Higgs branching ratios study

ILC physics WG general meeting

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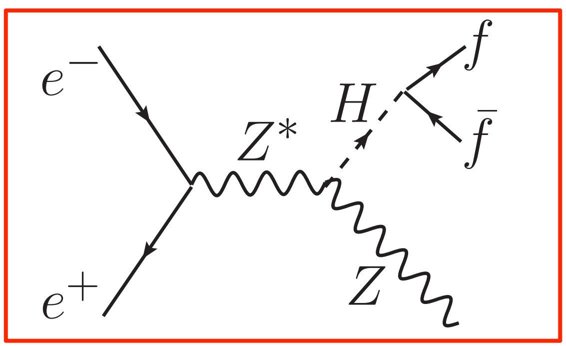
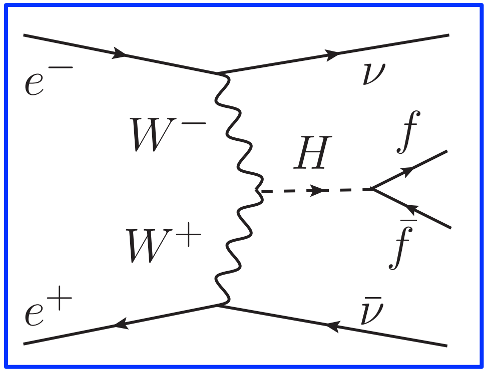
Higgs measurements at each energy

Ecm (GeV)	Lumi (fb^{-1})	Production	Targets
250	250	Zh	Recoil, BR
350	300	Zh+WW-fusion	tt
500	500	Zh+WW-fusion	ZHH, tth
1000	1000	WW-fusion	Rare channel

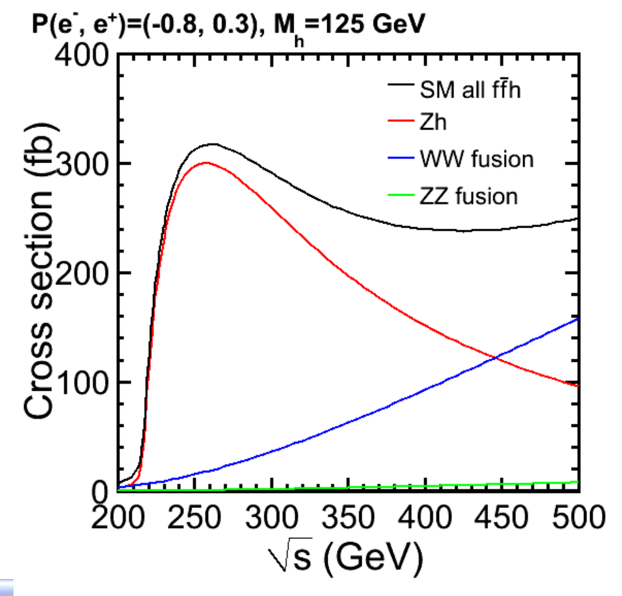
P(-0.8, +0.3)
M_h=125 GeV



Zh (Higgs-strahlung)



WW-fusion



Evaluate Zh channel for 250 and 350 GeV

Current results ΔσBR/σBR

Higgs mass should be updated from 120 GeV → 125 GeV

E_{cm} (GeV)	250	350	500	1000
Pol (e-,e+)	(-0.8,+0.3)	(-0.8,+0.3)	(-0.8,+0.3)	(-0.8,+0.2)
Lumi (fb^{-1})	250	250	500	1000
Mh (GeV)	120	120	120	125
h→bb	1.0%	1.0%	0.57%	0.39%
h→cc	6.9%	6.2%	5.2%	3.9%
h→gg	8.5%	7.3%	5.0%	2.8%
h→WW*	8.1%		3.0%	2.5%

Re-do with new 125 GeV full simulation samples

Higgs BR study update from LOI

Updates LOI analysis by latest software and input

	LOI	DBD (post)
Higgs mass	120 GeV	125 GeV
BR	Pythia	LHC Higgs XSWG
Ecm	250, 350, 500	250, 350, (500) 1000
Detector model	ILD_00	ILD_o1_v05
Software	ilcsoft v01-06	ilcsoft v01-16
Flavor tag	LCFIVTX	LCFIPlus

