TAU 2018: 15th International Workshop on Tau Lepton Physics

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Measurements of the Higgs Boson decaying to Tau Pairs at CMS

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(for the CMS collaboration)

Outline – LHC Run 2 Results

H(125) $\rightarrow 2\tau$ @

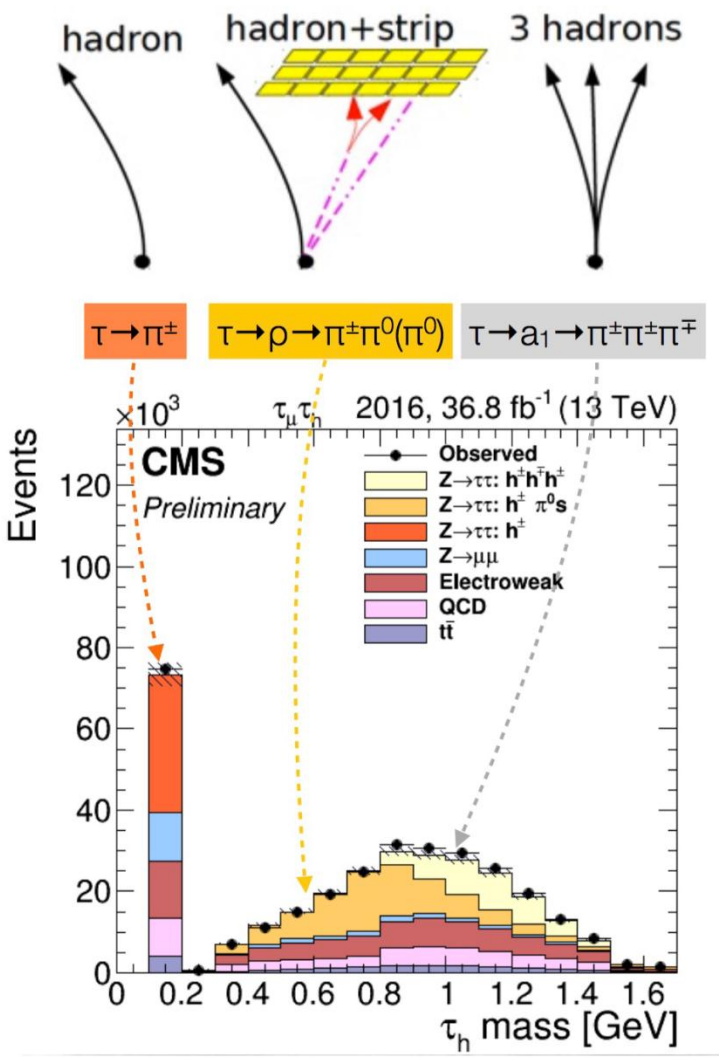
- H(125) in gluon fusion and VBF
- H(125) in associated W/Z mode
- Combination of production modes

H(125)→ττ

(gluon fusion and VBF process)

Tau Identification

CMS PAS-HIG-16-035



Higgs boson in ττ decay mode is the most promising channel to explore the Higgs-Yukawa coupling to fermions(decay rate to ττ is less than bb, but this channel has much less background)

Analysing Run-1 data, in 4 production modes led to the first evidence of Higgs boson coupling to fermions
Observed (expected) significance of 3.2 (3.7) σ

Hadron Plus Strips (HPS) algorithm updated for run2 with dynamic strip reconstruction
Tau leptons are reconstructed either in 1 prong or 3 prong modes

Developed MVA based discriminators to suppress misidentification of the taus by jets, electrons and muon

Full tau pair mass reconstruction using dedicated algorithm using secondary vertex and lifetime information

Event Categorisation

Event categorization has been changed in LHC Run-2

3 primary categories (mainly) based on the jet multiplicity of the di-tau events
In each category, events are further spitted depending on tau decay modes:
muon p_T (in 0-jet),
p_T of the Higgs boson(in boosted) and
mass of two forward jets (in VBF mode)

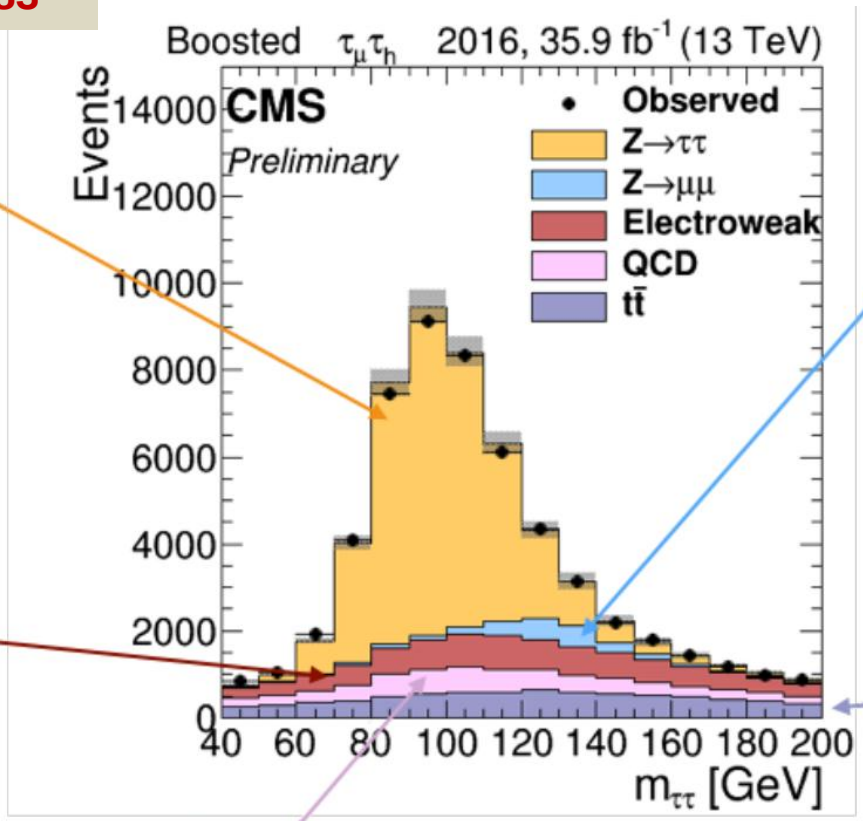
2D distributions are then unrolled to1D distributions which will be the input for the statistical interpretations

