Higgs Highlights from CMS

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CERN LHC Seminar
12 September 2023
**Where we stand**

**m_H:** Free parameter in the Standard Model

Once we know the mass, we know the couplings to SM particles, and can calculate all production and decay rates.

Also important ingredient for EW precision tests and for the stability of the EW vacuum.

**κ_b and κ_t:** Numerous BSM models lead to modifications of Higgs couplings to fermions: Precision needed!

**EFT/anomalous couplings:** A number of full run 2 results released, but targeting more production modes.

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Nature 607 (2022) 60-68
Today’s menu:
New analyses with the full run 2 dataset

1) Measurement of $m_H$ and the Higgs width in the $H \rightarrow ZZ \rightarrow 4l$ final state
Brand new for Higgs Hunting 2023/this LHC seminar!

2) Measurement of $t\bar{t}H$ and $tH$ production with $H \rightarrow bb$
New for EPS-HEP 2023

We also recently released two measurements of high-$p_T$ Higgs production in $bb$ (CMS-PAS-HIG-21-020) and $\tau\tau$ (CMS-PAS-HIG-21-017) final states (no time to cover today)

3) EFT/anomalous couplings in $H \rightarrow WW$
Brand new for this LHC seminar/Higgs Hunting 2023!
Contrasts could barely be more pronounced

Branching fractions

\( H \rightarrow bb: 58\% \)
\( H \rightarrow ZZ: 2.7\% \)
\( H \rightarrow ZZ \rightarrow 4l: 0.01\% \) (l=e,\( \mu \))

\( H \rightarrow ZZ \rightarrow 4l: \) As clean as it gets
1\% mass resolution
Large S/B

ttH(bb): As busy as it gets
10\% mass resolution
A priori tiny S/B

\[ \sigma_{ggH}/\sigma_{ttH} \sim 100 \]
1) Measurement of $m_H$ and the Higgs width in the $H \rightarrow ZZ \rightarrow 4l$ final state
Previous mass measurements

ATLAS-CMS run 1: 125.09 ± 0.24 GeV

CMS early run 2: 125.38 ± 0.14 GeV

This has for a long time been the most precise measurement, and has been used in all recent CMS results
Previous mass measurements

**ATLAS-CMS run 1**: $125.09 \pm 0.24$ GeV

**CMS early run 2**: $125.38 \pm 0.14$ GeV
*Phys. Lett. B 805 (2020) 135425*

**ATLAS full run 2**: $125.11 \pm 0.11$ GeV
*2308.04775 (sub. to PRL)*
Precision in $H \rightarrow ZZ \rightarrow 4l$

ATLAS run 1: $0.52 \text{ GeV}$
CMS run 1: $0.46 \text{ GeV}$

CMS early run 2: $0.21 \text{ GeV}$


ATLAS full run 2: $0.18 \text{ GeV}$

2308.04775 (sub. to PRL)
Event Selection and Datasets

Standard $\text{H} \rightarrow \text{ZZ}$ selection targeting $\text{H} \rightarrow \text{ZZ} \rightarrow 4\mu$, $2\mu 2e$, $4e$ final states:

- **Muons:** $p_T > 5 \text{ GeV}$, $|\eta| < 2.4$, loosely isolated
- **Electrons:** $p_T > 7 \text{ GeV}$, $|\eta| < 2.5$, BDT-based ID/isolation

Two of those need to have $p_T > 20 \text{ GeV}$ and $p_T > 10 \text{ GeV}$

Determine best ZZ candidate using a number of kinematic criteria

Legacy reprocessing: Improved tracker alignment → much reduced additive muon scale correction $\lambda$
Event Selection and Datasets

Standard H→ZZ selection targeting H→ZZ→4μ, 2μ2e, 4e final states:

- **Muons**: $p_T > 5$ GeV, $|\eta| < 2.4$, loosely isolated
- **Electrons**: $p_T > 7$ GeV, $|\eta| < 2.5$, BDT-based ID/isolation

Two of those need to have $p_T > 20$ GeV and $p_T > 10$ GeV

Determine best ZZ candidate using a number of kinematic criteria

*Updated ECAL calibration → Improved ECAL energy resolution*
Three main improvements

1) Introduced a beam spot constraint in the muon momentum reconstruction (VXBS)

Implements resolution by 5-8% in the $4\mu$ final state
Three main improvements

1) Introduced a beam spot constraint in the muon momentum reconstruction (VXBS)

Resolution further improved with kinematic fit, constraining the higher-mass Z boson candidate to be consistent with the expected Z boson lineshape

