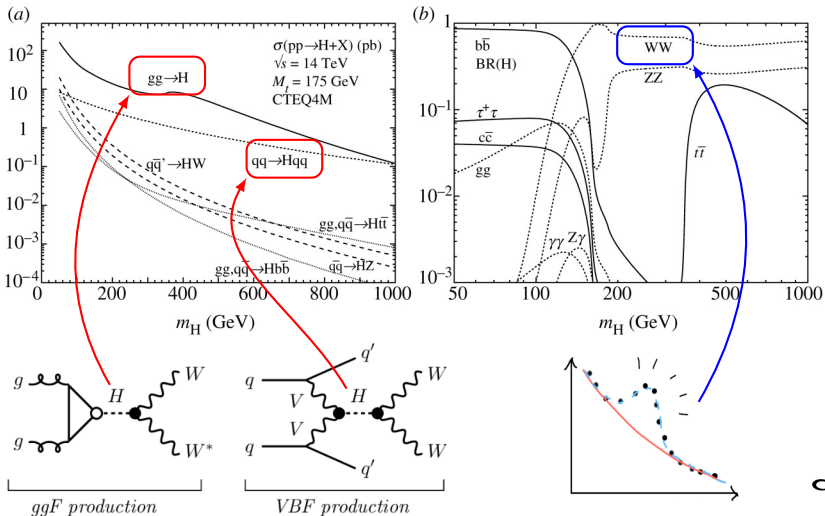


**Signal interpretations in the High mass Higgs  $\rightarrow$  WW search  
with 2016 data (HIG-17-033)**

**Dermot Moran (CIEMAT)**  
October 17, 2019

# Introduction

## High mass SM-like Higgs states predicted in many BSM models (2HDM and Electroweak Singlet)



Search for  $H \rightarrow WW$  from 200 GeV to 3 TeV with following final states :

$2\ell 2\nu$

- **Main Discriminant** : Higgs Visible mass  $m_T^l = \frac{1}{\sqrt{(p_{\ell\ell} + E_T^{miss})^2 - (\vec{p}_{\ell\ell} + \vec{p}_T^{miss})^2}}$
- **Channels** : Different (DF) & same flavour (SF)  $\ell\ell$
- **Categorization** : based on jet multiplicity and tagging of VBF-like events
- **Major backgrounds** : WW, DY and Top from data-driven estimates

$\ell\nu q\bar{q}$

- **Main Discriminant** : Higgs mass  $m_{WW}$  ( $m_W$  constraint on  $\ell\nu$  to estimate  $P_z^\nu$ )
- **Channels** :  $\ell$  flavour, Resolved & Boosted  $W_{Had}$
- **Categorization** : based on MELA and tagging of VBF-like events
- **Major backgrounds** : W+Jets and Top from data-driven estimates

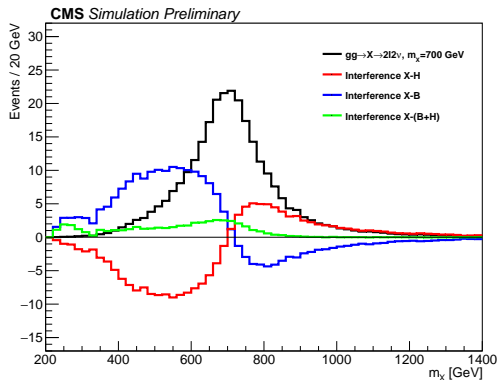
# Signal model

ggF and VBF  $H \rightarrow WW$  generated with POWHEG+JHUGen

Assume SM Width up to 1 TeV

Approximation above 1 TeV : Width =  $0.5 * m_X$

Interference with  $WW$  continuum and  $h(125)$  considered  
(Estimated with MELA reweighting of signal)



