Happy New Year 2012 !

Recent search for the Higgs boson by the Atlas experiment with 2011 data

Abstract :

Atlas experiment recorded up to 4.9 fb^{-1} of data in 2011 at an energy in the center of mass of 7 TeV. Recent searches for Higgs boson in scenario of Standard Model are reported.

Disclaimer : Focus mainly on three channels : $H \rightarrow \gamma\gamma$, $H \rightarrow 4l$, $H \rightarrow WW^{(*)} \rightarrow l\nu\, l\nu$ and combination ; remaining channels in backup

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Constraints on Higgs mass

High mass constraints

- Unitarity (scattering $W_L W_L$) $m_H < 700$ GeV
- Triviality ($\lambda(Q)$) $m_H < 750$ GeV

Low mass constraints

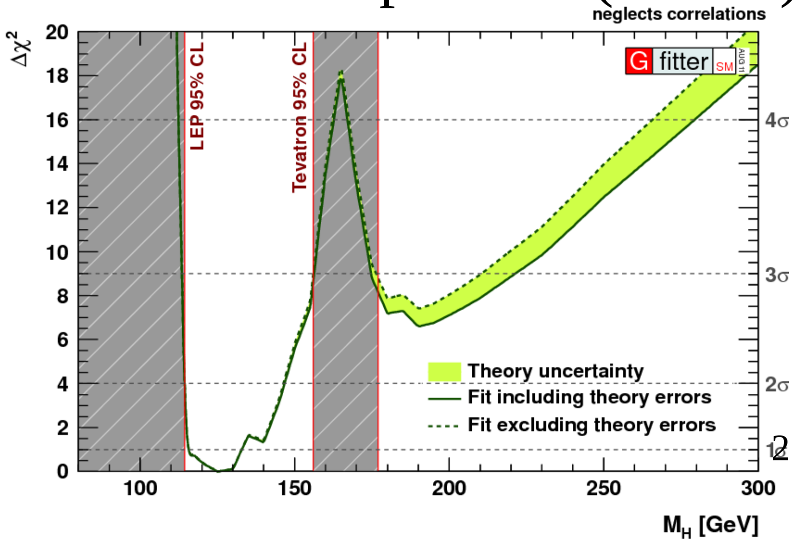
- vacuum stability $\lambda(m_t) > 0$
  - $m_H > 139$ GeV ($m_t = 178.1$ GeV) ($\Lambda = 10^{16}$ GeV)
  - $m_H > 74$ GeV ($\Lambda = 1$ TeV)

Experimental constraints

- LEP direct search :
  $m_H > 114.4$ GeV (95% CL)
- Tevatron direct seearch :
  [156 ; 177 GeV] excluded
- indirect search : global analysis electroweak observ.
- $m_H = 125^{+8}_{-10}$ GeV (68 % CL)

→Gfitter : LEP2, SLD, Tevatron and LHC
(only 40 pb^{-1} of LHC) ⟶

complete fit (+ LEP)



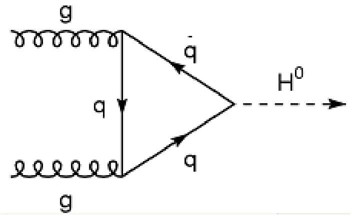
SM Higgs production

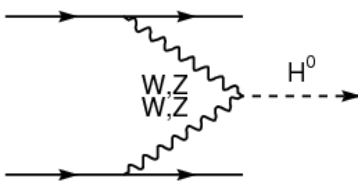
- SM Higgs production

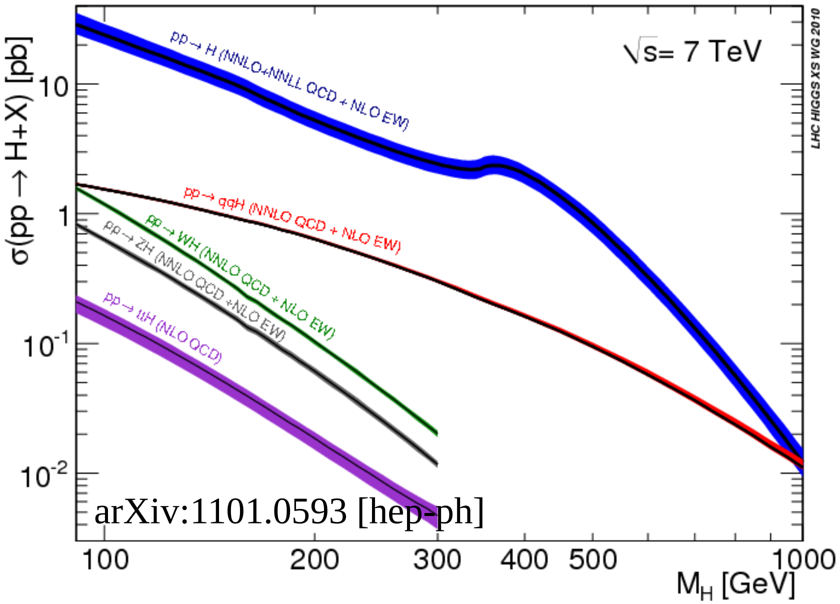
-gg fusion dominant

-VBF : ↑ with m_H

-Associated production : W/Z H, ttH







Yellow book : arXiv:1101.0593 [hep-ph]

-ggH NNLO, NNLL, NLO EW

uncert. : $^{+15}_{-20}$ % (pdf &scale separated)

-VBF NLO ; uncert. : 5 %

-WH NNLO ; uncert. : 5 %

-ZH NNLO ; uncert. : 5 %

-ttH NLO, 5 %

Decays and channels (SM)

H decays roughly to heaviest particle available in phase space

- SM Higgs decay

-H→γγ : low BR/clean

-H→WW dominant

-H→ZZ

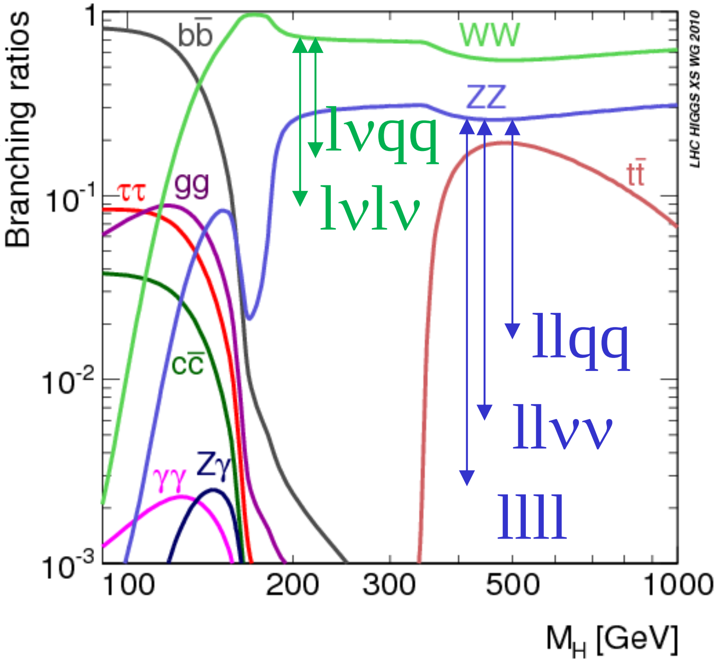
Br(W→lν) : 0.33

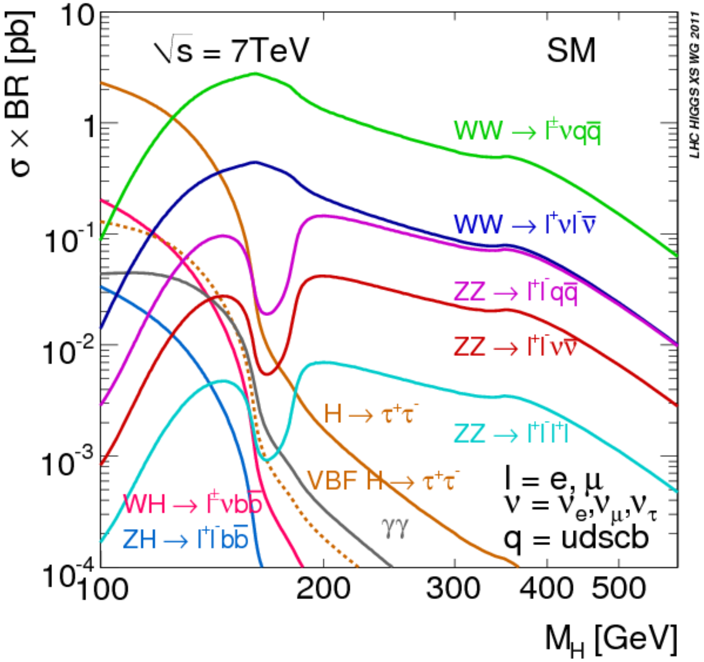
Br(W→jj) : 0.67

Br(Z→ll) : 0.1

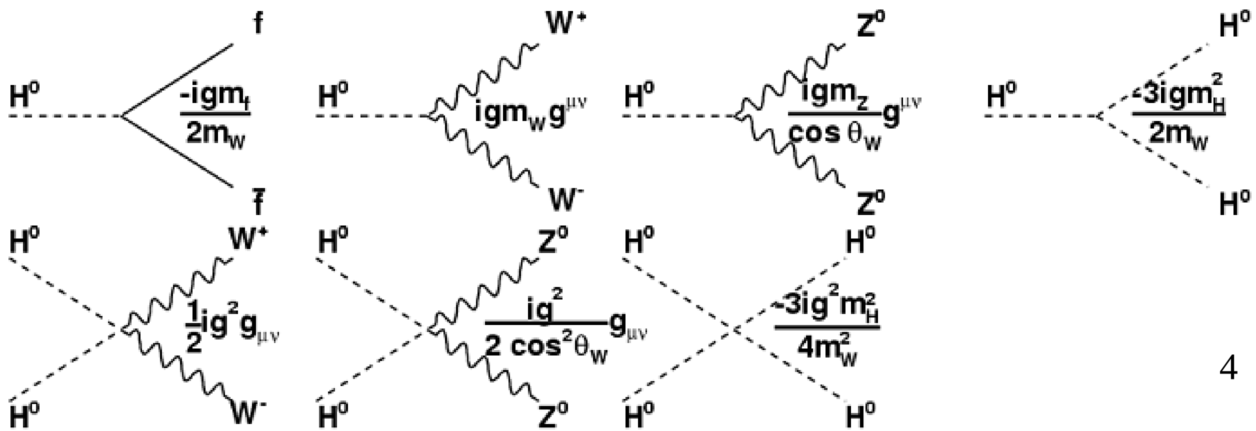
Br(Z→νν) : 0.2

Br(Z→jj) : 0.7





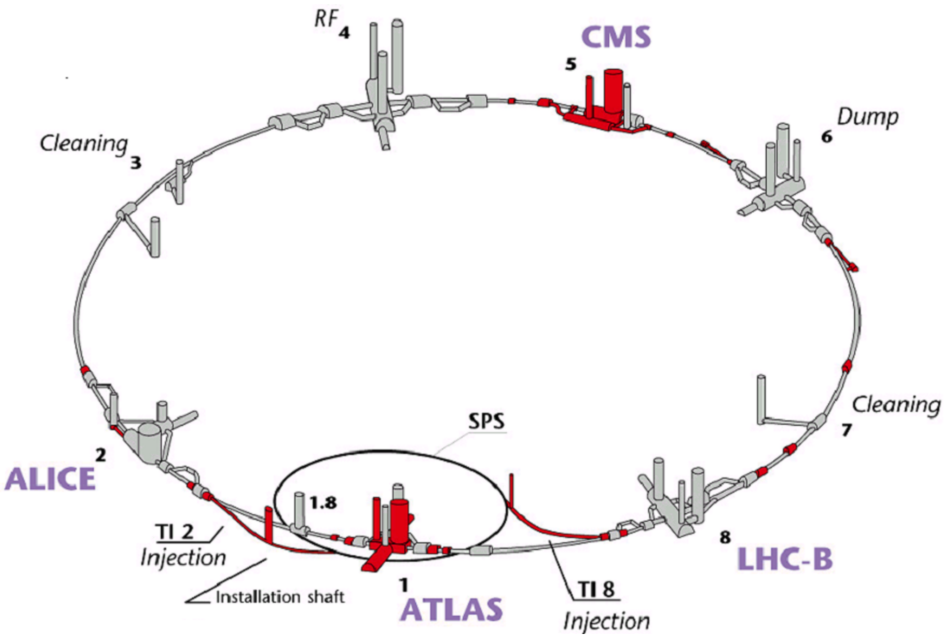
- Complementary decays : explore Higgs couplings



LHC

2011 campaign

- ≈27 km circonference, -100 m under ground
- proton proton, $\sqrt{s}$=14 TeV(→7 TeV)
- B=8,33 T (→≈4.16 T)
- ≈ 2800 bunches of protons (1 bunch ≈ 10^{11} p)→1380 bunches ; 1.5 10^{11} p
- collisions each 25 ns (→≈50 ns)



4 experiments :

-ATLAS, -CMS : general purpose

-LHCb : flavour physics, CP violation

-ALICE : quarks/gluons plasma

Inner Detector (|η|<2.5, B=2 T) ①

Si pixels, strips, Transition Radiation Tracker

Tracking, vertexing, e/π separation

$\sigma(p_T)/p_T < 3.8 \cdot 10^{-4}\, pT\, [GeV] \oplus 0.015$

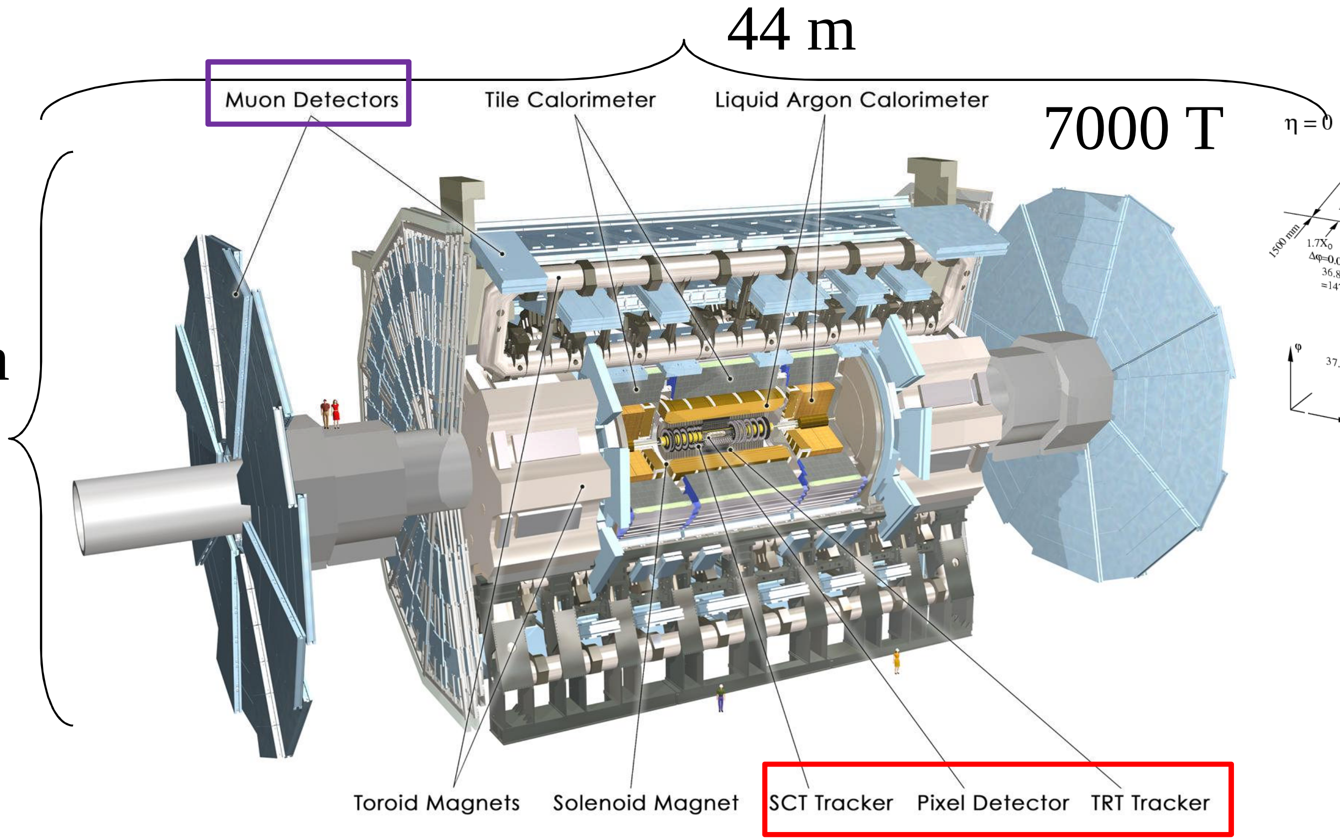
EM Calorimeter (|η|<3.2) ②

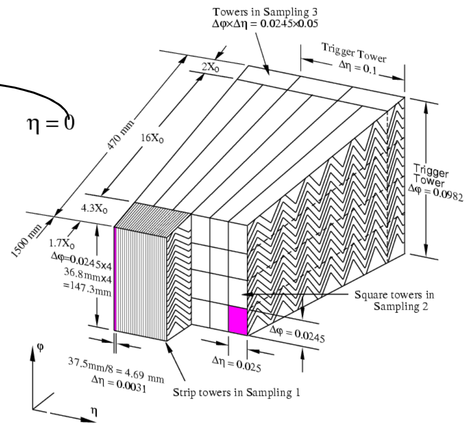
Pb-LAr accordion, longitudinal segmentation

e/γ separation

$\sigma(E)/E \approx 10\,\%/\sqrt{E} \oplus 0.7\,\%$

Atlas





Hadronic Calorimeter ③

Fe-scint. (|η|<1.7) ; Cu-LAr 1.5<|η|<3.2

Cu/W -LAr (fwd : 3.1<|η|<4.9)

Trigger, jet, MET ; $\sigma(E)/E \approx 50\,\%/\sqrt{E} \oplus 3\,\%$

Muon Spectrometer (|η|<2.7) ④

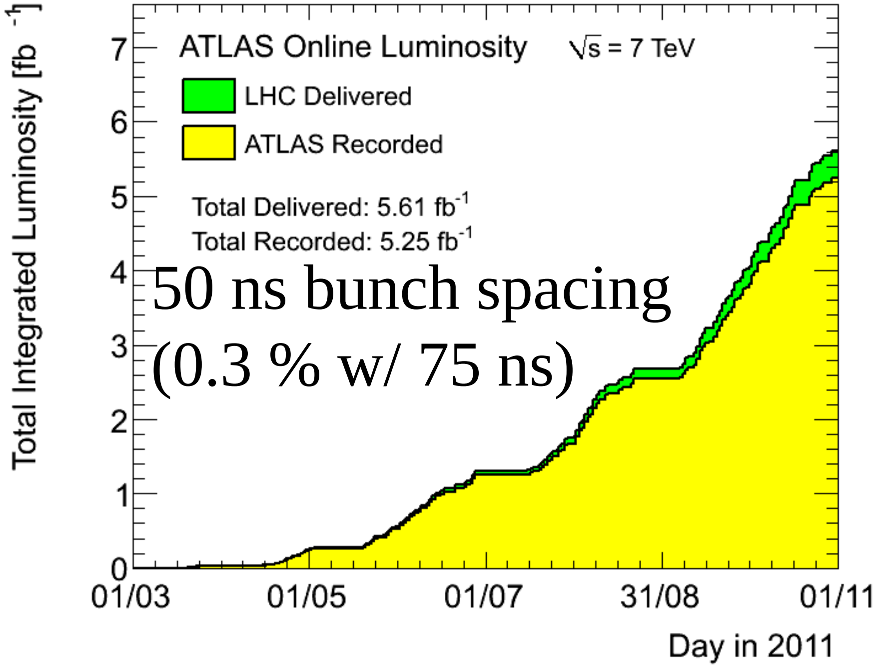
Air core toroid magnets, gas chambers

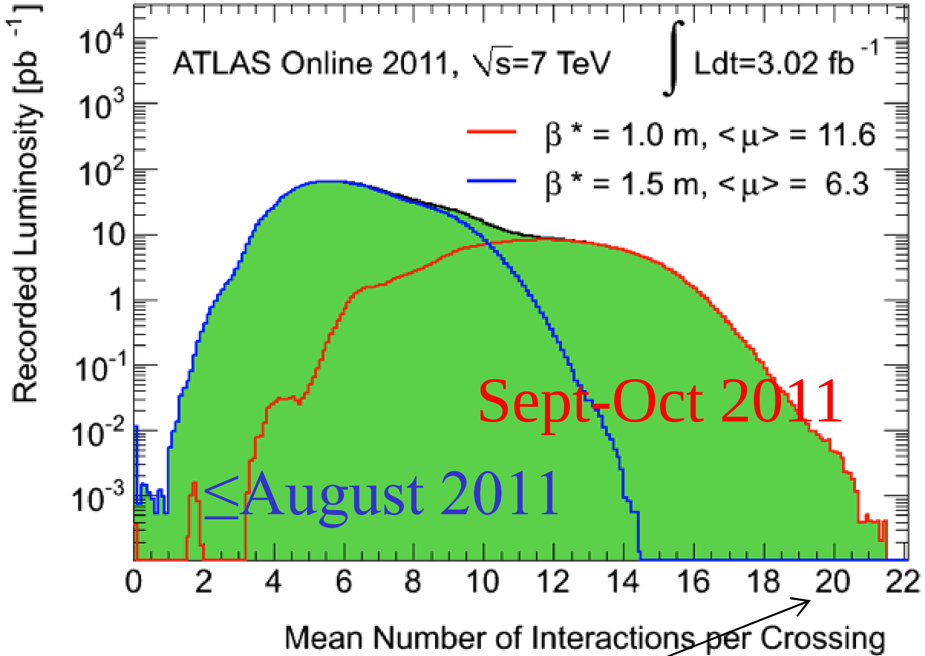
μ trigger and momentum measurement

$\sigma(p_T)/p_T = 2\%$ at 50 GeV ; 10 % at 1 TeV

Atlas data taking

Twiki AtlasPublic/LuminosityPublicResults





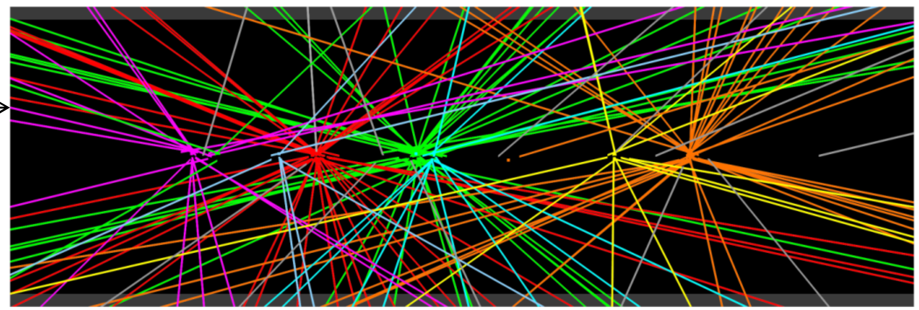
Peak luminosity≈3.6 10^{33} $cm^{-2}.s^{-1}$

Op. fraction of sub-detectors ≈ 93.5 %

≈12 interactions per bunch crossing

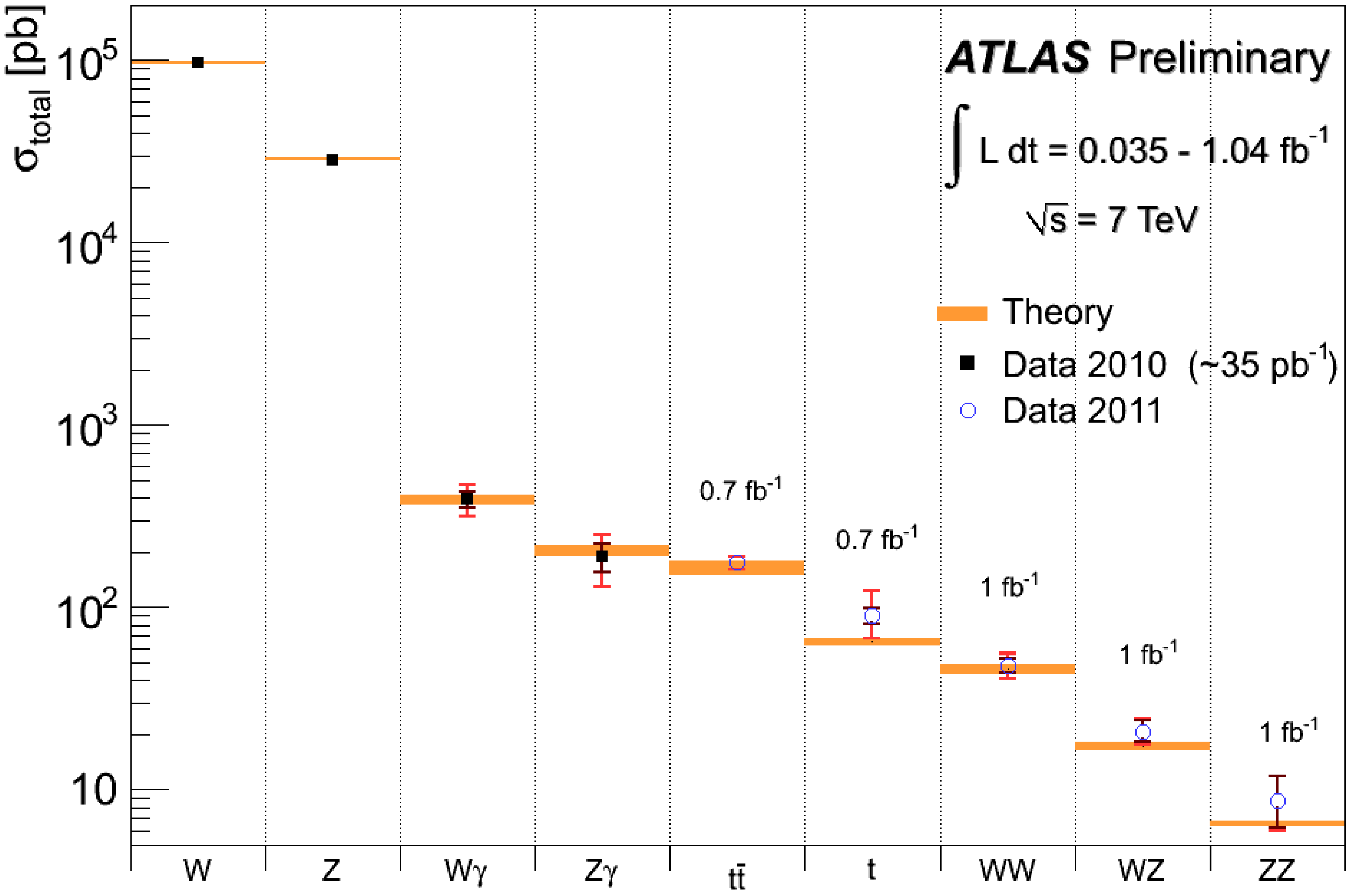
up to 20 !

eg : event w/ 7 vertices



Challenging for trigger, computing, reconstruction (MET, jets, …)

Main measurements background



σ(ZZ)xBR²(Z→ll) ≈σ(H→ZZ(*)→4l)

Control background ⇔ a path towards Higgs search

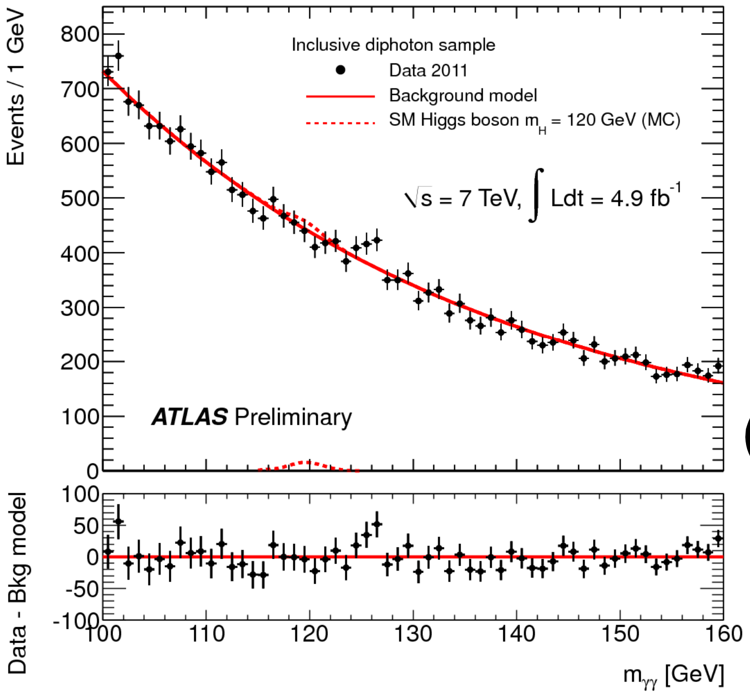
Good agreement data/theory

Statistical treatement

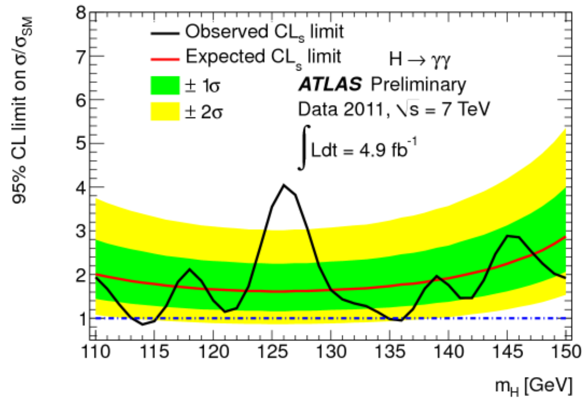
Hyp. testing : null hypothesis : {S+B ; B-only} ; reject null hyp.→altern. hyp

exclusion (S+B)   observation (B-only)

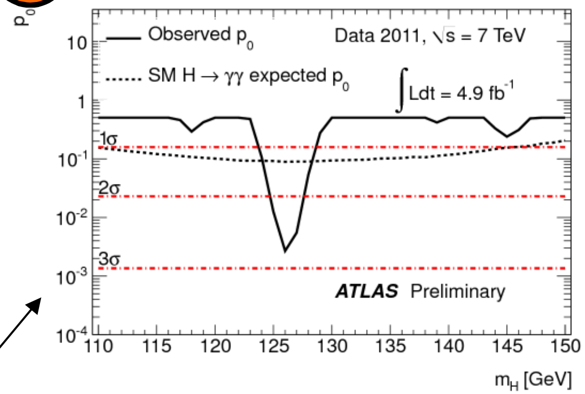
1 Invariant mass distribution



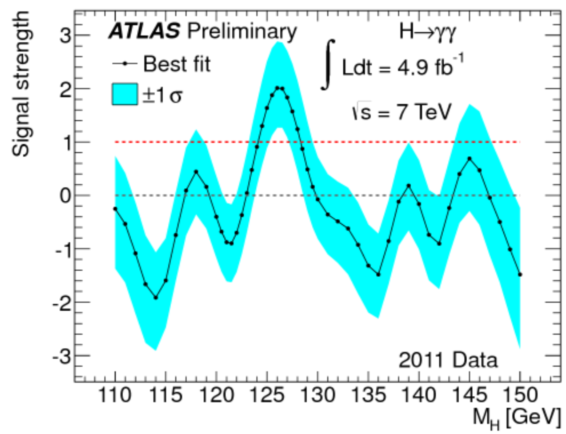
2 Limit exclusion of n xSM



3 Consistency w/ bkg-only hyp. : p_0



4 Fit signal (« μ »)



in addition : Look Elsewhere Effect :

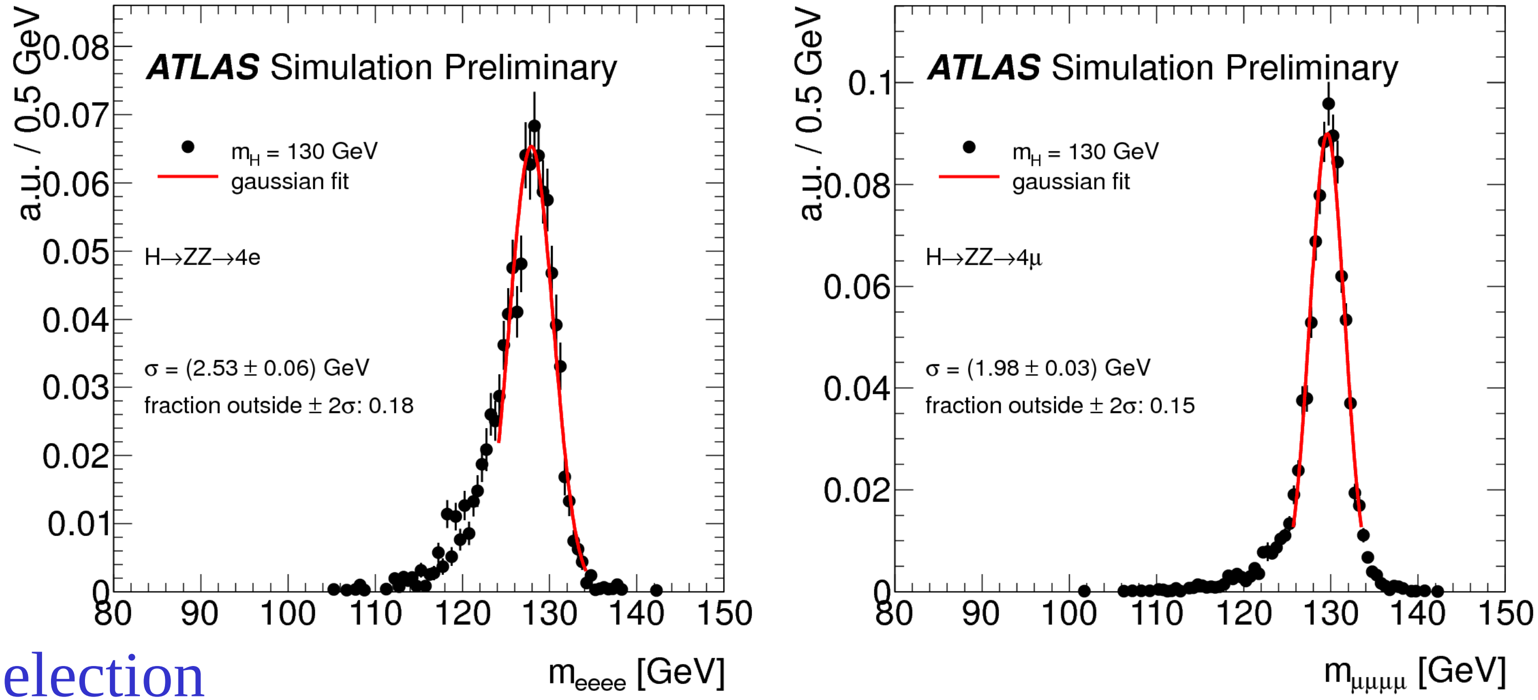
authorize to look « elsewhere » to current mass point

≈ float mass of Higgs

$H \rightarrow ZZ^{(*)} \rightarrow 4l$ $\quad 110 \leq m_H \leq 600$ GeV $\quad 4.8\ fb^{-1}$

Golden channel, fully reconstructed final state, clean, but small rates

examples of mass resolution :



- **Selection**

- 2 pairs OS same flavor leptons, p_T>7 GeV [≥2 w/ p_T>20 GeV] ; $|\eta|$<2.47/2.7 (e/μ)

- isolated (suppr. Z+jets, tt)

(Σp_T^{trk} ΔR<0.2 / p_T < 0.15) ; ($\Sigma E_T^{cells\ calo}$ ΔR<0.2 / p_T < 0.3)

leptons separated ΔR>0.1

- closest ll pair : $|m_{ll} - m_Z|$<15 GeV ; second one : $f(m_H)<m_{ll}<$115 GeV

- impact parameter significance <6/3.5 (e/μ) for two among four leptons(suppr. HF)

H→ZZ(*)→4l $110 \le m_H \le 600$ GeV   4.8 fb^{-1}

- Bkg

-primary : irreducible ZZ(*)

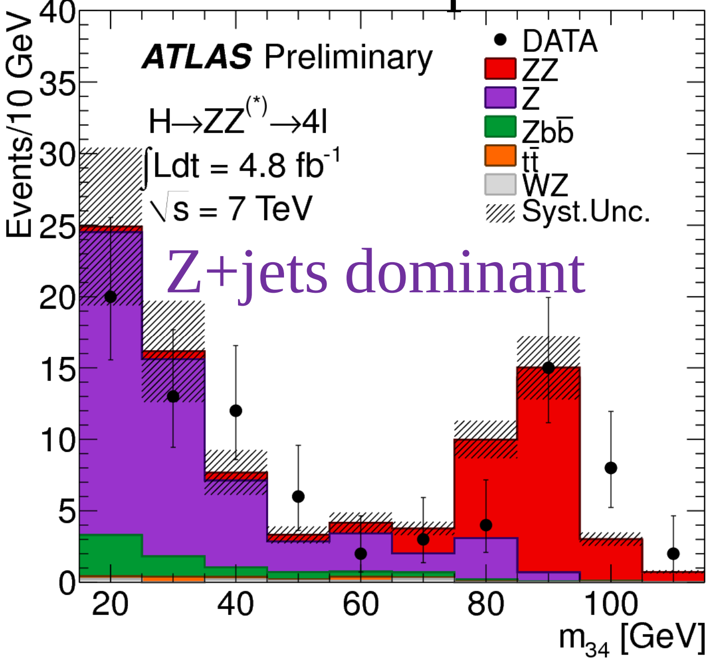
-secondary : Z+j, tt : additive lepton : HF / light jet

- evaluation background

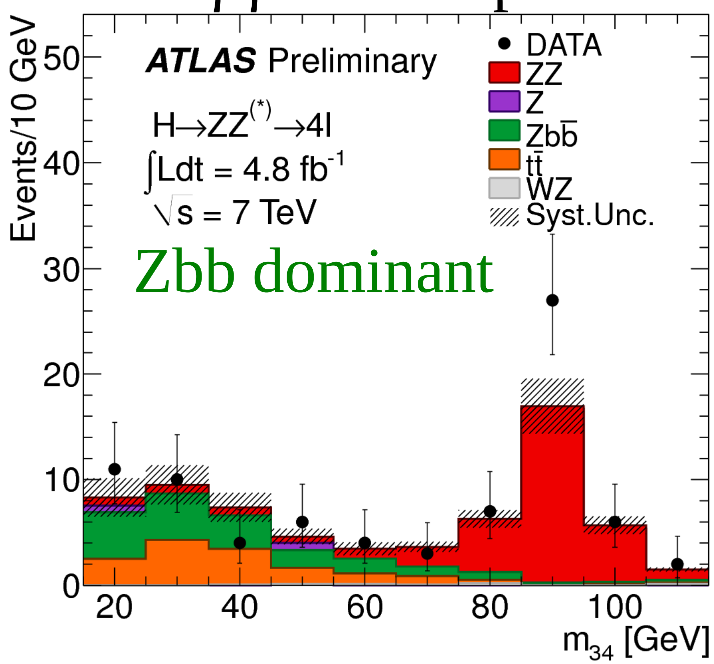
ZZ(*) : MC (low stat so far ; data-driven in future)

Z+j, tt : CR : remove charge , isolation requirements on second lepton pair (m_{34})

ee second pair



μμ second pair



tt : normalization checked w/ sel. OS e-μ pair consistent w/ Z
& 2 same-flavor leptons

