

# Higgs Branching Fraction study

KILC 2012 ACFA physics session

Apr. 24. 2012, Daegu, Korea

H. Ono (NDU)

# Higgs physics tasks for ILC

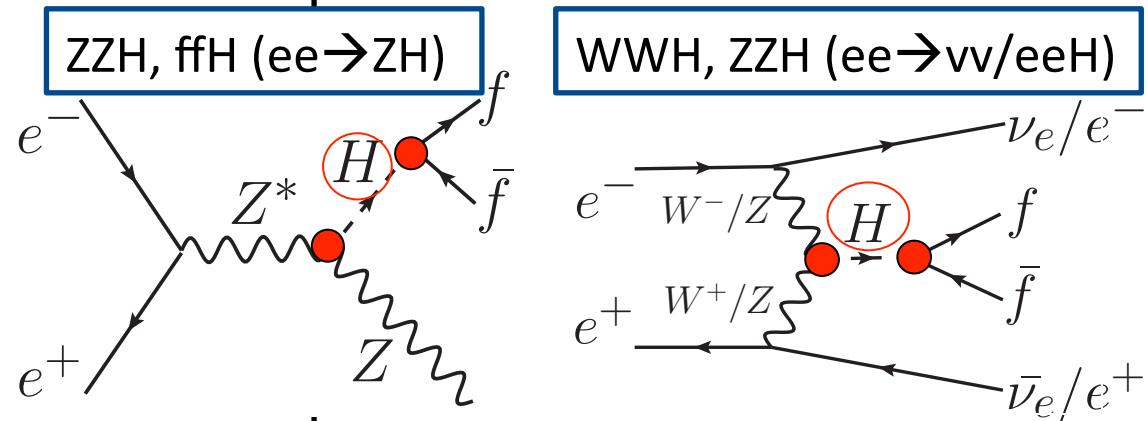
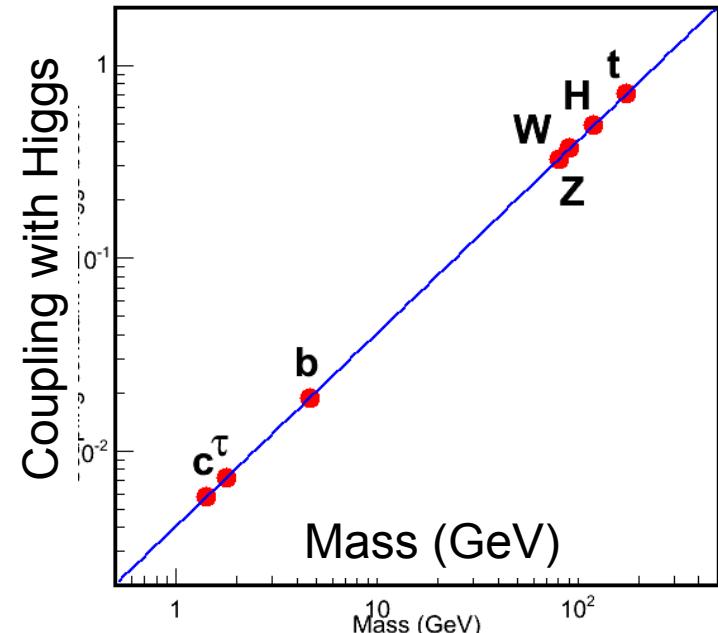
Higgs coupling with each particle

- ffH ( $t\bar{t}H$ ): Branching fraction  
 $\text{Br}(H \rightarrow f\bar{f}) \propto (g_{ffH})^2$
- WWH, ZZH: BR, W/Z-fusion
- HHH: Self coupling

Higgs properties to ID as “Higgs”

- Mass
- Spin
- CP
- Natural width
- ...

Update coupling precision



# Current Higgs physics situation

- LHC results indicate the light Higgs ( $M_H \sim 125$  GeV)
  - Focusing on the light Higgs analysis ( $M_H = 120$  GeV in LOI)
  - Increase the possibility to start ILC from  $E_{cm} \sim 250$  GeV  
Physics thresholds:  $250(ZH) \rightarrow 350(t\bar{t}) \rightarrow 500(ZHH, t\bar{t}H) \rightarrow 1$  TeV
- DBD Higgs physics study
  - $\nu\nu H \sigma x BR$  study is listed as benchmark process ( $\nu\nu H @ 1$  TeV)
  - $t\bar{t}H$  (1 TeV) and  $HHH$  (500 GeV) is also included
  - Also include all Higgs properties study for “physics chapter”
    - Compile current results from LOI and post into RDR results

# Higgs physics status table

Analysis	Observable	Physics	Energy	Status	Results	Assing and schedules
Mh	Mass	Mass	250 GeV	LOI, $Z \rightarrow ll$ recoil	30 MeV	new beam pram at 250 GeV
Total width	WWH, Br(WW*)	Total width	500 GeV	vvH (fusion) WWH	5%	Tian
spin	angular distribution	Spin		not yet		
spin	sigma_ZH(E), all ZH, $H \rightarrow bb$	Spin	210~250 (2 points)	need calculation	RDR	Scale from 250 GeV
CP	angular distribution	CP		RDR, not yet	RDR	
CP	sigma_tot	CP	250 GeV	need calculation	RDR	Ono
$Z \rightarrow ll$ recoil	Mh, sigma_ZH	ZZH coupling, Mh	250 GeV	LOI	2.5%	Tian Include ZH/eeH @500 GeV
$Z \rightarrow qq$ recoil	Mh, sigma_ZH	ZZH coupling, Mh	250 GeV	not yet		
Br(bb)	Branch	Yukawa coupling ffH	250, 350, 500, 1TeV	prepare publish (250,350), DBD	2.7%, 2.7%	Ono, publish 2012.04
Br(cc)	Branch	Yukawa coupling ffH	250, 350, 500, 1TeV	prepare publish (250,350), DBD	8.1%, 7.3%	Ono, publish 2012.04
Br(gg)	Branch	Loop coupling, NP in loop	250, 350, 500, 1TeV	prepare publish (250,350), DBD	9.1%, 7.9%	Ono, publish 2012.04
Br( $\tau\tau$ )	Branch	Yukawa coupling ffH	250, 500, 1TeV	RDR, not yet		Find somebody
Br( $\mu\mu$ )	Branch	Yukawa coupling ffH	250, 500, 1TeV	not yet, DBD		Calancha
Br(WW*)	Branch	WWH coupling, Spin	250, 500, 1TeV	qqqq (250) done, lvqq (250) on going DBD	13.4%	Ono, ACFA 2012.04
Br(ZZ*)	Branch	ZZH coupling, spin	250, 500, 1TeV	stand by (250)		Ono
Br( $Z\gamma$ )	Branch	Loop coupling	250, 500, 1TeV	stand by (250)		Calancha
Br( $\gamma\gamma$ )	Branch	Loop coupling	250, 500, 1TeV	on going (250)		Calancha, ACFA 2012.04
ZHH	sigma_ZHH	Self coupling	500 GeV	LOI, DBD, prepare publish	57%	Tian, Suehara
ttH	sigma_ttH	Yukawa coupling ffH	500, 1TeV	LOI, published, DBD	11%	Yonamine, Tanabe
vv/eeH (fusion)	sigma_vv/eeH	WWH, ZZH coupling	500 GeV	on going		Tian
tt	sigma_tt	Yukawa ttH (Higgs exchange)	350 GeV	not yet		Rohman

# BR study status table

Ecm	250 GeV				1 TeV		
$\sigma$ (fb)	354.1 fb				465.5 fb		
H decay	BR	$\sigma \times BR$	$250 \text{ fb}^{-1}$	$\Delta BR/BR$	$\sigma \times BR$	$1 \text{ ab}^{-1}$	$\Delta \sigma BR/\sigma BR$
$H \rightarrow bb$	64.1%	227.1	56777	2.7%	298.6	298552	Ono
$H \rightarrow cc$	3.1%	10.8	2703	8.1%	14.2	14211	Ono
$H \rightarrow gg$	7.0%	24.9	6225	9.0%	32.7	32733	Ono
$H \rightarrow WW^*$	15.0%	53.1	13286	Ono	69.9	69860	Ono
$H \rightarrow \mu\mu$	0.03%	0.11	28	Ono	0.15	149	Ono
$H \rightarrow \tau\tau$	8.7%	30.9	7727	TBD	40.6	40632	
$H \rightarrow ZZ^*$	1.7%	24.6	1516	Ono	8.0	7969	
$H \rightarrow \gamma\gamma$	0.27%	0.95	236	Tino	1.2	1243	
$H \rightarrow Z\gamma$	0.13%	0.45	112	Tino	0.6	591	

LOI and post  
(LCWS11)  
 $E_{cm}=250 \text{ GeV}$   
 $L=250 \text{ fb}^{-1}$   
 $P(e+, e-)=(0.3, 0.8)$

DBD  
 $E_{cm}=1 \text{ TeV}$   
 $L=1 \text{ ab}^{-1}$   
 $P(e+, e-)=(0.3, 0.8)$

Assuming  
 $\Delta \sigma/\sigma_{ZH}=2.5\%$   
 $H \rightarrow \tau\tau$  is lacking now  
 $H \rightarrow WW^*$  in this talk

$H \rightarrow WW^*$  study

# $H \rightarrow WW^*$ branching fraction analysis

$E_{cm}=250$  GeV,  $L=250$  fb $^{-1}$ ,  $\text{Pol}(e^+, e^-)=(-0.3, +0.8)$  LOI samples

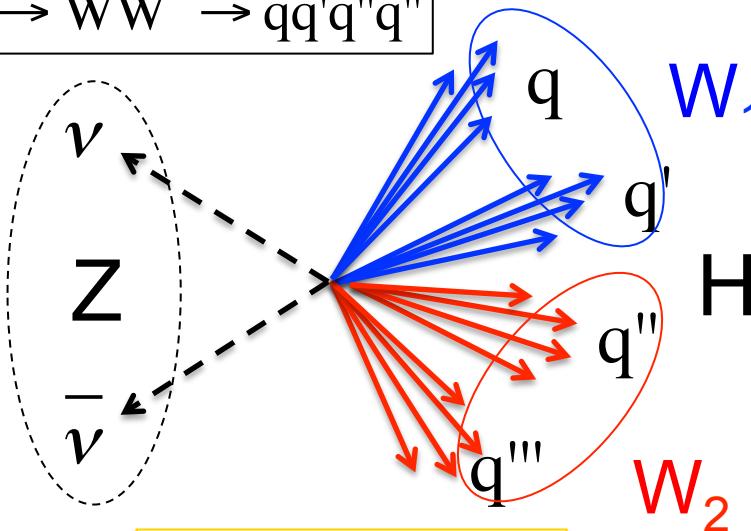
→ Adopt electron right handed pol. to suppress WW background

$ZH \rightarrow vvH \rightarrow vvWW^*$ ,  $WW^* \rightarrow qqqq$  (hadronic decay)

