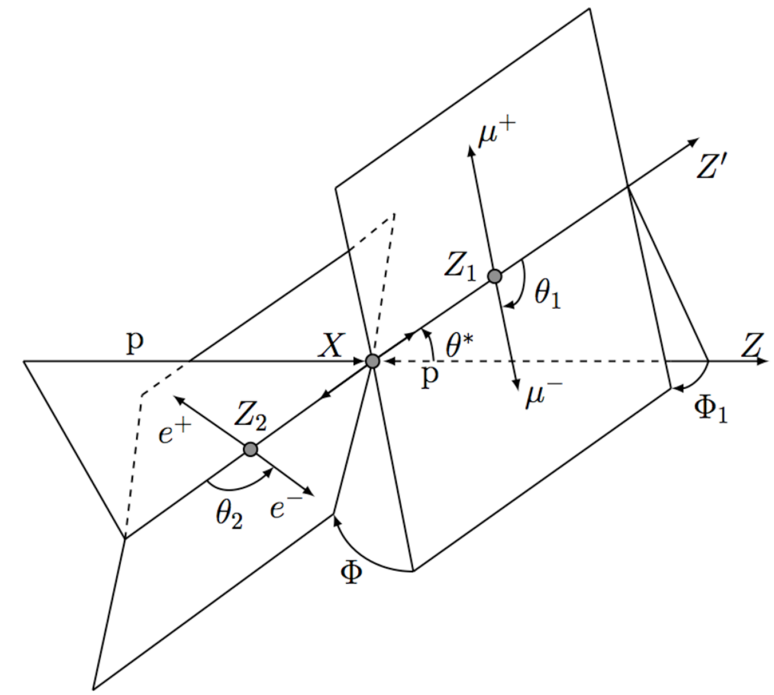






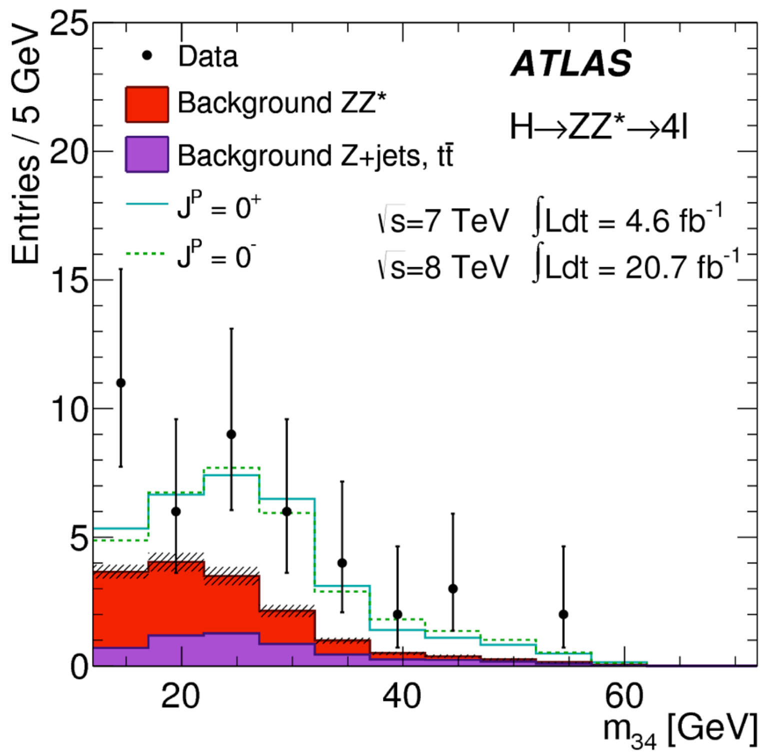
H→ZZ→4l Spin/CP

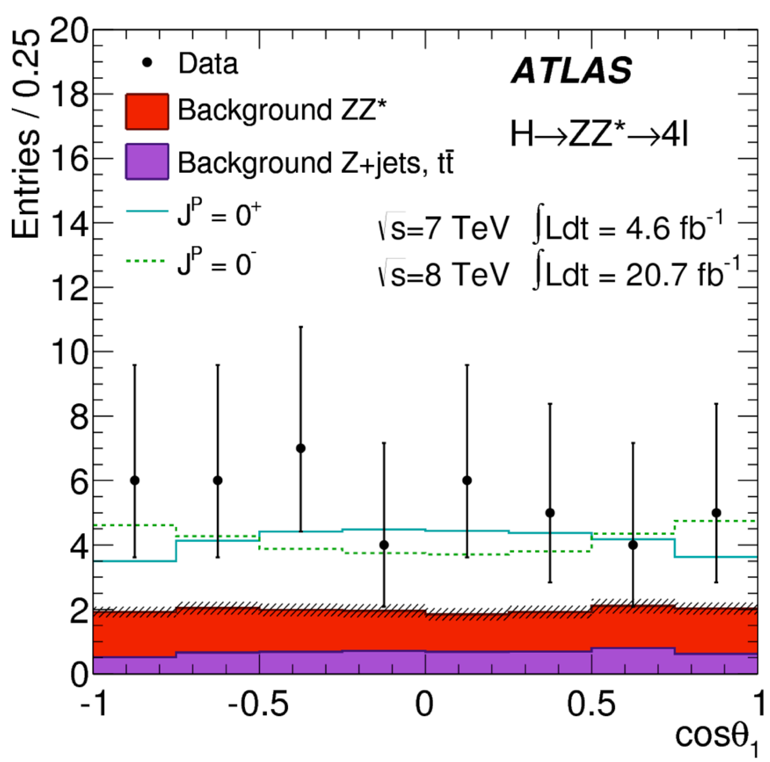
Ideal channel for spin/CP studies
- High S/B
- Complete event reconstruction
- Several spin/CP-sensitive observables available



5 production angles and
2 di-lepton invariant masses

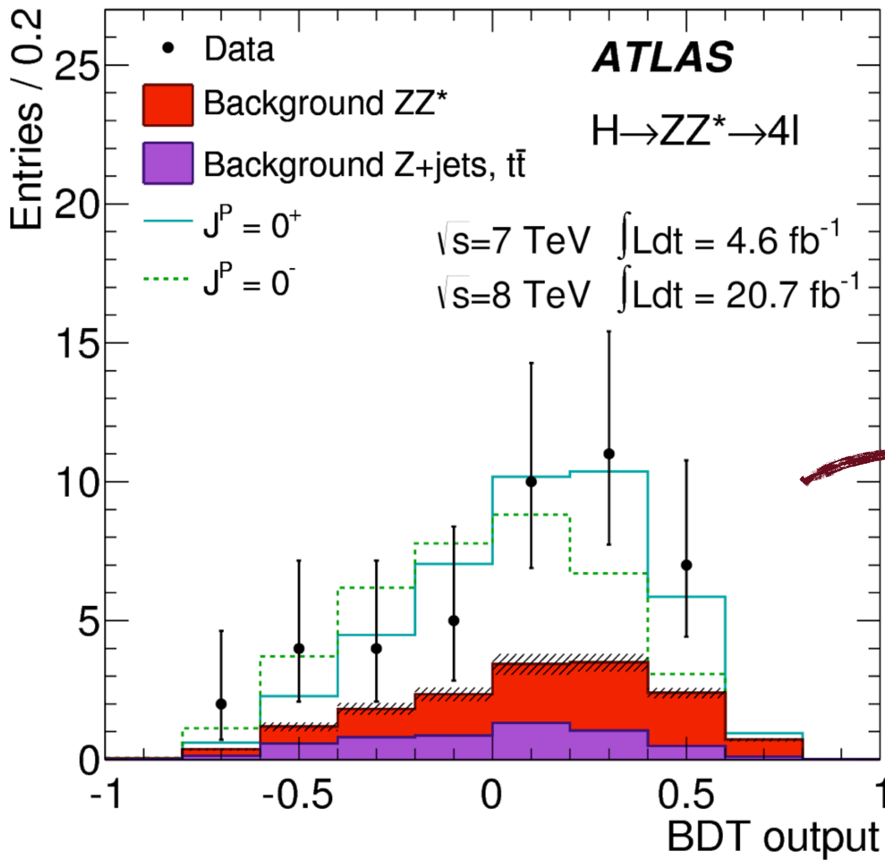
Two approaches:
- Separate BDT for each hypothesis
- ME corrected for acceptance/pairing effects

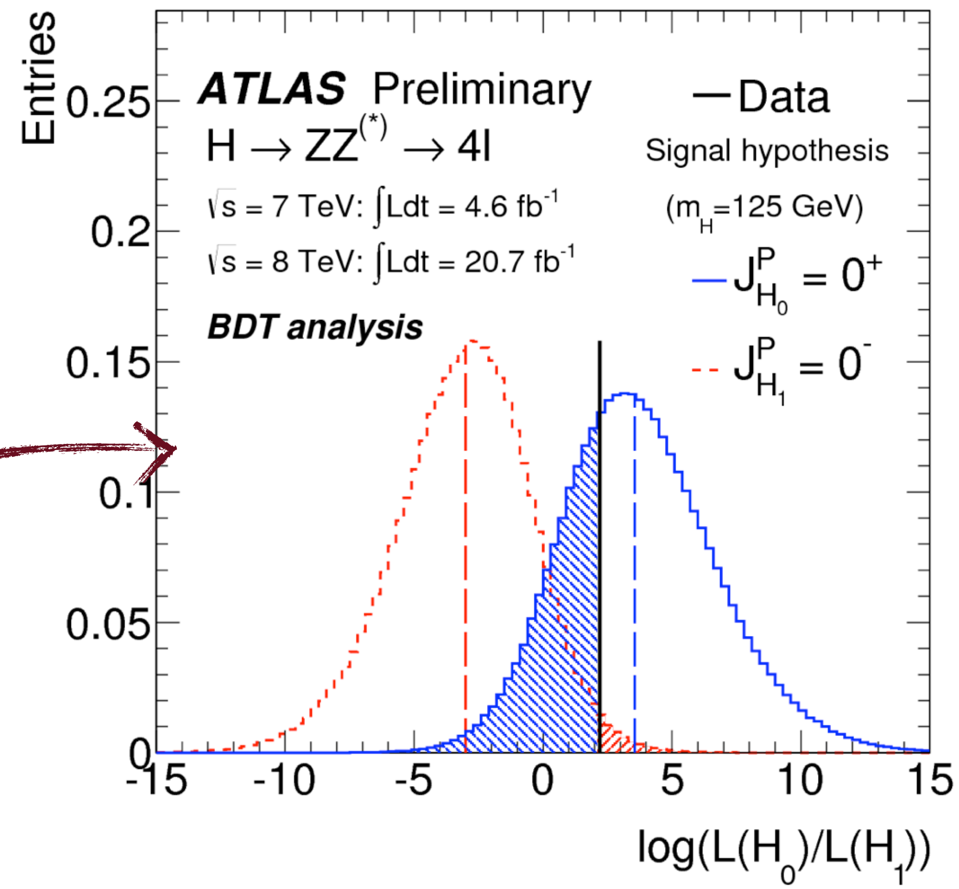




For 115 GeV < m_{4l} < 130 GeV
43 candidate events
16 background events
expect 18 SM Higgs events

