Standard Model Higgs searches with ATLAS

Yaquan Fang
University of Wisconsin, Madison

On behalf of the ATLAS collaboration
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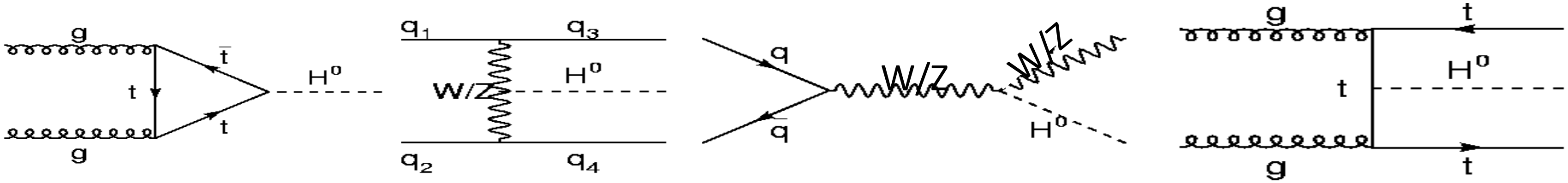
Introduction

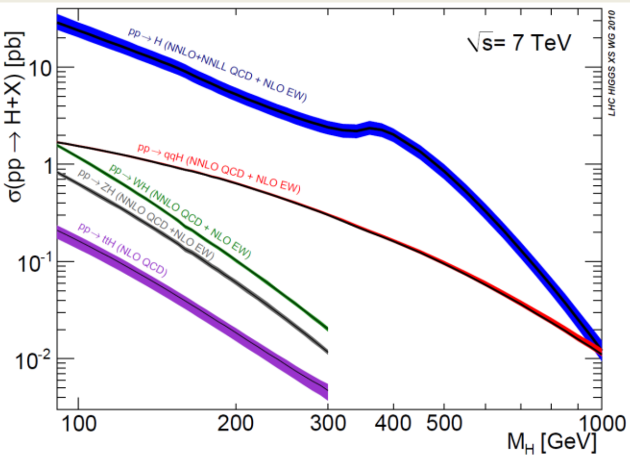
- LHC and ATLAS have successfully operated in 2010 and continue in 2011 and 2012.
- The recorded data by ATLAS detector : 45 pb^{-1} in 2010; 267 pb^{-1} until May 4^{th}, 2011.
- In this talk, we will address Higgs search with 2010 data.
  - $H \rightarrow \gamma\gamma$
  - $H \rightarrow WW \rightarrow l\nu l\nu / l\nu qq$
  - $H \rightarrow ZZ \rightarrow ll\nu\nu / llqq / 4l$
  - Is it possible that we exclude some standard model Higgs at early data?

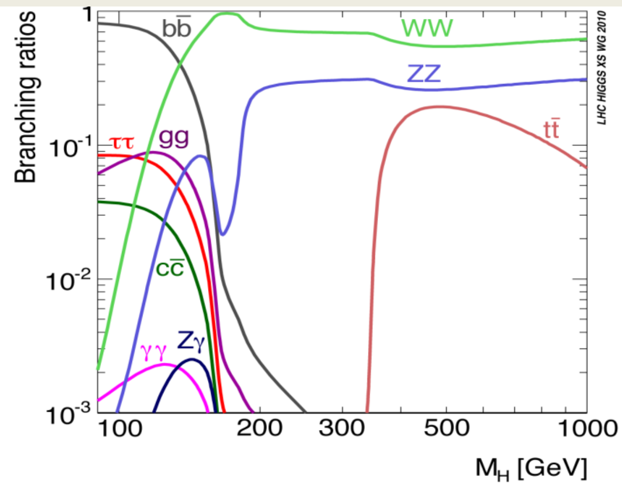
    Or what is the prospects for the exclusion/discovery in future?

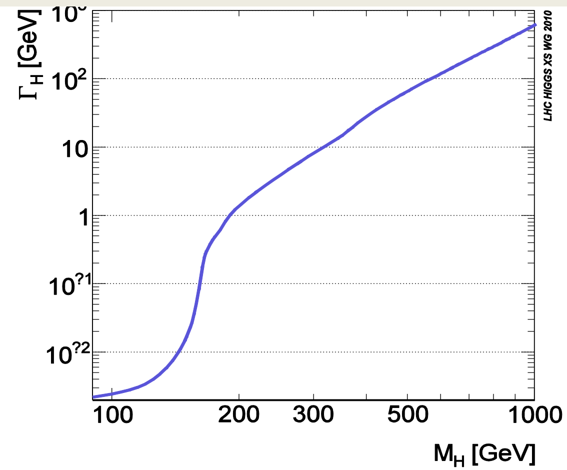
SM Higgs Productions and decays



arXiv:1101.0593 : *"Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables"*
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections







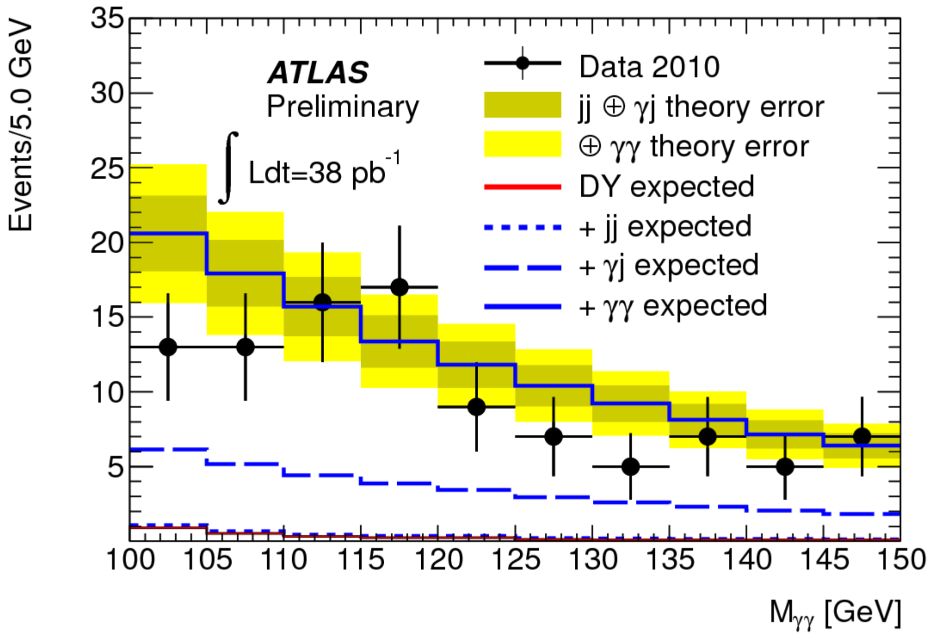
- The dominant production is gg Fusion: an order of magnitude higher than the sum of the other processes.
- VBF channel can be explored by tagging 2 forward jets and central jet veto to suppress QCD background.
- H→γγ (sideband) , H→ττ (VBF), H→bb (highest decay rate, but also high QCD background, may be feasible for the associated production) are important in low mass region.
- H→ZZ : for 4l sub-channel: clean final state, mass range 130<M_H<500 GeV except M_H= 2M_W
  for llνν/llqq sub-channels: higher branch ratio in Z→νν/qq; on shell Z-bosons are assumed in this study to reduce backgrounds.
- H→WW : Dominant one in intermediate and high mass regions.
- Low mass region Higgs, the mass resolutions of Higgs (e.g. H→γγ, H→ZZ→4l) are determined by the resolution of the detector.

