High mass H boson searches in H→WW and m_H=125 GeV projections for LHC Run-2

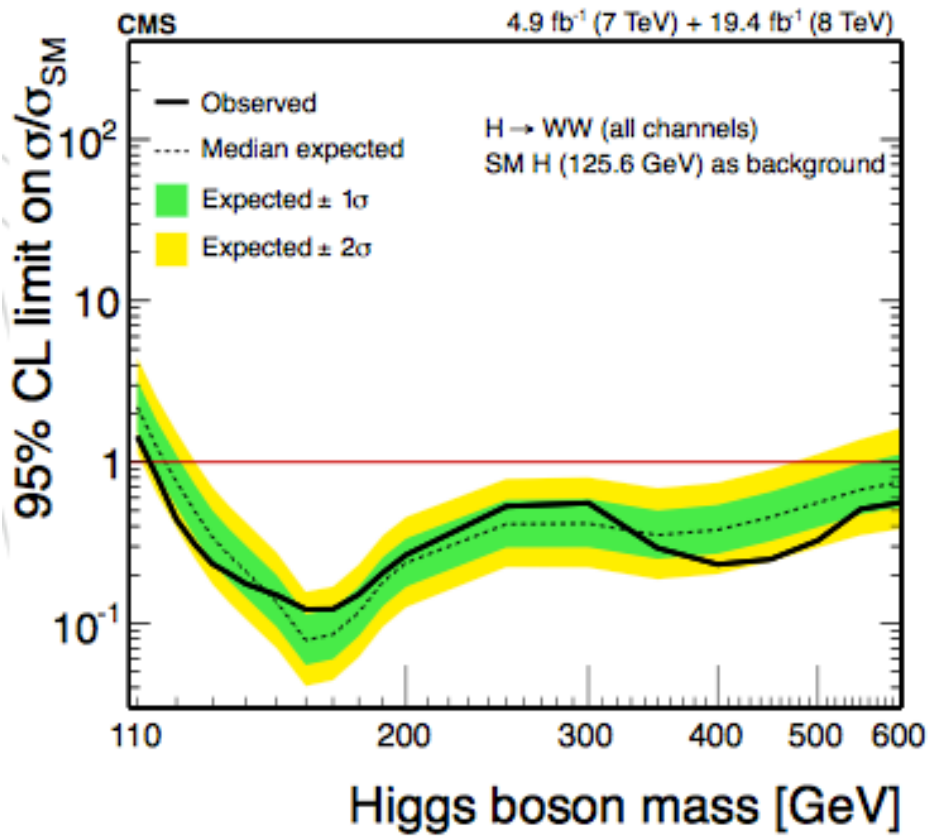
X. Janssen

Workshop on Scalar Sector in Belgium
IIHE (ULB/VUB) – January 23/24th 2014

High Mass H Boson Searches In H→WW→2l2ν

BSM/High mass interpretations

H→WW→leptons paper:



- **No second SM-like H in 114-600 GeV**
- **Other x-sections can be probed from the cards by re-scaling m**
- **… but valid only if the BSM model is not changing (too much) the second Higgs kinematic**
- **Analysis stop at 600 GeV !**

EWK Singlet:

Extra scalar ϕ_H mixing with "SM" Higgs:

$$\begin{pmatrix} \phi_{SM} \\ \phi_H \end{pmatrix} = \begin{pmatrix} \cos\omega & \sin\omega \\ -\sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} h \\ H \end{pmatrix}$$

- "SM" h @ ~126 GeV
- Need to scale μ, Γ and Interference
- Possibly go up to 1 TeV !

→ **Plans for lvlv, lvjj and lvJ analyses to be combined with H→ZZ in high mass paper by ~January**

2HDM Model:

- **Two scalar doublet with some assumptions on the model (Types I→IV)**
- **2 neutral Higgs with decays to VV**
- **More complex effects on inclusive and differential (H p_T) x-sections possible**

→ **Still unclear receipt but being discussed**

→ **Only consider it if ready !**

EWK Singlet Interpretation

- Extra scalar field ϕ_H, mixing with SM Higgs:

$$\begin{pmatrix} \phi_{SM} \\ \phi_H \end{pmatrix} = \begin{pmatrix} \cos\omega & \sin\omega \\ -\sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} h \\ H \end{pmatrix}$$

