Interference effect on higgs mass measurement at CEPC

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Outline

- Motivation and Background
- Interference effects in $e^+e^- \to H(\gamma\gamma)Z$ process
- Interference effects in the process of four-fermion final states
  - $e^+e^- \to H\left(b\bar{b}\right)Z(\mu^+\mu^-)$
  - $e^+e^- \to H(\tau^+\tau^-)Z(\mu^+\mu^-)$
- Summary and Outlook

“Higgs boson” was discovered in 2012 at LHC.
Up-to now, we know,

- It’s mass is around 125 GeV.
- It’s properties are roughly consistent with SM predictions.

The next crucial task is the precise measurements of the coupling constants, spin, decay width, and the mass.

Futrue e^+e^- colliders may play an import role

- International Linear Collider (ILC)
- Future Circular Collider Electron-Positron Collider (FCC-ee) , formerly known as Triple-Large Electron-Positron Collider (TLEP)

And

- Circular Electron Positron Collider (CEPC)

Two kinds of schemes with lots of works were discussed to understand the nature at LHC.

- “on-shell” and “off-shell” effects in the four-fermion final states through the intermediate process of Higgs decays to heavy vector boson pair.
- Mass shift effects in the di-photon final state due to the signal-background interference.

Interferometry in $gg \to H \to \gamma\gamma$ at the LHC

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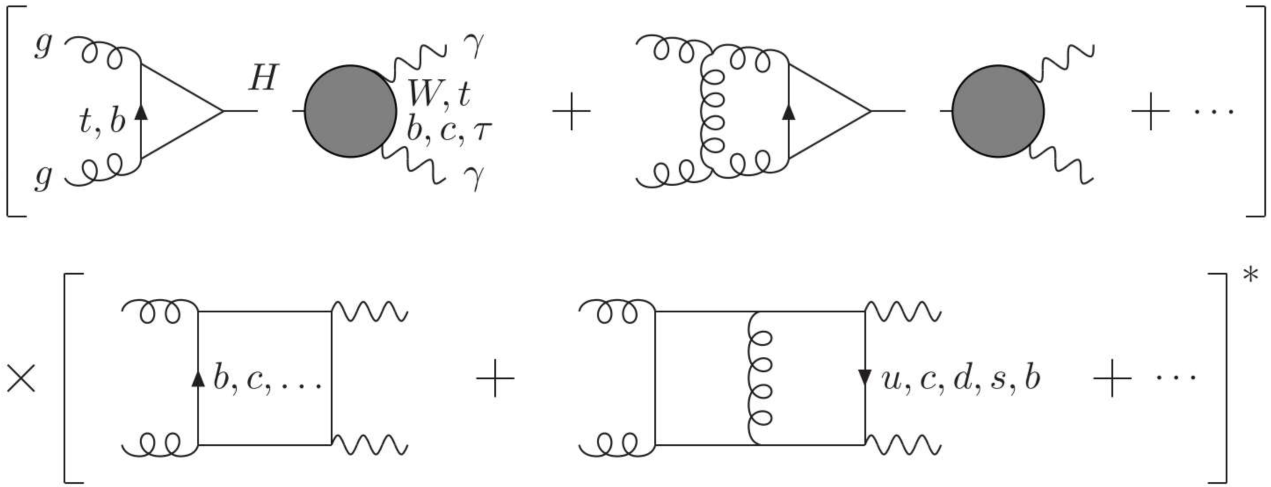

The interference is of order 5% in the SM

Smearing effects of the experimental resolutions

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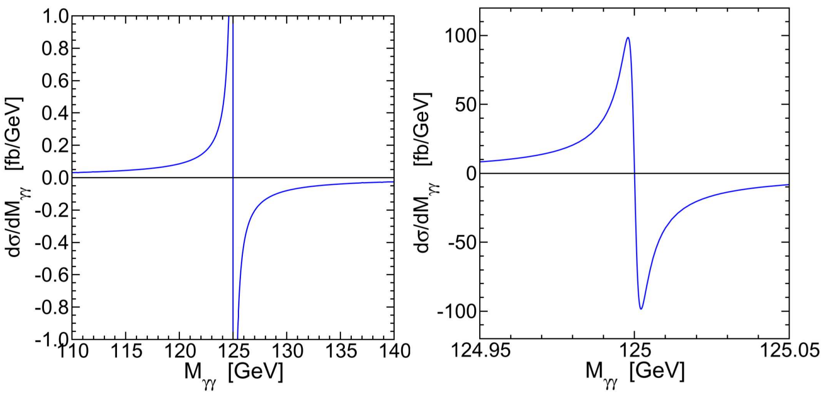