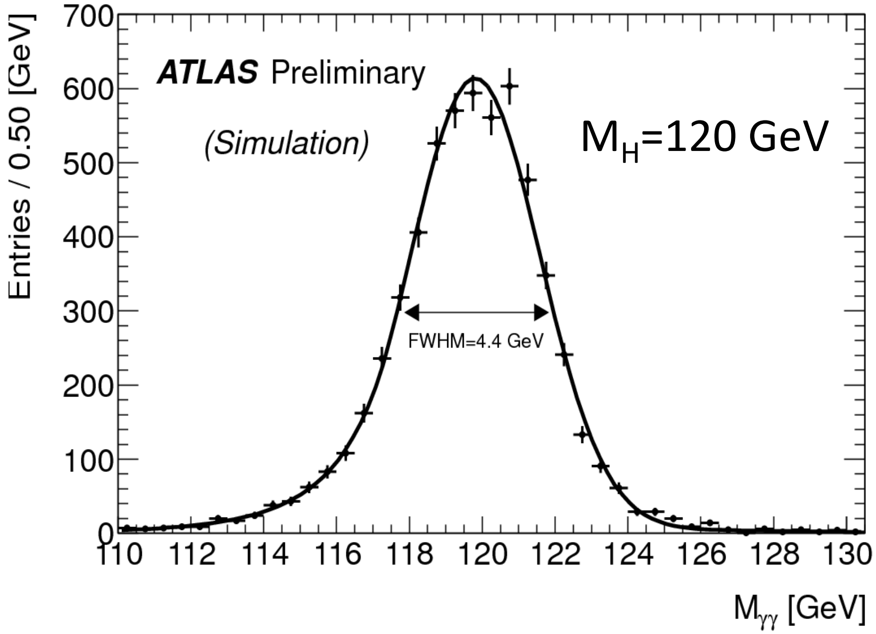
$H \rightarrow \gamma\gamma$ channel

ATLAS-CONF-2011-004
ATLAS-CONF-2011-025
ATLAS-CONF-2011-071

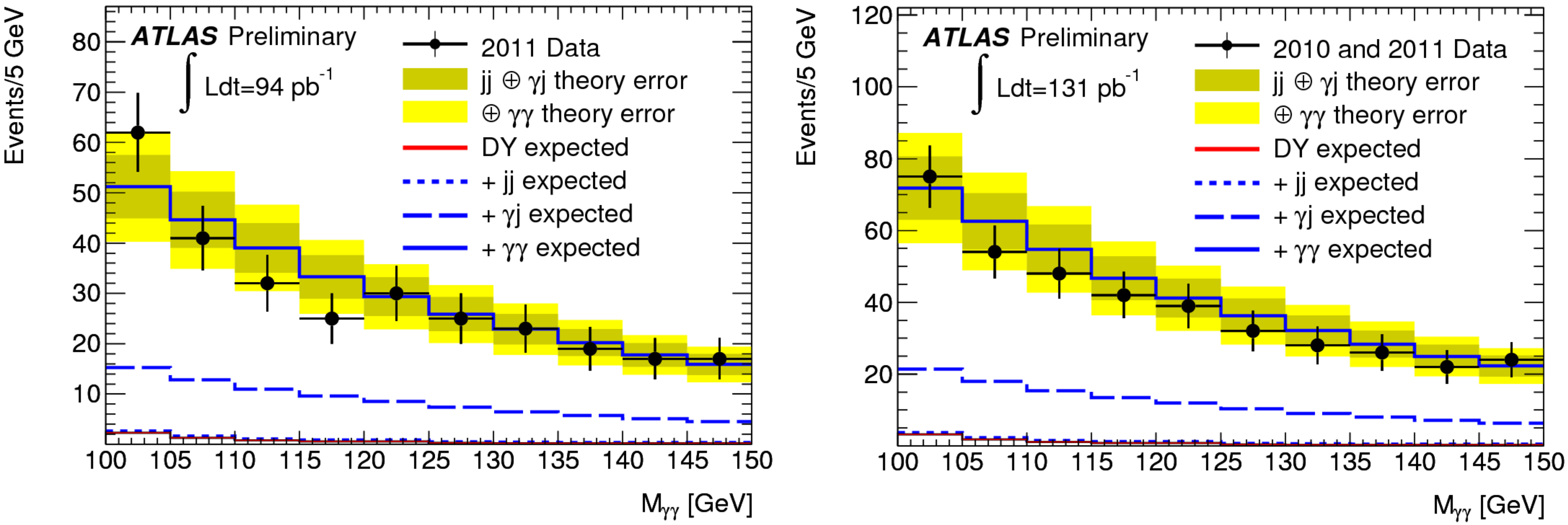
H→γγ channel with 38 pb^{-1}

- Selection: $P_{T\gamma1}$>40 GeV, $P_{T\gamma2}$>25 GeV and $|\eta_\gamma|$<2.37 excluding the crack region.
- Relevant backgrounds are γγ,γjet(jet faking as photon), di-jet and small Drell-Yan(electron misidentified as photon):
  - EM calorimeter based Photon ID and isolation efficiently suppress QCD γ-jet and di-jet.
  - Good reconstruction and vertex correction provide good resolution of di-photon resonance.
    - The average number of reconstructed primary vertices is 2.3 with 2010 data.





Di-photon mass distribution with the combination of 2011 data



- Good agreement between data and the Standard Model prediction in the 2010+2011 analyzed data sample.
- No excess is observed with 131 pb^{-1} data, neither with the analysis criteria described in three notes nor with other selections studied.

