Higgs branching ratio study for DBD

LCWS12 Higgs and EWSB session

Oct. 25 2012

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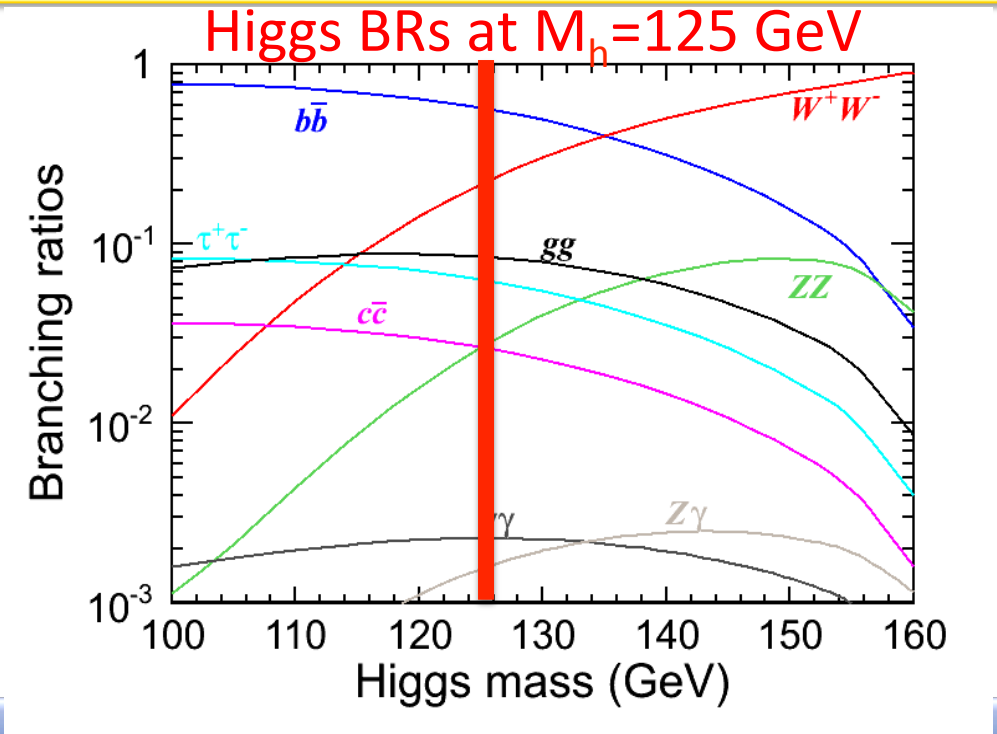
Higgs branching ratio (BR) study

Precise measurement of Higgs BRs is one of key issue in ILC to figure out the relation of Higgs-particles couplings

LHC discovered Higgs like boson at the mass of 125-126 GeV.
M_h=125 GeV is very attractive for the BRs measurement in ILC
→Many channels are accessible to BR with high precision



Channel	BRs @M_h=125 GeV
bb	57.8%
cc	2.7%
gg	8.6%
WW	21.6%
ττ	6.4%
ZZ	2.67%
ϒϒ	0.23%
μμ	0.02%

DBD Physics chapter

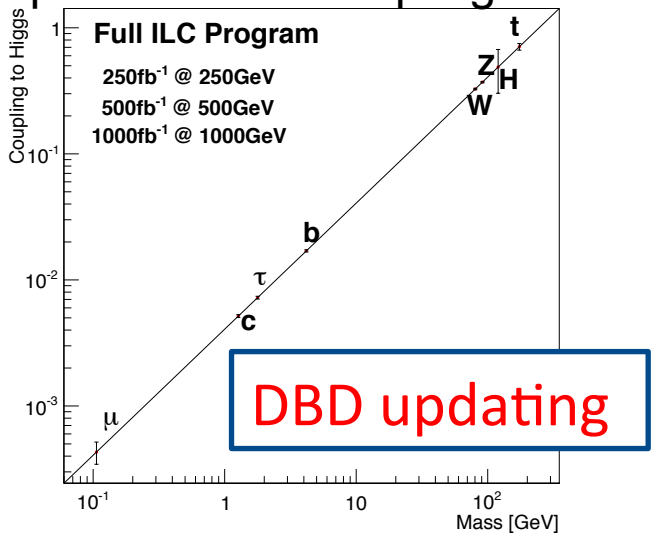
Higgs BRs in DBD physics chapter

ILC Higgs physics performances are summarized in DBD physics chapter

Higgs BRs summary (E_{cm}=250 GeV, L=250fb^{-1}, (e^-, e^+)=(0.8,0.3))

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	4-6%	5-7%
h→ZZ	1.7%	6.1	28(?)%	28(?)%
h→γγ	0.29%	1.02	23-30%	23-30%

Updated mass coupling relation



E_{cm}=250, 500 GeV study is still progressing with full simulation

- h→WW/ZZ, invisible and bb, cc, gg @500 GeV (H. Ono working in progress)
- h→ττ (S. Kawada Oct. 24 Higgs&EWSB)
- h→γγ, μμ (C. Calancha)

Ref. DBD physics chapter
http://lcsim.org/papers/DBDPhysics.pdf

These results used M_h=120 GeV → Update with 125 GeV

Higgs BR accuracies at M_h=125 GeV

Last LOI study used Pythia BR at M_h=120 GeV
→ Estimate Higgs BR accuracies at M_h=125 GeV with LHC tuned BRs
(Latest DBD sample use M_h=125 GeV with LHC tuned BRs)
→ Extrapolation from 120 GeV results (E_{cm}=250 GeV, L=250 fb^{-1})

