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

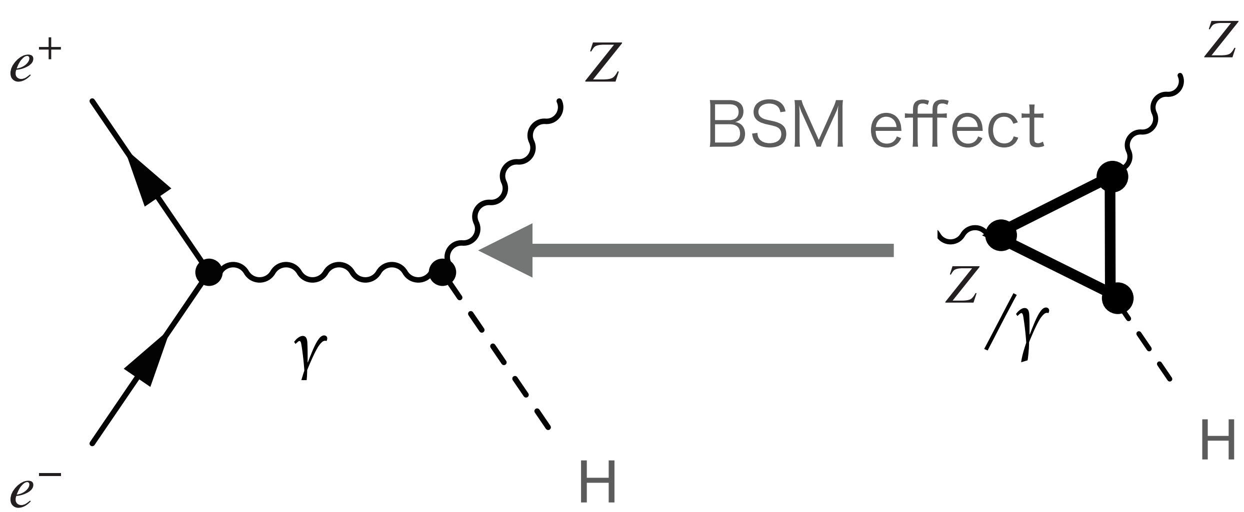
Yumi Aoki(SOKENDAI), Junping Tian(Tokyo Univ.)
, Keisuke Fujii(KEK),
Sunghoon Jung(Seoul National Univ.),
Junghwan Lee(Seoul National Univ.),

2021.3.9(Tue) @General Software & Analysis meeting

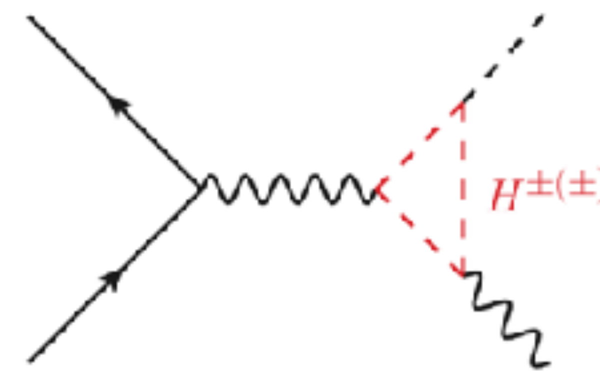
1.Motivation

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.



e.g. : Inert Triplet Model



Mawatari, et al, arXiv:1808.10268

This process can be also useful to constrain the dimension 6 EFT operators which can introduce effective anomalous hγZ and hγγ couplings.

