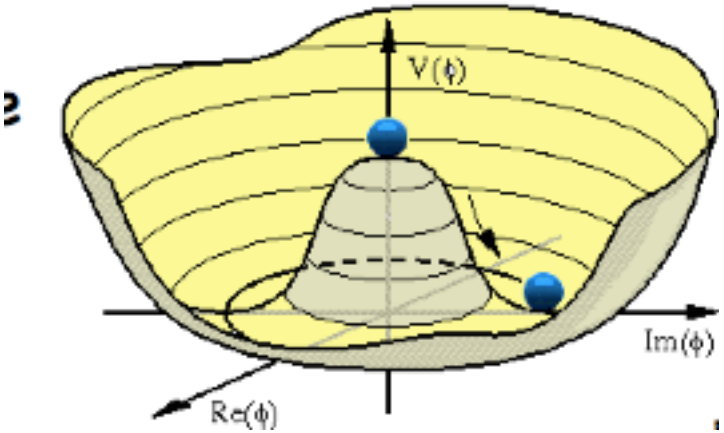
News from ATLAS Higgs Searches (Since last DESY - LHC Discussion Meeting)

Marcos Jimenez

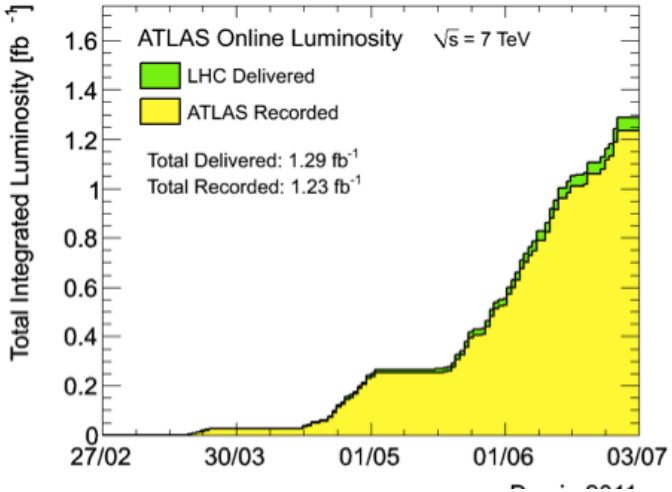


In the last LHC discussion meeting I presented the SM Higgs searches results up to EPS 2011 (July 25th):

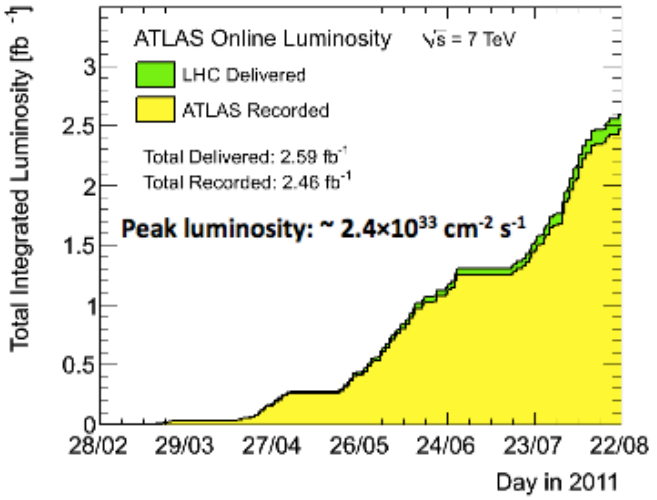
https://indico.desy.de/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=4274

Some Higgs search channels have been improved with substantially more data:

EPS conference



Lepton Photon conference



OUTLINE

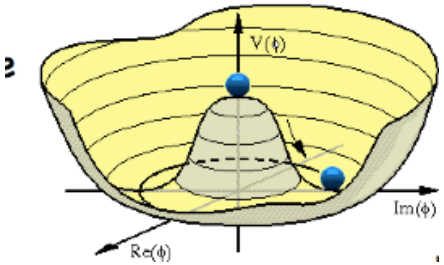
1 – Introduction
2 – New combined results with respect to EPS
3 – H->gg and channel updates
4 – Summary and Outlook

Introduction

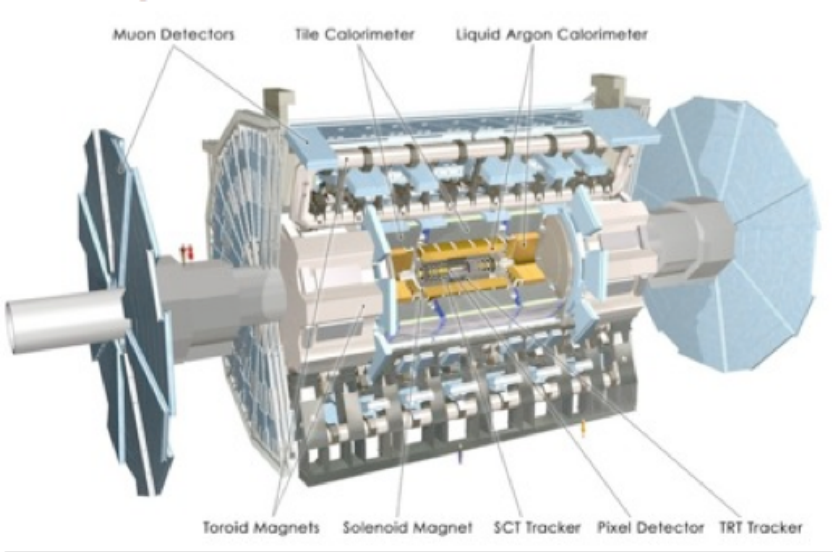
→ *The LHC has been running exceptionally well this year and has already delivered more than 2fb^-1 of data*

→ **LHC expects to deliver up to 5fb^1 of data by the end of 2011 !!**

→ **ATLAS and CMS combination by end of 2011 could exclude SM Higgs ! (or discover it)**



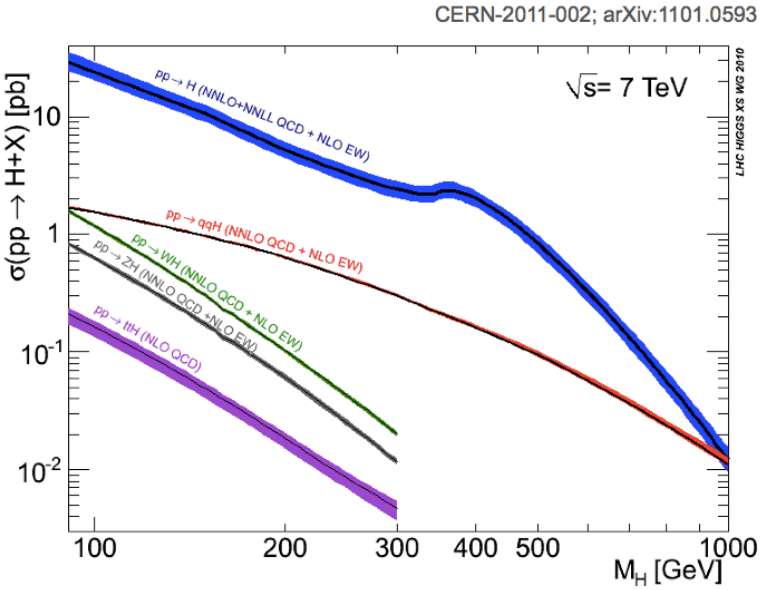
Year	Luminosity	Total	Beam energy
2011	4-5	4-5	3.5
2012	10	15	3.5/4
2013	0	15	-
2013	0	15	-
2014	10	25	6.5



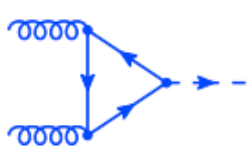
→ *The design of ATLAS was partially driven to provide high sensitivity to Higgs production*

→ *The ATLAS collaboration has carried out SM Higgs seaches in several channels using up to ~2fb^-1 of data*

Higgs Production at the LHC

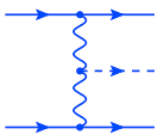


Gluon Fusion



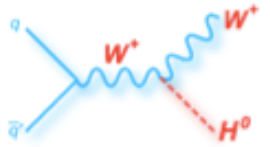
Theo Unc O(15%)

