LHC News

~ The latest results from ATLAS ~

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Outline

- Introduction

- The (selected) latest ATLAS results of
  - The standard model measurements
  - Higgs boson searches
  - New physics searches

- Future plans

- Summary

Introduction

- The standard model describes phenomena observed so far
- Higgs mechanism in SM is an effective description of EWSB, but Higgs boson has not been discovered yet

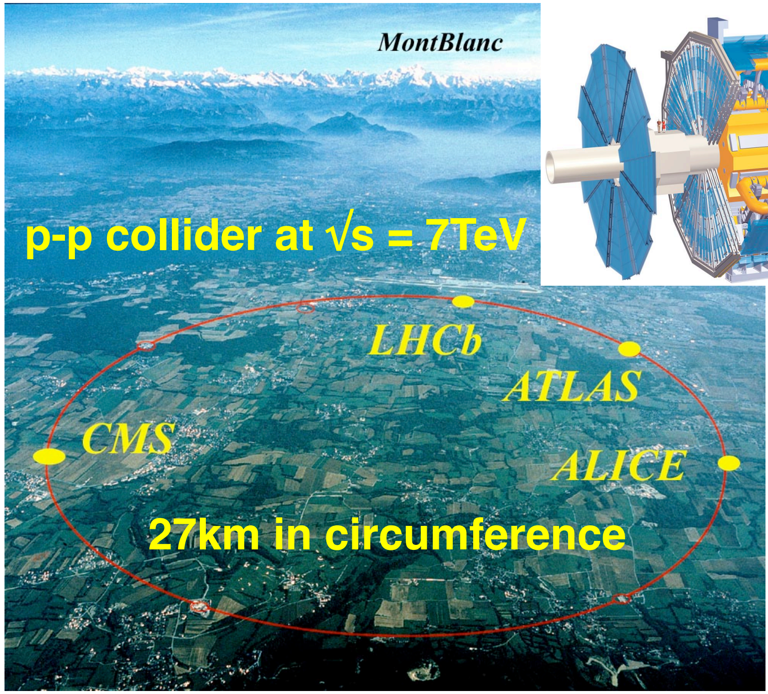
  → It is essential to discover the Higgs boson

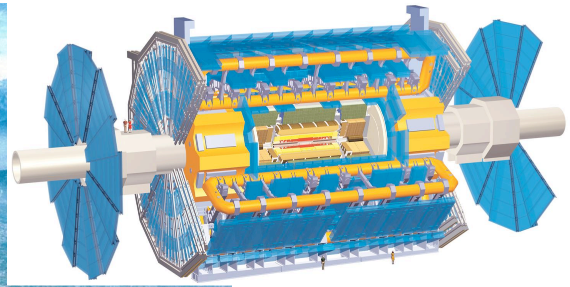
- The SM breaks down at a certain energy scale
  - Hierarchy : quadratic divergence of the Higgs mass,
    Weak scale << Plank scale
  - What is the underlying nature of EWSB?
- Dark matter cannot be explained by SM

  →New physics should exist to explain the particle physics at TeV scale

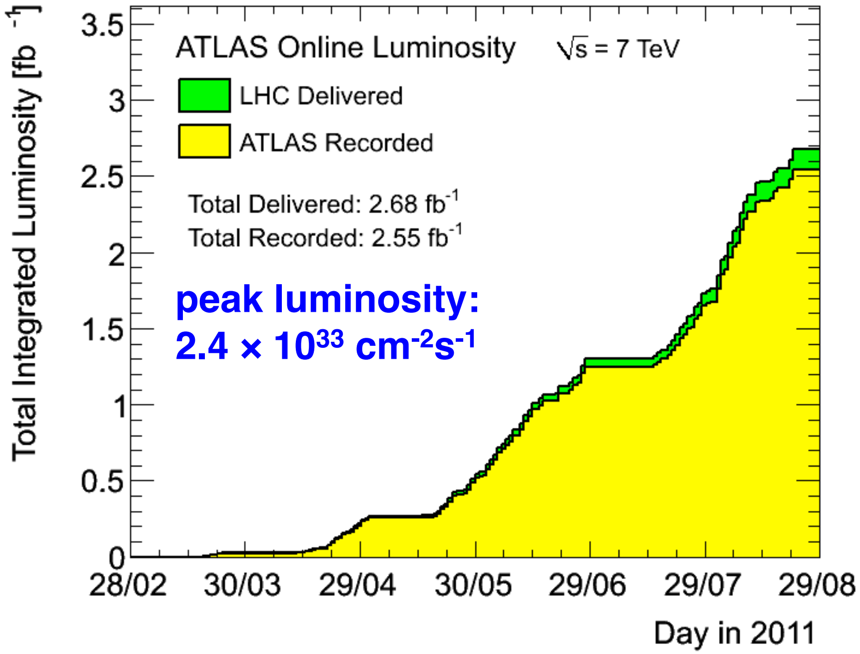
- ATLAS experiment aims at discovering
  - the new phenomena by precise measurements of the SM, — **SM physics**
  - the Higgs boson(s), and — **Higgs searches**
  - the new physics beyond the SM directly (SUSY?, ED?) — **New physics**

LHC-ATLAS experiment

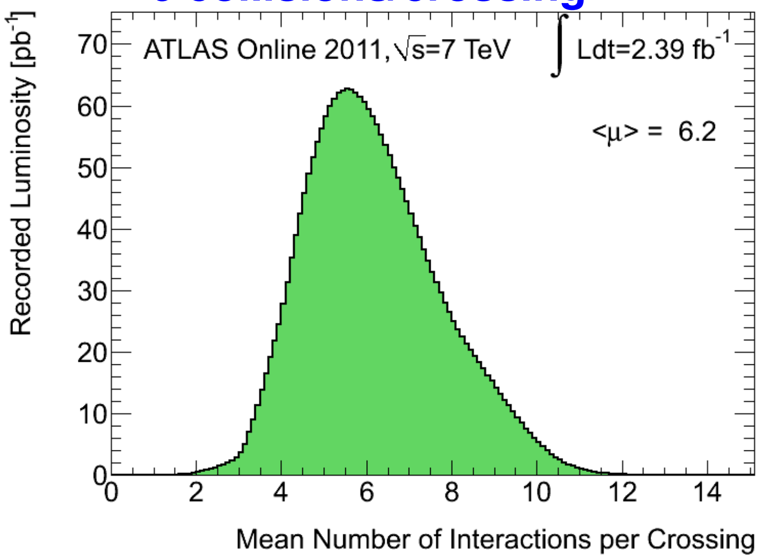




ATLAS: 25m × 44m general purpose detector

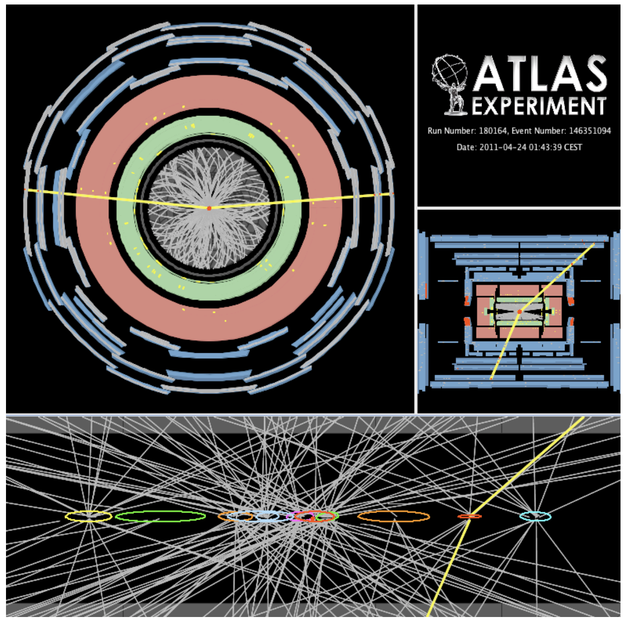


6 collisions/crossing



We made much progress on understanding detector performance with pileups

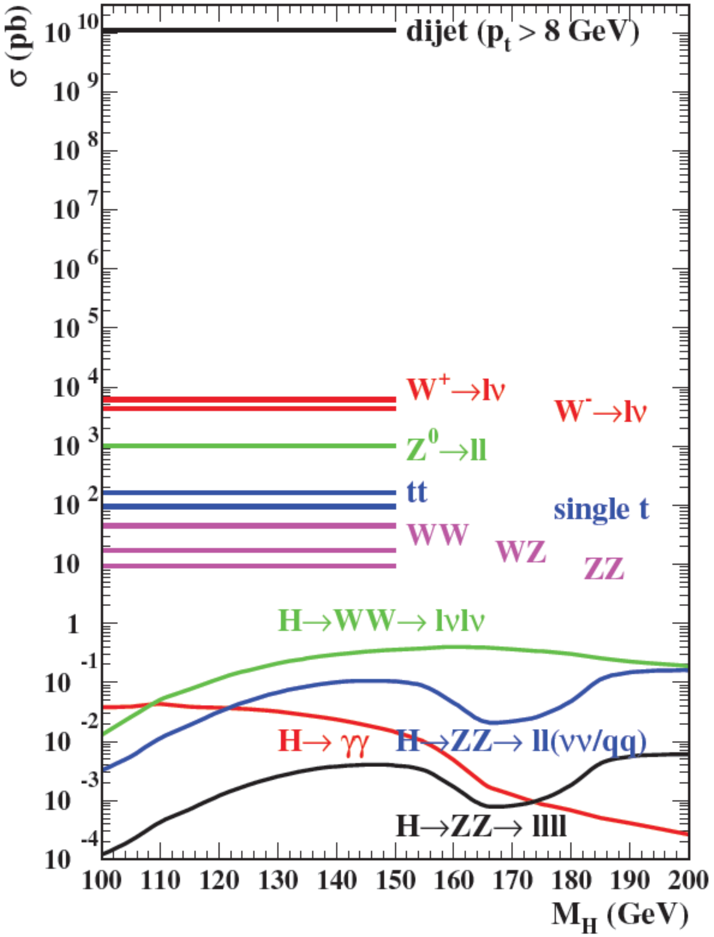
Z → μμ event with 11 collisions

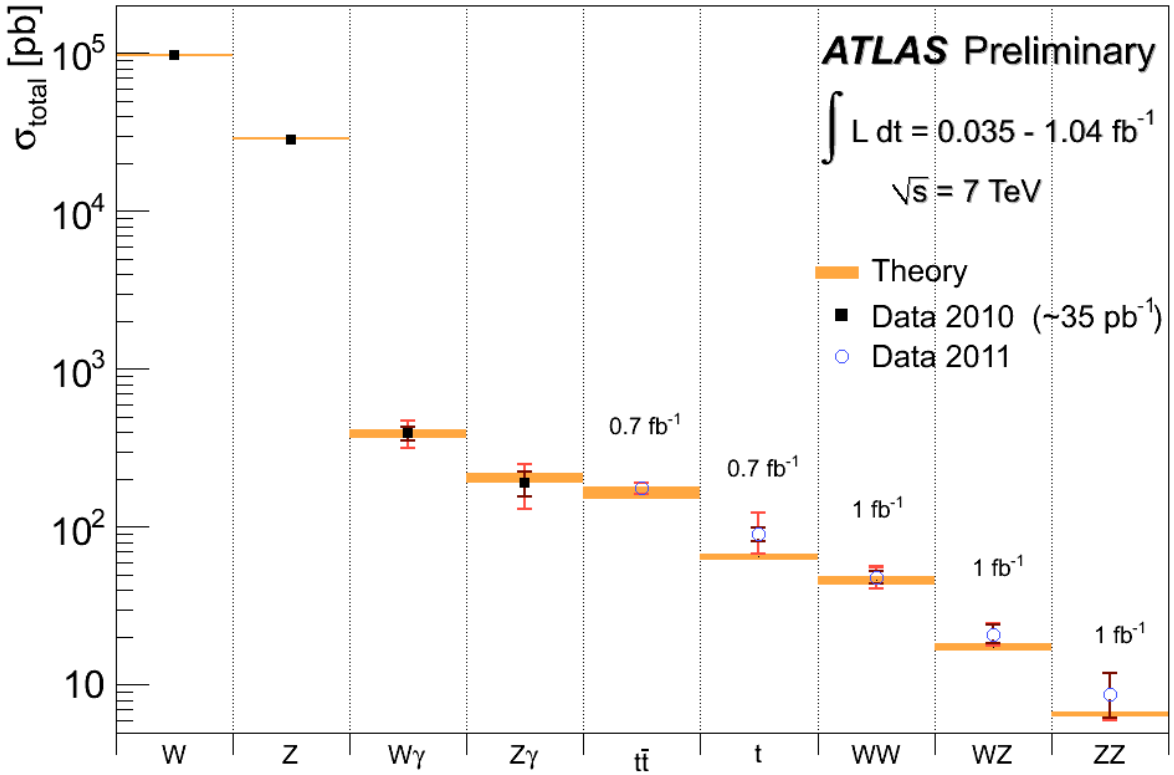


Standard model measurements

Standard model measurements

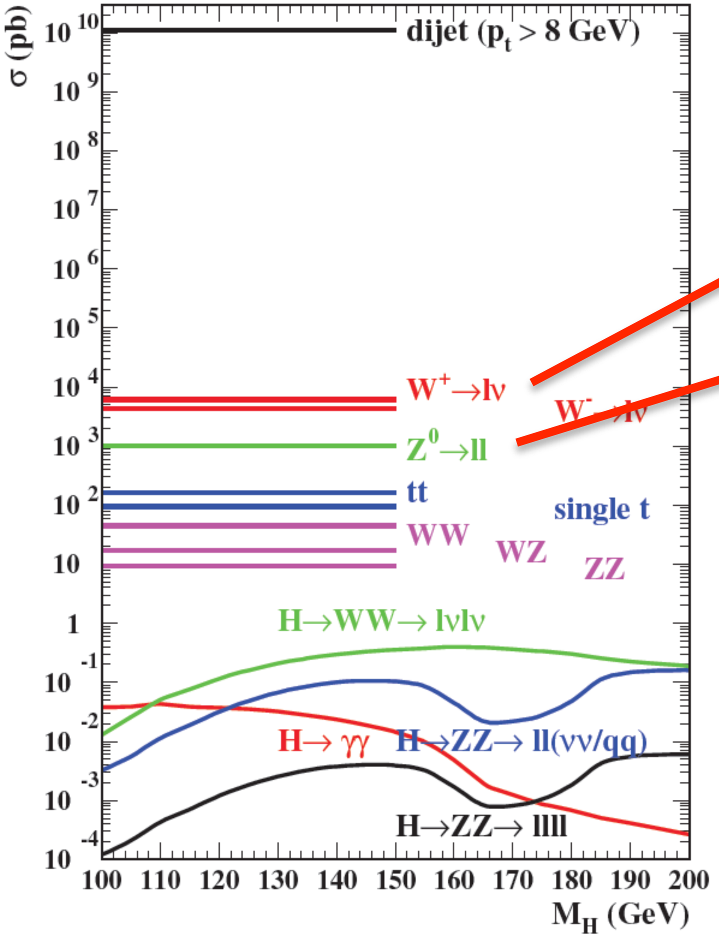
Most standard model processes have been already measured.

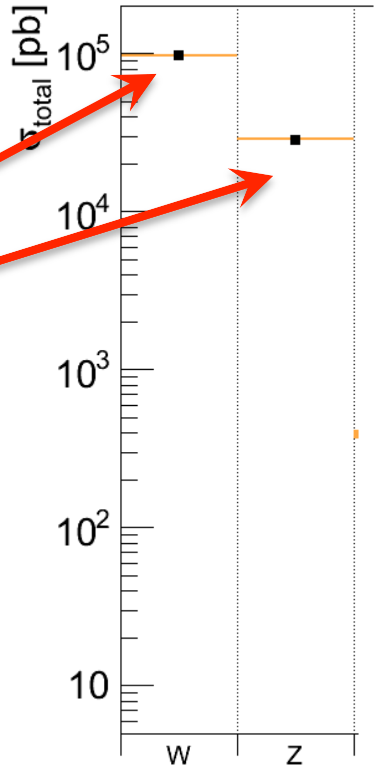


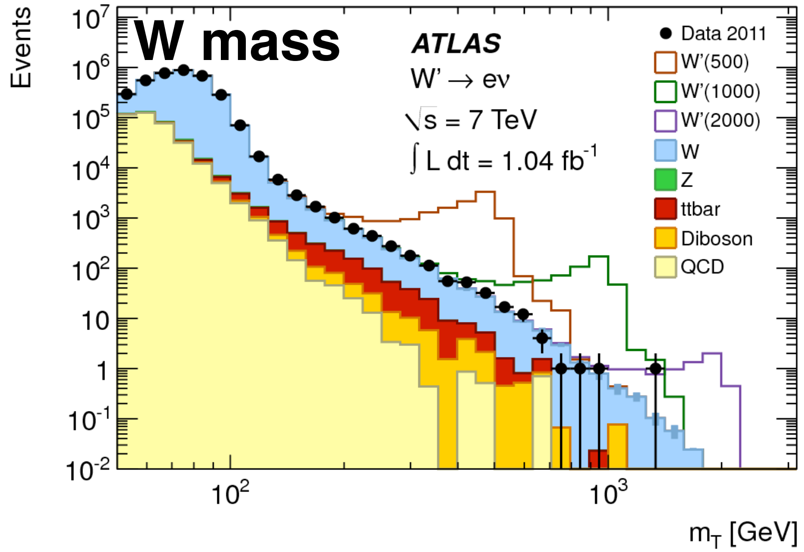


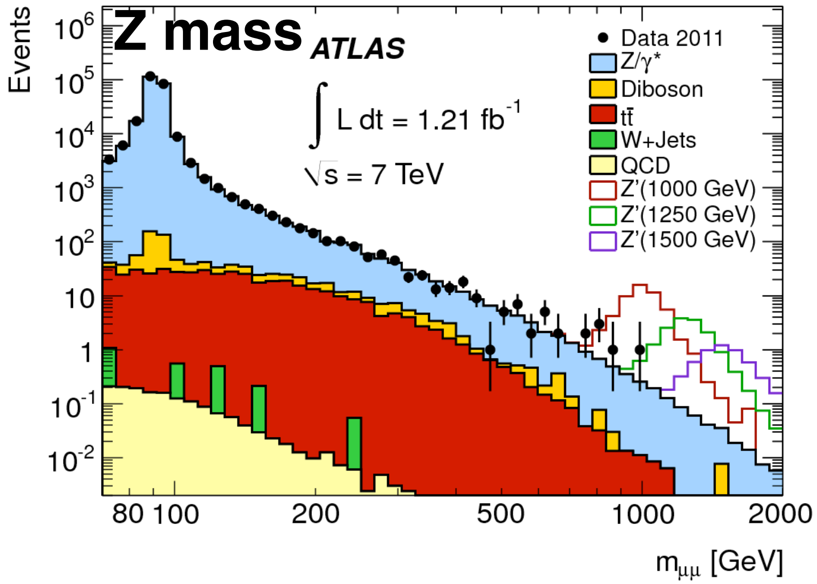
pp→W/Z + X

Most standard model processes have been already measured.



