

High mass “Higgs” (SM+BSM)

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for the ATLAS-CMS-theory
Heavy BSM Higgs contacts

HXSWG – Heavy BSM Higgs April 2013

Outline

- ❑ Brief description of **work going-on in the Heavy Higgs and BSM group**
- ❑ Remind of the **recipes defined for the SM heavy Higgs**
- ❑ Description of the preliminary recipes under discussion for the BSM case (**EW-singlet**)
- ❑ Brief/general ideas for **2HDM**

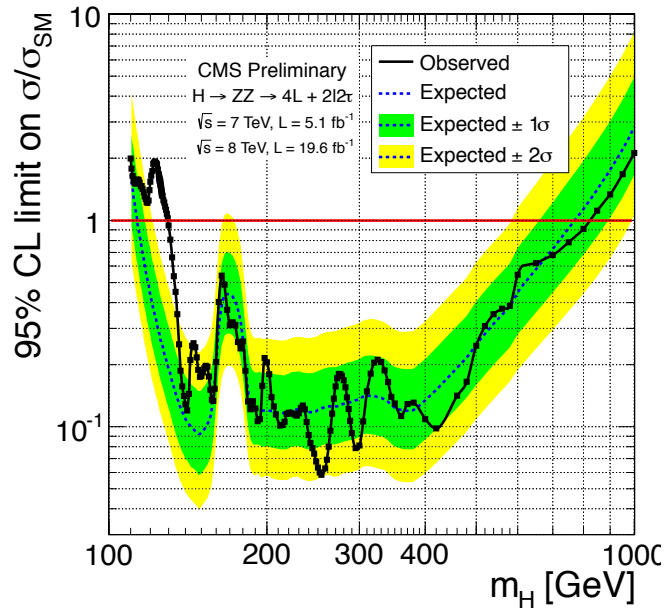
Scope of the group

□ Providing theoretical **guidelines**, in common between **CMS and ATLAS** to

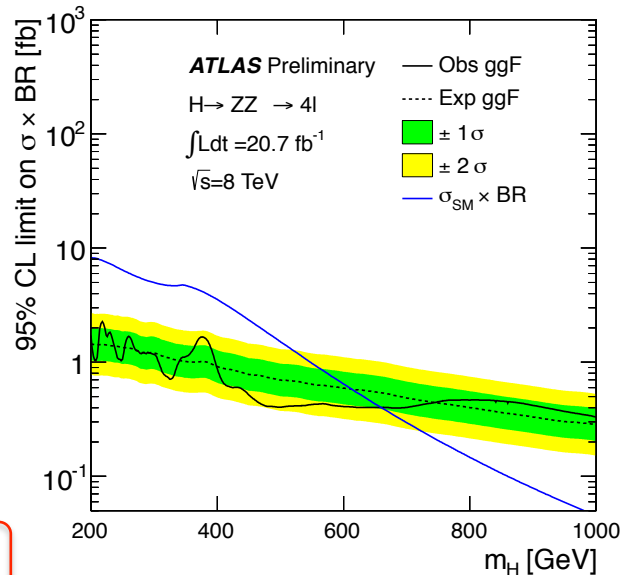
- characterize properly **heavy Higgs in the SM**
-> legacy results for SM limits up to 1 TeV
 - define **general benchmarks to reinterpret SM searches/ signatures in BSM scenarios**. Starting from most basic ones:
 - SM Higgs mixed with **EW-singlet** (*today*)
 - **2HDM** (*next meeting*)
 - Higgs triplet models
 - two near degenerate states at 126GeV in model-independent way
 - ...
- interests from experiments, to be worked out*
- first discussions about **more general study of EWSB mechanisms**
(*VV scattering workshop to be organized soon*)

Heavy Higgs public results (SM)