VBF



Theo unc O(7%)

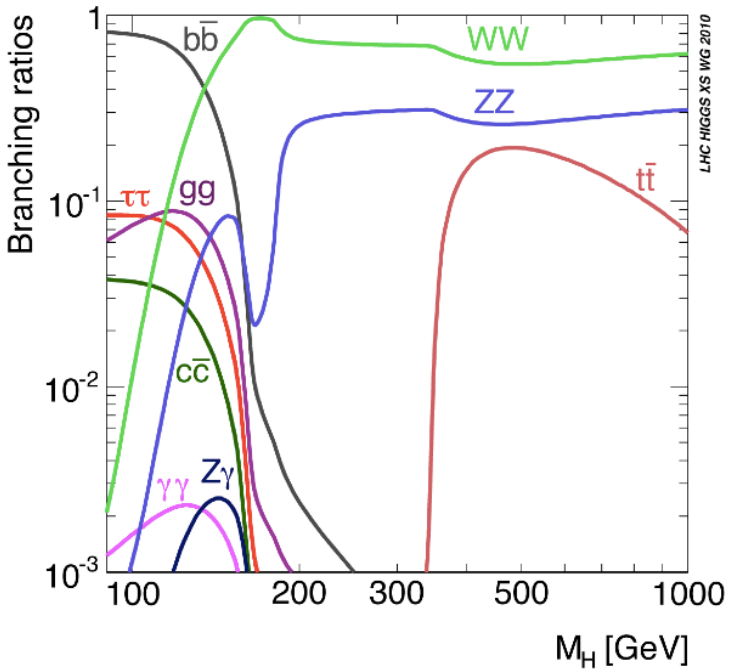
Higgs Strahlung



Theo unc. O(5%)

→ The Higgs decay branching ratios depend on the Higgs mass.

→ Higgs searches through various channels thus explore different ranges of potential Higgs masses



SM Higgs decay channels investigated at ATLAS and combined in a single mass exclusion fit

Channel		btag (veto)	Jets	MET (GeV)	Shape	Mass Range (GeV/c²)	Main backgrounds
γγ					M_{gg}	110-150	γγ (from sidebands)
WH		✓	2		M_{bb}	110-130	Top (3j - high M_{bb}) and W+jets (low M_{bb})
ZH		✓	2		M_{bb}	110-130	Z+jets (low M_{bb})
WW (lνlν)	0-jet		0	>30		110-240	WW (control region M_{ll})
	1-jet	veto	1	>30		110-240	Top (from reverse btag) and WW (M_{ll} CR)
WW (lνqq)	0-jet		0	>30	M_{WW}	200-600	W+jets (sidebands)
	1-jet	veto	1	>30	M_{WW}	200-600	W+jets (sidebands)
ZZ (llνν)		✓		>30	M_T	200-600	VV(from MC) and top (MC and checks)
ZZ (llqq)		✓	2	<50	M_{llqq}	200-600	Z+jets (from MC) and top (from MC)
ZZ (4l)		IP			M_{4l}	110-600	ZZ (from MC), Z+jets (MC) and top (CR)

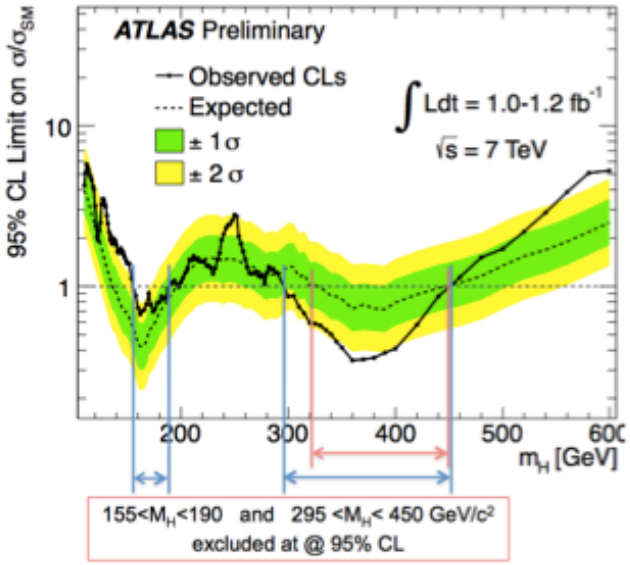
Low mass range (100-150)

Medium mass range (~100-250)

High mass range (200-600)

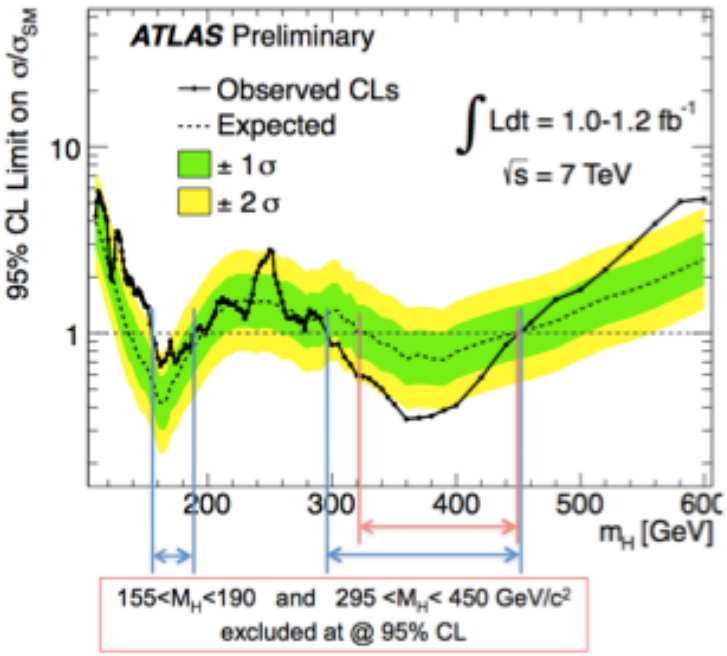
Exclusion Limits as of last LHC discussion meeting:

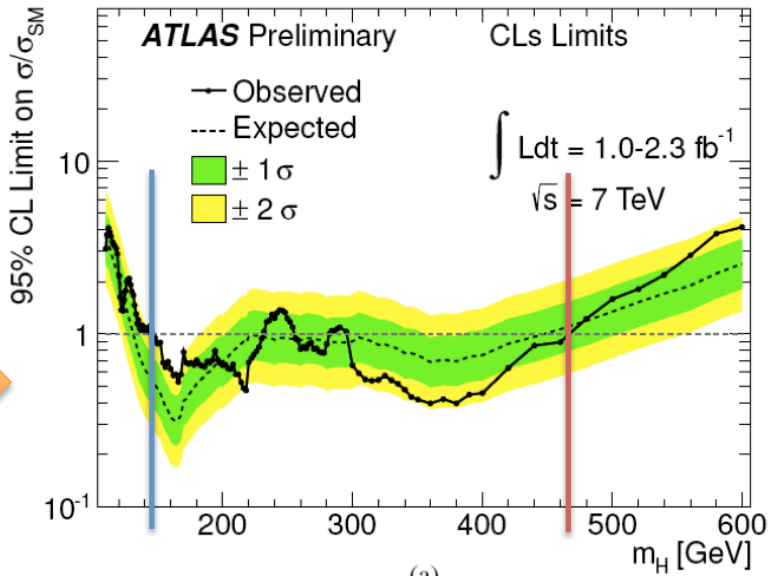
155-190 and 295-450 Mass range excluded!



There has been substantial improvement in the last month.. !