H→ZZ→4l Spin/CP



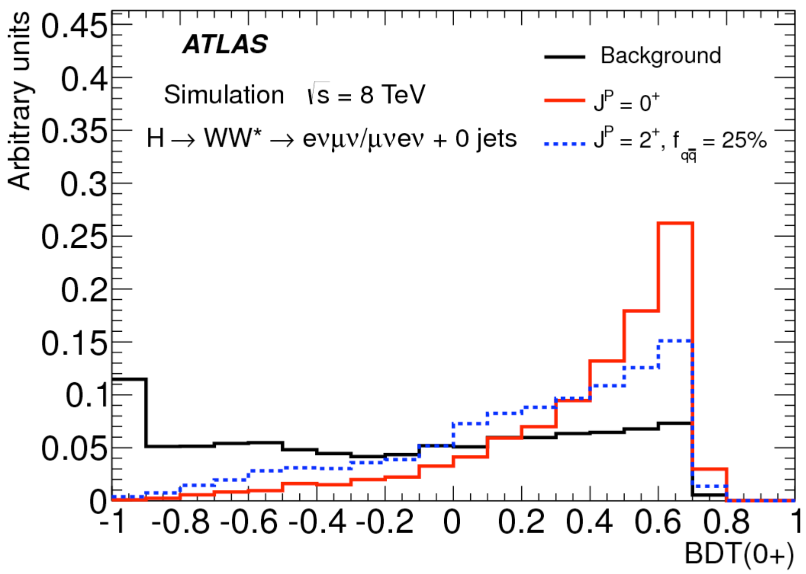


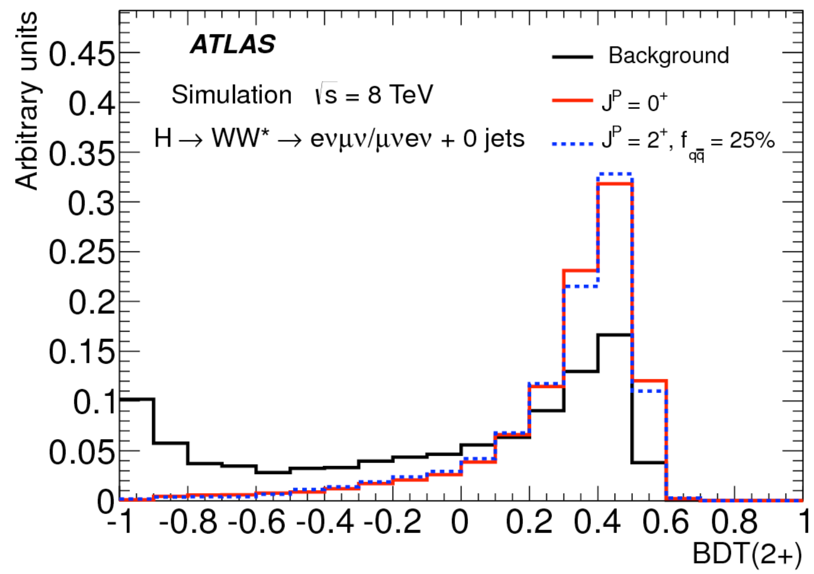
	CL	J^{CP}
Spin-0	97.8%	0^-
Spin-1	94.0%	1^-
	99.8%	1^+
Spin-2	97.4%	2^+ 100% qq
	96.1%	2^+ 75% qq
	96.5%	2^+ 50% qq
	96.4%	2^+ 25% qq
	83.1%	2^+ 0% qq

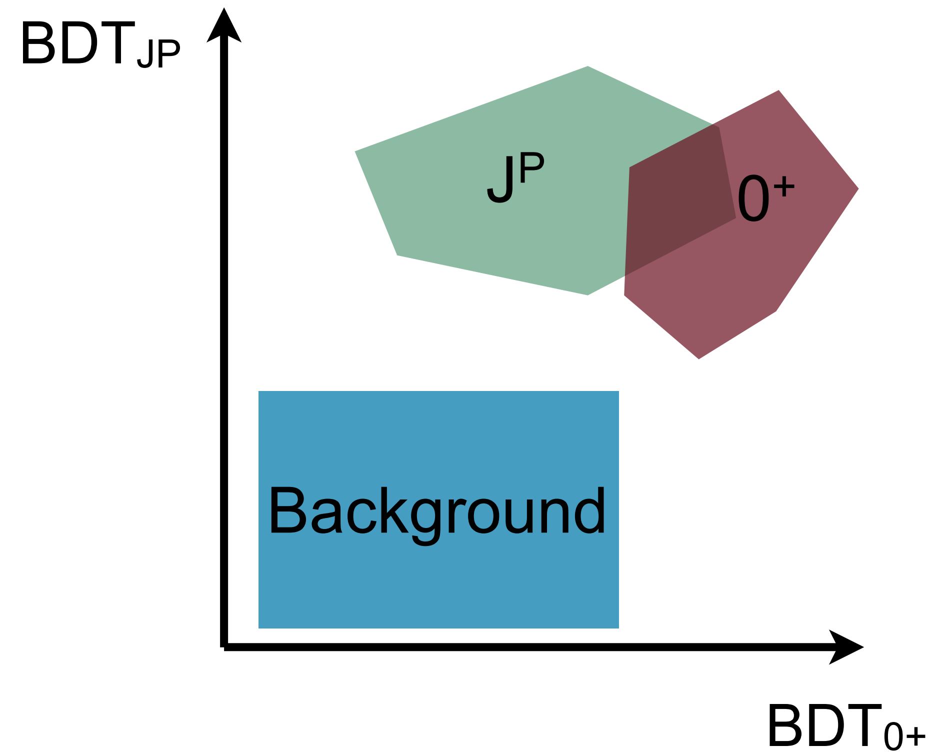
All studied alternative hypotheses disfavored wrt the 0^+ hypothesis.

