# High Mass Higgs Models

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BSM H → dibosons Meeting

# Introduction

- HBSM were asked to provide some **rough** numbers for BSM models @ 13 TeV to see which models we are sensitive to when
  - EWS
  - 2HDM – only ggF available atm
  - Htriplet – not yet available
- In addition to "model-indep", EWS maybe possible for high $m_H$ with early data
  - Reinterpretation of exotics boosted analysis for council meeting
- 2HDM only below $m_H$ ~ 350 GeV
  - Resolved analysis for Moriond
- Htriplet interesting for high $m_H$ for future (after council)
  - For now, HTriplet mostly to have an idea of if model independent limits on mass vs width are sensitive to BSM Higgs model
- Some first ideas on width and rate in these slides
  - Followed by some first estimates of interfernce effects

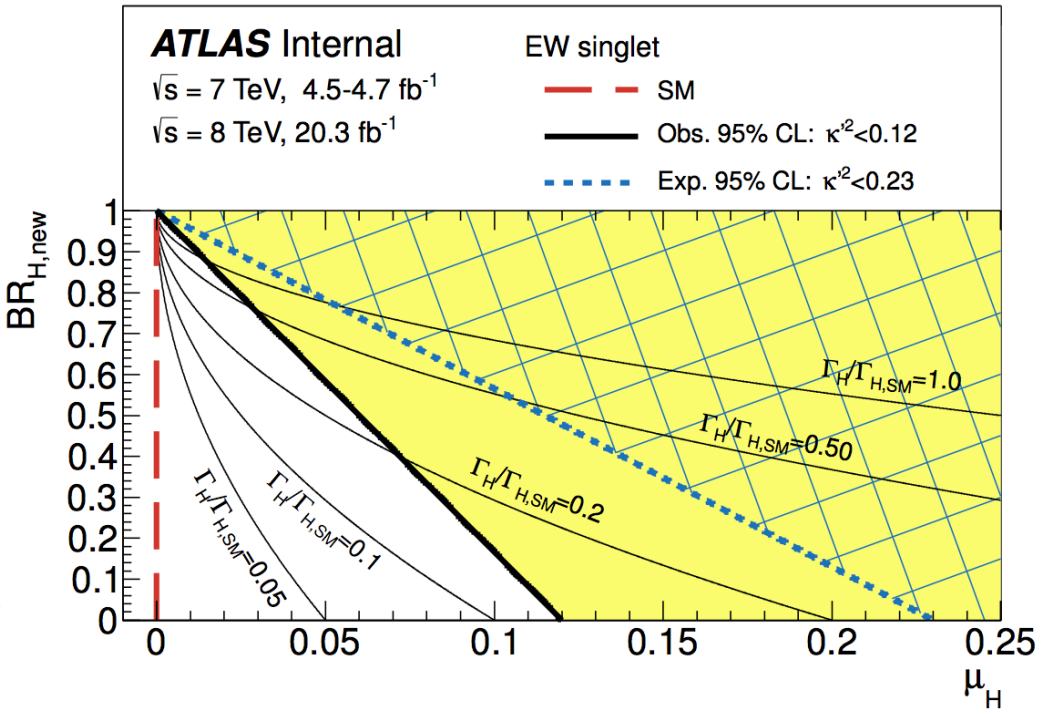
# Electroweak Singlet

- Extra singlet which mixes with SM double to reduce rate & width
  - PoI are k' and BR(H, new)

$$\sigma_H = \kappa'^2 \times \sigma_{H,\mathrm{SM}}$$

$$\Gamma_H = \frac{\kappa'^2}{1 - \mathrm{BR}_{H,\mathrm{new}}} \times \Gamma_{H,\mathrm{SM}}$$

$$\mathrm{BR}_{H,i} = (1 - \mathrm{BR}_{H,\mathrm{new}}) \times \mathrm{BR}_{H,\mathrm{SM},i}$$




- Based on the indirect results from the SM H couplings we have upper limit of:
  - $k'^2 < 0.12$ (0.23) for BR(H,new) = 0
- What is the corresponding limits on coupling/width for HBSM?

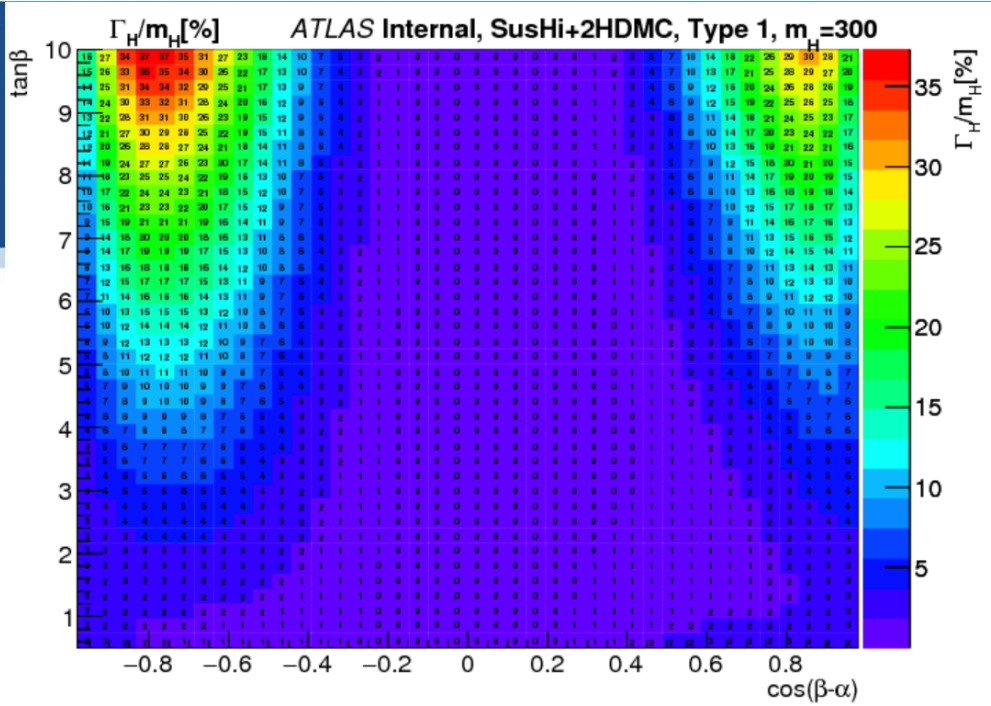
# Electroweak Singlet (2)

CERNYellowReportPageAt8TeV
CERNYellowReportPageBR
CERNYellowReportPageAt1314TeV

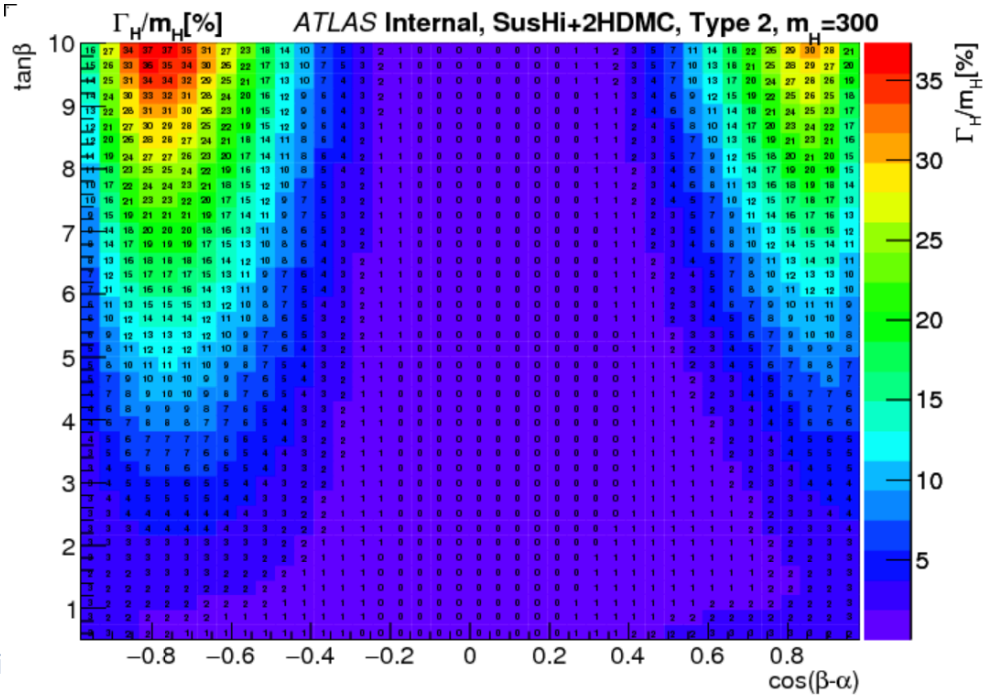
- Assuming limiting case of BR(H, new) = 0, for $m_H$ = 1 TeV get …
- Width: $\Gamma_H < k'^2 * \Gamma_{H,SM}$
  - Obs: 0.12 * 6.47E+02 = 78 GeV = 7.8% $m_H$
  - Exp: 0.23 * 6.47E+02 = 148 GeV = 14.8% $m_H$
  - In the ballpark where we can treat width OK
- Rate: $(\sigma * BR_{ZZ})_H < k'^2 * (\sigma * BR_{ZZ})_{H,SM}$
  - ggF ($\sigma * BR_{ZZ}$) = 7.04 fb (13.5 fb)
    - $< k'^2$ * (5.900 (13/8 TeV) * 0.0320 ($\sigma$ @ 8 TeV) * 3.11E-01 (BR)) pb
  - ggF ($\sigma * BR_{WW}$) = 14.06 fb (26.95 fb)
    - $< k'^2$ * (5.900 (13/8 TeV) * 0.0320 ($\sigma$ @ 8 TeV) * 6.21E-01 (BR)) pb
  - VBF ($\sigma * BR_{ZZ}$) = 2.46 fb (4.71 fb)
    - $< k'^2$ * (2.757 (13/8 TeV) * 0.0239 ($\sigma$ @ 8 TeV) * 3.11E-01 (BR)) pb
  - VBF ($\sigma * BR_{WW}$) = 4.92 fb (9.43 fb)
    - $< k'^2$ * (2.757 (13/8 TeV) * 0.0239 ($\sigma$ @ 8 TeV) * 6.21E-01 (BR)) pb
- Means we get ~ 1,2 events for H → ZZ,WW in 10 / fb at 13 TeV
  - Before BR for ZZ,WW decay

