



Measurements of the BEH scalar mass and other couplings in ATLAS and CMS

Moriond Electroweak 2018
11th March 2018

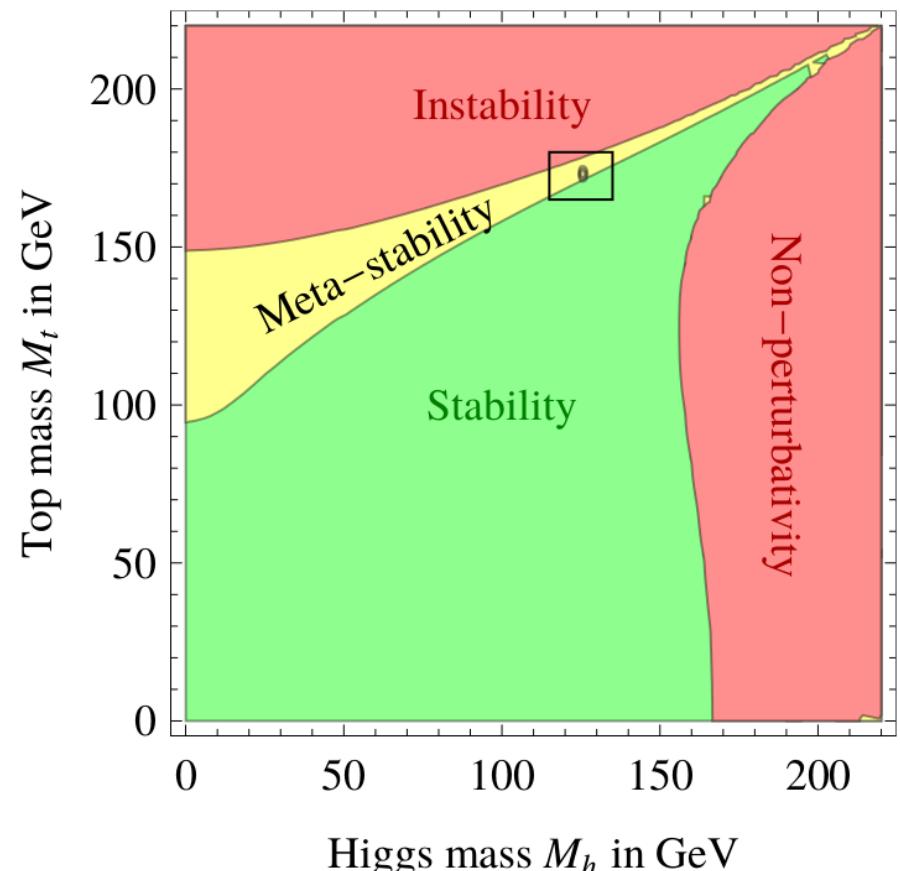
David Sperka (University of Florida)

On behalf of the ATLAS and CMS collaborations



Why measure the mass and couplings?

- $m(H)$ (or λ) is a free parameter of the SM, but its value has many implications
 - Hierarchy problem of the SM
 - In the absence of new physics, EW vacuum is near a critical point: [10.1007/JHEP08\(2012\)098](https://doi.org/10.1007/JHEP08(2012)098)
- Many reasons to measure it precisely

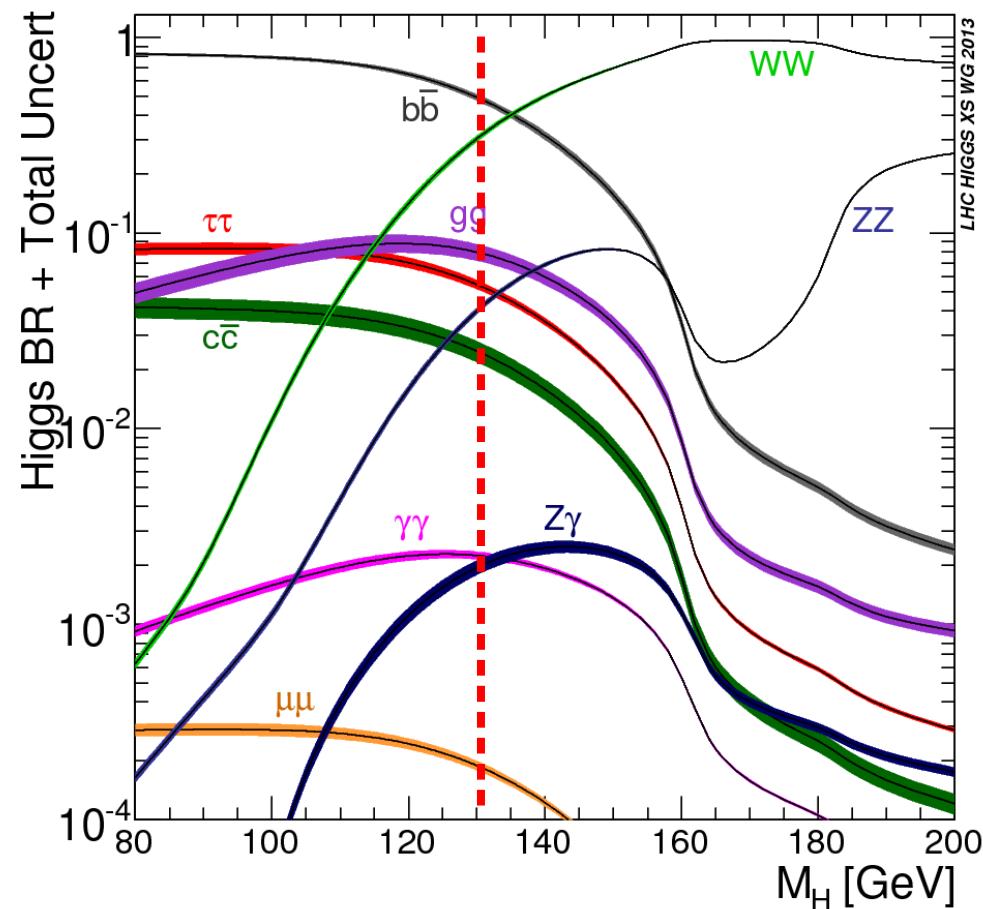


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[arXiv:1310.8361](https://arxiv.org/abs/1310.8361)

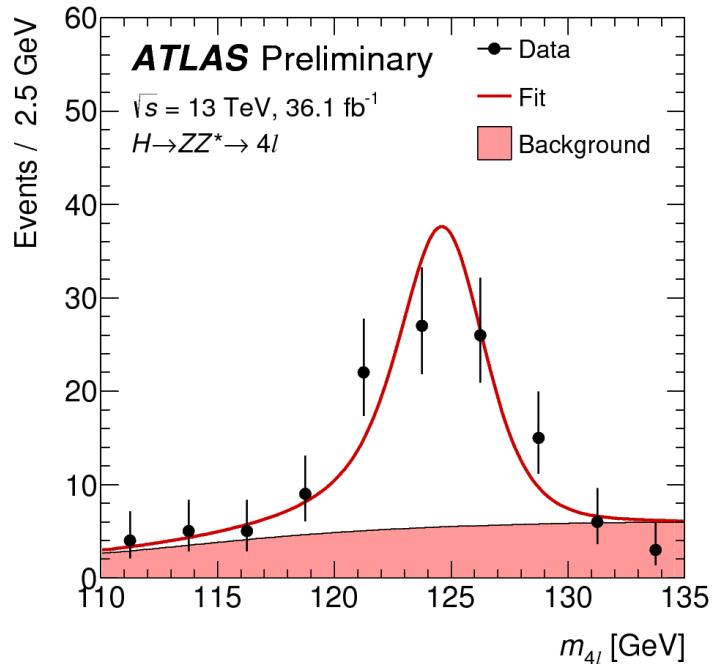
Model	κ_V	κ_b	κ_γ
Singlet Mixing	~ 6%	~ 6%	~ 6%
2HDM	~ 1%	~ 10%	~ 1%
Decoupling MSSM	~ -0.0013%	~ 1.6%	~ -.4%
Composite	~ -3%	~ -(3 - 9)%	~ -9%
Top Partner	~ -2%	~ -2%	~ +1%



- Want to measure couplings to ~% level to test BSM theories
- 100 MeV unc. in $m(H)$ means up to 0.9% unc. in BRs

$m(H)$ measurement in ATLAS

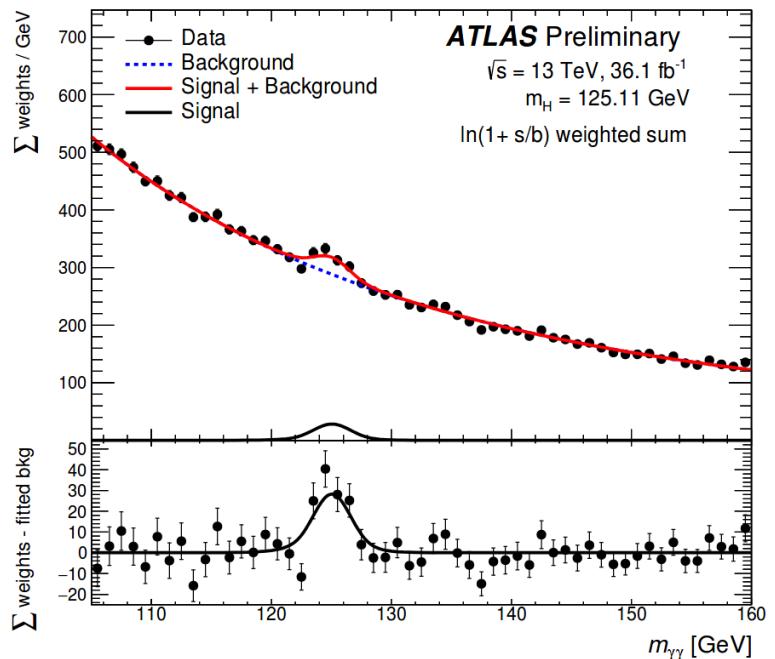
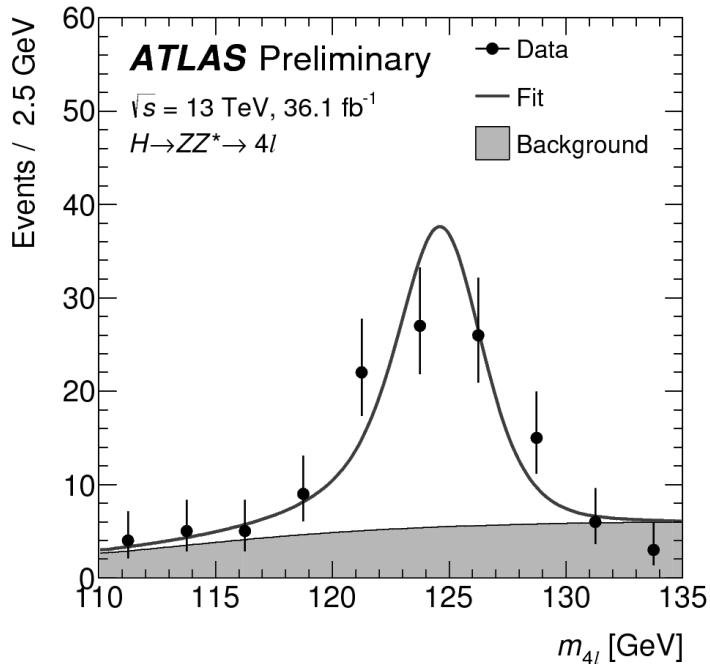
ATLAS-CONF-2017-046



- $H \rightarrow ZZ \rightarrow 4\ell$ channel very clean, with clear references ($Z \rightarrow 2\ell, 4\ell$)
- Kinematic fit of m_{12} leptons ($\sim 15\%$ gain)
- Per event mass uncertainties
- Main systematic: lepton energy/momentum scale

$m(H)$ measurement in ATLAS

ATLAS-CONF-2017-046

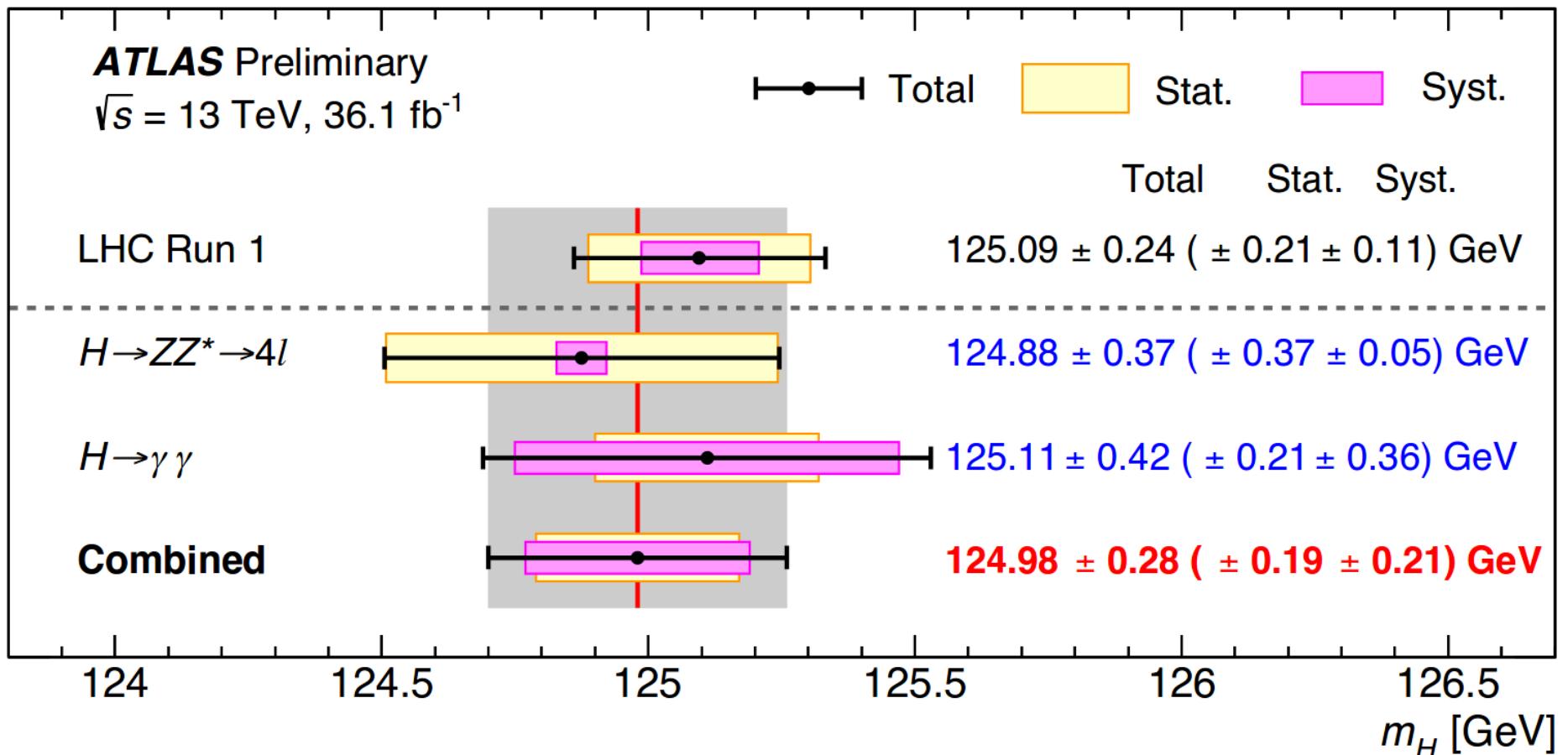


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- Kinematic fit of m_{12} leptons ($\sim 15\%$ gain)
- Per event mass uncertainties
- Main systematic: lepton energy/momentum scale

- $H \rightarrow \gamma\gamma$ channel has good statistics and mass resolution
- Different S/B and resolution cuts.
- Main systematics: photon energy scale (LAr cell non-linearity and layer calibration, material)

$m(H)$ measurement in ATLAS

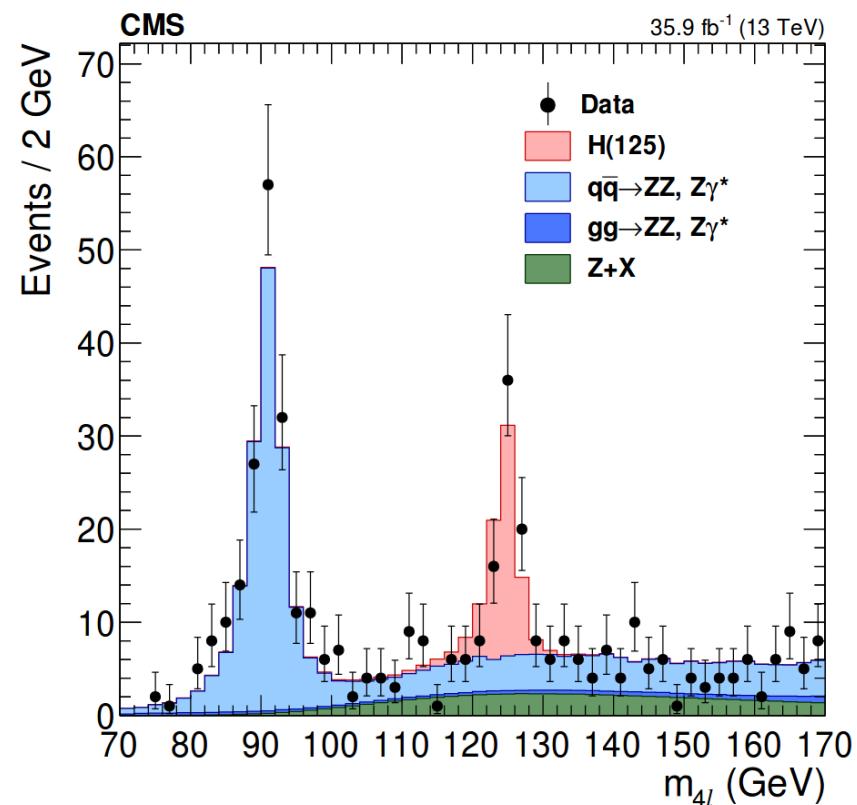
ATLAS-CONF-2017-046



m(H) measurement in CMS

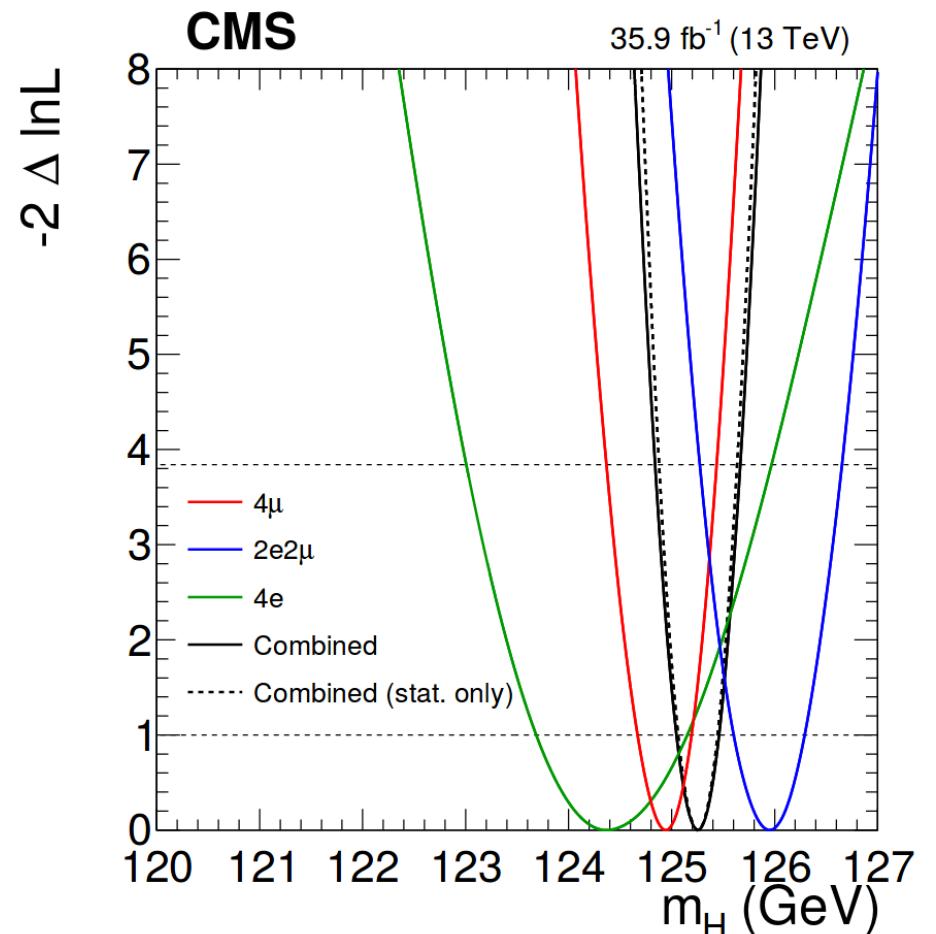
- $H \rightarrow ZZ \rightarrow 4\ell$ channel in CMS uses 3D fit
 - $m_{4\ell}$, ME discriminant, and per-event mass uncertainties
- Also includes kinematic fit of Z_1 leptons
 - ~8% improvement in 3D fit

No $m(Z_1)$ constraint	3D: $\mathcal{L}(m_{4\ell}, \mathcal{D}_{\text{mass}}, \mathcal{D}_{\text{bkg}}^{\text{kin}})$	2D: $\mathcal{L}(m_{4\ell}, \mathcal{D}_{\text{mass}})$	1D: $\mathcal{L}(m_{4\ell})$
Expected m_H uncertainty change	+8.1%	+11%	+21%
Observed m_H (GeV)	125.28 ± 0.22	125.36 ± 0.24	125.39 ± 0.25
With $m(Z_1)$ constraint	3D: $\mathcal{L}(m'_{4\ell}, \mathcal{D}'_{\text{mass}}, \mathcal{D}_{\text{bkg}}^{\text{kin}})$	2D: $\mathcal{L}(m'_{4\ell}, \mathcal{D}'_{\text{mass}})$	1D: $\mathcal{L}(m'_{4\ell})$
Expected m_H uncertainty change	—	+3.2%	+11%
Observed m_H (GeV)	125.26 ± 0.21	125.30 ± 0.21	125.34 ± 0.23



- Dominant systematic uncertainty comes from the lepton energy scale

***12% more precise compared
to Run 1 ATLAS+CMS
combination***



$$m_H = 125.26 \pm 0.21 (\pm 0.20 \text{ stat.} \pm 0.08 \text{ sys.}) \text{ GeV}$$

Higgs Couplings

	mass	charge	spin	particle	
QUARKS	$\approx 2.4 \text{ MeV}/c^2$	2/3	1/2	u	$\approx 2.4 \text{ MeV}/c^2$
				up	2/3 1/2
	$\approx 1.275 \text{ GeV}/c^2$	2/3	1/2	c	$\approx 1.275 \text{ GeV}/c^2$
				charm	2/3 1/2
	$\approx 172.44 \text{ GeV}/c^2$	2/3	1/2	t	$\approx 172.44 \text{ GeV}/c^2$
				top	2/3 1/2
	0	0	1	g	0
				gluon	0 0
	$\approx 125.09 \text{ GeV}/c^2$	0	0	H	$\approx 125.09 \text{ GeV}/c^2$
				Higgs	0 0
LEPTONS	$\approx 4.8 \text{ MeV}/c^2$	-1/3	1/2	d	$\approx 4.8 \text{ MeV}/c^2$
				down	-1/3 1/2
	$\approx 95 \text{ MeV}/c^2$	-1/3	1/2	s	$\approx 95 \text{ MeV}/c^2$
				strange	-1/3 1/2
	$\approx 4.18 \text{ GeV}/c^2$	-1/3	1/2	b	$\approx 4.18 \text{ GeV}/c^2$
GAUGE BOSONS				bottom	-1/3 1/2
	0	0	1	γ	0
				photon	0 1
	$\approx 0.511 \text{ MeV}/c^2$	-1	1/2	e	$\approx 0.511 \text{ MeV}/c^2$
				electron	-1 1/2
SCALAR BOSONS	$\approx 105.67 \text{ MeV}/c^2$	-1	1/2	μ	$\approx 105.67 \text{ MeV}/c^2$
				muon	-1 1/2
	$\approx 1.7768 \text{ GeV}/c^2$	-1	1/2	τ	$\approx 1.7768 \text{ GeV}/c^2$
				tau	-1 1/2
	0	1	1	Z	$\approx 91.19 \text{ GeV}/c^2$
GAUGE BOSONS				Z boson	0 1
	$< 2.2 \text{ eV}/c^2$	0	1/2	ν_e	$< 2.2 \text{ eV}/c^2$
				electron neutrino	0 1/2
	$< 1.7 \text{ MeV}/c^2$	0	1/2	ν_μ	$< 1.7 \text{ MeV}/c^2$
				muon neutrino	0 1/2
GAUGE BOSONS	$< 15.5 \text{ MeV}/c^2$	0	1/2	ν_τ	$< 15.5 \text{ MeV}/c^2$
				tau neutrino	0 1/2
	$\approx 80.39 \text{ GeV}/c^2$	± 1	1	W	$\approx 80.39 \text{ GeV}/c^2$
				W boson	± 1 1

Higgs Couplings

**Jason
Nielsen
(ATLAS)**

**Daniele
Zanzi
(ATLAS)**

**Marco
Peruzzi
(CMS)**

**Andrea
Marini
(CMS)**

**Michael
Kagan
(ATLAS
+CMS)**

**Ioannis
Nomidis
(ATLAS)**

QUARKS

mass $\approx 2.4 \text{ MeV}/c^2$
charge $2/3$
spin $1/2$

u

up

mass $\approx 1.075 \text{ GeV}/c^2$
charge $-1/3$
spin $1/2$

c

charm

mass $\approx 172.44 \text{ GeV}/c^2$
charge $2/3$
spin $1/2$

t

top

mass $\approx 4.8 \text{ MeV}/c^2$
charge $-1/3$
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d

down

mass $\approx 95 \text{ MeV}/c^2$
charge $-1/3$
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strange

mass $\approx 4.18 \text{ GeV}/c^2$
charge $-1/3$
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b