Resulting mass distribution (all final states)

Select range 105-140 GeV for further analysis
Three main improvements

1) Introduced a beam spot constraint in the muon momentum reconstruction (VXBS)

2) Categorise events based on per-event four-lepton mass uncertainty $\delta m_{4l}/m_{4l}$

- Start from single-lepton resolution based on covariance matrix
- Derive corrections with $Z \rightarrow ll$ events in bins of $p_T$ and $\eta$
- Resolutions are propagated to four-lepton candidate to predict $\delta m_{4l}$
Three main improvements

Resulting distributions show excellent agreement of data and predictions, validating the resolution model.
Three main improvements

1) Introduced a beam spot constraint in the muon momentum reconstruction (VXBS)

2) Categorise events based on per-event four-lepton mass uncertainty $\delta_{4l}/m_{4l}$

3) N-2D fit: 2D fit of $m_{4l}$ and kinematic discriminant in $N \delta m_{4l}/m_{4l}$ bins
   Independent fits in each lepton final state and year (different resolution and background)

Matrix-element based discriminant using the MELA package

$D = \frac{P_{\text{sig}}}{P_{\text{sig}} + P_{\text{bkg}}}$

CMS Preliminary 138 fb$^{-1}$ (13 TeV)
Three main improvements: Summary

1) Introduced a beam spot constraint in the muon momentum reconstruction (VXBS) ~5% improvement (15% with kinematic fit)

2) Categorise events based on per-event four-lepton mass uncertainty $\delta_{4l}/m_{4l}$ 8% improvement

3) N-2D fit: 2D fit of $m_{4l}$ and kinematic discriminant in N $\delta m_{4l}/m_{4l}$ bins 4% improvement
   Independent fits in each lepton final state and year (different resolution and background)
Resulting mass measurement:
Most precise measurement in single channel!

First, validate with $Z \rightarrow 4l$:
$m_Z = 91.17 \pm 0.12$ GeV ✓

Then, extract mass with 1D fit:
$m_H = 124.98 \pm 0.14$ (stat.) $\pm 0.05$ (syst.) GeV

Finally, with the full fit configuration:
$m_H = 125.04 \pm 0.12$ (stat.) $\pm 0.05$ (syst.) GeV

Dominated by statistical uncertainties.
Main systematic uncertainties:
Muon (0.03%) and electron (0.15%) scale uncertainties
Measuring the Higgs width: On-shell

**Higgs width in the SM:**

4.1 MeV

→ Result dominated by experimental resolution

Width extracted from 4l analysis just discussed, with a 1D fit including the improved muon momentum reconstruction (VXBS)

95% CL upper limit:

0.33 GeV obs. (0.75 exp.)

_Observed width narrower than expected, so using Feldman-Cousins approach to have correct coverage_
Measuring the Higgs width: Off-shell

Proposed by Kaola/Melnikov and Campbell et al

\[ \frac{\sigma_{\text{off-shell}}}{\sigma_{\text{on-shell}}} \propto \Gamma \]

For SM width (4.1 MeV):
Interference dominates w.r.t. pure H signal
\[ \rightarrow \text{deficit w.r.t. SM continuum ZZ production} \]
(which would also correspond to zero width)

For larger width values, H signal term starts to dominate
(SM width value fairly close to giving maximal negative interference)
Off-shell Higgs width: Previous results

\[ \Gamma_H = 3.2^{+2.4}_{-1.7} \text{ MeV} \]

First measurement: \( \Gamma_H = 3.2^{+2.4}_{-1.7} \text{ MeV} \) using partial run 2 data for \( H \rightarrow 4l \)

November 2021 LHC seminar (U. Sarica)

Nat. Phys. 18 (2022) 1329

\[ \Gamma_H = 4.5^{+3.3}_{-2.5} \text{ MeV} \]

November 2022 LHC seminar (R. Coelho Lopes De Sa)

2304.01532 (Sub. to PLB)
Off-shell Higgs width: Strategy

\( m_{4\ell} > 220 \text{ GeV}; \)
3 categories
based on MELA
discriminants

<table>
<thead>
<tr>
<th>Category</th>
<th>VBF-tagged</th>
<th>VH-tagged</th>
<th>Untagged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>( D_{2\text{jet}}^{VBF} &gt; 0.5 )</td>
<td>( D_{2\text{jet}}^{ZH} ) or ( D_{2\text{jet}}^{WH} &gt; 0.5 )</td>
<td>Rest of events</td>
</tr>
</tbody>
</table>