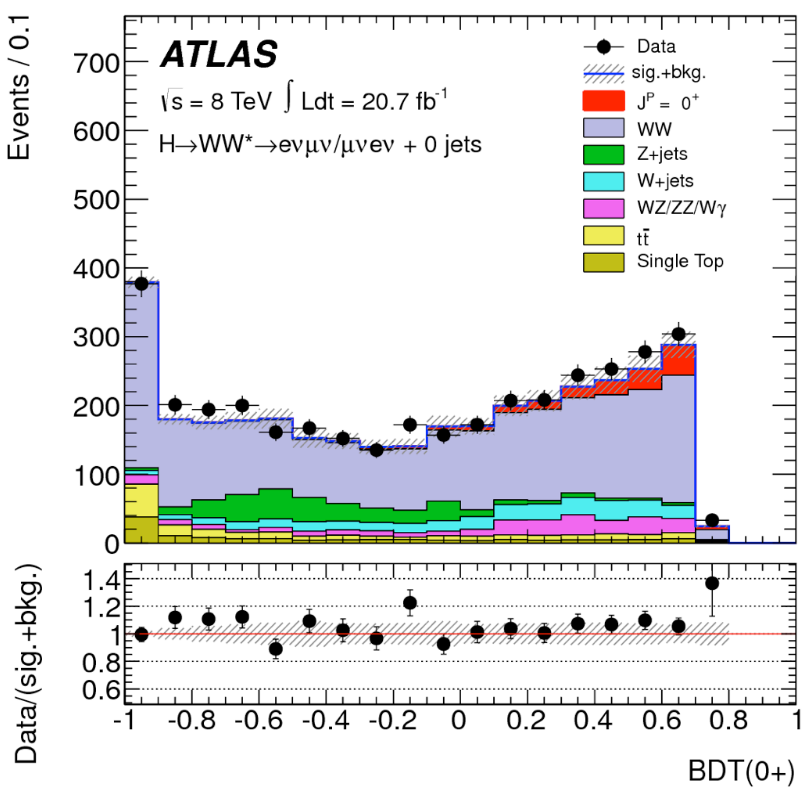
H→WW→lνlν Spin

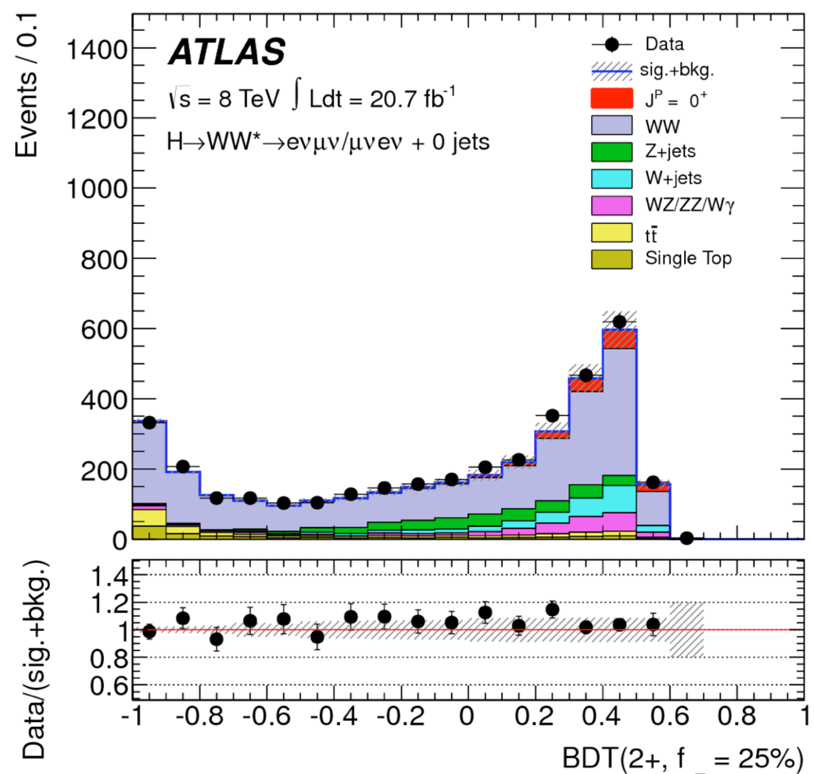
- Restricted to “different flavour” (eμ) events and no jets
- Rate analysis already exploits spin-0 nature of SM Higgs boson
    - Relax spin-sensitive requirements, while keeping background under control
- m_{ll}, $\Delta\varphi_{ll}$, p_{Tll}, m_T sensitive to spin











Two BDT classifiers are used:
- BDT_{0+}: SM Higgs signal against the sum of all backgrounds
- BDT_{JP}: J^P signal against the sum of all backgrounds
- Perform 2D-fit in (BDT_{0+},BDT_{JP})

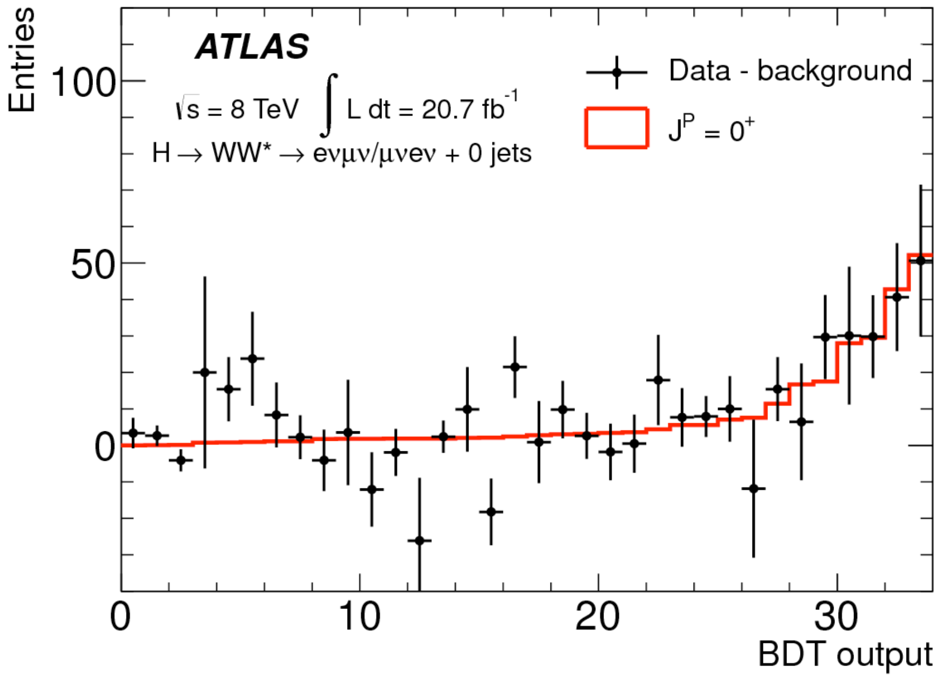
pT spectrum uncertainties found to have small effect

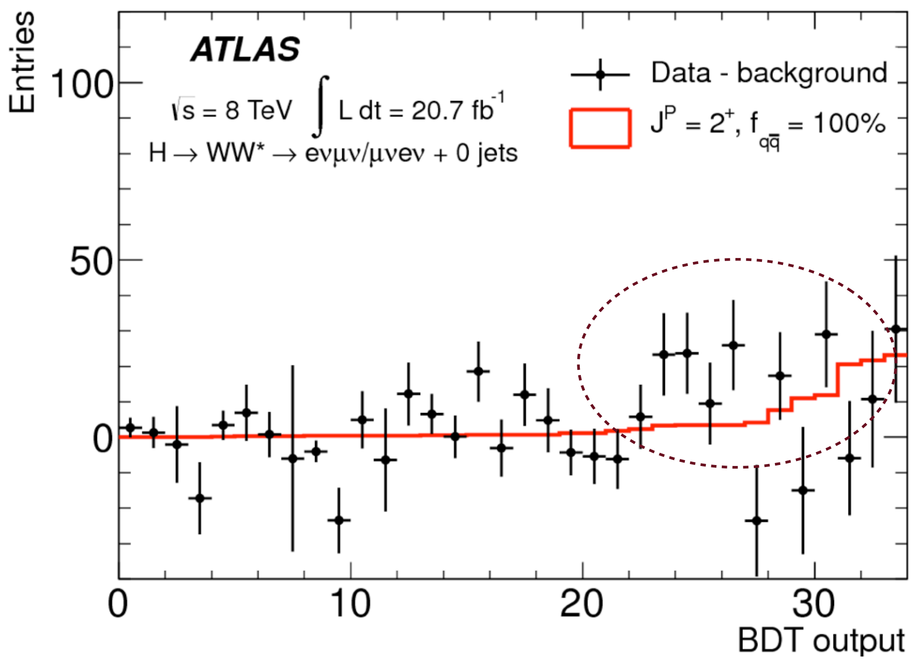
H→WW→lνlν Spin

Visualization of the results in the post-fit background-subtracted plots.

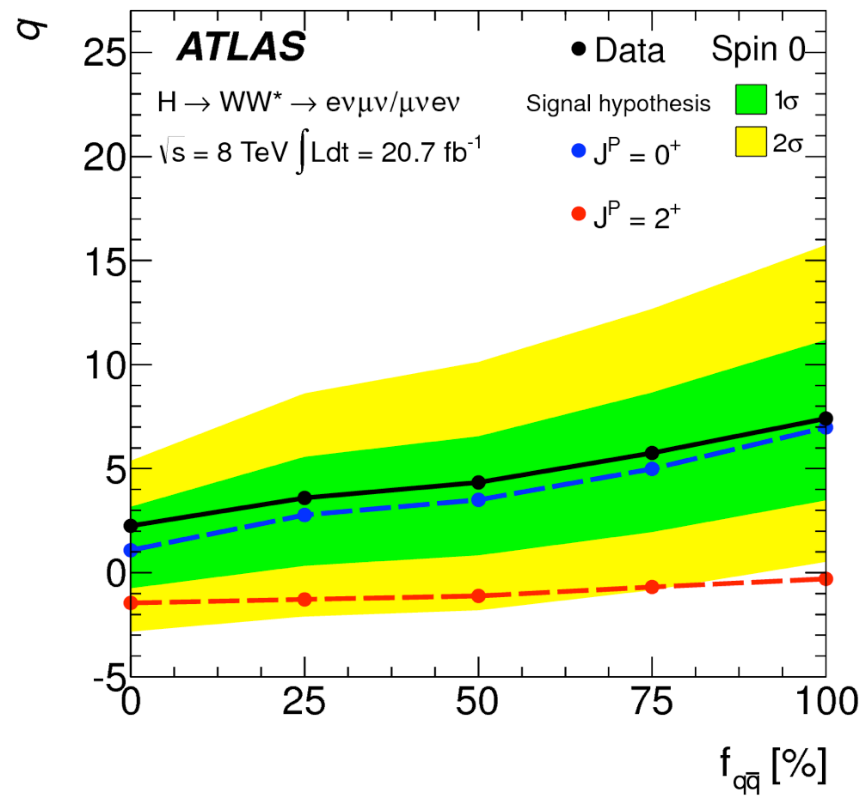
The (BDT_0,BDT_{JP}) distribution is remapped into an 1D distribution by ordering the bins by increasing expected signal. Empty bins (expected content <0.1) are removed.

Data more consistent with spin-0 with respect to spin-2





All studied alternative hypotheses are disfavored with respect to the 0^+ hypothesis.

