Overview of H$\rightarrow$ *invisible* Searches and Coupling Combination

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Structure of this Talk

- Will focus on the new results
- Cover H$\rightarrow$inv. and SM coupling combination
- Summary

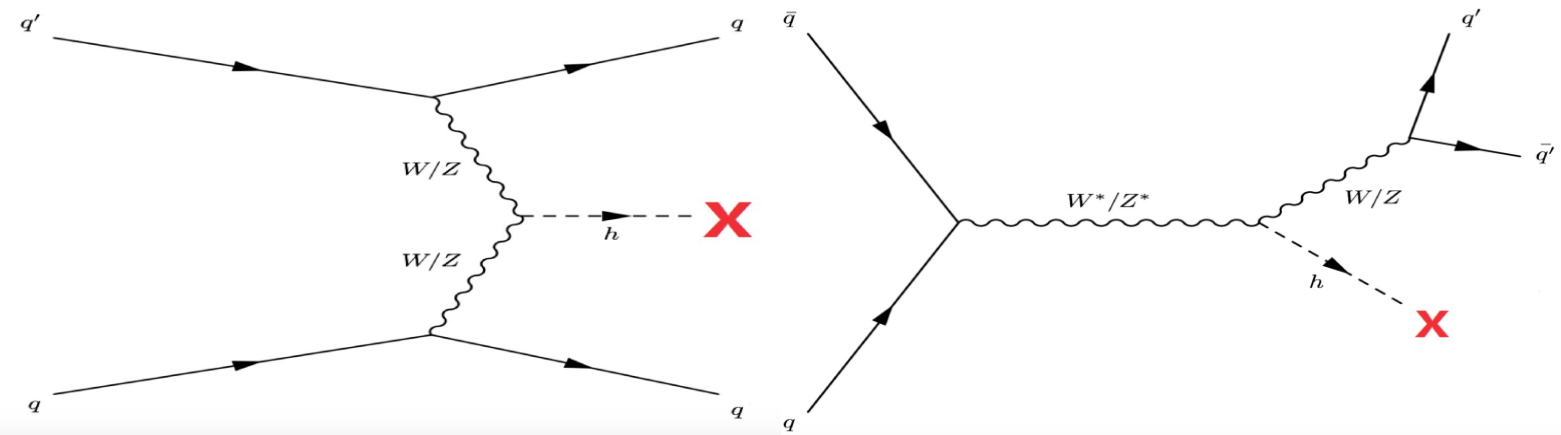
H→invisible Particles

Higgs couple with dark sector

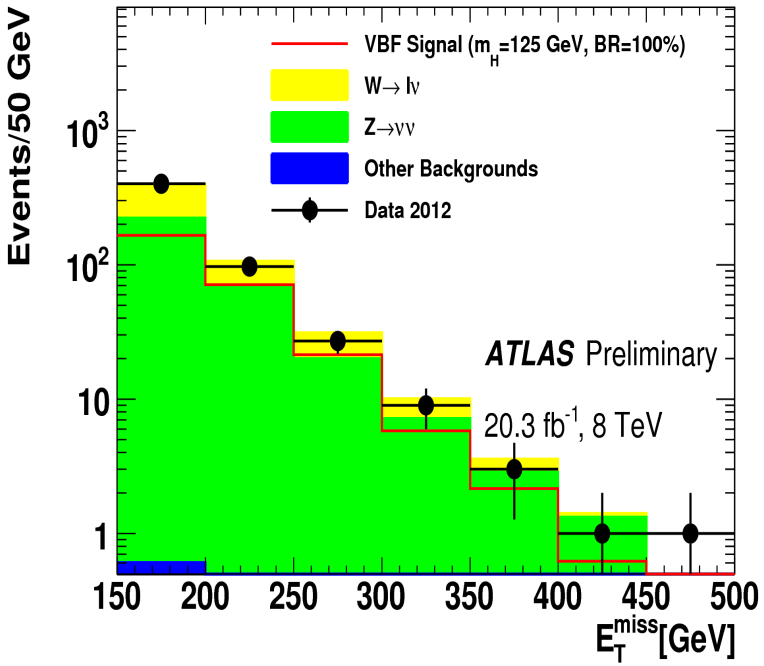
- sizable deviations from the SM expectation cannot be yet excluded; the total branching ratio of BSM decays of the Higgs boson is only weakly constrained
- One possible decay is to weakly interacting particles, as predicted by many extensions of the SM
- Looking for excess in the $E_{\mathrm{T}}^{\mathrm{miss}}$ spectrum. To suppress the hugh BGs, need a “tag”.

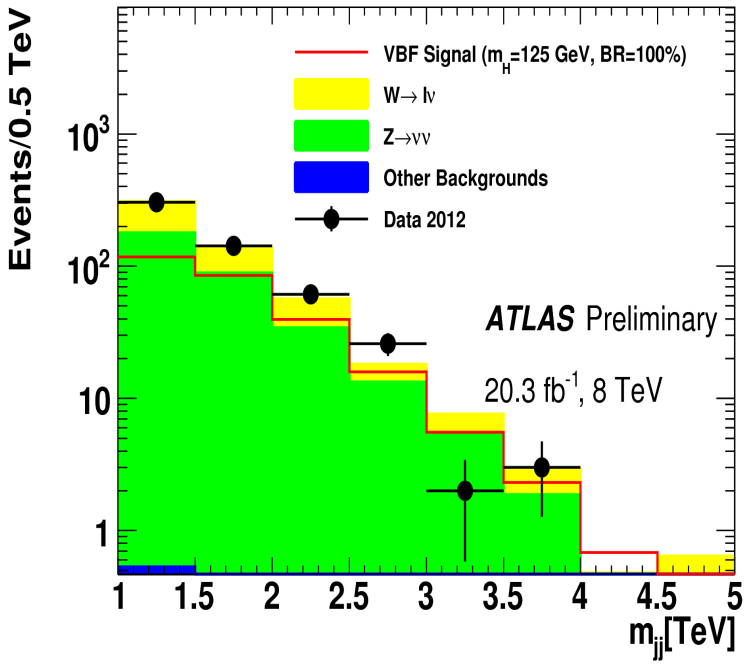
Different tags:

- VBF: two well-separated forward jets; high invariant mass m_{jj}
- hadronic VH: two or thee central jets, mass consistent with V