M_h	120 GeV				125 GeV			
	Pythia BR (LOI)		LHC BR		Pythia BR		LHC BR (DBD)	
	BR	ΔσBR/σBR	BR	ΔσBR/σBR	BR	ΔσBR/σBR	BR	ΔσBR/σBR
h→bb	65.7%	1.0%	64.9%	1.0%	58.4%	1.1%	57.8%	1.1%
h→cc	3.6%	6.9%	3.0%	7.6%	3.2%	7.7%	2.7%	8.5%
h→gg	5.5%	8.5%	8.8%	6.7%	5.3%	9.1%	8.6%	7.2%
h→WW	15.0%	8.2%	14.3%	8.4%	22.6%	7.1%	21.6%	7.2%

Required to simulate at M_h=125 GeV including cut efficiency
→ M_Z/M_h separation

Results are scaled from H.Ono, A. Miyamoto, arXiv:1207.0300 [hep-ex]
Higgs BRs are followed by LHC tuned value: arXiv:1101.0593v3 [hep-ph]

DBD detector benchmarking study

vvh detector benchmarking study

$e^+e^- \rightarrow \nu\nu h$ is one of the DBD detector benchmarking process

Observable: cross section times branching ratios (σ×BRs)

Decay channels: h→bb, cc, gg, WW*, μμ (Previous talk)

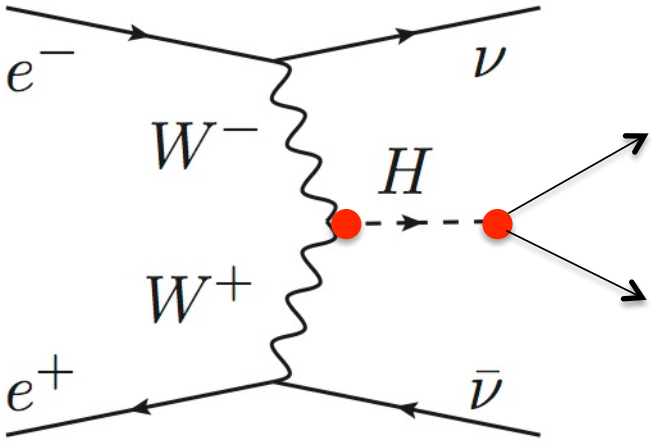
Evaluate ILD detector performance at E_{cm}=1 TeV

- Jet energy resolution (Reconstructed Higgs mass)
- Jet clustering and reconstruction (with γγ BG overlay)
- Flavor tagging performance (b/c tagging)
- Tracking performance, momentum resolution (h→μμ)

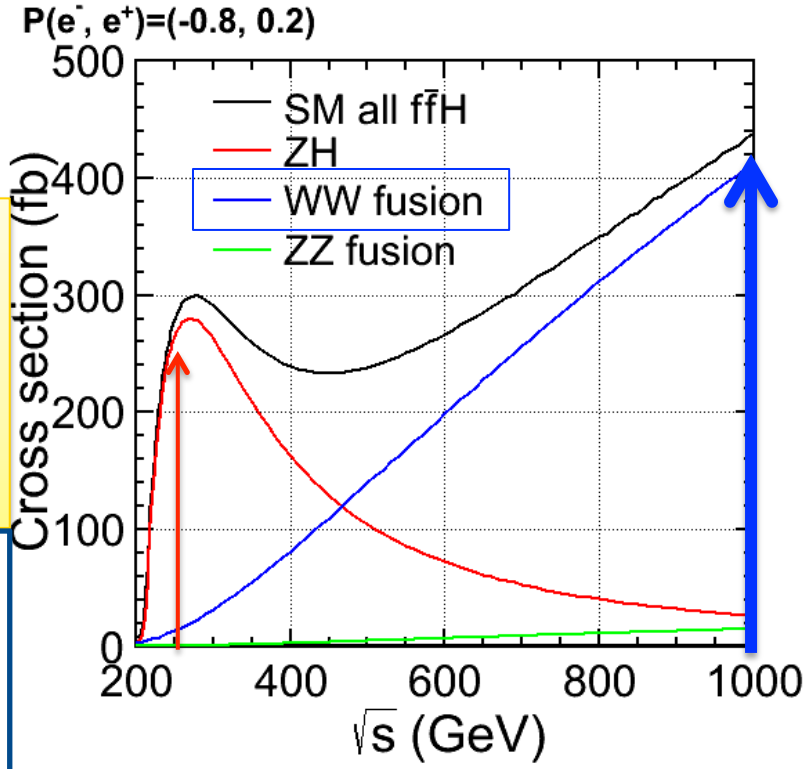
We perform a full detector simulation with
latest detector model and reconstruction packages in ILD

Higgs BR study at ILC 1 TeV

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)



1 TeV beam condition: 1000-B1b_ws
Luminosity: L=1 ab^{-1} (500 fb^{-1} both pol.)
Beam polarization P(e^-, e^+)=(0.8, 0.2)
γγ→hadron BG is overlaid

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

Simulation condition

Higgs signal sample

Higgs mass: M_h=125 GeV
CM energy: E_{cm}=1 TeV
Beam polarization: P(+-0.8, -+0.2)
L=500 fb^{-1} for both pol.

