The Latest ATLAS Higgs Results

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on behalf of the ATLAS Collaboration

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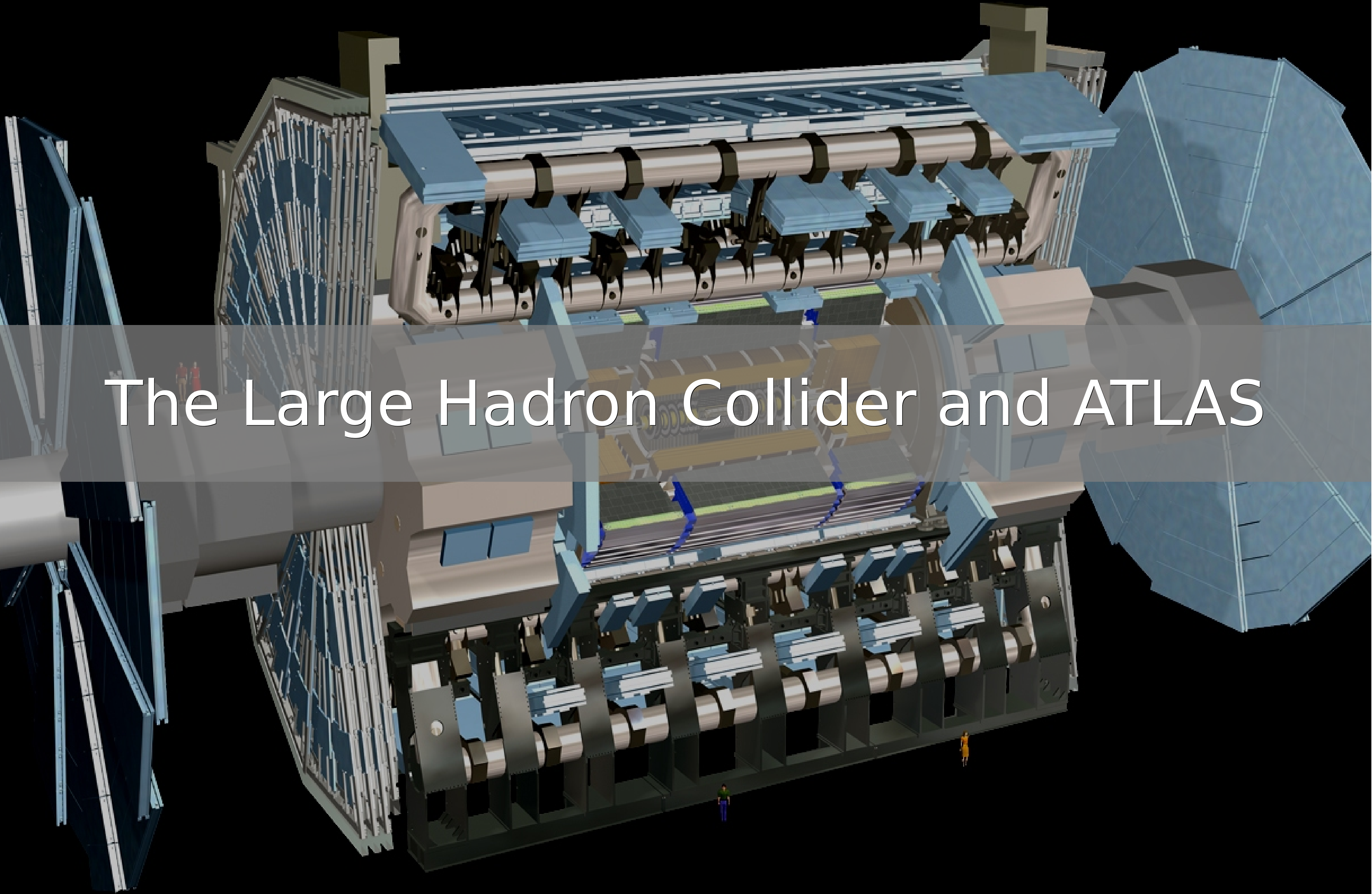
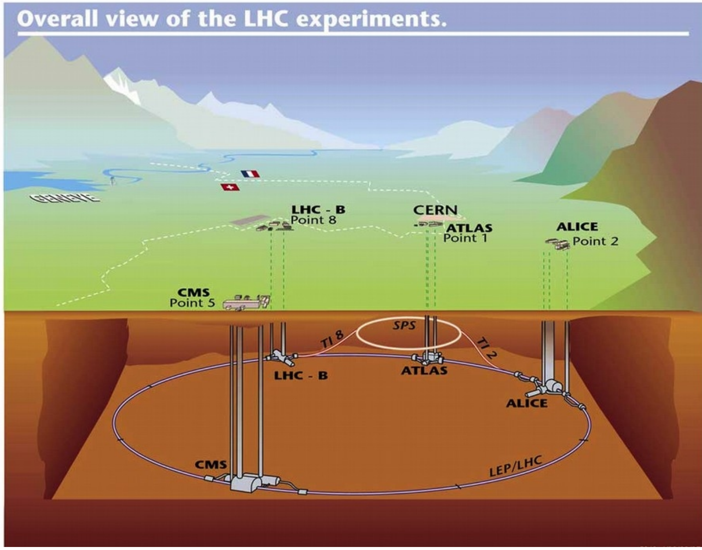
SMU | DEDMAN COLLEGE OF HUMANITIES & SCIENCES

The Large Hadron Collider and ATLAS

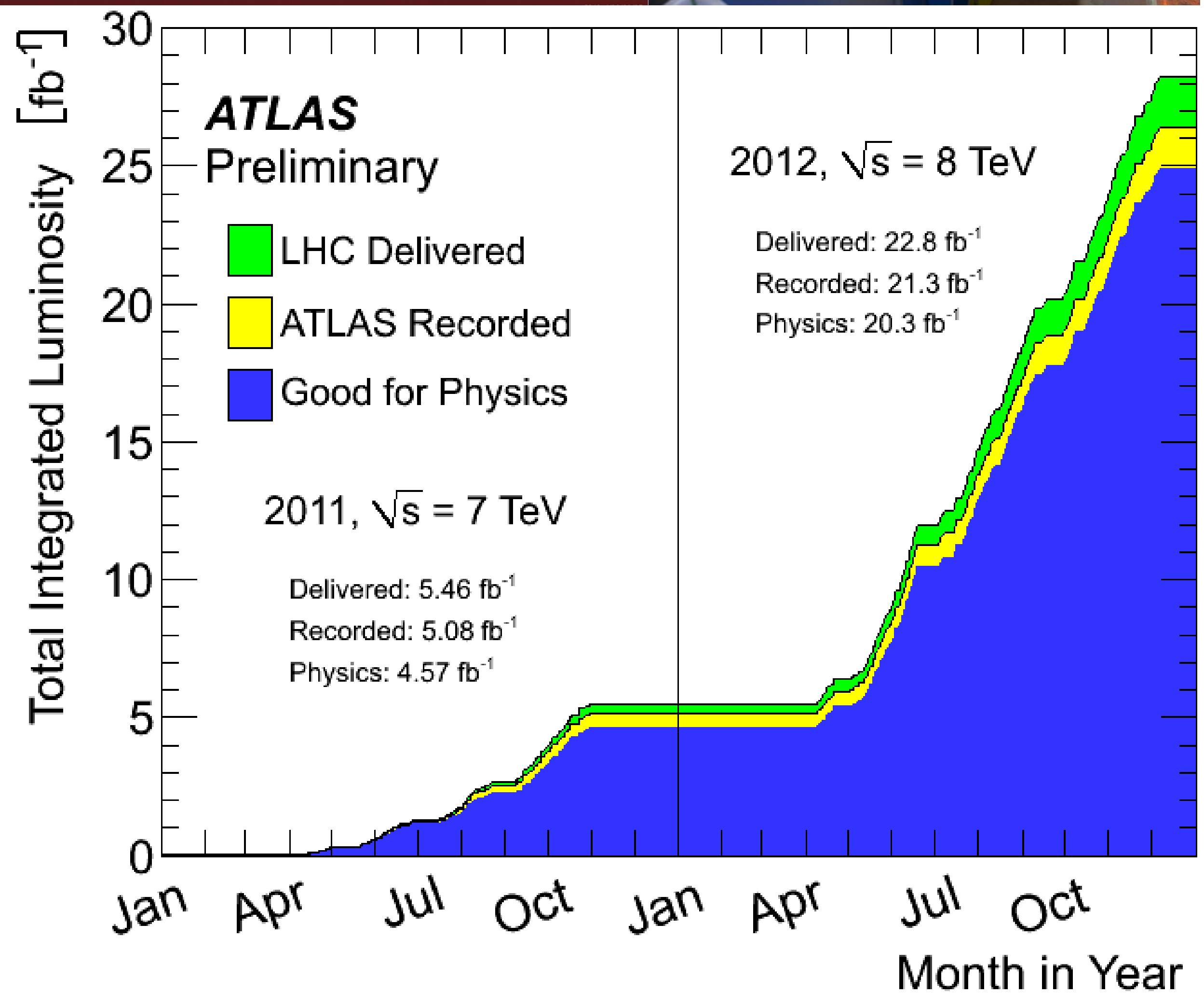


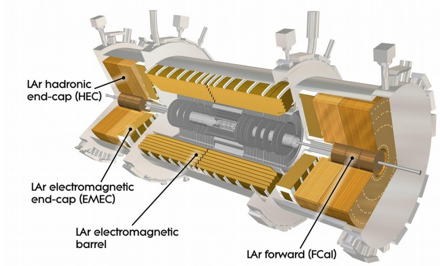


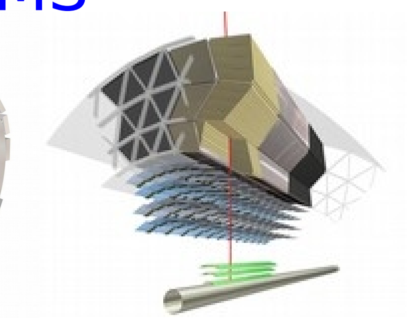
Outstanding Run 1 LHC performance!

Peak luminosity: $7.7 \times 10^{33}/cm^2/s$

>25/fb delivered to ATLAS and CMS







ATLAS collected physics-quality data 95% of the time.

4.57/fb ($\sqrt{s}$=7 TeV)
20.3/fb ($\sqrt{s}$=8 TeV)

Topic-by-Topic

SM Higgs and its properties

- ***Mass and couplings (ZZ+WW+$\gamma\gamma$):***
  Phys. Lett. B 726 (2013), pp. 88-119
  (Updated Mass): arXiv:1406.3827
- ***Spin and parity (ZZ+WW+$\gamma\gamma$):***
  Phys. Lett. B 726 (2013), pp. 120-144
- ***$H \to ZZ$ (on-shell cross-section and pT):*** ATLAS-CONF-2014-044
  (off-shell cross-section)
  ATLAS-CONF-2014-042
- ***$H \to \gamma\gamma$:*** ATLAS-CONF-2013-012
- ***$H \to WW$:*** ATLAS-CONF-2013-030
- ***$H \to Z\gamma$:*** ATLAS-CONF-2013-009
- ***$H \to bb$:*** ATLAS-CONF-2013-079
- ***$H \to \tau\tau$:*** ATLAS-CONF-2013-108
- ***$H \to \mu\mu$:*** ATLAS-HIGG-2013-07
- ***$H \to$ invisible:***
  Phys. Rev. Lett. 112, 201802 (2014)
- ***ttH($\gamma\gamma$):*** ATLAS-CONF-2014-043
- ***VH(WW):*** ATLAS-CONF-2013-075

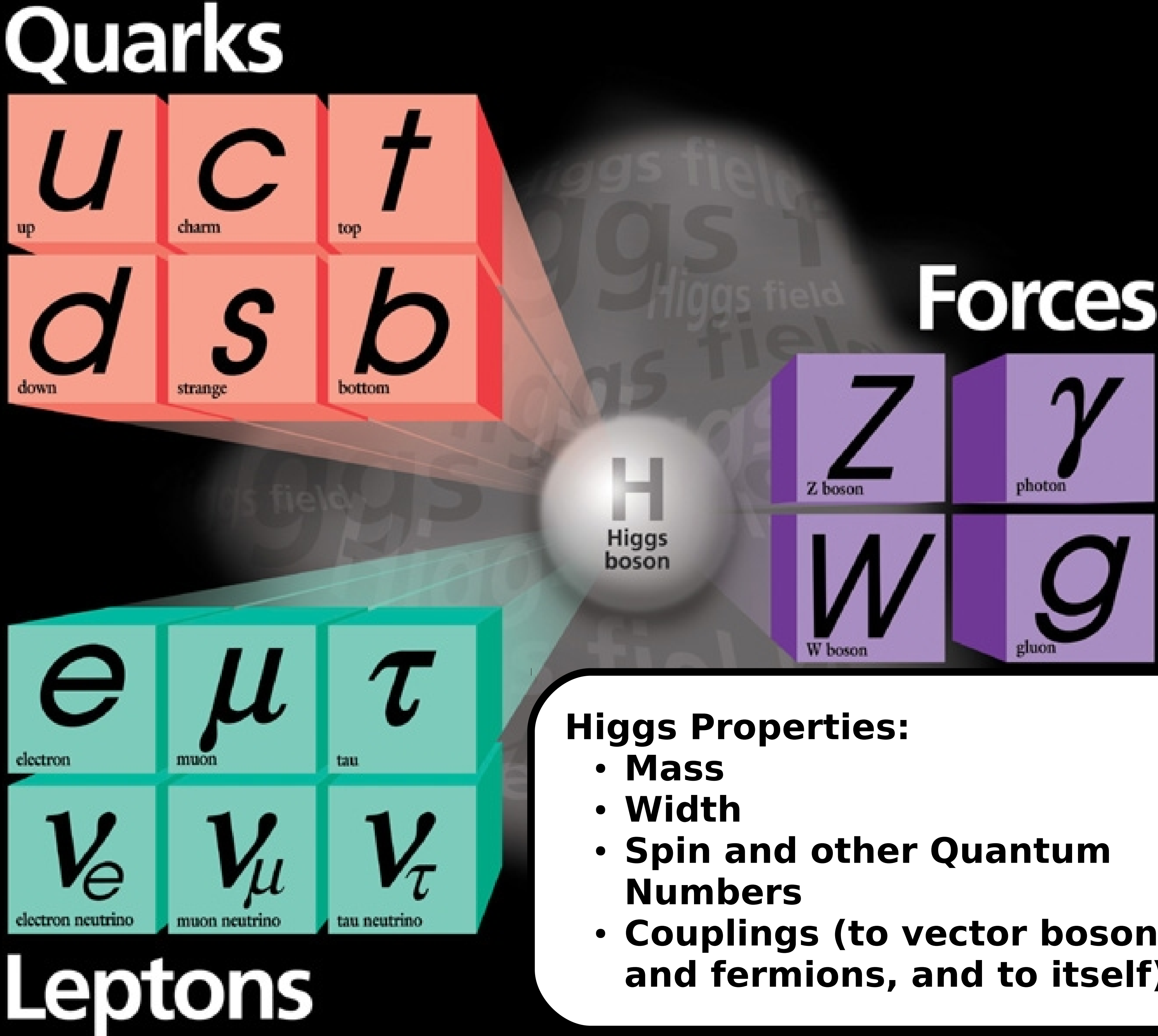
Additional Higgs Boson searches

- ***$H/h/A \to \tau\,\tau$:***
  ATLAS-CONF-2014-049
- ***$H^+ \to \tau\,\nu$:*** ATLAS-CONF-2013-090, JHEP03(2013)076
- ***$H^+ \to c\,\bar{s}$:***
  Eur. Phys. J. C, 73 6 (2013) 2465
- ***$H \to WW$ (2HDM):***
  ATLAS-CONF-2013-027
- ***Heavy $H \to \gamma\gamma$:***
  ATLAS-CONF-2014-031
- ***$X \to hh \to 4b$:***
  ATLAS-CONF-2014-005
- ***$X \to hh \to \gamma\gamma bb$:***
  ATLAS-HIGG-2013-29
- ***Multi-higgs cascade:***
  Phys. Rev. D 89, 032002 (2014)
- ***SM Higgs Couplings and New Phenomena:***
  ATLAS-CONF-2014-010