	ττ	μτ	eτ	eμ
0jet	$m_{\tau\tau}$	m_{vis}:τ DM	m_{vis}:τ DM	m_{vis} : μ pT
boosted	$m_{\tau\tau}$: H pT	$m_{\tau\tau}$: H pT	$m_{\tau\tau}$: H pT	$m_{\tau\tau}$: H pT
vbf	$m_{\tau\tau}$: m_{jj}	$m_{\tau\tau}$: m_{jj}	$m_{\tau\tau}$: m_{jj}	$m_{\tau\tau}$: m_{jj}

Background Estimation

PLB 779 (2018) 283

Z->ττ simulation: Madgraph N-Jet binned Drell-Yan Samples, corrections derived from Z(μμ) CR and applied



DY ℓ->τ fakes simulation: Madgraph N-Jet binned Drell-Yan Samples, corrections derived from Z(μμ) CR and applied. Additional ℓ->τ fake corrections.

W+Jets/VV: datadriven in control region for ℓτ

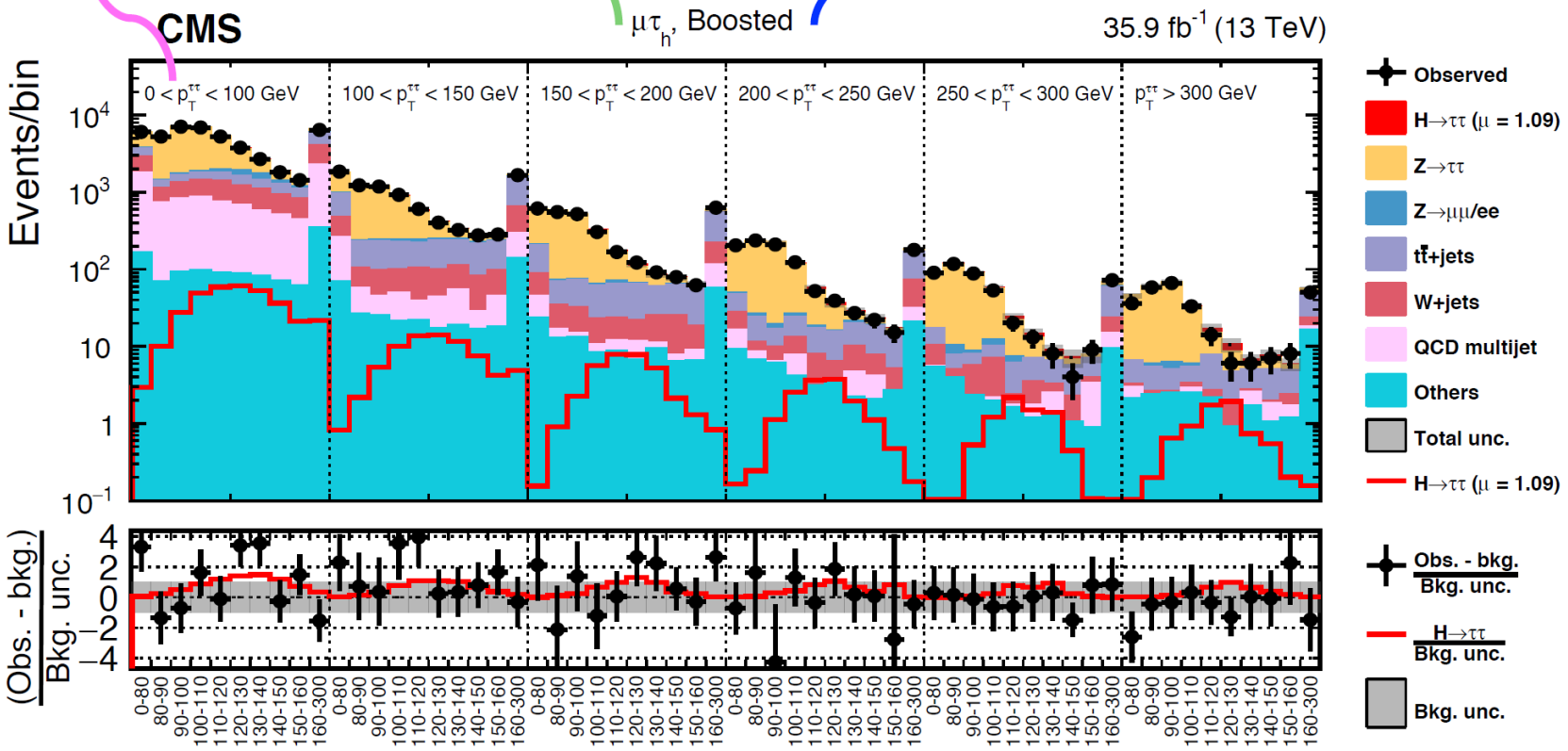
QCD: datadriven in control region, for ℓτ, ττ, eμ

