First results on Higgs boson searches (SM + MSSM) and prospects from ATLAS

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on behalf of the ATLAS Collaboration

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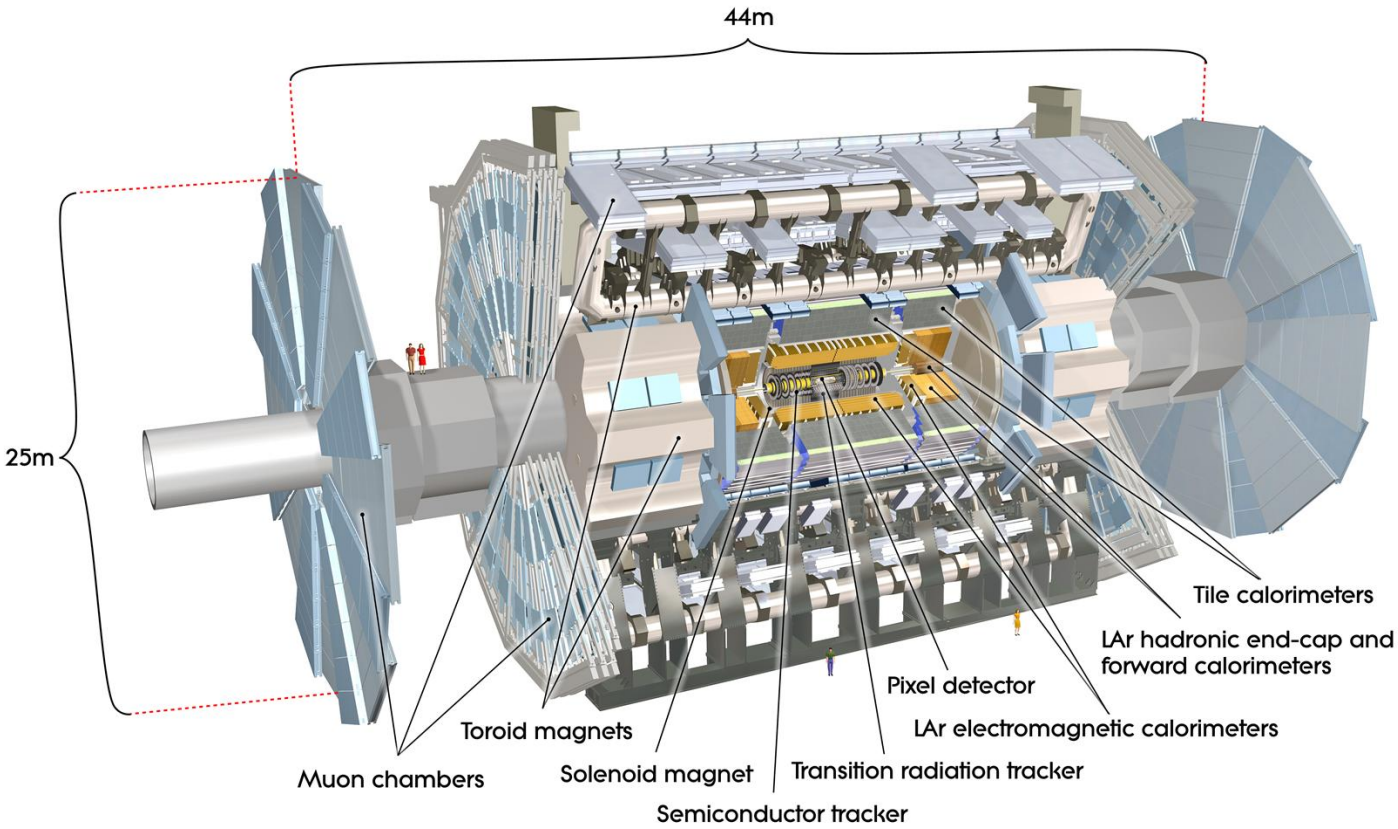
ATLAS Detector and Datasets

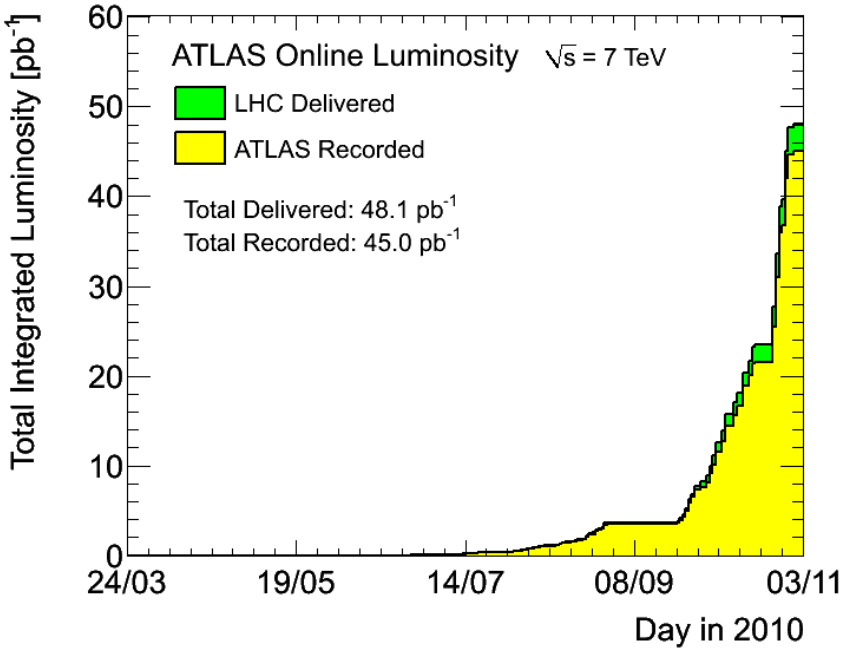
General purpose detector



Magnets:	2T solenoid 3 air-core toroids	EM Calo.:	sampling LAr technology
Tracking:	silicon + transition radiation tracker	Hadron Calo.:	plastic scintillator (barrel) LAr technology (endcap)
Muon:	independent system		

Datasets

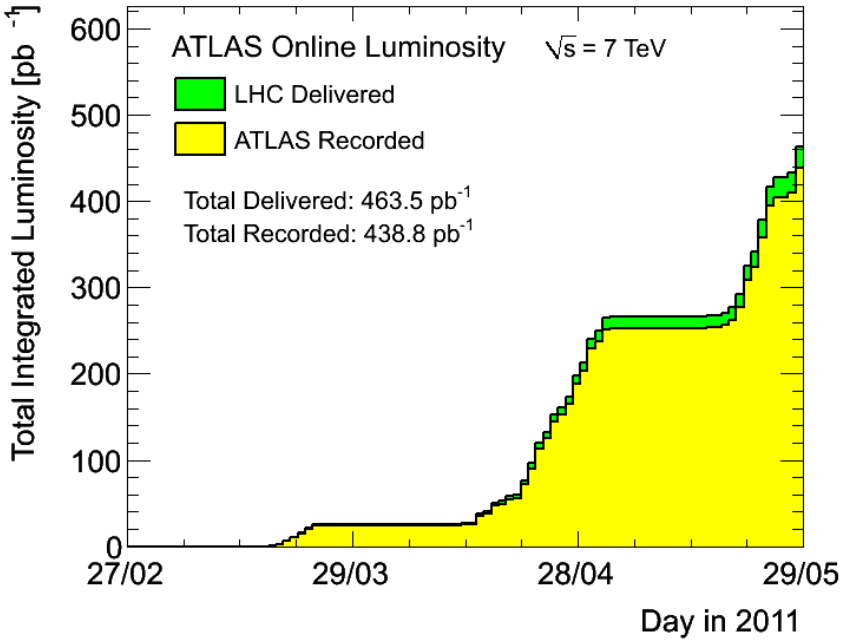
2010:



Peak Lumi.: $L \approx 2 \cdot 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Int. Lumi.: $\int L dt \approx 45\,\mathrm{pb}^{-1}$

