Study of $H\gamma Z$ coupling using $e^+e^- \to \gamma H$ at the ILC

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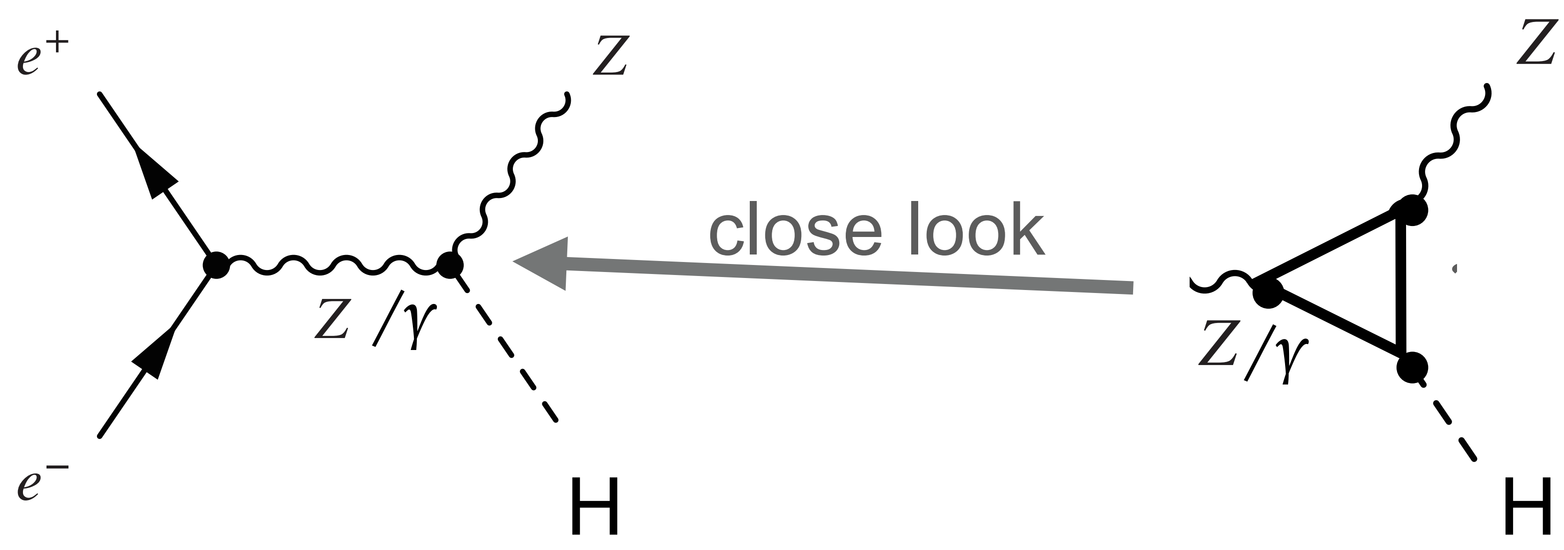
ILD Software and Analysis Meeting

Outline

1.Motivation

1. Find new physics via Hγγ and HγZ couplings
2. HγZ is needed for ZH/ZHH measurements

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



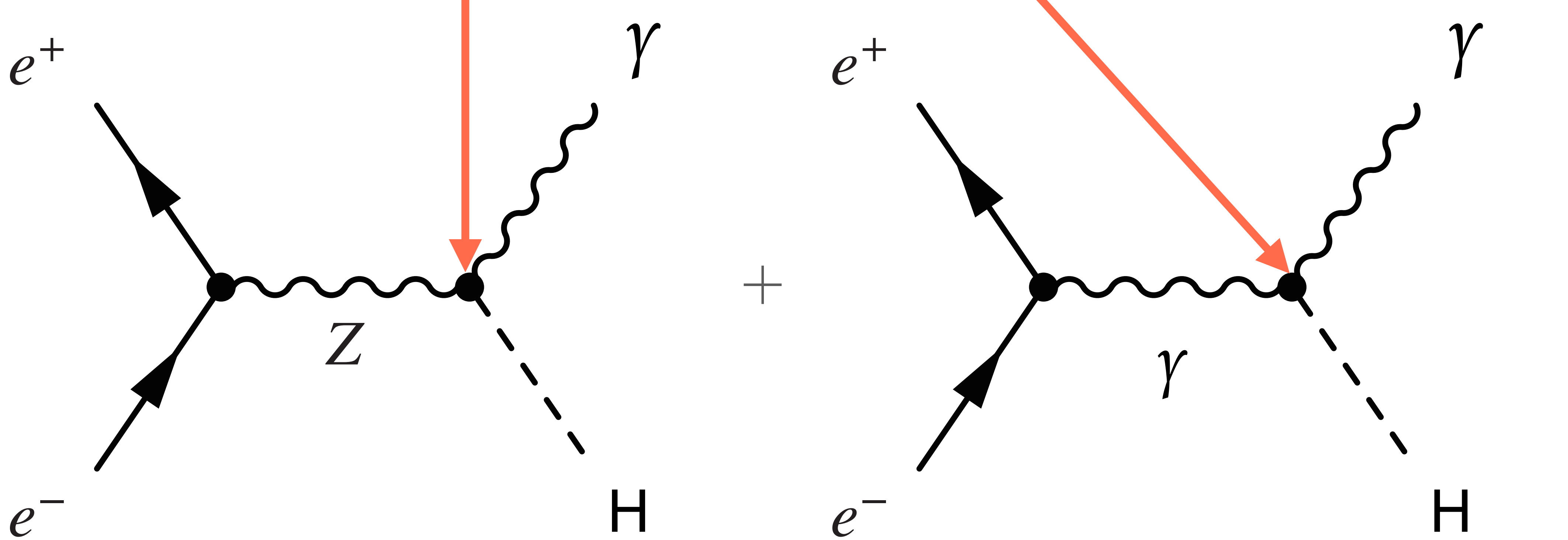
If we get different values of coupling constants with regard to SM, we get the key to new physics.

2. Theoretical framework

effective Lagrangian for e+e- —> γH

Coupling constant

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



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

2. Theoretical framework

partial decay width: (M$_H$ = 125 GeV) **arXiv:1101.0593**

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

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

This is calculation by EFT.

