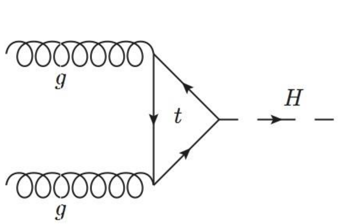
Higgs boson inclusive cross section and coupling measurements at CMS fermionic channels

EPS conference 21. August 2023

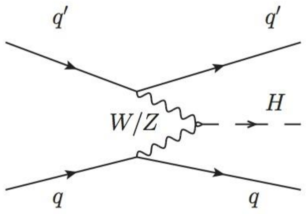
Pascal Bärtschi on behalf of the CMS Collaboration

Cross section and couplings measurements in different Higgs production modes and decays

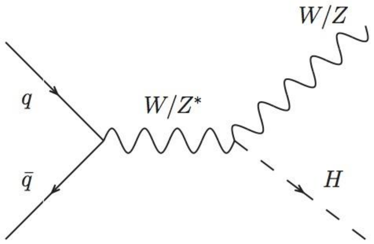
Higgs boson production modes



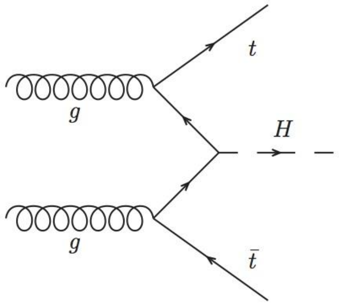
ggH



VBF



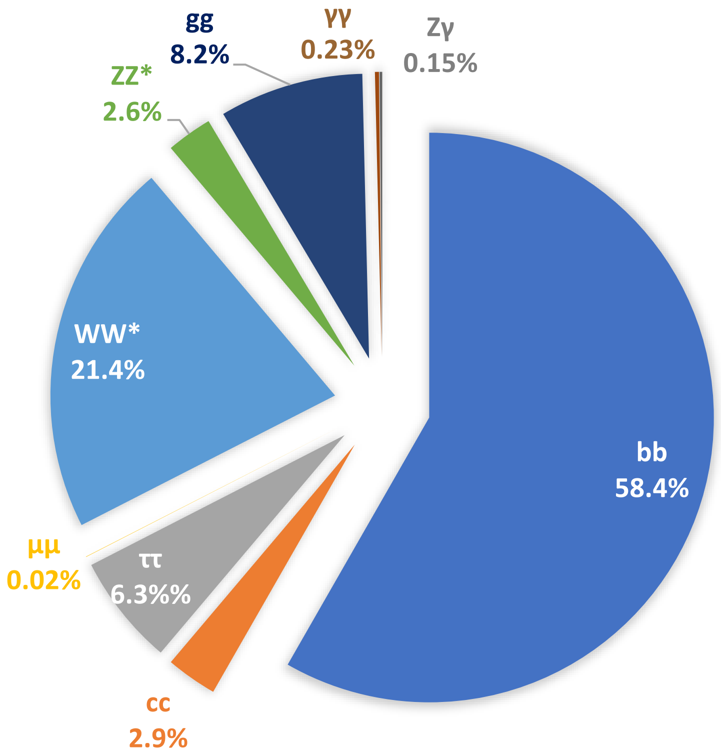
VH



ttH

Process	Cross section at 13 TeV
ggH	48.5 pb
VBF	3.78 pb
WH	1.37 pb
ZH	0.88 pb
ttH	0.51 pb

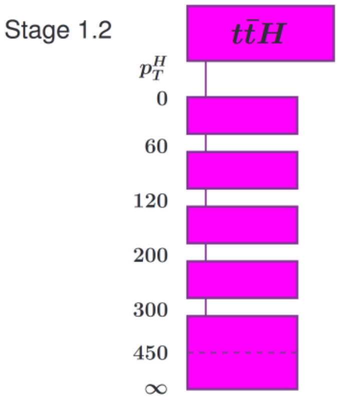
Higgs boson decay branching ratios

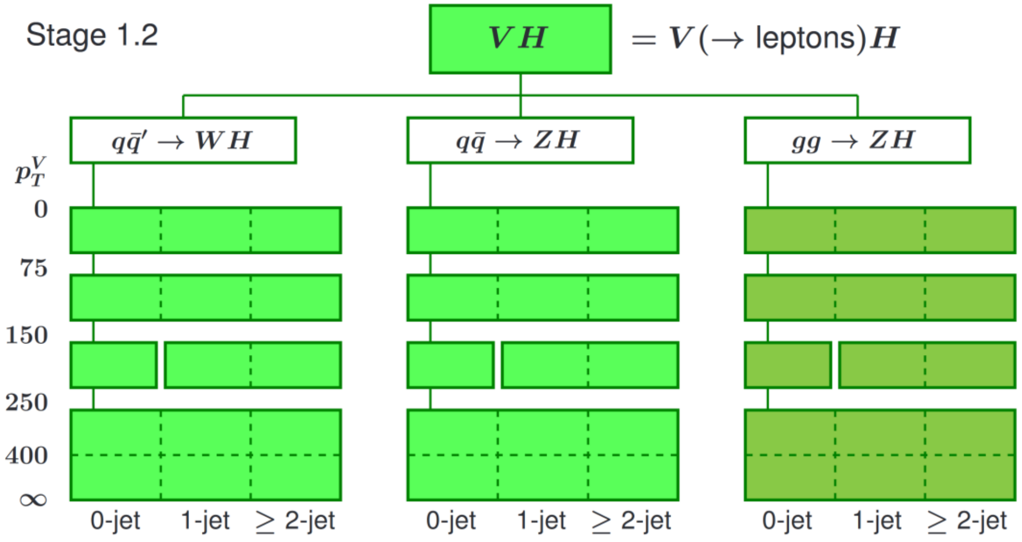


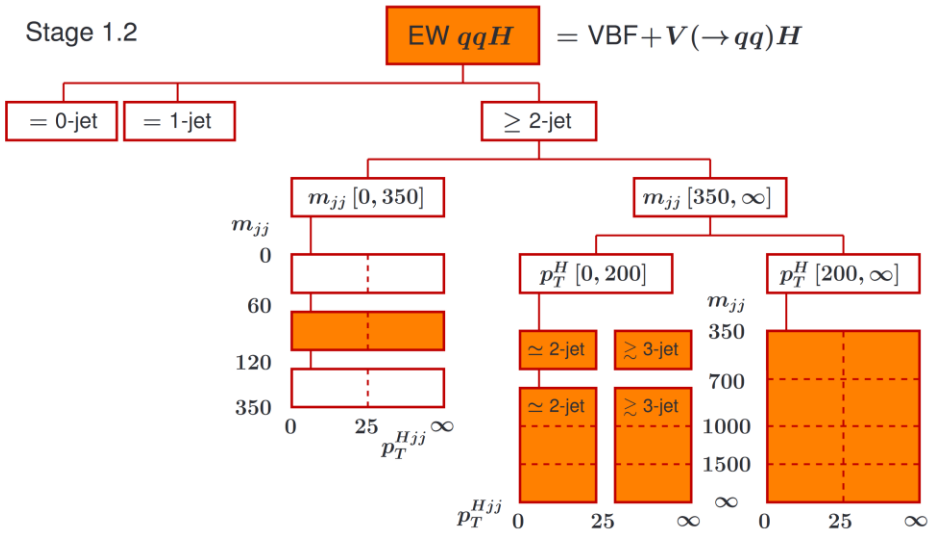
Simplified Template Cross section Scheme

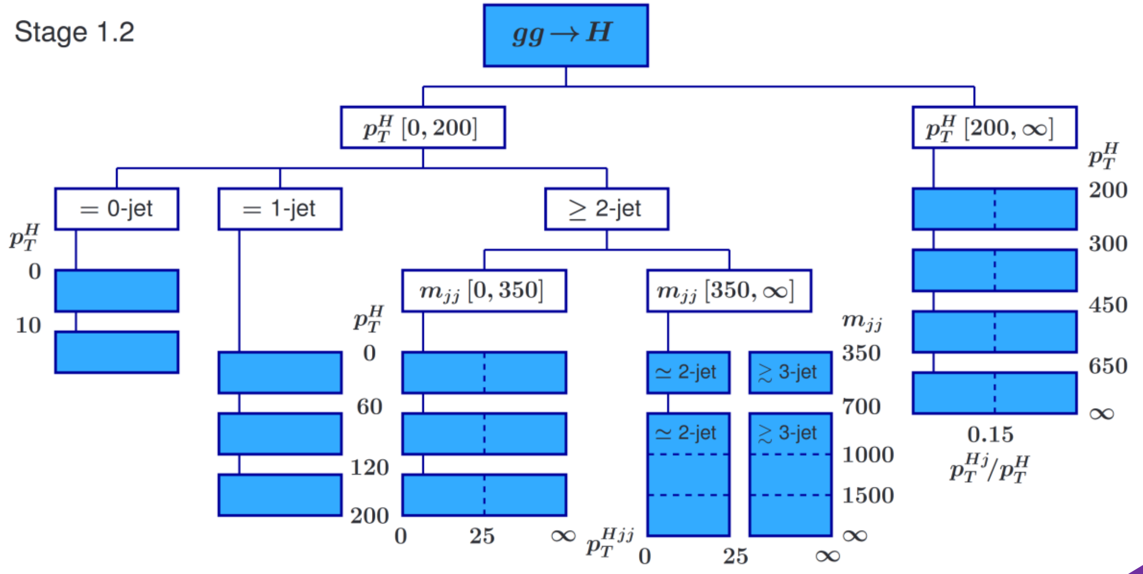
CMS, ATLAS and theorists made effort to coordinate differential measurements between experiment and theory

- Common scheme of phase space regions
- Reduced dependence on theory/ model uncertainties









Fermionic Higgs boson measurements at CMS

Higgs boson measurements in fermionic final states	
$H \to \tau\bar{\tau}$	Eur. Phys. J. C 83 (2023) 562
VBF ($H \to b\bar{b}$)	arXiv:2308.01253 (submitted to JHEP)
VH ($H \to b\bar{b}$)	CMS-PAS-HIG-20-001
ttH/tH ($H \to b\bar{b}$)	CMS-PAS-HIG-19-011 **NEW**
Boosted $H \to \tau\bar{\tau}$	CMS-PAS-HIG-21-017 **NEW**
Boosted $H \to b\bar{b}$	JHEP 12 (2020) 085
$H \to c\bar{c}$	Phys. Rev. Lett. 131 (2023) 041801
$H \to \mu\bar{\mu}$	JHEP 01 (2021) 148

Covered by this talk

Bosonic channels are covered by Roberto Seidita later in this session

Boosted Higgs boson measurements presented by Chayanit Asawatangtrakuldee in the parallel session on Monday morning

VH analysis

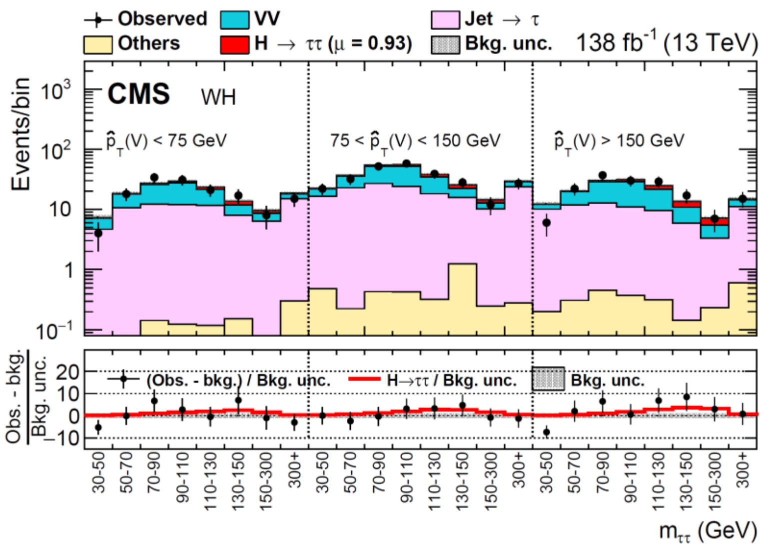
Final states based on the vector boson decay mode

- 1 lepton ($W \to e\nu, W \to \mu\nu$)
- 2 leptons ($Z \to ee, ZZ \to \mu\mu$)

and three final states of $H \to \tau\tau$: $\boldsymbol{e\tau_h, \mu\tau_h, \tau_h\tau_h}$

Dominant background: $W(\ell\nu)Z(\tau\tau)$ for WH
$ZZ \to 4\ell$ for ZH

2D distributions with $m_{\tau\tau}$ and p_T of vector boson

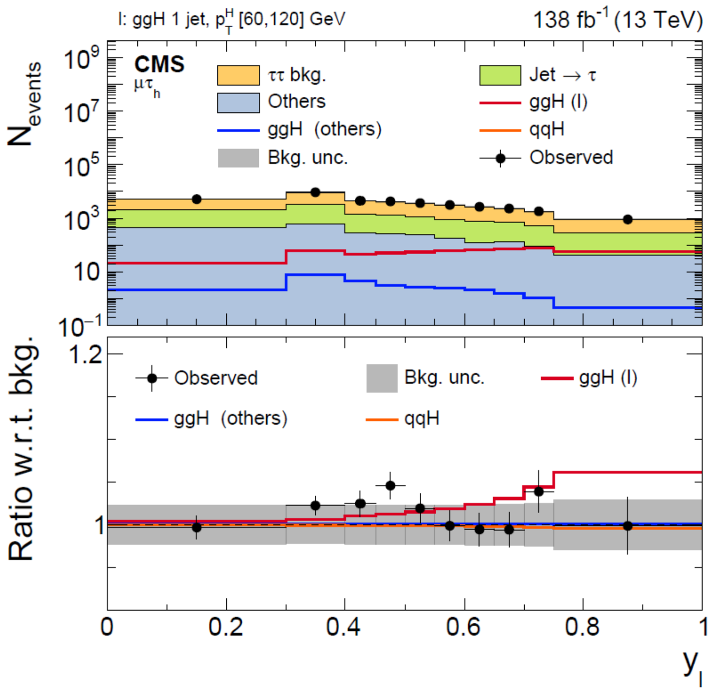


qqH, ggH analysis

Final states: $\boldsymbol{e\mu, e\tau_h\ \mu\tau_h, \tau_h\tau_h}$

Neural network multi classification with 15 signal classes and 5 background processes

Dominant backgrounds: Z+jets, W+jets, $t\bar{t}$, QCD multijet

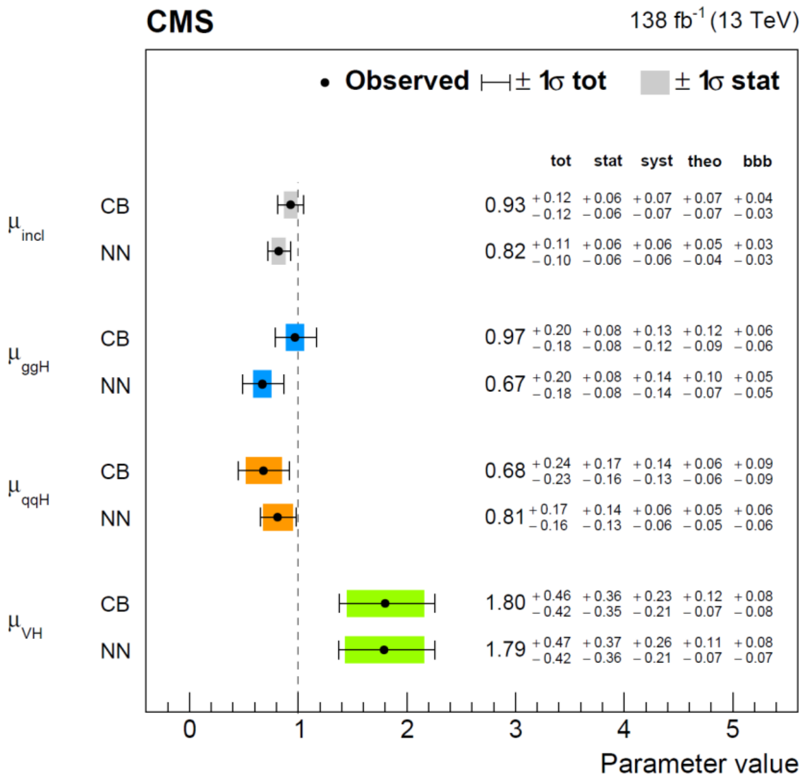


Output of NN in bin with ggH 1 Jet and p_T^H[60,120] GeV

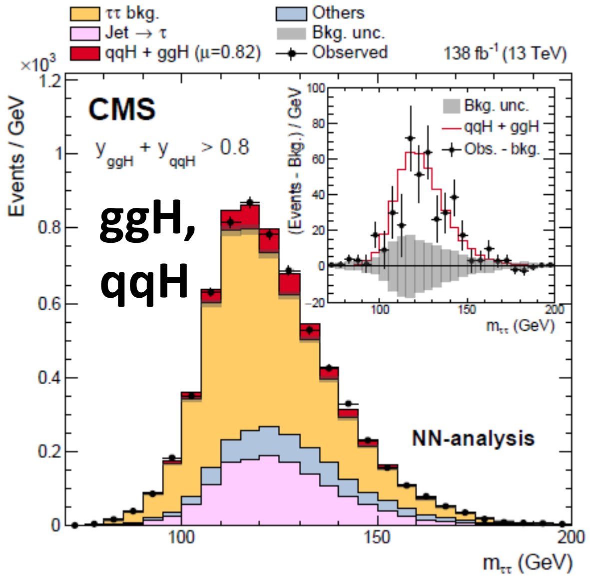
H→ $\tau\tau$ Inclusive results

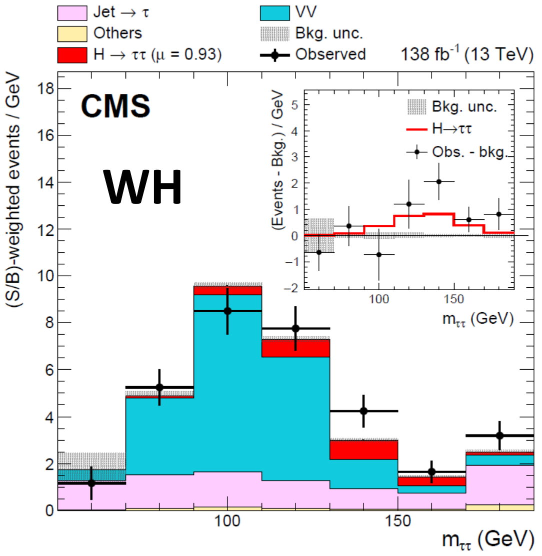
Inclusive signal strength: $\boldsymbol{\mu_{\text{incl}} = 0.82^{+0.11}_{-0.10}}$

