Combination of couplings and mass in ATLAS and CMS

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Introduction

- Higgs couplings and mass are important SM parameters
  - The mass was the last missing ingredient to the EWK fit
- Both ATLAS and CMS released updated results with the full run I statistics
- The LHC-HCG is taking care of combining the results of the 2 experiments
  - The combined results for the mass are ready ✓
  - Couplings combination is to be released soon (it also depends on the mass!)
- The full SM Higgs picture will be completed by the results on spin/parity (K. Liu) and width (M. Calandri)

Higgs mass measurement

Precise mass determination possible in 2 channels:

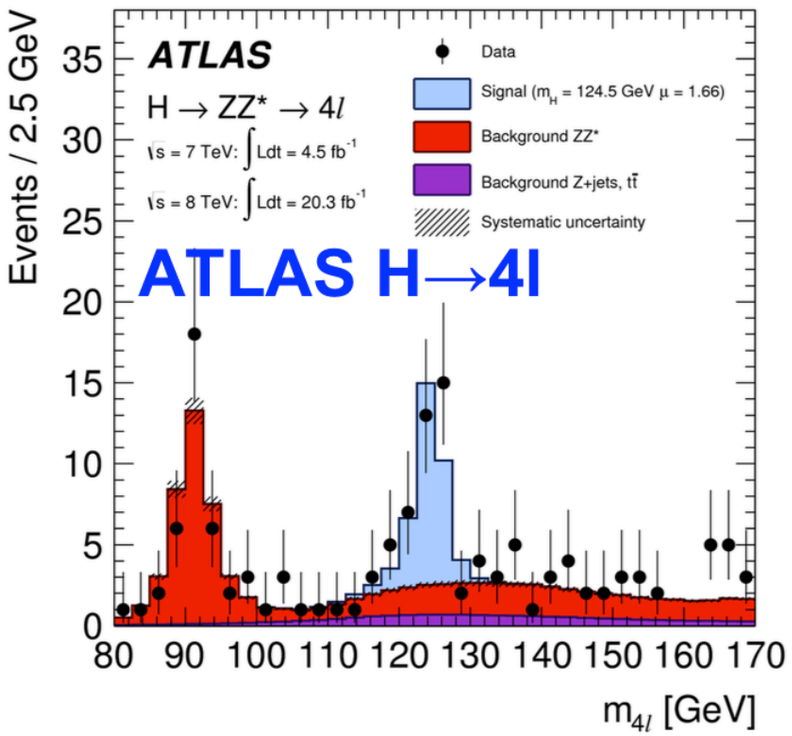
- 4l and γγ
- All other channels have ν or hadrons in final state

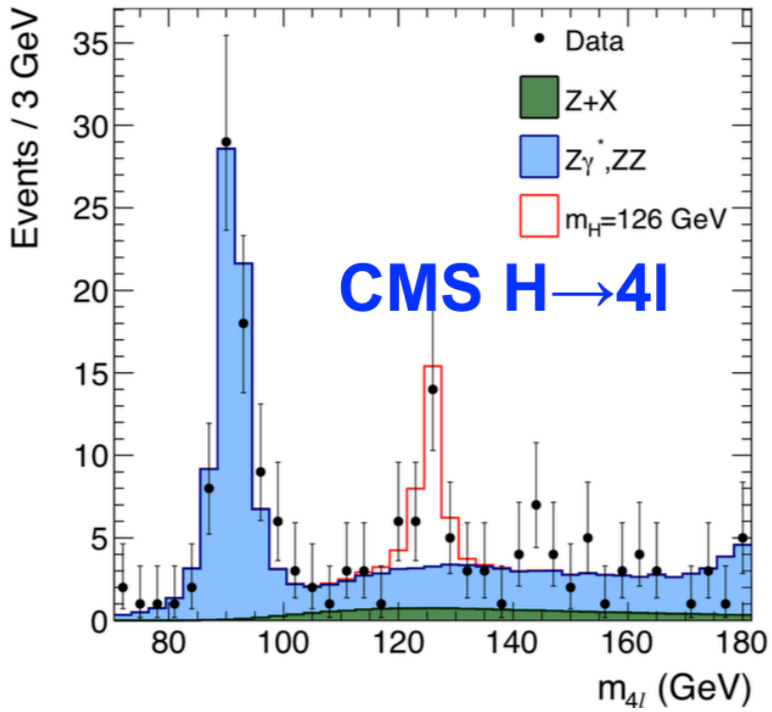
Comparable results among the experiments

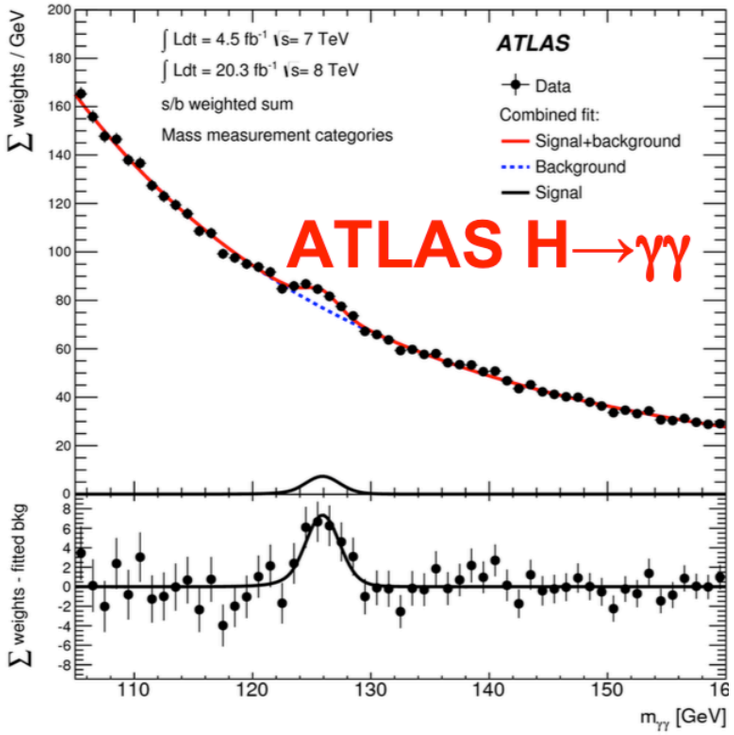
Lot of work to properly assess/ correlate/quantify all the systematics in the 2 experiment in order to combine properly the likelihoods.

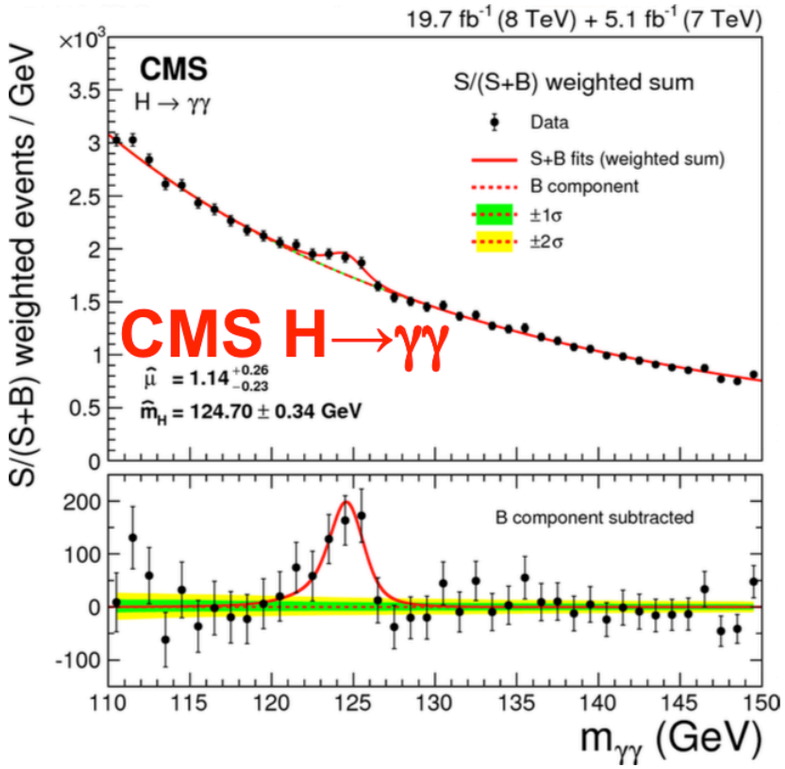
Individual results:

- ATLAS: Phys. Rev. D. 90, 052004 (2014)
- CMS: arXiv: 1412.8662



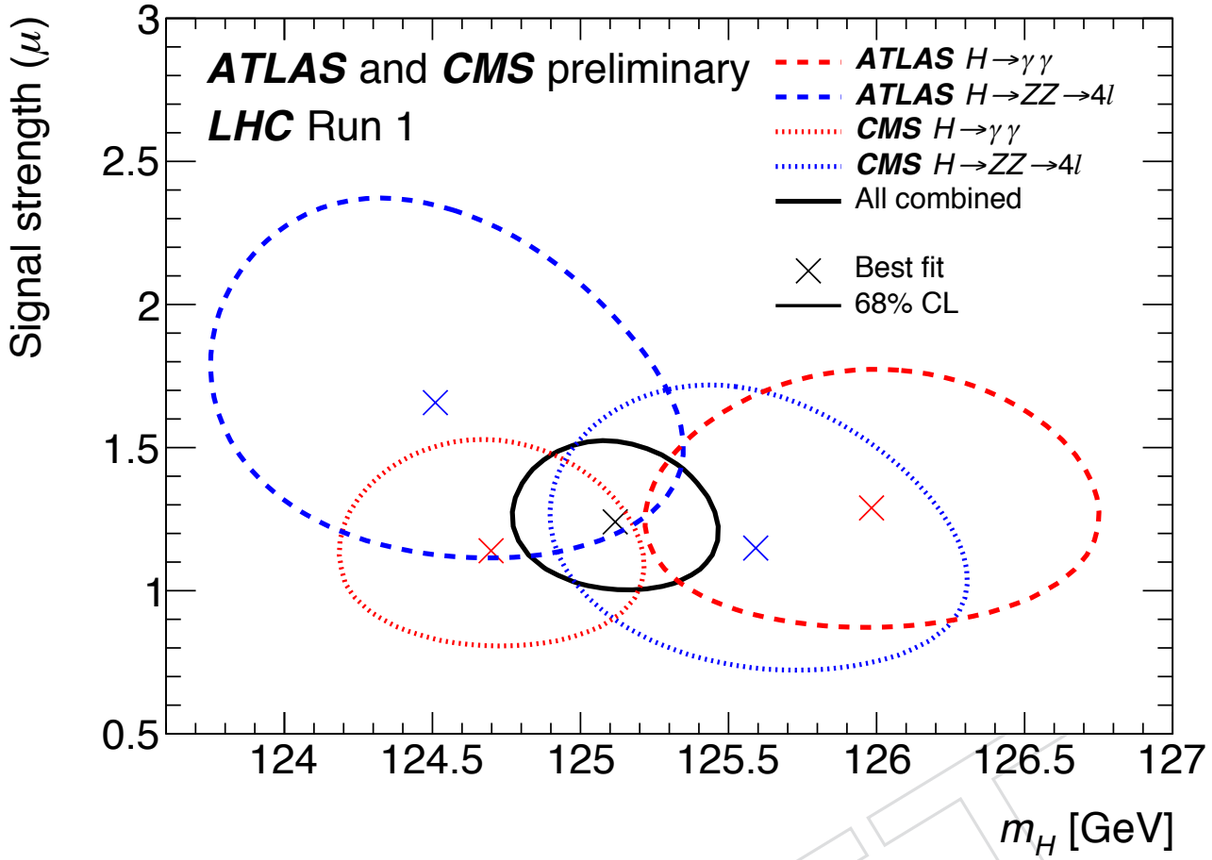




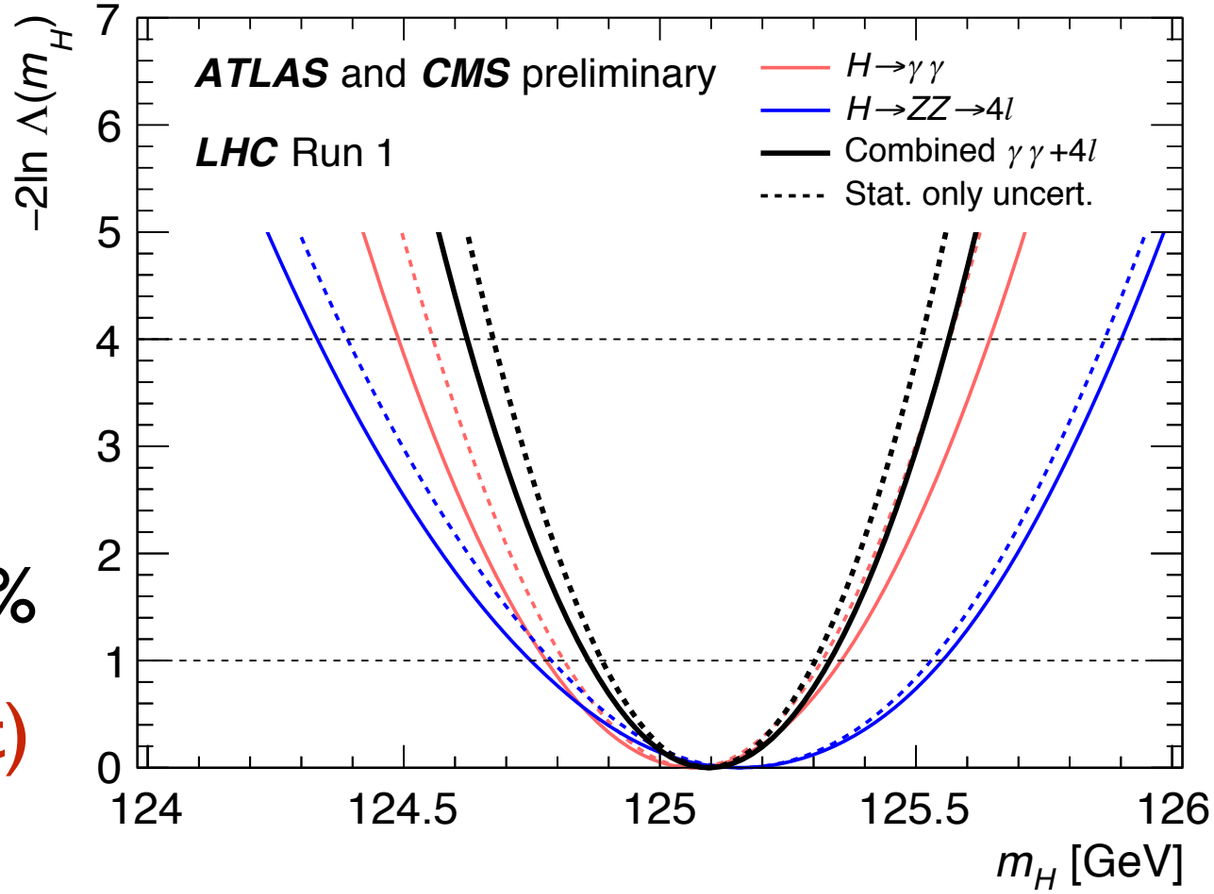


Combination results available at **arXiv:1503.07589**

Results from the experiments



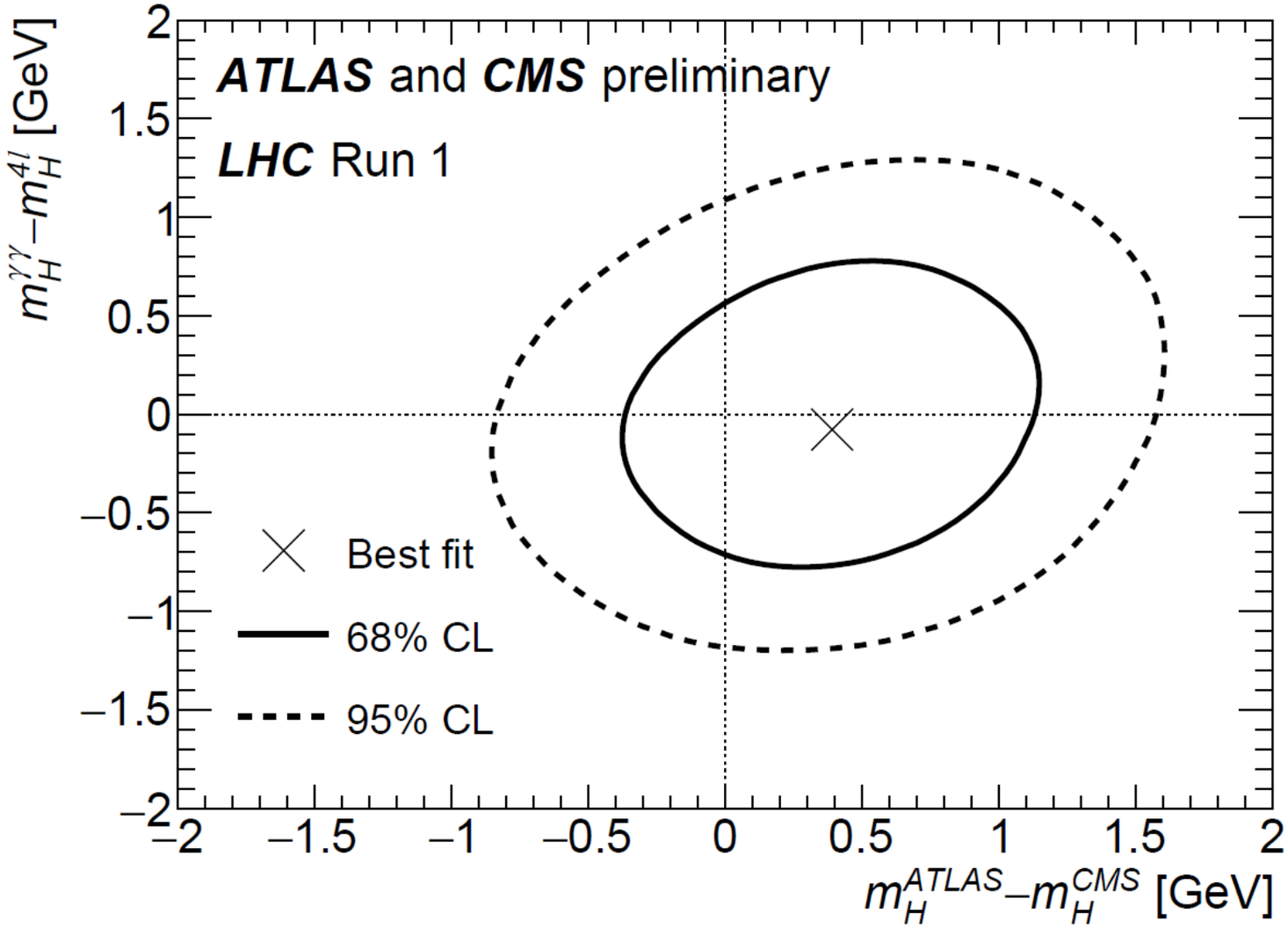
- To avoid assumptions, three signal strengths are introduced in the fit as free parameters when combining
  - $\mu_{ggF+ttH}$, μ_{VBF+VH} for γγ and μ^{4l} for 4l (the same in ATLAS and CMS)
- Interference is neglected (expect a few MeV mass shift)



- Good agreement between the combined γγ and 4l results
  - CMS γγ weight ~40%, CMS 4l ~23%, ATLAS γγ and 4l ~18-19%
- mγγ=125.07±0.25(stat)±0.14(syst)
  m4l=125.15±0.37(stat)±0.15(syst)

