ZH Branching ratio study

ILD software phone meeting
Oct. 13. 2010

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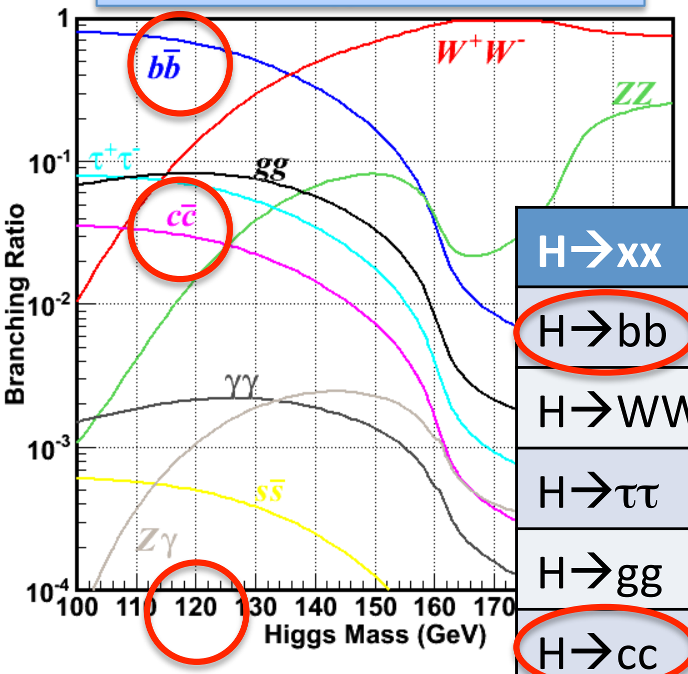
ZH Branching Ratio measurement

Higgs BR study at Ecm=250 GeV is one of the benchmark process in LOI
Higgs BR at Ecm=350 GeV is also the new benchmark process for DBD

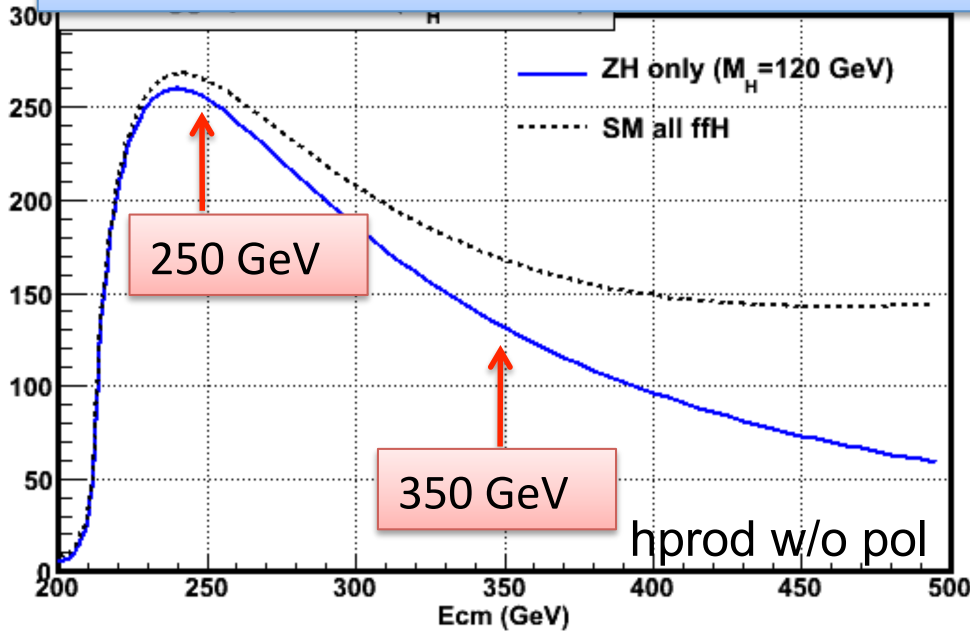
BR at M_H=120 GeV



H→xx	BR
H→bb	66.7%
H→WW	14.0%
H→ττ	6.8%
H→gg	5.5%
H→cc	3.6%

(in pythia)

SM Higgs production cross section



ZH (hprod)	254 fb^{-1}	131 fb^{-1}

Cross section	Ecm=250GeV	Ecm=350GeV
ZH (w/ beam pol)	319.4 fb^{-1}	274.9 fb^{-1}

SB2009 beam parameters

- New benchmark process includes the ZH BR study at Ecm=350 GeV
- SB2009 beam parameters effect need to be compared in BR study

Beam parameters	RDR		SB2009 w/ TF		SB2009 new	
Ecm (GeV)	250	350	250b	350	250	350
F (Hz)	5	5	2.5	5	10	5
bx (mm)	22	22	21	15	12	15
L (10^{34} $cm^{-2}s^{-1}$)	0.75	1.2	0.27	1.0	0.8	1.0

Luminosity reduction is indicated especially at low energy

New Ecm=350 GeV data samples are generated and analyzed with SB2009 w/ TF beam parameter (A. Miyamoto)

Miyamoto-san's slide at ILD optimization meeting 2010. Sep. 08

Simulation setup and signal samples

Event generation : whizard

Simulation and analysis : ilcsoft v01-06

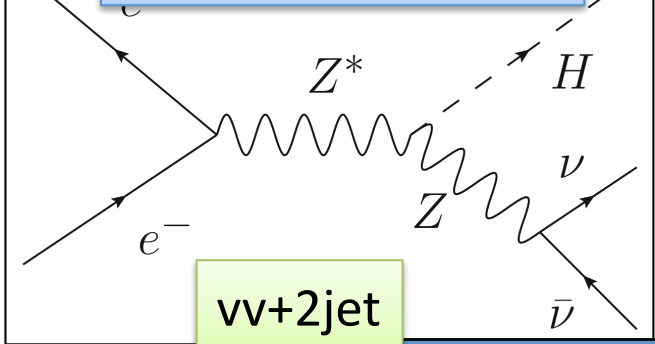
Detector model : ILD_00 full simulation

Beam parameter : RDR(LOI 250GeV), SB2009 w/ TF (350 GeV)

Data samples : DST sample produced in KEK (A. Miyamoto)

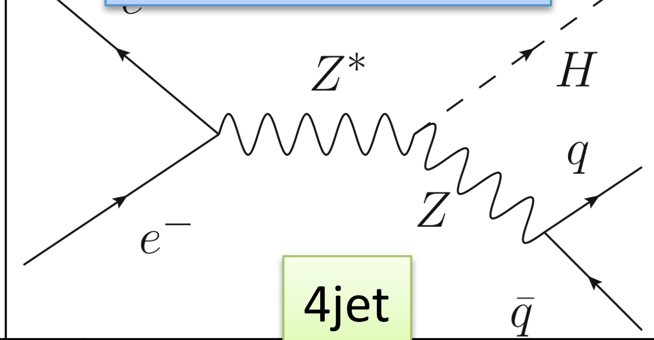
lfn:/grid/ilc/users/miyamoto/CDS/reconstructed/ILD_00/CMS_350

neutrino (ZH→vvH)



