SEARCH FOR A STANDARD MODEL HIGGS BOSON WITH ATLAS AT THE LHC

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MARCH 12TH 2012

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- STANDARD MODEL HIGGS COMBINATION
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INTRODUCTION

LARGE HADRON COLLIDER LHC

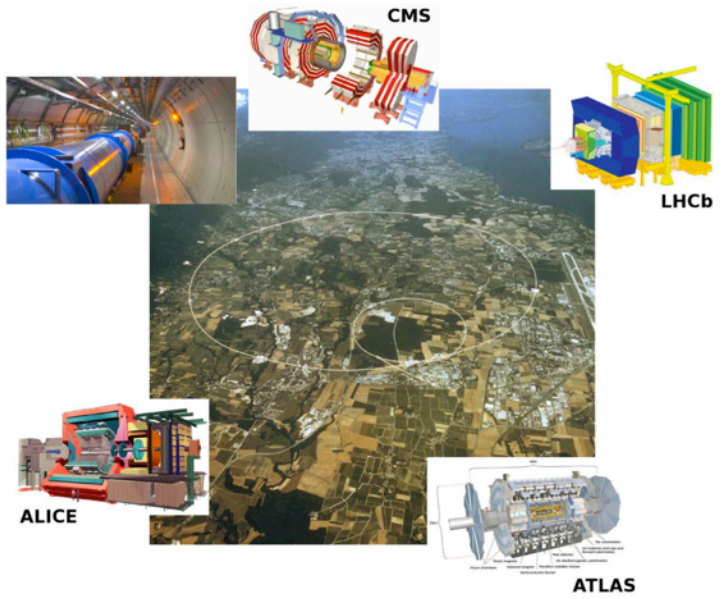
Proton-proton running at √s = 7 TeV

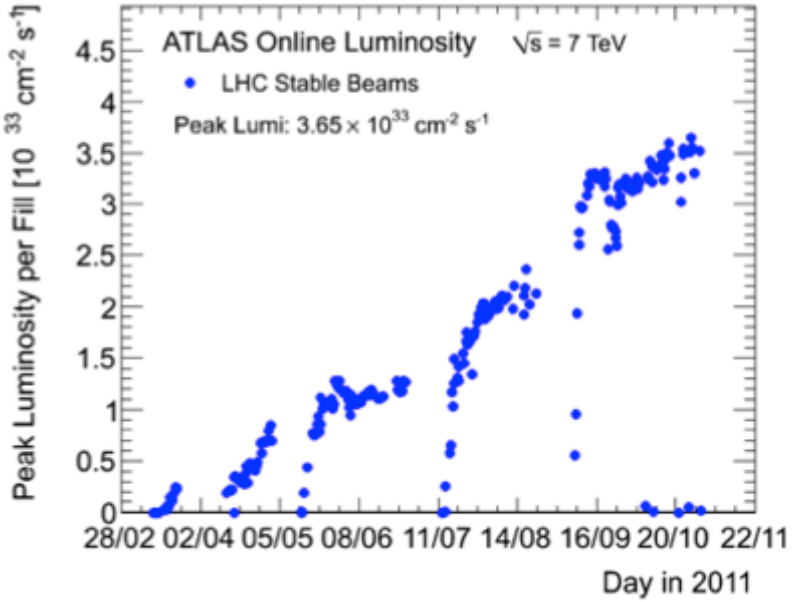
- Steadily increasing peak luminosities
- Stepwise increasing number of bunches and higher bunch charge
- Decrease of β^* from 1.5 to 1m in August 2011

	2010	2011
Peak luminosity ($cm^{-2}s^{-1}$)	$2.1 \cdot 10^{32}$	$3.65 \cdot 10^{33}$
ATLAS recorded integrated luminosity	45 pb^{-1}	5.25 fb^{-1}
Mean number of interactions per bunch crossing (pile-up)	~2	6.3 / 11.6

Heavy Ion running at $\sqrt{s_{NN}}$ = 2.76 TeV

- Pb-Pb collisions, 287 TeV on 287 TeV
- In total 158μb^{-1} recorded, 0.9 μb^{-1} in 2010

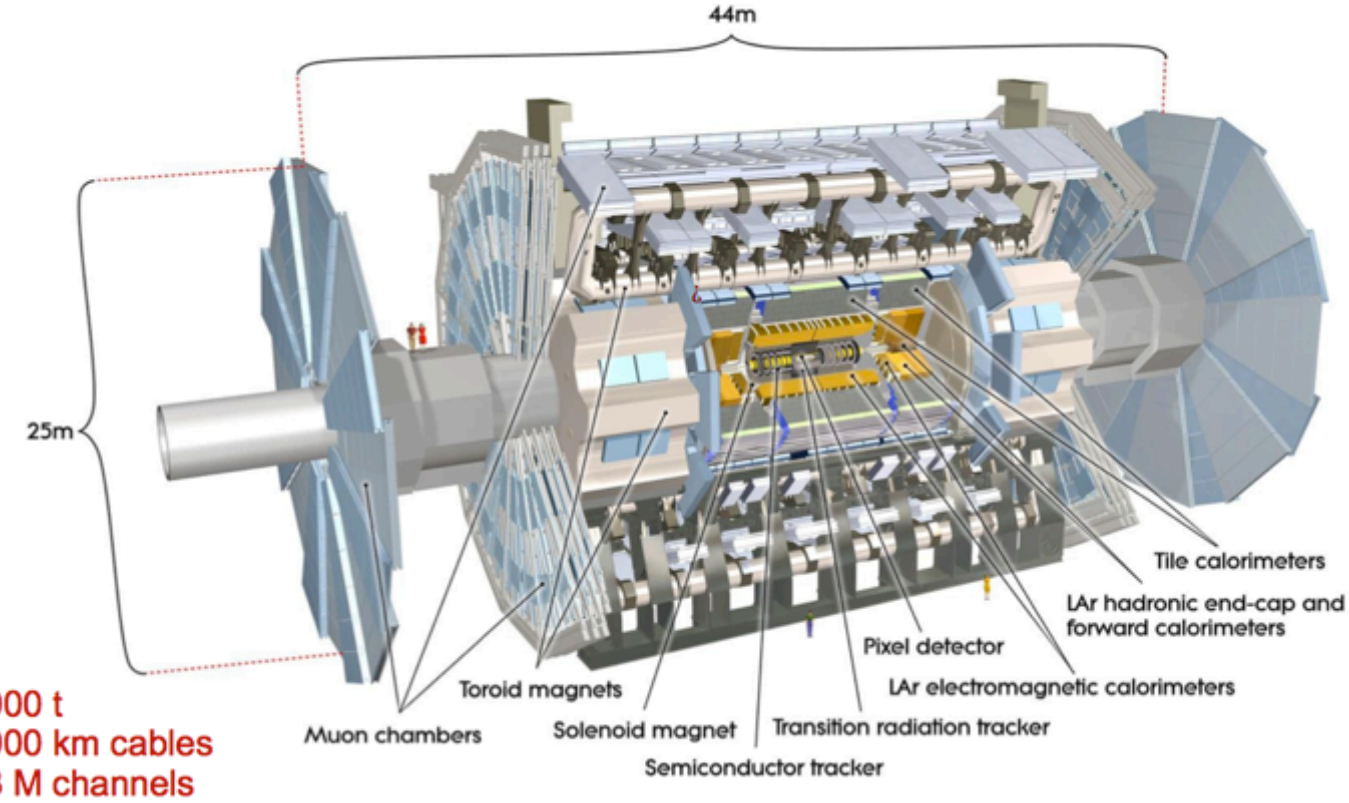




ATLAS DETECTOR

Muon Spectrometer: |η|<2.7
Air-core toroids with gas based muon chambers
$\sigma(p_T)/p_T$ = 2% @ 50GeV to 10% @ 1TeV (ID+MS)

EM Calorimeter: |η|<3.2
Pb-LAr Accordion
$\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.7\%$



Inner Detector: |η|<2.5, B=2T
Si pixels/strips and Trans. Rad. Det.
$\sigma(p_T)/p_T = 0.05\%\ p_T \oplus 1\%$

Hadronic Calorimeter: |η|<4.9
Fe/scintillating Tiles (central), Cu/W LAr (fwd)
$\sigma(E_{jet})/E_{jet} = 50\%/\sqrt{E} \oplus 3\%$

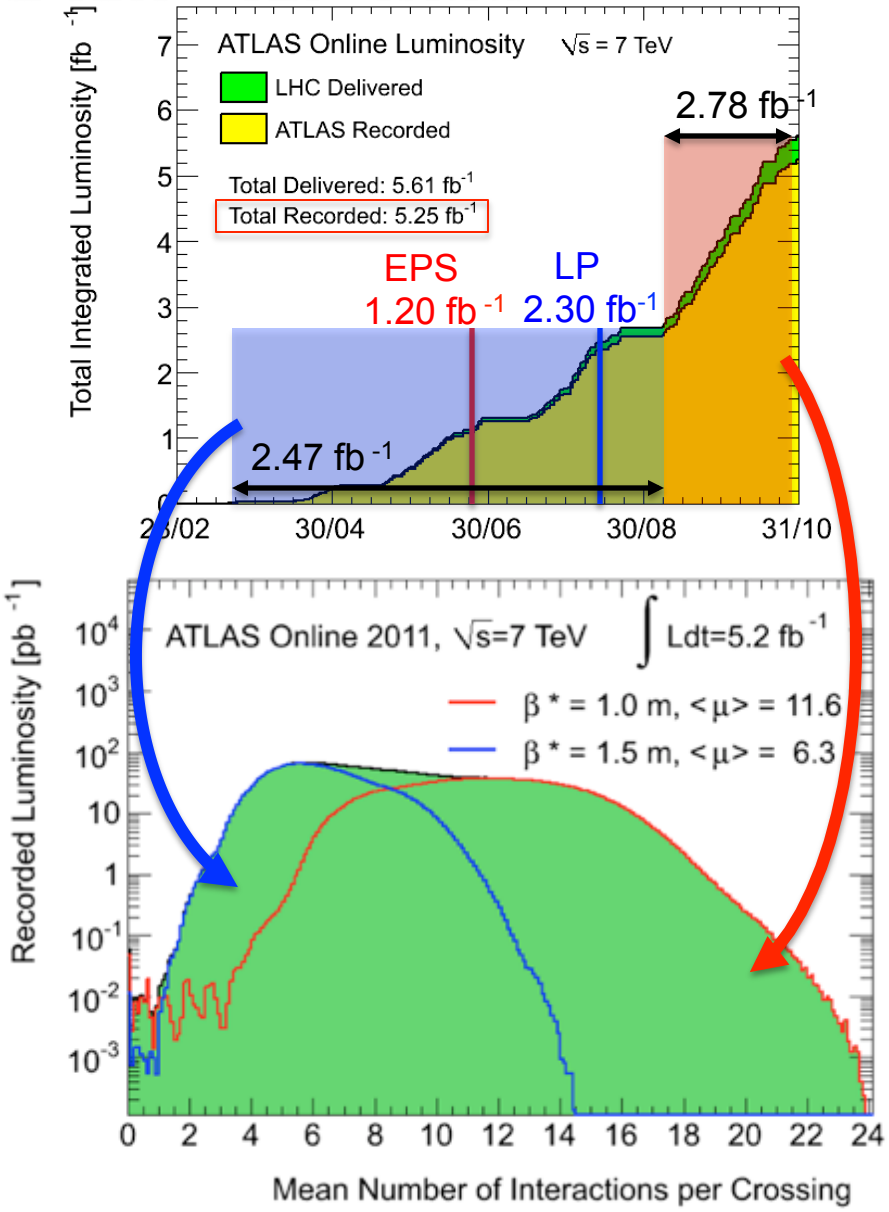
ATLAS DATA TAKING IN 2011

A huge amount of data collected in 2011 :

- Thanks to the LHC teams for this great job
- ATLAS data taking in 2011:
  - p-p collision at $\sqrt{s}$=7 TeV
  - peak luminosity : ~3.65x10^{33} cm^{-2} s^{-1}
  - O(5) fb^{-1} for analysis
  - data taking efficiency : ~93.5%

Pile-up challenge :

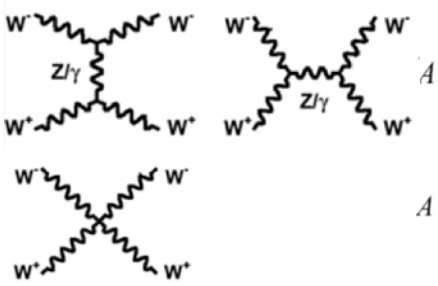
- 50 ns bunch train for ~all 2011 data
  in-and out-of-time pile up :
  <μ>~6 for 2.47 fb^{-1} of the data collected
  <μ>~12 for 2.78 fb^{-1} of the data collected
- Continuing details performances studies in presence of “high” pile-up



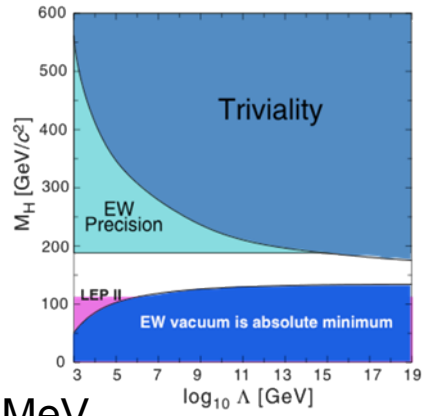
HIGGS BOSON

Standard Model :

- success
  - prediction (W,Z boson, top quark) in agreement with the experimental results
  - precision measurements in agreement with the theory

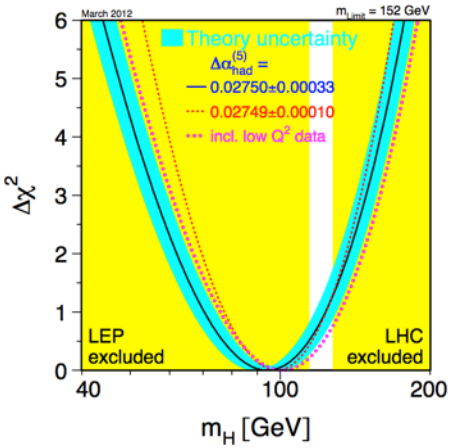


- limit of the Standard Model
  - generate by the Higgs mecanism
  - problem of unitarity
  - number of free parameter



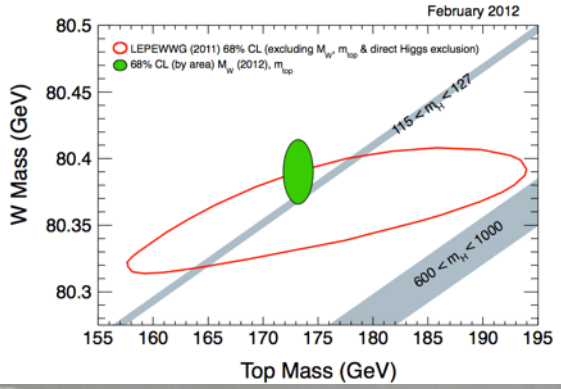
limits on the m_{Higgs} in the Standard Model :

- direct search limits (@95% CL)
  SINDRUM, Barr et al. (π,K decays): ~10-110 MeV
  CLEO+CUSB: ~2*mμ-5 GeV
  LEP+Tevatron+ATLAS+CMS: <114.4, 141-476 GeV

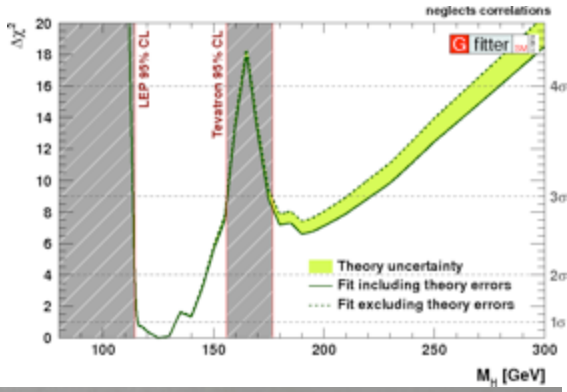


most likely value : $90\ ^{+29}_{-23}$ GeV

- fit electroweak
  m_{Higgs} < 152 GeV@ 95% CL



- limit of the theory
  m_{Higgs} < 1 TeV/c2
  (triviality, unitarity)



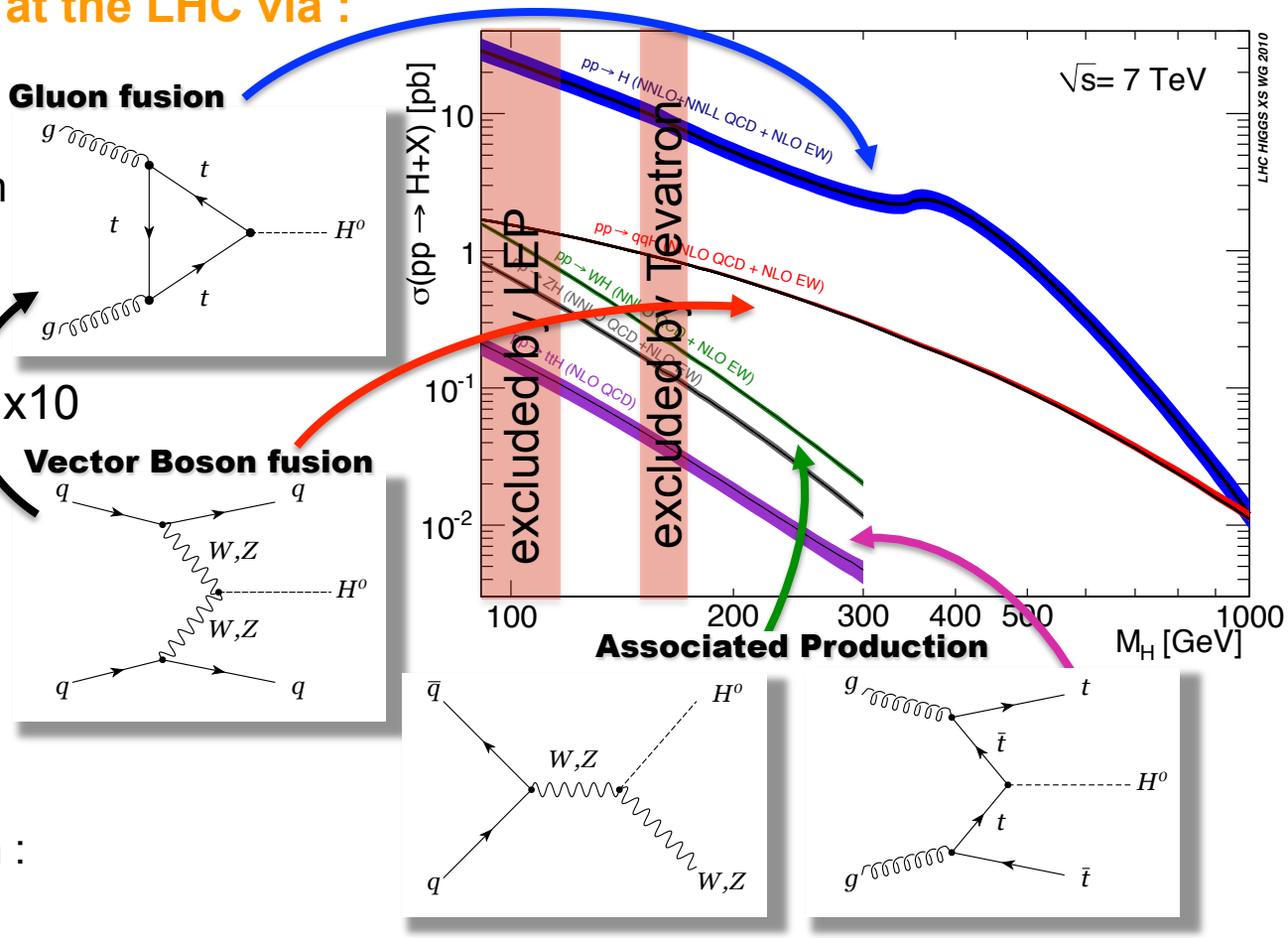
LHC HIGGS PRODUCTION

Higgs Boson production at the LHC via :

- Gluon fusion :
  - gg → H
  - dominant mechanism
  - channels :
    H → WW ,ZZ, γγ

- Vector Boson fusion :
  - qq → qqH
  - smaller but distinct
  - channels :
    H → ττ

- Associated Production :
  - qq → WH,ZH, ttH
  - the smallest
  - difficult
  - channels :
    H → bb



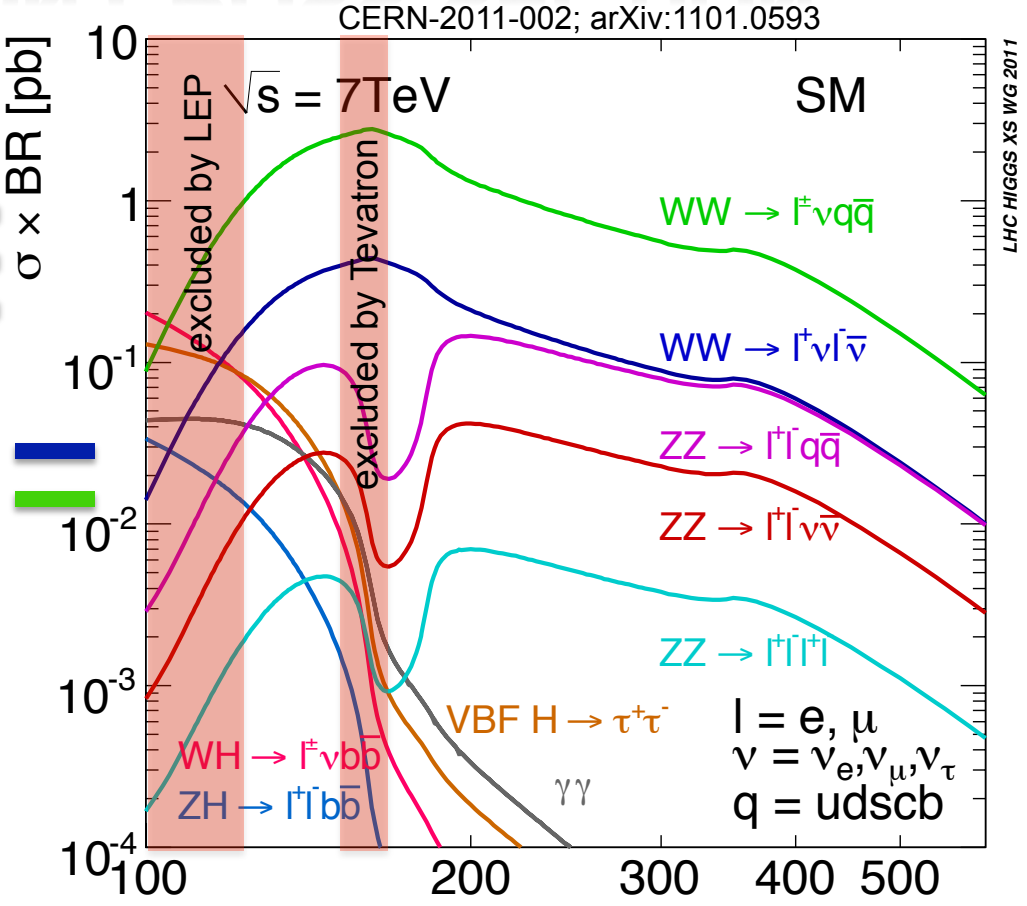
Typical uncertainties on total cross-sections

gg	15-20 %	NNLO + NNLL + NLO EW
VBF	5 %	NNLO + NLO EW
WH, ZH	5 %	NNLO + NLO EW
$t\bar{t}$H	15 %	NNLO

HIGGS BOSON CROSS-SECTION

Most important channels :

- $H \rightarrow ZZ^{(*)}$:
  - $ZZ \rightarrow llll$: "golden" mode
  - $ZZ \rightarrow ll\nu\nu$: good for high mass
  - $ZZ \rightarrow llqq$: good at high mass
- $H \rightarrow WW^{(*)}$:
  - $WW \rightarrow l\nu l\nu$: most sensitive
  - $WW \rightarrow l\nu qq$: important at high mass
- $H \rightarrow \gamma\gamma$:
  - rare channel
  - best for low mass
- $H \rightarrow \tau\tau$:
  - good s/b
  - low mass
  - rare
- $H \rightarrow bb$:
  - with associated production
  - useful but difficult



Events expected to be produced with L= 1fb^{-1}

m_H, GeV	$WW \rightarrow l\nu l\nu$	$ZZ \rightarrow 4l$	$\gamma\gamma$
120	127	1.5	43
150	390	4.6	16
300	89	3.8	0.04

STATISTICAL PROCEDURE

Used for individual channels and SM Higgs combination at ATLAS :

- Common parameters of interest is a cross-section scale factor :
  $\mu=\sigma/\sigma^{SM}$ $\mu=0$ is the background only model
  $\mu=1$ correspond to the nominal signal model

- Combined probability model is formed by identifying nuisance parameters ν associated to common systematic effects

- The profile likelihood ratio is used as a test statistics :
  $$\lambda(\mu) = L_{s+b}(\mu, \hat{\hat{\nu}}) / L_{s+b}(\hat{\mu}, \hat{\nu})$$
  one-sided variants of the test statistic are used for the upper-limits and discovery

- Nuisance parameters are “profiled” based on the data

- The distribution of the test statistic is obtained in two way :
  - ensemble tests with with Toy Monte Carlo using a fully frequentist procedure
  - using asymptotic distribution of likelihood ratio (improved χ^2 method)

- Primary results based on CLs
  - more relevant to protect against downward fluctuations
  - additional comparison with Bayesian procedure with a uniform prior on $\mu=\sigma/\sigma^{SM}$

- Use RooFit/RooStats

LIMIT PLOT

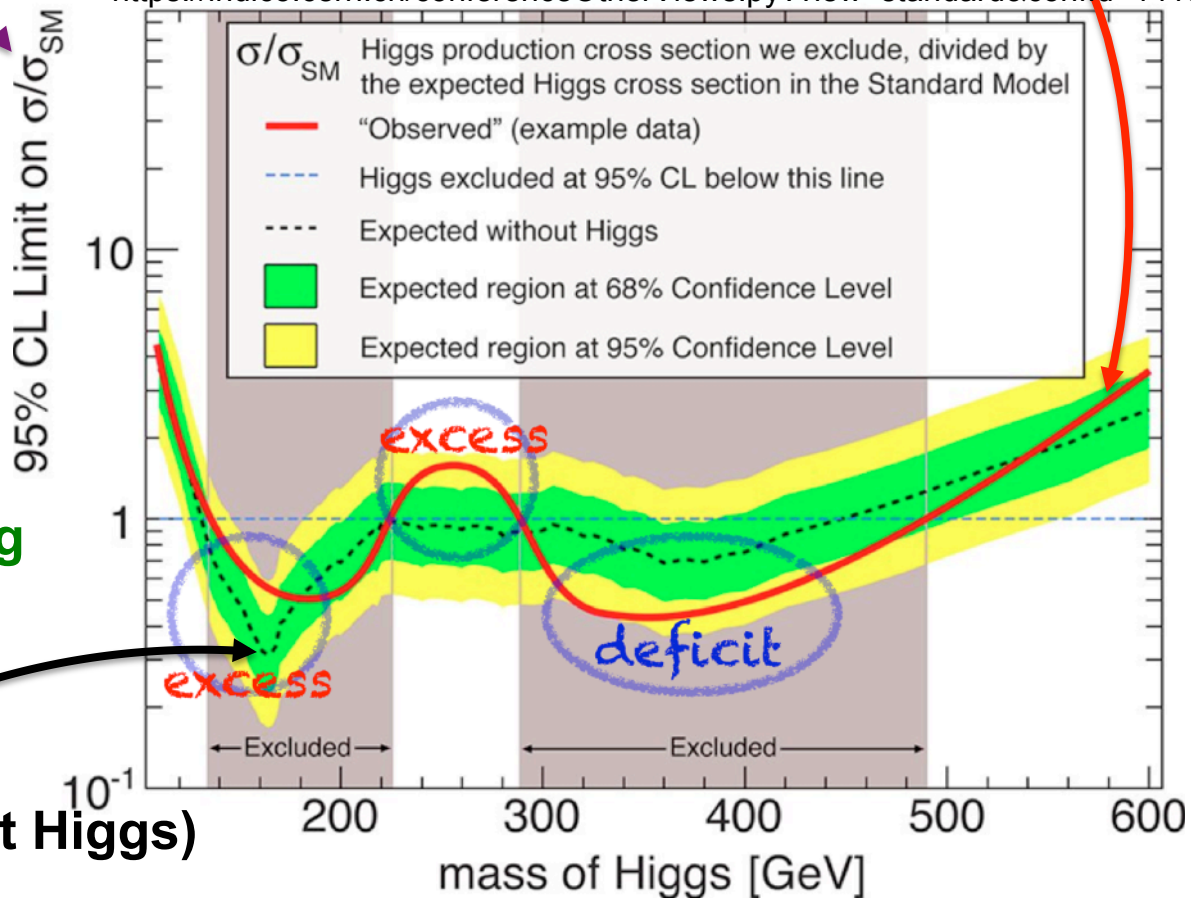
Understanding of the Yellow and Green bands :

- Upper limit on the Standard Model (SM) Higgs Boson production cross section divided by the Standard Model expectation as a function of m_{Higgs}

observed limit (data)

Eilam Gross
https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=141983

$\mu=\sigma/\sigma^{SM}$



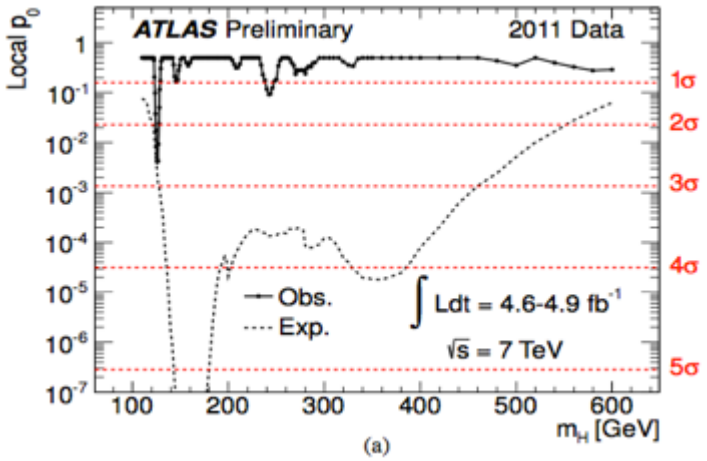
this is a 95% limit using the CLs method

expected limit (without Higgs)

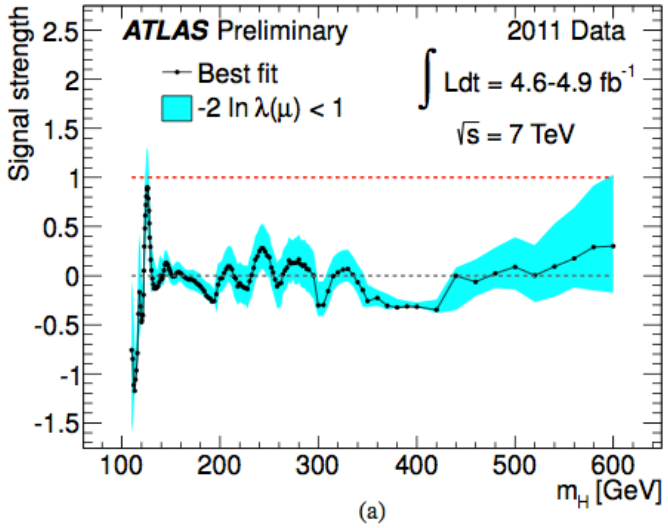
P_0 PLOT AND SIGNAL STRENGTH

p_0 plot and signal strength :

- local p_0 plot :



- signal strength plot



The observed local p-value characterize probabilities for the predicted background to fluctuate at least as high as the observed excesses

→ probability that the excess is caused by a background fluctuation

The observed global p-value include the look-elsewhere effect

→ probability for the fluctuation to occur on the full range

Best fit signal strength $\mu = \sigma/\sigma_{SM}$

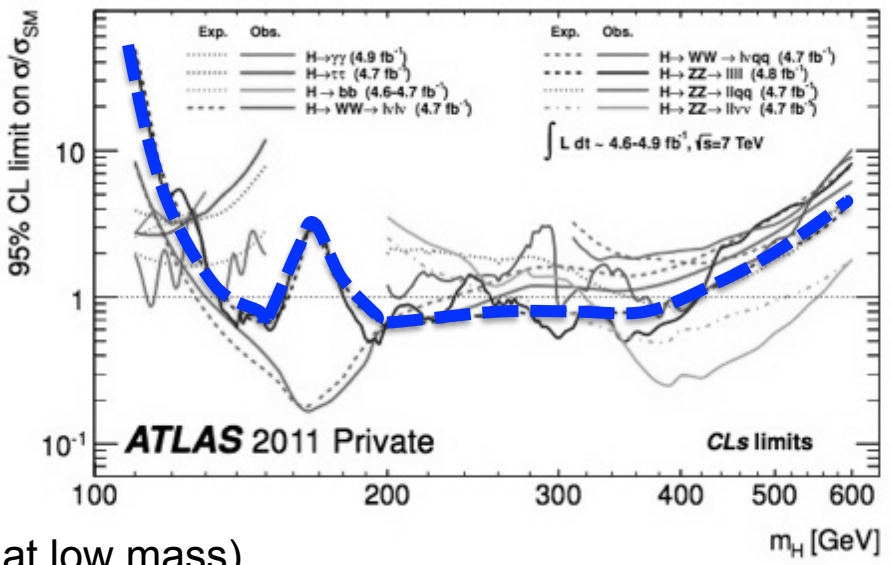
→ the μ value indicates by what factor the SM Higgs boson cross section would have to be scaled to best match the observed data

STANDARD MODEL HIGGS SEARCH IN FOUR LEPTONS

« GOLDEN CHANNEL »

$H \rightarrow ZZ^{(*)} \rightarrow 4l$: the "golden channel" :

- $H \rightarrow ZZ^{(*)} \rightarrow 4l$:
  signature :
  4 leptons (e,μ)
  $p_T^{1,2,3,4}$ > 20,20,7,7 GeV
  low σ x BR :
  3.1 fb^{-1} (m_{Higgs}=130 GeV)
  sensibility between m_{Higgs} :
  110 – 600 GeV
  possibility to reconstruct the mass
  good mass resolution
  narrow peak on low background (S/B ~ 1 at low mass)
  (limited by natural H width for m_{Higgs}>>200 GeV)