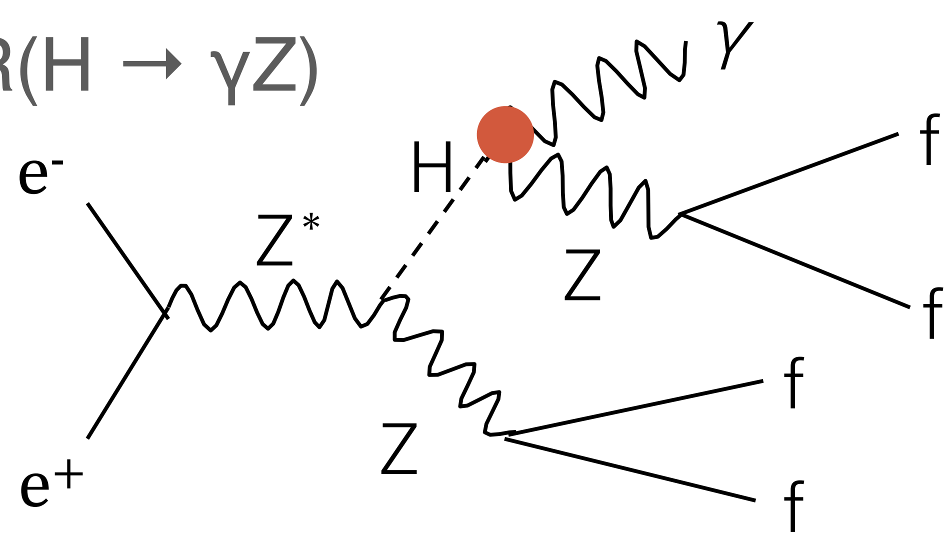
Q. H. Cao, et al, arXiv:1505.00654 [hep-ph]

Any deviation of the coupling constants from SM signals new physics.

2.Two ways to measure HγZ coupling

Higgs decay

BR(H → γZ)

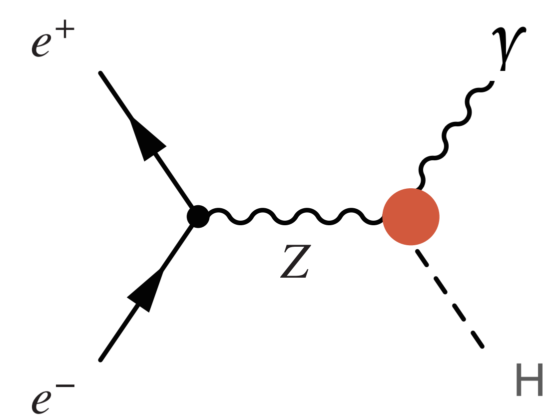


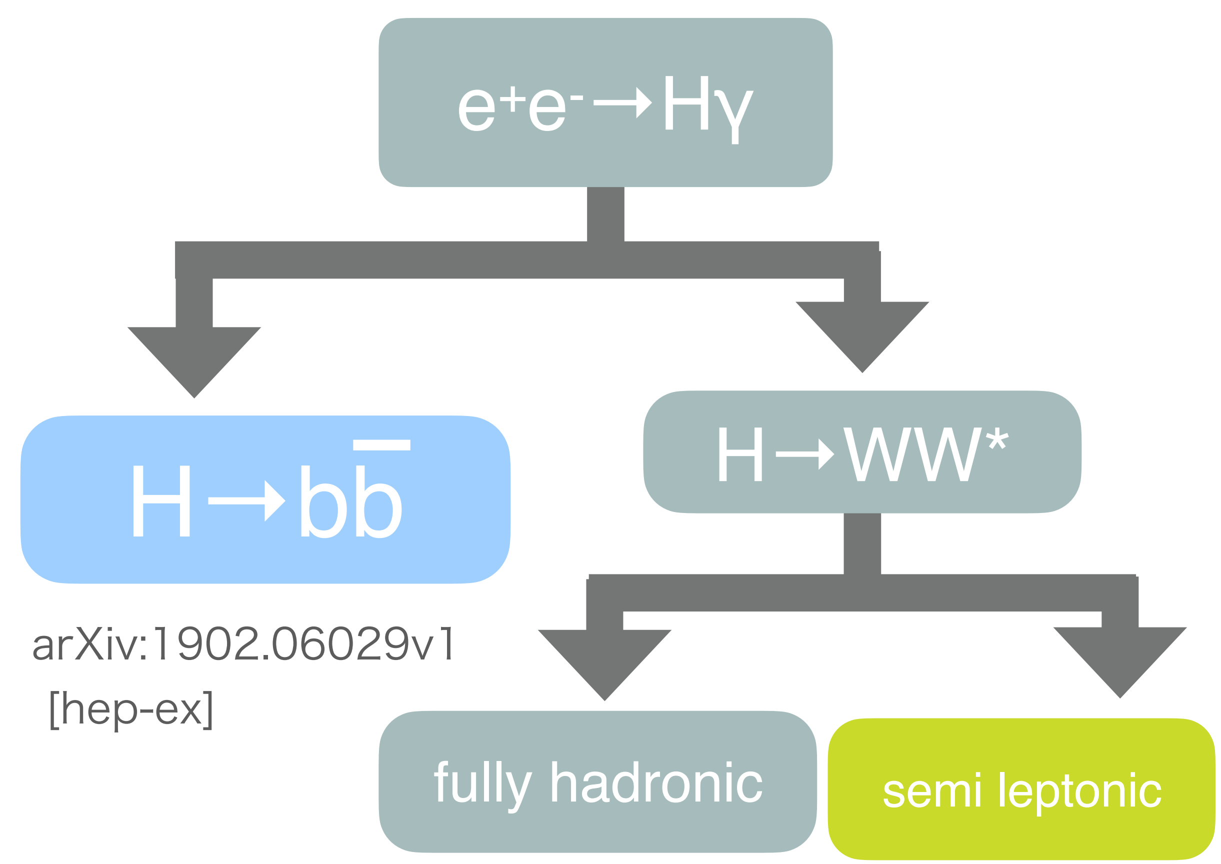
final state	BR
mmqqγ	4.7%
eeqqγ	4.7%
nnqqγ	28.0%
qqqqγ	48.9%
others	13.7%

