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

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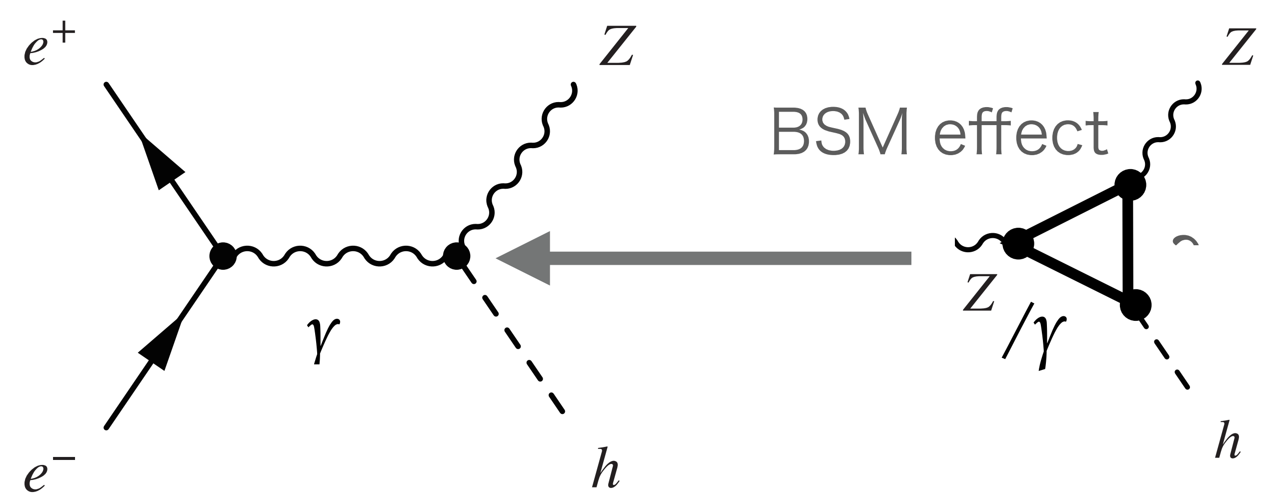
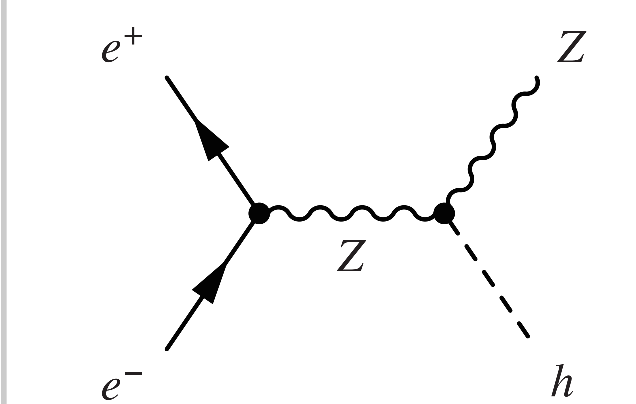
1.Motivation

Find new physics via Hγγ and HγZ couplings

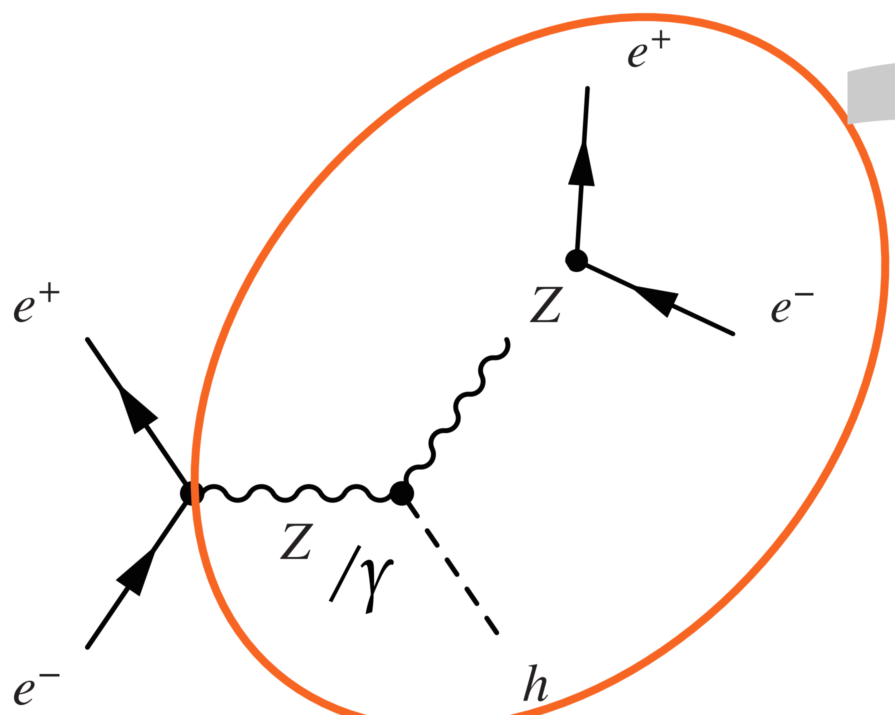
Higgs to γZ coupling in the Standard Model (SM) is a loop induced coupling.

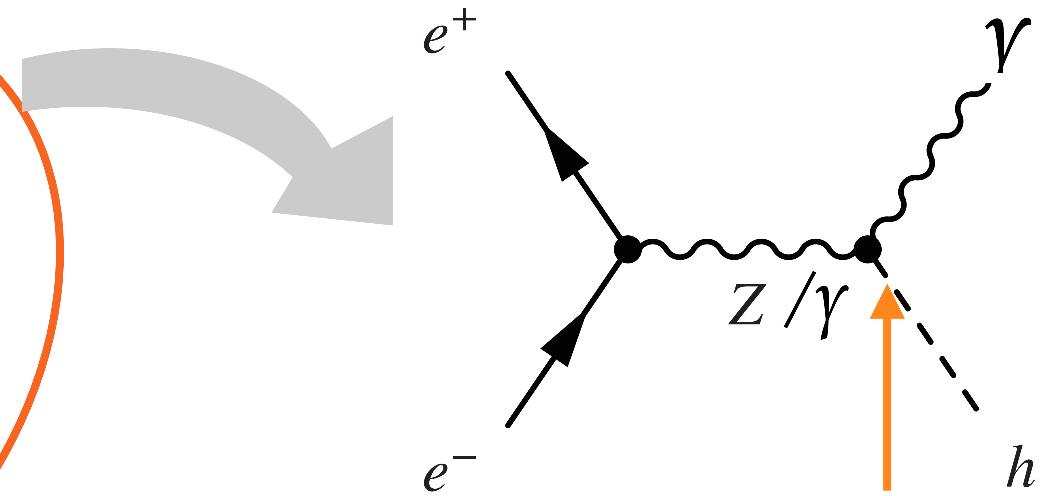




is exists at the tree level

However we can’t notice which particle is in the loop.

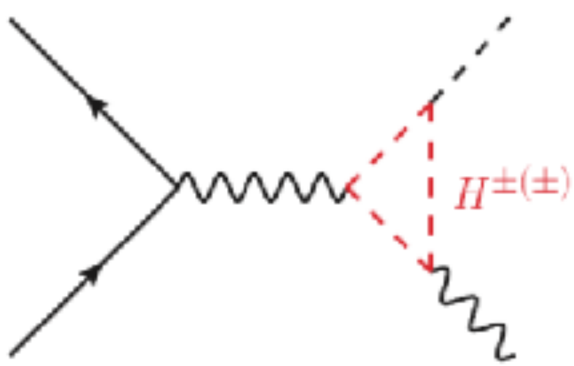




If we get different values of coupling constants with regard to SM, we get a key to new physics.