Results for combination analysis





Current ATLAS exclusion range (as of LEPTON-PHOTON conference in Mumbai)

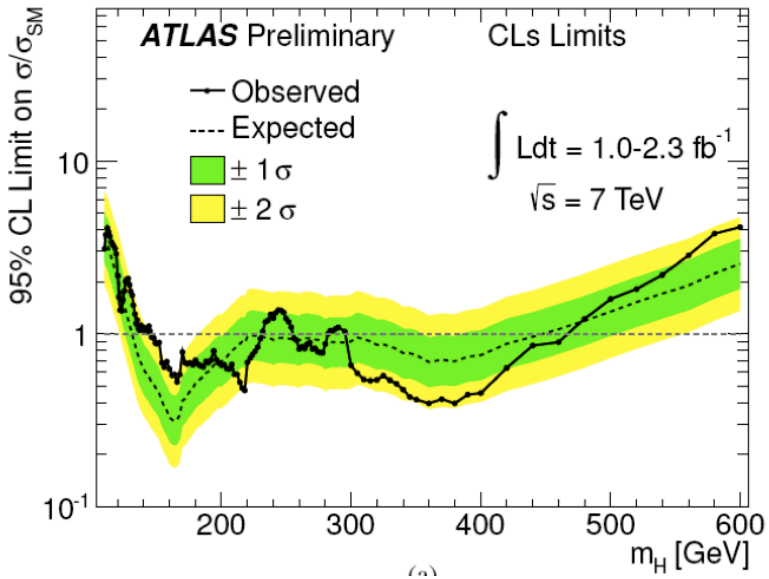
The exclusion range for the Higgs has been extended substantially in the month and is progressing very quickly as more data is included for the different channels .

146<m_H<232, GeV
256 <m_H< 282 GeV
296 <m_H< 466 GeV

A few words about how exclusion limits are obtained

There are two values in this type of plot:

- ***Observed exclusion limit***
- ***Expected exclusion limit***



How are these values obtained?

1 – Define a likelihood function:

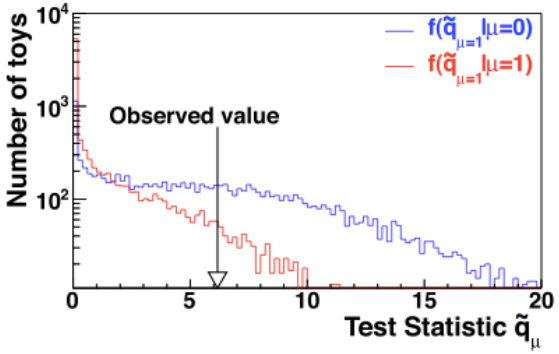
$$\mathcal{L}(\text{data}\,|\,\mu,\theta) = \text{Poisson}\,(\,\text{data}\,|\,\mu\cdot s(\theta)+b(\theta)\,)\cdot p(\tilde{\theta}|\theta)$$

H-> γγ case signal pdf is a crystal ball function while bkg pdf is falling exponential

2 – Define a test statistic to test data against against null hypothesis:

$$\tilde{q}_\mu \;=\; -2\ln\frac{\mathcal{L}(\text{data}|\mu,\hat{\theta}_\mu)}{\mathcal{L}(\text{data}|\hat{\mu},\hat{\theta})}$$

3 – Generate many toy MC samples under null hypothesis to get q_nu range to check how probable it is to get observed q_nu value

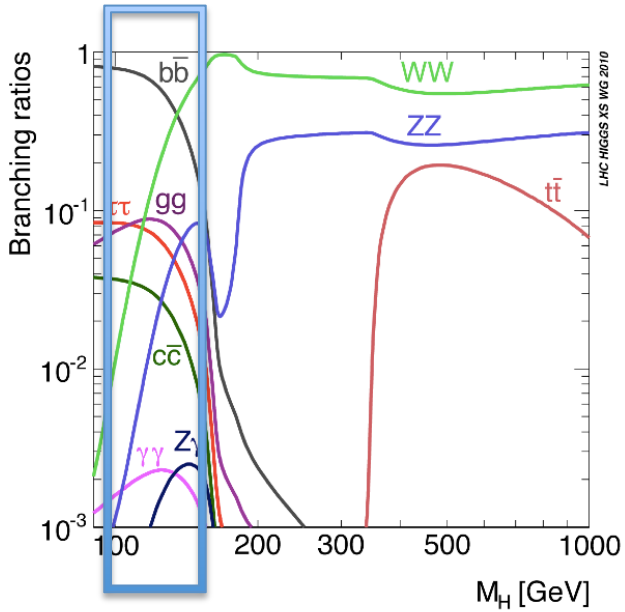


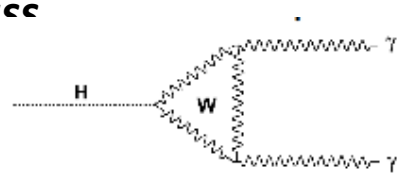
Higgs to γγ – low mass range

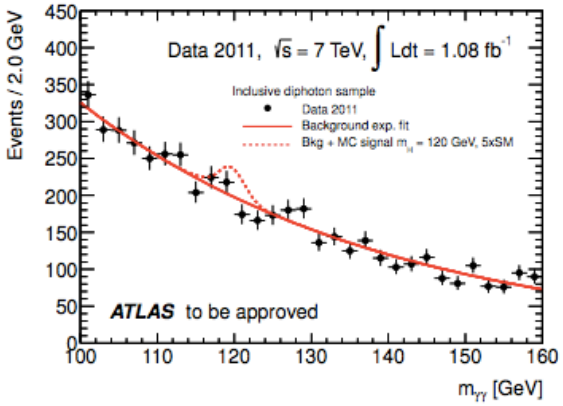
→ *This channel has a low branching ratio in range **100 < M_h < 150 GeV**, but good signal over background yield*

→ *Simple signature – 2 high pT photons* with pT1 > 40 and pT2 > 25 GeV

→ ***Photons must be isolated** and pass "**tight**" photon criteria*

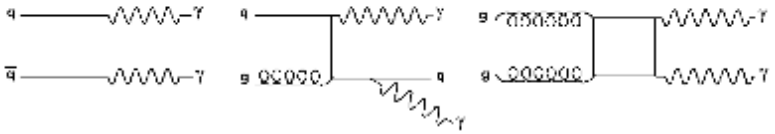




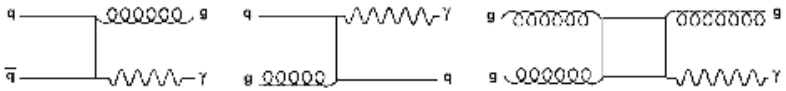


→ *Signal is a narrow peak over a smooth exponentially decaying background*

Irreducible background: pp→γγ + X



Reducible background: pp→γj , jj+ X

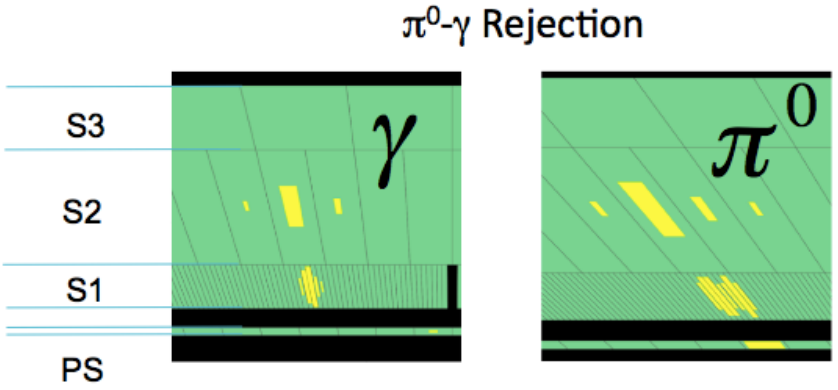


$O(\alpha_s\alpha)$ $O(\alpha_s\alpha)$ $O(\alpha^3_s\alpha)$

Higgs to γγ – Background treatment

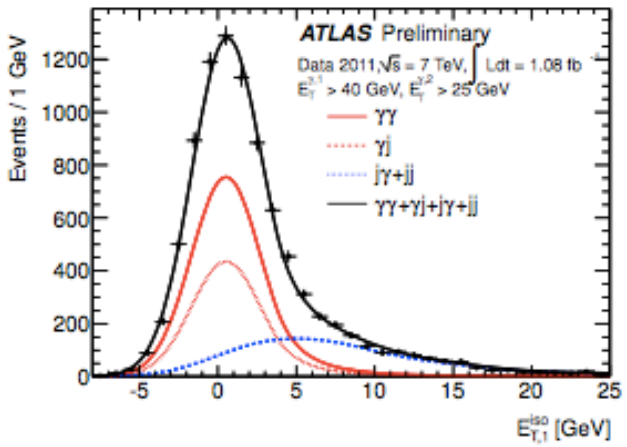
The reducible backgrounds contain jets in the final state misidentified as photons