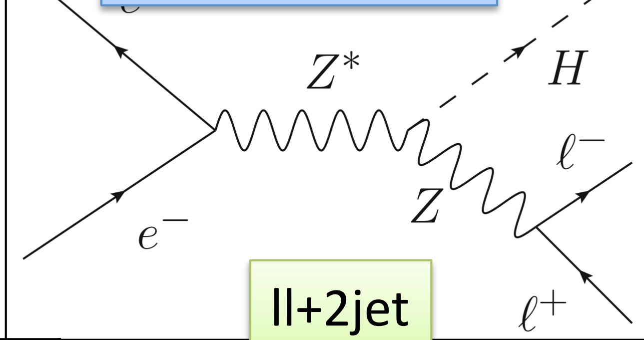
vv+2jet

hadron(ZH→qqH)



4jet

lepton(ZH→llH)



ll+2jet

Cross section	vvH	qqH	llH
250 GeV	77.4 fb	210.0 fb	31.7 fb
350 GeV	105.2 fb	144.4 fb	25.3 fb

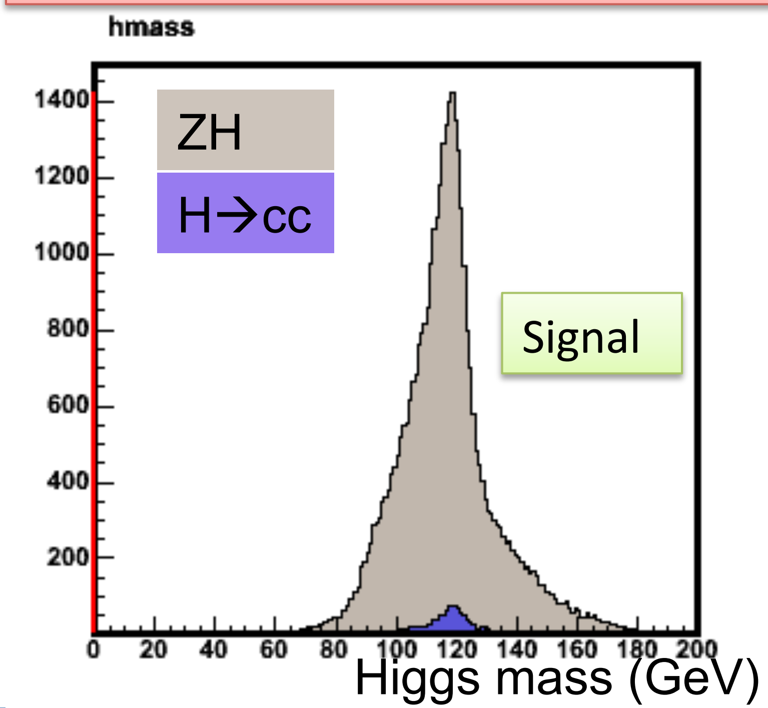
beam polarization
(e+,e-)=(+30%, -80%)

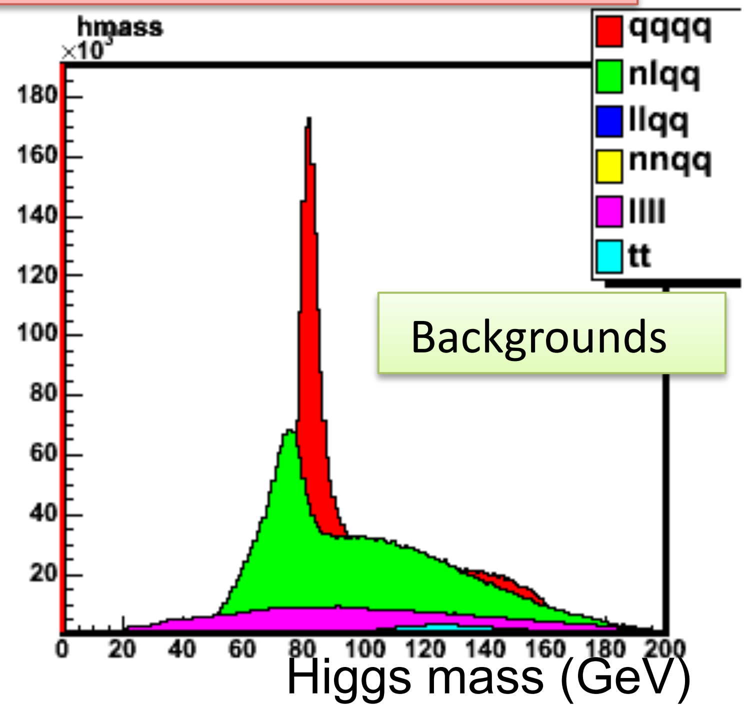
Background samples at 350 GeV

Following background samples are considered

- *qqqq, tt, llqq, vlqq, vvqq, llll* (*qq* is not included yet)
- *tt* is generated with physsim including threshold QCD correction
- Data are scaled to be L=250 fb^{-1}

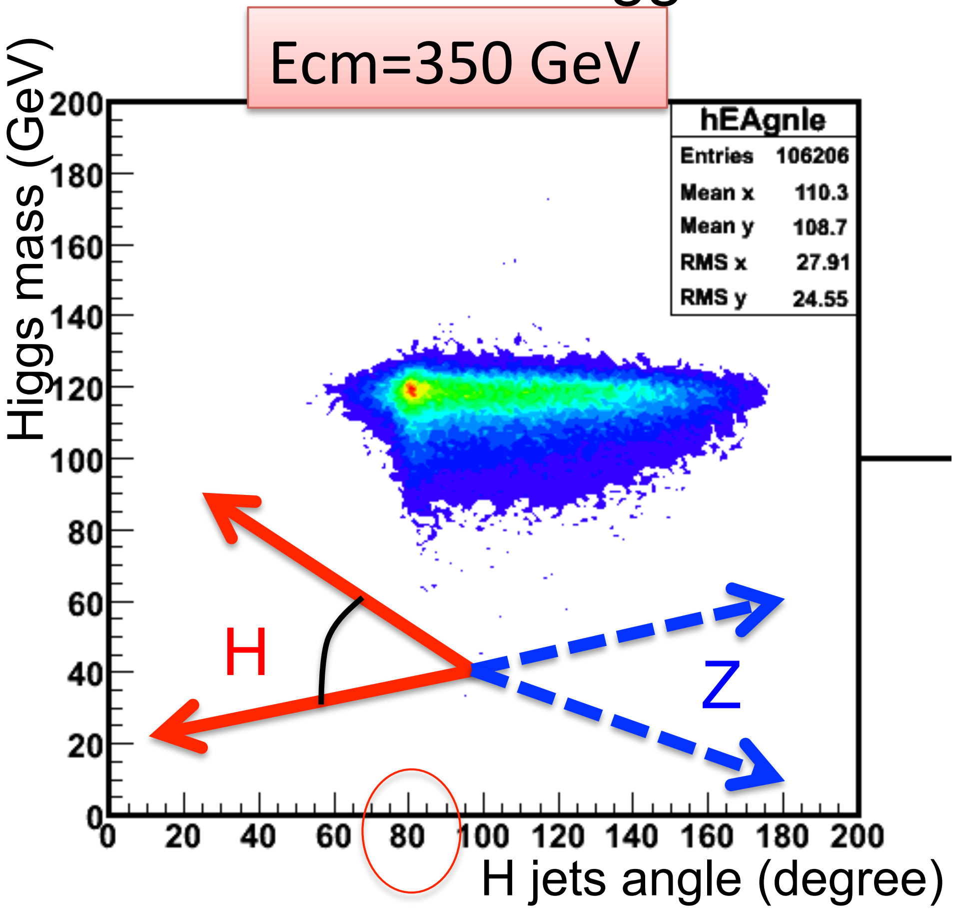
Reconstructed Higgs mass (Ecm=350 GeV, ZH→qqH hadronic)