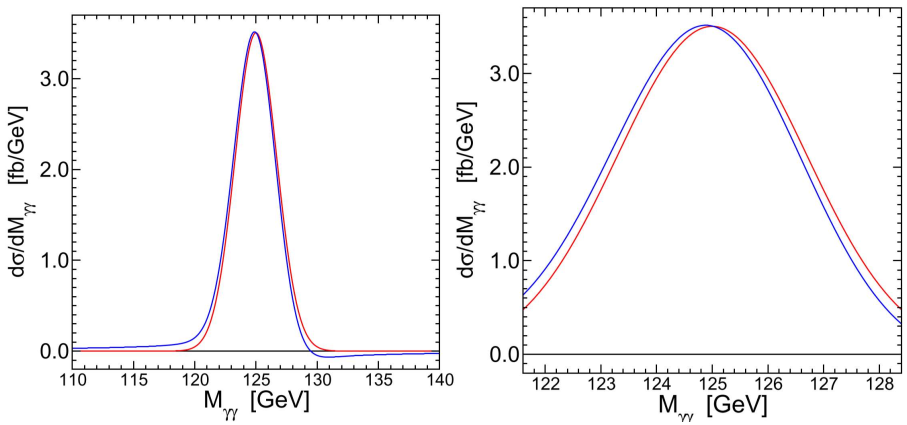

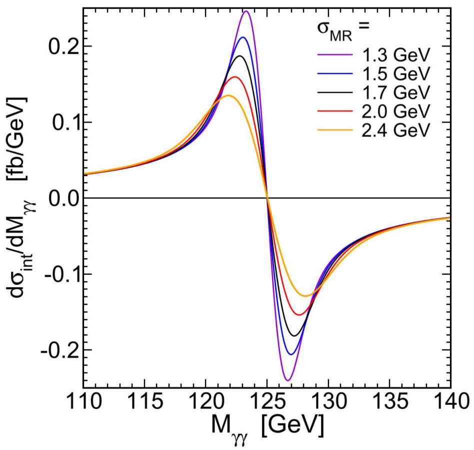

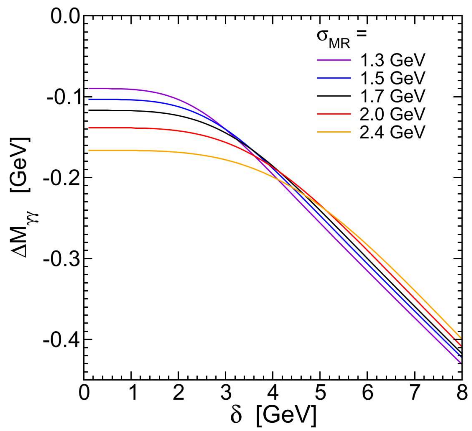

$q\bar{q}$ and $gq(\bar{q})$ channels were also included

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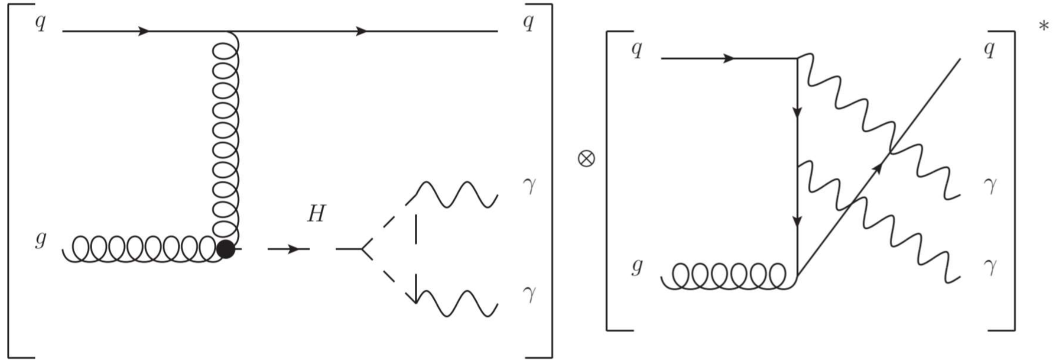
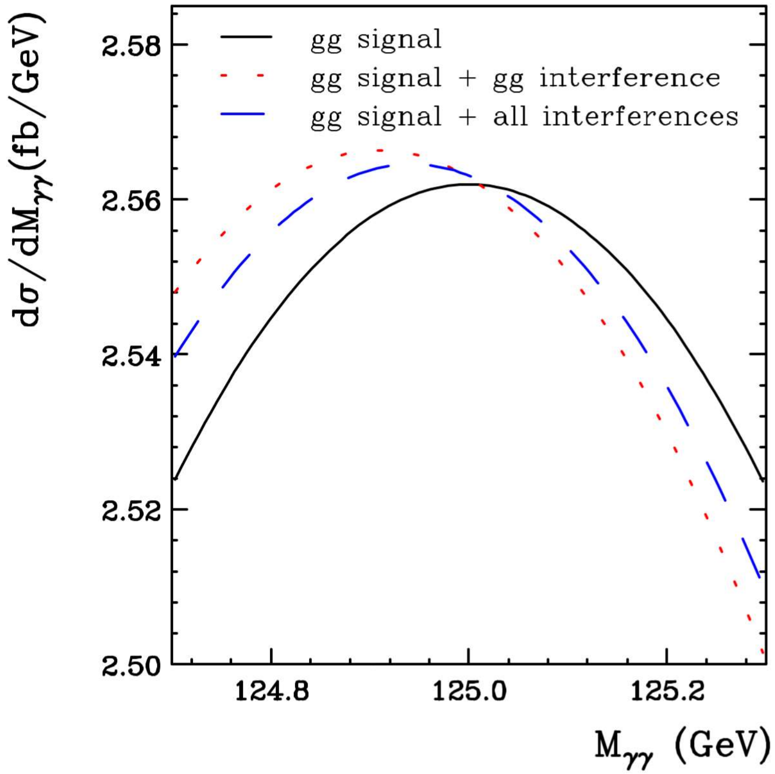
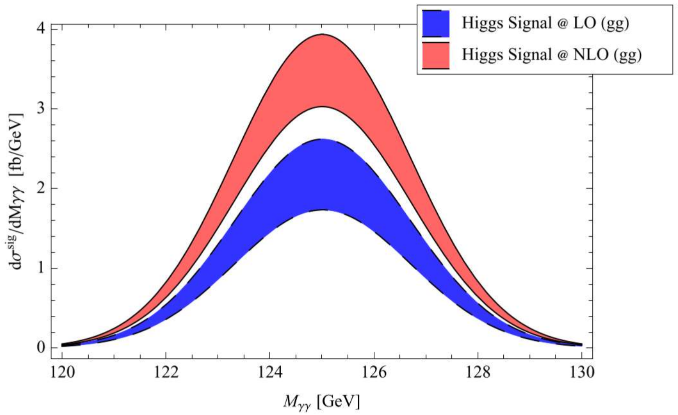
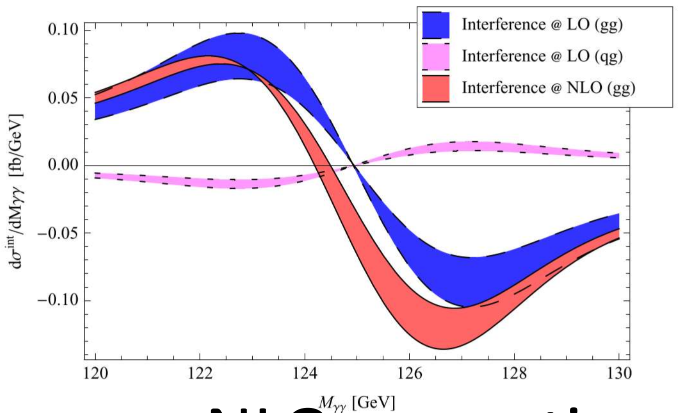


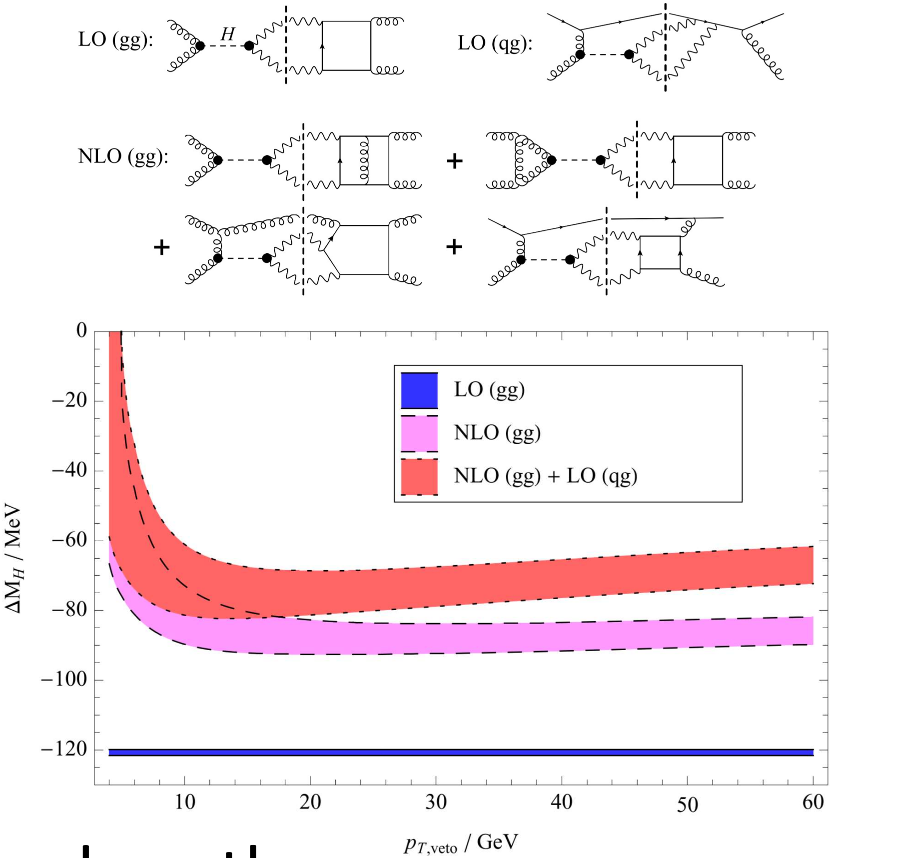


Contributions from these two channels amount up to 35% of the total interferometry at LO level.

Complete NLO calculations 1305.3854







NLO corrections reduce the mass shifts from LO by about 40%

Mass shift to bound Higgs width

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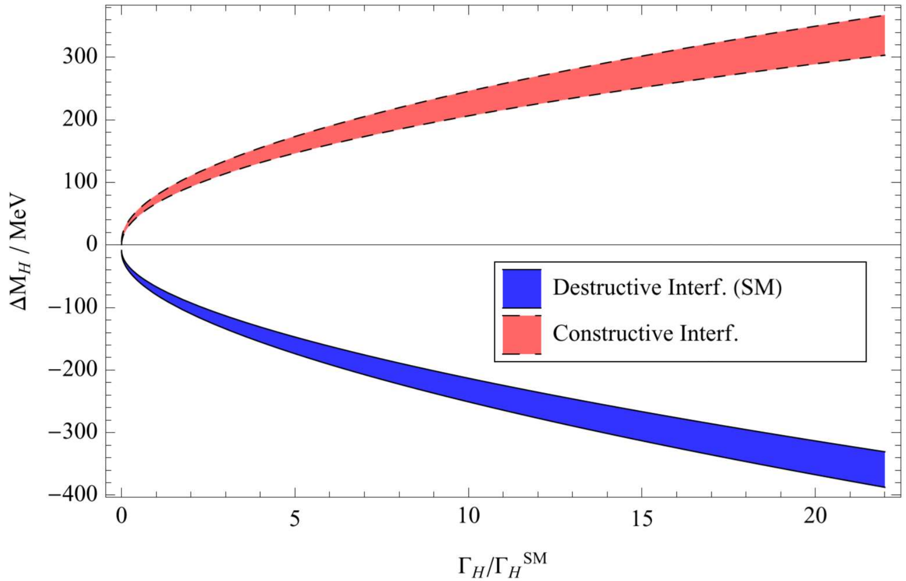
It provides a method to give a limit to higgs width