$ZH \rightarrow qqH \rightarrow qqWW^*$ ,  $WW^* \rightarrow l\nu qq$  (semi-leptonic decay)

$$e^+e^- \rightarrow \nu_e \bar{\nu}_e H$$

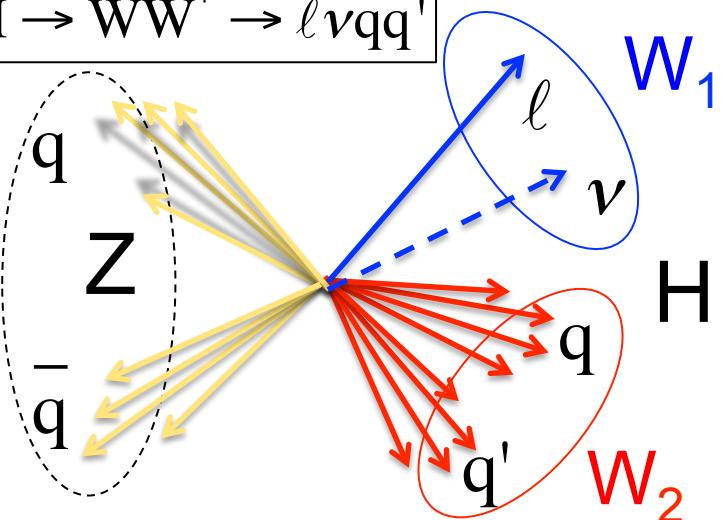
$$H \rightarrow WW^* \rightarrow qq'q''q'''$$



4 jet final state

$$e^+e^- \rightarrow q\bar{q}H$$

$$H \rightarrow WW^* \rightarrow \ell\nu qq'$$



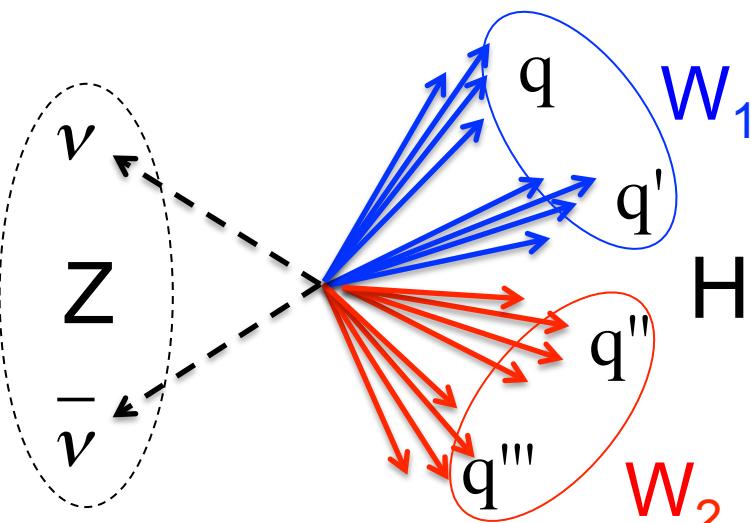
lepton + 4 jet final state

# 1. $\text{vvH} \rightarrow \text{vvWW}^* \rightarrow \text{vv} + \text{qqqq}$

$$e^+ e^- \rightarrow \nu_e \bar{\nu}_e H$$

$$H \rightarrow WW^* \rightarrow qq'q''q'''$$

1. Apply forced four-jets clustering
2. Require one on-shell W and  
4 jets consistent with Higgs
3. Minimum  $\chi^2$  pair as best candidate

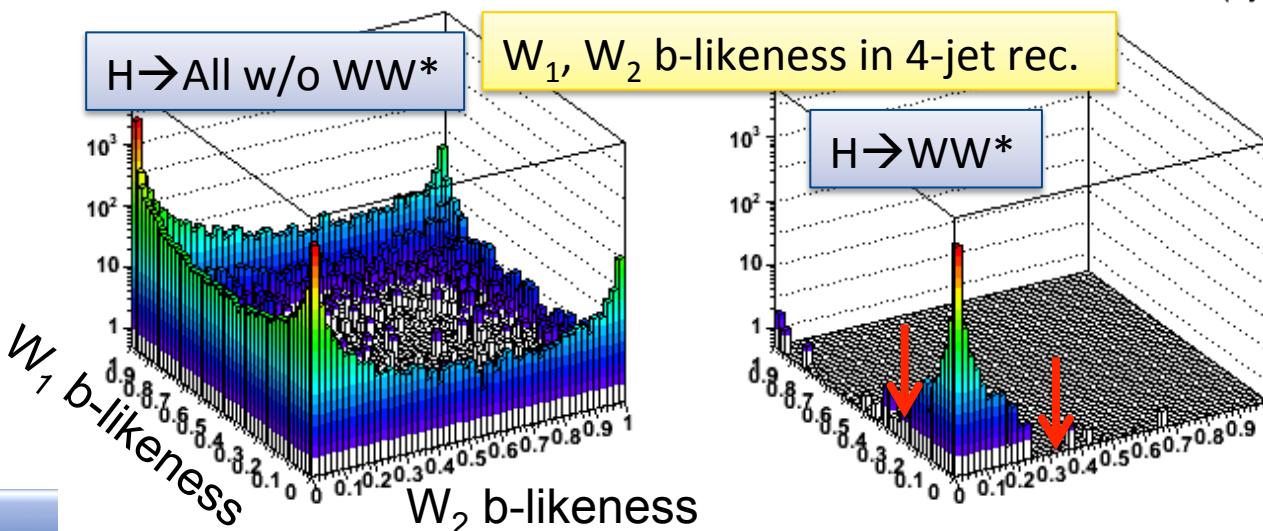
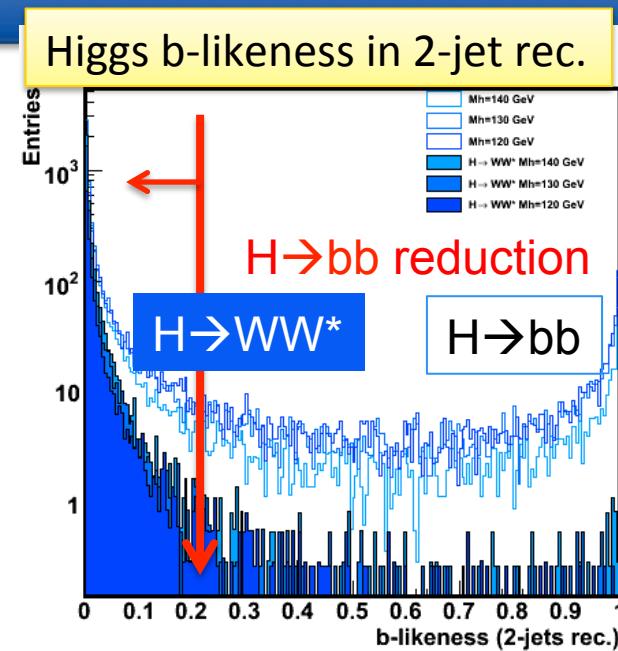
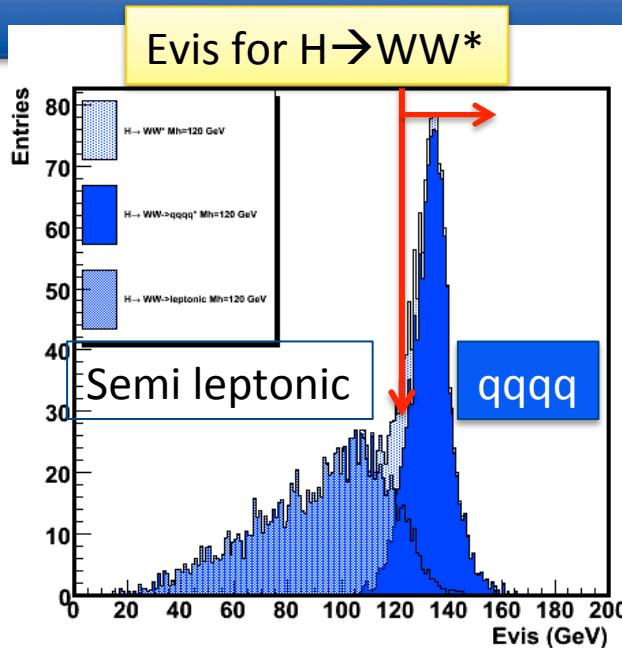


4 jet final state

$$\chi^2 = \left( \frac{M_W^{\text{Rec}} - M_W}{\sigma_W} \right)^2 + \left( \frac{M_H^{\text{Rec}} - M_H}{\sigma_H} \right)^2$$

Main background  
 $H \rightarrow bb, WW, ZZ$

# Event selection of $H \rightarrow WW^* \rightarrow qqqq$



$H \rightarrow bb$  becomes BG.  
Need to suppress them  
with flavor information

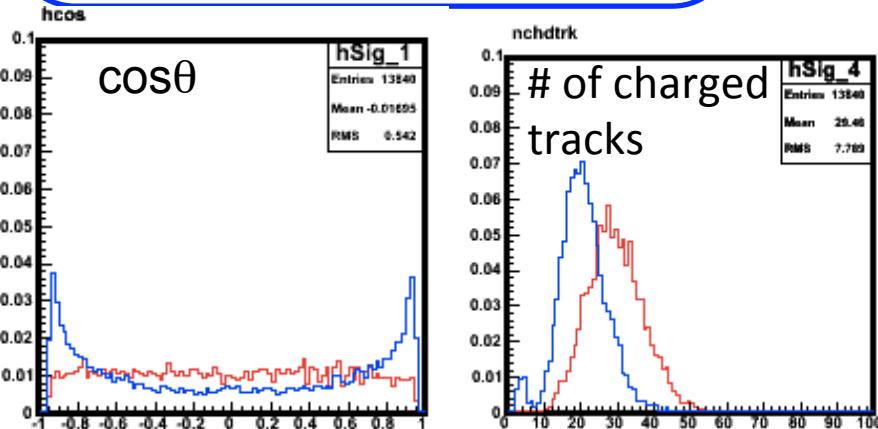
$$x\text{-likeness} = x_1 x_2 / (1-x_1)(1-x_2)$$

$x_{1,2}$ : flavor tagging output

# BG reduction of $\text{vvH} \rightarrow \text{vvWW}^* \rightarrow \text{vv} + \text{qqqq}$

## Selection criteria

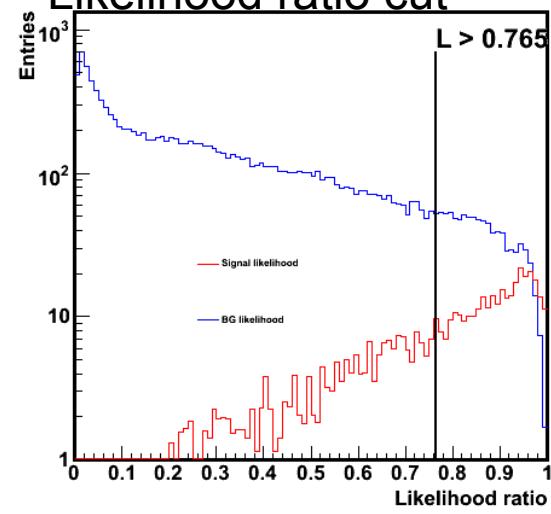
1.  $E_{\text{vis}} < 120 \text{ GeV}$
2.  $110 < M_H < 130 \text{ GeV}$
3.  $70 < M_{\text{miss}} < 140 \text{ GeV}$
4.  $Y_{12} > 0.0005$
5.  $|\cos\theta_h| < 0.95$
6.  $\text{Max } E_{\text{trk}} < 30 \text{ GeV}$
7.  $W_1/W_2 \text{ b-likeness} < 0.2$
8.  $\text{b-likeness (2j)} < 0.2$
9. likelihood  $> 0.7$