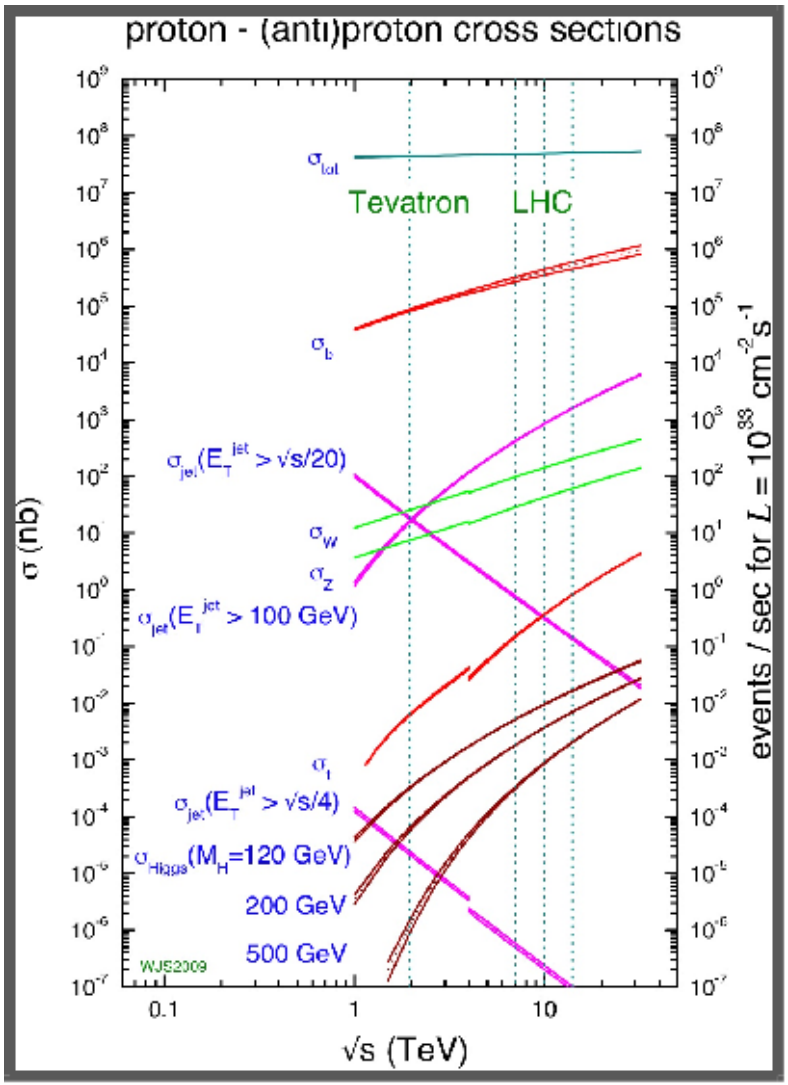
2011:



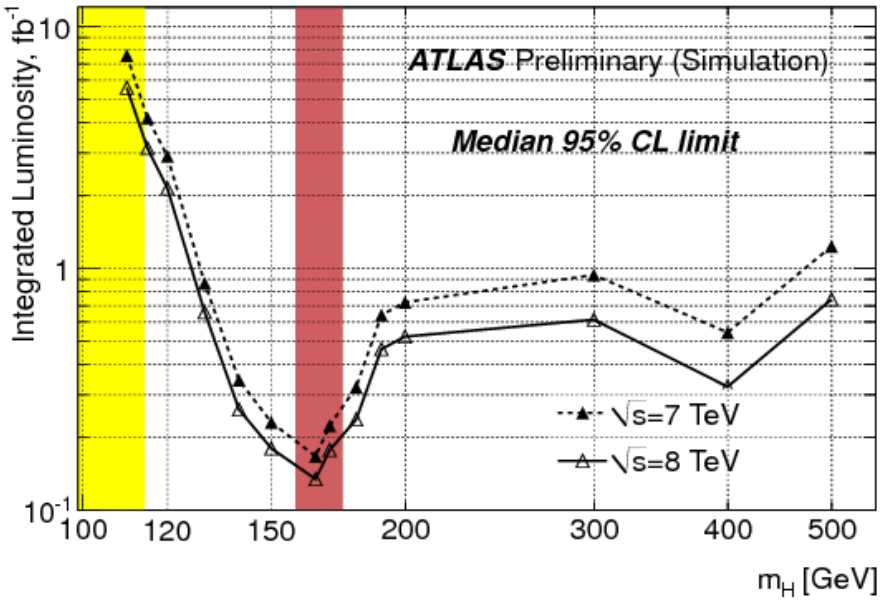
$L \approx 1.2 \cdot 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

$\int L dt \gtrsim 400\,\mathrm{pb}^{-1}$

Search for the Higgs boson



ATLAS measured most of known Standard Model (SM) processes with $\sim 40\,\mathrm{pb}^{-1}$ of data collected 2010



SM Higgs boson sensitivity will be reached soon

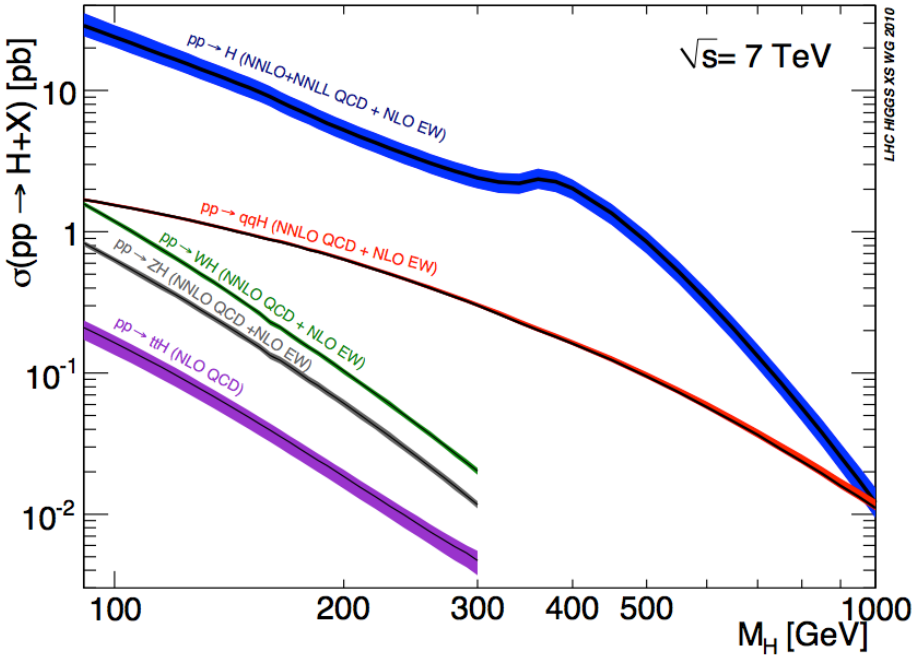
Higgs Productions at the LHC

Gluon fusion:

- known at NNLO (theo. uncert. O(15%))

Vector boson fusion:

- known at NLO (theo. uncert. O(5%))
- distinctive experimental signature: 2 forward jets and rapidity gap

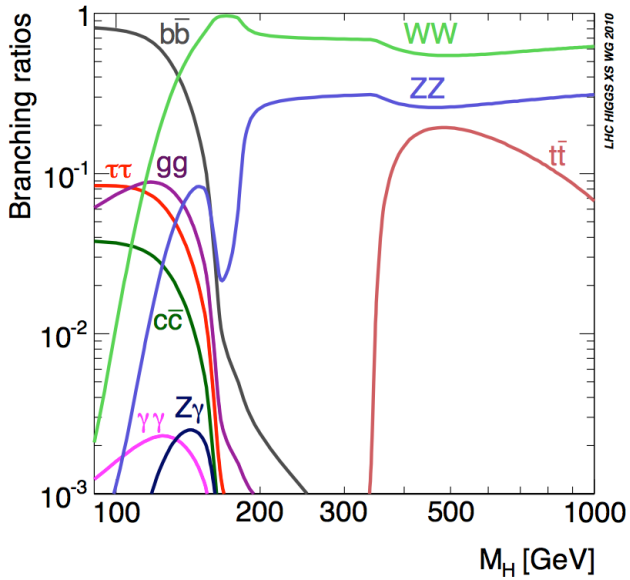


Intermediate to high m_H range:

- WW and ZZ most sensitive channels

Low to intermediate m_H range:

- $\gamma\gamma$: very clean but small BR
- $\tau\tau$: VBF to reduce BG
- bb: huge QCD BG, some potential in assoc. prod.