by Kazuki Fujii at LCWS2018

Higgs production

σ (e+e- →Hγ)





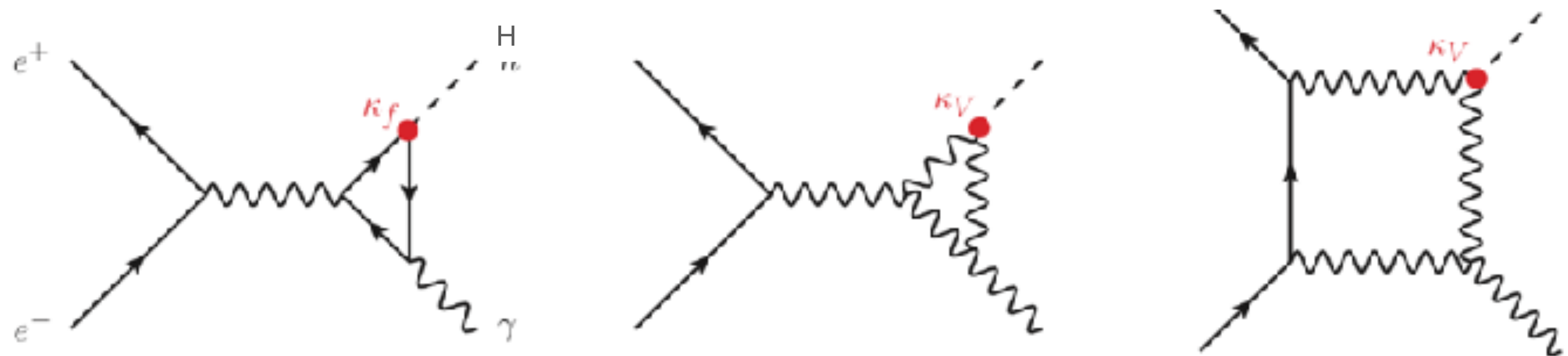
arXiv:1902.06029v1 [hep-ex]

arXiv:2002.07164 [hep-ex]

3. Theoretical framework for our analysis

SM one-loop predictions

The main Feynman diagrams



Mawatari, et al, arXiv:1808.10268

SM cross sections by one loop calculation:

e- e+

σ_{SM}=0.35 fb for (-100%,+100%)