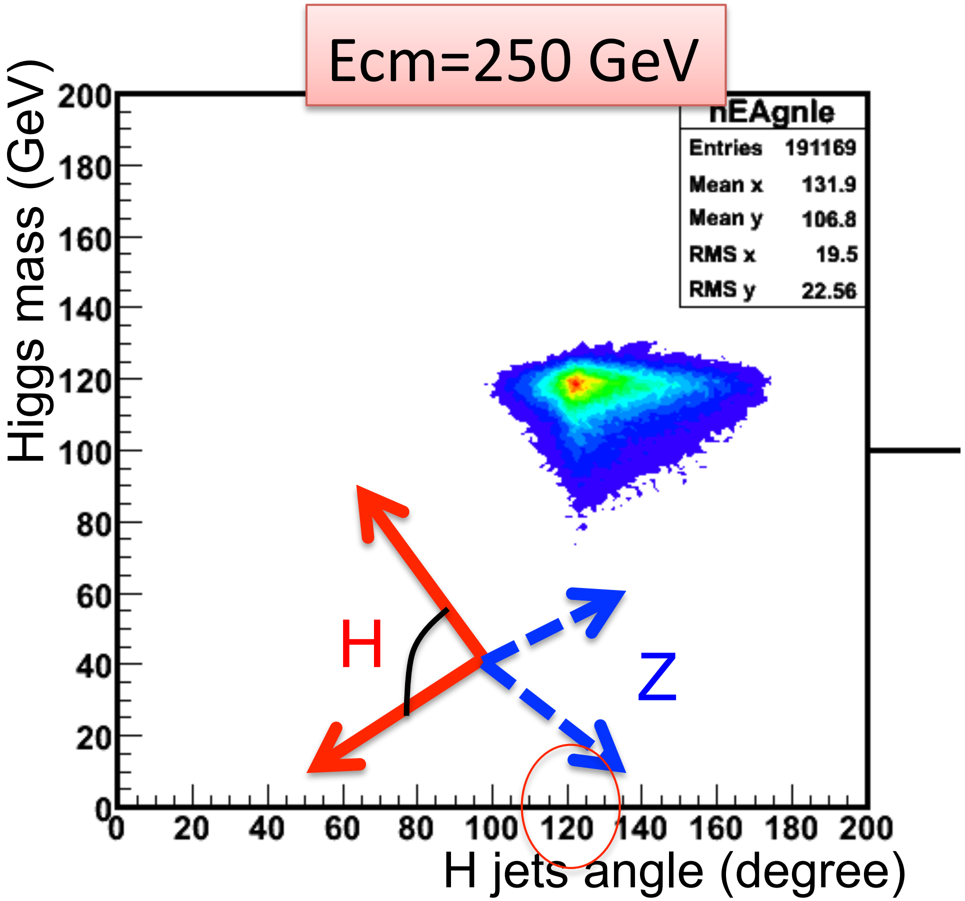




Event shape comparison for 250/350 GeV

Reconstructed Higgs mass vs Higgs jets angle in ZH→vvH





Jets angle becomes narrower at 350 GeV by boost

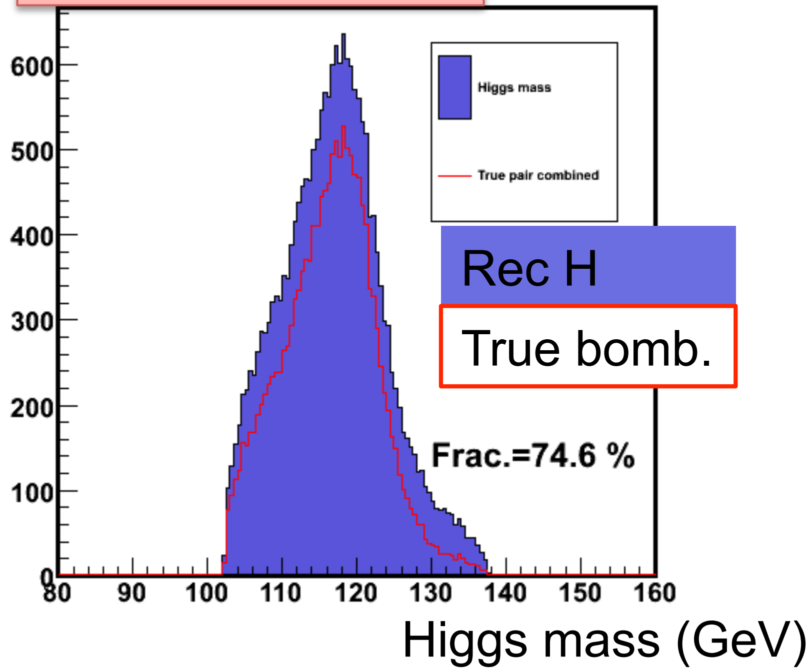
Jet paring performance will be improved for ZH→qqH

Jet pair combination performance

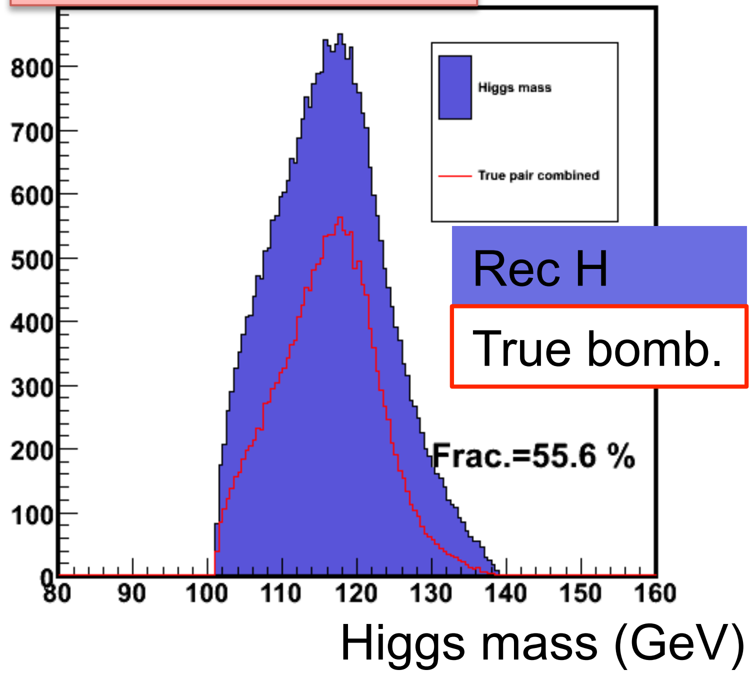
Higgs mass distribution only with $\chi^2 < 10$ cut, Entries are scaled to be $L=250fb^{-1}$