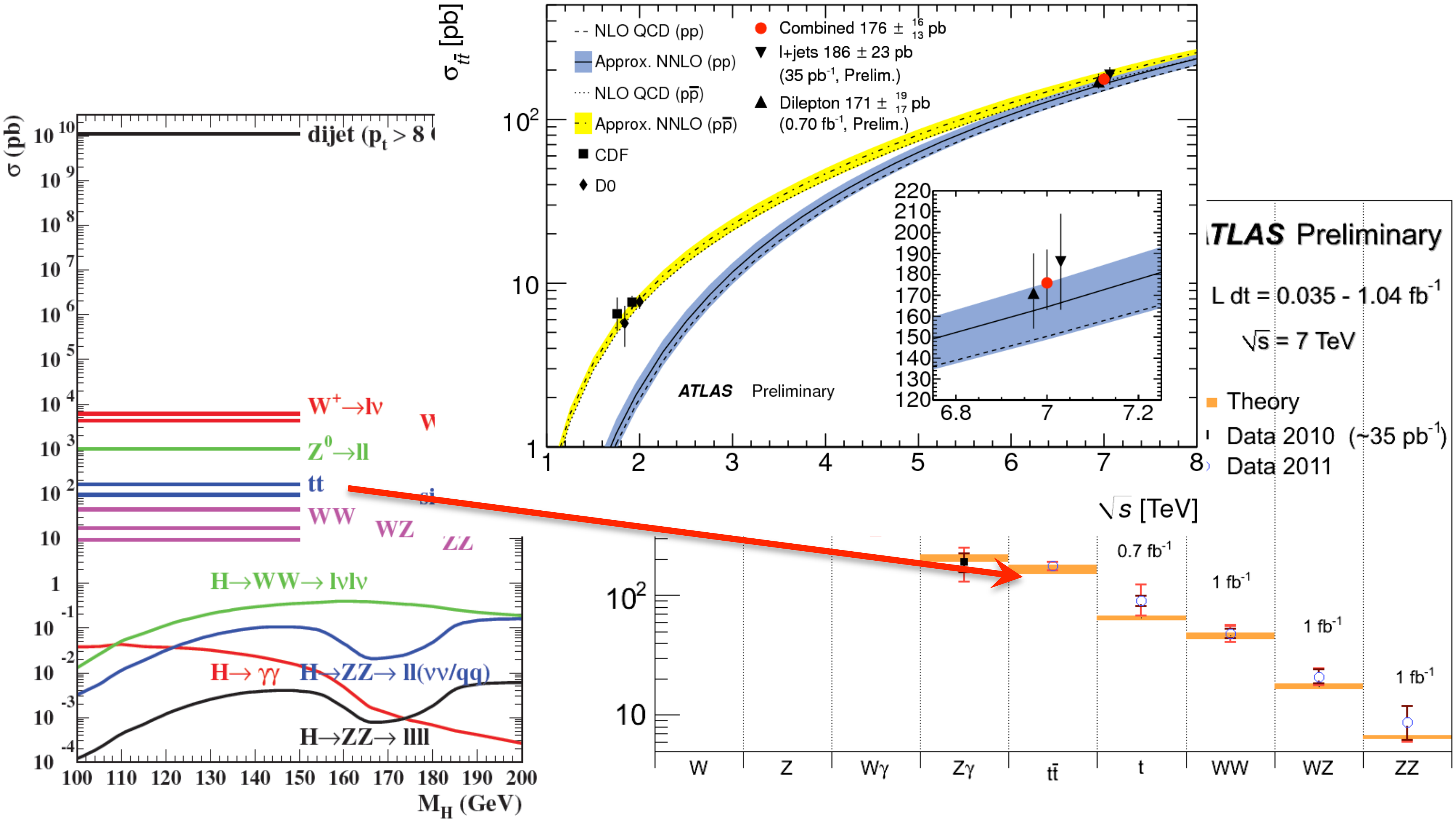






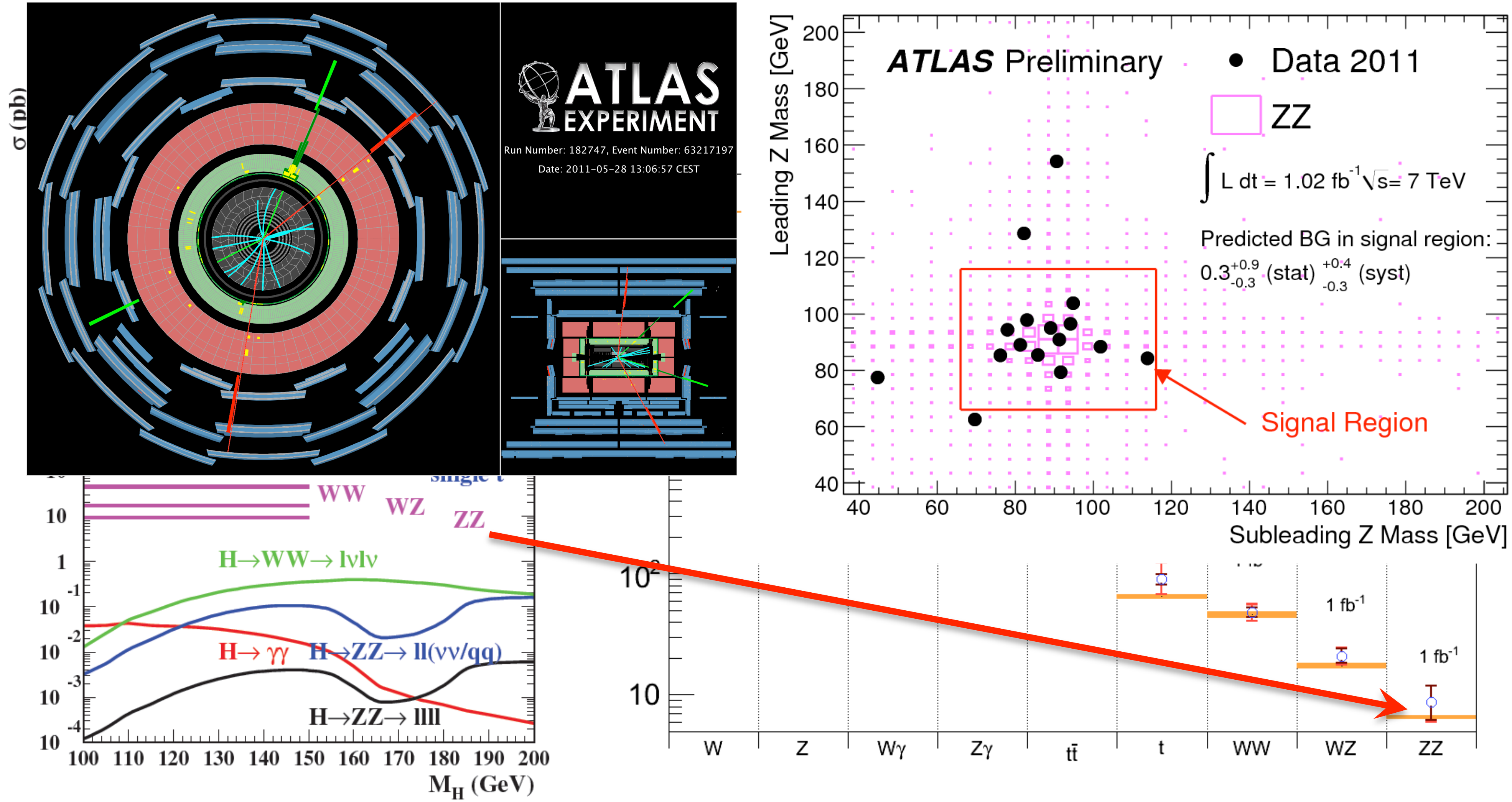
top quark pair

Most standard model processes have been already measured.



diboson production : pp→ZZ

Most standard model processes have been already measured.



Standard model physics

- We are moving on new phenomena searches from the precise measurements of QCD and Electroweak physics
  - W charge symmetry, Triple gauge coupling…
  - $t\bar{t}$ resonance, t→$H^{\pm}$b decays, bare quark V-A interaction…
  - …

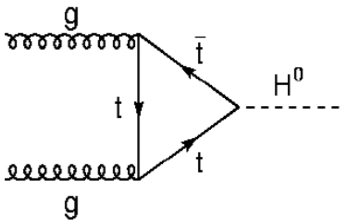
- Success of the well-know SM measurements allows us to look for Higgs boson and new physics BSM

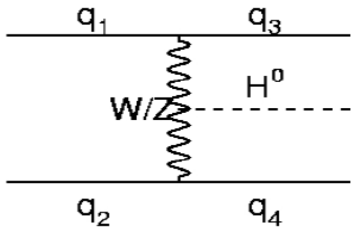
Higgs boson searches

Higgs production and decay

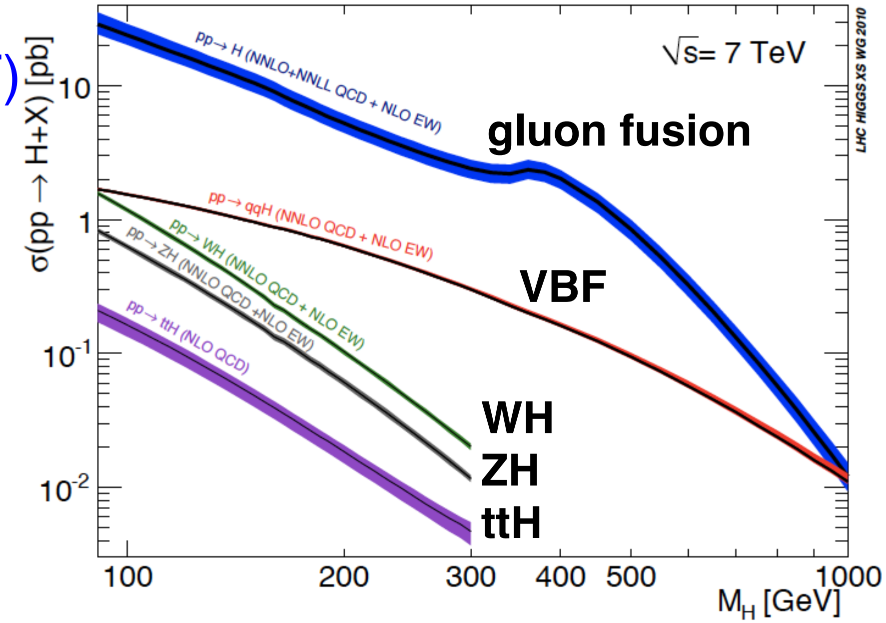
- Higgs production

gluon fusion (GF) Vector boson fusion (VBF)

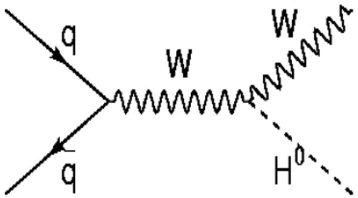


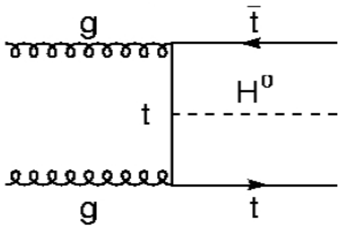


arXiv:1101.0593

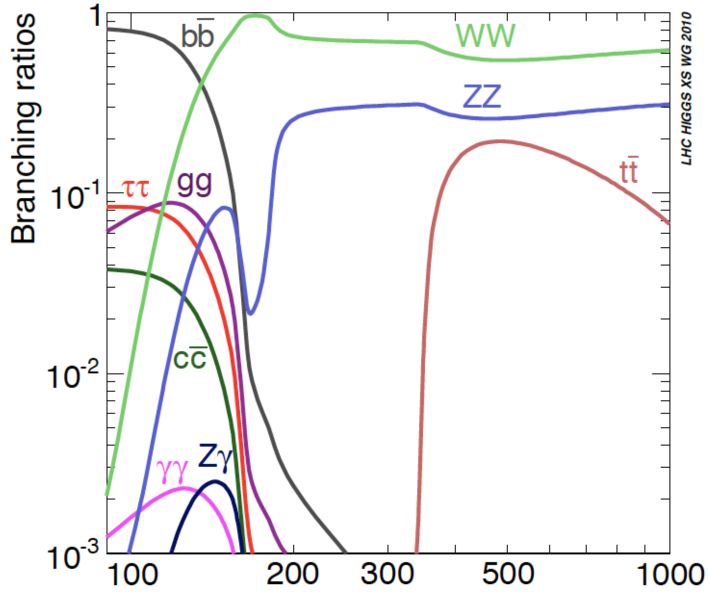


Associated production with W/Z, top quark (WH, ZH, ttH)





- Higgs decay
  - High mass Higgs
    - H→ $WW^{(*)}$→ lνlν, lνqq
    - H→$ZZ^{(*)}$ → 4l, 2lqq, 2lνν
  - Low mass Higgs
    - H→bb, ττ, or γγ

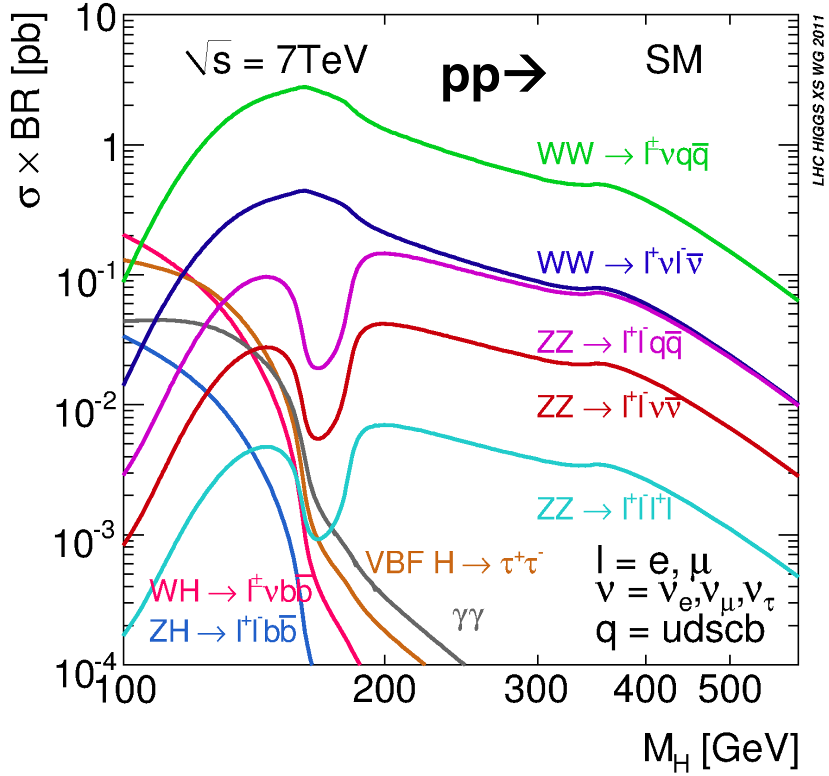


arXiv:1101.0593

M_H [GeV]

Higgs searches at ATLAS

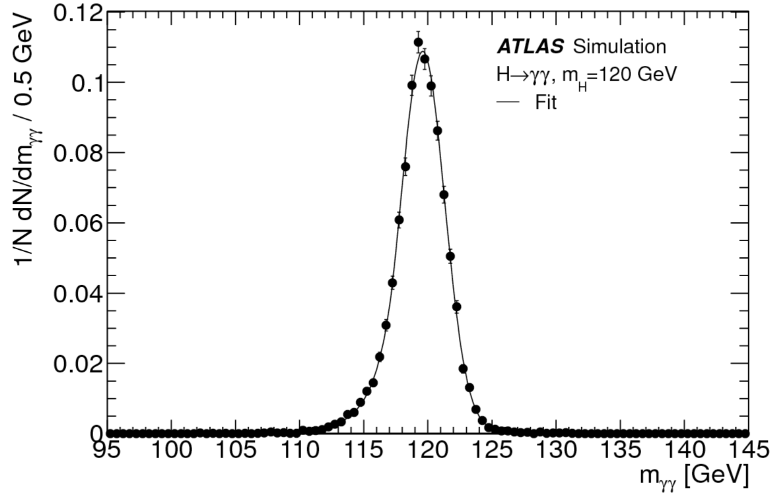
- $H \rightarrow \gamma\gamma$ **L = 1.08 fb^{-1}**
  - rare, the best for low mass
- WH/ZH, $H \rightarrow bb$ **L = 1.04 fb^{-1}**
  - $H \rightarrow bb$ can be used for associated productions
  - Important for Yukawa-coupling
- $H \rightarrow \tau\tau$ **L = 1.06 fb^{-1}**
  - good S/N, for low mass
- $H \rightarrow WW$ **L = 1.70 fb^{-1}**
  - lvlv : intermediate mass range
- $H \rightarrow ZZ$
  - 4l : golden channel **L = 2.2 fb^{-1}**
  - llvv : high mass search **L = 1.04 fb^{-1}**
  - llqq : high mass search **L = 1.04 fb^{-1}**

