Interference effects on Higgs mass measurement in $e^+e^- \rightarrow H(\gamma\gamma)Z$ at CEPC

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Outline

- Motivation
- Interference in **$e^+e^- \to H(\gamma\gamma)Z$** processs
- Discussion on systematic uncertainty in Higgs mass measurement

What we've learned from LHC since 2012:

- Higgs-like object exists at $M_H \approx 125$ GeV
- It looks consistent with Standard Model Higgs
- No significant sign of new physics associated the EWSB sector

Therefore, it is sensible to assume that this is indeed the Standard Model Higgs, and nothing more?

Several programs have already begun or been proposed to learn about the couplings of H to other Standard Model states through its production and decays, such as HL-LHC, ILC, FCC-ee, and CEPC

Clearly, we also want to know M_H as accurately as possible.

- The last parameter in the (old) Standard Model
- Enters into precision EW fits
- Stability of the Standard Model vacuum
- Standard candle for future work (new physics decaying to H?)
- The Higgs branching ratios are sensitive to its mass

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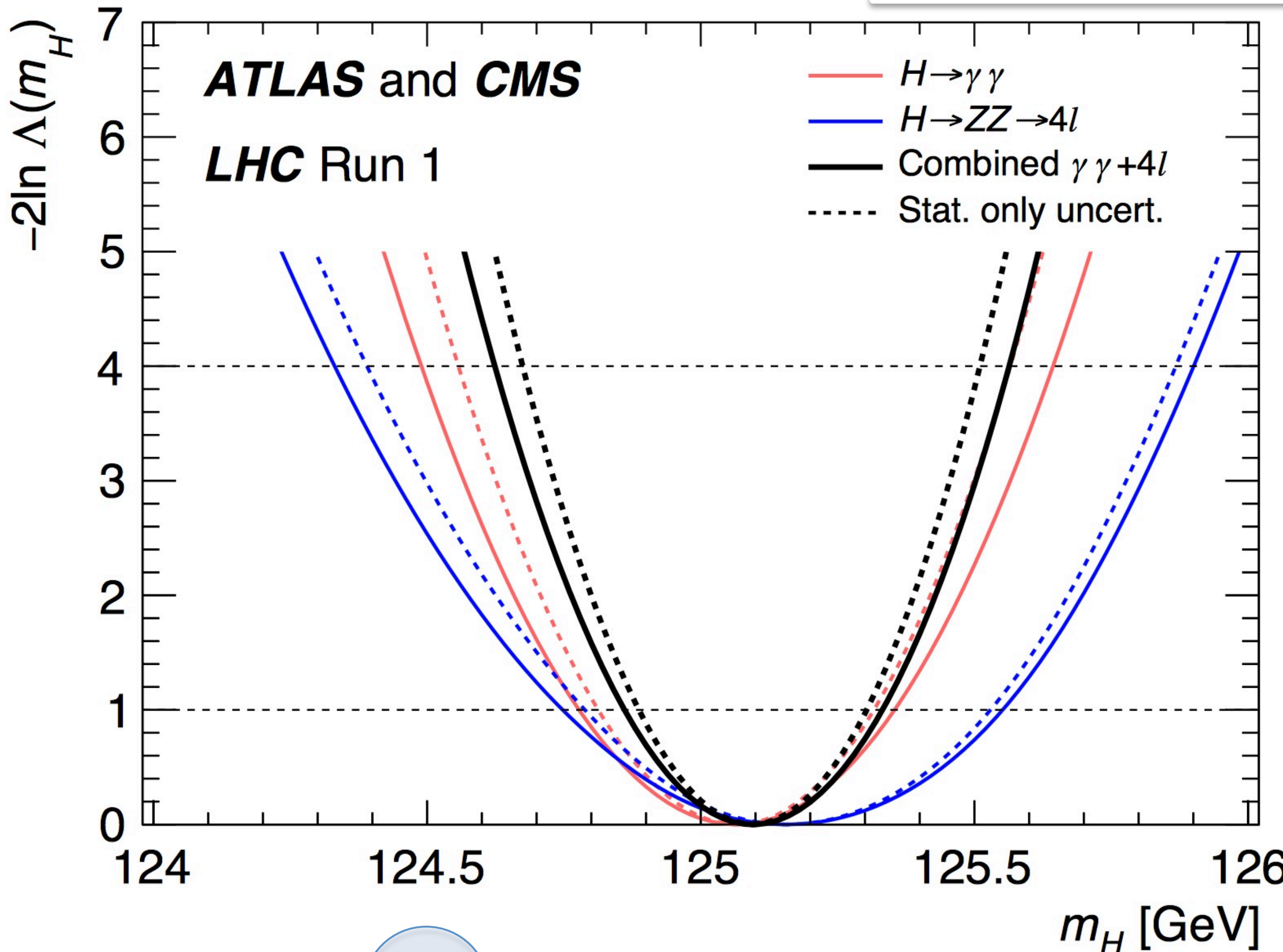
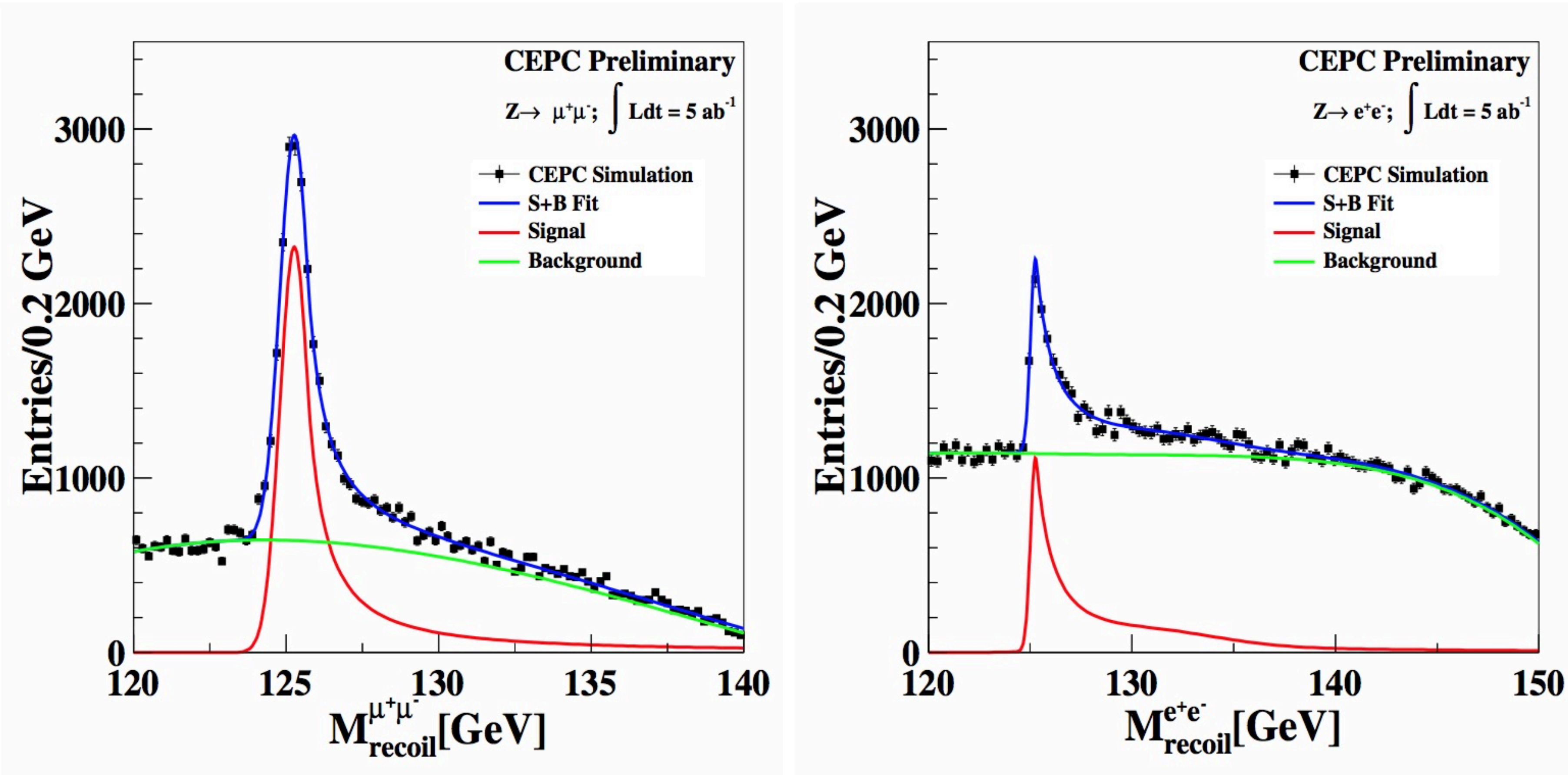