More ATLAS Higgs Details at this Conference

- SM Higgs in Boson Decay Modes –
  Elodie Tiouchichine – Monday, 14:30, E7
- SM Higgs Combination and Higgs Properties Measurements in ATLAS –
  Keisuke Yoshihara – Tuesday, 14:30, E7
- Higgs decays to fermions -
  Nicolas Morange – Tuesday, 17:35, E7
- BSM Higgs Searches in ATLAS -
  Martin zur Nedden – Friday, 14:50, E7

Higgs Properties



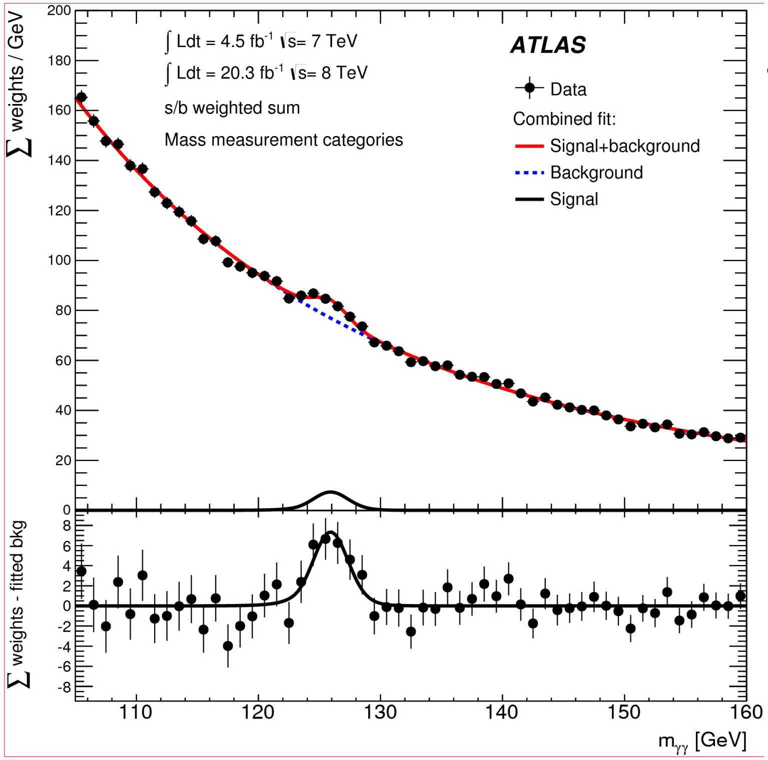
Higgs Properties:

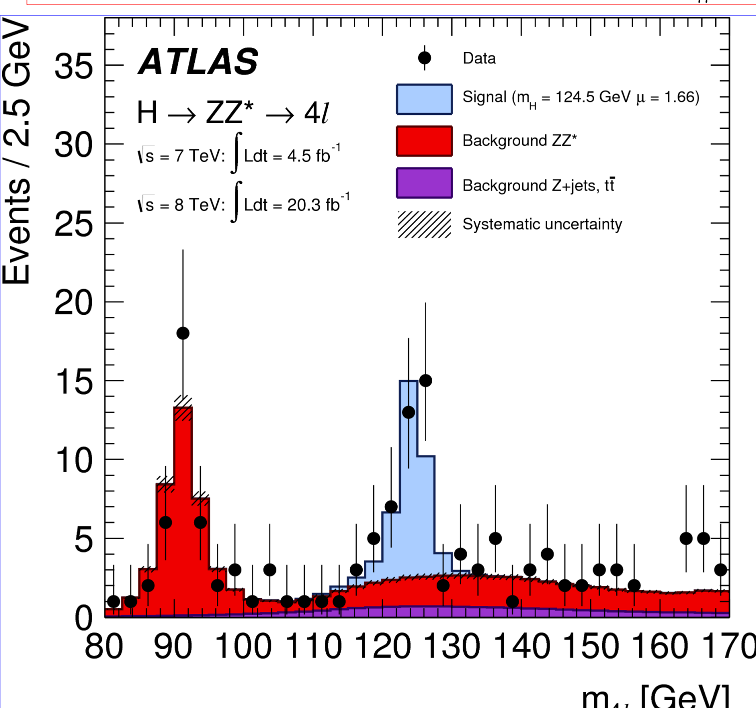
- **Mass**
- **Width**
- **Spin and other Quantum Numbers**
- **Couplings (to vector bosons and fermions, and to itself)**

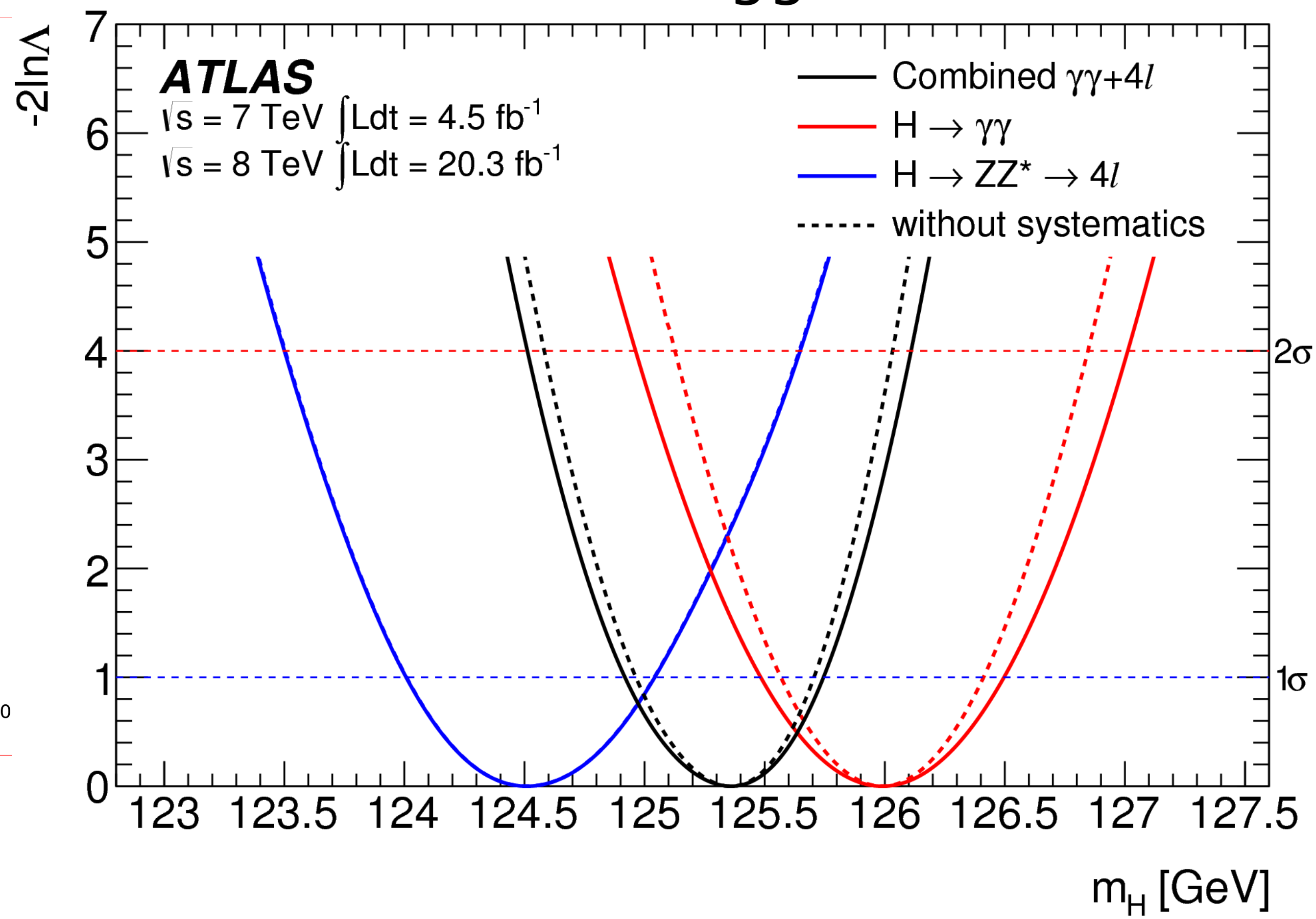
Mass

arxiv:1406.3827

The Latest ATLAS Higgs Mass Results







$$m_H^{\gamma\gamma} = 125.98 \pm 0.42\,(\text{stat.}) \pm 0.28\,(\text{syst.})\ \text{GeV}$$

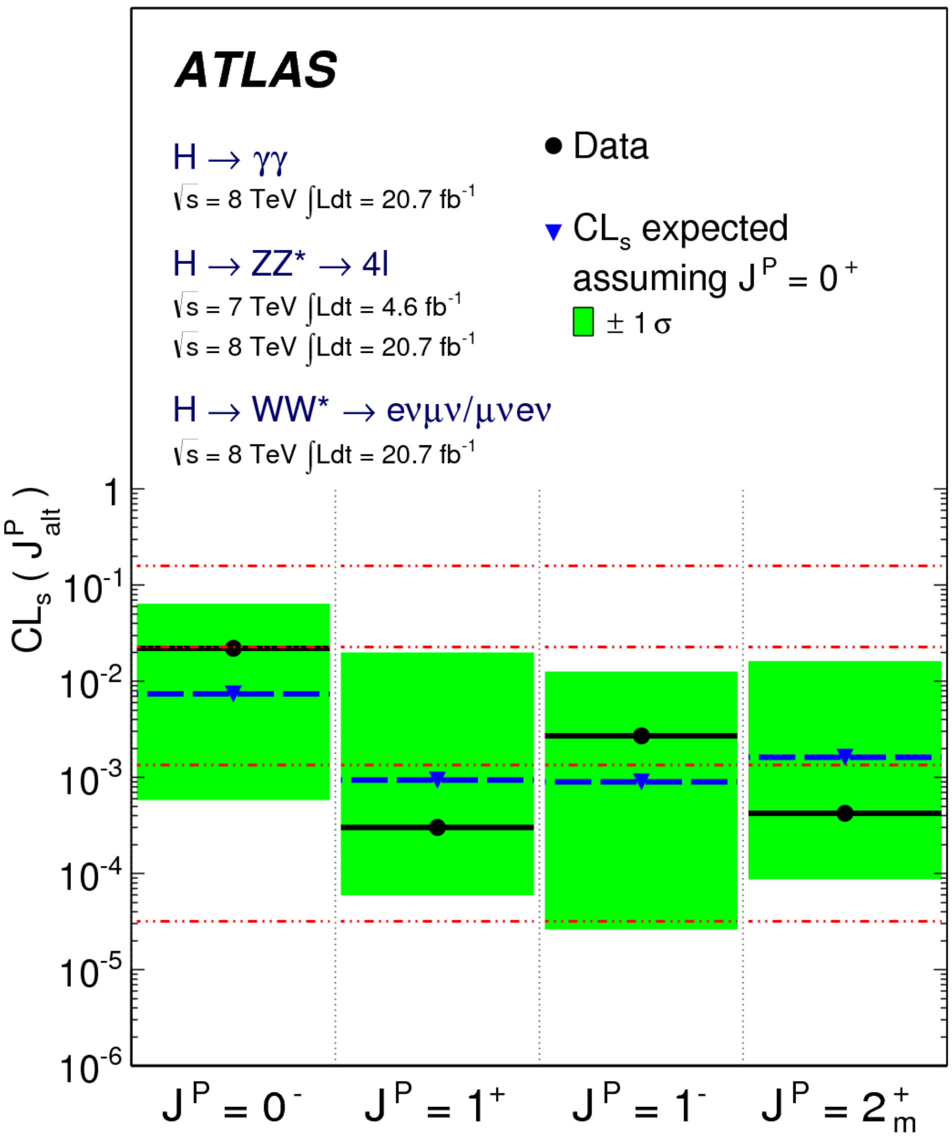
$$m_H^{ZZ} = 124.51 \pm 0.52\,(\text{stat.}) \pm 0.06\,(\text{syst.})\ \text{GeV}$$

