

# vvh 1TeV study for DBD

ILD Analysis meeting

Nov. 28 2012

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# Current status

- $h \rightarrow bb, cc, gg$  analysis
  - Evaluate results with template fitting
  - Right handed polarization is also analyzed
- $h \rightarrow WW^* \rightarrow 4j$ 
  - $h \rightarrow$ others background reduction
  - Right handed analysis are on-going
- aa BG reduction is still considering (PFO check)

# $h \rightarrow bb, cc, gg$ analysis

$E_{cm} = 1 \text{ TeV}$  with  $L = 500 \text{ fb}^{-1}$

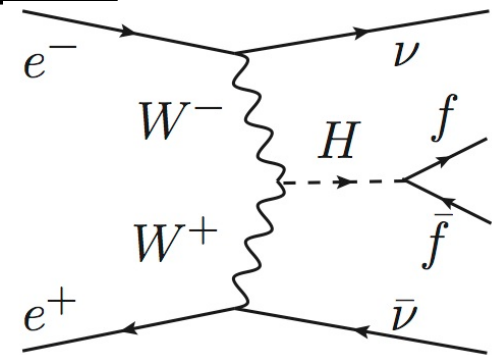
Signal:  $h \rightarrow bb, cc, gg$  2 jet final state

Considered backgrounds: 2f, 4f, 6f

Main background: 4f singleZnunu\_semileptonic

Estimated generated events for both polarization

$L = 500 \text{ fb}^{-1}$	(-0.8, +0.2)	(+0.8, -0.2)	Pol reduction
$h \rightarrow \text{All}$	223,408	30,697	86%
2f	3,890,180	2,699,560	31%
4f	9,168,850	6,341,460	31%
6f	121,842	34,163	72%
BG sum	13,180,872	9,075,183	31%
S/N	0.0169	0.0034	80%



Right handed pol case, signal is also reduced significantly because of production via W-fusion

