Recent ATLAS results:
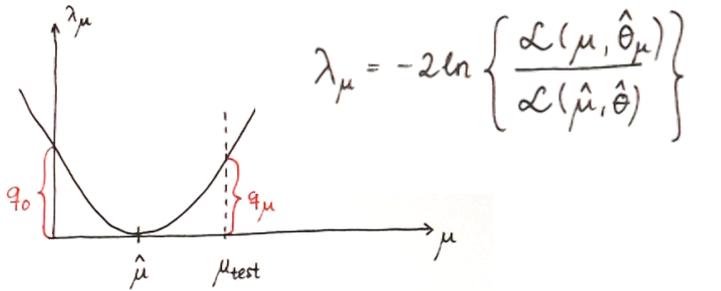# SM Higgs Boson Searches

"Spåtind 2012"
Nordic Conference on Particle Physics
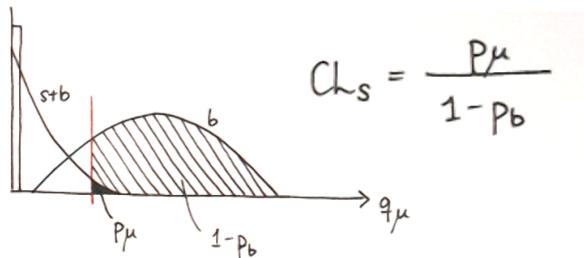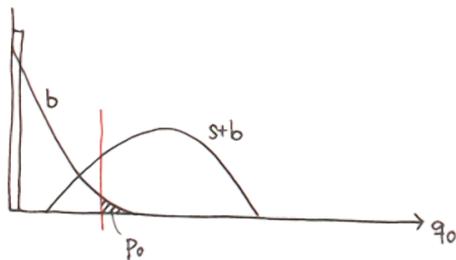
A. L. Read (U. Oslo/LAL)

Outline

- Combination statistics and LEE refresher
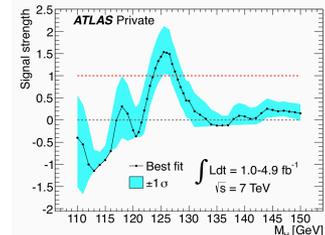- Status of SM Higgs search, November 2011
- Individual ATLAS SM Higgs search results
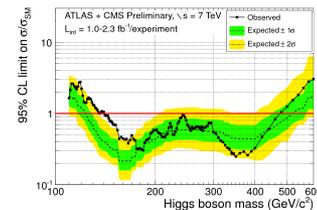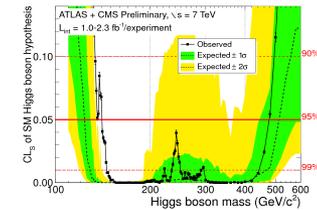- Combined ATLAS results, December 2011

Profile likelihood ratio, p_0 and CLs...in 60 seconds

$$\lambda_\mu = -2\ln\left\{\frac{\mathcal{L}(\mu, \hat{\hat{\theta}}_\mu)}{\mathcal{L}(\hat{\mu}, \hat{\theta})}\right\}$$

$$\hat{\mu} \approx \mu_{true} \pm \sigma_\mu, (\mu_{true} = 0, 1, whatever)$$

$$CL_s = \frac{P_\mu}{1 - P_b}$$

- p_0 to test background hypothesis

- CL_s to test signal hypothesis (e.g. μ=1)

- Signal limits on μ for CLs=e.g. 5%
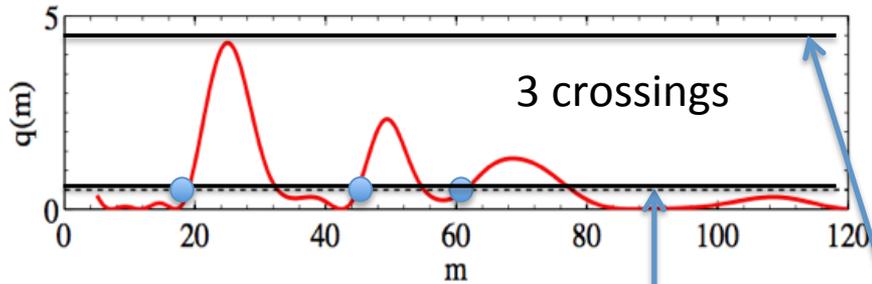
- $\hat{\mu}$ to estimate signal strength
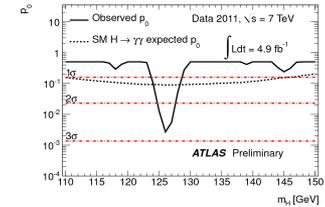
Follow LHCHCG Combination Procedures

Look-elsewhere effect

- Consider a search with predicted background 10^{-7}
  - 1 observed event is a 5.2σ discovery
- Now consider 10^7 searches each with 10^{-7} background
  - Expect on the average 1 event with local p-value of 10^{-7} but this is certainly not a discovery!
  - Probability to make a false discovery is
    $$P(n \geq 1 \mid b = 1) = 1 - e^{-1}(-1)^0 / 1! = 63\%$$
  - Trials factor from LEE is 0.63×10^7
- How to apply in general?!

[Look-elsewhere effect](#) (Gross&Vitells)

$$q_{test} = -2 \cdot llr \approx \Delta\chi^2$$

$$p_0^{global} \cong p_0^{local} + \left\langle N(q_{ref}) \right\rangle e^{-(q_{test}-q_{ref})/2}$$
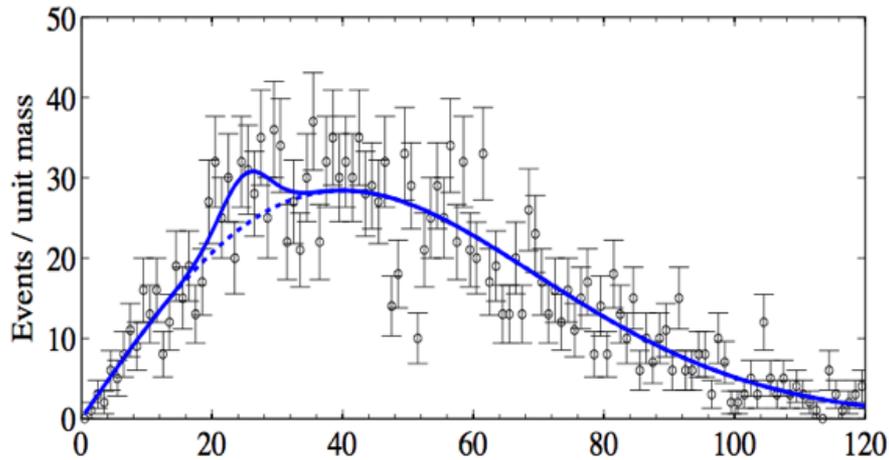
- Approximation best above 3σ
- Example:
  - q_{test} = 4.5 (2.1σ)
  - 3 crossings at 0.5σ
  - significance reduced to about 0.3σ
  - trials factor about 22

Local σ	Crossings	σ ref.	Trials factor	Global σ
3.5	3	1.0	47	2.3
5.0	3	2.0	290	3.8
7.0	3	2.0	400	6.1

95% CL exclusions:

SINDRUM, Barr et al. (π,K decays): ~10-110 MeV

CLEO+CUSB: ~2*m_μ-5 GeV
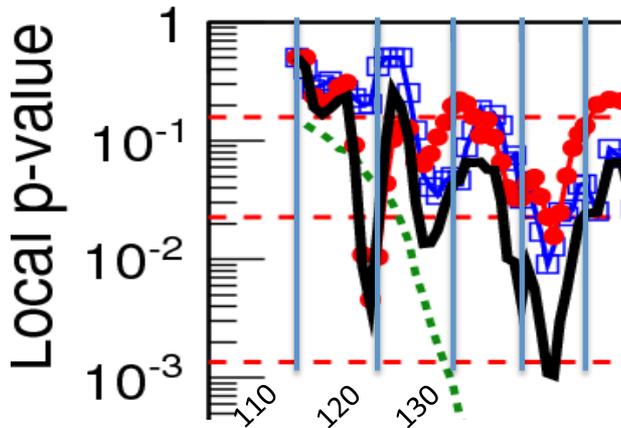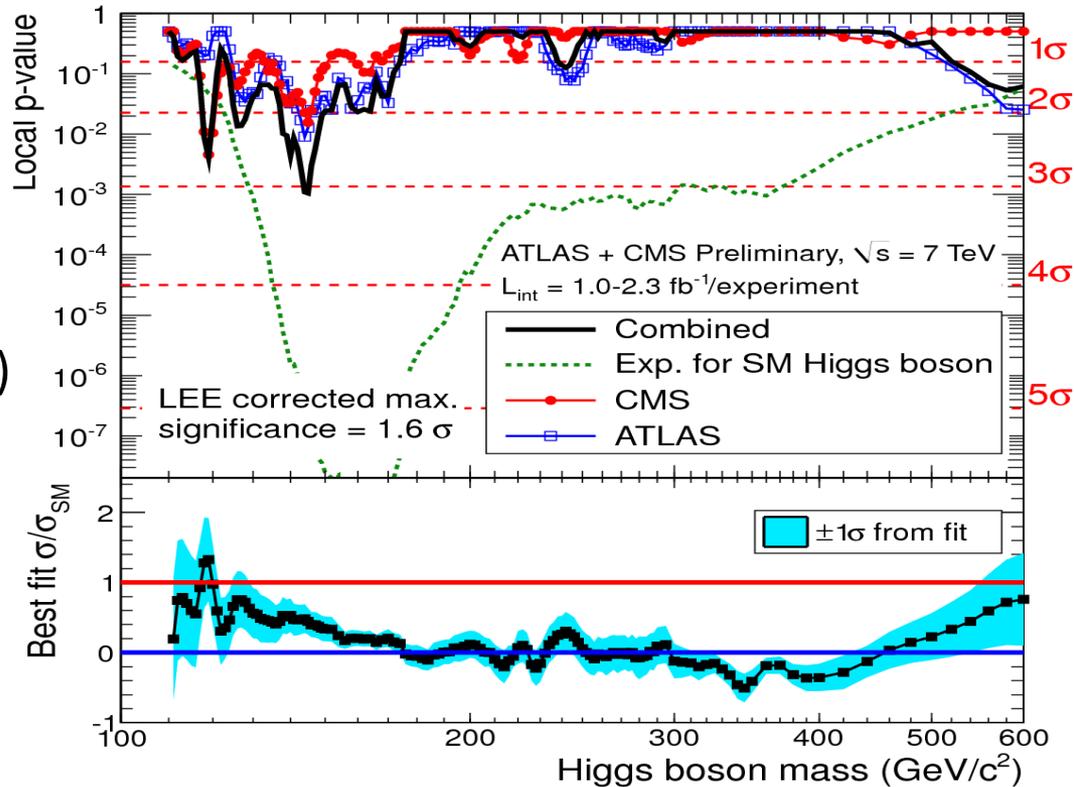
LEP+Tevatron: ~2*m_τ-114.4 GeV

Tevatron+ATLAS+CMS: 141-476 GeV
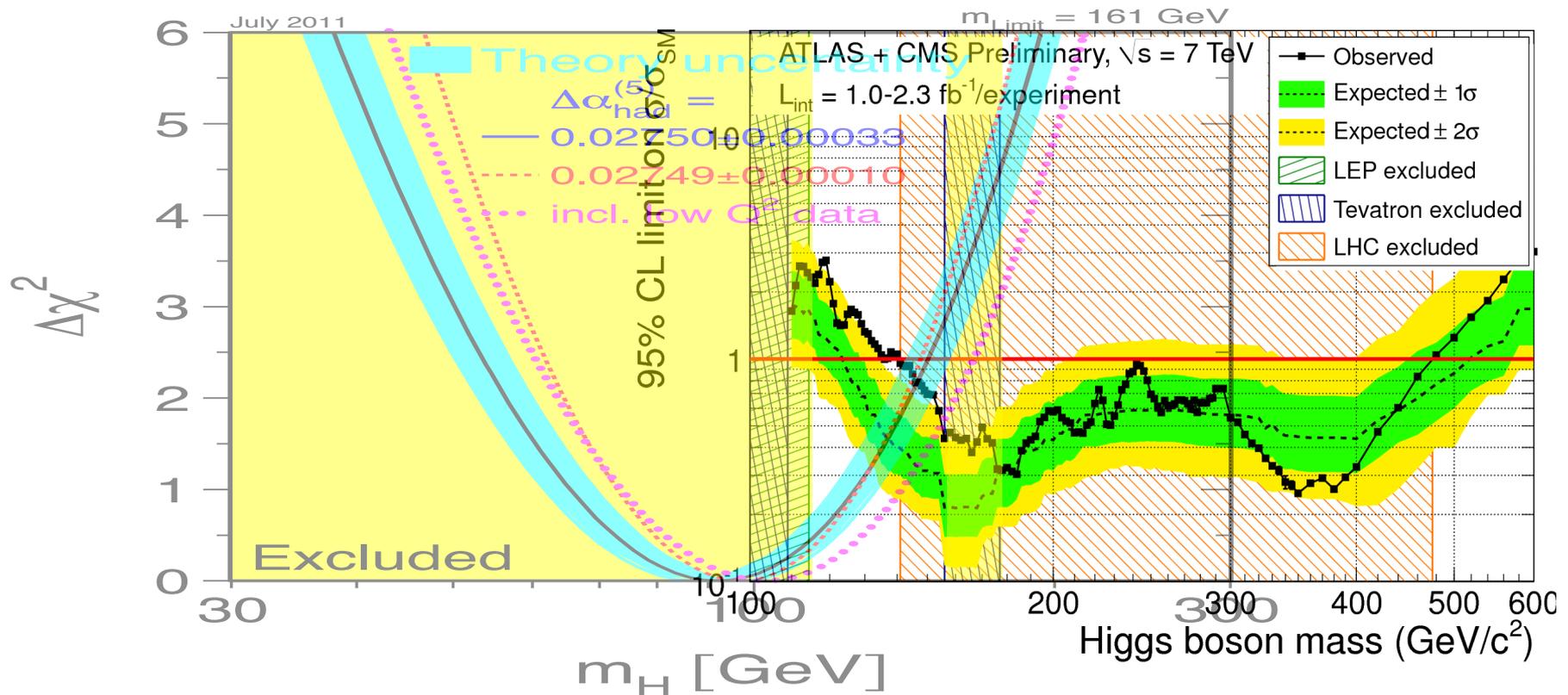
LHC test of background hypothesis @ HCP

- Dips of p_0(local)
  - 119 GeV (2.6 σ)
  - Ignored: 126 GeV (2.2 σ)
  - Ignored: 145 GeV (3.1 σ)
- Roughly (!) 0.9, 0.5, 1.6 σ global (up-crossings from data)