bottom

LEPTONS

mass $\approx 0.511 \text{ MeV}/c^2$
charge -1
spin $1/2$

e

electron

mass $\approx 105.67 \text{ MeV}/c^2$
charge -1
spin $1/2$

μ

muon

mass $\approx 1.7768 \text{ GeV}/c^2$
charge -1
spin $1/2$

τ

tau

mass $< 2.2 \text{ eV}/c^2$
charge 0
spin $1/2$

ν_e

electron
neutrino

mass $< 1.7 \text{ MeV}/c^2$
charge 0
spin $1/2$

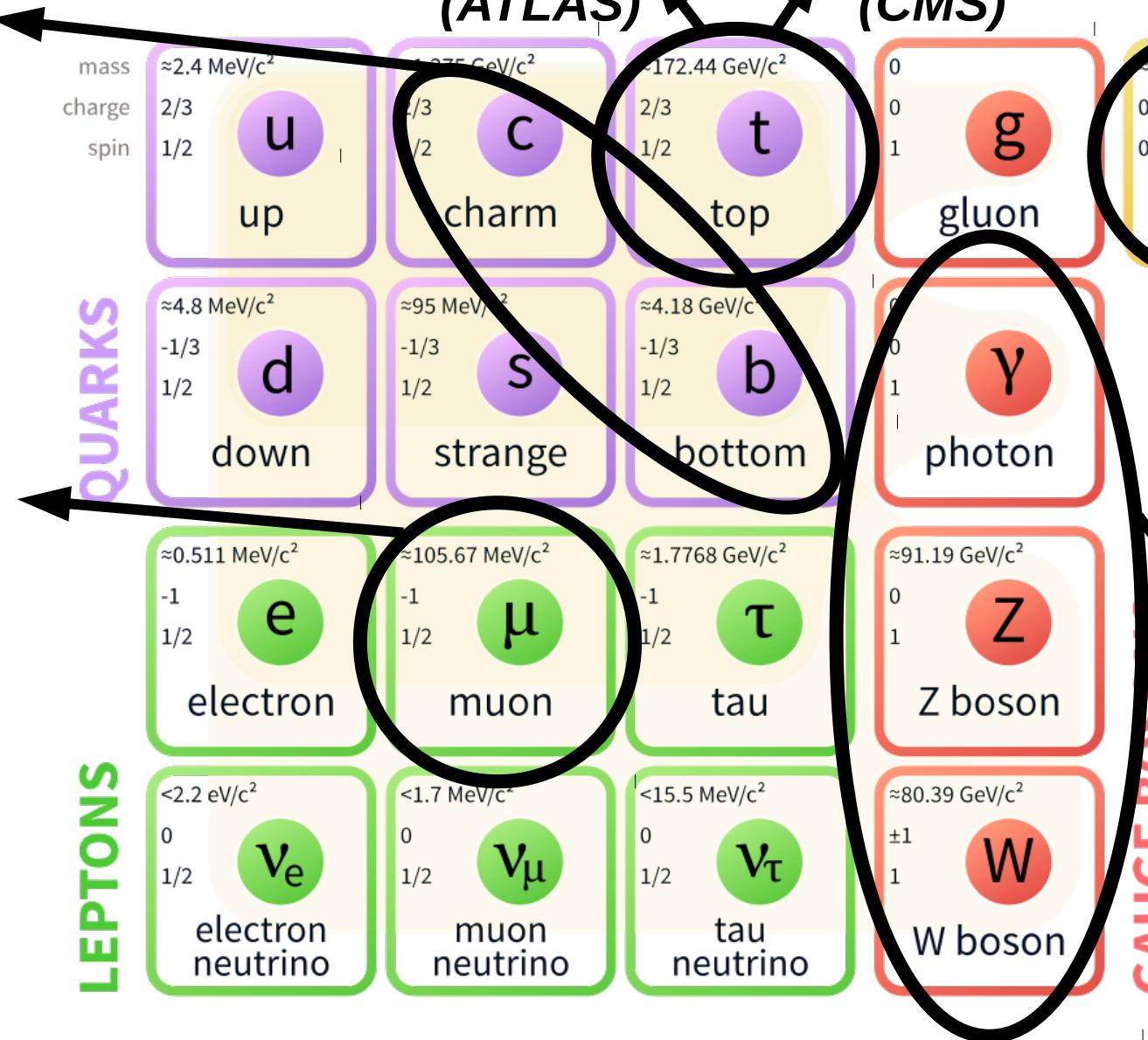
ν_μ

muon
neutrino

mass $< 15.5 \text{ MeV}/c^2$
charge 0
spin $1/2$

ν_τ

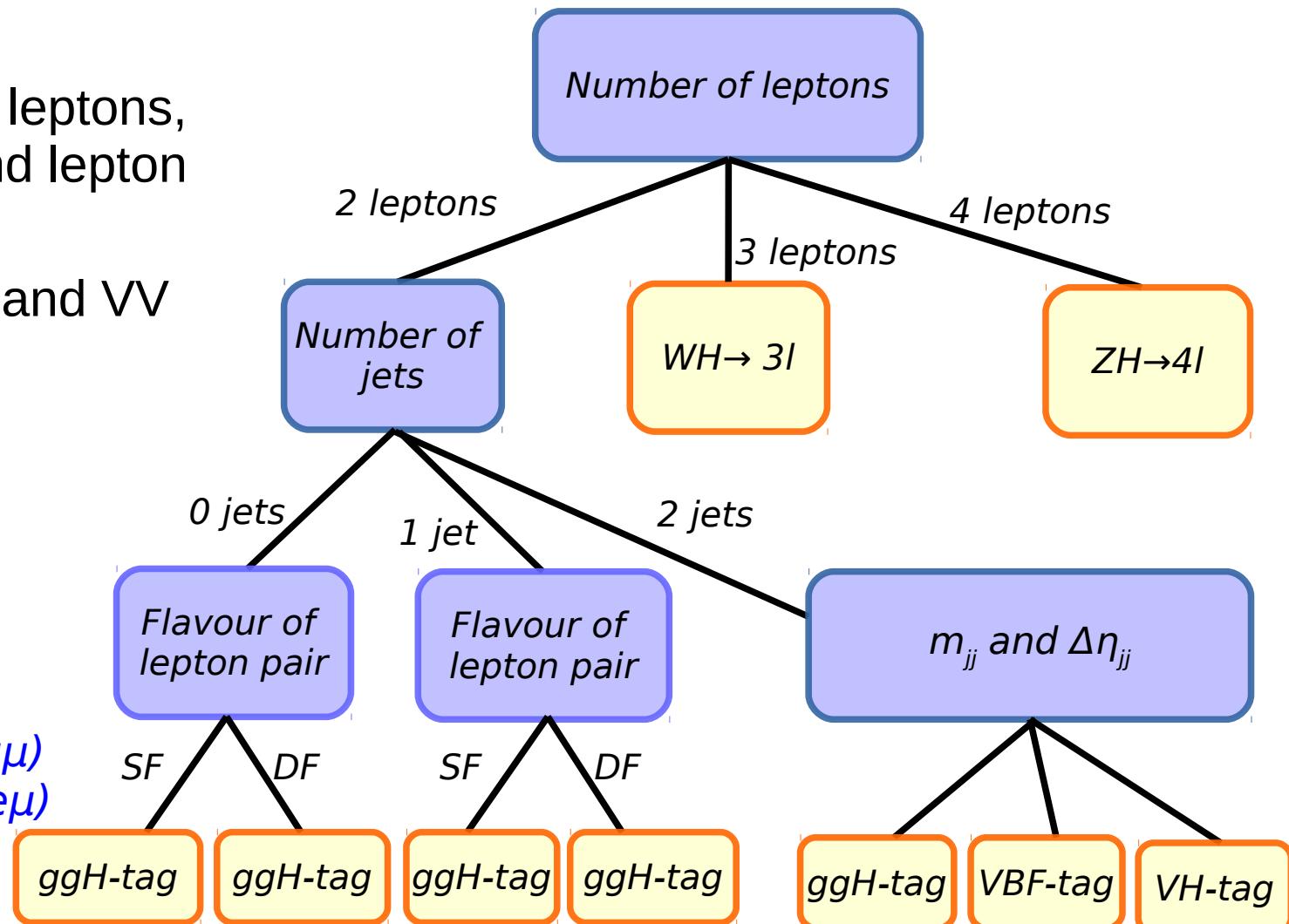
tau
neutrino



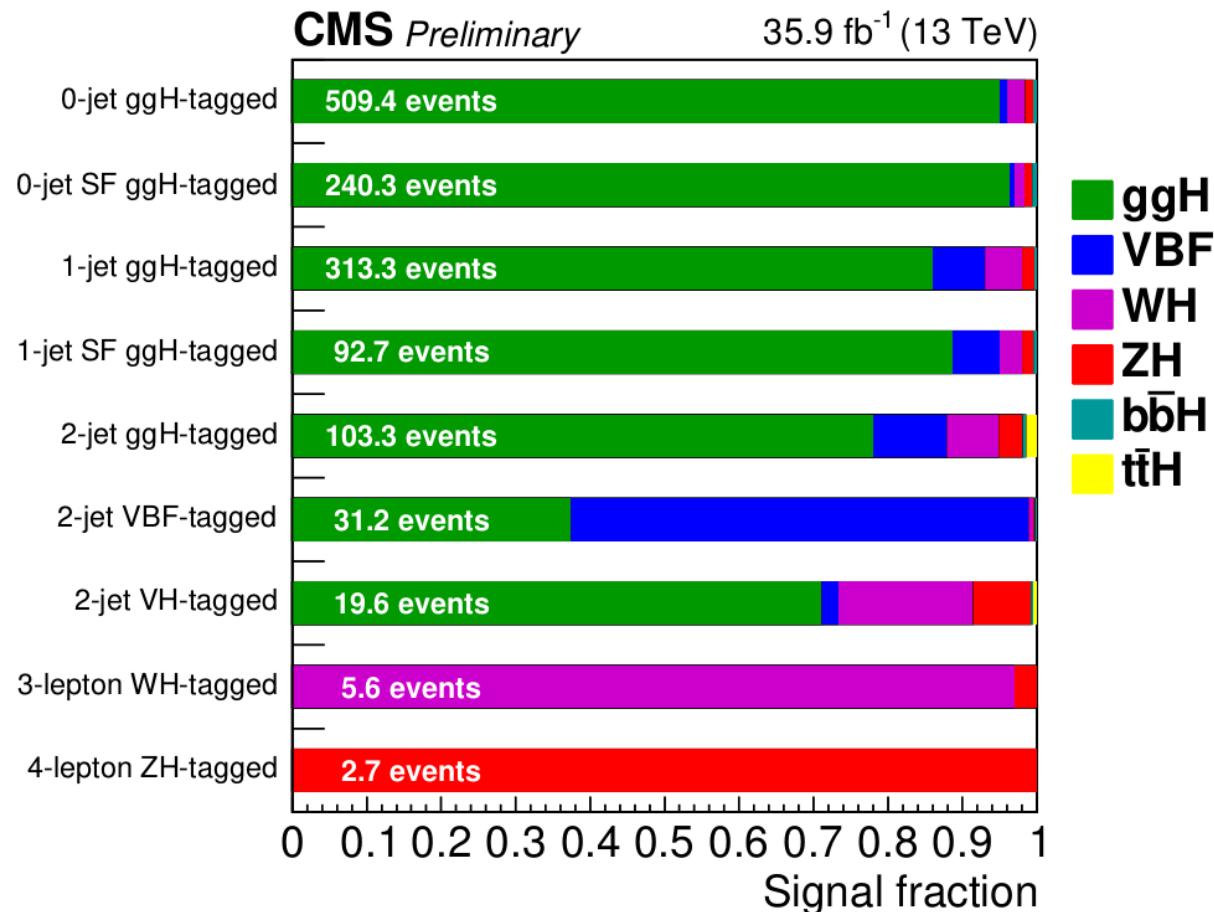
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				μ muon	$\approx 1.7768 \text{ GeV}/c^2$
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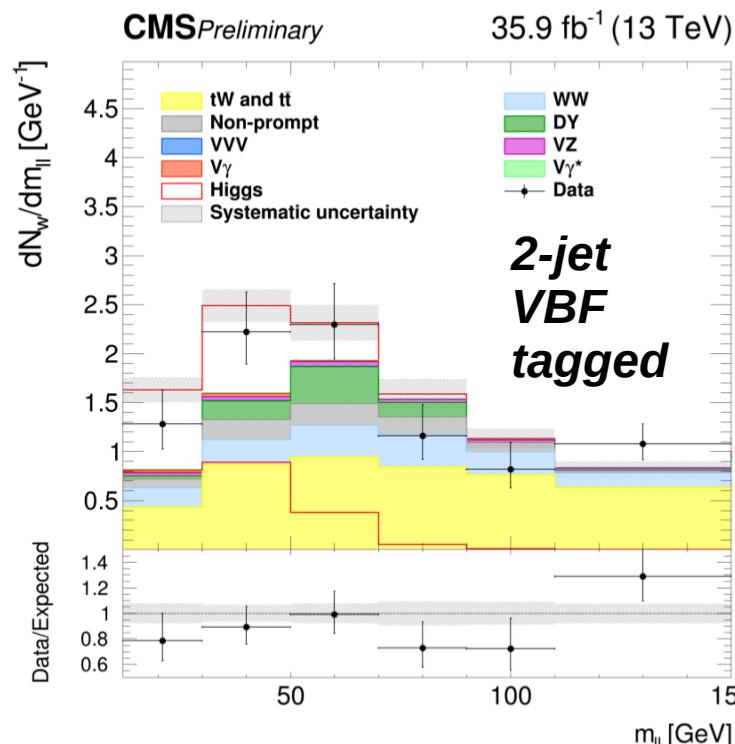
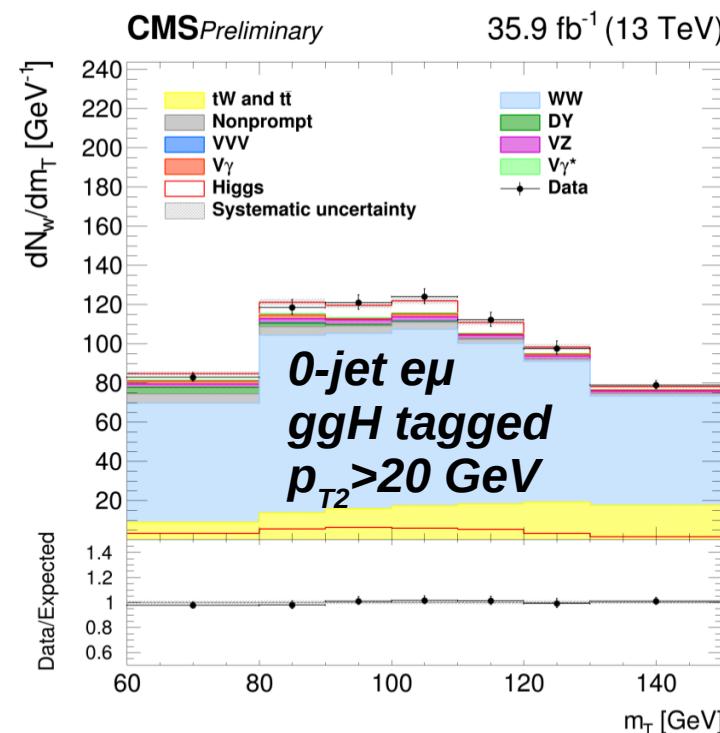
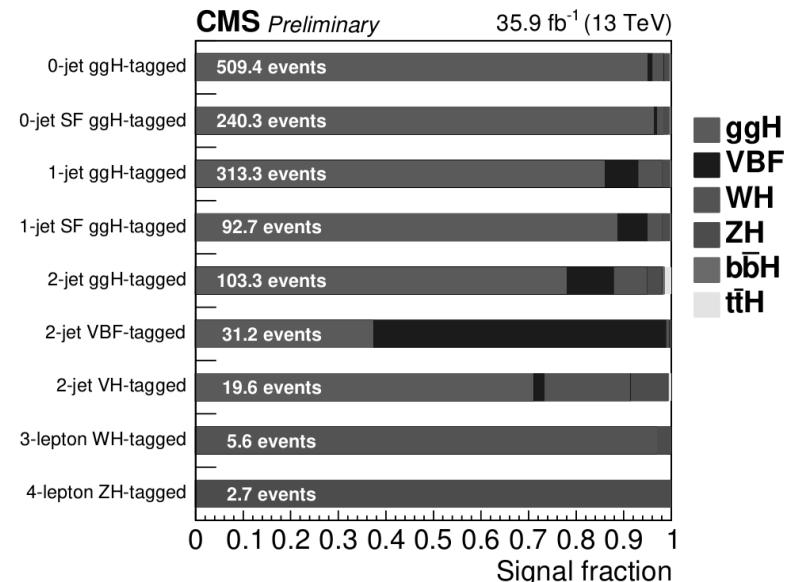
- Total of 30 signal regions target ggH, VBF, WH, and ZH prod.
- Split in number of leptons, number of jets, and lepton charge/flavor
- Dedicated tt, Z $\rightarrow\ell\ell$, and VV control regions fit simultaneously



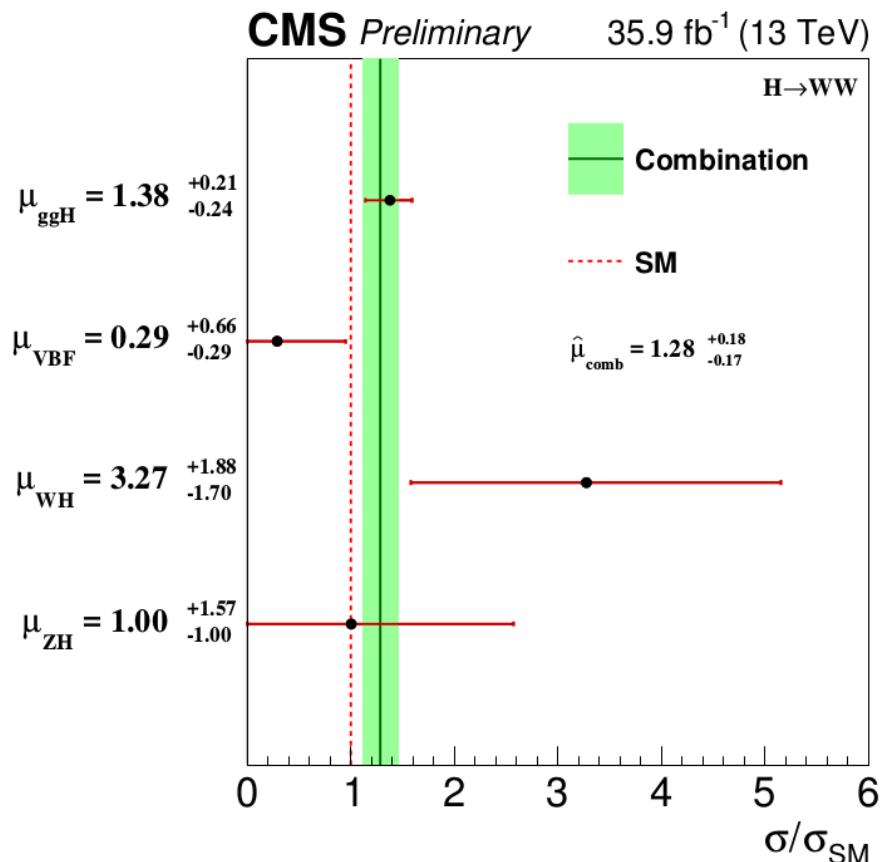
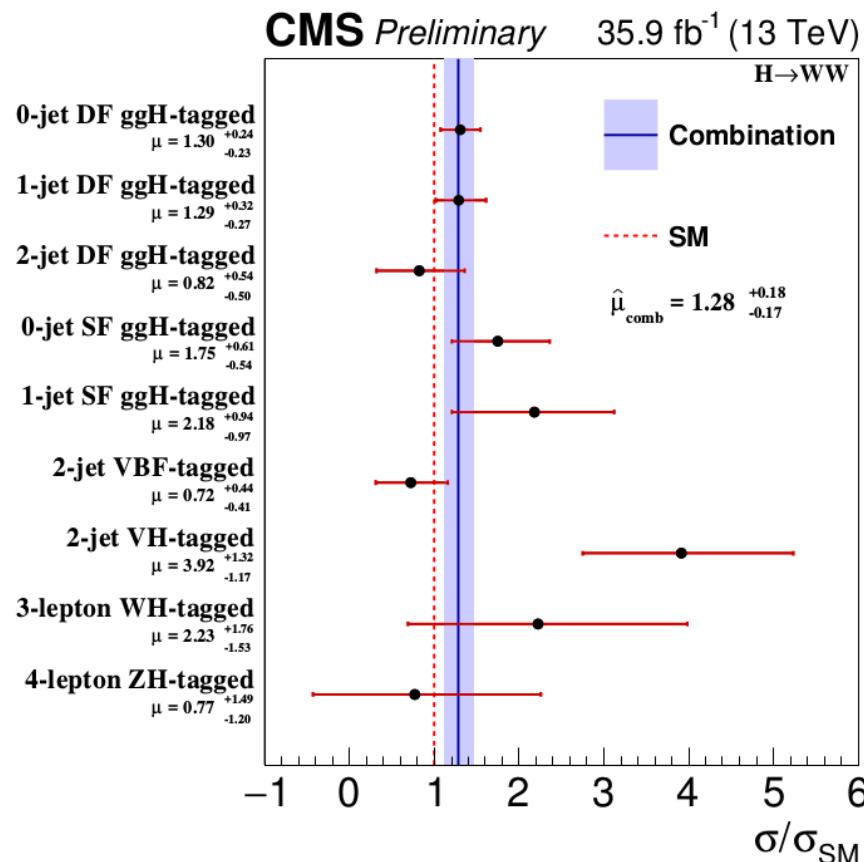
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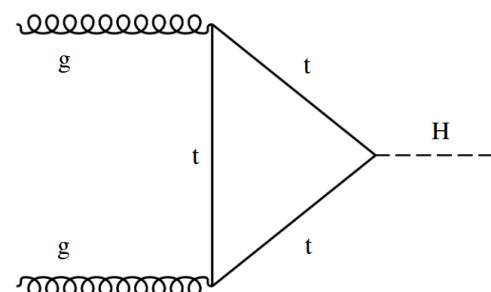
Signal extracted using binned templates of different sensitive observables depending on the category



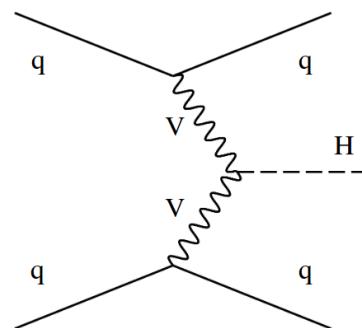
$$\hat{\mu} = 1.28^{+0.18}_{-0.17} = 1.28 \pm 0.10(\text{stat})^{+0.11}_{-0.11}(\text{syst})^{+0.10}_{-0.07}(\text{theo.})$$

- Main theoretical uncertainties are ggH cross section and jet bin migration
- Main experimental systematics come from the background rates, luminosity, and lepton identification efficiencies

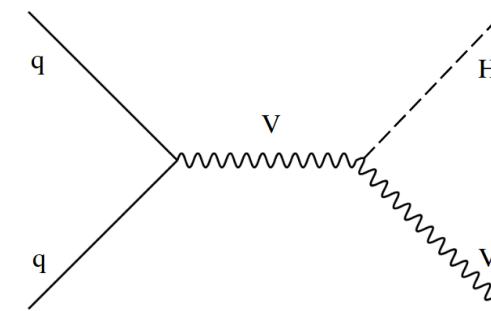
ggH



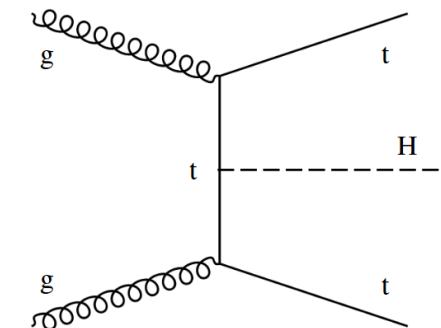
VBF



WH, ZH

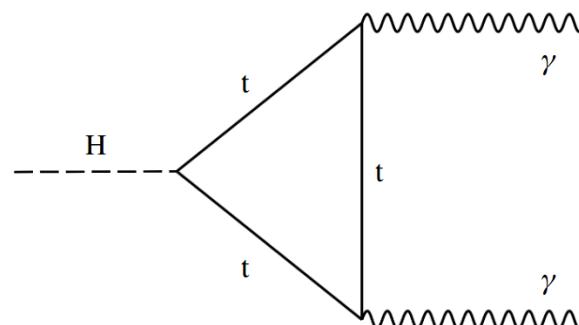


ttH

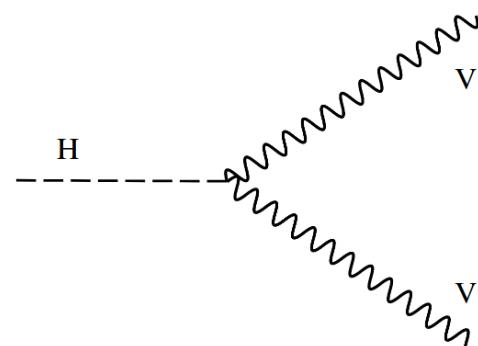


Combined Higgs Measurements

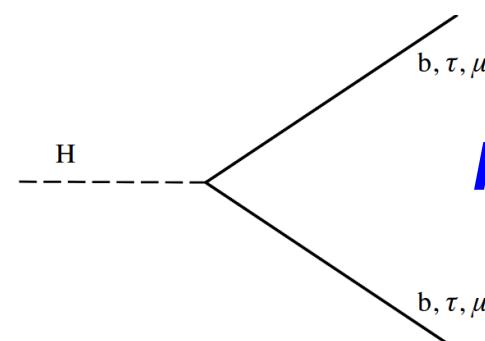
$H \rightarrow \gamma\gamma$



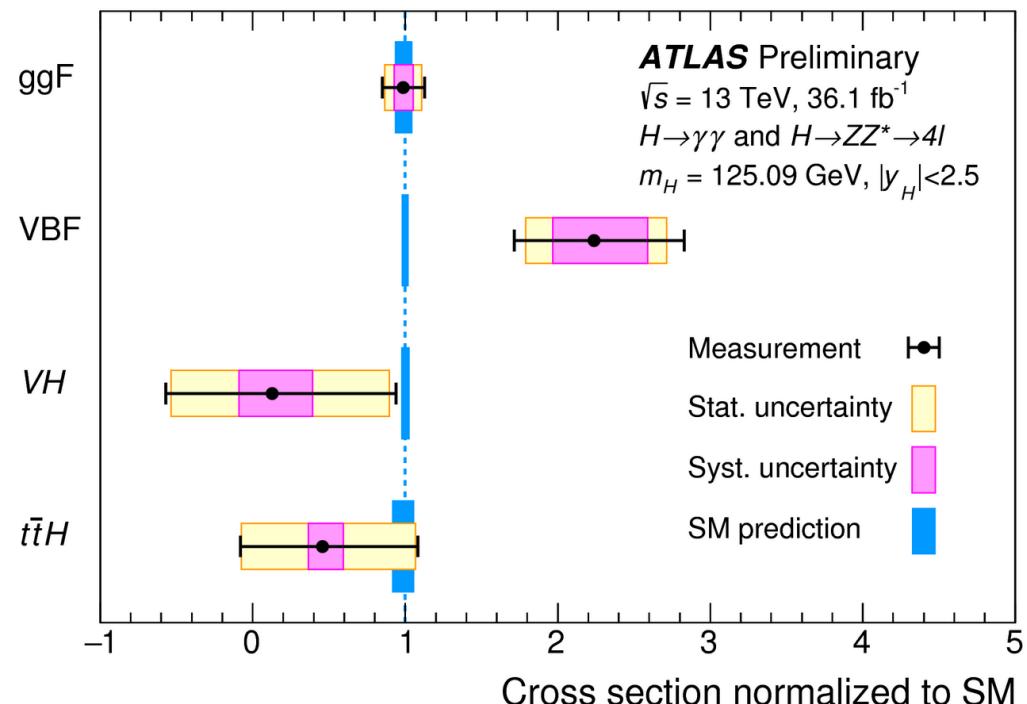
$H \rightarrow WW, ZZ$



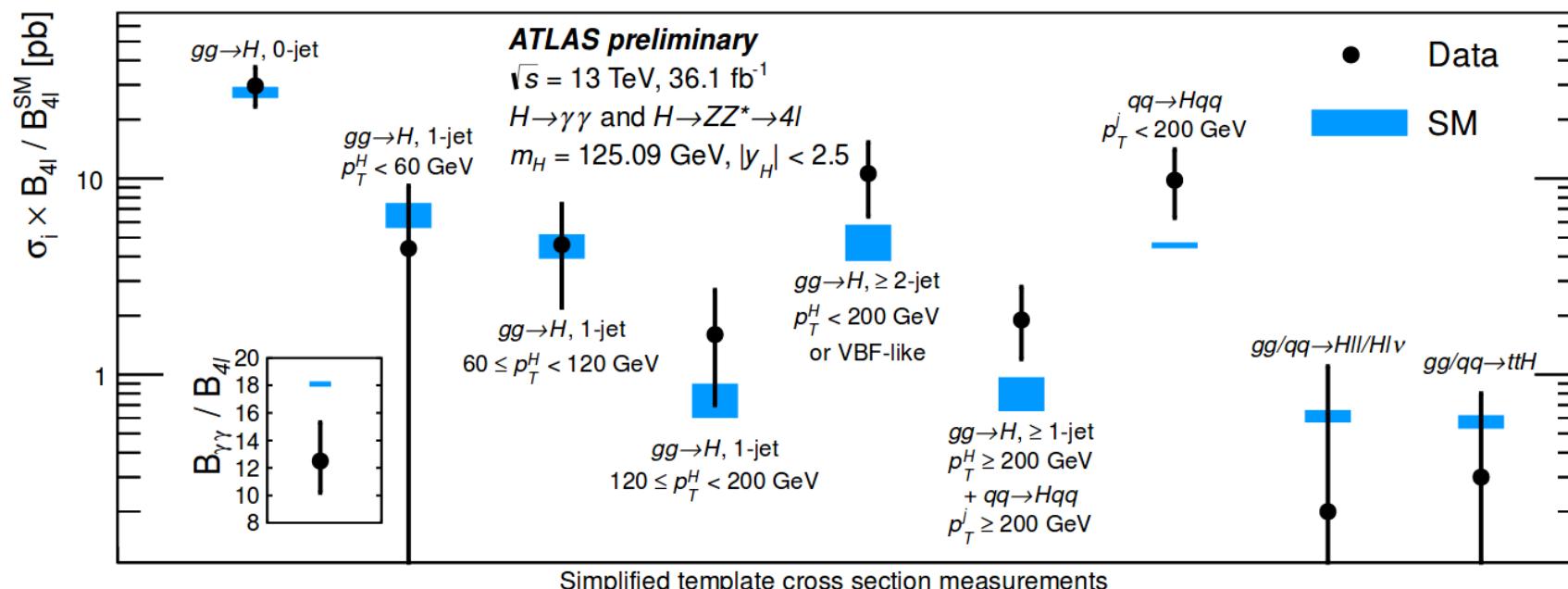
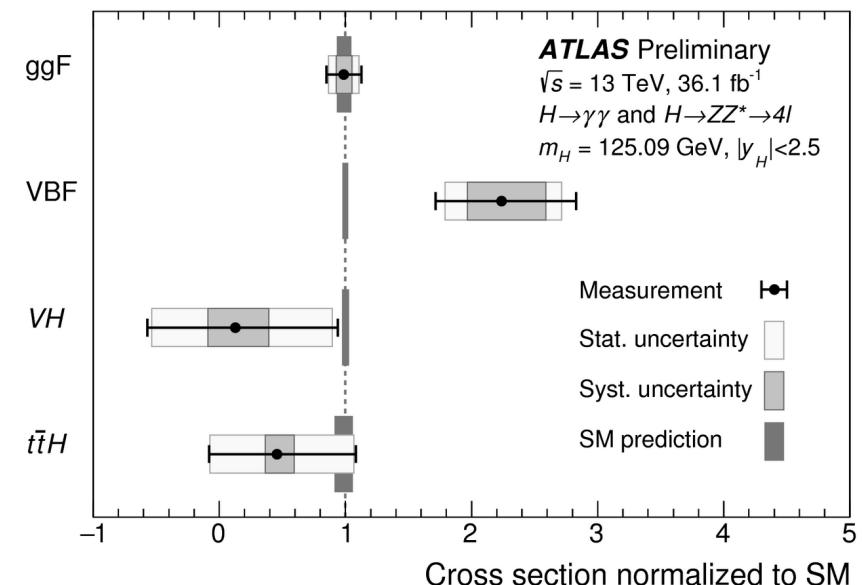
$H \rightarrow bb, \tau\tau, \mu\mu$



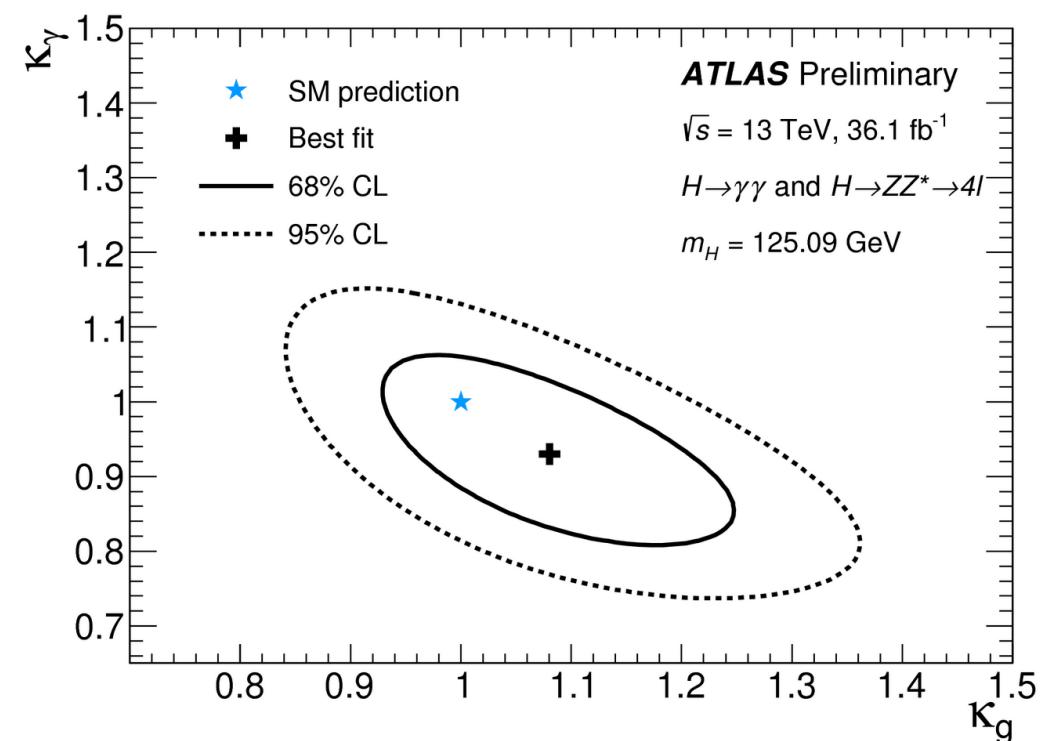
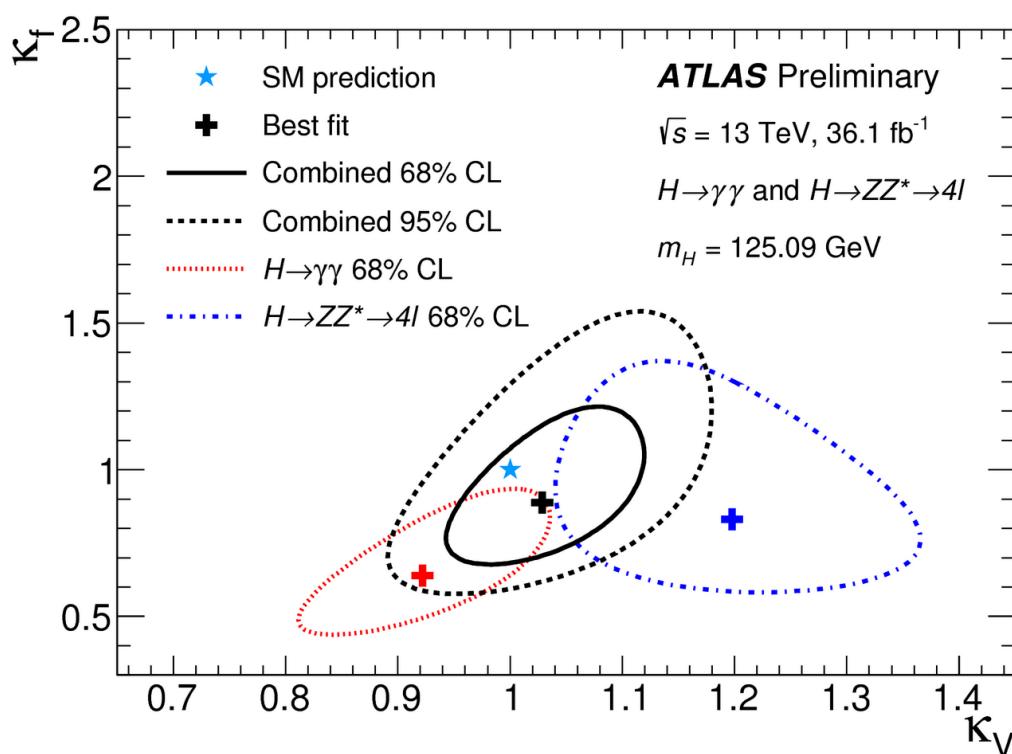
- Combination of ZZ and $\gamma\gamma$ decay channels
- Cross section measurements in the Simplified Template Cross Section (STXS) framework
 - Th. uncs. in SM predictions (blue bands) separated from exp. and th. uncs. in measurements
 - **For the usual prod. modes...**



- Combination of ZZ and $\gamma\gamma$ decay channels
- Cross section measurements in the Simplified Template Cross Section (STXS) framework
 - Th. uncs. in SM predictions (blue bands) separated from exp. and th. uncs. in measurements
 - ... and also more differentially



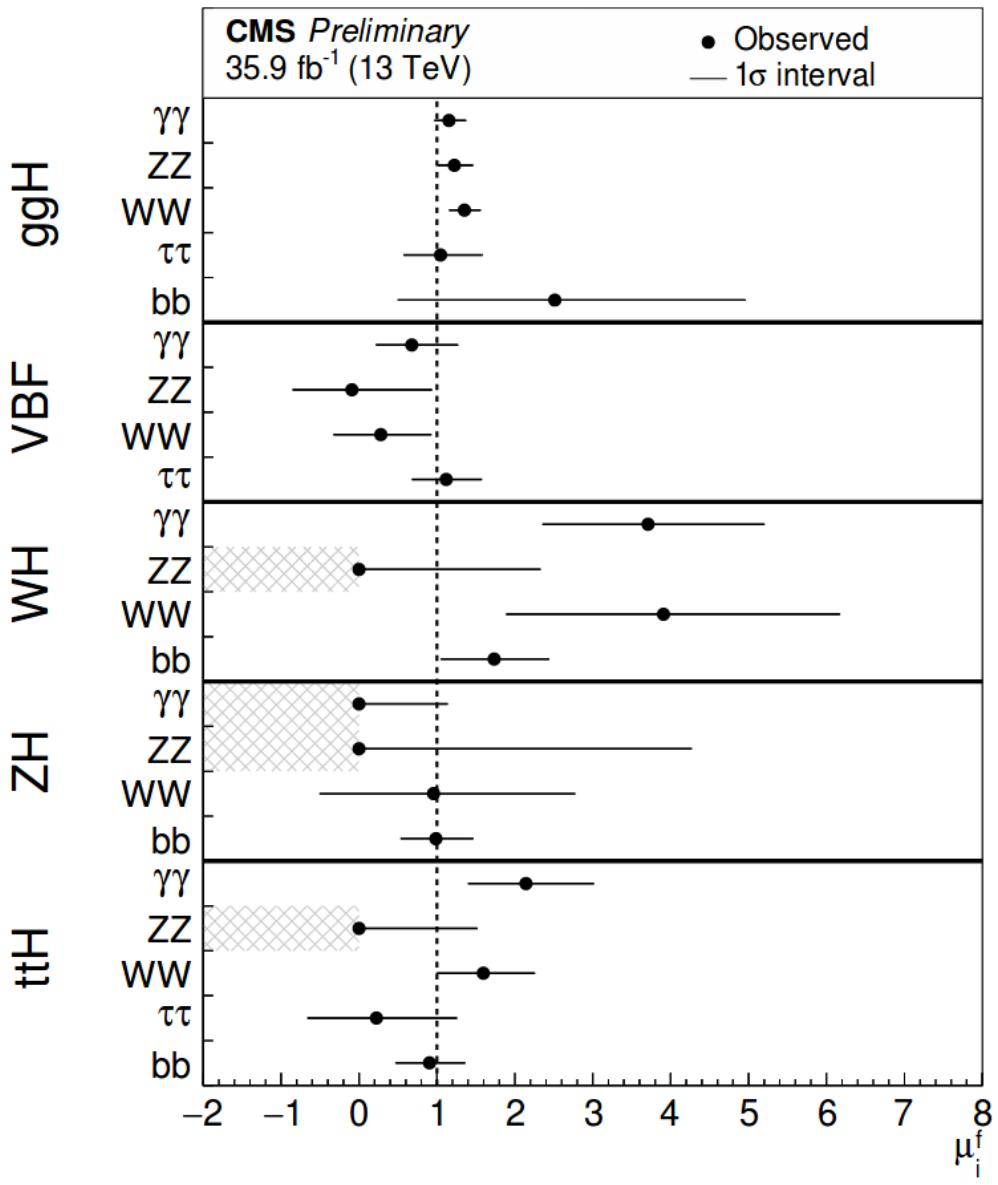
- Results also interpreted in terms of Higgs couplings using the leading order inspired “ κ -framework” model
- 2D regions found for κ_v vs. κ_F , and κ_g vs. κ_γ
 - Assuming no BSM contributions to total width



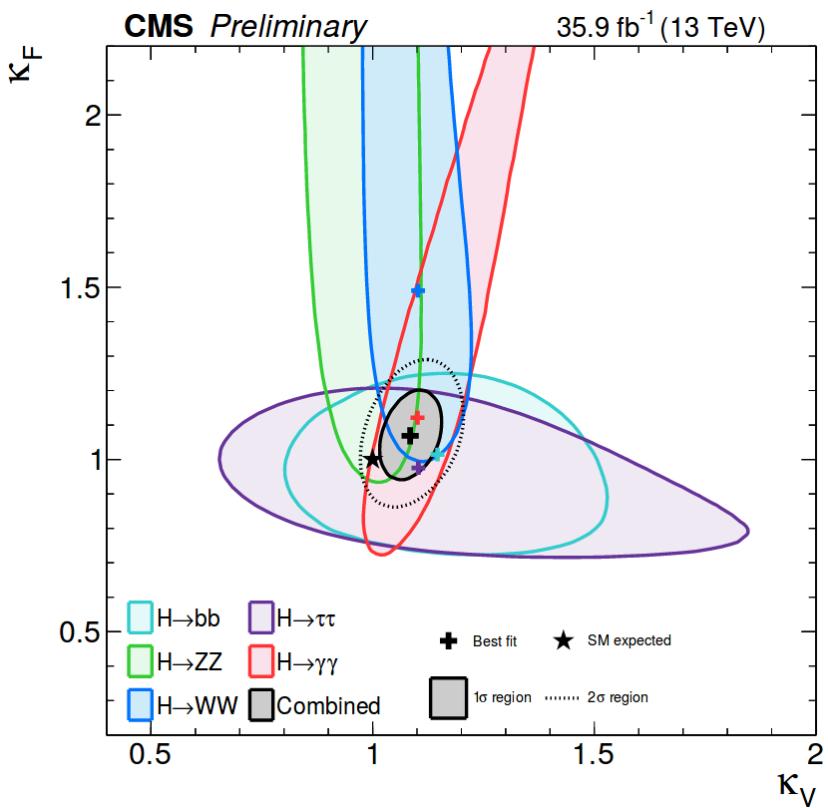
CMS Combination

CMS-PAS-HIG-17-031

NEW!



