

# ZH Branching ratio study

ILD detector optimization meeting

Nov. 17. 2010

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# Current status

- $\nu\nu H/\ell\ell H$  mode analysis is on-going
  - $\nu\nu H$  selection optimization has applied
  - $\ell\ell H$  mode analysis with lepton identification performance
- Compare with luminosity scaling
  - beam parameter dependence is checked for 250 and 350 GeV

# vvH study

# vvH cut optimization for 350 GeV

Ecm=250 GeV

1.  $80 < \text{MissingMass} < 140 \text{ GeV}$
2.  $20 < \text{Pt} < 70 \text{ GeV}$
3.  $|\text{PI}| < 60 \text{ GeV}$
4. # of chdtrack  $> 10$
5.  $\text{Pmax} < 30 \text{ GeV}$
6.  $\text{Y+} < 0.02$
7.  $0.2 < \text{Y-} < 0.8$
8.  $100 < \text{Mh} < 130 \text{ GeV}$

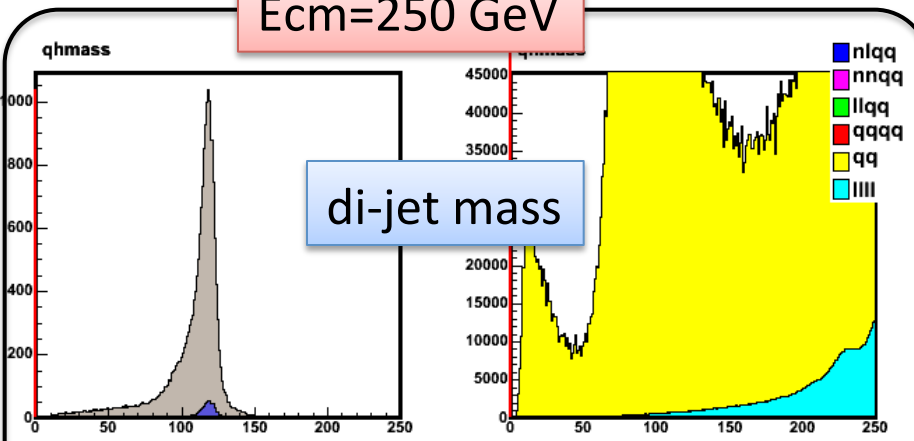
Ecm=350 GeV

1.  $50 < \text{MissingMass} < 250 \text{ GeV}$
2.  $10 < \text{Pt} < 140 \text{ GeV}$
3.  $|\text{PI}| < 130 \text{ GeV}$
4. # of chdtrack  $> 10$
5.  $\text{Pmax} < 60 \text{ GeV}$
6.  $\text{Y+} < 0.02$
7.  $0.05 < \text{Y-} < 0.8$
8.  $100 < \text{Mh} < 130 \text{ GeV}$

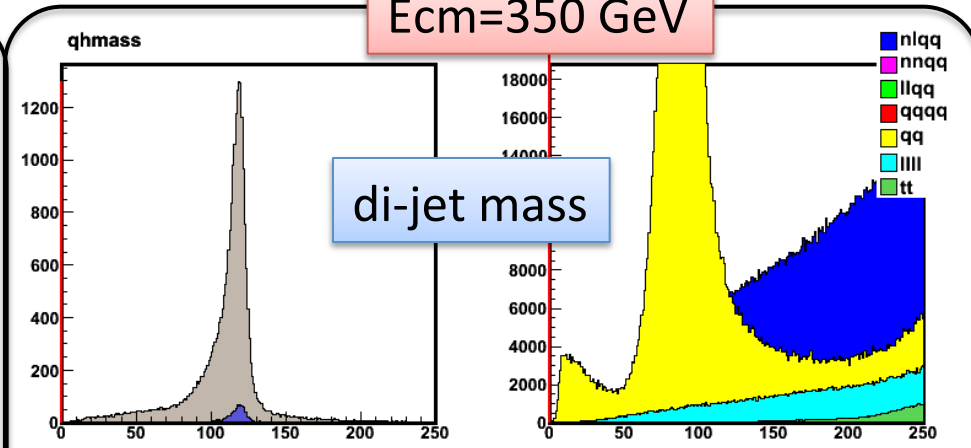
Selection criteria are optimized for vvH mode at 350 GeV