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

M_H : Ecm=350 GeV



M_H : Ecm=250 GeV



Slightly better mass reconstruction performance in 350 GeV
Better jet pair combination performance is achieved with same χ^2 cut

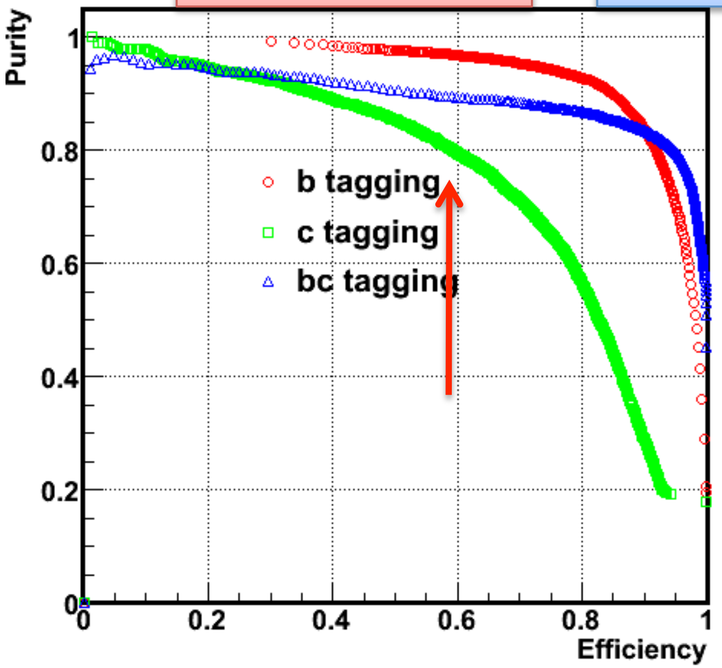
Flavor tagging performance comparison

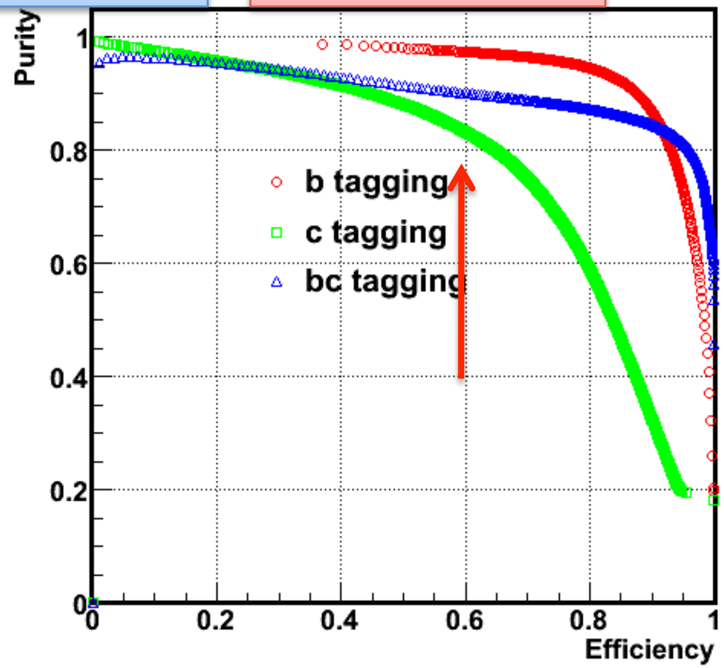
- Compare Flavor tagging performance at Ecm=250 with 350 GeV
- LCFIVTX is trained with *Z→qq* @91.2 GeV sample
- Use same quark composition sample (*ZZ→vvqq, Z→qq*)

Ecm=350 GeV

Efficiency vs purity

Ecm=250 GeV





Small performance difference is observed in c-tagging

BR measurement study (ZH→qqH only for now)

ZH→qqH selection criteria

Ecm=250 GeV

1. $\chi^2 < 10$
   (χ^2 of jet pair combination)
2. # of charged tracks > 4
3. $-\log10(Y_{34}) < 2.7$
   (Y_{34} : 3→4 Jet combination threshold)
4. thrust < 0.9
5. $|\cos\theta_{thrust}|<0.9$
6. $105 < \theta_{Hjets} < 160$ deg.
7. $110 < M_{Hfit} < 130$ GeV

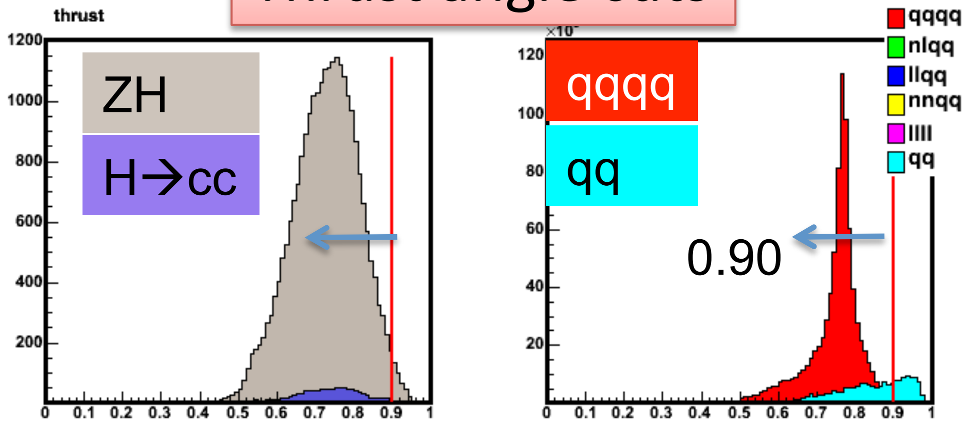
Ecm=350 GeV

1. $\chi^2 < 10$
2. # of charged track > 4
3. $-\log10(Y_{34}) < 2.7$
4. thrust < 0.85
5. $|\cos\theta_{thrust}|<0.8$
6. $70 < \theta_{Hjets} < 120$ deg.
7. $110 < M_{Hfit} < 130$ GeV