## Likelihood input variable

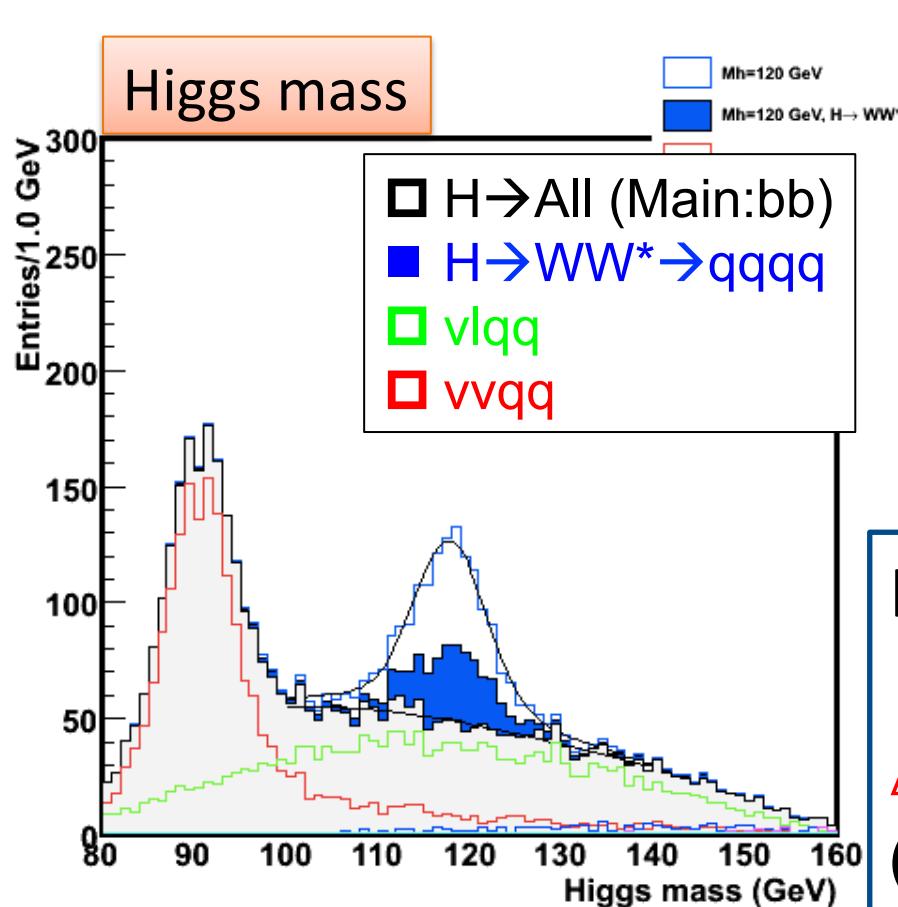
1. Missing mass
2.  $\cos\theta_h$
3.  $W_{11} Y_{34}$
4.  $W_1 \text{ b-likeness}$
5. # of charged tracks

## Likelihood ratio cut



# Relative accuracy of $\text{BR}(\text{H} \rightarrow \text{WW}^* \rightarrow \text{qqqq})$

$E_{\text{cm}}=250 \text{ GeV}$ ,  $L=250 \text{ fb}^{-1}$ ,  $P(e^+, e^-)=(-30\%, +80\%)$ ,  $M_H=120 \text{ GeV}$



	Gen	All cut
WW → qqqq	678	367
vvbb	7101	128
ZH all	10634	915
SM all	1938270	1361
Significance	0.49	7.7

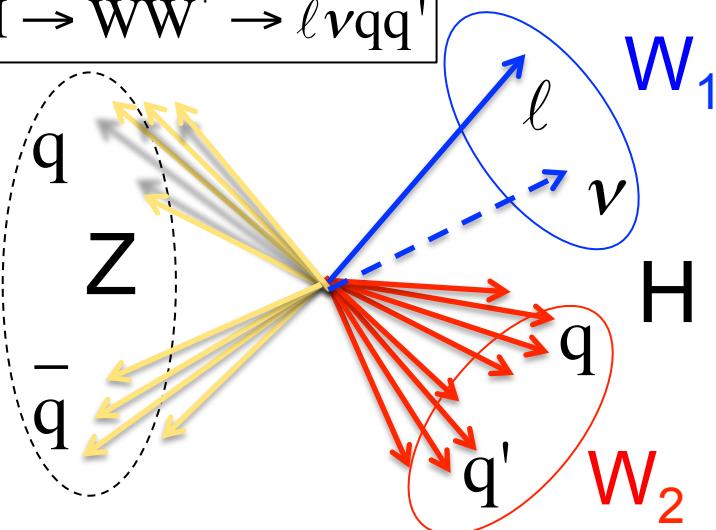
$\text{H} \rightarrow \text{bb}, \text{vlqq}$  remain as BG

$\Delta \text{BR}/\text{BR}(\text{H} \rightarrow \text{WW}^* \rightarrow \text{qqqq}) = 13.2\%$   
 $(\Delta \sigma/\sigma = 2.5\% \text{ } (\sigma_{\text{ZH}} \text{ uncertainty}))$

## 2. $qqH \rightarrow qqWW^* \rightarrow qq + l\nu qq'$

$$e^+ e^- \rightarrow q\bar{q}H$$

$$H \rightarrow WW^* \rightarrow \ell\nu qq'$$



lepton + 4 jet final state

$$\begin{aligned} q_H &= q_{WW} = q_{cm} - q_Z \\ q_{mis} &= q_{cm} - q_{all} \\ q_{W \rightarrow l\nu} &= q_{mis} + q_l \end{aligned}$$

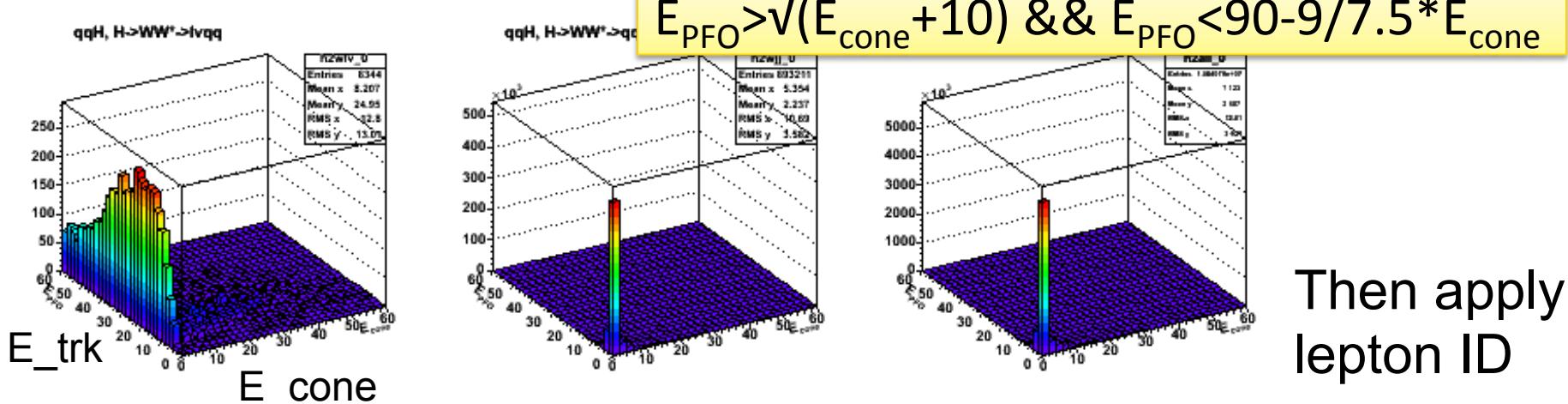
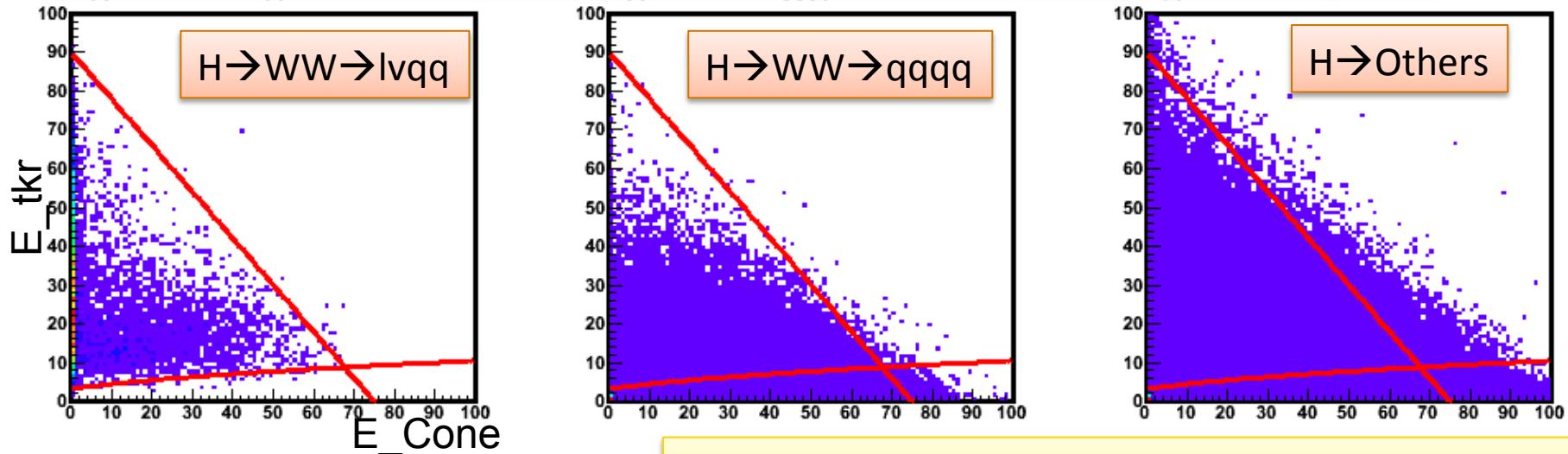
1. Find one-isolated lepton
  1. Isolated track finding
  2. lepton identification
2. Remove one-isolated lepton
3. Four-jets clustering to remaining  $s$   
One on-shell  $W$  ( $W \rightarrow l\nu$ ,  $W \rightarrow qq$ )  
 $M_{jj} \sim M_Z$  and  $M_{4j} \sim M_H$
4. Minimum  $\chi^2$  combination ( $\chi^2_{l\nu}$ ,  $\chi^2_{qq}$ )

$$\chi^2_{l\nu} = \left( \frac{M_{jj} - M_Z}{\sigma_Z} \right)^2 + \left( \frac{M_{W \rightarrow l\nu} - M_W}{3\sigma_W} \right)^2 + \left( \frac{M_{\ell\nu jj} - M_H}{\sigma_H} \right)^2$$

$$\chi^2_{jj} = \left( \frac{M_{jj} - M_Z}{\sigma_Z} \right)^2 + \left( \frac{M_{W \rightarrow jj} - M_W}{\sigma_W} \right)^2 + \left( \frac{M_{\ell\nu jj} - M_H}{\sigma_H} \right)^2$$

