Search for new phenomena in diboson production with lepton and photon final states with the ATLAS Detector

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on behalf of the ATLAS collaboration
University of Alberta

at EPS-HEP 2019, Ghent, Belgium
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Introduction

- Advantages of the lepton and photon channels
  - Good resolution, relatively high signal-to-background ratio
  - Benefit from the well developed analysis technic from higgs measurement channels

- Analysis covered:
  - Diphoton high mass search
    - 36.7 fb^{-1} ; Phys. Lett. B 775 (2017) 105
  - Diphoton low mass search
    - 80.4 fb^{-1} ; ATLAS-CONF-2018-025
  - ZZ high mass search.
    - 36.1 fb^{-1} ; Eur. Phys. J. C 78 (2018)
  - WW high mass search
    - 36.1 fb^{-1} ; Eur. Phys. J. C 78 (2018)
  - $Z\gamma$ high mass search
    - 36.1 fb^{-1} ; JHEP 10 (2017) 112

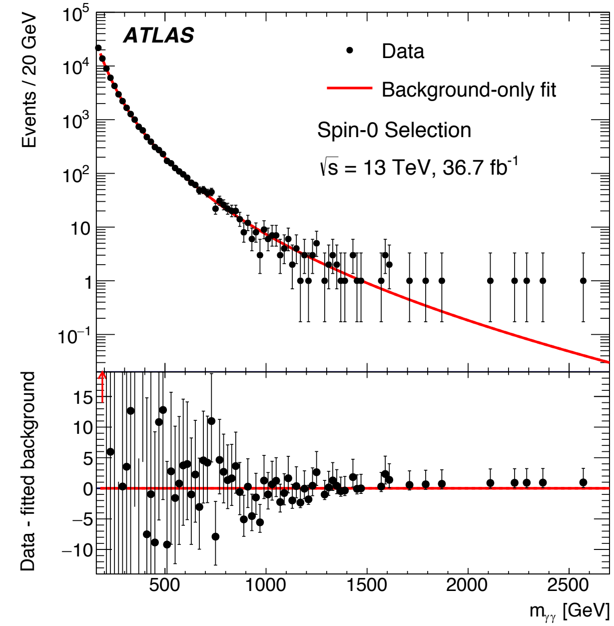
Diphoton high mass search

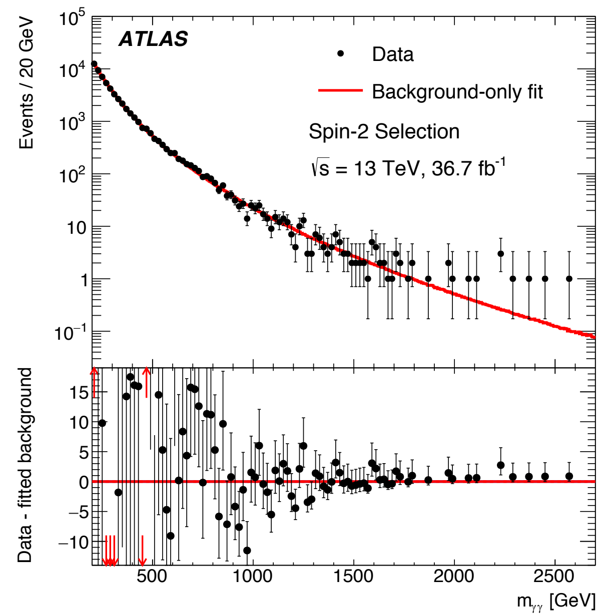
Phys. Lett. B 775 (2017) 105

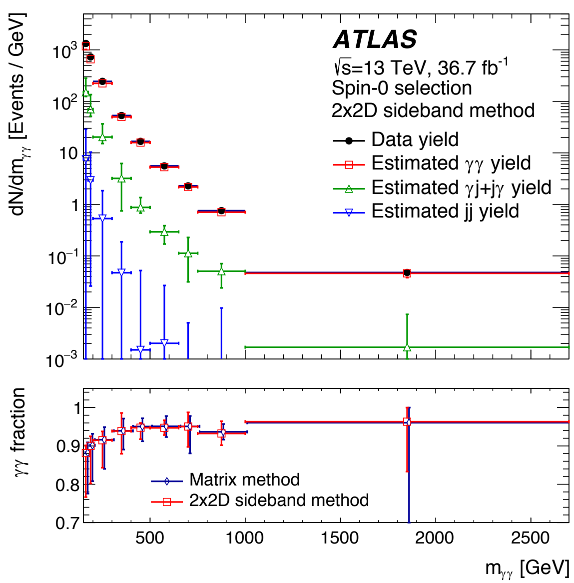
- Looking for resonances or deviations in diphoton invariant mass spectrum
- Kinematic selections optimized separately for spin-0 and spin-2 signals
- Fraction of jet-faking-photon background < 10%

- Resonant signal: functional form
- ADD signal: MC simulation

- Spin-0: background modeled by functional form
- Spin-2: Target Graviton signal at TeV scale, limited statistics. Shape of diphoton background from simulation, shapes of jet-faking-photon backgrounds from control samples, relative fractions from decomposition study