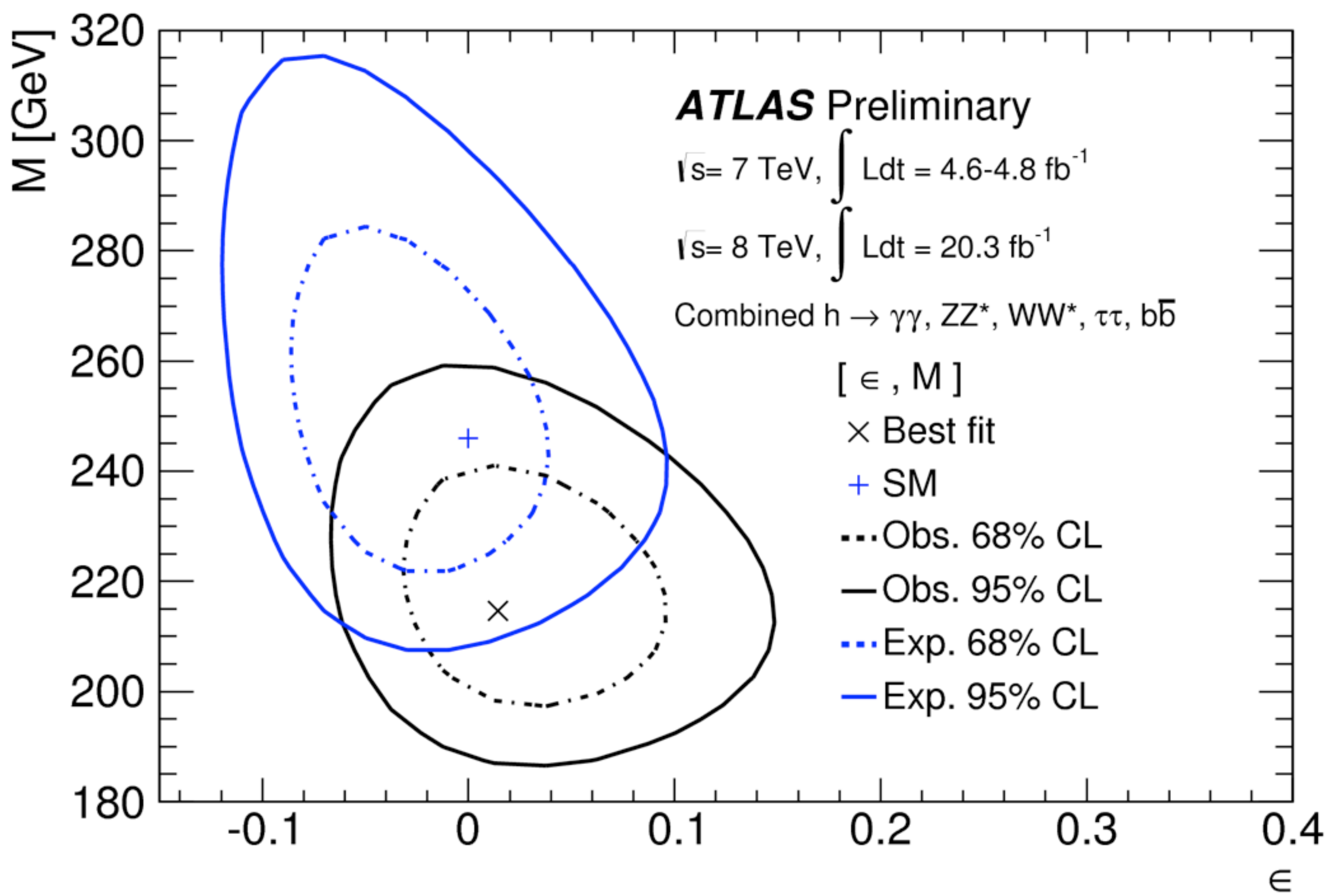


Mass Scaling of Higgs boson couplings

$$\kappa_{f,i} = v\frac{m_{f,i}^{\epsilon}}{M^{1+\epsilon}}$$

$$\kappa_{V,j} = v\frac{m_{V,j}^{2\epsilon}}{M^{1+2\epsilon}}$$

ε → mass scaling parameter
M→ VEV parameter



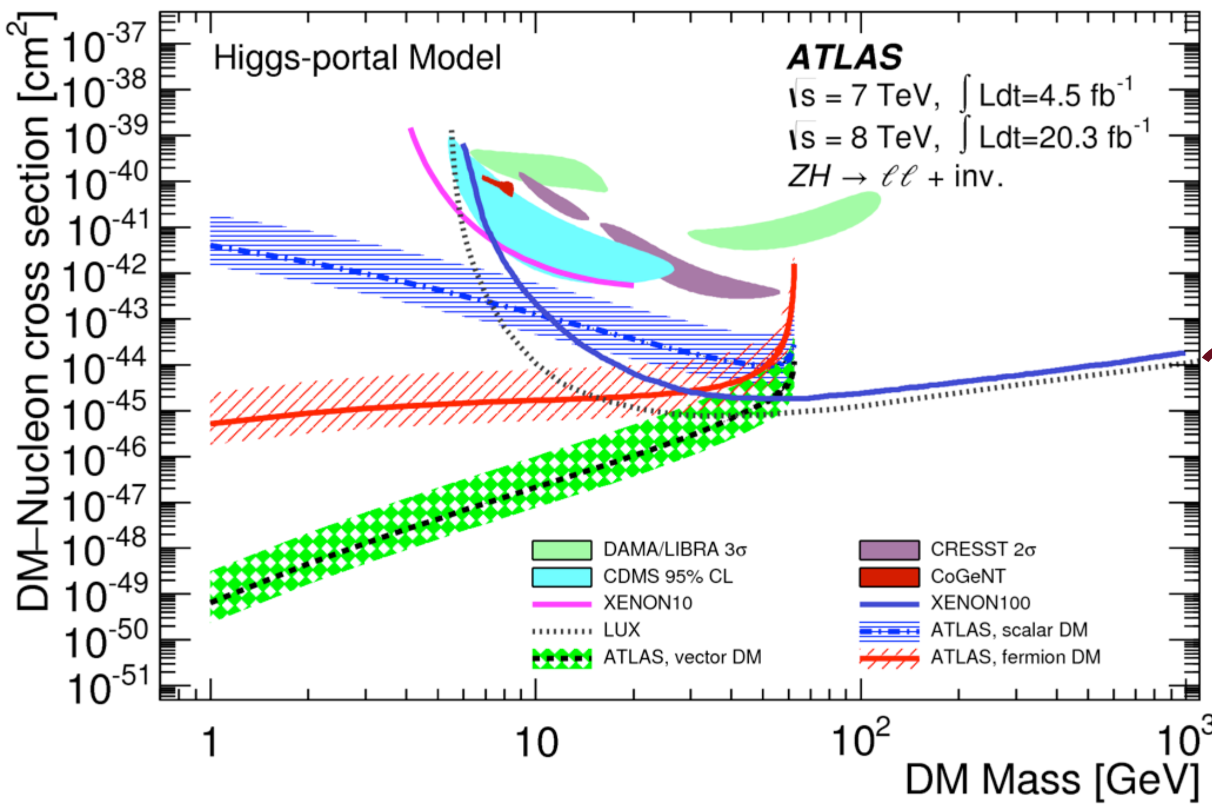
This parameterization (purely phenomenological) addresses explicitly the extent to which the H particle resembles a quantum excitation of the Englert-Brout-Higgs field that is thought to give masses to the particles of the Standard Model

Compatibility with SM @1.5σ

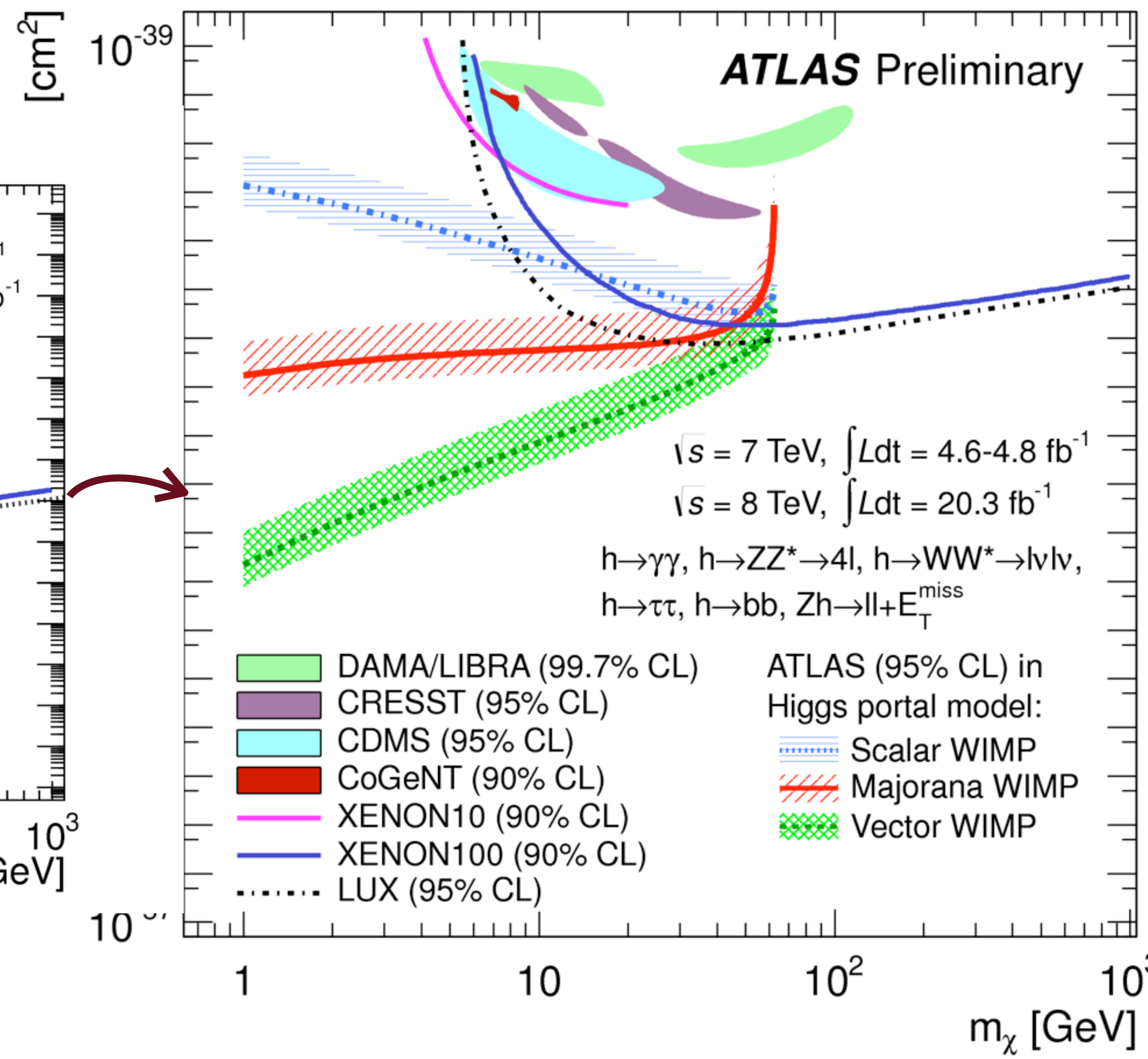
ZH(→inv)

