Search for SM Higgs in the $H \rightarrow \tau\tau$ decay channel with CMS

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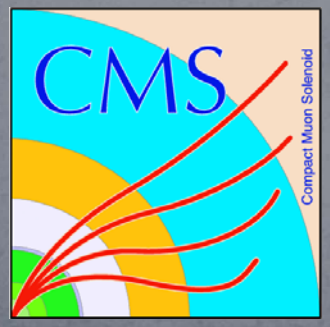
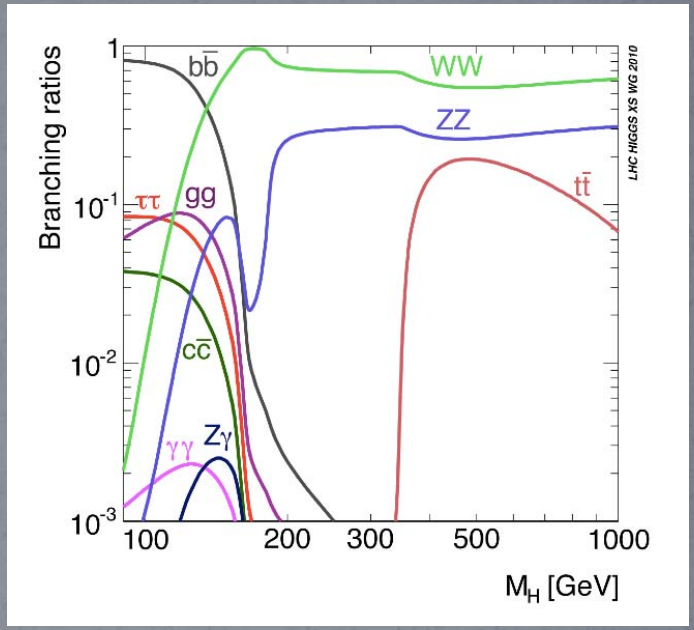
on behalf of the DESY/KIT analysis group

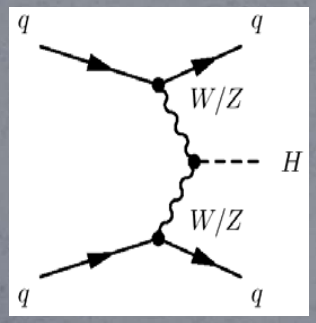
6th annual workshop
DESY Hamburg 3rd-6th December 2012
Physics at the Terrascale
Helmholz Alliance

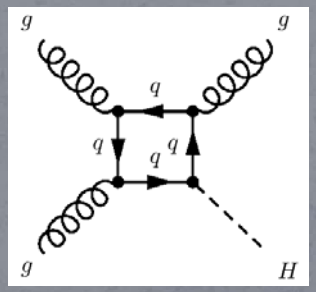


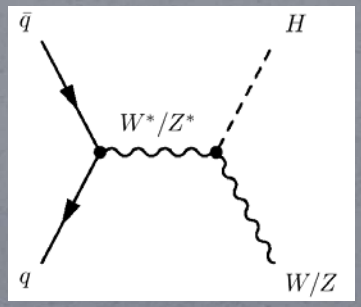
Introduction

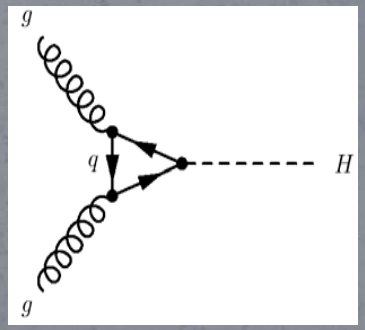
- Large rate at $m_h < 140$ GeV
- For a light Higgs BR(H→ττ)=8% - 1.8% H→ττ decay mode channel very promising!
- Accessible via all production mechanisms
- Test of the SM prediction for the τ Yukawa coupling.





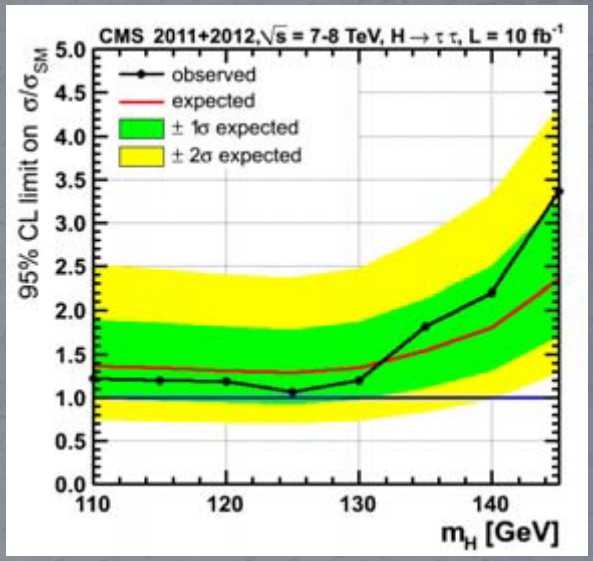






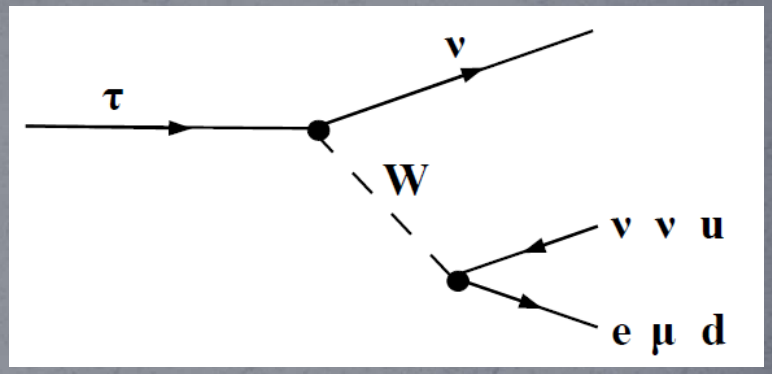
Results of Higgs Boson searches

- Discovery of a Boson with mass 125 GeV was announced in ICHEP conference
  - Luminosity 10fb^{-1}
  - Result driven by H→γγ and H→ZZ
  - No evidence for signal in fermionic decays
- Current status: Results announced in HCP conference
  - Luminosity 17fb^{-1}
  - Improved analysis
    - Re-reconstruction of 2012 dataset improved description of forward jet response
    - Significantly improved MET resolution
    - Simplification of VBF selection



Analysis strategy

- Final states analysed: H→ττ→...
  - μμ (DESY/KIT)
  - eμ
  - μ +had
  - e+had
  - had+had