TTbar: powheg MC eμ, ℓτ, ττ: datadriven all channels

unrolled slices

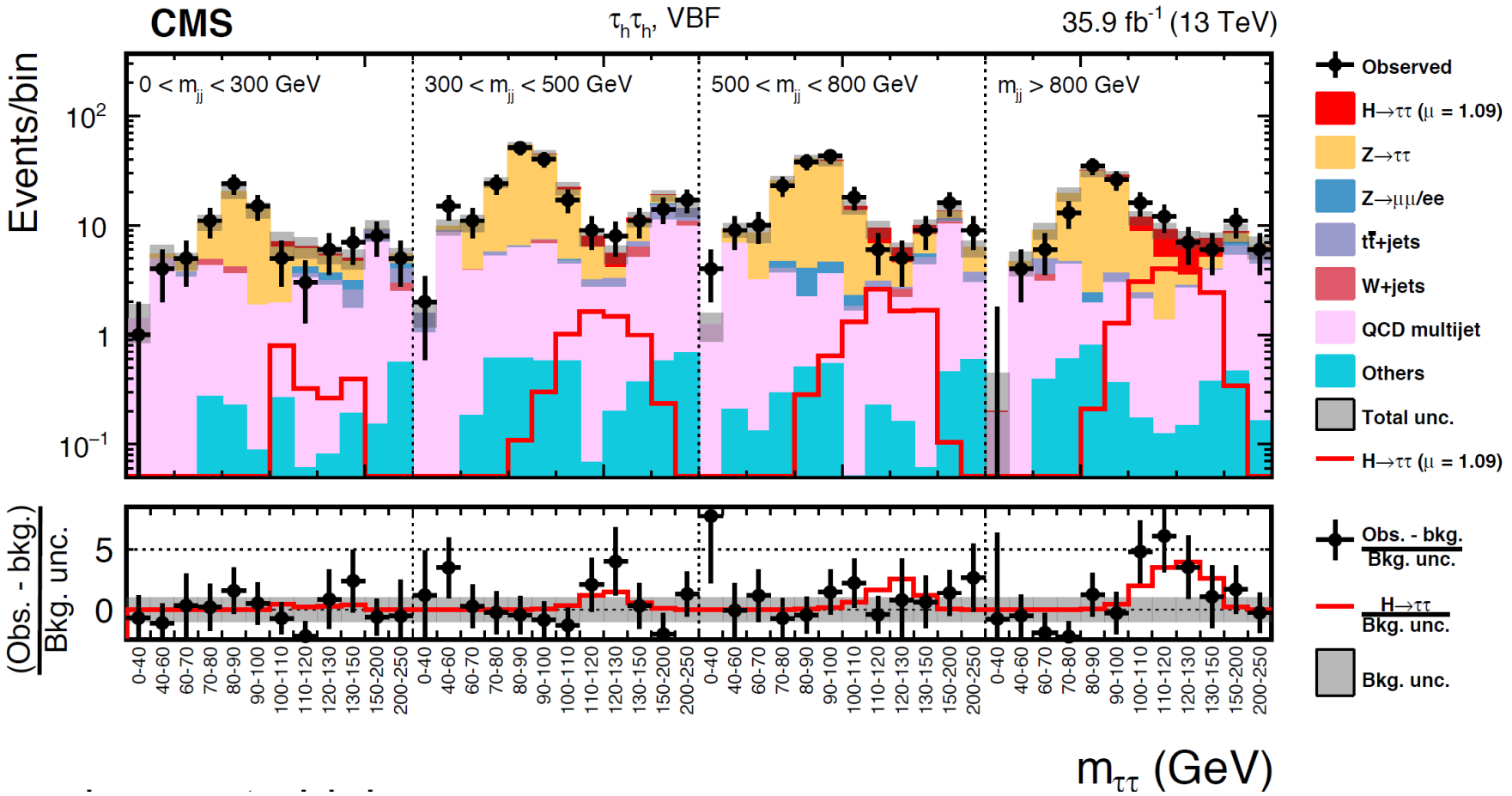
channel

category



mass

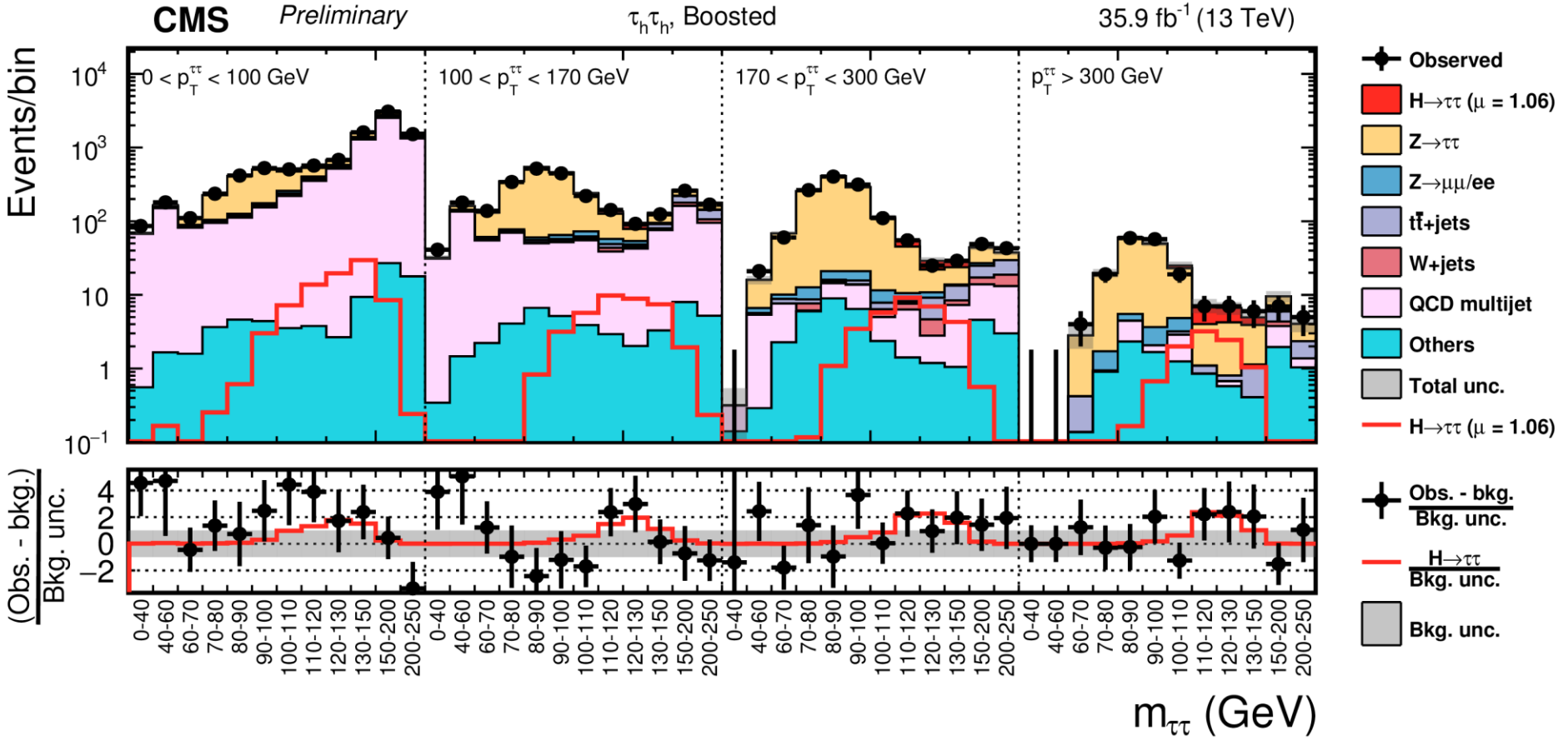
Background composition and signal sensitivity varies in each slices