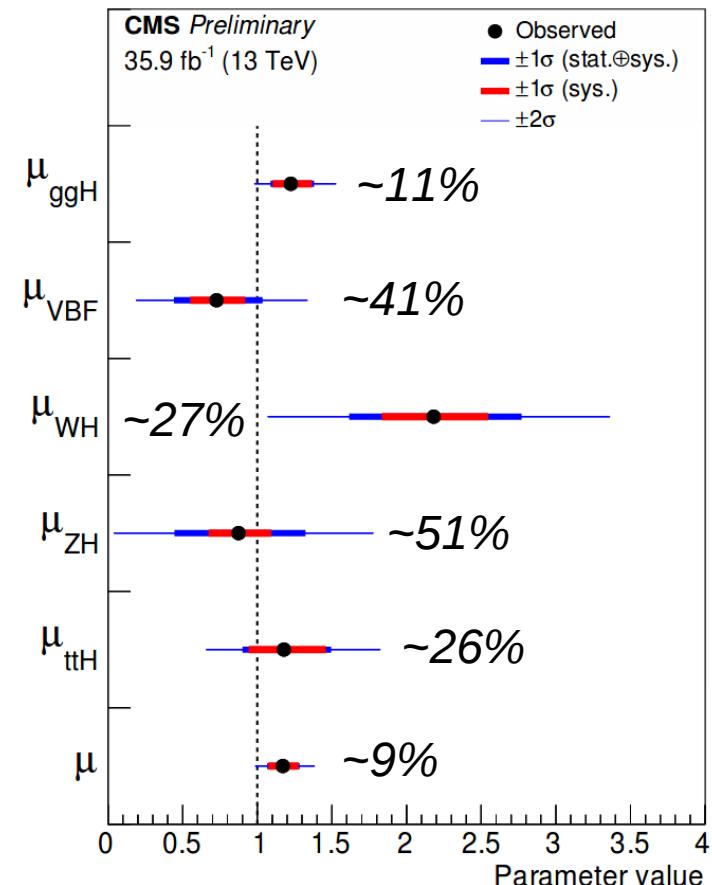
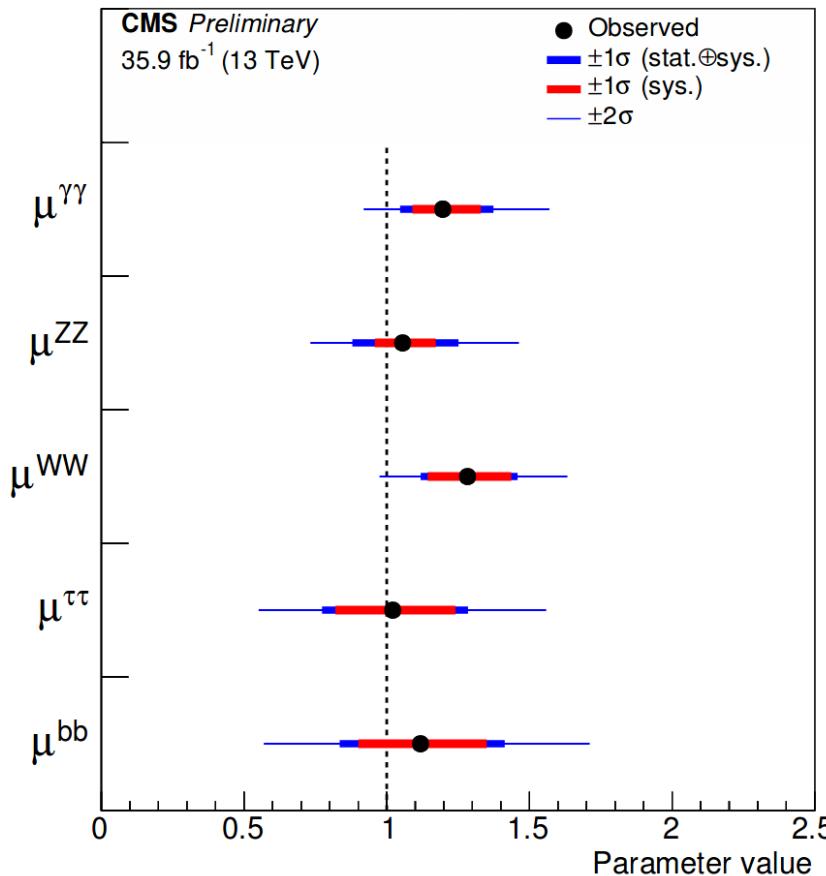
- Includes a wide range of H measurements using the full 2016 dataset
- Combined analysis sensitive to 22 out of 25 possible prod. x decay combinations



Production and Decay Modes

CMS-PAS-HIG-17-031

$$\mu = 1.17^{+0.10}_{-0.10} = 1.17^{+0.06}_{-0.06} \text{ (stat.)} \quad {}^{+0.06}_{-0.05} \text{ (sig. th.)} \quad {}^{+0.06}_{-0.06} \text{ (other sys.)}$$

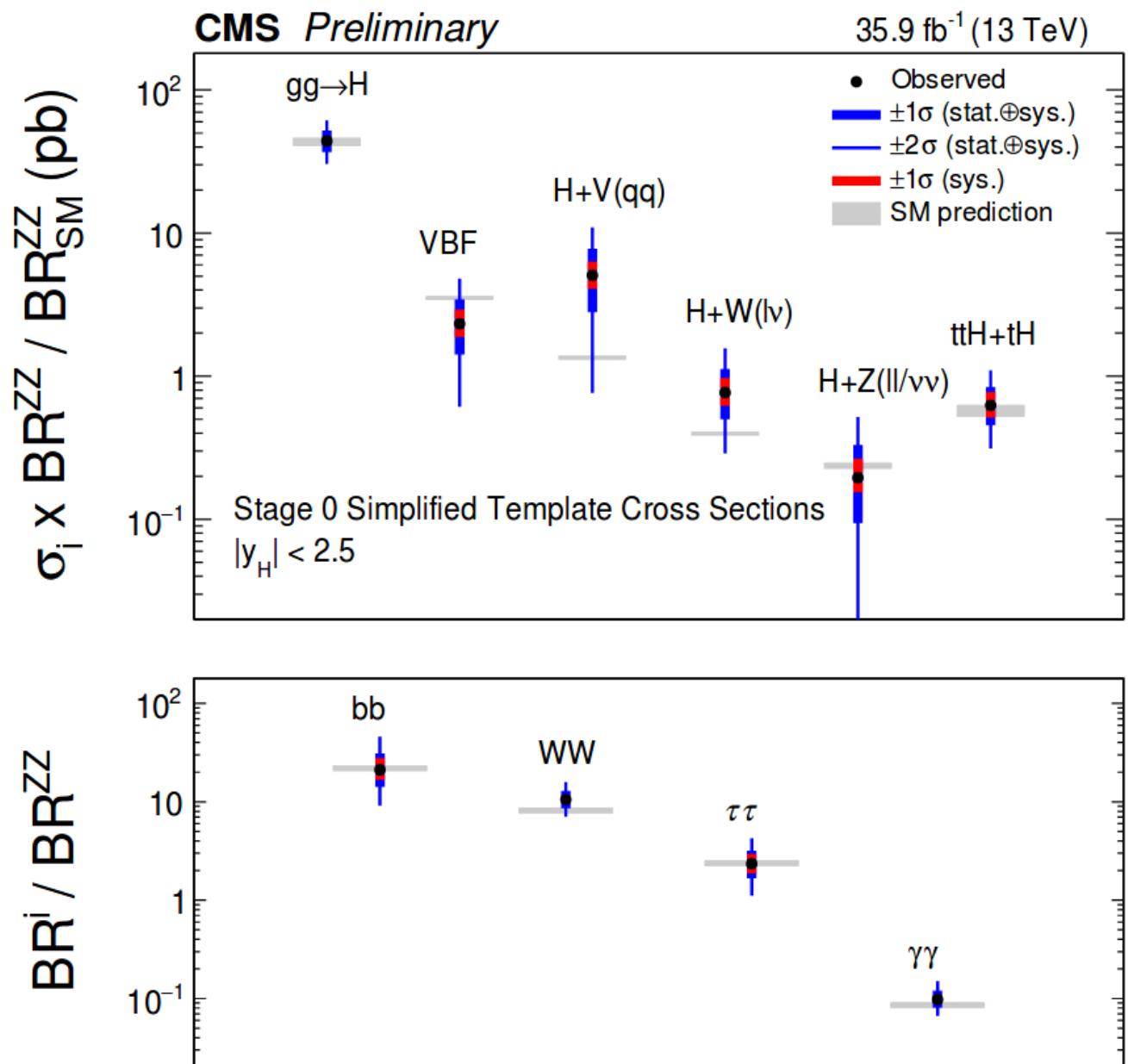


**Most precise measurement of gluon fusion, ttH, and total signal strength
(ATLAS+CMS Run 1 combination: $\mu_{ggH} = 1.03^{+0.16}_{-0.14}$)**

Template Cross Sections

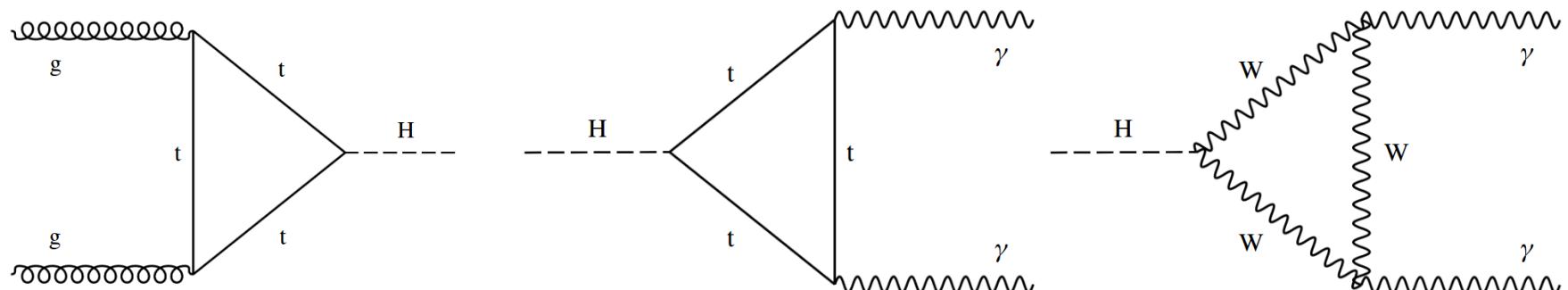
CMS-PAS-HIG-17-031

- Results quoted for the conventional production modes → VH split into $V(\ell\ell)$ and $V(qq)$
- Th. uncs. in SM predictions (grey bands) separated from exp. and th. uncs. in the measurements
- **First ever STXS measurement using 5 decay channels**



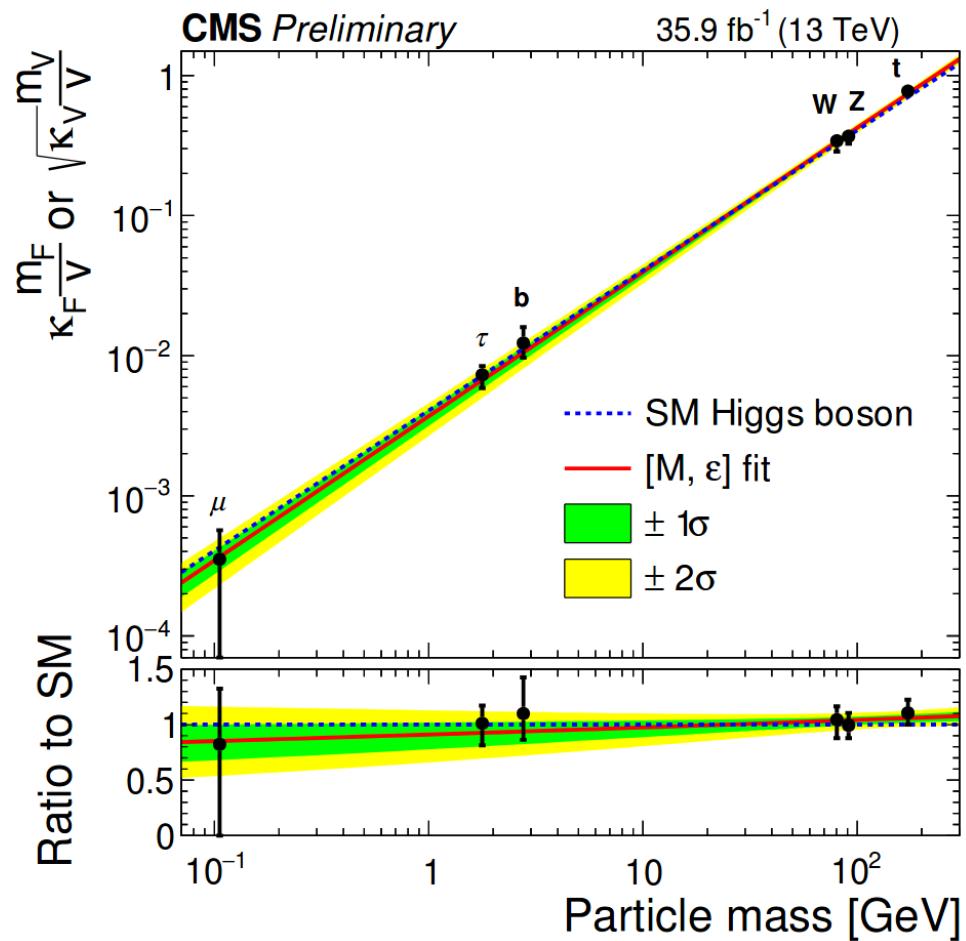
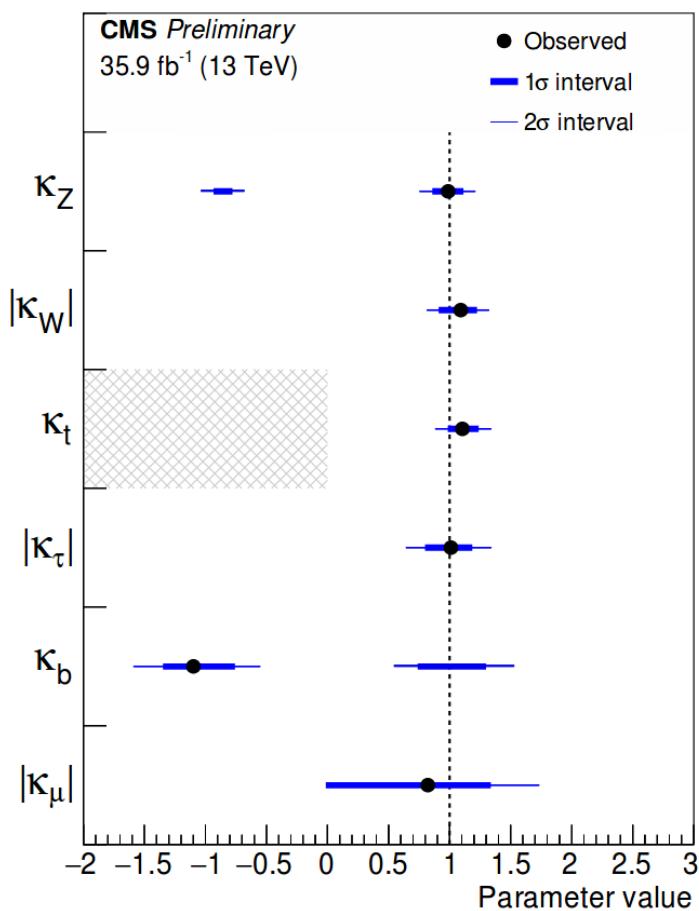
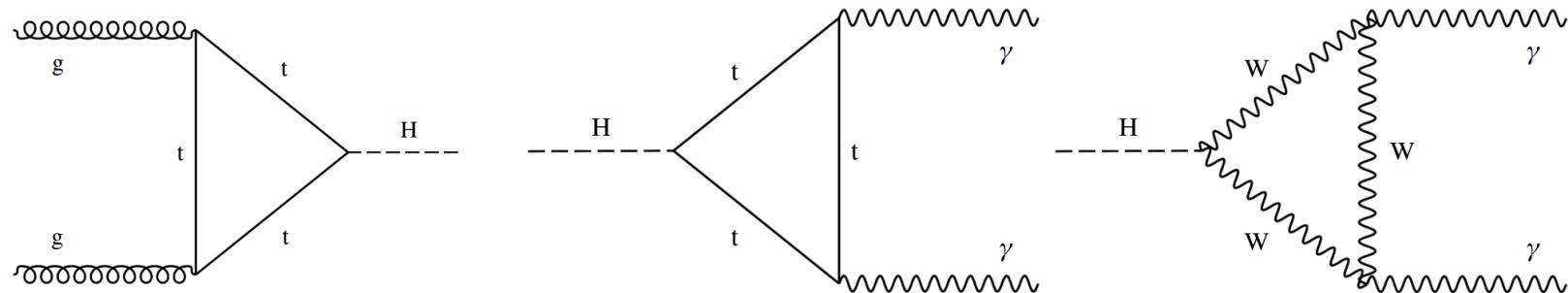
Couplings: Resolved Loops

CMS-PAS-HIG-17-031



Couplings: Resolved Loops

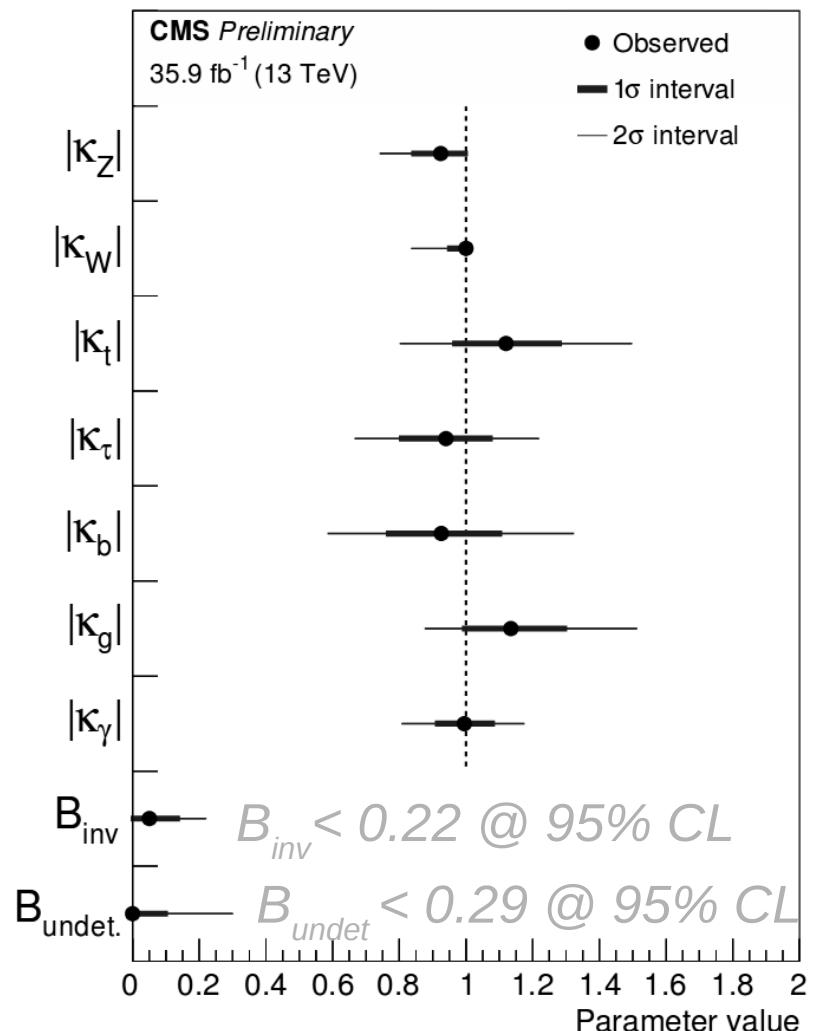
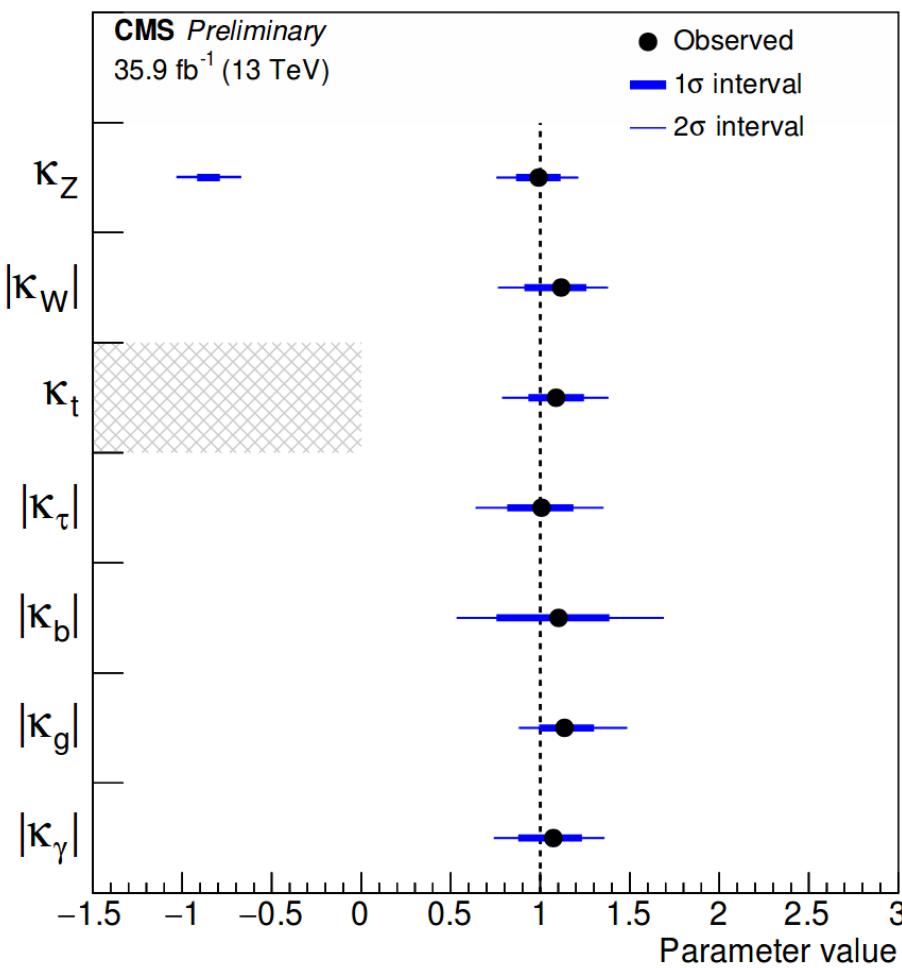
CMS-PAS-HIG-17-031



Couplings: Effective Loops

CMS-PAS-HIG-17-031

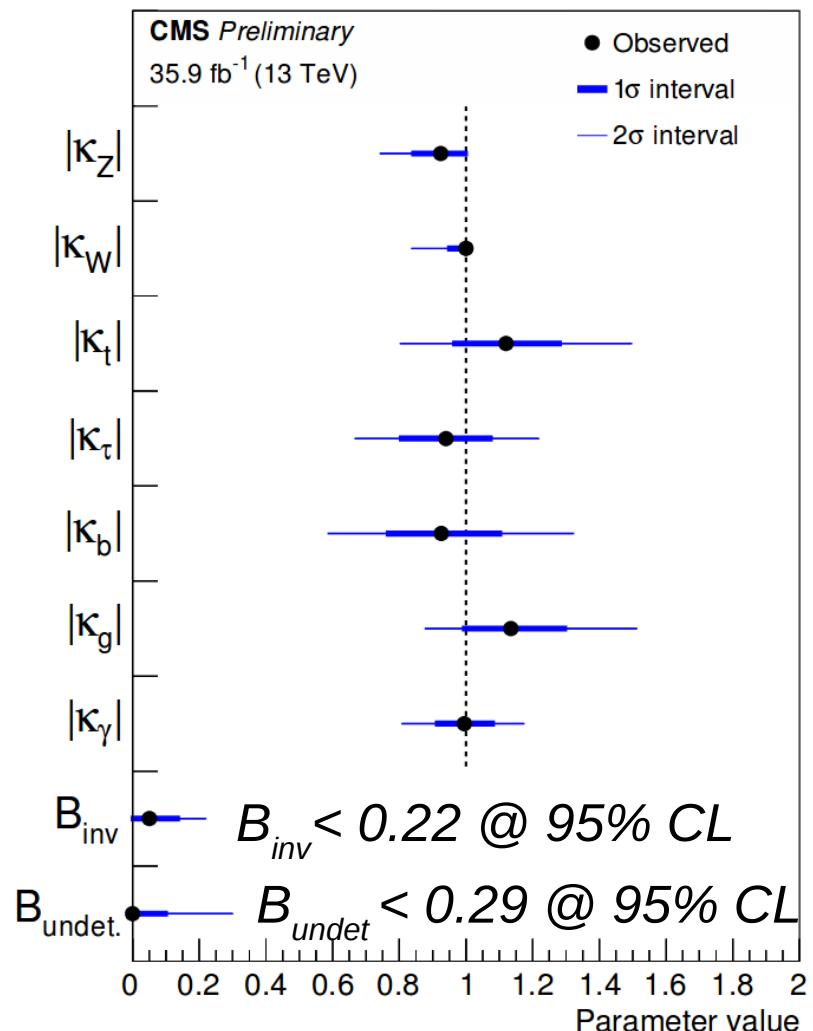
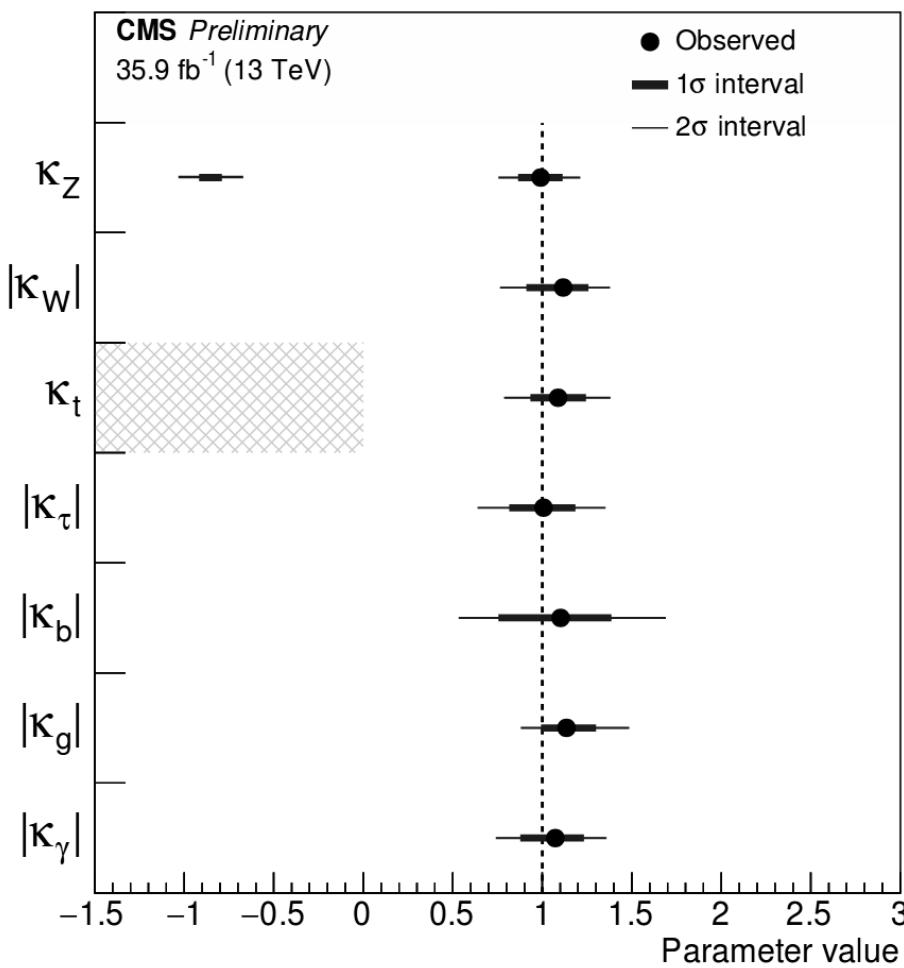
- No assumptions about loop processes (independent parameters)
- Two assumptions about total width: **No BSM decays...**



Couplings: Effective Loops

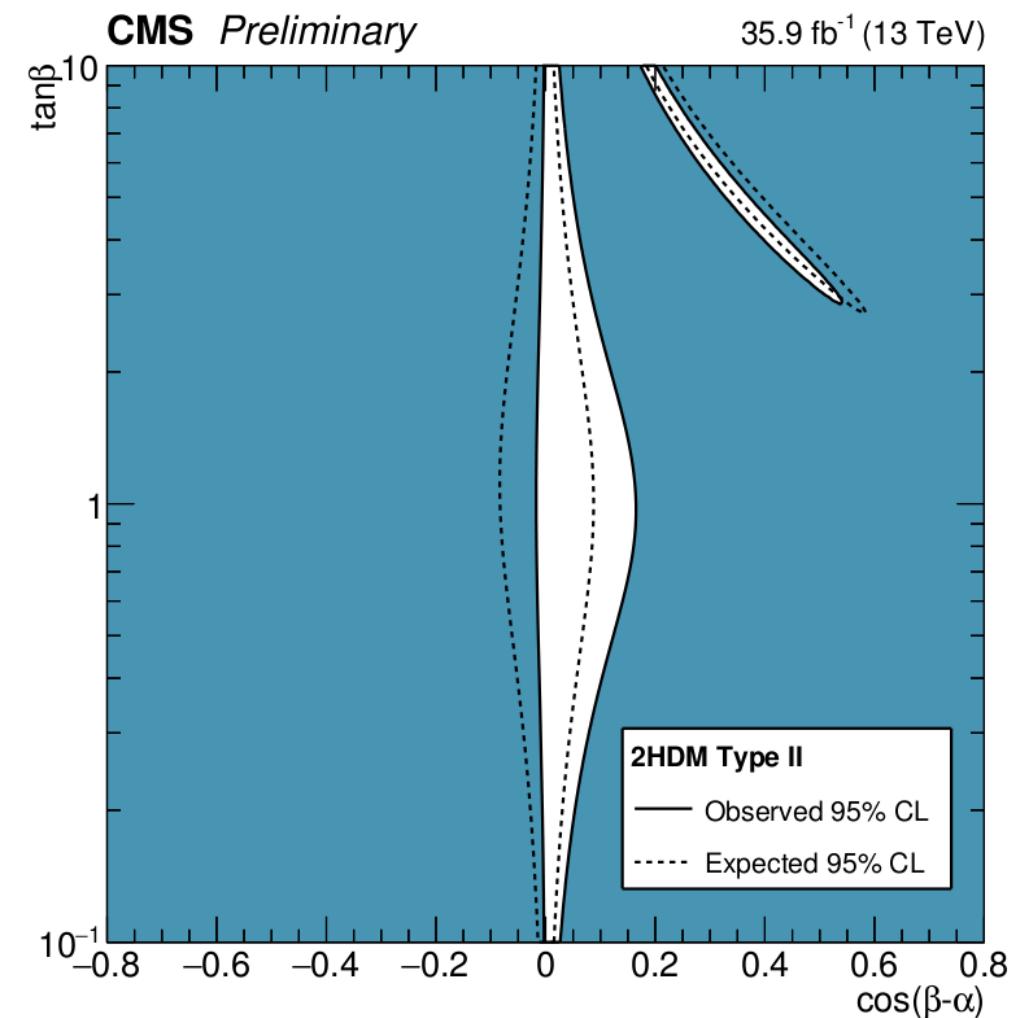
CMS-PAS-HIG-17-031

- No assumptions about loop processes (independent parameters)
- Two assumptions about total width: No BSM decays... or $\kappa_v < 1$



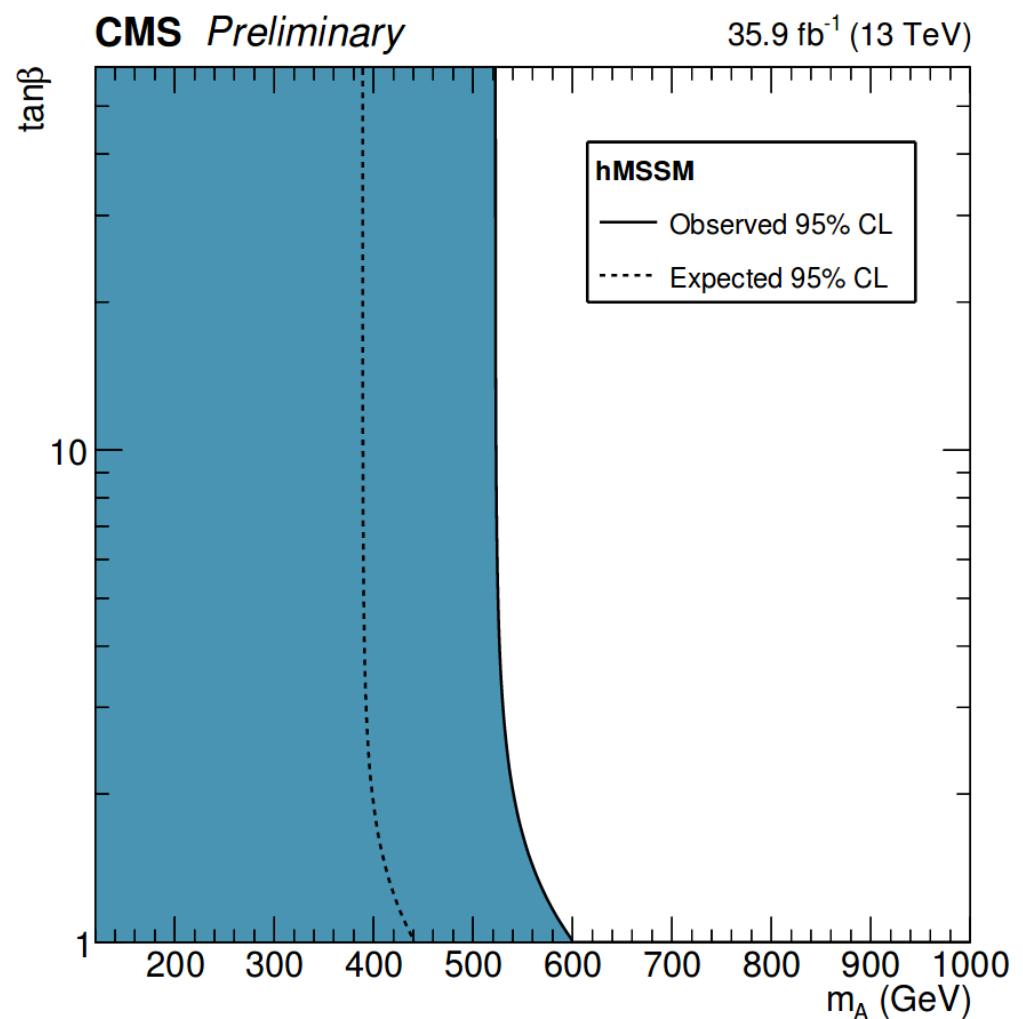
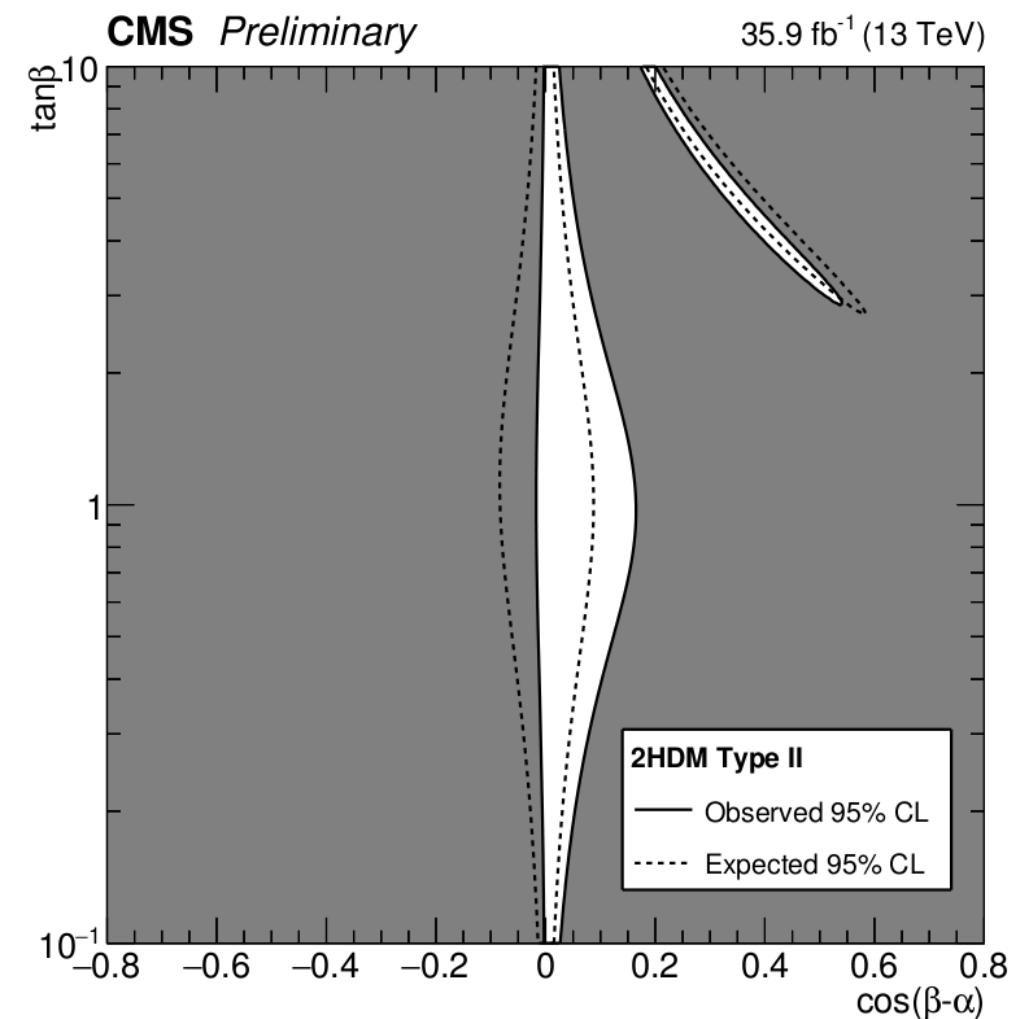
Constraints on BSM models