VBF Channel





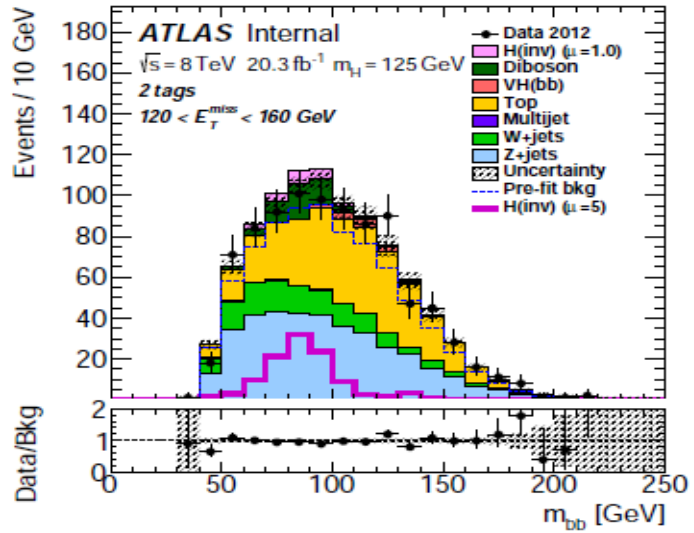
- $Z\nu\nu$+jets, $Wl\nu$+jets dominated;
- Simultaneous fit to $Z\rightarrow ll$, $W\rightarrow l\nu$ CRs
- **Br(H$\rightarrow$inv) $<$ 0.29 (0.35 exp)95% CL**

hadronic VH Channel, Selections

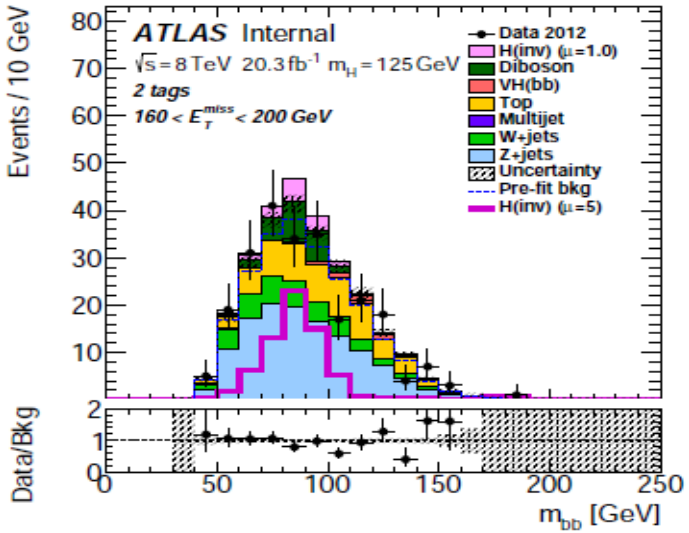
- Categorization: 0/1/2-tag $\otimes$ 2/3-jets $\otimes$ 4 different $E_{\mathrm{T}}^{\mathrm{miss}}$ bins
- different cuts for different categories, well physics motivated

$E_{\mathrm{T}}^{\mathrm{miss}}$ range (GeV)	120 - 160	160 - 200	200 - 300	> 300
Variable	Selection			
ΔR_{jj}, 2- and 3-jet events	0.7 - 2.0	0.7 - 1.5	< 1.0	< 0.9
m_{jj}, 2-jet events (GeV)	70 - 100	70 - 100	70 - 100	75 - 100
m_{jj}, 3-jet events (GeV)	50 - 100	55 - 100	60 - 100	70 - 100

m_{jj} Plots



(a)



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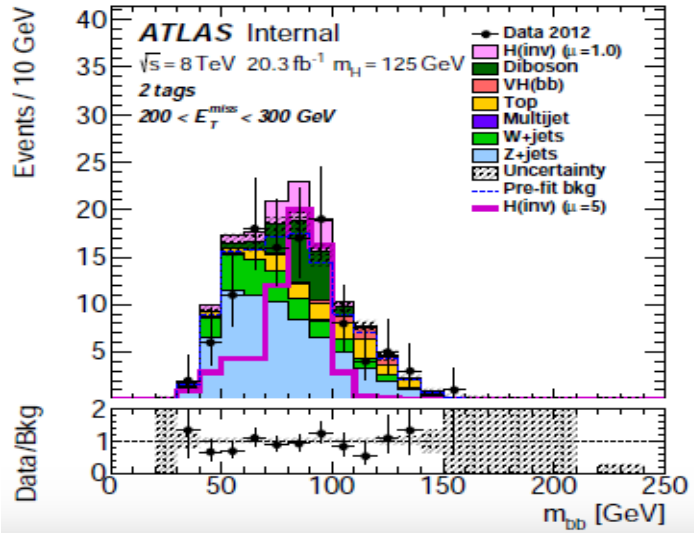
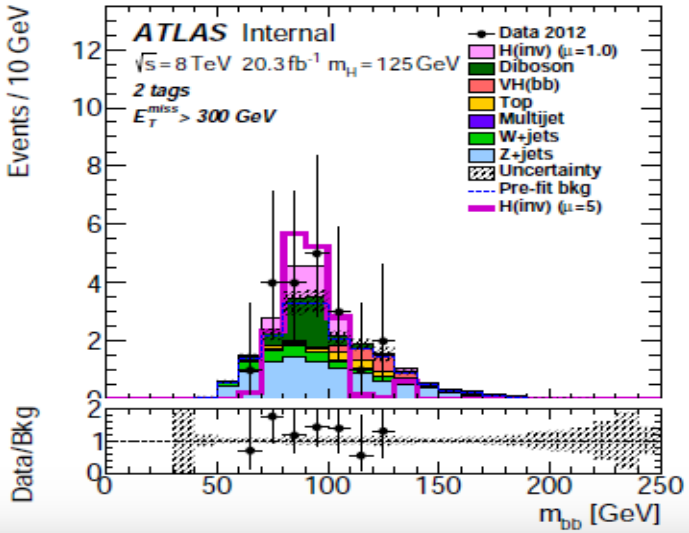
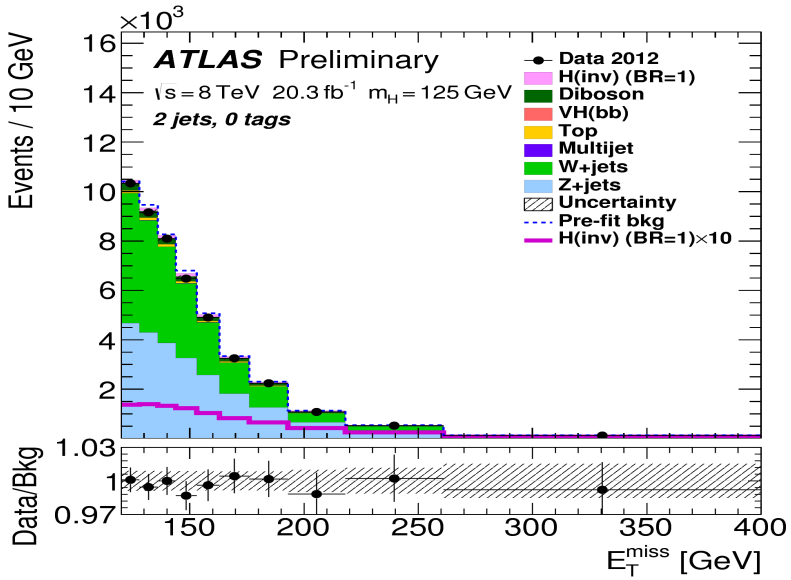
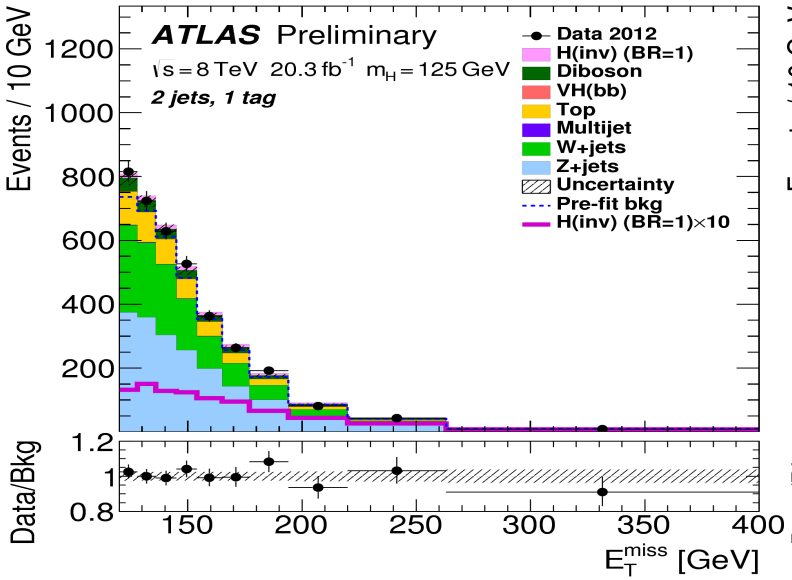