# Reconstruction and BG reduction

$h \rightarrow bb, cc, gg$  with two jet channel is studied with 2f, 4f, 6f BGs

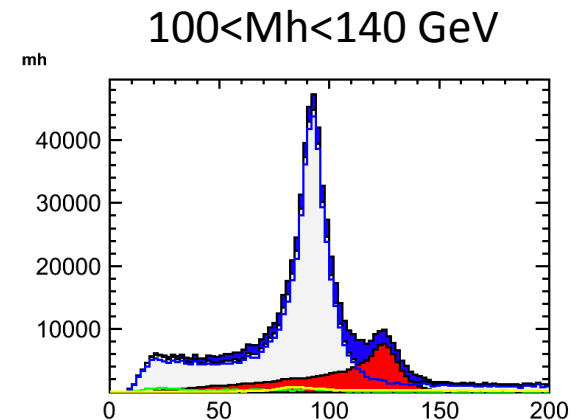
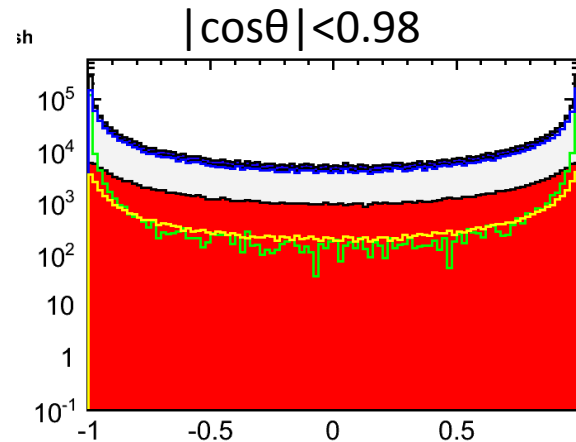
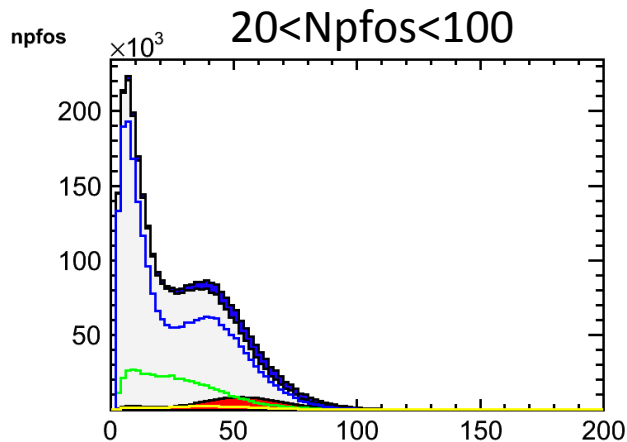
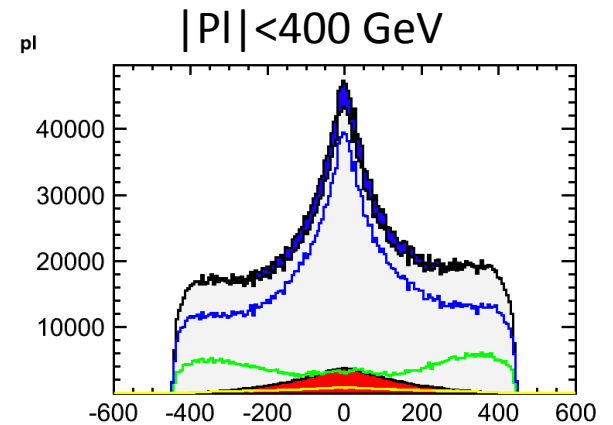
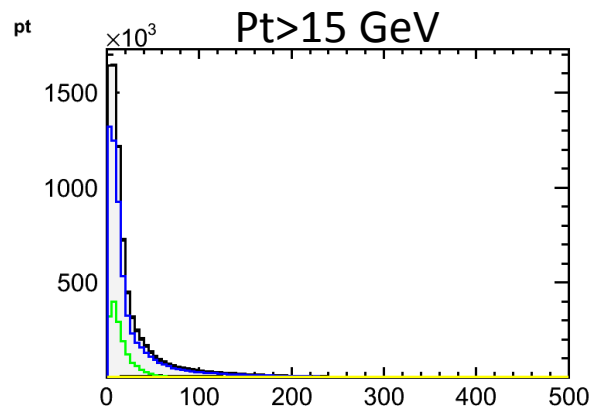
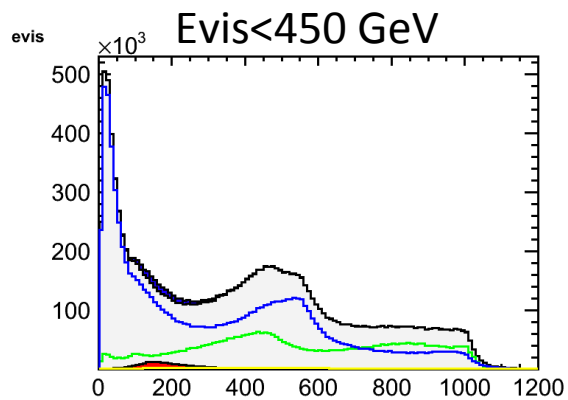
## Analysis strategy

1.  $k_t$  two jet clustering ( $R=1.1$ )
2. LCFIPlus with  $k_t$  selected PFOs
3. BG reduction
4. Evaluate  $\sigma BR$  with flavor template fitting  
b/c tagging output template

## Cut variables

1.  $E_{vis} < 450$  GeV
2.  $P_t > 15$  GeV
3.  $|P_I| < 400$  GeV
4.  $20 < N_{pfo} < 100$
5.  $|\cos\theta_{2j}| < 0.95$
6.  $110 < M_h < 140$  GeV

# Cut variables



# $h \rightarrow bb, cc, gg$ reduction summary

$E_{cm}=1 \text{ TeV}, L=500 \text{ fb}^{-1}, \text{pol}(e^-, e^+) = (-0.8, +0.2)$

cuts	Gen.	Evis	Pt	PI	Npfo	$ \cos\theta $	Mh	Eff
h->all	223,408	203,709	196,370	195,883	174,805	146,757	71,966	32.2%
h->bb	128,662	117,223	113,999	113,687	112,245	93,154	55,515	43.1%
h->cc	5,998	5,445	5,318	5,297	5,239	4,338	2,966	49.5%
h->gg	19,078	17,253	16,833	16,778	16,001	13,442	7,494	39.3%
h->WW	48,277	44,057	42,276	42,207	34,996	30,452	4,836	10.0%
2f	3,890,180	1,594,540	588,458	532,667	313,715	36,760	1,560	0.0%
4f	9,168,850	6,032,450	2,542,460	2,397,540	1,184,400	713,283	30,855	0.3%
6f	121,842	67,940	64,151	63,280	50,436	36,026	4,218	3.5%
BG all	13,180,900	7,694,940	3,195,070	2,993,490	1,548,550	786,069	36,633	0.3%