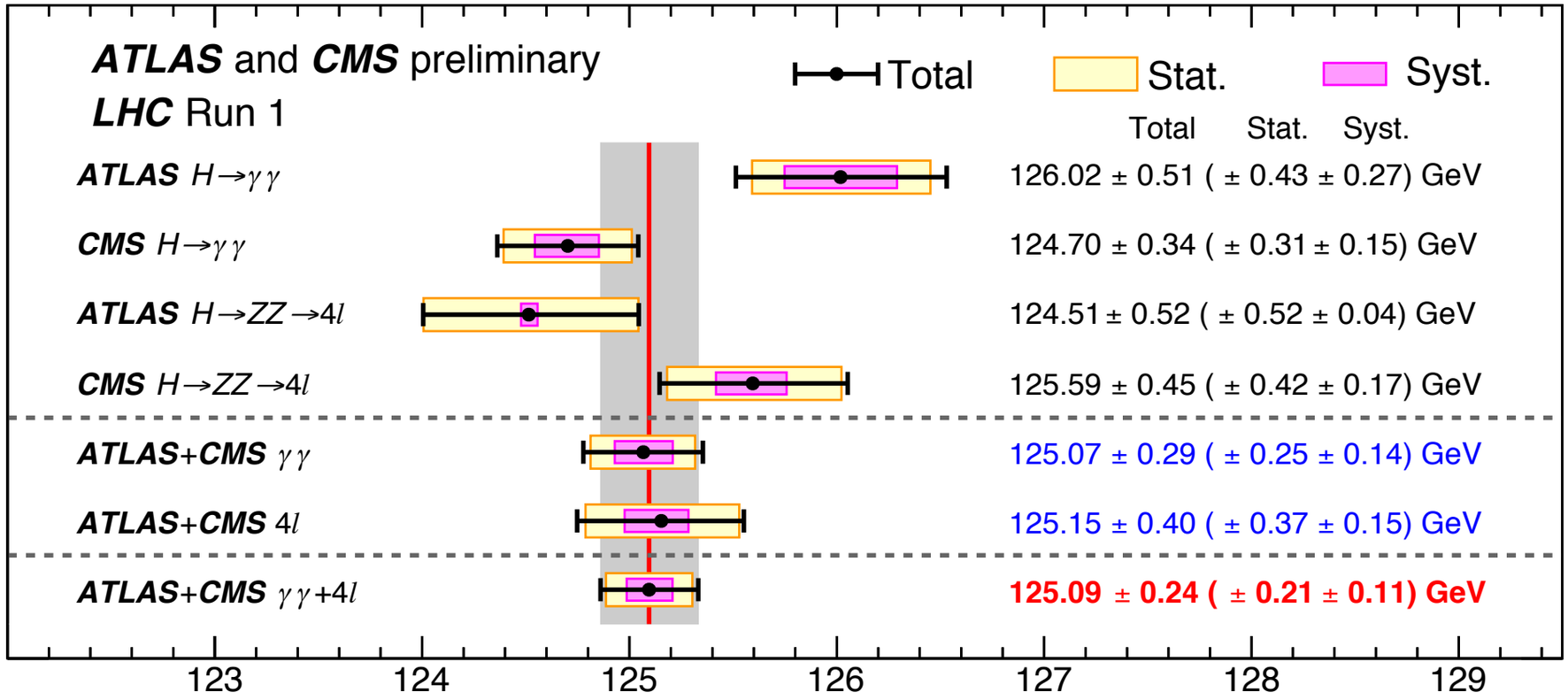
Compatibility checks

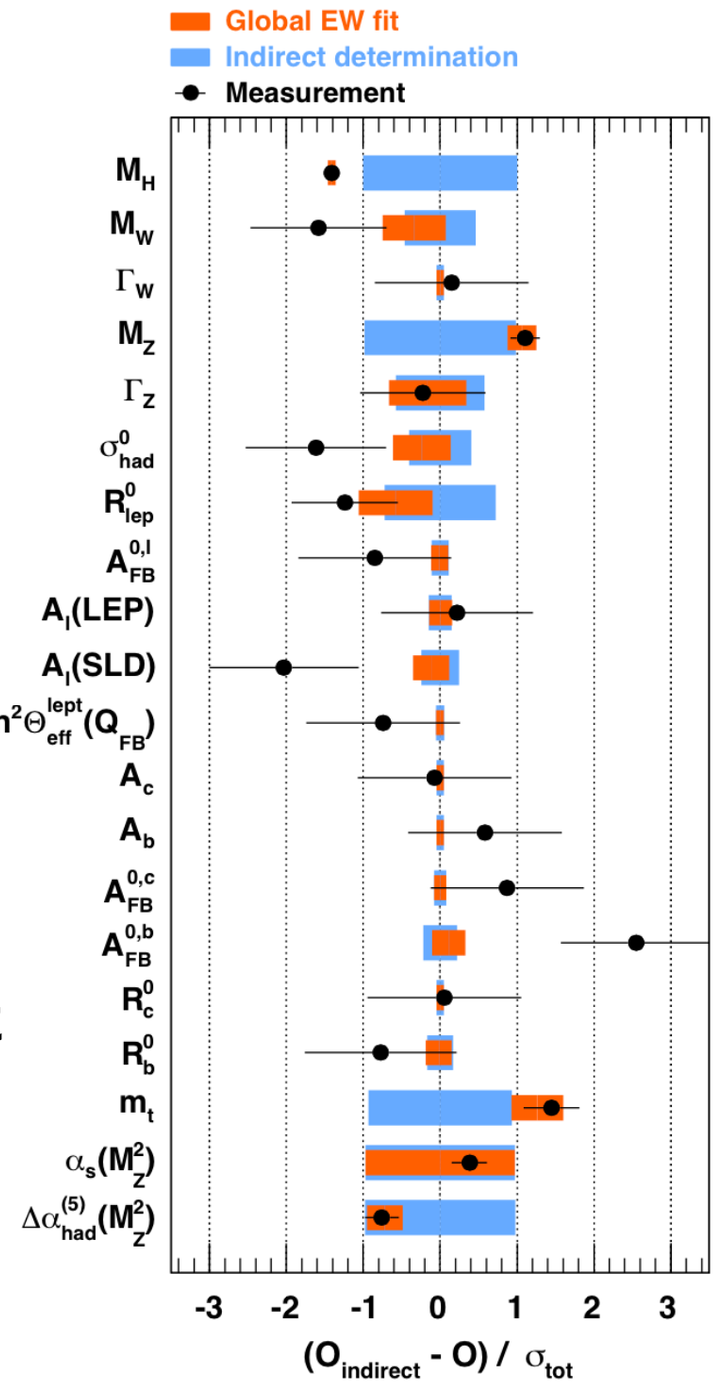
- All the signal strength factors are compatible with 1
- $\mu_{ggF+ttH} = 1.15^{+0.28}_{-0.25}$
- $\mu_{VBF+VH} = 1.17^{+0.58}_{-0.53}$
- $\mu_{4l} = 1.40^{+0.30}_{-0.25}$
- $\mu = 1.24^{+0.18}_{-0.16}$



- $m_{\gamma\gamma}$ and m_{4l} almost on top of each other
- Small difference between the experiments, well below 1σ
  - ATLAS: 125.36±0.37(stat)±0.18(syst) CMS: 125.02±0.27(stat)±0.15(syst)

Combined results

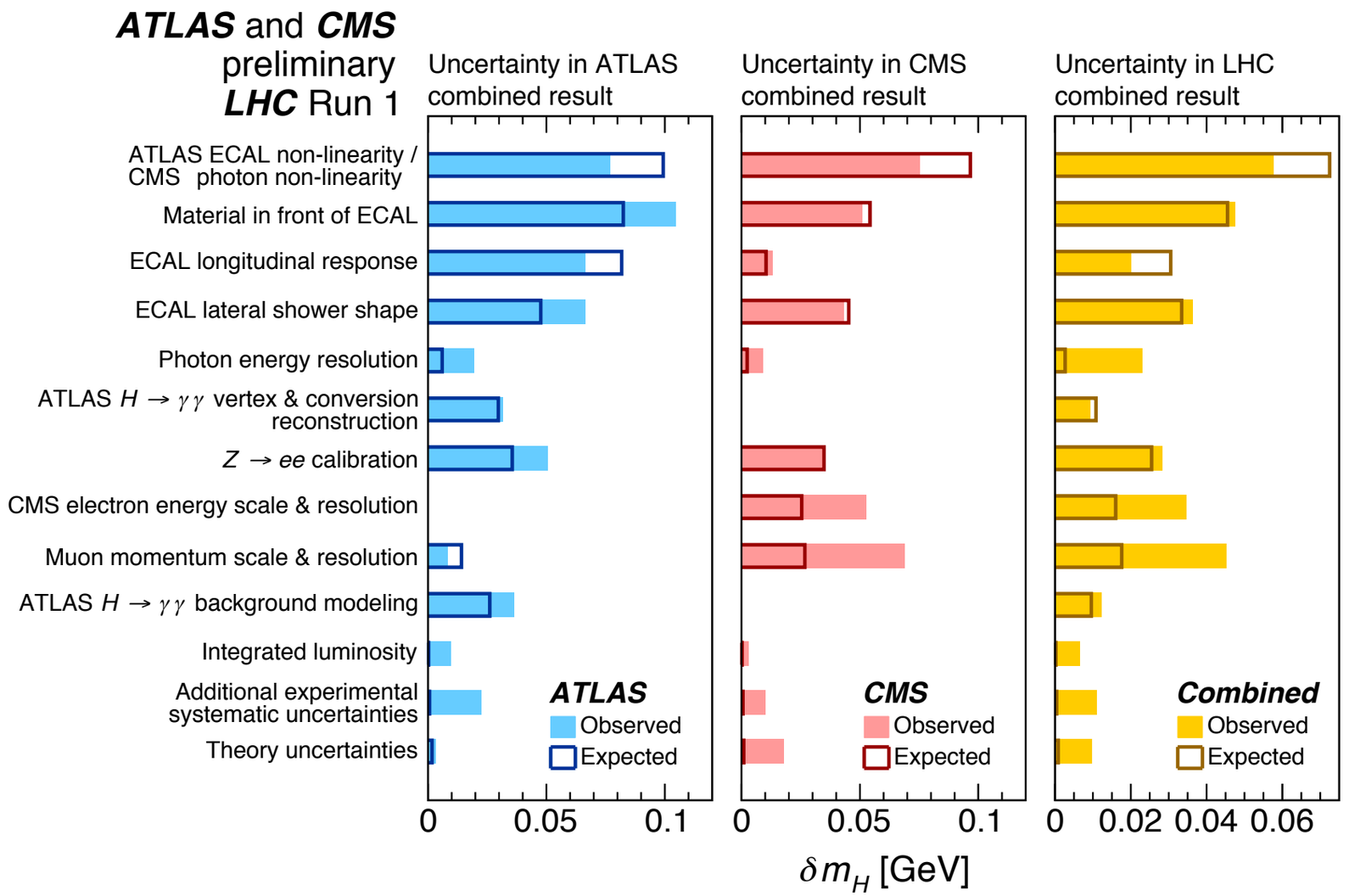




- m_H=125.09±0.21(stat)±0.11(syst) GeV
- 0.19% precision!
  - Among the most precise parameters of the EWK fit
- Mostly statical uncertainties
- Tensions mostly within experiments, no indications of channel dependencies

Systematic uncertainties

m_H=125.09±0.21(stat)±0.11(scale)±0.02(other)±0.01(th) GeV



- Measurement dominated by statistical uncertainties
- Systematics dominated by energy/momentum scale corrections (dominated by the available statistics)