H→ZZ$^{(*)}$→4l 110≤m_H≤600 GeV 4.8 fb^{-1}

- Final discriminant : m_{4l}

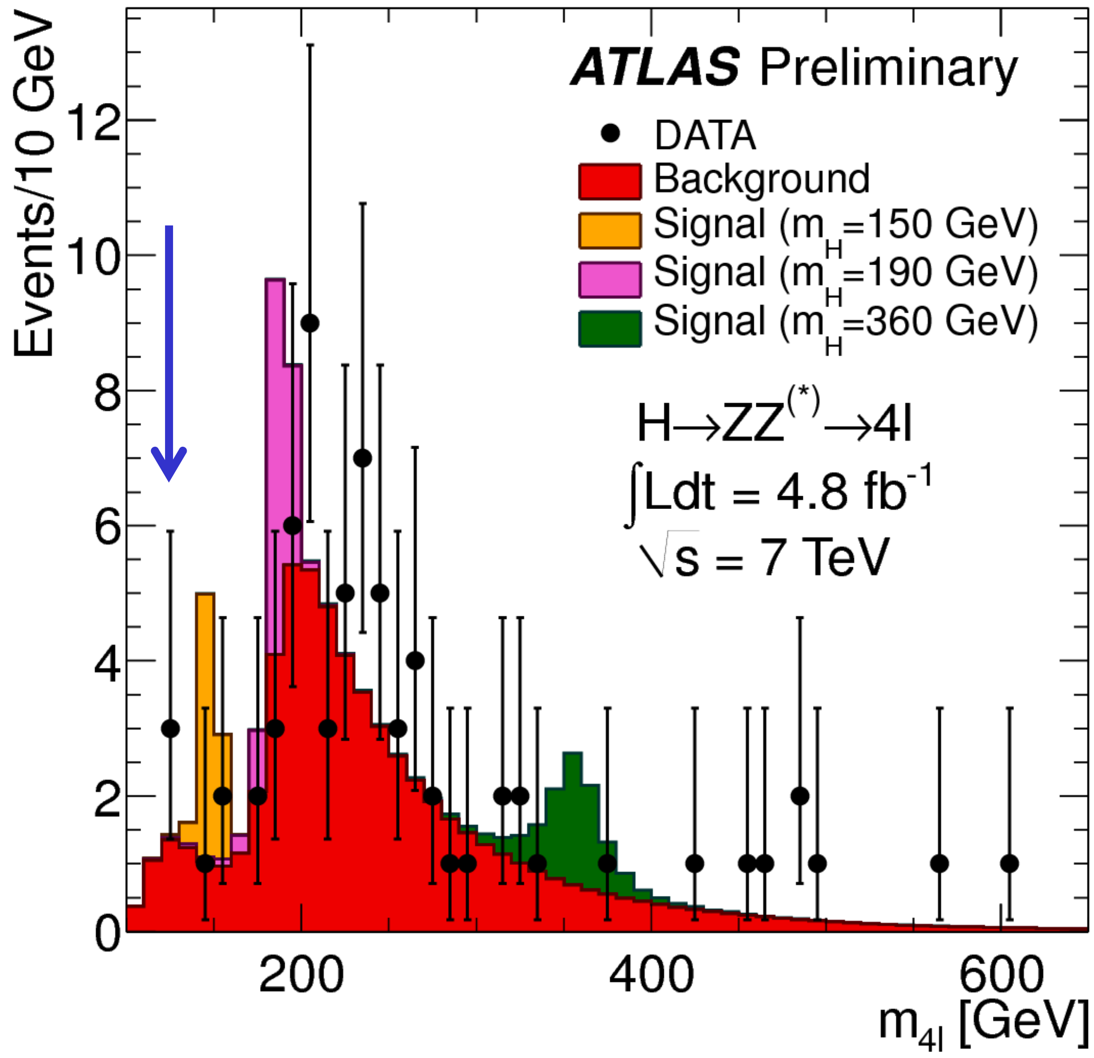
3 events of low masses :

-two events 2e2μ :

m=123.6 & 124.3 GeV

-one event 4μ :

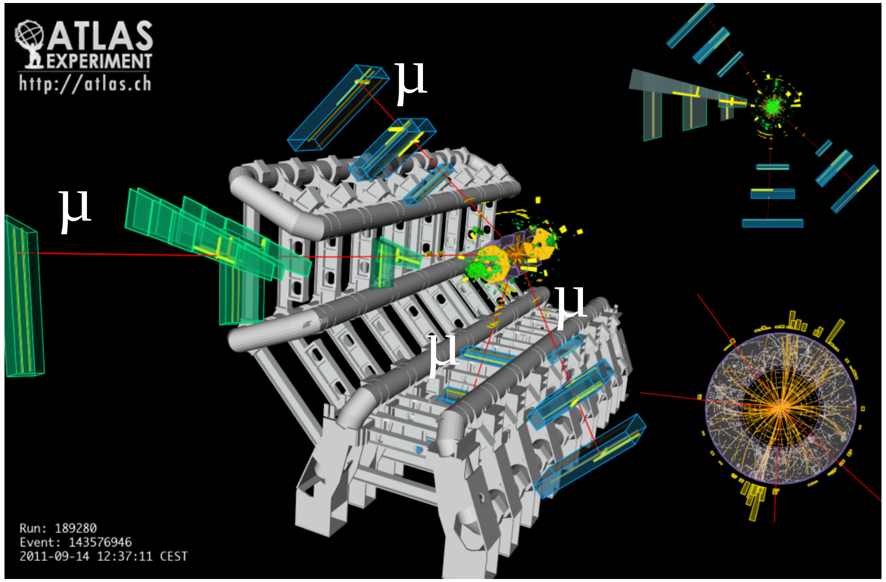
m=124.6 GeV



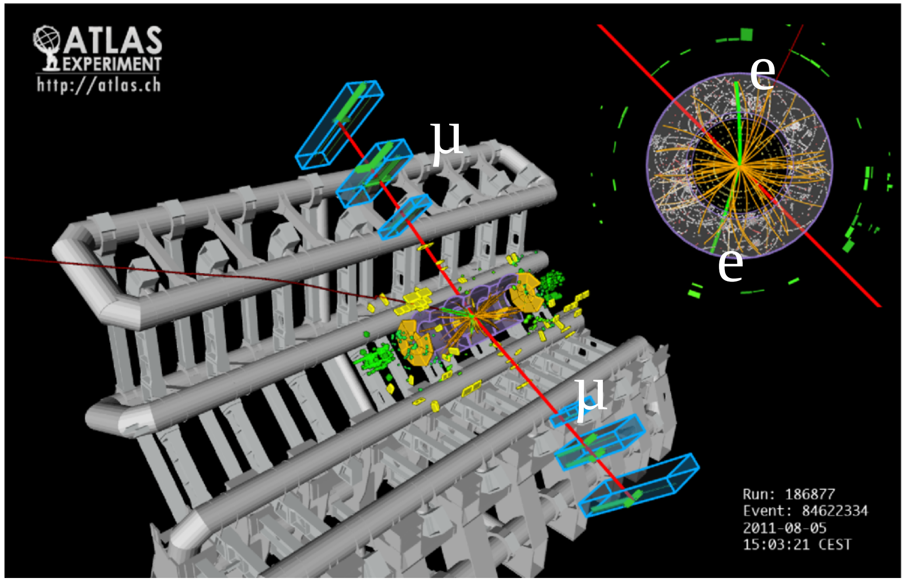
$H \rightarrow ZZ^{(*)} \rightarrow 4l$ $110 \leq m_H \leq 600$ GeV 4.8 fb^{-1}

Event displays

Candidate μμμμ
m_{4l}=124.6 GeV
m_{ll}^2=89.7 GeV
m_{ll}^2=24.6 GeV



Candidate 2μ2e
m_{4l}= 123.6 GeV
m_{ll}^1= 89.3 GeV
m_{ll}^2= 30.0 GeV



$H \rightarrow ZZ^{(*)} \rightarrow 4l$ $110 \leq m_H \leq 600$ GeV 4.8 fb^{-1}

- Systematics

Lepton rec., ident. eff ; momentum resolution & scale : from W, Z, J/ψ
→acceptance uncertainty on signal & irr. Bkg :
-Muon eff. 2e2μ/4μ : 0.16/0.22 %
-Electron eff. 4e ; 2e2μ (m_H={600/110 GeV}) : {2.3/8.0 %} ; {1.6/4.1 %}
-muon momentum resolution & scale uncertainty : small
-electron energy res. : small ; energy scale on m_{4l} 4e/2e2μ : 0.6 % ; 0.3 %

-$ZZ^{(*)}$ bkg : th. uncertainty : 15 % (conservative)
-Z+jets, Zbb : normalization : 45/40 % : stat. uncert. CR & MC based CR→SR
-tt : normalization : th. uncertainty : 10 %

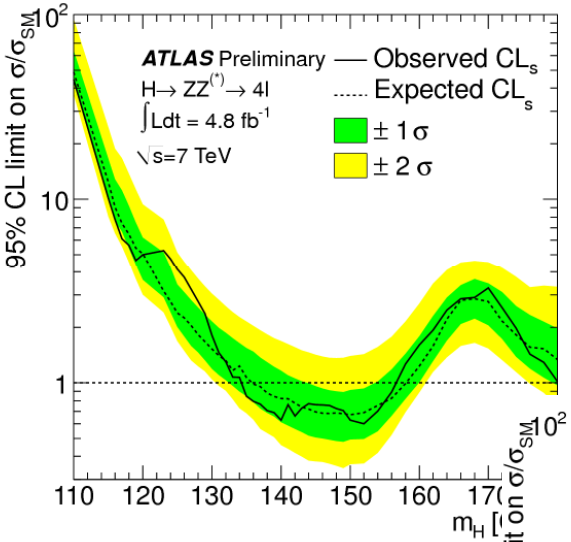
-th. σ Higgs : 15-20 % ggH, 3-9 % VBF, 3-4 % associated
-signal selection : 2 % (modelization kinematics)
-Luminosity : 3.9 %

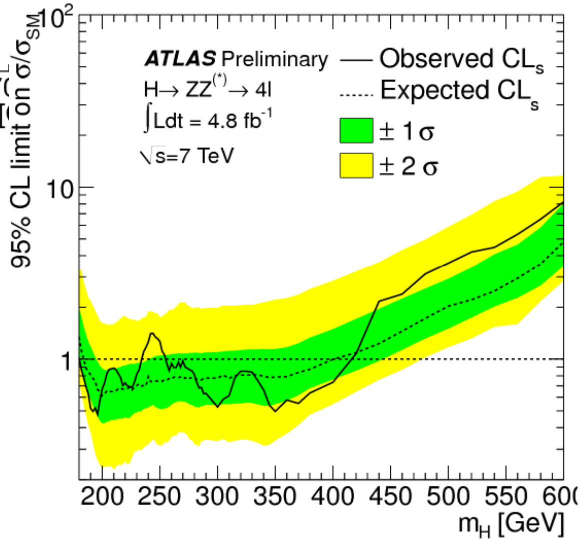
$H \rightarrow ZZ^{(*)} \rightarrow 4l$ $110 \leq m_H \leq 600$ GeV $4.8\ fb^{-1}$

- **Limits** :

Exclusion at 95 % CL :

m_H : [135 ; 156] U [181 ; 234] U [255 ; 415] GeV





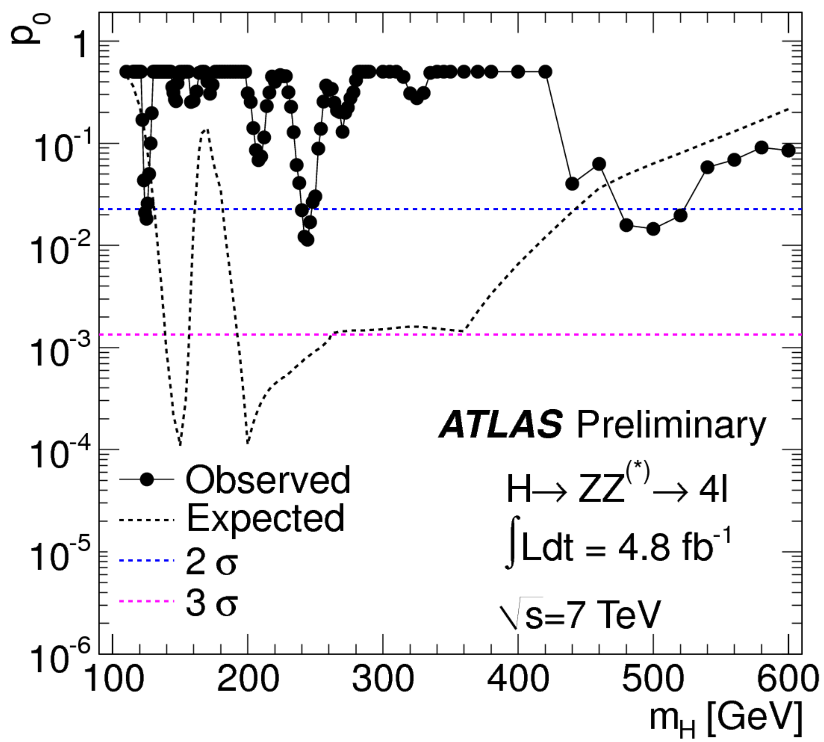
- **Consistency w/ bkg-only** hypothesis :

Largest deviations :

-m_H=125 GeV : p_0-value : 1.8 %

-m_H=244 GeV : p_0-value : 1.1 %

-m_H=500 GeV : p_0-value : 1.4 %



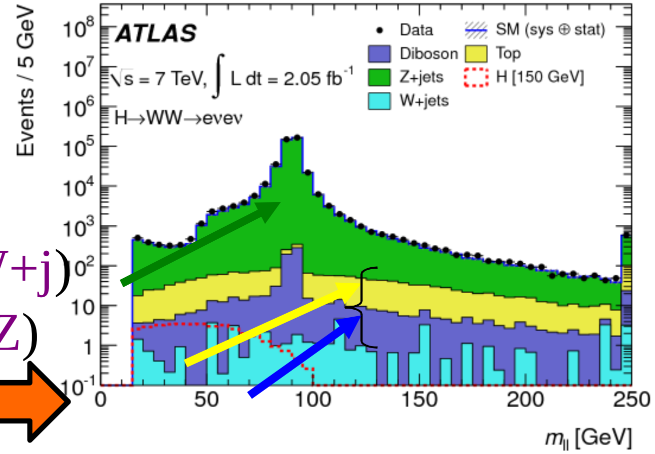
$H \to WW \to l\nu l\nu$ $l=e,\mu$; $\tau \to e/\mu$ $110 \le m_H \le 300$ GeV 2.05 fb^{-1}

- **Bkg**

-primary : QCD, W+j, DY (γ^*/Z), Y, top, WW

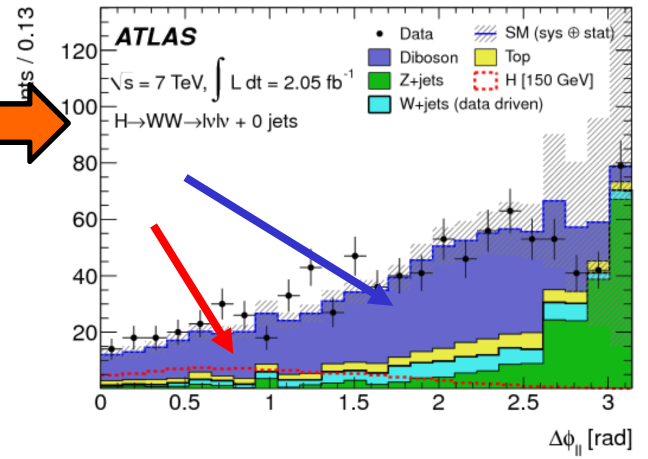
- **Selection**

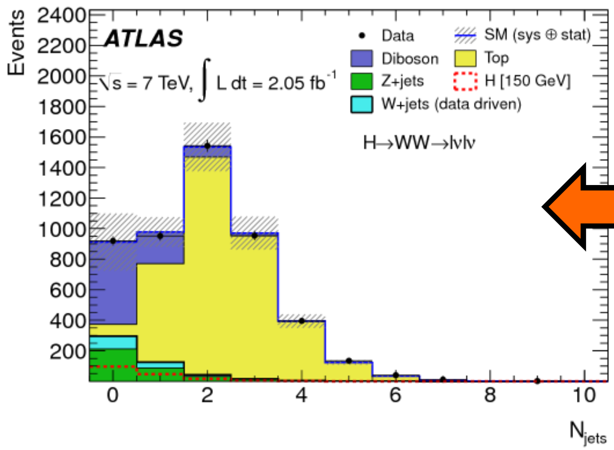
- =2 OS isol. l ; $E_T^{lead\ ;\ sub}$>25 ; 20/15 GeV (e/μ) (suppr. QCD, W+j)
- =flavor : m_{ll}> 15 GeV (suppr. Y) ; $|m_{ll}-m_Z|$>15 GeV (suppr. Z)
  ≠flavor : 10 GeV
- m_{ll}<f(m_H) (suppr. top, WW)



- MET_{rel}>40 GeV / 25 GeV (= / ≠flavor) (suppr. QCD, DY)
- $\Delta\phi_{ll}$<f(m_H) : spin-correlations (suppr. WW)

spin H : 0 ; leptons « roughly » same direction





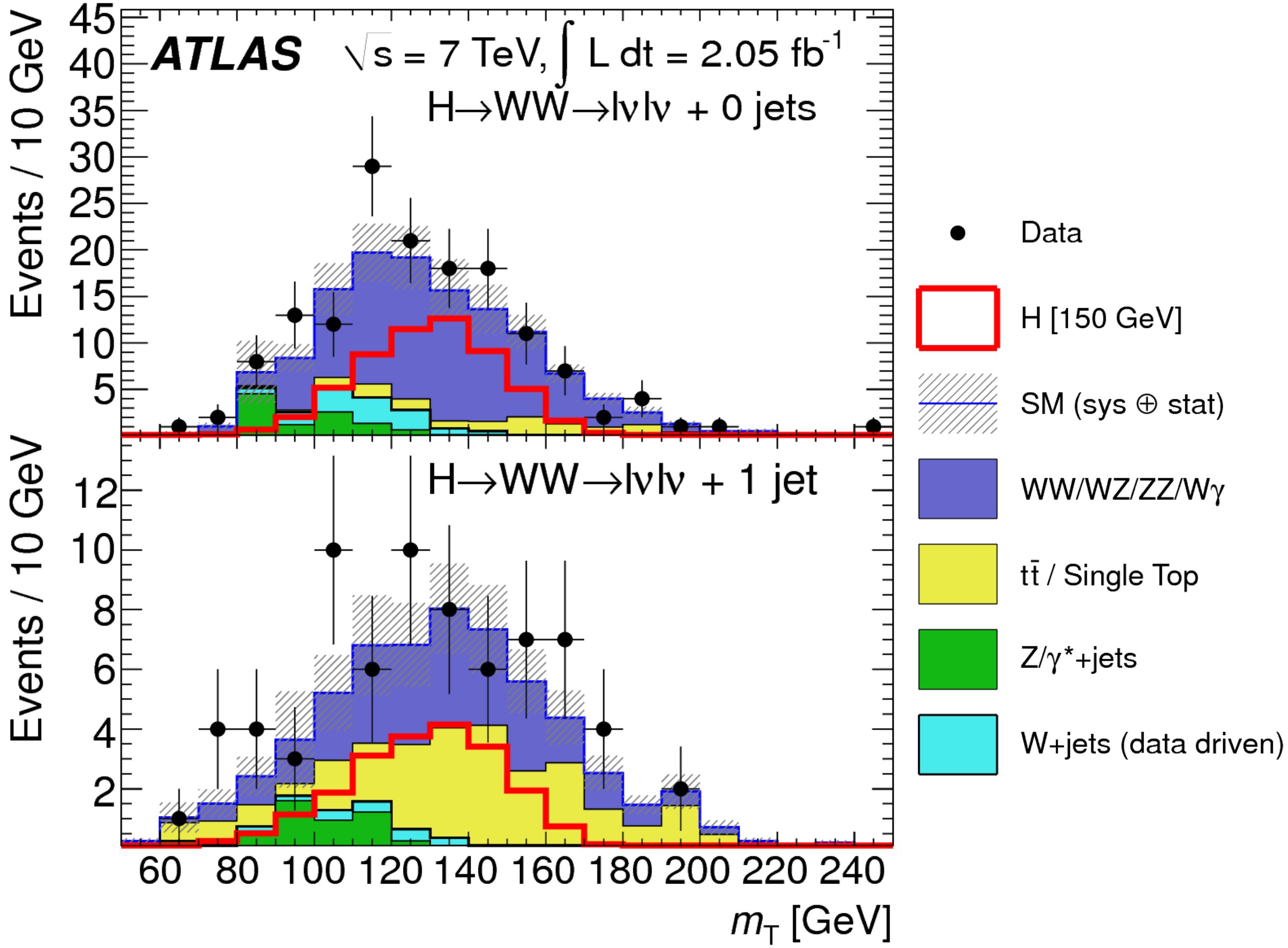
- **Categorization of #jets** (E_T>25 GeV, $|\eta|$<4.5)

- H+ 0 j : p_T^{ll}>30 GeV (suppr. Z+j, WW)
- H+ =1 j : b-jet veto (suppr. top)
  |vec p_T^{tot}|<30 GeV : veto hadr. activity wo/ high p_T jet
- #jets<2 (suppr. top)

$H \rightarrow WW \rightarrow l\nu l\nu$ $110 \leq m_H \leq 300$ GeV $2.05\ fb^{-1}$

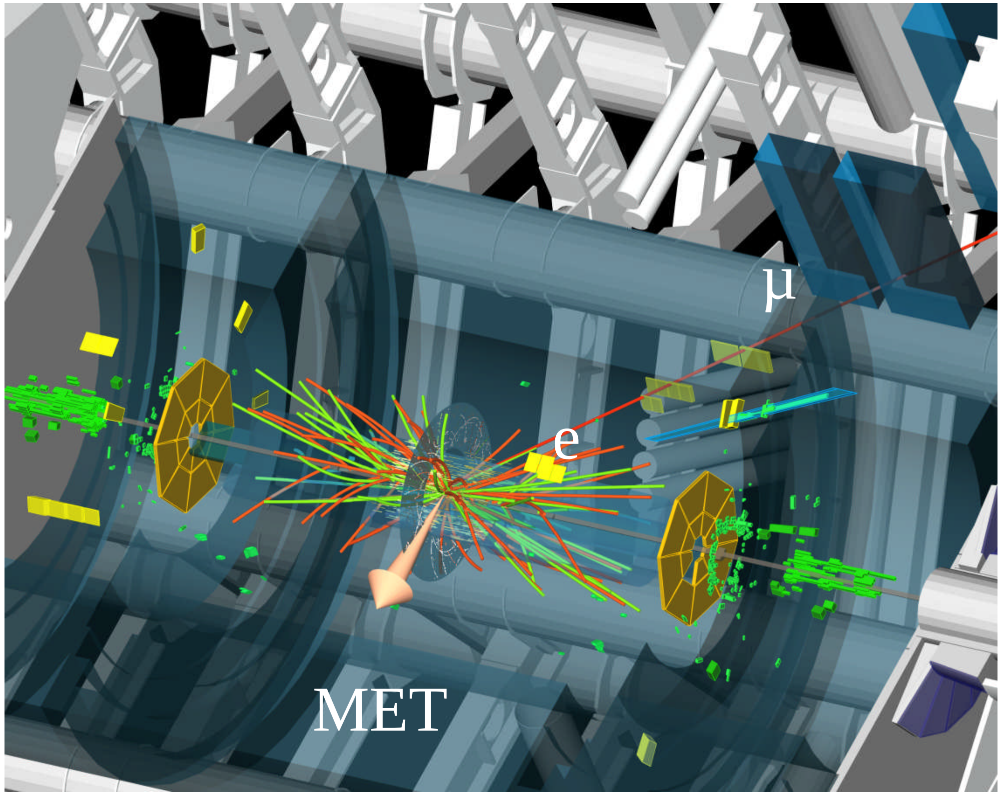
- final discriminant : transverse mass

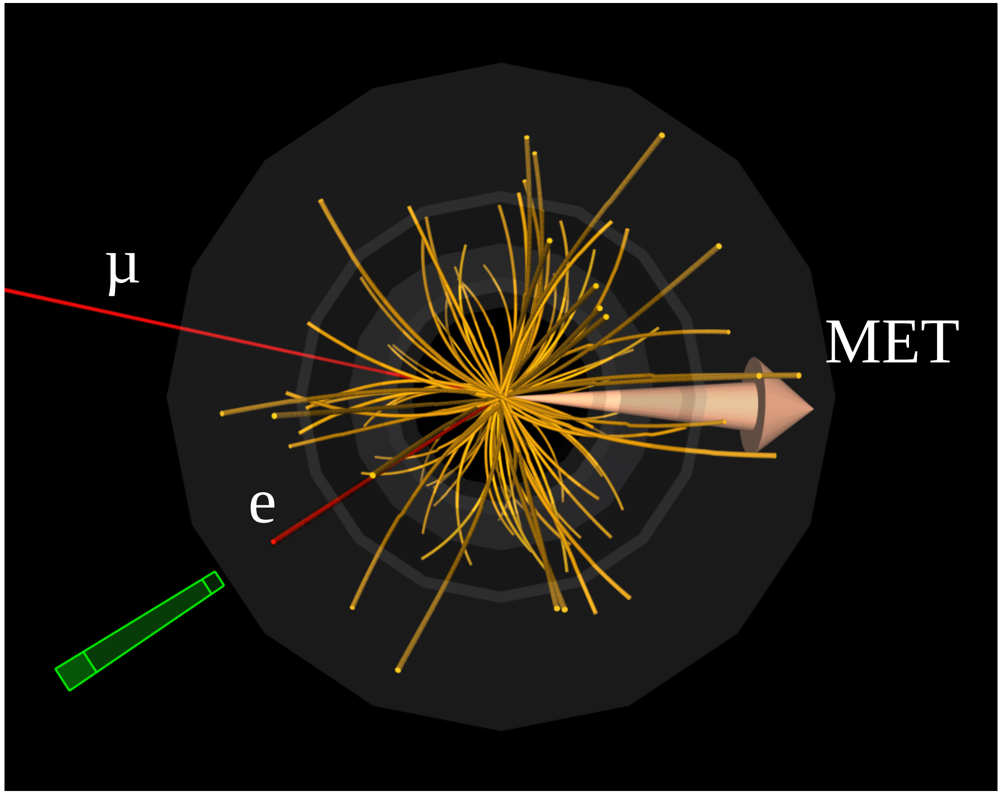
$f(m_H) < m_T < m_H$ (suppr. WW, top & interference {H ; gg→WW})



Event display

WW candidate ; eμ final state





H→WW→lνlν $110 \leq m_H \leq 300$ GeV   2.05 fb^{-1}

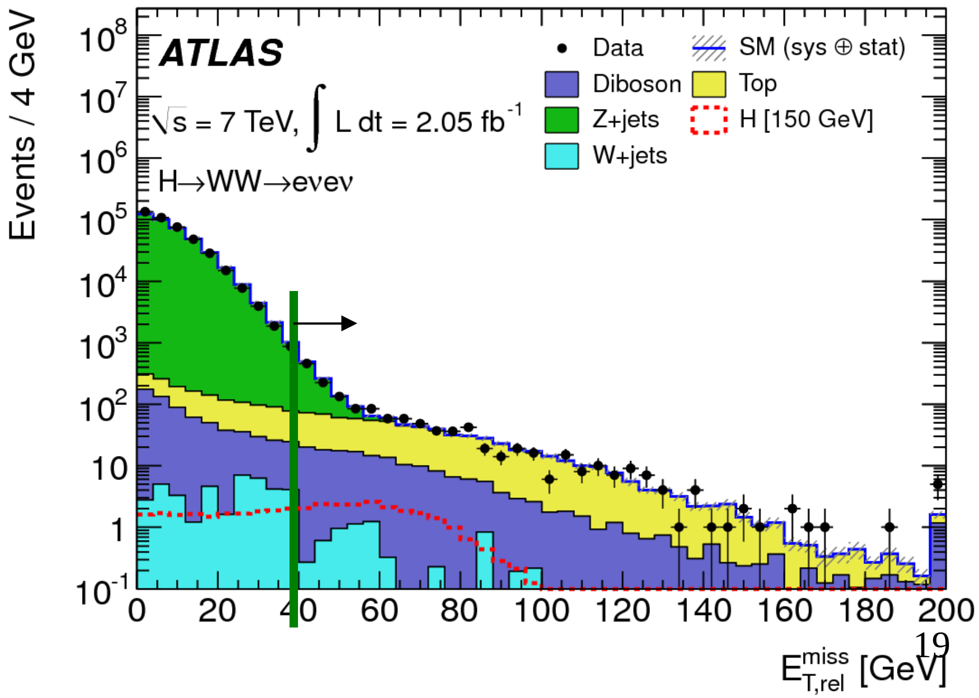
- Bkg measurement

-W+jets : fully data-driven
CR : relax identification & isolation on one lepton
Scale factors CR→SR : dijets selection

-others : MC corrected by scale factors from CR

-DY : correct mismodelling MET_{rel} : ≠{data ; MC} w/ MET_{rel}>40 GeV for $|m_{ll}-m_Z|$<10 GeV

-WW, top : normalization
*relax selection
*simultaneous fit on data
CR→SR : WW : MC
top : 0j : ε^2_{pass}(jet veto top)
1j : MC



- Systematics :

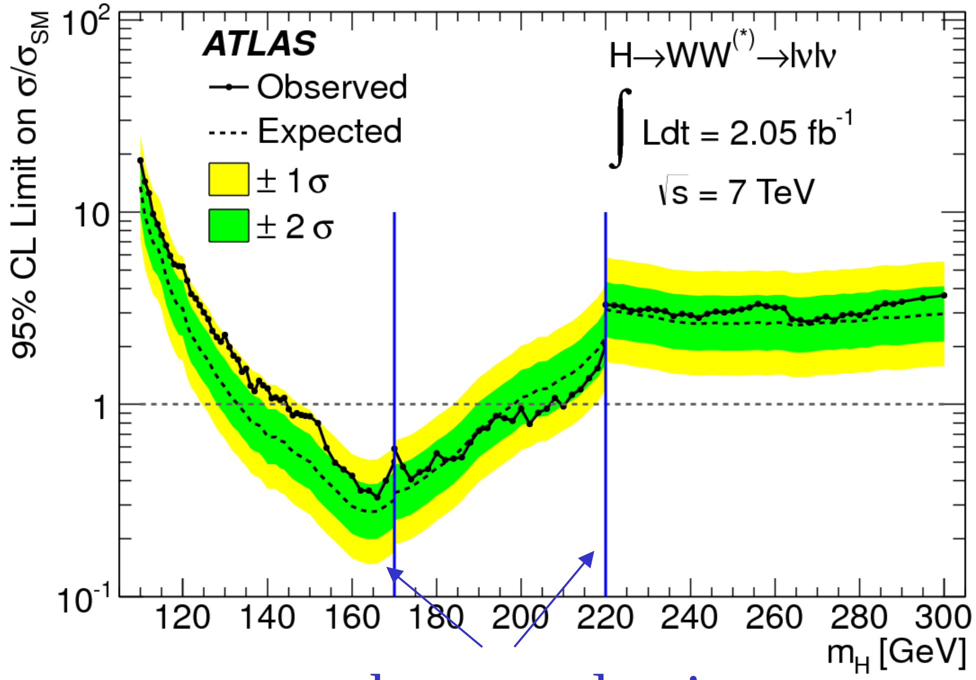
-Luminosity : 3.7 %
-theory uncertainty (ggH/VBF) : QCD scale : $^{+12}_{-8}$ % / 8 % ; pdf : 1 % / 4 %

-#jets : computed from uncertainty on σ : H+0j : 10 % ; H+1j : 20 %
-JES : <10 %
-pile-up : 7 %
-e/μ eff : from W, Z : 2-5 % / 0.3-1 % (f(|η|, p_T))
-lepton energy scale e/μ : <1 % ; <0.1 %
-lepton energy resolution e/μ : <0.6 % ; <5 %
-b-tagging : 6-15 % ; b-mistag rate : <21 %
-MET : 13 %

-WW : th. & exp. for CR→SR : H+0 j : 7.6 % ; H+1 j : 21 %
-top : H+0 j : 38 % ; H+1 j : 29 %

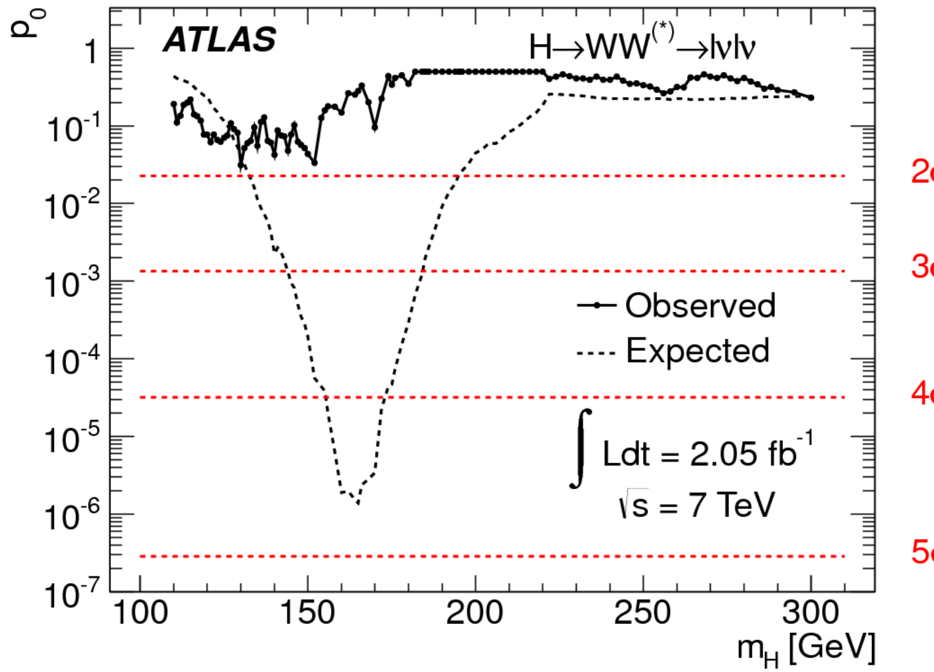
$H \rightarrow WW \rightarrow l\nu l\nu$ $110 \leq m_H \leq 300$ GeV $2.05\ fb^{-1}$

Limit : exclusion
Expected : $134 < m_H < 200$ GeV
Observed : $145 < m_H < 206$ GeV



change selection

Consistency w/ bkg-only hypothesis :
Largest deviation : 1.9 σ



$H \to \gamma\gamma$ $110 \leq m_H \leq 150$ GeV $4.9\ fb^{-1}$

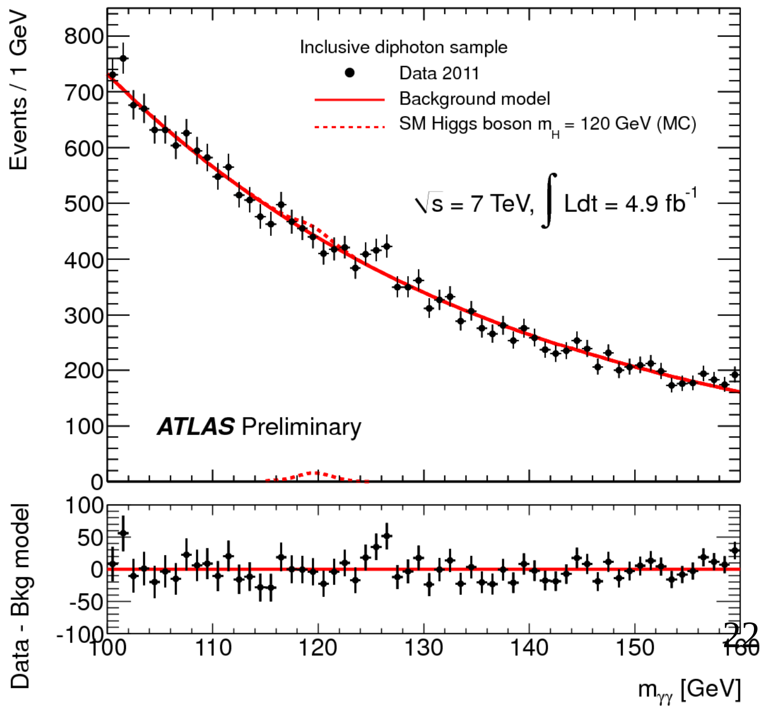
- Small BR, sharp peak on top of continuum

- Bkg : irreducible (dominant after identification) : $\gamma\gamma$
  reducible : γj, jj, Drell-Yan

- Invariant mass reconstruction : $m_{\gamma\gamma}^2 = 2E_1E_2(1-\cos\theta_{12})$
  -Primary vertex position
  -Energy calibration

- selection : 2 high-p_T (40 ; 25 GeV)
  isolated γ (isol.<5 GeV)

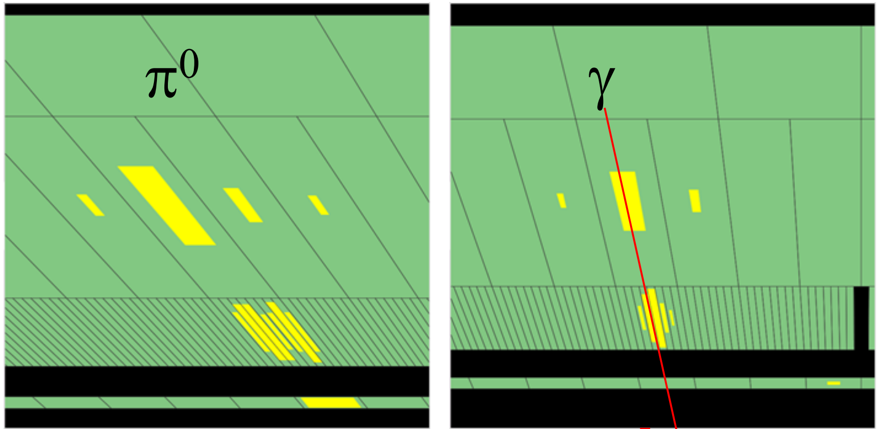
modelization bkg : exp(-ξx) shape
(here inclusive) ⟶



$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV $4.9\ fb^{-1}$

Fine segmentation of elmg calorimeter

- good separation π^0 / γ

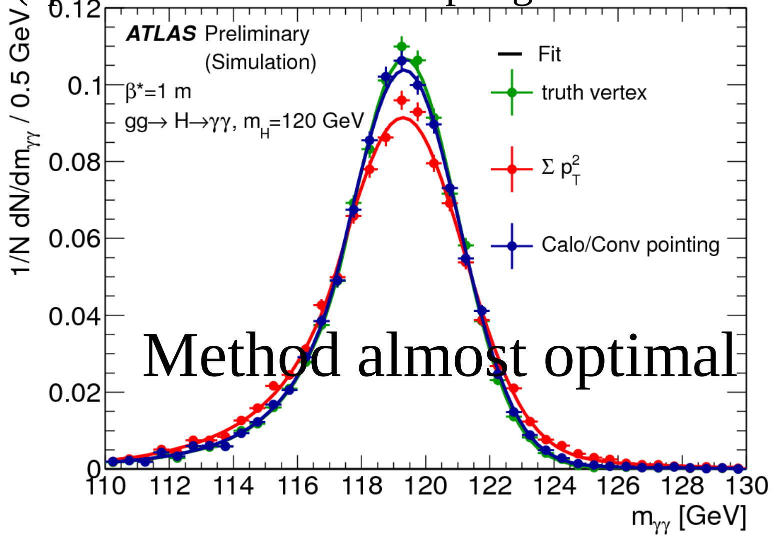


towards z axis

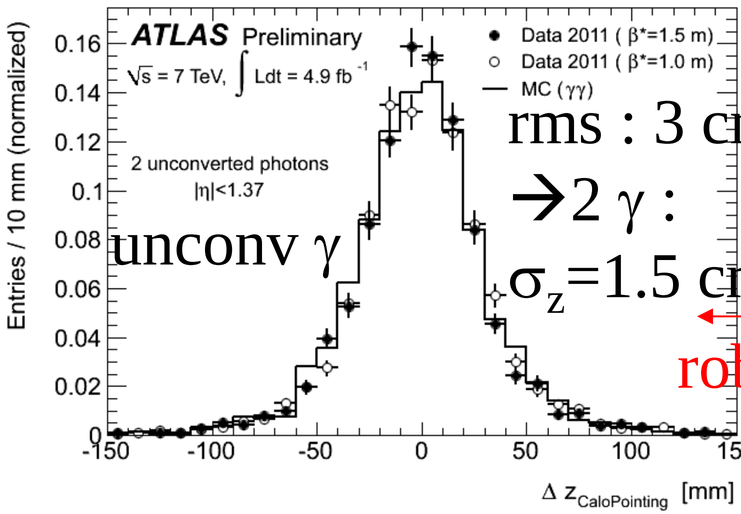
5.6 cm

- direction : calo pointing

(apart converted : 1st sampling & conversion point)



Method almost optimal



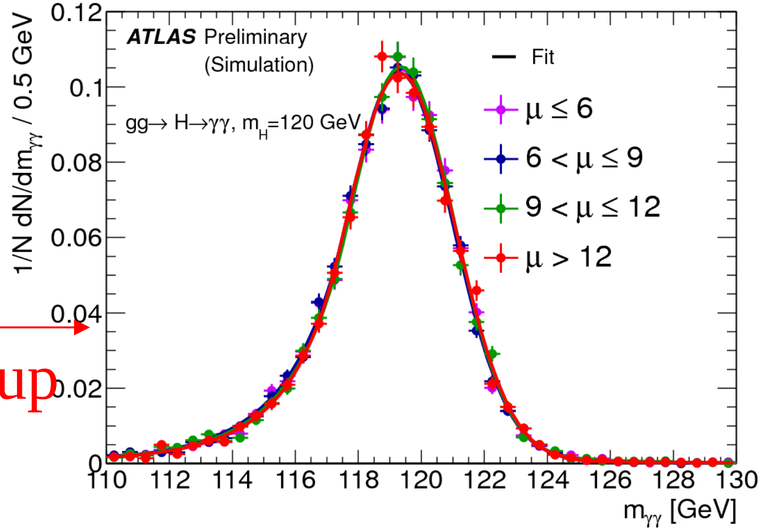
unconv γ

rms : 3 cm

$\rightarrow 2\ \gamma$:

σ_z=1.5 cm

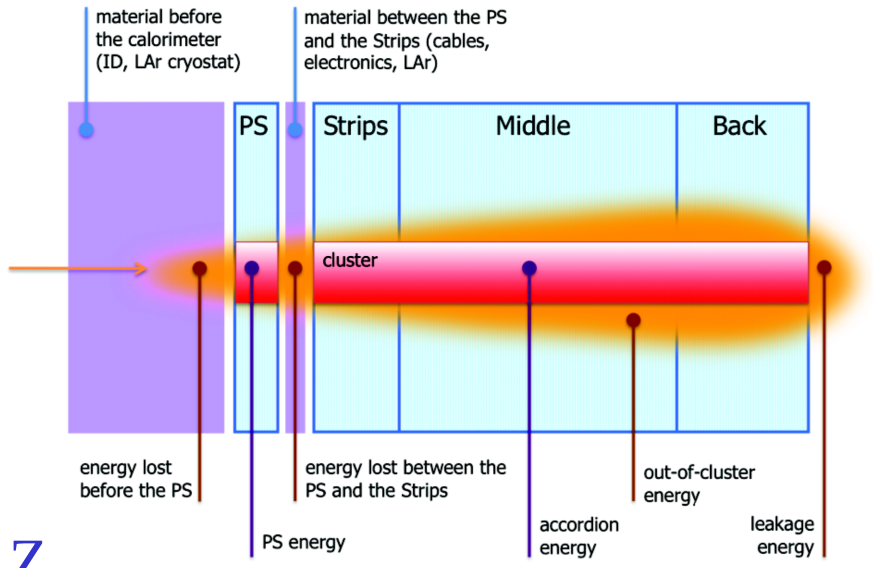
robust wrt pile-up



$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV $4.9\ fb^{-1}$

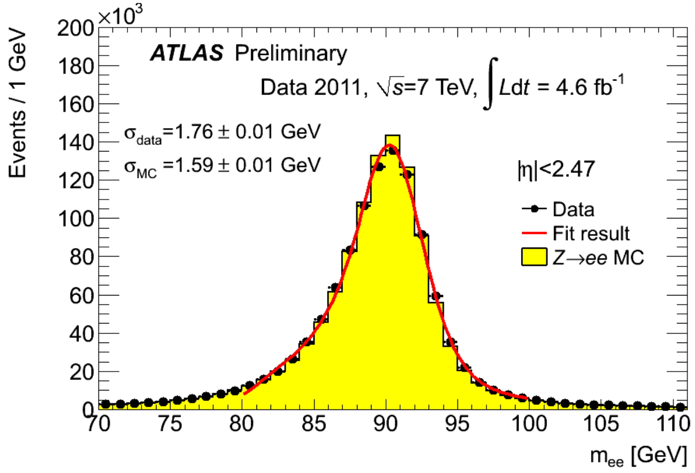
- **Calibration**

Cluster energy reconstruction :
Σ contributions :
-before calorimeter
-inside cluster
-outside cluster (lateral leakage)
-beyond EM calo (longitudinal leakage)



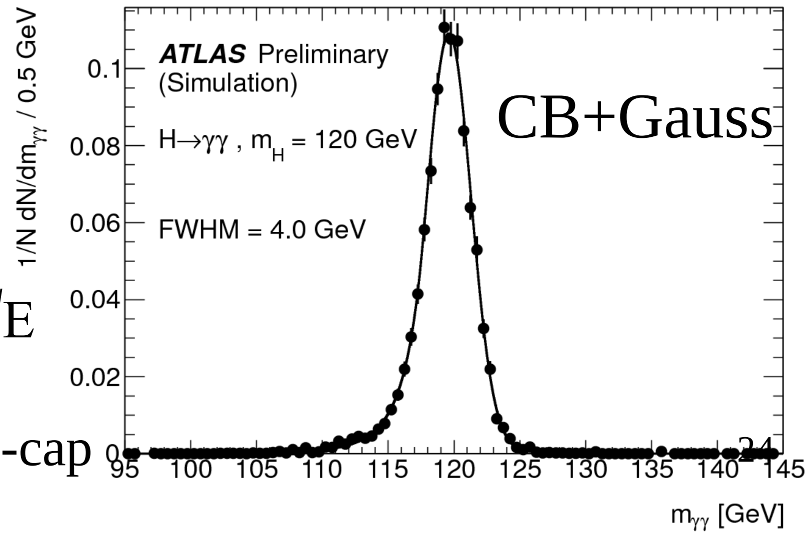
- **Improvement using corrections from Z**

Selection 2 OS electrons p_T>25 GeV, quality medium, compatible m_Z
26 bins of η ; $E_{mes}=E_{true}(1+\alpha)$; α from a likelihood fit

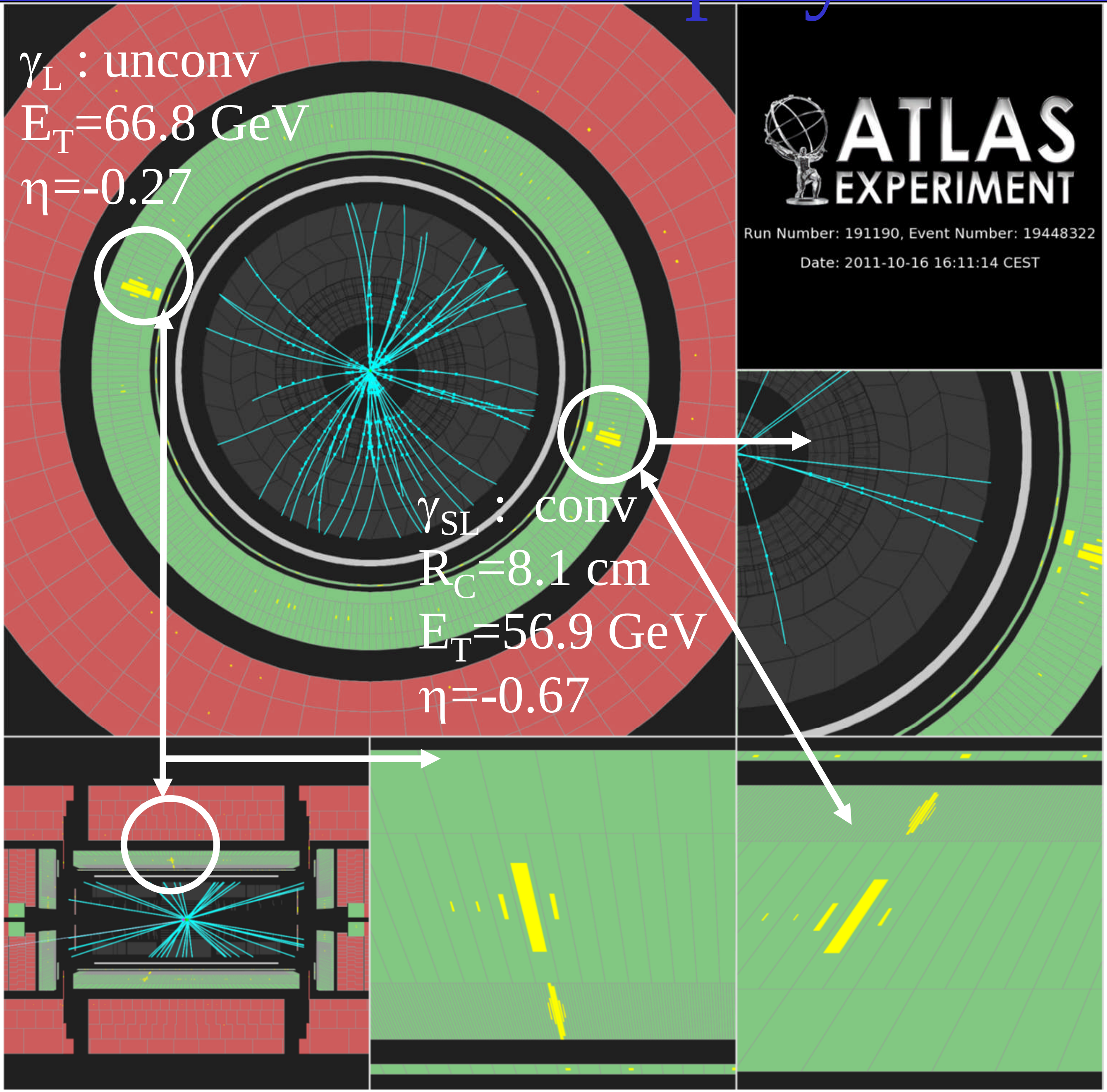


- sampl. term : 10 %/$\sqrt{E}$
- cst term :

1.2 % barrel ; 1.8 % end-cap



H→γγ $110 \leq m_H \leq 150$ GeV   4.9 fb^{-1}



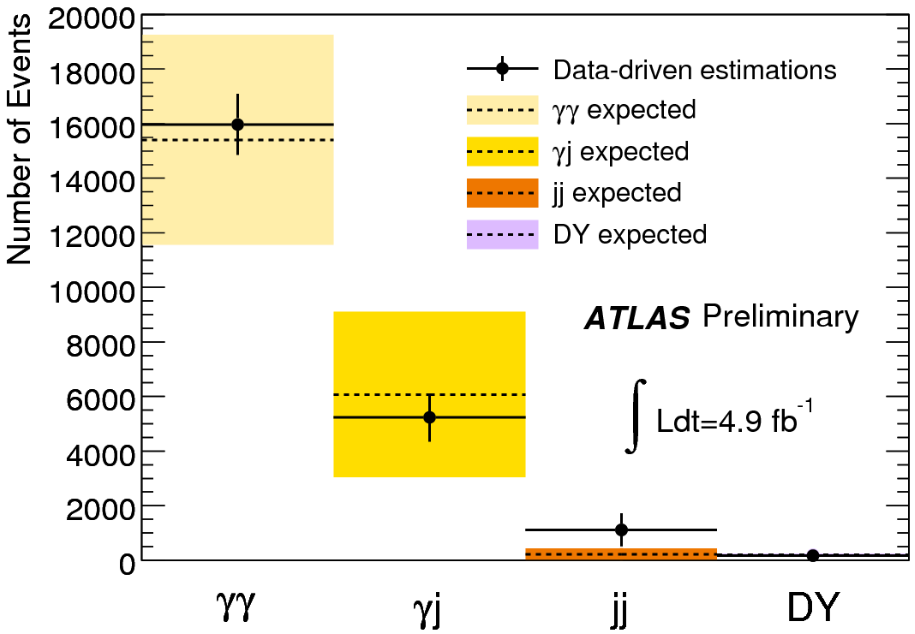
$m_{\gamma\gamma}$=125.8 GeV
$p_{T\gamma\gamma}$=10.4 GeV
$p_{Tt\gamma\gamma}$=3.1 GeV

$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV 4.9 fb^{-1}

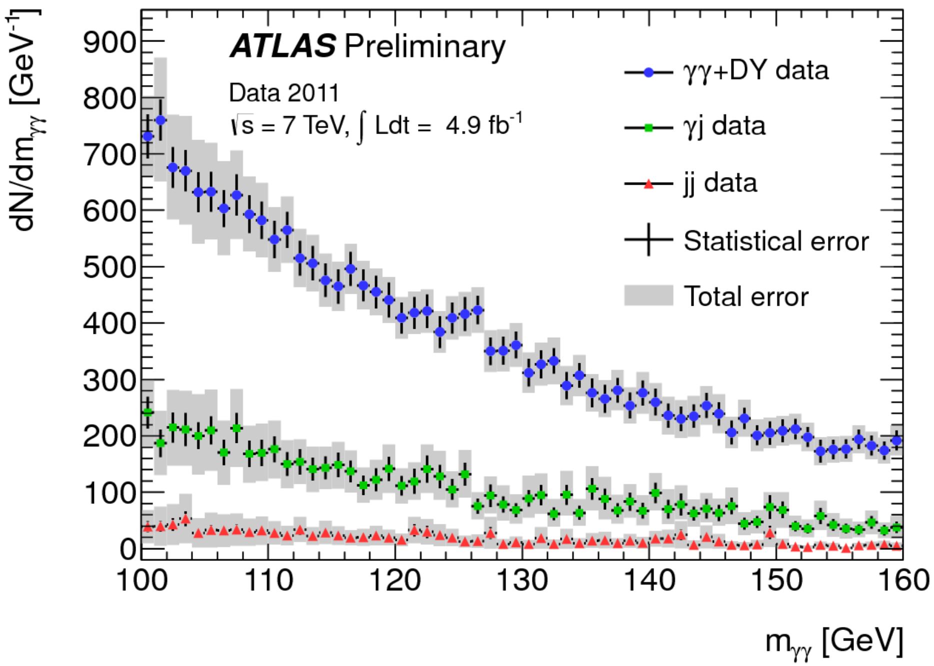
- Data-driven bkg estimation

-simultaneous two dimension A=B*C/D method : γγ, γj, jj

-e→γ fake rate : Drell-Yan



good agreement data/prediction



Purity γγ : 71 %

$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV $4.9\ fb^{-1}$

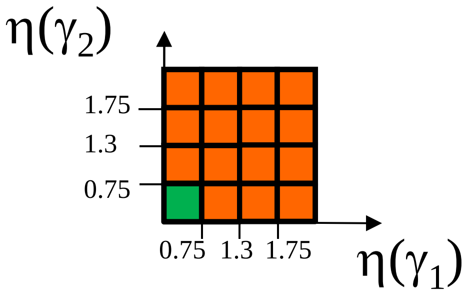
Categorization :

1 eta ; conv status of photons

both unconverted :

-unconv central : $|\eta_{1,2}|<0.75$

-unconv rest : $|\eta_{1\ or\ 2}|>0.75$



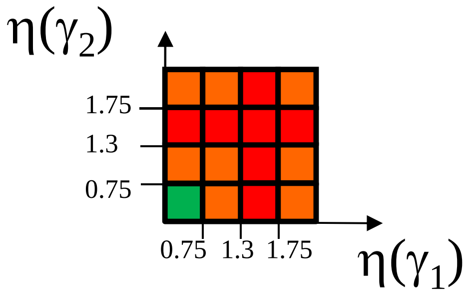
C1 C2

≥1 converted :

-conv (≥1) central : $|\eta_{1,2}|<0.75$

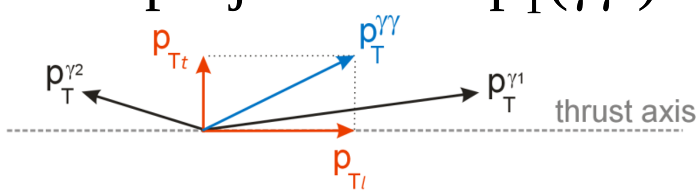
-conv (≥1) rest : $|\eta_{1,2}|<1.3$ or $|\eta_{1,2}|<1.75$ but ≥1 $|\eta_{1,2}|>0.75$

-conv (≥1) transition : ≥1 w/ $1.3<|\eta|<1.75$



C3 C4 C5 impr. 6-23 % on exp. limits

2 $p_{Tt}(\gamma\gamma)$: (transversal projection of $p_T(\gamma\gamma)$ on thrust axis)
low/high value



further 5-10 % on exp. limits

Combin. eta/conv/P_{Tt} : 9 categories

CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9
low	high	low	high	low	high	low	high	all

$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV $4.9\ fb^{-1}$

systematics

Type and source	Uncertainty
Event yield	
Photon reconstruction and identification	$\pm 11\%$
Effect of pileup on photon identification	$\pm 4\%$
Isolation cut efficiency	$\pm 5\%$
Trigger efficiency	$\pm 1\%$
Higgs boson cross section	$+15\% / -11\%$
Higgs boson p_T modeling	$\pm 1\%$
Luminosity	$\pm 3.9\%$
Mass resolution	
Calorimeter energy resolution	$\pm 12\%$
Photon energy calibration	$\pm 6\%$
Effect of pileup on energy resolution	$\pm 3\%$
Photon angular resolution	$\pm 1\%$
Migration	
Higgs boson p_T modeling	$\pm 8\%$
Conversion reconstruction	$\pm 4.5\%$

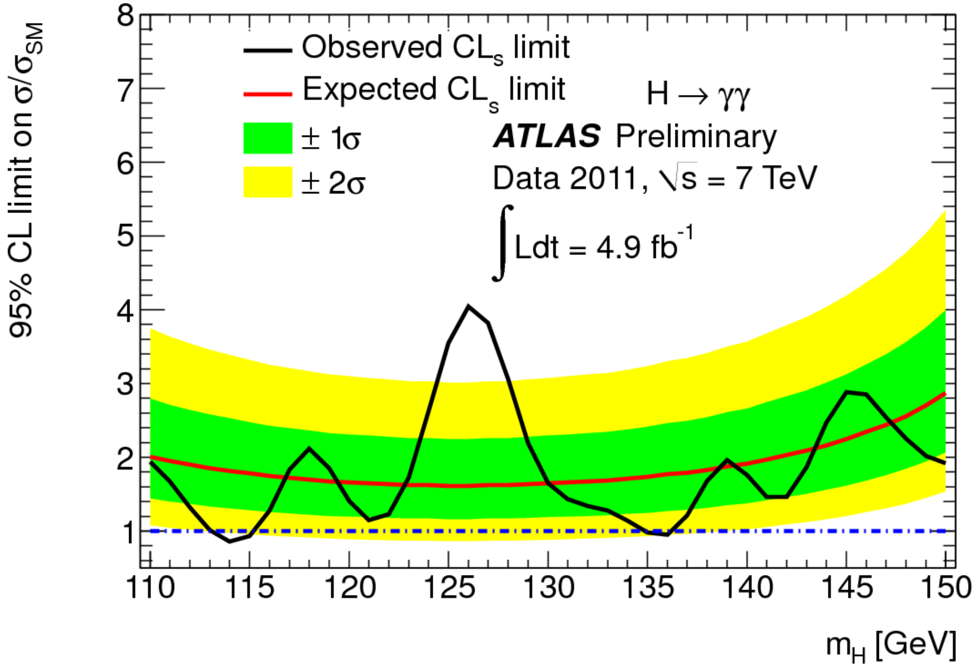
Spurious signal

Category	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9
Events	± 4.3	± 0.2	± 3.7	± 0.5	± 3.2	± 0.1	± 5.6	± 0.6	± 2.3

$H \rightarrow \gamma\gamma$ $110 \leq m_H \leq 150$ GeV 4.9 fb^{-1}

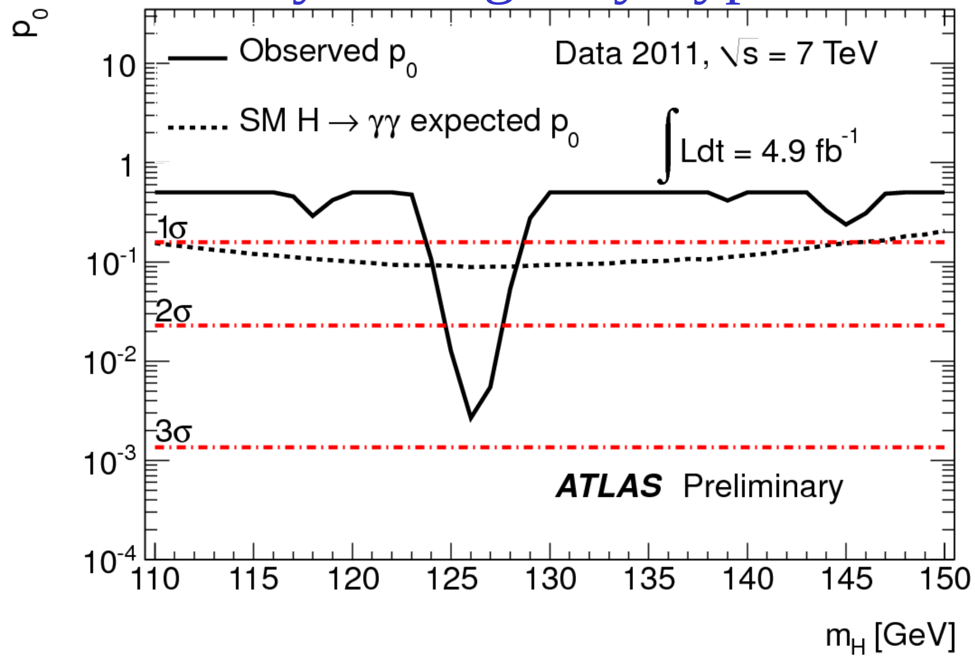
Statistics results

Limits



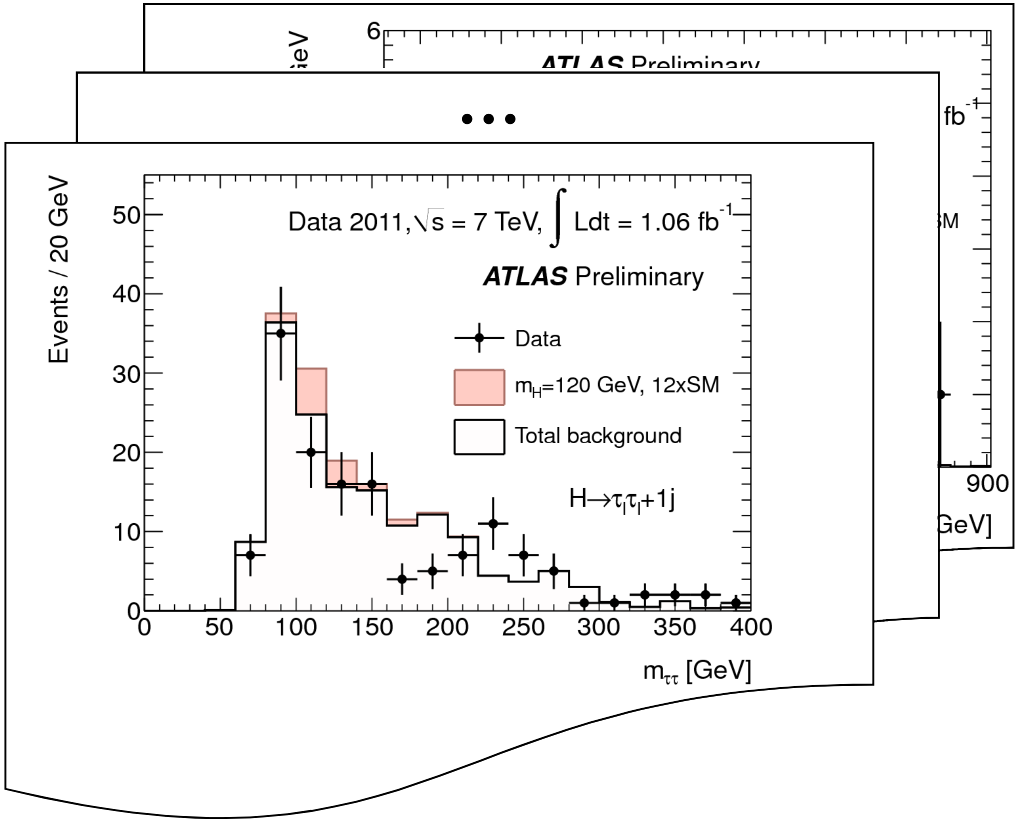
In range 0.9-4.0xSM ; exp. : 1.6-2.9
obs. excl. : [114 ; 115] ; [135-136] GeV

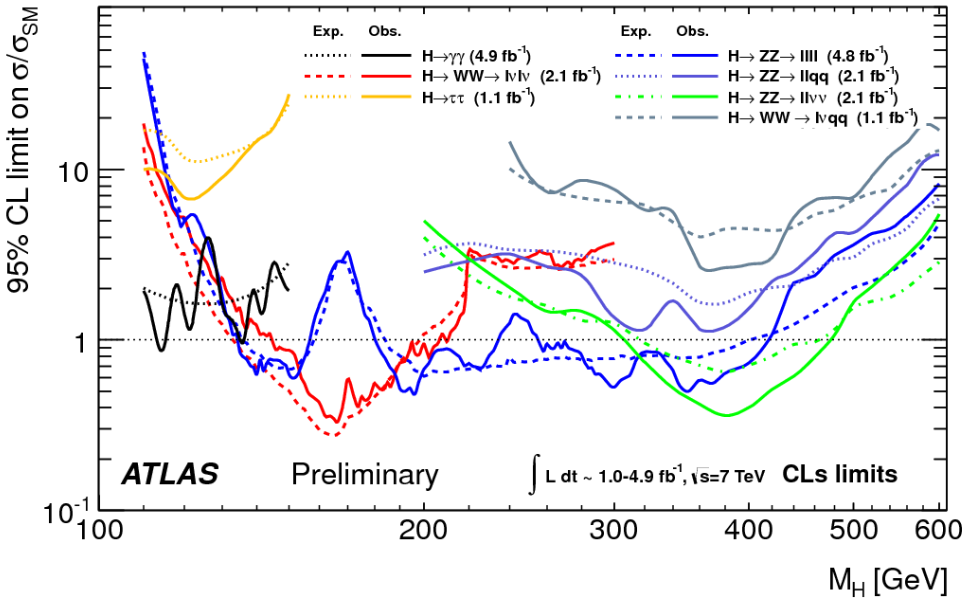
Consistency w/ bkg only hypothesis



max deviation at m_H=126 GeV
p_0=0.27 %⇔2.8 σ (expected : 1.4 σ)
w/ LLE : p_0=7 %⇔1.5 σ

Atlas Combination of SM channels



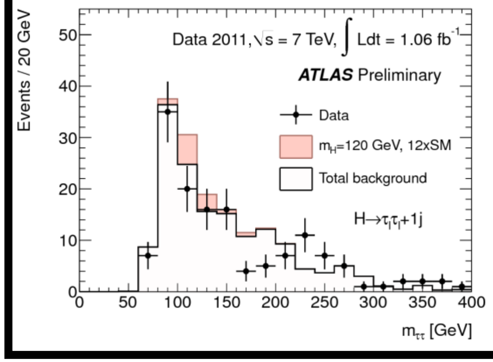


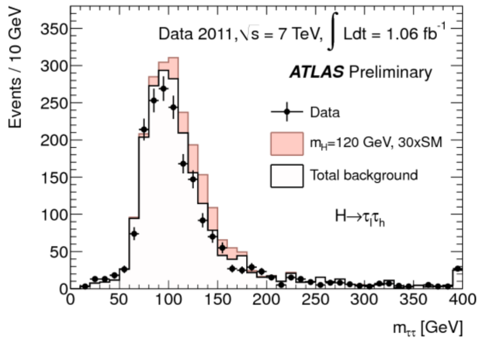
Atlas combination

Signal scaled

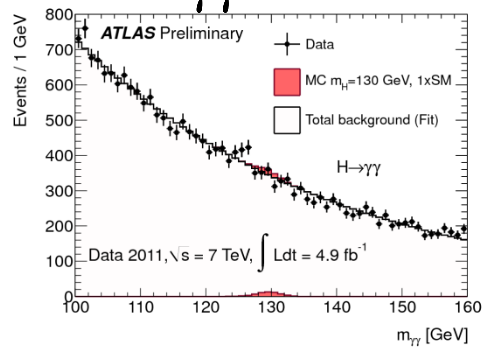
Signal non scaled

H→ττ

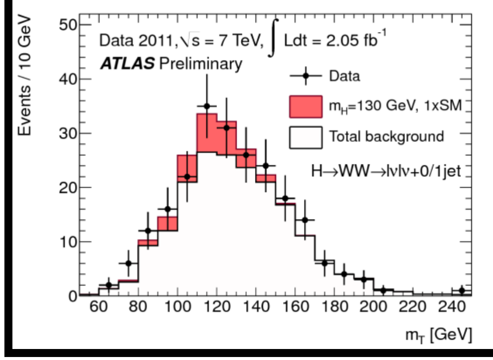


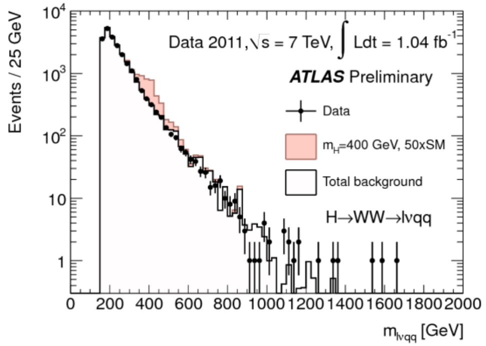


H→γγ



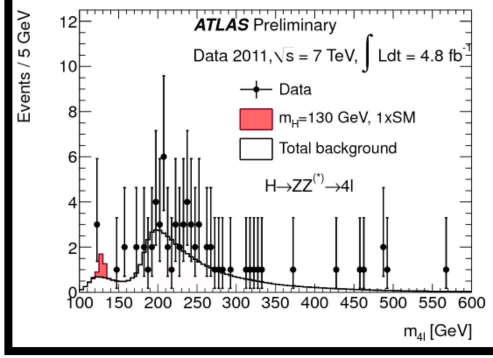
H→WW

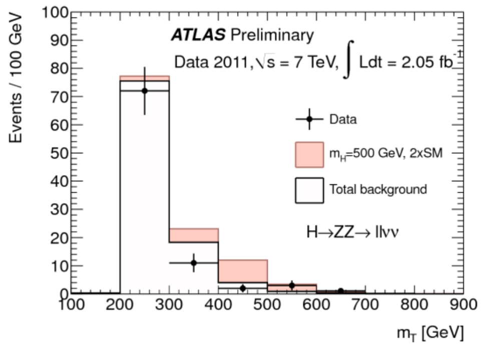




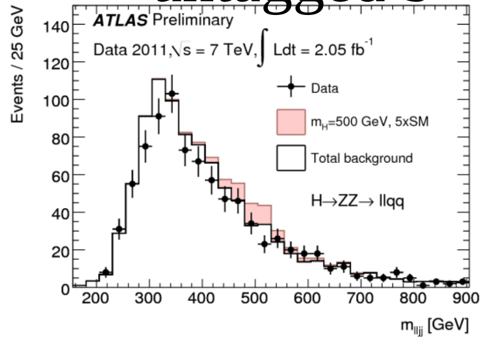
Very low sensitivity channels W(lν)H(bb), Z(ll)H(bb) not included in this specific combination

H→ZZ

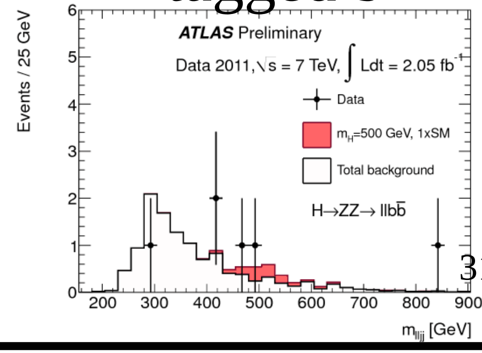




untagged b



tagged b



Correlated systematics

Overall effect on signal/bkg yields from a variation of 1 σ of source of systematics for a

- m_H=120 GeV for H→ττ, H→γγ, H→WW→lν lν, H→ZZ→llll
- m_H=300 GeV for H→WW→lν qq, H→ZZ→llνν, H→ZZ→llqq → **for illustration only**

(systematics for cross-section, resolution signal, migration btw categories, etc… are not printed in these tables, but considered in the final results)

Systematics for yields signal

signal

	$H\to\tau^+\tau^-$		$H\to\gamma\gamma$	$H\to WW^{(*)}$		$H\to ZZ^{(*)}$		
	$\ell\tau_{had}3\nu$	$\tau_\ell\tau_\ell+jet$		$\ell\nu\ell\nu$	$\ell\nu qq$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
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	-	-	-	-	-	-	

Systematics for yields background

background

fit fit

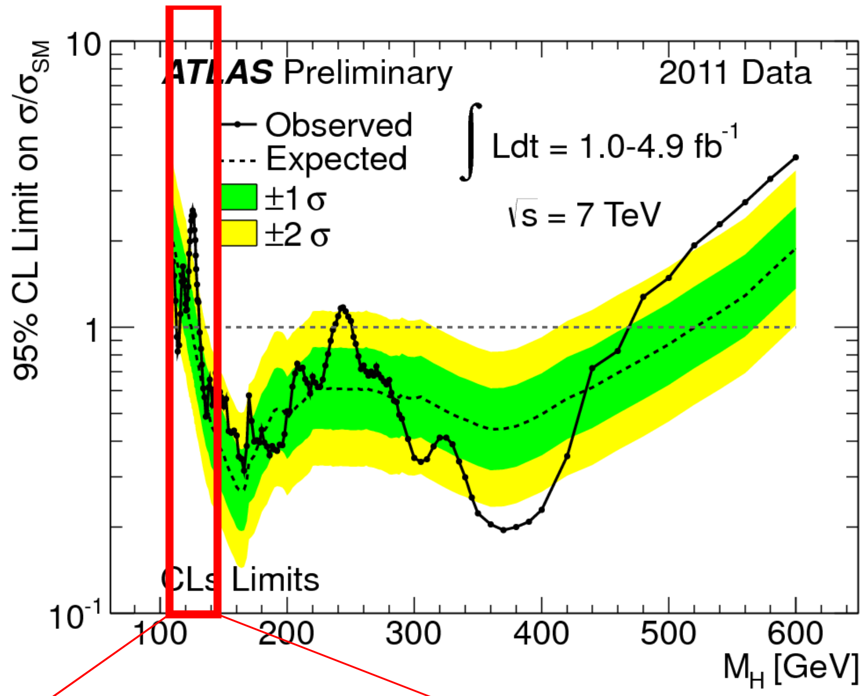
	$H\to\tau^+\tau^-$		$H\to\gamma\gamma$	$H\to WW^{(*)}$		$H\to ZZ^{(*)}$		
	$\ell\tau_{had}3\nu$	$\tau_\ell\tau_\ell+jet$		$\ell\nu\ell\nu$	$\ell\nu qq$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
Luminosity	$^{+3.0}_{-2.9}$	$^{+3.8}_{-3.6}$	-	±0.2	-	$^{+3.7}_{-3.6}$	$^{+2.4}_{-2.3}$	$^{+0.3}_{-0.2}$
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	-	-	-	-	-	-	

Upper limits

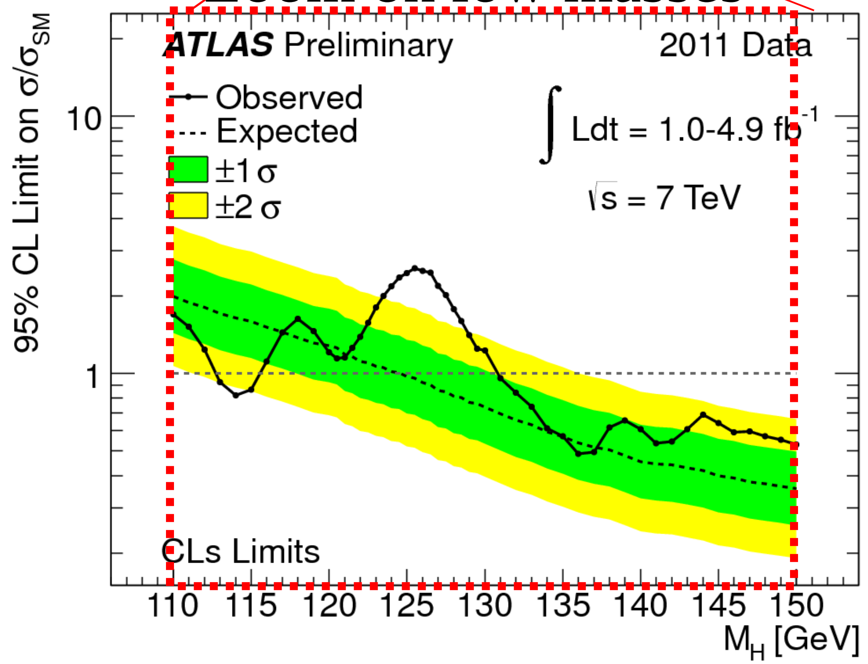
Excluded 95 % CL

-Observed : [112.7 ; 115.5] U [131 ; 237] U [251 ; 453] GeV

-Expected : [124.6 ; 520] GeV



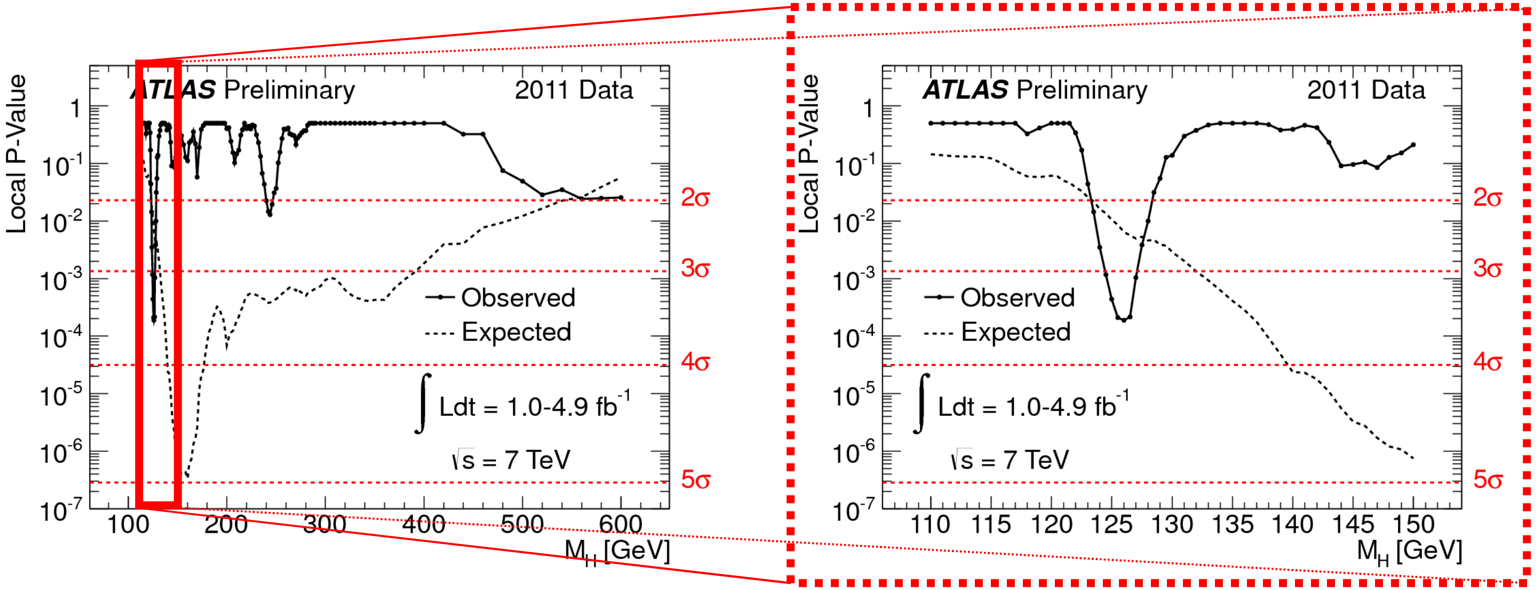
Zoom on low masses



Consistency of obs. w/ bkg-only hyp.

— obs. p-value
------ exp. p-value

small p-value
⇔low agreement
w/ bkg-only hyp.