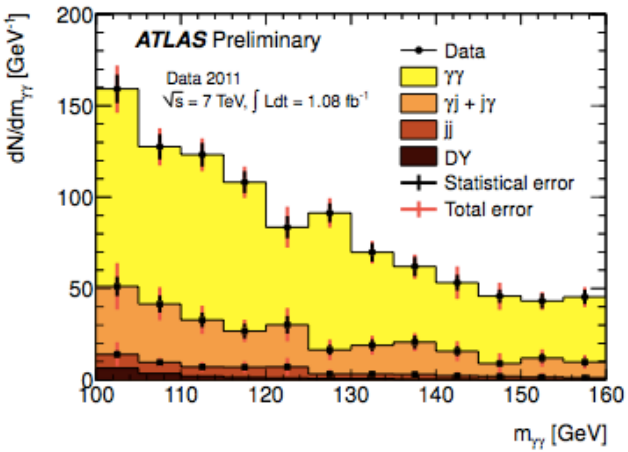
→ ***Jet is primarily composed of neutral pion which decays into two collimated photons***



The EM calorimeter ***is finely segmented in the eta direction*** and allows for rejection of background based on the shape of the object's shower

→ Calorimeter isolation is another powerful handle on background rejection and background determination

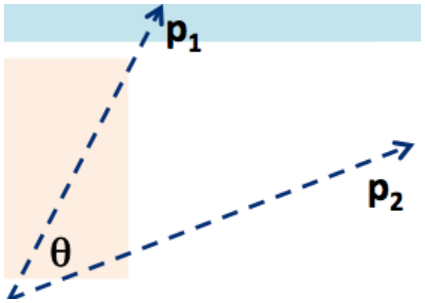




Higgs to γγ – Isolation and Invariant Mass Resolution

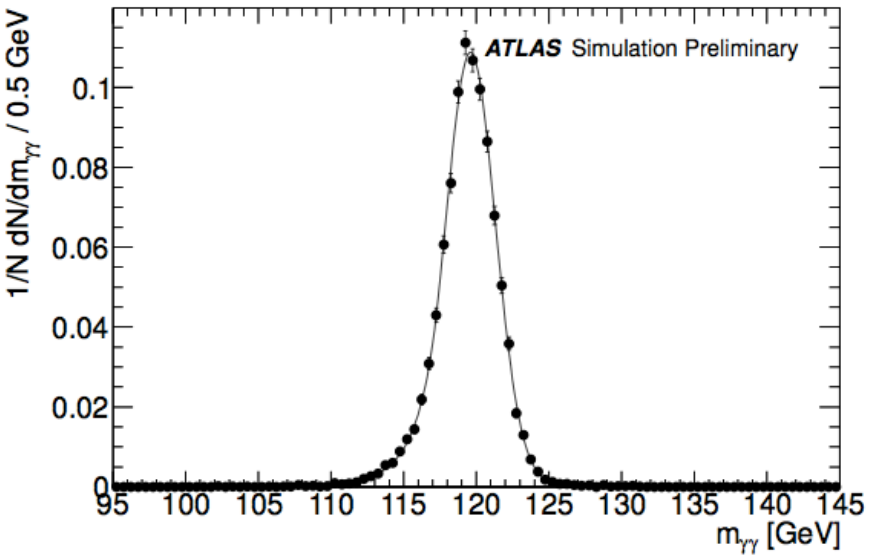
→ The invariant mass resultion is built from the energy measurement of the two Photons in the EM Calorimeter and their opening angle:

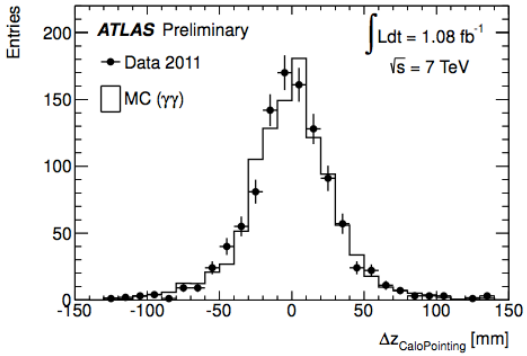
$$m^2 = 2P_1P_2(1-\cos\vartheta) \cong P_1P_2\vartheta^2$$



→ Energy scale calibration comes from Z->ee measurements and EM resolution is ~1.4 GeV

→ The other element going into the invariant mass is the opening angle, for this a pointing using the CALO layers is used





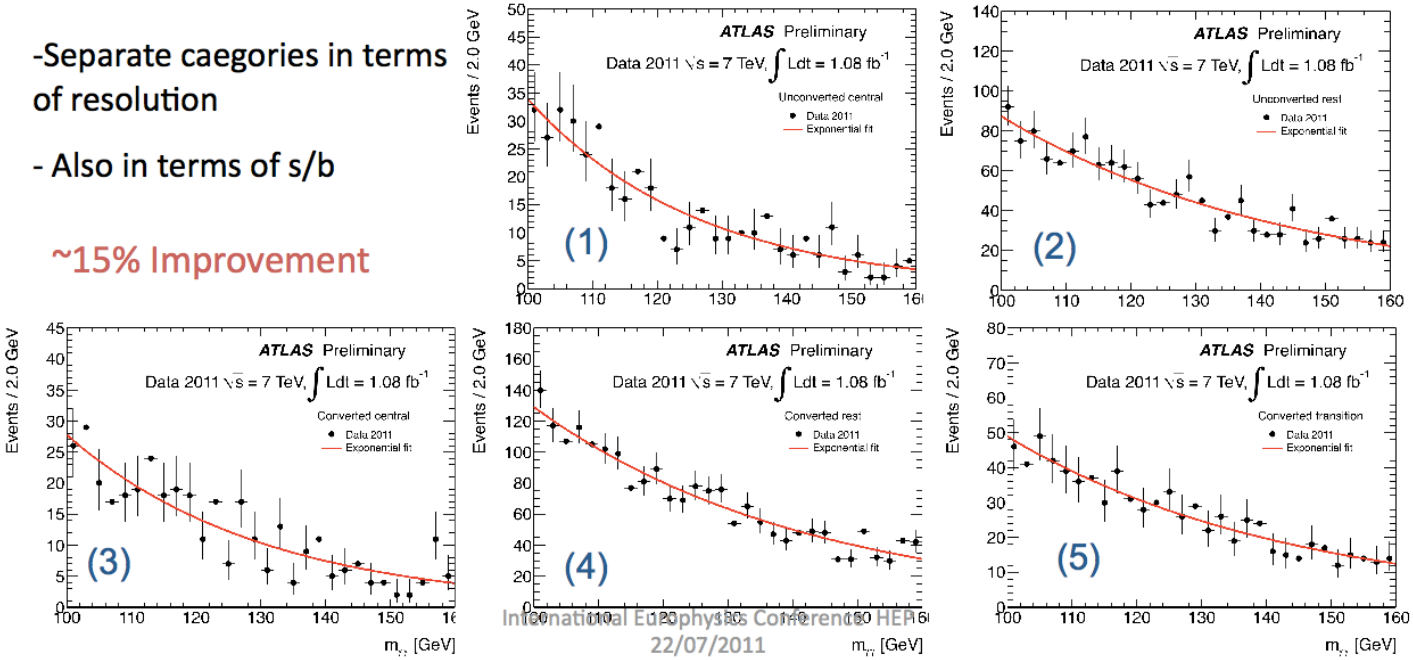
1.2 cm Resolution for unconv photons

Higgs to γγ -- results

-Separate caegories in terms of resolution

- Also in terms of s/b

~15% Improvement



~5000 events selected in ~1fb^-1 Data.