Exclusion limit

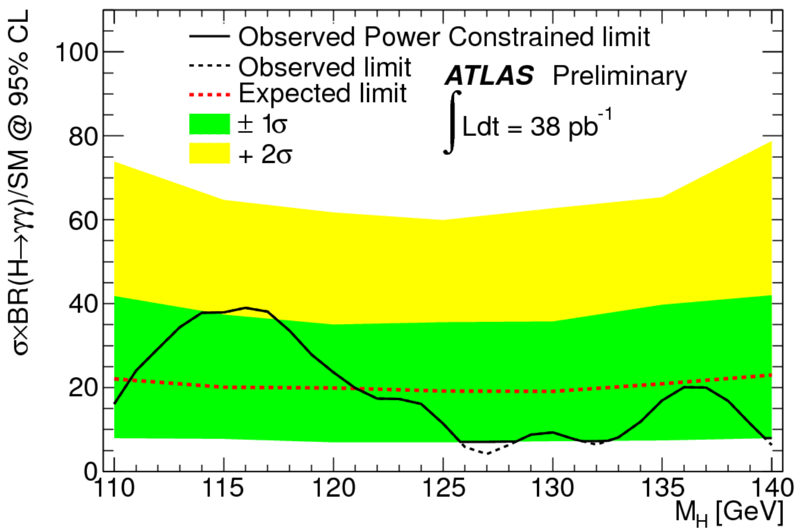
- Fit Model:
  - Signal described by Crystal ball plus a Gaussian.
  - Background exponential (range 100-150GeV).
    - Background normalization and the slope of exponential are allowed to float

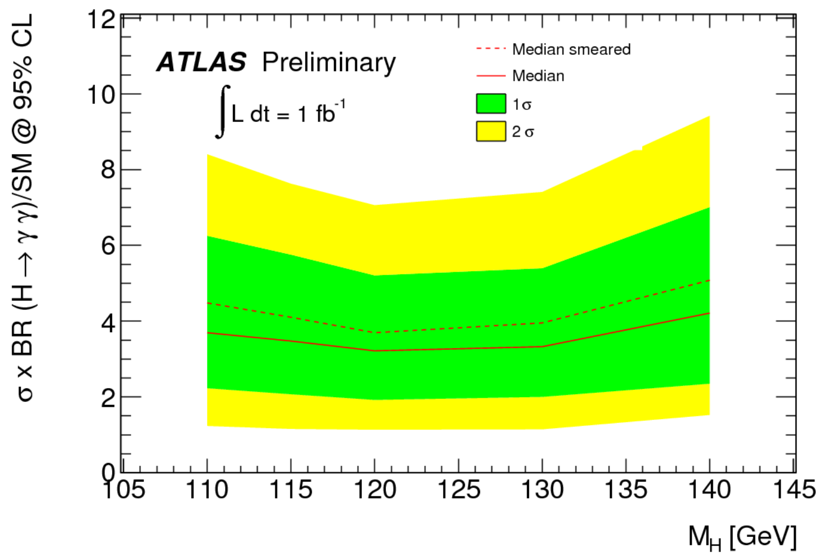
N_s expected after selection:

Higgs boson mass [GeV]	110	115	120	130	140
Number of signal events	$0.43^{+0.11}_{-0.09}$	$0.45^{+0.11}_{-0.10}$	$0.45^{+0.11}_{-0.10}$	$0.41^{+0.10}_{-0.08}$	0.31 ± 0.08

N_{data}=99

- Frequentist based Profile likelihood method CL_{s+b} is used with Power Constrained limit (PCL):
  - if the observed limit is lower than the -1σ of the expected limit, the later is taken as the observed limit.
- The observed limit (left) taking into account systematics is comparable to 2010 result of Tevatron.
- The projected limit of 1 fb^{-1} is shown in the right plot.



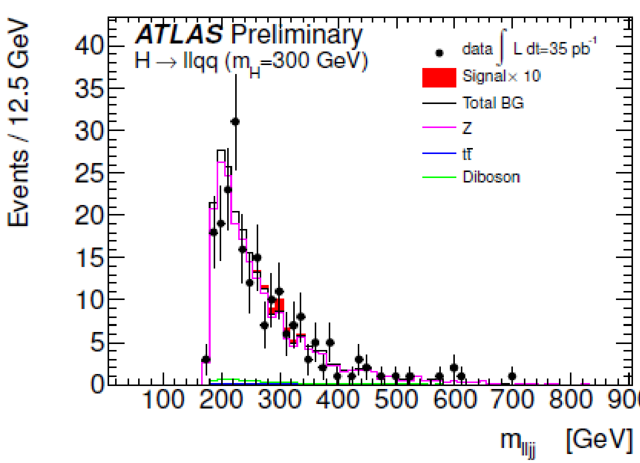


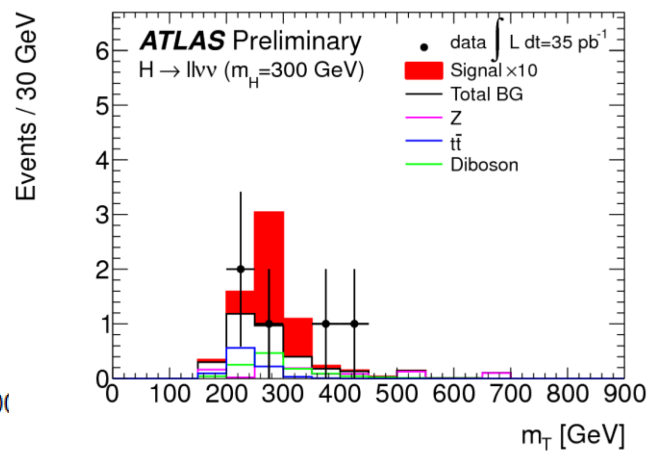
H→ZZ→4l/llqq/llvv channel

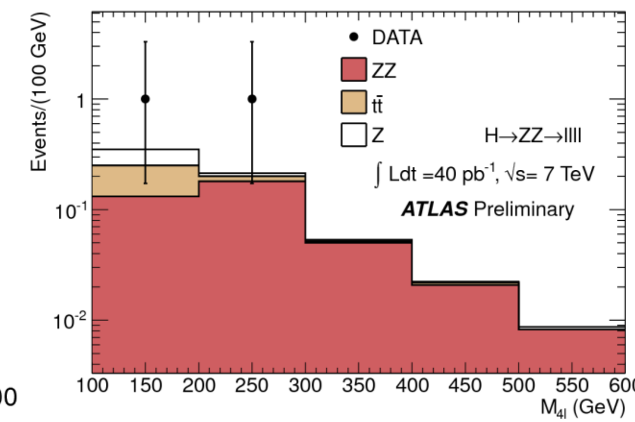
ATLAS-CONF-2011-026
ATLAS-CONF-2011-048

Event signature of H→ZZ→llνν/llqq/4l

- Common selection: 2 leptons (e,m) with P_T>20GeV 76 < M_{ll} <106 GeV
  - llqq: final discriminant M_{lljj} MET<50 GeV , 70< Mjj<105 GeV, M_H>360 GeV: P_T(jets)>50GeV, $\Delta\phi_{jj}$,$\Delta\phi_{ll}$ < π/2
  - llνν: final discriminant : transverse mass b-jet veto, MET>66/82GeV,$\Delta\phi_{ll}$ <2.64/2.25forM_H</≥260GeV
- 4l : P_T>20 GeV for 1st/2nd lepton; $P_{T3l,4l}$>15 GeV(e)/7GeV(μ); $|M_{l1l2}-M_z|$<15/12GeV for M_{4l}<170 GeV/>180 GeV.
- The background of subchannel llqq has higher statistics.
- Most background contributions (except ZZ) are controled by means of independent signal-free control samples.

