275. Study of the Standard Model Higgs boson decaying to taus at CMS

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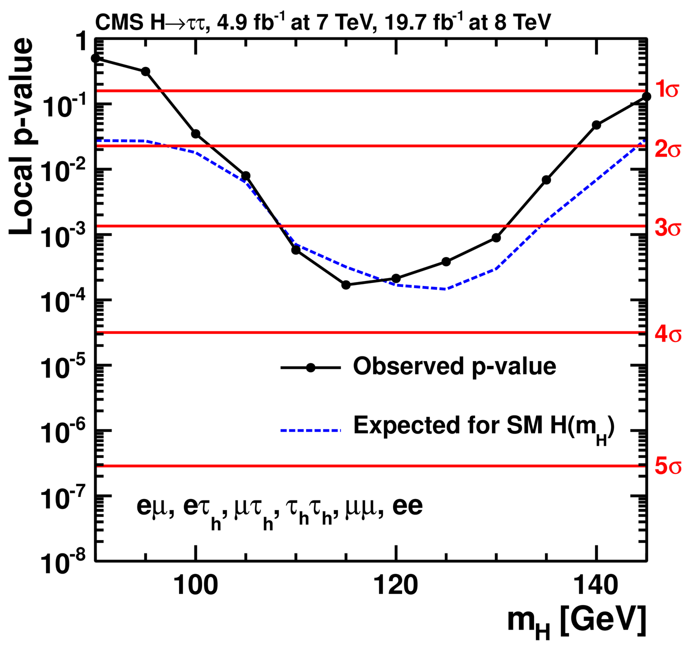
1. Does the H(125) boson decays to fermions with Yukawa couplings as in the Standard Model ?

The Higgs to tau tau decay channel is the most promising to answer

☑ good compromise between high signal yield and low background



With the LHC Run1 data at $\sqrt{s}$ = 7 and 8 TeV

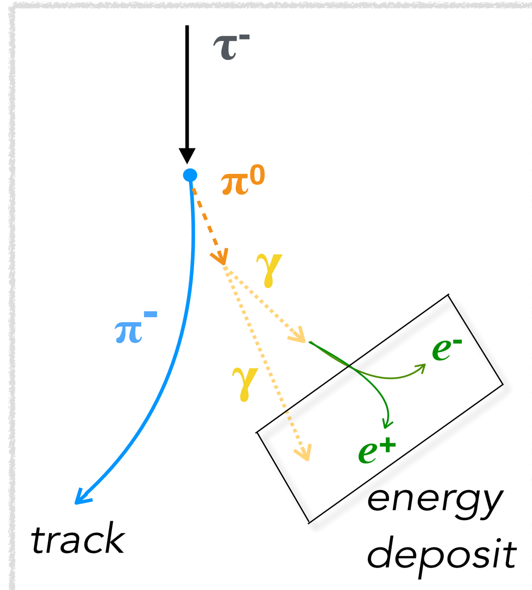
CMS expected 3.7 σ significance, observed 3.2 σ [1].

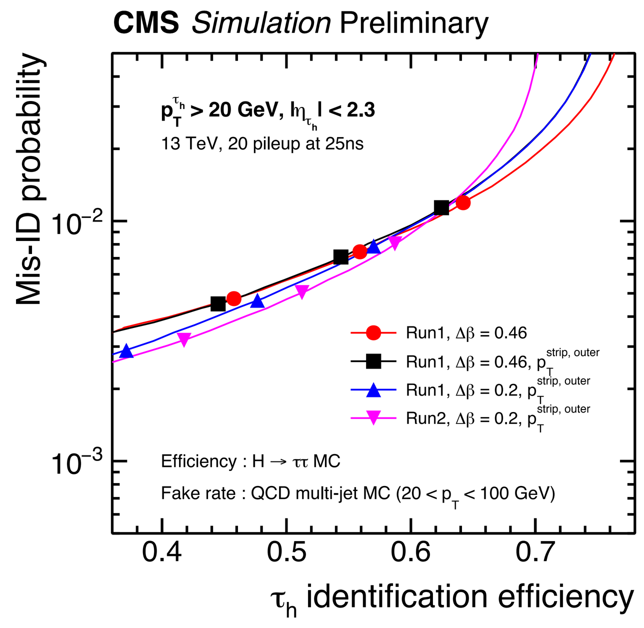
Combining with the ATLAS measurement, 5.0 σ expected significance, observed 5.5 σ [2].