# Di-jet mass, Missing mass distribution

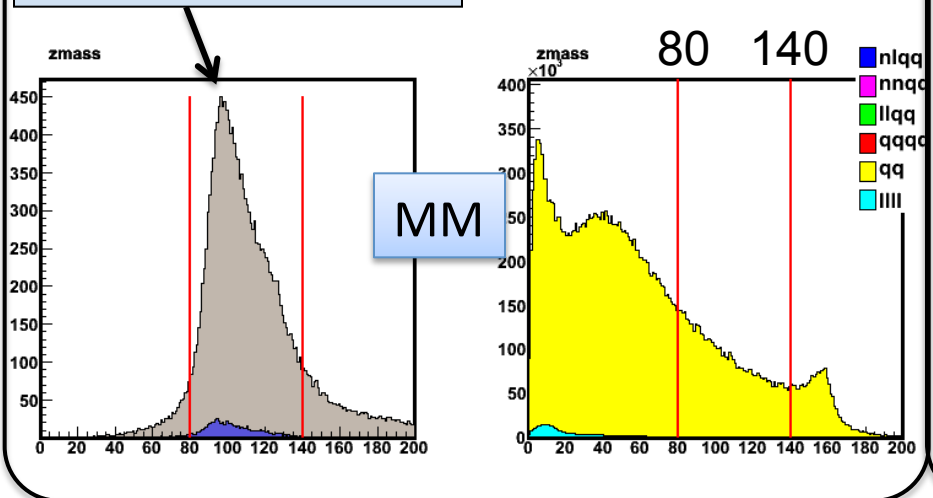
Ecm=250 GeV



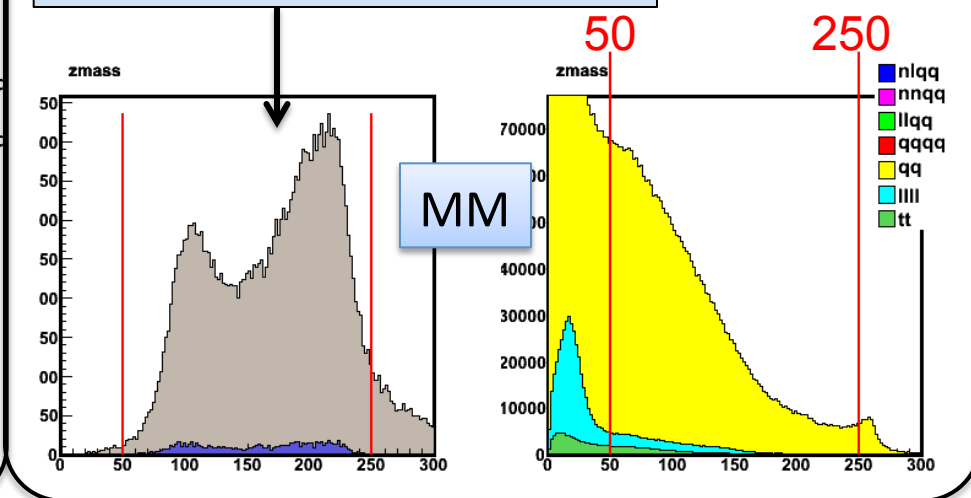
Ecm=350 GeV



Missing mass  $\sim M_Z$

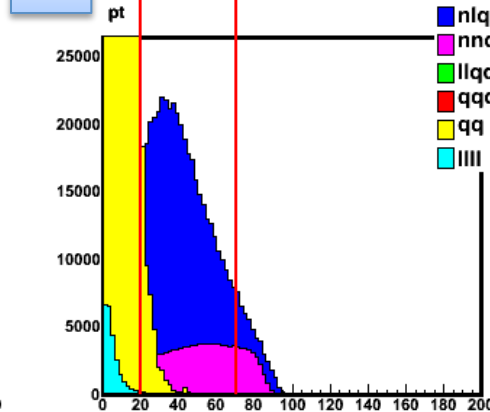
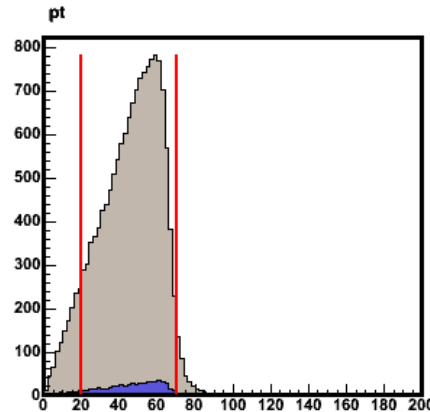
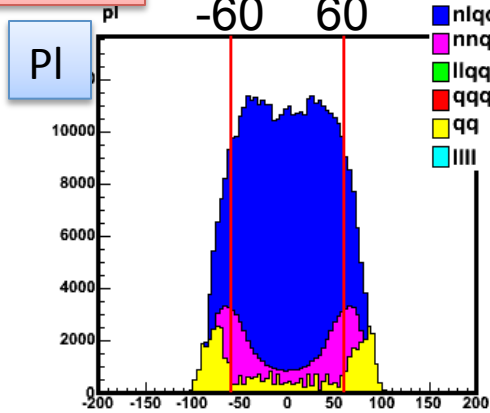
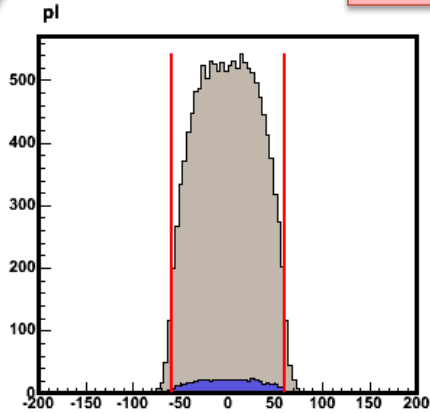