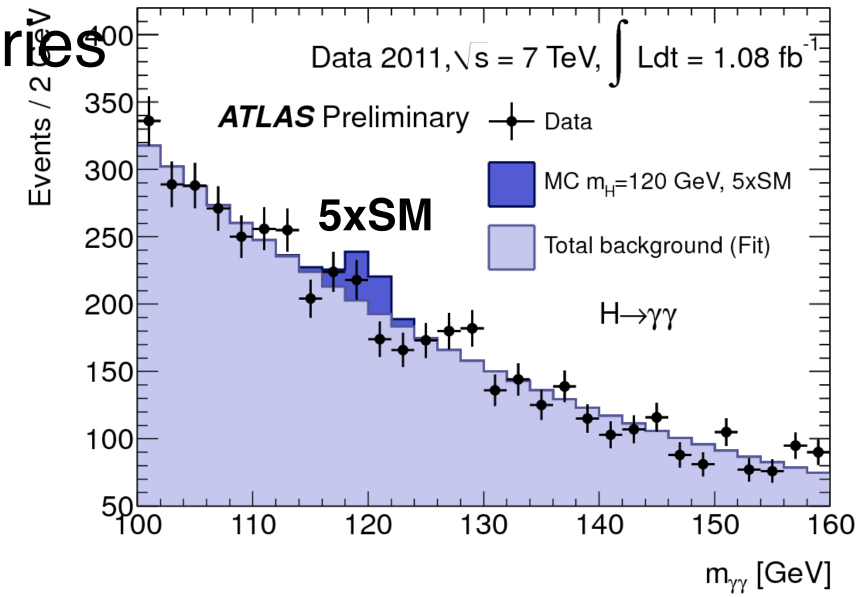


H→γγ : L=1.08 fb^{-1}

- Event selection
  - Two high quality isolated γ
  - p_{T1}>40GeV, p_{T2}>25GeV
- Background (from control sample)
  - pp → γγ+X (irreducible)
  - pp → γ-jet, jet-jet +X (reducible)
  - Estimated from control samples
    isolation and identification criteria
- Events are classified into 5 categories
  - direction of γ in η,
  - converted or unconverted
- Fit is performed to extract # singal
  - Exponential (background)
  - Crystal ball (signal)

Mass resolution ~1.7GeV

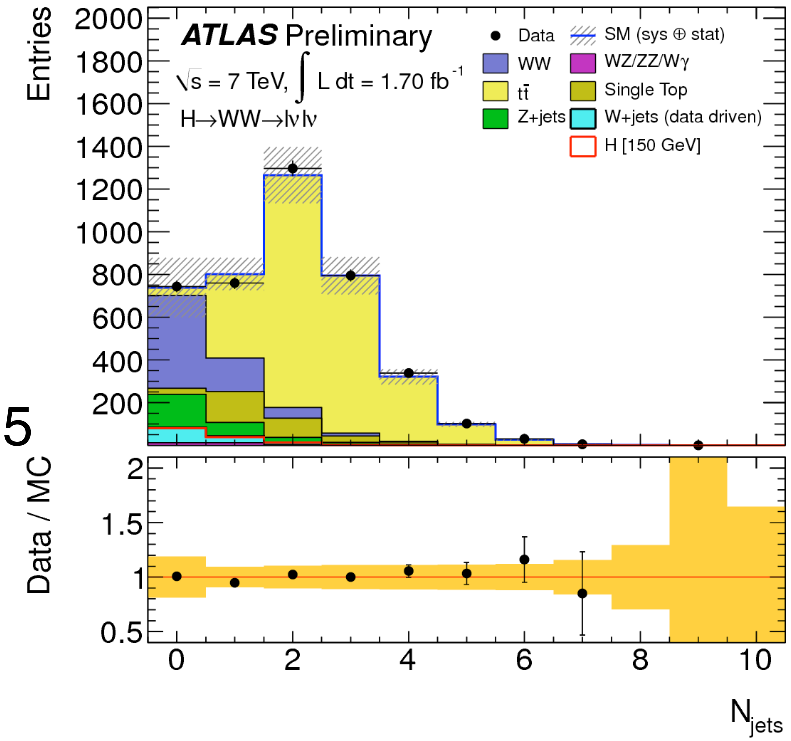




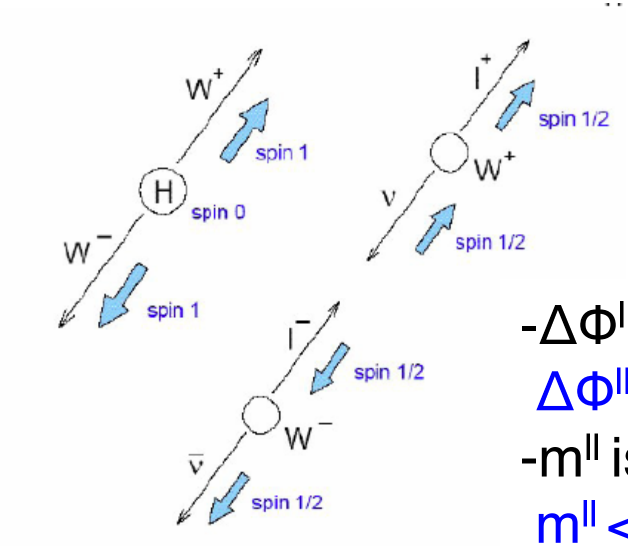
H→WW→lνlν : L=1.7 fb^{-1}

- Event selection
  - high-p_T opposite sign 2 leptons
  - large E_T^{miss}
  - Events are divided into two categories
    - WW with 0 jet (jet veto)
    - WW with 1 jet with pT>25GeV |η|<4.5
  - Topological cuts (p_T^{ll}, m^{ll}, $\Delta\phi^{ll}$)
  - $0.75 \times m_H < m_T < m_H$

$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - (P_T^{\ell\ell} + P_T^{miss})^2}$$



- Backgrounds
  - WW diboson
  - top quark
  - W+jets



-ΔΦ^{ll} is small

$\Delta\Phi^{ll} < 1.3$ (1.8)

-m^{ll} is also small

$m^{ll} < 50$ (65) GeV

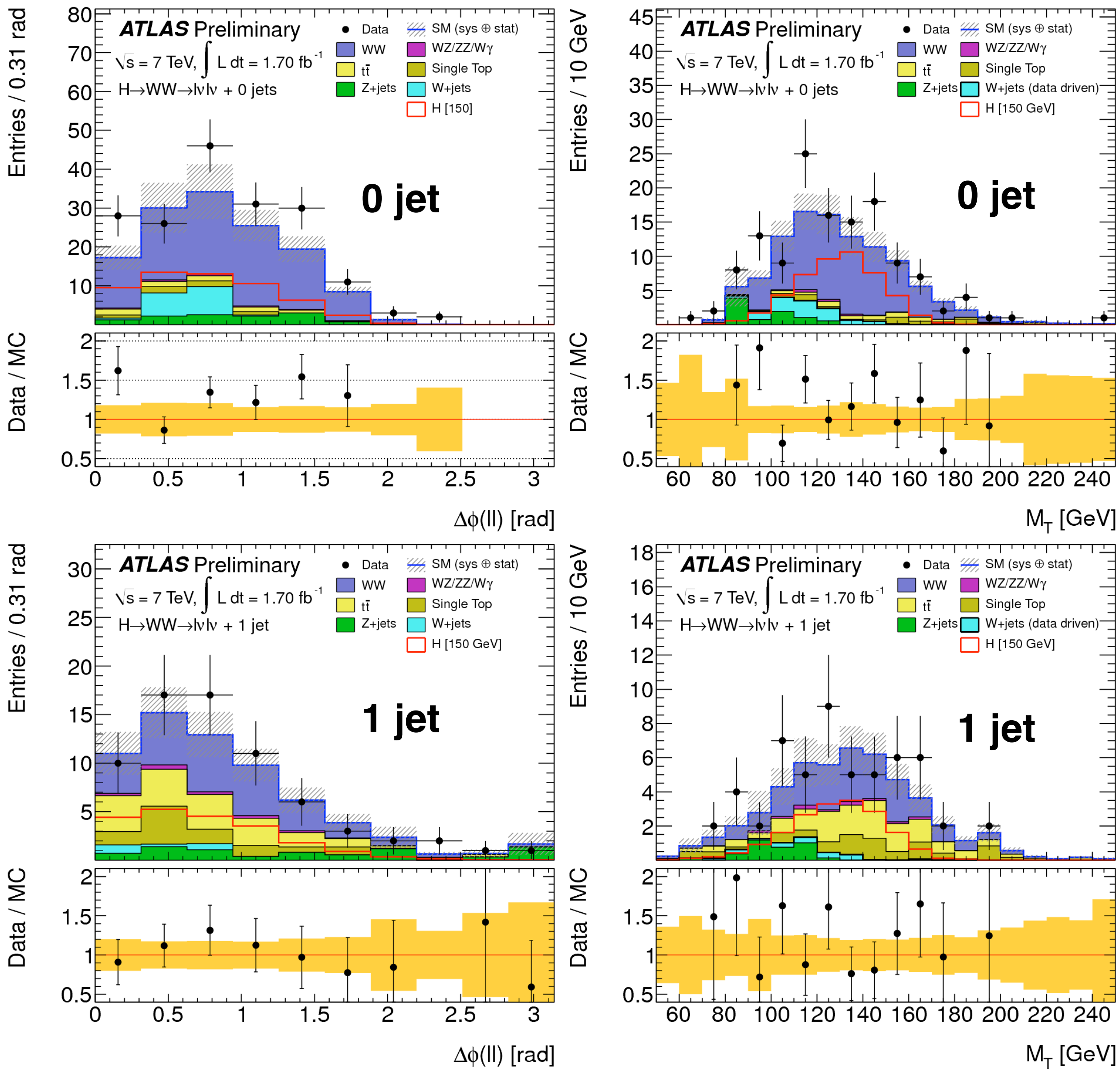
H→WW→lνlν : L=1.7 fb^{-1}

- counting method

	exp. total bkg.	data	sig. 150GeV
0-jet	53±9	70	34±7
1-jet	23±4	23	12±3

$\Delta\Phi^{ll}$ before $\Delta\Phi^{ll}$ and M_T cut

M_T before M_T cut



H→ZZ: L=2.2, 1.04 fb^{-1}

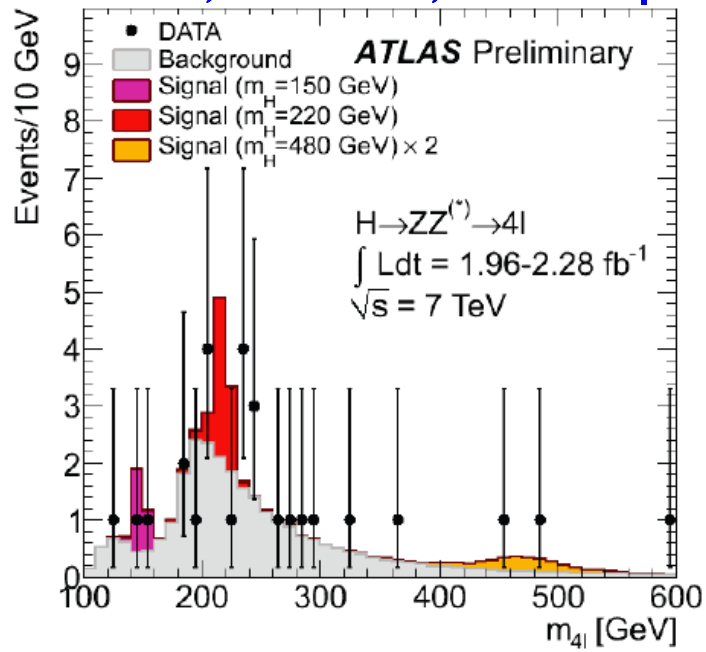
- Event selection
  - 2 isolated same-flavor leptons, Z mass window cuts
  - For H→ ZZ →4l
    - Another isolated same-flavor lepton pair
    - m_{4l} is the final discriminating variable
  - For H→ZZ→llqq
    - third lepton veto
    - at least 2 jets
    - E_T^{miss}<50GeV
    - m_{lljj} is the final discriminating variable
  - For H→ ZZ → llvv
    - third lepton veto
    - $E_T^{miss} > 66$ (82) GeV, depending on the "low" ("high") mass analysis
    - m_T is the final discriminating variable

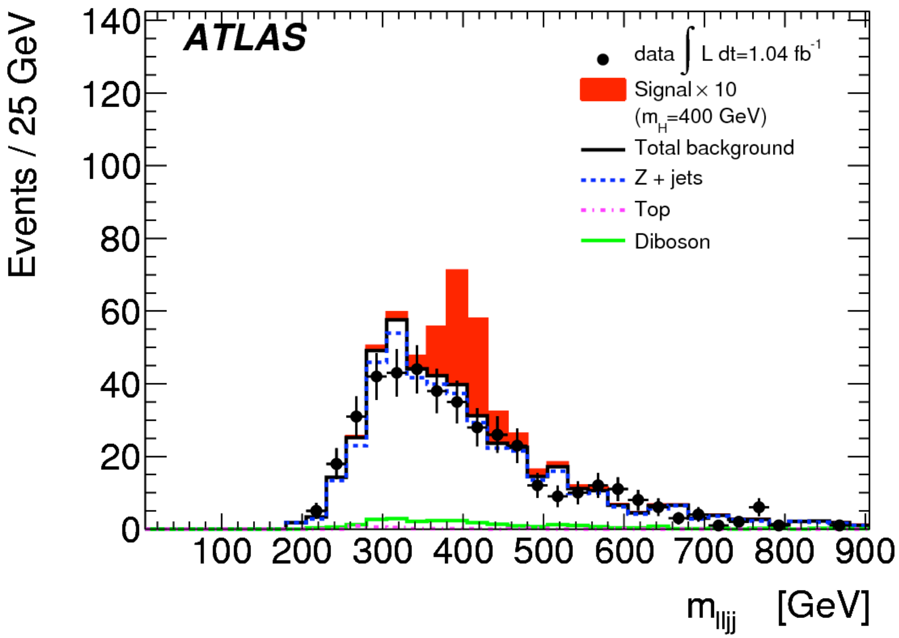
$$m_T^2 \equiv \left[\sqrt{m_Z^2+|\vec{P}_T^{ll}|^2}+\sqrt{m_Z^2+|\vec{P}_T^{miss}|^2}\right]^2-\left[\vec{P}_T^{ll}+\vec{P}_T^{miss}\right]^2$$

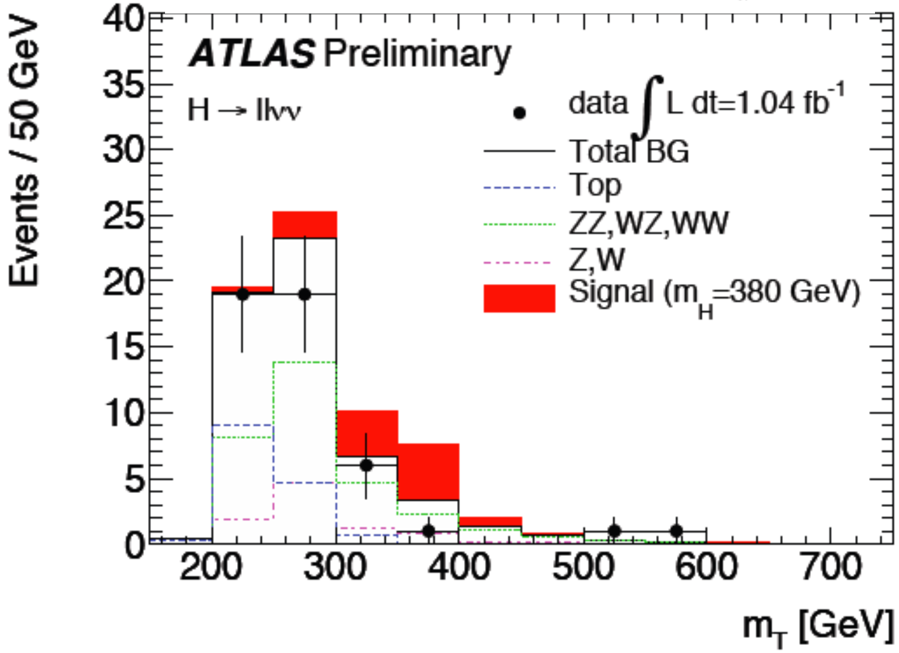
H→ZZ: L=2.2, 1.04 fb^{-1}

- Backgrounds
  - H→ ZZ→4l
    - irreducible ZZ
  - H→ZZ→llqq
    - Z+jets
  - H→ZZ→llνν
    - diboson, top quark, W/Z+jets