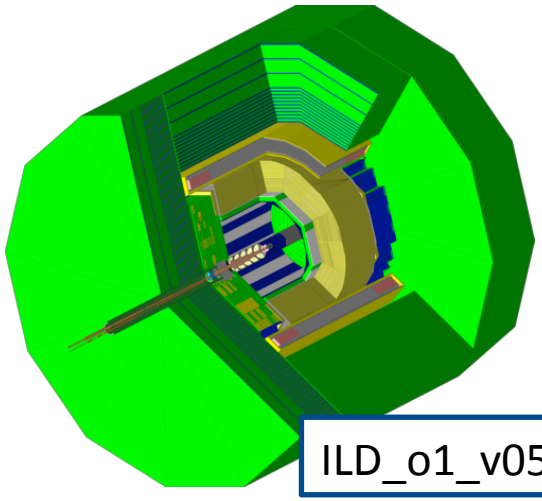
Software

Detector model: ILD_o1_v05
Simulation: Mokka v01-14-01-p00
Reconstruction: Marlin v01-16-p03

- More realistic detector model
- PandoraPFANew
- Rewrite tracking code
- New LCFIPlus flavor tagging
- γγ→hadron BG overlay

Higgs BRs @M_h=125 GeV

Channel	BRs
bb	57.8%
cc	2.7%
gg	8.6%
WW	21.6%
μμ	0.02%



ILD_o1_v05

H→bb, cc, gg channel analysis

H→bb, cc, gg channel

Analysis procedure

1. Two jet clustering and flavor tagging (LCFIPlus)
2. Background reduction (2f, 4f major BGs)
3. Extract ΔσBR/σBR with template fitting ToyMC
   Prepare flavor templates with LCFIPlus

- Reconstruction with γγ→hadron BGs overlaid
  →Use k_t jet clustering to suppress γγ BGs
- New flavor tagging (LCFIPlus with qq250_v01_p01 weight file)
- BGs: Only major 2f and 4f BGs (qq, vvqq, vlqq, llqq ,qqqq)

Check analysis scheme and show preliminary results using latest simulated/reconstructed samples

YY→hadron background treatment

k_t jet clustering: Reconstruct with removing beam particles

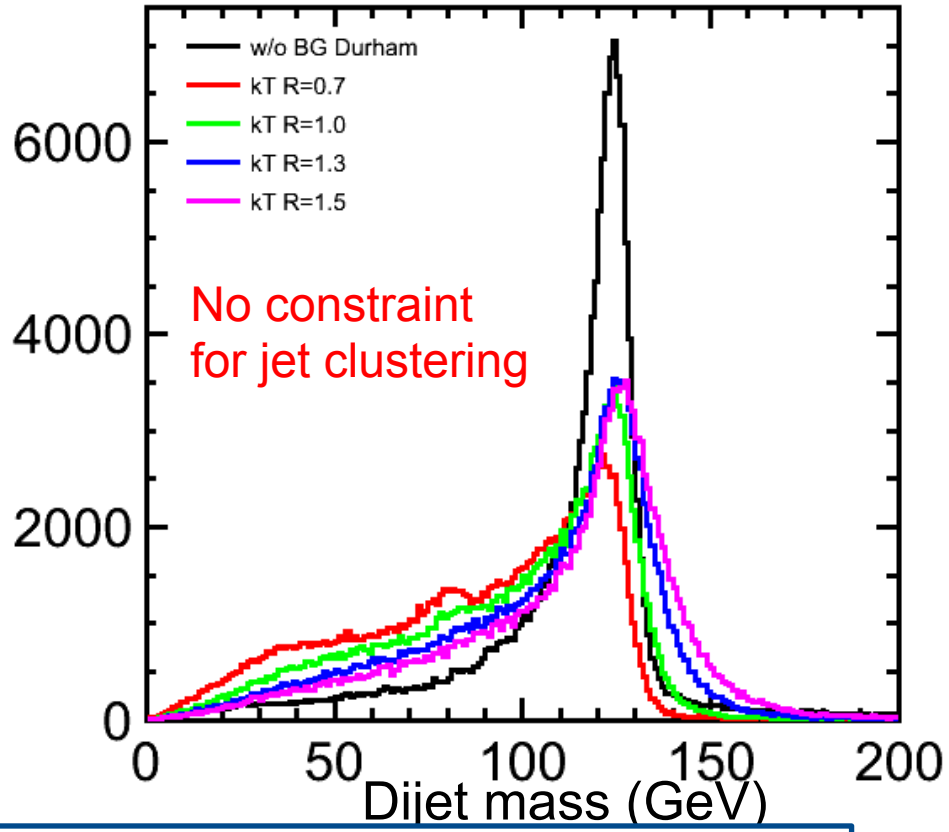
Jet reconstruction procedure

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

R=1.0~1.3 looks suitable
→Set R=1.1 at this moment
(CLIC 3 TeV vvh case: R=0.7)