Compare

SM predication(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

3.Method

Coupling constant

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

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 use c_γ by Hγγ measurement in LHC

If we measure the cross sections of e+e- ->γh for one beam polarizations, we can get $c_{\gamma Z}$.

3.Method

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

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

calculated by physsim

Left handed

Right handed

√s=250 GeV

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

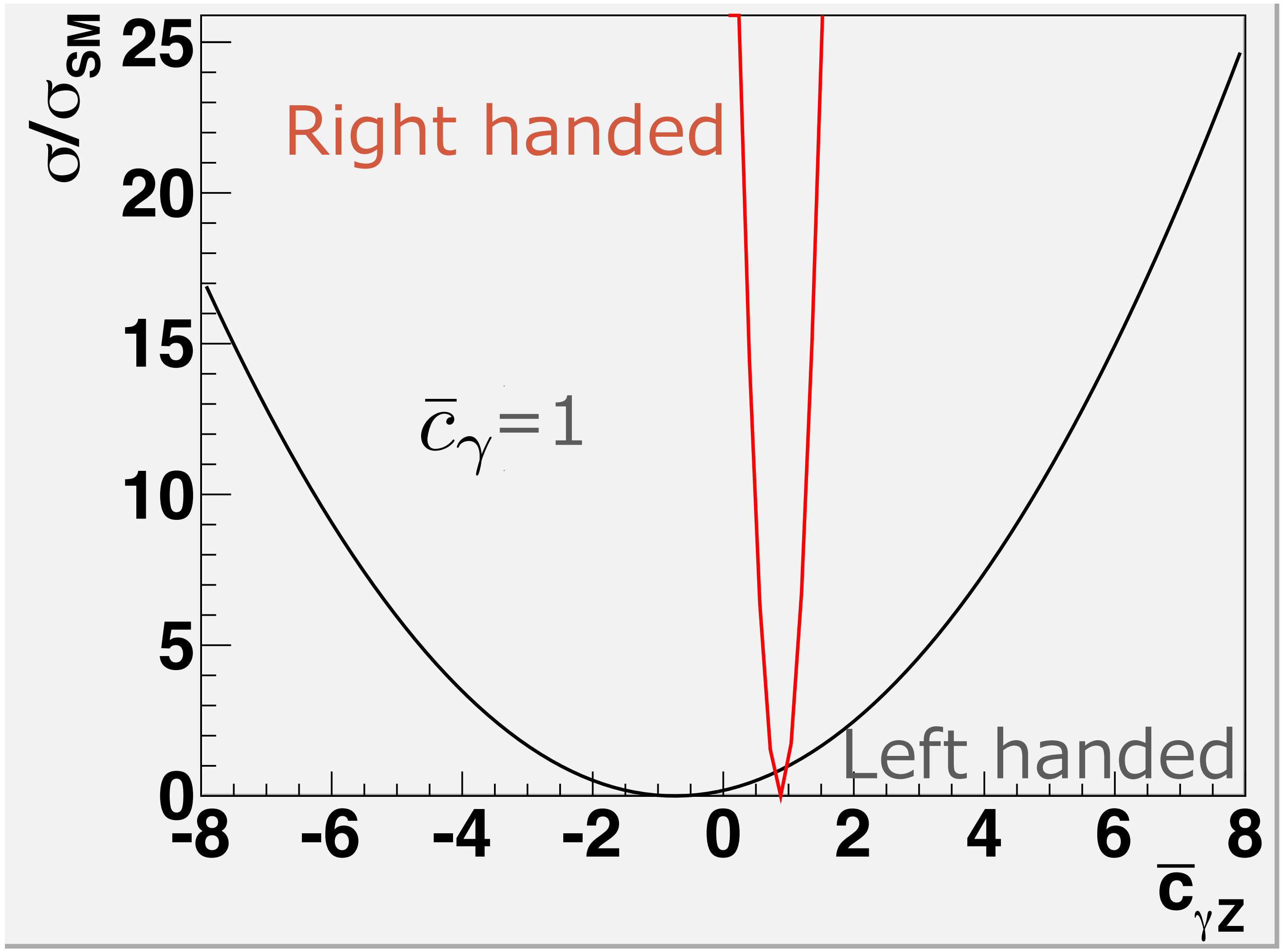
$$\frac{\sigma}{\sigma_{SM}} = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_{\gamma})^2$$

