Higgs branching ratios study for DBD

ILD and SiD joint physics meeting

Jan. 18 2013

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vvh @ 1 TeV analysis flow

E_{cm}=1 TeV $e^+e^- \rightarrow \nu_e \nu_e h$ (via WW-fusion)
L=500 fb^{-1} with both P(e-,e+)=(-+0.8, +-0.2) polarization
M_h=125 GeV
BG samples: 2f, 4f, 6f: main BGs are vvZ, vlW, eeZ→semileptonic

h→bb, cc, gg 2 jets channel

1. kt jet algorithm (R=1.1): Remove γγ BGs
2. Apply LCFIPlus and apply cuts on 2 jets
3. Flavor template fitting to extract σBR accuracies

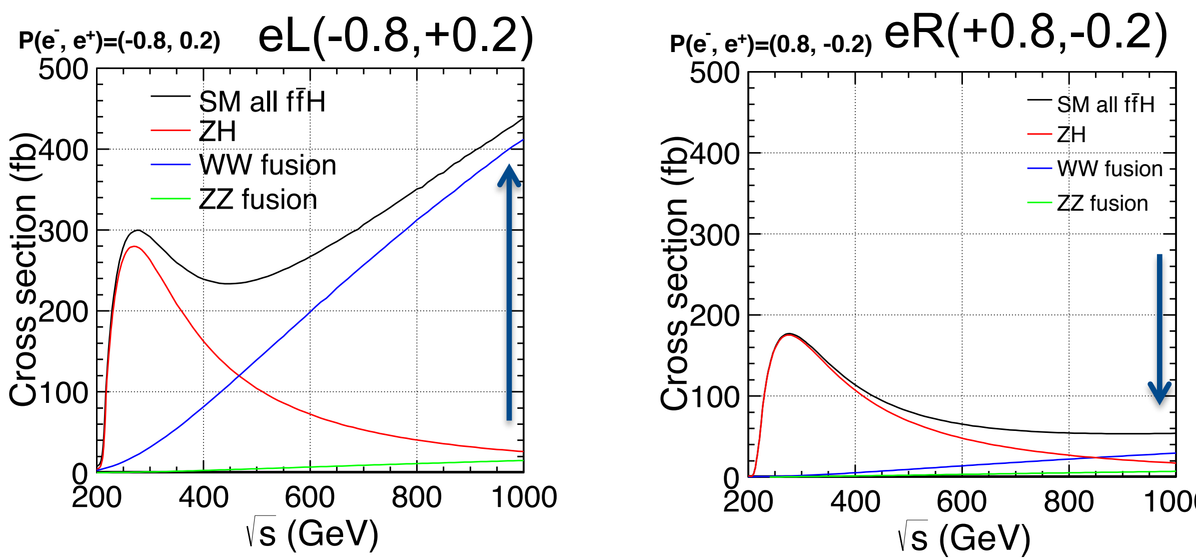
h→WW*→qqqq 4 jets channel

1. kt jet algorithm (R=0.9)
2. Apply LCFIPlus and four jet clustering
3. Cut with improve signal significance
4. Evaluate σBR accuracies

Expected events with L=500 fb^{-1}

Signal samples (L=500fb^{-1})

Category	$\sigma(-0.8, +0.2)$ (fb)	$\sigma(+0.8, -0.2)$ (fb)	N(−0.8, +0.2)	N(+0.8, −0.2)
$q\bar{q}h$	18	12	8,885	6,058
$\nu\bar{\nu}h$	404	33	202,022	16,549
$\ell\ell h$	25	16	12,501	8,089
$f\bar{f}h$	447	61	223,408	30,697



Expected BG events with $500\ fb^{-1}$

2f (L=$500fb^{-1}$)

$Z \to \ell\ell$	2,510	2,214	1.25×10^6	1.11×10^6
$Z \to q\bar{q}$	5,271	3,185	2.63×10^6	1.59×10^6
2f	7,780	5,399	3.89×10^6	2.70×10^6