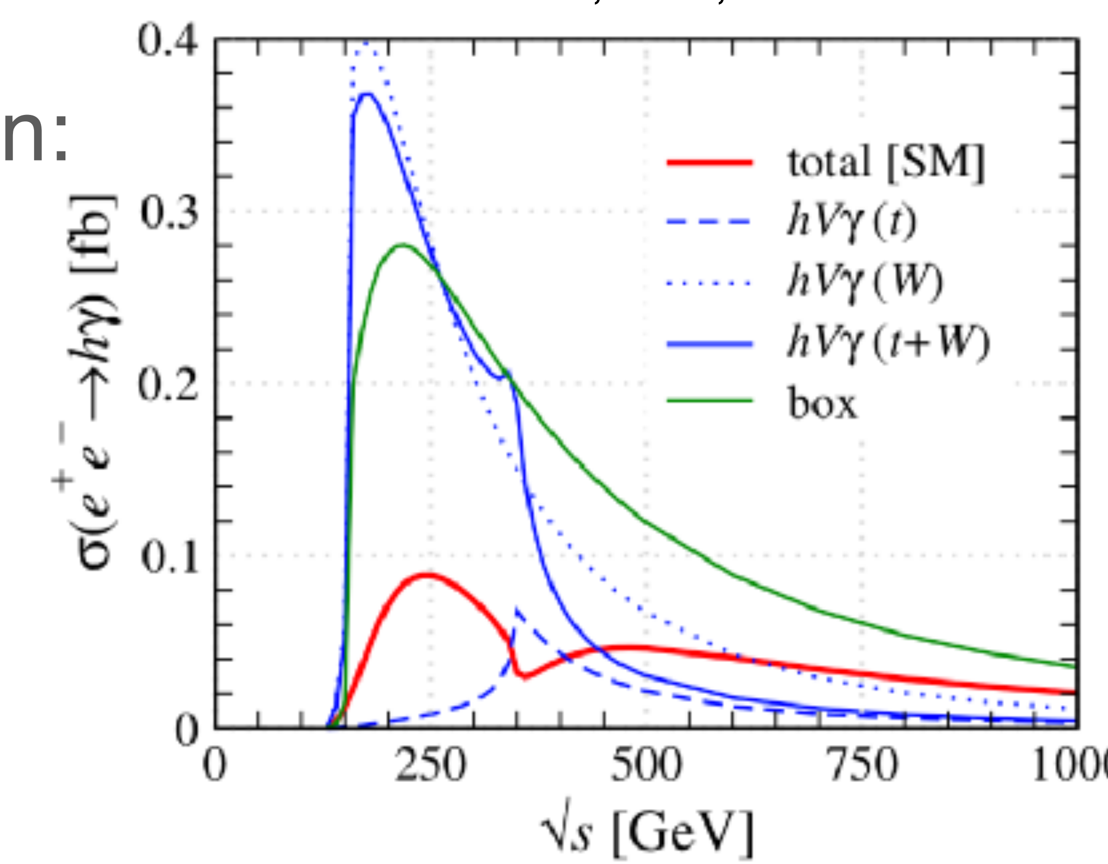
σ_{SM}=0.016 fb for (+100%,-100%)

σ_{SM}=**0.20 fb** for (-80%,+30%)

$\sqrt{s}$ = 250 GeV

Small !

This analysis is very challenging.