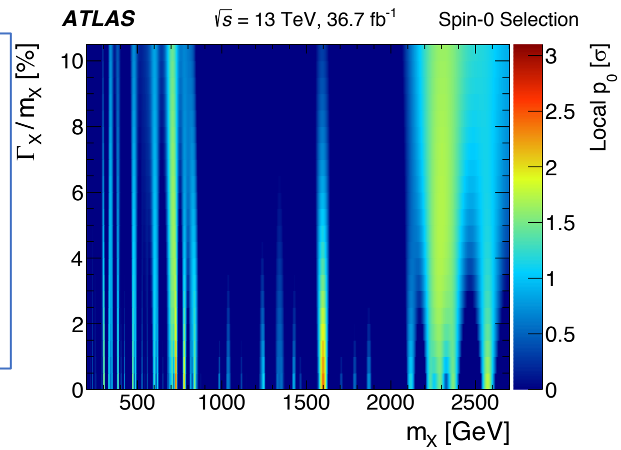


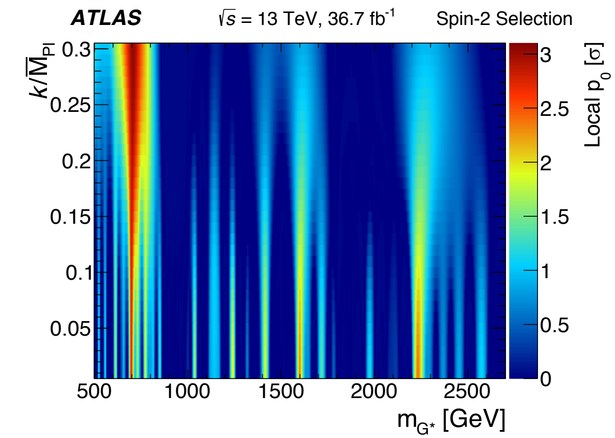




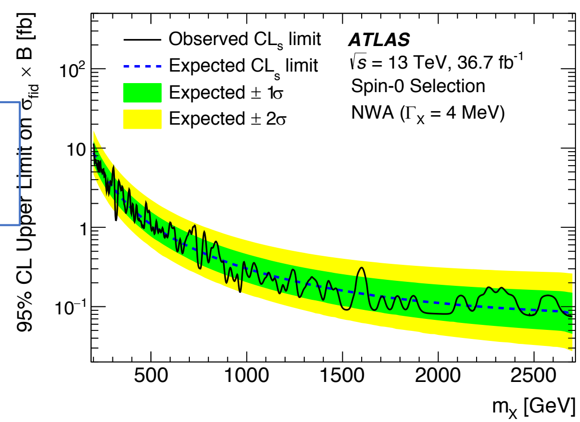
Diphoton high mass search

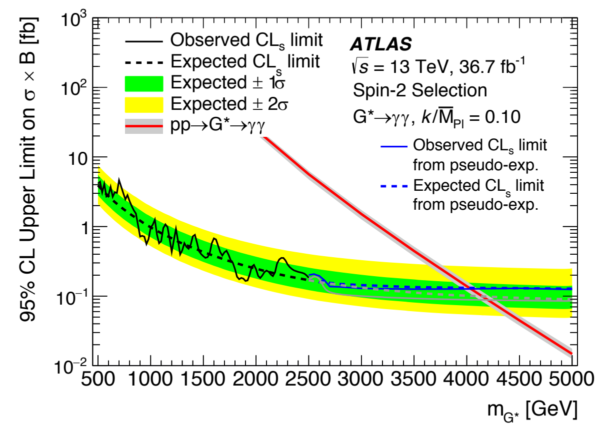
Spin-0: largest deviation at 730 GeV for narrow width, local (global) p-value 2.6 (0) σ
Spin=2: largest deviation at 708 GeV for $k/\overline{M}_{\mathrm{Pl}}$ =0.3, local (global) p-value 3.0 (0.8) σ





Limits on spin-0 NWA, spin-2 RS Graviton, spin-2 ADD model.





Limits on ADD model based on counting with M>2240 GeV:

	ADD formalism Parameter	GRW	Hewett positive	HLZ $n=3$	$n=4$	$n=5$	$n=6$
Without K-factor	M_S observed limit [TeV]	6.8	6.1	8.1	6.8	6.1	5.7
With K-factor	M_S observed limit [TeV]	7.2	6.5	8.6	7.2	6.5	6.1

Diphoton low mass search

ATLAS-CONF-2018-025

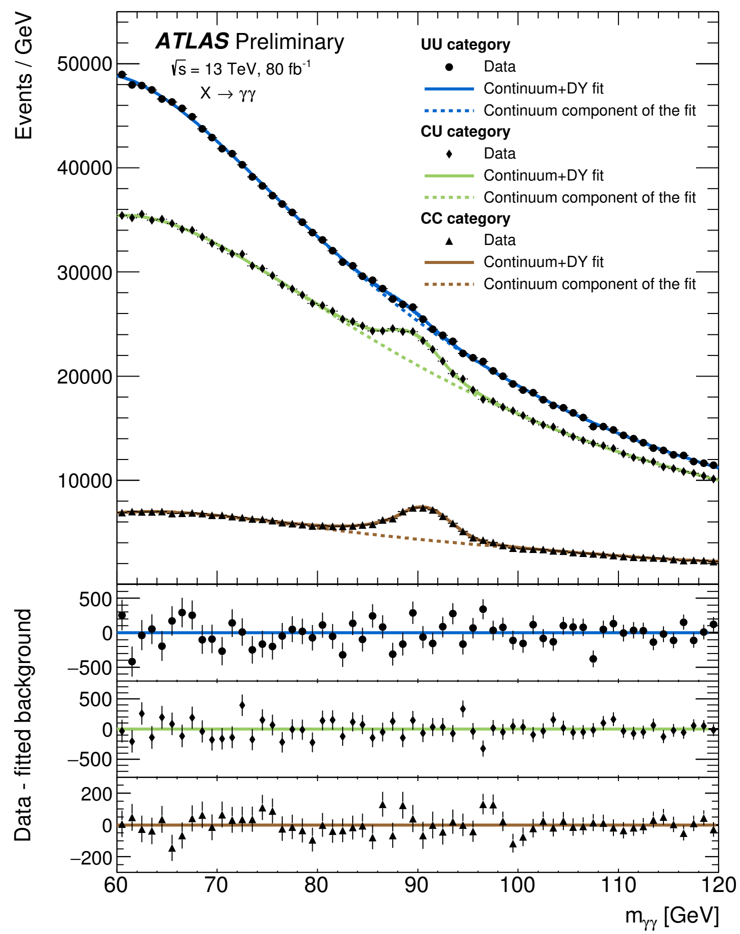
- Several model predict new resonances below higgs mass
- Search resonances in $m_{\gamma\gamma}$ 65-110 GeV

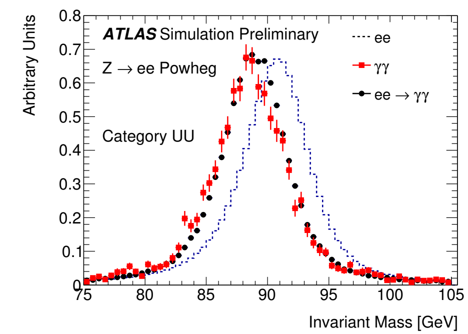
Signal and continuous background modeling similar to high mass search

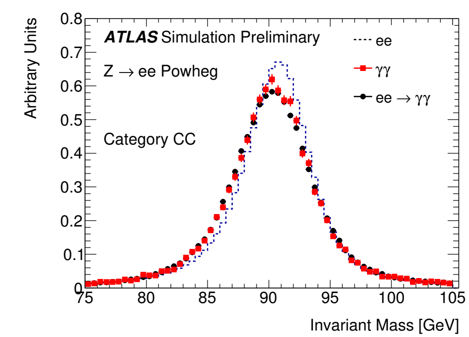
DY modelling:
- Data-driven based on data m_{ee}^{DY} template, with MC-based shape correction and further data-driven e->γ fake rate correction.
- modeled by functional form

