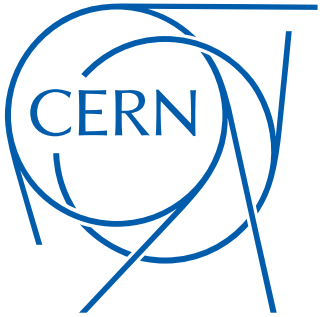
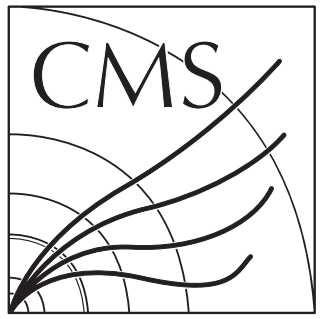




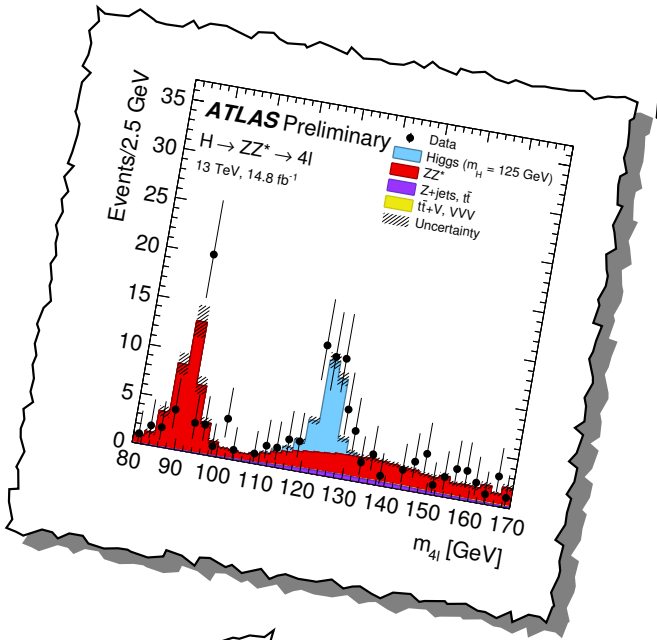
Status of 125 GeV Higgs Boson Measurements

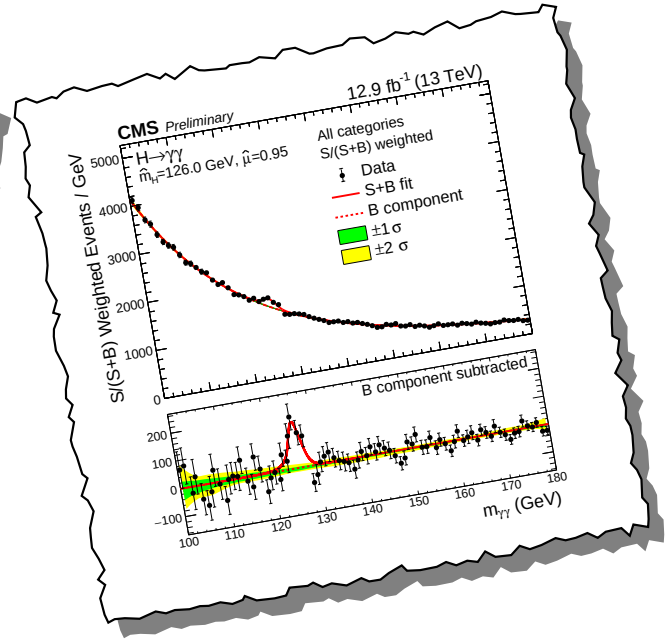
LHC Higgs Cross-section Working Group

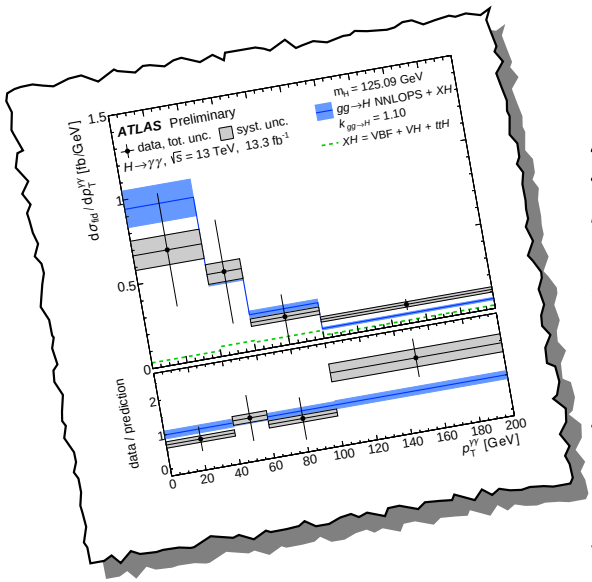
13th July 2017

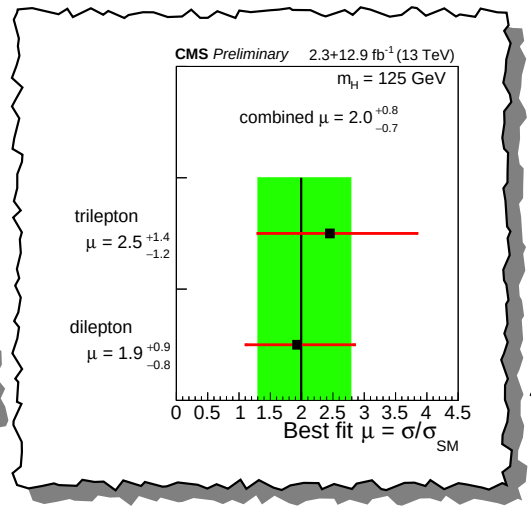
Andy Chisholm (CERN)
on behalf of the ATLAS and CMS collaborations

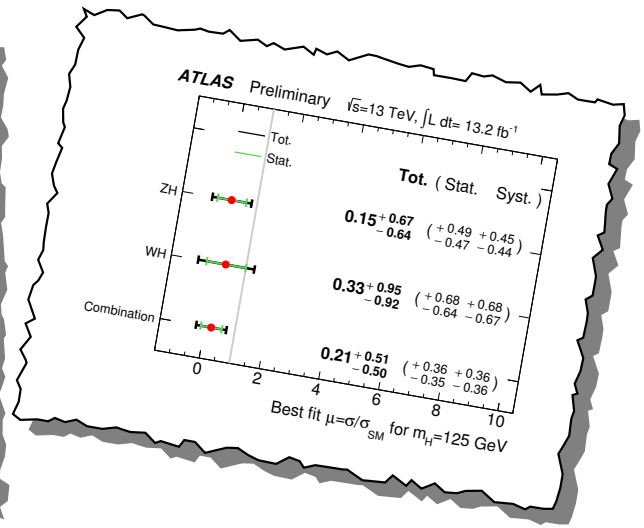
This time last year, the 125 GeV boson had been "rediscovered" with up to 15 fb^{-1} of 13 TeV data!





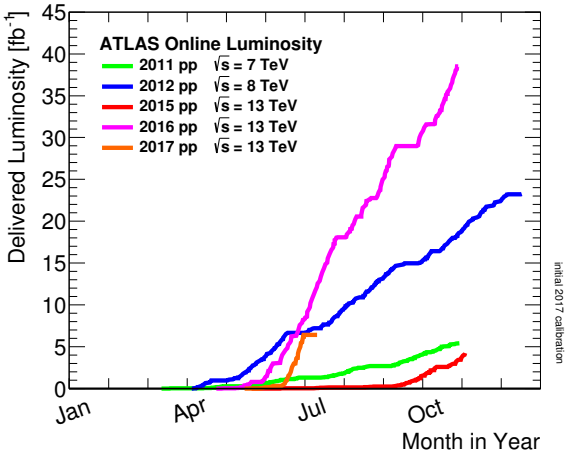


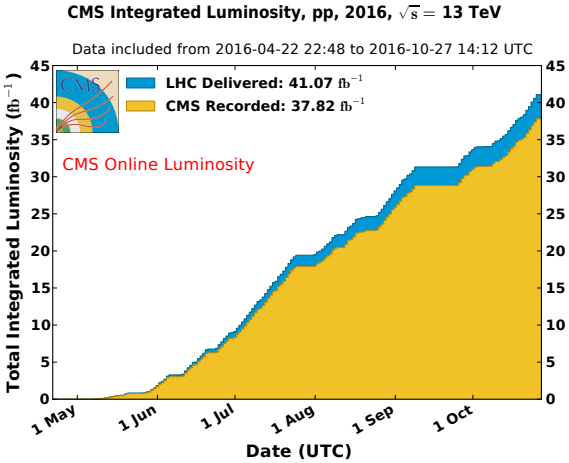


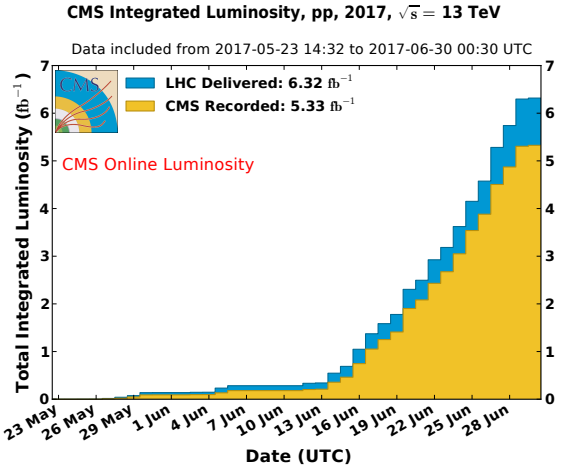


However, in most cases Run 1 measurements were still superior and several "mysteries" persisted...

Status of the ATLAS and CMS experiments and their latest results







Both experiments operated very sucessfully during the 2016 run!

- Over 40 fb^{-1} of *pp* collisions delivered by the LHC to ATLAS and CMS during 2016
- 2017 data taking run already underway, already over 6 fb^{-1} of *pp* collisions delivered!

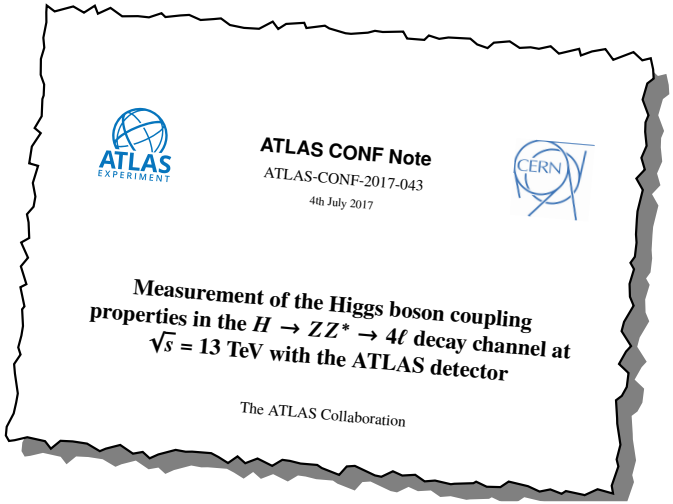
Outline for this summary

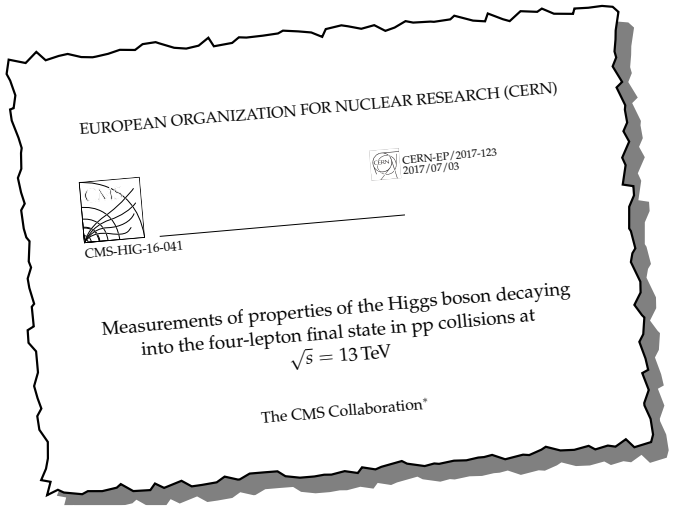
- Focus on results based on the full 2015+2016 dataset (typically over 35 fb^{-1}) and the many new and exciting results prepared for this week's EPS conference
- If a corresponding ATLAS/CMS result is not mentioned, it is likely over 1 year old

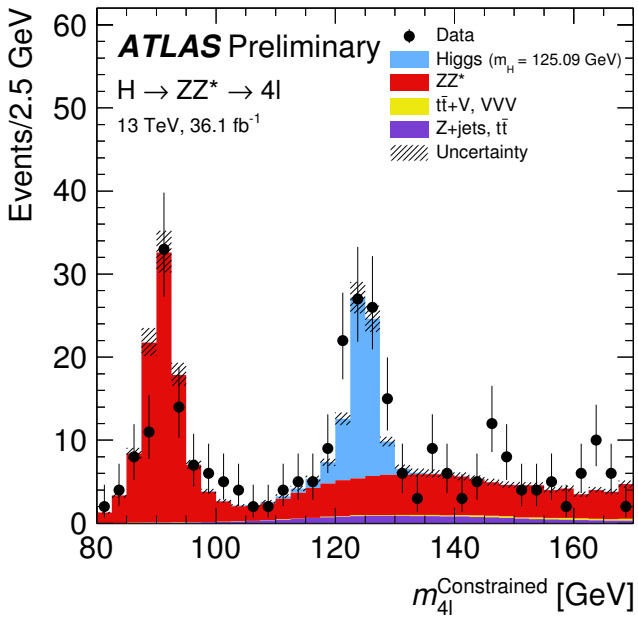
All results shown today along with all other public results can be found here:

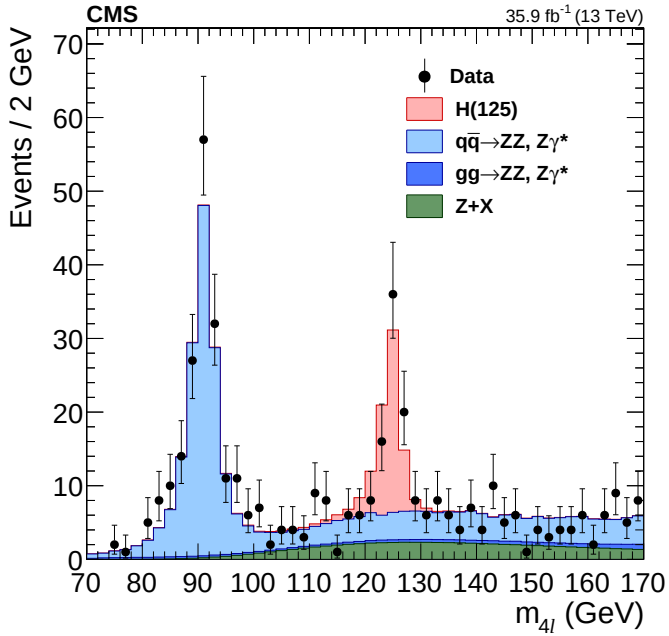
- **ATLAS** - http://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
- **CMS** - http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html

Measurements in the $H \to ZZ^* \to 4\ell$ channel



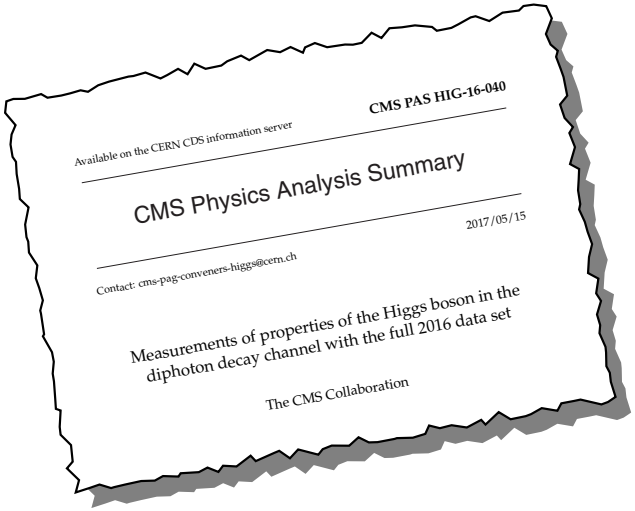


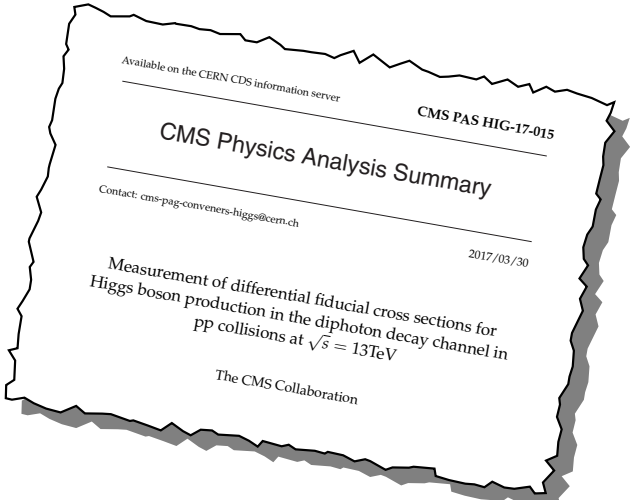


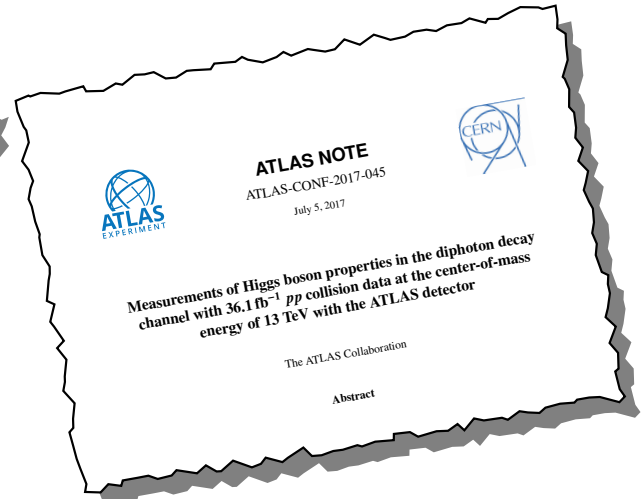


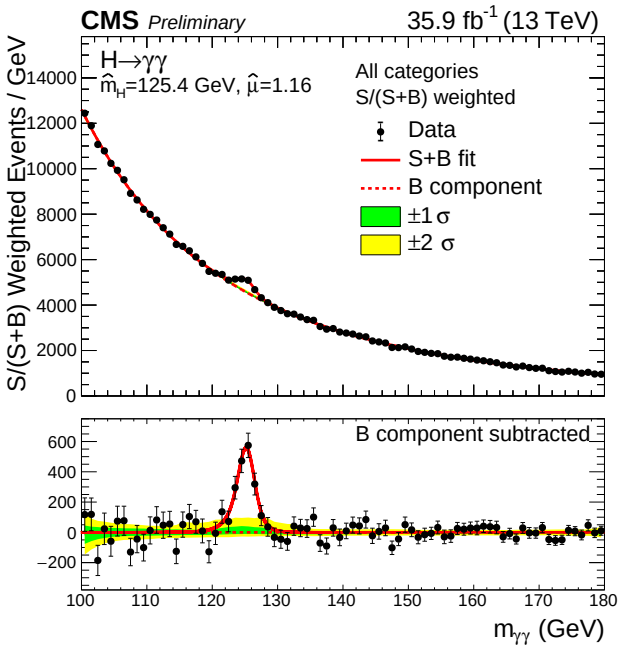
ATLAS and CMS have updated their analyses with over 35 fb^{-1} of 13 TeV data!