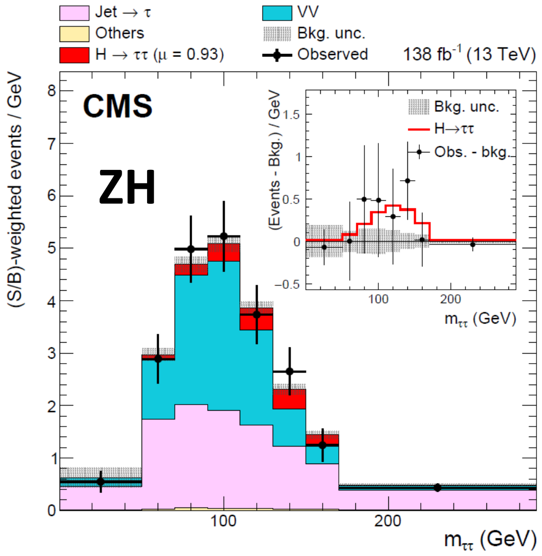
compatible with SM expectation within 2σ



[Eur. Phys. J. C 83 (2023) 562]





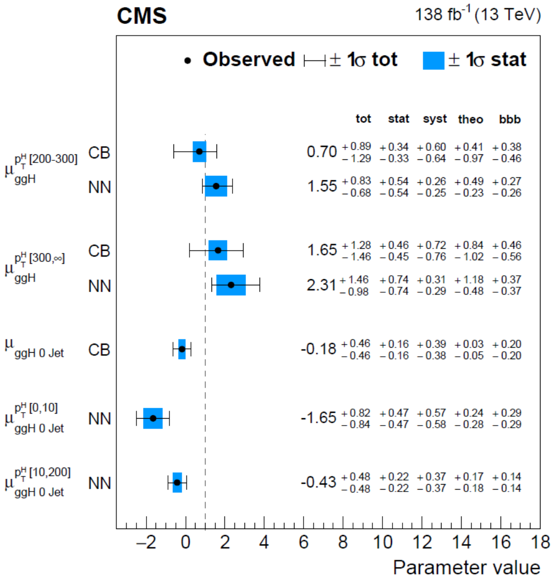


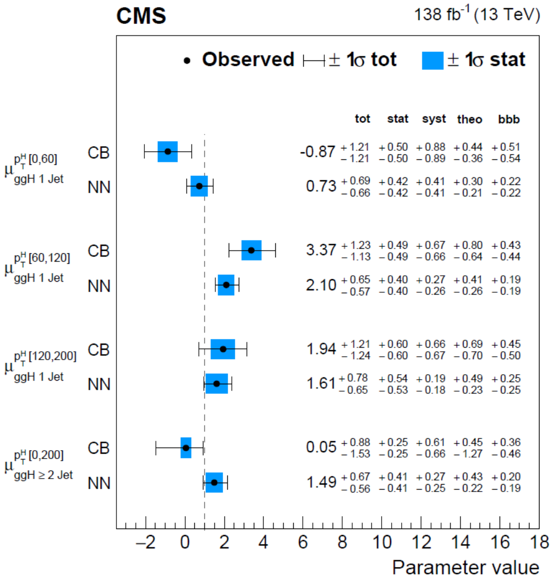
H→ $\tau\tau$ STXS results

STXS measurement performed in a total of 16 STXS bins

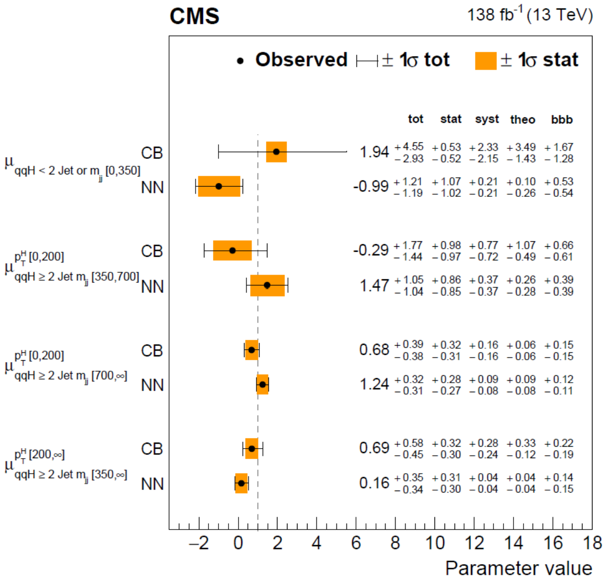
- 0 jet STXS bins: No signal observed, sensitivity to observe a signal comform with SM expecation is 2-3σ
- Other STXS bins: Signal compatible with SM expecation

ggH

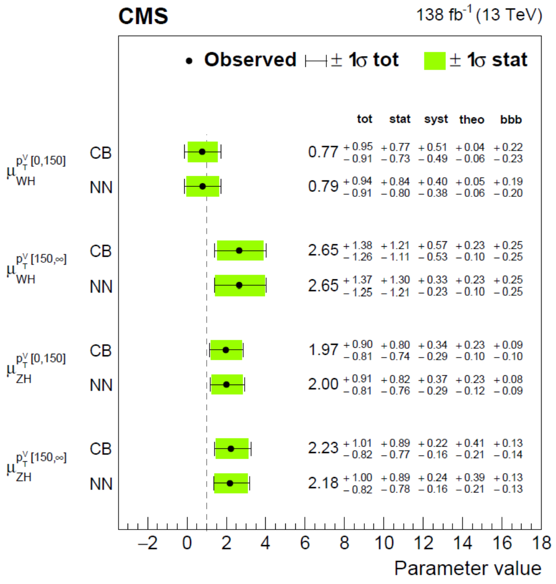




qqH



VH



[Eur. Phys. J. C 83 (2023) 562]

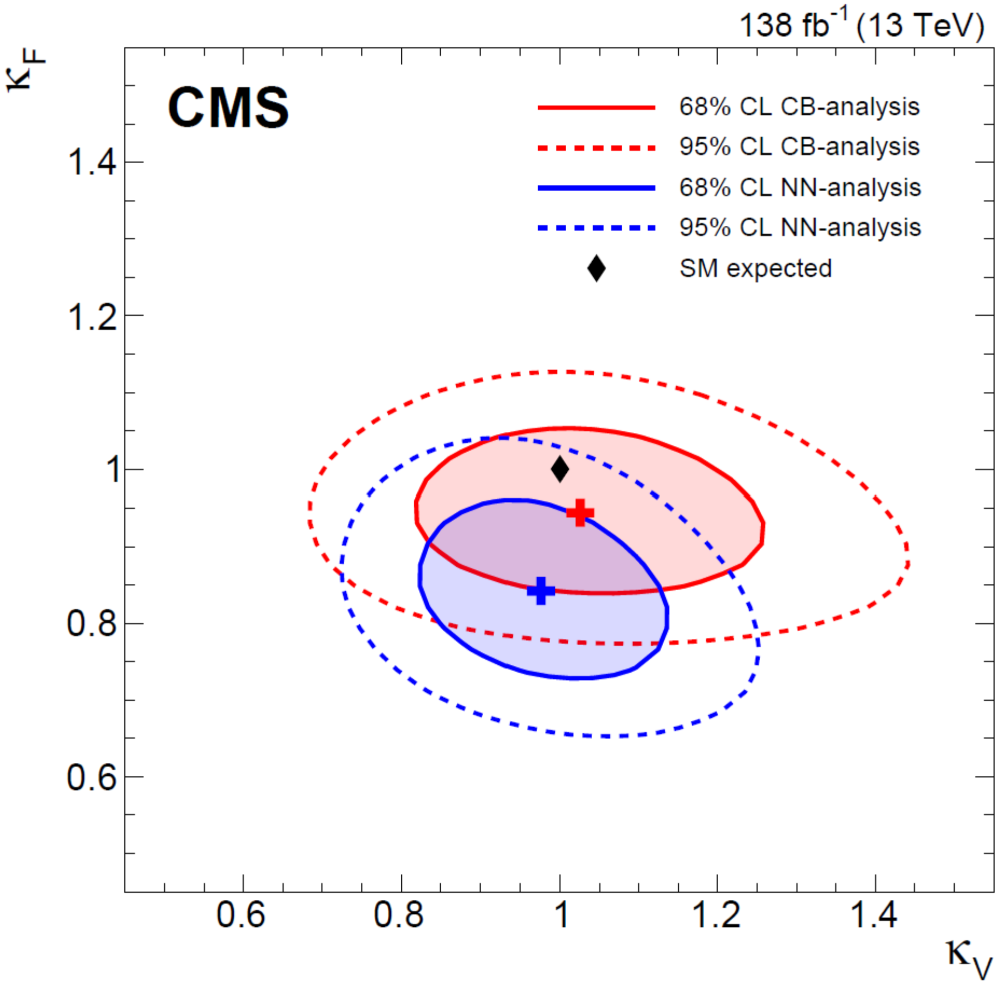
H→ $\tau\tau$ Coupling results

Higgs coupling to fermions (κ_F) and vector bosons (κ_V)

$H \rightarrow WW$ treated as signal

κ_V close to one, κ_F 15% lower than SM expection

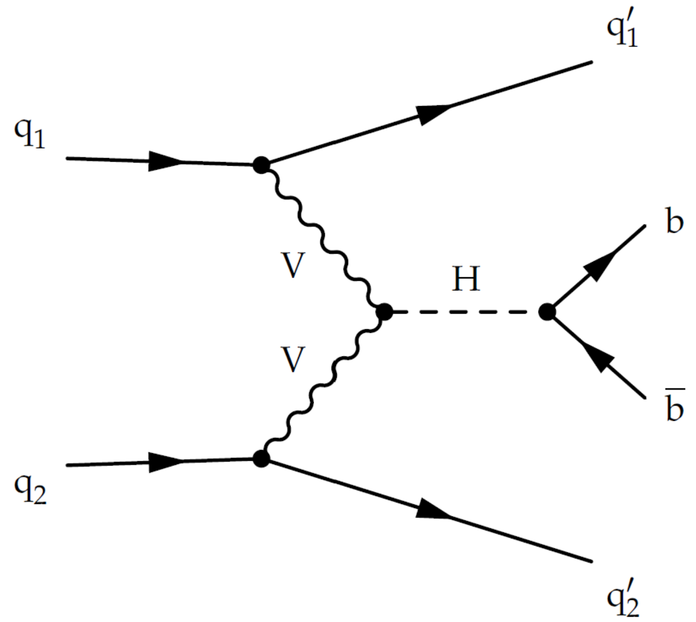
2D fit result is consistent with signal strengths shown in the previous slide



[Eur. Phys. J. C 83 (2023) 562]

VBF production of Higgs boson followed by $H \rightarrow b\bar{b}$ decay produces 4 jet final state

- Two jets in central region of detector (from $H \rightarrow b\bar{b}$)
- Two jets in forward and backward directions relative to beam line with large rapidity separation (VBF jets)



Previous measurement from CMS with Run 1 data at $\sqrt{s}$ =8 TeV:

$\mu^{\mathrm{qqH}}_{\mathrm{Hb\bar{b}}} = 2.8^{+1.6}_{-1.4}$

[Phys. Rev. D 92 (2015) 032008]

VBF (H→ bb) Analysis strategy

Dominant background: QCD multijet and Z+Jets

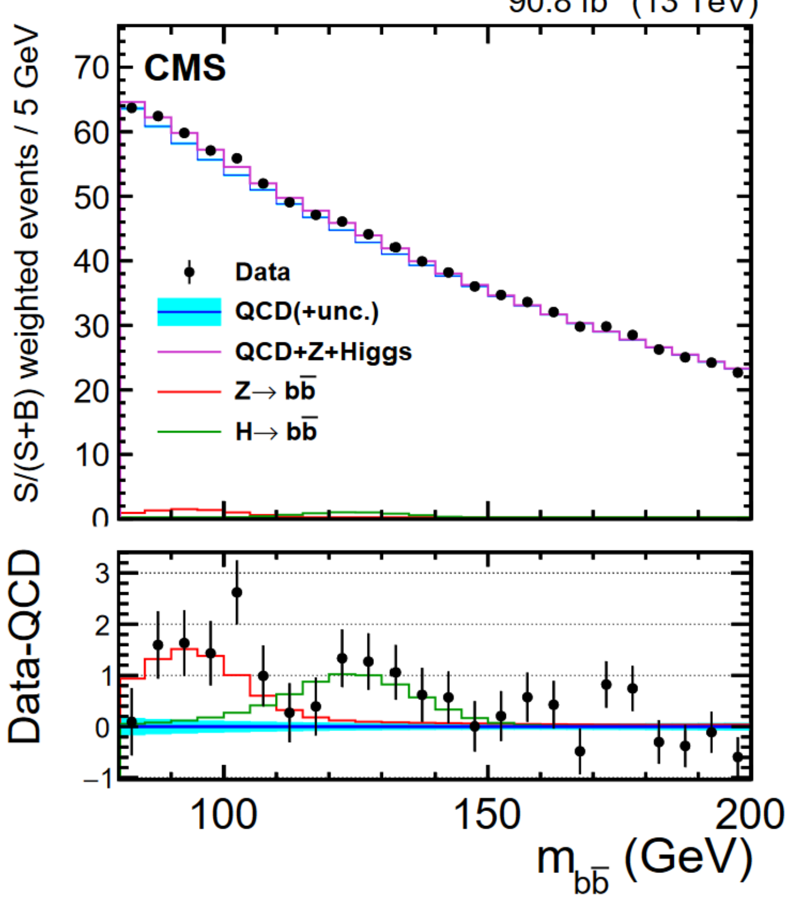
- QCD multijet: Estimated by fit to data in the side bands of the $m_{\mathrm{b\bar{b}}}$ distibution
- Z+Jets: Estimated from simulation

Boosted decision tree used to separate signal from background

18 categories defined based on the BDT scores:

- 5 per year for VBF
- 2 per year for ggH
- 2 per year for Z+Jets

[arXiv:2308.01253]



Signal is extracted from the $m_{\mathrm{b\bar{b}}}$ distribution

VBF (H→ bb) Results

VBF signal strength (ggH constrained to SM pred.):

$$\mu^{\mathrm{qqH}}_{\mathrm{Hb\bar{b}}} = 1.01^{+0.40}_{-0.27}(\mathrm{syst}) \pm 0.36(\mathrm{stat})$$

Observed significance of 2.4σ (exp. 2.7σ)

Inclusive signal strength (qqH+ggH):

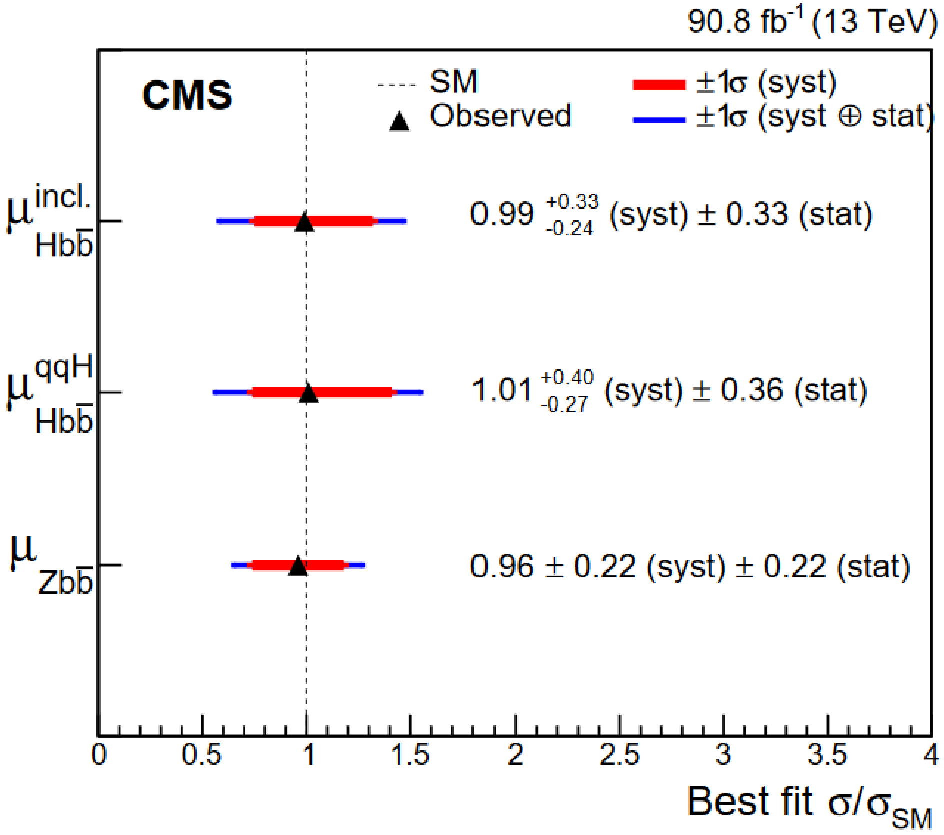
$$\mu^{\mathrm{incl.}}_{\mathrm{Hb\bar{b}}} = 0.99^{+0.33}_{-0.24}(\mathrm{syst}) \pm 0.33(\mathrm{stat})$$

Observed significance of 2.6σ (exp. 2.9σ)

$\mu_{\mathrm{Zb\bar{b}}}$ is left unconstrained for the fits

Systematic uncertainties:

- Theoretical uncertainties in signal process modelling
- Main experimental uncertainties are jet energy scale, b-tagging and trigger efficiency