1.- Unconverted-central: 2 UC In the central barrel calorimeter (|η|<0.75)

2.- Unconverted-rest: 2 UC , at least one not central

3.- Converted-central: at least 1 Conv., 2 central

4.- Converted-transition: at least 1Conv. And 1 near the transition barrel/end-cap(1.3< |η|<1.75)

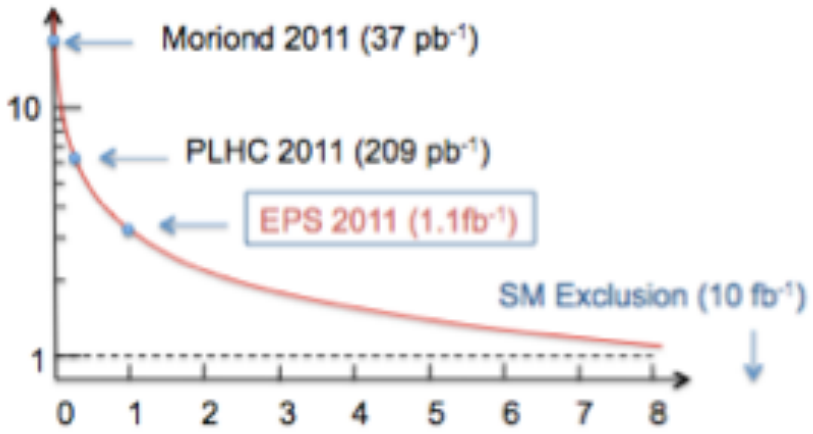
5.- Converted-rest: all other events with at least 1 Conv.

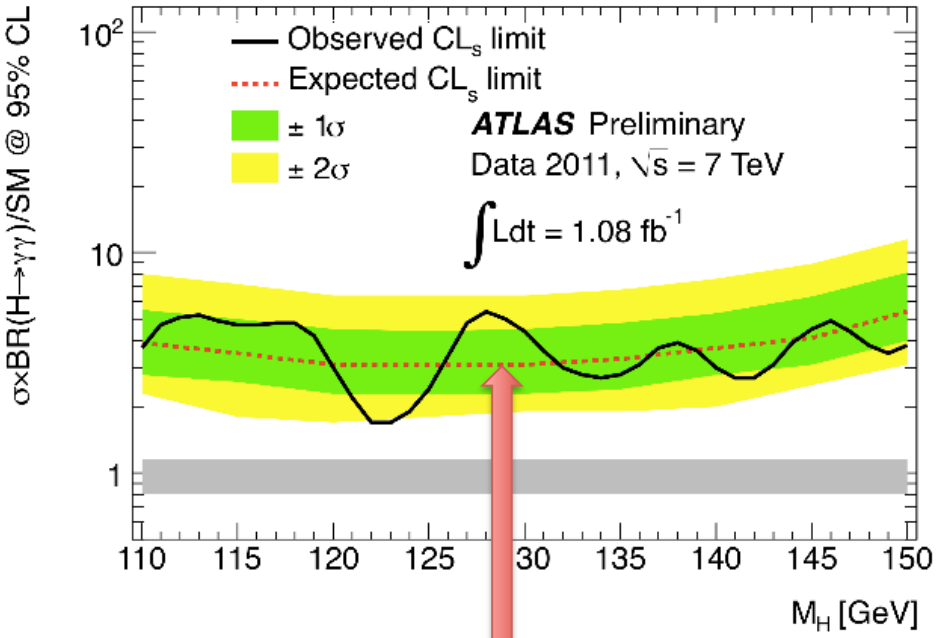
Higgs to γγ – results II

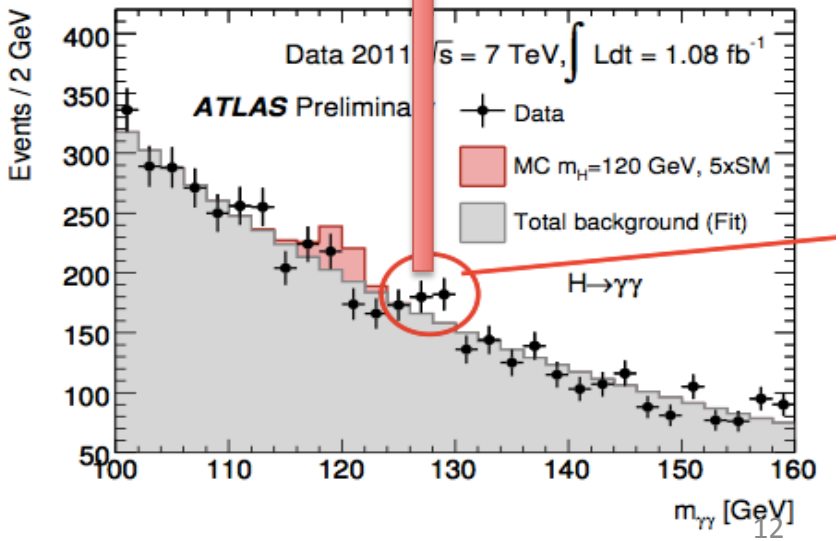
→Exclusion plots use a profile likelihood test (CL_s) to derive, given the current statistics, how many times the SM cross section for Higgs can be excluded at the 95% level

→ An excess in data results in less exclusion power than expected and thus goes in the direction of discovery

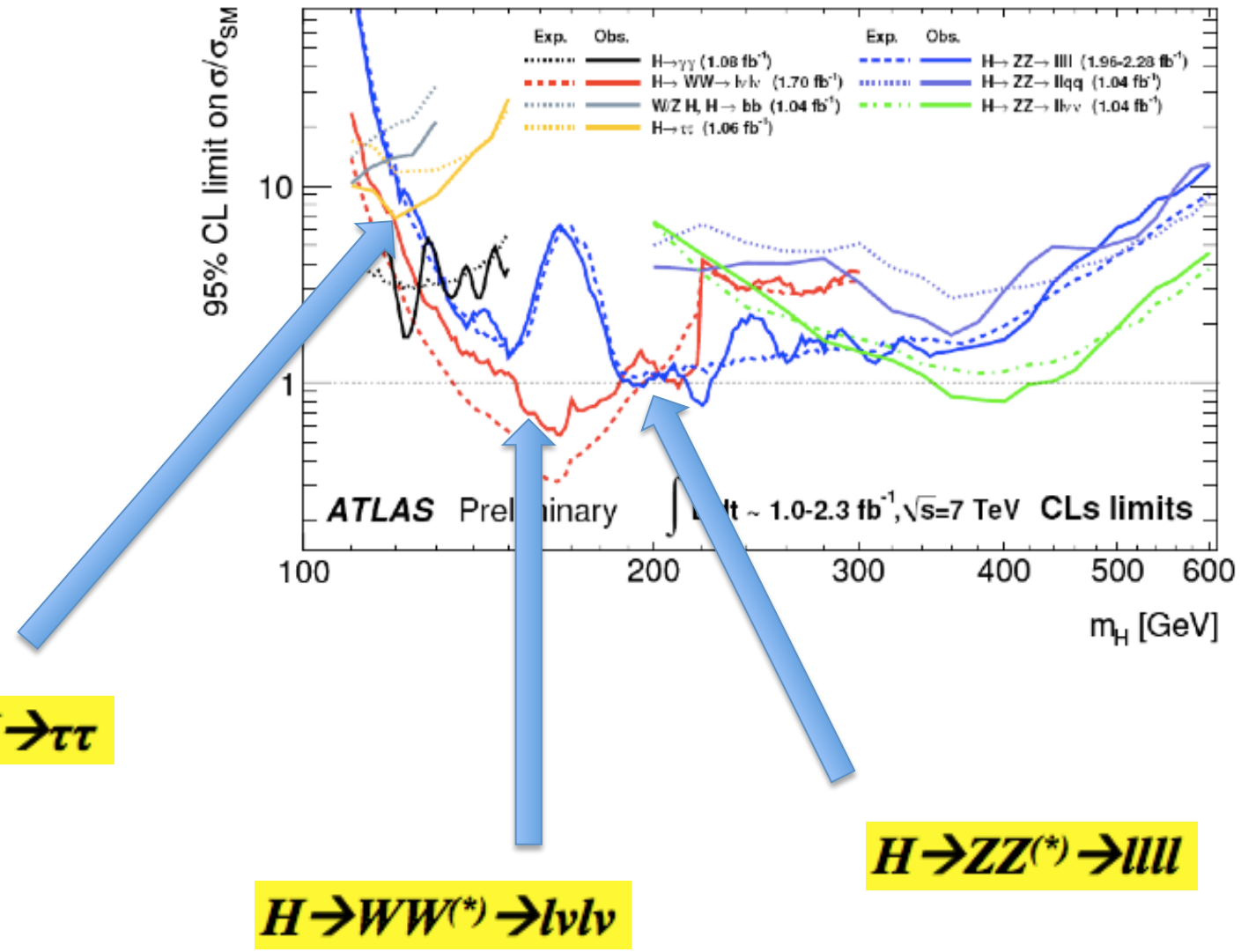
SM exclusion limit expected at around 10 fb^-1