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

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

3.Method

The cross section relative to SM



Left handed

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

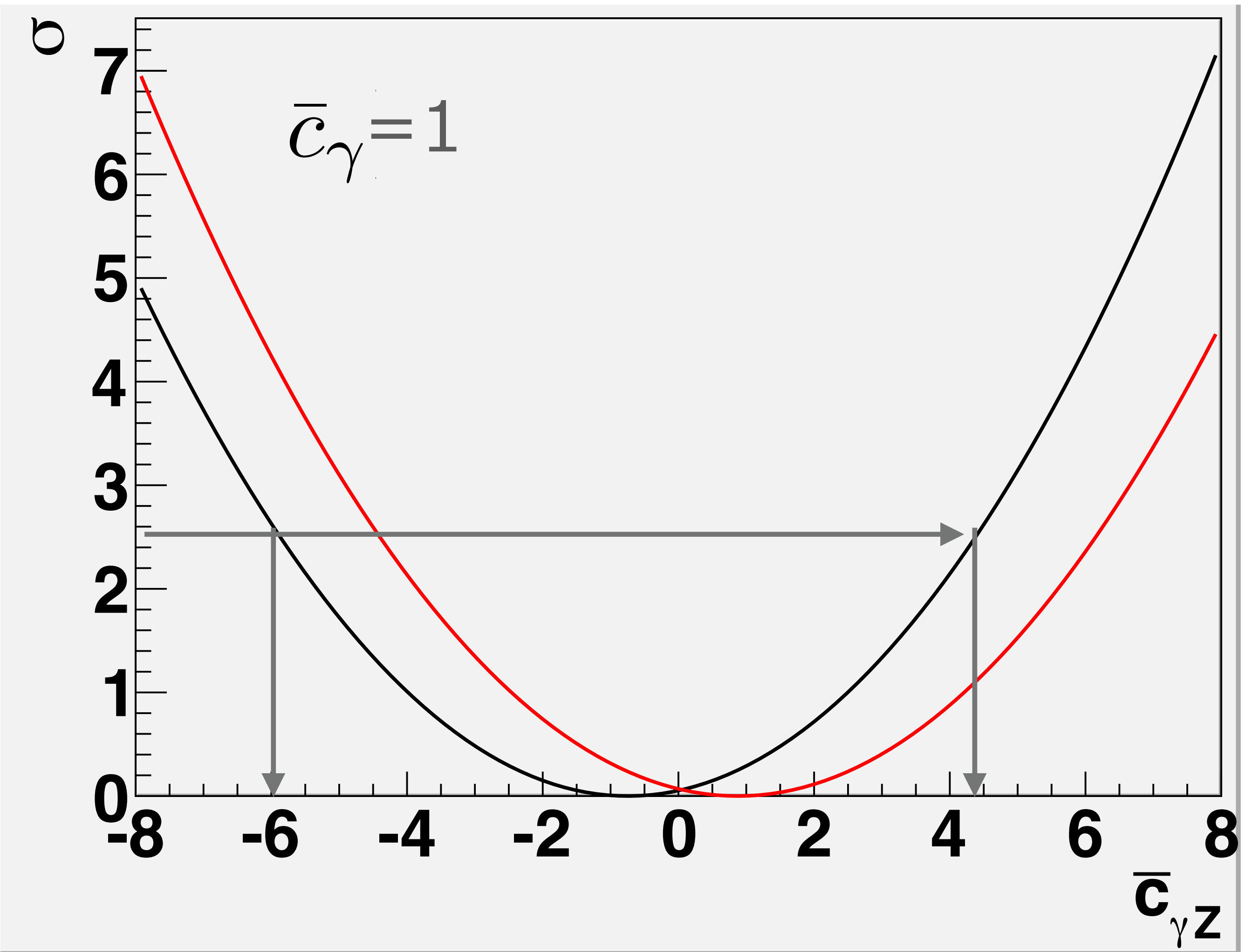
Right handed

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

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

3.Method

Absolute value of the cross section



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

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

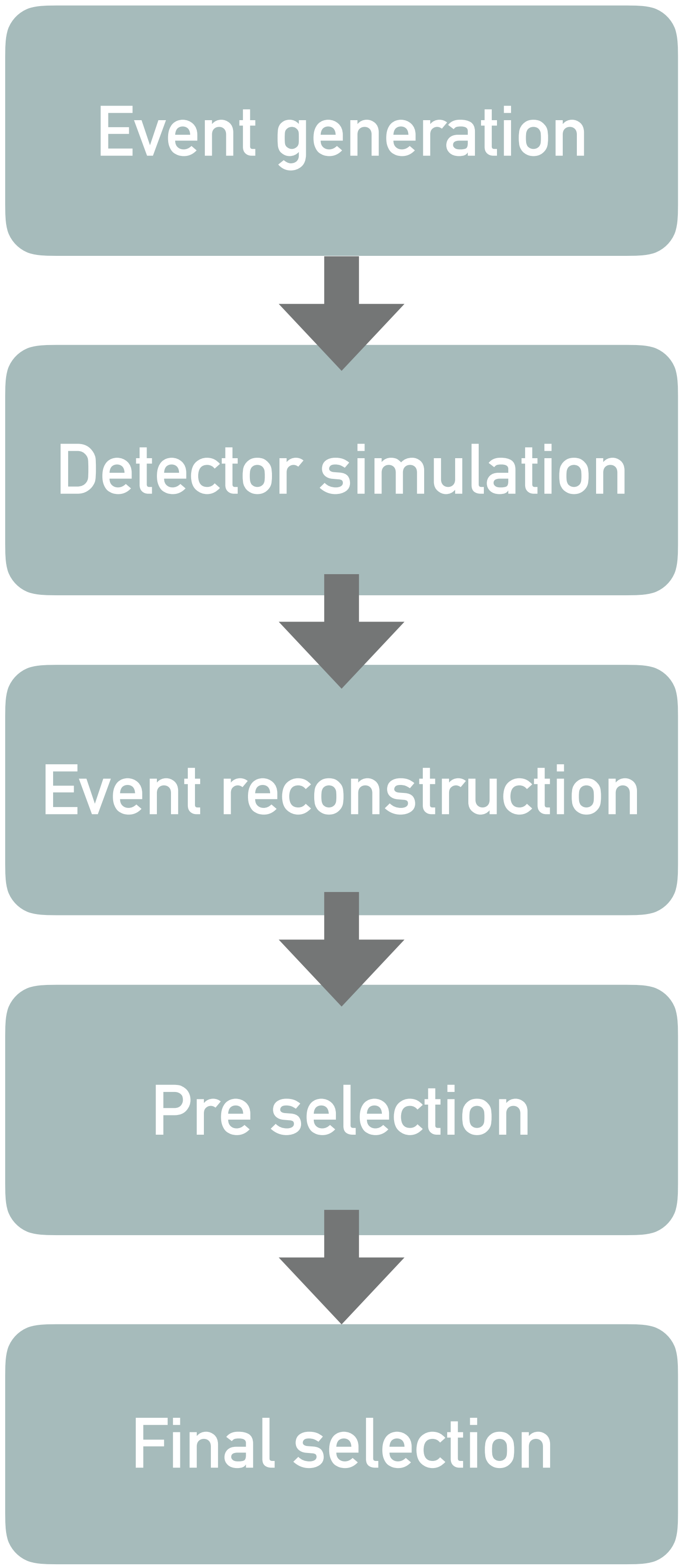
Right handed $\sigma_{SM} = 0.0014[fb]$

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

experimental observable : σ

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

4.Simulation framework



- Physsim
  $\sqrt{s}$=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 energetic monochromatic photon 93 GeV