# 2HDM: Width

- If stay within cos(β-α) region allowed by indirect limits then width generally remains low
  - $\Gamma_H/m_H < 0 - 15\%$




- If want to go out side this the width quickly increases
  - e.g. $\Gamma_H/m_H$ up to 40% for tanβ < 10; much wider above this



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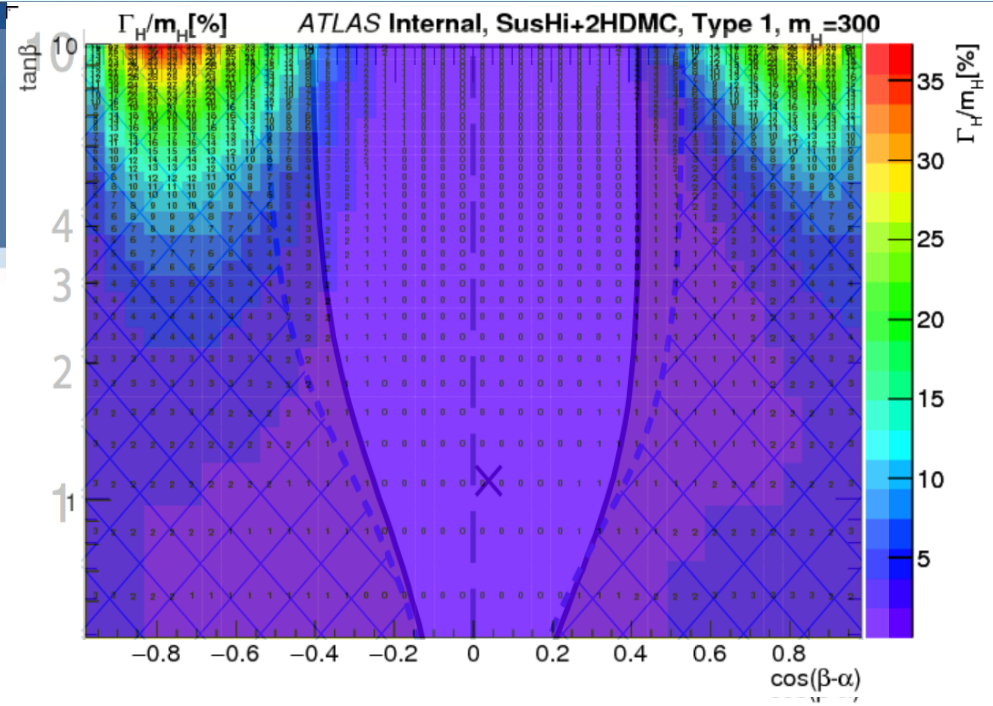


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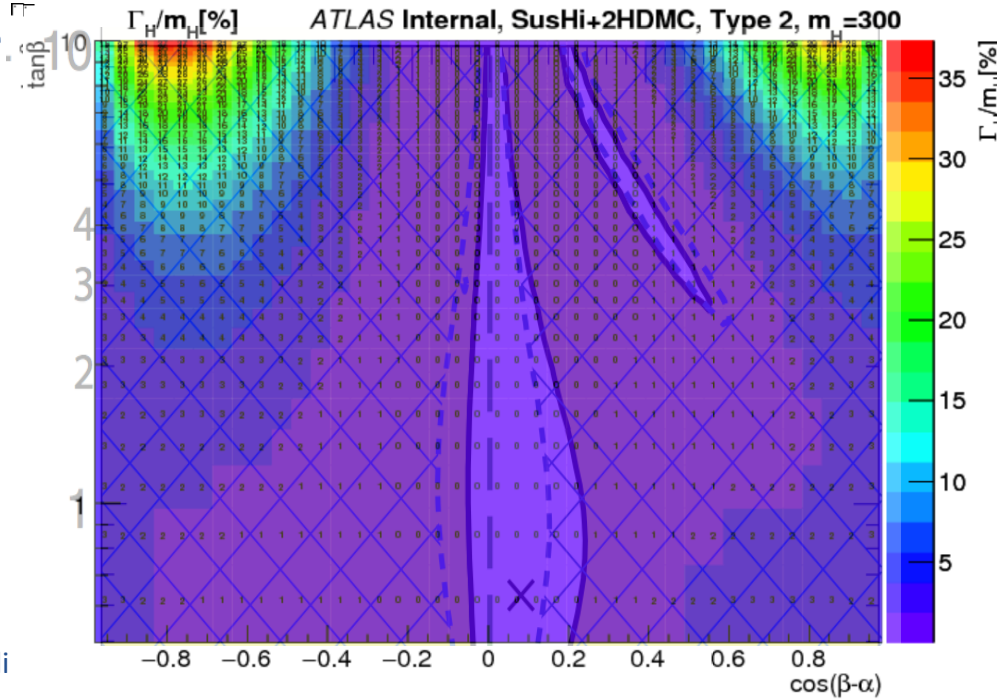
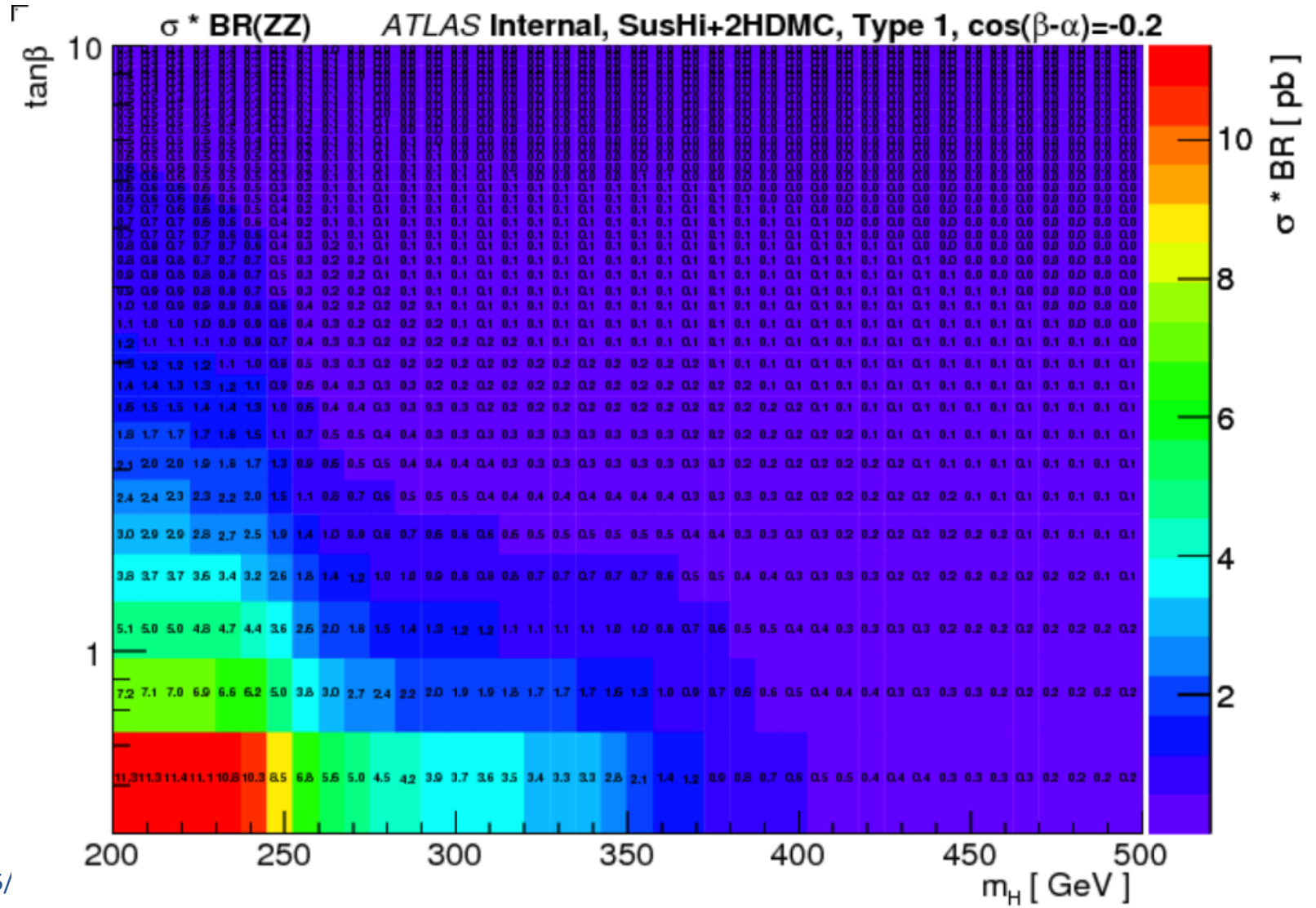


