Study of HγZ coupling at the ILC

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on behalf of ILD concept group
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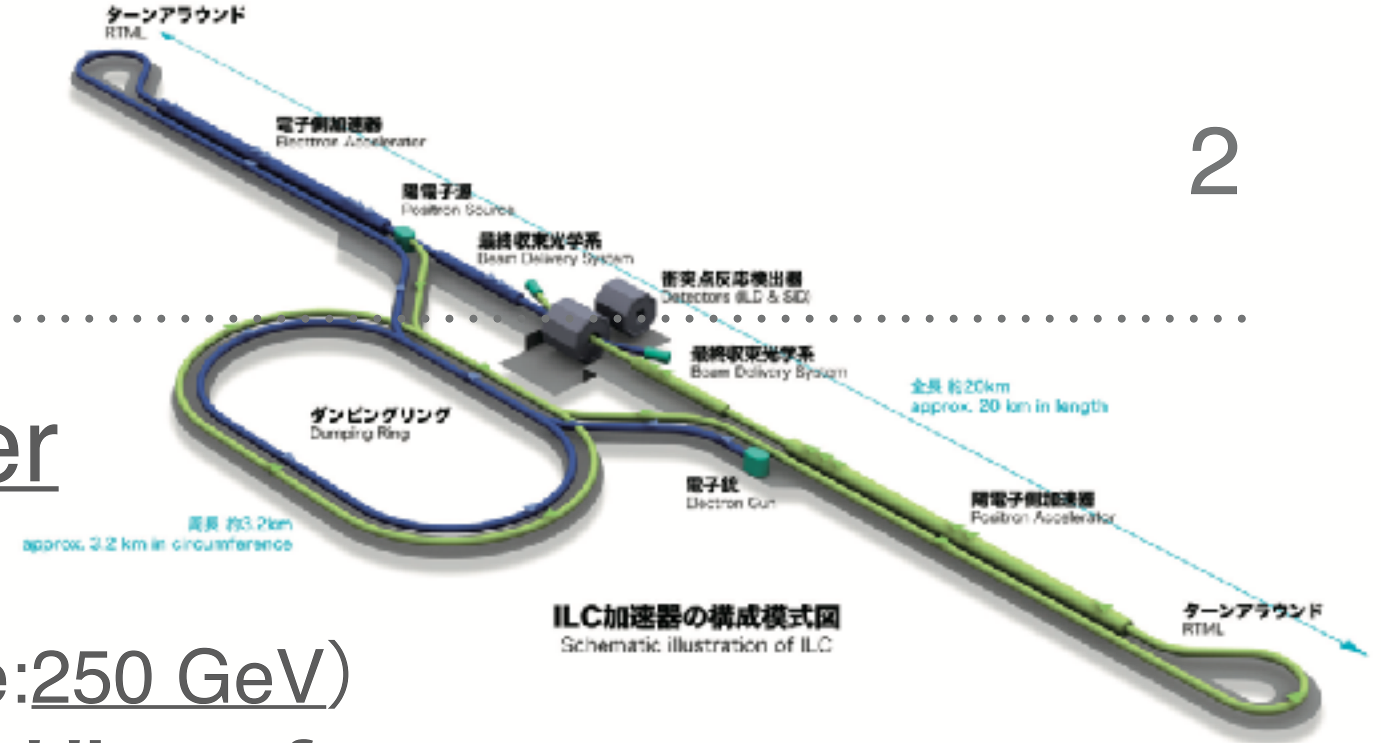
0.Background



International Linear Collider

↓

electron-positron collider（First stage:250 GeV）

Higgs factory

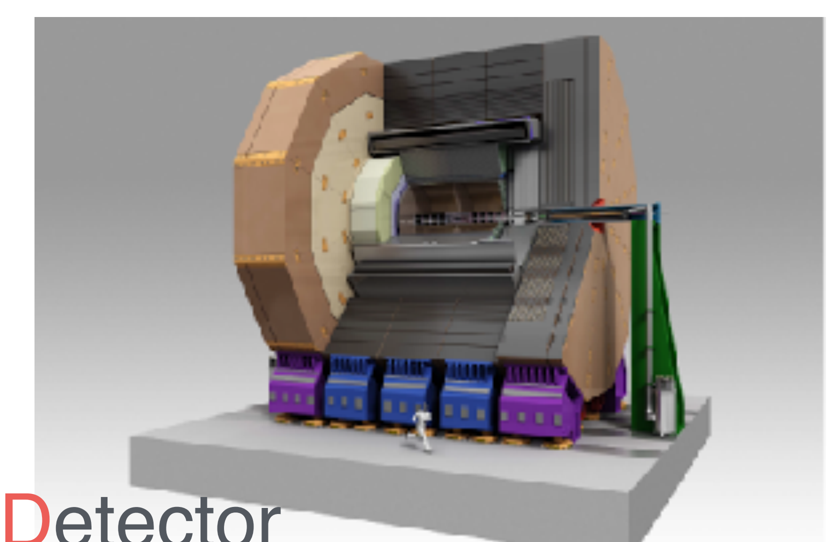
@Rei.Hori

Advantage of ILC

- Beam polarization for ±80% for electron , ±30% for positron
- Upgradable to 500 GeV, 1 TeV
- The only LC project with TDR and the key technologies mature and in hand
- Being seriously considered by the Japanese government

Advantage of ILD

- Based on Particle Flow Analysis, we can detect all particles without overlap.