Example of new physics： Inert Doublet Model

In this Inert Doublet Model, there is charged higgs which can modify this h gamma Z vertex

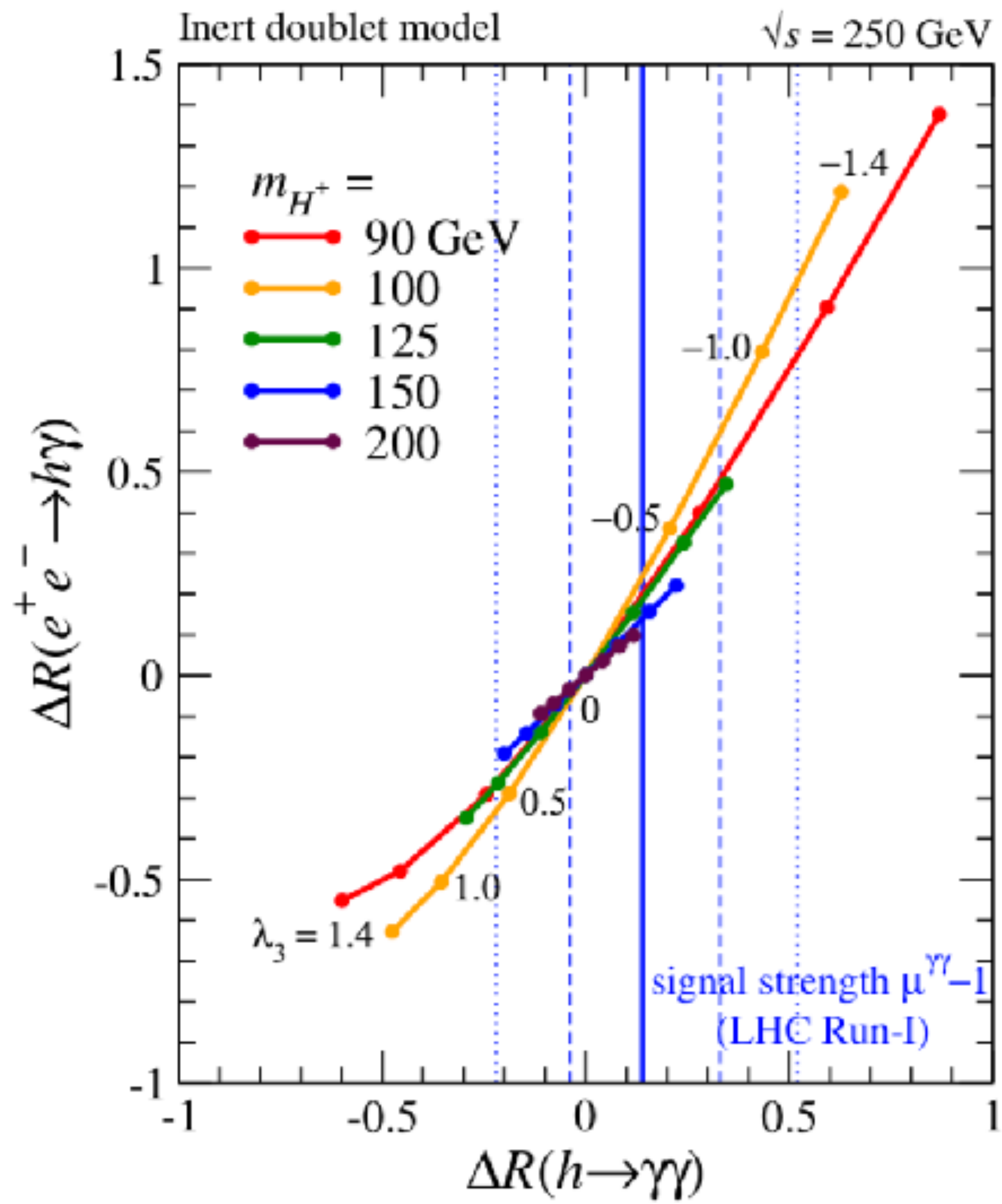


(d)

This plot shows the relative deviations of the e+e- to hγ cross section and the h to γγ decay rate from the Standard Model values.

Depending on model parameters, the deviation can be as large as 100%.

$\Delta R(e+e- \to h\gamma) = \sigma_{h\gamma}/\sigma_{SM} - 1$



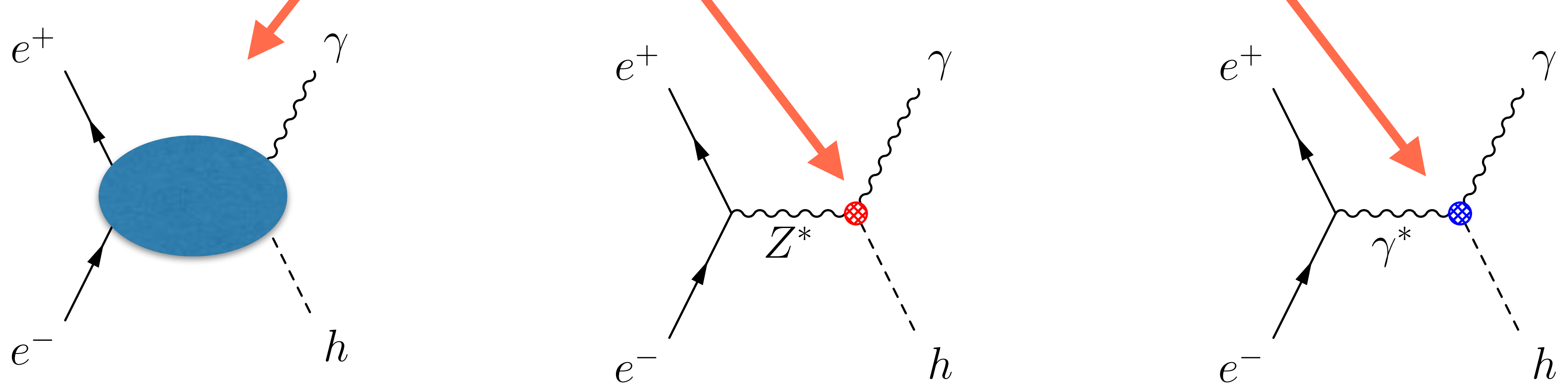
Mawatari, et al, arXiv:1808.10268

2. Theoretical framework for our analysis

The effective Lagrangian to include new physics contributions to the e+e- to hγ cross section model-independently

effective hγZ coupling　　effective hγγ coupling

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



ζ_{AZ} : effective coupling between Higgs and γZ
ζ_A : effective coupling between Higgs and γγ
Aμν, Zμν : field strength tensors