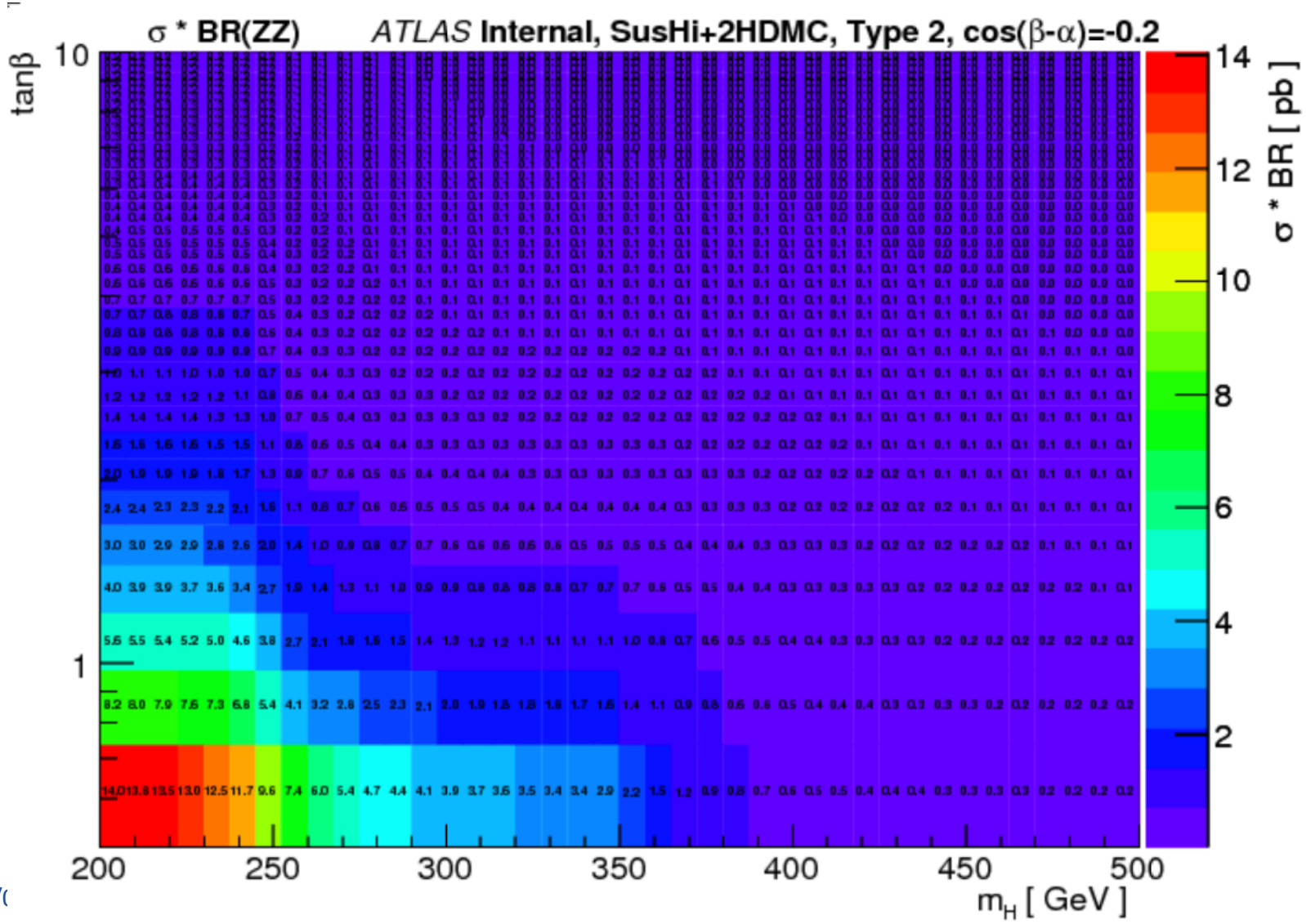
# 2HDM: Rate

- Take as a benchmark $\cos(\beta-\alpha) = \pm 0.2$ which is somewhere near indirect exclusion for $\tan\beta \sim 1$
  - 13 TeV $\sigma$ * BR for ggF
  - Have asked via LHC HXS WG3 for VBF numbers
    - Preliminary numbers (not final UR4 ones) should be possible on ~week
- For ZZ/WW limited to below ttbar threshold: $m_H < 350$ GeV
- Depending on type and decay, max $\sigma_{ggF}$ * BR = 10 – 40 pb
  - At lowest mass (i.e. 200 GeV) and low $\tan\beta$ (0.5)
    - Anyway where most sensitive in these channels
    - Doesn't increase much beyond this
    - Plots on next slides ...