ATLAS Combined Higgs Search
CERN Public Seminar
December 13, 2011

SM Higgs production and decay
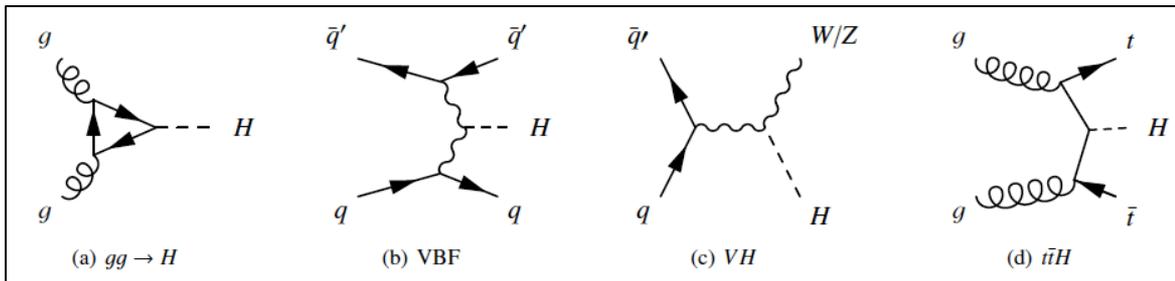
- +Trigger, bg-rejection, ID-eff.
- Theory uncert. Typically few-20%
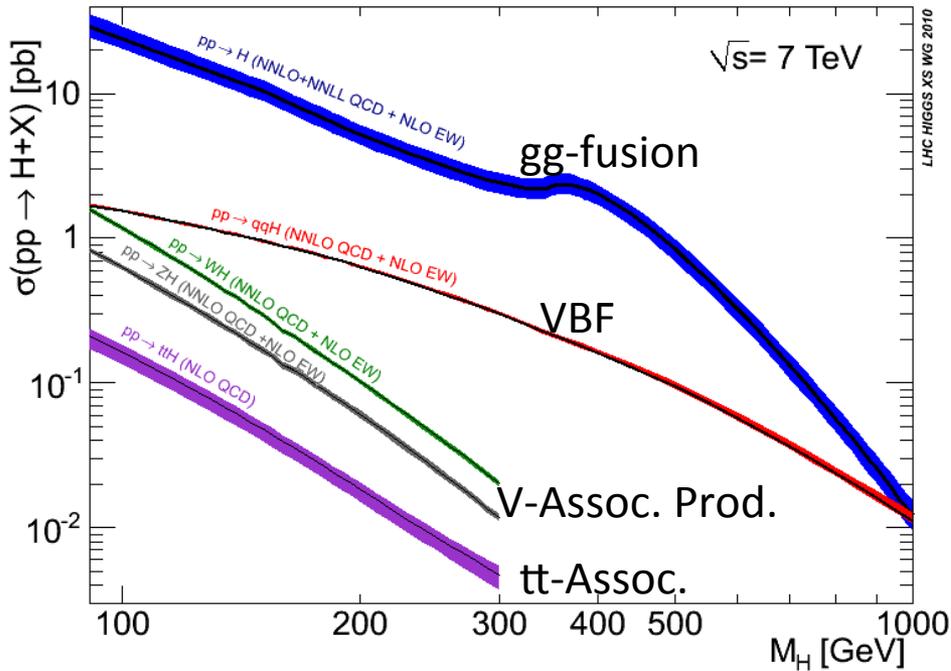
Important and fruitful theory-experiment collaboration: Higgs X-Sec Working Group

ATLAS Channels in Combination

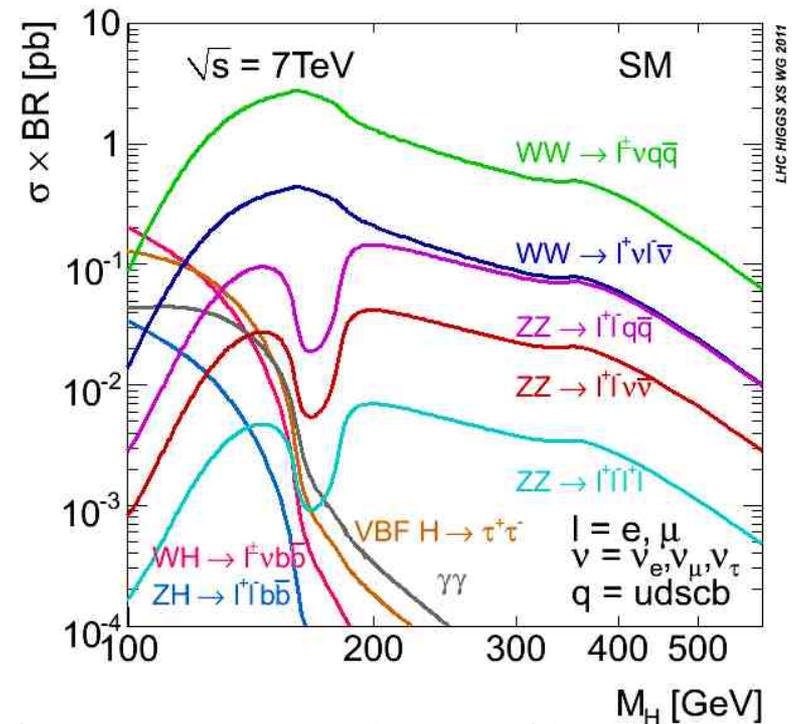| Higgs decay mode	Mass range (GeV)	Luminosity (1/fb)
VH->Vbb	-	Not included
WW->lvqq	240<-------->600	1.04 (EPS11) (Back in)
ττ->lh3ν,ll4ν	110<->150	1.06 (LP11)
ZZ->llqq	200<---------->600	2.05 New
ZZ->llνν	200<---------->600	2.05 New
WW->lνlν	110<-------->300	2.05 New
ZZ->4l	110<------------------>600	**4.8** New!
γγ	110<->150	**4.9** New!

ATLAS Updates

- $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^{(*)} \rightarrow 4l$ quickly analyzed due to relative simplicity

- $H \rightarrow WW \rightarrow l\nu qq$ back in combination, compliant with LHC Combination Procedures and LHC Cross-Section Working Group Recommendations.

- Other channels will be updated early in 2012.

$H \rightarrow \gamma\gamma$
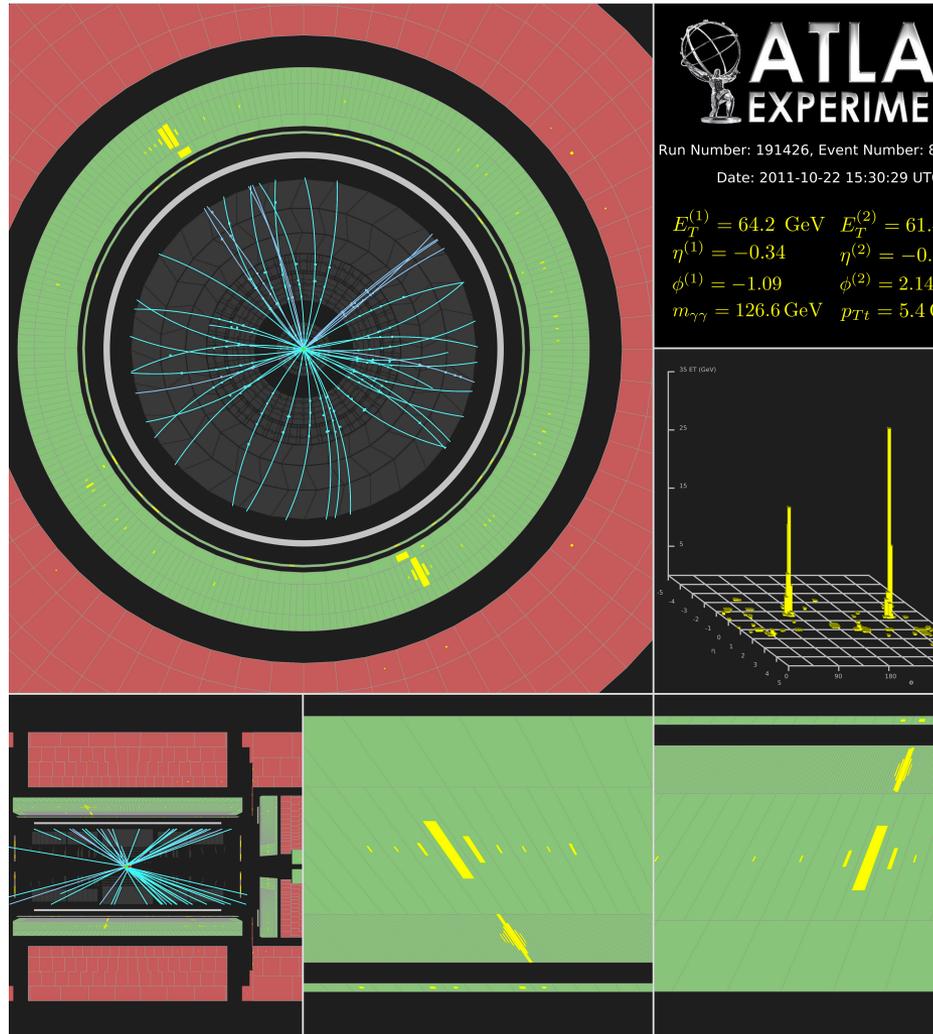
$H \rightarrow \gamma\gamma$

- 1.1 -> 4.9/fb

- ~70% of (data-driven) background is SM diphotons

- 9 categories based on $\gamma \rightarrow e^+e^-$ conversion status, position in the calorimeter, $p_T^{\gamma\gamma}$ w.r.t $\gamma\gamma$ thrust axis
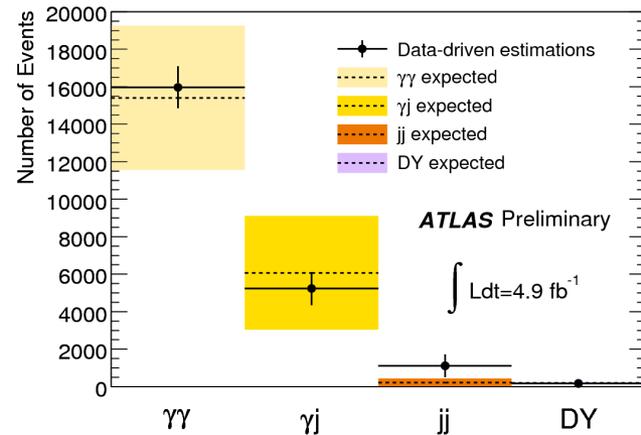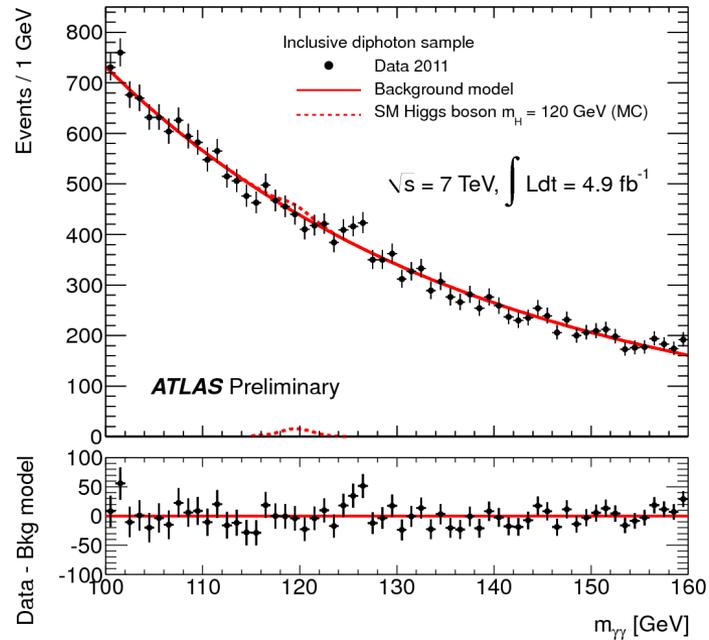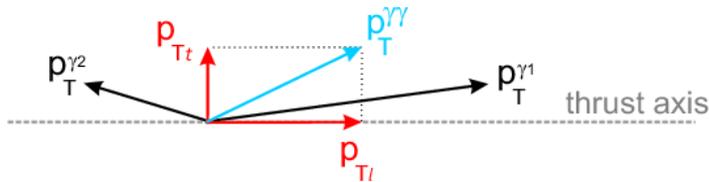
$H \rightarrow \gamma\gamma$ results
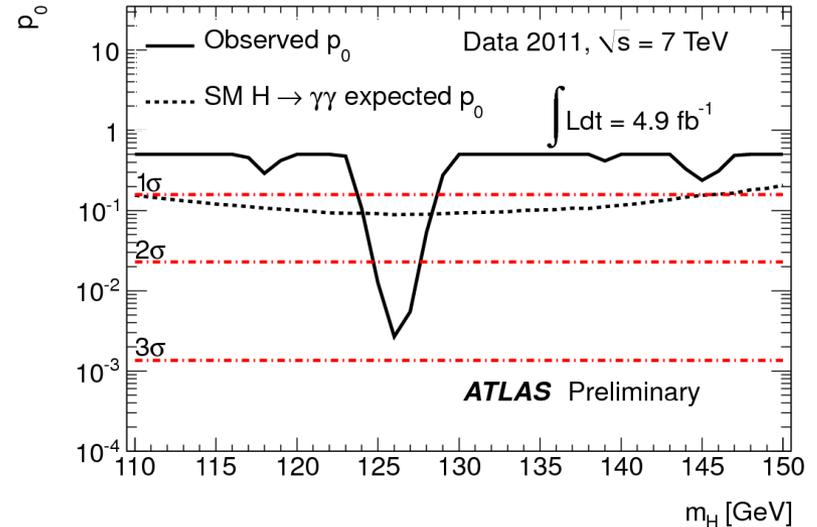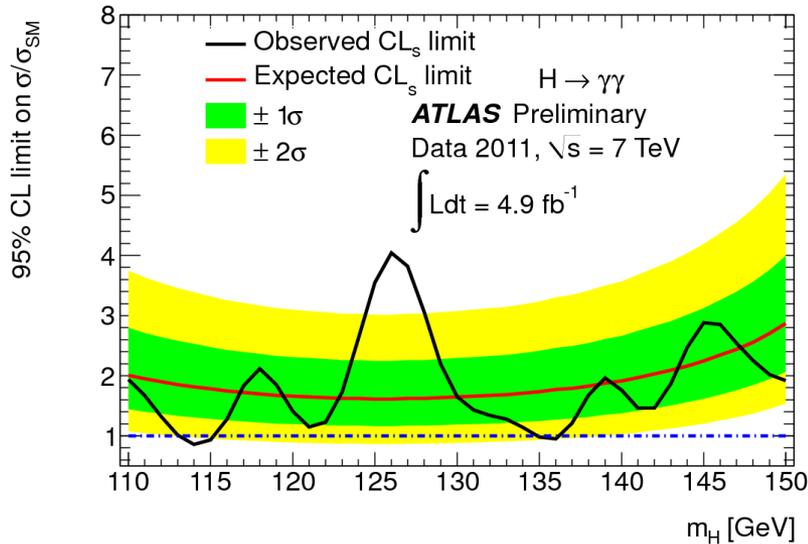
- Seen in isolation this channel has, at $m_H \sim 126$ GeV
  p_0 (local) = 0.27% (2.8 σ) or
  p_0 (global) = 6.5% (1.5 σ)

- P.S. LEP hint at 115-116 GeV is threatened

ATLAS EXPERIMENT

Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET

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

EtCut>0.3 GeV
PtCut>3.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm

Muon: blue
Cells:Tiles, EMC

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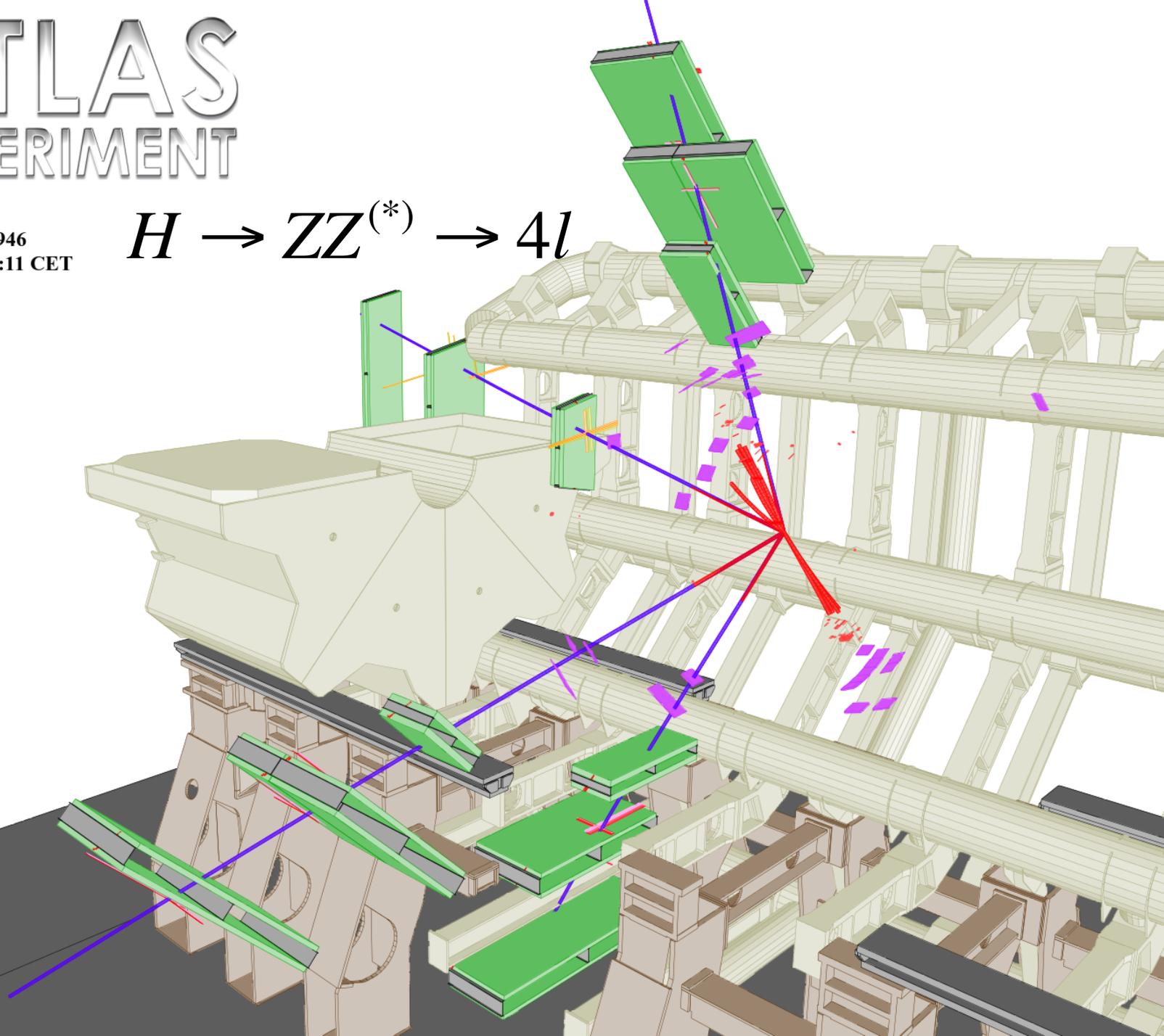
$$H \rightarrow ZZ^{(*)} \rightarrow 4l$$

