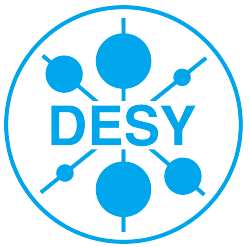
Latest H→γγ results in ATLAS.

Elisabeth Petit

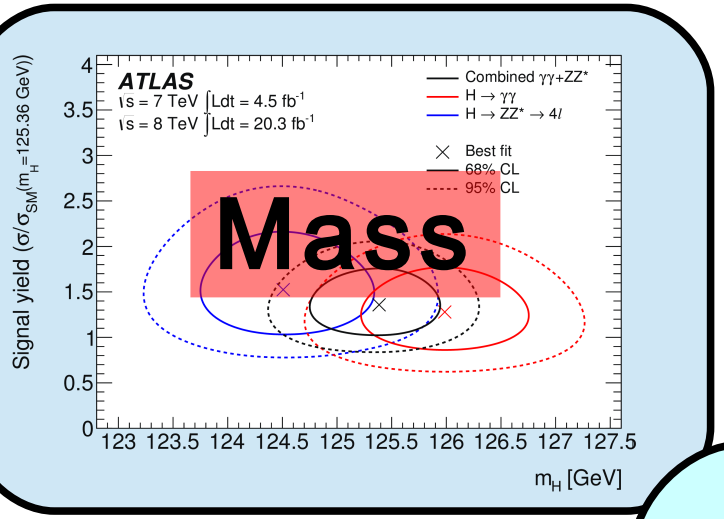


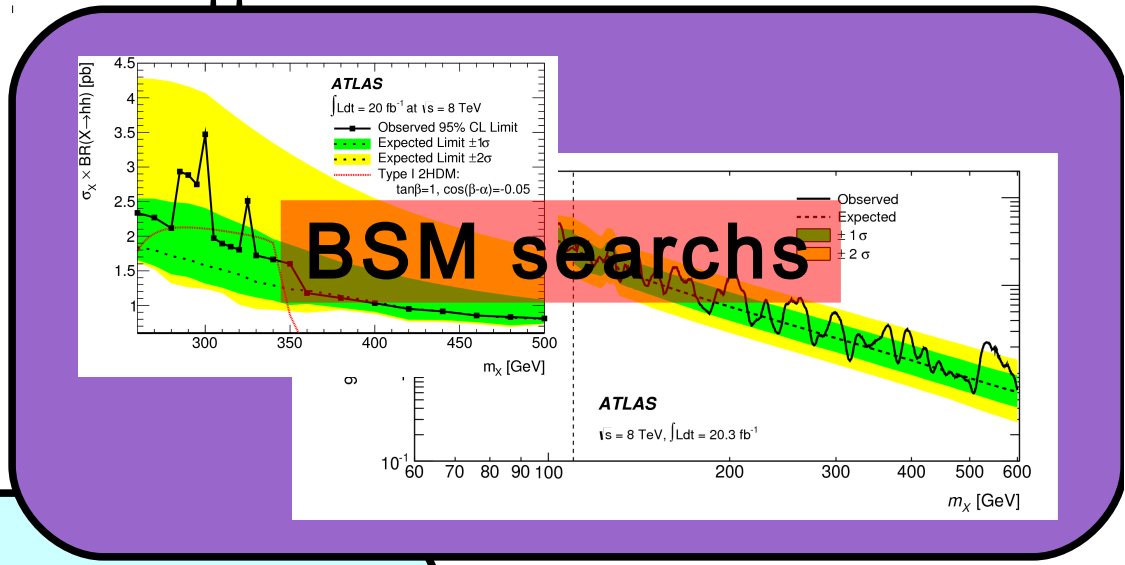
DESY LHC discussion meeting

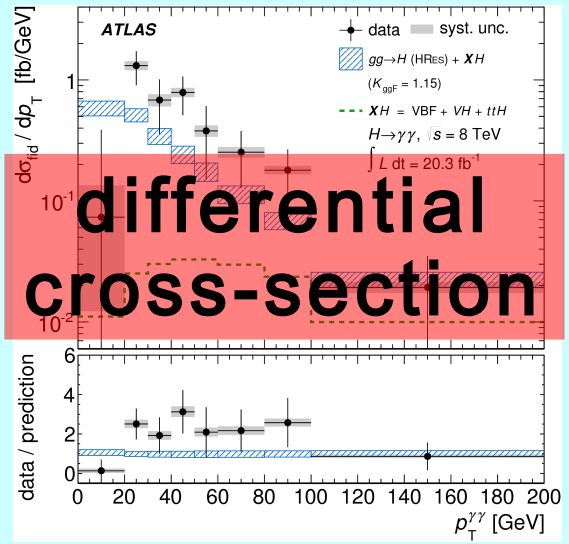
22nd of September 2014

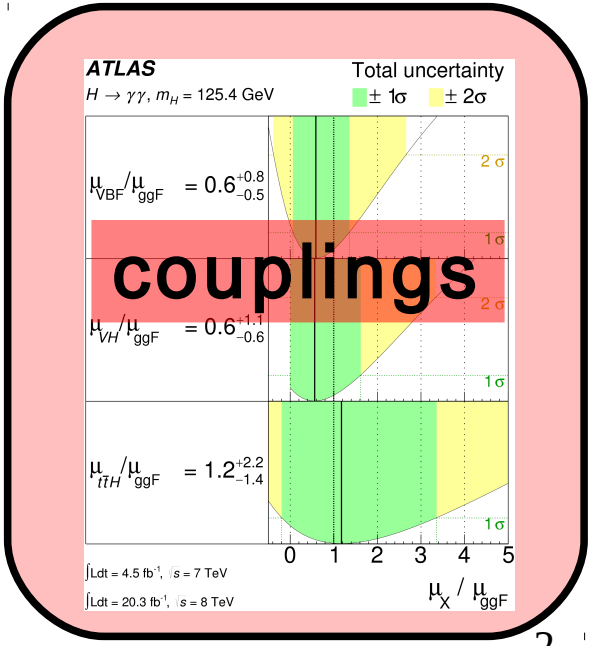
Introduction

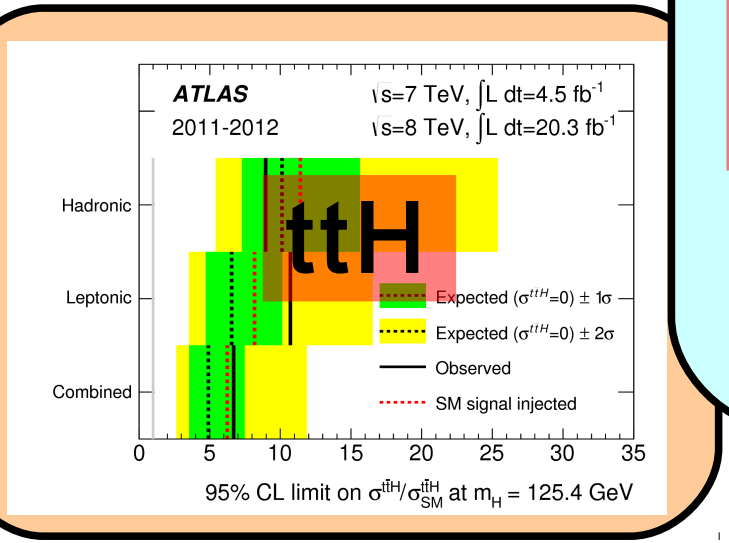
- Final results with run 1 dataset for the H→γγ channel









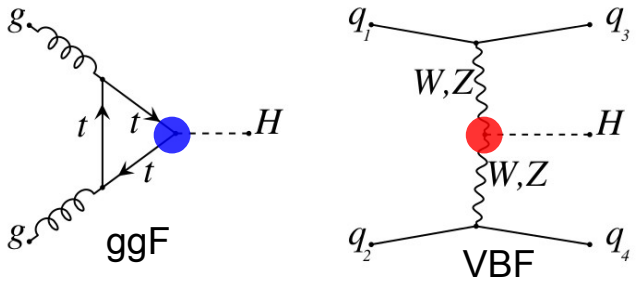


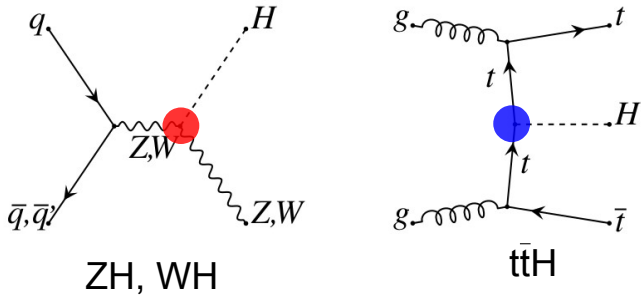
Part I:
Measurement of Higgs boson production in the diphoton decay channel