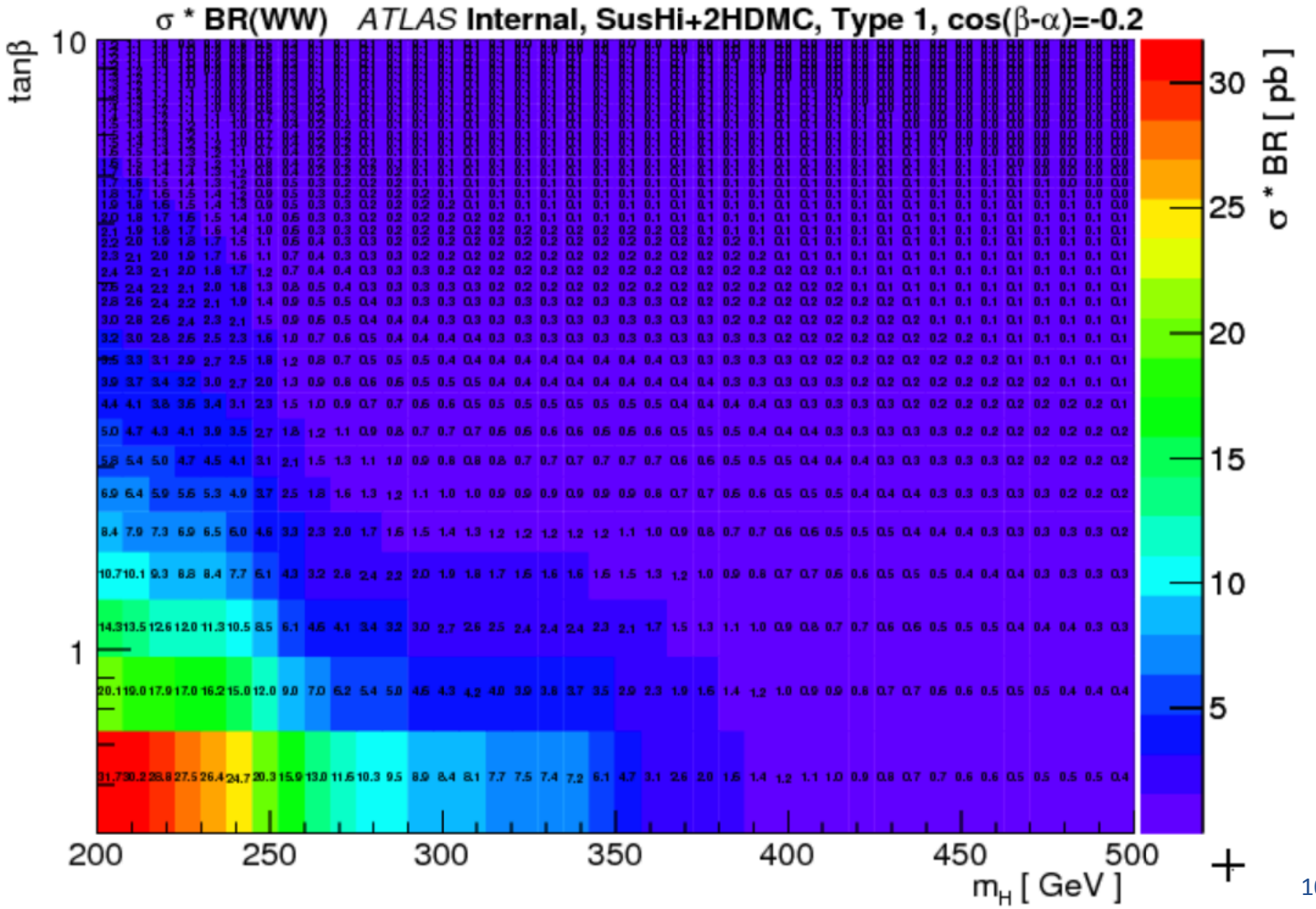
# 2HDM: ZZ Type 1: ≈ 10 pb



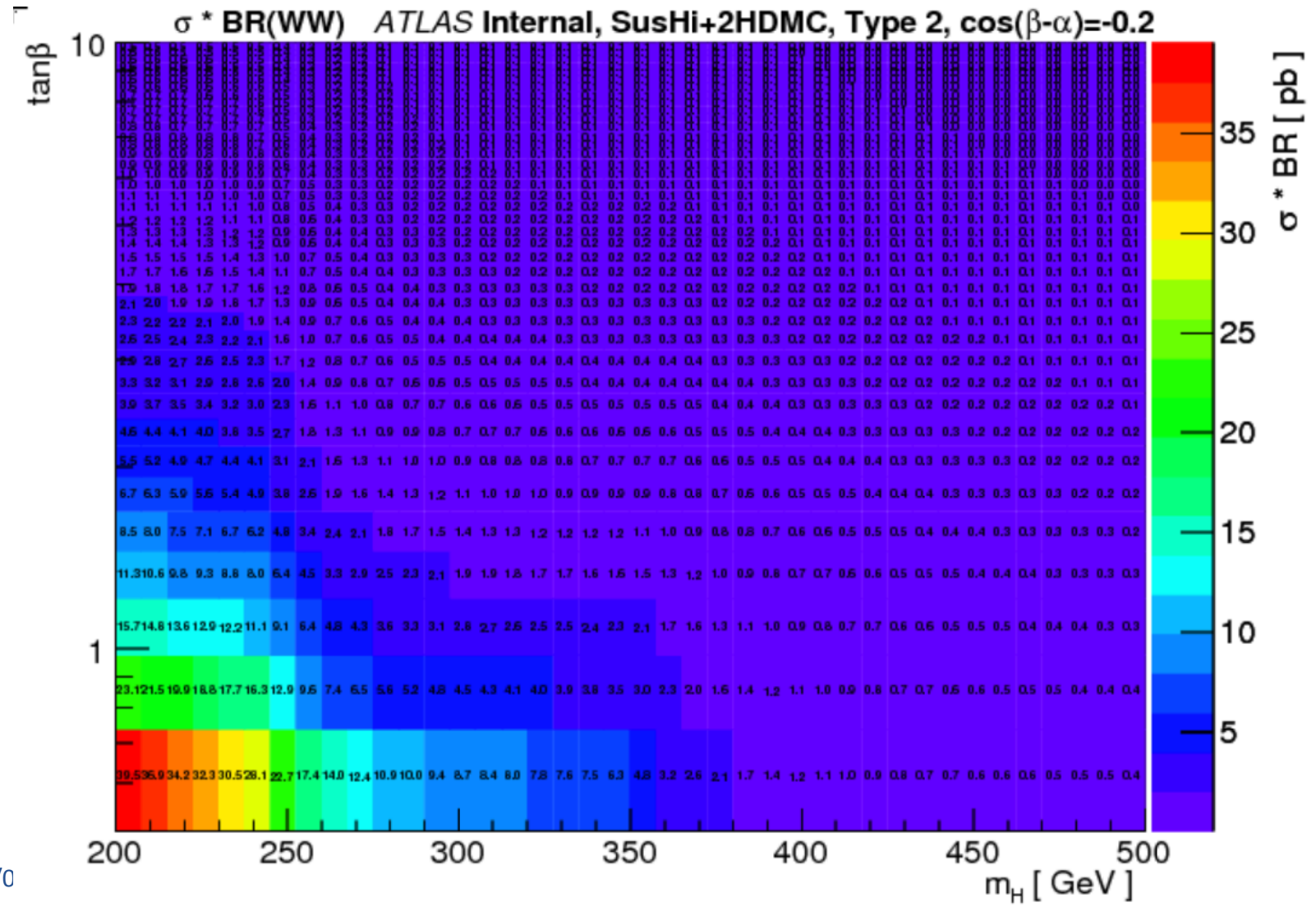
# 2HDM: ZZ Type 2: ≈ 15 pb



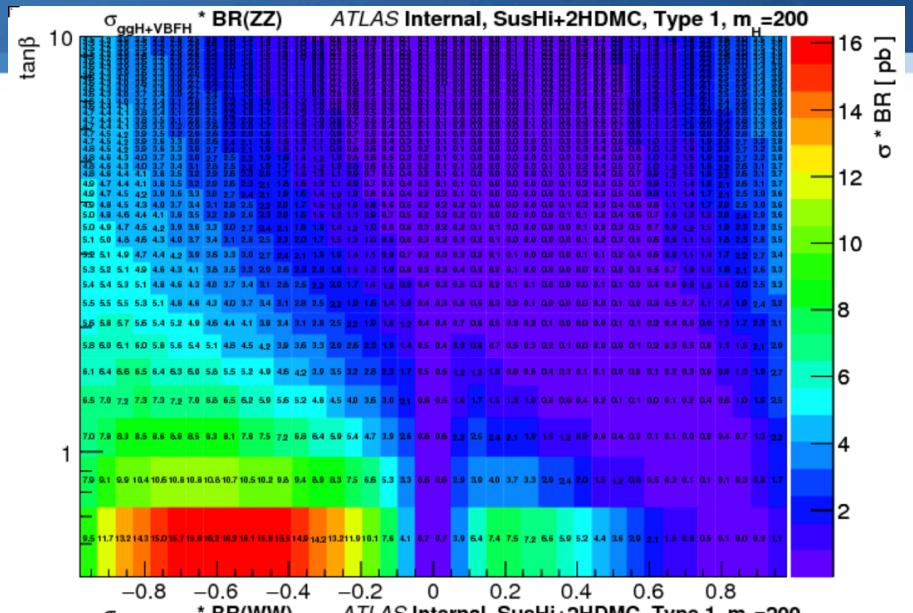
# 2HDM: WW Type 1: ≈ 30 pb

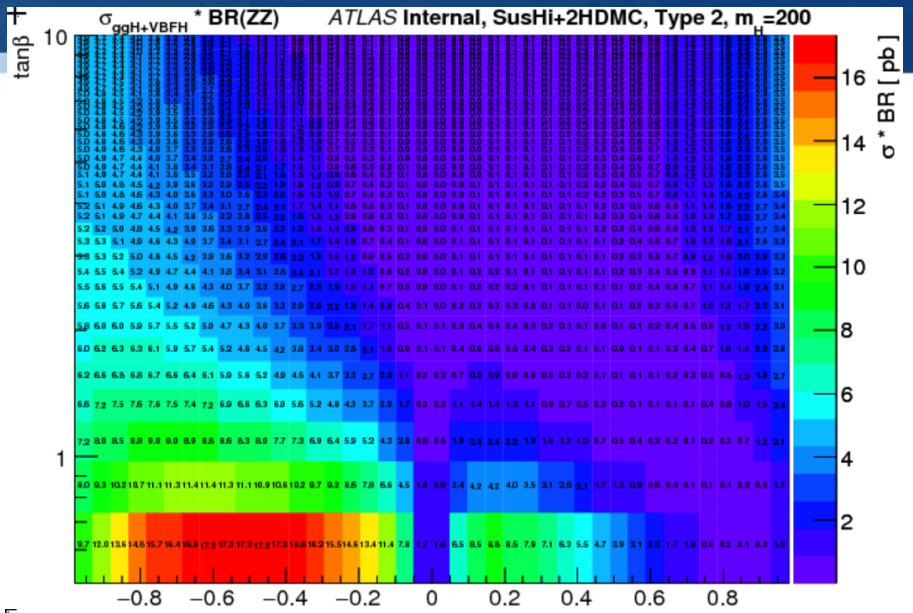