Observed and predicted 2D distributions in the VBF category of the $\tau_h\tau_h$ decay channel (From low m_{jj} to high m_{jj}).

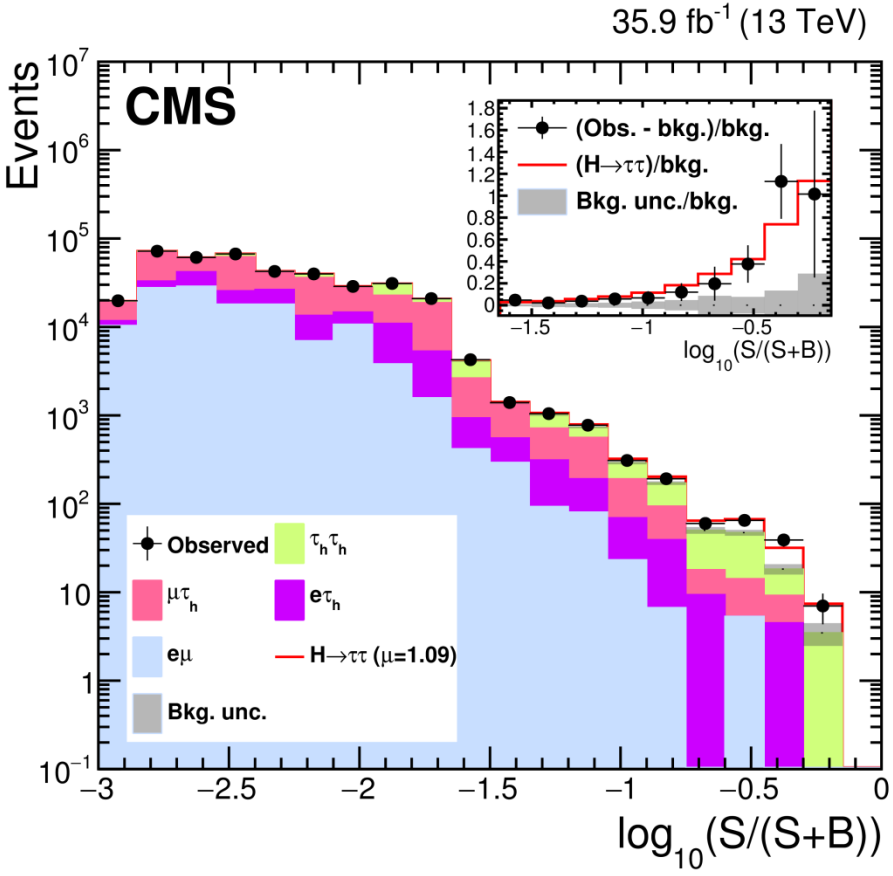
Higher S/B and higher purity for VBF production compared to ggH production mode