Ecm=250 and 350 GeV are re-analyzed with new samples

New 250, 350 GeV samples (M_h=125 GeV)

E_{cm}	250 GeV		350 GeV	
Signal	σ (fb)	N (250 fb^{-1})	σ (fb)	N (300 fb^{-1})
nnh	77.5	19,383	98.7	29,596
qqh	210.2	52,546	138.9	41,670
eeh	10.9	2,729	10.2	3,073
mumuh	10.4	2,603	6.9	2,061
tautauh	10.4	2,598	6.9	2,057
Total	319.4	79,860	261.5	78,457

M_h=125 GeV
Pol_L(-0.8, +0.3)

250 GeV, 250 fb^{-1}
350 GeV, 300 fb^{-1}

	250 GeV		350 GeV	
SM BGs	σ (fb)	N (250fb^{-1})	σ (fb)	N (300fb^{-1})
2f	$1.2x10^5$	$2.9x10^7$	$7.2x10^4$	$2.2x10^7$
4f	$4.1x10^8$	$1.0x10^7$	$3.1x10^4$	$9.4x10^6$
6f	Not considered		$1.4x10^2$	$4.3x10^5$
1f_3f	$1.3x10^6$	$3.3x10^8$	$1.6x10^6$	$4.8x10^8$
aa_2f	$5.8x10^5$	$1.4x10^8$	$9.6x10^5$	$2.9x10^8$

Extrapolated results (250 GeV)

Expected accuracies by extrapolating 120 GeV results to 125 GeV w/o cut eff. diff.

E_{cm}=250 GeV	M_h=120 GeV (L=250 fb^{-1})			M_h=125 GeV (L=250 fb^{-1})		
ΔσBR/σBR	bb	cc	gg	bb	cc	gg
ννh	1.7%	11.2%	13.9%	1.8%	12.9%	11.2%
qqh	1.5%	10.2%	13.1%	1.6%	11.8%	10.5%
eeh	3.8%	26.8%	31.3%	4.0%	31.4%	25.3%
μμh	3.3%	22.6%	23.9%	3.5%	26.3%	19.1%
Combined	1.0%	6.9%	8.5%	1.1%	8.0%	6.8%

BR	120 GeV	125 GeV
BR(bb)	65.7%	57.8%
BR(cc)	3.6%	2.7%
BR(gg)	5.5%	8.6%

Cross sections at Mh=120 and 125 GeV are almost comparable in LOI samples and new samples

Main contribution comes from BR difference between M_h=120 and 125 GeV

Extrapolated results (350 GeV)

Expected accuracies by extrapolating 120 GeV results to 125 GeV w/o cut eff. diff.

E_{cm}=350 GeV	M_h=120 GeV (L=250 fb^{-1})			M_h=125 GeV (L=300 fb^{-1})		
ΔσBR/σBR	bb	cc	gg	bb	cc	gg
ννh	1.4%	8.6%	9.2%	1.2%	8.0%	6.0%
qqh	1.5%	10.1%	13.7%	1.8%	13.1%	12.3%
eeh	5.3%	30.5%	35.8%	5.4%	33.6%	27.3%
μμh	5.1%	30.9%	33.0%	6.1%	40.2%	29.7%
Combined	1.0%	6.2%	7.3%	1.0%	6.6%	5.2%

BR	120 GeV	125 GeV
BR(bb)	65.7%	57.8%
BR(cc)	3.6%	2.7%
BR(gg)	5.5%	8.6%

Cross section	120 GeV	125 GeV
ννh	77.4 fb	98.7 fb
qqh	210.0 fb	138.9 fb
eeh	11.1 fb	10.2 fb
μμh	10.4 fb	6.9 fb