Challenges:
- trigger threshold effect at low mass
- DY process with ee final states with e faking γ

Categorization:
- UU: zero converted photon
- CU: one converted photon
- CC: two converted photon

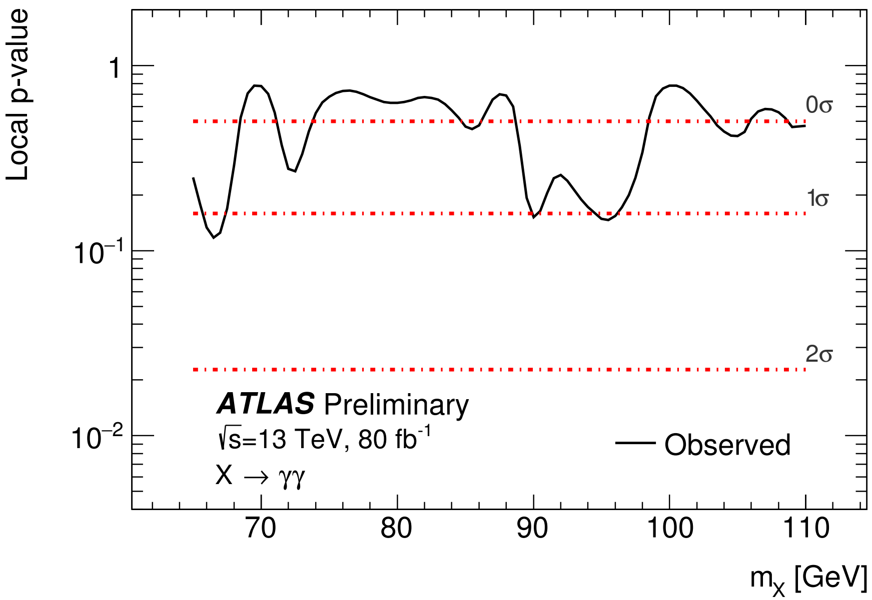


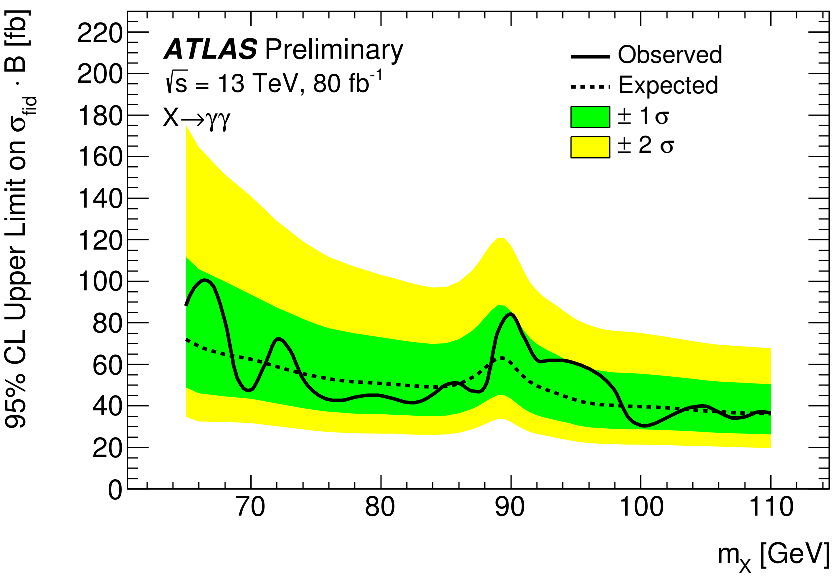




Diphoton low mass search

- No significant excess observed
- limits on NWA signals





ZZ high mass search

Eur. Phys. J. C 78 (2018)

ZZ->4l final states

- Good resolution and high signal-to-background ratio; good for low mass
- Invariant mass as discriminate variable

- 4e, 2e2μ, 4μ
- ggF and VBF enriched

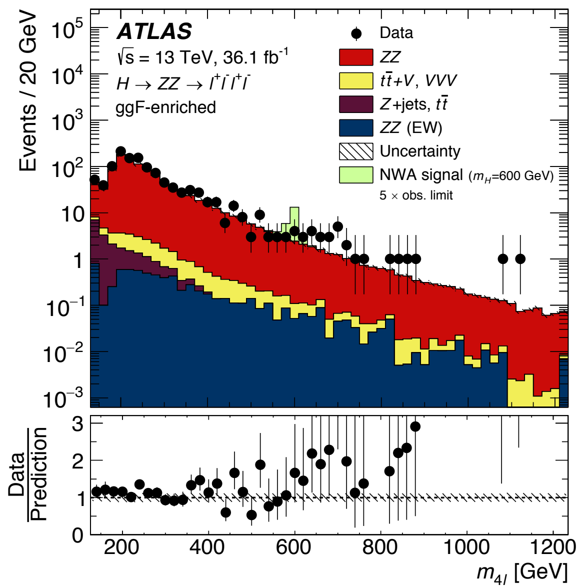
- ZZ, ttbar+V, VVV, ZZ(EW): MC simulation
- Z+jets, ttbar: data-driven