- Single coupling modifier: $C'^2 = \sin^2\omega$,
  results in simple scaling of width and cross-section:

$$\sigma = C'^2\sigma_{SM}, \qquad \Gamma = C'^2\Gamma_{SM}$$

- Adding some extra branching BR_{new} for H:

$$\sigma = C'^2(1 - BR_{new})\sigma_{SM}, \qquad \Gamma = \frac{C'^2}{1 - BR_{new}}\Gamma_{SM}$$

HOWTO:

- **SM H x-section scales as (1-C'²) → This is an indirect constraint on the model !**
- **Re-scale Γ_{SM} via a Breit-Wigner (ok for low resolution channel)**
- **Interference with non-resonant WW scales as 1/C'² in good approximation**
- **Scan C'2 in steps of 0.1 between 1 and 0.1**
- **Scan BR_{new} in steps of 0.1 between 0 and 0.5**

Analysis Method Reminder

0/1-jet H→WW→ 2l2ν DF Analysis

- **2 isolated (eμ/μe) leptons: p_T >10 ,20 GeV**
- **$p_{T,ll}$ > 30 GeV**
- **Missing E_T > 20 GeV**
- **Top veto: Jet b-tag + no soft μ**
- **Jet counting for |η|<4.7 and p_T>30 GeV**

Background from data driven techniques

- W+jets (fake rate method)
- Top (estimated from control region)
- Wγ /Wγ* (MC shapes + data norm.)
- DY→ττ (τ embedding)
- WW (fitted in combine)

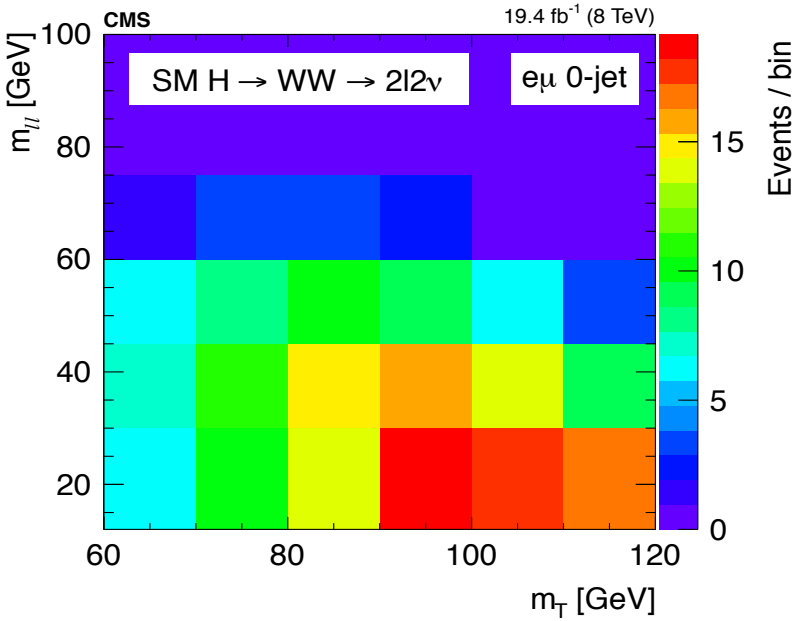
Other backgrounds:

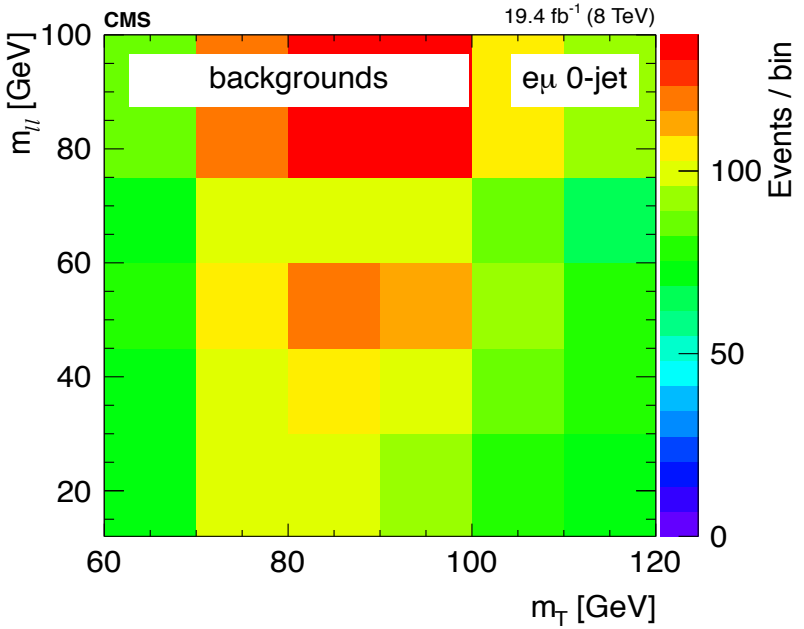
- ZZ/VZ/Tri-bosons → MC predictions

Signal Extraction

- **2D Shape analysis**:
  - → m_T : Higgs boson transverse mass
  - → m_{ll} : di-lepton invariant mass
- **Systematics as in the main analysis**