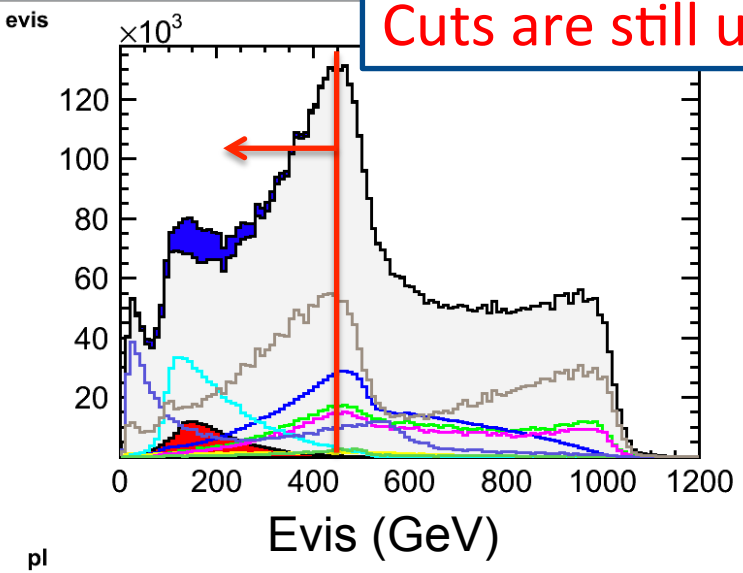
Higgs dijet rec. with γγ→hadron BG

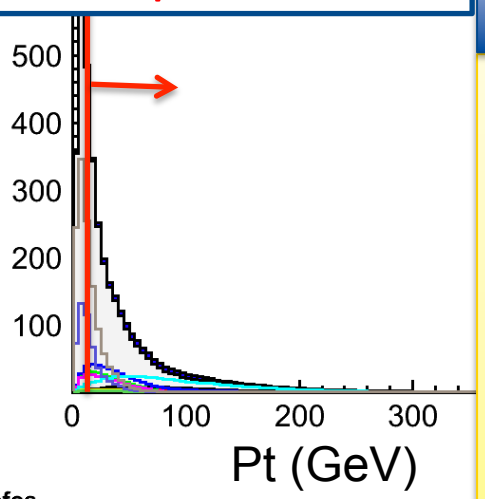


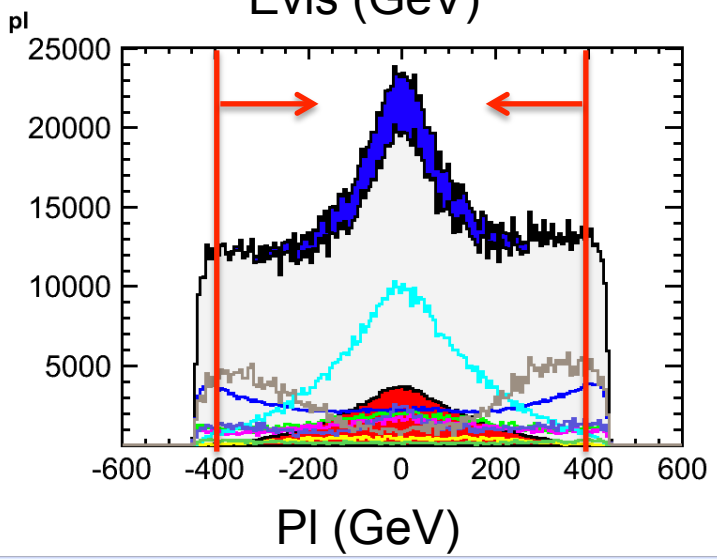
Check Higgs reconstruction and BG reduction with γγ BG overlay

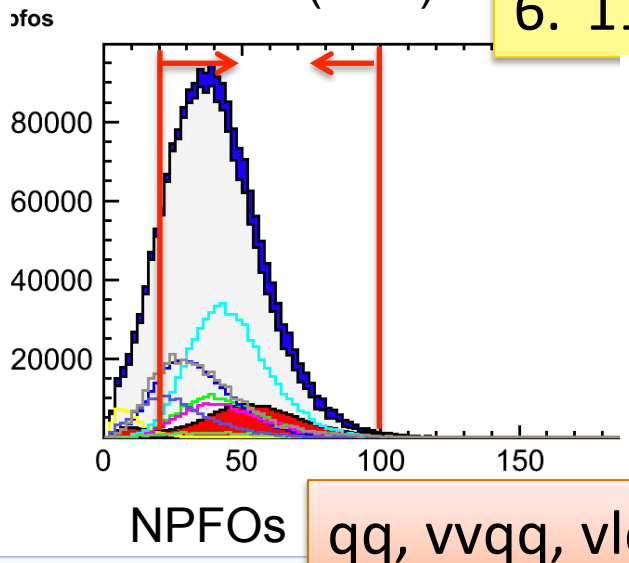
BG reductions (After k_t jet clustering)

Cuts are still under optimization



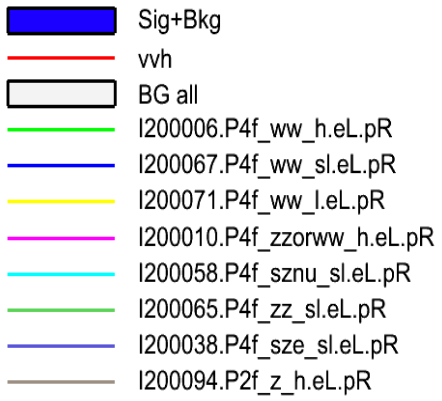






Cut condition

1. $E_{vis} < 450$ GeV
2. $P_t > 15$ GeV
3. $|P_l| < 400$ GeV
4. $20 < N_{PFOs} < 100$
5. $|\cos\theta_h| < 0.95$
6. $110 < M_h < 140$ GeV