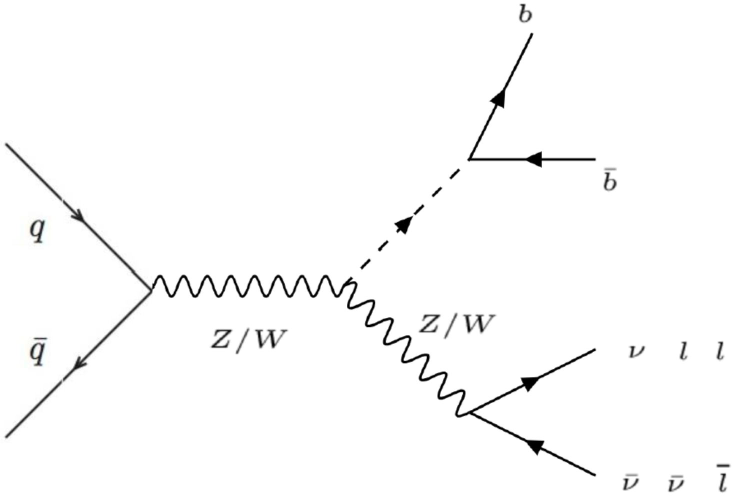


[arXiv:2308.01253]

VH (H→ bb) Introduction

Three channels:

- 0 lepton ($Z \rightarrow \nu\nu$)
- 1 lepton ($W \rightarrow l\nu$)
- 2 leptons ($Z \rightarrow \mu\mu/ee$)



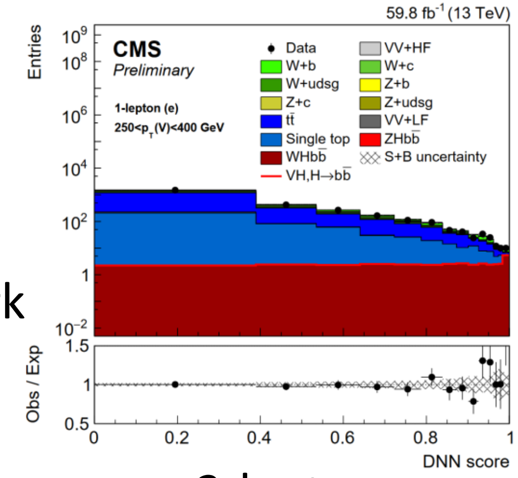
Dominant background: $t\bar{t}$, V+light jets, V+b jets

- Normalization of background contributions are constrained in fit to data in control regions enriched with background events

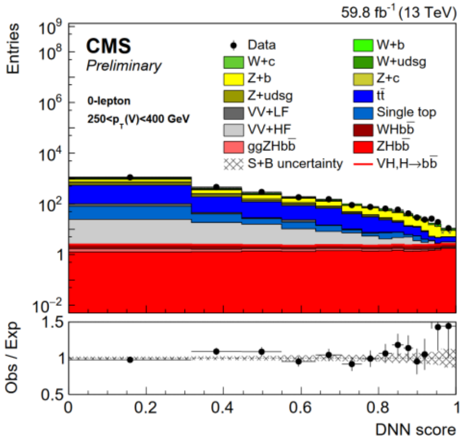
Two Higgs decay topologies are analyzed: Resolved and boosted

Signal is extracted using neural network

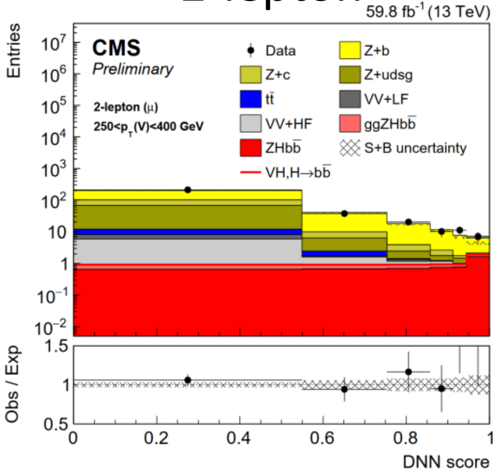
1-lepton



0-lepton



2-lepton



[CMS-PAS-HIG-20-001]

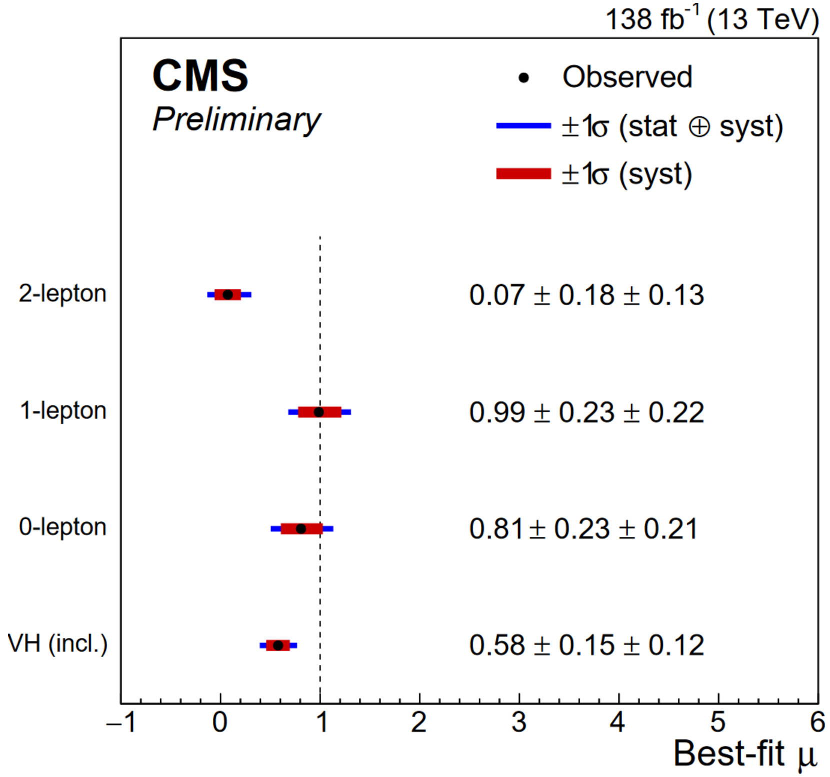
Inclusive signal strength:

$$\mu = 0.58^{+0.19}_{-0.18}$$

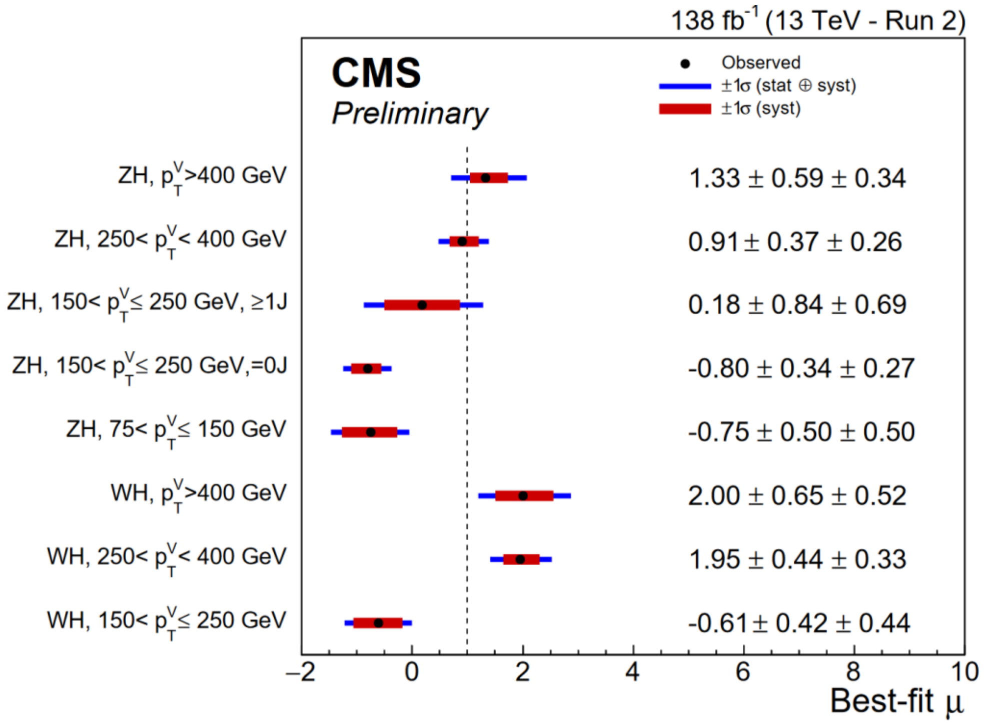
observed significance of 3.3σ (exp. 5.2σ)

Most important systematic uncertainties:

- Signal and background theory modelling
- B-tagging



STXS signal strengths



[CMS-PAS-HIG-20-001]

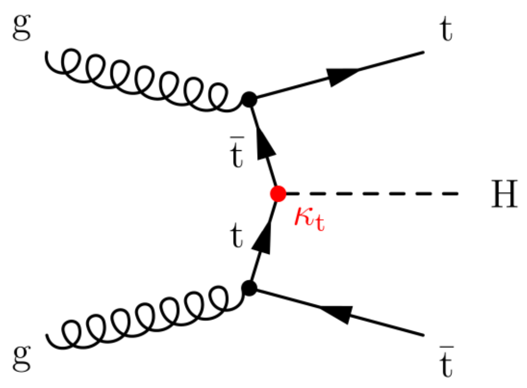
ttH/tH (H→bb) Introduction

NEW

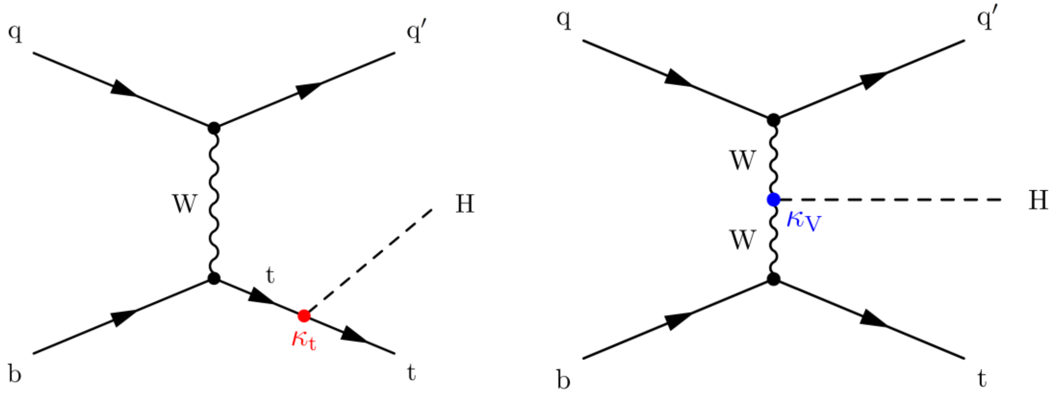
Targeting ttH and tH with $H \rightarrow bb$ in three final states:

- Fully hadronic (FH): 0 leptons → New final state analyzed
- Single lepton (SL): 1 lepton
- Dilepton (DL): 2 leptons

Associated production of ttH



Signature of signal events:
High-p_T b jets and depending on channel jets, isolated electrons , muons or missing transverse momentum



Associated production of tH, either with Higgs boson coupling to top quark or W boson

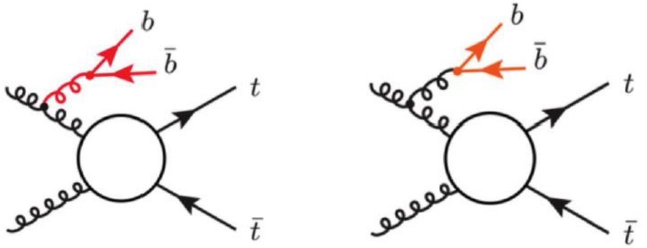
Dominant background:

- QCD multijet (FH channel)
- $t\bar{t}$ + jets

NEW

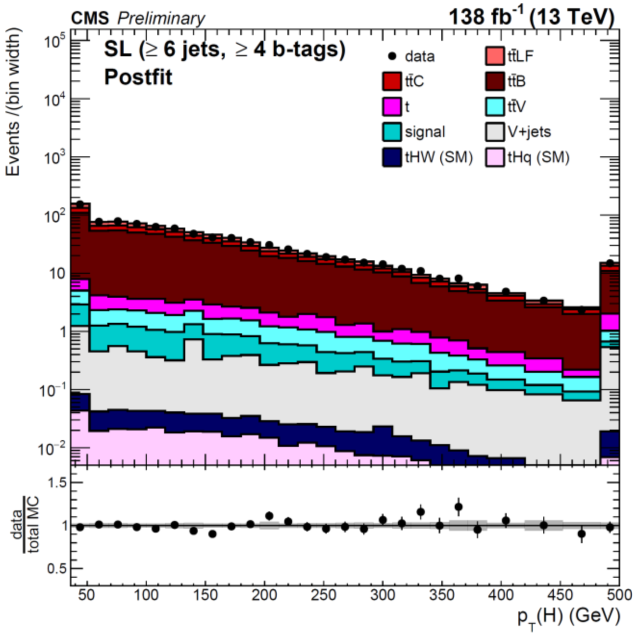
Three sources:
$t\bar{t}+B$: ≥ 1 additional b jet
$t\bar{t}+C$: ≥ 1 additional c jet, no b jet
$t\bar{t}+LF$: All other $t\bar{t}$ events

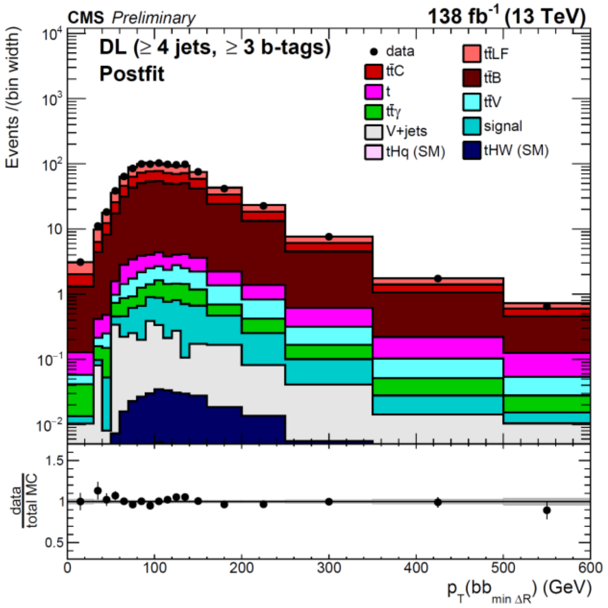
- MC simulation for ttB (Powheg ttbb NLO 4FS)
  - Additional b jets from matrix element instead of parton shower



- MC simulation for ttC and ttLF (Powheg tt NLO 5FS)

Normalization of ttB and ttC constrained by fit to data



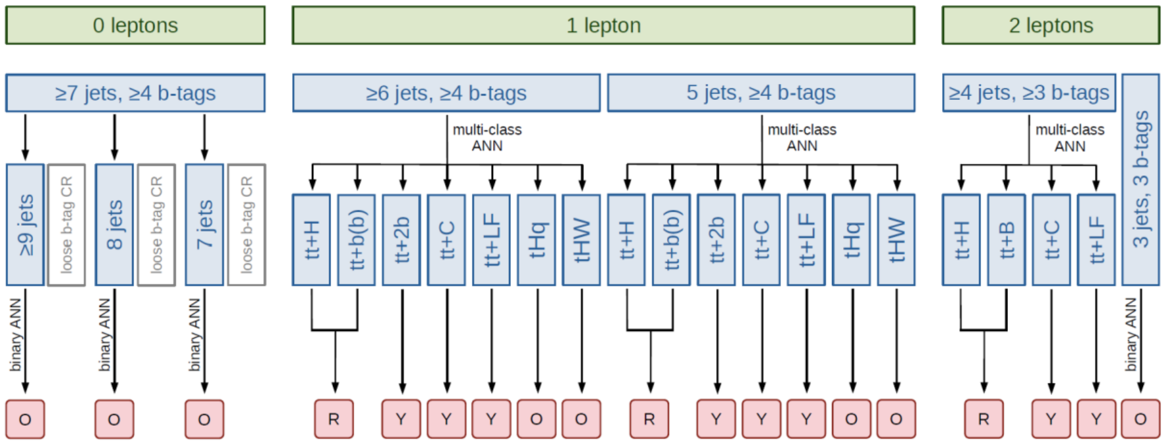


[CMS-PAS-HIG-19-011]

NEW

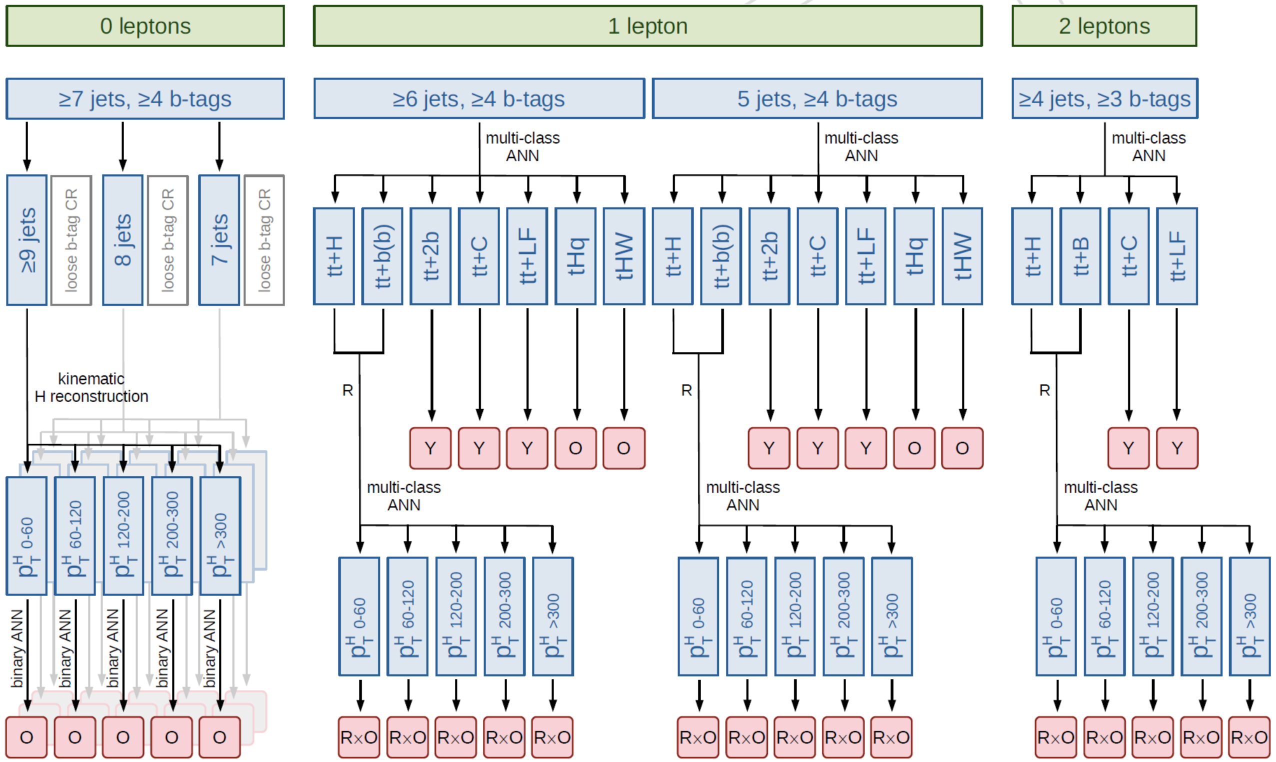
Artificial neural network used to separate signal from background, binary (0ℓ) or multi-classification ($1\ell, 2\ell$)