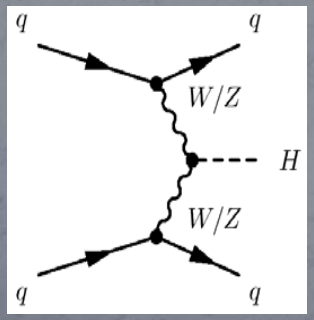


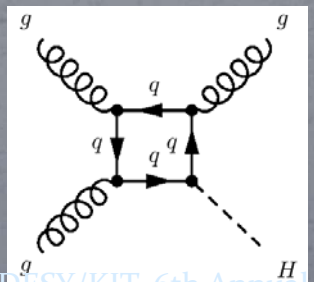
- Dedicated analysis for associated Higgs production with vector bosons
  - WH→lττ
  - ZH→llττ (l is μ or e)
- Basic pre-selection of events
  - opposite sign leptons
  - isolated
  - different triggers applied depending on the channel and the LHC period

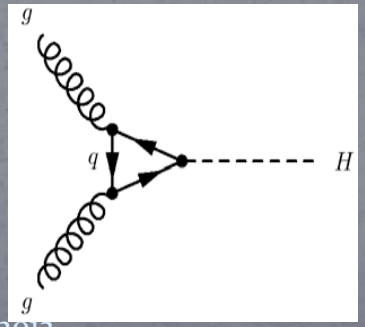
Event categories

- The events a divided into categories according to the jet multiplicity and lepton p_T

0 jets	low p_T • background calibration • no signal extracted	high p_T • background calibration • no signal extracted
1 jet	low p_T • Large statistics	high p_T • Improved $m_{\tau\tau}$ resolution • Suppressed $Z\rightarrow\tau\tau$ background
2 jets/VBF	$e\mu,\mu\tau_h,e\tau_h$: $m_{jj}>500$ GeV, $\Delta\eta_{jj}>3.5$, central jet veto $\tau_h\tau_h$: $m_{jj}>250$ GeV, $\Delta\eta_{jj}>2.5$ $\mu\mu$: MVA selection (discussed in detail later)	

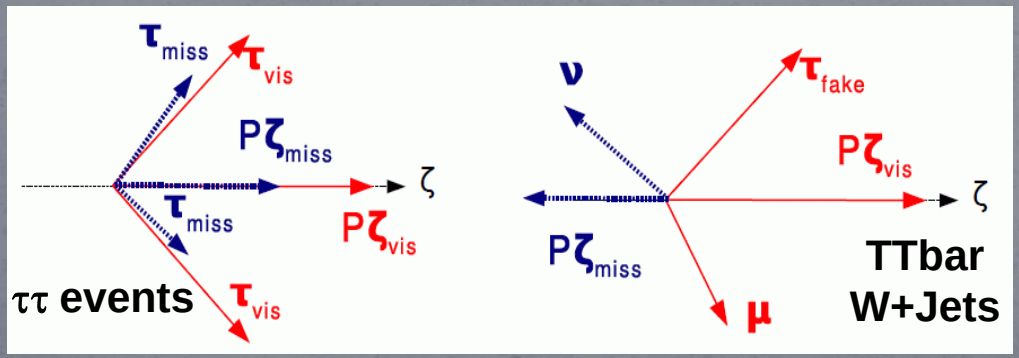


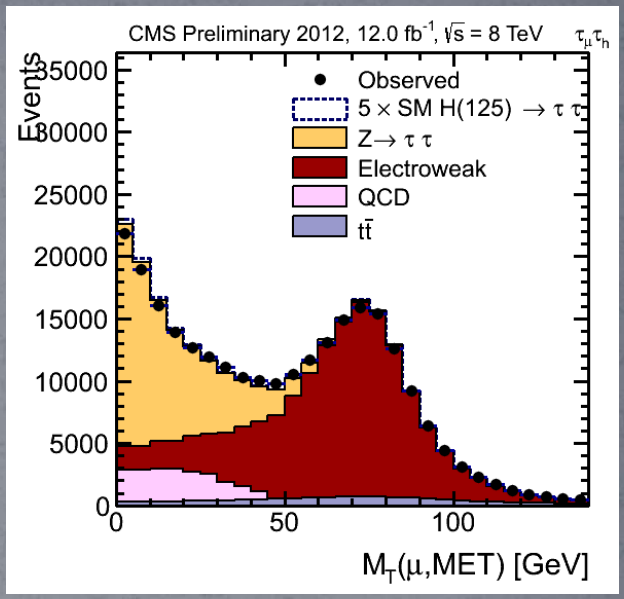


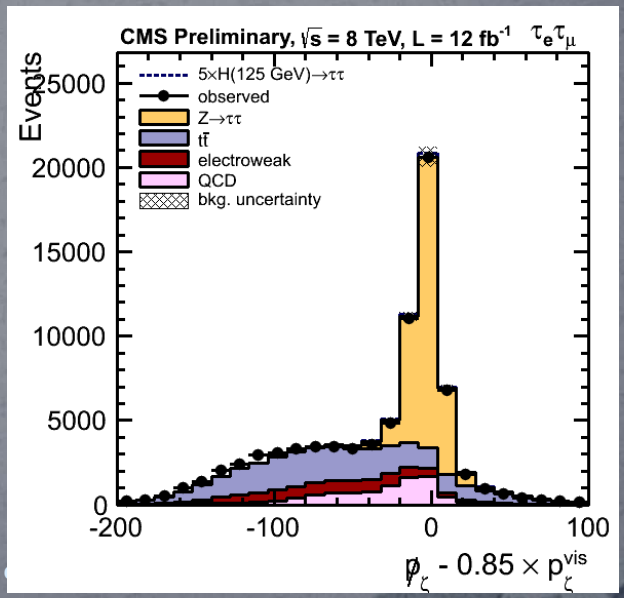


Topological selection

- For the $\mu\tau_h$, $e\tau_h$ and $e\mu$ final states further discrimination is needed against background (mainly W+Jets and ttbar jets)
  - In the $e\tau_h$ and $\mu\tau_h$ a cut is applied to the transverse mass:
    - $m_T = \sqrt{2 \cdot p_T(l) \cdot MET(1 - \cos(\Delta\varphi_l, MET))}$
      - m_T<20GeV
  - In the $e\mu$ the selection is based on :
    - $p^{cut}{}_\zeta(\alpha) = p^{miss}{}_\zeta - \alpha \cdot p^{vis}{}_\zeta$
      - $p^{cut}{}_\zeta$>-25GeV
      - the α value is determined in order to optimize the S/B ratio