- excess events for m_H=126 GeV ; p_0(local)=1.9x 10^{-4} (3.6 σ) [also m_H=245 GeV]

LEE : $p_0^{global} \approx p_0^{local} + N_0 e^{-\frac{1}{2}(u-u_0)}$

↑ crossing μ=0 :

6 : m_H : [110 ; 600] GeV ; p_0(global)=1.4 % (2.2 σ)

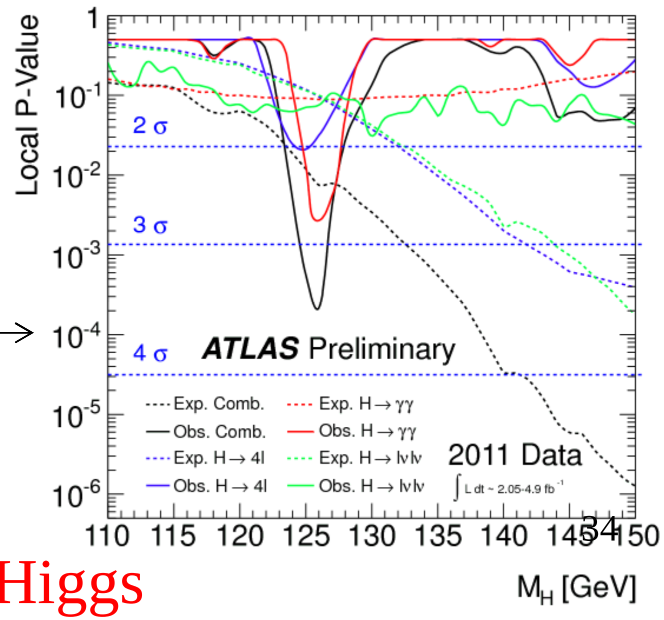
3 : m_H : [110 ; 146] GeV ; p_0(global)=0.6 % (2.5 σ)

- per channel :

-H→γγ : p_0(local/global)=2.8 σ/7 %

-H→ZZ$^{(*)}$→llll : p_0(local/global)=2.1 σ/33 %

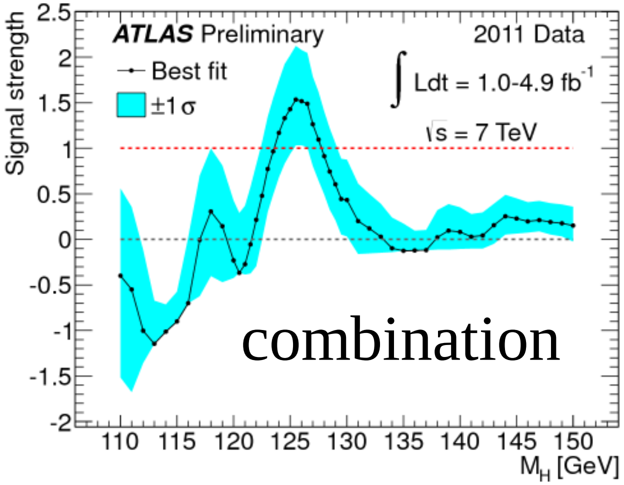
-H→WW$^{(*)}$→lνlν : p_0(local)=1.4 σ



Not enough statistics to make conclusion on ∃/∄ of Higgs

Best fit signal strength

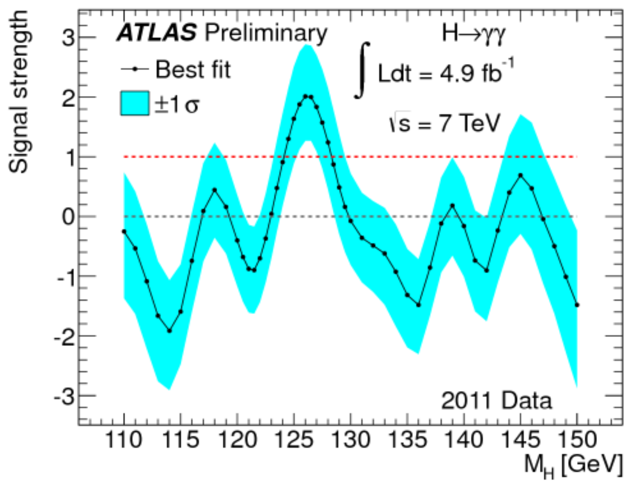
μ=0 : bkg-only
μ=1 : 1 xSM
μ=n : n xSM



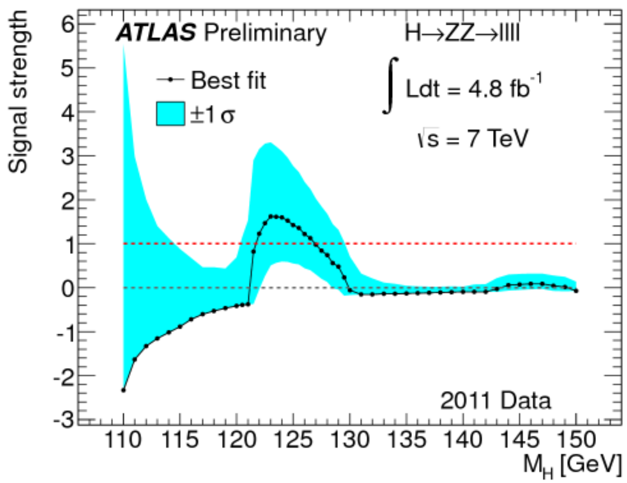
compatible w/ SM within fit uncertainty band

Negative values authorized but pdf ≥0
(not the case for p_0, limited to 0.5)

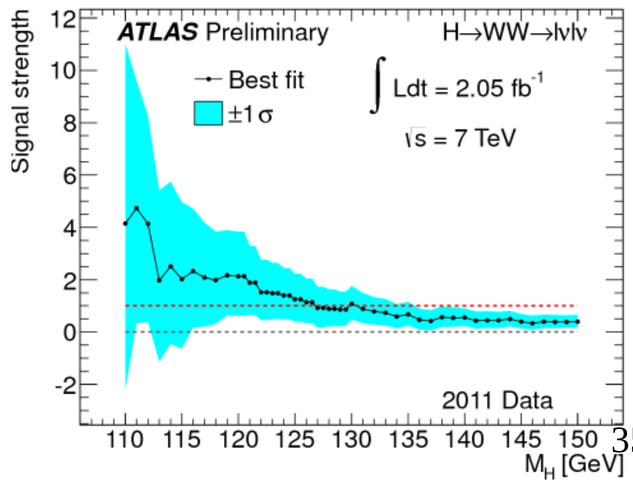
Higher than SM



compatible w/ SM



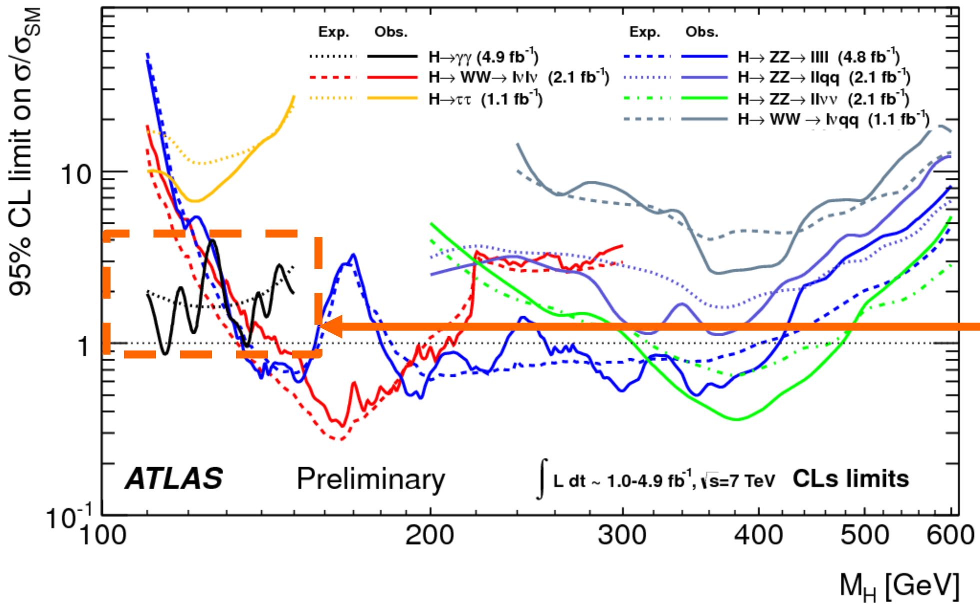
compatible w/ SM



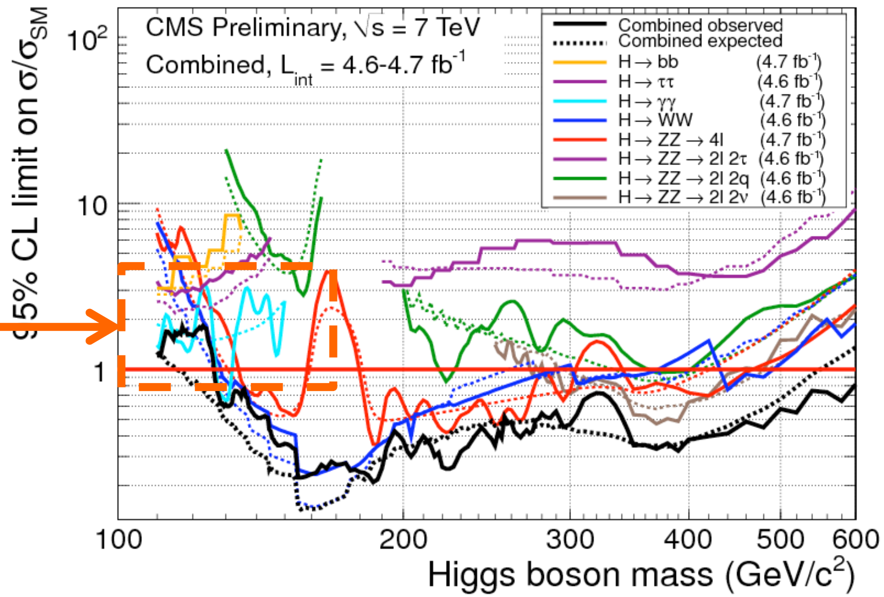
Comparison Atlas & CMS for the council

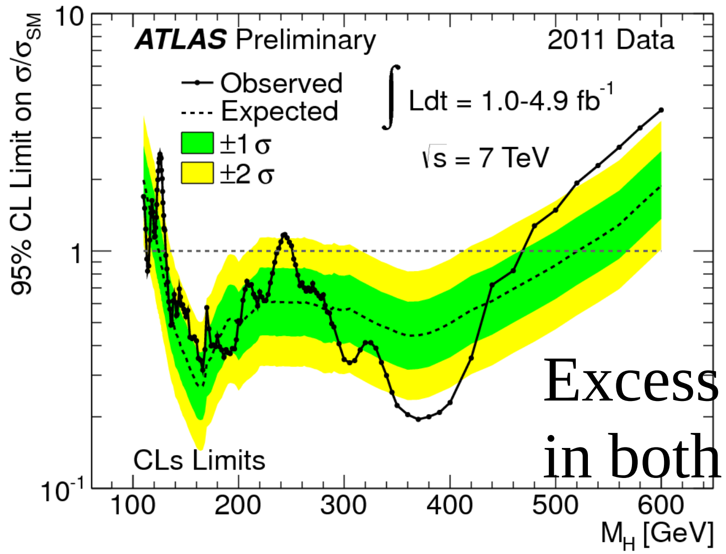
flashed

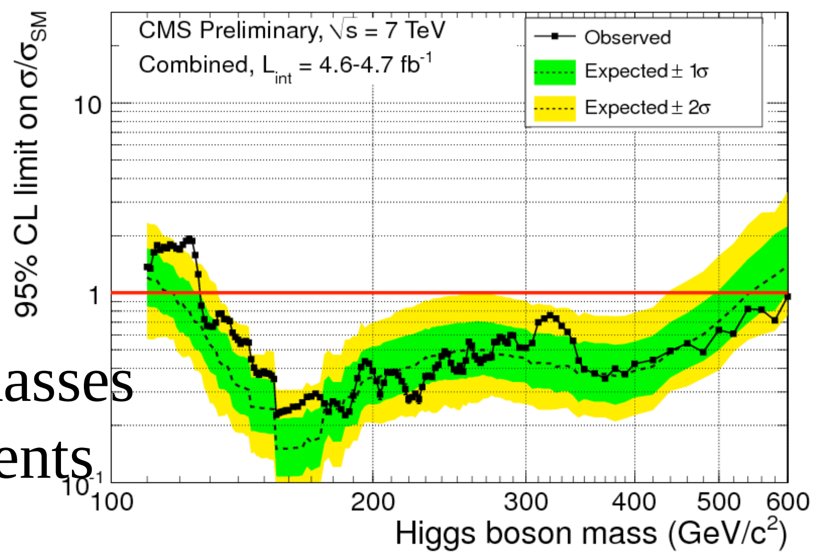
Atlas



CMS *CMS-PAS-HIG-11-032*





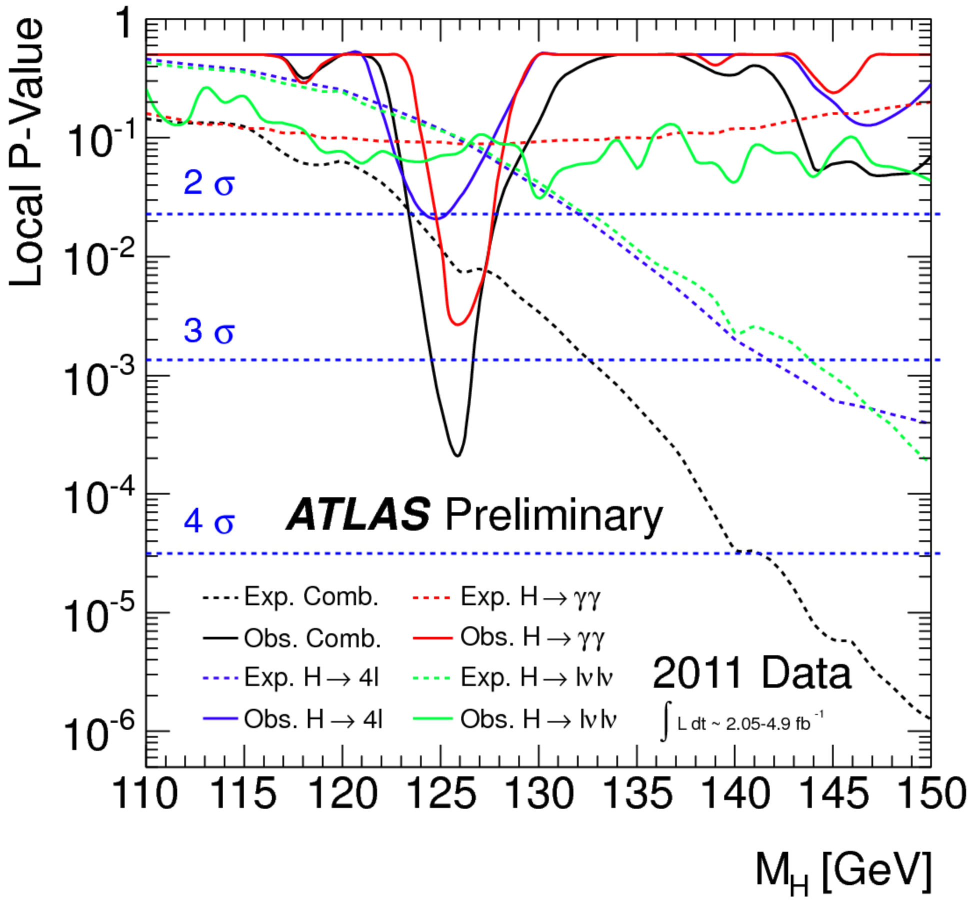


Excess at low masses
in both experiments

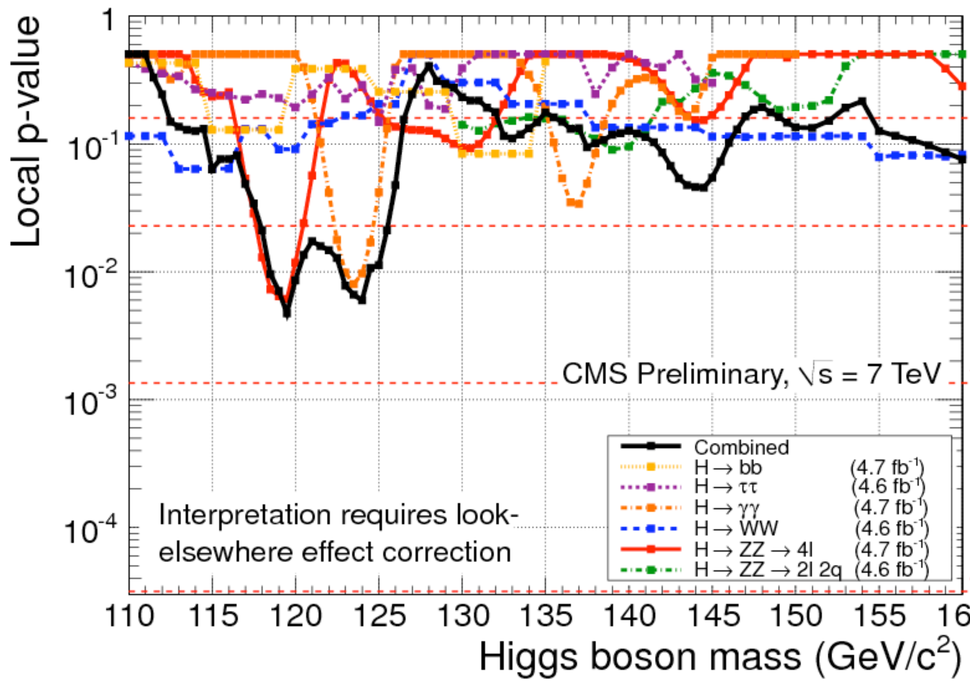
Comparison Atlas & CMS for the council

flashed

Atlas



CMS



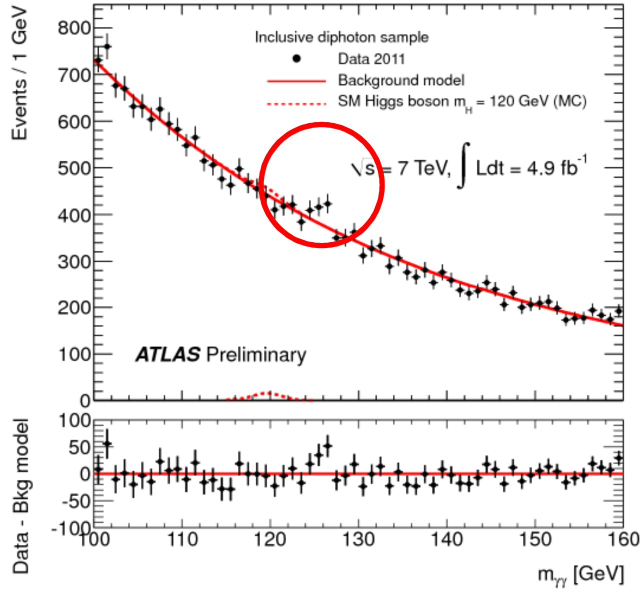
Excess in the same region 124-126 GeV

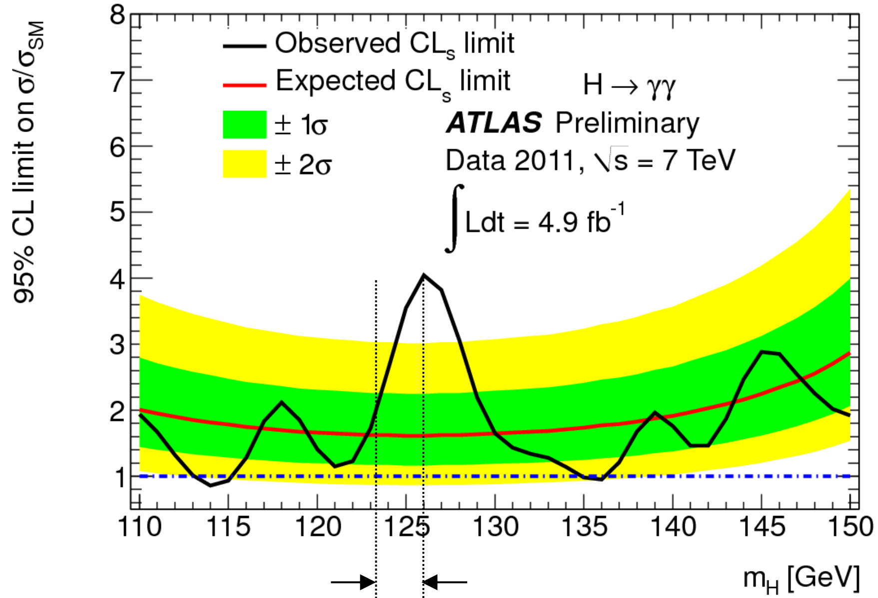
A bit higher for CMS (⇔more SM-like)

H→γγ

flashed

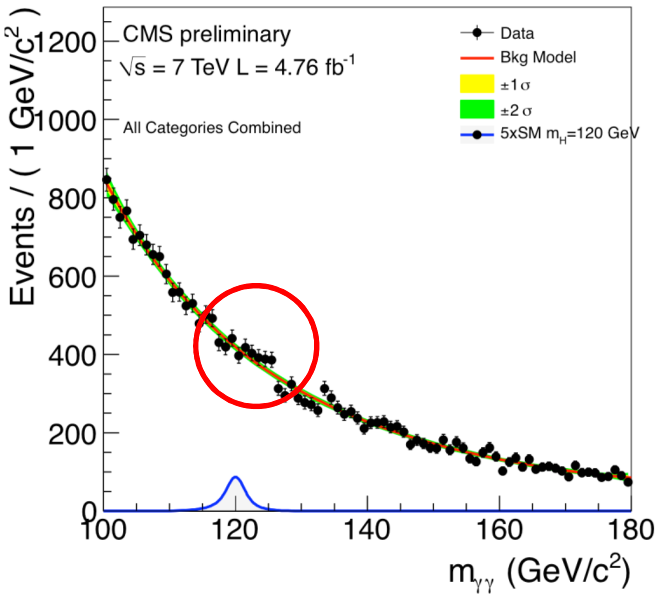
Atlas

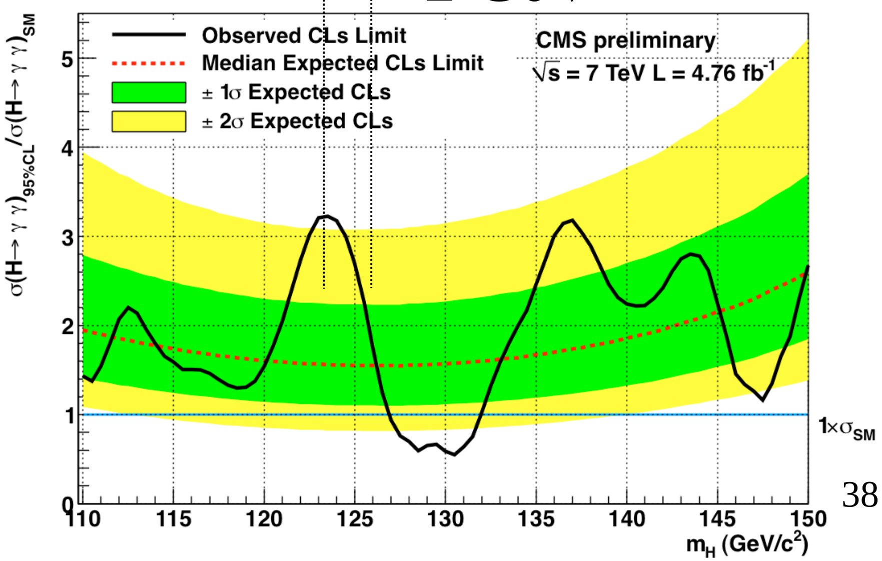




≈2 GeV

CMS

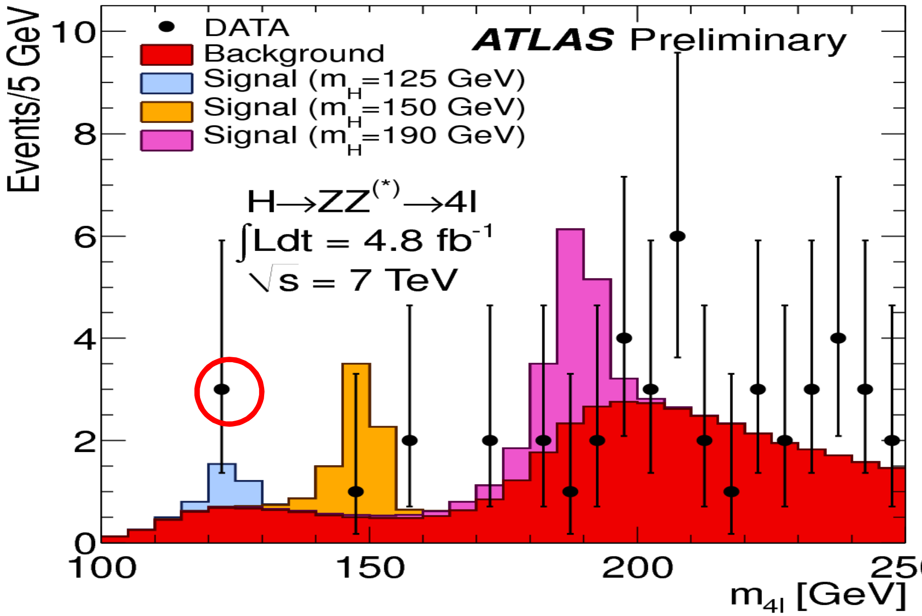




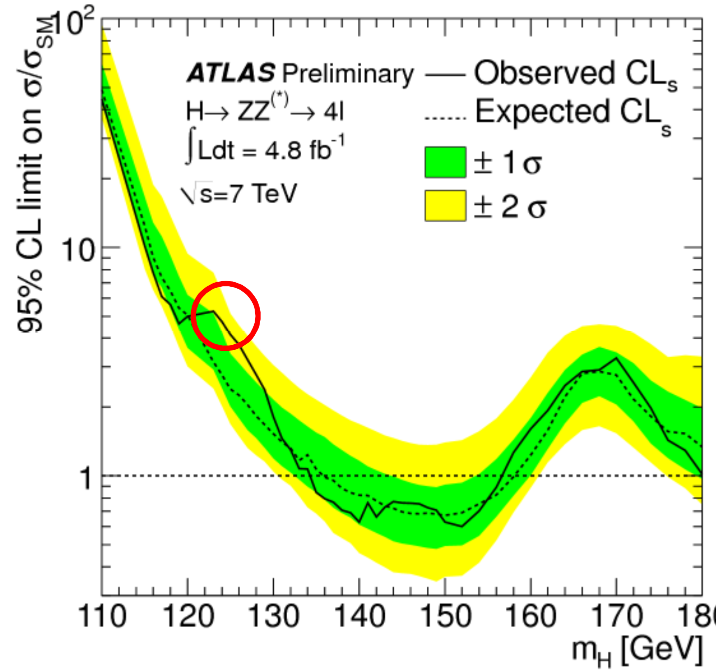
H→4l

flashed

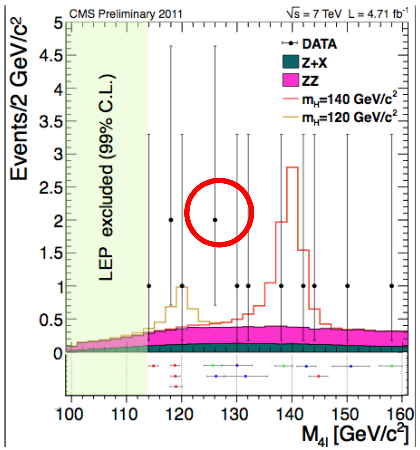
Atlas

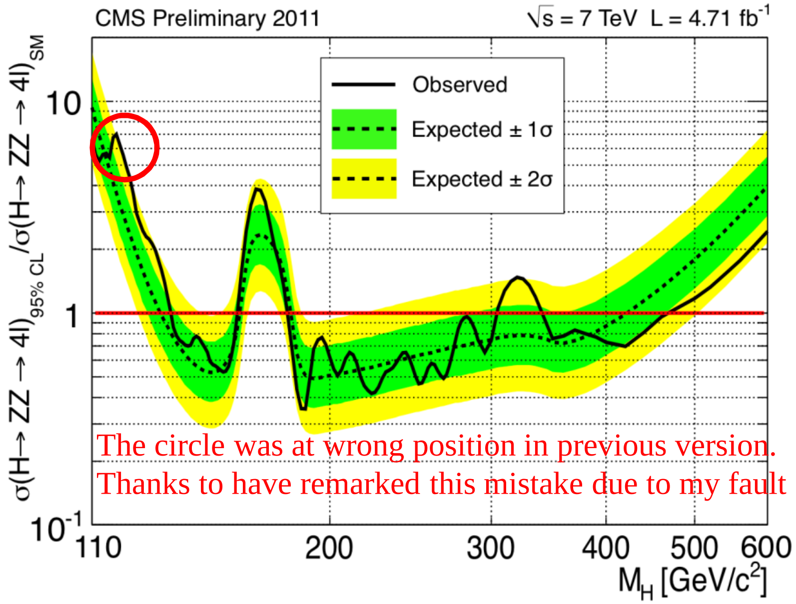


(x scale deformed to align plots)



CMS



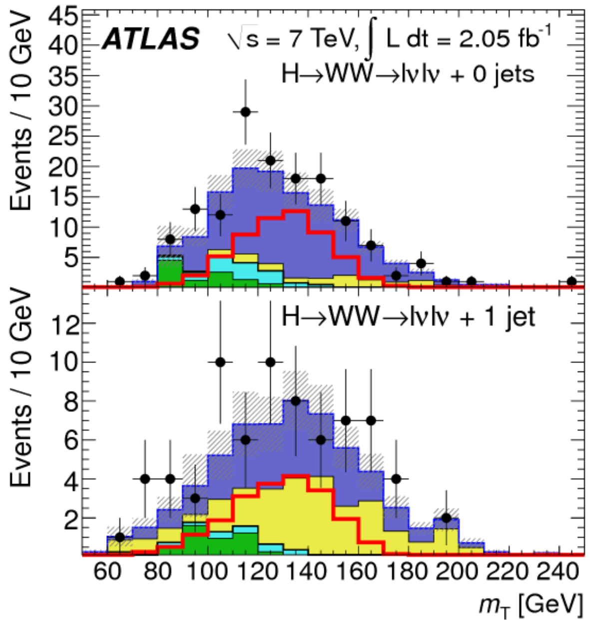


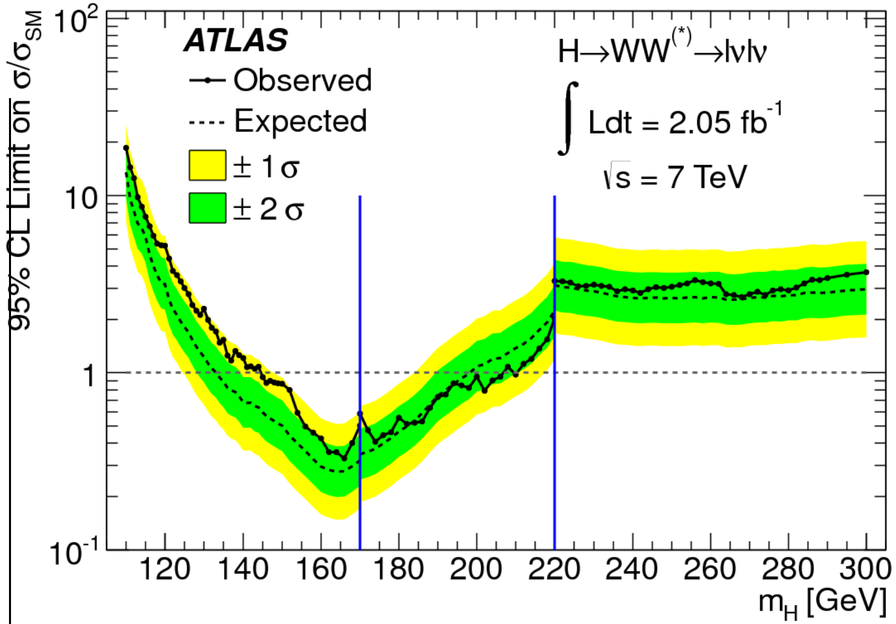
The circle was at wrong position in previous version.
Thanks to have remarked this mistake due to my fault

H→WW→lνlν

flashed

Atlas

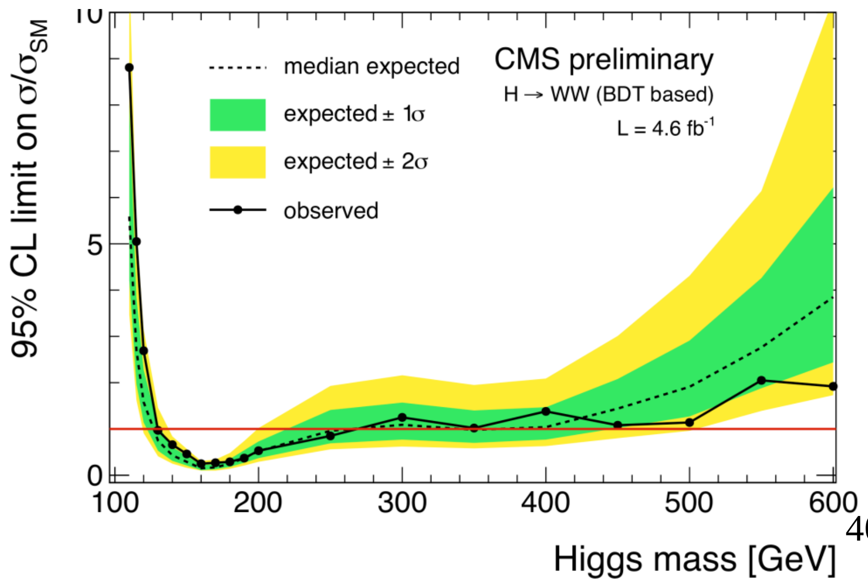




CMS

Transverse mass seems not public

See https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig11024TWiki

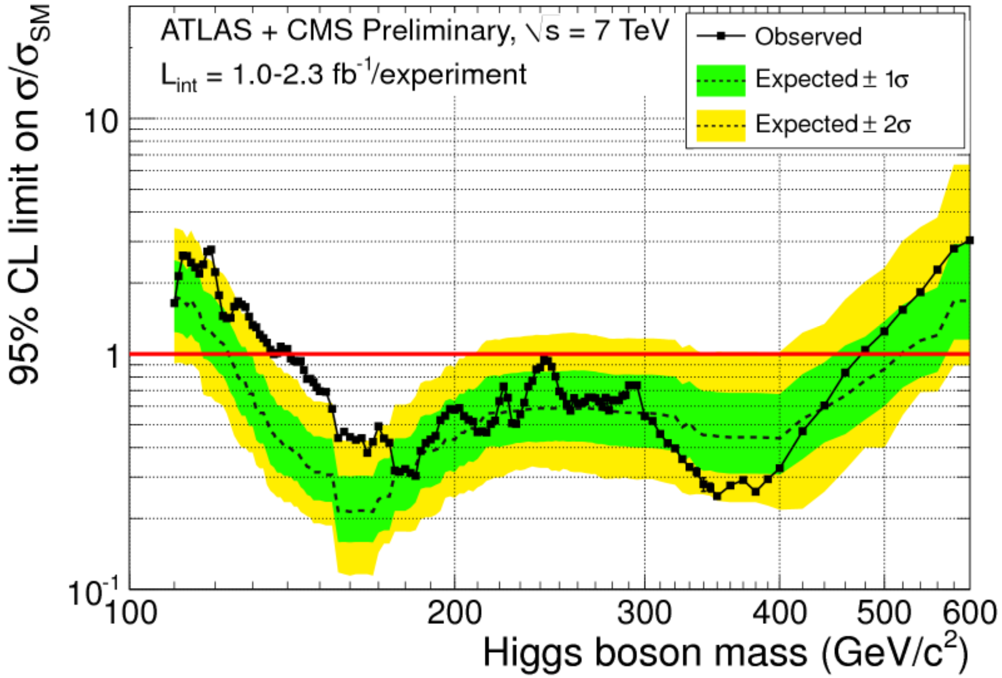


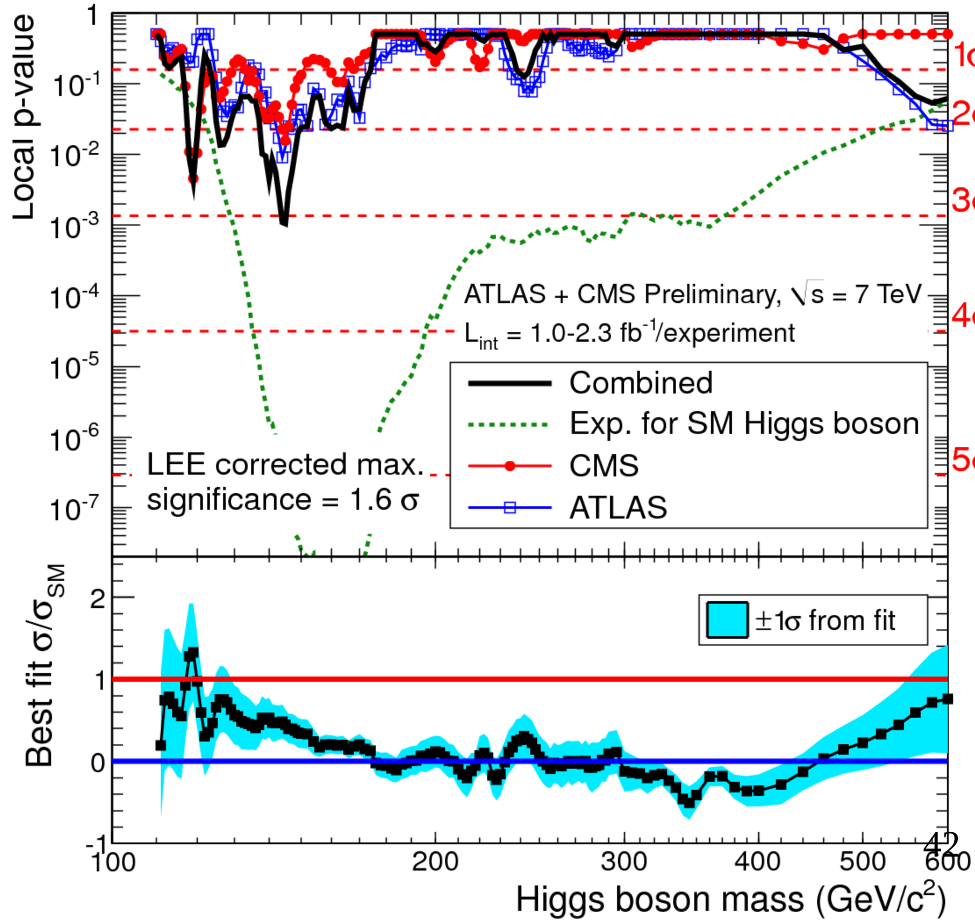
(previous) Combination Atlas/CMS w/ 1.0-2.3 fb^{-1}/experiment

Channel	Experiment	m_H range $[GeV]$	Luminosity (fb^{-1})	sub-channels
$H \to \gamma\gamma$	ATLAS	$110-150$	1.1	5 : η; conv. of photons
	CMS	$110-150$	1.7	8 : $p_{T_{\gamma\gamma}}$; η; conv. of photons
$H \to \tau\tau$	ATLAS	$110-150$	1.1	5 : $ll4\nu$: $ee, \mu\mu, e\mu$; $l\tau_{had}$: e, μ
	CMS	$110-140$	1.6	6 : $l\tau_{had}$: e, μ ; $e+\mu$; VBF $jets$ or not
$H \to bb$	ATLAS	$110-130$	1.0	$2 : WH, ZH$
	CMS	$110-135$	1.1	$5 : WH, ZH$; e, μ
$H \to WW \to l\nu l\nu$	ATLAS	$110-300$	1.7	6 : e, μ, $e\mu$; $0, 1$ j
	CMS	$110-600$	1.5	$4 : l_1 = l_2$, $l_1 \neq l_2$; $0, 1$ j
$H \to ZZ \to llll$	ATLAS	$110-600$	$2.0-2.3$	3 : 4μ, $2e2\mu$, $4e$
	CMS	$110-600$	1.7	3 : 4μ, $2e2\mu$, $4e$
$H \to ZZ \to 2l2\tau$	CMS	$180-600$	1.1	8 : $e\mu$; $\tau_{had}\tau_{had}$, $l\tau_{had}$: e, μ , $e\mu$
$H \to ZZ \to 2l2\nu$	ATLAS	$200-600$	2.0	2 : $ee, \mu\mu$
	CMS	$180-600$	1.1	2 : $ee, \mu\mu$
$H \to ZZ \to 2l2q$	ATLAS	$200-600$	1.0	2 : $ee, \mu\mu$
	CMS	$225-600$	1.6	6 : $ee, \mu\mu$; $0, 1, 2$ b

Uncertainties taken either : 100 % correlated (+ or -) or uncorrelated. Partially correlated broken down to sub-components 100 % correlated or uncorrelated, or considered as 100 % correlated (conservative)
→allow to factorize all constraints in likelihood

(previous) Combination Atlas/CMS w/ 1.0-2.3 fb^{-1}/experiment





Observed exclusion : 141-476 GeV

Expected exclusion : 124-520 GeV

p_0^{local} : 0.001→3.1 sigma

p_0^{global} : 0.05→1.6 sigma

Conclusion…

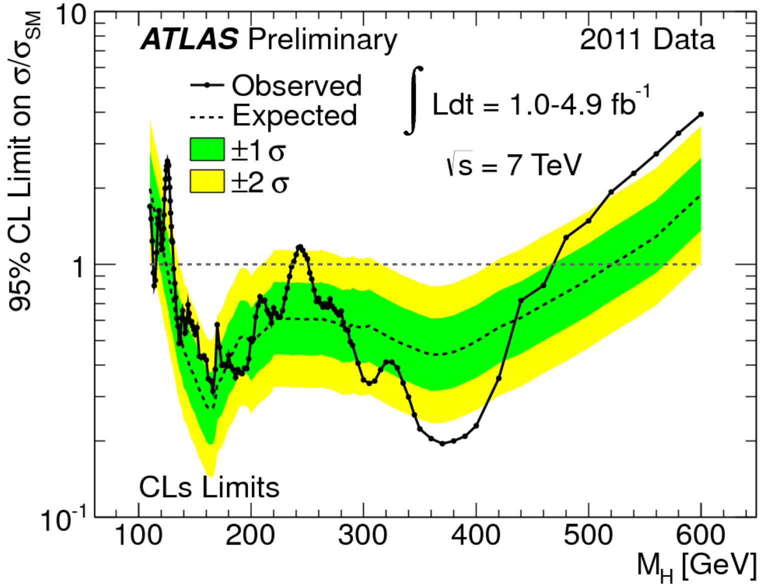
Search for Higgs boson by Atlas experiment continued w/ 2011 data

- Exploration continue for beyond SM Higgs
- Shrinking of viable region for existence of SM Higgs :

current status : excluded 95 % CL

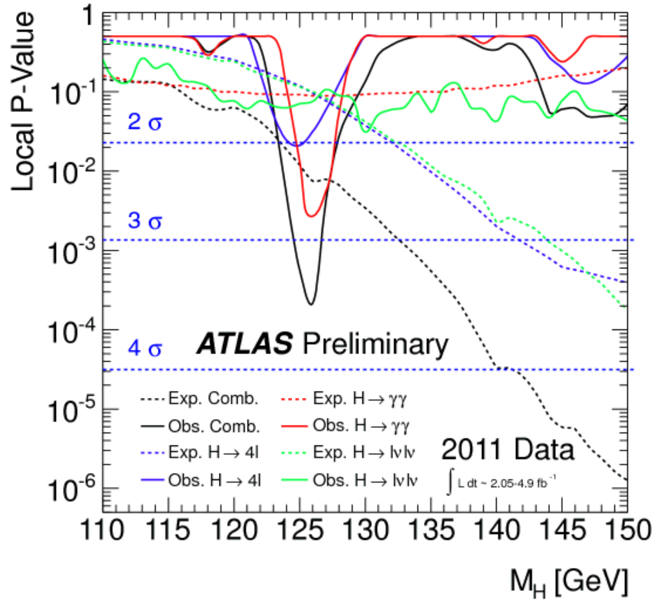
-Observed : [112.7 ; 115.5] U [131 ; 237] U [251 ; 453] GeV