Inclusive tH and ttH measurement



Distribution in template fit, event yield (Y), ANN output (O), likelihood ratio of ANN outputs (R)

STXS measurement



Distribution in template fit, event yield (Y), ANN output (O), likelihood ratio of ANN outputs (R)

[CMS-PAS-HIG-19-011]

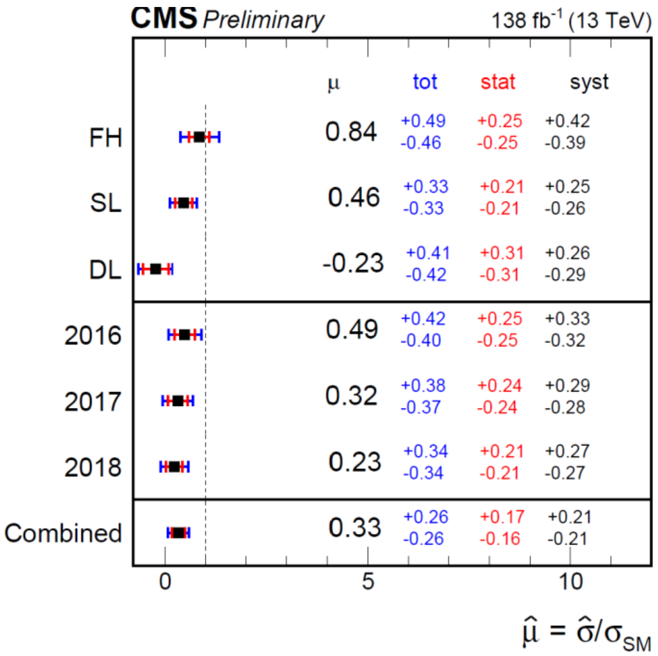
NEW

$t\bar{t}H$ signal strength:

$$\mu_{t\bar{t}H} = 0.33^{+0.26}_{-0.26} = 0.33^{+0.17}_{-0.16}(\text{stat})^{+0.20}_{-0.21}(\text{syst})$$

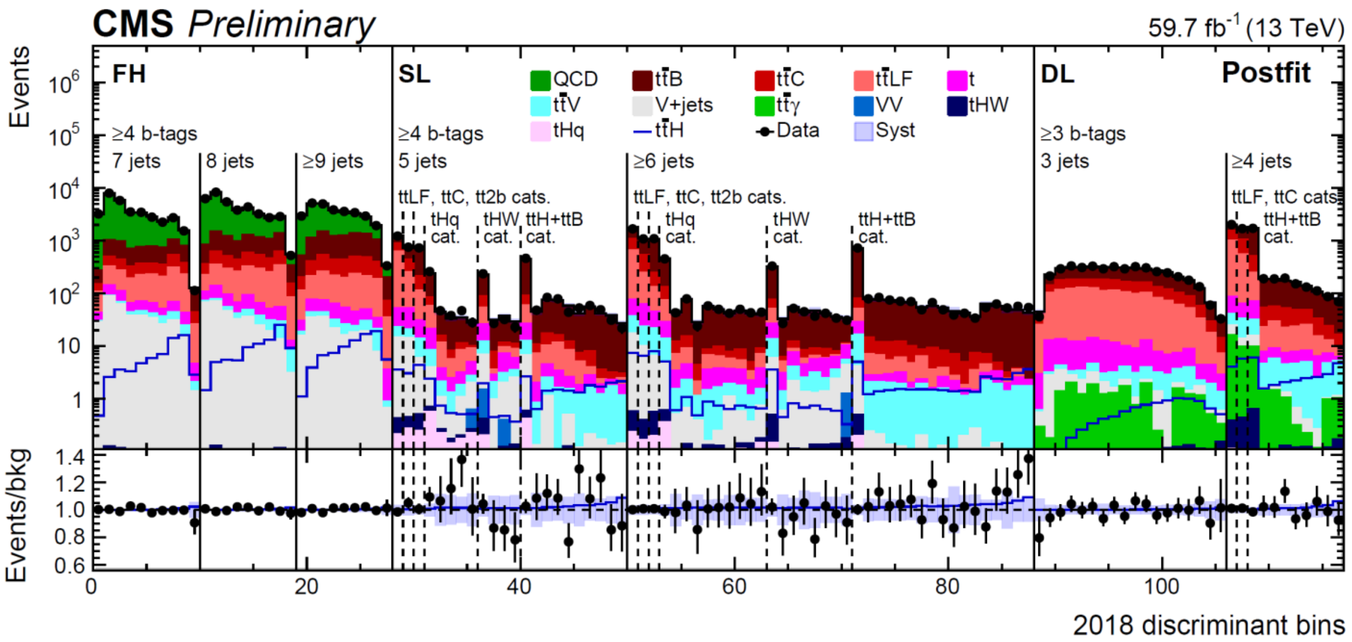
Observed signal significance 1.3σ (exp. 4.1σ)

Compatibility of $t\bar{t}H$ signal strength to SM expection is above 2σ



[CMS-PAS-HIG-19-011]

tH contribution assumed to confrom to SM expectation and treated as background

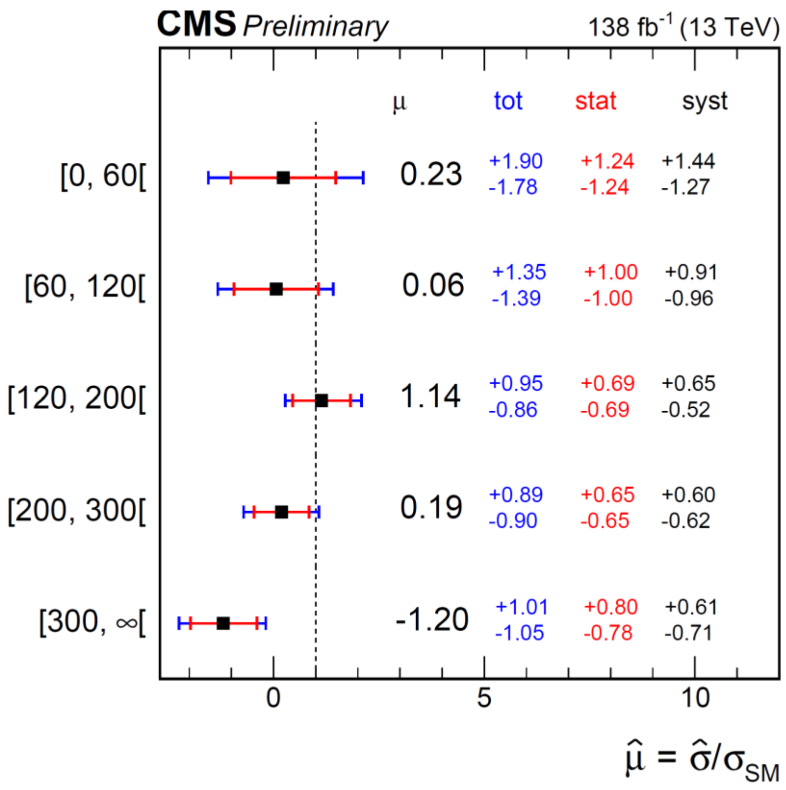


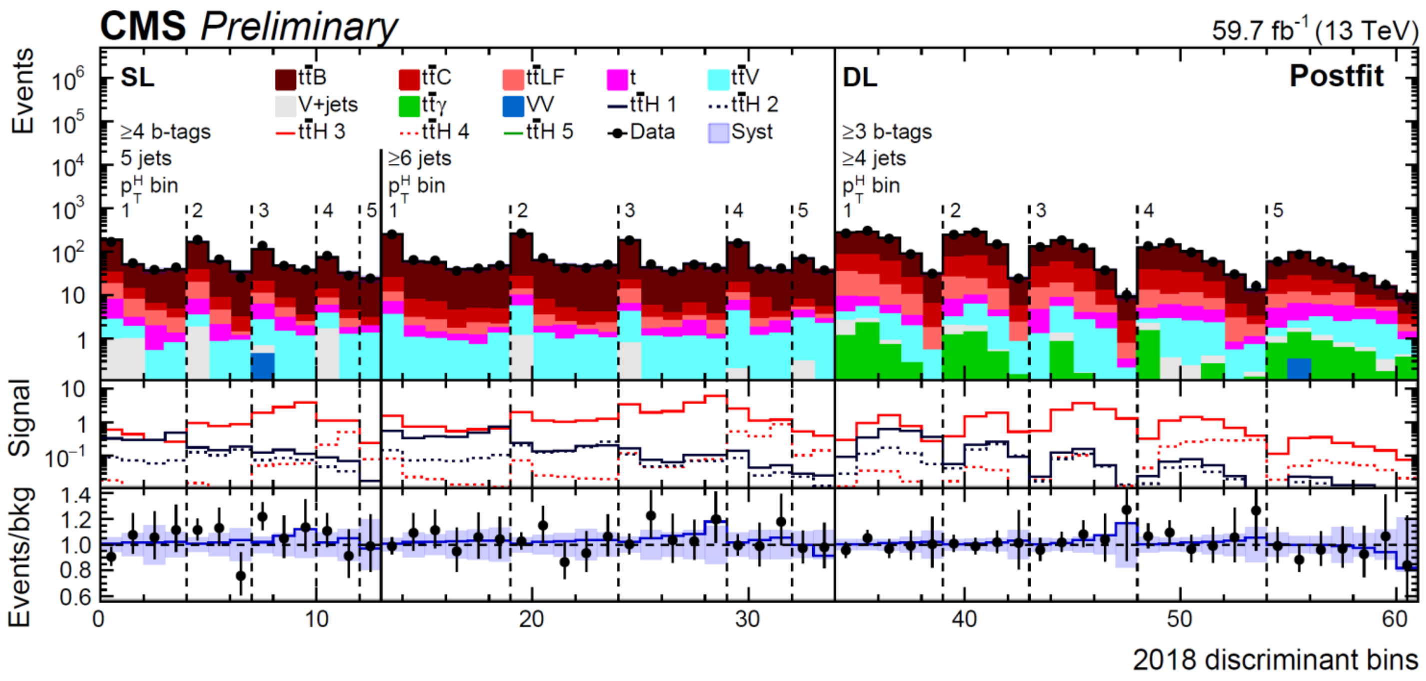
postfit distributions 2018

ttH (H→bb) STXS results

NEW

In 120 GeV to 300 GeV p_T^H bins: highest sensitivity





postfit STXS distributions 2018

tH (H→bb) Inclusive result

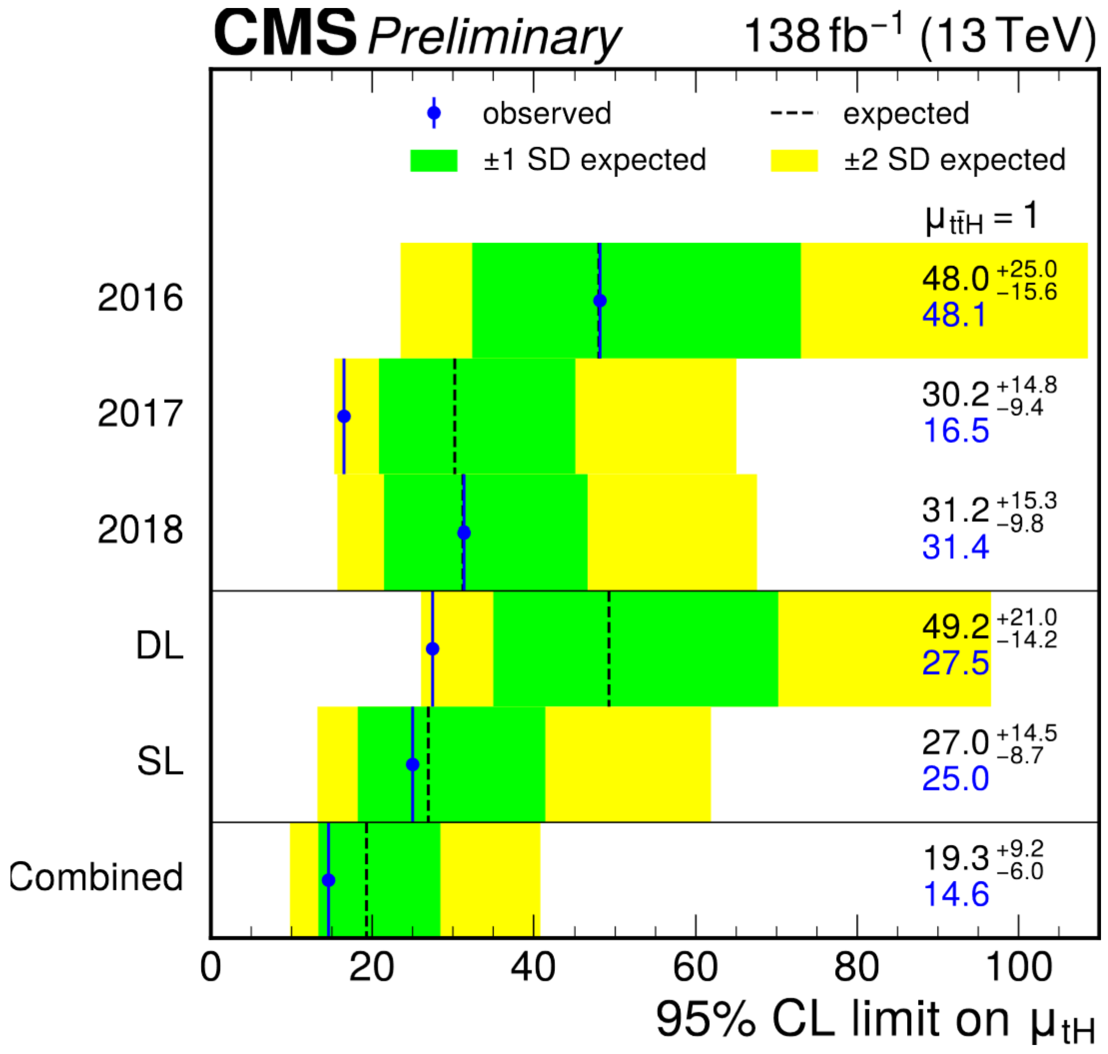
NEW

[CMS-PAS-HIG-19-011]

95% CL upper limit:

$\mu_{tH} = 14.6$ (exp $19.3^{+9.2}_{-6.0}$)

ttH contribution assumed to conform to SM expectation and treated as background



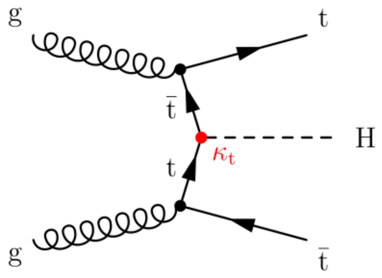
ttH/tH (H→bb) Coupling results

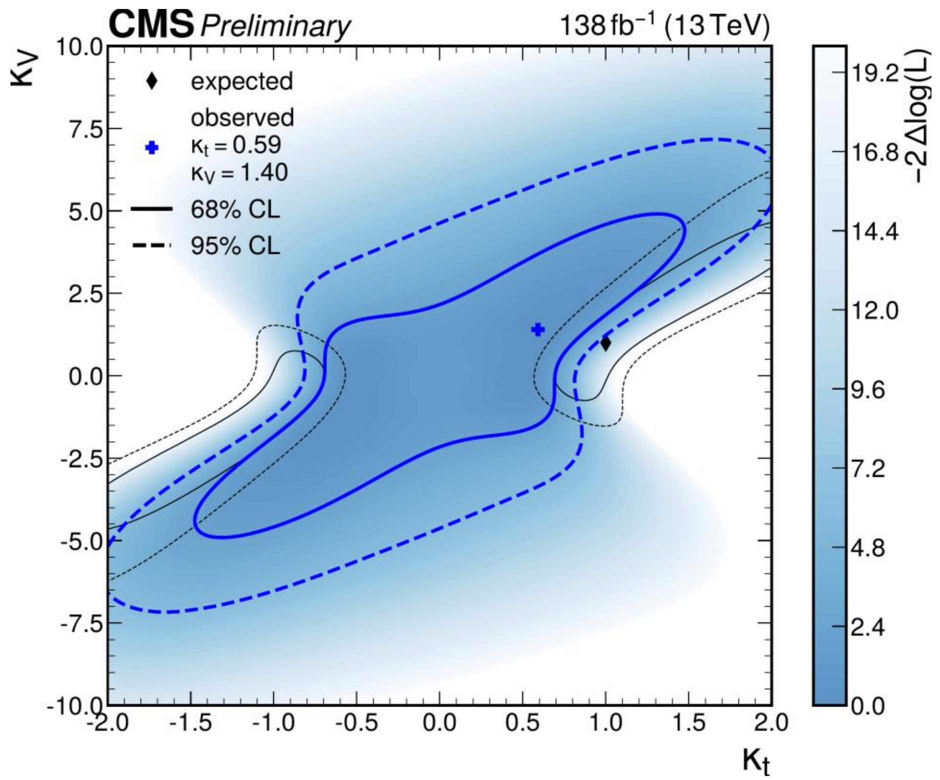
NEW

Coupling of Higgs boson to top quark (κ_t) and to vector boson (κ_V),
ttH and tH both treated as signal