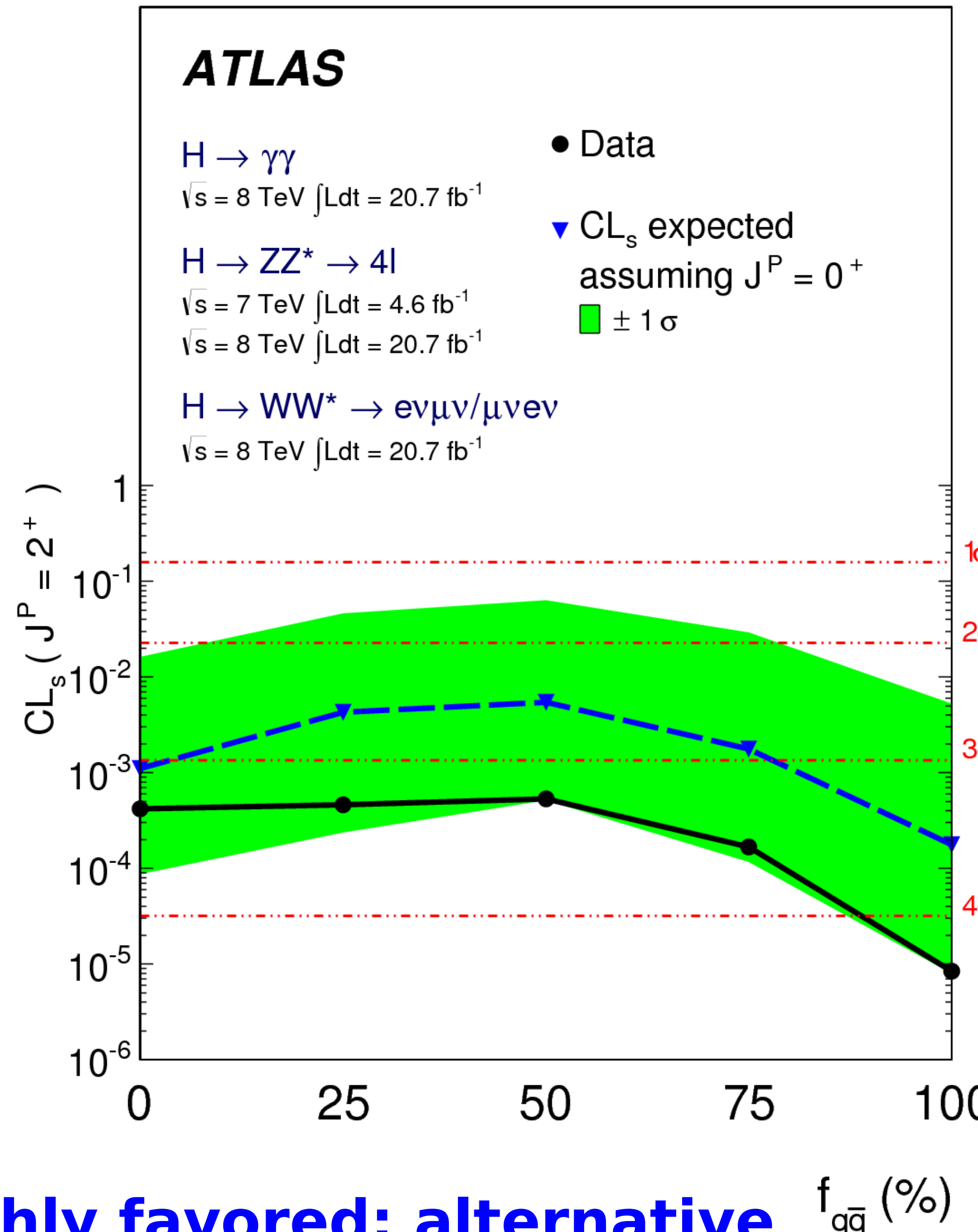
$$m_H = 125.36 \pm 0.37\,(\text{stat.}) \pm 0.18\,(\text{syst.})\ \text{GeV}$$

Spin and Parity Quantum Numbers

Phys. Lett. B 726 (2013), pp. 120-144

ATLAS Higgs Spin-Parity Results





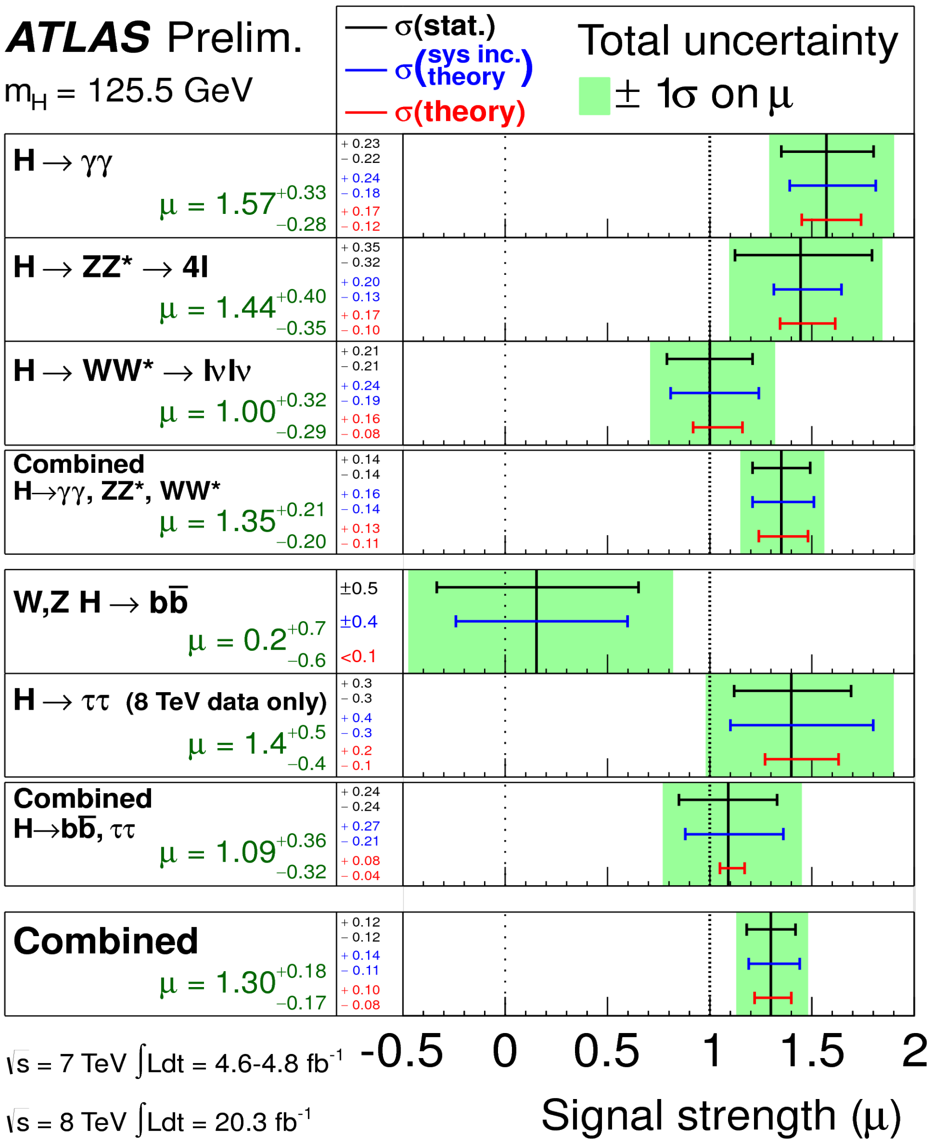
The J^P hypothesis 0^+ is highly favored; alternative hypotheses (0^-,1^+,1^-, and 2^+ with minimal SM couplings) are disfavored at the 97.8% CL or better.

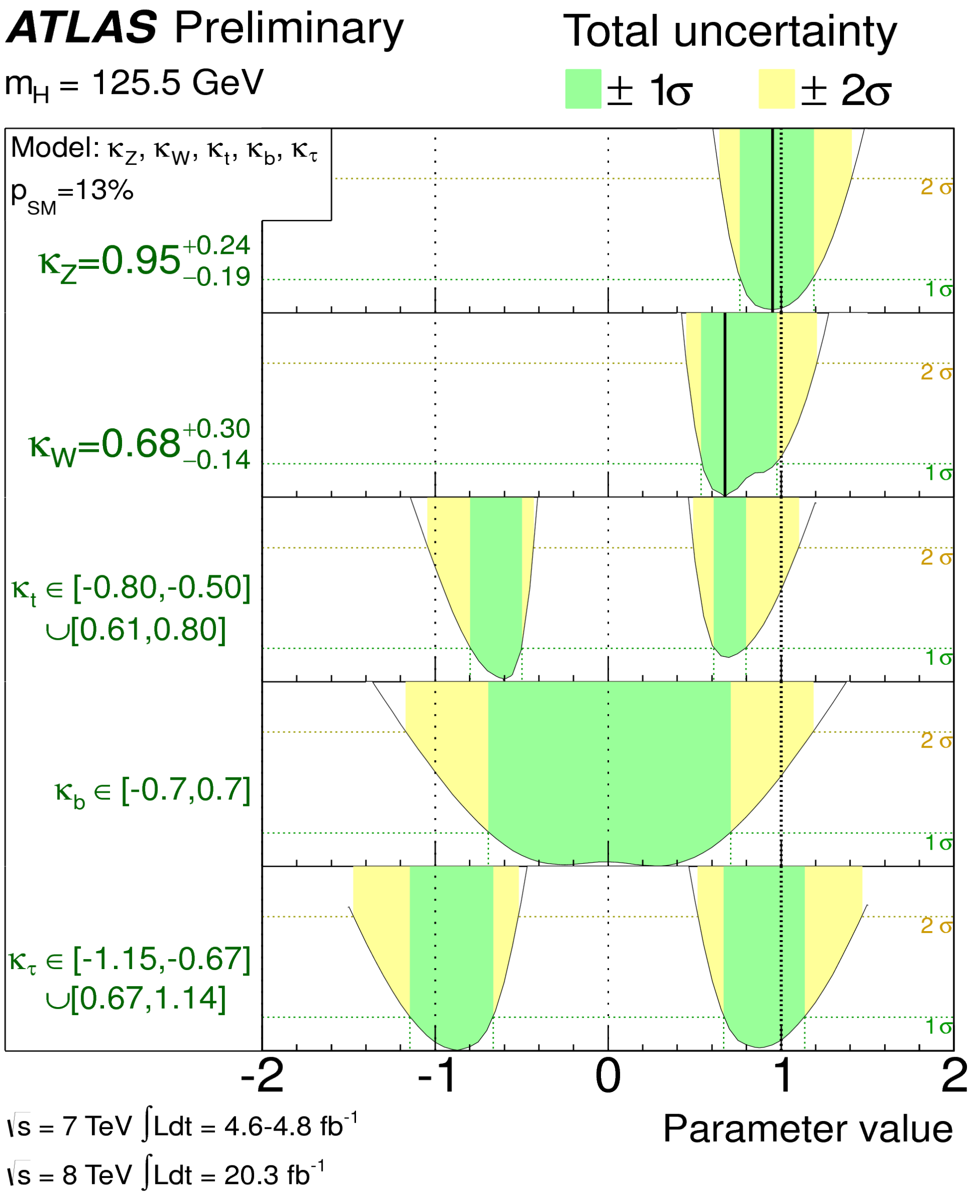
Couplings and On-Shell Signal Strength

ATLAS-CONF-2014-009

ATLAS Higgs Couplings Results

Coupling interpretation framework: arXiv:1307.1347 [hep-ph]





Standard Model-like couplings are consistent with the data, though non-SM couplings are still a possibility – Run 2 will greatly advance this effort.

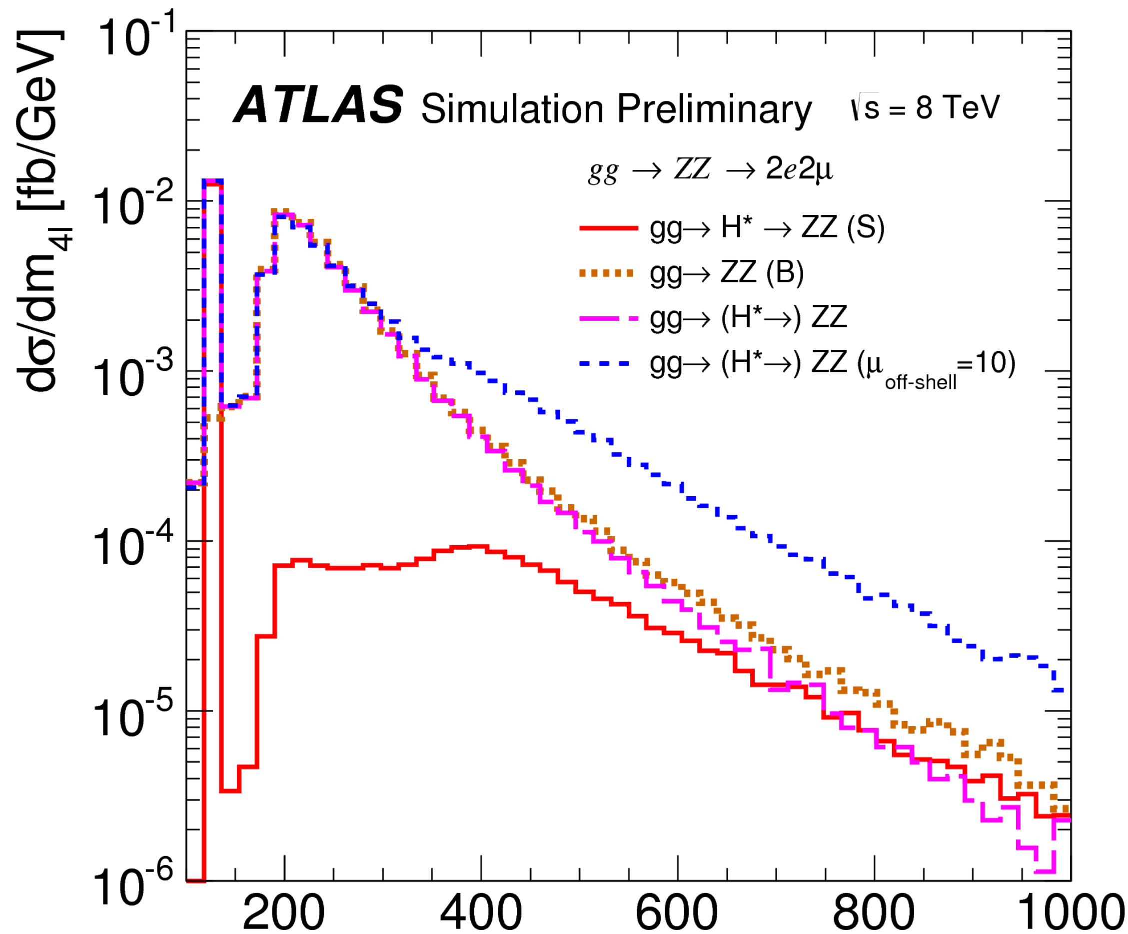
Off-Shell Signal Strength (Higgs Natural Width)

ATLAS-CONF-2014-042

By measuring the off-shell Higgs production cross-section (signal strength), we can <u>indirectly measure the Higgs natural width.</u>

Theoretical framework for this measurement summarized in several papers:

- *N. Kauer and G. Passarino, JHEP 08 (2012) 116, arXiv:1206.4803 [hep-ph].*
- *F. Caola and K. Melnikov, Phys.Rev. D 88 (2013) 054024, arXiv:1307.4935 [hep-ph].*
- *J. M. Campbell, R. K. Ellis, and C. Williams.JHEP 04 (2014) 060, arXiv:1311.3589 [hep-ph].*
- *J. M. Campbell, R. K. Ellis, and C. Williams. Phys.Rev. D 89 (2014) 053011, arXiv:1312.1628 [hep-ph].*



Significant destructive interference between gg → ZZ and gg → H* → ZZ must be taken into account to make this measurement.