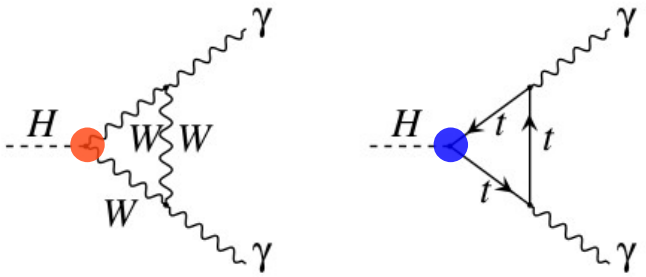
submitted to Phys. Rev. D, 1408.7084

Aim of the analysis

- Ultimate goal: test couplings of Higgs boson to fermions and bosons
- Measurements of signal rates relative to SM predictions (signal strengths) for the main production mechanisms
- Use m_H=125.4±0.4 GeV from the mass paper (HIGG-2013-12) as input
- From inclusive diphoton sample divide the events into categories that maximise sensitivities to production mechanisms







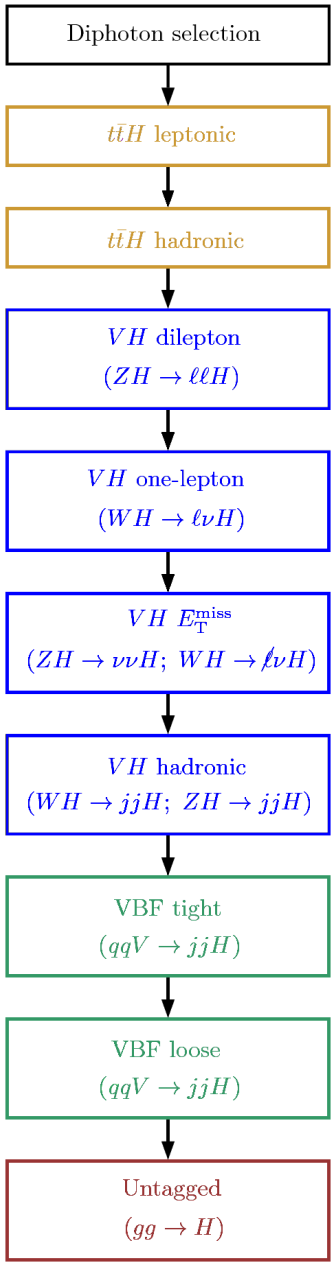
Changes wrt last paper

- First results on run-1 dataset published in Physics Letters B, Volume 734
- Improved material description
- Improved calibrations
  - mass resolution improved by 10%
  - resolution uncertainty reduced by factor 2
- Reduced uncertainties on photon ID and isolation
- New categories
  - added ttH leptonic, hadronic
  - split VH into 1-lepton (WH) and 2-lepton (ZH)

- Overall gain on combined signal strength ~10%

Categorisation

- Divide diphoton selection in sequential, exclusive categories



N_{sig} = 0.6, 80.3% ttH

N_{sig} = 0.6, 84.1% ttH

N_{sig} = 0.3, 99.1% ZH

N_{sig} = 1.7, 89.8% WH

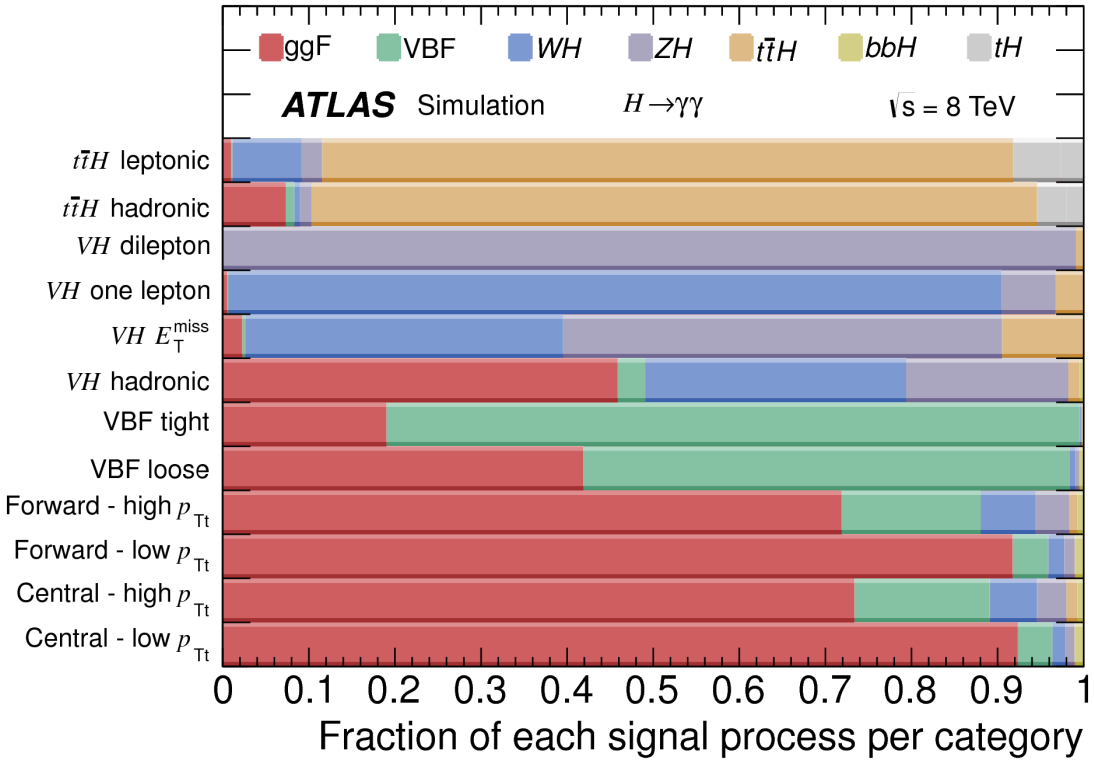
N_{sig} = 1.1, 87.9% VH

N_{sig} = 3.2, 49.1% VH

N_{sig} = 5.7, 80.5% VBF

N_{sig} = 9.3, 56.5% VBF

N_{sig} = 371.5, 90.5% ggF

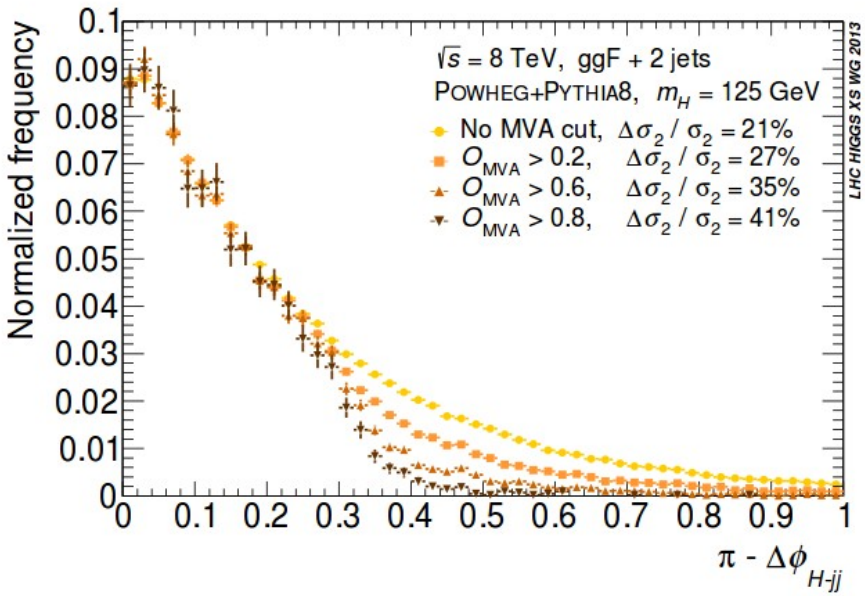


Systematic uncertainties

- Summary of uncertainties on the signal strength:

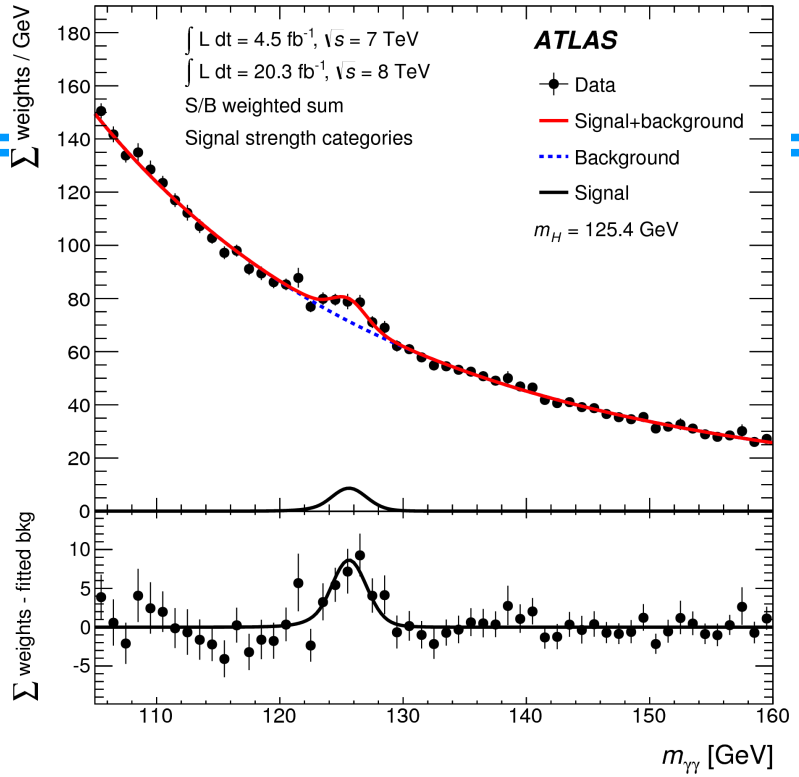
Uncertainty group	$\sigma_{\mu}^{\text{syst.}}$
Theory (yield)	0.09
Experimental (yield)	0.02
Luminosity	0.03
MC statistics	< 0.01
Theory (migrations)	0.03
Experimental (migrations)	0.02
Resolution	0.07
Mass scale	0.02
Background shape	0.02

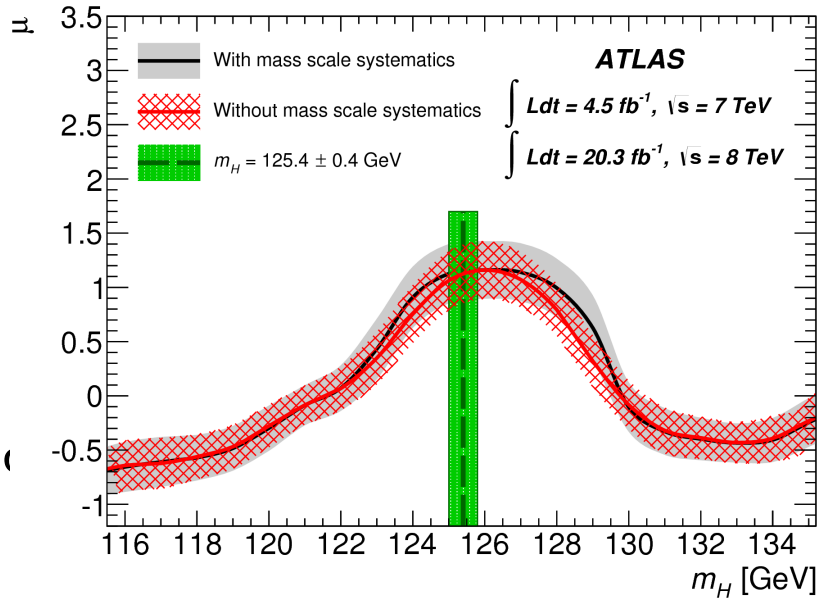
- Theoretical uncertainties on yield
  - BR: 5%
  - QCD scale+PDF: up to 8% (ggF)
- Theoretical uncertainty on migration
  - Higgs p_T modelling for ggF: weighted to match the HRes2.1 prediction, up to 24% migration uncertainty
  - ggF cross section with one or two jets
    - use of ST method
    - adapted for MVA selection of VBF category
    - up to 52% migration uncertainty



Results

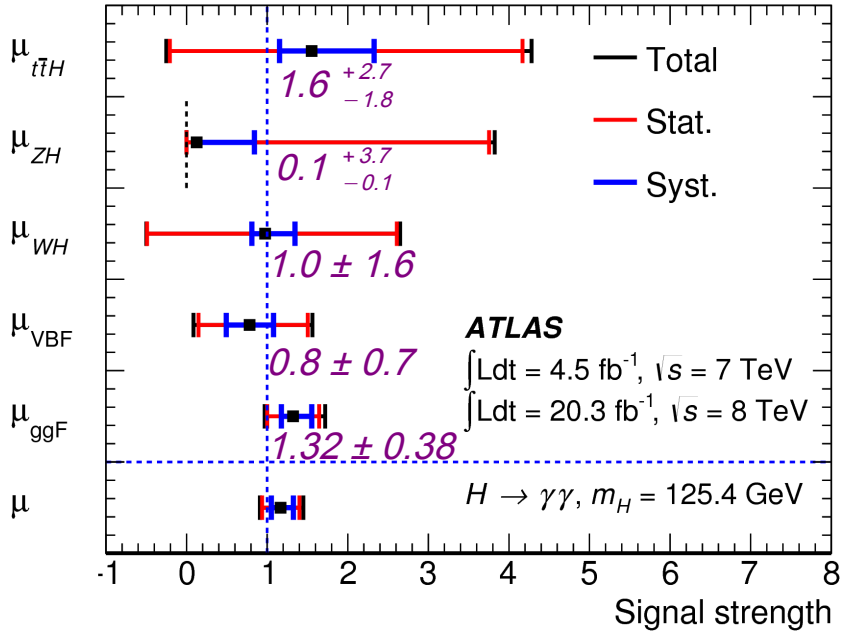
- Local significance at 125.4 GeV:
  - expected: 4.6σ
  - observed: 5.2σ
- Signal strength:
  - $\mu = 1.17 \pm 0.23\,(\text{stat})\ ^{+0.10}_{-0.08}\,(\text{syst})\ ^{+0.12}_{-0.08}\,(\text{th})$
  - 0.7σ compatibility with SM (μ=1)
- Compatibility with previous results
  - Phys. Lett. B 726, 88 (2013)
  - $\mu = 1.55\ ^{+0.33}_{-0.28}$
  - consistent with each other at the level of ~2.3 σ

