Rare Higgs Boson Decays at ATLAS

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On behalf of ATLAS Collaboration

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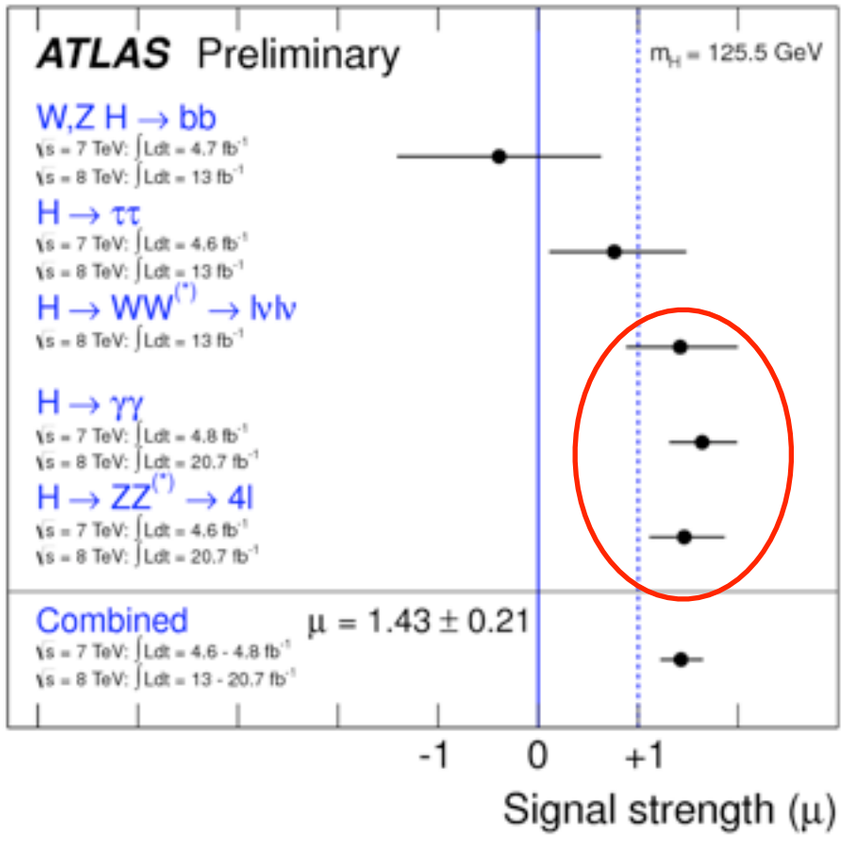
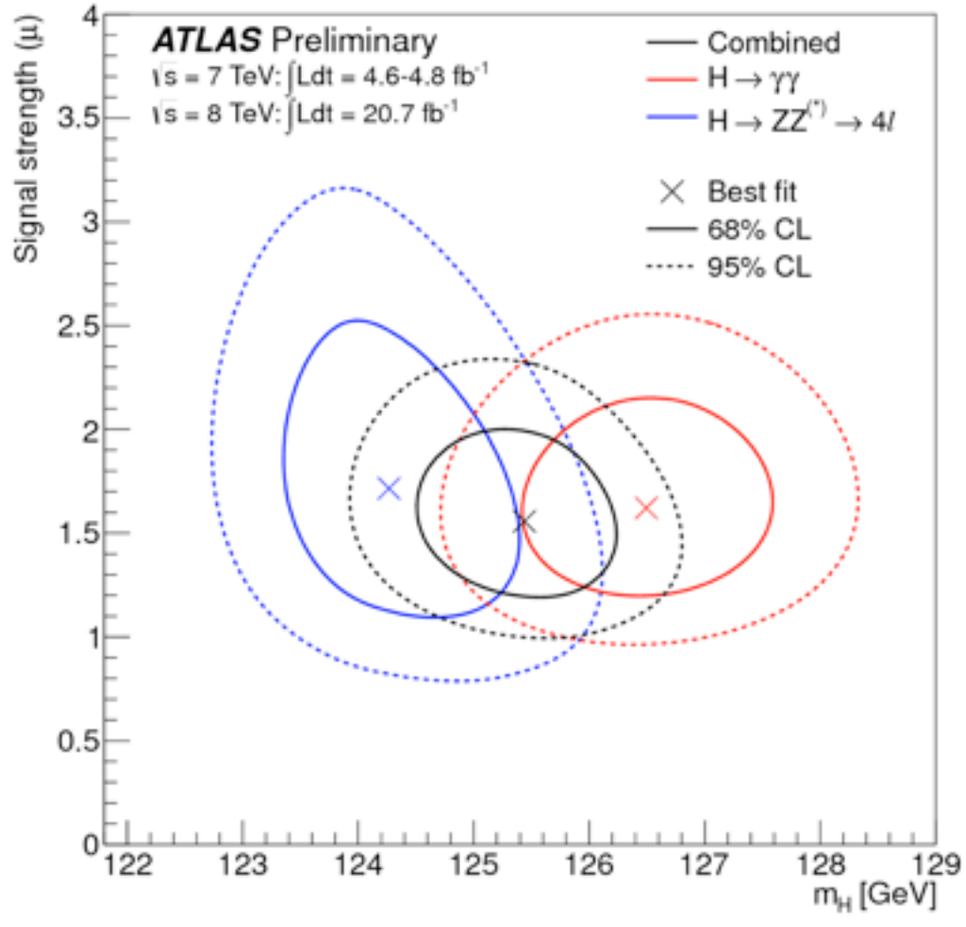
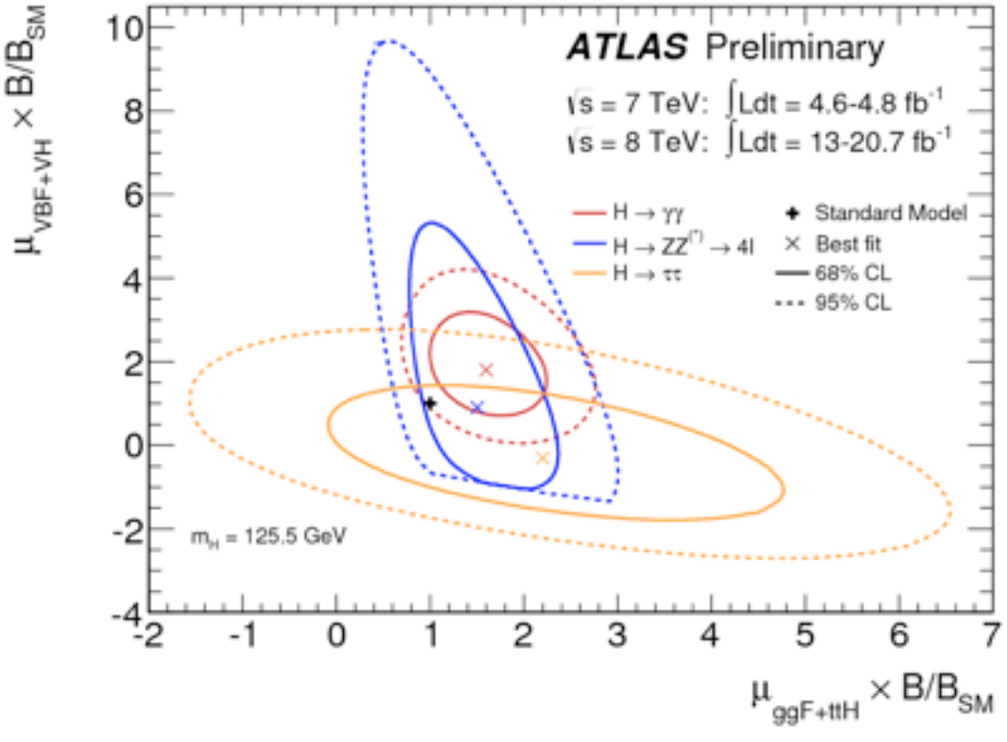
New Boson Discovery



[ATLAS-CONF-2013-010]

$$\mu_f = \frac{\sigma(pp\to H)BR(H\to f)}{[\sigma(pp\to H)BR(H\to f)]^{SM}}$$



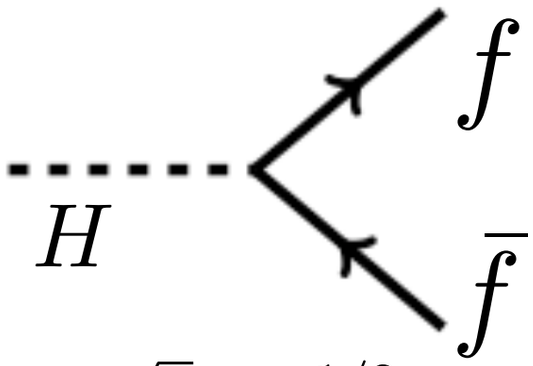


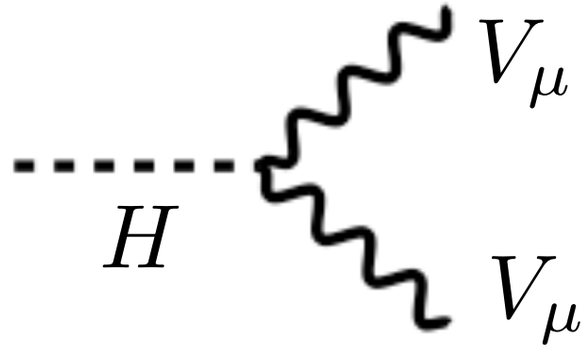
- See yesterday's talk by E. Lipeles

ATLAS discovery Phys. Lett. B716 (2012)

CMS discovery Phys. Lett. B716 (2012)

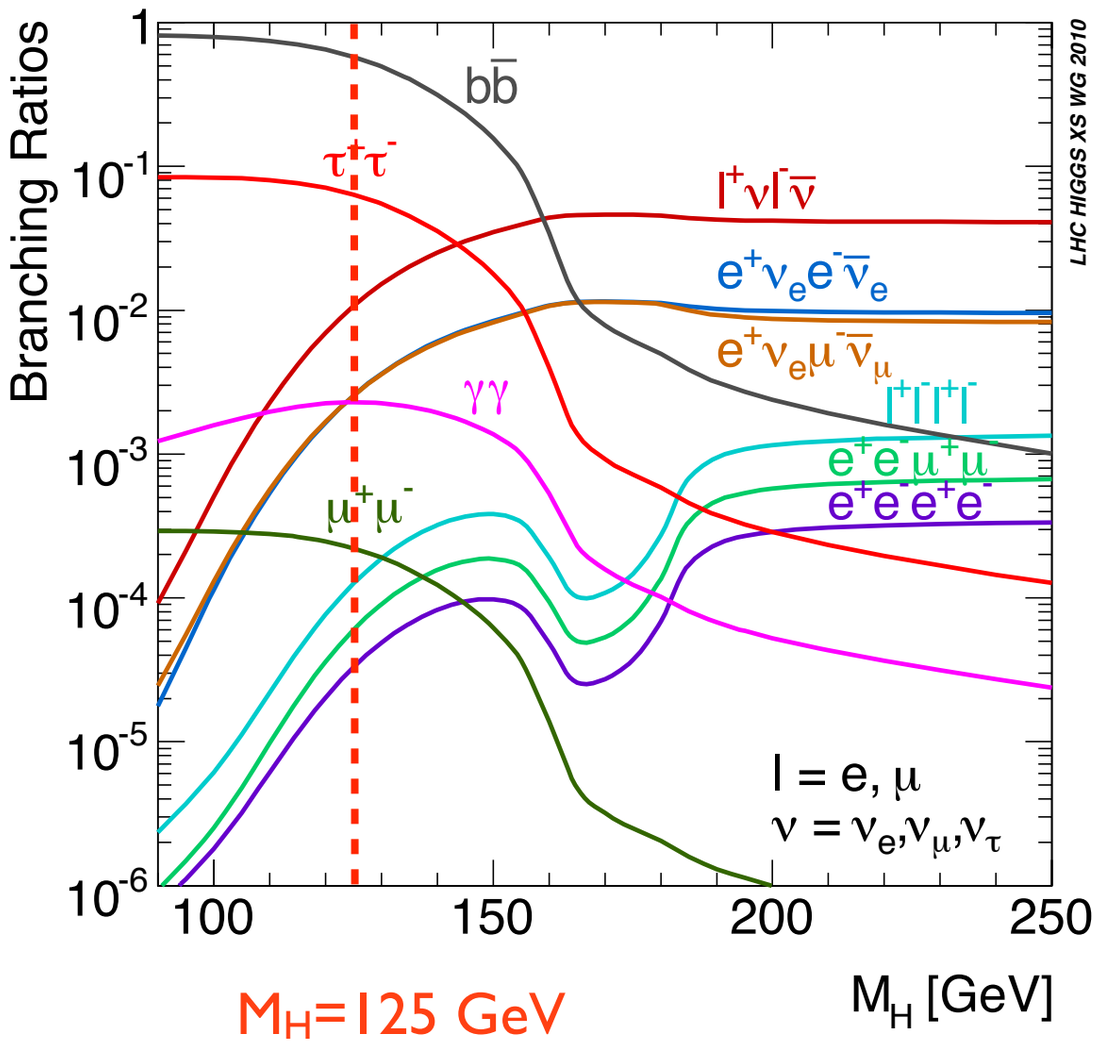
The Standard Model Higgs Boson





$g_{Hff} = m_f/v = (\sqrt{2}G_\mu)^{1/2} m_f \times (i)$

$g_{HVV} = 2M_V^2/v = 2(\sqrt{2}G_\mu)^{1/2} M_V^2 \times (-ig_{\mu\nu})$



M_H=125 GeV

BR(H →l$\mu^+\mu^-$)=(2.17± 0.13)x10^{-4}

- Higgs boson is a spin-0, CP-even boson ($J^P=0^+$).
- The Higgs boson mass is a free parameter in the Standard Model
  - Must be measured
- The couplings are determined entirely by the masses of the fermions and bosons
- Directly probe SM Higgs couplings to second generation fermions