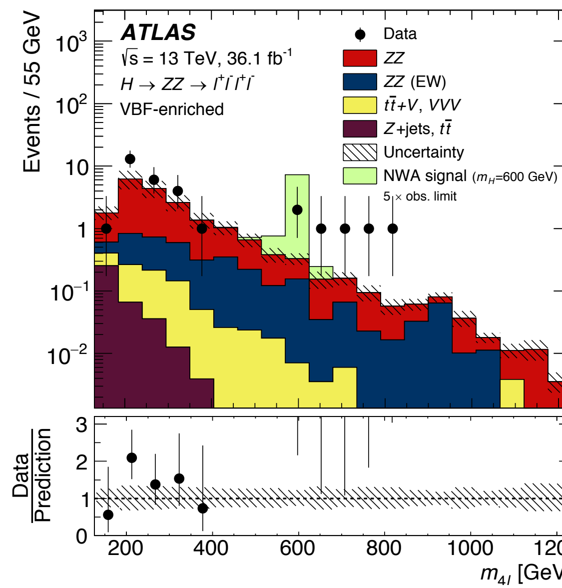
ZZ->ll$\nu\nu$ final states

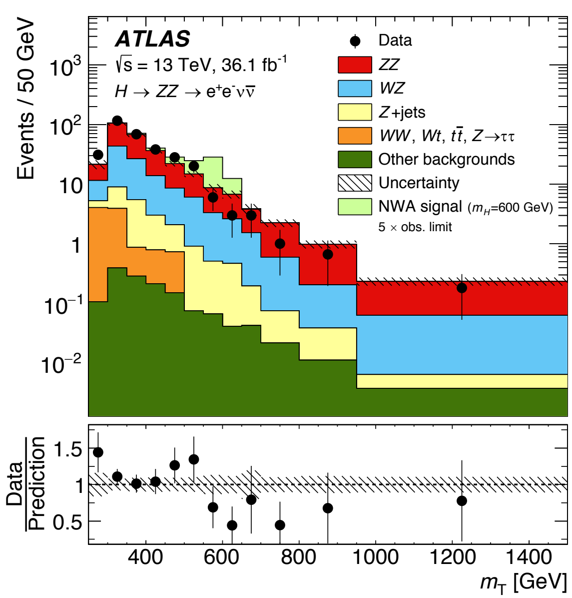
- Large branch ratio; good for high mass
- Transverse mass as discriminant variable

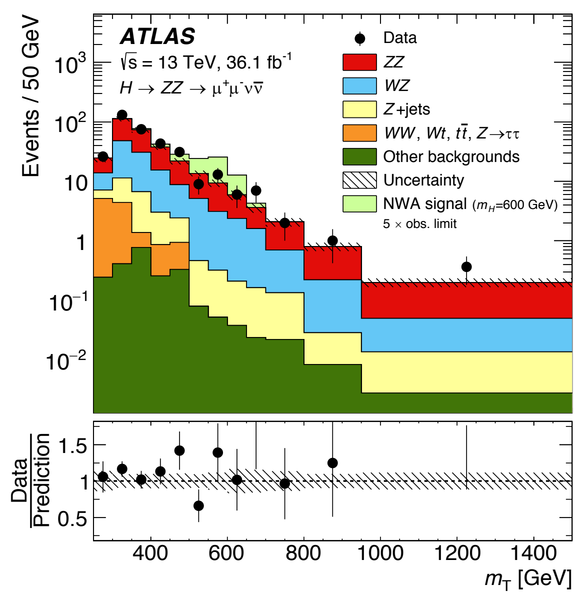
- ee$\nu\nu$, $\mu\mu\nu\nu$
- ggF and VBF enriched

- ZZ, Other backgrounds(ttbar+V, VVV): MC simulation
- WZ, Z+jets, WW, Wt, ttbar, Z->tautau: data-driven





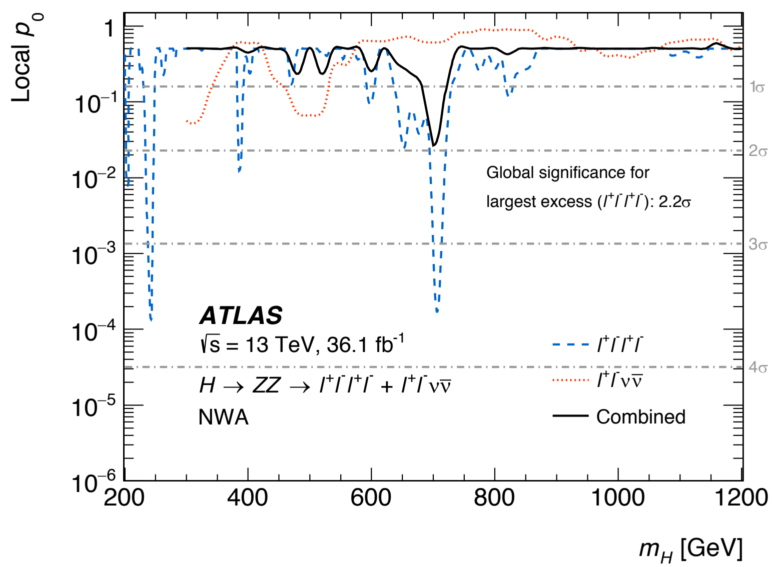


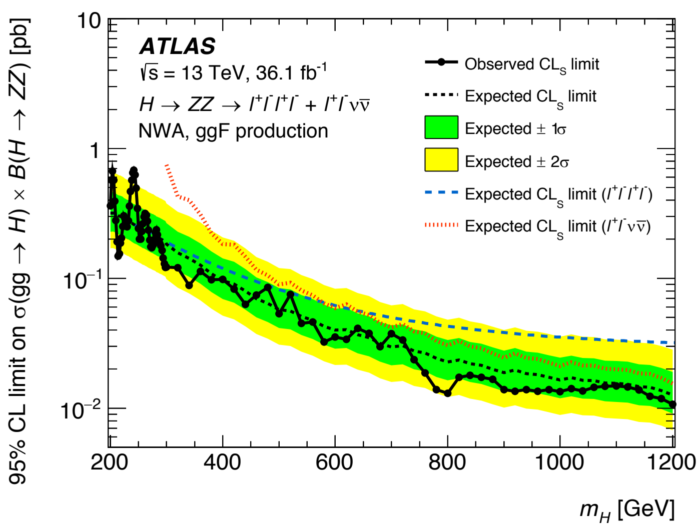


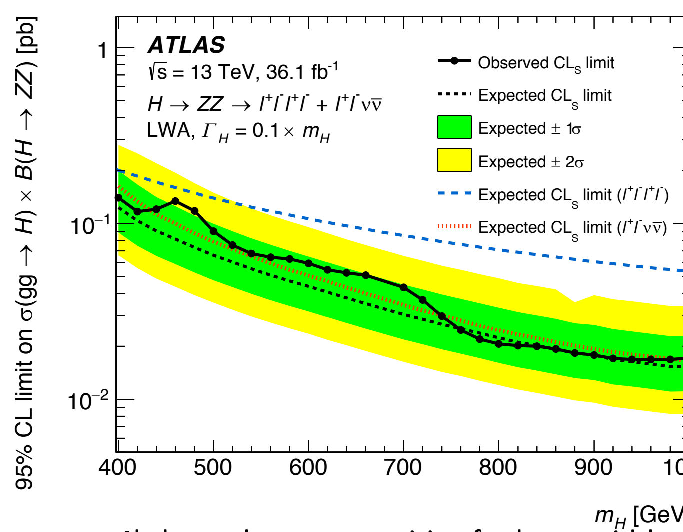
ZZ high mass search

- Two excesses found in 4l channel at 240 and 700 GeV, each with local (global) significance 3.6 (2.2) σ
- Excess at 240 GeV mostly from 4e channel
- No excess at 700 GeV in ll$\nu\nu$

- Limits on spin-0 narrow width approximation (NWA) and large width approximation (LWA) signals. In LWA, width up to 10% and including interference between H-h and H-B.
- Limits also on Type-I and Type-II 2HDM, RS Graviton.