2. 2 b jets

3. m(bb) （invariant mass） = higgs mass

Main backgrounds

e+e- ->qq(bar)

e+e- ->γZ

5. Event selection

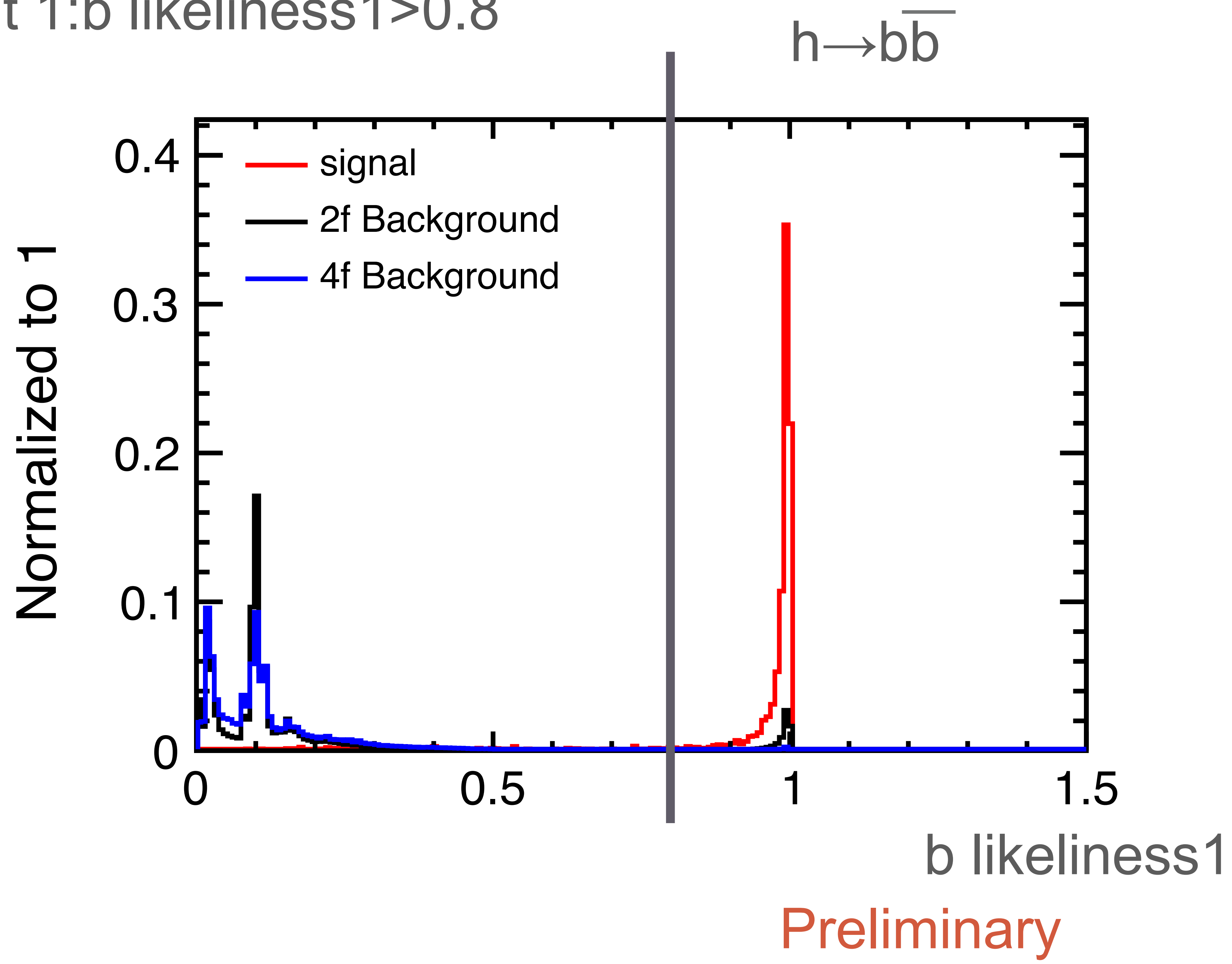
① Pre selection

- Isolated photon finder
  - Photon ID
  - E_γ > 50 GeV
  - recovery : merge split photon
    cone angle(cosθcone=0.998)
- Other particles → 2jet clustering
  (using Durham)
- Flavor tagging（b likeness for each jet）