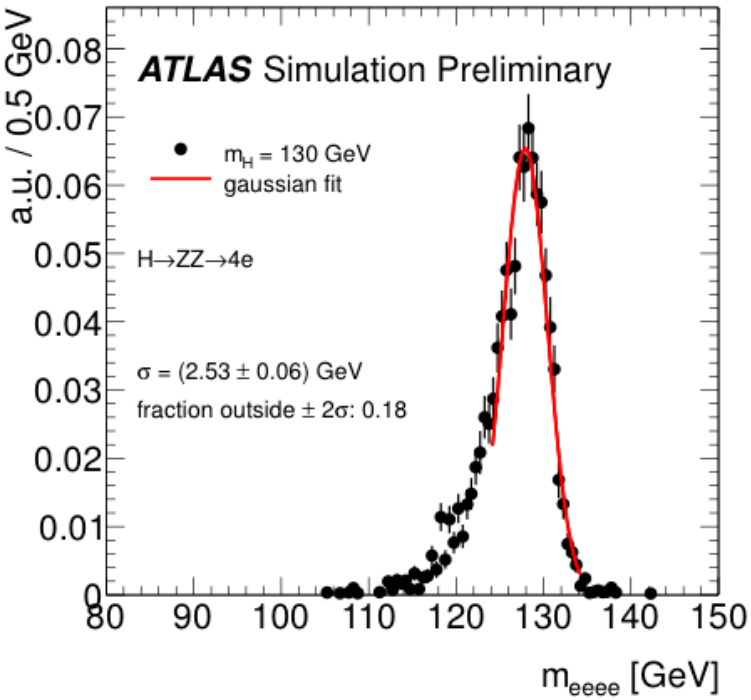
SM Higgs production σ^{SM} and BR

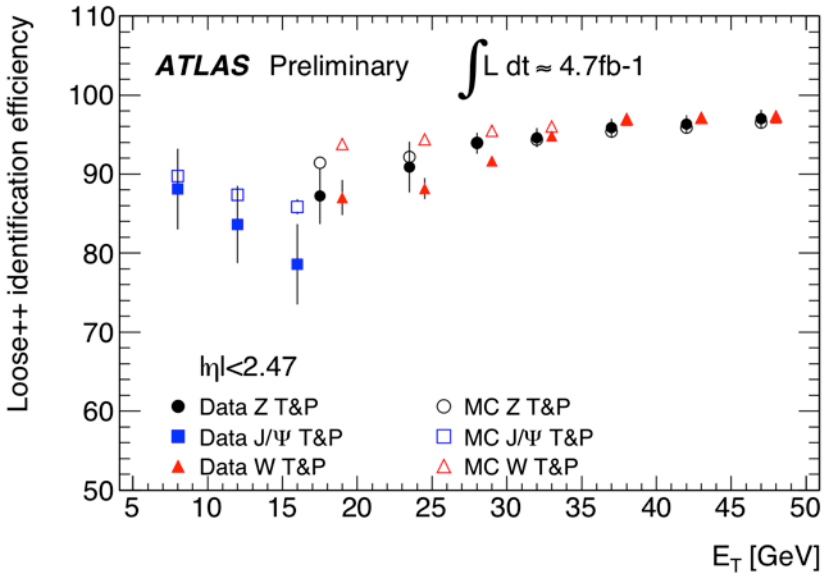
m_H [GeV]	$\sigma(gg \rightarrow H)$ [pb]	$\sigma(qq' \rightarrow Hqq')$ [pb]	$\sigma(q\bar{q} \rightarrow WH)$ [pb]	$\sigma(q\bar{q} \rightarrow ZH)$ [pb]	$\mathrm{BR}(H \rightarrow ZZ^{(*)} \rightarrow 4\ell)$ $[10^{-3}]$
130	$14.1^{+2.7}_{-2.1}$	$1.154^{+0.032}_{-0.027}$	0.501 ± 0.020	0.278 ± 0.014	0.19
150	$10.5^{+2.0}_{-1.6}$	$0.962^{+0.028}_{-0.021}$	0.300 ± 0.012	0.171 ± 0.009	0.38
200	$5.2^{+0.9}_{-0.8}$	$0.637^{+0.022}_{-0.015}$	0.103 ± 0.005	0.061 ± 0.004	1.15
400	2.0 ± 0.3	$0.162^{+0.010}_{-0.005}$	–	–	1.21
600	0.33 ± 0.06	$0.058^{+0.005}_{-0.002}$	–	–	1.23

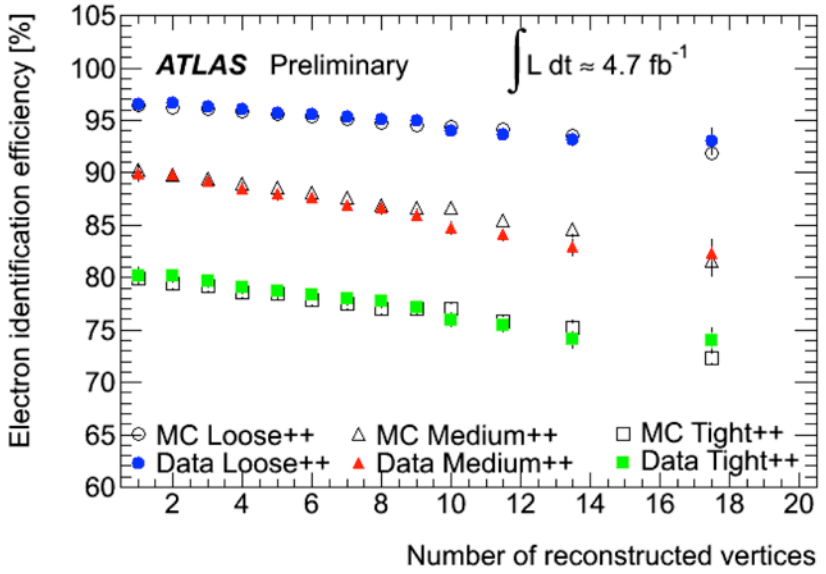
ELECTRON IDENTIFICATION

Electron reconstruction and identification in 2011 :

- $H \rightarrow ZZ^{(*)} \rightarrow 4e$
  crucial to understand low-p_T electrons
  use brem refitted track fro electrons (“GSF”)
  mass resolution :
  2.5 GeV (2 %)



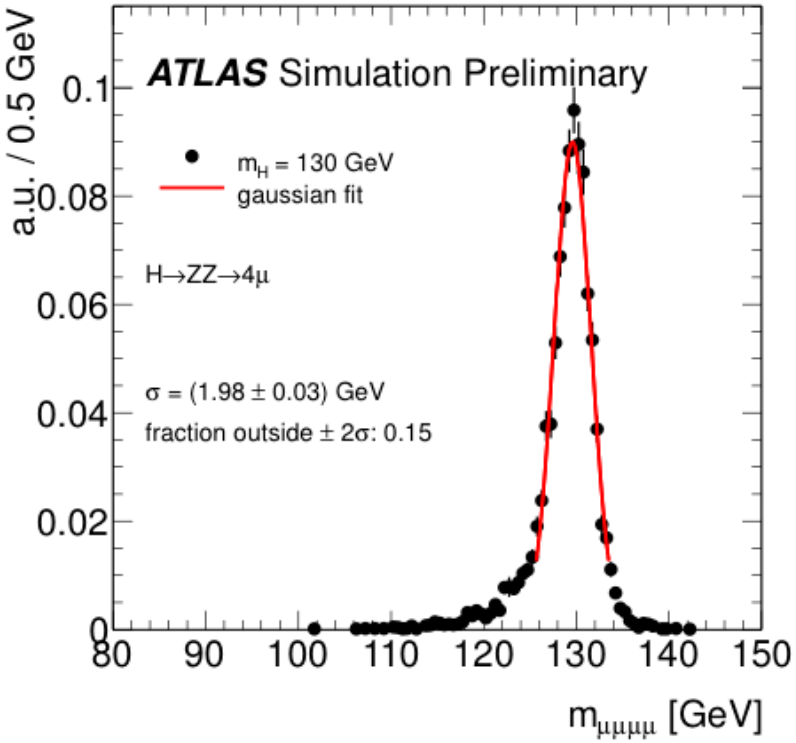


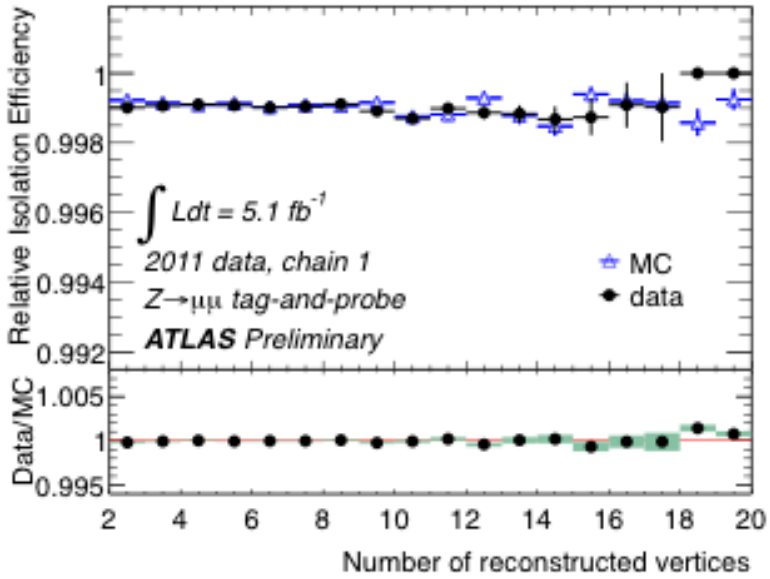


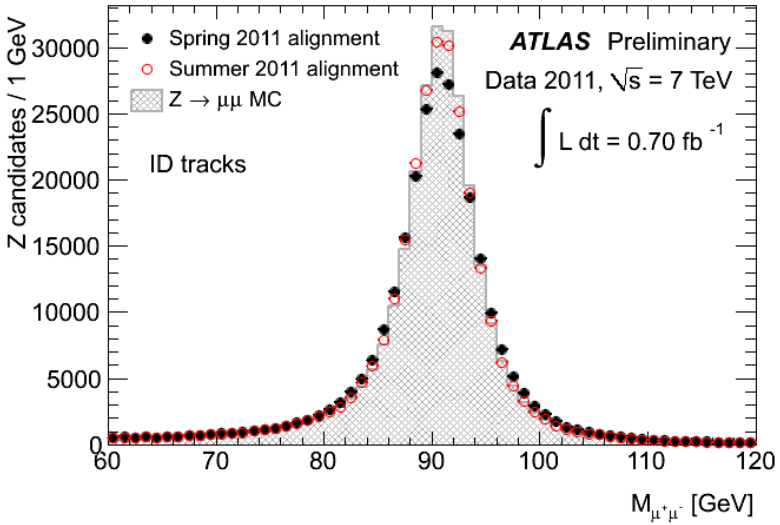
MUON IDENTIFICATION

Muon reconstruction and identification in 2011 :

- $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$
  crucial to understand low-p_T muons
  mass resolution :
  2.0 GeV (1.5 %)







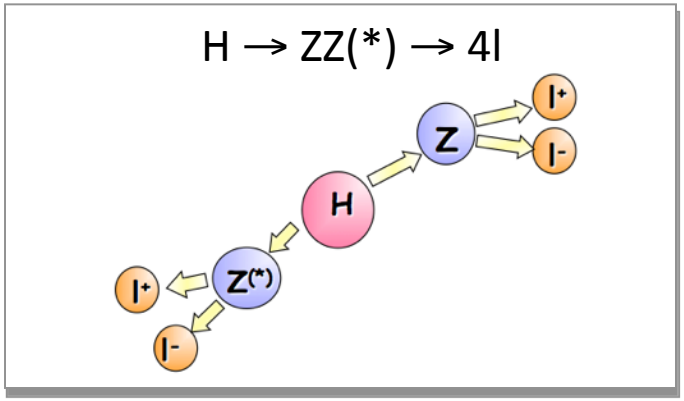
SIGNAL AND BACKGROUND

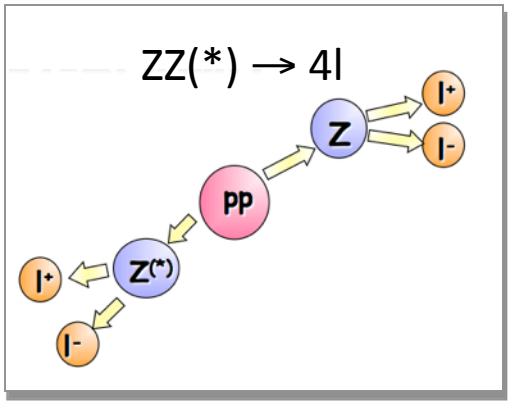
$H \rightarrow ZZ^{(*)} \rightarrow 4l$ signal and background :

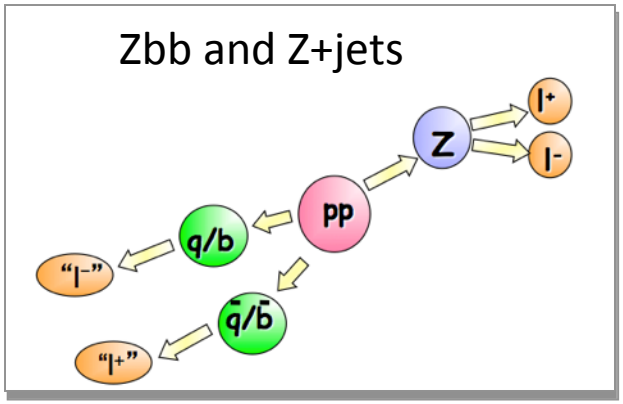
- Signal :
  $H \rightarrow ZZ(*) \rightarrow 4l$
  production mode : gg,VBF, ZH and WH
  4 leptons : $p_T^{1,2,3,4} > 20,20,7,7$ GeV

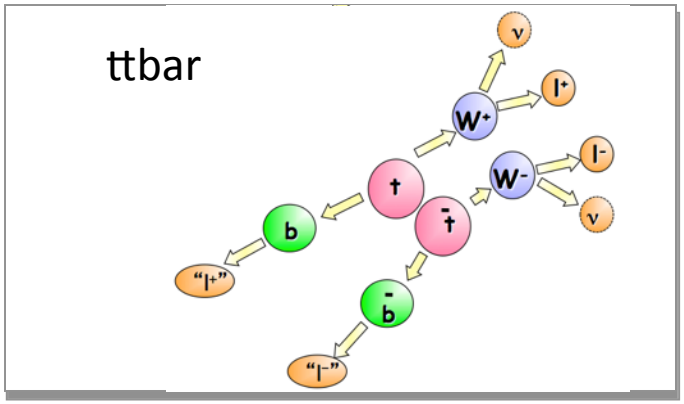
- Backgrounds:
  ZZ(*) (irréductible)

  for $m_{4l}<2*m_Z$:
  Zbb, Z+jets and ttbar (reducible)
  (leptons venant de b/q-jets→l)





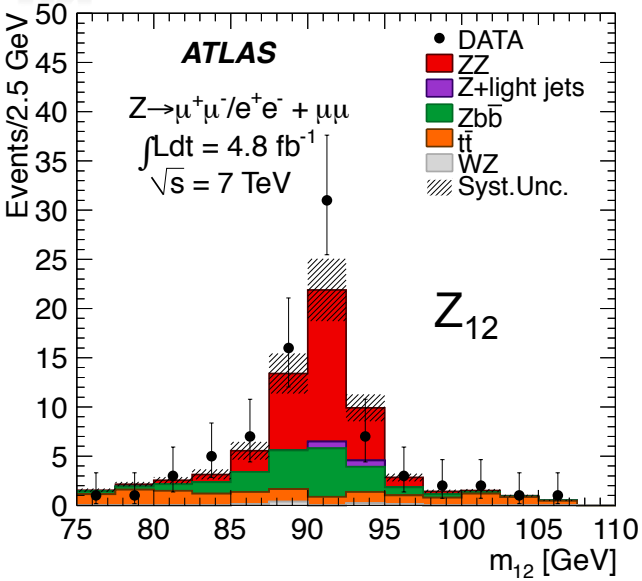


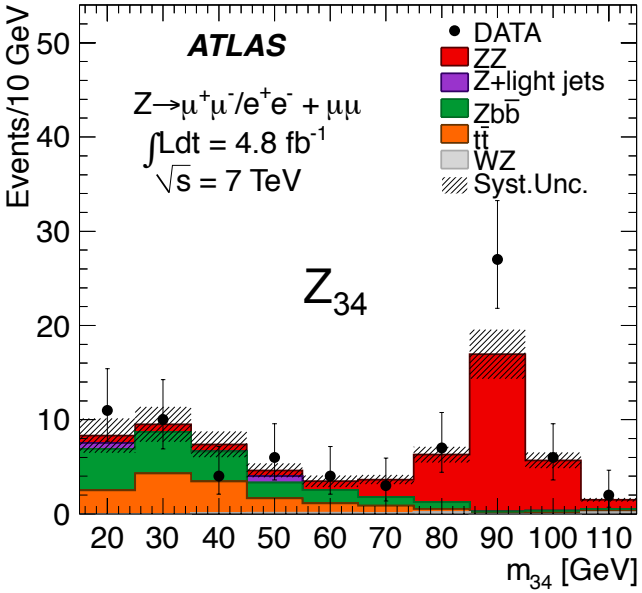


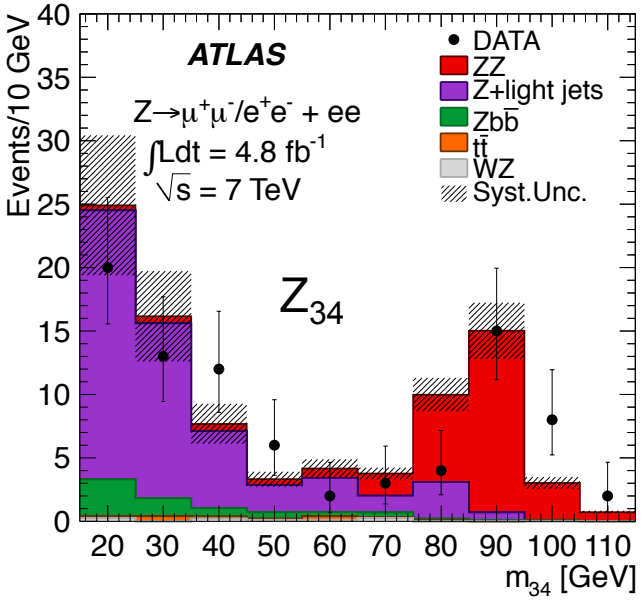
EVENT SELECTION

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

- selection :
  - 4 leptons : $p_T^{1,2,3,4} > 20,20,7,7$ GeV
  - two same-flavor/opposite-sign isolated lepton pairs
    Z_{12} (m_{12}), the reconstructed Z closer to the PDG
    Z_{34} (m_{34}) the other Z
  - lepton pair mass cuts :
    $|m_{12}-m_Z|<15$ GeV
    $m_{34}<115$ GeV and $m_{34}>m_{Threshodl}(m_{4l})$(15-60 GeV)



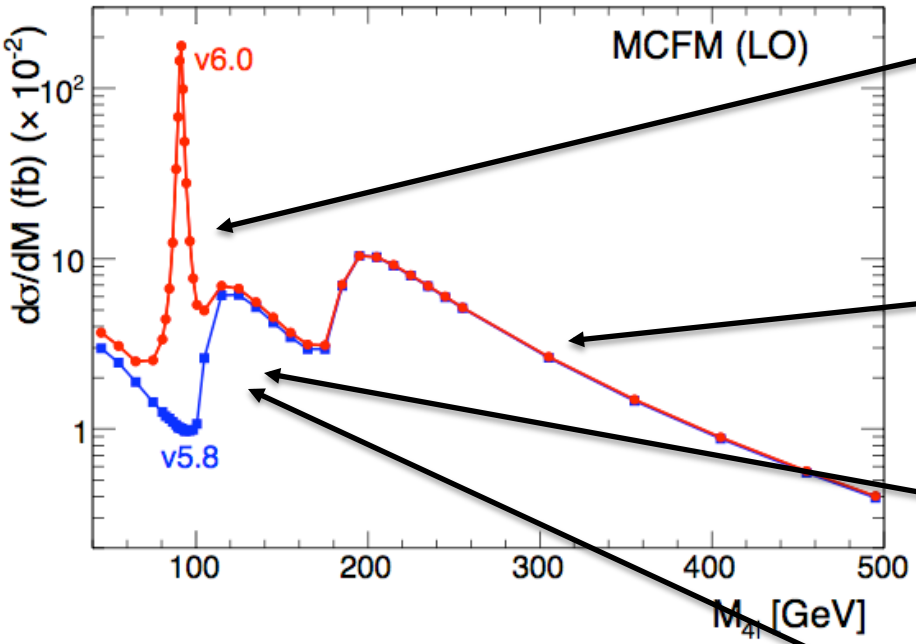


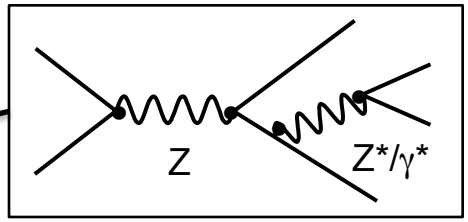


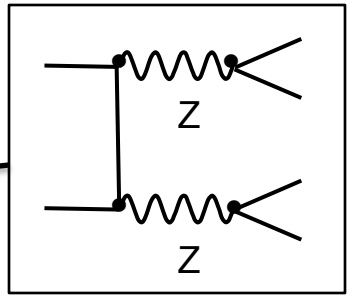
ZZ BACKGROUND

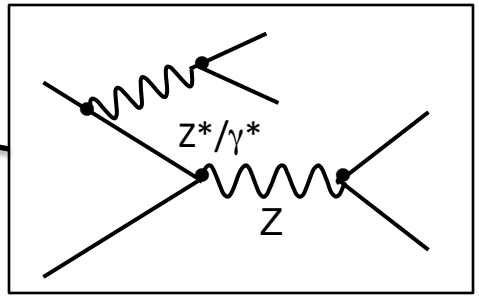
SM ZZ background :

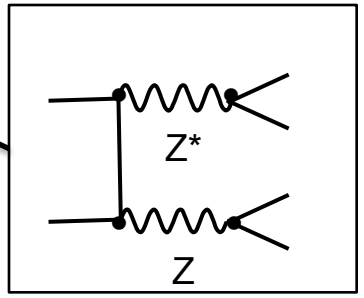
- use MC simulation (Pythia) and MCFM shape and cross section











- but ATLAS is also doing a cross section measurement :

$$\sigma_{ZZ}^{\text{tot}} = 8.5^{+2.7}_{-2.3}(\text{stat})^{+0.4}_{-0.3}(\text{syst}) \pm 0.3(\text{lumi})\ \text{pb}$$

NLO prediction (MCFM) : $6.5^{+0.3}_{-0.2}$ pb

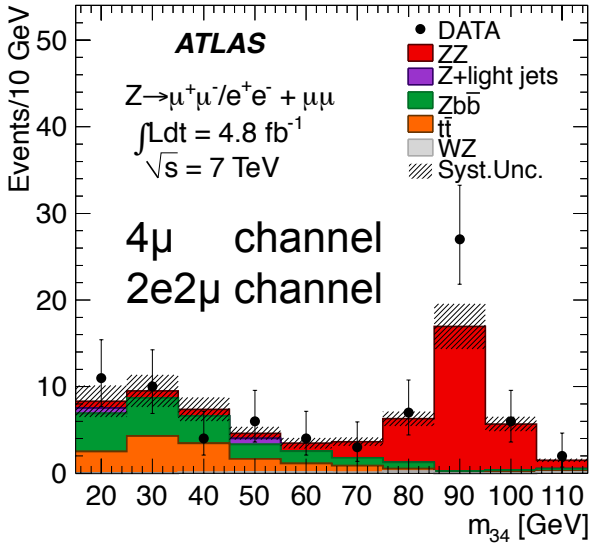
- Normalize ZZ production to MC expectation including both qq/gq → ZZ and gg → ZZ
  Theory uncertainty ~15% (arXiv:0906.2500)

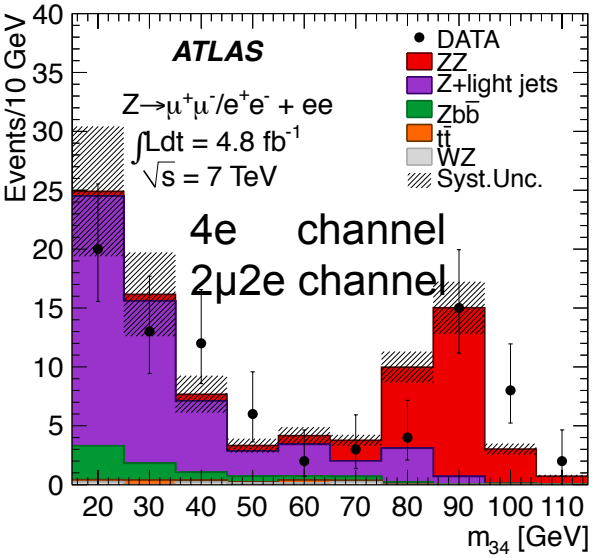
BACKGROUND

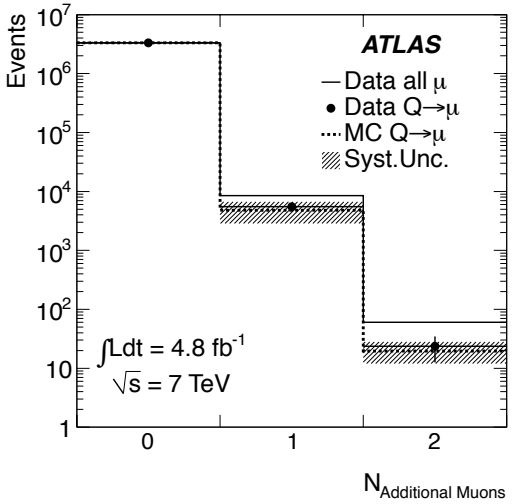
Background estimation using data driven method :

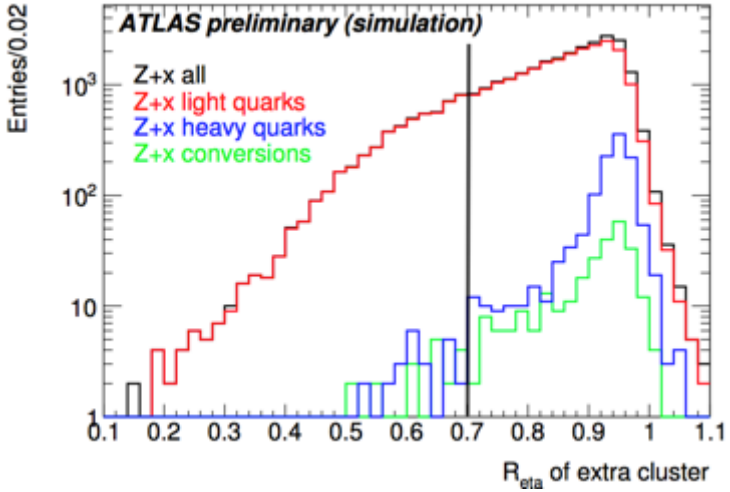
- Normalize top production to MC expectation
  verified in control region :
  → $e^{\pm}\mu_{\mp}$ pair consistent with m_Z and
  two additional same-flavor leptons
  theory uncertainty 10%

- Normalize Z+jets production using control regions
  control region :
  → without charge, isolation and impact parameter criteria
  on the second lepton pair : Z(→ll) + μμ/ee
  separate different components
  eventually extrapolate to signal region
  uncertainties 40-45 %









SYSTEMATIC UNCERTAINTIES

Systematic uncertainties :

- Experimental systematic uncertainties

Systematic uncertainties	Total
luminosity	3.9 %
muon efficiency	0.16-0.22 %
electron efficiency	1.6-8.0 %
electron energy scale	0.3-0.6 %

cut efficiency for electrons low-E_T electrons
→ overall systematic uncertainty (5% for E_t<15 GeV)

- For background estimated with data-driven, systematic uncertainties are uncorrelated

Systematic uncertainties	Total	statistical uncertainty
Z+jet	45 % +shape	in the control sample and the MC-based extrapolation to the signal region
Zbb	40 % +shape	in the control sample and the MC-based extrapolation to the signal region

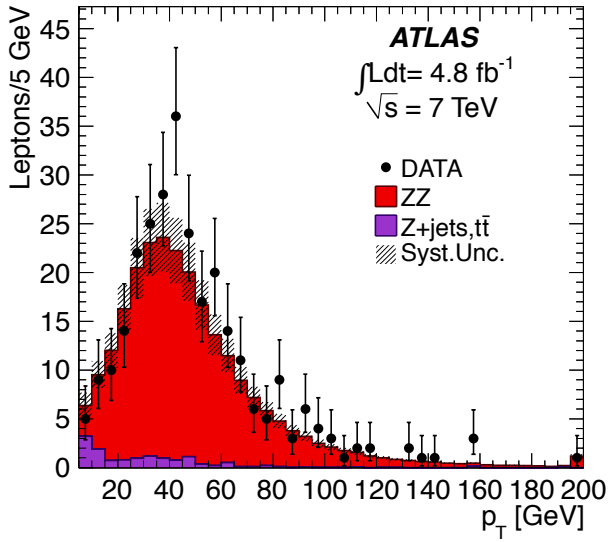
- Careful treatment of theory uncertainties (ATLAS-CMS LHC combination working group)

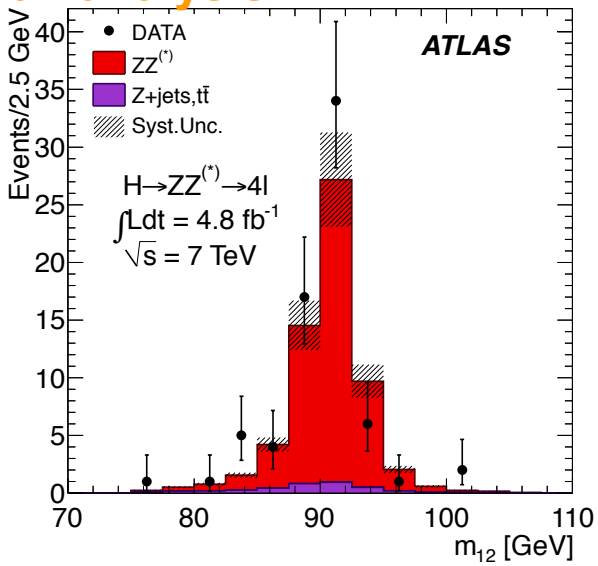
Process	QCD Scale (depend of m_H)	PDF+α_S	Total
ggF	+12/-7 %	±8 %	+20/-15 %
VBF	±1 %	±4 %	±5 %
WH/ZH	±1 %	±4 %	±5 %
ttbar	±4 %	±4 %	±10 %
ZZ (SM)	±5 % + 10% (gg → ZZ) + shape	±4 %	±12 %

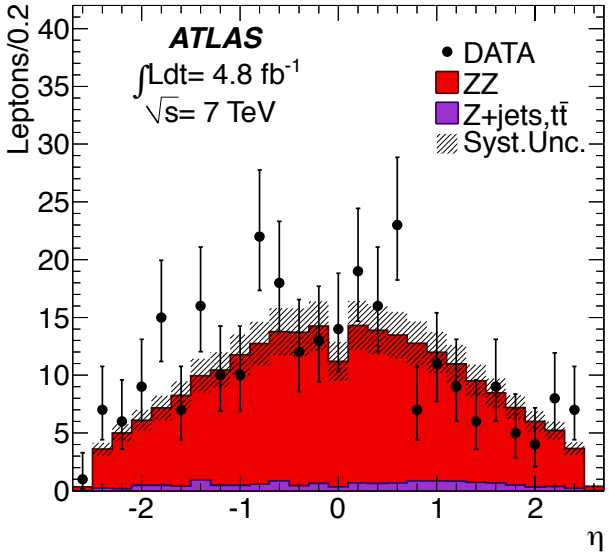
line shape (150%) x (m_{Higgs}(TeV))^3	Total
m_{Higgs}= 300	±4 %
m_{Higgs}= 400 GeV	±10 %
m_{Higgs}= 500 GeV	±19 %
m_{Higgs}= 600 GeV	±32 %

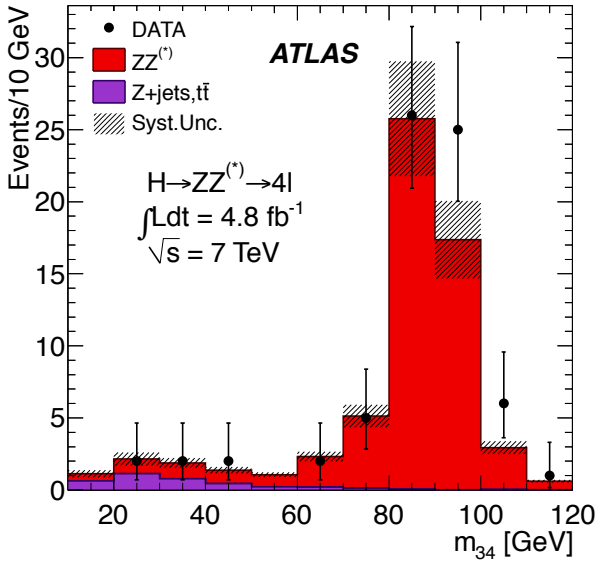
KINEMATICS

Some kinematic distribution after the full analysis :





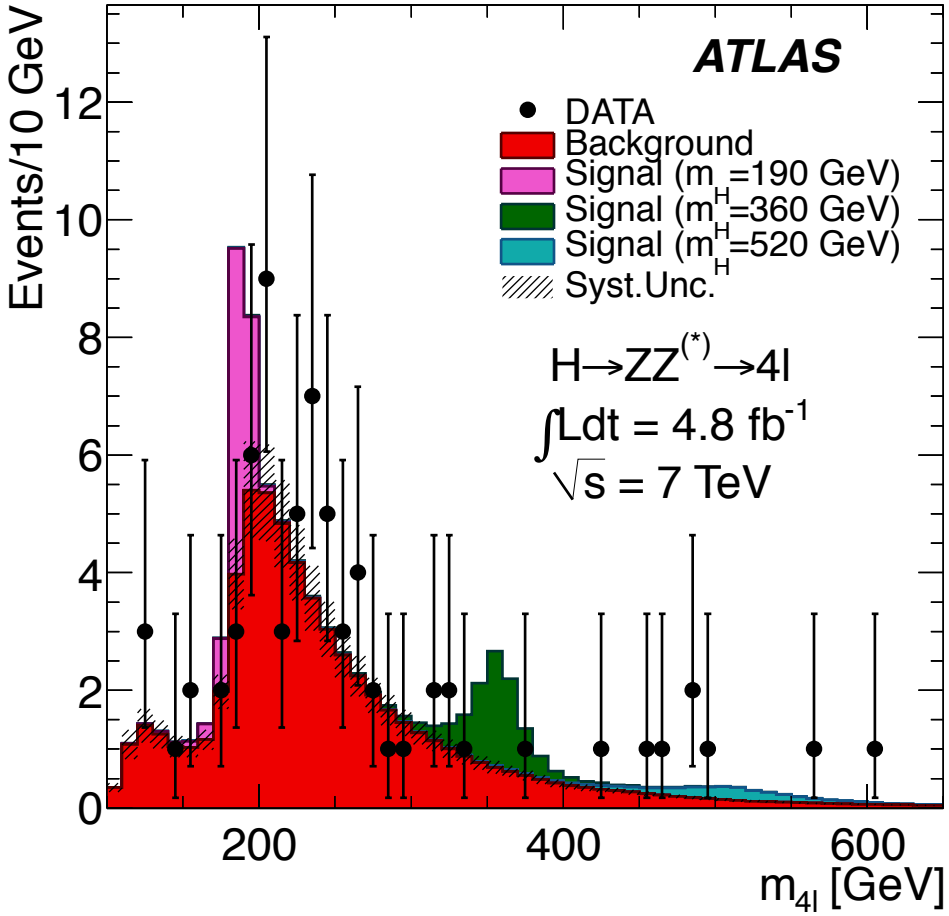




MASS SPECTRUM

Expected and observed signal and background :

- Mass distribution after the full selection



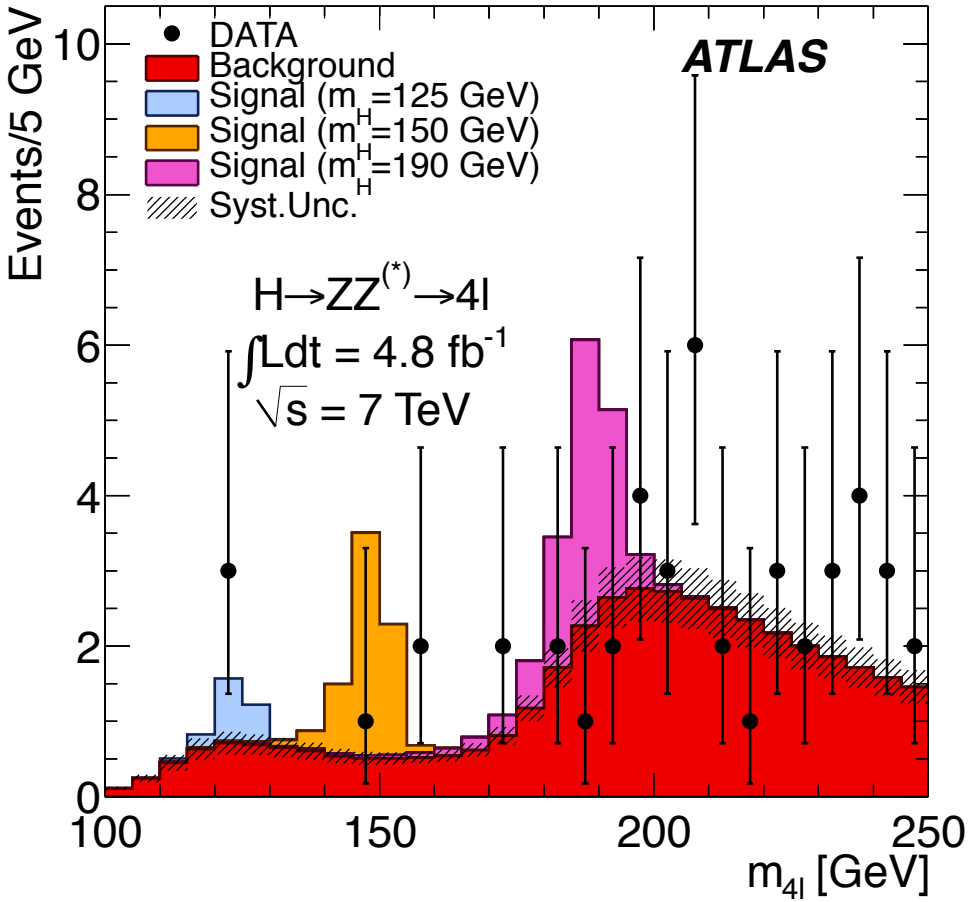
- over all good agreement data/MC
  71 candidates (data) :
  62 ± 9 expected events (MC)

- in details
  candidates (data) :
  24 4μ
  30 2e2μ
  17 4e
  expected events (MC)
  18.6 ± 2.8 4μ
  29.7 ± 4.5 2e2μ
  13.4 ± 2.0 4e.

