Study of HγZ coupling at the ILC

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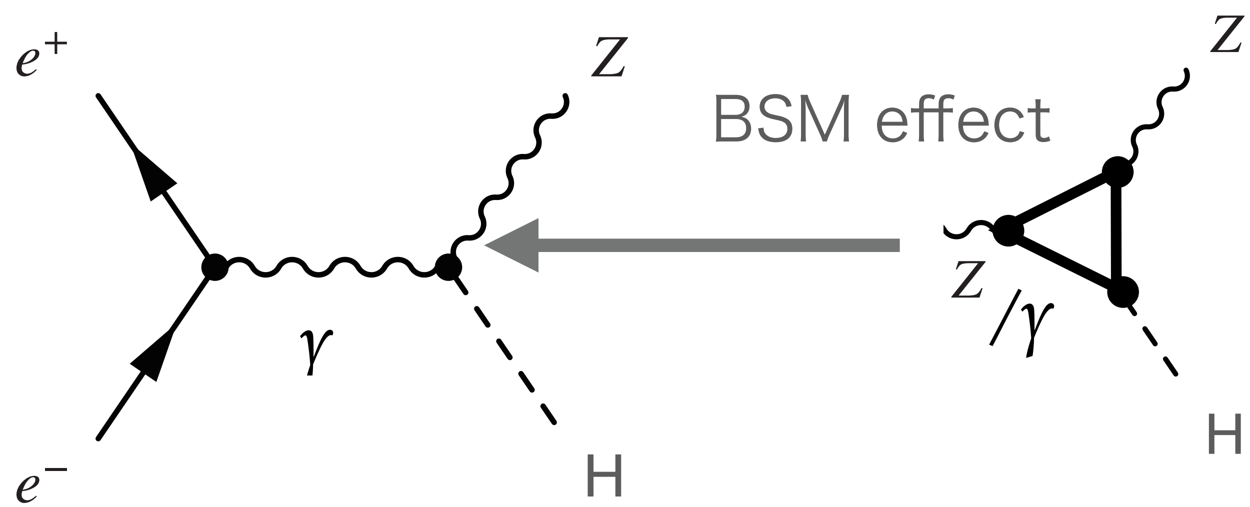
@Software and analysis meeting

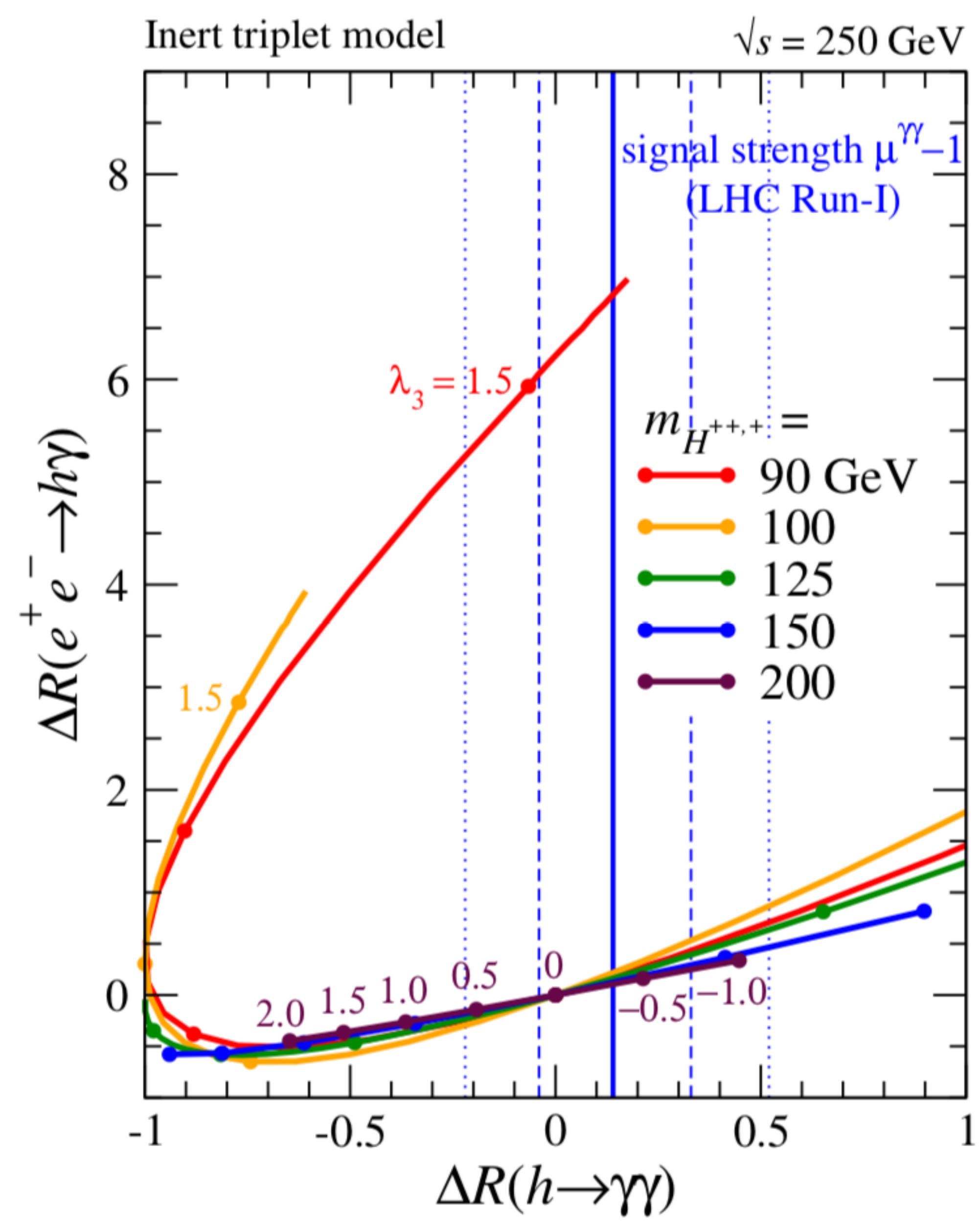
1.Motivation

To find new physics via Hγγ and HγZ couplings

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

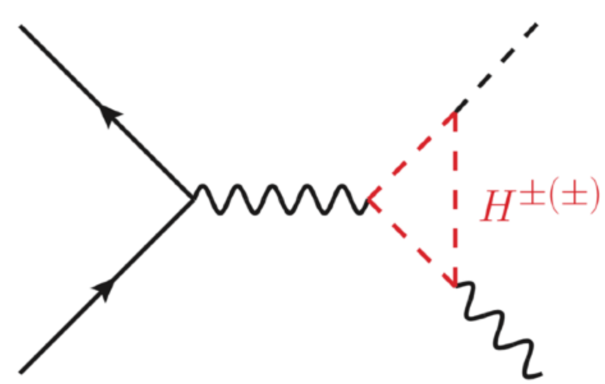
→We expect BSM amplitude can be larger than SM amplitude.