5. Event selection

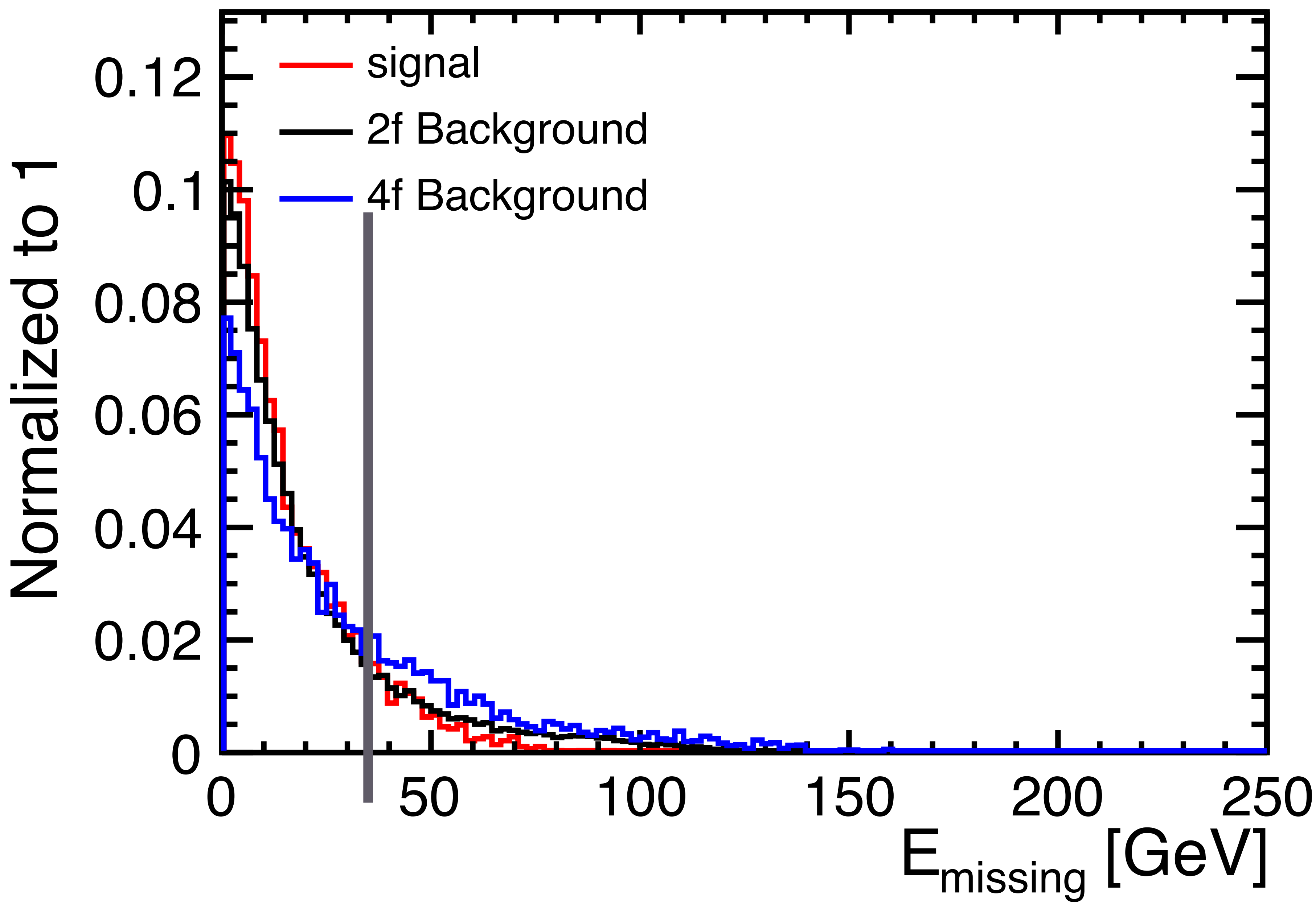
② Final selection

-Cut 1:b likeliness1>0.8



5. Event selection

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

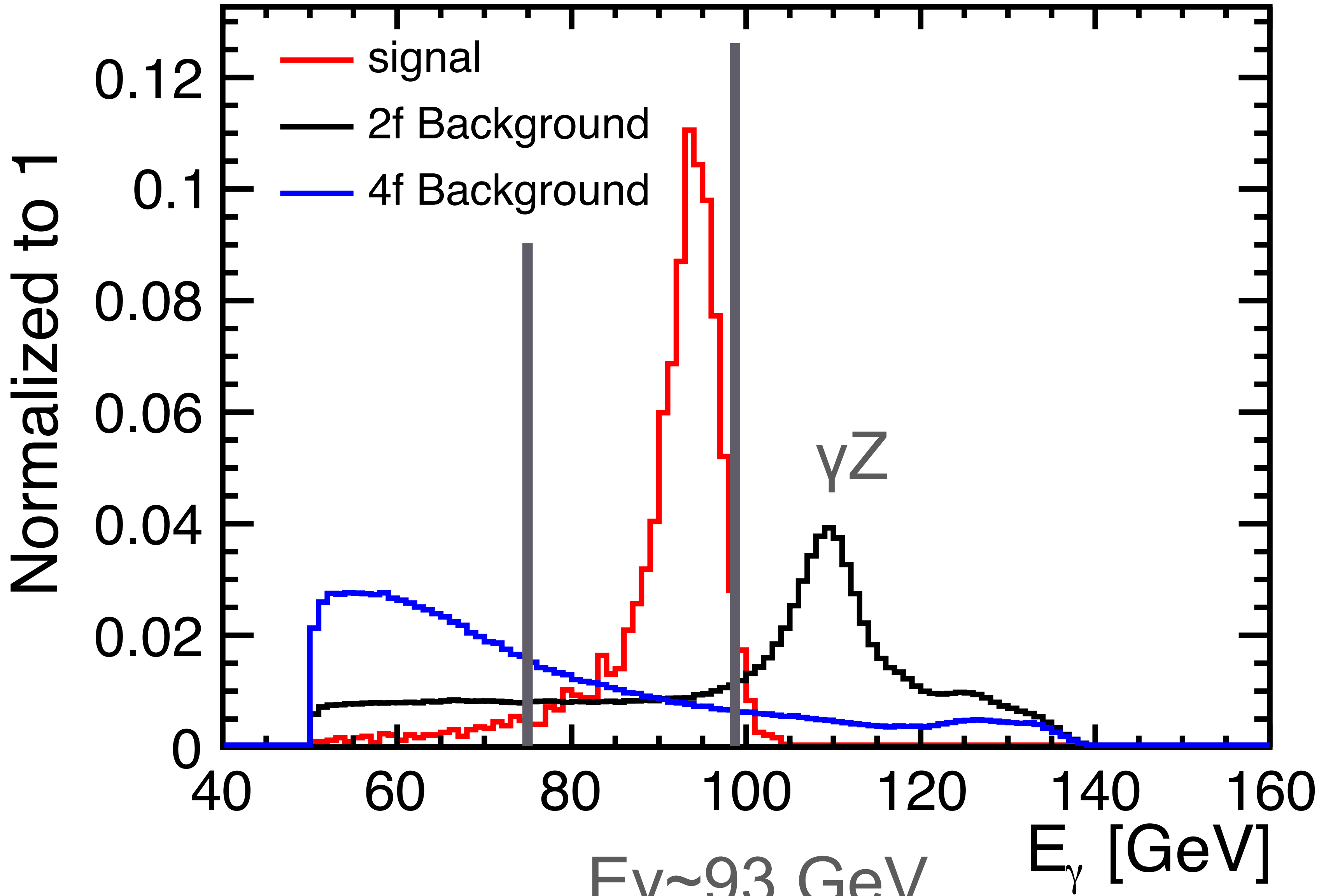


Preliminary

5. Event selection

② Final selection

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