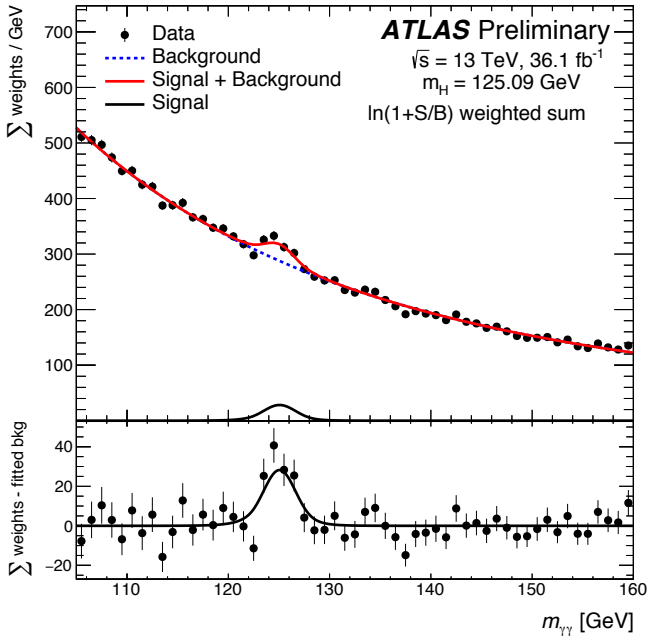
Measurements in the $H \to \gamma\gamma$ channel







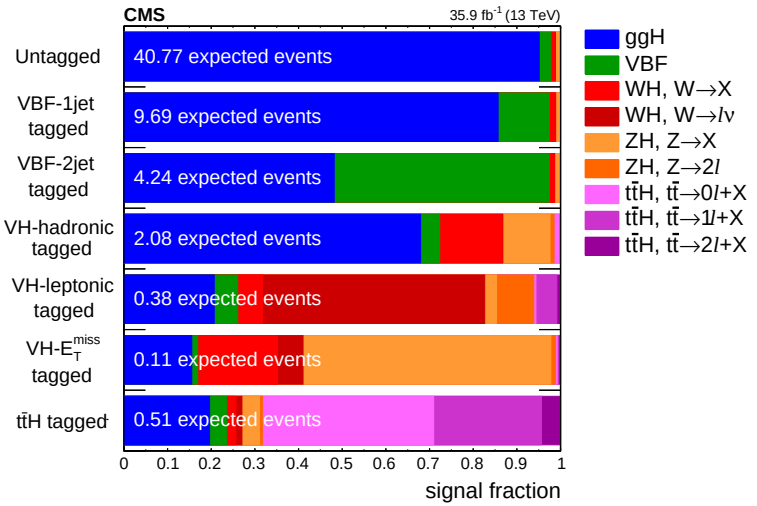




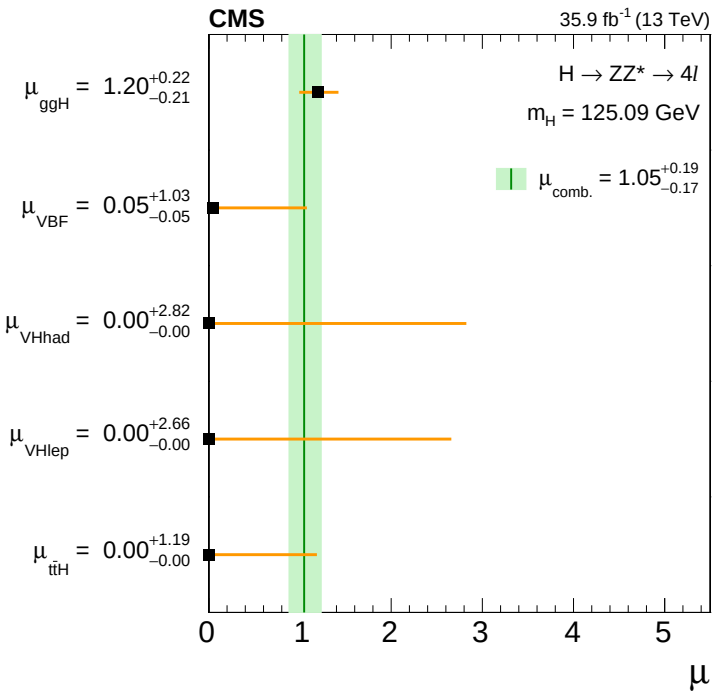
ATLAS and CMS have updated their analyses with over 35 fb^{-1} of 13 TeV data!

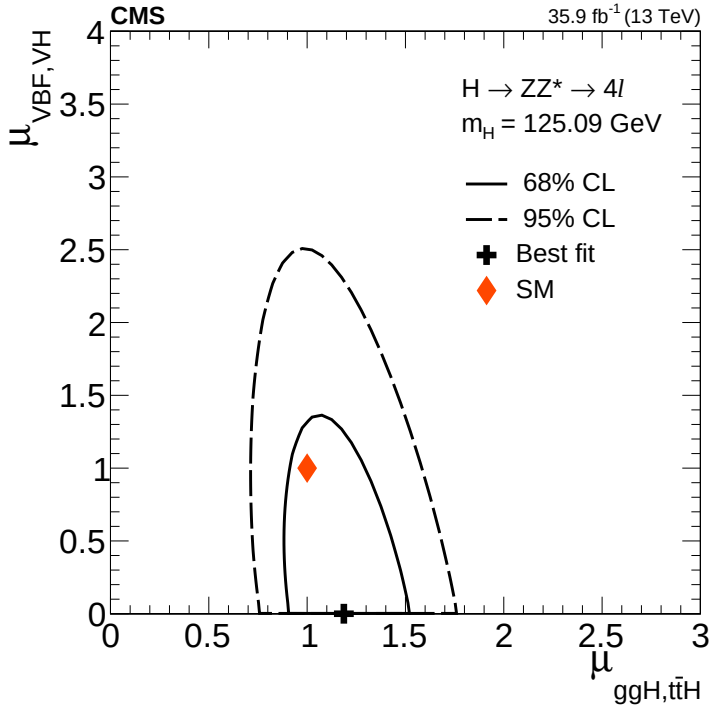
$H \to ZZ^* \to 4\ell$ - CMS Coupling Measurements (arXiv:1706.09936)

- Events categorised to enrich different production mechanisms
- ME-based discriminants used to exploit full production/decay information
- ggF still pervasive and statistics are low in most exclusive categories



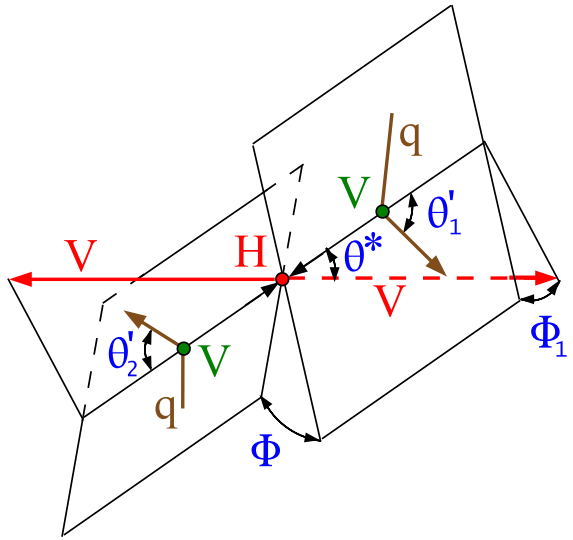
Combined signal strength $\mu = 1.05^{+0.15}_{-0.14}$ **(stat.)** $^{+0.11}_{-0.09}$ **(syst.)**



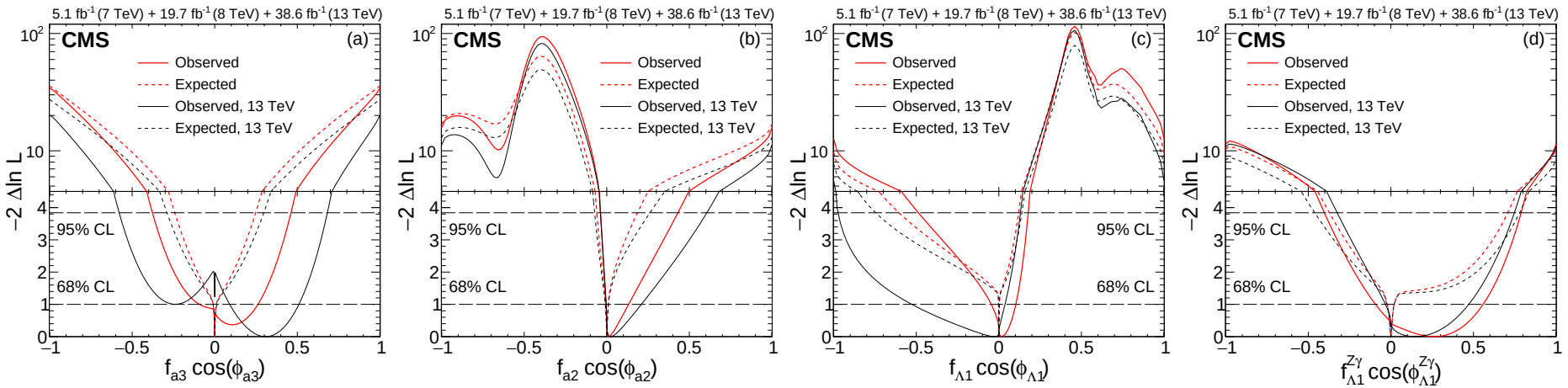


$H \to 4\ell$ - CMS Anomalous Couplings Search (arXiv:1707.00541)

- Use ME techniques to extract coupling information in $H \to 4\ell$ decays including angular observables as input
- Target associated Higgs boson production with two quark jets in either vector boson fusion or associated production with a vector boson
- Measure product of effective cross-section ratios f_{ai} and phases ϕ_{ai} sensitive to anomalous Higgs interactions



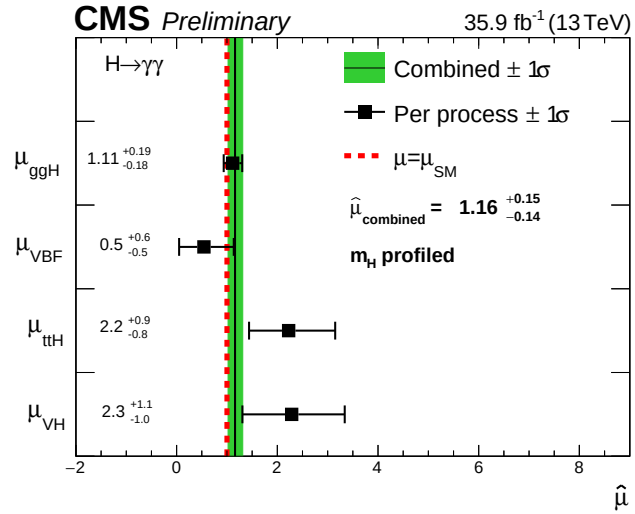
All observations consistent with expectations for SM Higgs boson...

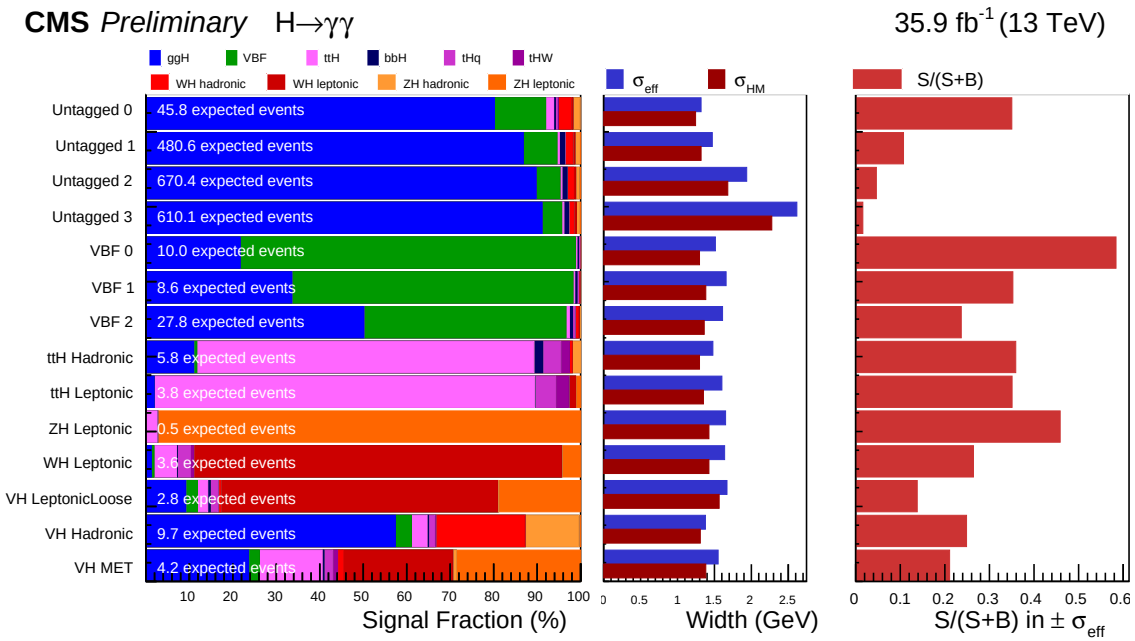


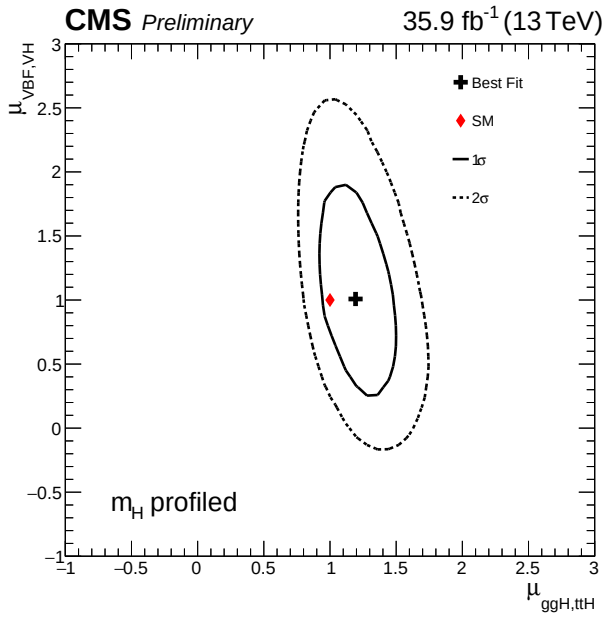
Comparable ATLAS results in ATLAS-CONF-2017-043, also consistent with SM...

$H \to \gamma\gamma$ - CMS Coupling Measurements (CMS-PAS-HIG-16-040)

- Events categorised into VBF-like, $t\bar{t}H$-like, VH-like and "untagged" based on event properties and BDT classifiers for VBF and $t\bar{t}H$
- Best fit for $t\bar{t}H$ $\mu = 2.2^{+0.9}_{-0.8}$, corresponding to 3.3σ significance w.r.t. the absence of $t\bar{t}H$ production



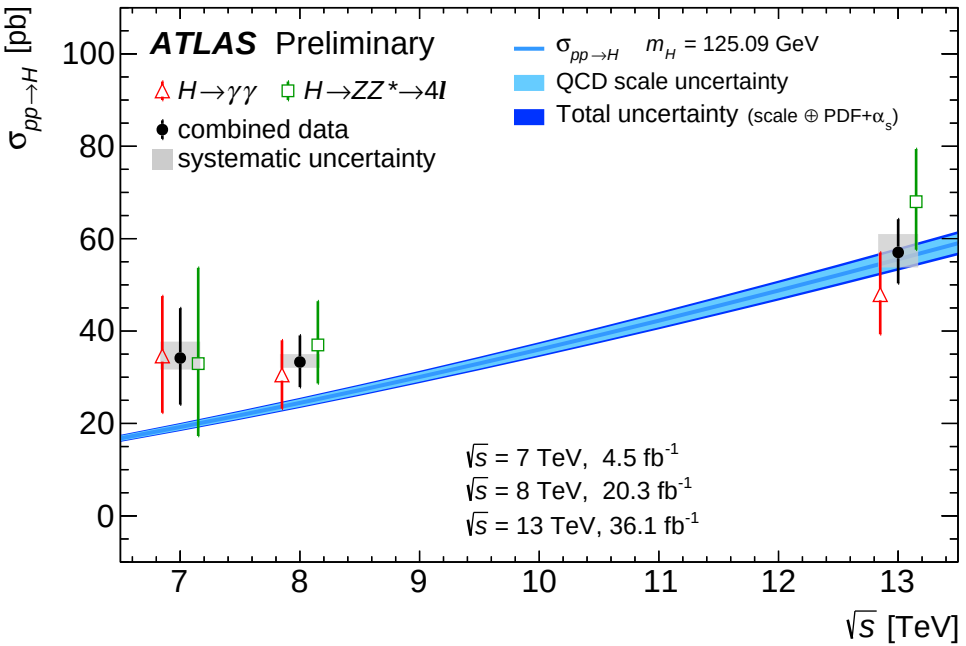


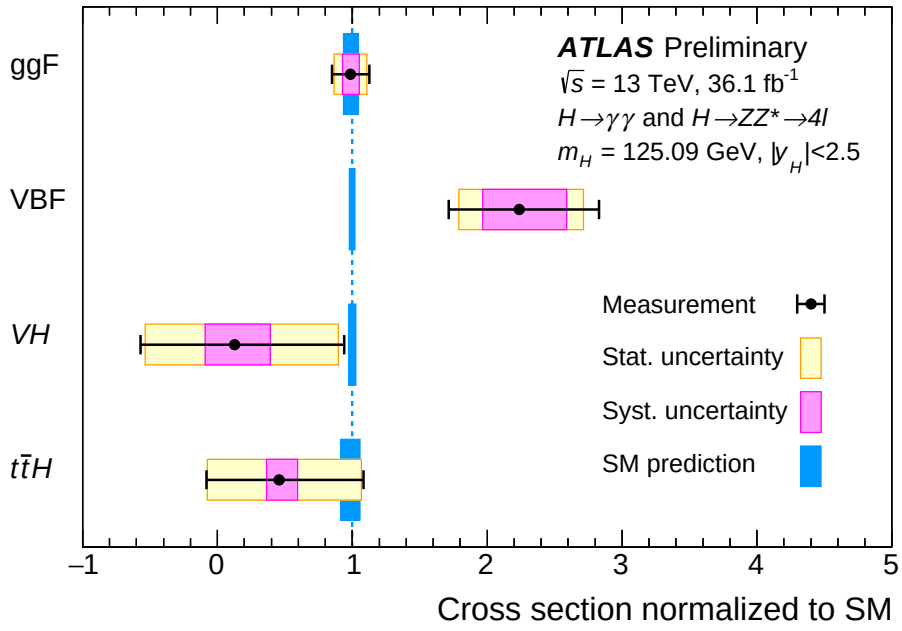


Combined signal strength $\mu = 1.16^{+0.11}_{-0.09}$ (stat.)$^{+0.08}_{-0.10}$ (syst.)$^{+0.06}_{-0.05}$ (theo.)