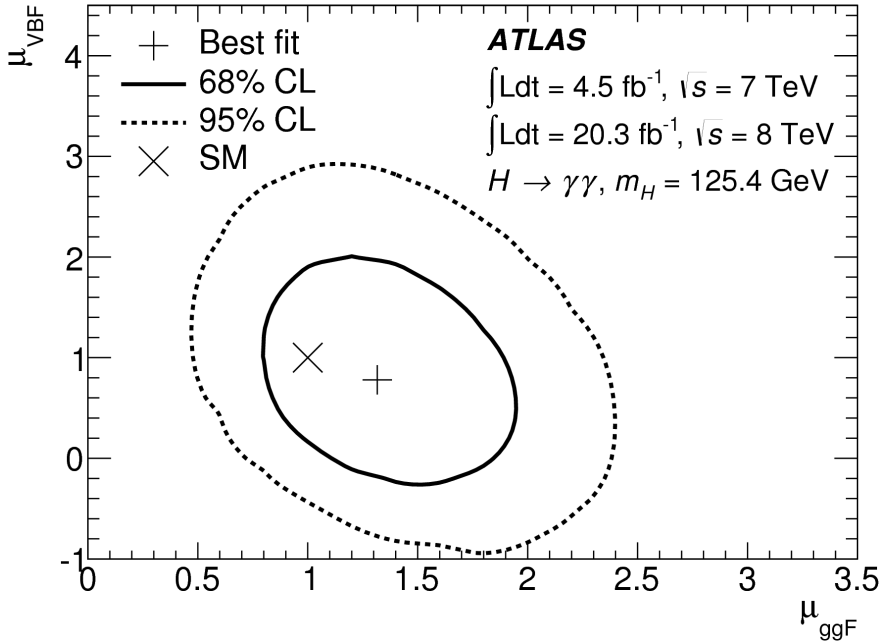




Signal strength /production mode

- Extracted from simultaneous fit on 12 categories





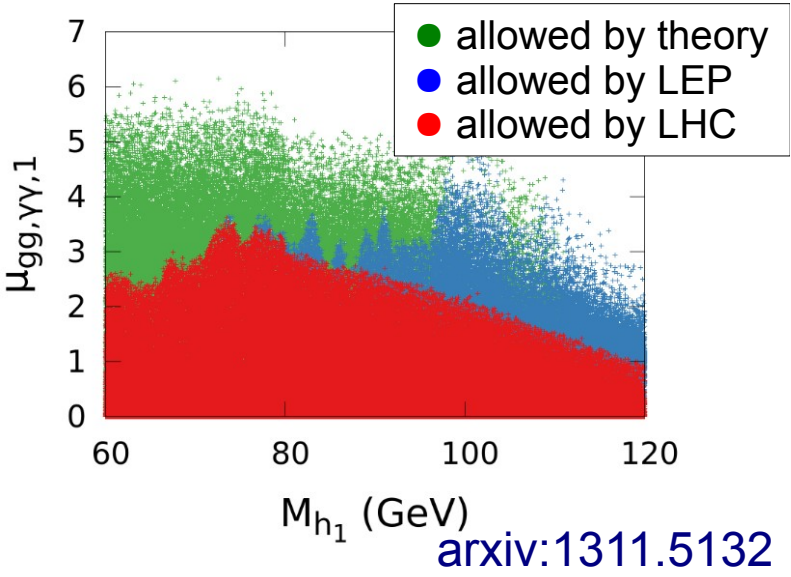
- Ratios of μ_i/μ_{ggF}
  - test the production through VBF, VH and ttH independently of BR(H→γγ)
  - $\mu_{VBF}/\mu_{ggF} = 0.6\ ^{+0.8}_{-0.5}$
  - $\mu_{VH}/\mu_{ggF} = 0.6\ ^{+1.1}_{-0.6}$
  - $\mu_{ttH}/\mu_{ggF} = 1.2\ ^{+2.2}_{-1.4}$
  - not significantly different from 0, consistent with SM

Part II:
Search for scalar diphoton resonances in the mass range 65-600 GeV at $\sqrt{s}$ = 8 TeV

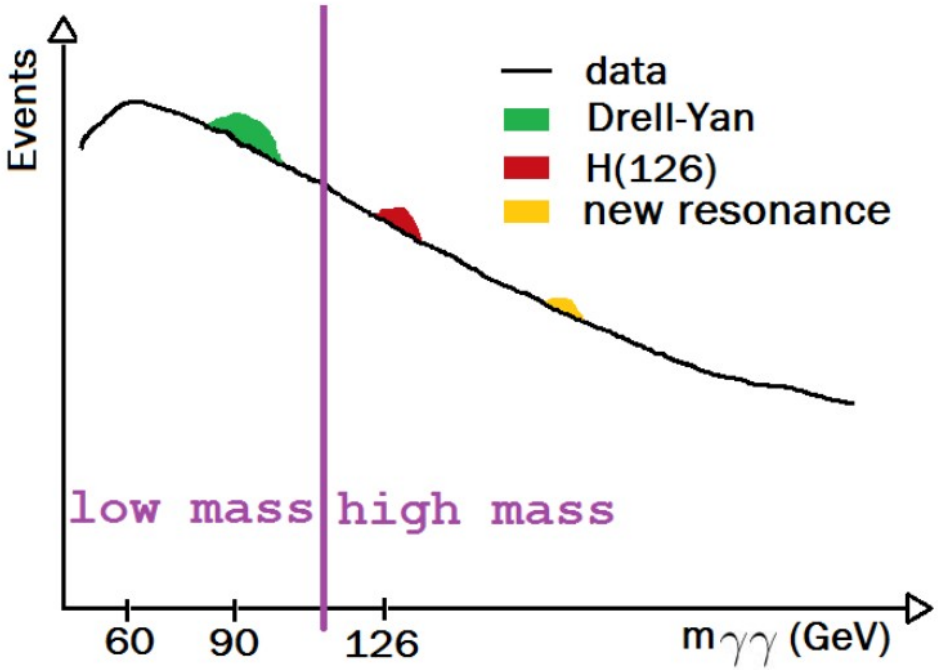
accepted by Phys. Rev. Lett. , 1407.6583

Analysis overview

- Many models predict other Higgs bosons at higher or lower mass
- Range: 65 (trigger) – 600 (statistics) GeV
- Key points
  - stay as close as possible to $H \rightarrow \gamma\gamma$ methods
  - be as model-independent as possible
- Hypotheses
  - narrow: natural width < calorimeter resolution ($\Gamma_X < 0.09 + 0.01 * m_X$)
  - spin 0
- Analysis split in two:

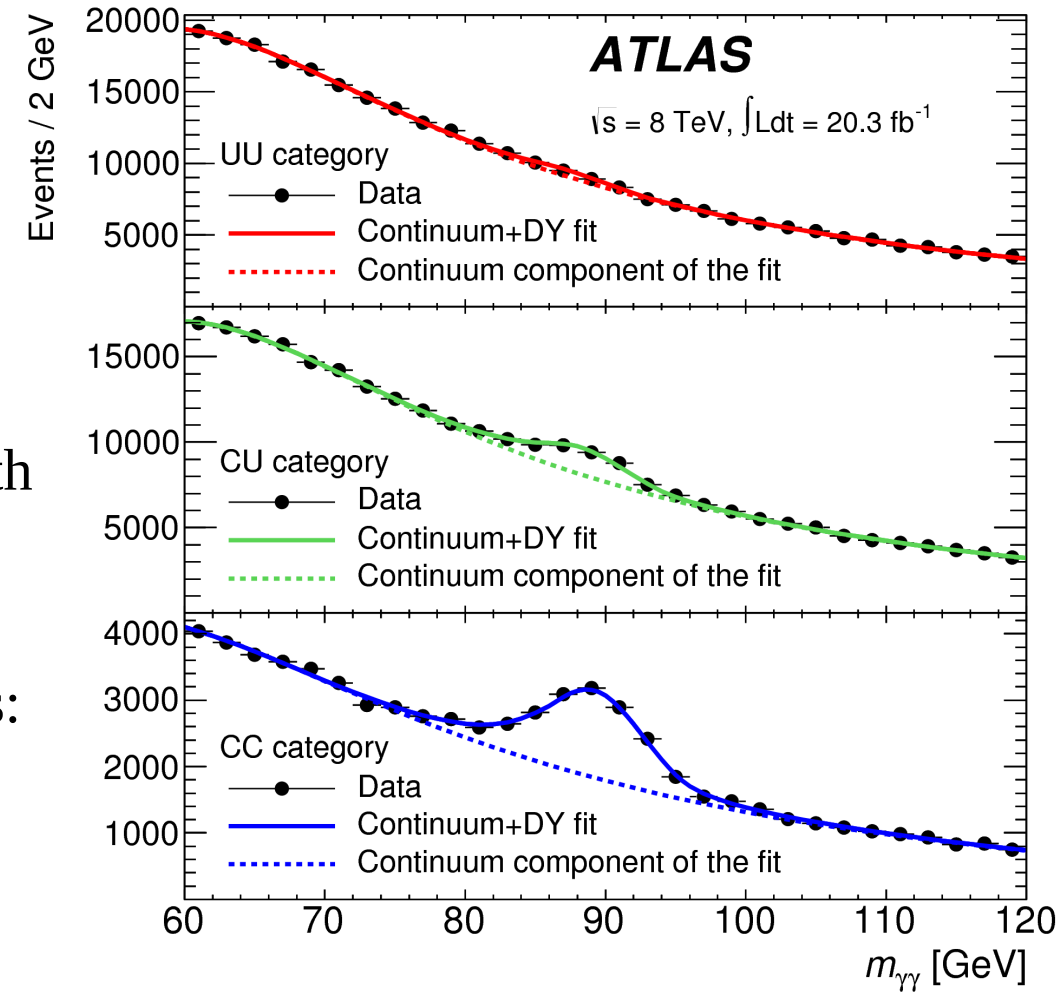


arxiv:1311.5132



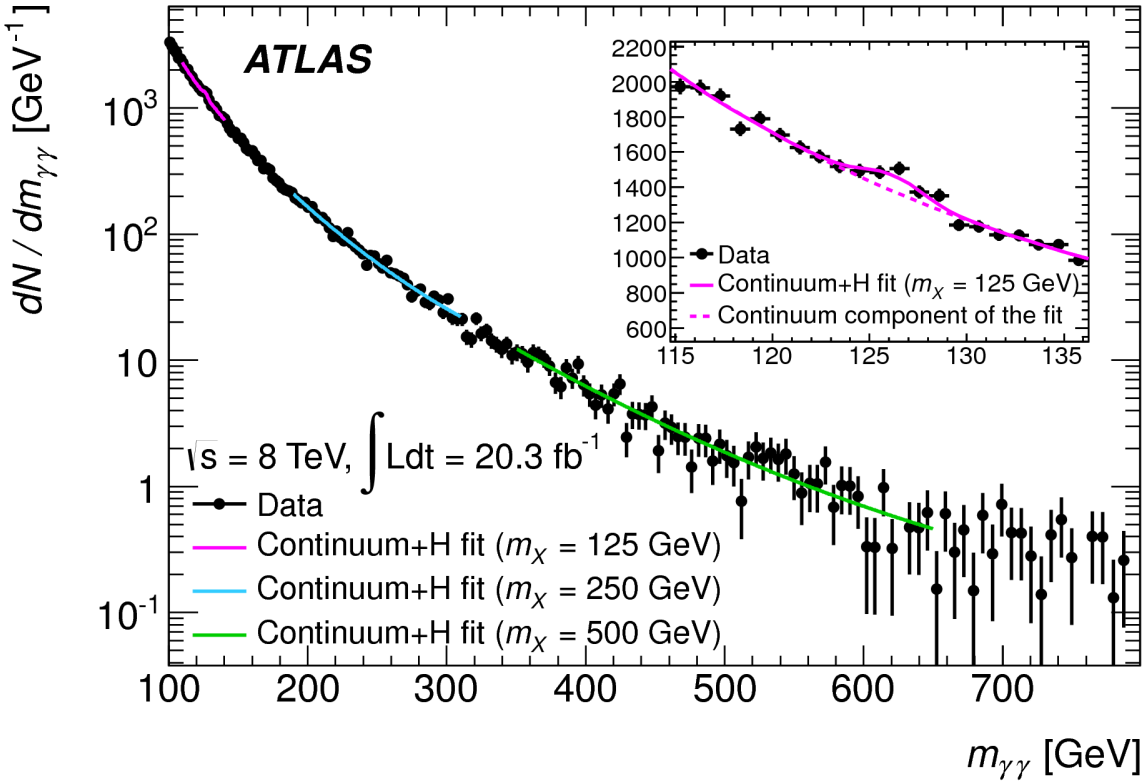
Low-mass analysis

- 60 < mγγ < 120 GeV
- Selection cuts
  - E_T > 22 GeV
  - tight isolated photons
- Continuum background + Z→ee with e faking γ as background
- Separate events into three categories:
  - both photons unconverted
  - one unconverted, one converted
  - both photons converted



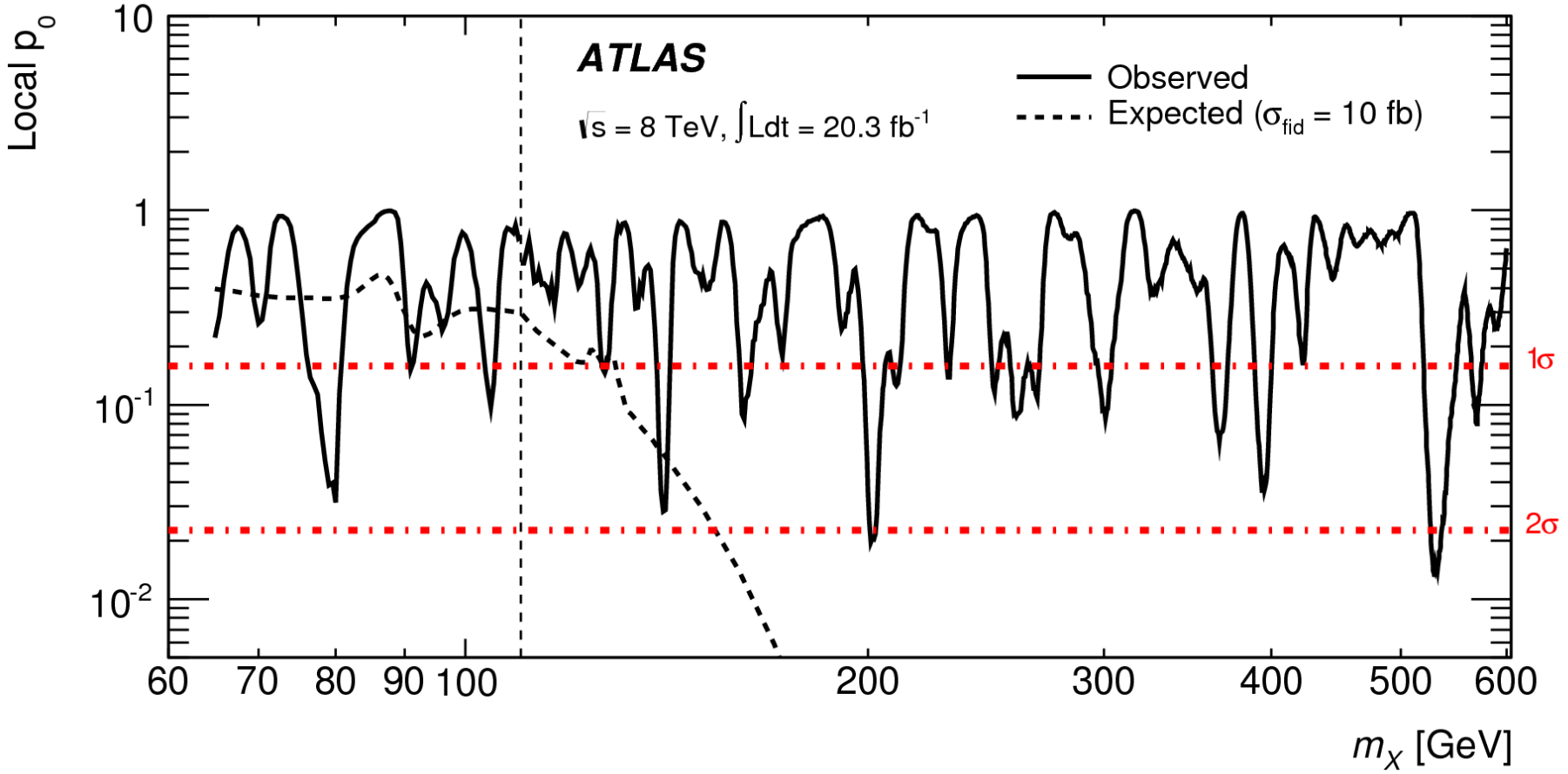
High-mass analysis

- 100 < mγγ < 800 GeV
- Selection cuts
  - $E_T^{\gamma 1}/m_{\gamma\gamma} > 0.4$ and $E_T^{\gamma 2}/m_{\gamma\gamma} > 0.3$
  - tight, isolated photons
- Fits in mass sliding windows around each tested mass
- H(125 GeV) as additional background (μ = 1)



p-values

- p0 (= probability that peak comes from background fluctuations)



- No significant excess over one order in magnitude in mass
- Two fluctuations around 2σ
  - 0σ with look-elsewhere-effect

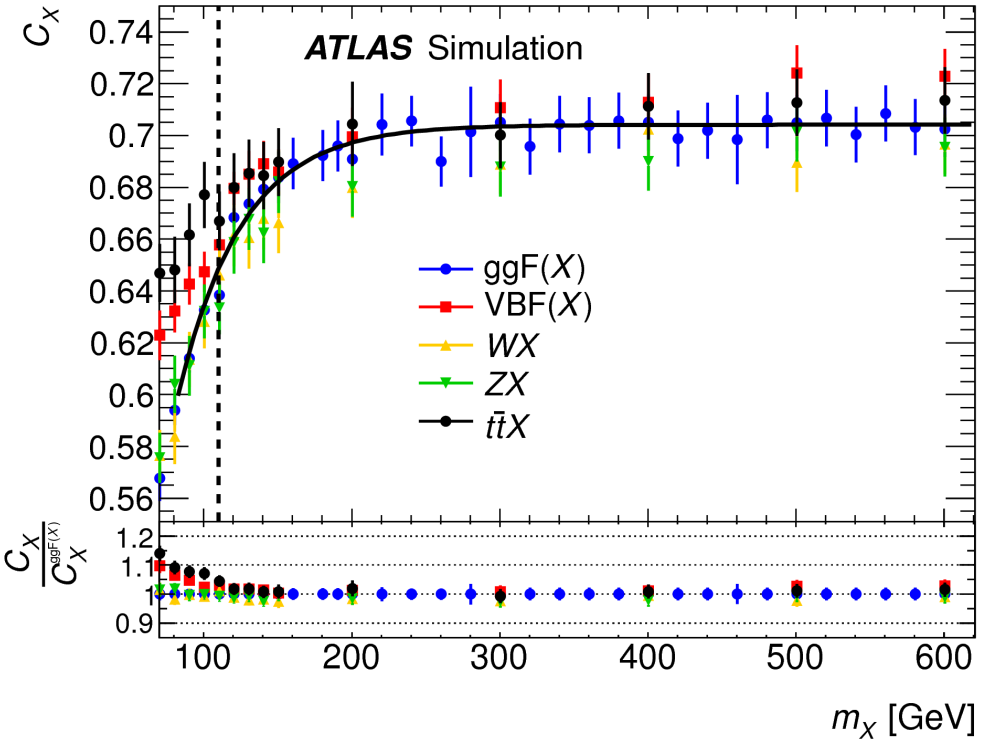
Limit on fiducial cross-section (1)

