Search for $H \rightarrow e^+e^-$ using $140 fb^{-1}$ of 13 TeV pp collision data with the ATLAS experiment

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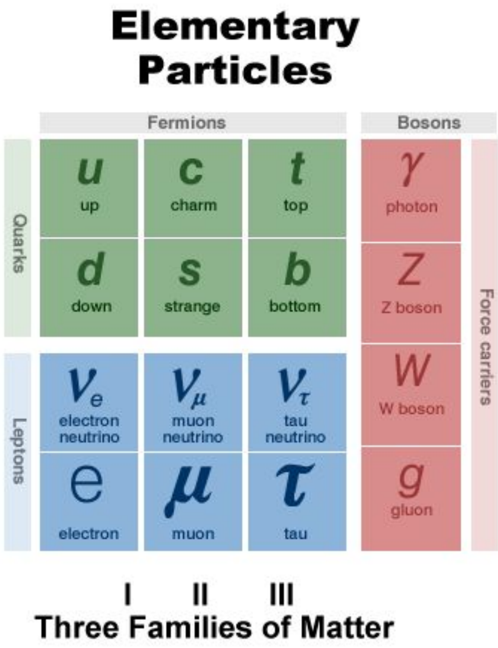


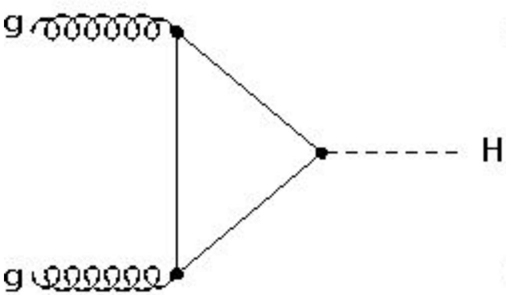
Introduction

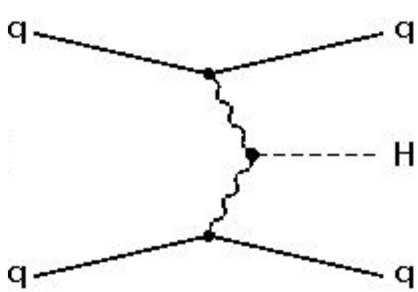
- Search for direct decay from Higgs to e^+e^-
- Previous measurements and observations of the Higgs boson have been of third generation fermions and gauge bosons, so first generation fermions are mostly unexplored
- There are no results for this decay at 13 TeV, previous result was from CMS with 8 TeV data [1]
- Despite the low SM branching ratio (~$5x10^{-9}$), this search has similar backgrounds and efficiencies to the H->$\mu^+\mu^-$ search [2], so we can use similar methodology

[1]
Phys.Lett. B744 (2015) 184-207
arXiv:1410.6679

[2]
ATLAS-CONF-2018-026

Analysis Outline





Today's presentation covers 4 steps of the analysis:

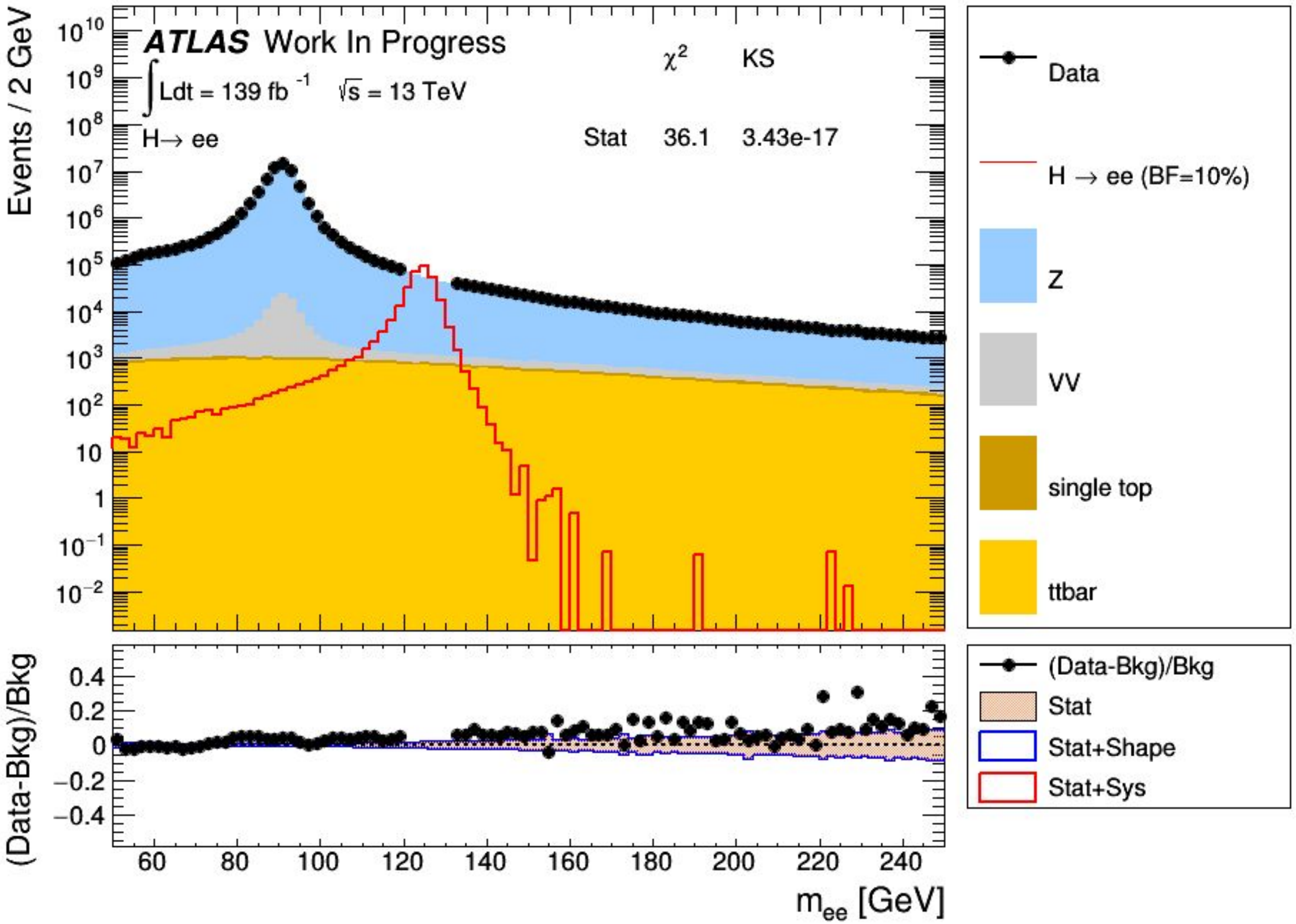
- Event selection
- Event categorisation
- Fit to signal Monte Carlo (gluon-gluon fusion [ggF] and vector boson fusion [VBF], among others) to parameterise signal probability distribution function (PDF)
- Fit to data, with smooth PDF fitted to sidebands for the background, and fitted signal model used for signal efficiency
  - Branching ratio used as parameter of interest
  - Production cross-sections assumed to be SM values

Event Selection

Electrons	Jets (used in VBF category)
$p_T > 7$ GeV	$p_T > 30$ GeV
$\|\eta\| < 2.47$	$\|\eta\| < 4.5$

- Events pass a single electron trigger
- Two opposite sign electrons
  - $p_T > 27$ GeV for leading, $p_T > 15$ GeV for sub-leading
- Sig(MET) = MET/($\Sigma(p_T)^{jets+leps})^{1/2} < 3.5$ GeV$^{1/2}$
- No events with jets tagged as containing a b-hadron (using a tagging algorithm with 60% efficiency)
- The signal region is defined as $110 < M_{ee} < 160$ GeV

M_{ee} distribution after selection



Background MC not used in analysis

Event categorisation

VBF

p_T^{ee} [GeV]	Cent	Forw
<15	LowC	LowF
>15 <50	MidC	MidF
>50	HiC	HiF

Seven orthogonal categories are used, the first is designed to select "VBF-like" events:

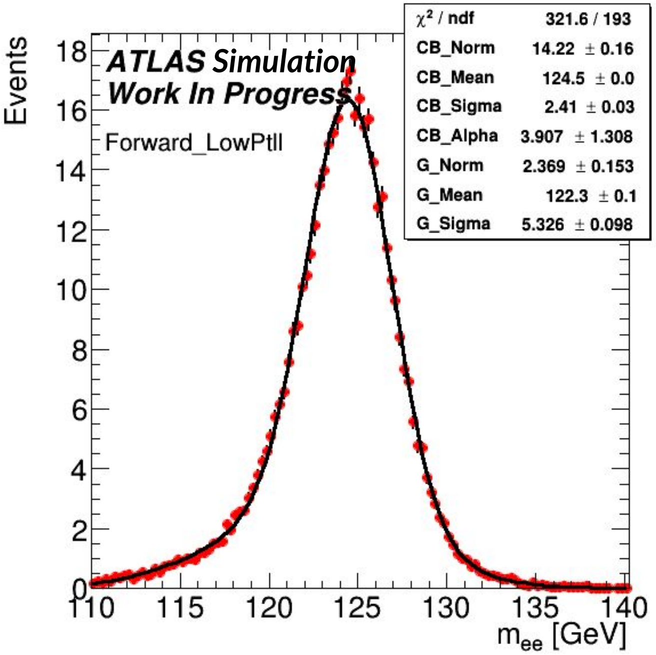
- Two (or more) jets
- Leading jets in opposite ends of the detector ($\eta_1\eta_2 < 0$)
- $\Delta(\eta_1, \eta_2) > 3$
- $M(j_1, j_2) > 500$ GeV

Non VBF-like events are split kinematically by electron η

- Central ($|\eta_{e1}| < 1.0$ AND $|\eta_{e2}| < 1.0$)
- Forward (NOT Central)

And then split further into low, medium, or high di-electron p_T

Signal Modeling

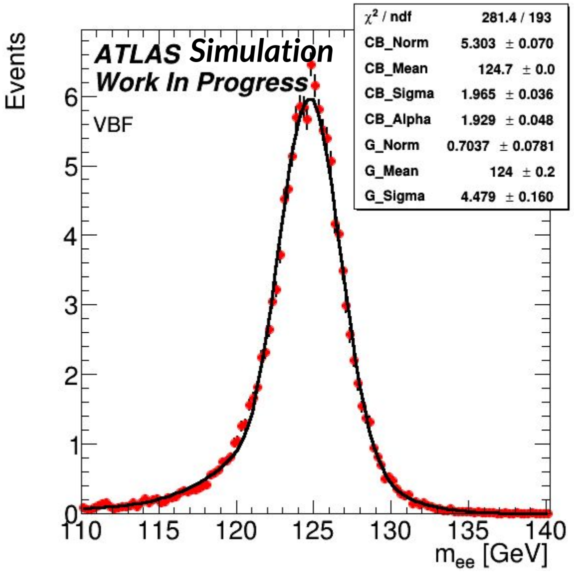


Model signal as sum of a Gaussian and Crystal Ball:

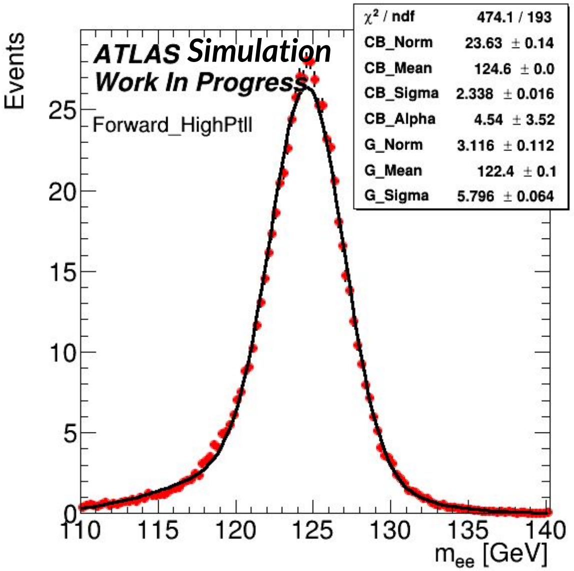
$$F_{sig} = (1 - f)\, CB(M_{ee}\, ; \boldsymbol{\mu}_C\, , \boldsymbol{\sigma}_C\, , \alpha\, , n) + f\, G\,(M_{ee}\, ; \boldsymbol{\mu}_G\, , \boldsymbol{\sigma}_G)$$