4f (L=500 fb^{-1})

vlW→semileptonic

vvZ→semileptonic

eeZ→semileptonic

$\ell\ell\ell\ell$	8,547	8,431	4.27×10^6	4.22×10^6
$\nu\ell qq$	7,727	1,197	3.86×10^6	0.60×10^6
$\nu\nu\ell\ell$	4,929	733	2.46×10^6	0.37×10^6
$\nu\nu qq,\ \ell\ell qq$	3,844	2,485	1.92×10^6	1.24×10^6
qqqq	1,979	213	0.99×10^6	0.11×10^6
4f	27,028	13,060	13.5×10^6	6.5×10^6

6f (L=500 fb^{-1})

ZWW	234	66	0.12×10^6	0.03×10^6
$t\bar{t}$	449	170	0.22×10^6	0.06×10^6
6f	693	239	0.35×10^6	0.12×10^6

Cuts for h→bb, cc, gg channel @ 1 TeV

1. Visible energy: 40 < E_{vis} < 450 GeV
2. Transverse momentum: P_T>20 GeV
3. Longitudinal momentum: $|P_Z|$<400 GeV
4. # of PFOs: N_{PFOs}>20
5. $|\cos\theta_h|$<0.98
6. Dijet mass: 110<Mh<150 GeV

After all cuts,
flavor template fitting is applied

Cuts	$h \to b\bar{b}$	$h \to c\bar{c}$	$h \to gg$	$h \to$ other	2f	4f	6f
Generated	128,701	6,058	19,044	69,605	3,890,180	13,514,000	346,419
E_{vis}	117,196	5,504	17,223	62,132	1,509,560	6,496,150	127,582
P_T	111,662	5,266	16,541	57,591	397,594	3,728,650	118,476
P_Z	111,350	5,247	16,490	57,494	360,477	3,516,270	117,336
N_{PFO}	110,995	5,212	16,473	40,567	198,131	2,337,060	104,438
$\|\cos\theta_h\|$	103,857	4,872	15,533	38,800	49,689	1,847,580	92,833
M_h	63,883	3,467	9,132	6,895	2,901	93,094	12,839
Efficiency	49.6%	57.2%	48.0%	9.9%	0.1%	0.7%	3.7%

h→bb, cc, gg template fitting analysis

Apply flavor template fitting with log-likelihood binned fitting

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

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

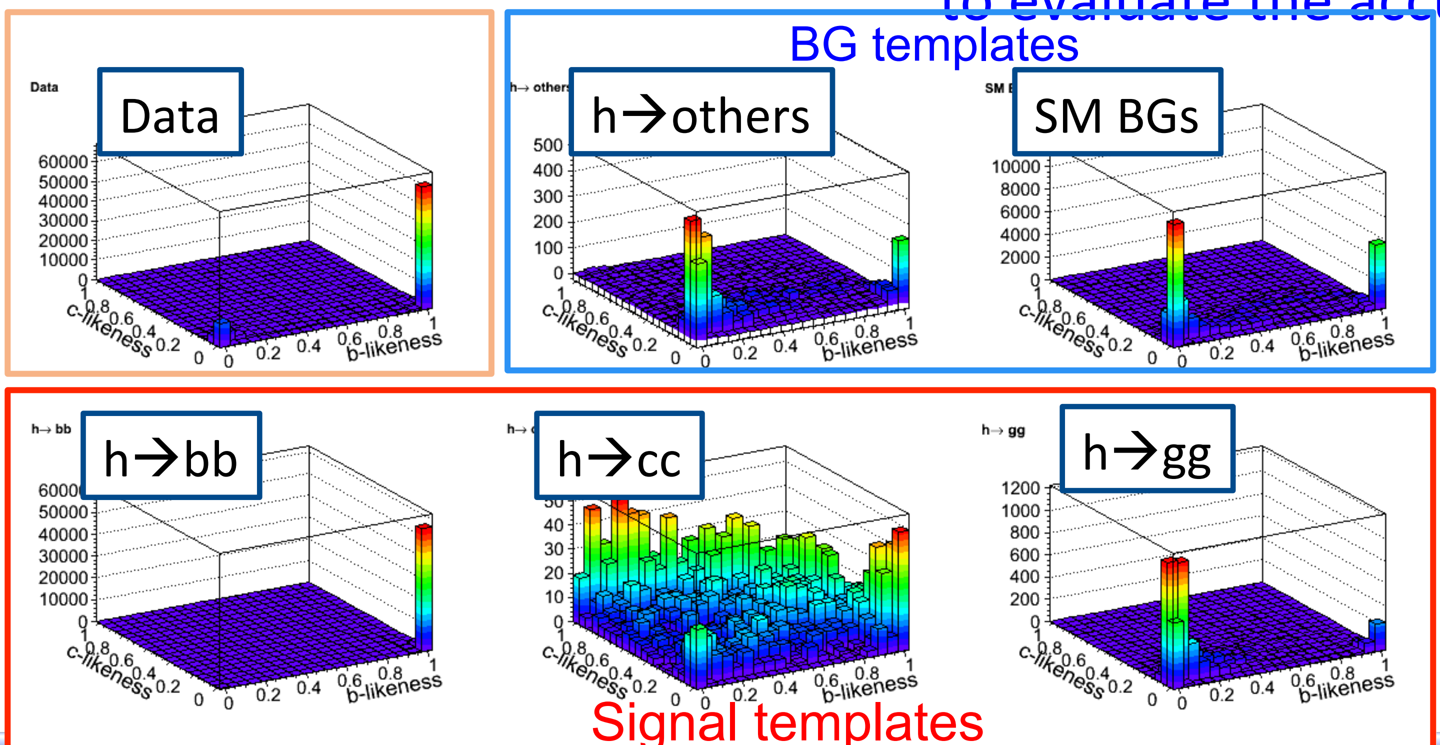
(r_{xx} is a fitted parameter)