Observables: \( m_{4\ell}, D_{bkg}^{VBF+\text{dec}}, D_{bkg}^{VH+\text{dec}}, m_{4\ell}, D_{bkg}^{VH+\text{dec}}, D_{bkg}^{VBF+\text{dec}}, m_{4\ell}, D_{bkg}^{\text{kin}}, D_{bkg}^{gg,\text{dec}} \)

bsi: background-signal interference
dec: decay information

\( bkg: \) background-signal interference
\( \text{dec: decay information} \)
Off-shell Higgs width: Results

Signal strengths for off-shell VBF/VH production ($\mu_V$) and for ggF ($\mu_F$) consistent with SM expectation

Extracted width: $\Gamma_H = 2.9^{+2.3}_{-1.7}$ MeV
Consistent with SM and confirms previous results
2) Measurement of ttH and tH production with $H \rightarrow bb$
ttH/tH with H→bb: signature

With t→bW and W→lν or W→jj:
The usual three tt final states (dilepton, l+jets, fully-hadronic) + H→bb decay:

**ttH(bb):** 4b + (0, 1, 2 leptons) + jets
**tHq(bb):** 3b + (0, 1 leptons) + jets (including forward jet)
**tHW(bb):** 3b + (0, 1, 2 leptons) + jets

**Essential: b-tagging!** DeepJet algorithm improves efficiency by 5-10% at same mistag rate
Operate at 75-80% signal efficiency, 1.5-2% mistag rate for light-flavoured jets
Backgrounds are crucial

In particular the irreducible tt+bb background:
Lots of work on the theory side, coordinated by the LHC Higgs WG, in the past years

Based on these recommendations, **new setup for ttbb simulation:**
- NLO accuracy simulation using Powheg-Box-Res (Jezo et al) with OpenLoops (Buccioni et al) in the 4FS
- 4FS preferred since additional b jets are simulated at the ME level
- $\mu_R$ and $\mu_F$ chosen based on several phenomenological studies (YR4 Jezo et al Cascioli et al Buccioni et al)

<table>
<thead>
<tr>
<th></th>
<th>tt sample</th>
<th>ttbb sample</th>
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</thead>
<tbody>
<tr>
<td>POWHEG version</td>
<td>Powheg v2</td>
<td>Powheg-Box-Res</td>
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<tr>
<td>PYTHIA version</td>
<td>8.230</td>
<td>8.230</td>
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<tr>
<td>Flavour scheme</td>
<td>5</td>
<td>4</td>
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<tr>
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<td>NNPDF3.1</td>
<td>NNPDF3.1</td>
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<tr>
<td>$m_t$</td>
<td>172.5 GeV</td>
<td>172.5 GeV</td>
</tr>
<tr>
<td>$m_b$</td>
<td>0</td>
<td>4.75 GeV</td>
</tr>
<tr>
<td>$\mu_R$</td>
<td>$\sqrt{\frac{1}{2} (m_{T,t}^2 + m_{T,t}^2)}$</td>
<td>$\frac{1}{2} \sqrt{m_{T,t} \cdot m_{T,b} \cdot m_{T,b}}$</td>
</tr>
<tr>
<td>$\mu_F$</td>
<td>$\mu_R$</td>
<td>$\frac{1}{4} [m_{T,t} + m_{T,t} + m_{T,b} + m_{T,b} + m_{T,b}]$</td>
</tr>
<tr>
<td>$h_{damp}$</td>
<td>$1.5 \cdot m_t$</td>
<td>$1.379 \cdot m_t$</td>
</tr>
<tr>
<td>Tune</td>
<td>CP5</td>
<td>CP5</td>
</tr>
</tbody>
</table>
Strategy: Fully-hadronic channel (FH)

**Categories** based on \( n(\text{jets}) \) and \( n(\text{b-tags}) \)
- Three signal regions, requiring \( 60(72) \text{ GeV} < m_{\text{qq}} < 100(90) \text{ GeV} \)
- For each signal region two loose b-tag control regions: One to estimate the QCD background; the other to train the ANNs
- Three further validation regions with \( m_{\text{qq}} \) outside of the signal window

Train **artificial neural network (ANN)** against all backgrounds, using various inputs:
- kinematic variables
- matrix element discriminant

Fit ANN discriminant output
Strategy: Dilepton channel (DL)

Two Categories based on n(jets) and n(b-tags)

