

ZH Branching ratio study @350 GeV

IWLC2010 ECFA WS @CERN

Higgs SUSY and Cosmology session

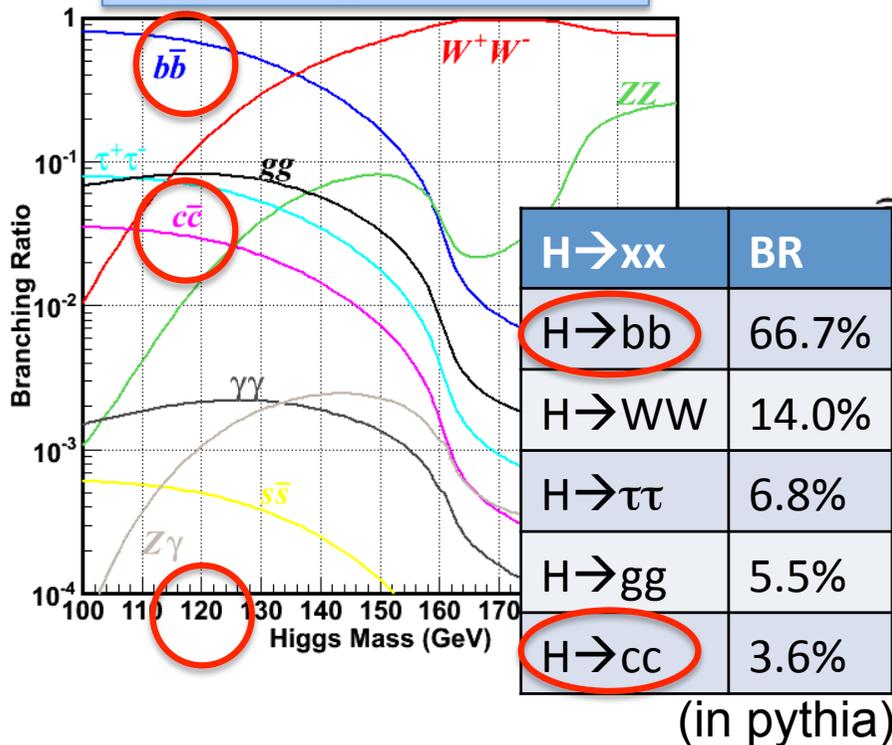
Oct. 19. 2010

H. Ono (NDU)

ZH Branching Ratio measurement

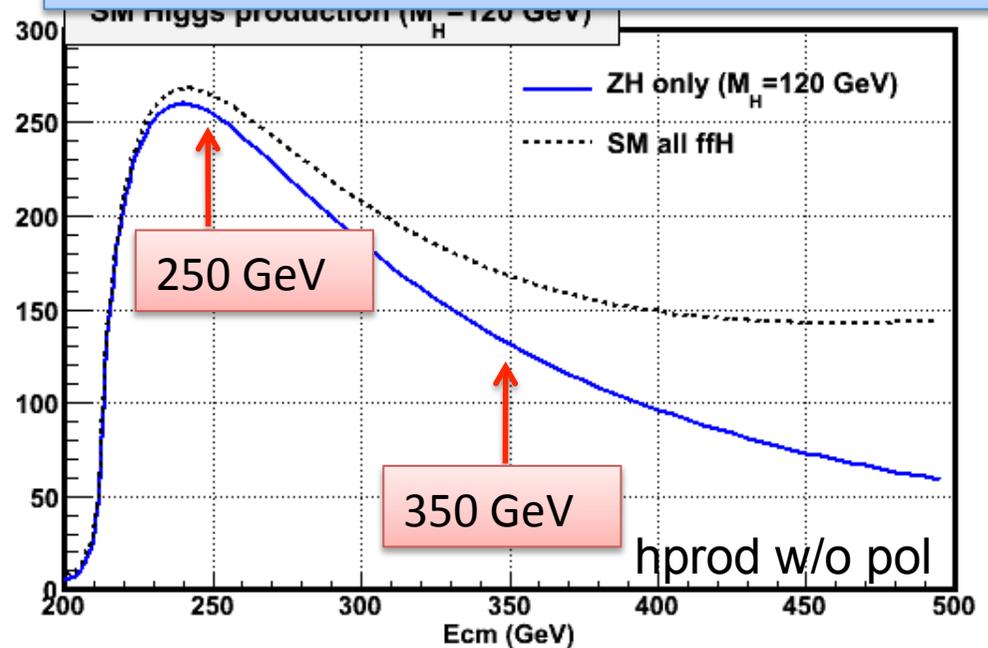
Higgs BR study at $E_{cm}=250$ GeV is one of the benchmark process in LOI
 Higgs BR at $E_{cm}=350$ GeV is also the new benchmark process for DBD

BR at $M_H=120$ GeV



ZH (hprod)	254 fb ⁻¹	131 fb ⁻¹
------------	----------------------	----------------------

SM Higgs production cross section



Cross section	$E_{cm}=250\text{GeV}$	$E_{cm}=350\text{GeV}$
ffH (w/ beam pol)	319.4 fb ⁻¹	274.9 fb ⁻¹

SB2009 beam parameters

- New benchmark process includes the ZH BR study at $E_{cm}=350$ GeV
- SB2009 beam parameters effect need to be compared in BR study

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

Luminosity reduction is considered especially at low energy in old parameters
From the beam operation side, higher E_{cm} is prefer in terms of the luminosity

New $E_{cm}=350$ GeV data samples are generated
with SB2009 w/ TF beam parameter (A. Miyamoto/KEK)
Start to analyze this data samples

Simulation setup and signal samples

Event generation : whizard

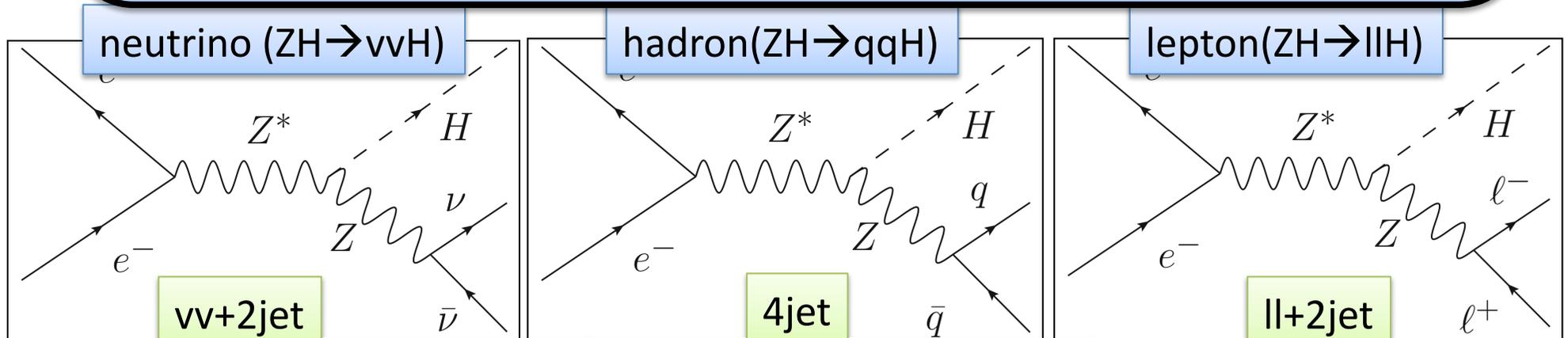
Simulation and analysis : ilcsoft v01-06