# Find one-isolated lepton for $W \rightarrow l\nu$

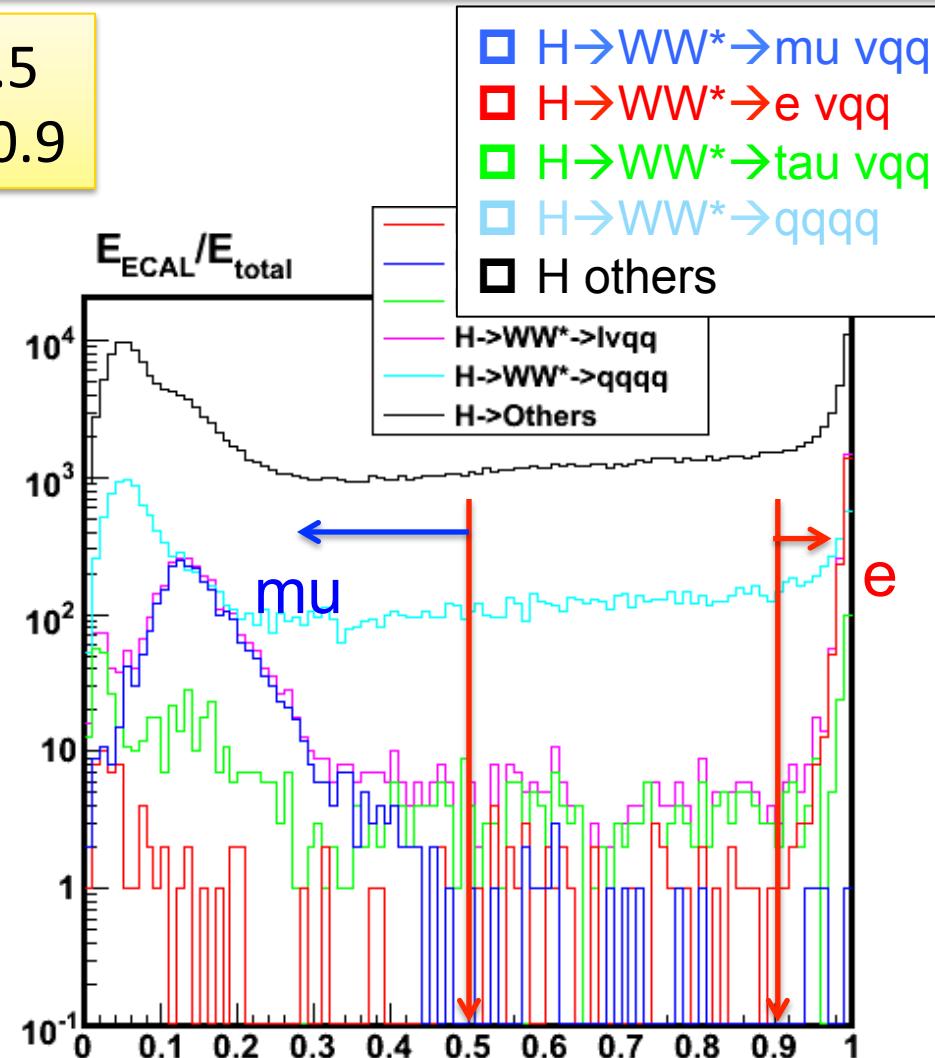
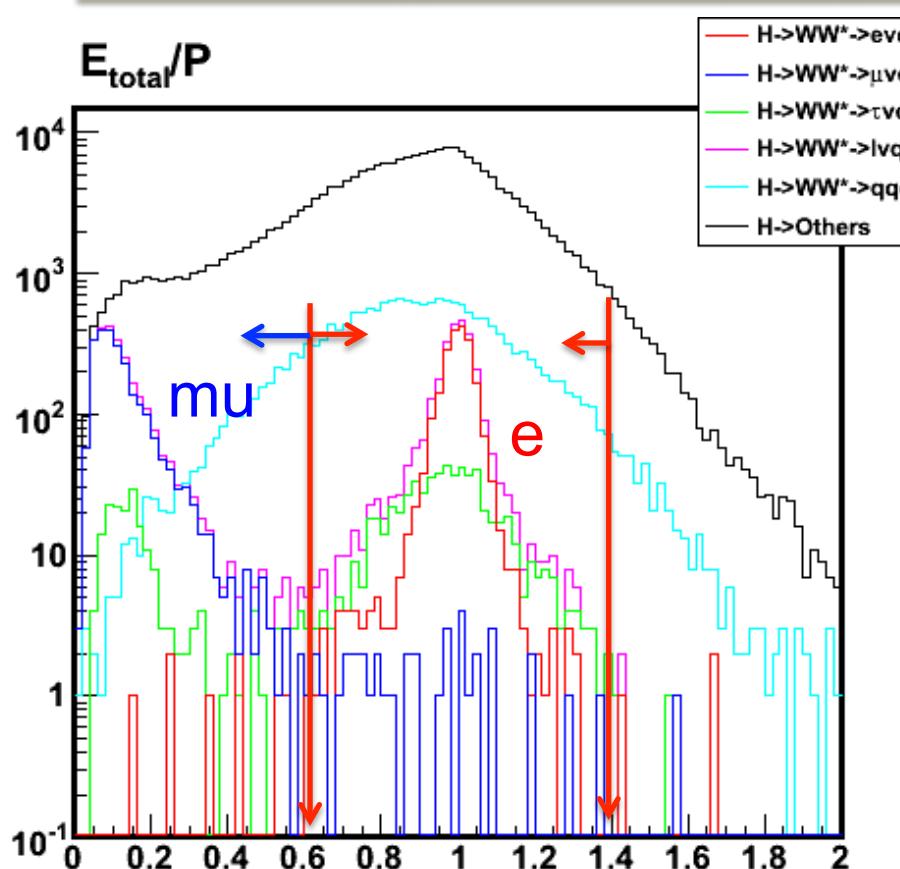
Find isolated lepton from charged tracks ( $E_{\text{trk}}$  vs  $E_{\text{cone}(5 \text{ degree})}$ )



Then apply  
lepton ID

# One lepton ID for $W \rightarrow l\nu$ with CAL Edep

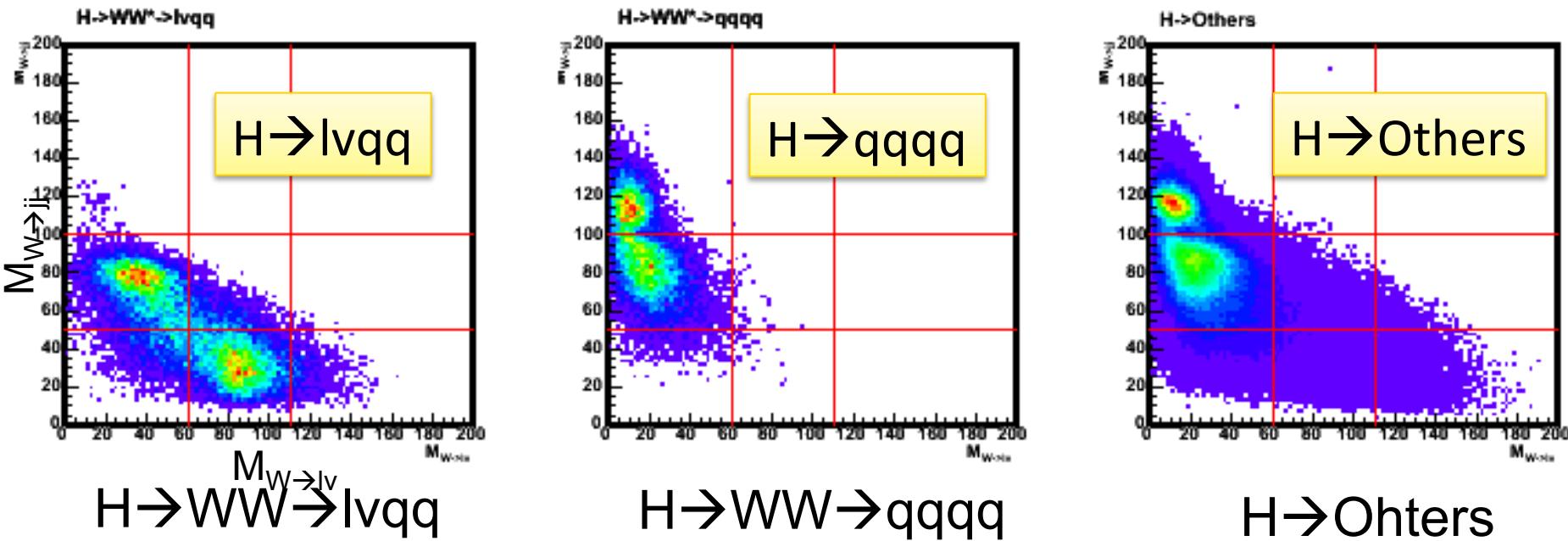
MuID:  $E_{\text{total}}/P < 0.6$ ,  $E_{\text{ecal}}/E_{\text{total}} < 0.5$   
 eID:  $0.6 < E_{\text{total}}/P < 1.4$ ,  $E_{\text{ecal}}/E_{\text{total}} > 0.9$



# $H \rightarrow WW^* \rightarrow l\nu qq$ reconstruction

Reconstruct as **one-isolated lepton+4 jet**

Mass correlation of  $Z \rightarrow qq + WW \rightarrow l\nu qq$ ,  $M_{W \rightarrow l\nu}$ ,  $M_{W \rightarrow qq}$   
( $M_{W \rightarrow l\nu} = M(q_{\text{lep}} + q_{\text{mis}})$ )



H $\rightarrow$ WW $\rightarrow$ lνqq

H $\rightarrow$ WW $\rightarrow$ qqqq

H $\rightarrow$ Others

Require  $W \rightarrow l\nu$  on-shell ( $60 < M_{Wl\nu} < 120$  GeV,  $M_{Wjj} < 60$  GeV)  
to suppress backgrounds