Physics model : Yield =  $\mu * \mathbf{S} + \sqrt{\mu} * \mathbf{I} + B$

Using **NNLO+NNLL ggF** and **NNLO VBF**  $\sigma$  from **YR4**

ggF and VBF predictions available up to 3 TeV

N3LO ggF  $\sigma$  also available

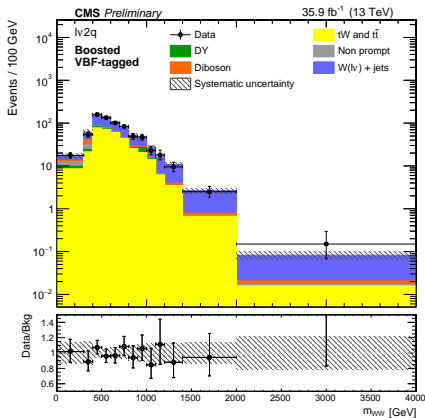
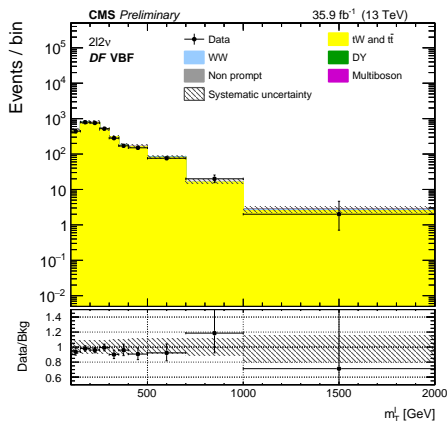
Large difference at high mass wrt NNLO+NNLL

Infinite top mass limit means N3LO not so SM-like at high mass

**A number of hypotheses for  $f_{VBF}(= \sigma_{vbf}/\sigma_{Total})$  implemented**

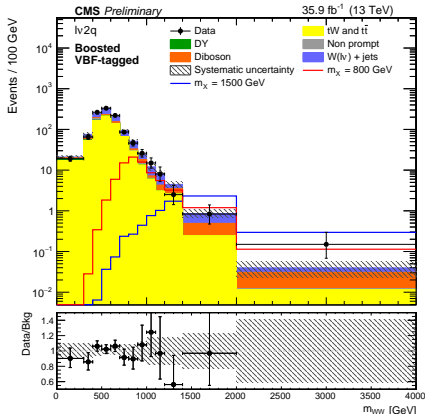
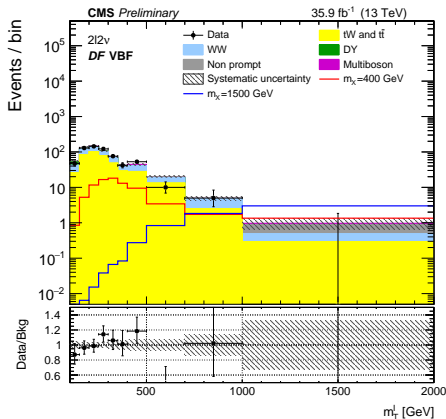
$f_{VBF} = \text{SM value}$ ,  $f_{VBF} = 0$ ,  $f_{VBF} = 1$  and  $f_{VBF}$  allowed to float

# $2l2\nu$ and $l\nu q\bar{q}$ discriminants in CR



Used to constrain background predictions

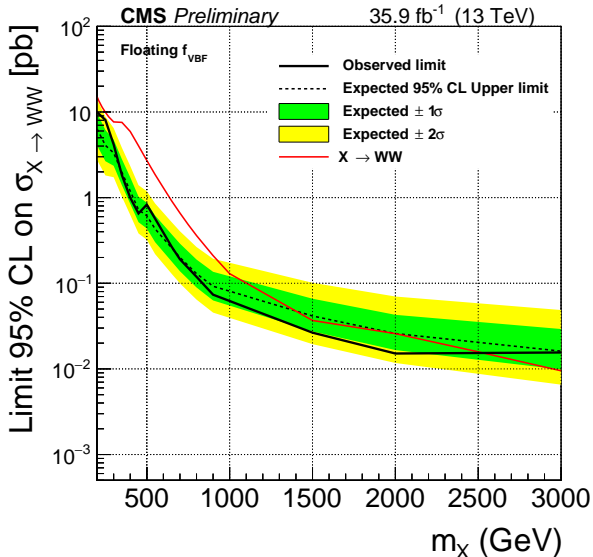
# $2l2\nu$ and $l\nu q\bar{q}$ discriminants in SR