Unfortunately, at LHC,

$$m_H^{\gamma\gamma} - m_H^{ZZ} = +2.3^{+0.6}_{-0.7} \pm 0.6 \text{ GeV (ATLAS)}$$
$$= -0.4 \pm 0.7 \pm 0.6 \text{ GeV (CMS)},$$

The shift is small in the di-photon + Jet final states

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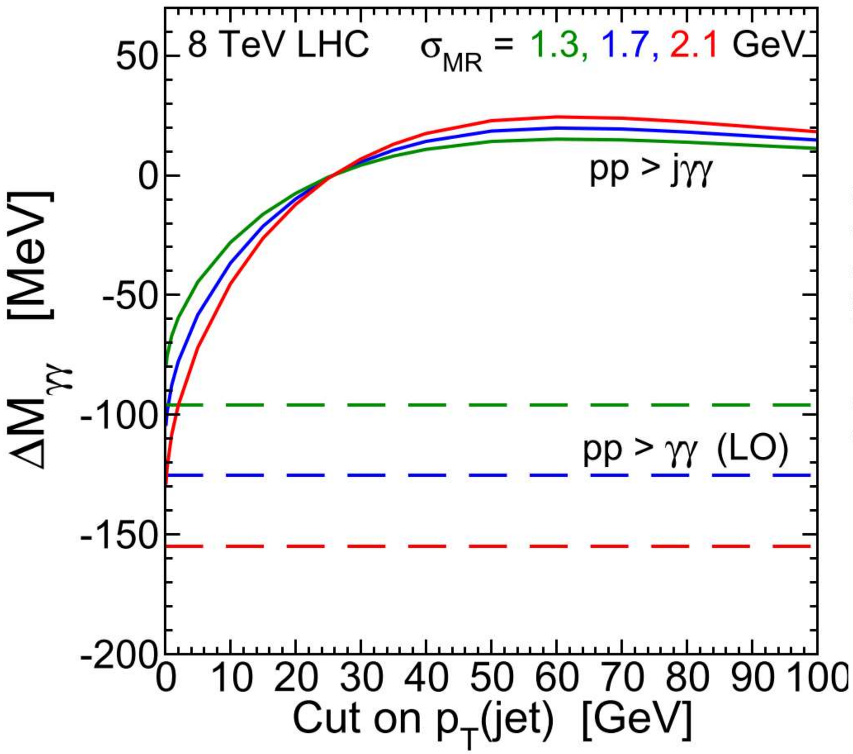

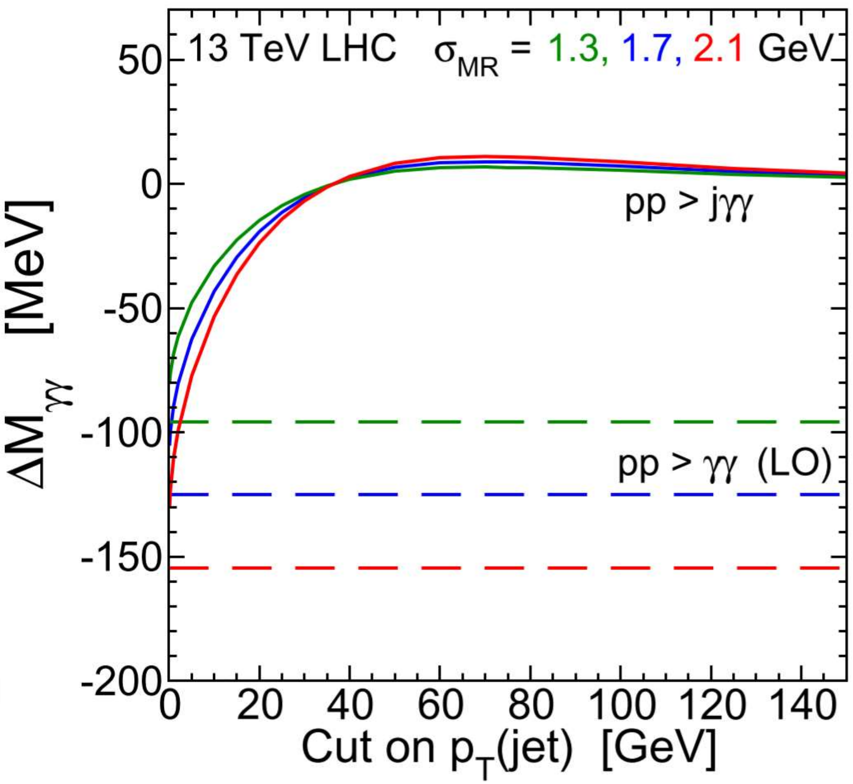

Interference effects at a photon colliders ($\gamma\gamma \to H \to b\bar{b}$ as an example)

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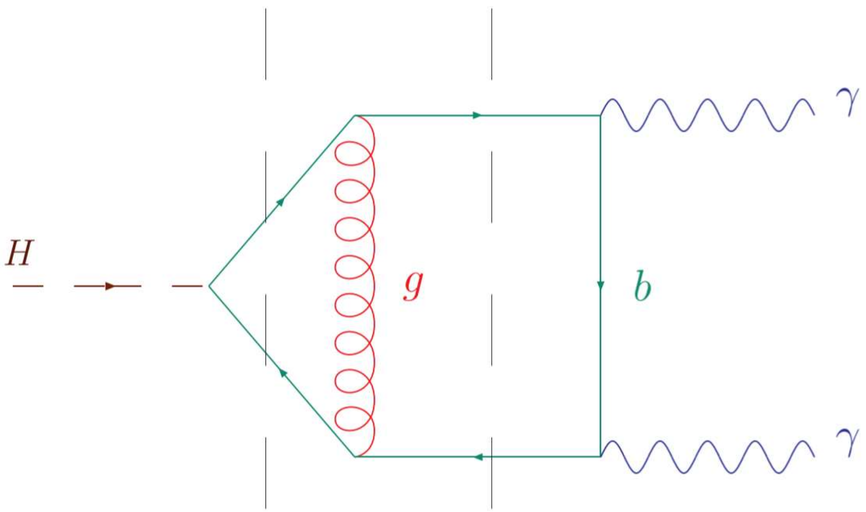
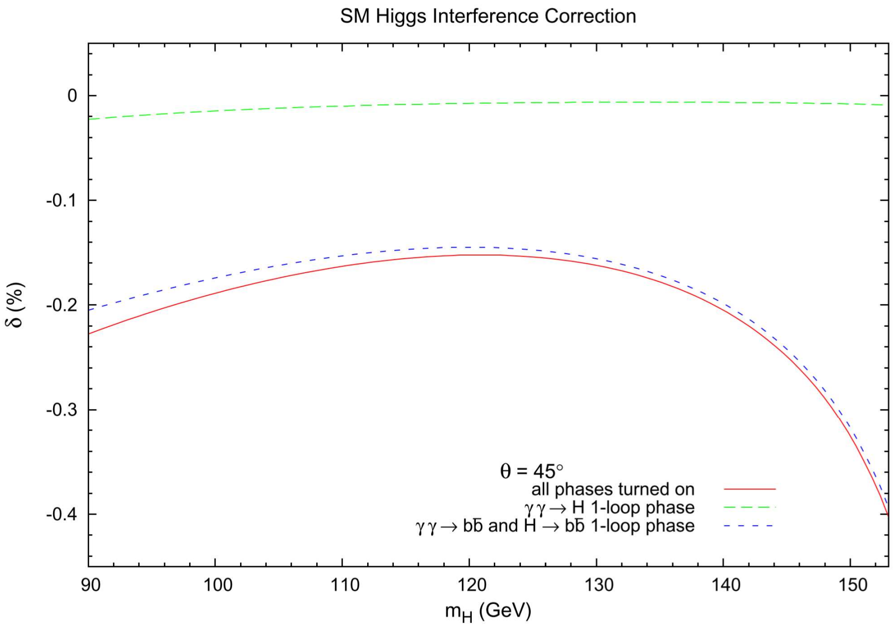
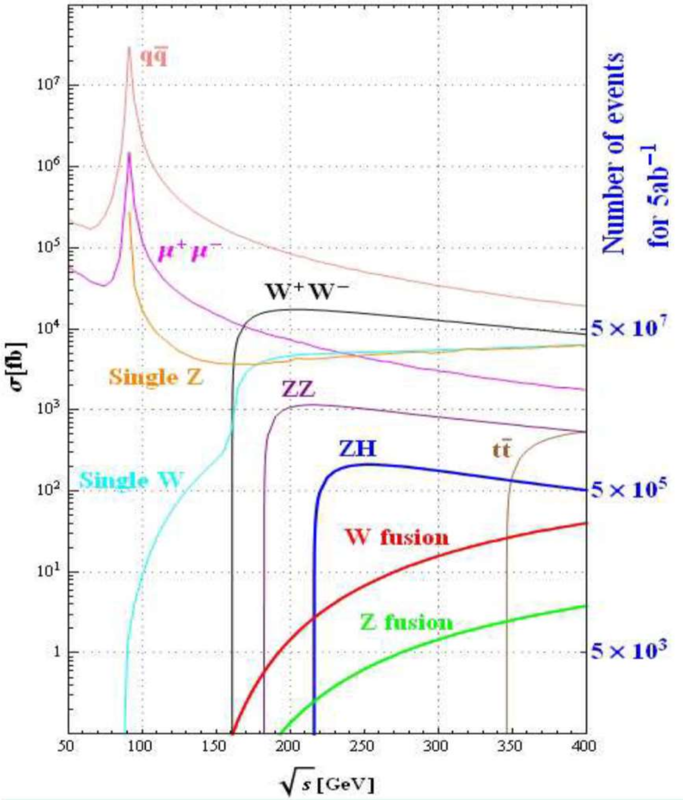