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

e.g. : Inert Triplet Model

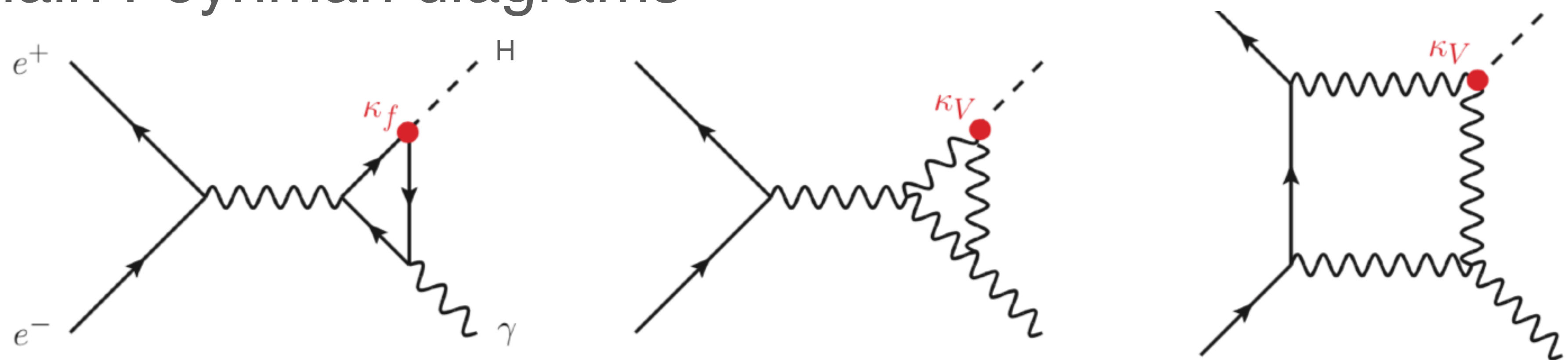


Mawatari, et al, arXiv:1808.10268

3. Theoretical framework for our analysis

SM one-loop predictions

The main Feynman diagrams



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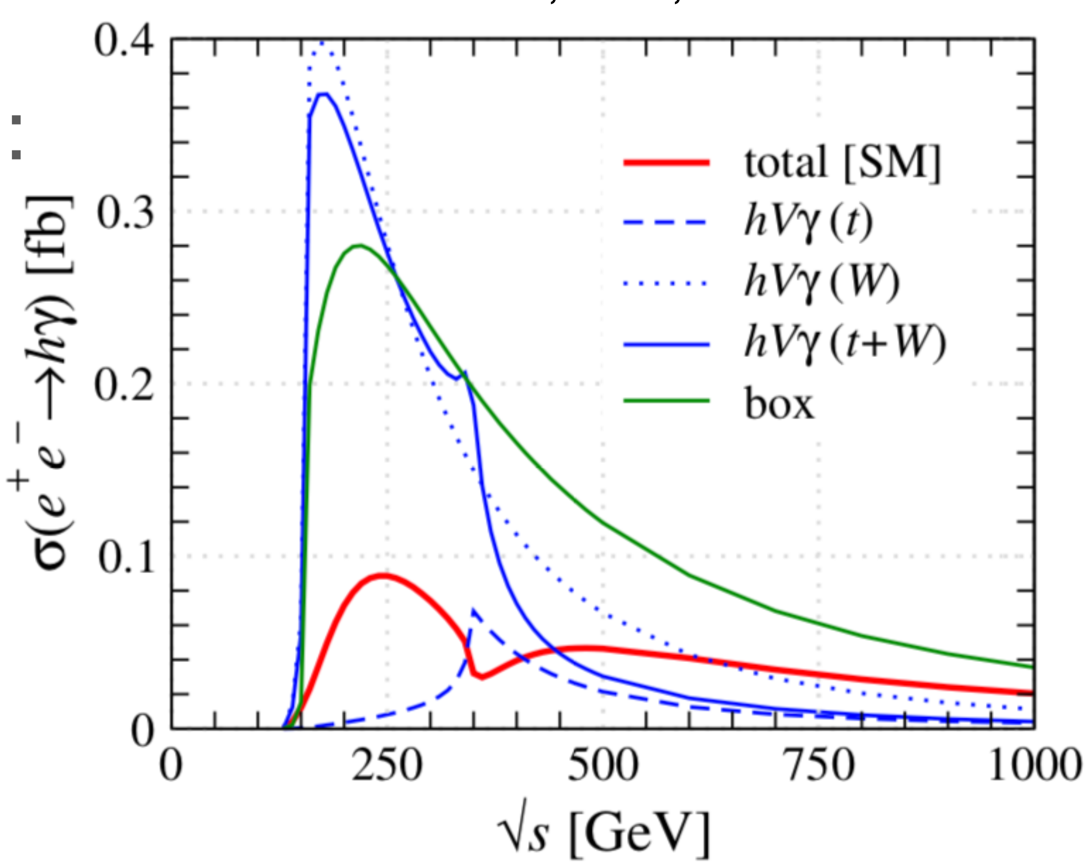


※For unpolarized beam

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 !

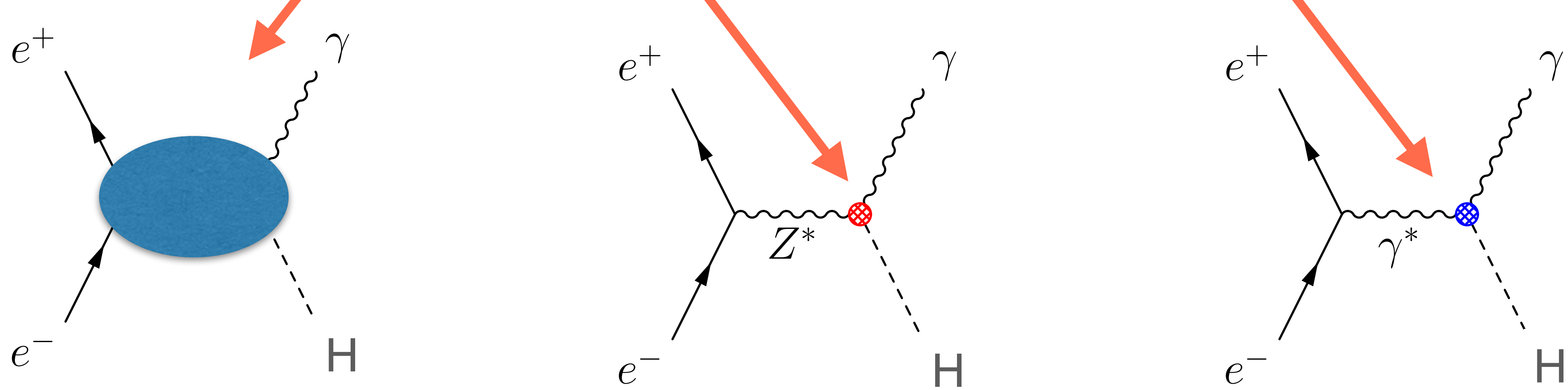
This analysis is very challenging.

