Study of HγZ coupling using e+e- -> γ H at the ILC

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Outline

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2. Theoretical framework
3. Experimental method
4. Simulation framework
5. Event selection
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1.Motivation

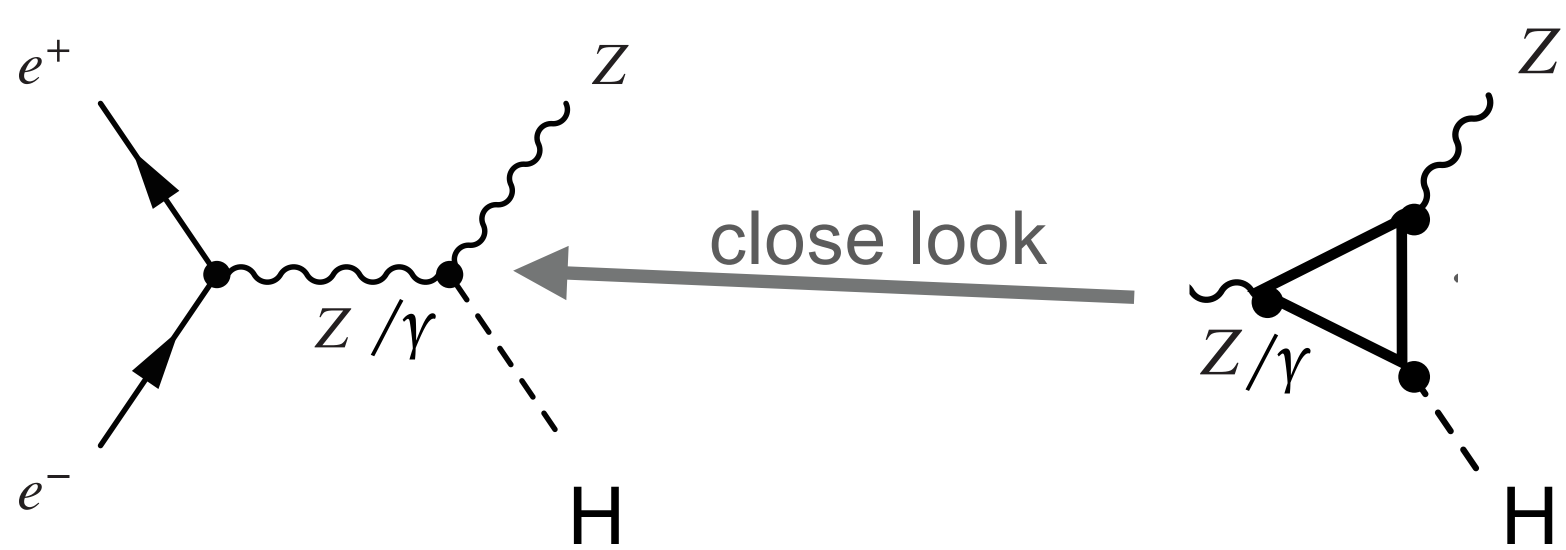
- Find new physics via Hγγ and HγZ couplings which can receive corrections from heavy particles

  If we get different values of coupling constants with regard to SM, we get the key to new physics.

- HγZ is needed for ZH/ZHH measurements in BSM

  Higgs to γZ coupling in the Standard Model (SM) is a loop induced coupling.

  e.g. e+e- -> Zh



2. Theoretical framework

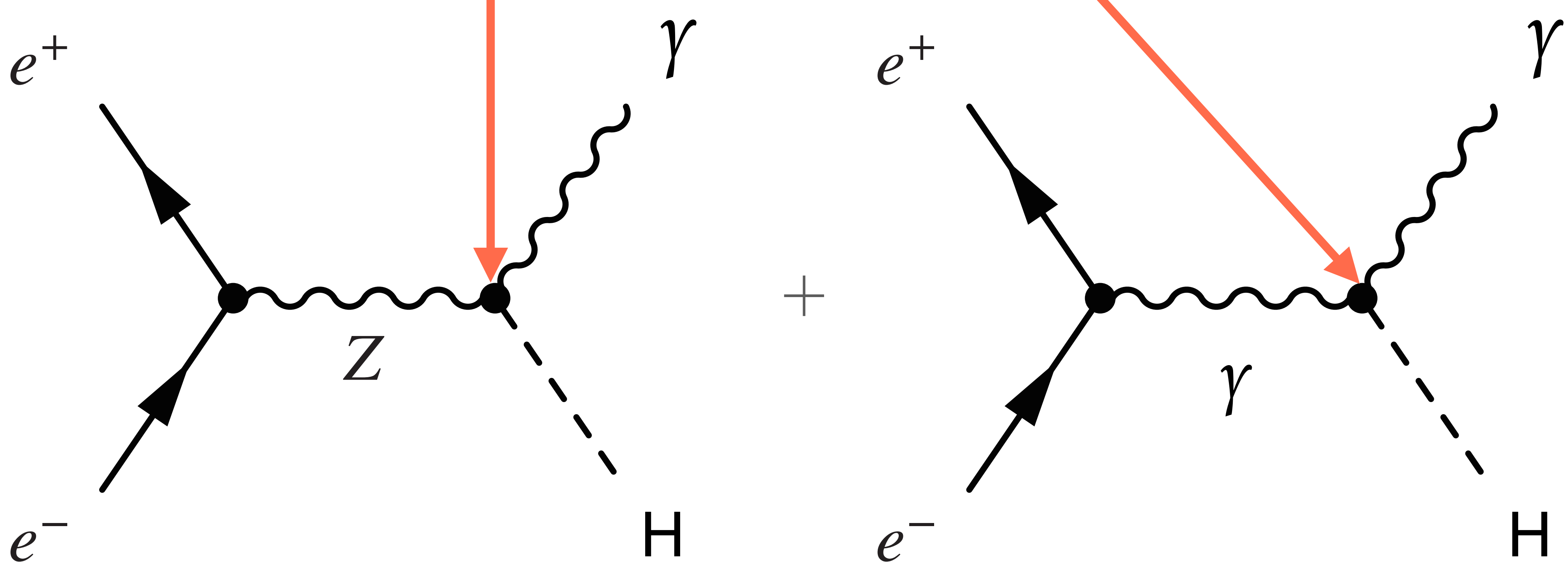
effective Lagrangian for e+e- —> γH

Coupling constant

$$L_{\gamma H} = \frac{c_{\gamma Z}}{4\Lambda} A_{\mu\nu} Z^{\mu\nu} H + \frac{c_{\gamma}}{4\Lambda} A_{\mu\nu} A^{\mu\nu} H$$

effective hγZ coupling

effective hγγ coupling



$c_{\gamma Z}$: effective coupling between Higgs and γZ (dimensionless)
c_{γ} : effective coupling between Higgs and γγ
Λ : effective new physics scale

2. Theoretical framework

partial decay widths of h->γγ and h->γZ: (calculation by EFT)

$$\Gamma_{\gamma\gamma} = \frac{M_H^3}{64\pi}(\frac{c_\gamma}{\Lambda})^2$$

(M_H = 125 GeV)

arXiv:1101.0593

$$\Gamma_{\gamma Z} = \frac{M_H^3}{128\pi}(\frac{c_{\gamma Z}}{\Lambda})^2(1 - \frac{M_Z^2}{M_H^2})^3$$

Standard model loop calculation

$\Gamma_{\gamma Z}$: 6.25 x 10^{-3} MeV —> $c_{\gamma Z}$ / Λ = 1.12 x 10^{-1} / TeV

$\Gamma_{\gamma\gamma}$: 9.27 x 10^{-3} MeV —> c_γ / Λ = 3.09 x 10^{-2} / TeV

By comparing with standard model loop calculation, we can extract the standard model values of $c_{\gamma Z}$ / Λ and c_γ / Λ.