Measuring off-shell Higgs production

$$\frac{\sigma^{gg\to H\to ZZ}_{\text{on-shell}}}{\sigma^{gg\to H\to ZZ}_{\text{on-shell, SM}}} = \mu_{\text{on-shell}} = \frac{\kappa^2_{g,\text{on-shell}} \cdot \kappa^2_{V,\text{on-shell}}}{\Gamma_H/\Gamma_H^{\text{SM}}}$$

On-shell signal strength measurement sensitive to on-shell coupling scale factors and Higgs natural width.

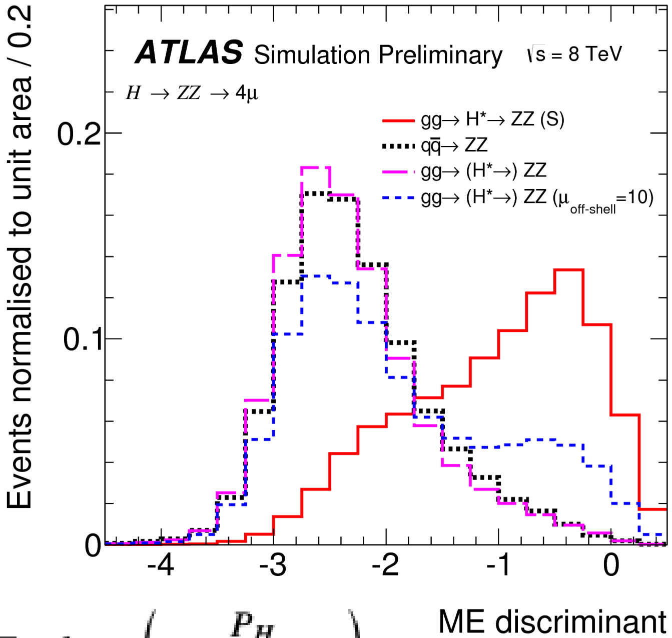
$$\frac{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell}}}{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell, SM}}} = \mu_{\text{off-shell}} = \kappa^2_{g,\text{off-shell}} \cdot \kappa^2_{V,\text{off-shell}}$$

Off-shell signal strength measurement sensitive only to off-shell coupling scale factors.

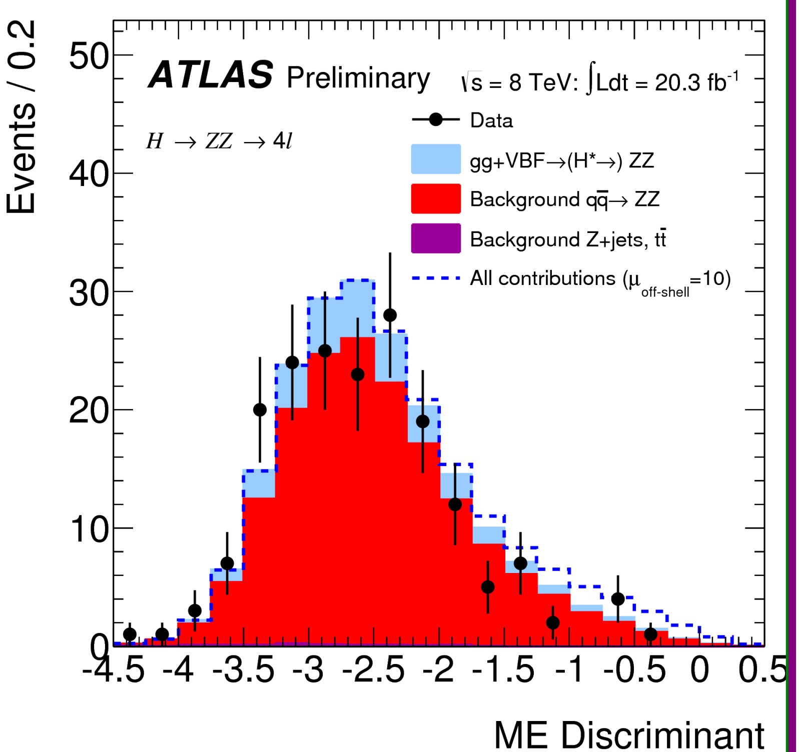
Theory assumptions in the interpretation:

- Any new physics that modifies the off-shell couplings doesn't modify the SM backgrounds
- To obtain an interpretation on the width, one combines the on-shell and off-shell measurements assuming that $\kappa_{i,\text{on-shell}} = \kappa_{i,\text{off-shell}}$

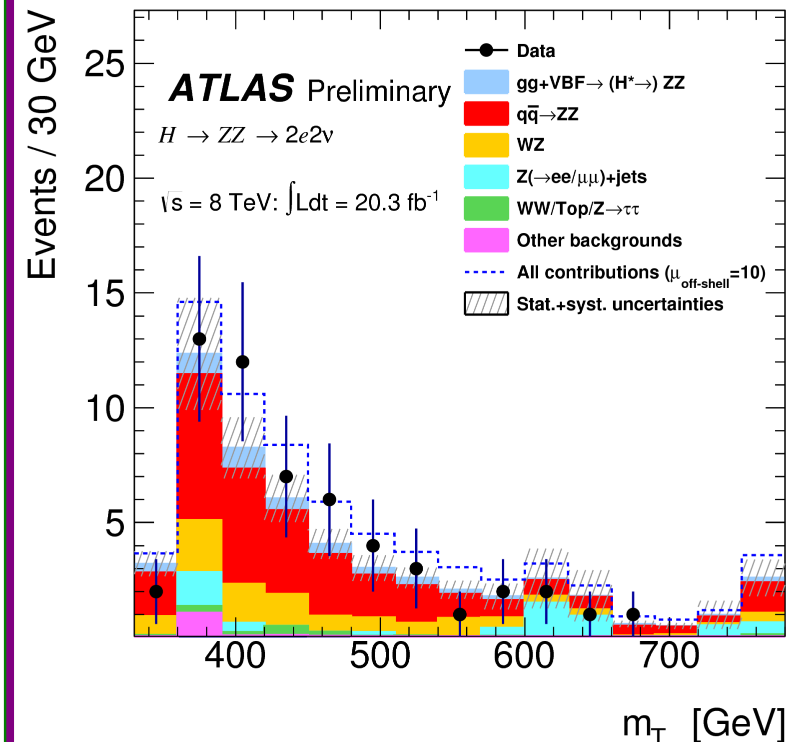
$H \rightarrow ZZ^{(*)} \rightarrow 4l$

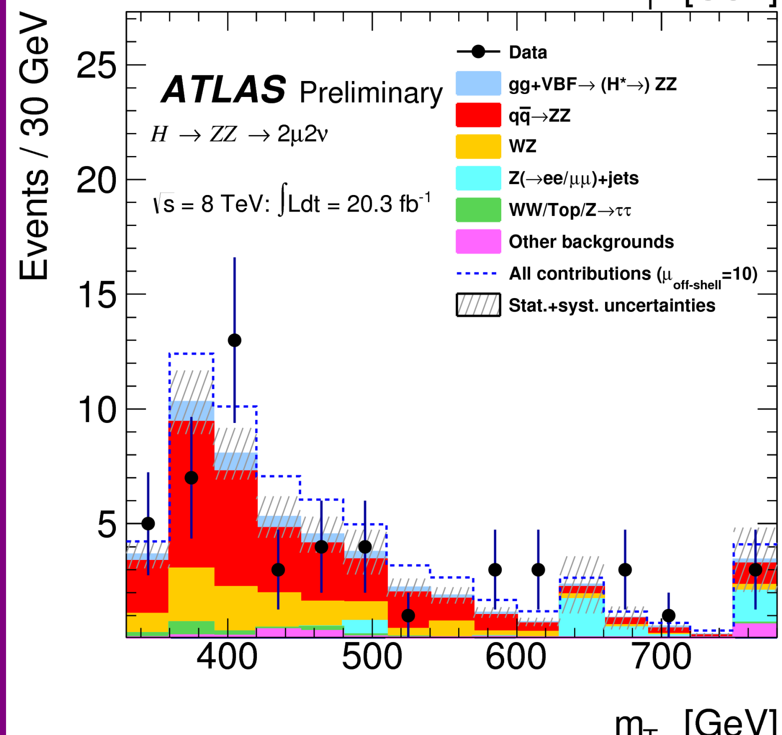


$$\mathrm{ME} = \log_{10}\left(\frac{P_H}{P_{gg} + c \cdot P_{q\bar{q}}}\right)$$



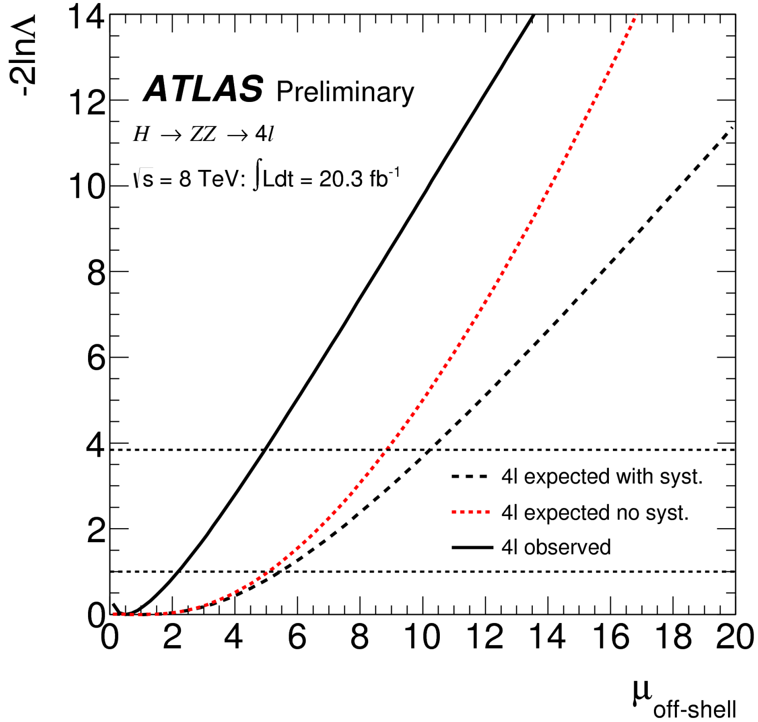
$H \rightarrow ZZ^{(*)} \rightarrow 2l2\nu$

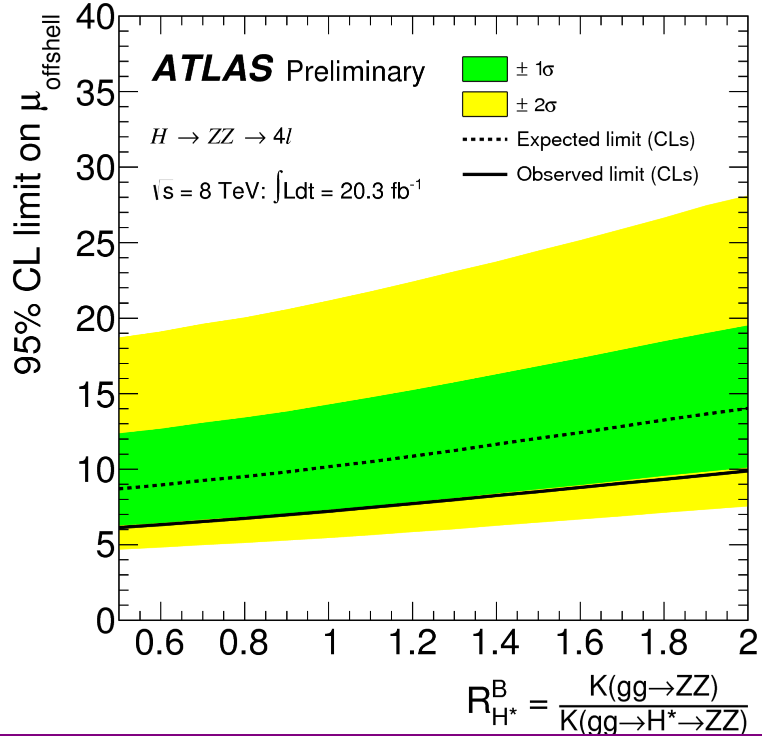




$2l2\nu$ event selection indirectly results in correlation of efficiency with pT(ZZ) and jet multiplicity.

Acceptance systematics are evaluated by varying the showering and hadronization models.