Contribution from t-channel

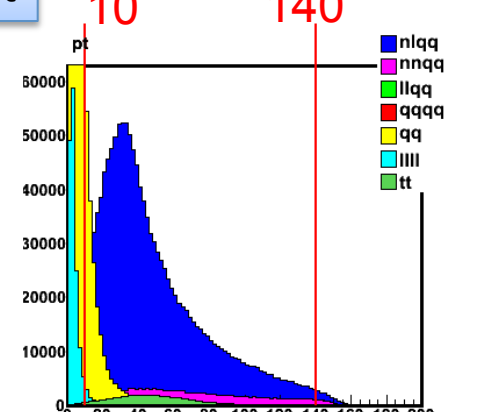
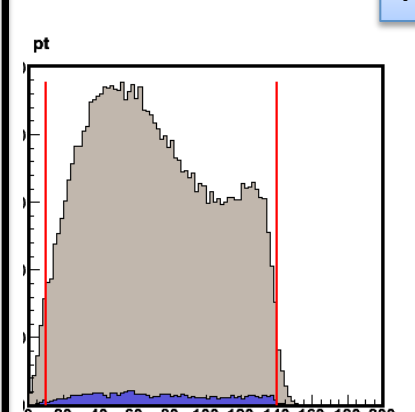
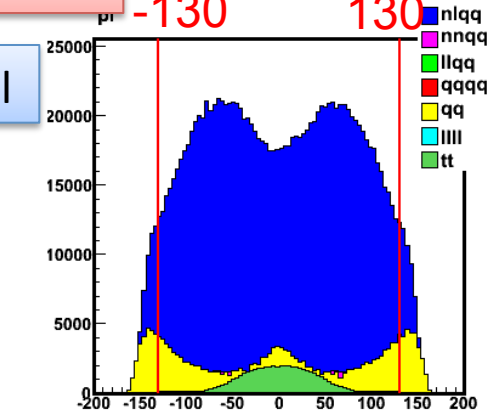
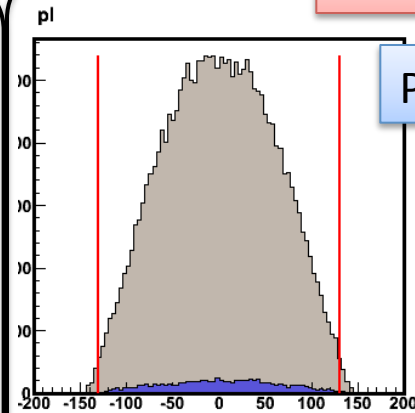


# vvH cut parameters

250 GeV



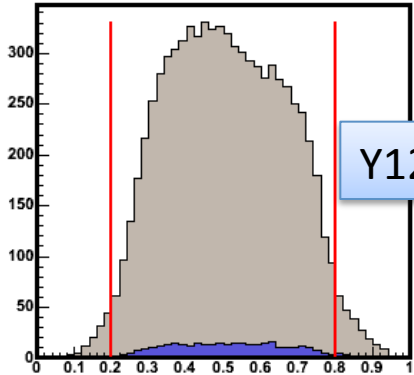
350 GeV



# $\nu\nu H$ cut parameters cont'd

250 GeV

hj1yminus

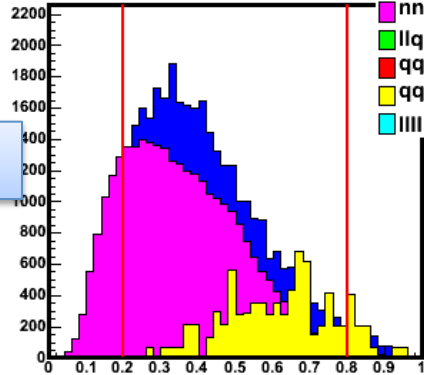


Y12(-)

0.2

0.8

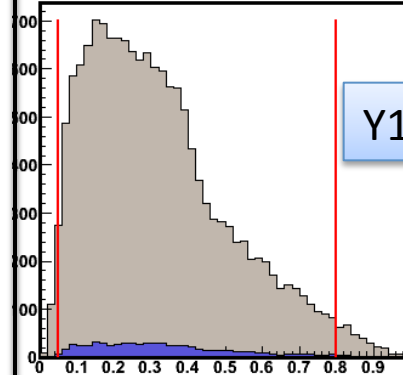
hj1yminus



- nlqq
- nnqq
- llqq
- qqqq
- qq
- llll

350 GeV

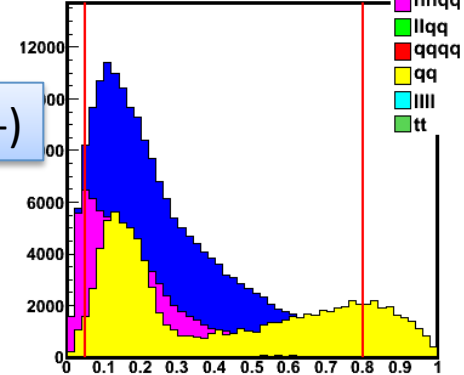
hj1yminus



Y12(-)

0.05

hj1yminus



- nlqq
- nnqq
- llqq
- qqqq
- qq
- llll
- tt

# BG reduction summary (vvH)

250 GeV	No cuts	MM	Pt	PI	nchdtrk	Pmax	Y+	Y-	Mh	Eff.
H→cc	698	635	567	553	547	476	344	329	315	45.20%
H→bb	12904	11521	10282	10014	9955	9123	6801	6510	5863	45.44%
ZH→vvH all	19124	15448	13730	13336	12920	11741	7807	7471	6731	35.20%
SM Bkg	44827141	6214068	549361	392398	374863	204988	74393	62505	19059	0.04%
$S_{cc}/\sqrt{B}$	0.10	0.25	0.76	0.88	0.89	1.05	1.26	1.31	2.28	
$S_{bb}/\sqrt{B}$	1.93	4.62	13.87	15.99	16.26	20.15	24.93	26.04	42.47	

350 GeV	No cuts	MM	Pt	PI	nchdtrk	Pmax	Y+	Y-	Mh	Eff.
H→cc	930	917	892	892	878	845	678	478	442	47.59%
H→bb	17604	17298	16870	16870	16752	16291	12915	8721	7425	42.18%
ZH→vvH all	25990	23897	23303	23303	21895	21172	15447	10275	8708	33.51%
SM Bkg	18102000	4822840	1727390	1706180	1619980	973874	475892	181206	20071	0.11%
$S_{cc}/\sqrt{B}$	0.22	0.42	0.68	0.68	0.69	0.86	0.98	1.12	3.12	
$S_{bb}/\sqrt{B}$	4.14	7.88	12.84	12.92	13.16	16.51	18.72	20.49	52.41	