$H \rightarrow \mu^+\mu^-$ Analysis

Perform an inclusive search for $H \rightarrow \mu^+\mu^-$ in

21 fb^{-1} of data collected by ATLAS at $\sqrt{}8$ TeV

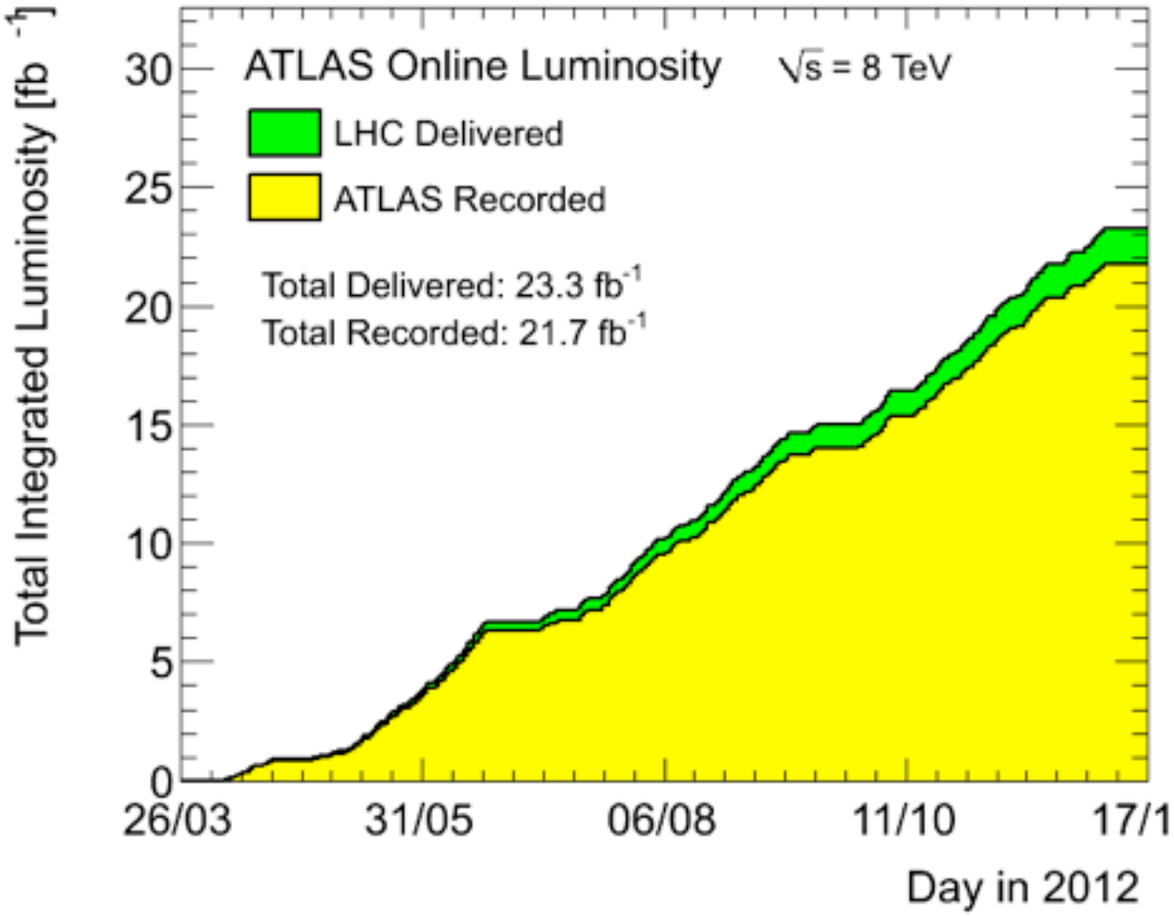
Derive signal shape by using simulated Monte Carlo samples (MC)

Determine best background model from MC a data in control regions

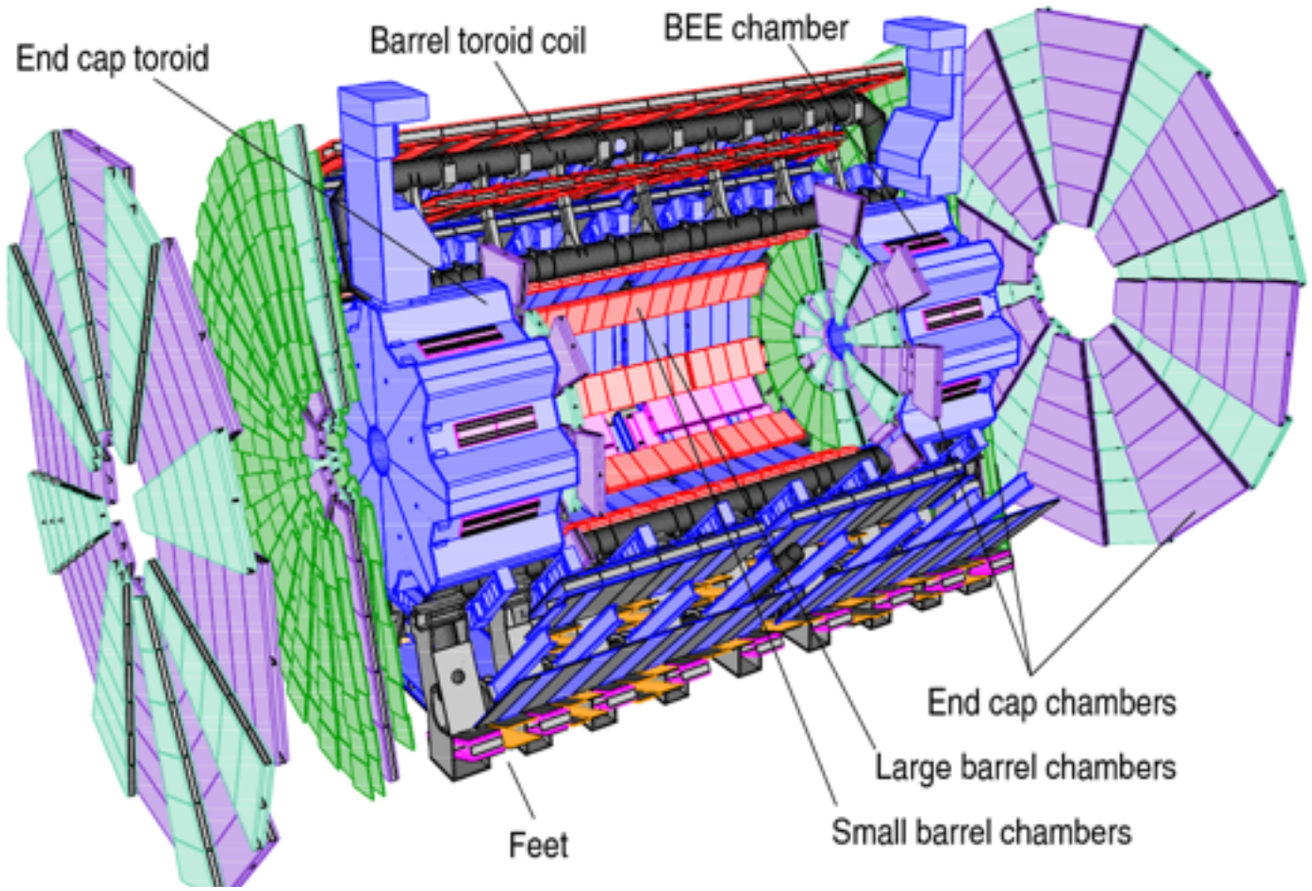
Improve sensitivity to the signal by introducing event categories

Evaluate the systematics uncertainties - both theoretical and detector related

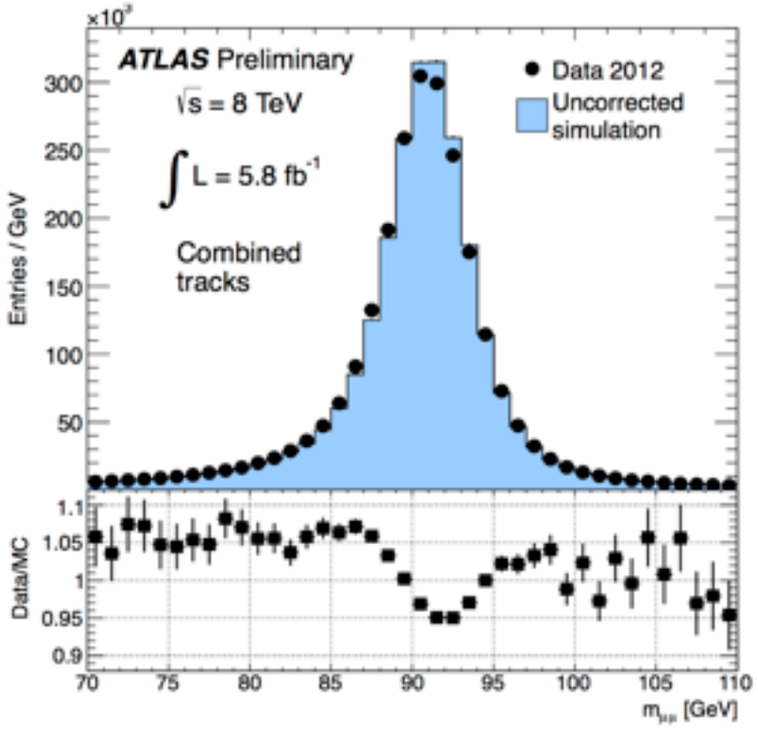
Use $m_{\mu\mu}$ distribution to look for excess, derive limits on production cross section