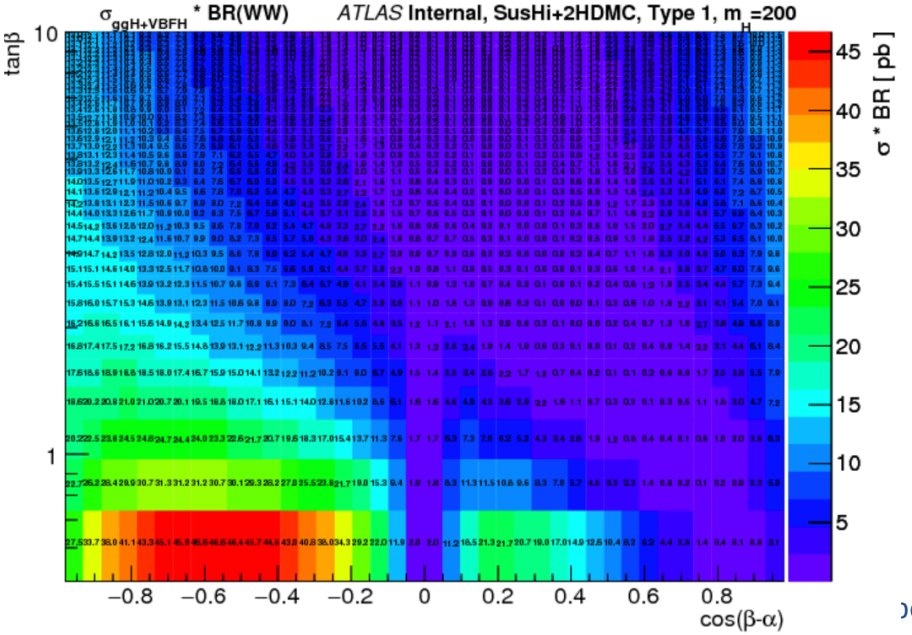
# 2HDM: WW Type 2: ≈ 40 pb

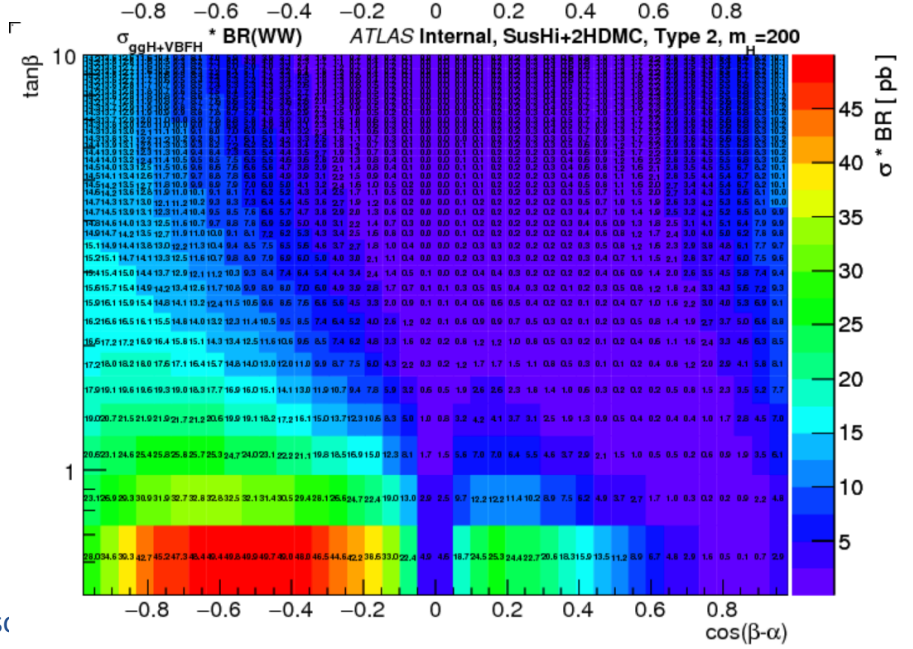


# 2HDM: Beyond cos(β-α) = ±0.2



# HTriplet

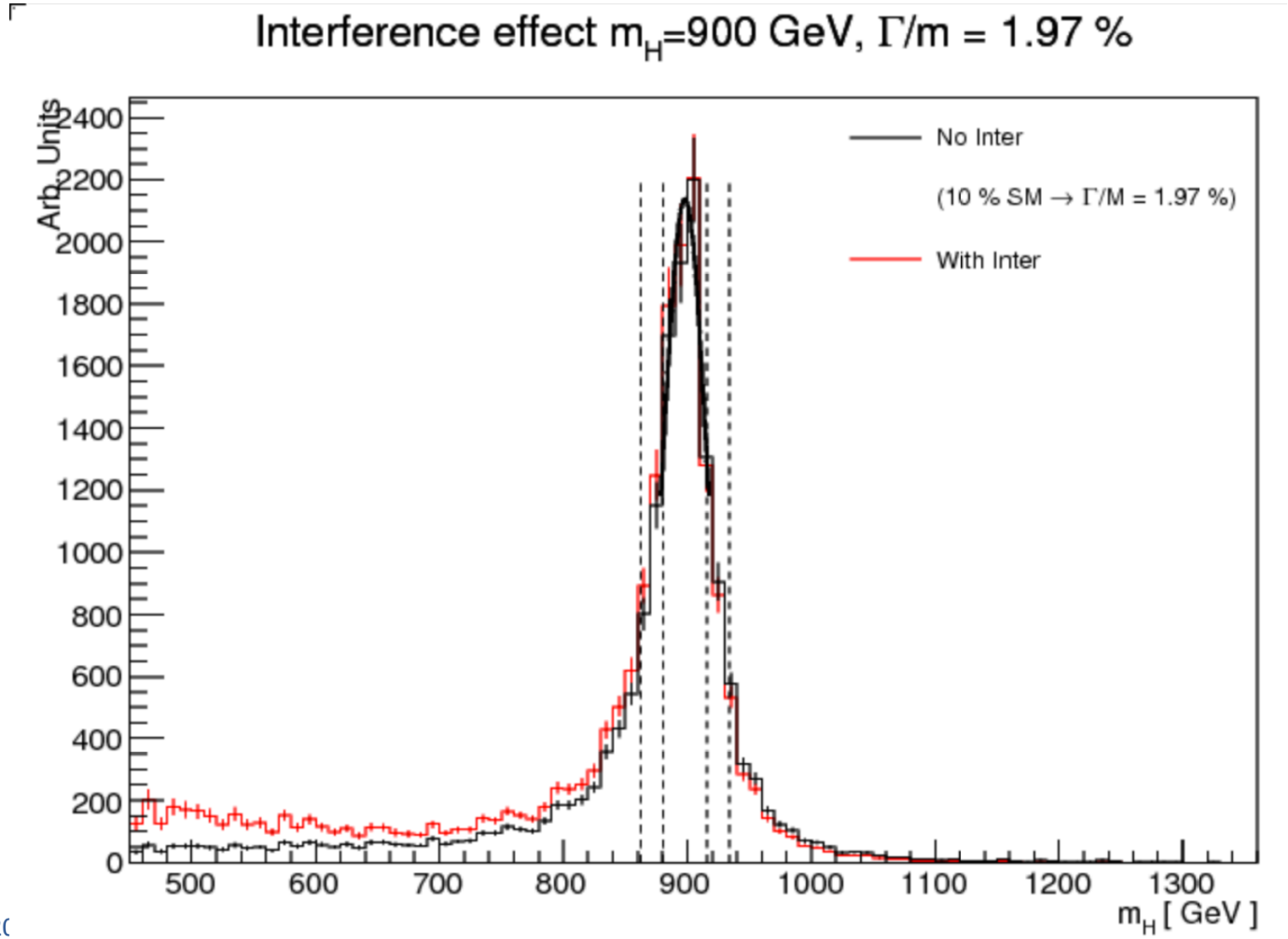
- Have asked Heather Logan for rough numbers