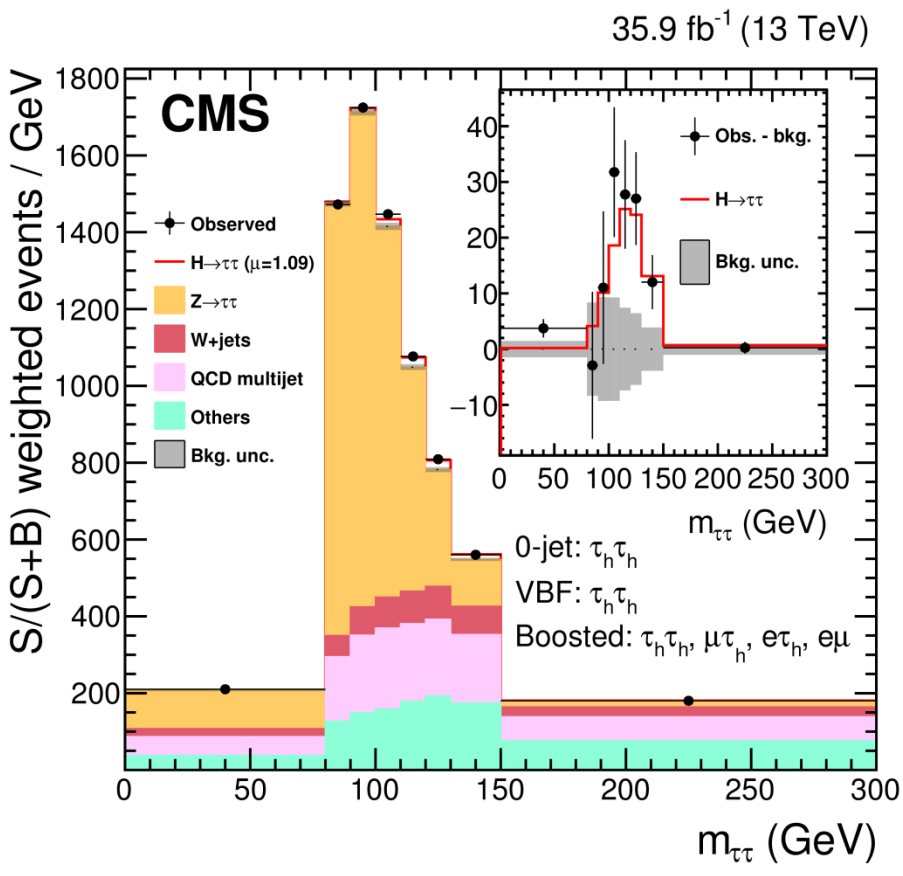
Visible excess of data on top of the SM prediction



Observed and predicted 2D distributions in the boosted category of the $\tau_h\tau_h$ decay channel in increasing p_T

Observation of Excess



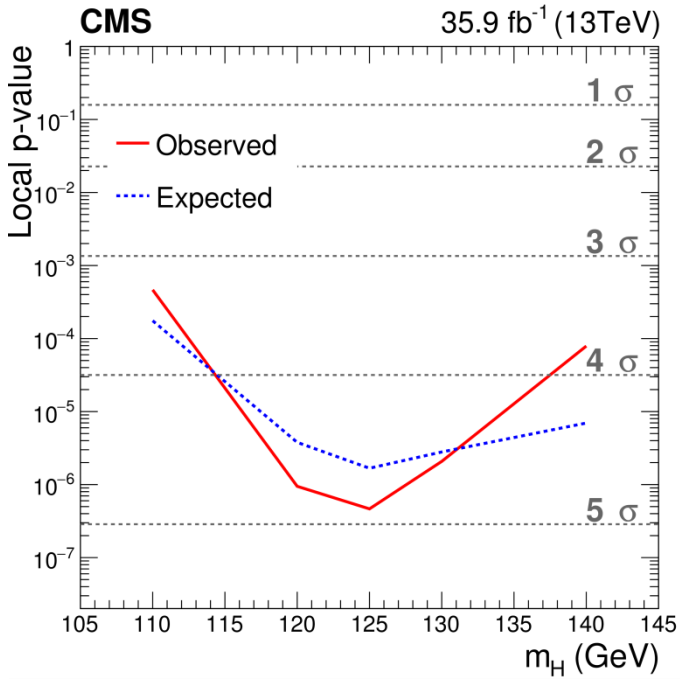


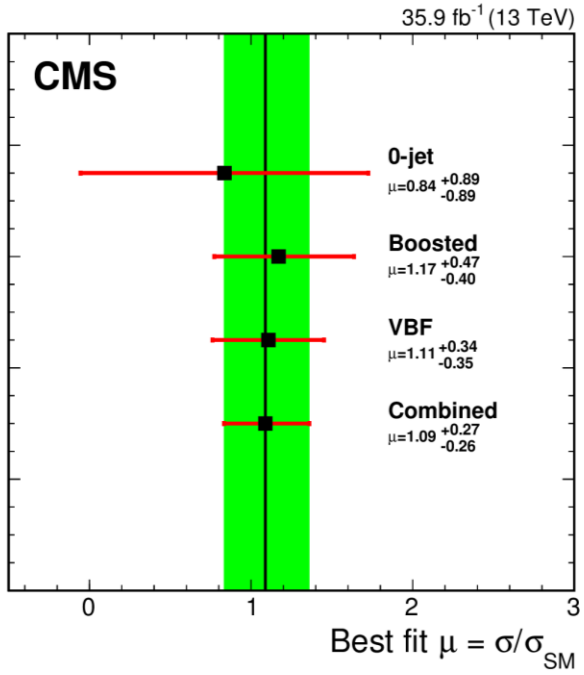
Reorder the bins based on log(S/S+B)