- Compute fiducial cross-section: $\sigma_{\text{fid}} \cdot \text{BR} = \frac{N^{\text{signal}}}{C_X \cdot L}$

  from the fit

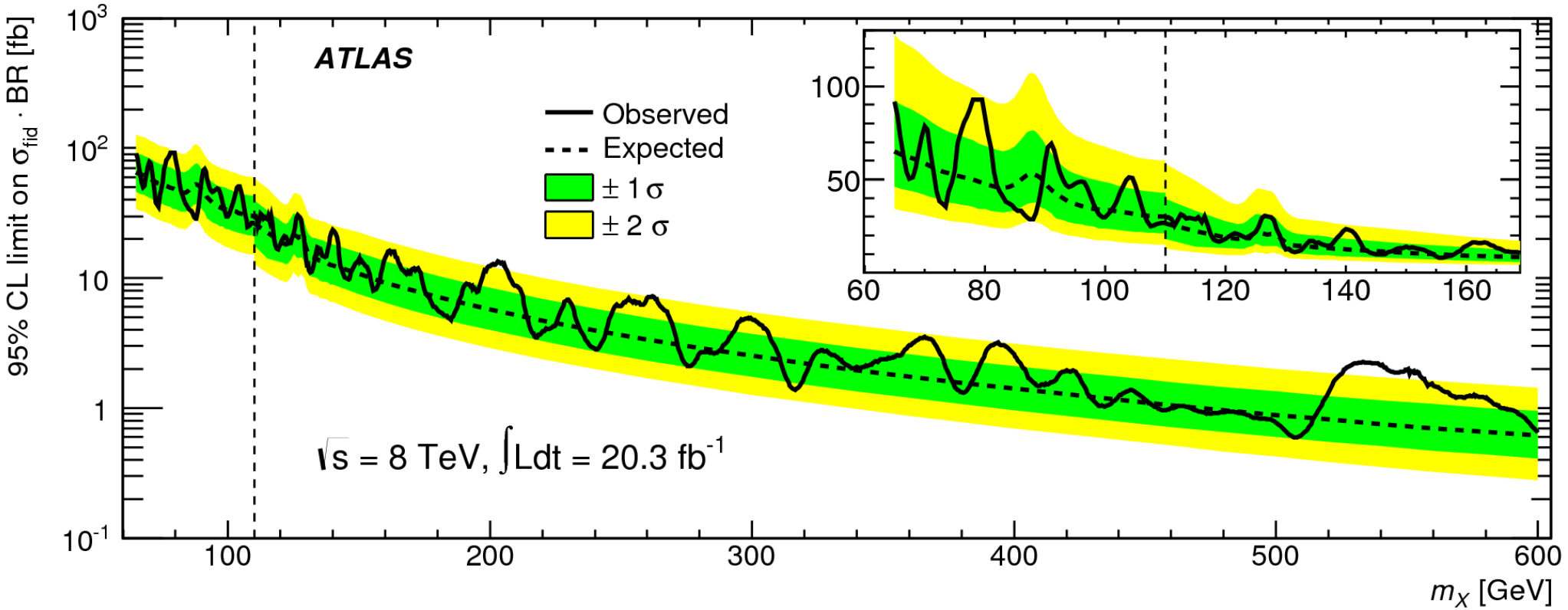
  correction factors

- Fiducial volume at low-mass:
  - $E_T^{\gamma 1} > 22$ GeV
  - $|\eta| < 2.37$
  - particle isolation < 12 GeV
- Fiducial volume at high-mass:
  - $E_T^{\gamma 1}/m_{\gamma\gamma} > 0.4$, $E_T^{\gamma 2}/m_{\gamma\gamma} > 0.3$
  - $|\eta| < 2.37$
  - particle isolation < 12 GeV
- C_X factor computed with ggF sample
  - other production modes used to assess residual model dependence
  - 10 → 4% uncertainty



Limit on fiducial cross-section (2)

- 95% CL limit:



- Limit from 90 fb to 1 fb

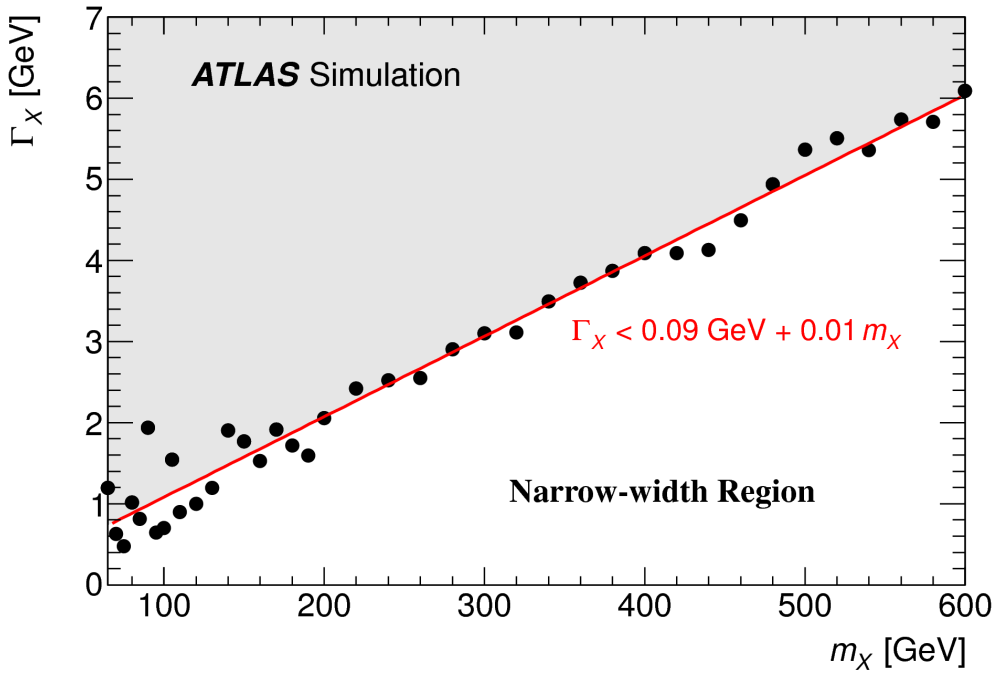
Conclusion

- Final results in the $H \rightarrow \gamma\gamma$ channel with run 1
  - final performance (calibration, identification, etc)
- Measurement of Higgs boson production
  - improved categorisation to be sensitive to all production modes
  - signal strength wrt SM: $\mu = 1.17 \pm 0.27$
  - signal strengths for all production modes
  - no significant deviations from SM
  - still limited by statistics
- Search for additional $\gamma\gamma$ resonances
  - from 65 to 600 GeV
  - no excess seen, limit on fiducial cross-section done over one order in magnitude in mass
  - results available in HEPDATA and Rivet routine