v: vacuum expectation value

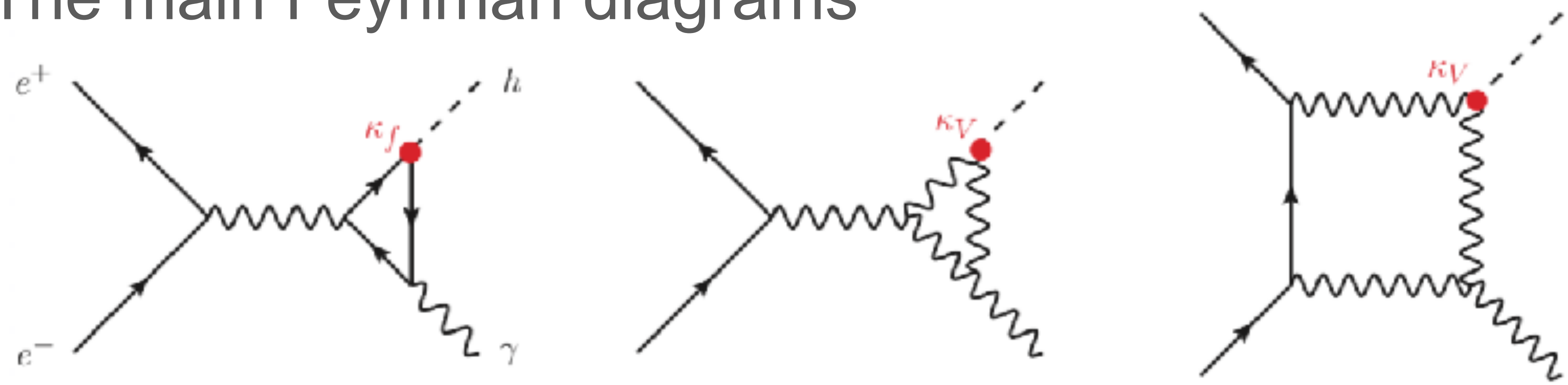
Phys.Rev. D94 (2016) 095015

SM one-loop predictions

e+e- ->h gamma is a loop induced process in SM

The main Feynman diagrams

Mawatari, et al, arXiv:1808.10268



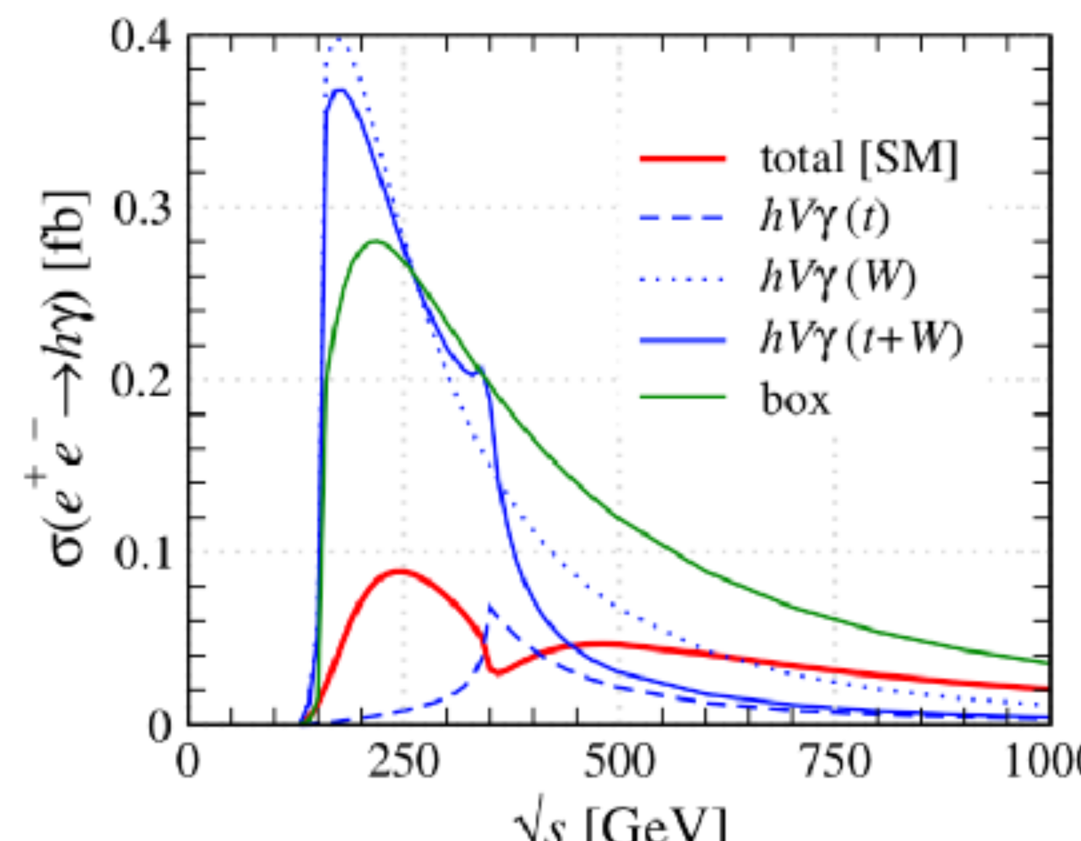
The cross sections by one loop calculation

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%)



※For not polarized beam

Destructive interferences

$\sqrt{s}$ = 250 GeV

3.Experimental Method

Coupling constant

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

measure this 2 parameters

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

for two different beam polarizations

So that ζ_{AZ} and ζ_A can be determined separately

② Since ζ_A can be constrained already by measurement of h→ γγ branching ratio at LHC, we can extract ζ_{AZ} parameter by just measuring cross section for a single polarization.

3.Experimental Method (Continued)

The total cross section in EFT is calculated by full loop SM amplitude and interference between SM and EFT operators

→The cross section normalized to SM can be written as below

interference between one-loop SM amplitude and EFT

$$\frac{\sigma_{\gamma H}}{\sigma_{SM}} = 1 - 201\zeta_A - 273\zeta_{AZ} \qquad \text{(eLpR)}$$

$$\frac{\sigma_{\gamma H}}{\sigma_{SM}} = 1 + 492\zeta_A - 311\zeta_{AZ} \qquad \text{(eRpL)}$$

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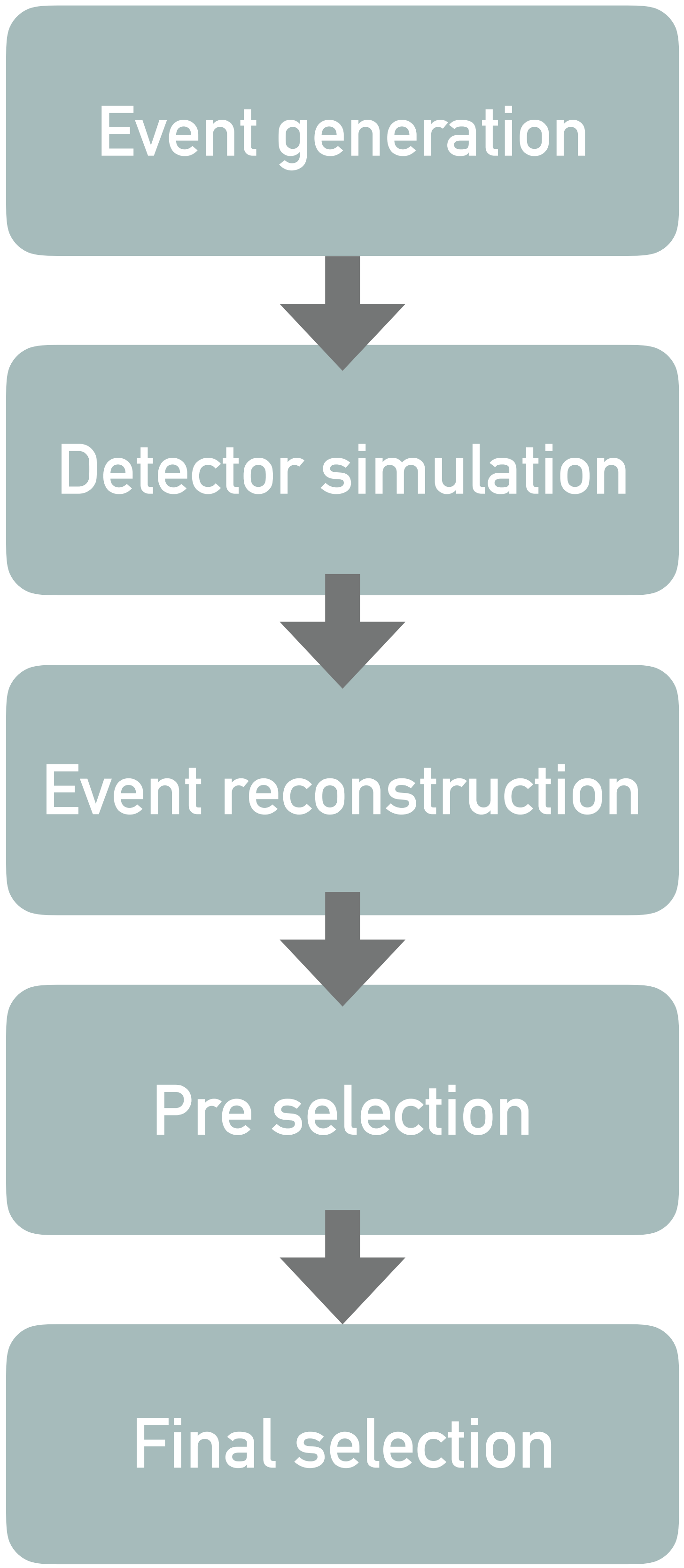
4.Simulation framework