$H \to 4\ell$ and $H \to \gamma\gamma$ - Rates and couplings (ATLAS-CONF-2017-047)

Combined coupling and total cross section measurements with $H \to 4\ell$ and $H \to \gamma\gamma$

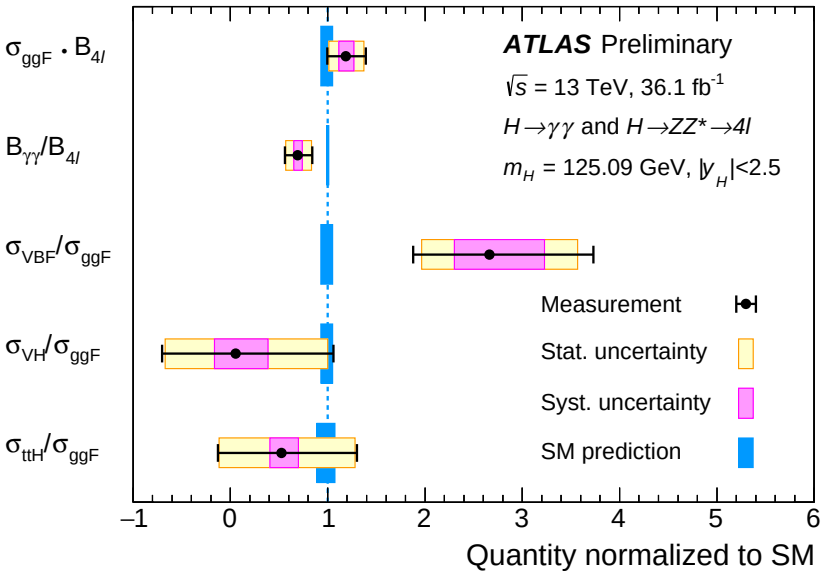


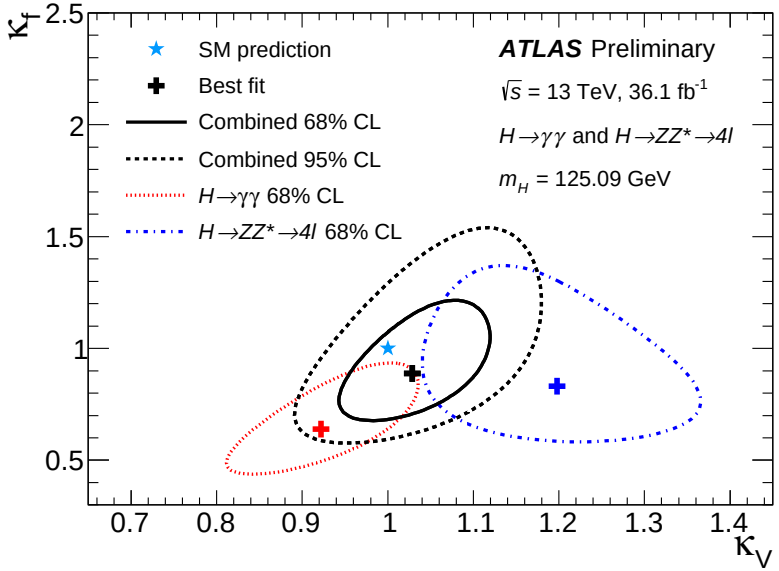


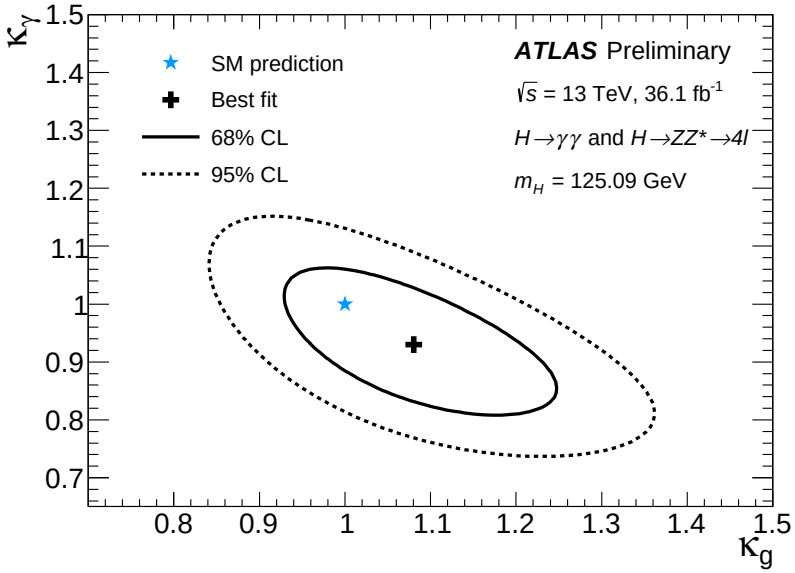
- Total $pp \to H + X$ cross sections compared to SM predictions at up to N^{3}LO QCD (with POWHEG NNLOPS acceptance corr.)
- Cross sections for ggF, VBF, VH, and $t\bar{t}H$ shown normalised to the SM predictions (assumption of SM branching fractions)
- While ggF rate is very consistent with SM, VBF rate is in excess of SM prediction

Many more measurements in the individual notes:
ATLAS-CONF-2017-045 ($\gamma\gamma$) and ATLAS-CONF-2017-043 (4ℓ)

Combined $H \to 4\ell$ and $H \to \gamma\gamma$ total cross-section ratios and κ couplings



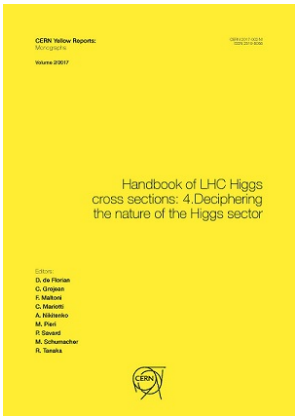


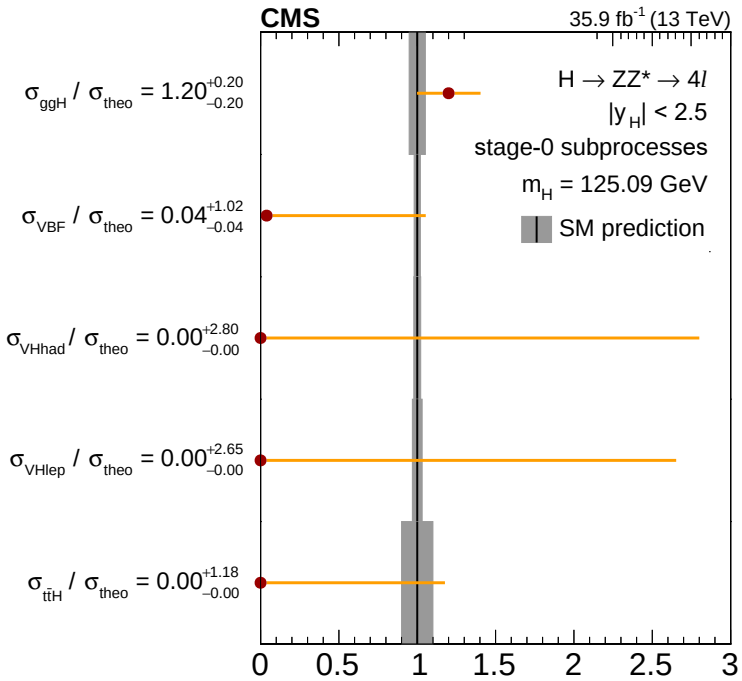


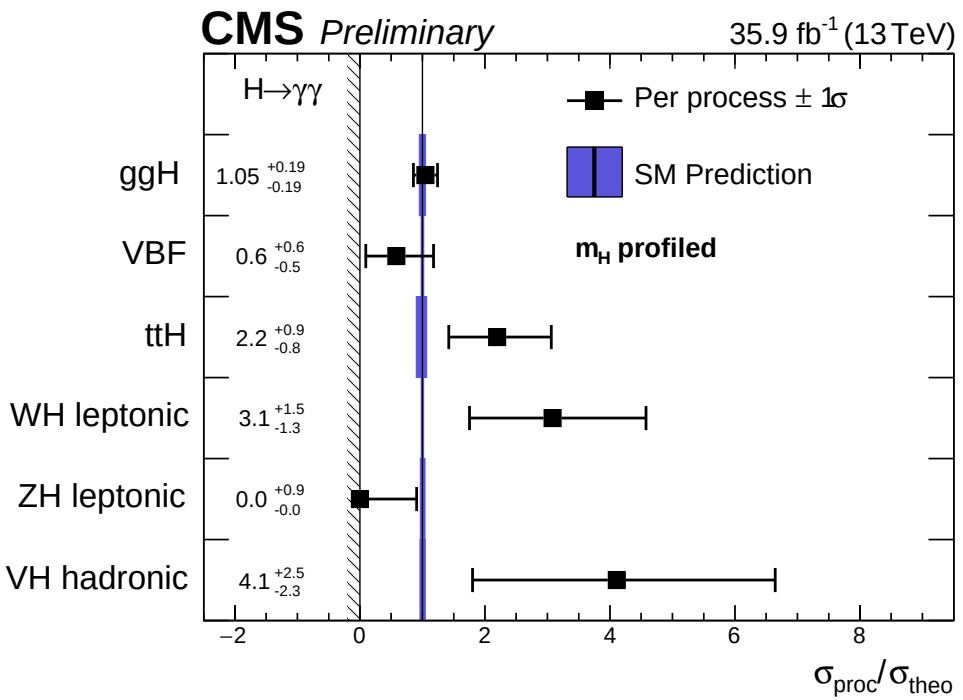
- Braching fraction ratio $B(H \to \gamma\gamma)/B(H \to 4\ell)$ measured to be slightly below SM expectation
- Individual channels prefer κ_V value lower/higher than SM, though combination consistent with SM

CMS Simplified Template Cross-sections

- Measurement strategy detailed in LHC-HXSWG YR4
- Cross-section for Higgs production in for various sub-processes for a simplified fiducial volume defined as $|y_H| < 2.5$
- Theoretical uncertainties on overall signal cross sections are removed but kept if they cause migration between categories

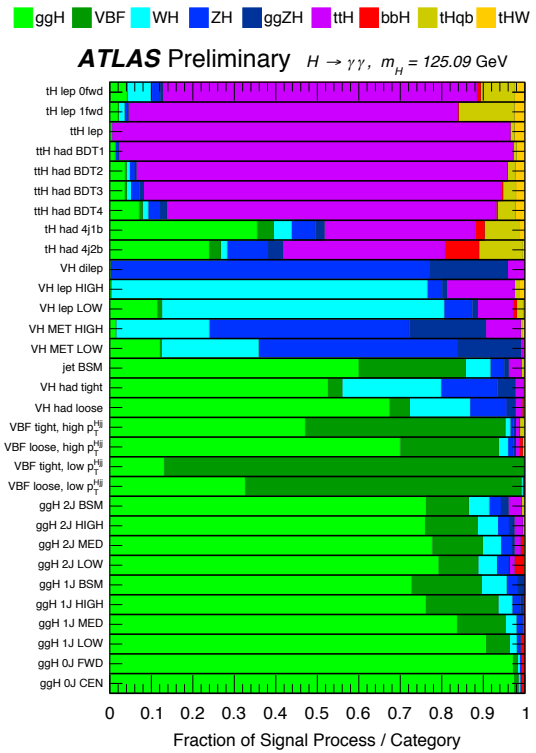


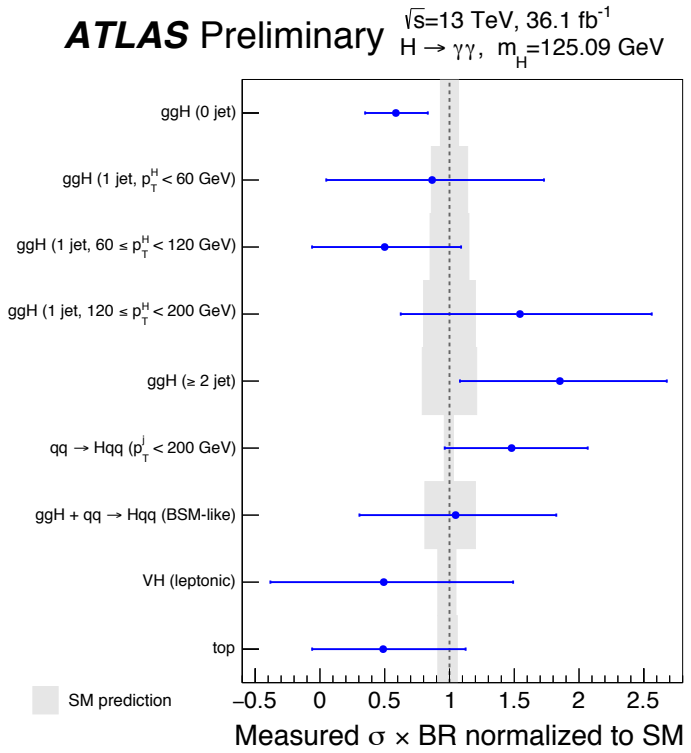


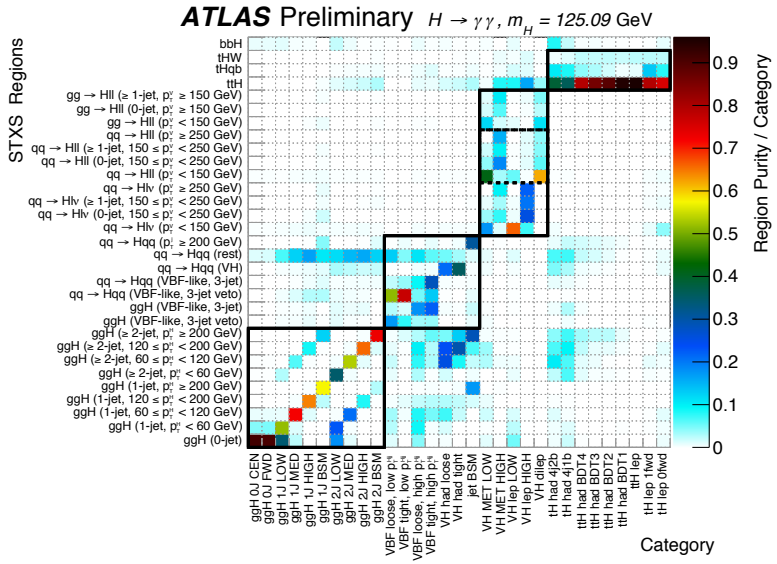


ST cross sections for the stage 0 sub-processes, normalised to the SM prediction

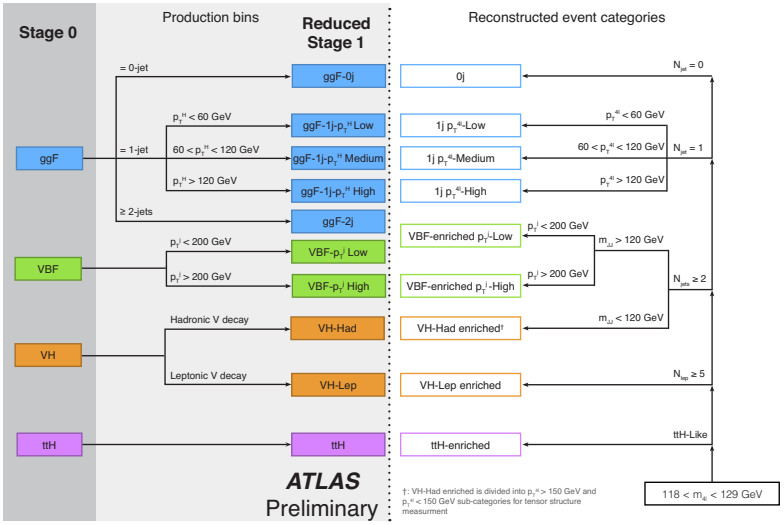
ST Cross-sections with $H \to \gamma\gamma$ (ATLAS-CONF-2017-045)

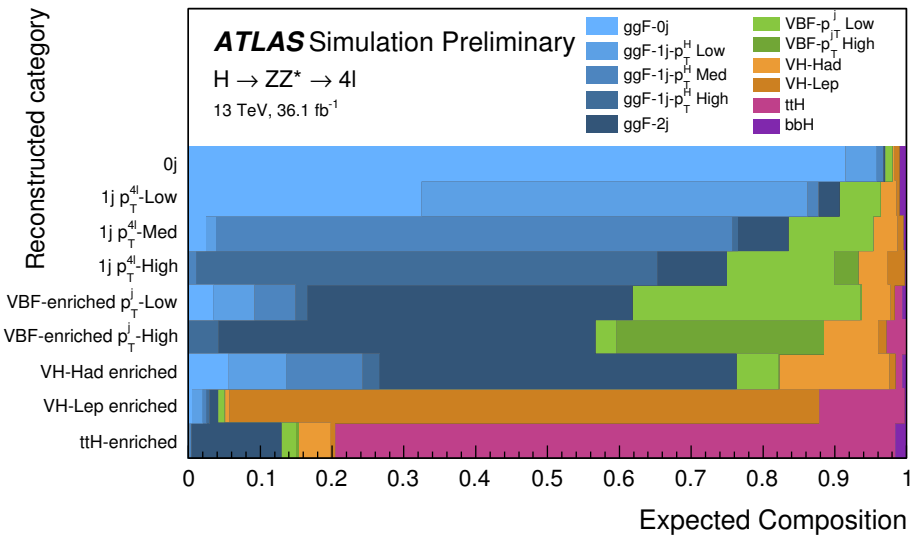


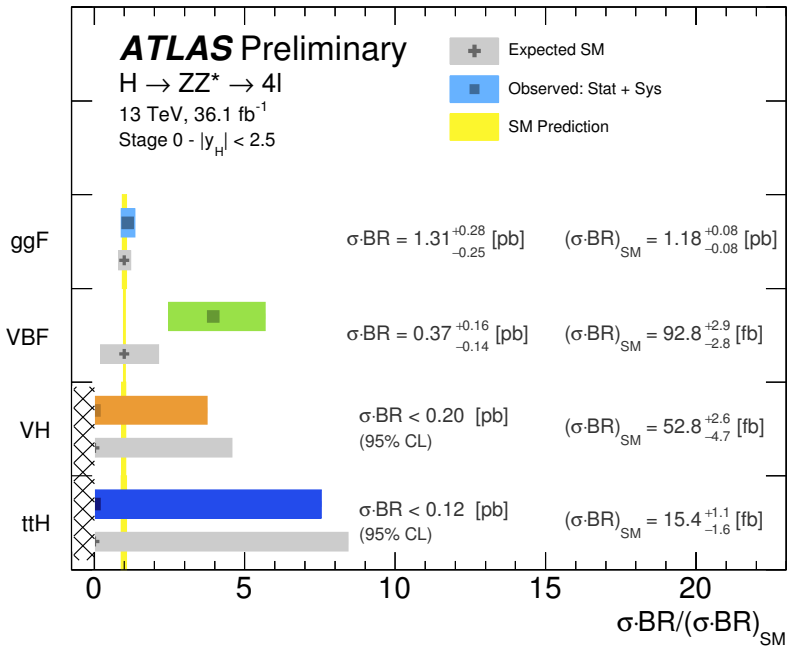


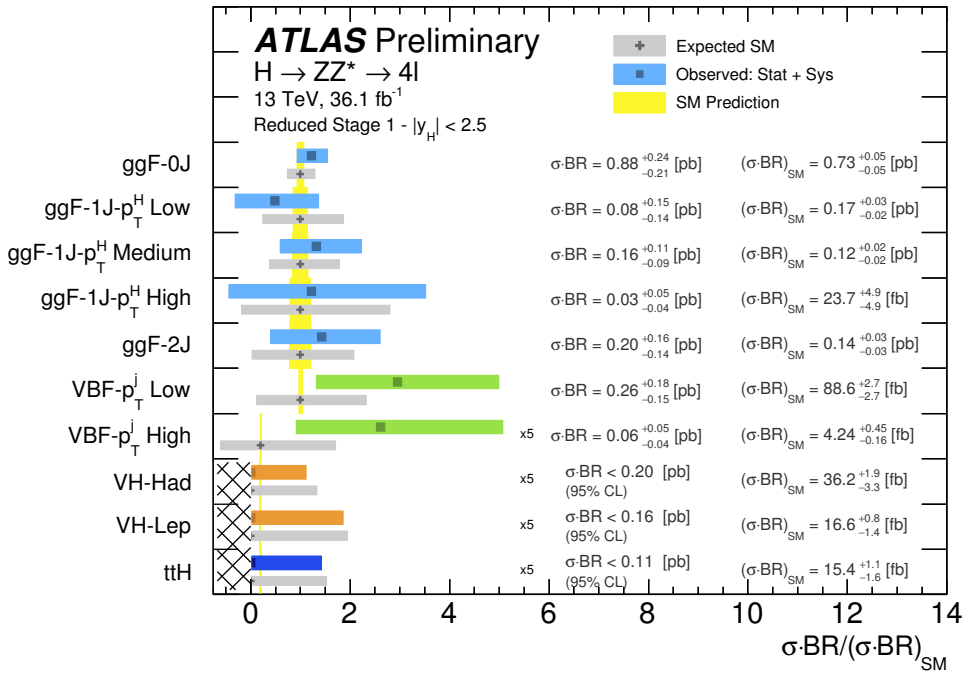


ST Cross-sections with $H \to ZZ^* \to 4\ell$ (ATLAS-CONF-2017-043)



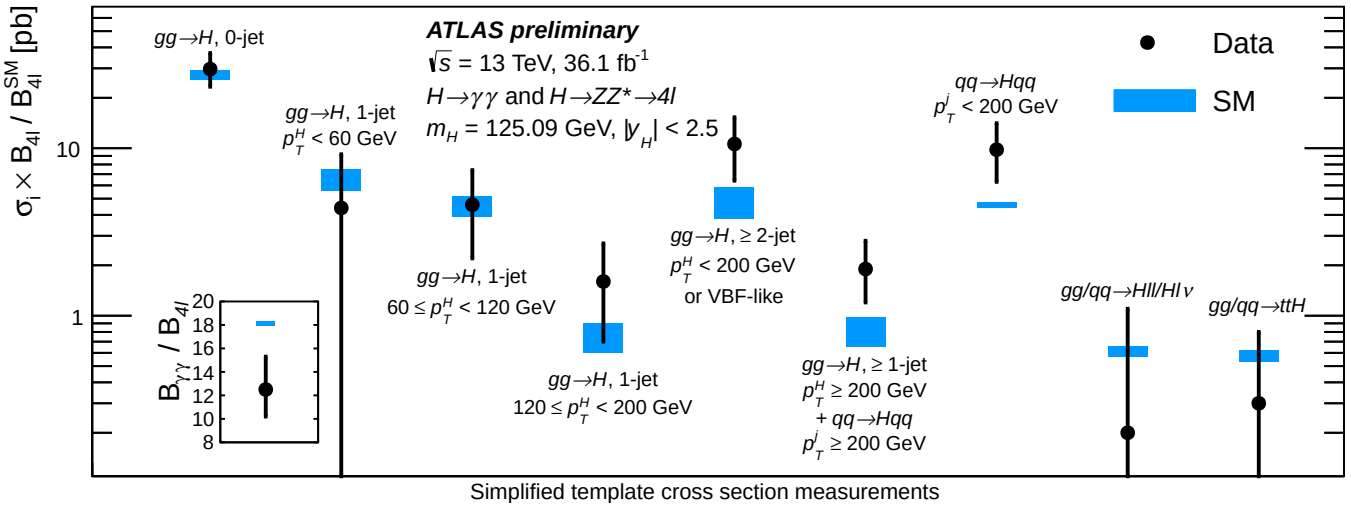


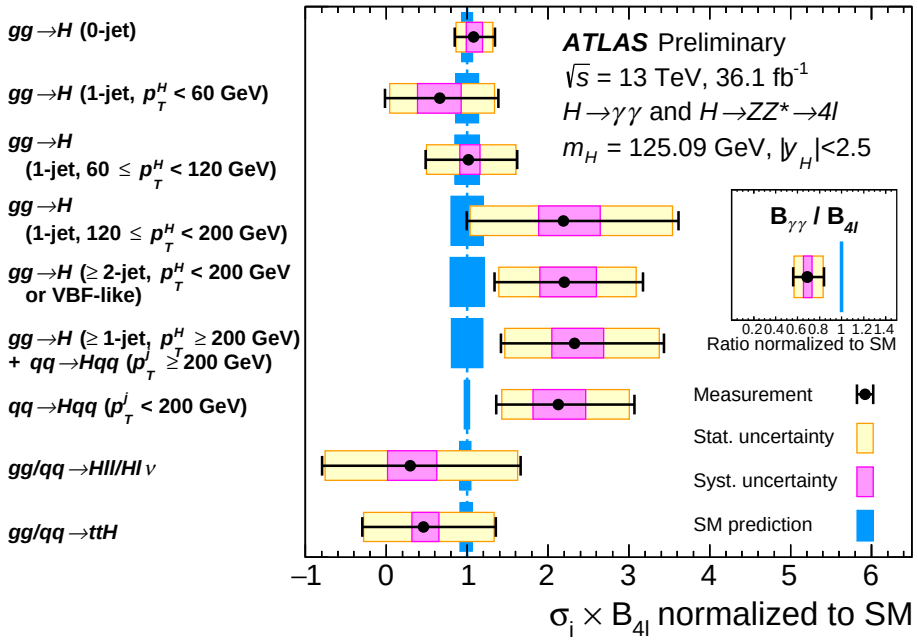




SM normalised ST cross-sections for the stage 0 (left) and reduced stage 1 (right)

ATLAS Simplified Template Cross-sections for combination of $H \to 4\ell$ and $H \to \gamma\gamma$





- Performed for merged STXS stage-1 regions, both absolute (top) and normalised to SM prediction (left)
- Measurements in regions with ≥ 2 jets and/or high p_T^H slightly in excess of SM prediction?