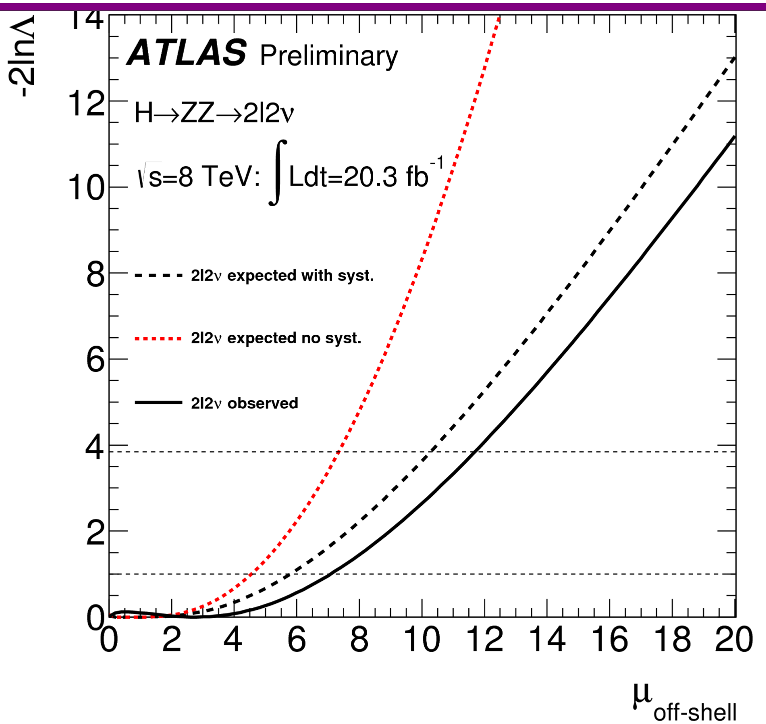


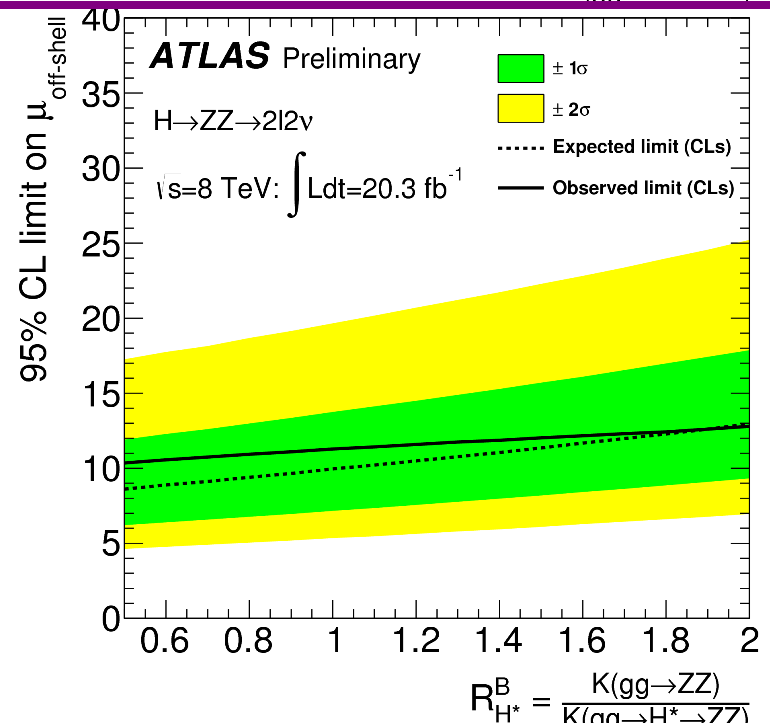
Expected [Achieved] 95% CL Limit on $\mu_{off\text{-}shell}$

ZZ → 4l

< (8.7-14.0)xSM

[<(6.1-9.9)xSM]





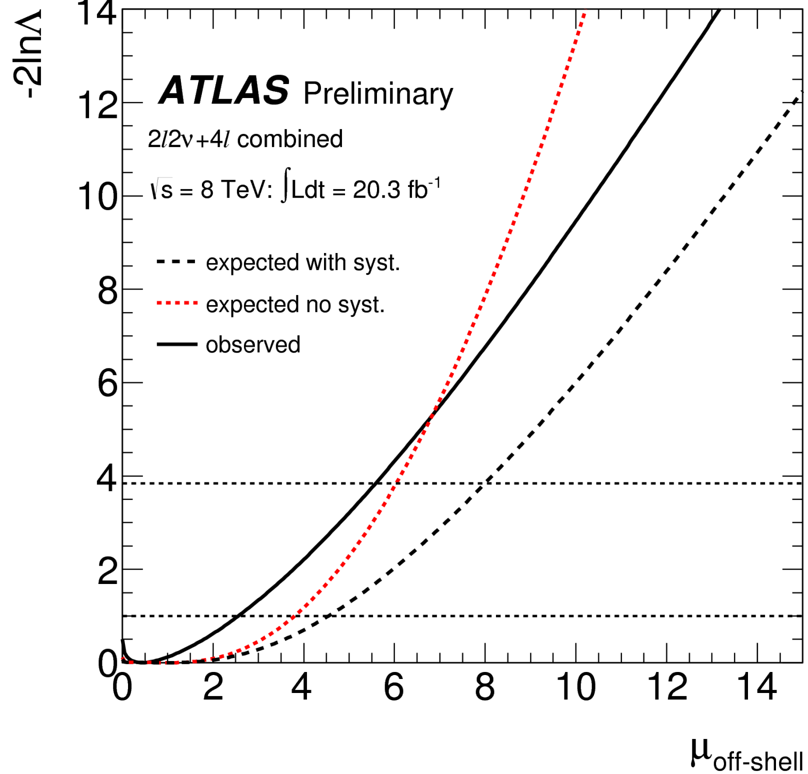
ZZ → 2l2ν

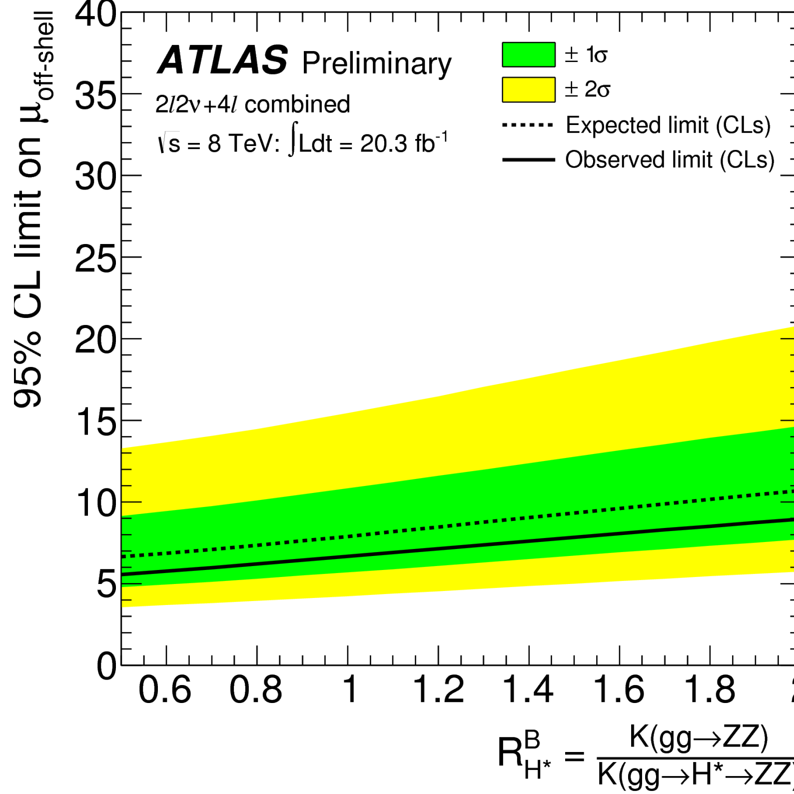
< (8.6-12.9)xSM

[<(10.4-12.8)xSM]

Source of systematic uncertainties	95% CL on $\mu_{\text{off-shell}}$
QCD scale for $gg \to ZZ$	9.5
QCD scale for the $gg \to (H^* \to)ZZ$ interference	9.2
QCD scale for $q\bar{q} \to ZZ$	8.8
PDF for $pp \to ZZ$	8.7
EW for $q\bar{q} \to ZZ$	8.7
Luminosity	8.8
electron efficiency	8.7
μ efficiency	8.7
All systematic	10.2
No systematic	8.7

The dominant systematics in the 4l measurement are theory-driven; there are no high-ranking systematics arising from the analysis methodology. This holds true for the 2l2ν channel as well.



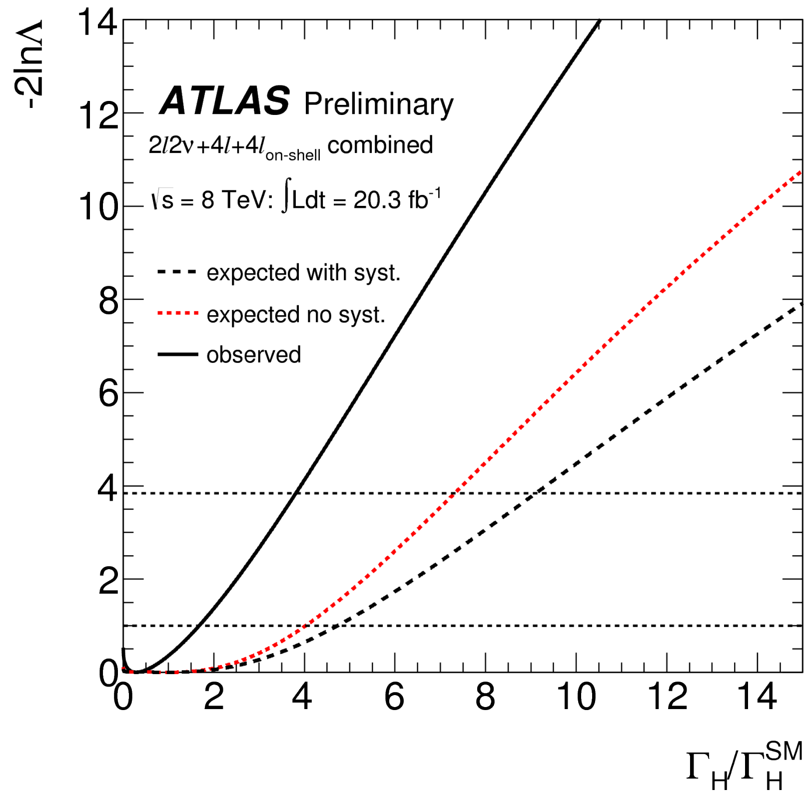


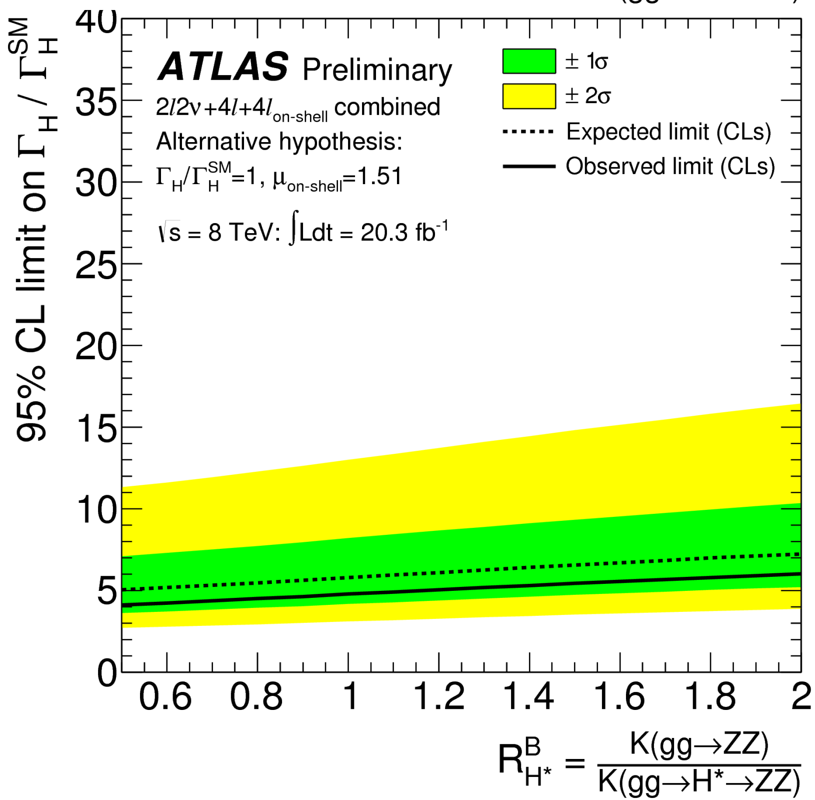
Expected [Achieved] 95% CL Limit on $\mu_{\text{off-shell}}$

COMBINED

< (6.6-10.7)xSM

[<(5.6-9.0)xSM]