CMS-PAS-HIG-17-031



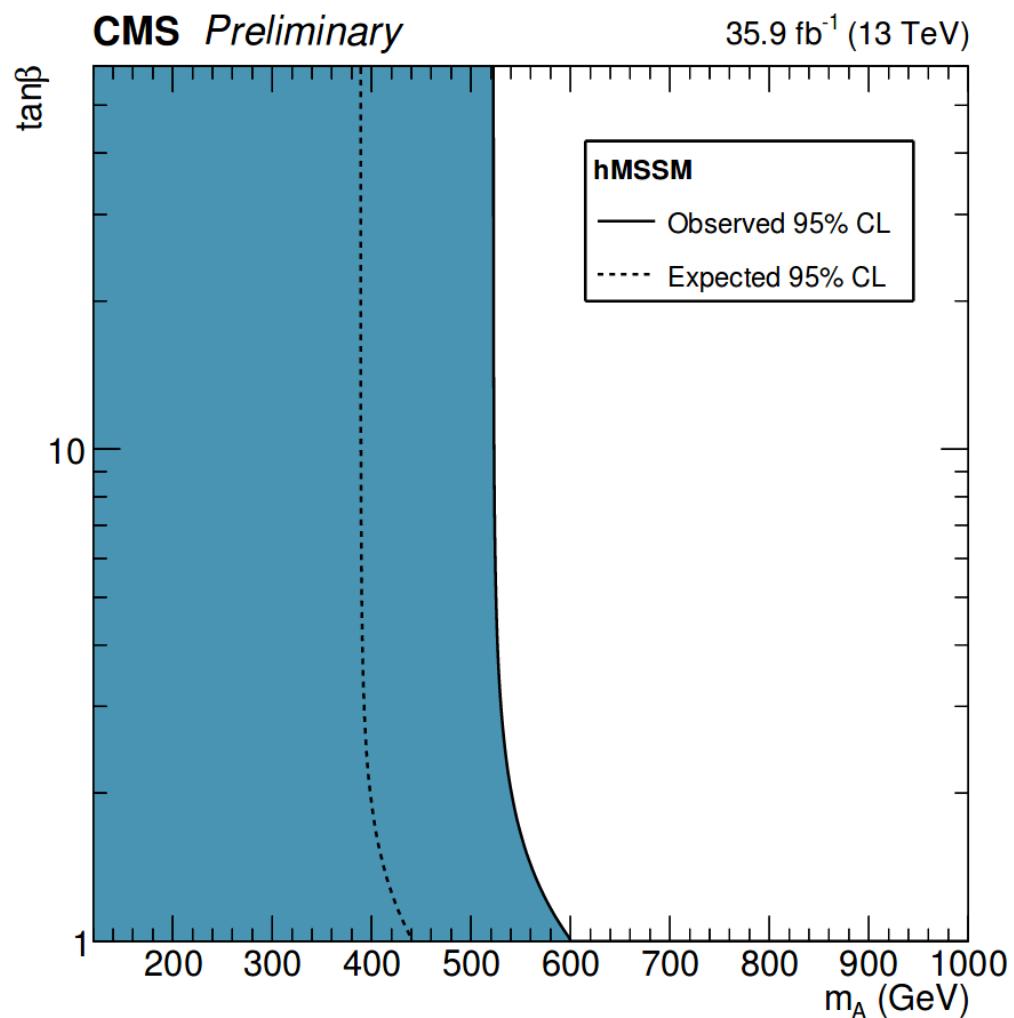
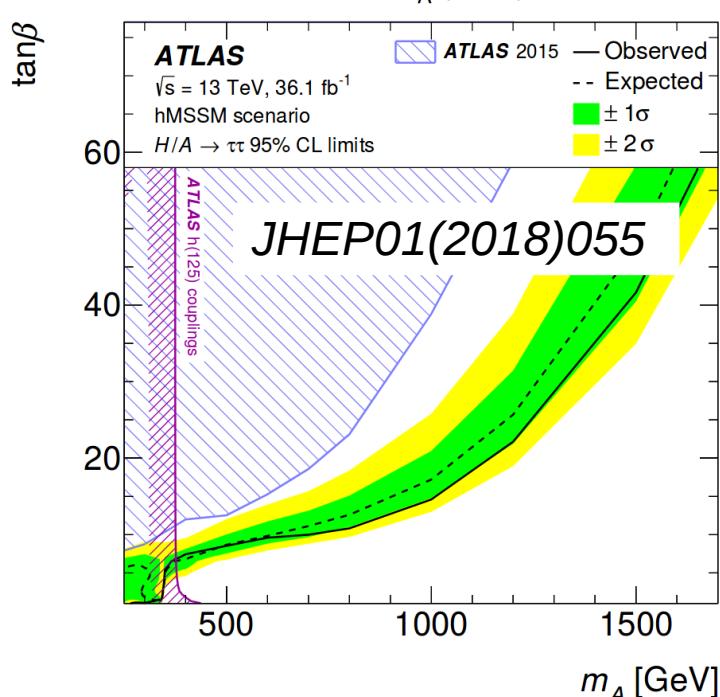
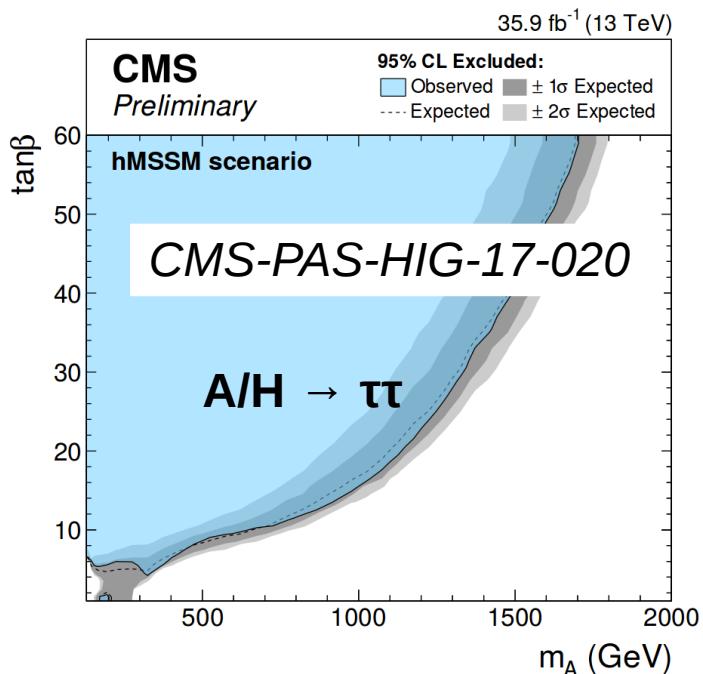
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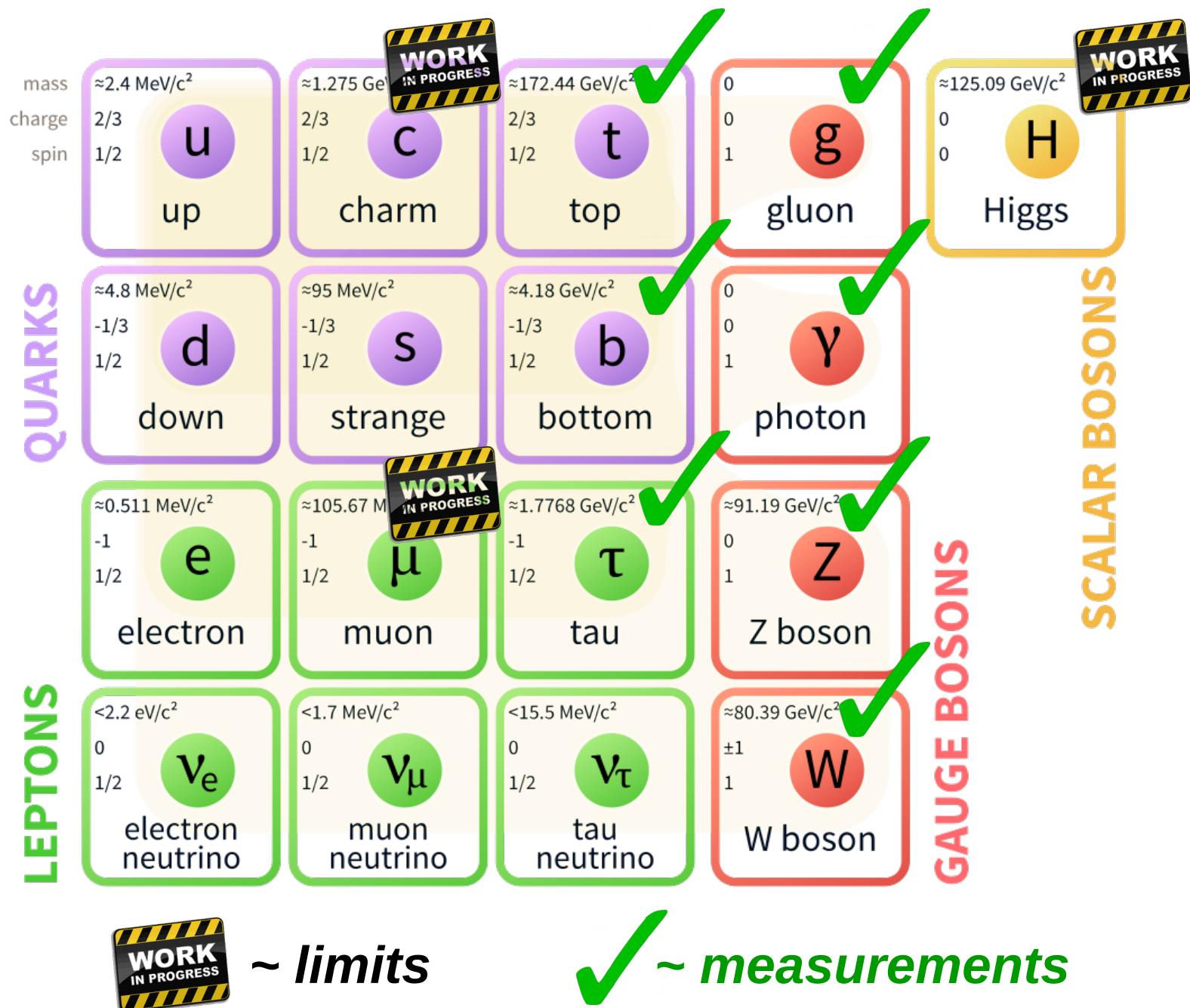


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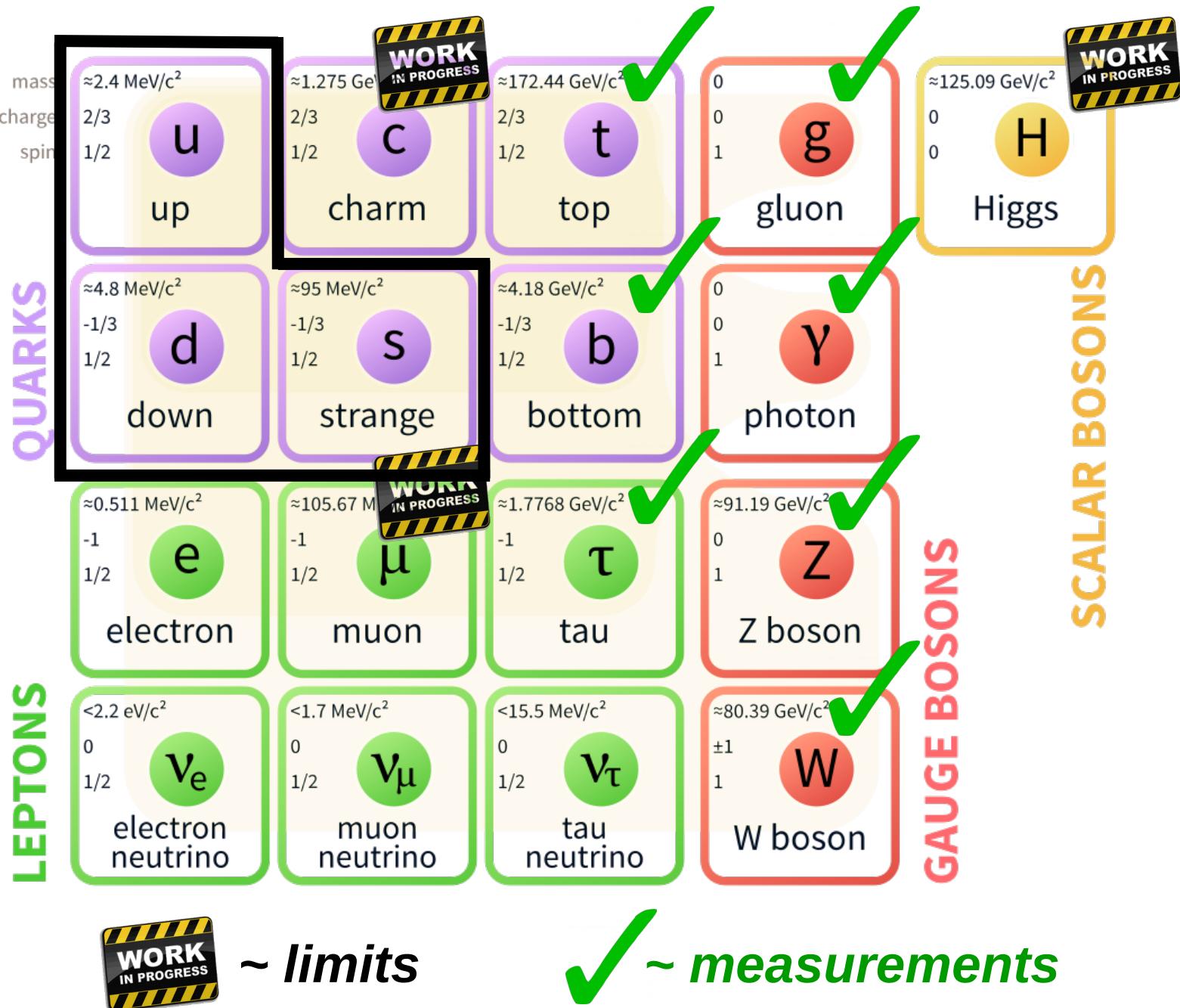


Higgs Couplings



Higgs Couplings

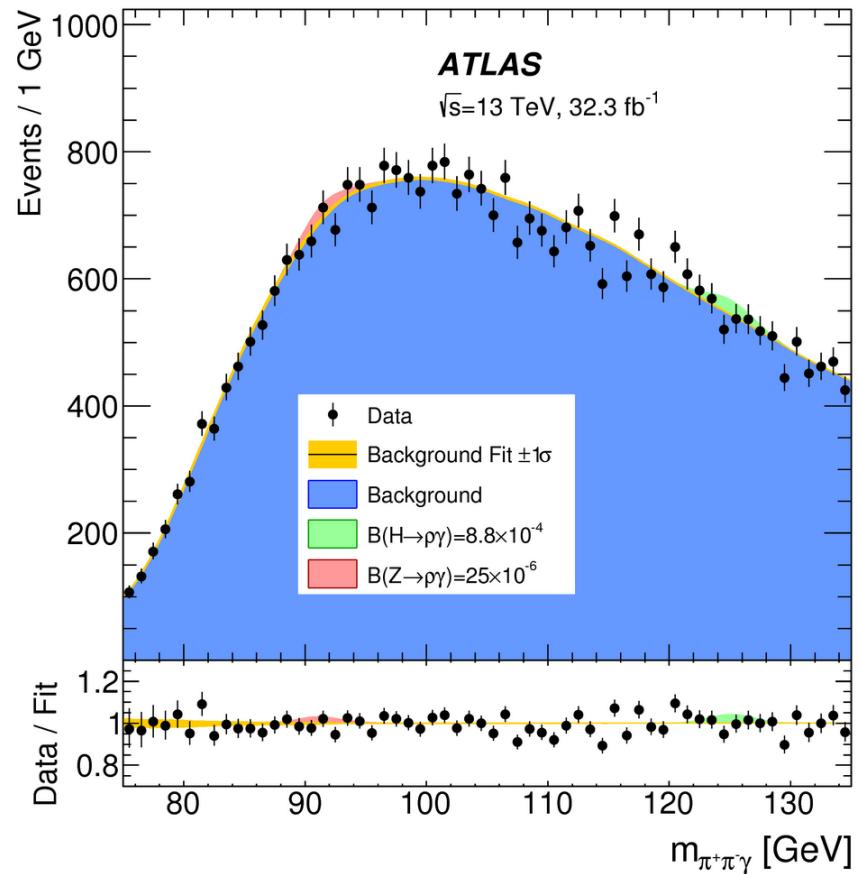
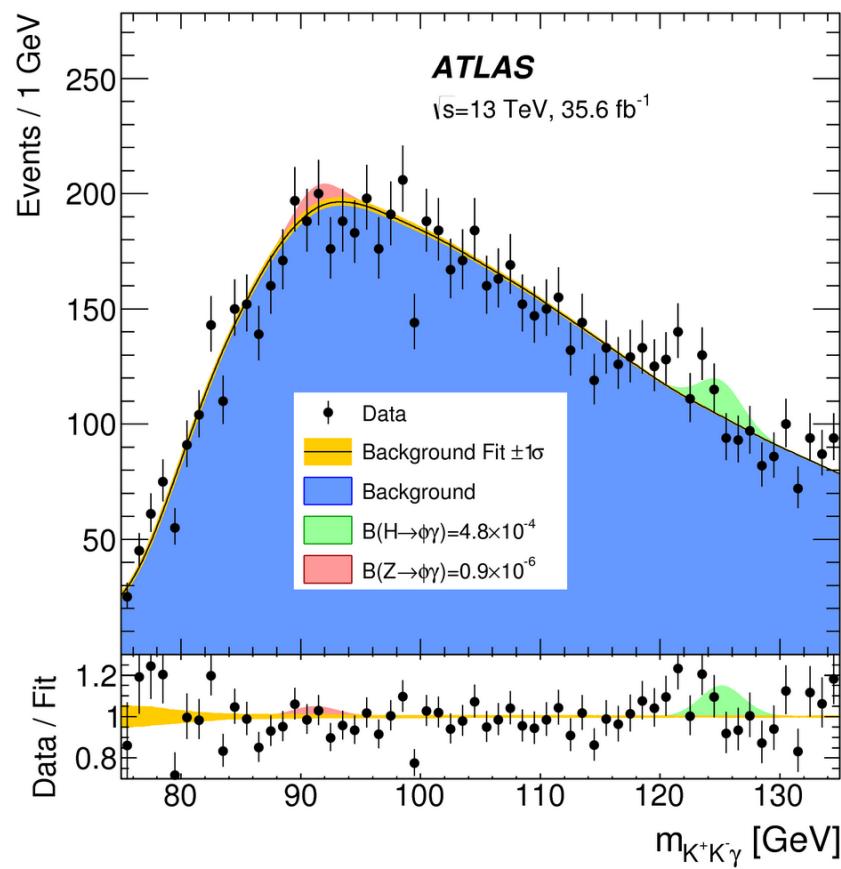
?



ATLAS search for $H \rightarrow \phi\gamma, \rho\gamma$

arXiv:1712.02758

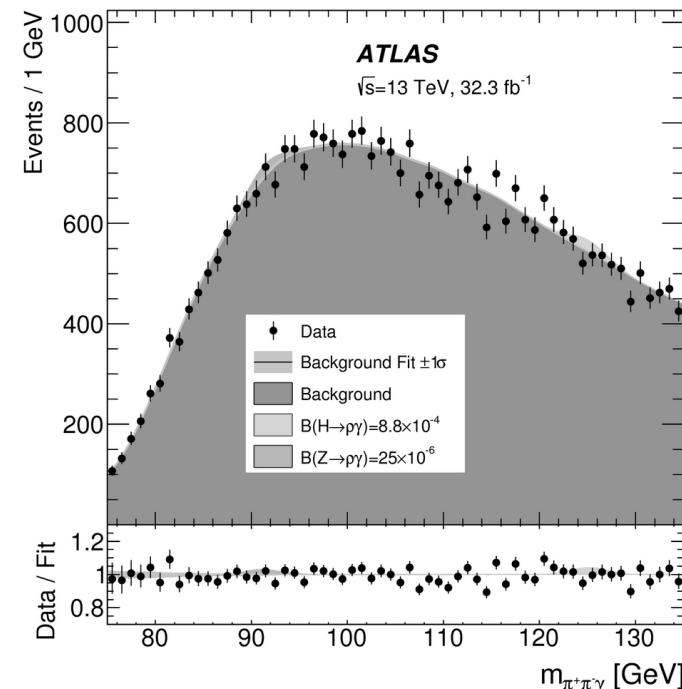
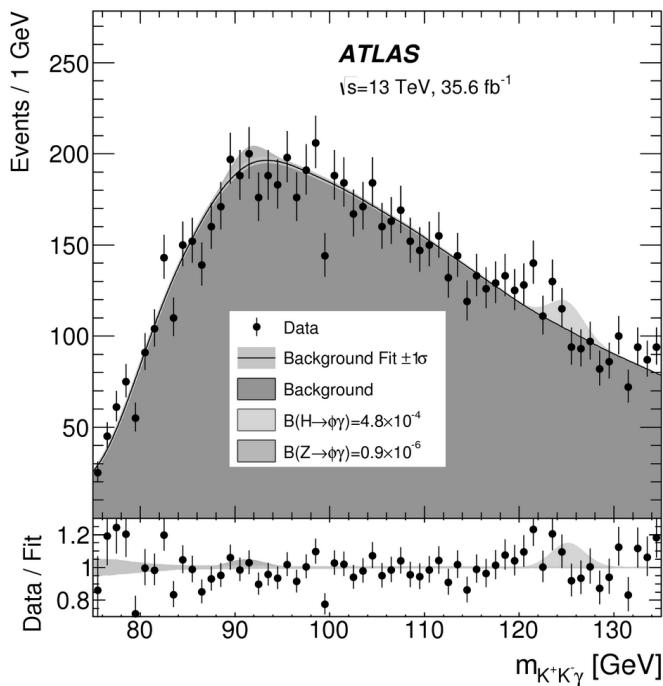
- Look for deviations from SM to constrain light quark couplings
- Search for a resonance in the $K^+K^-\gamma$ and $\pi^+\pi^-\gamma$ mass distribution



ATLAS search for $H \rightarrow \phi\gamma, \rho\gamma$

arXiv:1712.02758

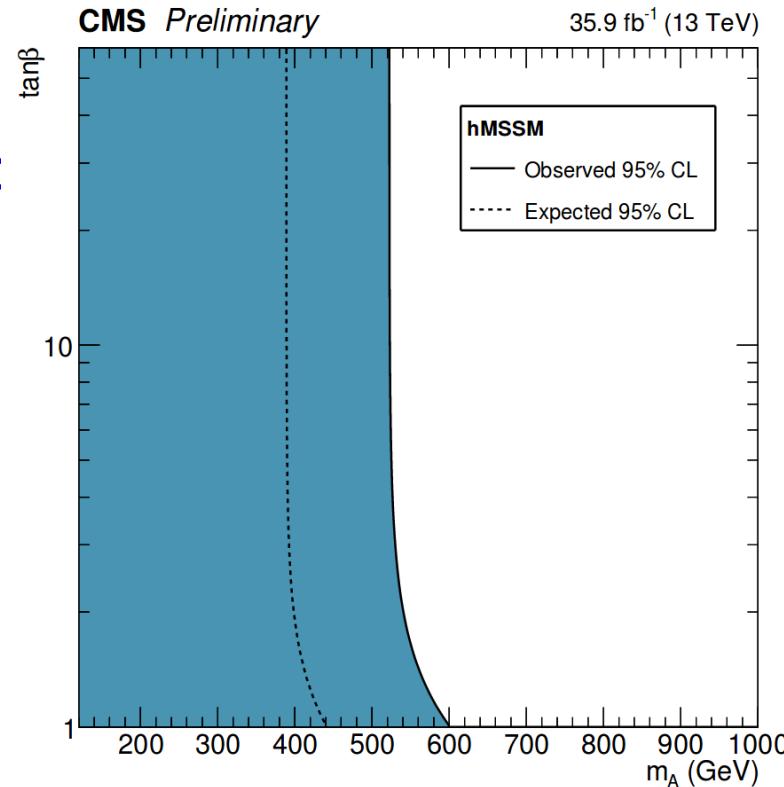
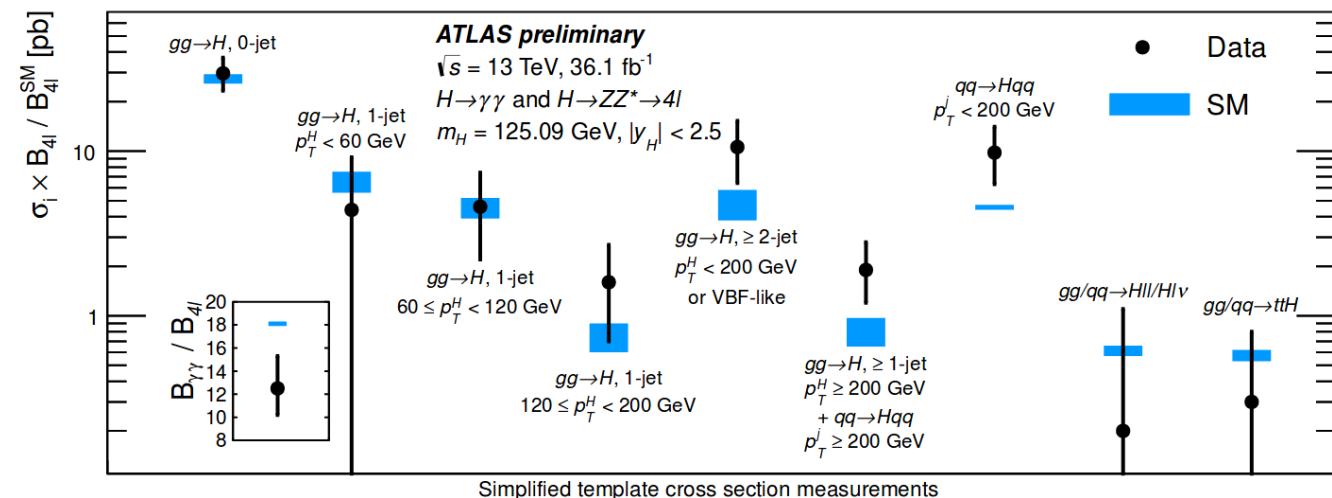
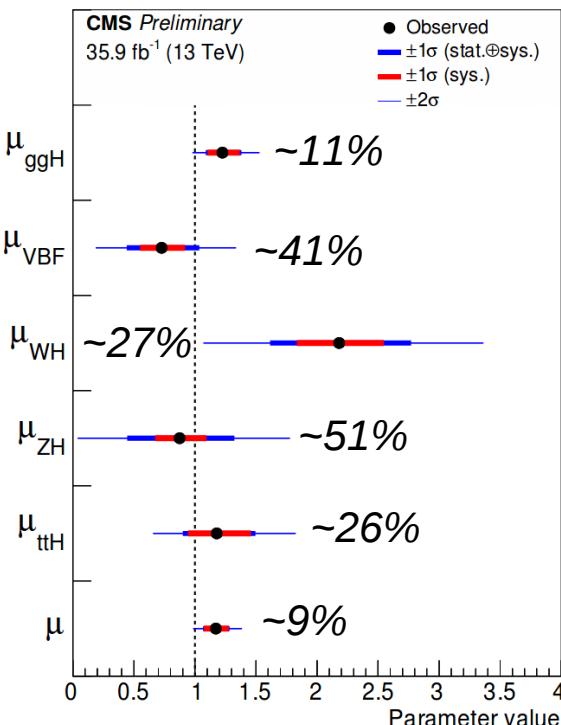
- Decay proceeds directly and indirectly, look deviations from SM
- Search for a resonance in the $K^+K^-\gamma$ and $\pi^+\pi^-\gamma$ mass distribution



Branching Fraction Limit (95% CL)	Expected	Observed
$\mathcal{B}(H \rightarrow \phi\gamma) [10^{-4}]$	$4.2^{+1.8}_{-1.2}$	4.8 $\sim 208x$ SM
$\mathcal{B}(Z \rightarrow \phi\gamma) [10^{-6}]$	$1.3^{+0.6}_{-0.4}$	0.9 $\sim 87x$ SM
$\mathcal{B}(H \rightarrow \rho\gamma) [10^{-4}]$	$8.4^{+4.1}_{-2.4}$	8.8 $\sim 52x$ SM
$\mathcal{B}(Z \rightarrow \rho\gamma) [10^{-6}]$	33^{+13}_{-9}	25 $\sim 597x$ SM

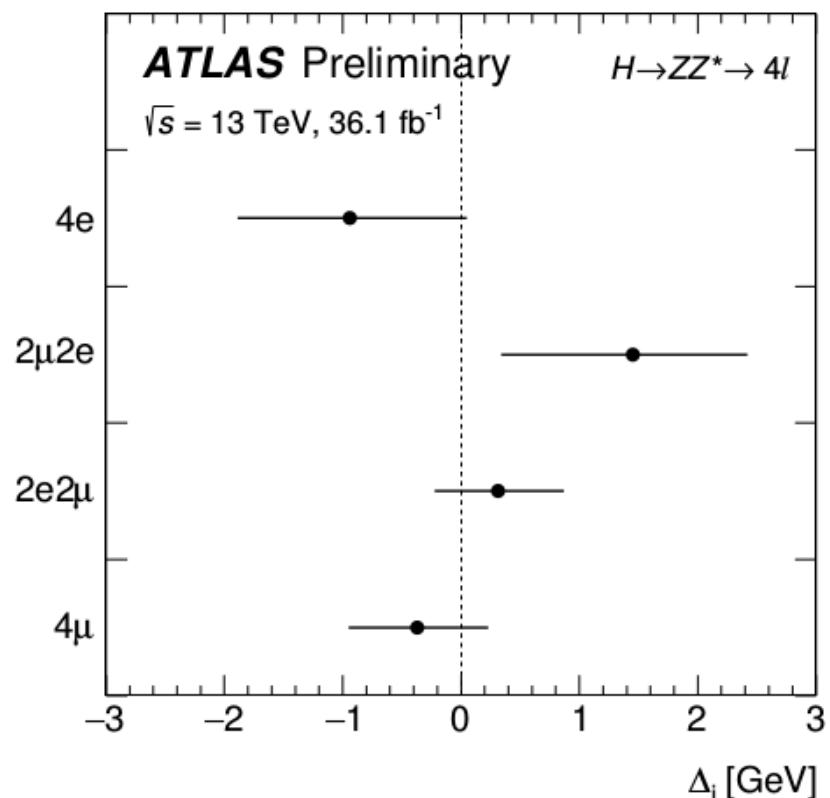
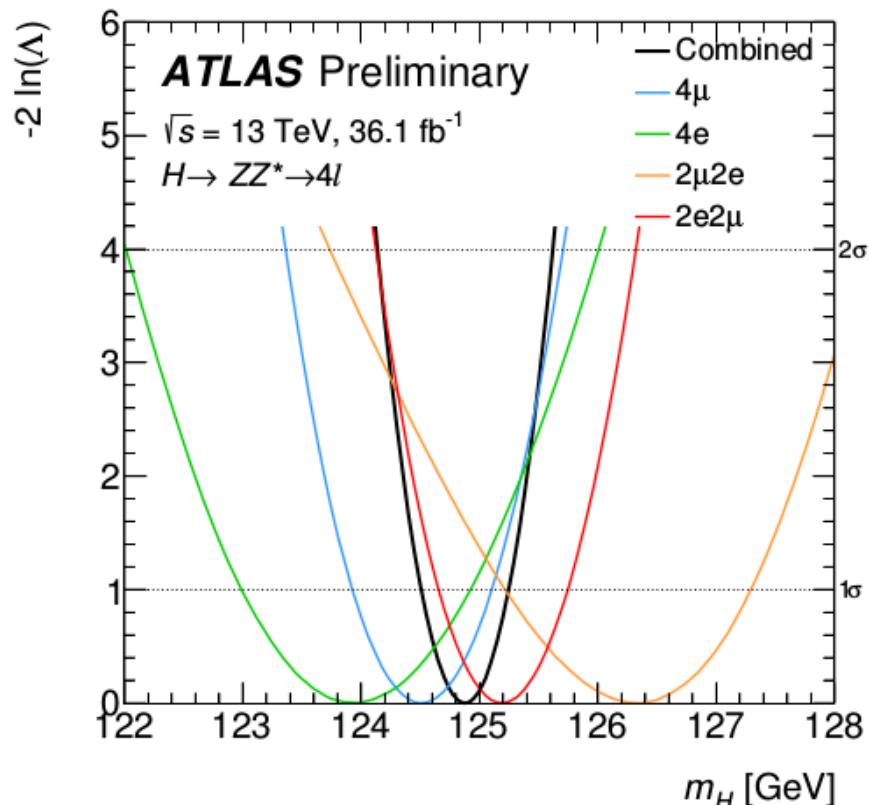
Summary

- Precision Higgs measurements are truly starting to put the SM (and BSM) to the test
- First combined 13 TeV results shown, surpassing Run 1 precision in key measurements, e.g. ggH
- With more data, should be able to see the deviations predicted by many BSM models



Backup

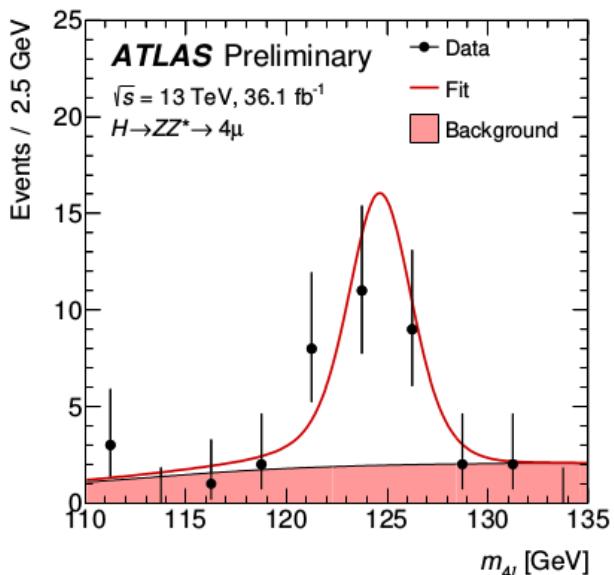
ATLAS m(H) measurement



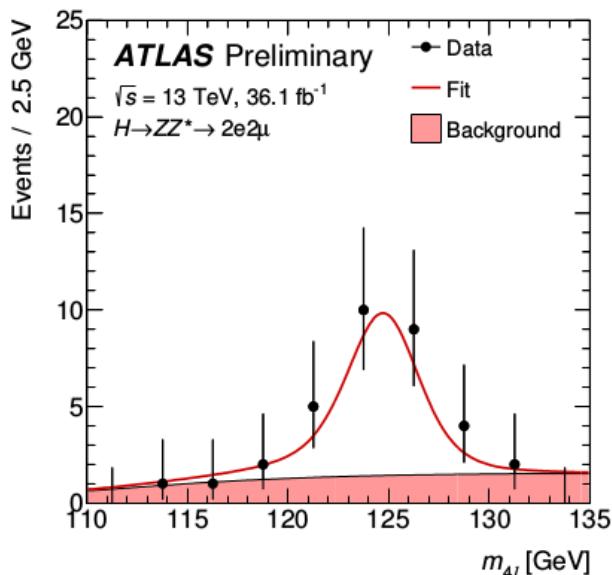
Category	m_Z in simulation [GeV]	m_Z in data [GeV]
4 μ	$91.19^{+0.41}_{-0.41}$	$91.46^{+0.42}_{-0.41}$
4e	$91.19^{+1.02}_{-1.03}$	$91.75^{+1.08}_{-1.06}$
2 μ 2e	$91.18^{+1.11}_{-1.11}$	$91.31^{+1.62}_{-1.33}$
2e2 μ	$91.19^{+0.90}_{-0.90}$	$92.49^{+0.91}_{-0.94}$
Combined	$91.19^{+0.34}_{-0.34}$	$91.62^{+0.35}_{-0.35}$

Systematic effect	Uncertainty on $m_H^{ZZ^*}$ [MeV]
Muon momentum scale	40
Electron energy scale	20
Background modelling	10
Simulation statistics	8