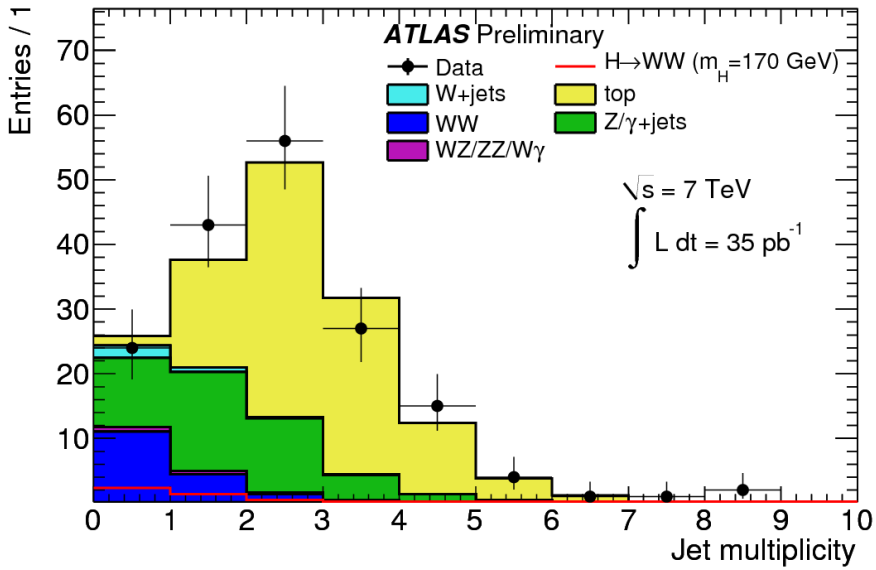


Intermediate m_H: $H \to WW^{(*)} \to \ell\nu\,\ell\nu$

- Most sensitive channel in the $m_H = 130$-190 GeV range
- large event yields and clean signature by lack of mass resolution
- Main backgrounds: WW, di-bosons (WZ/ZZ/Wγ), W/Z+Jets, Drell-Yan, top, QCD

Common pre-selection:

- 2 isolated high p_T leptons
- suppress low mass resonances with lower bound cut on $m_{\ell\ell}$
- Z^0 veto ($|m_{\ell\ell} - m_Z| > 10$ GeV)
- $\not{E}_T$
- transverse plane angle $\Delta\phi_{\ell\ell}$ cut



Exclusive analysis in bins of jet multiplicities:

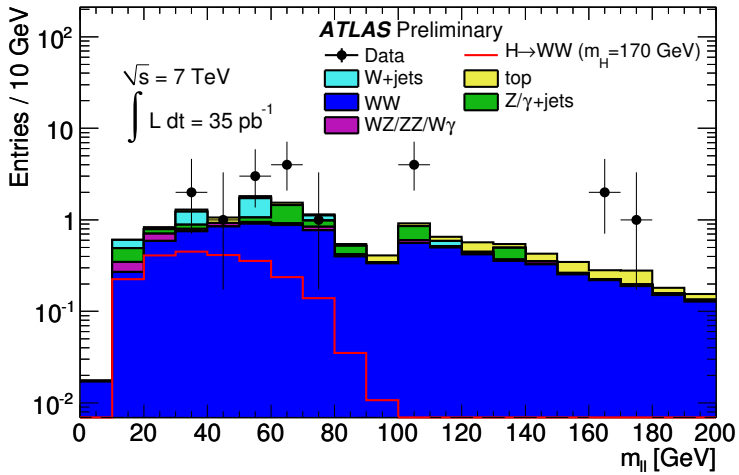
- 0-jets: optimized for gluon-fusion, purest channels, least affected by top BG
- 1-jet: more affected by top BG
- 2-jets: optimized for VBF (tag jets in opposite hemispheres, rapidity gap), small signal expected

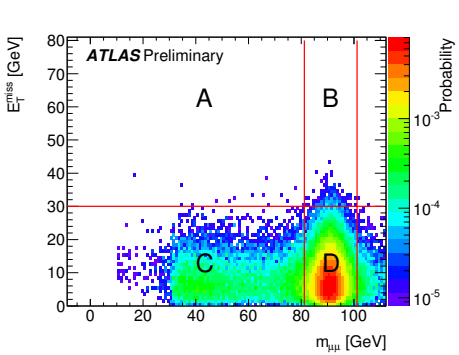
$H \to WW^{(*)} \to \ell\nu\,\ell\nu$ Background estimation

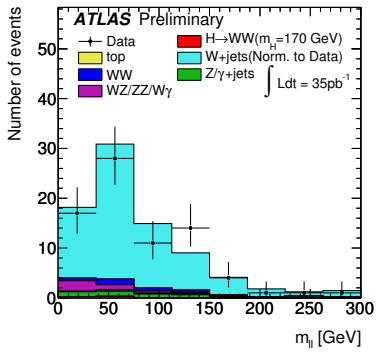
Data driven techniques to estimate each contribution

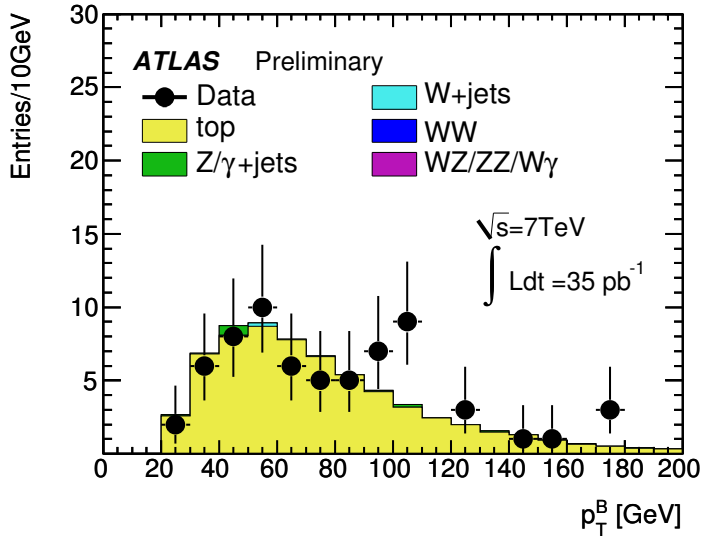
- Main backgrounds estimated in control regions, extrapolated into signal region
- Cross-contamination of different backgrounds in various control regions taken into account

- WW background from side-bands in $m_{\ell\ell}$ and m_T:
  - small $m_H \to$ high $m_{\ell\ell}$ WW dominated
  - large $m_H \to$ low $m_{\ell\ell}$ WW dominated
- Top: estimate jet-veto efficiency in enriched samples with b-tagging
- W+jets:
  - kinematic from control sample with relaxed lepton ID
  - lepton fake probability from independent jet-trigger sample
- Z+jets: background estimated using ABCD method in $m_{\ell\ell}$ - MET plane



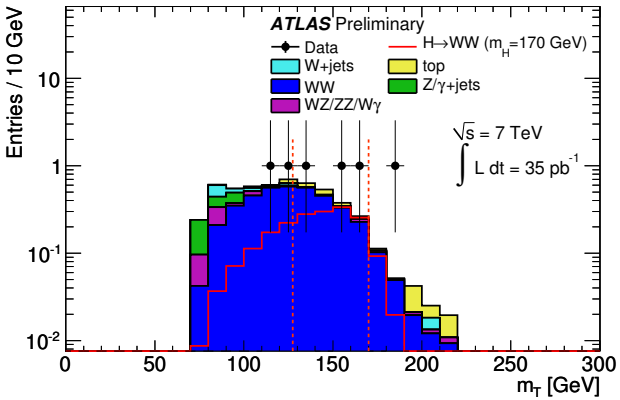


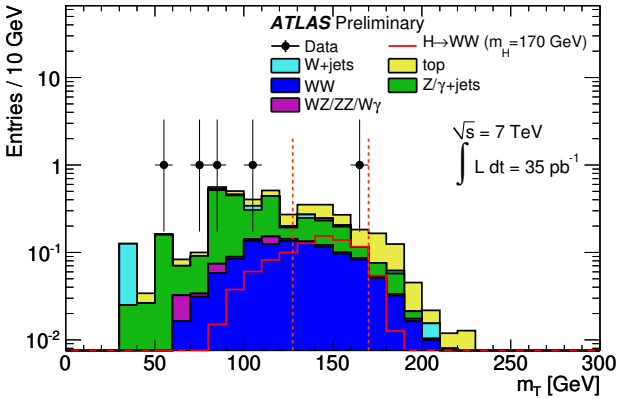




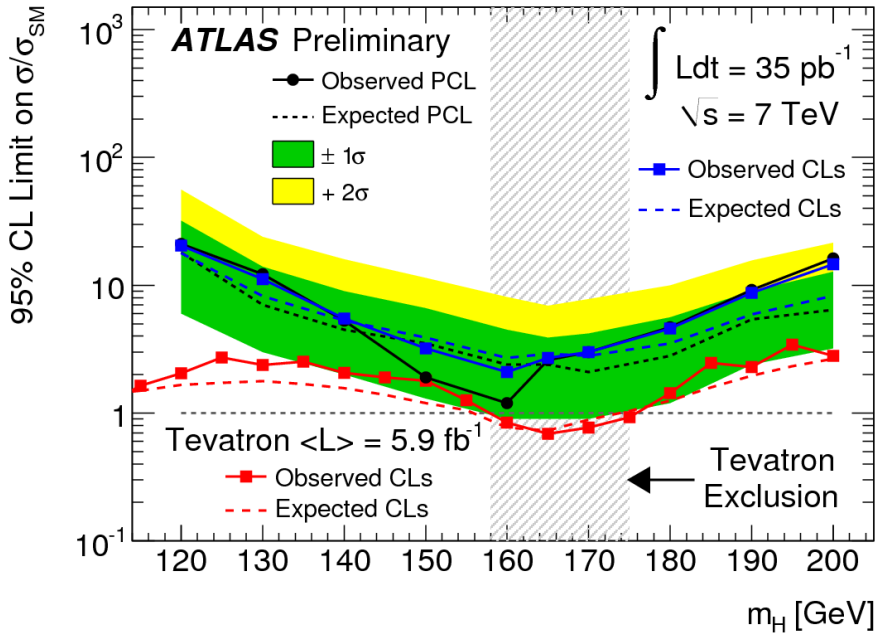
$H \to WW^{(*)} \to \ell\nu\,\ell\nu$ Results