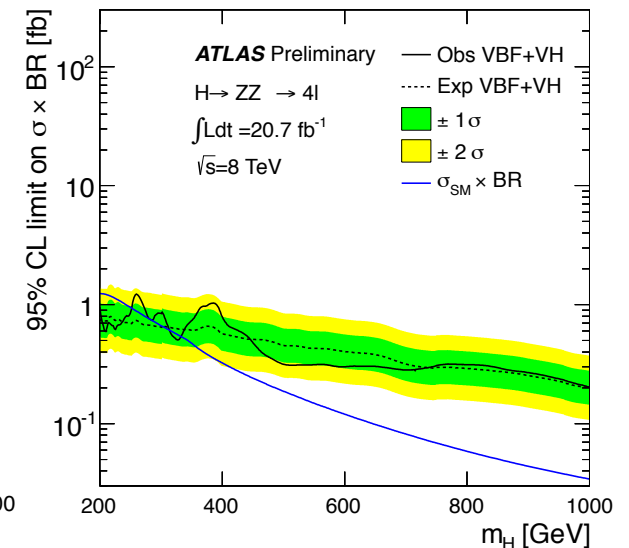
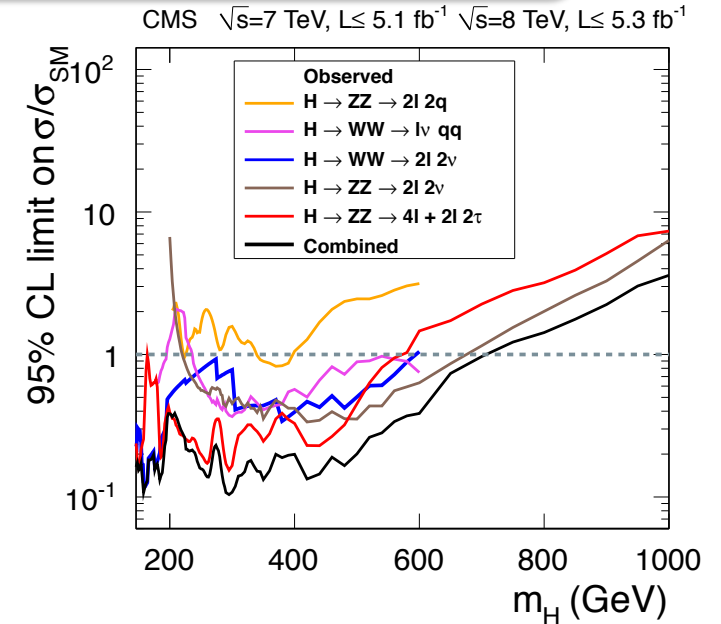
□ CMS total lumi (Moriond): $H \rightarrow 4l$



□ ATLAS total lumi (Moriond): $H \rightarrow 4l$



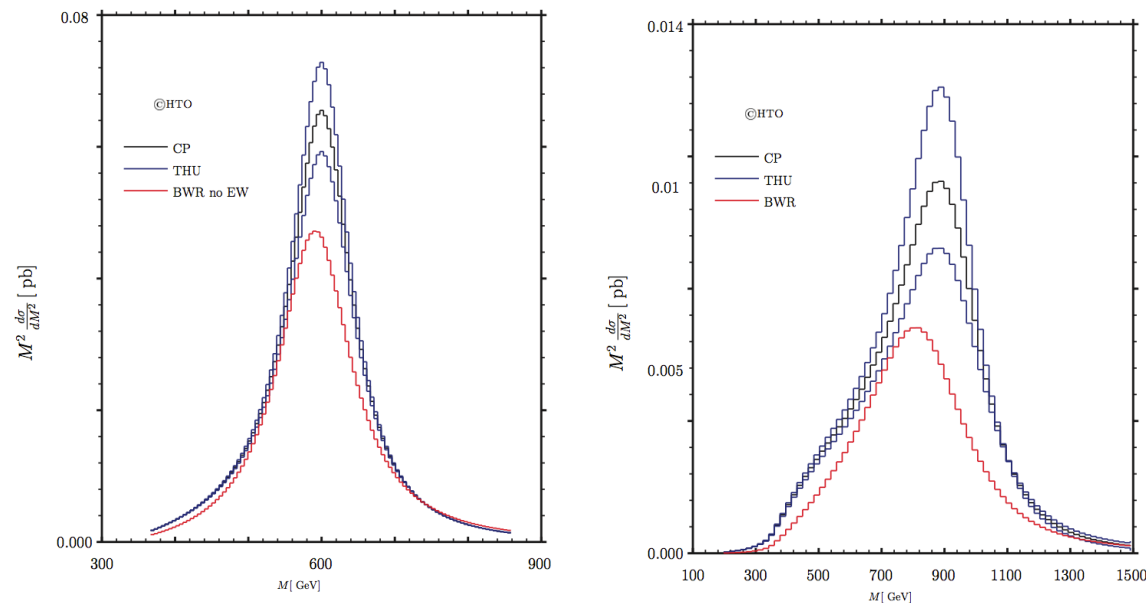
□ CMS published (5.1 + 5.3 fb^{-1}): $H \rightarrow VV$



