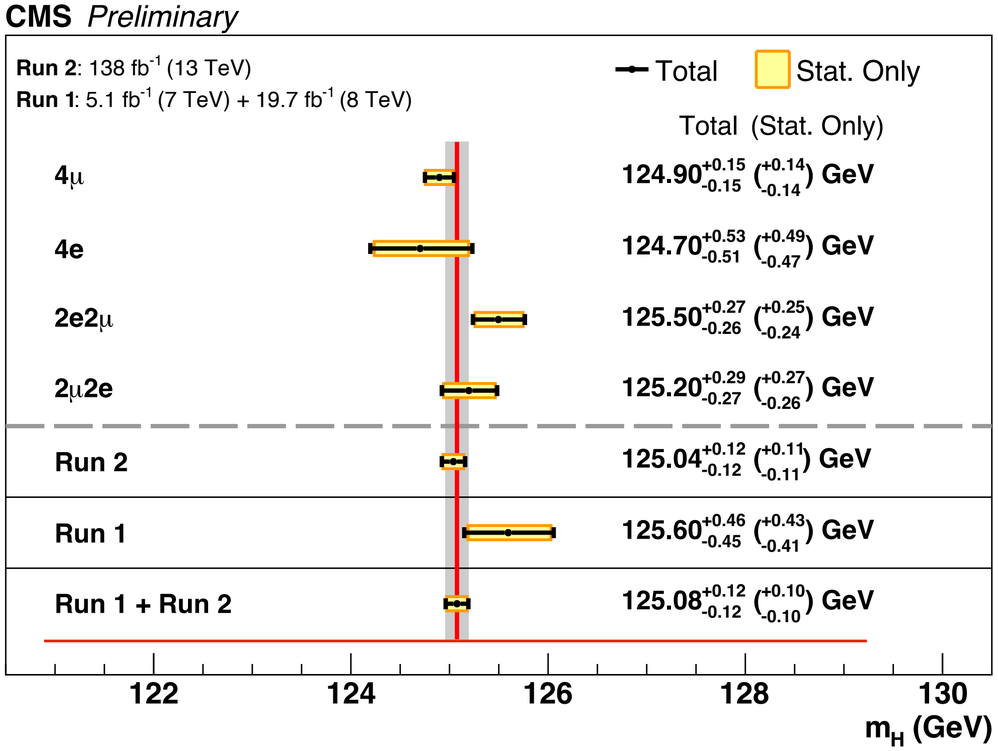
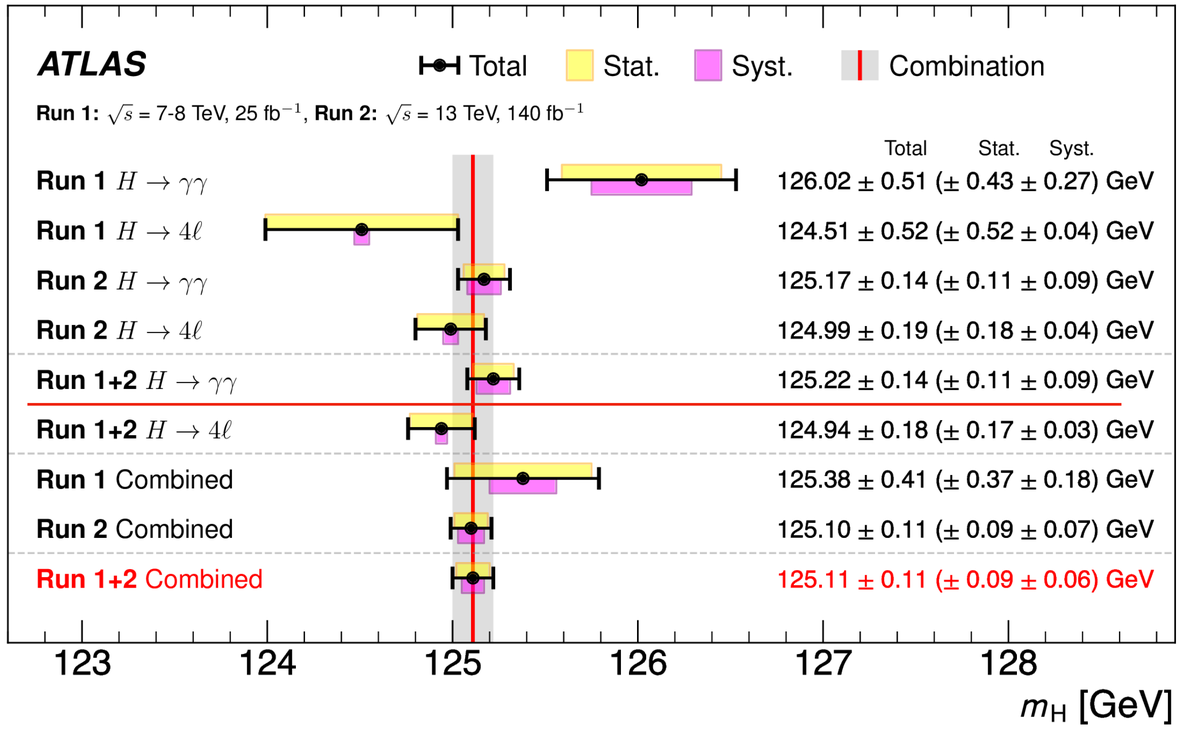
Higgs boson mass