Better significance is achieved at  $E_{cm}=350$  GeV



# Relative BR comparison

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

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

Efficiency	Ecm=250 GeV		Ecm=350 GeV	
mode	neutrino	hadron	neutrino	hadron
e <sub>bb</sub>	45.5%	39.0%	47.6%	31.7%
e <sub>cc</sub>	45.2%	41.9%	42.2%	35.4%

Fitted results	Ecm=250 GeV		Ecm=350 GeV	
mode	neutrino	hadron	neutrino	hadron
rbb	0.871+-0.008	0.774+-0.013	0.853+-0.007	0.788+-0.009
rcc	0.0470+-0.004	0.046+-0.005	0.051+-0.003	0.047+-0.003
BR(cc)/BR(bb)	0.054+-0.004	0.055+-0.006	0.053+-0.003	0.054+-0.003
$\Delta$ BR(cc)/BR(bb)	7.75%	10.15%	5.87%	6.48%

Consider template fitting stability (Statistics)

**Very preliminary result**

# IIH study

# Electron/Muon identification

## Lepton ID

Lepton identification at 250 GeV

- Isolated lepton track
  - ConeE < 20 GeV (cone angle < 10°)
- High momentum lepton track
  - $10 < E_{\text{PFO}} < 90 \text{ GeV} \rightarrow 10 < E_{\text{PFO}} < 160 \text{ GeV}$  for 350 GeV

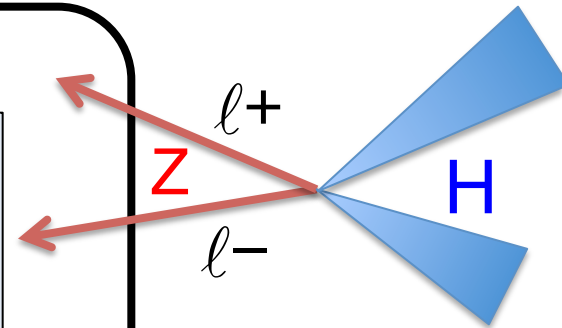
## Electron ID

- $E_{\text{Ecal}}/E_{\text{Total}} > 0.9$
- $0.7 < E_{\text{Total}}/P < 1.2$

## Muon ID

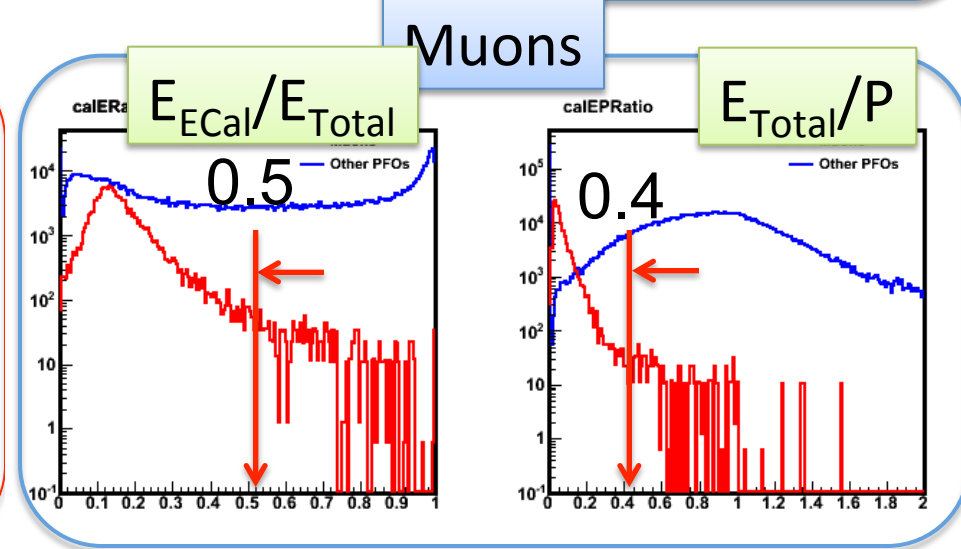
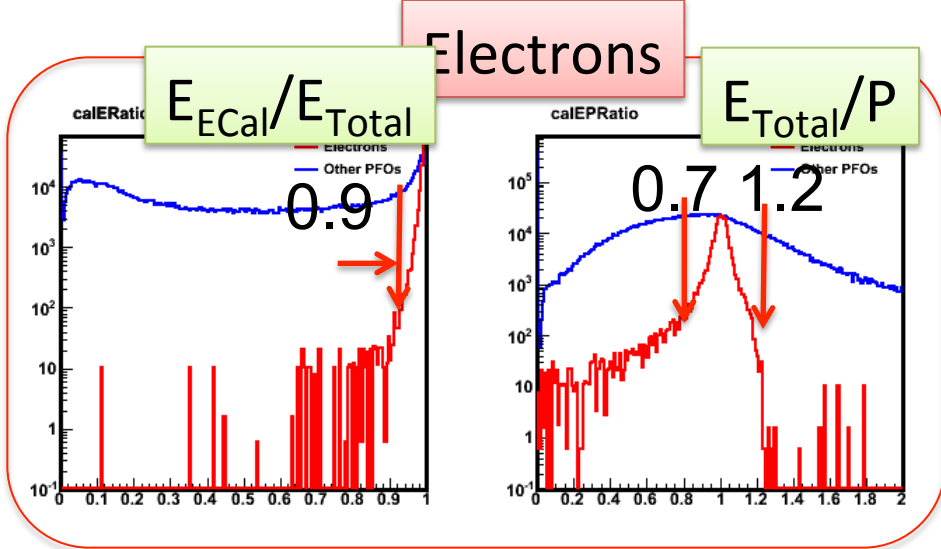
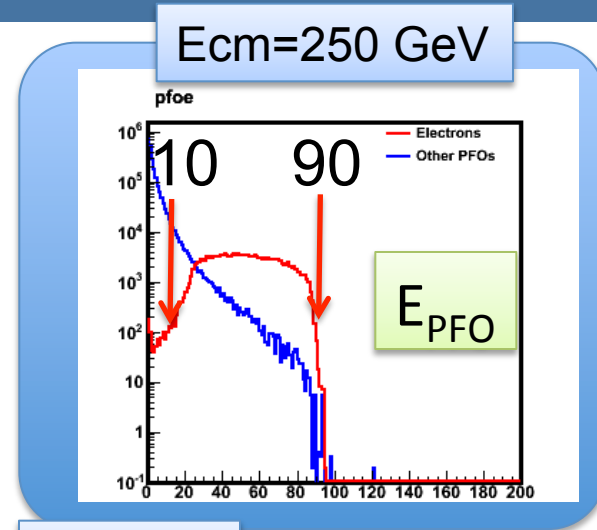
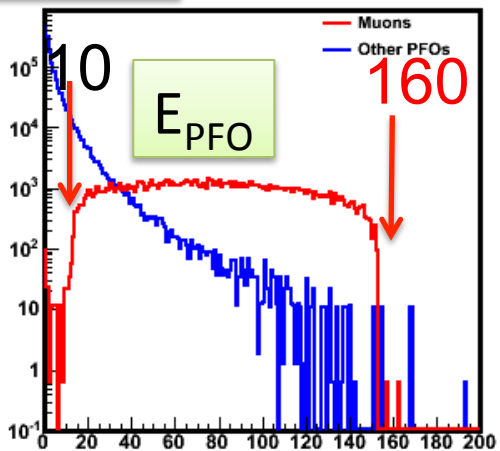
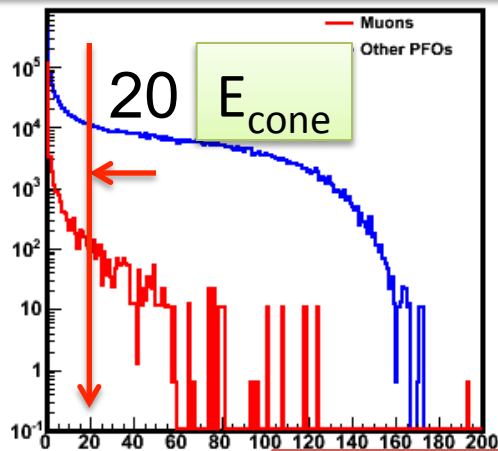
- $E_{\text{Ecal}}/E_{\text{Total}} < 0.5$
- $E_{\text{Total}}/P < 0.4$