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

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

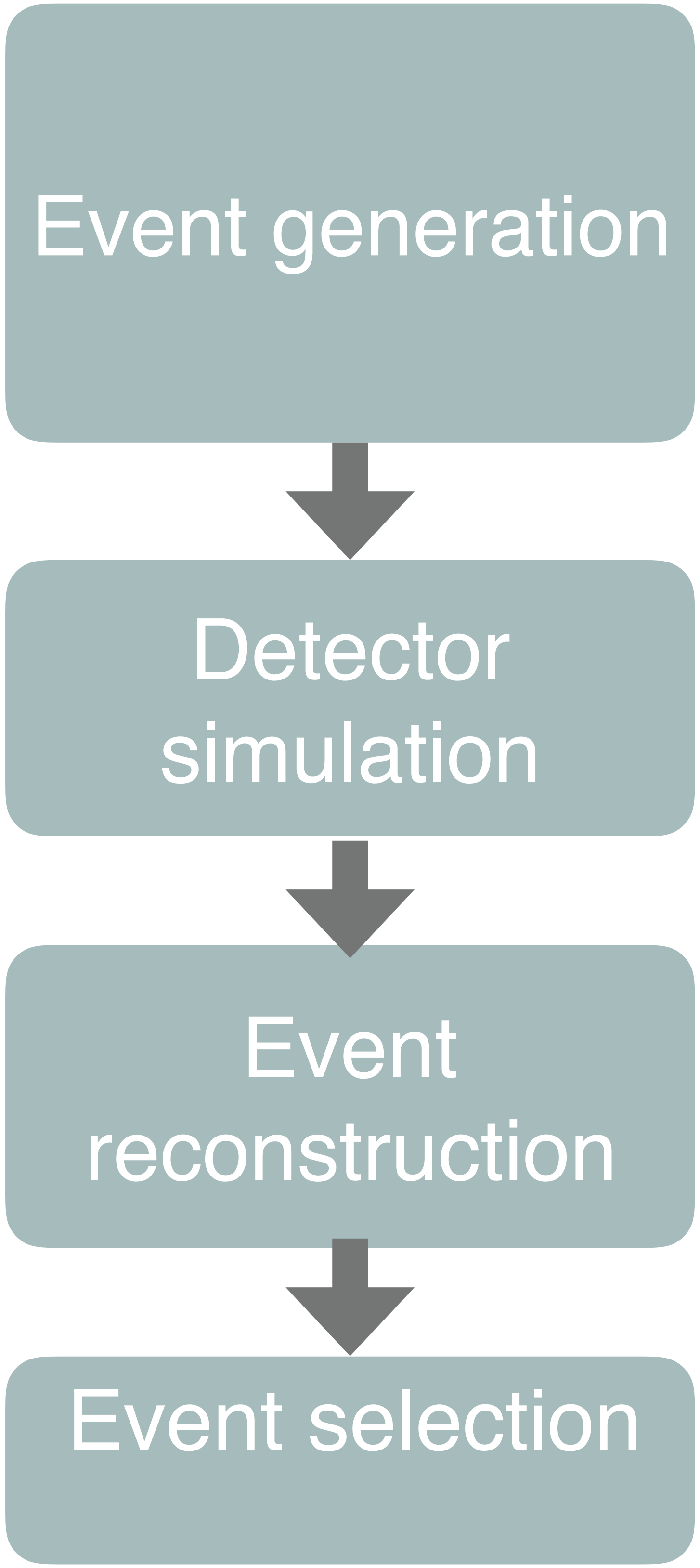


Phys.Rev. D94 (2016) 095015

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

Since ζ_A 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}
- 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)

9. Event selection - h→WW*

Signal: $e^+e^- \to \gamma h \to \gamma(WW^*)$

one W decays hadronically (W_1), and another decays leptonically(W_2)

Signal signatures

1. there is one isolated monochromatic photon with energy 93 GeV
2. there are 2 jets that originated from the hadronically decayed W
3. the sum of four momenta of the 2 jets, the lepton and leptin neutrino is consistent with Higgs hypothesis,
4. either one of the two-jets or the lepton-neutrino systems has an invariant mass consistent with the on-sell W hypothesis
5. there are no b-quark jets

Main backgrounds $e^+e^- \to W^+W^-(\gamma)$

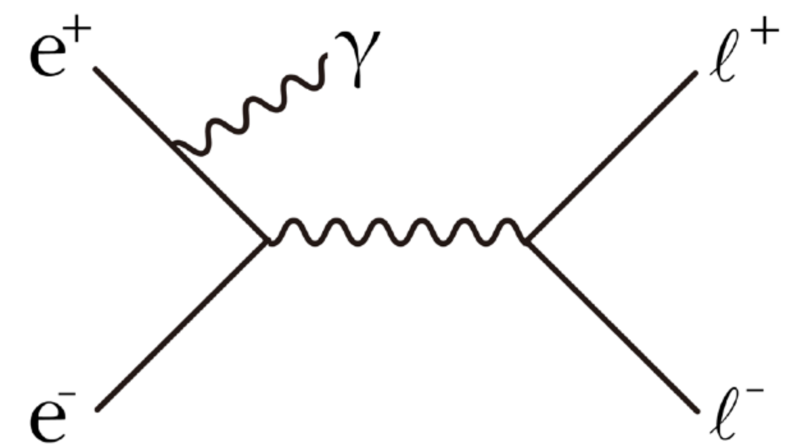
9. Event selection - $h \rightarrow WW^*$

① Pre-selection

1. Isolated lepton tagging
2. Photon selection
3. Fast Jet clustering
4. Thrust reconstruction
5. Vertex finding
6. Final analysis

- ➤ Photon ID
- ➤ $E_\gamma > 50$ GeV
- ➤ 2jet clustering (Durham)
- ➤ Flavor tagged（LCFI+）

10. Signal & Background - h→WW* (1)



$e^+e^- \to \gamma h \to \gamma(WW^*)$	e^+e^- -> 2l
number of particles in a jet →many	number of particles in a jet →1(muon)

# of particle>1

number of charged particles in a jet →many	number of charged particles in a jet →1(electron), 3(tau->3pion)