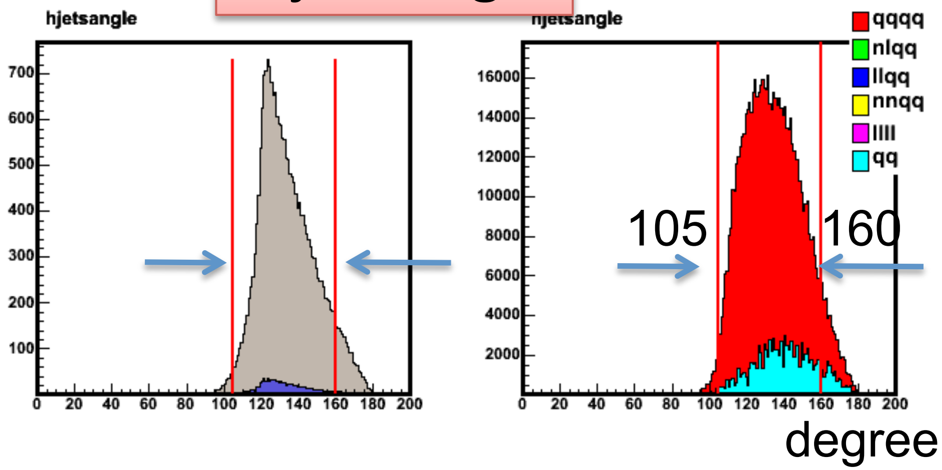
Selection criteria is optimized for 350 GeV from the different event shape
Higgs decay jets angle becomes narrower by boost

ZH→qqH cut optimization at 250 GeV

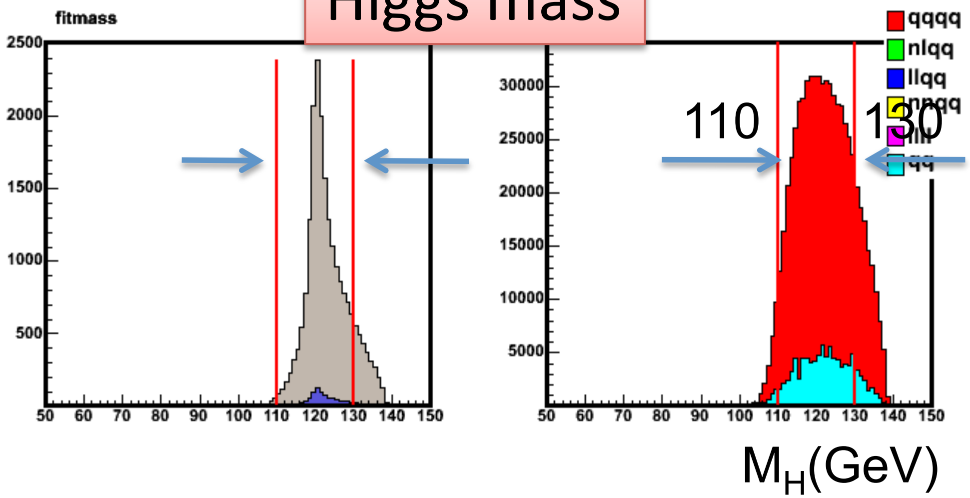
Thrust angle cuts



H jets angle



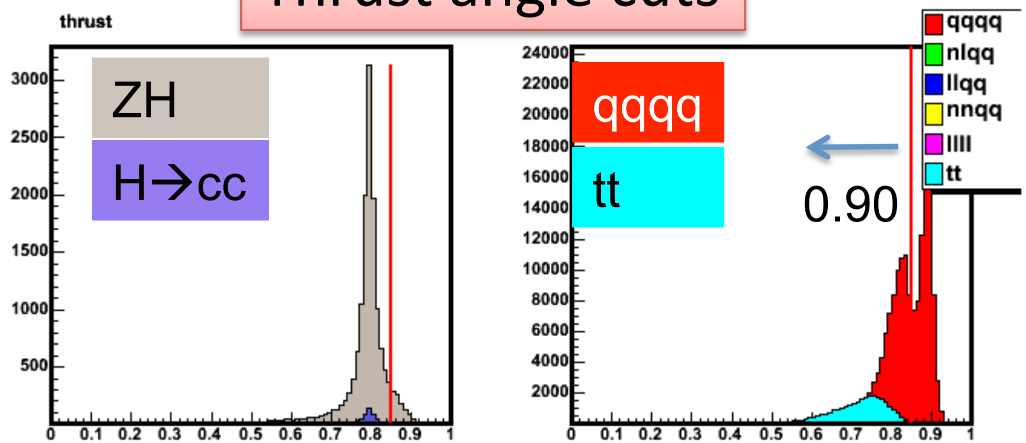
Higgs mass



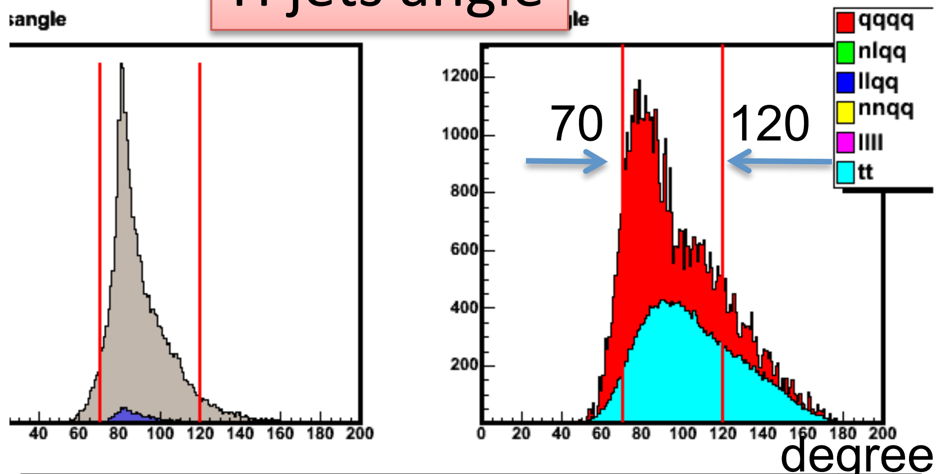
250 GeV final state will be spherical compare to 350 GeV especially for hadronic mode