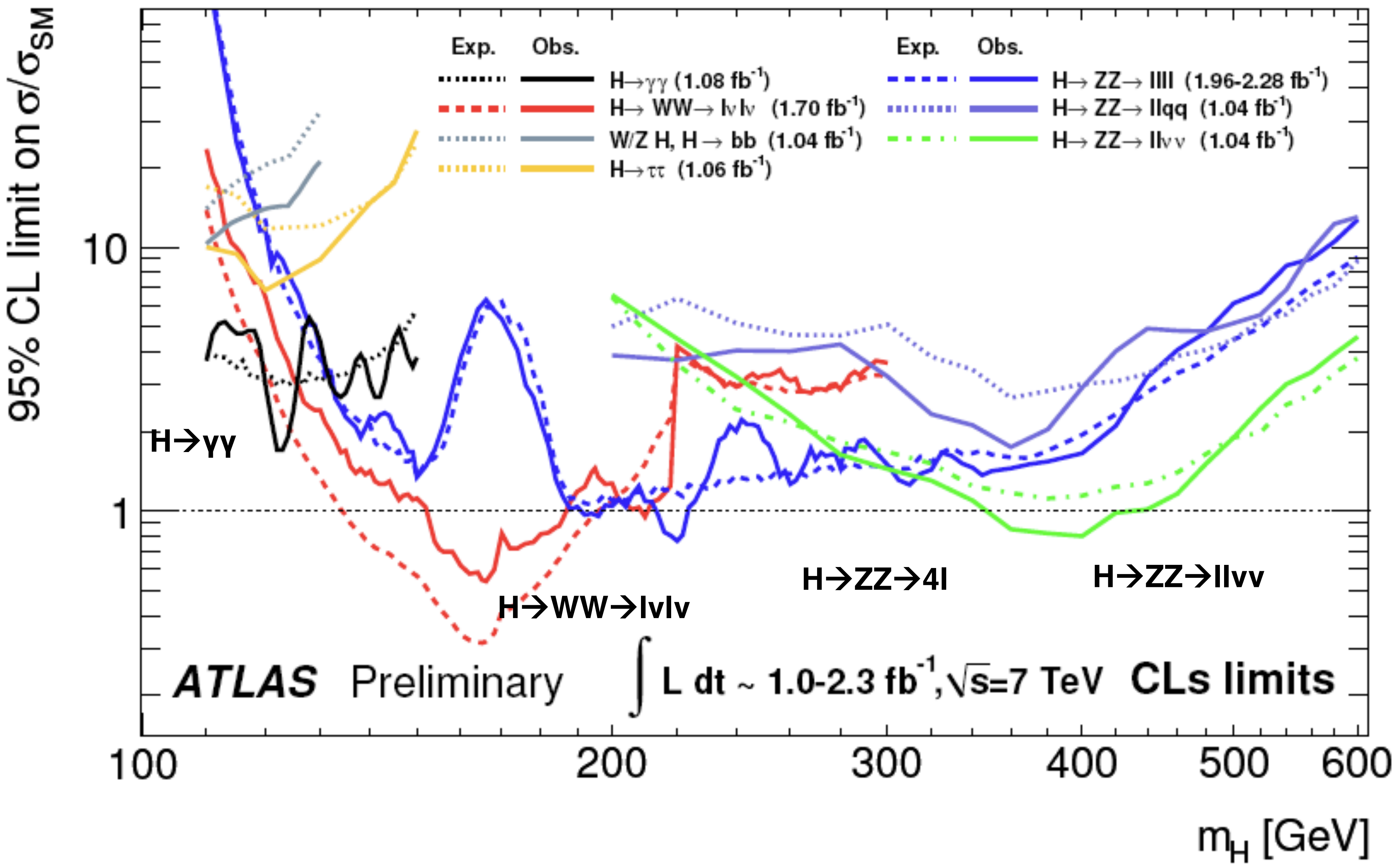
H→ ZZ→4l, 27 events, 28 ± 4 expected



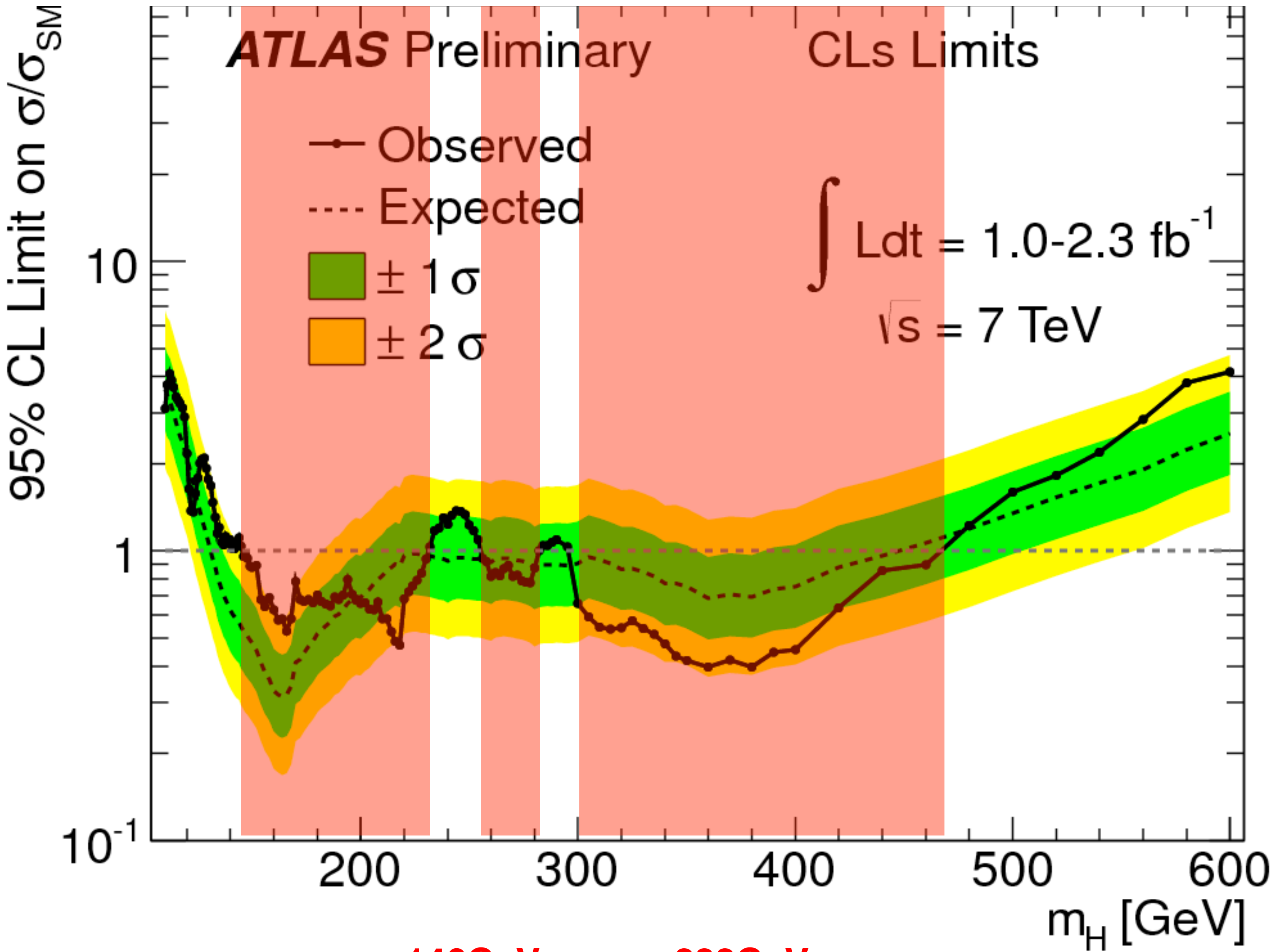




Limit for each channel



Combined limit

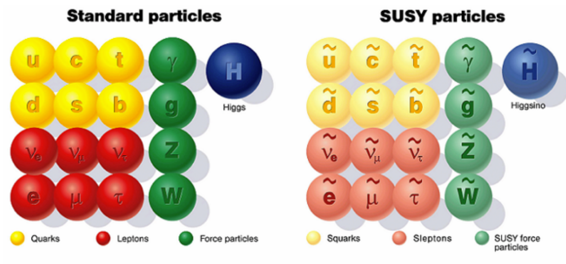


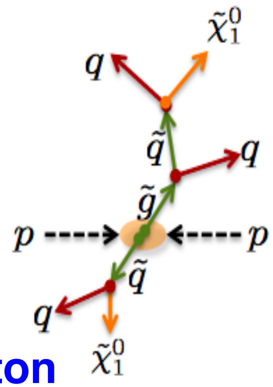
SM Higgs of $146\text{GeV} < m_H < 232\text{GeV}$, $256\text{GeV} < m_H < 282\text{GeV}$, $296\text{GeV} < m_H < 466\text{GeV}$ is excluded at 95% C.L.

New physics searches

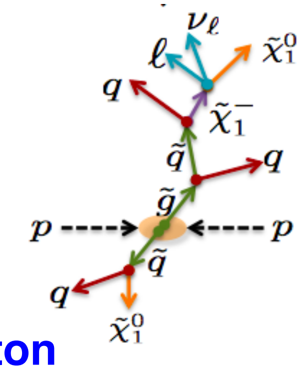
This talk will cover

- Supersymmetry (with E_T^{miss})
  - →Decays end up with LSP
    - ➤ Jets + E_T^{miss}
      - Squark and Gluino production is dominant
    - ➤ Lepton + Jets + E_T^{miss}
      - leptons from Charginos, Slepton, W/Z
    - ➤ 3rd generation (b-jets+E_T^{miss})
      - gluinos preferentially decay to 3rd generation
      - direct production require >1fb^{-1}



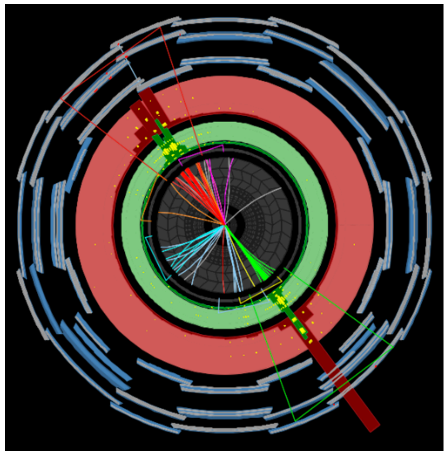


0-lepton

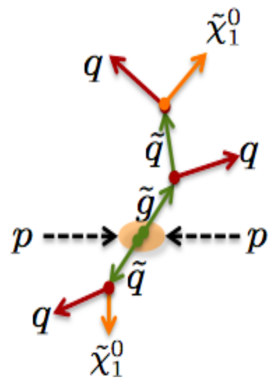


1-lepton

- Heavy particle resonances
  - → Predicted by numerous extension of the SM
    - ➤ dilepton
      - Randall Sundrum KK graviton, GUT-inspired Z'…
    - ➤ Dijet
      - Exited quark, strong gravity, contact interaction



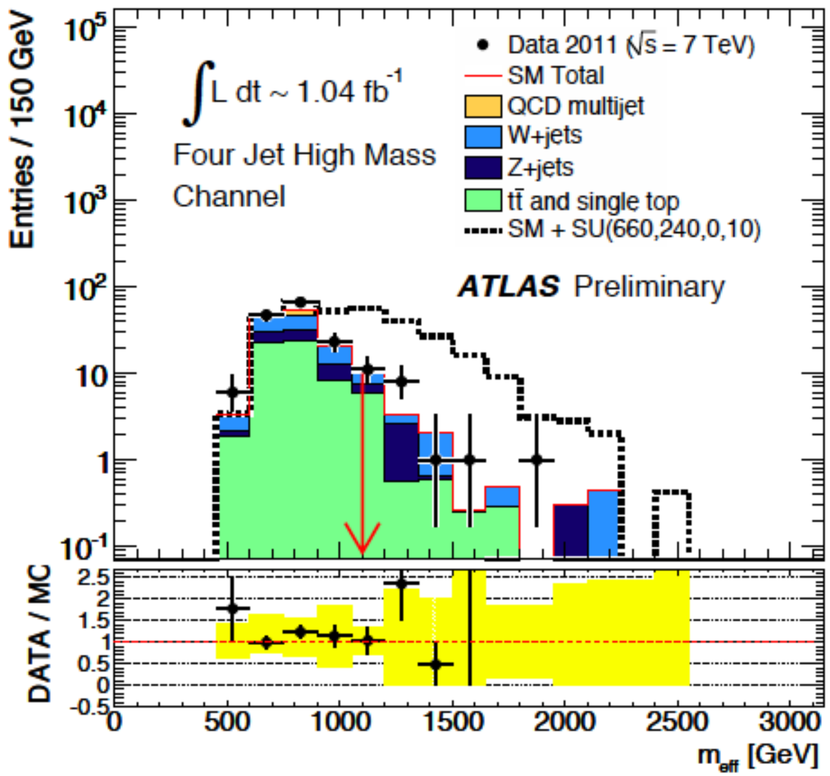
SUSY : jets + E_T^{miss}

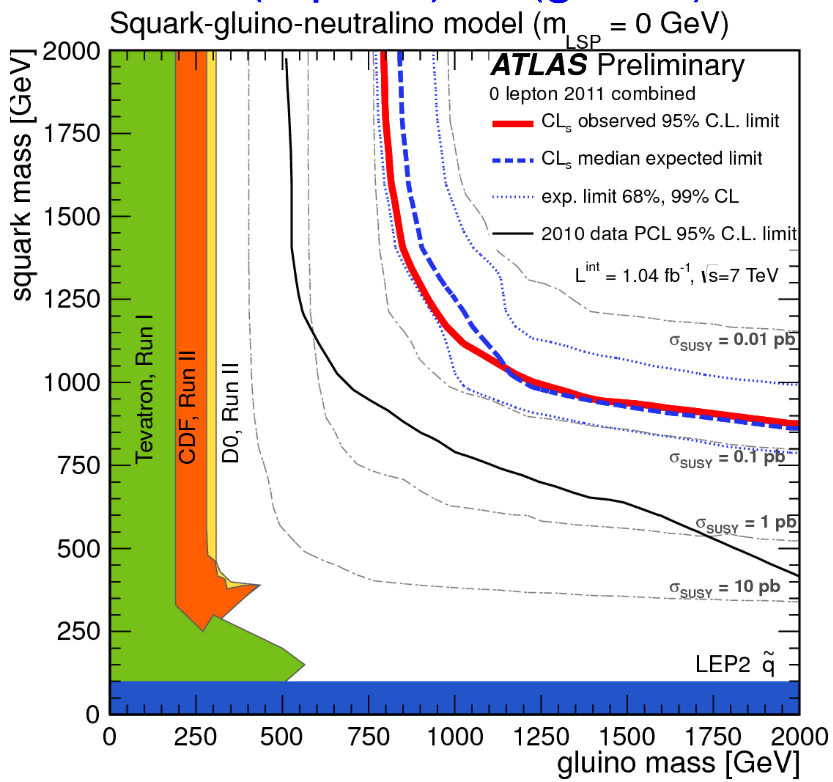


- Cut on p_T of jets, E_T^{miss}
  - Signal regions are optimized to maximize sensitivity to different production processes
- Main backgrounds are W/Z+jets, top quark, multijet
  - Estimated from one or more dedicated control regions

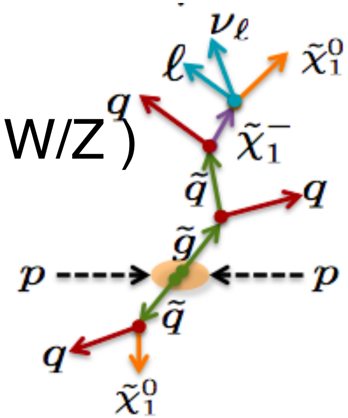
$$m_{eff} = \sum \left| \vec{P}_T^{\,jet} \right| + E_T^{miss}$$

up to m_{SUSY}~1TeV is excluded, for m(squark)=m(gluino)

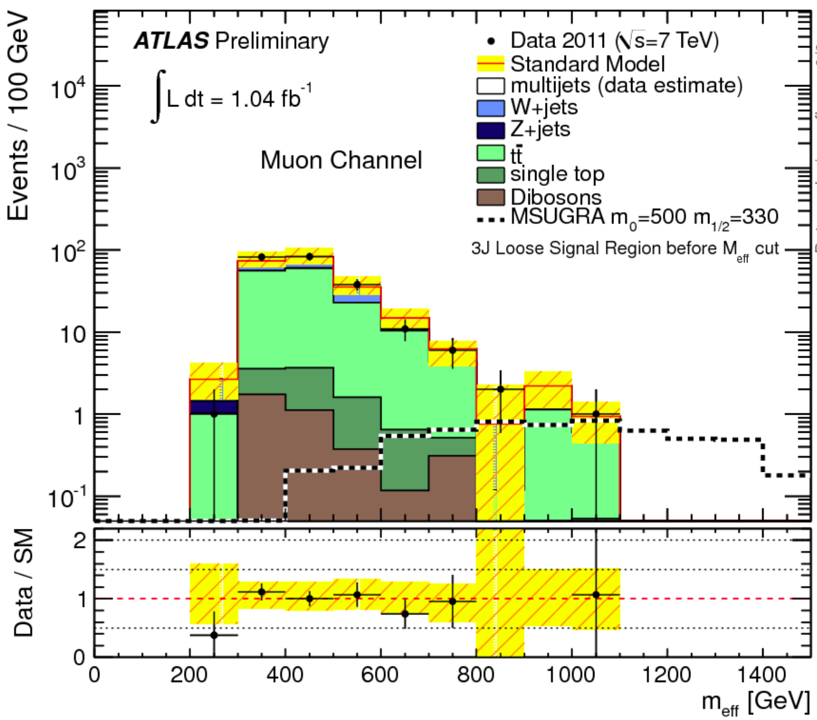


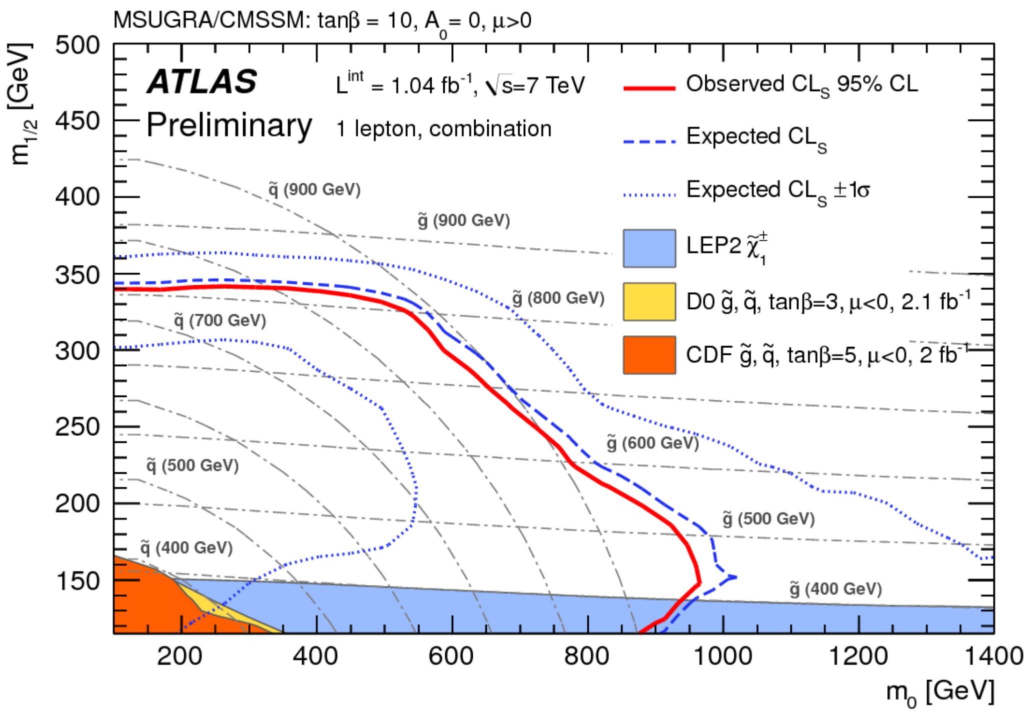


SUSY: 1 Lepton + jets + E_T^{miss}



- Event selection (4 signal regions)
  - Exactly one isolated high p_T lepton (from chagino,slepton, W/Z)
    - suppress QCD background, help in trigger
  - 3 or 4 jets
- Backgrounds
  - W+jets, multijets, top quarks (data driven estimation with support of MC)