-Expected : [124.6 ; 520] GeV



- 3.6 σ excess wrt bkg exp. for m_H=126 GeV

excess {H→γγ, H→ZZ$^{(*)}$→llll}>>expected



Higgs if it exists, would most probably be in the range [116 ; 131] GeV

Not enough statistics to make conclusion on ∃/∄ of Higgs

…Prospects

- improve analysis :

-update H→WW$^{(*)}$→lνlν, W/Z H→bb, H→ττ w/ O(5 fb^{-1})

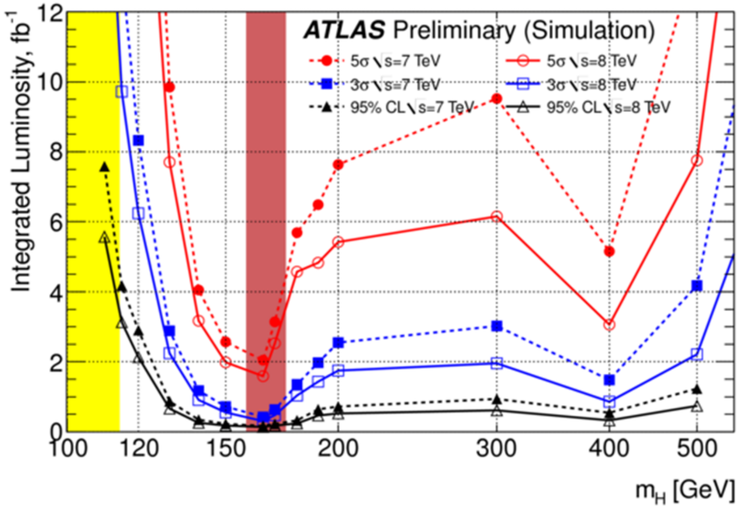
-relax kinematic cuts (eg p_T lepton) to increase acceptance for low masses

-improve identification (MVA, etc)

-further categorization, exclusive channels, new discriminating variables

-combine with CMS : not before publication of individual results

- 2012 : running at 8 TeV and 20 fb^{-1}



20 fb^{-1} per experiment would allow :

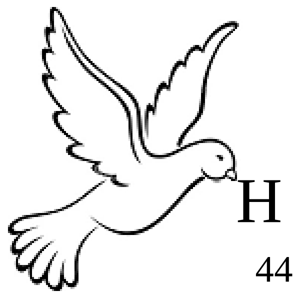
-Atlas alone : 5 σ discovery at m_H≈125 GeV

-Atlas+CMS : 5 σ down to m_H≈116 GeV

-8 TeV : gain sensitivity ≈10 %

- What will be with Higgs ? Nobody can answer, yet
- LHC running in 2012 will most probably bring an answer

→enthousiastic future, possible surprises (good or bad) : let's remain stoic

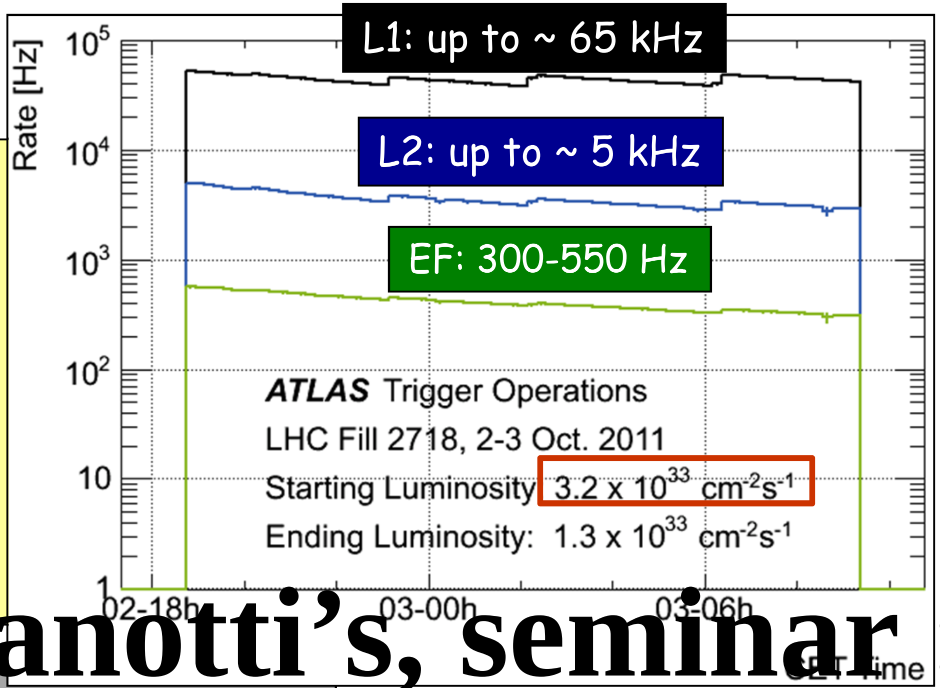


Backup

seminars of F. Gianotti (Atlas) and G. Tonelli (CMS) : https://indico.cern.ch/conferenceDisplay.py?confId=164890

Trigger

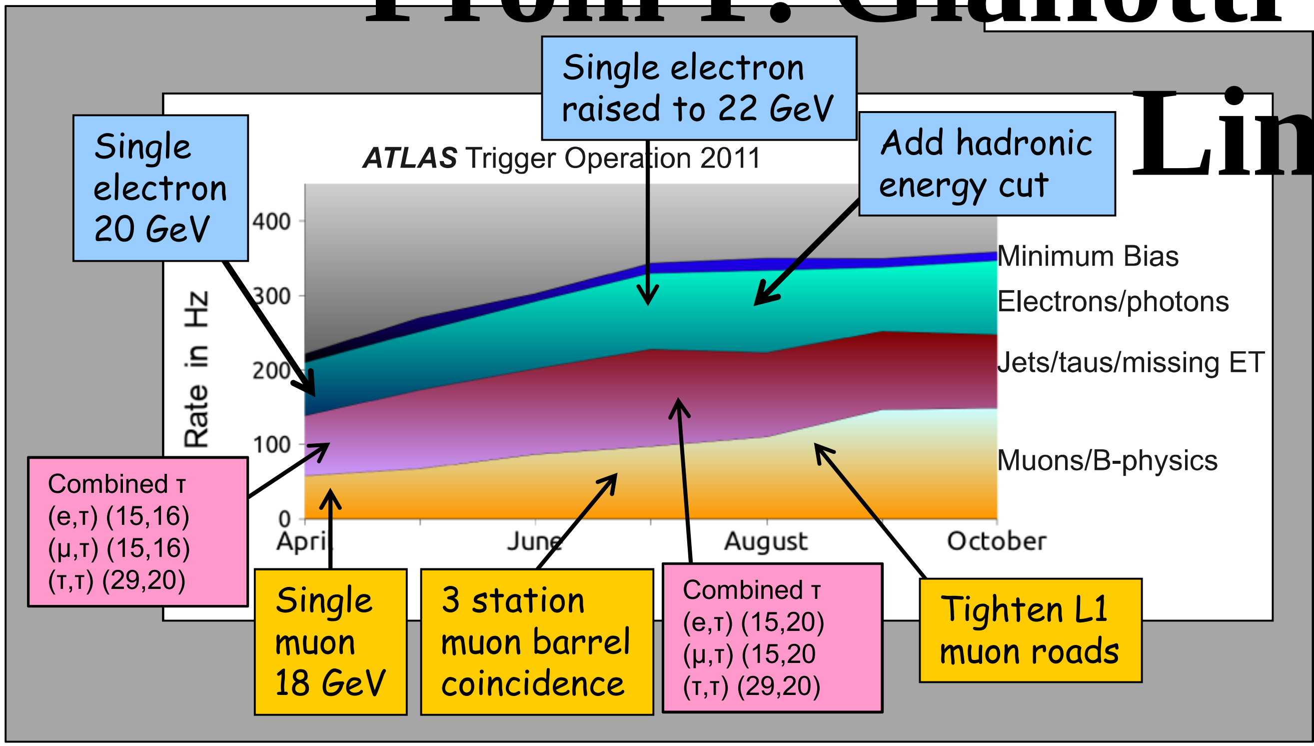
- ❑ Coping very well with rapidly-increasing luminosity (factor ~10 over 2011) and pile-up by adapting prescales, thresholds, menu.
- ❑ Strive to maximise physics (e.g. keeping low thresholds for inclusive leptons)
- ❑ Main menu complemented by set of calibration/support triggers: e.g. special $J/\psi \rightarrow ee$ stream (few Hz) for unbiased low-p_T electron studies



From F. Gianotti's, seminar :

Link :

link : https://indico.cern.ch/conferenceDisplay.py?confId=164890



Typical recorded rates for main streams:

e/γ	~ 100 Hz
Jets/τ/E_T^{miss}	~ 100 Hz
Muons	~ 150 Hz

Managed to keep inclusive lepton thresholds ~ stable during 2011

From F. Gianotti's, seminar : Link :

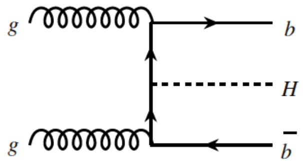
link : https://indico.cern.ch/conferenceDisplay.py?confId=164890

2011 Physics Proton Trigger Menu (end of run L = 3.3 10^{33} $cm^{-2}s^{-1}$)					
	Offline Selection	**Trigger Selection**		**L1 Rate (kHz) at 3e33**	**EF Rate (Hz) at 3e33**
		L1	EF		
Single leptons	Single muon > 20GeV	11 GeV	18 GeV	8	100
	Single electron > 25GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons > 17, 12GeV	11GeV	15,10GeV	8	4
	2 electrons, each > 15GeV	2x10GeV	2x12GeV	2	3
	2 taus > 45, 30GeV	15,11GeV	29,20GeV	7.5	15
Two photons	2 photons, each > 25GeV	2x12GeV	20GeV	3.5	5
Single jet plus MET	Jet pT > 130 GeV & MET > 140 GeV	50 GeV & 35 GeV	75GeV & 55GeV	0.8	18
MET	MET > 170 GeV	50 GeV	70GeV	0.6	5
Multi-jets	5 jets, each pT > 55 GeV	5x10GeV	5x30GeV	0.2	9
TOTAL				**<75**	**~400 (mean)**

Beyond SM Higgs : MSSM

- MSSM (2HDM type II) : h, H, A, H, $H^{\pm}$ (A : CP odd)

-neutral (h/H/A) :



bbH : enhanced for tan β >>

ggH : top and bottom loop : different couplings

VBF : not viable for CP-odd Higgs ; else coupling ≤ SM

WH/ZH : idem

ttH : suppressed for large tan β

Φ	$g_{\Phi\bar{u}u}/g_{H^{SM}\bar{u}u}$	$g_{\Phi\bar{d}d}/g_{H^{SM}\bar{d}d}$	$g_{\Phi VV}/g_{H^{SM}VV}$
h^0	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\sin(\beta-\alpha)$
H^0	$\sin\alpha/\sin\beta$	$\cos\alpha/\cos\beta$	$\cos(\beta-\alpha)$
A^0	$1/\tan\beta$	$\tan\beta$	0

suppressed for large tan β — enhanced for large tan β — ≤SM

dominant decay : bb, ττ

-charged ($H^{\pm}$) :

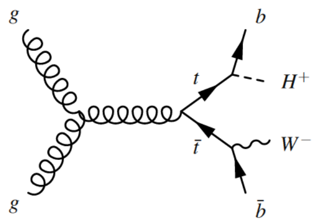
*light Higgs ($m_{H+}<m_t$) : top decay to H^+

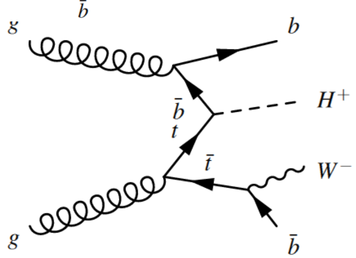
dominant decay : τν (tan β>3), cs (low tan β)

*heavy H^+ $m_{H+}>m_t$: gb→tH+

$m_{H+}\approx m_t$: gg and t→bH^+

decay : H^+→tb ; H^+→τν sizeable (high tan β)





Beyond SM Higgs : NMSSM ; 4SM

many free param in MSSM : soft SUSY breaking terms, μ prob. : fine-tuning

- NMSSM : CP even : $\{H_1, H_2, H_3\}$
  CP odd : $\{A_1, A_2\}$
  charged : $\{H^+, H^-\}$

Light CP-odd Higgs boson : A_1

$A_1 \rightarrow \mu\mu$

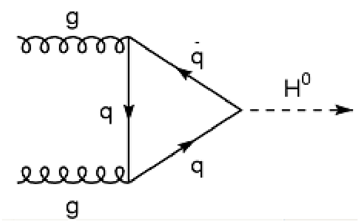
if $9.2 < m_{a1} < 12$ GeV, can account anomalous μ magnetic moment
- could explain some discrepancy by Babar wrt SM
- extra degree of freedom could satisfy dark matter limits

$m_{a1} < 2m_B$: escapes LEP limits

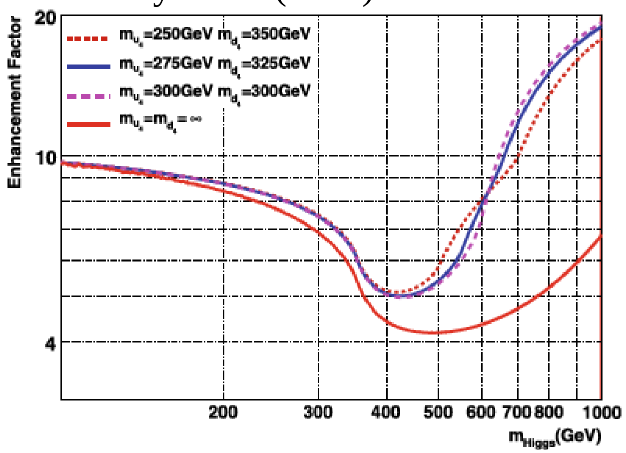
- {Left-Right symmetric ; Higgs triplet ; Little Higgs}

double charged Higgs : $H^{\pm\pm}$

- 4^{th} generation : gg fusion ↑

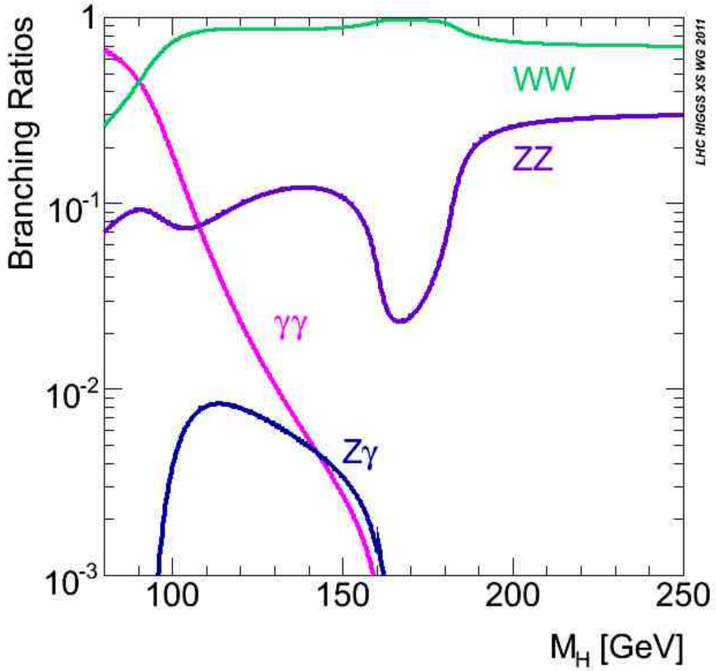


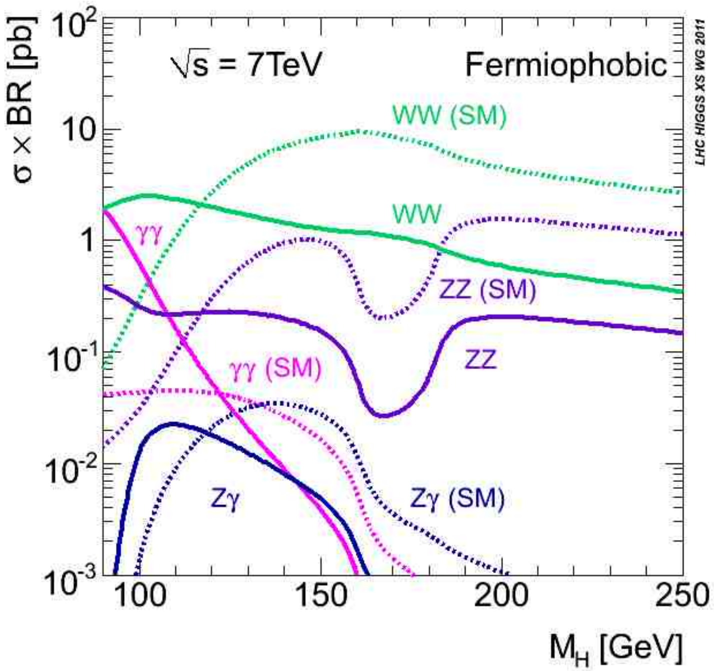
Eur. Phys. J. **C** (2010) 66 : 119-126



Fermiophobic scenario

H-fermions coupling : suppressed (« phoby of fermions »)
→ggH, ttH suppressed ; H→bb suppressed ; H→γγ : strongly enhanced
Two opposite effects : global : increase of σxBR





Production modes : VBF and VH : recoiling jets and vector boson
→p_T of Higgs can be exploited

Channels investigated by Atlas w/ data

SM
Beyond SM

- $H \rightarrow bb$ (VH) ATLAS-CONF-2011-103 ; http://cdsweb.cern.ch/record/1369826
- $H \rightarrow \tau\tau$ (ll, $l\tau_{had}$, $\tau_{had}\tau_{had}$) ATLAS-CONF-2011-132 ; http://cdsweb.cern.ch/record/1383835
- $H \rightarrow \tau\tau$ (ll 4ν) +j ATLAS-CONF-2011-133 ; http://cdsweb.cern.ch/record/1383836
- $H \rightarrow \gamma\gamma$ ATLAS-CONF-2011-161 ; http://cdsweb.cern.ch/record/1406356
- $H \rightarrow WW^{(*)} \rightarrow l\nu\ l\nu$ arXiv:1112.2577 ; http://arxiv.org/abs/1112.2577
- $H \rightarrow WW^{(*)} \rightarrow l\nu\ qq$ arXiv:1109.3615 ; http://arxiv.org/abs/1109.3615
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$ ATLAS-CONF-2011-162 ; http://cdsweb.cern.ch/record/1406357
- $H \rightarrow ZZ \rightarrow ll\ \nu\nu$ ATLAS-CONF-2011-148 ; http://cdsweb.cern.ch/record/1392668
- $H \rightarrow ZZ \rightarrow ll\ qq$ ATLAS-CONF-2011-150 ; https://cdsweb.cern.ch/record/1397901
- combination ($\leq 4.9\ fb^{-1}$) ; ATLAS-CONF-2011-163 http://cdsweb.cern.ch/record/1406358
- prospectives 8 TeV ATL-PHYS-PUB-2011-001 ; http://cdsweb.cern.ch/record/1323856/
- Atlas/CMS ATLAS-CONF-2011-157 ; http://cdsweb.cern.ch/record/1399599
- $H^{\pm} \rightarrow \tau_{lep}\ \nu$ w/ tt ATLAS-CONF-2011-151 ; https://cdsweb.cern.ch/record/1398187
- $H^{\pm} \rightarrow \tau + j$ w/ tt ATLAS-CONF-2011-138 ; http://cdsweb.cern.ch/record/1383841
- $H^{\pm} \rightarrow cs$ ATLAS-CONF-2011-094 ; http://cdsweb.cern.ch/record/1367737
- $a_1 \rightarrow \mu\mu$ ATLAS-CONF-2011-020 ; http://cdsweb.cern.ch/record/1336749
- $H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}$ ATLAS-CONF-2011-127 ; http://cdsweb.cern.ch/record/1383792
- Higgs SM4 ATLAS-CONF-2011-135 ; http://cdsweb.cern.ch/record/1383838
- $H \rightarrow \gamma\gamma$ fermiophobic ATLAS-CONF-2011-149 ; https://cdsweb.cern.ch/record/1397815

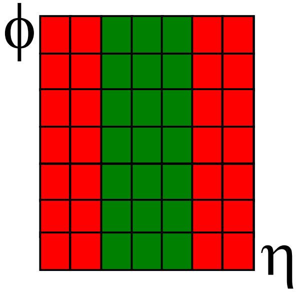
Identification of electrons/photons

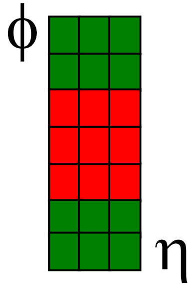
Track/cluster matching & exploits various quantities of shower shape. Ex :

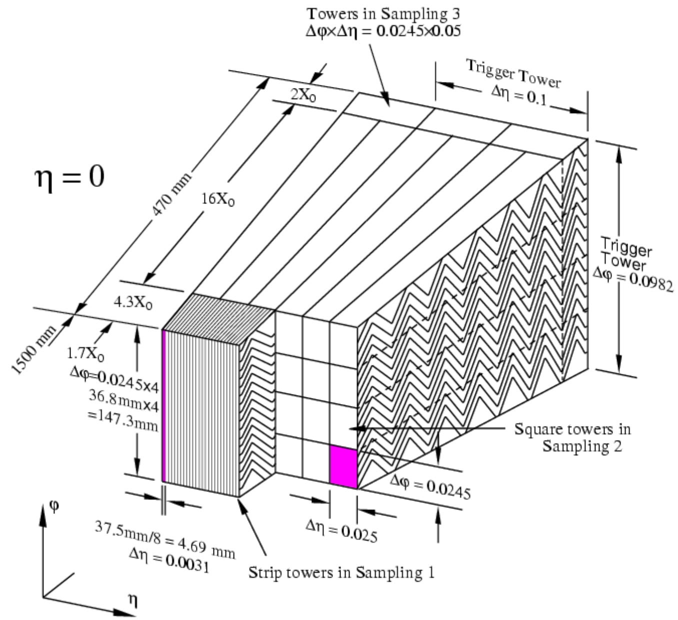
- Energy ratios

$-R_{had}=E_t^{had}/E_T$

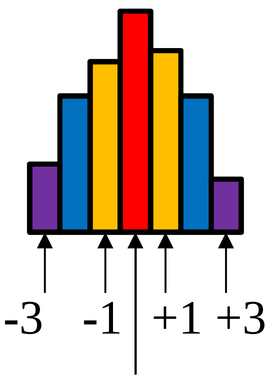
$-R_\eta=E^{S2}_{3x7}/E^{S2}_{7x7}$ $-R_\phi=E^{S2}_{3x3}/E^{S2}_{3x7}$







$-F_{side}=\dfrac{E(\pm3)-E(\pm1)}{E(\pm1)}$

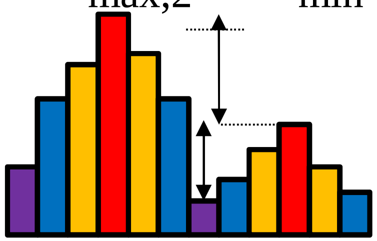


(strips)

high for fake photon
low for low photon

$-E_{ratio}$: asym. $\{1^{st}\ ;\ 2^{nd}\}$ max

$-\Delta E=E^{S1}_{max,2}-E^{S1}_{min}$



(strips)

- Widths

Σ weighted E
in 2^{nd} or 1st sampling

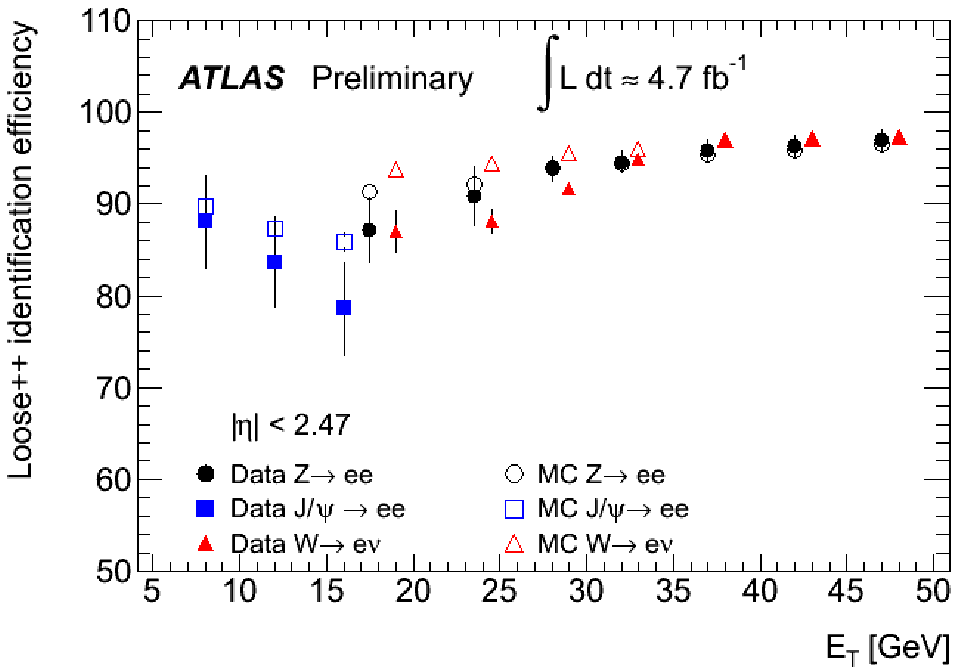
etc.

•Data/MC disagreement : Fudge Factor (FF)

Electrons

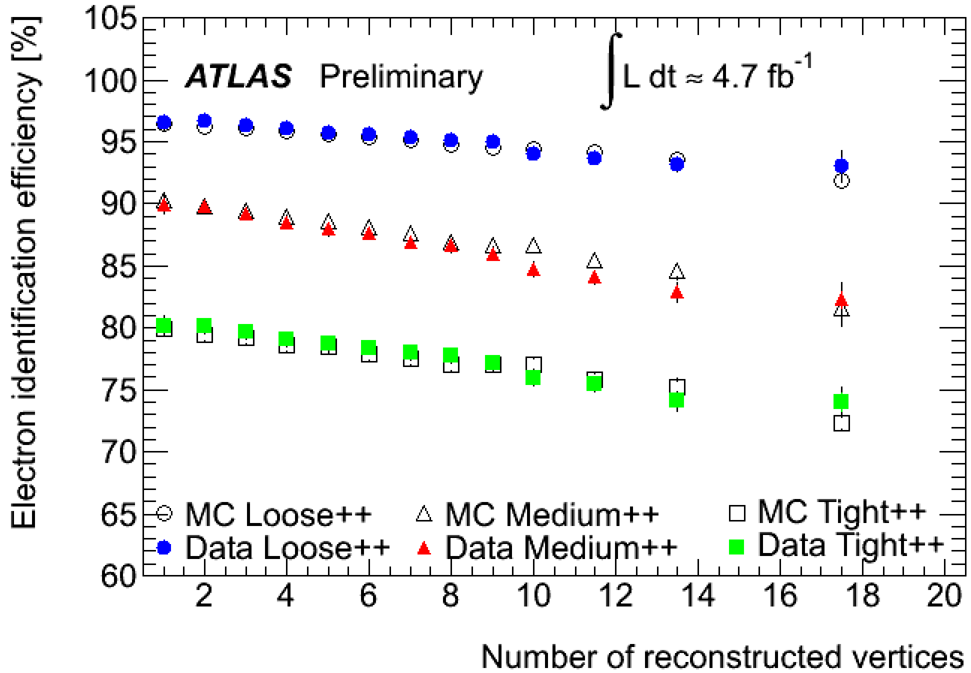
Efficiency measurement : tag & probe method
applied to Z→ee, W→en, J/ψ→ee

J/ψ→ produced promptly & in decay of B-hadrons (non promptly)→≠eff



Impact of PU

Deterioration w/ PU mainly from increasing
hadronic activity overlayed to electron calo shower



Granularity elmg calorimeter

EM calorimeter				
Number of layers and $\|\eta\|$ coverage				
Presampler	1	$\|\eta\| < 1.52$	1	$1.5 < \|\eta\| < 1.8$
Calorimeter	3	$\|\eta\| < 1.35$	2	$1.375 < \|\eta\| < 1.5$
	2	$1.35 < \|\eta\| < 1.475$	3	$1.5 < \|\eta\| < 2.5$
			2	$2.5 < \|\eta\| < 3.2$
Granularity $\Delta\eta \times \Delta\phi$ versus $\|\eta\|$				
Presampler	0.025×0.1	$\|\eta\| < 1.52$	0.025×0.1	$1.5 < \|\eta\| < 1.8$
Calorimeter 1st layer	$0.025/8 \times 0.1$	$\|\eta\| < 1.40$	0.050×0.1	$1.375 < \|\eta\| < 1.425$
	0.025×0.025	$1.40 < \|\eta\| < 1.475$	0.025×0.1	$1.425 < \|\eta\| < 1.5$
			$0.025/8 \times 0.1$	$1.5 < \|\eta\| < 1.8$
			$0.025/6 \times 0.1$	$1.8 < \|\eta\| < 2.0$
			$0.025/4 \times 0.1$	$2.0 < \|\eta\| < 2.4$
			0.025×0.1	$2.4 < \|\eta\| < 2.5$
			0.1×0.1	$2.5 < \|\eta\| < 3.2$
Calorimeter 2nd layer	0.025×0.025	$\|\eta\| < 1.40$	0.050×0.025	$1.375 < \|\eta\| < 1.425$
	0.075×0.025	$1.40 < \|\eta\| < 1.475$	0.025×0.025	$1.425 < \|\eta\| < 2.5$
			0.1×0.1	$2.5 < \|\eta\| < 3.2$
Calorimeter 3rd layer	0.050×0.025	$\|\eta\| < 1.35$	0.050×0.025	$1.5 < \|\eta\| < 2.5$
Number of readout channels				
Presampler	7808		1536 (both sides)	
Calorimeter	101760		62208 (both sides)	

$\geq 0.025/8$

Summary cuts identification electron/photons

Type	Description	Variable name
Loose electron and photon cuts		
Acceptance of the detector	$\|\eta\| < 2.47$ for electrons, $\|\eta\| < 2.37$ for photons ($1.37 < \|\eta\| < 1.52$ excluded)	-
Hadronic leakage	Ratio of E_T in the 1st sampling of the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| < 0.8$ and $\|\eta\| > 1.37$)	R_{had1}
	Ratio of E_T in the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| > 0.8$ and $\|\eta\| < 1.37$)	R_{had}
Middle layer of the EM calorimeter	Ratio in η of cell energies in 3×7 versus 7×7 cells.	R_η
	Lateral width of the shower	w_2
Medium electron cuts (in addition to the loose cuts)		
Strip layer of the EM calorimeter	Total lateral shower width (20 strips)	w_{stot}
	Ratio of the energy difference associated with the largest and second largest energy deposits over the sum of these energies	E_{ratio}
Track quality	Number of hits in the pixel detector (at least one)	-
	Number of hits in the pixels and SCT (at least seven)	-
	Transverse impact parameter (<5 mm)	d_0
Track matching	$\Delta\eta$ between the cluster and the track in the strip layer of the EM calorimeter	$\Delta\eta_1$
Tight electron cuts (in addition to the medium electron cuts)		
B-layer	Number of hits in the B-layer (at least one)	
Track matching	$\Delta\phi$ between the cluster and the track in the middle of the EM calorimeter	$\Delta\phi_2$
	Ratio of the cluster energy to the track momentum	E/p
TRT	Total number of hits in the TRT (used over the acceptance of the TRT, $\|\eta\| < 2.0$)	-
	Ratio of the number of high-threshold hits to the total number of TRT hits (used over the acceptance of the TRT, $\|\eta\| < 2.0$)	-
Tight photon cuts (in addition to the loose cuts, applied with stricter thresholds)		
Second layer of the EM calorimeter	Ratio in ϕ of cell energies in 3×3 and 3×7 cells	R_ϕ
Strip layer of the EM calorimeter	Shower width for three strips around maximum strip	w_{s3}
	Total lateral shower width	w_{stot}
	Fraction of energy outside core of three central strips but within seven strips	F_{side}
	Difference between the energy of the strip with the second greatest energy and the energy of the strip with the smallest energy between the two leading strips	ΔE
	Ratio of the energy difference associated with the largest and second largest energy deposits over the sum of these energies	E_{ratio}

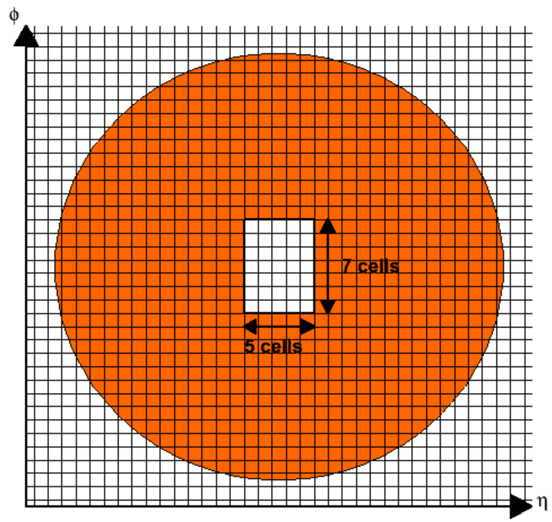
Calorimeter isolation & pile-up

Transverse isolation energy :

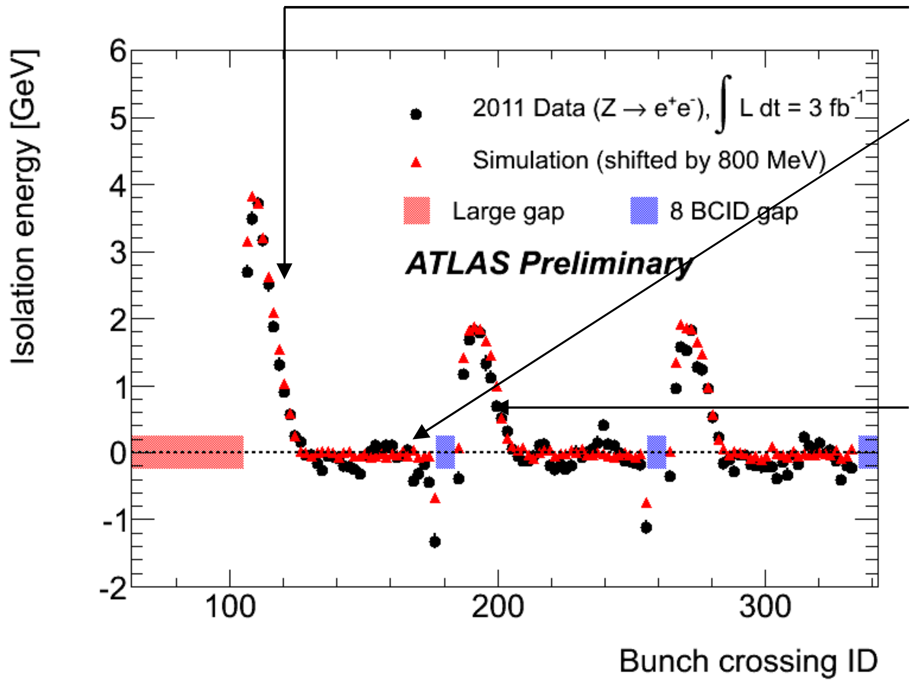
- $\Sigma_{R=0.4}$ cells elmg & hadronic calo around elmg objects
- Subs. core 5x7 cells around barycenter of elmg object
- Corrections from out-of-core energy leakage
- Corrections from UE & in-time pile-up

event-by-event

subs. using ambient ρ_E



Mean for Z decays



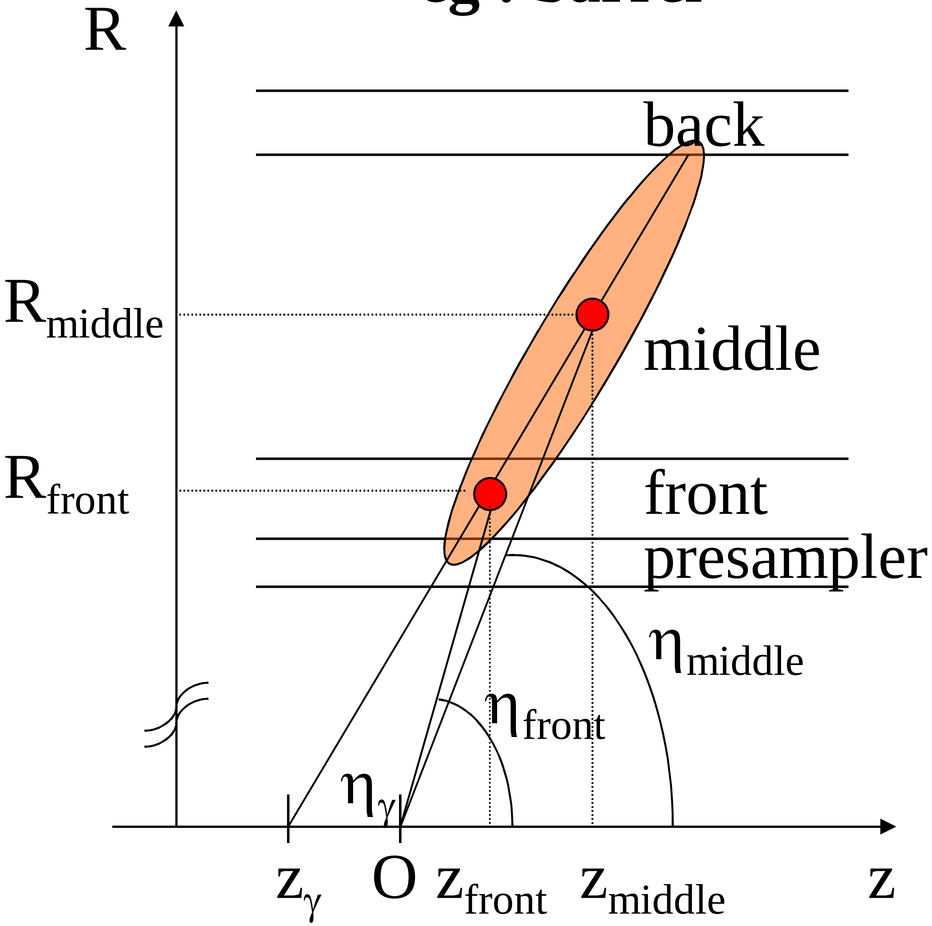
- constructive interference : increases mean
- cancelation of in-time & out-of-time PU for 12 bunches spaced of 50 ns (⇔600 ns)
- Mean isolation : independent bunch position train
- After gap of 8 bunch crossing : cancellation incomplete again (other bunches)

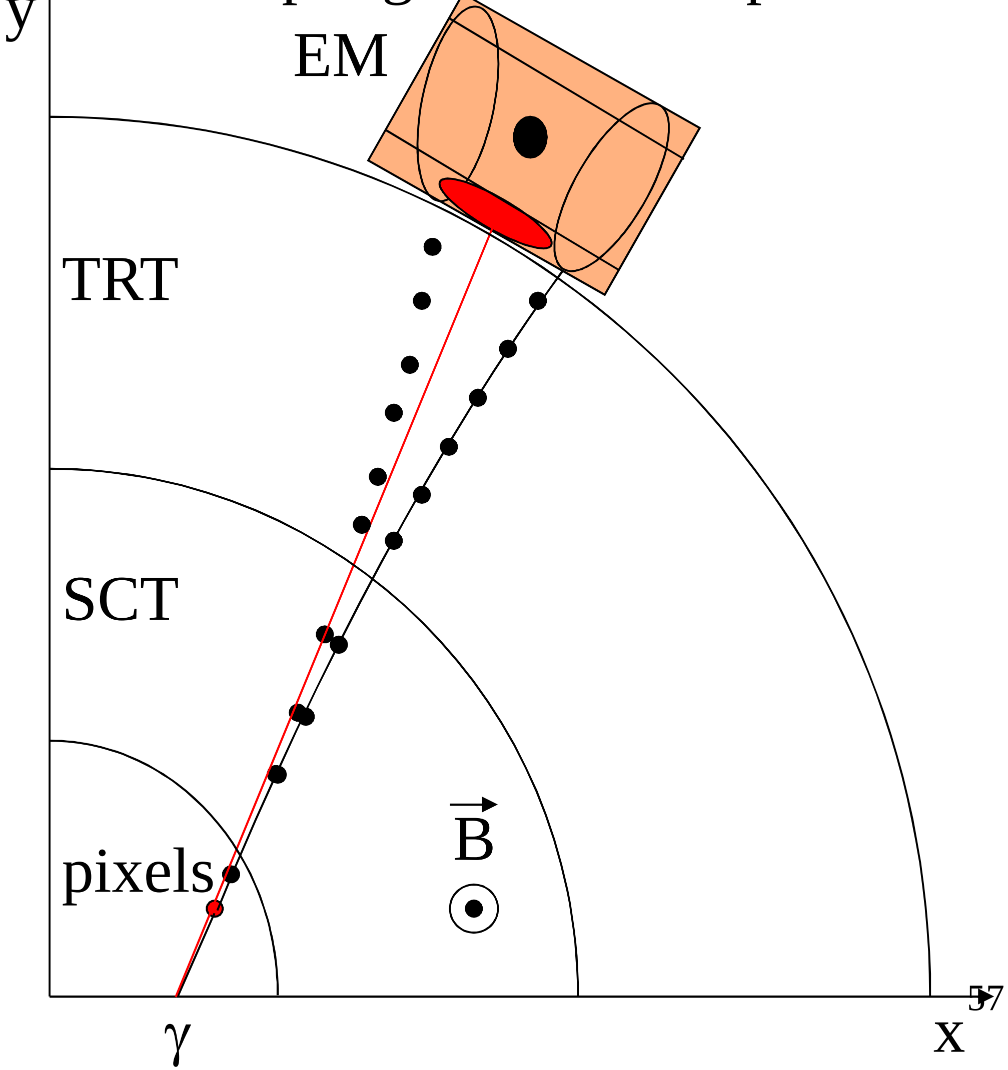
Direction of photons

(direction of electron : tracks)