$$m_H = 125.09 \pm 0.24 \text{ GeV}$$

$$= 125.09 \pm 0.21\,(\text{stat.}) \pm 0.11\,(\text{syst.})\ \text{GeV}$$

~0.006GeV at CEPC

Goal in CEPC preCDR: ~6MeV



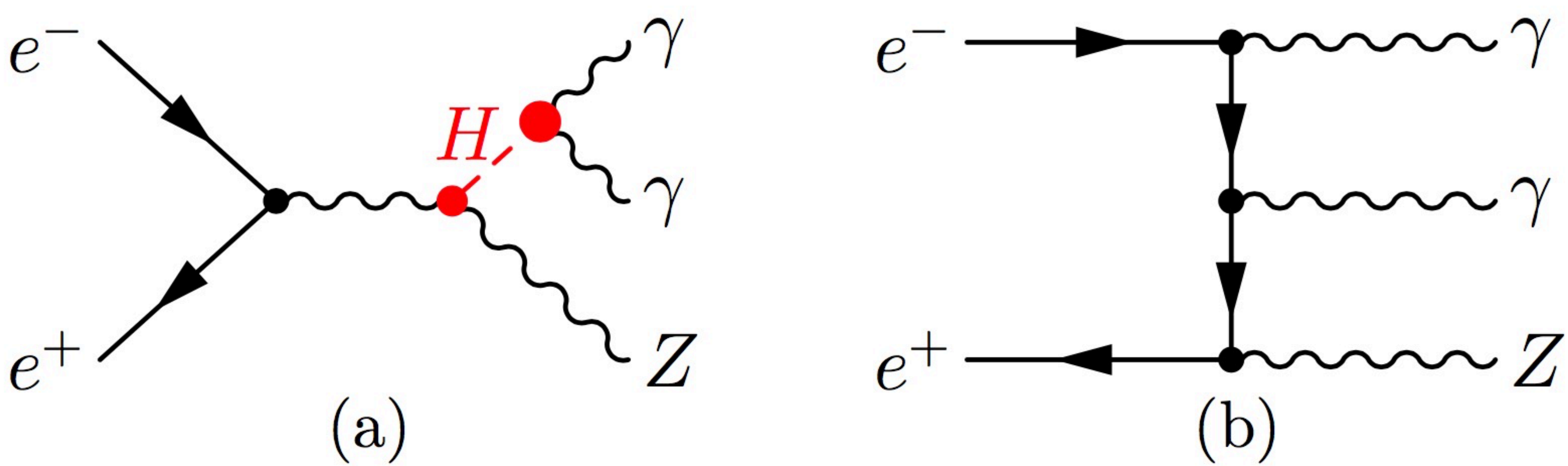
Fit to the ee/μμ recoil mass spectra: only experimental uncertainties