# Interference

# Interference: Using run 1 reweights

- Run 1 8 TeV reweight results for H+ZZ interf. (as used for EWS)
  - Use the SM CPS **ZZ** samples and reweight width down to a given width relativistic BW using run 1 Powheg weights
  - See affect of then applying interference on generated $m_H$ line-shape (signal only) coming from gg2VV run 1 procedure
  - Use 900 GeV as a benchmark and reweight to various widths in range we are interested in. Will only get worse at higher mass.
- This has several caveats
  - Interference depends on line-shape and signal strength, which in singlet or doublet will be necessarily lower the SM (kV<1)
  - The h+H interference will reduce the effect (as opposite)
  - At least for 900 GeV though the low mass bump in the line shape is not really an issue
- Seems like even if cut around 1σ of mass peak then interference bcomes important effect on line-shape above about 5%
  - Plots for various widths on next slides

# Interference @ 900 GeV



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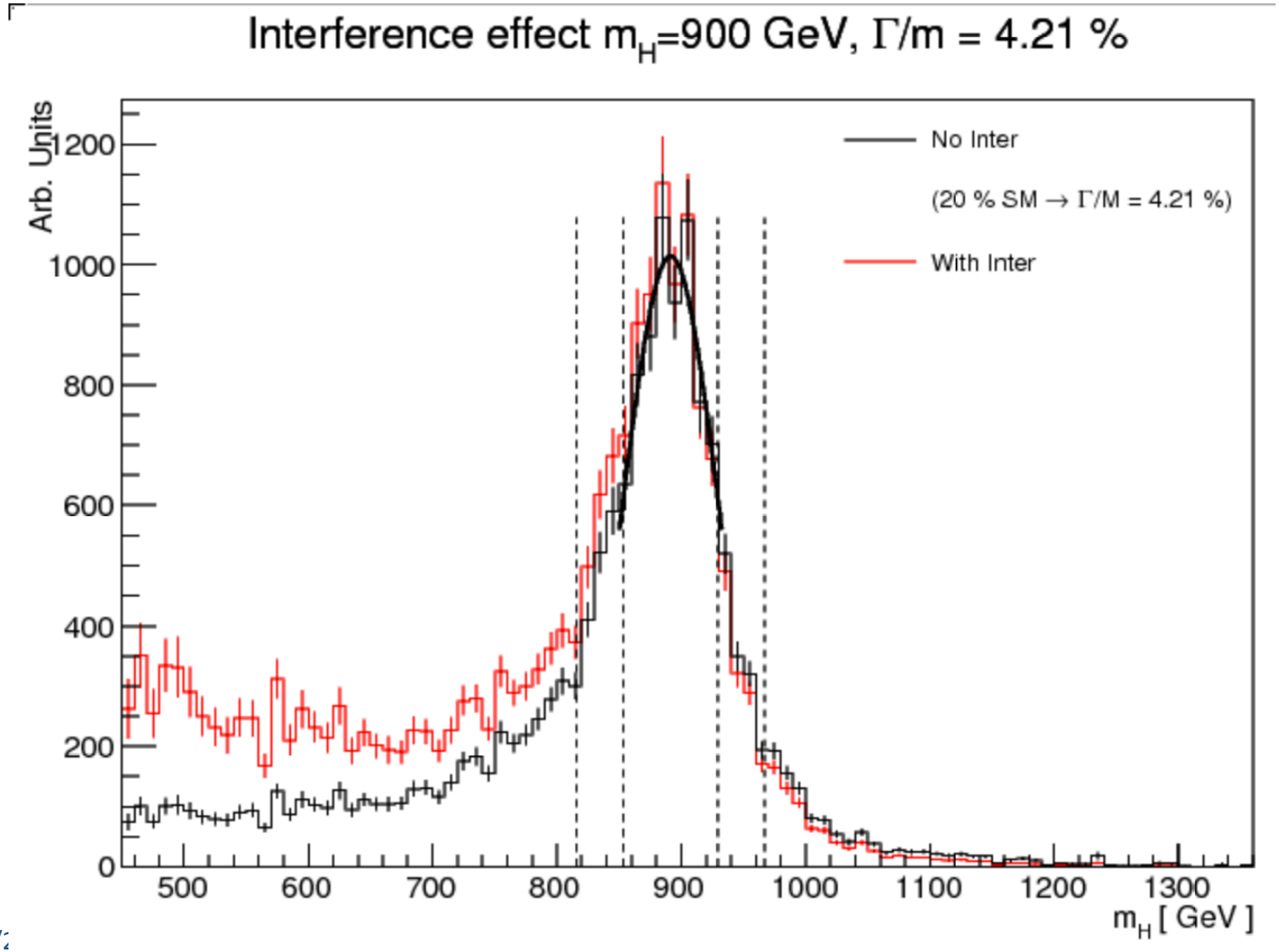

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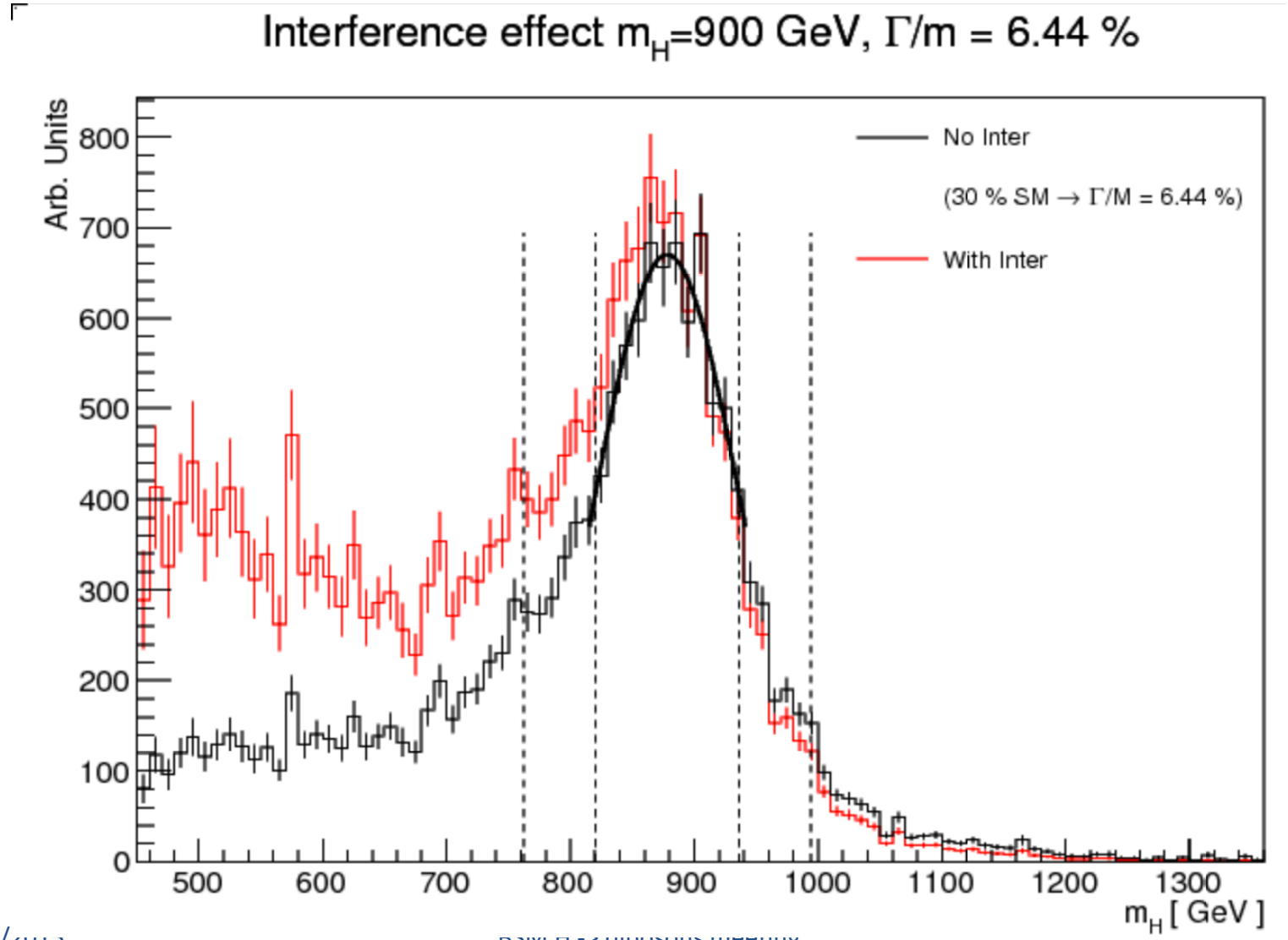