[CMS-PAS-HIG-19-011]

ttH production rate $\propto \kappa_t^2$

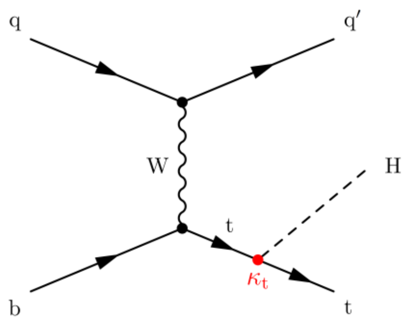


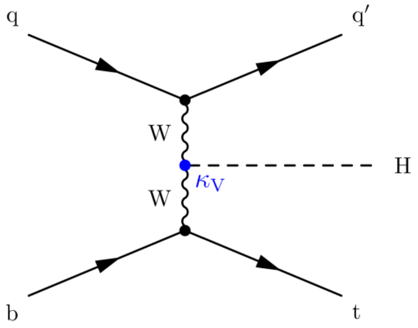


compatible with SM expection at level of 2σ

for tHq and tHW interference occurs:

$$\sigma_{\text{tHq}} = \left(2.63 \cdot \kappa_t^2 + 3.58 \cdot \kappa_V^2 - 5.21 \cdot \kappa_t \kappa_V\right)\sigma_{\text{tHq}}^{\text{SM}}$$
$$\sigma_{\text{tHW}} = \left(2.91 \cdot \kappa_t^2 + 2.40 \cdot \kappa_V^2 - 4.22 \cdot \kappa_t \kappa_V\right)\sigma_{\text{tHW}}^{\text{SM}}$$



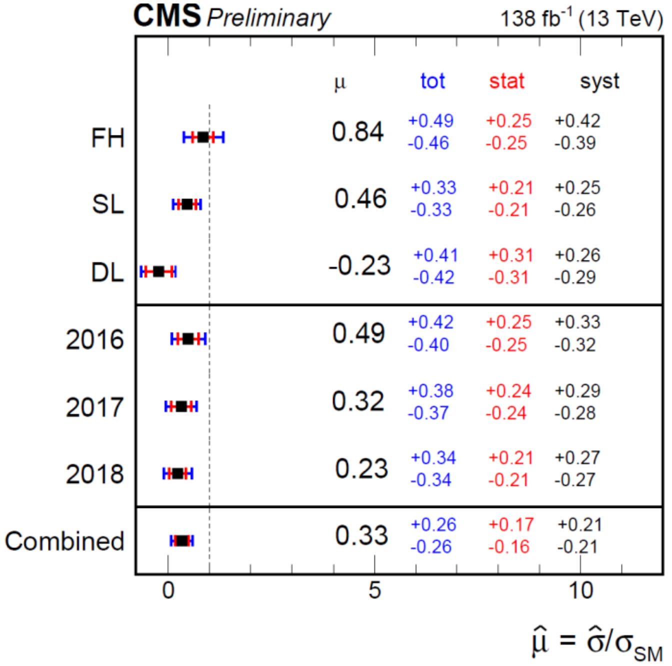


Anomalous couplings covered by Matteo Bonanomi on Tuesday

Presented recent results from the fermionic Higgs inclusive cross section and coupling measurements of CMS with full Run 2 data

- ttH/tH $(H \rightarrow bb)$
- VH $(H \rightarrow bb)$
- VBF $(H \rightarrow bb)$
- ggH,qqH, VH $(H \rightarrow \tau\tau)$

Run 3 currently ongoing, expected to further improve the sensitivity of the analyses



ttH signal strength

Posters covering the presented analyses:
«Measurement of ttH and tH production in the H(bb) channel at CMS» by Valeria Botta
«Measurements of Higgs boson production in decay channel with a tau lepton pair» by Pascal Bärtschi

Thank you for the attention!

Back up

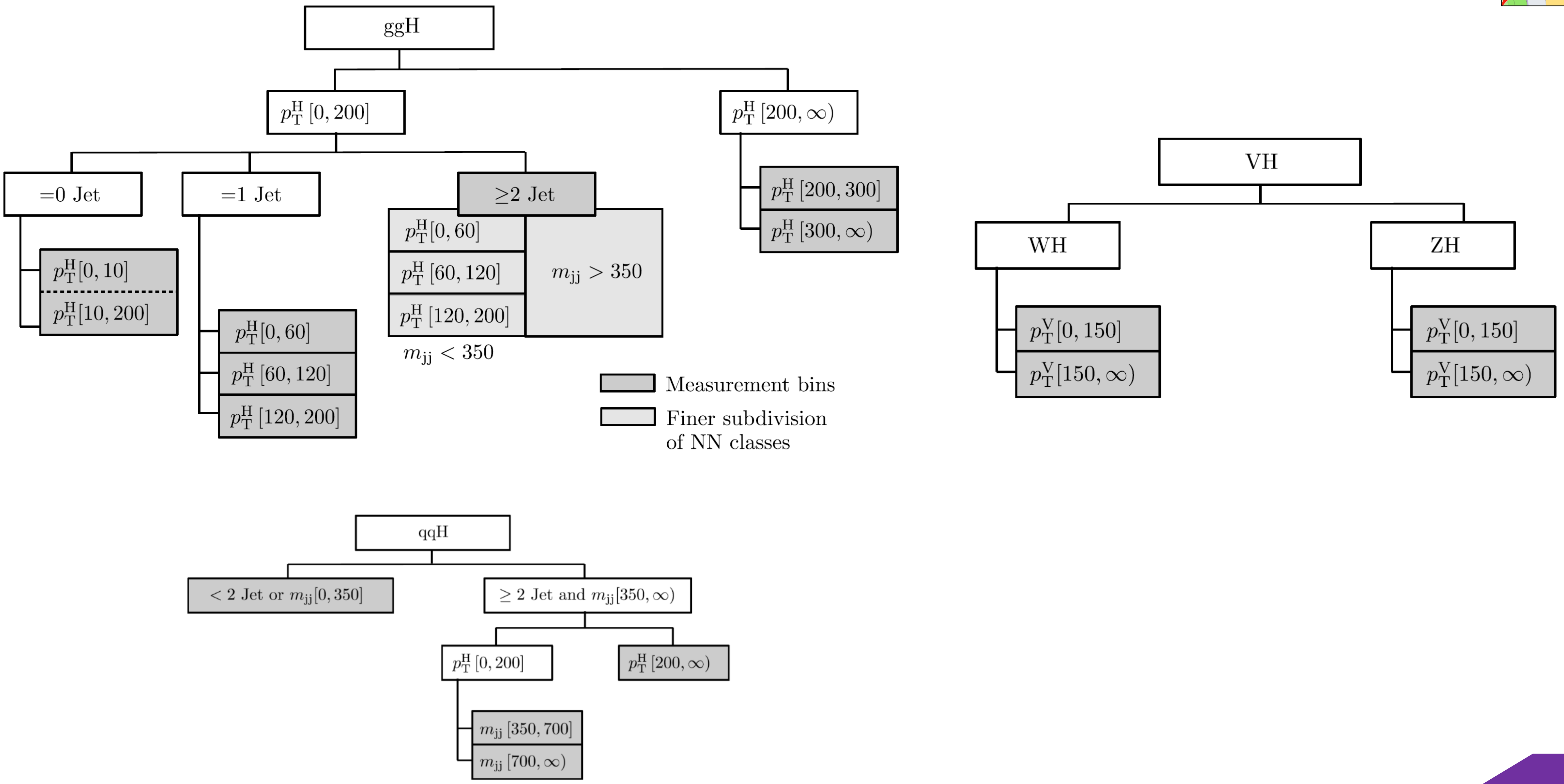
H→ $\tau\tau$ Processes and selection

Universität Zürich[UZH]

CMS

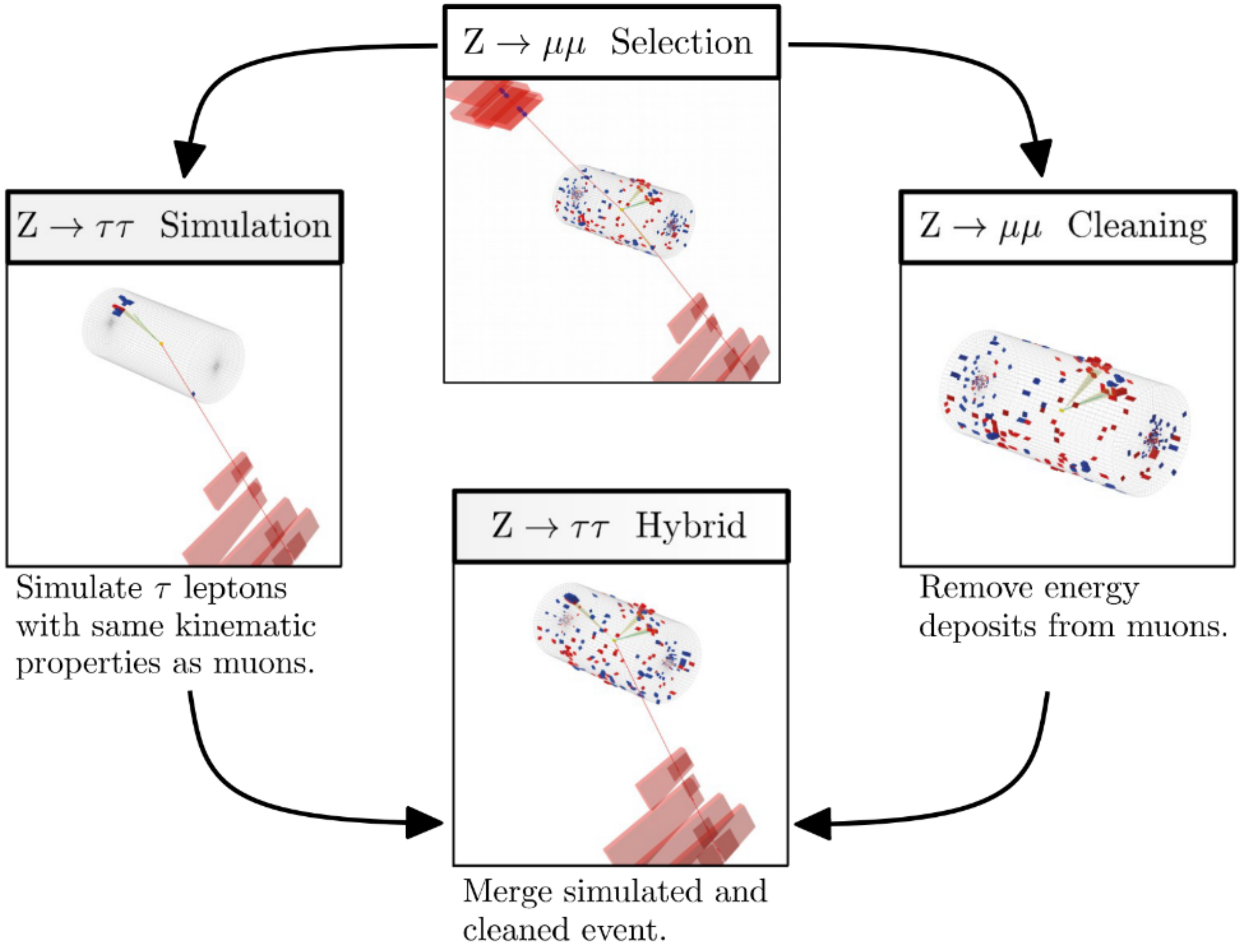
Process	Classes per final state			
	eμ	eτ_h	$\mu\tau_h$	$\tau_h\tau_h$
τ-embedding	genuine τ	genuine τ	genuine τ	genuine τ
QCD/F_F-method	jet $\to \ell$	jet $\to \tau_h$	jet $\to \tau_h$	jet $\to \tau_h$
$t\bar{t}(e/\mu + X)$	tt	tt	tt	misc
$Z \to \ell\ell$	misc	zll	zll	misc
Diboson/single t	db	misc	misc	misc

Final state	Category	Selection	Observables
$\ell\tau_h$, eμ	0-jet	0 jet	$m_{\tau\tau}$, $p_T^{\tau_h}$ ($\ell\tau_h$) $m_{\tau\tau}$ (eμ)
	VBF low p_T^H	$\geq$2 jets, $m_{jj} > 350$ GeV, $\hat{p}_T^H < 200$ GeV	$m_{\tau\tau}$, m_{jj}
	VBF high p_T^H	$\geq$2 jets, $m_{jj} > 350$ GeV, $\hat{p}_T^H > 200$ GeV	$m_{\tau\tau}$, m_{jj}
	Boosted 1 jet	1 jet	$m_{\tau\tau}$, $\hat{p}_T^H$
	Boosted $\geq$2 jets	Not in VBF, $\geq$2 jets	$m_{\tau\tau}$, $\hat{p}_T^H$
$\tau_h\tau_h$	0-jet	0 jet	$m_{\tau\tau}$
	VBF low p_T^H	$\geq$2 jets, $\Delta\eta_{jj} > 2.5$ (2.0 for 2016), $100 < \hat{p}_T^H < 200$ GeV	$m_{\tau\tau}$, m_{jj}
	VBF high p_T^H	$\geq$2 jets, $\Delta\eta_{jj} > 2.5$ (2.0 for 2016), $\hat{p}_T^H > 200$ GeV	$m_{\tau\tau}$, m_{jj}
	Boosted 1 jet	1 jet	$m_{\tau\tau}$, $\hat{p}_T^H$
	Boosted $\geq$2 jets	Not in VBF, $\geq$2 jets	$m_{\tau\tau}$, $\hat{p}_T^H$


ggH
pTH [0, 200]
pTH [200, ∞)
=0 Jet
=1 Jet
≥2 Jet
pTH[0, 10]
pTH[10, 200]
pTH[0, 60]
pTH [60, 120]
pTH [120, 200]
mjj > 350
mjj < 350
pTH [200, 300]
pTH [300, ∞)
Measurement bins
Finer subdivision
of NN classes
VH
WH
ZH
pTV[0, 150]
pTV[150, ∞)
qqH
< 2 Jet or mjj[0, 350]
≥ 2 Jet and mjj[350, ∞)
pTH [0, 200]
pTH [200, ∞)
mjj [350, 700]
mjj [700, ∞)

Estimation of all backgrounds with two real τ (mostly from Z boson decay)

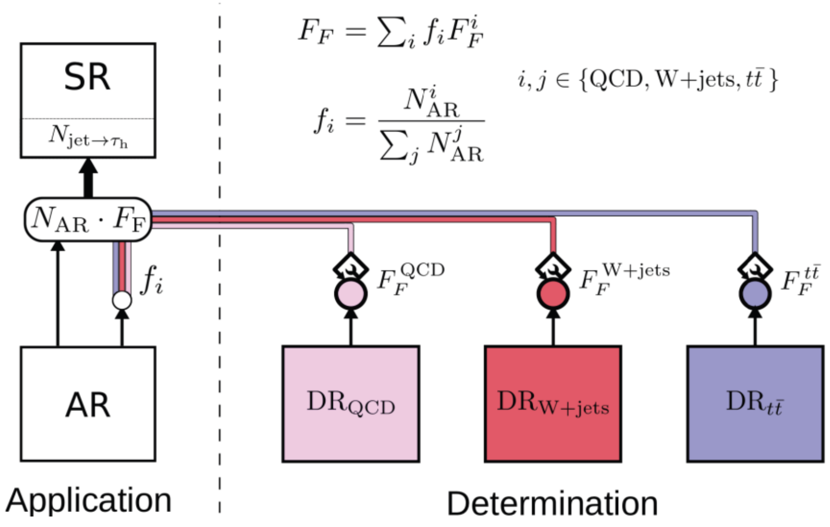
- $\mu\mu$ events selected in data
- Energy deposits of muons removed, replaced by simulated tau leptons with the same kinematics



Estimation of background with jets initiated by quarks or gluons and misidentified as hadronically decaying tau leptons (especially $\tau_h\tau_h$ channel has large contribution)

- Anti-isolation region: Tau lepton isolation vs jets is reverted
- 3 determination regions for QCD multijet, W+Jets and $t\bar{t}$ (for $\tau_h\tau_h$ channel only QCD)
- Fake factors weighted with fraction of background contribution in AR:

$$F_F = f_{\mathrm{W+jets}} \cdot F_F^{\mathrm{W+jets}} + f_{\mathrm{QCD}} \cdot F_F^{\mathrm{QCD}} + f_{\mathrm{t\bar{t}}} \cdot F_F^{\mathrm{t\bar{t}}}$$