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



DST sample
include t-channel

Cross section	$\nu\nu H$	qqH	llH
250 GeV	77.4 fb	210.0 fb	31.7 fb
350 GeV	105.2 fb	144.4 fb	25.3 fb

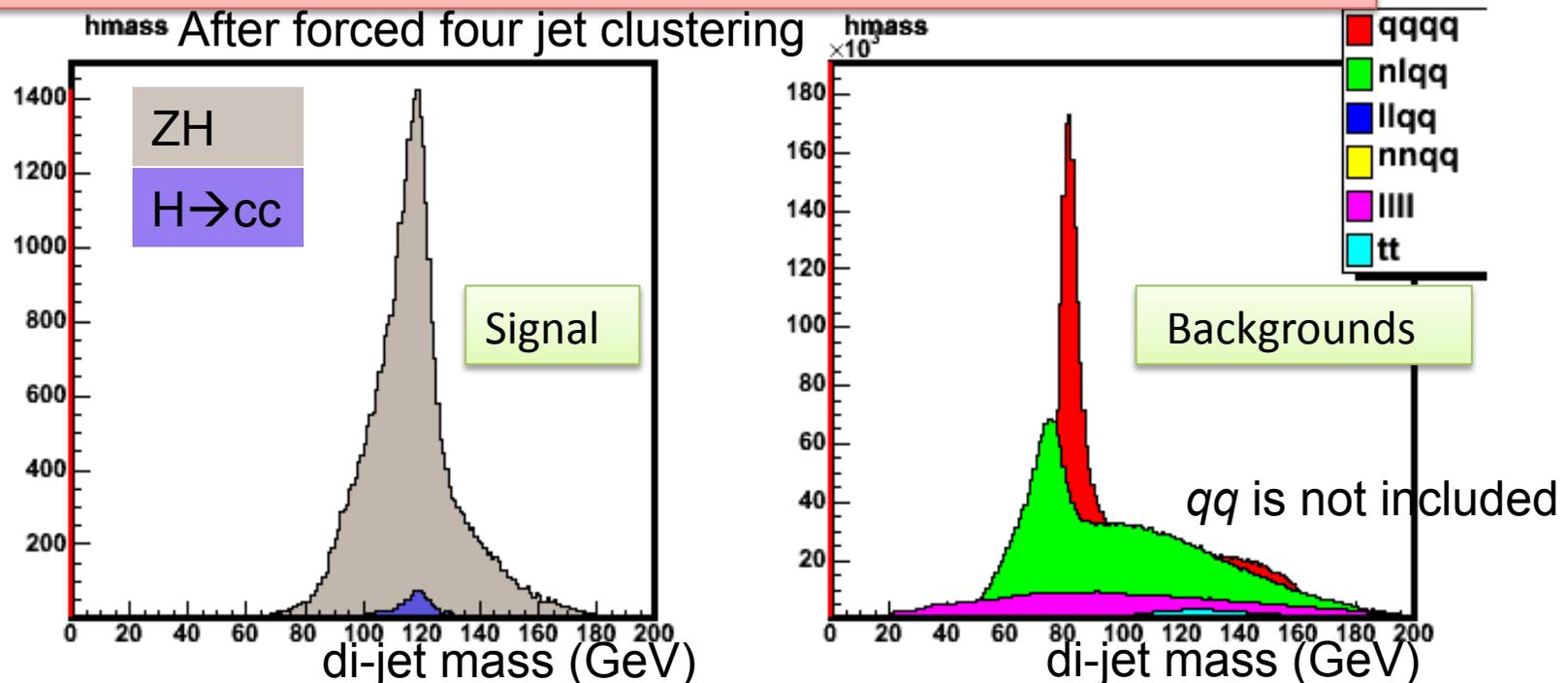
Beam polarization
(e^+, e^-) = (+30%, -80%)

Background samples at 350 GeV

Following background samples are considered

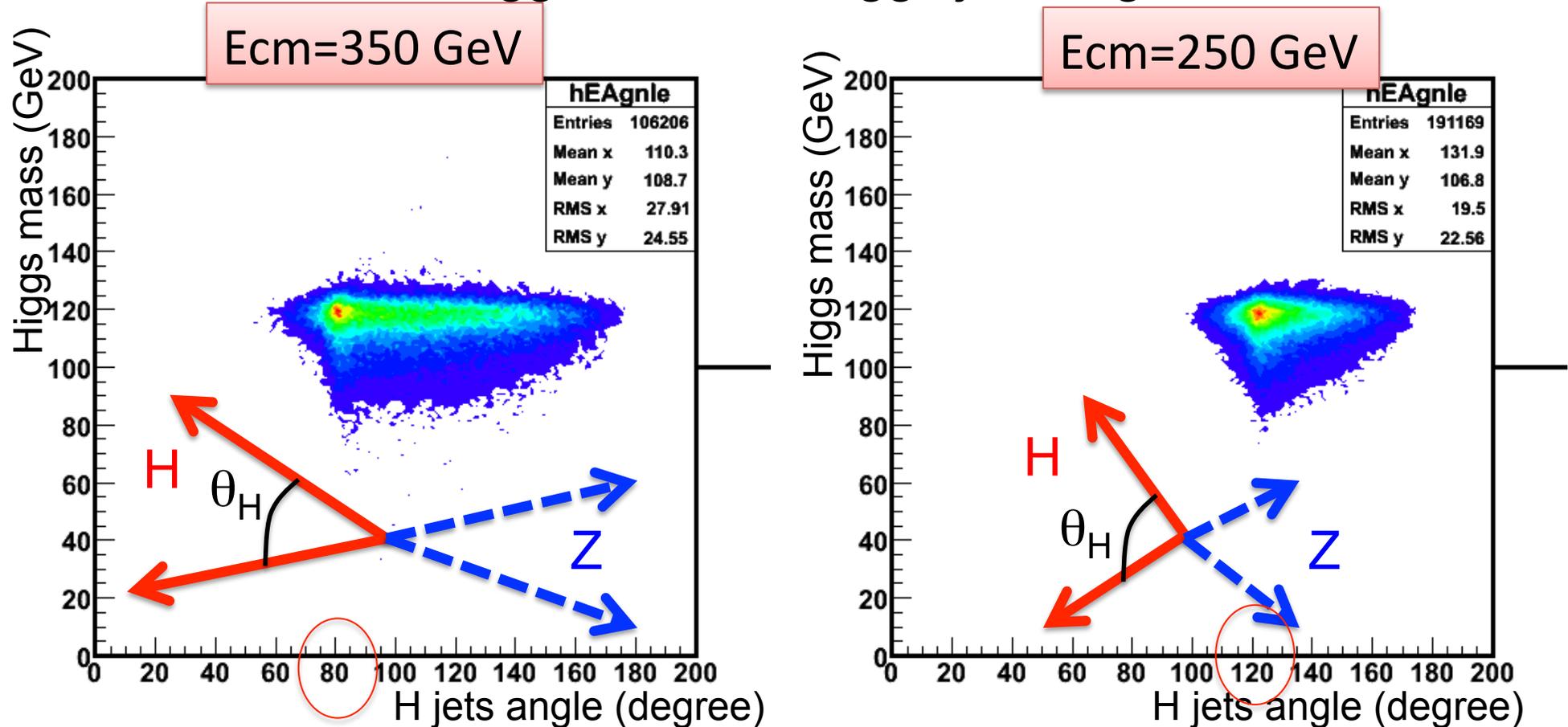
- $qqqq$, tt , $llqq$, $vlqq$, $vvqq$, $llll$ (qq is not included yet), WW/ZZ
- tt is generated with physsim including threshold enhancement
- All data are scaled to be the luminosity of $\mathcal{L}=250 \text{ fb}^{-1}$