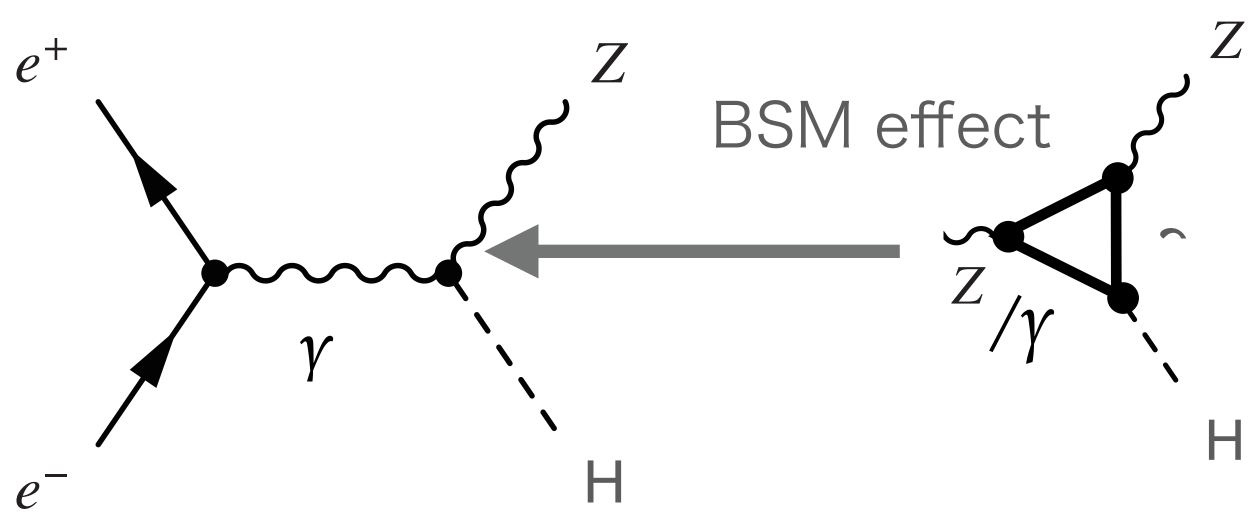
International Large Detector

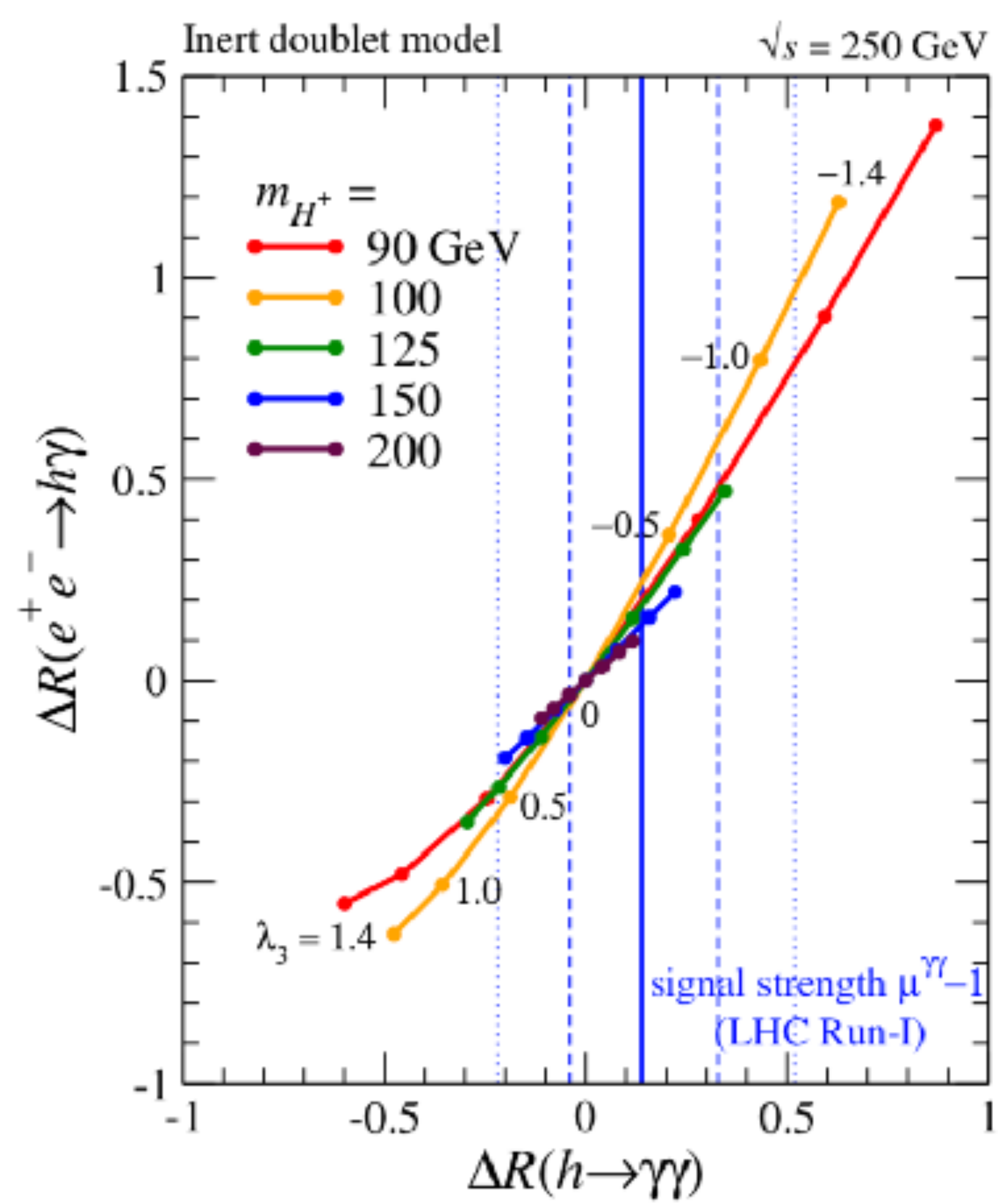
1.Motivation

To find new physics via Hγγ and HγZ couplings

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

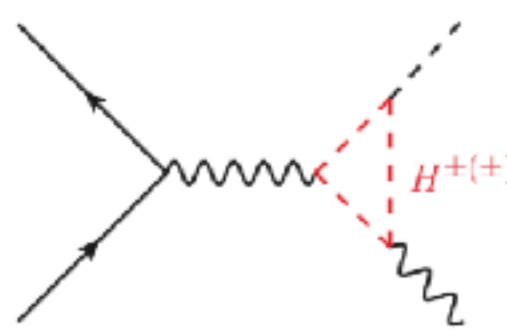
→We expect BSM amplitude can be larger than SM amplitude.