CEPC



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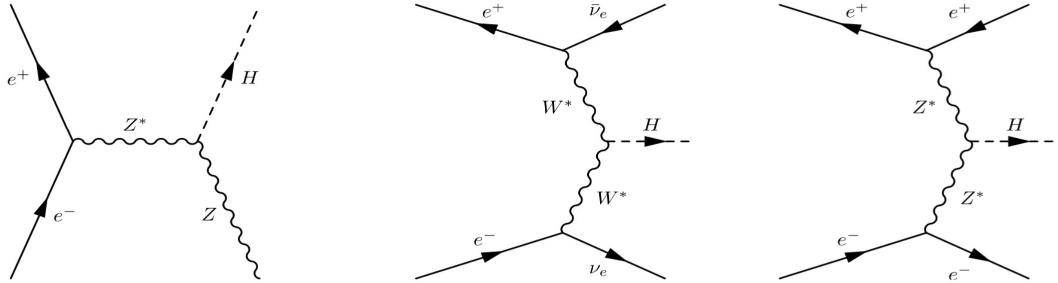

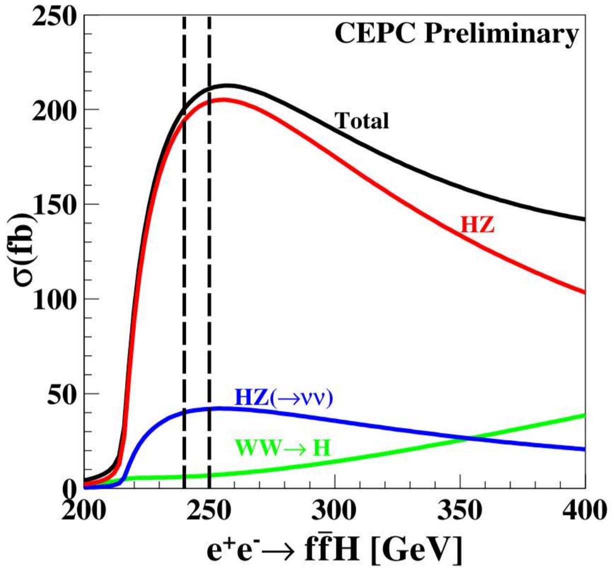

$$e^+e^- \to H(\gamma\gamma)Z$$

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Similar study at ILC

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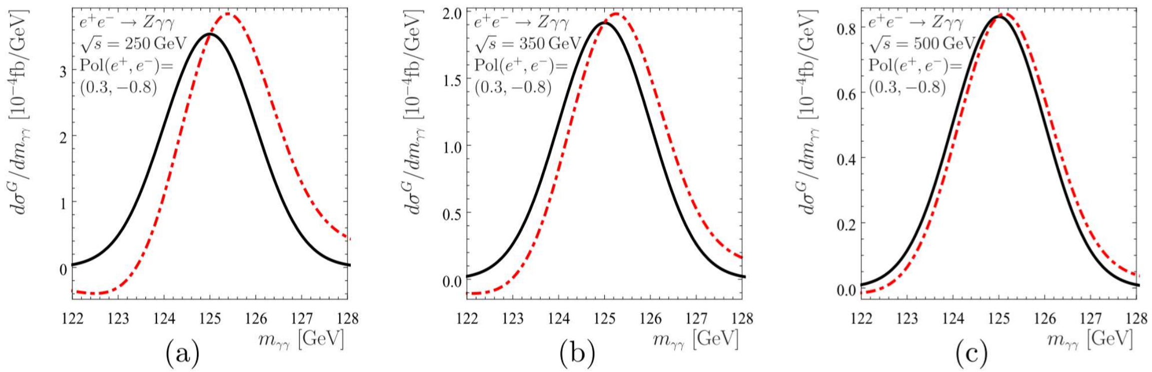
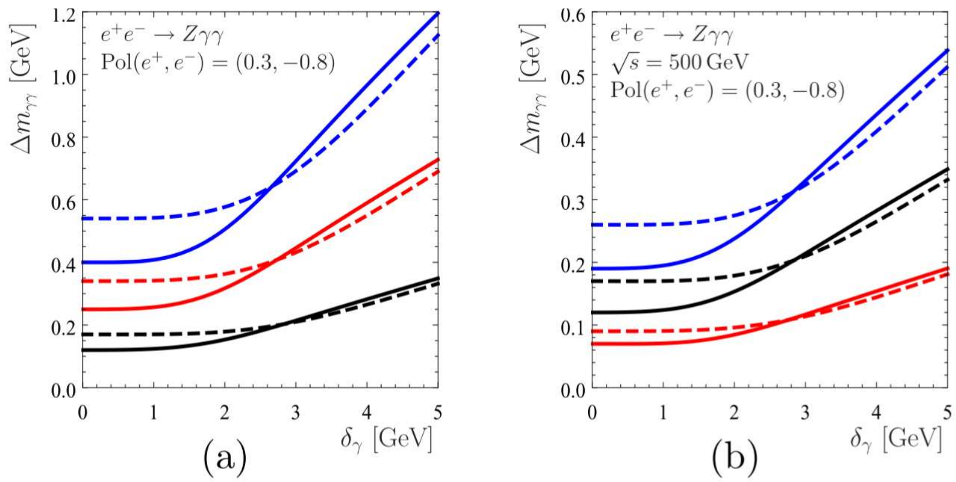
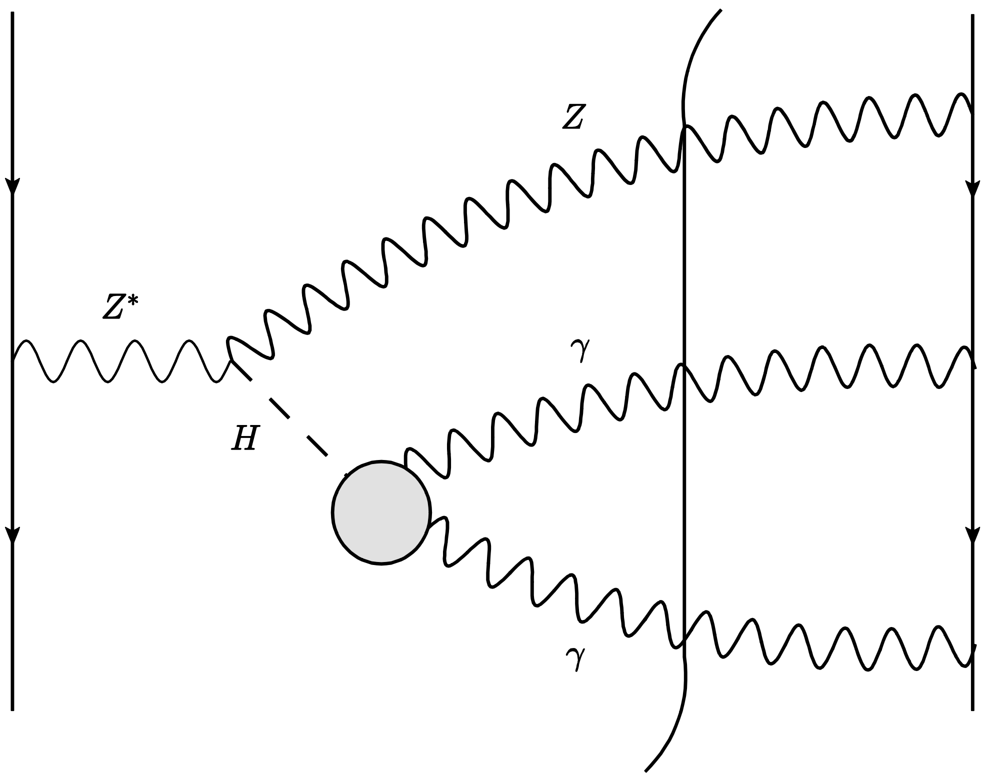