# BG reduction for $\text{qqH} \rightarrow \text{qqWW}^*$ $\text{WW}^* \rightarrow \text{lvqq}$

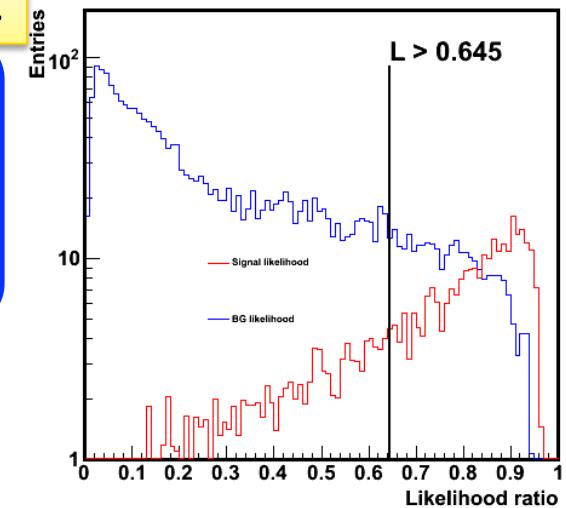
## Selection criteria

1. Require one isolated lepton
2.  $150 < E_{\text{vis}} < 250 \text{ GeV}$
3.  $|\text{P}_T| < 60 \text{ GeV}$
4.  $\text{thrust} < 0.9$ ,  $\text{minorThrust} > 0.1$
5.  $\Upsilon_{34} < 2.8$
6.  $\chi^2 < 120$
7.  $N_{\text{PFO}} < 40$
8.  $|\cos\theta_W| < 0.9$
9.  $60 < M_{\text{Wlv}} < 120 \text{ GeV}$ ,  $M_{\text{Wqq}} < 50 \text{ GeV}$
10.  $E_{\text{lep}} > 20 \text{ GeV}$
11.  $E_{\text{miss}} < 80 \text{ GeV}$
12.  $80 < M_Z < 120 \text{ GeV}$
13.  $\text{LR} > 0.65$
14.  $110 < Z \text{ Recoil mass} < 140 \text{ GeV}$

## Likelihood input

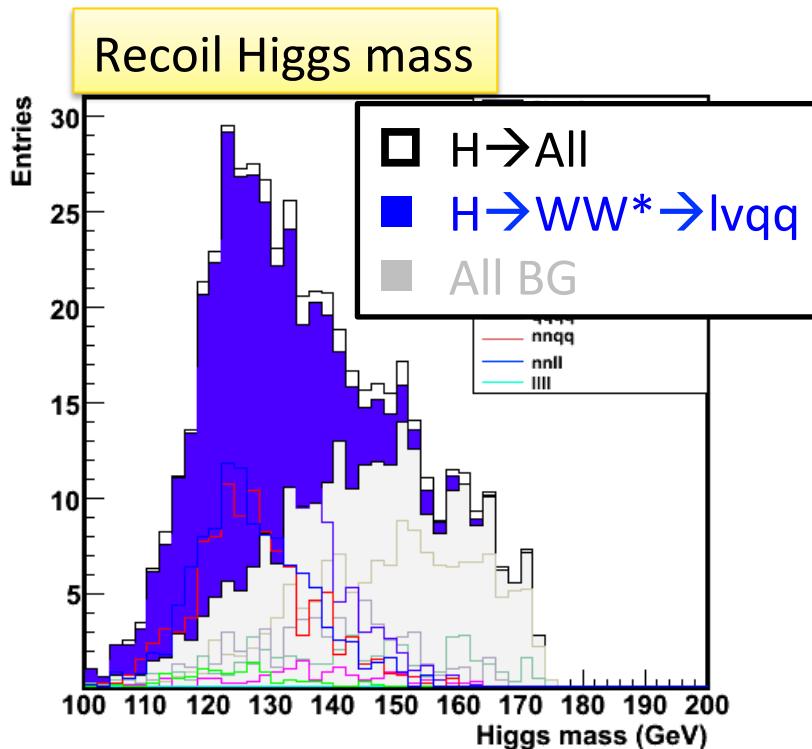
1.  $\cos\theta_W$
2.  $M_{\text{wqq}}$
3.  $M_{\text{Wlv}}$
4.  $N_{\text{PFO}}$

## Likelihood ratio



Cuts	One lep	LR	Mh
$H \rightarrow \text{All}$	29631	322	291
$H \rightarrow \text{WW} \rightarrow \text{lvqq}$	2018	288	268
$H \rightarrow \text{WW} \rightarrow \text{qqqq}$	1824	0	0
BG	11303991	792	511
Significance	0.6	8.6	9.5

# Relative accuracy of $\text{BR}(\text{H} \rightarrow \text{WW}^*)$



Preliminary

$\text{qqH} \rightarrow \text{qqWW}^*, \text{WW}^* \rightarrow \ell\nu\text{qq}$   
 $\Delta \text{Br}/\text{Br}(\text{H} \rightarrow \text{WW}^* \rightarrow \ell\nu\text{qq}) = 10.6\%$

$\text{vvH} \rightarrow \text{vvWW}^*, \text{WW}^* \rightarrow \text{qqqq}$   
 $\Delta \text{Br}/\text{Br}(\text{H} \rightarrow \text{WW}^* \rightarrow \text{qqqq}) = 13.2\%$

Preliminary

Combined result

$\Delta \text{Br}/\text{Br}(\text{H} \rightarrow \text{WW}^*) = 8.4\%$

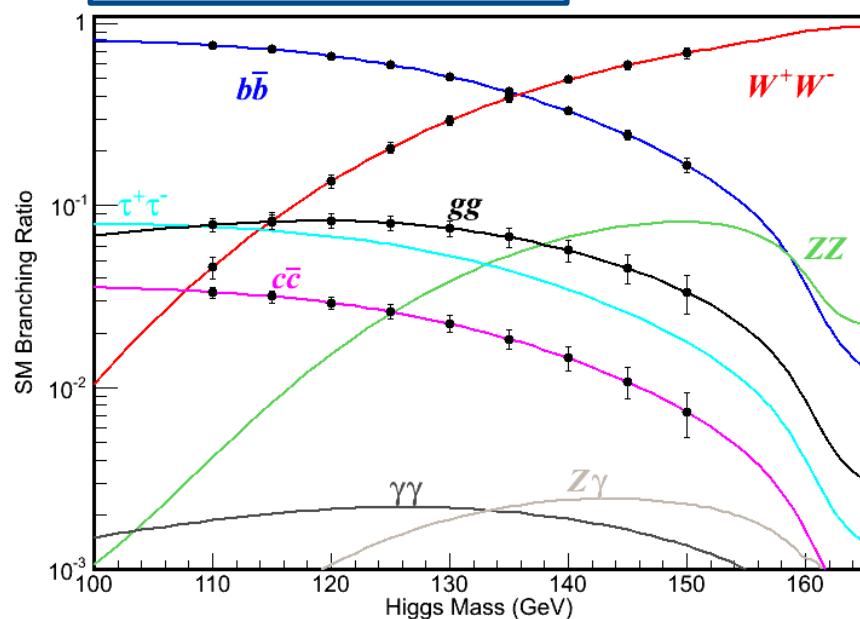
Include  $\Delta\sigma/\sigma = 2.5\%$  uncertainty

WWH coupling is also studied with  $\text{vvH} \rightarrow \text{vvWW}$  (W-fusion) at 500 GeV (Next talk)

# Summary table of Higgs BR study

$E_{cm}=250 \text{ GeV}$ ,  $L=250\text{fb}^{-1}$ ,  $P(e^+, e^-)=(+0.3, -0.8) \text{ or } (-0.3, +0.8)$

Higgs BR v.s.  $M_H$



Scale from 120 GeV results

$M_H$	120 GeV			125 GeV		
	$\sigma$ (fb)	354.1 fb		279.9 fb		
H decay	BR	$\sigma \times BR$	$\Delta BR/BR$	BR	$\sigma \times BR$	$\Delta BR/BR$
$H \rightarrow b\bar{b}$	64.1%	227.1	2.7%	59.5%	188.6	3.0%
$H \rightarrow c\bar{c}$	3.1%	10.8	8.1%	2.6%	8.3	9.1%
$H \rightarrow gg$	7.0%	24.9	9.0%	8.0%	25.5	9.6%
$H \rightarrow WW^*$	15.0%	35.3	8.4%	20.8%	43.2	7.2%
$H \rightarrow \tau\tau$	8.7%	30.9	TBD	6.1%	19.4	
$H \rightarrow ZZ^*$	1.7%	6.1	Ono	2.6%	8.1	
$H \rightarrow \gamma\gamma$	0.27%	0.95	Tino	0.2%	0.7	
$H \rightarrow Z\gamma$	0.13%	0.45	Tino	0.2%	0.5	

Assuming  $\sigma_{ZH}$  uncertainty:  $\Delta\sigma/\sigma=2.5\%$

Whizard+pythia and HDECAY

# Summary

- $H \rightarrow WW^*$  analysis
  - $\Delta Br/Br(H \rightarrow WW^* \rightarrow qqqq) = 13.6\%$  ( $vvH$ ,  $H \rightarrow WW^* \rightarrow qqqq$ )
  - $\Delta Br/Br(H \rightarrow WW^* \rightarrow lvqq) = 10.6\%$  ( $qqH$ ,  $H \rightarrow WW^* \rightarrow lvqq$ )
  - Combined:  $\Delta Br/Br(H \rightarrow WW^*) \sim 8\%$  as preliminary
- $H \rightarrow ZZ$  is on-going,  $H \rightarrow \tau\tau$  to be assigned
  - $H \rightarrow \mu\mu$  also to be done for DBD benchmarking
- DBD  $vvH$  @1 TeV is also on going
  - $H \rightarrow bb$ ,  $cc$ ,  $gg$  will start with same strategy
  - $H \rightarrow WW$  will try at 1 TeV
  - $H \rightarrow \mu\mu$  as next