2. How are tau leptons identified? Tau leptons decay inside the CMS detector

- leptonically to e or μ and neutrinos, BR = 35%
- semi-hadronically (τ_h) to pion(s) and neutrino, BR = 65%

τ_h reconstructed based on **number of tracks** and ***strip-shaped* electromagnetic energy deposits** [3].





MVA discriminator against jet fakes, based on energy deposit around the tau and lifetime information. Chosen selection has ε~60% and misidentification rate~1%.

Most likely final states for ττ pairs: $\tau_h\tau_h$, $\mu\tau_h$, $e\tau_h$, $e\mu$.

Triggers used to select the events, p_T thresholds in GeV

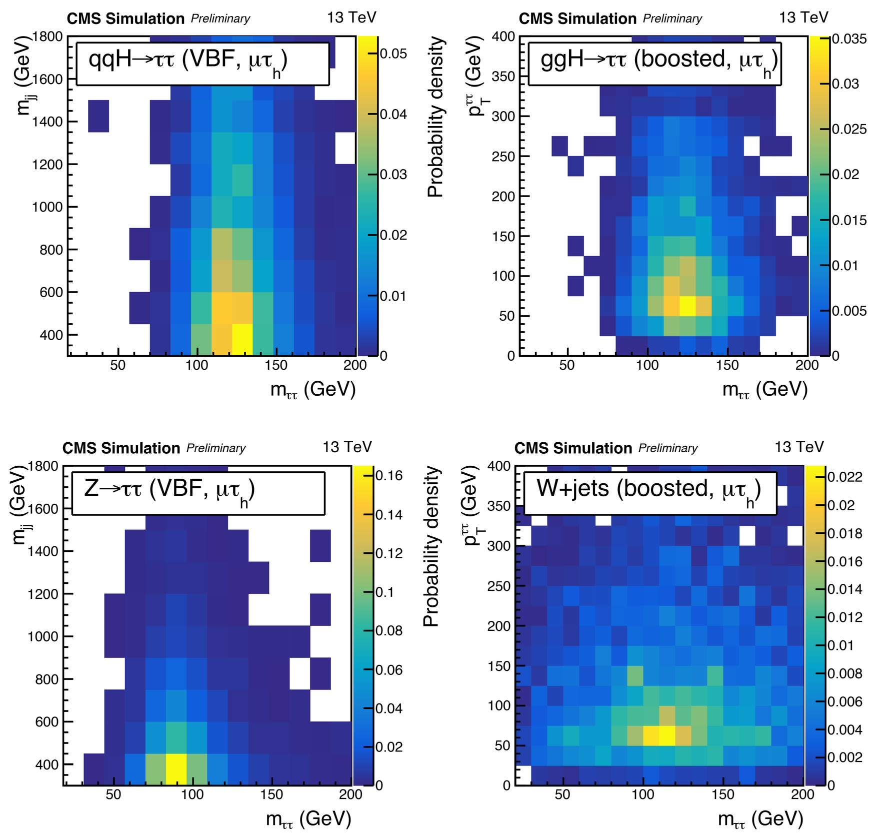
$\tau_h\tau_h$: τ_h(35) & τ_h(35)	$e\tau_h$: e(25)
$e\mu$: e(12)&μ(23), e(23)&μ(8)	$\mu\tau_h$: μ(22), μ(19) & τ_h(21)

3. The signal is extracted from 2D distributions in three categories

1. **0-jet**: targeting gg Higgs production
2. **VBF**: targeting VBF Higgs production
3. **Boosted**: all other events that do not enter one of the previous categories (ggH+jets, VBF failing VBF selection, V(hadrons)H)

Variables used for the 2-D distributions

	0-jet	VBF	Boosted
$e\mu$	p_T^μ, m_{vis}		
$e\tau_h$, $\mu\tau_h$	$\tau_h^{\text{decay mode}}$, m_{vis}	m_{jj}, $m_{\tau\tau}$	$p_T^{\tau\tau}$, $m_{\tau\tau}$
$\tau_h\tau_h$	$m_{\tau\tau}$		