LOW MASS SPECTRUM

Expected and observed signal and background :

- Mass distribution after the full selection



In the region m_{4l} < 140 GeV
3 events are observed:

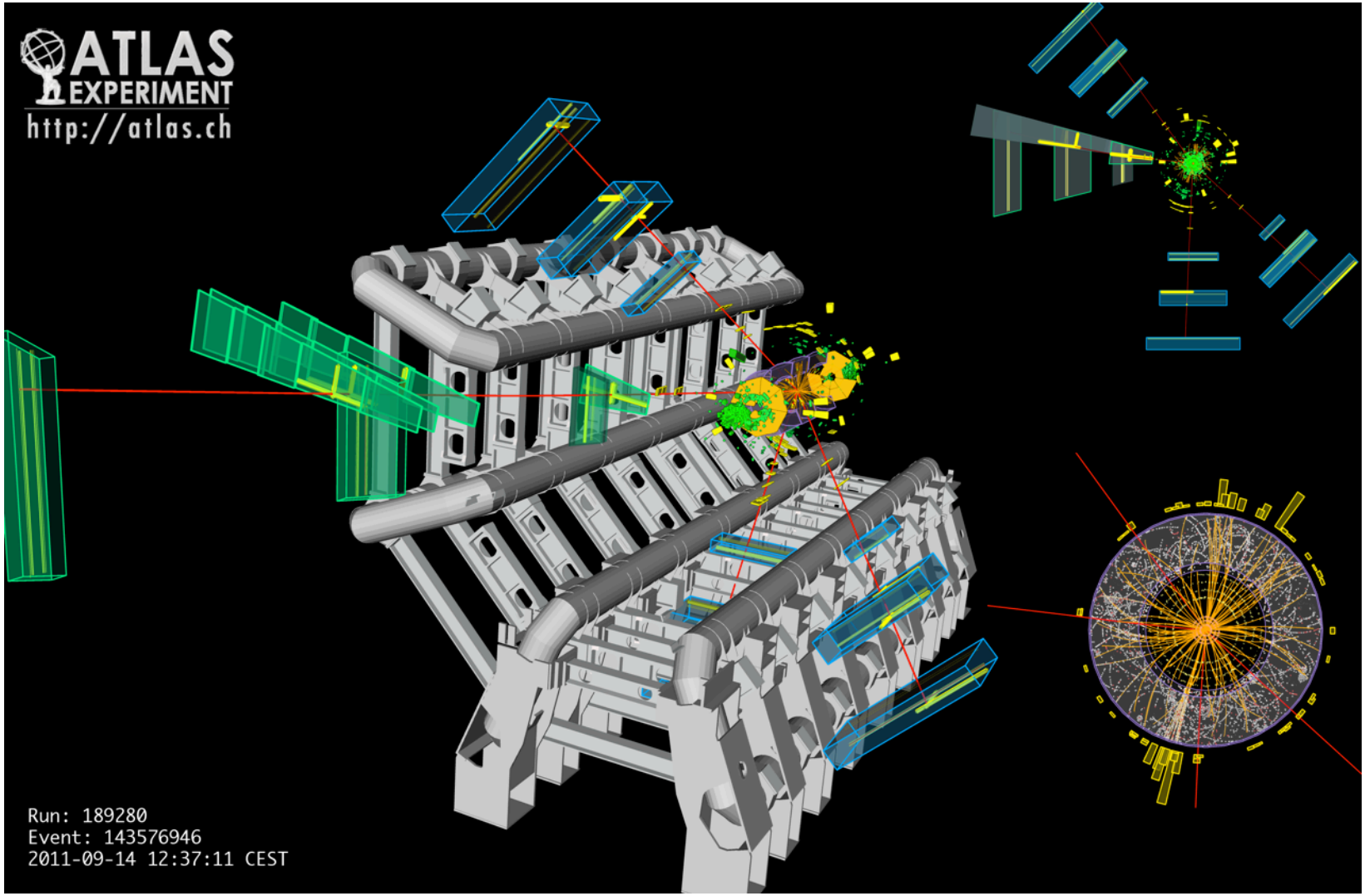
- two 2e2μ events
  m_{4l}=123.6 GeV
  m_{4l}=124.3 GeV

- one 4μ event
  m_{4l}=124.6 GeV

EVENT DISPLAY

4μ candidate :

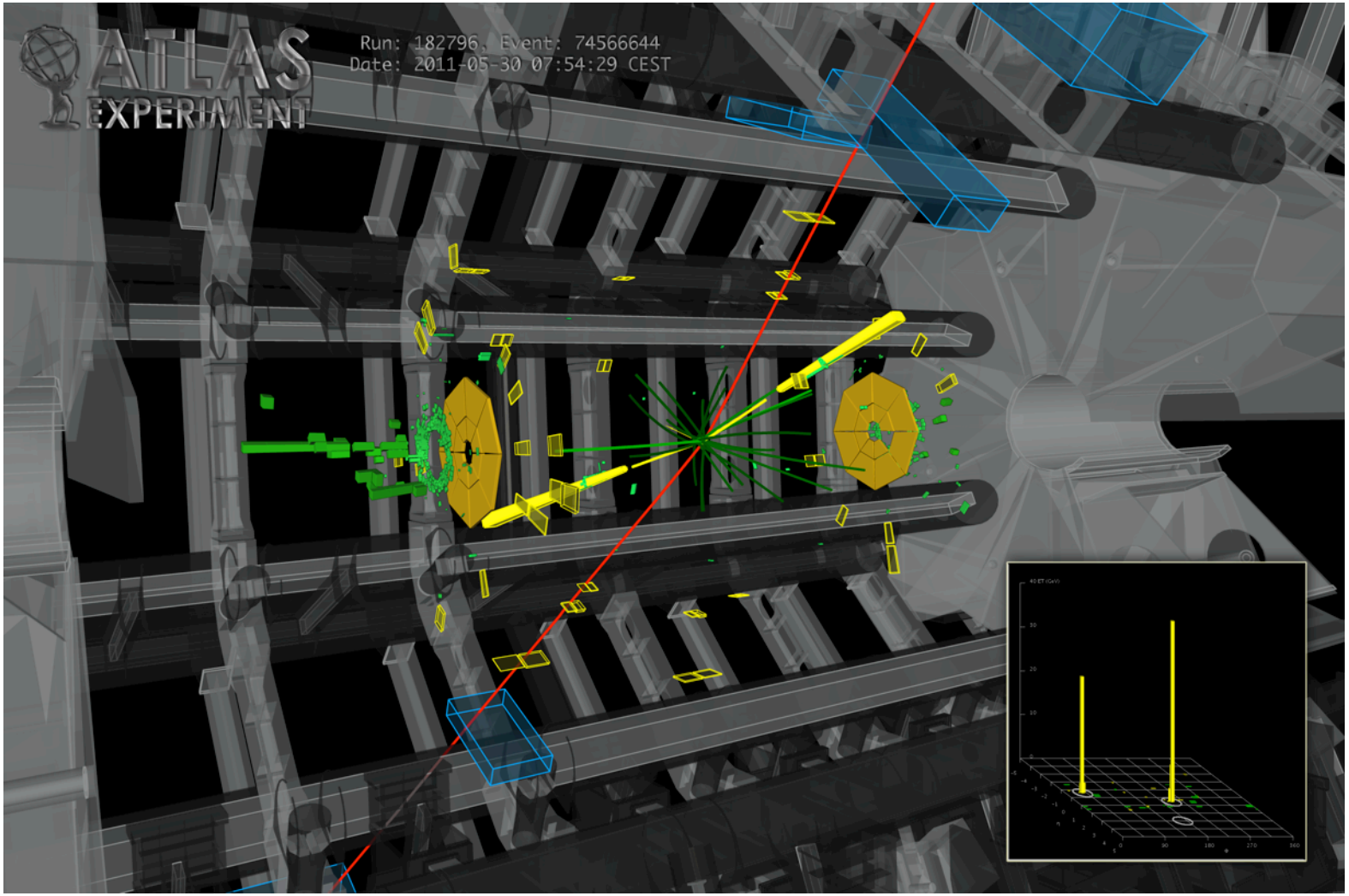
m_{4l}= 124.6 GeV m_{12}= 89.7 GeV, m_{34}= 24.6 GeV



EVENT DISPLAY

2e2μ candidate :

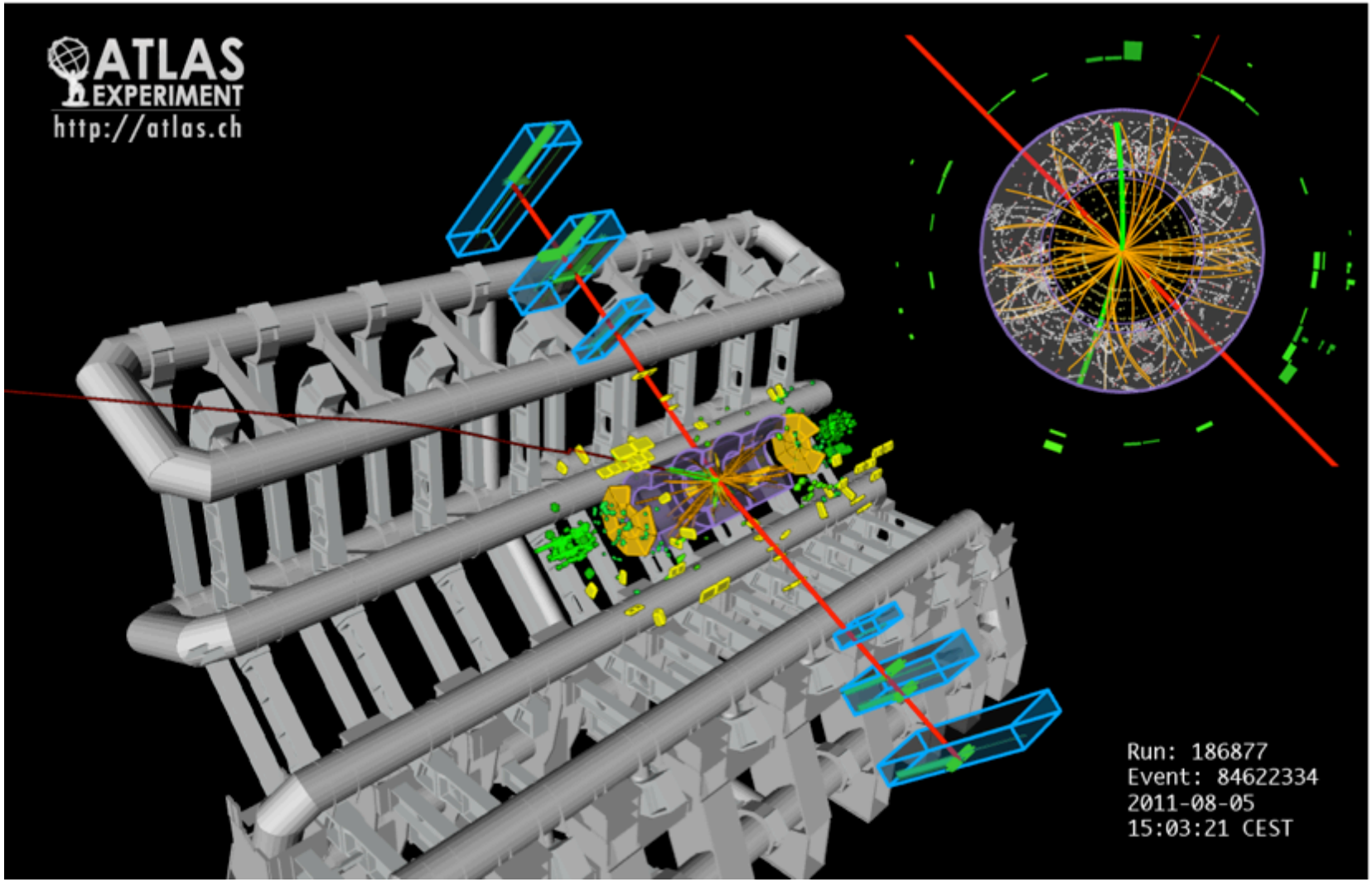
m_{4l}= 124.3 GeV m_{12}= 76.8 GeV, m_{34}= 45.7 GeV



EVENT DISPLAY

2e2μ candidate :

m_{4l}= 123.6 GeV m_{12}= 89.3 GeV, m_{34}= 30.0 GeV

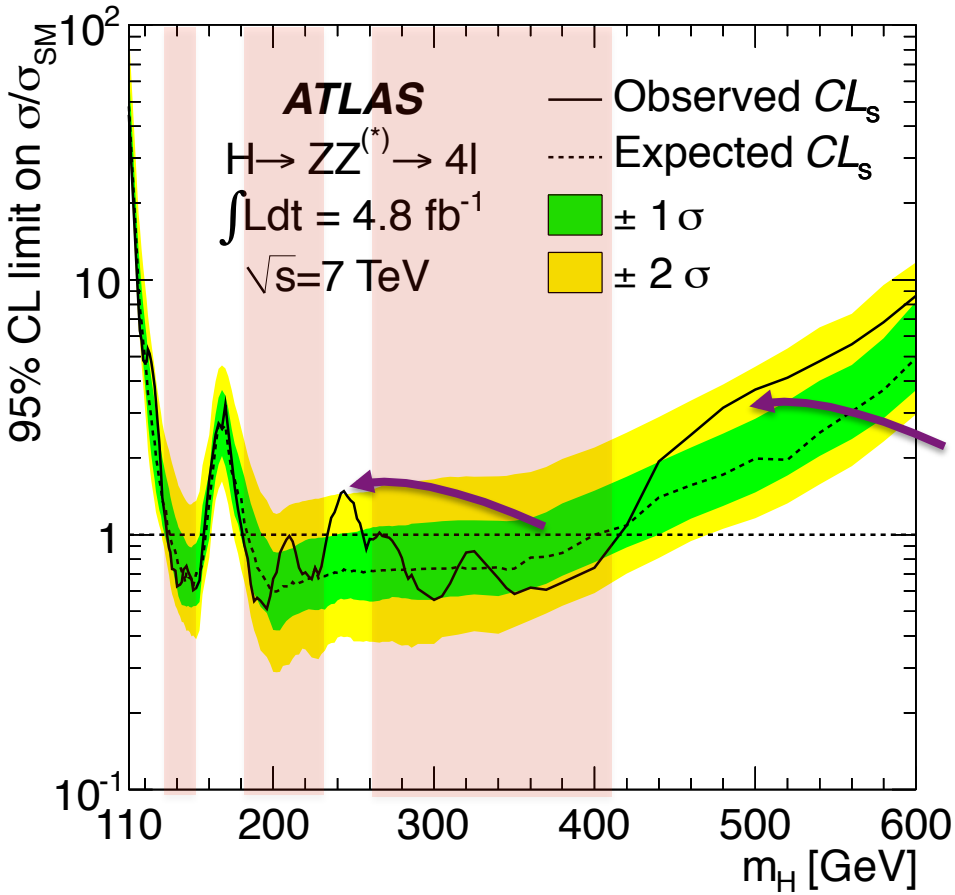


EXCLUSION LIMITS

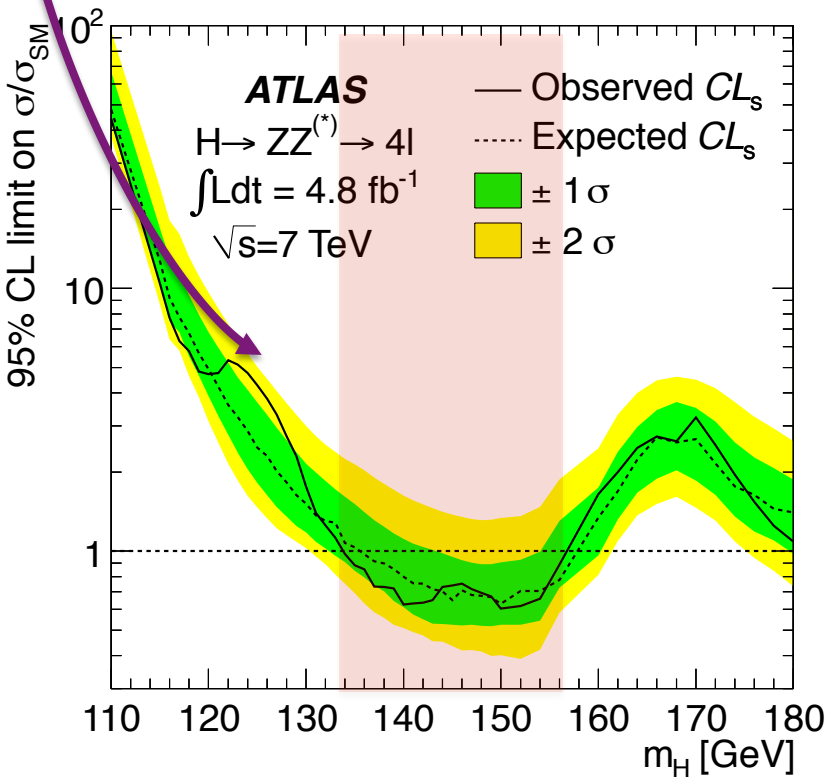
Exclusion limits with $H \rightarrow ZZ^{(*)} \rightarrow 4l$:

- Standard Model Higgs Boson excluded at 95% CL :
  - 134−156 GeV
  - 182−233 GeV (137-157 GeV)
  - 256−265 GeV
  - 268−415 GeV (184-400 GeV)

some “excess” that leads to weaker-than-expected limit



zoom at low mass

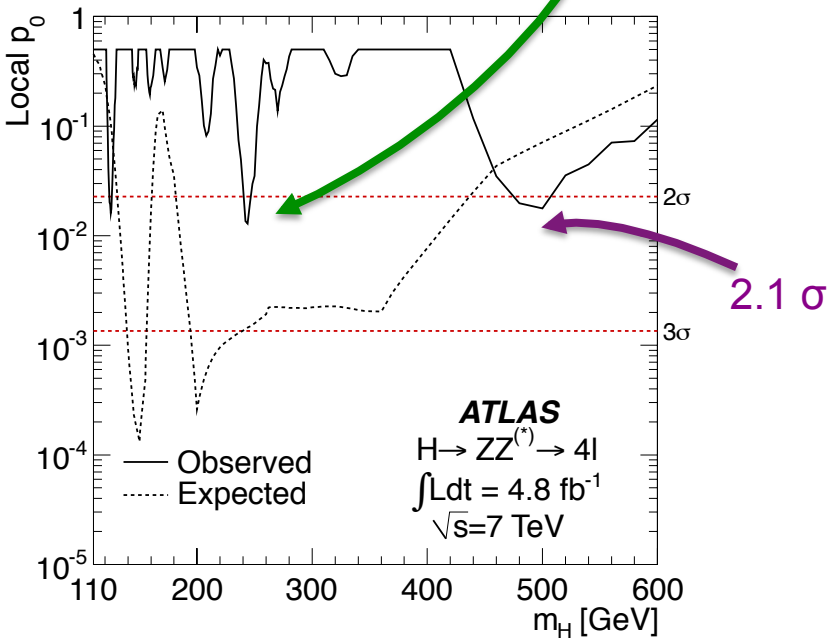


P_0-VALUE

Local and global p_0-value :

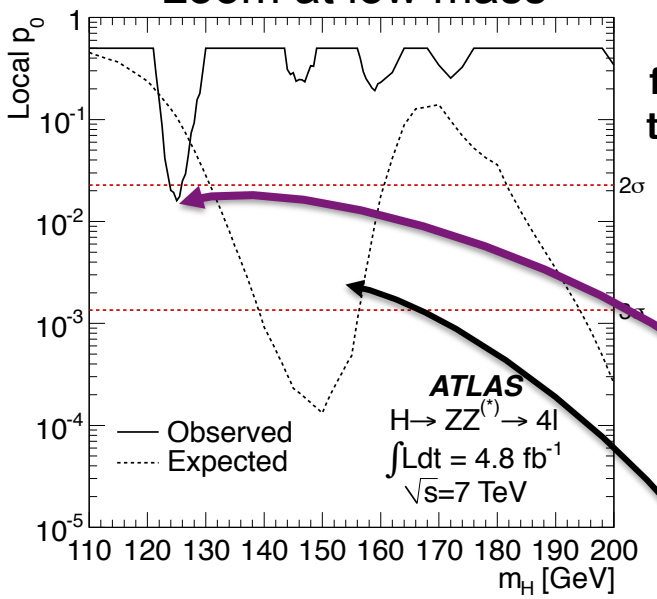
- Local p0-value express compatibility to no signal hypothesis

excluded by the LHC combination (ATLAS+CMS) Nov 2011



2.1 σ

zoom at low mass



p-values do not include the trials factor arising from the look-elsewhere effect (LEE)

2.1 σ
3 events in
1 GeV bin

- Global p0 include Look Elsewhere Effect
(probability for the fluctuation to occur on the full range)

m_{Higgs} (GeV)	Local p_0	Global p_0	Expected from SM
125	2.1 σ	0(50%)	1.3 σ
244	2.2 σ	0(50%)	3.0 σ
500	2.1 σ	0(50%)	1.5 σ

hypothesis of a Standard Model Higgs boson production signal

SUMMARY

Summary :

- A search for the Standard Model Higgs boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow 4l$ has been performed using the ~4.8 fb^{-1} of pp collisions at $\sqrt{s}$ = 7 TeV
- The background yields have been studied with looser event selections, demonstrating good agreement of the background modeling with the observation
- 71 candidates fulfilling all the selection criteria have been identified
- We can exclude the following mass range using only $H \rightarrow ZZ^{(*)} \rightarrow 4l$:
  134−156 GeV
  182−233 GeV
  256−265 GeV
  268−415 GeV
- The largest deviations from the background expectation are observed for
  m_H = 125 GeV with a p_0-value of 2.1 σ
  m_H = 244 GeV with a p_0-value of 2.2 σ
  m_H = 500 GeV with a p_0-value of 2.1 σ

  These p_0-values increase substantially once the “look-elsewhere” effect is considered

STANDARD MODEL HIGGS COMBINATION AT ATLAS

CHANNELS INCLUDED

channels used in the SM Higgs combination at ATLAS :

- Low mass searches : $m_{Higgs} < 140$ GeV
  W/ZH with $H \rightarrow bb$, $H \rightarrow \tau\tau$, $H \rightarrow \gamma\gamma$

- Intermediate mass searches : $120 \text{ GeV} < m_{Higgs} < 180$ GeV
  $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$

- Higgs mass searches : $180 \text{ GeV} < m_{Higgs} < 600$ GeV
  $H \rightarrow WW \rightarrow l\nu qq$, $H \rightarrow ZZ^{(*)} \rightarrow llll$, $H \rightarrow ZZ \rightarrow ll\nu\nu$, $H \rightarrow ZZ \rightarrow llqq$

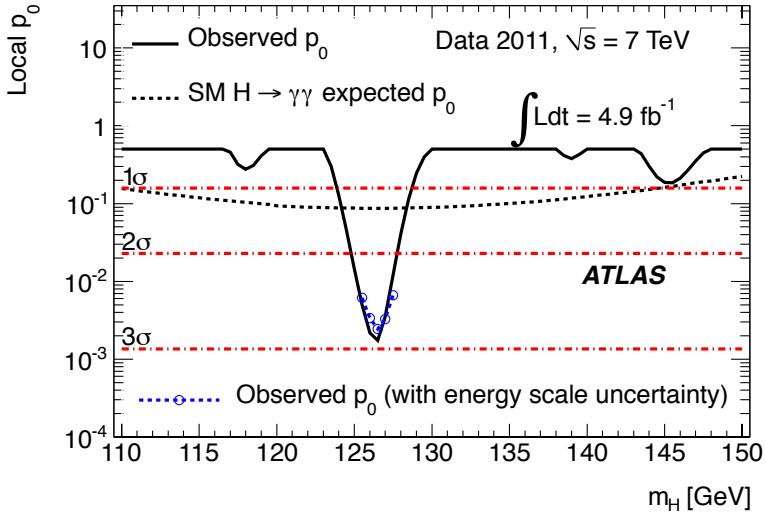
Channel	Mass range (GeV)	Backaground	Int Luminosity (fb^{-1})	
$H \rightarrow \gamma\gamma$	110 – 150	$\gamma\gamma$, γj, jj	4.9	
$H \rightarrow bb$ (WH,ZH)	100 - 130	W/Z +jets, ttbar	4.7	NEW
$H \rightarrow \tau\tau$	100 - 150	$Z \rightarrow \tau\tau$, ttbar	4.7	NEW
$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$	110 - 600	WW, ttbar, W/Z +jet	4.7	NEW
$H \rightarrow WW \rightarrow l\nu qq$	200 - 600	W + jets, ttbar, multijets	4.7	NEW
$H \rightarrow ZZ^{(*)} \rightarrow llll$	110 - 600	ZZ(*), Z +jets, ttbar	4.8	
$H \rightarrow ZZ \rightarrow ll\nu\nu$	200 - 600	diboson, ttbar, Z + jets	4.7	NEW
$H \rightarrow ZZ \rightarrow llqq$	300 - 600	Z + jets, ttbar, diboson	4.7	NEW

LOW MASS CHANNEL

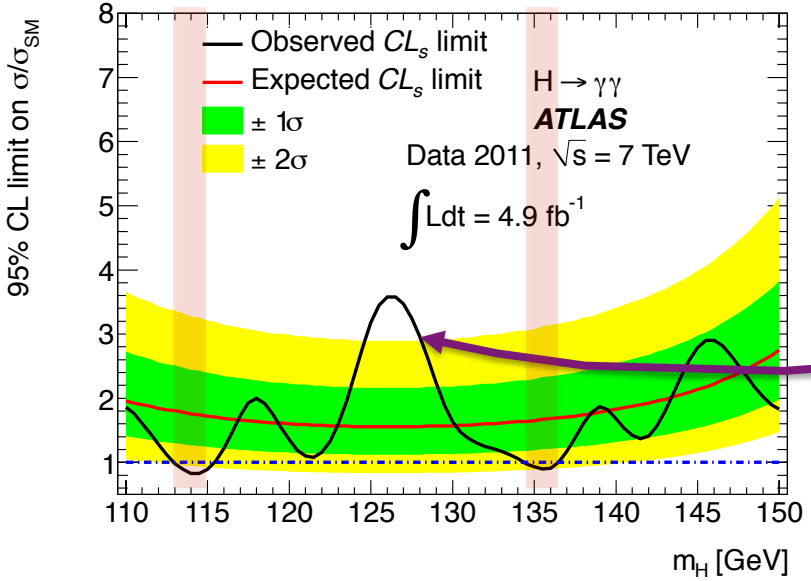
Key points of the analysis :

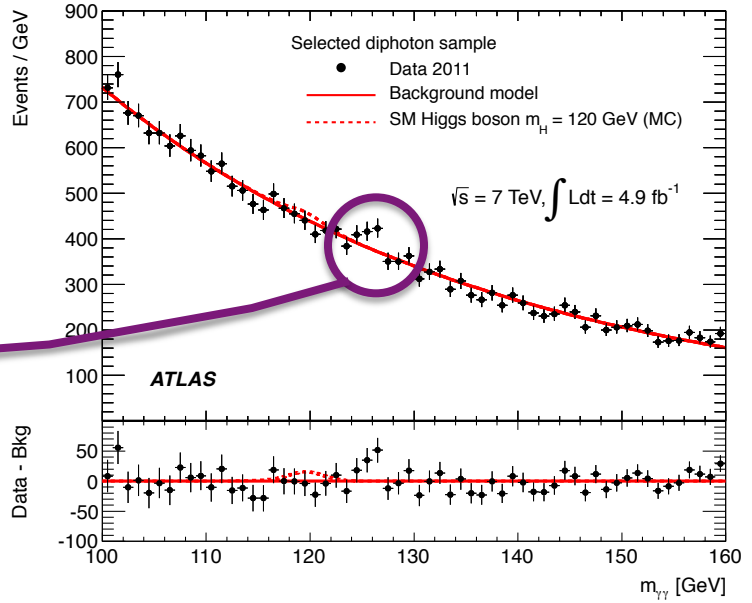
- $H \rightarrow \gamma\gamma$ (4.9 fb^{-1})
  m_H : 110-150 GeV
  9 categories
  $E_T^{1,2}(\gamma_1,\gamma_2)$>40,25 GeV
  good mass resolution (1.7%)
  $m_{\gamma\gamma}$ shape and unbinned
  bkg : $\gamma\gamma$, γj, jj (from side band)
  exclusion limit : 113-115, 134.5-136 GeV

local significance : 2.8 σ at 126 GeV
global significance : 1.5 σ (for m_H =110-150 GeV)



combined H→γγ search





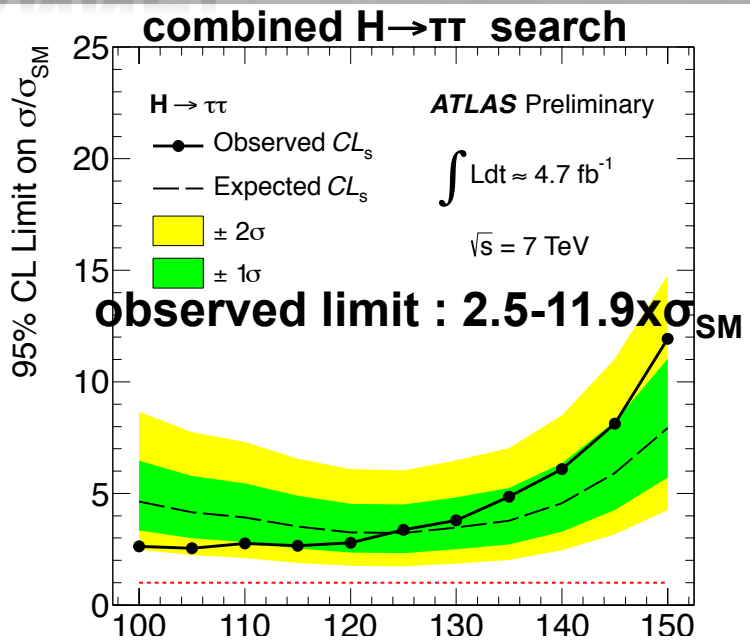
LOW MASS CHANNEL

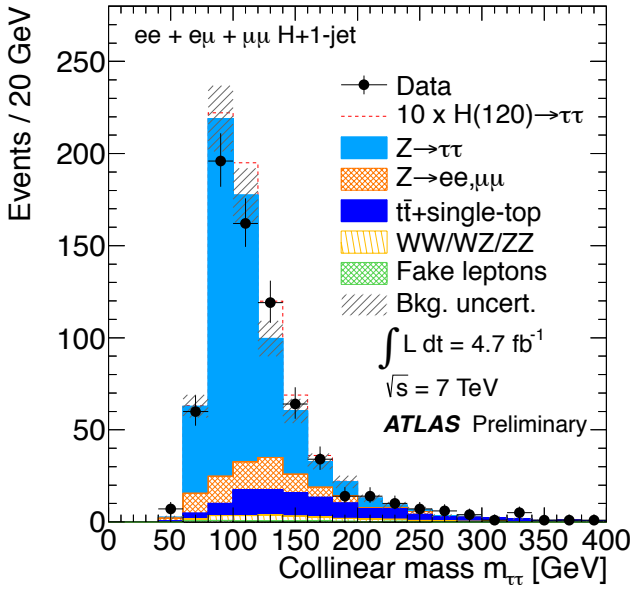
Key points of the analysis :

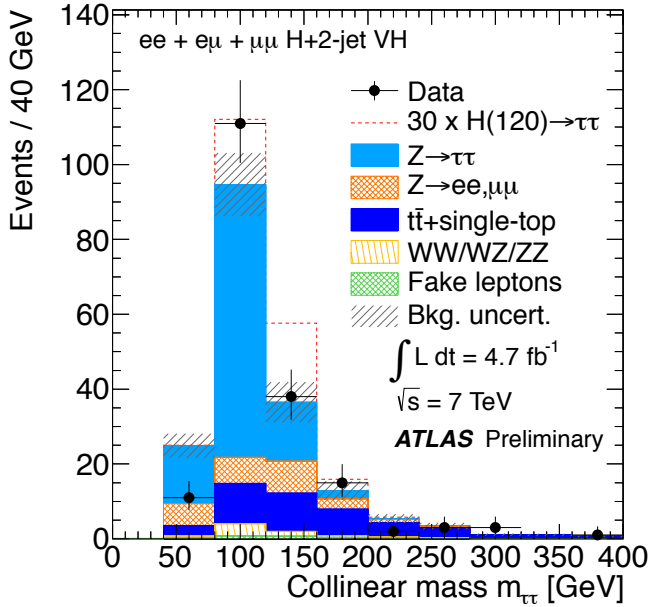
NEW

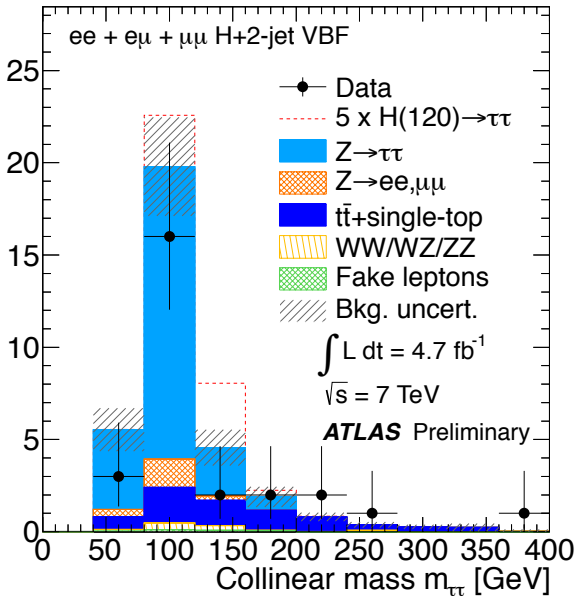
- $H \rightarrow \tau\tau \rightarrow (ll4\nu, l\tau_{had}3\nu, \tau_{had}\tau_{had}2\nu)$ (4.7 fb^{-1})
  m_H : 100-150 GeV
  12 category (0-jet, 1-jet, 2-jet VH, 2-jet VBF)
  $E_t^{\tau had}$>15,20 GeV
  mass resolution (~10 %)
  $m_{\tau\tau}$ shape
  bkg : $Z/\gamma^* \rightarrow \tau\tau$ +jets, ttbar