At discovery in 2012, mass known with accuracy of about ±0.6 GeV in each experiment

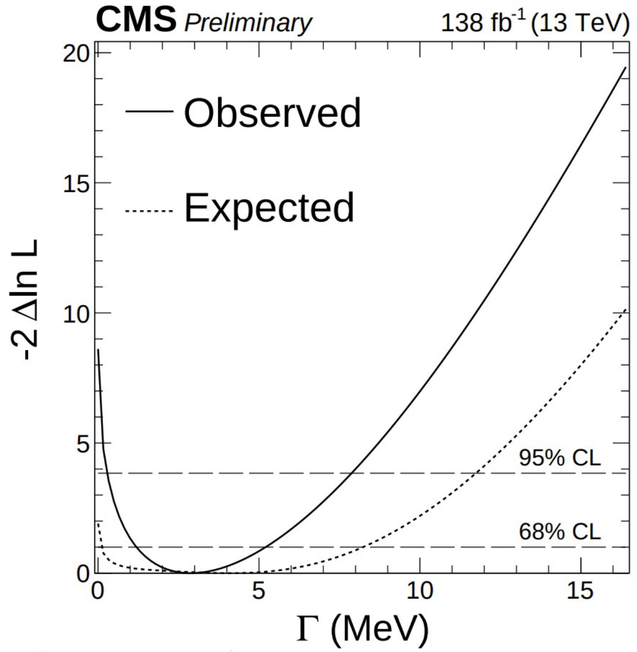
Today we are around 0.1 GeV ~factor 5–6 improvement relative to discovery (in line w. ×30 increase in # of Higgses
BUT as well substantial work to reduce the systematics)

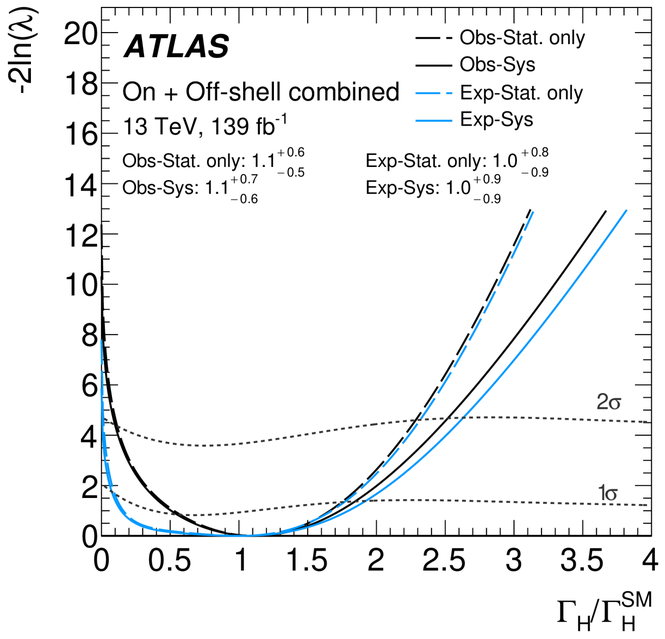


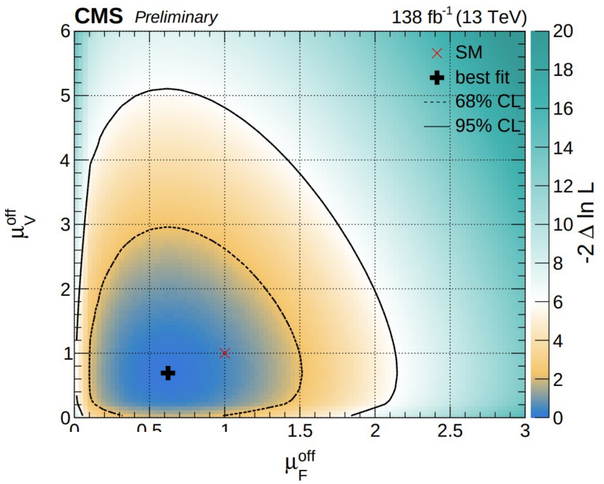


Uncertainties on mass are magnified by ×10 on critical ZZ* branching ratio (0.1% → 1%)
Mass-shift as a function of the Higgs boson width to be considered |
ATLAS and CMS combination ?