4. How are the background processes suppressed and modelled?

Z(ττ) irreducible background

→ corrections to the simulation from Z($\mu\mu$) events

QCD events, dominating in $\tau_h\tau_h$

→ estimated from data in events with relaxed isolation (for $\tau_h\tau_h$) or same-sign τ pairs (other channels)

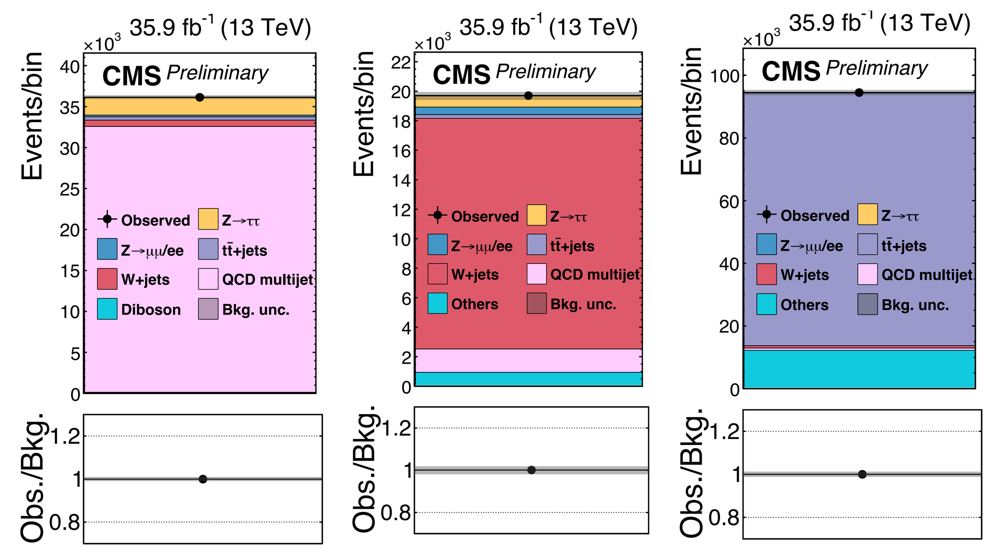
W+jets events, mostly in $\mu\tau_h$ and $e\tau_h$

→ reduced selecting low $m_T(\ell$,MET)

ttbar events, especially in $e\mu$

→ in tau decays, directions of neutrinos and leptons are close (D_ζ variable).

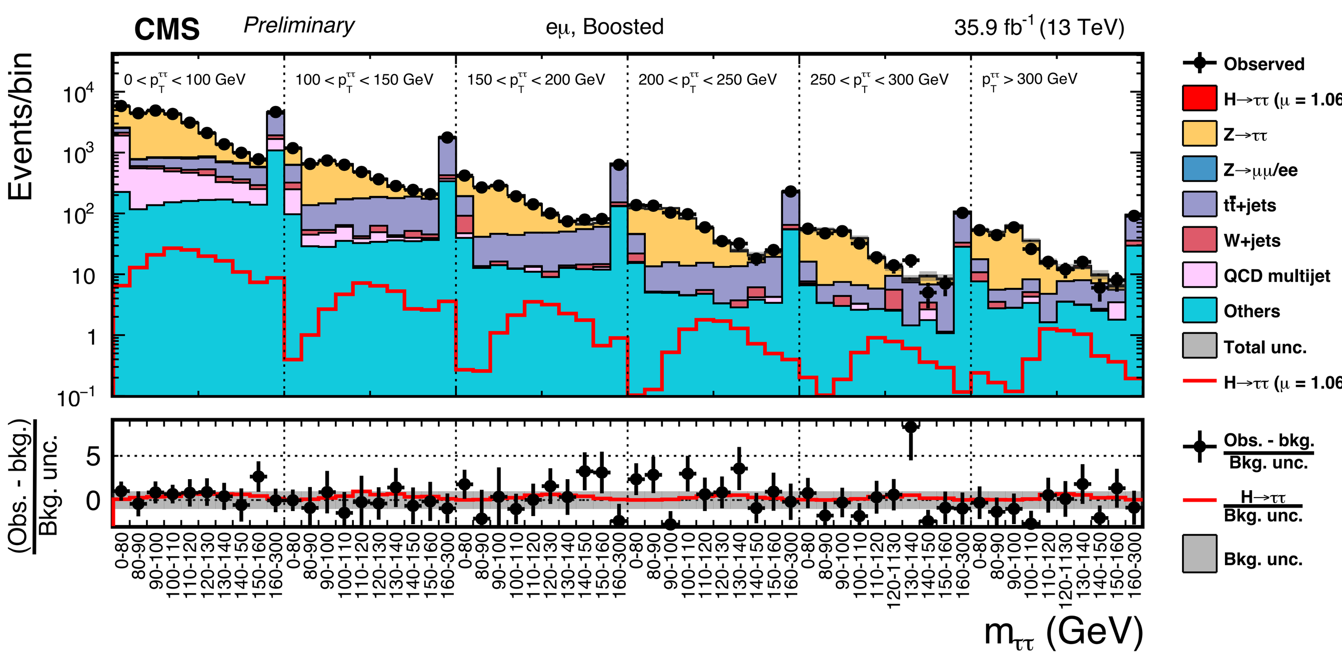
Normalisation of QCD, W+jets and ttbar derived in the final fit from 12 control regions