Energy deposit fraction in ECal



# Lepton identification at 350 GeV

First require charged PFOs



# Electron/Muon ID performance

Refer with the recoil mass study ID in LOI

Electron ID

$$E_{\text{ECal}}/E_{\text{total}} > 0.6$$
$$E_{\text{total}}/P > 0.9$$

Muon ID

$$E_{\text{ECal}}/E_{\text{total}} < 0.5$$
$$E_{\text{total}}/P < 0.3$$

Efficiency	Electron	Muon
Ecm=250 GeV	93.3%	95.7%
Ecm=350 GeV	93.1%	96.7%
Recoil mass 250 GeV	98.8 %	95.4 %

Muon ID looks consistent, electron case have small difference from the different selection criteria? → Try with same criteria

# Luminosity consideration

# Peak luminosity dependence

Reference value :  $L_{\text{peak}}=2.0 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$ ,  $L_{\text{int}}=500 \text{fb}^{-1}$  at RDR 500 GeV

	RDR (LOI)			SB2009 w/ TF			NB w/TF		
Ecm (GeV)	250	350	500	250	350	500	250	350	500
Peak L ( $10^{34} \text{cm}^{-2}\text{s}^{-1}$ )	0.75	1.2	2.0	0.27	1.0	2.0	0.8	1.0	2.0
Integrated L ( $\text{fb}^{-1}$ )	187.5	300	500	67.5	250	500	200	250	500