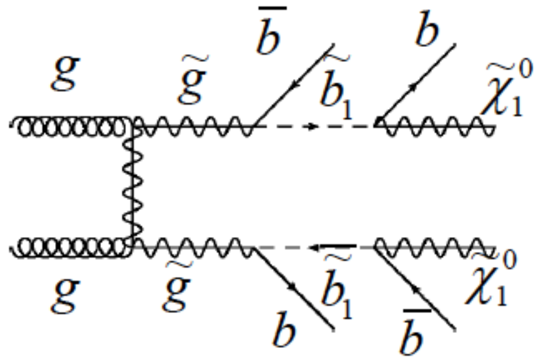




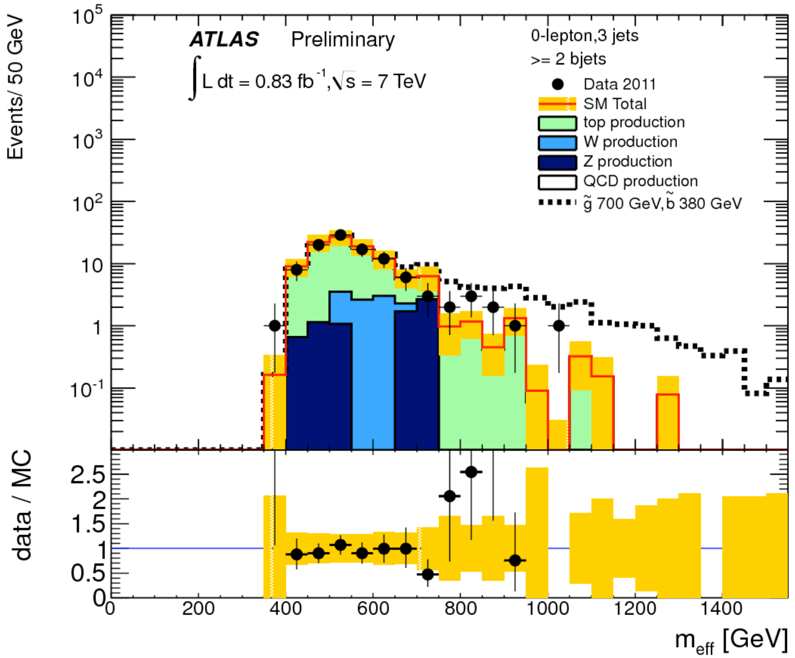
up to m_{SUSY}~875GeV is excluded, for m(squark)=m(gluino)

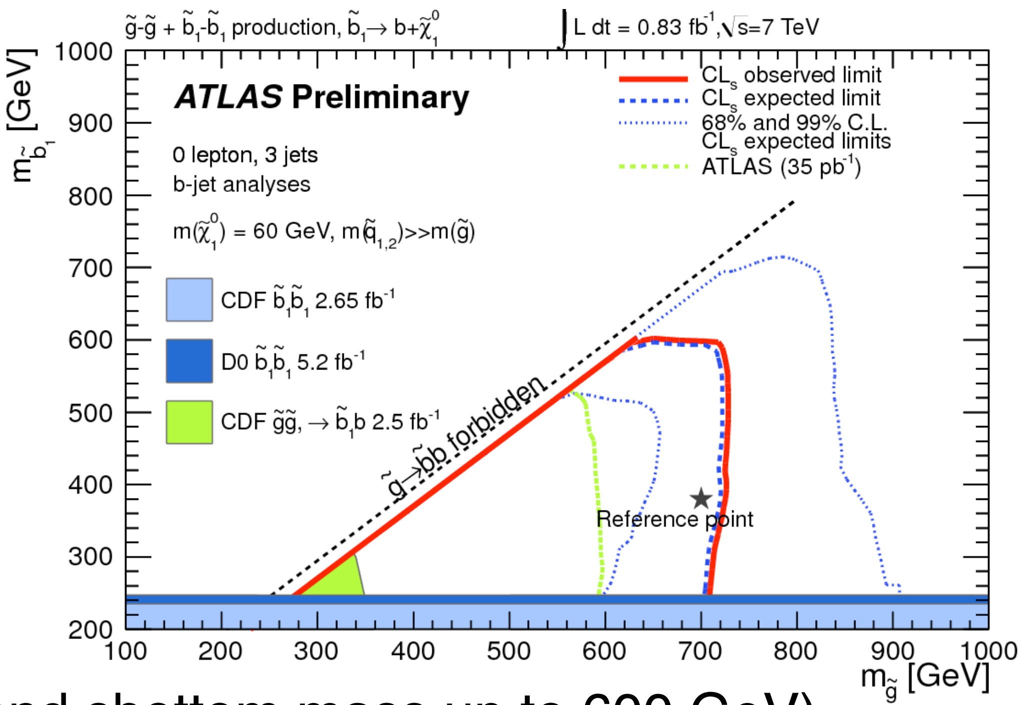
SUSY : b-jets + E_T^{miss}

- Event selections (4 signal regions)
  - 3 high pT jets
  - E_T^{miss} > 130 GeV
  - ≥ 1 b-jets or ≥ 2 b-jets
- Backgrounds
  - W/Z+jets, top quark (from MC), multijet (derived from data)



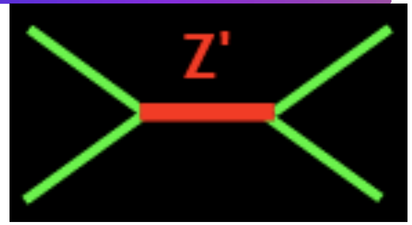
$\tilde{g} \rightarrow \tilde{b}b \rightarrow bb\tilde{\chi}_1^0$





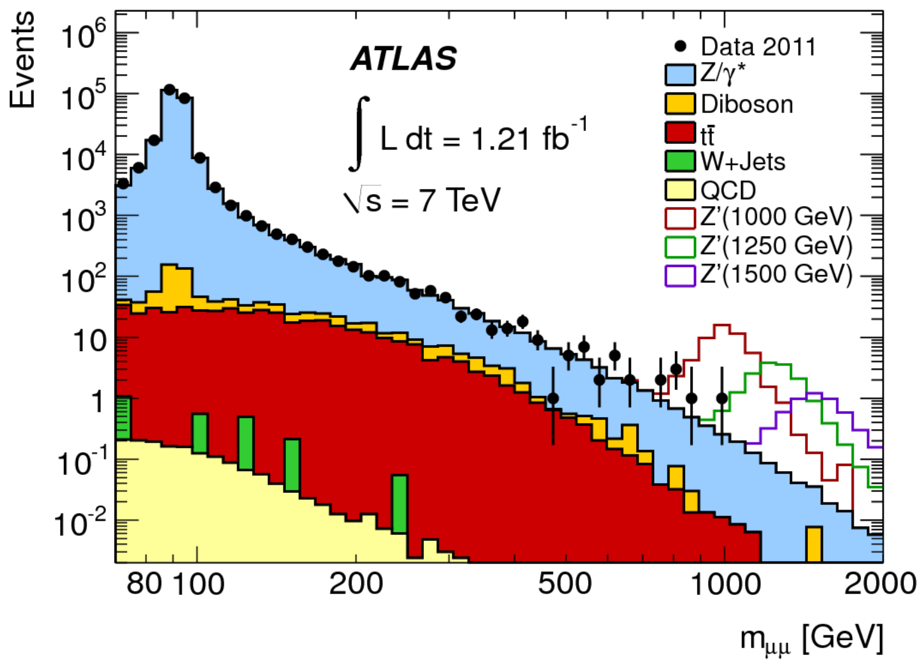
gluino mass below 720GeV (and sbottom mass up to 600 GeV) is excluded with 95% C.L.

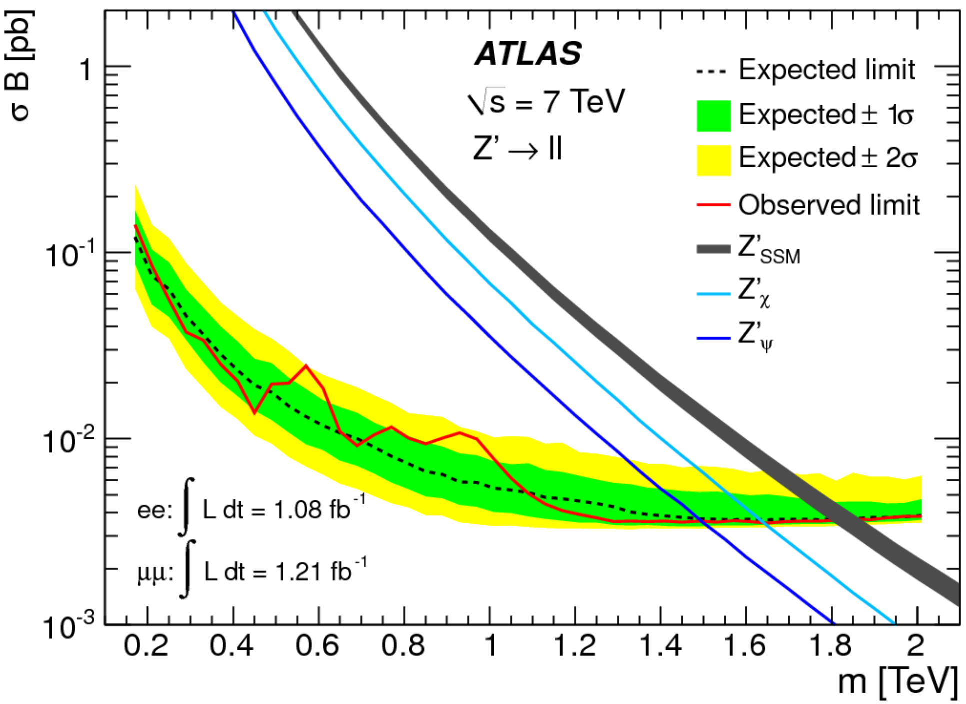
Heavy resonance search : dilepton



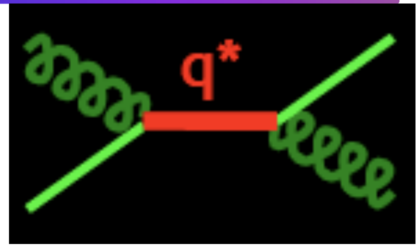
- Benchmark models for Z'
  - Sequential SM (i.e. same coupling to fermions as Z)
  - GUT-inspired heavy Z'
  - Randall-Sundrum Kaluza-Klein graviton excitation (G^*)
- Event selection
  - Isolated same flavor lepton pair
  - reconstruction of high pT of lepton is challenging

95 % CL. Mass Limits:
Z'_{SSM} 1.83 TeV
G^* 1.63 TeV



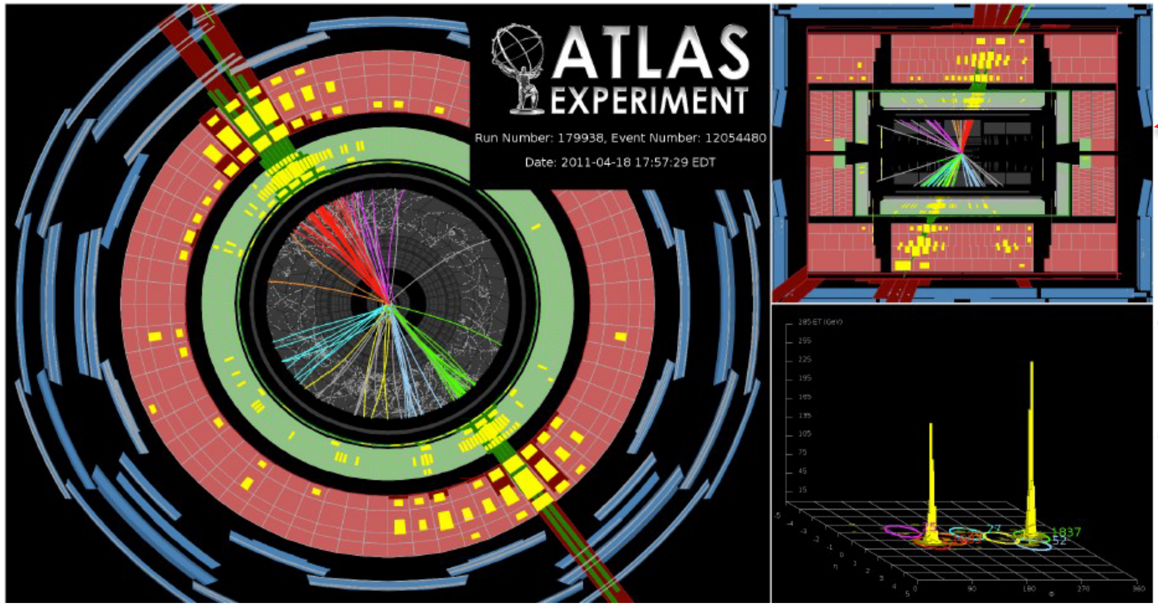


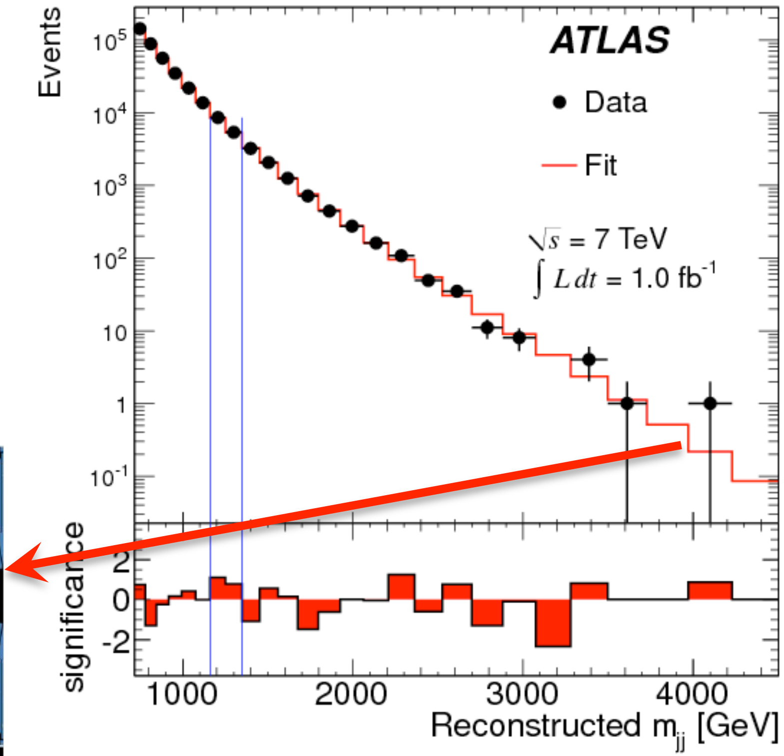
Heavy resonance search : Dijet



- Benchmark models
  - Exited quarks (q*)
  - axigluons
  - Color octet scalar
- Analysis
  - Look for the resonance above phenomenological fit of the m_{jj} data

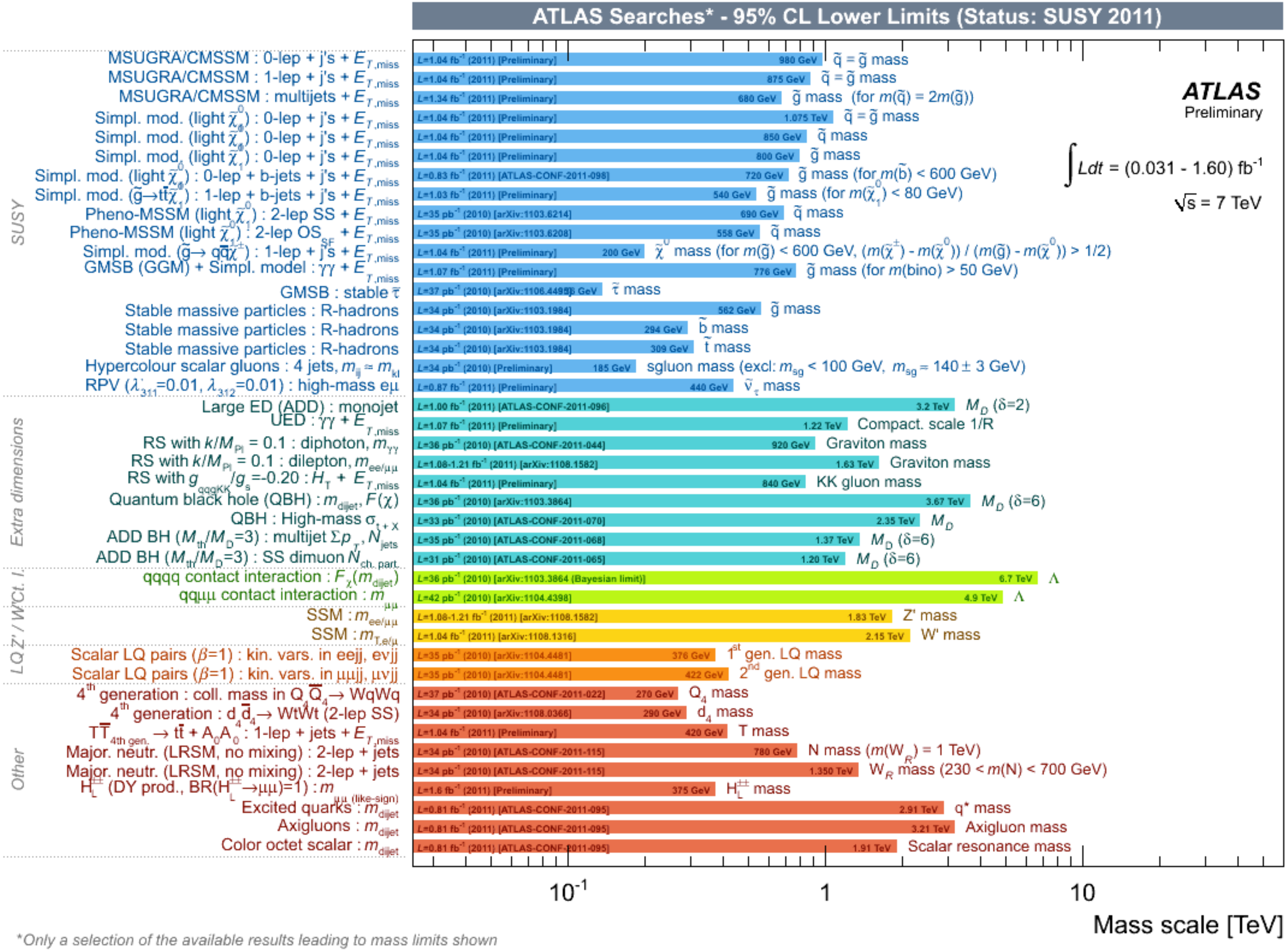
m(jet-jet) = 4 TeV   Missing E_T = 100 GeV