Data consistent with SM backgrounds

→ Set limits on  $\sigma_{X \rightarrow WW}$  in the context of a number of different models

# Limits on $\sigma_{X \rightarrow WW}$ for SM-like Higgs





# 2HDM Interpretations

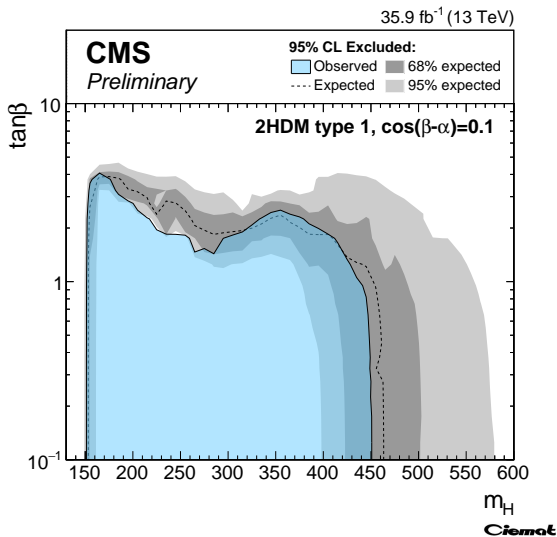
**h(125)** is the light Neutral CP-even Higgs boson

**Signal (H)** is the heavy Neutral CP-even Higgs boson

**Type-1 and Type-2**

benchmarks from  
LHCHSWG 2HDM group

**Assume  $\cos(\beta - \alpha) = 0.1$**   
for compatibility with h(125)



# MSSM Interpretations

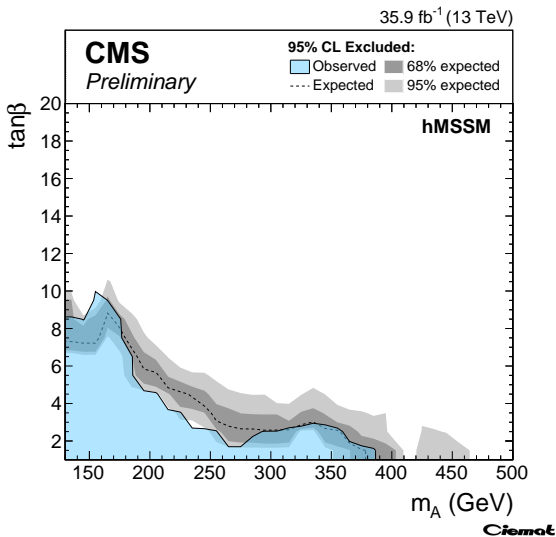
**Signal (H)** is the heavy  
Neutral CP-even Higgs boson

$m_h^{mod+}$  and **hMSSM**

LHCHSWG 2013-2016  
benchmark scenarios

Low values of  $m_A$  and  $\tan\beta$   
excluded

Complement MSSM  $H \rightarrow \tau\tau$   
limits



$$\mathbf{m}_h^{125}, \mathbf{m}_h^{125}(\text{alignment}), \mathbf{m}_h^{125}(\tilde{\chi}) \text{ and } \mathbf{m}_h^{125}(\tilde{\tau})$$

**LHCHSWG 2018 benchmark scenarios also considered for Paper**

Low values of  $m_A$  and  $\tan \beta$  excluded

# Summary

- High mass Higgs  $\rightarrow$  WW search with 2016 data used a number of signal interpretations
- SM-like limits based on YR4 ggF and VBF  $\sigma$  values
- 2HDM limits (with  $\cos(\beta - \alpha) = 0.1$ )
- Several MSSM benchmark scenario limits