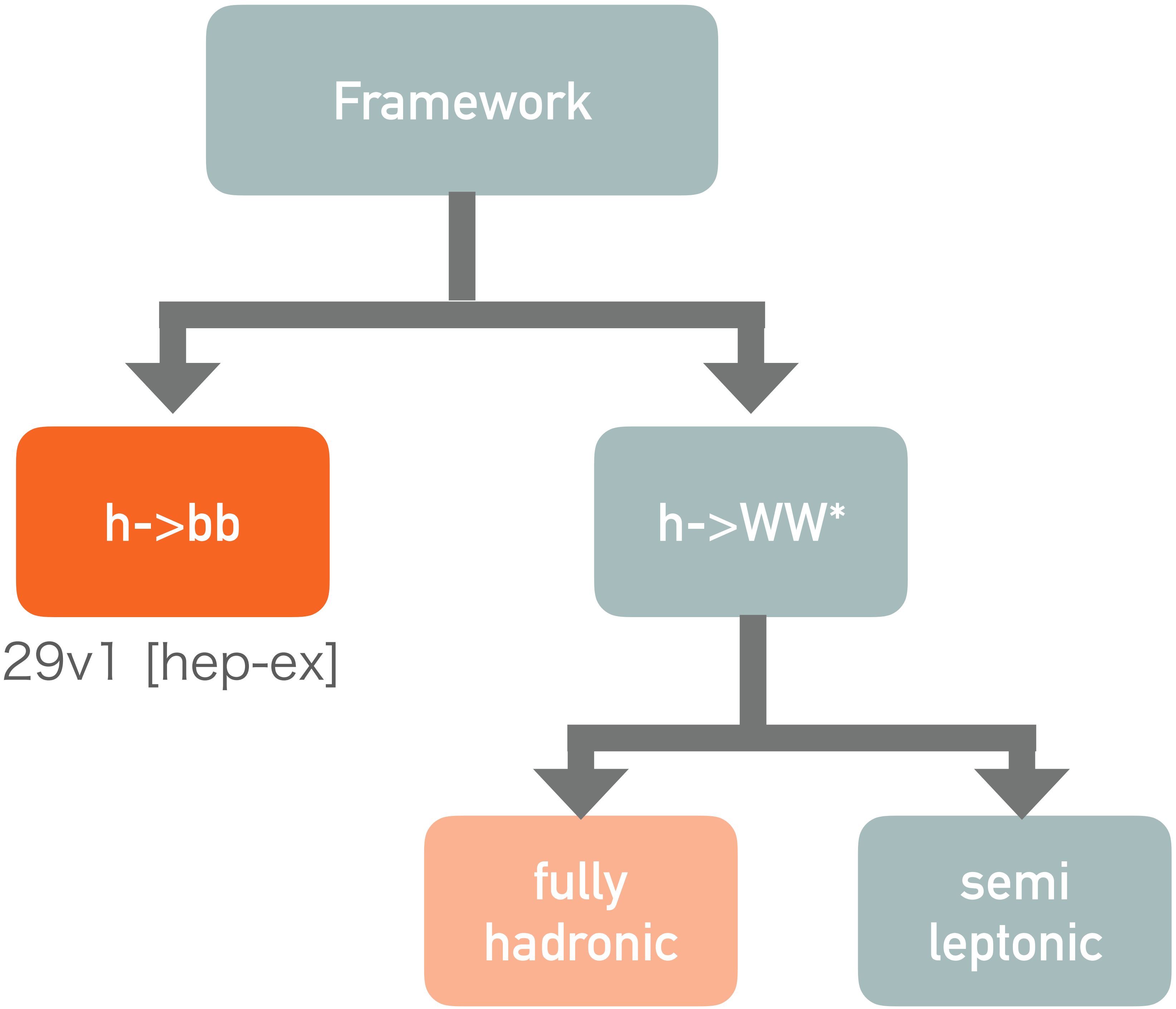
- Physsim

  $\sqrt{s}$=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

Strategy



arXiv:1902.06029v1 [hep-ex]

h->bb

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)

6. Result

h->bb

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

Reduction table Preliminary

N_s:Number of signal
N_B:Number of back ground

	Signal	background	Significance
Expected	237	3.14×10^{8}	0.01
Pre selection	222	6.54×10^{7}	0.02
btag>0.8	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

5. Event selection

① Pre selection

Signal: $e^+e^- \to \gamma h \to \gamma(WW^*) \to \gamma$ (4f)

Signal signatures

1. Isolated monochromatic photon with energy 93 GeV
2. 4 jets（fully hadronic)
3. m(4jet)= higgs mass
4. one of m(2jet)= W mass

Main backgrounds

e^+e^- ->W^+W^-(γ)

5. Event selection

① Pre-selection

・Isolated photon

- ➤ Photon ID
- ➤ $E_\gamma >$ 50 GeV

※The split photon clusters within a small cone are recovered

→Left events except photon

- ➤ 4jet clustering (Durham)
- ➤ Flavor tagged（LCFI+）

For signal

number of decay w to qq=2

Strategy

$e^+e^- \to \gamma h \to \gamma(WW^*)$	e+e- -> 2f
number of particles in jet →many	number of particles in jet →(l,v)One