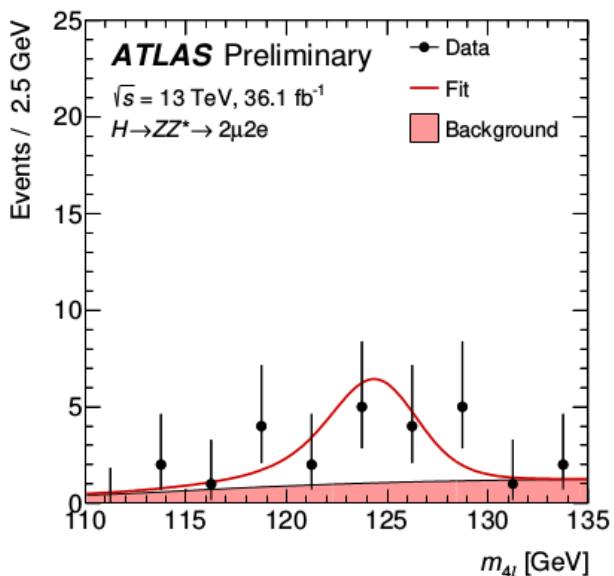
ATLAS m(H) measurement



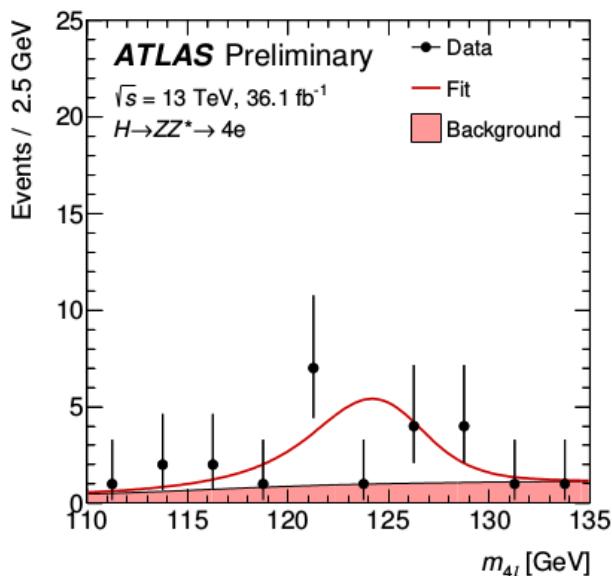
(a)



(b)

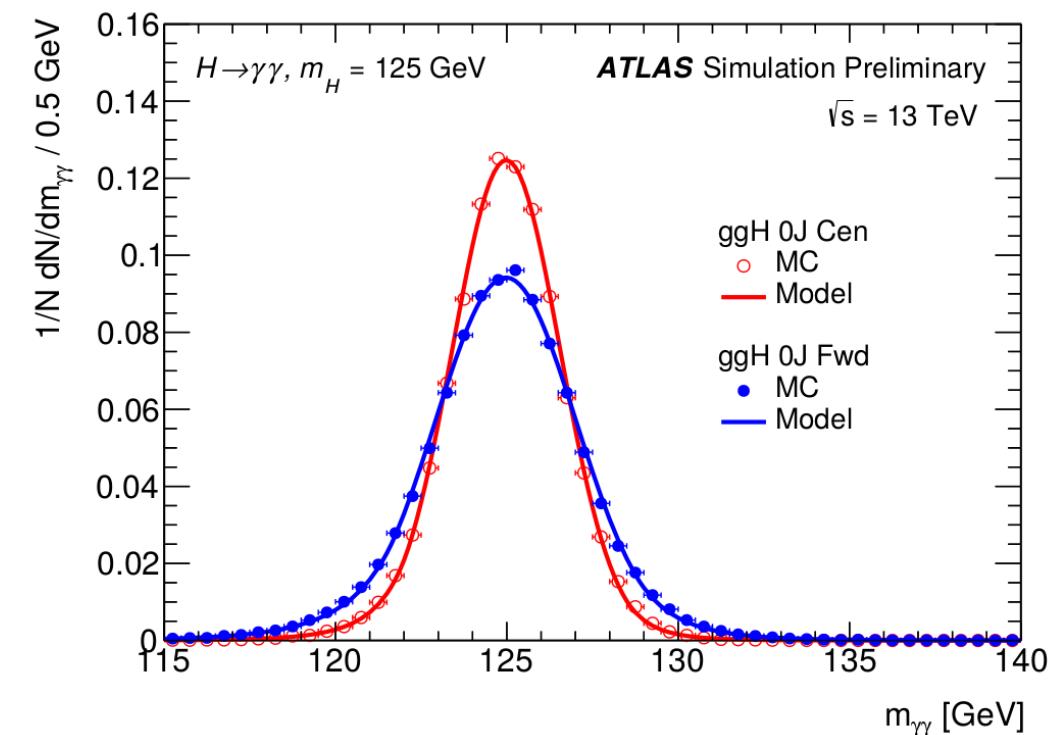


(c)



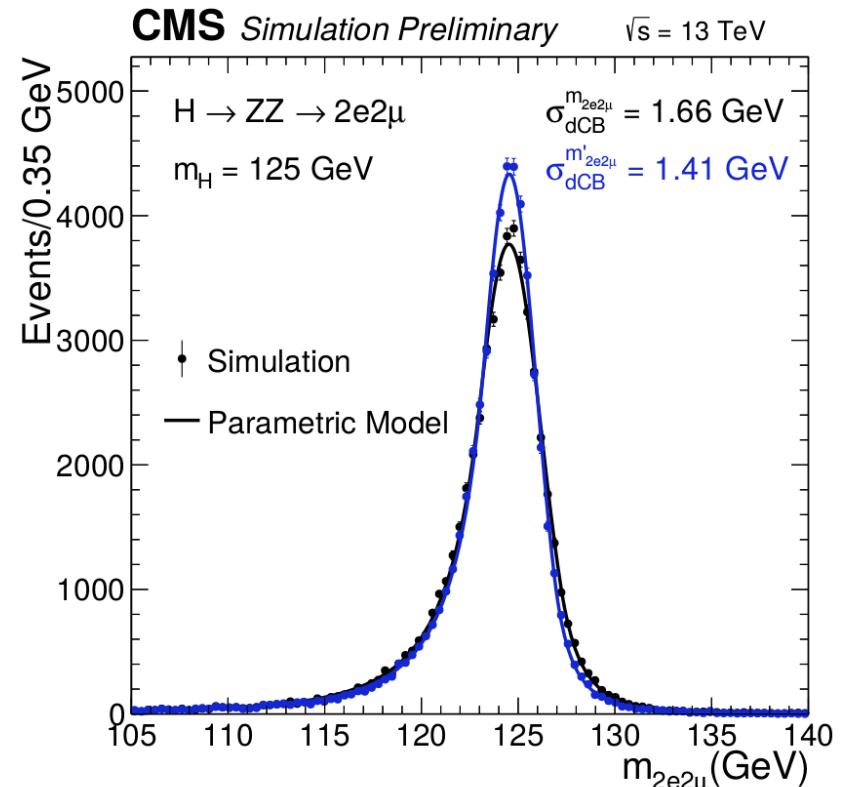
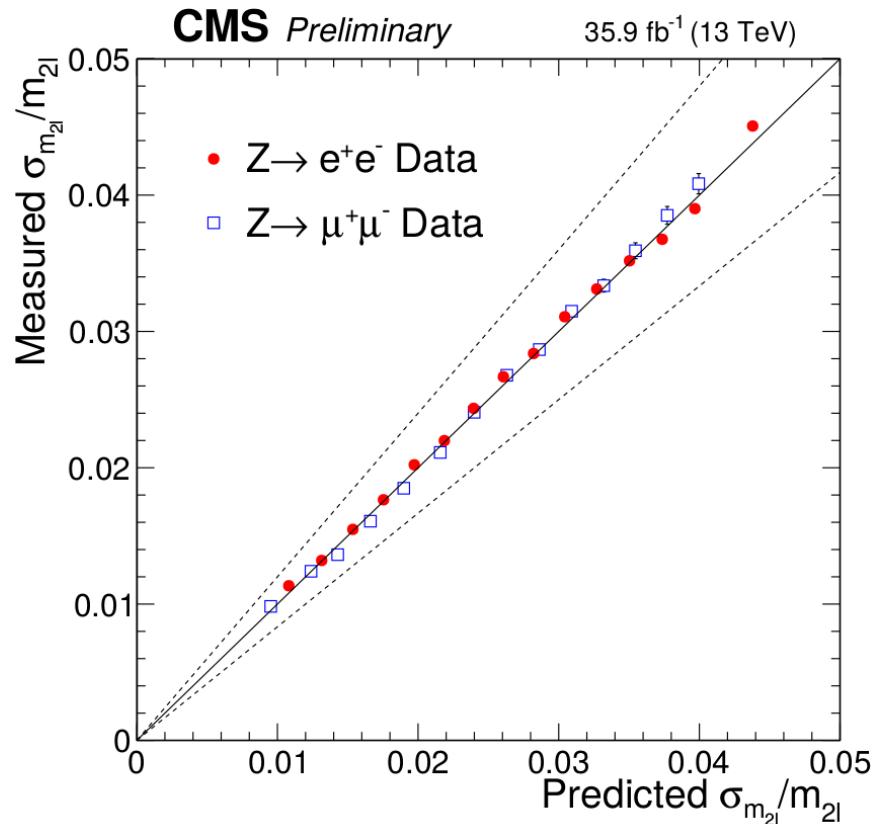
(d)

ATLAS m(H) measurement



Source	Systematic uncertainty on $m_H^{\gamma\gamma}$ [MeV]
LAr cell non-linearity	± 200
LAr layer calibration	± 190
Non-ID material	± 120
Lateral shower shape	± 110
ID material	± 110
Conversion reconstruction	± 50
$Z \rightarrow ee$ calibration	± 50
Background model	± 50
Primary vertex effect on mass scale	± 40
Resolution	$^{+20}_{-30}$
Signal model	± 20

CMS m(H) measurement



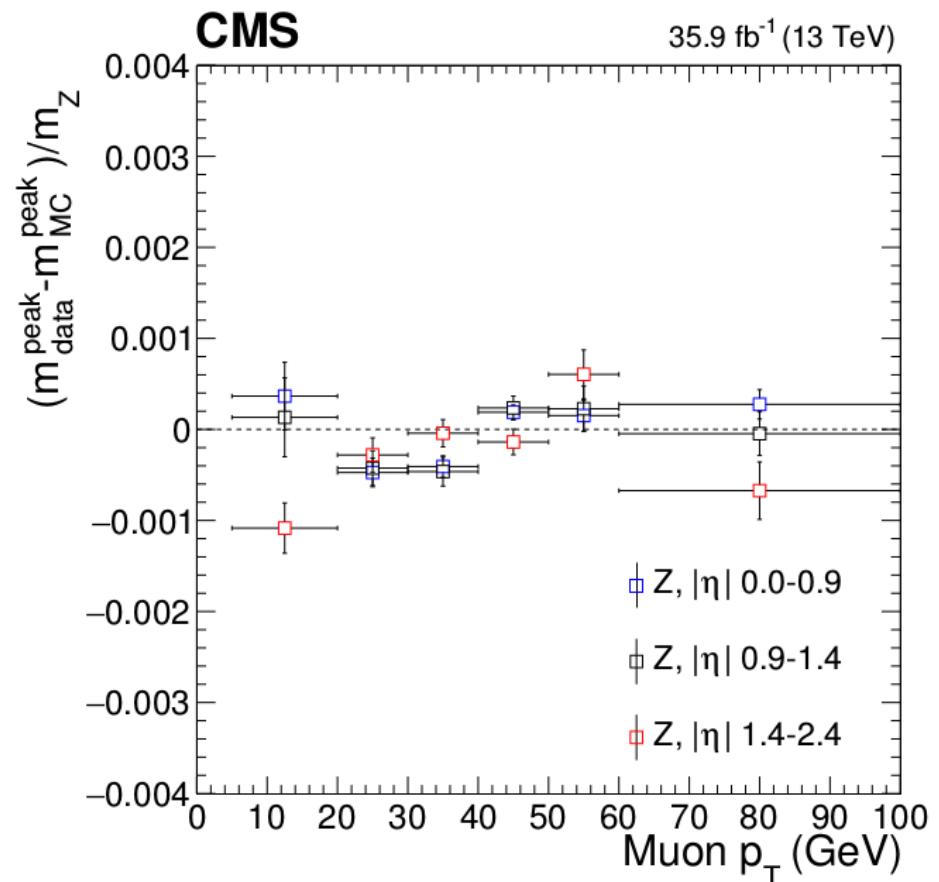
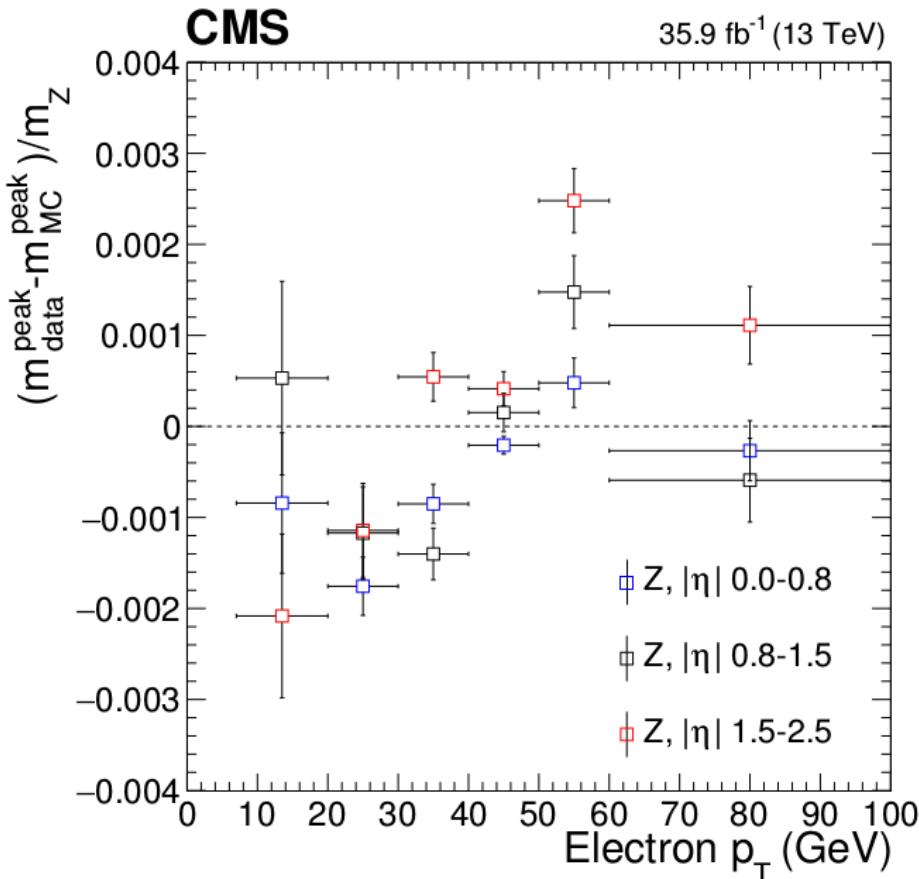
$$m_Z^{4\mu} = 90.85 \pm 0.27 \text{ (stat)} \pm 0.04 \text{ (syst)} \text{ GeV}$$

$$m_Z^{4e} = 90.85 \pm 0.74 \text{ (stat)} \pm 0.28 \text{ (syst)} \text{ GeV}$$

$$m_Z^{2e2\mu} = 90.61 \pm 0.48 \text{ (stat)} \pm 0.10 \text{ (syst)} \text{ GeV}$$

$$m_Z = 90.84 \pm 0.23 \text{ (stat)} \pm 0.07 \text{ (syst)} \text{ GeV}$$

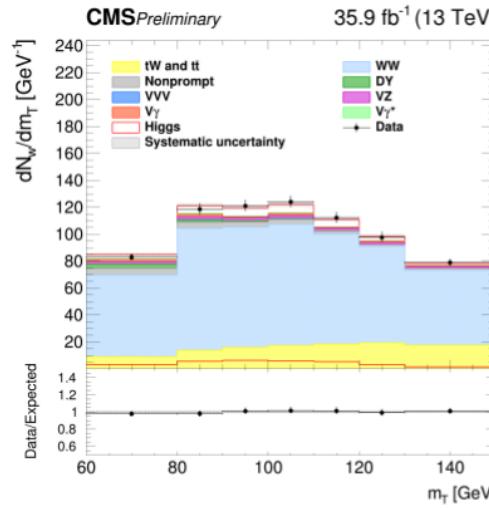
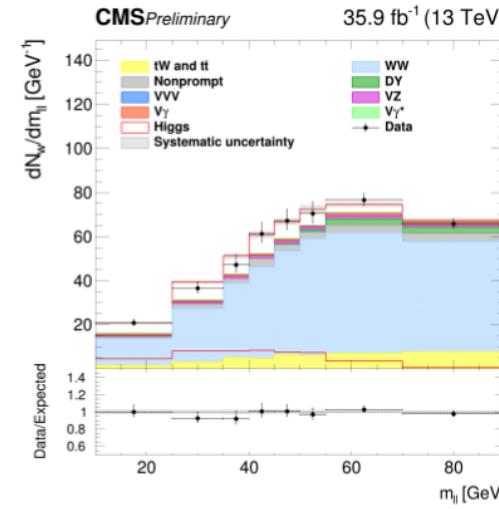
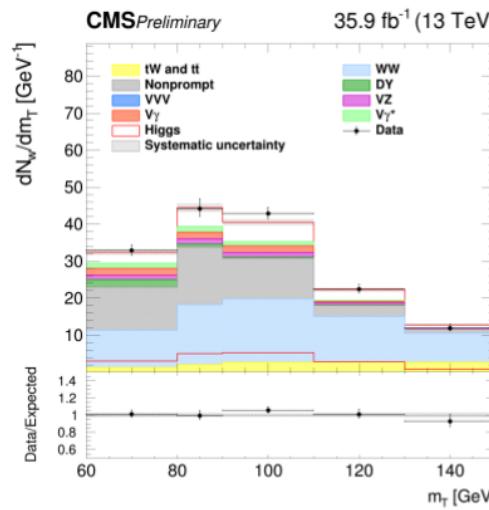
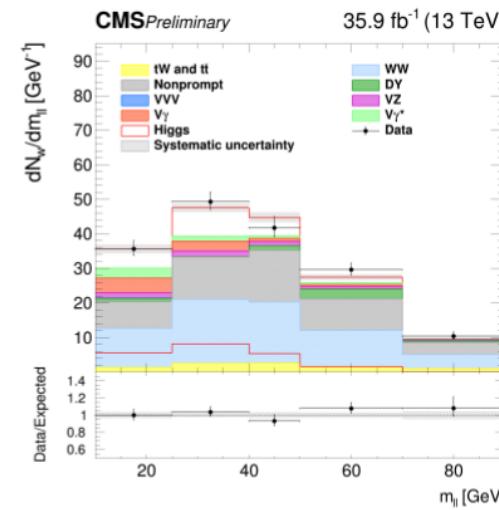
CMS m(H) measurement



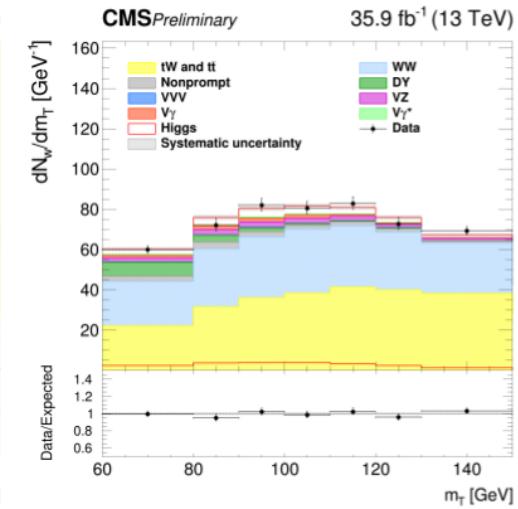
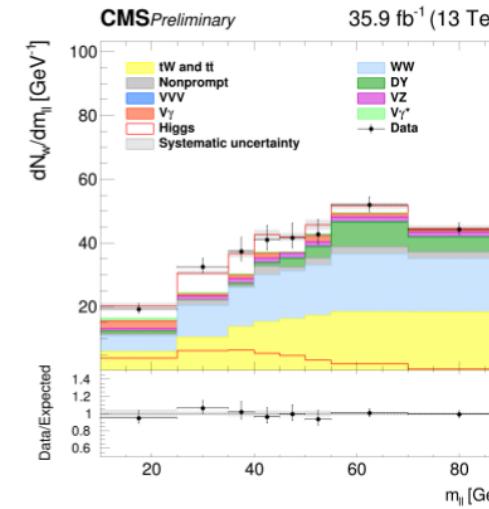
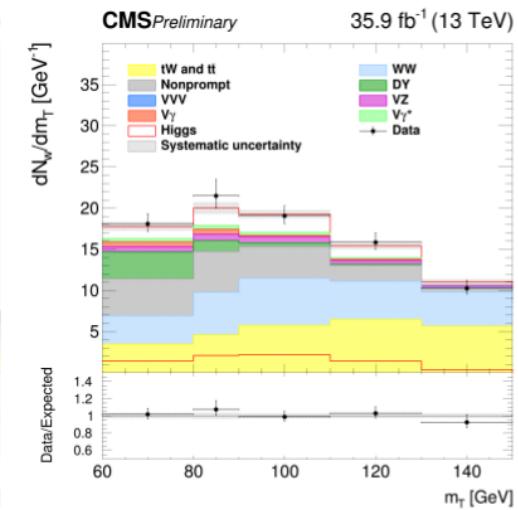
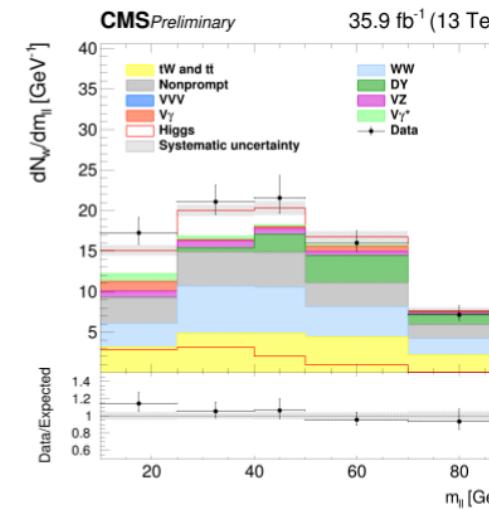
Category	Subcategory	Requirements
preselection	-	$m_{\ell\ell} > 12 \text{ GeV}$, $p_{\text{T}1} > 25 \text{ GeV}$, $p_{\text{T}2} > 10(13) \text{ GeV}$ for μ (e), $E_{\text{T}}^{\text{miss}} > 20 \text{ GeV}$, $p_{\text{T}}^{\ell\ell} > 30 \text{ GeV}$, $p_{\text{T}3} < 10 \text{ GeV}$ electron and muon with opposite charge
0-jet ggH-tagged	$e^+\mu^- p_{\text{T}2} > 20 \text{ GeV}$	$m_{\text{T}} > 60 \text{ GeV}$, $m_{\text{T}}^{\ell 2, E_{\text{T}}^{\text{miss}}} > 30 \text{ GeV}$ subleading lepton $p_{\text{T}} > 20 \text{ GeV}$ no jets with $p_{\text{T}} > 30 \text{ GeV}$
	$e^-\mu^+ p_{\text{T}2} > 20 \text{ GeV}$	no b-tagged jets with p_{T} between 20 and 30 GeV
	$\mu^+e^- p_{\text{T}2} > 20 \text{ GeV}$	
	$\mu^-e^+ p_{\text{T}2} > 20 \text{ GeV}$	
	$e^+\mu^- p_{\text{T}2} < 20 \text{ GeV}$	$m_{\text{T}} > 60 \text{ GeV}$, $m_{\text{T}}^{\ell 2, E_{\text{T}}^{\text{miss}}} > 30 \text{ GeV}$ subleading lepton $p_{\text{T}} < 20 \text{ GeV}$ no jets with $p_{\text{T}} > 30 \text{ GeV}$
	$e^-\mu^+ p_{\text{T}2} < 20 \text{ GeV}$	no b-tagged jets with p_{T} between 20 and 30 GeV
	$\mu^+e^- p_{\text{T}2} < 20 \text{ GeV}$	
	$\mu^-e^+ p_{\text{T}2} < 20 \text{ GeV}$	
1-jet ggH-tagged	$e^+\mu^- p_{\text{T}2} > 20 \text{ GeV}$	$m_{\text{T}} > 60 \text{ GeV}$, $m_{\text{T}}^{\ell 2, E_{\text{T}}^{\text{miss}}} > 30 \text{ GeV}$ subleading lepton $p_{\text{T}} > 20 \text{ GeV}$ exactly one jet with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$
	$e^-\mu^+ p_{\text{T}2} > 20 \text{ GeV}$	
	$\mu^+e^- p_{\text{T}2} > 20 \text{ GeV}$	
	$\mu^-e^+ p_{\text{T}2} > 20 \text{ GeV}$	
	$e^+\mu^- p_{\text{T}2} < 20 \text{ GeV}$	$m_{\text{T}} > 60 \text{ GeV}$, $m_{\text{T}}^{\ell 2, E_{\text{T}}^{\text{miss}}} > 30 \text{ GeV}$ subleading lepton $p_{\text{T}} < 20 \text{ GeV}$ exactly one jet with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$
	$e^-\mu^+ p_{\text{T}2} < 20 \text{ GeV}$	
	$\mu^+e^- p_{\text{T}2} < 20 \text{ GeV}$	
	$\mu^-e^+ p_{\text{T}2} < 20 \text{ GeV}$	
2-jet ggH-tagged	$e\mu$	at least two jets with $p_{\text{T}} > 30 \text{ GeV}$ $m_{\text{T}}^{\ell 2, E_{\text{T}}^{\text{miss}}} > 30 \text{ GeV}$ and $m_{\text{T}} > 60 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$ $m_{jj} < 65 \text{ GeV}$ or $105 \text{ GeV} < m_{jj} < 400 \text{ GeV}$

CMS H \rightarrow WW

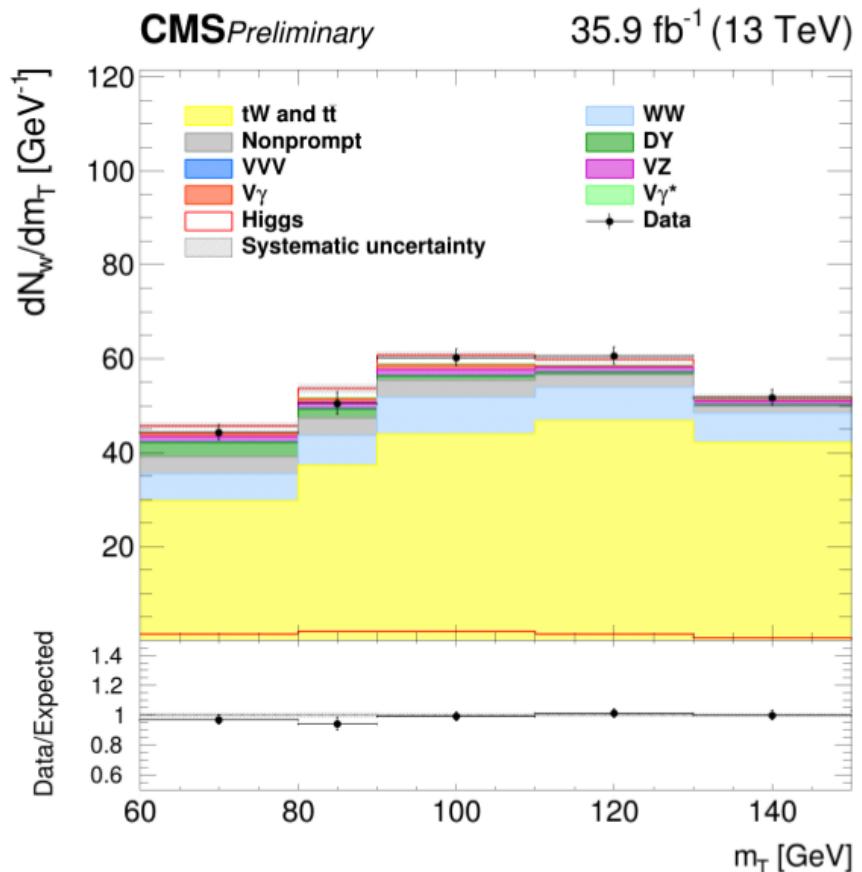
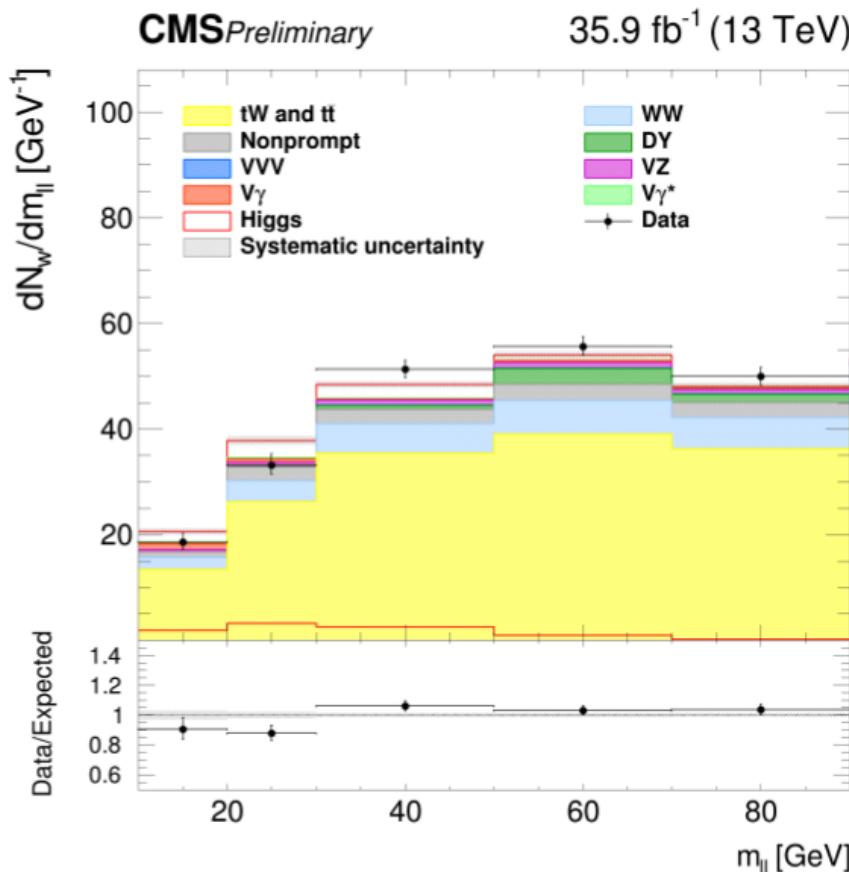
$e\mu$ 0-jet ggH tagged



$e\mu$ 1-jet ggH tagged

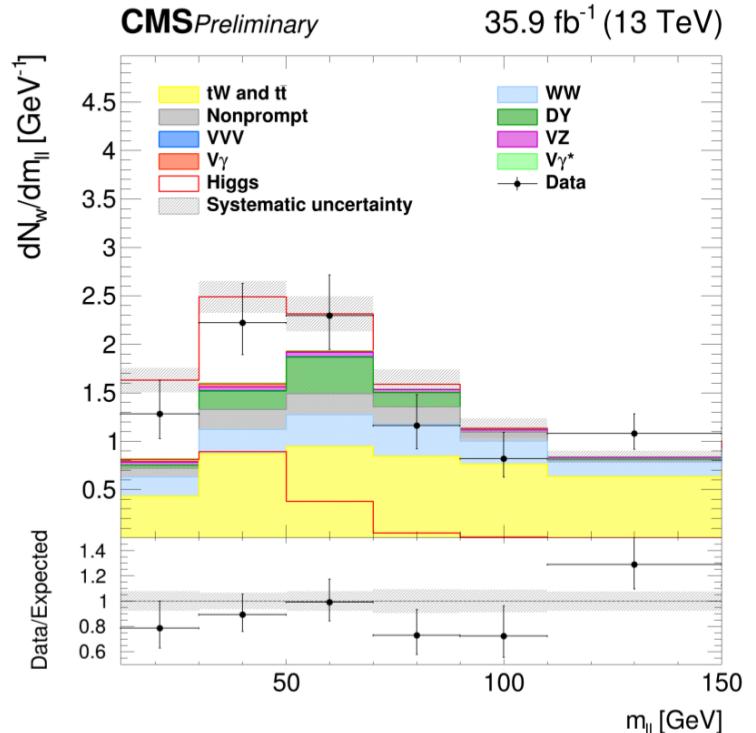


$e\mu$ 2-jet ggH tagged



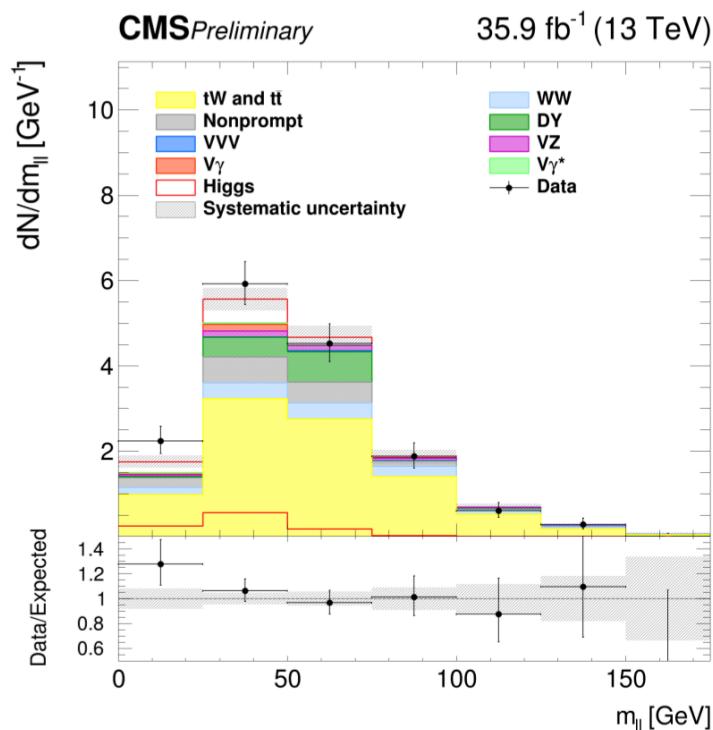
$e\mu$ 2-jet VBF tagged

Category	Subcategory	Requirements
preselection	-	$m_{\ell\ell} > 12 \text{ GeV}$, $p_{T1} > 25 \text{ GeV}$, $p_{T2} > 10(13) \text{ GeV}$ for $\mu(e)$, $E_T^{\text{miss}} > 20 \text{ GeV}$, $p_T^{\ell\ell} > 30 \text{ GeV}$, $p_{T3} < 10 \text{ GeV}$ electron and muon with opposite charge
2-jet VBF-tagged	$e\mu$ low m_{jj}	exactly two jets with $p_T > 30 \text{ GeV}$ $60 \text{ GeV} < m_T < 125 \text{ GeV}$ leptons η between the two leading jets $400 \text{ GeV} < m_{jj} < 700 \text{ GeV}$ and $ \Delta\eta_{jj} > 3.5$ no b-tagged jets with $p_T > 20 \text{ GeV}$
	$e\mu$ high m_{jj}	exactly two jets with $p_T > 30 \text{ GeV}$ $60 \text{ GeV} < m_T < 125 \text{ GeV}$ leptons η between the two leading jets $m_{jj} > 700 \text{ GeV}$ and $ \Delta\eta_{jj} > 3.5$ no b-tagged jets with $p_T > 20 \text{ GeV}$



$e\mu$ 2-jet VH tagged

Category	Subcategory	Requirements
preselection	-	$m_{\ell\ell} > 12 \text{ GeV}$, $p_{T1} > 25 \text{ GeV}$, $p_{T2} > 10(13) \text{ GeV}$ for $\mu(e)$, $E_T^{\text{miss}} > 20 \text{ GeV}$, $p_T^{\ell\ell} > 30 \text{ GeV}$, $p_{T3} < 10 \text{ GeV}$ electron and muon with opposite charge
2-jet VH-tagged	$e\mu$	at least two jets with $p_T > 30 \text{ GeV}$ two leading jets with $ \eta < 2.5$ $60 \text{ GeV} < m_T < 125 \text{ GeV}$ and $\Delta R_{\ell\ell} < 2$ no b-tagged jets with $p_T > 20 \text{ GeV}$ $65 \text{ GeV} < m_{jj} < 105 \text{ GeV}$ and $ \Delta\eta_{jj} < 3.5$