# of charged particle >3（→1)

12. Signal & Background - h→WW* (2)

$e^+e^- \to \gamma h \to \gamma(WW^*)$	$e^+e^- \to W^+W^-(\gamma)$

m(W1)~80.4 GeV or m(W2)~80.4 GeV

m2jlv = higgs mass | m(2jlv) | m2jlv = center mass energy

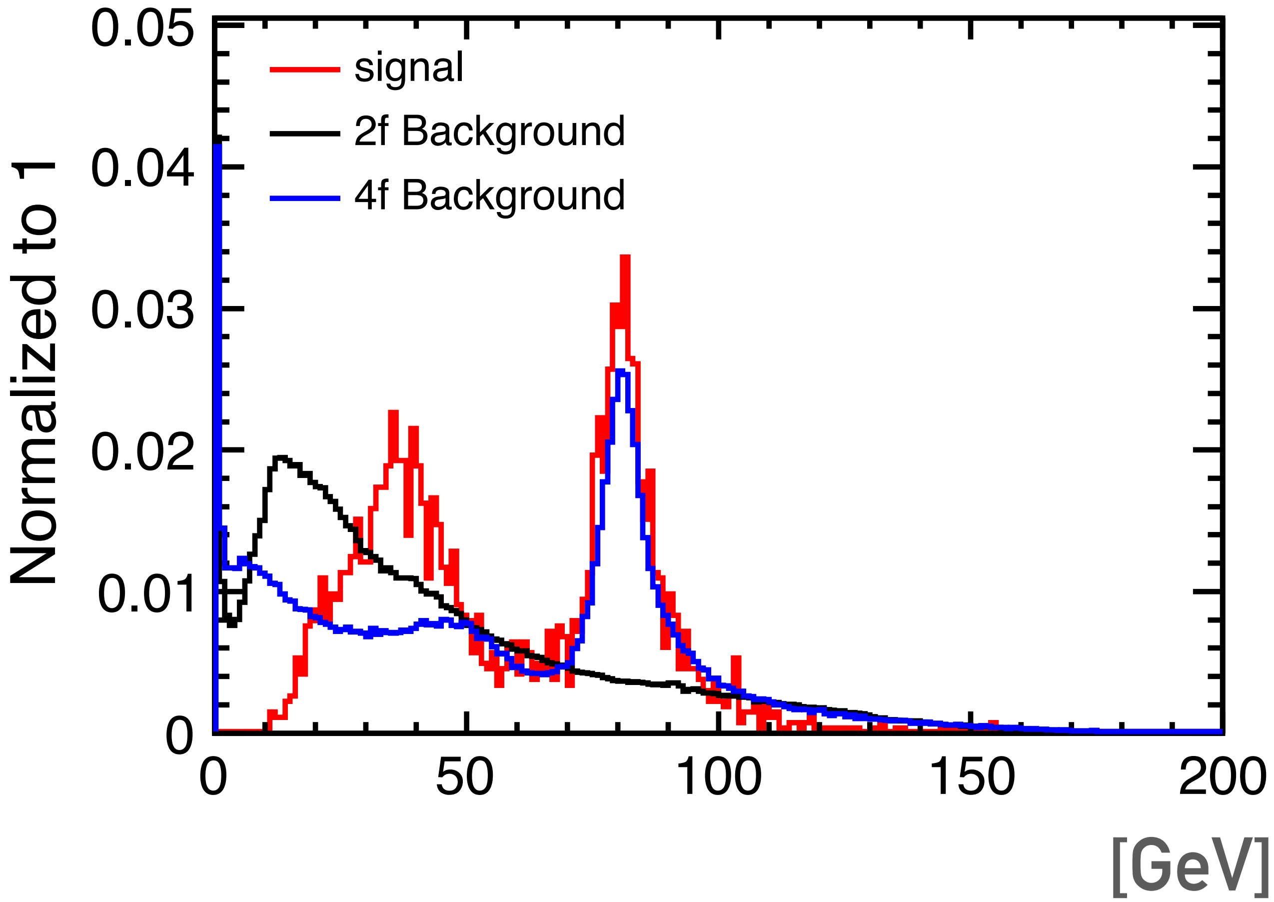
※m2jlv is the invariant mass of the 2-jet plus lepton-neutrino system