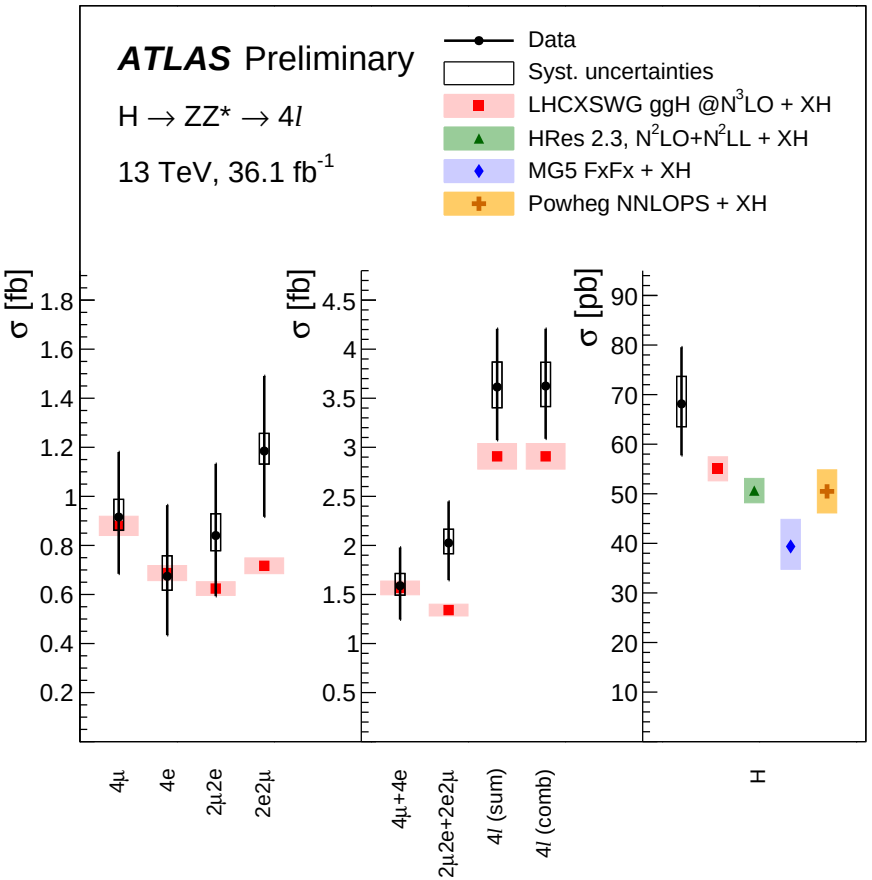
Fiducial and Differential Cross-section Measurements in the $H \to ZZ^* \to 4\ell$ and $H \to \gamma\gamma$ channels

New 36 fb^{-1} results from ATLAS and CMS in $H \to 4\ell$ and $H \to \gamma\gamma$ channels

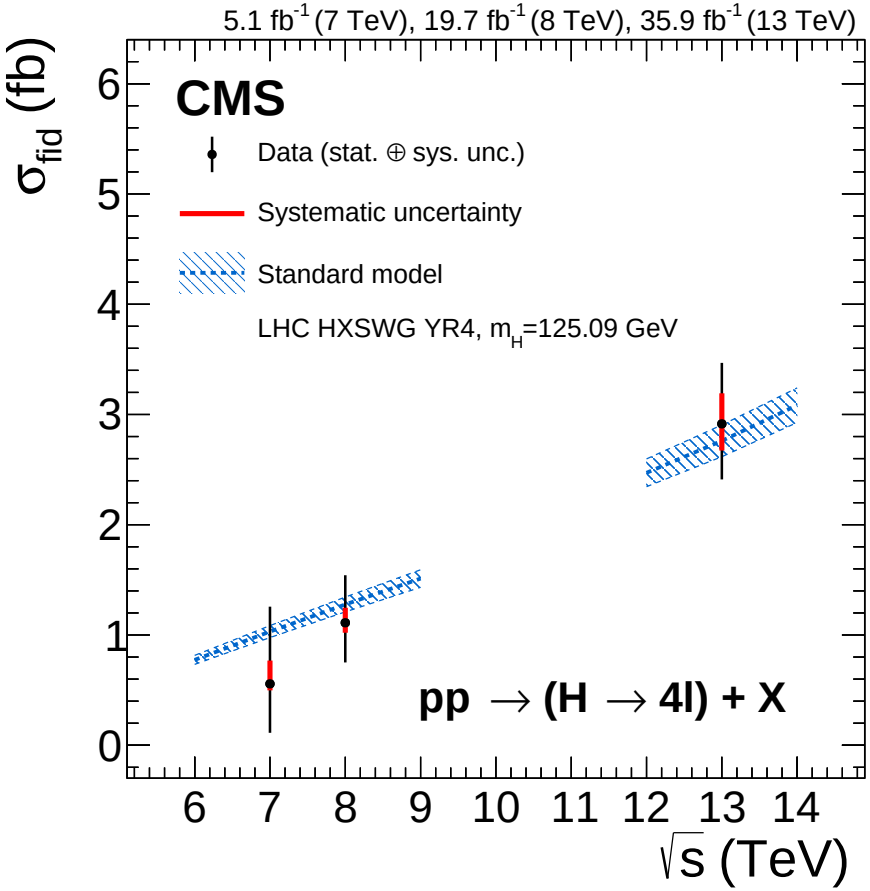
- Model independent total cross sections measured in a fiducial volume closely matched to experimental acceptance
- Decouple theory and experimental uncertainties (contrary to traditional signal strength)
- Compared to latest YR4 cross-sections including ggF prediction at N^{3}LO

$H \to ZZ^* \to 4\ell$ - Incusive Fiducial Cross-section Measurements

ATLAS (CONF-2017-032)



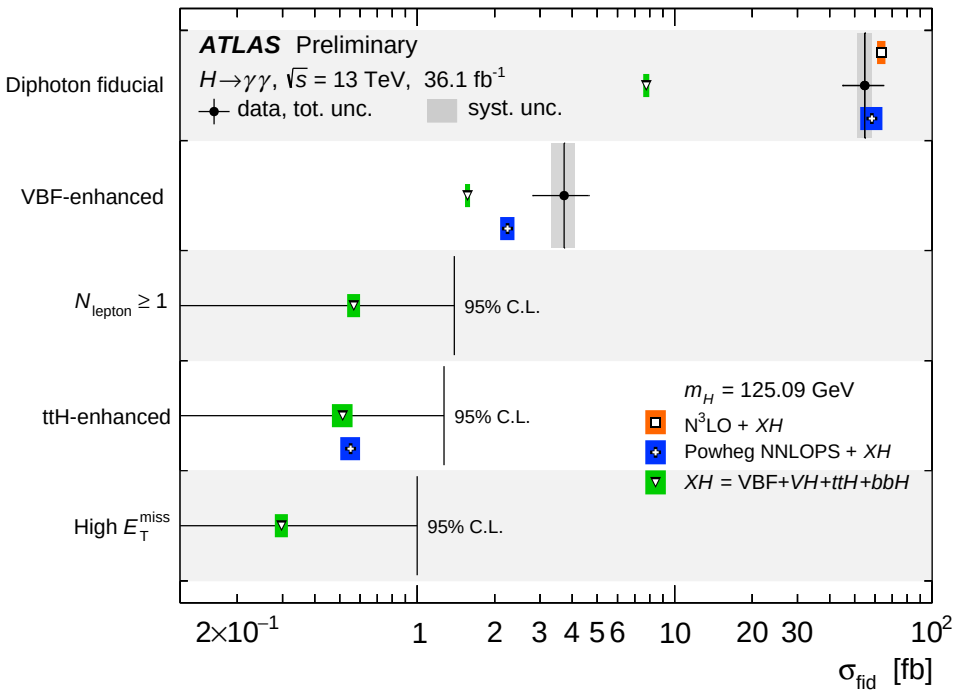
CMS (arXiv:1706.09936)



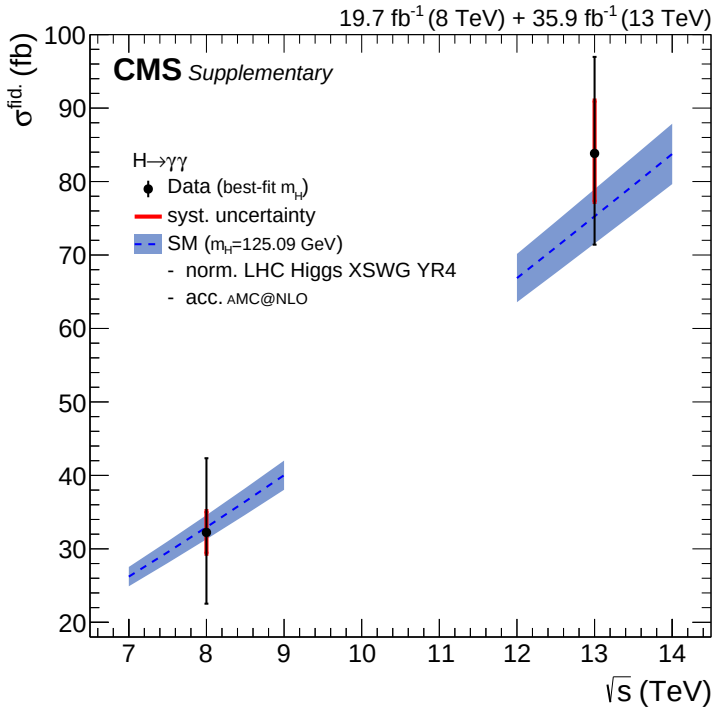
- Both experiments use a comparable fiducial volume
- All total cross sections from YR4 with acceptances calculated using POWHEG NNLOPS simulation (HRES for 7/8 TeV CMS reuslt)

$H \to \gamma\gamma$ - Incusive Fiducial Cross-section Measurements

ATLAS (CONF-2017-045)



CMS (PAS-HIG-17-015)



- Compared to acceptance corrected (with Powheg NNLOPS) N^{3}LO prediction (arXiv:1602.00695)
- $|\eta^\gamma| < 1.37$ or $1.52 < |\eta^\gamma| < 2.37$ and (sub-)leading photon must be greater than (0.25) 0.35

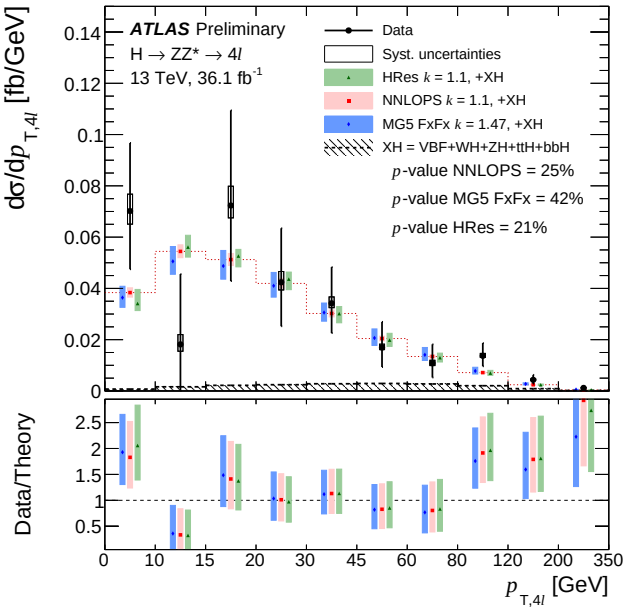
- Compared to MADGRAPH_aMC@NLO prediction normalised to HXSWG YR4 total cross-section
- $|\eta^\gamma| < 2.5$ and (sub-)leading photon $p_T^\gamma / m_{\gamma\gamma}$ must be greater than (1/4) 1/3

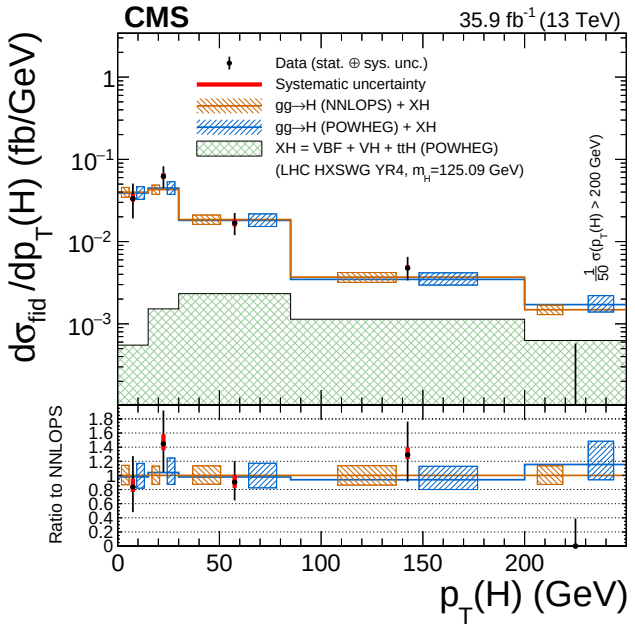
Higgs p_T distribution

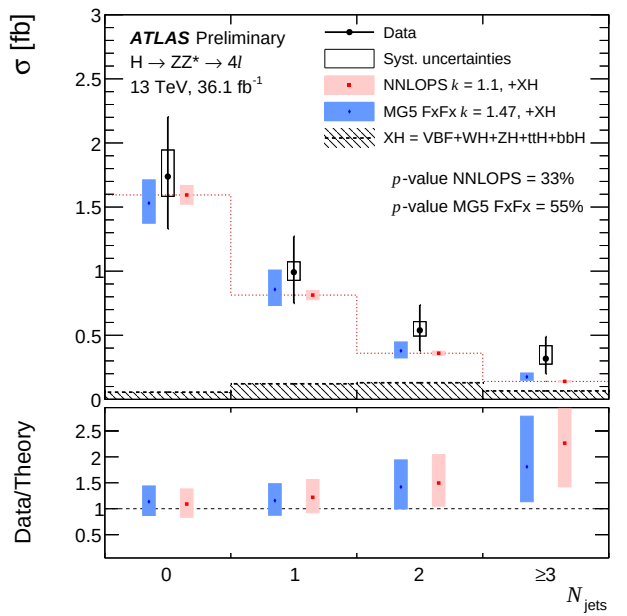
- Sensitive to perturbative QCD predictions