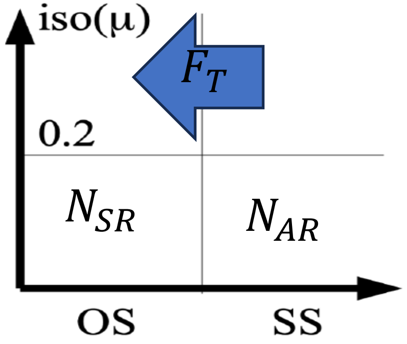


H→ $\tau\tau$ OS/SS method

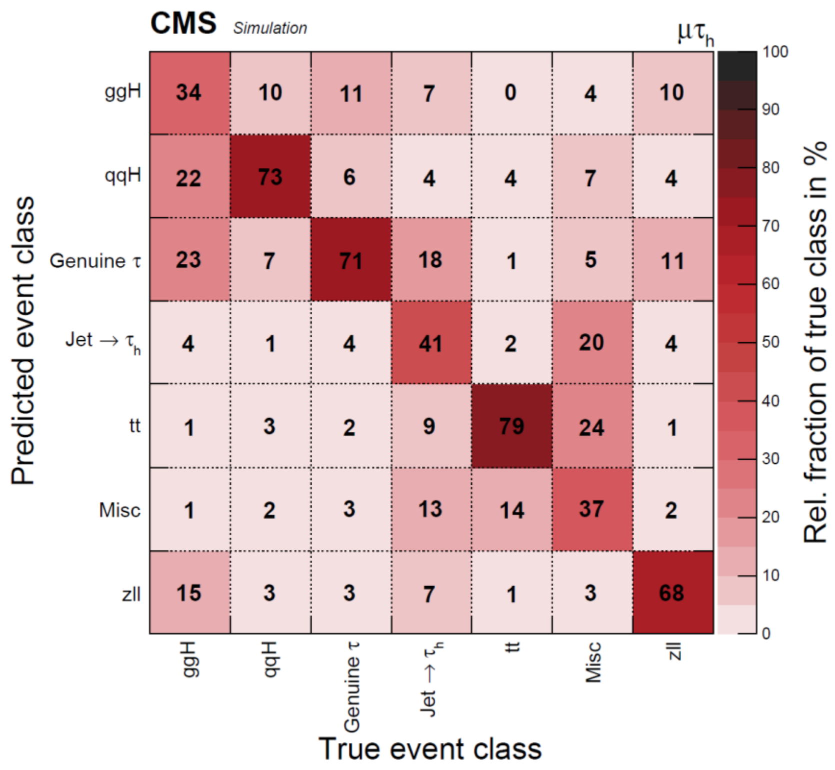
Estimate background with jets misidentified as electrons or muons in $e\mu$ channel

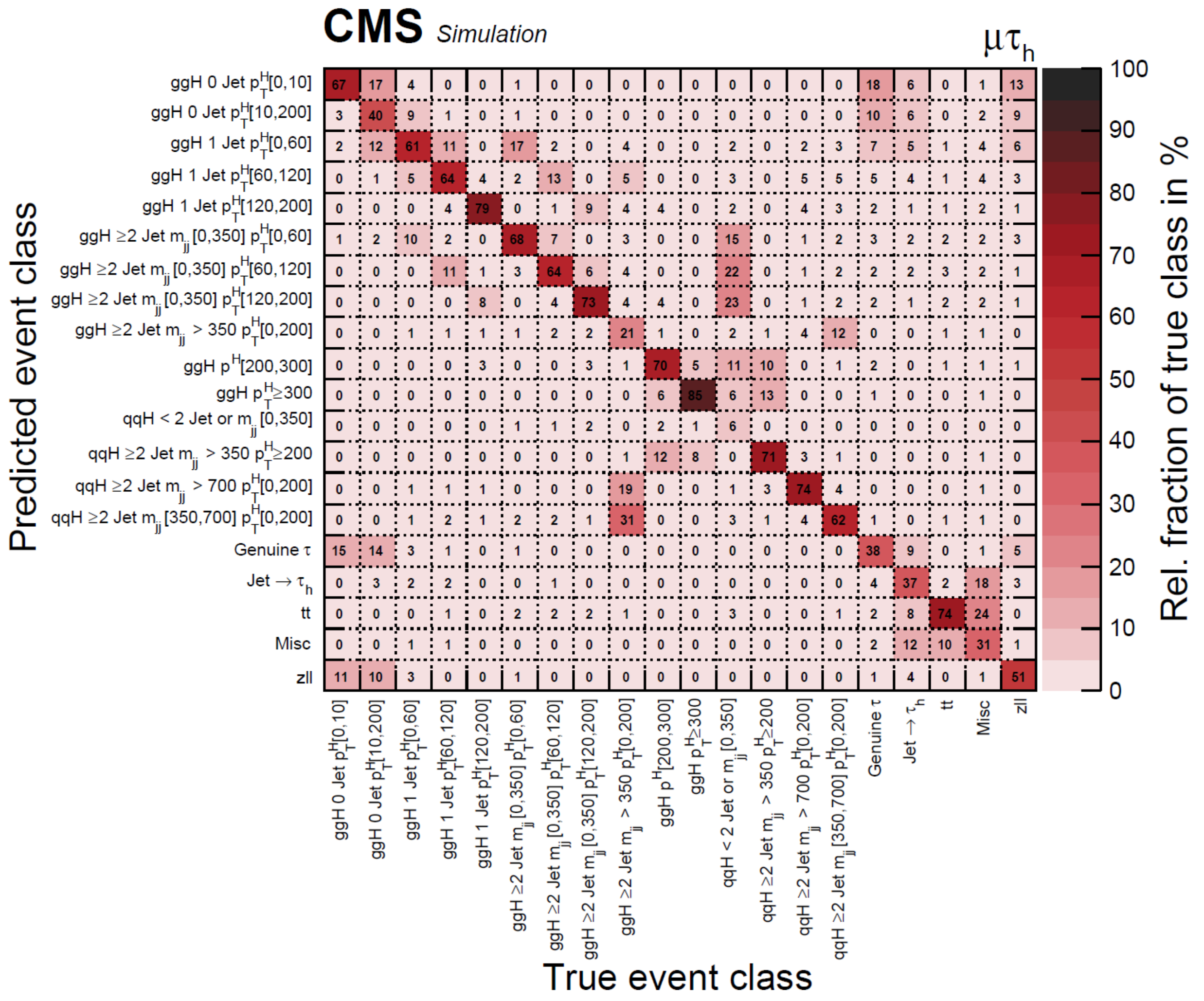
- Application region defined with same sign of q_e and q_μ
- Determination region with anti-isolated muons and isolated electrons give transfer factor F_T from AR to SR
- Extrapolate the number of fake leptons to the signal region with:

$$N_{SR} = F_T N_{AR}$$



H→ $\tau\tau$ Correlation plots

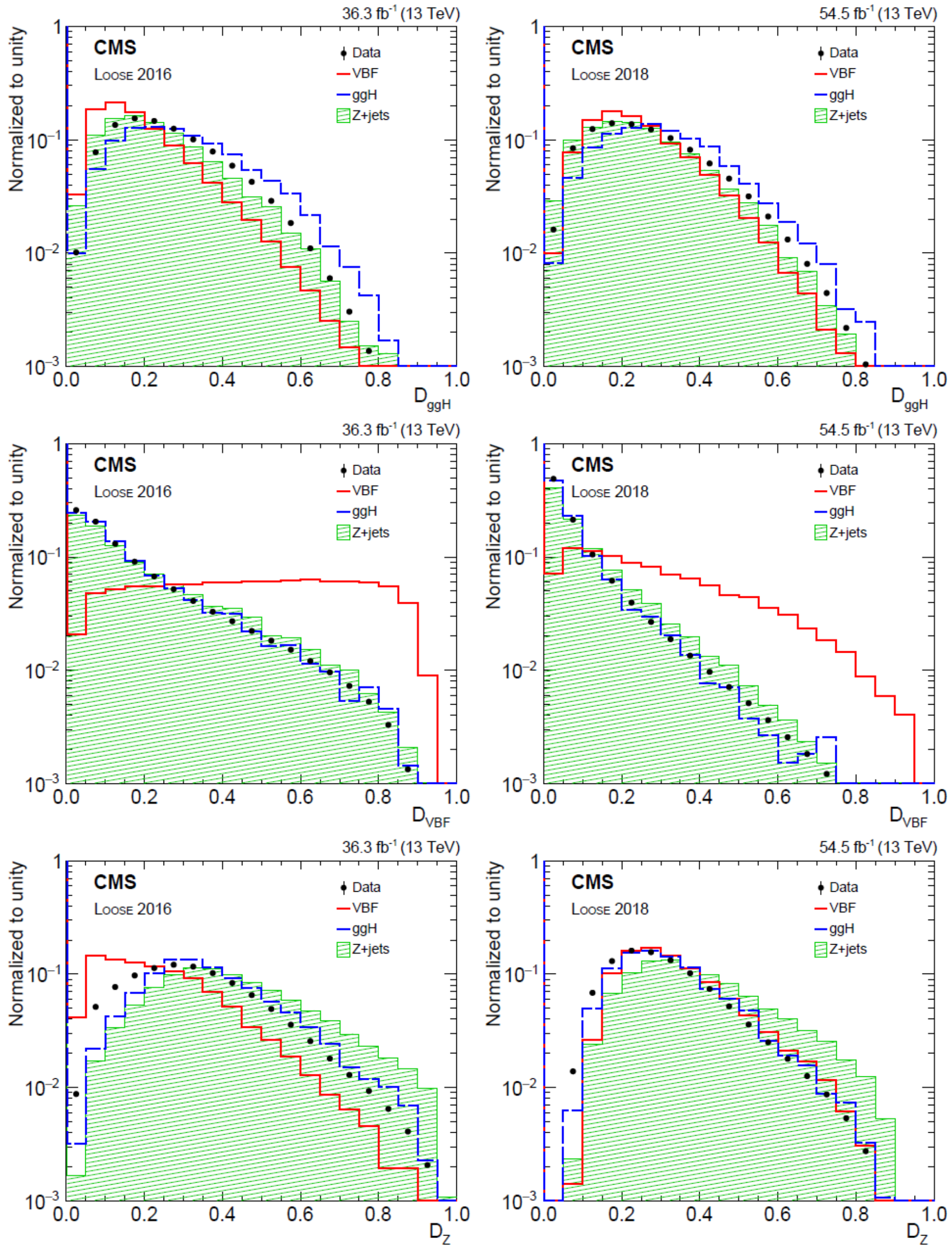


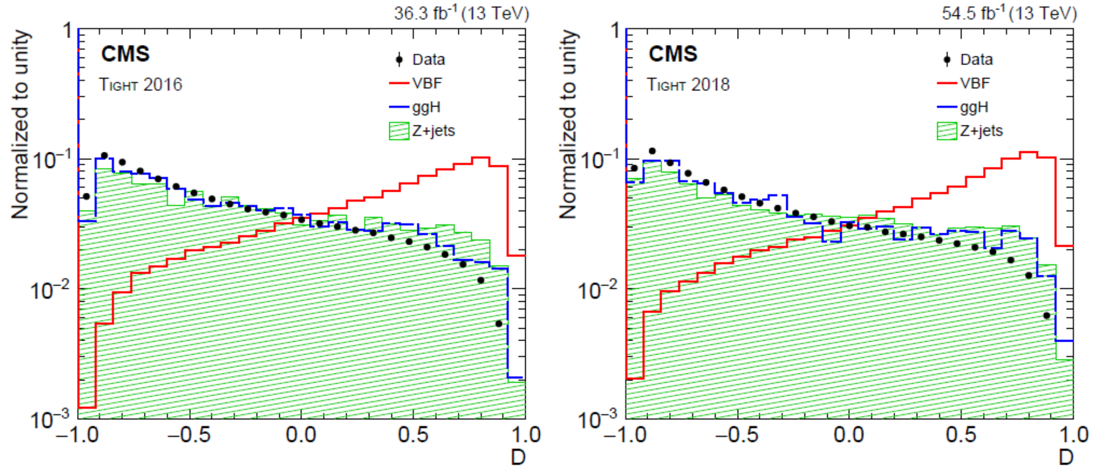


VBF (H→ bb) categories

Category	BDT score boundaries	Targeted process
	2016	
Tight 1	$0.25 < D < 0.50$	VBF
Tight 2	$0.50 < D < 0.75$	VBF
Tight 3	$0.75 < D$	VBF
Loose G1	$0.50 < D_{ggH} < 0.55$	ggH
Loose G2	$0.55 < D_{ggH}$	ggH
Loose V1	$D_{ggH} < 0.50, 0.80 < D_{VBF} < 0.85$	VBF
Loose V2	$D_{ggH} < 0.50, 0.85 < D_{VBF}$	VBF
Loose Z1	$D_{ggH} < 0.50, D_{VBF} < 0.80, 0.60 < D_{Z} < 0.75$	Z+jets
Loose Z2	$D_{ggH} < 0.50, D_{VBF} < 0.80, 0.75 < D_{Z}$	Z+jets
	2018	
Tight 1	$0.25 < D < 0.50$	VBF
Tight 2	$0.50 < D < 0.75$	VBF
Tight 3	$0.75 < D$	VBF
Loose G1	$0.55 < D_{ggH} < 0.60$	ggH
Loose G2	$0.60 < D_{ggH}$	ggH
Loose V1	$D_{ggH} < 0.55, 0.50 < D_{VBF} < 0.55$	VBF
Loose V2	$D_{ggH} < 0.55, 0.55 < D_{VBF}$	VBF
Loose Z1	$D_{ggH} < 0.55, D_{VBF} < 0.50, 0.60 < D_{Z} < 0.70$	Z+jets
Loose Z2	$D_{ggH} < 0.55, D_{VBF} < 0.50, 0.70 < D_{Z}$	Z+jets

VBF (H→ bb) DNN outputs





VBF ($H \to bb$) Systematics

Source of systematic uncertainty	Impact on signal strength [%]
VBF parton shower	13.0
Jet energy scale	7.7
Trigger efficiency	6.7
Parton shower (final-state radiation)	5.6
b jet regression smearing	3.3
b tagging efficiency	3.0
Pileup modeling	2.3
b jet regression scale	2.0
Jet energy resolution	1.5

Previous measurement from CMS :

$\mu^{\mathrm{qqH}}_{\mathrm{Hb\bar{b}}} = 2.8^{+1.6}_{-1.4}$ with 2.2σ significance (exp. 0.8σ)

[Phys. Rev. D 92 (2015) 032008]

Recent Measurement from ATLAS :

$\mu^{\mathrm{qqH}}_{\mathrm{Hb\bar{b}}} = 0.95^{+0.38}_{-0.36}$ with 2.6σ significance (exp. 2.8σ)

[Eur. Phys. J. C 81 (2021) 537]

b jet energy regression Comput Softw Big Sci 4, 10 (2020)

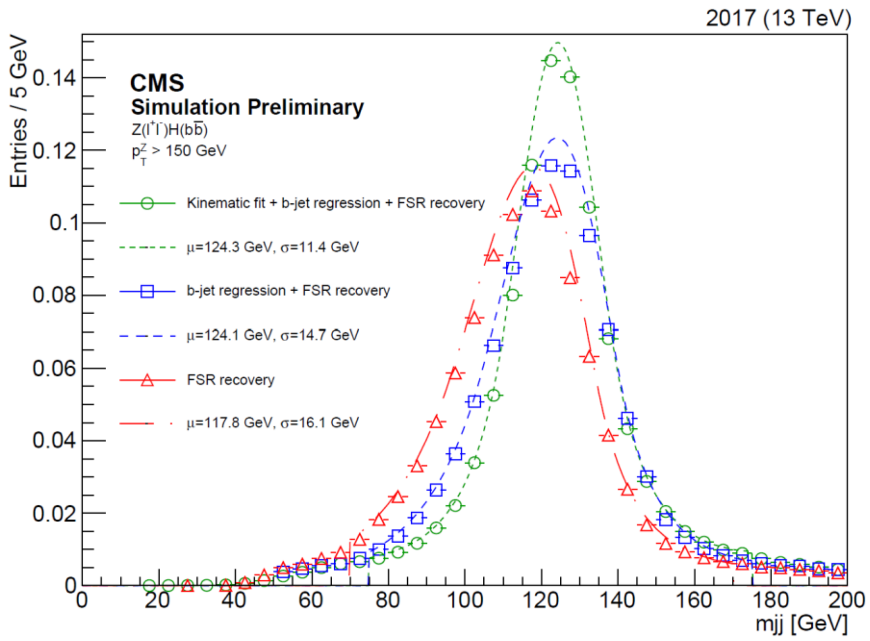
- DNN regression on b jet specific kinematic properties for jet momentum reconstruction

Dedicated smearing and scaling correction to account for different jet resolution in data and MC

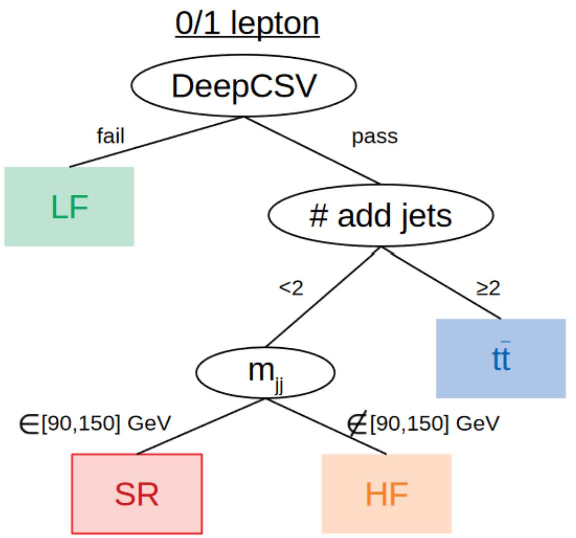
- Fit uses 2-jet event topology in which the jet resolution can be measured by the jet system balance against the Z in the transverse plane

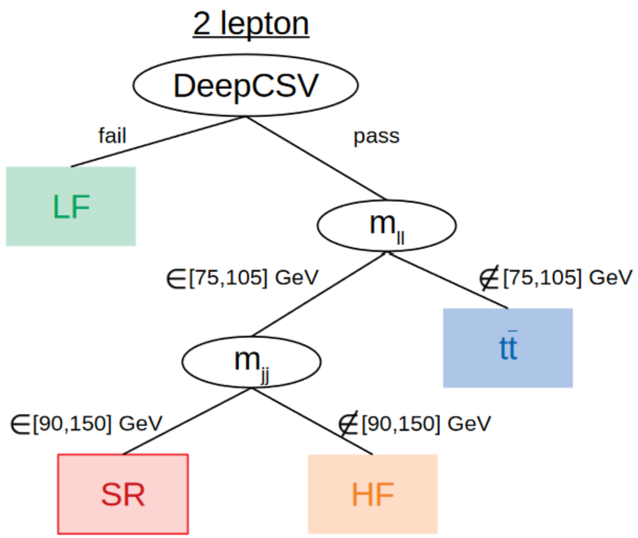
Kinematic fit (2 lepton channel)

- Use information about Z mass to constrain mass of Higgs boson reconstructed from jets and final state radiation
- possible due to better momentum resolution of leptons than jets and absence of intrinsic MET in 2 lepton channel
- fit of lepton and jet kinematics takes into account uncertainties