NB : New baseline parameter

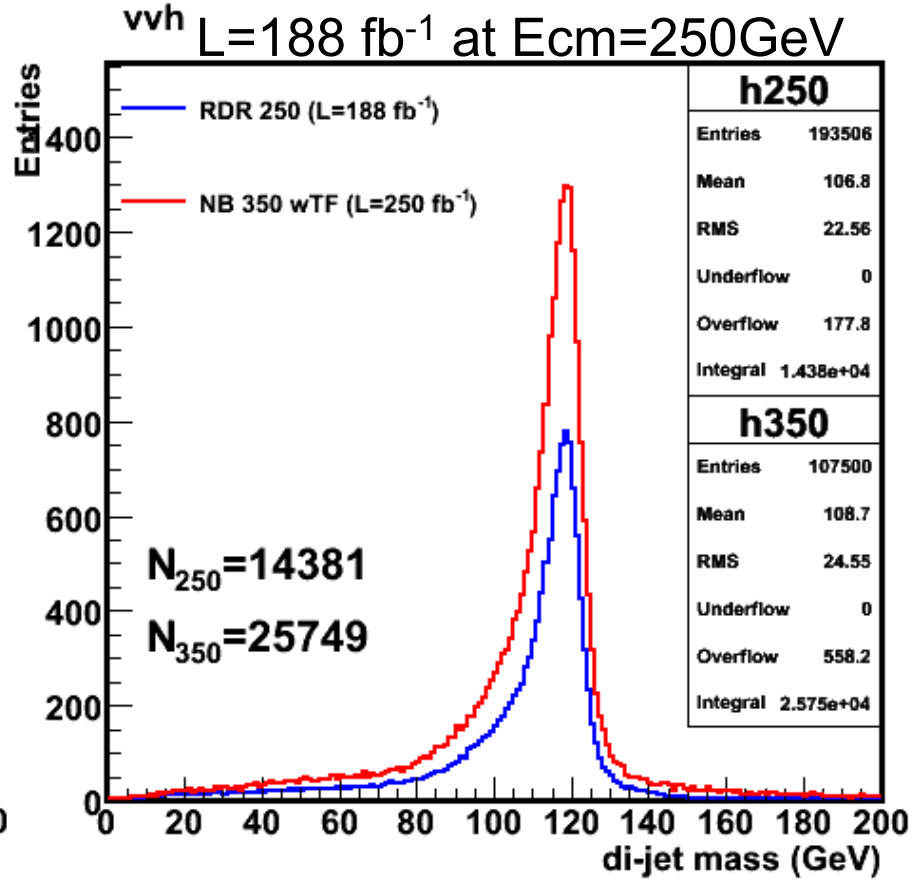
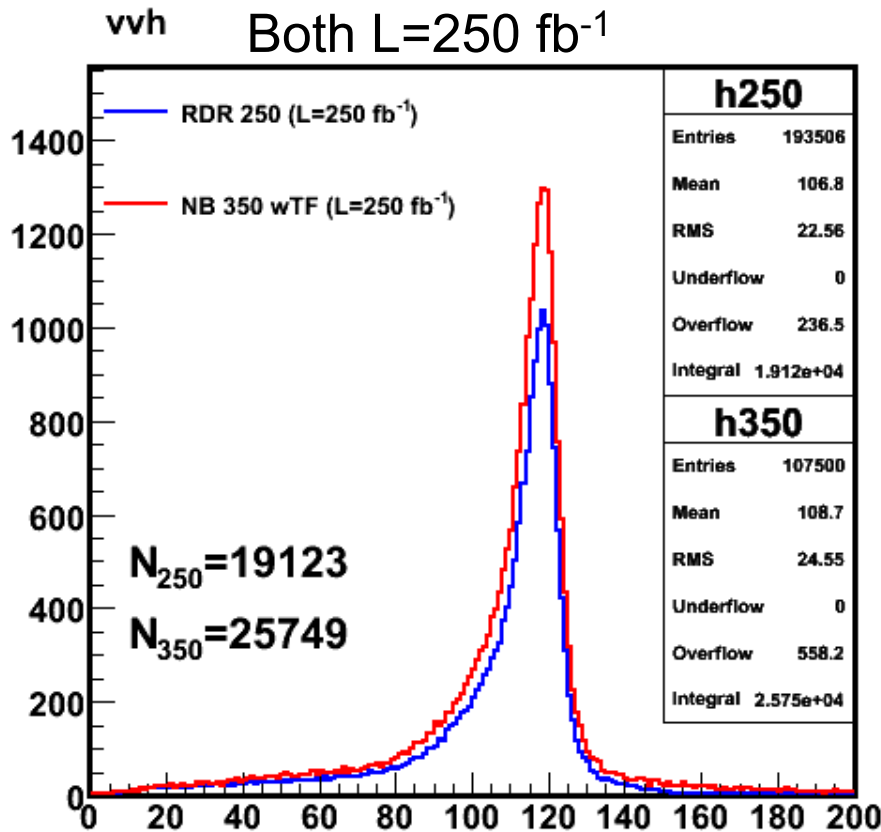
Production cross section with beam polarization ( $e^+,e^-$ )=(+30%, -80%)

Cross section	250 GeV	350 GeV
vvH	77.44 fb	105.23 fb
qqH	210.03 fb	144.40 fb
llH (eeH/ $\mu\mu$ H/ $\tau\tau$ H)	34.60 fb (12.55/11.66/10.39 fb)	25.25 fb (10.96/7.16/7.14 fb)