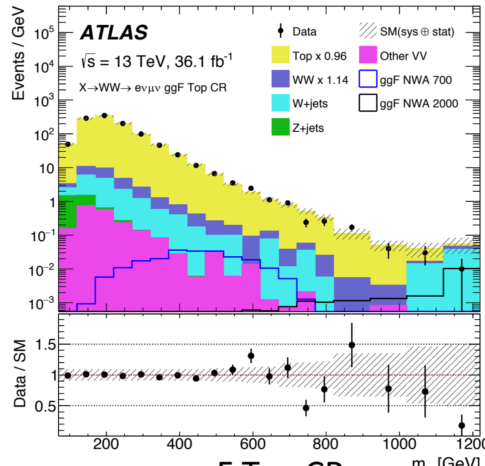


4l channel not competitive for large-widths

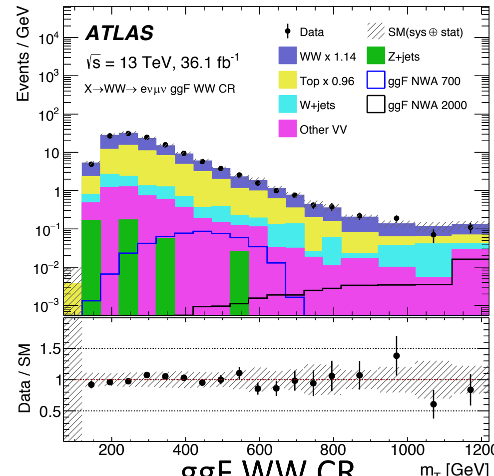
WW high mass search

Eur. Phys. J. C 78 (2018)

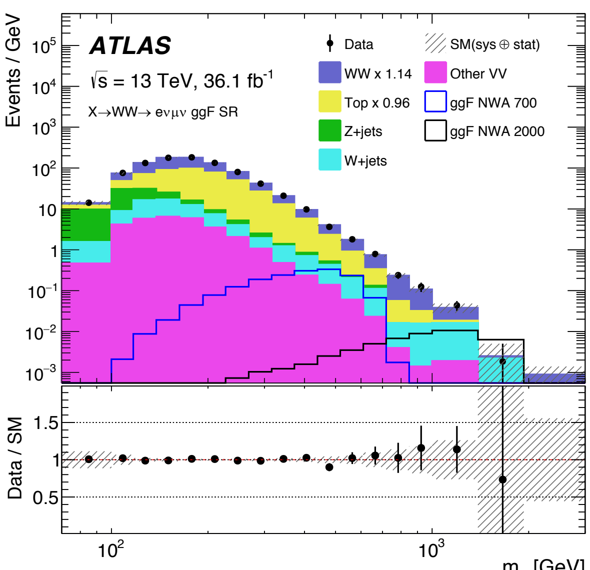
- WW→eν$\mu\nu$ final states
- Categorization: ggF, VBF 1jet and VBF 2jets
- Background:
  - Top and WW: simultaneous fit in signal and control regions
  - W+jets: control region scaled by fake factor
  - Others: MC simulation