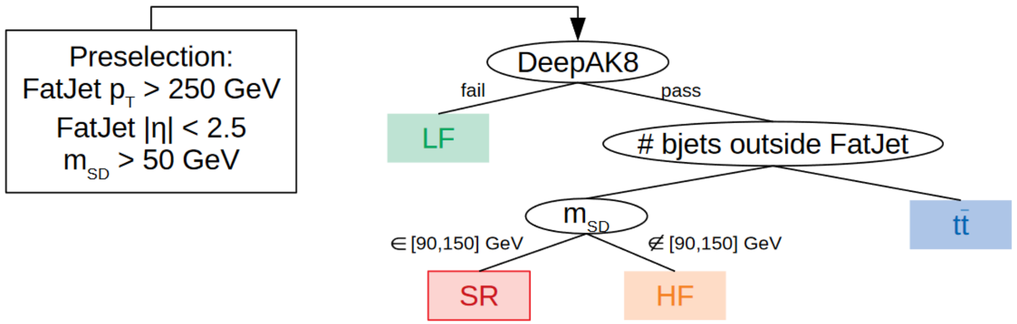


Resolved topology

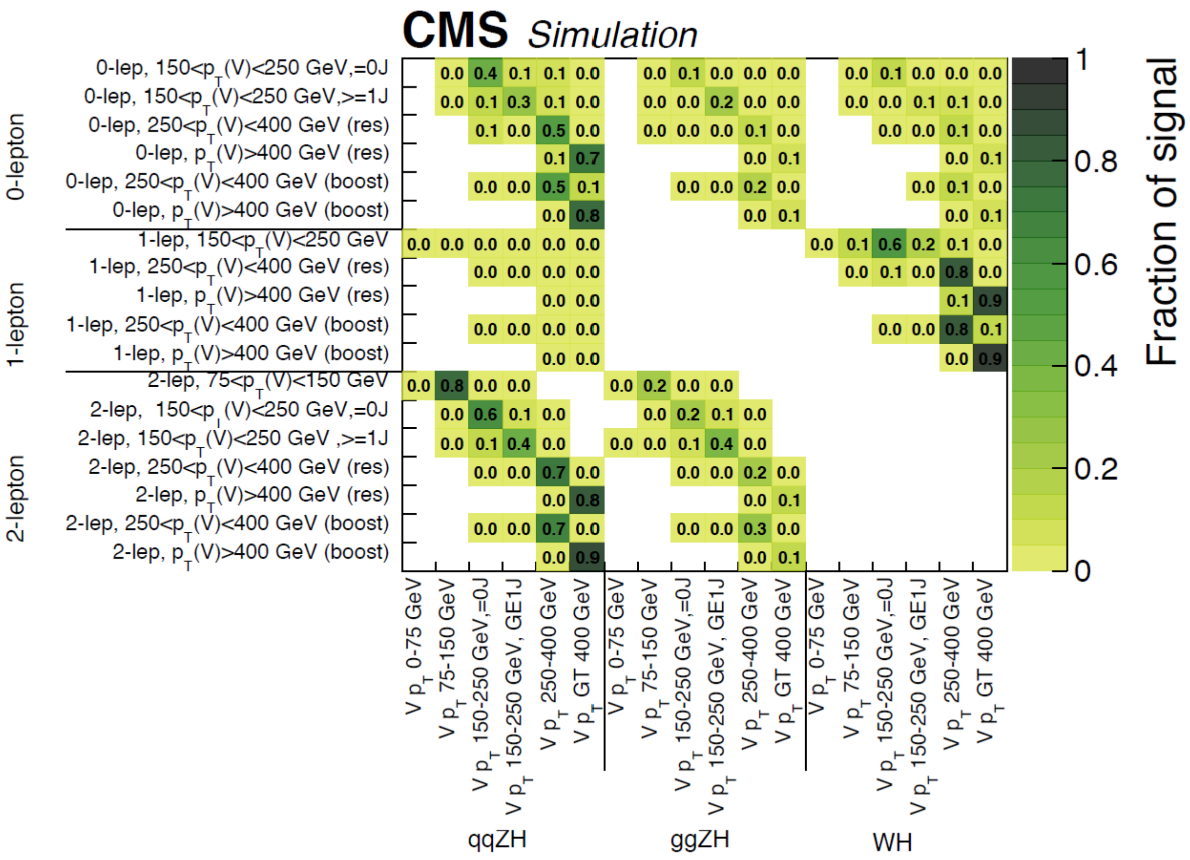


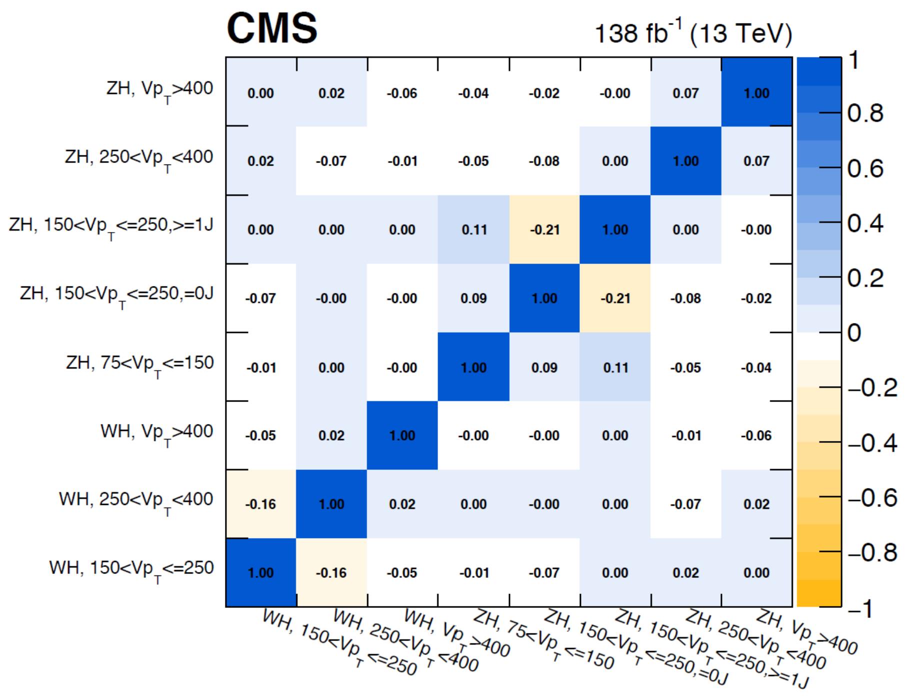


Boosted topology

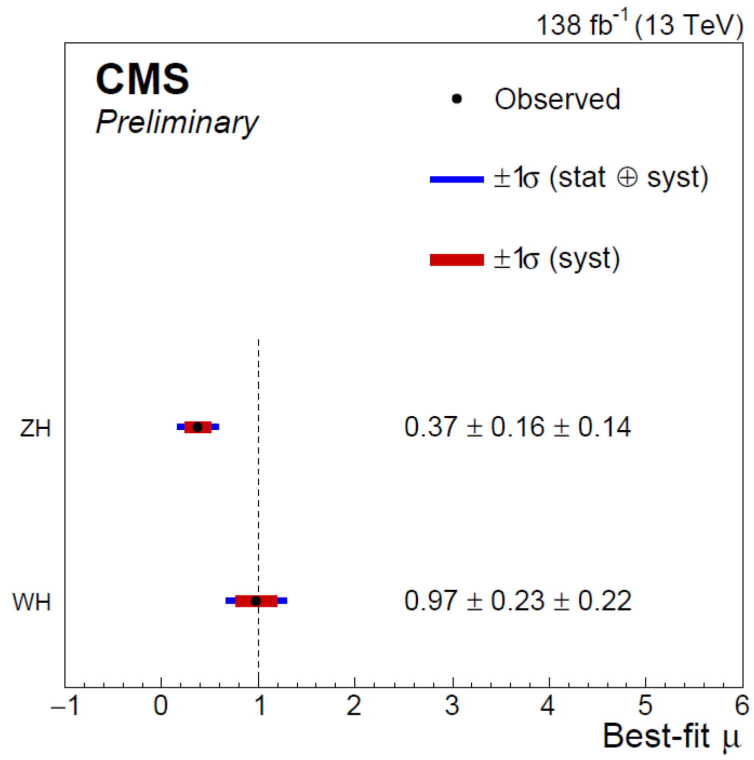


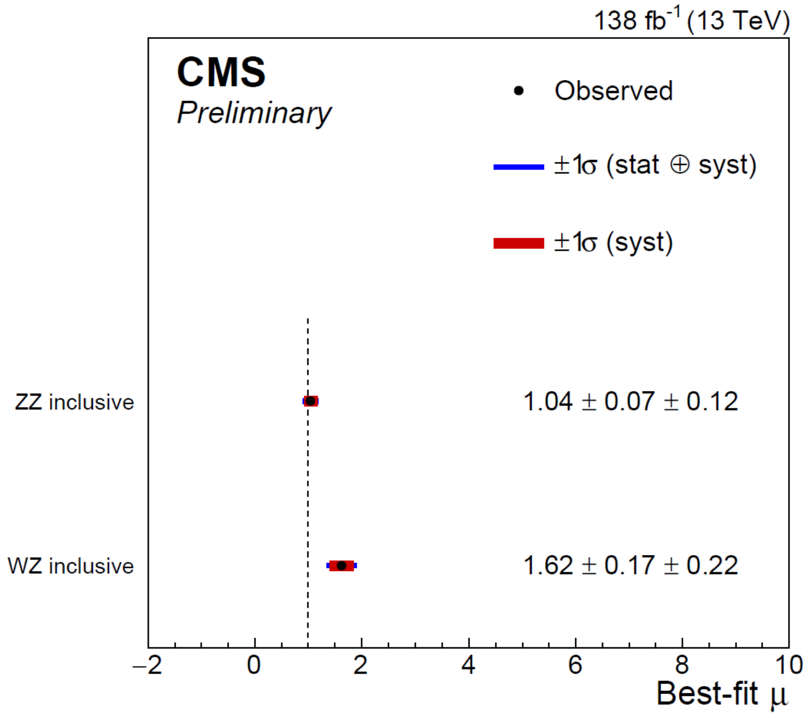
VH (H→bb) Correlation plots





VH (H→bb) Results





Previous result (parial Run II results):

- Expected sensitivity 4.2σ
- $\mu = 1.06 \pm 0.26$ (2016+2017)
- $\mu = 1.08 \pm 0.34$ (2017)

CMS-PAS-HIG-18-016

VH (H→bb) Impacts

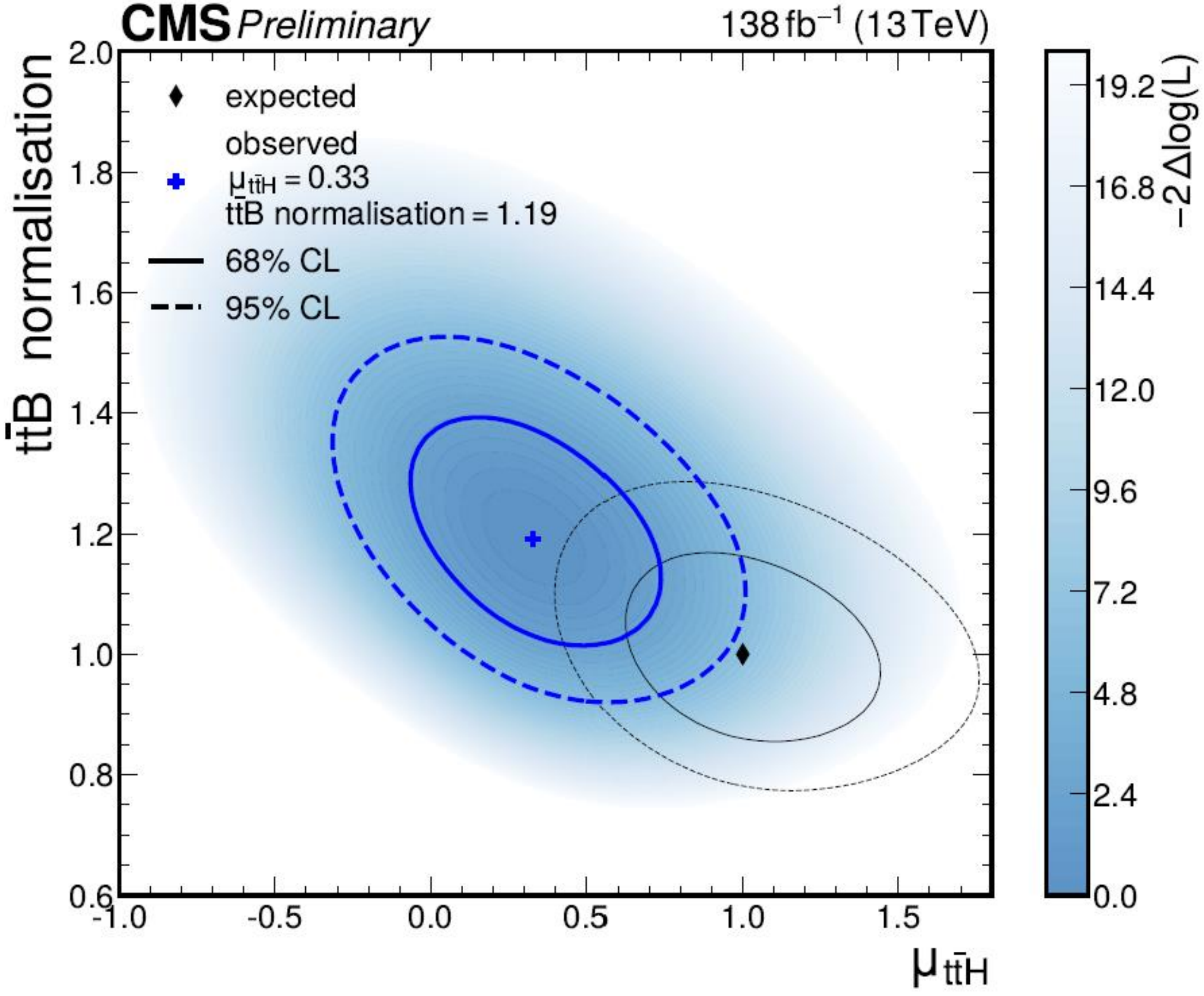
	$\Delta\ \mu$
Background (theory)	+0.067 −0.064
Signal (theory)	+0.082 −0.060
MC stats.	+0.092 −0.093
Sim. modelling	+0.070 −0.066
b tagging	+0.059 −0.041
Jet energy resolution	+0.045 −0.057
Luminosity	+0.041 −0.034
Jet energy scale	+0.029 −0.036
LeptonID	+0.016 −0.002
Trigger(MET)	+0.001 −0.001

ttH (H→bb) Observed likelihood-ratio test statistic

Postfit values of background normalisation in combined fit:

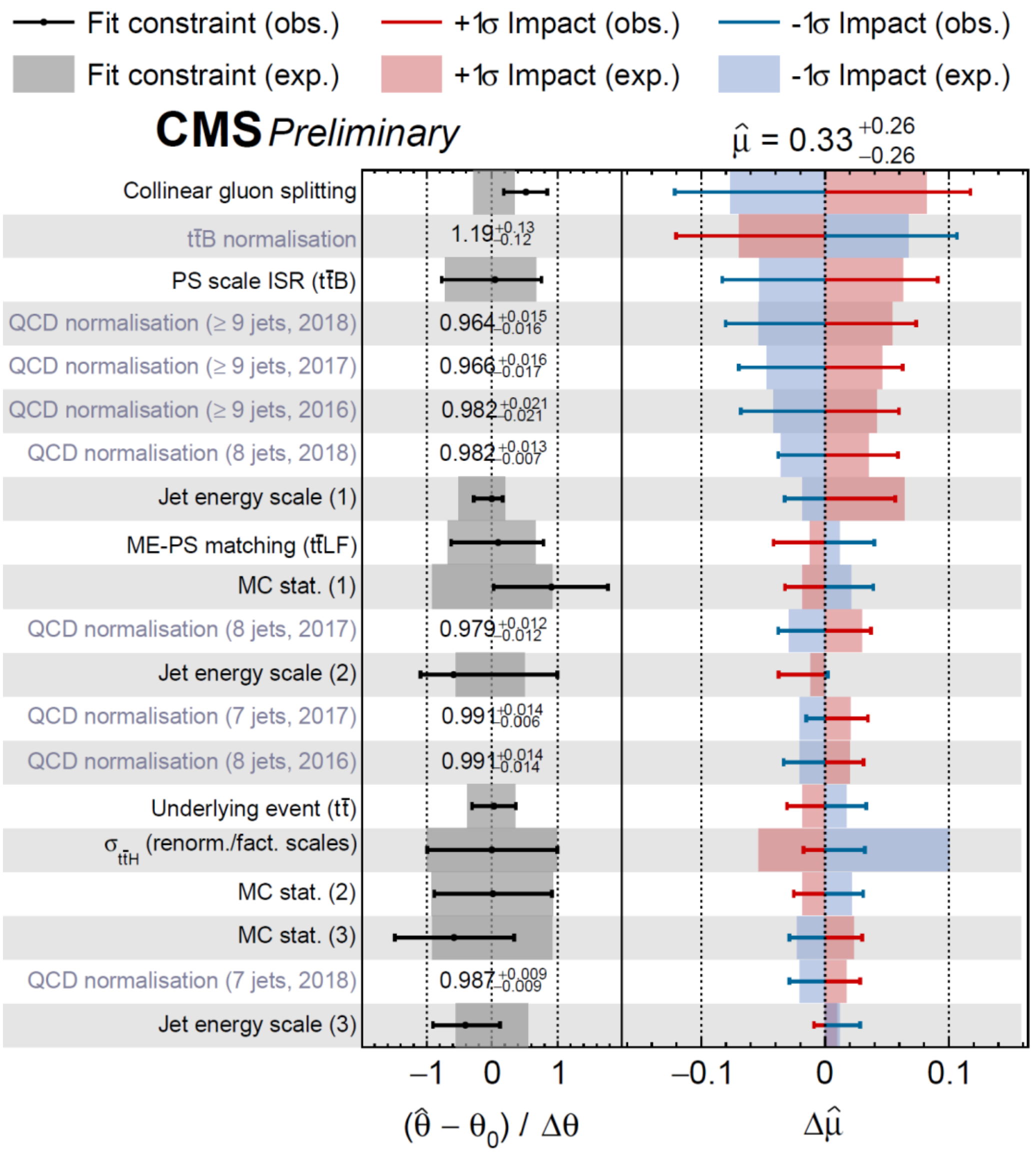
ttB normalisation: $1.19^{+0.13}_{-0.12}$