- unconv. photons & TRT standalone conv. photons : calorimeter pointing
- conv. photons non TRT standalone : 1st sampling+conversion point

eg : barrel





Statistical treatement

Profile likelihood test statistics, CLs prescription, asymptotic method
Check w/ pseudo-experiments & w/ Bayesian

Statistical treatement

- Quantification consistency of hyp. wrt signal strenght « μ »
(μ=0 : bkg ; μ=1 : signal) :

p_μ-value of the test statistics : probability than a given unknown measurement is more extremal than what is really measured

- p-value<x %→Confidence Level (CL) at (100-x) % of the observation

- problem : ↓ fluct. of bkg : could exclude signal for which no sensitivity

→conservative solution at LHC :

- $CL_S = \dfrac{CL_{s+b}}{CL_b} > CL_{s+b}$ →test $CL_s<0.05$ for exclusion

- Exclusion/upper limits : test consistency of obs/exp. w/ signal-only hyp.

p_μ-value : Prob(bkg-only exp. is more signal-like than observed one)

- Observation/discovery : test consistency of obs/exp. w/ bkg-only hyp.

p_0 : Prob than bkg+sig exp. is more bkg-like than observed one

construction such than p_0=can't be > 50 % if bkg ↓

Possible statistical results

- Observed exclusion and expected exclusion

confortable w/ exclusion (within CL : sometimes resurrection of an exclusion)

- Observed exclusion but expected non exclusion

exclusion wo sensitivity : typical : statistical fluctuation down of bkg

- Expected exclusion but observed non exclusion

statistical fluctuation up of bkg or signal

- low expected p-value and high observed p_0-value

Signal (within significance)

- low expected p-value but high observed p_0-value

Non deviation of results with SM

- high expected p-value but low observed p_0-value

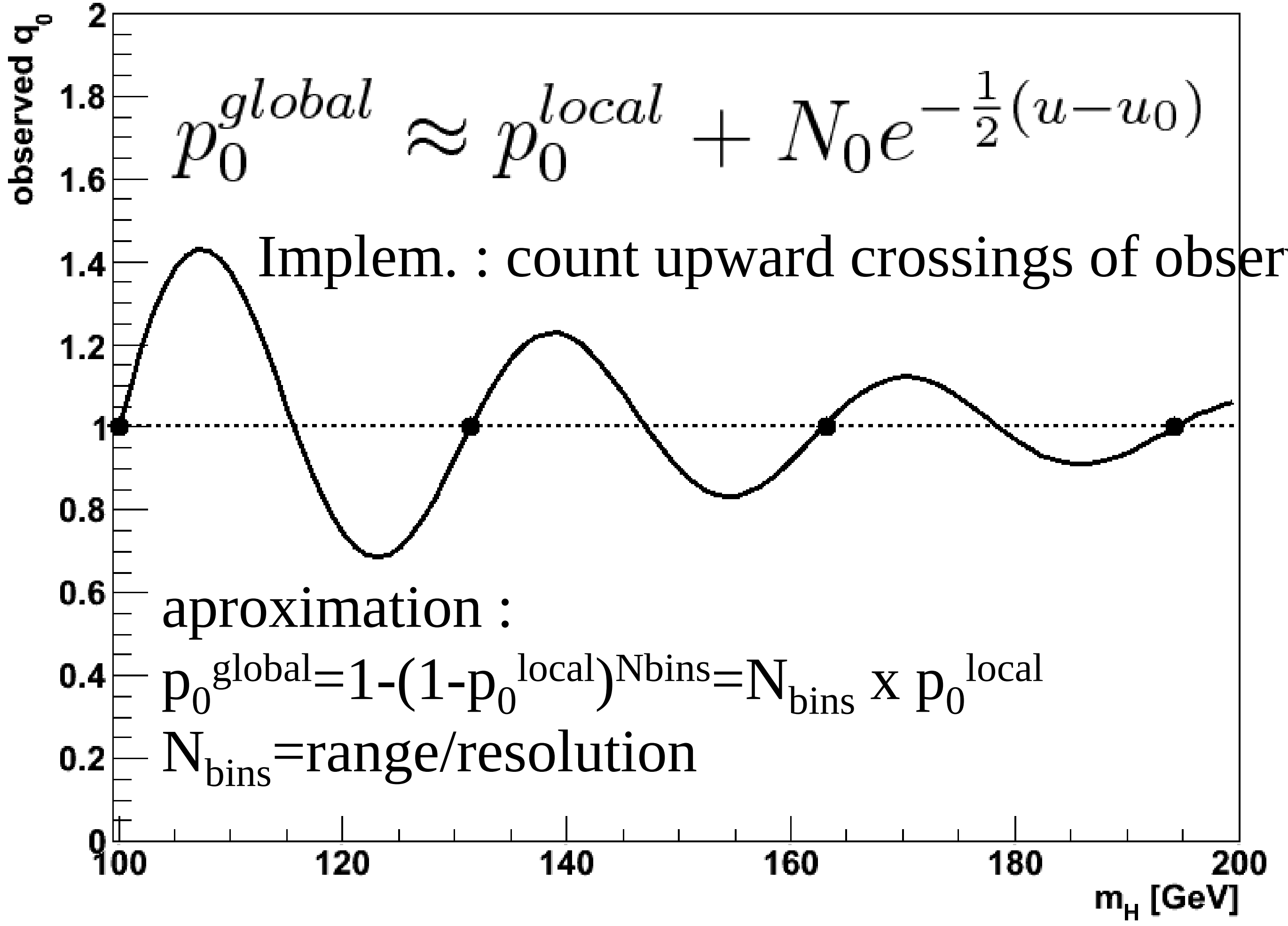
statistical fluctuation down of bkg or signal

Look-elsewhere effect

-Authorize to look « elsewhere » to the current mass point

-The bigger the mass window for analysis, the bigger Prob($\exists \geq 1$ fluctuation)

-$p_0^{local} \rightarrow p_0^{global}$: corrective factor : « trial factor »



$$p_0^{global} \approx p_0^{local} + N_0 e^{-\frac{1}{2}(u-u_0)}$$

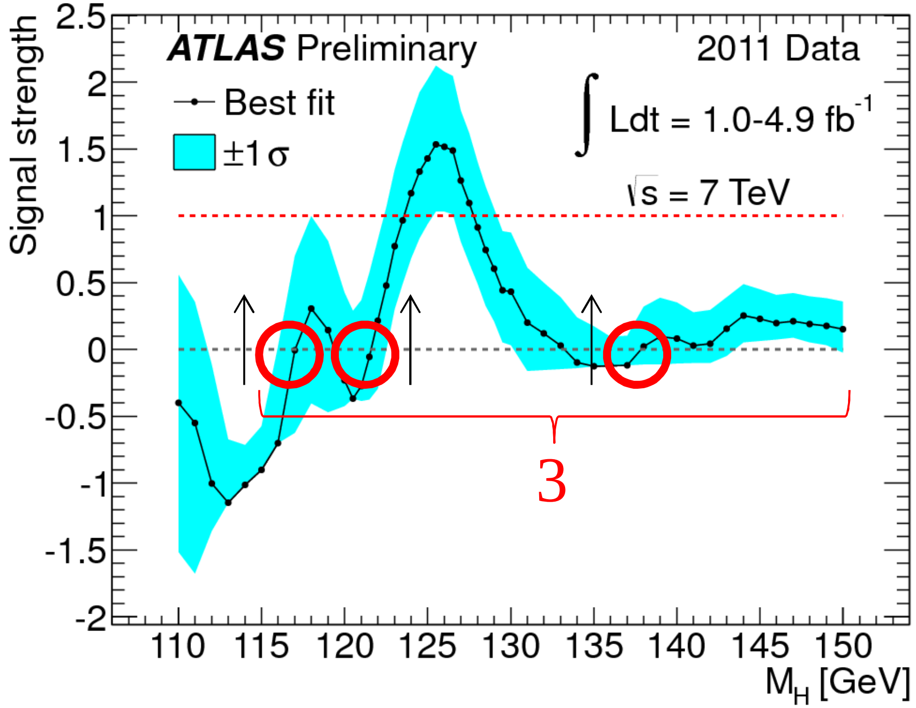
Implem. : count upward crossings of observed fitted μ (or q_0) w/ ref

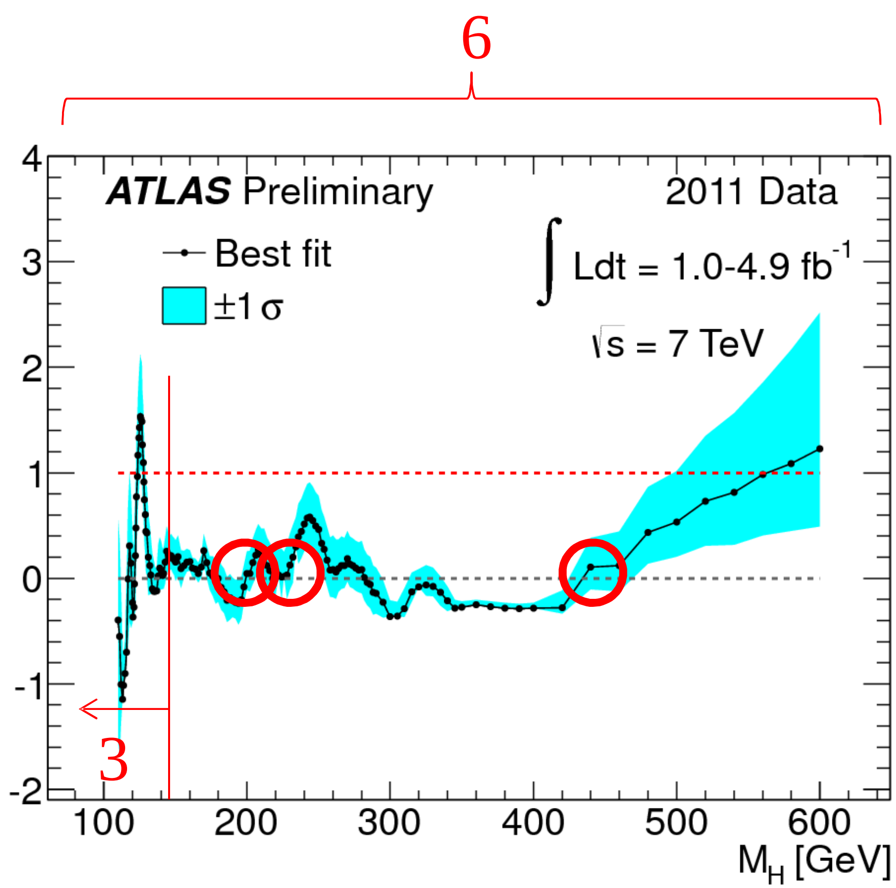
aproximation :

$p_0^{global}=1-(1-p_0^{local})^{N_{bins}}=N_{bins} \times p_0^{local}$

N_{bins}=range/resolution

eg for computing for LEE



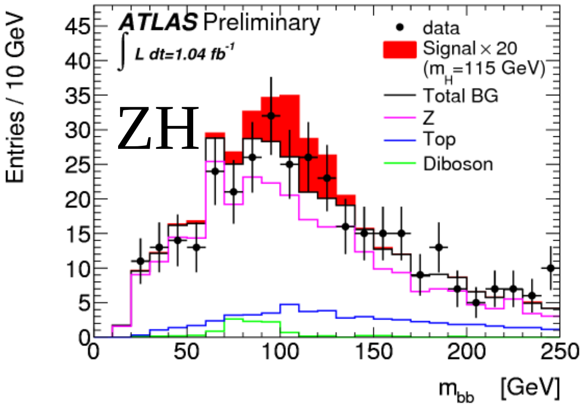


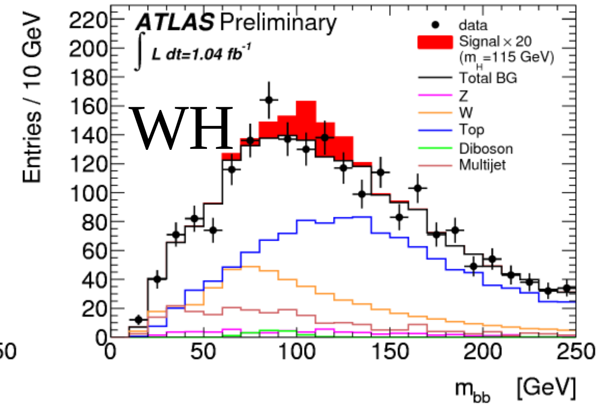
Individual channels : (I) beyond SM

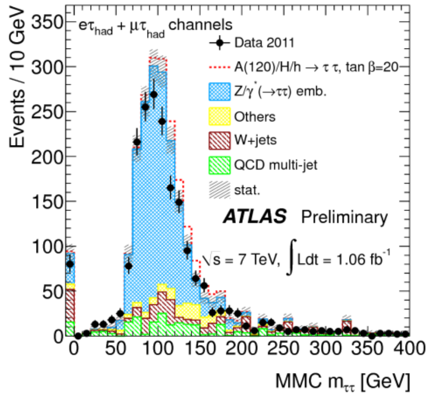
Statistical independance of channels with same final state :
eg : in SM : {Z(ll)H(bb) ; H→ZZ→ll bb}
→use mutual exclusive selection (range of masses, etc.)

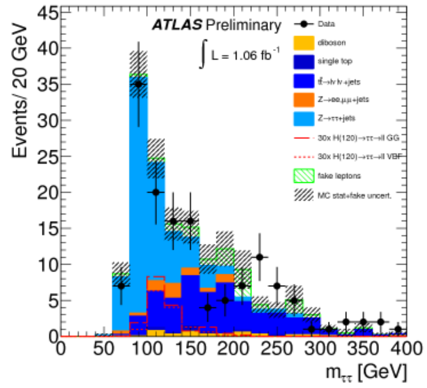
Final discriminant variables (SM)

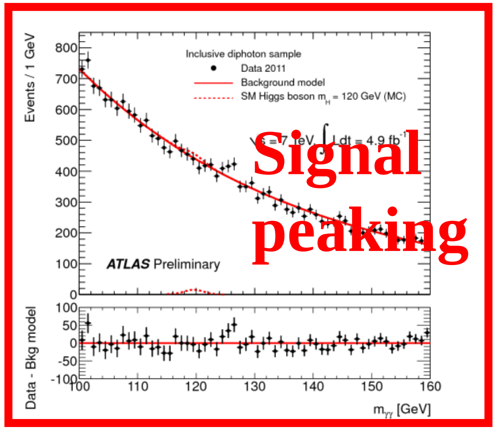
typical : invariant or transverse mass

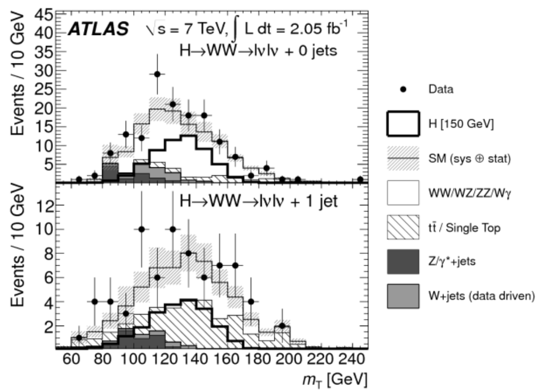


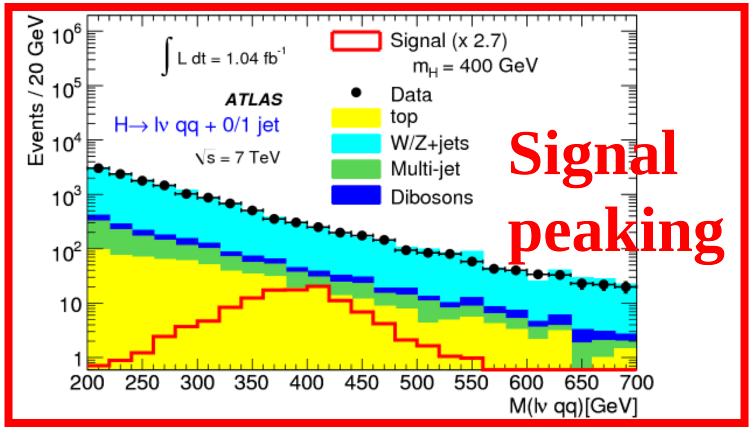


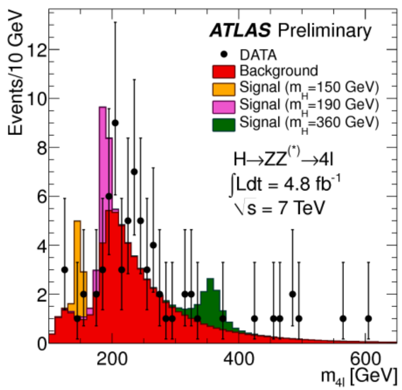


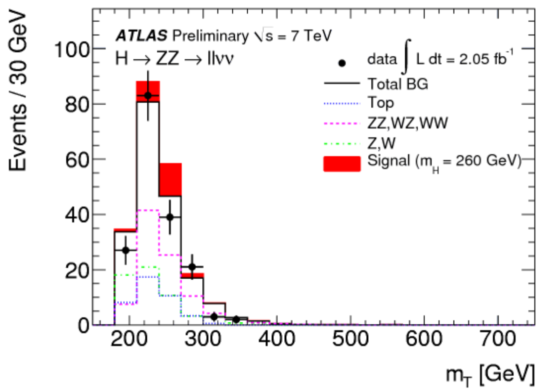


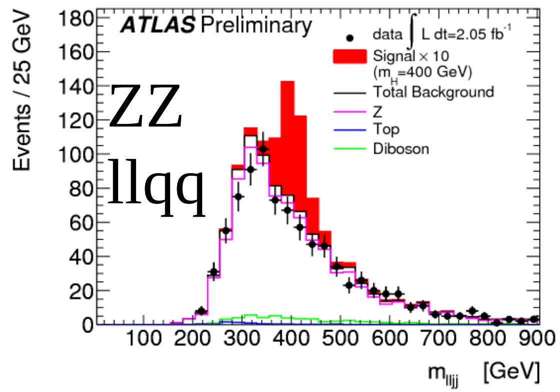




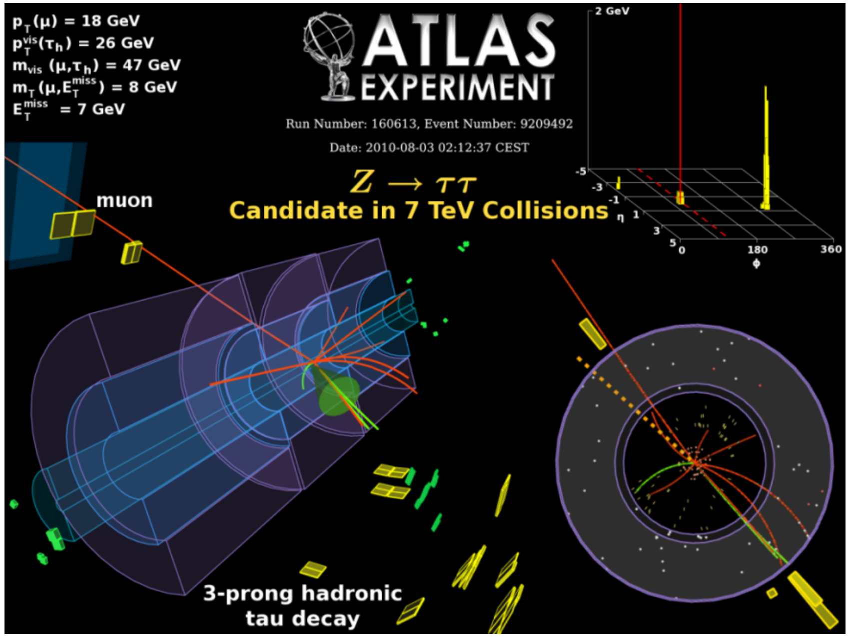








MSSM $A/H/h \rightarrow \tau\tau$



ZZ, WW dominant for SM for m_H>140 GeV
MSSM : HVV : suppressed by $\cos^2(\beta-\alpha)$; AVV : 0
While coupling to T3=-1/2 enhanced for high tan β, and proportional to m_f
$\rightarrow\tau\tau$ decay promising

$A/H/h \rightarrow \tau\tau \rightarrow e\mu+4\nu$, [90-450 GeV], 1.06 fb^{-1}, data 2011, ATLAS-CONF-2011-132
$A/H/h \rightarrow \tau\tau \rightarrow e\tau_{had}+3\nu$, [90-450 GeV], 1.06 fb^{-1}, data 2011, ATLAS-CONF-2011-132
$A/H/h \rightarrow \tau\tau \rightarrow \tau_{had}\tau_{had}+2\nu$, [90-450 GeV], 1.06 fb^{-1}, data 2011, ATLAS-CONF-2011-132

Tau invariant mass reconstruction

- $M_{\tau\tau}^{visible}$: use visible tau decays : broaden $m_{\tau\tau}$ → reduces sensitivity
- $M_{\tau\tau}^{effective}$ (m_T) uses visible $\sqrt{(p_{\tau+}+p_{\tau-}+p_{miss})^2}$: applicable to fraction events
- Coll. approx : assumpt. : $\nu \approx$ collinear w/ vis. τ decays ; $m_{\tau\tau}=m_{vis}/\sqrt{(x_1 x_2)}$

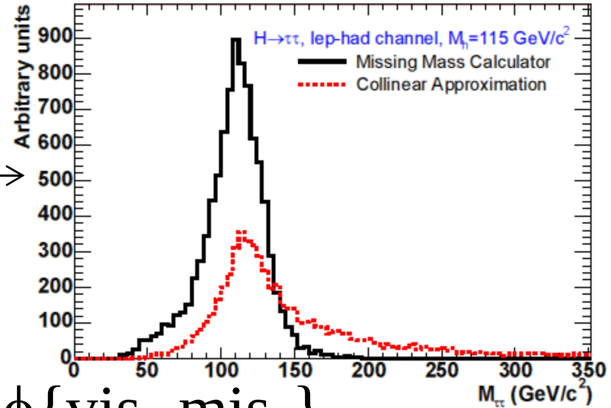
  x_i : fraction of visible momentum for τ_i
- Missing Mass Calculator : (arxiv:1012.4686)

Solving system of 4 equations :

E_{xmiss}, E_{ymiss}, m_τ^2, m_τ^2=

$f(p_{miss1}, \sin\theta_{miss1}, \phi_{miss1}, p_{miss2}, \sin\theta_{miss2}, \phi_{miss2}, p_{vis1}, p_{vis2}, \Delta\theta\{vis_1,mis_1\}, \Delta\theta\{vis_2,mis_2\})$

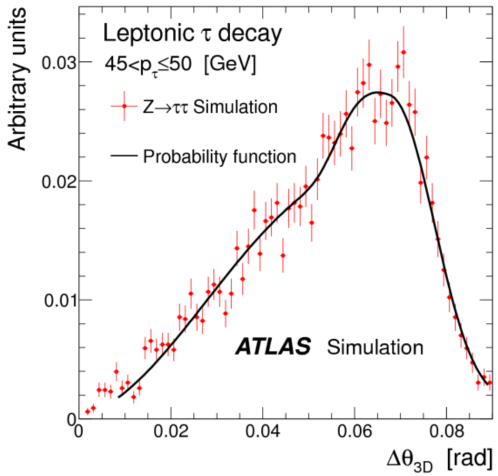
performance →

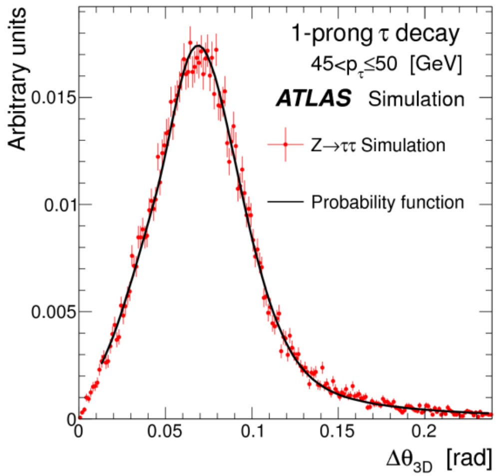


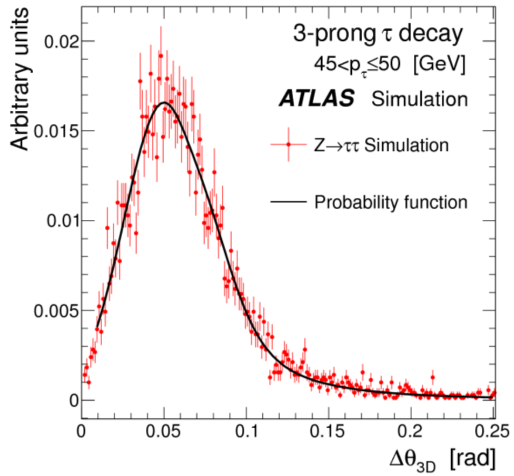
#constraints < #unknown

⇔system solved for a grid of points in $\Delta\phi\{vis_1,mis_1\}$, $\Delta\phi\{vis_2,mis_2\}$

At each point compute $\Delta\theta^{3D}\{vis,mis\}$ and weight by probability (from simu)







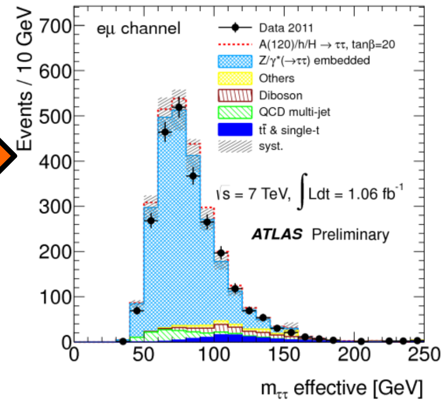
MSSM A/H/h→ττ→eμ+4ν   90≤m_H≤450 GeV   1.06 fb^{-1}

- Selection

- =1 isol. e & μ, p_T>10-22 GeV=f(trigger), OS, suppr. Z/γ*→ll (e,μ), tt, 1-t
- MET>thr1 : suppr. QCD, Z/γ*→ll (e,μ)
- $|p_{Te}|+|p_{T\mu}|$+MET<120 GeV
- Δφ(e,μ)>2.0

(last two cuts:) suppr. tt, 1-t, WW/WZ/ZZ

uses $m_{\tau\tau}^{effect}$

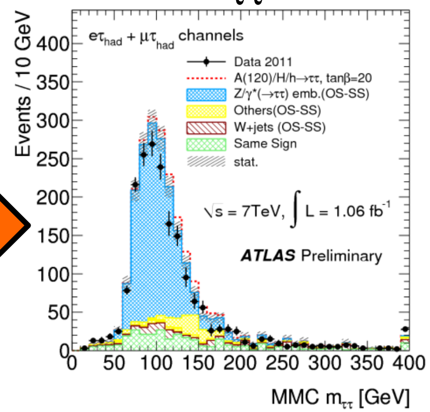


MSSM A/H/h→ττ→lτ_{had}+3ν

- Selection

- =1 isol. or μ p_T>25/20 GeV: suppr. Z/γ*→ll, tt, 1-t
- opposite charge τ_{had} p_T>20 GeV
- MET>20 GeV : suppr. QCD, Z/γ*→ll
- m_T<30 GeV : suppr. W→lν

uses $m_{\tau\tau}^{MMC}$

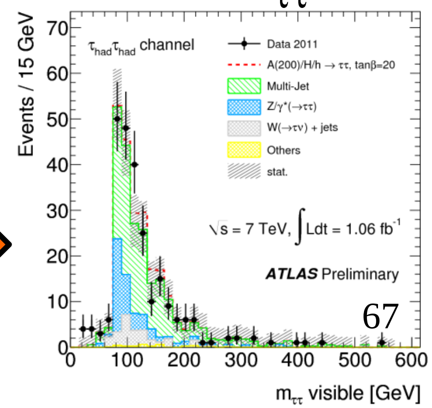


MSSM A/H/h→ττ→$\tau_{had}\tau_{had}$+2ν

- Selection

- =2 opposite charge τ_{had} p_T>45/30 GeV : suppr. Z, W, QCD
- MET>25 GeV : suppr. QCD, Z
- veto e, μ

uses $m_{\tau\tau}^{vis}$

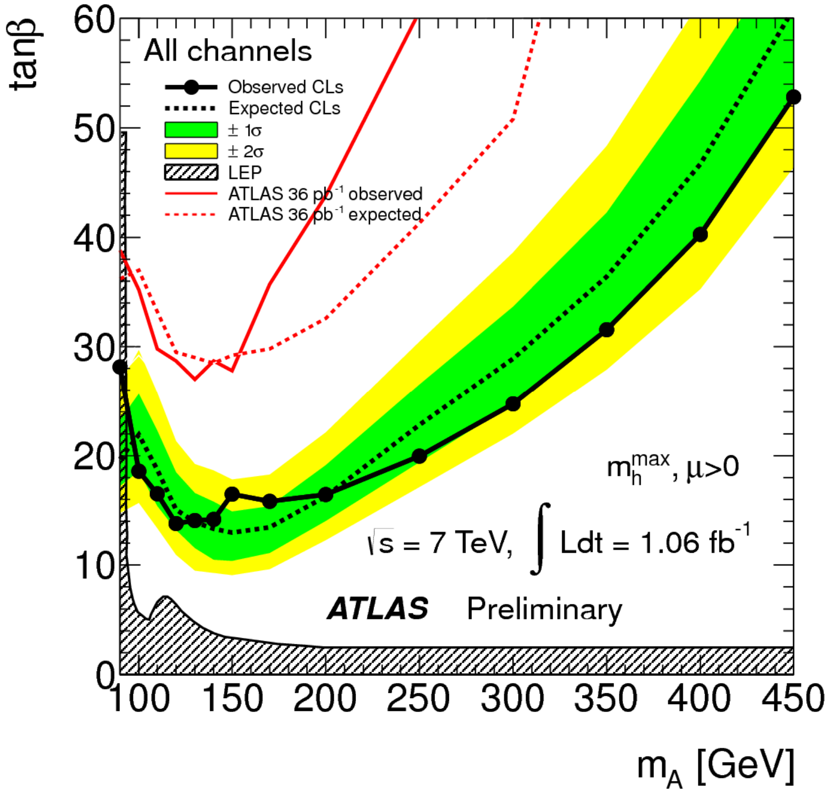


MSSM A/H/h→ττ→eμ+4ν $90 \leq m_H \leq 450$ GeV   1.06 fb^{-1}

MSSM A/H/h→ττ→$l\tau_{had}$+3ν

MSSM A/H/h→ττ→$\tau_{had}\tau_{had}$+2ν

Limits   combination



MSSM charged Higgs

$H^+ \rightarrow \tau_{lep}\nu$ w/ tt [90-160 GeV], 1.03 fb-1, data 2011, ATLAS-CONF-2011-151

$H^\pm \rightarrow \tau_{had}$ j [90-160 GeV], 1.03 fb^{-1}, data 2011, ATLAS-CONF-2011-138

$H^\pm \rightarrow$cs, [90-130 GeV], 35 pb^{-1}, data 2011, ATLAS-CONF-2011-094

$H^{\pm\pm} \rightarrow \mu^\pm\mu^\pm$ [100-400 GeV], 1.6 fb-1, data 2011, ATLAS-CONF-2011-127

- signature

$t \rightarrow Wb$ (SM) $t \rightarrow H^+b$ (beyond SM)

└→ $l\,\nu$ └→ $\tau\,\nu$ light H+, tan $\beta > 3$: $BR(H^+ \rightarrow \tau\nu) > 90$ %

└→ $\tau\,\nu$ └→ $l\,\nu$…

└→ $l\,\nu$… $\rightarrow l(W)$ / $l(\tau)$

$BR(H^+ \rightarrow \tau\nu \rightarrow l+\nu\ldots) \approx 35$ %

$BR(W \rightarrow l+\nu\ldots) \approx 25$ % increases tt→1 ; 2 leptons

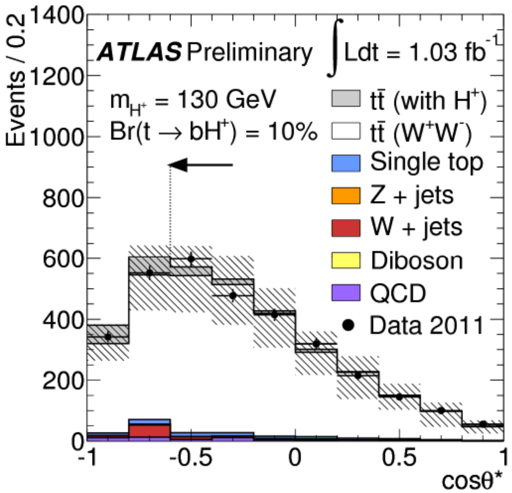
Not enough : viable strategy : discriminating variable : $m_{lb} \rightarrow \cos\theta^* = (2m_{bl}^2)/(m_t^2 - m_W^2)$

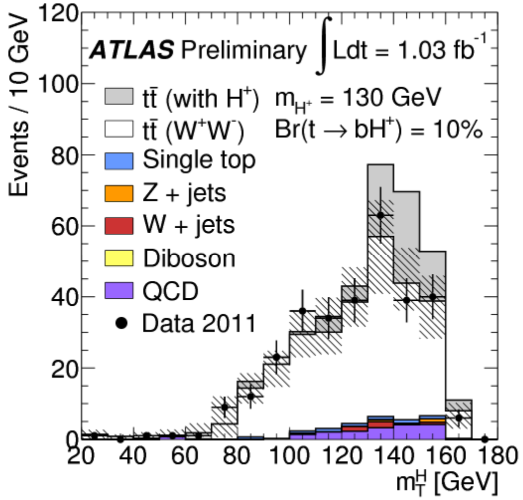
- selection

Production : tt

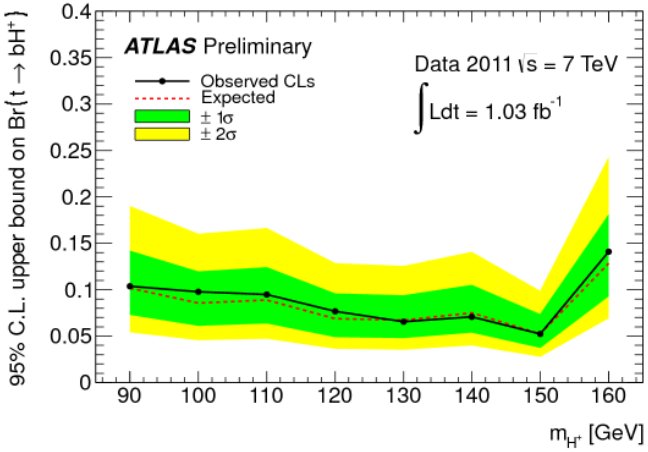
- 1 lepton and 2 leptons channels
- ≥2 jets (# = f(channel), =2 b-jets
- for 2 l : $m_{ll} > 15$ GeV & $|m_{ll} - m_Z| > 10$ GeV (suppr. Z)
- MET>40 GeV
- eμ channel : $\Sigma\ |p_T|$ (l, jets) >130 GeV
- $\cos\theta^* < 1$

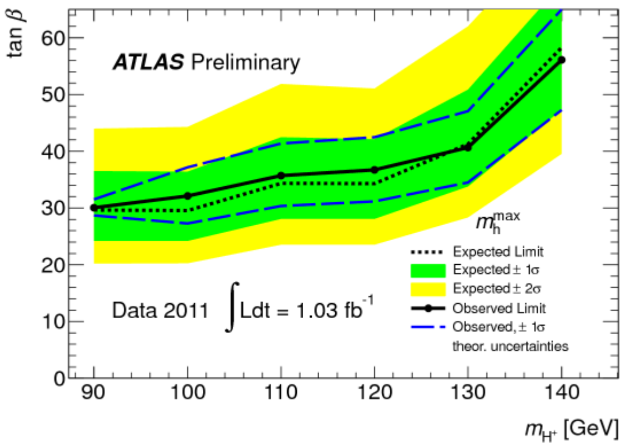
Final discriminant : transverse mass





Limits





$B(t \rightarrow bH^+) < 5.2\text{-}14.1$ %

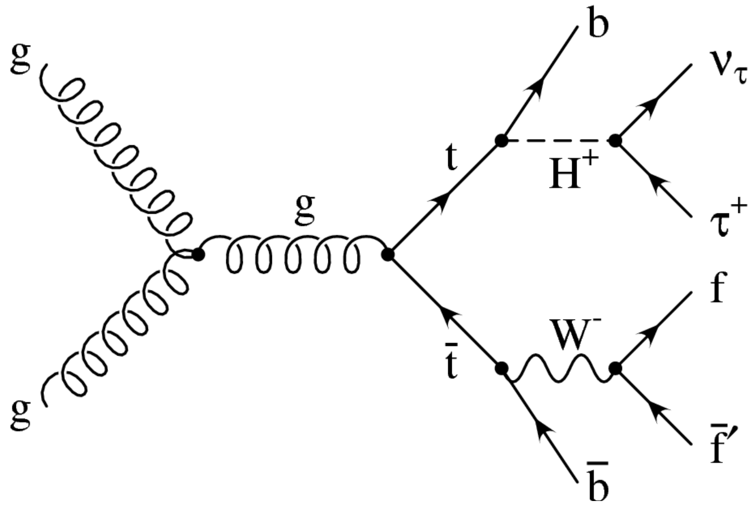
m_H^{max} scenario : $\tan\beta > 30\text{-}56$ excluded

(m_H in [90 ; 140 GeV])

MSSM $H^{\pm} \rightarrow \tau_{had}$ j $90 \leq m_H \leq 140$ GeV 1.03 fb^{-1}

- Production mechanism

Low mass : $t \rightarrow H^+ b$

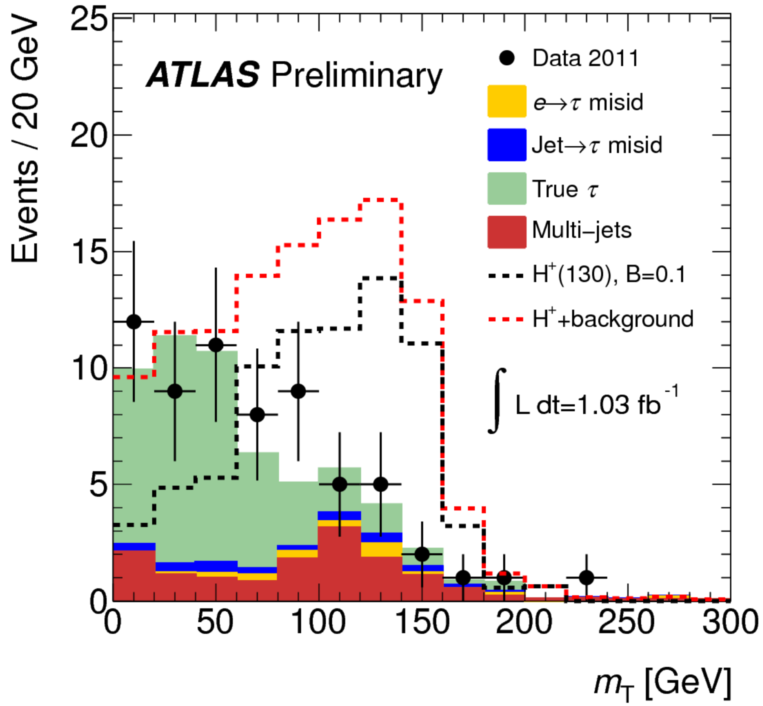


- background

tt, multijets, 1-t, W+j

- Selection

- $\geq$ 4 j (apart τ jets)
- =1 τ jet (veto second)
- veto electron/muon
- $\geq$ 1 b-jet
- MET>40 GeV
- Topology consistent w/ $t \rightarrow qqb$
-final discriminant variable : m_T