Expected [Achieved] 95% CL Limit on Γ_H/Γ_H^{SM}

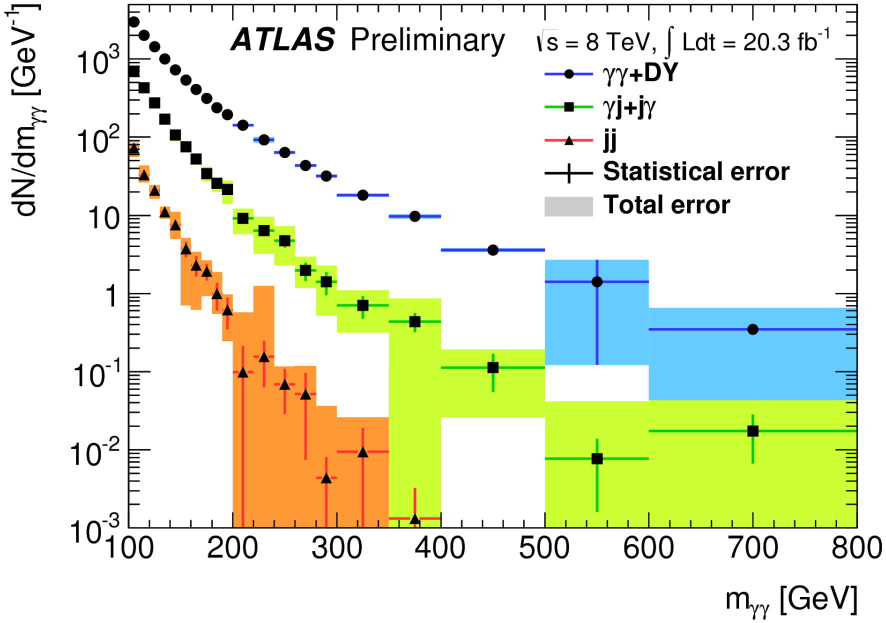
$\mu_{\text{on-shell}} = 1.51$

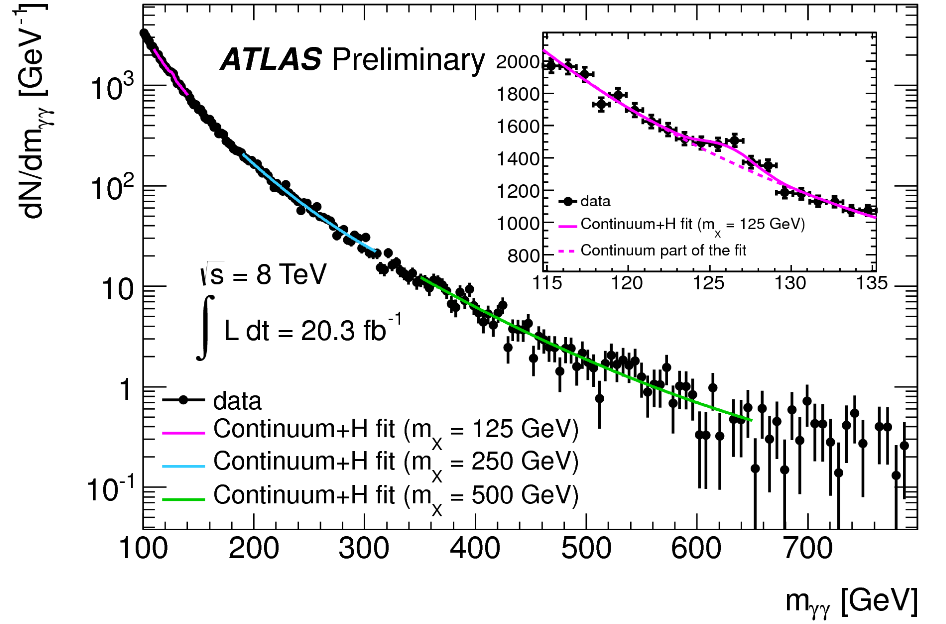
< (5.0-7.2)xSM

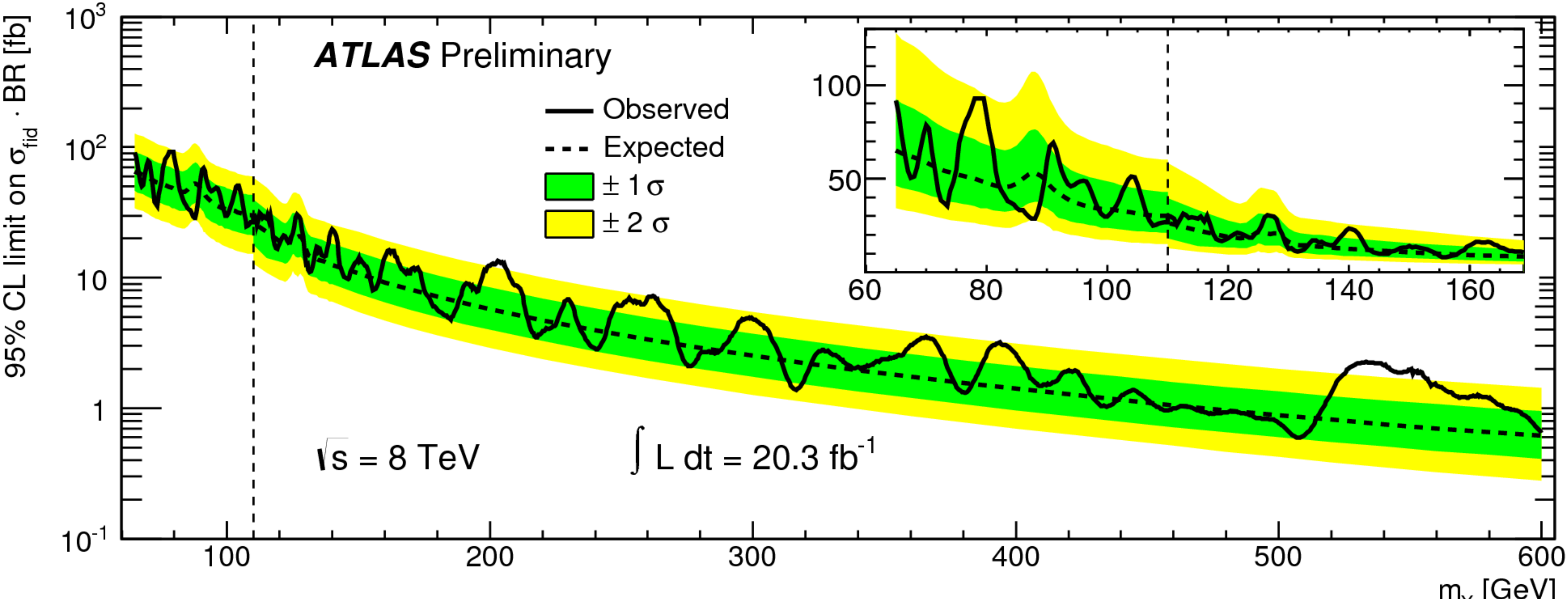
[<(4.1-6.0)xSM]

Searches for Additional Higgs Bosons

Scalar Resonances Decaying to γγ


ATLAS Preliminary
√s = 8 TeV, ∫ Ldt = 20.3 fb-1
γγ+DY
γj+jγ
jj
Statistical error
Total error
dN/dmγγ [GeV-1]
mγγ [GeV]

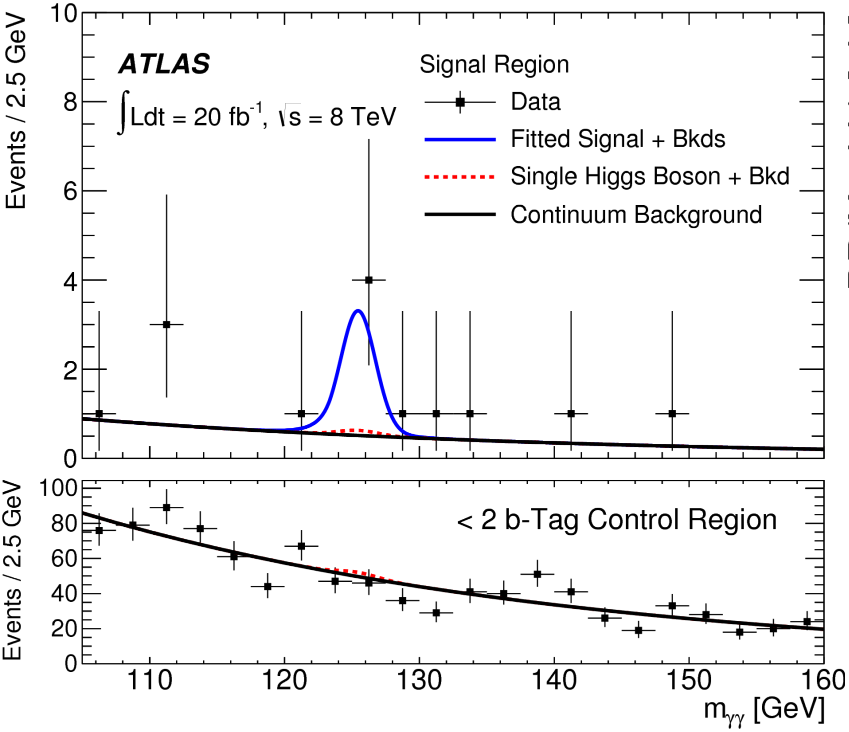

ATLAS Preliminary
√s = 8 TeV
∫ L dt = 20.3 fb-1
data
Continuum+H fit (mX = 125 GeV)
Continuum+H fit (mX = 250 GeV)
Continuum+H fit (mX = 500 GeV)
Continuum part of the fit
dN/dmγγ [GeV-1]
mγγ [GeV]

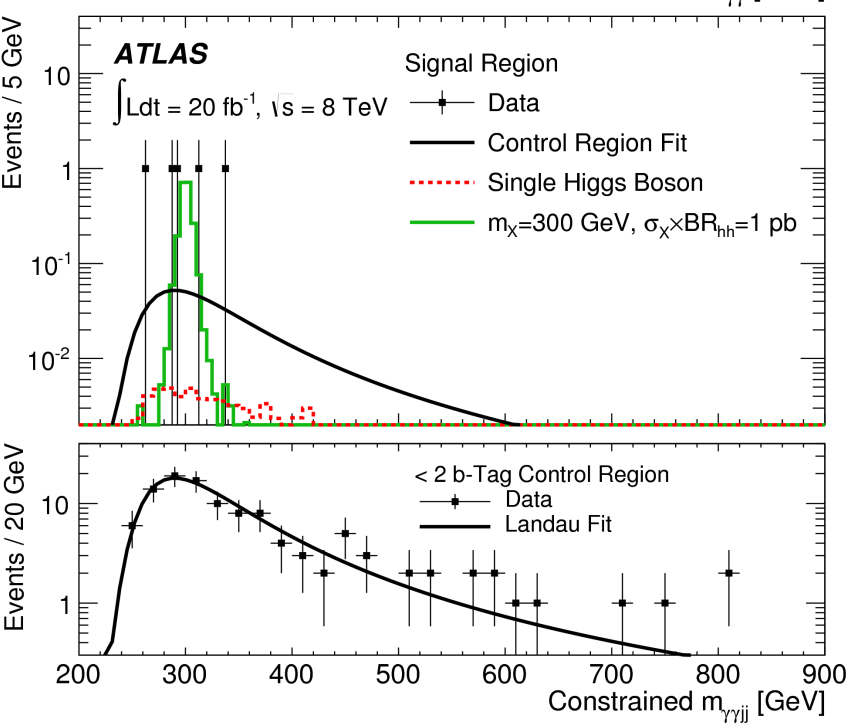

ATLAS Preliminary
Observed
Expected
± 1 σ
± 2 σ
√s = 8 TeV
∫ L dt = 20.3 fb-1
95% CL limit on σfid · BR [fb]
mX [GeV]