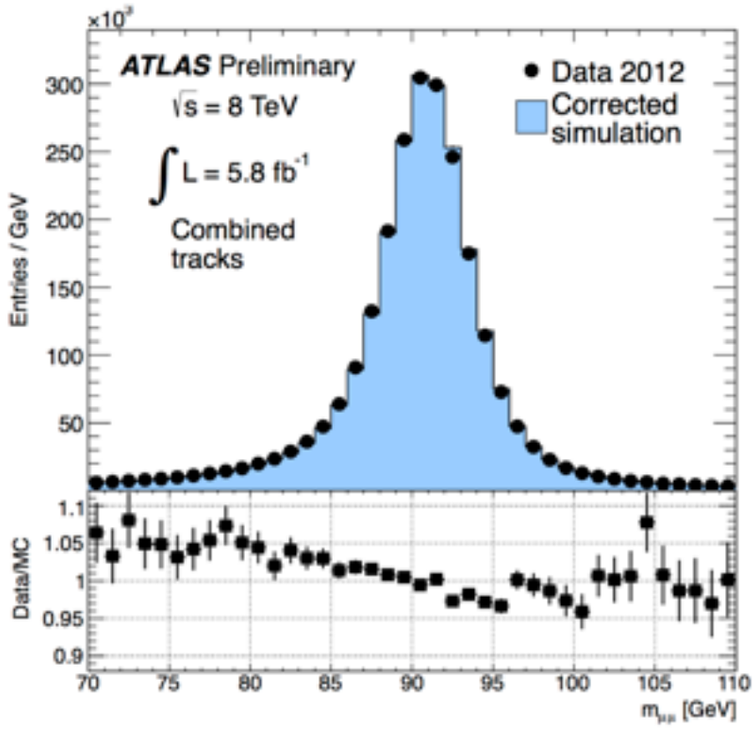


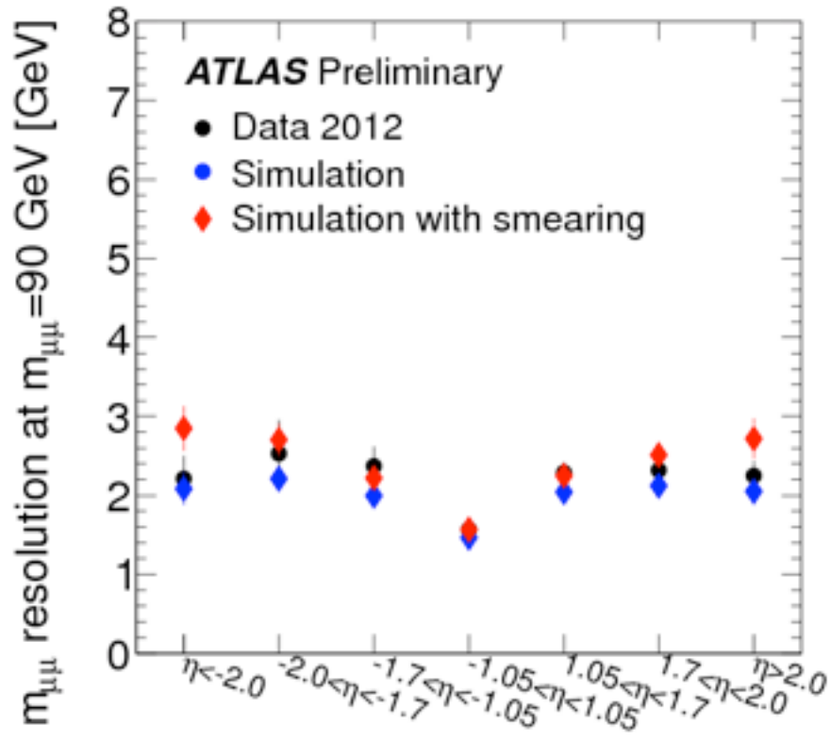
Muon Reconstruction in ATLAS

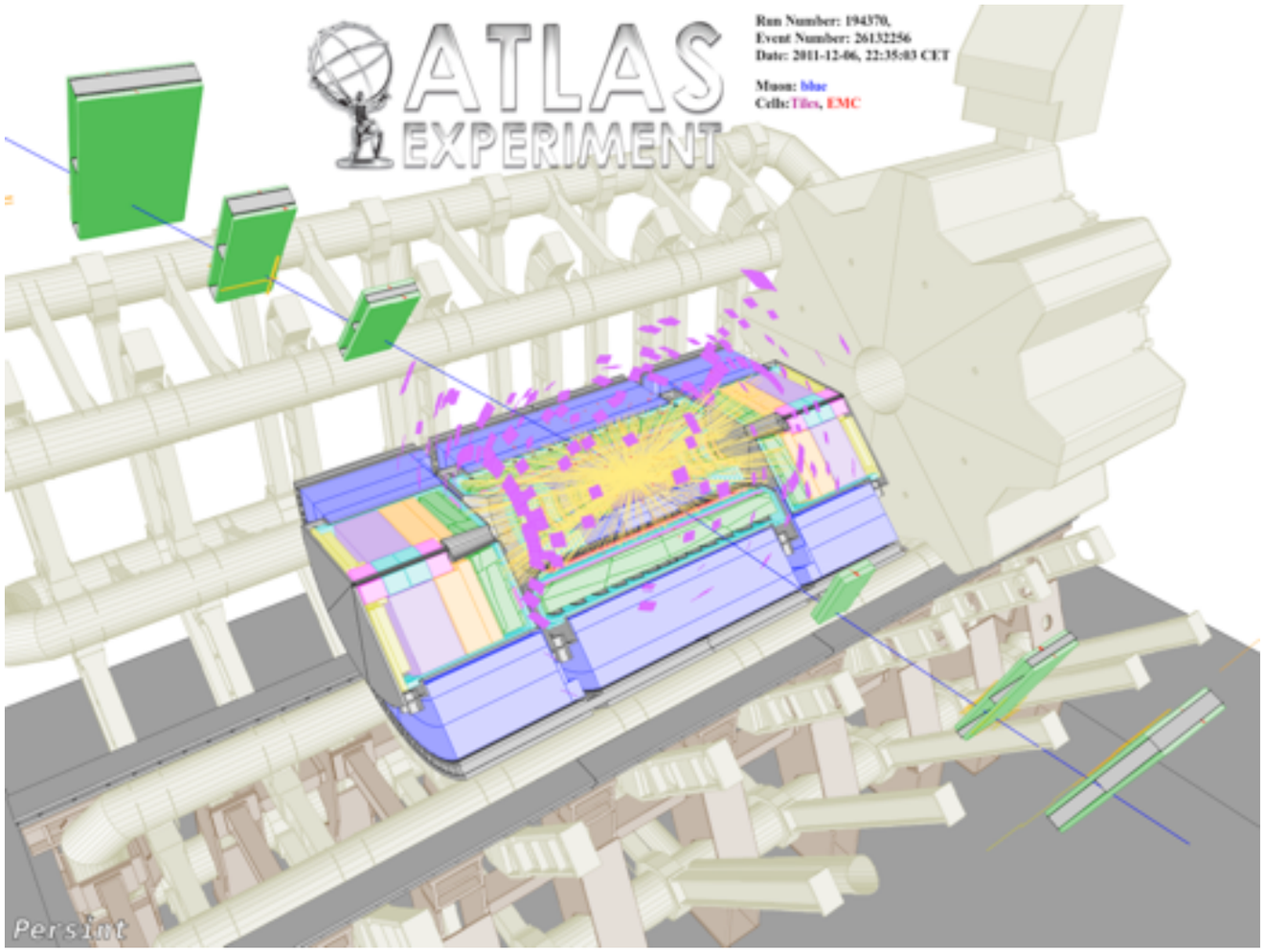


- Muon track segments are reconstructed locally in individual muon chambers
- Segments are combined to form track candidates
- Muon track candidates are combined with track candidates from inner tracking detector to form combined muons