Any deviation from SM in coupling constants signals new physics.

e.g. : Inert Doublet Model

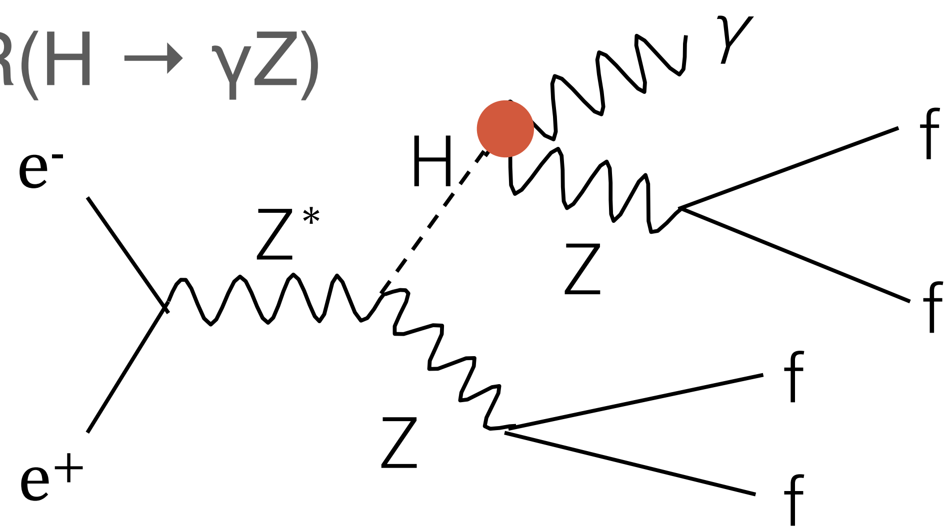


Mawatari, et al, arXiv:1808.10268

2.Two ways to measure hγZ coupling

Higgs decay

BR(H → γZ)

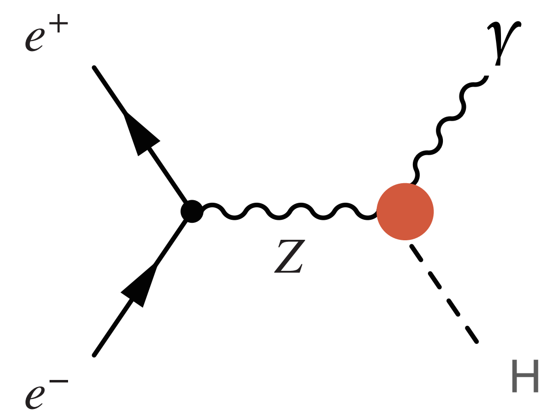


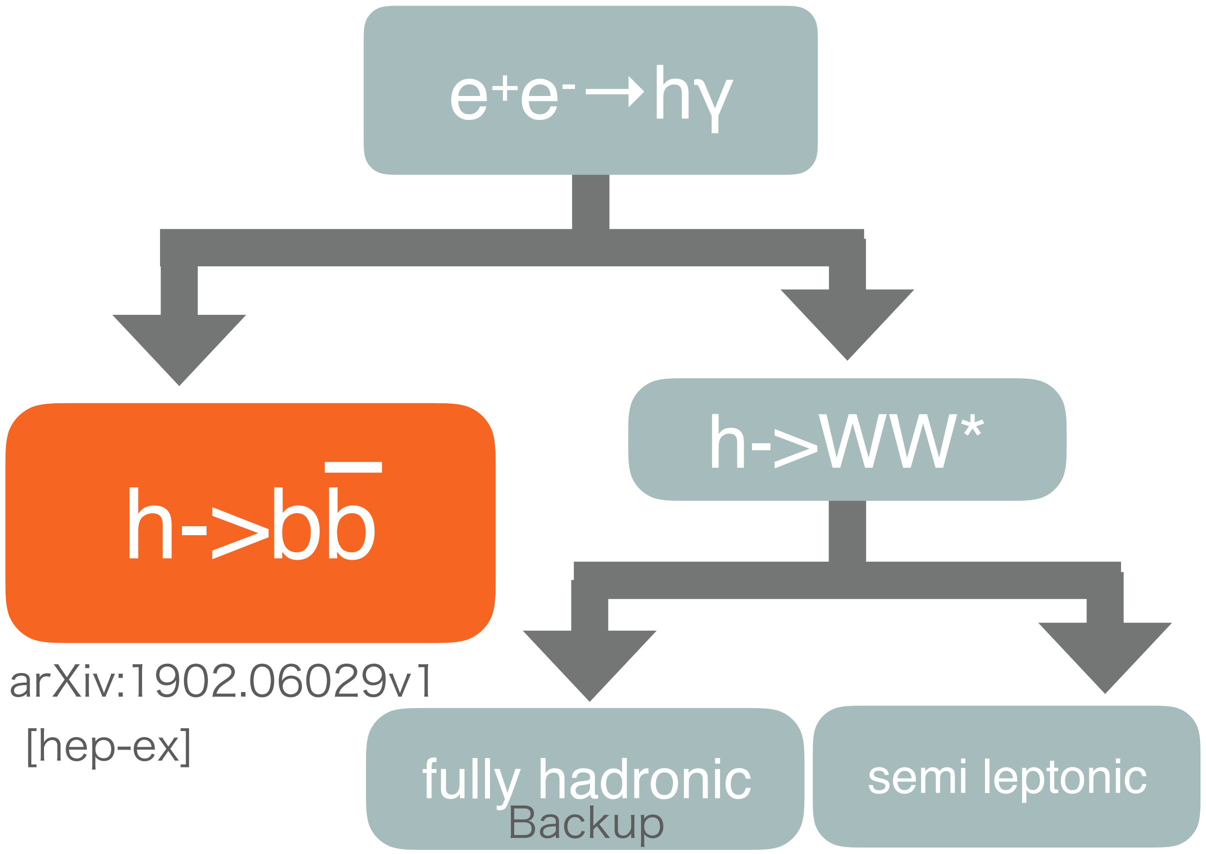
final state	BR
mmqqγ	4.7%
eeqqγ	4.7%
nnqqγ	28.0%
qqqqγ	48.9%
others	13.7%

by Kazuki Fujii at LCWS2018

Higgs production

σ (e+e- →Hγ)