Higgs candidate di-jet mass ($E_{\text{cm}}=350 \text{ GeV}$, $ZH \rightarrow qqH$ hadronic)



Event shape comparison for 250/350 GeV

Reconstructed Higgs mass vs Higgs jets angle in $ZH \rightarrow \nu\nu H$



Jets angle becomes narrower at 350 GeV by boost

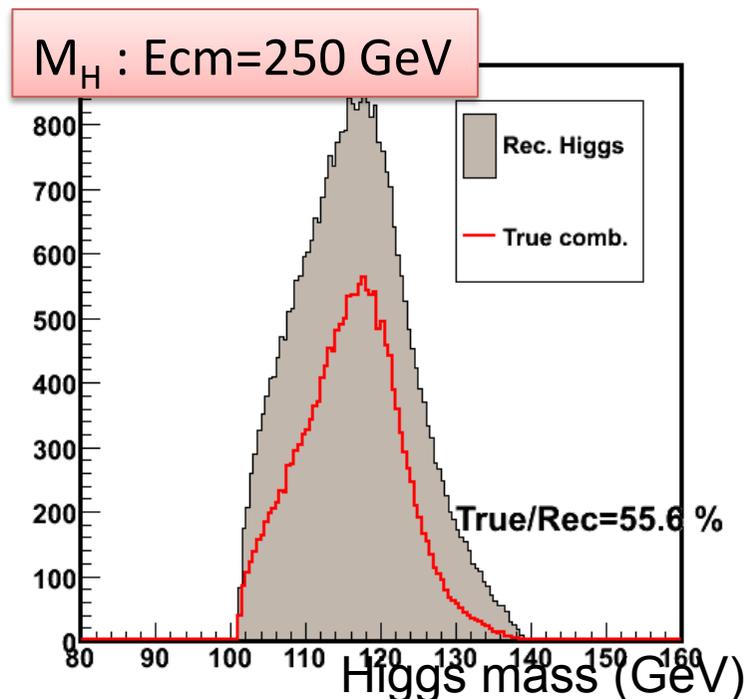
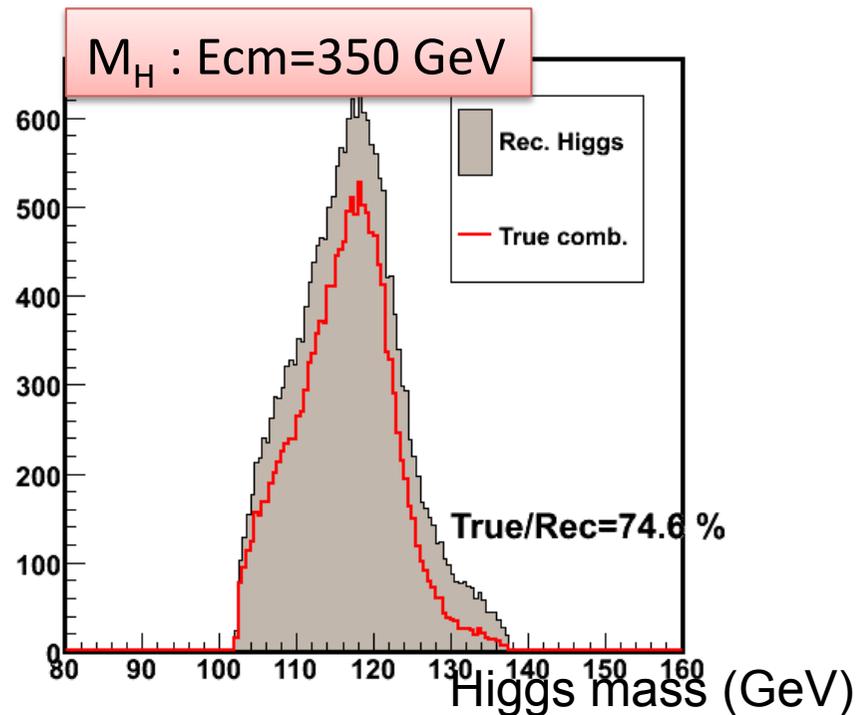
H/Z miss jet pairing will be reduced at $ZH \rightarrow qqH$ (4 jet)

Jet pair combination in $ZH \rightarrow qqH$

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

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

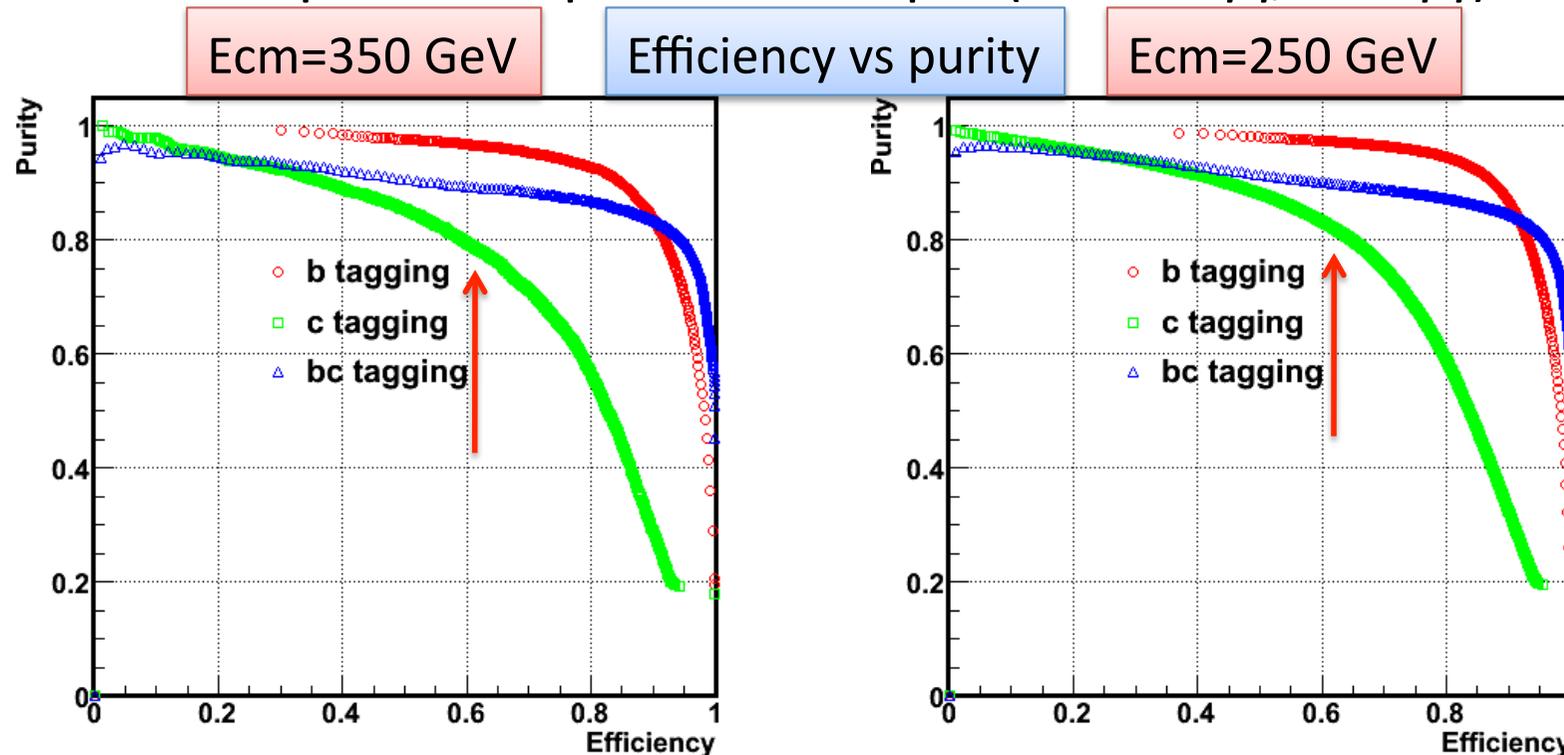
Select minimum χ^2 combination after forced four jet clustering



