Search for additional Higgs bosons at high mass decaying to WW with CMS Experiment

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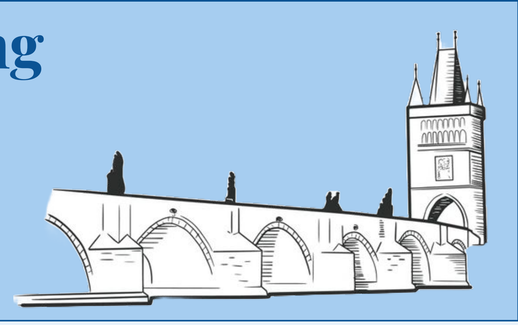


Search of a higher mass scalar resonance that decays into two W bosons to investigate possible extension of Standard Model.

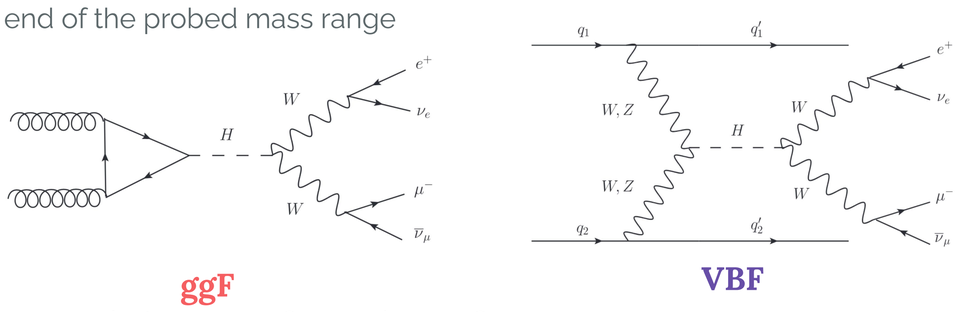
Search performed at CMS Experiment with proton proton collision at √s = 13 TeV recorded during Run II corresponding to an integrated luminosity of **138 fb^{-1}** .

Model **independent limit on the signal cross section** and **Two Higgs Doublet** (THDM) [1] model and **Minimal Supersymmetric Standard Model** (MSSM) [2] [3] interpretation pursued.

Focus on di-leptonic final state, either same flavour final state or different flavour final state.

Signal

Two production mechanism probed: **ggF** and **VBF**, with VBF especially relevant at the higher end of the probed mass range

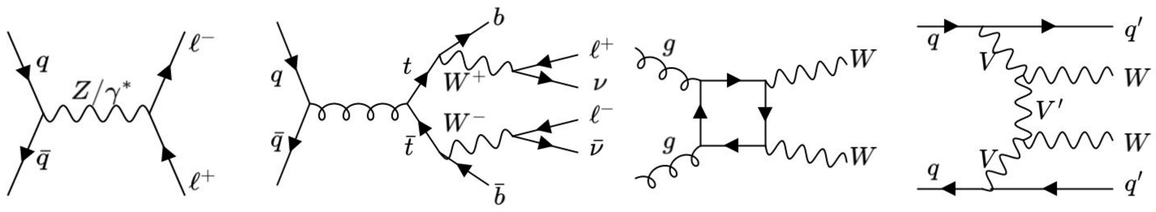


ggF VBF

- Mass range between 115 GeV and 5000 GeV
- Mass samples generated with POWHEG v2 with the decay into two W bosons modeled with JHUGEN
  - Samples generated with SM width but reweighted to different width hypotheses with **Matrix Element Likelihood Analysis**, using the relative width with respect to the mass
- Considered the interference between SM Higgs, High mass candidate and non resonant WW

Background

Most relevant backgrounds are:



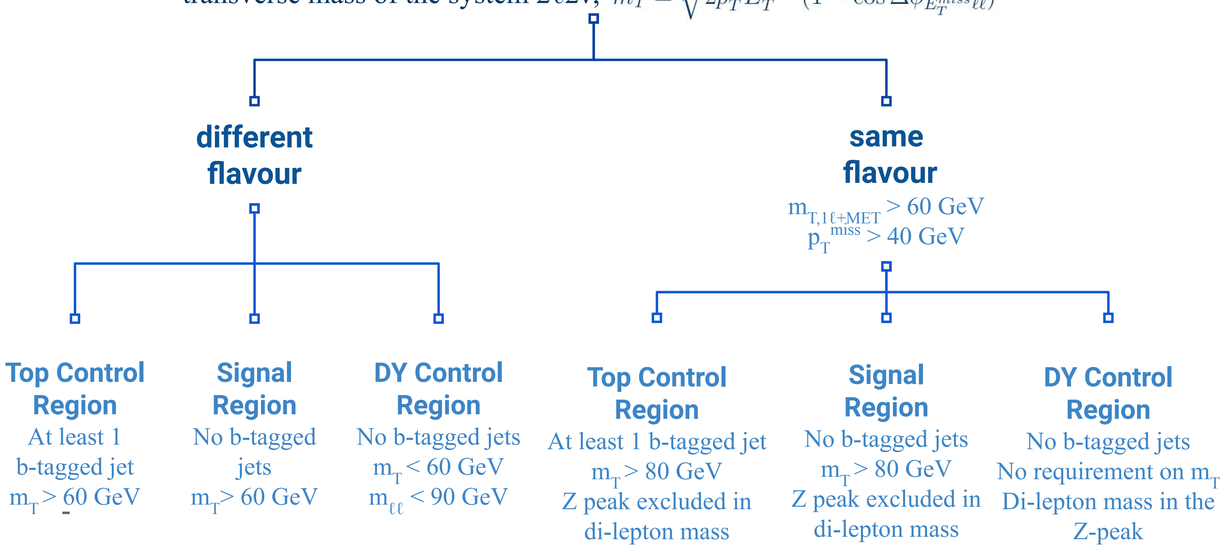
DY ttbar ggWW qqWWqq

- **DY** dominant in same flavour category, estimated from MC.
- In different flavour, due to Z → ττ → leptons chain, **DY** estimated with an embedding technique.
- **ttbar** is a relevant background and single top in minor fraction both estimated from MC.
- **WW**, **Vγ*, VZ, VVV** and **SM Higgs** processes are also estimated from MC.
- **Non-prompt leptons** are estimated using a data driven technique.

Analysis Strategy

Preselection

two isolated leptons with a third lepton excluded and requirements on the di-lepton p_T and mass, search for 2 ν: requirement on the missing p_T on the transverse plane and requirement on the transverse mass of the system 2ℓ2ν, $m_T = \sqrt{2p_T^{\ell\ell}E_T^{miss}(1-\cos\Delta\phi_{E_T^{miss}\ell\ell})}$



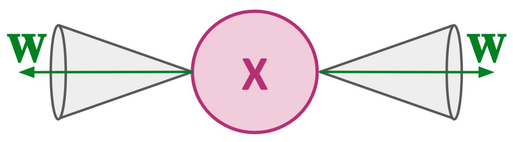
DY and ttbar are estimated through a **Normalization Factor** in their respective control Regions.

The selection in the Same Flavour aims to further reduce DY background.

- DY estimated in the m_Z window and ttbar estimated in b-jets enriched regions.

Additional cuts used for signal hypotheses $m_X \geq 1000$ GeV.

- Highly boosted W → highly displaced leptons in φ and back to back in the longitudinal plane along z.



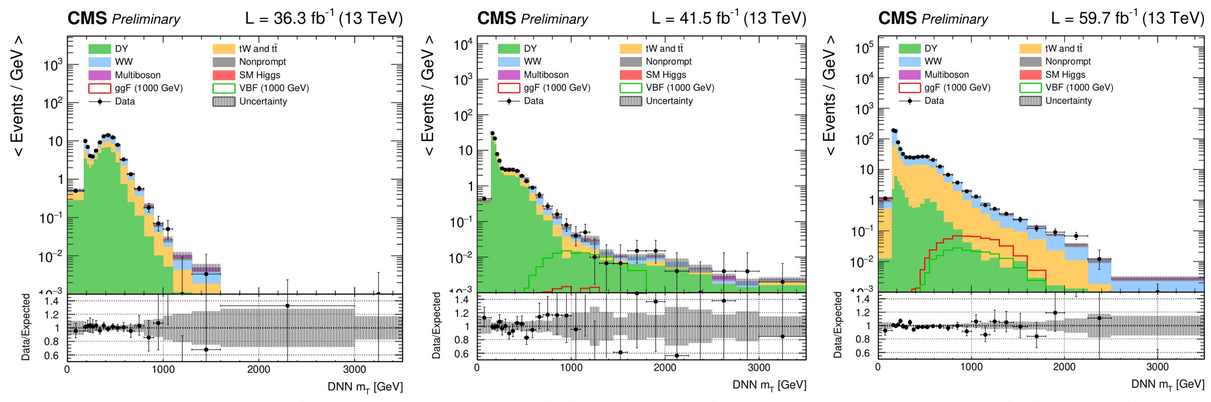
Further selection is obtained using a **DNN to classify the Signal Region**:

- ggF events, VBF events and untagged.
- Trained with di-jet variables and transverse mass of the di-lepton system and MET.

Fit model

Discriminating variable is the **reconstructed resonance mass** obtained from the **output of a DNN**.

- Trained with the same variables as the one categorizing the Signal Region besides di-jet variables.
- Better performance than $m_{reco} = \sqrt{(E_{\ell\ell}+p_T^{miss})^2 - (\vec{p}_{\ell\ell}+\vec{p}_T^{miss})^2}$



m_T *notag ee same flavour* m_T *vbf μμ same flavour* m_T *ggF eμ different flavour*

The three nodes of each final state is part of the fit.

Interference taken into account in the fit with a common pdf, SBI, that contains signal, background and the relative interference, with r as a signal strength:

- $S(r-\sqrt{r}) + SBI\sqrt{r} + B(1-\sqrt{r})$

Different f_{VBF} considered: ggF only, VBF only, f_{VBF} SM and floating f_{VBF}.