Heavy Higgs in SM: lineshape

- ❑ Large Higgs width at high mass \rightarrow **Breit-Wigner approx. (production times decay) fails**
- ❑ Proper lineshape implemented in **Complex Pole Scheme**: *Nucl.Phys. B864 (2012) 530-579*
 - \rightarrow preserving Gauge invariance
 - \rightarrow allowing to separate S and I \rightarrow NLO effect can be included in the signal model
 - \rightarrow EW corrections and theoretical uncertainties provided

Results at 8 TeV:



(CPS recently implemented in POWHEG, HAWK, MC@NLO, ...)

- ❑ Alternative lineshape proposal based on **effective lagrangian** *arXiv:1211.4835*

Heavy Higgs in SM: interference

- ❑ Large **S/B interference in $gg \rightarrow VV$** for high mass Higgs:

full S+B+I computation available at LO only (until recently, see today talk!)

large K-factor LO \rightarrow NNLO for signal (expected large corrections for I as well)



- extract I from LO MC ($gg2VV$, MCFM) and use to correct S_{NNLO}
- uncertainty for higher order on I evaluated from signal K-factors: *JHEP 1208 (2012) 146*

uncert. bands

additive

$$S_{NNLO} + I_{LO}$$

multiplicative

$$S_{NNLO} + I_{LO} \times K_{NNLO}(m_{VV})$$

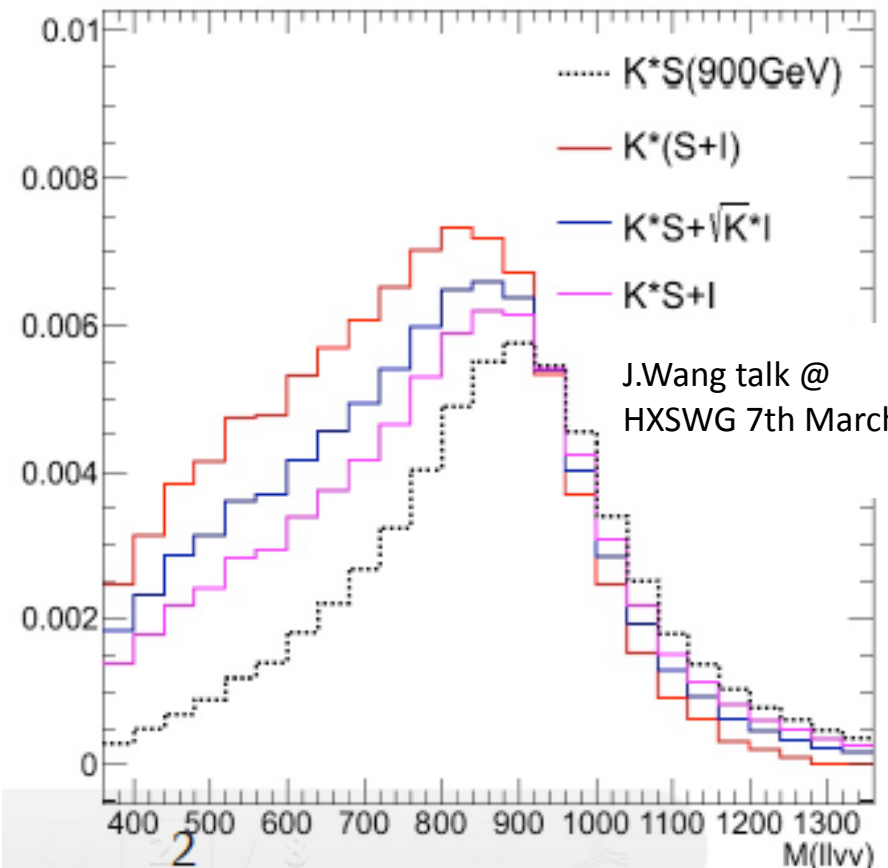
using same K-factor as signal

intermediate

$$S_{NNLO} + I_{LO} \times K_{NNLO}^{gg}(m_{VV})$$

ad-hoc k-factor which stays in between the two above

- ❑ *Today talk: proposal to use multiplicative with small uncertainty (10%)*



J.Wang talk @
HXSWG 7th March

Heavy Higgs in SM: VBF

- **CPS** already implemented in Powheg VBF
- S/B interference in VBF has been studied in the past (eg. Phantom @ LO)
-> recently **new tools for S+B+I at NLO** (VBF@NLO, new Powheg version)

... proper recipe to include interference corrections **to be implemented**,
expected for the legacy papers on SM upper limits up to 1 TeV ...

Higgs mixed with EW-singlet

Two resonances with couplings rescaled wrt to SM

- coupling of h126 (h) = $C \times \text{SM}$ • coupling of heavy Higgs (H) $\sim C' \times \text{SM}$
- unitarization: $C'^2 + C^2 = 1$, ie $C' = \cos\theta$, $C = \sin\theta$ -> **1 free parameter: θ mixing angle**
- considering **H \rightarrow hh decay (+ new unknown decays)**
-> **1 additional free parameter (BR_{new})**

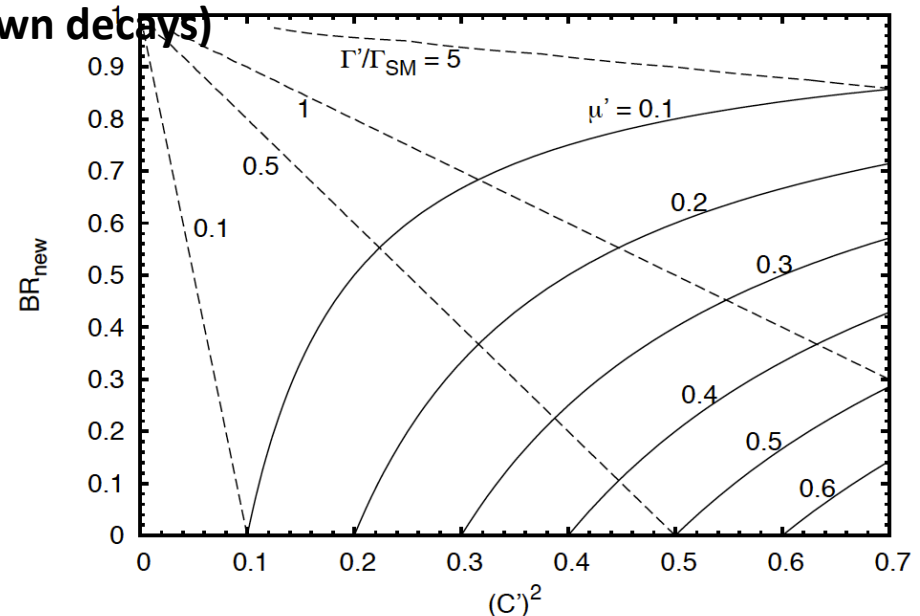


- heavy Higgs search in **2 parameters space for each m_H hypothesis**

$$\mu' = C'^2(1 - \text{BR}_{\text{new}})$$

$$\Gamma'_{\text{tot}} = \frac{C'^2}{(1 - \text{BR}_{\text{new}})} \Gamma_{\text{SM}}.$$