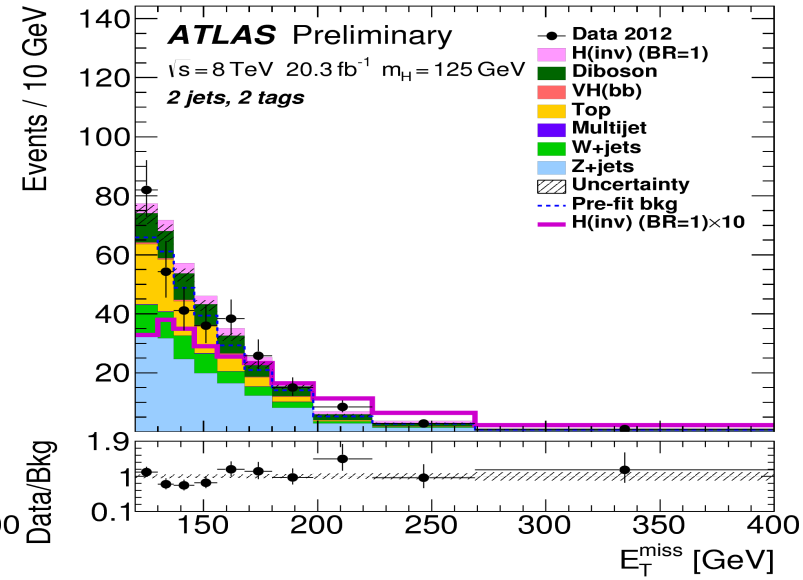


Higher $E_{\mathrm{T}}^{\mathrm{miss}}$, the best S/B

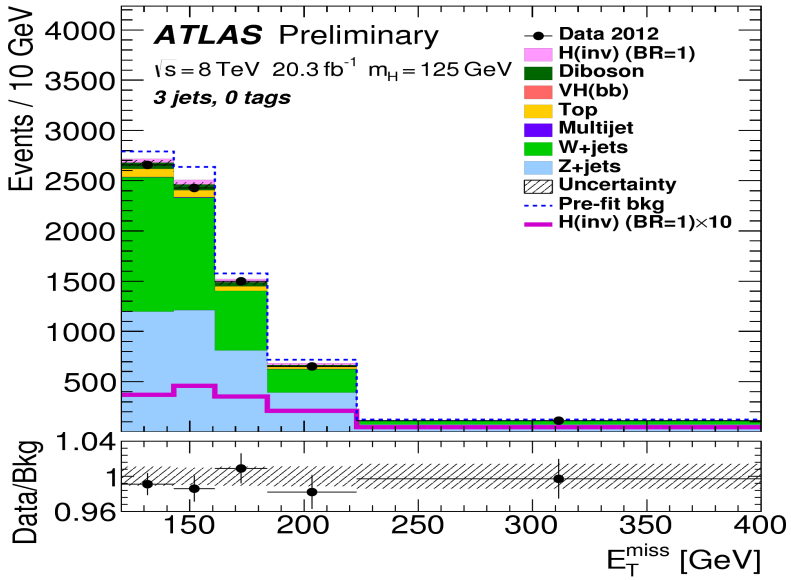
hadronic VH Channel, Final 2-jet Plots

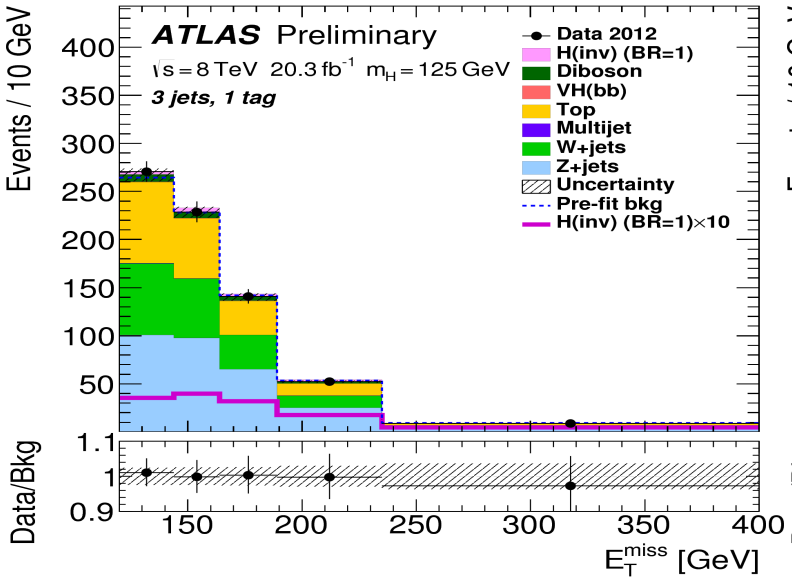


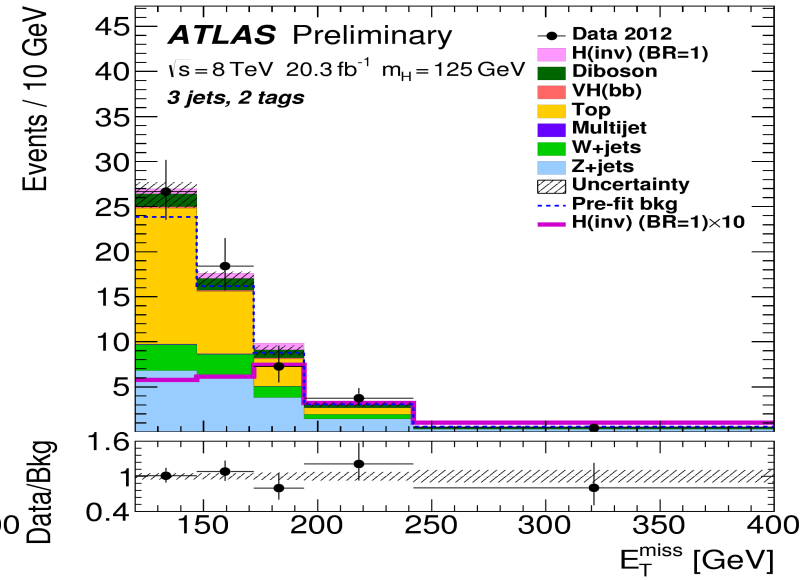




hadronic VH Channel, Final 3-jet Plots





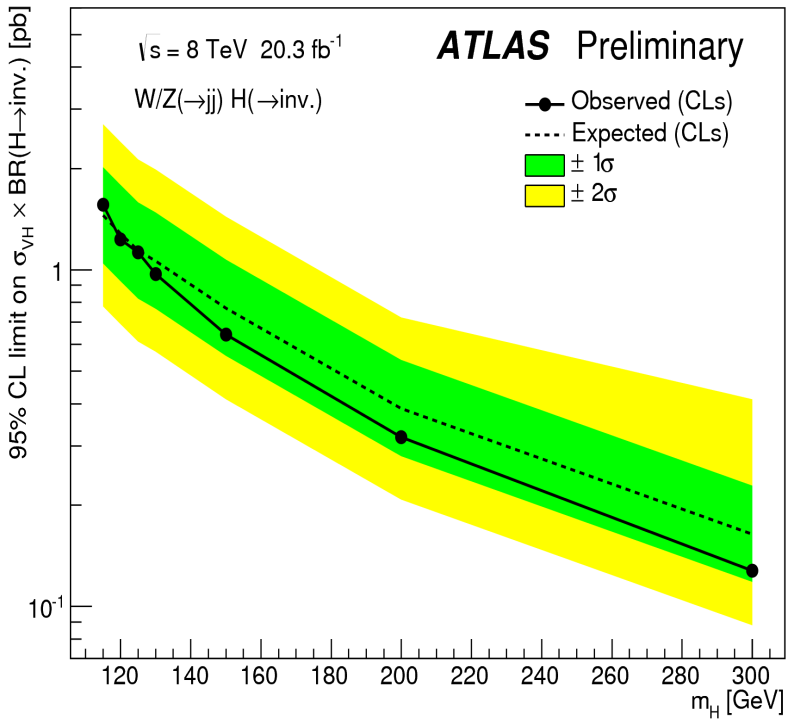


Details of the Systematic Impacts

Source	Impact on $\Delta\mu$	
Object systematic uncertainties		
Jets & $E_{\mathrm{T}}^{\mathrm{miss}}$	$+0.22$	-0.22
Luminosity	$+0.04$	-0.03
b-tagging	$+0.05$	-0.04
Background systematic uncertainties		
Diboson	$+0.26$	-0.29
Z+jets	$+0.21$	-0.22
W+jets	$+0.15$	-0.16
$t\bar{t}$	$+0.06$	-0.05
Multijet	$+0.07$	-0.07
Total		
Total systematic uncertainty	$+0.41$	-0.43
Data statistical uncertainty	$+0.12$	-0.12
Total uncertainty	$+0.43$	-0.44

- Jet/$E_{\mathrm{T}}^{\mathrm{miss}}$, di-boson related systematics most important
- Then the modelling of Z+jets

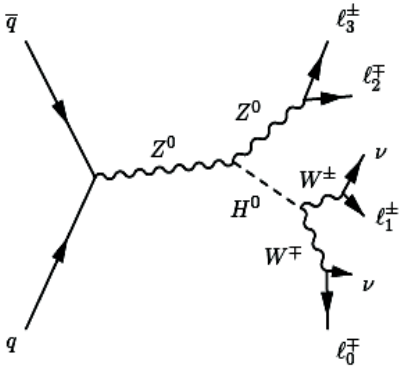
Sensitivity



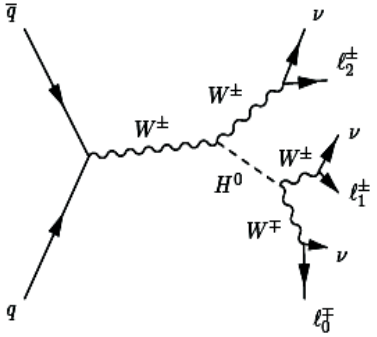
- With ggF signals included, **Br(H→inv) $<$ 0.78 (0.86 exp)95% CL**.
- Note: Z($\rightarrow ll$)H($\rightarrow inv.$) has Br(H→inv) $<$ 0.75 for 2011 + 2012 data.