Signal significance=218.4 before template fitting

# $h \rightarrow bb, cc, gg$ reduction summary

$E_{cm} = 1 \text{ TeV}$ ,  $L = 500 \text{ fb}^{-1}$ ,  $\text{pol}(e^-, e^+) = (+0.8, -0.2)$

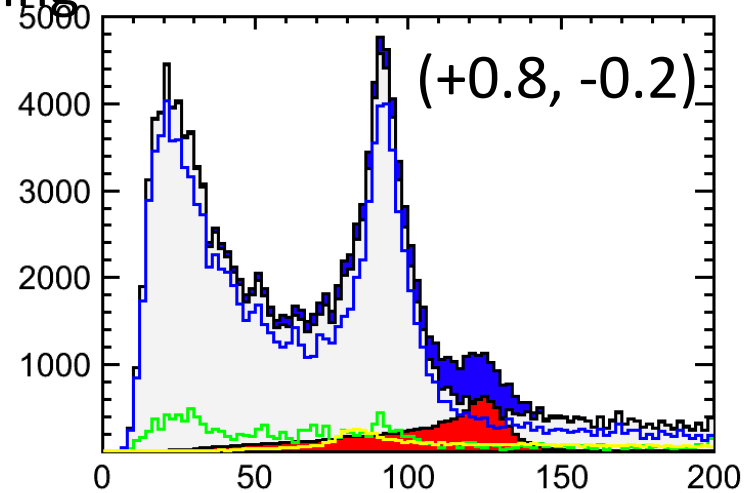
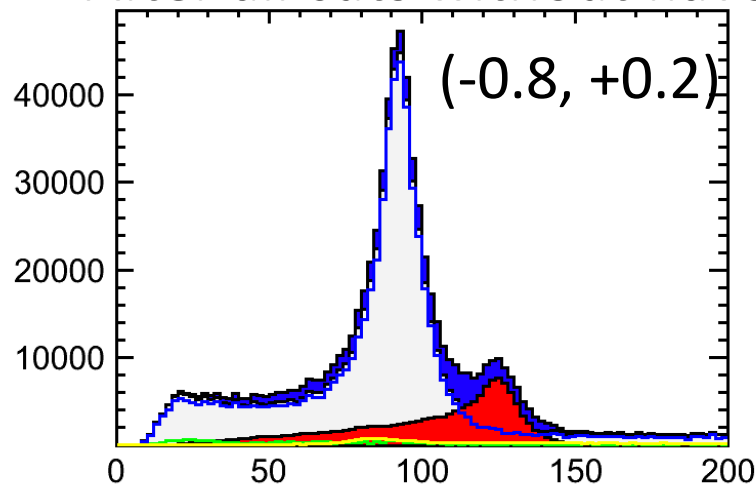
cuts	Gen.	Evis	Pt	PI	Npfo	$ \cos\theta $	Mh	Eff
h->all	30,697	18,161	17,452	17,351	15,396	12,252	5,914	19.3%
h->bb	17,767	10,428	10,086	10,029	9,850	7,757	4,561	25.7%
h->cc	808	473	455	453	448	356	241	29.8%
h->gg	2,567	1,478	1,436	1,425	1,355	1,067	600	23.4%
h->WW	6,582	3,947	3,787	3,769	3,100	2,564	412	6.3%
2f	2,699,560	1,133,530	406,949	368,120	202,050	21,730	912	0.0%
4f	6,341,460	4,644,610	1,428,520	1,329,260	533,157	301,280	9,220	0.1%
6f	34,163	22,445	20,406	20,096	16,002	10,229	1,224	3.6%
BG all	9,075,180	5,800,590	1,855,870	1,717,470	751,209	333,240	11,356	0.1%