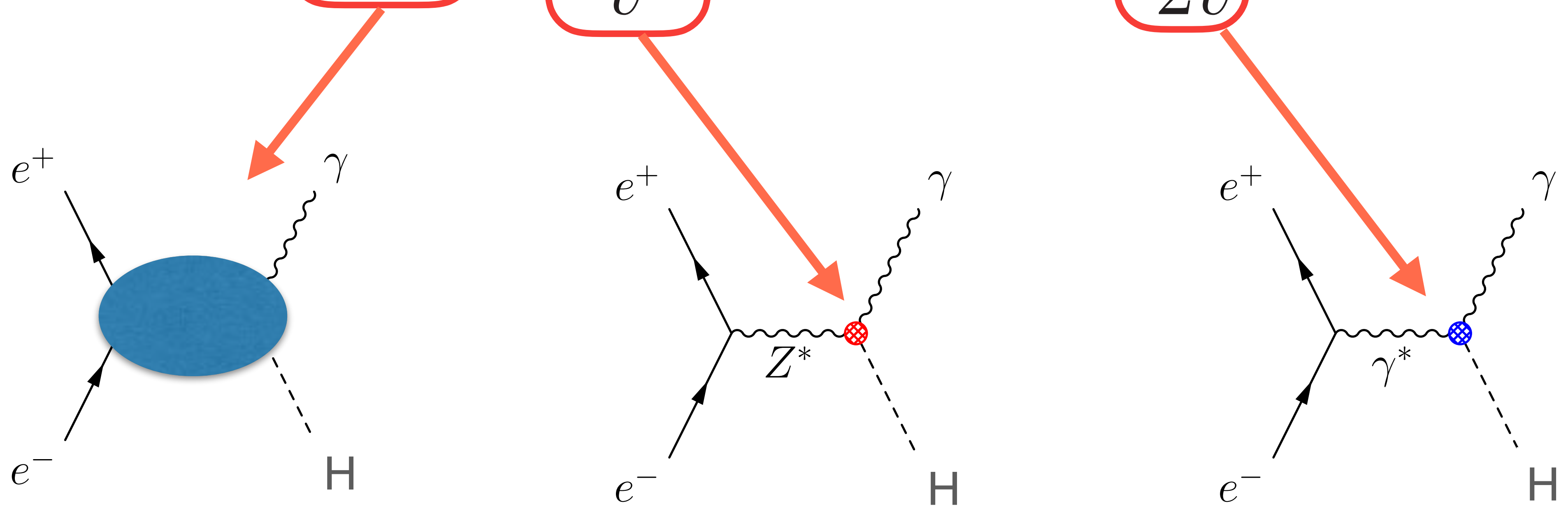
arXiv:1902.06029v1 [hep-ex]

3. Theoretical framework for our analysis

The effective field theory (EFT) Lagrangian to include new physics contributions to the $e^+e^- \to h\gamma$ cross section model-independently

effective hγZ coupling   effective hγγ coupling

$$L_{\gamma H} = L_{\rm SM} + \frac{\zeta_{AZ}}{v} A_{\mu\nu} Z^{\mu\nu} H + \frac{\zeta_A}{2v} A_{\mu\nu} A^{\mu\nu} H$$



Phys.Rev. D94 (2016) 095015

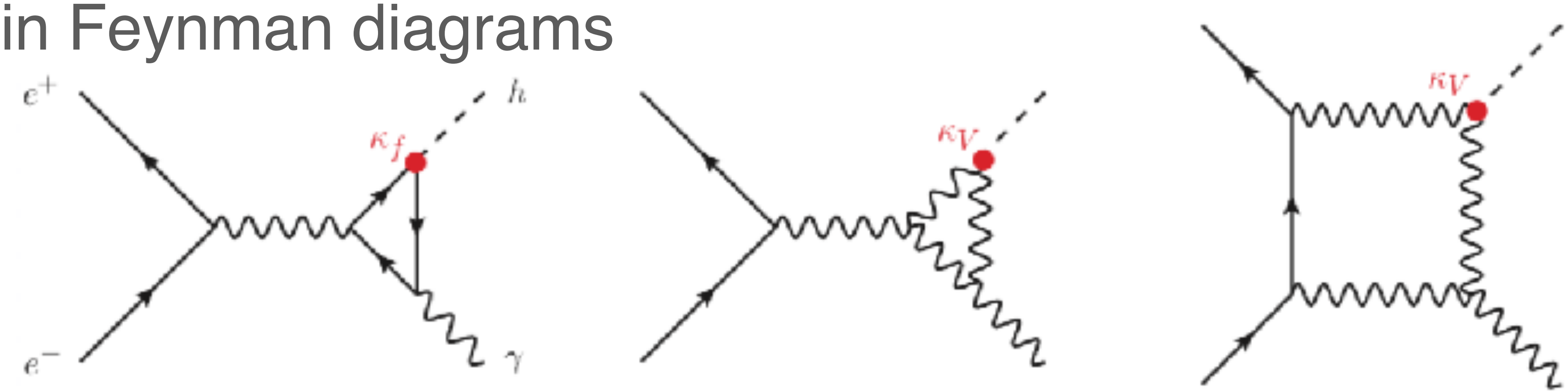
$A_{\mu\nu}$, $Z_{\mu\nu}$: field strength tensors   v: vacuum expectation value

Since ζ_A can be constrained already by measurement of $h \to \gamma\gamma$ branching ratio at LHC, we can extract ζ_{AZ} parameter by just measuring cross section for a single polarization.