Same flavor categories

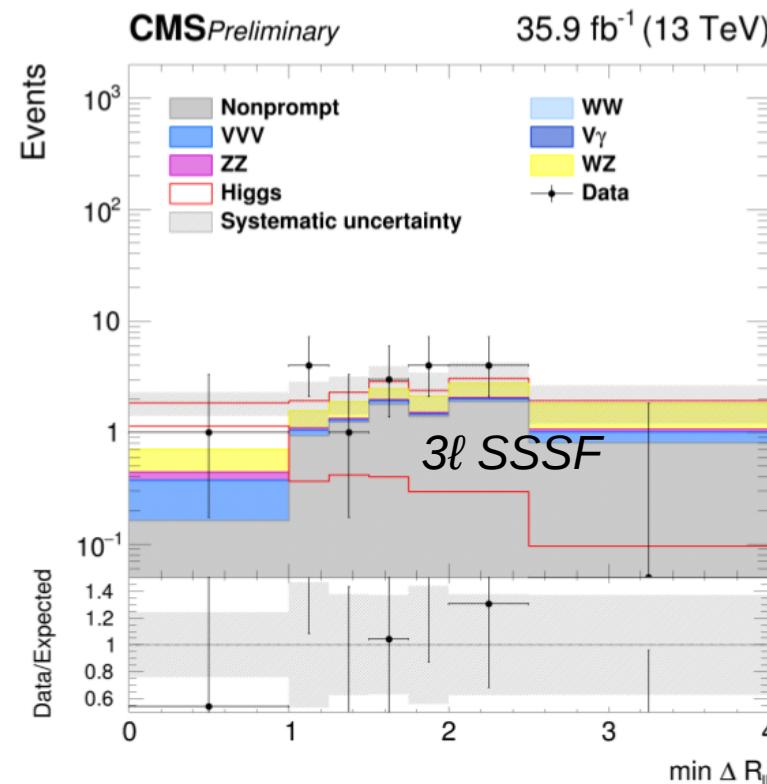
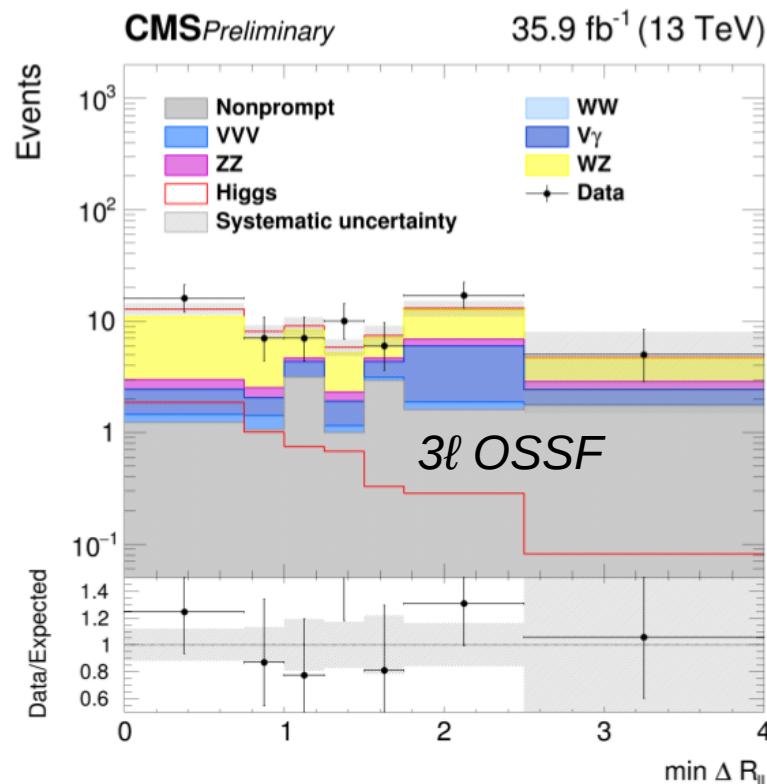
Category	Subcategory	Requirements
preselection	-	$m_{\ell\ell} > 12 \text{ GeV}$, $p_{\text{T}1} > 20(25) \text{ GeV}$ for μ (e), $p_{\text{T}2} > 10(13) \text{ GeV}$ for $\mu(e)$, track $E_{\text{T}}^{\text{miss}} > 20 \text{ GeV}$, $p_{\text{T}}^{\ell\ell} > 30 \text{ GeV}$, $p_{\text{T}3} < 10 \text{ GeV}$ two electrons or two muons with opposite charge
0-jet ggH-tagged	$e^+e^- p_{\text{T}2} < 20 \text{ GeV}$ $\mu^+\mu^- p_{\text{T}2} < 20 \text{ GeV}$	DYMVA > 0.991 , $m_{\ell\ell} < 55 \text{ GeV}$, $m_{\text{T}} > 50 \text{ GeV}$, $p_{\text{T}2} < 20 \text{ GeV}$, $\Delta\phi_{\ell\ell} < 1.7$ no jets with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$
	$e^+e^- p_{\text{T}2} \geq 20 \text{ GeV}$ $\mu^+\mu^- p_{\text{T}2} \geq 20 \text{ GeV}$	DYMVA > 0.991 , $m_{\ell\ell} < 55 \text{ GeV}$, $m_{\text{T}} > 50 \text{ GeV}$, $20 \text{ GeV} < p_{\text{T}2} < 50 \text{ GeV}$, $\Delta\phi_{\ell\ell} < 1.7$ no jets with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$
1-jet ggH-tagged	e^+e^- $\mu^+\mu^-$	DYMVA > 0.95 , $m_{\ell\ell} < 57 \text{ GeV}$, $50 < m_{\text{T}} < 155 \text{ GeV}$, $p_{\text{T}1} < 50 \text{ GeV}$, $\Delta\phi_{\ell\ell} < 1.75$ exactly one jet with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$

3 ℓ categories

Category	Subcategory	Requirements
preselection	-	$\min-m_{\ell^+\ell^-} > 12 \text{ GeV}$, $p_{\text{T}1} > 25 \text{ GeV}$, $p_{\text{T}2} > 20 \text{ GeV}$, $p_{\text{T}3} > 15 \text{ GeV}$, $p_{\text{T}4} < 10 \text{ GeV}$, total lepton charge sum ± 1
3-lepton WH-tagged	OSSF	no jets with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$ $E_{\text{T}}^{\text{miss}} > 50 \text{ GeV}$, $\min-m_{\ell^+\ell^-} < 100 \text{ GeV}$ Z-veto $ m_{\ell\ell} - m_Z > 25 \text{ GeV}$ $\Delta\phi(\ell\ell\ell, E_{\text{T}}^{\text{miss}}) > 2.2$
		no jets with $p_{\text{T}} > 30 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$ $\Delta\phi(\ell\ell\ell, E_{\text{T}}^{\text{miss}}) > 2.5$
	SSSF	

4 ℓ categories

Category	Subcategory	Requirements
preselection	-	four tight and isolated leptons, with zero total charge $p_{\text{T}} > 25 \text{ GeV}$ for the leading lepton $p_{\text{T}} > 15 \text{ GeV}$ for the second leading lepton $p_{\text{T}} > 10 \text{ GeV}$ for the remaining two leptons additional leptons veto Z_0 dilepton mass larger than 4 GeV X dilepton mass larger than 4 GeV
4-lepton ZH-tagged	XSF	$ m_{\ell\ell} - m_{Z_0} < 15 \text{ GeV}$ $10 \text{ GeV} < m_X < 50 \text{ GeV}$ $35 \text{ GeV} < E_{\text{T}}^{\text{miss}} < 100 \text{ GeV}$ four lepton invariant mass larger than 140 GeV
	XDF	$ m_{\ell\ell} - m_{Z_0} < 15 \text{ GeV}$ $10 \text{ GeV} < m_X < 70 \text{ GeV}$ $E_{\text{T}}^{\text{miss}} > 20 \text{ GeV}$ no b-tagged jets with $p_{\text{T}} > 20 \text{ GeV}$



tt scale factors

Final state	Category	Scale factor
Different flavor	0-jet ggH-tagged	0.94 ± 0.05
	1-jet ggH-tagged	0.94 ± 0.03
	2-jet ggH-tagged	0.98 ± 0.02
	2-jet VH-tagged	0.98 ± 0.03
	2-jet VBF-tagged	1.01 ± 0.04
Same flavor	0-jet ggH-tagged	1.03 ± 0.06
	1-jet ggH-tagged	0.98 ± 0.02

DY → π scale factors

Final state	Category	Scale factor
Different flavor	0-jet ggH-tagged	0.94 ± 0.06
	1-jet ggH-tagged	1.02 ± 0.05
	2-jet ggH-tagged	0.99 ± 0.09
	2-jet VH-tagged	0.99 ± 0.13
	2-jet VBF-tagged	1.04 ± 0.16

WW scale factors

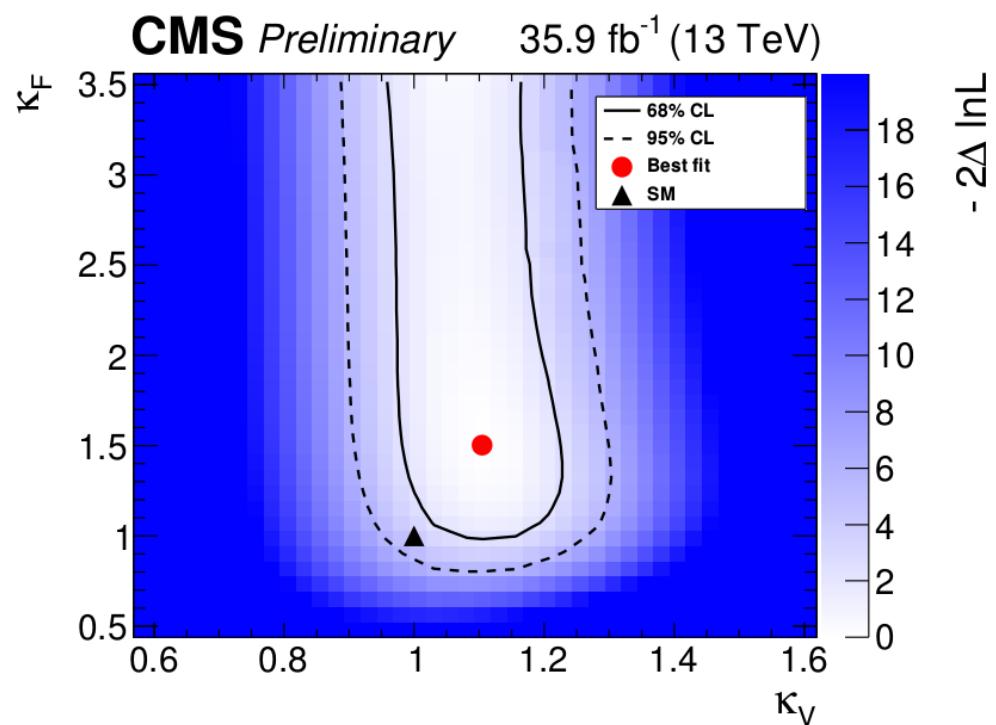
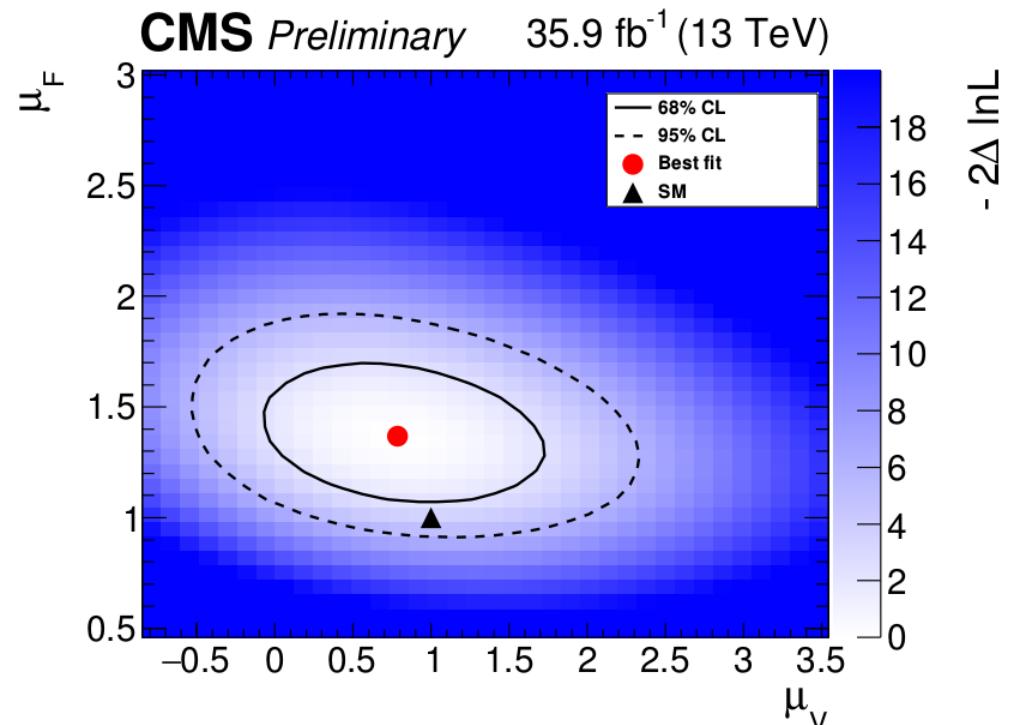
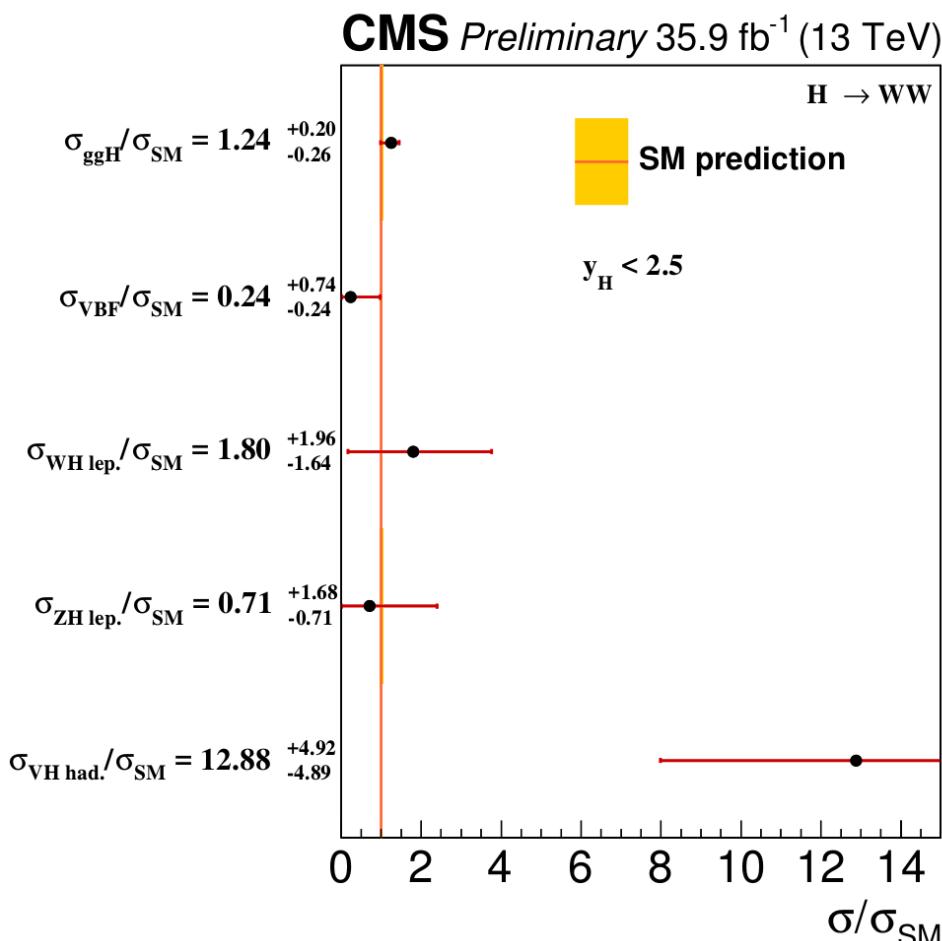
Final state	Category	Scale factor
Different flavor	0-jet ggH-tagged	1.16 ± 0.05
	1-jet ggH-tagged	1.05 ± 0.13
	2-jet ggH-tagged	0.80 ± 0.04
	2-jet VH-tagged	0.6 ± 0.6
	2-jet VBF-tagged	0.5 ± 0.5
Same flavor	0-jet ggH-tagged	1.13 ± 0.07
	1-jet ggH-tagged	1.03 ± 0.18

	Category					
	0-jet		1-jet		0-jet SF	
	ggH-tagged	ggH-tagged	ggH-tagged	ggH-tagged	ggH-tagged	ggH-tagged
ggH	483.1 (642.1)		269.1 (339.3)		231.2 (324.6)	
VBF	5.6 (7.4)		22.1 (29.4)		1.5 (2.5)	
WH	12.4 (16.4)		15.8 (20.6)		3.3 (4.3)	
ZH	5.2 (6.9)		5.0 (6.7)		2.6 (3.4)	
t̄tH	< 0.1 (< 0.1)		0.2 (0.2)		< 0.1 (< 0.1)	
b̄bH	3.4 (4.4)		1.5 (2.0)		1.7 (2.3)	
Signal	509 (677)		313 (398)		240 (337)	
± total unc.	(± 31)		(± 19)		(± 24)	
WW	7850.5 (9087.5)		3553.1 (3727.4)		1596.2 (1805.2)	
top	2505.1 (2421.5)		5394.5 (5224.2)		334.1 (339.3)	
Nonprompt	1554.6 (1006.1)		780.8 (481.8)		301.3 (259.9)	
DY	153.6 (154.3)		283.3 (301.8)		437.3 (459.2)	
VZ/V γ^*	367.9 (384.5)		327.1 (337.9)		100.8 (104.0)	
V γ	212.9 (210.1)		136.5 (128.0)		23.1 (25.8)	
Other diboson	5.1 (5.3)		3.5 (3.7)		9.3 (9.4)	
Triboson	9.3 (9.6)		16.4 (16.8)		1.2 (1.2)	
Background	12659 (13279)		10495 (10222)		2803 (3004)	
± total unc.	(± 141)		(± 178)		(± 97)	
Data	13964		10591		3364	
						1308

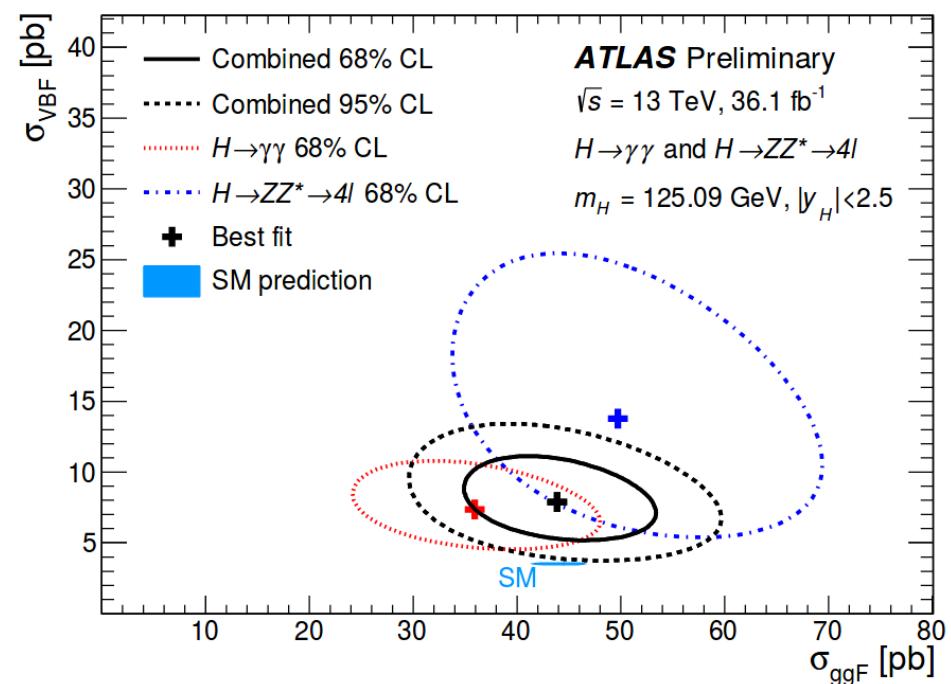
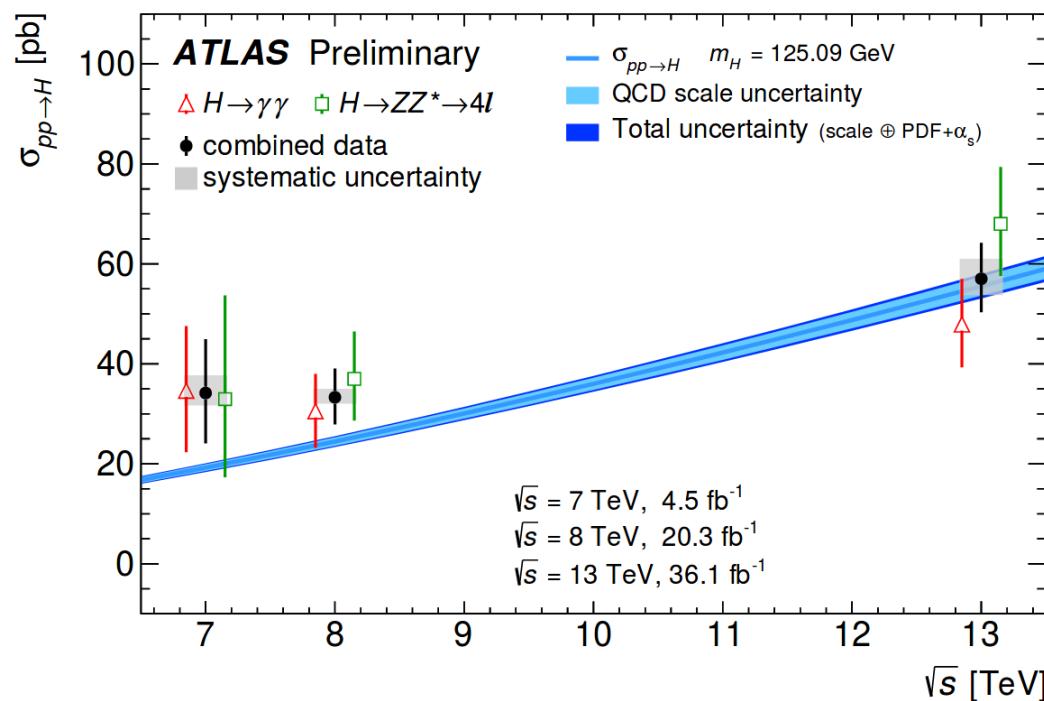
CMS H → WW

	Category					
	2-jet ggH-tagged	2-jet VBF-tagged	2-jet VH-tagged	3-lepton WH-tagged	4-lepton ZH-tagged	
ggH	80.4 (100.6)	11.6 (14.6)	13.9 (17.4)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
VBF	10.3 (13.3)	19.2 (24.5)	0.4 (0.6)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
WH	7.2 (9.3)	0.2 (0.2)	3.6 (4.6)	5.4 (7.2)	< 0.1 (< 0.1)	
ZH	3.3 (4.3)	< 0.1 (< 0.1)	1.5 (2.1)	0.2 (0.2)	2.7 (3.5)	
t̄tH	1.6 (2.1)	< 0.1 (< 0.1)	0.1 (0.2)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
b̄bH	0.6 (0.7)	< 0.1 (0.1)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
Signal	103 (130)	31 (40)	20 (25)	5.6 (7.4)	2.7 (3.5)	
± total unc.	(± 16)	(± 3)	(± 3)	(± 0.7)	(± 0.3)	
WW	1048.3 (860.1)	69.4 (46.0)	52.0 (33.5)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
top	5196.9 (5186.9)	157.0 (158.3)	229.9 (229.2)	< 0.1 (< 0.1)	0.3 (0.3)	
Nonprompt	358.8 (305.0)	29.8 (20.0)	41.5 (37.1)	19.2 (21.2)	< 0.1 (< 0.1)	
DY	110.2 (112.4)	20.4 (18.5)	28.9 (30.0)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
VZ/Vγ*	136.0 (137.1)	7.1 (6.9)	10.5 (10.4)	< 0.1 (< 0.1)	< 0.1 (< 0.1)	
Vγ	58.8 (52.6)	2.8 (2.8)	4.2 (4.6)	3.8 (9.6)	< 0.1 (< 0.1)	
Other diboson	2.1 (2.3)	0.3 (0.3)	1.2 (1.3)	28.6 (32.8)	12.7 (12.6)	
Triboson	15.2 (15.3)	0.3 (0.3)	2.0 (2.0)	2.1 (2.1)	0.4 (0.4)	
Background	6926 (6672)	287 (253)	370 (348)	57 (70)	13.3 (13.3)	
± total unc.	(± 502)	(± 17)	(± 37)	(± 7)	(± 0.6)	
Data	6802	285	386	85	15	

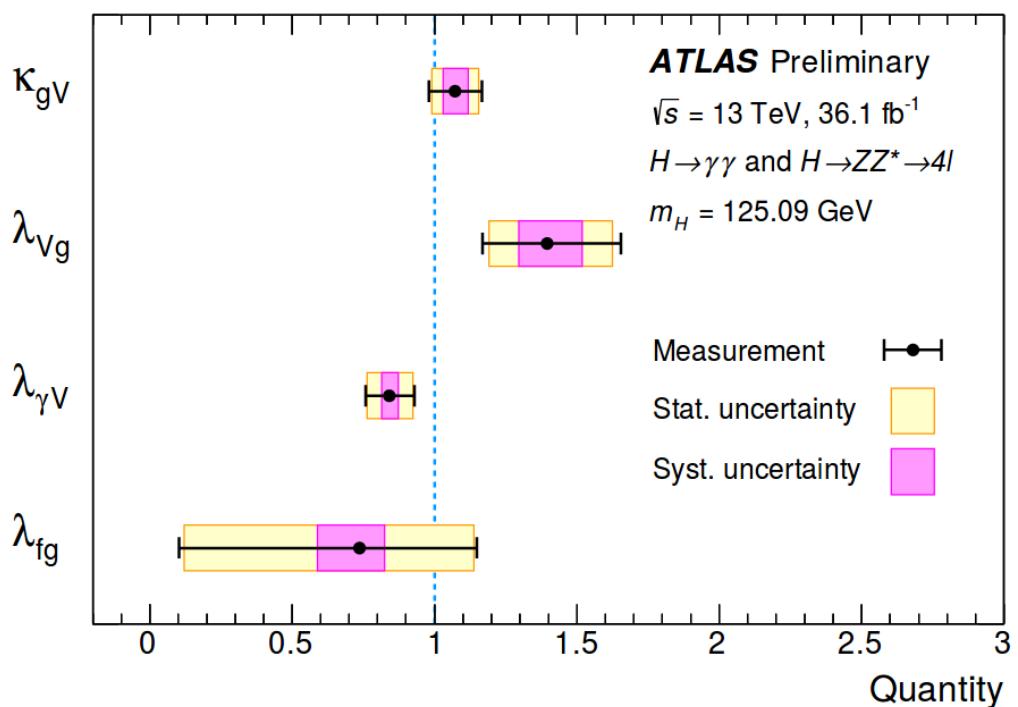
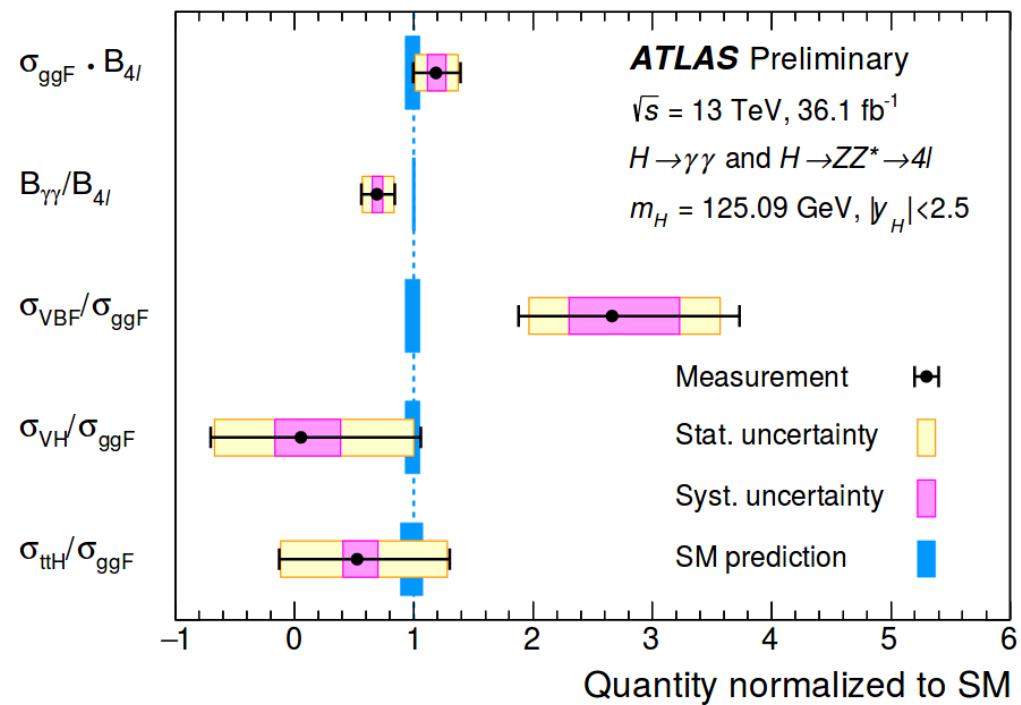
CMS $H \rightarrow WW$



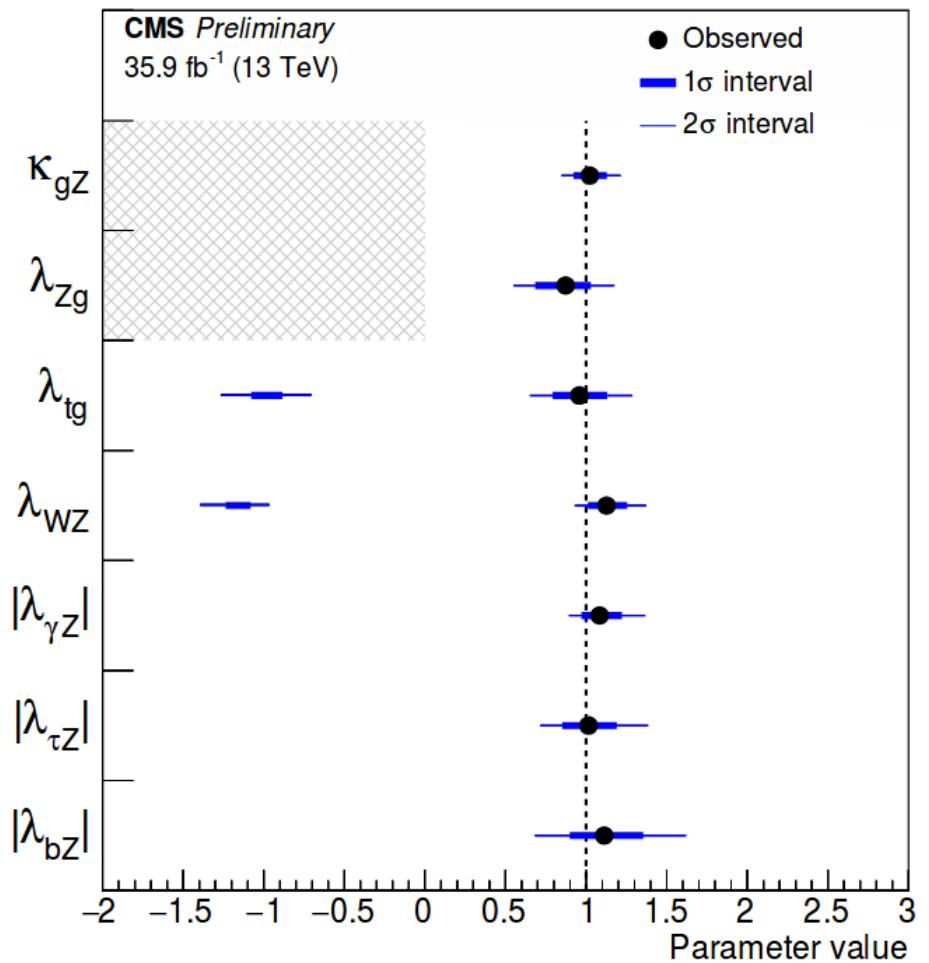
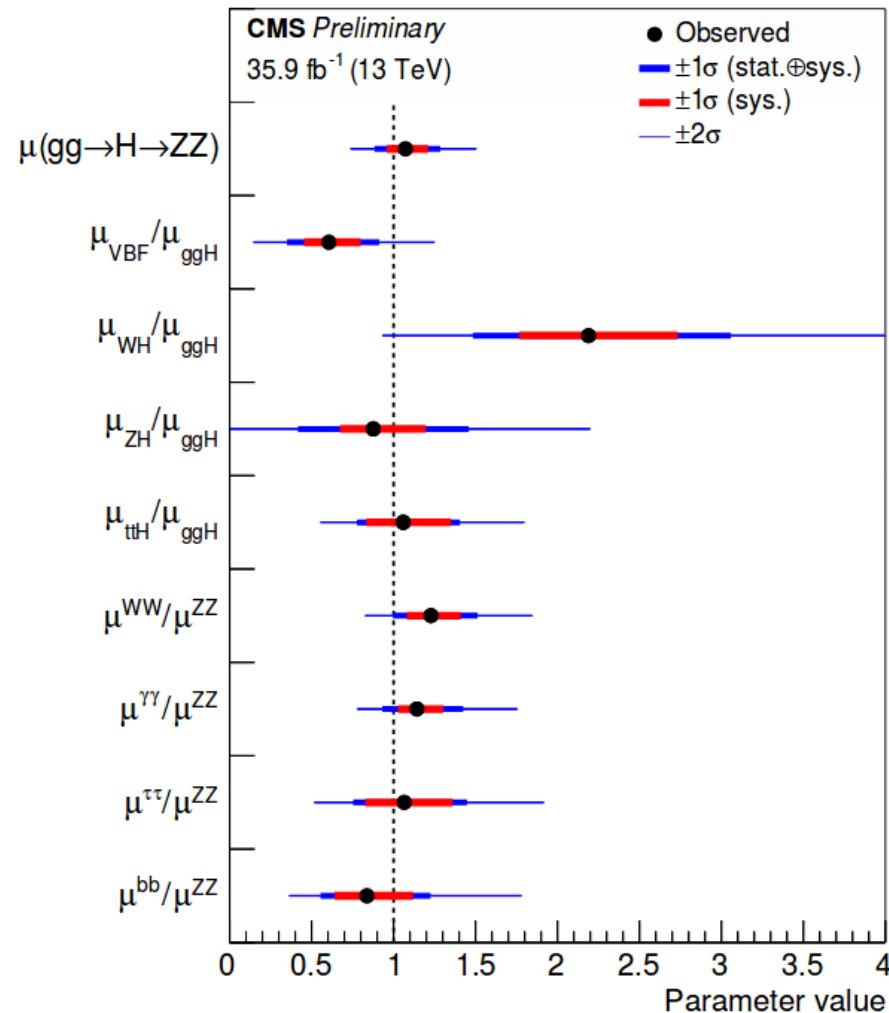
ATLAS Combination



