Higgs branching ratio study II

ILC Tokubetsu-Suishin annual meeting

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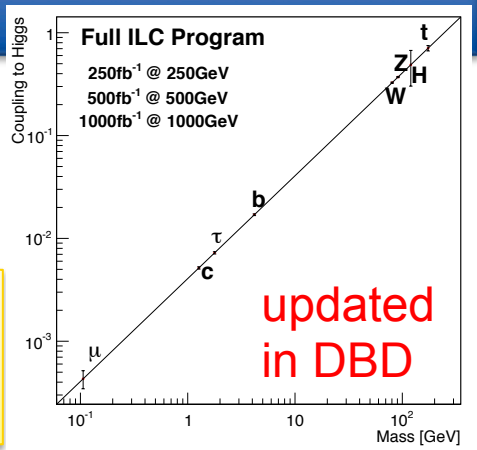
Higgs branching ratio study

ILC Higgs Branching ratio (BR) measurement

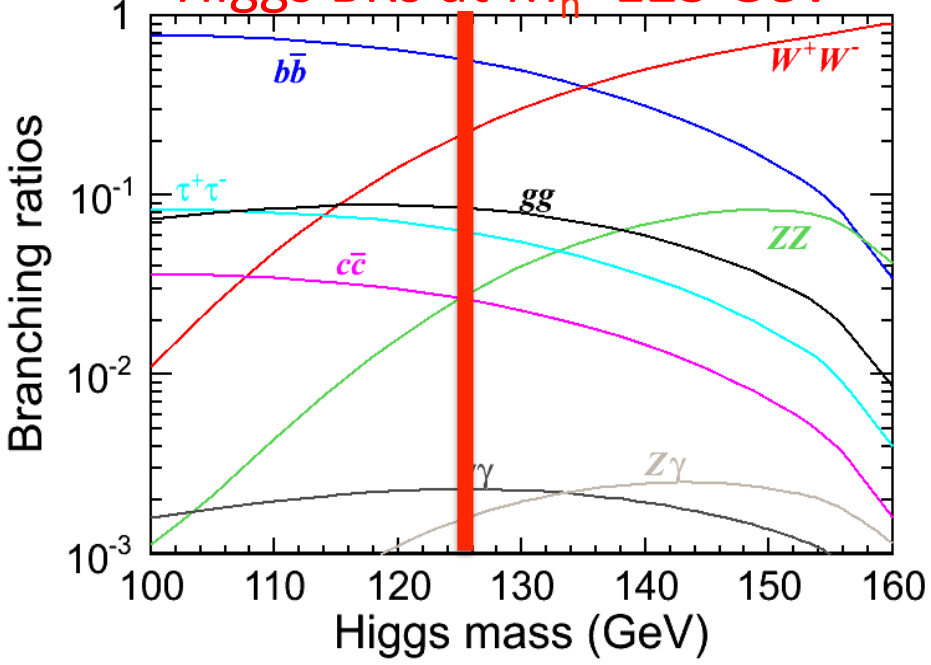
- Evaluate absolute BRs (σBR+σ from recoil)
- Reveal mass-coupling relation

LHC discovered Higgs-like boson at M=125-126 GeV

Accessible for each fermion/boson



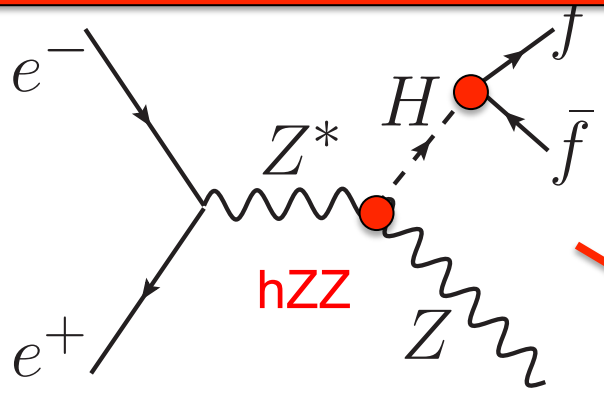
Higgs BRs at M_h=125 GeV



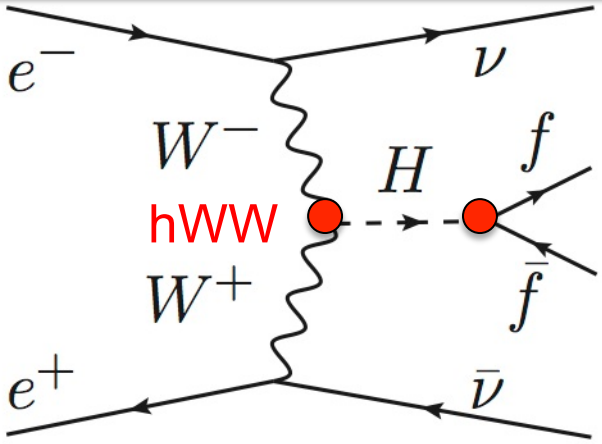
Mode	BRs @125 GeV
bb	57.8%
cc	2.7%
gg	8.6%
WW	21.6%
ττ	6.4%
ZZ	2.67%
γγ	0.23%
μμ	0.02%