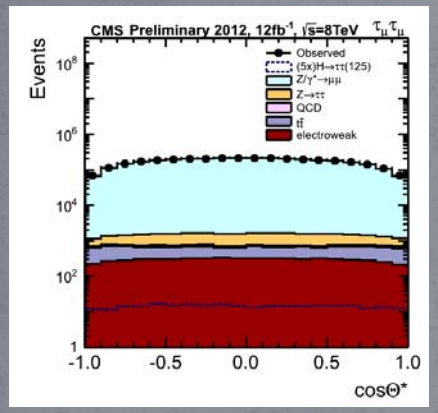


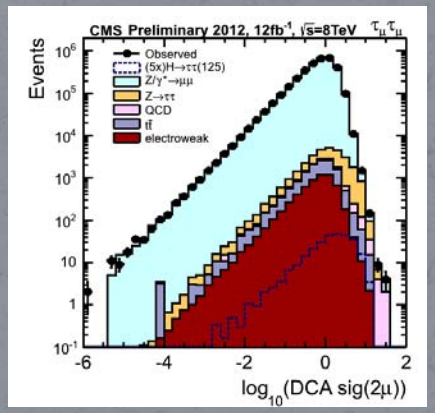


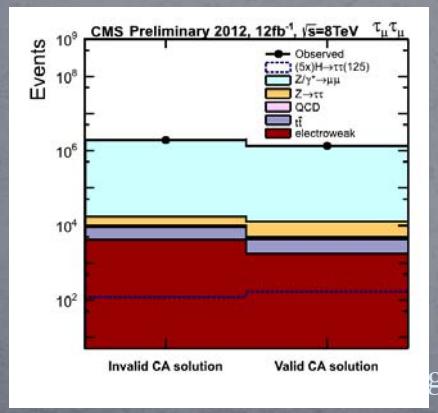


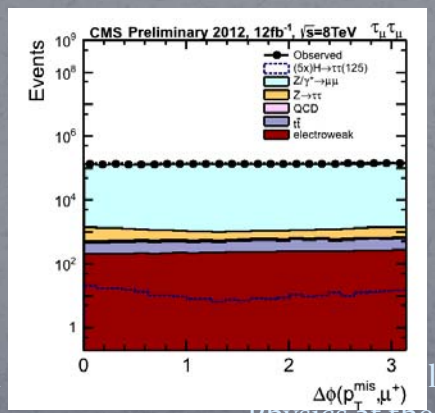
MVA analysis in the μμ final state

- The H→ττ→μμ decay channel is challenging
  - Large Drell-Yan background Z/γ*→μμ
  - Small topological branching fraction of the ττ→μμνννν decays, (Br ~ 3%).
- A Boosted Decision Tree (BDT) is trained using μ kinematic variables and tau decay length information (Distance of Closest Approach)

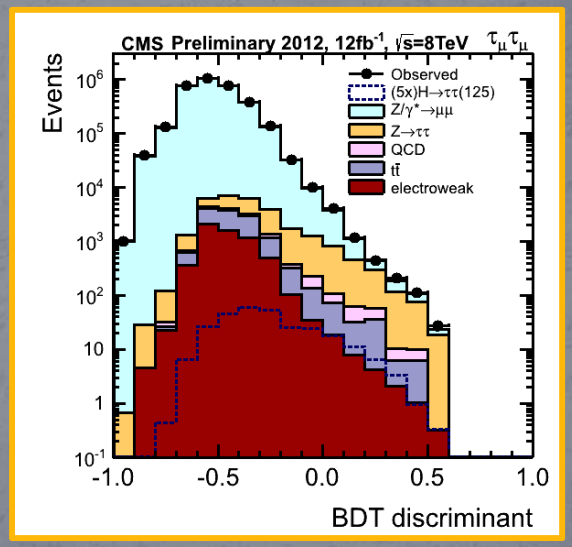






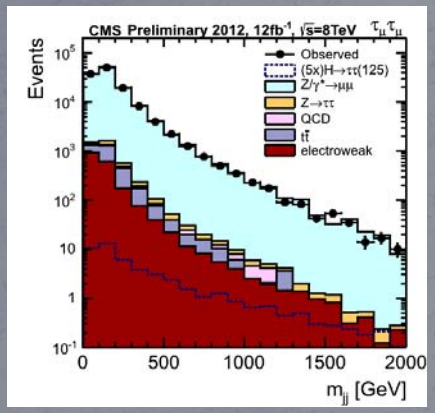


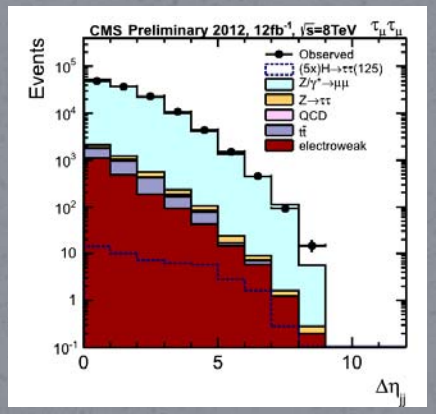
Cut optimised for each category

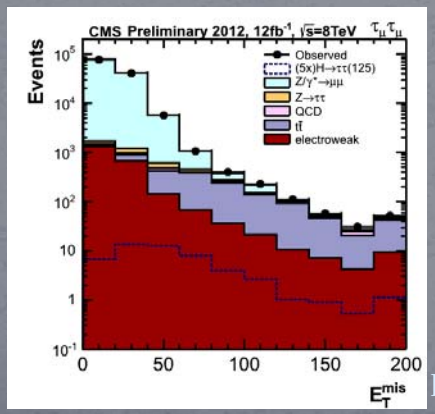


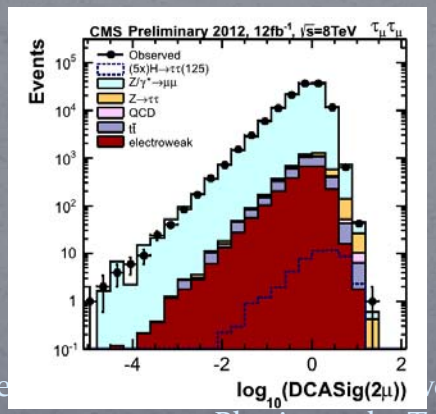
MVA analysis in the μμ final state

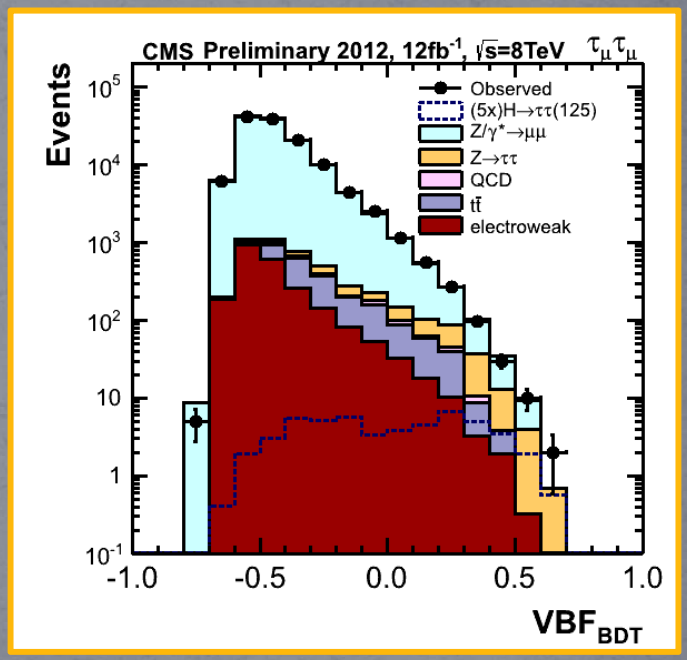
- VBF dedicated selection
  - BDT trained using μ kinematic variables ,tau decay length information, MET and jet related variables m_{jj}, $\Delta\eta_{jj}$