Let's take a simple example

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

arXiv:1503.07830
arXiv:1505.06981

Feynman diagrams at ee collider



The ISR Z-return is the dominant background in experiment, it also causes the theoretical uncertainty through interference

For most cases except the interference effect: narrow width approximation adopted

$$\frac{1}{(s-M_H^2)^2+M_H^2\Gamma_H^2}=\frac{\pi}{M_H\Gamma_h}\delta(s-M_H^2)$$

Because $\Gamma_H \approx 4.2$ MeV $\approx (3.4\times10^{-5})M_H$, this is usually fine.

The cross section can be parameterized as

$$\frac{d\sigma_{ee\to Z\gamma\gamma+ZH(\gamma\gamma)}}{dm} = C(m) + \frac{1}{D(m)}[S(m) + (m^2 - \Gamma^2)I(m)]$$

Where

m = the diphoton invariant mass

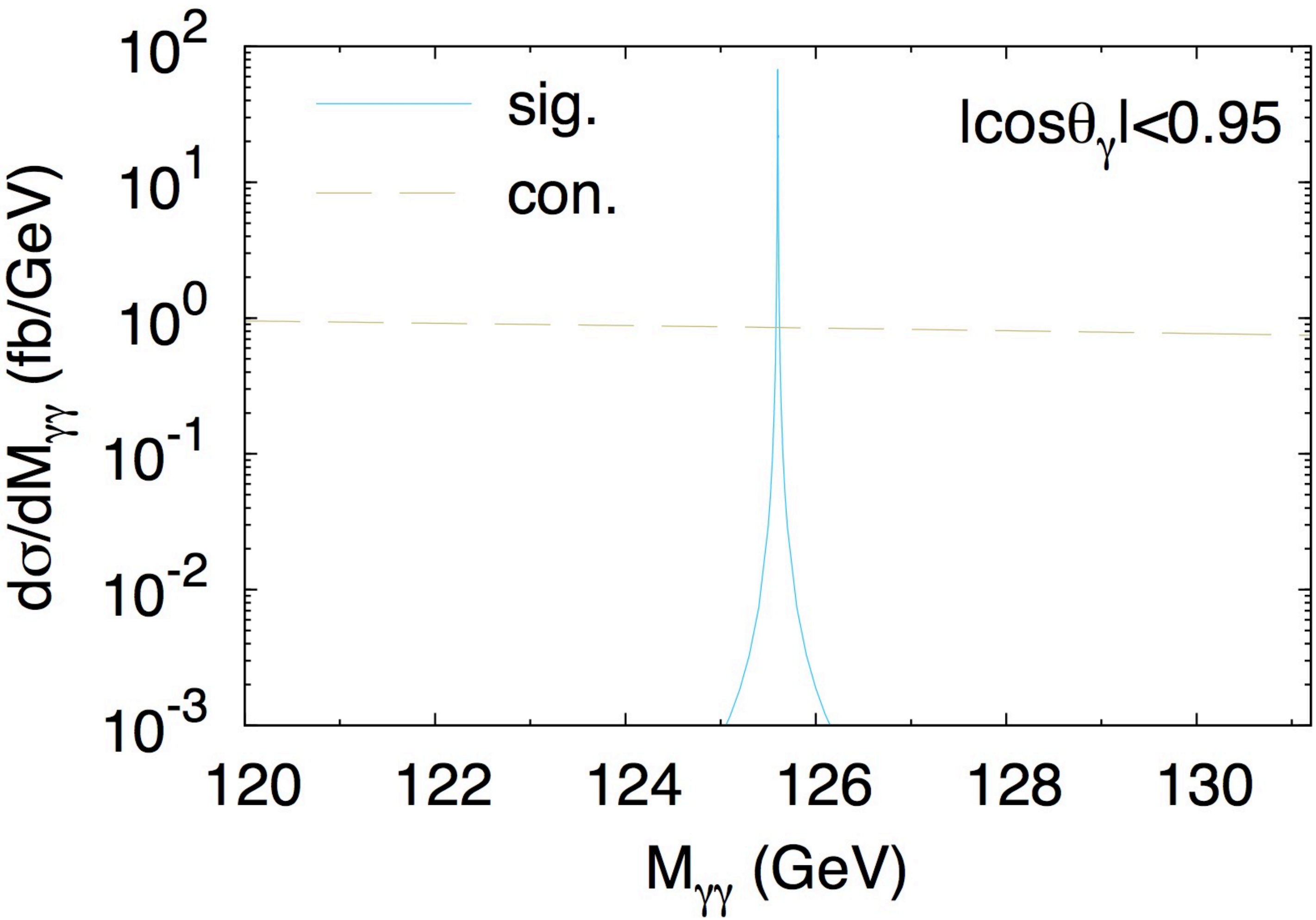
D(m) = $(m^2 - M_H^2)^2 + M_H^2\,\Gamma^2_H$