Data Period	2011 (7 TeV)	2012 (8 TeV)
$ZZ \to \ell\ell\nu\nu$	$20.0 \pm 0.7 \pm 1.6$	$91 \pm 1 \pm 7$
$WZ \to \ell\nu\ell\ell$	$4.8 \pm 0.3 \pm 0.5$	$26 \pm 1 \pm 3$
Dileptonic $t\bar{t}$, Wt, WW, $Z \to \tau\tau$	$0.5 \pm 0.4 \pm 0.1$	$20 \pm 3 \pm 5$
$Z \to ee$, $Z \to \mu\mu$	$0.13 \pm 0.12 \pm 0.07$	$0.9 \pm 0.3 \pm 0.5$
W + jets, multijet, semileptonic top	$0.020 \pm 0.005 \pm 0.008$	$0.29 \pm 0.02 \pm 0.06$
Total background	$25.4 \pm 0.8 \pm 1.7$	$138 \pm 4 \pm 9$
Signal ($m_H = 125.5$ GeV, $\sigma_{\mathrm{SM}}(ZH)$, BR($H \to$ inv.) = 1)	$8.9 \pm 0.1 \pm 0.5$	$44 \pm 1 \pm 3$
Observed	28	152

Dark Matter



Higgs-portal Model
ATLAS
√s = 7 TeV, ∫Ldt=4.5 fb⁻¹
√s = 8 TeV, ∫Ldt=20.3 fb⁻¹
ZH → ℓℓ + inv.
DAMA/LIBRA 3σ
CDMS 95% CL
XENON10
LUX
ATLAS, vector DM
CRESST 2σ
CoGeNT
XENON100
ATLAS, scalar DM
ATLAS, fermion DM
DM–Nucleon cross section [cm²]
DM Mass [GeV]



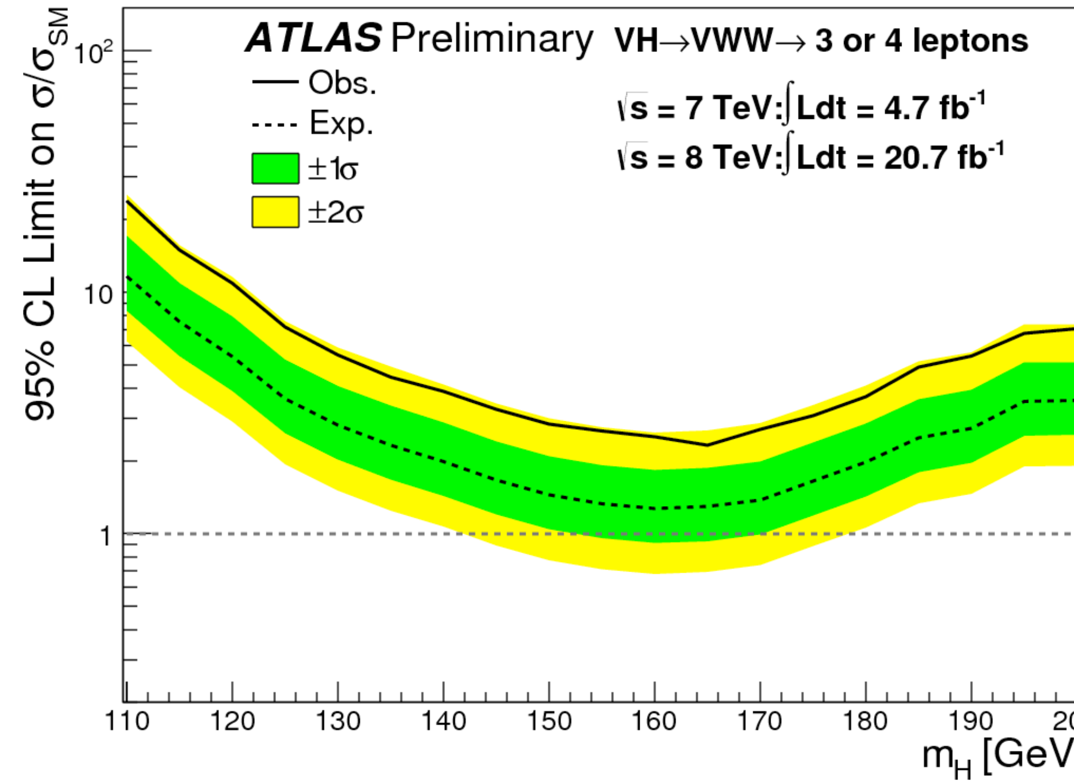
ATLAS Preliminary
√s = 7 TeV, ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV, ∫Ldt = 20.3 fb⁻¹
h→γγ, h→ZZ*→4l, h→WW*→lνlν,
h→ττ, h→bb, Zh→ll+E_T^miss
DAMA/LIBRA (99.7% CL)
CRESST (95% CL)
CDMS (95% CL)
CoGeNT (90% CL)
XENON10 (90% CL)
XENON100 (90% CL)
LUX (95% CL)
ATLAS (95% CL) in
Higgs portal model:
Scalar WIMP
Majorana WIMP
Vector WIMP
[cm²]
m_χ [GeV]

"Exclusive" Higgs boson final states

VH(→WW)

ATLAS-CONF-2013-075

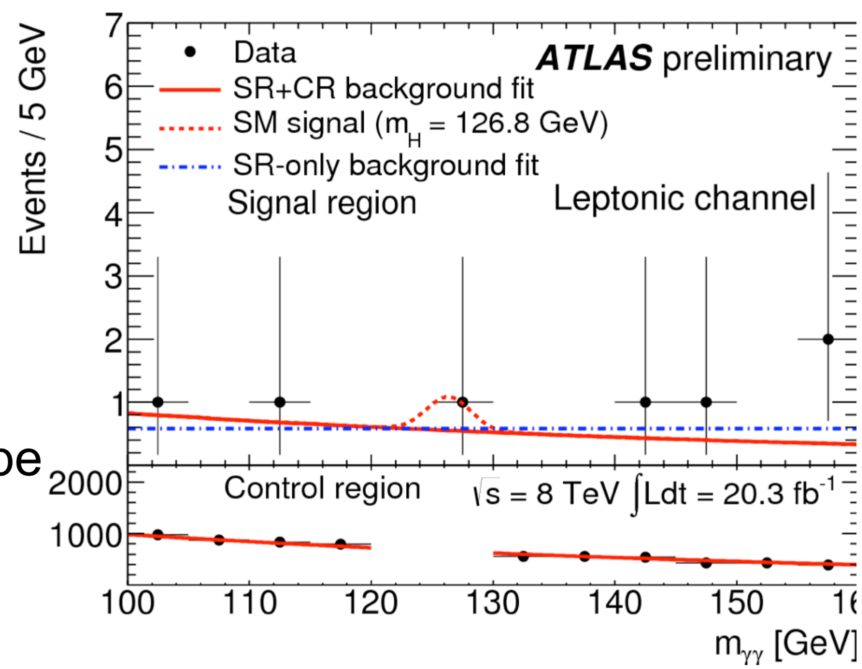
- Analysis designed to select VH(→WW)
- 3 lepton final state
  - WH→WWW→lvlvlv
  - 3 leptons, $|\Sigma Q|=1$, 0 b-tags, m_{ll},MET, $\Delta\varphi_{ll}$
- 4 lepton final state
  - ZH→ZWW→lllvlv
  - 4 leptons, MET, 0 b-tags, m_{ll}
- Remove overlap with H→WW→lvlv analysis
- 95% CL upper limit on ttH production @m_H=125 GeV: 7.2 (3.6)xSM

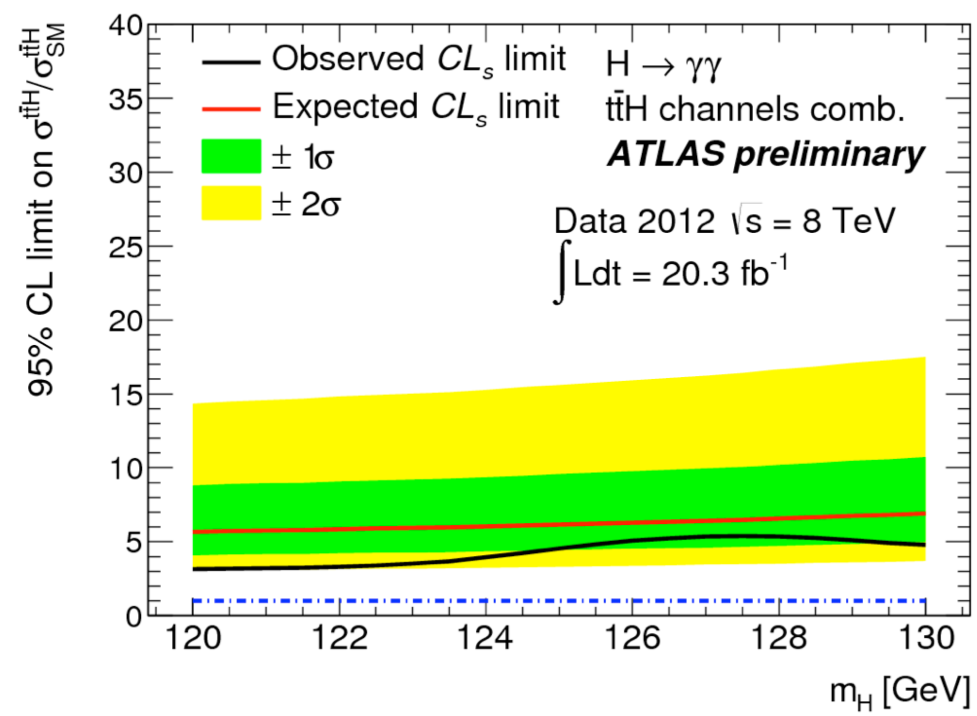


ttH(→γγ)