Typical diagrams for interference contribution



Calculation frame

$$\frac{\mathrm{d}\sigma^{\mathrm{sig}}}{\mathrm{d}M_{\gamma\gamma}} = \frac{\left|\mathcal{A}_{\mathrm{e^+e^-\to ZH}}\mathcal{A}_{\mathrm{H}\to\gamma\gamma}\right|^2}{(m_{\gamma\gamma}^2 - m_{\mathrm{H}}^2)^2 + m_{\mathrm{H}}^2 \Gamma_{\mathrm{H}}^2},$$

$$\frac{\mathrm{d}\sigma^{\mathrm{int}}}{\mathrm{d}M_{\gamma\gamma}} = \frac{-2(m_{\gamma\gamma}^2 - m_{\mathrm{H}}^2)R - 2m_{\mathrm{H}}\Gamma_{\mathrm{H}} I}{(m_{\gamma\gamma}^2 - m_{\mathrm{H}}^2)^2 + m_{\mathrm{H}}^2 \Gamma_{\mathrm{H}}^2},$$

Here, narrow-width approximation was adopted.

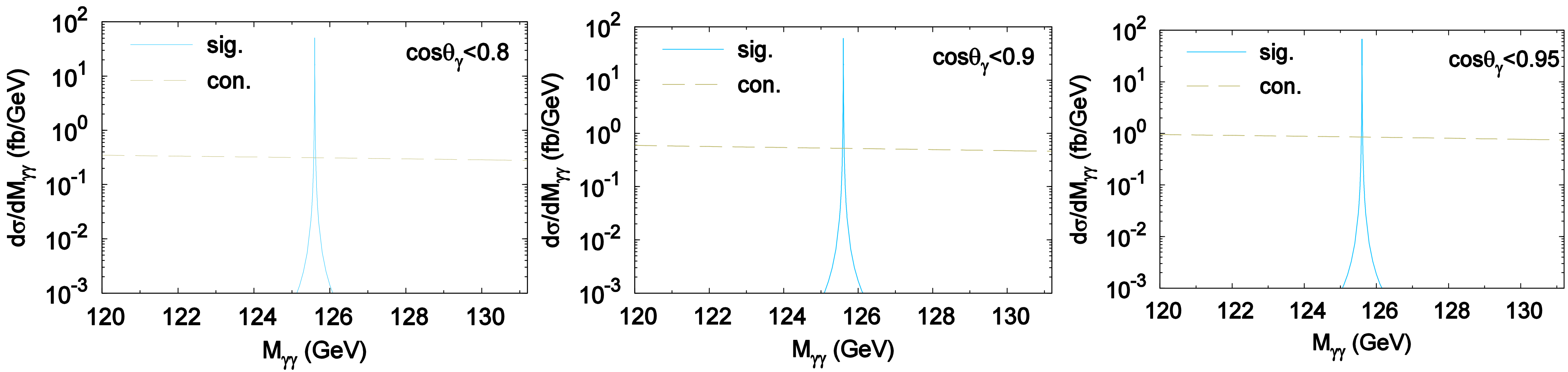
$$\frac{1}{s - m_H^2} \to \frac{1}{s - m_H^2 + i m_H \Gamma_H}$$

Higgs interaction with di-photon at one loop level

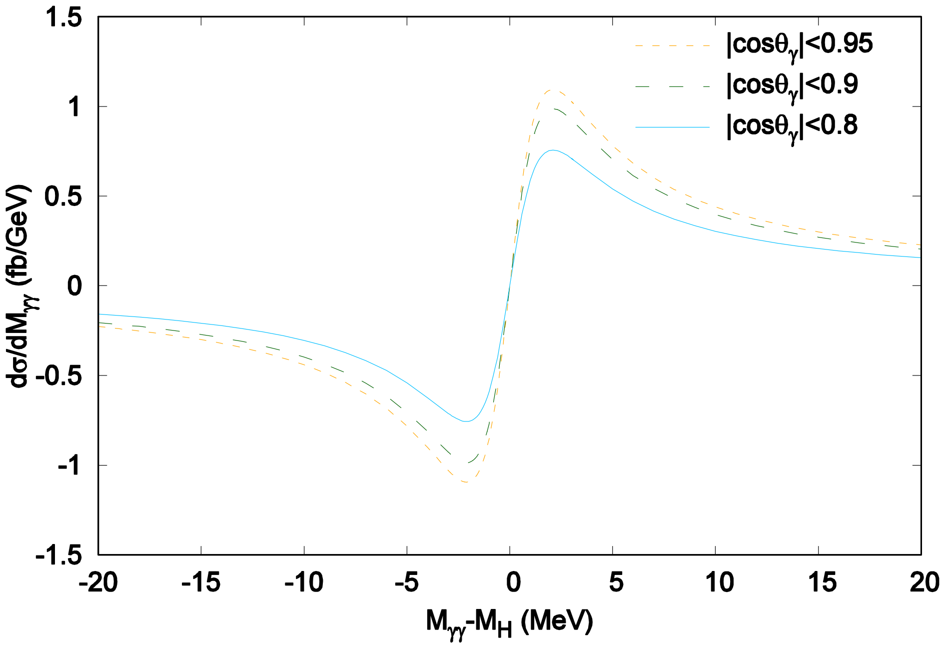
$$C_\gamma = -\frac{\alpha h}{4\pi v}\left[F_1(4m_W^2/h) + \sum_{f=t,b,c,\tau} N_c^f e_f^2 F_{1/2}(4m_f^2/h)\right]$$

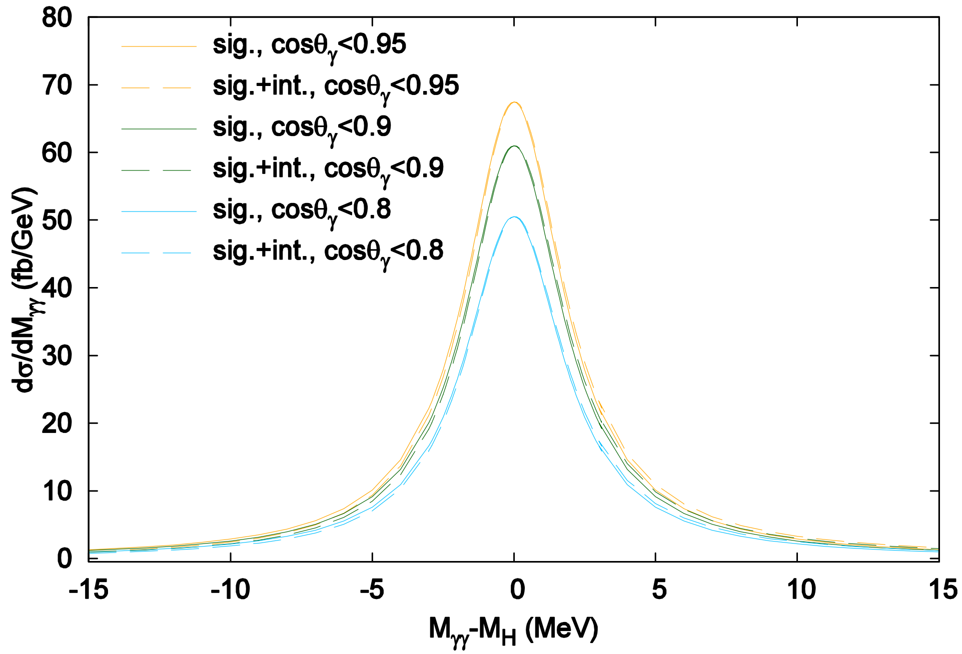
- For 1) the contributions at the three- and four-loop can be neglected in comparison with the one-loop decay rate,
- and 2) the QCD and EW corrections are nearly completely cancelled in the numerical calculations for 125 GeV Higgs.