b-likeness=$b_1 b_2 / (b_1 b_2 + (1-b_1)(1-b_2))$

b_1, b_2: Btag jet 1, 2

N_{data} is fluctuated wit Poisson

5,000 times of Toy MC is applied to evaluate the accuracy of σBR



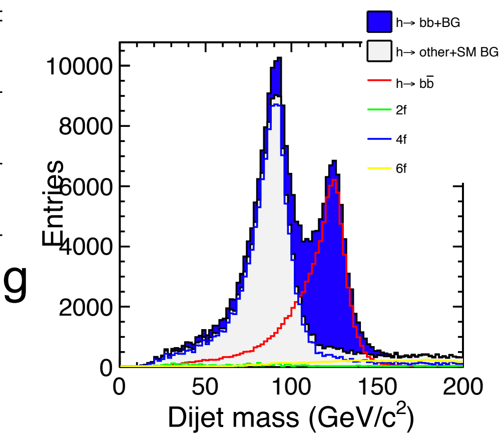
h→bb, cc, gg hadronic channel @ 1 TeV

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

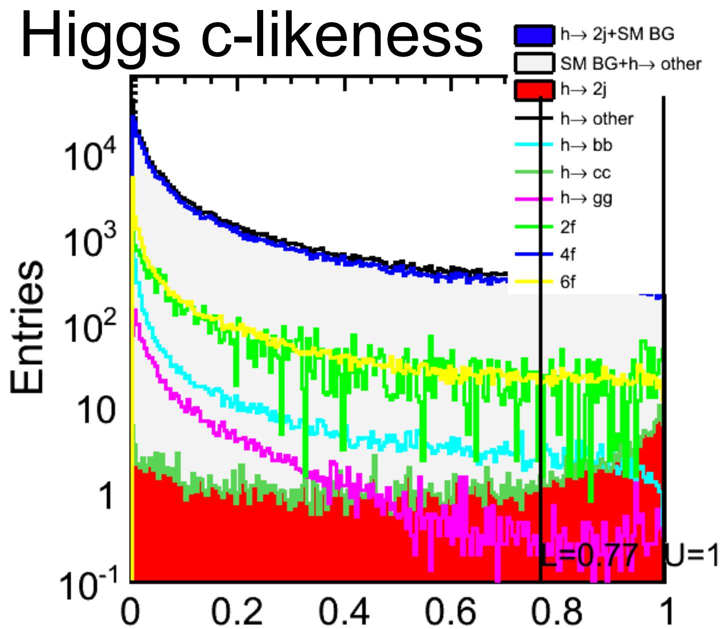
Measurement accuracies on L=500 fb^{-1} L/R and 1 ab^{-1} only with P(-0.8, +0.2)