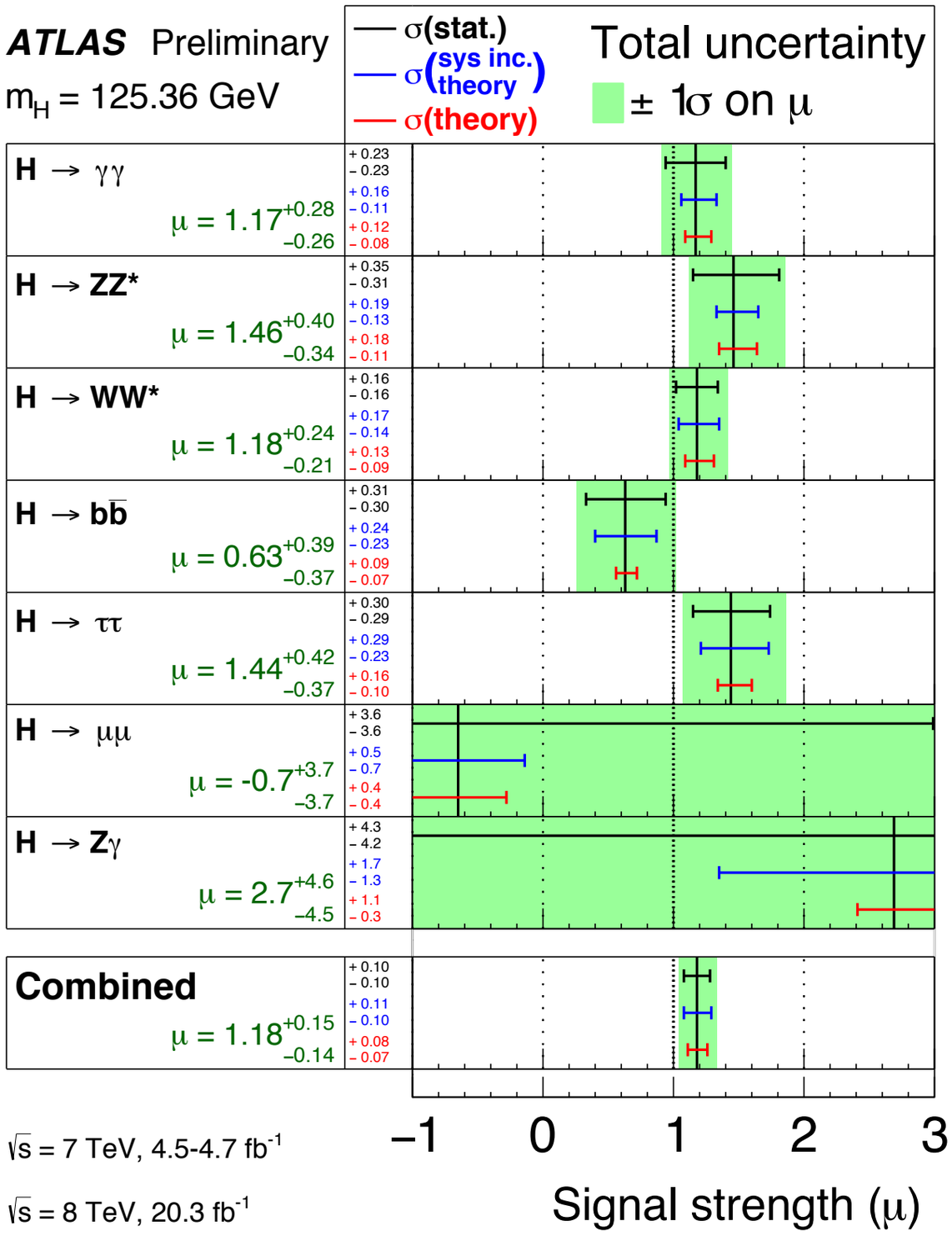
Measure of the signal strength

- Measure of the ratio μ between the observed/predicted event rate
- SM kinematics for production and decay
- Disentangle for production mechanism and decay mode in different channels

	H→γγ	H→ZZ	H→WW	H→ττ	H→bb	H→Zγ	H→μμ
ggH	ATLAS CMS	ATLAS CMS	ATLAS CMS	ATLAS CMS		ATLAS CMS	ATLAS CMS
VBF	ATLAS CMS	ATLAS CMS	ATLAS CMS	ATLAS CMS		ATLAS CMS	ATLAS CMS
VH	ATLAS CMS	ATLAS CMS	ATLAS CMS	CMS	ATLAS CMS	ATLAS CMS	CMS
ttH	ATLAS CMS	ATLAS CMS	ATLAS CMS	ATLAS CMS	ATLAS CMS		