Sensitive to the polar angle cut



Interferometry contribute little to cross sections





Smearing effects from the detector resolution

1) Convolute integrals with a Gaussian function

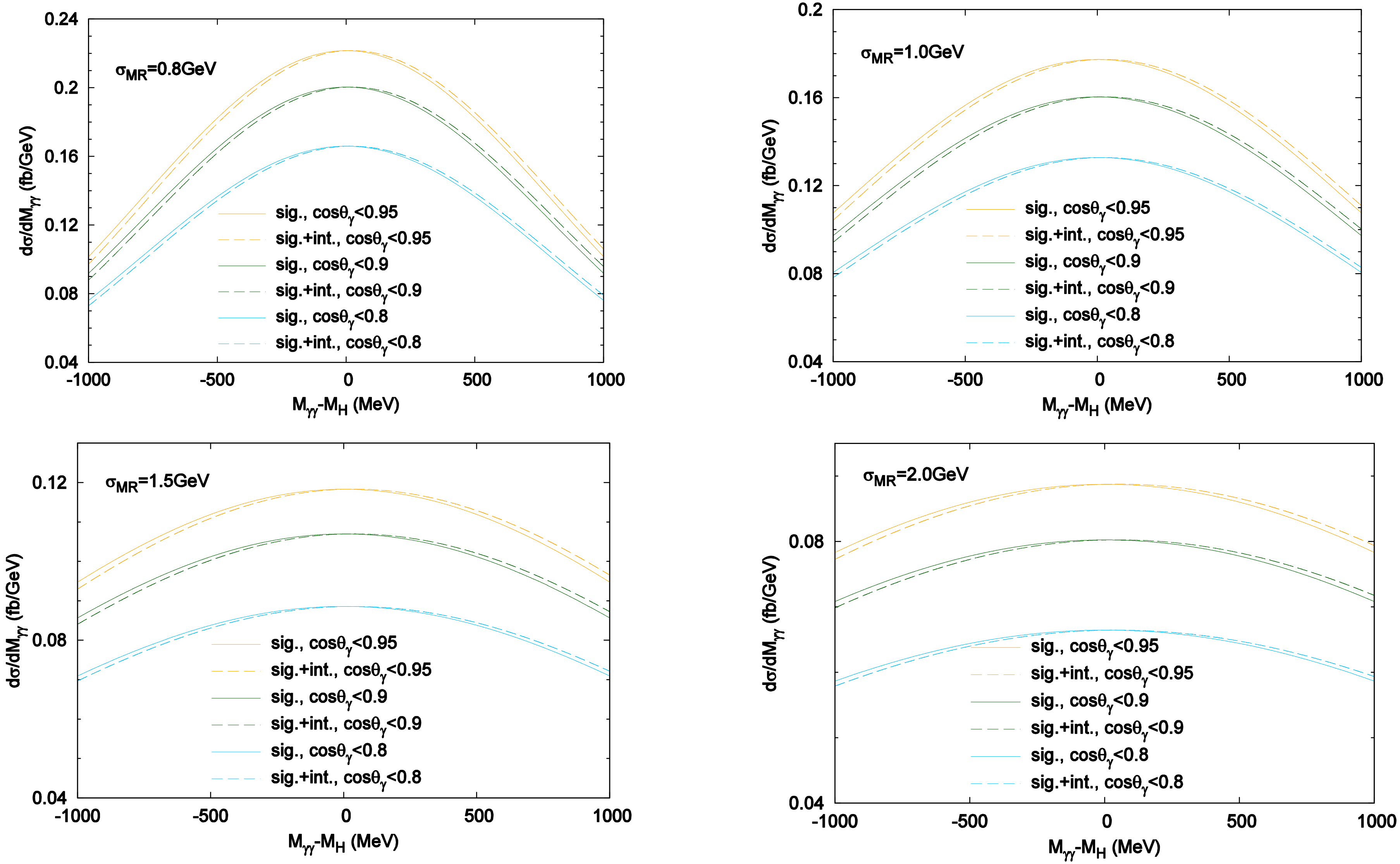
$$\frac{d\sigma}{dM_{\gamma\gamma}} = \int dM \left(\frac{d\sigma}{dM}\right) \frac{1}{\sigma_{MR}\sqrt{2\pi}} \exp\left[-\frac{(M_{\gamma\gamma}-M)^2}{2\sigma_{MR}^2}\right]$$

2) Make a least-square fit to the line shape

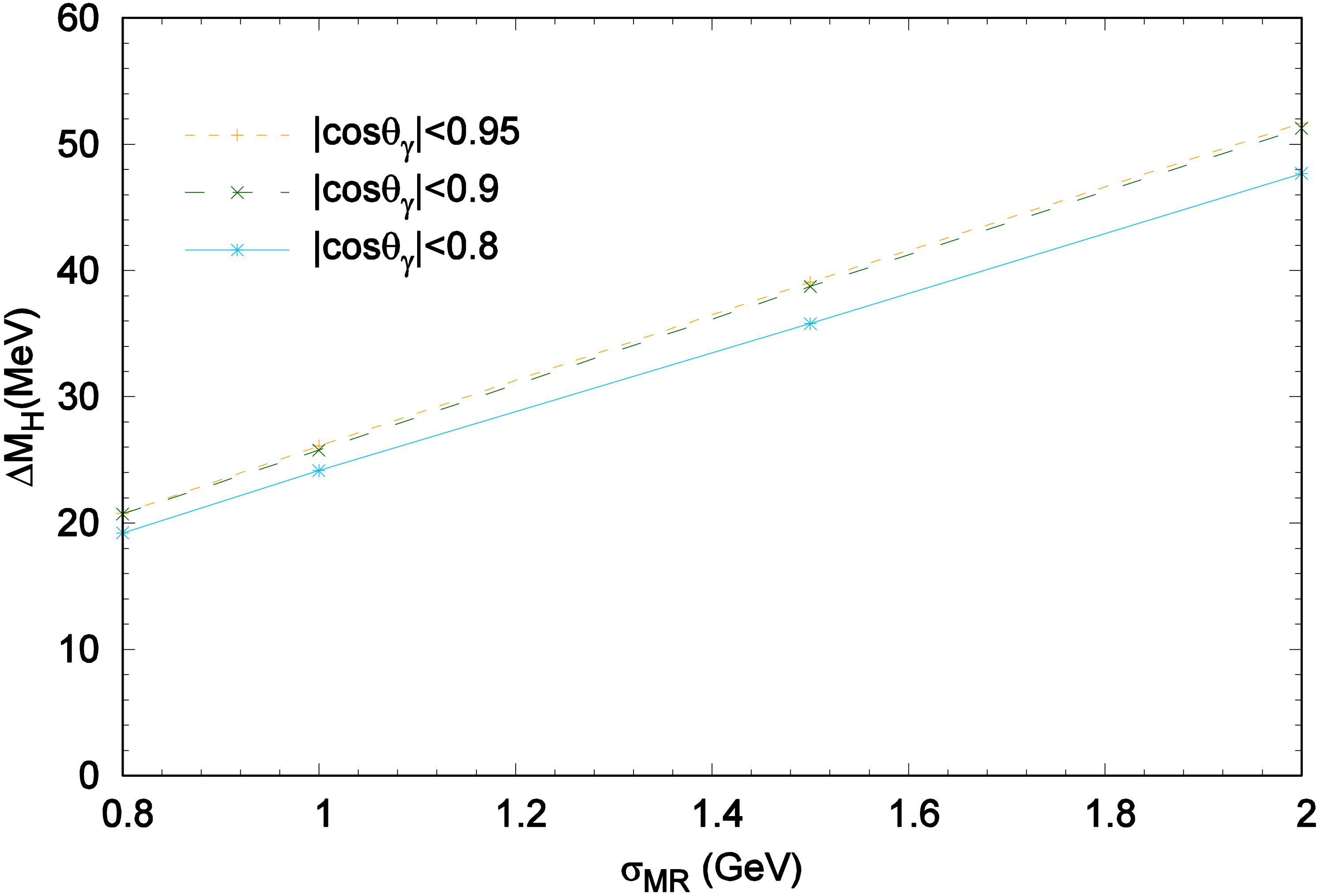
$$< M_{\gamma\gamma} >= \frac{\int dM_{\gamma\gamma}\, M_{\gamma\gamma} \left(\frac{d\sigma}{dM_{\gamma\gamma}}\right)}{\int dM_{\gamma\gamma} \left(\frac{d\sigma}{dM_{\gamma\gamma}}\right)}$$