Higgs boson production process

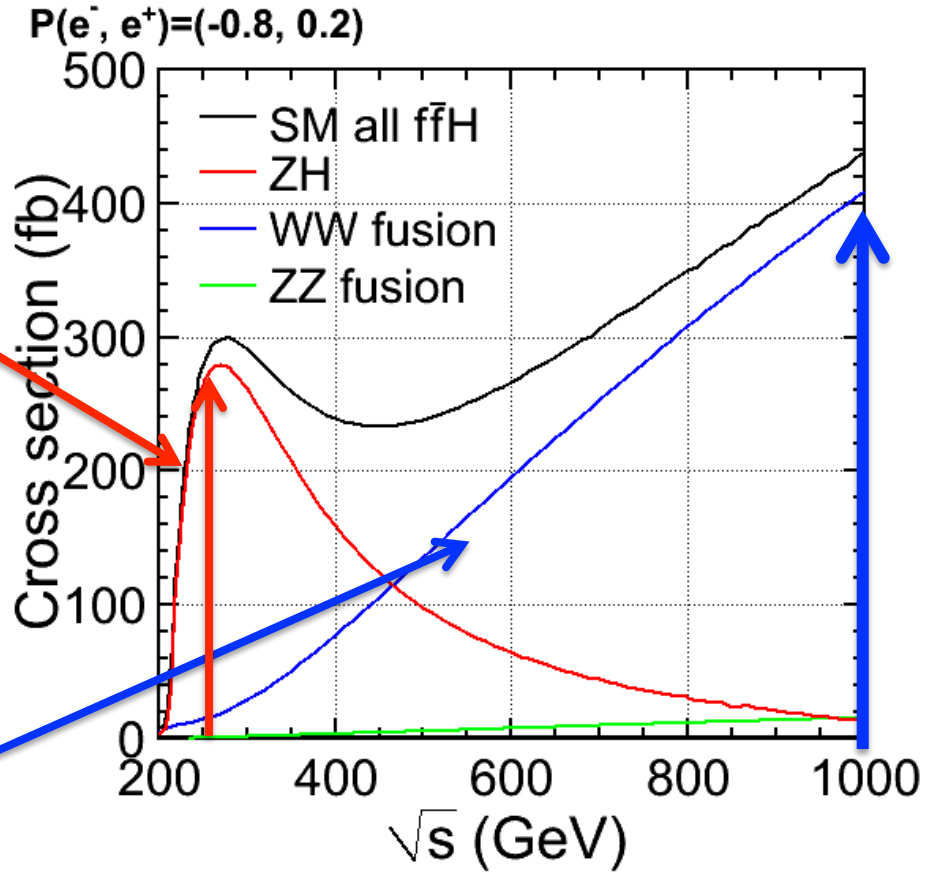
Higgs-strahlung process (Zh)



WW-fusion process (vvh)



Production cross section v.s. E_{cm}



Higgs production process depend on E_{cm}

Higgs physics at each energy

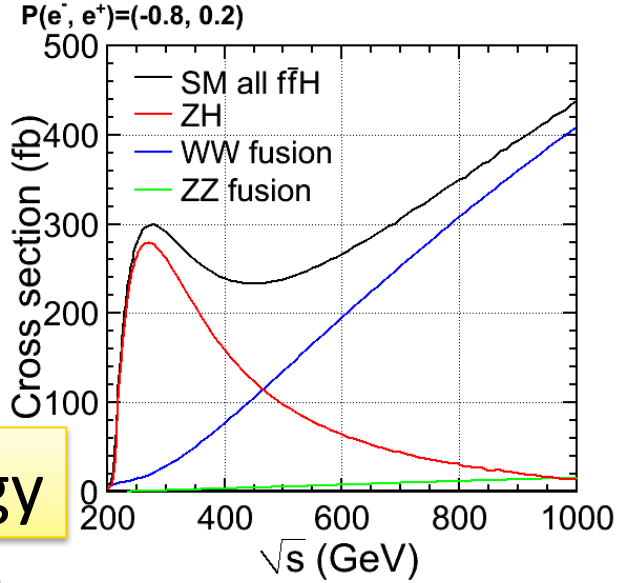
Energy threshold from physics and Higgs cross section

Ecm (GeV)	Int. Lumi. (fb^{-1})	Beam pol.	Higgs prod.	Target
250	250	(-+0.8, +-0.3)	Zh	Recoil, hZZ, hff
350	250	(-+0.8, +-0.3)	Zh+vvh	tt, hWW, Higgs width
500	500	(-+0.8,+-0.3)	vvh+Zh	Zhh, hhh, htt, hWW
1000	1000	(-+0.8,+-0.2)	vvh	New particle

Zh threshold is best for Z recoil study (250 GeV for 125 GeV Higgs)

Higher luminosity and cross section at higher energy (Statistical gain)

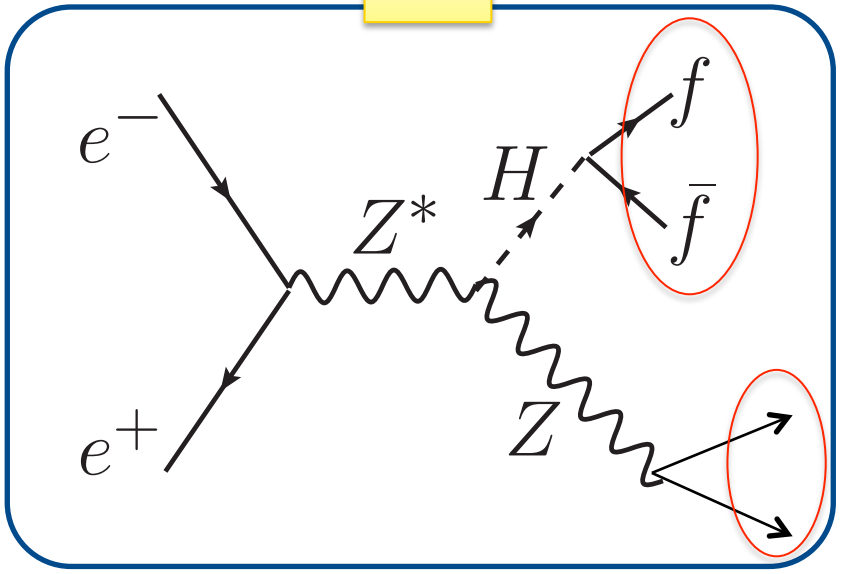
Higgs study should be done at each energy