qq, vvqq, vlqq, llqq, qqqq BGs

Summary table of background reduction

Preliminary results, cuts are still under optimization

	Rec	E_{vis}	P_t	P_l	N_{pfos}	cosθ	M_h
vvh (all)	201,836	200,023	192,924	192,542	171,868	145,640	71,648
h→bb	116,282	115,145	112,057	111,791	110,425	92,452	55,289
h→cc	5,374	5,316	5,204	5,185	5,132	4,290	2,940
h→gg	17,199	16,941	16,542	16,499	15,754	13,356	7,467
vvZ_vvqq	617,433	601,746	579,275	573,401	558,399	462,394	18,900
eeZ_eeqq	670,799	498,090	178,669	161,356	101,471	32,710	1,418
WW	1,192,184	784,006	630,315	564,090	453,957	171,725	6,608
ZZ	90,018	57,299	46,502	41,239	37,434	16,492	854
ZZWWmix	345,650	223,756	168,428	155,564	148,100	56,879	2,252
qq	1,682,720	1,270,250	425,503	371,130	297,932	27,341	1,093
BG all	4,563,770	3,413,160	2,011,160	1,850,560	1,581,770	761,584	30,833

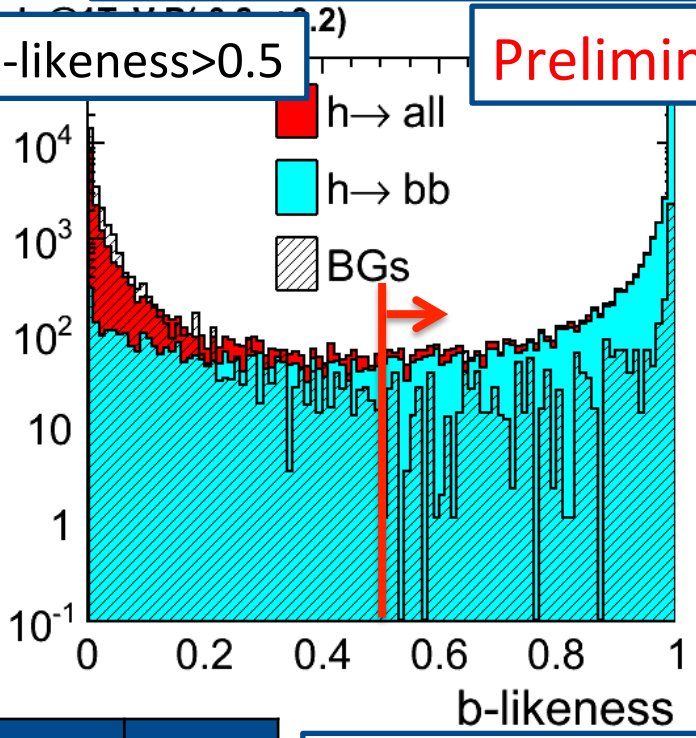
Efficiency=35.5%, $S/\sqrt{(S+B)}$=223.5 for vvH→all