ATLAS-CONF-2013-080

- Two channels
  - Leptonic (single-/di-lepton tt)
    ≥ 1 lepton, ≥1 b-tag and MET>20
  - Hadronic
    ≥ 6 jets, ≥2 b-tags and 0 leptons
- Analysis procedure similar to H→γγ
  - Include CR to constrain BKG shape
- 95% CL upper limit on ttH production @m_H=126.8 GeV: 5.3 (6.4)xSM
- Also ttH(→bb) from 2011 dataset [ATLAS-CONF-2012-135]



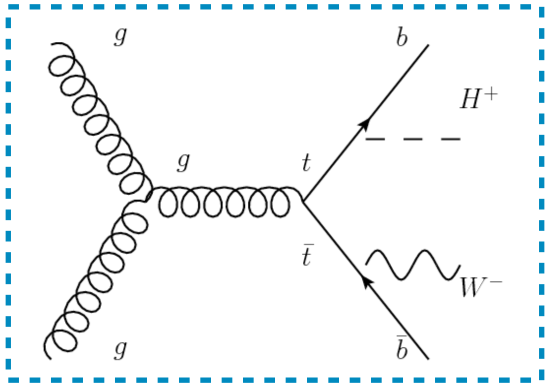


$H^{\pm}\to\tau\nu$

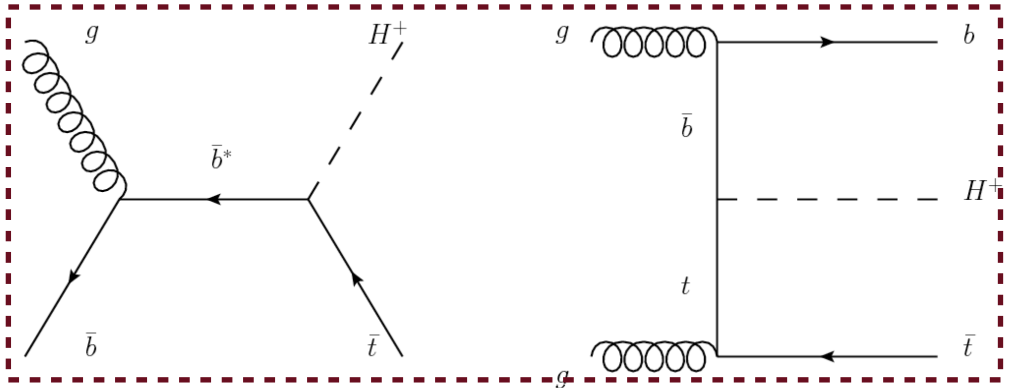
ATLAS-CONF-2013-090

- Search for $H^{\pm}\to\tau\nu$
- Production depends on m_{H+}
- Observation means New Physics!

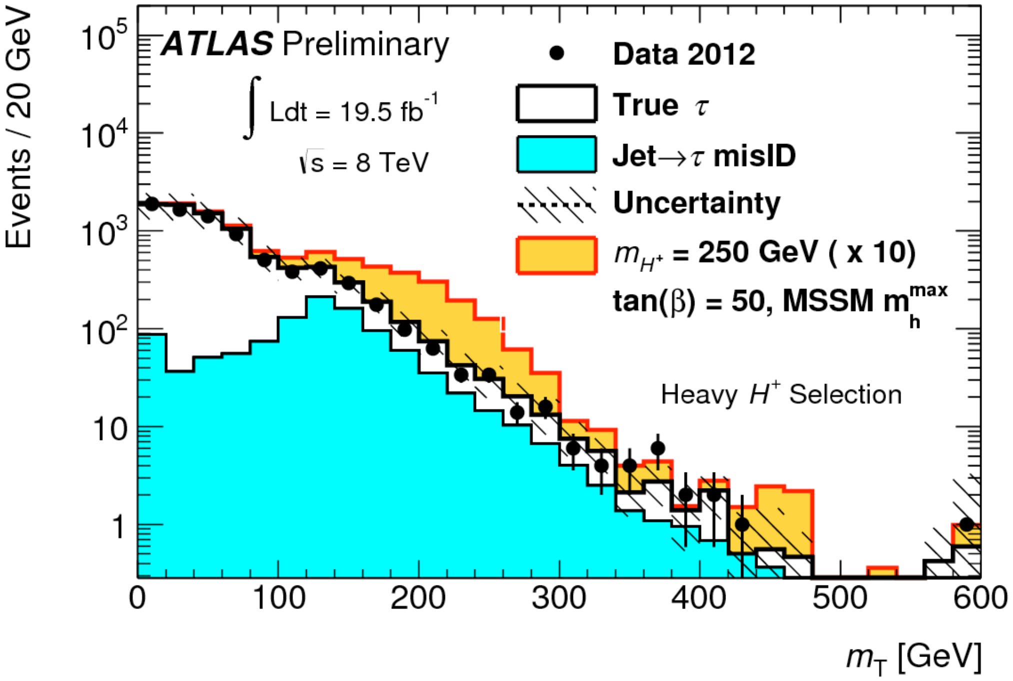
Signature : $Z\to e^+e^-/\mu^+\mu^-$ + large MET
Main Backgrounds: $ZZ\to ll\nu\nu$, $WZ\to l\nu ll$, $WW\to l\nu l\nu$
Signal Contributions from

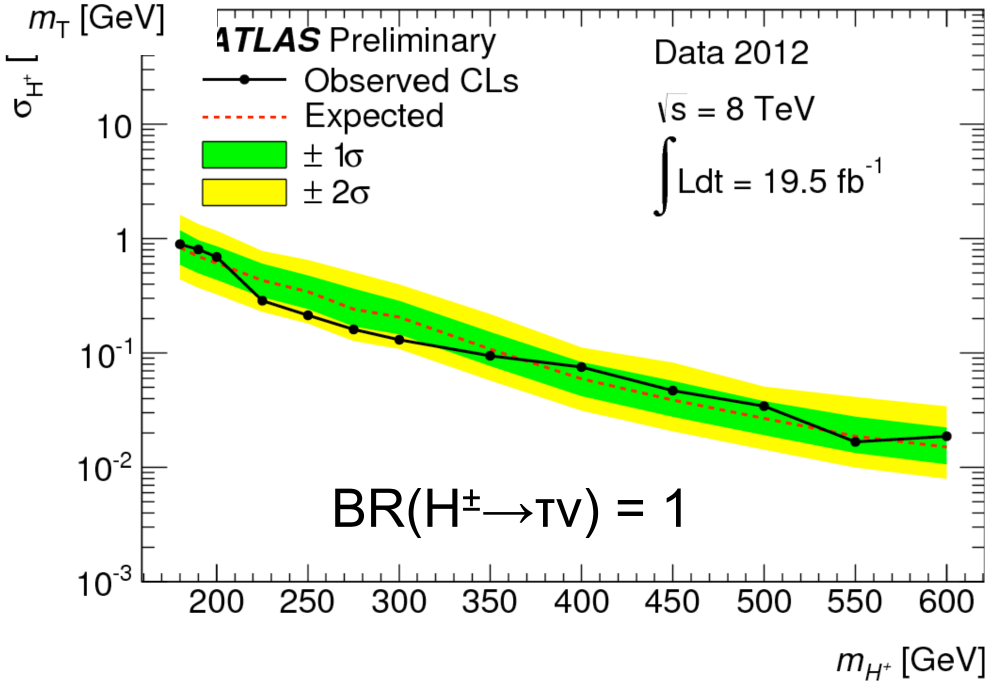


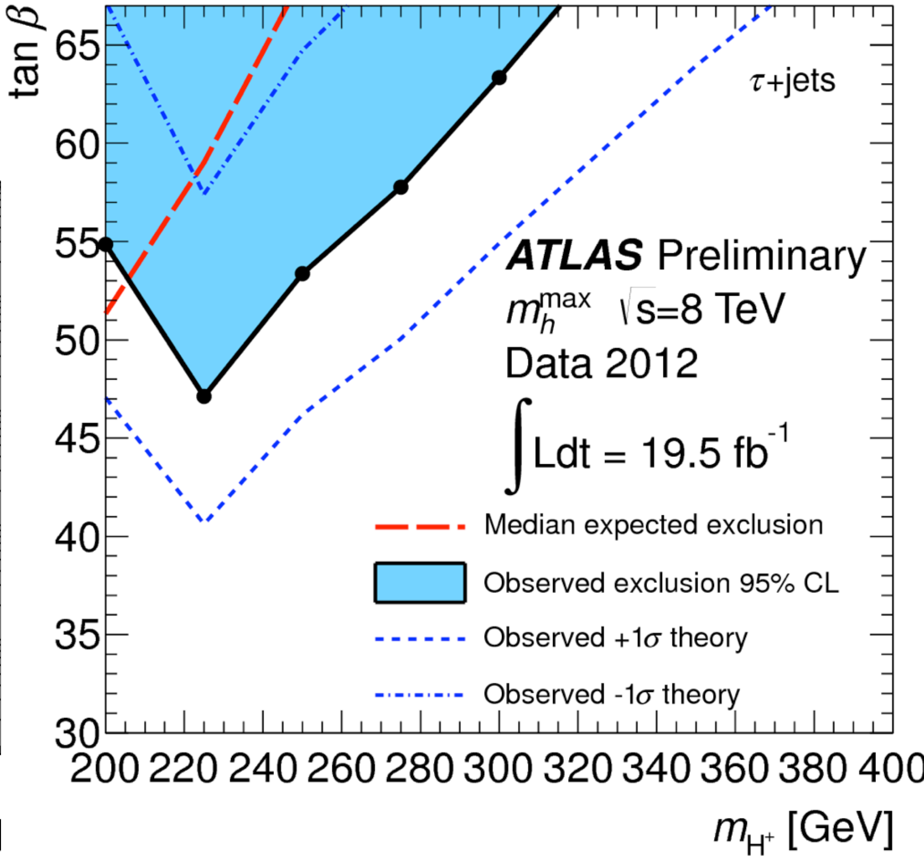
Light $H^{\pm}$ ($m_{H\pm}<m_t$)