※For unpolarized beam

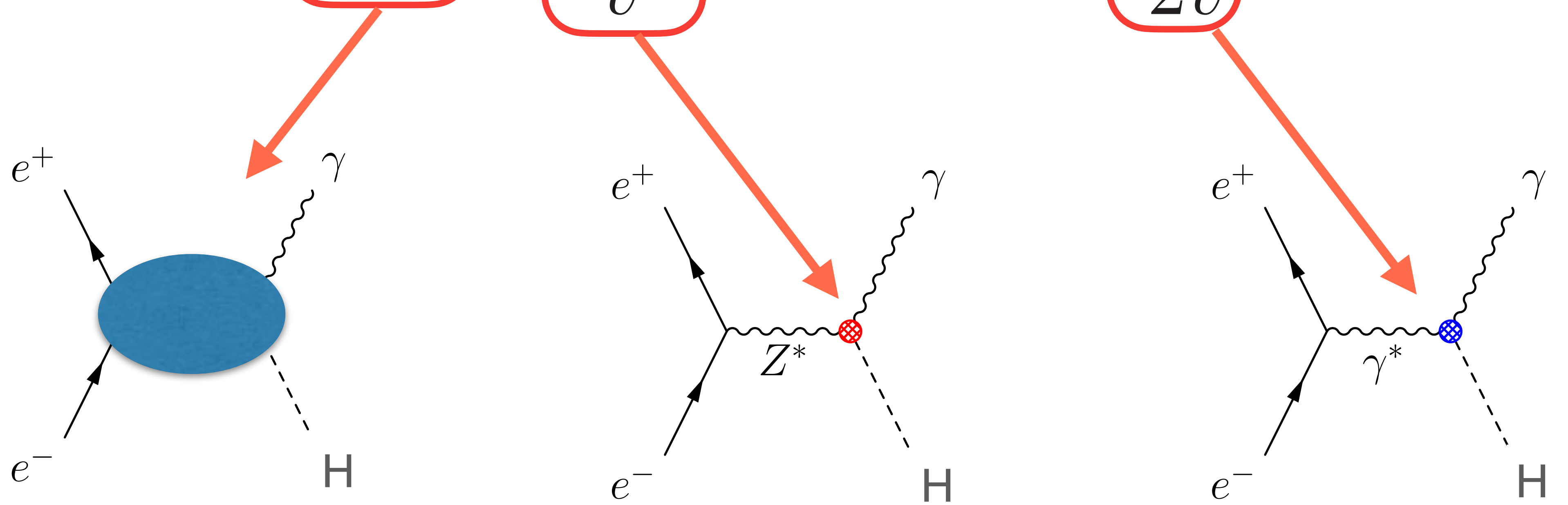
Destructive interference

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 h$\gamma\gamma$ coupling