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

Flavor tagging performance comparison

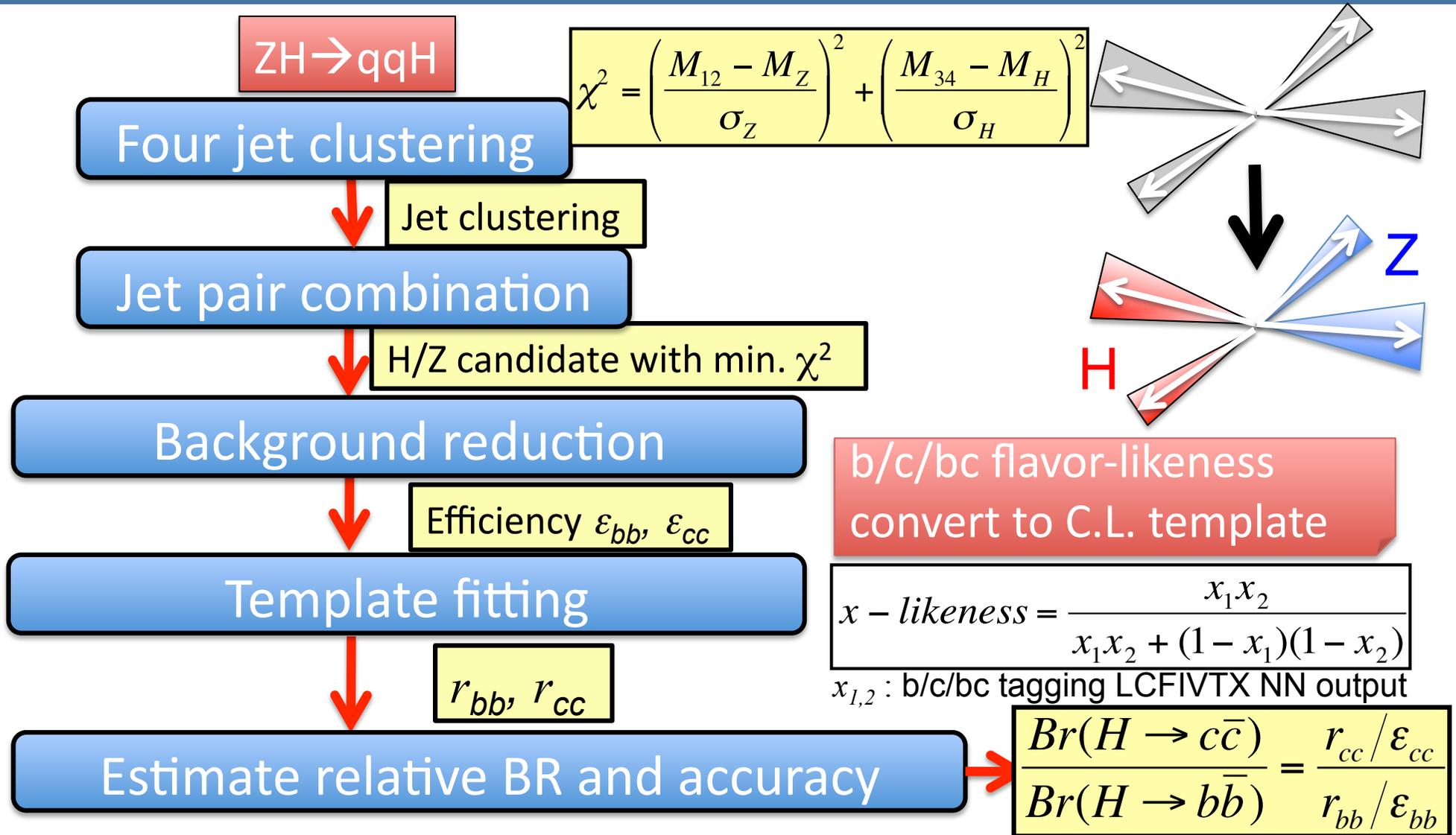
- Compare Flavor tagging performance at $E_{cm}=250$ with 350 GeV
- LCFIVTX is trained with $Z \rightarrow qq$ @91.2 GeV sample
- Use same quark composition sample ($ZZ \rightarrow vvqq, Z \rightarrow qq$)



Slightly decrease the performance from 250 at 350 GeV in c-tagging

BR measurement study ($ZH \rightarrow qqH$ only for now)

ZH → qqH analysis procedure



ZH \rightarrow qqH cut optimization

Ecm=250 GeV

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

Ecm=350 GeV

1. $\chi^2 < 10$
2. # of charged track > 4
3. $-\log_{10}(Y_{34}) < 2.7$
4. thrust < 0.85
5. $|\cos\theta_{\text{thrust}}| < 0.9$
6. $70 < \theta_{\text{Hjets}} < 120$ deg.
7. $110 < M_{\text{H}} < 130$ GeV