Energy of isolated monochromatic photon ~93 GeV | mγ

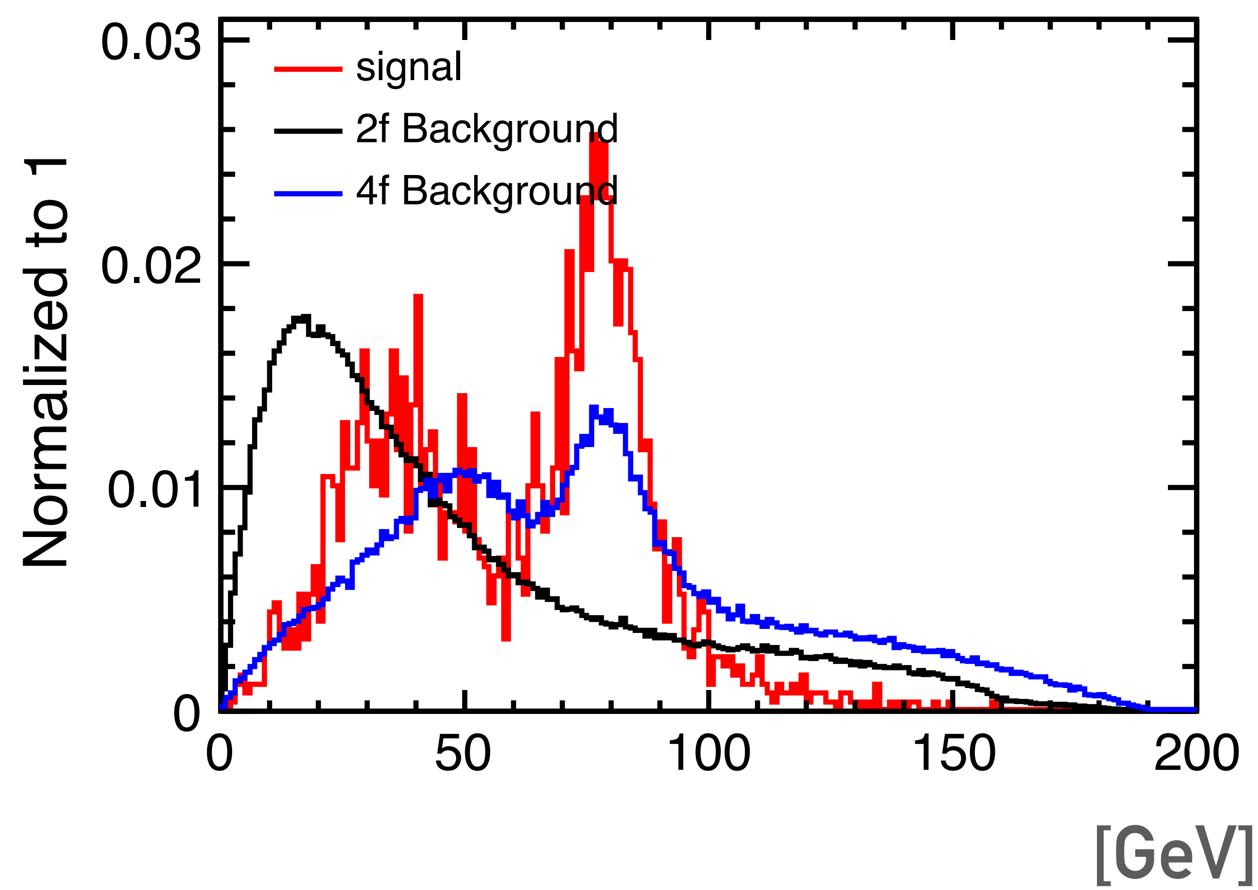
13. Event selection - h→WW*

|mw1-80.4|<10 GeV or |mw2-80.4|<9.4 GeV

mw1

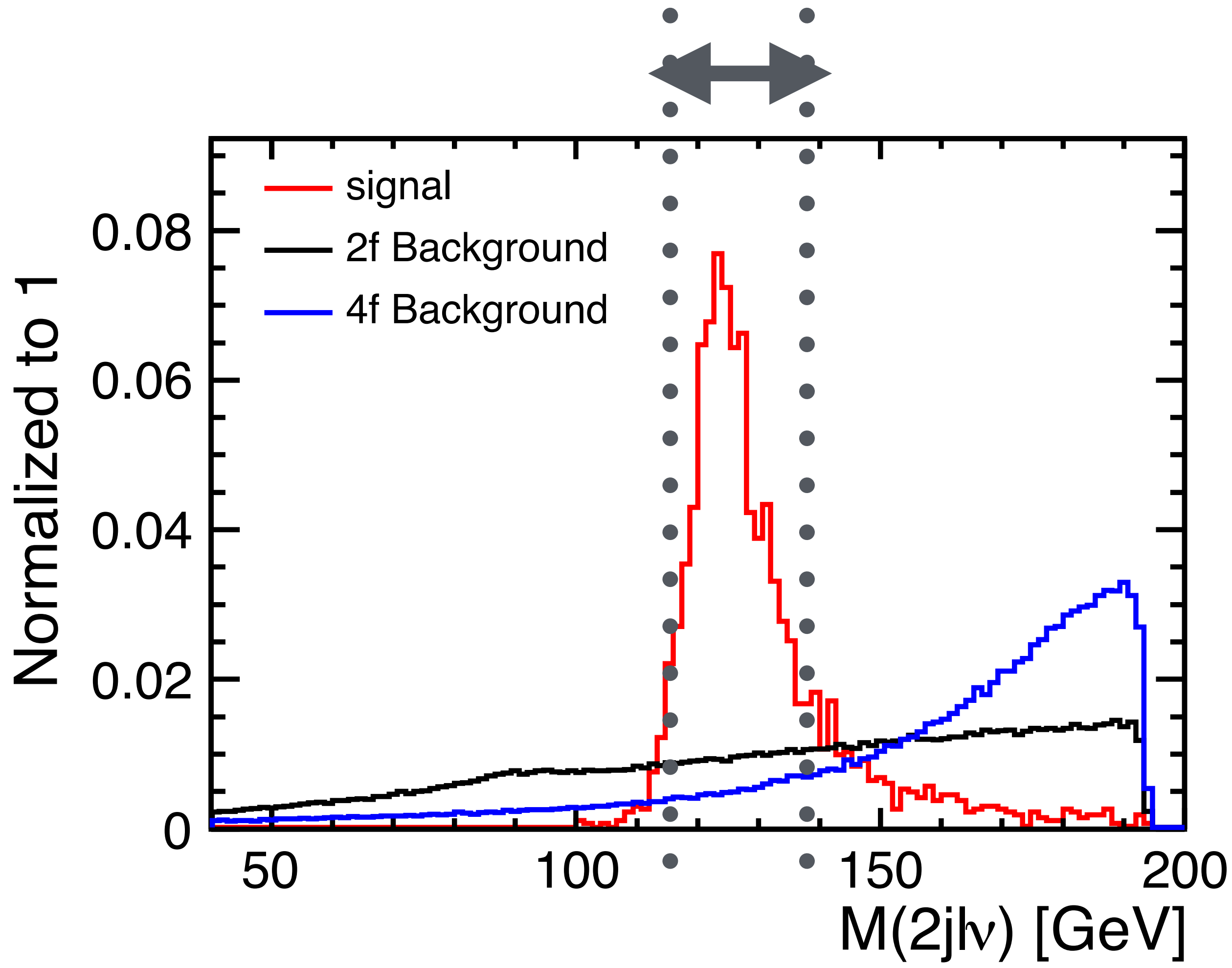


mw2

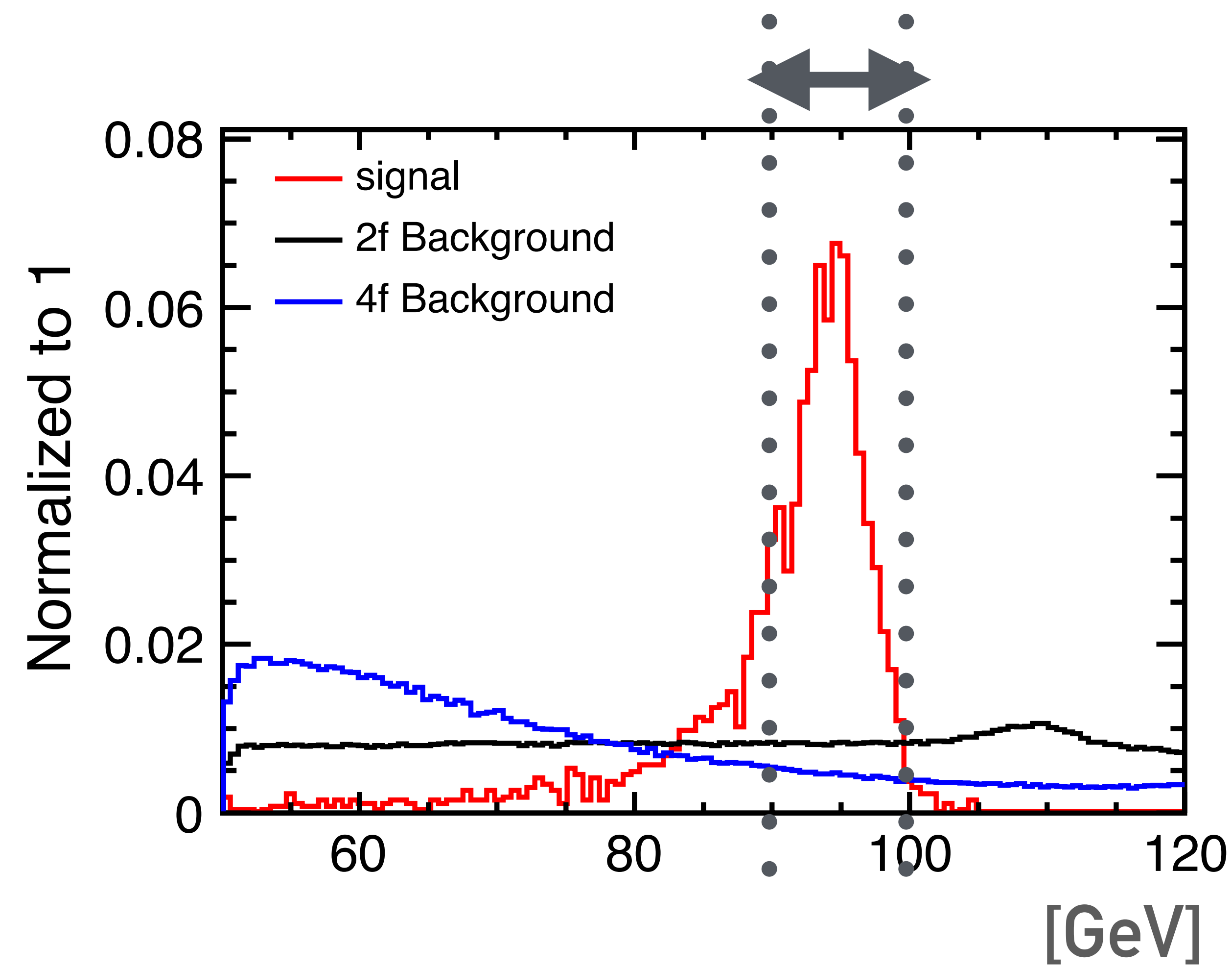


13. Event selection - h→WW*

114<m(2jlν)<135

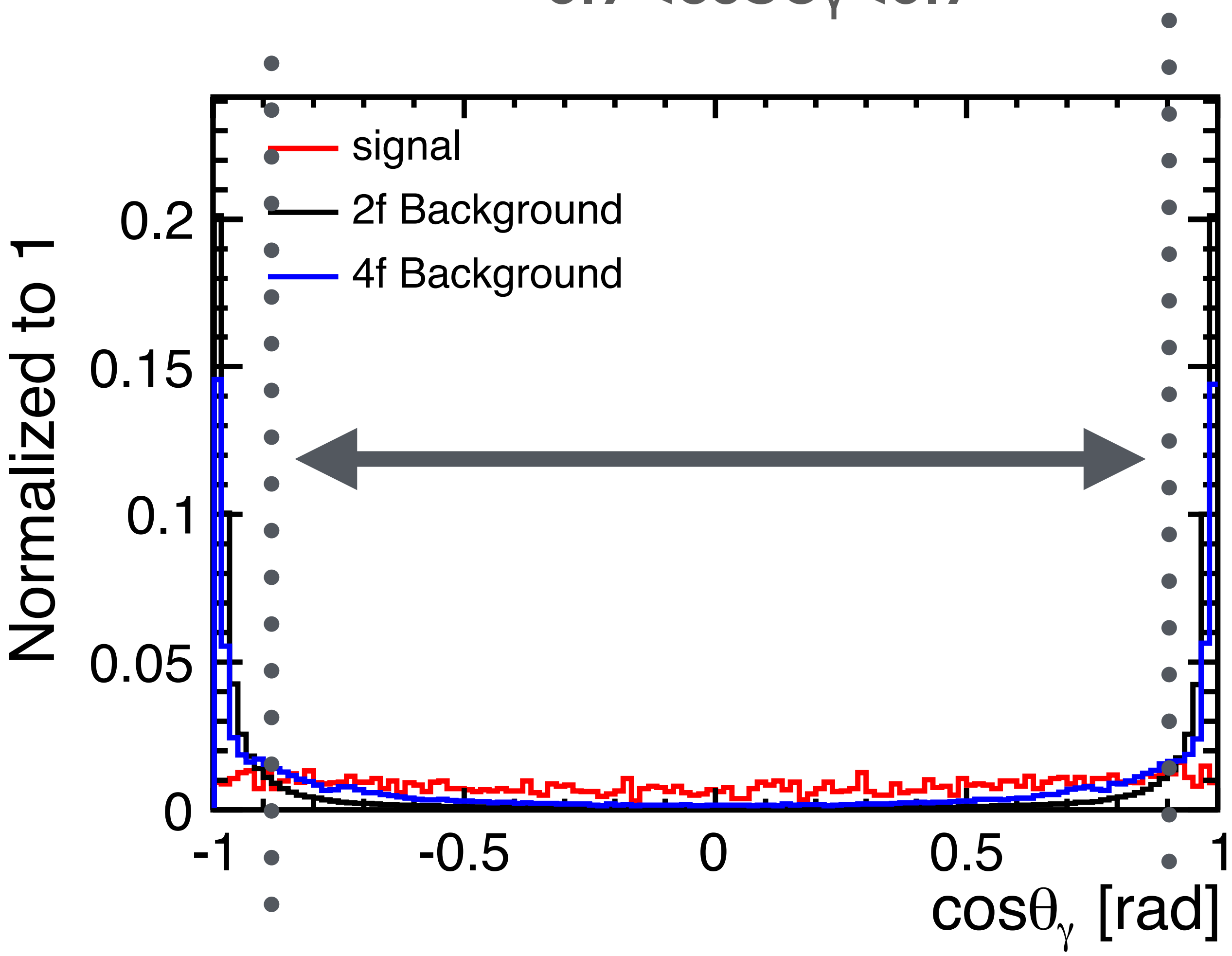


90<Eγ<98

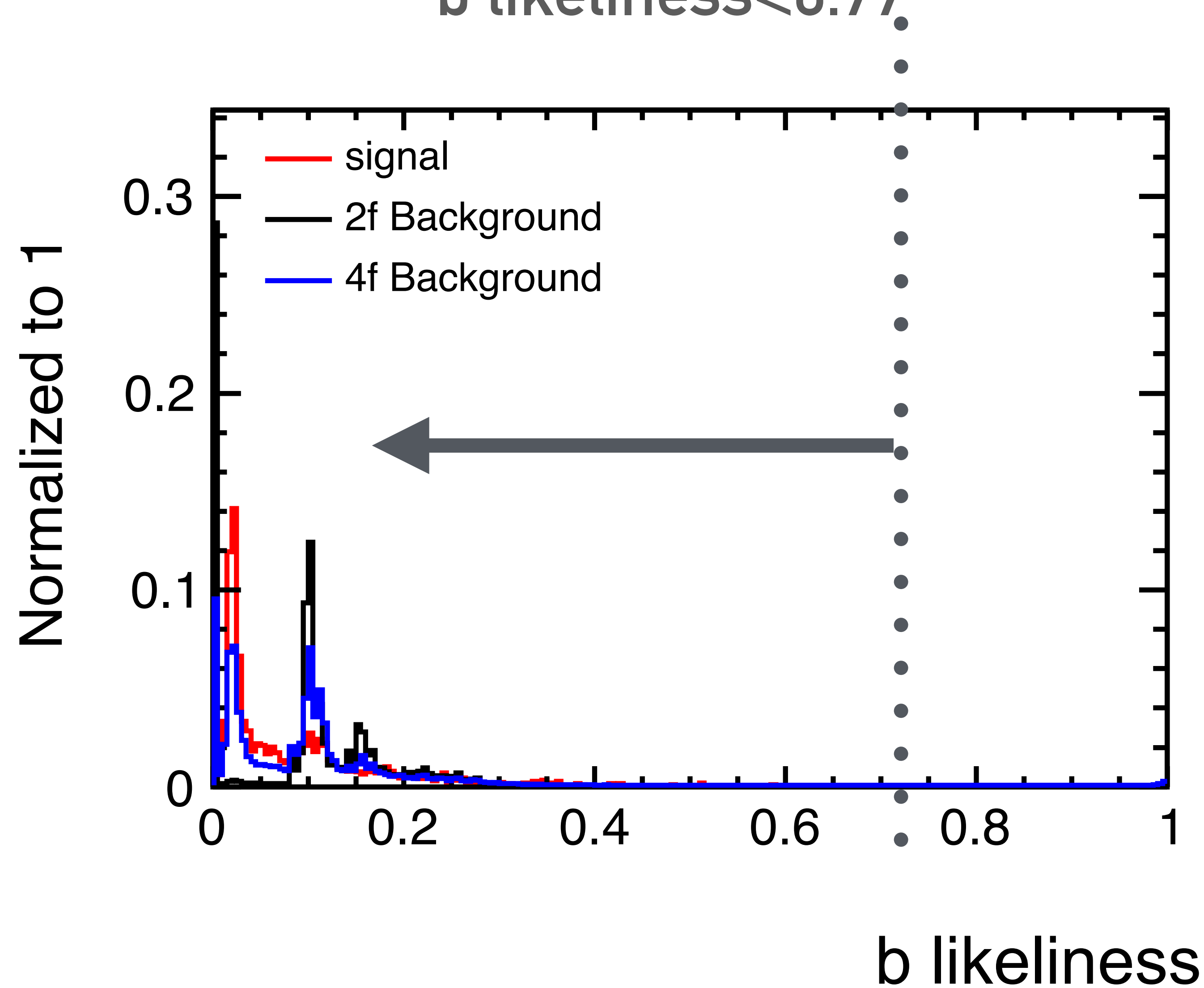


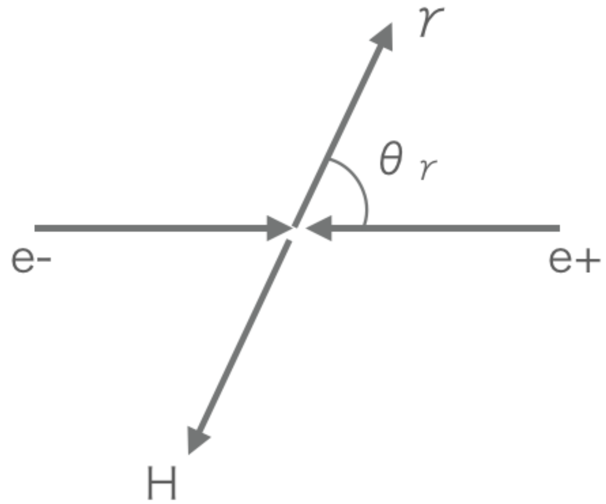
13. Event selection - h→WW*

$-0.9<\cos\theta_\gamma<0.9$

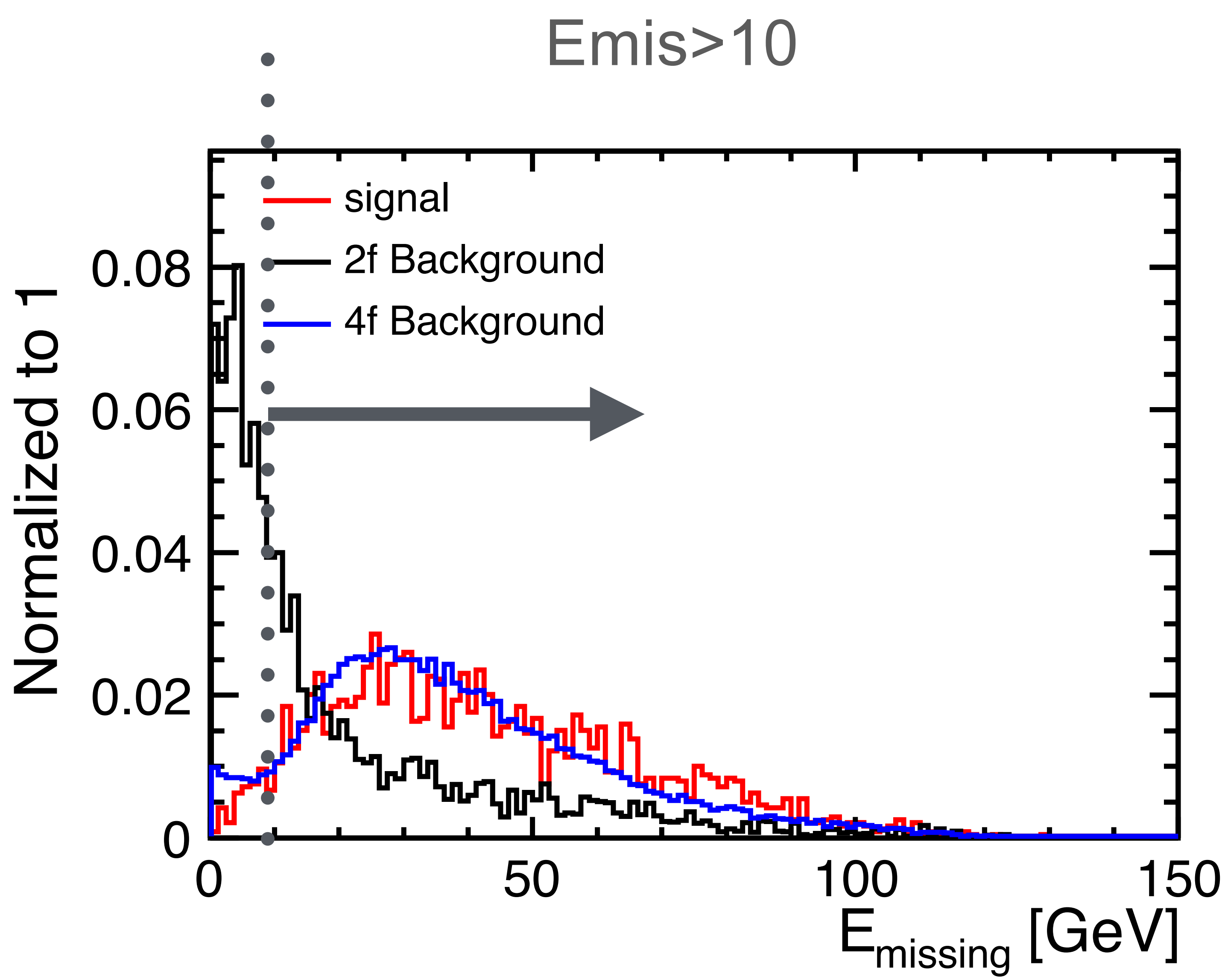