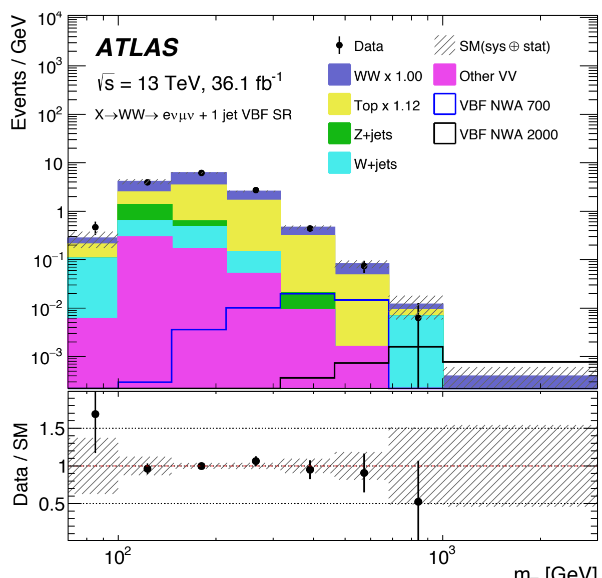
ggF Top CR



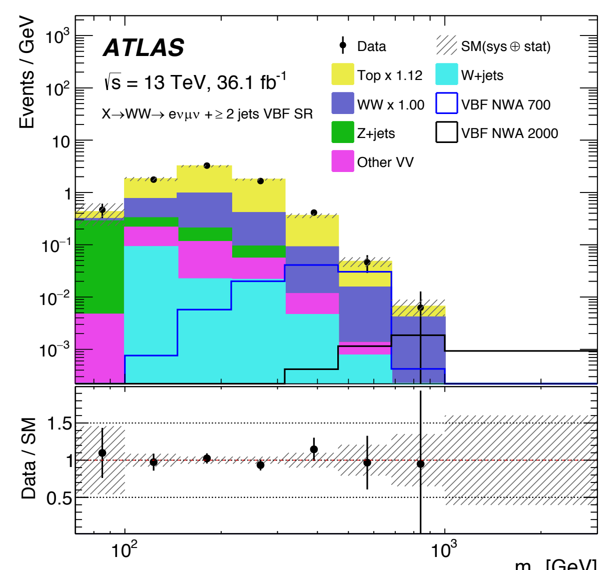
ggF WW CR



ggF SR



VBF 1jet SR



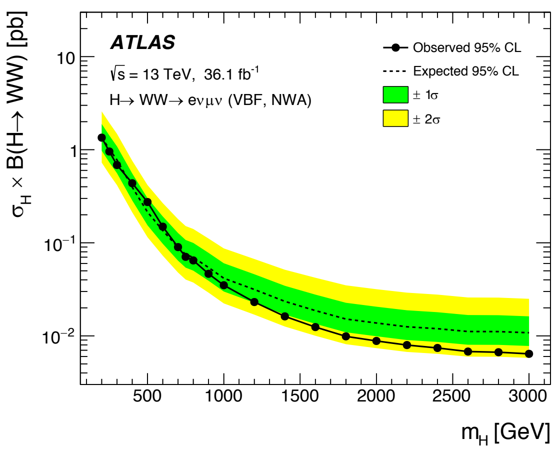
VBF 2jet SR

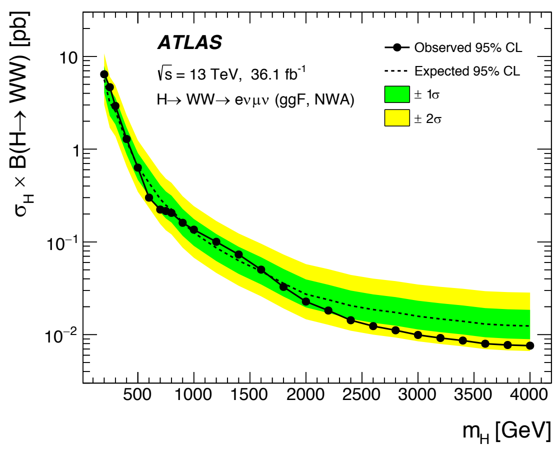
WW high mass search

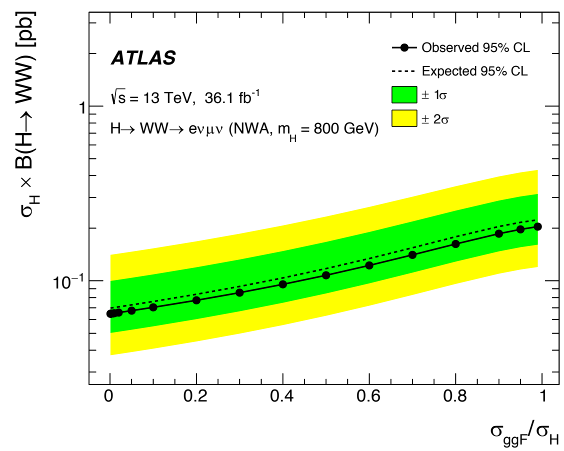
- No significant excess found
- Limits set on Higgs with NWA and LWA (up to 15% width)
- Also interpreted for 2HDM, Georgi-Machacek model, Heavy Vector Triplet (HVT), RS graviton and effective Lagrangian model (ELM)

	$\mathrm{SR_{ggF}}$	Top $\mathrm{CR_{ggF}}$	WW $\mathrm{CR_{ggF}}$
WW	$11\,500 \pm 800$	820 ± 120	$3\,360 \pm 220$
Top quark	$11\,800 \pm 600$	$52\,550 \pm 330$	$2\,610 \pm 180$
Z/γ^*	$1\,420 \pm 110$	111 ± 20	20.9 ± 2.0
W+jets	$1\,180 \pm 320$	710 ± 190	280 ± 70
VV	866 ± 34	101 ± 12	250 ± 11
Background	$26\,740 \pm 170$	$54\,290 \pm 250$	$6\,510 \pm 80$
Data	26 739	54 295	6 515

	$\mathrm{SR_{VBF1J}}$	$\mathrm{SR_{VBF2J}}$	Top $\mathrm{CR_{VBF}}$	WW $\mathrm{CR_{VBF1J}}$
WW	390 ± 50	120 ± 26	61 ± 11	265 ± 32
Top quark	450 ± 50	391 ± 24	$5\,650 \pm 90$	167 ± 18
Z/γ^*	45 ± 11	24 ± 6	68 ± 19	74 ± 12
W+jets	52 ± 13	8.9 ± 2.5	91 ± 24	43 ± 11
VV	32 ± 7	16.6 ± 1.9	20 ± 9	38 ± 4
Background	972 ± 29	563 ± 22	$5\,890 \pm 80$	596 ± 22
Data	978	560	5 889	594





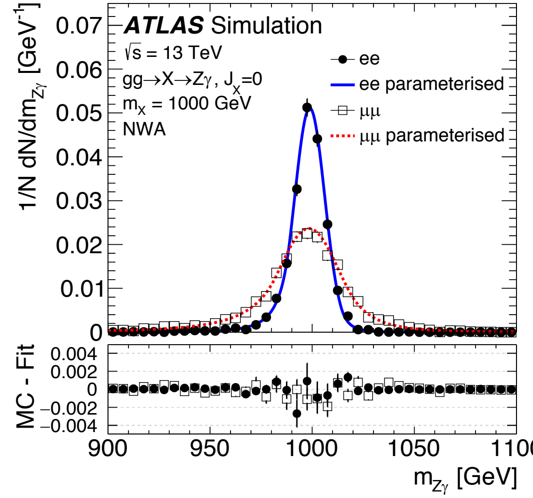


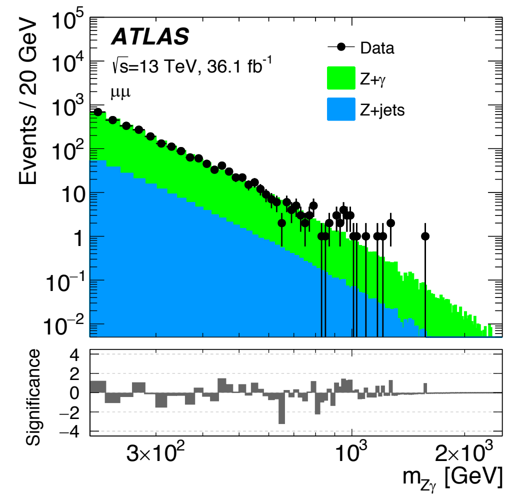
$Z\gamma$ high mass search

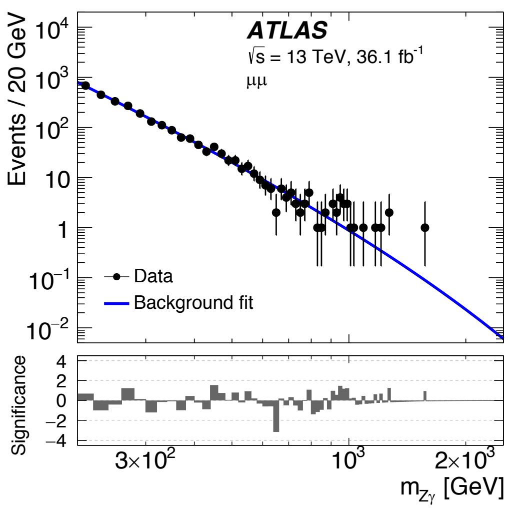
JHEP 10 (2017) 112

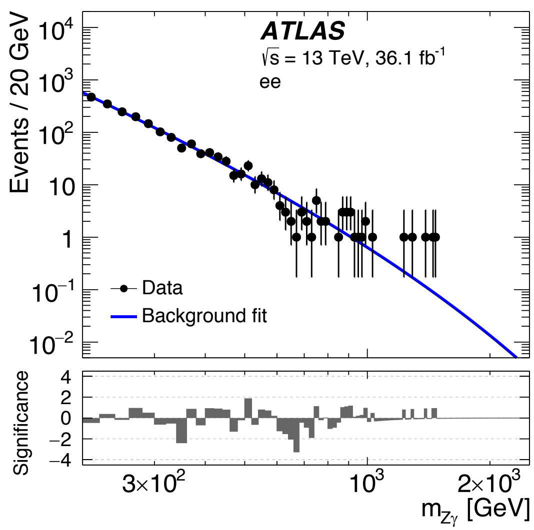
- Z(->ee/$\mu\mu$)γ final states.
- Two categories eeγ and $\mu\mu\gamma$