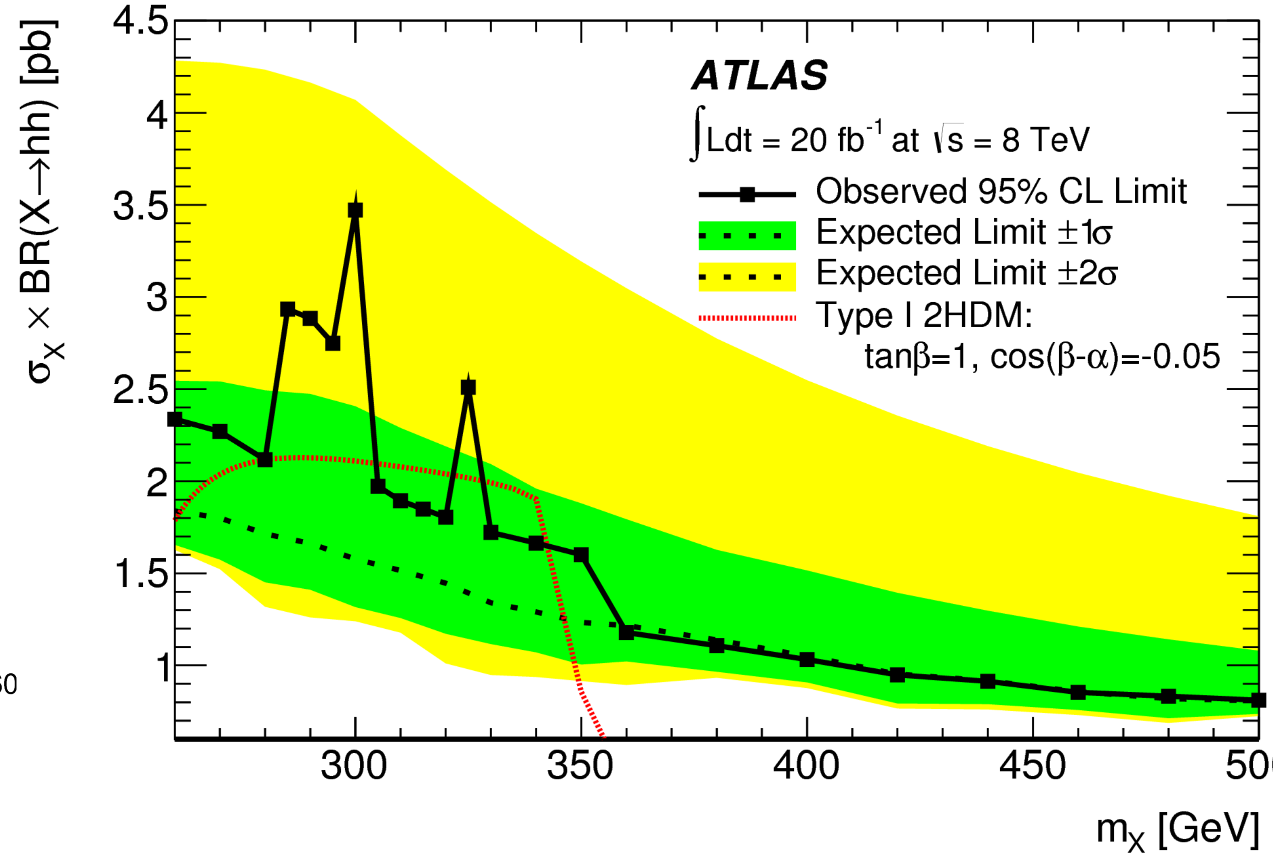
$X \to hh \to bb\gamma\gamma$

arXiv:1406.5053

$X \to hh \to bb\gamma\gamma$



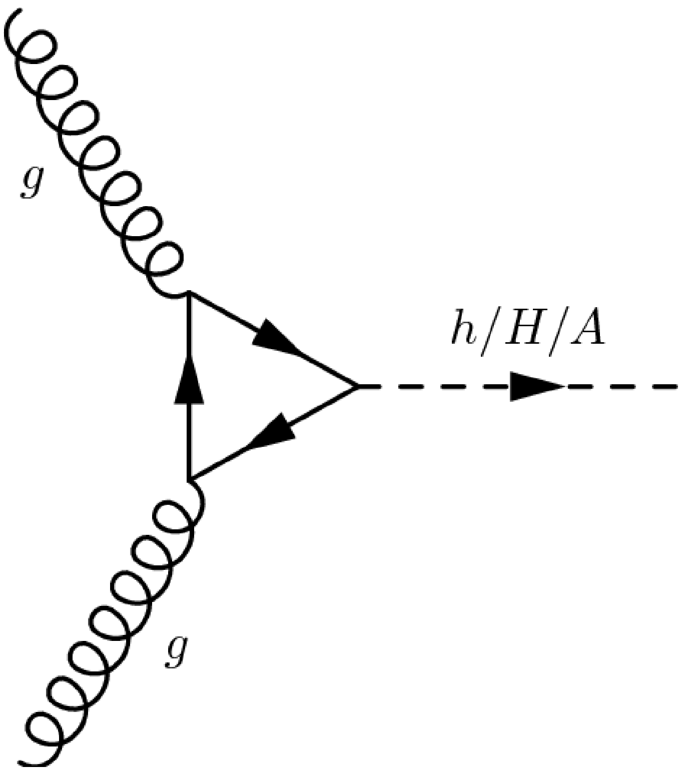


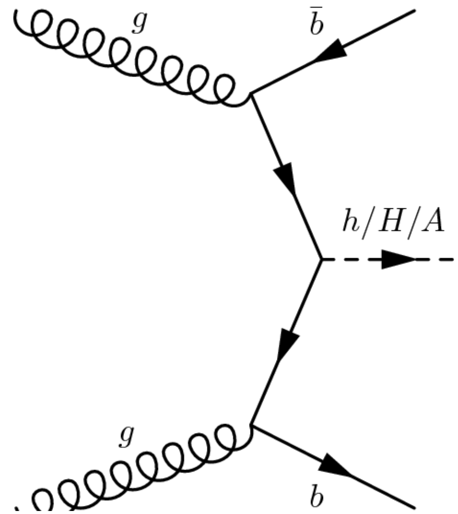


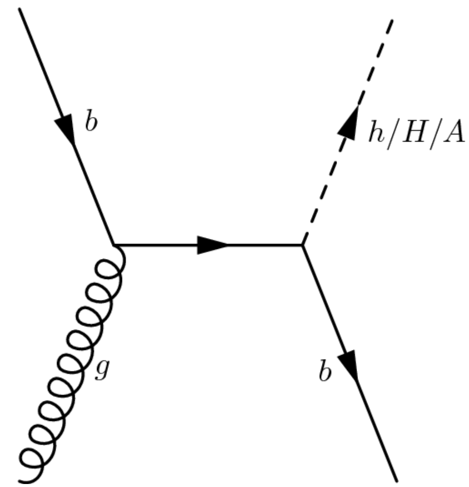
This demonstrates that we can probe di-higgs production at the LHC, important to also probing the SM production of this final state. This result is also compared to expectations from a type-I 2HDM.

$A^0/H^0/h^0 \rightarrow \tau^+ \tau^-$
(Released <24 hours ago)

A/H/h → ττ: Production







Significant MSSM neutral Higgs production mechanism at any tanβ

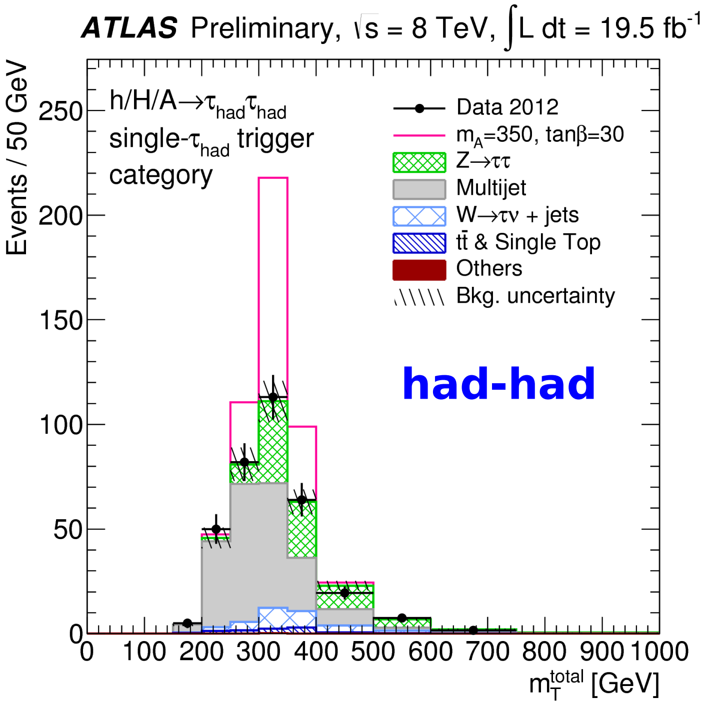
b-associated production can be significant at large tanβ

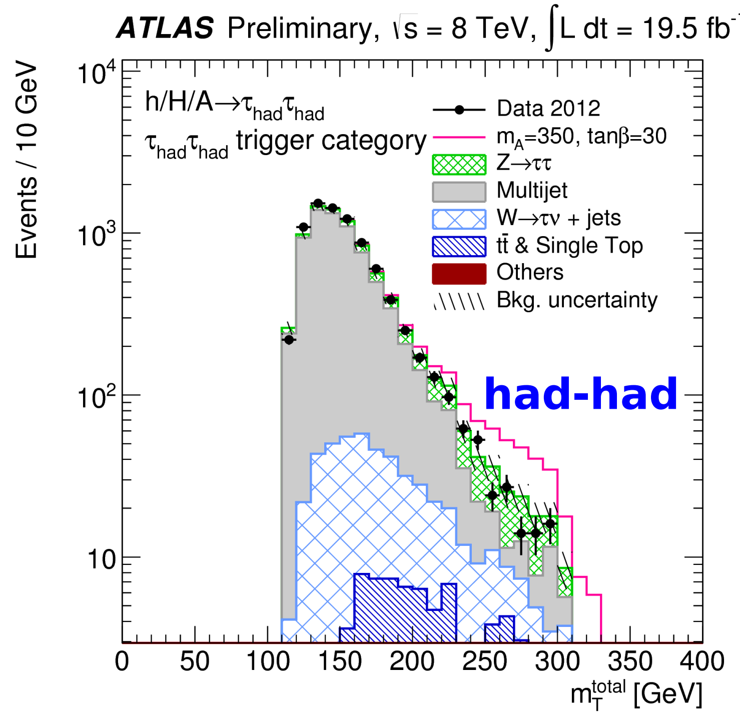
The τ τ decay mode can have a significant branching fraction. It is reconstructed in three final states: lep-lep, lep-had, and had-had.

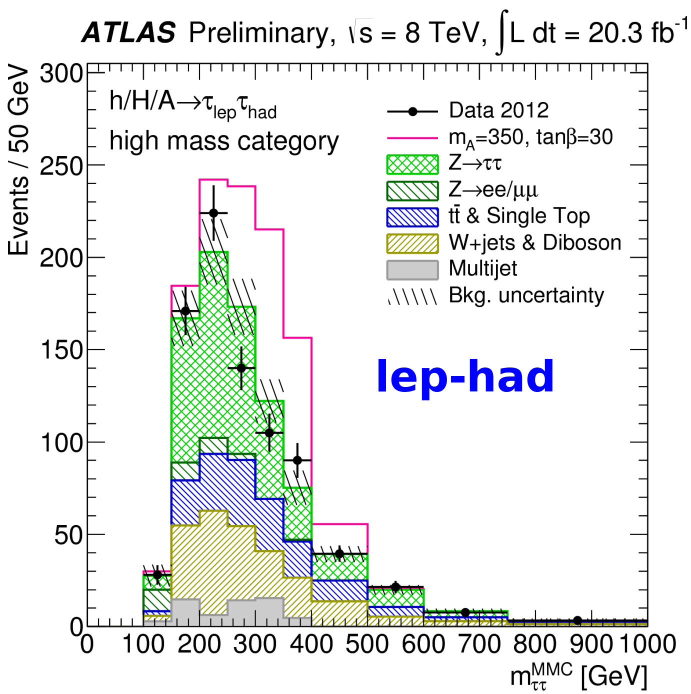
Phys.Rept.457:1-216,2008

ATLAS-CONF-2014-049

A/H/h→ττ: high-mass results in data



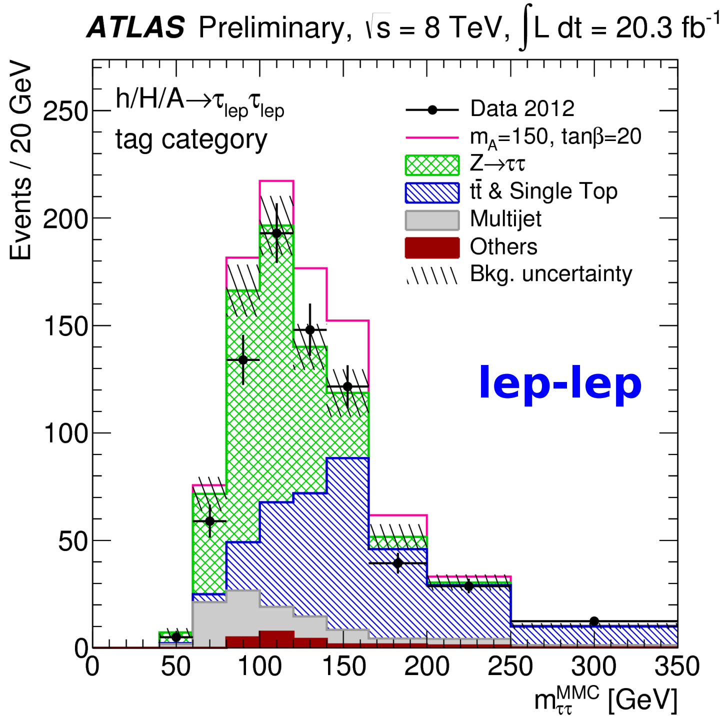


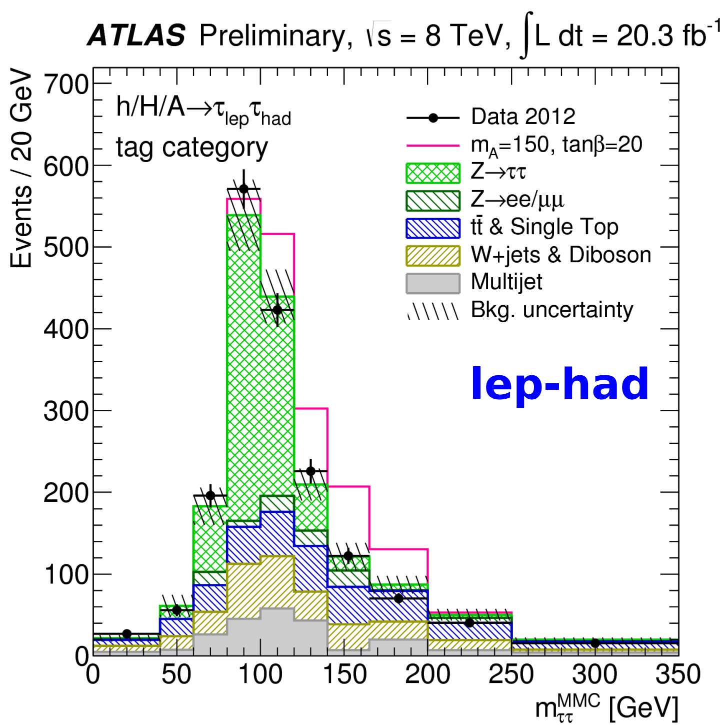


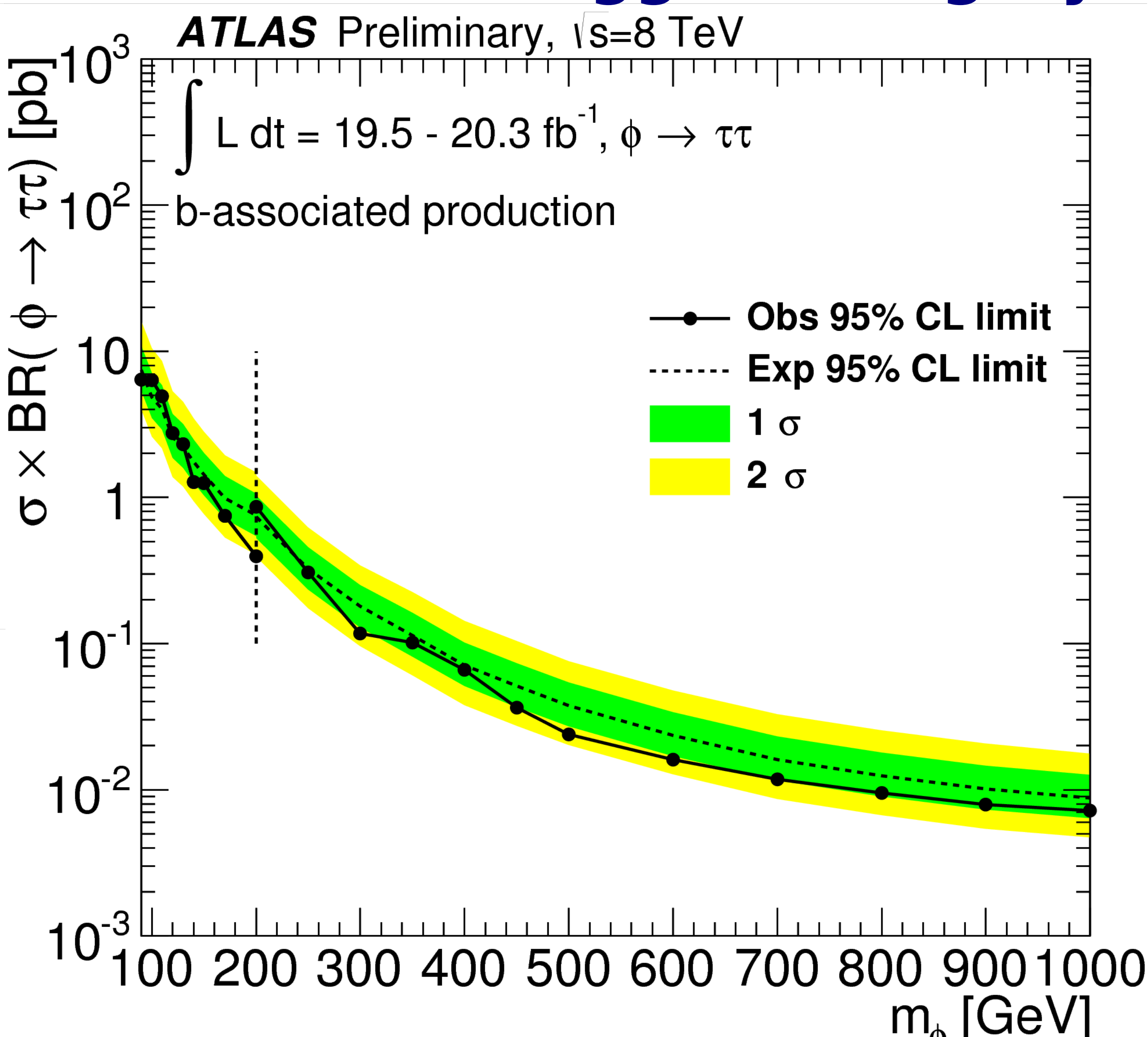
Separate optimizations are done in the lep-had decay channel for the high-mass and low-mass parts of this search. This helps provide the best sensitivity at high mass. The had-had channel is ONLY used at high mass.