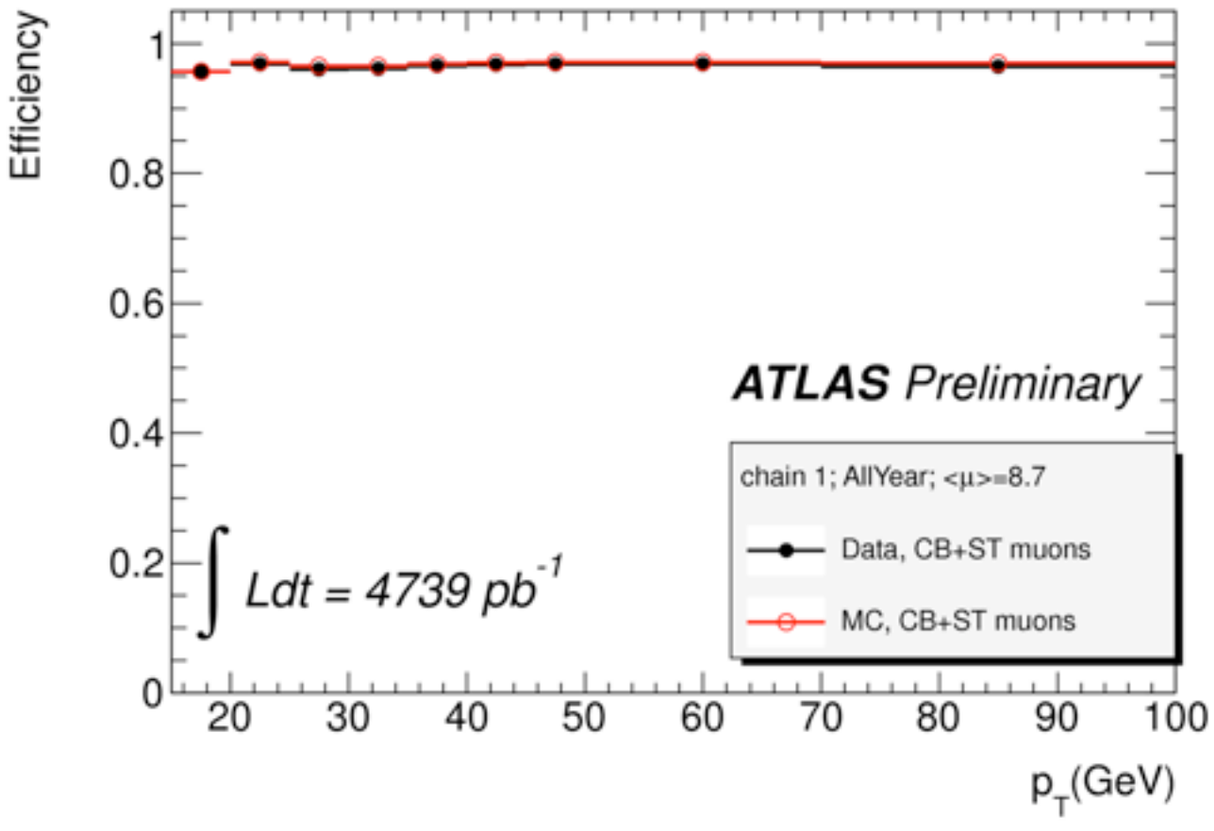


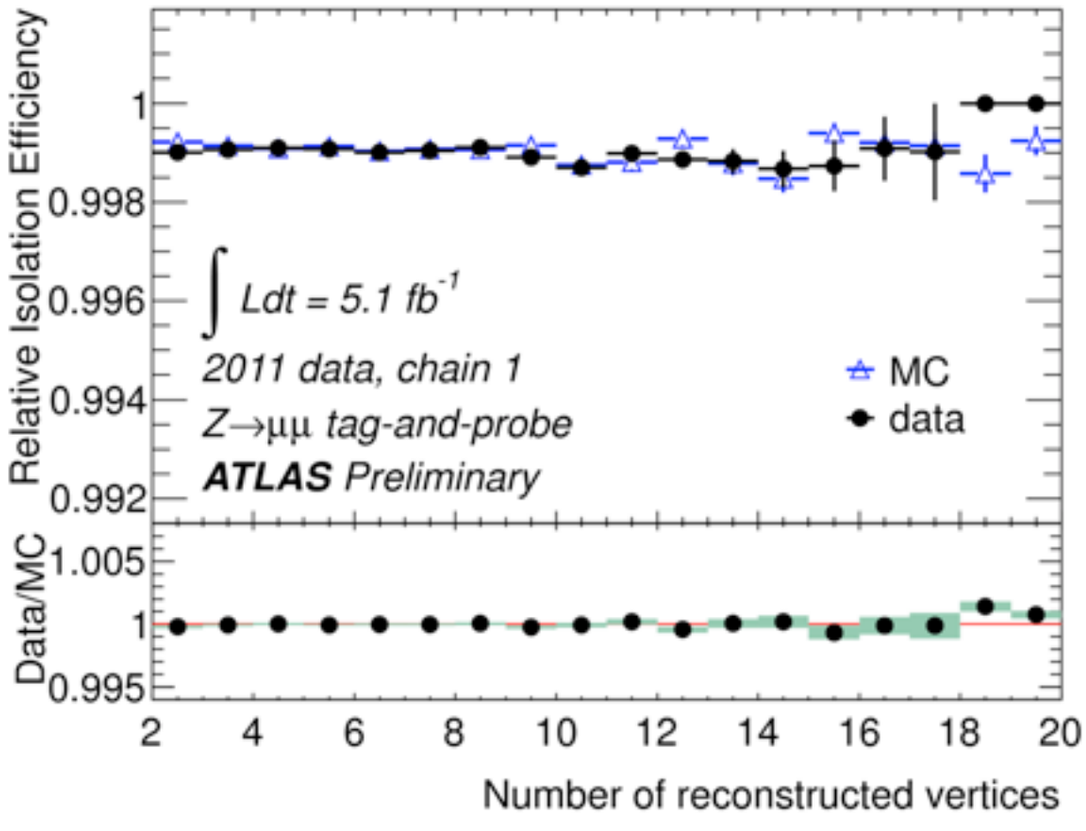




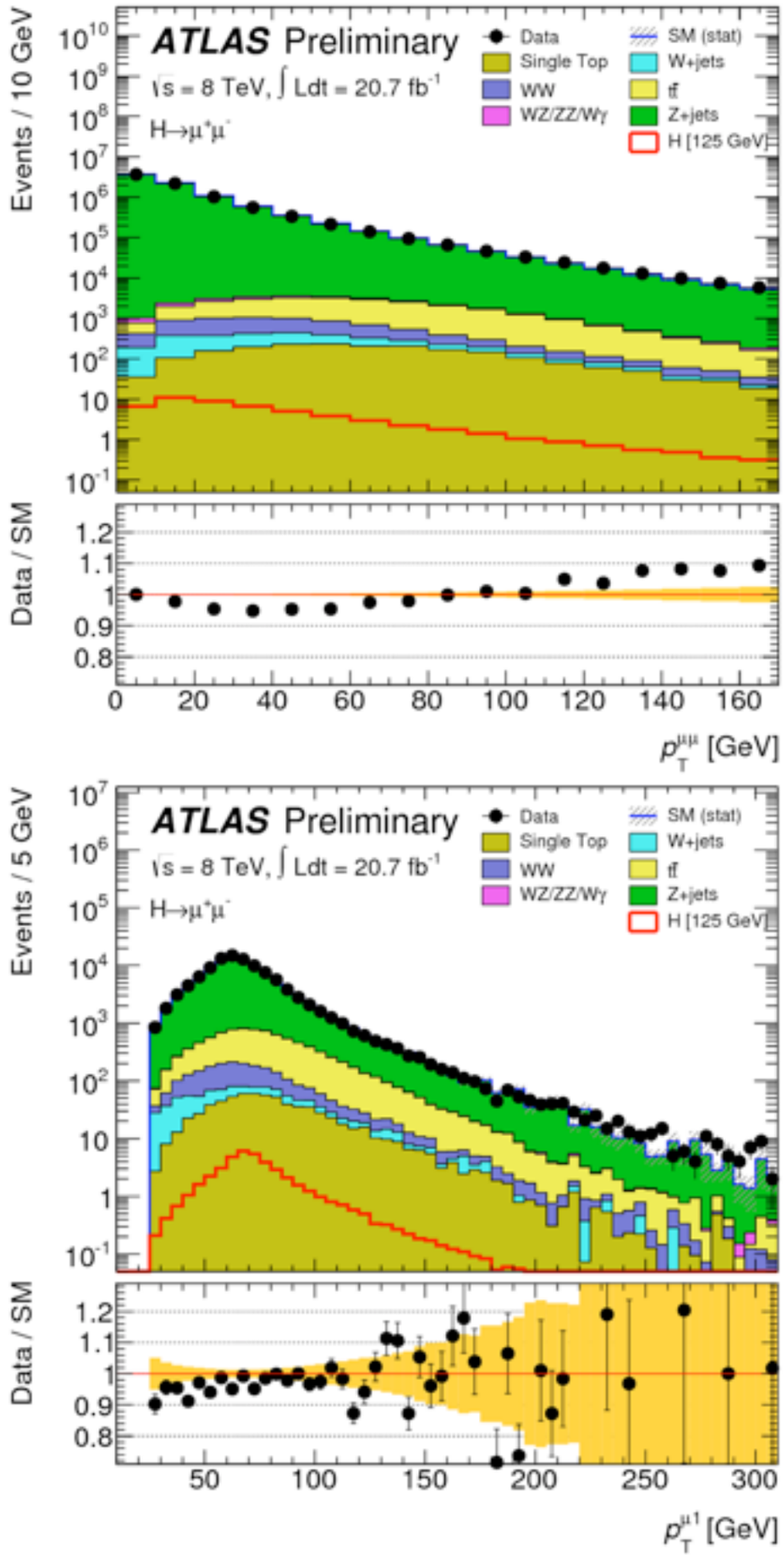


- Select two isolated opposite-sign muons:
  - Leading muon p_T>25 GeV (trigger)
  - Subleading muon p_T >15 GeV



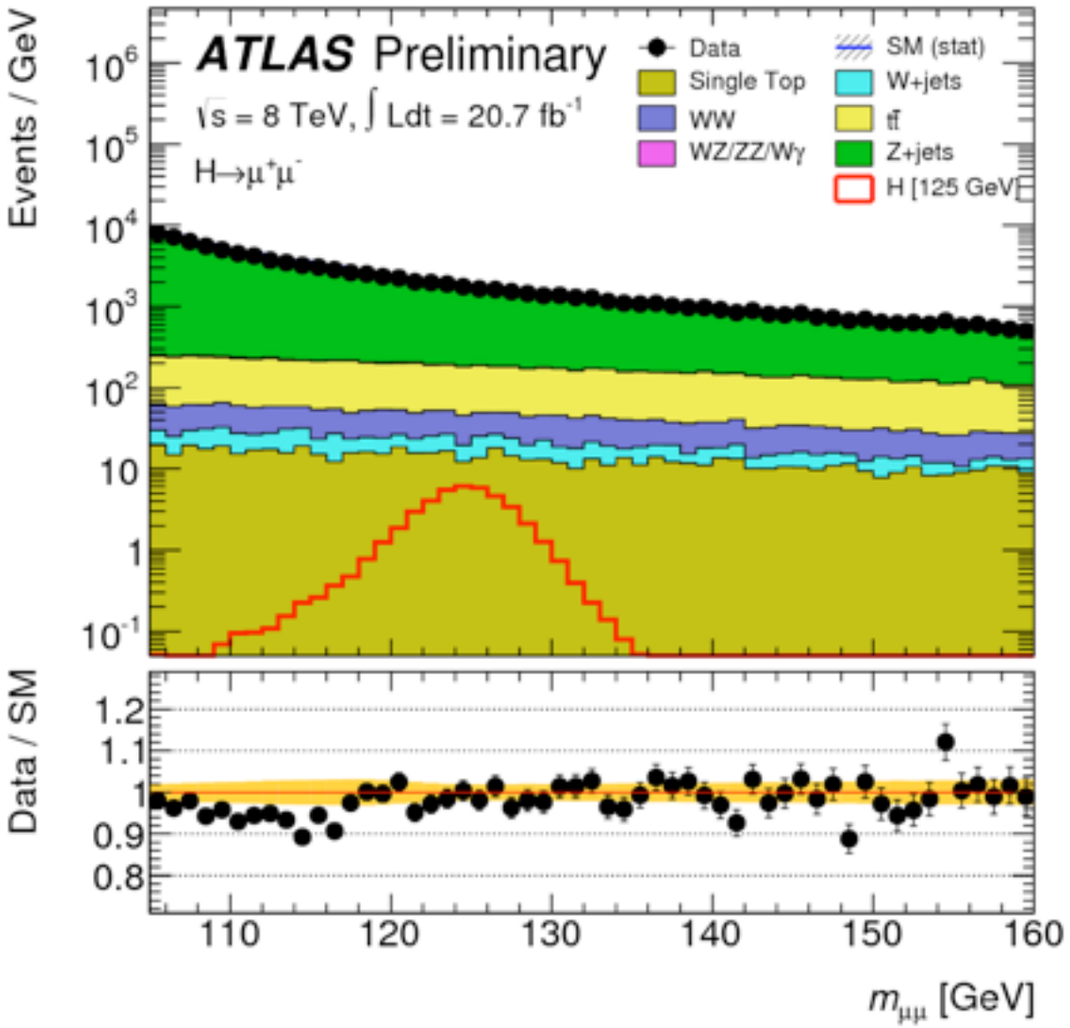


Event Selection and Control Regions



- Di-muon invariant mass $m_{\mu\mu}$ >105 GeV
- Di-muon transverse momentum $p_T^{\mu\mu}$ > 15 GeV
  - Suppress Drell-Yan and Z+jets backgrounds
- Set up additional control regions to validate background fit function and make sure that no artificial peaks created in spectrum due to top, di-boson:
- Low transverse momentum $p_T^{\mu\mu}$ < 15 GeV
- High $E_T^{miss} > 40$ GeV
- b-jet requirement: N(b-tagged jets) ≥ 1

Mass Distribution and Event Categories



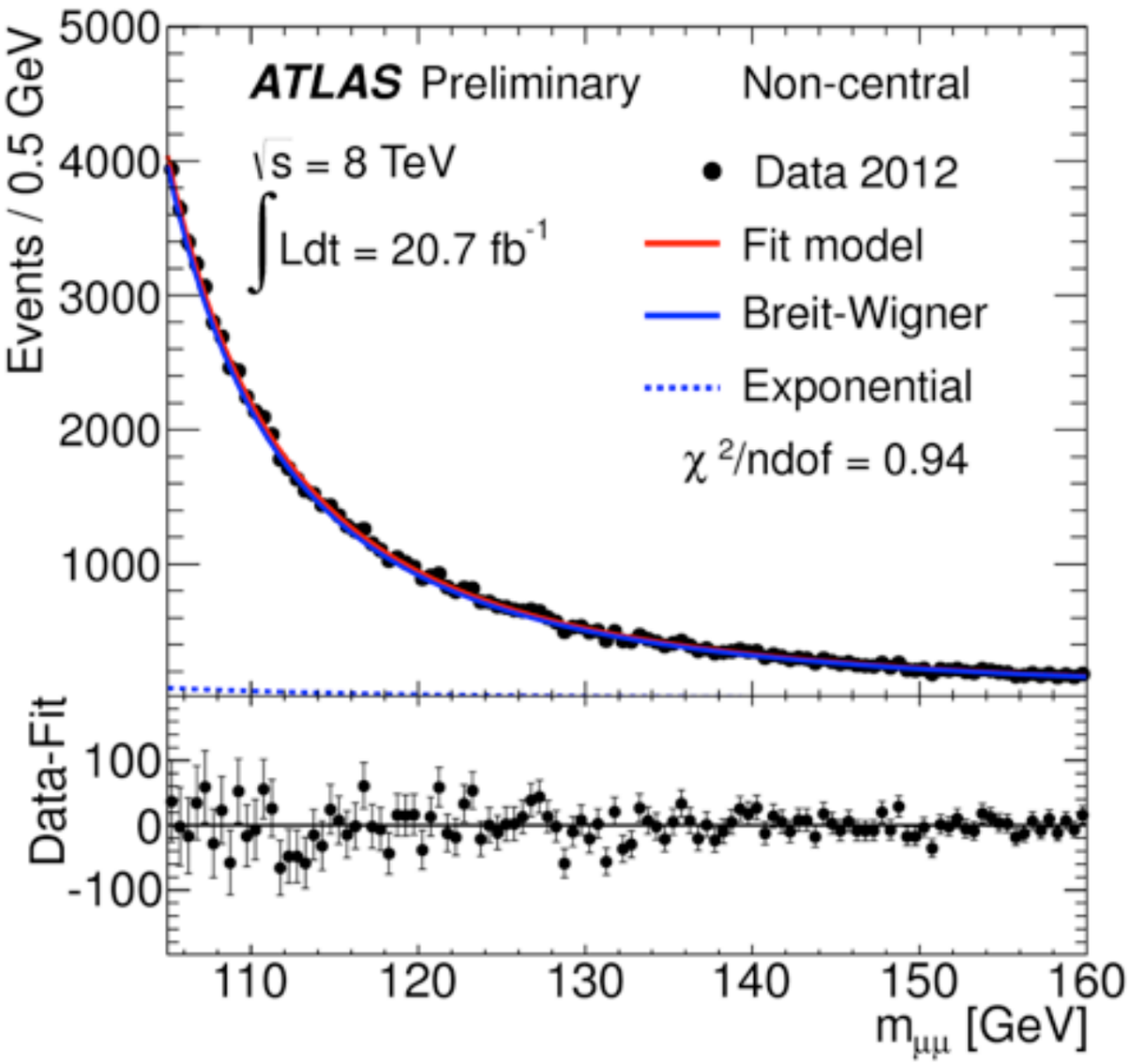
- The selected events are further subdivided into "central" and "non-central" categories to maximize the search sensitivity
  - based on di-muon mass resolution
  - Central: $|\eta_1|<1.0$ and $|\eta_2|<1.0$
  - Non-central: All remaining events