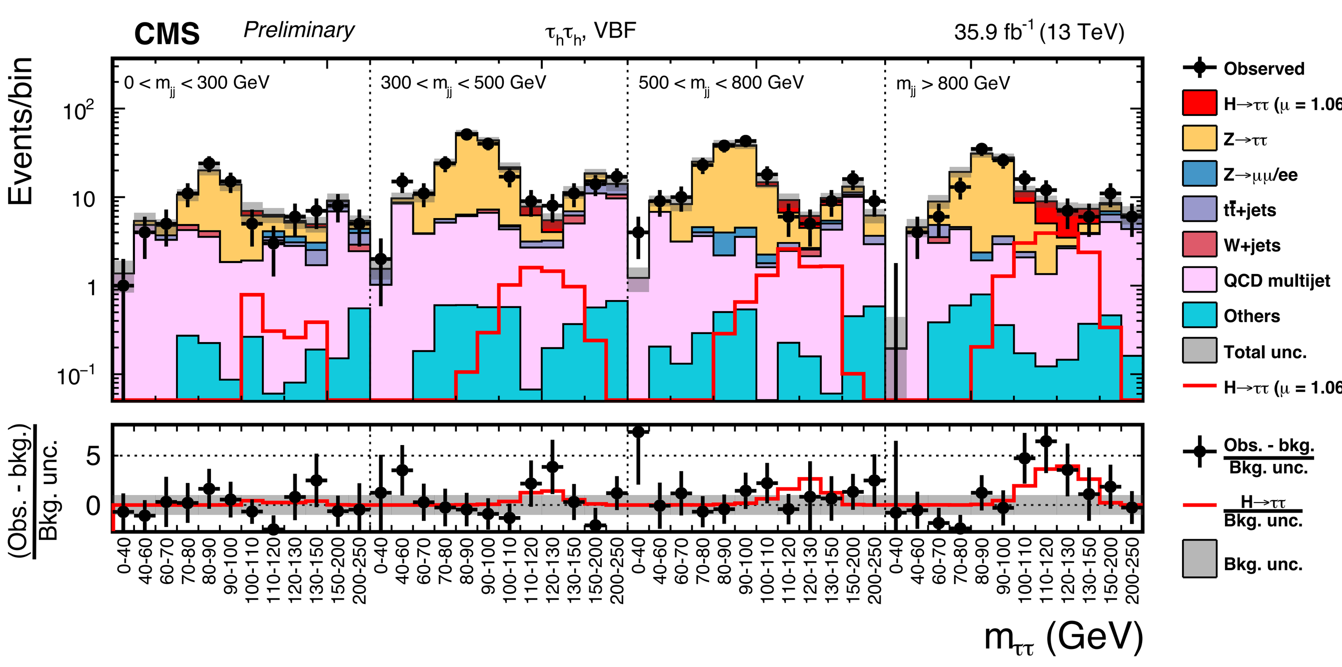


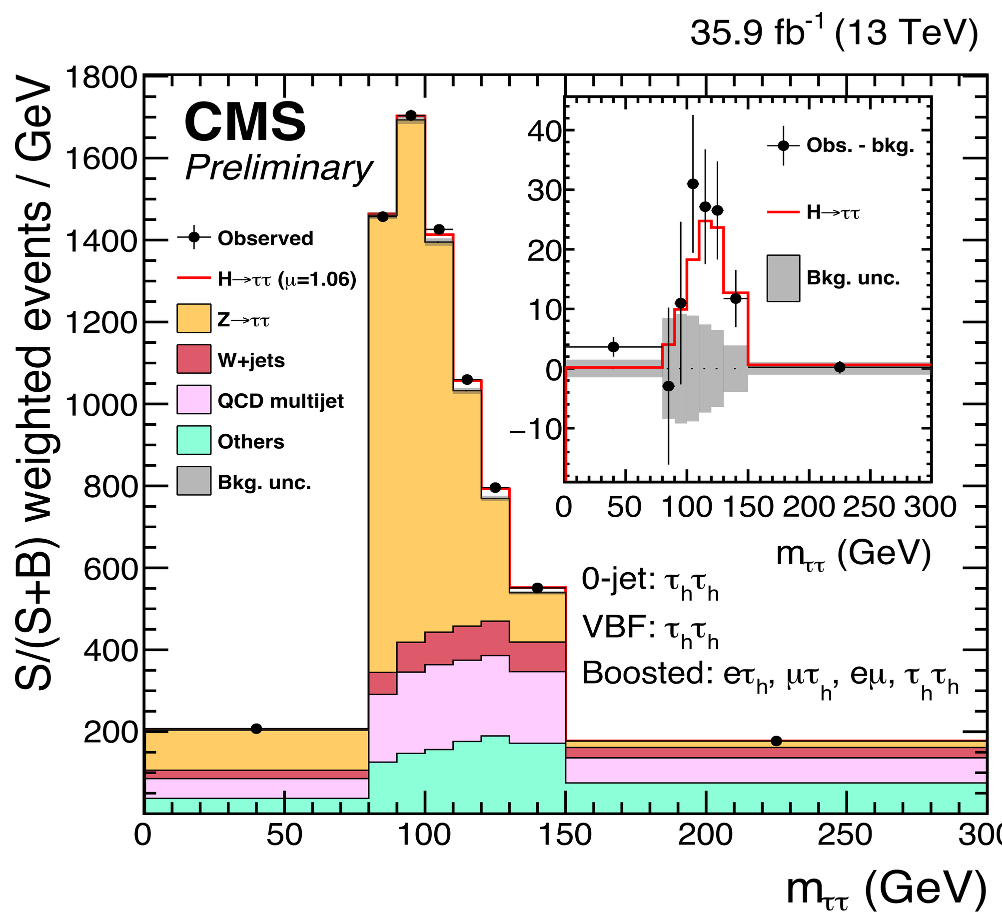
From the left: QCD control region in $\tau_h\tau_h$ boosted, W+jets control region for $\mu\tau_h$ 0 jet, ttbar control region in $e\mu$ channel.

5. Results - Observation of the H(ττ) decay mode with a significance of 4.9 σ and a signal strength $\hat{\mu}$=1.06±0.25 [4]