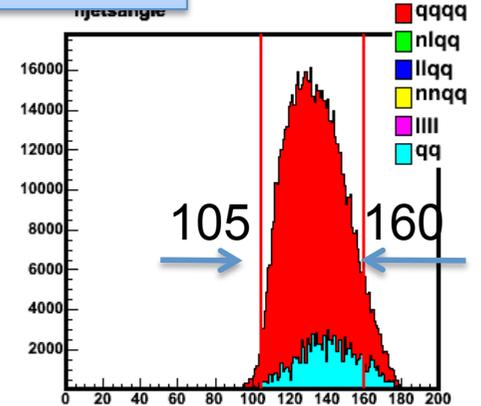
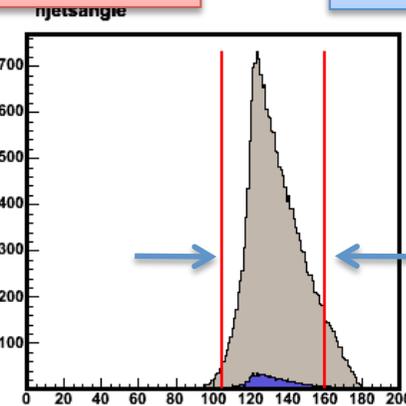
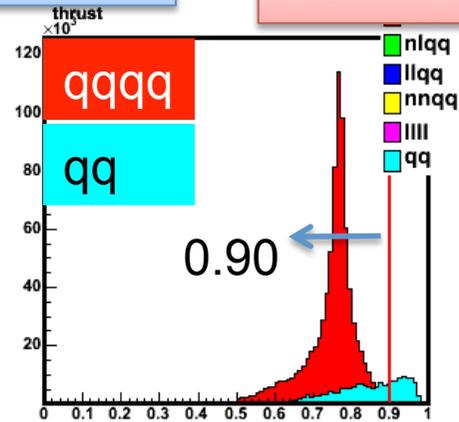
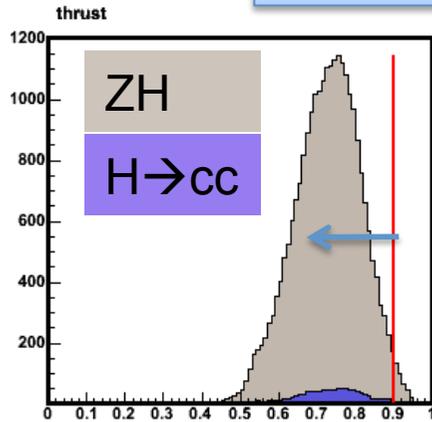
Selection criteria is optimized for 350 GeV
Higgs jets angle becomes narrower by boost

ZH → qqH cut optimization at 350 GeV

Thrust angle cuts

Ecm=250GeV

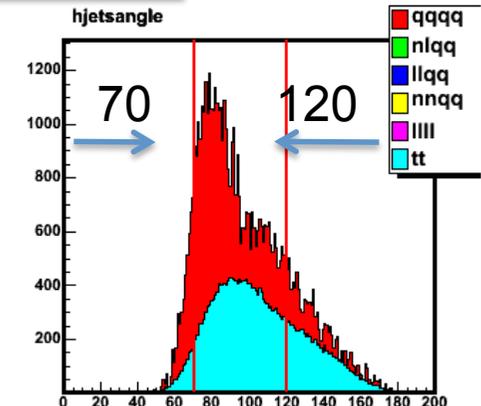
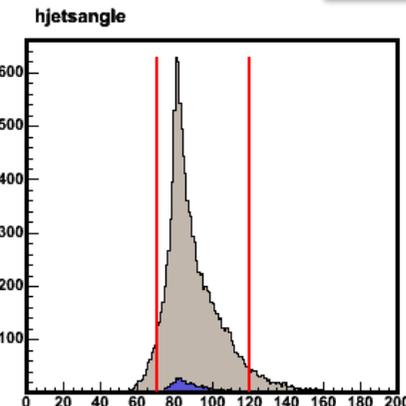
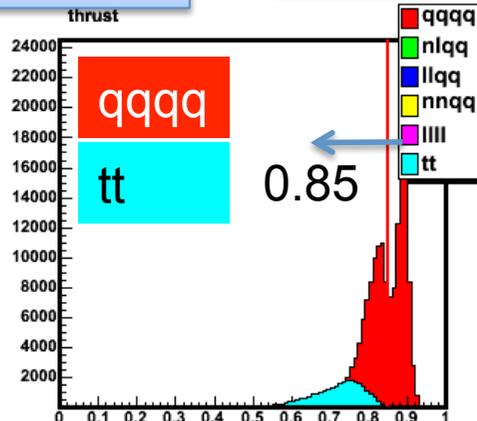
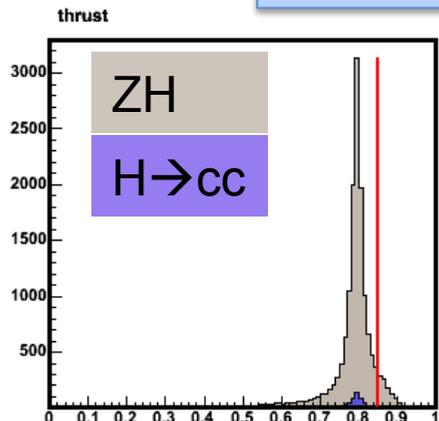
H jets angle



Thrust angle cuts

Ecm=350GeV

H jets angle



WW makes two peaks?

degree

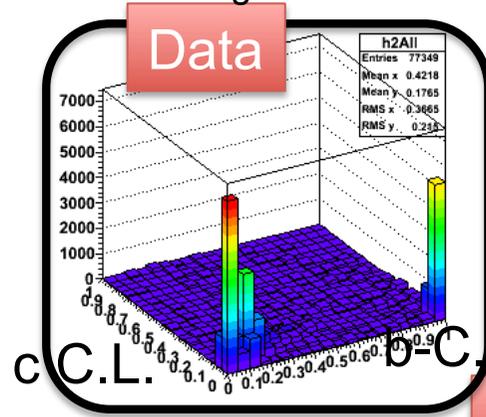
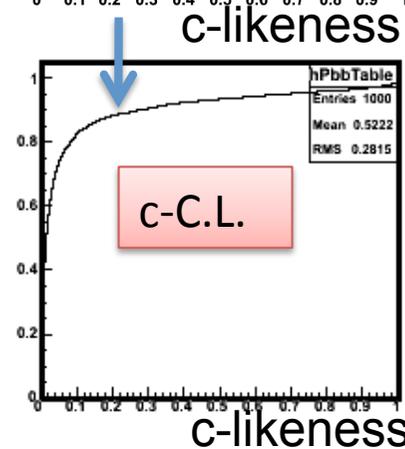
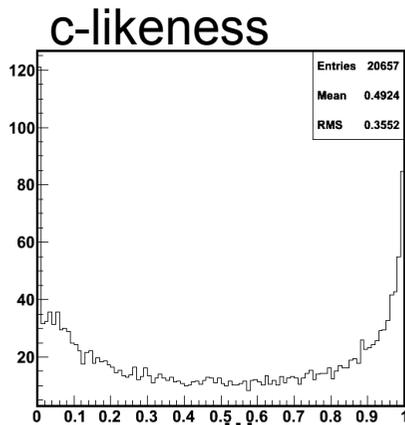
Background reduction summary ($ZH \rightarrow qqH$)

250 GeV	No cuts	chi2	Ntrack	-Log(Y34)	thrust	cos θ	θ_H	M_H	Eff
H \rightarrow cc	1916	1460	1114	1102	1081	963	890	804	41.9%
H \rightarrow bb	34963	24568	19542	19351	19013	16854	15488	13651	39.0%
ZH \rightarrow 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%
$S_{cc}/\nu B$	0.05	0.31	1.05	1.10	1.12	1.15	1.13	1.13	
$S_{bb}/\nu B$	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	cos θ	θ_H	M_H	Eff
H \rightarrow cc	1296	899	672	652	599	562	525	465	35.5%
H \rightarrow bb	24051	14919	11589	11275	10410	9675	8879	7665	31.7%
ZH \rightarrow qqH all	36099	20203	14905	14546	13524	12572	11278	9723	26.8%
SM Bkg	8266030	509774	209765	197726	114841	85787	60331	32896	0.4%
$S_{cc}/\nu B$	0.45	1.26	1.47	1.47	1.77	1.92	2.14	2.56	
$S_{bb}/\nu B$	8.37	20.90	25.30	25.36	30.72	33.03	36.15	42.26	