For the rest of the channels, I will only mention the ones that have been updated with respect to last report



$H \rightarrow \tau\tau$

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

$H \rightarrow ZZ^{(*)} \rightarrow llll$

Higgs to ττ – channel now included in combination

This channel has a low branching ratio in the low ***mass range 110-140 GeV*** but has a clear Final-state signal and is therefore valuable

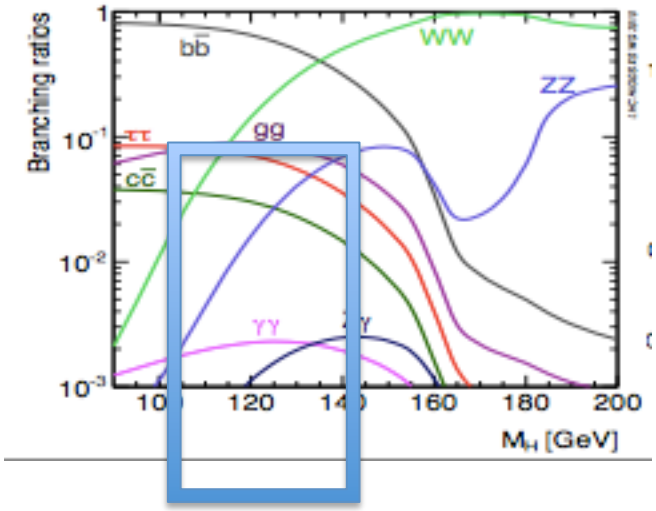
→ 2 decay modes considered :

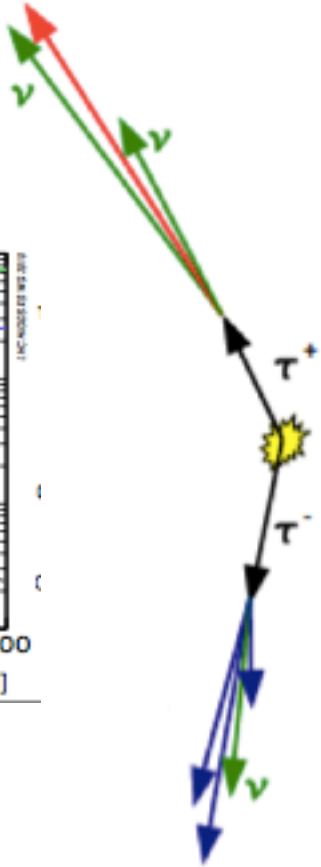
H-> ττ -> ll + 4 neutrinos

- ***Require 2 leptons and large MET***
- ***Assume neutrinos are collinear with leptons***

H-> ττ -> l + (tau)3 neutrinos

- ***Require 1 lepton from a purely leptonic tau decay and a tau candidate with large MET***





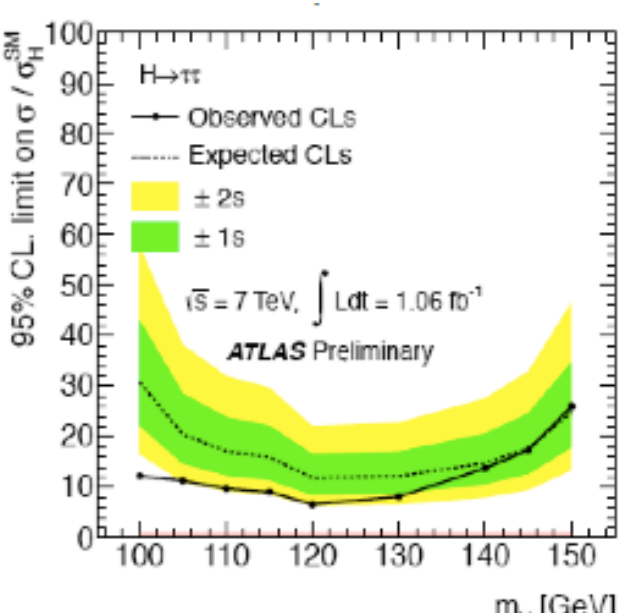
Demand of high pT jet (>40 GeV) in final state selects VBF (or NLO GF) provides boost in transverse plane and enlarges MET, which makes the event easier to distinguish from Z->ll background

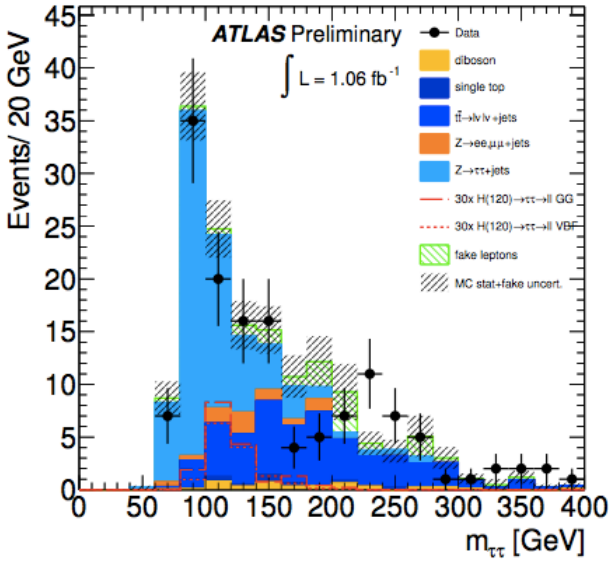
Higgs to ττ – results

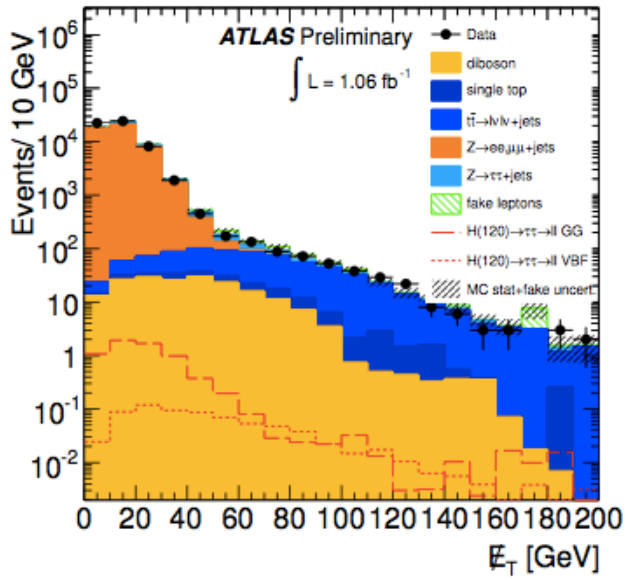
→ VBF Higgs production has larger MET values

→ Collinear assumption allows estimate of MET carried by each leptonic decay and allows for reconstruction of invariant mass

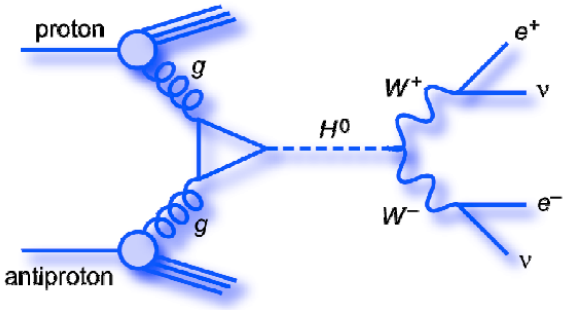
→ Results are promising – a few times SM is excluded