VH(WW) Analysis

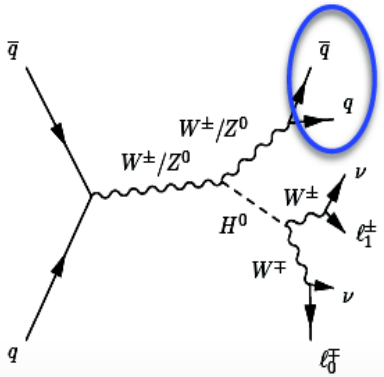
4 leptons



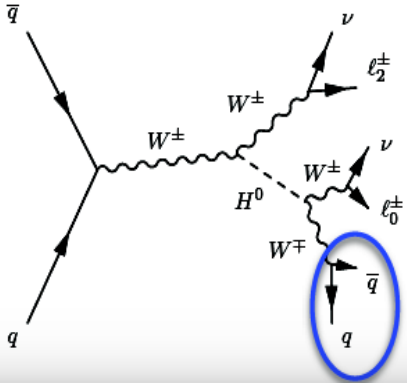
3 leptons



2 OS leptons



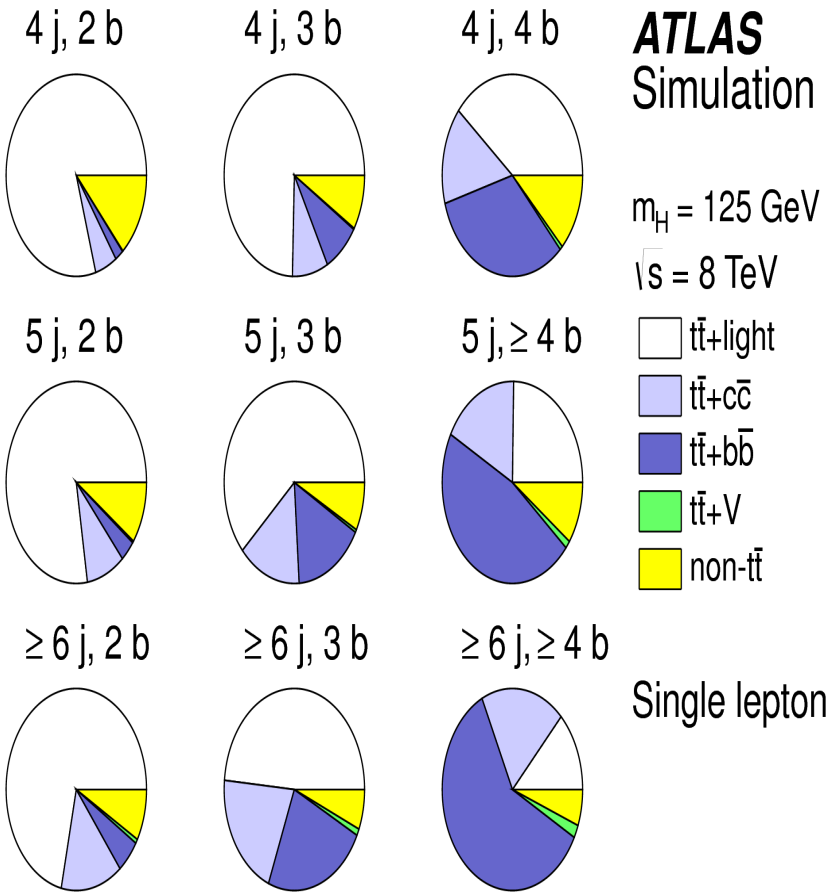
2 SS leptons



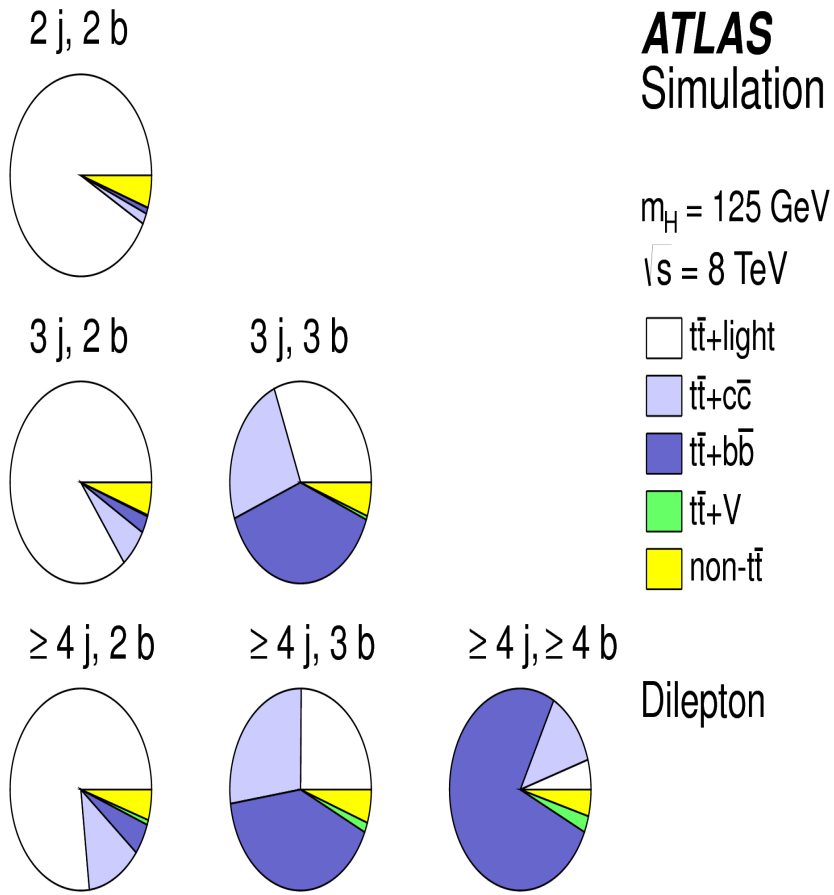
- Categories depending on number of leptons and jets, OS-SS
- VV, VVV are the main backgrounds, then top and Z/W+jets
- Results: $\mu^{WH} = 2.1^{+1.5}_{-1.3}(stat.)^{1.0}_{-0.9}(sys.)$, $\mu^{ZH} = 4.9^{+3.7}_{-2.9}(stat.)^{1.7}_{-1.0}(sys.)$ $\mu^{VH} = 2.9^{+1.2}_{-1.1}(stat.)^{0.8}_{-0.6}(sys.)$

ttH(bb) Categorization

l+jet channel:

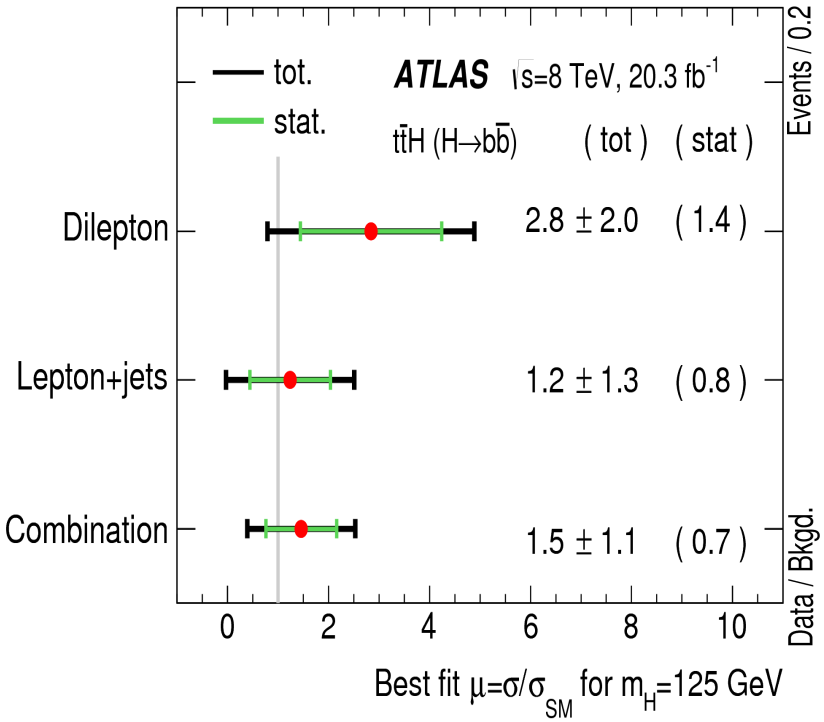


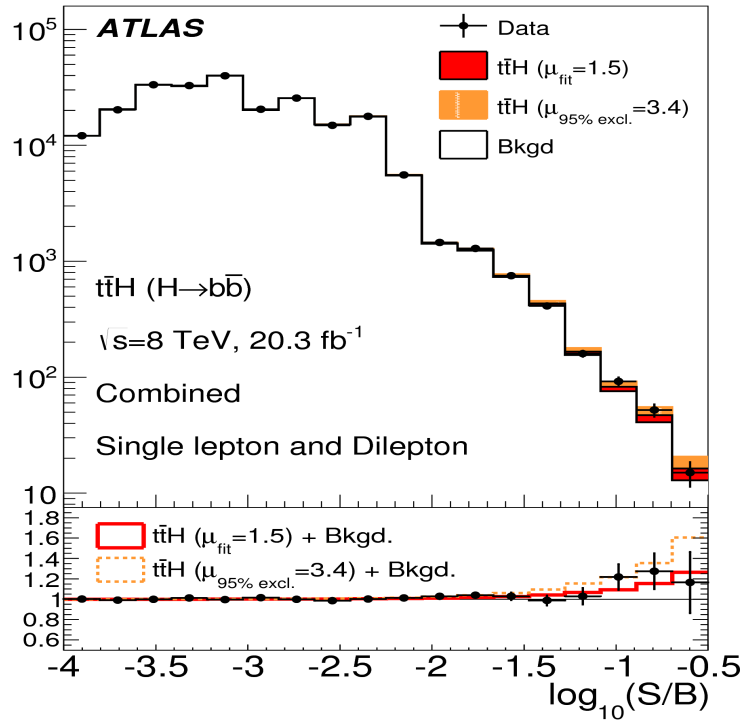
di-lepton channel:



ttH(bb) Results

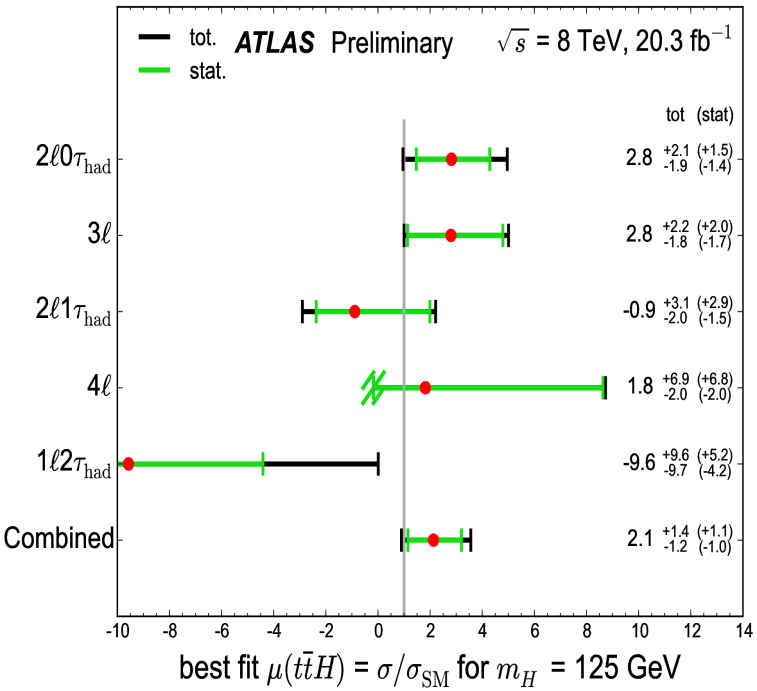
Combined $\mu = 1.5 \pm 1.1$; $\mu < 3.4 obs(2.2 exp)$ @95% CL