# of particle>5

number of charged particles in jet →many	number of charged particles in jet →One

# of charged particle >1

y43, y32 →large

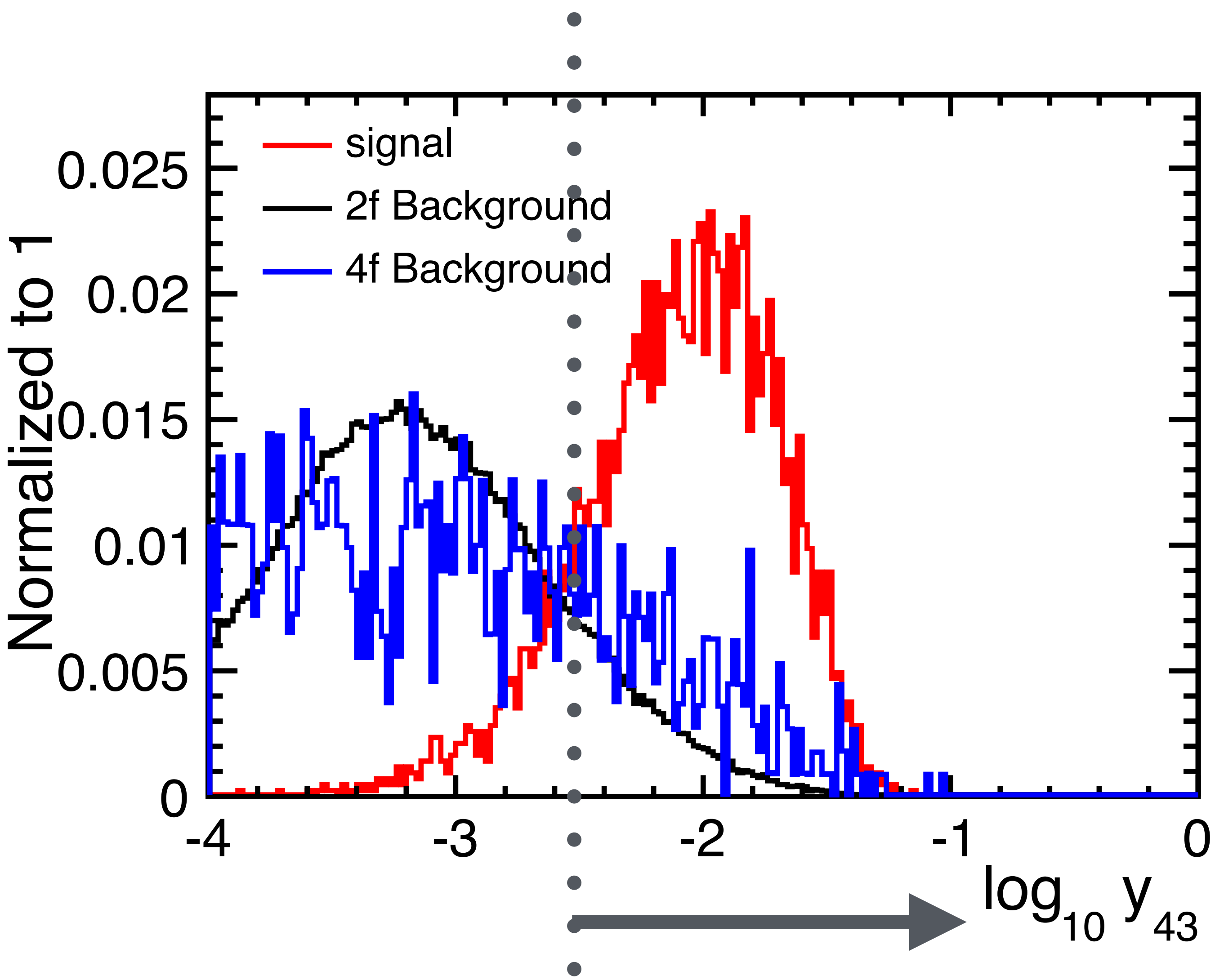
y43, y32

y43, y32 →relatively small

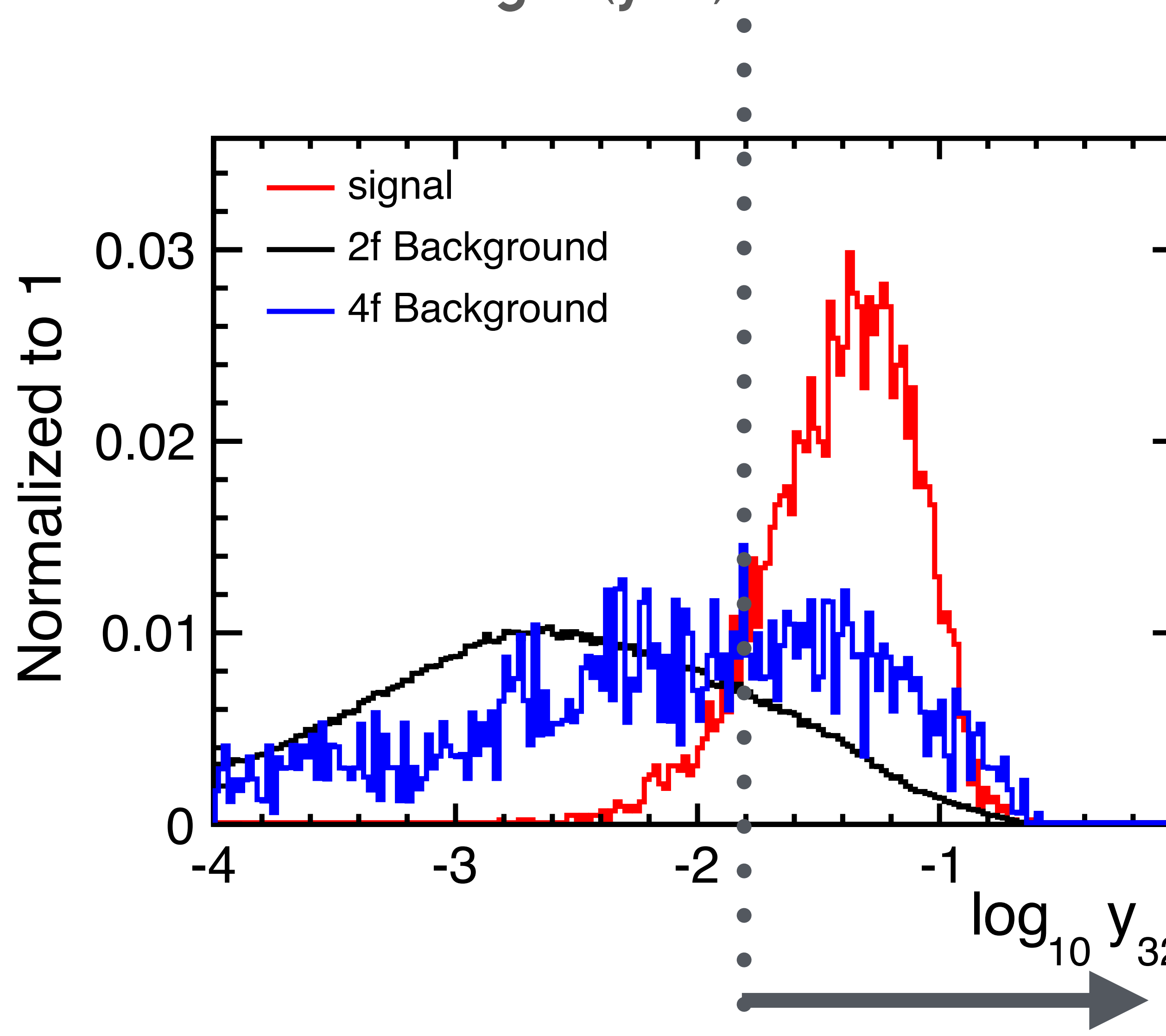
5. Event selection

The distribution of y43 and y32 for signal and background events

log10(y43)>-2.5



log10(y32)>-1.8



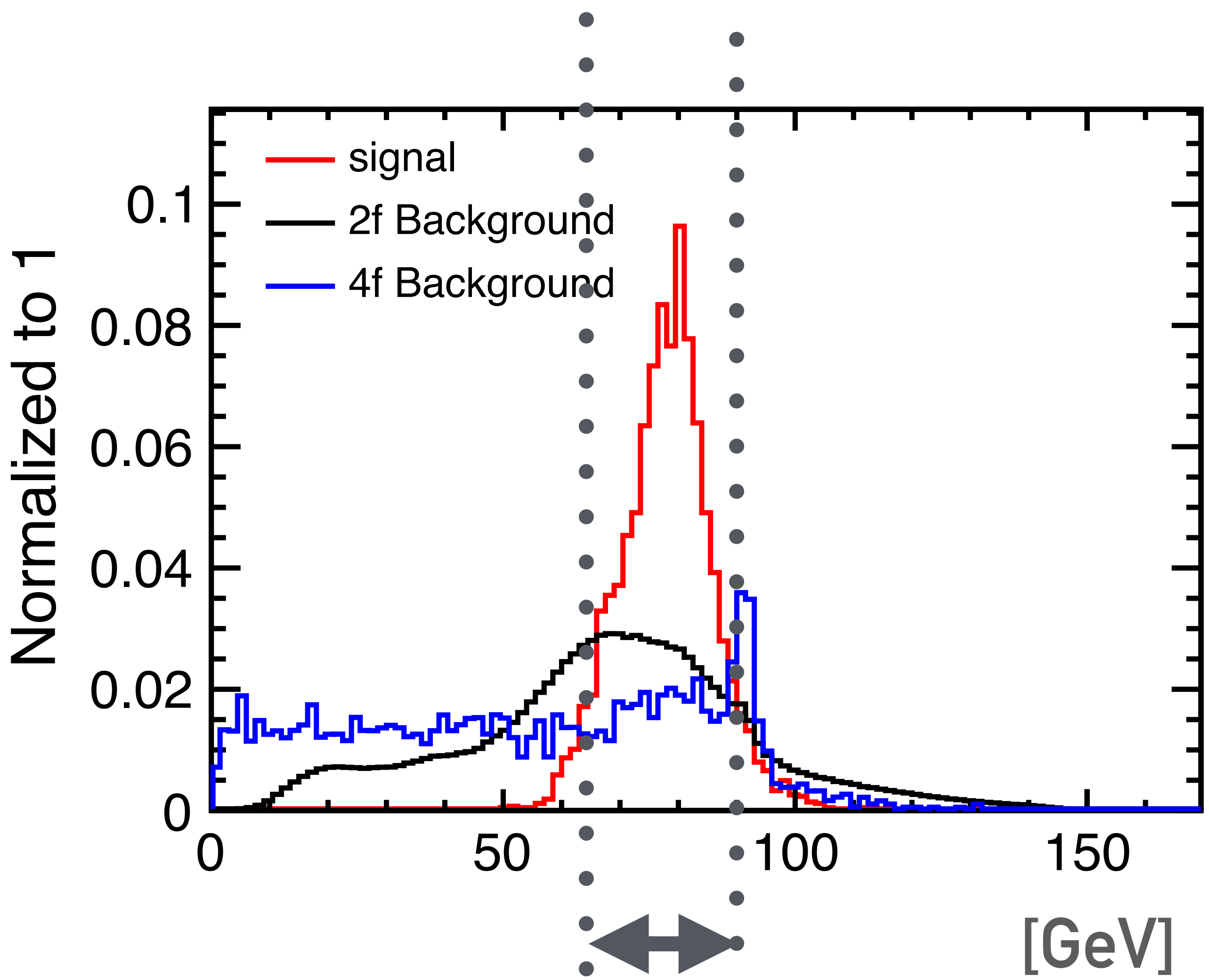
※ This plot is for events after the pre selection