Signal significance=60.4 before template fitting

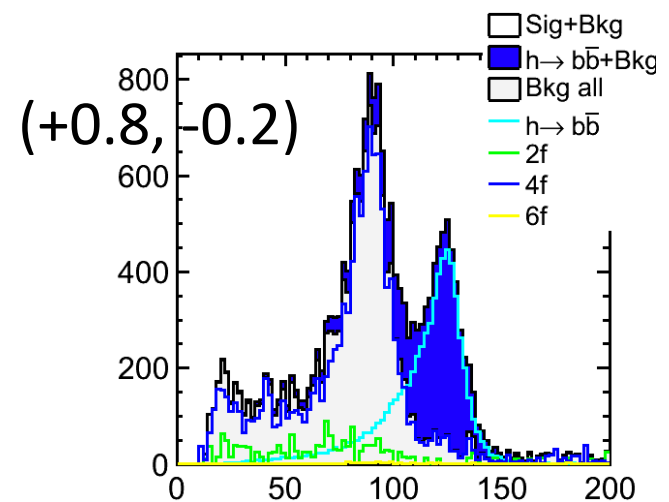
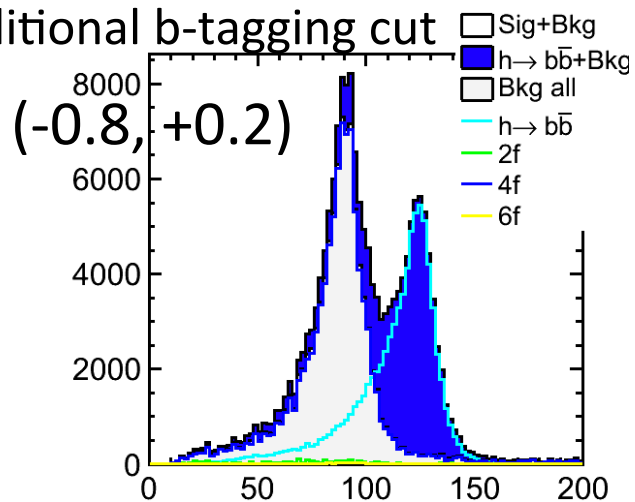
S/N becomes worse with right handed polarization by signal reduction