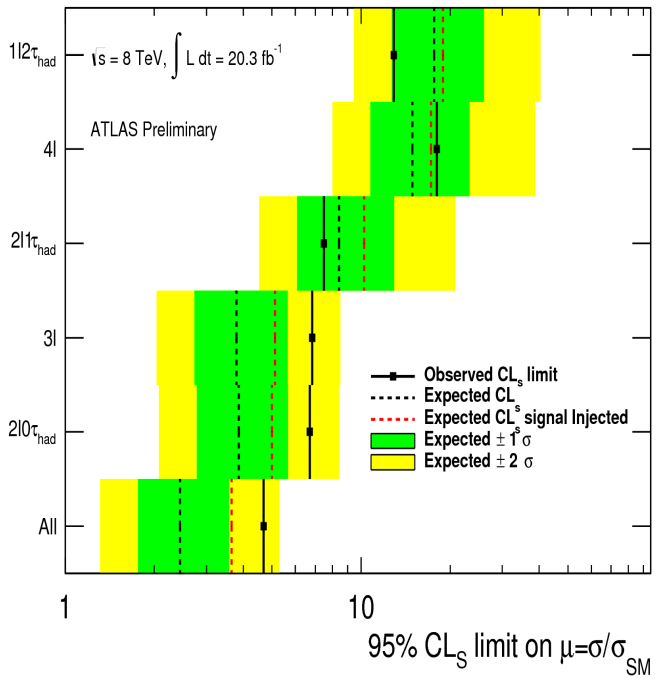




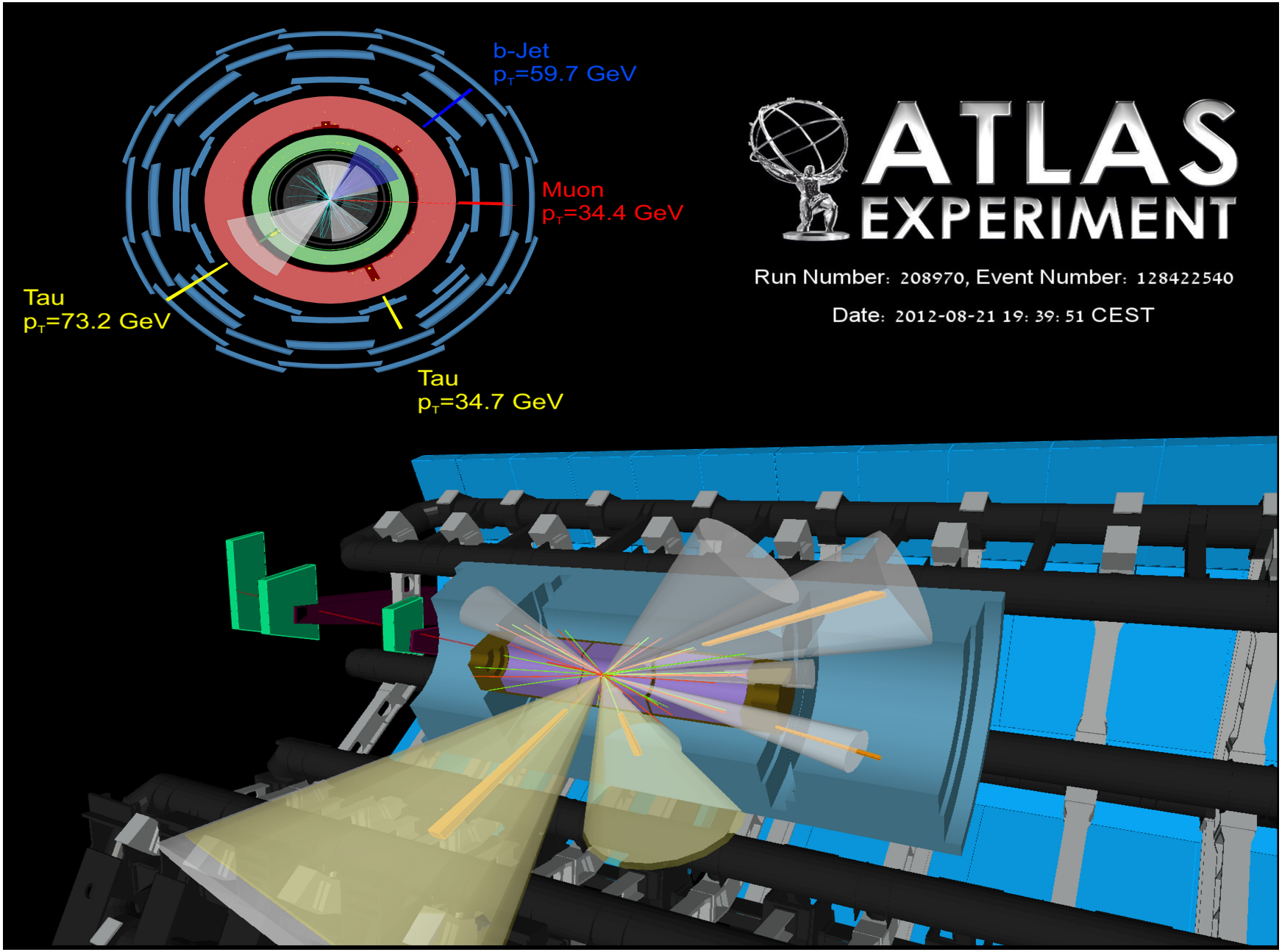
ttH($WW/\tau\tau$) Results

Combined $\mu = 2.1^{+1.4}_{-1.2}$; $\mu < 4.7\ obs(2.4\ exp)$ @95% CL

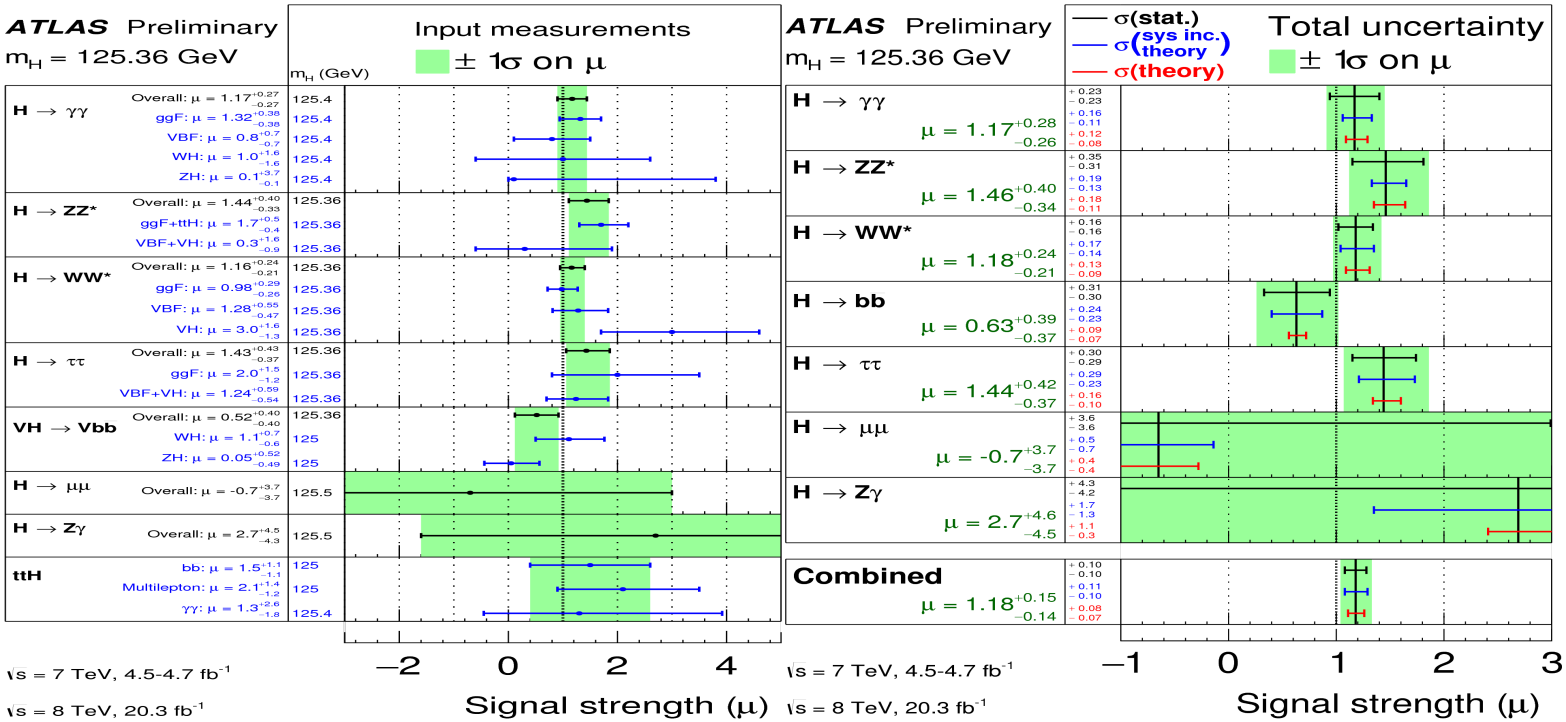




ttH($WW/\tau\tau$) Event Display: 1l2tau candidate

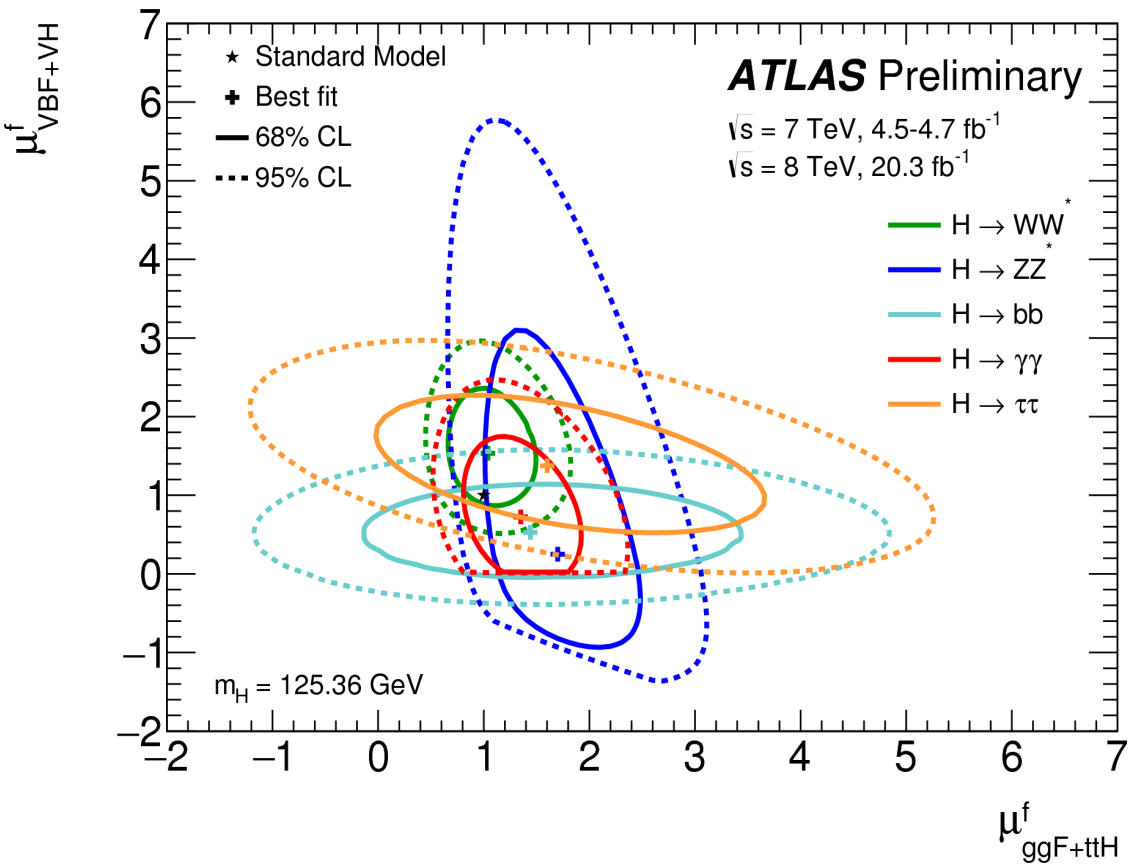


Summary of the μ Measurements



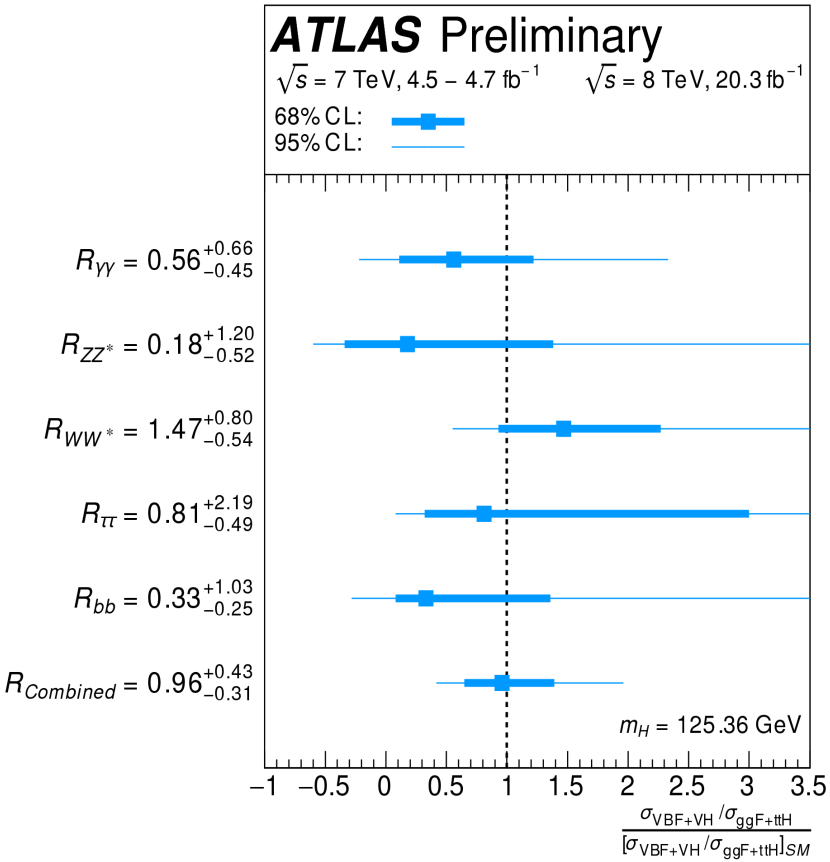
- Summary of the signal-strength measurements, as published; ttH($\rightarrow \gamma\gamma$) is included in ttH
- Higgs boson signals corresponding to the same decay channel are combined together