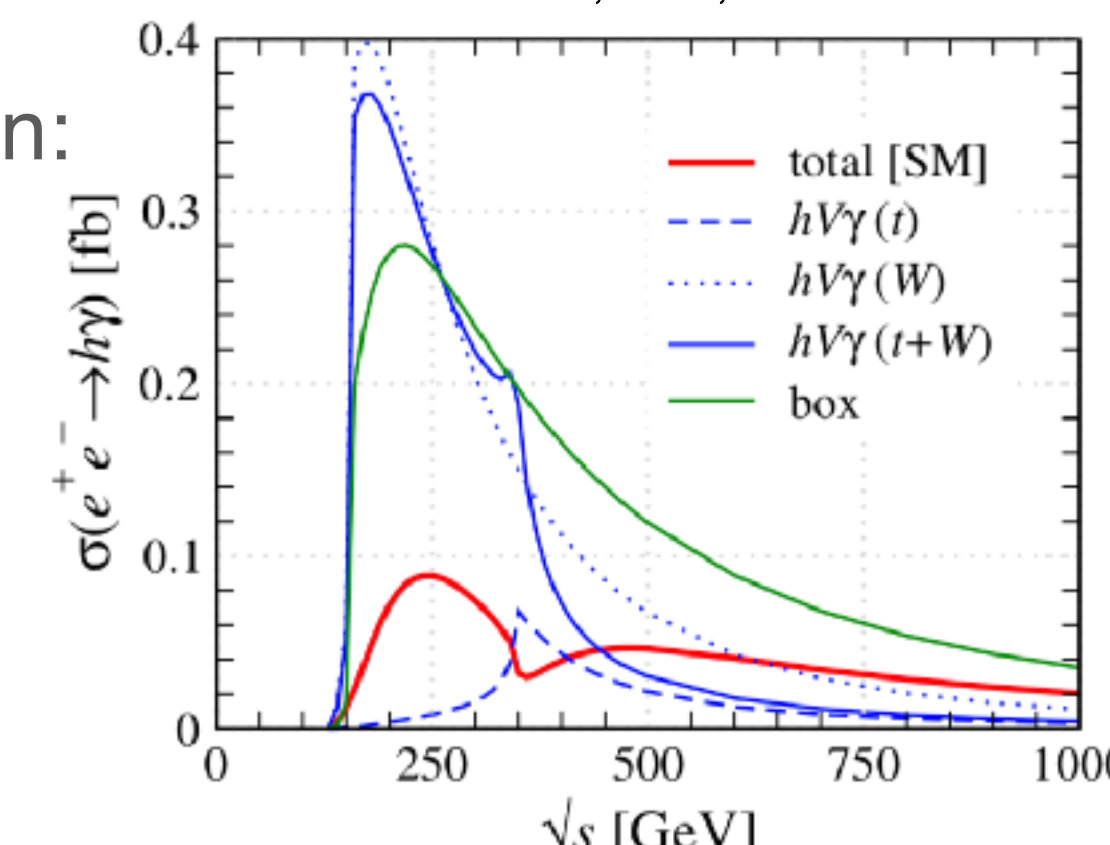
3. Theoretical framework for our analysis

SM one-loop predictions

The main Feynman diagrams



Mawatari, et al, arXiv:1808.10268



※For not polarized beam

Destructive interference

SM cross sections by one loop calculation:

e^- e^+

σ_{SM}=0.35 fb for (-100%,+100%)

σ_{SM}=0.016 fb for (+100%,-100%)

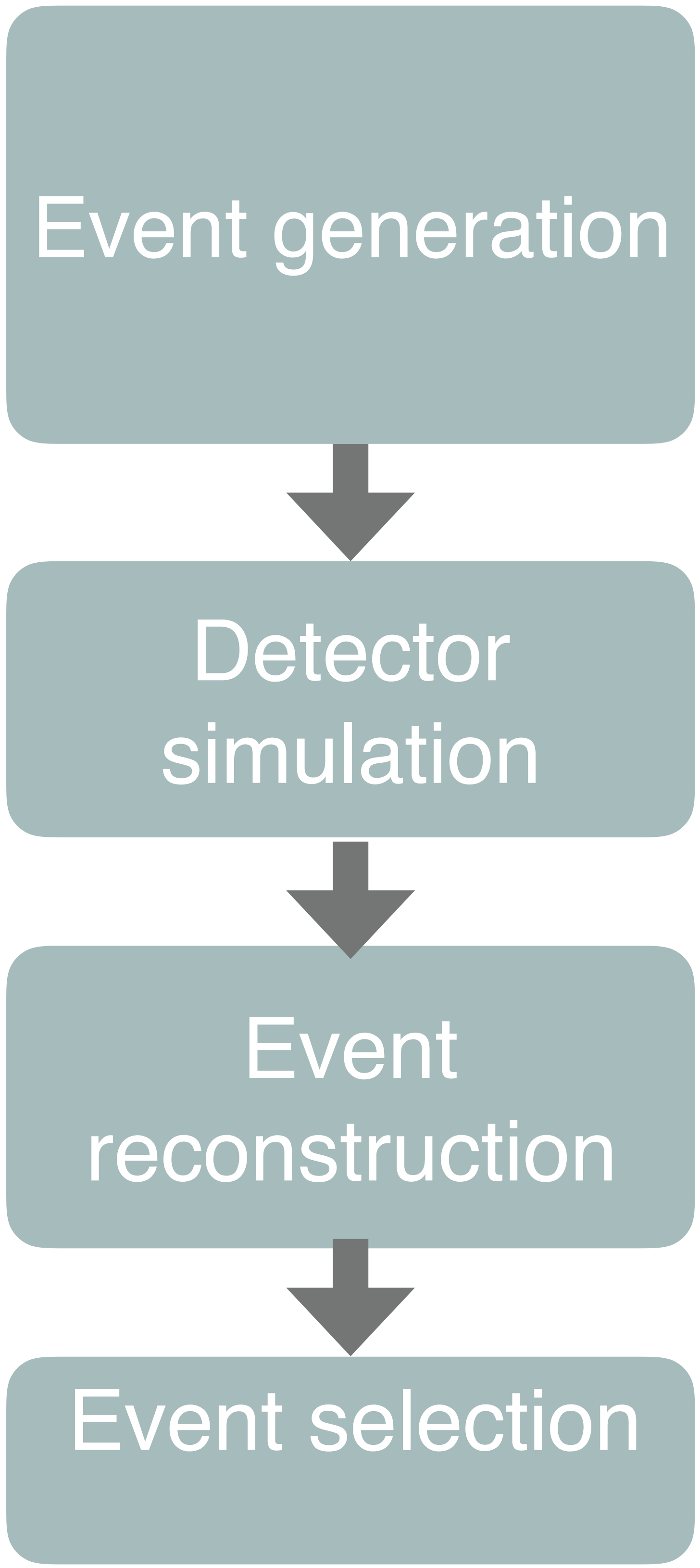
σ_{SM}=**0.20 fb** for (-80%,+30%)

$\sqrt{s}$ = 250 GeV

Small !