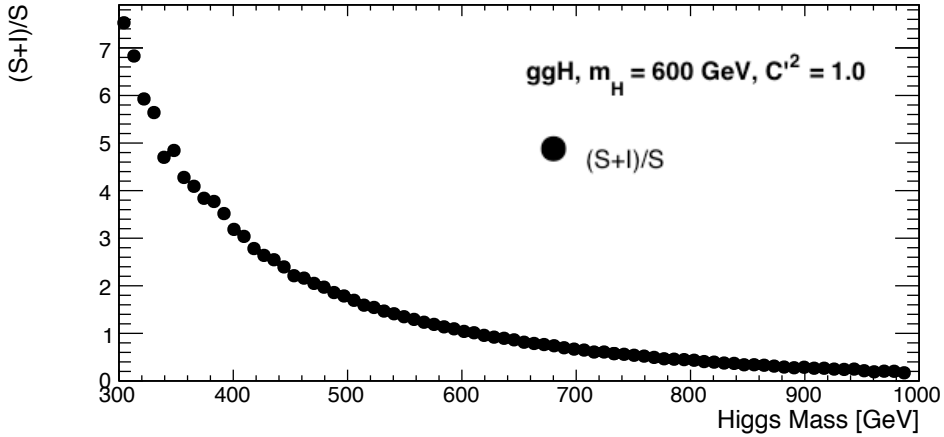
Extension up to 1 TeV
→ Adapt 2D binning and selection for high mH

