Interference effects in diphoton production for VBF

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OUTLINE

- Motivation
- Signal-background interference in $H \rightarrow \gamma\gamma$: inclusive case
- Signal-background interference in $H \rightarrow \gamma\gamma$ + 2 jets
- Conclusions

Motivation

$$m_H = 125.36 \pm 0.37(\text{stat}) \pm 0.18(\text{syst})\ \text{GeV}$$

1

Collecting enough luminosity

Experimental uncertainty could be reduced to 0.1 GeV

Need for smaller theoretical errors

$$m_H = 124.70 \pm 0.31(\text{stat}) \pm 0.15(\text{syst})\ \text{GeV}$$

2

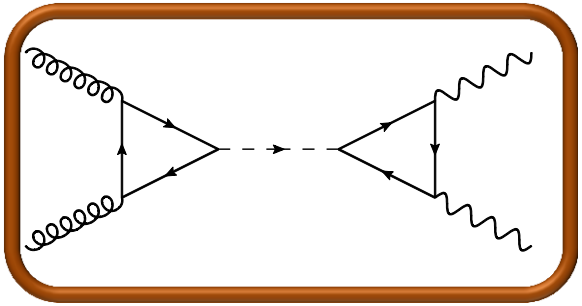
Mass shift → Set a bound to the Higgs Boson Width

THE γγ CHANNEL

- Important for an intermediate mass Higgs for its clean signature (discovery!!)
- Suppressed process (1-loop decay)
- Other main avaible decay channels hadronic

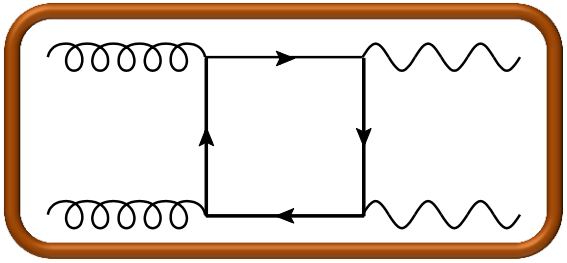
INCLUSIVE CASE

$gg \Rightarrow H \Rightarrow \gamma\gamma$



- 2-loop
- $\mathcal{O}(g_s^2)$

Interferes with…



- 1-loop
- $\mathcal{O}(g_s^2)$

$gg \Rightarrow \gamma\gamma$ continuum

INTERFERENCE

Changes the XS by:

[Dicus, Willenbrock] Phys. Rev. D 37 (1988) 1801

$$\delta\hat{\sigma}_{ij\to X+H\to\gamma\gamma} = -2(\hat{s}-m_H^2)\times\frac{\mathrm{Re}\left(\mathcal{A}_{ij\to X+H}\mathcal{A}_{H\to\gamma\gamma}\mathcal{A}^*_{\mathrm{cont}}\right)}{(\hat{s}-m_H^2)^2+m_H^2\Gamma_H^2} - 2m_H\Gamma_H\times\frac{\mathrm{Im}\left(\mathcal{A}_{ij\to X+H}\mathcal{A}_{H\to\gamma\gamma}\mathcal{A}^*_{\mathrm{cont}}\right)}{(\hat{s}-m_H^2)^2+m_H^2\Gamma_H^2}$$

Real part of Higgs propagator ⇒ **Odd in s around m_H**

Negligible to the total XS

Imaginary part of Higgs propagator ⇒ **Quark mass suppression for the relevant helicities**