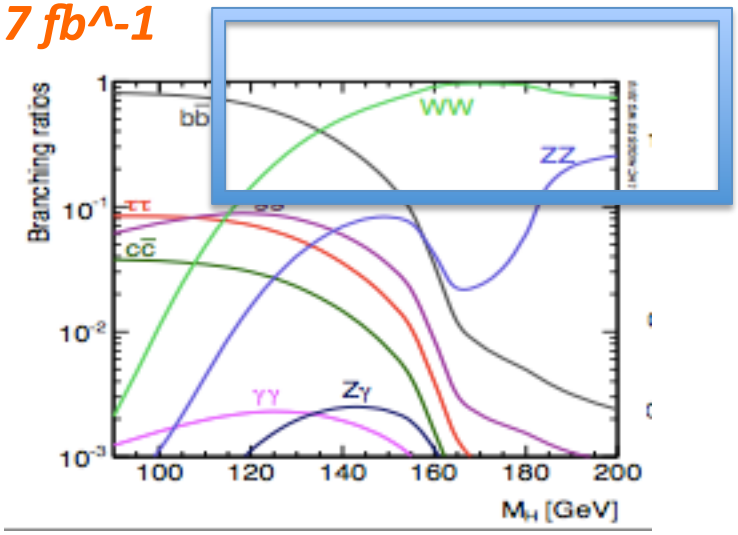






H→ WW → lvlv Channel – updated to 1.7 fb^-1





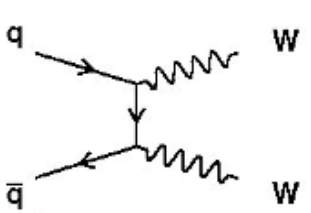
→ *This channel combines large branching fraction with clean final state*

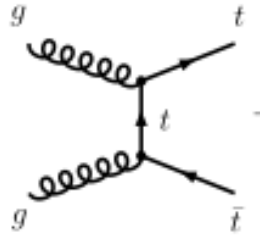
- ***Sensitive to Higgs production in range 120 < M_H < 240 GeV***
- ***has largest sensitivity of any SM channel for M_H ~ 160 GeV***

SIGNATURE

- *2 opposite sign leptons (e or mu) in final state*
- *Large MET*
- *2 categories defined (H+0 jet and H+1 jet) to tune selection according to specific backgrounds*

Dominant Backgrounds after selection are WW and tt:

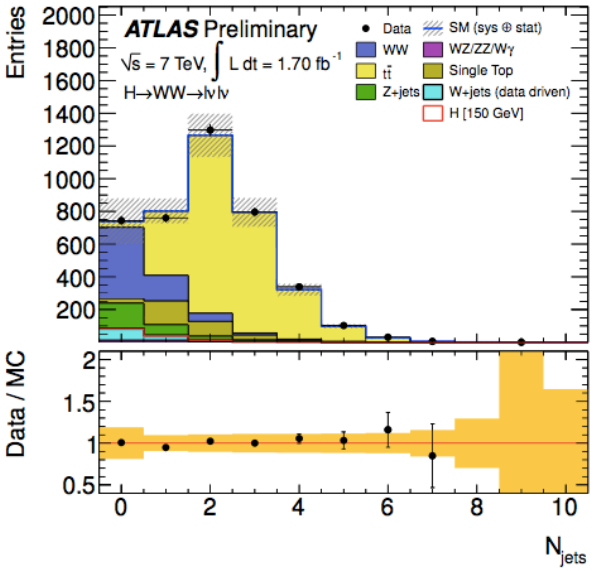




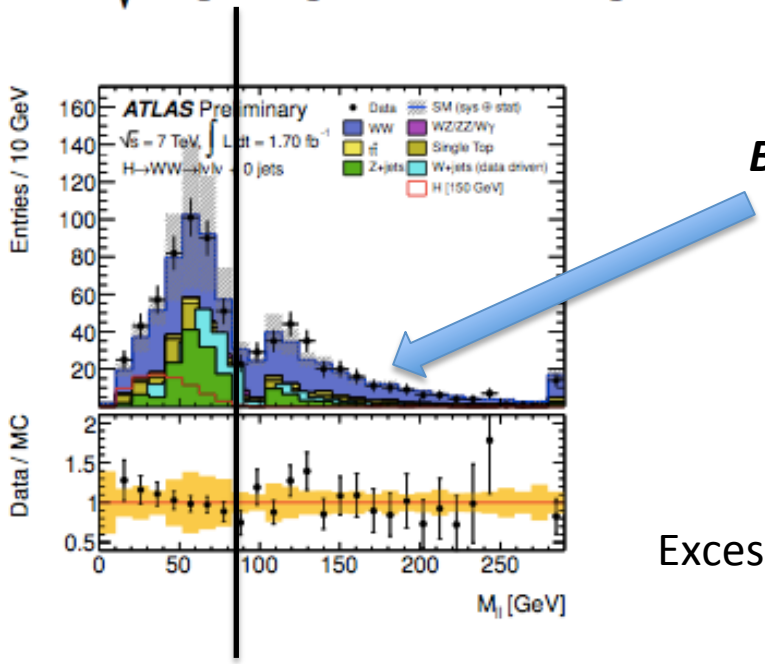
Selection and Background Estimates for H + 0 jet and H + 1 jet categories

BOTH CATEGORIES (Topological cuts)

- *|Pt ll| < 30 GeV*
- *Dileption Mll < 60 GeV*
- *Dileption opening angle in Phi < 1.8 radians*
- *Transverse mass < ~150*



$$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{P}_{\mathrm{T}}^{\ell\ell} + \mathbf{P}_{\mathrm{T}}^{\mathrm{miss}})^2}$$



→ **Jet multiplicity well described by MC**

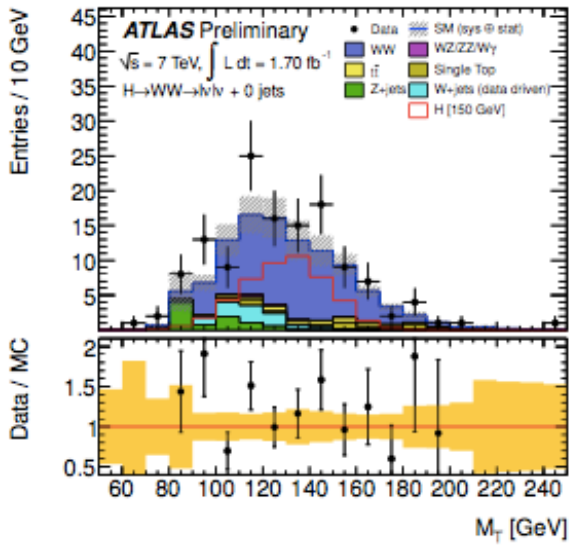
Background enriched region for SM WW

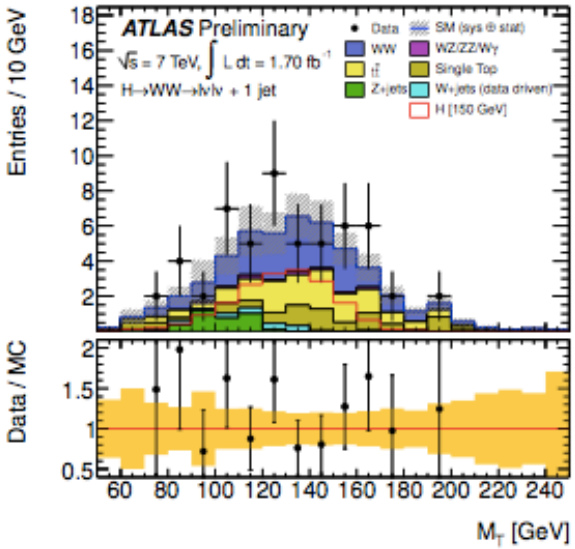
In addition, H+ 1 jet category

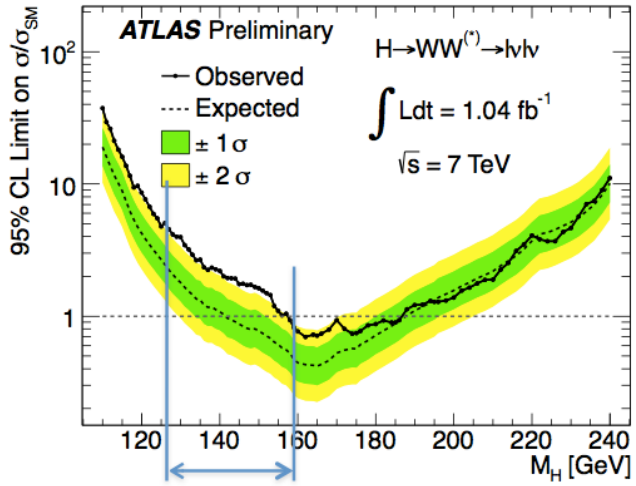
- *b-jet veto*
- *Cut on Pt of H + jet system*
- *Cut on |m_tt – m_z| < 25 GeV*