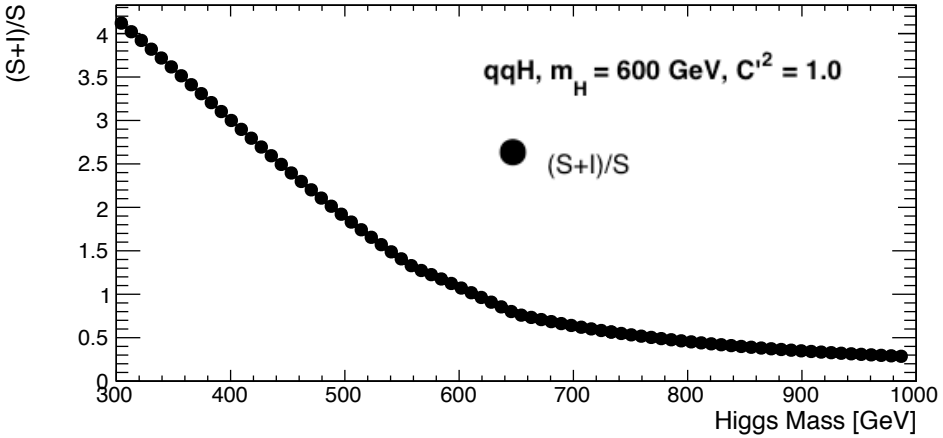


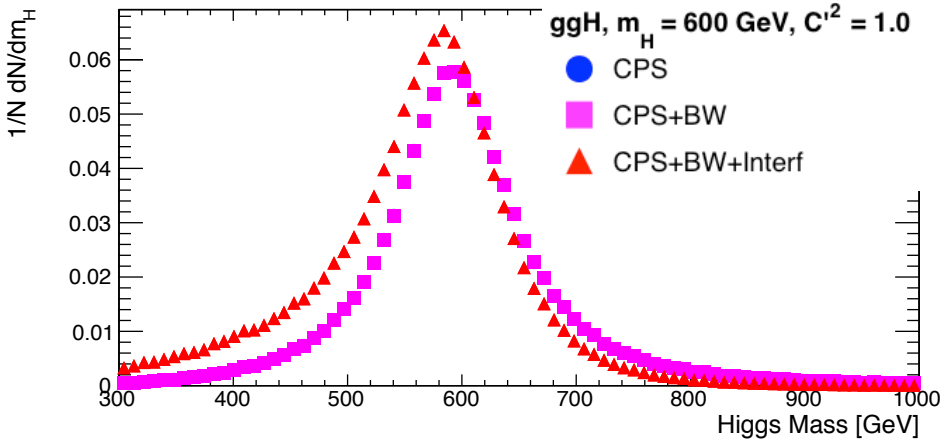


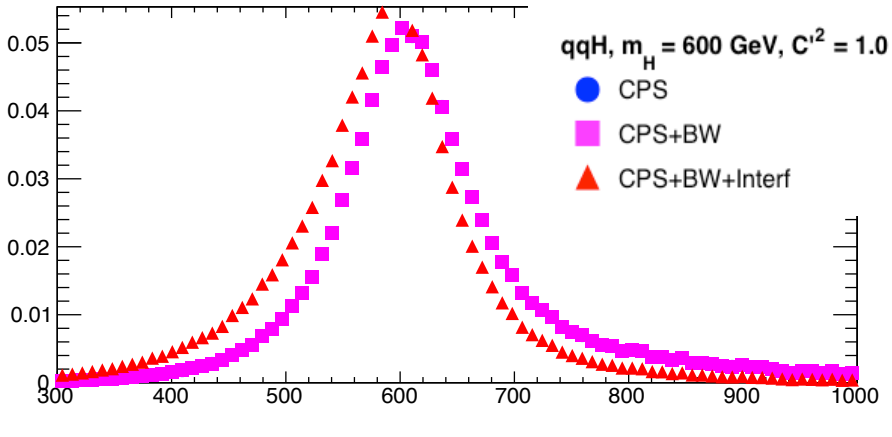
Interference

- **ggH:** computed within HXSWG framework with MCFM (Qiang Li + ATLAS people)
  → **Available (and having an effect) for m_H >= 300 GeV**
  → https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HiggsBSM
- **qqH: see https://indico.cern.ch/conferenceDisplay.py?confId=286018**