Higgs boson width



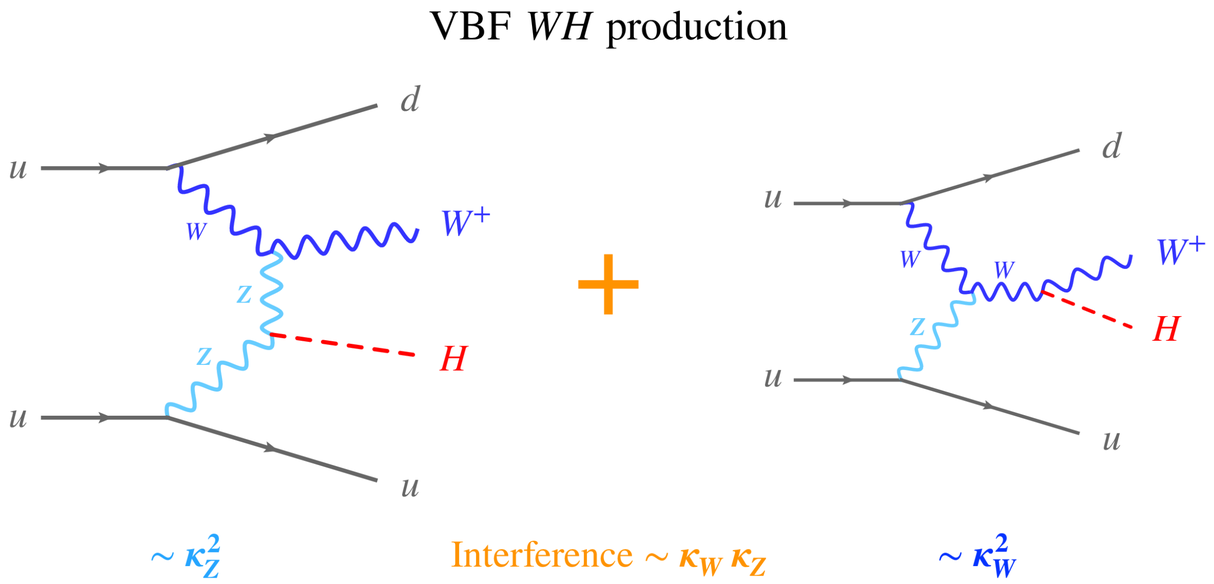




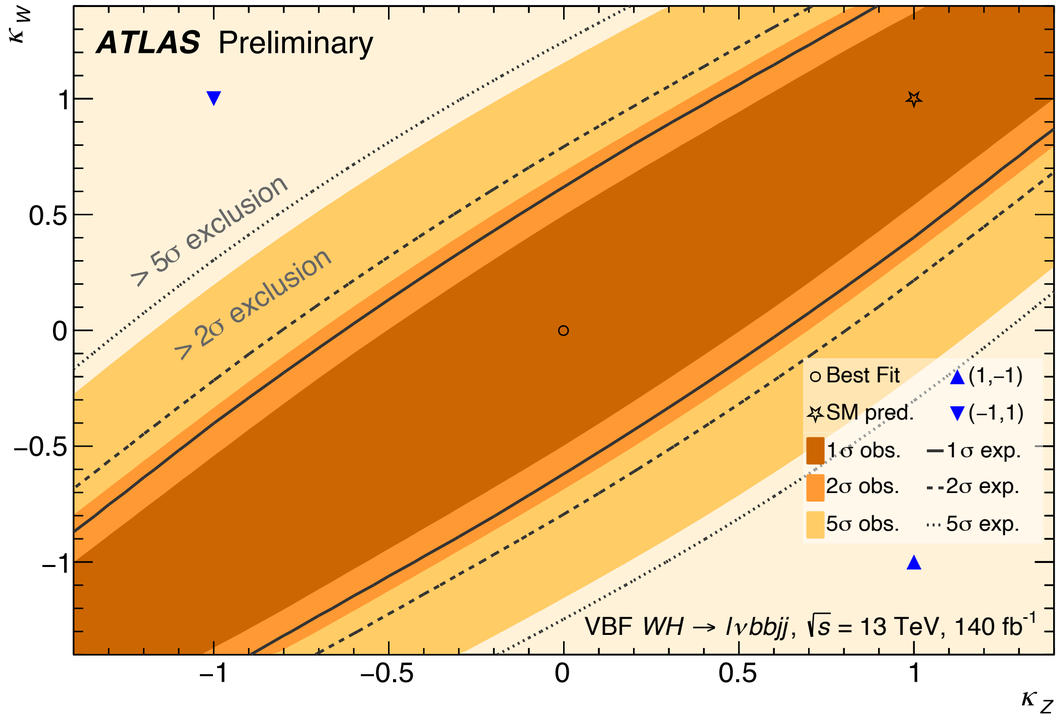
Measurement is statistically limited
Main uncertainties related to dominant background