Signal strength by decay channel

ATLAS-CONF-2015-007



Combined
μ = 1.00 ± 0.14

H → γγ tagged
μ = 1.12 ± 0.24

H → ZZ tagged
μ = 1.00 ± 0.29

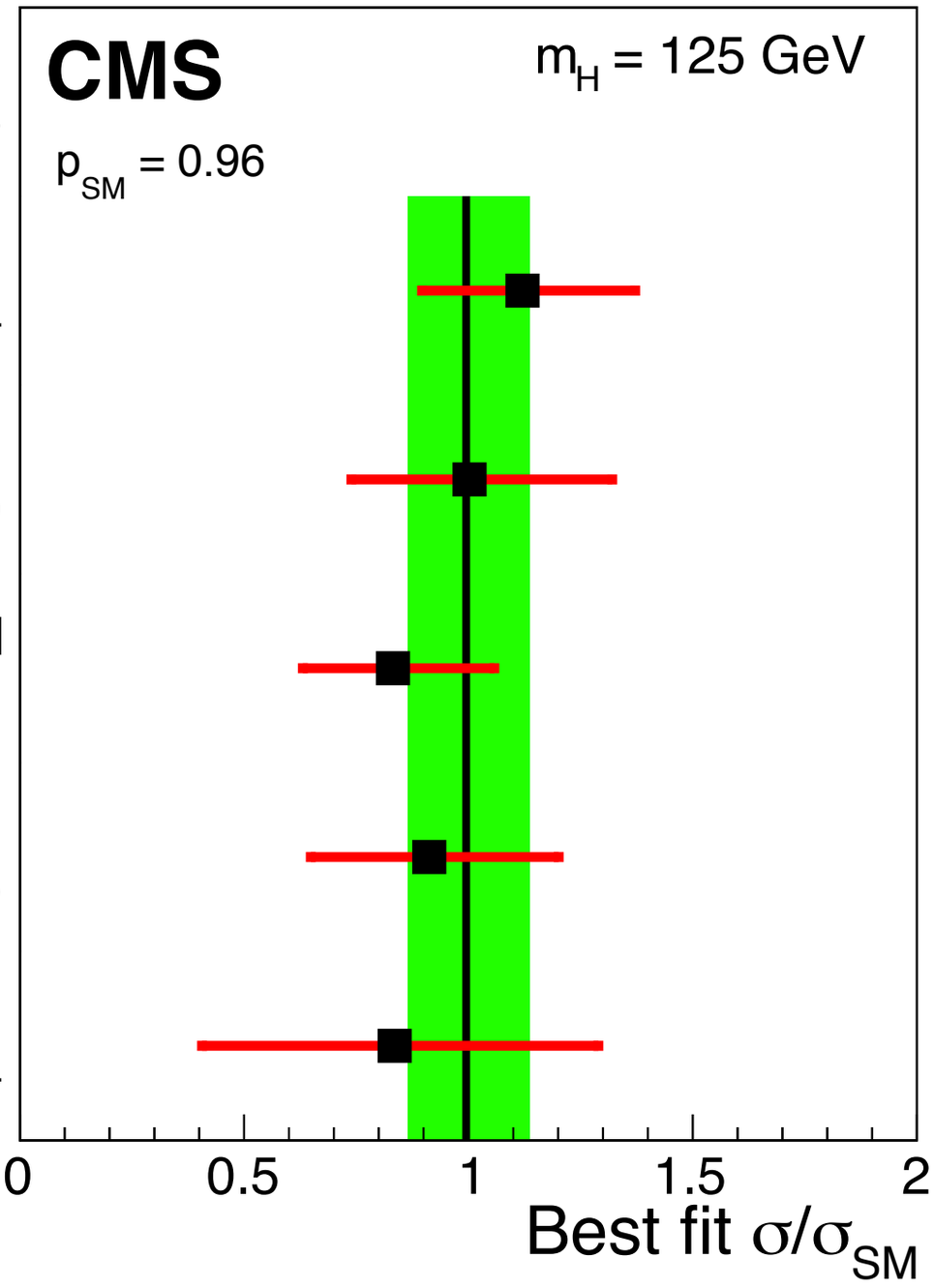
H → WW tagged
μ = 0.83 ± 0.21

H → ττ tagged
μ = 0.91 ± 0.28

H → bb tagged
μ = 0.84 ± 0.44

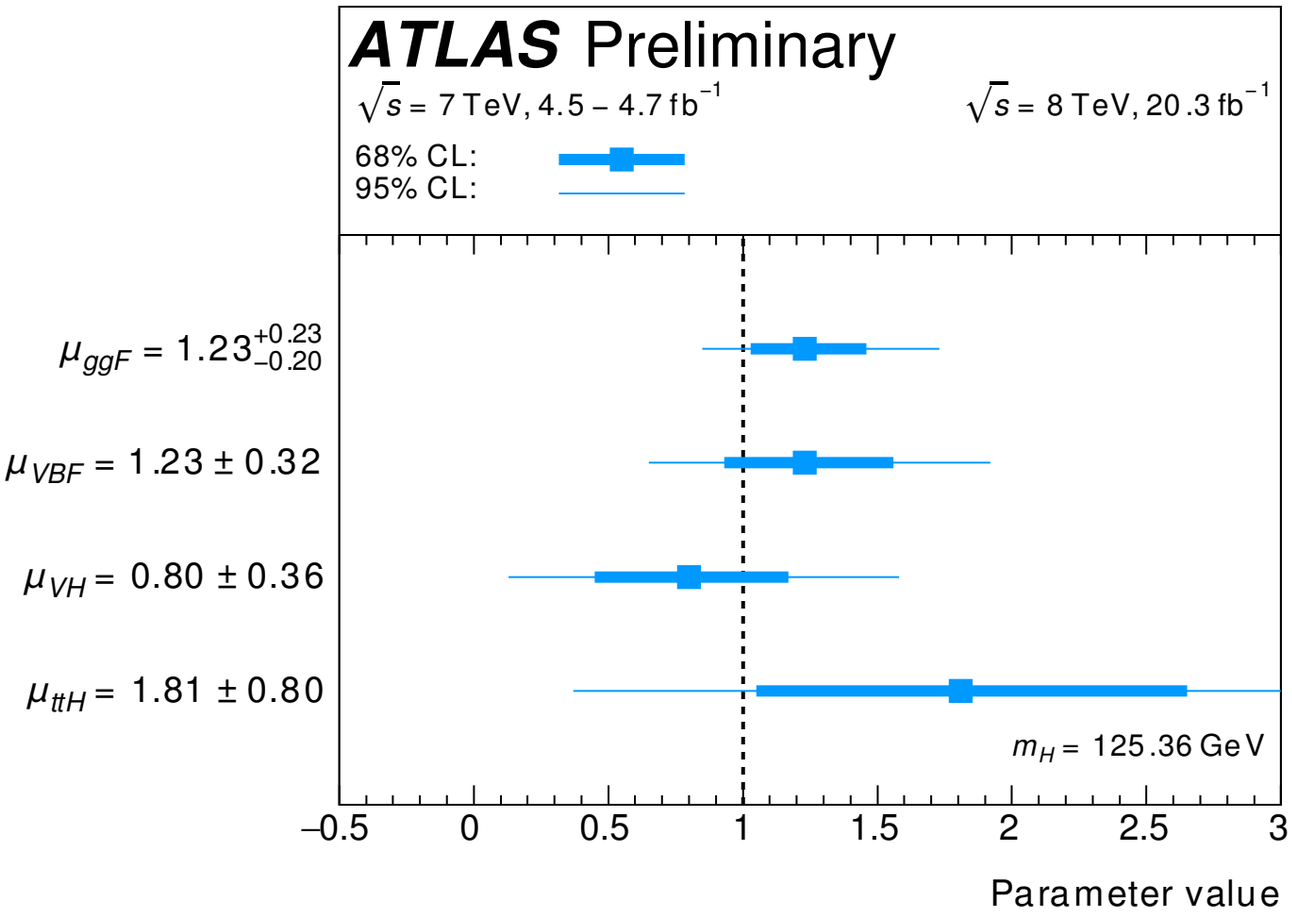
arXiv: 1412.8662

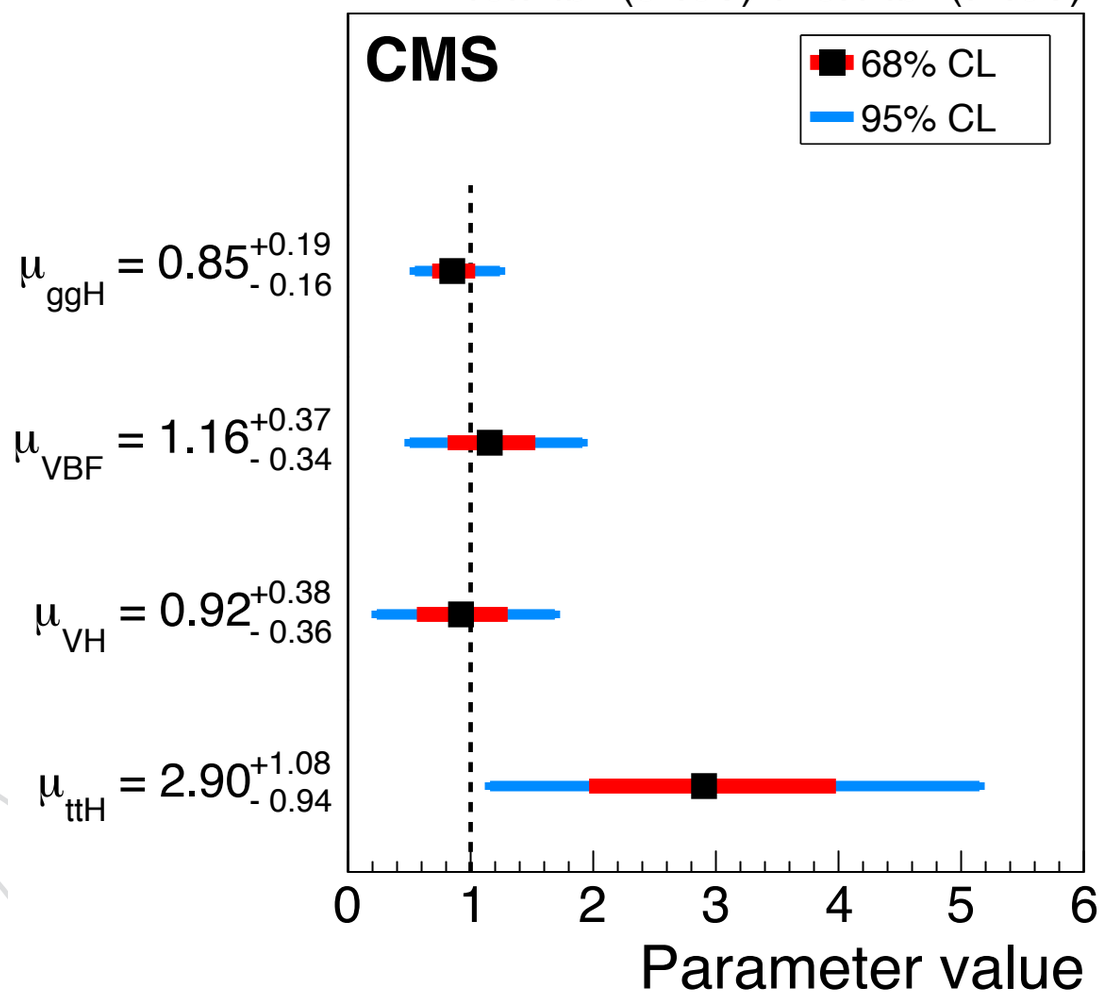
19.7 fb^{-1} (8 TeV) + 5.1 fb^{-1} (7 TeV)



- No deviations from the SM

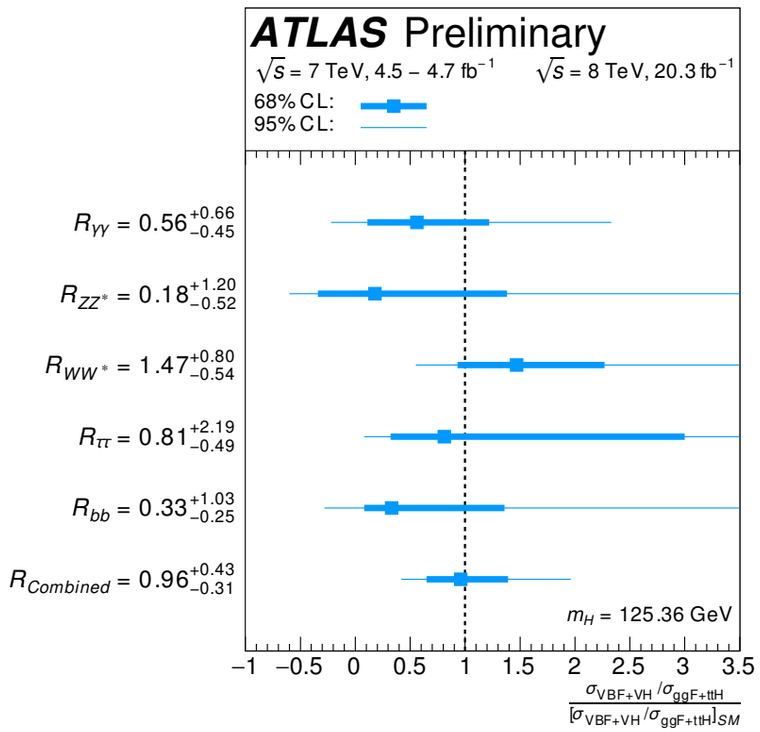
Signal strength by production





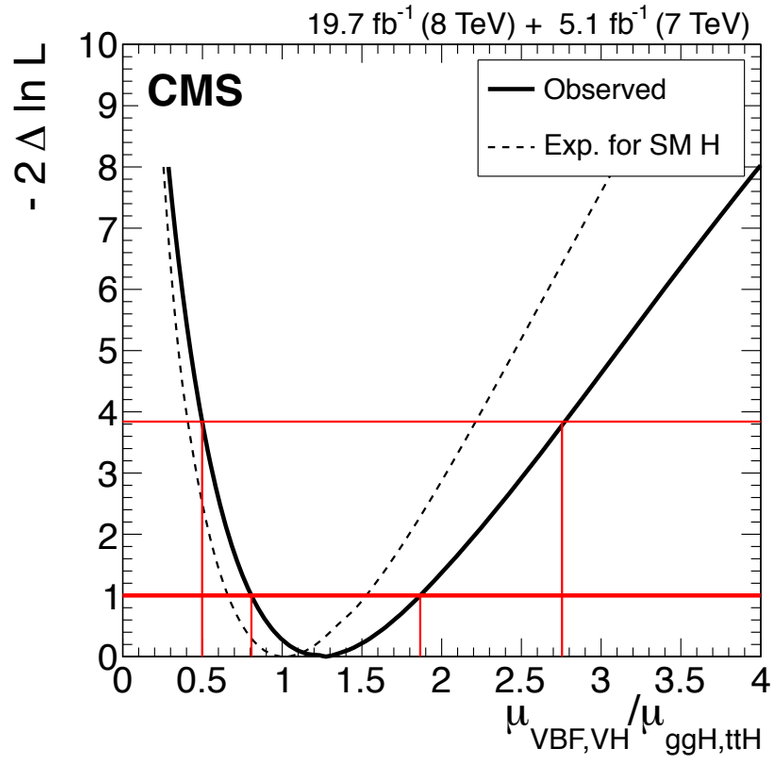
- Assume SM values for ratios between different branching fractions
- Small 1-2σ excess in ttH, consistent among the 2 experiments
  - Compatible with SM