- Analysis optimized in each jet-bin and for each mass hypothesis
- final discriminating observable: transverse mass $m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - (P_T^{\ell\ell} + P_T^{miss})^2}$





m_H=170 GeV	0-Jets	1-Jet	2-Jets
Data	3	1	0
BG	1.8±0.1	1.2±0.1	0.02±0.01
Higgs	1.26±0.02	0.6±0.01	0.6±0.01



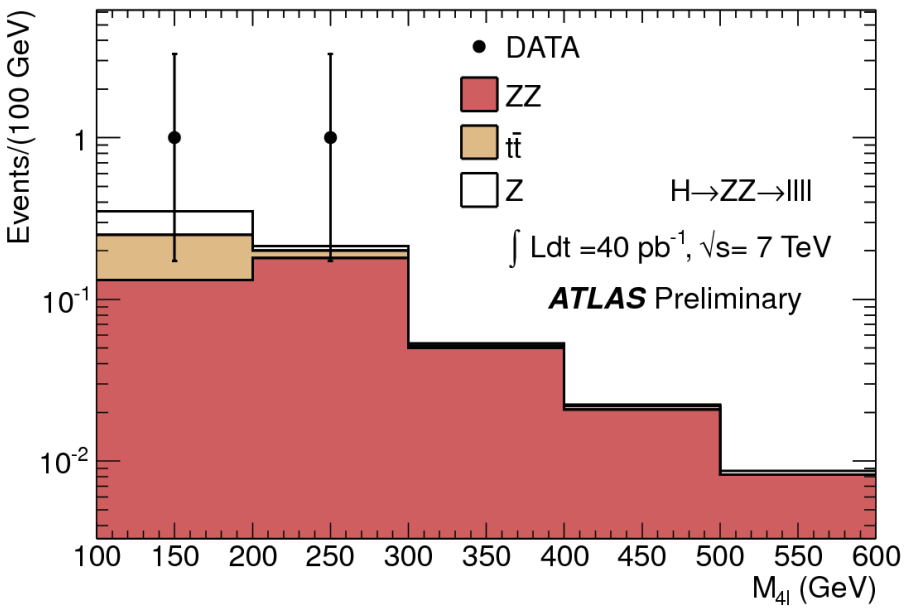
Most sensitive around m_H=160 GeV for SM-like Higgs boson

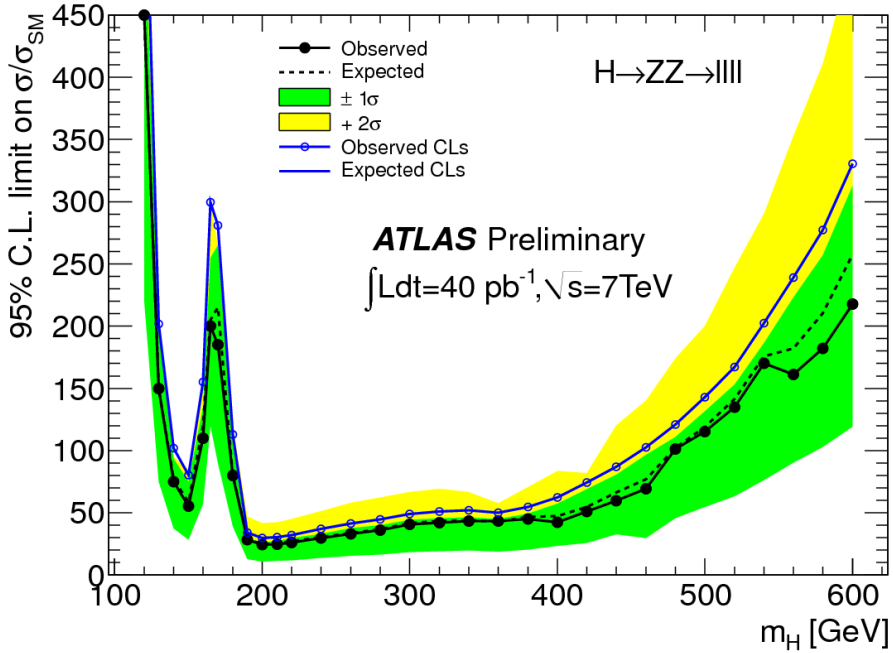
$H \to ZZ^* \to 4$ LEPTONS

Clean unambiguous signature, low background, robust against pileup but small event yield due to low Z^0 leptonic BR, golden channel to measure m_H

Simple selection:

- two pairs of opposite sign and same flavor leptons p_T>20 GeV
- consistent with 2 Z^0 decays
- isolated leptons without significant impact parameter





for $m_H \approx 200$ GeV sensitivity comparable with other channels due to clean signature

High m_H: $H \to ZZ \to \ell\ell(qq/\nu\nu)$

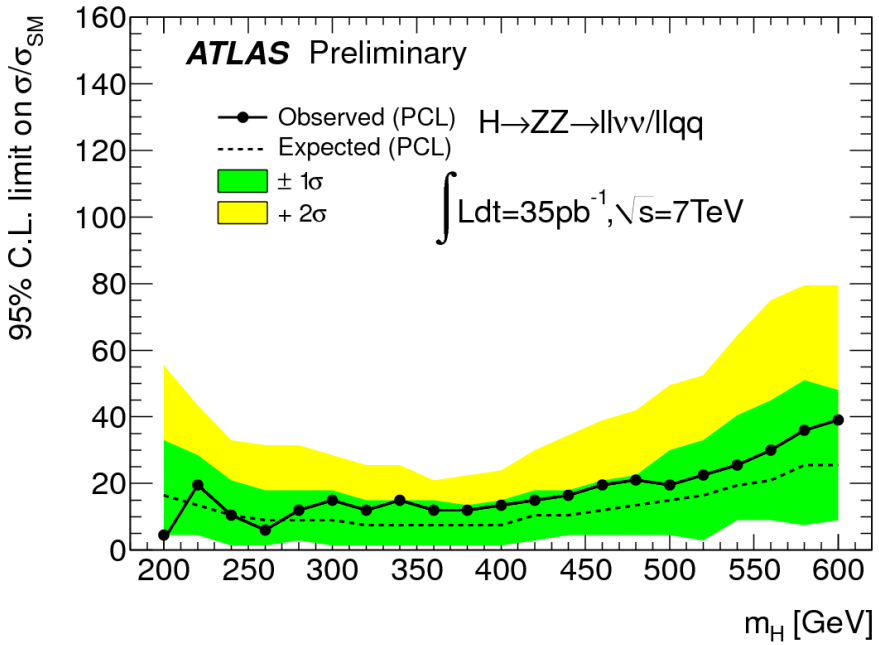
Much less clean topologies compared to 4ℓ channel, but a factor $\sim$27 higher BR (for $\ell\ell qq$)
More sensitive than 4ℓ for large m_H when background from W/Z+jets get small
Backgrounds:

- Z/W+jets, $t\bar{t}$ control regions from sidebands in m_{jj} and $m_{\ell\ell}$ and reversed cuts, backgrounds estimated with MC and normalization checks from control regions
- Background from QCD multi-jets negligible (checked with data-driven techniques with relaxed lepton-ID)
- Di-boson background (ZZ/WW/WZ) estimated from MC

Analysis optimized for low and high m_H:

	llqq m_H<360 GeV	llqq m_H>360 GeV
Data	216	11
BG	226 ±28	9.88 ± 1.75
Higgs	0.60±0.12 (m_H=200 GeV)	0.24±0.05 (m_H=400 GeV)

	ll$\nu\nu$ m_H<280 GeV	ll$\nu\nu$ m_H>280 GeV
Data	5	5
BG	5.76 ± 1.38	3.45 ± 0.86
Higgs	0.19±0.04 (m_H=200 GeV)	0.30 ± 0.06 (m_H=400 GeV)