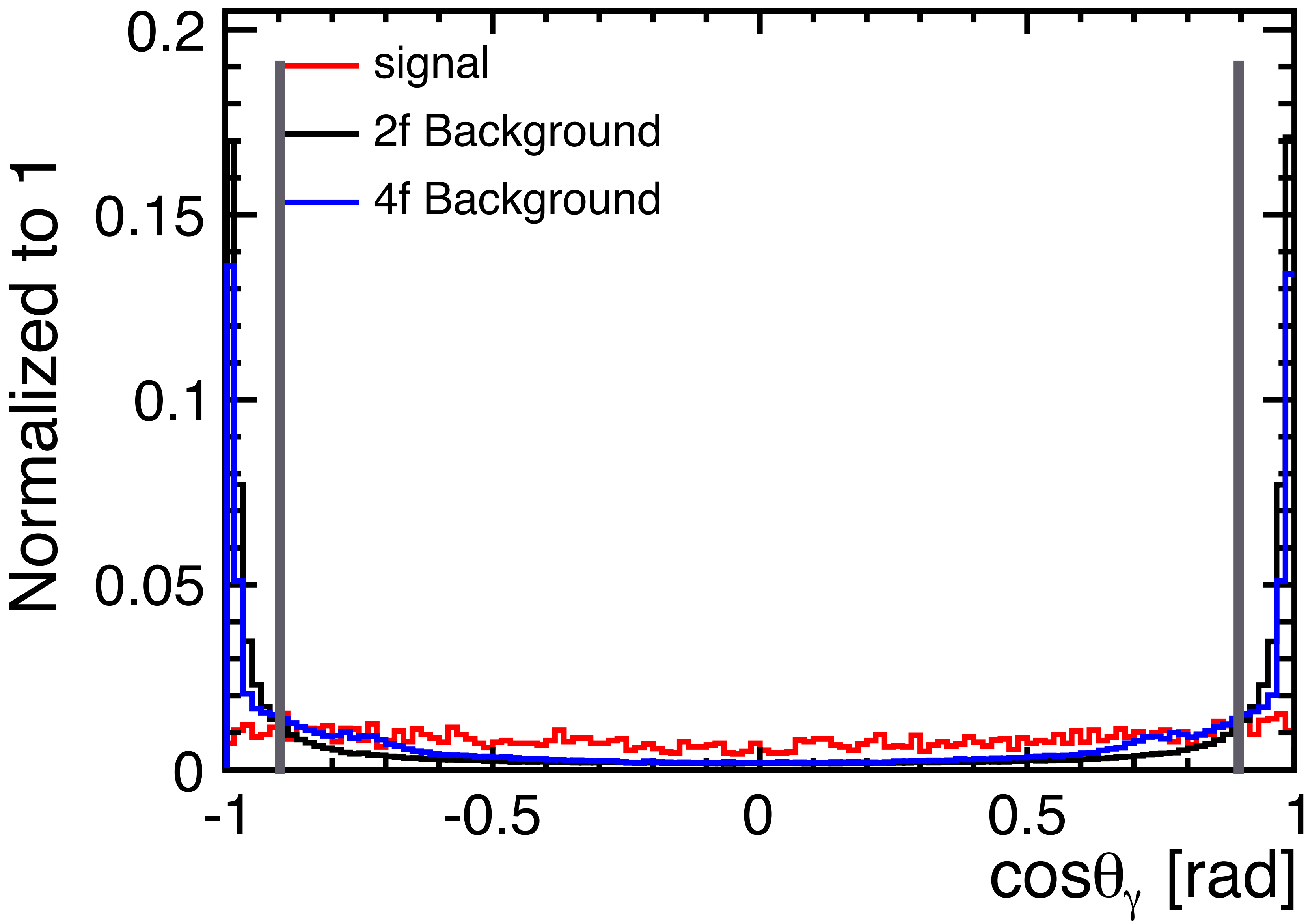
Eγ~93 GeV

Preliminary

5. Event selection

② Final selection

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



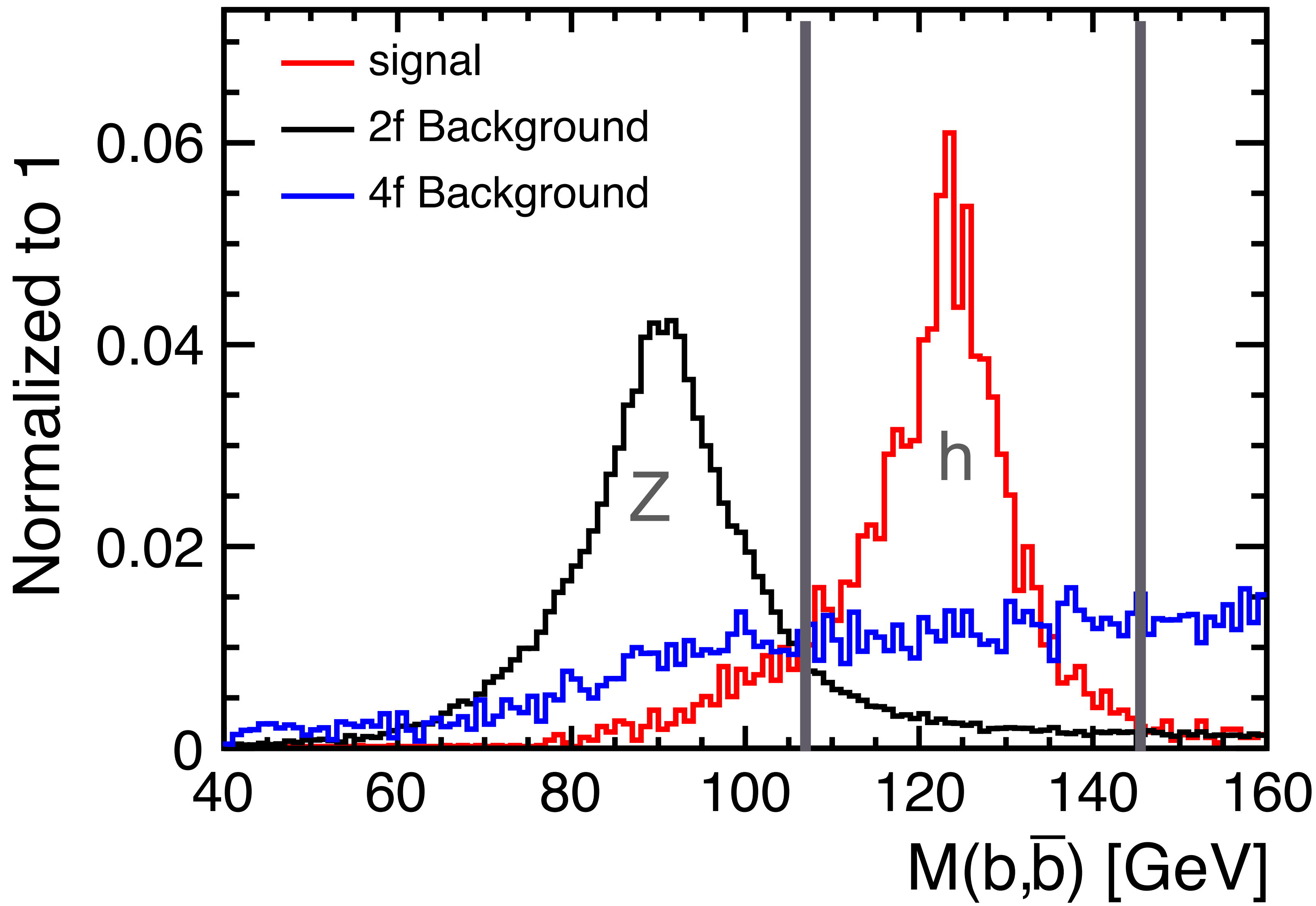
Preliminary

5. Event selection

② Final selection

-Cut 5 ： Mass of higgs(bb invariant mass)

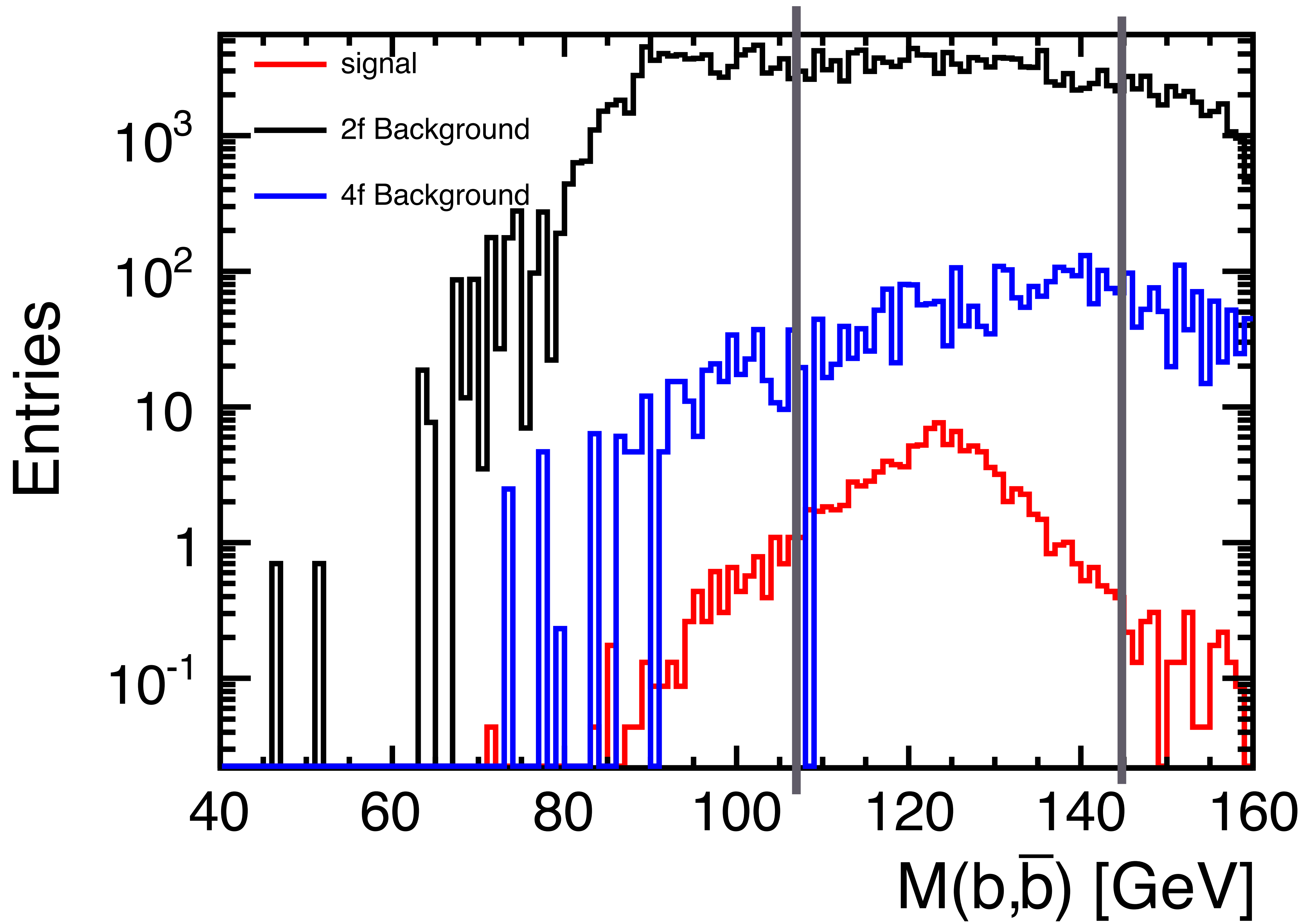
106 GeV<M(b,b)<145 GeV



Preliminary

5. Event selection

After cut 4 , correct normalization



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

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

Significance = 0.30 for SM

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

= 5.46 × 0.29 [fb]

=1.58 [fb]