Excess in signal region is smaller with more stats…

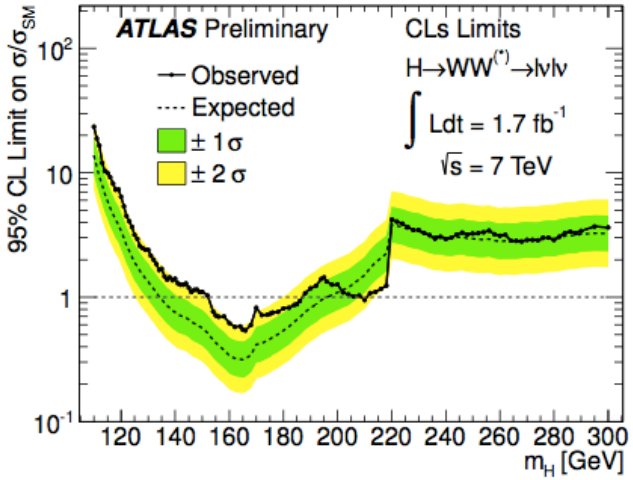
H→ WW → lvlv Channel -- Results







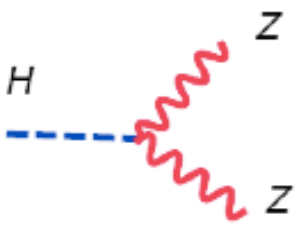
1 fb^-1



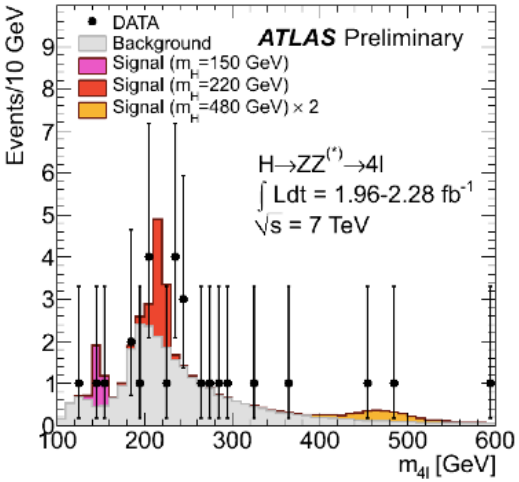
1.7 fb^-1

Excess observed in region of 130-150 GeV is now compatible with Bkg-only assumption ~2σ

H→ ZZ → 4l Channel (Golden Channel)

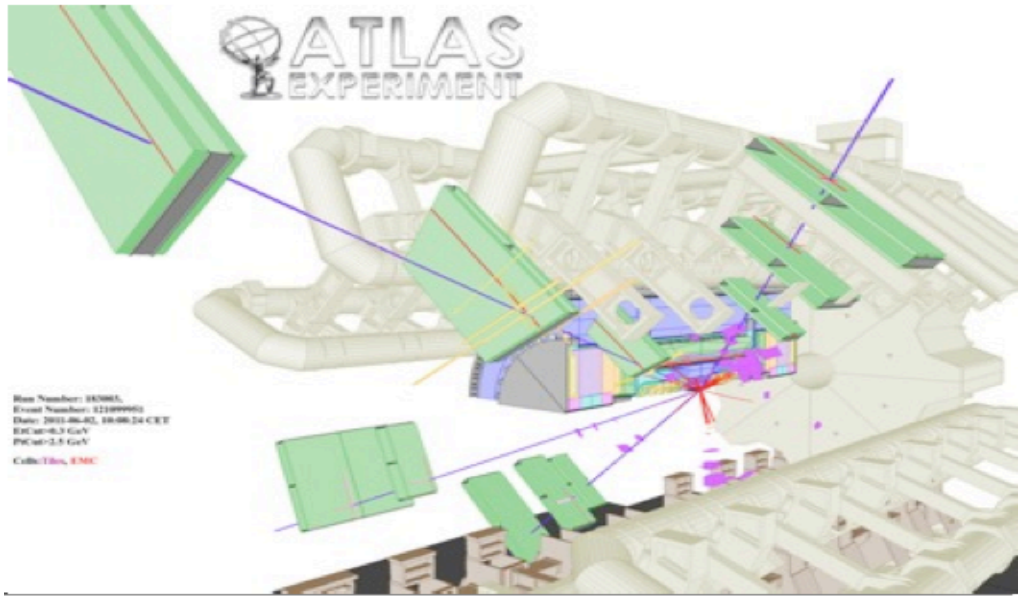


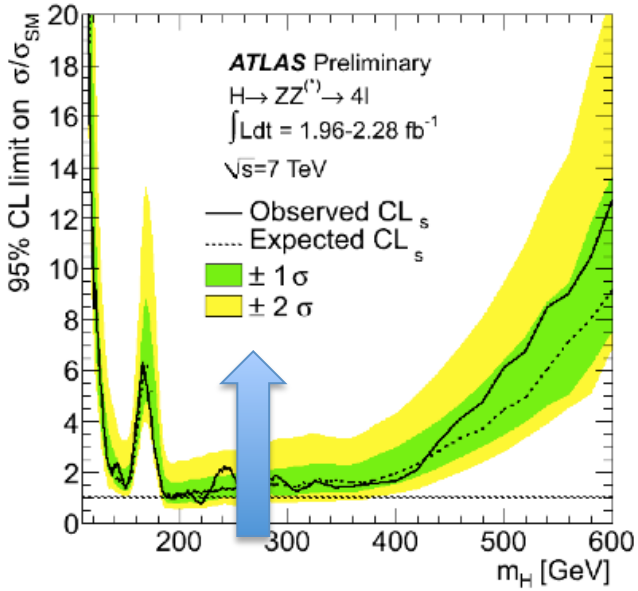
→ ***Very clean final state and relatively high branching ratio in range 110 < M_h < 600 GeV***



→ Main background is SM ZZ production, where the higgs should appear as a narrow peak over background

Analysis carried out with 2.0-2.3fb^-1 of data but only 24 events recorded





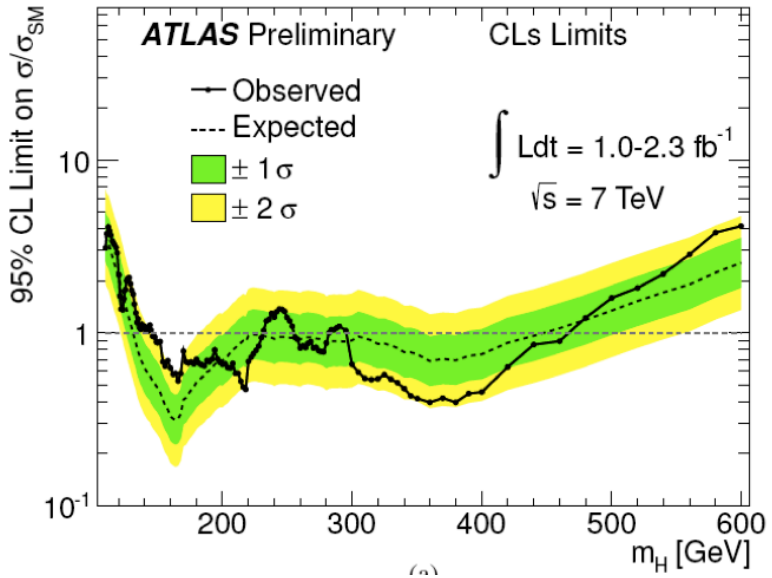
High sensitivity already despite low stats

Symmary and Conclusions

→ **An update on SM Higgs ATLAS searches has been shown**

- **H->ττ analysis now included in combined search with 1fb^-1**
- **H->llvv updated to 1.7 fb^-1 → Excess is now compatible with background only assumption**
- **H->llll has been updated with 2.0-2.3 fb^-1 and already provides exclusion limits**

→ ***The exclusion range has increased substantially with respect to last update– things are moving very fast!***



OUTLOOK

→ ***All the other channels are being currently updated to include all new data available***

→ ***Combination between ATLAS and CMS on the way***

→ ***Expect 4-5 fb^-1 by the end of 2011***
-Combination between CMS and ATLAS should leave little space for Higgs to hide…