LCFIPlus flavor tagging

b/c tagging with simple flavor tagging output cut is tested

b-likeness>0.5

Preliminary

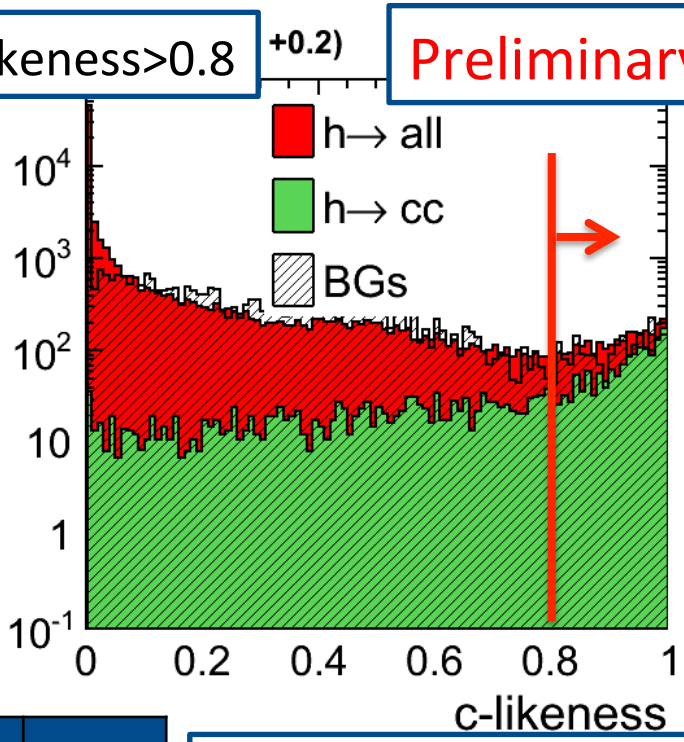


	Ncut
h→bb	51,943
h→Other	891
SM BGs	3,869

h→bb
after mass cut
Signal purity: 92%
Significance: 218

c-likeness>0.8

Preliminary



	Ncut
H→cc	1,384
H→Other	1,260
SM BGs	2,179

h→cc
after mass cut
signal purity: 29%
Significance: 20

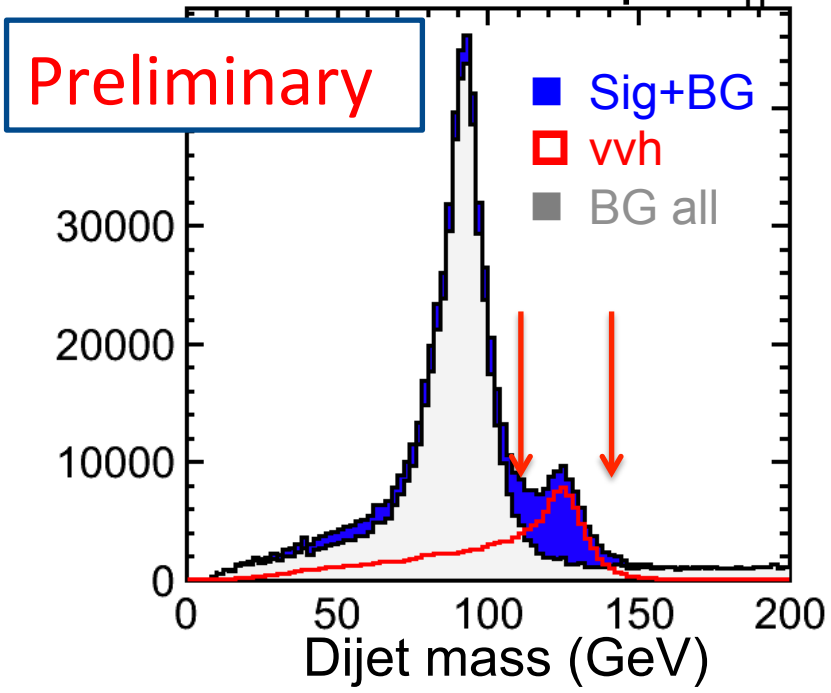
x-likeness=$x_1x_2/(x_1x_2+(1-x_1)(1-x_2))$

Reconstructed dijet mass distribution

1. k_t two jet clustering
2. Apply all cuts

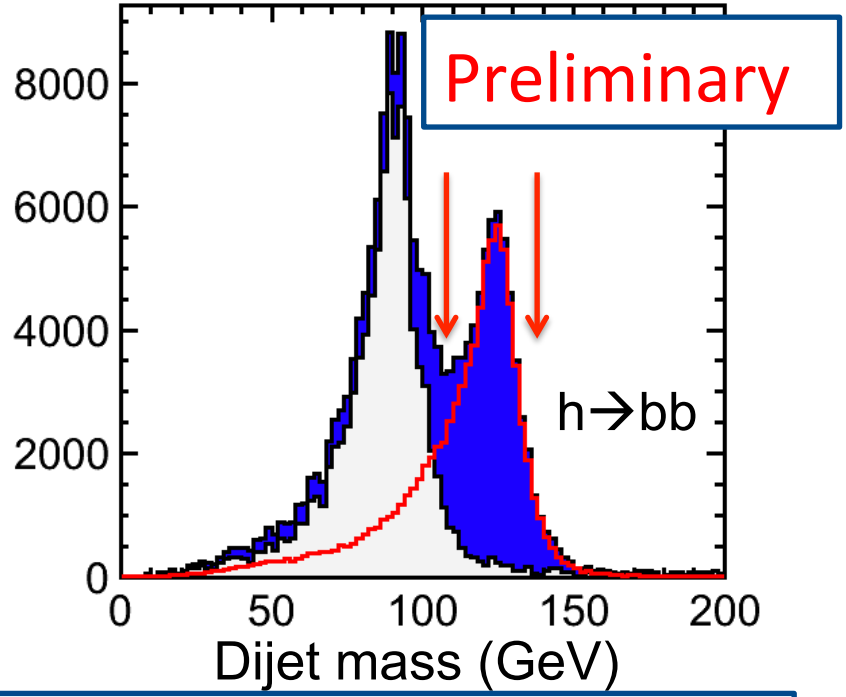
L=500 fb^{-1}
$(e^-,e^+)=(-0.8,+0.2)$

After all cuts except M_h cut



b-tag

Apply b-likeness>0.5



Separate signal and BGs even with γγ BGs (120→125 GeV gain too)
New flavor tagging also working well for physics study