3.Experimental Method

Coupling constant

$$L_{\gamma H} = \frac{c_{\gamma Z}}{4\Lambda} A_{\mu\nu} Z^{\mu\nu} H + \frac{c_{\gamma}}{4\Lambda} A_{\mu\nu} A^{\mu\nu} H$$

measure this 2 parameters

① Measure the cross sections of e+e- ->γh

for at least two different beam polarizations

So that c_γ and $c_{\gamma Z}$ can be determined separately

② Since $\frac{c_\gamma}{4\Lambda}$ can be constrained already by measurement of h→γγ branching ratio at LHC, we can extract other parameter by just measuring cross section for a single polarization.

3.Experimental Method (Continued)

γZ and γγ diagrams have the same momentum dependence in the cross section formula

→phase space integration can be factored out

→The cross section normalized to SM can be written as

$$\frac{\sigma_{e^+e^-\to h\gamma}}{\sigma_{SM}} = (a\bar{c}_{\gamma z} + b\bar{c}_{\gamma})^2$$

Coefficient a and b are calculated by physsim

Left handed beam polarizations

$$\frac{\sigma}{\sigma_{SM}} = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2$$

Right handed √s=250 GeV

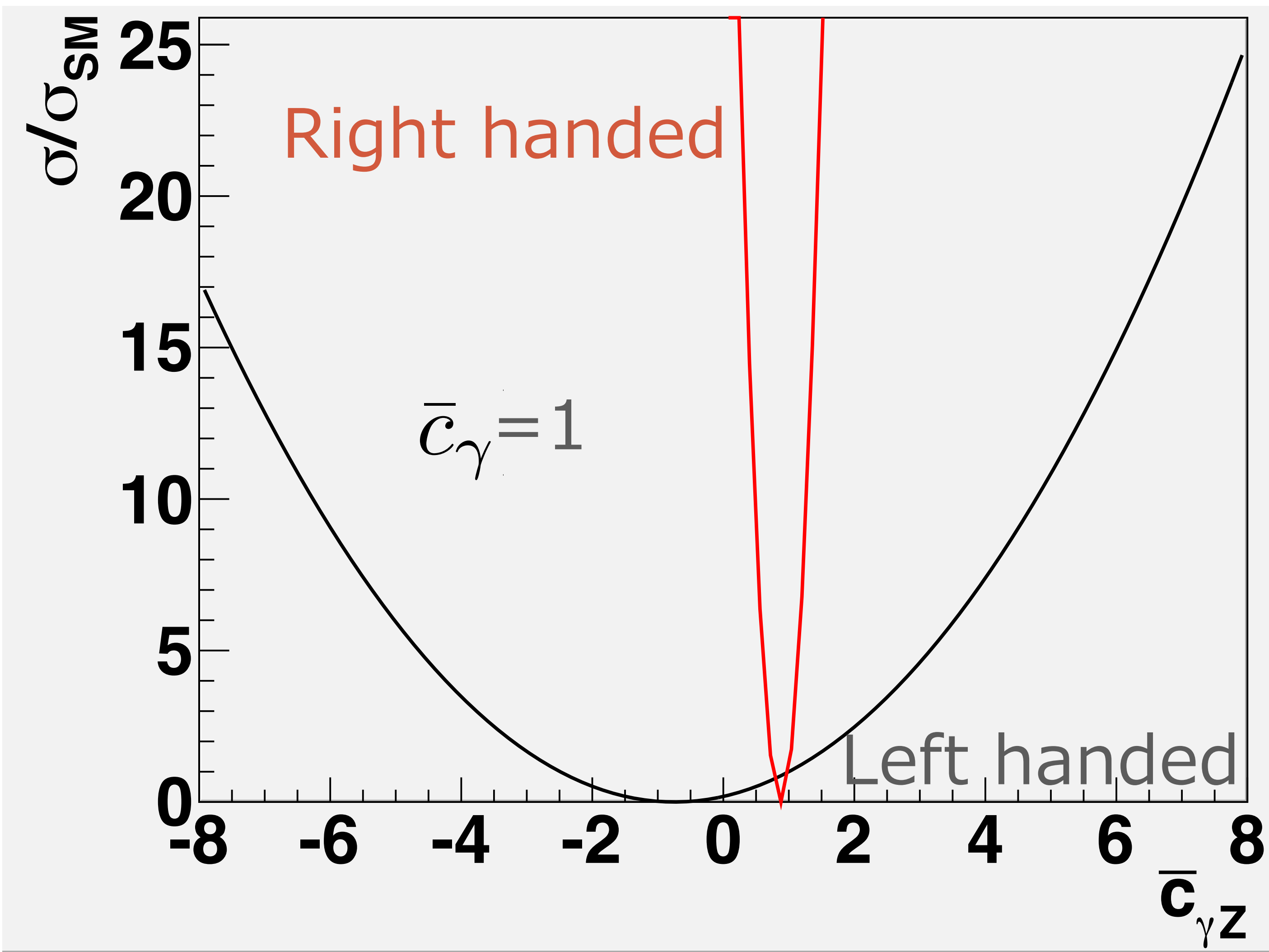
$$\frac{\sigma}{\sigma_{SM}} = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_{\gamma})^2$$

$$\bar{c}_{\gamma z} = \frac{c_{\gamma z}}{c_{\gamma z(SM)}}$$

$$\bar{c}_{\gamma} = \frac{c_{\gamma}}{c_{\gamma(SM)}}$$

3.Experimental Method (Continued)

The cross section relative to SM



Left handed

$$\frac{\sigma}{\sigma_{SM}} = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_\gamma)^2$$