ZH→qqH cut optimization at 350 GeV

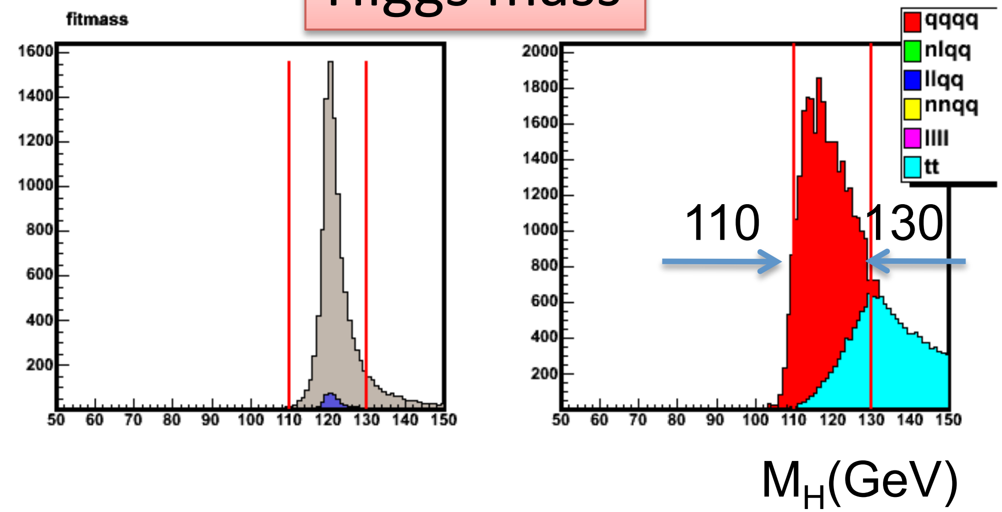
Thrust angle cuts



H jets angle



Higgs mass



From the different event shape, cut positions are optimized for 350 GeV.

S/√N looks improving with cut parameter optimization at Ecm=350 GeV for qqqq BG.

Background reduction summary (ZH→qqH)

250 GeV	No cuts	chi2	Ntrack	-Log(Y34)	thrust	cosθ	θH	Mh	Eff
H→cc	1916	1460	1114	1102	1081	963	890	804	41.9%
H→bb	34963	24568	19542	19351	19013	16854	15488	13651	39.0%
ZH→qqH all	52507	32430	25252	25037	24656	21856	20041	17617	33.6%
SM Bkg	44825201	2608604	1120793	1002011	935788	696026	621975	504788	1.1%
BG w/o qq	9472101	1388294	824641	818608	815228	591524	533500	430998	4.6%
$S_{cc}/\sqrt{B}$	0.05	0.31	1.05	1.10	1.12	1.15	1.13	1.13	
$S_{bb}/\sqrt{B}$	0.86	5.27	18.46	19.33	19.65	20.20	19.64	19.21	

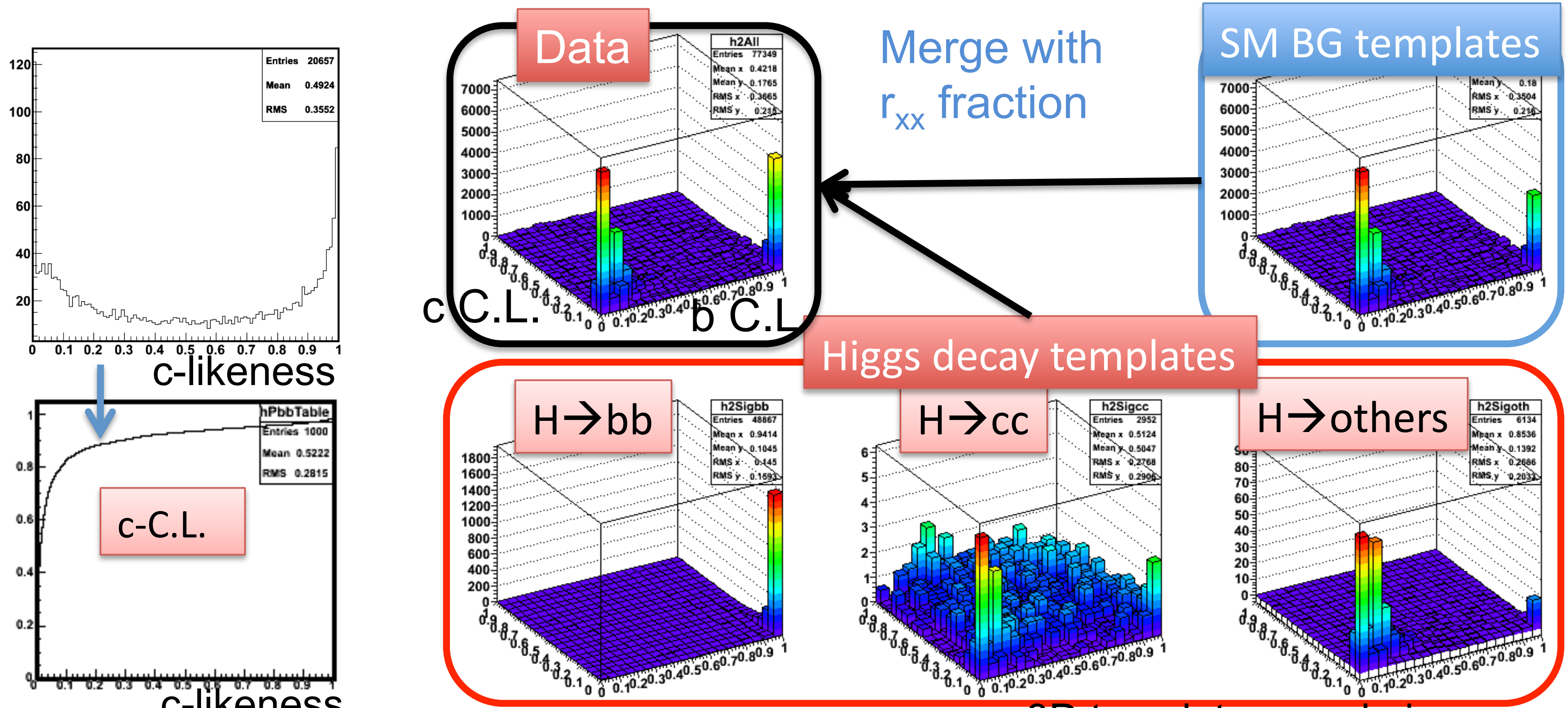
350 GeV	No cuts	chi2	Ntrack	-Log(Y34)	thrust	cosθ	θH	Mh	Eff
H→cc	1296	899	672	652	599	562	525	465	35.9%
H→bb	24051	14919	11589	11275	10410	9675	8879	7665	31.9%
ZH→qqH all	36099	20203	14905	14546	13524	12572	11278	9723	26.9%
SM Bkg	8266030	509774	209765	197726	114841	85787	60331	32896	0.4%
$S_{cc}/\sqrt{B}$	0.45	1.26	1.47	1.47	1.77	1.92	2.14	2.56	
$S_{bb}/\sqrt{B}$	8.37	20.90	25.30	25.36	30.72	33.03	36.15	42.26	

Template fitting strategy

Template fitting is applied with minimizing χ^2

Fitted parameters: $r_{bb/cc/others}$

$$\chi^2 = \sum_{i=1}^{n_b}\sum_{j=1}^{n_c}\sum_{k=1}^{n_{bc}} \left(\frac{N^{data}_{ijk} - \sum_{s=bb/cc/others} r_s \left(\frac{N^{ZH}}{N^s}\right) N^s_{ijk} - r_{bkg} N^{bkg}_{ijk}}{\sigma_{N^{all}_{ijk}}} \right)^2$$