σBR accuracy with template fitting

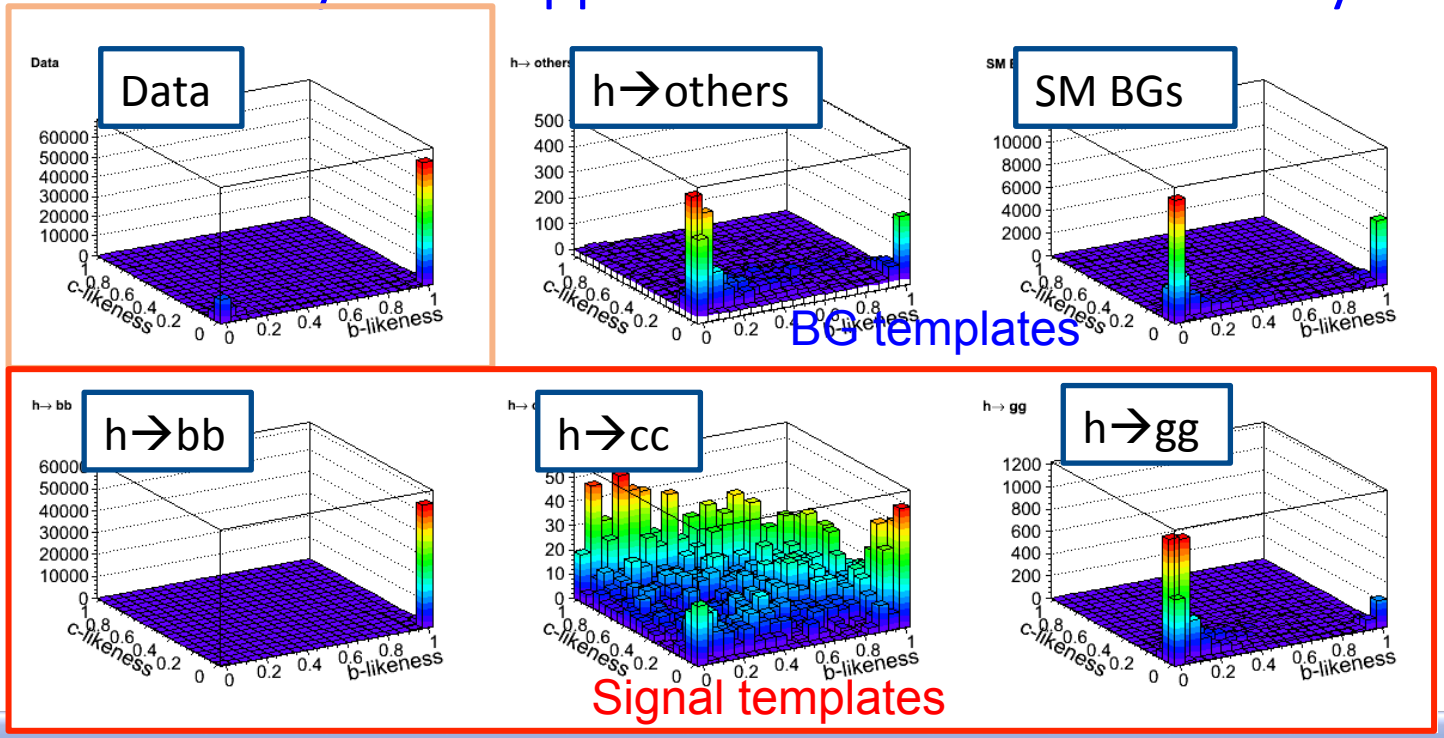
Prepare flavor templates of h→bb, cc, gg signal and BGs

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

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

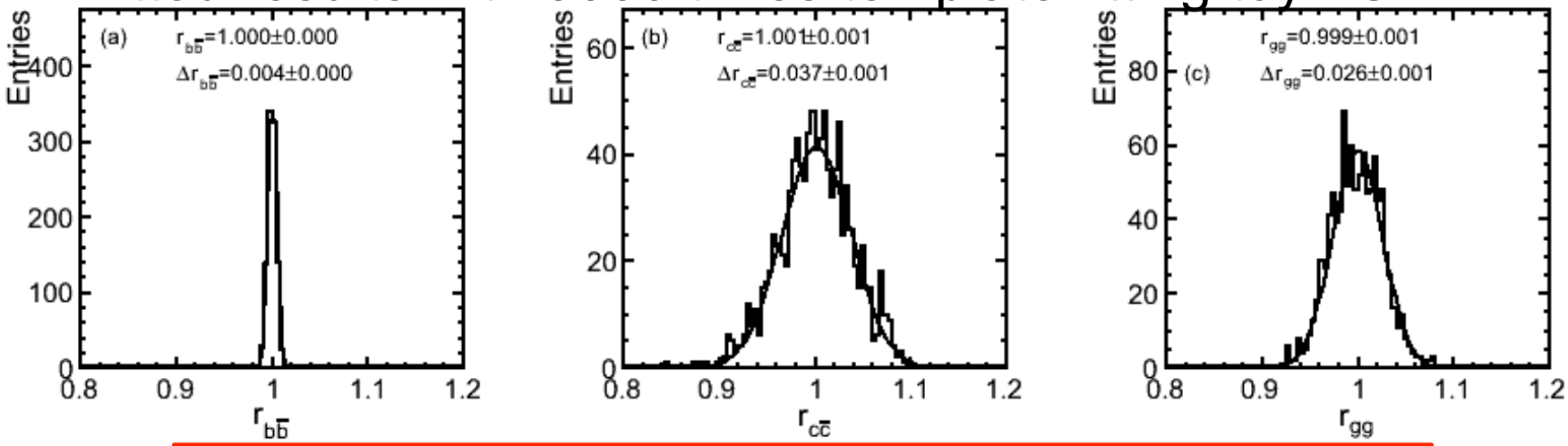
(r_{xx} is a fitted parameter)

5000 times of Toy MC is applied to evaluate the accuracy of σBR



Toy MC of template fitting

Fitted results with 5000 times template fitting toyMC



Very preliminary results only with major BGs
Analysis scheme is checked and working well

