Higgs lineshapes in BSM models

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LHC XS WG, BSM and Heavy Higgs
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courtesy S. Bolognesi and others

BSM recommendations (tentative)

Define couplings for h_1 (m = 126 GeV) as C_V and C_f

Define heavy higgs couplings, h_2, as C'_V and C'_f

Unitarization of VV→VV scattering and VV→ff require:

$$C_V^2 + C_V'^2 = 1.$$

$$C_V C_f + C'_V C'_f = 1.$$

Two proposed benchmarks:

1. C'_V and C'_f scale in the same way
2. C'_V and C'_f scale differently

Consider the simplest case first:

$C = C_v = C_f$

$\mu = C^2$

where μ is SM signal strength

Benchmark model #1:

$C'^2 = (1-C^2)$, but also must consider decays to new states, BR_{new} (i.e. h2 → h1 h1)

Thus we consider the cross-section and width to scale accordingly:

$\mu' = C'^2 \times (1 - BR_{new})$ and $\Gamma' = (C'^2/(1-BR_{new})) \times \Gamma_{SM}$

Current bounds

CMS: $\mu = 0.88 \pm 0.21$

ATLAS: $\mu = 1.35 \pm 0.24$

→

CMS: μ' (CL95) > 0.46 → $C'^2 < 0.46$

ATLAS: μ' (CL95) > 0.13 → $C'^2 < 0.13$

Re-weighting scheme

- BSM interpretations require scaling width and cross-section simultaneously
- Current re-weighting scheme
  - Re-weight POWHEG MC from relativistic running width $BW_{run}(\Gamma_{SM})$ to complex pole scheme $BW_{CPS}(\Gamma_{SM})$
  - Re-weight for ggWW interference effects
- Modifications
  - Additional re-weighting to go from $BW_{CPS}(\Gamma_{SM})$ to $BW_{CPS}(\Gamma')$
    - Propose to do an reweighting using analytic BW_{CPS}
    - Can we also use POWHEG CPS implementation altering the width?
  - Scale interference effects by C' accordingly, "S" and "Intf"
    - Computations performed in MCFM altering the width
- Tests in context of HWW

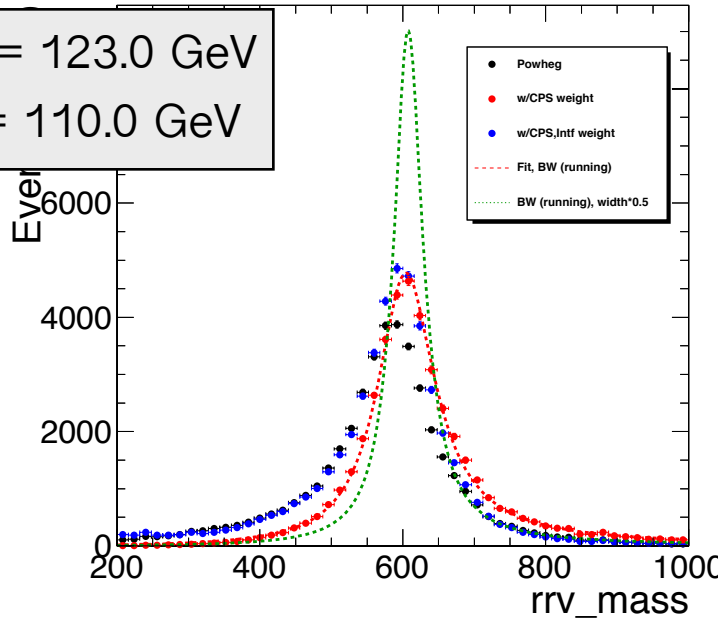
some preliminary fits

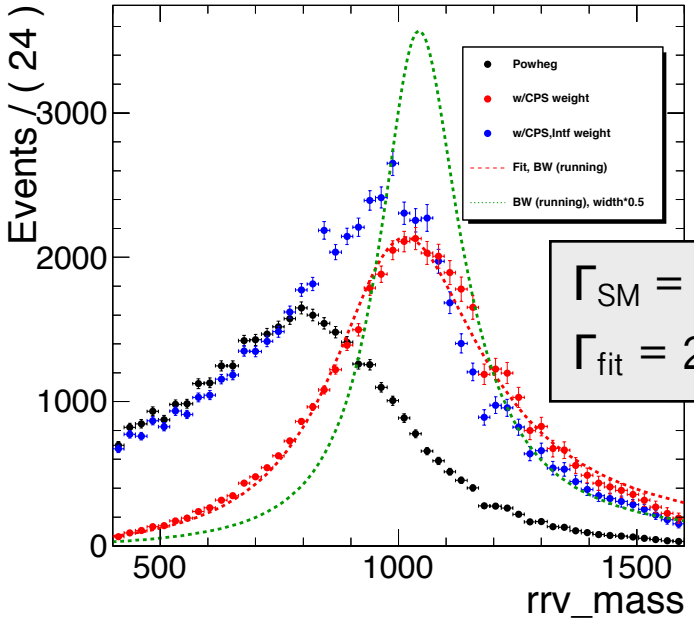
Fitting of the GEN level signal distributions