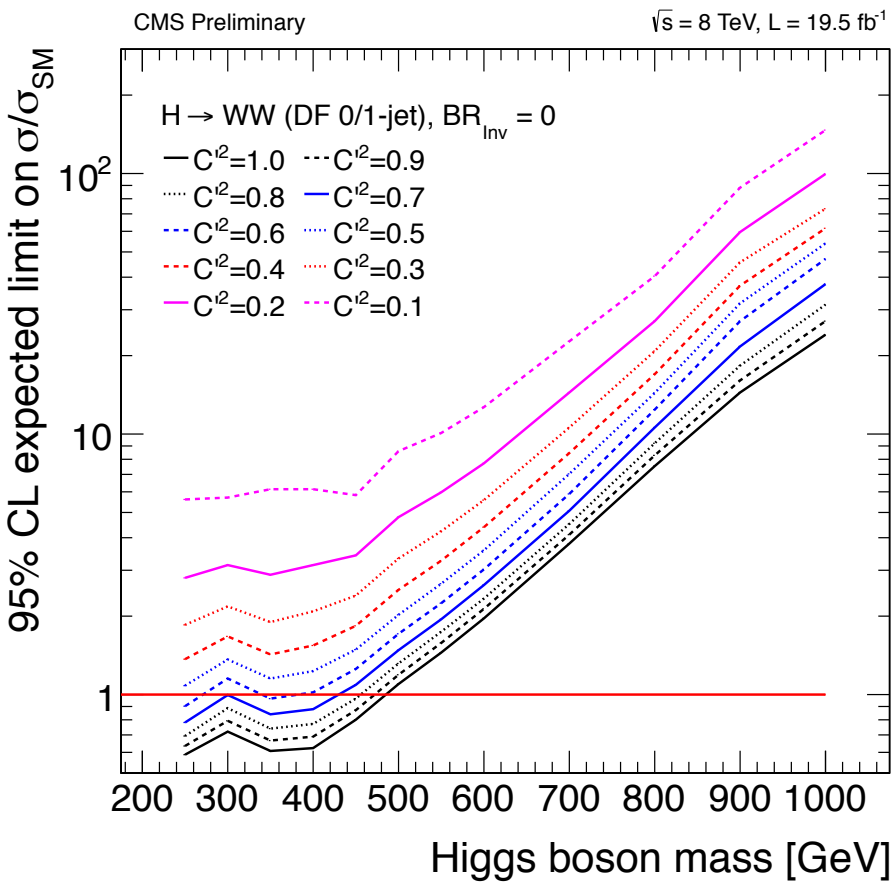




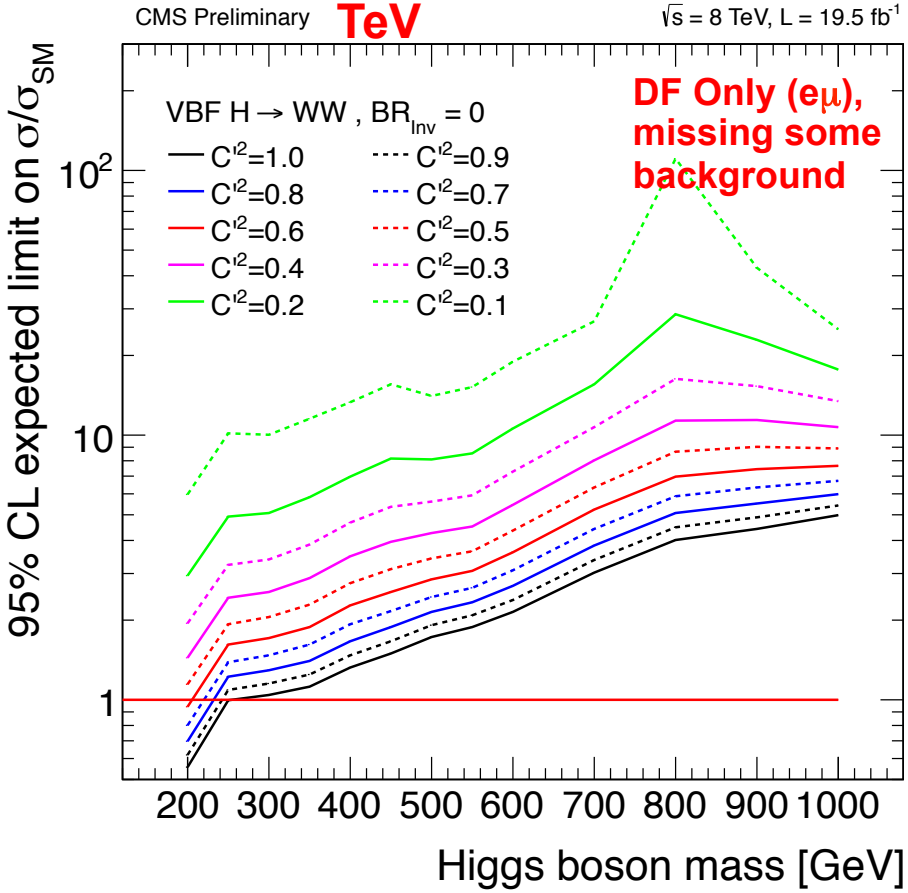
→ **Other C'²: Change BW width + Scale to I by 1/C'² and redo the convolution**

Expected limits (to be updated …)

0+1 jet, DF, 8 TeV



VBF tag, DF, 8 TeV



- **Need to add some systematics (Interference, ….) , OF (ee/μμ), 7 TeV, …**
- **Need to optimize 0/1-jet binning @ high m_H**
- **More cross-checks needed: 125 GeV influence, VBF@800 GeV behavior, …**

→ **Relatively good constraints on EWK Singlet model at intermediate masses**
→ **Combination with other WW and ZZ channels ongoing …**