C(m) = background

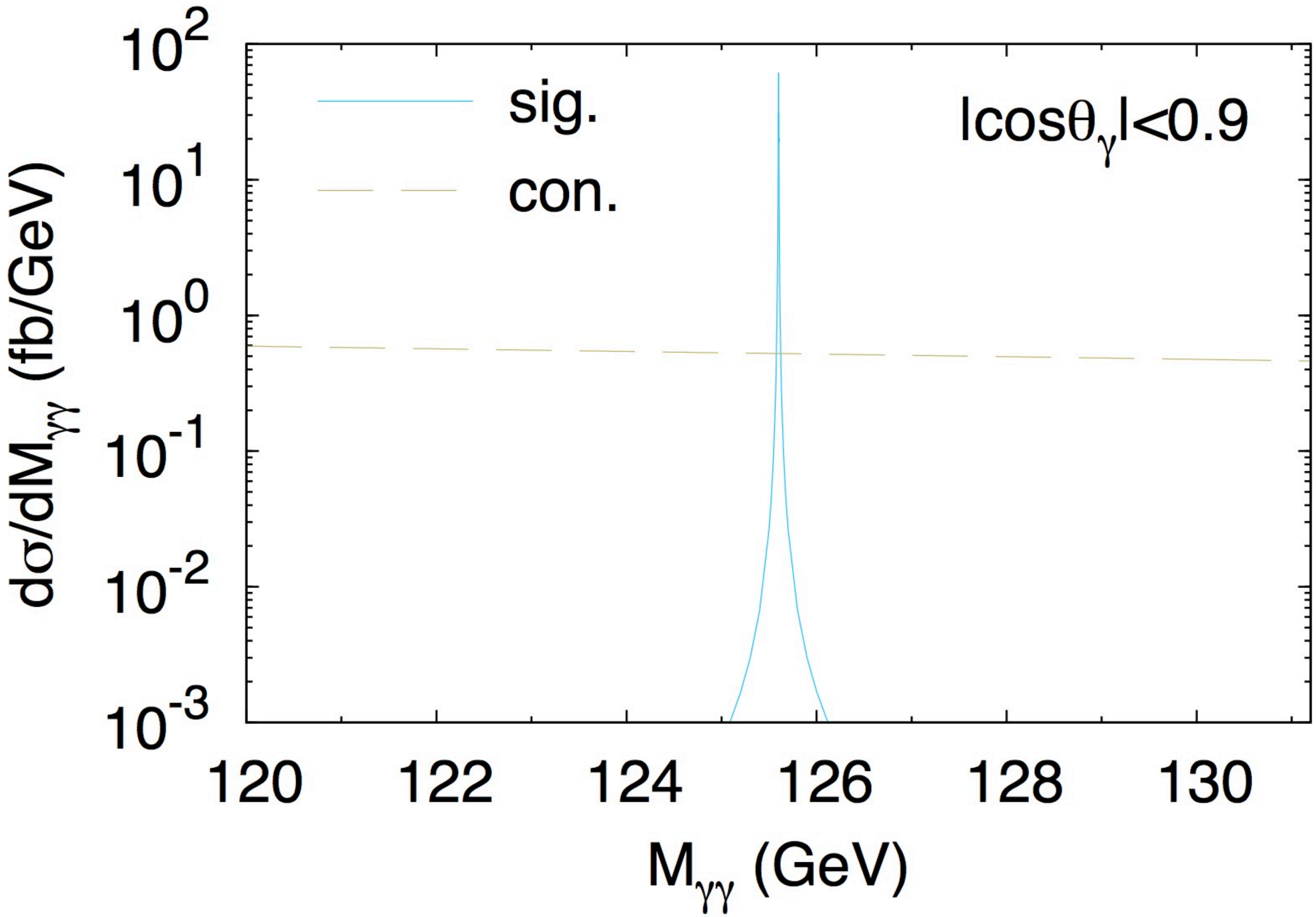
S(m) = signal (with small contribution from interference)

I(m) = pure interference term

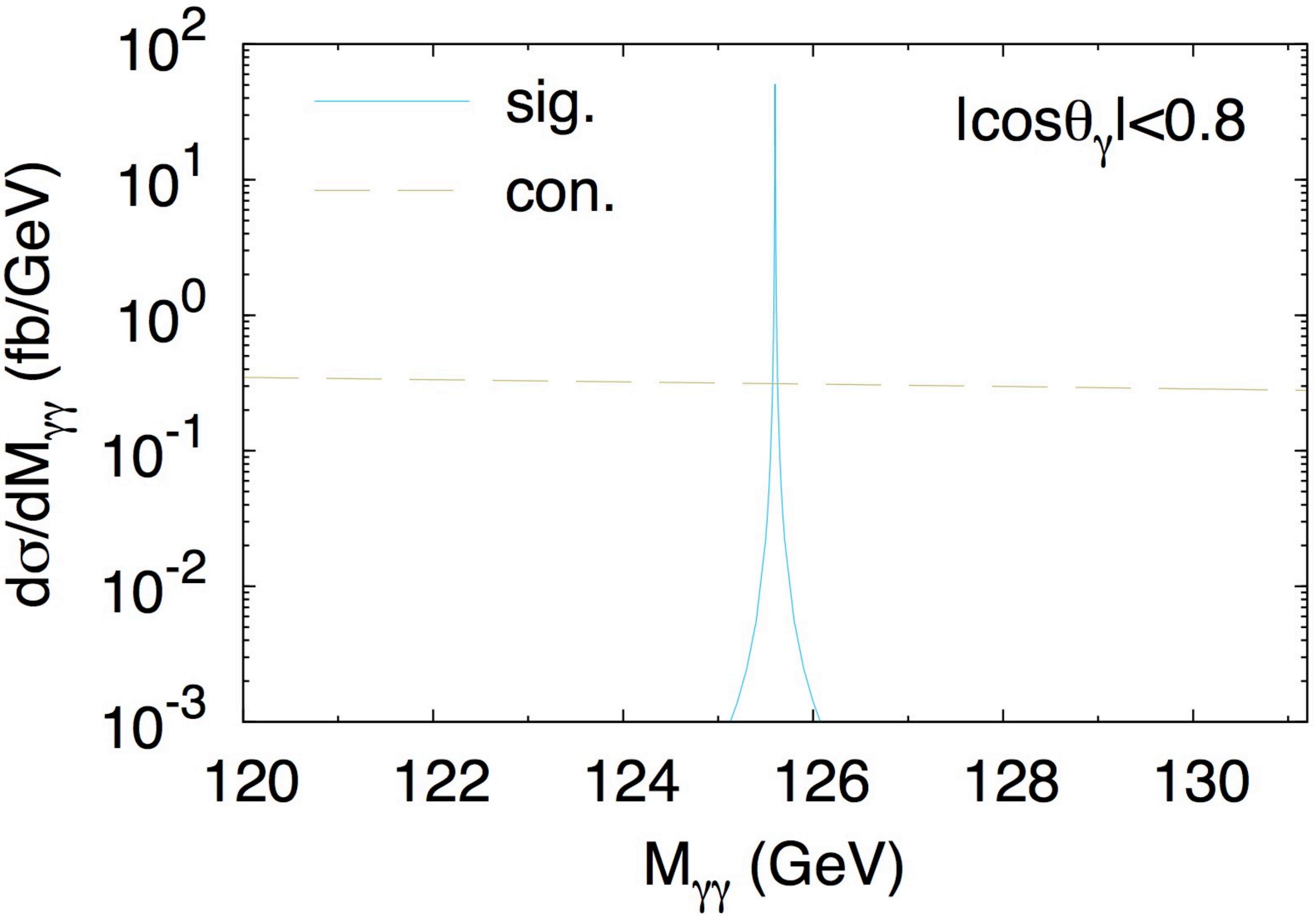
ee→ Z γγ sensitive to the polar angle cut