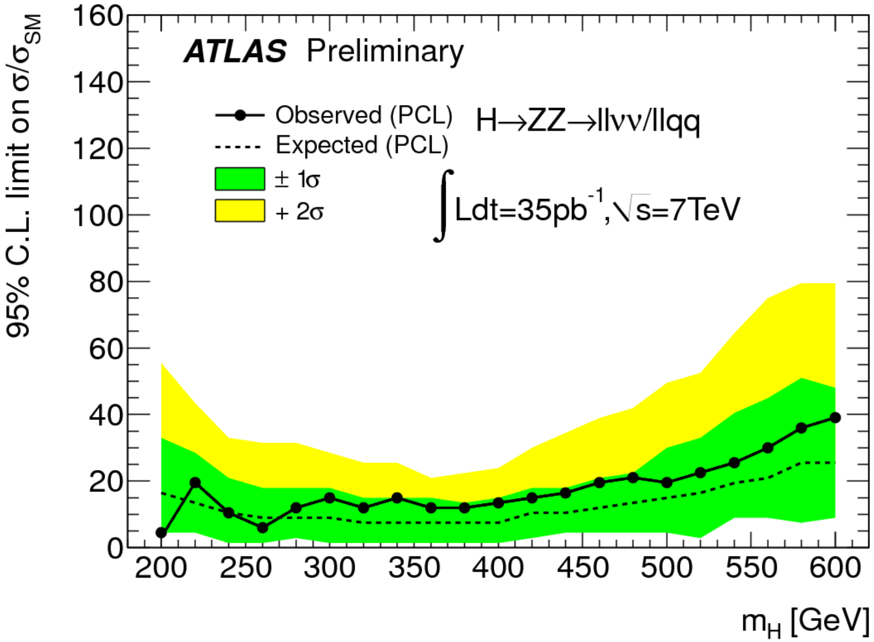


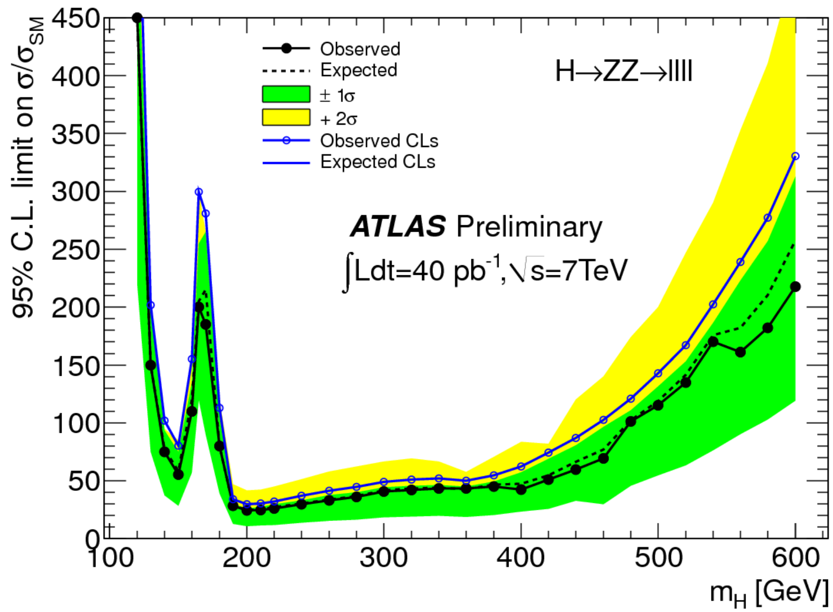




$$m_T^2 \equiv \left[\sqrt{m_Z^2 + |\vec{p}_T^{\,\ell\ell}|^2} + \sqrt{m_Z^2 + |\vec{p}_T^{\,\rm miss}|^2} \right]^2 - \left[\vec{p}_T^{\,\ell\ell} + \vec{p}_T^{\,\rm miss} \right]^2$$

Limit setting for H→ZZ





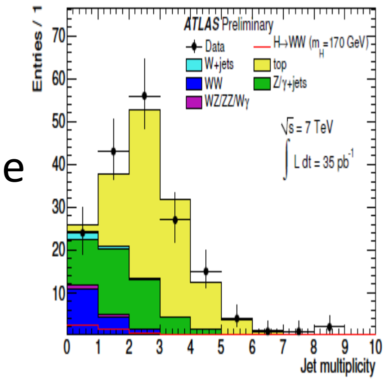
- The observed limit for combination of H→ZZ→llνν/llqq is from 3.5 to 39 σ_{SM} using CL_{s+b} method with power constrained limit.
- The lowest limit for H→ZZ*→4l is 30 around 200 GeV.

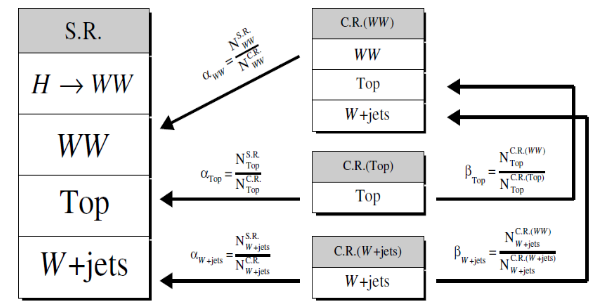
$H \rightarrow WW \rightarrow l\nu l\nu / l\nu qq$ channel

ATLAS-CONF-2011-005
ATLAS-CONF-2011-052

The selection for H→WW

- H→WW→lvlv:
  - 2 leptons(e,μ) with P_T>20(15)GeV
  - M_{ll}>15,|M_z-M_{ll}|>10 GeV for the same flavor leptons; M_{ll}<65 GeV
  - MET>30 GeV.
  - $\Delta\phi_{ll}$<1.3(1.8) for M_H<170/≥170 GeV.
  - Dedicated selections for H+0,1,2jets (detail in ATLAS-CONF-2011-005)





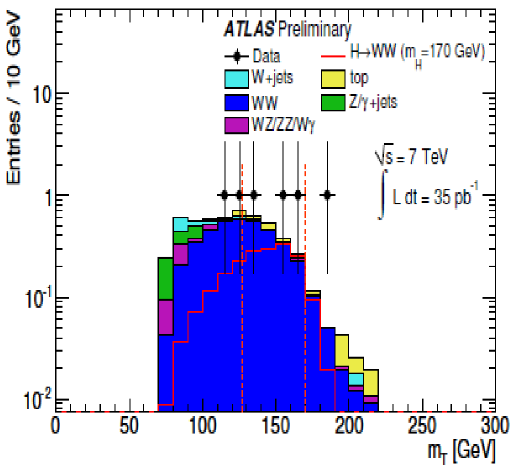
The contribution of different backgrounds are estimated with data-driven methods and various systematic uncertainties are taken into account propagating from the control region to the signal region.