- Signal modeled by functional form
- Background modeled by functional form
  - Shape: $Z\gamma$ from simulation, Z+jets from data control samples
  - Background fraction: data-driven method



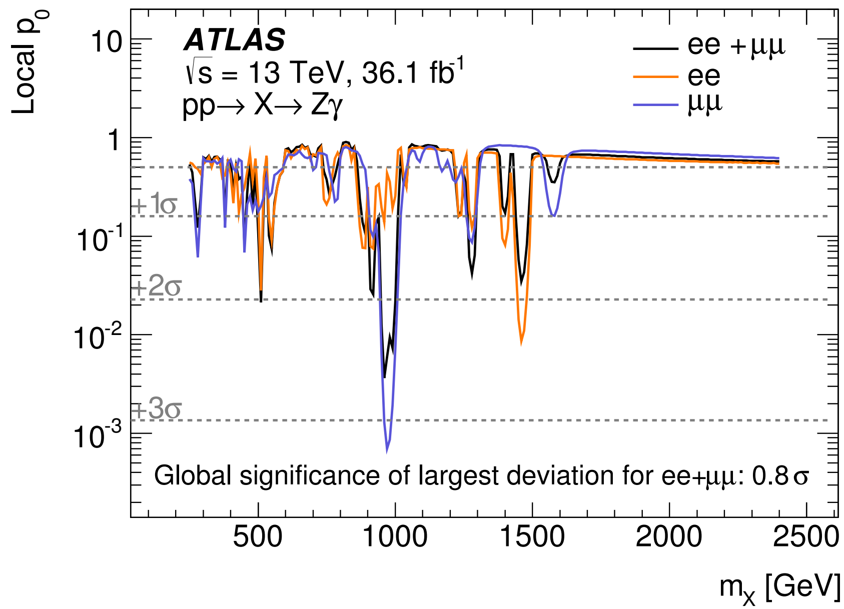


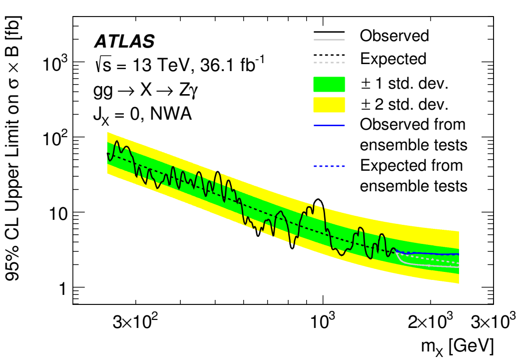


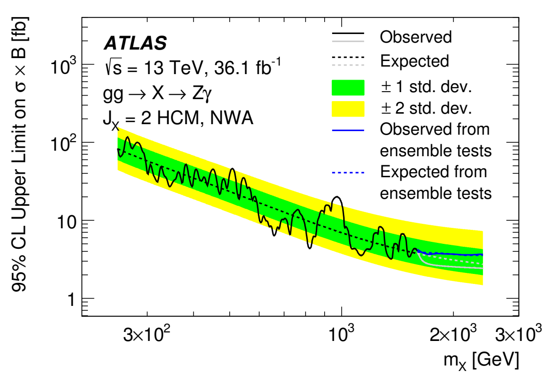


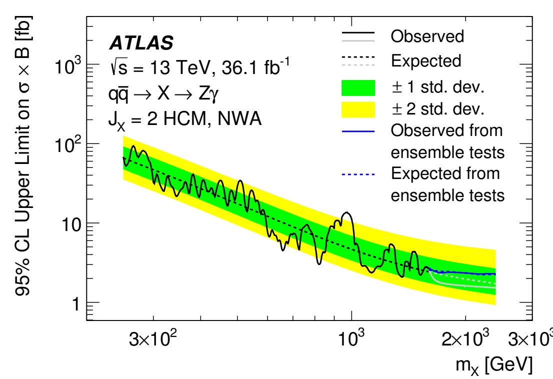
Zγ high mass search

- Largest derivation 2.96 (0.8) σ for local (global) p-value at 960 GeV
- Limits on spin-0 signals, as well spin-2 signals with Higgs Characterisation Model (HCM)