- $\boldsymbol{\mu}$ = mean, $\boldsymbol{\sigma}$ = width
- α = “cut-off” parameter of Crystal Ball
- n = “slope” parameter of Crystal Ball (fixed to 1)
- f = fractional contribution of the Gaussian

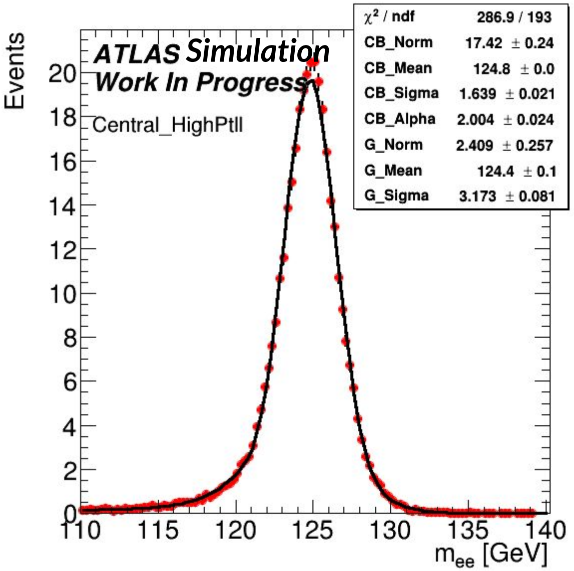
Signal Fits



ATLAS Simulation
Work In Progress
VBF
χ² / ndf 281.4 / 193
CB_Norm 5.303 ± 0.070
CB_Mean 124.7 ± 0.0
CB_Sigma 1.965 ± 0.036
CB_Alpha 1.929 ± 0.048
G_Norm 0.7037 ± 0.0781
G_Mean 124 ± 0.2
G_Sigma 4.479 ± 0.160
Events
m_ee [GeV]

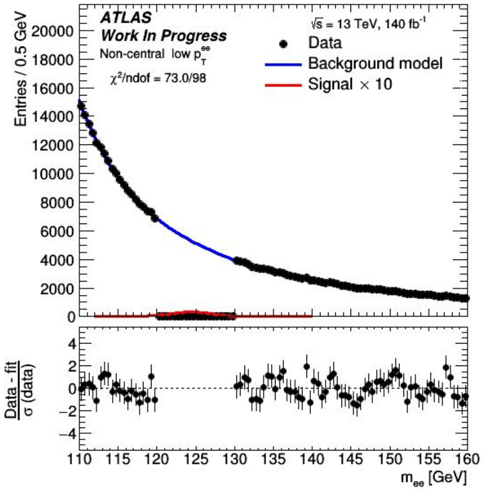


ATLAS Simulation
Work In Progress
Forward_HighPtll
χ² / ndf 474.1 / 193
CB_Norm 23.63 ± 0.14
CB_Mean 124.6 ± 0.0
CB_Sigma 2.338 ± 0.016
CB_Alpha 4.54 ± 3.52
G_Norm 3.116 ± 0.112
G_Mean 122.4 ± 0.1
G_Sigma 5.796 ± 0.064
Events
m_ee [GeV]



ATLAS Simulation
Work In Progress
Central_HighPtll
χ² / ndf 286.9 / 193
CB_Norm 17.42 ± 0.24
CB_Mean 124.8 ± 0.0
CB_Sigma 1.639 ± 0.021
CB_Alpha 2.004 ± 0.024
G_Norm 2.409 ± 0.257
G_Mean 124.4 ± 0.1
G_Sigma 3.173 ± 0.081
Events
m_ee [GeV]

Background Modeling



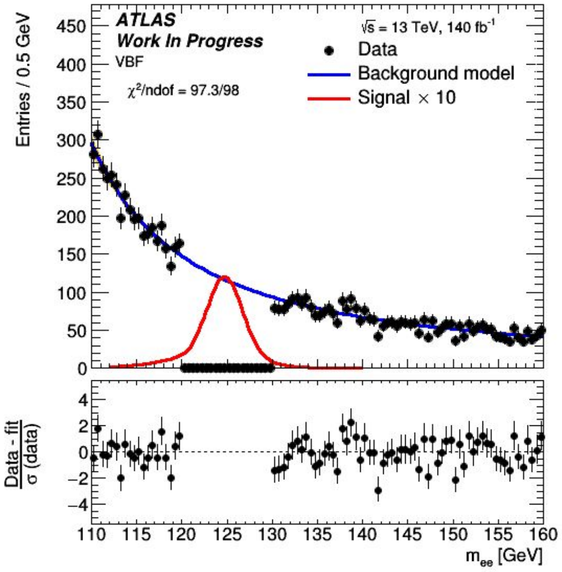
Sum of two functions:

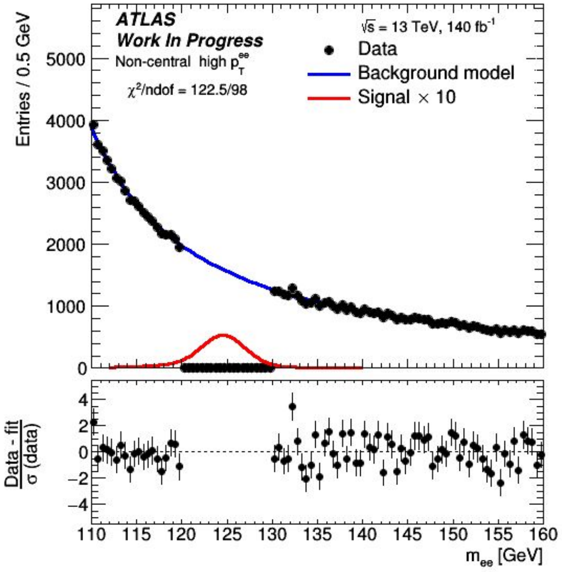
- Breit-Wigner (resonance) ⊗ Gaussian (detector) (Z/γ^*)
- Exponential/x^3 (VV/top)

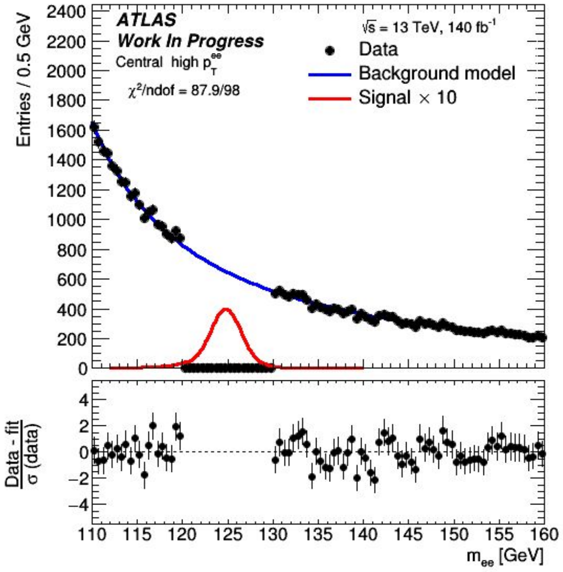
$$F_{bkg} = f\,[\,BW(M_{ee}\,;M_Z, \Gamma_Z) \otimes G(M_{ee}\,;\boldsymbol{\sigma}_G)\,] + (1 - f)\,\exp(B\,M_{ee}) / (M_{ee})^3$$

- M_Z and Γ_Z set to PDG values (91.2 GeV and 2.49 GeV)
- $\boldsymbol{\sigma}_G$ - resolution found using simple Gaussian fit to signal peak in MC, then fixed in fit to data
- B floating between -1 and 1, f floating between 0 and 1