	$\lvert m_H - m_{\mu\mu}\rvert \leq 5$ GeV
Signal [125 GeV]	37.7 ± 0.2
WW	250 ± 4
$WZ/ZZ/W\gamma$	30 ± 1
$t\bar{t}$	1374 ± 13
Single Top	151 ± 5
Z+jets	15810 ± 130
W+jets	88 ± 6
Total Bkg.	17700 ± 130
Observed	17442

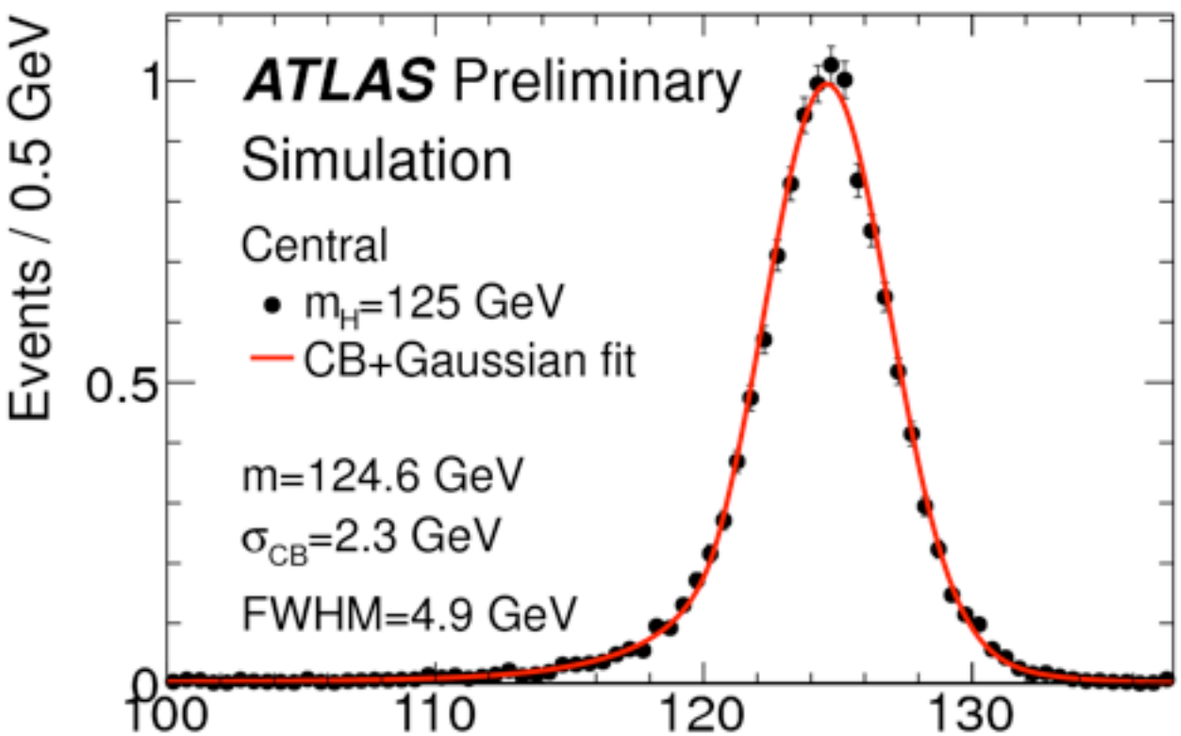
Background Modeling

- Background is dominated by the DY production
- Breit-Wigner + Exponential pdf
- Validated on background Monte-Carlo samples and data control region
- Found to perform best, other models examined:
- Breit-Wigner + $1/m^3$
- Exponential + Chebychev polynomial

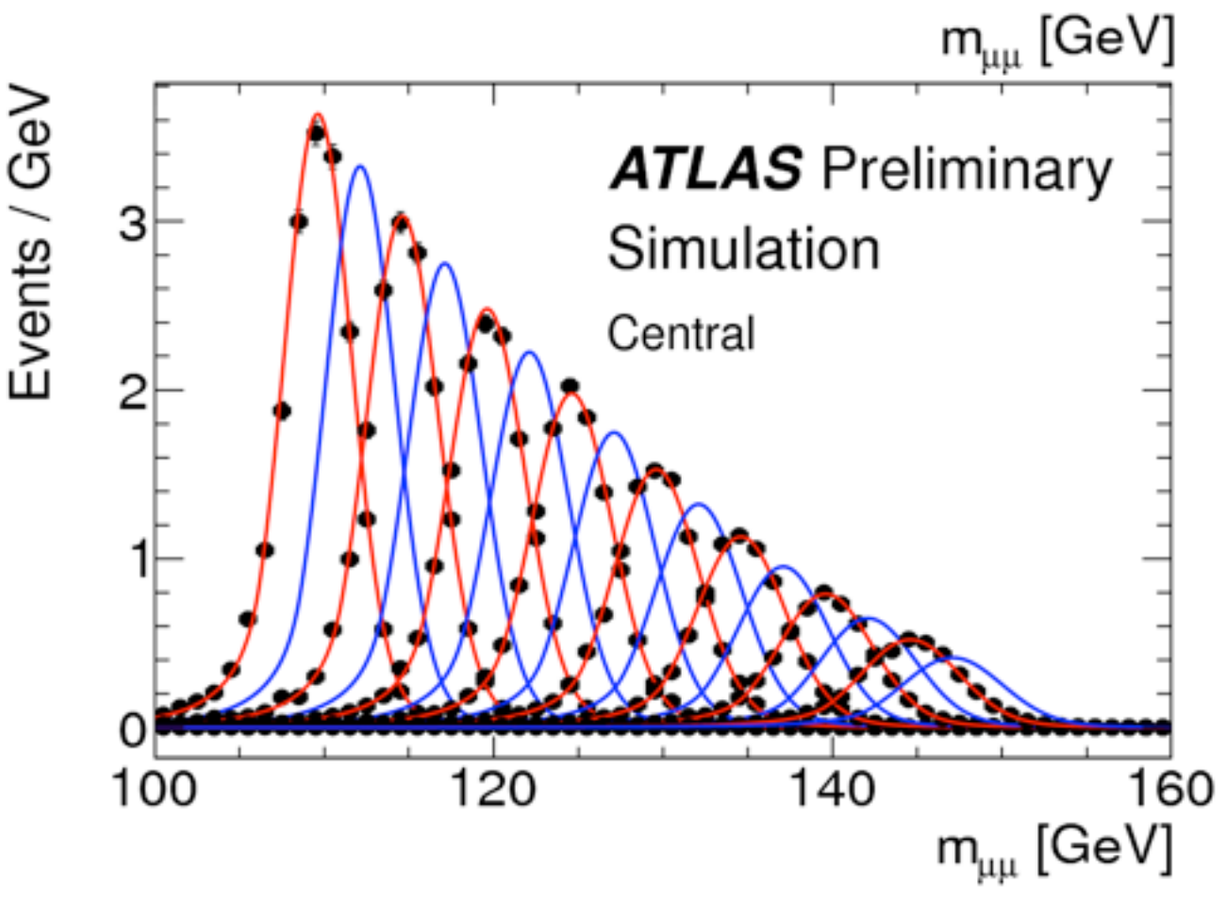
Fit to data in control region
$p_T^{\mu\mu} < 15$ GeV