3) The mass shift can be got as

$$\Delta M_{\gamma\gamma} =< M_{\gamma\gamma} > - M_H$$

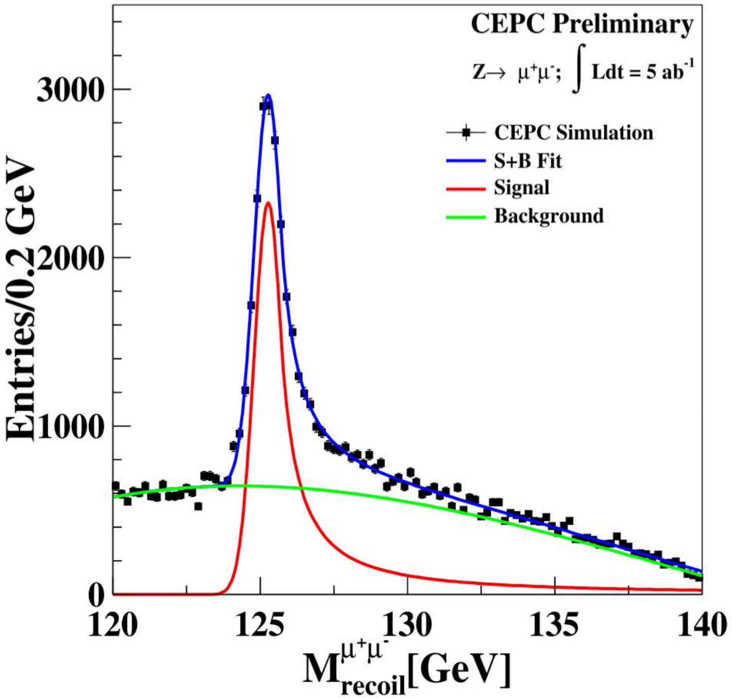


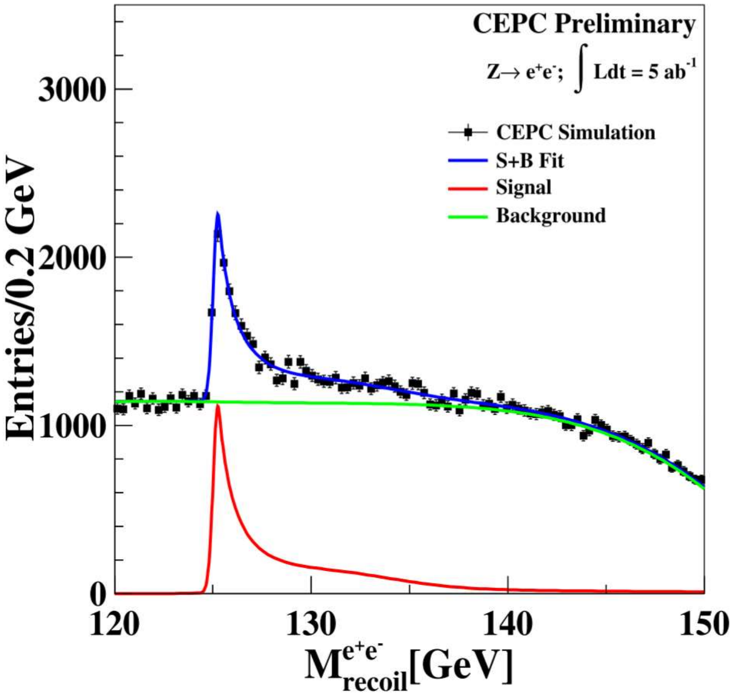
σ_{MR}=0.8GeV
σ_{MR}=1.0GeV
σ_{MR}=1.5GeV
σ_{MR}=2.0GeV
$d\sigma/dM_{\gamma\gamma}$ (fb/GeV)
$M_{\gamma\gamma}$-M_H (MeV)
sig., $\cos\theta_\gamma$<0.95
sig.+int., $\cos\theta_\gamma$<0.95
sig., $\cos\theta_\gamma$<0.9
sig.+int., $\cos\theta_\gamma$<0.9
sig., $\cos\theta_\gamma$<0.8
sig.+int., $\cos\theta_\gamma$<0.8



60
50
40
30
20
10
0
0.8
1
1.2
1.4
1.6
1.8
2
ΔM_H(MeV)
σ_MR (GeV)
|cosθ_γ|<0.95
|cosθ_γ|<0.9
|cosθ_γ|<0.8

Recoil mass method





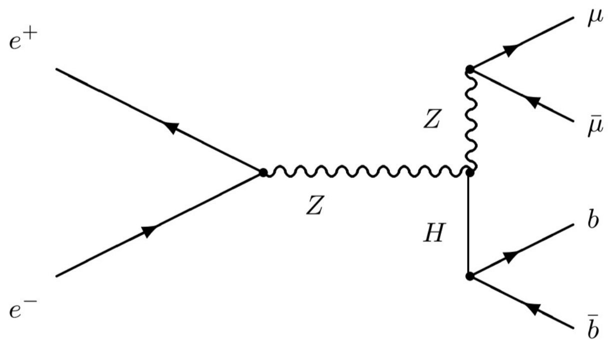
$$m^2_{\mathrm{recoil}} = (\sqrt{s} - E_{f\bar{f}})^2 - p^2_{f\bar{f}} = s - 2E_{f\bar{f}}\sqrt{s} + m^2_{f\bar{f}}$$

Measurement precisions on Higgs mass

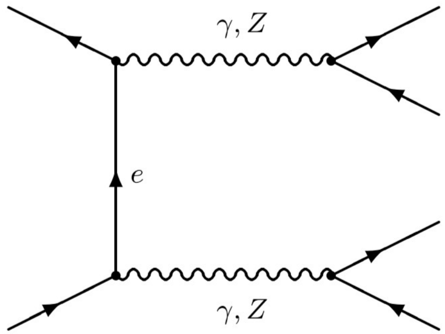
Z decay mode	ΔM_H (MeV)	$\Delta\sigma(ZH)/\sigma(ZH)$	$\Delta g(HZZ)/g(HZZ)$
ee	14	2.1%	
$\mu\mu$	6.5	0.9%	
$ee + \mu\mu$	5.9	0.8%	0.4%
$q\bar{q}$		0.65%	0.32%
$ee + \mu\mu + q\bar{q}$		0.51%	0.25%