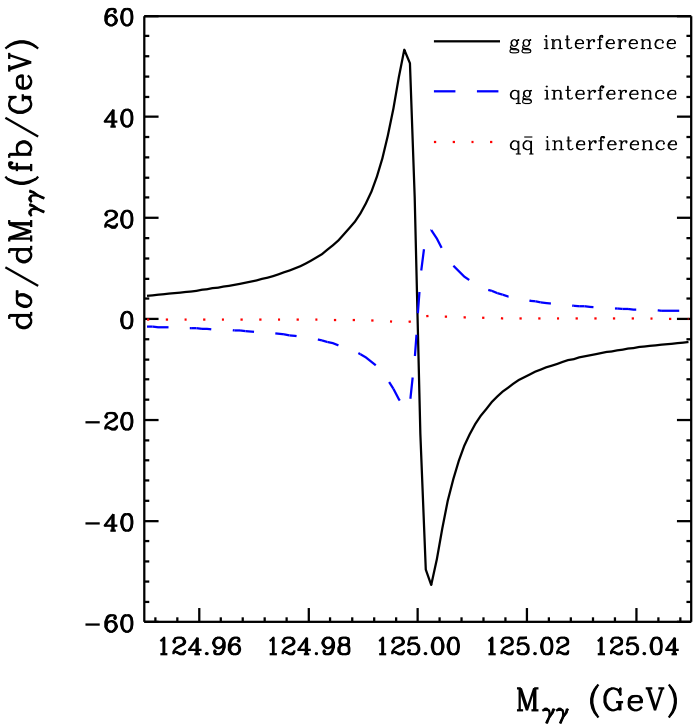
$\delta\hat{\sigma}$ Has a small effect in the total γγ rate

[S. Martin] 2012 arXiv:1208.1533 [hep-ph]

Real part of the amplitudes → Has a quantifyable effect on the diphoton invariant mass peak position → **Shift**

- Calculated $q\bar{q}$ and qg channels
  - Together with gg

} Complete $O(\alpha_s^2)$ calculation of the signal-background interference



Dominant channel

3 times smaller

2 orders smaller

} Opposite sign!!

Position of maximum and minimum

↓

Located near $M_{\gamma\gamma} = M_H \pm \Gamma_H/2$

↓

Generates a shift of $\mathcal{O}(1\,\mathrm{MeV})$

[De Florian et al] 2013 arXiv:1303.1397 [hep-ph]

SMEARING EFFECTS

[S. Martin] 2012 arXiv:1208.1533 [hep-ph]

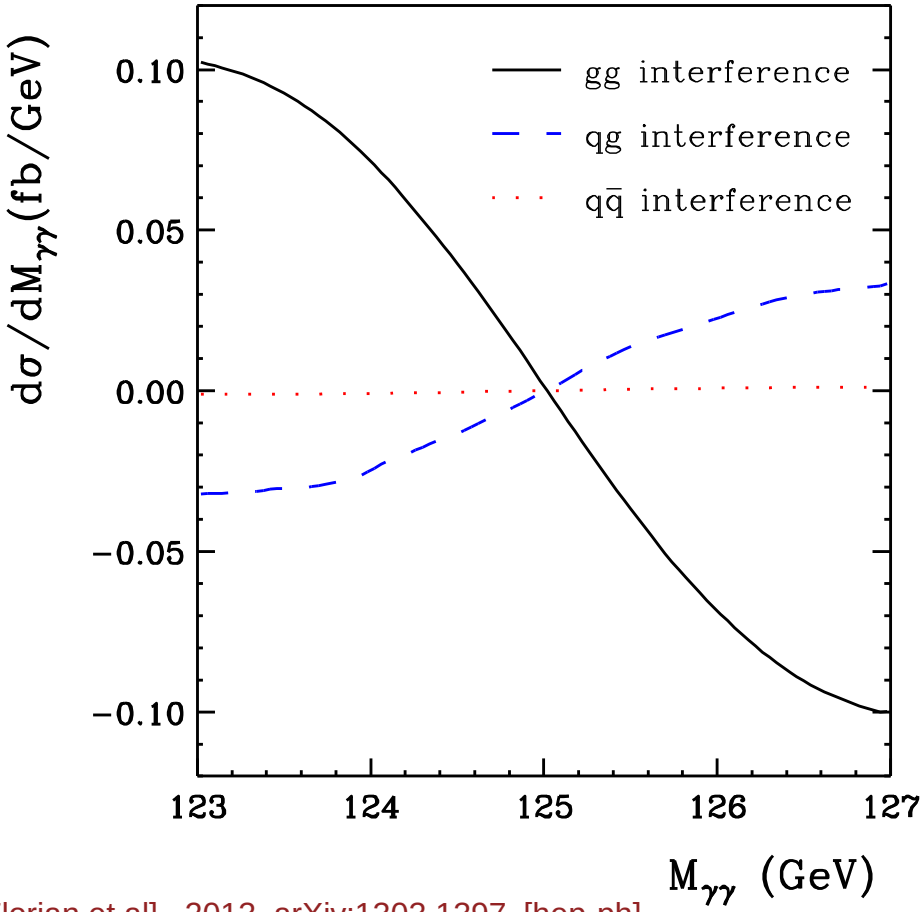
Convolute the cross section with a gaussian function