Integrated luminosity	500 fb^{-1}	500 fb^{-1}	1 ab^{-1}
Beam polarization P(e$^-$, e$^+$)	P(−0.8, +0.2)	P(+0.8, −0.2)	P(−0.8, +0.2)
r_{bb}	1.0000±0.0045	0.9982±0.0167	1.000±0.0033
r_{cc}	1.001±0.044	1.039±0.200	1.001±0.031
r_{gg}	0.998±0.032	1.035±0.158	0.999±0.022
$\Delta\sigma BR/\sigma BR(h \to b\bar{b})$	0.45%	1.7%	0.33%
$\Delta\sigma BR/\sigma BR(h \to c\bar{c})$	4.4%	19.3%	3.1%
$\Delta\sigma BR/\sigma BR(h \to gg)$	3.2%	15.3%	2.2%

Higgs mass with B-tagging
(h→bb) b-likeness>0.24



Flavor tagging efficiency check



Check simple c-likeness cut efficiencies

Require c-likeness>0.8

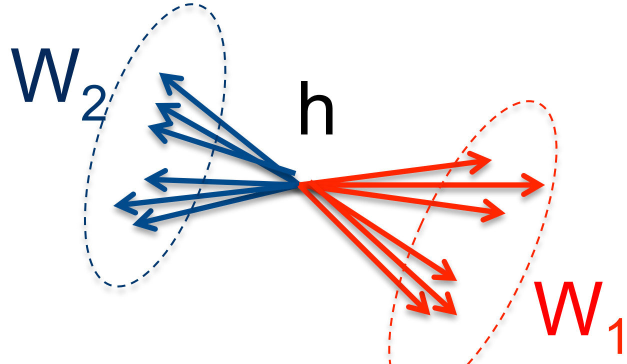
Signal significance of h→cc
signf(h→cc)=17.3 with Eff(h→cc)=25%

	h->bb	h->cc	h->gg	h->other	2f	4f	6f	BG all
Mh	63,883	3,467	9,132	6,895	2,901	93,094	12,839	108,834
clikeness>0.8	707	1,512	101	543	166	4,056	593	4,815
Eff Mh	49.6%	57.2%	48.0%	9.9%	0.1%	0.7%	3.7%	0.6%
Eff clikeness	0.5%	25.0%	0.5%	0.8%	0.0%	0.0%	0.2%	0.0%

h→WW* channel @ 1 TeV

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=0.9)
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



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

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

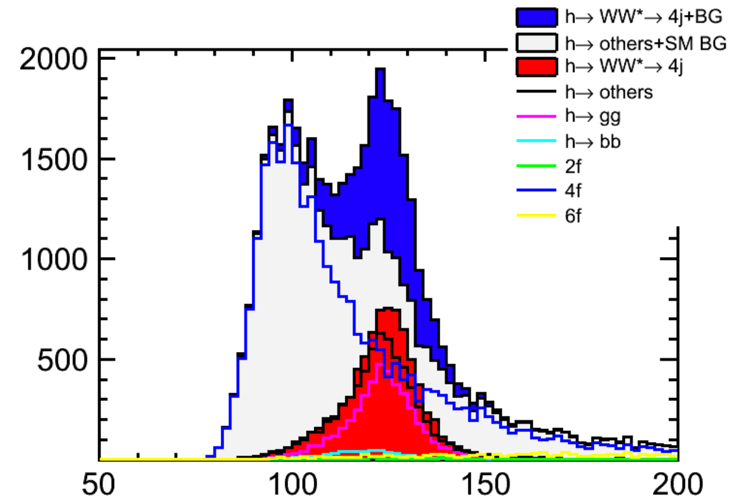
← Checking with removing M_{4j} since no effect to jet combination

h→WW*→4j cut summary

Cut values	h → WW* (hadronic)	h → other	2f	4f	6f
Generated	21,976	201,432	3,890,180	13,514,000	346,419
E_{vis}	18,820	162,621	818,392	3,316,290	43,651
P_T	16,584	140,702	45,223	1,423,250	34,103
P_Z	16,456	139,847	42,439	1,379,470	33,924
N_{PFO}	13,971	86,663	1,655	354,065	20,226
$\vert\cos\theta_j\vert$	12,898	75,551	801	259,592	18,410
$-\log_{10} Y_{45}$	12,897	73,318	766	256,172	18,333
$-\log_{10} Y_{34}$	11,391	31,902	258	123,613	16,031
$-\log_{10} Y_{23}$	10,938	27,569	234	103,482	15,698
$\sum \mathrm{Btag}_j$	10,395	10,543	207	86,525	8,649
M_{W_1}	9,254	8,689	124	54,340	8,066
M_{W_2}	8,705	7,609	38	36,530	2,504
M_h	7,797	6,373	24	13,757	541
Efficiency	35.5%	3.2%	0.0%	0.1%	0.2%

h→others mainly comes from h→gg

Need to consider this effect or improve result



Higgs mass distribution

L=500 fb^{-1}

(e^-,e^+)=(-0.8, +0.2)