$$e^+e^- \to H\left(b\bar{b}\right)Z(\mu^+\mu^-)$$

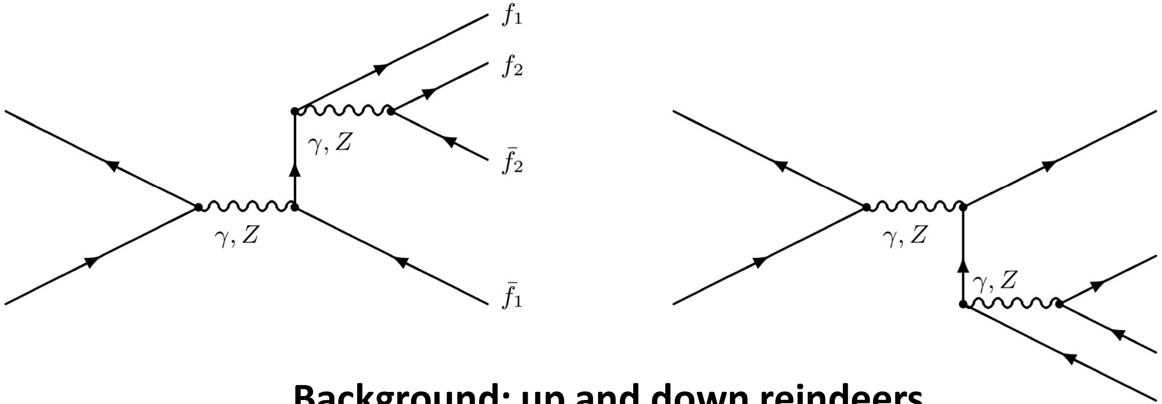
Typical diagrams from the 1+24 diagrams



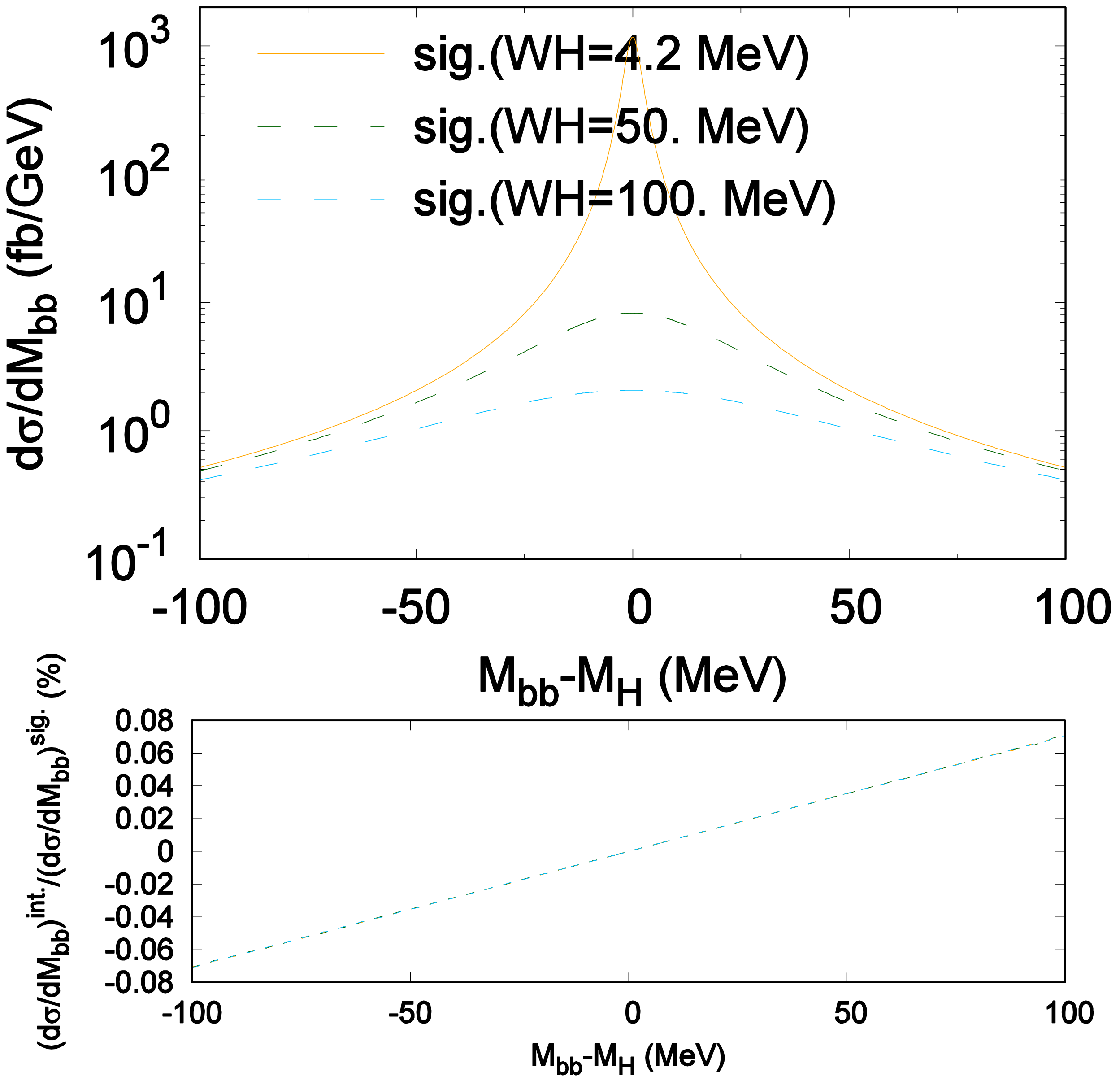
Signal: crayfish



background: crab

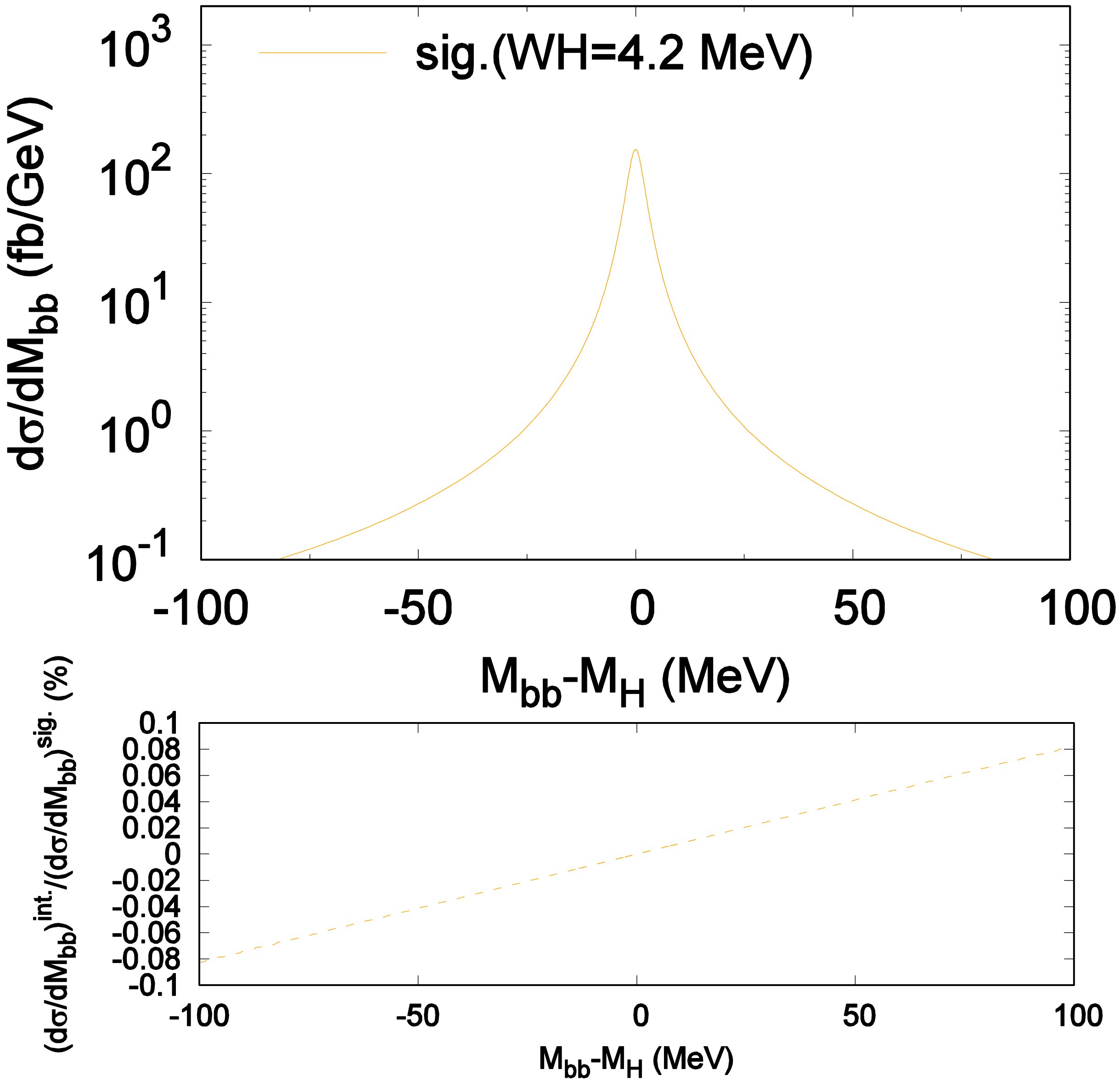


Background: up and down reindeers



sig.(WH=4.2 MeV)
sig.(WH=50. MeV)
sig.(WH=100. MeV)
dσ/dM_bb (fb/GeV)
M_bb-M_H (MeV)
(dσ/dM_bb)^int./(dσ/dM_bb)^sig. (%)
M_bb-M_H (MeV)

$$e^+e^- \rightarrow H(\tau^+\tau^-)Z(\mu^+\mu^-)$$



sig.(WH=4.2 MeV)
dσ/dM_bb (fb/GeV)
M_bb-M_H (MeV)
(dσ/dM_bb)^int./(dσ/dM_bb)^sig. (%)
M_bb-M_H (MeV)

Summary&Outlook

- $H(\gamma\gamma)Z$: Higgs mass shifts range 20~50 MeV due to interferometry in the $\gamma\gamma$ distributions. (Future, $\delta M \sim 100-200$ MeV on exp. aspect)

The NLO EW corrections for $Z\gamma\gamma$ final states enhance the LO cross sections by 2.32% with $\sqrt{s} \approx 250$ GeV at ILC[1311.7340].

So what's the effects of the NLO corrections to the mass shifts?

- $H(b\bar{b})Z(\mu^+\mu^-)$:
- $H(\tau^+\tau^-)Z(\mu^+\mu^-)$:Interference effects are zero, far less than the experimental measurement accuracy.
- $H(gg)Z(\mu^+\mu^-)$ is in processing.
- …

Thank you!