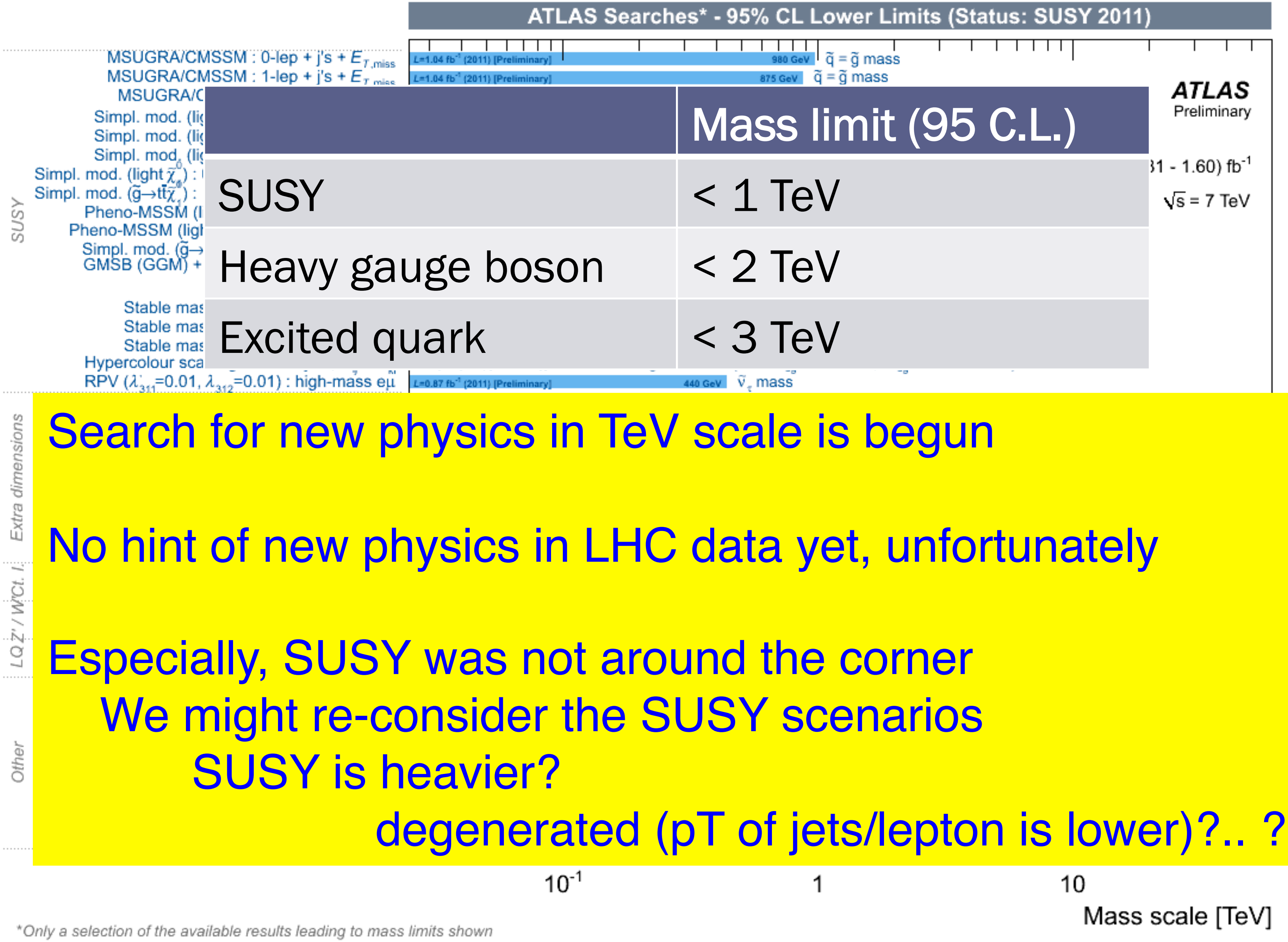
Model	95% CL Limits (TeV)	
	Expected	Observed
Excited Quark q^*	2.77	2.91
Axigluon	3.02	3.21
Color Octet Scalar	1.71	1.91

Summary of the current searches



*Only a selection of the available results leading to mass limits shown

Summary of the current searches



	Mass limit (95 C.L.)
SUSY	< 1 TeV
Heavy gauge boson	< 2 TeV
Excited quark	< 3 TeV

Search for new physics in TeV scale is begun

No hint of new physics in LHC data yet, unfortunately

Especially, SUSY was not around the corner

We might re-consider the SUSY scenarios

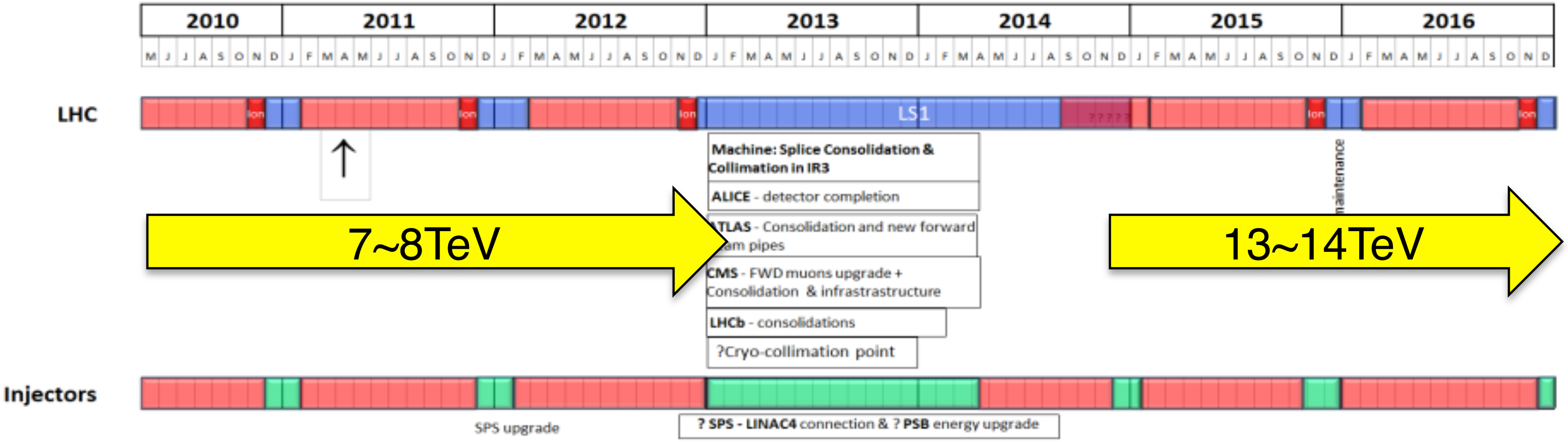
SUSY is heavier?

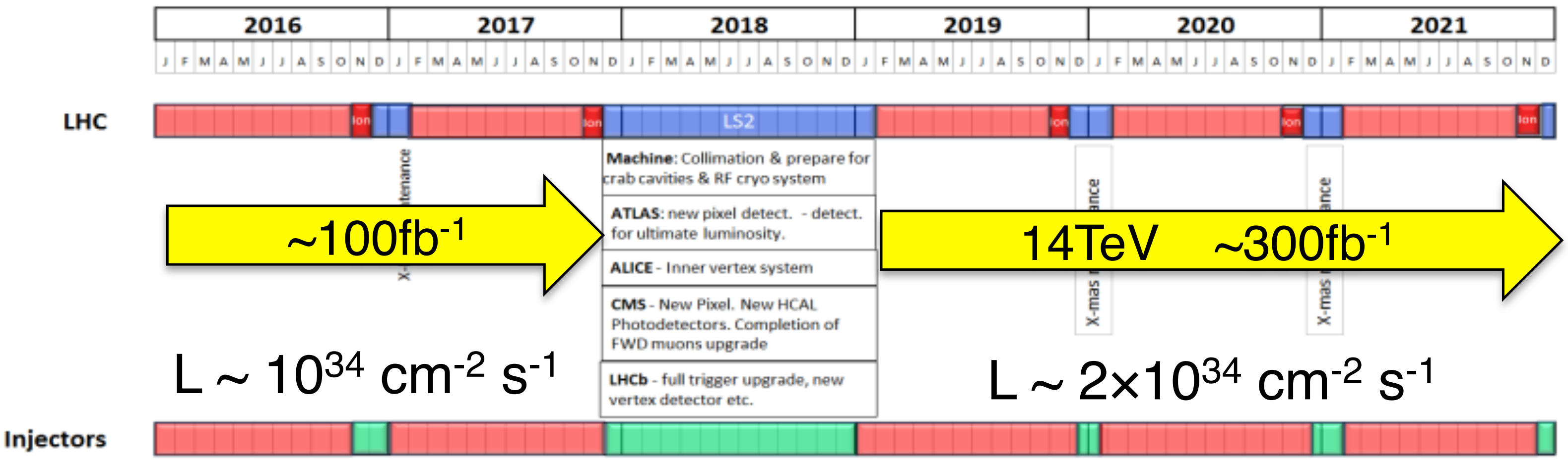
degenerated (pT of jets/lepton is lower)?.. ?

Future plan

10 years plan

Not approved





2022
LS3
Installation of the HL-LHC hardware. Preparation for HE-LHC

HL-LHC

peak luminosity $5\times10^{34} cm^{-2}s^{-1}$

longer lifetime

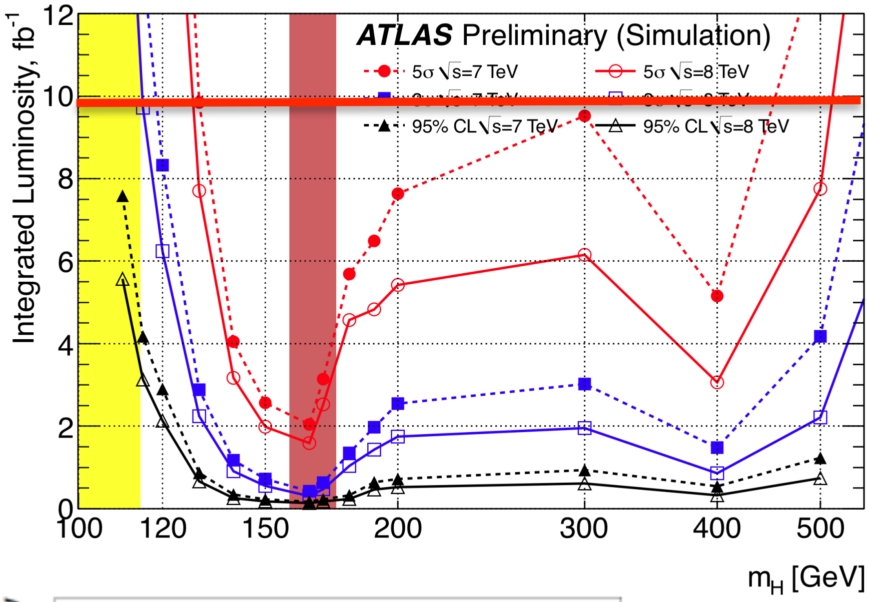
Goal:

$200\sim300 fb^{-1}$/year

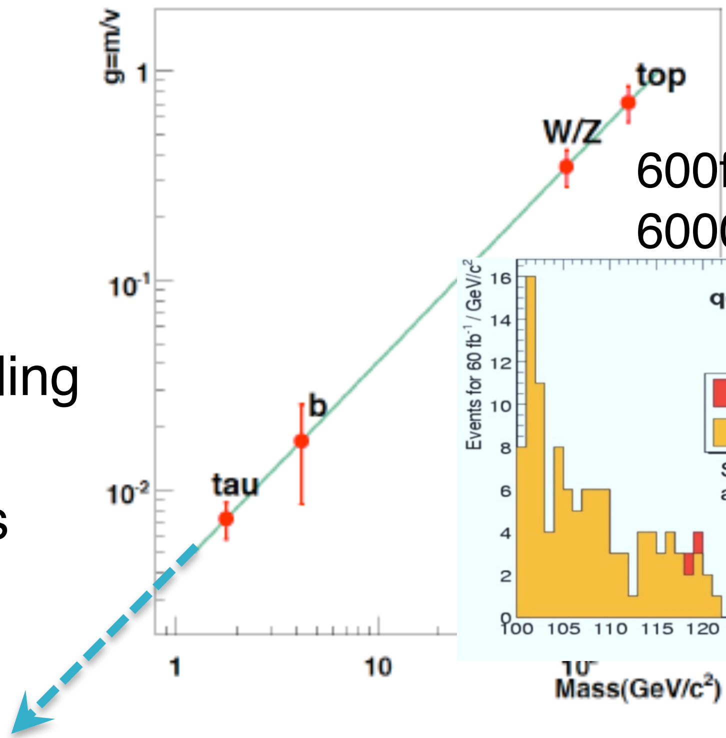
$3000 fb^{-1}$ in total??

Future Plans

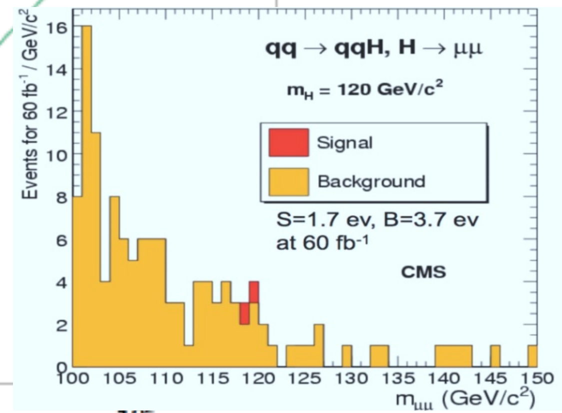
- by 2012
  - 3σ observation of Higgs up to 120 GeV will be achieved (only ATLAS)
  - SUSY ~ 1TeV



- From 2014 – 2021(√s=13~14TeV)
  - More searches for new physics
  - Higgs property measurements
    - Yukawa-coupling



600fb^{-1} → 3.5σ
6000fb^{-1} →9.5σ



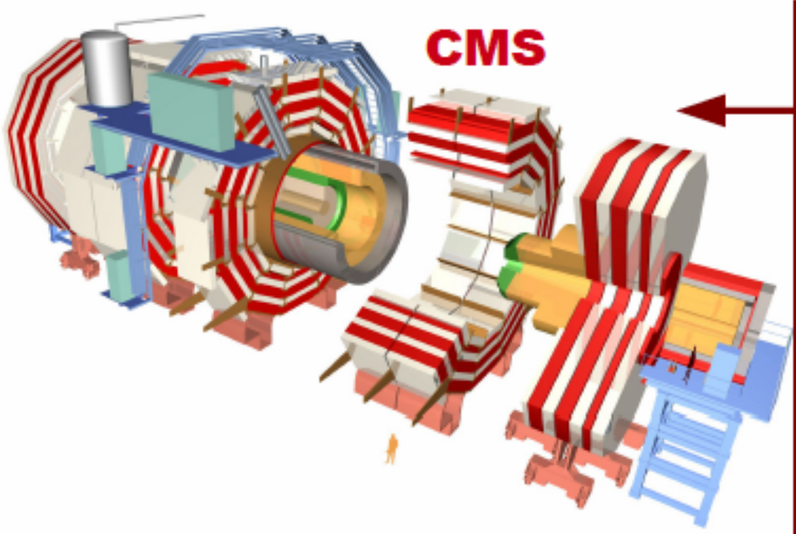
- HL-LHC (<3000fb^{-1})
  - Can add H→μμ for Yukawa coupling measurement?
  - New physics using high-x partons
    - advantage of p-p collider

Summary

- LHC is delivering data of p-p collision so well
- ATLAS has produced an impressive number of results
  - Most standard model process has been measured
  - High mass Higgs starts excluding
  - Large parameter space of the new physics starts excluding
- Unfortunately, new physics didn't seem to be around the corner
- We have many rooms to be explore
  - more 7 TeV or 8 TeV collision data until 2012
  - 13-14 TeV data from 2014 to 2012
  - HL-LHC will follow

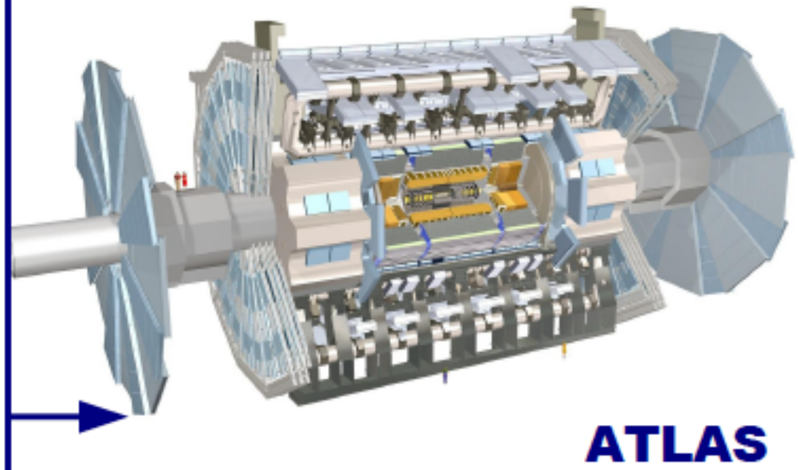
Backup slides

Detector performance



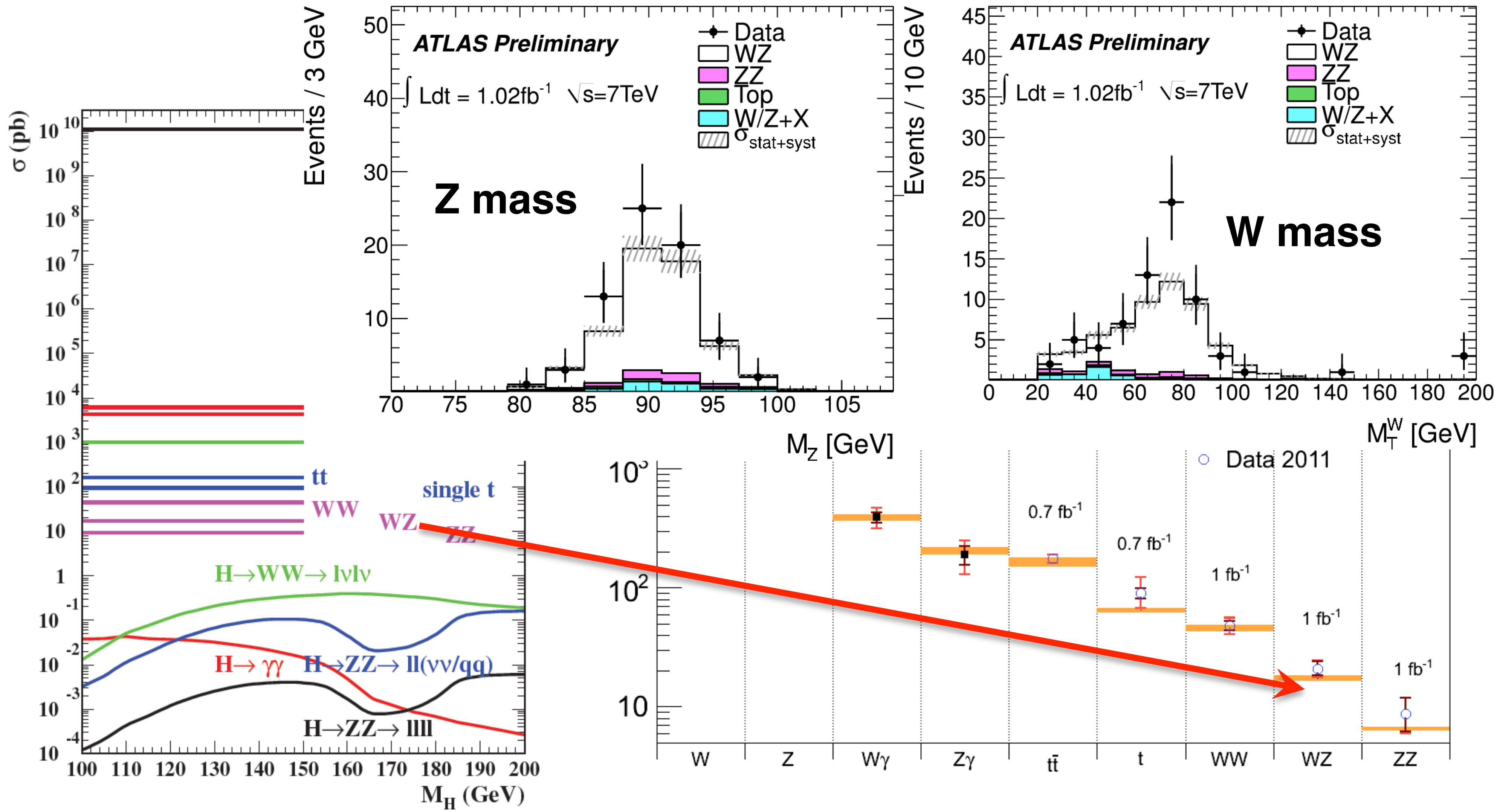
- 3.8T solenoid containing calorimeters
- Silicon tracker: $\sigma(p_T)/p_T \sim 15\%$ at 1TeV
- EM cal: homogeneous Lead-Tungstate crystal, $\sigma_E/E \sim 3\%/\sqrt{E[GeV]} \oplus 0.5\%$
- HAD cal: Brass-scint., $\geq 7\lambda_0$ $\sigma_E/E \sim 100\%/\sqrt{E[GeV]} \oplus 5\%$
- Iron return yoke muon spectrometer