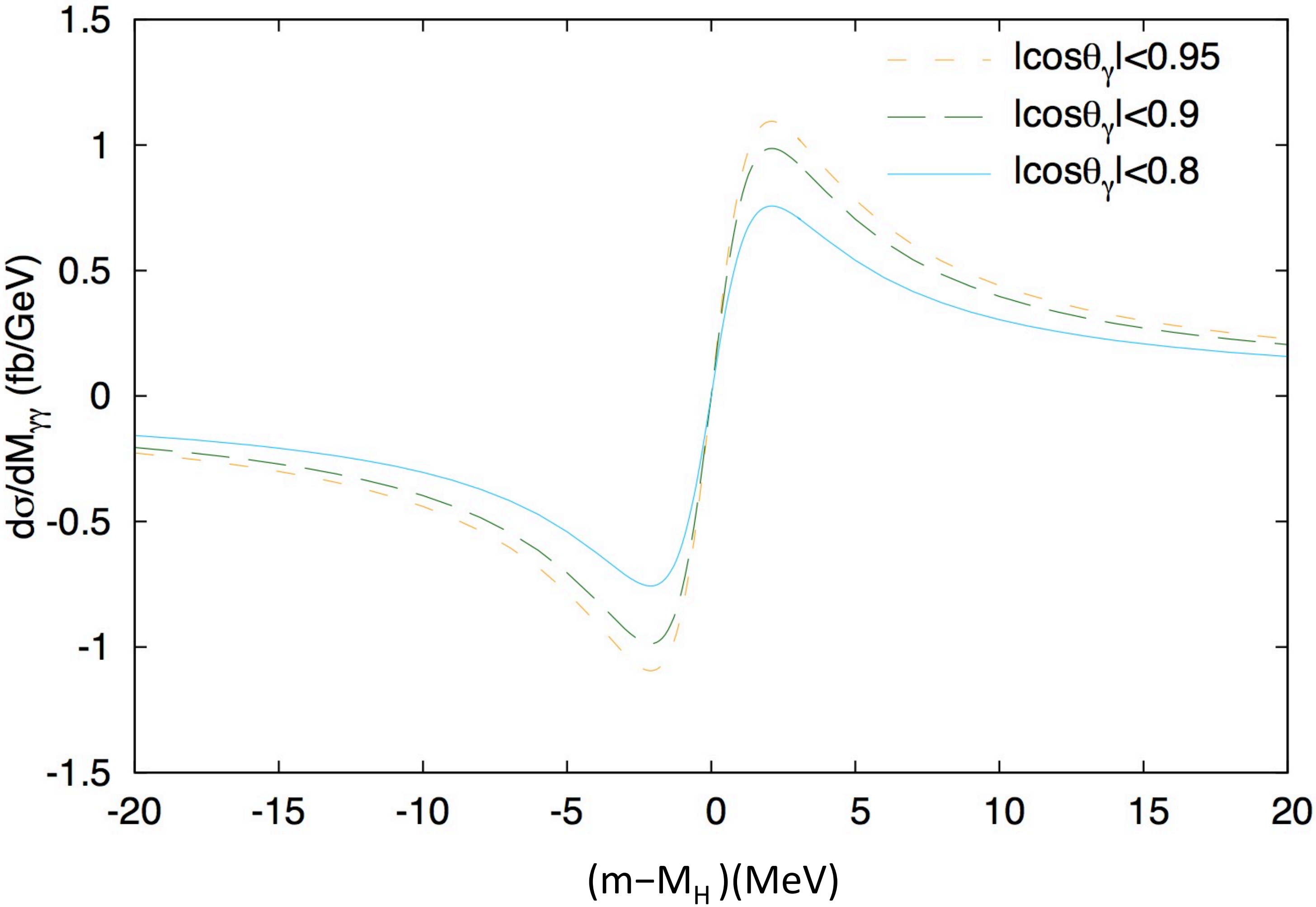


ee→ Z γγ sensitive to the polar angle cut

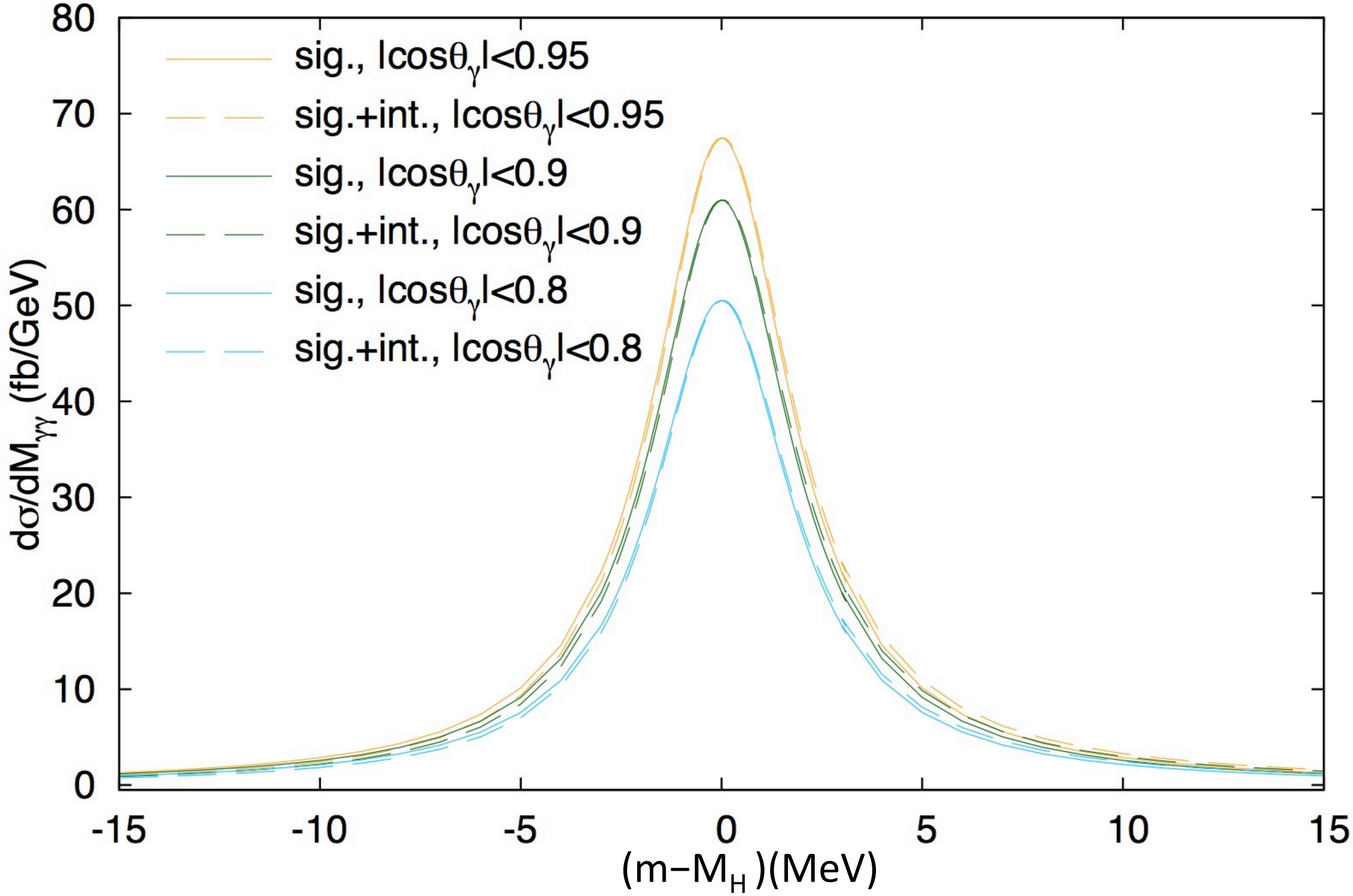


ee→ Z γγ sensitive to the polar angle cut



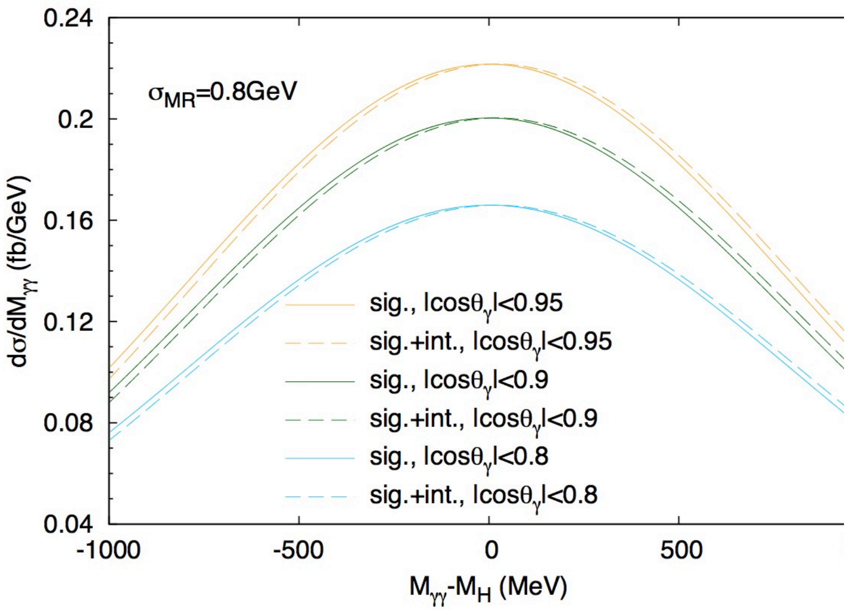


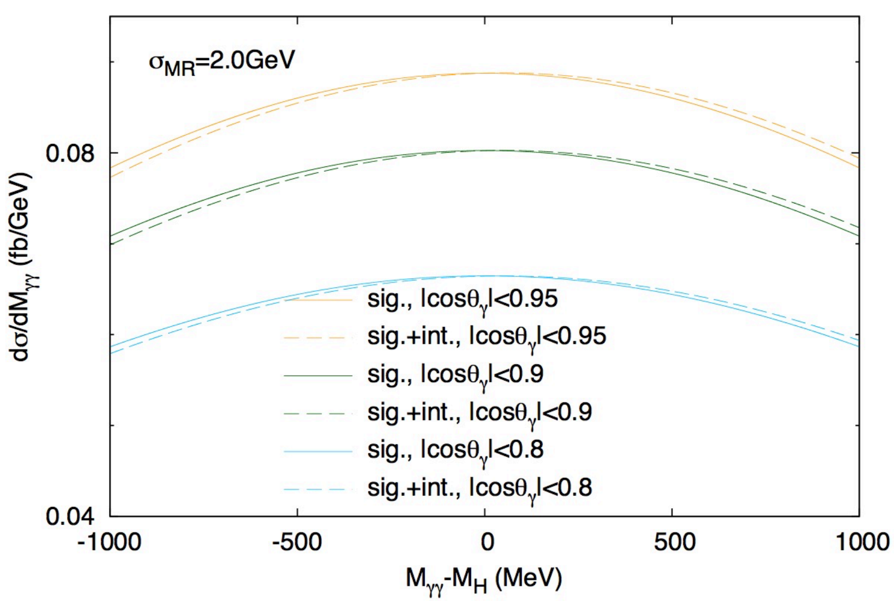