ttC normalisation: $1.07^{+0.20}_{-0.19}$



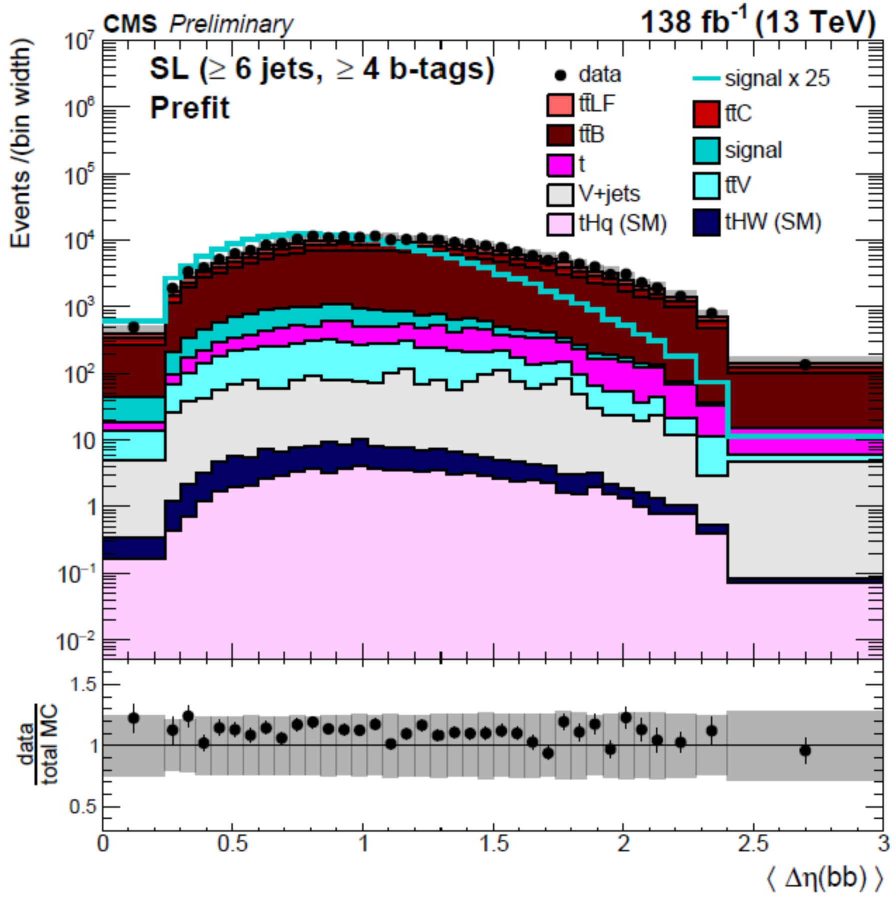
ttC normalisation profiled

ttH (H→bb) Pulls and impacts

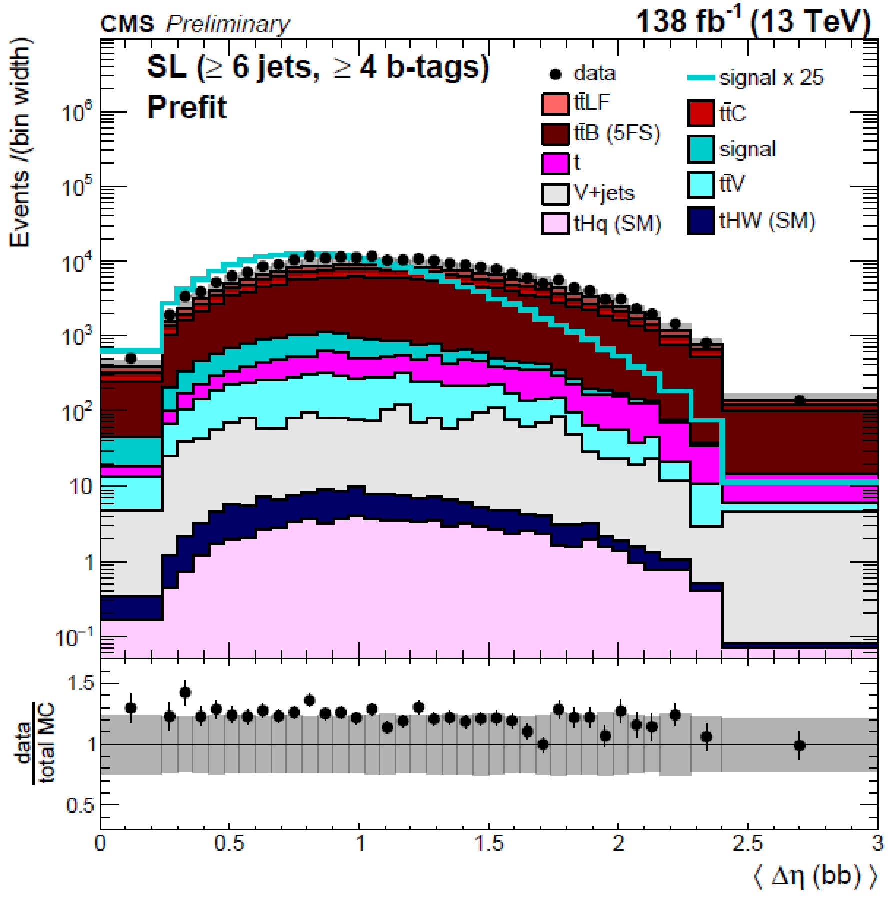


ttH (H→bb) Comparison ttB 4FS vs 5FS

Average $\Delta\eta$ between any two b-tagged jets for events in the SL channel after the baseline selection in the (≥ 6 jets, ≥4b tags) category



$t\bar{t}b\bar{b}$ 4 FS sample used

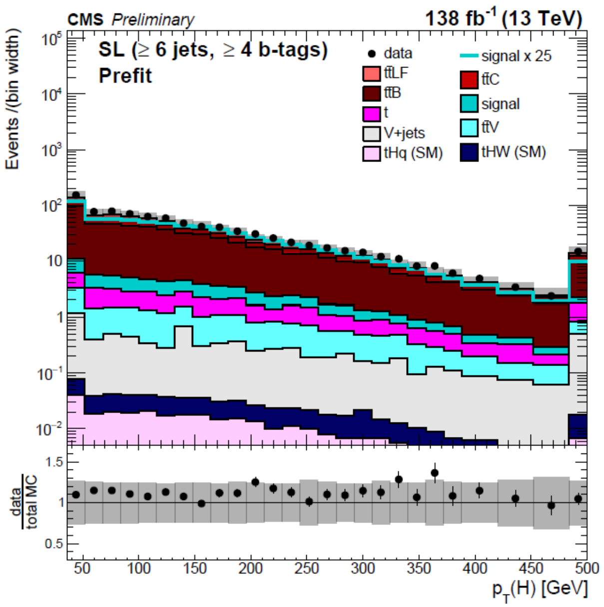


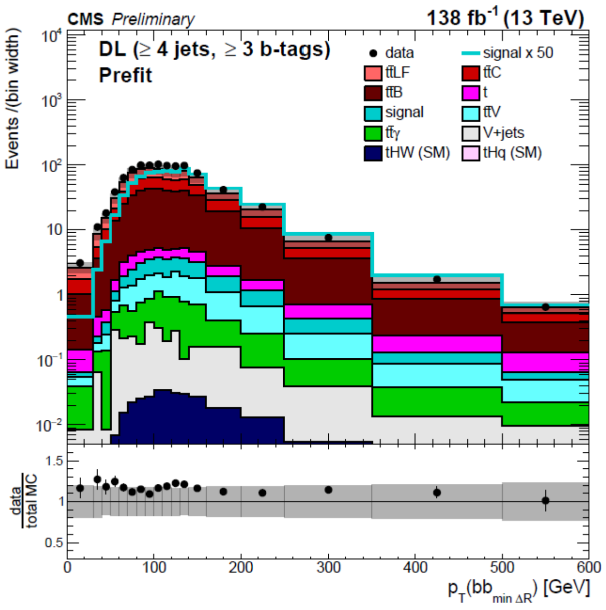
$t\bar{t}$ 5 FS sample used

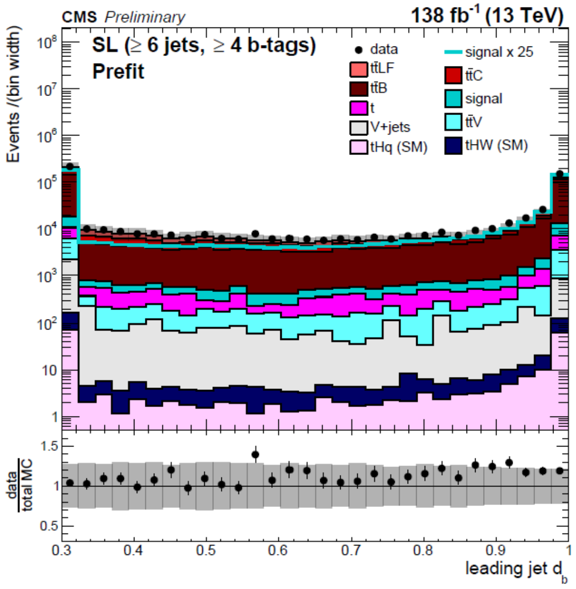
ttH (H→bb) data/MC comparison

ttH inclusive goodness-of-fit test taking into account postfit uncertainty model: $p = 0.88$

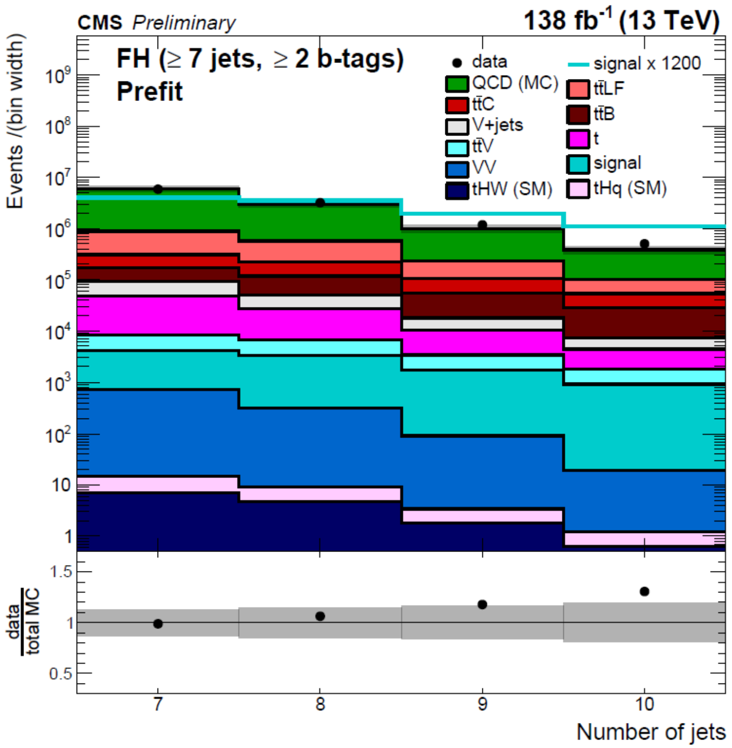
STXS Goodness-of-fit test: $p = 0.89$

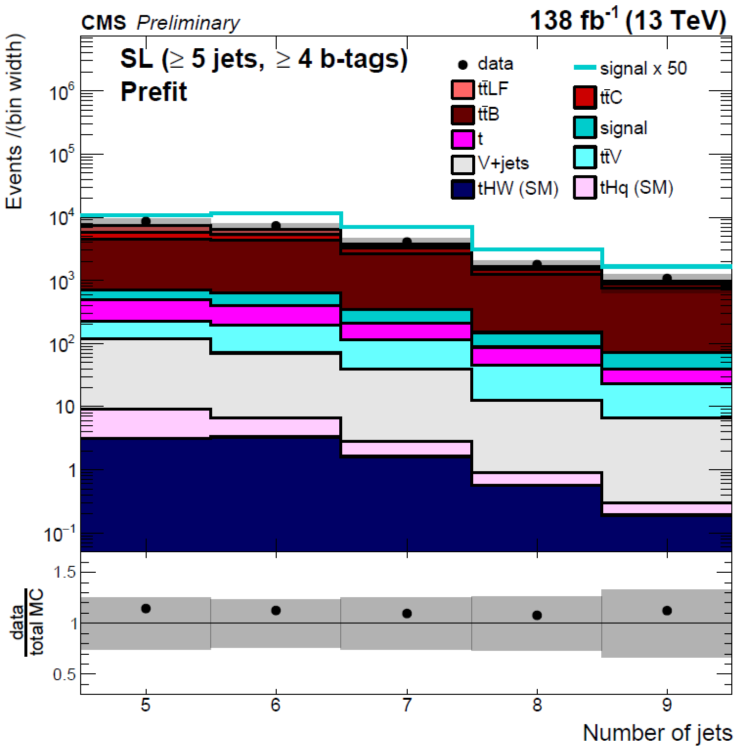


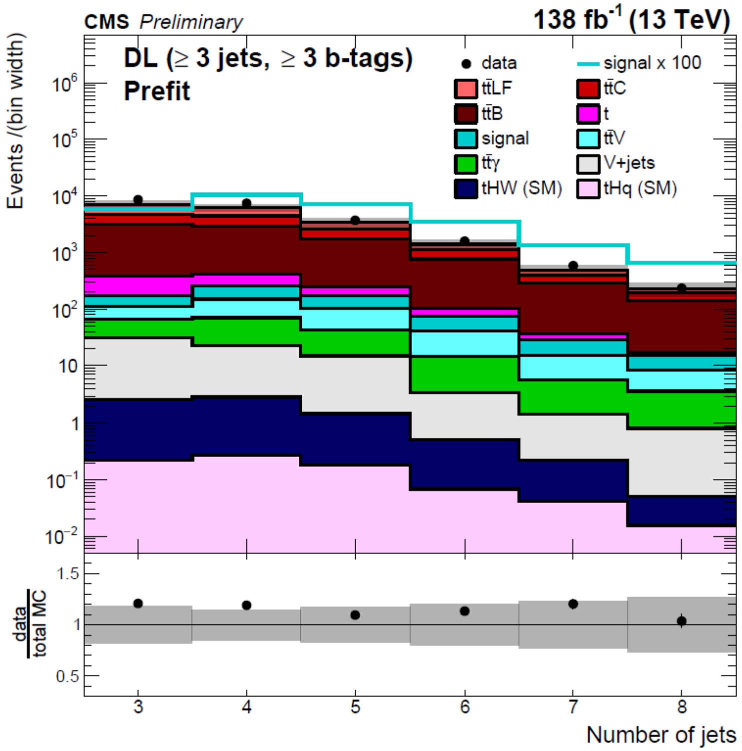




ttH (H→bb) Jet multiplicity distributions







QCD background prediction
taken from simulation

ttH (H→bb) Compatibility to SM and STXS vs incl.

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Compatibility of $t\bar{t}H$ inclusive against SM expectation:
p-value: 0.02 (2.4σ)

Compatibility of best-fit STXS values with SM:
p-value: 0.21 (1.3σ)

Compatibility of best-fit STXS values with inclusive $t\bar{t}H$:
p-value: 0.67 (0.4σ)

$p_T(H)$	$\hat{\mu} \pm \text{tot} \, (\pm\text{stat} \; \pm\text{syst})$
0–60 GeV	$0.2^{+1.9}_{-1.8} \begin{pmatrix} +1.2 & +1.4 \\ -1.2 & -1.3 \end{pmatrix}$
60–120 GeV	$0.1^{+1.4}_{-1.4} \begin{pmatrix} +1.0 & +0.91 \\ -1.0 & -0.96 \end{pmatrix}$
120–200 GeV	$1.14^{+0.95}_{-0.86} \begin{pmatrix} +0.69 & +0.65 \\ -0.69 & -0.52 \end{pmatrix}$
200–300 GeV	$0.19^{+0.89}_{-0.90} \begin{pmatrix} +0.65 & +0.60 \\ -0.65 & -0.62 \end{pmatrix}$
> 300 GeV	$-1.2^{+1.0}_{-1.1} \begin{pmatrix} +0.80 & +0.61 \\ -0.78 & -0.71 \end{pmatrix}$

Best-fit results of $\mu_{t\bar{t}H}$ in different STXS bins

Compatibility to JHEP 03 (2019) 026 using ony SL+DL in 2016 (approximated number, assuming uncorrelated datasets among analyses and neglecting the uncertainty on the signal strength of JHEP 03 (2019) 026):
p-value : 0.41 (0.8σ)

Previous measurement

CMS Collaboration, “Search for $t\bar{t}H$ production in the $H \rightarrow b\bar{b}$ decay channel with leptonic $t\bar{t}$ decays in proton-proton collision at $\sqrt{s} = 13$ TeV”, JHEP 03 (2019) 026
Dataset: 2016, L = 35.9/fb.
Analysed channels: single lepton (SL) + dilepton (DL).
ttbar+jets modelling: all events from 5FS POWHEG sample. Rate unc. of 50% on tt+bb/b/2b/c
Categories and observables for final fit:

- DL: (>=4j, 3b) and (>=4j,>=4b). Fit BDT output and MEM, respectively.
- SL: (4j,>=3b), (5j,>=3b), (>=6j, >=3b). Multiclass ANN with nodes for ttH, tt+bb, tt+b, tt+2b, ttC, ttLF.

Result: **μ** = 0.72 ± 0.45, significance of 1.6 **σ** (2.2 **σ** exp.)

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CMS

Correlations of the best-fit $t\bar{t}H$ signal-strength modifiers $\mu^i_{t\bar{t}H}$ in the different STXS bins i and the global ($t\bar{t}B$) and per-bin ($t\bar{t}B^i$) ttB background normalization parameters