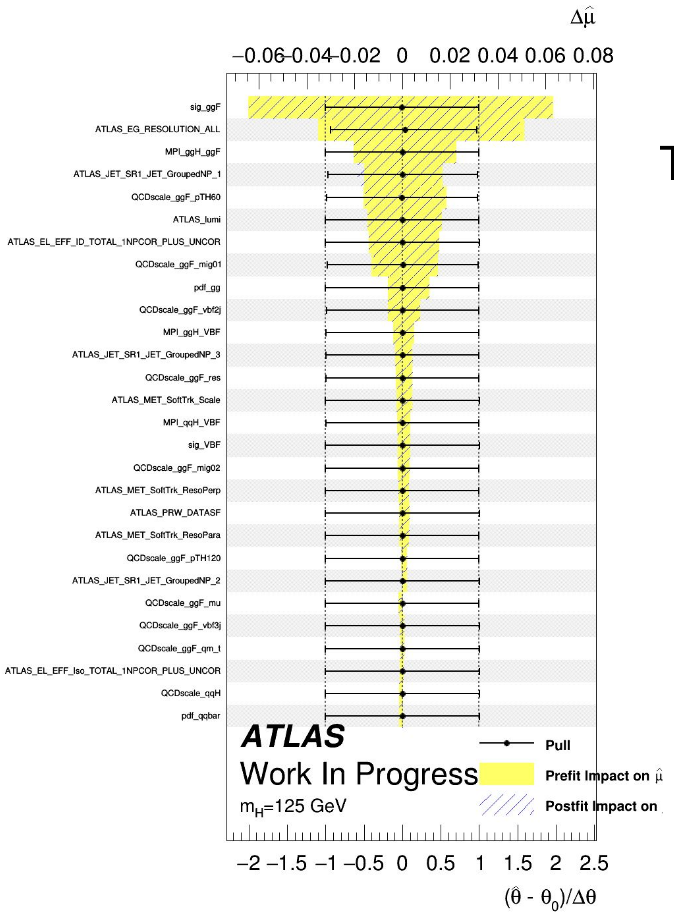
Background Fits







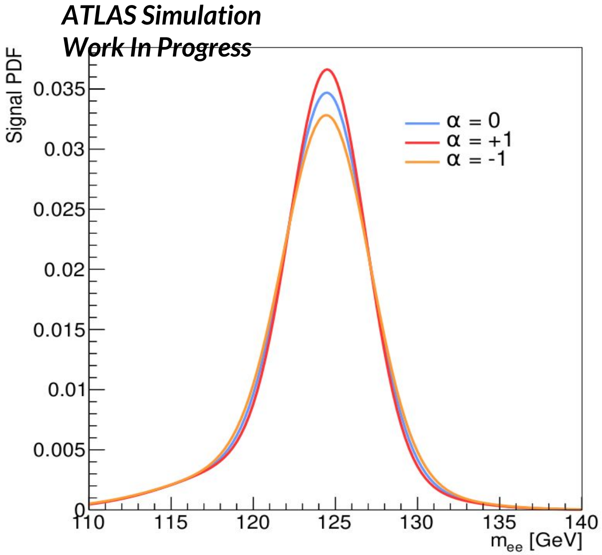
Systematic Variations



Three sources of systematics are considered

- Experimental shape and normalisation systematics on the signal, e.g. detector resolution in signal MC
- Theoretical signal systematics, e.g. the uncertainty on σ_{ggF} (since we are measuring a branching ratio)
- “Spurious signal” uncertainty, based on the background (mis-)modeling