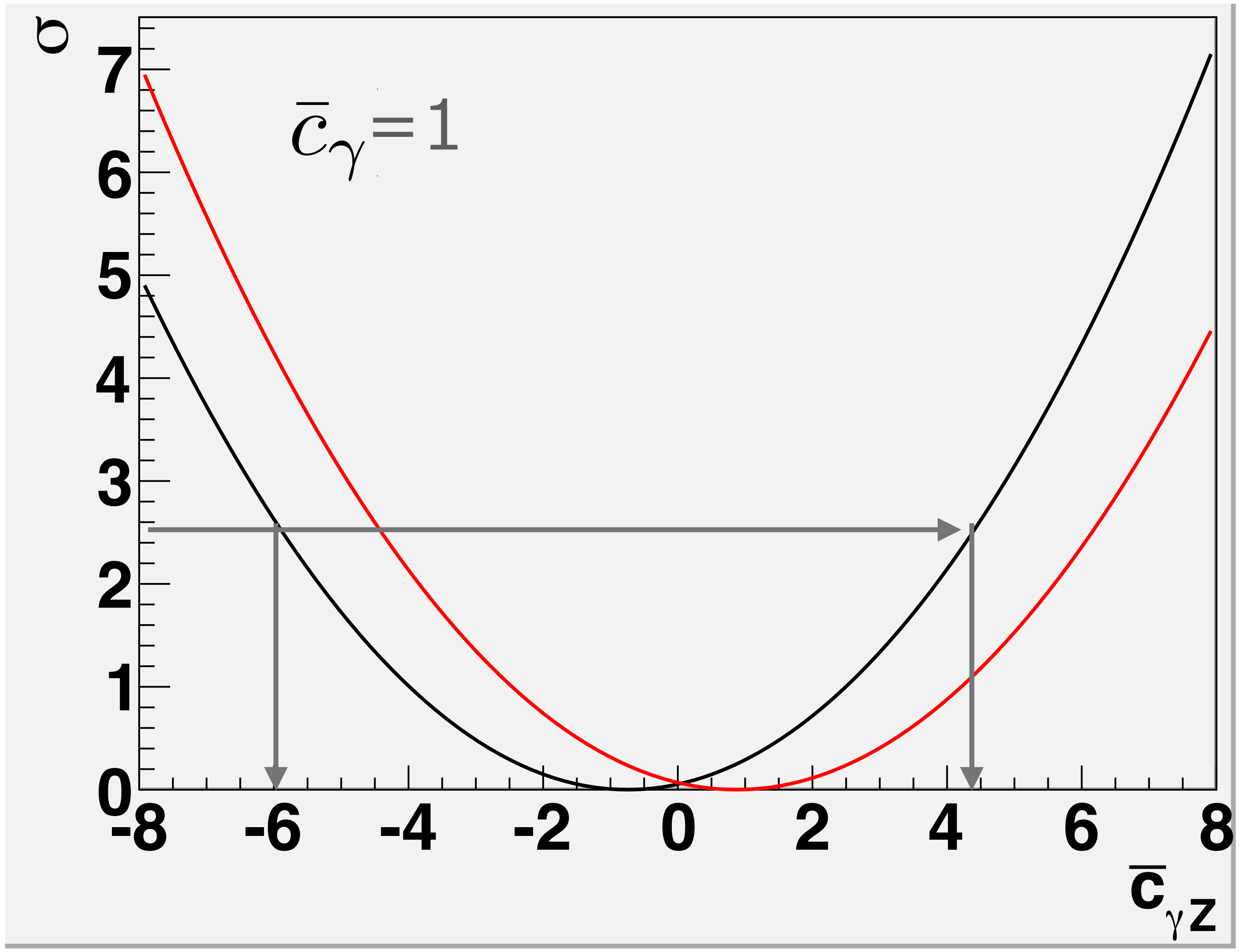
Right handed

$$\frac{\sigma}{\sigma_{SM}} = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_\gamma)^2$$

If cγZ(bar) change, the cross section change like this graph.

3.Experimental Method (Continued)

Absolute value of the cross section



Left handed $\sigma_{SM} = 0.29[fb]$

$$\sigma_L = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_\gamma)^2\sigma_{SM}$$

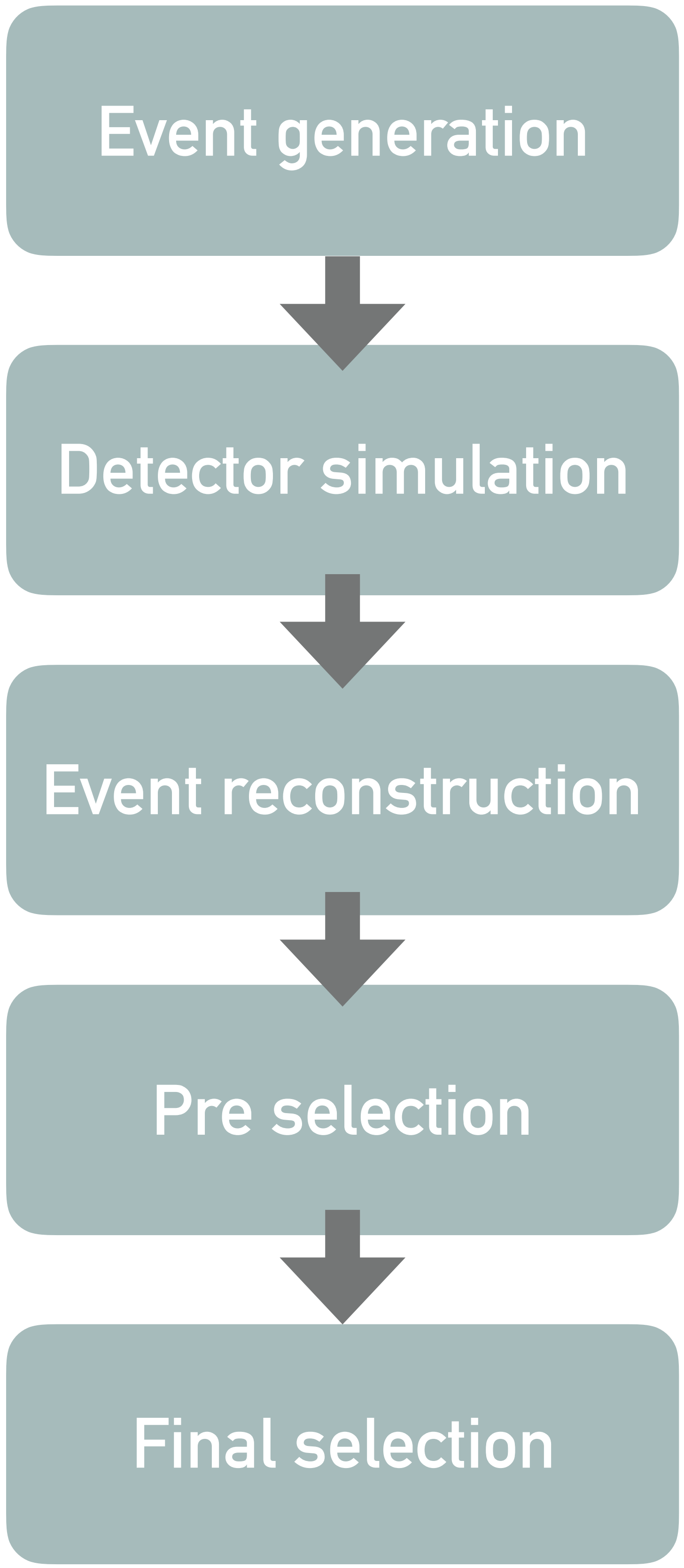
Right handed $\sigma_{SM} = 0.0014[fb]$

$$\sigma_R = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_\gamma)^2\sigma_{SM}$$

experimental observable : σ

We can get $c_{\gamma z}$ by this formula.