This analysis is challenging.

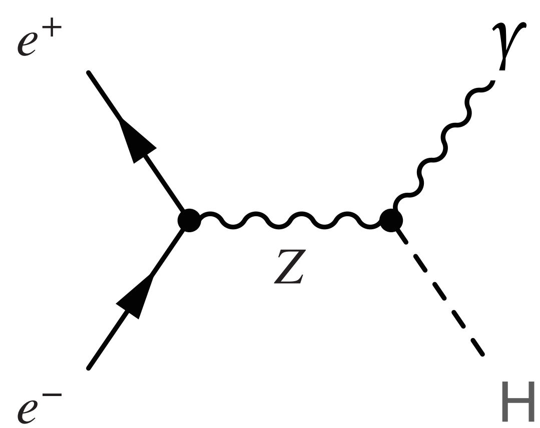
4.Simulation framework



- $\sqrt{s}$=250 GeV
  Integrated Luminosity: 2000 fb^{-1}
- background : 2f,4f
- ISR and Beamstrahlung effects are included
- ILD full simulation
- Geat4 based, realistic detailed detector model
- Full reconstruction chain from detector signals to 4-vectors

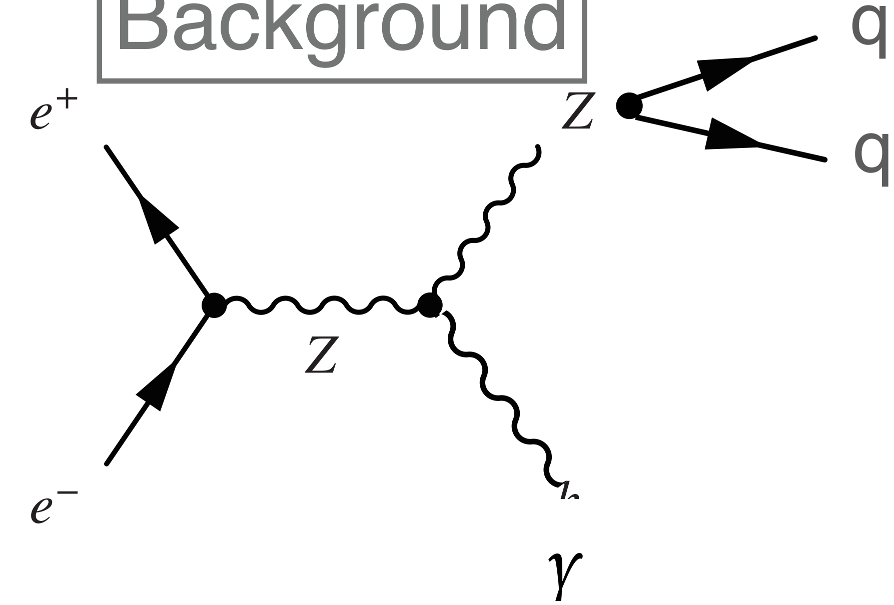
5. Signal & Background

Signal



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

Background



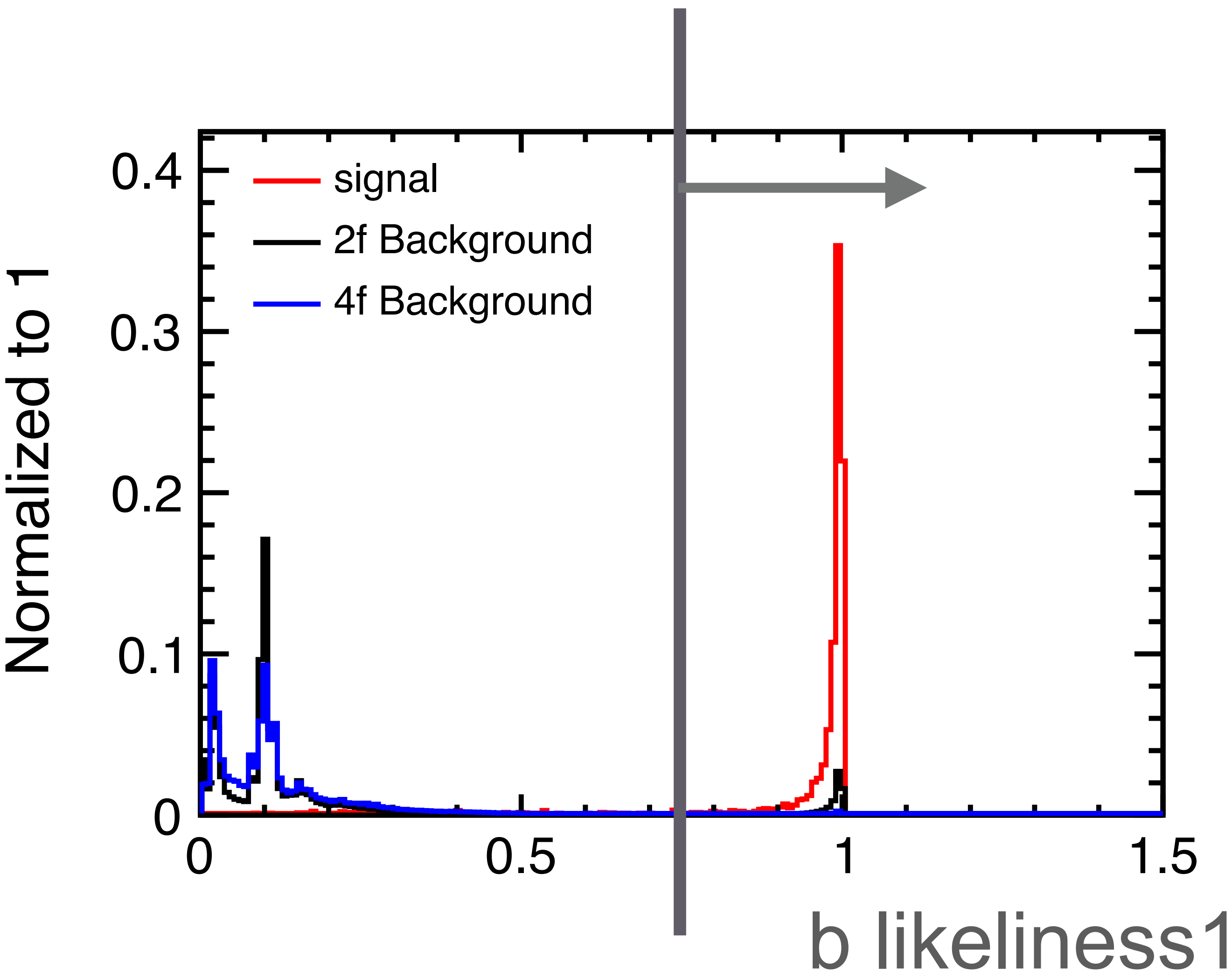
$e^+e^- \to \gamma Z \to \gamma qq$
(radiative return)