Signal Modeling

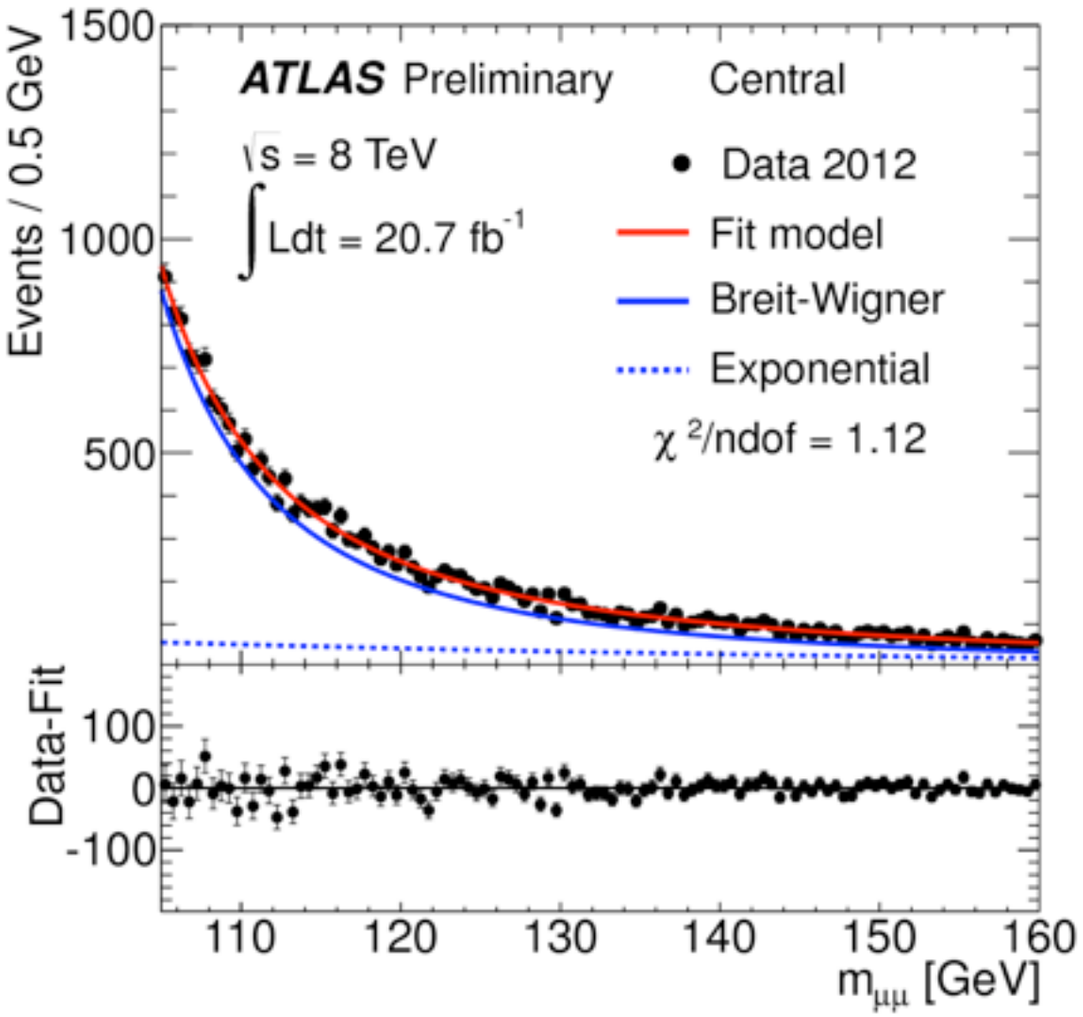


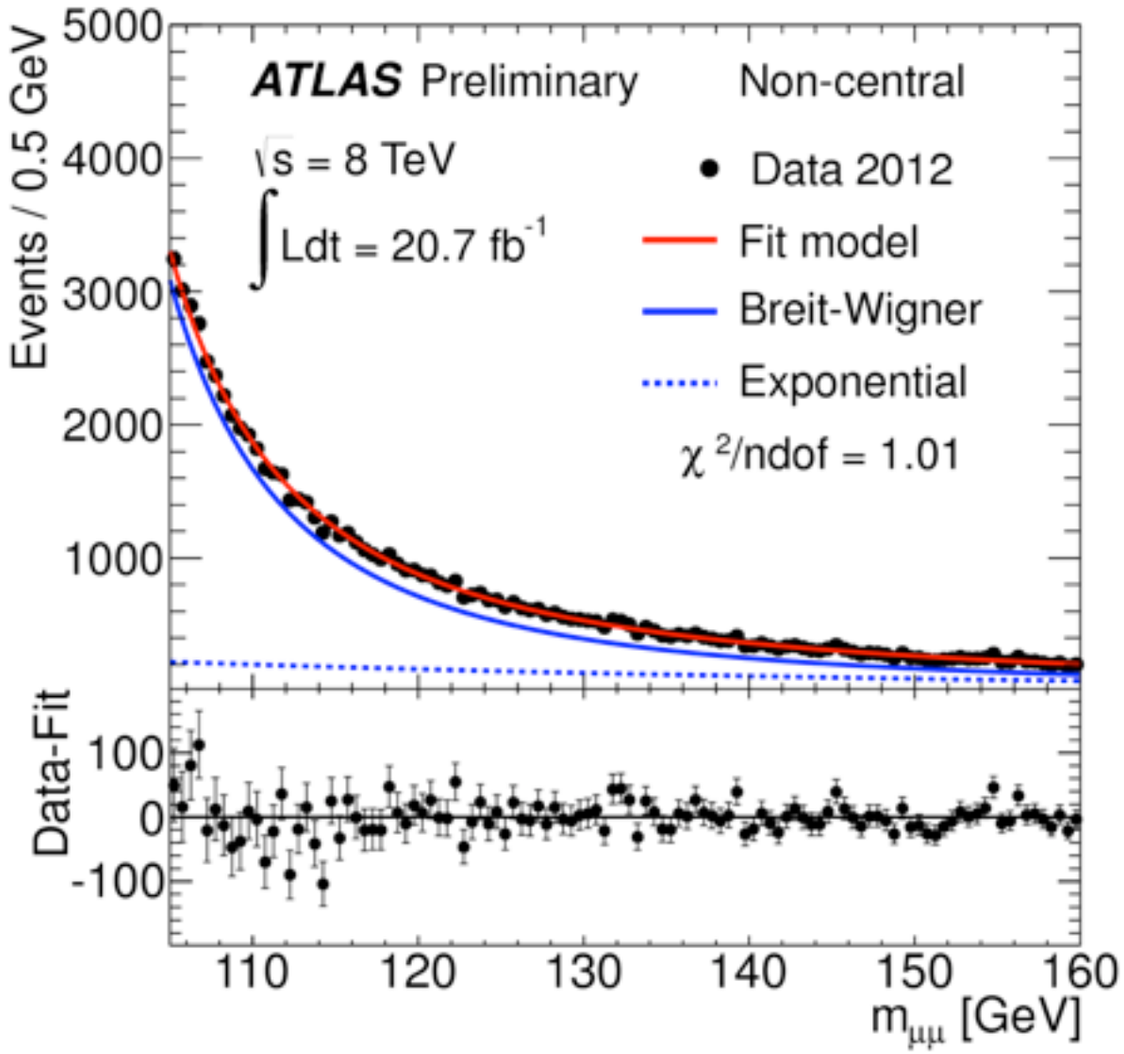
- Signal generated in [110,150] GeV range in 5 GeV steps
- Crystal Ball + Gaussian pdf
- Validated on combination of all signal Monte-Carlo samples



- The signal shape is interpolated between available simulated Higgs masses in 0.5 GeV steps
- Shape is fixed when fitting to data

Invariant Mass Distribution in Signal Region





- Data well modeled by background pdf in signal region

Systematic Uncertainties

- Largest systematic uncertainty is due to theoretical uncertainty on the Higgs boson production cross-section (m_H=125 GeV): 15%
- Uncertainty on the branching fraction of $H \rightarrow \mu\mu$ (m_H=125 GeV): 6%

Uncertainty	Upward [%]	Downward [%]
Ren./Fac. Scale	0.1	-0.3
ISR	1.3	-2.5
FSR	-0.4	0.1
PDF	0.2	0.2
Total inclusive	+1.3	-2.6

Experimental Uncertainties

Source of Uncertainty	Treatment in the analysis
Luminosity	3.6%
Muon Selection Efficiency	0.3-1% as a function of η and p_T
Muon Momentum Scale and Resolution	< 1%
Muon Trigger	< 1%
Muon Track Isolation	< 1%
Pile-up reweighting	< 1%

Results

- No excess observed above the background
  - calculate a local p-value for background to fluctuate in observed spectrum
- 95% CL upper limits on the Higgs boson production are determined using a modified frequentist CL_s method based on a Poisson log-likelihood ratio statistical test

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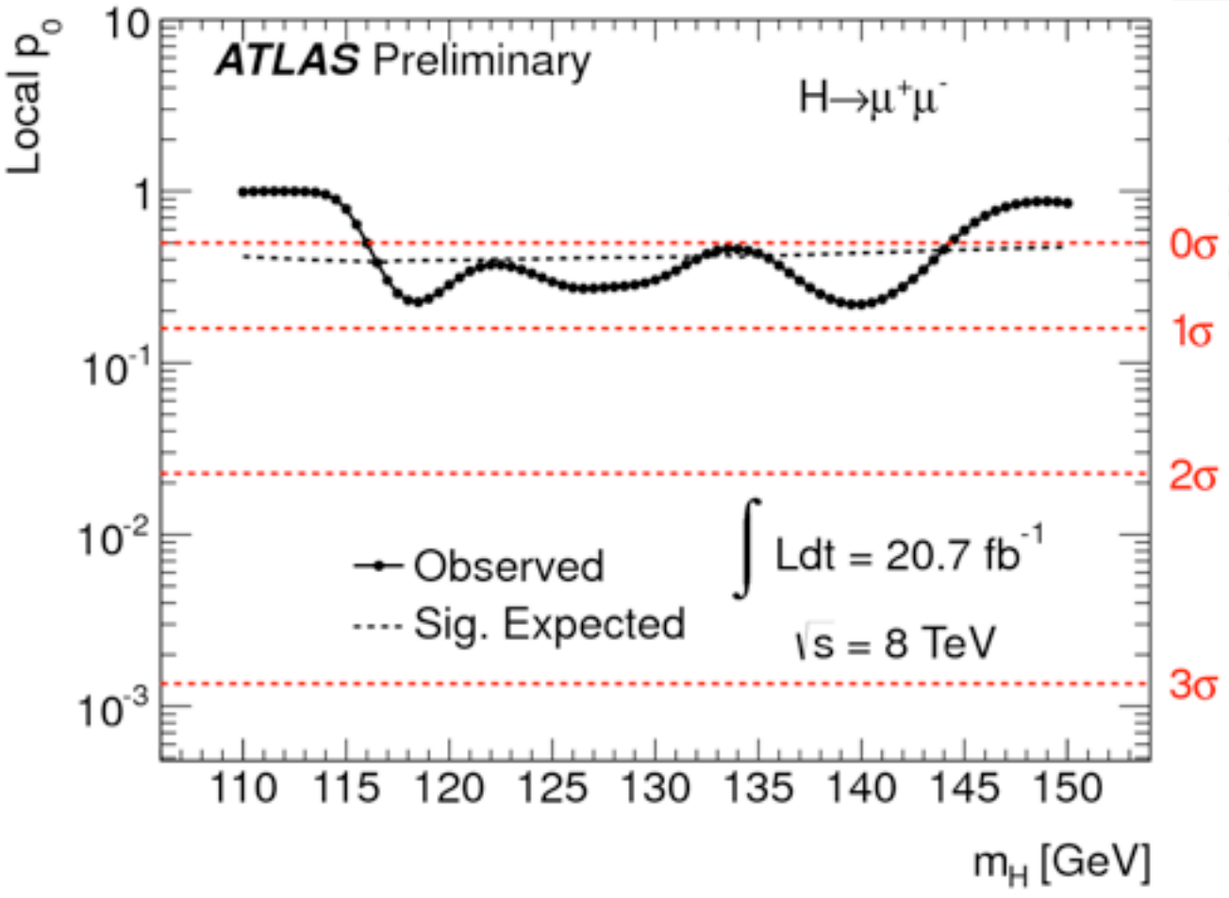
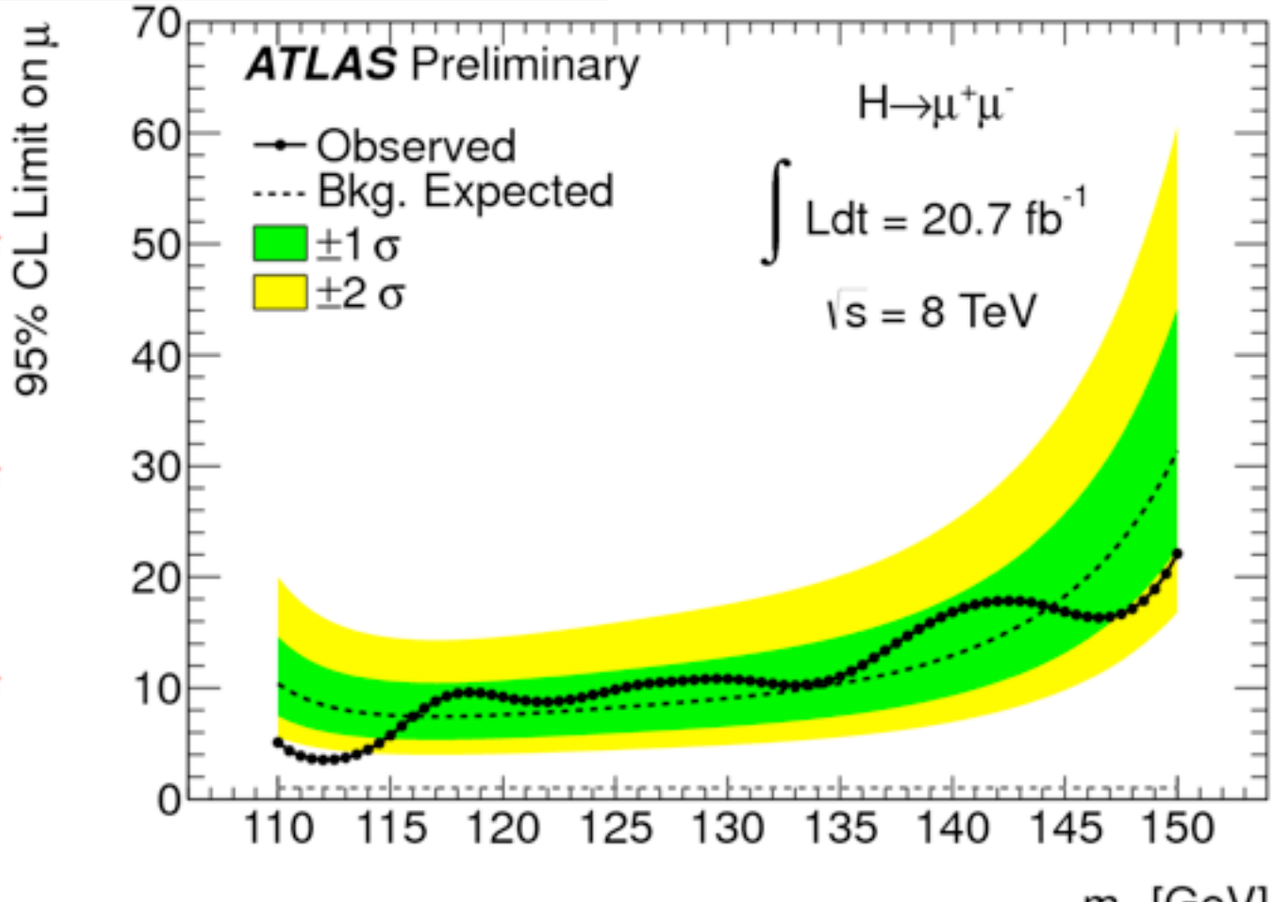
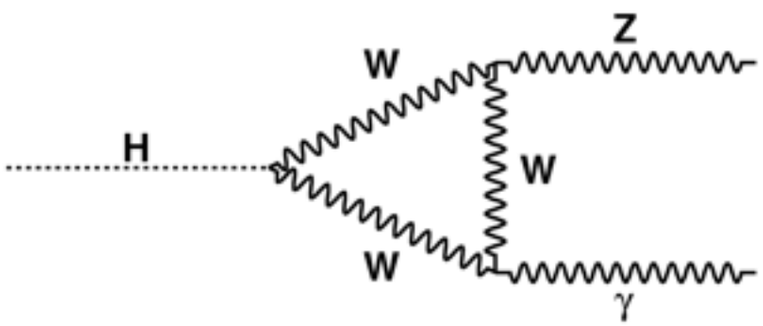
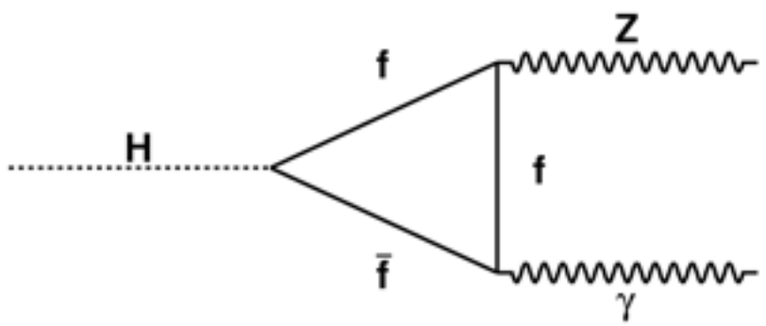