# Reconstructed mass distribution

mh After all cuts without flavor tagging



Additional b-tagging cut

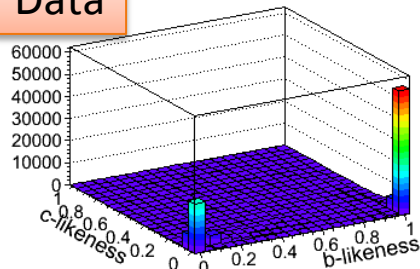




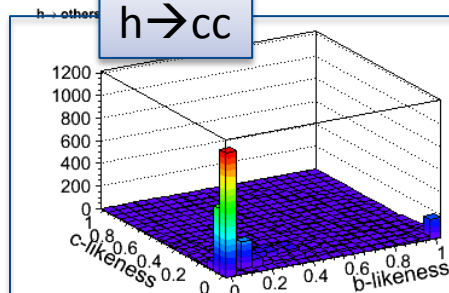
# Flavor template from LCFIPlus

Prepare flavor template with LCFIPlus output

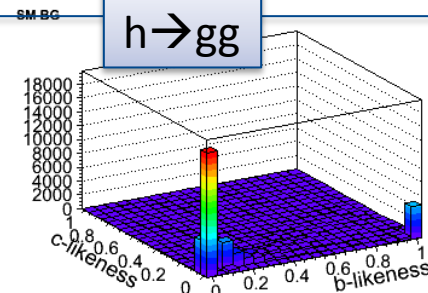
Data



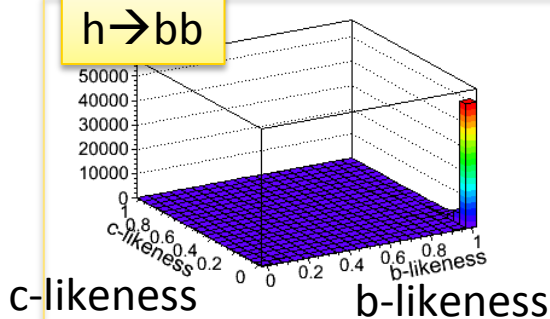
$h \rightarrow cc$



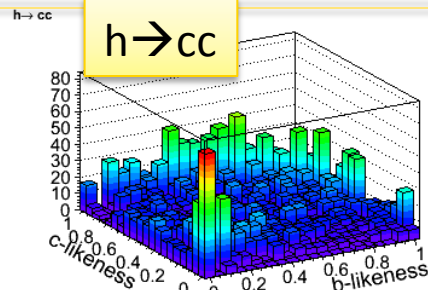
$h \rightarrow gg$



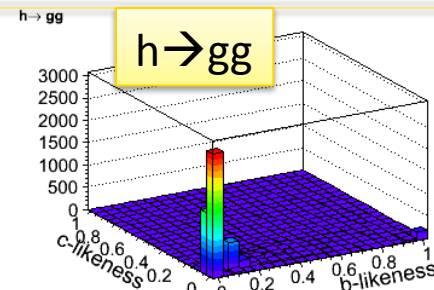
$h \rightarrow bb$



$h \rightarrow cc$



$h \rightarrow gg$



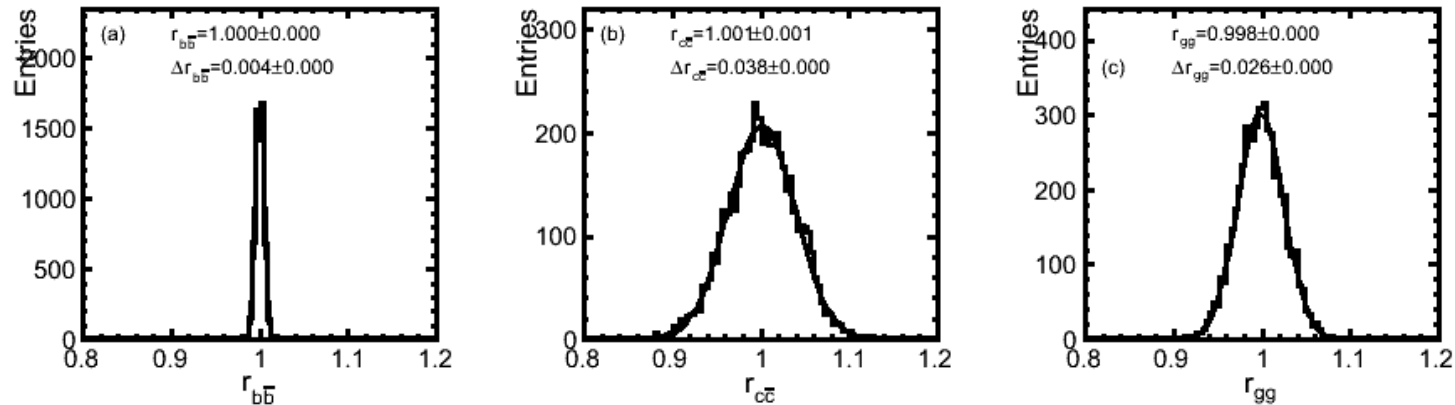
$$r_{xx} = \sigma BR / \sigma BR^{SM}(h \rightarrow xx)$$

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

( $r_{xx}$  is a fitted parameter)

# Toy MC fitted results

5000 times of Toy MC template fitting is applied to extract  $\sigma_{BR}$



Fitted results	(-0.8, +0.2)	(+0.8, -0.2)
$r_{bb} \pm \Delta r_{bb}$	$1.000 \pm 0.004$	
$r_{cc} \pm \Delta r_{cc}$	$1.001 \pm 0.038$	
$r_{gg} \pm \Delta r_{gg}$	$0.998 \pm 0.026$	
$\Delta\sigma_{BR}/\sigma_{BR}(h \rightarrow bb)$	0.4%	
$\Delta\sigma_{BR}/\sigma_{BR}(h \rightarrow cc)$	3.8%	
$\Delta\sigma_{BR}/\sigma_{BR}(h \rightarrow gg)$	2.6%	

Right handed is on-going with same samples.