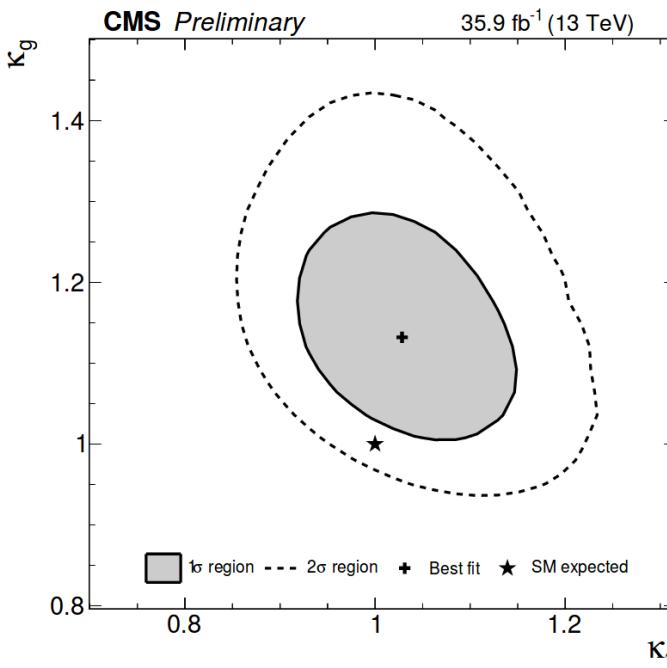
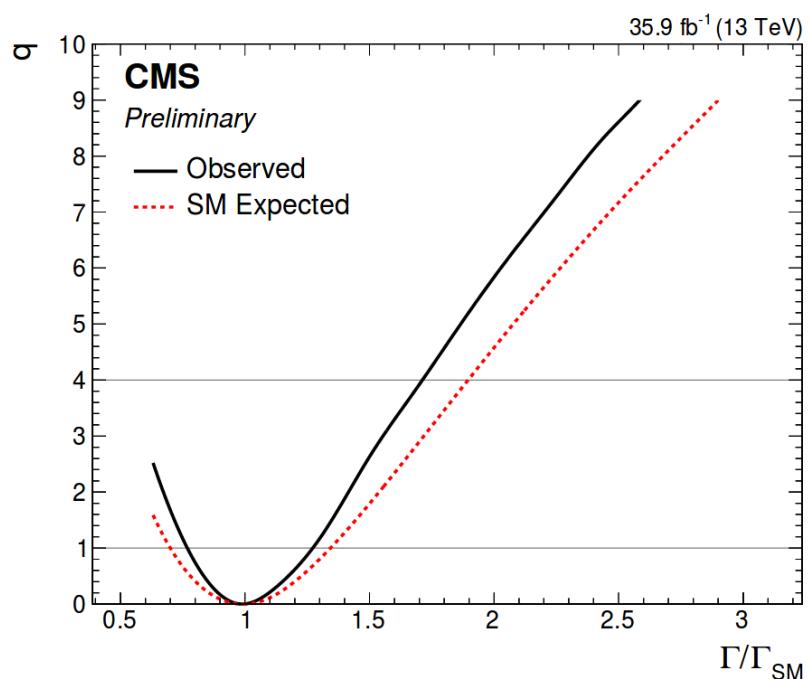
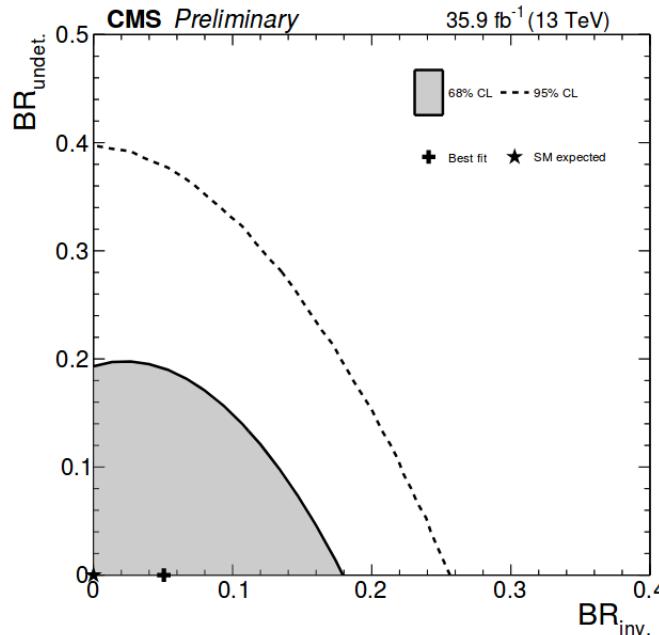
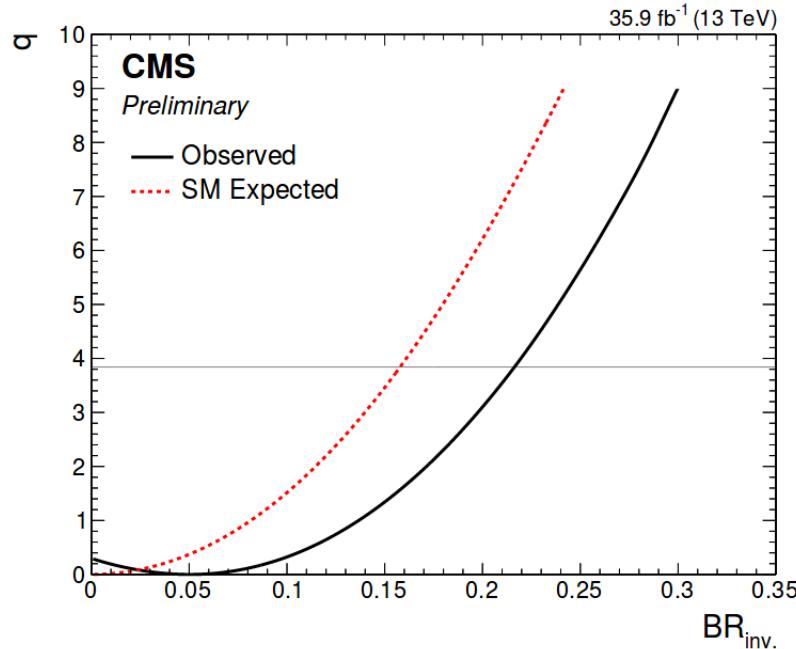
ATLAS Combination



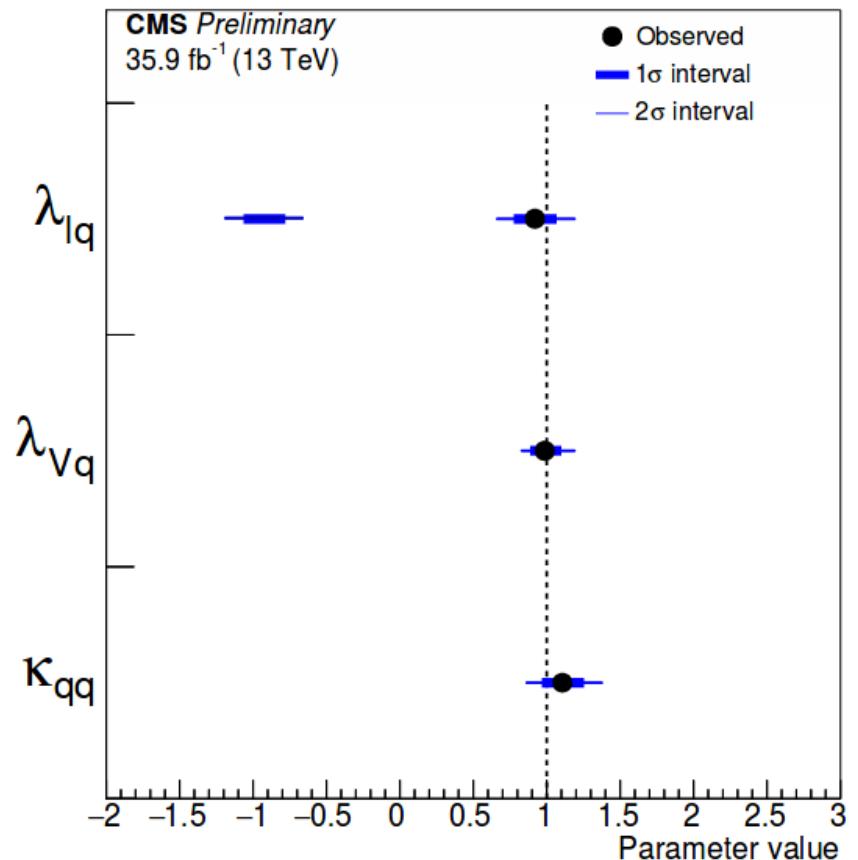
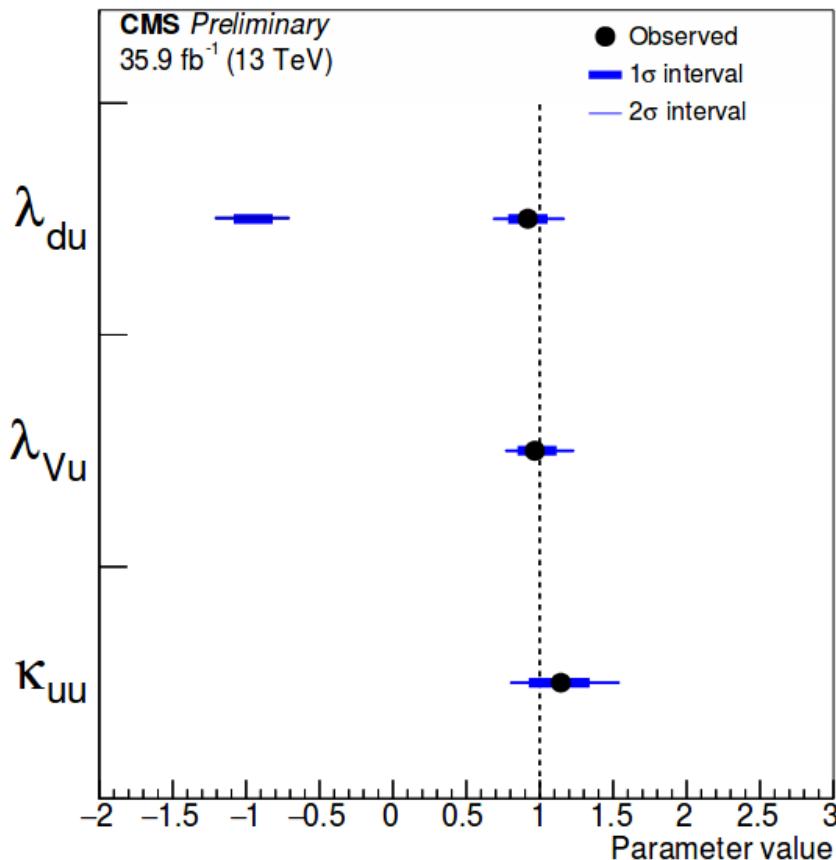
CMS Combination



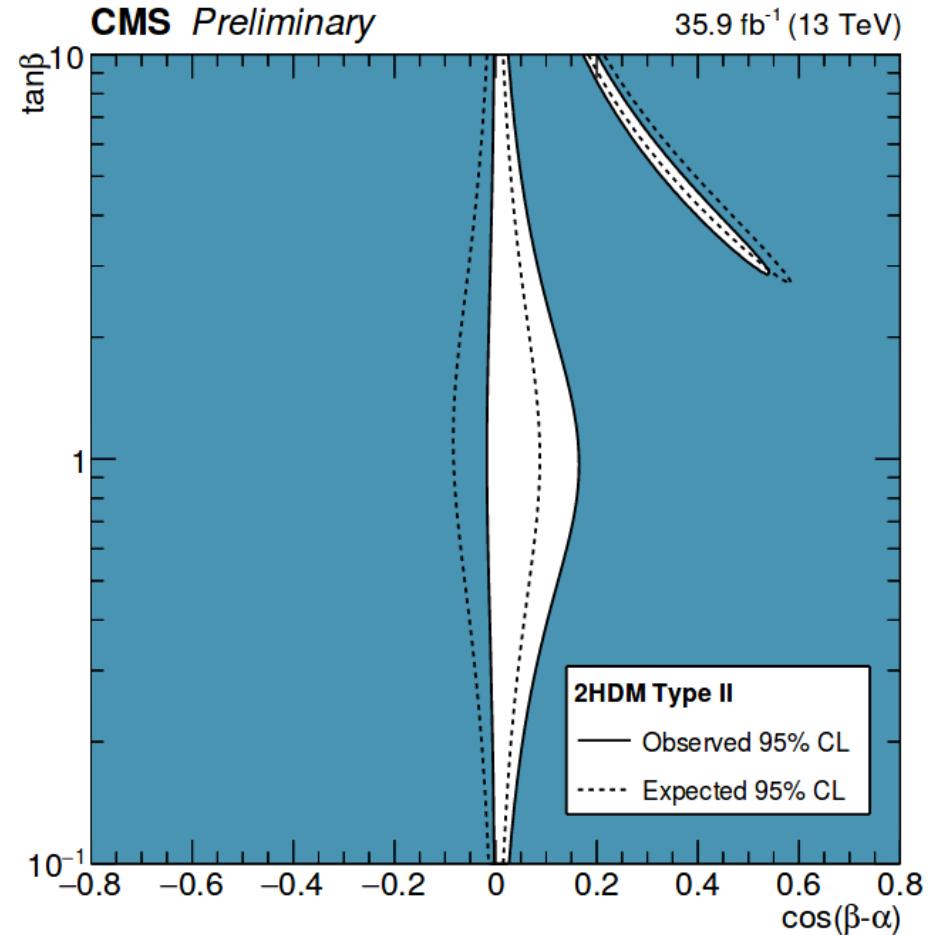
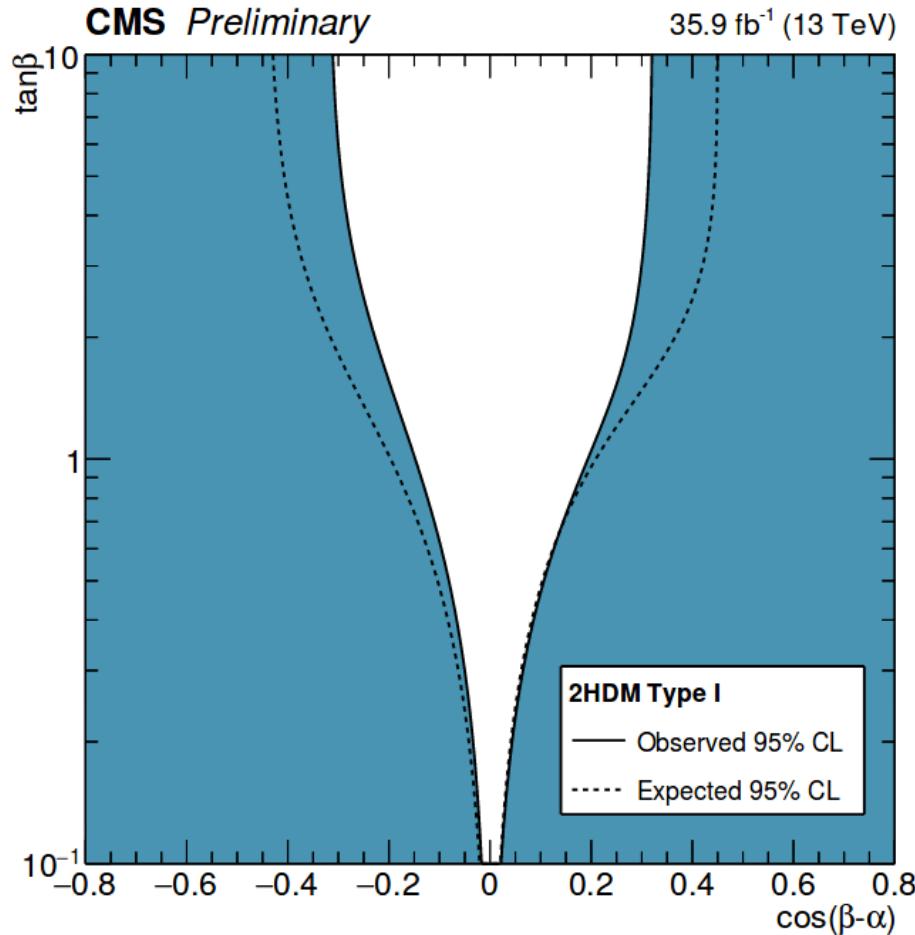
CMS Combination



CMS Combination



Constraints on benchmark BSM models

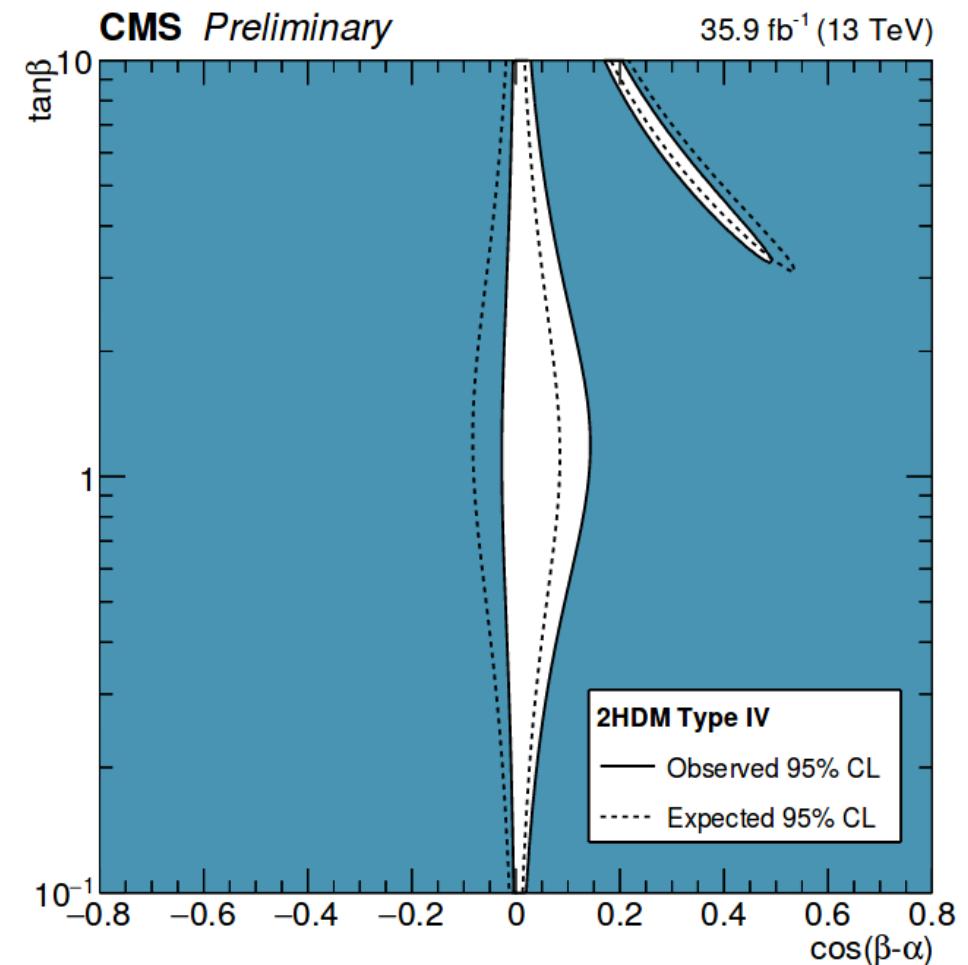
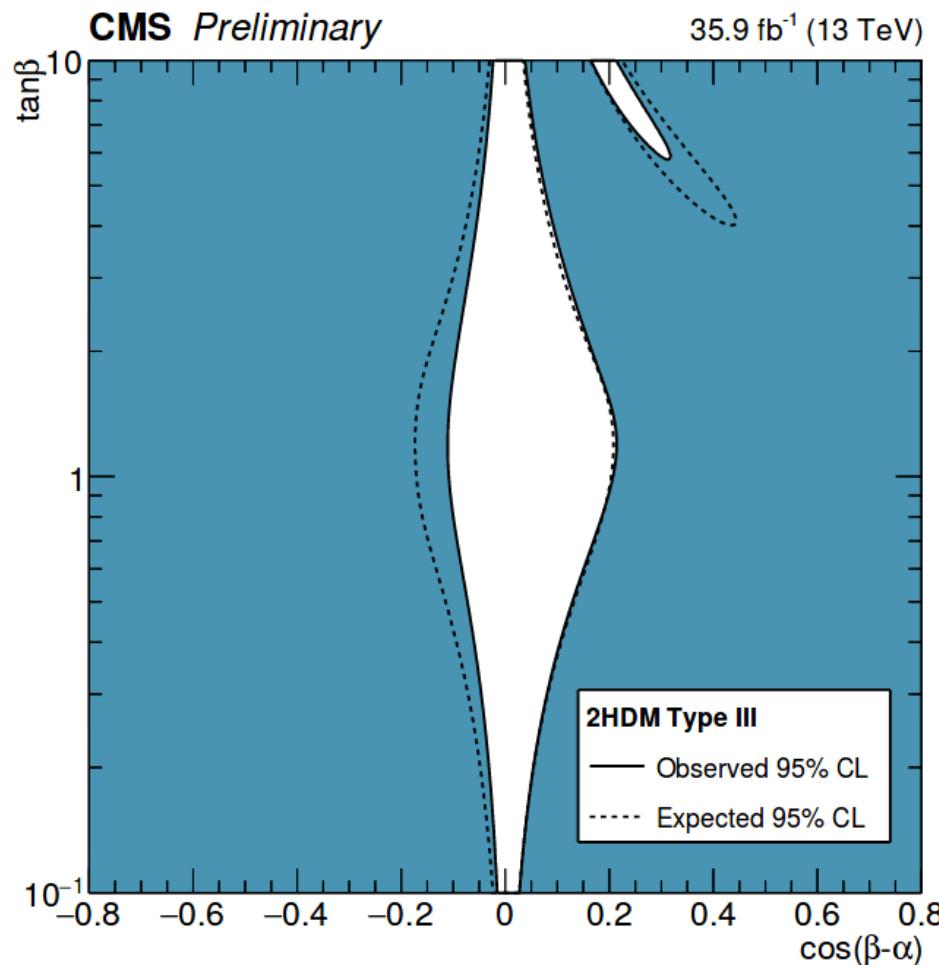


	2HDM				hMSSM
	type I	type II	Type III	Type IV	
κ_V	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\frac{s_d + s_u \tan \beta}{\sqrt{1 + \tan^2 \beta}}$
κ_u	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$s_u \frac{\sqrt{1 + \tan^2 \beta}}{\tan \beta}$
κ_d	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$s_d \sqrt{1 + \tan^2 \beta}$
κ_ℓ	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$\cos(\alpha) / \sin(\beta)$	$s_d \frac{\sqrt{1 + \tan^2 \beta}}{\tan \beta}$

$$s_u = \frac{1}{\sqrt{1 + \frac{(m_A^2 + m_Z^2)^2 \tan^2 \beta}{(m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta))^2}}}$$

$$s_d = s_u \cdot \frac{m_A^2 + m_Z^2 \tan \beta}{m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta)}$$

Constraints on benchmark BSM models

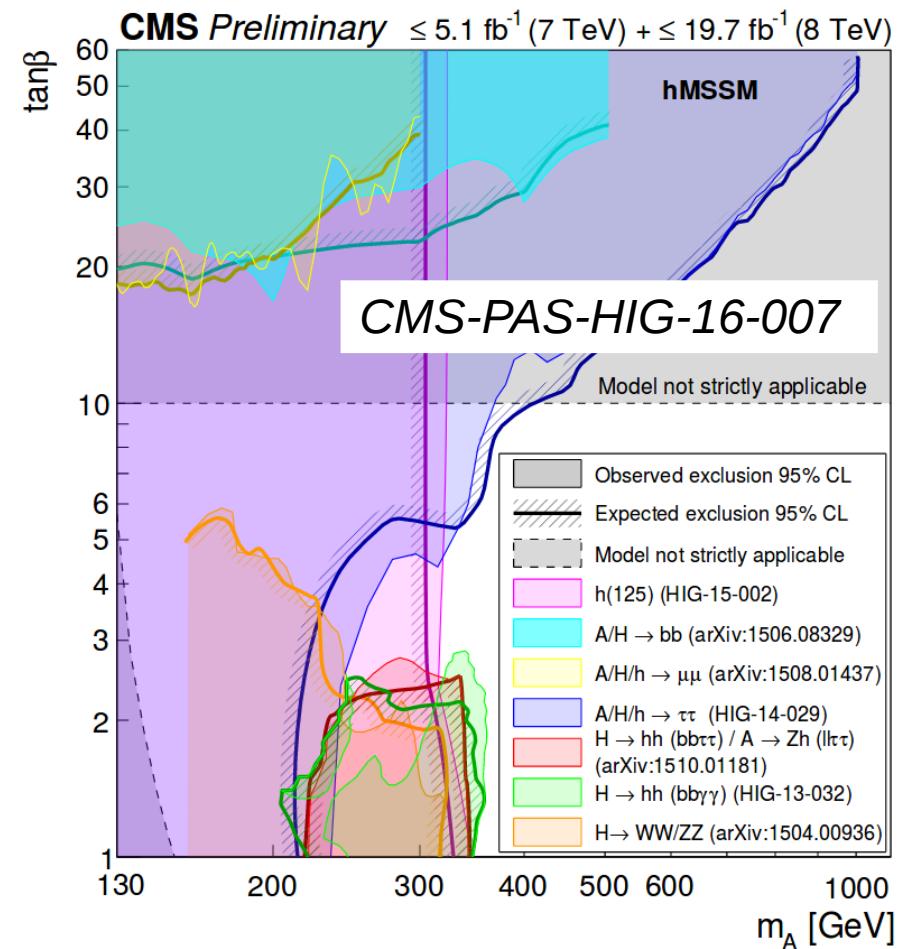
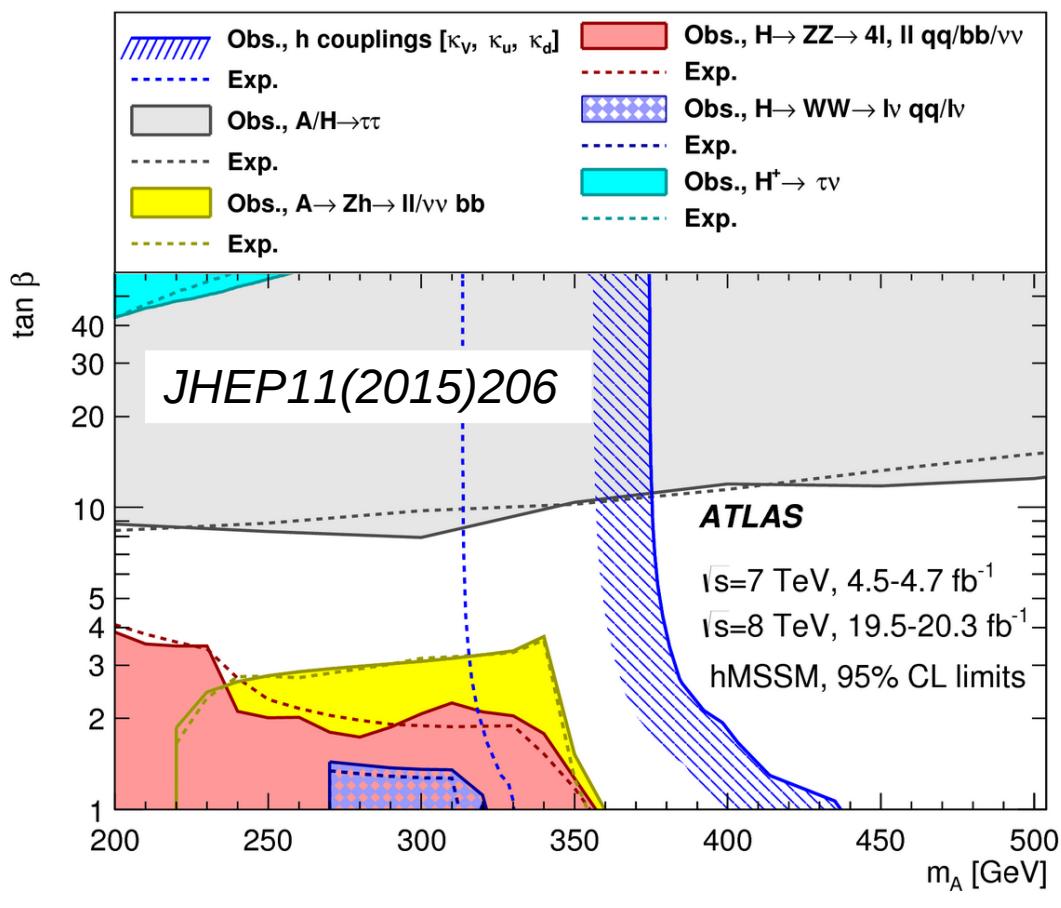


	2HDM				hMSSM
	type I	type II	Type III	Type IV	
κ_V	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$s_d + s_u \tan \beta$
κ_u	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$s_u \frac{\sqrt{1 + \tan^2 \beta}}{\tan \beta}$
κ_d	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$s_d \sqrt{1 + \tan^2 \beta}$
κ_ℓ	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$\cos(\alpha) / \sin(\beta)$	$s_d \sqrt{1 + \tan^2 \beta}$

$$s_u = \frac{1}{\sqrt{1 + \frac{(m_A^2 + m_Z^2)^2 \tan^2 \beta}{(m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta))^2}}}$$

$$s_d = s_u \cdot \frac{m_A^2 + m_Z^2 \tan \beta}{m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta)}$$

Constraints on benchmark BSM models



2HDM					hMSSM
κ_V	type I	type II	Type III	Type IV	
κ_u	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$	$\frac{s_d + s_u \tan \beta}{\sqrt{1 + \tan^2 \beta}}$
κ_d	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$	$s_u \frac{\sqrt{1 + \tan^2 \beta}}{\tan \beta}$
κ_ℓ	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$	$s_d \sqrt{1 + \tan^2 \beta}$

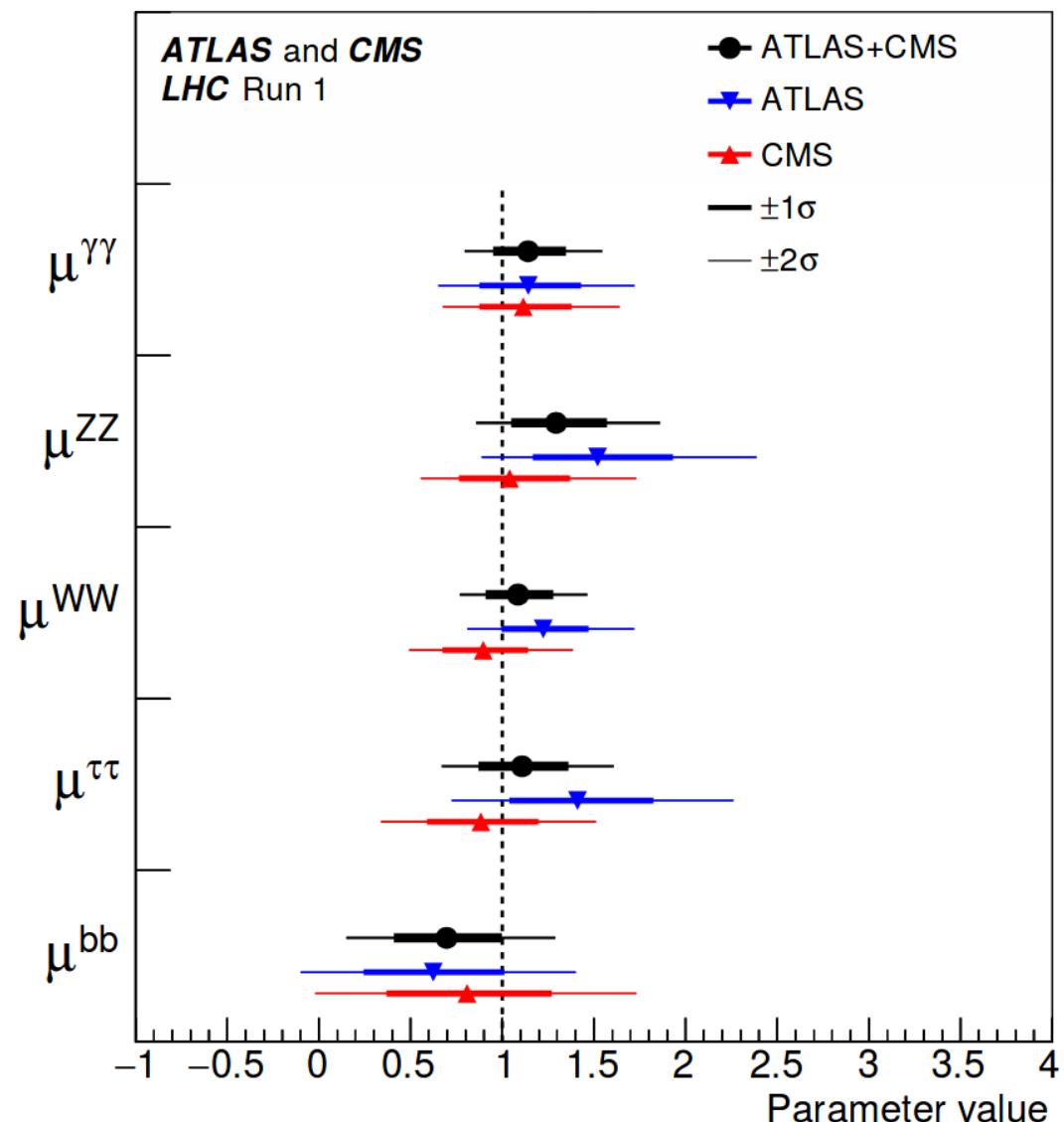
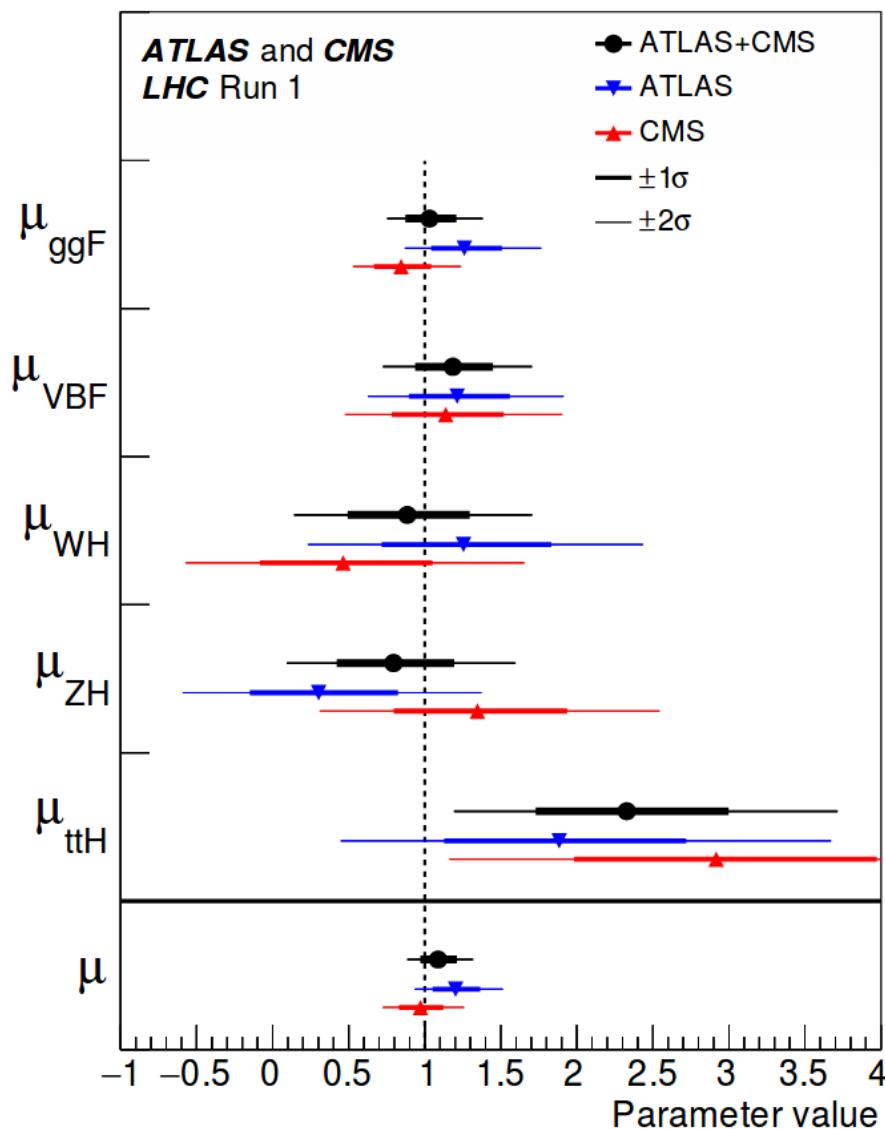
$$s_u = \frac{1}{\sqrt{1 + \frac{(m_A^2 + m_Z^2)^2 \tan^2 \beta}{(m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta))^2}}}$$

$$s_d = s_u \cdot \frac{m_A^2 + m_Z^2 \tan \beta}{m_Z^2 + m_A^2 \tan^2 \beta - m_H^2 (1 + \tan^2 \beta)}$$