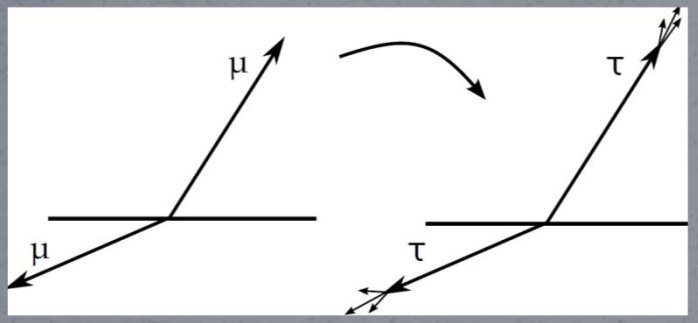


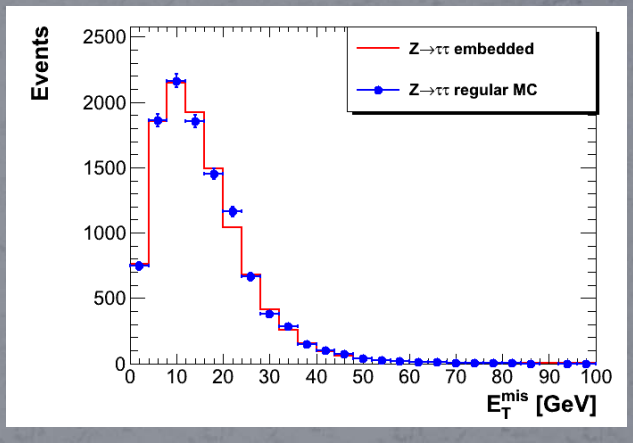




Background estimation

- $Z \rightarrow \tau\tau$: most important irreducible background estimated from an embedded sample.
  - This sample is derived from $Z \rightarrow \mu\mu$ events in data where each muon has been replaced by a simulated τ lepton.

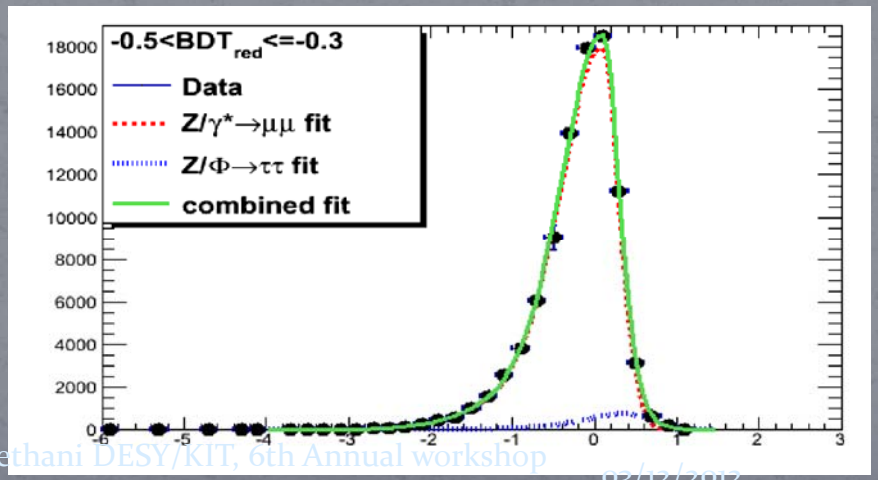




Other Background contributions	
QCD	Normalisation and shape taken from SS/OS or fake rate
ttbar	Shape from simulation ; normalisation from side band
$Z \rightarrow ee(\mu\mu)$	Estimated from simulation, corrected for efficiency and $e \rightarrow \tau_h$ and $j \rightarrow \tau_h$ fake rate
Diboson/W+Jets	Shape from simulation ; normalisation from side band

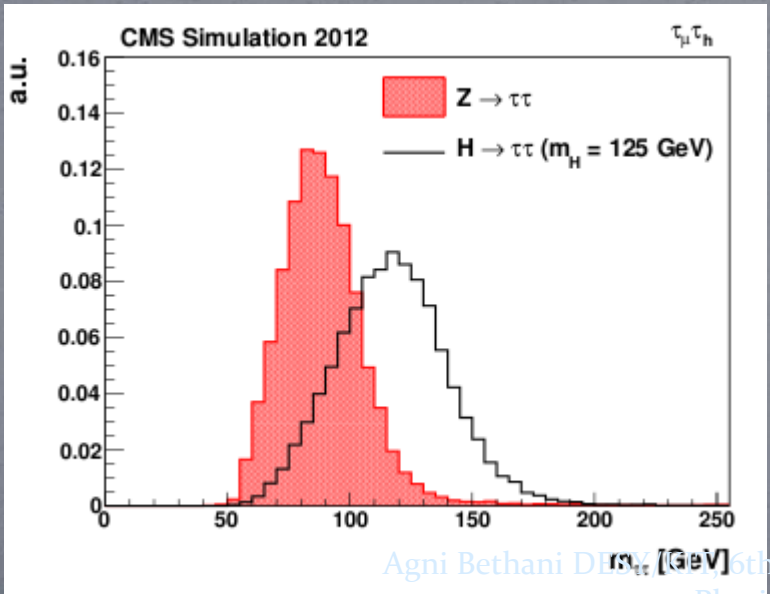
Background estimation

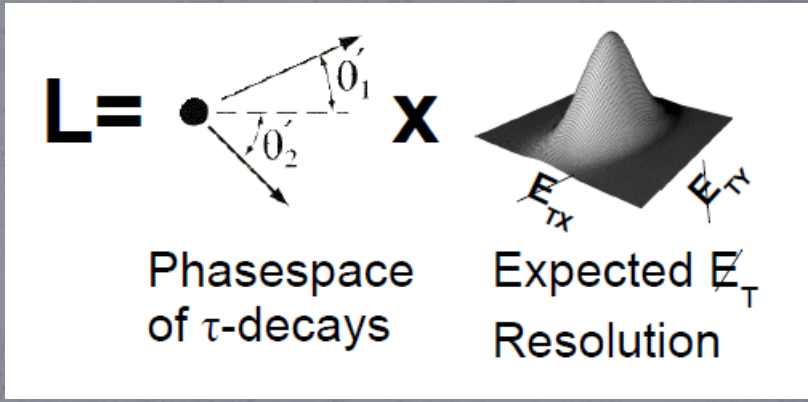
- **Z→μμ for the μμ final state**
  - Shape from MC, normalisation from fit to DCA significance.
    - The fit is performed in bins of visible mass, "reduced BDT" and reconstructed τ pair mass. The reduced BDT is trained with the same variables as the BDT used for background rejection apart from the DCA significance.