-> width different than SM



- observation of **h126 put experimental limits on value of mixing angle (on possible width and xsec range for heavy mass search)** $\mu_h' = \sin^2\theta \times \mu_h^{\text{SM}}$

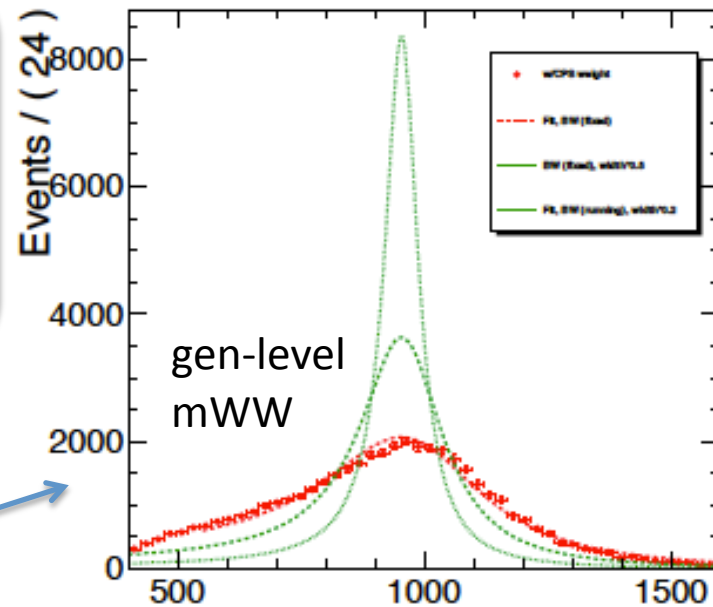
- *Today talk: same kinematics, same QCD corrections and uncertainties as SM heavy Higgs !!!
-> all SM recipe/computations can be used... what about EWK-corrections?*