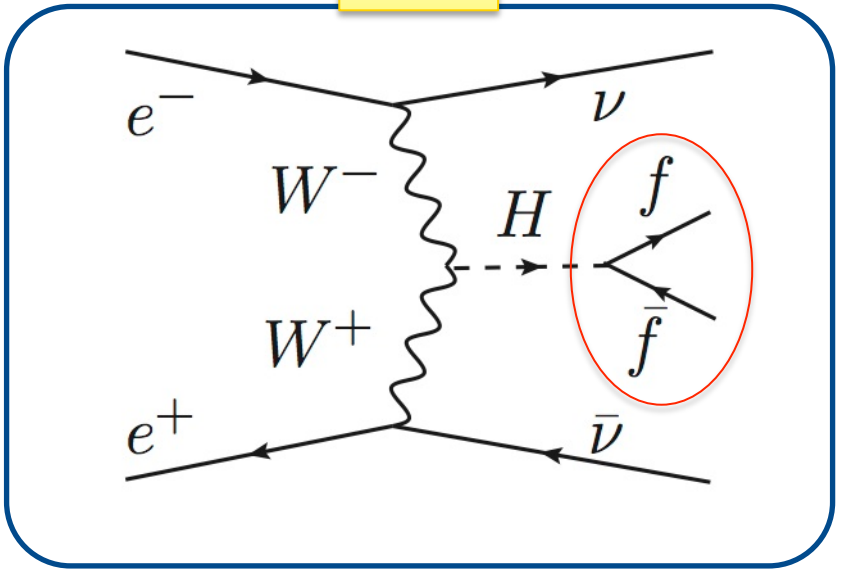
Higgs BR study at each energy

Higgs hadronic decay channel

Zh



vvh



Produce associated with Z
Reconstruct Z→νν, qq, ll

Zh→νvh (2 jets)
Zh→qqh (4 jets)
ZH→llh (ll+2 jets)

Only Higgs decay is visible

vvh→bb, cc, gg (2 jets)

h→WW* (qqqq, lνqq, lνlν)

h→bb, cc, gg analysis

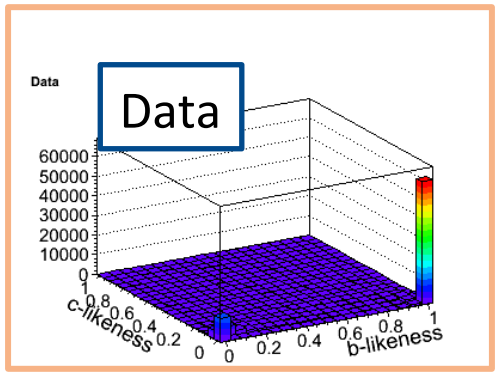
After the cuts, prepare flavor templates of signals and BGs

$r_{xx}=\sigma BR/\sigma BR^{SM}(h\rightarrow xx)$

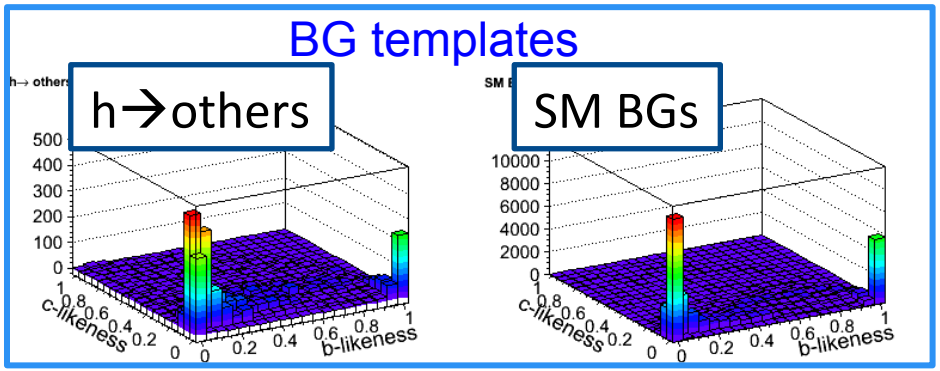
$N^{data}=\Sigma r_{xx} * N^{template}(h\rightarrow xx)+N^{BG}$

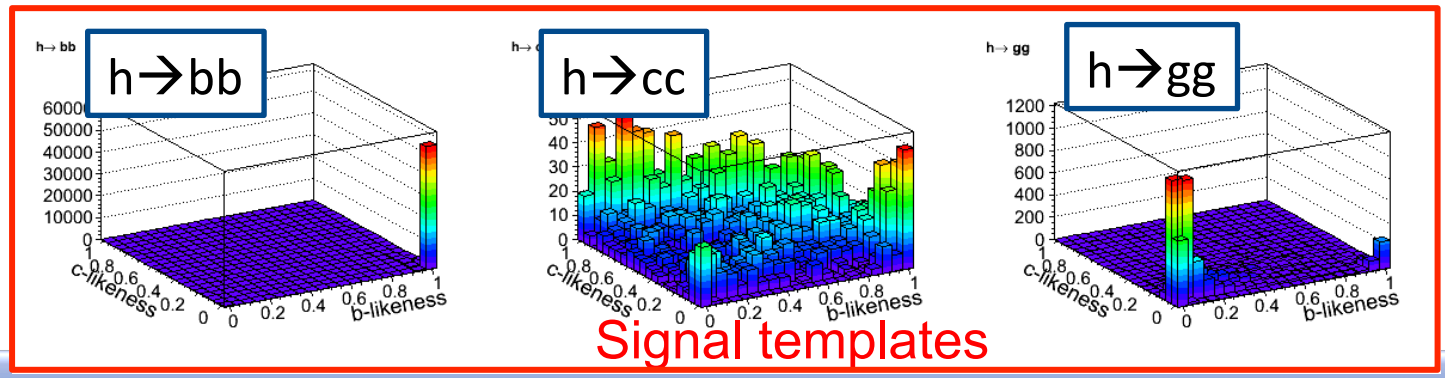
(r_{xx} is a fitted parameter)

N_{data} is fluctuated wit Poisson 5,000 times of Toy MC is applied to evaluate the accuracy of σBR



BG templates





Higgs BR study at 250 GeV (Post LOI)

LOI and post LOI studies are performed to investigate the measurement accuracies of Higgs BRs