4.Simulation framework



- Physsim

  √s=250 GeV
  Integrated Luminosity: 2000 fb^{-1}
  back ground : DBD sample

- ILD full simulation (Mokka)

- iLCSoft v01-16-02
  MarlinReco, PandoraPFA,
  LCFI+, Isolated photon finder, jet clustering

5. Event selection

Signal: $e^+e^- \to \gamma H \to \gamma(b\bar{b})$

Signal signatures

1. Isolated monochromatic photon with energy 93 GeV
2. 2 b jets
3. m(bb)（invariant mass）= higgs mass

Main backgrounds

e+e- ->γqq(bar) dominated by e+e- → γZ (radiative return)

5. Event selection

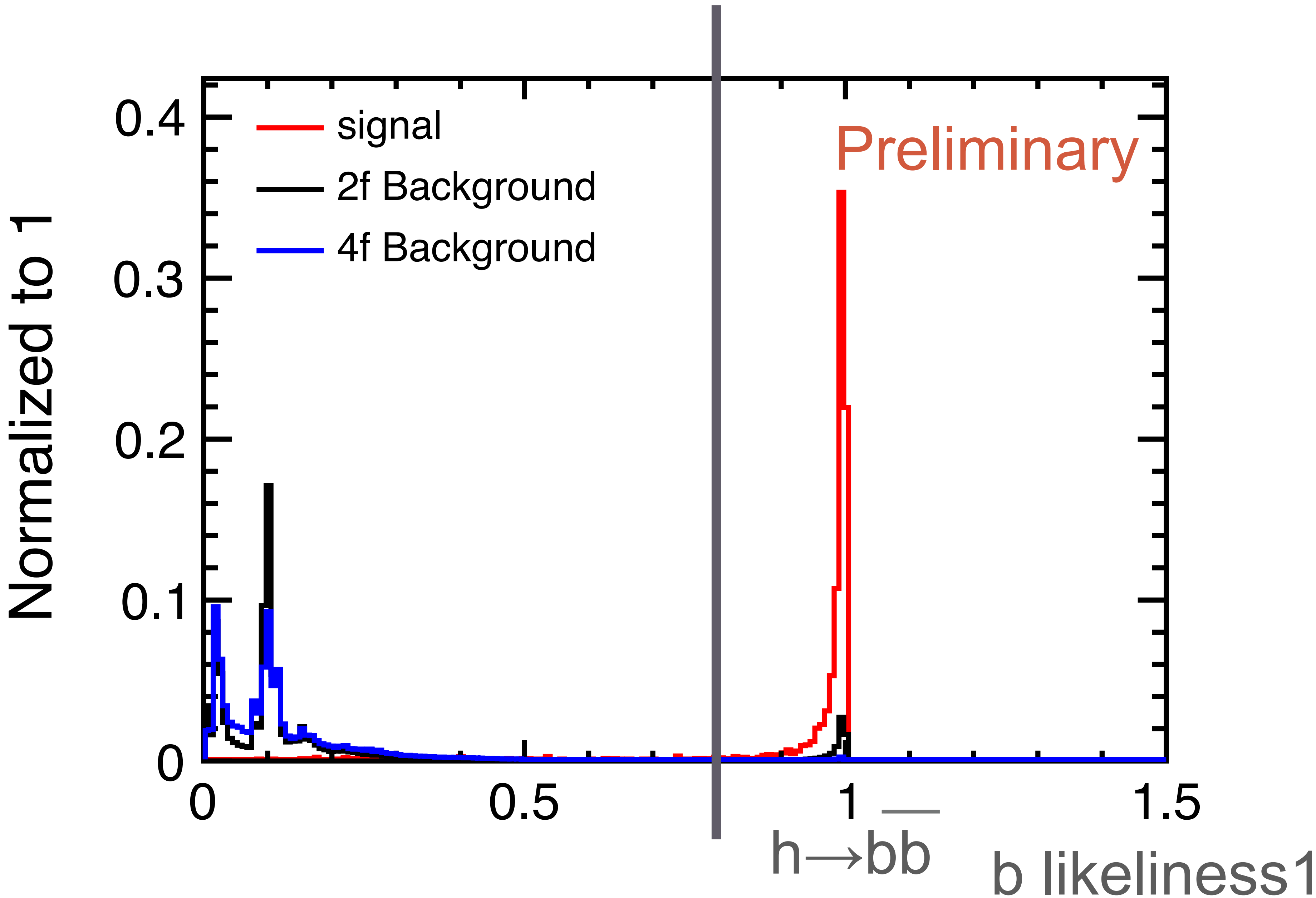
① Pre selection

- Isolated photon
  - ➤ Photon ID
  - ➤ E_γ > 50 GeV
  - ➤ The split photon clusters within a small cone are recovered
    cone angle($\cos\theta_{cone}$=0.998)

- Other particles
  - ➤ clustered into 2jet (using Durham)
  - ➤ Flavor tagged（LCFI+）