  No significant excess is observed in the mass range : 100 - 150 GeV









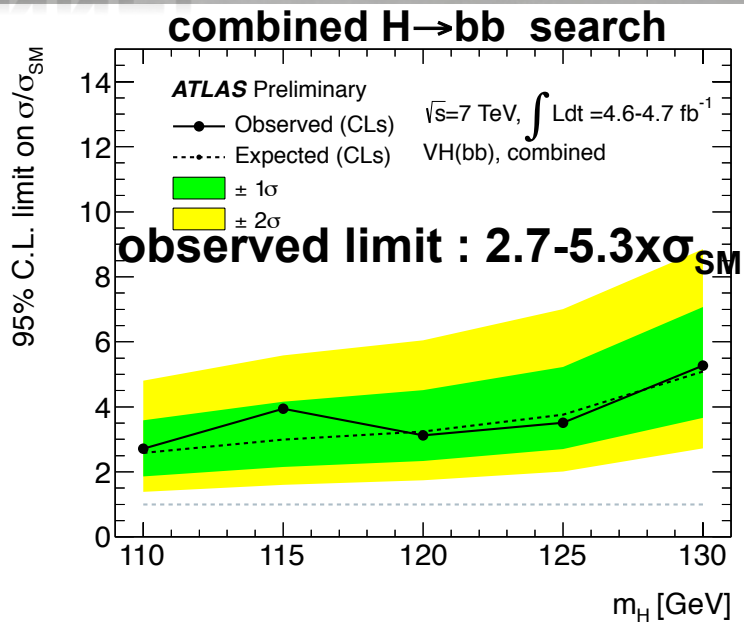
LOW MASS CHANNEL

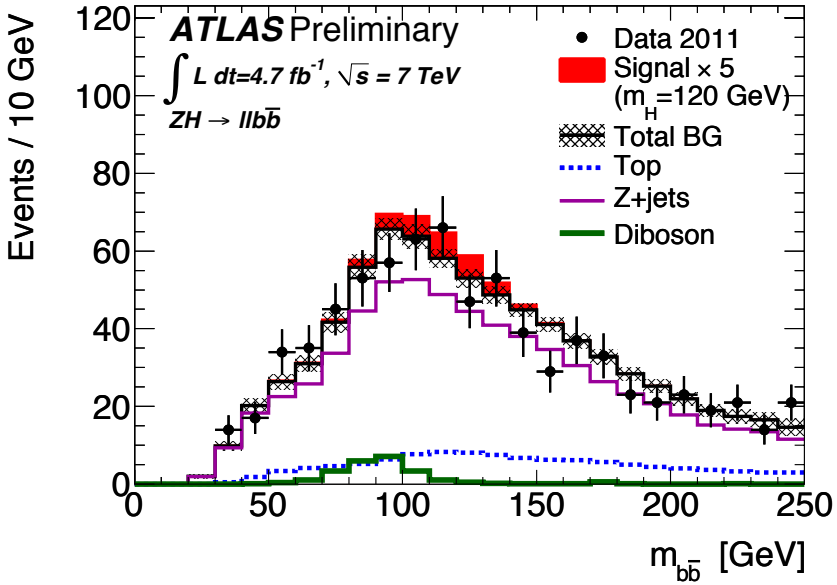
Key points of the analysis :

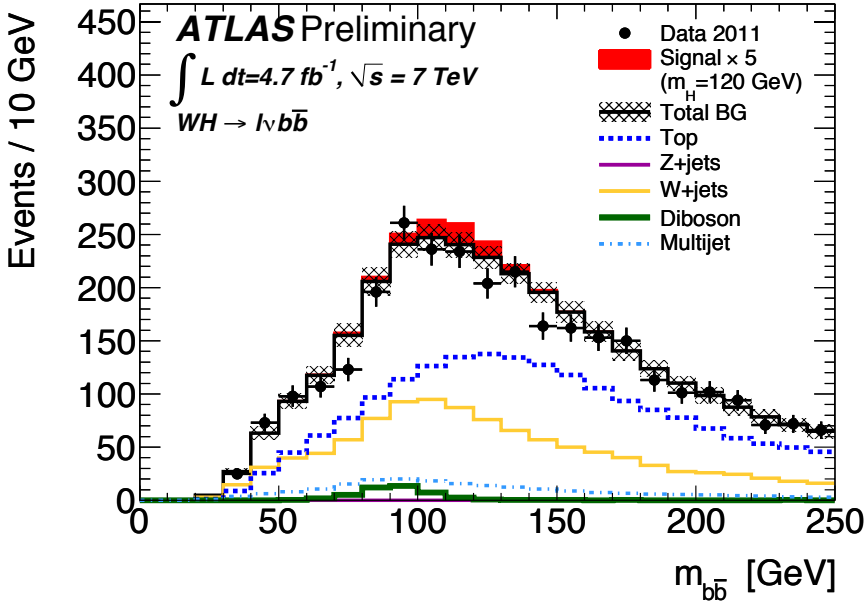
- H → bb (4.7 fb^{-1})
  m_H : 110-130 GeV
  11 category (p_T, E_T^{miss}, lvbb, llbb,vvbb)
  $E_t^{b-,jet}$>45,25 GeV
  mass resolution (~10 %)
  m_{bb} shape
  bkg : W/Z+(b)jets, ttbar

NEW

No significant excess is observed in the mass range : 110–130 GeV



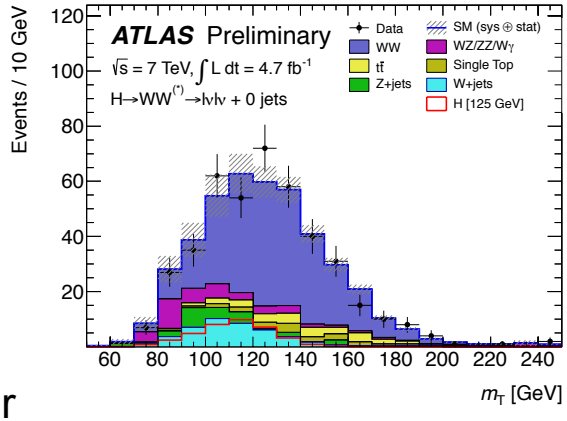


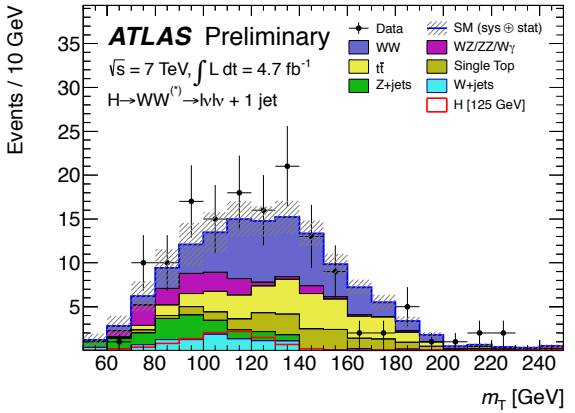


INTERMEDIATE MASS CHANNELS

Key points of the analysis :

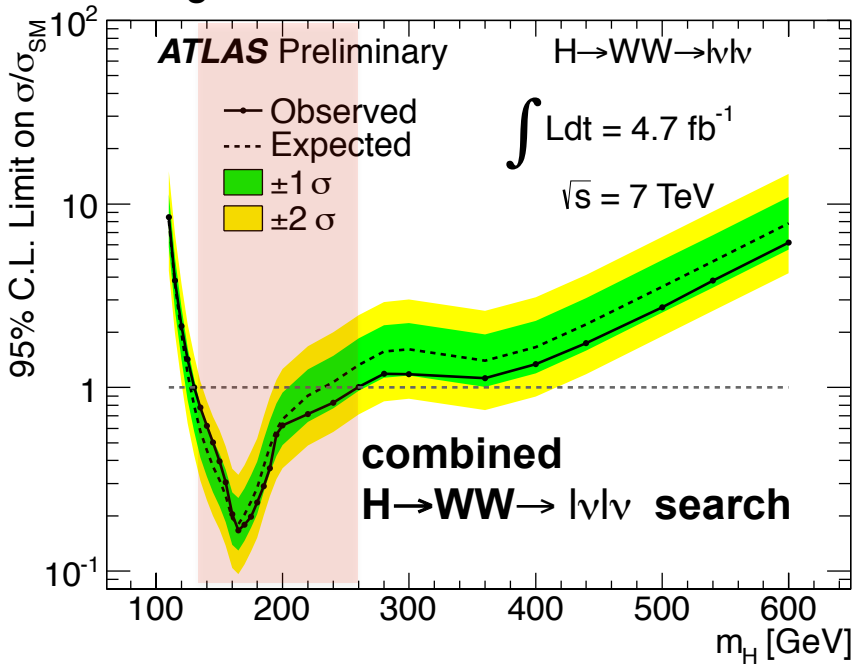
- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ (4.7 fb^{-1})
  - m_H : 110-600 GeV
  - 9 category (0-jet,1-jet, VBF)
  - $E_t^{l1,l2}$>20,15 GeV
  - mass resolution (~20 %)
  - m_T shape : 0-jet,1-jet
  - cutting and counting : VBF
  - bkg : WW,W+jets, Z+jets, ttbar





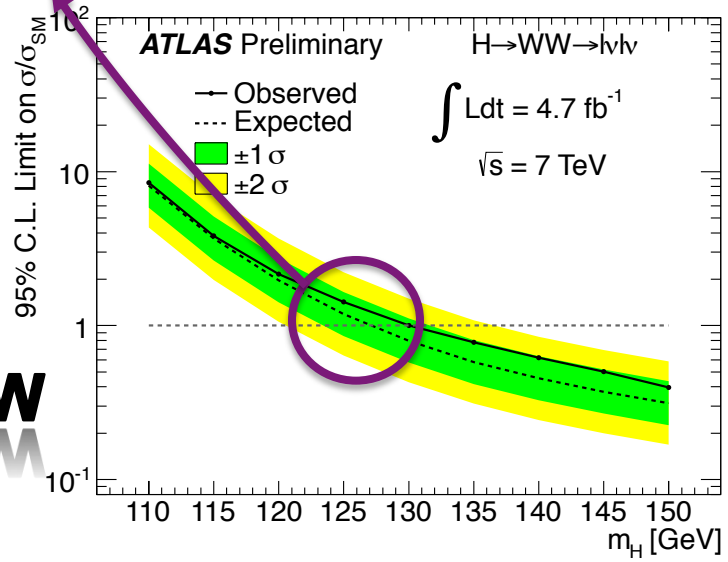
observed exclusion : 130 < m_{Higgs}< 260 GeV

No significant excess is observed



no significant excess

zoom at low mass



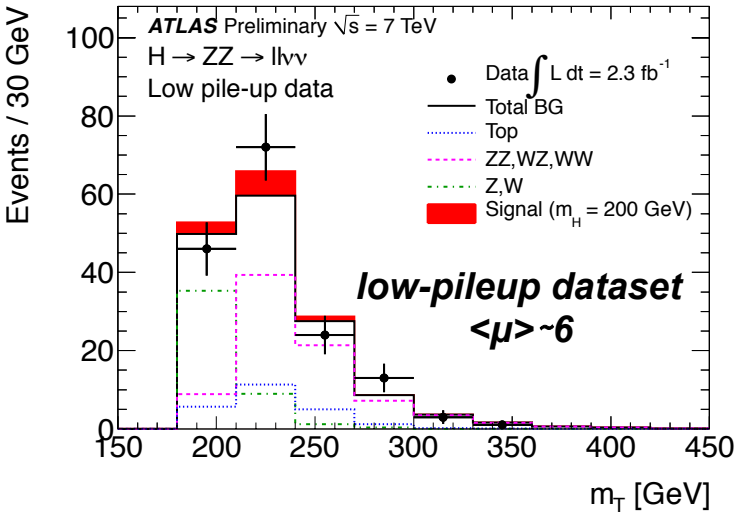
HIGH MASS CHANNELS

Key points of the analysis :

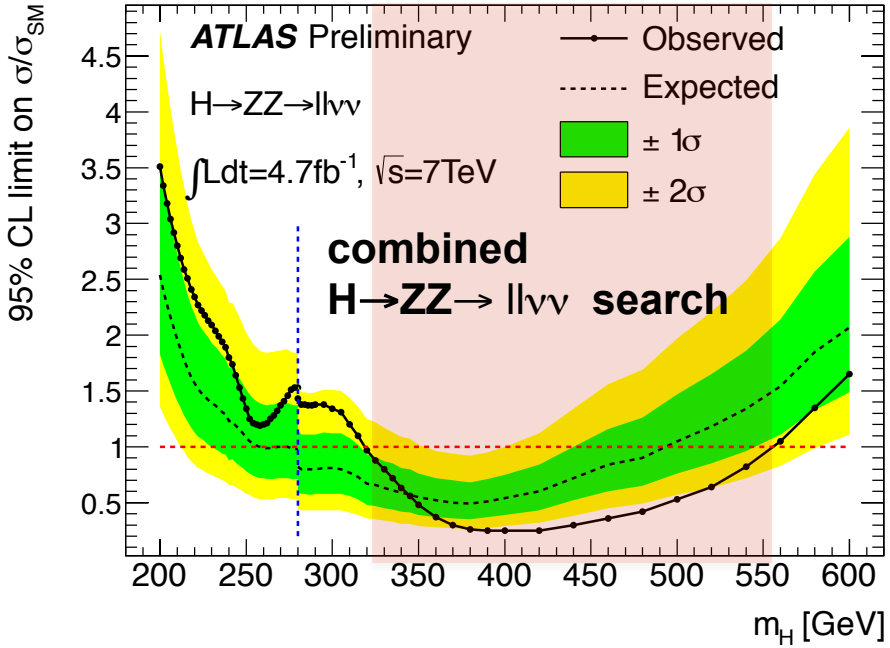
- $H \rightarrow ZZ \rightarrow ll\nu\nu$ (4.7 fb^{-1})
  m_H : 200-600 GeV
  4 category (low/high pile up)
  $E_t^{l1,l2}$>20,15 GeV
  mass resolution (~20 %)
  m_T shape
  bkg : bkg : ZZ, WZ, WW, ttbar

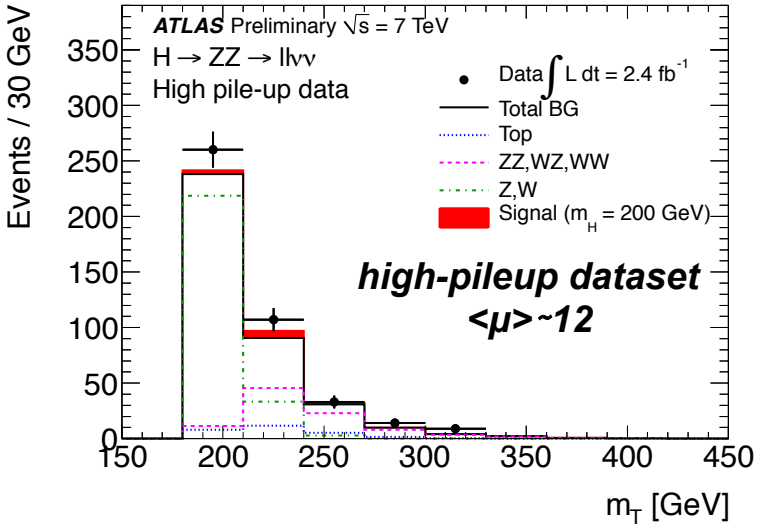
NEW

different selections for m_H <280 GeV and m_H ≥280 GeV



No significant excess is observed





observed exclusion : 320 < m_{Higgs}< 560 GeV

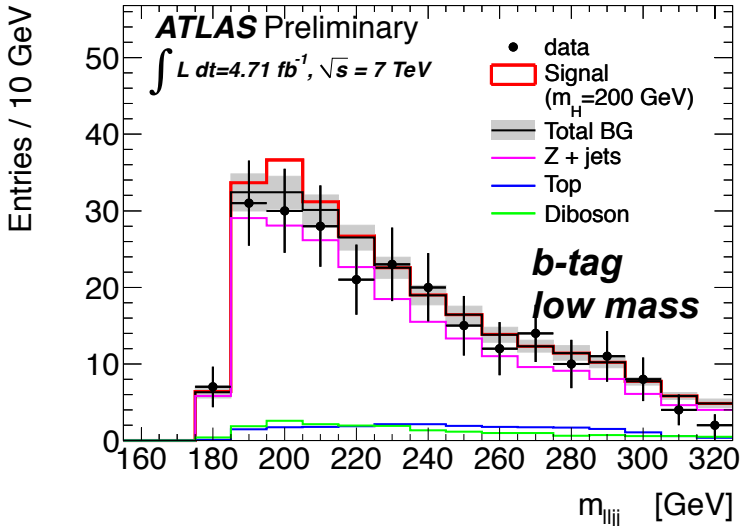
HIGH MASS CHANNELS

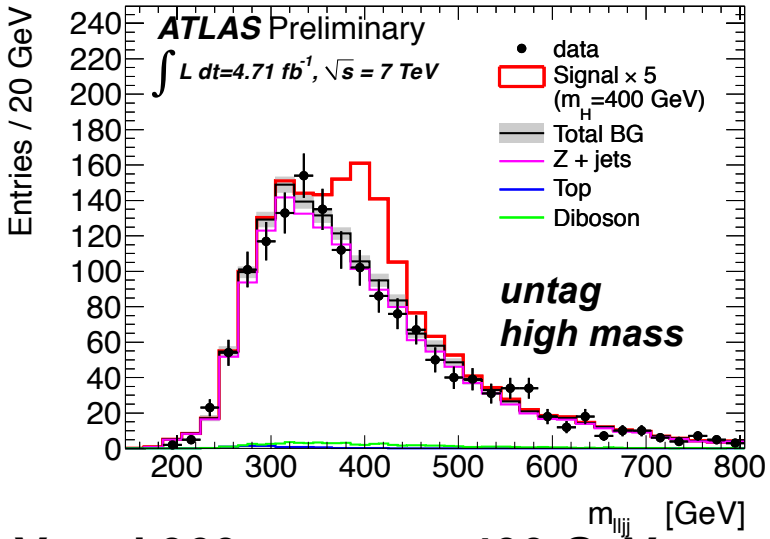
Key points of the analysis :

- $H \rightarrow ZZ \rightarrow llqq/bb$ (4.7 fb^{-1})
  m_H : 200-600 GeV
  2 category (untag, 2 b-tag)
  E_t^j>25 GeV
  mass resolution (~20 %)
  $m_{lljj/bb}$ shape
  bkg : Z+jets, ttbar

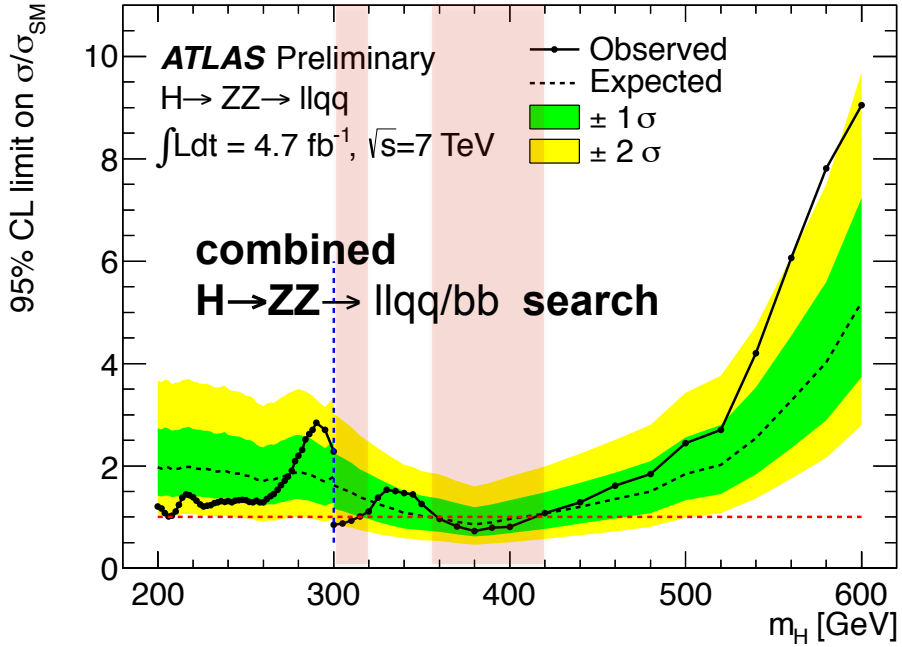
NEW

different selections for m_H <300 GeV and m_H ≥300 GeV





No significant excess is observed



observed exclusion : 300 < m_{Higgs}< 310 GeV and 360 < m_{Higgs}< 400 GeV

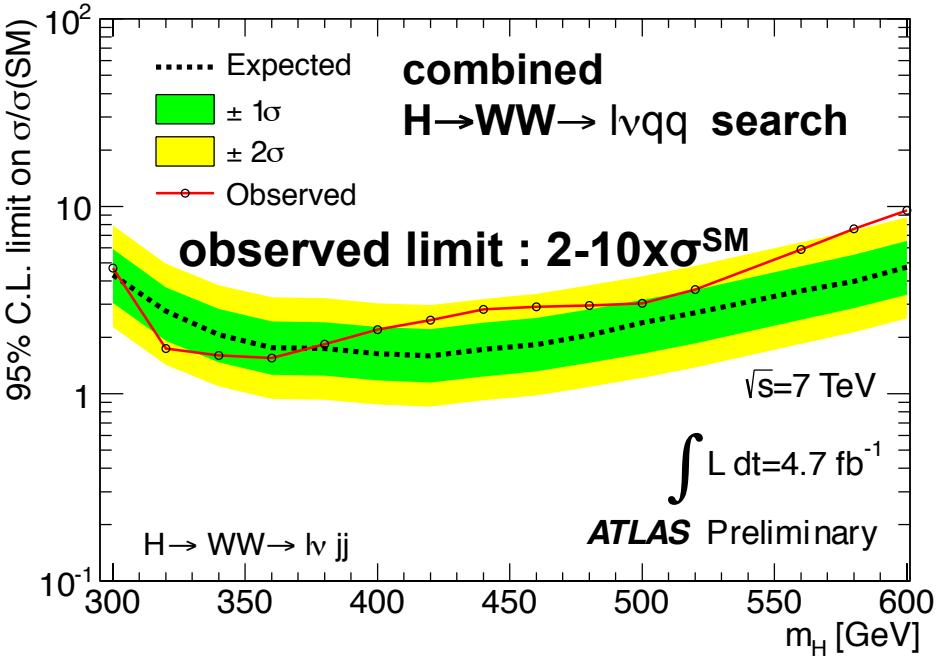
HIGH MASS CHANNELS

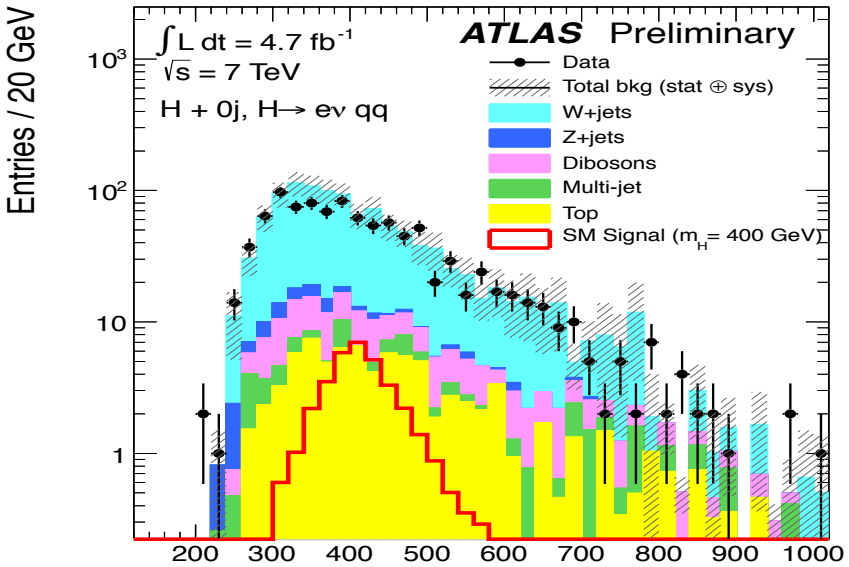
Key points of the analysis :

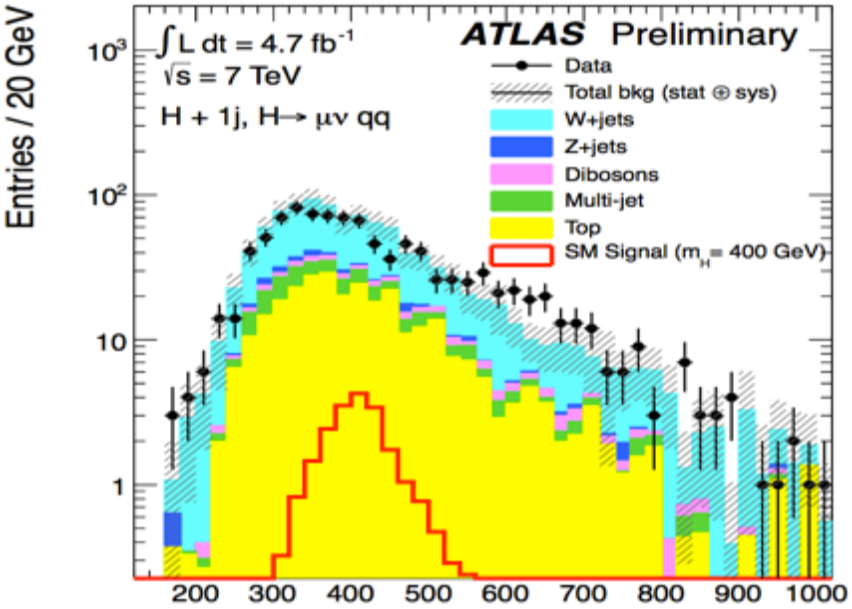
- $H \rightarrow WW \rightarrow l\nu qq$ (4.7 fb^{-1})
  m_H : 110-600 GeV
  6 category (0-jet,1-jet, VBF)
  $E_t^{l1,l2}$>20,15 GeV
  mass resolution (~20 %)
  $m_{l\nu qq}$ shape
  bkg : W+jets, ttbar

NEW

No significant excess is observed



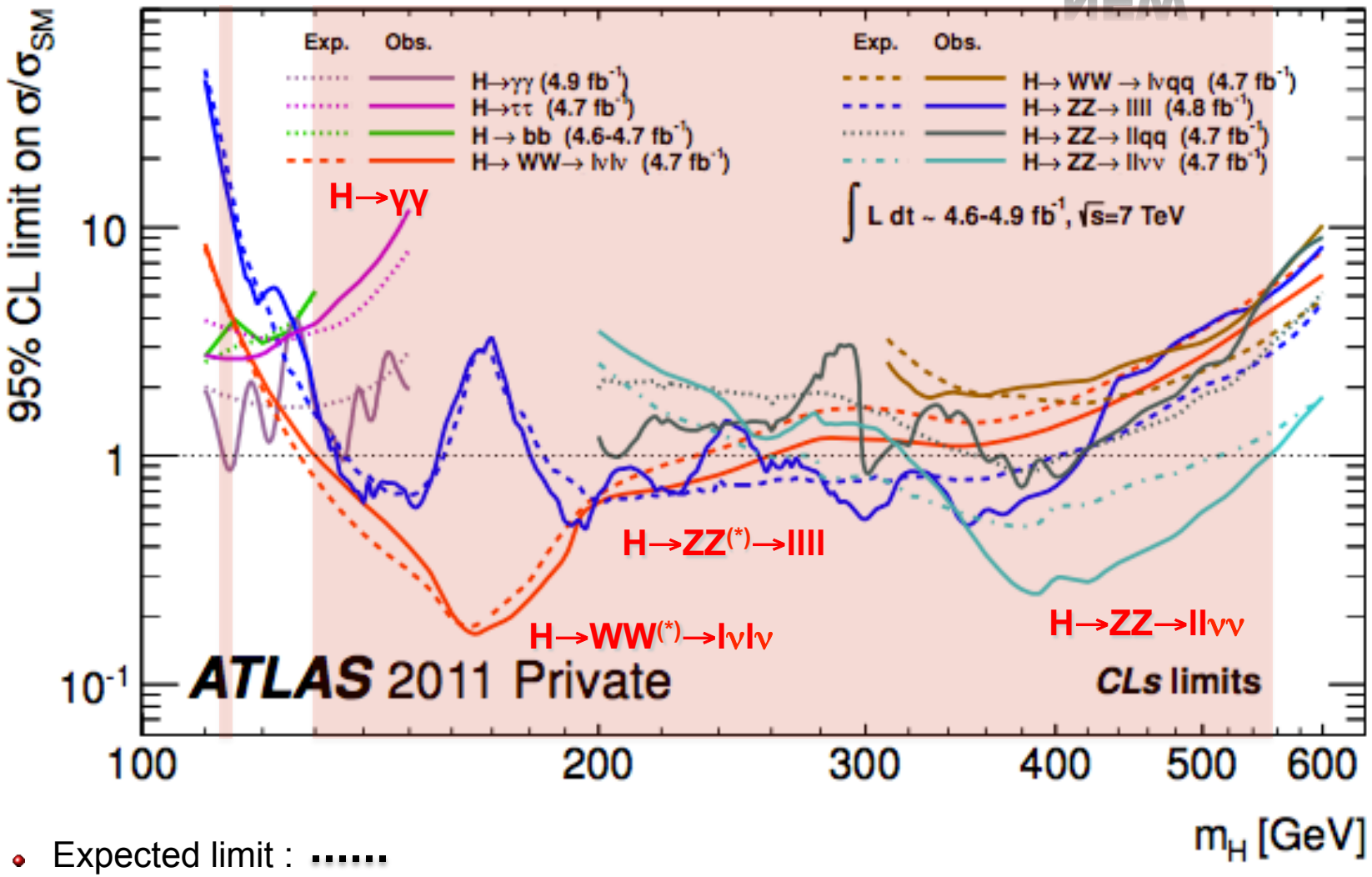




SUMMARY OF THE CHANNELS

Summary of the individual channels (Moriond 2012) :

NEW



- Expected limit : ------
- Observed limit : ——

SYSTEMATIC UNCERTAINTIES

Treatment of the systematic uncertainties between the different channels :

- Correlated systematic uncertainties (Jet Energy Scale, Luminosity, …)

	$H \to \tau^+\tau^-$		$H \to \gamma\gamma$	$H \to b\bar{b}$	$H \to WW^{(*)}$	$H \to ZZ^{(*)}$		
	$\tau_\ell\tau_{had}$	$\tau_\ell\tau_\ell + jet$			$\ell\nu\ell\nu$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
Luminosity	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7	±3.7
e/γ eff.	±3.5	$^{+2.0}_{-2.1}$	$^{+11.6}_{-10.4}$	±2.3	±2.2	±3.3	±1.2	±1.1
e/γ E. scale	$^{+1.3}_{-0.1}$	$^{+0.2}_{-0.5}$	-	$^{+1.5}_{-1.6}$	±0.1	-	$^{+0.8}_{-1.1}$	-
e/γ res.	-	±3.7	-	$^{+2.1}_{-1.5}$	±0.1	-	-	-
μ eff.	±1.0	$^{+2.0}_{-2.1}$	-	$^{+1.1}_{-2.0}$	±0.6	±1.2	$^{+0.8}_{-0.7}$	±0.6
μ res.	-	$^{+0.4}_{-0.6}$	-	±5.8	±1.6	-	-	-
Jet/τ/MET E. scale	$^{+19}_{-16}$	$^{+3.3}_{-10.0}$	-	$^{+21}_{-17}$	±6.1	-	$^{+5.9}_{-4.0}$	$^{+3.7}_{-10.4}$
JER	-	±2.0	-	±2.5	$^{+2.2}_{-1.8}$	-	-	$^{+2.1}_{-0.0}$
MET	-	$^{+4.4}_{-5.3}$	-	$^{+5.5}_{-6.1}$	-	±0.6	$^{+6.6}_{-4.2}$	-
b-tag eff.	-	-	-	$^{+37}_{-33}$	±0.1	-	$^{+4.3}_{-4.4}$	-

HCP, Nov 2011 systematic values

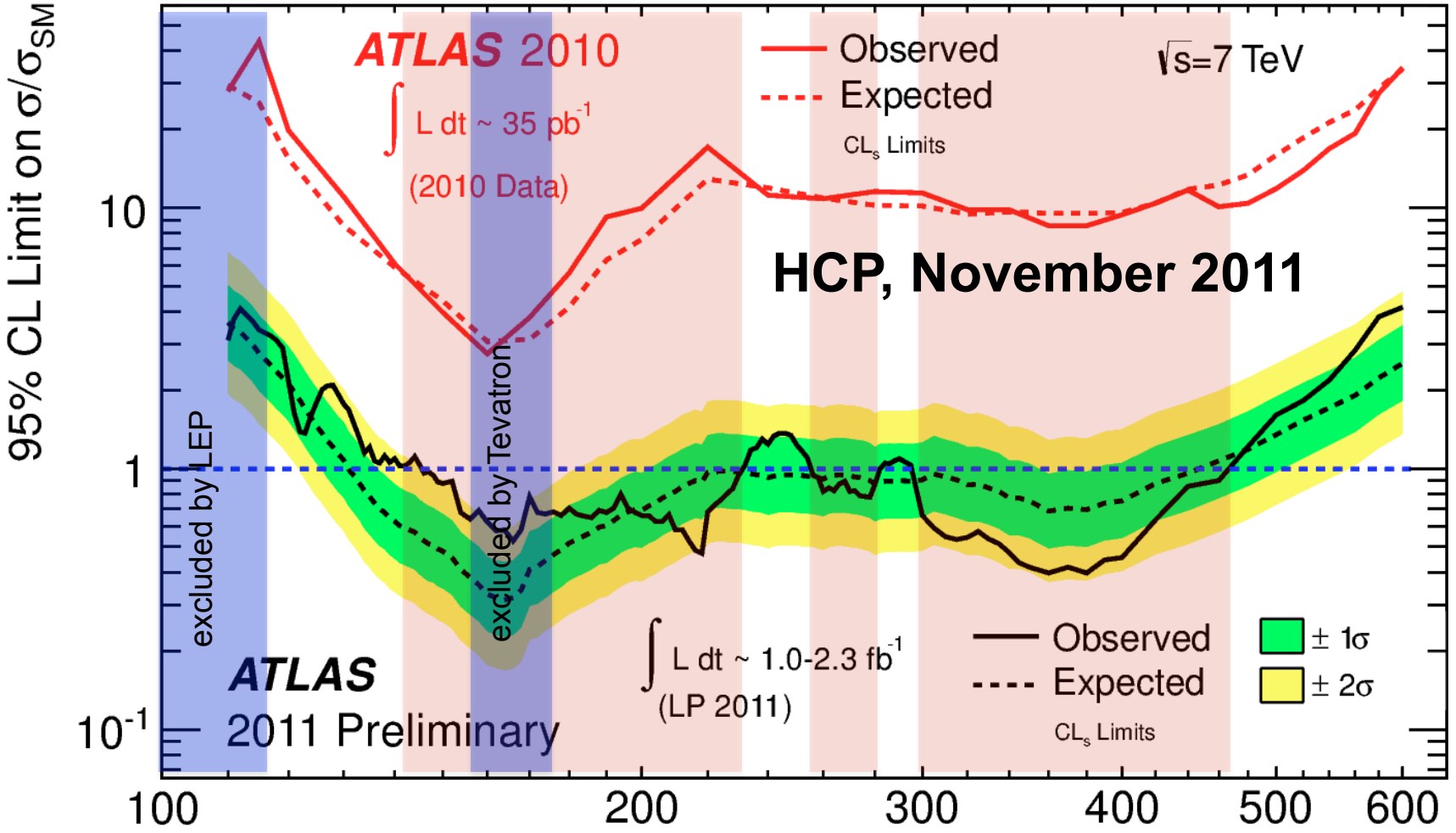
- For background estimated with data-driven, systematic uncertainties are uncorrelated
- Careful treatment of theory uncertainties (ATLAS-CMS LHC combination working group)