• Measure bkg

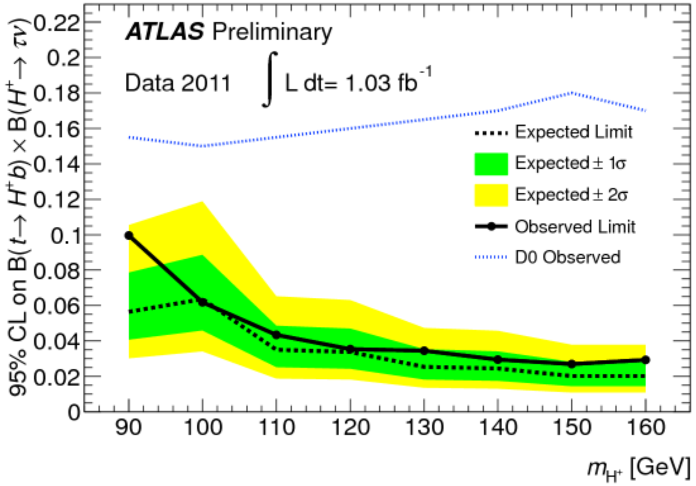
Enriched multijets sample

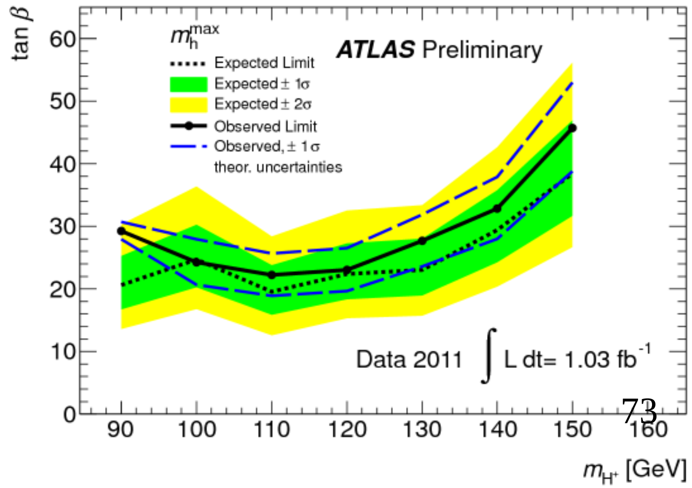
τ : loose \ tight & revert b-tagging

fit MET

BR($t \rightarrow bH^{\pm}$)xBR($H^{\pm} \rightarrow \tau\nu$) : 0.03-0.10 for m_H in [90 ; 160]

m_h^{max} scenario : tan β>22-30 for 22-30 for m_H in [90 ; 140]





MSSM $H^{\pm} \rightarrow cs$ $90 \leq m_H \leq 130$ GeV $35\ pb^{-1}$

- Production mechanism

Low mass : $t \rightarrow H^+ b$

- Signature : 1 lepton, 4 jets

-similar to semi-leptonic tt, apart $mjj \neq m_W$

Increase of $tt \rightarrow jj$ due to additional all hadronic decay mode $tt \rightarrow H^+ b H^- b$

- background

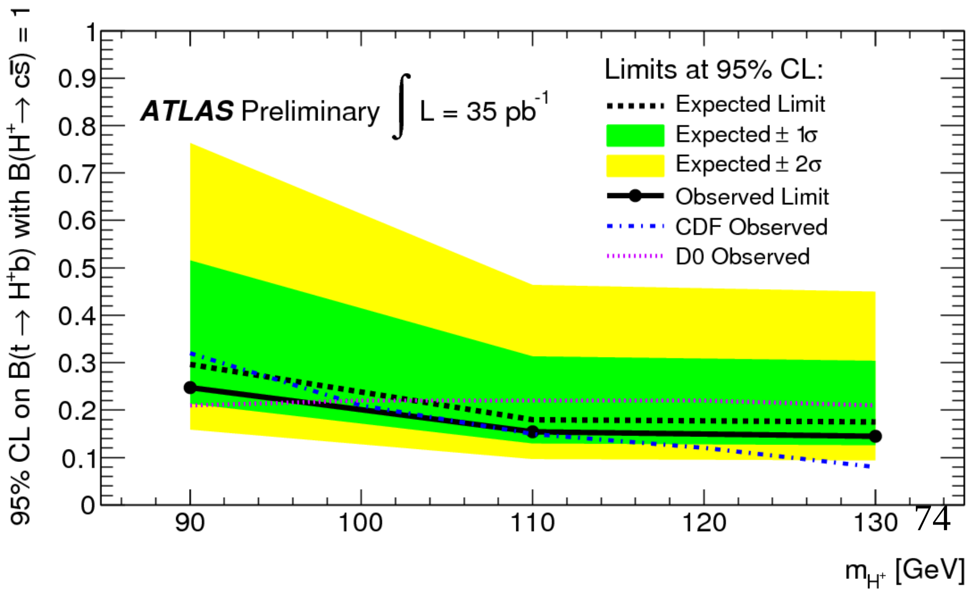
Primary : tt

Secondary : 1-t, W/Z+j, WW, WZ, ZZ, QCD

- selection

- =1 lepton (e, μ)
- MET>35/20 GeV (e, μ) (suppr. QCD)
- m_T(l ; MET)>thr (suppr. QCD)
- ≥ 4j (suppr. W+j)
- ≥ 1 b-jet
- Combinatory of jets : kinematic fitter

Observed limits : B=0.25 to 0.14

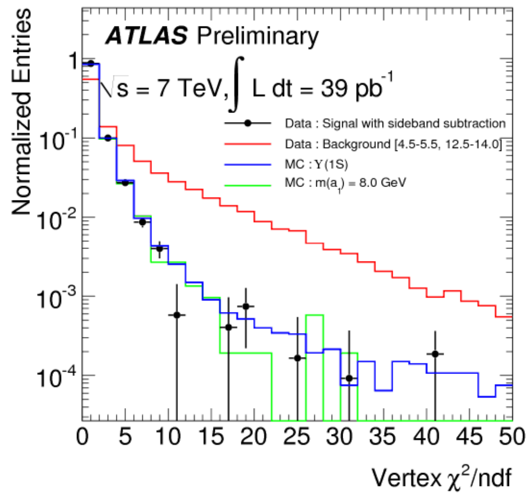


NMSSM $a_1 \rightarrow \mu\mu$ $0 \leq m_{a1} \leq 12$ GeV $39\ pb^{-1}$

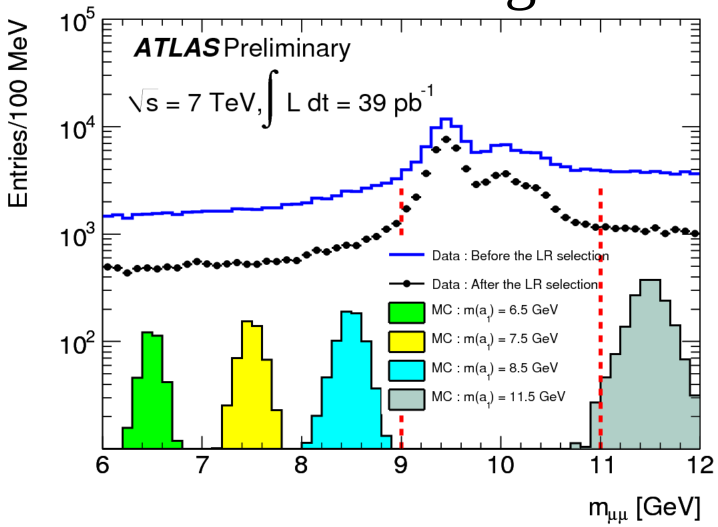
$m_{a1} < 2m_B$: escapes LEP limits ; search a_1 in mass range [6-9]U[11-12] GeV

Selection : 2μ OS, $4.5 < m_{\mu\mu} < 14$ GeV

- Likelihood ratio : $\chi^2(\mu\mu)$ vertex fit, μ isolation



- Pdfs from data : bkg : sidebands ; signal : Υ



Systematics

Luminosity : 3%

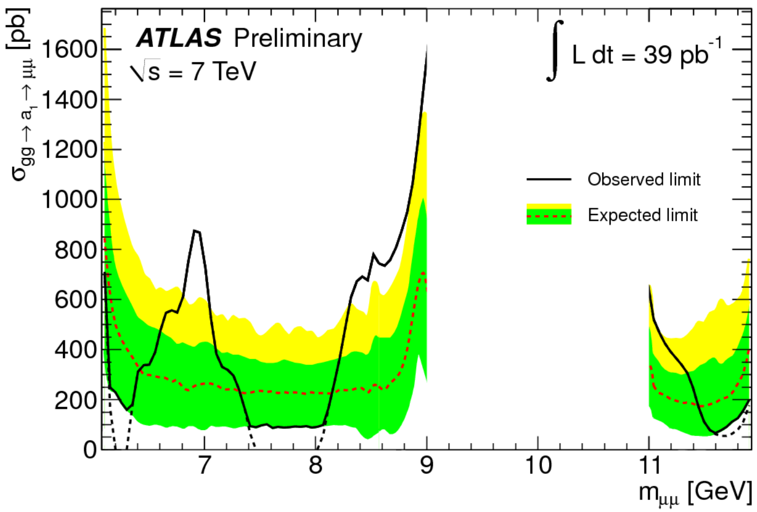
Generator : 60-30 %

Di-muon efficiency : 14 %

Trigger : 10 %

Likelihood ratio modeling : 3 %

limits on σ



Look Elsewhere Effect : 70-90

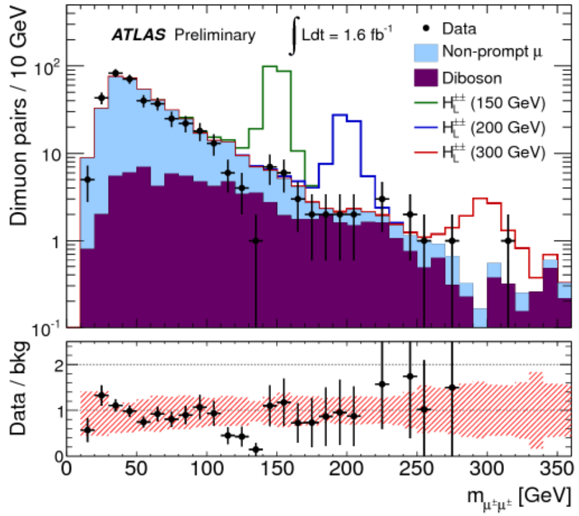
$H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm}$ $100 \leq m_H \leq 400$ GeV 1.6 fb^{-1}

- background

-primary : HV, decay-in-flight π/K
-secondary WZ, ZZ, WW
-tertiary : ttW

- selection

- =2 μ same charge



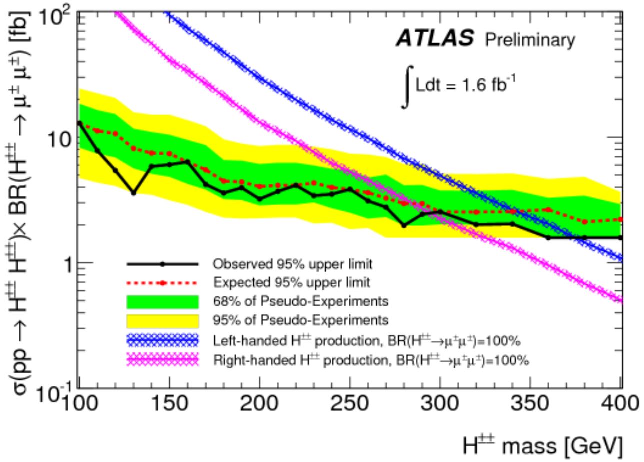
$\sigma(H^{\pm\pm})$x$BR(H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm})$<13-1.6 fb^{-1}

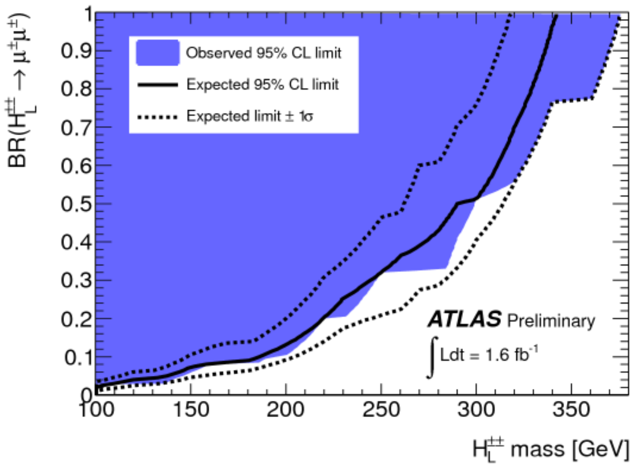
Left-Right symmetric model :

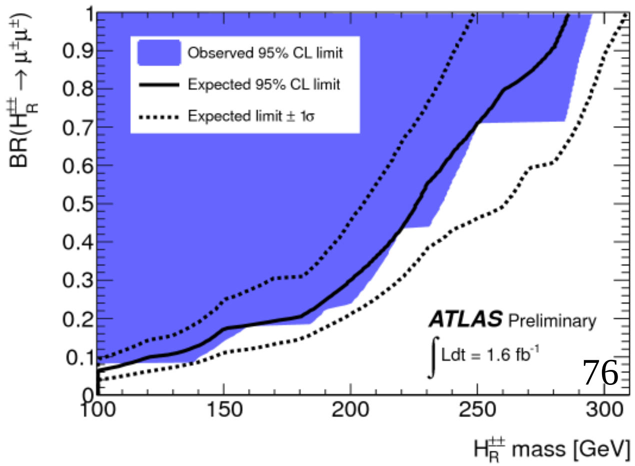
if $BR(H^{\pm\pm} \rightarrow \mu^{\pm}\mu^{\pm})$=100%

-exclude $H^{\pm\pm}_L$ <375 GeV

-exclude $H^{\pm\pm}_L$ <295 GeV







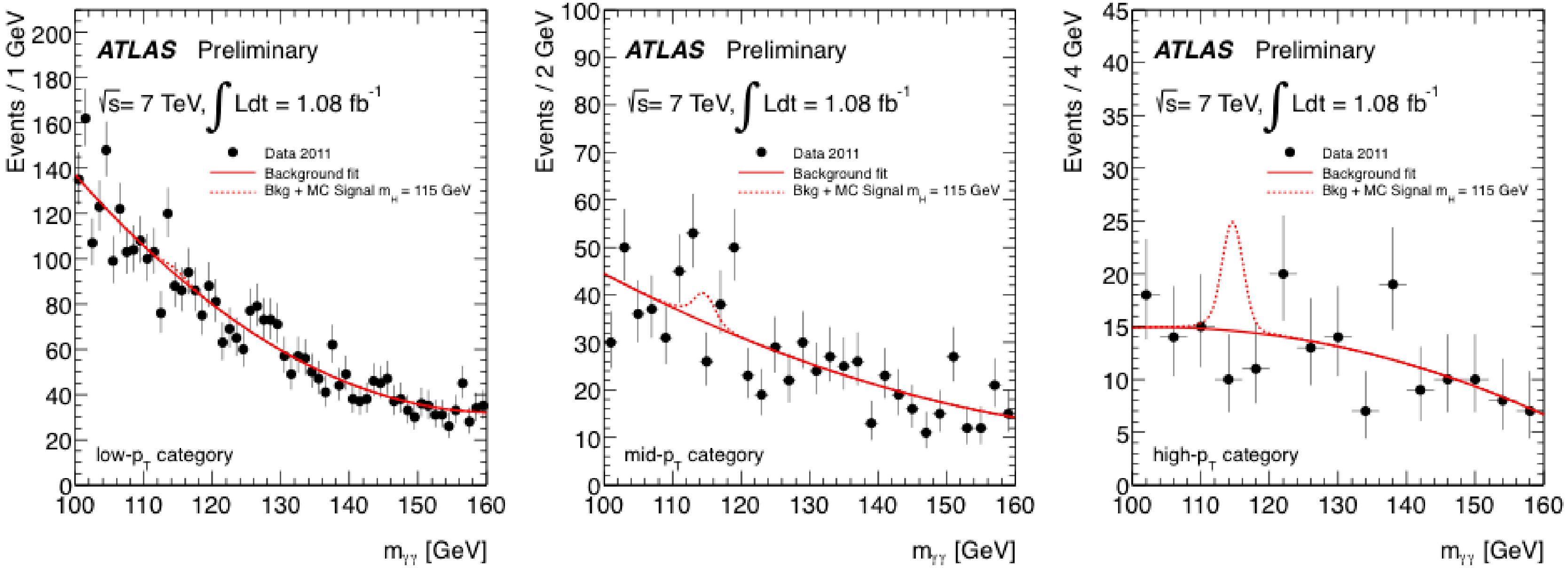
Fermiophobic H→γγ $110 \leq m_H \leq 130$ GeV $1.08\ fb^{-1}$

- ggH, ttH non existing→VBF, WH, ZH

exploits $p_{T\gamma\gamma}$ category to improve sensitivity $p_T \leq 50$ GeV ; $50 < p_T \leq 100$ GeV ; $p_T > 100$ GeV

- Deformed inv. mass due to turn-on of high-p_T

→avoid exponential shape : uses Bernstein-based polynomial 2[th] order



Drawback of $p_{T\gamma\gamma}$: turn-on effect on invariant mass. New variable : P_{Tt} introduced later on for SM analysis H→γγ

Fermiophobic H→γγ $110 \leq m_H \leq 130$ GeV $1.08\ fb^{-1}$

Systematics

Production mode (VBF, VH) : 4 %
5% added linearly for EW radiative corrections } →9 %

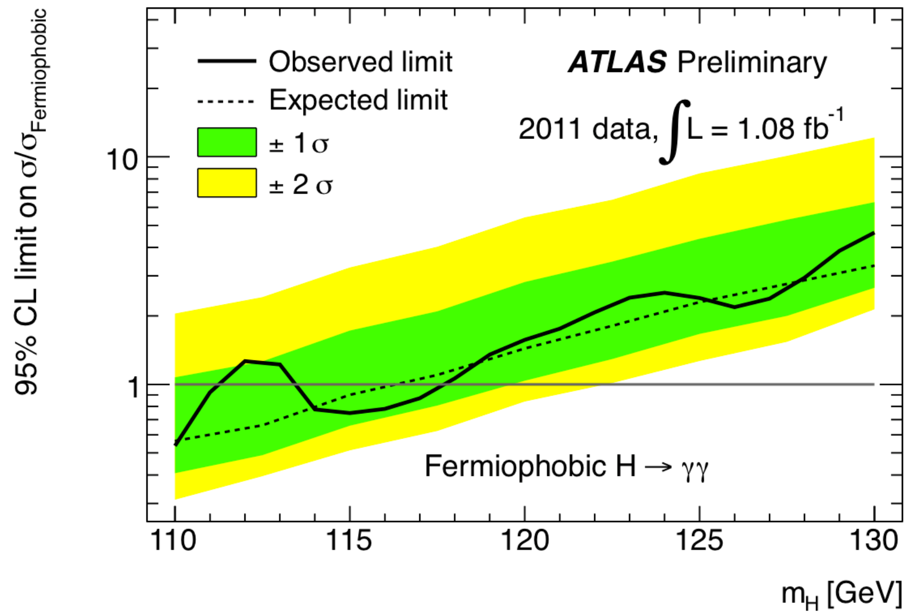
Common uncertainties of summer 2011 H→γγ analysis (EPS 2011)

Total rate uncertainty : 15 %

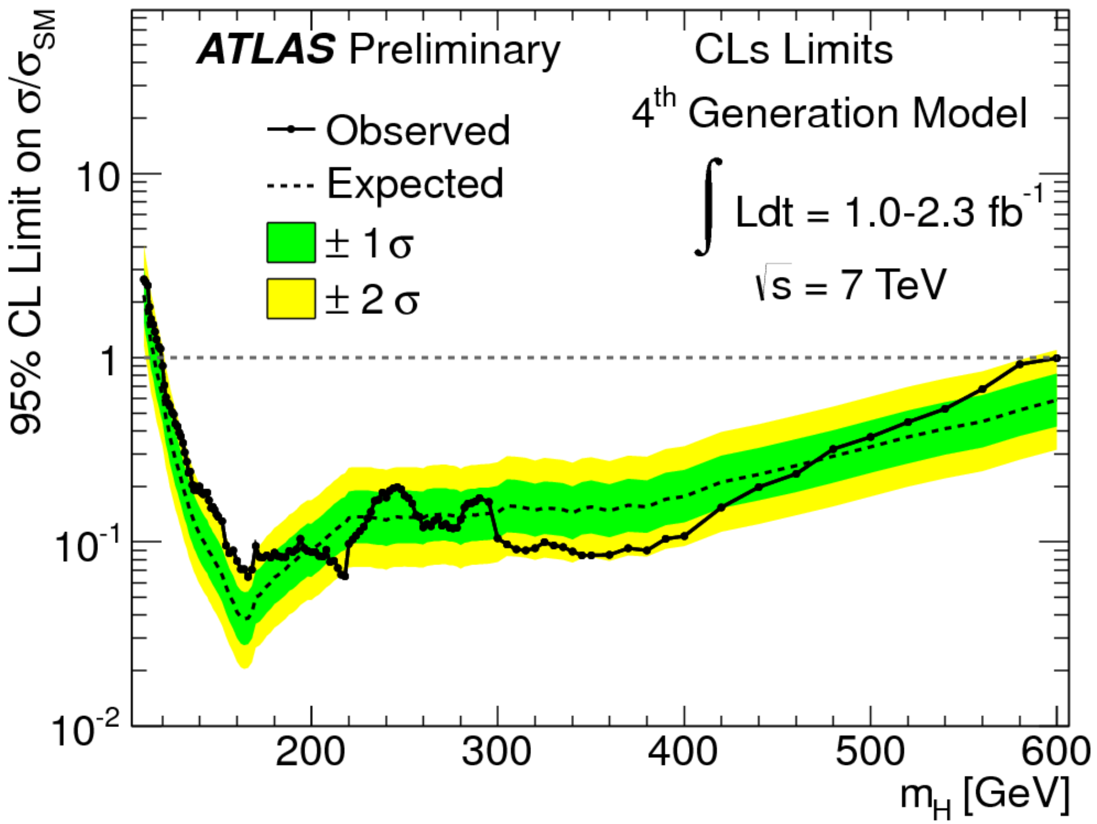
Signal invariant mass resolution : same as for EPS note SM

Bkg modelization/spurious signal : deviation of bkg mass to fit

→±6.5 events for low p_T ; ±2.2 events for middle p_T ; ±0.65 events for high p_T



Limit on SM4 : 4th generation of fermions



Excluded at 95 % : m_H : 119-593 GeV

Individual channels : (II) SM

Low masses : $m_H<140$ GeV

$H\rightarrow\gamma\gamma$; $H\rightarrow bb$; $H\rightarrow\tau\tau$

Intermediate/high mass : 130-600 GeV

$H\rightarrow WW\rightarrow l\nu l\nu$; $H\rightarrow ZZ\rightarrow 4l$

High mass

$H\rightarrow ZZ\rightarrow ll\nu\nu$; $H\rightarrow ZZ\rightarrow llqq$; $H\rightarrow WW\rightarrow lnqq$

$H \rightarrow bb$ $110 \leq m_H \leq 130$ GeV $1.04\ fb^{-1}$

W(lν)H(bb)

- Bkg

-Primary : tt

-Secondary : 1-t, QCD, W+j

-Tertiary : Z+j, WW, WZ, ZZ

Z(ll)H(bb)

- Bkg

-Primary : Z+j

-Secondary : tt, QCD, ZZ, WZ

-exactly 2 j ; b-tagged (suppr. tt)

-discriminating variable : m_{bb}

- Selection :

-exactly 1 isol. lepton (suppr. Z, tt)

-MET>25 GeV (suppr. $Z \rightarrow ll$; QCD)

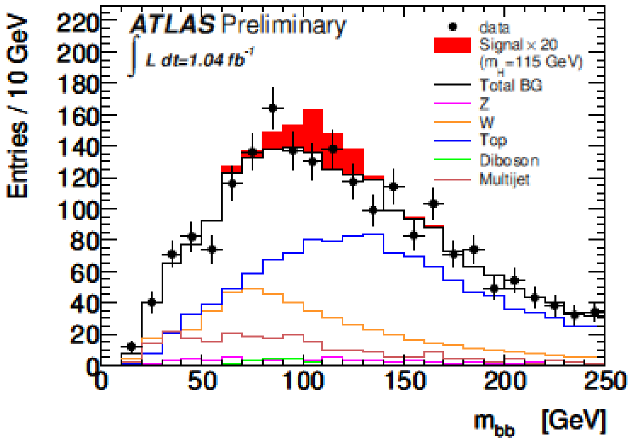
-{l ; MET} comp. w/ W

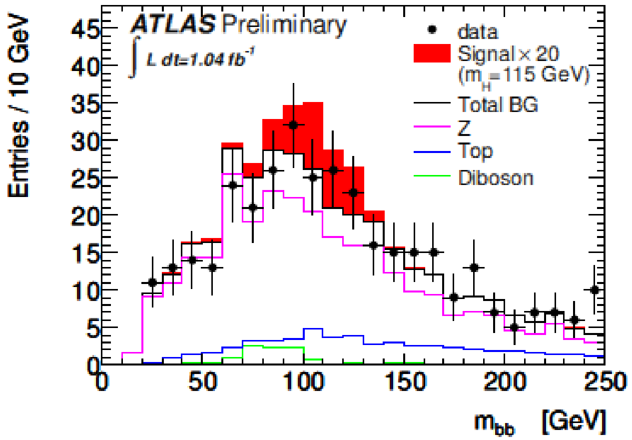
-m_T>40 GeV

- =2 OS (apart e) same flav isol. l, $m_{ll} \approx m_Z$

(suppr. non Z bkg : tt, QCD)

-MET<50 GeV (suppr. tt)





H→bb

- Measurement of bkg W+j :

-top : MC, normalization : data sideband m_{bb} & sub. other contrib from data

-QCD : template method, fit MET for normalization

-W+j : data-driven template m_{jj} ; substract non-W by MC ; normalization : sideband fit m_{bb}

-Z+j : MC & normalization : fit on data

-WZ/WW/ZZ : MC

- Measurement of bkg Z+j :

-Z+j : MC, normalization : sidebands m_{bb} (non Z+j substracted from data)

-ZZ : irreducible : MC (small : difficult to constraint w/ data)

-top : MC, normalization : sidebands m_{ll} & b-tagging criteria

-QCD : e channel : l : L\T : template m_{ll} w/ ≥2 j

μ channel : MC semileptonic bb, cc : negligeable after $m_{\mu\mu}$ cut

H→bb $110 \le m_H \le 130$ GeV $1.04\ fb^{-1}$

- Dominant systematics

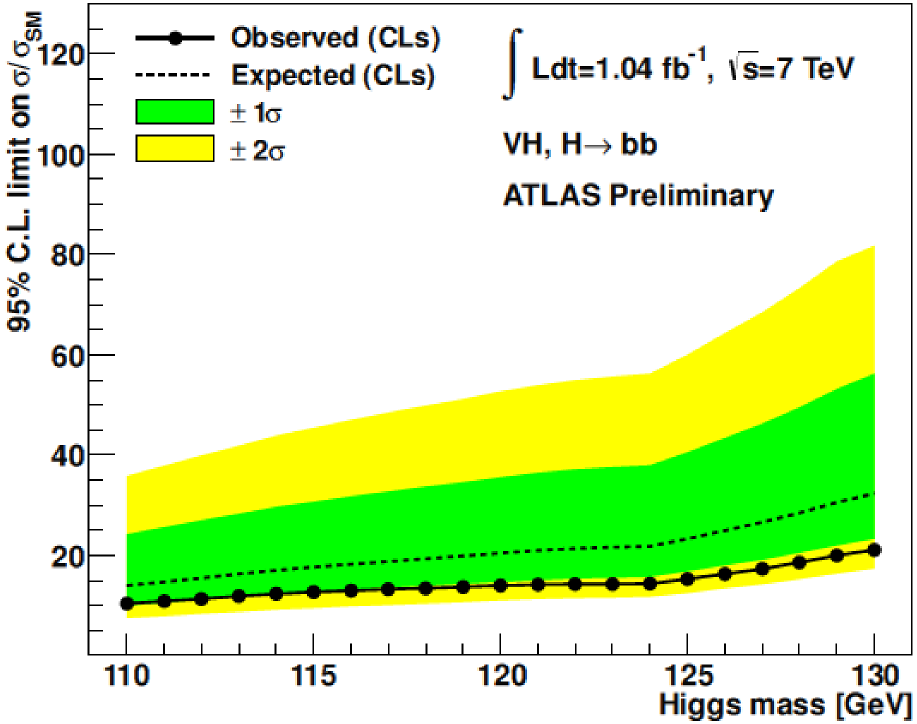
-JES : 2-7 %

-Jet energy resolution : 5-12 %

-b-tagging eff. : 5-14 %

-b mistag-rate : 8-12 %

-Muon momentum scale : 2-16 %



10-20 xSM

Not as competitive as other channels

H→bb   110≤m_H≤130 GeV   1.04 fb^{-1}

- Systematics

-Detector and rec related systematic

Source of Uncertainty	Treatment in analysis
Jet Energy Scale (JES)	$2-7\%$ as a function of p_T and η
Jet Pile-up Uncertainty	$2-7\%$ as a function of p_T and η
b-quark Energy Scale	2.5%
Jet Energy Resolution	$5-12\%$
Electron Selection Efficiency	$0.7-3\%$ as a function of p_T, $0.4-6\%$ as a function of η
Electron Trigger Efficiency	$0.4-1\%$ as a function of η
Electron Reconstruction Efficiency	$0.7-1.8\%$ as a function of η
Electron Energy Scale	$0.1-6\%$ as a function of η, pileup, material effects etc.
Electron Energy Resolution	Sampling term 20%, a small constant term has a large variation with η
Muon Selection Efficiency	$0.2-3\%$ as a function of p_T
Muon Trigger Efficiency	< 1%
Muon Momentum Scale	$2-16\%$ η-dependent systematic on scale
Muon Momentum Resolution	p_T and η-dependent resolution smearing functions, systematic $\leq 1\%$
b-tagging Efficiency	$5-14\%$ as a function of p_T
b-tagging Mis-tag Fraction	$8-12\%$ as a function of p_T andη
Missing Transverse Energy	Add/subtract object uncertainties in E_T^{miss}

-non detector and rec related systematics

Source of Uncertainty	Treatment in analysis	
	ZH	WH
Luminosity	3.7%	3.7%
Higgs boson cross-section	5%	5%
Background norm. and shape:		
Top	9%	6%
Z+jets	9% plus shape	9%
W+jets	negligible	14% plus shapes
ZZ	11%	negligible
WZ	11%	11%
WW	negligible	11%
QCD multijets	100%	50%

-Impact on signal yields

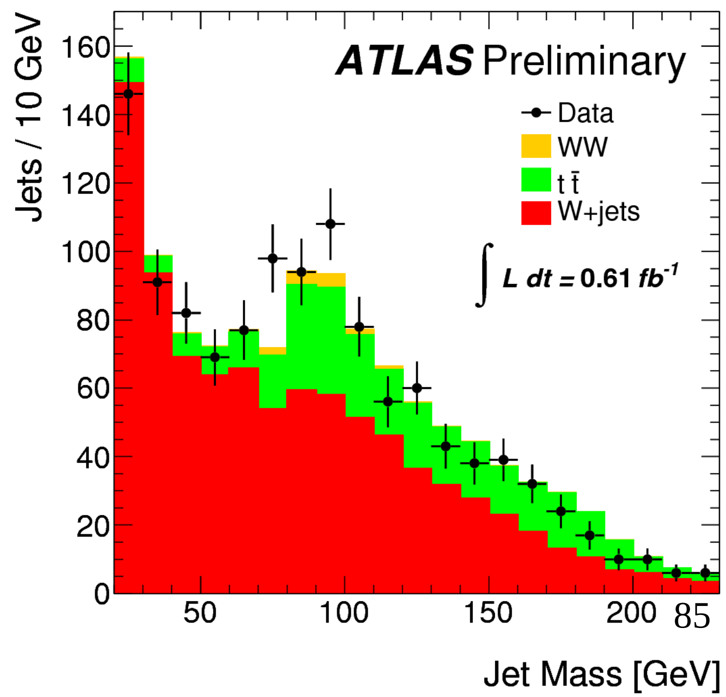
Source of Uncertainty	Effect on $ZH \to \ell\ell b\bar{b}$ signal		Effect on $WH \to \ell\nu b\bar{b}$ signal	
	m_H = 115 GeV	m_H = 130 GeV	m_H = 115 GeV	m_H = 130 GeV
Electron Energy Scale	< 1%	< 1%	1%	1%
Electron Energy Resolution	< 1%	< 1%	1%	1%
Muon Momentum Resolution	1%	3%	4%	1%
Jet Energy	9%	7%	1%	3%
Jet Energy Resolution	< 1%	< 1%	1%	1%
Missing Transverse Energy	2%	2%	2%	3%
b-tagging Efficiency	16%	17%	16%	17%
b-tagging Mis-tag Fraction	< 1%	< 1%	3%	3%
Electron Efficiency	1%	1%	1%	1%
Muon Efficiency	1%	1%	1%	1%
Luminosity	4%	4%	4%	4%
Higgs Cross-section	5%	5%	5%	5%

alternative approach : boosted Higgs : $p_T(H)>200$ GeV

$p_T(H)>200$ GeV : rej. 95 % signal ; $p_T(H)$ ↑→ Δϕ↓
→jet substructure technique
Loss of statistics compensated by increase of S/B

Selection : W→lν consistent with $p_T>200$ GeV
Background :
Primary : tt
Secondary : W+j
Tertiary : WW

useful control sample : encouraging
observation of peak at m_W fom tt →lν b qq b

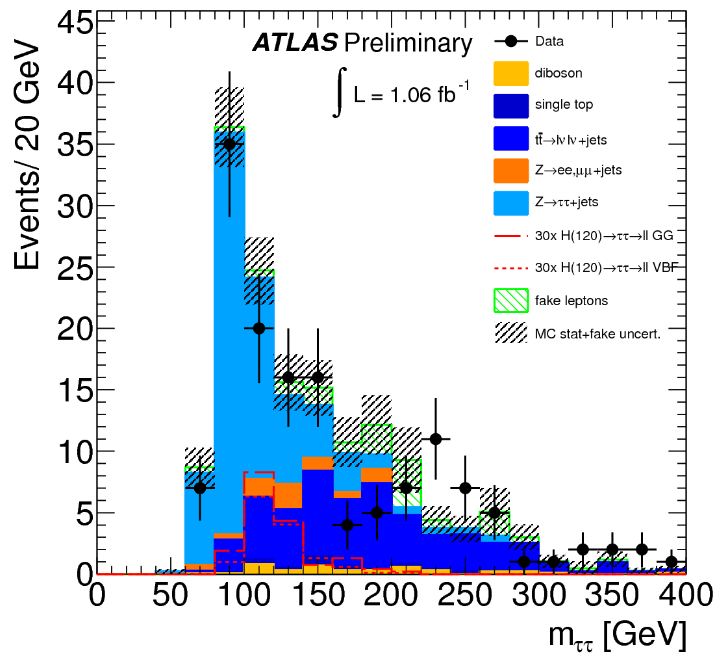


$H \rightarrow \tau\tau \rightarrow ll+4\nu$ $110 \leq m_H \leq 140$ GeV $1.06\ fb^{-1}$

- Selection

- ≥ 1 high p_T jet ⇔ boost of Higgs: increases $p_T(H) \rightarrow$ MET
- MET>thr : suppr. $Z/\gamma^* \rightarrow ll$ (e,μ), QCD
- =2 isolated opposite charge leptons (e, μ) : $N_e+N_\mu=2$
- $m_{ll}>20$ GeV (suppr. Y) ; thr1 $<m_{ll}<$ thr2 : suppr. $Z/\gamma^* \rightarrow ee, \mu\mu$
- Collinear approximation : low thr $<x_{1,2}<$ high thr

→ neutrinos collinear to charged leptons
- $0.3 < \Delta\phi_{ll} < 2.5$: suppr. $Z/\gamma^* \rightarrow ee, \mu\mu$, tt
- $|\eta_j|>0.5$: to boost Higgs system : jets from tt more central : suppr. tt
- $m_{\tau\tau j}>225$ GeV : suppr. $Z/\gamma^* \rightarrow ee, \mu\mu, \tau\tau$
- $100<m_{\tau\tau}<150$ GeV



- Bkg

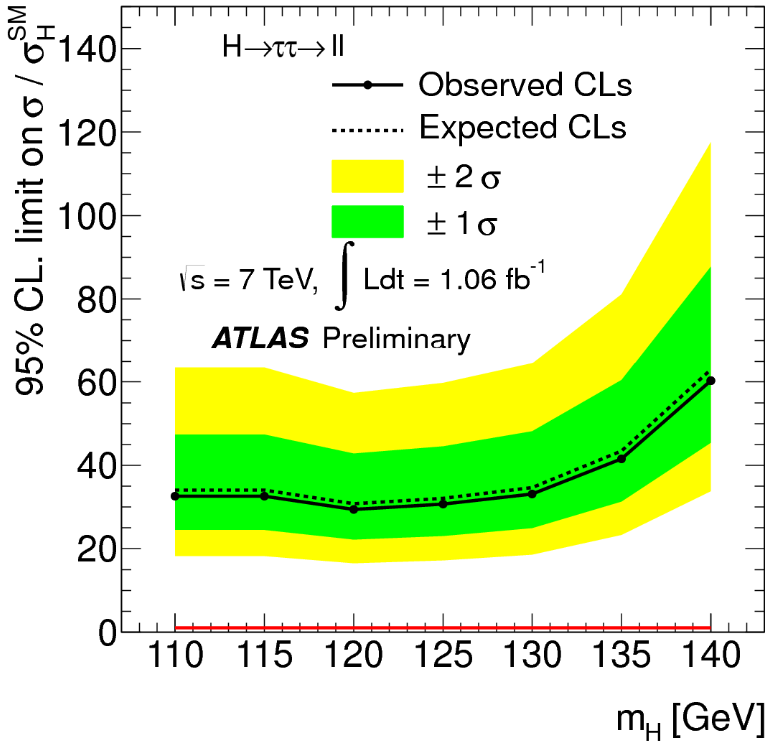
-Primary : $Z/\gamma^* \rightarrow \tau\tau$, $Z/\gamma^* \rightarrow ll$

-Secondary : tt, 1-t, WW, WZ, ZZ

$H \rightarrow \tau\tau \rightarrow ll+4\nu$ $110 \leq m_H \leq 140$ GeV $1.06\ fb^{-1}$

- Evaluation background

-$Z/\gamma^* \rightarrow \tau\tau$: data-driven : τ-embedding technique $Z/\gamma^* \rightarrow \mu$
-tt, 1-t, $Z \rightarrow ll$, WW, WZ, ZZ : MC
-tt, Z : confirmed by data w/ Control Regions
-fake leptons : template method

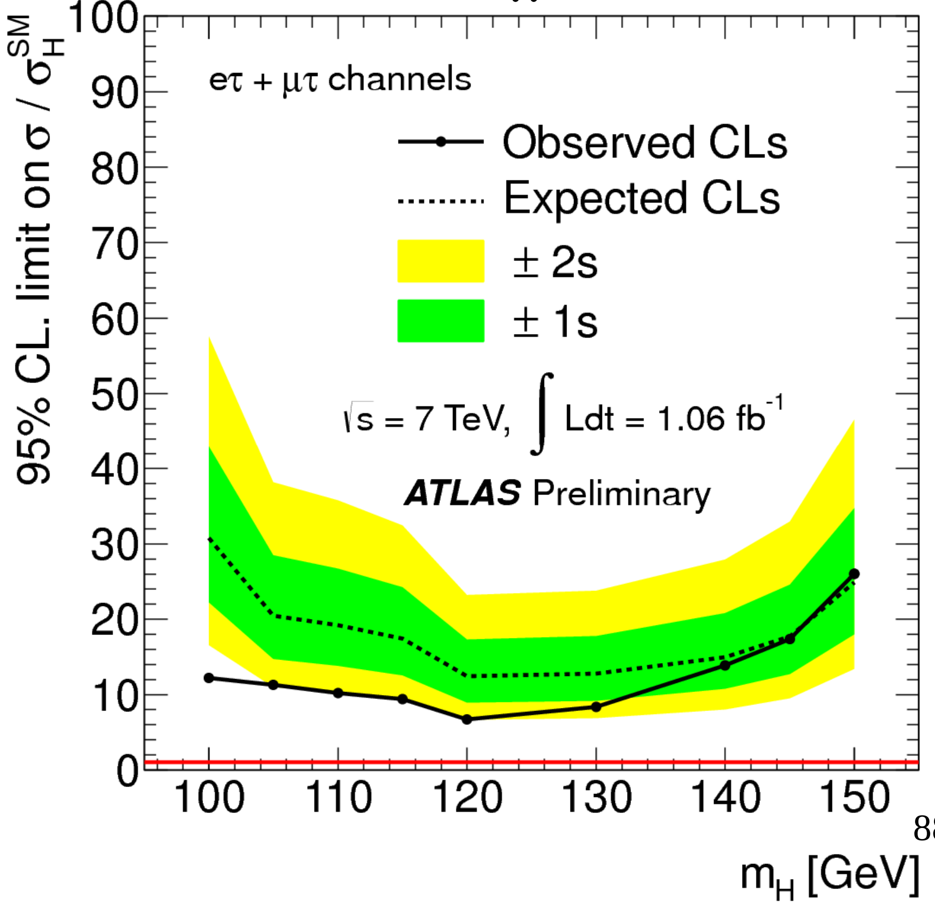


$H \rightarrow \tau\tau \rightarrow l\tau_{had}+3\nu$ $100 \le m_H \le 150$ GeV $1.06\ fb^{-1}$