Heavy $H^{\pm}$ ($m_{H\pm}>m_t$)

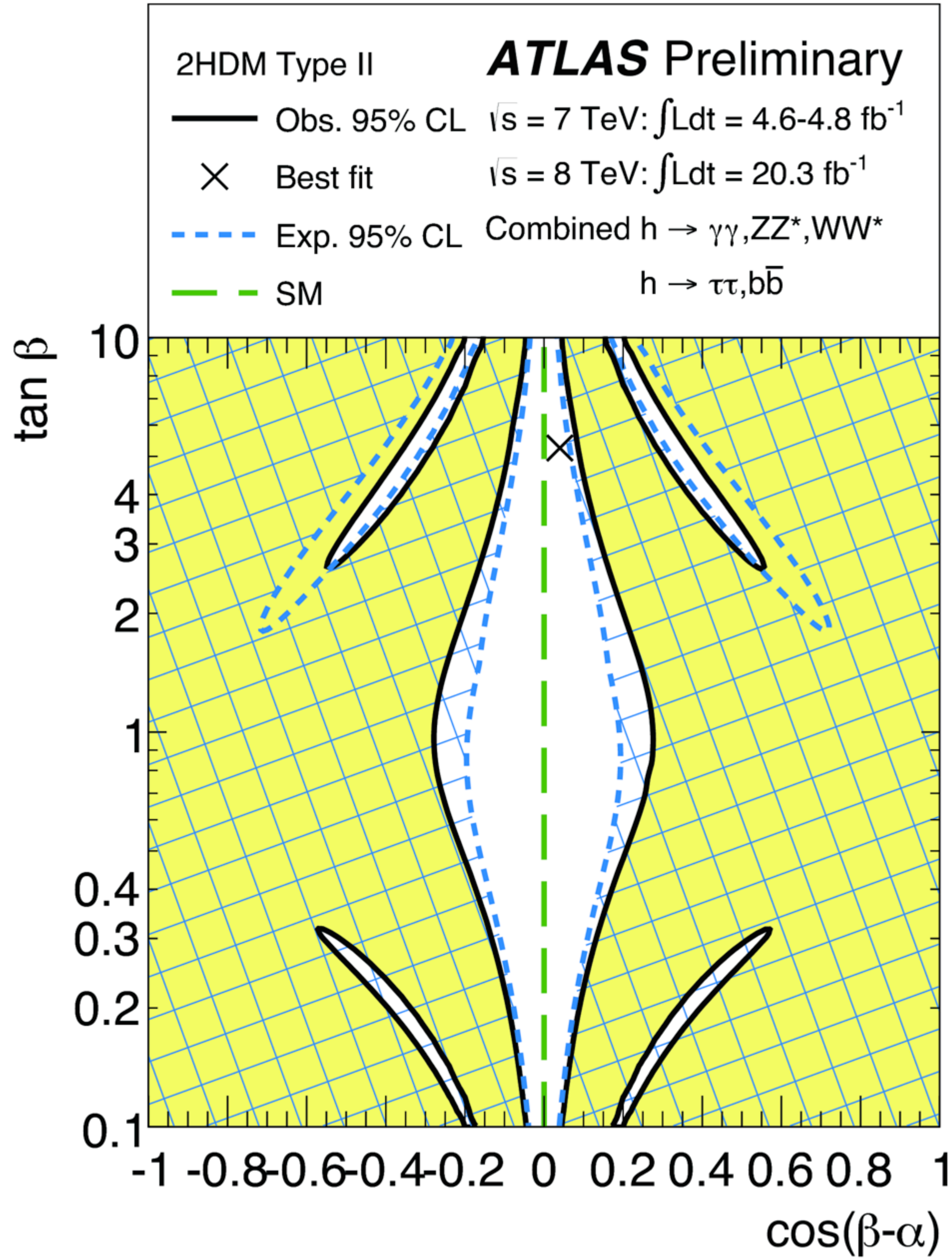




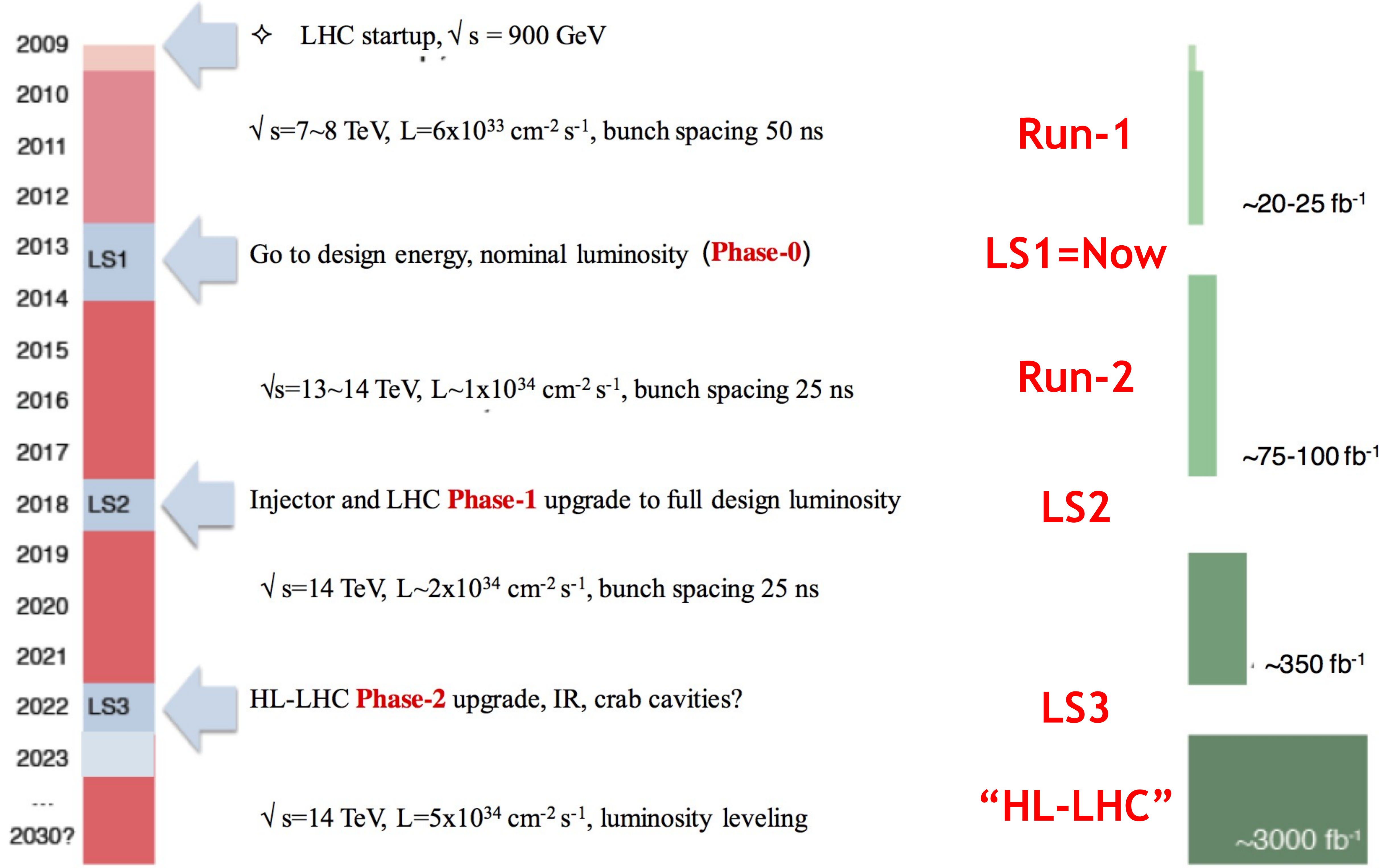


Text

ATLAS-CONF-2014-010

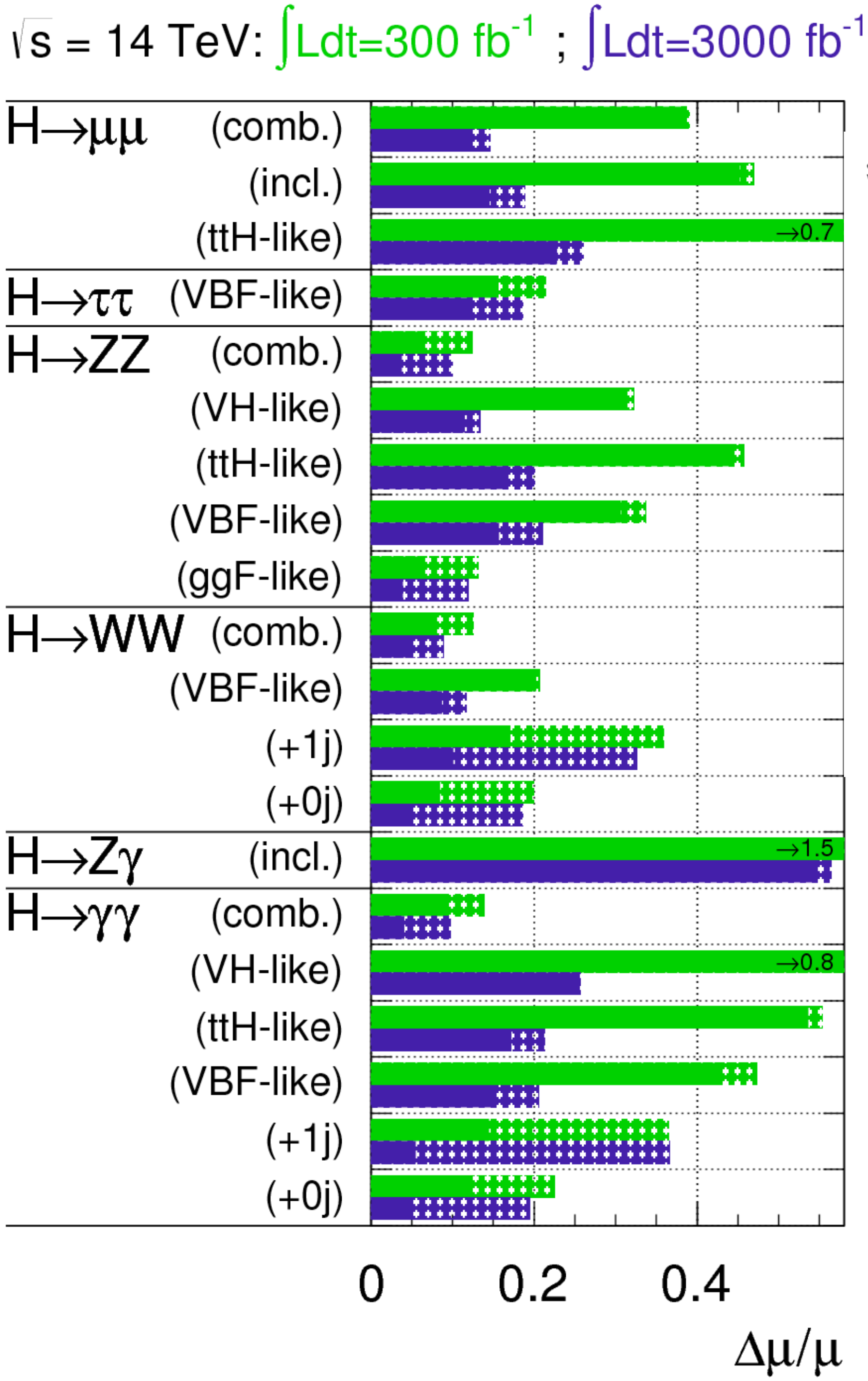


Higgs boson physics prospects



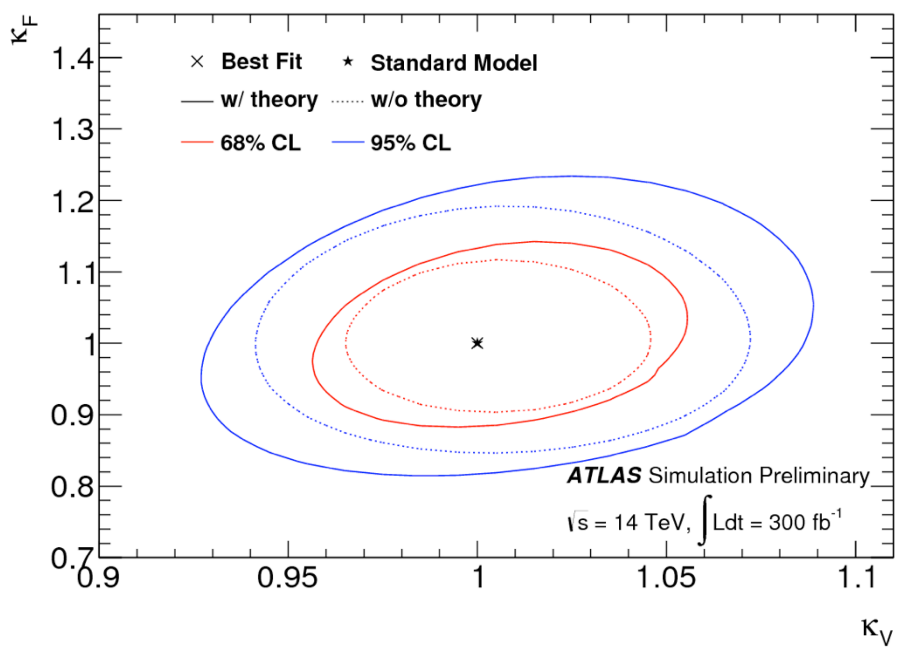
Prospects for Run II/III and HL-LHC

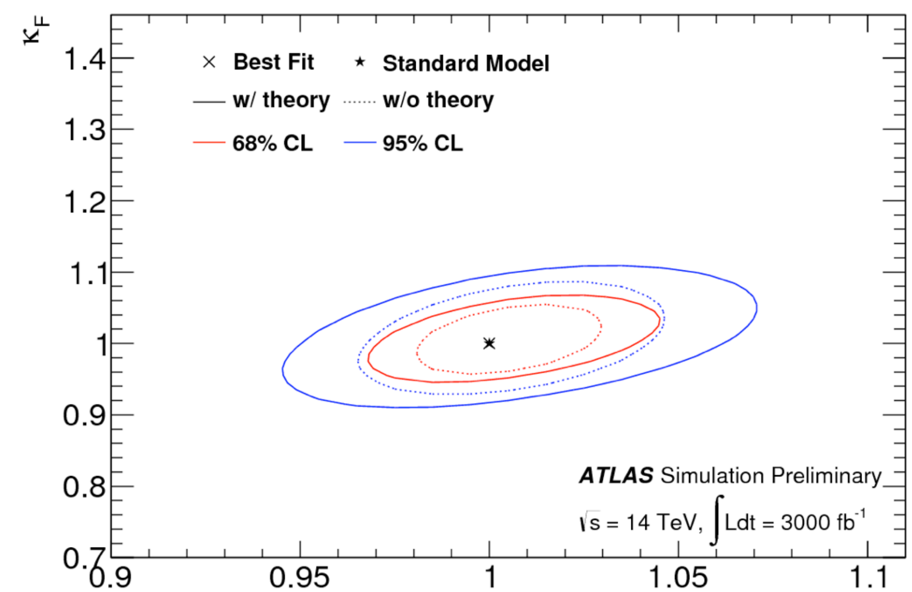
ATL-PHYS-PUB-2013-014