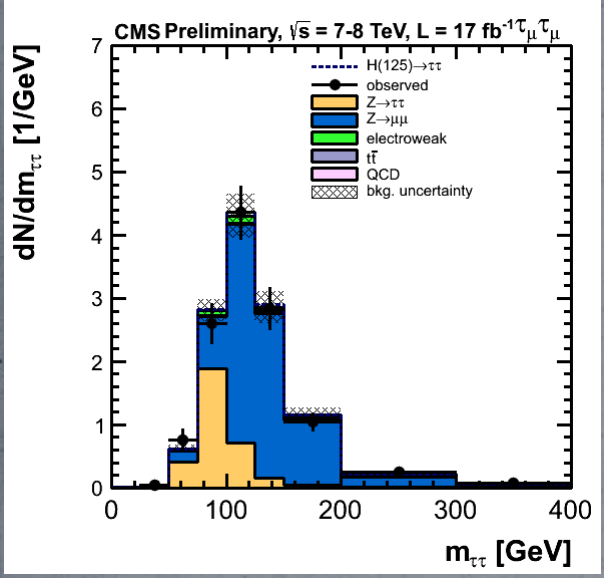
Reconstruction of τ pair

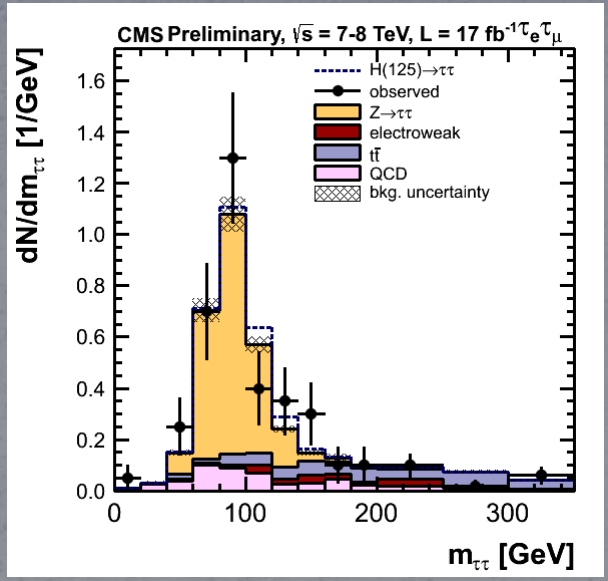
- The invariant mass of the two τ is determined with maximum likelihood method
  - Inputs: four-vector information of visible leptons, x- and y- component of MET on event by event basis
  - Free parameters: ϕ, x, ($m_{\nu\nu}$) per τ (4-6 parameters).
  - Scan of $m_{\tau\tau}$ from m_{τ} up to 2TeV
  - 15-20% resolution of the reconstructed $m_{\tau\tau}$ mass.