Production Mode	QCD Scale	PDF+α_s	Total
ggF	+12/-7 %	±8 %	+20/-15 %
VBF	±1 %	±4 %	±5 %
WH/ZH	±1 %	±4 %	±5 %
ttH	±4 %	±8 %	±12 %

change with m_{Higgs}

SM HIGGS COMBINATION AT ATLAS

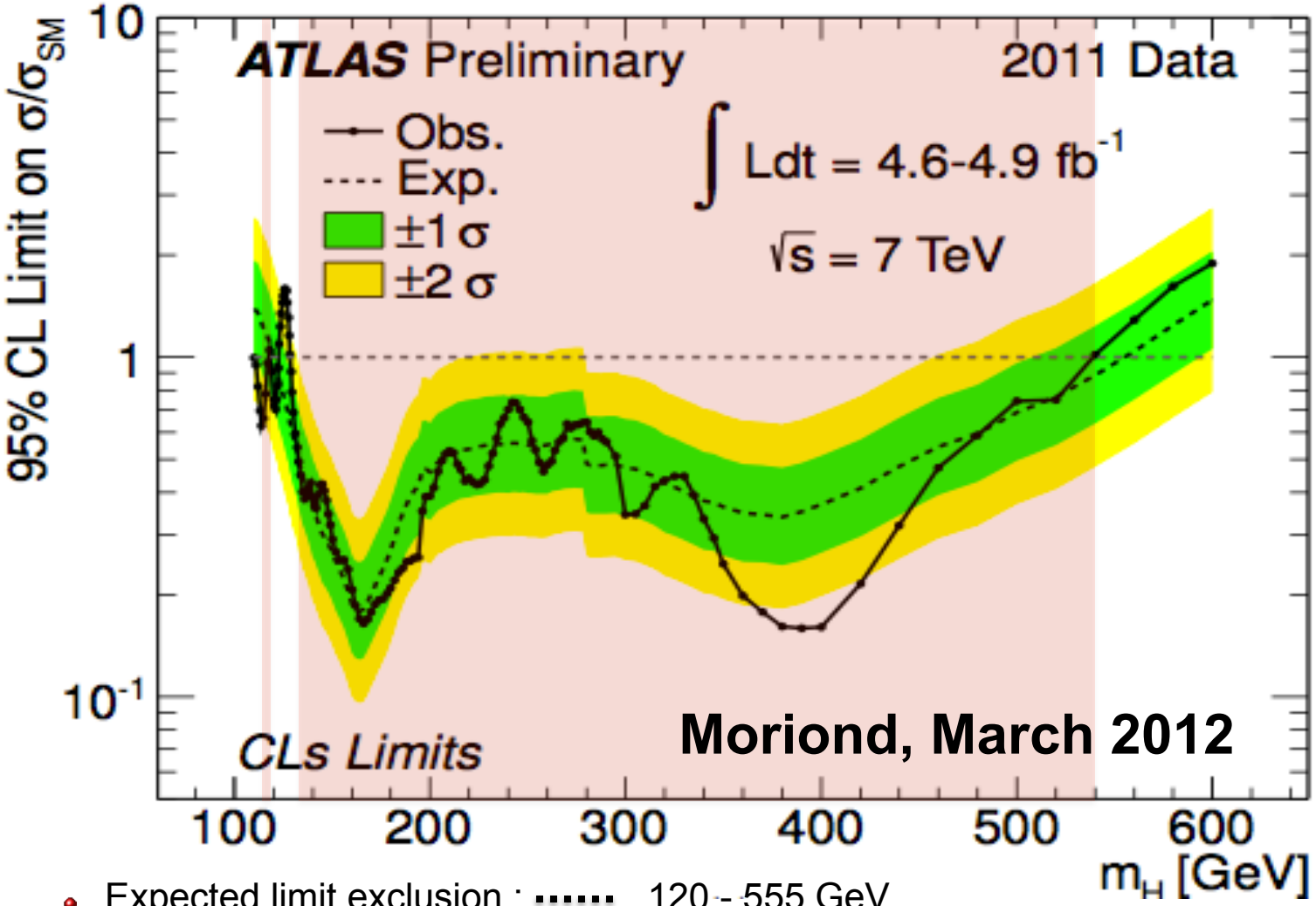
SM Higgs Combination at ATLAS with 2010 and 2011 data (HCP 2011) :



- Expected limit exclusion : ····· 131 - 450 GeV
- Observed limit exclusion : ——— 146 - 230 GeV and 256 - 282 GeV and 296 - 459 GeV

SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with all 2011 data (Moriond 2012) :



NEW

- Expected limit exclusion : ····· 120 - 555 GeV
- Observed limit exclusion : ——— 110.0–117.5 GeV and 118.5-122.5 GeV and 129–529 GeV

SM HIGGS COMBINATION AT ATLAS

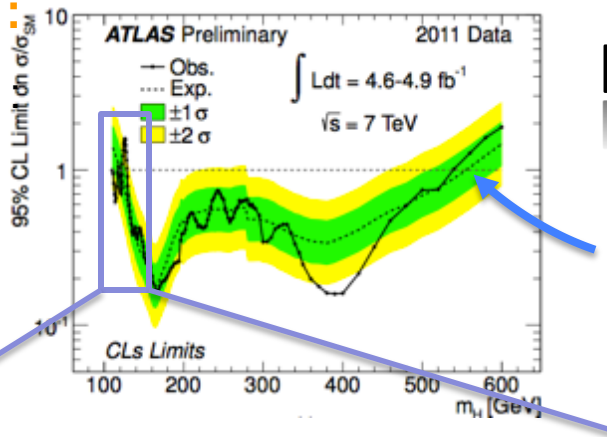
SM Higgs Combination at ATLAS with 2011 data :

- Standard Model Higgs Boson excluded at 95% CL
  $110.0 < m_{Higgs} < 117.5$ GeV
  $118.5 < m_{Higgs} < 122.5$ GeV
  $129 < m_{Higgs} < 439$ GeV
  (expected : $120 < m_{Higgs} < 555$ GeV)

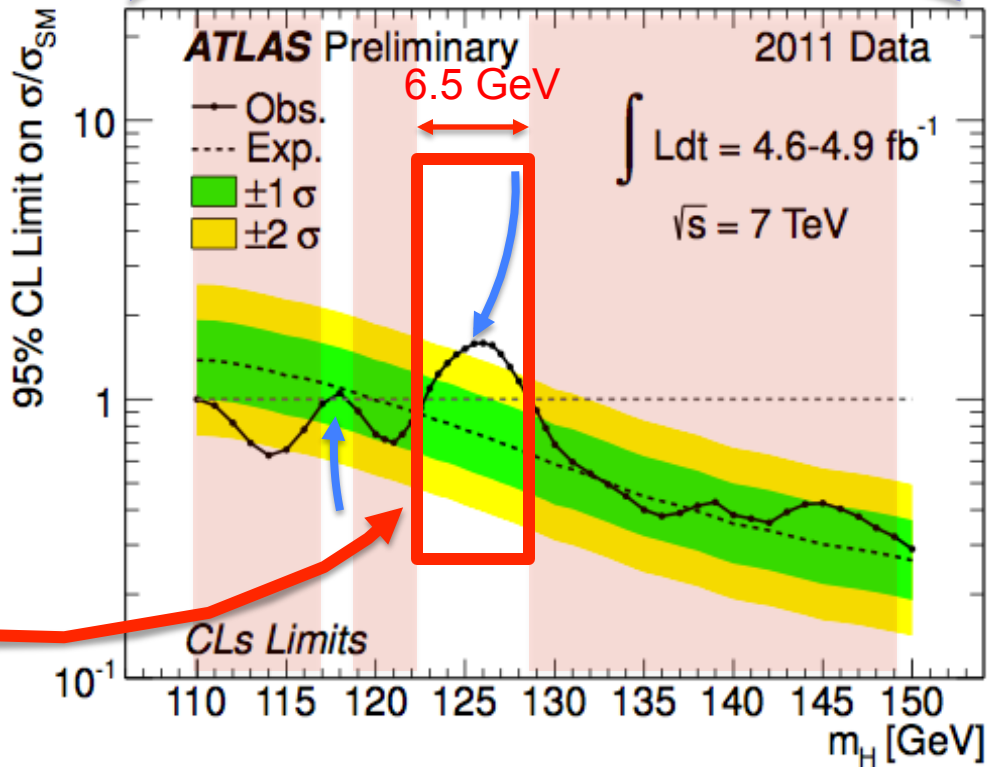
- Still some "excess" that leads to weaker-than-expected limit

- Some "hole" in the exclusion range due to some "excess" in around
  m_{Higgs} 110.0 -117.5 GeV
  m_{Higgs} 118.5 -122.5 GeV
  m_{Higgs}~ 439 GeV

- Interesting region now :
  m_{Higgs} **118.5** - **122.5** GeV
  more channels
  but difficult one

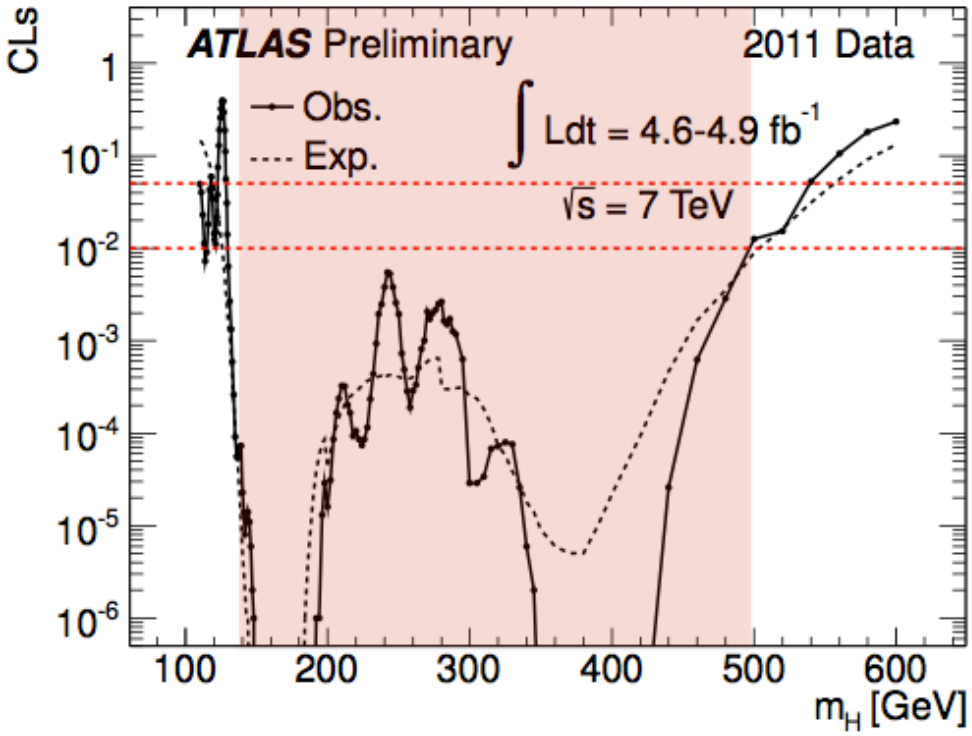


NEW

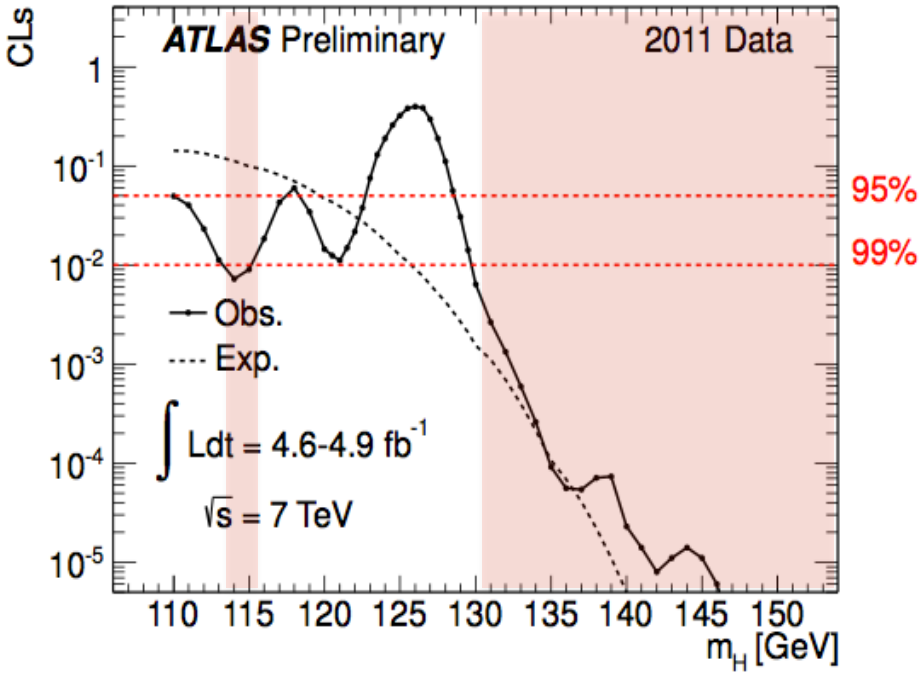


SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :



NEW



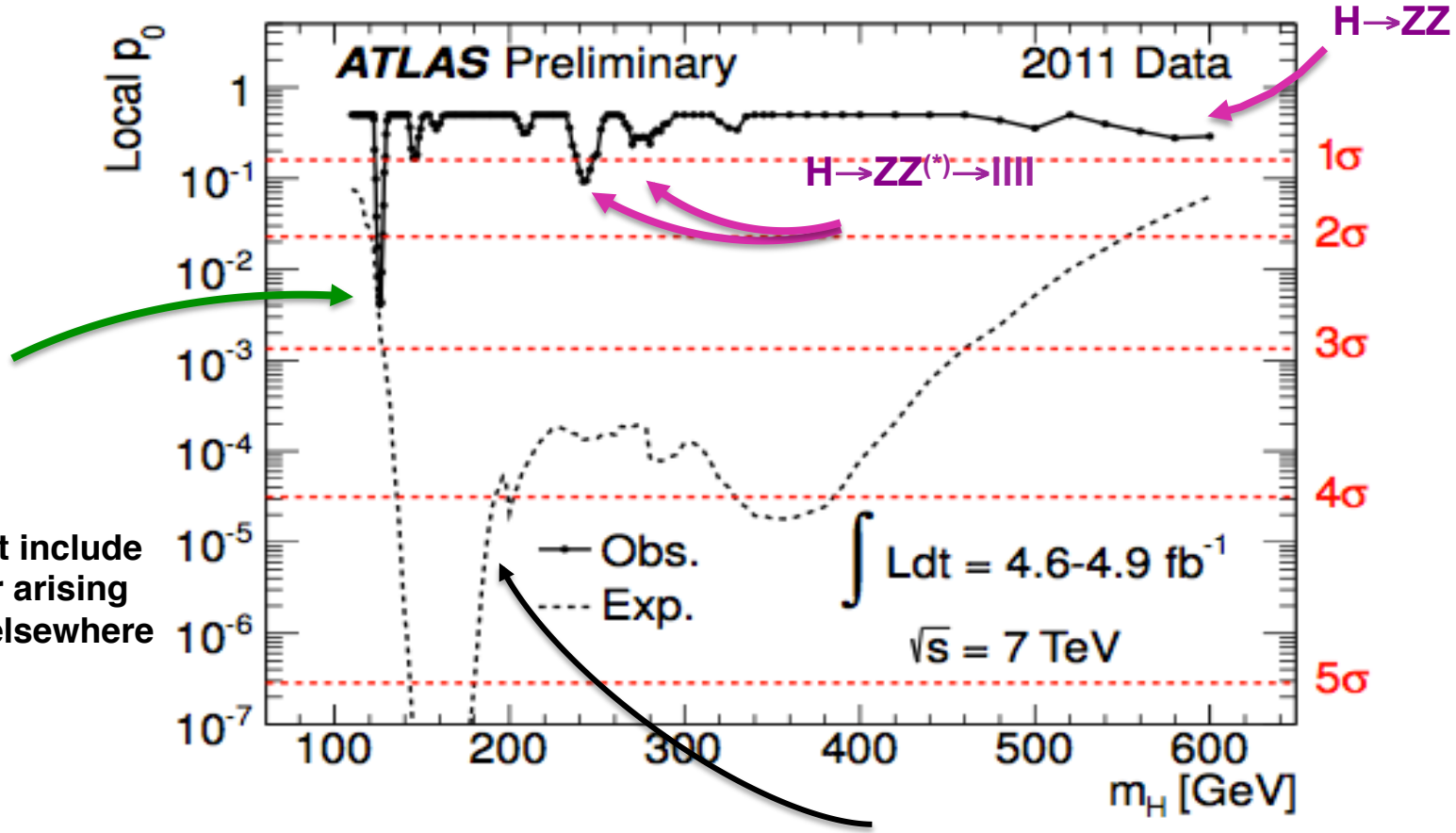
- Observed limit exclusion : —— ~115 GeV and 130–486 GeV at 99%

LOCAL P-VALUES

Local p-value of the SM Higgs combination at ATLAS (Moriond 2012):

- The observed local p-value characterize probabilities for the predicted background to fluctuate at least as high as the observed excesses

NEW



~2.5 σ

p-values do not include the trials factor arising from the look-elsewhere effect (LEE)

hypothesis of a Standard Model Higgs boson production signal

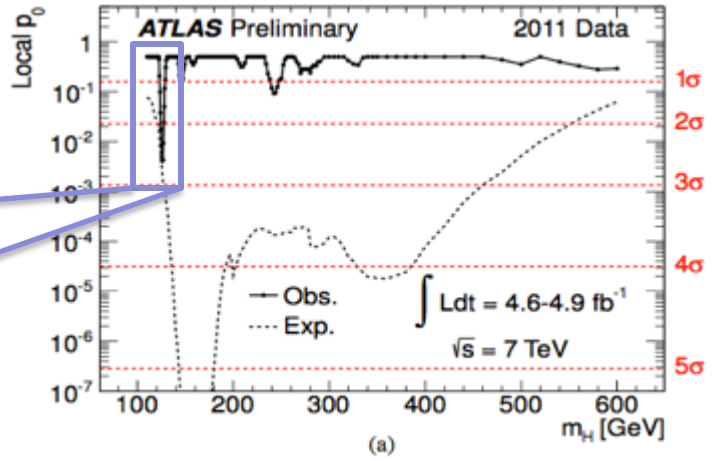
LOCAL P-VALUES

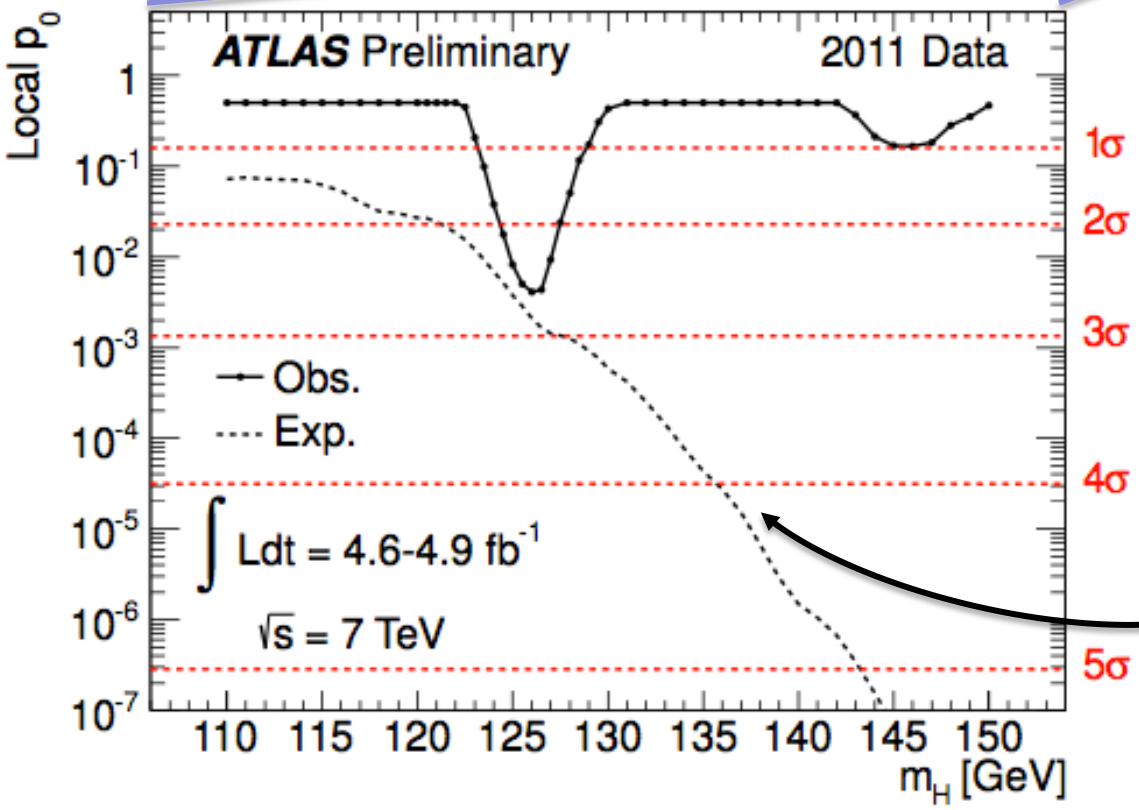
Local p-value of the SM Higgs combination at ATLAS (Moriond 2012) :

- The observed local p-value characterize probabilities for the predicted background to fluctuate at least as high as the observed excesses

NEW

- Excess of 2.5 σ is observed for 126 GeV
- For a SM Higgs at 126 GeV : 2.9 σ expected





p-values do not include the trials factor arising from the look-elsewhere effect (LEE)

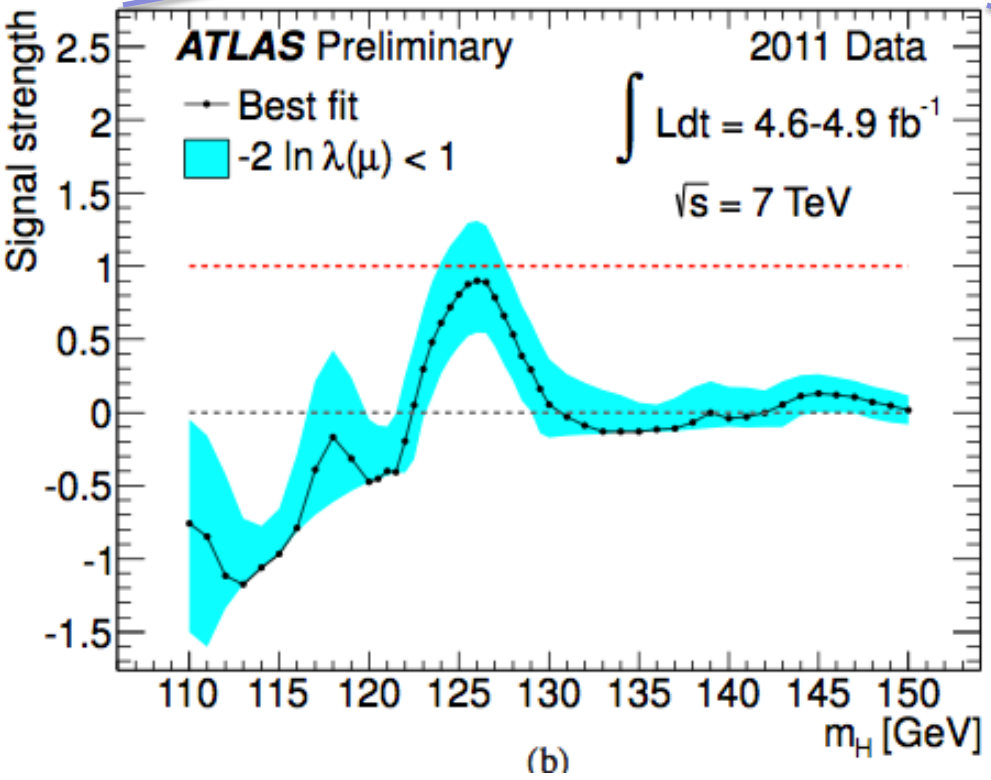
hypothesis of a Standard Model Higgs boson production signal

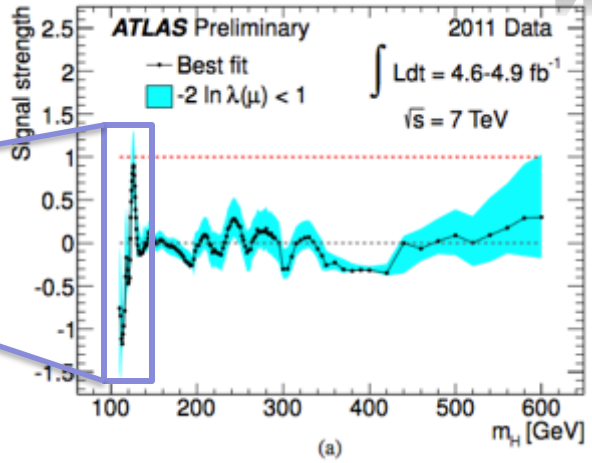
SIGNAL STRENGTH

Best fit signal strength $\mu = \sigma/\sigma_{SM}$:

NEW

- The μ value indicates by what factor the SM Higgs boson cross section would have to be scaled to best match the observed data
- Best-fit signal strength at 126 GeV: $\hat{\mu} = 0.9^{+0.4}_{-0.3}$





ANATOMY OF AN OBSERVED EXCESS

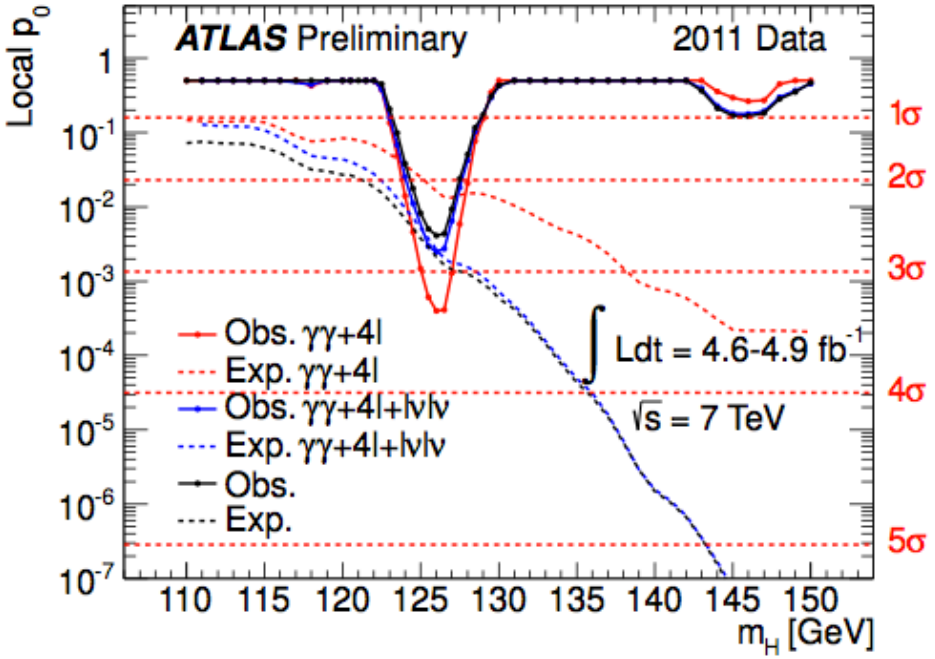
Observed excess :

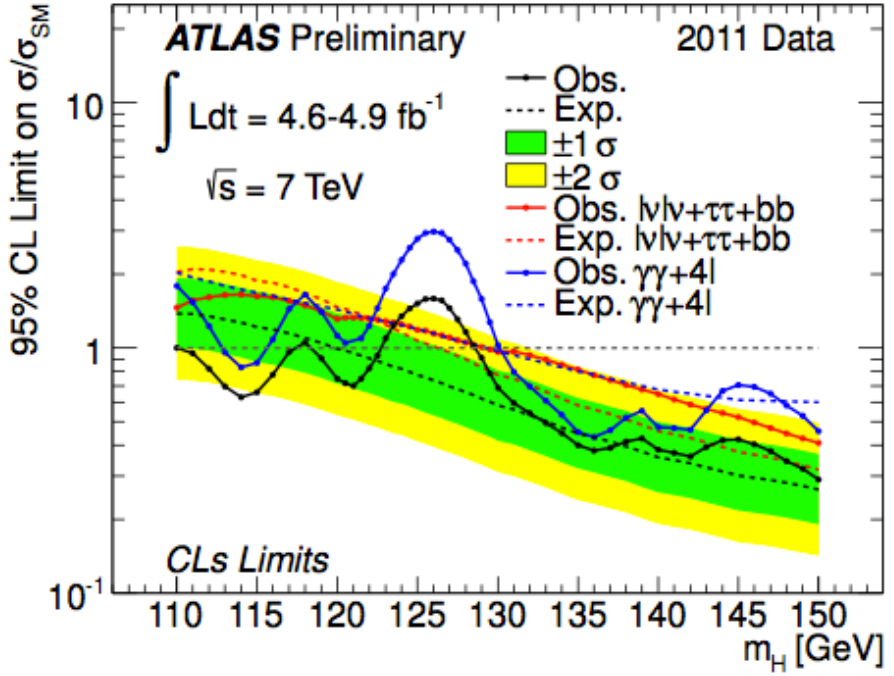
- Excess is mainly observed in two high-resolution channels:
  $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ(*) \rightarrow 4\ell$: 3.4 σ local significance (combined)

NEW

- No such excess in :
  $H \rightarrow WW(*) \rightarrow \ell\nu\ell\nu$, $H \rightarrow \tau\tau$, $H \rightarrow bb$
  All channels combined: 2.5σ local significance

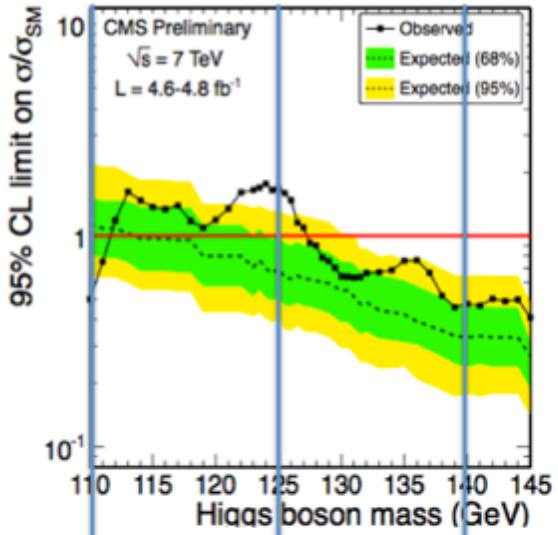
- Global probability of such a background fluctuation anywhere in the full explored mass range (110-600 GeV) : 30%
  mass range (110-146 GeV) : 10%

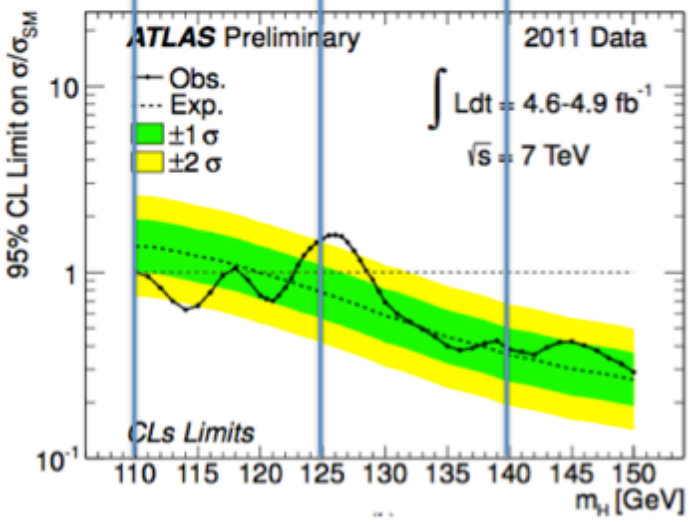


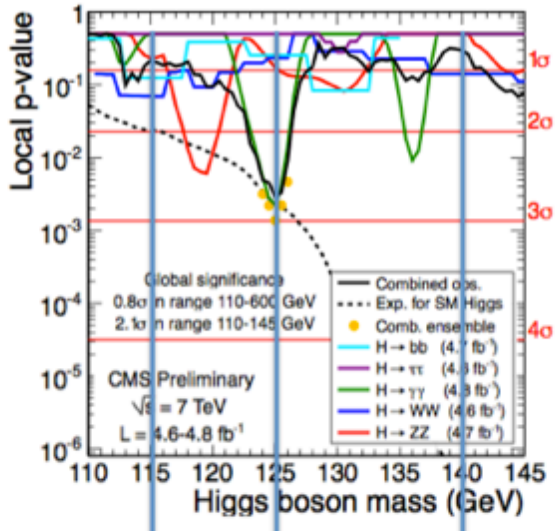


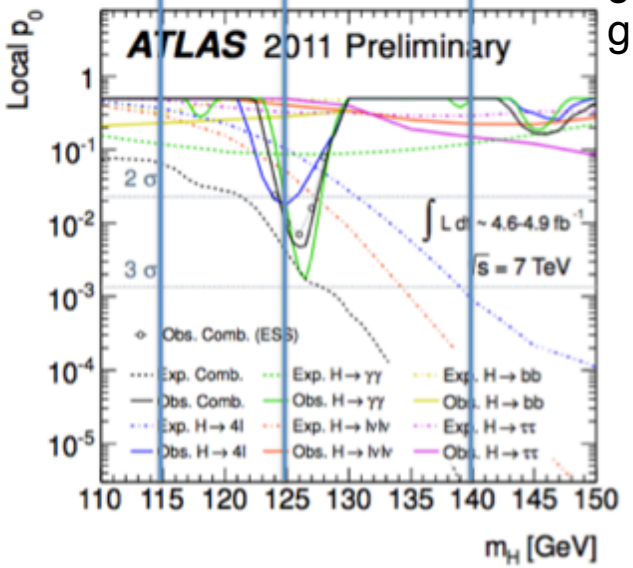
SM HIGGS COMBINATION AT ATLAS VS CMS

SM Higgs Combination at ATLAS vs CMS with 2011 data :









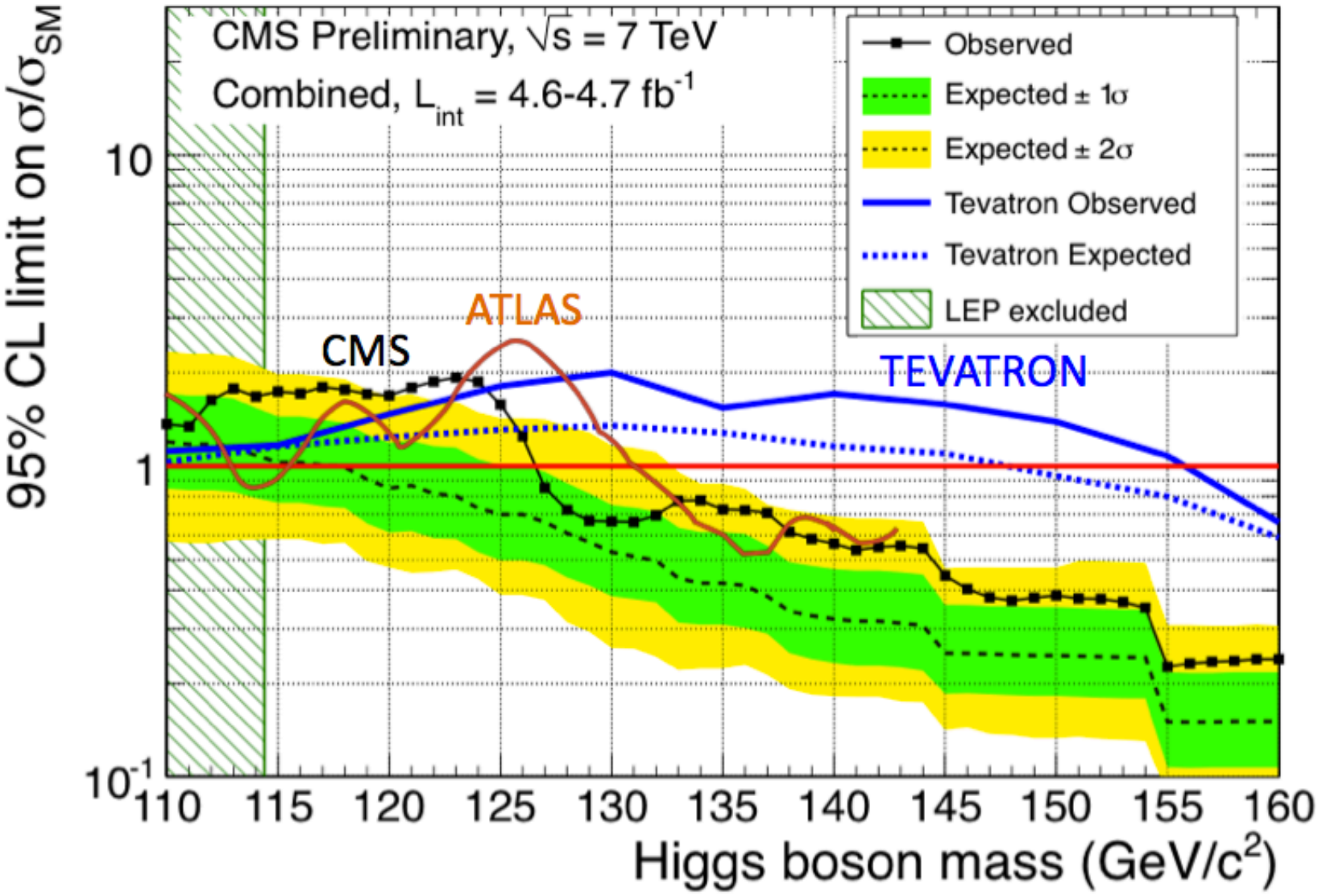
NEW

CMS :
127.5- 600 GeV
(at 95% CL)
129 - 525 GeV
(at 99% CL)

some excess :
125 GeV
local 2.8σ
global 0.8σ (110-600 GeV)
global 2.1σ (110-145 GeV)