125 GeV H→WW→2l2ν projections at LHC Run-2 @ √s = 13 TeV

Methodology

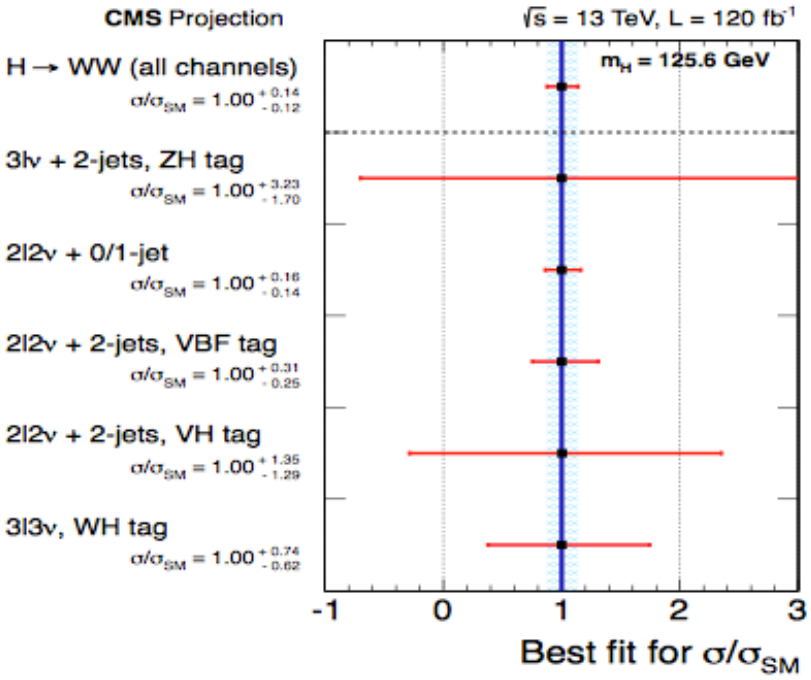
- $H \to WW$ channel most sensitive channel to measure couplings at this point once m_H is known
- Will show projections for several measurements at $\sqrt{s} = 13$ TeV
  - $\mathcal{L} = 30$ fb^{-1}: first nominal year in run-II
  - $\mathcal{L} = 120$ fb^{-1}: full expected integrated luminosity in three years after the start
- Lower luminosity than current official projections (300/3000 fb^{-1}), but using all existing analyses
- Procedure:
  - starting from just approved $H \to WW$ analyses at $\sqrt{s} = 8$ TeV, make use the same data cards, $m_H = 125.6$ GeV
    - for $V(qq)H$ using shape-based analysis, no other changes in the default analyses otherwise
  - assume same reconstruction and selection efficiency: big assumption, keep it like this for now
    - acceptance (due to PDFs) is smaller at higher energies, but (should) affect similarly signal and background processes

MCFM

process	$\sigma_{13\ \mathrm{TeV}}/\sigma_{8\ \mathrm{TeV}}$
ggH	2.32
VBF	2.09
WH	1.89
ZH	1.99
$Z/\gamma^* \to \ell\ell$	1.71
$W + \mathrm{jets}$	1.68
WW	2.34
$WZ/W\gamma^*$	1.99
ZZ	2.03
top	3.31
VVV	2.500
$W\gamma$	1.71

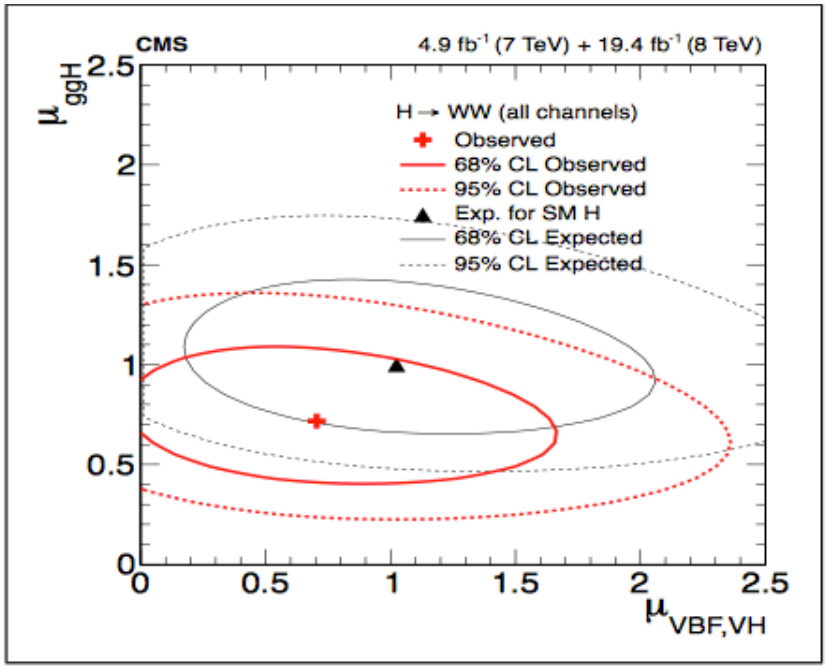
Expected significance and μ measurements

category	expected significance		
	7+8 TeV	30 fb^{-1} at 13 TeV	120 fb^{-1} at 13 TeV
all channels	5.80	8.78	15.19
0/1 jets	5.32	8.21	14.28
VBF	2.17	2.98	4.88
$\text{V}(qq)\text{H}$	0.65	0.66	0.79
$\text{WH} \to 3\ell 3\nu$	0.74	1.02	1.64
ZH	0.19	0.23	0.42
$\text{V}(qq)\text{H} + \text{WH} \to 3\ell 3\nu + \text{ZH}$	1.00	1.23	1.87