- 2T solenoid inside calorimeters
- Silicon+TRT tracker + electron ID
- EM cal: Longitudinally segmented Lead-Ar: $\sigma_E/E \sim 10\%/\sqrt{E[GeV]} \oplus 0.7\%$
- HAD cal: Fe-scint + Cu-Ar, $\geq 11\lambda_0$ $\sigma_E/E \sim 50\%/\sqrt{E[GeV]} \oplus 3\%$
- Air-toroid muon sp.: $\int \sqrt{B}.dl = 1$ to 7 T.m



diboson production : pp→WZ

Most standard model processes have been already measured.



WH→lvbb / ZH→llbb : L=1.04 fb^{-1}

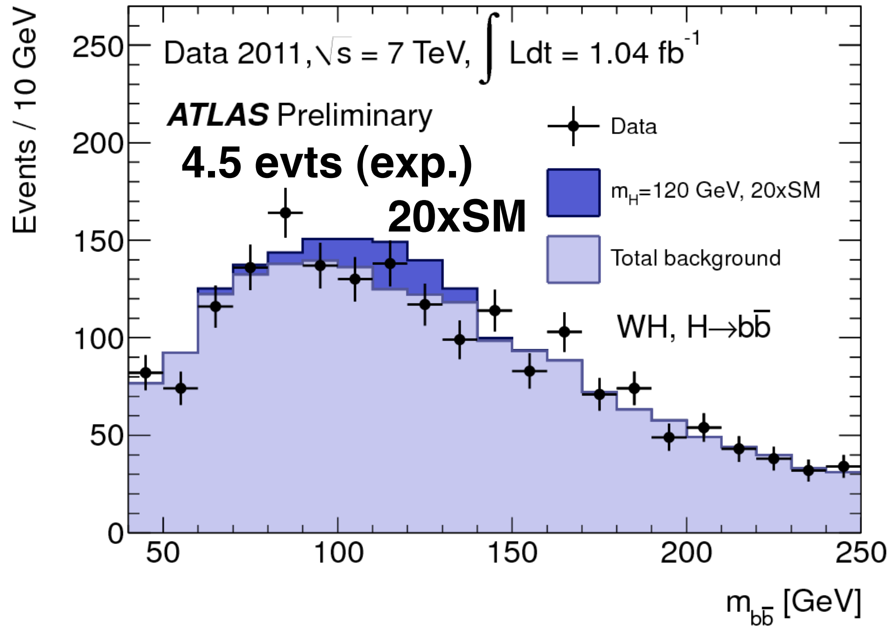
- Event selection
  - W→lν or Z→l$^+$l$^-$
  - exactly two b-jets with p_T>25GeV
- Backgrounds
  - W+jets, Z+jets, top quark, multijet

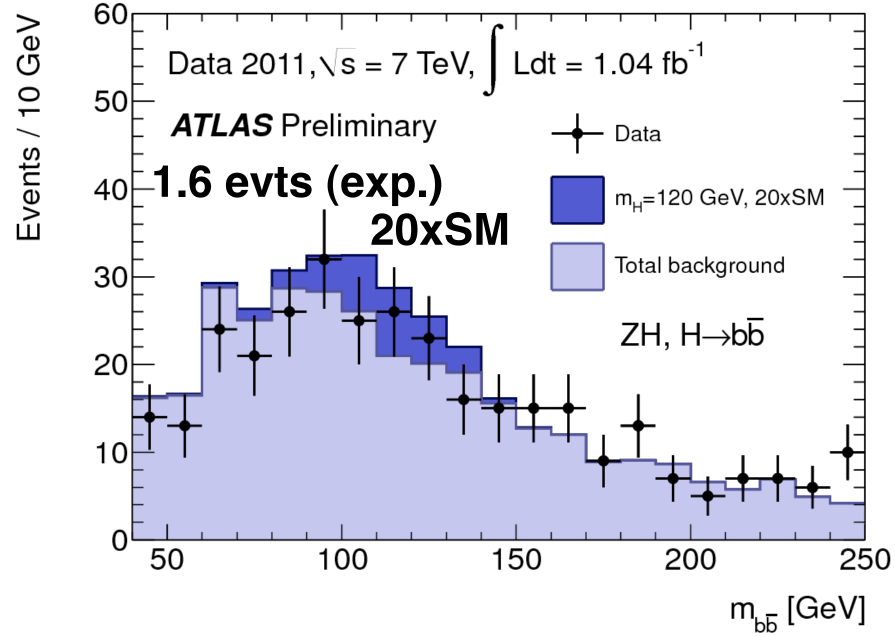
WH

Source	expected events		(stat.)		(sys.)
Z+jets	54.4	±	3.9	±	12.3
W+jets	466.7	±	1.4	±	66.5
Top-quark	1141.8	±	8.8	±	78.0
Multijet	193.0	±	9.4	±	96.5
WZ	16.1	±	2.2	±	3.4
WW	4.8	±	1.1	±	1.4
Total background	1876.8	±	13.7	±	147.2
Data	1888				

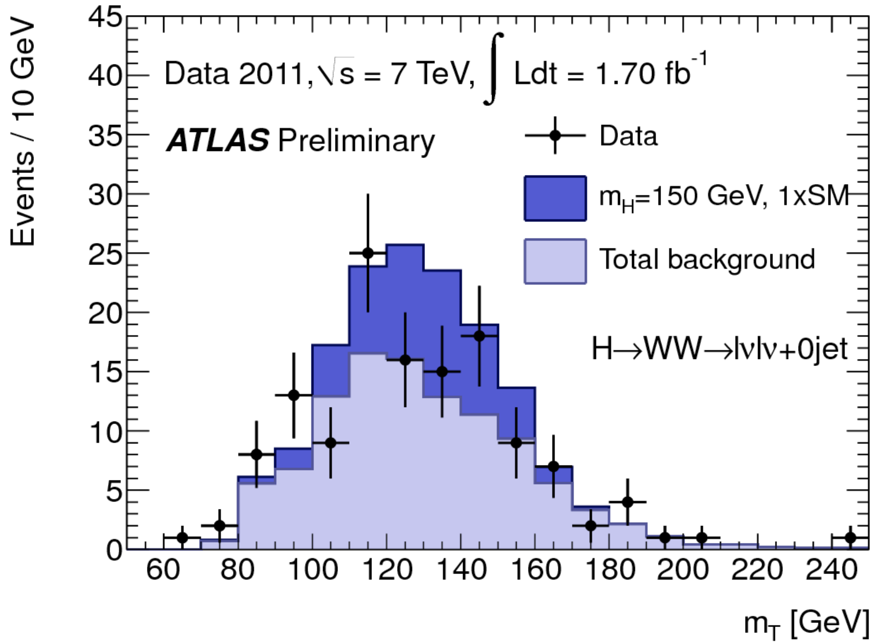
ZH

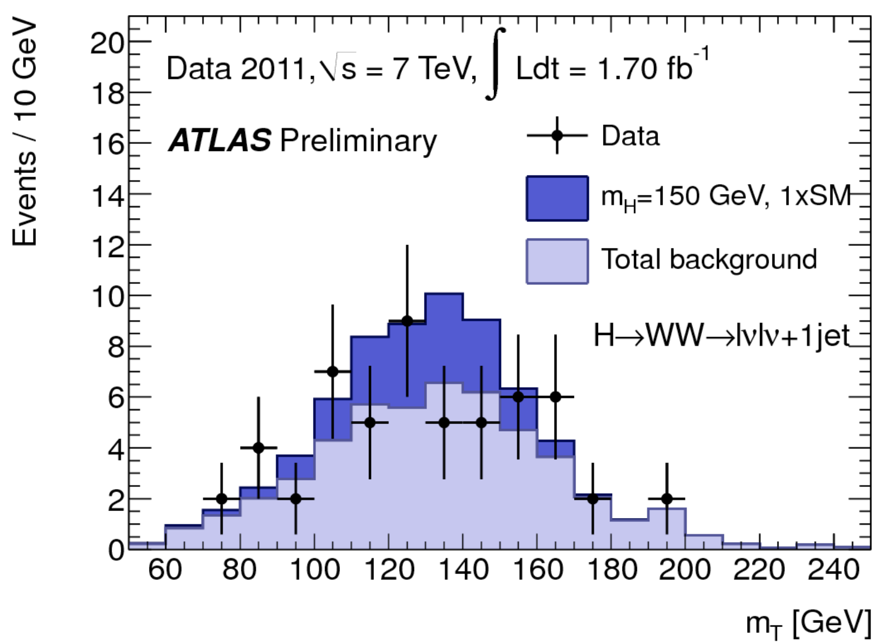
Source	expected events		(stat.)		(sys.)
Z+jets	261.0	±	7.8	±	24.6
Top-quark	52.0	±	1.3	±	10.6
Multijet	1.4	±	0.4	±	1.4
ZZ	9.2	±	1.1	±	2.3
WZ	1.1	±	0.3	±	0.3
Total background	324.7	±	8.0	±	27.9
Data	329				





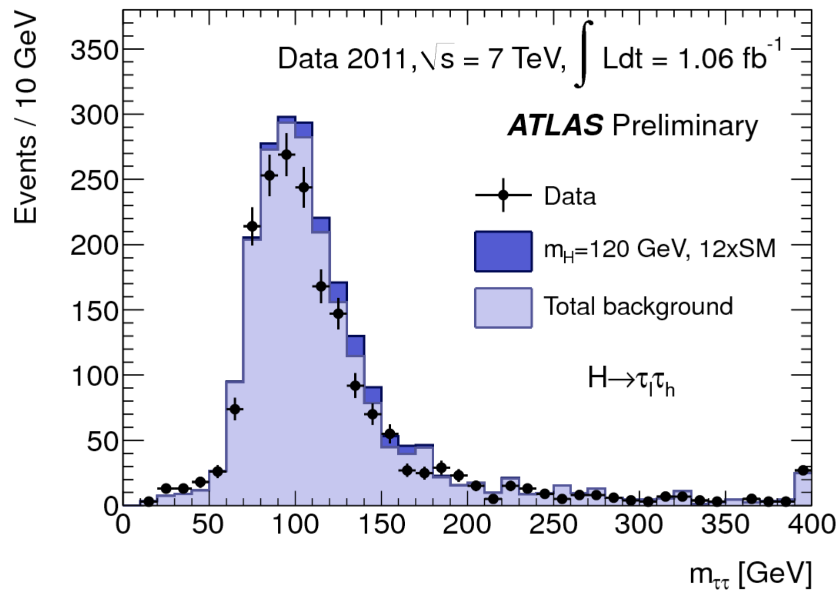
H→WW (m_H=120GeV)

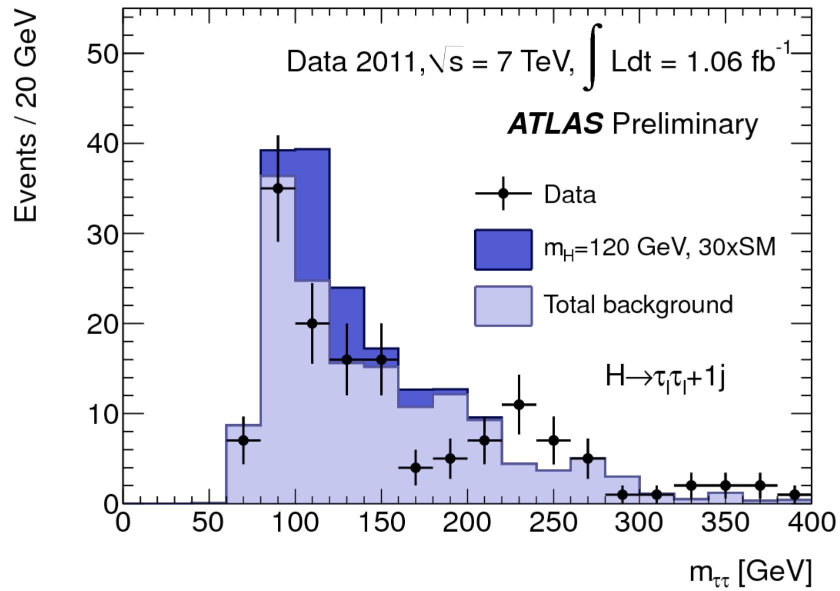




H→ τ τ : L=1.06 fb^{-1}

- H→ τ τ →l τ_{had} 3ν (lepton-hadron)
  - ➤ Event selections
    - one lepton from
    - 1 or 3 tracks in a calorimeter jet
    - E_T^{miss} > 20GeV
    - MT(l, E_T^{miss})< 30 GeV





Yields (Higgs analysis)

	$H \to \tau^+\tau^-$		$H \to \gamma\gamma$	$H \to b\bar{b}$	$H \to WW^{(*)}$		$H \to ZZ^{(*)}$		
	$\tau_\ell \tau_{had}$	$\tau_\ell \tau_\ell + jet$			$\ell\nu\ell\nu$ 0-jet	$\ell\nu\ell\nu$ 1-jet	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
m_H=120 GeV									
s	8.0	0.8	15.9	5.5	3.9	1.4	0.2	-	-
b	1218	47.1	723	992	36.5	12.9	0.6	-	-
N_{obs}	1072	46	787	1131	47	14	0	-	-
m_H=150 GeV									
s	-	-	6.9	-	33.8	11.9	2.0	-	-
b	-	-	416	-	53.4	23.4	0.6	-	-
N_{obs}	-	-	405	-	70	23	1	-	-
m_H=200 GeV									
s	-	-	-	-	13.9	6.5	5.2	4.5	31.4
b	-	-	-	-	39.6	25.1	5.7	62.0	7433
N_{obs}	-	-	-	-	36	28	5	54	7225
m_H=300 GeV									
s	-	-	-	-	11.3	7.1	3.3	9.1	6.8
b	-	-	-	-	120.6	76.3	4.5	42.3	195
N_{obs}	-	-	-	-	130	78	4	38	200
m_H=400 GeV									
s	-	-	-	-	-	-	2.3	9.0	9.8
b	-	-	-	-	-	-	4.1	33.1	207
N_{obs}	-	-	-	-	-	-	2	45	239

Systematic uncertainties (Higgs)

	$H \to \tau^+\tau^-$		$H \to \gamma\gamma$	$H \to b\bar{b}$	$H \to WW^{(*)}$	$H \to ZZ^{(*)}$		
	$\tau_\ell\tau_{had}$	$\tau_\ell\tau_\ell + jet$			$\ell\nu\ell\nu$	$\ell\ell\ell\ell$	$\ell\ell\nu\nu$	$\ell\ell qq$
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	-	$^{+4.3}_{-4.4}$	-

ATLAS Japan

list of models × signatures

- Many extensions of the SM have been developed over the past decades:
- Supersymmetry
- Extra-Dimensions
- Technicolor(s)
- Little Higgs
- No Higgs
- GUT
- Hidden Valley
- Leptoquarks
- Compositeness
- 4th generation (t', b')
- LRSM, heavy neutrino
- etc...

(for illustration only)

- 1 jet + MET
- jets + MET
- 1 lepton + MET
- Same-sign di-lepton
- Dilepton resonance
- Diphoton resonance
- Diphoton + MET
- Multileptons
- Lepton-jet resonance
- Lepton-photon resonance
- Gamma-jet resonance
- Diboson resonance
- Z+MET
- W/Z+Gamma resonance
- Top-antitop resonance
- Slow-moving particles
- Long-lived particles
- Top-antitop production
- Lepton-Jets
- Microscopic blackholes
- Dijet resonance
- etc...