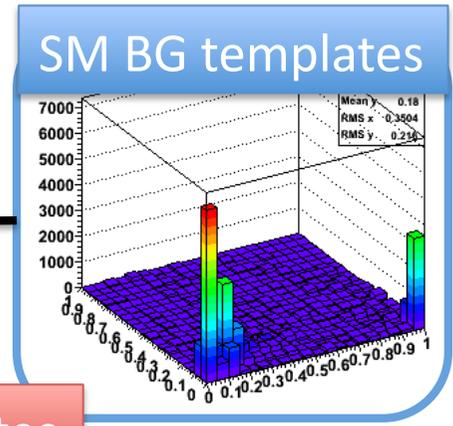
Template fitting for BR measurement

- Template fitting is applied with minimizing χ^2
- b/c/bc-likenss 3D templates
- Fitted parameters: $r_{bb/cc/others/bkg}$

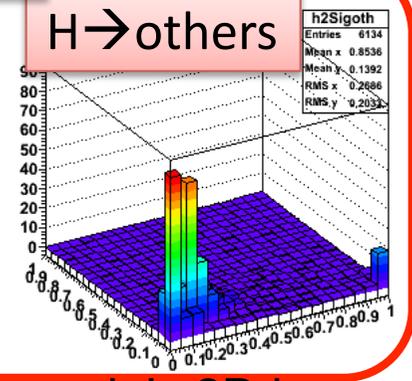
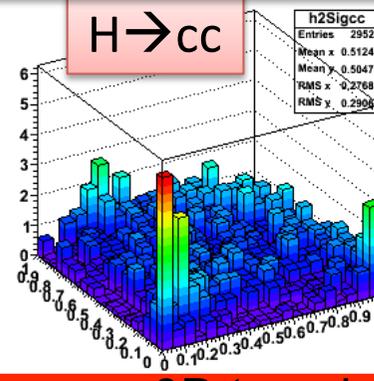
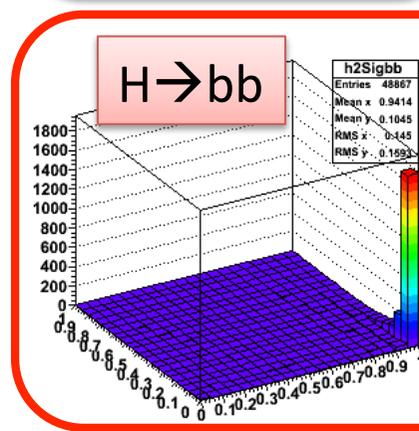
$$\chi^2 = \sum_{i=1}^{n_b} \sum_{j=1}^{n_c} \sum_{k=1}^{n_{bc}} \left(\frac{N_{ijk}^{data} - \sum_{s=bb/cc/others} r_s \left(\frac{N^{ZH}}{N^s} \right) N_{ijk}^s - r_{bkg} N_{ijk}^{bkg}}{\sigma_{N_{ijk}^{all}}} \right)^2$$



Merge with r_{xx} fractions



Higgs decay templates



3D template sample's 2D image

Relative BR comparison

Relative branching fraction has checked for Ecm=250, 350 GeV with 1,000 times toy MC

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

Efficiency	Ecm=250 GeV		Ecm=350 GeV
	neutrino	hadron	hadron
ϵ_{bb}	36.8%	39.0%	31.7%
ϵ_{cc}	41.8%	41.9%	35.5%

Fitted results	Ecm=250 GeV			Ecm=350 GeV
mode	neutrino	hadron	w/o qq	hadron
r_{bb}	0.853+-0.009	0.774+-0.013	0.775+-0.014	0.788+-0.008
r_{cc}	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
$\Delta BR(cc)/BR(bb)$	7.94%	10.15%	9.68%	6.18%

(statistic error only)

Measurement accuracy looks improved in hadron mode, caused by better S/\sqrt{N} ? Preliminary result

Summary and next step

- Compare $E_{cm}=250/350$ GeV samples
 - Different final state event shape is observed by boost effect
 - Jet pair combination in qqH (4 jets) mode is improved
 - Consistent result is obtained for flavor tagging performance in $ZZ \rightarrow \nu\nu qq$ sample
 - Selection criteria is optimized for 350 GeV (better S/\sqrt{N})
- Compare the relative BR measurement accuracy
 - Measurement accuracy looks improving at 350 GeV in hadronic mode which is caused by better S/\sqrt{N} ?
 - qq background should be included
- Consider beam luminosity difference in BR analysis

Backup

Background reduction ($ZH \rightarrow qqH$, 250 GeV)

250 GeV	No cuts	chi2	Ntrack	-Log (Y34)	thrust	cos θ	θ_H	Mh	Eff
H \rightarrow cc	1916	1460	1114	1102	1081	963	890	804	41.9%
H \rightarrow bb	34963	24568	19542	19351	19013	16854	15488	13651	39.0%
ZH \rightarrow 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%
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	

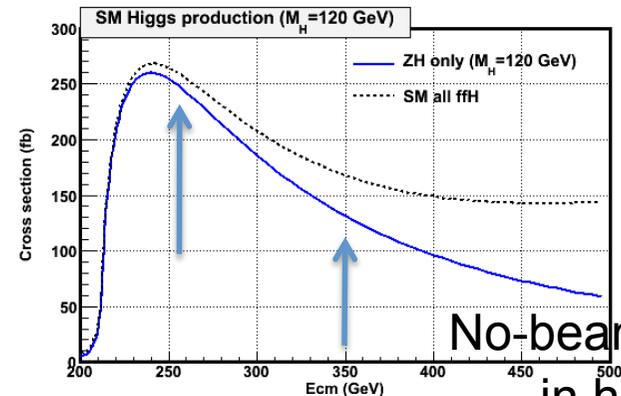
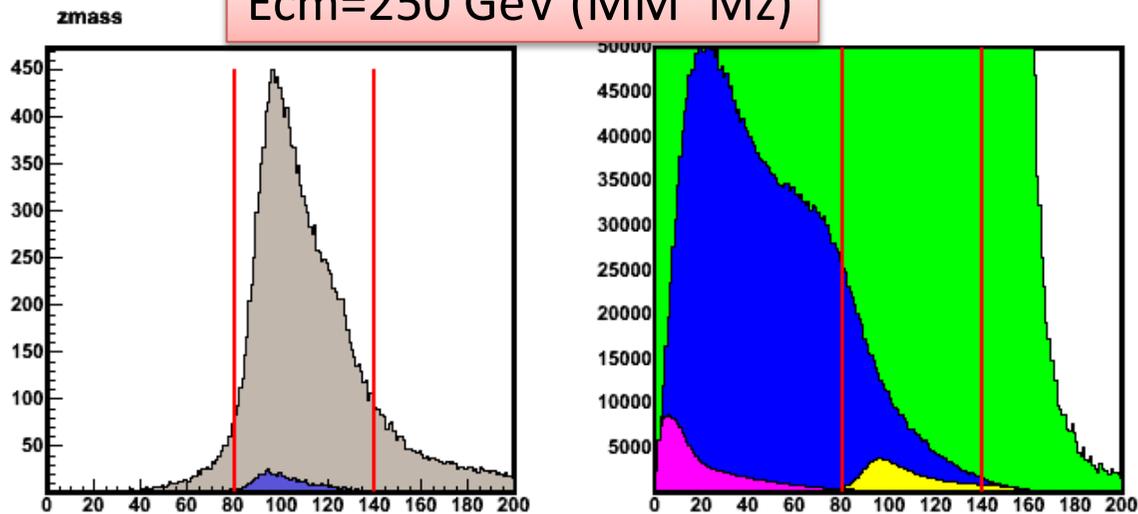
Background reduction ($ZH \rightarrow qqH$, 350 GeV)