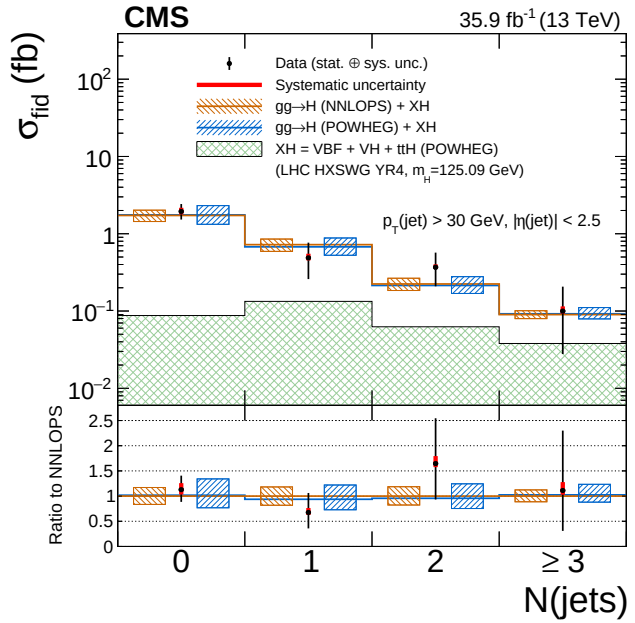
N_{jet} distribution

- Sensitive to production mode composition and gluon emission



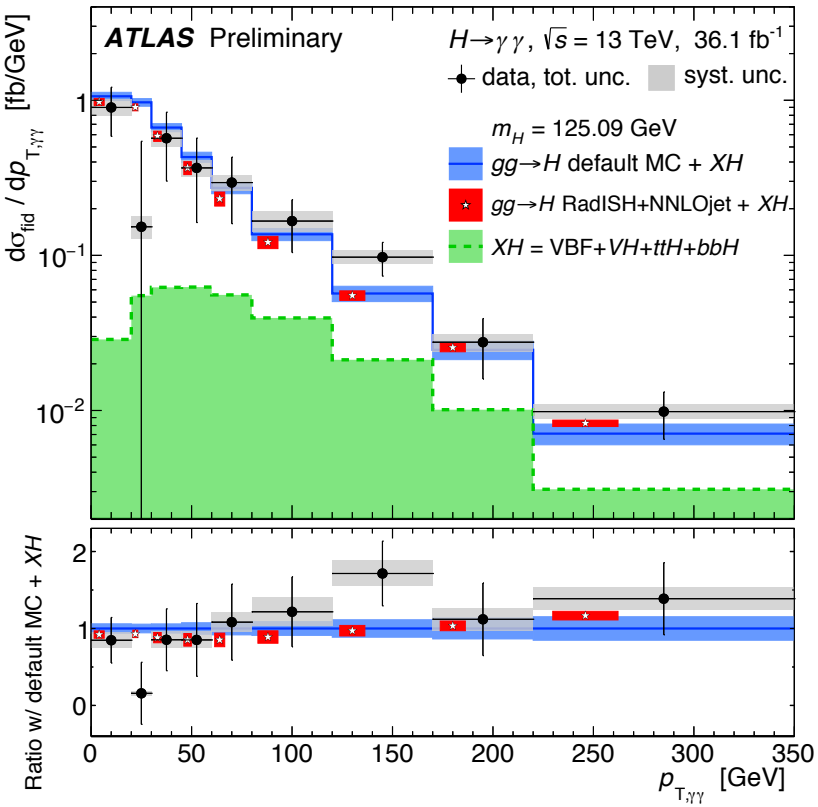


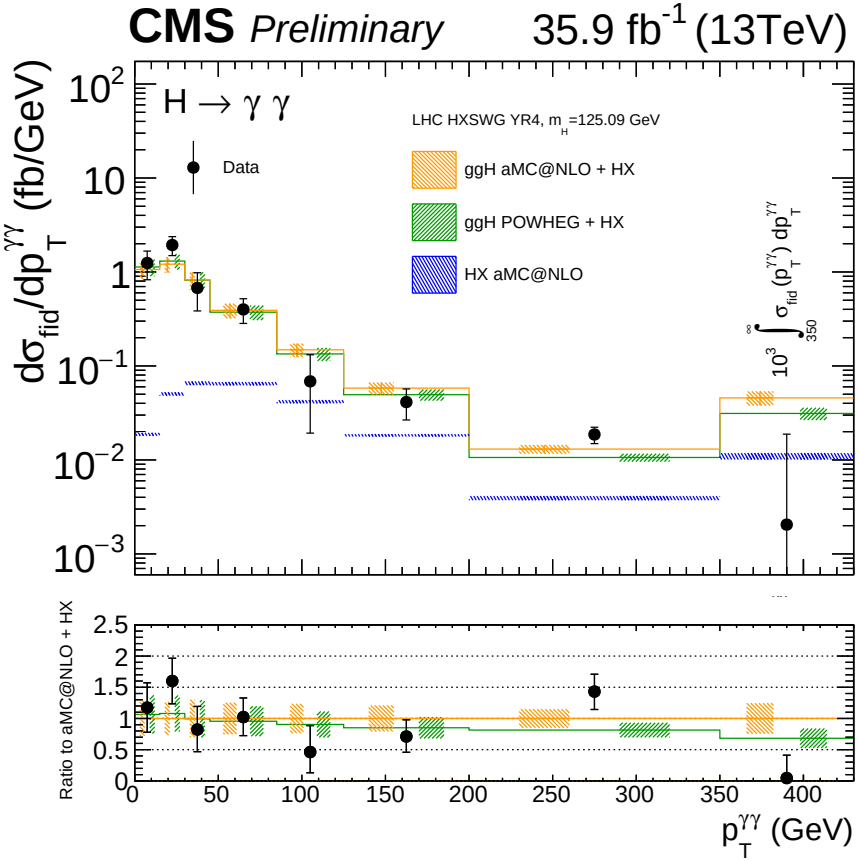




$H \to \gamma\gamma$ - Differential Fiducial Cross-section Measurements

p_T^H distribution





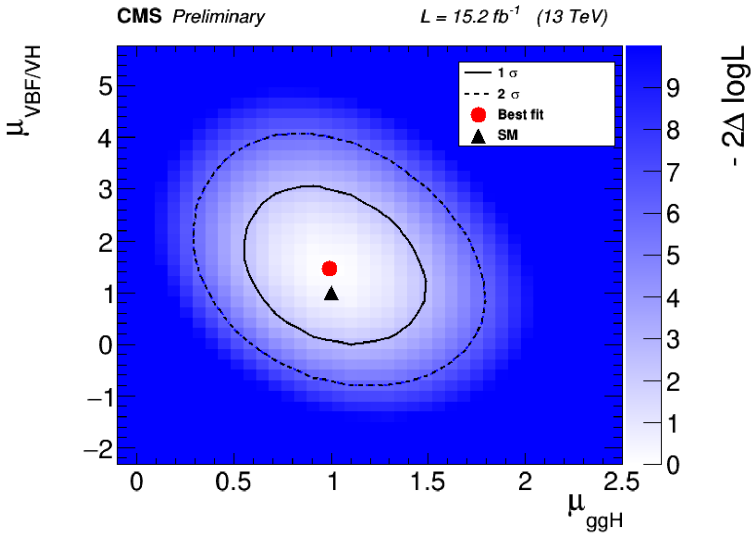
- Both p_T^H measurements with $H \to \gamma\gamma$ find distribution broadly compatible with SM prediction
- Though perhaps some hint for excess at high p_T^H, as seen on previous slide with $H \to 4\ell$?

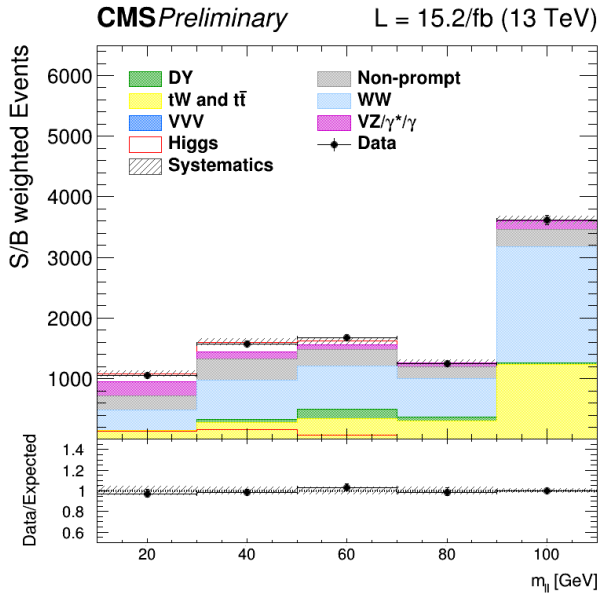
$H \to WW$ - Latest CMS update (CMS-PAS-HIG-16-021)

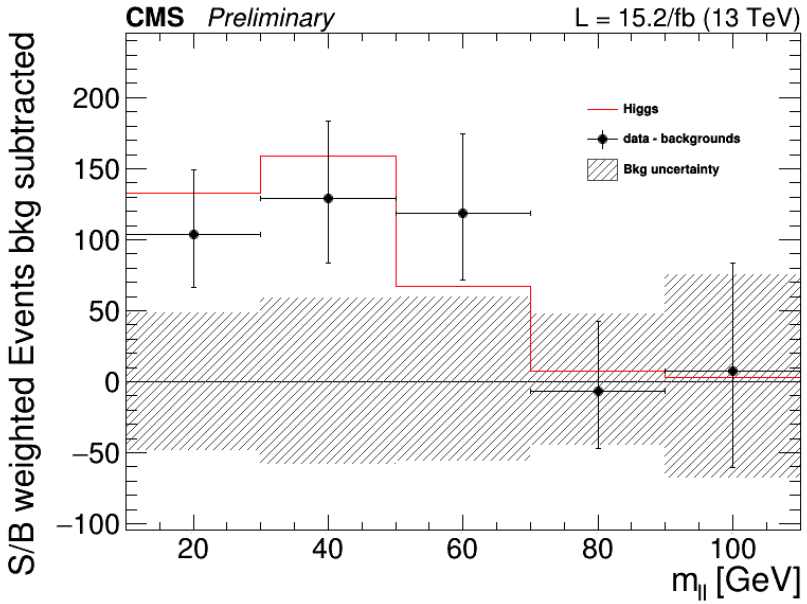
Latest news from LHC on $H \to WW$

- Performed with 15.2 fb^{-1} of 13 TeV data in $W(e\nu)W(\mu\nu)$ channel
- Specific categories for ggF, VBF and VH production

Observe (expect) combined significance of $4.3\,(4.1)\sigma$ and measure $\mu = 1.05^{+0.27}_{-0.25}$

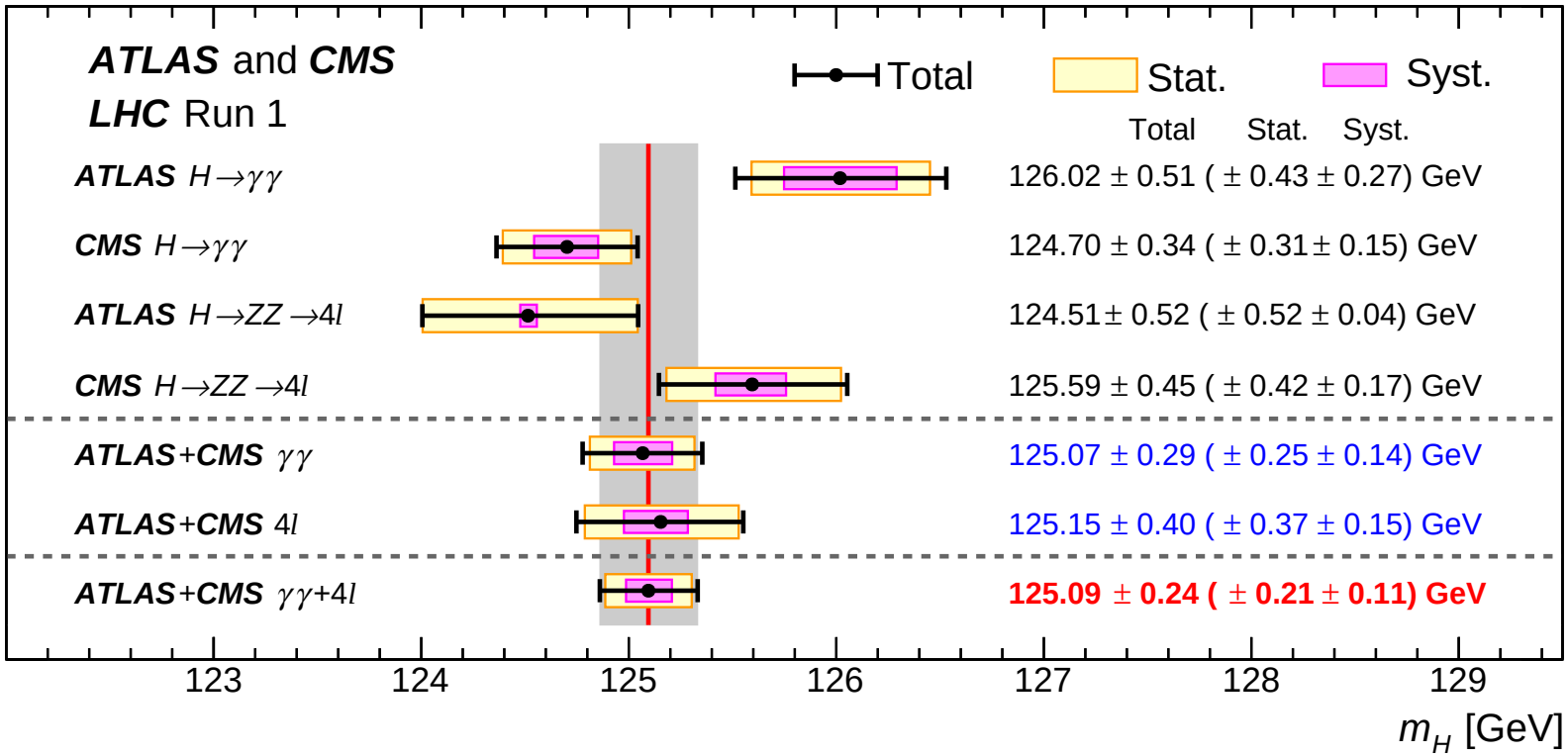






Can look forward to further from ATLAS and CMS with larger 13 TeV datasets soon!

Latest updates on m_H and Γ_H



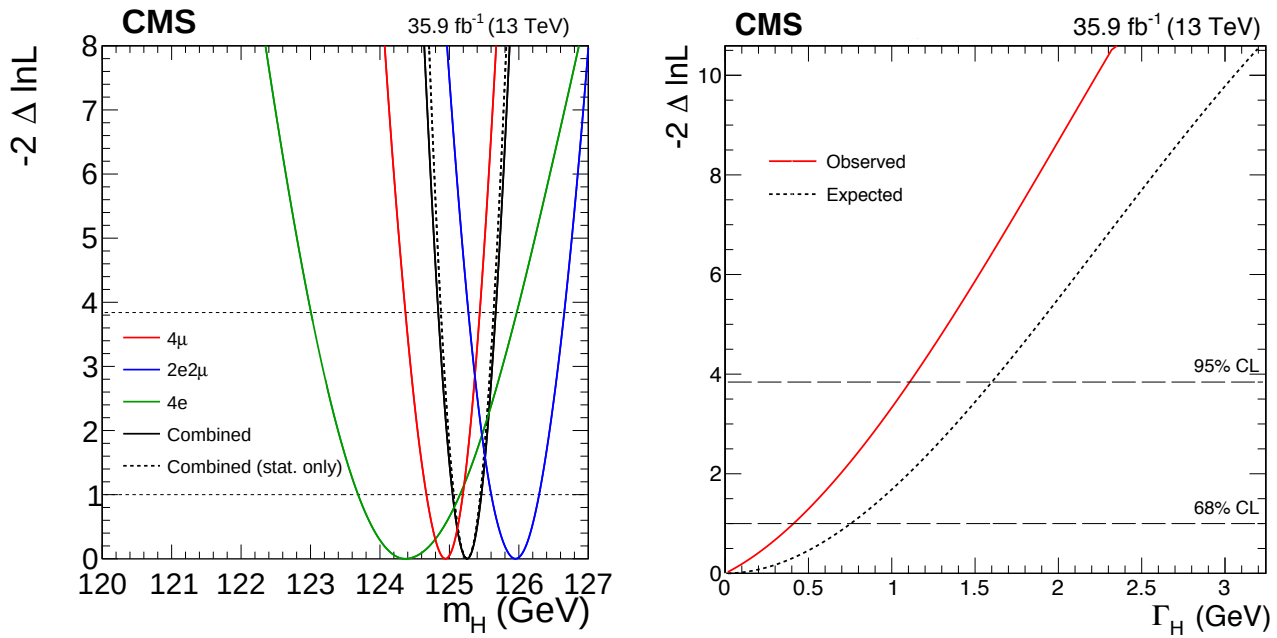
ATLAS and CMS Phys. Rev. Lett. 114 (2015) 191803 (arXiv:1503.07589)

- Precision an m_H achieved in Run 1 was already very impressive!
- However, Run 1 measurements were limited by statistical uncertainties...
- What can the larger Run 2 datasets offer?

m_H and Γ_H - Latest measurements with $H \to 4\ell$ (arXiv:1706.09936)

$m_H = 125.26 \pm 0.20$ (stat.) ± 0.08 (syst.) GeV

- Exploit kinematic fit and per-lepton resolution information, precision on m_H limited by stat. unc., syst. unc. dominated by lepton momentum scale unc.
- Precision at level of Run 1 ATLAS+CMS combination! (125.09 ± 0.21 (stat.) ± 0.11 (syst.) GeV)



$\Gamma_H < 1.10$ GeV at 95% CL

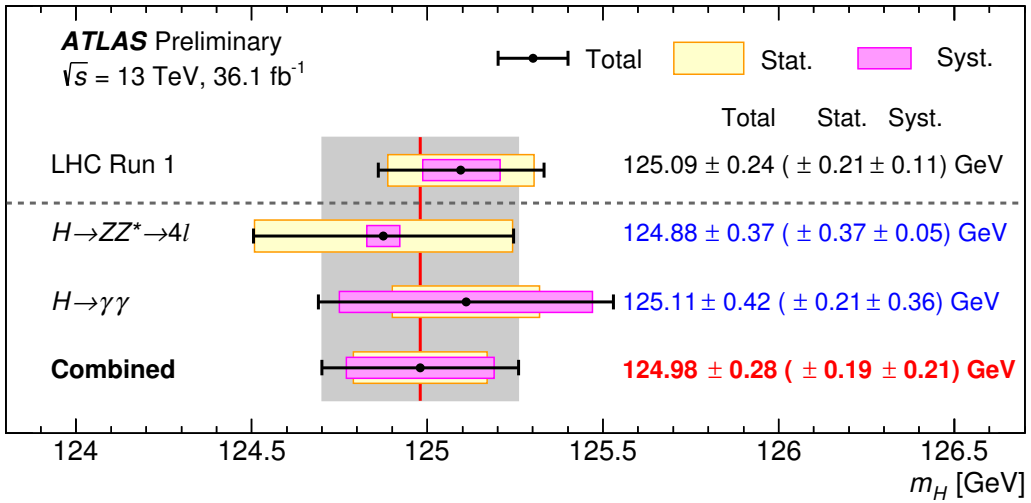
- ✓ Direct measurement with on-shell production, no assumptions on BSM physics
- ✗ Measurement limited by $m_{4\ell}$ resolution, only sensitive at the ~ 1 GeV level

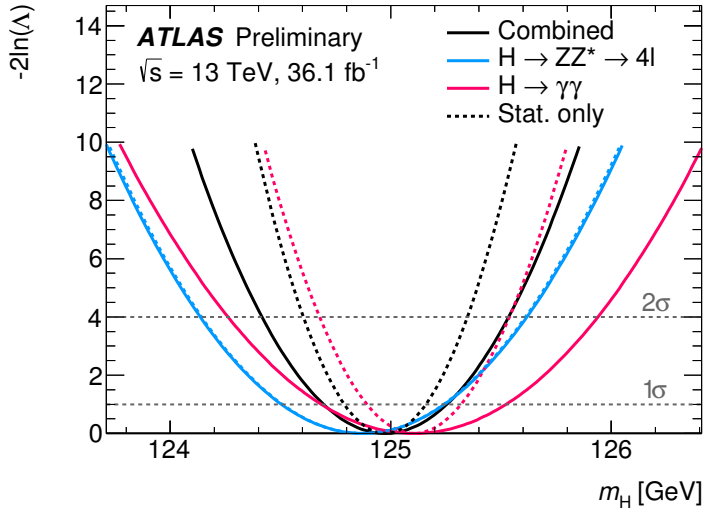
m_H - Latest ATLAS measurement (ATLAS-CONF-2017-046)

Combined measurement in $H \to 4\ell$ and $H \to \gamma\gamma$ channels:
$m_H = 124.98 \pm 0.19$ (stat.) ± 0.21 (syst.) GeV

- Per-event method used in $H \to 4\ell$ case, cross-checked with template method
- Likelihood fit with analytical PDF used for $H \to \gamma\gamma$ channel
- Uncertainty on combined m_H value dominated by systematics

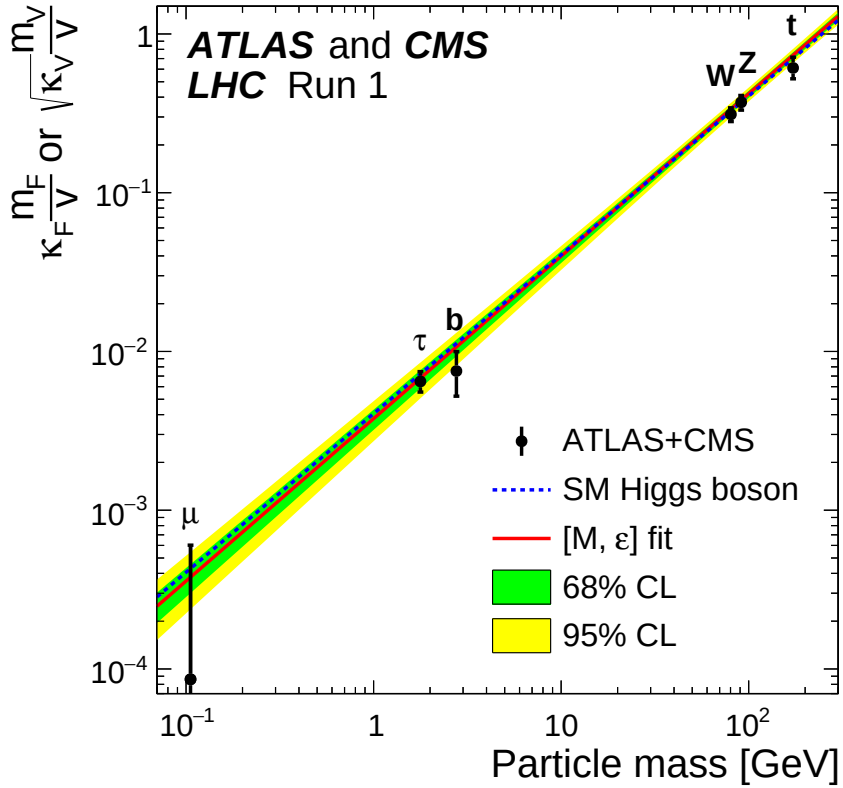
Source	Systematic uncertainty on m_H [MeV]
LAr cell non-linearity	90
LAr layer calibration	90
Non-ID material	60
ID material	50
Lateral shower shape	50
$Z \to ee$ calibration	30
Muon momentum scale	20
Conversion reconstruction	20





Improved precision from both experiments, while $H \to 4\ell$ still very much statistically limited, the ATLAS $H \to \gamma\gamma$ uncertainty is now dominated by systematics!