In the most signal-sensitive category, train multi-class ANN:
- b-tag information is used as input (via a b-tag likelihood ratio)
- Events are assigned to most probable category

Fit variables:
- Joint ttH & ttB category: Likelihood ratio of ANN outputs
- tt+C, tt+LF: Event yield
Strategy: Lepton+jets channel (LJ)

Two categories based on n(jets) and n(b-tags)

Compared to DL channel:
- More fine-grained background categories
- Likelihood ratio only with respect to tt+b(b) events
- Dedicated tHq and tHW nodes
- Additional ANN inputs:
  - H→bb candidate identified with dedicated BDT
  - Fine-grained b-tag information

\[ tt+2b: \text{2 b hadrons close enough to be in a single jet} \]
Validation plots

pre-fit
QCD dominant background (here from MC)

Scaled to the outcome of the final fit to data
Good modelling of observables sensitive to relative ratio of different tt+B components (e.g. gluon splitting)
Fitted distributions (2018)

CMS Preliminary

59.7 fb⁻¹ (13 TeV)

other years in backup

2018 discriminant bins
Results

Deficit of a bit more than 2 standard deviations w.r.t. the SM prediction, with syst. unc. > stat. unc.

Consistent with ATLAS (*) result: $\mu = 0.35^{+0.36}_{-0.34}$

As in previous ttH(bb) analyses, larger ttB rate than expected

(*) JHEP 06 (2022) 97
Systematic uncertainties

<table>
<thead>
<tr>
<th>Uncertainty source</th>
<th>$\Delta_\mu_{\text{TTH}}$ (observed)</th>
<th>$\Delta_\mu_{\text{TTH}}$ (expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total experimental</td>
<td>$+0.10 / -0.10$</td>
<td>$+0.11 / -0.10$</td>
</tr>
<tr>
<td>jet energy scale and resolution</td>
<td>$+0.08 / -0.07$</td>
<td>$+0.09 / -0.09$</td>
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<tr>
<td>b tagging</td>
<td>$+0.07 / -0.06$</td>
<td>$+0.06 / -0.02$</td>
</tr>
<tr>
<td>luminosity</td>
<td>$+0.02 / -0.02$</td>
<td>$+0.01 / -0.01$</td>
</tr>
<tr>
<td>Total theory</td>
<td>$+0.16 / -0.16$</td>
<td>$+0.18 / -0.14$</td>
</tr>
<tr>
<td>tt + jets background</td>
<td>$+0.15 / -0.16$</td>
<td>$+0.12 / -0.11$</td>
</tr>
<tr>
<td>signal modelling</td>
<td>$+0.06 / -0.01$</td>
<td>$+0.13 / -0.06$</td>
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<tr>
<td>Size of the simulated event samples</td>
<td>$+0.13 / -0.12$</td>
<td>$+0.10 / -0.10$</td>
</tr>
<tr>
<td>Total systematic</td>
<td>$+0.20 / -0.21$</td>
<td>$+0.23 / -0.19$</td>
</tr>
<tr>
<td>Statistical</td>
<td>$+0.17 / -0.16$</td>
<td>$+0.17 / -0.17$</td>
</tr>
<tr>
<td>background normalisation</td>
<td>$+0.13 / -0.13$</td>
<td>$+0.13 / -0.13$</td>
</tr>
<tr>
<td>ttB and ttC normalisation</td>
<td>$+0.12 / -0.12$</td>
<td>$+0.12 / -0.12$</td>
</tr>
<tr>
<td>QCD normalisation</td>
<td>$+0.01 / -0.01$</td>
<td>$+0.01 / -0.01$</td>
</tr>
<tr>
<td>Total</td>
<td>$+0.26 / -0.26$</td>
<td>$+0.28 / -0.25$</td>
</tr>
</tbody>
</table>

- **tt+jets uncertainties** most important

Also given the interesting results, extensively validated robustness of tt+B model, e.g. using inclusive tt+jets MC, tt+B scaled by factor of 1.2
STXS fit strategy

Additional categories for $p_T(H)$ bins

Events assigned using dedicated ANN that has the $p_T$ bin as target
STXS distributions (2018)
STXS Results

Quite significant correlations in the first few bins

Consistent with SM within $1.3\sigma$

Fitting a single inclusive $\mu$ value gives results that are consistent with the inclusive fit within 3% but 20% larger uncertainties
Including tH as signal