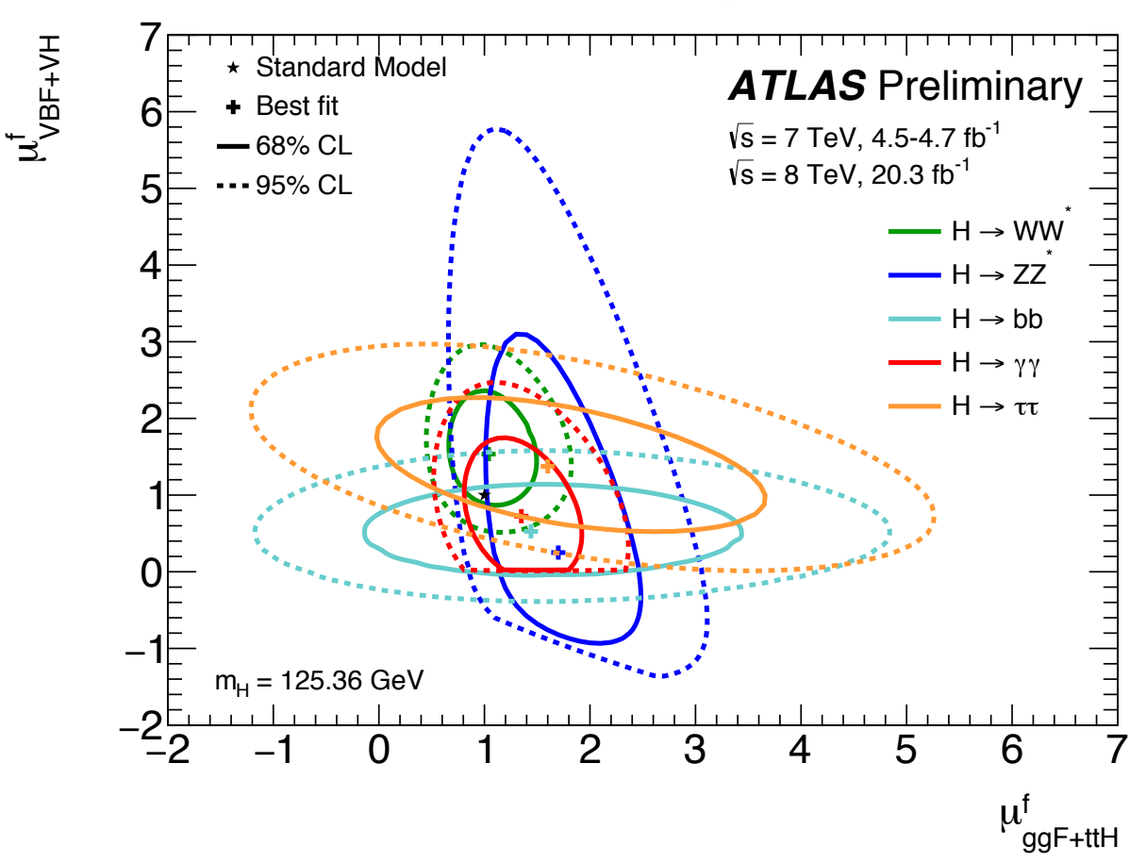
Comparison between ggH and VBF



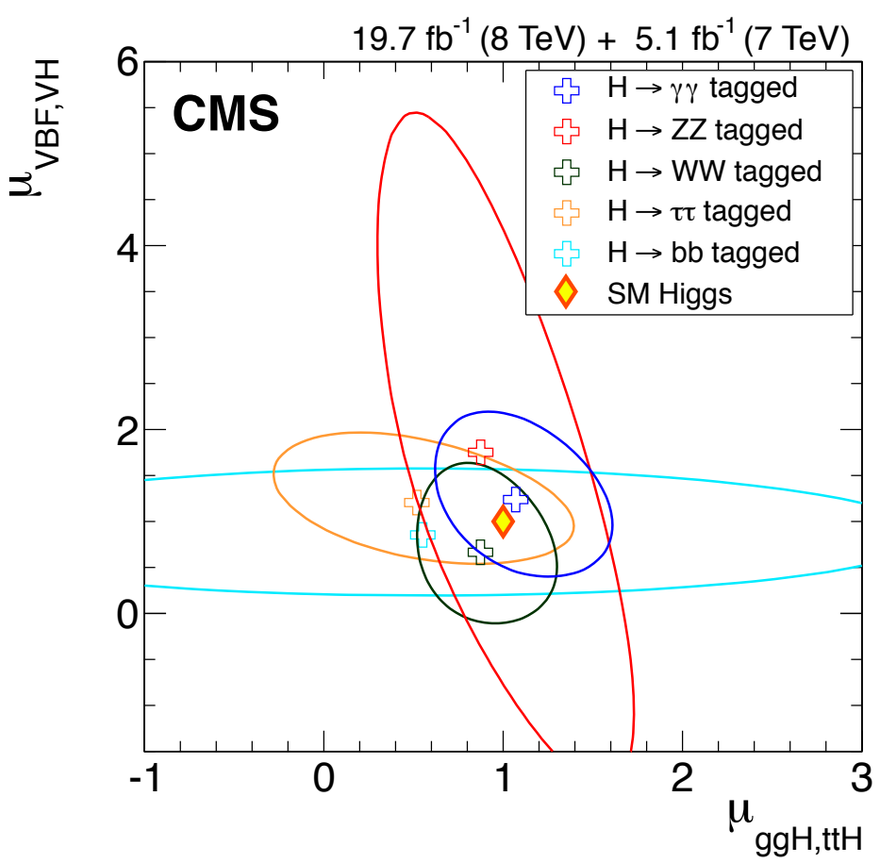
Remove assumptions on decay BR

- Separate ggH(+ttH) from VBF (+VH) production
- BR(H→ff) cancels in the ratio

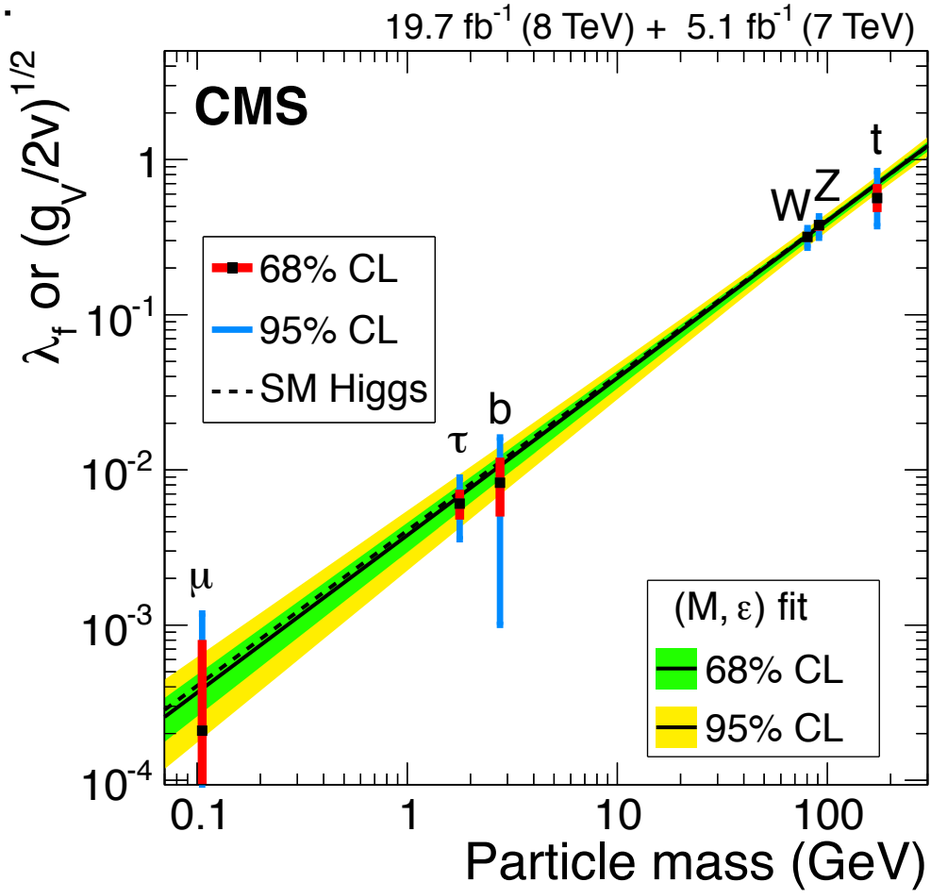


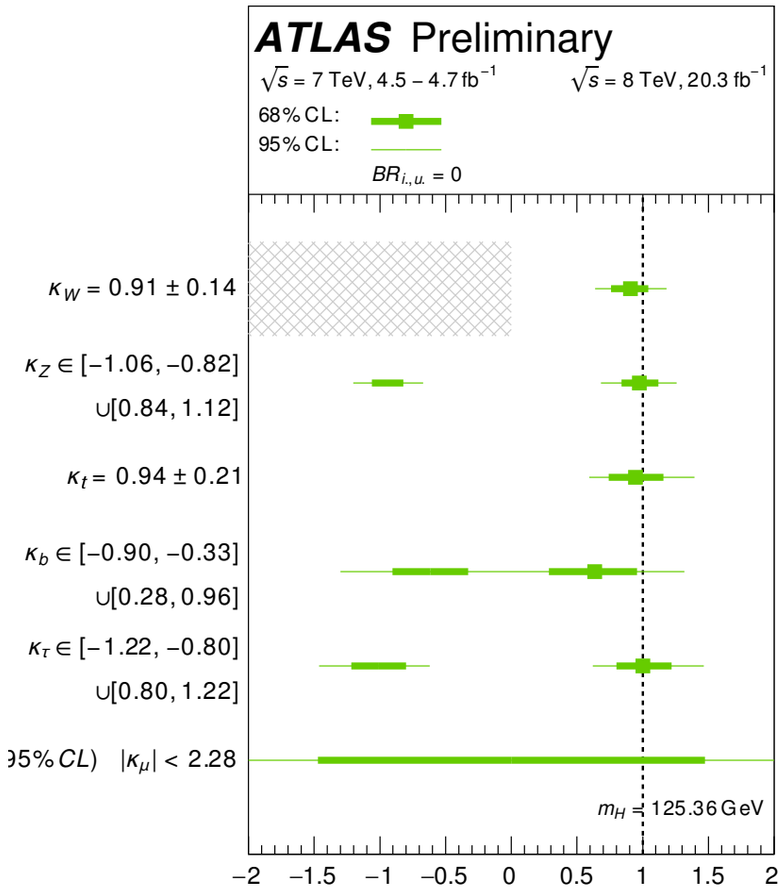