Process	Uncertainty	Final State	Value (%)
ggF Signal Region			
$qq \to ZZ$	QCD Scale	$2\ell 2\nu$	4–40
$qq \to ZZ + 2j$	QCD Scale	4ℓ	21–28
$qq \to ZZ + 2j$	QCD Scale	$2\ell 2\nu$	22–37
$qq \to ZZ + 2j$	Parton Shower	$2\ell 2\nu$	1–67
$gg \to H^* \to ZZ$	Parton Shower	4ℓ	27
$gg \to H^* \to ZZ$	Parton Shower	$2\ell 2\nu$	8–45
$gg \to ZZ$	Parton Shower	4ℓ	38
$gg \to ZZ$	Parton Shower	$2\ell 2\nu$	6–43
$WZ + 0j$	QCD Scale	$2\ell 2\nu$	1–54
1-jet Signal Region			
$gg \to H^* \to ZZ$	Parton Shower	4ℓ	27
$gg \to H^* \to ZZ$	QCD Scale	$2\ell 2\nu$	13–18
$gg \to ZZ$	Parton Shower	4ℓ	38
$gg \to ZZ$	QCD Scale	$2\ell 2\nu$	18–20
$qq \to ZZ$ (EW)	QCD Scale	$2\ell 2\nu$	7–18
2-jet Signal Region			
$qq \to ZZ + 2j$	QCD Scale	4ℓ	18–26
$qq \to ZZ + 2j$	QCD Scale	$2\ell 2\nu$	8–32
$gg \to H^* \to ZZ$	Parton Shower	4ℓ	27
$gg \to ZZ$	Parton Shower	4ℓ	38
$gg \to ZZ$	QCD Scale	$2\ell 2\nu$	18–20
$WZ + 2j$	QCD Scale	$2\ell 2\nu$	20–22
$qq \to ZZ$ Control Regions			
$qq \to ZZ + 2j$	QCD Scale	4ℓ	26
Three-lepton Control Regions			
$WZ + 2j$	QCD Scale	$2\ell 2\nu$	28

Combinations



$$\sigma_{\mathrm{VBF},WH} \propto \kappa_Z^2 |\mathcal{M}_Z|^2 + \kappa_W^2 |\mathcal{M}_W|^2 - 2\,\kappa_Z \kappa_W\, \Re[\mathcal{M}_Z^\dagger \mathcal{M}_W]$$
$$= \kappa_Z^2 |\mathcal{M}_Z|^2 + \kappa_W^2 |\mathcal{M}_W|^2 - 2\,\kappa_Z^2 \lambda_{WZ}\, \Re[\mathcal{M}_Z^\dagger \mathcal{M}_W]$$

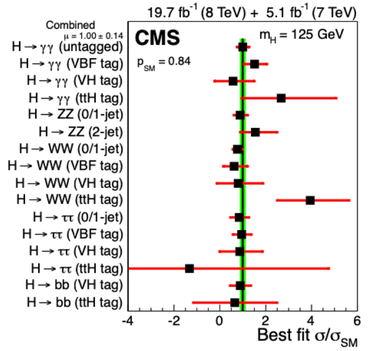


Another channel (as tH) to be considered to study the coupling signs

Combinations

Increasing complexity

CMS has developed a set of roofit based suite of tools called combine (also available outside CMS) to ease combination efforts and ensure consistency across analyses.



2012: Run 1 combination (Eur. Phys. J. C 75 (2015) 212)

- 216 (sub-)categories, 2500 nuisance parameters, 6+1 dimensions fit

2017: Run2 combination (Eur. Phys. J. C 79 (2019) 421)

- 265 Event categories, 5500+ nuisance parameters, 24 dimensions fit (in the most complex model)
- Runs in a bit more then 24 hours

2022: 10-years since the discover (Nature 607 (2022) 60-68)

- 900 Event categories, STXS1.2 POI +EFT and anomalous couplings.
- ~4K nuisance parameters + MC statistical uncertainties (8000+ NP in total)
- 16GB+ to build the likelihood model, 10GB+ to perform the fit
- Runs in 24-48 hours!
- We had to use loss-y strategies to constraint the model complexity