Fit with $\mu_{ttH} = 1$

Joint fit:
$tH$ and $tH$ results nearly uncorrelated
Probing the CP structure of the top-Higgs coupling

\[ \mathcal{A}(Htt) = -\frac{m_t}{v} \bar{\psi}_t \left( \kappa_t + i\tilde{\kappa}_t \gamma_5 \right) \psi_t \]

Dividing into pure CP-even (\( \kappa_t \)) and pure CP-odd (\( \tilde{\kappa}_t \)) components

tH cross section grows for significant CP admixture (opposite but less pronounced for ttH)

Observed constraints consistent with SM (\( \kappa_t = 1, \tilde{\kappa}_t = 0 \)) at the 2 SD level

Results in terms of mixing angle and CP fraction in backup
3) Chasing new physics in $H\rightarrow WW$ decays
Looking for anomalous HVV and Hgg couplings using:
1. the two quark jets from VBF/VH production
2. the $H\rightarrow WW$ decay products
3. the two quark jets from $ggH + 2$-jet production

Kinematic discriminants built using the MELA package

Two approaches for HVV couplings with different relations/symmetry assumptions, giving 4 or 3 anomalous couplings

In the latter case, translation to SMEFT Higgs and Warsaw bases possible (and reported)
H→WW anomalous couplings: Results

CMS Preliminary

138 fb⁻¹ (13 TeV)

Fit $D_{\Lambda_1}$ in bins of $m_{ll}/D_{VBF}$
(targeting $\Lambda_1$ in VBF)

$f_{\Lambda_1}$ scan in
3-parameter model
Constraints in SMEFT Higgs basis

Results consistent with the SM (91% compatibility)
Sensitivity similar to $H \to ZZ$  
(Phys. Rev. D 104 (2021) 052004)
Summary

1) Most precise $m_H$ measurement in a single channel: $m_H = 125.08 \pm 0.12$ GeV
Now almost certain that it will round to 125 GeV!

Constraints on the Higgs boson width consistent with previous evidence

2) Updated measurement of $t\bar{t}H(bb)$ production, with a significant increase in expected sensitivity, and an observed signal strength of $0.33 \pm 0.26$

3) New search for anomalous couplings in $H \rightarrow WW$ decays and derived EFT constraints

Thanks to all the analysis teams for their tremendous efforts!
Additional information
Vacuum stability

Via CERN courier, based on Particle Data Group/\textit{JHEP} 12 089

The results presented in this talk will tighten the constraints
**H → ZZ → 4l**

Signal parameterisation: Double-side Crystal Ball (DCSB) + Landau

For on-shell width, convoluted with Breit-Wigner

Irreducible backgrounds: 3rd order Bernstein polynomial

Reducible backgrounds: Landau function

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**Events / 1 GeV**

**CMS Preliminary**

138 fb⁻¹ (13 TeV)
H → ZZ → 4l
mass
distributions

CMS-PAS-HIG-21-019
Comparison with other ttH measurements

Similar sensitivity as multilepton measurement
ttH(bb): Systematic uncertainties

PS scale, ME-PS matching, and collinear gluon splitting uncertainties considered as partially correlated between the years