5. Event selection

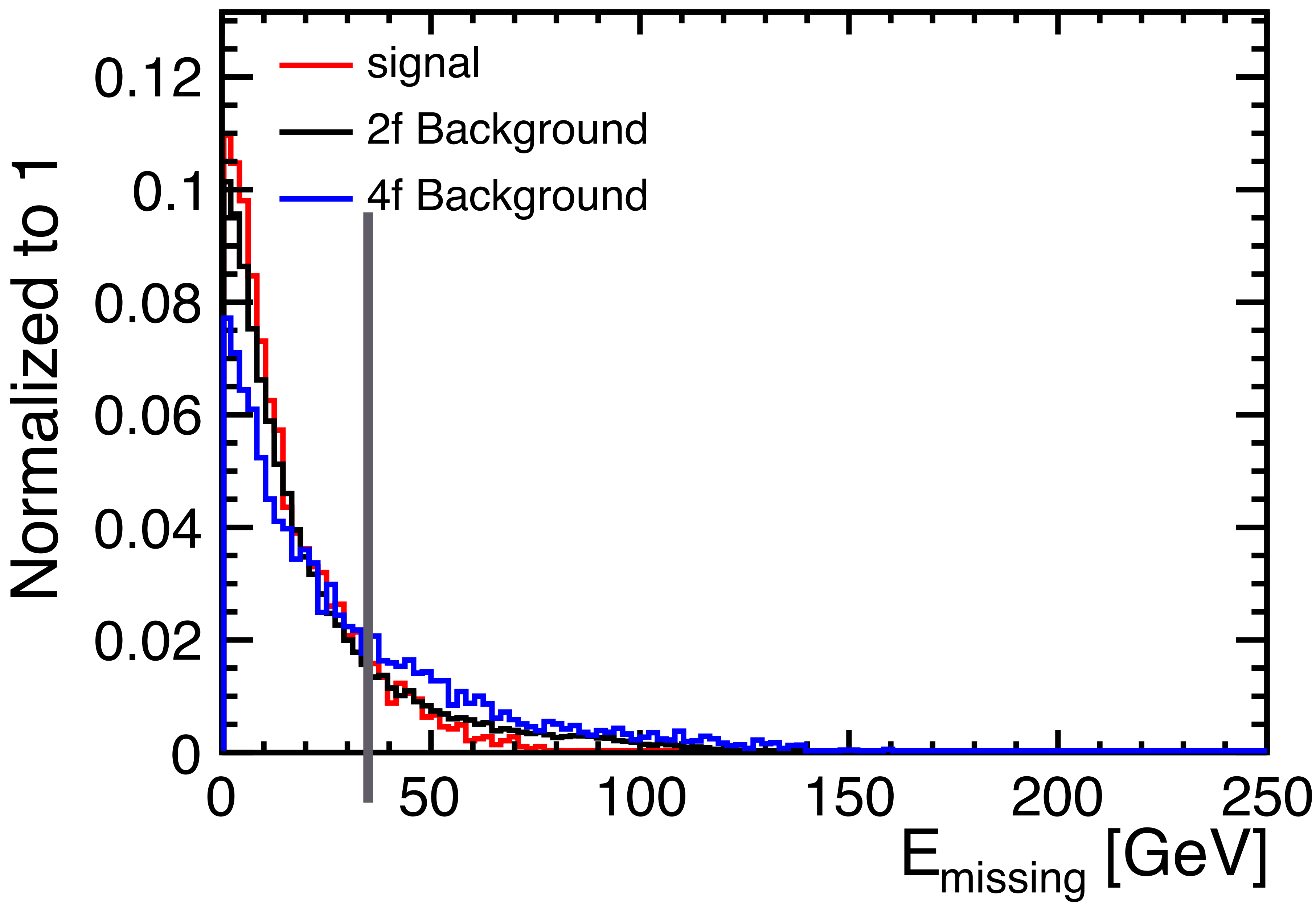
② Final selection
-Cut 1:b likeliness1>0.8 →Suppress light flavor γqq