$$\sigma_{\mathrm{MR}} = 1.7\,\mathrm{GeV}$$

Simulate the effects of the detector (smearing of photon energies)

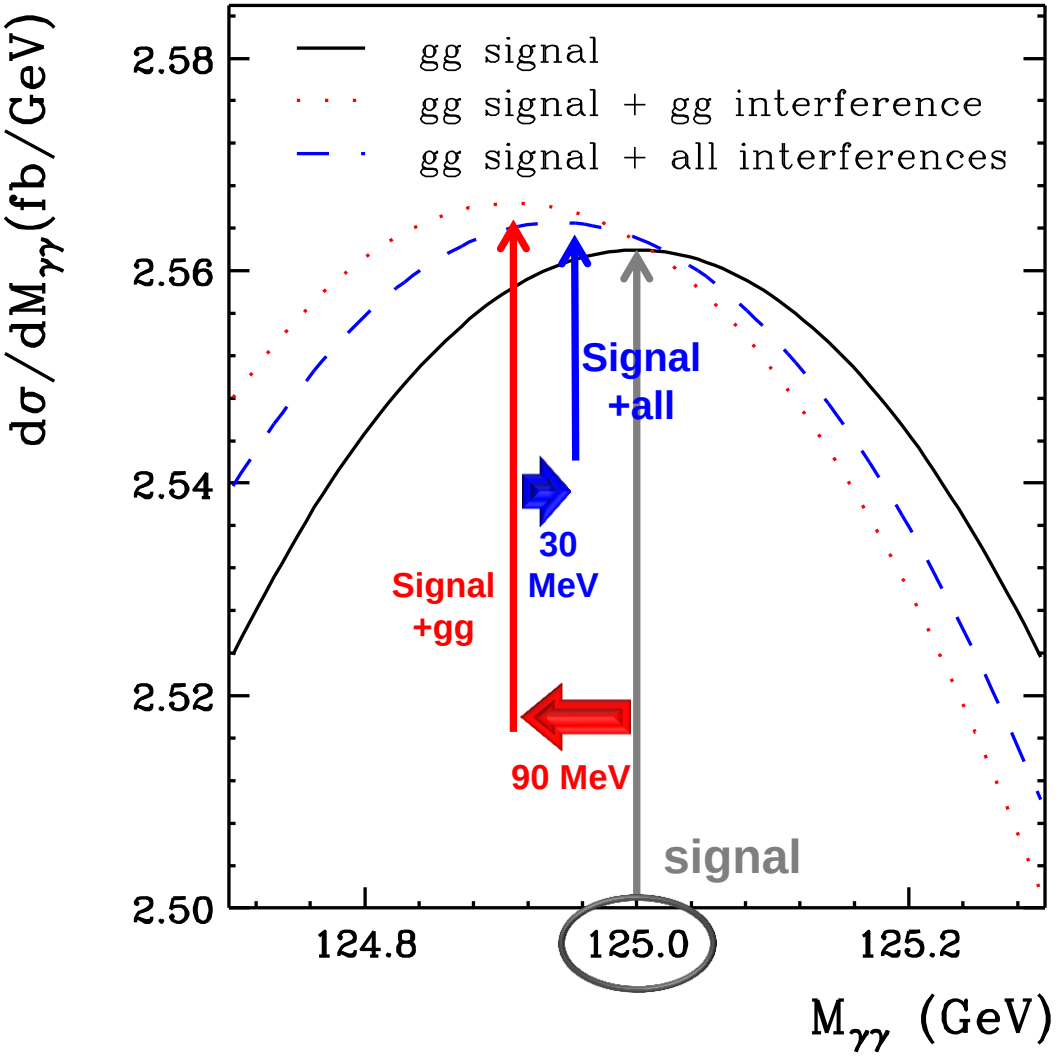
- Position of peak (and dip) shifted as much as 2 GeV