SM Compatibility

Parameterisation	p -value (q_{SM})	DOF	Parameters of interest
Global signal strength	6.12% (3.51)	1	μ
Production processes	9.21% (9.46)	5	$\mu_{\text{ggH}}, \mu_{\text{VBF}}, \mu_{\text{WH}}, \mu_{\text{ZH}}, \mu_{\text{ttH}}$
Decay modes	43.4% (4.85)	5	$\mu^{\gamma\gamma}, \mu^{ZZ}, \mu^{WW}, \mu^{\tau\tau}, \mu^{bb}$
$\sigma_i \cdot \text{BR}^f$ products	50.4% (21.3)	22	$\sigma_{\text{ggH}} \cdot \text{BR}^{bb}, \sigma_{\text{ggH}} \cdot \text{BR}^{\tau\tau}, \sigma_{\text{ggH}} \cdot \text{BR}^{WW}, \sigma_{\text{ggH}} \cdot \text{BR}^{ZZ}, \sigma_{\text{ggH}} \cdot \text{BR}^{\gamma\gamma},$ $\sigma_{\text{VBF}} \cdot \text{BR}^{\tau\tau}, \sigma_{\text{VBF}} \cdot \text{BR}^{WW}, \sigma_{\text{VBF}} \cdot \text{BR}^{ZZ}, \sigma_{\text{VBF}} \cdot \text{BR}^{\gamma\gamma}, \sigma_{\text{WH}} \cdot \text{BR}^{bb},$ $\sigma_{\text{WH}} \cdot \text{BR}^{WW}, \sigma_{\text{WH}} \cdot \text{BR}^{ZZ}, \sigma_{\text{WH}} \cdot \text{BR}^{\gamma\gamma}, \sigma_{\text{ZH}} \cdot \text{BR}^{bb}, \sigma_{\text{ZH}} \cdot \text{BR}^{WW},$ $\sigma_{\text{ZH}} \cdot \text{BR}^{ZZ}, \sigma_{\text{ZH}} \cdot \text{BR}^{\gamma\gamma}, \sigma_{\text{ttH}} \cdot \text{BR}^{\tau\tau}, \sigma_{\text{ttH}} \cdot \text{BR}^{WW}, \sigma_{\text{ttH}} \cdot \text{BR}^{ZZ},$ $\sigma_{\text{ttH}} \cdot \text{BR}^{\gamma\gamma}, \sigma_{\text{ttH}} \cdot \text{BR}^{bb}$
Ratios of σ and BR relative to $\text{gg} \rightarrow H \rightarrow ZZ$	24.5% (11.5)	9	$\mu_{\text{ggH}}^{ZZ}, \mu_{\text{VBF}}/\mu_{\text{ggH}}, \mu_{\text{WH}}/\mu_{\text{ggH}}, \mu_{\text{ZH}}/\mu_{\text{ggH}}, \mu_{\text{ttH}}/\mu_{\text{ggH}}, \mu^{WW}/\mu^{ZZ},$ $\mu^{\gamma\gamma}/\mu^{ZZ}, \mu^{\tau\tau}/\mu^{ZZ}, \mu^{bb}/\mu^{ZZ}$
Simplified template cross sections with branching fractions relative to BR^{ZZ}	17.2% (14.0)	10	$\sigma_{\text{ggH}} \cdot \text{BR}^{ZZ}, \sigma_{\text{VBF}} \cdot \text{BR}^{ZZ}, \sigma_{H+V(qq)} \cdot \text{BR}^{ZZ}, \sigma_{H+W(\ell\nu)} \cdot \text{BR}^{ZZ},$ $\sigma_{H+Z(\ell\ell/vv)} \cdot \text{BR}^{ZZ}, \sigma_{\text{ttH}} \cdot \text{BR}^{ZZ}, \text{BR}^{bb}/\text{BR}^{ZZ}, \text{BR}^{\tau\tau}/\text{BR}^{ZZ}, \text{BR}^{WW}/\text{BR}^{ZZ},$ $\text{BR}^{\gamma\gamma}/\text{BR}^{ZZ}$
Couplings, SM loops	46.9% (5.60)	6	$\kappa_Z, \kappa_W, \kappa_t, \kappa_\tau, \kappa_b, \kappa_\mu$
Couplings vs mass	17.1% (3.54)	2	M, ϵ
Couplings, BSM loops	57.7% (5.68)	7	$\kappa_Z, \kappa_W, \kappa_t, \kappa_\tau, \kappa_b, \kappa_\gamma, \kappa_g$
Couplings, BSM loops and decays including $H \rightarrow \text{inv. channels}$	78.6% (5.53)	9	$\kappa_Z, \kappa_W, \kappa_t, \kappa_\tau, \kappa_b, \kappa_\gamma, \kappa_g, \text{BR}_{\text{inv.}}, \text{BR}_{\text{undet.}}$
Ratios of coupling modifiers	56.7% (5.77)	7	$\kappa_{gZ}, \lambda_{WZ}, \lambda_{\gamma Z}, \lambda_{tg}, \lambda_{bZ}, \lambda_{\tau Z}, \lambda_{Zg}$
Fermion and vector couplings	16.9% (3.55)	2	κ_F, κ_V
Fermion and vector couplings, per decay mode	63.9% (7.89)	10	$\kappa_F^{bb}, \kappa_F^{\tau\tau}, \kappa_F^{WW}, \kappa_F^{ZZ}, \kappa_F^{\gamma\gamma}, \kappa_V^{bb}, \kappa_V^{\tau\tau}, \kappa_V^{WW}, \kappa_V^{ZZ}, \kappa_V^{\gamma\gamma}$
Up vs down-type couplings	25.5% (4.06)	3	$\lambda_{Vu}, \lambda_{du}, \kappa_{uu}$
Lepton vs quark couplings	26.5% (3.97)	3	$\lambda_{\ell q}, \lambda_{Vq}, \kappa_{qq}$

Run 1 Results: ATLAS+CMS Combination



ATLAS+CMS Combination

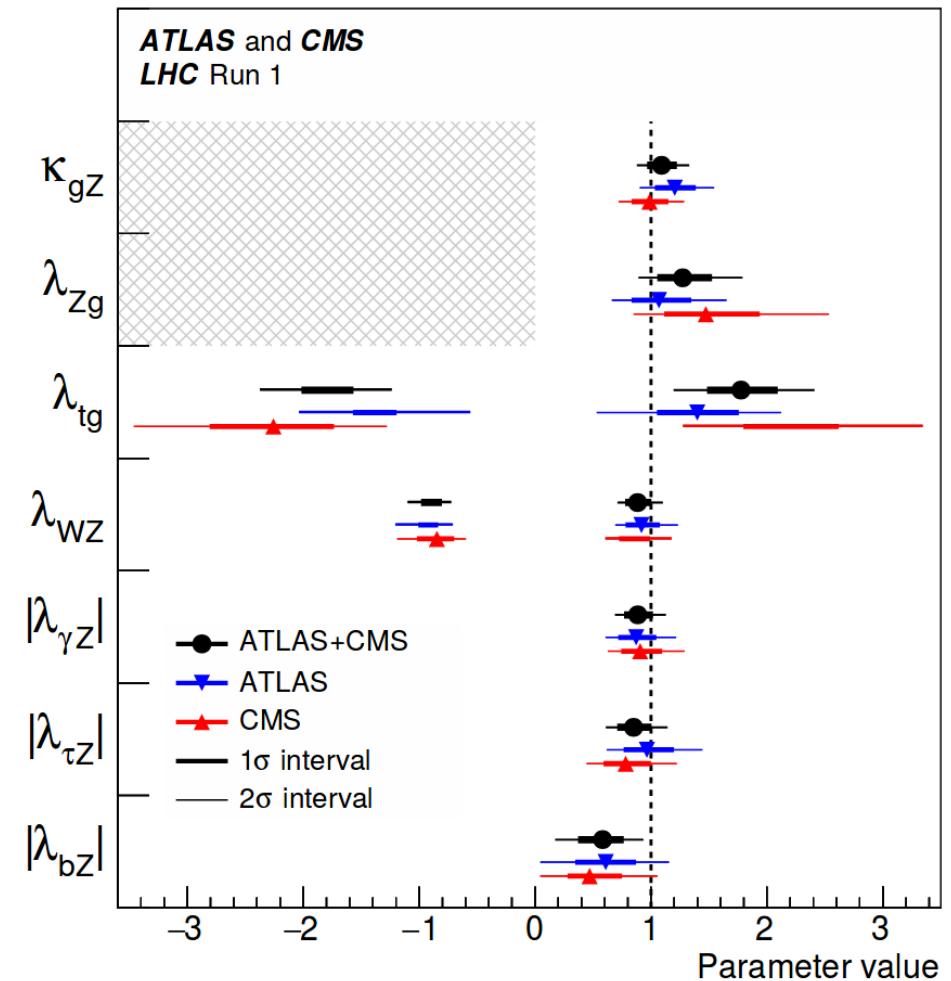
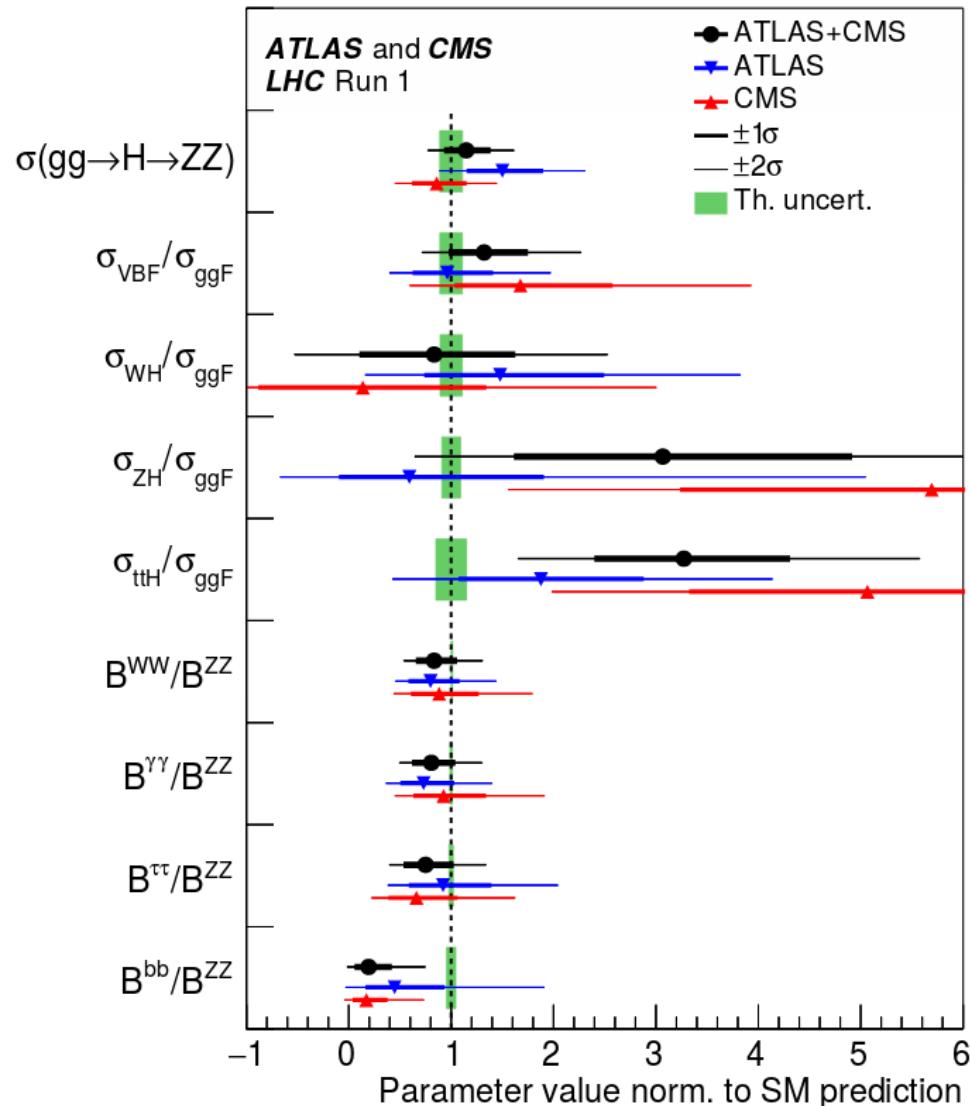
CMS Run 2

Production process																
ggH				VBF			WH			ZH			ttH			
Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.		
1.23 (+0.11) (-0.11)	+0.14 (+0.07) (-0.07)	+0.08 (+0.09) (-0.08)	+0.12 (+0.10)	0.73 (+0.29) (-0.27)	+0.30 (+0.24) (-0.23)	+0.24 (+0.17) (-0.15)	2.18 (+0.53) (-0.51)	+0.58 (+0.43) (-0.42)	+0.46 (+0.34) (-0.32)	+0.34 (+0.20) (-0.18)	+0.44 (+0.42) (-0.40)	+0.39 (+0.38) (-0.37)	+0.20 (+0.19) (-0.17)	1.18 (+0.28) (-0.25)	+0.31 (+0.16) (-0.16)	+0.16 (+0.23) (-0.20)
Decay mode																
H → bb				H → ττ			H → WW			H → ZZ			H → γγ			
Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.	Best fit value	Uncertainty Stat.	Uncertainty Syst.		
1.12 (+0.28) (-0.27)	+0.29 (+0.19) (-0.18)	+0.19 (+0.21) (-0.20)	+0.22 (+0.20)	1.02 (+0.24) (-0.23)	+0.26 (+0.15) (-0.14)	+0.15 (+0.21) (-0.19)	1.28 (+0.14) (-0.13)	+0.17 (+0.09) (-0.09)	+0.09 (+0.14) (-0.10)	+0.14 (+0.11) (-0.10)	+0.19 (+0.18) (-0.16)	+0.16 (+0.15) (-0.14)	+0.10 (+0.10) (-0.08)	1.20 (+0.14) (-0.12)	+0.17 (+0.10) (-0.10)	+0.12 (+0.09) (-0.07)

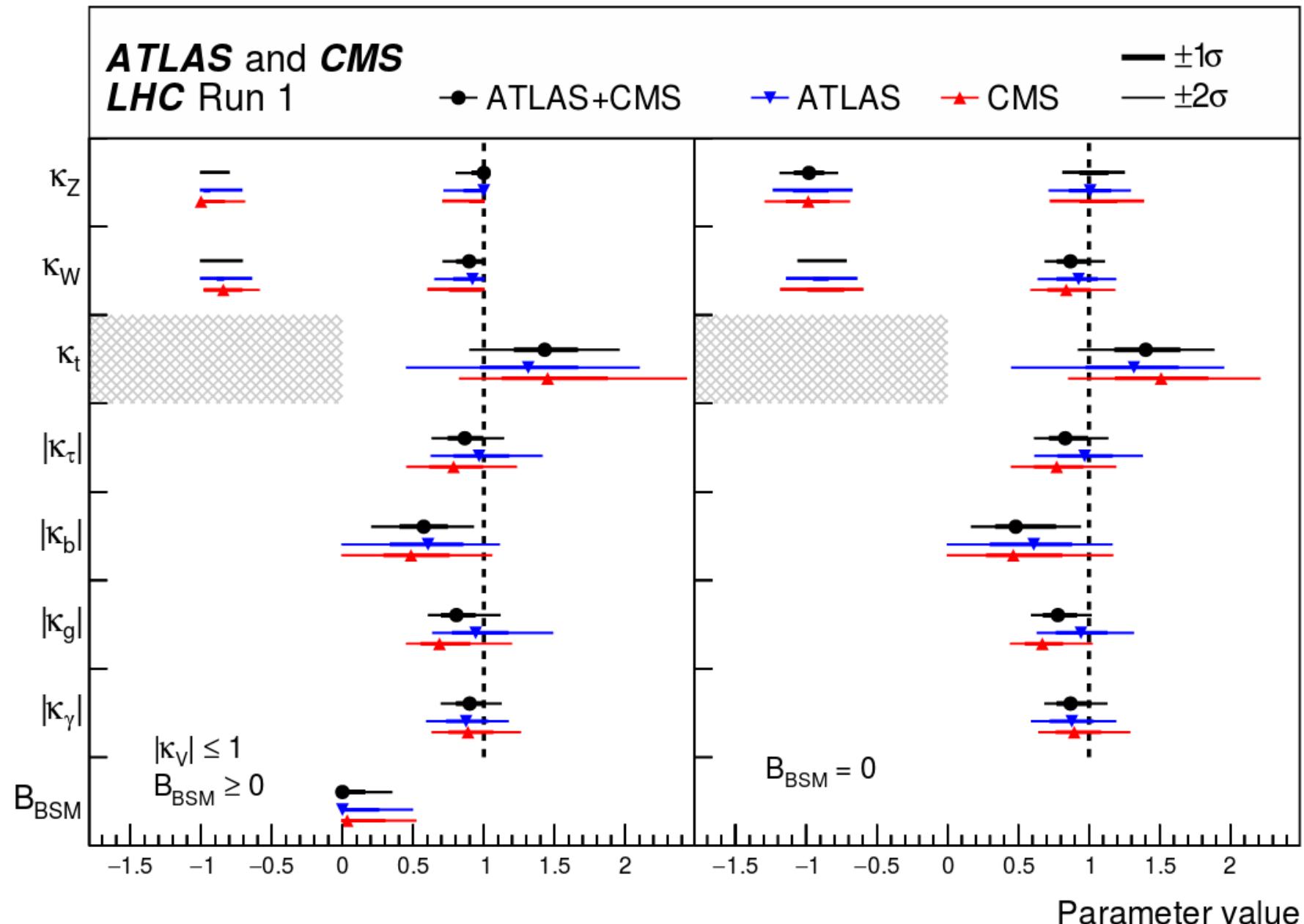
ATLAS+CMS Run 1

Production process	ATLAS+CMS	ATLAS	CMS	Decay channel	ATLAS+CMS	ATLAS	CMS
μ_{ggF}	1.03 (+0.16) (-0.14)	1.26 (+0.21) (-0.18)	0.84 (+0.18) (-0.16)	$\mu^{\gamma\gamma}$	1.14 (+0.19) (-0.18)	1.14 (+0.27) (-0.25)	1.11 (+0.25) (-0.23)
μ_{VBF}	1.18 (+0.25) (-0.23)	1.21 (+0.33) (-0.30)	1.14 (+0.37) (-0.34)	μ^{ZZ}	1.29 (+0.26) (-0.23)	1.52 (+0.40) (-0.34)	1.04 (+0.32) (-0.26)
μ_{WH}	0.89 (+0.40) (-0.38)	1.25 (+0.56) (-0.52)	0.46 (+0.57) (-0.53)	μ^{WW}	1.09 (+0.18) (-0.16)	1.22 (+0.23) (-0.21)	0.90 (+0.23) (-0.21)
μ_{ZH}	0.79 (+0.38) (-0.36)	0.30 (+0.51) (-0.45)	1.35 (+0.58) (-0.54)	$\mu^{\tau\tau}$	1.11 (+0.24) (-0.22)	1.41 (+0.40) (-0.36)	0.88 (+0.30) (-0.28)
μ_{ttH}	2.3 (+0.5) (-0.5)	1.9 (+0.7) (-0.7)	2.9 (+1.0) (-0.9)	μ^{bb}	0.70 (+0.29) (-0.27)	0.62 (+0.37) (-0.37)	0.81 (+0.45) (-0.43)
				$\mu^{\mu\mu}$	0.1 (+2.5) (-2.5)	-0.6 (+3.6) (-3.6)	0.9 (+3.6) (-3.5)

Run 1 Results: ATLAS+CMS Combination



Run 1 Results: ATLAS+CMS Combination



ATLAS+CMS Combination

CMS Run 2

BR _{inv.} = 0				
Parameter	Best fit	Uncertainty		
		Stat.	Syst.	
κ_Z	0.99 $(^{+0.11}_{-0.11})$	$+0.09$ $(^{+0.09}_{-0.09})$	$+0.06$ $(^{+0.06}_{-0.06})$	
κ_W	1.12 $(^{+0.12}_{-0.12})$	$+0.10$ $(^{+0.09}_{-0.09})$	$+0.08$ $(^{+0.07}_{-0.07})$	
κ_t	1.09 $(^{+0.14}_{-0.14})$	$+0.08$ $(^{+0.08}_{-0.09})$	$+0.12$ $(^{+0.12}_{-0.12})$	
κ_τ	1.01 $(^{+0.17}_{-0.18})$	$+0.11$ $(^{+0.11}_{-0.11})$	$+0.12$ $(^{+0.11}_{-0.11})$	
κ_b	1.10 $(^{+0.27}_{-0.33})$	$+0.19$ $(^{+0.19}_{-0.17})$	$+0.19$ $(^{+0.17}_{-0.15})$	
κ_g	1.14 $(^{+0.15}_{-0.13})$	$+0.10$ $(^{+0.10}_{-0.09})$	$+0.11$ $(^{+0.10}_{-0.09})$	
κ_γ	1.07 $(^{+0.15}_{-0.18})$	$+0.10$ $(^{+0.10}_{-0.10})$	$+0.11$ $(^{+0.07}_{-0.07})$	

ATLAS+CMS Run 1

Parameter	ATLAS+CMS Measured	ATLAS+CMS Expected uncertainty	ATLAS	CMS
			Measured	Measured
Parameterisation assuming $B_{\text{BSM}} = 0$				
κ_Z	-0.98		1.01	-0.99
	$[-1.08, -0.88] \cup [0.94, 1.13]$	$[-1.01, -0.87] \cup [0.89, 1.11]$	$[-1.09, -0.85] \cup [0.87, 1.15]$	$[-1.14, -0.84] \cup [0.94, 1.19]$
κ_W	0.87		0.92	0.84
	$[0.78, 1.00]$	$[-1.08, -0.90] \cup [0.88, 1.11]$	$[-0.94, -0.85] \cup [0.78, 1.05]$	$[-0.99, -0.74] \cup [0.71, 1.01]$
κ_t	$1.40^{+0.24}_{-0.21}$	$+0.26$ -0.39	$1.32^{+0.31}_{-0.33}$	$1.51^{+0.33}_{-0.32}$
$ \kappa_\tau $	$0.84^{+0.15}_{-0.11}$	$+0.16$ -0.15	$0.97^{+0.19}_{-0.19}$	$0.77^{+0.18}_{-0.15}$
$ \kappa_b $	$0.49^{+0.27}_{-0.15}$	$+0.25$ -0.28	$0.61^{+0.26}_{-0.31}$	$0.47^{+0.34}_{-0.19}$
$ \kappa_g $	$0.78^{+0.13}_{-0.10}$	$+0.17$ -0.14	$0.94^{+0.18}_{-0.17}$	$0.67^{+0.14}_{-0.12}$
$ \kappa_\gamma $	$0.87^{+0.14}_{-0.09}$	$+0.12$ -0.13	$0.88^{+0.15}_{-0.15}$	$0.89^{+0.19}_{-0.13}$

Run 1 Results:

ATLAS+CMS Combination

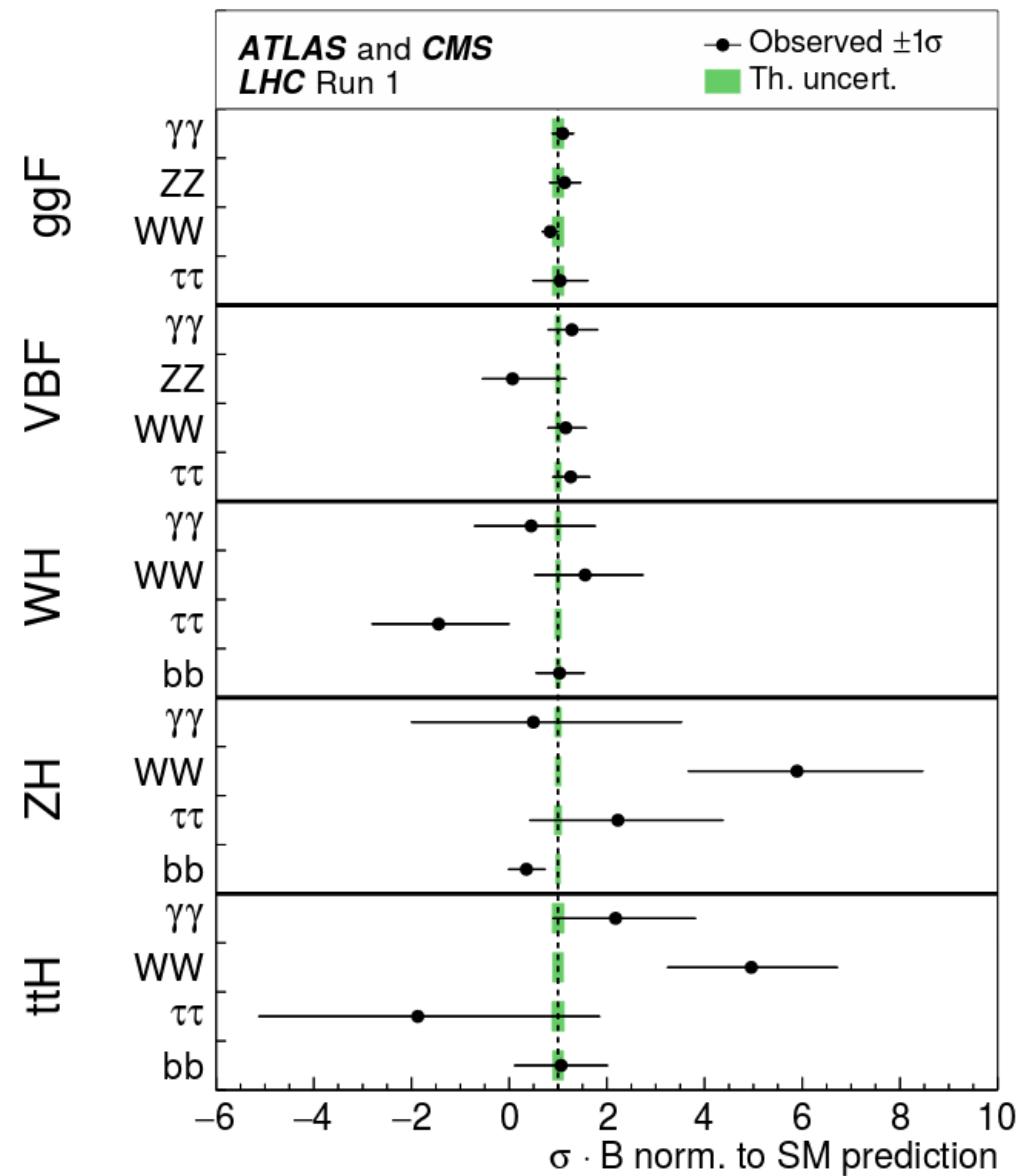
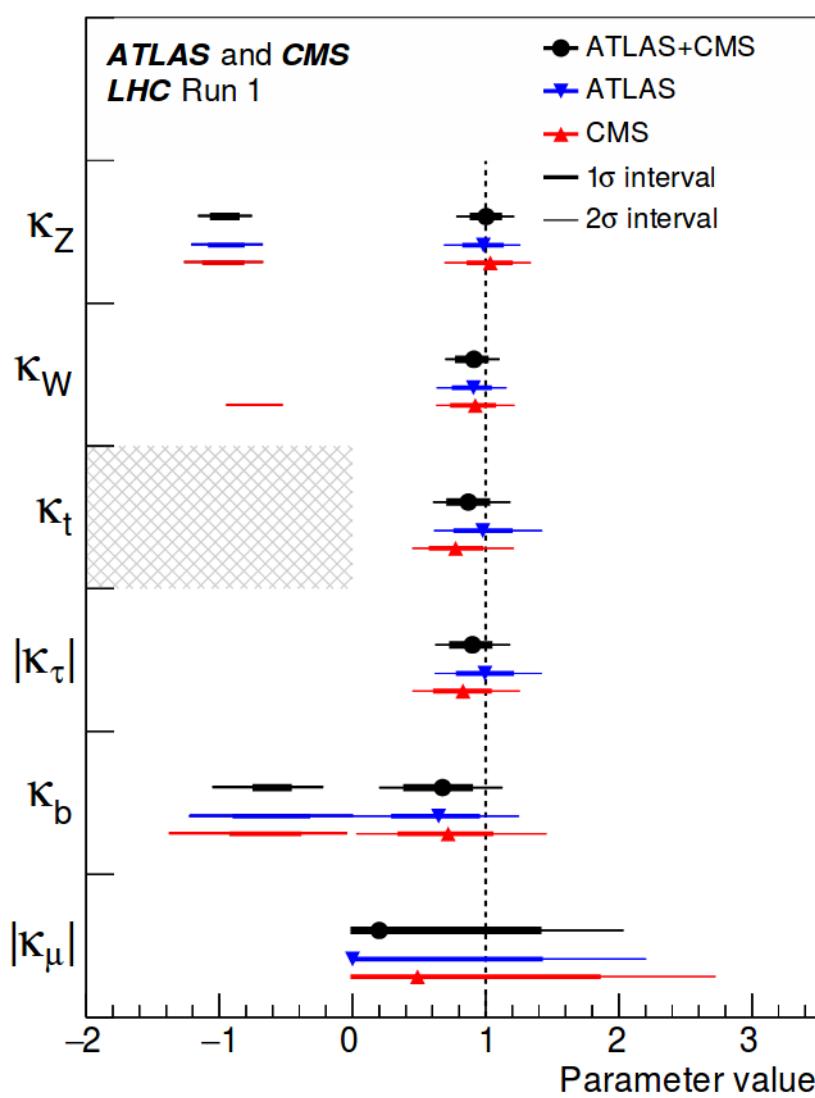
CMS Run 2

BR _{inv.} > 0, $\kappa_V < 1$			
Parameter	Best fit	Uncertainty	
		Stat.	Syst.
κ_Z	0.89 $^{+0.09}_{-0.08}$	$^{+0.07}_{-0.07}$	$^{+0.05}_{-0.04}$
	($^{+0.00}_{-0.11}$)	($^{+0.00}_{-0.09}$)	($^{+0.00}_{-0.06}$)
κ_W	1.00 $^{+0.00}_{-0.05}$	$^{+0.00}_{-0.04}$	$^{+0.00}_{-0.02}$
	($^{+0.00}_{-0.12}$)	($^{+0.00}_{-0.09}$)	($^{+0.00}_{-0.07}$)
κ_t	1.12 $^{+0.17}_{-0.16}$	$^{+0.09}_{-0.09}$	$^{+0.14}_{-0.13}$
	($^{+0.18}_{-0.15}$)	($^{+0.13}_{-0.09}$)	($^{+0.12}_{-0.12}$)
κ_τ	0.91 $^{+0.13}_{-0.13}$	$^{+0.08}_{-0.08}$	$^{+0.11}_{-0.10}$
	($^{+0.14}_{-0.15}$)	($^{+0.09}_{-0.11}$)	($^{+0.11}_{-0.11}$)
κ_b	0.91 $^{+0.19}_{-0.16}$	$^{+0.12}_{-0.11}$	$^{+0.14}_{-0.11}$
	($^{+0.18}_{-0.23}$)	($^{+0.13}_{-0.17}$)	($^{+0.13}_{-0.15}$)
κ_g	1.17 $^{+0.18}_{-0.14}$	$^{+0.11}_{-0.10}$	$^{+0.14}_{-0.11}$
	($^{+0.17}_{-0.12}$)	($^{+0.13}_{-0.09}$)	($^{+0.10}_{-0.09}$)
κ_γ	0.96 $^{+0.09}_{-0.08}$	$^{+0.06}_{-0.06}$	$^{+0.07}_{-0.05}$
	($^{+0.08}_{-0.12}$)	($^{+0.07}_{-0.09}$)	($^{+0.05}_{-0.07}$)
$\text{BR}_{\text{inv.}}$	0.04 $^{+0.09}_{-0.00}$	$^{+0.03}_{-0.03}$	$^{+0.08}_{-0.00}$
	($^{+0.08}_{-0.00}$)	($^{+0.04}_{-0.00}$)	($^{+0.07}_{-0.00}$)
$\text{BR}_{\text{undet.}}$	0.00 $^{+0.09}_{-0.00}$	$^{+0.08}_{-0.00}$	$^{+0.03}_{-0.00}$
	($^{+0.20}_{-0.00}$)	($^{+0.17}_{-0.00}$)	($^{+0.11}_{-0.00}$)

ATLAS+CMS Run 1

Parameter	ATLAS+CMS Measured	ATLAS+CMS Expected uncertainty	ATLAS	CMS
			Measured	Measured
Parameterisation assuming $ \kappa_V \leq 1$ and $B_{\text{BSM}} \geq 0$				
κ_Z	1.00		1.00	-1.00
	[0.92, 1.00]	[-1.00, -0.89] \cup [0.89, 1.00]	[-0.97, -0.94] \cup [0.86, 1.00]	[-1.00, -0.84] \cup [0.90, 1.00]
κ_W	0.90		0.92	-0.84
	[0.81, 0.99]	[-1.00, -0.90] \cup [0.89, 1.00]	[-0.88, -0.84] \cup [0.79, 1.00]	[-1.00, -0.71] \cup [0.76, 0.98]
κ_t	$1.43^{+0.23}_{-0.22}$	$+0.27_{-0.32}$	$1.31^{+0.35}_{-0.33}$	$1.45^{+0.42}_{-0.32}$
$ \kappa_\tau $	$0.87^{+0.12}_{-0.11}$	$+0.14_{-0.15}$	$0.97^{+0.21}_{-0.17}$	$0.79^{+0.20}_{-0.16}$
$ \kappa_b $	$0.57^{+0.16}_{-0.16}$	$+0.19_{-0.23}$	$0.61^{+0.24}_{-0.26}$	$0.49^{+0.26}_{-0.19}$
$ \kappa_g $	$0.81^{+0.13}_{-0.10}$	$+0.17_{-0.14}$	$0.94^{+0.23}_{-0.16}$	$0.69^{+0.21}_{-0.13}$
$ \kappa_\gamma $	$0.90^{+0.10}_{-0.09}$	$+0.10_{-0.12}$	$0.87^{+0.15}_{-0.14}$	$0.89^{+0.17}_{-0.13}$
B_{BSM}	$0.00^{+0.16}$	$+0.19$	$0.00^{+0.25}$	$0.03^{+0.26}$

Run 1 Results: ATLAS+CMS Combination



Run 1 Results:

ATLAS+CMS Combination

CMS Run 2

Parameter																										
κ_W		κ_Z		κ_t		κ_b		κ_τ		κ_μ																
Best fit value	Uncertainty	Best fit value	Uncertainty	Best fit value	Uncertainty	Best fit value	Uncertainty	Best fit value	Uncertainty	Best fit value	Uncertainty															
Stat.	Syst.	Stat.	Syst.	Stat.	Syst.	Stat.	Syst.	Stat.	Syst.	Stat.	Syst.															
1.09 (+0.11) (-0.10)	+0.12 (-0.08)	+0.08 (+0.08) (-0.06)	+0.09 (+0.09) (-0.09)	+0.09 (+0.06) (-0.06)	+0.07 (-0.07)	0.99 (+0.11) (-0.11)	+0.11 (-0.10)	+0.08 (+0.07) (-0.08)	+0.09 (+0.09) (-0.09)	1.11 (+0.11) (-0.12)	+0.12 (-0.11)	+0.33 (-0.24)	+0.29 (-0.16)	+0.15 (-0.17)	-1.10 (+0.23) (-0.22)	+0.16 (-0.15)	+0.11 (+0.16) (-0.15)	+0.12 (+0.16) (-0.16)	1.01 (+0.17) (-0.15)	+0.16 (-0.10)	+0.11 (+0.12) (-0.10)	+0.12 (+0.12) (-0.11)	0.82 (+0.45) (-1.01)	+0.50 (-0.45)	+0.49 (+0.44) (-1.00)	+0.11 (+0.07) (-0.11)

ATLAS+CMS Run 1

Parameter	ATLAS+CMS Measured	ATLAS+CMS Expected uncertainty	ATLAS Measured	CMS Measured
κ_Z	1.00 [-1.05, -0.86] \cup [0.90, 1.11]	[-1.00, -0.88] \cup [0.90, 1.10]	0.98 [-1.07, -0.83] \cup [0.84, 1.12]	1.03 [-1.11, -0.83] \cup [0.87, 1.19]
κ_W	$0.91^{+0.10}_{-0.12}$	$+0.10_{-0.11}$	$0.91^{+0.12}_{-0.15}$	$0.92^{+0.14}_{-0.17}$
κ_t	$0.87^{+0.15}_{-0.15}$	$+0.15_{-0.18}$	$0.98^{+0.21}_{-0.20}$	$0.77^{+0.20}_{-0.18}$
$ \kappa_\tau $	$0.90^{+0.14}_{-0.16}$	$+0.15_{-0.14}$	$0.99^{+0.20}_{-0.20}$	$0.83^{+0.20}_{-0.21}$
κ_b	0.67 [-0.73, -0.47] \cup [0.40, 0.89]	[-1.24, -0.76] \cup [0.74, 1.24]	0.64 [-0.89, -0.33] \cup [0.30, 0.94]	0.71 [-0.91, -0.40] \cup [0.35, 1.04]
$ \kappa_\mu $	$0.2^{+1.2}_{-1.2}$	$+0.9$	$0.0^{+1.4}_{-1.4}$	$0.5^{+1.4}_{-1.4}$

Run 1 Results: ATLAS+CMS Combination