- 2.0-2.3 -> 4.8/fb
- Improved e-ID and reco (brem. fitting/GSF)
- For m_H=130 FWHM=4.5 GeV (4μ) – 6.5 GeV (4e)
- For m_H=400 FWHM=35 GeV ($\sim\Gamma_H$)
- m_{4l} in likelihood
  - $|m_{12}-m_Z| < 15$ GeV
  - $m_{34} > 15$-60 GeV for mH=120->=200 GeV
- Good mass-resolution and few candidates
  - Structures in p_0 and limits

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

|	μμμμ		eeμμ		eeee	
	Low $m_{4\ell}$	High $m_{4\ell}$	Low $m_{4\ell}$	High $m_{4\ell}$	Low $m_{4\ell}$	High $m_{4\ell}$
Int. Luminosity	4.81 fb^{-1}		4.81 fb^{-1}		4.91 fb^{-1}	
$ZZ^{(*)}$	2.0±0.3	16.3±2.4	2.8±0.6	25.2±3.8	1.3±0.3	10.3±1.5
Z, $Zb\bar{b}$, and $t\bar{t}$	0.16±0.06	0.02±0.01	1.4±0.5	0.17±0.08	1.6±0.7	0.18±0.08
Total Background	2.2±0.3	16.3±2.4	4.2±0.8	25.4±3.8	2.9±0.8	10.5±1.5
Data	3	21	3	27	2	15
$m_H = 125$ GeV	0.58 ± 0.10		0.73 ± 0.13		0.25 ± 0.05	
$m_H = 130$ GeV	1.00 ± 0.17		1.22 ± 0.21		0.43 ± 0.08	
$m_H = 150$ GeV	2.1 ± 0.4		2.9 ± 0.4		1.12 ± 0.18	
$m_H = 200$ GeV	4.9 ± 0.7		7.7 ± 1.0		3.1 ± 0.4	
$m_H = 300$ GeV	2.9 ± 0.4		4.9 ± 0.6		2.1 ± 0.3	
$m_H = 400$ GeV	2.0 ± 0.3		3.3 ± 0.5		1.49 ± 0.21	
$m_H = 600$ GeV	0.34 ± 0.04		0.62 ± 0.10		0.30 ± 0.06	

- "Low mass": 100 < m_{4l} < 180 GeV

- "High mass": 180 < m_{4l} < 600 Gev

$$H \rightarrow ZZ^{(*)} \rightarrow 4l$$
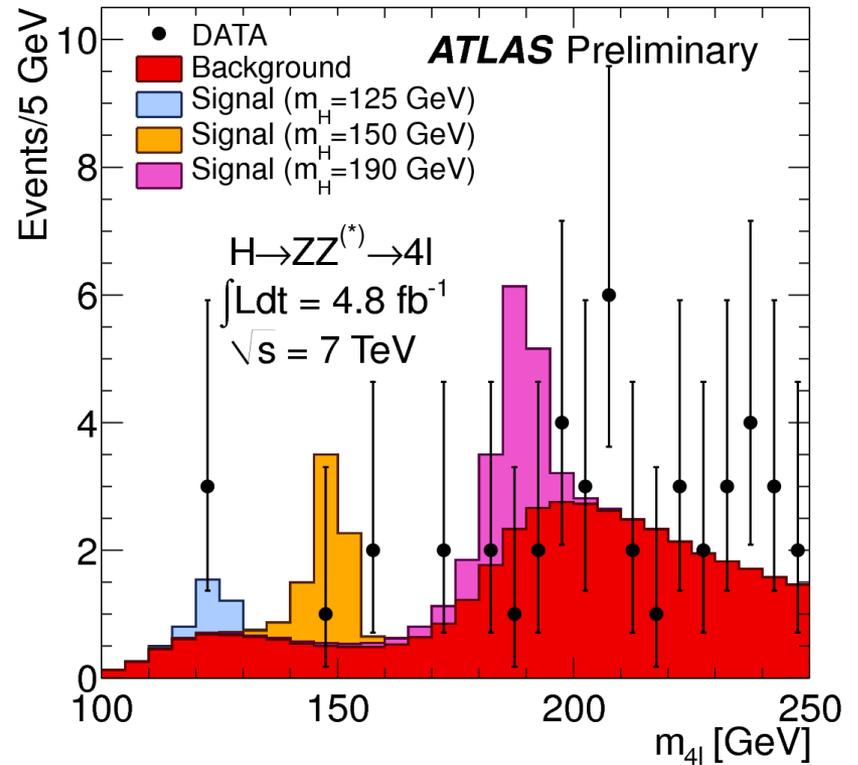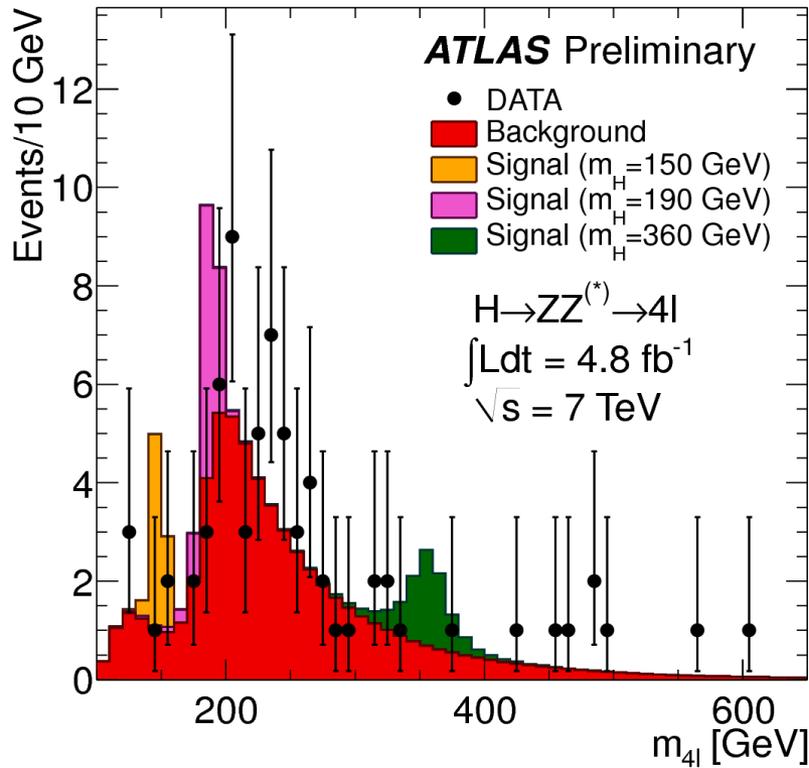
$H \rightarrow ZZ^{(*)} \rightarrow 4l$ signal limits
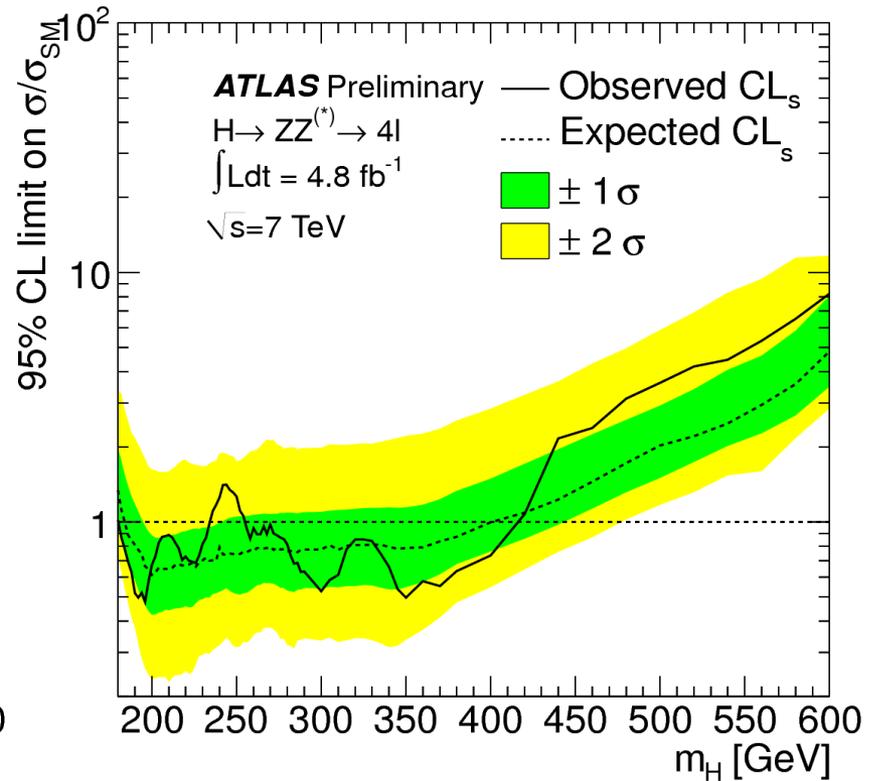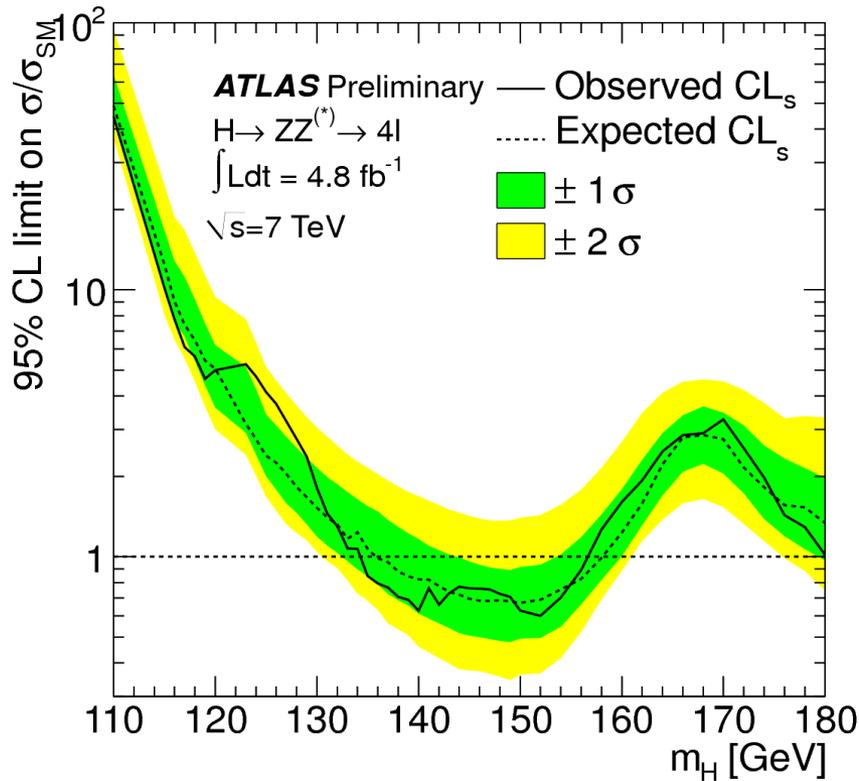
- No-signal expected exclusion: 137-158, 185   -   400 GeV
- Excluded regions: 135-156, 181-234, 255-415 GeV

$H \rightarrow ZZ^{(*)} \rightarrow 4l$ background tests
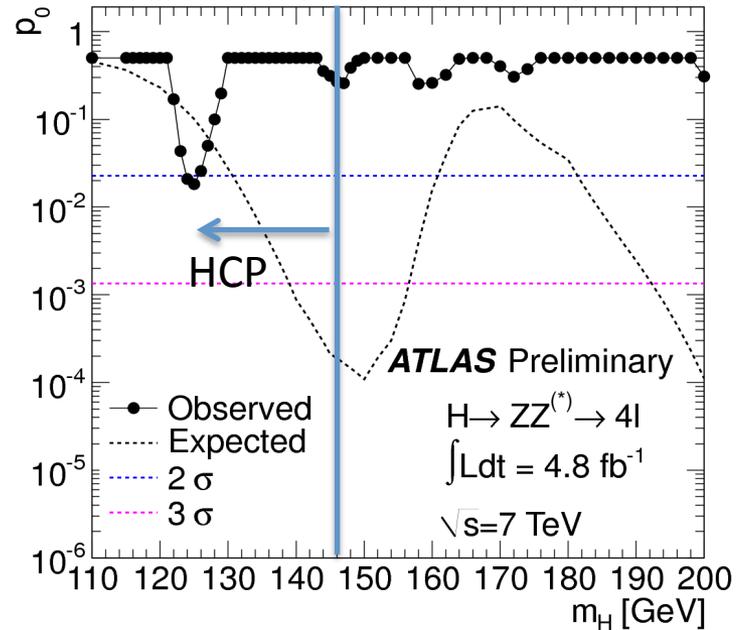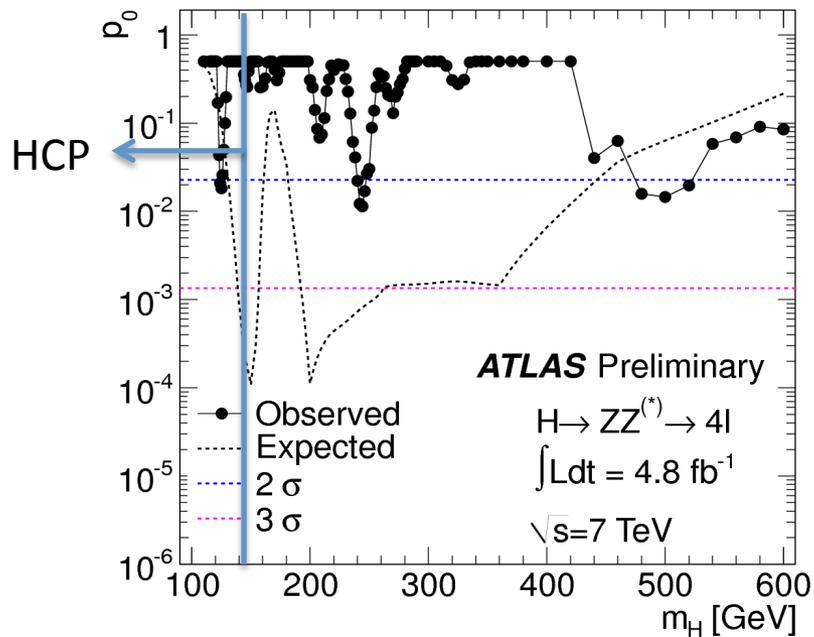
- p_0 (local) of 1.8 % (125 GeV), 1.1% (244 GeV), 1.4% (500 GeV)
- p_0 (global) > 50% for all peaks if entire mass range considered for LEE, O(30%) for lowest peak if LEE restricted to HCP allowed region (146 GeV @ 99% CL)
- Seen in isolation, none of the excesses of this channel are significant