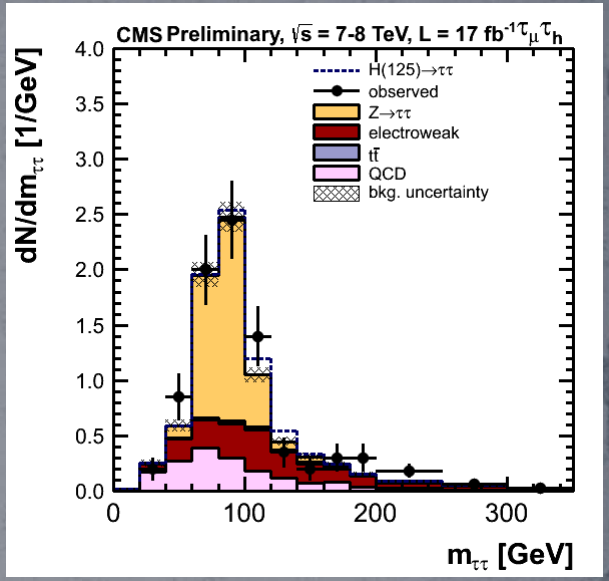


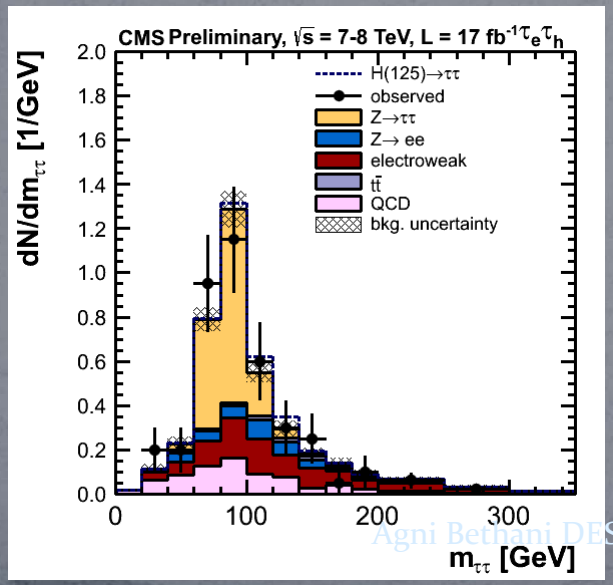


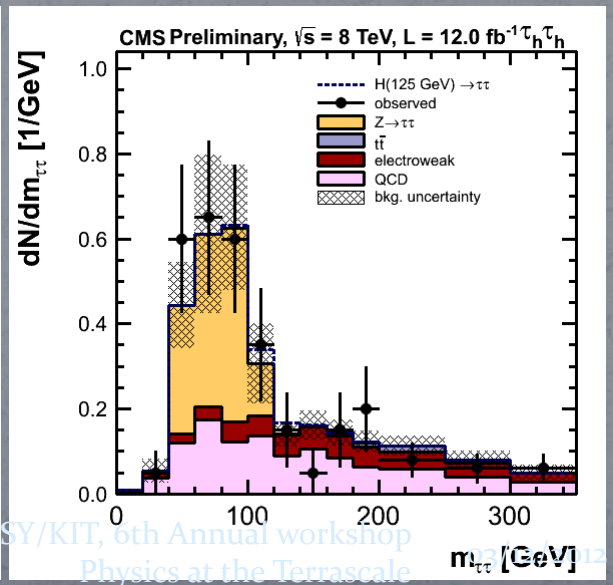
Mass distributions for the VBF category





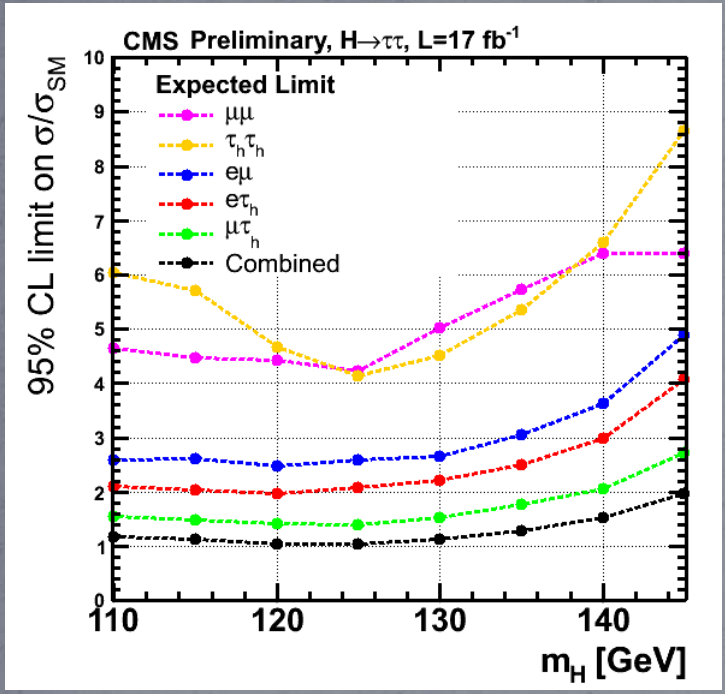


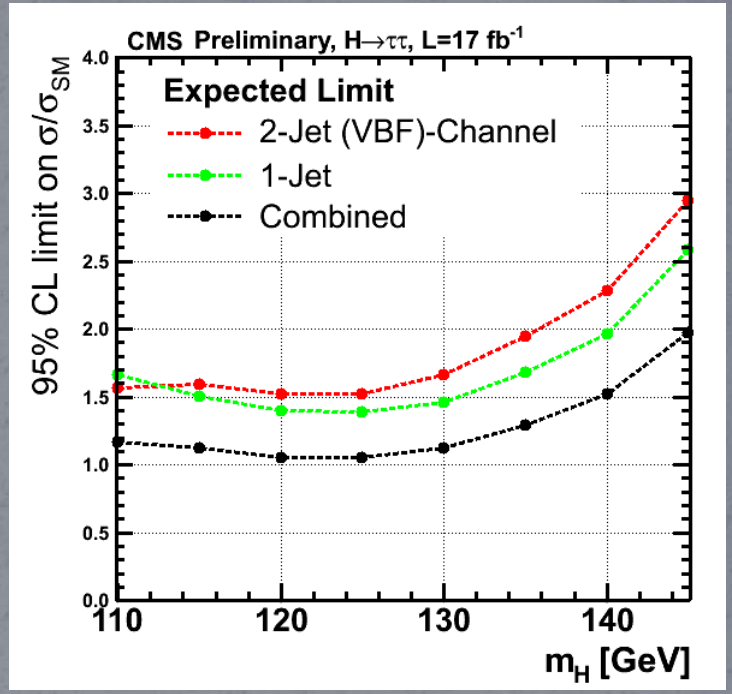




- In the μμ final state the final discriminating object is a 2D distribution of the $m_{\tau\tau}$ and m_{vis}

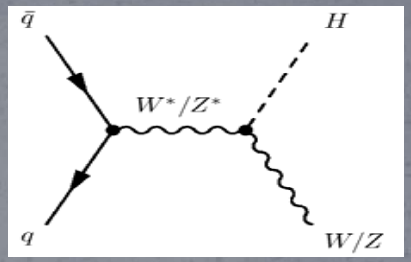
Sensitivity of the analysis



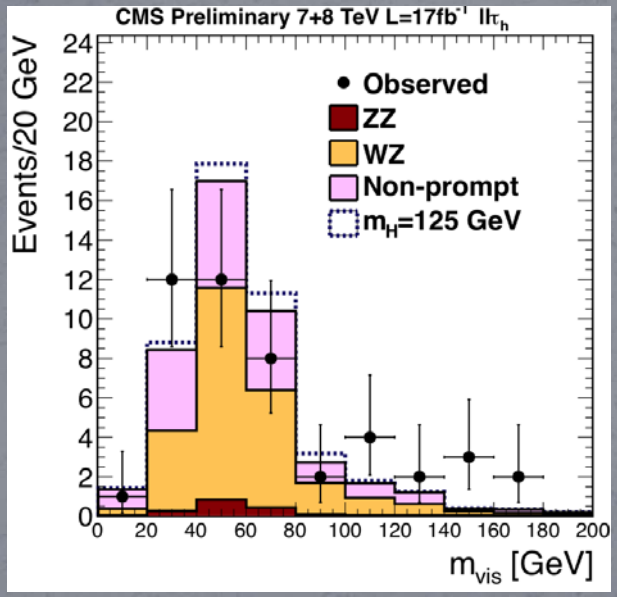


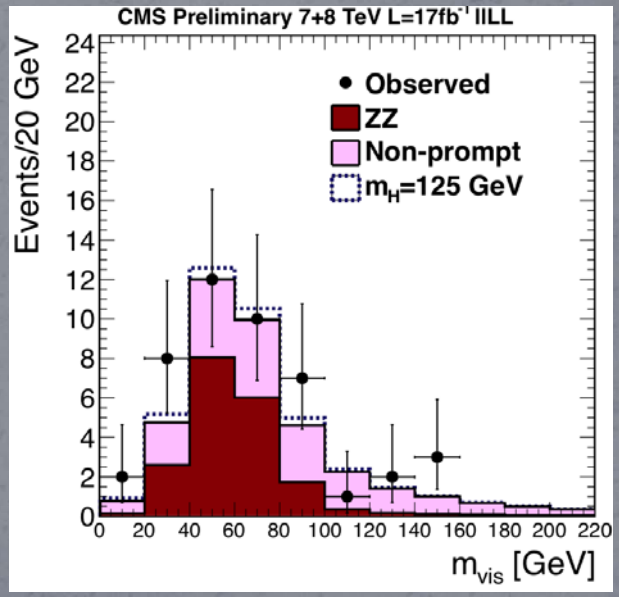
- Most sensitive channel is the $\mu\tau_h$
- VBF and combined 1 jet category have similar strength