- H→WW→lvqq:
  - one lepton with P_T>30 GeV, veto events with more than one lepton with p_T>20 GeV.
  - MET>30 GeV.
  - Two /three jets with P_T>30 GeV |η|<4.5, jets from W (71<M_{qq}<91 GeV) with |η|<2.8; b jet veto.
- Both sub-channels categorize events with different jet bins to optimize the analysis sensitivities.

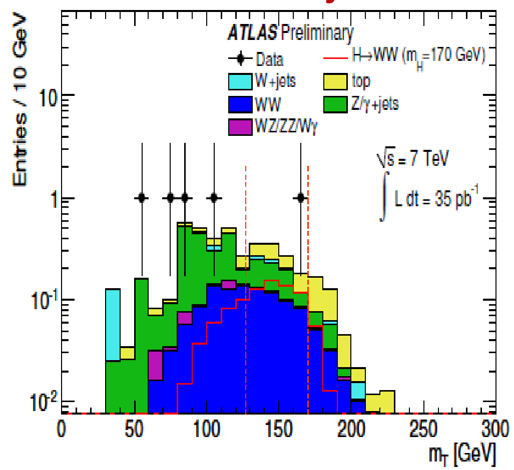
Results after selections

$H \to WW \to l\nu l\nu$:

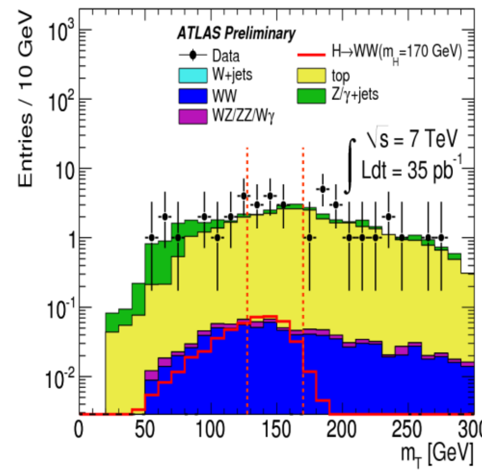
H+0jet



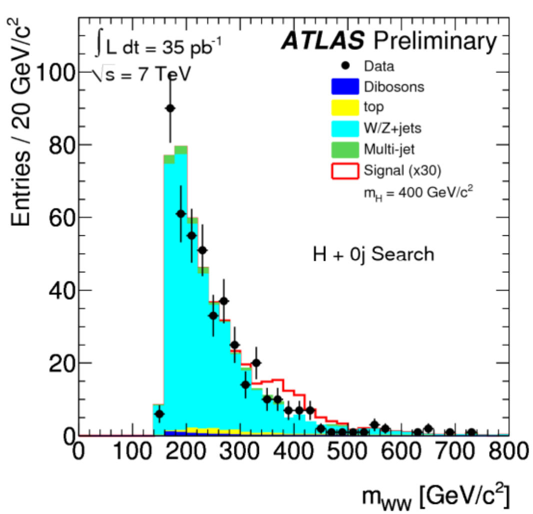
H+1jet

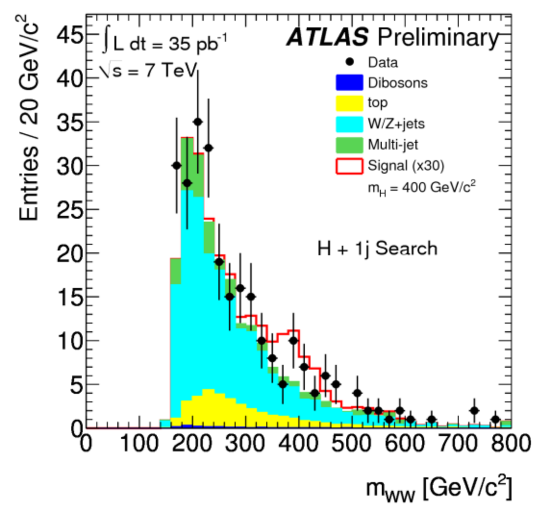


H+2jets after cut of ηj1*ηj2<0

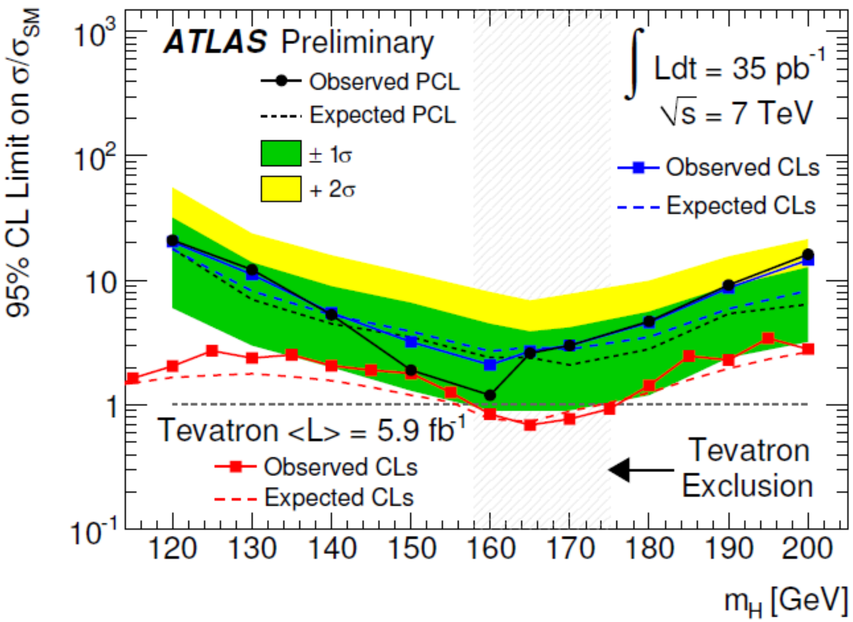


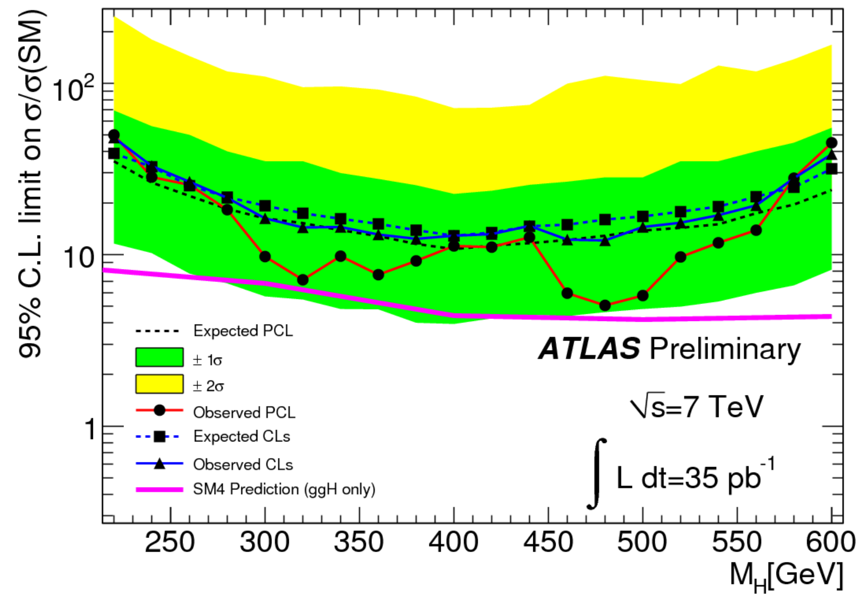
$H \to WW \to l\nu qq$:





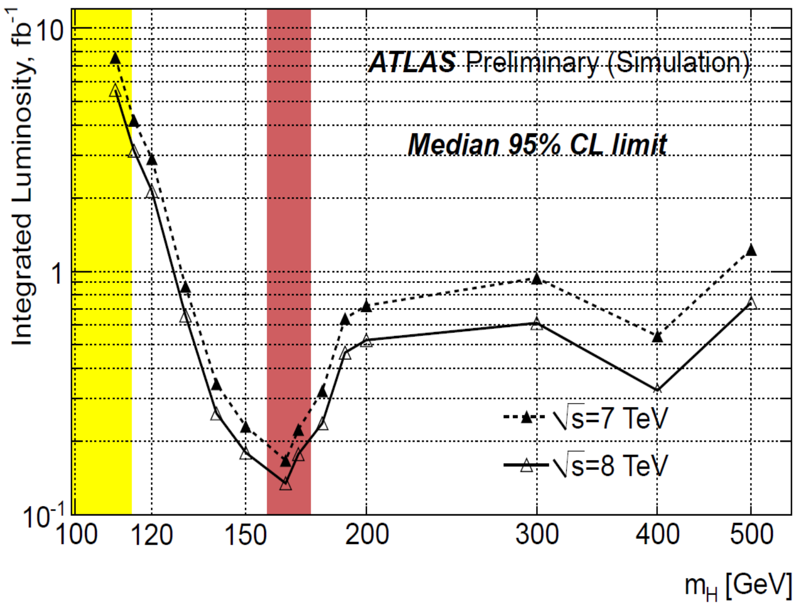
Limits for H→WW→lνlν/lνqq

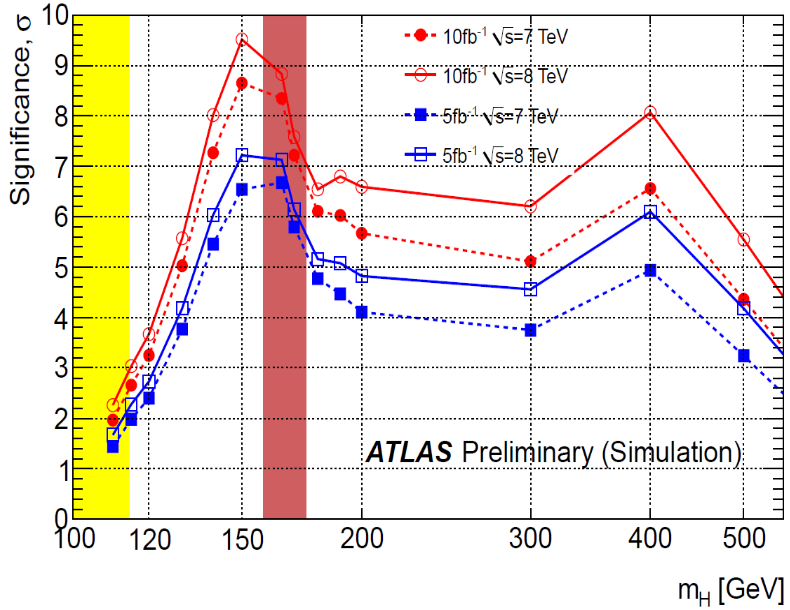




For H→WW→lνlν subchannel, 1.2Xσ_{SM} is excluded at 160 GeV which is the best limit for Higgs study with 2010 data.
For H→WW→lνqq subchannel, 11.2Xσ_{SM} is excluded at 400 GeV.

Prospects





- With luminosity of a few fb^{-1}, ATLAS expects to reach the exclusion region of LEP.
- With ~5 fb^{-1}/7TeV, we start to have 5σ discovery; we expect to have 3σ observation in the mass range 125-500 GeV.
- With 10 fb^{-1}/7TeV, we expect to have 5σ discovery within mass range 130-400 GeV.

Conclusion and outlook

- With the data of 2010, there are no SM Higgs boson mass has been excluded by the ATLAS detector.
  - At 160 GeV, 1.2Xσ_{SM} is excluded.
  - For H→γγ, the observed exclusion is from 8 to 38 SM Higgs prediction. The result is comparable with the 2010 result of Tevatron.
  - The region of SM Higgs boson masses above 200 GeV has been explored for the first time.
- With a couple of fb^{-1}, ATLAS expects to exclude the whole mass region above 115 GeV.
- With the about 5 fb^{-1}, a 5σ discovery starts to be possible.