Systematics



Signal modeling fit is repeated for each systematic set to +1σ and -1σ

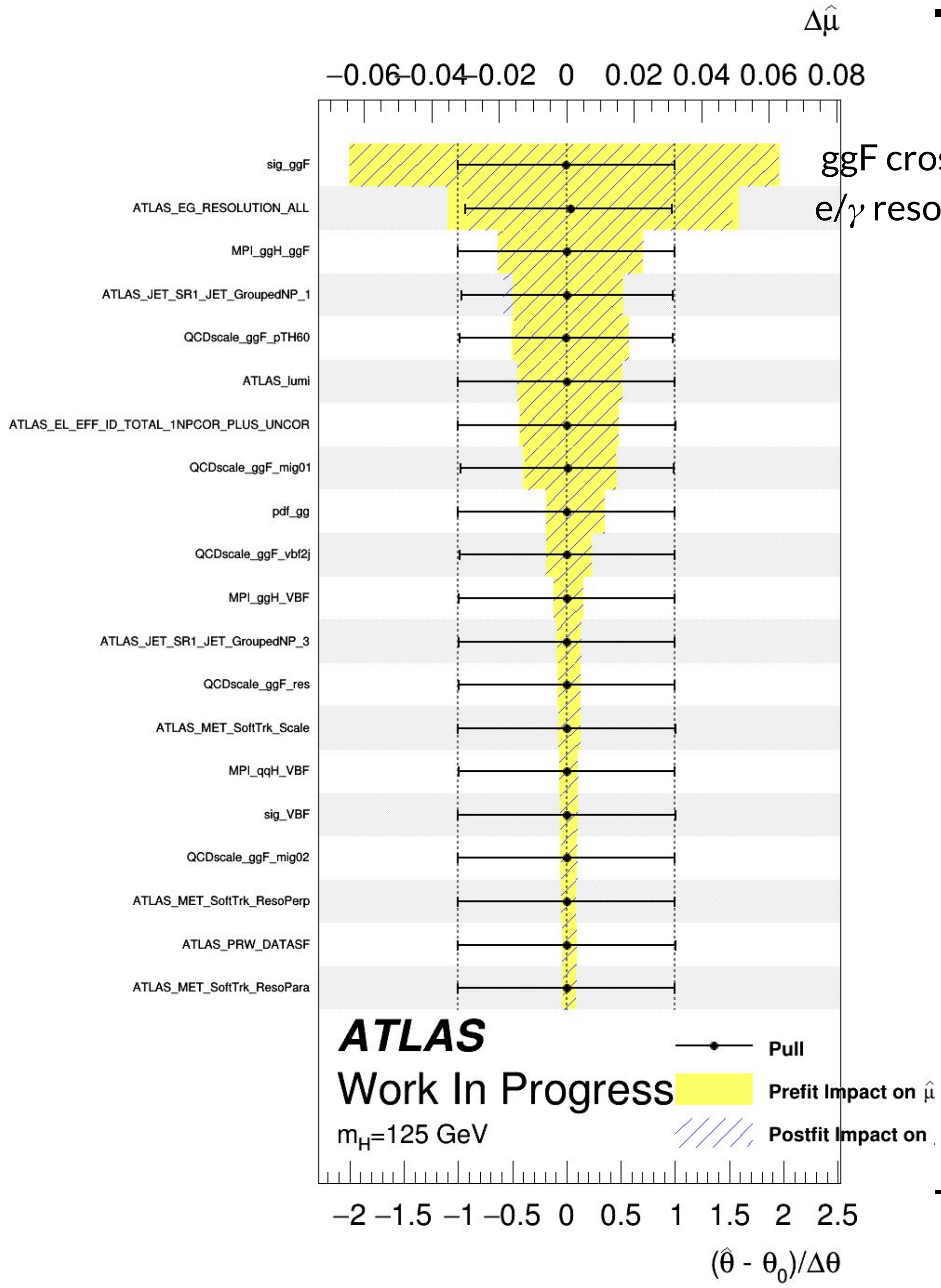
In the final fit to data, each systematic is represented by a nuisance parameter

The largest impact comes from the theoretical uncertainty on the ggF cross-section

However these uncertainties are still small compared to the statistical uncertainty

Spurious signal systematic still under investigation, but from preliminary results it is also expected to be small

Systematics (Asimov Fit)



ggF cross section

e/γ resolution

Final Fitting/Results

CMS Paper:

Phys.Lett. B744 (2015) 184-207 arXiv:1410.6679

Likelihood computed from data and fitted PDFs (including systematic nuisance parameters

95% CL_S limit on the branching ratio BR(H->ee) computed through a scan of BR hypotheses

Expected limits on BR(H->ee) at 140fb^{-1}, compared with CMS observed limit at 19.7 fb^{-1}, 8 TeV [x10^{-4}] :

CMS exp (19.7 fb^{-1})	CMS obs (19.7 fb^{-1})	Expected	+2σ	+1σ	-1σ	-2σ
24	19	3.3	6.3	4.6	2.4	1.8

Conclusions

CMS Paper:

Phys.Lett. B744 (2015) 184-207
arXiv:1410.6679

Expected limits on BR (H -> e^+e^-) are factor ~5.5 better than previously observed limits on the same branching ratio

While luminosity alone does not account for this improvement, there is a large increase (factor ~2.3) in the production cross-section that contributes

Some analysis techniques have also changed which contributes to the change

Also shows an ~1.4 factor improvement in sensitivity from an interpretation of the 80fb^{-1} ATLAS H->$\mu\mu$ result, close to what you would expect from the increase in luminosity

This is due to this analysis using much more similar techniques to the ATLAS H->$\mu\mu$ analysis