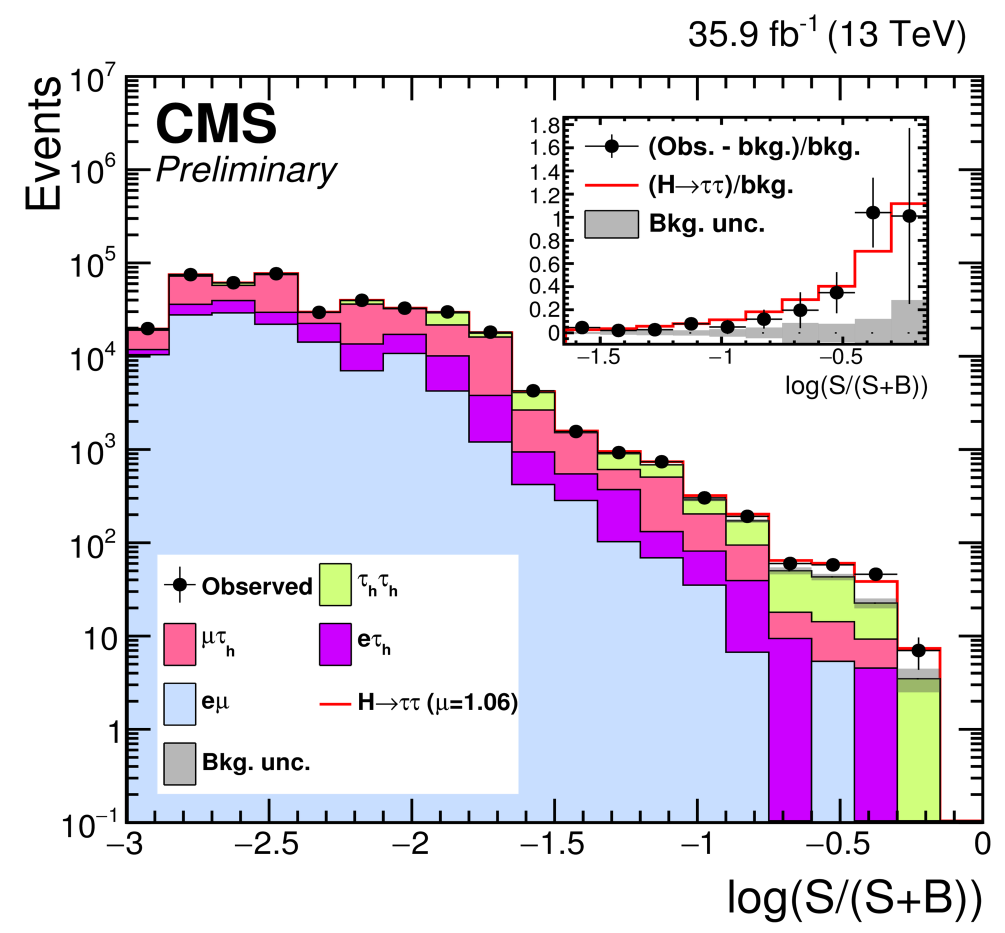
Observed and predicted 2D distributions after the global fit. A total of 12 distributions are used to derive the result.







Combined observed and predicted $m_{\tau\tau}$ distribution for the $\tau_h\tau_h$ channel and boosted categories of the other channels. The mass distribution is weighted according to S/(S+B).



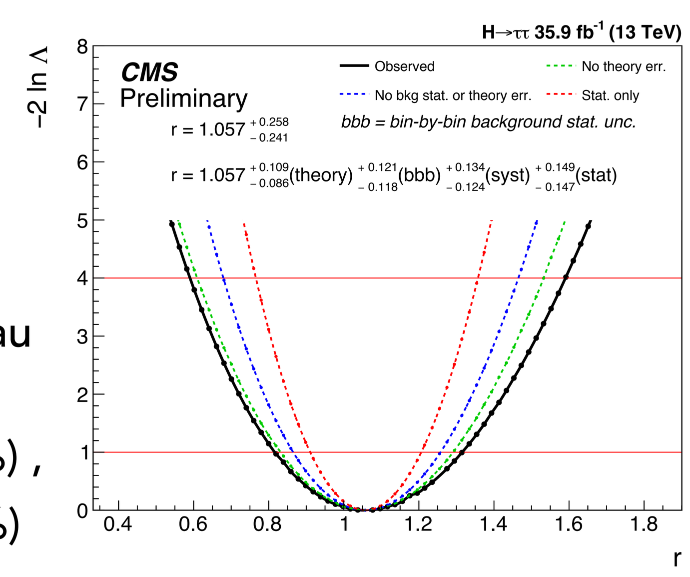
Decimal logarithm of the ratio between the expected signal and signal plus background in each bin of the mass distributions, in all signal regions.