<table>
<thead>
<tr>
<th>Source</th>
<th>Type</th>
<th>Correlation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renorm./fact. scales</td>
<td>R</td>
<td>correlated</td>
<td>Scale uncertainty of (N)NLO prediction, independent for ttH, tHq, tHW, t cüm, V+jets, VV</td>
</tr>
<tr>
<td>PDF+R (gg)</td>
<td>R</td>
<td>correlated</td>
<td>PDF uncertainty for gg initiated processes, independent for ttH, tHq, tHW, and others</td>
</tr>
<tr>
<td>PDF+R (q\bar{q})</td>
<td>R</td>
<td>correlated</td>
<td>PDF uncertainty of q\bar{q} initiated processes (tHW, WZ) except tHq</td>
</tr>
<tr>
<td>PDF+R (gg)</td>
<td>R</td>
<td>correlated</td>
<td>PDF uncertainty of gg initiated processes (single t) except tHW</td>
</tr>
<tr>
<td>Collinear gluon splitting$^1$</td>
<td>S</td>
<td>correlated</td>
<td>Additional 100% rate uncertainty on tt + 2b component of ttb background</td>
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<tr>
<td>$\mu_R$ scale</td>
<td>S</td>
<td>correlated</td>
<td>Renormalisation scale uncertainty of the ME generator, independent for ttH, tHq, tHW, ttb (ttbb sample), other t (tt sample)</td>
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<tr>
<td>$\mu_F$ scale</td>
<td>S</td>
<td>correlated</td>
<td>Factorisation scale uncertainty of the ME generator, independent for ttH, tHq, tHW, ttb (ttbb sample), other t (tt sample)</td>
</tr>
<tr>
<td>PDF shape</td>
<td>S</td>
<td>correlated</td>
<td>From NNPDF variations, independent for tHq, tHW, ttb (ttbb sample), other tt (tt sample) and ttH</td>
</tr>
<tr>
<td>PS scale ISR$^2$</td>
<td>S</td>
<td>correlated</td>
<td>Initial state radiation uncertainty of the PS (PYTHIA), independent for ttH, ttb (ttbb sample), other tt (tt sample)</td>
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<tr>
<td>PS scale ISR$^3$</td>
<td>S</td>
<td>correlated</td>
<td>Final state radiation uncertainty of the PS (PYTHIA), independent for ttH, ttb (ttbb sample), other tt (tt sample)</td>
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<tr>
<td>ME-PS matching (tt)$^4$</td>
<td>R</td>
<td>correlated</td>
<td>NLO ME-PS matching (for tt + jets events), independent for ttb, tt+c, ttlf</td>
</tr>
<tr>
<td>Underlying event (tt)</td>
<td>R</td>
<td>correlated</td>
<td>Underlying event (for all tt + jets events)</td>
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<tr>
<td>STXS migration</td>
<td>R</td>
<td>correlated</td>
<td>Signal, only in STXS measurement</td>
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<td>STXS acceptance</td>
<td>S</td>
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<td>Signal, only in STXS measurement</td>
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<tr>
<td>Integrated luminosity</td>
<td>R</td>
<td>partially</td>
<td>Signal and all backgrounds</td>
</tr>
<tr>
<td>Lepton ID/Iso (2 sources)</td>
<td>S</td>
<td>uncorrelated</td>
<td>Signal and all backgrounds</td>
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<tr>
<td>Trigger efficiency (4 sources)</td>
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<td>Signal and all backgrounds</td>
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<td>L1 prefireing correction</td>
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<td>Signal and all backgrounds</td>
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<td>Pileup</td>
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<td>Signal and all backgrounds</td>
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<td>Jet energy scale (11 sources)</td>
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<td>Signal, tt + jets and single t</td>
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<td>Jet energy resolution</td>
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<td>b tag big. contam. (2 sources)</td>
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<td>Signal and all backgrounds</td>
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<td>Signal and all backgrounds</td>
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<tr>
<td>b tag charm (2 sources)</td>
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<td>Signal and all backgrounds</td>
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<td>$T_{\text{loose}}$ correction</td>
<td>S</td>
<td>uncorrelated</td>
<td>QCD background estimate</td>
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<tr>
<td>Size of the MC samples</td>
<td>S</td>
<td>uncorrelated</td>
<td>Statistical uncertainty of signal and background prediction due to limited sample size</td>
</tr>
</tbody>
</table>
ttH/tH CP results

CMS Preliminary

-2Δlog(L) vs. $f_{CP}$

$-2\Delta \log(L) = \frac{\bar{\kappa}_t^2}{\bar{\kappa}_t^2 + \kappa_t^2} \cdot \text{sign} \left( \bar{\kappa}_t / \kappa_t \right)$

CMS Preliminary

-2Δlog(L) vs. $\cos \alpha$

$\cos \alpha = \frac{\kappa_t}{\sqrt{\bar{\kappa}_t^2 + \kappa_t^2}}$
Search for boosted $H \rightarrow \tau \tau$ decays

Measurements at high Higgs boson $p_T$ particularly sensitive to (heavy) new physics:
- Higgs decay products merged, requiring dedicated reconstruction/boosted Higgs tagger

$H \rightarrow \tau \tau$ analysis:
- targets 4 main decay modes: $\tau_h \tau_h$, $\mu \tau_h$, $e \tau_h$, and $e \mu$
- dedicated reconstruction algorithm

Obs. signal strength $1.64^{+0.68}_{-0.54}$
$H \rightarrow \tau \tau$ with $p_T(H) > 250$ GeV established with $3.5 \sigma$ significance (2.2 exp.)
Search for boosted H → bb decays

Compared to previous run 2 result (JHEP 12 (2020) 085):
• Improved boosted H → bb tagger (DeepDoubleB)
• Explicitly targets VBF production - first exploration of Higgs pT > 450 GeV in VBF production!

Observed signal strengths: $2.1^{+1.9}_{-1.7}$ (ggH) and $5.0^{+2.1}_{-1.8}$ (VBF)