Highly antisymmetric nature of the interference terms is enhanced by the convolution



[De Florian et al] 2013 arXiv:1303.1397 [hep-ph]

SIGNAL + INTERFERENCE (with smearing)

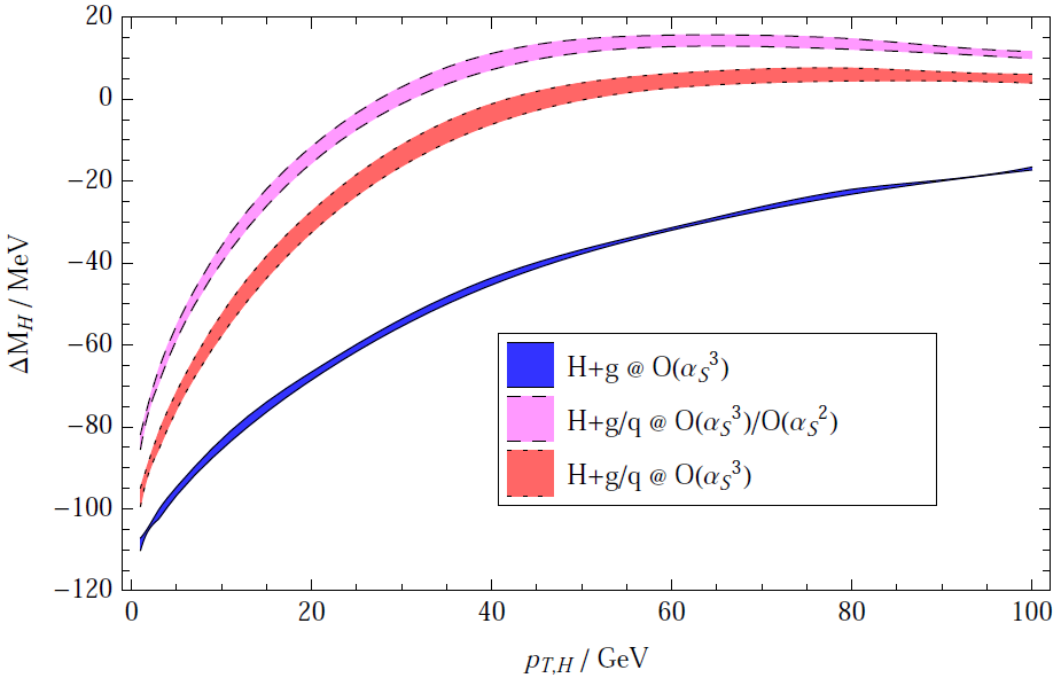


Realistic simulation performed by ATLAS → Slightly smaller shifts

MASS SHIFT AT NLO AND WIDTH DEPENDANCE

[Dixon,Li] arXiv:1305.3854

- Shift depends on Γ_H ⇒ We can use it to bound its value
- Maintaining the Higgs signal constant ⇒ Shift proportional to $\sqrt{\Gamma_H}$
- Less model dependent than off-shell measurements