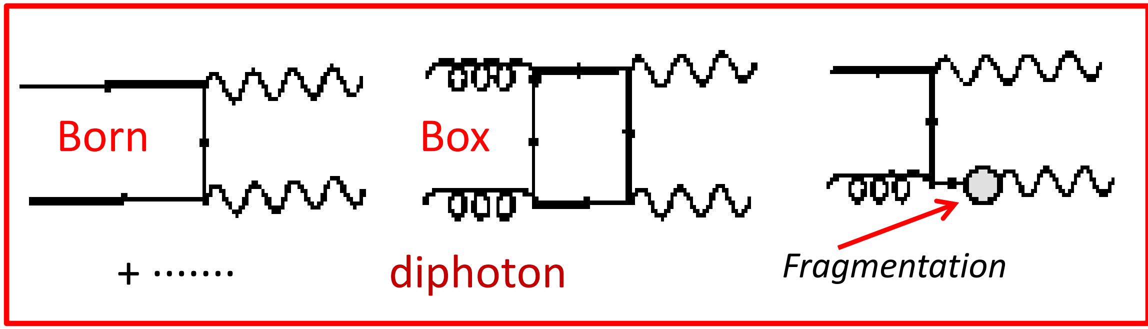
  (Of course, we prefer the latter).

Backup slides

Background Processes for H→γγ

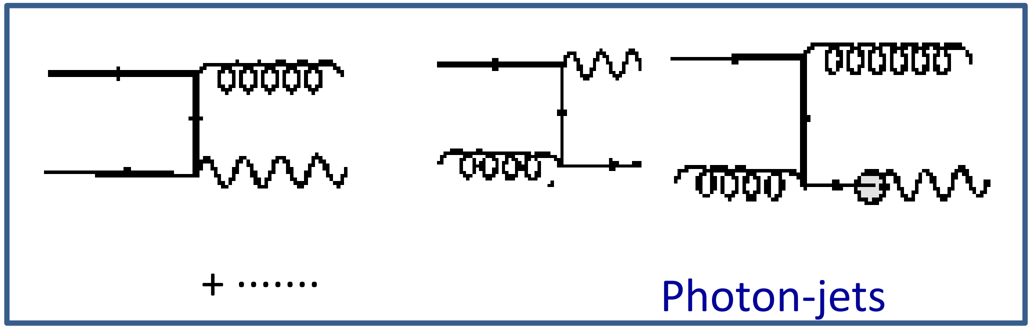
Irreducible Bkg (diphoton):

- *Born and Box processes*
- *Use Resbos/Diphox at NLO*
- *Fragmentation is taken into account at NLO by Diphox*
- *Difficult to simulate fragmentation, causing uncertainty O(20%).*



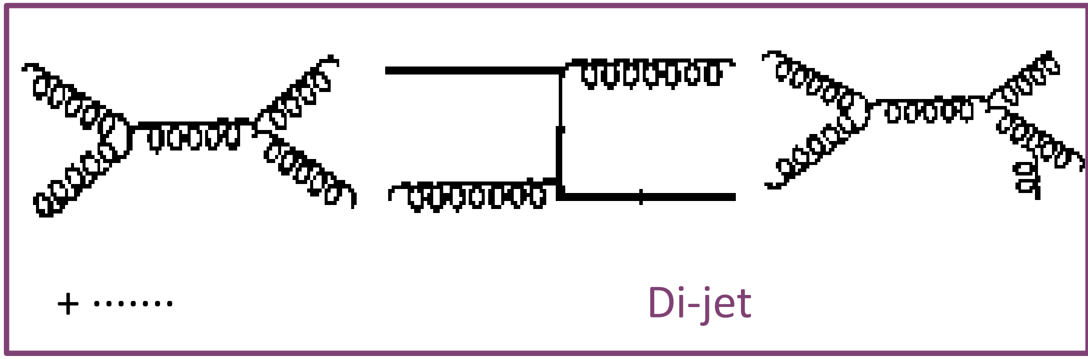
Reducible bkg:

- *Photon-jet /di-jet with one/two jet faking as a photon/photons.*
- *Due to excellent jet rejection, reducible bkg is comparable or smaller than irreducible bkg.*
- *Difficult to simulate a parton into a leading pi0, which entails an uncertainty O(50%).*

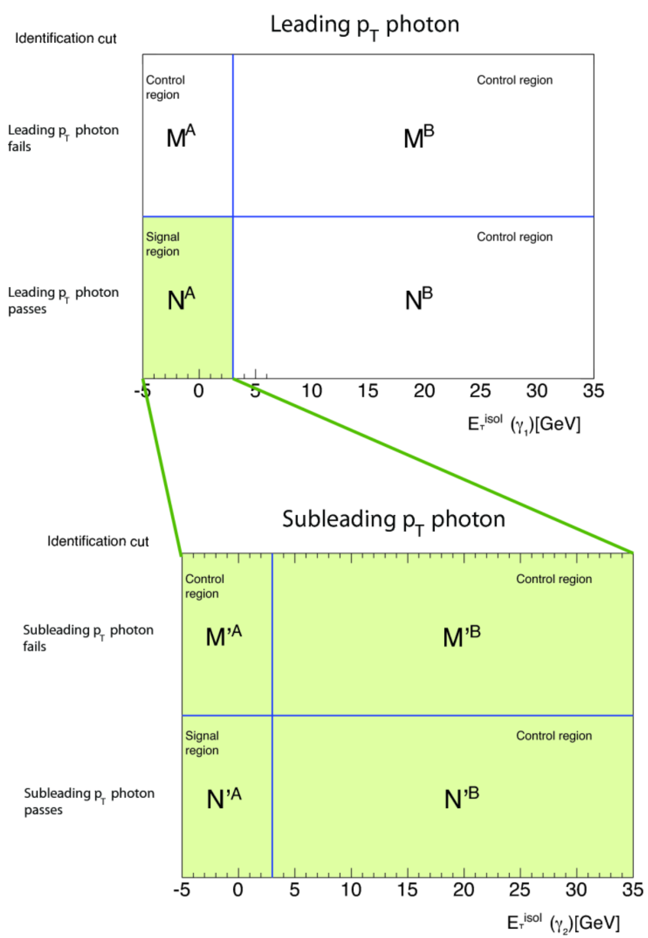


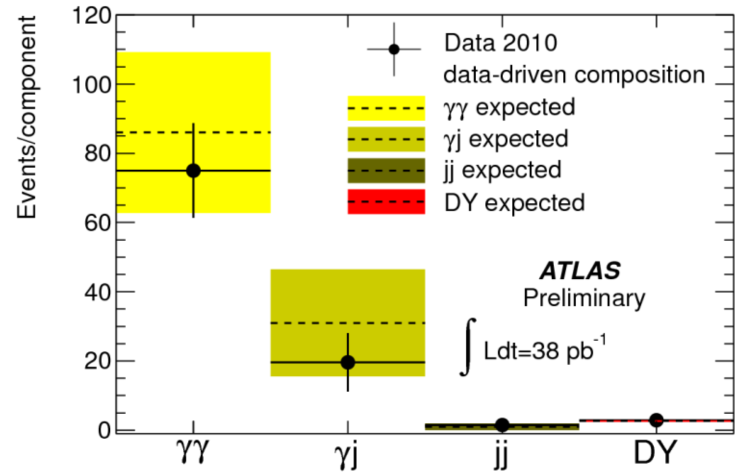
Drell-Yan:

- *Small contribution.*
- *But having single track conversions has considerably enhanced this background.*



H→γγ: Background estimation





The backgrounds are from: γγ, γjet, dijet and Drell-Yan.