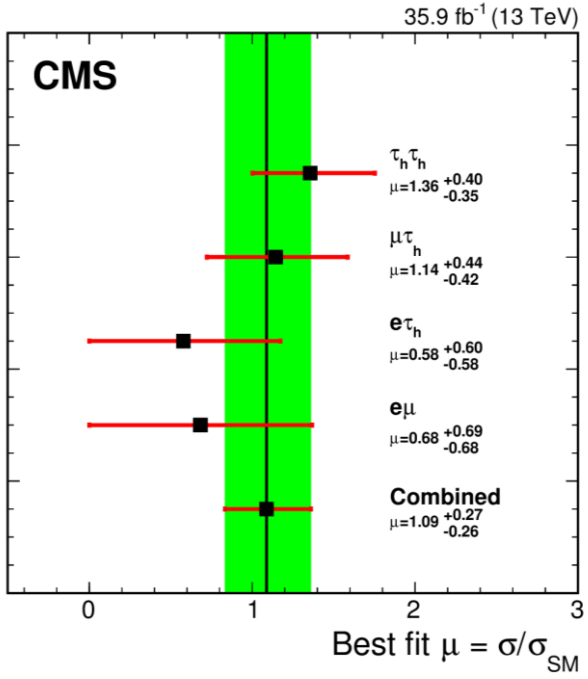
Sensitive bins are shifted to the right-side of the distribution and less sensitive to left

Bins are weighted according to S/S+B
Higgs signal peaks around 125 GeV

PLB 779 (2018) 283







4.9 (4.7) σ observed (expected) significance

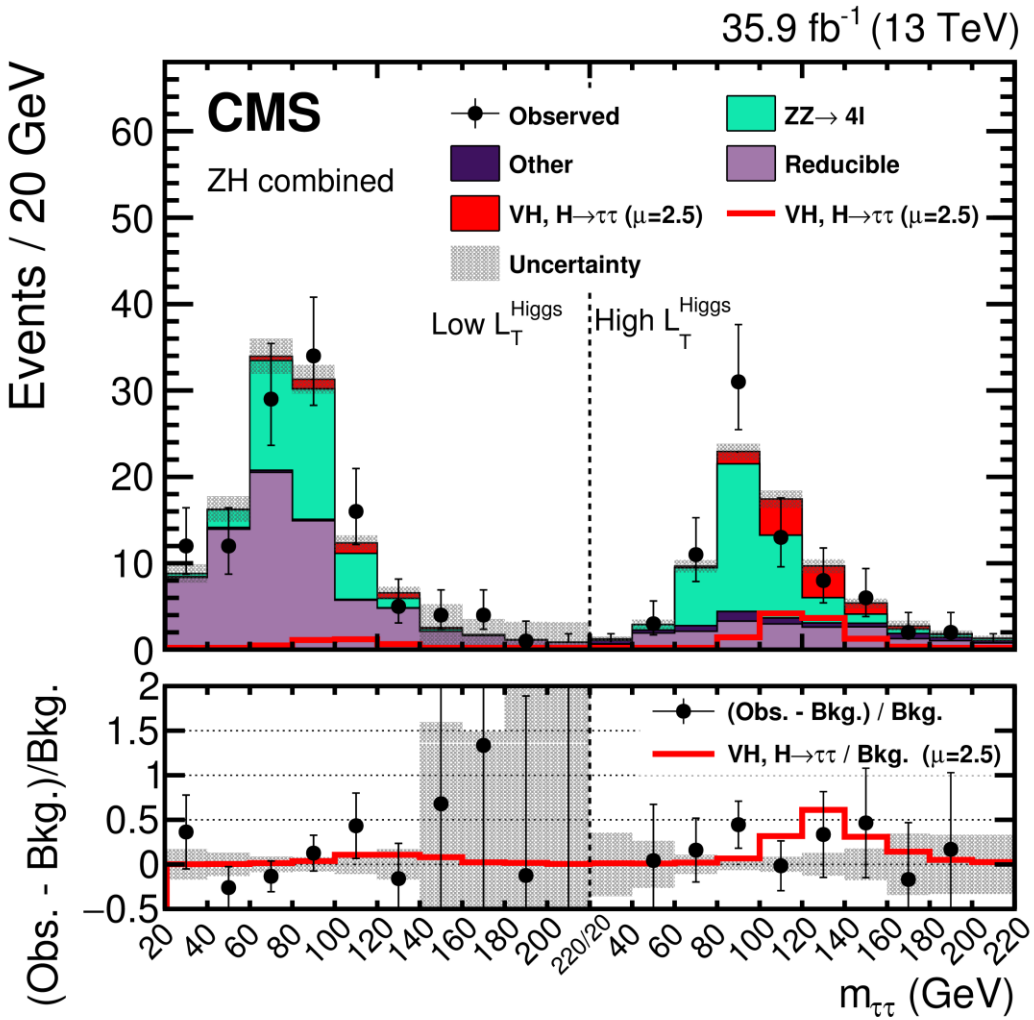
- Combining with run1 we would have 5.9 σ **(the first observation of the Higgs coupling to tau leptons in a single experiment)**
- Signal strength of 1.09 +- 0.26
- **$\tau_h\tau_h$ is the most sensitive channel**
- **VBF is the most sensitive category**

H(125)→ττ

(VH process)

CMS HIG-18-007

- 8 final states are explored eeeμ,eeeτ$_h$,eeμτ$_h$,eeτ$_h$τ$_h$, μμeμ, μμeτ$_h$, μμμτ$_h$, μμτ$_h$τ$_h$
- Clean signatures with ZZ as irreducible background. Other are WZ and Z+jets
- L_T (scalar sum of the lepton p_T from H decay) is used to improve the sensitivity)
- High L_T category is more sensitive
- The excess of data in most of the bins near Higgs mass