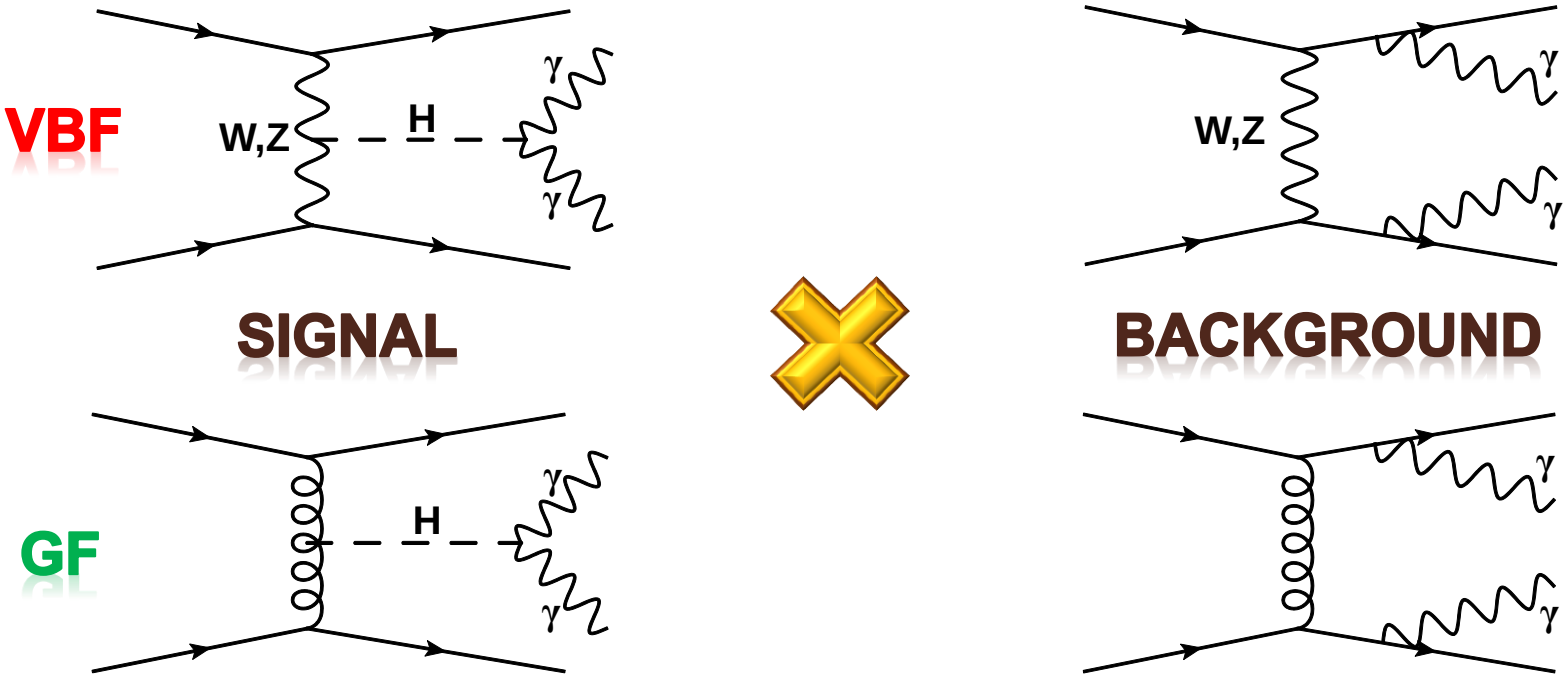


- Shift shows a strong dependance on pT_H
- pT_H > 30GeV can be used as "control" mass