Searches targeting the fermion Yukawa couplings



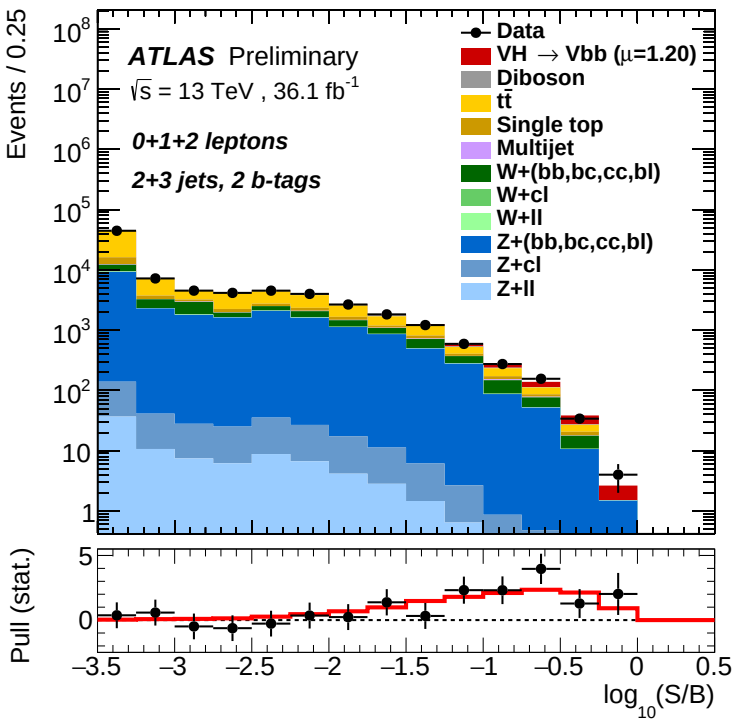
- This time last year, the Run 1 ATLAS and CMS couplings combination summarised our best knowledge of the fermion couplings
- Notable unsatisfactorily large uncertainty on muon coupling while *b* quark coupling seems to deviate slightly from the Yukawa trend

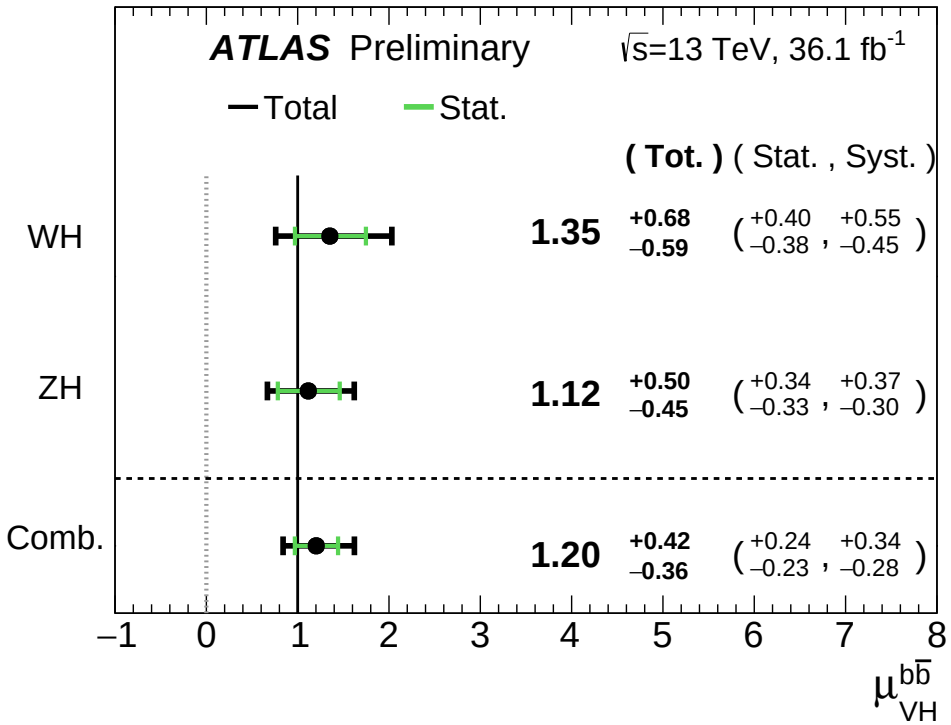
What progress has been made recently?

Search for $H \to b\bar{b}$ - Assoc. VH Production (ATLAS-CONF-2017-041)

VH channel traditionally expected to be brightest hope of finding $H \to b\bar{b}$ at LHC

- Search for events with 0, 1 or 2 leptons ($Z \to \nu\nu$, $W \to \ell\nu$ and $Z \to \ell\ell$) and ≥ 2 b-tagged jets, focus on high p_T^V events to suppress V + jets and $t\bar{t}$ background
- BDT trained on kinematic variables for each channel (0, 1, 2ℓ) used as S/B discriminant

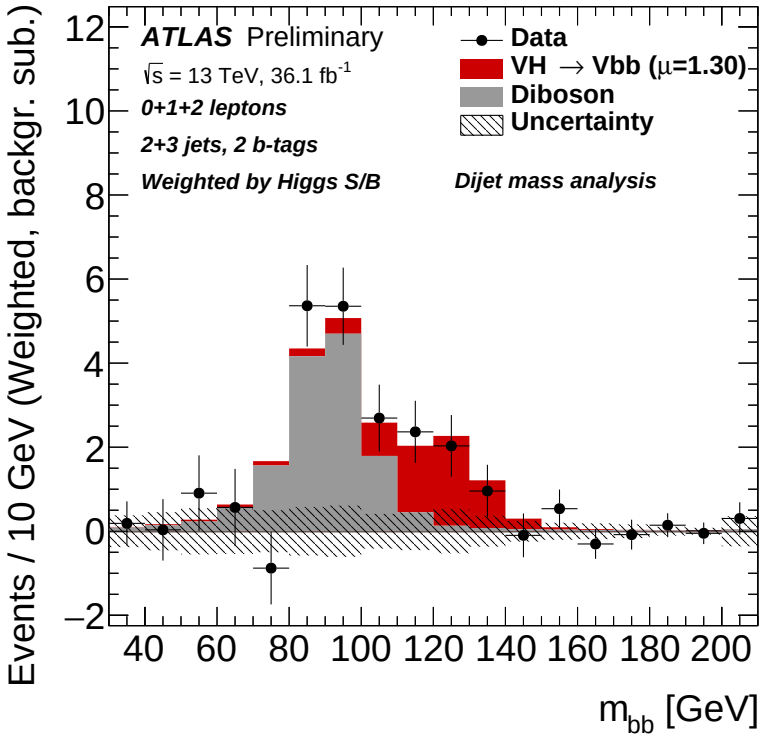


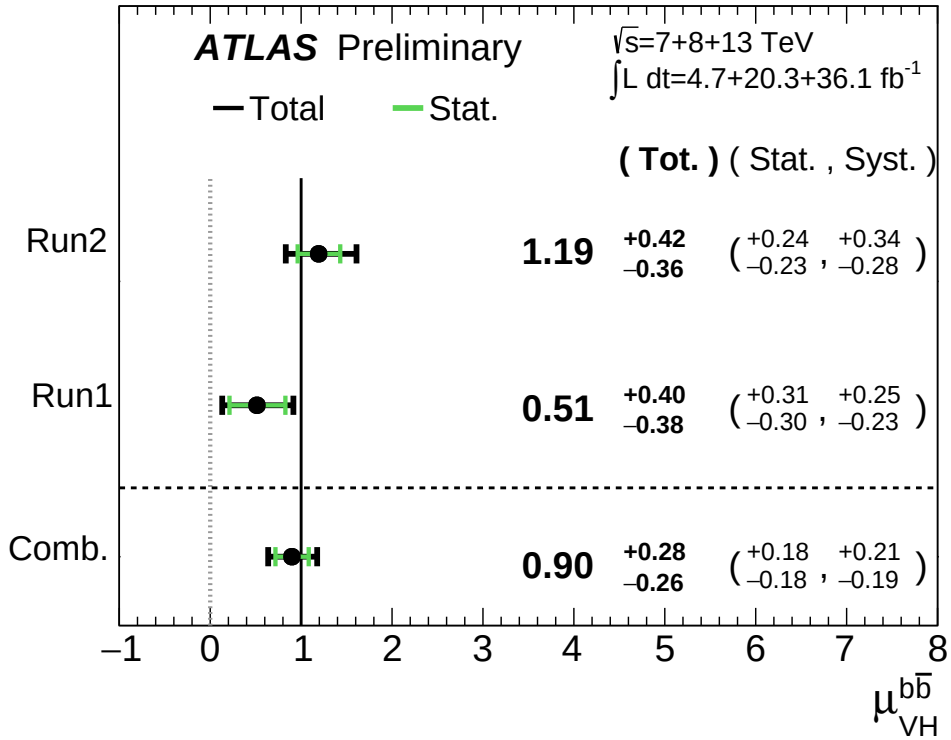


Observed (expected) significance 3.5 (3.0)σ

Search for $H \to b\bar{b}$ - Assoc. VH Production (ATLAS-CONF-2017-041)

- Analysis validated with measurement of $VZ(b\bar{b})$ production, observe (expect) $5.8(5.3)\sigma$ evidence and rate $\mu_{VZ} = 1.11^{+0.25}_{-0.22}$ consistent with SM
- Additional cut-based cross-check analysis using $m_{b\bar{b}}$ as S/B discriminant finds consistent signal strength with significance $3.5\,(2.8)\sigma$ observed (expected)

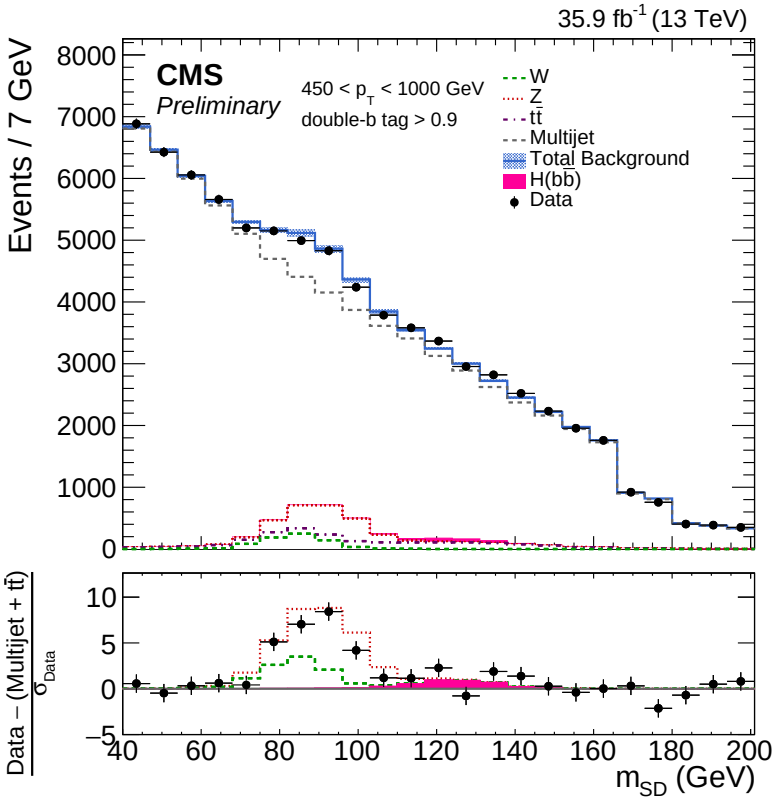


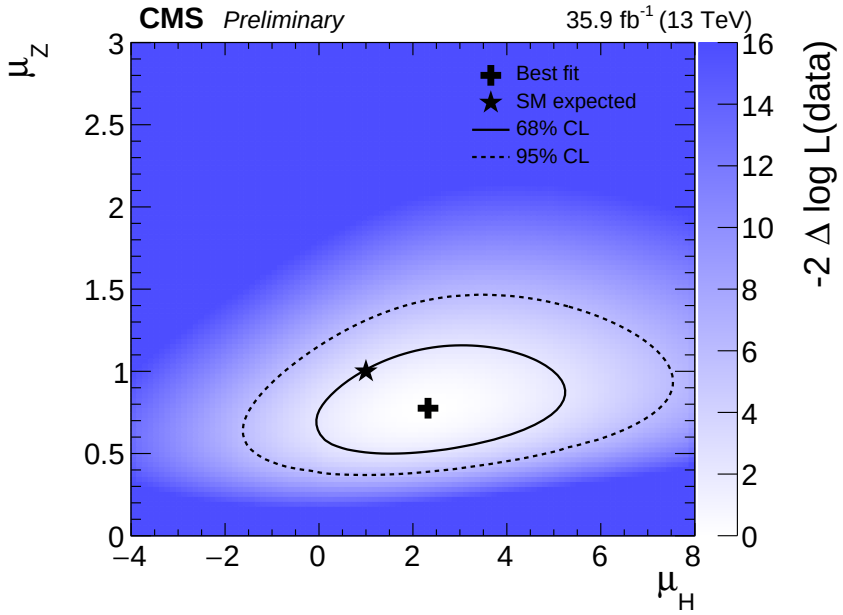


Combination with Run 1 results (arXiv:1409.6212) observe (expect) significance of $3.6\,(4.0)\sigma$, first evidence for $H \to b\bar{b}$ at the LHC!

Search for $H \to b\bar{b}$ - Boosted Inclusive (CMS PAS HIG-17-010)

Boosted $H \to b\bar{b}$ decays in inclusive production a complementary approach to VH





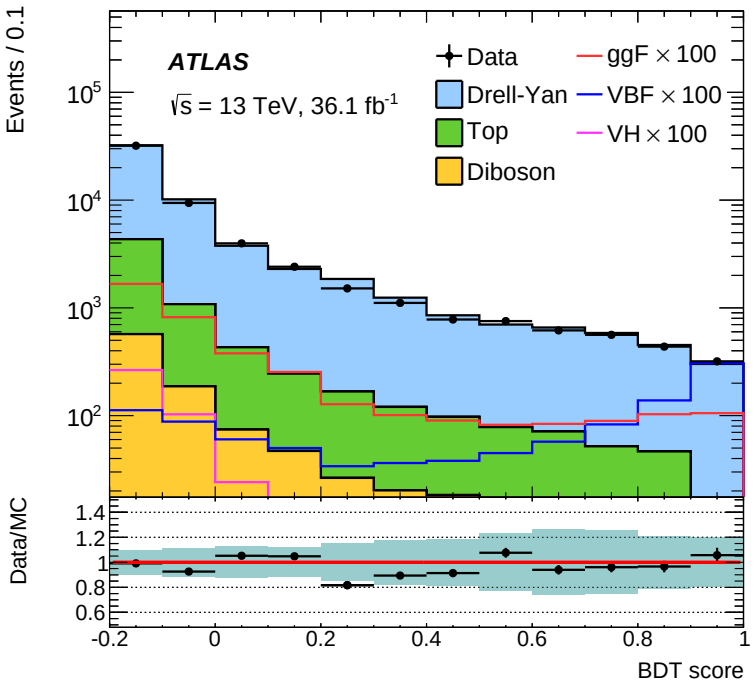
	H	H no p_T corrections	Z
Observed best fit	$\mu H = 2.3^{+1.8}_{-1.6}$	$\mu'_H = 3.2^{+2.2}_{-2.0}$	$\mu Z = 0.78^{+0.23}_{-0.19}$
Expected significance	0.7σ ($\mu H = 1$)	0.5σ ($\mu'_H = 1$)	5.8σ ($\mu_Z = 1$)
Observed significance	1.5σ	1.6σ	5.1σ

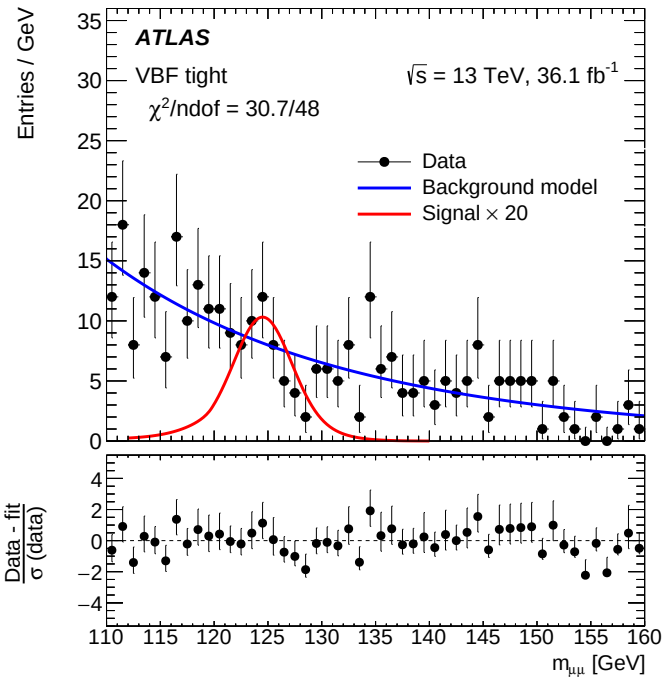
- Exploit particle flow reconstruction to search for high p_T anti-k_T $R = 0.8$ "H-jet"
- Apply "soft drop" grooming algorithm and use jet mass (m_{SD}) as S/B discriminant
- Use double-b tagging algorithm to suppress non-$b\bar{b}$ backgrounds

Observe 1.5σ excess, corresponds to cross section of 74^{+51}_{-49} fb (for $p_T > 450$ GeV), approach validated with 5.1σ observation of boosted $Z \to b\bar{b}$ production

Search for $H \to \mu^+\mu^-$ - (ATLAS arXiv:1705.04582)

$H \to \mu^+\mu^-$ decays represent the current best probe of the 2nd generation coupling



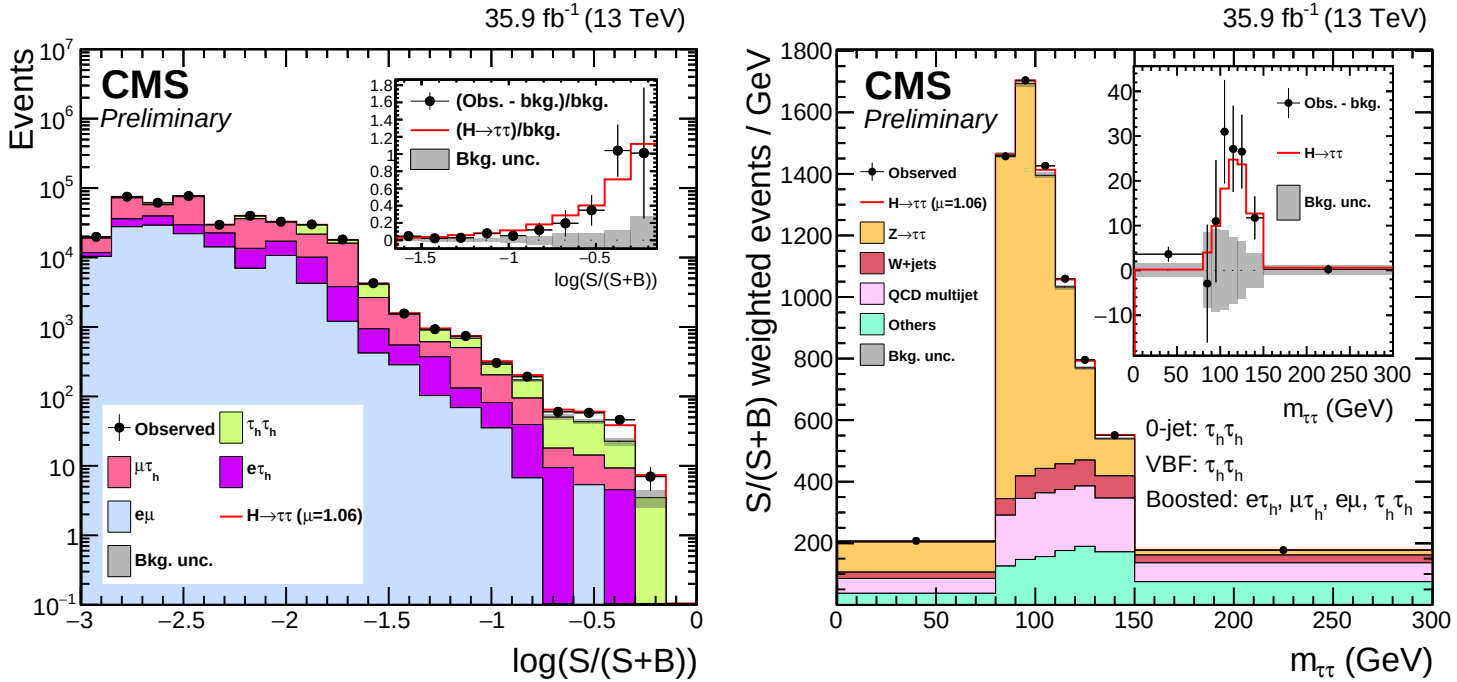


- Look for events with exactly two muons and classify them with BDT trained on jet-based variables sensitive to VBF production (m_{jj}, $p_T^{\mu^+\mu^-}$, $\Delta\eta_{jj}$, ΔR_{jj} et al.)
- Define two VBF-like categories (BDT > 0.9 and $0.7 <$ BDT < 0.9) and split remaining ggF-like events (BDT < 0.7) into six categories based on $p_T^{\mu^+\mu^-}$ and $|\eta^\mu|$
- $m_{\mu^+\mu^-}$ fitted for all categories and combined with Run 1 result (arXiv:1406.7663)

Measure $\mu = -0.1 \pm 1.4$ with a 95% CL limit of $\mu < 2.8\,(2.9)$ observed (expected)!