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

- $e^+ e^-, e^\pm \mu^\mp, \mu^+ \mu^-$ leptonic final states
- H+0,1 jet exclusive final states (gg, VBF, VH)
- $m_{ll'} > 10\, GeV \quad or \quad (m_{ll} > 15\, GeV \ and \ |m_{ll} - m_Z| > 15\, GeV)$
- Sliding transverse mass cut

$$0.75 \cdot m_H < m_T < m_H \ for \ m_H < 220\, GeV$$

$$0.60 \cdot m_H < m_T < m_H \ for \ m_H > 220\, GeV$$

- Mass-dependent $\Delta\phi_{ll}$ cut (spin correlations)

$$\Delta\phi_{ll} < 1.3 \ for \ m_H < 170\, GeV$$

$$\Delta\phi_{ll} < 1.8 \ for \ 170\, GeV < m_H < 220\, GeV$$

- $E_{T,rel}^{miss} = E_T^{miss} \cdot \sin(\min(\pi/2, \Delta\varphi_{miss,l,j})) > 40(ll), 25(ll')\, GeV$
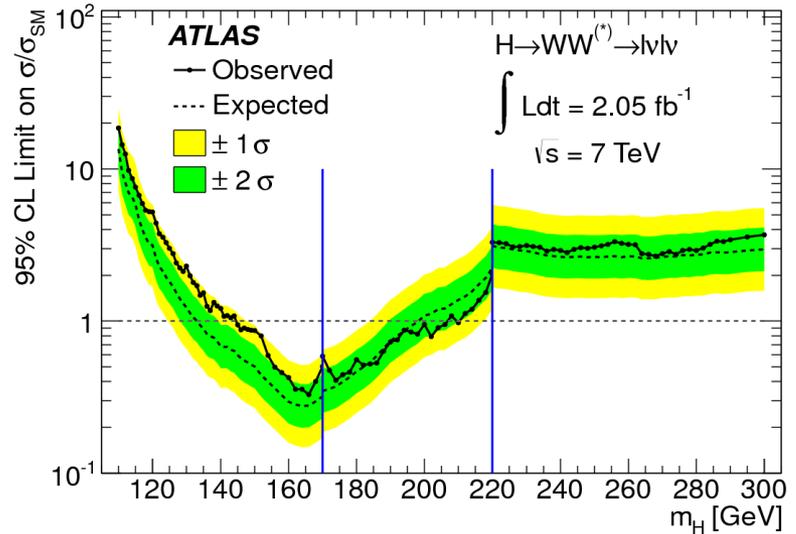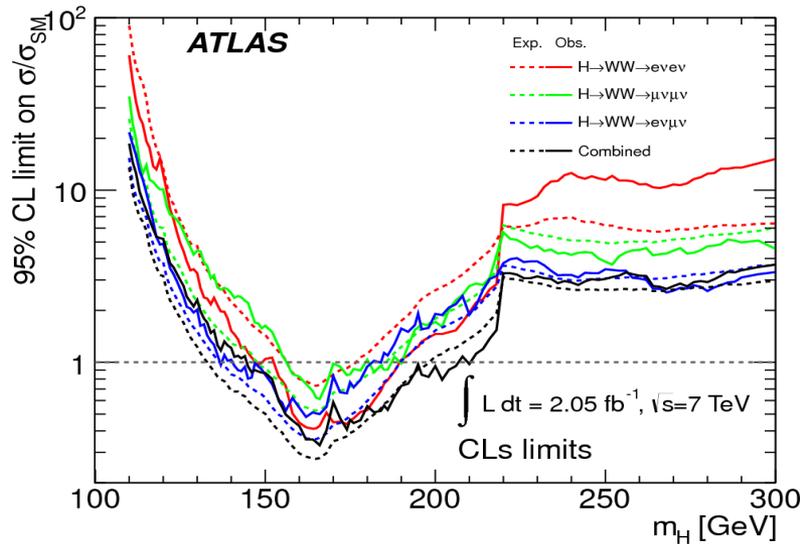
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$

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

TABLE I: The expected numbers of signal ($m_H = 150$ GeV) and background events after the requirements listed in the first column, as well as the observed numbers of events in data. All numbers are summed over lepton flavor.

| $H + 0$-jet Channel	Signal	WW	W + jets	Z/γ^* + jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
Jet Veto	99 ± 21	524 ± 52	84 ± 41	174 ± 169	42 ± 14	32 ± 8	15 ± 4	872 ± 182	920
$p_T^{\ell\ell} > 30$ GeV	95 ± 20	467 ± 45	69 ± 34	30 ± 12	39 ± 14	29 ± 8	13 ± 4	648 ± 60	700
$m_{\ell\ell} < 50$ GeV	68 ± 15	118 ± 15	21 ± 8	13 ± 8	7 ± 4	5.8 ± 1.8	1.9 ± 0.6	166 ± 19	199
$\Delta\phi_{\ell\ell} < 1.3$	58 ± 13	91 ± 12	12 ± 5	9 ± 6	6 ± 3	5.8 ± 1.8	1.7 ± 0.6	125 ± 15	149
$0.75\, m_H < m_T < m_H$	40 ± 9	52 ± 7	5 ± 2	2 ± 4	2.4 ± 1.6	1.5 ± 1.0	1.1 ± 0.5	63 ± 9	81
$H + 1$-jet Channel	Signal	WW	W + jets	Z/γ^* + jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
1 jet	50 ± 9	193 ± 20	38 ± 21	74 ± 65	473 ± 124	174 ± 26	14 ± 2	967 ± 145	952
b-jet veto	48 ± 9	188 ± 19	35 ± 19	73 ± 61	174 ± 49	66 ± 11	14 ± 2	549 ± 83	564
$|\mathbf{p}_T^{tot}| < 30$ GeV	39 ± 7	154 ± 16	18 ± 9	38 ± 32	106 ± 30	50 ± 9	9.7 ± 1.5	376 ± 48	405
$Z \rightarrow \tau\tau$ veto	39 ± 7	150 ± 17	18 ± 8	34 ± 23	102 ± 23	48 ± 8	9 ± 2	361 ± 38	388
$m_{\ell\ell} < 50$ GeV	26 ± 6	33 ± 5	3.3 ± 1.4	8 ± 7	20 ± 7	11 ± 3	1.8 ± 0.5	77 ± 12	90
$\Delta\phi_{\ell\ell} < 1.3$	23 ± 5	25 ± 4	2.1 ± 1.0	4 ± 6	17 ± 6	9 ± 3	1.5 ± 0.4	60 ± 10	72
$0.75\, m_H < m_T < m_H$	14 ± 3	12 ± 3	0.9 ± 0.4	1.3 ± 1.9	8 ± 2	4.0 ± 1.6	0.7 ± 0.3	28 ± 4	29
Control Regions	Signal	WW	W + jets	Z/γ^* + jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
WW 0-jet ($m_H < 220$ GeV)	1.7 ± 0.4	223 ± 30	20 ± 15	6 ± 8	25 ± 10	15 ± 4	8 ± 3	296 ± 36	296
WW 0-jet ($m_H \geq 220$ GeV)	10 ± 2	173 ± 23	24 ± 12	13 ± 19	15 ± 6	8 ± 3	3.3 ± 0.6	236 ± 33	258
WW 1-jet ($m_H < 220$ GeV)	1.0 ± 0.3	76 ± 13	5 ± 3	5 ± 5	56 ± 14	23 ± 5	5.3 ± 1.4	171 ± 21	184
WW 1-jet ($m_H \geq 220$ GeV)	5.8 ± 1.5	51 ± 9	3.9 ± 1.8	10 ± 10	35 ± 9	18 ± 4	2.8 ± 0.6	120 ± 17	129
$t\bar{t}$ 1-jet	0.9 ± 0.3	3.9 ± 1.0	-	1 ± 17	184 ± 64	80 ± 19	0.2 ± 0.9	270 ± 69	249

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

- Largest excess 1.9 σ
- No-signal expected 95% CL exclusion in range 134-200 GeV
- Exclusion at ≥95% CL in region 145-206 GeV
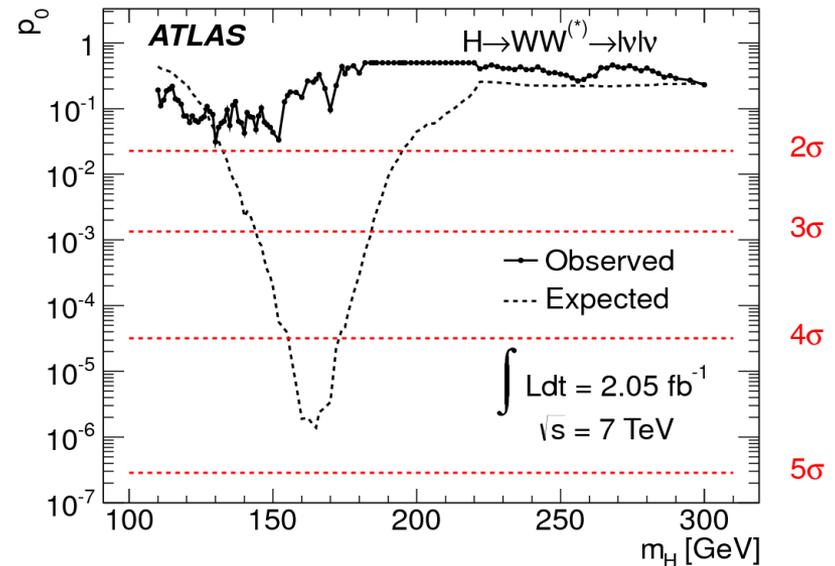
$$H \rightarrow ZZ \rightarrow l^+ l^- \nu \bar{\nu}, l = e, \mu$$

- Some similarity to $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ but no eμ channel and $|m_Z - m_{ll}| < 15\, GeV$
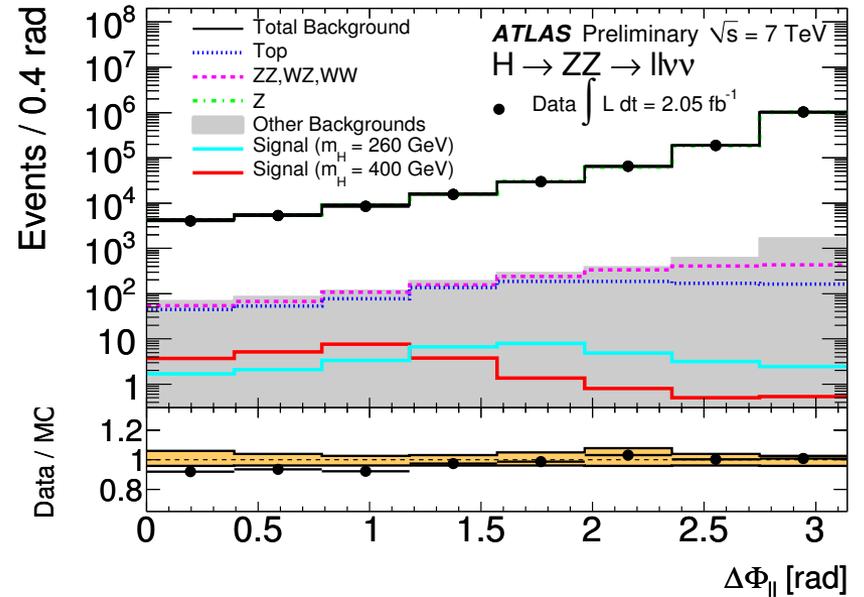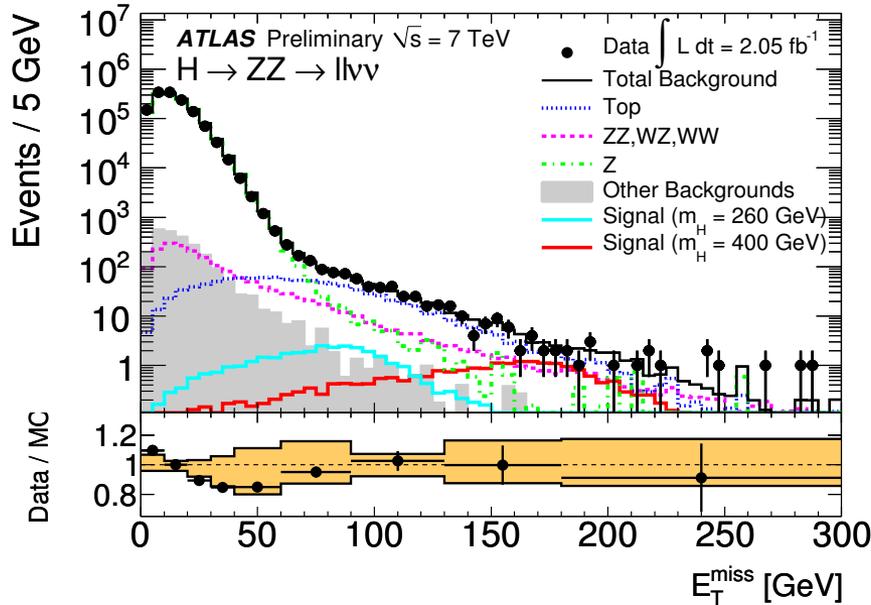
$$H \rightarrow ZZ \rightarrow l^+ l^- \nu_l \nu_l, l = e, \mu$$

|	mH < 280 GeV	mH > 280 Gev
ETmiss	> 66 GeV	> 82 GeV
Lepton opening angle	$1 < \Delta\phi_{ll} < 2.64$	$\Delta\phi_{ll} < 2.25$

$$H \rightarrow ZZ \rightarrow l^+ l^- \nu_l \bar{\nu_l}, l = e, \mu$$

| Source	low m_H search	high m_H search	
Z + jets	$40.5 \pm 4.1 \pm 3.1$	$9.9 \pm 2.1 \pm 3.6$	
W + jets	$17 \pm 4 \pm 17$	$6.1 \pm 1.7 \pm 6.1$	
top	$40 \pm 1 \pm 12$	$20.9 \pm 1.0 \pm 6.2$	
Multijet	$1.2 \pm 0.7 \pm 0.6$	$0.4 \pm 0.4 \pm 0.2$	
ZZ	$35.1 \pm 0.7 \pm 4.1$	$29.6 \pm 0.6 \pm 3.5$	
WZ	$32.4 \pm 1.0 \pm 3.8$	$23.2 \pm 0.8 \pm 2.7$	
WW	$25.4 \pm 0.7 \pm 3.1$	$9.4 \pm 0.4 \pm 1.1$	
Total BG	$192 \pm 6 \pm 35$	$100 \pm 3 \pm 17$	
Data	175	89	
m_H [GeV]	Signal expectation		s/b
200	$9.9 \pm 0.2 \pm 1.8$		8%
300		$19.9 \pm 0.3 \pm 3.5$	24%
400		$19.6 \pm 0.3 \pm 3.4$	57%
500		$8.8 \pm 0.1 \pm 1.5$	60%
600		$3.6 \pm 0.0 \pm 0.6$	60%