# Backup

# ZH $\rightarrow$ vvH, H $\rightarrow$ WW\* $\rightarrow$ qqqq BG reduction summary

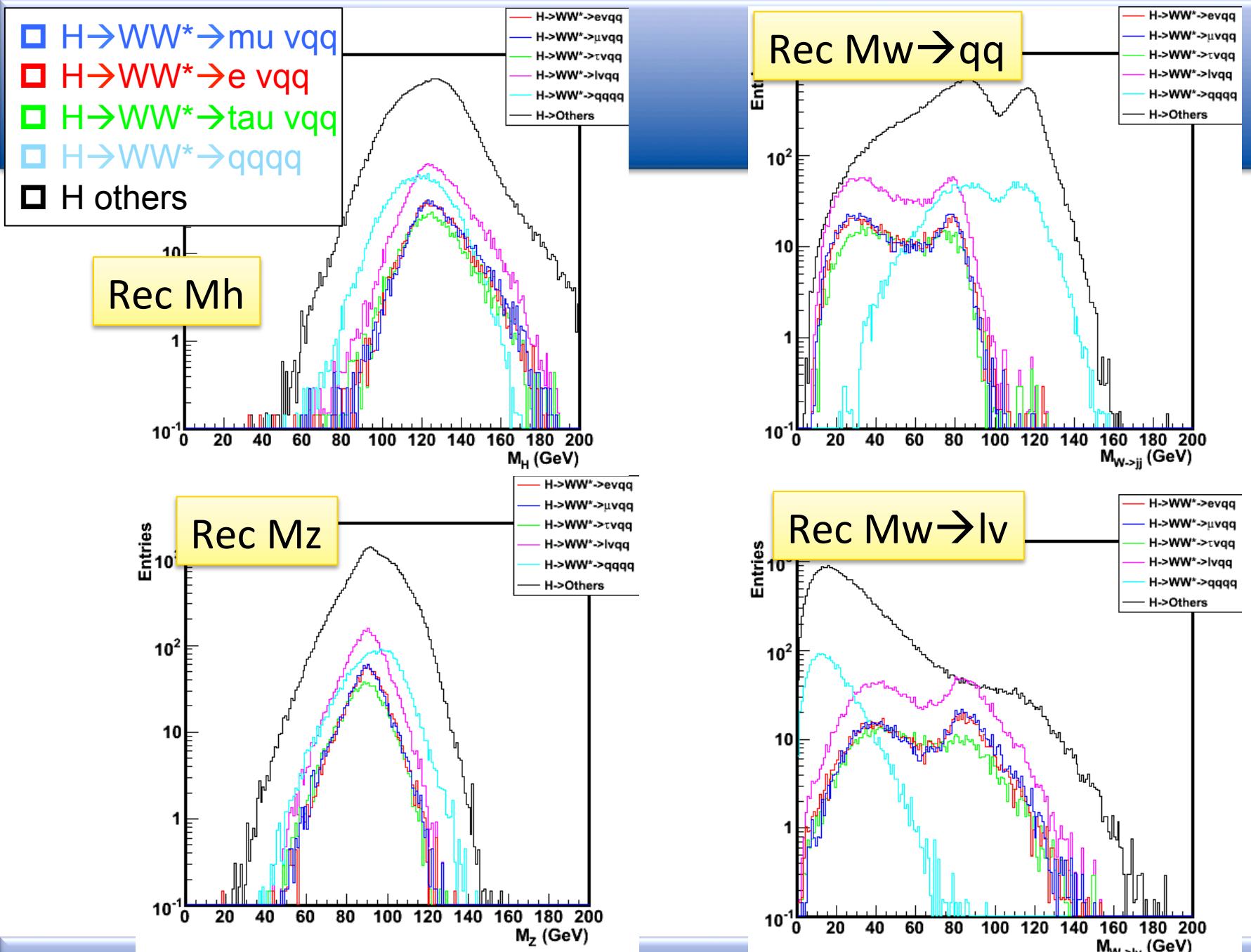
	Gen	Rec	Mh	MissM	Y-	cos	w-blike	b-like(2j)	Etrk	LR
vvww4j	678	678	611	604	603	579	564	548	536	367
vvww	1486	1408	638	632	629	604	589	573	561	372
vvbb	7101	7101	4628	4585	4001	3816	662	300	293	128
ZH all	10634	10396	6255	6194	5463	5219	1988	1592	1553	915
nlqq	298103	298103	34186	16975	14132	12410	11986	11746	11114	1060
nnqq	63649	63649	2382	2334	1890	1712	1400	1354	1290	230
llqq	335756	335753	5502	2611	2278	913	612	571	535	68
nnll	108074	58504	6249	5553	90	80	80	80	70	0
qqqq	378726	378726	529	172	170	18	11	9	9	2
llll	753964	752157	16913	6836	2159	471	447	432	363	0
SM all	1938270	1886890	65761	34481	20719	15603	14535	14191	13380	1361
Sig.	0.49	0.49	2.28	3.00	3.73	4.01	4.39	4.36	4.39	7.70

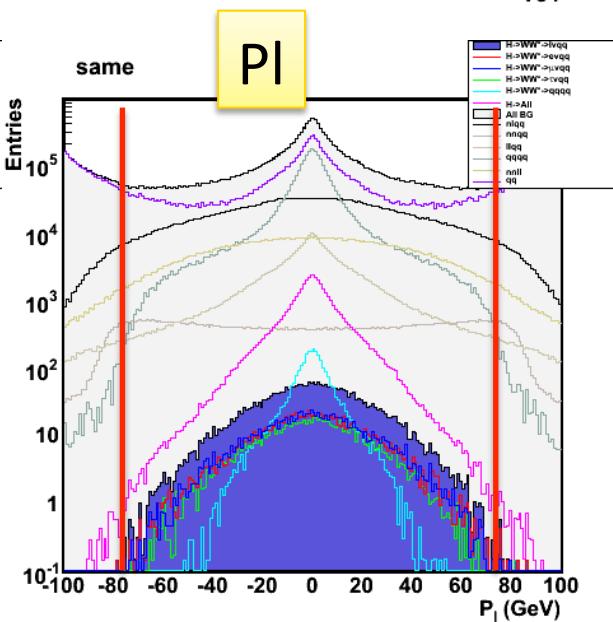
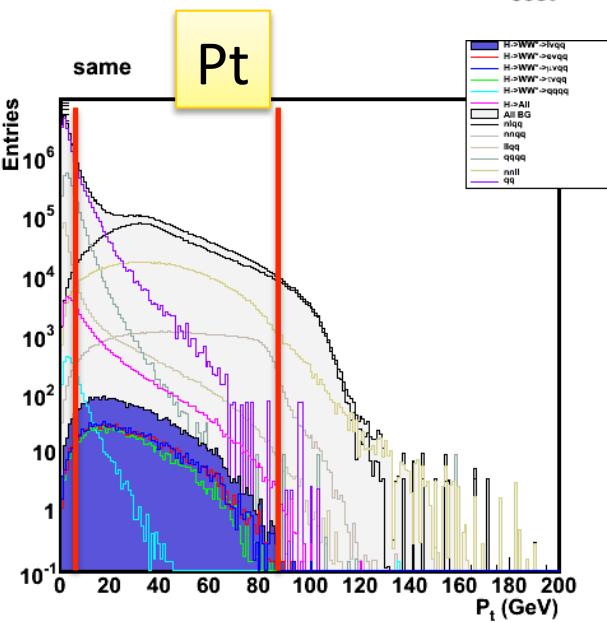
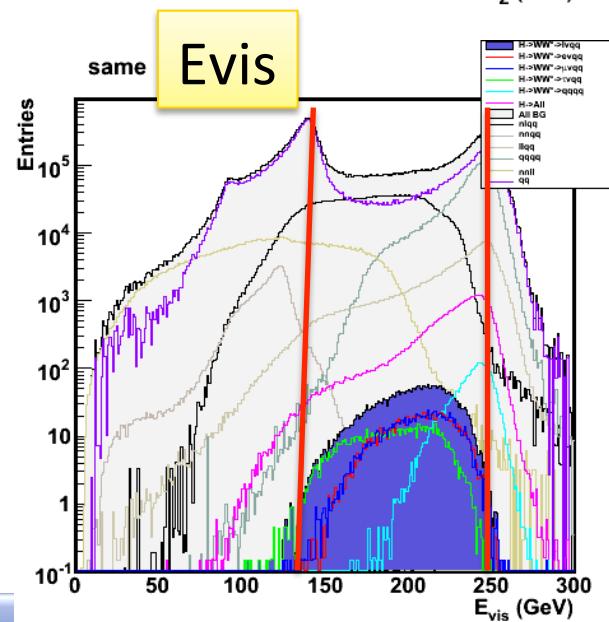
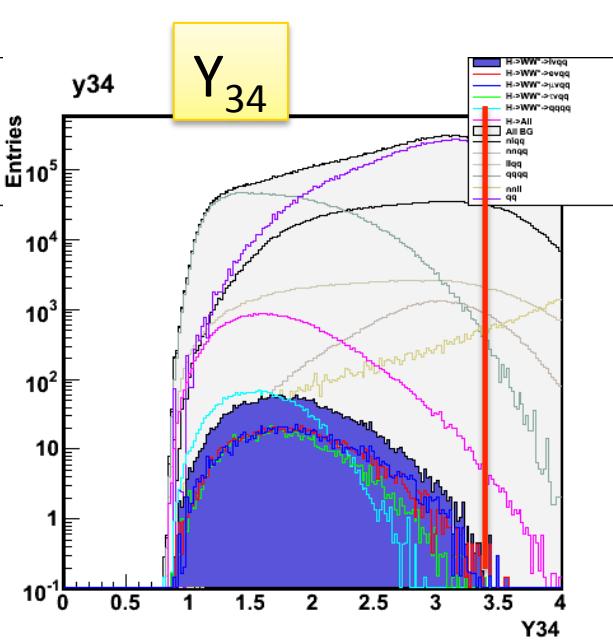
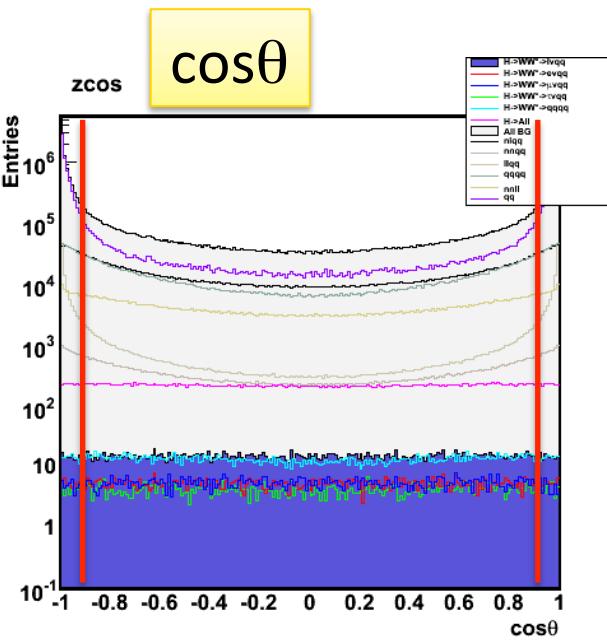
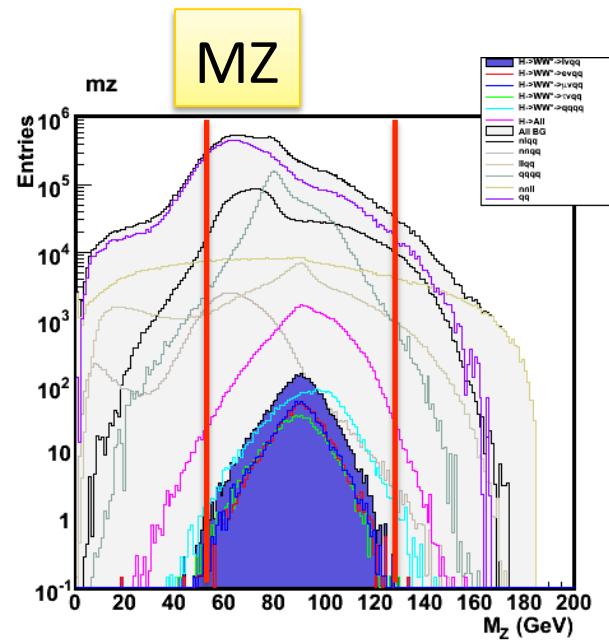
Signal significance: 7.7 for vvH $\rightarrow$ vvWW\* $\rightarrow$ vv+qqqq