- **2x2D method is designed for di-photon analysis :**
  - **Two variables: photon ID, isolation used (left diagrams),**
    - **there is low correlation between two variables after loose ID.**
    - **one can extrapolate background (fake photons) in signal region $N^A = N^B/M^B\ M^A$**
  - **implement it on leading photon, then subleading photon (2X2D).**
  - **data-driven extraction of Nγγ, Nγj, Njγ, Njj**
- **The contribution of Drell-Yan:**
  - **Fake rate of e→γ is measured from Z(ee) with one electron faking as a photon**
- **The estimated components of backgrounds are consistent with theoretical prediction within uncertainties.**

Extraction of Exclusion Sensitivity

• ***We perform a statistical study of the exclusion sensitivity at 38 pb^{-1}.***

a : CLs+b method: CL = 1-P_{value}(s+b) with test statistic :

$$\tilde{q}_\mu = \begin{cases} -2ln\frac{\mathcal{L}(\mu,\hat{\hat{\theta}})}{\mathcal{L}(0,\hat{\hat{\theta}})} & \hat{\mu} < 0, \\ -2ln\frac{\mathcal{L}(\mu,\hat{\hat{\theta}})}{\mathcal{L}(\hat{\mu},\hat{\theta})} & 0 \leq \hat{\mu} \leq \mu, \\ 0 & \hat{\mu} > \mu \end{cases}$$

Power constraint limit (the observed limit is lower than the -1σ of the expected limit, the later is taken as the observed limit) is used for the observed limit to reduce false exclusion.

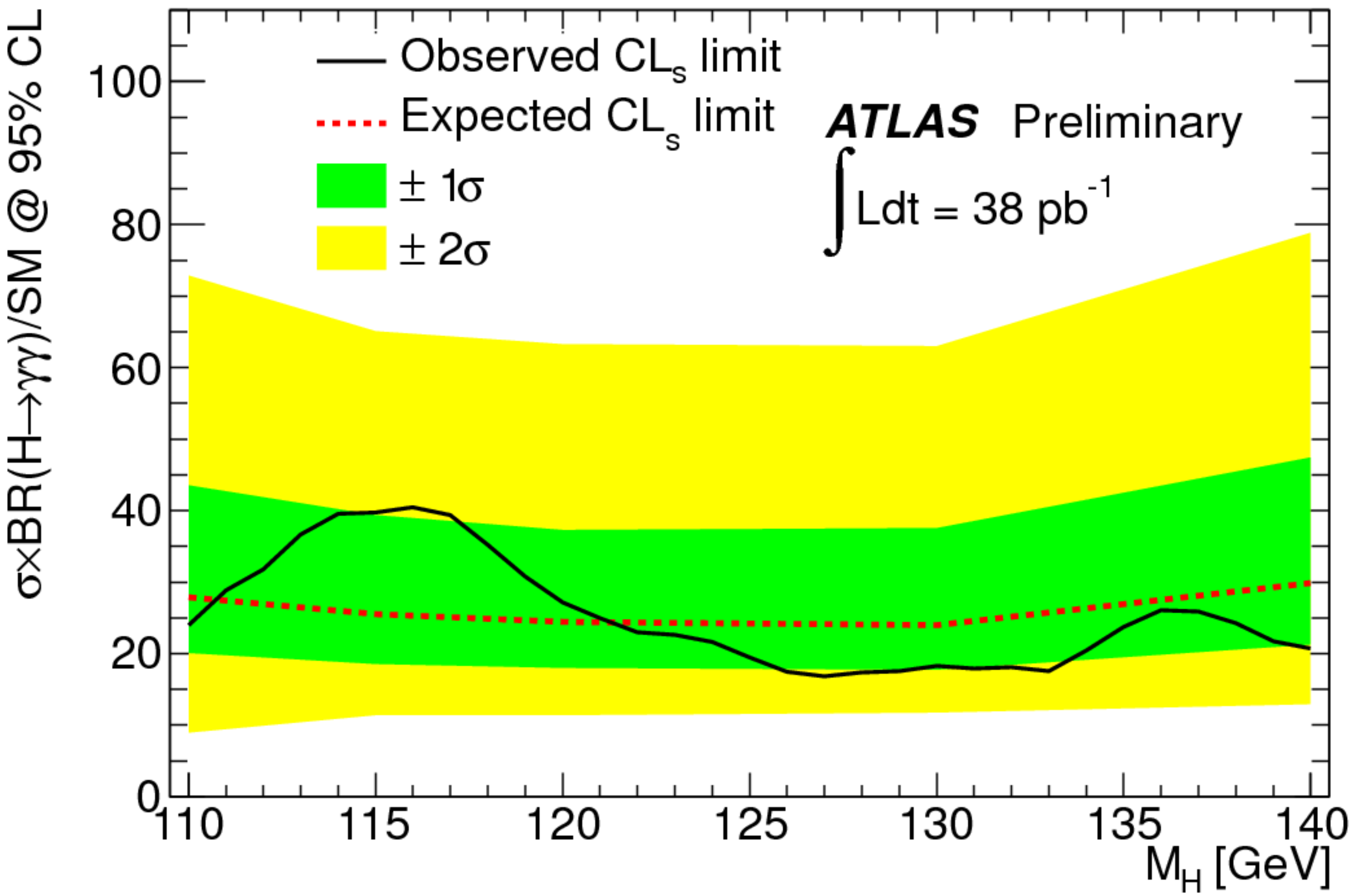
Background: shape and normalization are the nuisance parameters.

b: CL_s is used for the purpose of comparison with results from Tevatron.
reduce the false exclusion, but conservative.

Systematics in H→γγ

	Source	Uncertainty
	Luminosity	$\pm 3.4\%$
Theory	Cross-section (scales)	$^{+20}_{-15}\%$
Efficiency	Photon identification	$\pm 11\%$
	Photon isolation	$\pm 10\%$
	Trigger	$^{+1.1}_{-3.7}\%$
Resolution	Calibration	$\pm 13\%$
	$e \rightarrow \gamma$ extrapolation	
	Pile-up	

CLs limit for H→γγ



Limits for H→ZZ→llνν/llqq