- Selection

- =1 isol. or μ ; p_T>25 GeV/20 GeV: suppr. $Z/\gamma^* \rightarrow ll$ (e,μ), tt, 1-t
- opposite charge τ_{had}
- MET>20 GeV : suppr. QCD, $Z/\gamma^* \rightarrow ll$ (e,μ)
- m_T<30 GeV : suppr. $W \rightarrow l\nu$

uses $m_{\tau\tau}^{MMC}$



$H \rightarrow WW \rightarrow l\nu qq$ $240 \le m_H \le 600$ GeV $1.04\ fb^{-1}$

- Bkg

-primary : W+j

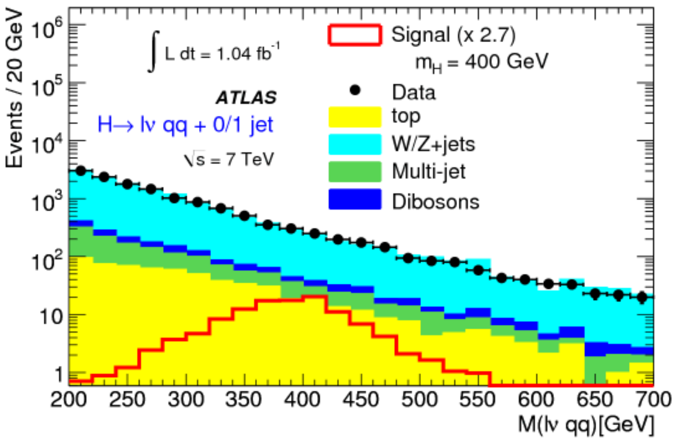
-secondary : Z+j, QCD, top, dibosons (WW, WZ, ZZ)

- Selection

- =1 isolated lepton (e/μ) ; veto 2 leptons : statistically independant of $H \rightarrow ZZ \rightarrow ll\nu\nu$
- MET>30 GeV
- =2/3 jets (H+0j / H+1j)
- veto b-jets (suppr. top)
- $m_{jj} \approx m_W$

- final discriminant : $m_{l\nu qq}$; $m_{l\nu} \approx m_W$

→good relative resolution



H→WW→lνqq 240≤m_H≤600 GeV 1.04 fb^{-1}

- Evaluation background

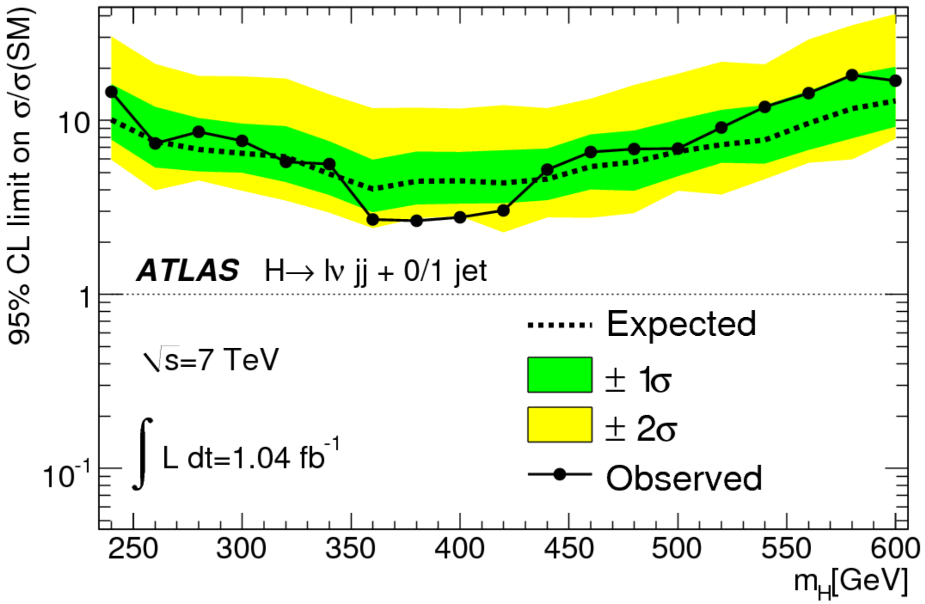
-QCD : loosen electron identification & invert isolation μ

- systematics signal

Objet reco ; dominant : JES, resolution

- Limits :

likelihood fit to exponential decreasing bkg+signal template



$H \rightarrow ZZ \rightarrow llqq$ $200 \leq m_H \leq 600$ GeV $2.05\ fb^{-1}$

Higher BR than 4l channel (x21), but less clean (jets)

Z on-shell : reduces background

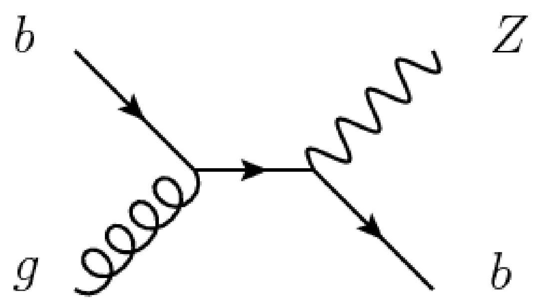
- Bkg

-primary : Z+j
-secondary : tt :
-tertiary : ZZ, WZ

- Selection
  - same-flavor di-lepton, m_{ll} compatible with m_Z
    -muons : OS
    -electrons : not requested : bremsstrahlung
  - ≥ 2 j, $m_{jj} \approx m_Z$
  - MET<50 GeV : suppr. tt
  - large Higgs mass : Z boosted : $\Delta\phi_{ll}$<thr ; $\Delta\phi_{jj}$<thr

- Categorization of b-jets : 2 b-jets ; <2 b-jets

dominant Z+jets : b rare : ≈ 2% (b-pdf from proton)
O(20%) signal contains b-jets

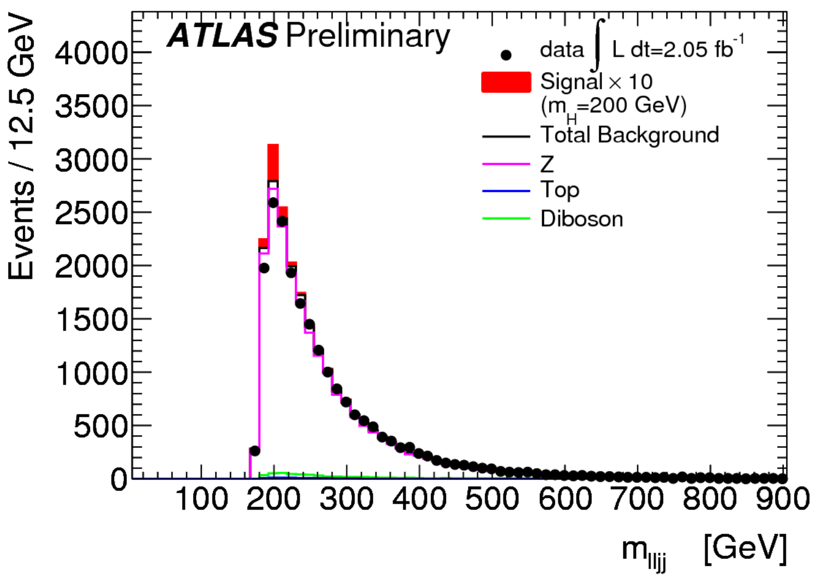


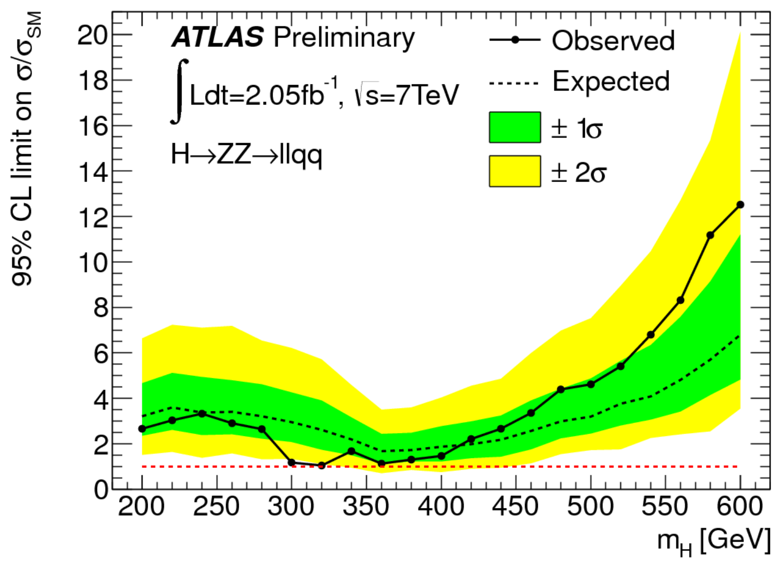
$H \rightarrow ZZ \rightarrow llqq$ $200 \leq m_H \leq 600$ GeV   2.05 fb^{-1}

- Background from control samples :

-Z+jets : MC (10 % less than data), scale factor from data (sidebands $m_{jj} \neq Z$ peak)
-tt : MC, scale factor from data : sidebands $m_{ll} \neq Z$ peak
-ZZ irreducible : difficult to constraint : Z+j contamination & signal in CR : MC
-WZ, W+j : MC
-QCD multijets : e : relax lepton id ; normalization : multicomponent fit to m_{ll}
μ : μμ+j : ABCD isolation ; $m_{\mu\mu}$ wrt Z
, W+jets : sidebands with m_{jj}, m_{ll}, reversed cuts
-WW/WZ/ZZ : MC, uncertainty 15 %

- Final discriminant : m_{4l}
- Limits : btw 1.2 and 12xSM





$H \rightarrow ZZ \rightarrow ll\nu\nu$ $200 \leq m_H \leq 600$ GeV $2.05\ fb^{-1}$

Higher BR than 4l channel (x6), but less clean (MET)

Z on-shell : reduces background

contrib of $H \rightarrow WW \rightarrow l\nu l\nu$

Statistical independance from mutual exclusion in selection (#l, m_{ll}, MET, etc.)

- Bkg

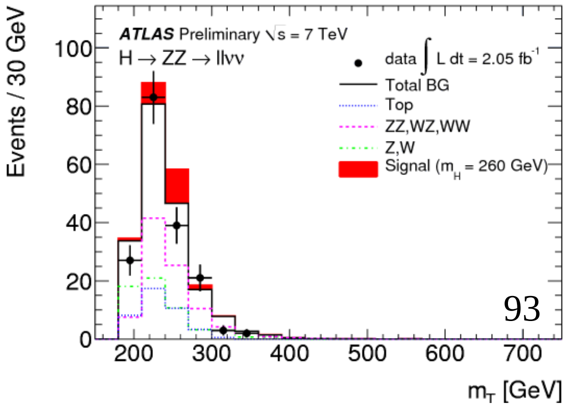
-primary : Z+j

-secondary : top, W, QCD

- Selection
  - same-flavor OS leptons, m_{ll} compatible with m_Z : suppr. top, W, QCD
  - MET>m($_H$) ; $\Delta\phi$(vector p_T,vector p_T^{miss})>0.3 : suppr. fake MET
  - Veto $\geq$1 b-jet : suppr. top
  - large Higgs mass : Z boosted : $\Delta\phi_{ll}$<f(m_H)
  - high mass : additive cut : $\Delta\phi$(vector p_T^{miss}, vector p_T^{ll})>thr

- Final discriminating variable

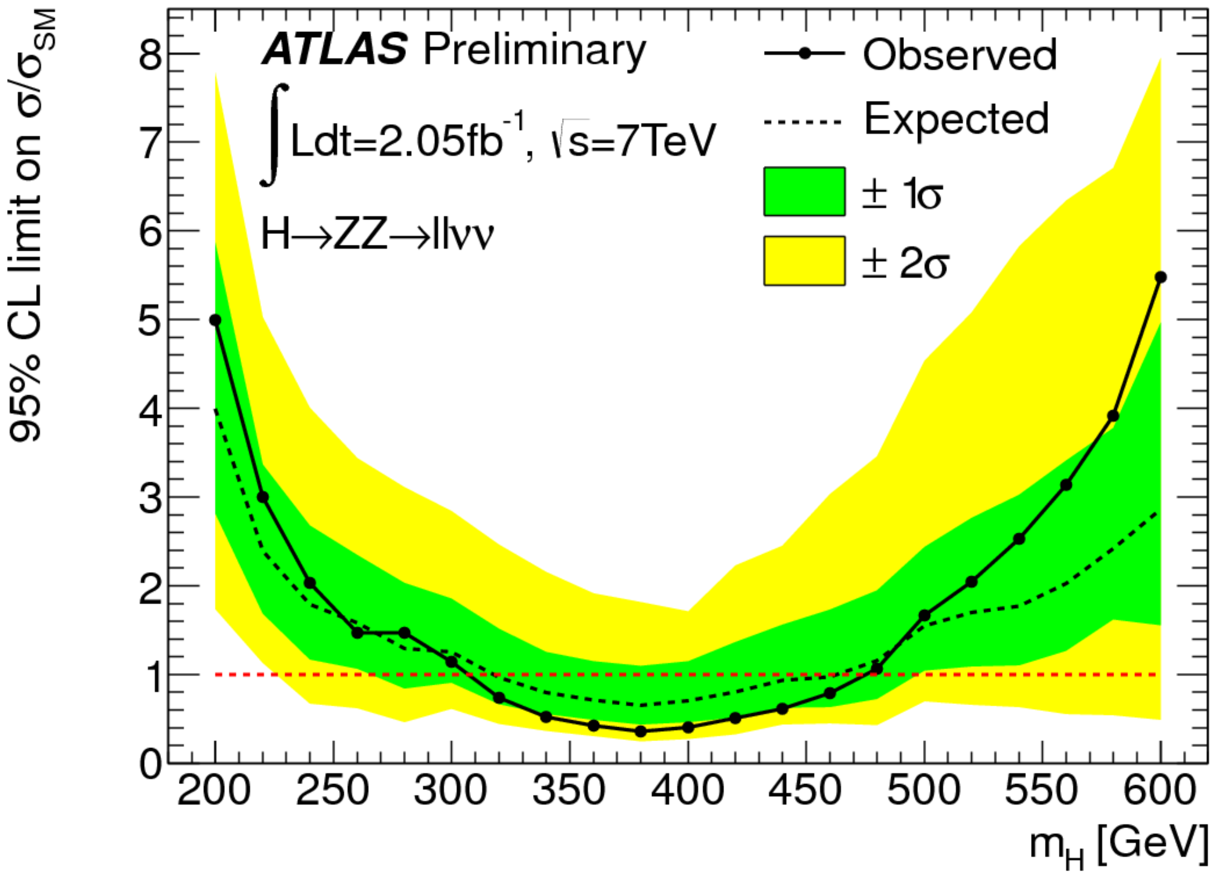
m_T

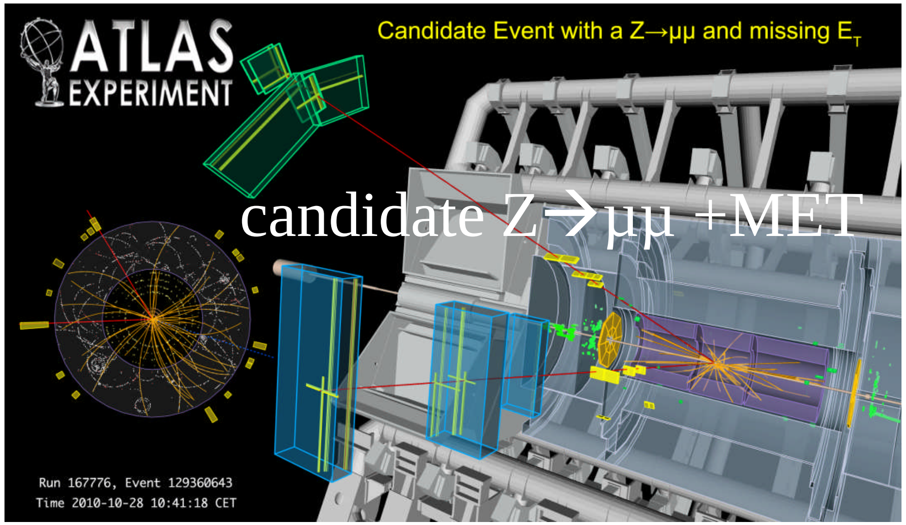


- Limits :

Exclusion at 95 % CL :

m_H : [310 ; 470] GeV





candidate Z→μμ +MET

Trigger for H→γγ

EF_2g20_loose : L1_EM14 : coarse elmg calorimeter granularity ; pT>14 GeV on each photon

EF : full elmg calorimeter granularity ; photon loose identification

Efficienty measurement bootstrap method :

- $\mathrm{Eff}^{EF\_2g20\_loose} = \mathrm{eff}^{EF\_g20\_loose}_{lead} \times \mathrm{eff}^{EF\_g20\_loose}_{sub}$
- $\mathrm{Eff} = \mathrm{eff}^{EF\_g20\_loose}_{tight\ photon} = \mathrm{eff}^{EF\_g20\_loose}_{L1} \times \mathrm{eff}^{L1}_{MinBias}$

L1 : L1_EM14 (D-K) ; L1_EM12 (L-M) (L1_EM14 prescaled)

Systematics : diff eff. MC H→γγ & fake photons from dijets selection

Difference btw tag & probe and pseudo tag & probe (⇔no inv. mass cut)

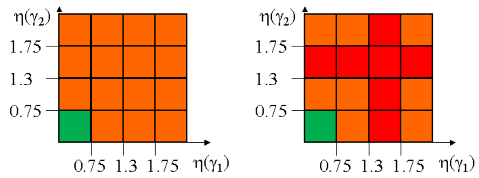
Select one tight photon passing cuts=tag

Other = probe ; require $m_{\gamma\gamma}$ compatible with m_Z

Max of difference between methods : systematics

Prospects : g30_g20_loose

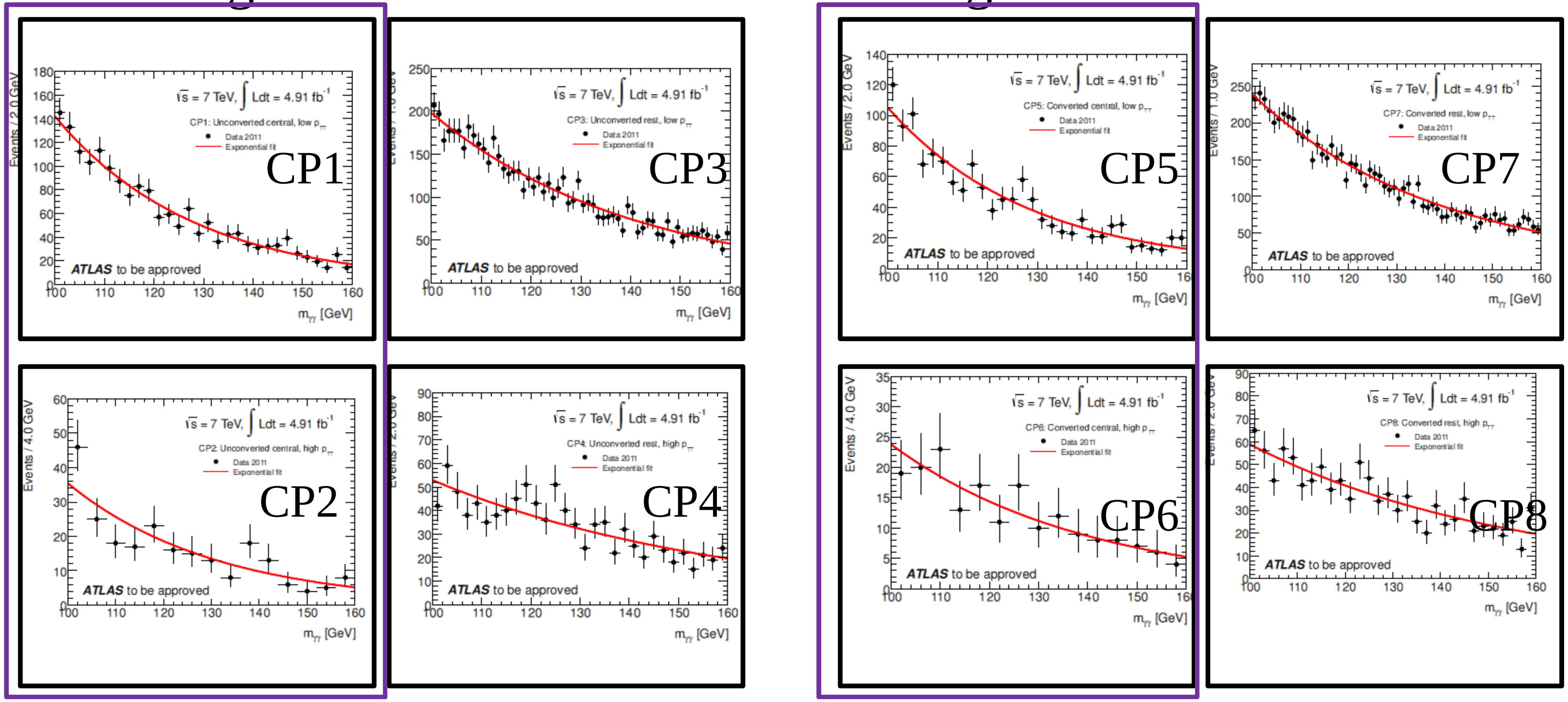
$M_{\gamma\gamma}$ per category $p_{Tt}/\eta/\text{conv}$

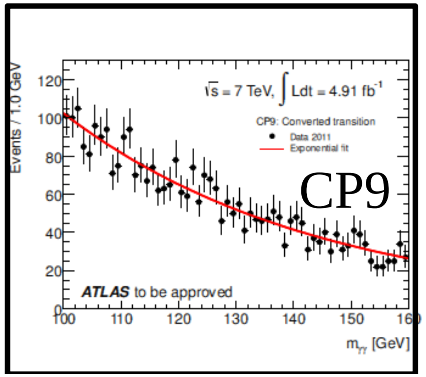


Unconv good | Unconv rest | conv good | conv medium

Low p_{Tt}

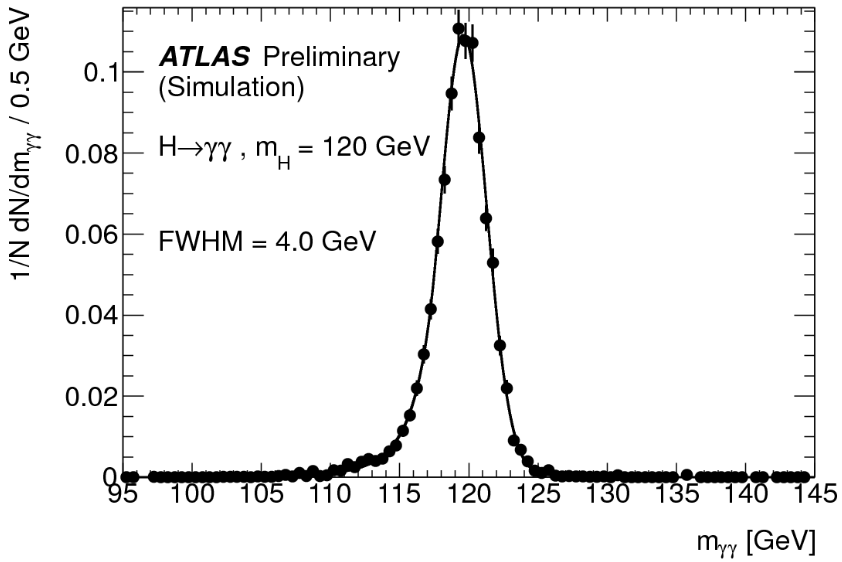
High p_{Tt}





Resolution H→γγ

Atlas



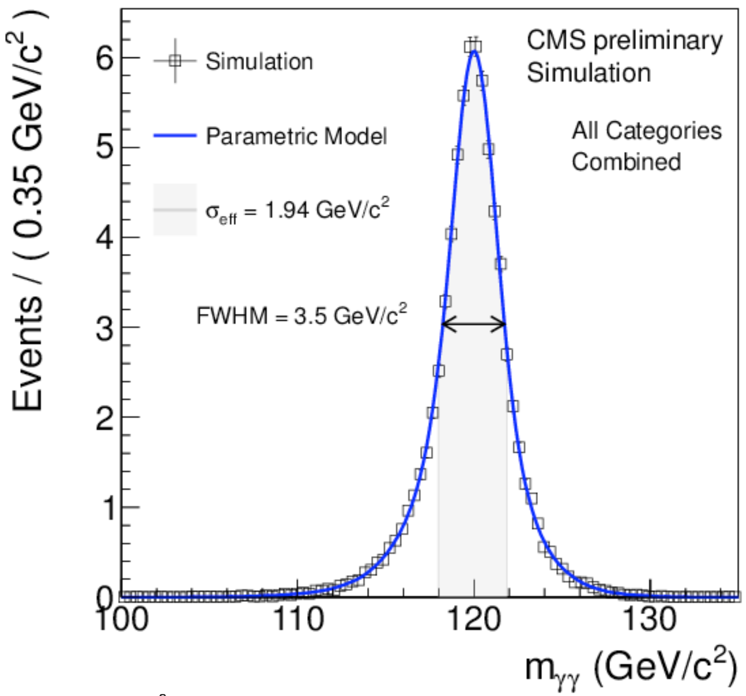
Invariant mass signal resolution H→γγ

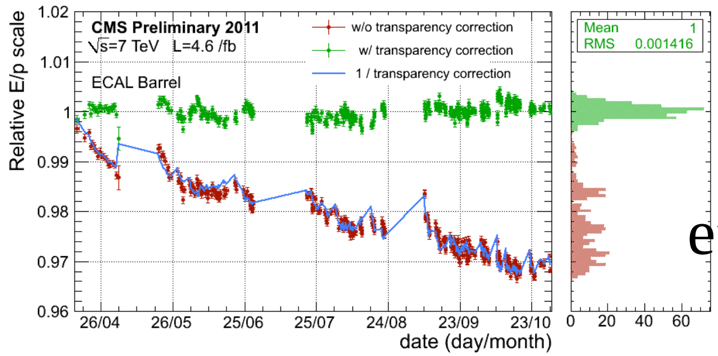
-Inclusive : σ_{CB} : 1.7 GeV

-Best category (unconv central) : 1.4 GeV

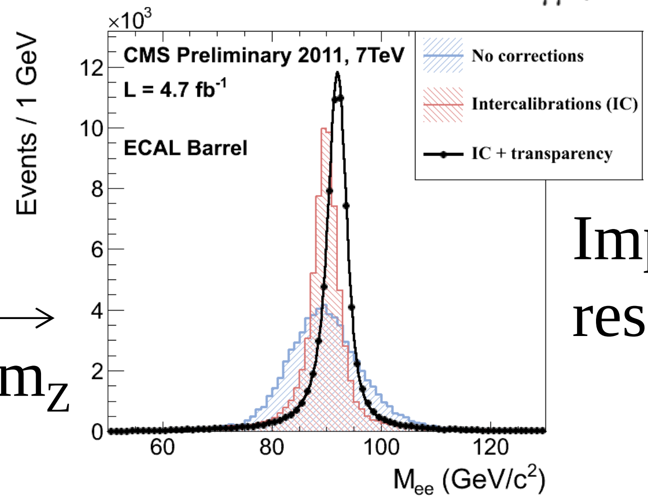
-Worst category (conv. transition) : 2.3 GeV

CMS





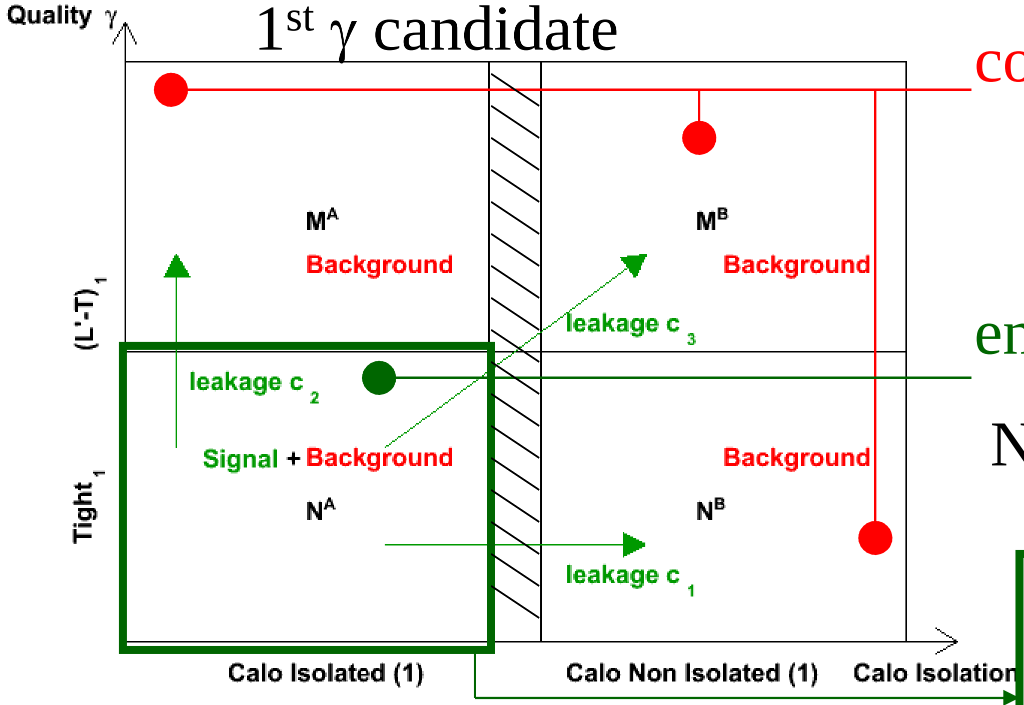
effect on m_Z



Improved resolution w/ lasers

2x2D sideband method (old one)

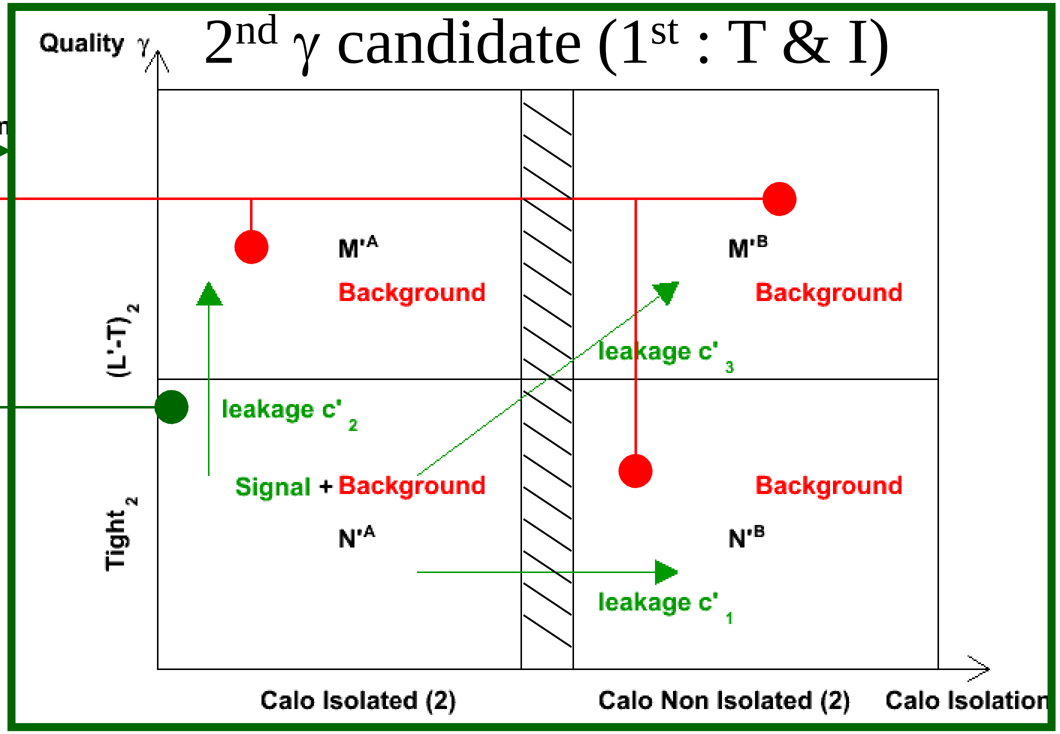
gap region : not considered for the **nominal** measurement



control region (bkg)

enriched γ+X region (γγ+γj)

N^A_{sig} : #signal in N^A



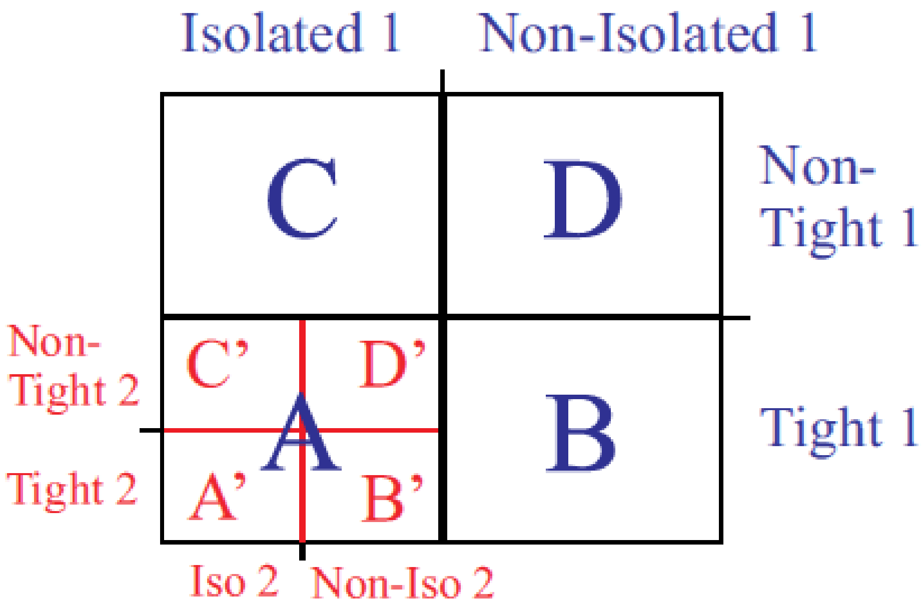
control region (bkg)

enriched γγ region (and jet γ)

N'^A_{sig} : #signal in N'^A

Introduction to improved 2x2D method

• Remembrance of standard 2x2D method : sequential subdivision



8 regions to count events but 7 independent regions

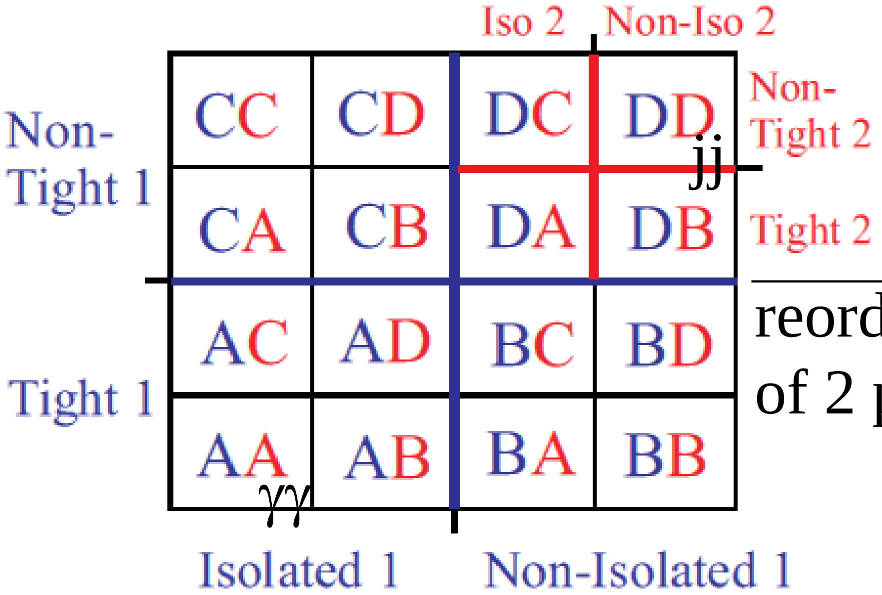
→ additional MC input : asymmetry parameter : $\alpha=N_{j\gamma}/(N_{j\gamma}+N_{\gamma j})$

• improved 2x2D method : simultaneous subdivision → 4x4=16 regions

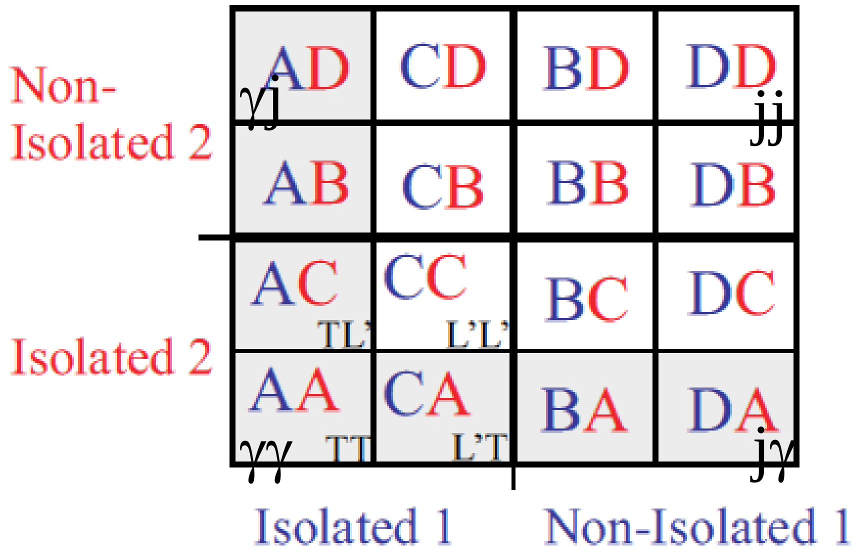
Reduce systematics

Improved 2x2D method

same but different view
(for pedagogy purpose only)

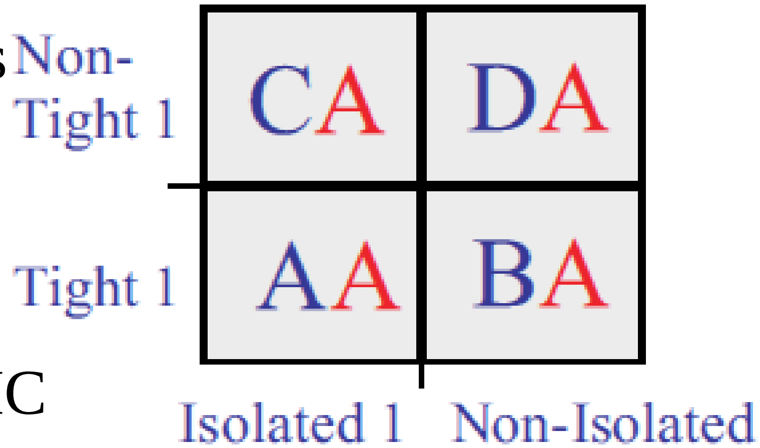


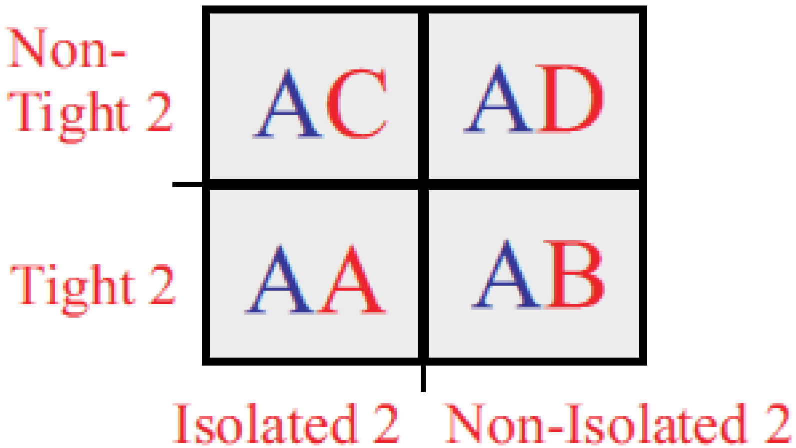
reordered in plane of 2 photons



• neglect different fake rate for jets in jj and γj/jγ

→2x2D sidebands





Leakages from MC

Deduce fake rates f_1, f_2 : Prob true Loose' jet to pass isolation cut
Eff for true tight identified photon to pas isolation cut : ε_1, ε_2

4x4 matrix (N=Non-Isolated ; I=Isolated)

$$\begin{pmatrix} N_{II} \\ N_{IN} \\ N_{NI} \\ N_{NN} \end{pmatrix} = \begin{pmatrix} \varepsilon_1\varepsilon_2 & \varepsilon_1 f_2 & f_1\varepsilon_2 & f_1 f_2 \\ \varepsilon_1(1-\varepsilon_2) & \varepsilon_1(1-f_2) & f_1(1-\varepsilon_2) & f_1(1-f_2) \\ (1-\varepsilon_1)\varepsilon_2 & (1-\varepsilon_1)f_2 & (1-f_1)\varepsilon_2 & (1-f_1)f_2 \\ (1-\varepsilon_1)(1-\varepsilon_2) & (1-\varepsilon_1)(1-f_2) & (1-f_1)(1-\varepsilon_2) & (1-f_1)(1-f_2) \end{pmatrix} \begin{pmatrix} N_{\gamma\gamma}^{TT} \\ N_{\gamma j}^{TT} \\ N_{j\gamma}^{TT} \\ N_{jj}^{TT} \end{pmatrix}$$

Deduce yields in TITI regions

$$\begin{aligned} N_{\gamma\gamma}^{TITI} &= \varepsilon_1\varepsilon_2 N_{\gamma\gamma}^{TT} \\ N_{\gamma j}^{TITI} &= \varepsilon_1 f_2 N_{\gamma j}^{TT} \\ N_{j\gamma}^{TITI} &= f_1\varepsilon_2 N_{j\gamma}^{TT} \\ N_{jj}^{TITI} &= f_1 f_2 N_{jj}^{TT} \end{aligned}$$