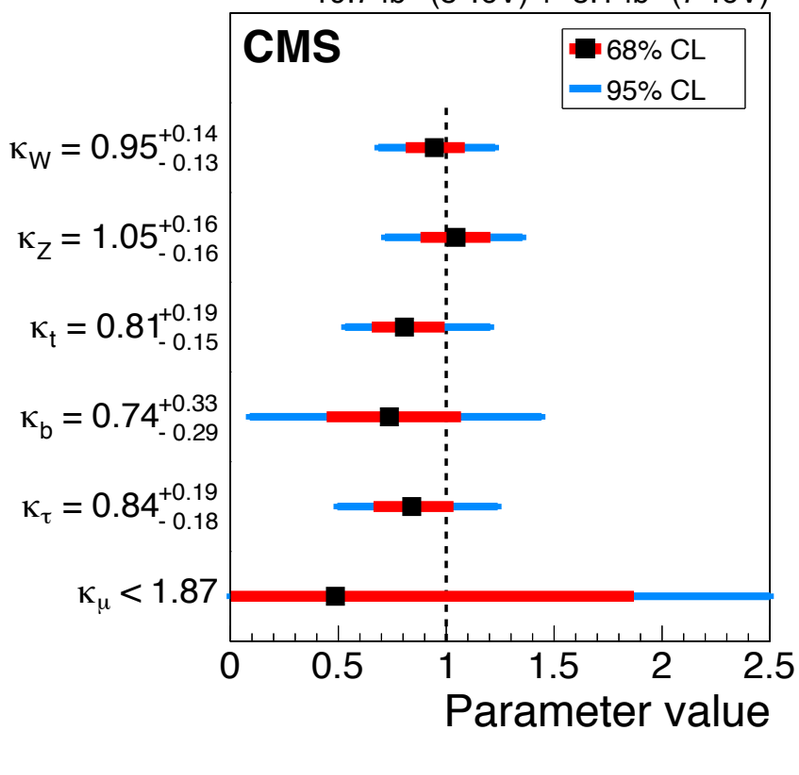
Good agreement with SM

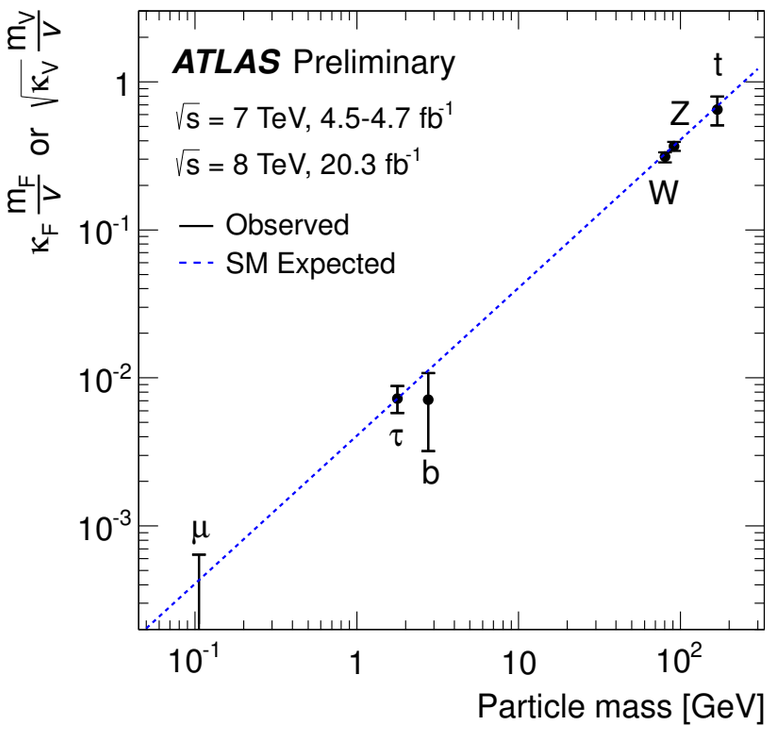


Absolute couplings

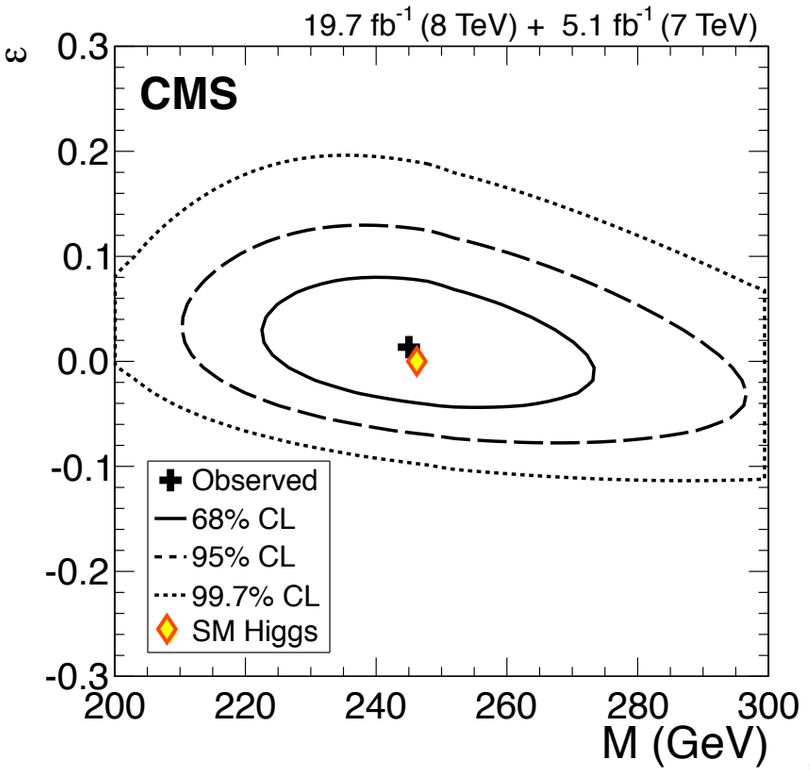






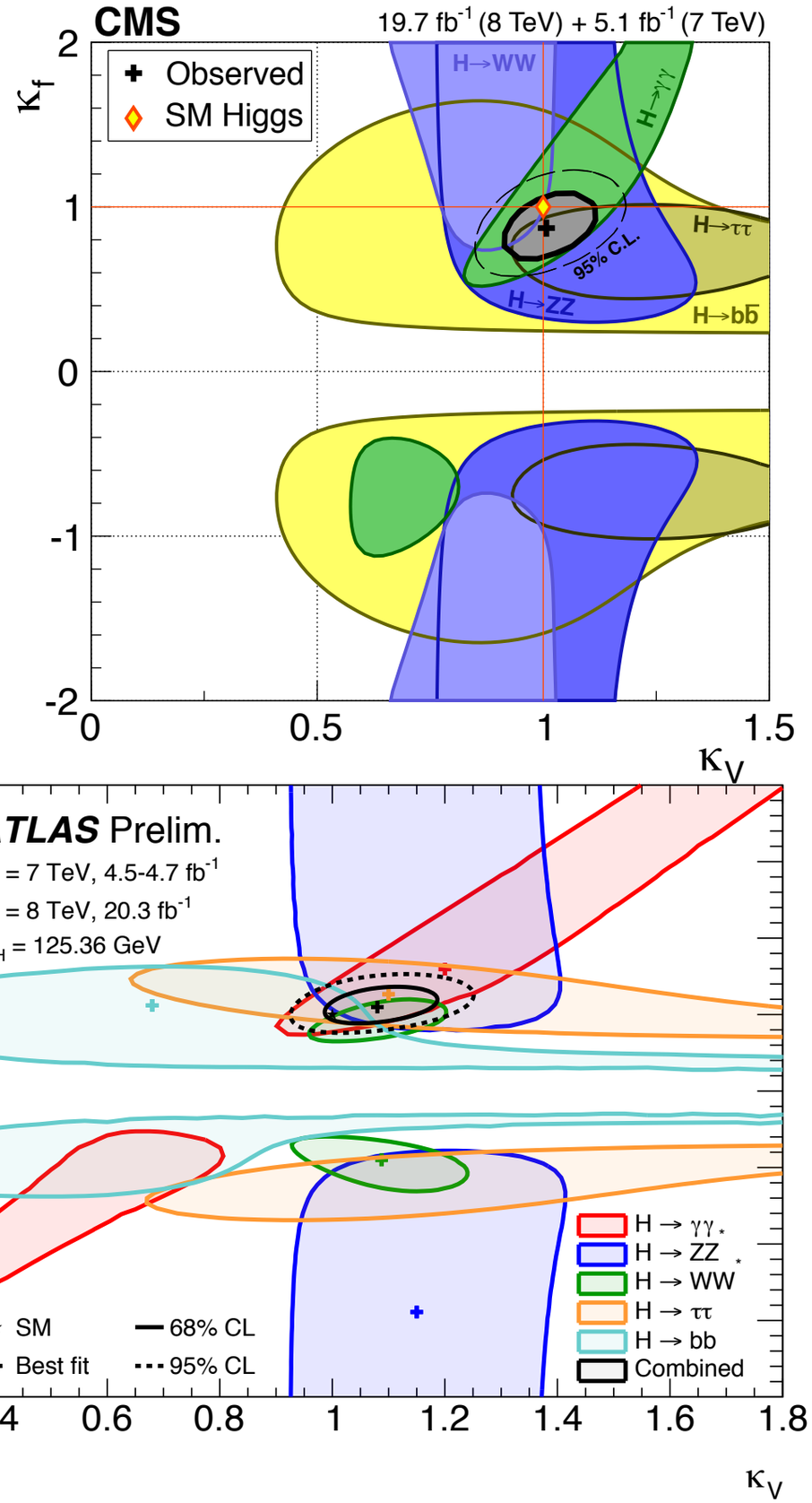


- Assume only SM particles in loops, no invisible decays
- All results compatible with the SM