$H \to \tau^+\tau^-$ - (CMS PAS HIG-16-043)

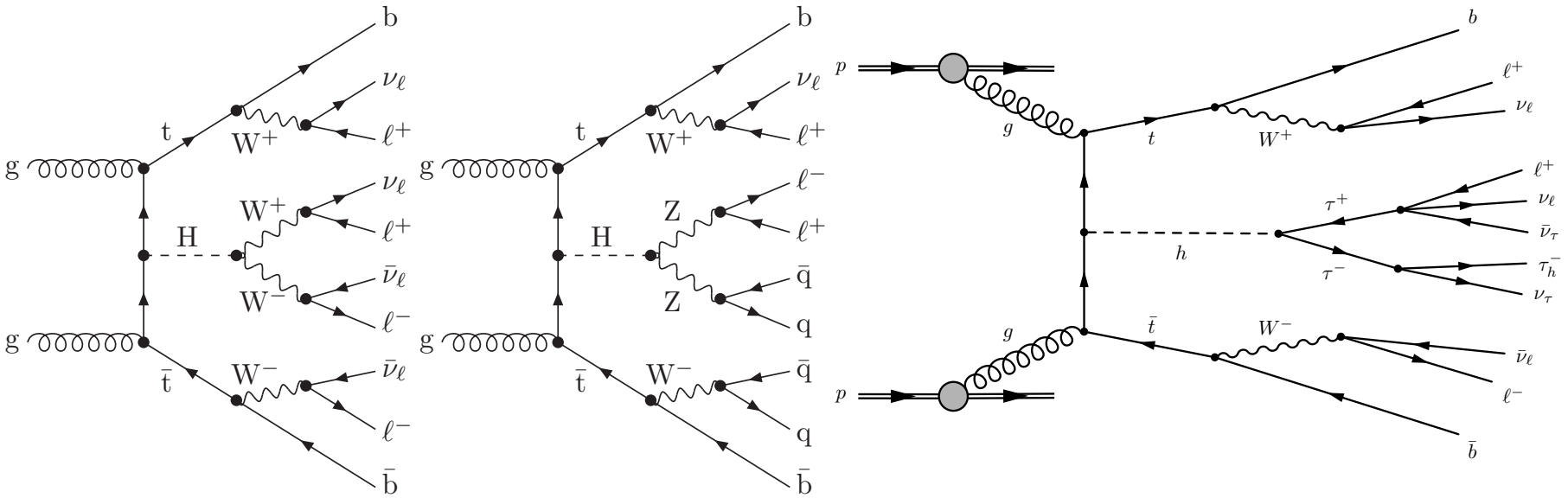
$H \to \tau^+\tau^-$ remains the only observed leptonic decay and a clean Yukawa probe



- Latest CMS analysis with 35.9 fb^{-1} at $\sqrt{s} = 13$ TeV further establishes $H \to \tau^+\tau^-$
- Target both semi-hadronic and leptonic τ decays and categorise events into "0-jet" (ggF-like no extra jets), "VBF" (2 jets with high $m_{jj}/\Delta\eta_{jj}$) and "Boosted" (the rest)
- Clear excesses observed in distribution of $S/(S+B)$ ranked fit bins (left) and $S/(S+B)$ weighted SVFIT $m_{\tau\tau}$ distribution (right)

Significance of 4.9 (4.7)σ observed (expected) with $\mu = 1.06^{+0.25}_{-0.24}$!
Combination with Run 1 CMS result yields significance of 5.9 (5.9)σ observed

Searches targeting the top Yukawa coupling

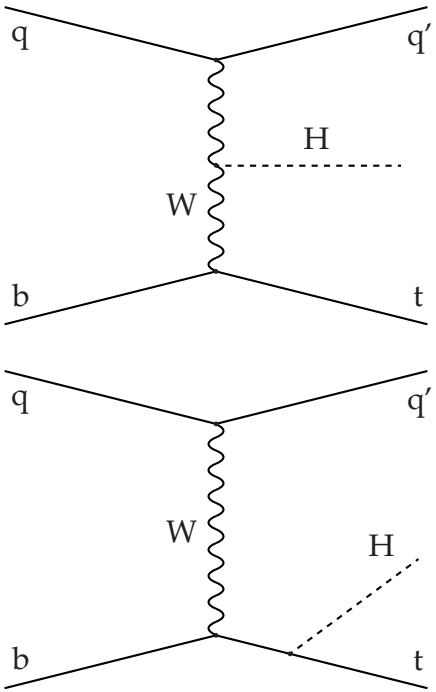


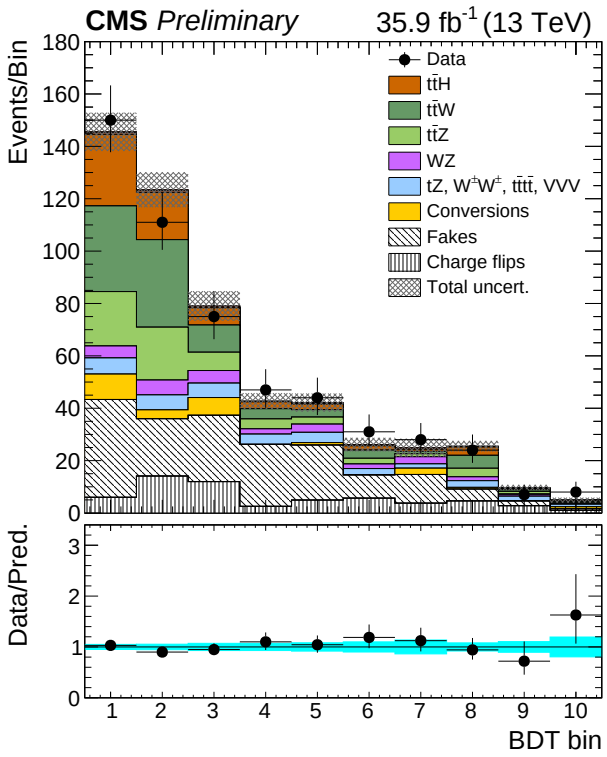
- Several exciting recent analyses targeting the top Yukawa coupling
- Searches in multi-lepton channels now firmly arriving at SM level sensitivity
- Typically built around multi-variate analysis techniques
- Generally suffer from large uncertainties on background modelling, most analyses already systematics dominated
- Worth remembering both ATLAS and CMS also have $t\bar{t}H$ categories in their $H \to \gamma\gamma$ and $H \to 4\ell$ analyses

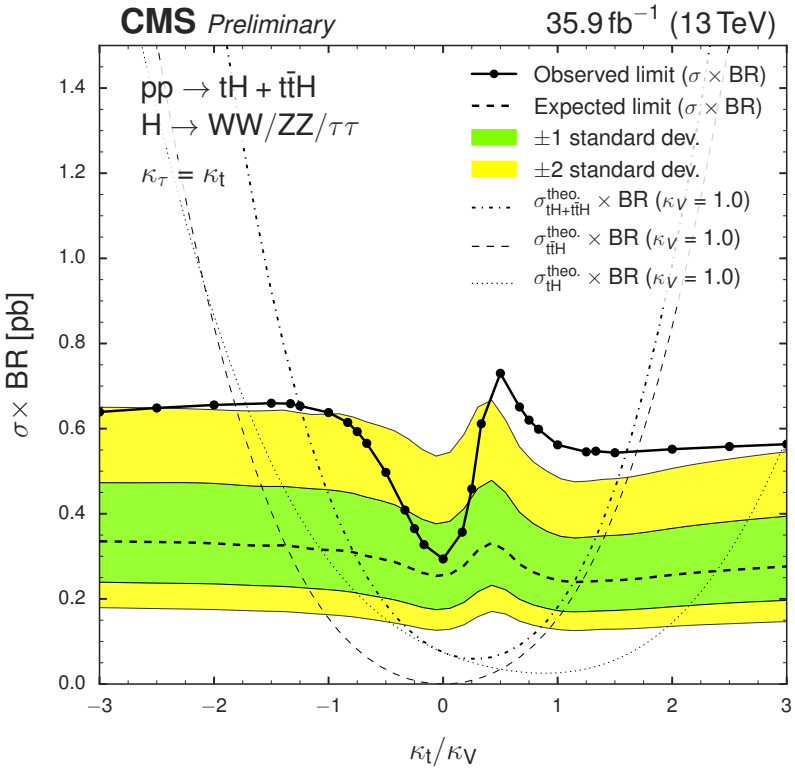
Diagrams from CMS-PAS-HIG-17-00(3)4

tHq production - $H \rightarrow$ multilepton search (CMS PAS HIG-17-005)

Channel sensitive to the relative sign of κ_t and κ_V due to interference of LO diagrams







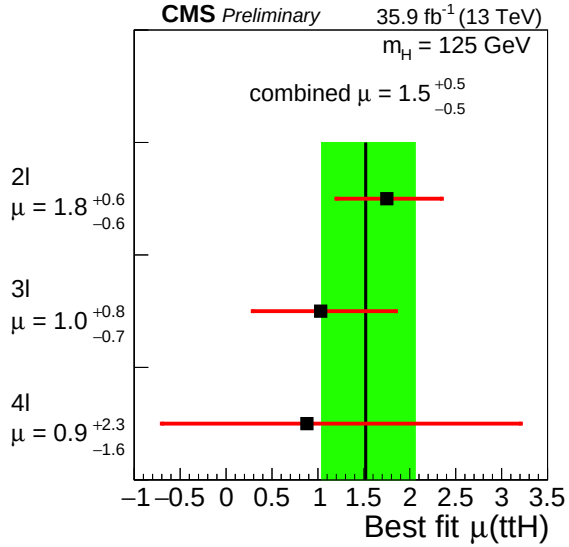
- Final state targets $H \rightarrow WW^{\star}, ZZ^{\star}, \tau\tau$ decays combined with a $t \rightarrow W(\ell\nu)b$ decay
- Analysis focus on same-sign $\ell\ell$ and $\ell\ell\ell$ channels
- Multivariate techniques used to discriminate the signal ($tH + t\bar{t}H$) from backgrounds

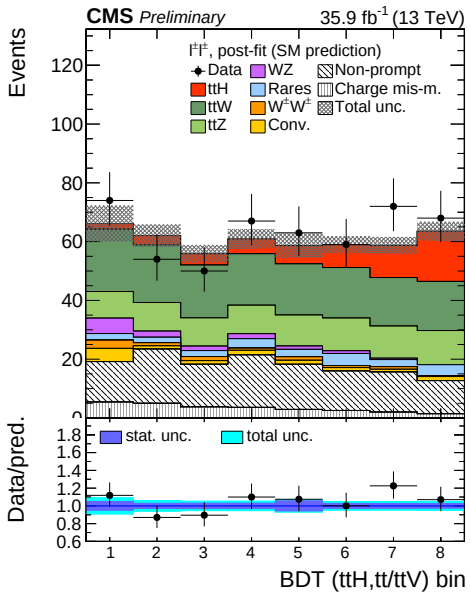
Best fit $\mu = 1.8 \pm 0.3$ (stat.) ± 0.6 (syst.) with observed significance of 2.7σ!

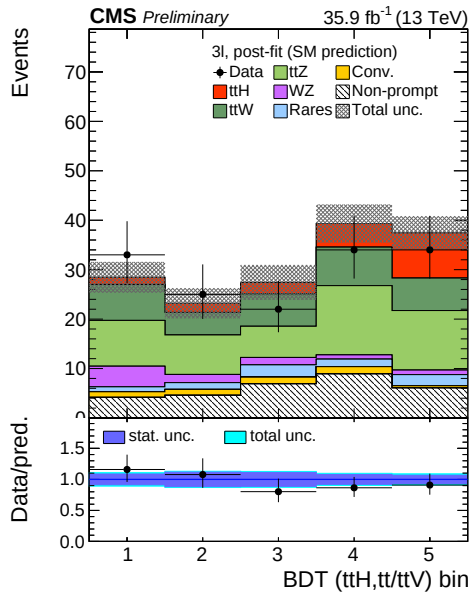
$t\bar{t}H$ production - $H \to$ multilepton search (CMS PAS HIG-17-004)

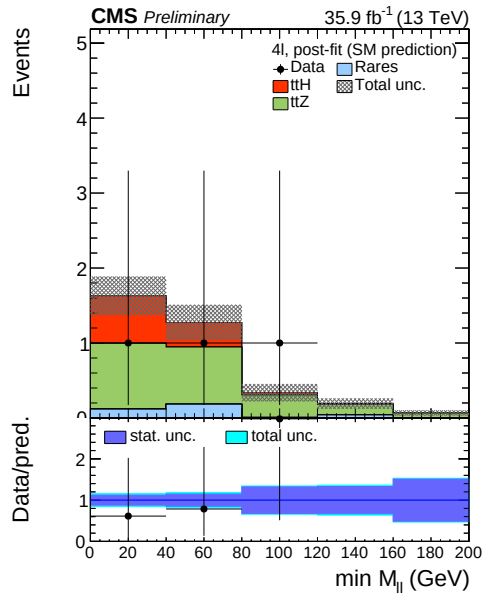
Excitement has surrounded $t\bar{t}H$ since Run 1 ATLAS+CMS combination found high signal strength of $\mu = 2.3 \pm 0.7$

- As for tHq, the final state targets $H \to WW^\star, ZZ^\star, \tau\tau$ decays combined with a $t \to W(\ell\nu)b$ decay
- Analysis focus on same-sign two lepton (2LSS), three lepton (3L) and four lepton (4L) channels
- Two multivariate discriminants (BDT) trained to separate signal from irreducible of $t\bar{t}W$ and $t\bar{t}Z$ background







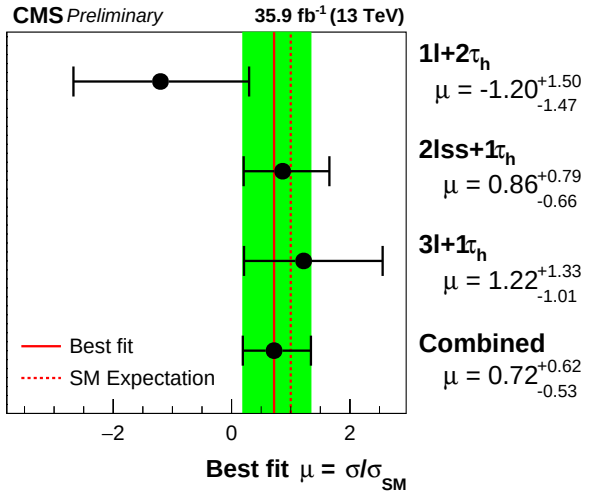


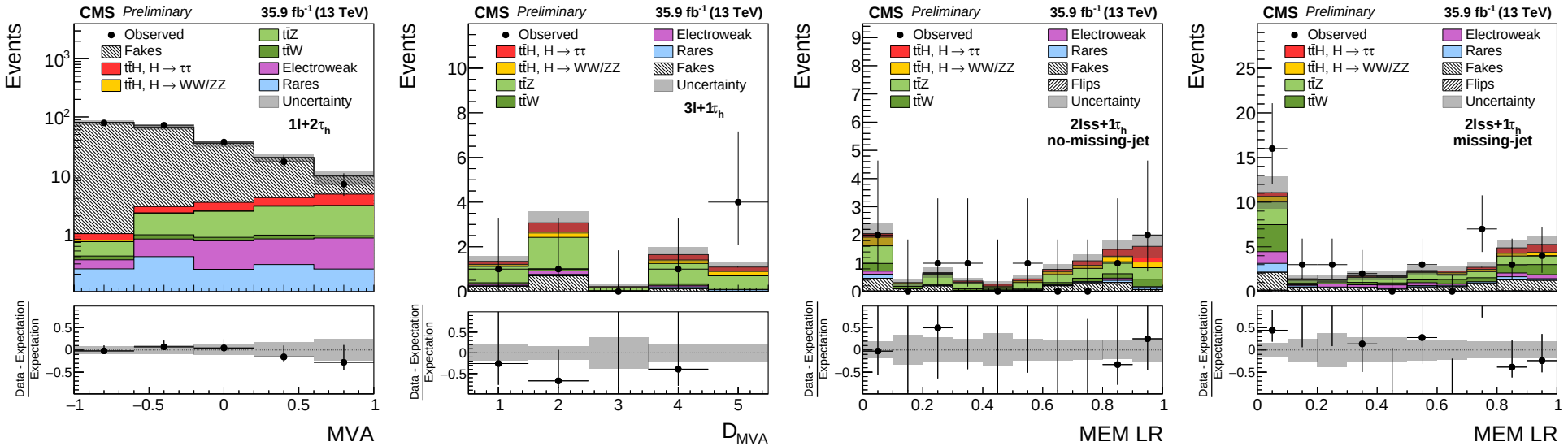
Observe $\mu = 1.5 \pm 0.5$ and significance of 3.3σ, further evidence for $t\bar{t}H$ production!

$t\bar{t}H$ production - τ lepton-based search (CMS PAS HIG-17-004)

Complementary to $t\bar{t}H$ search in multi e/μ final state

- Aim to reconstruct final states with at least one hadronic τ decay (τ_h), sensitive to $H\tau\tau$ but also $H \to WW^\star, ZZ^\star$
- Exploit three categories, each with a separate S/B discriminant: $1\ell + 2\tau_h$, $2\ell(SS) + \tau_h$ and $3\ell + \tau_h$
- $1\ell + 2\tau_h$ uses BDT trained against $t\bar{t}$, $2\ell(SS) + \tau_h$ uses matrix element discriminant and $3\ell + \tau_h$ uses 2 BDTs trained against $t\bar{t}W$ and $t\bar{t}Z$





Observe $\mu = 0.72^{+0.61}_{-0.53}$ and significance of 1.4σ

Summary

Both experiments have made a significant move forward with Run 2 data, beyond "rediscovery" and towards surpasssing the Run 1 measurements

- New measurements of fiducial, template and differential cross-sections in $H \to \gamma\gamma$ and $H \to 4\ell$ channels, now firmly moving beyond inclusive signal strengths and model dependent quantities
- Precision on m_H achieved by single Run 2 measurements now poised to overtake Run 1 ATLAS + CMS combination!
- Substantial progress towards establishing Yukawa-like lepton couplings in $H \to \ell\ell$
- First evidence at the LHC for $H \to b\bar{b}$ decays in the VH channel
- Exciting evidence for $t\bar{t}H$ production in multi-lepton final states

Prospects for 2017 data taking look very promising, can expect further exciting results in the near future!