t-channel diagram  
is also included

# vvH sample luminosity comparison

Higgs candidate di-jet mass distribution without selection criteria

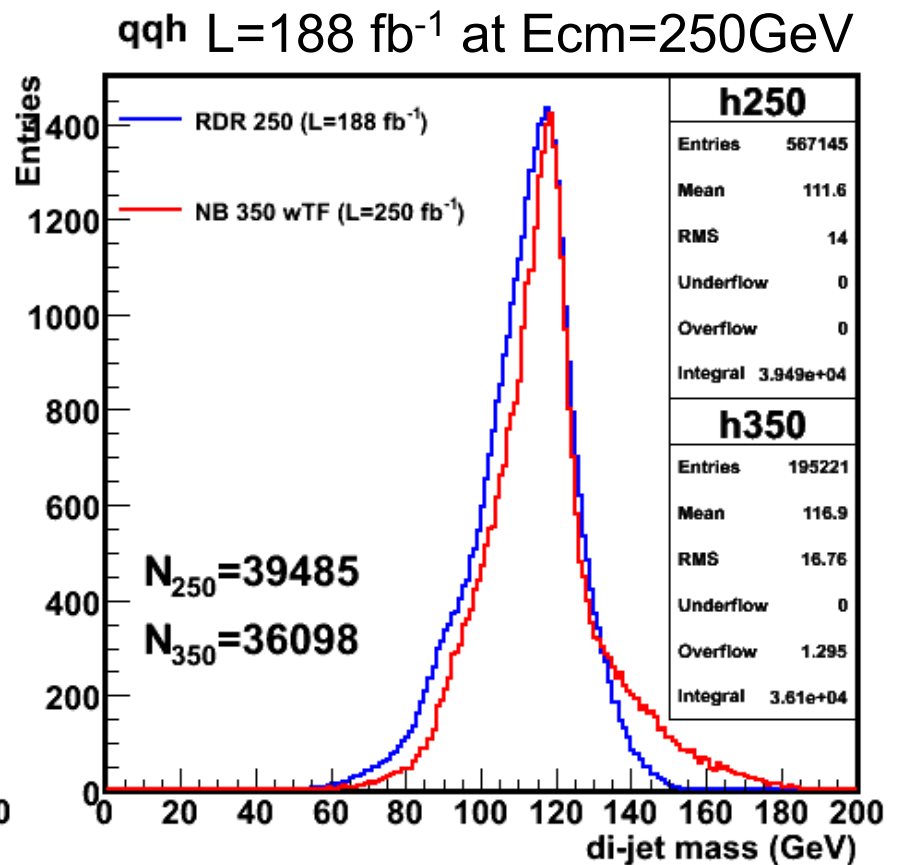
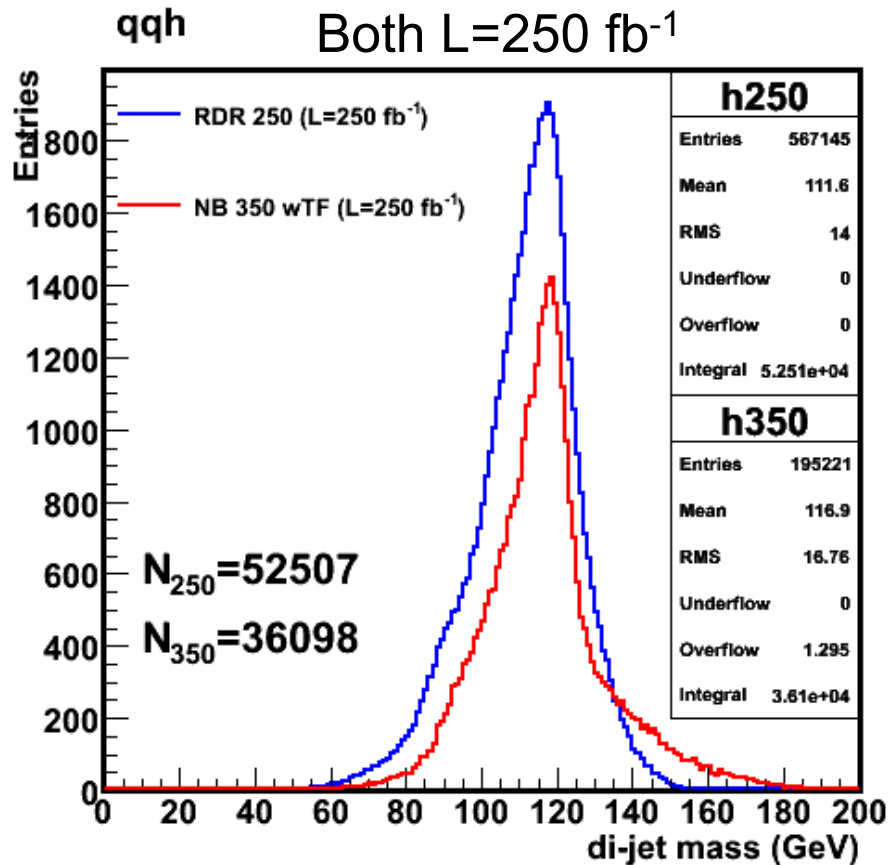


Without any selections. Difference becomes large because of increasing the t-channel contribution at 350 GeV (Larger x-sec)



# qqH sample luminosity comparison

Higgs candidate di-jet mass distribution without selection criteria



IIH analysis is still on-going, next compare with recoil mass distribution

# Next step

- IIH mode will proceed to BR accuracy study
- Analyze BR accuracy including luminosity difference between 250 and 350 GeV

# Backup

# BG reduction ( $ZH \rightarrow \nu\nu H$ , 250 GeV)

250 GeV	No cuts	MM	Pt	PI	nchdtrk	Pmax	Y+	Y-	Mh	Eff.
$H \rightarrow cc$	698	635	567	553	547	476	344	329	315	45.20%
$H \rightarrow bb$	12904	11521	10282	10014	9955	9123	6801	6510	5863	45.44%
$\nu\nu H$ all	19124	15448	13730	13336	12920	11741	7807	7471	6731	35.20%
qqqq	4048390	3889	140	137	137	126	2	2	1	0.11%
qq	35353300	5488020	48578	15128	14913	10671	8048	7019	2475	19.18%
nlqq	4114190	560258	410528	323540	309618	153727	36918	31571	12760	66.73%
llqq	398320	10980	2964	2687	2607	1917	373	339	228	35.93%
nnqq	149979	124840	85775	49749	47584	38545	29052	23573	3594	31.20%
llll	762962	26082	1376	1156	4	2	1	1	0	0.00%
SM Bkg	44827141	6214068	549361	392398	374863	204988	74393	62505	19059	0.04%
$S_{cc}/\nu B$	0.2	0.7	0.8	0.9	0.9	1.1	1.3	1.4	2.4	
$S_{bb}/\nu B$	4.2	13.5	14.5	16.3	16.6	20.7	26.4	27.6	45.5	