Zh with E_{cm}=250 GeV, L=250 fb^{-1}, (e^-, e^+)=(0.8,0.3), M_h=120 GeV

Mode	BR	σBR	ΔσBR/σBR	ΔBR/BR
h→bb	65.7%	232.8	1.0%	2.7%
h→cc	3.6%	12.7	6.9%	7.3%
h→gg	5.5%	19.5	8.5%	8.9%
h→WW*	15.0%	53.1	8.2%	8.6%
h→ττ	8.0%	28.2	4.2%	4.9%
h→ZZ	1.7%	6.1	28(?)%	28(?)%
h→YY	0.29%	1.02	23-30%	23-30%

h→bb, cc, gg, WW*, (ZZ*) (H. Ono)
- vvh, qqh, llh combined
- arXiv:1207.0300

h→ττ
(S. Kawada, T. Suehara, T. Tanabe)
- qqh, llh are combined

h→γγ (C. Constantino)
- Studying DBD h→μμ

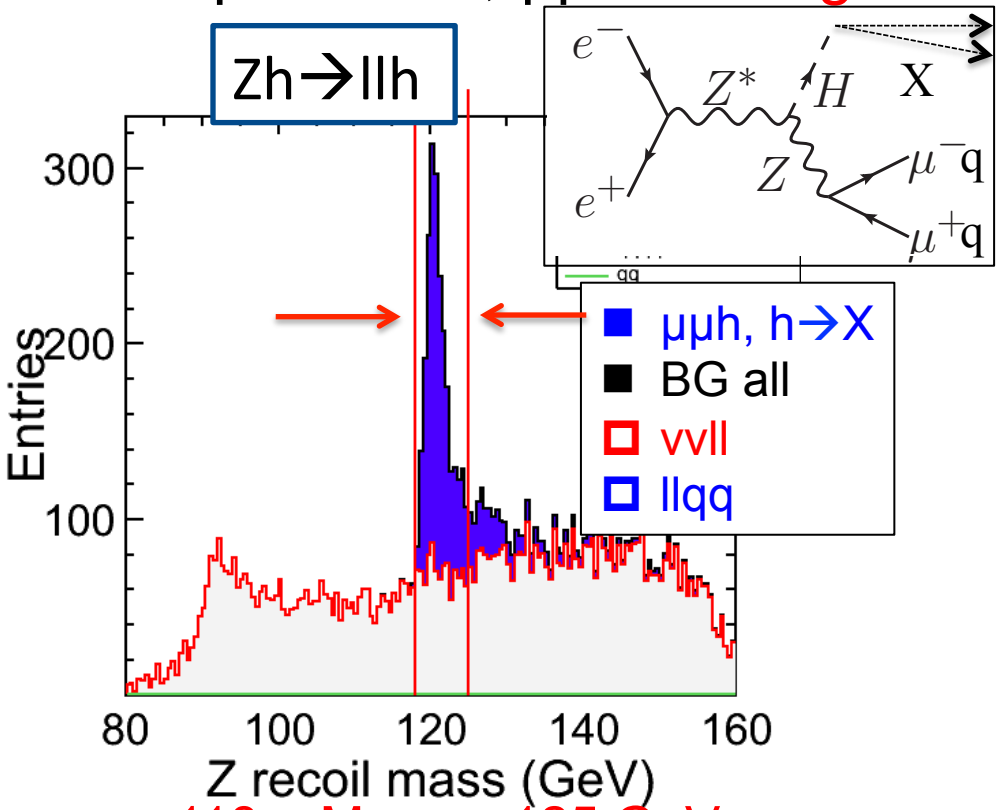
2.5% of Δσ/σ is considered from recoil study → Absolute BR measurement

In addition, h→invisible decay is also evaluated with full-simulation

h→Invisible decay

h→ZZ→vvvv pseudo signal is used with full simulation

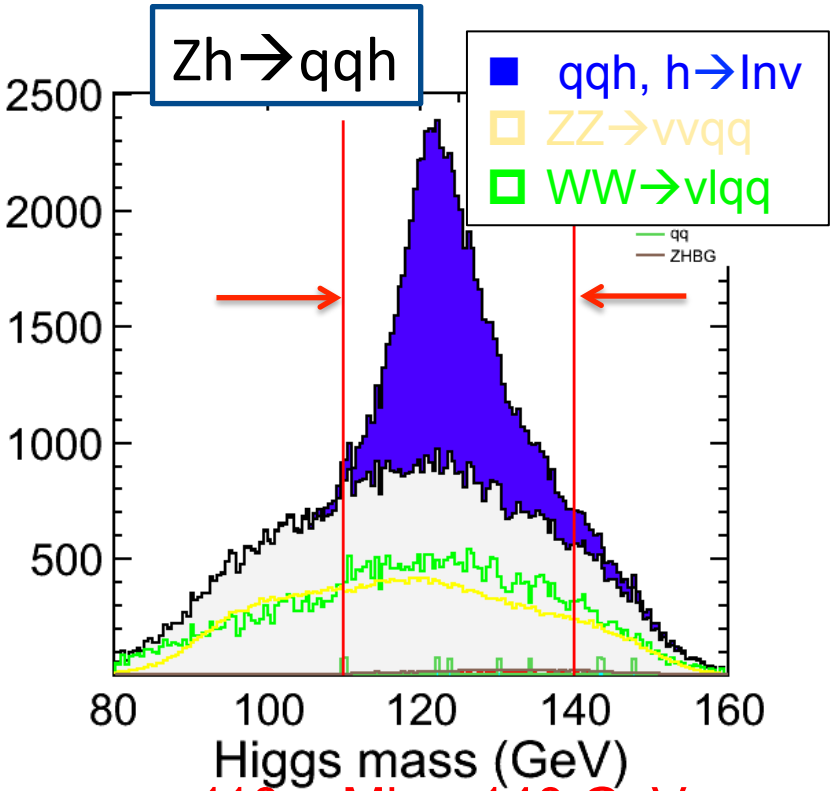
Require Z→ll,qq + nothing at Ecm=250 GeV, L=250 fb-1



118 < M_{recoil} < 125 GeV

CL 95% upper limit: 5.7%

in BR(h→Inv)=100%



110 < Mh < 140 GeV

CL 95% upper limit: 1.1%

in BR(h→Inv)=100%

Higgs BR study at 350, 500 GeV (Post LOI)

Increase WW-fusion (vvh) contribution above Zh threshold
tt, tth, Zhh should be also target of concurrent study