350 GeV	No cuts	chi2	Ntrack	-Log (Y34)	thrust	cos θ	θ_H	Mh	Eff
H \rightarrow cc	1296	899	672	652	599	553	516	460	35.5%
H \rightarrow bb	24051	14919	11589	11275	10410	9636	8811	7623	31.7%
ZH \rightarrow 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

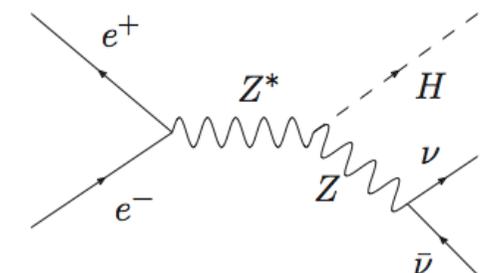
$e^+e^- \rightarrow \nu\nu H$ Missing mass distribution

$E_{cm}=250$ GeV ($MM \sim M_Z$)

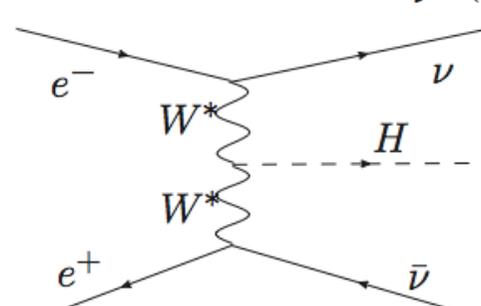
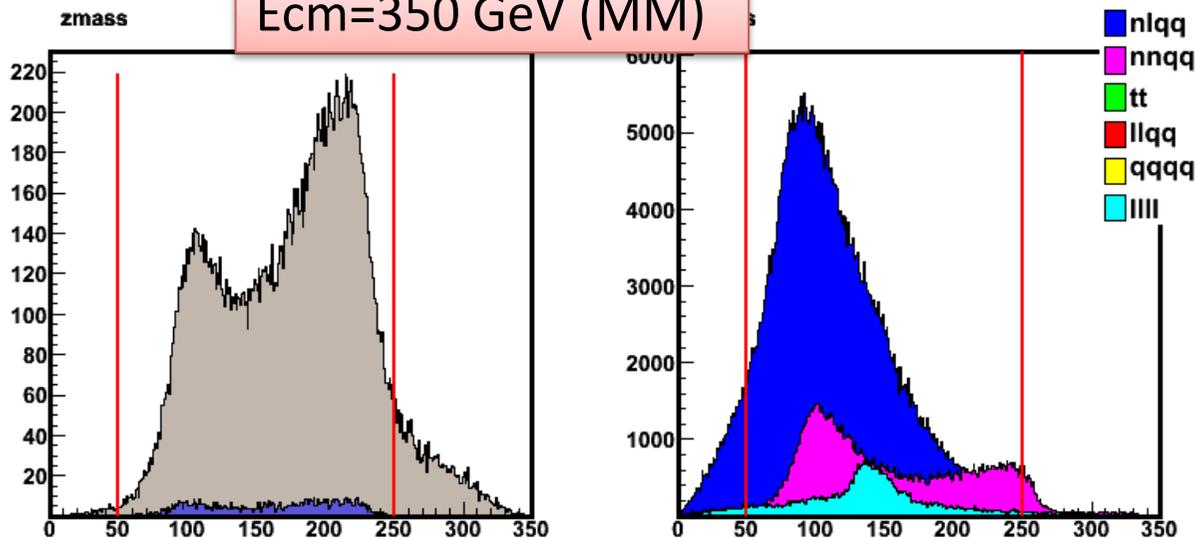


No-beampol
in hprod

s-channel : 131.4fb



$E_{cm}=350$ GeV (MM)