|cosθ$_\gamma$|<0.95
|cosθ$_\gamma$|<0.9
|cosθ$_\gamma$|<0.8
dσ/dM$_{\gamma\gamma}$ (fb/GeV)
1.5
1
0.5
0
-0.5
-1
-1.5
-20
-15
-10
-5
0
5
10
15
20
(m−M$_H$)(MeV)



sig., |cosθγ|<0.95
sig.+int., |cosθγ|<0.95
sig., |cosθγ|<0.9
sig.+int., |cosθγ|<0.9
sig., |cosθγ|<0.8
sig.+int., |cosθγ|<0.8
dσ/dMγγ (fb/GeV)
(m−MH)(MeV)
80
70
60
50
40
30
20
10
0
-15
-10
-5
0
5
10
15

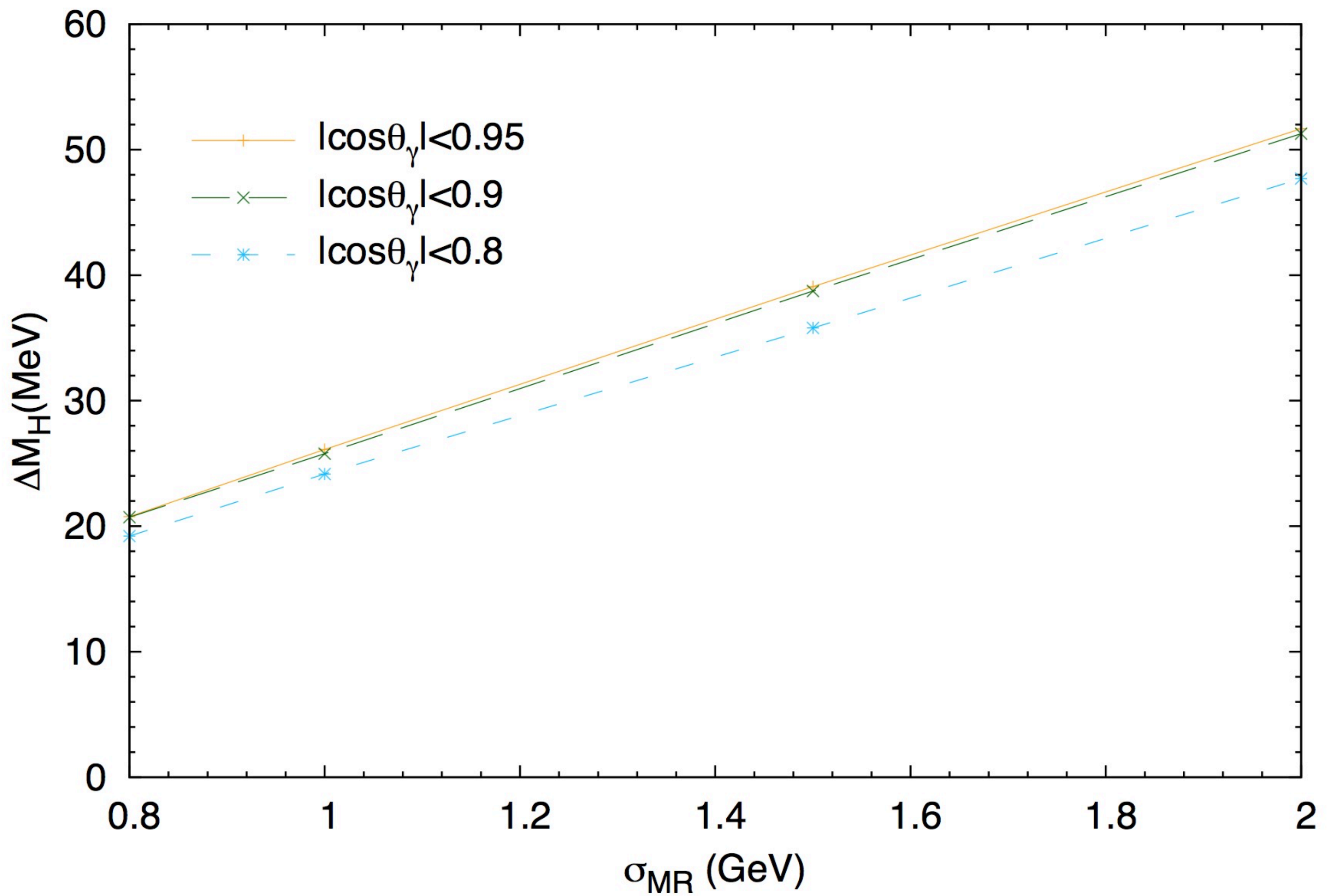
A Gaussian used to model the detector resolution, varying from 0.8-2.0GeV