Idea: re-weight from Γ_{SM} to Γ', but need to find a reasonable analytic shape to do it

Points: Powheg lineshape, Powheg lineshape including CPS reweighting,
Powheg lineshape including CPS reweighting + interference reweighting
Lines: BW running width, BW running width (width x 0.5)

Γ_{SM} = 123.0 GeV
Γ_{fit} = 110.0 GeV



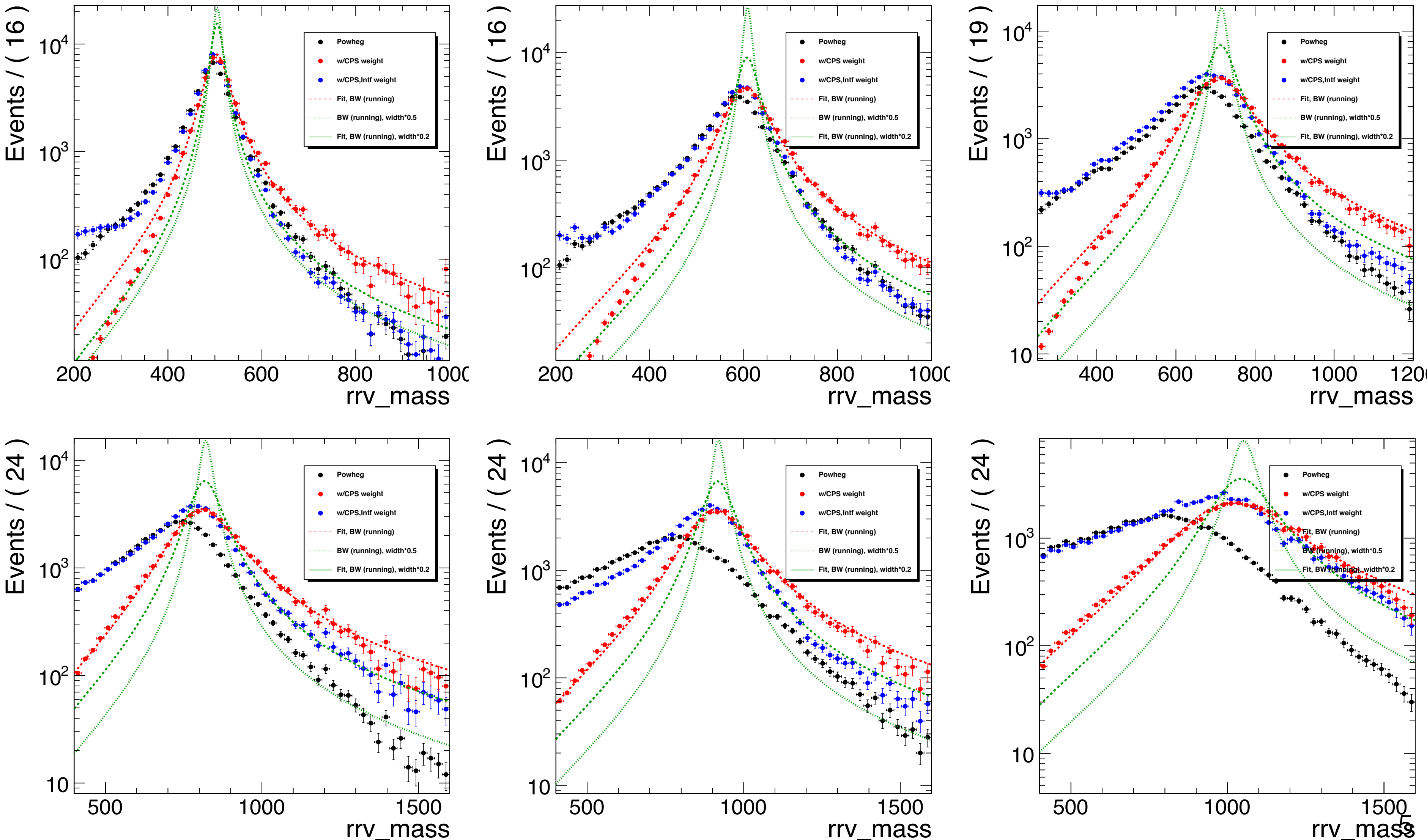


Γ_{SM} = 304.0 GeV
Γ_{fit} = 264.9 GeV

Running width BW does a reasonable job if fitting the lineshape, albeit with wrong Γ_{fit}