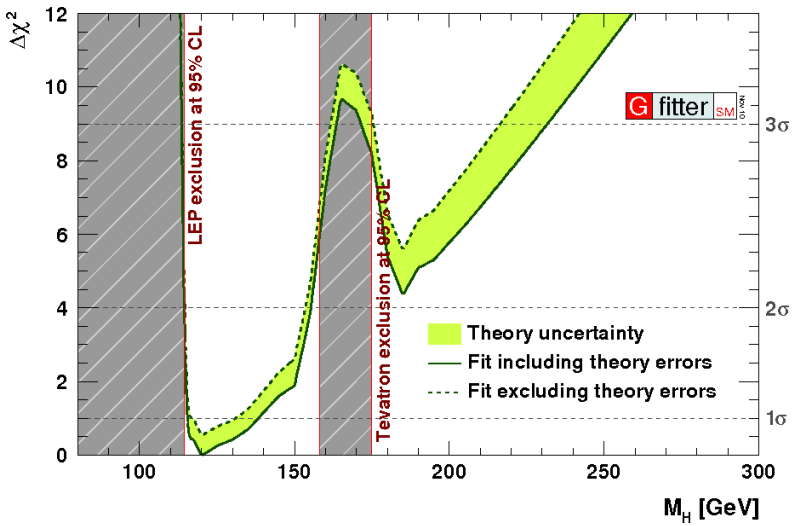


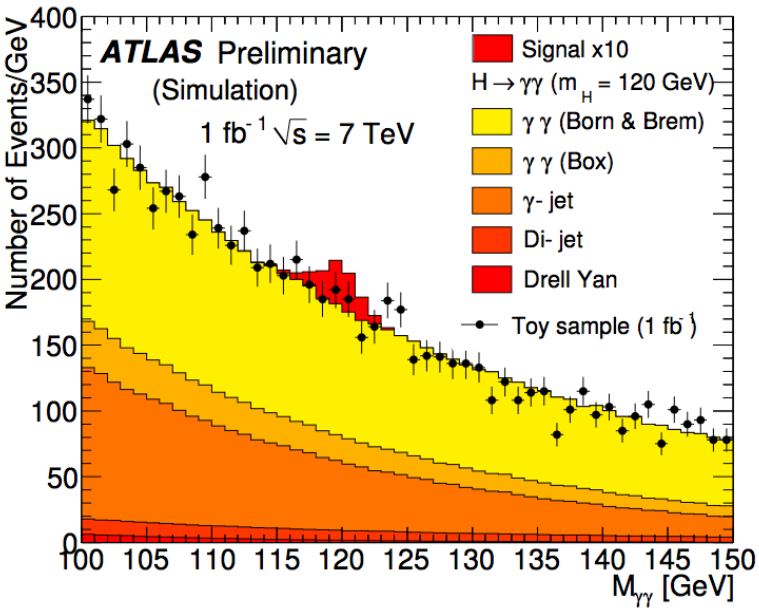
no excess observed in data

Cross section limits at $\sim$10 x σ_{SM}

Low m_H search: $H \to \gamma\gamma$

- SM prefers light Higgs Boson, m_H<158 GeV
- $H \to \gamma\gamma$ has small BR (∼0.2%), but largest event yield after all cuts at low m_H
- Expect 25 events/fb^{-1} at $\sqrt{s} = 7$ TeV (includes all efficiencies)





Backgrounds:

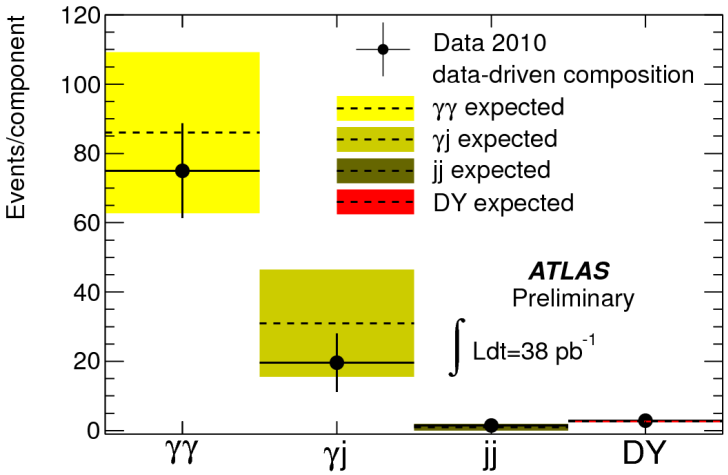
- irreducible: $\gamma\gamma$
- reducible: γ-Jet, Jet-Jet (handles: mass resolution, photon-ID, isolation)

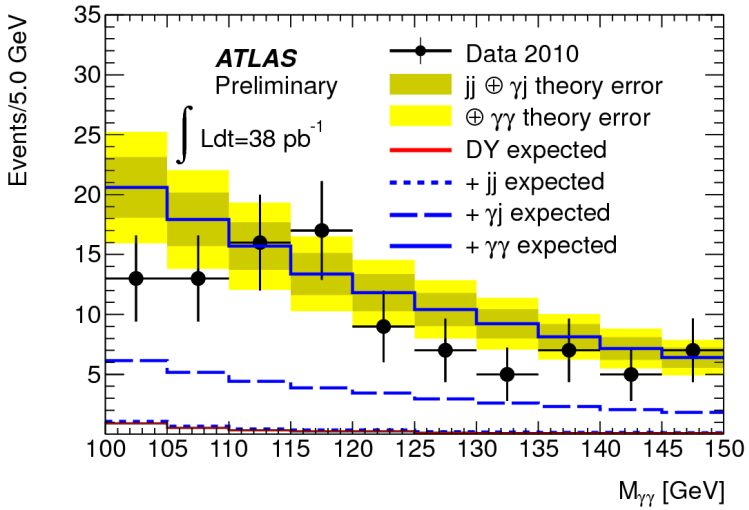
Experimental requirements:

- excellent mass resolution
- precise primary vertex reconstruction
- photon pointing and conversions tracks

$H \to \gamma\gamma$ RESULTS

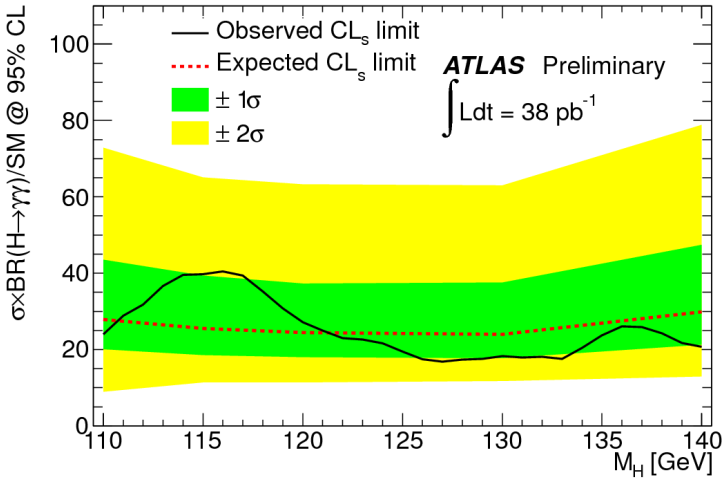
Backgrounds estimated with data-driven techniques:





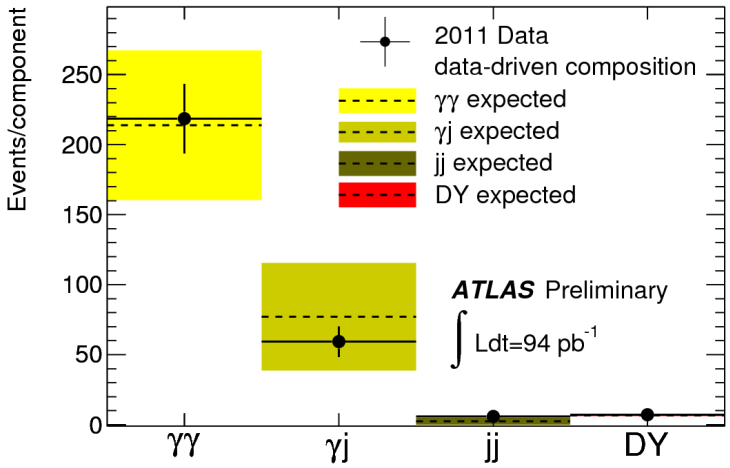
Exclusion limits:

- m_H=127 GeV: 8 x σ_{SM}
- m_H=116 GeV: 38 x σ_{SM}
- Sensitivity close to current Tevatron limits