b likeliness<0.77

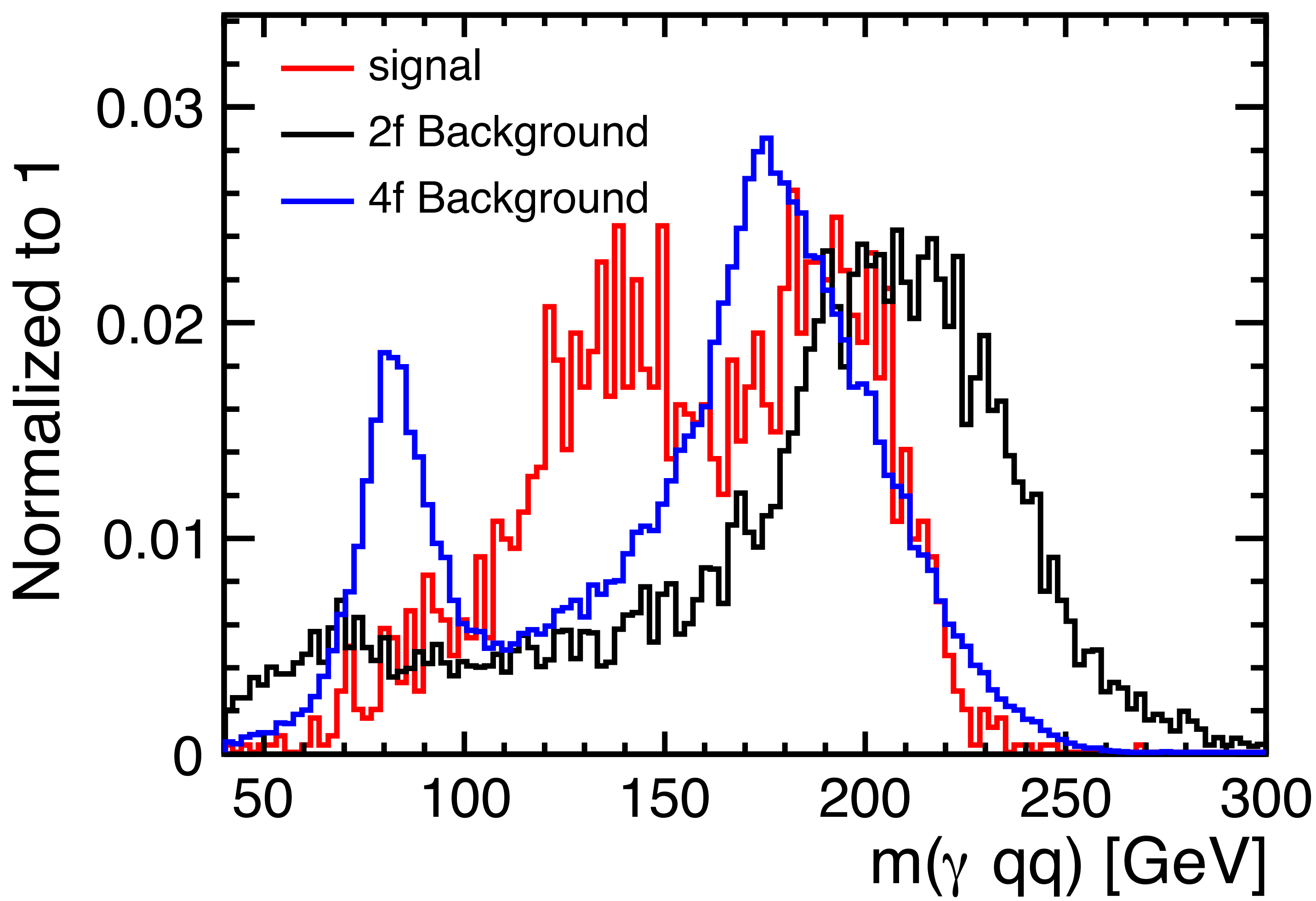


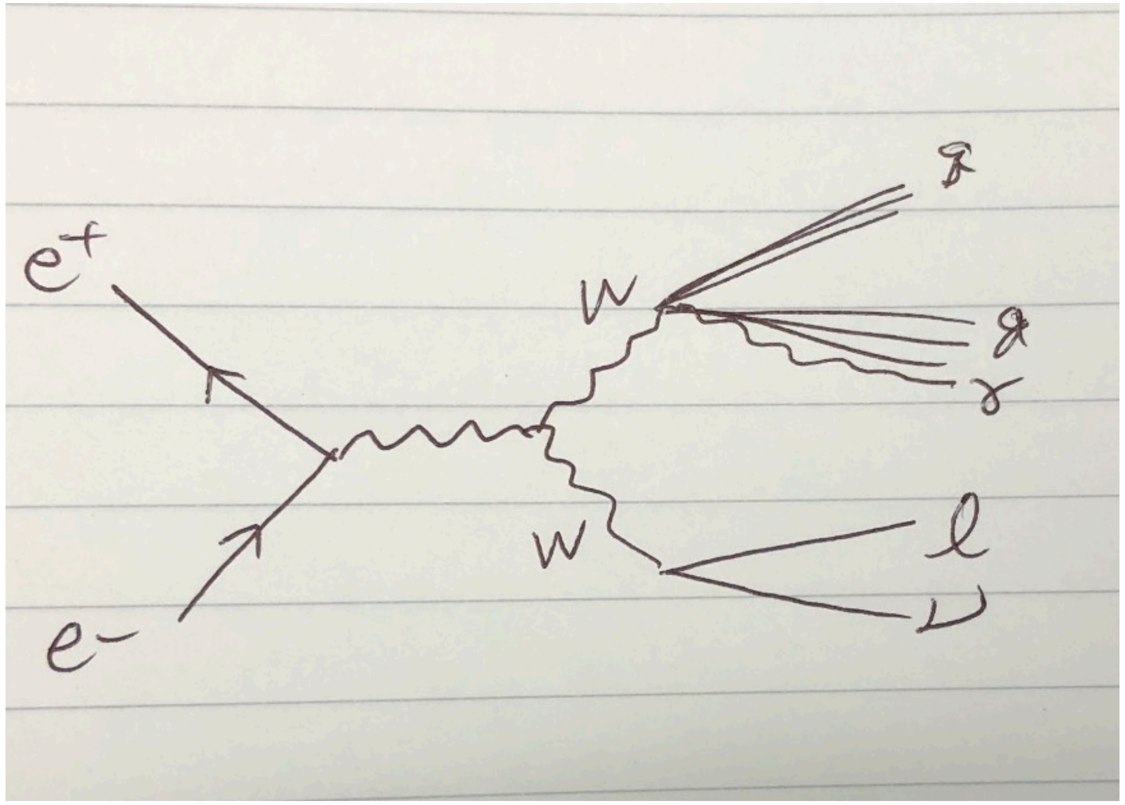


13. Event selection - h→WW*



2 peaks of 4f background





➤ 105 < m(gamma qq) <190

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

14. Reduction table - h→WW*

	2f_z_l	2f_z_h	4f_l	4f_sl	4f_h	total bg
Expected	76354500	156093000	11311300	36796200	33599400	314154000
Pre selection	27569400	243294	810986	854344	1590	29479600
# of particle>1	14288200	242055	423677	845268	1590	15800800
# of charged particle >1	105572	220662	12563	