Signal		Background
2 b jets	Btag	qq not necessarily bb
m(2jet)= Higgs mass	m(2jets)	m(2jet)=Z mass
Energy of isolated monochromatic photon ~93 GeV	E_γ	Energy of photon ~108 GeV

6. Event selection

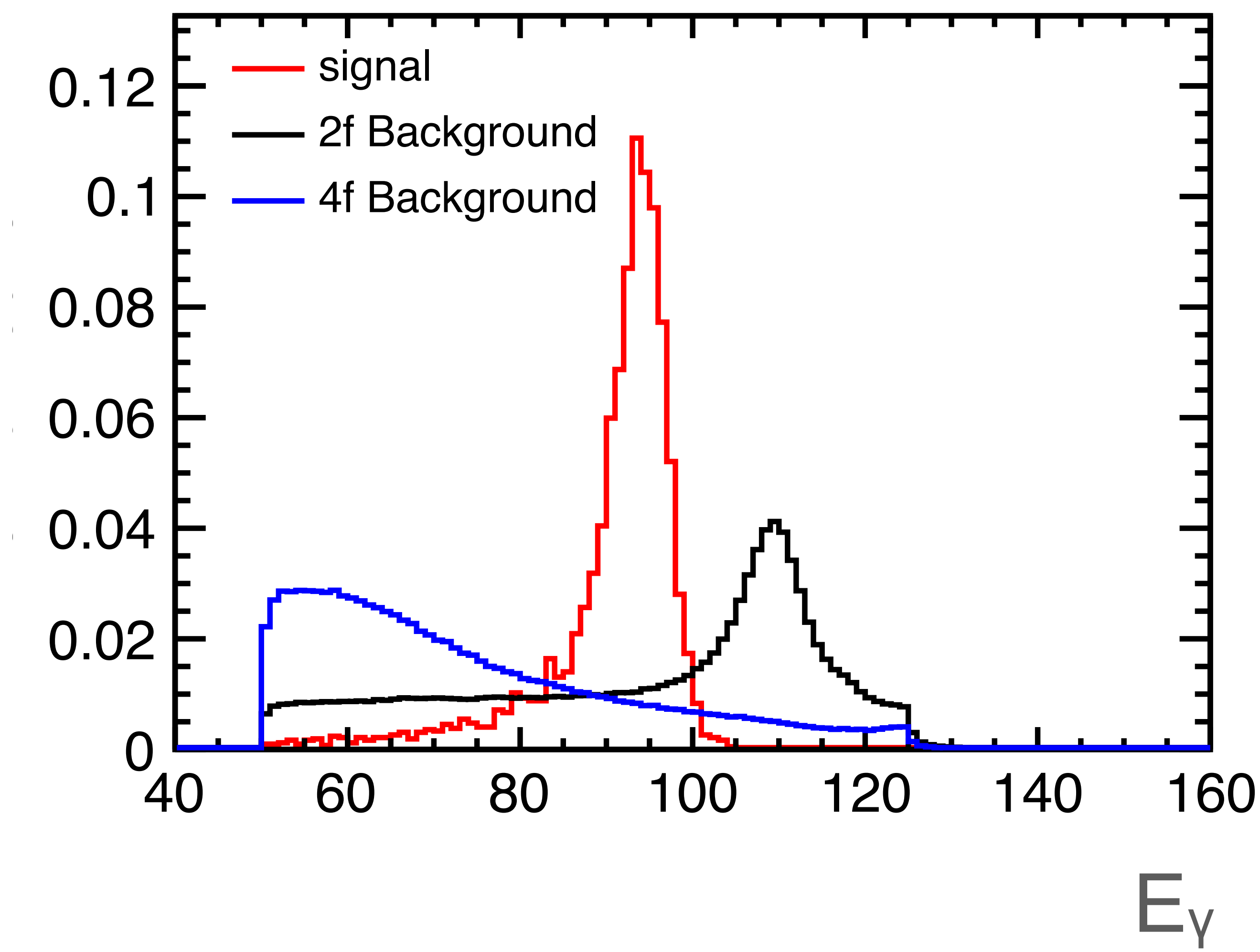
Btag

b likeliness > 0.77



E_γ

Energy of photon
(later used for MVA)