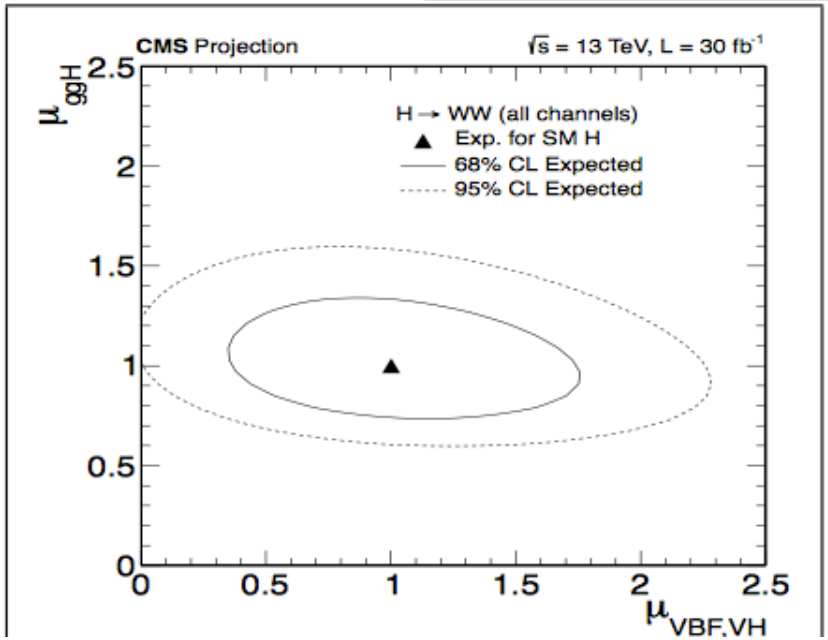


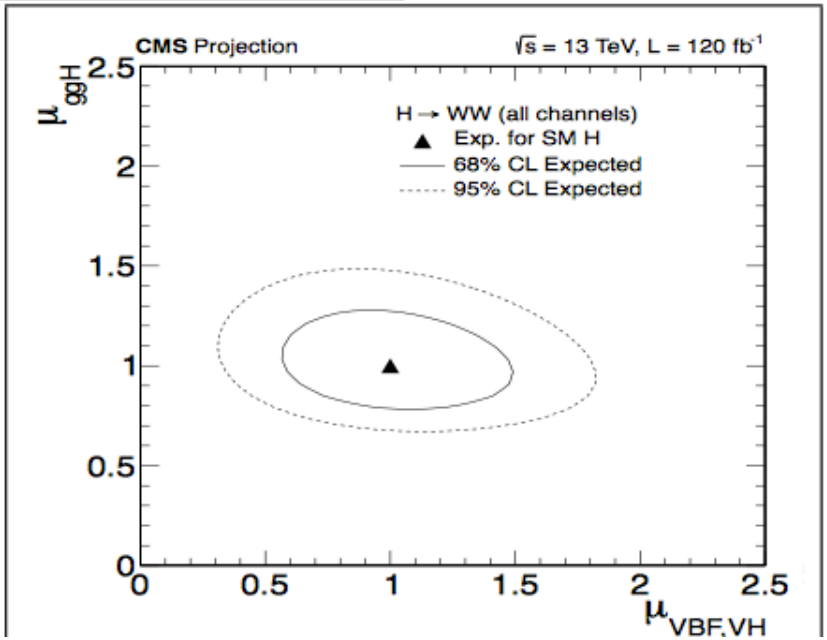
- Combined μ ($\equiv \sigma/\sigma_{SM}$) measurement precision ~11%
  - limited by PDF and QCD scale uncertainty in ggH mode
  - precision in ggH and VBF categories get closer and closer
  - relative improvement on μ_{ggH} is the smallest one