746458	1590	1086840
|mw1-80.4|<10 GeV or |mw2-80.4|<9.4 GeV	19326	67596	2556	507732	48.4	597258
114<m(2jlv)<135	2920	10055	374	20774	4.7	34128
90<Eγ<98	2362	6564	261	15240	4.7	24432
-0.9<cosΘ<0.9	557	2696	38.2	8742	0	12034
105 < m(γqq)< 190	168	175	10.3	306	0	659
Emis>10	60	6	10.1	248	0	324
bmax1<0.77	60	6	10.1	227	0	303

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

14. Reduction table - h→WW*

	total bg	Signal	Signal semi-lep	Significance
Expected	314154000	88.5	40.2	0.005
Pre selection	29479600	29.3	23.5	0.01
# of particle>1	15800800	25.3	23.3	0.02
# of charged particle >1	1086840	20.2	20.0	0.02
|mw1-80.4|<10 GeV or |mw2-80.4|<9.4 GeV	597258	13.6	13.6	0.02
114<m(2jlv)<135	34128	10.9	10.9	0.06
90<Eγ<98	24432	9.8	9.8	0.06
-0.9<cosΘ<0.9	12034	8.7	8.7	0.08
105 < m(γqq)< 190	659	5.6	5.6	0.22
Emis>10	324	5.5	5.5	0.30
bmax1<0.77	303	5.5	5.5	0.31

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 **0.31σ** for SM at $\sqrt{s}$=250 GeV, 2000 fb^{-1}.

Next step

- TMVA
- Combine with other channels
- Understand the role of this measurement in a global EFT analysis.