Experimentally, a signature standpoint makes a lot of sense:

- ✓ **practical**
- ✓ **less model-dependent**
- ✓ **important to cover every possible signature**

From LP2011 presented by Henri Bachacou

list of models × signatures

- Many extensions of the SM have been developed over the past decades:
- Supersymmetry
- Extra-Dimensions
- Technicolor(s)
- Little Higgs
- No Higgs
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- Hidden Valley
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- 1 jet + MET
- jets + MET
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- Diphoton + MET
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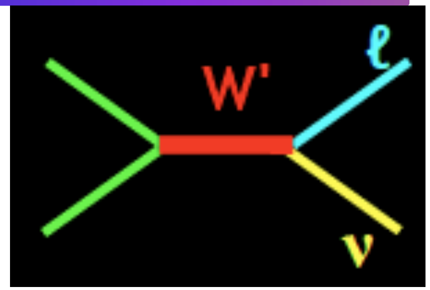
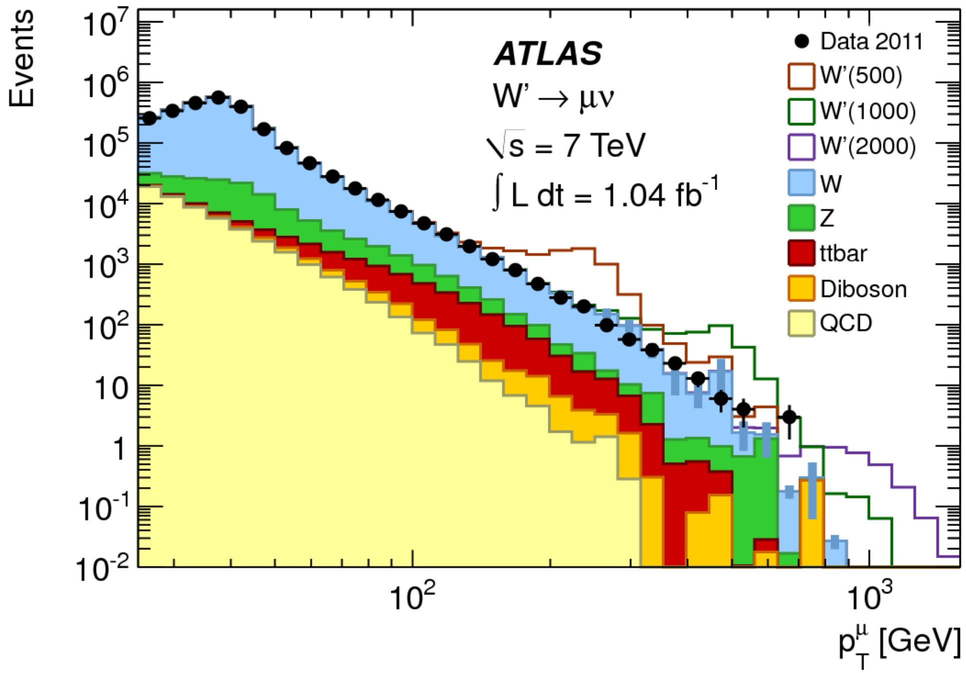
- etc...

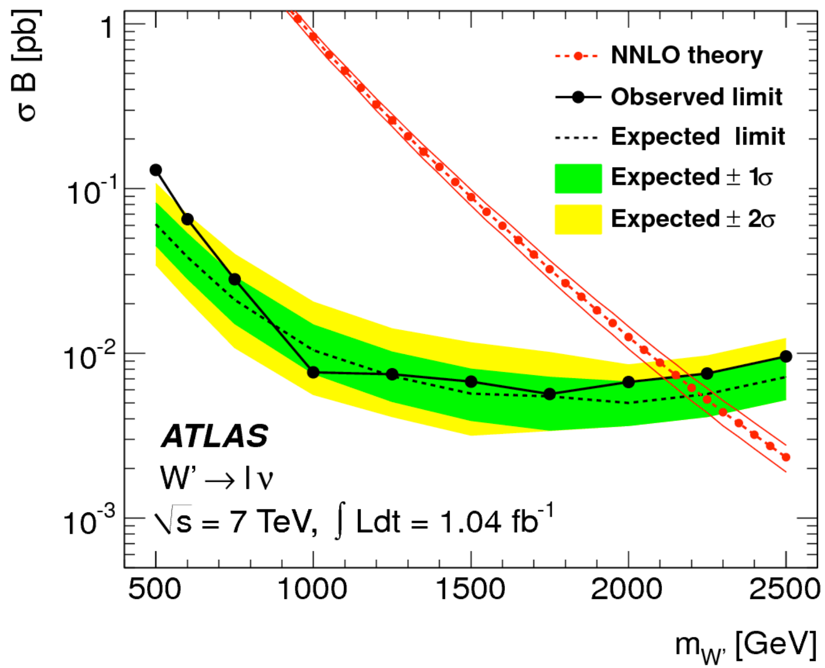
From LP2011 presented by Henri Bachacou

W' searches



- Benchmark models for Z'
  - Sequential SM (i.e. same coupling to fermions as W)
- Event selection
  - One Isolated lepton & large E_T^{miss}





Mass of W'_{SSM} up to 2.15 TeV is excluded at 95% C.L.

WW yields

Table 12: Numbers of expected events after all cuts for the signal (m_H = 110 – 170 GeV) and the total background in the $H + 0$ jet channel for an integrated luminosity of 1.7 fb^{-1}. The observed numbers of events are also shown. The nominal numbers correspond to the background estimations described in Sections 6 and 7. Also shown are the signal and background values resulting from the fit for two different scenarios, without any signal (signal strength $\mu = 0$) and with the signal present (signal strength $\mu = 1$).

		Nominal		Fit with $\mu = 0$		Fit with $\mu = 1$		
m_H [GeV]	Lepton Flavors	Signal	Total Bkg.	Signal	Total Bkg.	Signal	Total Bkg.	Observed
110	ee	0.043	3.2	0	3.1	0.046	3.1	0
	$e\mu$	0.41	12.1	0	11.8	0.44	11.6	17
	$\mu\mu$	0.26	9.5	0	9.3	0.27	9.2	12
115	ee	0.13	3.6	0	3.5	0.15	3.4	0
	$e\mu$	1.10	15.9	0	15.3	1.20	14.8	21
	$\mu\mu$	0.73	10.6	0	10.3	0.78	10.0	14
120	ee	0.39	4.6	0	4.6	0.43	4.5	4
	$e\mu$	2.1	18.3	0	18.3	2.3	17.3	22
	$\mu\mu$	1.42	13.4	0	13.6	1.55	13.0	21
125	ee	0.93	6.0	0	5.9	1.03	5.6	4
	$e\mu$	4.3	21.3	0	20.8	4.7	18.8	22
	$\mu\mu$	2.6	15.3	0	15.2	2.9	14.0	23
130	ee	1.48	7.1	0	7.0	1.63	6.4	5
	$e\mu$	6.1	23.9	0	23.7	6.8	20.4	24
	$\mu\mu$	4.4	16.4	0	16.6	4.8	14.5	26
135	ee	2.3	7.6	0	7.4	2.6	6.4	7
	$e\mu$	8.8	25.0	0	24.2	9.8	19.5	23
	$\mu\mu$	6.2	17.3	0	17.2	6.9	13.9	26
140	ee	3.1	8.1	0	8.2	3.4	6.6	8
	$e\mu$	12.1	26.0	0	26.5	13.2	20.0	26
	$\mu\mu$	8.4	17.3	0	18.0	9.2	13.4	28
145	ee	4.1	8.4	0	8.6	4.4	6.7	8
	$e\mu$	14.5	27.3	0	28.2	15.4	20.5	27
	$\mu\mu$	9.4	17.3	0	18.3	10.0	13.1	30
150	ee	5.2	8.4	0	8.9	5.3	6.5	9
	$e\mu$	17.5	27.7	0	29.8	18.1	20.7	32
	$\mu\mu$	11.1	17.3	0	19.0	11.5	12.8	29
155	ee	7.0	8.2	0	8.1	7.0	4.1	8
	$e\mu$	21.2	26.9	0	26.5	21.2	13.1	27
	$\mu\mu$	13.3	17.3	0	17.3	13.7	7.2	24
160	ee	8.4	7.9	0	8.0	7.8	3.4	6
	$e\mu$	26.4	26.1	0	26.6	24.7	10.2	30
	$\mu\mu$	17.4	15.6	0	16.0	16.9	4.2	22
165	ee	9.1	7.3	0	7.4	8.2	2.4	6
	$e\mu$	27.4	24.6	0	25.0	25.4	8.1	29
	$\mu\mu$	17.2	14.8	0	15.1	15.9	3.8	20
170	ee	10.5	12.6	0	13.7	11.1	6.5	13
	$e\mu$	31.4	40.1	0	44.3	33.2	20.5	52
	$\mu\mu$	19.1	24.8	0	27.7	20.6	10.4	33

WW yields

Table 13: Numbers of expected events after all cuts for the signal (m_H = 175 – 300 GeV) and the total background in the $H + 0$ jet channel for an integrated luminosity of 1.7 fb^{-1}. The observed numbers of events are also shown. The nominal numbers correspond to the background estimations described in Sections 6 and 7. Also shown are the signal and background values resulting from the fit for two different scenarios, without any signal (signal strength $\mu = 0$) and with the signal present (signal strength $\mu = 1$).

		Nominal		Fit with $\mu = 0$		Fit with $\mu = 1$		
m_H [GeV]	Lepton Flavors	Signal	Total Bkg.	Signal	Total Bkg.	Signal	Total Bkg.	Observed
175	ee	8.8	11.5	0	11.9	9.3	5.7	12
	$e\mu$	25.5	37.0	0	38.6	27.2	18.3	44
	$\mu\mu$	16.0	23.5	0	24.6	17.3	9.7	28
180	ee	6.9	10.4	0	10.6	7.4	5.7	10
	$e\mu$	20.7	33.6	0	34.8	22.5	18.3	41
	$\mu\mu$	12.8	21.6	0	22.3	14.1	10.6	25
185	ee	5.1	9.1	0	8.9	5.7	5.0	10
	$e\mu$	15.2	29.9	0	29.8	16.9	16.7	37
	$\mu\mu$	10.1	19.5	0	19.0	11.3	9.9	17
190	ee	3.9	8.0	0	7.6	4.4	4.7	10
	$e\mu$	11.3	26.3	0	25.5	12.8	15.8	33
	$\mu\mu$	7.5	17.3	0	16.4	8.5	9.3	12
195	ee	3.0	6.9	0	6.4	3.4	4.4	8
	$e\mu$	8.9	23.2	0	21.8	10.0	15.2	27
	$\mu\mu$	5.7	15.2	0	14.1	6.4	9.4	12
200	ee	2.4	5.8	0	5.0	2.7	3.2	7
	$e\mu$	7.0	20.3	0	17.5	8.0	11.5	20
	$\mu\mu$	4.5	13.5	0	11.4	5.2	6.8	9
220	ee	3.3	25.2	0	27.5	3.4	24.9	38
	$e\mu$	15.0	144.3	0	153.0	15.4	139.4	138
	$\mu\mu$	5.3	49.4	0	53.1	5.4	48.6	52
240	ee	2.5	24.8	0	27.8	2.6	25.6	45
	$e\mu$	13.1	130.2	0	141.0	13.4	130.5	127
	$\mu\mu$	4.7	47.4	0	51.7	4.8	48.0	45
260	ee	2.5	23.2	0	24.7	2.6	22.9	36
	$e\mu$	10.3	112.1	0	116.2	10.8	107.9	102
	$\mu\mu$	4.1	43.3	0	45.6	4.3	42.4	43
280	ee	2.2	21.0	0	22.7	2.3	21.4	32
	$e\mu$	8.5	92.8	0	98.4	8.6	92.4	86
	$\mu\mu$	3.2	37.3	0	40.2	3.3	37.7	39
300	ee	2.1	17.1	0	19.1	2.1	17.9	28
	$e\mu$	6.6	71.1	0	77.6	6.6	73.0	69
	$\mu\mu$	2.6	32.4	0	35.7	2.6	33.6	33

WW yields

Table 14: Numbers of expected events after all cuts for the signal (m_H = 110 – 170 GeV) and the total background in the $H + 1$ jet channel for an integrated luminosity of 1.7 fb^{-1}. The observed numbers of events are also shown. The nominal numbers correspond to the background estimations described in Sections 6 and 7. Also shown are the signal and background values resulting from the fit for two different scenarios, without any signal (signal strength $\mu = 0$) and with the signal present (signal strength $\mu = 1$).

		Nominal		Fit with $\mu = 0$		Fit with $\mu = 1$		
m_H [GeV]	Lepton Flavors	Signal	Total Bkg.	Signal	Total Bkg.	Signal	Total Bkg.	Observed
	ee	0.020	0.87	0	0.88	0.019	0.87	2
110	$e\mu$	0.18	3.9	0	3.9	0.18	3.8	3
	$\mu\mu$	0.090	4.3	0	4.4	0.090	4.4	7
	ee	0.055	1.10	0	1.07	0.051	1.04	2
115	$e\mu$	0.43	5.0	0	4.7	0.42	4.5	3
	$\mu\mu$	0.21	4.7	0	4.7	0.20	4.6	7
	ee	0.14	1.23	0	1.25	0.13	1.19	3
120	$e\mu$	0.78	6.3	0	6.2	0.75	5.9	3
	$\mu\mu$	0.44	5.4	0	5.5	0.41	5.3	8
	ee	0.27	1.42	0	1.48	0.27	1.38	3
125	$e\mu$	1.39	7.2	0	7.4	1.41	6.8	6
	$\mu\mu$	0.82	6.5	0	6.7	0.84	6.4	10
	ee	0.40	1.57	0	1.67	0.38	1.45	3
130	$e\mu$	2.4	8.7	0	9.1	2.4	8.2	8
	$\mu\mu$	1.35	6.2	0	6.6	1.33	6.1	10
	ee	0.67	2.2	0	2.3	0.65	2.2	4
135	$e\mu$	3.2	9.8	0	10.2	3.1	9.0	9
	$\mu\mu$	1.90	6.5	0	6.9	1.85	6.3	11
	ee	1.01	2.4	0	2.6	0.79	2.3	3
140	$e\mu$	4.4	11.4	0	11.8	3.6	10.6	10
	$\mu\mu$	2.5	6.8	0	7.1	2.0	6.4	11
	ee	1.38	2.5	0	2.6	0.94	2.2	4
145	$e\mu$	5.3	12.5	0	12.6	3.6	11.7	10
	$\mu\mu$	3.0	7.7	0	7.9	2.0	7.2	9
	ee	1.68	2.8	0	2.9	0.99	2.5	5
150	$e\mu$	6.3	12.9	0	13.0	3.8	12.1	11
	$\mu\mu$	3.9	7.7	0	7.8	2.3	7.3	7
	ee	2.2	3.1	0	3.2	1.26	2.7	6
155	$e\mu$	8.3	12.5	0	12.9	5.0	11.1	12
	$\mu\mu$	4.8	7.6	0	7.8	2.8	6.9	7
	ee	3.4	3.1	0	3.2	1.67	2.5	5
160	$e\mu$	11.0	12.5	0	12.9	5.7	10.9	13
	$\mu\mu$	6.3	7.6	0	7.9	3.1	6.7	7
	ee	3.4	3.3	0	3.3	1.50	2.8	5
165	$e\mu$	11.7	12.5	0	12.7	5.3	10.8	13
	$\mu\mu$	6.7	7.6	0	7.6	3.1	6.7	5
	ee	3.9	6.5	0	6.6	1.83	6.0	7
170	$e\mu$	12.9	19.8	0	20.2	6.6	18.4	20
	$\mu\mu$	7.8	12.4	0	12.8	3.8	11.0	13

WW yields

Table 15: Numbers of expected events after all cuts for the signal (m_H = 175 – 300 GeV) and the total background in the H + 1 jet channel for an integrated luminosity of 1.7 fb^{-1}. The observed numbers of events are also shown. The nominal numbers correspond to the background estimations described in Sections 6 and 7. Also shown are the signal and background values resulting from the fit for two different scenarios, without any signal (signal strength $\mu = 0$) and with the signal present (signal strength $\mu = 1$).

		Nominal		Fit with $\mu = 0$		Fit with $\mu = 1$		
m_H [GeV]	Lepton Flavors	Signal	Total Bkg.	Signal	Total Bkg.	Signal	Total Bkg.	Observed
175	ee	3.4	6.3	0	6.3	1.63	5.8	4
	$e\mu$	11.7	18.7	0	18.6	5.6	16.9	18
	$\mu\mu$	6.9	12.4	0	12.4	3.3	10.9	13
180	ee	2.7	4.9	0	4.8	1.51	4.4	3
	$e\mu$	9.6	17.6	0	17.5	5.2	16.0	16
	$\mu\mu$	5.7	11.9	0	12.0	3.0	10.5	14
185	ee	2.1	4.1	0	4.1	1.19	3.8	3
	$e\mu$	7.4	16.5	0	16.3	4.3	15.0	15
	$\mu\mu$	4.1	11.1	0	11.0	2.3	9.8	11
190	ee	1.76	3.9	0	4.0	1.24	3.9	3
	$e\mu$	5.3	15.2	0	15.5	3.7	14.2	16
	$\mu\mu$	3.3	10.3	0	10.5	2.2	9.7	11
195	ee	1.20	3.4	0	3.7	1.05	3.5	2
	$e\mu$	4.1	14.8	0	16.4	3.5	15.5	19
	$\mu\mu$	2.8	8.9	0	9.5	2.4	8.7	12
200	ee	0.98	2.8	0	2.9	0.80	2.7	1
	$e\mu$	3.3	14.1	0	15.8	2.7	15.0	17
	$\mu\mu$	2.2	8.2	0	8.7	1.68	8.1	10
220	ee	1.53	13.3	0	13.8	1.65	12.8	12
	$e\mu$	8.5	76.6	0	80.2	9.2	72.9	79
	$\mu\mu$	2.6	24.4	0	26.7	2.9	23.9	35
240	ee	1.33	13.4	0	14.0	1.37	13.1	16
	$e\mu$	7.7	73.0	0	75.4	7.9	70.0	72
	$\mu\mu$	2.3	24.8	0	26.6	2.4	24.4	33
260	ee	1.33	12.3	0	13.4	1.49	12.4	19
	$e\mu$	6.3	66.5	0	71.2	7.0	66.5	67
	$\mu\mu$	2.3	23.3	0	25.5	2.6	23.5	31
280	ee	1.22	11.2	0	11.5	1.20	10.7	20
	$e\mu$	5.1	56.8	0	55.2	5.0	52.2	45
	$\mu\mu$	1.97	22.2	0	22.4	1.95	21.0	26
300	ee	1.07	9.6	0	9.9	1.09	9.3	19
	$e\mu$	4.3	47.8	0	46.6	4.4	44.0	38
	$\mu\mu$	1.76	18.9	0	19.1	1.79	17.9	21