Experimental uncertainties

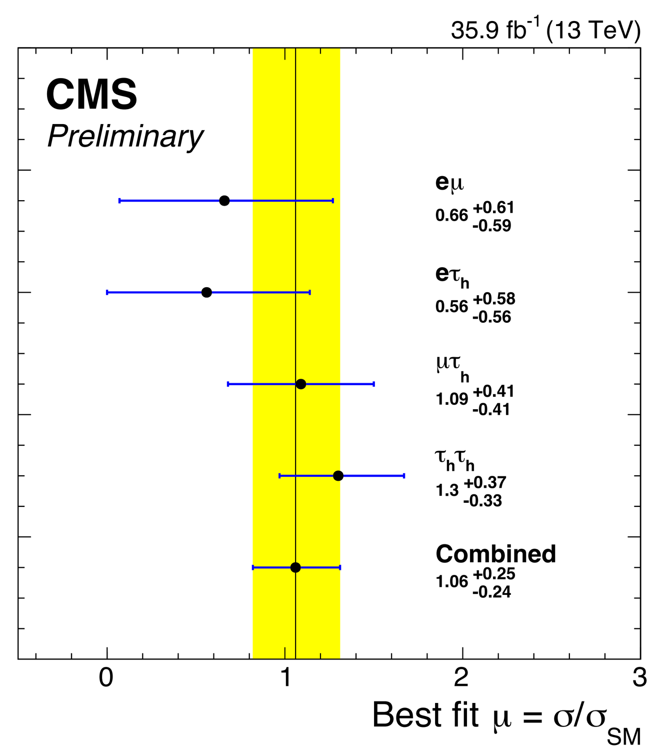
Experimental uncertainties are dominated by the τ_h reconstruction.

Uncertainties affecting the di-tau mass shape:

- genuine τ_h energy scale (1.2%) , $e/\mu \rightarrow \tau_h$ energy scale (1.5-3%)
- missing energy scale uncertainties (event by event).

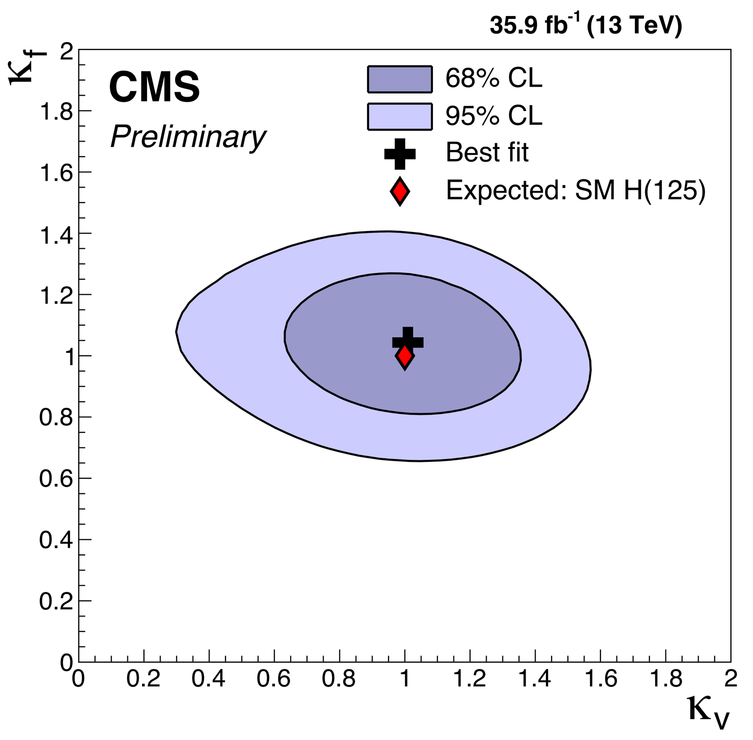


Profile likelihood ratio as a function of the signal strength.



Left: Best-fit signal strength per channel, for m_H= 125 GeV. The best-fit signal strength combining all channels is $\hat{\mu}$=1.06±0.25.

Right: Fit of the Higgs coupling strength to gauge bosons and fermions, for m_H=125 GeV. The H(WW) process is taken into account as signal process, too.



References

[1] Evidence for the 125 GeV Higgs boson decaying to a pair of tau leptons, JHEP 05 (2014) 104

[2] Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at $\sqrt{s}$= 7 and 8 TeV, JHEP 08 (2016) 045

[3] Performance of reconstruction and identification of τ leptons in their decays to hadrons and ν_τ in LHC Run-2, CMS-TAU-16-002

[4] Observation of the SM scalar boson decaying to a pair of τ leptons with the CMS experiment at the LHC, CMS-PAS-HIG-16-043

CMS-PAS-HIG-16-043