ATLAS,CMS AND TEVATRON

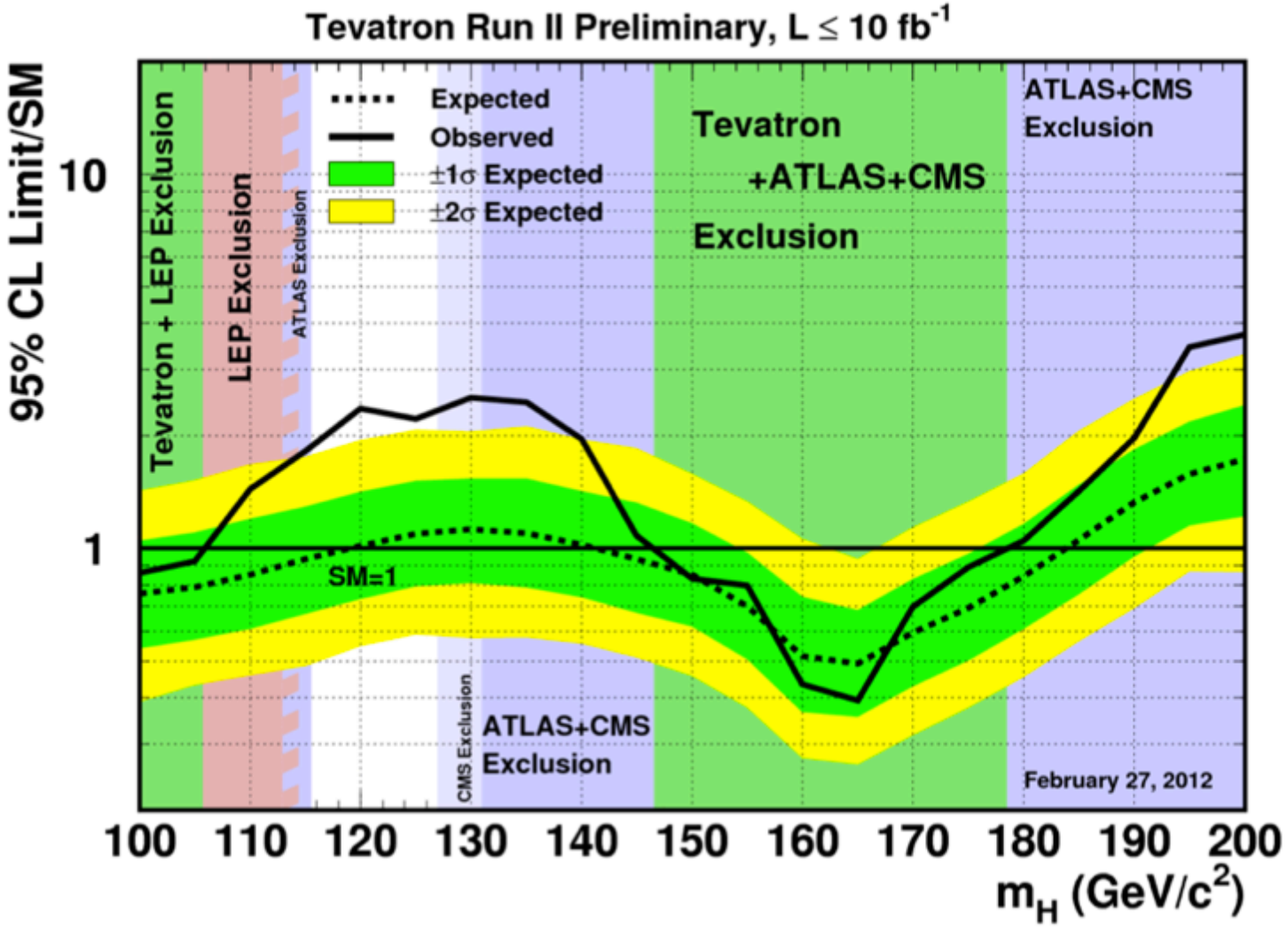
SM Higgs Combination at ATLAS, CMS and Tevatron, January 2011 :



NEW TEVATRON RESULTS

SM Higgs Combination at Tevatron (Moriond 2012) :

NEW



Tevatron :
147 - 179 GeV
(at 95% CL)

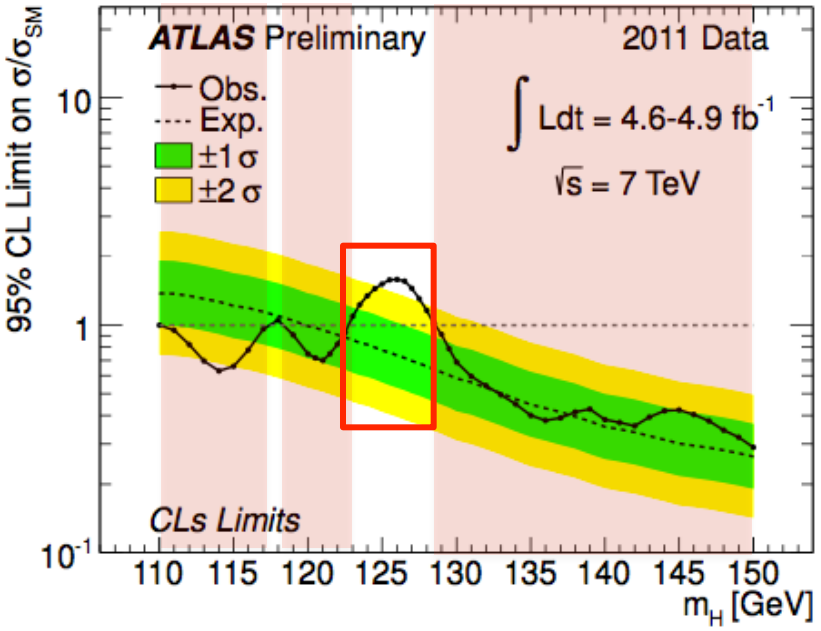
some excess :
115 - 135 GeV
2.7 σ (2.2 σ)

PROJECTION FOR 2012

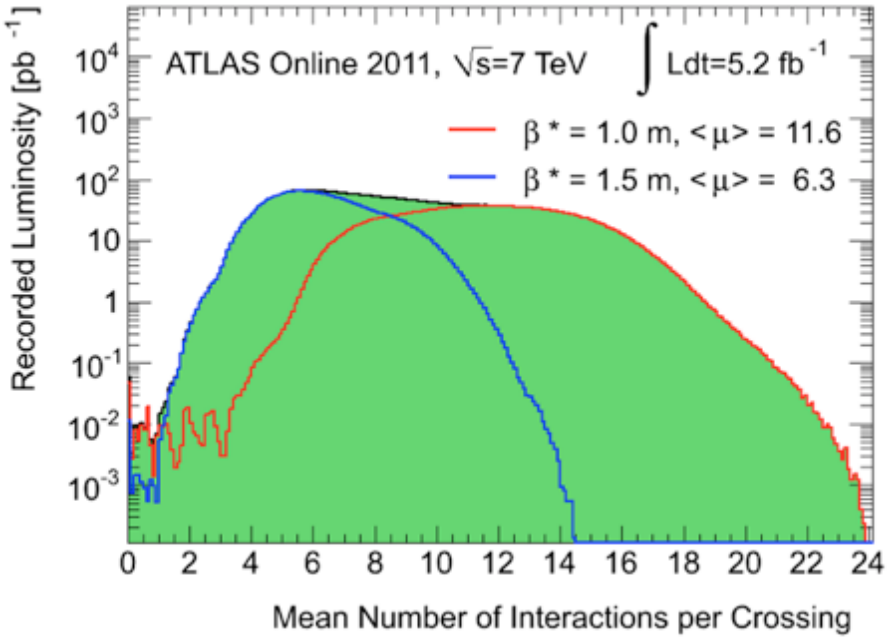
What we can expect in 2012 :

- Exclusion or evidence at 5 σ with 15-20 fb^{-1}
  whole mass range between 110-600

ATLAS Higgs combination Moriond 2012



Pile-up in 2011 data



- challenges for 2012 :
  √s=8 TeV of p-p collisions
  pic luminosity : ~6.2-6.8x10^{33} cm^{-2} s^{-1} (2 x maximum pic in 2011 data)
  <μ> : ~31-35 (3 x maximum average value in 2011 data
  O(15-20) fb^{-1} [1] (3-4 x 2011 data

CONCLUSION

Conclusion :

- Thanks to the excellent LHC operations, ATLAS has collected more than 5 fb^{-1} of data (p-p collision at 7 TeV)
- The LHC dominates the SM Higgs with 5 fb^{-1}
- ATLAS has performed a Higgs Boson search corresponding to and integrated luminosity between 4.6 and 4.9 fb^{-1} using several channels
- Modest excesses observed of 2.5 σ (2.9 σ) is found (expected) at 126 GeV
- Exclusion limits at 95% C.L are set for a SM-like Higgs boson in the mass region :
  $110.0 < m_{Higgs} < 117.5$ GeV
  $118.5 < m_{Higgs} < 122.5$ GeV
  $129 < m_{Higgs} < 439$ GeV
- In the low-mass region no exclusion was possible due to a moderate excess of observed events compared to the expectation
- The excess is most compatible with the Standard Model Higgs boson hypothesis with m_H around 126 GeV. Statistical significance not large enough to distinguish signal from the background fluctuations (yet)

OUTLOOK

Outlook :

- Possibility to have LHC and/or LHC+Tevatron SM Higgs combination before the summer

- Prepare 2012 analysis:
  - by optimizing the object performances (e, μ, τ, …)
  - by reducing the systematic and optimizing the selections

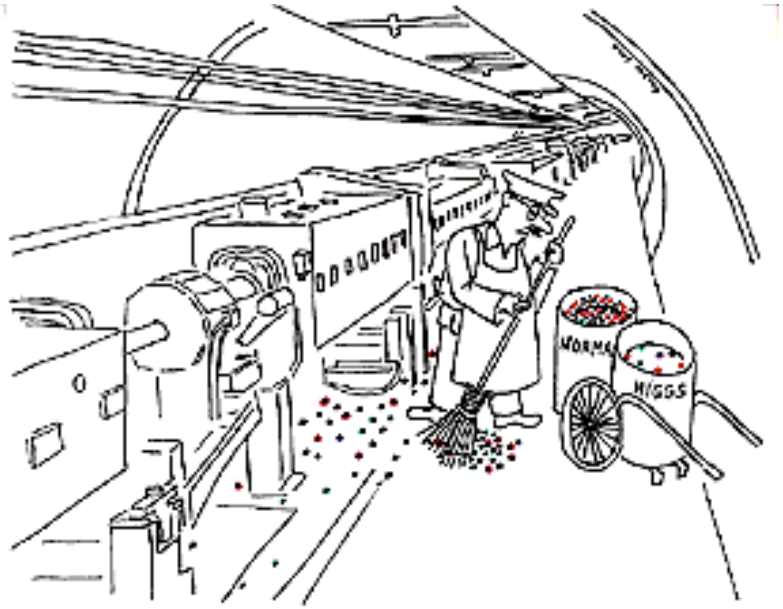
- By the end of 2012 with O(15-20 fb^{-1}) a conclusive answer on the Standard Model Higgs will be obtained

- If 126 GeV persists and becomes significant:
  - measurement of mass
  - ττ, bb, WW, ZZ decays all accessible for measurements
  - consequences for BSM…

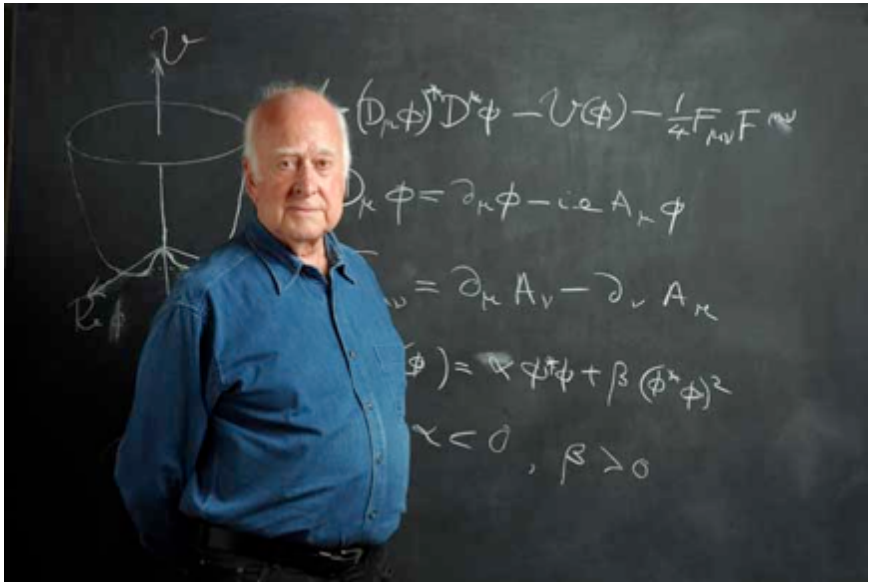
- If not:
  - go down in the couplings
  - don't forget high mass
  - other signatures (e.g. invisible)

- Very exiting times ahead …

STAY TUNED



"Run! I've discovered the Higgs bison."



BACK UP

DOCUMENTATIONS

ATLAS Public Documents :

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

- ATLAS Luminosity and pile-up
  https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults
- LHC Higgs Cross-section working group
  https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections
- Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables
  CERN-2011-002, arXiv:1101.0593
  http://cdsweb.cern.ch/record/1318996
- Search for the Standard Model Higgs boson in the diphoton decay channel with 4.9 fb−1 of ATLAS data at sqrt(s) =7 TeV
  arXiv:1202.1408
  http://arxiv.org/abs/1202.1408
- Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a b-quark pair using up to 4.7 fb−1 of pp collision data at sqrt(s) = 7 TeV with the ATLAS detector at the LHC
  ATLAS-CONF-2012-015
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-015
- Search for the Standard Model Higgs boson in the H-> tau^+ tau^- decay mode with 4.7 fb^-1 of ATLAS data at 7 TeV
  ATLAS-CONF-2012-014
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-014

DOCUMENTATIONS

ATLAS Public Documents :

- Search for the Standard Model Higgs boson in the H->WW->lvlv decay mode with 4.7 fb−1 of ATLAS data at sqrt(s) = 7 TeV
  ATLAS-CONF-2012-012
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-012

- Search for the Standard Model Higgs boson in the decay channel H -> ZZ -> 4l with 4.8 fb−1 of ATLAS data at sqrt(s) = 7 TeV
  arXiv:1202.1415
  http://arxiv.org/abs/1202.1415

- Search for a Standard Model Higgs in the H->ZZ->llvv decay channel with 4.7 fb-1 with the ATLAS detector
  ATLAS-CONF-2012-016
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-016

- Search for a Standard Model Higgs boson in the mass range 200--600 GeV in the H->ZZ->llqq decay channel with the ATLAS detector
  ATLAS-CONF-2012-017
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-017

- Search for the Higgs boson in the H->WW->lvjj decay channel using 4.7 fb-1 of pp collisions at sqrt{s} = 7 TeV with the ATLAS detector
  ATLAS-CONF-2012-018
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-018

DOCUMENTATIONS

ATLAS Public Documents :

- Combined search for the Standard Model Higgs boson using up to 4.9 fb−1 of pp collisions at sqrt(s) = 7 TeV with the ATLAS detector at the LHC
  arXiv:1202.1408
  http://arxiv.org/abs/1202.1408

- An update to the combined search for the Standard Model Higgs boson with the ATLAS detector at the LHC using up to 4.9 fb−1 of pp collision data at sqrt(s) = 7 Tev
  ATLAS-CONF-2012-019
  https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-019

Data and MC expectations :

The expected numbers of background events, with their systematic uncertainty, separated into “Low-m4l” (m4l < 180 GeV) and “High-m4l” (m4l ≥ 180 GeV) regions, compared to the observed numbers of events.

	$\mu^+\mu^-\mu^+\mu^-$		$e^+e^-\mu^+\mu^-$		$e^+e^-e^+e^-$	
	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	4.8 fb^{-1}		4.8 fb^{-1}		4.9 fb^{-1}	
$ZZ^{(*)}$	2.1 ± 0.3	16.3 ± 2.4	2.8 ± 0.6	25.2 ± 3.8	1.2 ± 0.3	10.4 ± 1.5
$Z+$ jets 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	4.3 ± 0.8	25.4 ± 3.8	2.8 ± 0.8	10.6 ± 1.5
Data	3	21	3	27	2	15
$m_H = 130$ 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	
$m_H = 400$ 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	

COMMON LHC SYSTEMATICS

Theoretical Systematics

PDF+α_s uncertainties

nuisance	groups of physics processes
pdf_gg	$gg \to H$, $t\bar{t}H$, VQQ, $t\bar{t}$, tW, tb (s-channel), $gg \to VV$
pdf_qqbar	VBF H, VH, V, VV, $\gamma\gamma$
pdf_qg	tbq (t-channel), γ+jets

QCD scale uncertainties

nuisance	groups of physics processes
QCDscale_ggH	total inclusive $gg \to H$
QCDscale_ggH1in	inclusive $gg/qg \to H+ \geq 1$ jets
QCDscale_ggH2in	inclusive $gg/qg \to H+ \geq 2$ jets
QCDscale_qqH	VBF H
QCDscale_VH	associate VH
QCDscale_ttH	$t\bar{t}H$
QCDscale_V	W and Z
QCDscale_VV	WW, WZ, and ZZ up to NLO
QCDscale_ggVV	$gg \to WW$ and $gg \to ZZ$
QCDscale_ZQQ	Z with heavy flavor $q\bar{q}$-pair
QCDscale_WQQ	W with heavy flavor $q\bar{q}$-pair
QCDscale_ttbar	$t\bar{t}$, single top productions are lumped here for simplicity

Phenomenological uncertainties

nuisance	groups of physics processes
UEPS	all processes sensitive to modeling of UE and PS

Acceptance uncertainties

nuisance	comments
QCDscale_WW_EXTRAP	extrap. factor α for deriving WW bkgd in HWW analysis
QCDscale_ttbar_EXTRAP	extrap. factor α for deriving $t\bar{t}$ bkgd in HWW analysis

Instrumental Systematics

Instrumental uncertainties

nuisance	comments
lumi	uncertainties in luminosities

EXPERIMENTAL SYSTEMATICS

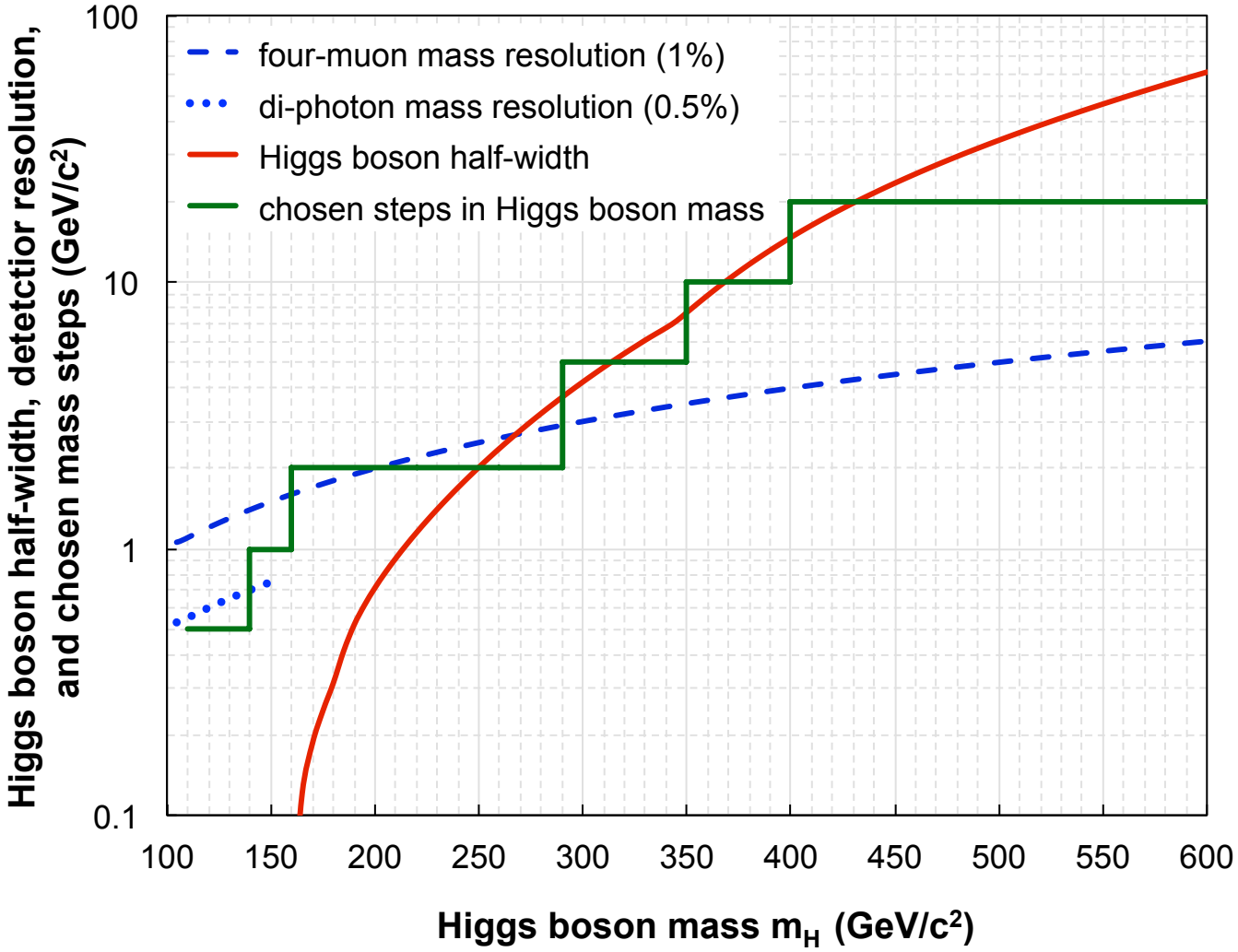
Instrumental Systematics

Physics object	Source	Uncertainty on signal yield	Most affected channels
	luminosity	3.9%	
Photon	efficiency	11%	$\gamma\gamma$
Electron	efficiency	<3%	4ℓ
	energy scale	<1%	
	energy resolution	<0.5%	
Muon	efficiency	<1%	4ℓ
	momentum resolution	<1%	
Jet	energy scale	up to 12%	$\tau\tau$, $b\bar{b}$, $\ell\ell jj$, $\ell\nu jj$
	resolution	up to 20%	$\ell\nu jj$
b-tagging	efficiency	up to 15%	$b\bar{b}$
τ-jet	efficiency	up to 8%	$\tau\tau$

MASS STEPS

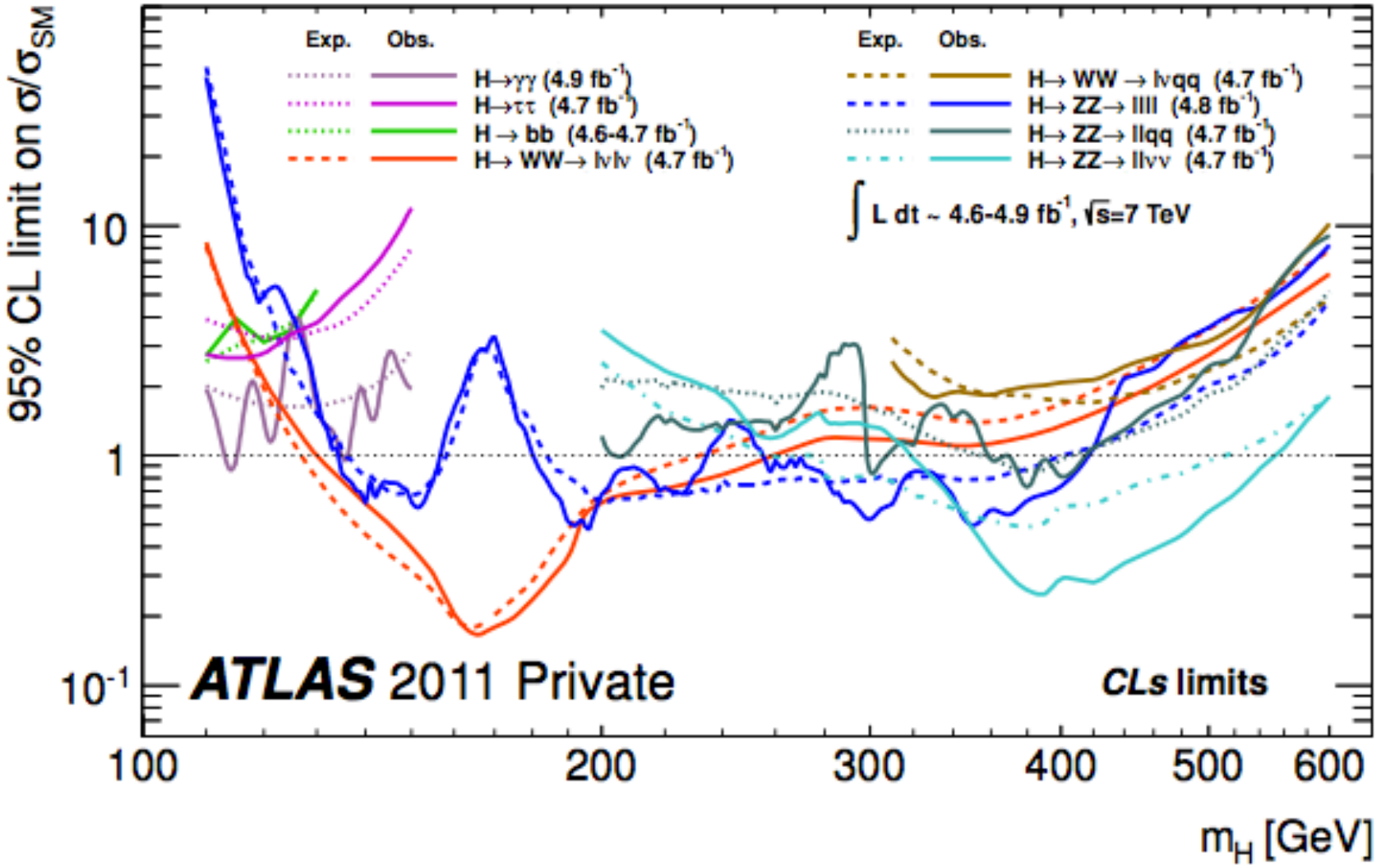
Higgs Decay Width and Mass Resolution :

- Prepared for the LHC combination (ATLAS+CMS)



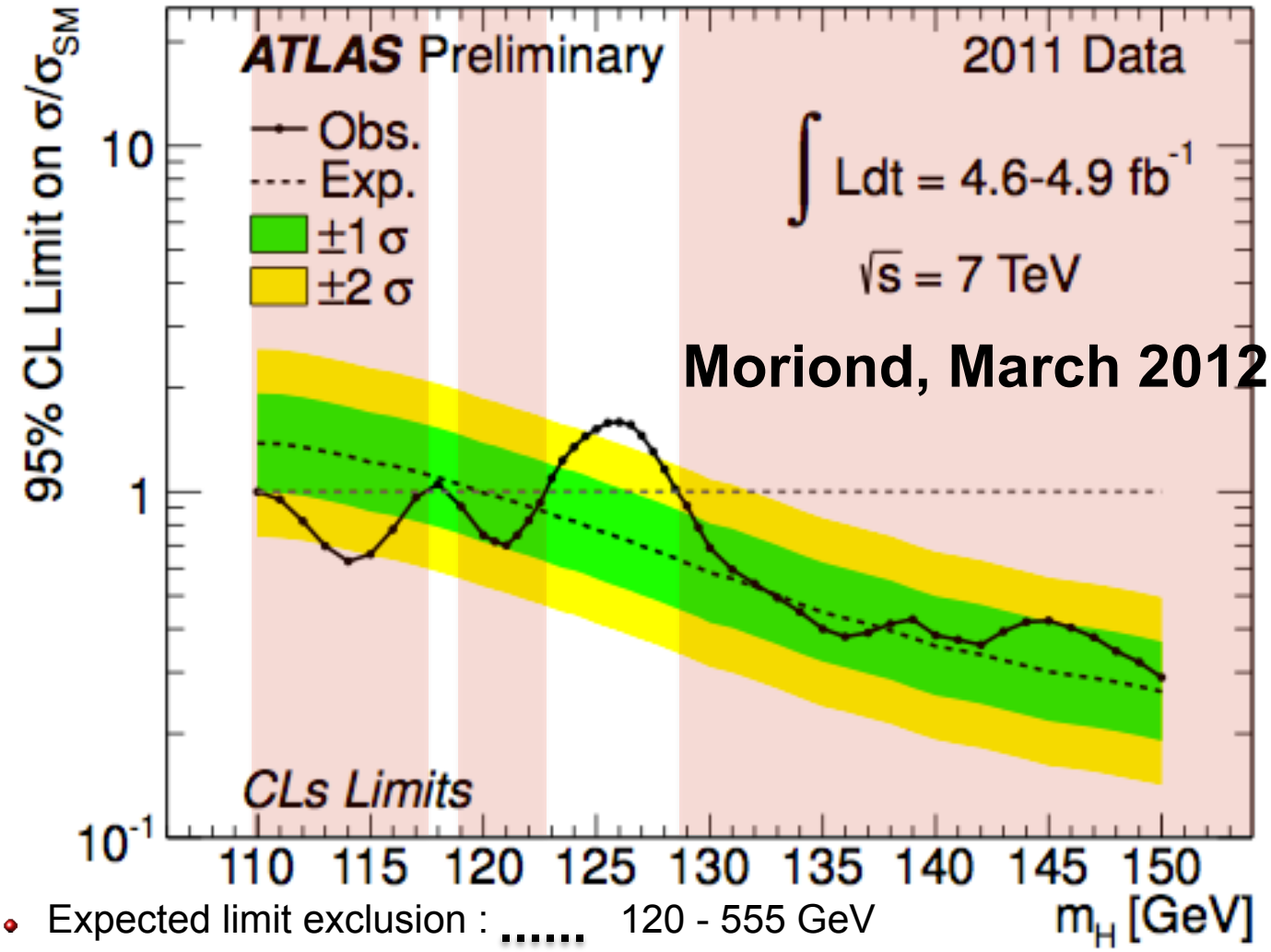
SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :



SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with all 2011 data (Moriond 2012) :



- Expected limit exclusion : ..... 120 - 555 GeV
- Observed limit exclusion : ____ 110.0–117.5 GeV and 118.5-122.5 GeV and 129–529 GeV

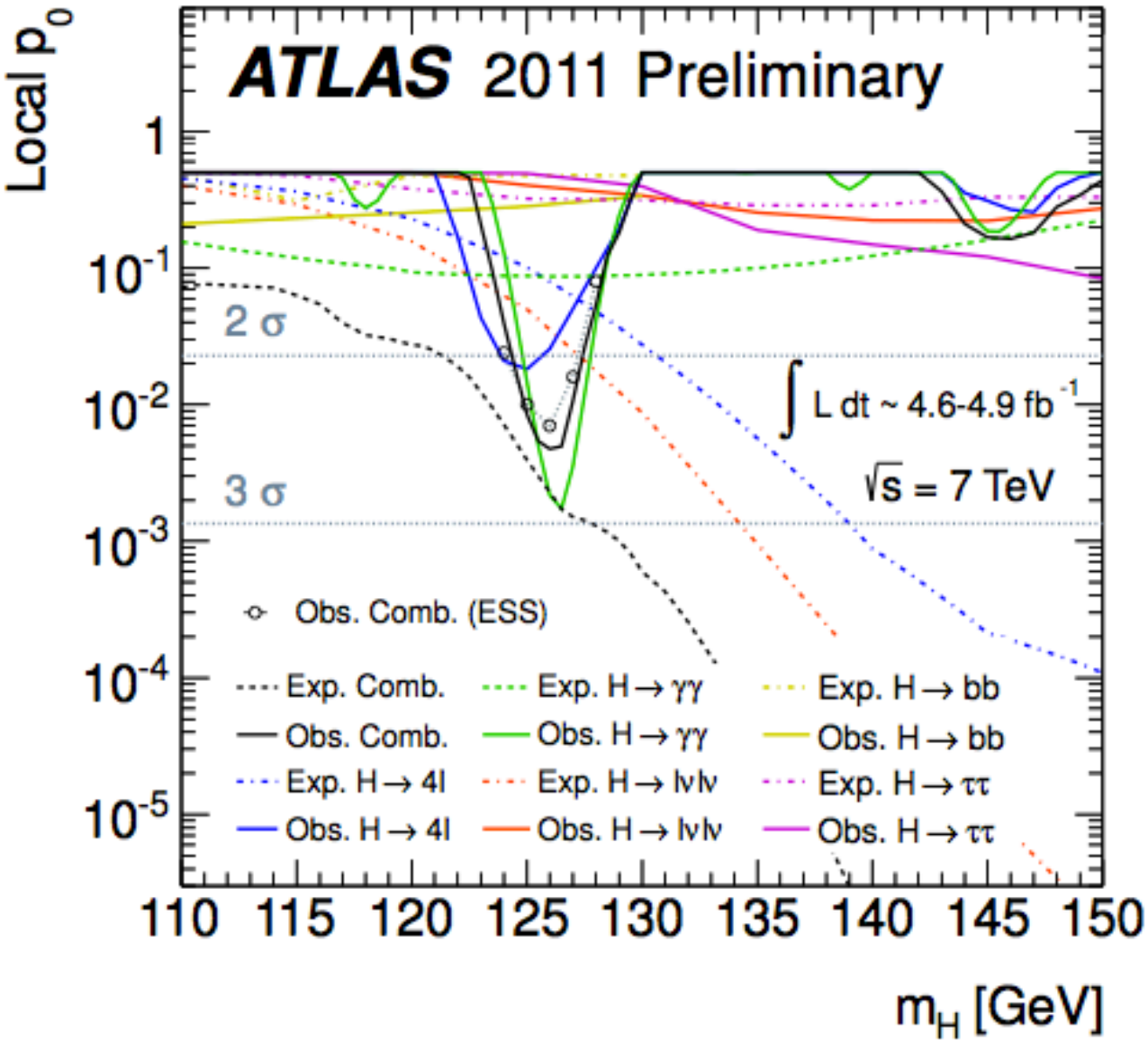
SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :

Higgs Decay	Subsequent Decay	Additional Sub-Channels	m_H Range	L [fb^{-1}]
$H \to \gamma\gamma$	–	9 sub-channels ($p_T^{\text{thrust}} \otimes \eta_\gamma \otimes$ conversion)	110-150	4.9
$H \to ZZ$	$\ell\ell\ell'\ell'$	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	110-600	4.8
	$\ell\ell\nu\bar{\nu}$	$\{ee, \mu\mu\} \otimes$ {low pile-up, high pile-up}	200-280-600	4.7
	$\ell\ell q\bar{q}$	$\{b$-tagged, untagged$\}$	200-300-600	4.7
$H \to WW$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu\mu\} \otimes$ {0-jet, 1-jet, VBF}	110-300-600	4.7
	$\ell\nu q\bar{q}'$	$\{e, \mu\} \otimes$ {0-jet, 1-jet}	300-600	4.7
$H \to \tau^+\tau^-$	$\ell\ell 4\nu$	$\{e\mu\} \otimes$ {0-jet} $\oplus$ {1-jet, VBF, VH}	110-150	4.7
	$\ell\tau_{\text{had}}3\nu$	$\{e, \mu\} \otimes$ {0-jet} $\otimes \{E_T^{\text{miss}} \gtrless 20$ GeV$\}$ $\oplus \{e, \mu\} \otimes$ {1-jet, VBF}	110-150	4.7
	$\tau_{\text{had}}\tau_{\text{had}}2\nu$	{1-jet}	110-150	4.7
$VH \to b\bar{b}$	$Z \to \nu\bar{\nu}$	$E_T^{\text{miss}} \in \{[120, 160), [160, 200), \geq 200$ GeV$\}$	110-130	4.6
	$W \to \ell\nu$	$p_T^W \in \{< 50, 50-100, 100-200, \geq 200$ GeV$\}$	110-130	4.7
	$Z \to \ell\ell$	$p_T^Z \in \{< 50, 50-100, 100-200, \geq 200$ GeV$\}$	110-130	4.7

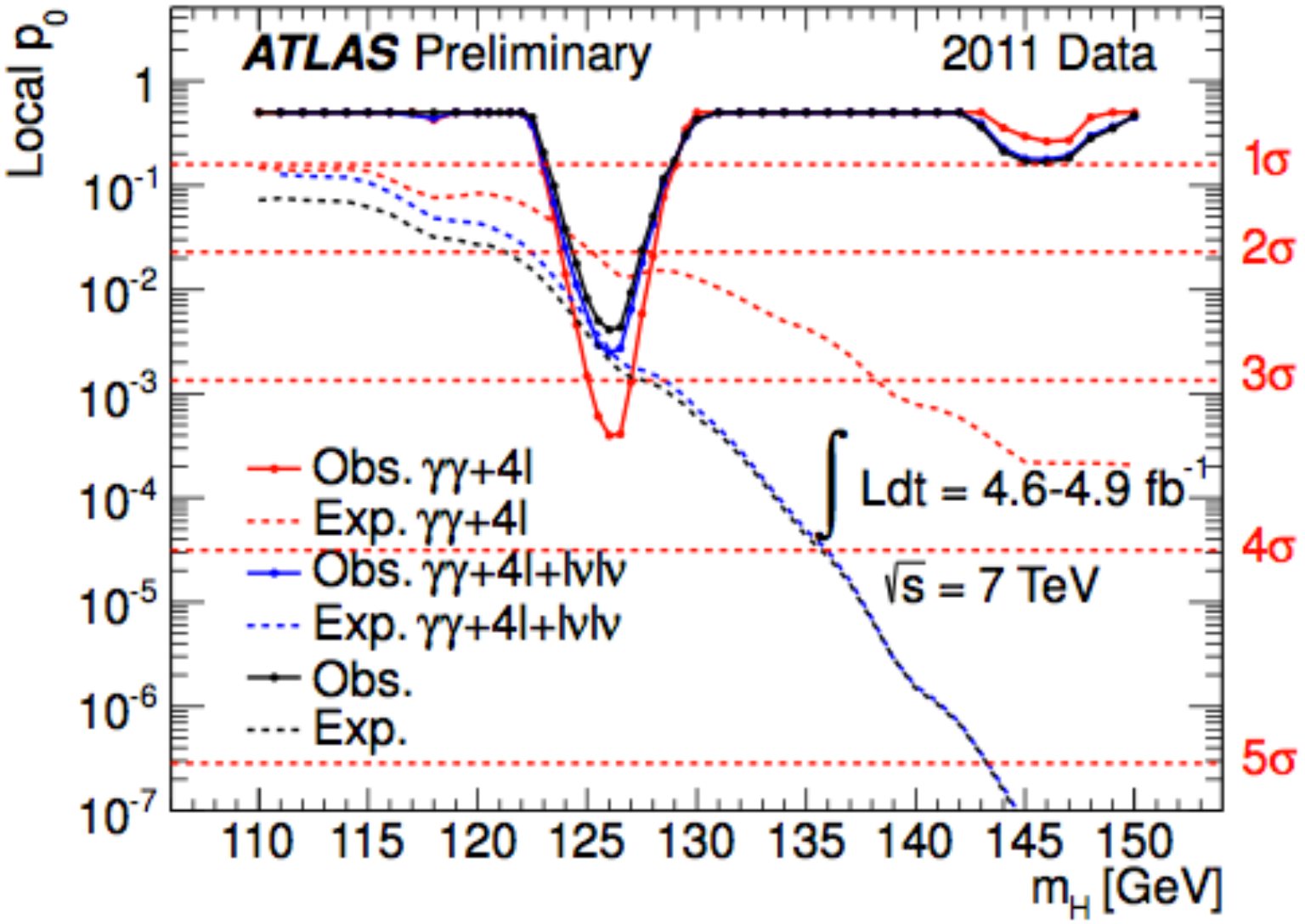
SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :



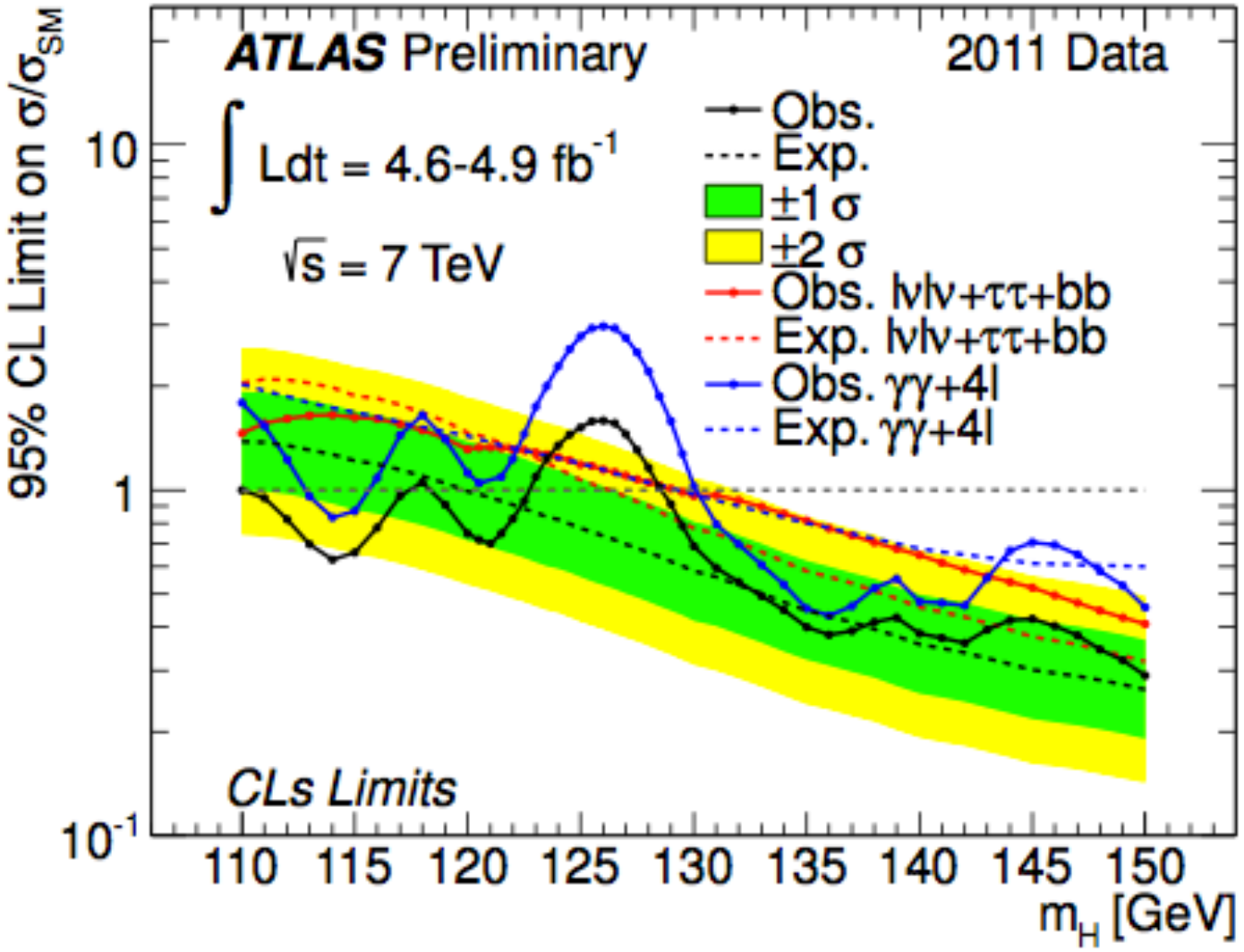
SM HIGGS COMBINATION AT ATLAS

SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :



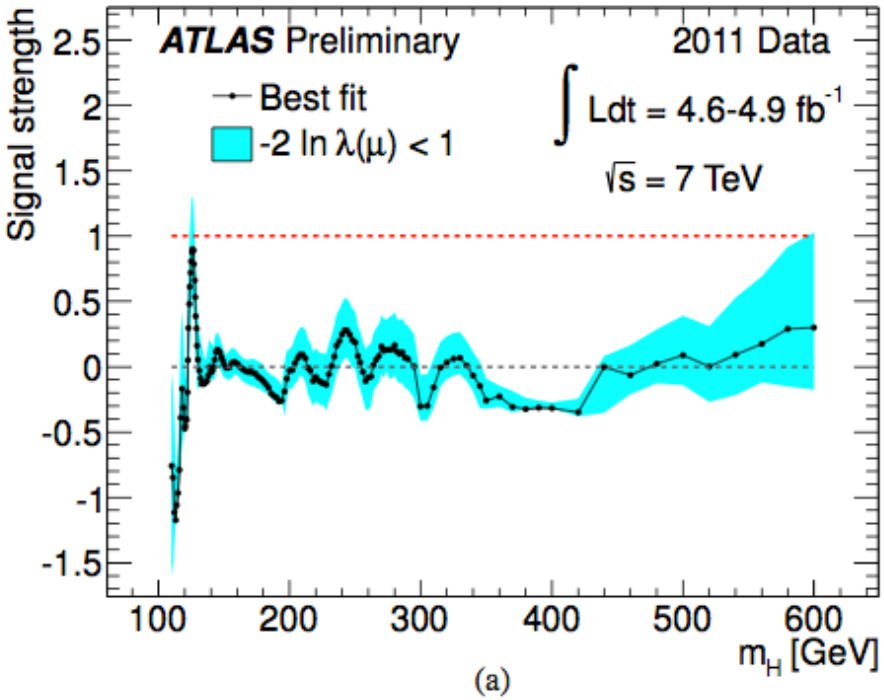
SM HIGGS COMBINATION AT ATLAS

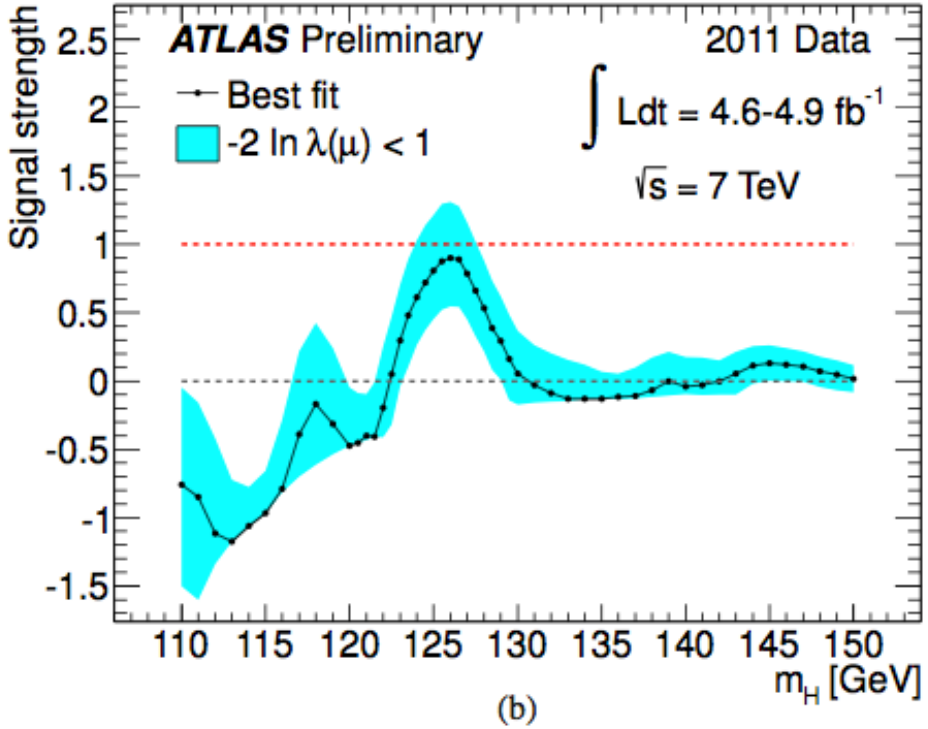
SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :



SM HIGGS COMBINATION AT ATLAS

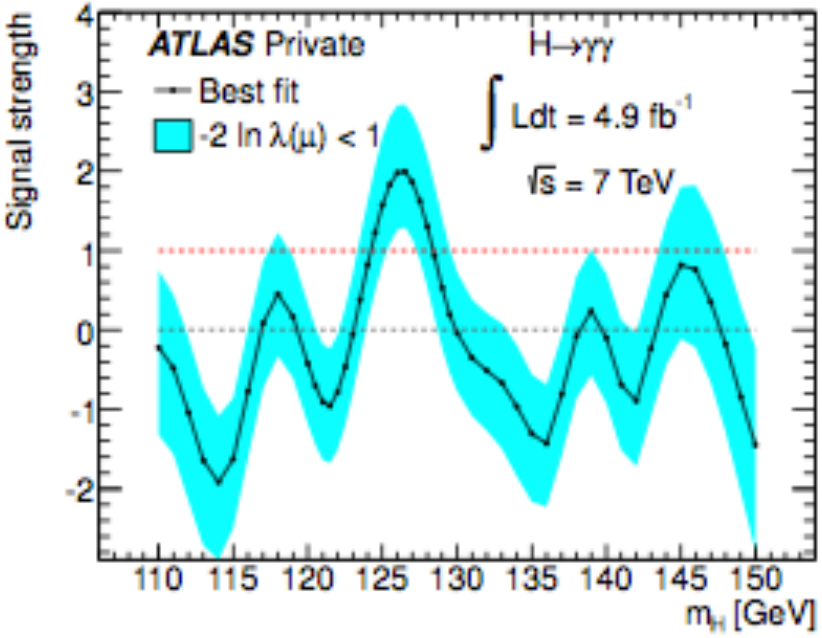
SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :

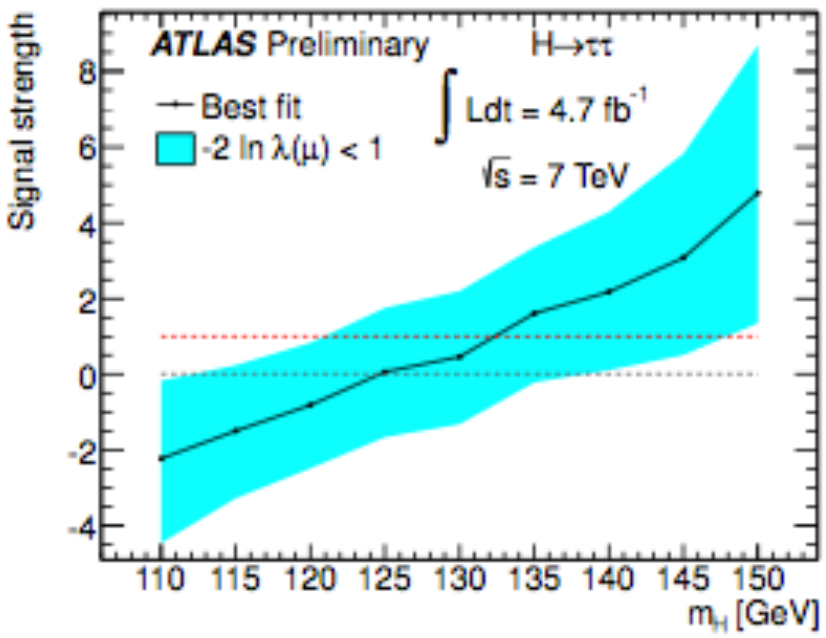




SM HIGGS COMBINATION AT ATLAS

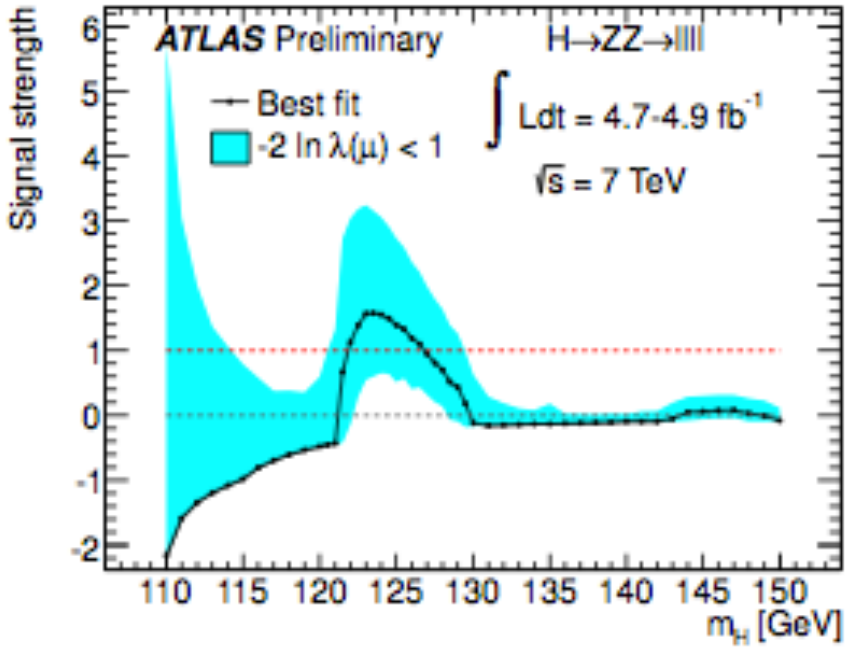
SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :

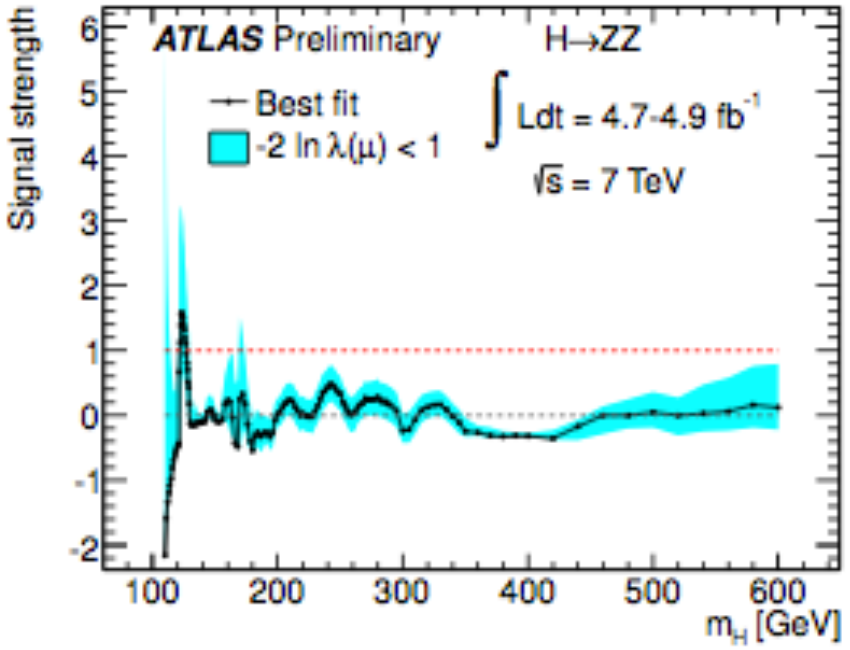




SM HIGGS COMBINATION AT ATLAS

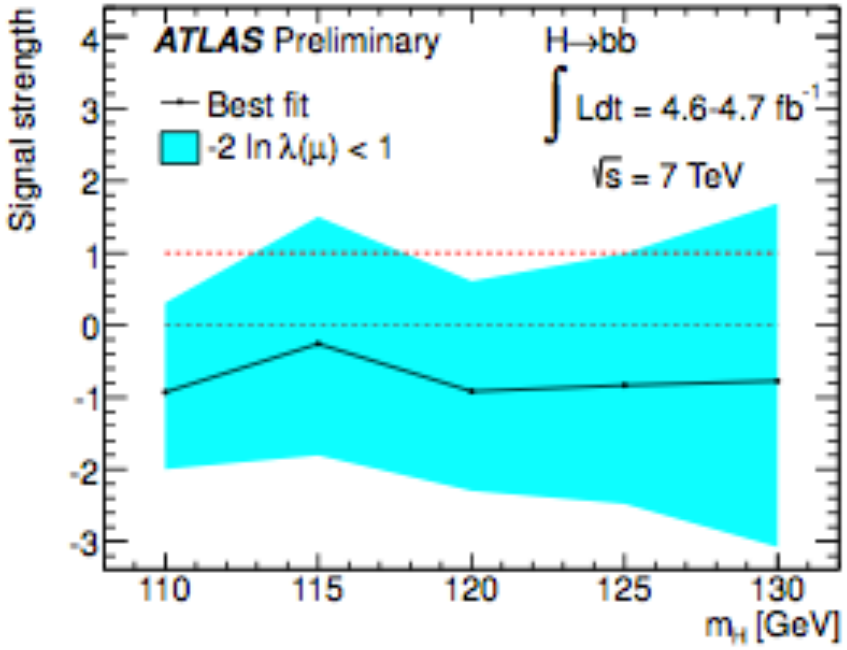
SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :

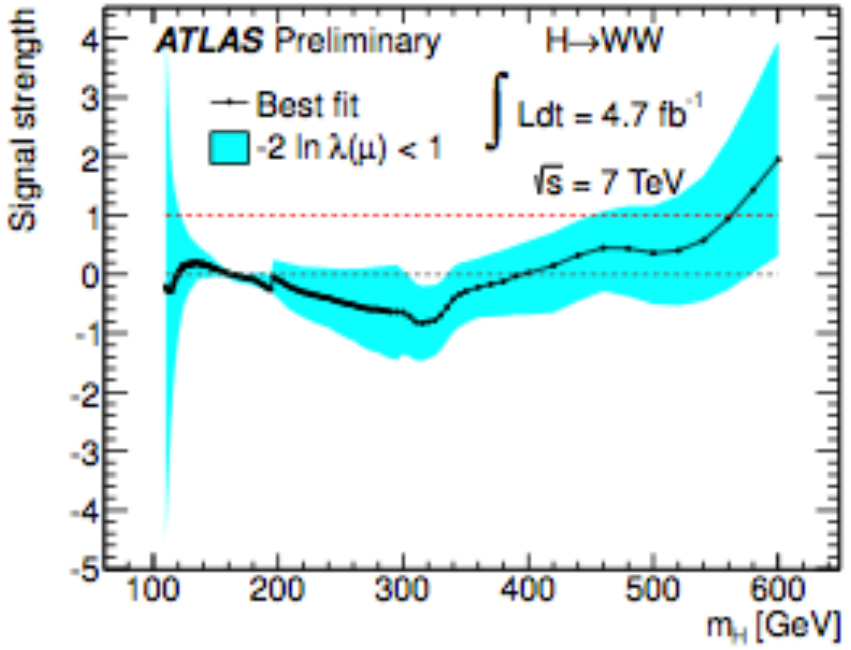




SM HIGGS COMBINATION AT ATLAS

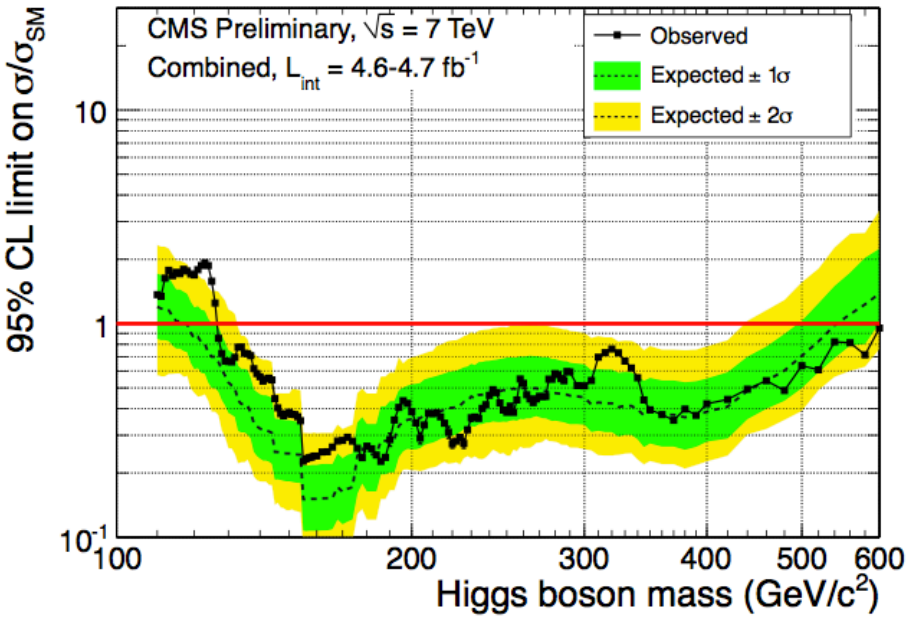
SM Higgs Combination at ATLAS with 2011 data (Moriond 2012) :

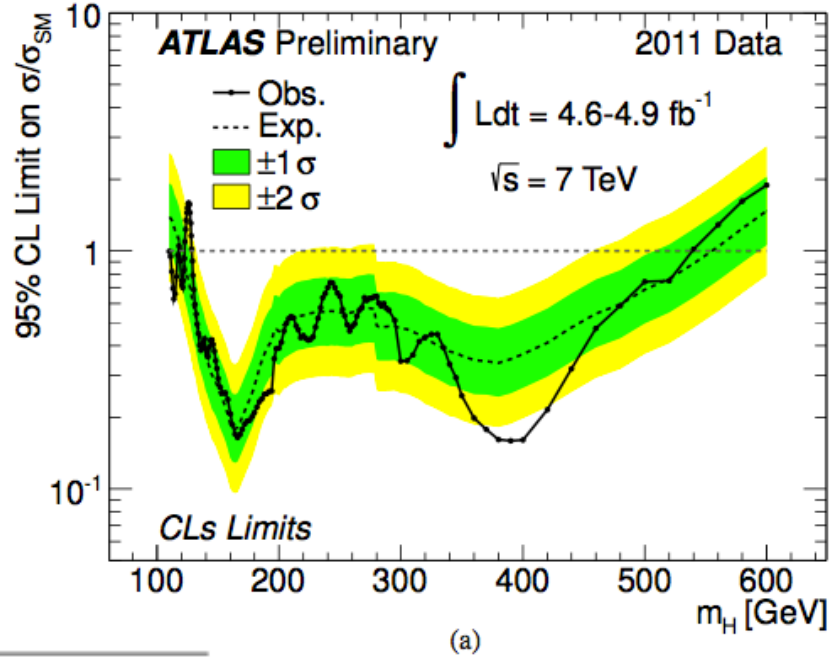




SM HIGGS COMBINATION AT ATLAS VS CMS

SM Higgs Combination at ATLAS vs CMS with 2011 data (Moriond 2012) :





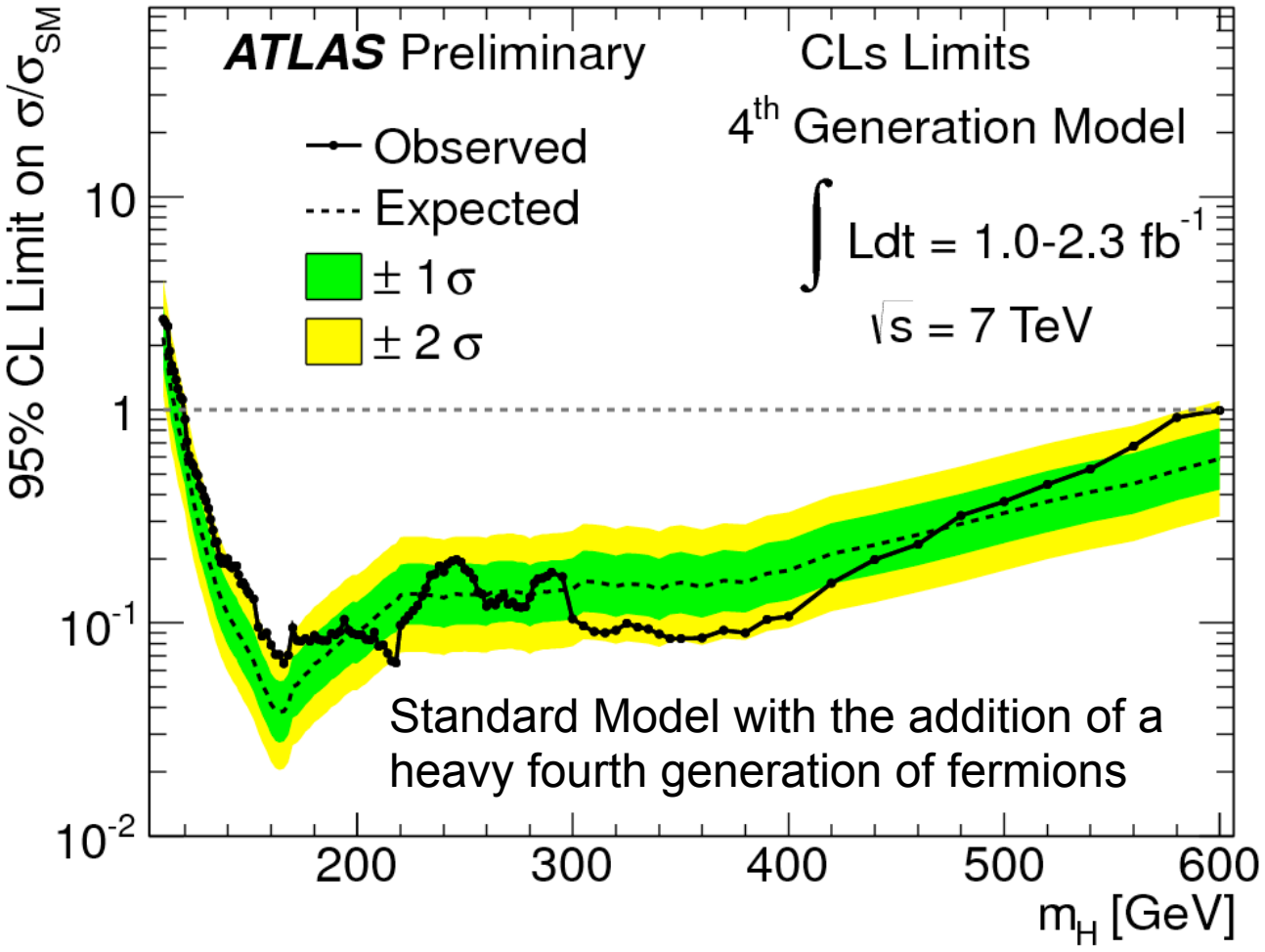
(a)

Channel	m_H range (GeV/c^2)	Lumi (fb^{-1})	sub-channels	m_H resolution
$H \to \gamma\gamma$	110 – 150	4.7	4	1–3%
$H \to \tau\tau$	110 – 145	4.6	9	20%
$H \to bb$	110 – 135	4.7	5	10%
$H \to WW \to \ell\nu\ell\nu$	110 – 600	4.6	5	20%
$H \to ZZ \to 4\ell$	110 – 600	4.7	3	1–2%
$H \to ZZ \to 2\ell 2\tau$	190 – 600	4.7	8	10–15%
$H \to ZZ \to 2\ell 2\nu$	250 – 600	4.6	2	7%
$H \to ZZ \to 2\ell 2q$	130 – 164 200 – 600	4.6	6	3%

HEAVY FOURTH GENERATION

ATLAS SM Higgs Combination with the addition of a 4th generation of fermions :

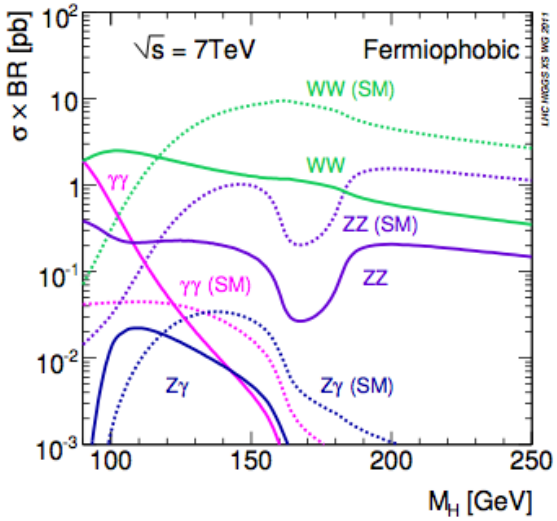
- Expected exclusion : 116 - 600 GeV
- Observed exclusion : 119 - 593 GeV

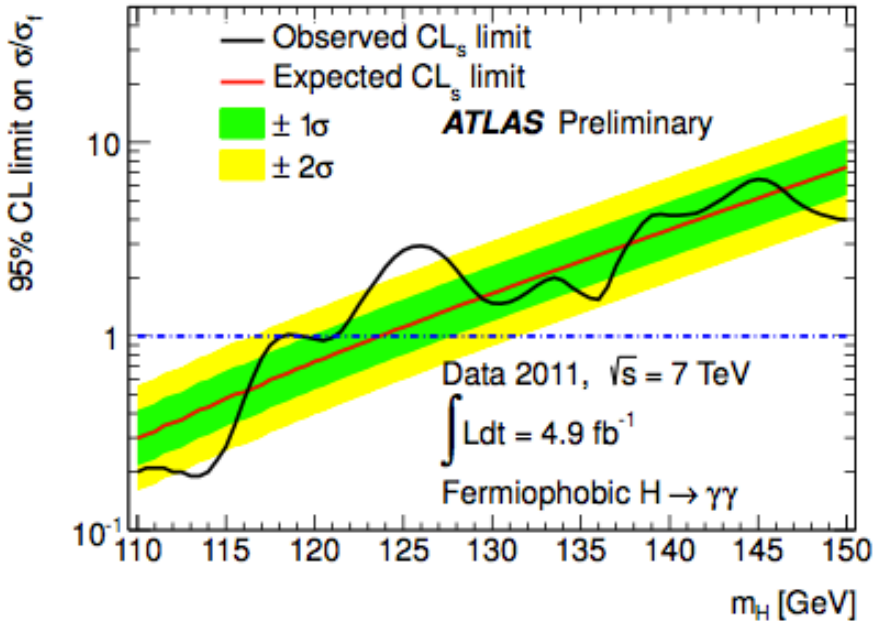


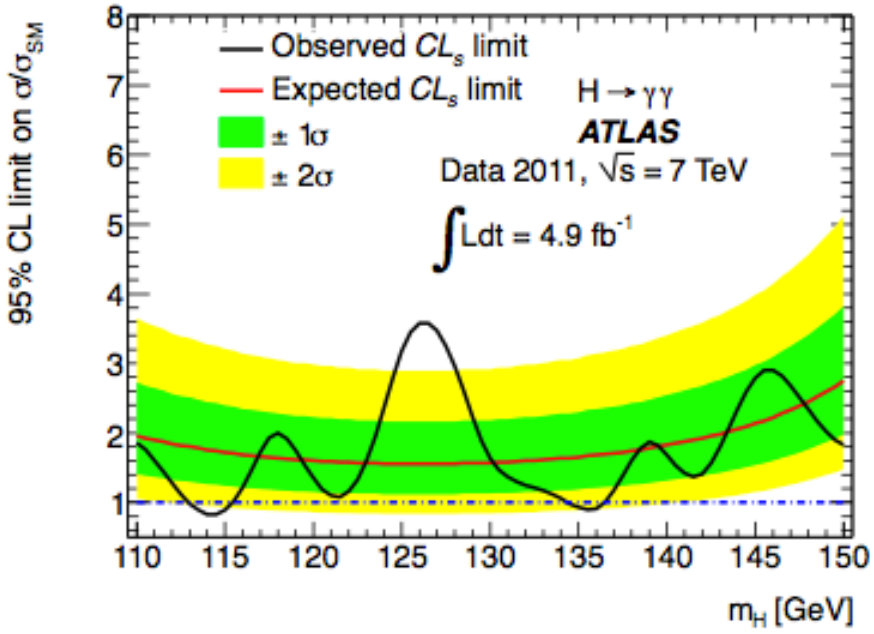
FERMIOPHOBIC HIGGS

Fermiophobic Higgs at ATLAS with 2011 data (Moriond 2012):