Strategy

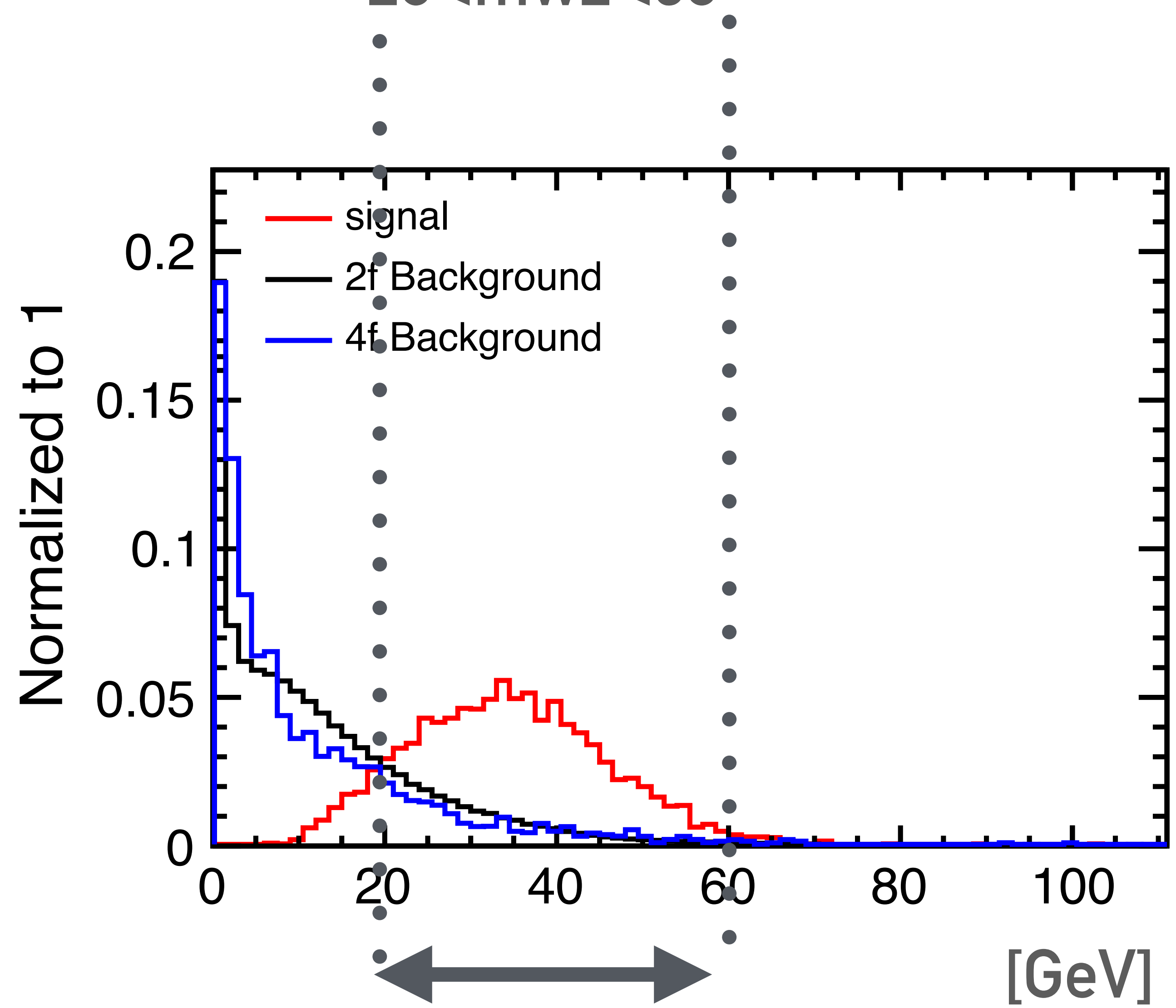
$e^+e^- \to \gamma h \to \gamma(WW^*)$		$e^+e^- \to W^+W^-(\gamma)$
mass other than real W < 50 GeV	m(W2)	mass other than real W ~80 GeV
m(4jets)= higgs mass	m(4jets)	m(4jets)= center mass energy
Energy of isolated monochromatic photon ~93 GeV	mγ	Energy of photon ~small