more fits

Fitting of several mass points and also adding the line BW($C'^2 \times \Gamma_{fit}$) where C'^2 = 0.2, 0.5



scaling of width

Unfortunately there is not a simple linear correlation with the SM width

```
 mass:  500 , gammaSM:  68.0 , gammaFit:  57.66
 mass:  550 , gammaSM:  93.0 , gammaFit:  79.73
mass:  600 , gammaSM:  123.0 , gammaFit:  110.03
mass:  700 , gammaSM:  199.0 , gammaFit:  178.46
mass:  800 , gammaSM:  304.0 , gammaFit:  242.51
mass:  900 , gammaSM:  449.0 , gammaFit:  232.85
mass:  1000 , gammaSM:  647.0 , gammaFit:  551.35
```

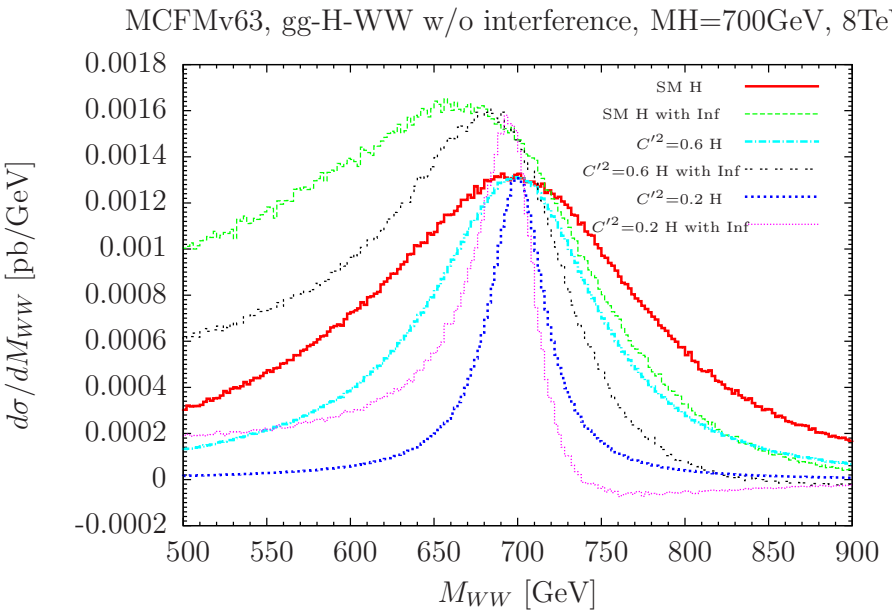
interference reweighting, SM case

- Interference contribution (I) can be separated from LO contribution (S), parameterized as:
  $1 + R_2$ where $R_2 = I/S$
- Systematic uncertainties comparing against K factors
  - R2 = 1, sqrt(K_{gg})/K_{NNLO}, 1/K_{NNLO}
- Can we scale the SM interference contribution to BSM benchmarks?

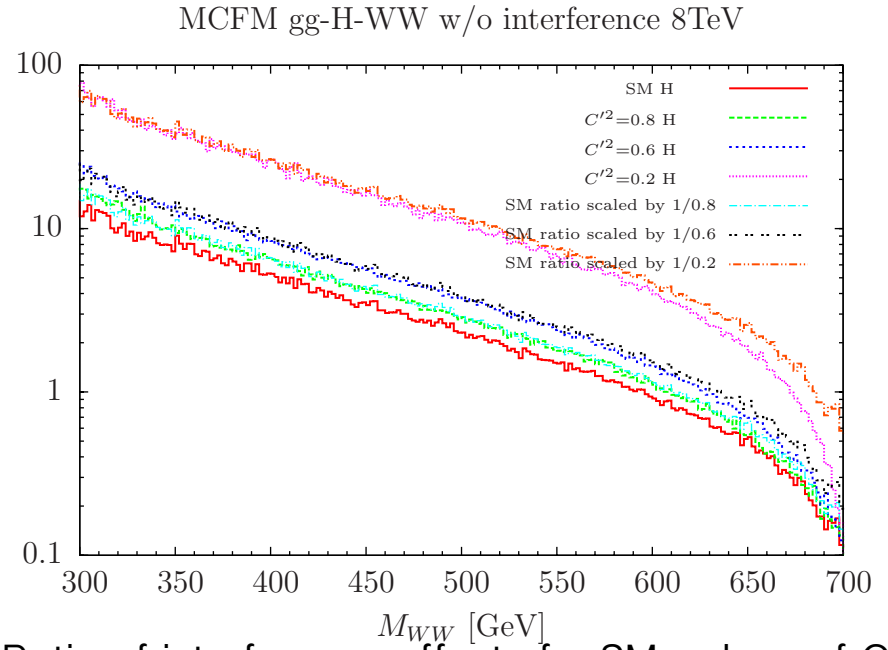
interference scaling

Interference effects computed in MCFM

Modification of Higgs width and couplings



Distributions of mass with and without interference for different values of C'