Back-up

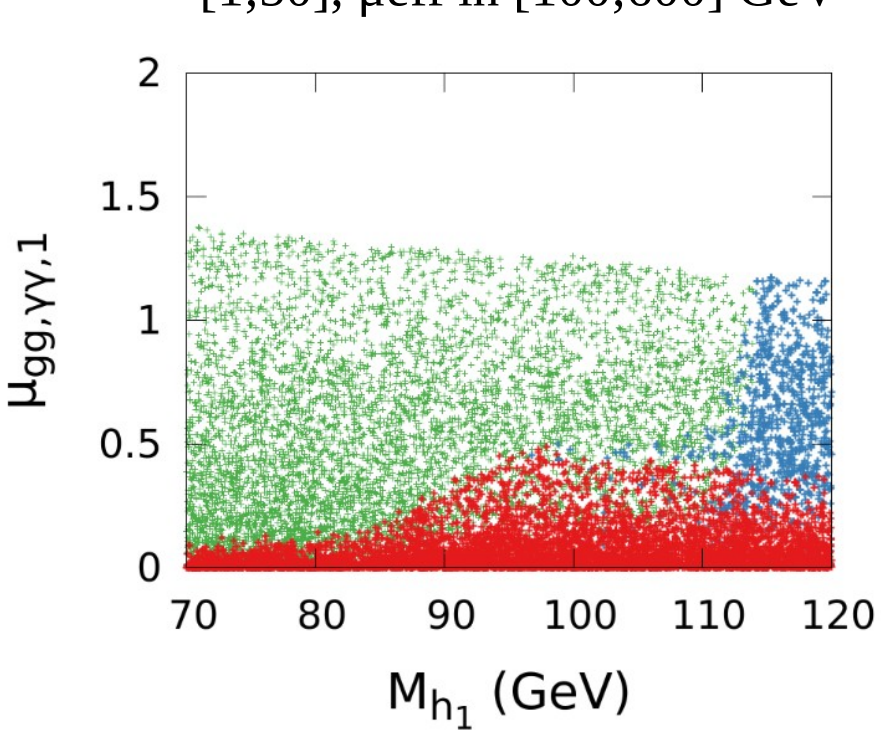
Influence of signal width

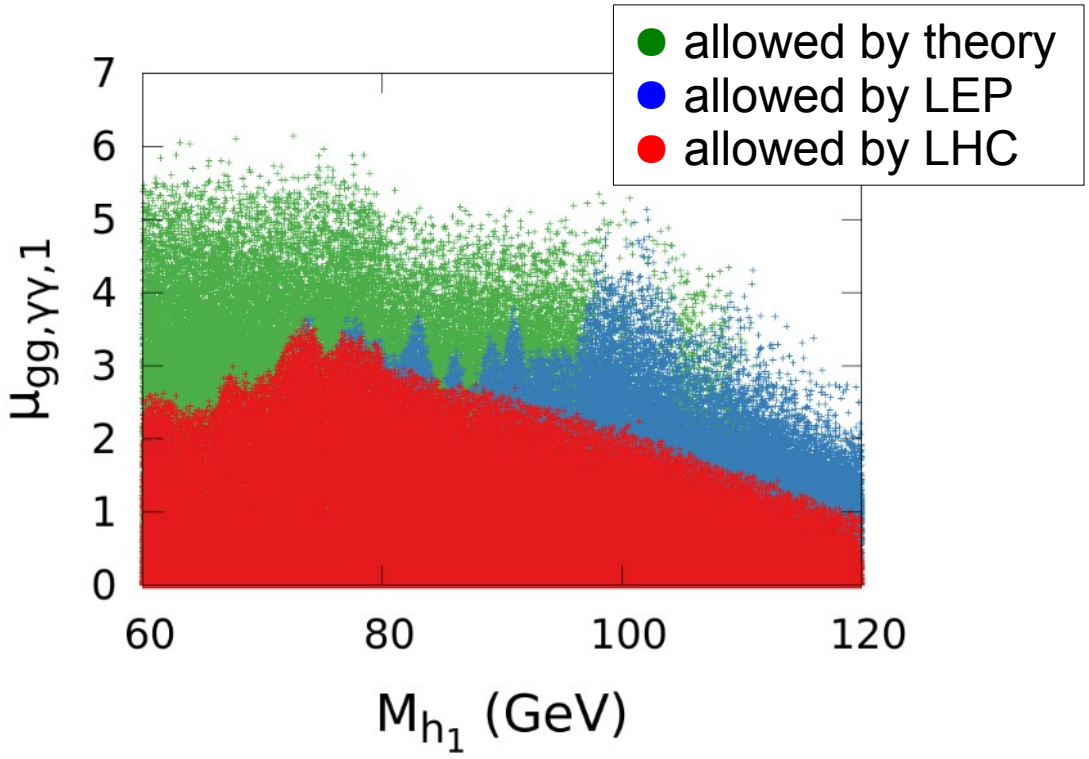
- H → γγ samples with Narrow Width Approximation
  - here NWA ⇔ width of Breit-Wigner = 4.07 MeV
  - reco width = resolution only
- Analysis valid as long as mγγ width dominated by calorimeter resolution
  - ΓX < 0.09 + 0.01*mX
  - 10 % bias on signal yield



Sensitivity of results at low mass

- No ATLAS benchmark for h < 125 GeV yet
- Examples from arxiv:1311.5132
  - 2HDM type I, tanβ in [1/50;50], sin(β-α) in [-1;1], mA in [300;1000], mH+ in [300;1000], and mh<120 GeV
  - NMSSM with mf = 500 GeV, mq=2TeV, mgaugino=100,500,1 TeV, tanβ in [1;50], μeff in [100;600] GeV



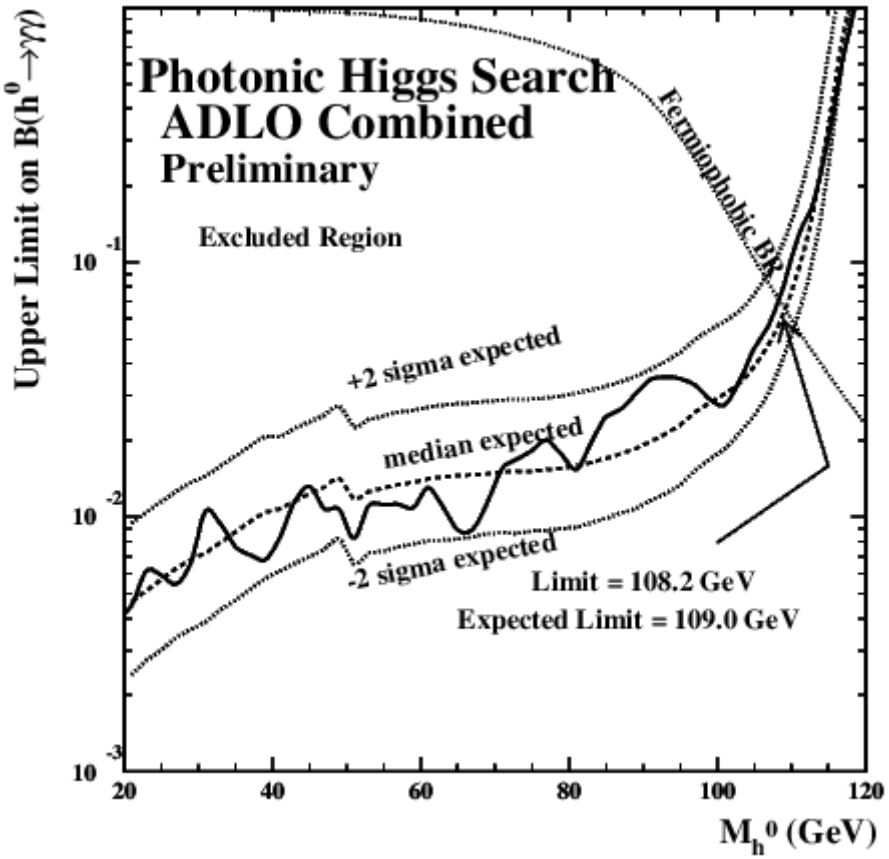


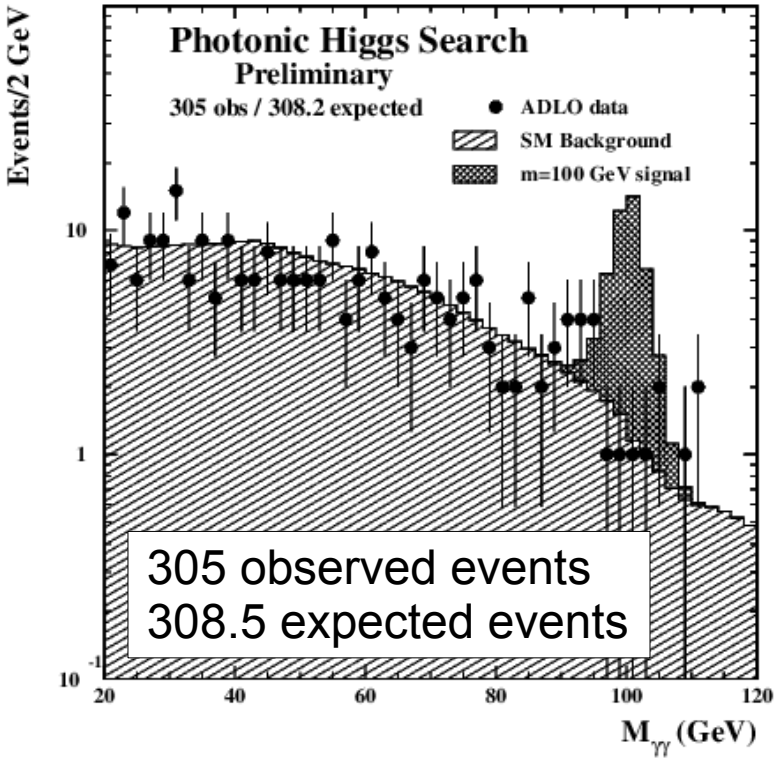
Limit settings

- Statistical model: new resonance X, H(126), non-resonant background, Drell-Yan
  - $N_X(m_X,\sigma_{fid},\theta_{NX},\theta_{SS}) = \sigma_{fid}.L.C_H$
- 95% limit on σ_{fid} with same estimator as main analysis
  - CLs technique, asymptotic approximation
- Low-mass analysis:
  - fit range ($m_{\gamma\gamma}$): 60-120 GeV, limit range (m_X): 70-110 GeV
- High-mass analysis:
  - fit range ($m_{\gamma\gamma}$): 100-700 GeV, limit range (m_X): 110-600 GeV