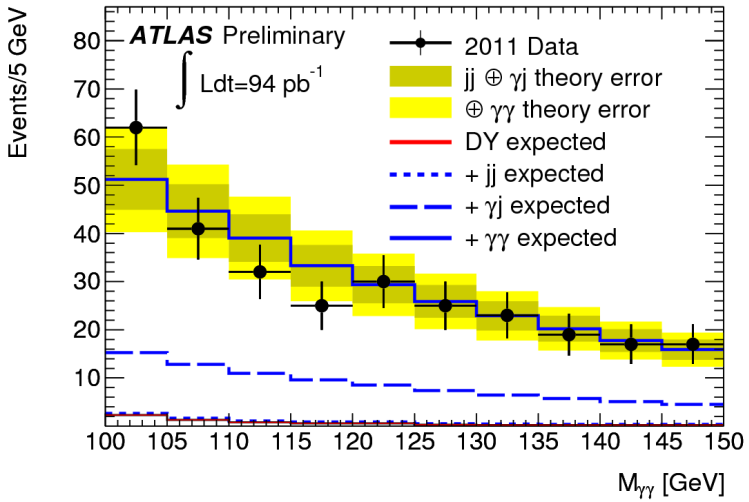


$H \to \gamma\gamma$ RESULTS, 2011 UPDATE

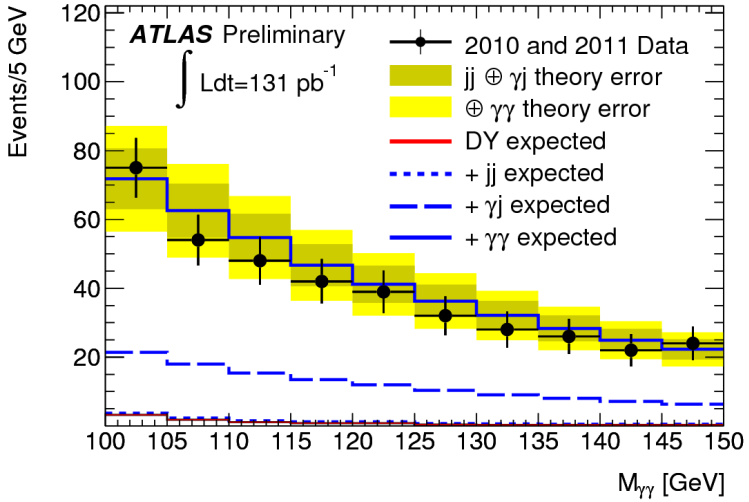
2011:



2011:



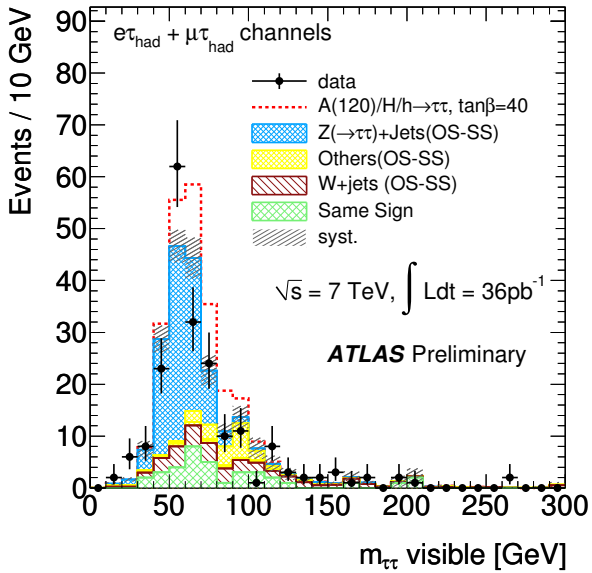
2010+2011:



SUSY Higgs: $h/H/A \to \tau\tau$

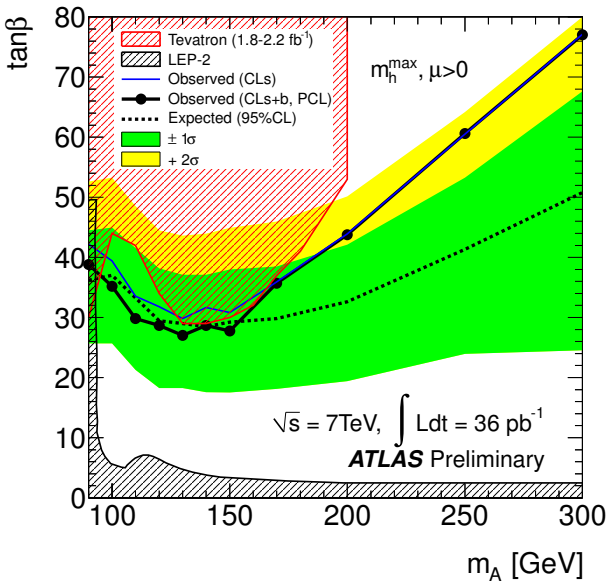
- MSSM Higgs sector: 5 bosons h, H, A, H^+, H^- with 2 parameters m_A, $\tan\beta$ at LO
- Higgs coupling to b, τ enhanced for high $\tan\beta \to$ Search for: $h \to \tau\tau$ ($\ell\tau_{had}3\nu$,$e\mu4\nu$)
- Backgrounds: $Z \to \tau\tau$, ($Z \to \ell\ell$, W+jets (ℓh), $t\bar{t}(e\mu)$, QCD)
- Use of data-driven techniques to predict QCD and W+jets BG from same sign data.
- Main background $Z \to \tau\tau$ estimated from MC and shape validated with embedding technique using data

$m_{\tau\tau}$ (visible) after all cuts:



	Data	Total BG	h/H/A $\tan\beta = 40$ m_A=120 GeV
$\ell\tau_{had}$	206	206±35	55.3 ±0.9
$e\mu$	70	63±7	15.2±0.3

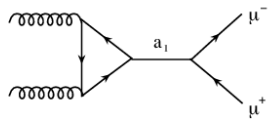
Limits in (m_A, $\tan\beta$) plane:



extends Tevatron exclusion region

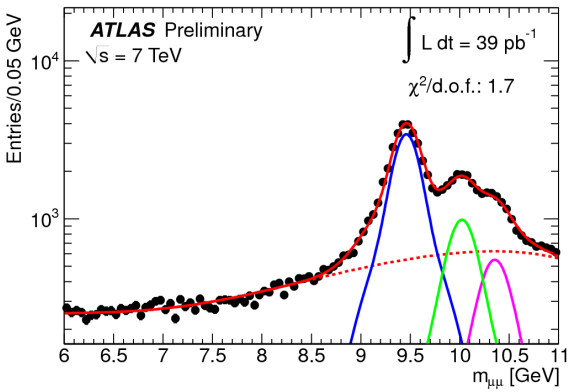
Light *CP*-odd Higgs boson in $\mu\mu$ final state

- In NMSSM: additional singlet complex field leads to additional CP-even and odd Higgs
- For low CP-odd masses ($m_{a1} < 2m_b$) lightest CP-even Higgs avoids LEP limits
- Search for direct production in 6-9 GeV and 11-12 GeV mass range, avoiding Υ resonances

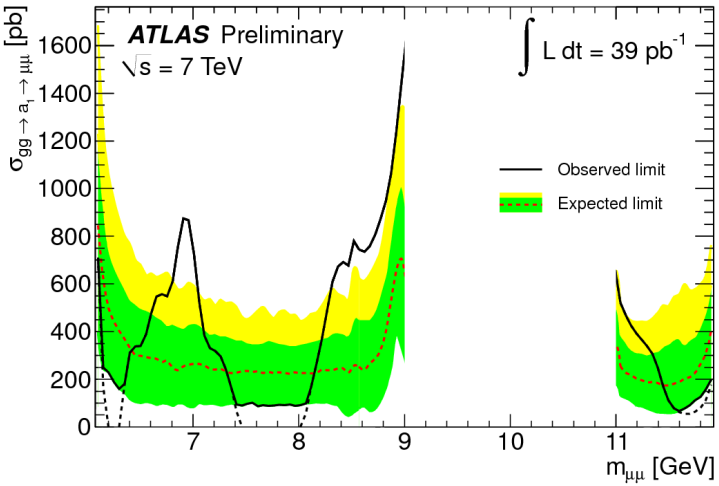


Selection:

- two isolated muons with $p_T > 4$ GeV
- Likelihood-ratio selection on primary vertex χ^2/ndf and calorimetric isolation, PDFs derived from data



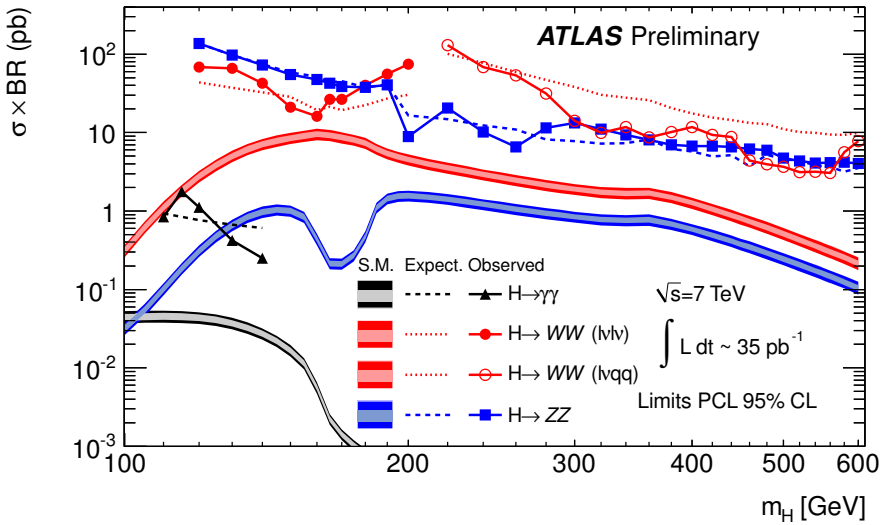
No significant excess in data, limits on σxBR