L=500 fb^{-1}, (e^-,e^+)=(-0.8, +0.2)
2f, 4f major BG only

Need to include other possible BGs
Need to evaluate contribution from γγ BGs

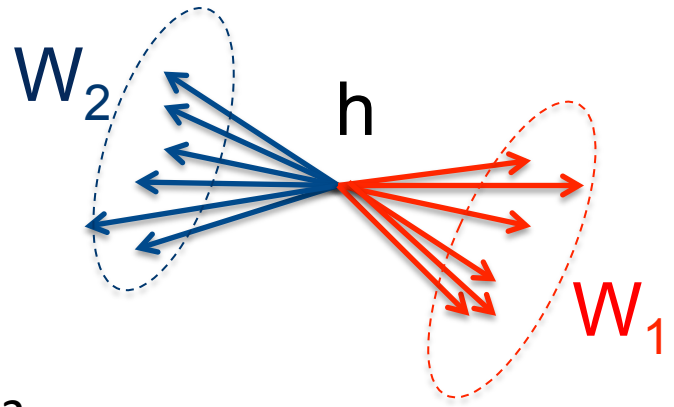
Channel	ΔσBR/σBR
h→bb	~0.5%
h→cc	~5%
h→gg	~3%

h→WW* analysis

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



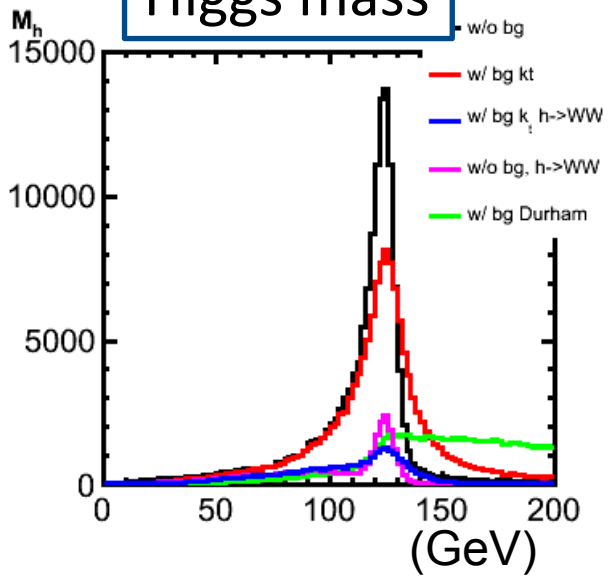
$$\chi^2 = \left(\frac{M_{12}-M_W}{\sigma_W}\right)^2 + \left(\frac{M_{4j}-M_h}{\sigma_H}\right)^2$$

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

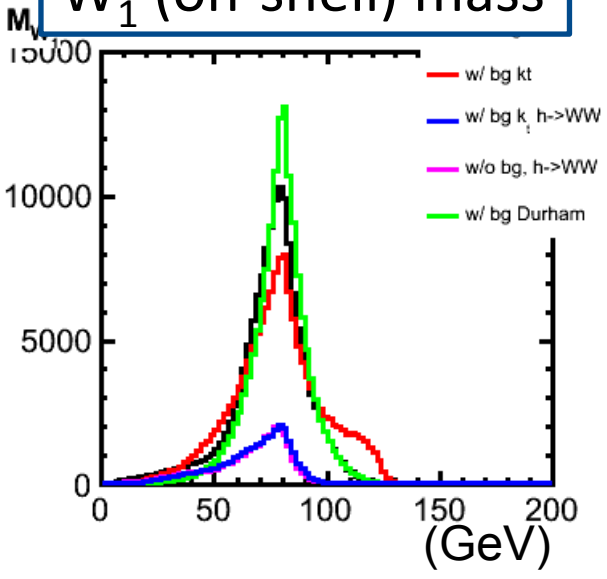
Reconstructed mass distribution

H→WW* hadronic decay channel reconstruction
Forced four jet clustering w/ or w/o γγ background

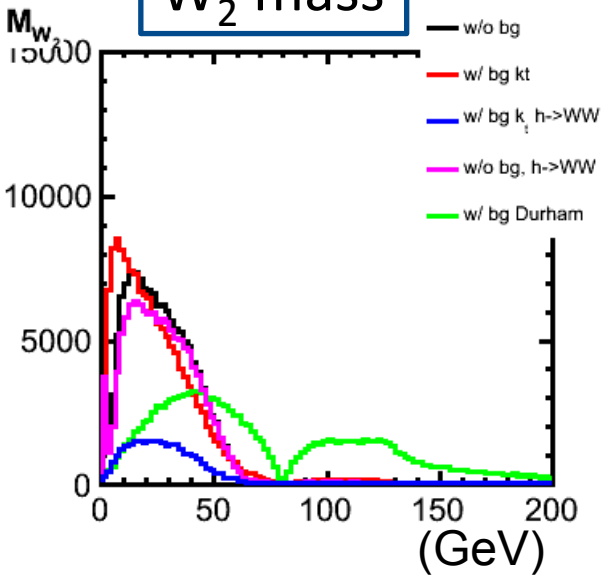
Higgs mass



W_1 (on-shell) mass



W_2 mass



k_t Jet clustering suppress the γγ background
These studies are still ongoing…

Conclusion and next step

We study the vvh @1 TeV benchmarking channel
using latest reconstructed samples with ilcsoft v01-16-p03

Next step (Time is very limited by DBD publish)

- Background overlay reduction
  →Consider k_t jet algorithm with additional cuts
  →Evaluate the influence of γγ BGs with no-BG sample
- Check performance of LCFIPlus
  →Compare with 1 TeV weight sample
- Consider all 2f, 4f, 6f backgrounds and other possible contributions
- Many thanks to ilcsoft software developers, and generator and sim/rec samples producers!