3D template sample image

Relative BR comparison

Relative branching fraction has checked for Ecm=250, 350 GeV

$$\frac{Br(H \to c\bar{c})}{Br(H \to b\bar{b})} = \frac{r_{cc}/\varepsilon_{cc}}{r_{bb}/\varepsilon_{bb}}$$

ZH→vvH neutrino mode analysis is now in progress

Efficiency	Ecm=250 GeV		Ecm=350 GeV	
	neutrino	hadron	neutrino	hadron
ε_{bb}	36.8%	39.0%		31.7%
ε_{cc}	41.8%	41.9%		35.4%

Fitted results	Ecm=250 GeV			Ecm=350 GeV
mode	neutrino	hadron	w/o qq	hadron
rbb	0.853+−0.009	0.774+−0.013	0.775+-0.014	0.788+−0.008
rcc	0.052+−0.004	0.046+−0.005	0.046+-0.004	0.048+−0.002
BR(cc)/BR(bb)	0.054+−0.004	0.055+−0.006	0.055+-0.005	0.054+−0.003
ΔBR(cc)/BR(bb)	7.94%	10.15%	9.68%	6.18%

statistic only

Preliminary

Measurement accuracy looks improved in hadron mode, caused by better S/√N?

Summary and next step

- Compare Ecm=250/350 GeV samples for ZH→qqH
  - Boost effect is observed for angles and Mh distribution
  - Jet pair combination in qqH (4 jets) mode is improved
  - Consistent result is obtained for flavor tagging performance in *ZZ→vvqq* sample
  - Selection criteria is optimized for 350 GeV (better S/√N)
- Compare the relative BR measurement accuracy
  - qq sample production is in progress
  - qqqq 4j background reduction looks better at Ecm=350 GeV
  - ZH→vvH, llH are also checked
  - Check the generated samples completely copied from grid?
    - File copy miss?

Backup

Background reduction (ZH→qqH, 250 GeV)

250 GeV	No cuts	chi2	Ntrack	-Log (Y34)	thrust	cosθ	θH	Mh	Eff
H→cc	1916	1460	1114	1102	1081	963	890	804	41.9%
H→bb	34963	24568	19542	19351	19013	16854	15488	13651	39.0%
ZH→qqH all	52507	32430	25252	25037	24656	21856	20041	17617	33.6%
qqqq	4048390	1299950	824215	818221	814909	591276	533302	430869	10.6%
qq	35353100	1220310	296152	183403	120560	104502	88475	73790	0.2%
nlqq	4114190	25981	119	105	90	80	55	14	0.00%
llqq	398319	42195	307	252	215	158	133	87	0.02%
nnqq	149979	0	0	0	0	0	0	0	0.00%
llll	761223	20168	0	0	0	0	0	0	0.00%
SM Bkg	44825201	2608604	1120793	1002011	935788	696026	621975	504788	1.1%
BG w/o qq	9472101	1388294	824641	818608	815228	591524	533500	430998	4.6%
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Background reduction (ZH→qqH, 350 GeV)

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H→bb	24051	14919	11589	11275	10410	9636	8811	7623	31.7%
ZH→qqH all	36099	20203	14905	14546	13524	12523	11191	9675	26.8%
qqqq	3094510	322790	179720	167952	85560	54839	39092	27214	0.9%
tt	166459	49314	29138	29096	28832	25962	17568	5428	3.3%
vlqq	3343060	81620	638	489	350	270	158	43	0.0%
llqq	468202	33186	235	173	90	74	51	28	0.0%
vvqq	119416	142	35	16	9	9	2	0	0.0%
llll	1074390	22722	0	0	0	0	0	0	0.0%
SM Bkg	8266030	509774	209765	197726	114841	81155	56871	32713	0.4%
$S_{cc}/\sqrt{B}$	0.45	1.26	1.47	1.47	1.77	1.94	2.16	2.54	
$S_{bb}/\sqrt{B}$	8.37	20.90	25.30	25.36	30.72	33.83	36.95	42.15	

qq samples generation is still in progress

Flavor tagging performance on ILD LOI

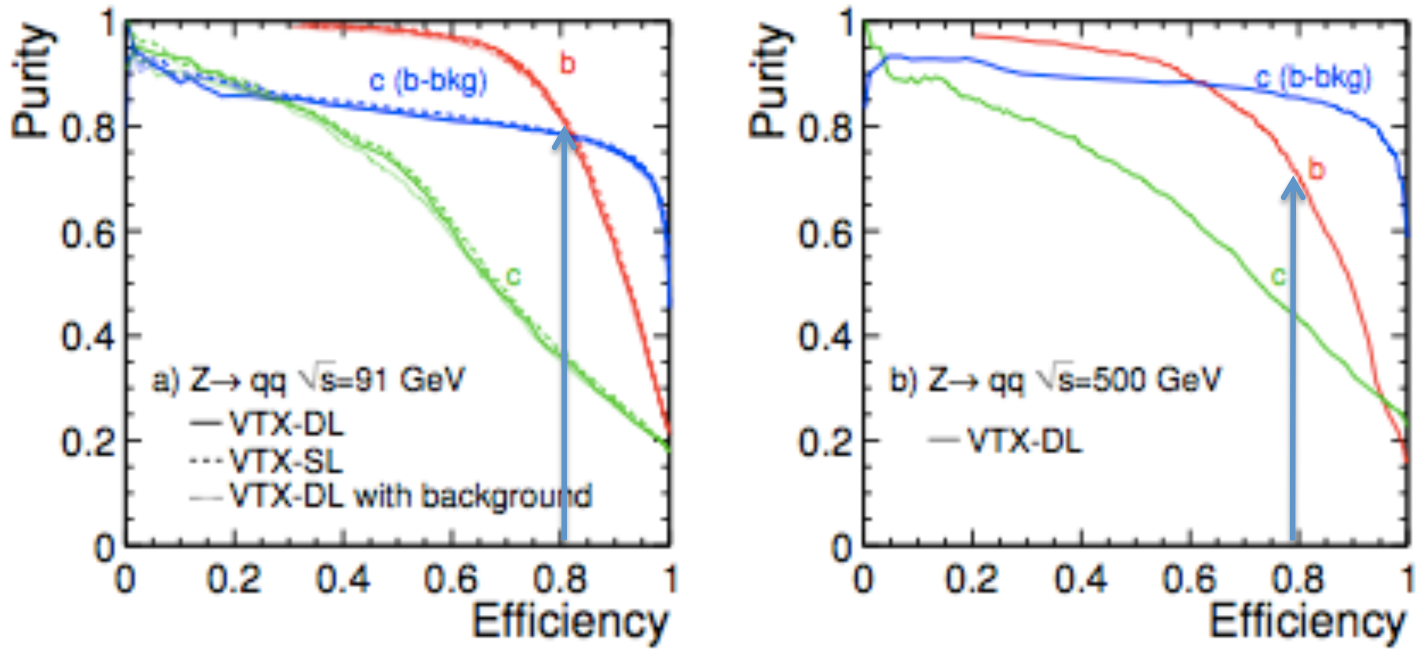


FIGURE 1.2-11. a) Flavour tagging performance of the ILD detector for 91 GeV $Z \to q\bar{q}$ events for both the three double-sided ladders (VTX-DL) layout and with five single-sided ladder layout (VTX-SL). Also shown for the VTX-DL is the impact of background on the flavour tagging performance. b) Flavour tagging performance of the ILD detector for 91 GeV $Z \to q\bar{q}$ events for the VTX-DL layout. In all cases the acceptance corresponds to $|\cos\theta_{\mathrm{jet}}| < 0.95$.