Lineshape and interference for EW-singlet

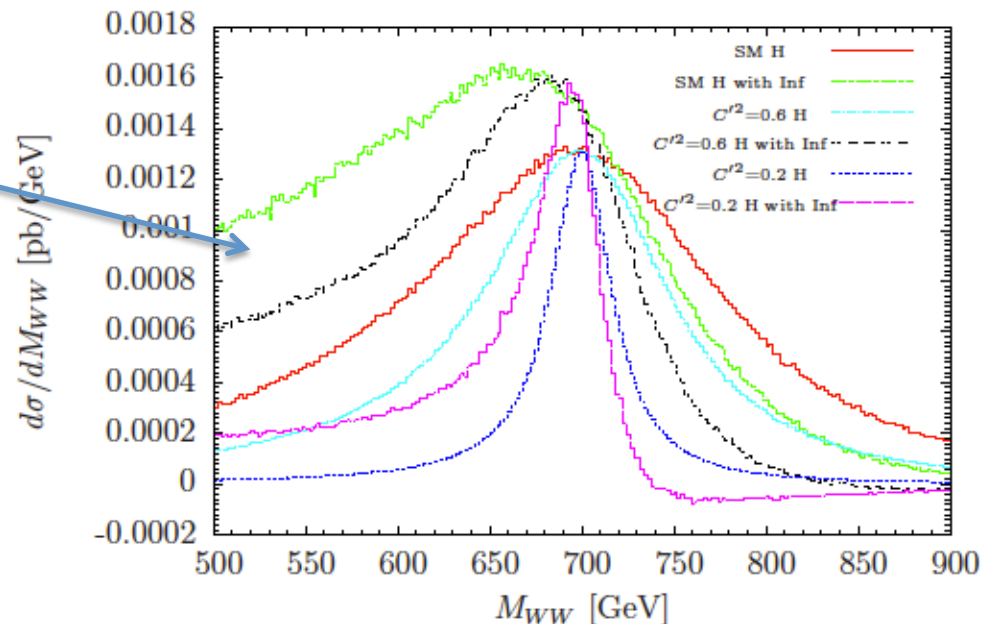
N.Tran, Q.Li talk @
HXSWG 7th March

□ Preliminary recipe

- fit the SM CPS lineshape with relativistic Breit-Wigner
- **rescale Γ with $C^2 = \cos^2\theta$**
- **full model implemented in LO MC (gg2VV, MCFM)**