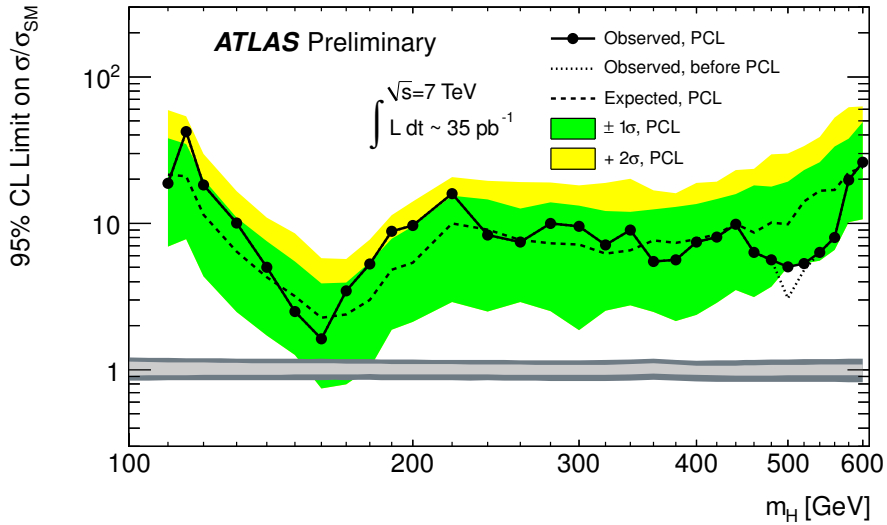
Combination for SM Higgs boson search (I)

Combination of SM Higgs boson decay channels for m_H = 110 - 600 GeV:
$H \to \gamma\gamma$, $H \to ZZ^{(*)} \to \ell\ell\ell\ell$, $H \to ZZ \to \ell\ell\nu\nu$, $H \to ZZ \to \ell\ell qq$,
$H \to WW^{(*)} \to \ell\nu\ell\nu$, $H \to WW \to \ell\nu qq$

Individual limits:



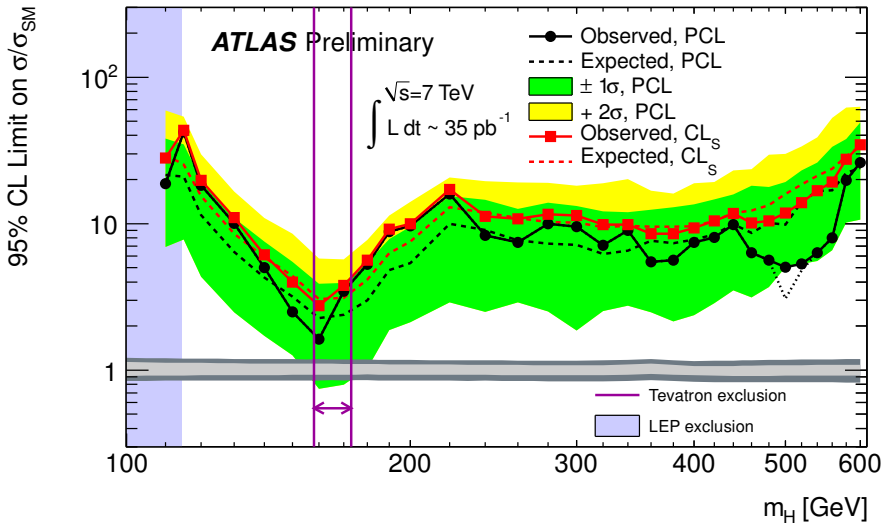
Combination:



m_H= 160 - 170 GeV expected exclusion 2.3 x σ_{SM}

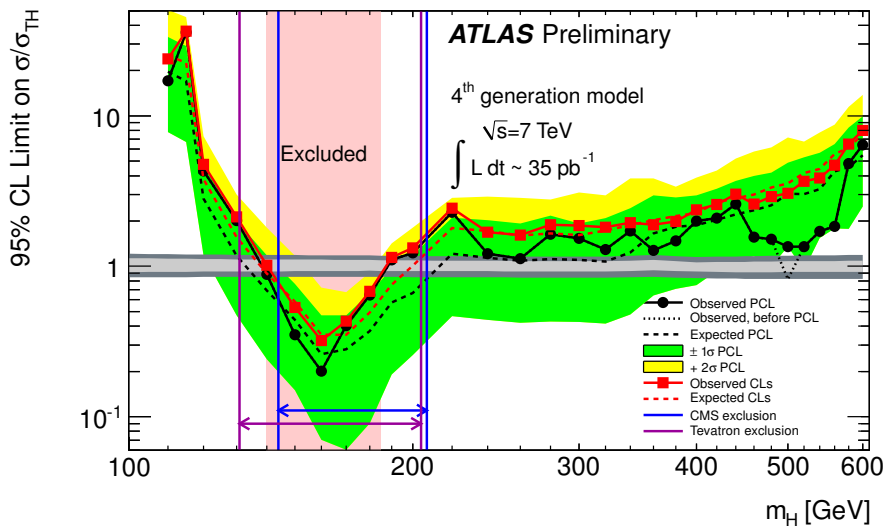
Combination for SM Higgs boson search II

CL_s limits and other experiments:



4th generation exclusion:

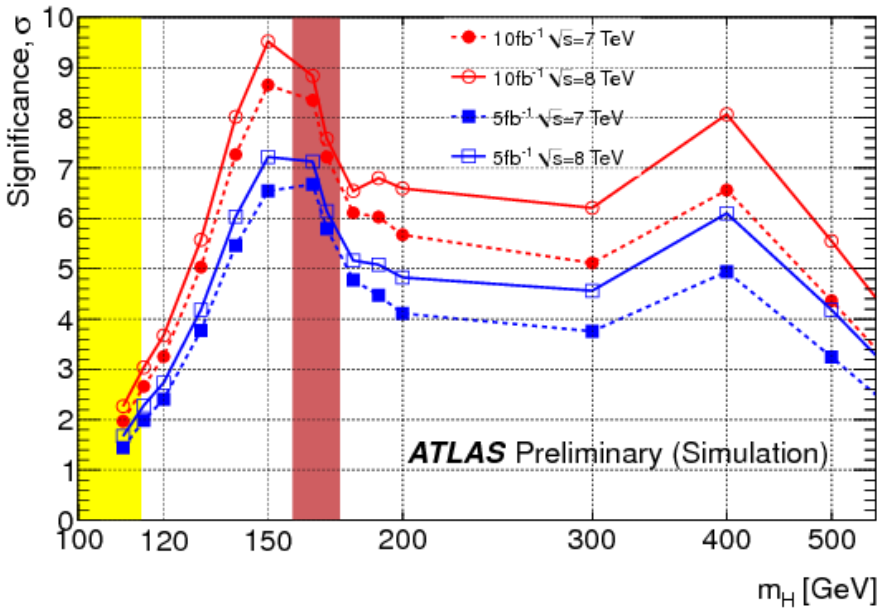
(with 4th generation of high mass quarks and leptons with SM-like couplings to the Higgs boson)

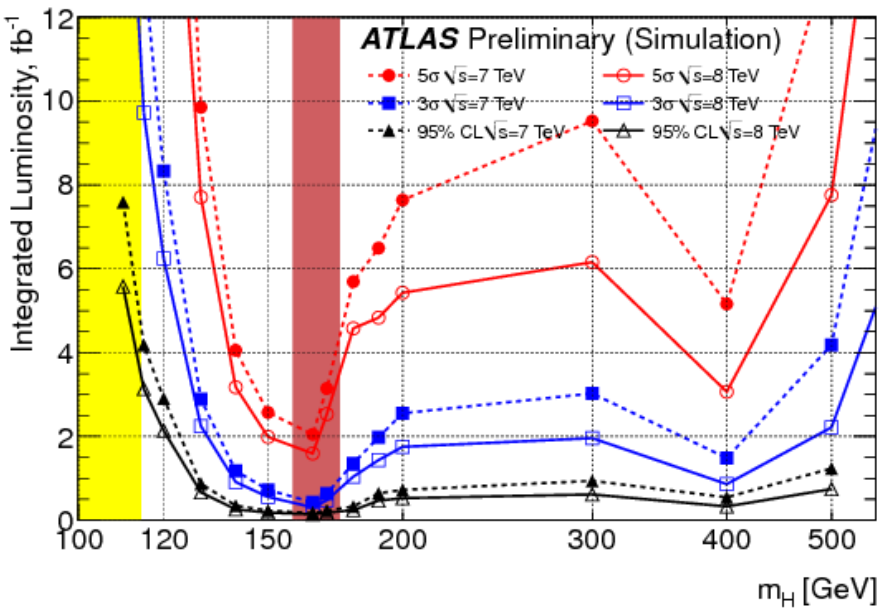


Exclusion for $m_H^{4th} = 140$ - 185 GeV

Summary and Future perspectives

- ATLAS detector performs very well, but no hint for Higgs at LHC with $\sim$40 pb^{-1} yet: inclusive and simple cut-based selections
- 1-3 fb^{-1} are expected in 2011 ($\sim 1\mathrm{fb}^{-1}$ until June) and more in 2012 $\rightarrow$ ATLAS will be able to make a statement about the SM Higgs boson existence over a large m_H range





with <4 fb^{-1} we could exclude down to LEP limit, but hopefully we will not do so!