CMS HIG-18-007

WH semi-leptonic

- $e\mu\tau_h$, $\mu\mu\tau_h$ channels

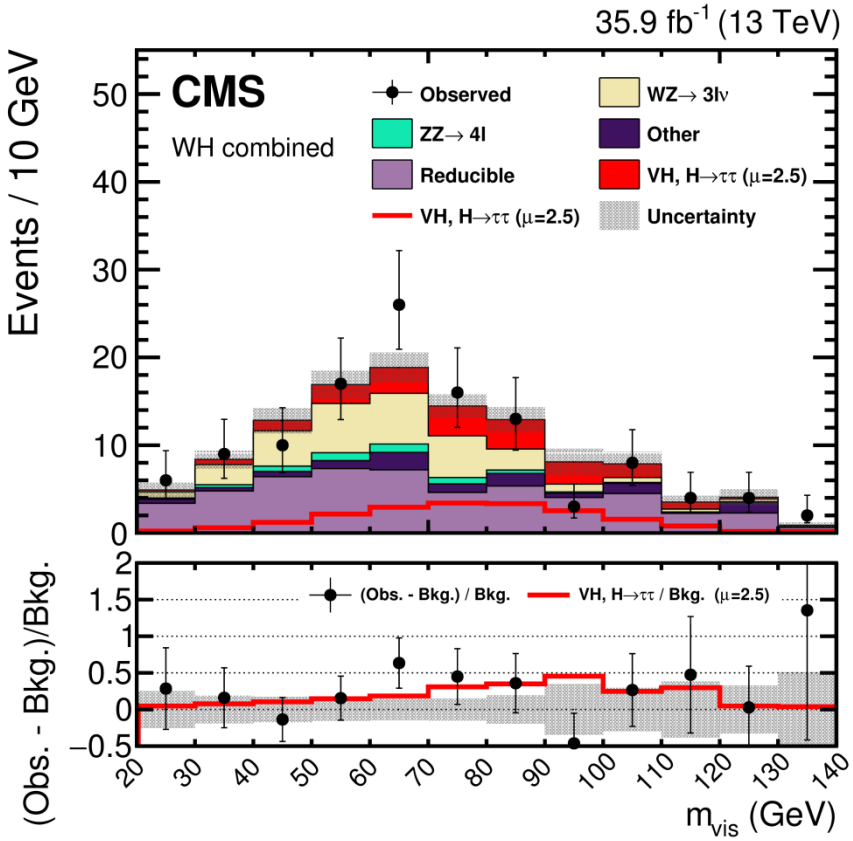
WZ is the irreducible background.
Other backgrounds like Z+jets and top pair are highly suppressed by requiring 2 leptons to be same sign

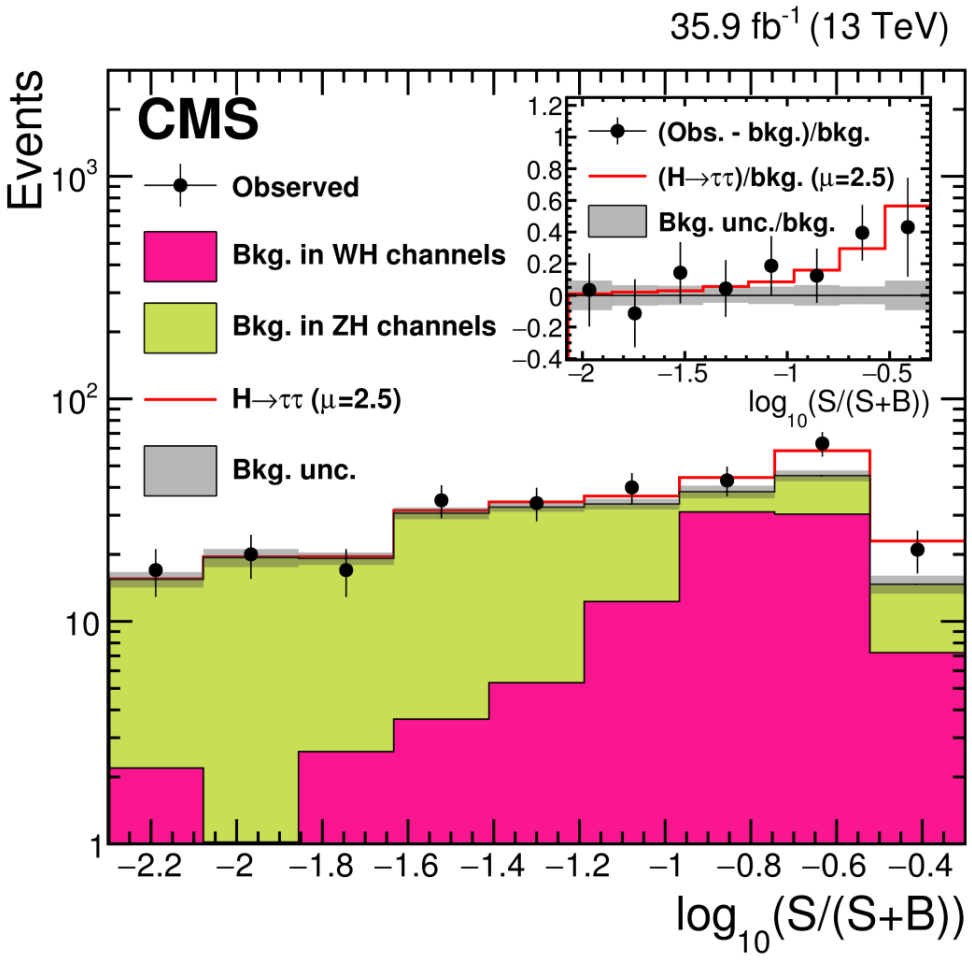
WH hadronic

- $e\tau_h\tau_h$, $\mu\tau_h\tau_h$ channels

Larger background w.r.t other VH channels

The excess of data in most of the bins near Higgs signal
To extract the limit, all 4 WH channels are fitted simultaneously