# BG reduction ( $ZH \rightarrow \nu\nu H$ , 350 GeV)

350 GeV	No cuts	MM	Pt	P	nchdtrk	Pmax	Y+	Y-	Mh	Eff.
H $\rightarrow$ cc	930	917	892	892	878	845	678	478	442	47.59%
H $\rightarrow$ bb	17604	17298	16870	16870	16752	16291	12915	8721	7425	42.18%
$\nu\nu H$ all	25990	23897	23303	23303	21895	21172	15447	10275	8708	33.51%
qqqq	3094510	105289	14939	14939	14939	13347	1498	871	5	0.00%
qq	9632260	2943540	199590	188661	182420	154830	131999	48260	3269	0.03%
tt	166459	52002	50641	50641	50443	44176	1726	1311	210	0.13%
nlqq	3343170	1377330	1306440	1298210	1235490	638976	240865	96615	12545	0.38%
llqq	468340	47674	15421	15305	14632	10316	2445	1381	207	0.04%
nnqq	151150	139791	131615	129852	122032	112223	97356	32767	3834	2.54%
llll	1246160	157213	8750	8572	23	6	3	1	1	0.00%
SM Bkg	18102000	4822840	1727390	1706180	1619980	973874	475892	181206	20071	0.11%
Scc/sqrt(B)	0.22	0.42	0.68	0.68	0.69	0.86	0.98	1.12	3.12	
Sbb/sqrt(B)	4.14	7.88	12.84	12.92	13.16	16.51	18.72	20.49	52.41	

# BG reduction ( $ZH \rightarrow qqH$ , 350 GeV)

350 GeV	No cuts	chi2	nTracks	$-\text{Log}(Y_{34})$	thrust	$\cos\theta$	$\theta_H$	Mh	Eff.
$H \rightarrow cc$	1296	899	672	652	599	553	516	460	35.50%
$H \rightarrow bb$	24051	14919	11589	11275	10410	9636	8811	7623	31.70%
qqH all	36099	20203	14905	14546	13524	12523	11191	9675	26.80%
qqqq	3094510	322790	179720	167952	85560	54839	39092	27214	0.88%
qq	9631930	463312	93869	51746	29232	25431	20666	14562	0.15%
tt	166459	49314	29138	29096	28832	25962	17568	5428	3.26%
nlqq	3343060	81620	638	489	350	270	158	43	0.00%
llqq	468202	33186	235	173	90	74	51	28	0.01%
nnqq	119416	142	35	16	9	9	2	0	0.00%
llll	1074390	22722	0	0	0	0	0	0	0.00%
SM Bkg	17898000	973086	303634	249472	144073	106586	77537	47274	0.26%
$S_{cc}/\sqrt{B}$	0.31	0.91	1.22	1.30	1.58	1.69	1.85	2.12	
$S_{bb}/\sqrt{B}$	5.69	15.12	21.03	22.57	27.43	29.52	31.64	35.06	

# BG reduction ( $ZH \rightarrow qqH$ , 250 GeV)

250 GeV	No cuts	chi2	nTracks	$-\text{Log}(Y_{34})$	thrust	$\cos\theta$	$\theta_H$	Mh	Eff.
$H \rightarrow cc$	1916	1460	1114	1102	1081	963	890	804	41.95%
$H \rightarrow bb$	34963	24568	19542	19351	19013	16854	15488	13651	39.04%
qqH all	52507	32430	25252	25037	24656	21856	20041	17617	33.55%
qqqq	4048390	1299950	824215	818221	814909	591276	533302	430869	10.64%
qq	35353100	1220310	296152	183403	120560	104502	88475	73790	0.21%
nlqq	4114190	25981	119	112	94	83	59	18	0.00%
llqq	398319	42195	307	274	225	165	139	111	0.03%
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	1.13%
Scc/sqrt(B)	0.05	0.31	1.05	1.10	1.12	1.15	1.13	1.13	
Sbb/sqrt(B)	0.86	5.27	18.46	19.33	19.65	20.20	19.64	19.21	

# BG reduction (qqH) $L=250\text{fb}^{-1}$

250 GeV	No cuts	chi2	nTracks	$-\text{Log}(Y34)$	thrust	$\cos\theta$	$\theta_H$	Mh	Eff.
H $\rightarrow$ cc	1916	1460	1114	1102	1081	963	890	804	41.95%
H $\rightarrow$ bb	34963	24568	19542	19351	19013	16854	15488	13651	39.04%
qqH all	52507	32430	25252	25037	24656	21856	20041	17617	33.55%
SM Bkg	44825201	2608604	1120793	1002011	935788	696026	621975	504788	1.13%
Scc/sqrt(B)	0.05	0.31	1.05	1.10	1.12	1.15	1.13	1.13	
Sbb/sqrt(B)	0.86	5.27	18.46	19.33	19.65	20.20	19.64	19.21	

350 GeV	No cuts	chi2	nTracks	$-\text{Log}(Y34)$	thrust	$\cos\theta$	$\theta_H$	Mh	Eff.
H $\rightarrow$ cc	1296	899	672	652	599	553	516	460	35.50%
H $\rightarrow$ bb	24051	14919	11589	11275	10410	9636	8811	7623	31.70%
qqH all	36099	20203	14905	14546	13524	12523	11191	9675	26.80%
SM Bkg	17898000	973086	303634	249472	144073	106586	77537	47274	0.26%
Scc/sqrt(B)	0.31	0.91	1.22	1.30	1.58	1.69	1.85	2.12	
Sbb/sqrt(B)	5.69	15.12	21.03	22.57	27.43	29.52	31.64	35.06	