BR, Luminosity, and σ are different

Zh→vvh @ 250 GeV

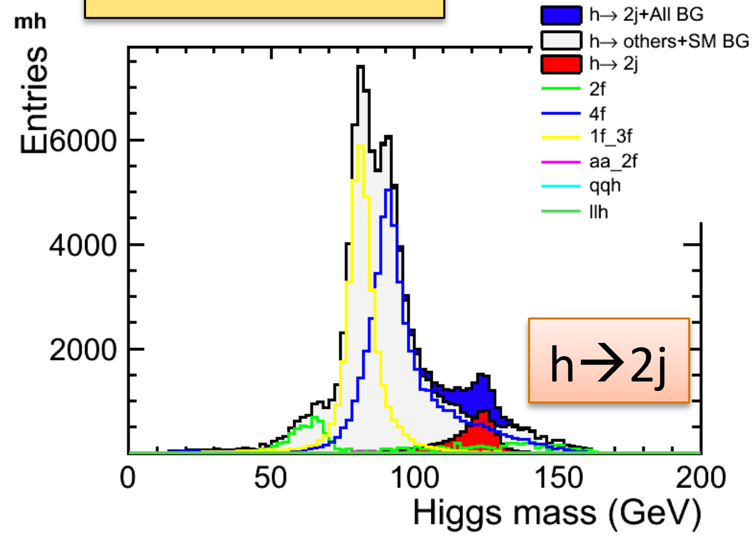
Zh→vvh, E_{cm}=250 GeV, L=250fb^{-1}, P(-0.8, +0.3)

Apply LCFIPlus vertex finder and forced two-jet clustering

vvh cut flow

1. 110<M_{vis}<140 GeV
2. Thrust > 0.8
3. 20 < P_t < 70 GeV
4. |Pz|<60 GeV
5. # of particle in jet > 10
6. P_{max}<30 GeV
7. -$\log_{10}(Y_{23})$<0.02
8. 0.2<-$\log_{10}(Y_{12})$<0.9
9. 80 < M_{miss} < 150 GeV
10. LR > 0.35