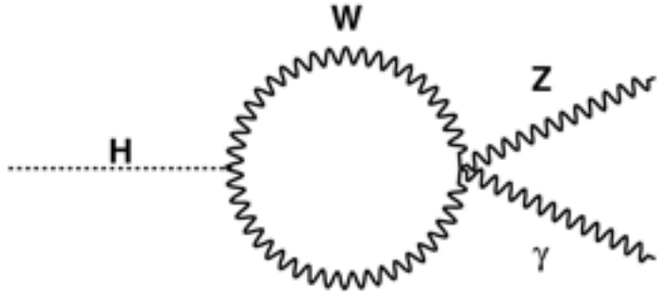


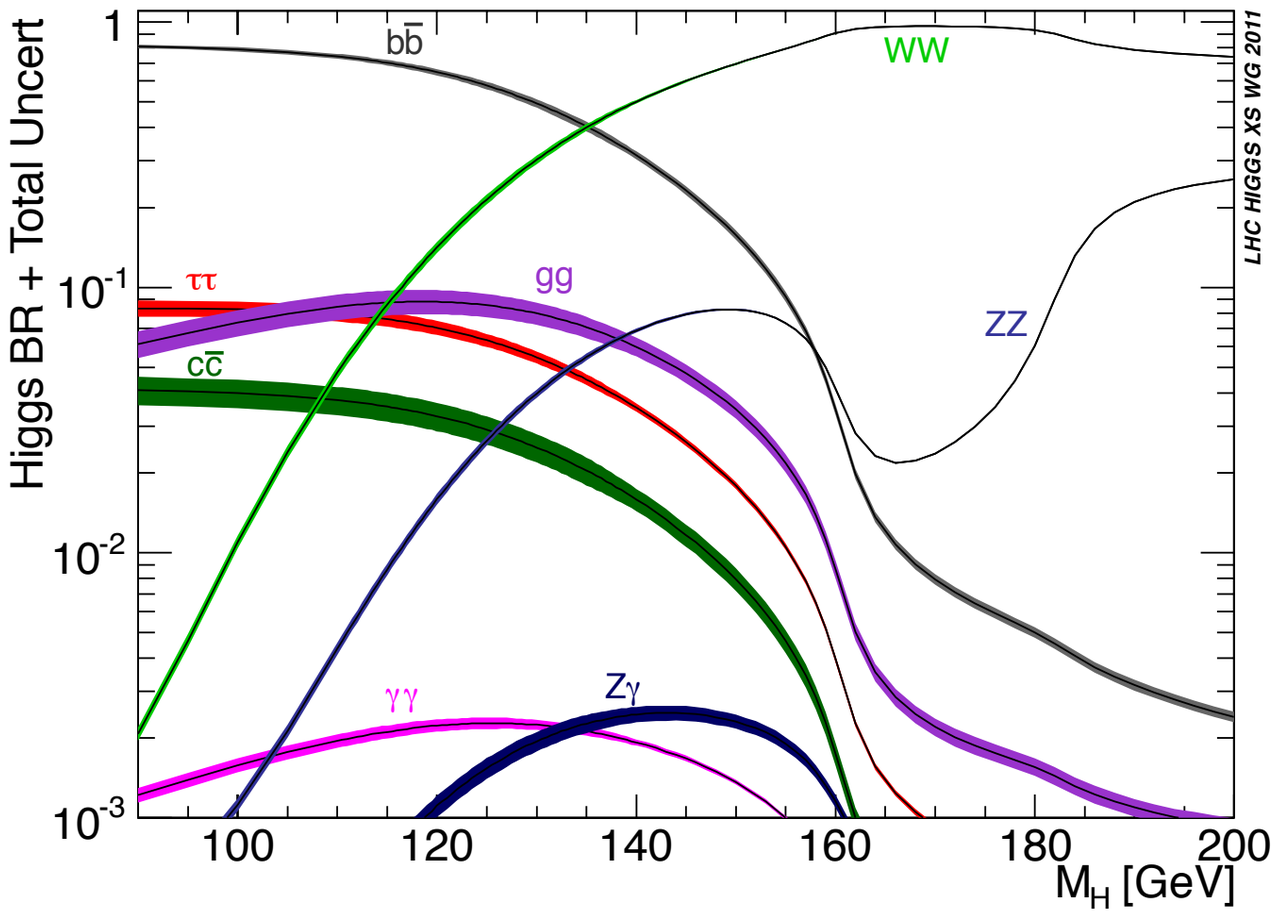
- The observed (expected) limit at a Higgs boson mass of 125 GeV is 9.8 (8.2) times the Standard Model prediction

SM Higgs Decays to Zγ







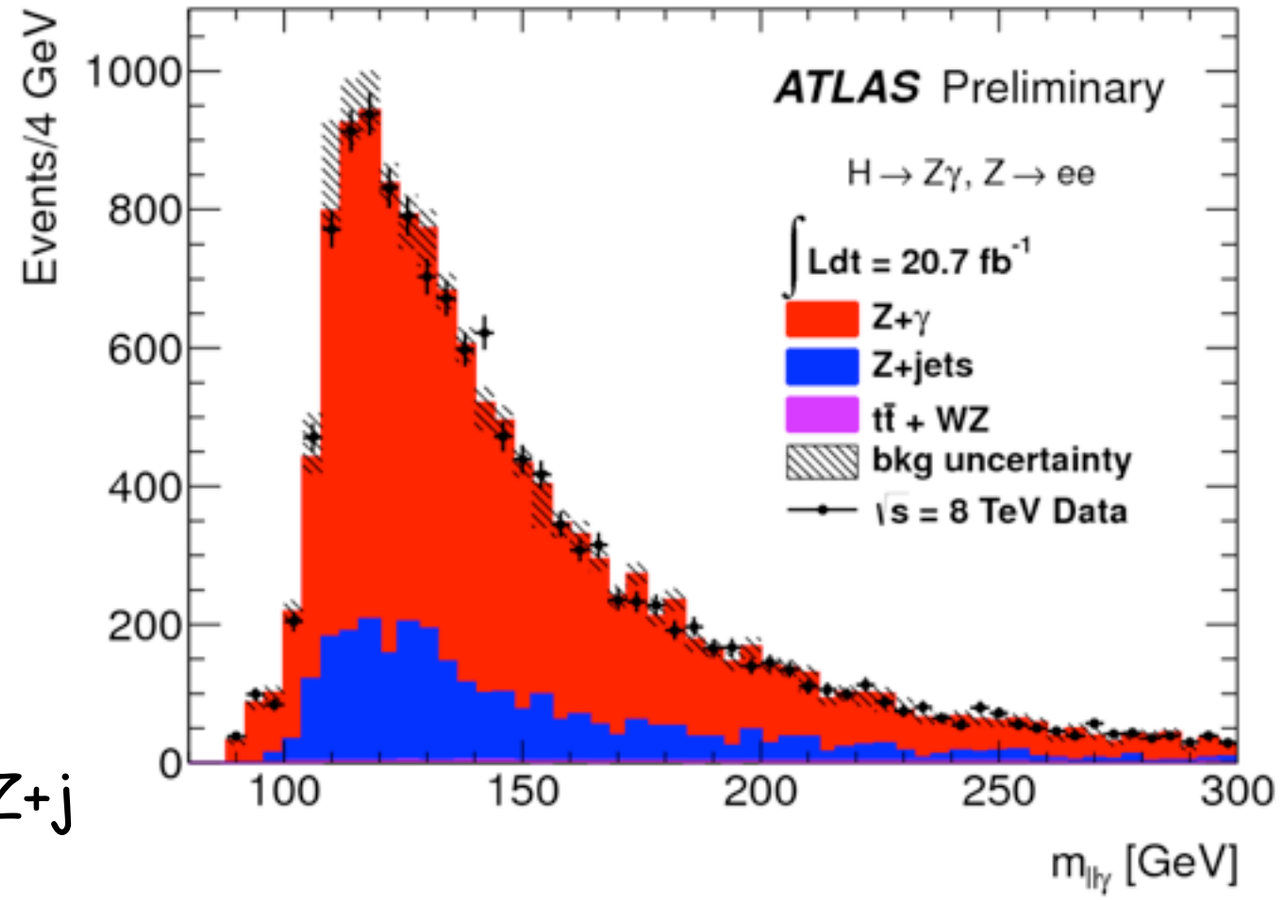


- BF(H→γγ)/BF(H→Zγ) sensitive to physics beyond the SM
- BF(Z→ll) ~ 6.7% (l=e,μ)
- Yield comparable to SM H→4l
- Expect ~15 events in full 2011+2012 data for m_H=125 GeV, but larger background than for H→4l

H→Zγ Signal Selection and Backgrounds

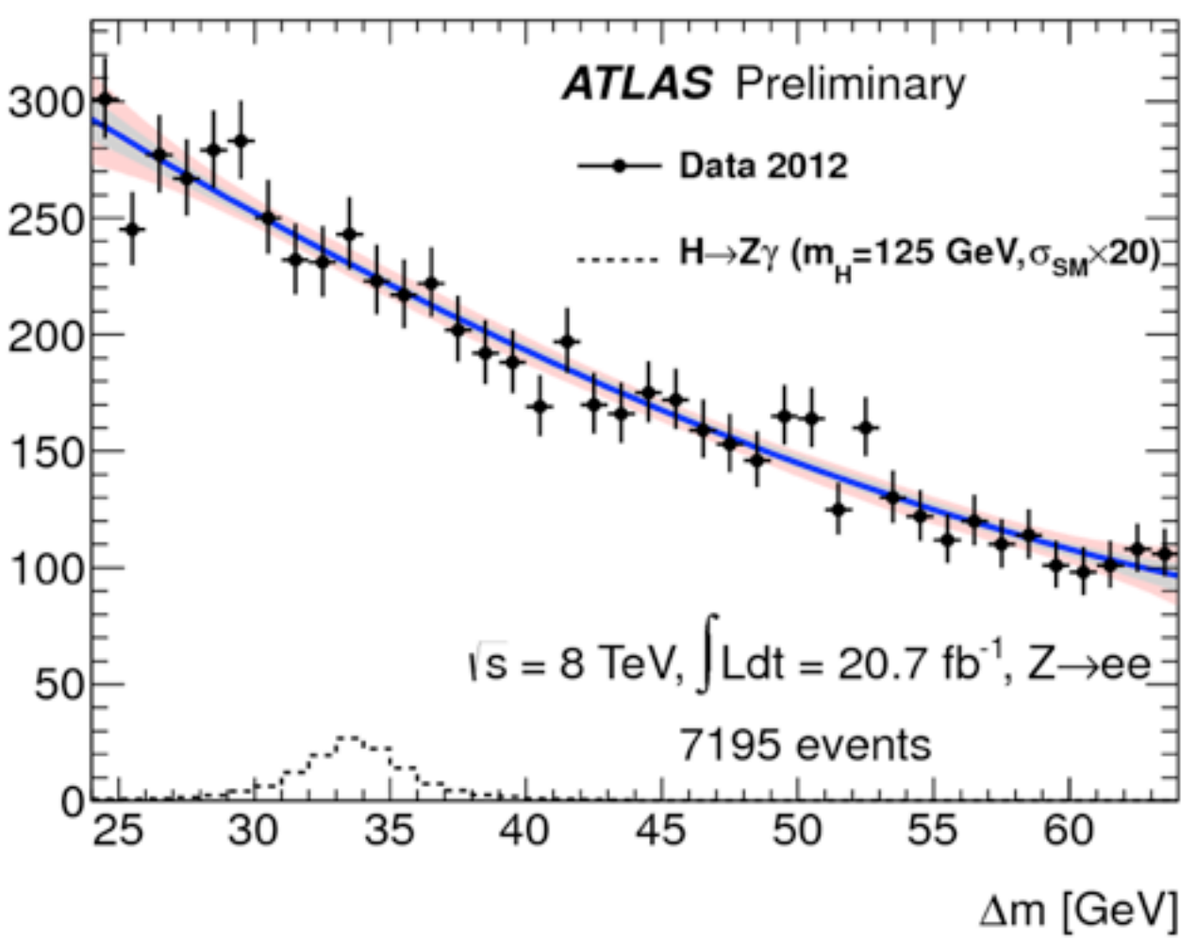
- Analysis strategy:
  - 2 SF-OS isolated leptons (p_T>10 GeV and m_{ll}>m_Z-10 GeV)
  - 1 isolated photon ($E_{T\gamma}$>15 GeV and $\Delta R_{l\gamma}$>0.3)
- Categories: SF (e^+e^- / $\mu^+\mu^-$) and 7/8 TeV
- Main backgrounds: SM Z+γ (~82%) and Z+j (~17%, suppressed by γ selections)
  - No background peaks in $m_{ll\gamma}$ or $\Delta m = m_{ll\gamma} - m_{ll}$
  - Obtained from fit in sidebands (similar to H→γγ) of discriminating variable