H → γγ at LEP

- Search for HZ → γγjj, HZ → γγll, HZ → γγνν
- Context of fermiophobic Higgs
- Limit on BR(H → γγ)

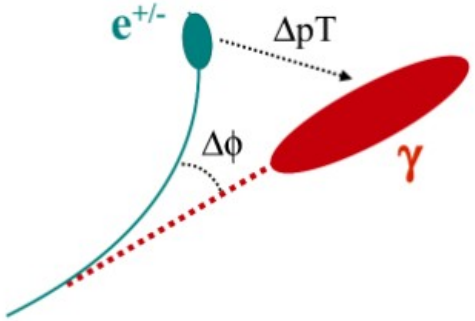


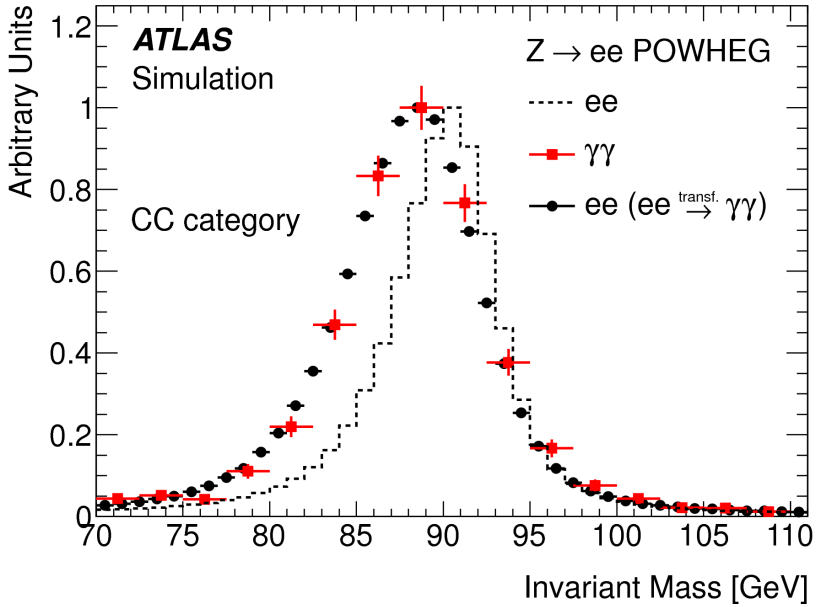


- Limit on σ(ee → ZH)*BR(H → γγ) ~ 1 pb

Z→ee background (1)

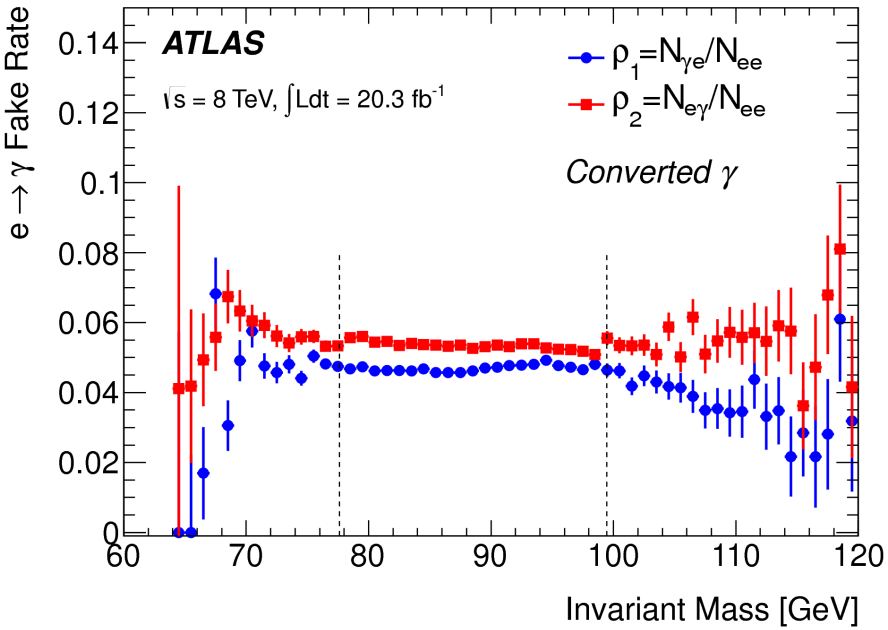
- Build a template to describe the fake photon background coming from electrons
- Number of estimated events: from e → γ fake rate
- Shape: from Z→ee data
- Z peak in shifted wrt Z peak in ee (2 GeV)
  - e reconstructed using the photon reconstruction and calibration
  - most of e reconstructed as photon have large Bremsstrahlung
  - shift and smear the Δp_T and $\Delta\varphi$ distributions



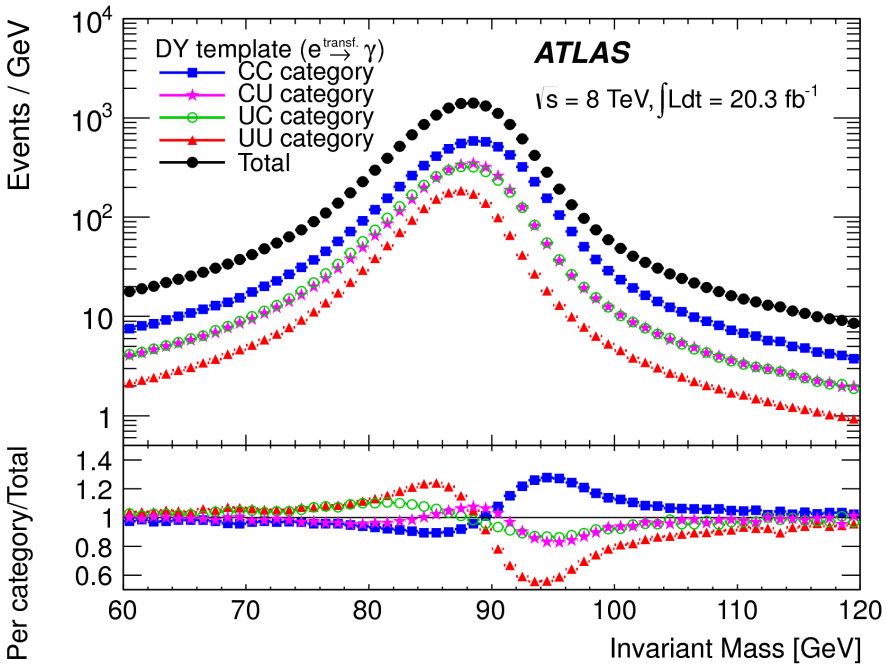


Z→ee background (2)

- Fake rates computed from data
  - measured on Z→ee data



- Templates for each category:



Systematic uncertainties

- Signal yield
  - few %
- Signal modelling
  - energy resolution
- CH factors
  - process dependence
- Continuum bkg
- Higgs (126 GeV)
- Drell-Yan

TABLE II. Summary of the systematic uncertainties

Signal and Higgs boson yield		*Z component of Drell–Yan*	
Luminosity	2.8%	Normalization[b]	9–25%
Trigger	0.5%	Peak position[b]	1.5–3.5%
γ identification[a]	1.6–2.7%	Template shape[b]	1.5–3%
γ isolation[a]	1–6%	*Higgs boson background*	
Energy resolution[a b]	10–40%	Cross-section[c]	9.6%
Signal and Higgs boson peak position		Branching ratio	4.8%
Energy scale	0.6%	C_X *factor*	
Continuum $\gamma\gamma$, γj, jj, *DY*		Topology[a]	3–15%
Signal bias[a]	1–67 events	Pile-up & U. E.[a]	1.4–3.2%

[a] mass-dependent.
[b] category-dependent.
[c] factorization scale + PDF uncertainties [31].

CMS high-mass γγ results

- Limit in 150-850 GeV
- 0.1 GeV < Γ_X < 10%*m_X
- Spin 0 and spin 2