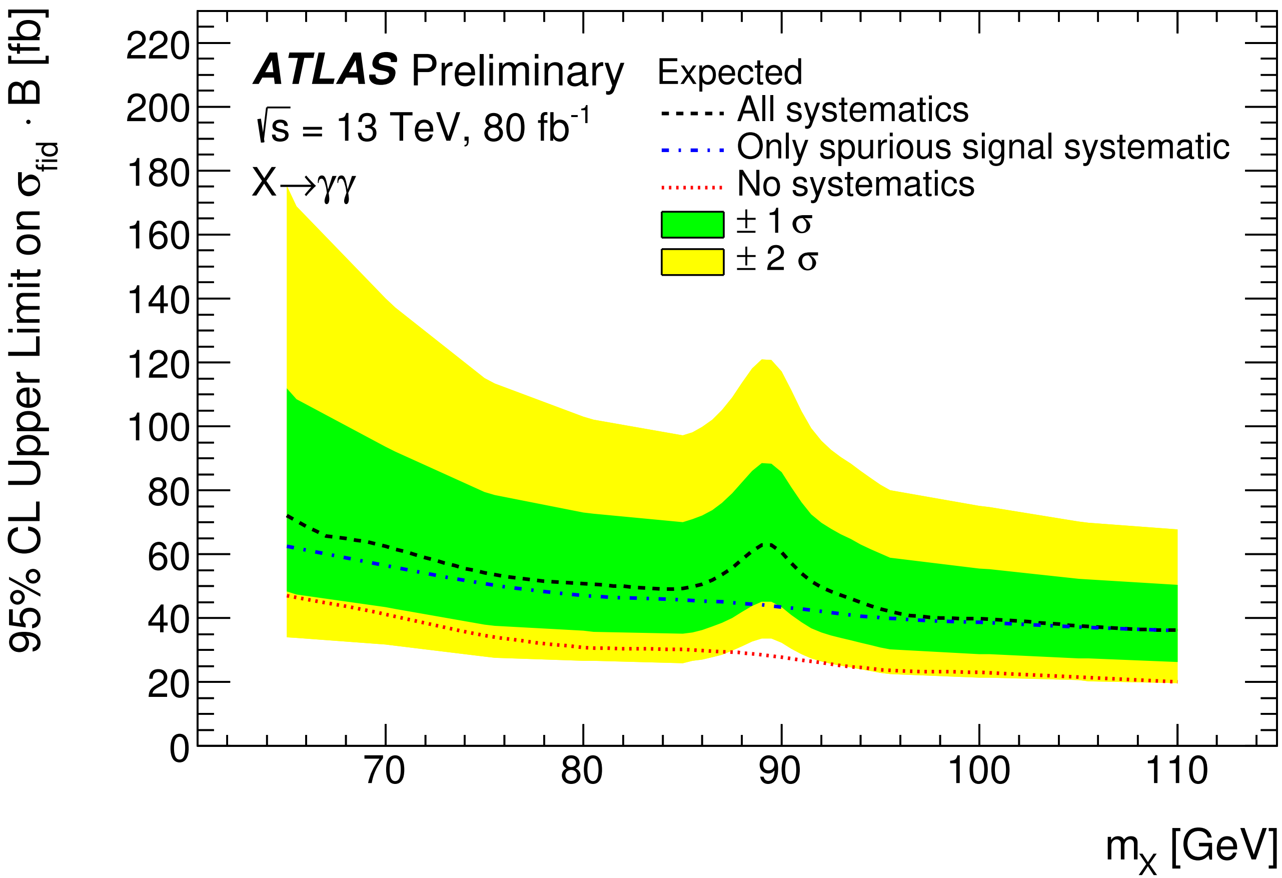


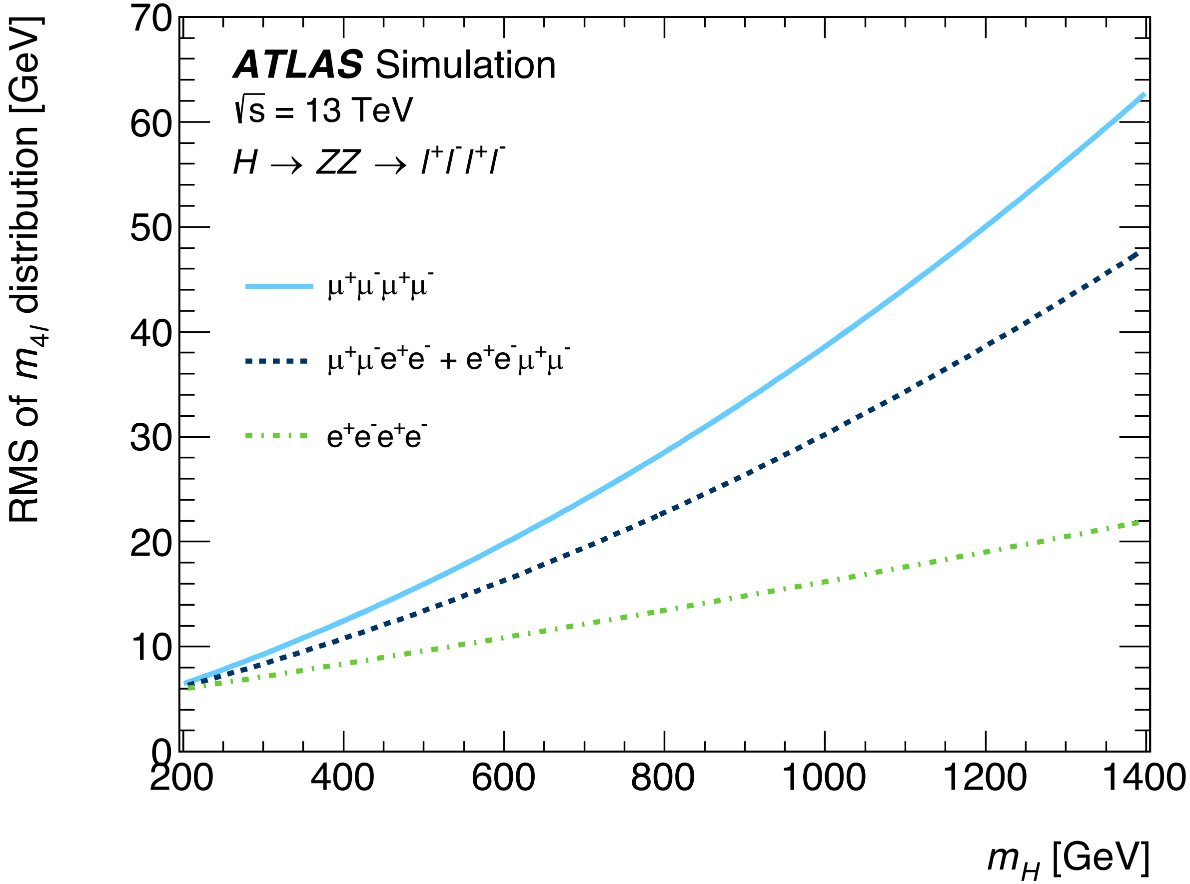
Summary

- Analyses presented for ZZ high mass search (36.1 fb^{-1}), WW high mass search (36.1 fb^{-1}), diphoton high mass search (36.7 fb^{-1}), $Z\gamma$ high mass search (36.1 fb^{-1}), and diphoton low mass search (80.4 fb^{-1}).

- No significant excess found, limits set on various models.

Backup


ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 80 fb^{-1}
X→γγ
Expected
All systematics
Only spurious signal systematic
No systematics
± 1 σ
± 2 σ
95% CL Upper Limit on $\sigma_{fid} \cdot B$ [fb]
m_X [GeV]
0
20
40
60
80
100
120
140
160
180
200
220
70
80
90
100
110



ATLAS Simulation
√s = 13 TeV
H → ZZ → l+l-l+l-
μ+μ-μ+μ-
μ+μ-e+e- + e+e-μ+μ-
e+e-e+e-
RMS of m4l distribution [GeV]
0
10
20
30
40
50
60
70
200
400
600
800
1000
1200
1400
mH [GeV]