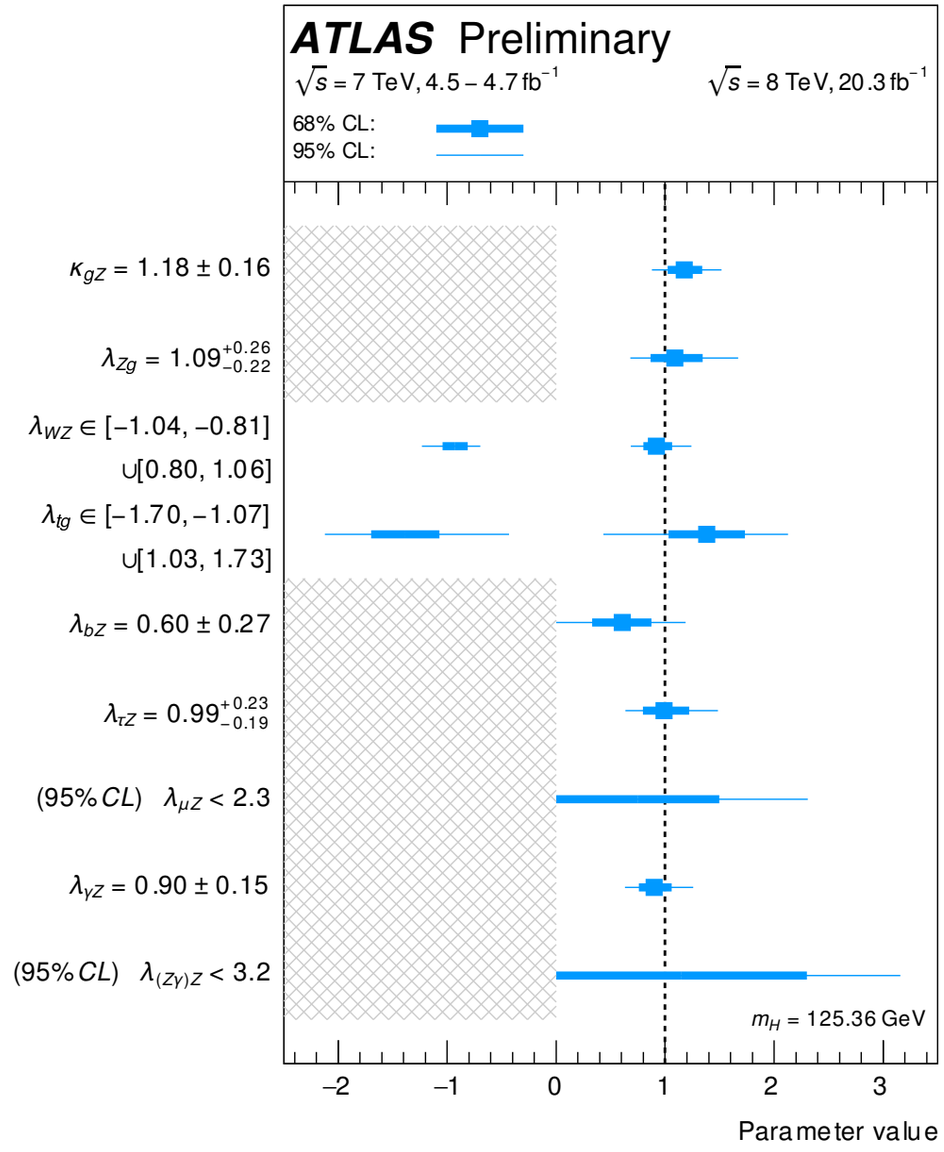
Couplings to fermions and gauge

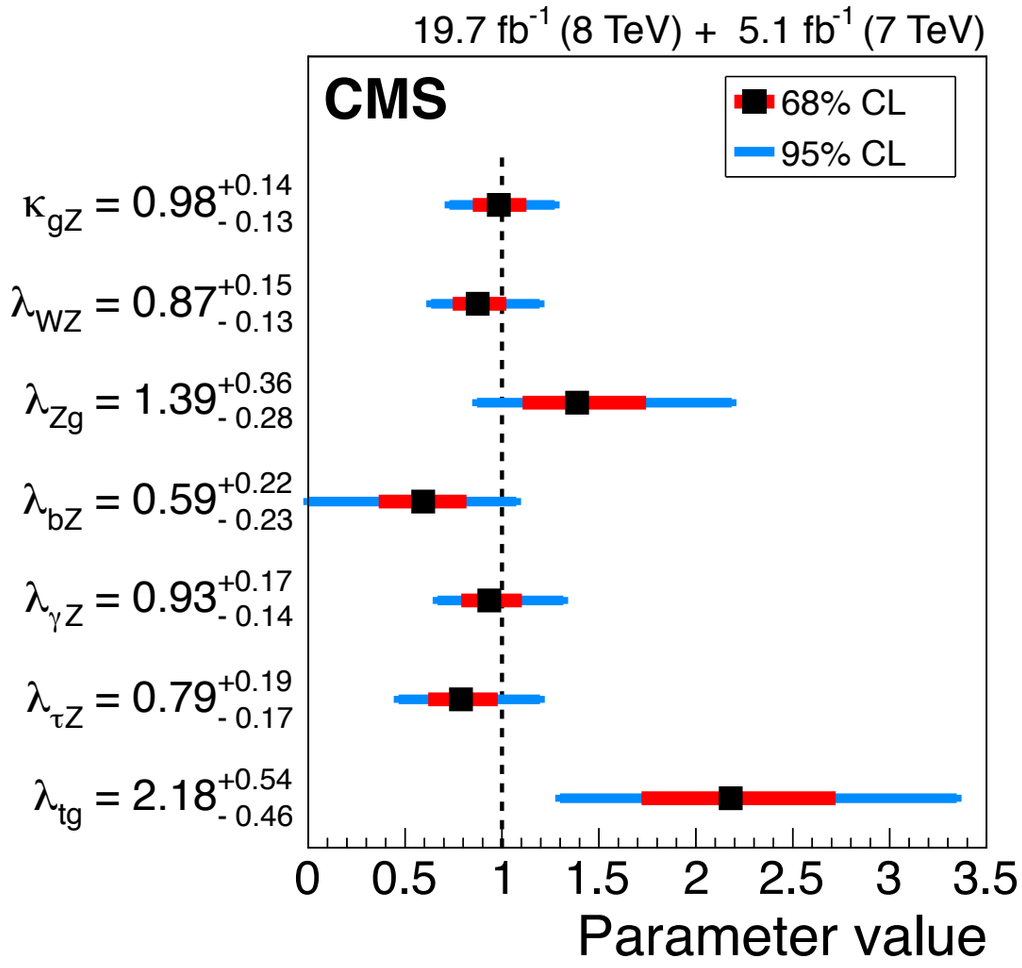
- For each coupling, introduce a scale factor k that accounts for deviations from SM (by definition $k_i=1$ is SM)
- Explore differences between Yukawa and gauge couplings by introducing 2 k factors k_f and k_V
- Assume SM H width and no additional effects in the loops
- Sign ambiguity resolved by interference in γγ,tH decays
- Good agreement with the SM



Higgs coupling ratios

Fit ratio of couplings $\lambda_{ij}=k_i/k_j$ in order to avoid assumptions on ratios of production mechanisms and branching fractions

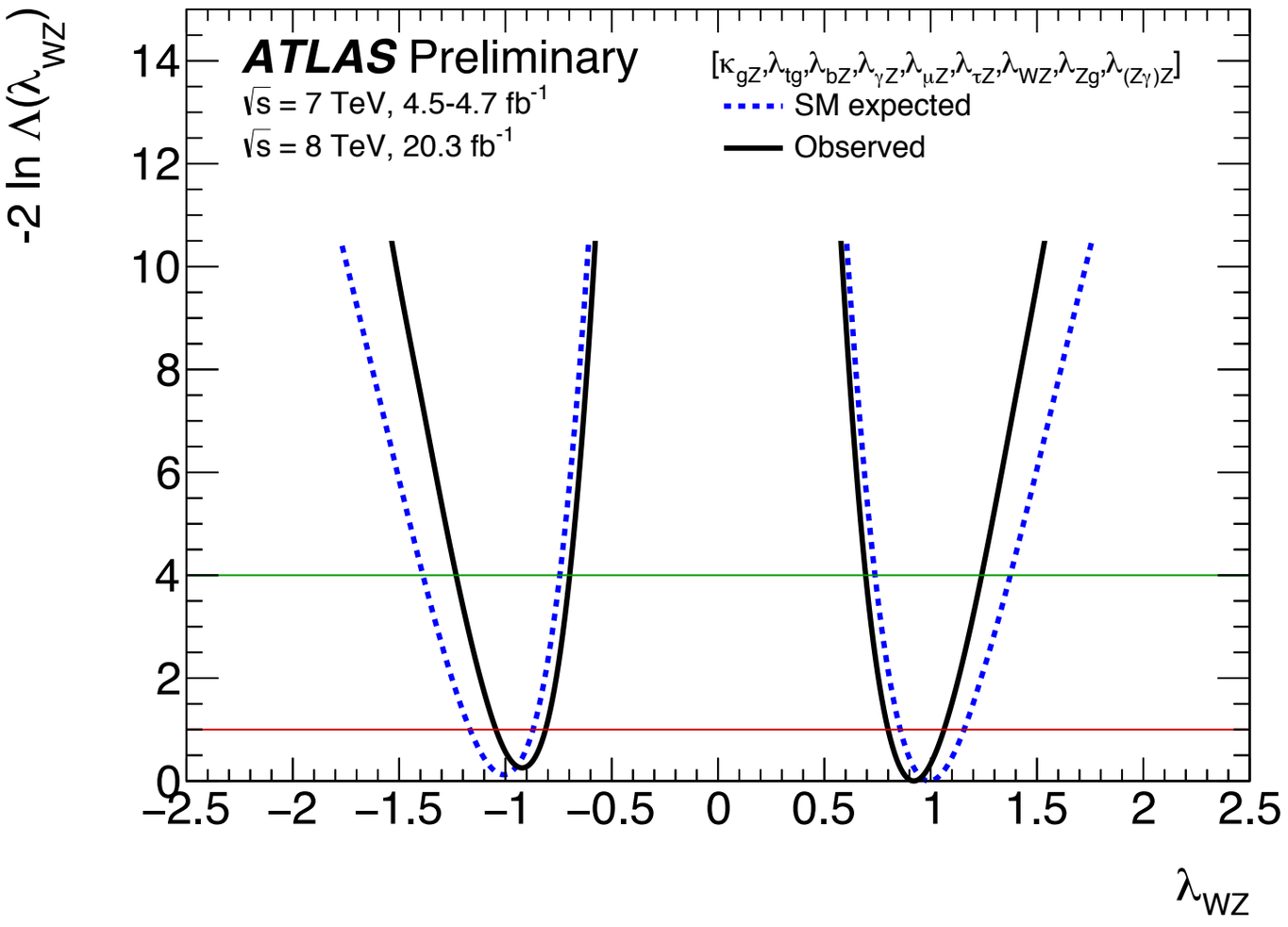


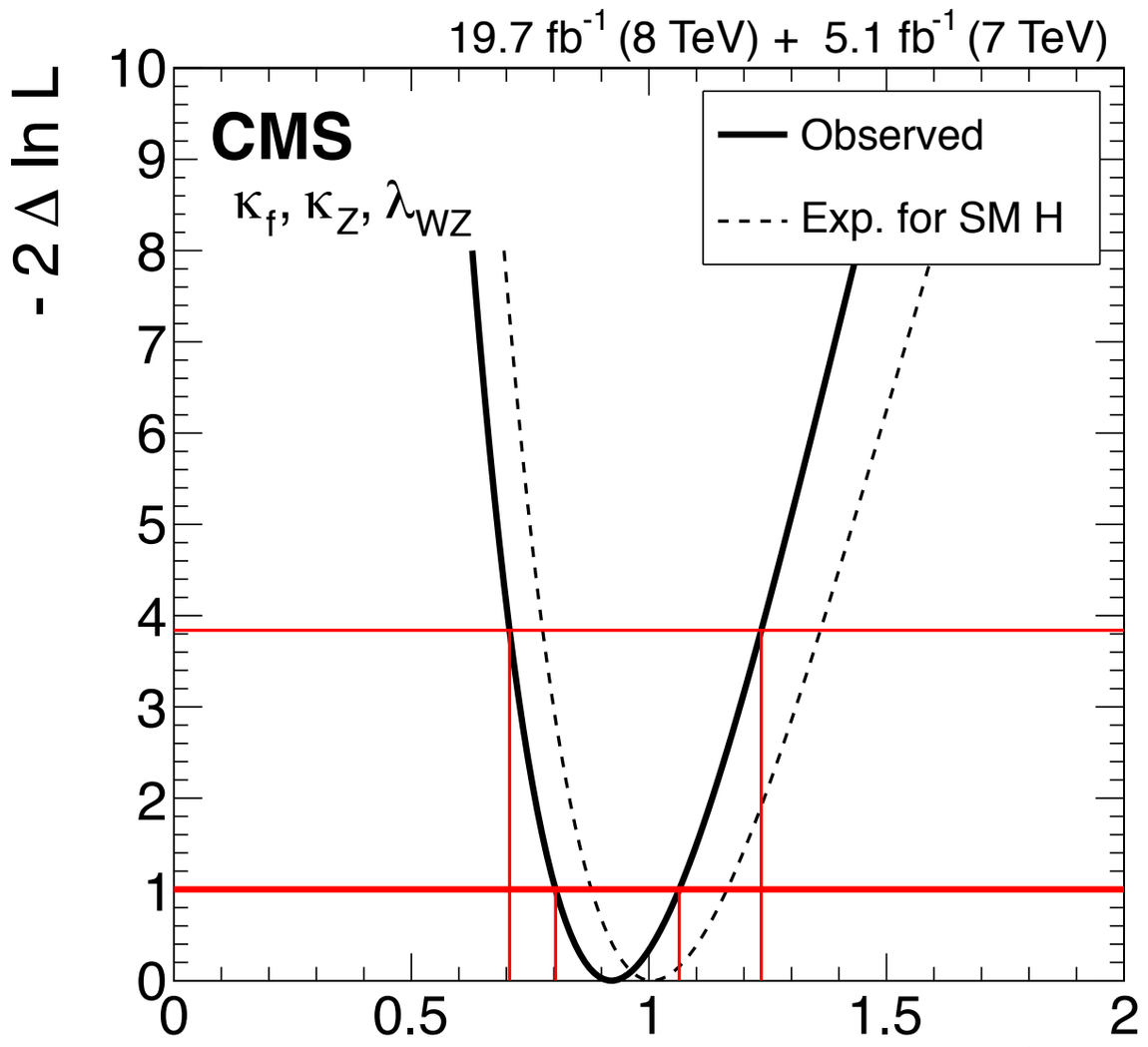


- Most general measurement possible within the k framework
  - We will do better in run2
- No assumptions on particle content in loops
- No assumptions on BSM decay modes or Γ_H

Custodial symmetry

- In the SM custodial symmetry prevents deviations from $\lambda_{WZ}=1$
- No assumptions on other couplings





- CMS: $\lambda_{WZ}=0.94^{+0.22}_{-0.18}$
  ATLAS: $\lambda_{WZ}=0.92^{+0.14}_{-0.12}$
- Negative solutions sligthly disfavoured thanks to tH and ZH productions

Conclusions

- ATLAS and CMS combined results produced an amazingly precise Higgs mass measurement m_H=125.09±0.24 GeV
  - Result dominated by statistical uncertainties, will improve in run2
- Measurement of the Higgs boson coupling to the SM particles show very good agreement with SM expectations within the current uncertainties
  - Only deviation observed so far in ttH production, between 1 and 2σ
  - Combination of couplings (ongoing) will provide a better picture
  - No more room for large deviations from the SM. The study of the couplings in "rare" production/decays channel is a priority for run2

BACKUP

K-framework

Fit to the absolute couplings

slide 30

Absolute couplings

- Relaxing the asssumptions, e.g. allowing for the BR to invisible to float and for the presence of non-SM particles in loops or only keeping the total Higgs width unmodified does not have a huge impact on the measured couplings
  - Couplings values are quite stable (within these uncertainties)