$$H \rightarrow ZZ \rightarrow l^+ l^- \nu_l \bar{\nu}_l, l = e, \mu$$
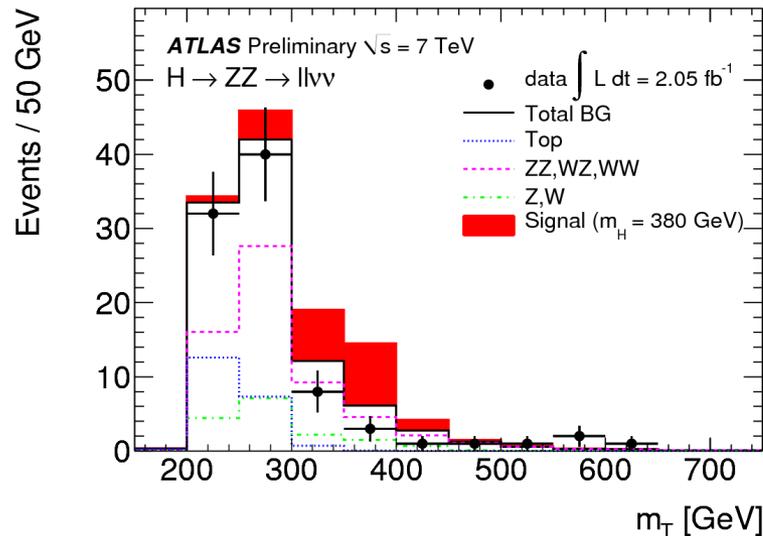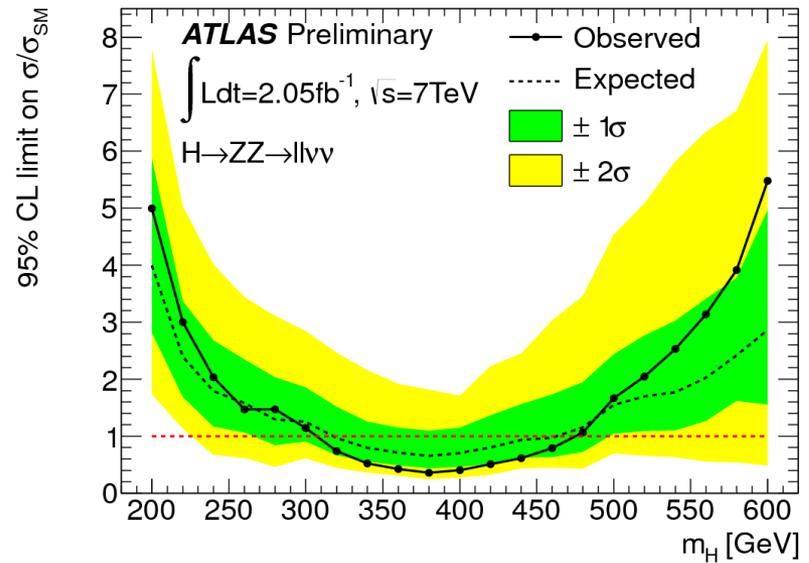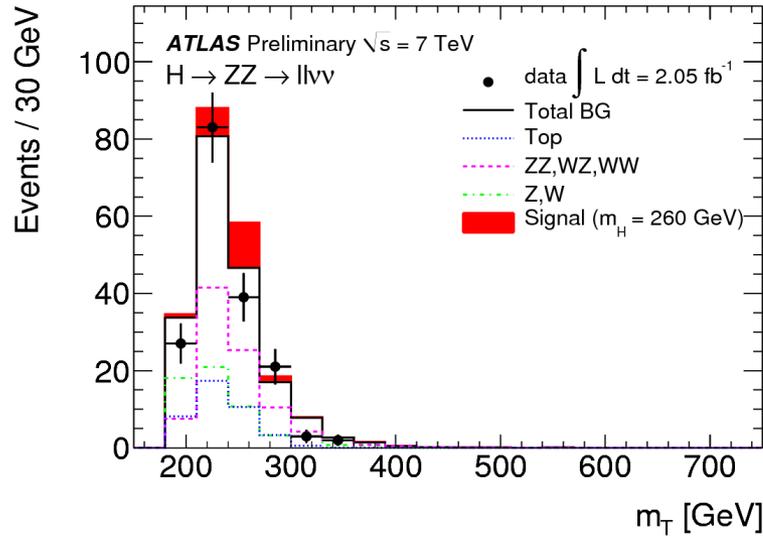
- Fit to m_T distribution
- No-signal expected 95% CL exclusion between 320-460 GeV
- 95% CL excluded region 310-470 GeV
- Impact on limit of uncertainty in off-shell Higgs production ~3-20% for 200-600 GeV

$$H \rightarrow ZZ \rightarrow l^+ l^- q\bar{q}$$

- Small missing E_T

- Leptonic+hadronic Z decays

- Z+jets background, Z->bb 20%: 2b-tagged and untagged categories
  - ε_b~70%, light q-rejection ~100

- Z's boosted for mH>300 GeV ("low/high mass" searches)

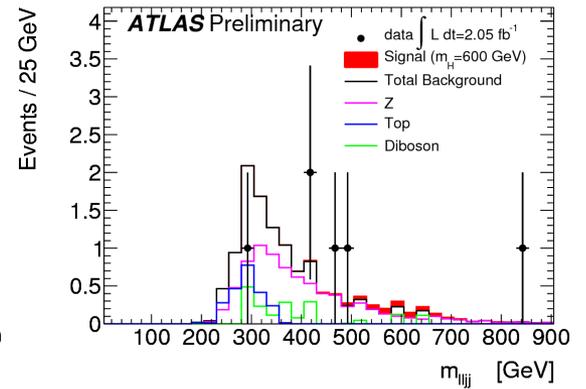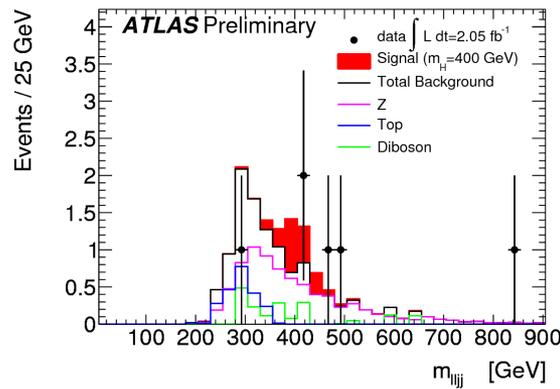$$H \rightarrow ZZ \rightarrow l^+l^-q\bar{q}$$

ATLAS Higgs - Nordic Particle Physics - A. L. Read
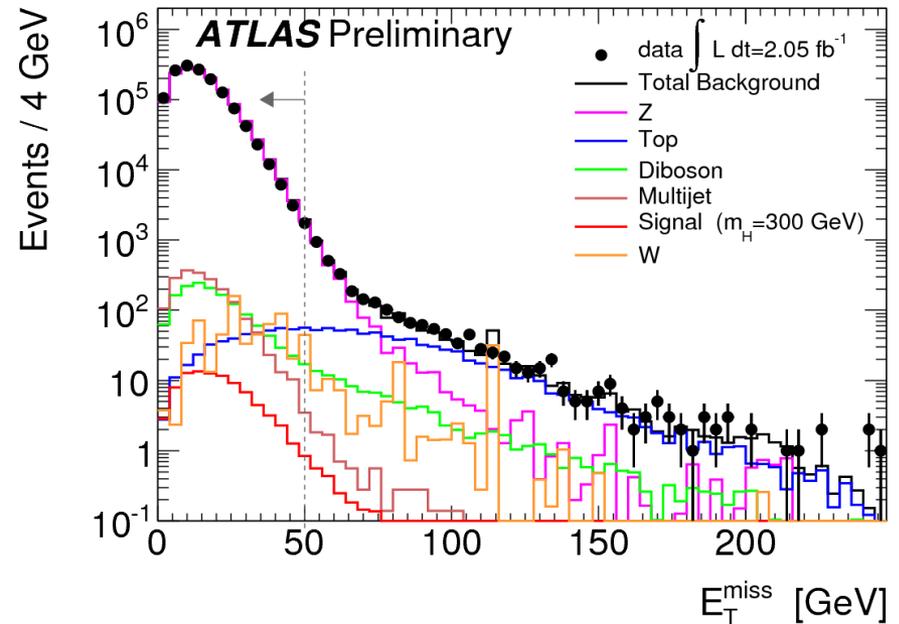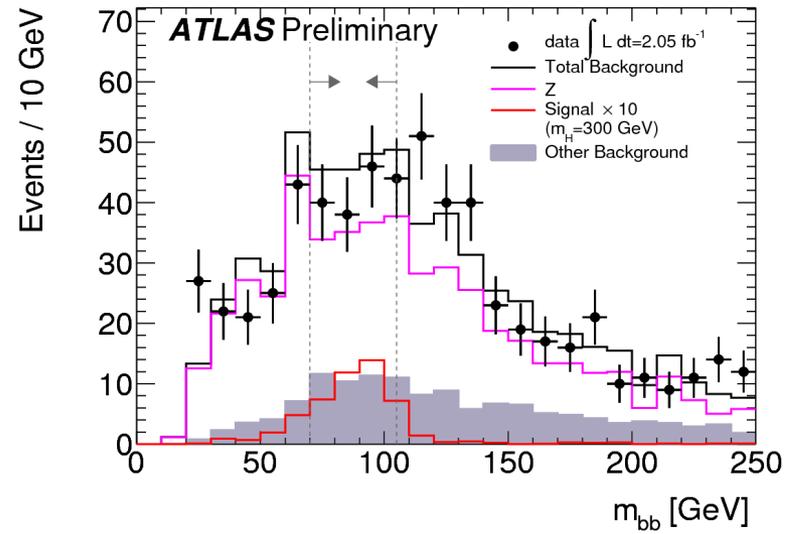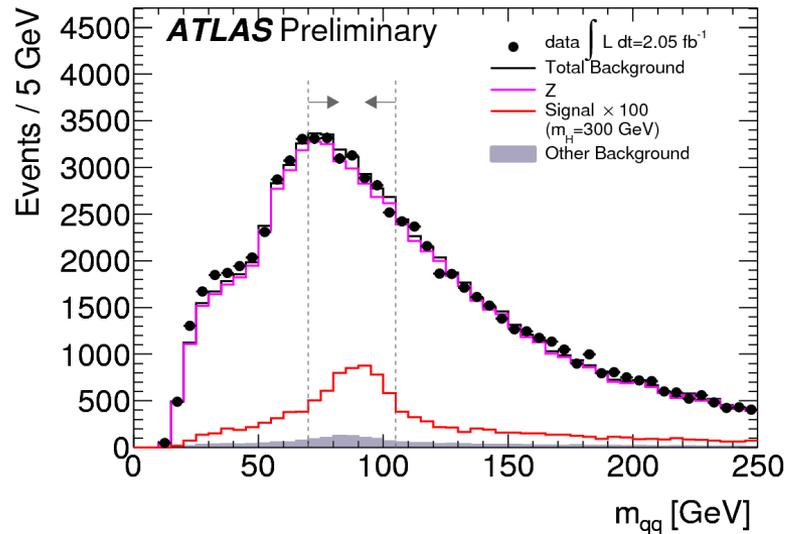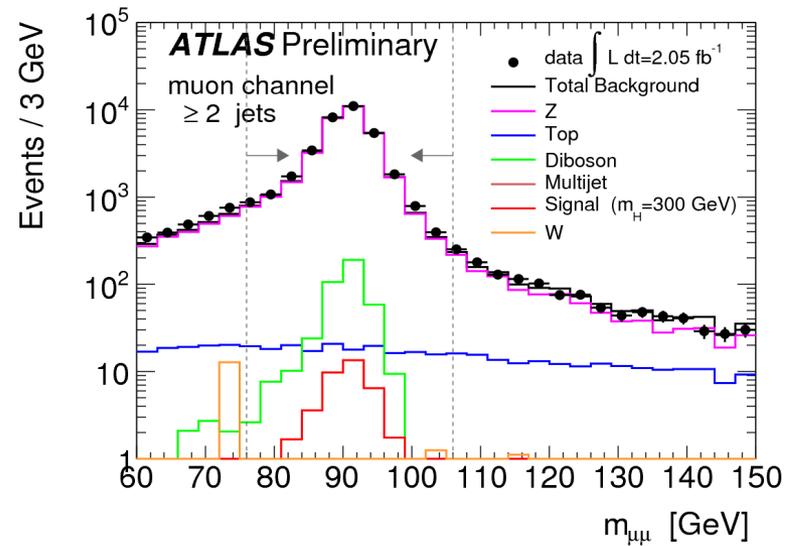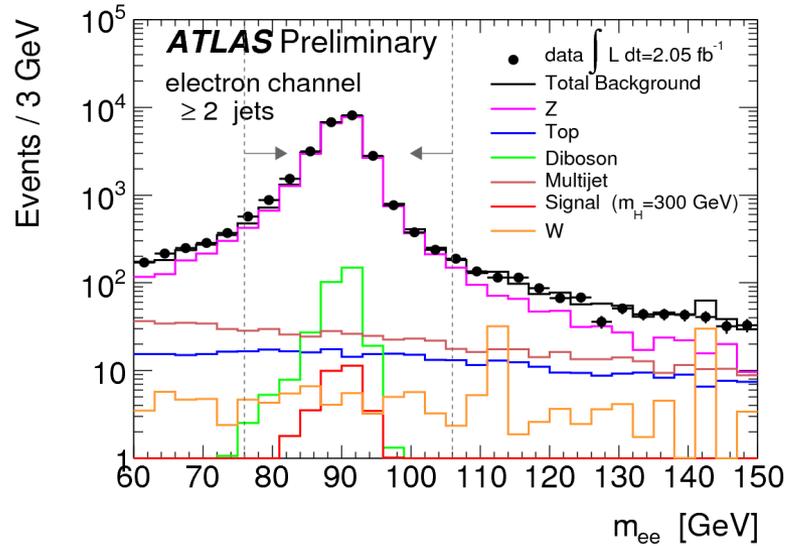
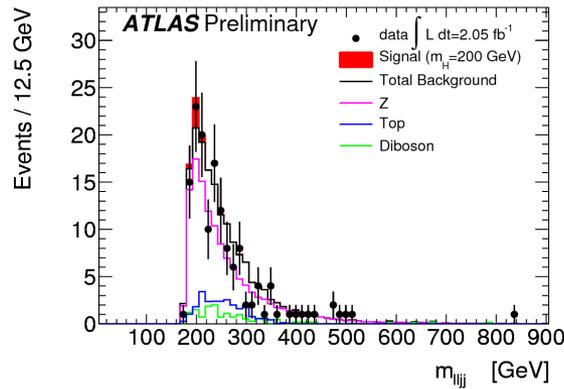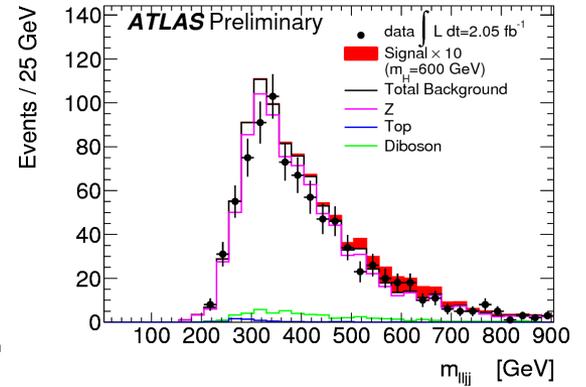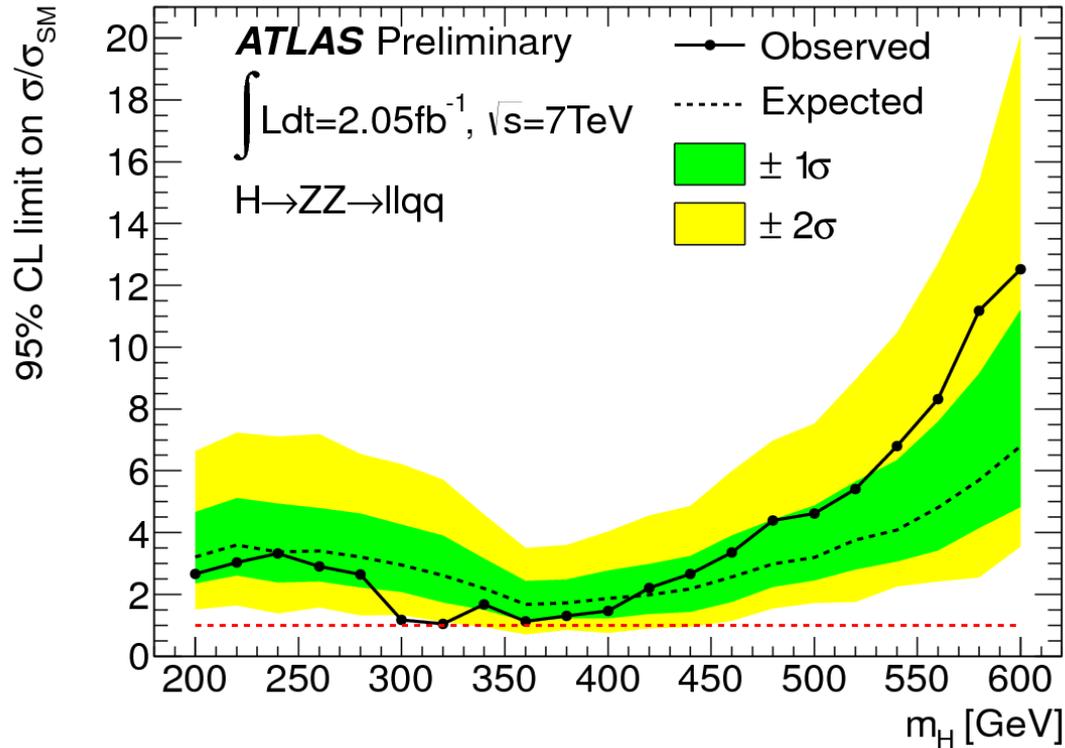# $H \rightarrow ZZ \rightarrow l^+l^- q\bar{q}$