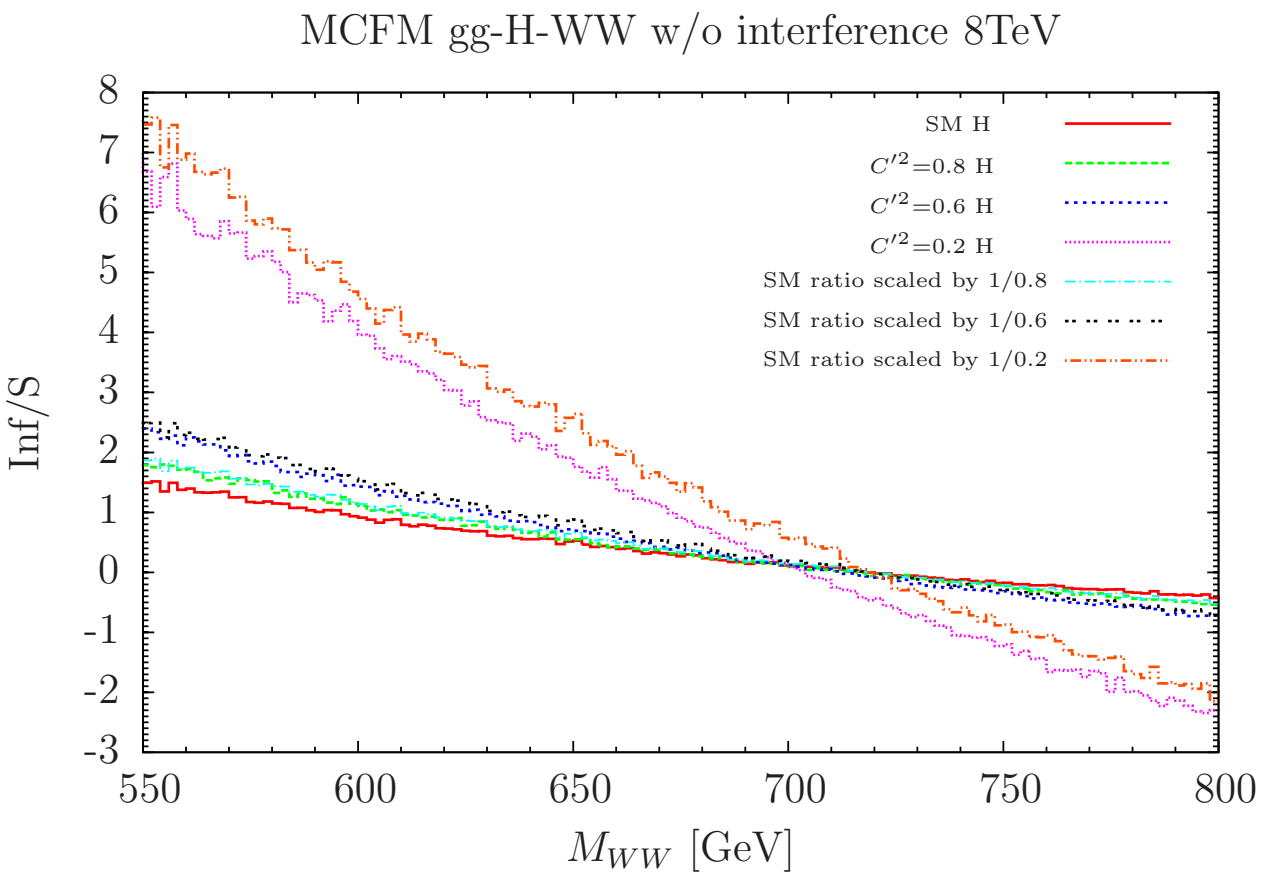


Ratio of interference effects for SM, values of C' and C'^{2} scaling of the SM interference

Scaling SM interference contribution shows similar trend but not perfect agreement

backup

zoom


MCFM gg-H-WW w/o interference 8TeV
Inf/S
M_{WW} [GeV]
SM H
C'^2=0.8 H
C'^2=0.6 H
C'^2=0.2 H
SM ratio scaled by 1/0.8
SM ratio scaled by 1/0.6
SM ratio scaled by 1/0.2
8
7
6
5
4
3
2
1
0
-1
-2
-3
550
600
650
700
750
800