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

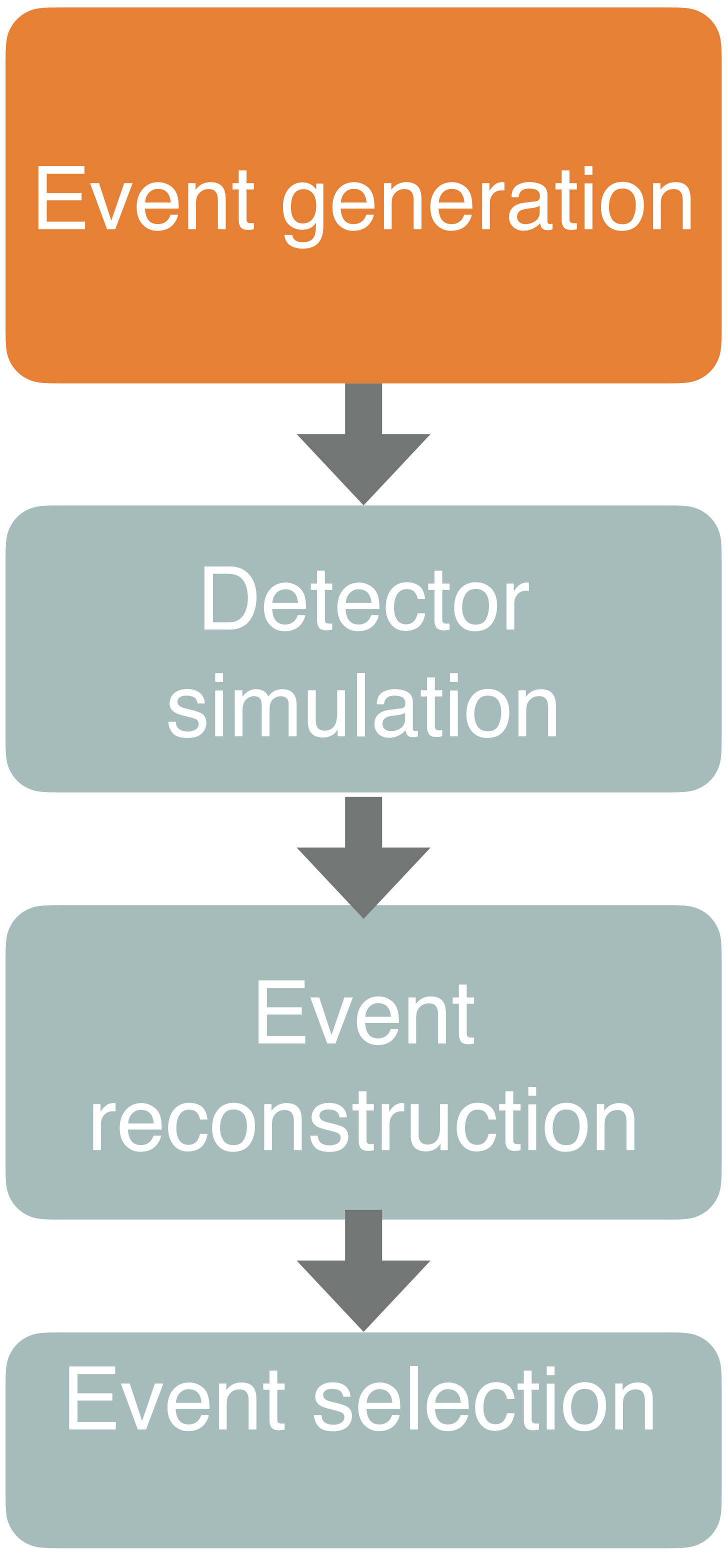


Phys.Rev. D94 (2016) 095015

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

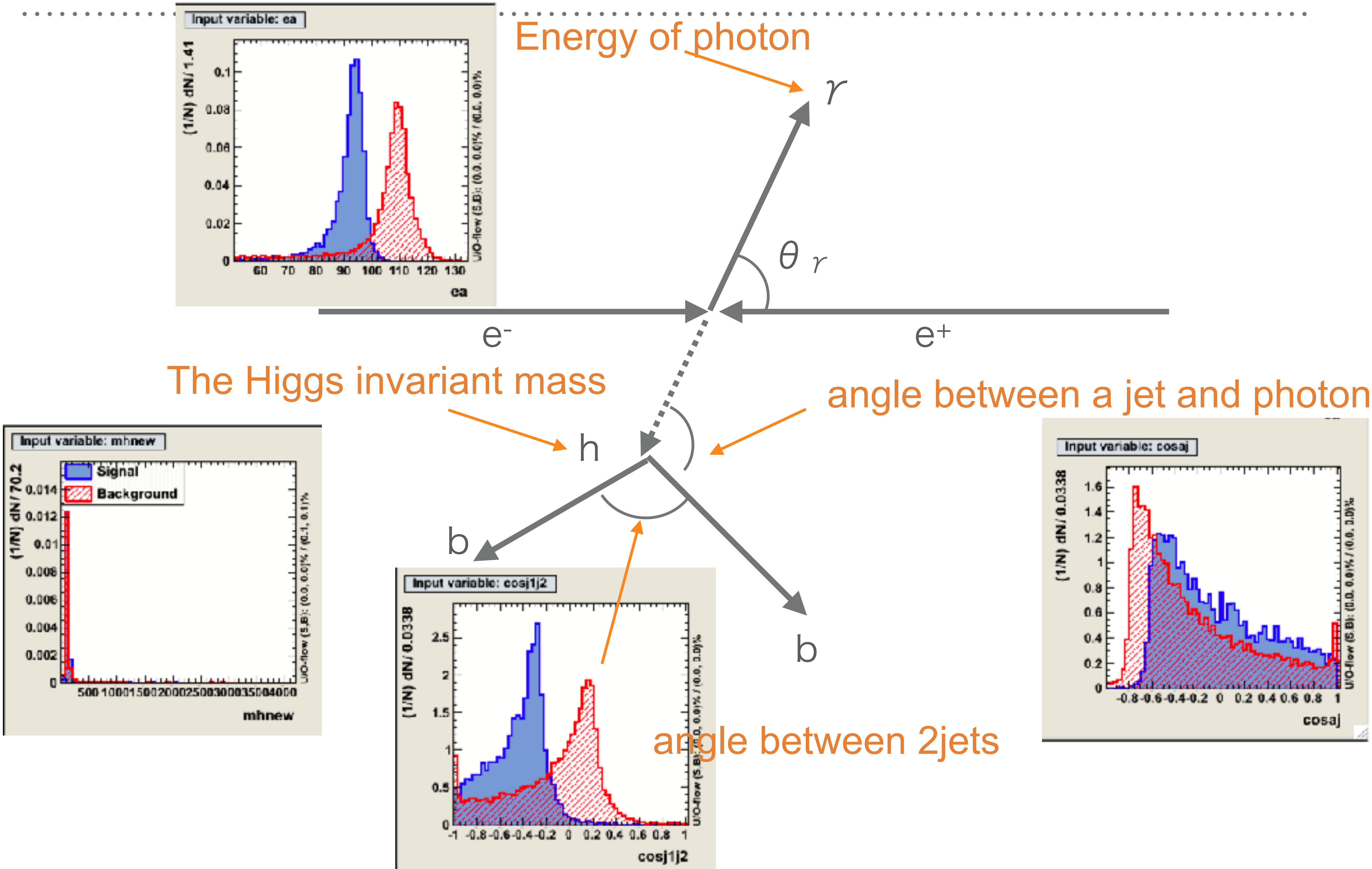
Since ζ_A is already constrained by measurement of $H \to \gamma\gamma$ branching ratio at LHC, we can extract ζ_{AZ} parameter by just measuring cross section for a single beam polarization.