※ This plot is for events after the pre selection

5. Event selection

② Final selection
-Cut 2: missing energy<35 GeV

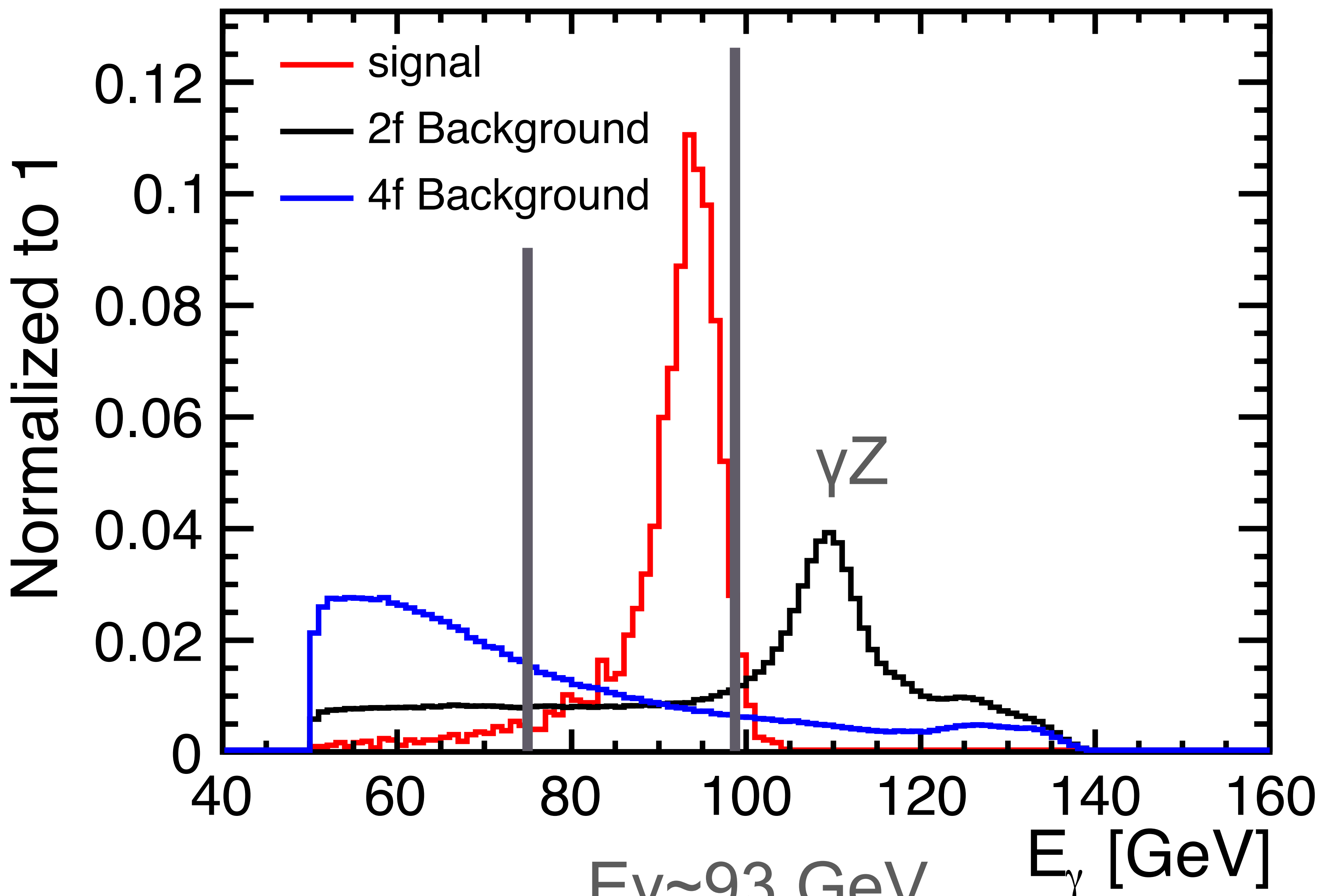


Preliminary

5. Event selection

② Final selection

-Cut 3: Photon energy(Eγ) 75 GeV<Eγ<98 GeV



Eγ~93 GeV

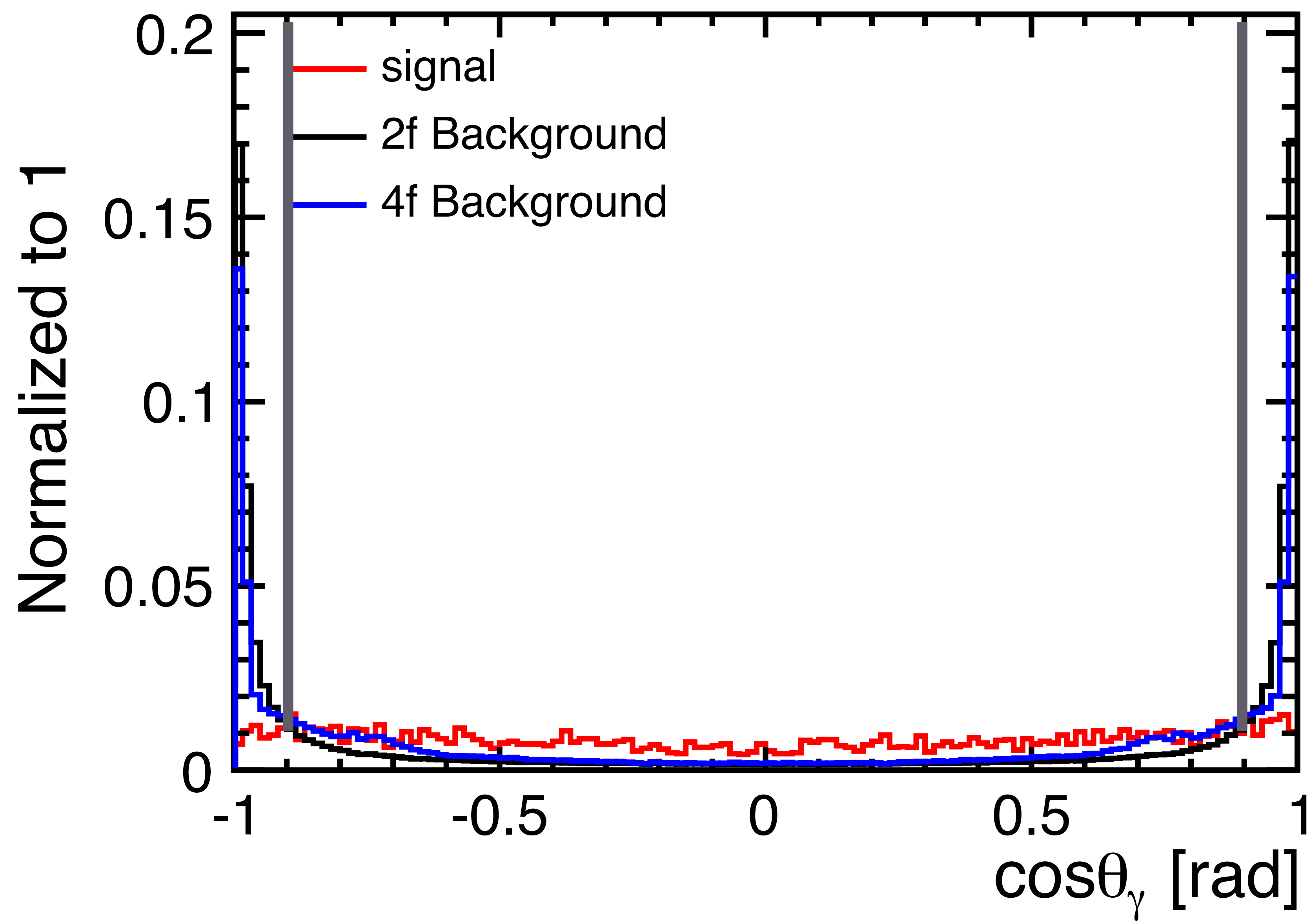
Preliminary

5. Event selection

② Final selection

-Cut 4 : Polar angle of photon $-0.9<\cos\theta_{\gamma}<0.9$

the background have very forward or backward photon

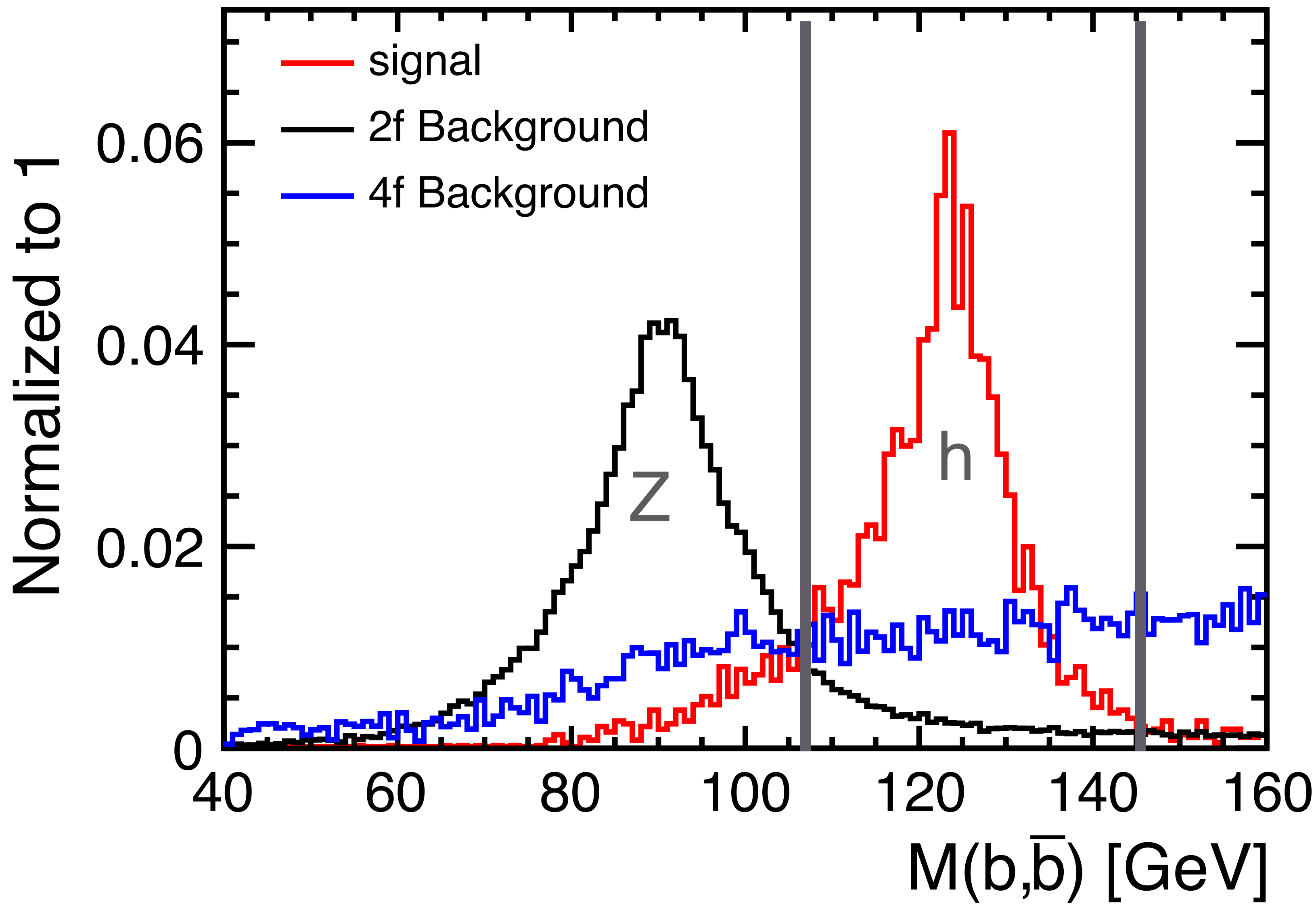


Preliminary

5. Event selection

② Final selection
-Cut 5 ：bb invariant mass

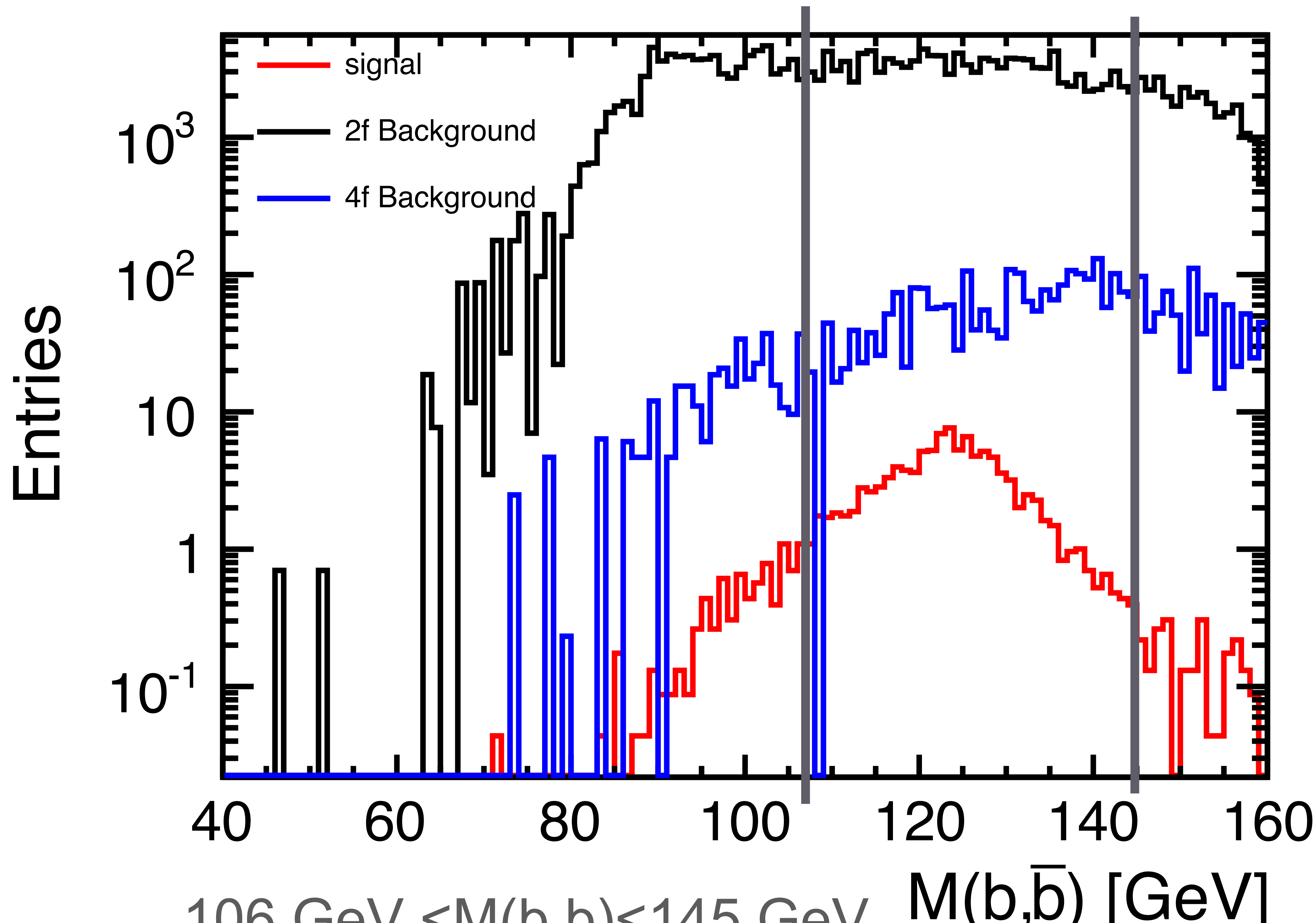
106 GeV<M(b,b)<145 GeV



Preliminary

5. Event selection

After all the other cuts, normalized to Integrated Luminosity: 2000 fb^{-1}



106 GeV <M(b,b)<145 GeV

The background is 3 orders higher than in the case of standard model.

6. Result

$$significance = \frac{N_s}{\sqrt{N_s + N_B}}$$

Reduction table Preliminary

N_s:Number of signal
N_B:Number of back ground

	Signal	background	Significance
Expected	196	314,154,000	0.01
Pre selection	184	68,287,700	0.02
btag>0.8	164	4,914,990	0.07
E_{mis}<35	150	4,268,840	0.07
75<Eγ<98	135	415,621	0.21
-0.9<cosθγ<0.9	126	290,768	0.23
106<M(b,b)<145	108	129,259	0.30

6. Result

→95% C.L upper limit $\sigma = \frac{1.64}{significance}\sigma_{SM}$

Significance = 0.30 for SM

= 5.46 × 0.29 [fb]