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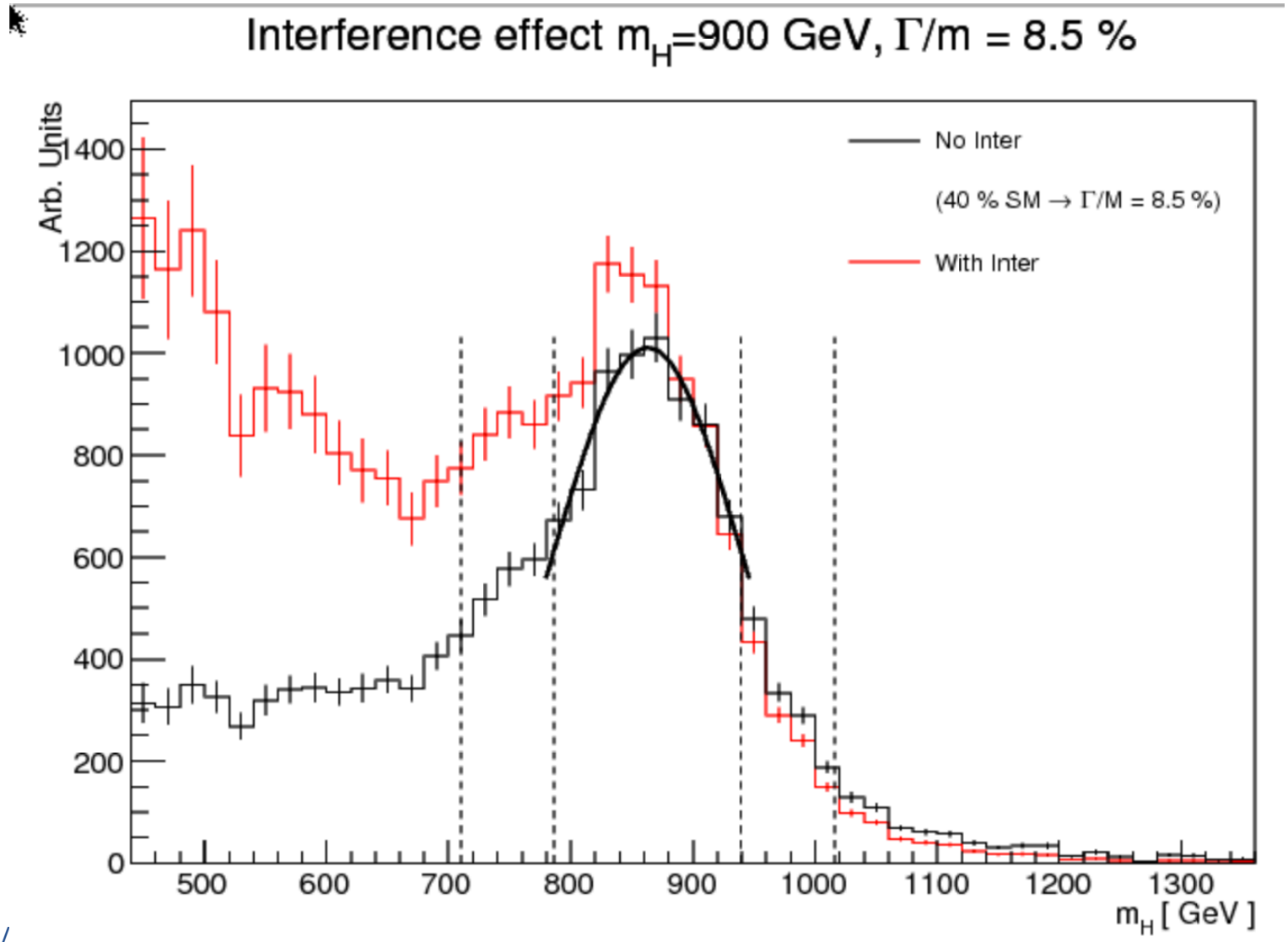

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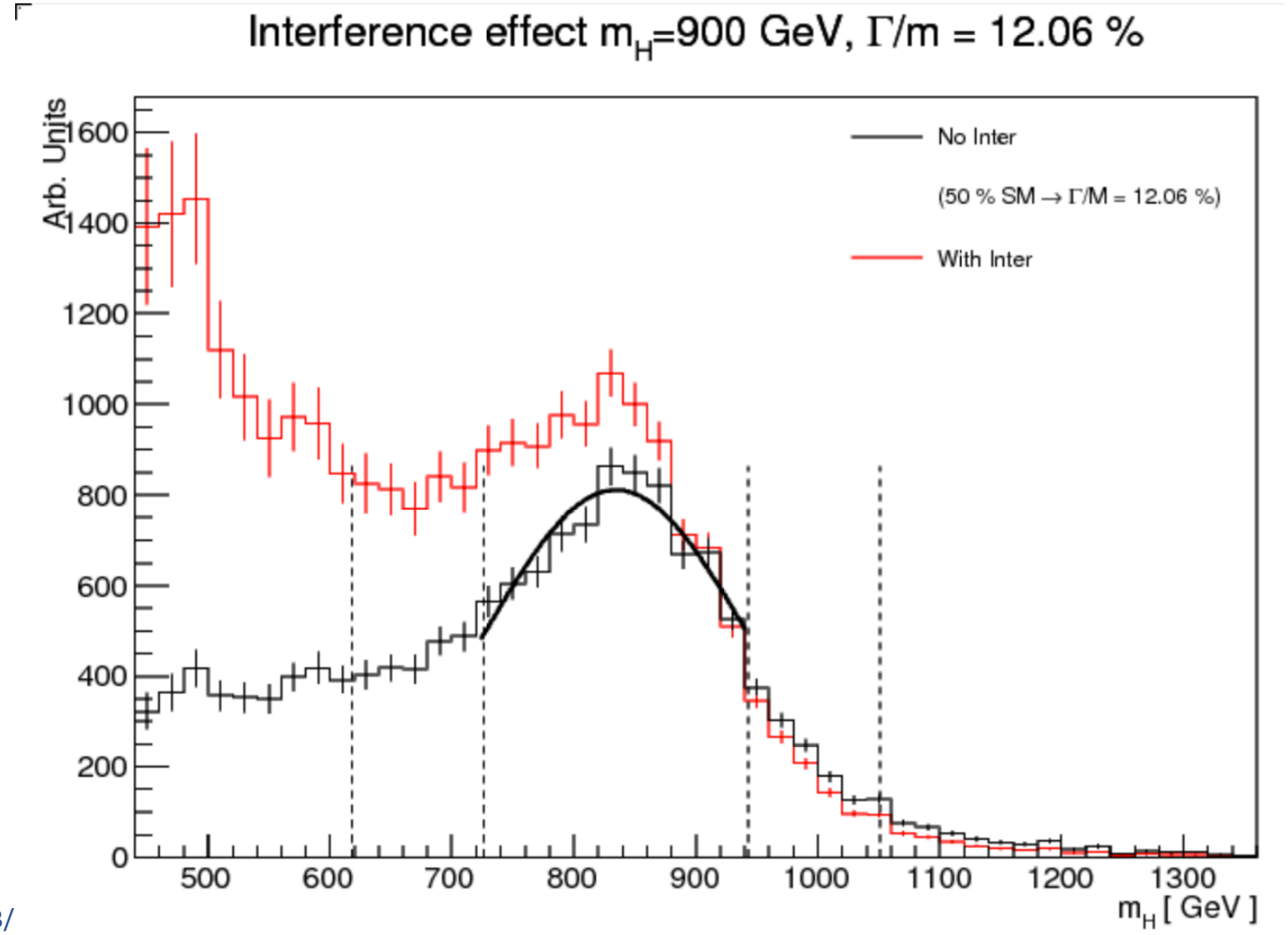


# Interference gg2VV EWS

- Latest versions of gg2VV allow S + B + interference with VV & h
  - http://arxiv.org/abs/arXiv:1502.04113