4.Simulation framework

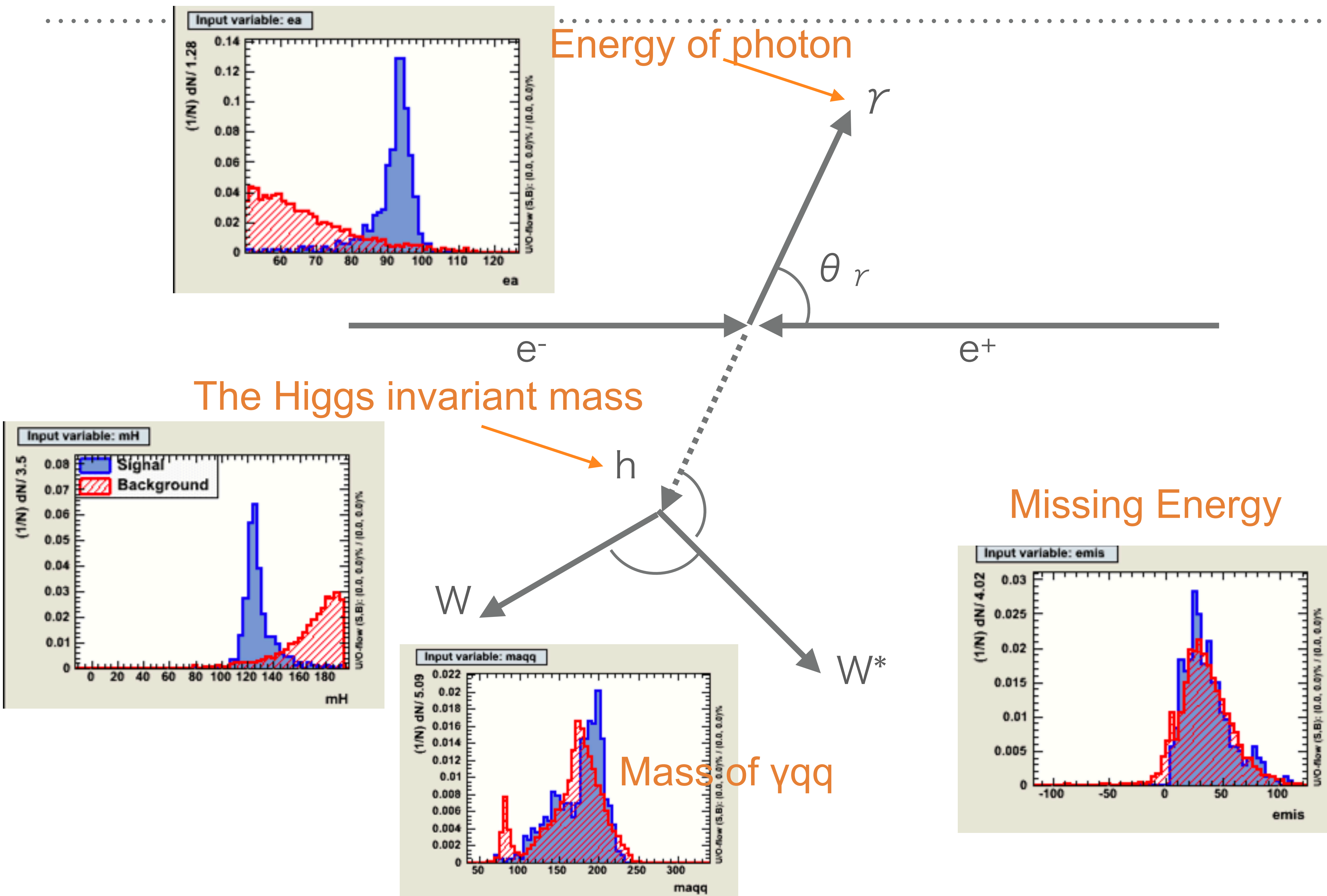


- $\sqrt{s}$=250 GeV
  Integrated Luminosity: 2000 fb^{-1}
  (900 fb^{-1} for Left handed)
- background : 2f,4f (DBD sample)
- ISR and Beamstrahlung effects are included
- ILD full simulation (Mokka)
- Geant4 based, realistic detailed detector model
- Full reconstruction chain from detector signals to 4-vectors
  (iLCSoft v01-16-02/ MarlinReco, PandoraPFA, LCFI+, Isolated photon finder, jet clustering)
- $E_{\gamma} > 50$ GeV

5. Analysis - Input variables for MVA



5. Analysis - Input variables for MVA



5. Analysis - Result of h→bb (Left handed)

Reduction table

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

N_S:Number of signal N_B:Number of background

	total bg	Signal	Significance
Expected	1.4×10^8	107	0.01
Pre selection	2.9×10^7	100	0.02
b likeliness>0.77	2.2×10^7	90	0.06
E_{mis}<35	1.9×10^6	82	0.06
mvabdt > 0.025	34814	48	0.26
-0.92<$\cos\theta_\gamma$<0.92	21257	43	0.29

Preliminary

→95% C.L upper limit

$$\sigma_{\gamma H} = \sigma_{SM} + \frac{1.64}{\text{significance}}\sigma_{SM}$$

(Significance = 0.29 for SM)

=2.33 [fb] (Left handed beam polarization case)

5. Analysis - Reduction table

	total bg	Signal	Significance
Expected	1.4×10^{8}	18.0	0.003
Pre selection	1.3×10^{7}	11.0	0.004
# of charged particle >3	306997	5.4	0.010
$\lvert mw1-80.4\rvert<10$ GeV or $\lvert mw2-80.4\rvert<9.4$ GeV	184537	3.7	0.009
b likeliness<0.77	175276	3.7	0.009
mvabdt>0.1	214	1.8	0.12
$-0.93<\cos\theta_{\gamma}<0.93$	35	1.6	0.26

Preliminary

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

Significance = 0.26 for SM

=2.56 [fb] (Left handed)

8. Summary

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

- signal significance **0.29σ** for SM at $\sqrt{s}$=250 GeV, 900 fb^{-1}.($h \to bb$)

  0.26σ for SM at $\sqrt{s}$=250 GeV, 900 fb^{-1}.($h \to WW^*$ semi-leptonic)

- Calculate background upper limit statistically

- Check the cosθγ distribution for confirm method validity

Next step

- Right handed case should be analyzed
- Combing right handed case