E_{cm}=350 GeV, L=250 fb^{-1}
E_{cm}=500 GeV, L=500 fb^{-1}
$(e^-, e^+)=(-0.8,+0.3)$, M_h=120 GeV

350 GeV: Zh
500 GeV: vvh

Mode	BR	ΔσBR/σBR 350 GeV (Zh)	ΔσBR/σBR 500 GeV (vvh)
h→bb	65.7%	1.0%	0.57%
h→cc	3.6%	6.2%	5.2%
h→gg	5.5%	7.3%	5.0%
h→WW*	15.0%		3.0%

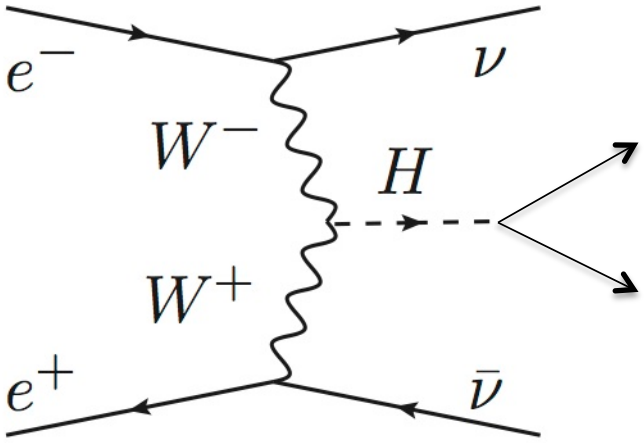
h→bb, cc, gg (H. Ono)
- Template fitting method with flavor tagging

h→WW* (J. Tian)
- Evaluate WWH coupling
- Evaluate Higgs width

Full detector simulation is performed. Need to estimate other channels…

Higgs BR study at 1 TeV (DBD)

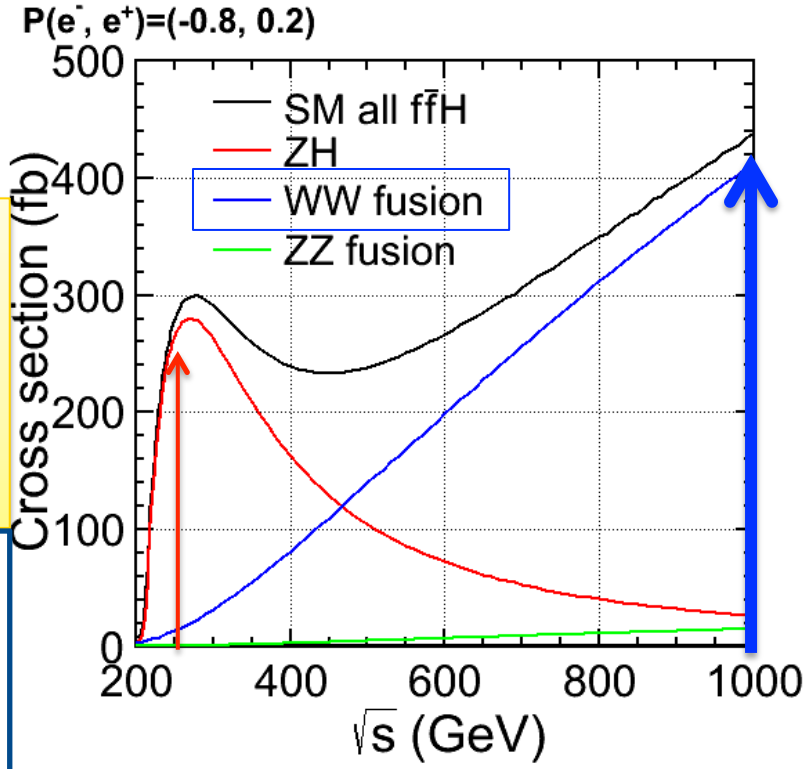
Higgs mainly produced via $e^+e^- \rightarrow \nu_e\nu_e h$ (WW-fusion)



h→bb, cc, gg (two jets)
h→WW* (four jets via hadronic decay)
h→μμ (dilepton)-→C. Constantino (KEK)

Ecm=1 TeV
Luminosity: L=1 ab^{-1} (500 fb^{-1} both pol.)
Beam polarization $P(e^-, e^+)=(0.8, 0.2)$
γγ→hadron BG is overlaid (4 event/BX)

Larger cross section than Zh@250 GeV
→Statistical gain (xsec and luminosity)
→Measure smaller BR channels



YY→hadron background treatment

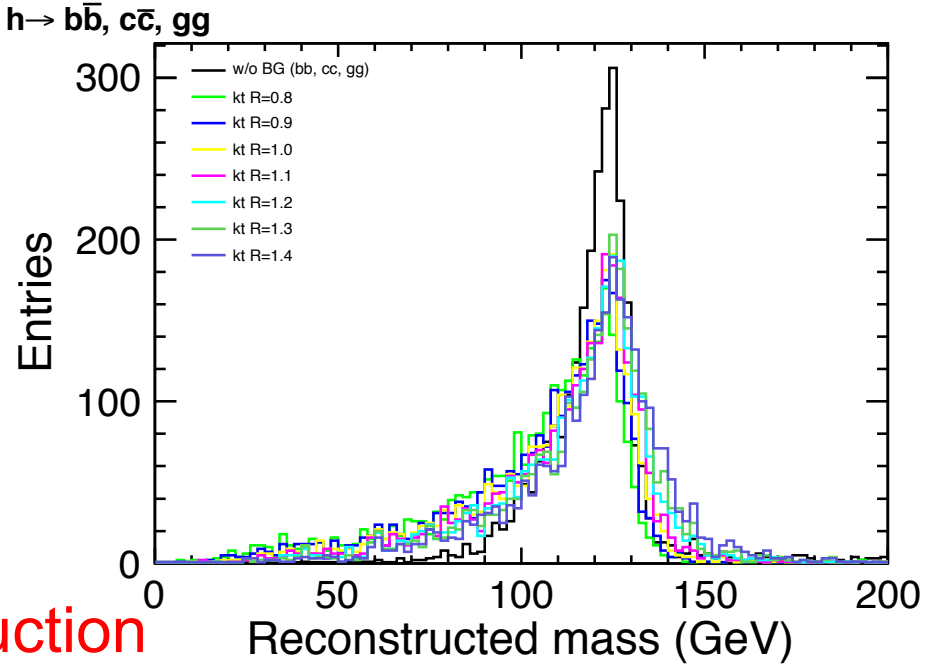
Beam related particle (4.0 event/BX) is treated with k_t jet clustering (commonly used in hadron collider study)