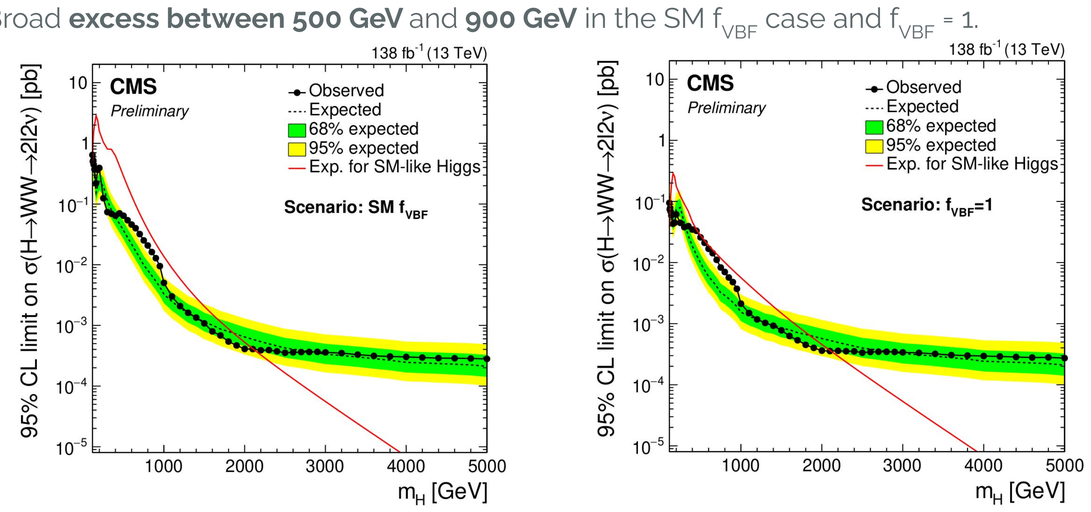
THDM implemented considering the lighter boson mass as 125 GeV and m_X, α. β as free parameters → 2D phase space of cos(β - α) and tanβ at fixed m_X .

MSSM baseline scenario with M_H^{125},

Results

Maximum likelihood fit of data in all channels is performed with background hypothesis only and signal+background model.

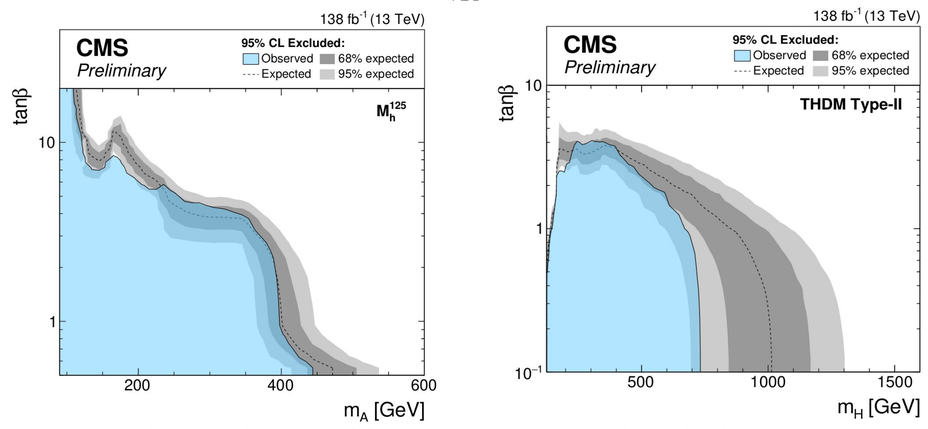
Broad **excess between 500 GeV** and **900 GeV** in the SM f_{VBF} case and f_{VBF} = 1.



Limits with SM f_{VBF} *Limits with* $f_{VBF} = 1$

Scenario	*Mass [GeV]*	*Local significance [σ]*	*Global significance [σ]*
SM f_{VBF}	800	3.2	1.7 ± 0.2
$f_{VBF} = 1$	650	3.8	2.6 ± 0.2
$f_{VBF} = 0$	950	2.6	0.4 ± 0.6
Floating f_{VBF}	650	3.8	2.4 ± 0.2

Highest local significance for the different scenario for different f_{VBF} *scenario*



Exclusion limit for MSSM scenario considering M_h^{125} *Exclusion limit for THDM Type-II selecting* $\cos(\beta-\alpha) = 0.1$

Outlook

Di-leptonic final state high mass H → WW search is public [4] .

Improved results with respect to the 2016 Analysis only [5] .

Semi-leptonic final state and combination are on-going.

Read the paper here !

References:

[1] G.C. Branco et al., Physics Reports, 516 (2012), https://doi.org/10.1016/j.physrep.2012.02.002

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[4] CMS collaboration, CMS-PAS-HIG-20-016, CDS-CERN (2022), http://cds.cern.ch/record/2803723

[5] CMS collaboration, JHEP 2020, 34 (2020), https://doi.org/10.1007/JHEP03(2020)034