Significance=46.2

ΔσBR/σBR(h→WW*) = 2.2%

Current results of Higgs BR study at 1 TeV

E_{cm}=1 TeV, L=500 fb^{-1}, and 1 ab^{-1}
(e^-, e^+)=(-+0.8, +-0.2), M_h=125 GeV

Results are still preliminary and under review in ILD

Integrated luminosity	500 fb^{-1}		1 ab^{-1}
Beam polarization $P(e^-, e^+)$	$P(-0.8, +0.2)$	$P(+0.8, -0.2)$	$P(-0.8, +0.2)$
$\Delta\sigma BR/\sigma BR(h \to b\bar{b})$	0.45%	1.7%	0.33%
$\Delta\sigma BR/\sigma BR(h \to c\bar{c})$	4.4%	19.3%	3.1%
$\Delta\sigma BR/\sigma BR(h \to gg)$	3.2%	15.3%	2.2%
$\Delta\sigma BR/\sigma BR(h \to WW^* \to 4j)$	2.2%	10.1%	1.5%

We have still contribution from h→gg in h→WW* analysis,
Consider to include these contribution
Need to update my analysis for h→WW* channel

Comments

- How we show results? Luminosity $500_L/500_R$
  - Each separately?
  - How about 1 ab^{-1} with P(-0.8,+0.2)?
- How about the BGs
  - Need other channels? we only include 2f, 4f, 6f
  - 1f_3f is available with small statistics
- How about $h \rightarrow \mu\mu$ in SiD?
  - Calancha Constantino study this channel.

Backup

h→bb, cc, gg right-handed (+0.8,-0.2)

BG reduction summary with same cut condition with left-handed

Cuts	$h \to b\bar{b}$	$h \to c\bar{c}$	$h \to gg$	$h \to$ other	2f	4f	6f
Expected # of events	17,768	812	2,566	9,551	2,699,560	6,530,160	119,252
E_{vis}	10,415	478	1,482	5,654	1,061,400	3,250,000	42,110
P_T	9,834	448	1,412	5,237	274,644	1,050,350	38,049
P_Z	9,779	446	1,402	5,208	248,259	968,328	37,675
N_{PFO}	9,719	442	1,396	3,675	125,786	493,405	33,592
$\lvert \cos\theta_h \rvert$	8,816	404	1,269	3,388	28,724	372,467	29,632
M_h	5,256	283	740	612	1,699	17,464	4,063
Efficiency	29.6%	34.8%	28.8%	6.4%	0.1%	0.3%	3.4%

h→WW* right-handed case

BG reduction summary with same cut condition with left-handed

Cut values	$h \to WW^*$ (hadronic)	$h \to$ other	2f	4f	6f
Generated	2,972	27,725	2,699,560	6,530,160	119,252
E_{vis}	1,462	12,923	578,006	1,691,400	13,428
P_T	1,271	11,090	33,509	285,222	8,600
P_Z	1,262	11,021	31,760	274,641	8,553
N_{PFO}	1,069	6,753	1,062	59,706	5,029
$\lvert\cos\theta_j\rvert$	984	5,893	489	40,486	4,538
$-\log_{10} Y_{45}$	984	5,695	475	40,130	4,517
$-\log_{10} Y_{34}$	860	2,460	193	20,817	4,091
$-\log_{10} Y_{23}$	823	2,131	191	17,467	4,024
$\sum Btag_j$	781	822	131	15,419	1,610
M_{W_1}	694	677	114	8,828	1,478
M_{W_2}	653	585	38	5,892	499
M_h	586	482	13	2,328	114
Eff	19.7%	1.7%			

h→WW* background reduction