- simulate S+B+I for different values of $C^2 = \cos^2\theta$
- extract I_{LO} and use to correct above signal lineshape
- **as in SM, but 100% uncertainty on I**
-> can the SM K-factors be used to set smaller uncertainty bands? (multiplicative/additive)

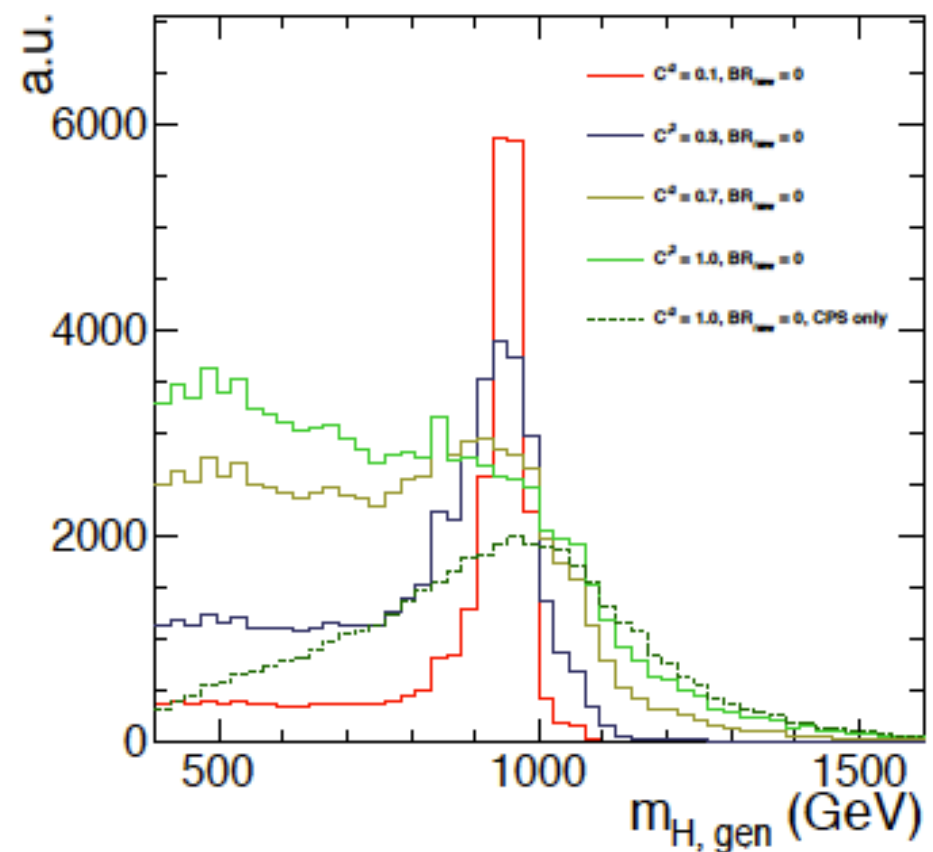
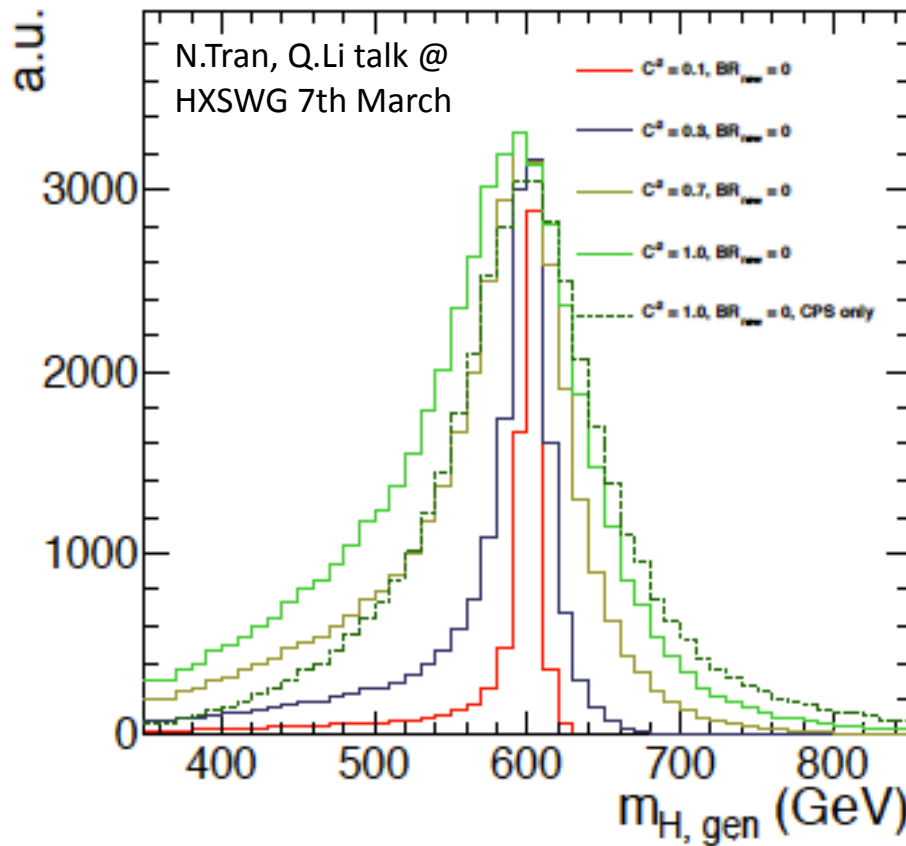