Likelihood contours in the ($\mu^f_{ggF+ttH}$, μ^f_{VBF+VH}) plane



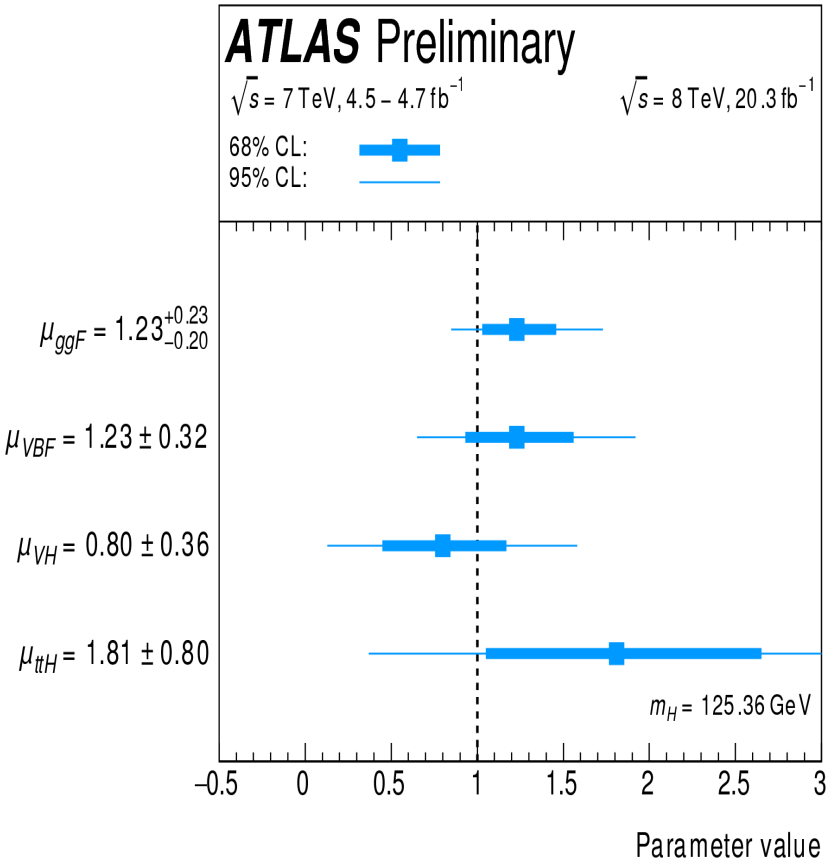
- categorised into two groups according to the Higgs boson couplings to fermions or vector bosons. Potential deviations from the SM can be tested with two signal-strength parameters,
- The SM expectation (1,1) is within the 68% CL contour of most of these measurements.

cross-section ratio



- this ratio reduces to the ratio of production cross sections as the Higgs boson decay branching ratios cancel
- The combination yields an overall value of the cross-section ratio between the boson- and fermion-mediated processes

signal-strength values of different production modes



- The signal-strength in reasonable agreement with the SM predictions
- Results indicates evidence for ttH production, this process remains to be firmly established in future LHC runs

Summary

- Many new ATLAS Higgs results have been released recently using RunI data. ttH, H$\rightarrow$ *inv.*, Spin/CP combination, coupling combination ...
- Check the ATLAS public results pages to get the full list
- All measurements are consistent with SM prediction
- Analyses are generally statistics-limited; Wait Run 2 data with great expectation!