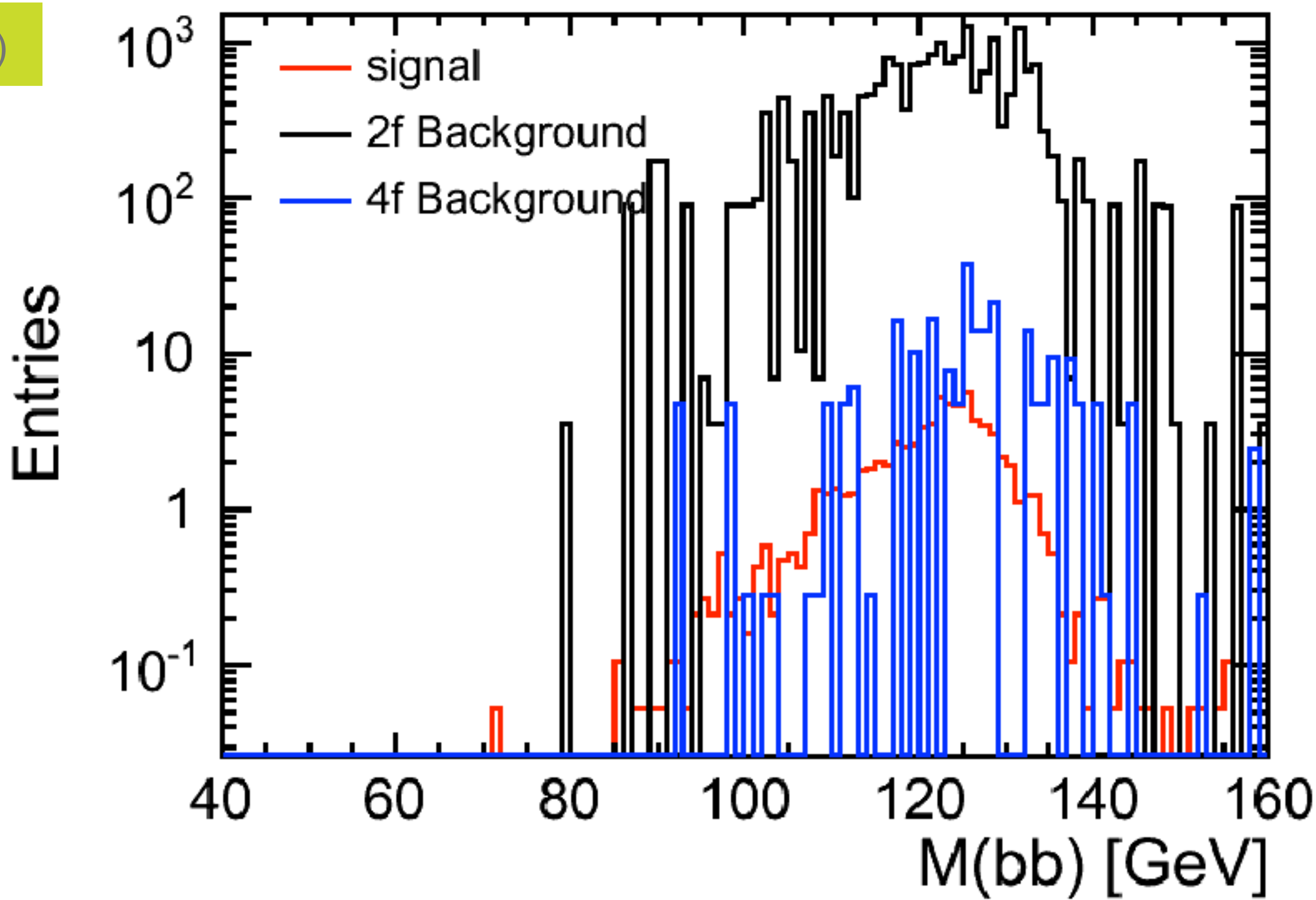


6. Event selection

The distribution of m(bb) after all the other cuts, normalized to

Integrated Luminosity: 2000 fb^{-1}

m(2jets)



7. Result

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

Reduction table Preliminary

N_s:Number of signal
N_B:Number of background

	Signal	background	Significance
Expected	237	3.14×10^8	0.01
Pre selection	222	6.54×10^7	0.02
btag>0.77	200	4.96×10^6	0.09
E_{mis}<35	182	4.30×10^6	0.09
mvabdt > 0.0126	75	1.98×10^4	0.53

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

= 4.1 × 0.35 [fb] Significance = 0.53 for SM

=1.43 [fb] (Left handed)

8. Combined result

$$L_{\gamma H} = L_{\rm SM} + \frac{\zeta_{AZ}}{v} A_{\mu\nu} Z^{\mu\nu} H + \frac{\zeta_A}{2v} A_{\mu\nu} A^{\mu\nu} H$$

Higgs production (h->bb)

Significance = 0.53 for SM

4.1> $\frac{\sigma_{\gamma H}}{\sigma_{SM}} = 1 - 201\zeta_A - 273\zeta_{AZ}$ >0 assume ζ_A =0

@95 % C.L.

Phys.Rev. D94 (2016) 095015

-0.011 < ζ_{AZ} <0.0037

@95 % C.L.

Higgs decay

Significance = 2.31 ± 0.03 for SM

1.71> $\frac{\mathrm{BR}(H \to \gamma Z)}{\mathrm{BR}_{SM}} = 1 + 290\zeta_{AZ}$ >0 arXiv:1708.09079v3 [hep-ph]

@95 % C.L.

-0.0034< ζ_{AZ} **<0.0024**

@95 % C.L.

Combined expected 1σ bound on ζ_{AZ} **-0.0015 < ζ_{AZ} < 0.0015**

9. Summary

We have performed a full simulation study of $e^+e^- \to H\gamma$ at 250 GeV ILC, using ILD detector.

We found signal significance **0.53σ** for SM at $\sqrt{s}$=250 GeV, 2000 fb^{-1}.

To parametrize BSM effects model independently, we adopt an EFT Lagrangian containing an anomalous HγZ coupling.

We found the $e^+e^- \to H\gamma$ process gives the following constraint on the coefficient for this anomalous coupling, ζ_{AZ} :

$$-0.011(@95\%\ C.\ L.) < \zeta_{AZ} < 0.0037$$

Combining with constraint from BR(H→γZ) measurement at ILC, we found 1σ bound : $-0.0015 < \zeta_{AZ} < 0.0015$

Next step

- Include h->WW* channel (on going).
- Understand the role of this measurement in a global EFT analysis.