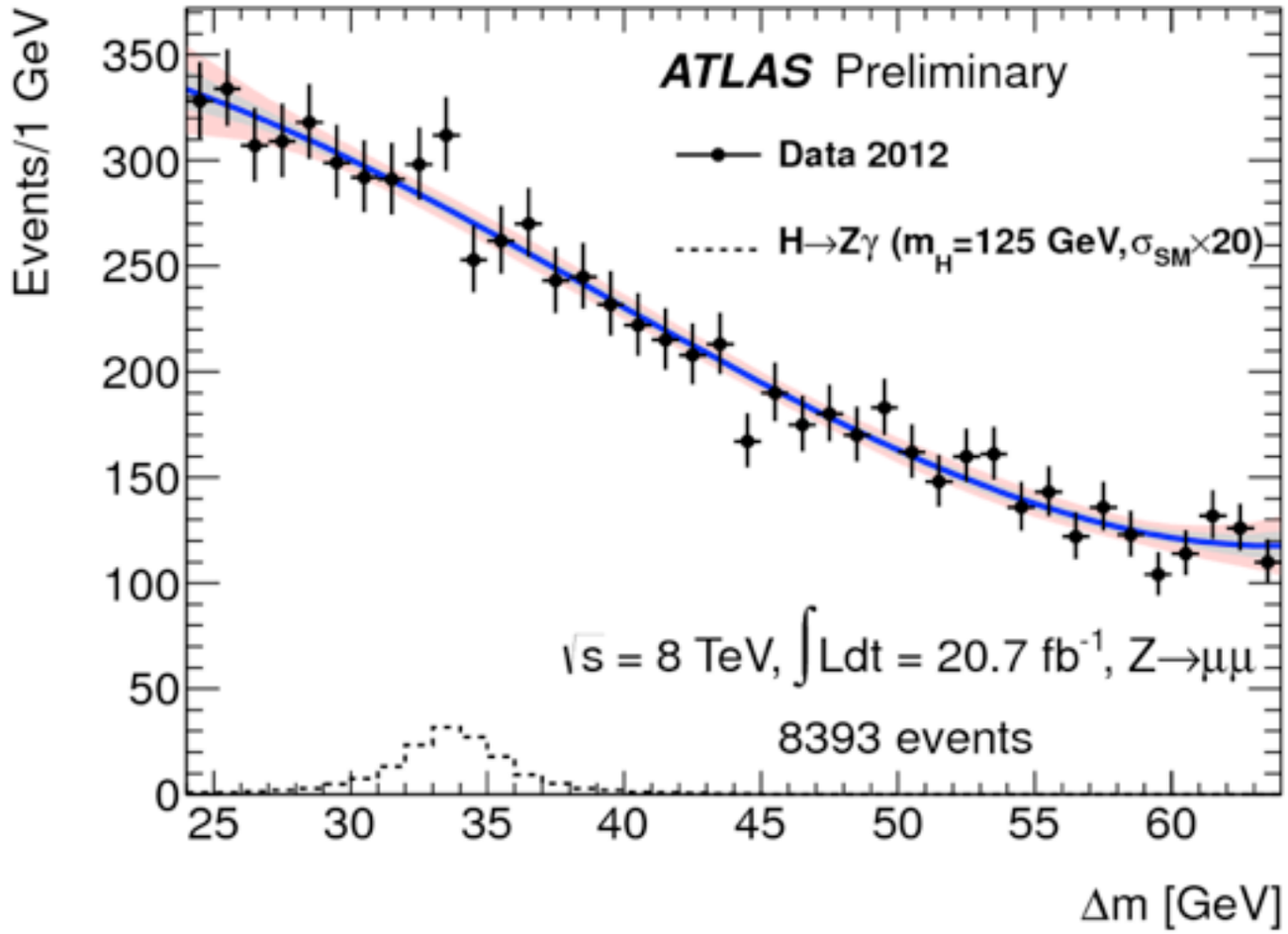
    $\Delta m = m_{ll\gamma} - m_{ll}$



Data-driven background decomposition (photon ID vs isolation)
after subtraction of tt+WZ to disentangle Z+γ from Z+j

H→Zγ Limit Extraction





- Limit is extracted from $\Delta m = m_{ll\gamma} - m_{ll}$
  - Small uncertainties due to the lepton energy scale
  - Insensitive to possible H→llγ 3 particle Dalitz decays
- Backgrounds are fixed from fits to data

H→Zγ Limit Extraction

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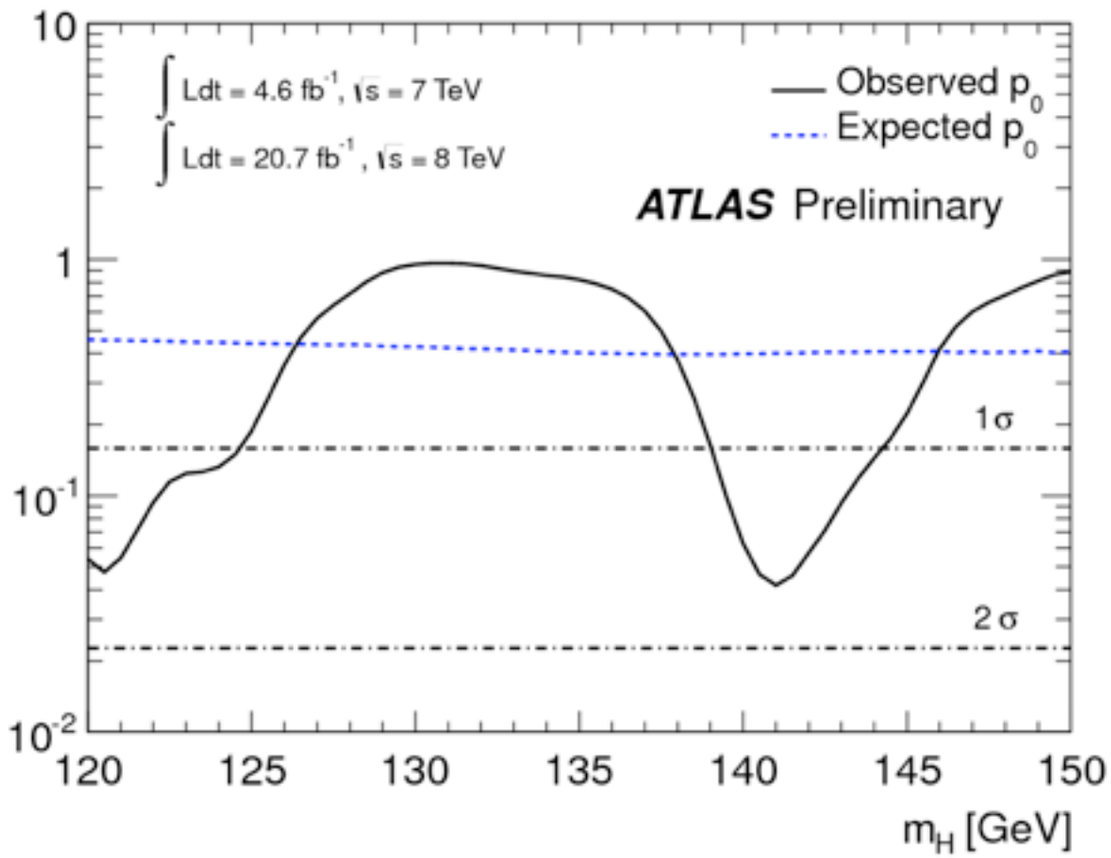

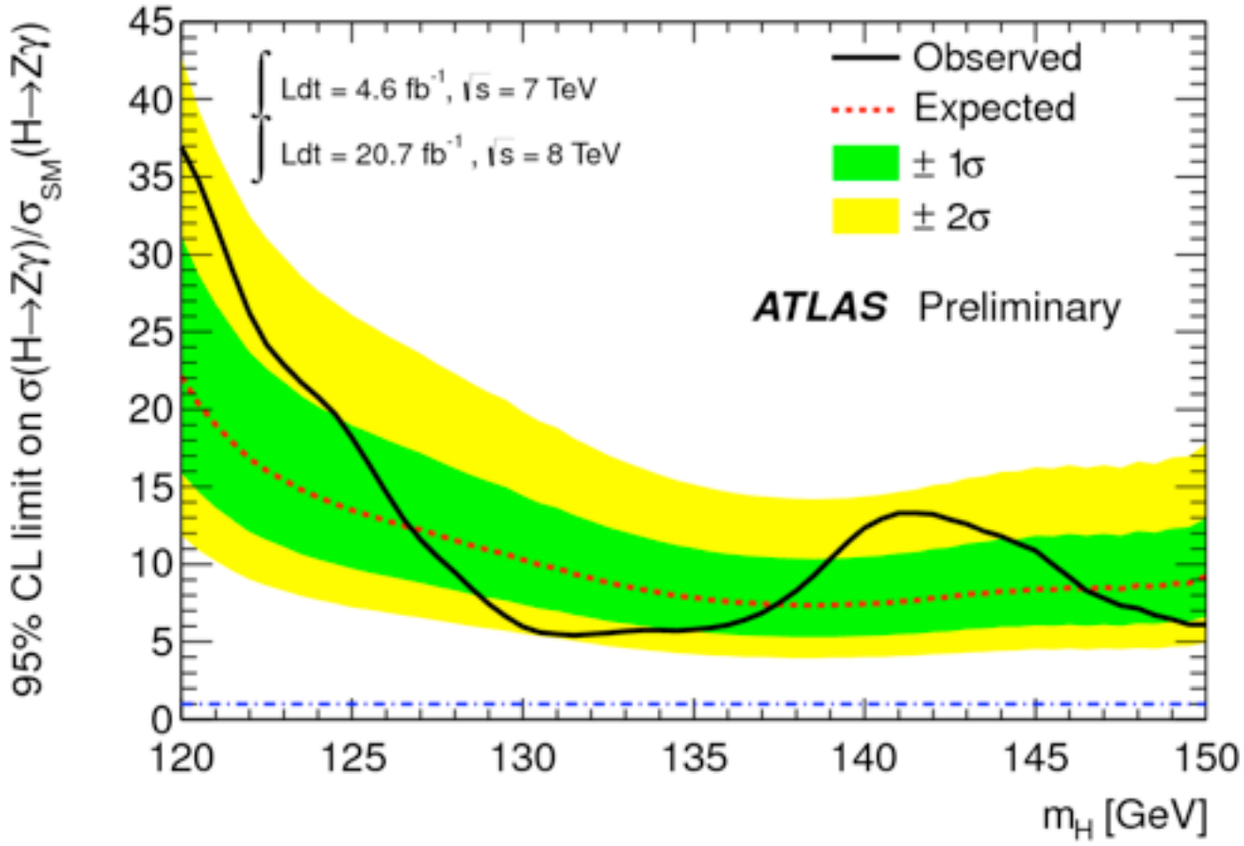

- Observed (expected) significance at 125 GeV: 0.14σ (0.89σ)
- Maximum significance at 141 GeV: 1.7σ
- Observed (expected) upper limit at 125 GeV: 18.2xSM (13.5xSM)

Summary

- Searches for a Standard Model Higgs in the di-muon and Zγ channels has been presented
- In the absence of a signal exclusion limits have been calculated
- Combination of results from 8 TeV and 7 TeV data sets in preparation for publication