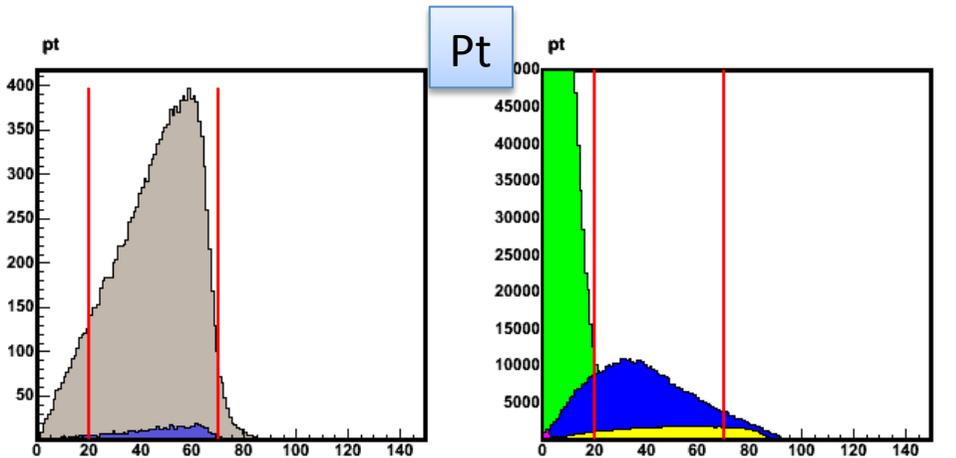
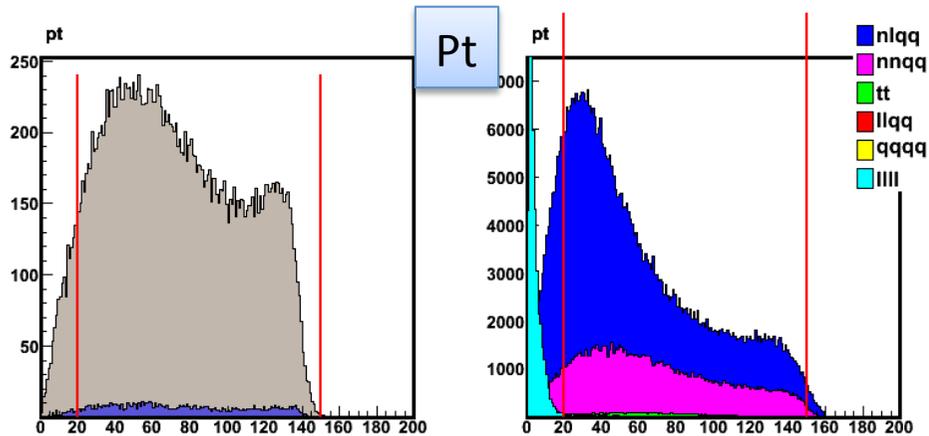
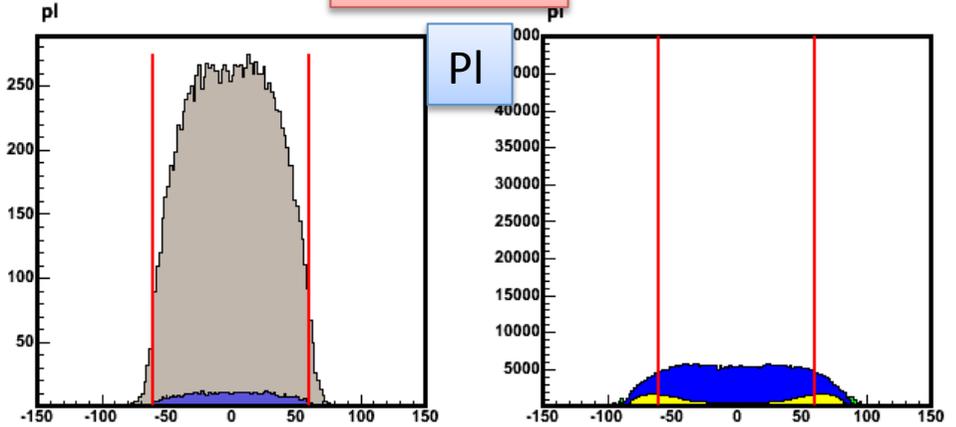
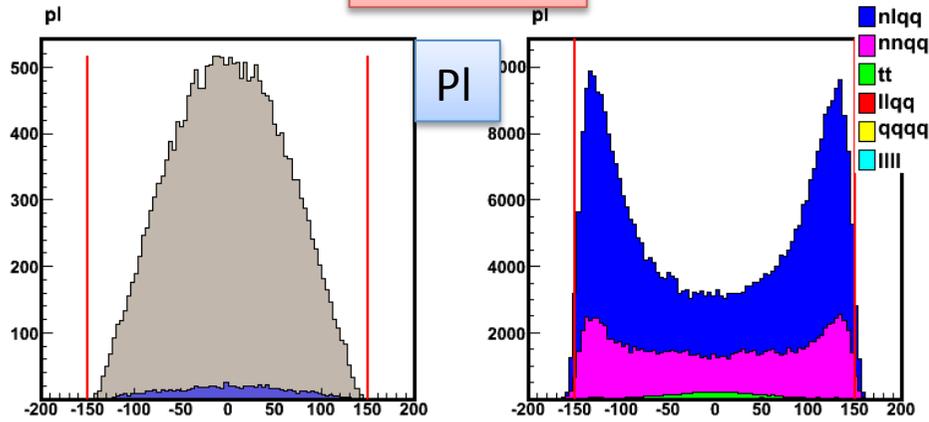


t-channel : 33.03fb

vvH cut values distribution

350 GeV

250 GeV



Flavor tagging performance on ILD LOI

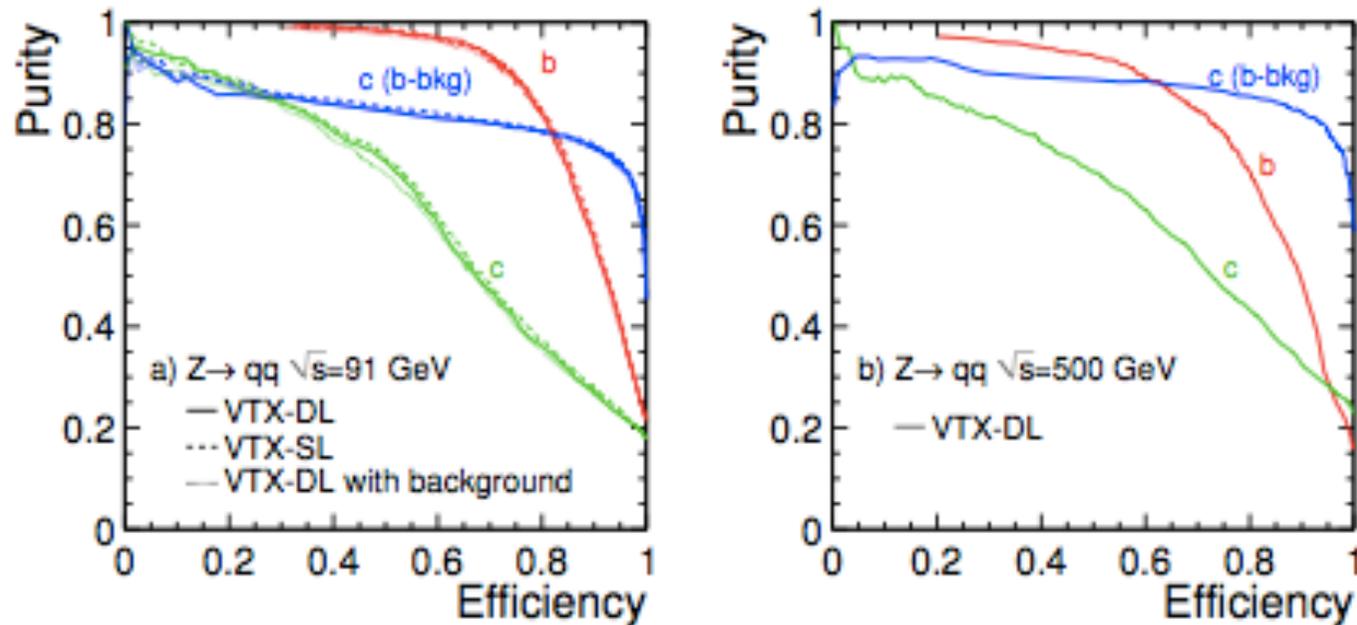


FIGURE 1.2-11. a) Flavour tagging performance of the ILD detector for 91 GeV $Z \rightarrow q\bar{q}$ events for both the three double-sided ladders (VTX-DL) layout and with five single-sided ladder layout (VTX-SL). Also shown for the VTX-DL is the impact of background on the flavour tagging performance.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

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
γ_{ex} (*10 ⁻⁶)	10	10	10	10	10	10	10	10	10	10	10
γ_{ey} (*10 ⁻⁸)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
β_x (mm)	22	22	20	21	21	15	11	21	21	15	11
β_y (mm)	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σ_z (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σ_x eff (*10 ⁻⁹ m)	948	802	639	927	927	662	474	927	927	662	474
σ_y 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

Beam parameter table from LCWS2010

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
$\beta_x^*(\text{mm})$	16	12(21)	15	11	30
$\sigma_x^*(\text{mm})$	904	700(927)	662	474	554
$\sigma_y^*(\text{mm}), \text{wTF}$	6.0	5.3(6.4)	4.5(5.0)	3.8	2.7
$L(\times 10^{34} \text{cm}^{-2} \text{s}^{-1}), \text{wTF}$	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.

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