μ_{ggH} and $\mu_{VBF,VH}$

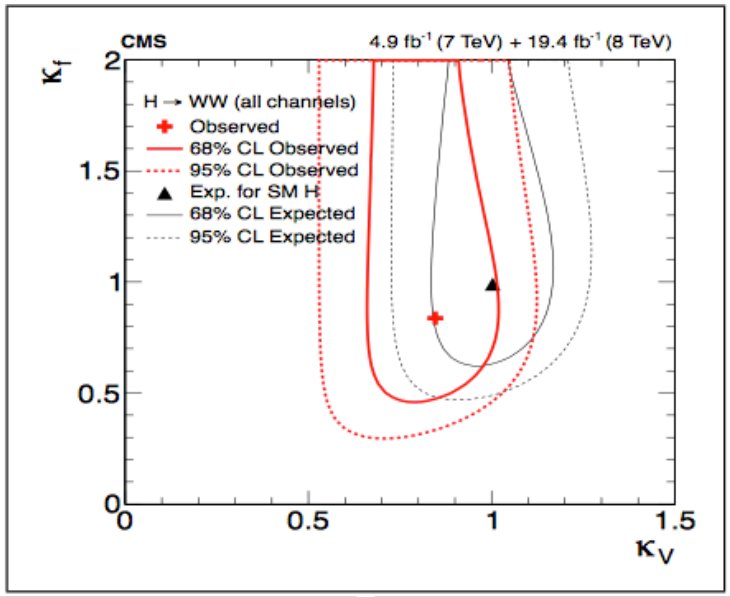


- **Bigger improvement in VBF,VH expected**
- **ggH is limited by theory uncertainty faster with increasing luminosity (QCD scale & PDF')**

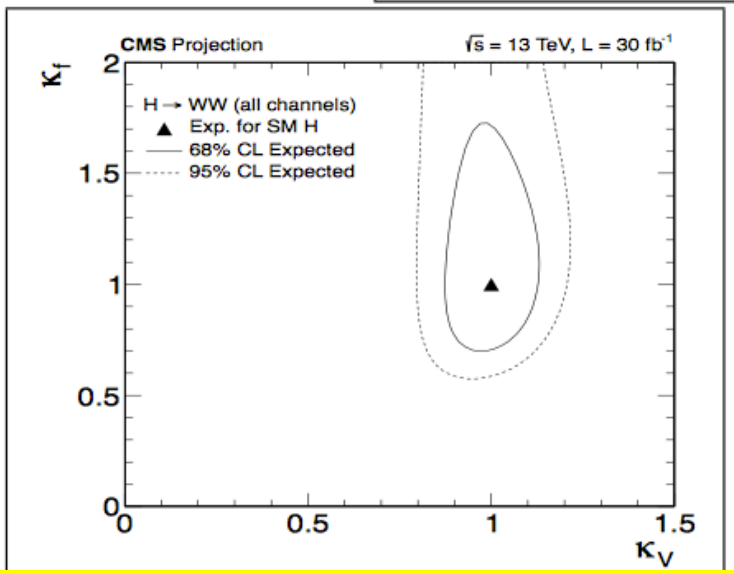


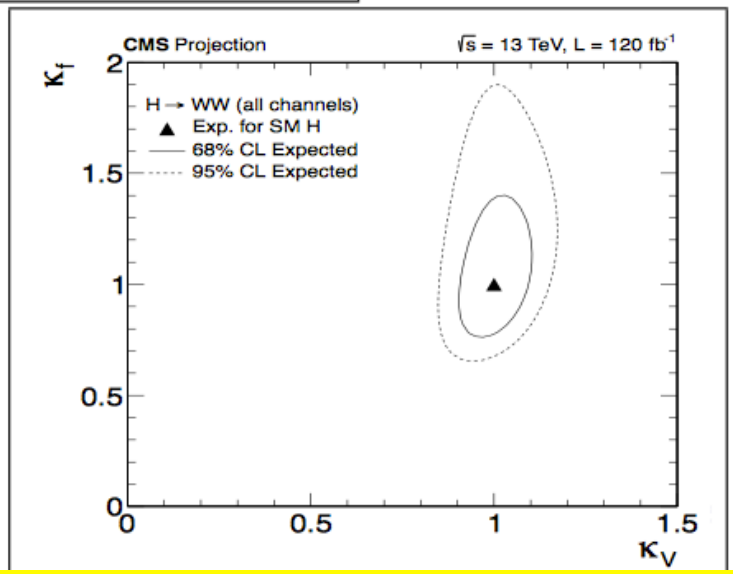


Couplings: (K_V,K_f)



- κ_V measurement less affected thanks to the increasing role of VBF and VH categories
- Precision at the ~10% level using H → W W channels only





- H→ WW → 2l2n channels expected to play a key role in 125 GeV H Boson cross-section measurement and coupling fits at run-2