ZH→ννH analysis

Ecm=250 GeV selection criteria

- 80<MissMass<140 GeV
- 20<Pt<70 GeV
- |Pl|<60 GeV
- # chdtrk>10
- P_{max}<30 GeV
- Y+<0.02”
- 0.2<Y-<0.8
- 100<MH<130 GeV

Now optimizing vvH mode for 350 GeV

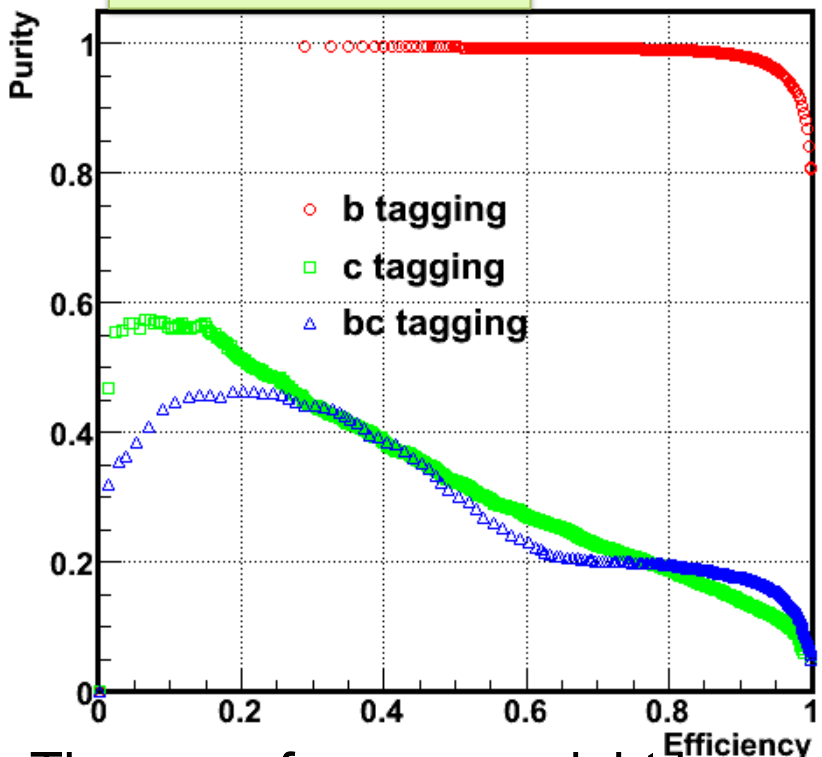
Higgs decay flavor tagging performance

Flavor tagging performance in ZH→qqH four jet clustering case

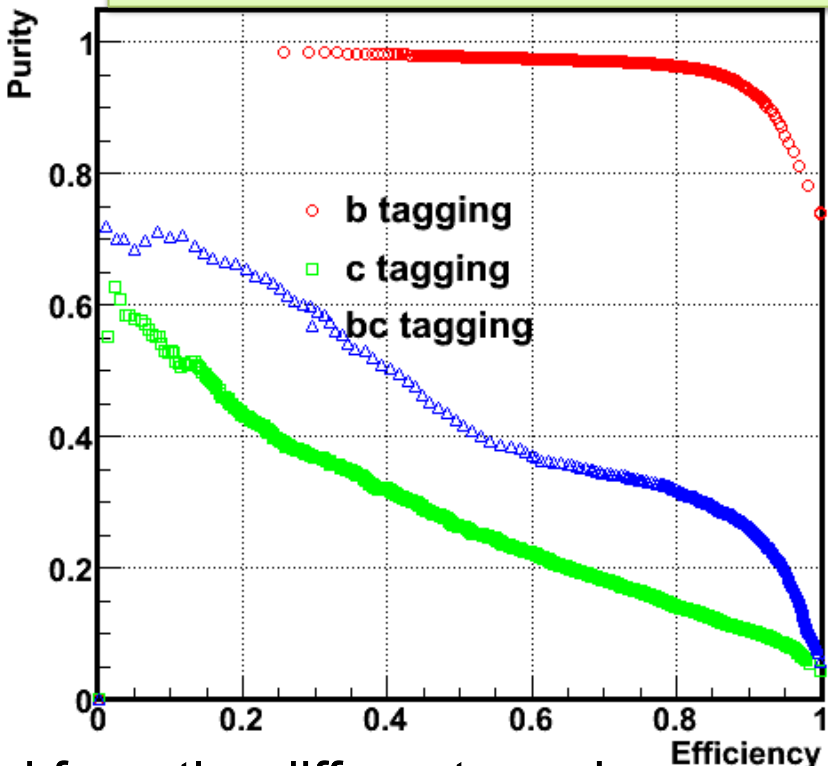
H→qq comparison

Ecm=350 GeV

χ^2<10 selection



Remove miss combination in H→qq



These performance might be caused from the different quark composition from Z→qq training sample

SB2009 beam parameters

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- ($*10^{10}$)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ ($*10^{10}$)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex ($*10^{-6}$)	10	10	10	10	10	10	10	10	10	10	10
γey ($*10^{-8}$)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx (mm)	22	22	20	21	21	15	11	21	21	15	11
βy (mm)	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff ($*10^{-9}$ m)	948	802	639	927	927	662	474	927	927	662	474
σy eff ($*10^{-9}$ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} $cm^{-2}s^{-1}$)	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

SB2009 new beam parameters

	200	250	350	500	1000
Rate (Hz)	10	10(5)	5	5	4
$\Delta p/p$(e-)(%)	0.22	0.22(0.220)	0.22(0.218)	0.21(0.207)	0.11
$\Delta p/p$(e+)(%)	0.17	0.14(0.130)	0.10(0.093)	0.07(0.065)	0.04
β_x*(mm)	16	12(21)	15	11	30
σ_x*(mm)	904	700(927)	662	474	554
σ_y*(mm), wTF	6.0	5.3(6.4)	4.5(5.0)	3.8	2.7
L($\times 10^{34}$ cm^{-2}s^{-1}),wTF	0.5	0.8(0.27)	1.0	2.0	2.8[2]

[1]parameters different from sb2009 are listed. Values in ( ) are SB2009 values.
[2] Luminosity without traveling focus.

Miyamoto-san's slide at ILD optimization meeting 2010. Sep. 08