Jet reconstruction procedure

1. Apply k_t two jet clustering
2. Use only jet associated PFOs
3. Reapply flavor tagging and jet clustering with LCFIPlus

Optimize R parameter used in k_t algorithm

Higgs dijet rec. with γγ→hadron BG



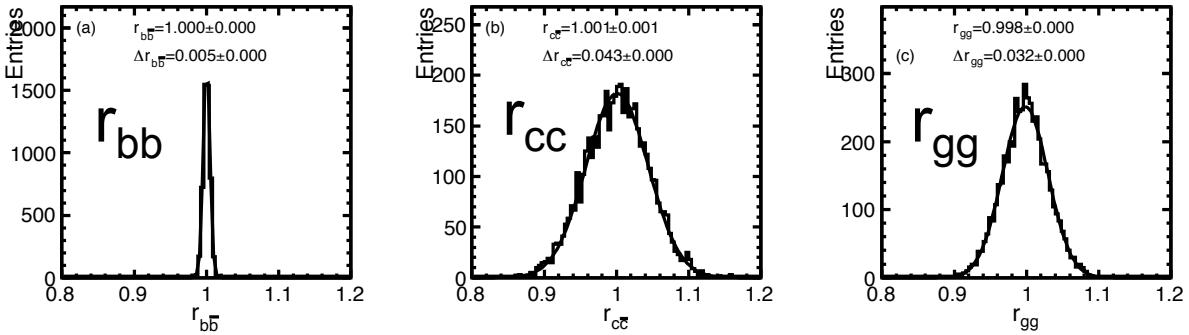
Select R=1.1 for 2 jet reconstruction

Check Higgs reconstruction and BG reduction with γγ BG overlay

h→bb, cc, gg hadronic channel

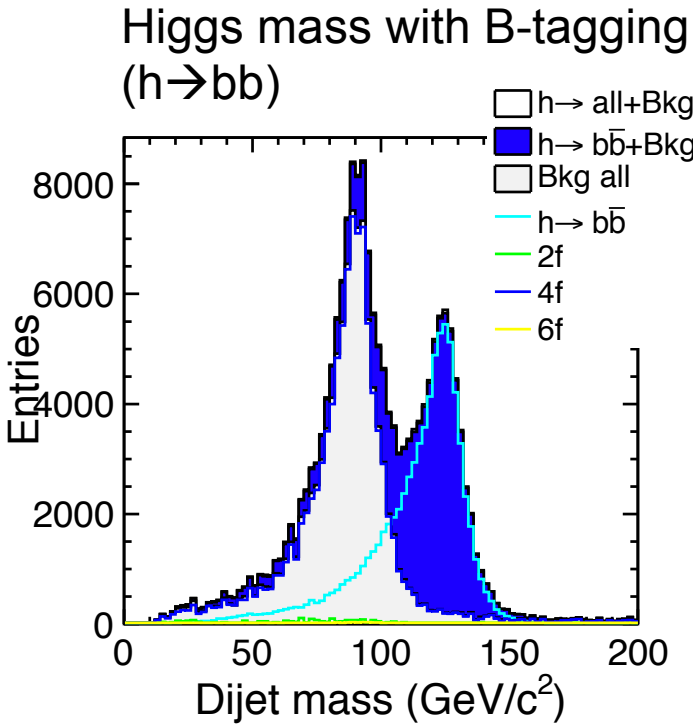
Flavor template for h→bb, cc, gg and others are prepared
Template fitting is performed to evaluate accuracy of σBR

Fitted r_{bb}, r_{cc}, r_{gg}



L=500 fb^{-1}, P(-0.8, +0.2) result with Toy-MC

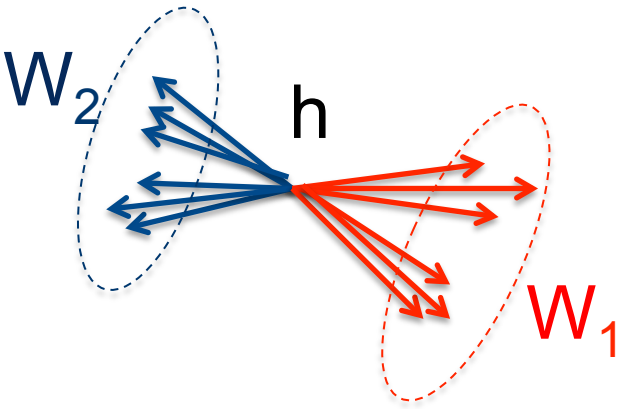
Higgs decay channel	Fitted results
r_{bb}	1.000±0.0046
r_{cc}	1.001±0.043
r_{gg}	0.998±0.032
$\Delta\sigma BR(\mathrm{h} \to \mathrm{bb})/\sigma\mathrm{BR}$	0.46%
$\Delta\sigma BR(\mathrm{h} \to \mathrm{c\bar{c}})/\sigma\mathrm{BR}$	4.3%
$\Delta\sigma BR(\mathrm{h} \to \mathrm{gg})/\sigma\mathrm{BR}$	3.2%



H→WW* channel

h→WW* (one on-shell W) from Higgs decay
h→WW*→qqqq fully hadronic decay channel is considered