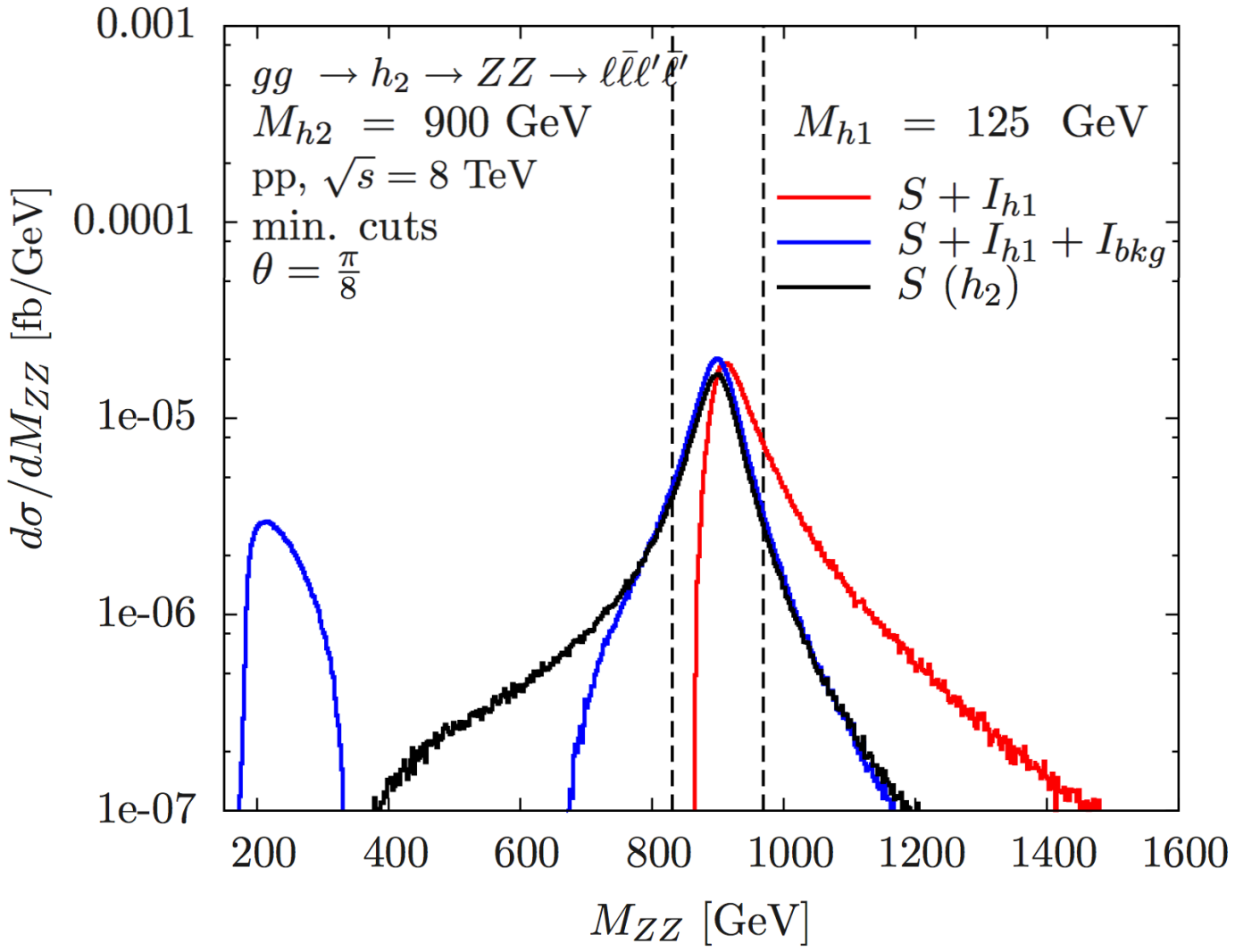
- From paper look at 900 GeV plots

| | | | $h_1$ | $h_2$ | | | |
|---|---|---|---|---|---|---|---|
| | | $M$ [GeV] | 125 | 300 | 600 | 900 | |
| k'² ≈ 0.05 | $\theta = \pi/15$ | $\Gamma$ [GeV] | $4.77358 \times 10^{-3}$ | 0.5383 | 6.42445 | 21.4215 | Γ/m (H) ≈ 0.5% |
| k'² ≈ 0.17 | $\theta = \pi/8$ | $\Gamma$ [GeV] | $4.2577 \times 10^{-3}$ | 1.70204 | 20.7236 | 69.1805 | Γ/m (H) ≈ 7.8% |

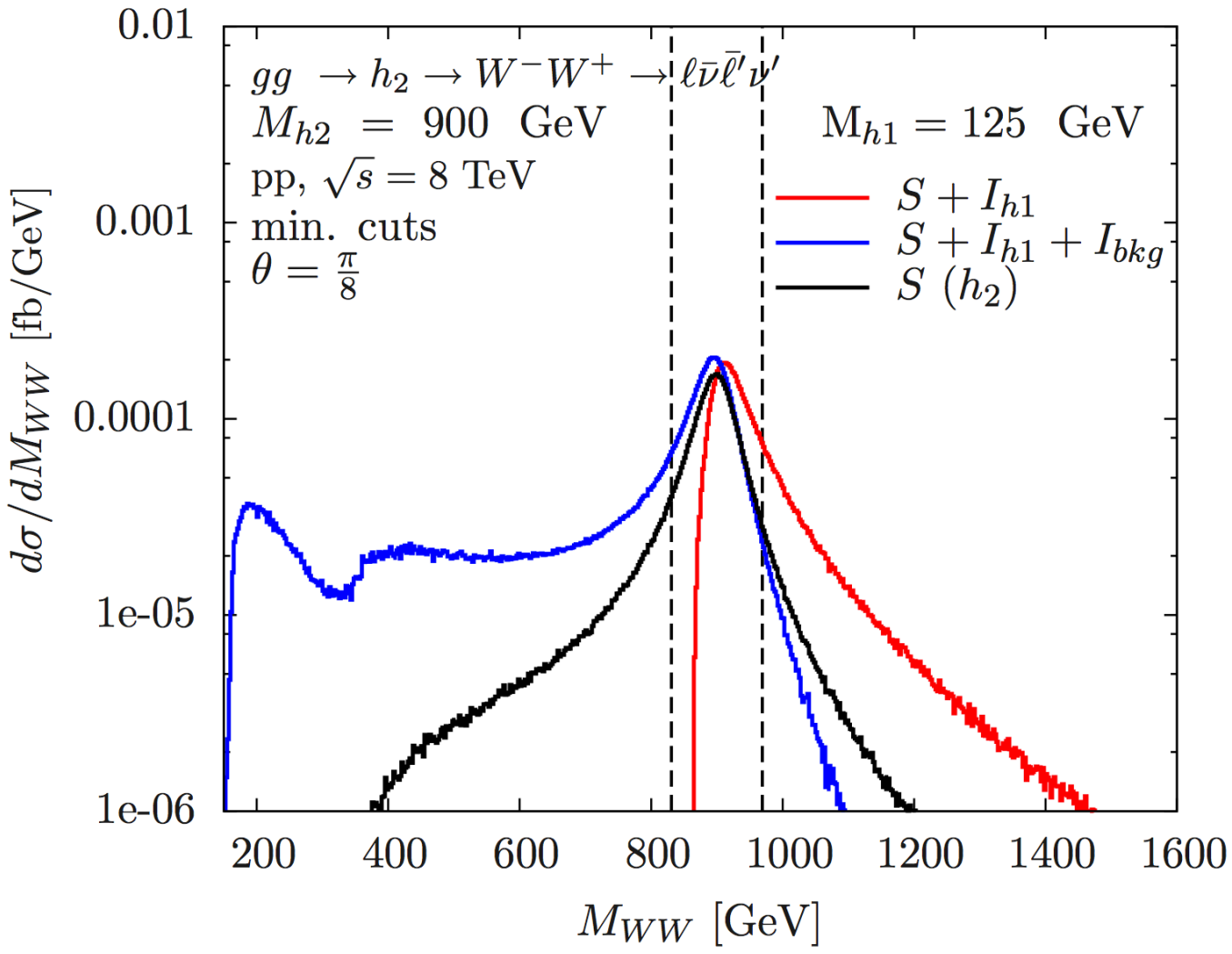
- Interference not negligible for 7.8% width, esp. for WW
  - Again, will only get worse with mass
  - Plots on next page
    - Compare blue to black

- Need to take interference into account for EWS

# Interference gg2VV EWS: ZZ



# Interference gg2VV EWS: WW



# Summary

- EWS is natural early model for high $m_H$
  - Width in region not rules out by couplings stays “reasonable”
  - However, interference not negligible
    - Even if stay within ~m±Γ
  - Can take into account with gg2VV
    - Need to define procedure for generating / reweighting samples
    - What about VV bkg for channels (e.g. 4l) where VV is dominant bkg
- Also have “model-independent”
  - Here should again restrict $m_{VV}$ range
  - No model-independent was of having interference
  - Neglect for first results
    - Later can use Michael’s method