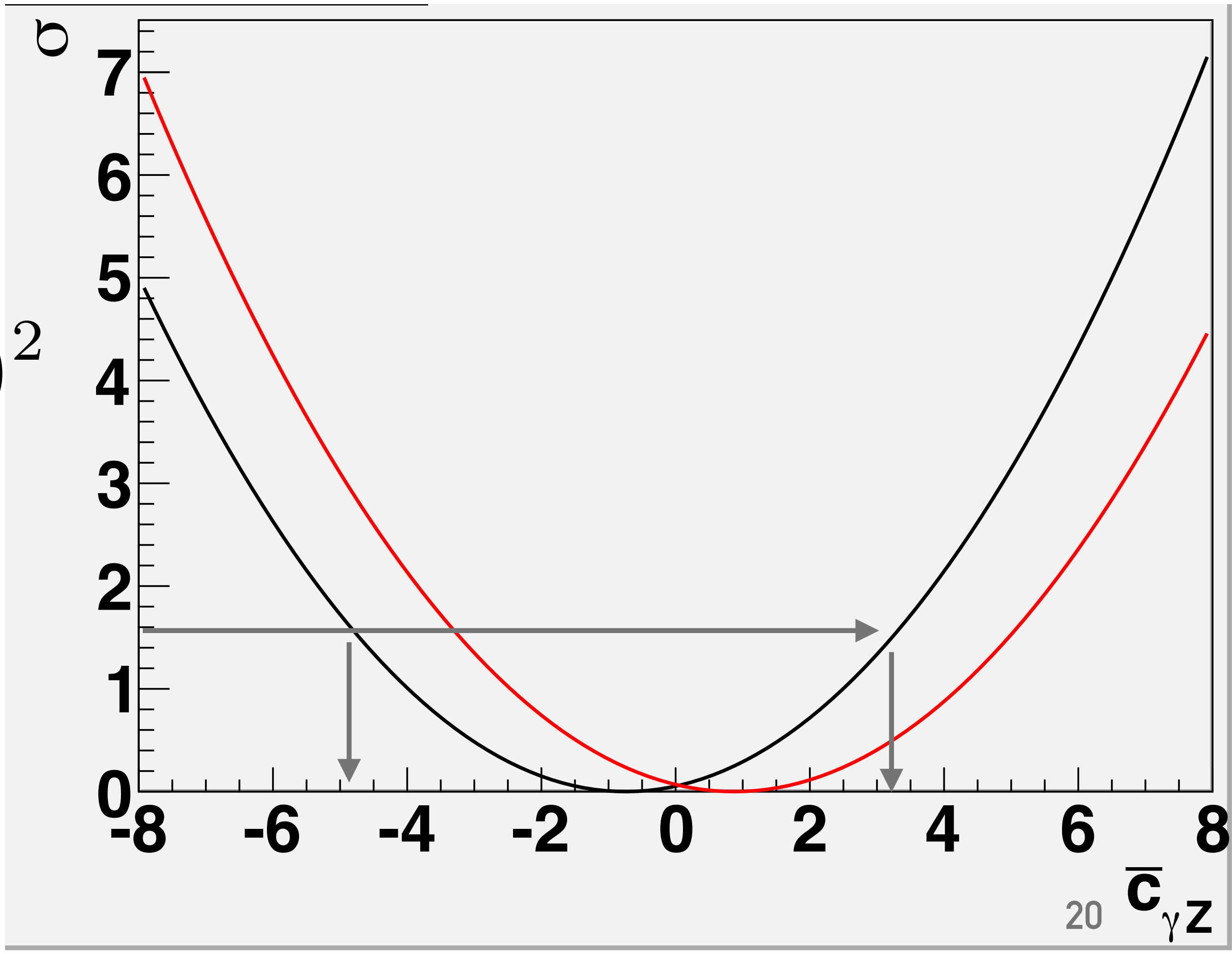
$$\sigma_L = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2\sigma_{SM}$$

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

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

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

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



7. Summery

I simulate HγZ coupling constant to get the key to new physics

Significance for e+e- ->hγ process
~ 0.30σ for SM at $\sqrt{s}$=250 GeV, 2000 fb^{-1}

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

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

Next step

- optimize event selection
- do analysis for right handed beam polarization
- interpret cγZ bounds based on full 1-loop calculation
- Compare bounds with other method

Back up

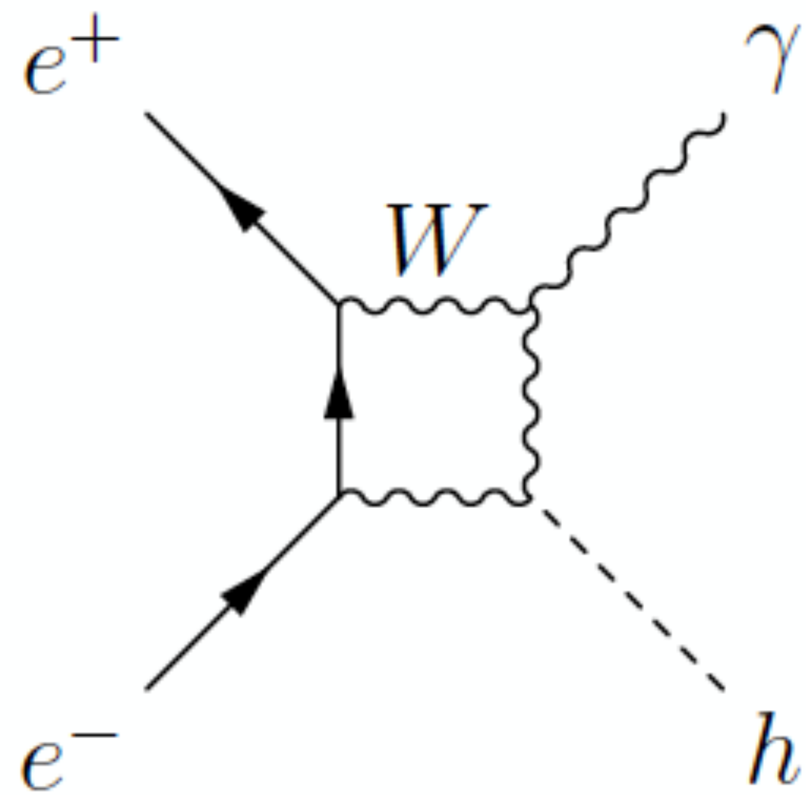
5. Event selection

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.