ATLAS-CONF-2014-049

A/H/h→ττ: b-tagged category



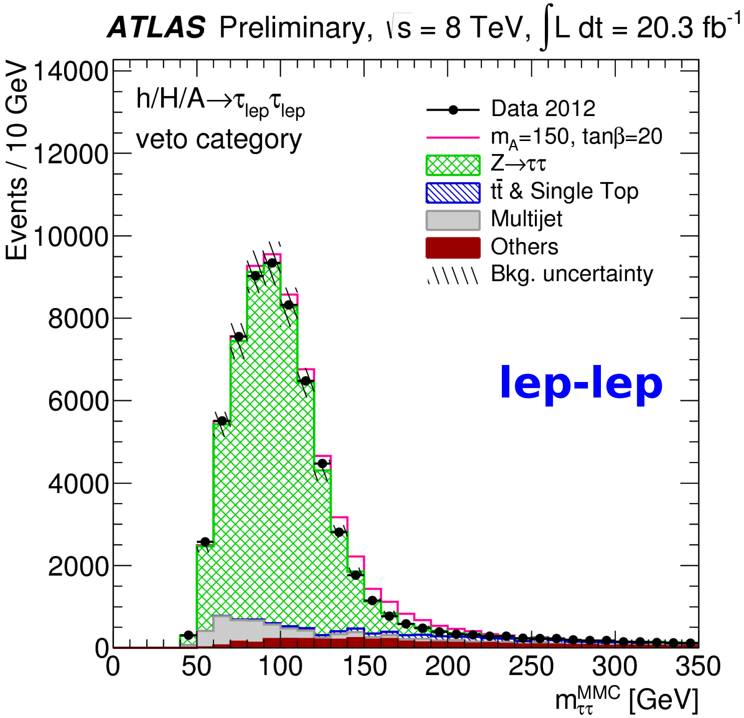


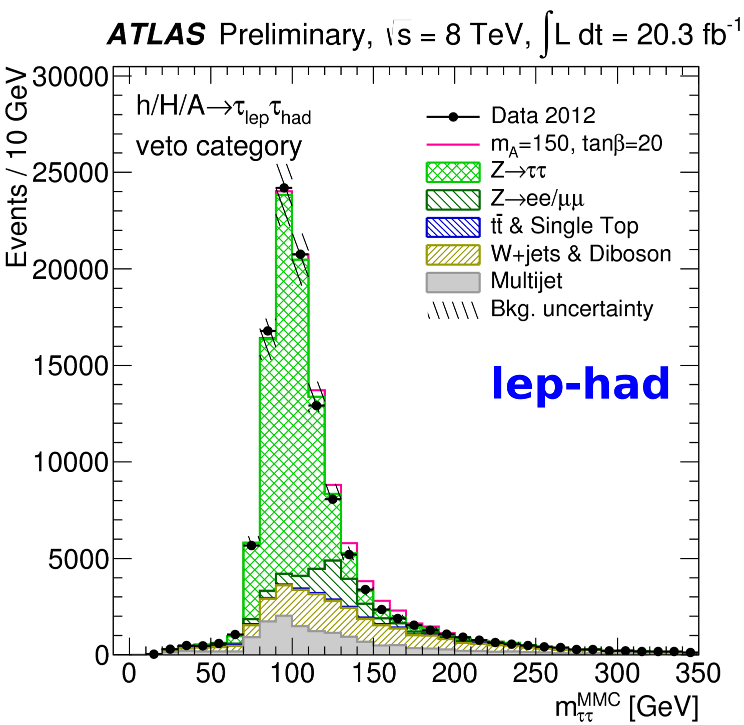


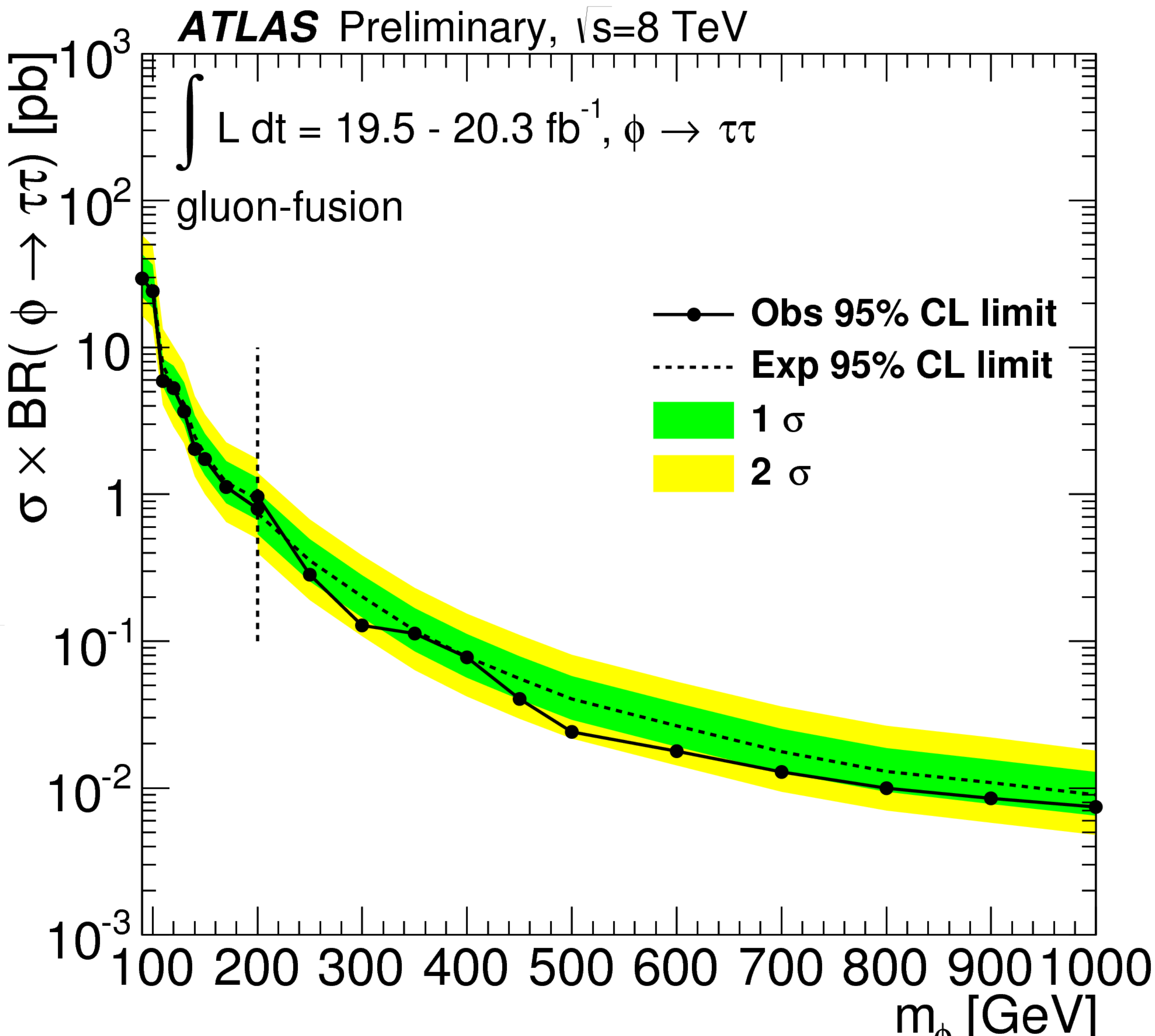
Model-independent σ×BR limits in b-tagged category achieve limits down to ~10fb at high mass.

ATLAS-CONF-2014-049

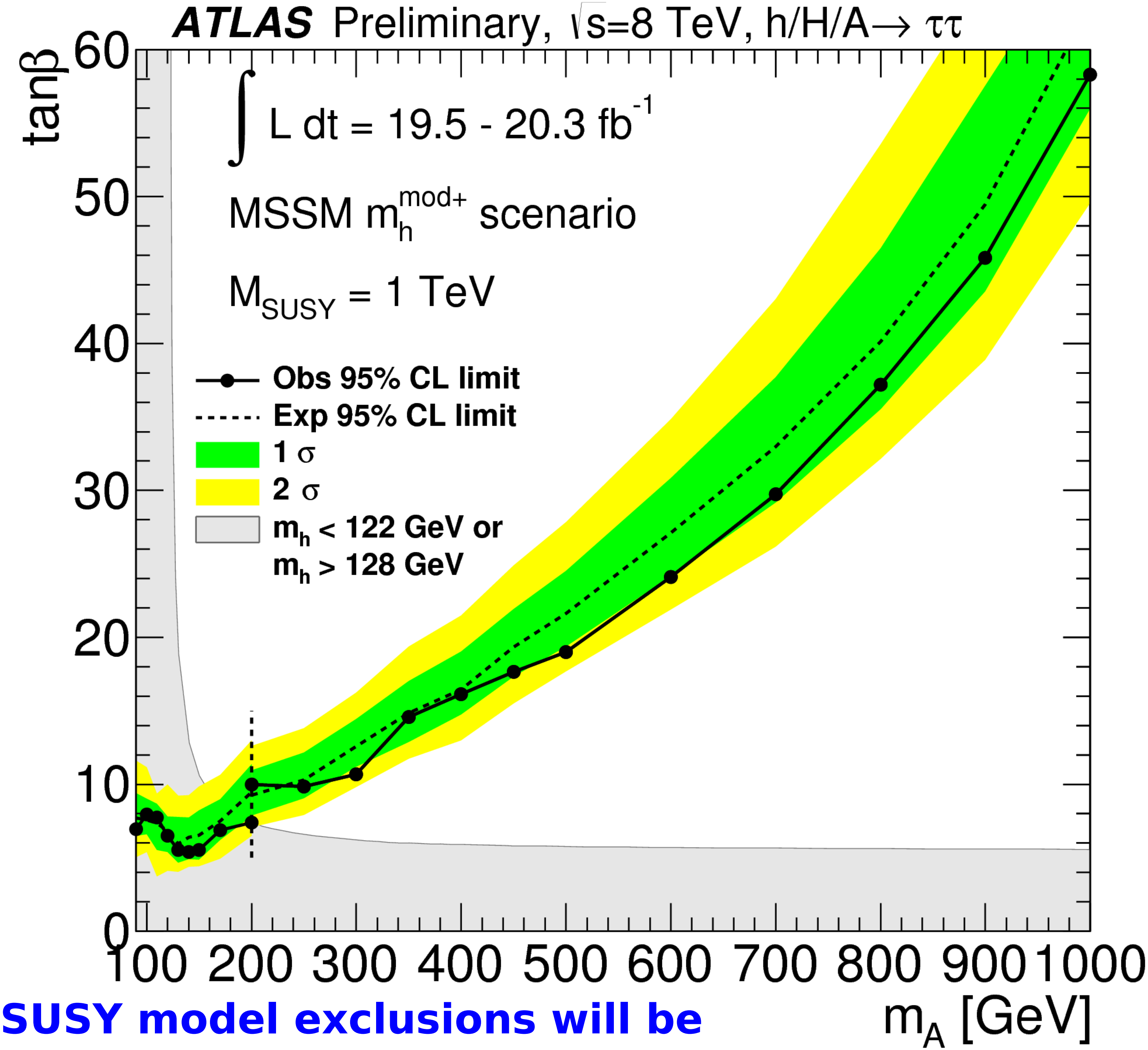
A/H/h→ττ: b-vetoed category







Model-independent σ×BR limits in b-vetoed category also achieve limits down to ~10fb at high mass.



Other SUSY model exclusions will be available in the conference note.

ATLAS-CONF-2014-049

Conclusions

Conclusions

- ATLAS finalizing Run 1 SM Higgs Results

$$m_H^{combined} = 125.36 \pm 0.37\,(\text{stat.}) \pm 0.18\,(\text{syst.})\ \text{GeV}$$

$$\mu_{on-shell}^{combined} = 1.30^{+0.18}_{-0.17}$$

$$\mu_{off-shell}^{ZZ} < 5.9 - 9.0 \quad \left(\Gamma_H / \Gamma_H^{SM} < 4.1 - 6.0\right)$$ (both at 95% CL)

Couplings and spin-parity so-far compatible with SM

- ATLAS finalizing Run 1 BSM Higgs Searches
  - Recent results in A/H/h → τ τ, X → γγ, and X → hh → bbγγ achieved excellent sensitivity but observed no significant non-SM effects.
- Run 2 shall be very exciting!