A fermiophobic benchmark model, in which the Higgs field couplings to all fermions are set to zero while the couplings to bosons are kept at their SM values

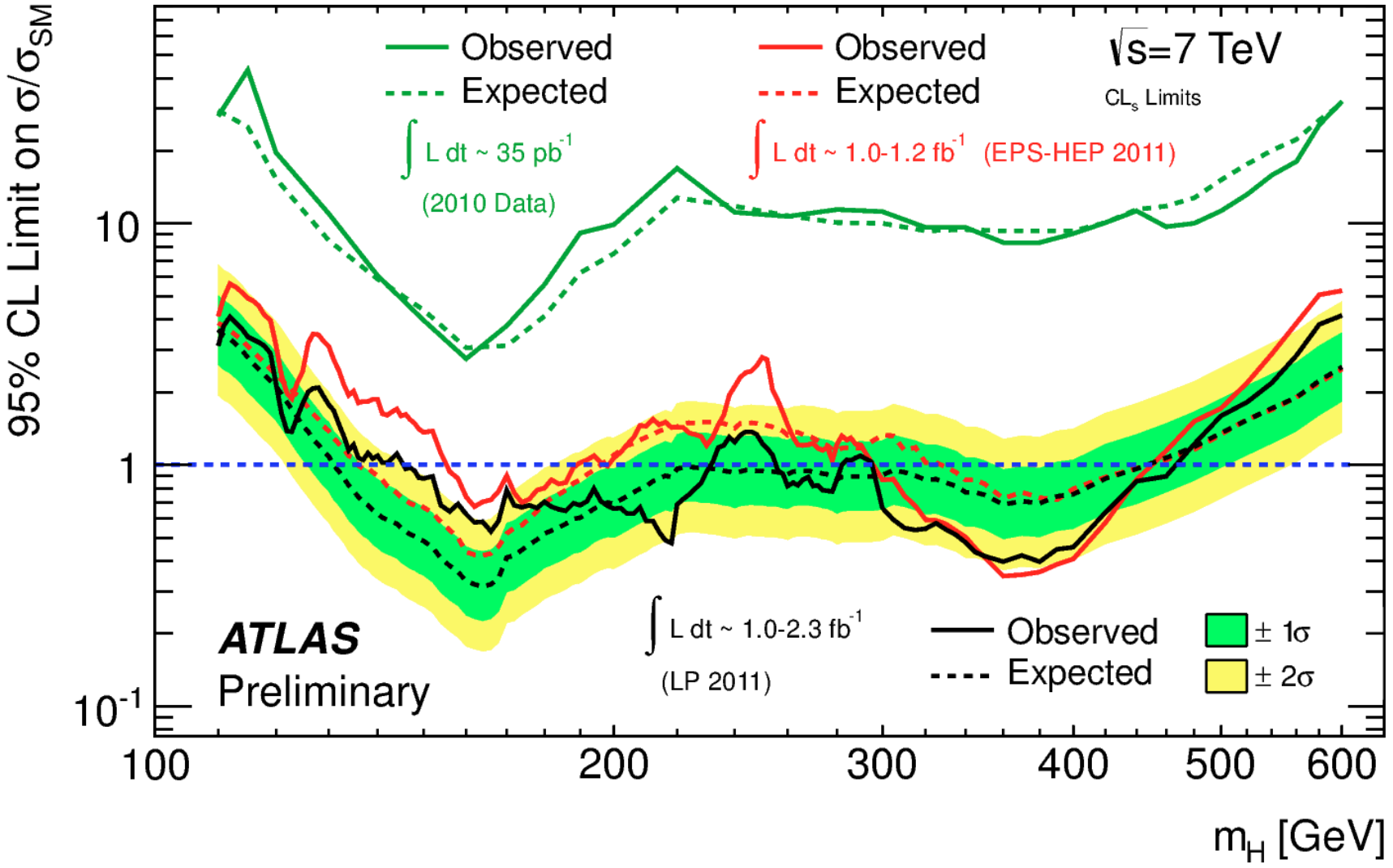






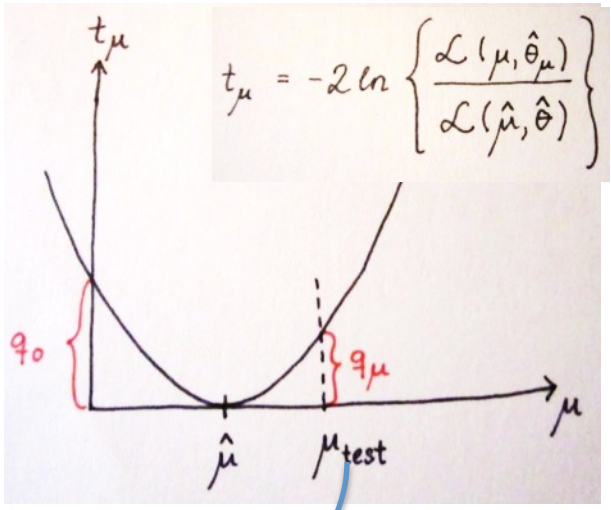
SM HIGGS COMBINATION AT ATLAS

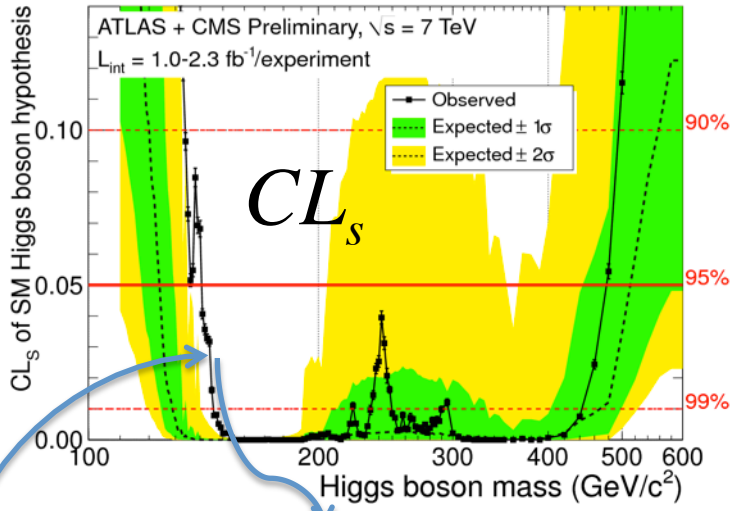
SM Higgs Combination at ATLAS with 2011 data (LP 2011) :



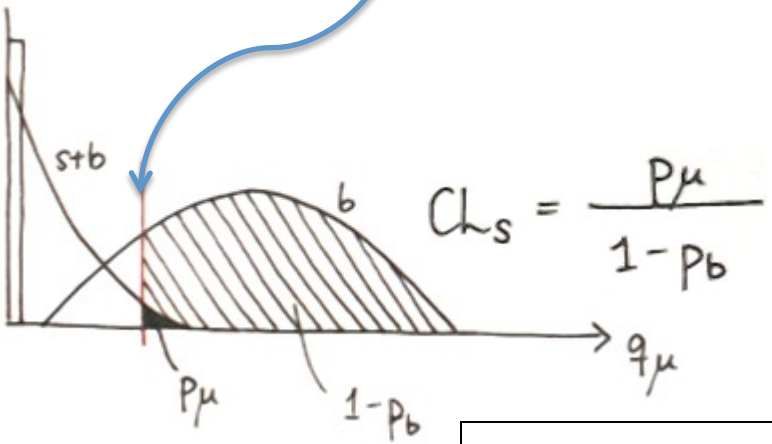
PROFILE LIKELIHOOD RATIO

Profile likelihood ratio: CLs and μ^{up}_{95} :





$$\mu_{95}^{up} = \mu(CL_s = 0.05)$$



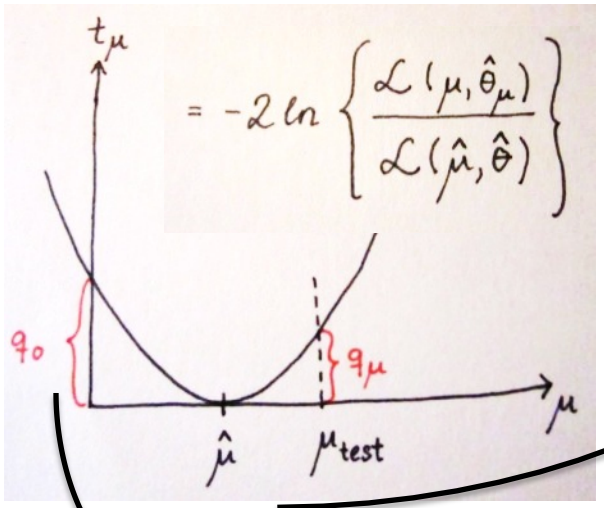
μ_{95}^{up}

p_μ : test signal+background
CL_s : ~test signal

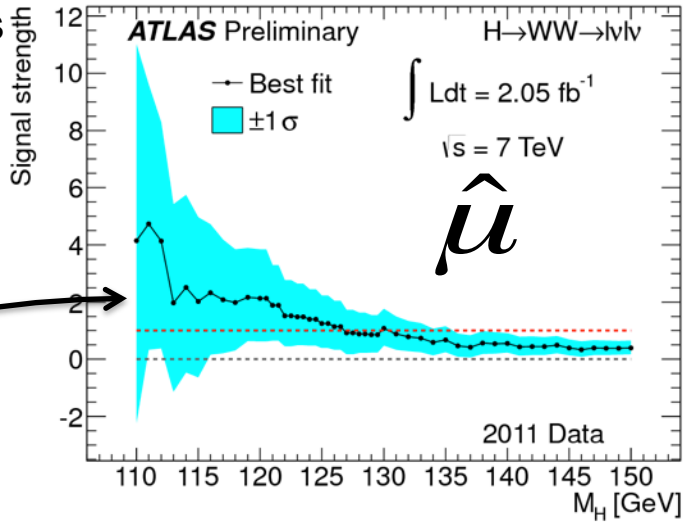
PROFILE LIKELIHOOD RATIO

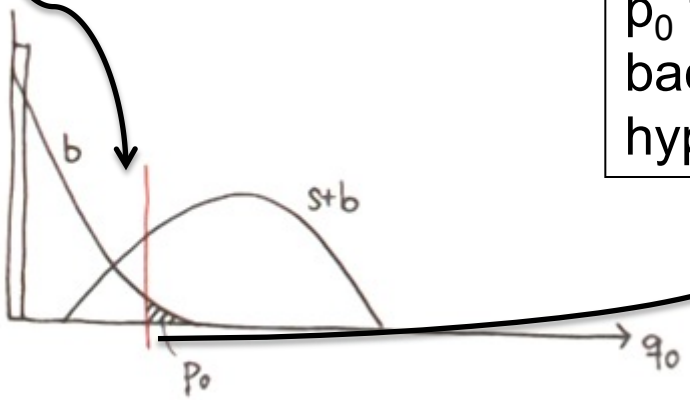
Profile likelihood ratio: p_0 and $\hat{\mu}$:

- The observed local p-value characterize probabilities for the predicted background to fluctuate at least as high as the observed excesses

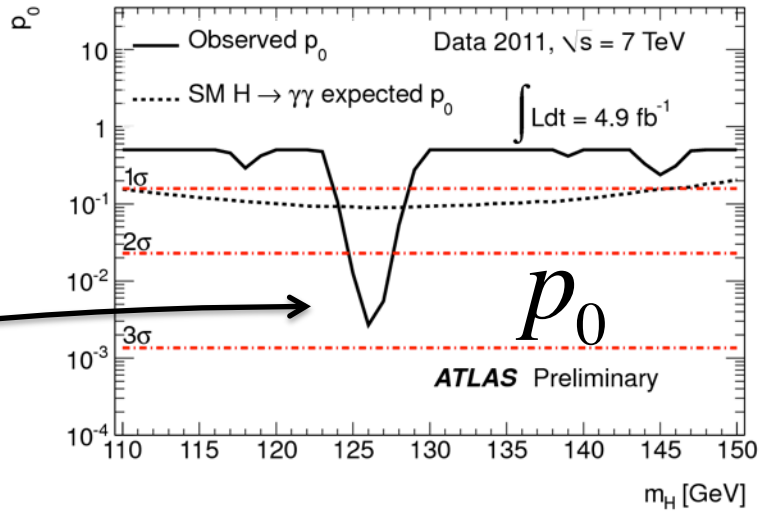


$\hat{\mu}$ to estimate signal strength





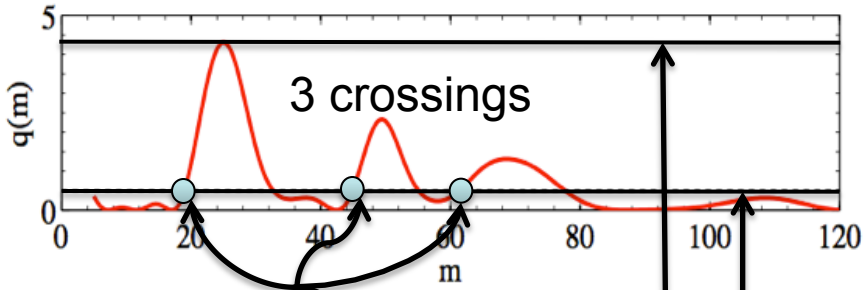
p_0 to test background hypothesis



LOOK-ELSEWHERE EFFECT (LEE)

Look-elsewhere effect (LEE) :

- We need to calculate the chance of observing a statistical fluctuation as large as or larger than that in our data, in this larger class of searches.
  This is the Look Elsewhere Effect (LEE)



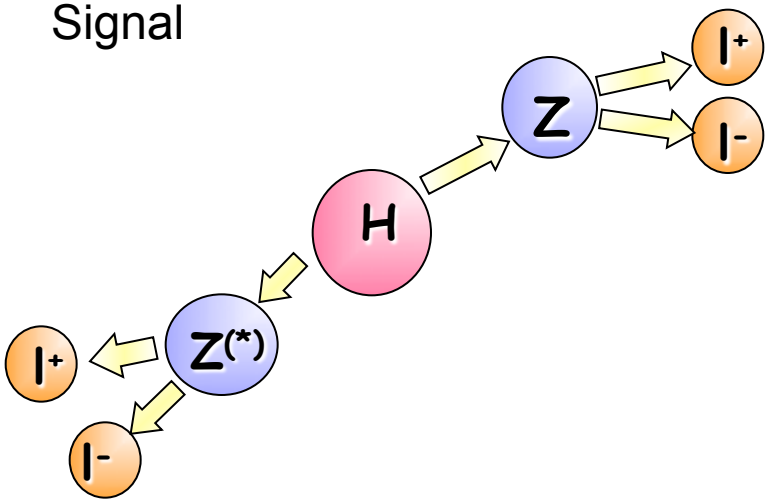
$$q_{test} = 2 \cdot \log(L(m))$$

$$p_0^{global} \cong p_0^{local} + \left\langle N(q_{ref}) \right\rangle e^{-(q_{test} - q_{ref})/2}$$

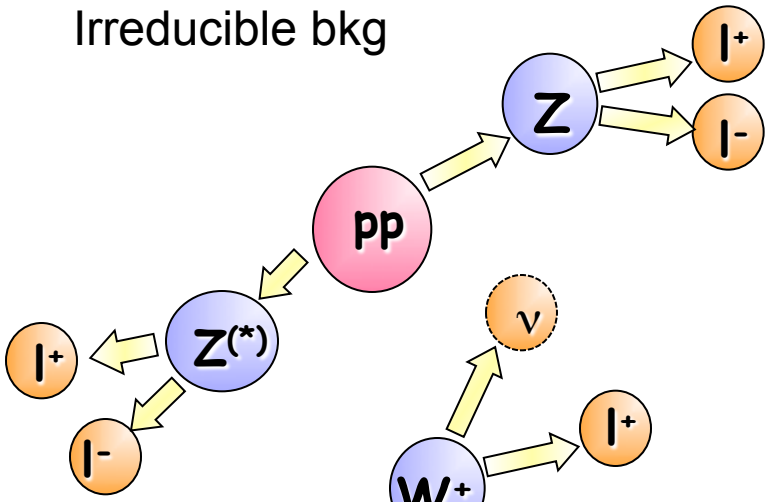
- Note: Approximation best above 3σ
  Example:
  - q_{test}= 4.5 (2.1σ)
  - 3 crossings at 0.5σ
  - Local significance of 2.1σ reduced to global significance of about 0.3σ
  - trials factor $p_0^{global} / p_0^{local} \cong 22$

SIGNAL AND BACKGROUND

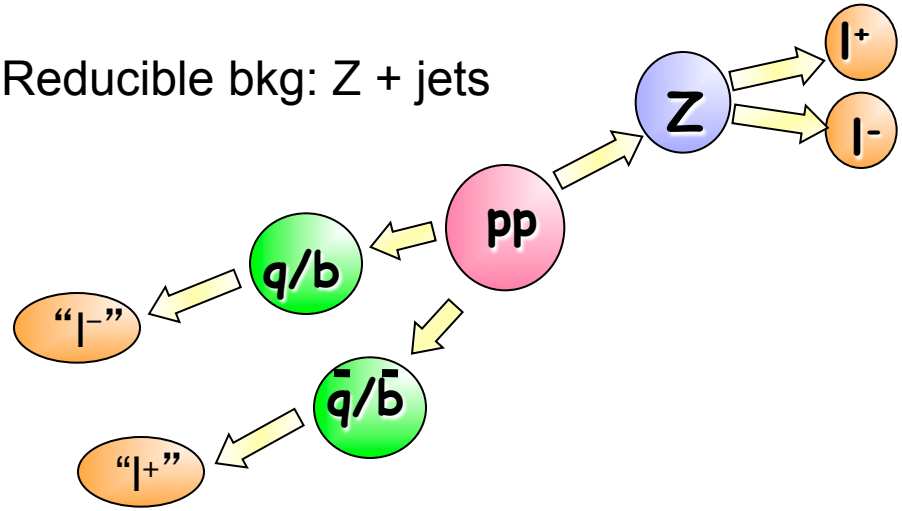
Signal

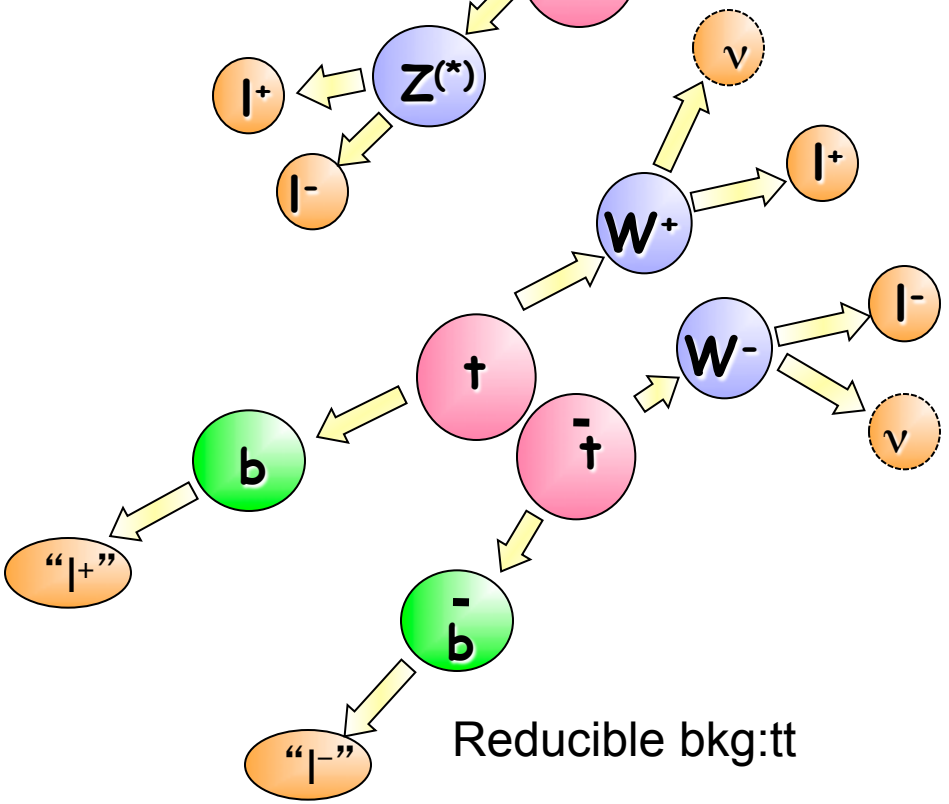


Irreducible bkg



Reducible bkg: Z + jets

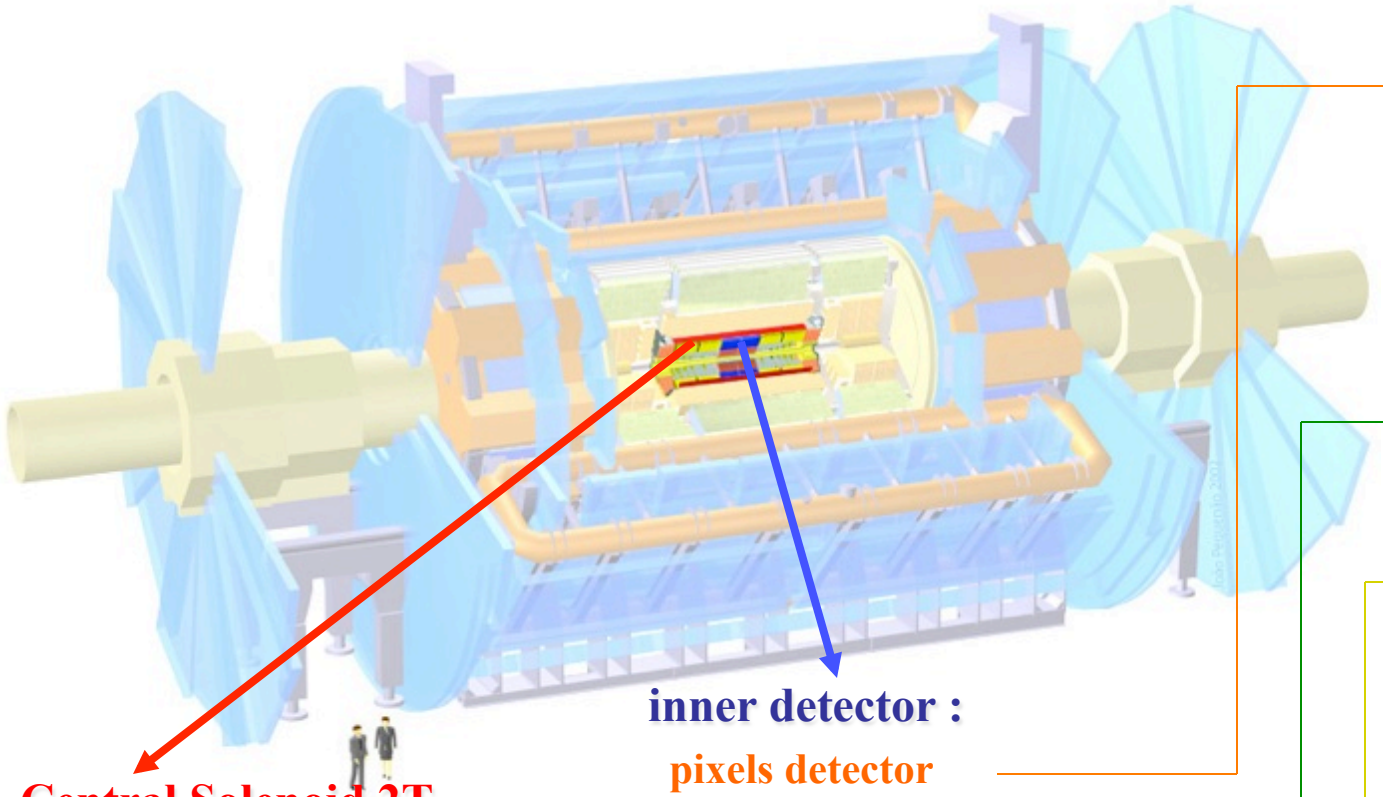


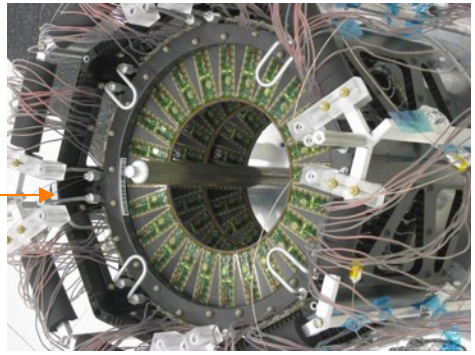


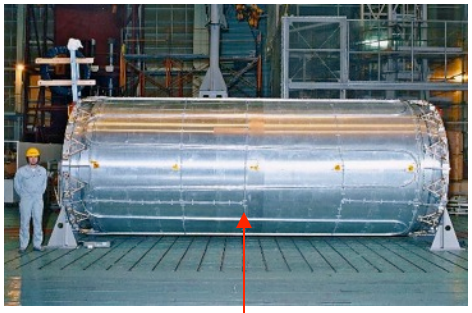
Reducible bkg:tt

- **Impulsion resolution :**

  $\sigma(p)/p = 0.05\ \%\ p\ (GeV) \oplus 1\%$ for $|\eta|<2.5$







inner detector :

pixels detector

SCT (Semi-Conductor Tracker)

TRT (Transition Radiation Tracker)

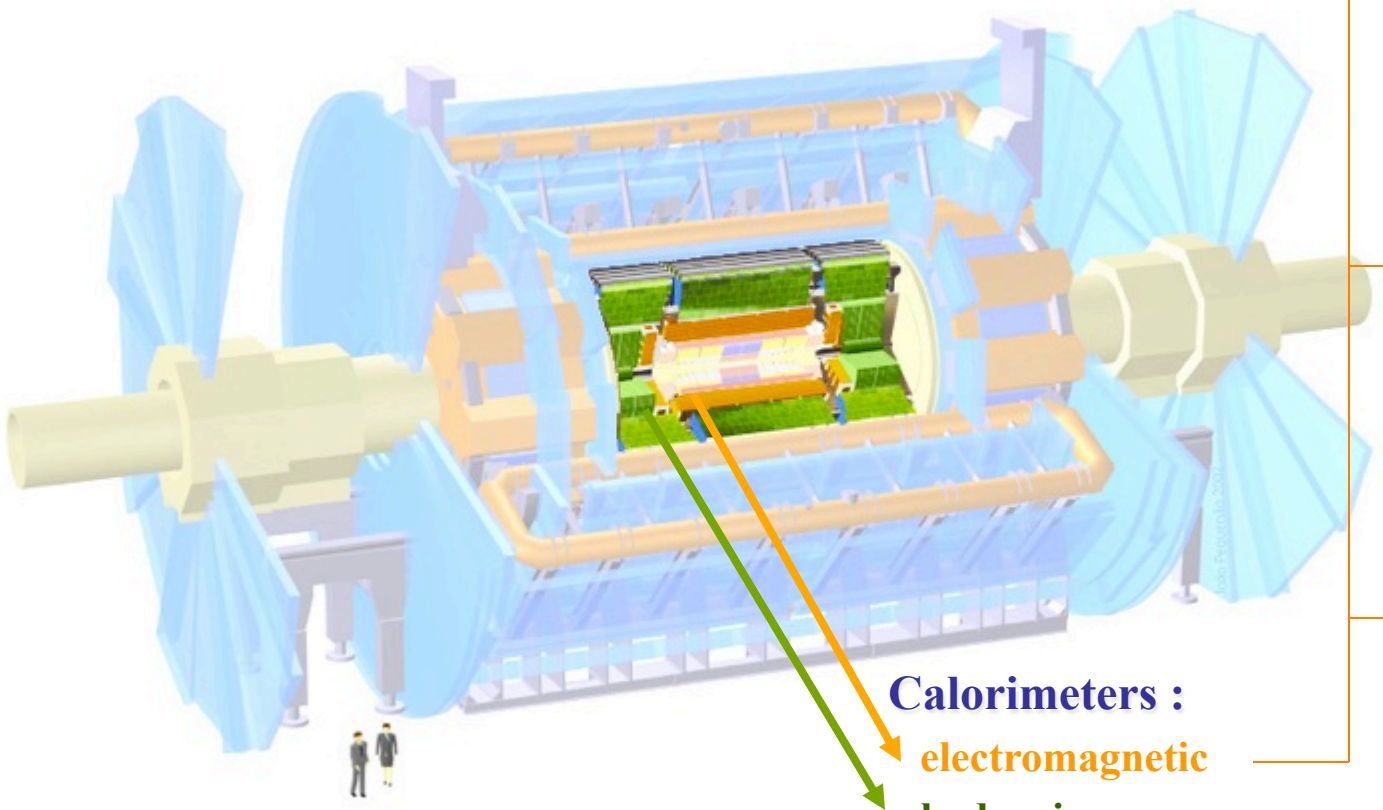
Central Solenoid 2T

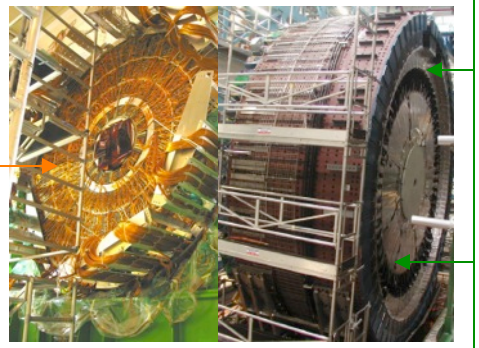
- **Energy resolution (GeV) :**

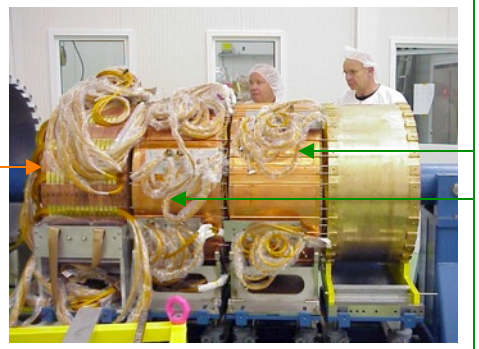
  electromagnetic : $\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.3/E \oplus 0.7\%$ for $|\eta|<3.2$

  hadronic : $\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\%$ for $|\eta|<3$

  : $\sigma(E)/E = 100\%/\sqrt{E} \oplus 5\%$ for $3<|\eta|<5$







Calorimeters :

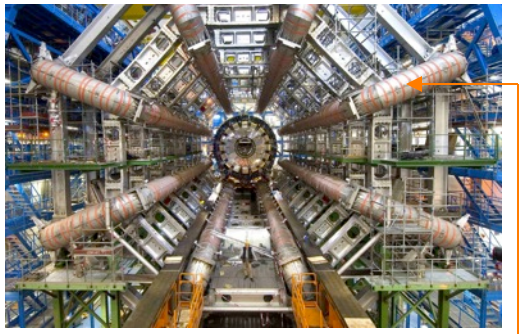
electromagnetic

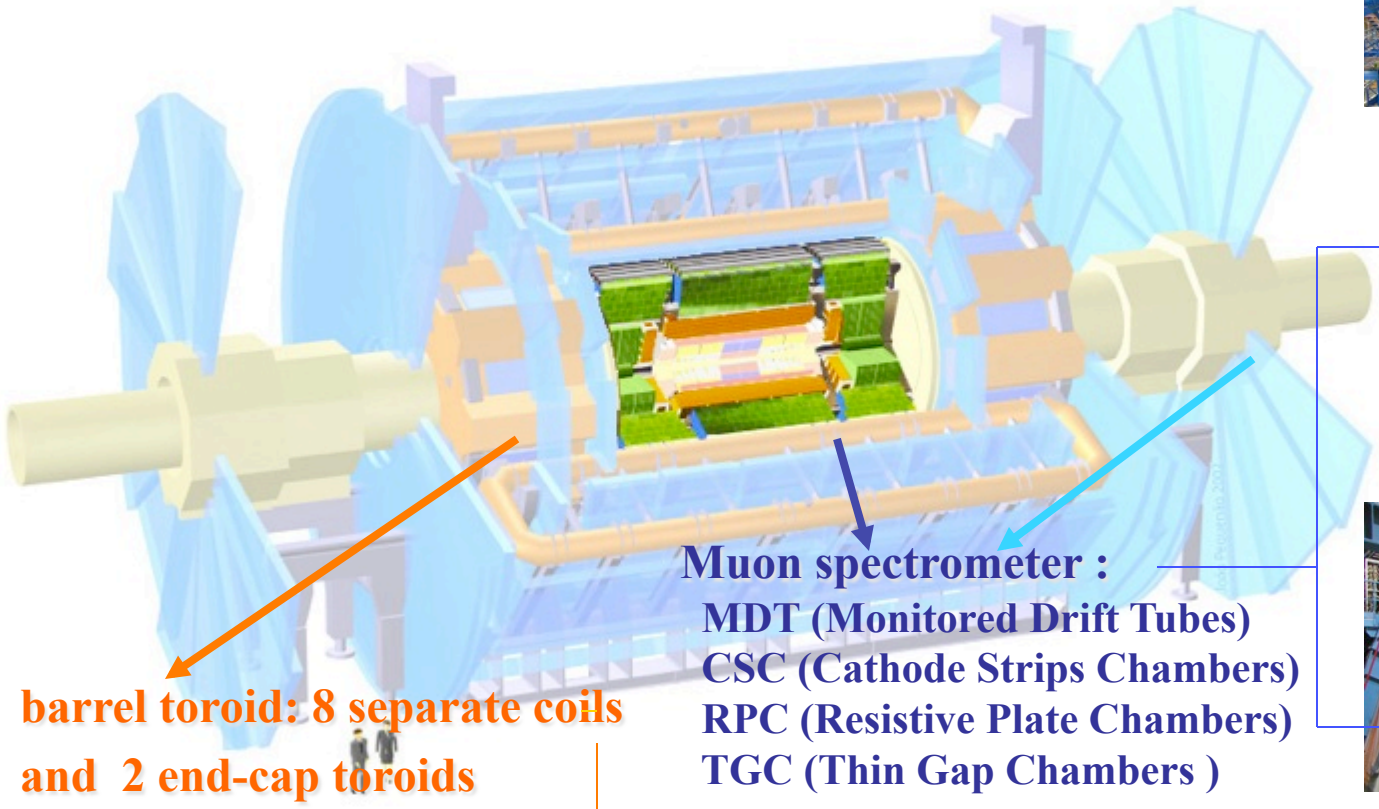
hadronic

- **Impulsion resolution :**

  $\sigma(p_T)/p_T < 3\%$ for $10<p_T<250$ GeV and for $|\eta|<2.7$

  $\sigma(p_T)/p_T = 10\%$ at1 TeV





barrel toroid: 8 separate coils and 2 end-cap toroids

Muon spectrometer :
- MDT (Monitored Drift Tubes)
- CSC (Cathode Strips Chambers)
- RPC (Resistive Plate Chambers)
- TGC (Thin Gap Chambers)