Documentation

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/

$H \to \gamma\gamma$	ATLAS-CONF-2011-071, ATLAS-CONF-2011-025
$H \to ZZ$	ATLAS-CONF-2011-048, ATLAS-CONF-2011-026
$H \to WW$	ATLAS-CONF-2011-052, ATLAS-CONF-2011-005
$h/H/A \to \tau\tau$	ATLAS-CONF-2011-024
CP-odd Higgs boson in $\mu\mu$	ATLAS-CONF-2011-020
Charged Higgs	ATLAS-CONF-2011-018, ATLAS-CONF-2011-051

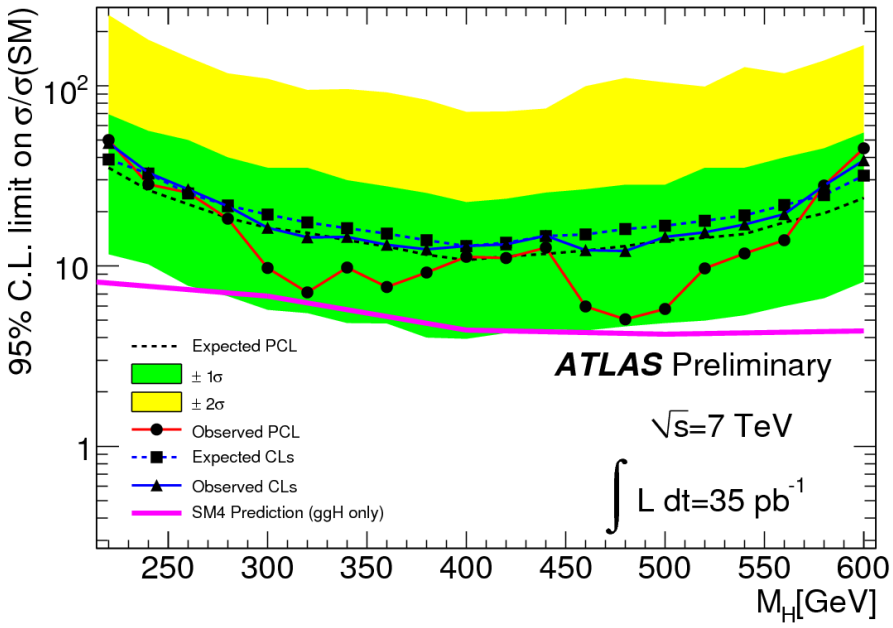
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/WebHome

SM Higgs Combination	ATLAS-HIGG-2011-01-002, CERN-PH-EP-2011-076

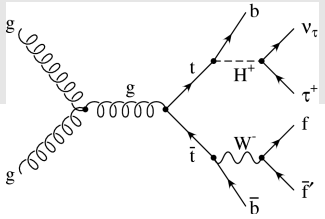
BACKUP

High m_H: $H \to WW \to \ell\nu qq$

- Most sensitive channel when m_H>400-500 GeV
- Cross section limits at ∼10-20 x σ_{SM}

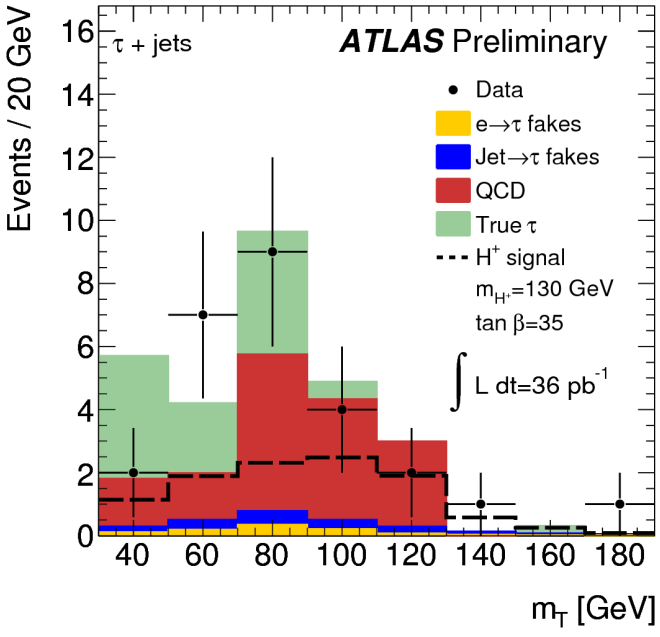


SUSY Higgs: $H^{\pm} \to \tau_h \nu$



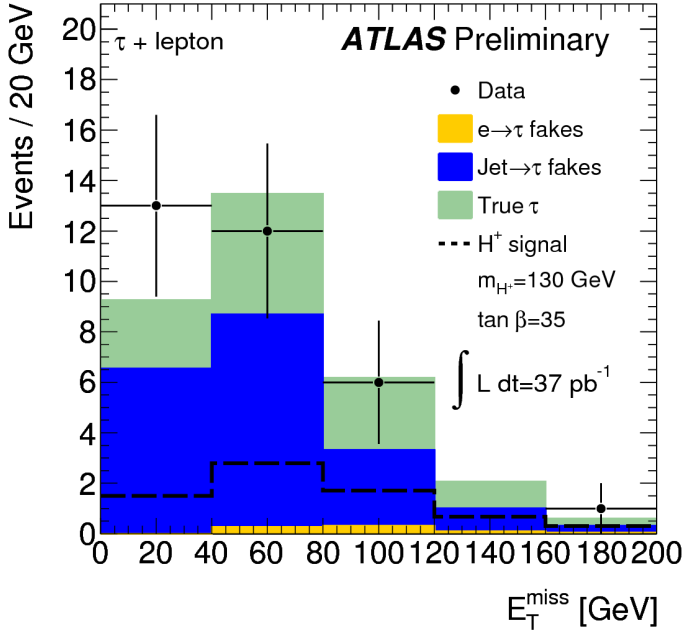
Hadronic tau, hadronic W:

- $b\tau_{had}\nu bqq$ ie. 1 τ-jet, 2b, 2q, 2ν
- largely data driven SM estimates
- good agreement so far



Hadronic tau, leptonic W:

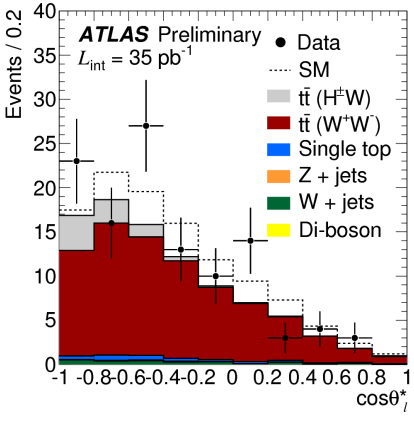
- $b\tau_{had}\nu b\ell\nu$ ie. 1 τ-jet, 2b, 1ℓ, 3ν
- largely data driven SM estimates
- good agreement so far

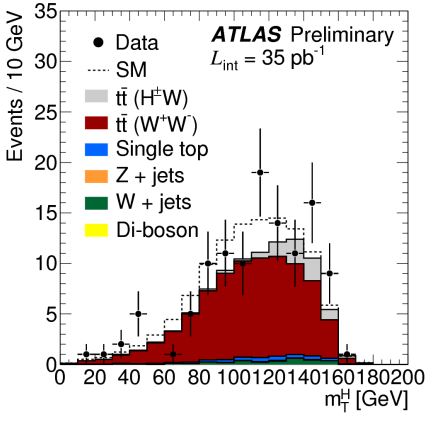


SUSY Higgs: $H^{\pm} \to \tau_{e/\mu}\nu$

Leptonic τ, hadronic W:

- $b\tau e/\mu\nu bqq$ ie. 1 ℓ , 2b, 2q, 3ν
- SM estimates from MC only
- Distributions of discriminating variables
- fair agreement with SM
- signal alters the distributions
- more luminosity needed to distinguish





Leptonic τ, leptonic W :

- $b\tau e/\mu\nu b\ell\nu$ ie. 2ℓ , 2b, 4ν
- similar plots (not shown)
- exclusion plots for 1 fb^{-1} MC study