# ZH $\rightarrow$ qqH, H $\rightarrow$ WW\* $\rightarrow$ lvqq

## BG reduction summary

Cuts	H $\rightarrow$ All	H $\rightarrow$ WW $\rightarrow$ lvqq	H $\rightarrow$ WW $\rightarrow$ qqqq	nlqq	nnqq	llqq	qqqq	nnll	qq	BG	signif
Gen	35400	2199	2276	289791	63648	282729	378725	101648	22270532	23387075	0.5
One isolep	29631	2018	1824	222975	31004	183648	267925	80846	10517590	11303991	0.6
Evis	26832	1982	1573	171262	195	145458	227215	15460	2947916	3507509	1.1
$\chi^2$	26374	1966	1558	111818	179	92567	223383	3579	2253618	2685148	1.2
PI	26324	1949	1558	101287	174	87692	220156	3138	1803921	2216371	1.3
Thrust	25746	1928	1556	89436	129	55437	215099	656	1188415	1549174	1.5
Minor Thrust	24492	1908	1552	63941	97	35931	194100	209	365769	660049	2.3
Y34	24321	1870	1552	33914	68	34936	192342	13	327507	588782	2.4
N <sub>PFO</sub>	23984	1866	1552	26054	59	25890	192280	0	313813	558098	2.4
$\cos\theta_{W \rightarrow l\nu}$	20057	1673	1223	21774	52	19155	129589	0	156611	327184	2.8
M <sub>W<math>\rightarrow</math>l<math>\nu</math></sub>	2007	814	3	14599	51	4563	2188	0	8772	30175	4.5
M <sub>W<math>\rightarrow</math>q<math>q</math></sub>	1323	691	1	10445	42	2446	1005	0	6233	20173	4.7
Elep	845	538	0	7502	1	1572	283	0	2062	11421	4.9
Emiss	696	497	0	4394	0	1304	273	0	1555	7528	5.5
Mz	577	424	0	1805	0	961	207	0	1009	3984	6.3
LR	322	288	0	197	0	79	85	0	430	792	8.6
Mh	291	268	0	90	0	44	64	0	311	511	9.5



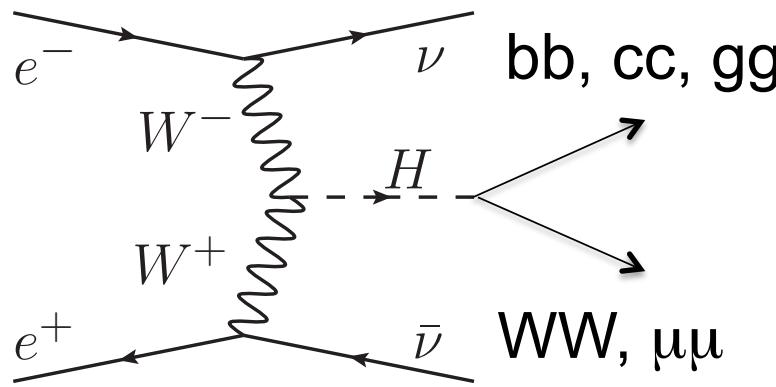


**vνH @ 1 TeV for DBD study**

# vvH @ 1 TeV for DBD

DBD benchmark process:  $\sigma^* \text{BR}$  for  $H \rightarrow \mu\mu, bb, cc, WW, gg$

Main produced through W-fusion



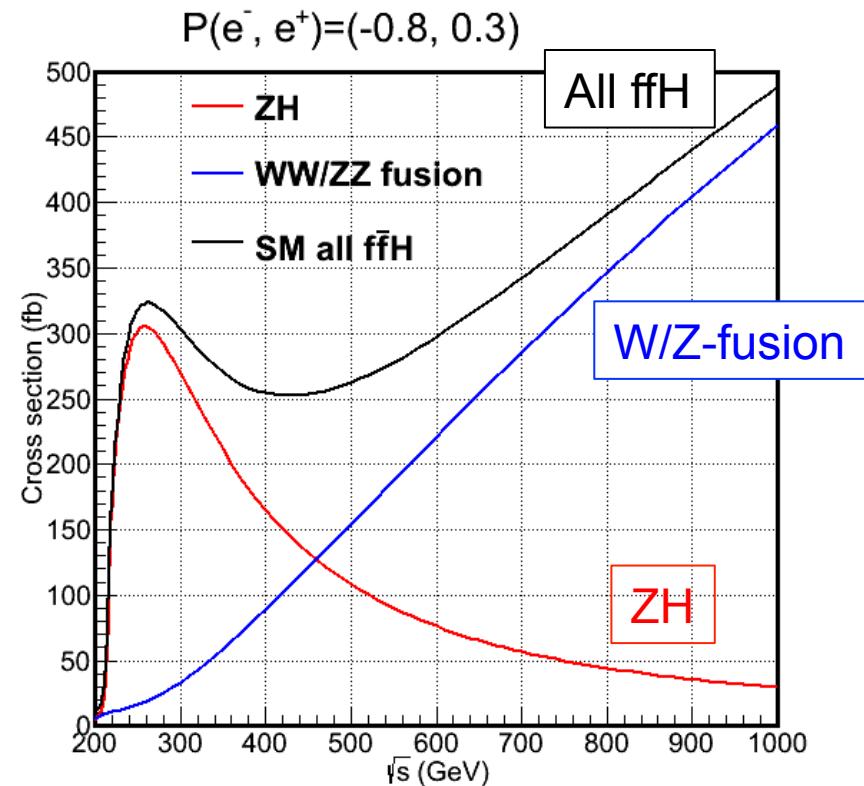
$H \rightarrow bb, cc, gg$  (Hadronic decay)

Di-jet reconstruction

Same strategy as LOI 250 GeV

$H \rightarrow \mu\mu$ : Muon ID

$H \rightarrow WW^*$ : qqqq 4j channel



Main backgrounds (WW, ZZ)  
 $ee \rightarrow ll$  for  $H \rightarrow \mu\mu$

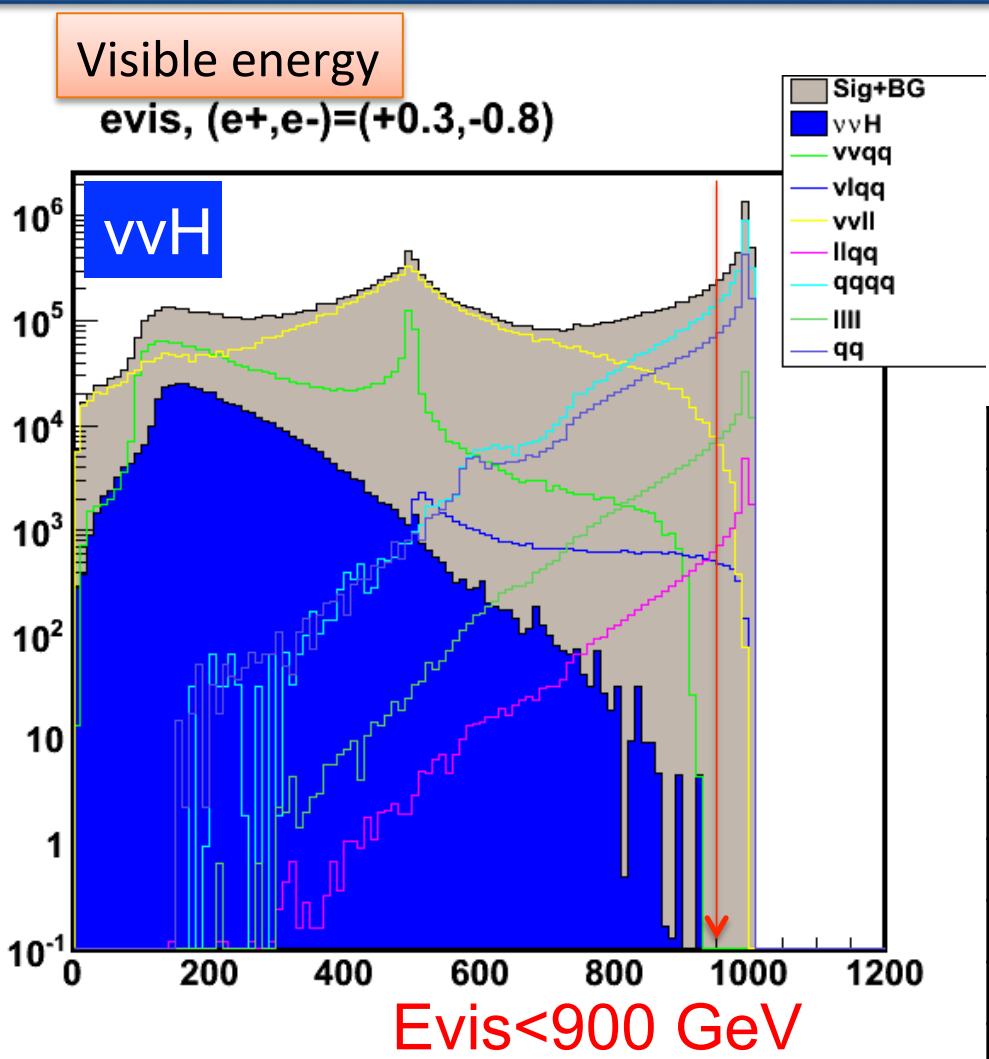
# Events at 1 TeV with L=1 ab<sup>-1</sup>

$\sigma^* \text{BR}$	$\sigma(e\text{-L})$	$\sigma(e\text{-R})$	$\sigma(+0.3, -0.8)$	$\sigma(-0.3, +0.8)$	$N(+0.3, -0.8)$	$N(-0.3, +0.8)$
$\sigma(vvH)$	795.37	5.49	465.48	31.05	465483	31049
$\sigma^* \text{BR}(bb)$	510.13	3.52	298.55	19.91	298552	19914
$\sigma^* \text{BR}(cc)$	24.28	0.17	14.21	0.95	14211	948
$\sigma^* \text{BR}(gg)$	55.93	0.39	32.73	2.18	32733	2183
$\sigma^* \text{BR}(WW)$	119.37	0.82	69.86	4.66	69860	4660
$\sigma^* \text{BR}(\mu\mu)$	0.25	0.00	0.15	0.01	149	10
$\sigma^* \text{BR}(\tau\tau)$	69.43	0.48	40.63	2.71	40632	2710
$\sigma^* \text{BR}(ZZ)$	13.62	0.09	7.97	0.53	7969	532
$\sigma^* \text{BR}(\gamma\gamma)$	2.12	0.01	1.24	0.08	1243	83
$\sigma^* \text{BR}(z\gamma)$	1.01	0.01	0.59	0.04	591	39
$vvqq$	12955	21	7580	466	7.6 M	0.47 M
$qq$	8749	4862	5288	3151	5.4 M	3.2 M
$qqqq$	6740	257	3952	386	4.0 M	0.39 M
$llll$	6537	6454	4050	4004	4.1 M	4.0 M
$vvll$	5731	117	3357	269	3.4 M	0.27 M
$llqq$	2671	2311	1643	1445	1.6 M	1.4 M
$vvqq$	2490	71	1459	129	1.5 M	0.13 M
$tt$	578	258	347	171	0.35 M	0.17 M

DBD  
benchmarking

2f, 4f, tt, 6f  
background

# vvH @ 1 TeV pre-selection (MC only)



$(e^+, e^-) = (+0.3, -0.8)$   
 $E_{\text{cm}} = 1 \text{ TeV}, L = 1 \text{ ab}^{-1}$   
 Require  $E_{\text{vis}} < 900 \text{ GeV}$   
 Suppress 4f BG  
 Need to suppress vvqq, vlqq

mode	xsec	No cut	$E_{\text{vis}} < 900$	Cut eff.
vvh	465.48	465483	465478	100.0%
vlqq	7580	7637450	6835470	89.5%
qq	5288	5670560	1612630	28.4%
qqqq	3952	3951660	947843	24.0%
lILL	4050	4050220	1058720	26.1%
vVll	3357	3329550	3295990	99.0%
llqq	1643	1643230	316901	19.3%
vvqq	1459	1416430	1416310	100.0%
tt	347	347310		
ZWW	134	134000		