Visible mass



Significance: S/√(S+B)=51.2
Efficiency = 40.2%

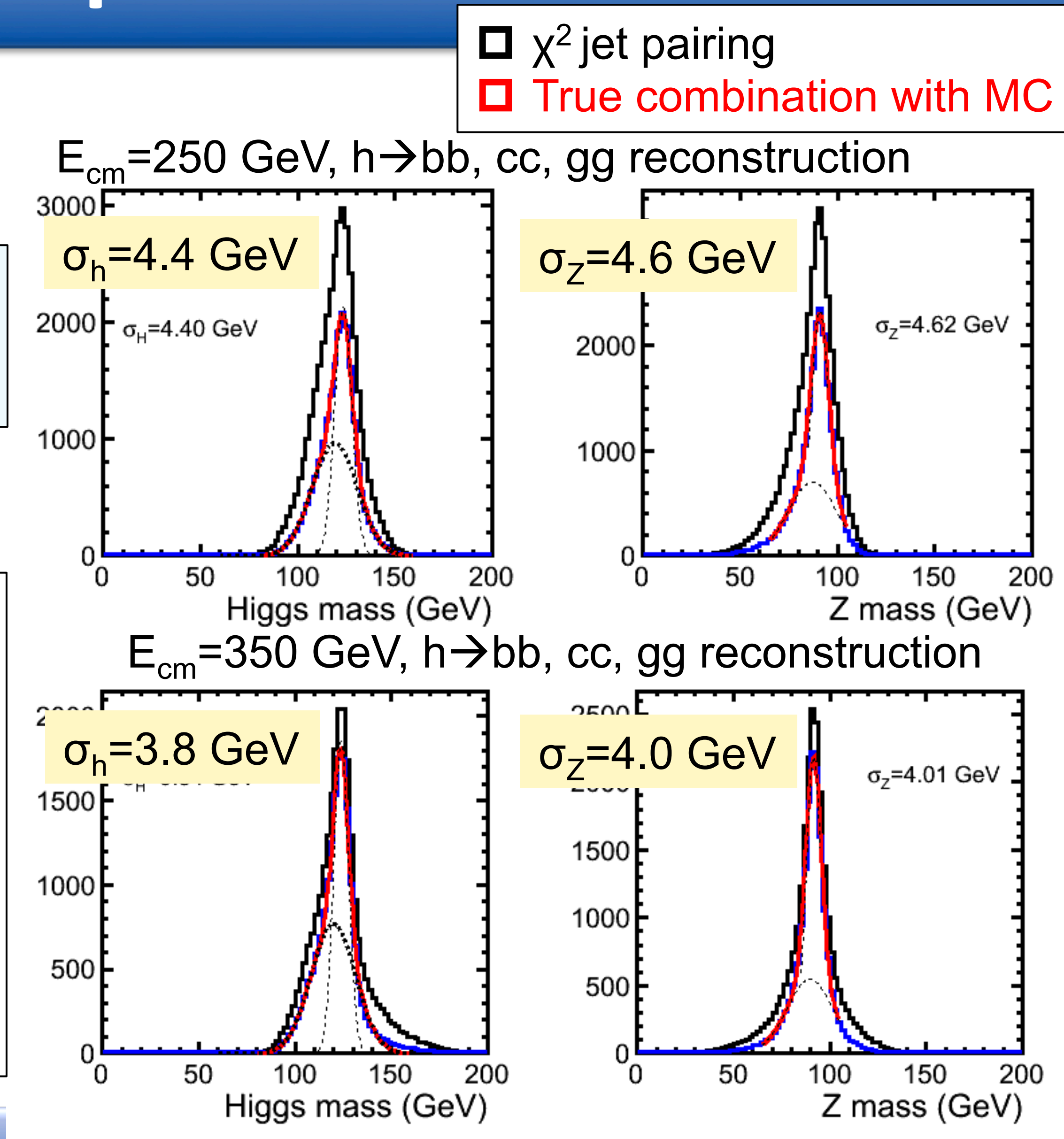
Zh→nnh @250 GeV cut summary

	nnh signal				SM backgrounds				
	h->bb	h->cc	h->gg	h->others	2f	4f	1f_3f	aa_2f	Other ZH
No cut	11,223	520	1,649	5,990	2.9×10^7	1.1×10^7	3.1×10^8	165,658,000	60,477
30<Pt<100 GeV	8,882	422	1,333	4,043	504,080	3,685,600	257,605	1,499	6,203
|Pz|<60 GeV	8,678	413	1,299	3,919	433,467	3,138,710	183,052	1,179	6,096
# of PFOs >30	8,546	394	1,299	2,557	104,294	2,218,070	100,198	0	5,540
100<Evis<150 GeV	8,085	370	1,223	2,234	2,073	380,255	51,872	0	791
80<Mmiss<120	6,750	326	1,117	1,803	1,644	190,468	20,822	0	645
Thrust>0.8	5,858	284	754	534	1,514	79,182	9,052	0	246
-Log10(Y34)>2.0	5,770	282	719	400	1,482	74,113	8,884	0	204
-Log10(Y23)>1.5	5,360	260	624	225	1,360	52,351	8,138	0	143
110<Mh<140 GeV	4,858	250	620	173	986	16,349	499	0	112
LR>0.35	4,511	215	589	134	572	4,437	246	0	53
Efficiency	40.2%	41.4%	35.7%	2.2%	1.9.E-05	4.0.E-04	8.0.E-07	0.0%	8.8.E-04

Zh→qqh jet pair combination

Jet paring from four jets

$$\chi^2 = \left(\frac{M_{12}\text{-}M_Z}{\sigma_Z}\right)^2 + \left(\frac{M_{34}\text{-}M_H}{\sigma_H}\right)^2$$



Slightly wider distribution compare to the M_h=120 GeV

250 GeV
M_h=4.4 GeV, M_z=4.7 GeV

350 GeV
M_h,M_z=3.8 GeV

Zh→qqh at 250 GeV

Cut parameters are optimized for 125 GeV Higgs mass

vvh cut flow

1. $\chi^2<50$
2. $E_{vis}>200$
3. $0.5<-Log_{10}(y_{34})<2.7$
4. Particle in jet >0
5. # of chd trk>20
6. $|\cos\theta_{thrust}|<0.90$
7. Thrust<0.9
8. $\theta_{hjj} > 110$
9. $\theta_{Zjj} > 90$
10. 80<Mz<100
11. 110<Mh<150
12. LR>0.685