To find all of the details I omitted:

- **ATLAS** - http://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
- **CMS** - http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html

Additional Slides

ATLAS POWHEG "NNLOPS" Sample

Process	Generator	Showering	PDF set	Order of calculation	σ[pb] $\sqrt{s} = 13$ TeV
ggH	POWHEG NNLOPS	PYTHIA8	PDF4LHC15	N^{3}LO(QCD)+NLO(EW)	48.52
VBF	POWHEG BOX	PYTHIA8	PDF4LHC15	NNLO(QCD)+NLO(EW)	3.78
WH	POWHEG BOX	PYTHIA8	PDF4LHC15	NNLO(QCD)+NLO(EW)	1.37
$q\bar{q}' \to ZH$	POWHEG BOX	PYTHIA8	PDF4LHC15	NNLO(QCD)+NLO(EW)	0.76
$gg \to ZH$	POWHEG BOX	PYTHIA8	PDF4LHC15	NNLO(QCD)+NLO(EW)	0.12
$t\bar{t}H$	MADGRAPH5_AMC@NLO	PYTHIA8	NNPDF3.0	NLO(QCD)+NLO(EW)	0.51
$b\bar{b}H$	MADGRAPH5_AMC@NLO	PYTHIA8	CT10	5FS(NNLO)+4FS(NLO)	0.49
$tHq\bar{b}$	MADGRAPH5_AMC@NLO	PYTHIA8	CT10	4FS(LO)	0.07
tHW	MADGRAPH5_AMC@NLO	HERWIG++	CT10	5FS(NLO)	0.02
$\gamma\gamma$	SHERPA	SHERPA	CT10		

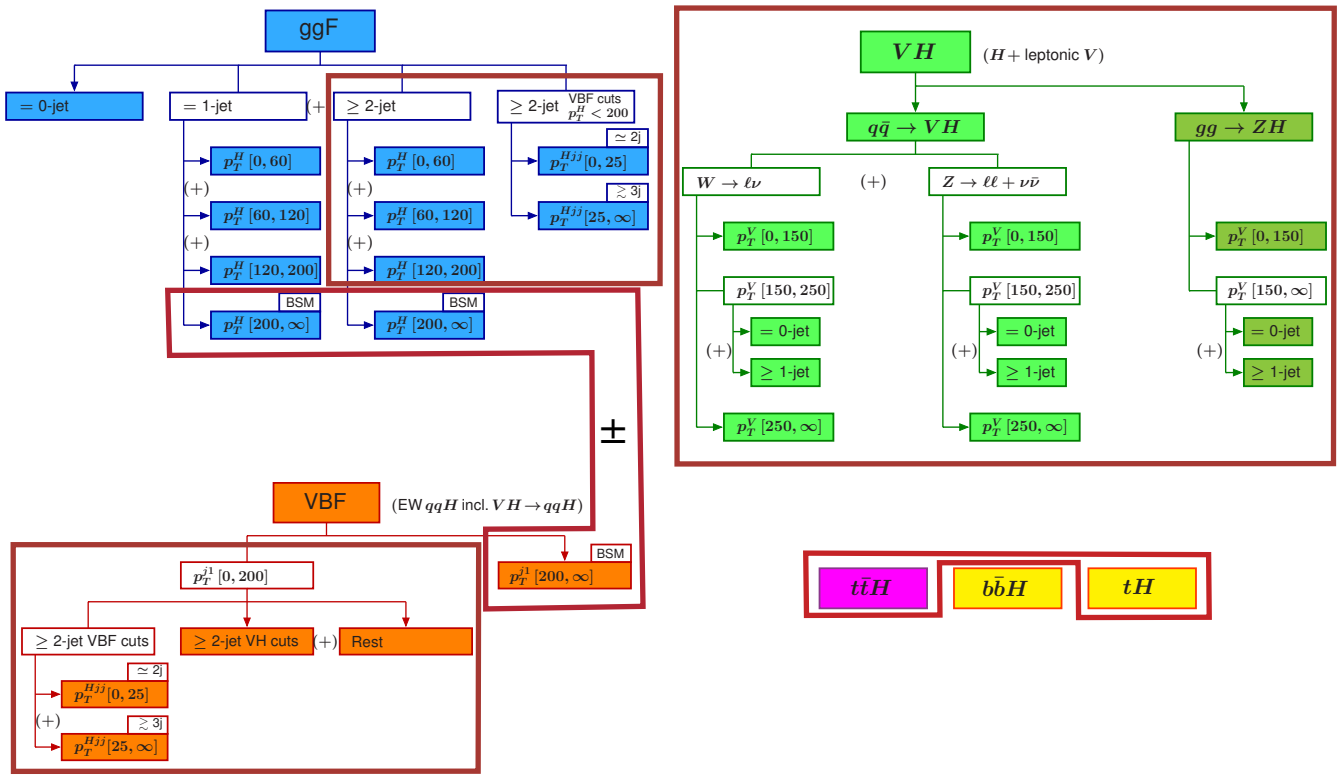
ATLAS (ATLAS-CONF-2017-032)

Leptons and jets	
Muons:	$p_{\mathrm{T}} > 5$ GeV, $\lvert\eta\rvert < 2.7$
Electrons:	$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.47$
Jets:	$p_{\mathrm{T}} > 30$ GeV, $\lvert y\rvert < 4.4$
Jet-lepton overlap removal:	$\Delta R(\mathrm{jet}, \ell) > 0.1\,(0.2)$ for muons (electrons)
Lepton selection and pairing	
Lepton kinematics:	$p_{\mathrm{T}} > 20, 15, 10$ GeV
Leading pair (m_{12}):	SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Subleading pair (m_{34}):	remaining SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Event selection (at most one quadruplet per channel)	
Mass requirements:	$50 < m_{12} < 106$ GeV and $12 < m_{34} < 115$ GeV
Lepton separation:	$\Delta R(\ell_i, \ell_j) > 0.1\,(0.2)$ for same- (different-) flavour leptons
J/ψ veto:	$m(\ell_i, \ell_j) > 5$ GeV for all SFOS lepton pairs
Mass window:	$115\ GeV < m_{4\ell} < 130$ GeV

CMS (arXiv:1706.09936)

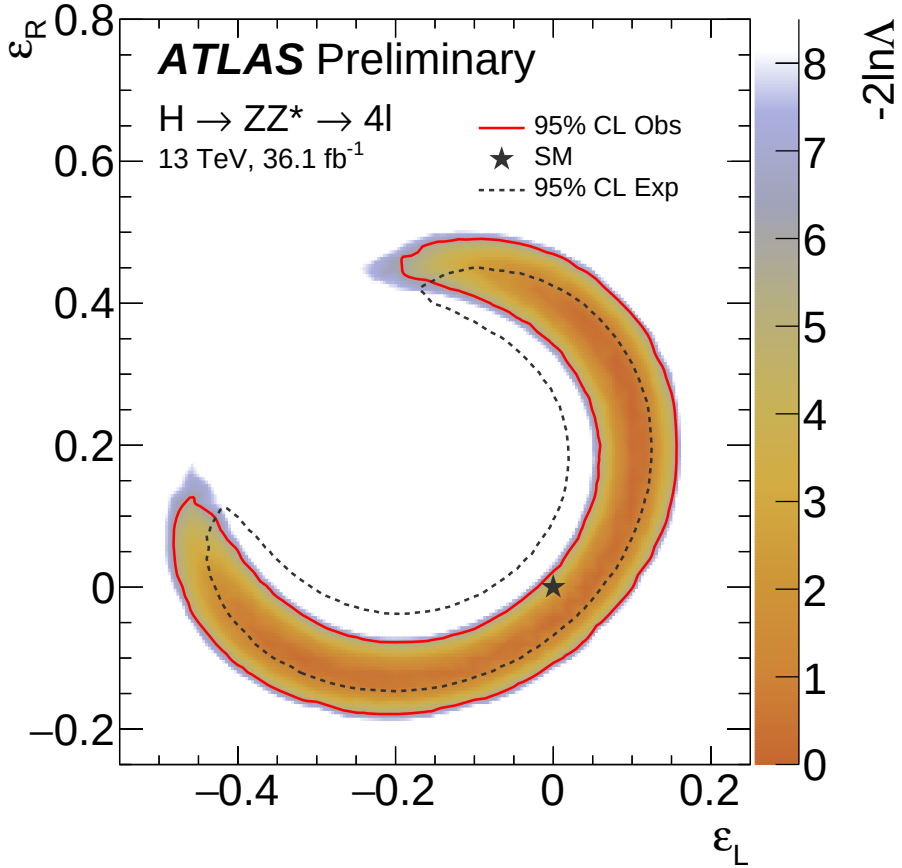
Lepton kinematics and isolation	
Leading lepton p_{T}	$p_{\mathrm{T}} > 20\,\mathrm{GeV}$
Subleading lepton p_{T}	$p_{\mathrm{T}} > 10\,\mathrm{GeV}$
Additional electrons (muons) p_{T}	$p_{\mathrm{T}} > 7\,(5)\,\mathrm{GeV}$
Pseudorapidity of electrons (muons)	$\lvert\eta\rvert < 2.5\,(2.4)$
Sum p_{T} of all stable particles within $\Delta R < 0.3$ from lepton	$<0.35 p_{\mathrm{T}}$
Event topology	
Existence of at least two same-flavor OS lepton pairs, where leptons satisfy criteria above	
Invariant mass of the Z_1 candidate	$40 < m_{Z_1} < 120\,\mathrm{GeV}$
Invariant mass of the Z_2 candidate	$12 < m_{Z_2} < 120\,\mathrm{GeV}$
Distance between selected four leptons	$\Delta R(\ell_i, \ell_j) > 0.02$ for any $i \neq j$
Invariant mass of any opposite-sign lepton pair	$m_{\ell^+\ell^-} > 4\,\mathrm{GeV}$
Invariant mass of the selected four leptons	$105 < m_{4\ell} < 140\,\mathrm{GeV}$

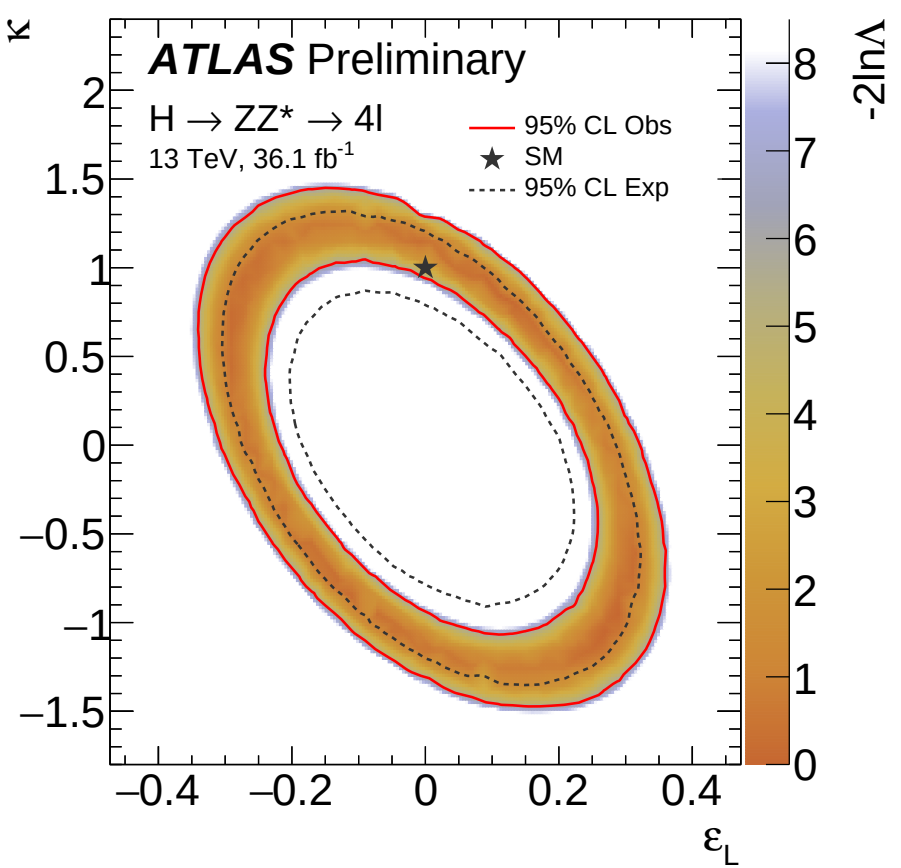
STXS - Merged Stage-1 Regions (ATLAS-CONF-2017-047)



The merged STXS stage-1 regions defined for the measurements. All regions enclosed by red boxes are merged, except for the sum and difference indicated by the ± sign connecting two merged $gg \to H$ regions with one $qq \to Hqq$ region. The $b\bar{b}H$ region is merged with the $gg \to H$ bins.

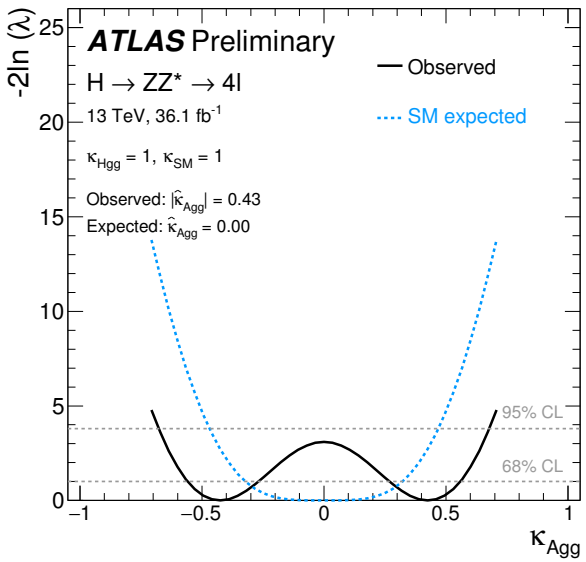
Limits on modified Higgs boson decays within the framework of pseudo-observables

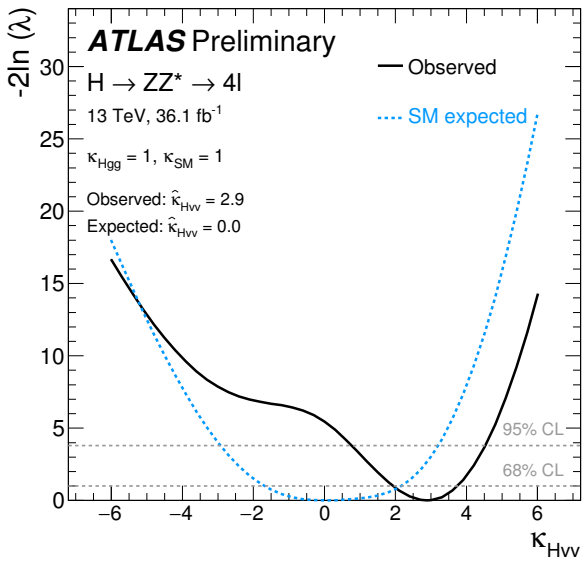


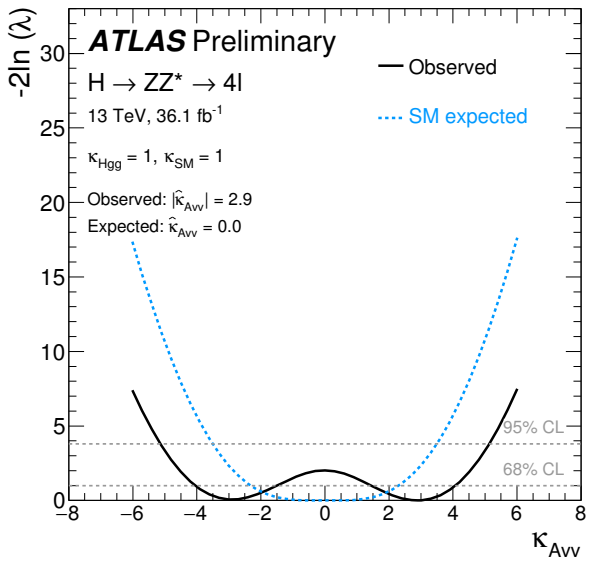


- Limits set in planes ϵ_R and ϵ_L (Higgs coupling modifier for left- and right-handed leptons) and κ (Higgs coupling modifier for Z bosons)

$H \to 4\ell$ - Anomalous Couplings Search (ATLAS-CONF-2017-043)







- Effective Lagrangian terms with coupling parameters κ_{AHVV}, κ_{AVV} and κ_{Agg} are considered as possible BSM admixtures to the corresponding SM-like interactions.
- These terms describe the CP-even (scalar) and CP-odd (pseudo-scalar) BSM interaction with vector bosons and the CP-odd BSM interaction with gluons, respectively.

$H \to \gamma\gamma$ - (ATLAS-CONF-2017-045)

Process	Measurement region	Stage 1 region
ggH + $gg \to Z(\to qq)H$	0-jet	0-jet
	1-jet, $p_{\mathrm{T}}^{H} < 60\,GeV$	1-jet, $p_{\mathrm{T}}^{H} < 60\,GeV$
	1-jet, $60 \le p_{\mathrm{T}}^{H} < 120\,GeV$	1-jet, $60 \le p_{\mathrm{T}}^{H} < 120\,GeV$
	1-jet, $120 \le p_{\mathrm{T}}^{H} < 200\,GeV$	1-jet, $120 \le p_{\mathrm{T}}^{H} < 200\,GeV$
	$\ge$ 1-jet, $p_{\mathrm{T}}^{H} > 200\,GeV$	1-jet, $p_{\mathrm{T}}^{H} > 200\,GeV$
		$\ge$ 2-jet, $p_{\mathrm{T}}^{H} > 200\,GeV$
	$\ge$ 2-jet, $p_{\mathrm{T}}^{H} < 200\,GeV$ or VBF-like	$\ge$ 2-jet, $p_{\mathrm{T}}^{H} < 60\,GeV$
		$\ge$ 2-jet, $60 \le p_{\mathrm{T}}^{H} < 120\,GeV$
		$\ge$ 2-jet, $120 \le p_{\mathrm{T}}^{H} < 200\,GeV$
		VBF-like, $p_{\mathrm{T}}^{Hjj} < 25\,GeV$
		VBF-like, $p_{\mathrm{T}}^{Hjj} \ge 25\,GeV$
$qq' \to Hqq'$ (VBF + VH)	$p_{\mathrm{T}}^{j} < 200\,GeV$	$p_{\mathrm{T}}^{j} < 200\,GeV$, VBF-like, $p_{\mathrm{T}}^{Hjj} < 25\,GeV$
		$p_{\mathrm{T}}^{j} < 200\,GeV$, VBF-like, $p_{\mathrm{T}}^{Hjj} \ge 25\,GeV$
		$p_{\mathrm{T}}^{j} < 200\,GeV$, VH-like
		$p_{\mathrm{T}}^{j} < 200\,GeV$, Rest
	$p_{\mathrm{T}}^{j} > 200\,GeV$	$p_{\mathrm{T}}^{j} > 200\,GeV$
VH (leptonic decays)	VH leptonic	$q\bar{q} \to ZH$, $p_{\mathrm{T}}^{Z} < 150\ GeV$
		$q\bar{q} \to ZH$, $150\ GeV < p_{\mathrm{T}}^{Z} < 250\ GeV$, 0-jet
		$q\bar{q} \to ZH$, $150\ GeV < p_{\mathrm{T}}^{Z} < 250\ GeV$, $\ge$ 1-jet
		$q\bar{q} \to ZH$, $p_{\mathrm{T}}^{Z} > 250\ GeV$
		$q\bar{q} \to WH$, $p_{\mathrm{T}}^{W} < 150\ GeV$
		$q\bar{q} \to WH$, $150\ GeV < p_{\mathrm{T}}^{W} < 250\ GeV$, 0-jet
		$q\bar{q} \to WH$, $150\ GeV < p_{\mathrm{T}}^{W} < 250\ GeV$, $\ge$ 1-jet
		$q\bar{q} \to WH$, $p_{\mathrm{T}}^{W} > 250\ GeV$
		$gg \to ZH$, $p_{\mathrm{T}}^{Z} < 150\ GeV$
		$gg \to ZH$, $p_{\mathrm{T}}^{Z} > 150\ GeV$, 0-jet
		$gg \to ZH$, $p_{\mathrm{T}}^{Z} > 150\ GeV$, $\ge$ 1-jet
top-associated production	top	$t\bar{t}H$
		tHW
		$tHqb$
$b\bar{b}H$	merged w/ ggH	$b\bar{b}H$

Objects	Definition
Photons	$\lvert\eta\rvert < 1.37$ OR $1.52 < \lvert\eta\rvert < 2.37$, $p_{\mathrm{T}}^{\mathrm{iso},0.2}/p_{\mathrm{T}}^{\gamma} < 0.05$
Jets	anti-k_t, $R = 0.4$, $p_{\mathrm{T}} > 30\,\mathrm{GeV}$, $\lvert y\rvert < 4.4$
Leptons, ℓ	e or μ, $p_{\mathrm{T}} > 15\,\mathrm{GeV}$, $\lvert\eta\rvert < 2.47$ (excluding $1.37 < \lvert\eta\rvert < 1.52$ for $\ell = e$)

Fiducial region	Definition
Diphoton fiducial	$N_{\gamma} \ge 2$, $p_{\mathrm{T}}^{\gamma_1} > 0.35\,m_{\gamma\gamma}$, $p_{\mathrm{T}}^{\gamma_2} > 0.25\,m_{\gamma\gamma}$
VBF-enhanced	Diphoton fiducial, $N_j \ge 2$, $m_{jj} > 400$ GeV, $\lvert\Delta y_{jj}\rvert > 2.8$, $\lvert\Delta\phi_{\gamma\gamma,jj}\rvert > 2.6$
$N_{\mathrm{lepton}} \ge 1$	Diphoton fiducial, $N_{\ell} \ge 1$
High $E_{\mathrm{T}}^{\mathrm{miss}}$	Diphoton fiducial, $E_{\mathrm{T}}^{\mathrm{miss}} > 80$ GeV, $p_{\mathrm{T}}^{\gamma\gamma} > 80$ GeV
$t\bar{t}H$-enhanced	Diphoton fiducial, ($N_j \ge 4$, $N_{\text{b-jets}} \ge 1$) OR ($N_j \ge 3$, $N_{\text{b-jets}} \ge 1, N_{\ell} \ge 1$)