Sizeable shift observed and increases with resolution

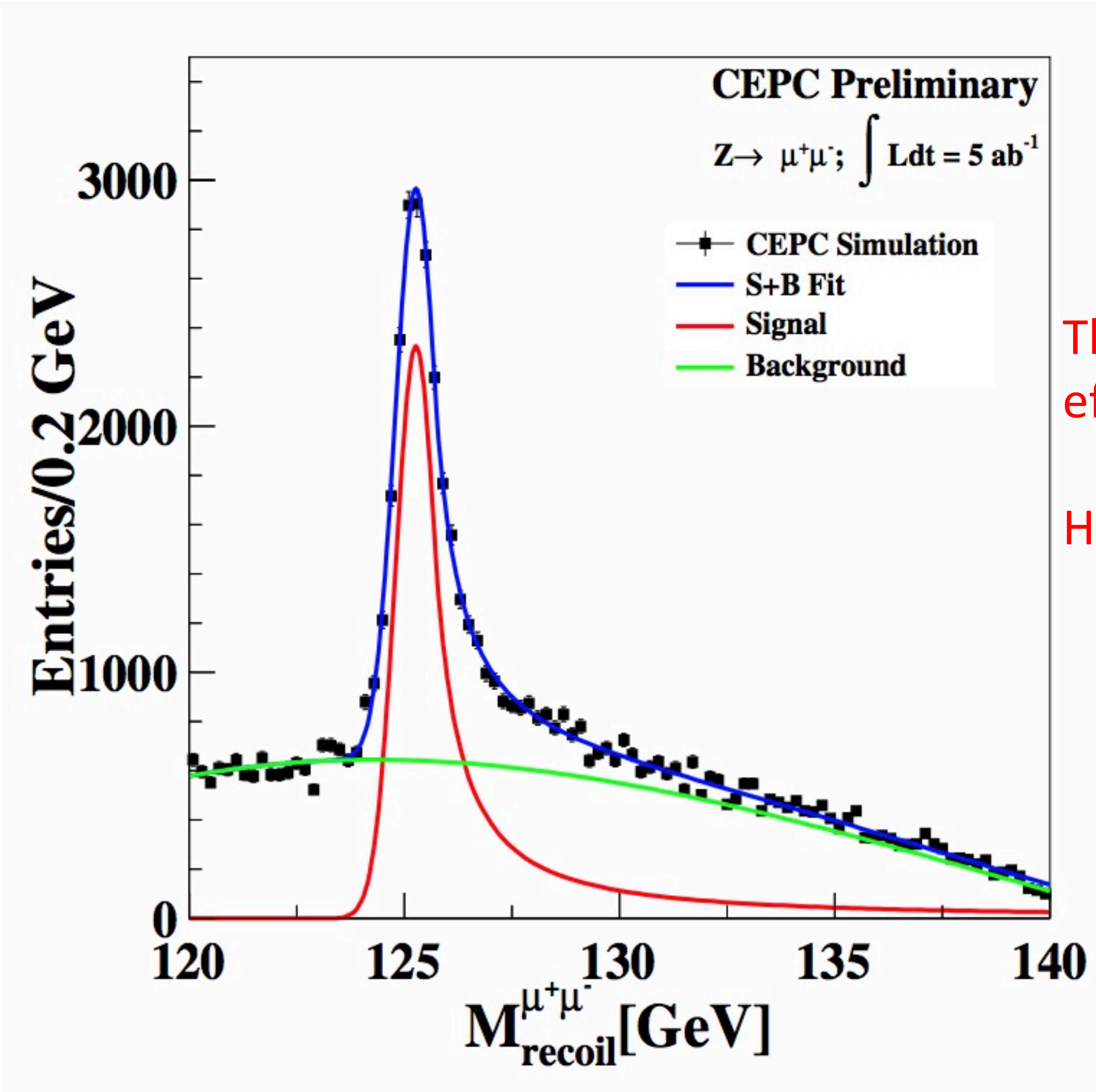
The detector resolution affects the mass shift



Discussion on $H \rightarrow \gamma\gamma$

- δM ~ 50MeV due to interference when σ=2GeV
- Bad resolution amplifies the shift
- Polar angle cut reduces the background level, so does the mass shift of Higgs
- The B($H \rightarrow \gamma\gamma$)~0.23%, less than 1000 can be selected for the further Higgs mass measurement → δM=100−200MeV.
- Interference effect not a urgent issue here. If LX10 or more?
- But in case of the model independent measurement : ee and $\mu\mu$ recoil mass

μμ chanel:22K signals, δM=6.5MeV



The potential interference effect not been considered yet …

How?

Summary

- Precision mass measurement is important to Higgs study and to new physics
- The interference effect has to be taken into account when M_H is measured with di-photon final state when statistics increase
- The same effect should be evaluated carefully in cases of O(10MeV) precision