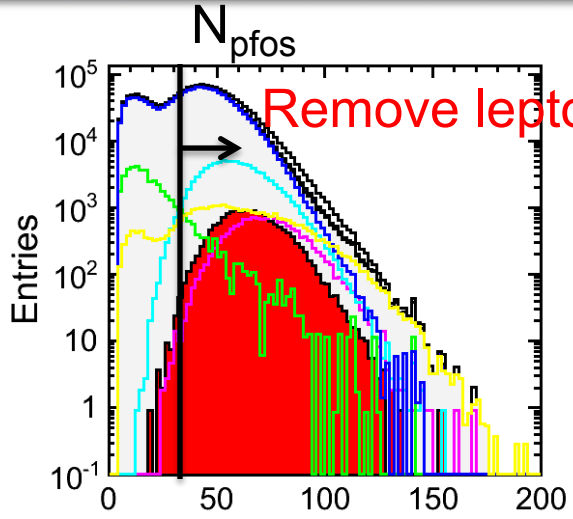
1. Apply forced four jet clustering with k_t jet clustering (R=1.1)
2. Apply flavor tag for jet associated particles with LCFIPlus
3. Jet clustering and paring for W_1, W_2 (W_1 is on-shell with J_1, J_2)
4. Select best candidate with minimizing χ^2

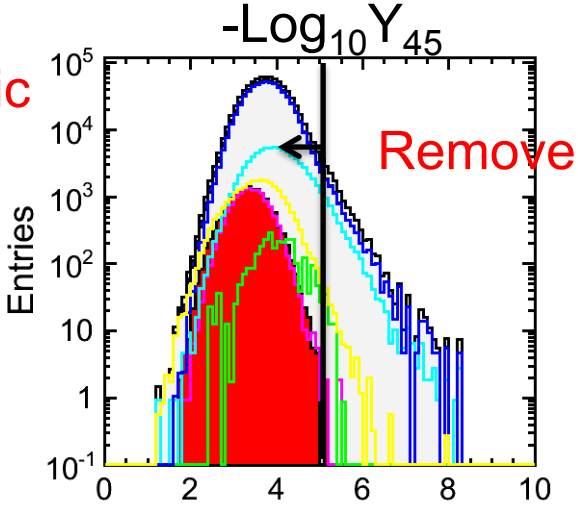


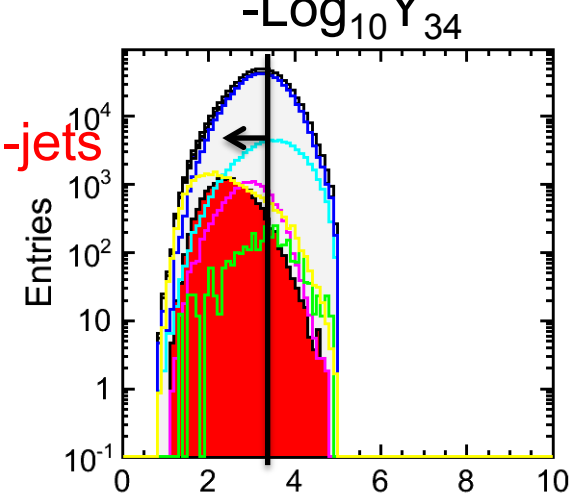
$$\chi^2 = \left(\frac{M_{12}-M_W}{\sigma_W}\right)^2 + \left(\frac{M_{4j}-M_h}{\sigma_h}\right)^2$$