b-Tagged
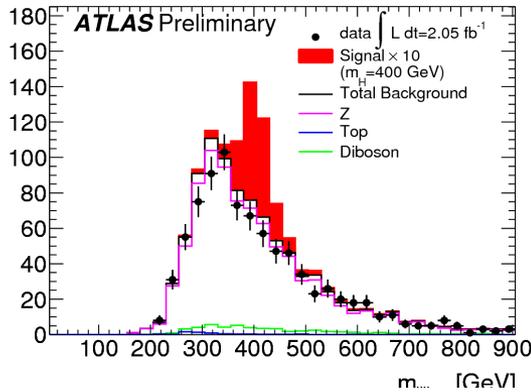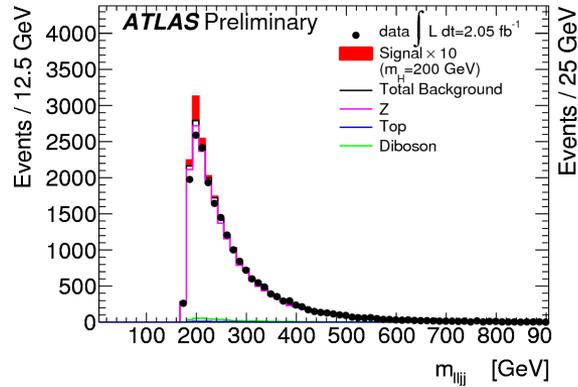
Low-mass   High-mass
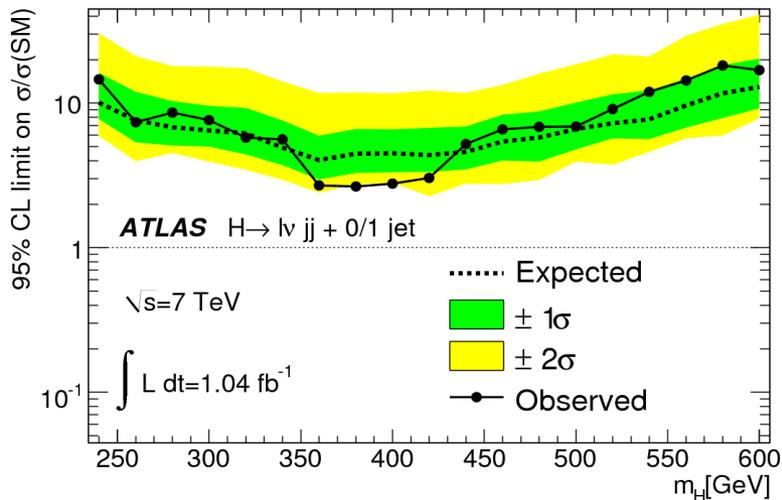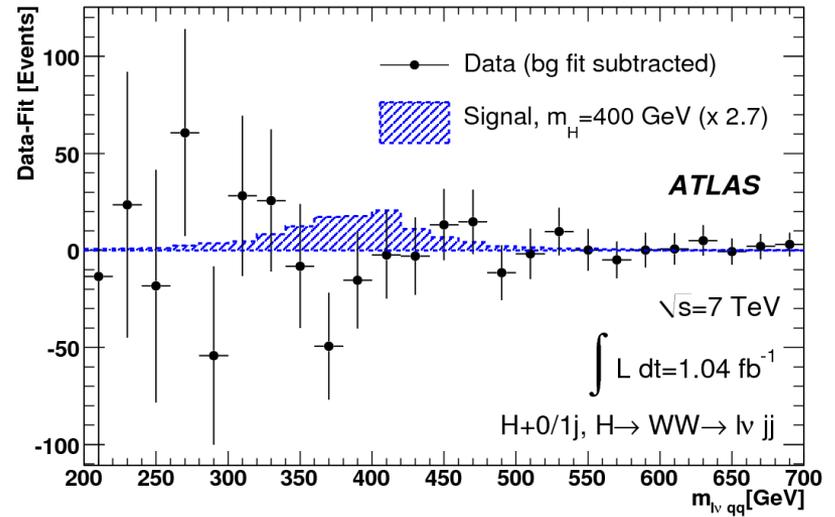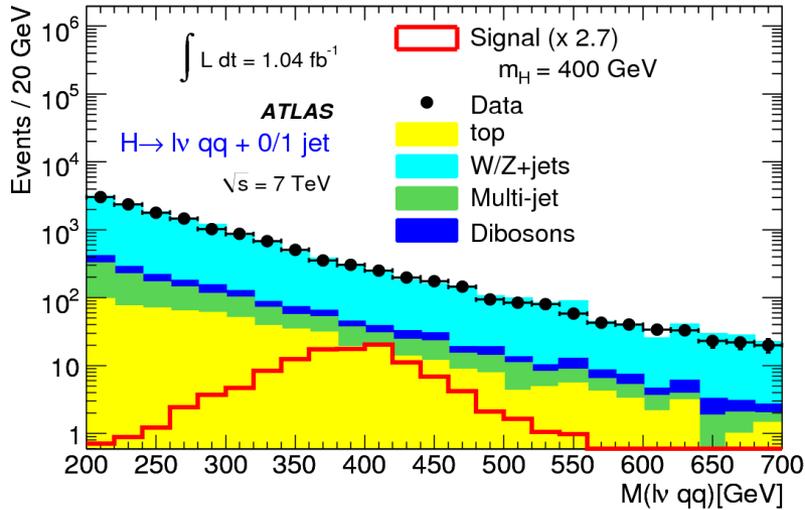
$$H \rightarrow ZZ \rightarrow l^+l^- q\bar{q}$$

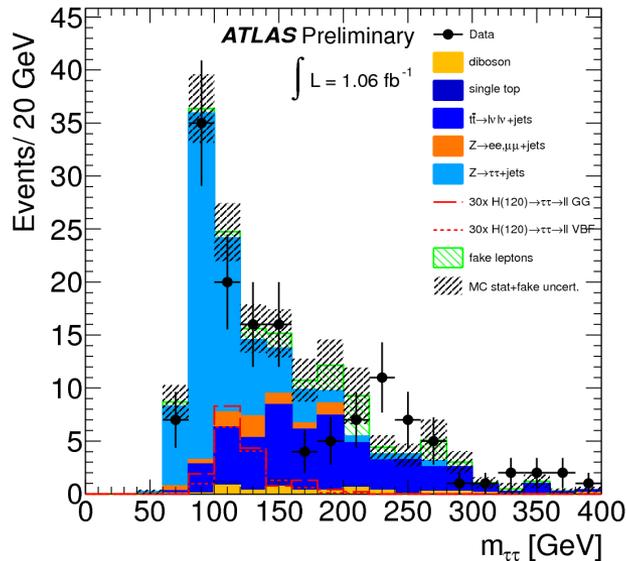

- p_0=0.13-0.5 (no sig. excesses)
- Max signal sensitivity @ 360 GeV
  - 1.7xSM expected limit
  - 1.2xSM excluded @ 95% CL
- Limits 1.2-12xSM 200-600 GeV

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

- No excesses
- Maximum signal sensitivity 4.5 x SM @ 400 GeV
- Exclude 2.7-20 x SM between 250-600 GeV

$H \to \tau^+\tau^- \to l^+l^-\,4\nu$

|	$ee + \mu\mu + e\mu$
$Z/\gamma^* \to \tau^+\tau^-$	25.4 ± 2.7
$Z/\gamma^* \to \ell^+\ell^-\ (\ell{=}e,\mu)$	3.7 ± 1.2
$t\bar{t}$	13.2 ± 2.2
Single-t	1.2 ± 0.5
Di-boson	1.6 ± 0.6
Backgrounds with fake Leptons	2.2 ± 0.9
Total Background expectation	47.4 ± 3.9
Observed data	46

SM signal	$gg \to H$	VBF
$m_H = 110$ GeV	0.39 ± 0.06	0.35 ± 0.02
$m_H = 115$ GeV	0.39 ± 0.06	0.35 ± 0.02
$m_H = 120$ GeV	0.44 ± 0.05	0.38 ± 0.02
$m_H = 130$ GeV	0.40 ± 0.04	0.33 ± 0.01
$m_H = 140$ GeV	0.21 ± 0.02	0.19 ± 0.01

- 2 leptons, 1 jet (VBF, gg-NLO), missing energy
- H-boost enhances S/B after toplogical selection
- Collinear approximation used to estimate $m_{\tau\tau}$ (ν's // to l's)
- Count events in mass window 100-150 GeV
- Irreducible Z->ττ estimated by embedding simulated τ's into $\mu^+\mu^-$(Z) events
- Exclusion limits ~30xSM obtained
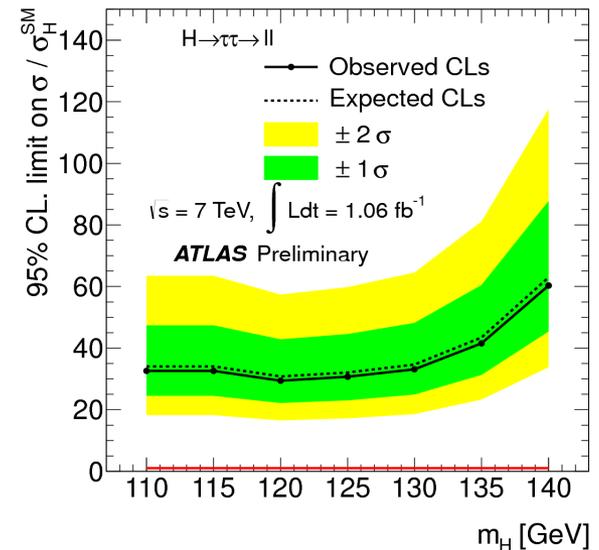
$H \rightarrow \tau^+\tau^- \rightarrow lh3\nu$
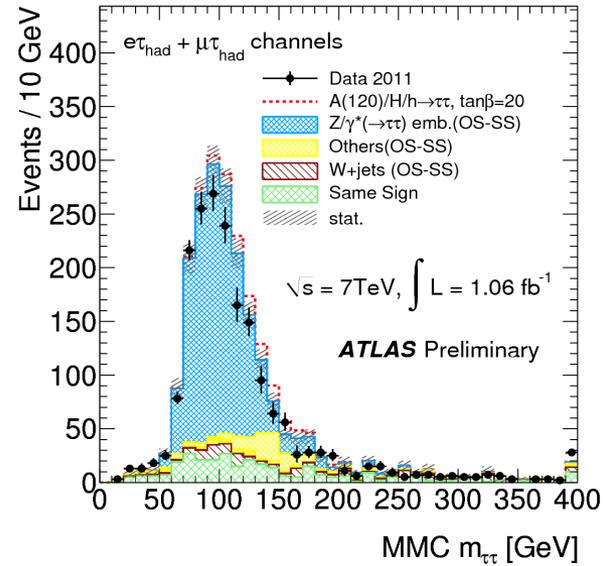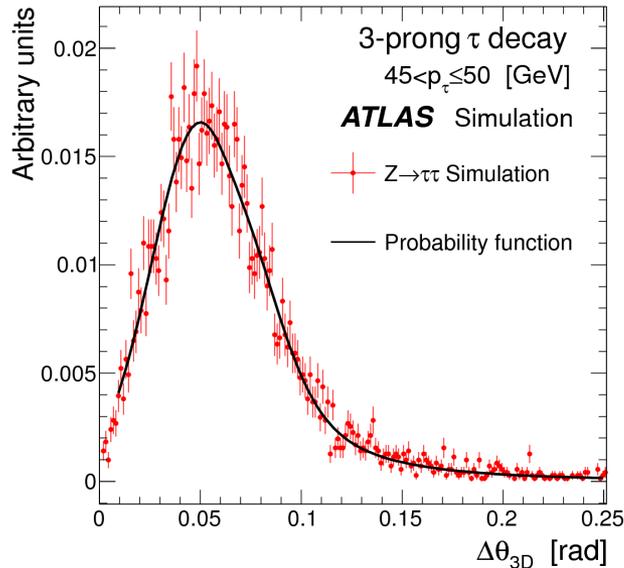
- 1 leptonic, 1 hadronic decay, missing E_T
- MMC (Missing Mass Calculator), allows non-collinear ν's, mode of $m_{\tau\tau}$ from scanning over under-determined kinematic variables, weighted by pdf of 3D opening angle between visible and invisible decay products
- Exclusion 7-26 x SM (expected 12-30)
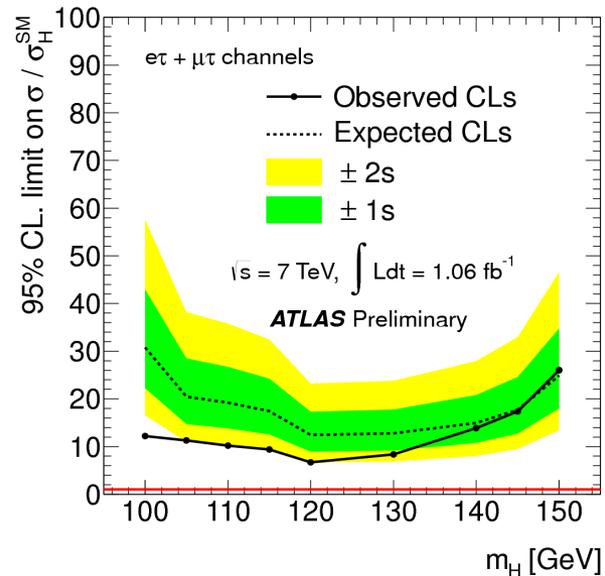
Combined Results

$$L(m_H, \mu, \vec{\vartheta}) = \prod_i L_i(m_H, \mu, \vec{\vartheta}_i)$$

$$\lambda_\mu = -2\ln\left\{\frac{\mathcal{L}(\mu, \hat{\hat{\theta}}_\mu)}{\mathcal{L}(\hat{\mu}, \hat{\theta})}\right\}$$
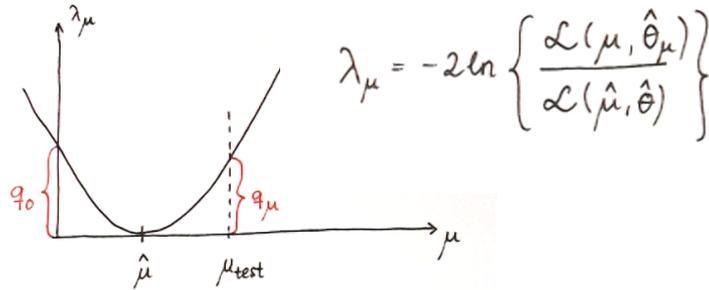
Correlated syst. uncert. on signal yield (%)

for a Higgs boson mass hypothesis of 120 GeV for the $H \to \gamma\gamma$, $H \to \tau\tau \to \ell\tau_{had}3\nu$, $H \to \tau\tau \to \ell^+\ell^-4\nu$, $H \to WW^{(*)} \to \ell^+\nu\ell^-\overline{\nu}$ and $H \to ZZ^{(*)} \to \ell^+\ell^-\ell^+\ell^-$ analyses and 300 GeV for the $H \to ZZ \to \ell^+\ell^-q\overline{q}$, $H \to ZZ \to \ell^+\ell^-\nu\overline{\nu}$ and $H \to WW \to \ell\nu q\overline{q'}$ analyses.