MCFMv63, gg-H-WW w/ interference, MH=700GeV, 8TeV



EW-singlet heavy Higgs

Examples from $WW \rightarrow \text{lnj}$: lineshape (S+I) at gen level for different values of $C^2 = \cos^2\theta$



Heavy Higgs in 2HDM

❑ Different xsec/width rescaling for fermions/bosons (up/down fermions, leptons/quarks, ...)

- **different kinematics** (eg H pT) than SM Higgs (to be checked)
- QCD corrections and uncertainties available -> **implementing appropriate rescaling of the pieces of the QCD corrections according to the modified couplings** of the heavy-H, in order to get useful signal cross-section numbers.
- **new EWK corrections and uncertainties** need to be computed (?)

... work on-going ... (next meeting)

❑ Once proper rescaling of couplings identified (ie, which benchmarks points are reasonable to check)

-> **previous recipe for lineshape and interference can be adapted (hopefully just including new K-factors)**

Conclusions and agenda

❑ Work on-going for proper characterization of **heavy Higgs in general BSM scenarios**:

- **EWK singlet**: are the EWK corrections the same as in the SM case?
If not, can they be easily computed?

*(today first talk:
EWK-singlet and EWK corrections)*

- **2HDM**: QCD corrections/uncertainties are being rescaled with modified couplings. What about EWK corrections?

(next meeting will be devoted to 2HDM)

❑ Study of **heavy Higgs in SM: first step** needed to extend the recipes to BSM scenarios
SM calculations may often be redone/re-casted easily to these basic/general BSM scenarios

*(today second talk:
gg->VV S+B+I at NNLO with soft collinear approx.)*