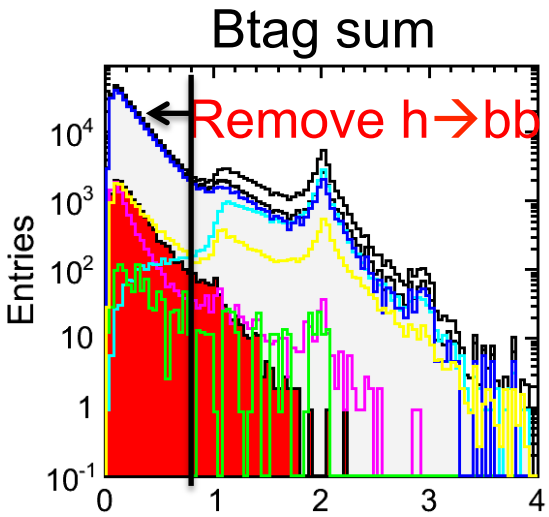
L=500 fb^{-1}
$(e^-,e^+)=(-0.8, +0.2)$

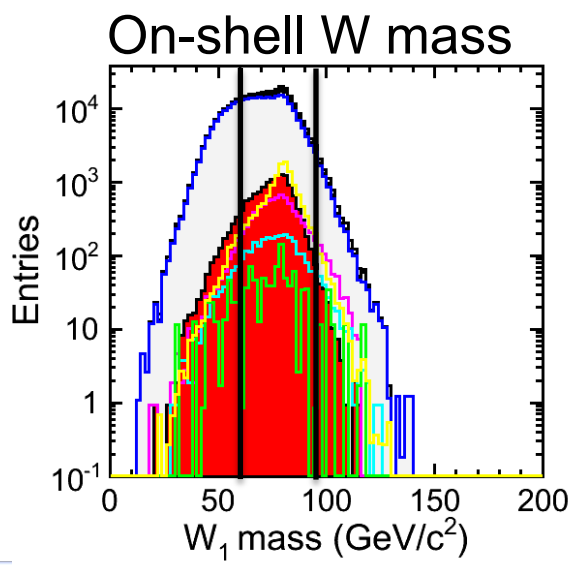
h→WW* background reduction

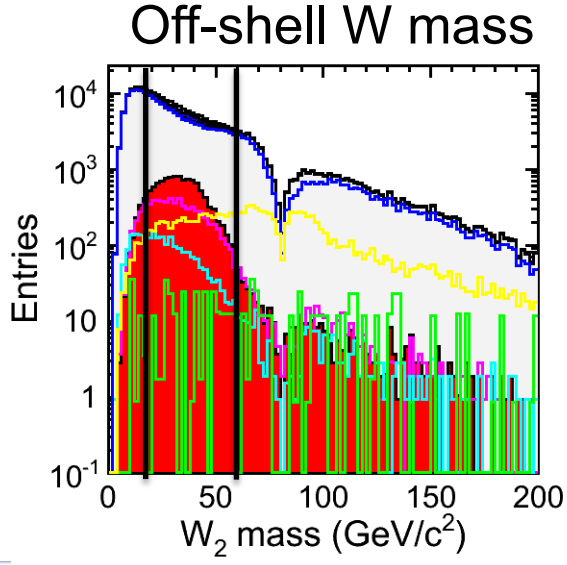






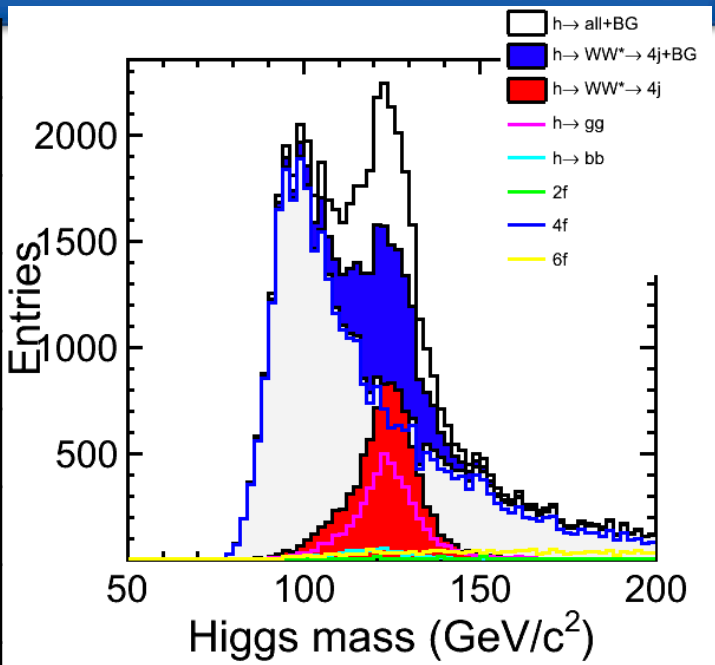






h→WW*→4j reconstruction

Cut	h→WW*→4j	h→other	SM BGs
Generate	21,976	201,432	17,750,600
110<Evis<400	18,820	162,621	4,178,330
35<Pt	16,584	140,702	1,503,690
−350<Pz<350	16,456	139,847	1,456,940
50<Npfos	13,971	86,663	375,899
$\|\cos\theta_j\|$<0.98	12,898	75,551	278,763
y45<5.0	12,897	73,318	275,230
y34<3.1	11,391	31,902	139,896
y23<2.5	10,938	27,569	119,425
(Btag sum)<0.8	10,395	10,543	95,390
60<Mw1<95	9,254	8,689	62,519
15<Mw2<60	8,705	7,609	39,061
105<Mh<140	7,797	6,373	14,322



L=500 fb^{-1}
$(e^-,e^+)=(-0.8, +0.2)$

Significance=46.2

$\Delta\sigma BR/\sigma BR$ = 2.2%

Higgs BR study at 1 TeV

E_{cm}=1 TeV, L=1 ab^{-1}
(e^-, e^+)=(0.8,0.2), M_h=125 GeV

Preliminary results

Mode	ΔσBR/σBR 500 fb^{-1} (-0.8, +0.2)	ΔσBR/σBR 1ab^{-1} (-0.8, +0.2)
h→bb	0.46%	0.35%
h→cc	4.3%	3.2%
h→gg	3.2%	2.3%
h→WW*	2.2%	

1 TeV: vvh

h→bb, cc, gg (H. Ono)
- Flavor tagging template fitting method

h→WW* (H.Ono)
- Cut based analysis

h→μμ (C. Constantino)
- Next talk

We discuss with SiD group to select luminosity and polarization
But maybe need to have self-consistency in ILD (500L+500R)

Summary of Zh at M_h=125 GeV

ee→Zh

We studied with full simulation

Extrapolate to 125 GeV

Ecm (GeV)	250	350	500	1000	250	350	500	1000
Mh	120	120	120	125	125	125	125	125
Lumi (fb^{-1})	250	250	500	500	250	250	500	500
Pol. (e^-, e^+)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.2)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.2)
σ(Zh)xBR(bb)	1.0%	1.0%	1.6%***		1.1%	1.0%	1.7%	
σ(Zh)xBR(cc)	6.9%	6.2%	11%***		8.5%	6.8%	13%	
σ(Zh)xBR(gg)	8.5%	7.3%	13%***		7.2%	5.7%	11%	
σ(Zh)xBR(WW*)	8.2%		13%***		7.2%		11%	
σ(Zh)xBR(ττ)	4.2%		7%**		5.5%			
σ(Zh)xBR(ZZ)	28%**		45%**		24%			
σ(Zh)xBR(γγ)	27%**		36%**		32%			
σ(Zh)xBR(μμ)								

Preliminary

Higgs BRs are followed by LHC tuned value: arXiv:1101.0593v3 [hep-ph]

Summary of vvh at M_h=125 GeV

ee→vvh

We studied with full simulation

Extrapolate to 125 GeV

Ecm (GeV)	250	350	500	1000	250	350	500	1000
Mh	120	120	120	125	125	125	125	125
Lumi (fb^{-1})	250	500	500	500	250	500	500	1000
Pol. (e^-, e^+)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.2)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.3)	(0.8, 0.2)
σ(vvh)xBR(bb)	6.6%*		0.57%	0.46%	7.6%		0.62%	0.35%
σ(vvh)xBR(cc)			5.2%	4.3%			6.2%	3.2%
σ(vvh)xBR(gg)			5.0%	3.2%			4.1%	2.3%
σ(vvh)xBR(WW*)			3.0%	2.2%			2.6%	1.6%
σ(vvh)xBR(ττ)			5%**	2%**			7%	
σ(vvh)xBR(ZZ)								
σ(vvh)xBR(γγ)			28%**	5%**			32%	
σ(vvh)xBR(μμ)				33%				25%

Preliminary

Higgs BRs are followed by LHC tuned value: arXiv:1101.0593v3 [hep-ph]

Conclusion

- Performance of "Possible BR decays" should be shown to demonstrate the potential of ILC measurement
  - DBD physics chapter and summary
- vvh @ 1 TeV benchmark study is now on-going
- Several studies should be continue
  - Different Ecm, Mh=125 GeV
  - h→ZZ* (I studied but now pending…) should be done.

- My personal view, we need to consider possible ILC running plan: Ecm running time, luminosity, precision.