Associated production with vector bosons

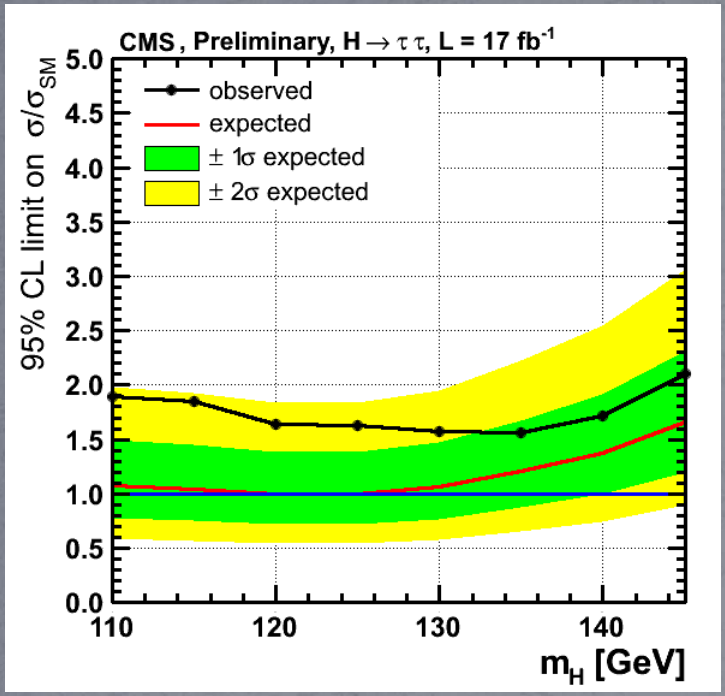


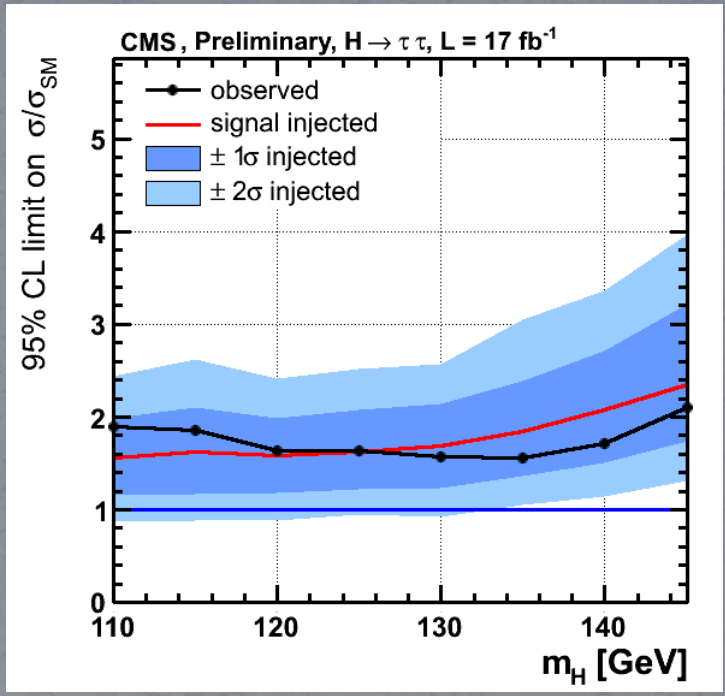
- Small background compared to to inclusive H→ττ decay channels.
- Signal extracted from mass of visible decay products (m_{vis}).





Combined results





- Exclusion sensitivity(125 GeV) ~ 1. Observed limit(125 GeV) ~ 1.6
- Compatible with Higgs boson signal at 125 GeV but also with background only hypothesis.

Summary

- Analysis of 17fb^{-1} is performed in 5 final states plus 2 more from the dedicated analysis to the associated Higgs production with vector bosons
- Observation compatible with both background only and signal plus background hypothesis
- Limits are set on signal strength.
- Looking forward to analyse more data. Expected ~ 25fb^{-1} by the end of this year.

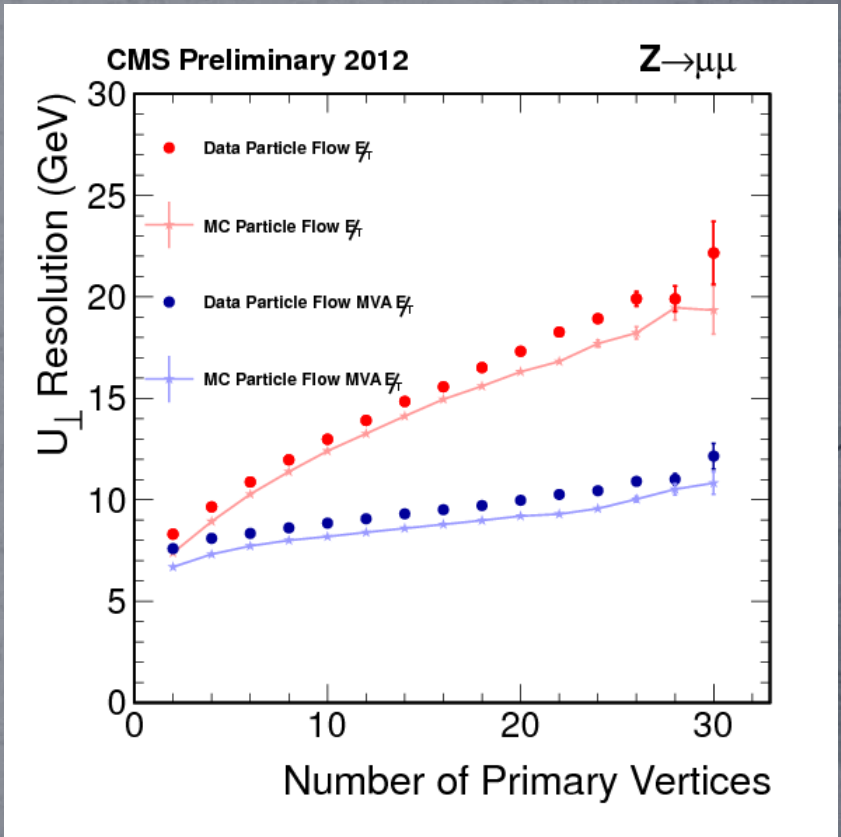
Thank you for your attention!