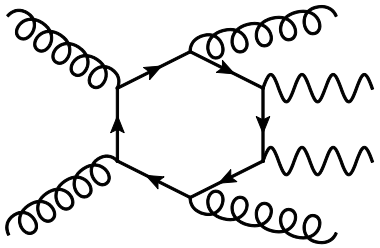
Mass shift in $\gamma\gamma$ + 2 jets

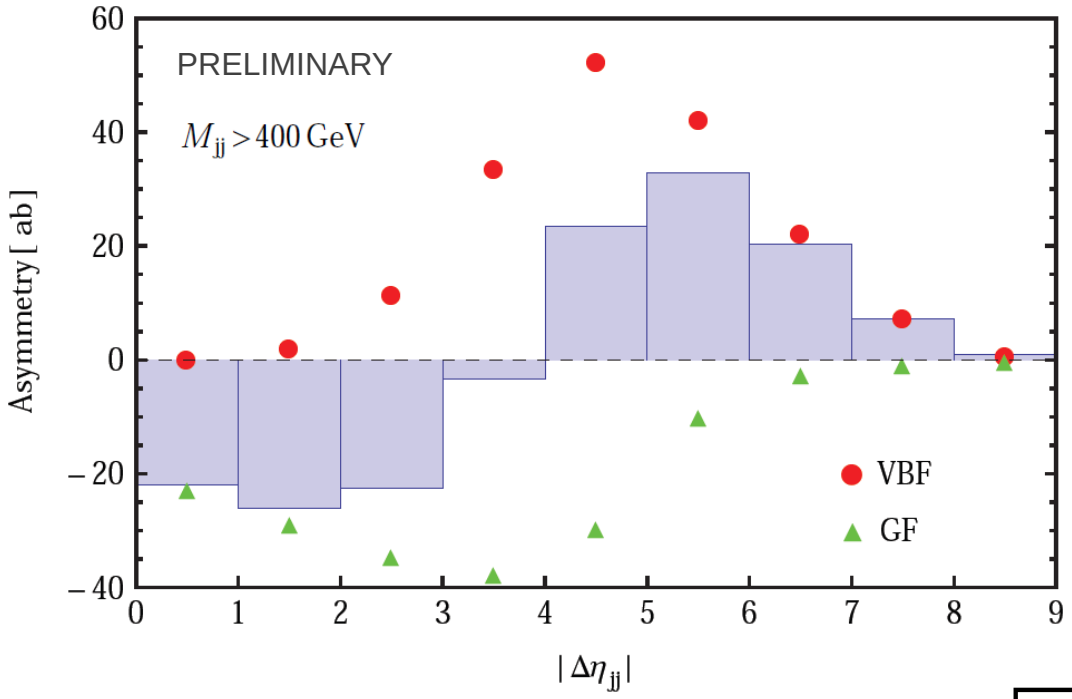
ALL RESULTS PRELIMINARY

In collaboration with F. Coradeschi, D. De Florian, L. Dixon, NF, S. Hoeche, H. Ita, Y. Li, J. Mazzitelli, **IN PROGRESS**



- Calculation purely LO
- Analytic amplitudes obtained with the help of FeynCalc and FormCalc
- Interface with numeric phase-space integration via a custom fortran program
- Gluon channel contribution (formally higher order) in progress





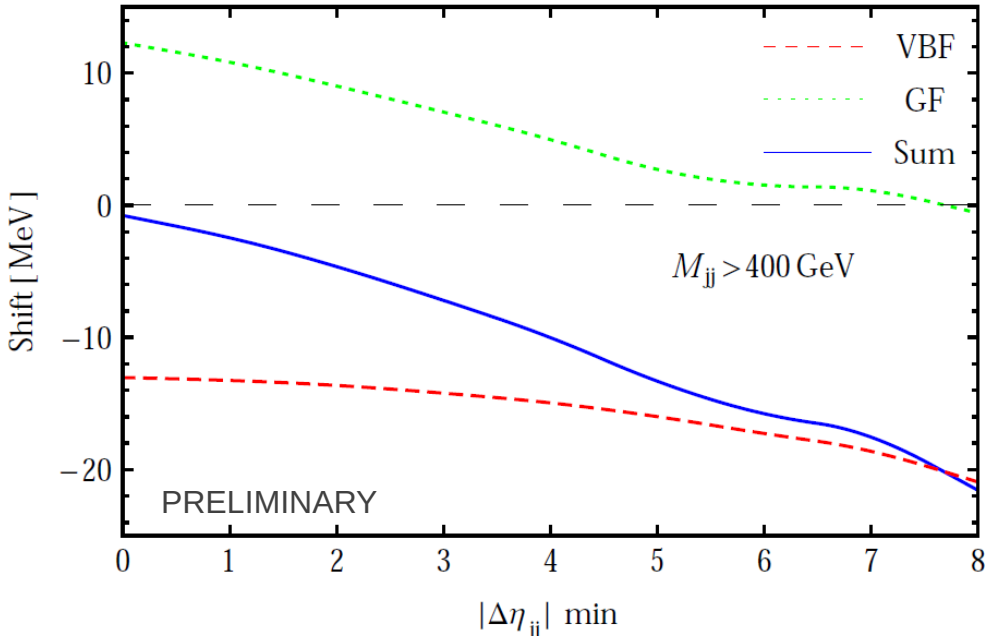
- Asymmetry here is:

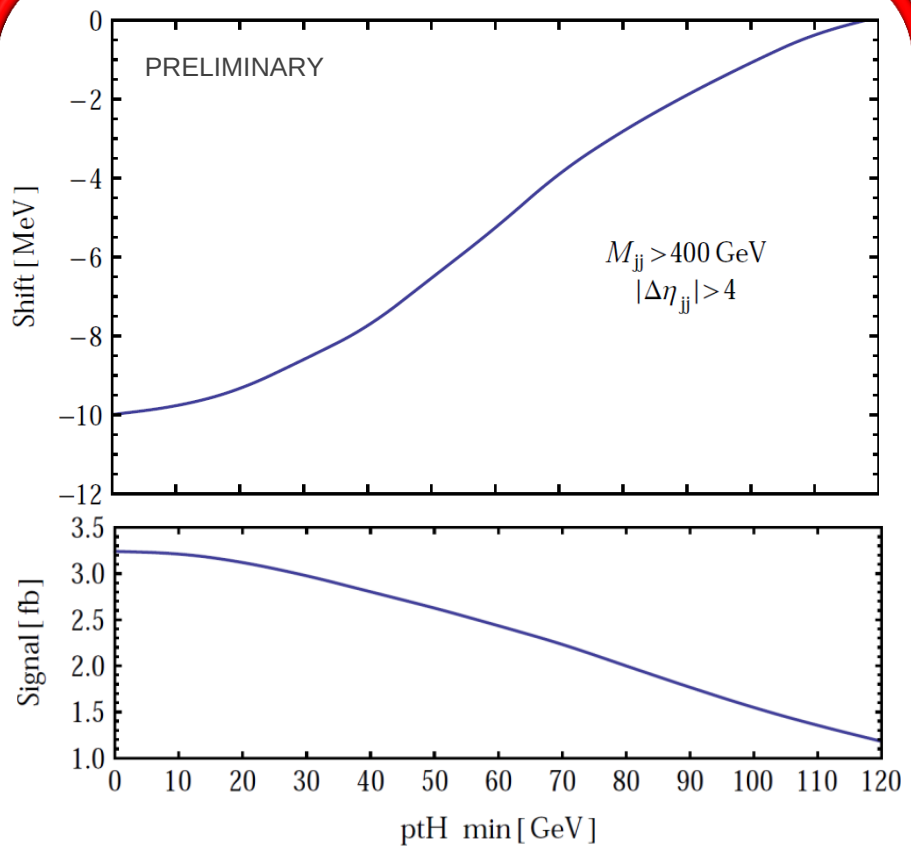
$$A = \int_{120\ \mathrm{GeV}}^{125\ \mathrm{GeV}} \frac{d\sigma}{dM_{\gamma\gamma}} dM_{\gamma\gamma} - \int_{125\ \mathrm{GeV}}^{130\ \mathrm{GeV}} \frac{d\sigma}{dM_{\gamma\gamma}} dM_{\gamma\gamma}$$

- Contributions have opposite sign:

VBF
Shifts towards lower masses

GF
Shifts towards higher masses

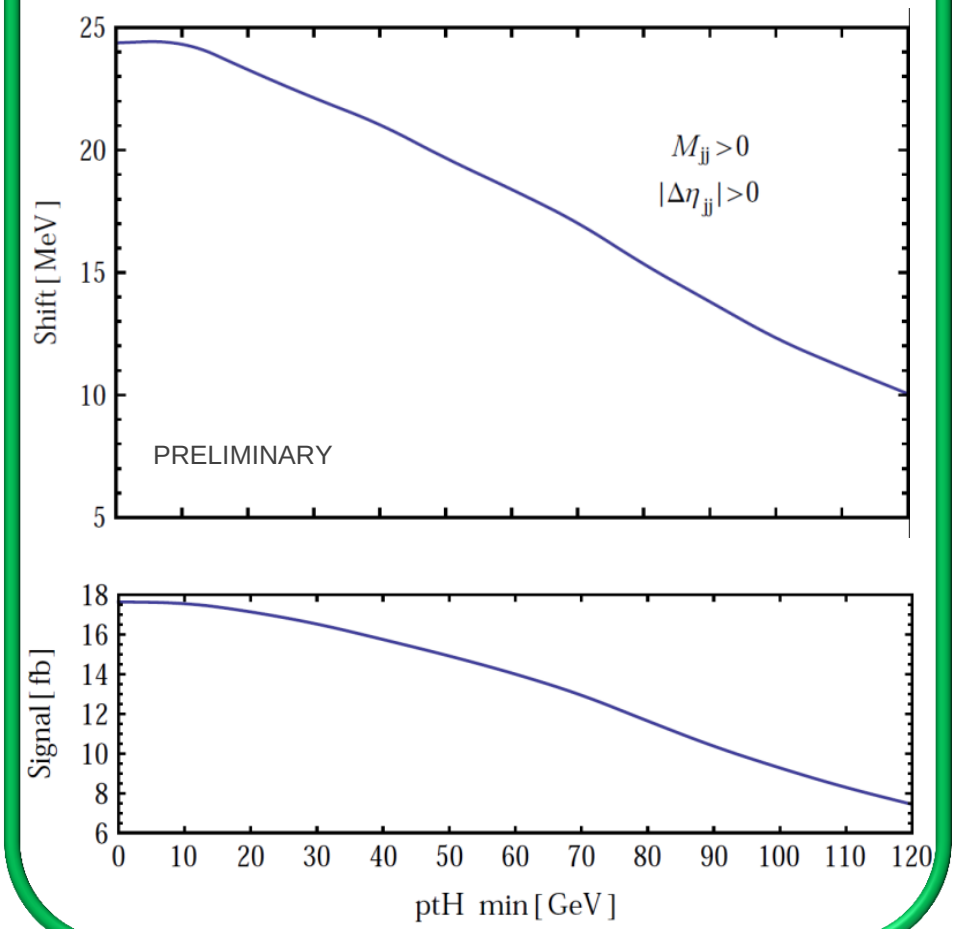




- VBF cuts
- Negative shift

Higher ptH ⇒ Smaller shift

- No VBF cuts, so GF dominates
- Positive shift



SOME REMARKS

- Much smaller shift than in inclusive case → Using only this for bounding the width is not so good

- VBF more robust theoretically than high-pT_H region in the inclusive $pp \rightarrow \gamma\gamma$

It can be used as a control region to compare with the inclusive case

- Changing the cuts we can look to maximize the difference between the shift in these results and in the inclusive case

Conclusions

- Signal-background interference leads to a shift in the diphoton inv mass peak
- The mass shift depends on the Higgs width, and can therefore be used to bound its value
- In the inclusive case the shift is O(50-100 MeV) for SM values
- Much smaller shifts for Higgs + 2 jets; VBF and GF with opposite signs
- Can be used as a control region against the inclusive case

Thanks!!