$H \rightarrow ZZ^*$  study

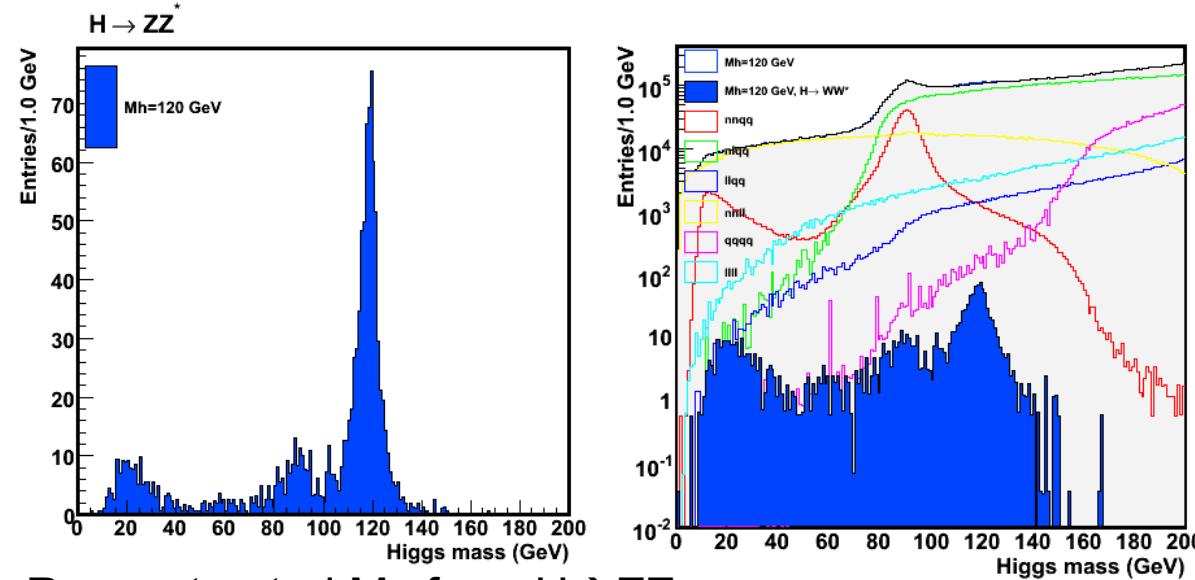
# H $\rightarrow$ ZZ\* analysis

ZH $\rightarrow$ vvH, H $\rightarrow$ ZZ $\rightarrow$ 4j (4j clustering)

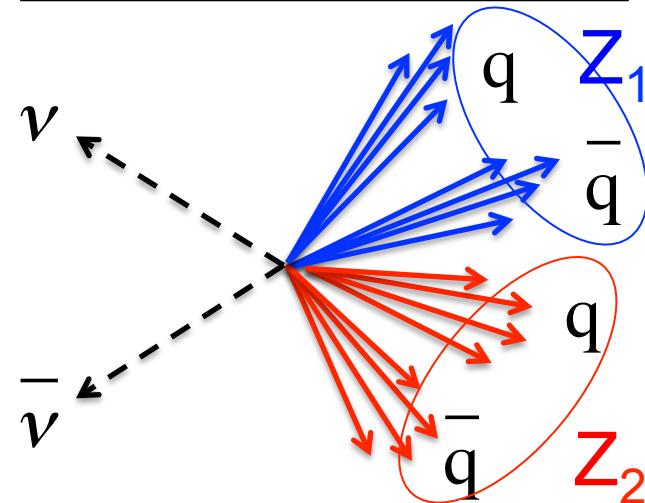
Ecm=250 GeV, L=250 fb-1, (e+, e-)=(+0.3, -0.8)

N(H $\rightarrow$ ZZ)=292 events, Start with L=1000fb $^{-1}$  with N(H $\rightarrow$ ZZ)=1141 events

$$\chi^2 = \left( \frac{M_{j_1 j_2} - M_Z}{\sigma_Z} \right)^2 + \left( \frac{M_{4j} - M_H}{\sigma_H} \right)^2$$

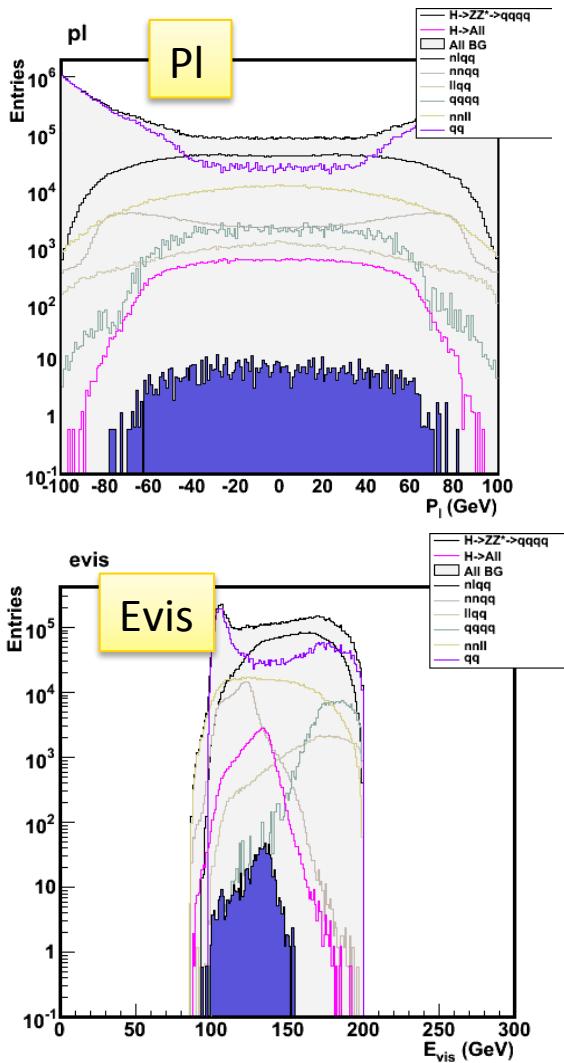


Reconstructed M<sub>H</sub> from H $\rightarrow$ ZZ



4 jet final state

# Cuts summary

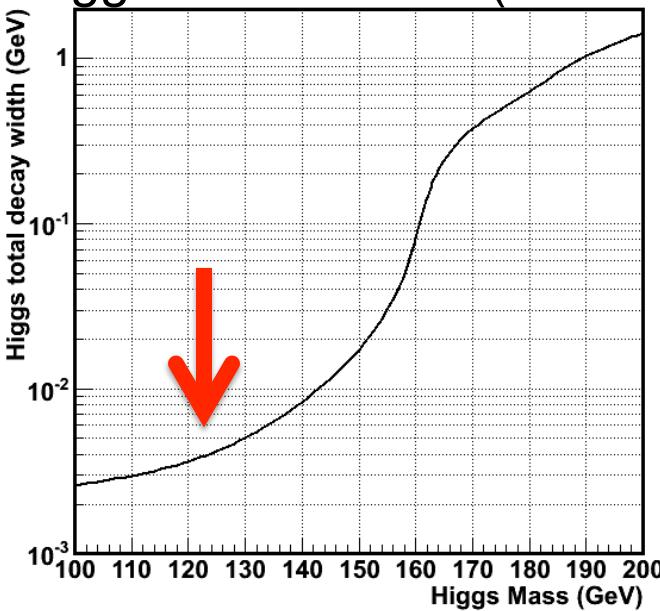


	H all	$H \rightarrow ZZ \rightarrow 4j$	BG all	S/Sqrt(S+B)
Rec	75630	1141	178725654	0.0853297
mm	64939	830	53304500	0.113614
evis	63848	820	45835275	0.121035
z11y34	62536	808	43960551	0.121779
hcos	55802	720	2752999	0.429608
pl	27463	339	1117809	0.316771
pt	54673	703	2074970	0.481728
hmass	49722	645	1410928	0.533687

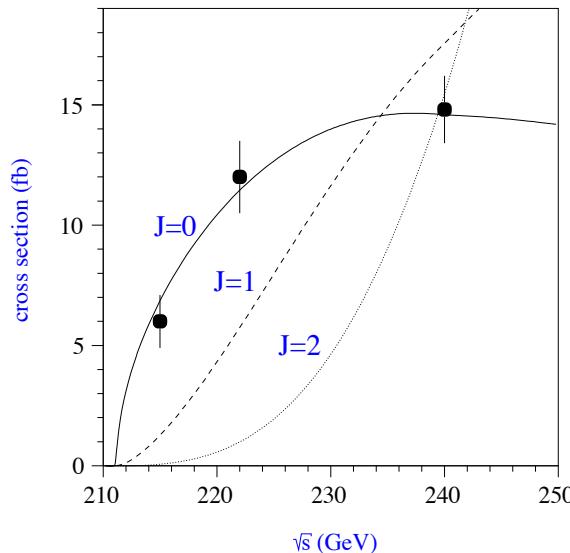
Need to improve BG suppression  
Right handed polarization is also considered

# Higgs properties to be measured

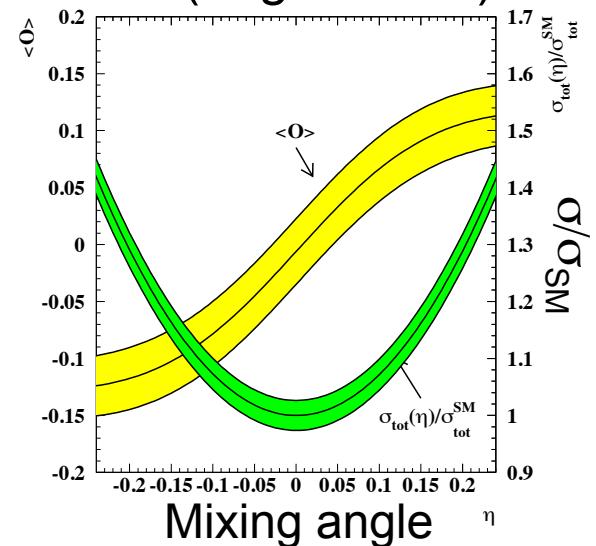
Higgs natural width (HDECAY)



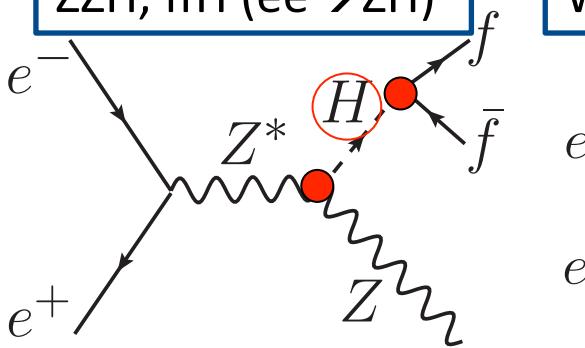
Spin (xsec scan)



CP (angular dist)



ZZH, ffH ( $ee \rightarrow ZH$ )



WWH, ZZH ( $ee \rightarrow vv/eeH$ )