	$H \to \tau^+\tau^-$		$H \to \gamma\gamma$	$H \to WW^{(*)}$		$H \to ZZ^{(*)}$		
	$\ell\tau_{had}3\nu$	$\tau_\ell\tau_\ell + jet$		$\ell\nu\ell\nu$	$\ell\nu qq$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
Luminosity	$^{+3.8}_{-3.6}$	$^{+3.8}_{-3.6}$	$^{+4.0}_{-3.8}$	$^{+3.8}_{-3.6}$	$^{+3.8}_{-3.6}$	$^{+3.9}_{-3.8}$	$^{+3.8}_{-3.6}$	$^{+3.8}_{-3.6}$
e/γ eff.	± 3.5	± 2.0	$^{+13.5}_{-11.9}$	± 2.0	± 0.9	± 2.9	± 1.2	± 1.2
e/γ E. scale	$^{+1.3}_{-0.1}$	± 0.3	-	± 0.4	-	-	± 0.7	± 0.4
e/γ res.	-	$^{+0.2}_{-0.5}$	-	$^{+0.20}_{-0.05}$	-	-	± 0.25	± 0.1
μ eff.	± 1.0	± 2.0	-	-	± 0.3	± 0.16	± 0.7	± 0.5
μ res. Id.	-	$^{+0.2}_{-0.5}$	-	$^{+0.02}_{-0.04}$	-	-	± 1.1	± 1.1
μ res. MS.	-	-	-	$^{+0.04}_{+0.08}$	-	-	$^{+1.1}_{-1.0}$	± 1.1
Jet/τ/MET E. scale	$^{+18.9}_{-16.4}$	$^{+3.4}_{-10.0}$	-	$^{+4.46}_{-6.47}$	$^{+18.4}_{-15.5}$	-	± 1.6	± 15.0
JER	-	± 2.0	-	$^{+1.8}_{-1.7}$	$^{+9.0}_{-8.2}$	-	$^{+0.3}_{-0.0}$	$^{+4.0}_{-0.0}$
MET	-	$^{+4.4}_{-5.3}$	-	$^{+1.8}_{-1.7}$	-	-	-	-
b-tag eff.	-	-	-	± 0.5	-	-	± 0.3	± 3.7
τ eff.	± 9.1	-	-	-	-	-	-	-

Note: Signal uncertainties affect limit, less important for testing background.

Correlated syst. uncert. (relative) on background

| | $H \to \tau^+\tau^-$ | | $H \to \gamma\gamma$ | $H \to WW^{(*)}$ | | $H \to ZZ^{(*)}$ | | |
	$\ell\tau_{had}3\nu$	$\tau_\ell\tau_\ell + jet$		$\ell\nu\ell\nu$	$\ell\nu qq$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
Luminosity	$+3.0$ -2.9	$+3.8$ -3.6	-	±0.2	-	$+3.7$ -3.6	$+2.4$ -2.3	$+0.3$ -0.2
e/γ eff.	±2.4	$+0.5$ -1.6	-	±2.3	±0.8	±1.6	±0.8	±0.1
e/γ E. scale	$+0.9$ -0.3	±0.8	-	$+0.2$ -0.1	-	-	$+1.7$ -1.6	±0.1
e/γ res.	-	$+0.3$ -2.6	-	$+0.1$ -0.0	-	-	±0.6	±0.2
μ eff.	±1.4	$+0.5$ -1.6	-	-	±0.3	±0.1	±0.5	±0.03
μ res. Id.	-	$+0.3$ -2.6	-	-0.03 -0.06	-	-	$+1.7$ -1.6	±0.2
μ res. MS.	-	-	-	$+0.00$ -0.02	-	-	$+1.7$ -1.6	±0.2
Jet/τ/MET E. scale	$+10.0$ -8.9	$+7.0$ -9.8	-	$+8.5$ -10.4	-	-	$+6.9$ -5.2	±1.0
JER	-	±2.5	-	$+3.3$ -3.0	-	-	$+1.8$ -0.0	$+0.3$ -0.0
MET	-	$+0.4$ -2.7	-	$+0.6$ -0.5	-	-	-	-
b-tag eff.	-	-	-	±1.8	-	-	$+7.0$ -5.5	±0.2
τ eff.	±7.2	-	-	-	-	-	-	-

for a Higgs boson mass hypothesis of 120 GeV for the $H \to \gamma\gamma$, $H \to \tau\tau \to \ell\tau_{had}3\nu$, $H \to \tau\tau \to \ell^+\ell^-4\nu$, $H \to WW^{(*)} \to \ell^+\nu\ell^-\overline{\nu}$ and $H \to ZZ^{(*)} \to \ell^+\ell^-\ell^+\ell^-$ analyses and 300 GeV for the $H \to ZZ \to \ell^+\ell^-q\overline{q}$, $H \to ZZ \to \ell^+\ell^-\nu\overline{\nu}$ and $H \to WW \to \ell\nu q\overline{q}'$ analyses.

Note: Important for testing background hypothesis.

CLs limits all channels
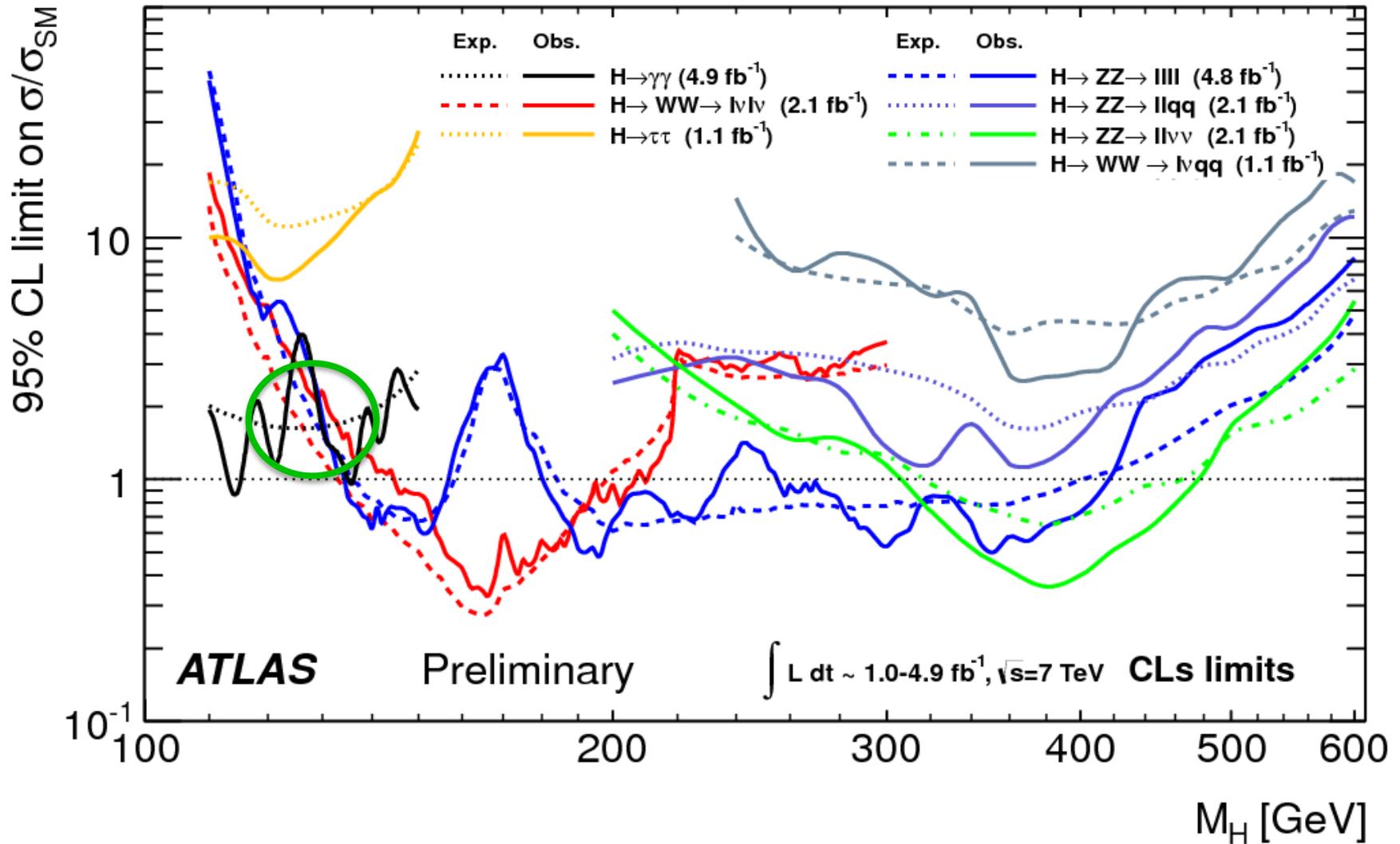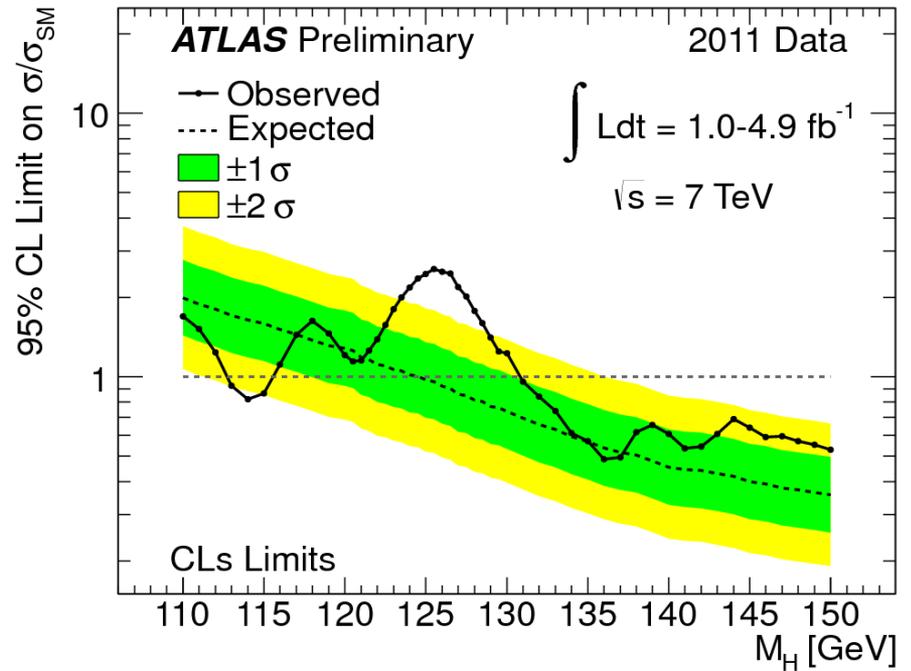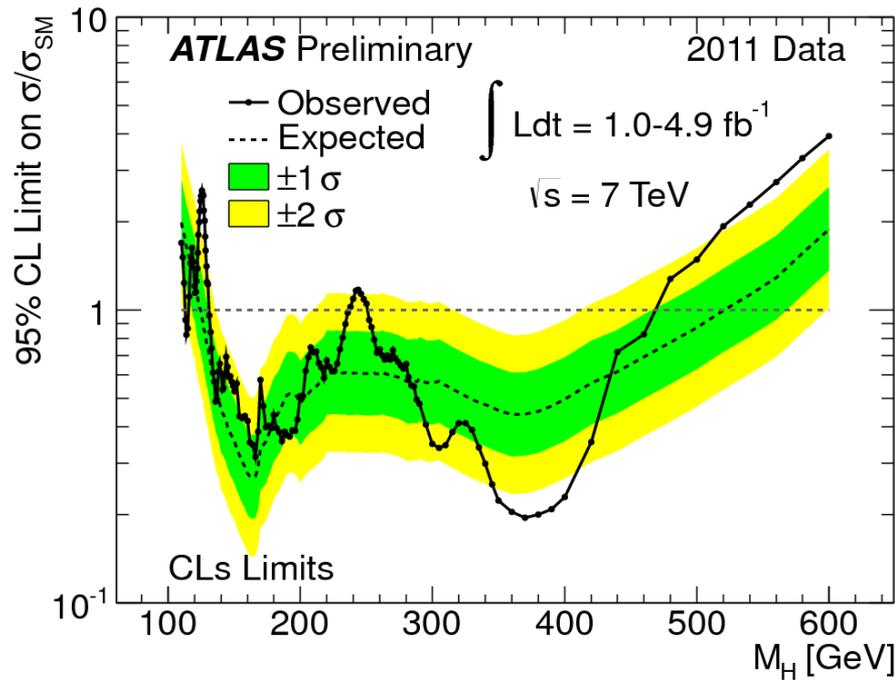
CLs – test of SM signal hypothesis
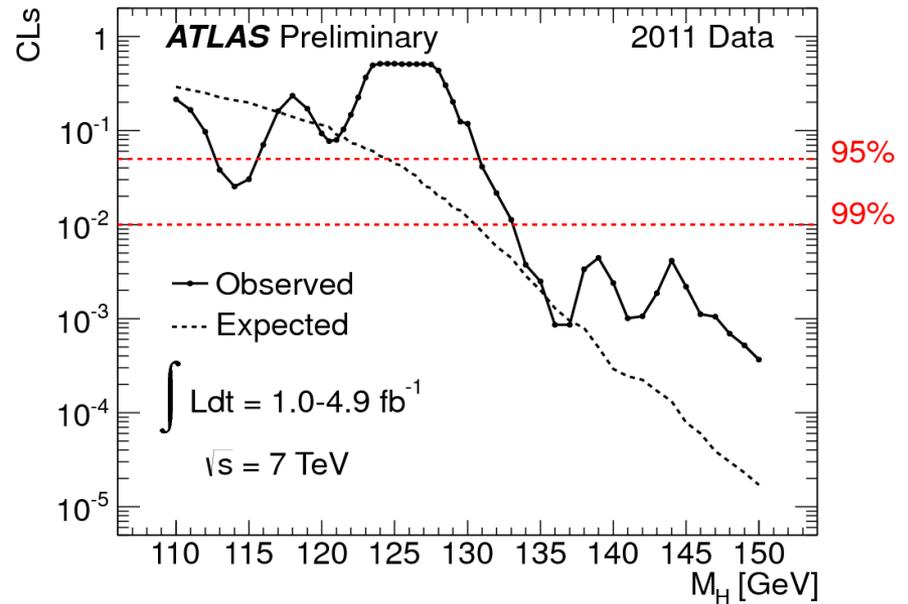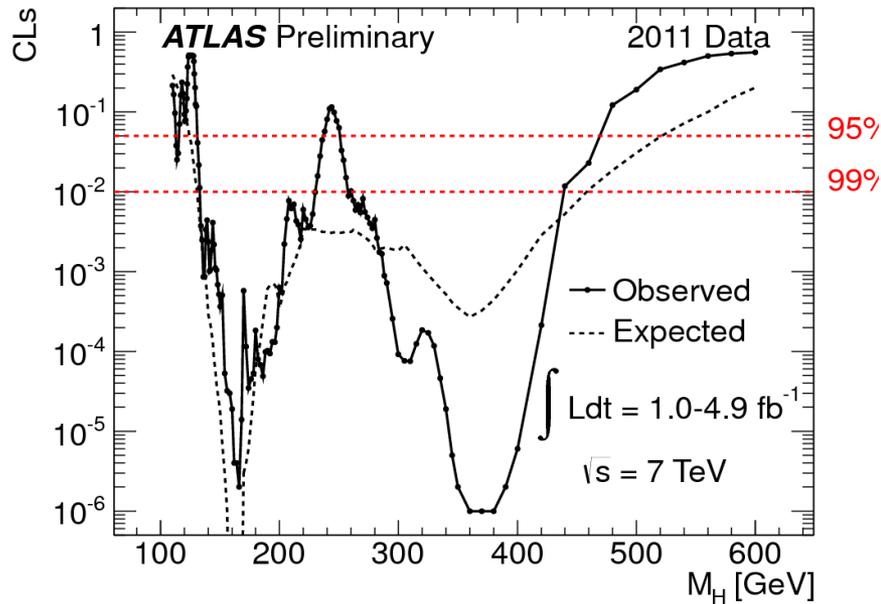
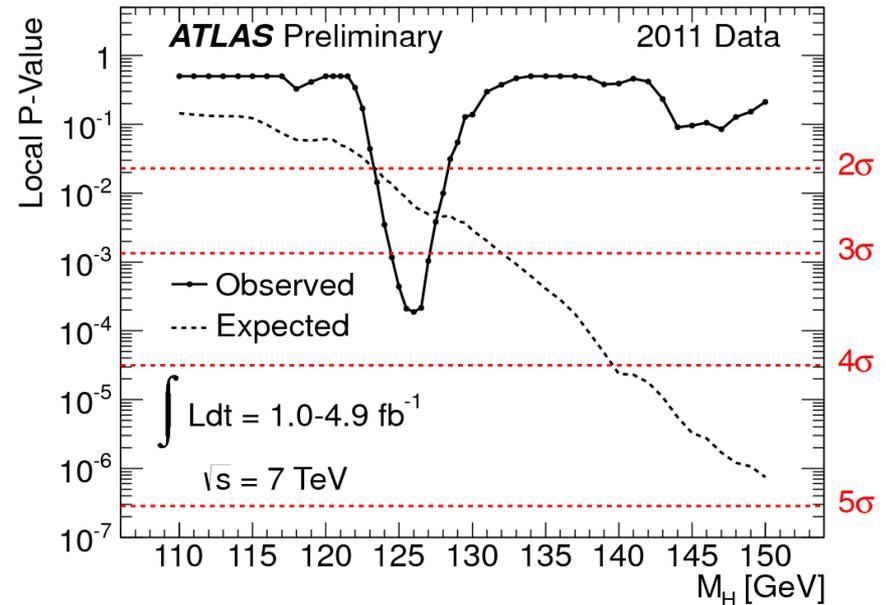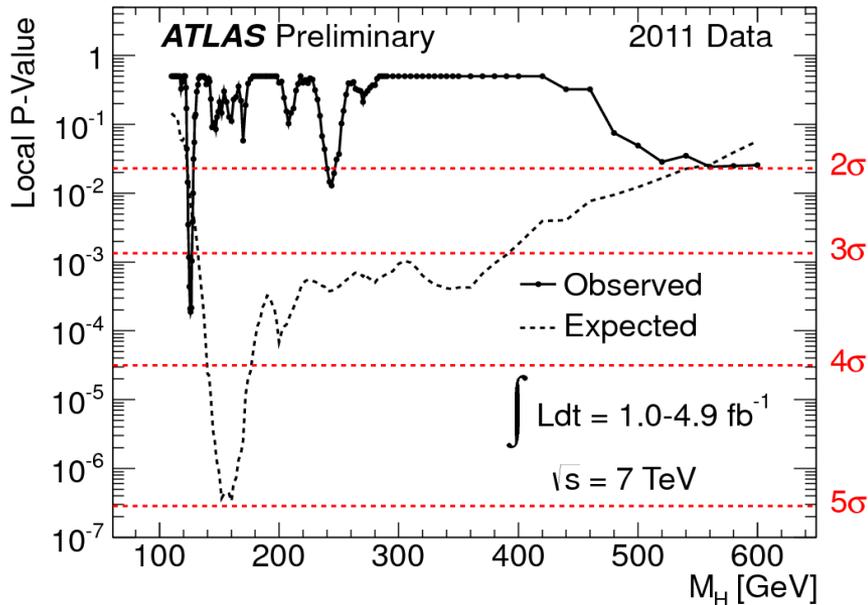Expected exclusion region: 125-520 GeV
Observed exclusions: 112.7-115.5, 131-237, 251-453 GeV