5. Event selection

65<mw1<90

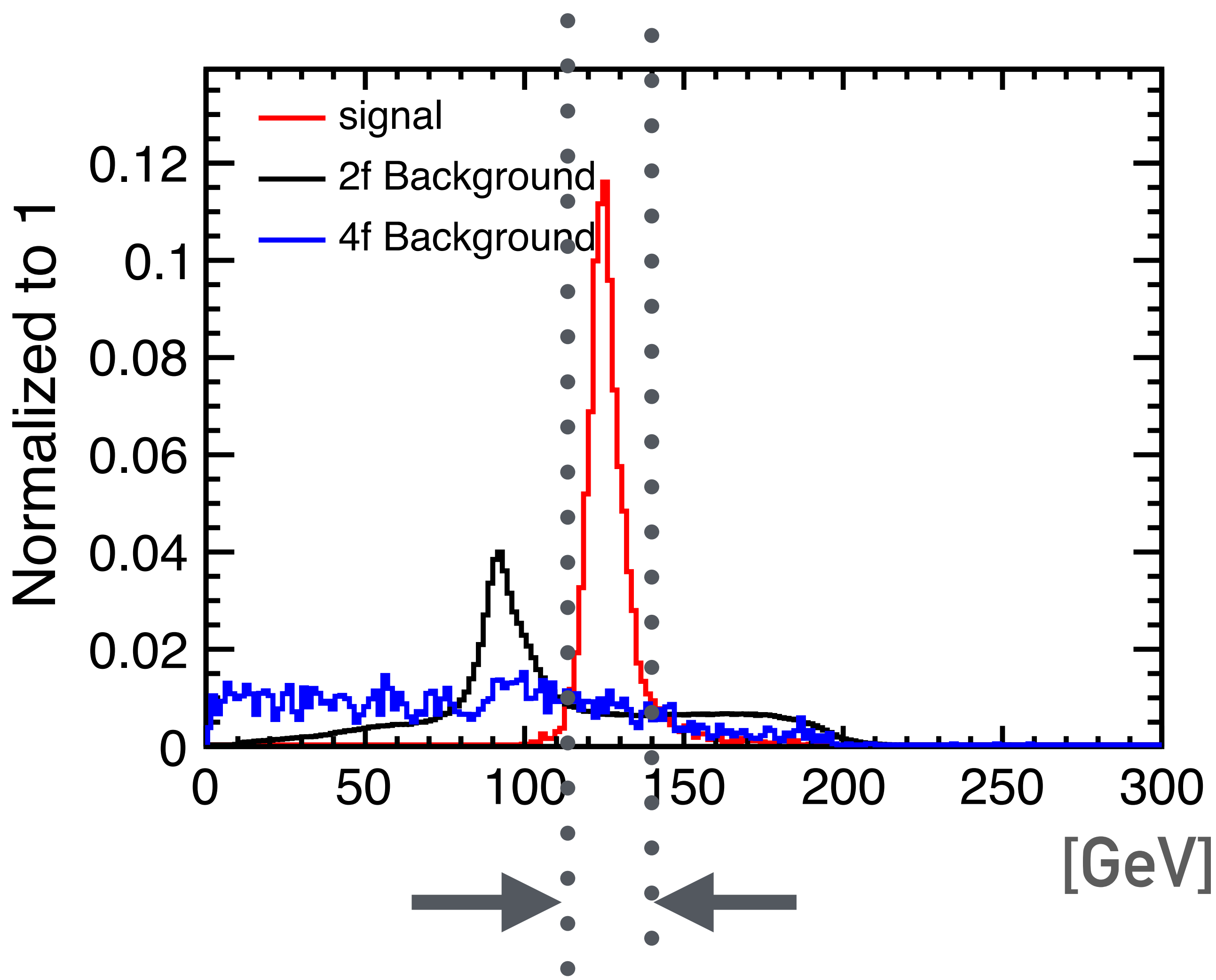


20<mw2<60

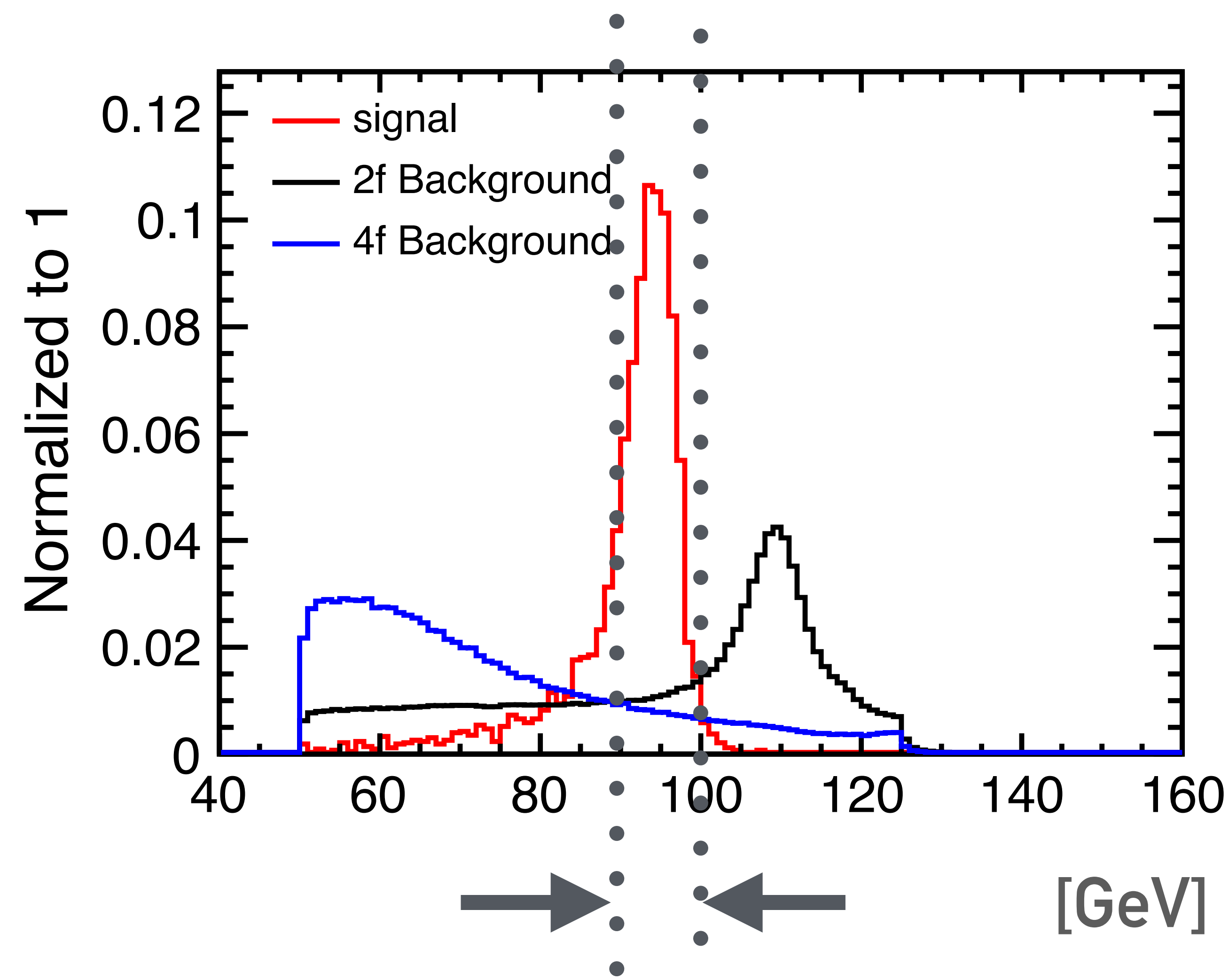


5. Event selection

115<m(4jets)<135

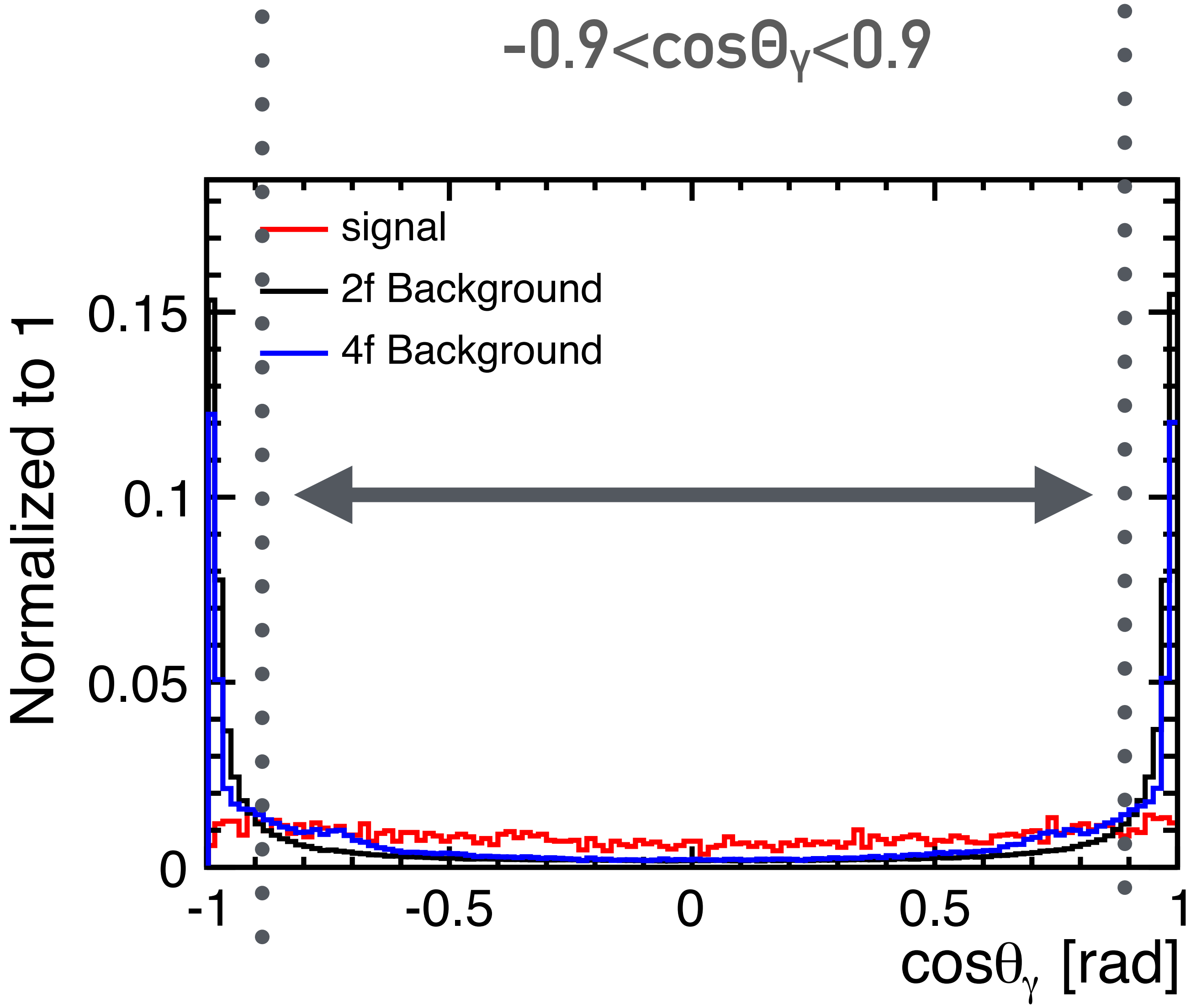


90<Eγ<100

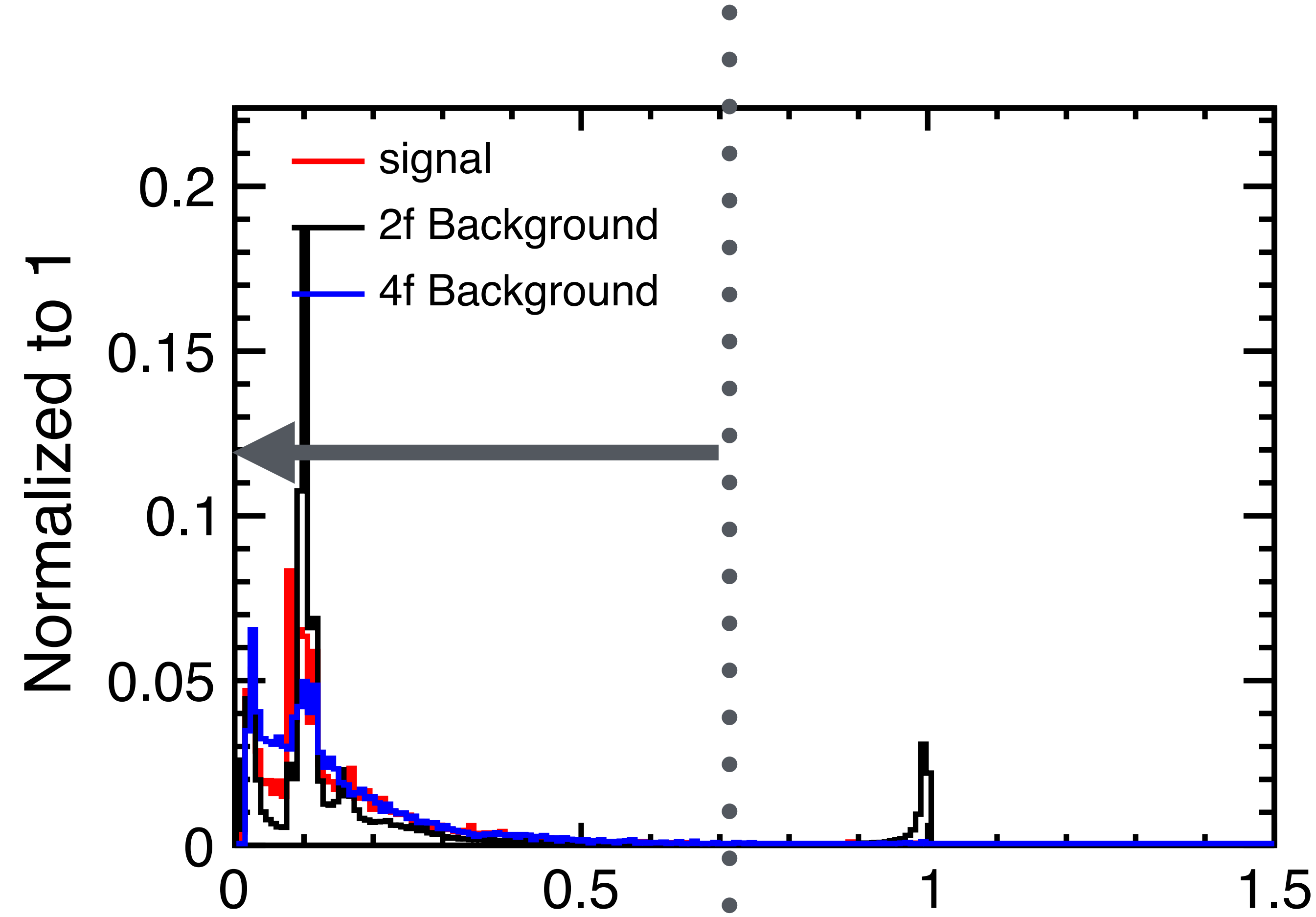


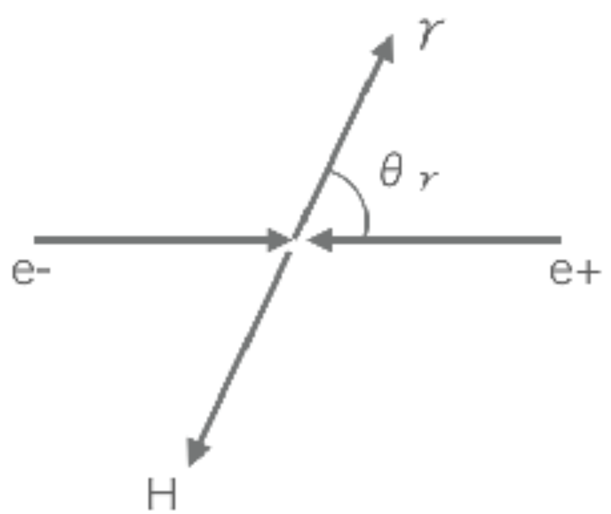
5. Event selection

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



b likelyness<0.7





6. Reduction table

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

	2f_h	4f_h	total bg	Signal	Signal hadronic	Significance
Expected	156093000	33599400	314154000	88.5	40.2	0.005
Pre selection	27978300	760090	61010200	80.5	37.7	0.01
# of particle>5	10295600	681904	11233500	36.5	32.0	0.01
# of charged particle >1	5940470	591493	6646540	28.0	25.9	0.01
log10(y43)>-2.5 log10(y32)>-1.8	951914	527681	1515780	21.8	20.9	0.02
65<mw1<90	348875	495465	860262	19.2	18.9	0.02
20<mw2<60	235286	311623	559275	17.6	17.4	0.02