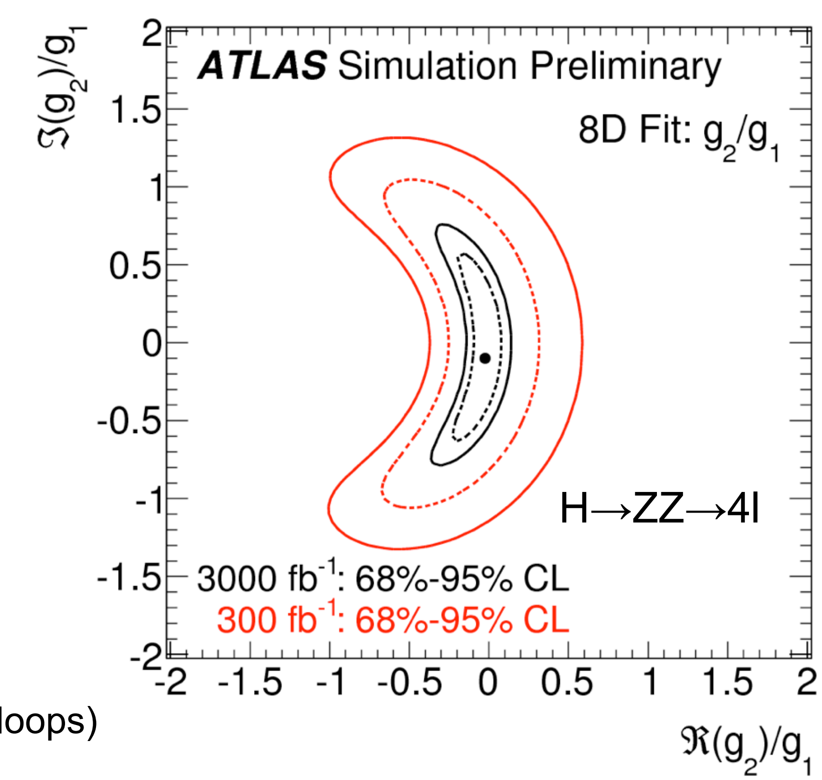
Several open topics in the Higgs sector for future studies:

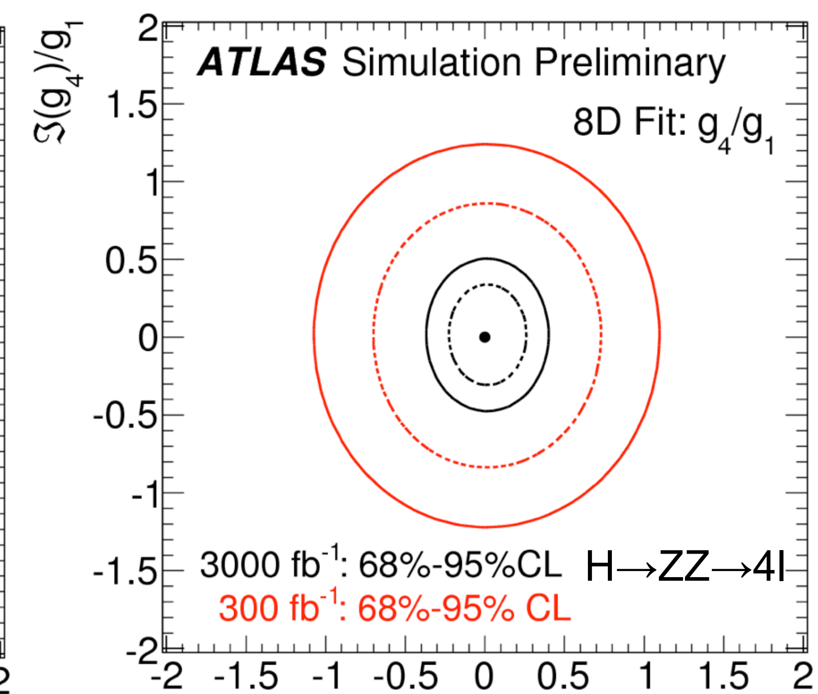
- Rare decays & Couplings - CP studies
- BSM Higgs boson searches - Higgs boson pair production





ATL-PHYS-PUB-2013-014





ATL-PHYS-PUB-2013-013

g_1 CP-even HZZ coupling
g_2 CP-even HZZ coupling (loops)
g_4 CP-odd HZZ coupling