LR inputs

1. Thrust
2. # of particles from h decay
3. $-Log_{10}(Y_{12})$
4. $-Log_{10}(Y_{23})$
5. Minimum jets angle
6. Mh

After the selections template fitting is applied for each channel h→bb, cc, gg and BGs templates are prepared

Signal significance=30.1
Efficiency=33.9%

Zh→qqh cut summary

cuts	h->bb	h->cc	h->gg	h->others	2f	4f	1f_3f	aa_2f	ZH others
No cut	30,334	1,399	4,499	16,314	3.0.E+07	1.1.E+07	3.1.E+08	1.7.E+08	27,314
chi2<50	26,303	1,246	4,067	8,773	3.8.E+06	2.7.E+06	1.8.E+08	7.0.E+07	5,263
Evis>200	26,134	1,244	4,065	8,501	2.2.E+06	2.4.E+06	57,636	2,434	4,674
0.5<-log10(y34)<2.7	25,850	1,230	4,040	8,475	904,843	2.3.E+06	15,601	674	4,611
Particle in jet >0	25,446	1,204	3,998	7,659	488,383	2.1.E+06	2,485	228	1,926
# of chd trk>20	25,423	1,202	3,998	7,531	475,755	2.1.E+06	1,852	188	1,755
$\lvert\cos\theta\rvert<0.90$	22,394	1,058	3,532	6,605	396,735	1.5.E+06	565	72	1,539
Thrust<0.9	21,918	1,033	3,502	6,581	259,777	1.4.E+06	500	62	1,489
$110<\theta_{hjj}$	21,123	994	3,246	5,861	242,540	1.3.E+06	470	62	1,406
$90<\theta_{Zjj}$	20,839	980	3,163	5,667	224,017	1.2.E+06	448	62	1,378
80<Mz<100	18,486	885	2,833	4,632	173,464	885,324	310	40	1,172
110<Mh<150	18,486	885	2,833	4,632	173,441	885,311	310	40	1,172
LR>0.685	10,279	412	1,927	2,752	36,652	121,654	29	10	439
Efficiency	33.9%	29.5%	42.8%	16.9%	1.2.E-03	1.1.E-02	9.4.E-08	6.0.E-08	1.6.E-02

Current results E_{cm}=250 GeV

Ecm=250 GeV with comparison between extrapolated and simulated results

E_{cm}=250 GeV	Extrapolated 125 GeV (250 fb^{-1})			Simulated 125 GeV (250fb^{-1})		
ΔσBR/σBR	bb	cc	gg	bb	cc	gg
ννh	1.8%	12.9%	11.2%	1.6%	13.4%	9.3%
qqh	1.6%	11.8%	10.5%	1.6%	22.3%	15.5%
eeh	4.0%	31.4%	25.3%	4.3%	59.4%	36.9%
μμh	3.5%	26.3%	19.1%	3.4%	32.7%	21.0%
Combined	1.1%	8.0%	6.8%	1.0%	10.6%	7.3%

Preliminary results

Discrepancies in qqh and eeh on h→cc/gg channels.
(eeh and μμh contributions are relatively small)
These reasons are still under investigation.

Current results E_{cm}=350 GeV

Analysis with the 350 GeV with same procedure with 250 GeV
Only cut parameters are optimized for the 350 GeV

E_{cm}=350 GeV	Extrapolated M_h=125 GeV (L=300 fb^{-1})			Simulated M_h=125 GeV (L=300 fb^{-1})		
ΔσBR/σBR	bb	cc	gg	bb	cc	gg
ννh	1.2%	8.0%	6.0%	1.3%	9.7%	7.9%
qqh	1.8%	13.1%	12.3%			
eeh	5.4%	33.6%	27.3%			
μμh	6.1%	40.2%	29.7%			
Combined	1.0%	6.6%	5.2%			

Preliminary results

Other channels are still on-going
Slightly worse than expected in ννh. Need to separate ZH and WW-fusion

Summary and next steps

- Analyze Higgs hadronic decay at 250 and 350 GeV
  Zh→qqh, eeh are still under investigation
- H→WW* study for both 250 and 350 GeV
- 500 GeV is also next target