115<mx<135	53738	15634	74447	15.7	15.6	0.06
90<Ey<100	21447	5494	27290	11.8	11.8	0.07
-0.9<cosθ<0.9	10636	3758	14525	10.3	10.3	0.09
bmax1<0.7	9746	3696	13558	10.0	10.0	0.09

6. Result

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

Significance = 0.09 for SM

= 18.2 × 0.35 [fb]

=6.37 [fb]　(Left handed)

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

asume ζ_A =0

-0.063> ζ_{AZ} >0.0037

7. Summary

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

・Significance for e+e- ->hγ process (h->WW*)

~ 0.09σ for SM at √s=250 GeV, 2000 fb^{-1}

・model independent upper limit for cross section : $\sigma_{\gamma H}$< 6.78 fb(95% C.L.)

・Corresponding bounds : -0.0077> ζ_{AZ} >0.0037

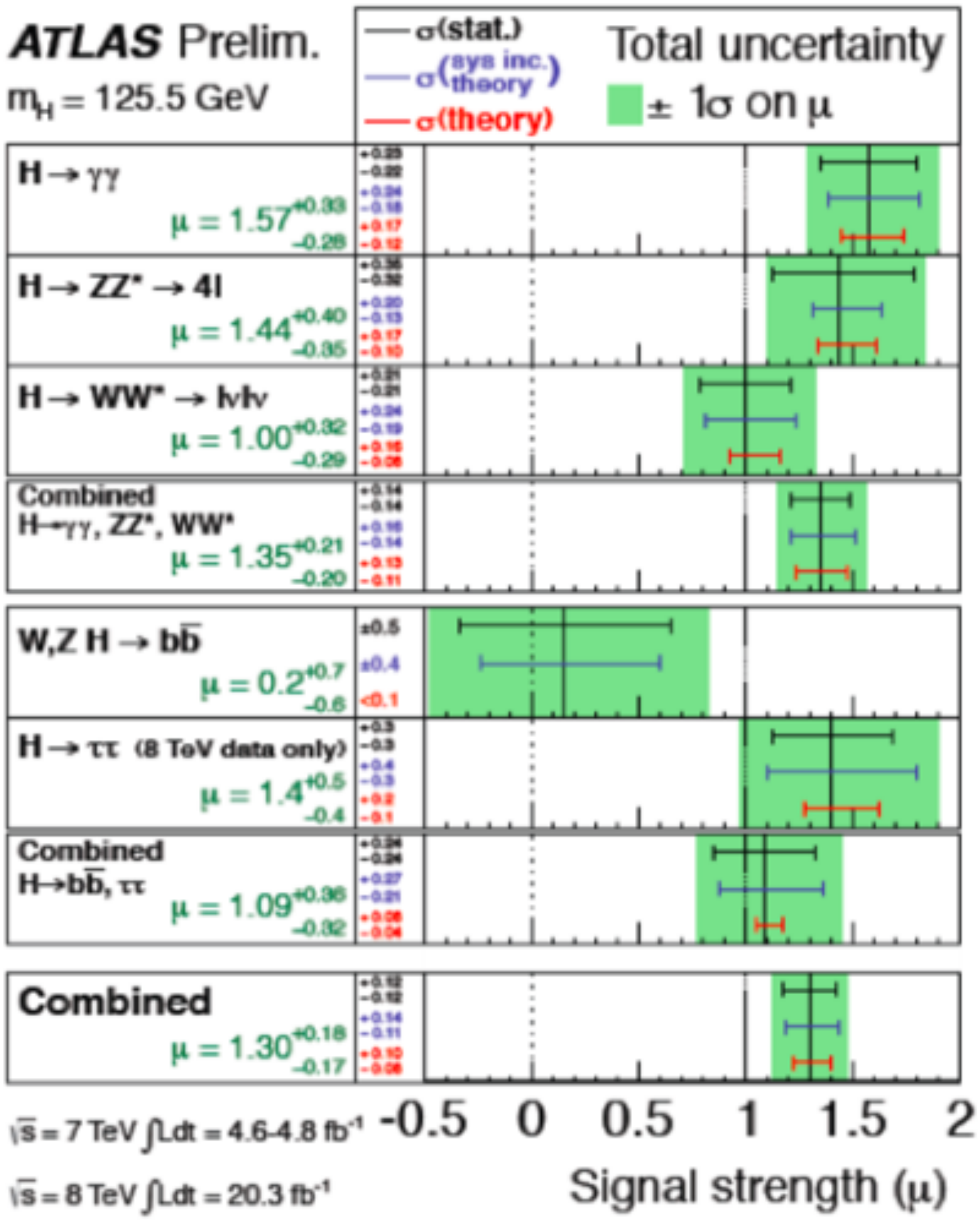
Next step

・Fully hadronic

-TMVA

・Semi leptonic (lvqq)

Understand the role of this measurement in one global EFT analysis



The Beautiful Physics of LHC Run 2

arXiv:1412.2666v1 [hep-ph] 8 Dec 2014