(LHC@HCP: Expected 124-520, Observed 141-476)

CLs upper limits on σ/σ$_{SM}$

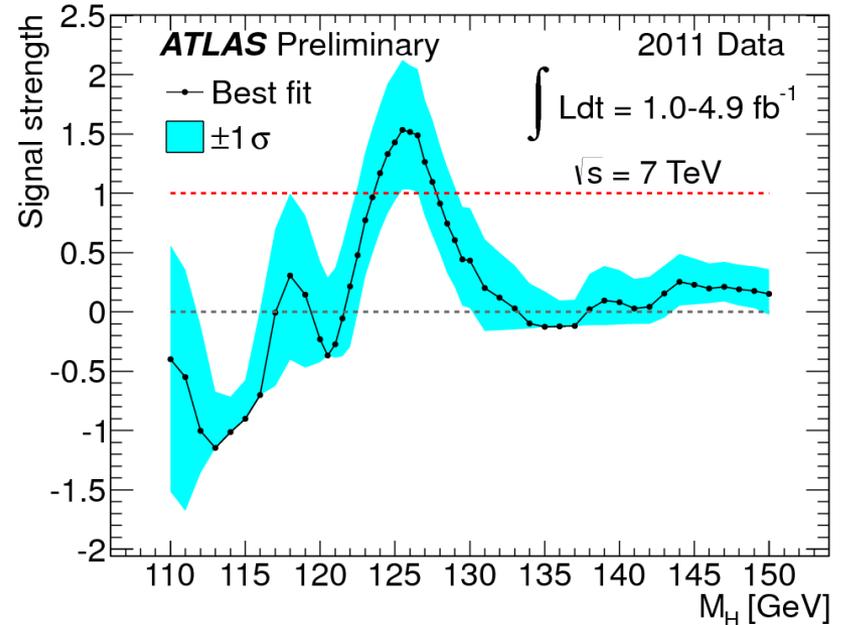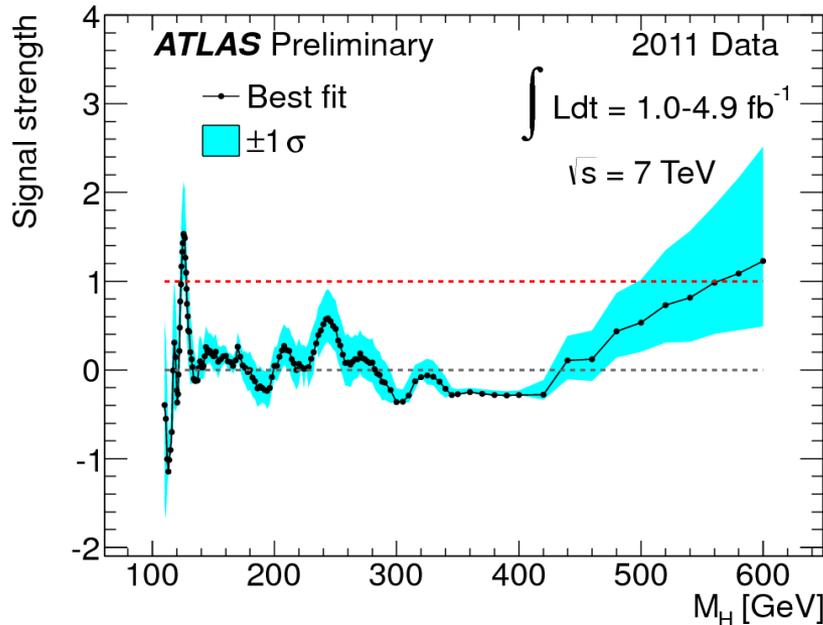# p$_0$ – test of background hypothesis

- At 126 GeV local p$_0$=1.9 x 10-4 (3.6 σ)
- 6 crossings in full mass range (see also Cyan Band plots)
  - Global p$_0$=1.1% (2.3 σ)

Estimate of signal strength μ=σ/σ$_{SM}$
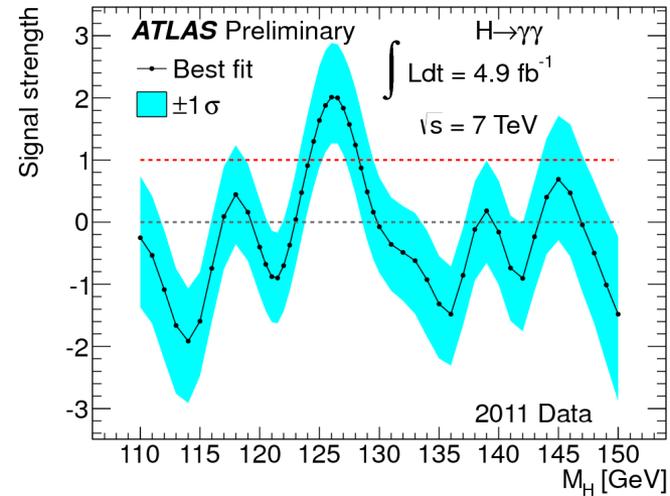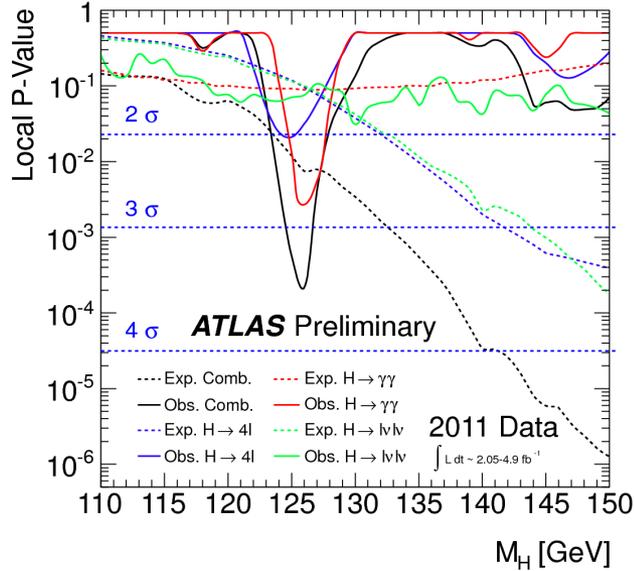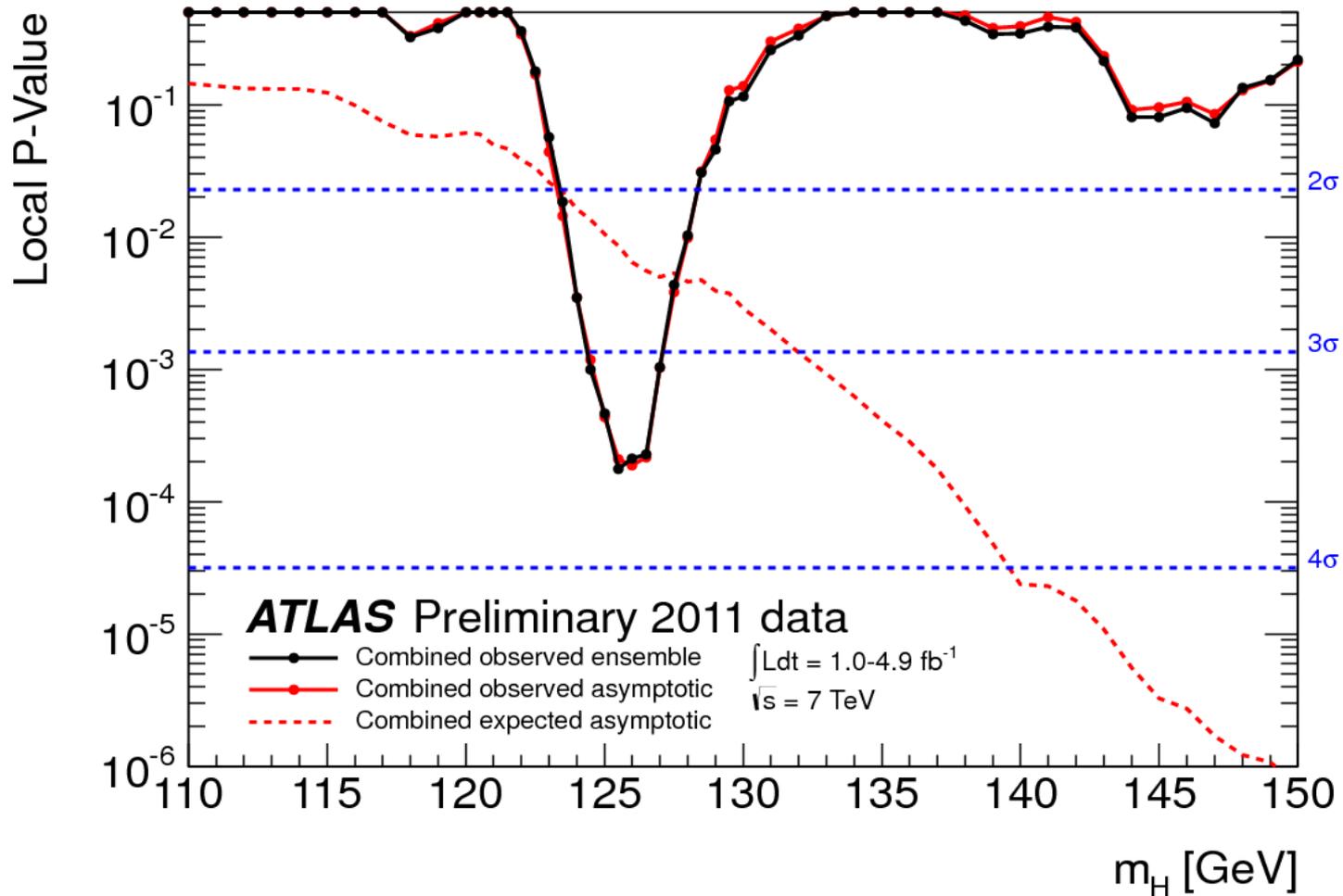

- Allowing negative values of μ using a specific treatment to not allow pdfs to have negative values.
- Don't use these to set limits or test background hypothesis, they are for illustration.

Signal strength ~1.5 around 126 GeV is not incompatible with SM Higgs expectation of 1

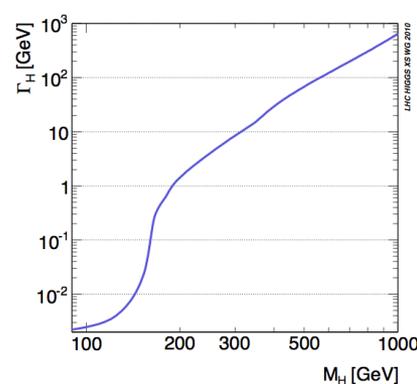# 3 most sensitive channels
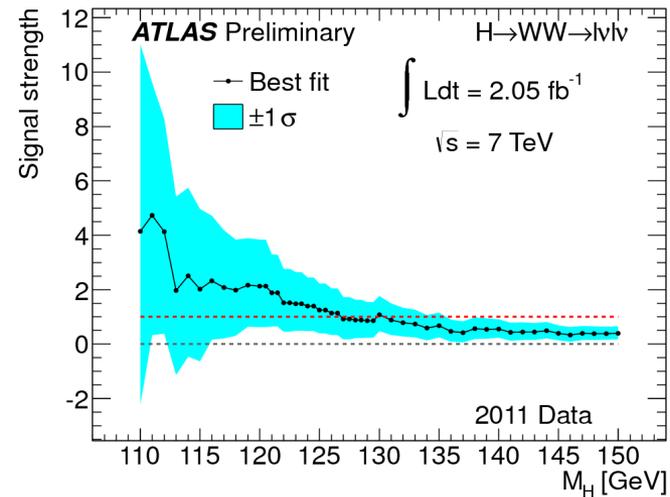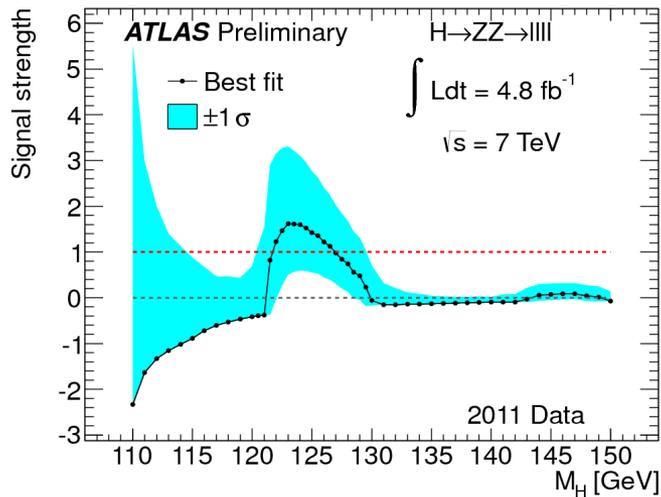
Asymptotics (baseline) vs. MC ensemble

Next steps

- Finalize 2011 results
- Combine published ATLAS+CMS 2011 results
  - Inter-experiment energy scale systematics important
- Prepare improved analyses for 2012
  - ~4 times data and a bit higher √s could take ATLAS+CMS within spitting distance of 5σ or exclude present excess as fluctuation
  - Should decide on LEE-region before the data arrive
- If ~124-6 GeV persists:
  - Measurement of mass (ML, not Mσ)
  - γγ: It's not a vector
  - ττ, bb, WW, ZZ decays all accessible for measurements
  - Consequences for BSM…
- If not:
  - Go down in the couplings
  - Don't forget (difficult) high mass

Conclusions

- Preliminary results for SM Higgs boson searches with ATLAS in up to 4.9/fb of 2011 data

- Expected exclusion region m_H=124.6-520 GeV

- 3 regions excluded at >= 95% CL
  - 112.7-115.5, 131-237, 251-453 GeV

- Excesses observed in 3 most sensitive channels near m_H=126 GeV (local: 2.7, 2.0, 1.4 σ)
  - Global probability for background to give this combined excess is approximately 1%