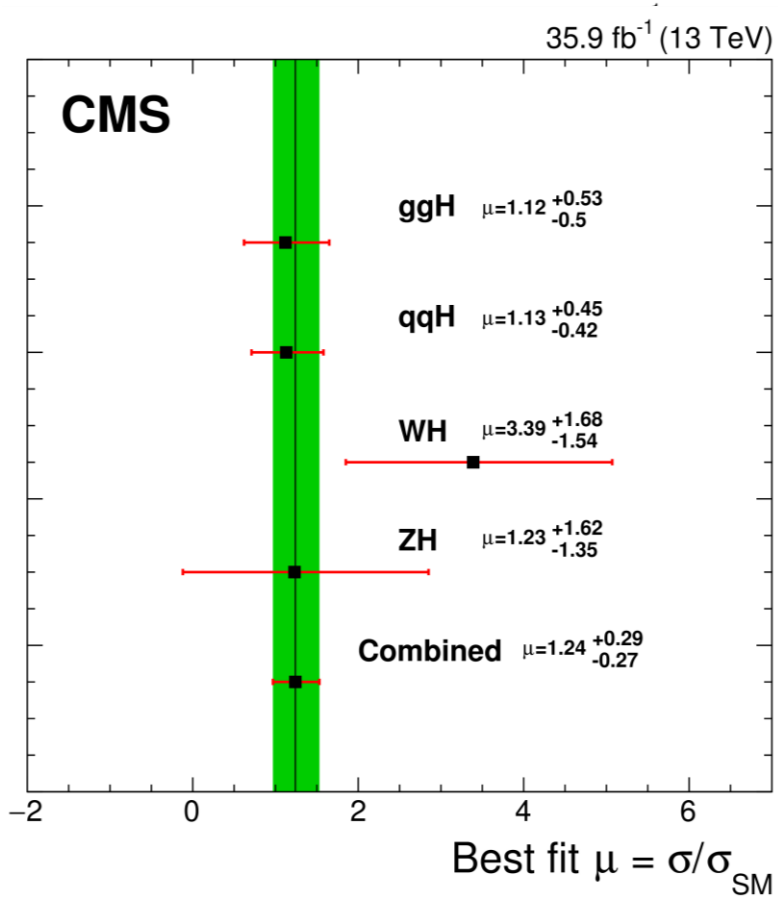
2.3 (1.0) σ observed (expected) significance

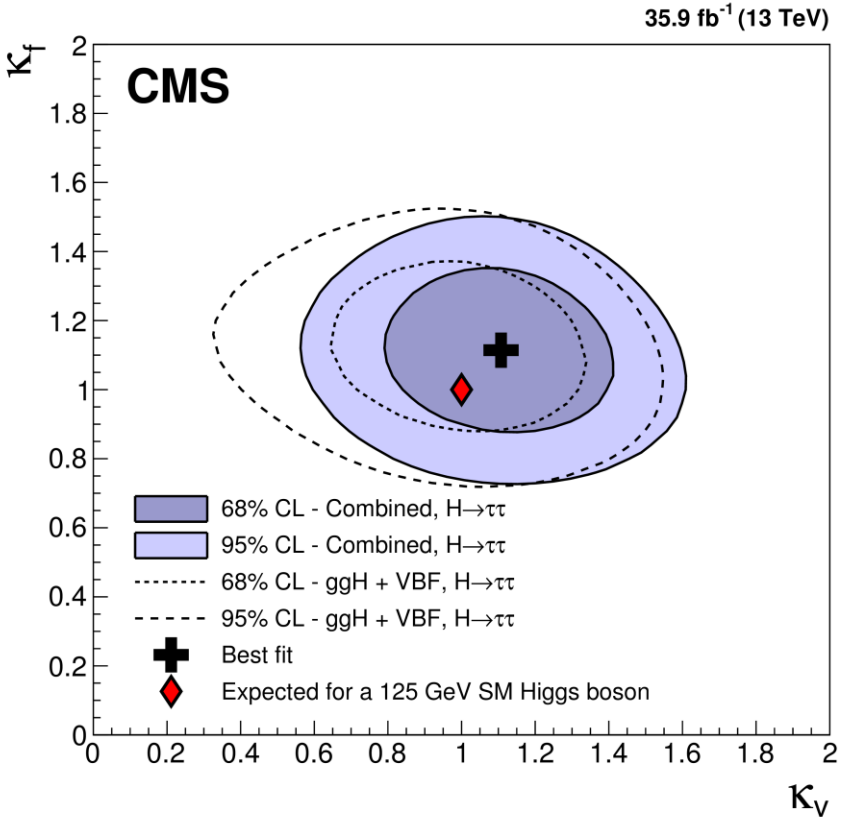
The signal strength is **2.5 ± 1.4**

ZH and WH production modes have similar sensitivity

Combination

Best-Fit and Couplings





- **Observation of the Higgs boson in ττ decay**
- **5.5 (4.8) σ observed (expected) significance**
- The combined signal strength is **1.24 ± 0.28**

- Higgs couplings to bosons and fermions are compatible with SM expectation
- Higgs boson decays to W or Z pairs, are considered as part of the signal

Summary

First observation of the SM Higgs boson to a pair of tau leptons with a single experiment

5.9 observed significance by combining 2016 (excluding VH) + Run-1 data

5.5 observed significance by 2016 data

The best fit value is consistent with 1.0 within one standard deviation

The coupling to both fermions and bosons are compatible with those predicted by SM

Next steps:

Measuring the Higgs coupling to tau lepton more precisely, as we accumulate more data

Measuring the Higgs anomalous coupling in ττ final state

CP properties, ……

New results will appear soon!