Systematic uncertainties

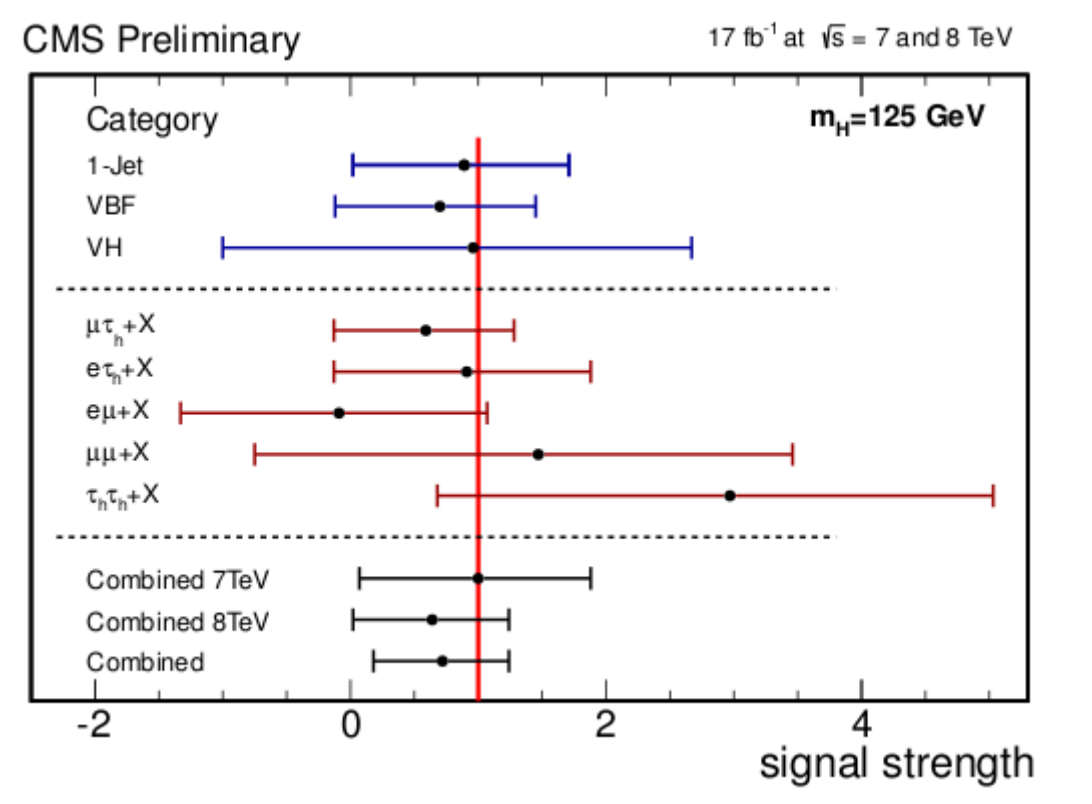
Experimental Uncertainties		Propagation into Limit Calculation		
Uncertainty	Uncert.	*0-Jet*	*Boost*	*VBF*
Electron ID & Trigger (*)	$\pm 2\%$	$\pm 2\%$	$\pm 2\%$	$\pm 2\%$
Muon ID & Trigger (*)	$\pm 2\%$	$\pm 2\%$	$\pm 2\%$	$\pm 2\%$
Tau ID & Trigger (*)	$\pm 7\%$	$\pm 7\%$	$\pm 7\%$	$\pm 7\%$
JES (Norm.) (*)	$\pm 2.5 - 5\%$	$\mp 1\%$	$\pm 5\%$	$\pm 10\%$
b-Tag Efficiency (*)	$\pm 10\%$	$\mp 1\%$	$\mp 2\%$	$\mp 2\%$
Mis-Tagging (*)	$\pm 30\%$	$\mp 1\%$	$\mp 1\%$	$\mp 1\%$
Norm. $Z \to \tau\tau$	$\pm 3\%$	$\pm 3\%$	$\pm 5\%$	$\pm 13\%$
Norm. $t\bar{t}$ (*)	$\pm 10 - 30\%$	$\pm 10\%$	$\pm 12\%$	$\pm 30\%$
Norm *EWK*	$\pm 30\%$	$\pm 30\%$	$\pm 15 - 30\%$	$\pm 30 - 100\%$
Norm Fakes	$\pm 10 - 30\%$	$\pm 10\%$	$\pm 10\%$	$\pm 30\%$
Lumi (Signal & EWK)	$\pm 2.2(5)\%$	$\pm 2.2(5)\%$	$\pm 2.2(5)\%$	$\pm 2.2(5)\%$
Norm. $W + jets$	$\pm 10 - 30\%$	$\pm 10\%$	$\pm 10 - 30\%$	$\pm 30\%$
Norm. Z: l fakes τ_h	$\pm 20 - 100\%$	$\pm 20 - 30\%$	$\pm 20 - 100\%$	$\pm 30\%$
Norm. Z: jet fakes τ_h	$\pm 20\%$	$\pm 20\%$	$\pm 20\%$	$\pm 30\%$

Reconstruction of MET

- Combining several different methods of MET reconstruction into an MVA regression
  - Trained on recoil of Z→μμ events in data.
- Significantly improved resolution
- Significantly reduced pile up dependency
- Large impact on H→ττ analysis
  - MET is part of the event selection
  - MET is used in the τ pair mass reconstruction



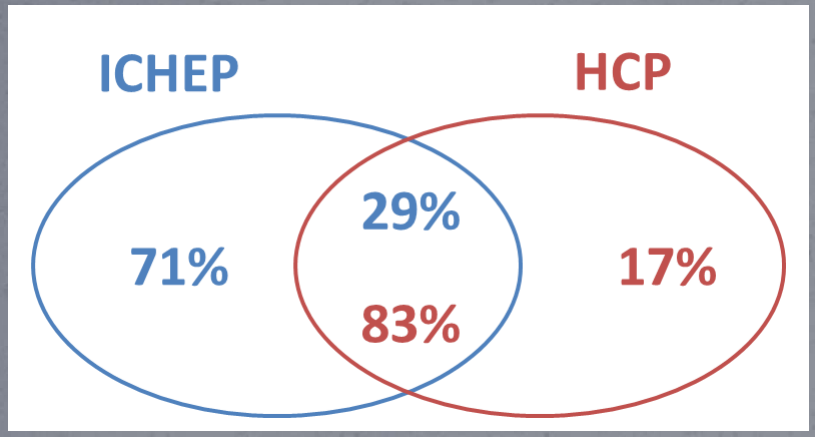
Signal strength



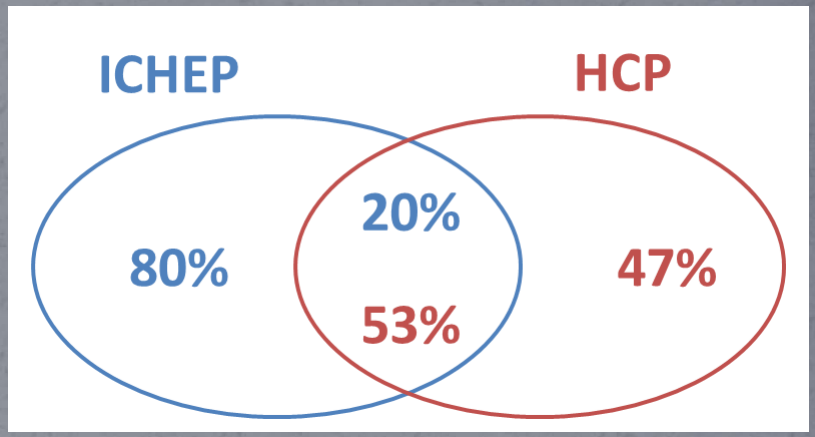
- Signal strength after fit: 0.72±0.52
- Compatible with the SM

Overlap with ICHEP dataset

- 2011 data



- 2012 data



Embedding method