=1.58 [fb] （Left handed）

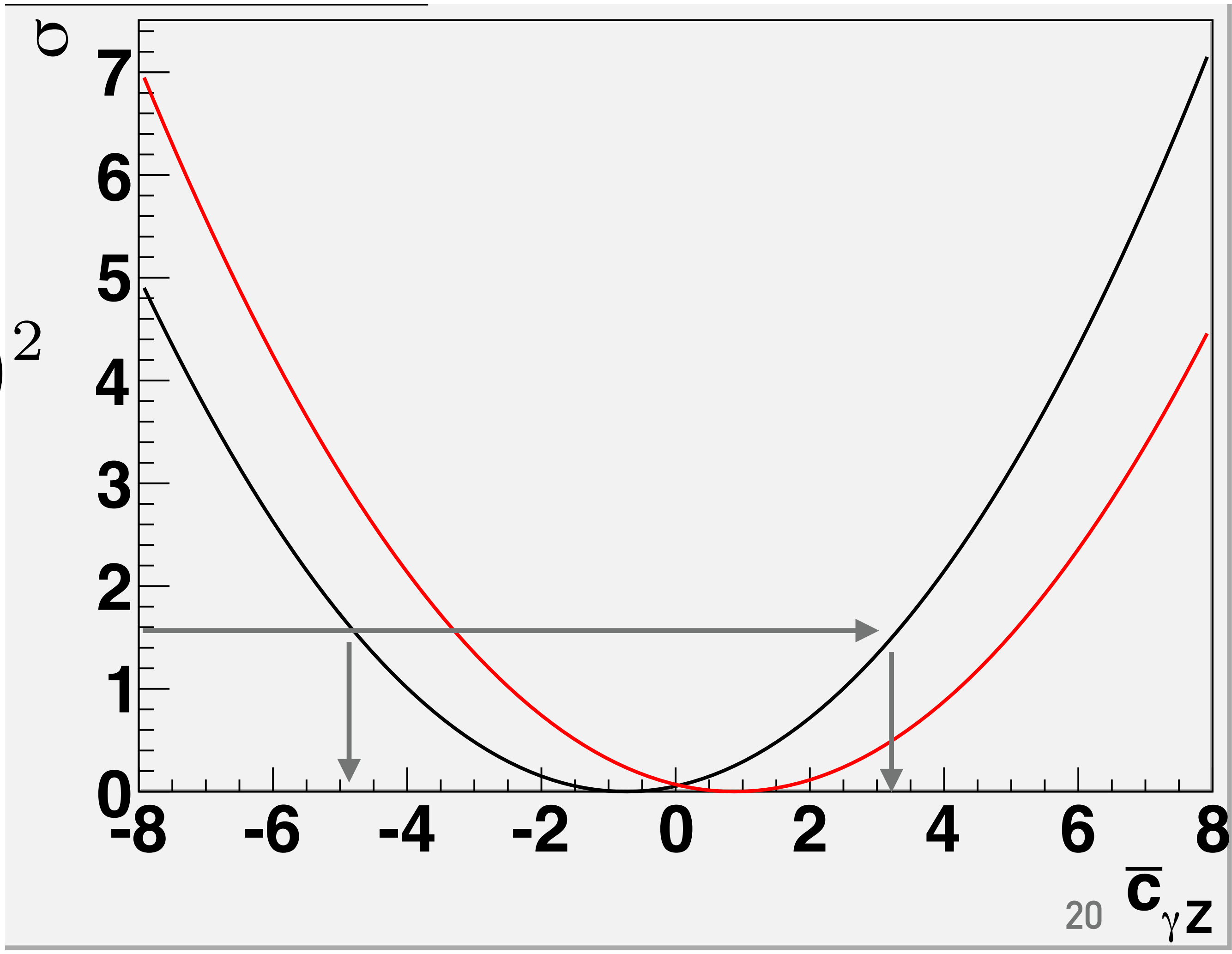
$$\sigma_L = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2\sigma_{SM}$$

$$\frac{\sigma_L}{\sigma_{SM}} = 5.46 = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2$$

$-4.82 < \bar{c}_{\gamma z} < 3.33$

$c_{\gamma Z(SM)} = 0.112$

$-0.54 < c_{\gamma Z} < 0.37$ (Λ=1 TeV)



7. Summery

・I simulated and analyzed e+e- -> h gamma process

・Significance for e+e- ->hγ process

~ 0.30σ for SM at √s=250 GeV, 2000 fb^{-1}

・model independent upper limit for cross section : $\sigma_{h\gamma}$< 1.6 fb(95% C.L.)

・Corresponding bounds : -4.82< $\bar{c}_{\gamma z}$<3.33

※This is the first look at this process and the results are very preliminary.

Next step

・optimize event selection

・do analysis for right handed beam polarization

・interpret cγZ bounds based on full 1-loop calculation

・Understand the role of this measurement in one global EFT analysis

Back up

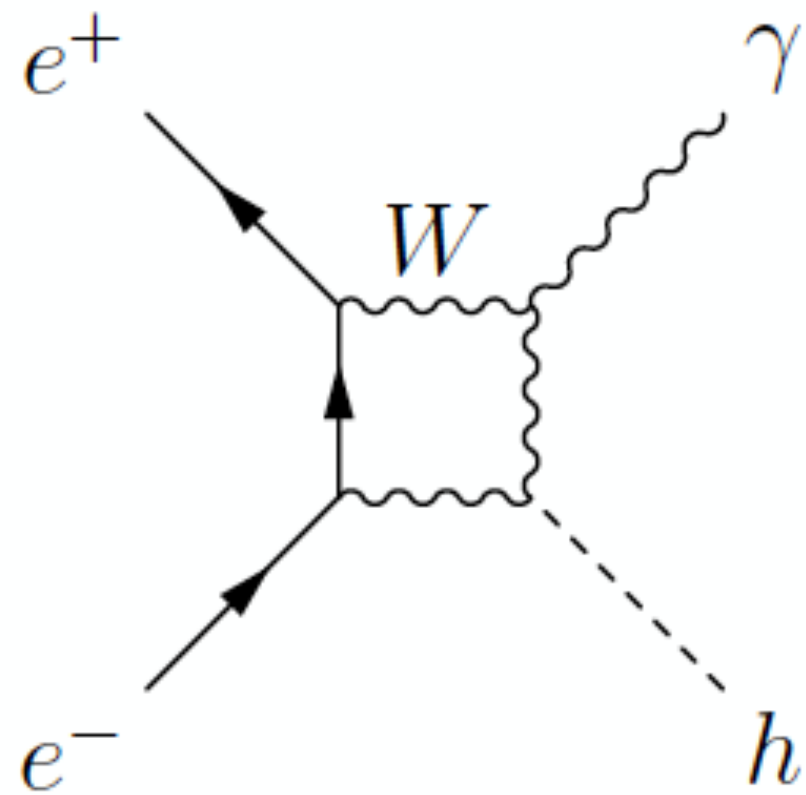
5. Event selection

Back ground

		characteristic	How to remove
f f		back to back	cosθ2f
γZ→γ(f f)	γll	few track number	nTrack
	γqq,γcc	no b	b-tag
	γbb	different angular distribution	Eγ,cosθγ
	common	m(bb)~m(Z)	m(ff)
W^+W^-→4f Z^+Z^-	4j	4 jet	Y3→2, Eγ
	2j+2l	Nisolep=2	N_{isolep}=0, Eγ
	2j+vv	large missing energy	E_{miss},Eγ
	2j+lv	missing energy	N_{isolep}=0, E_{miss}
	common	m(ff)=m(W)	b-tag, m(ff)

l:lepton q:quark j:jet v:neutrino

About Box diagram



- This diagram is also exist
- We ignore this first, and if calculate of this diagram is finished, we include this.