# $h \rightarrow WW^* \rightarrow 4j$ analysis

## Analysis strategy

1.  $k_t$  four jet clustering ( $R=0.9$ )
2.  $\chi^2 = (M_{12} - M_W)^2 / \sigma_W^2 + (M_{4j} - M_h)^2 / \sigma_h^2$   
Minimum pair is selected
3. LCFIPlus with  $k_t$  selected PFOs
4. BG reduction
5.  $h \rightarrow$  other BG consideration

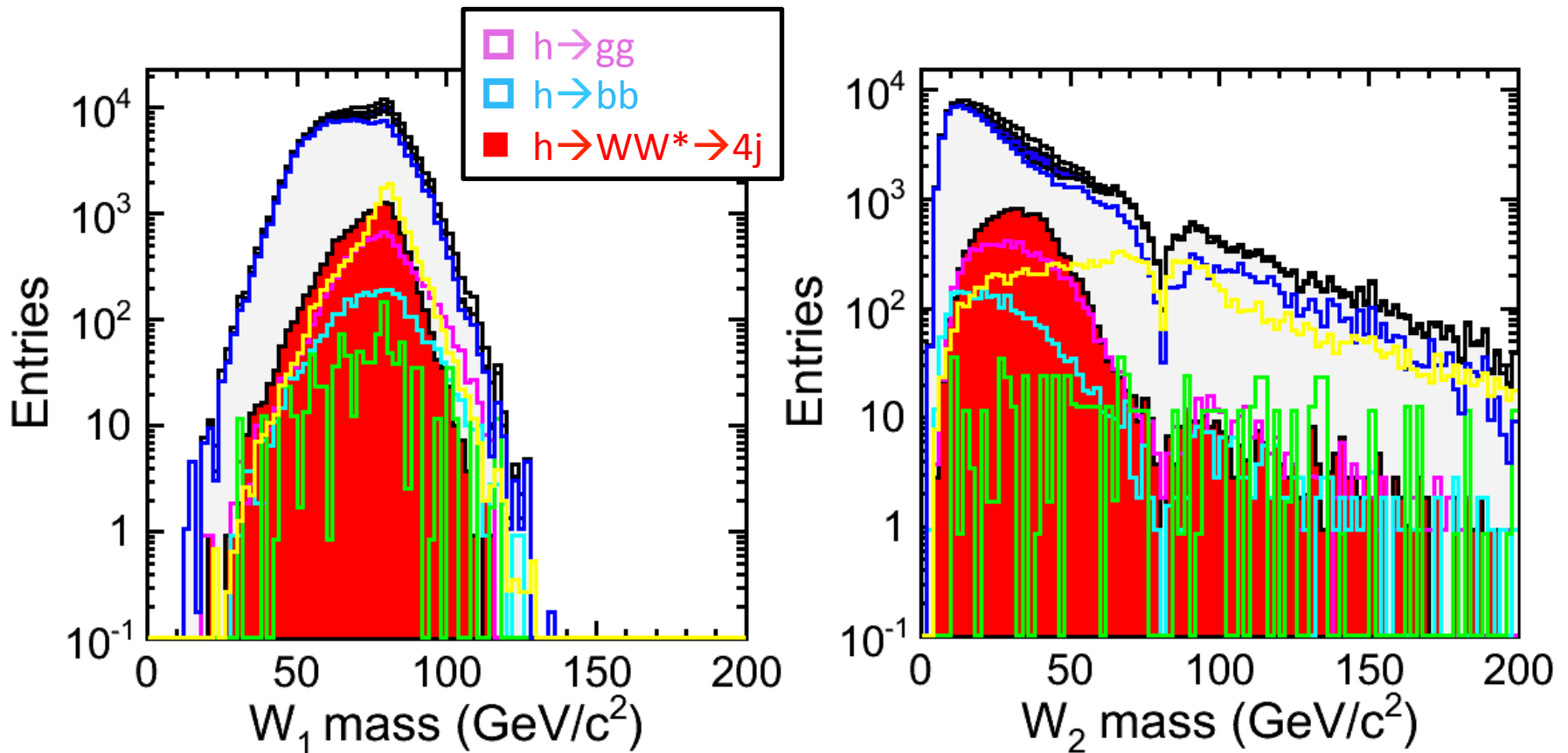
## Cut variables

1.  $100 < E_{vis} < 400$  GeV
2.  $P_t > 35$  GeV
3.  $|P_I| < 350$  GeV
4.  $N_{pfo} > 40$
5.  $|\cos\theta_{W12}| < 0.98$
6.  $y_{45} < 5.0$
7.  $y_{34} < 3.5$
8.  $y_{23} < 2.5$
9.  $B_{tag_{W1+W2}} < 1.0$
10.  $60 < M_{W1} < 95$  GeV
11.  $15 < M_{W2} < 60$  GeV
12.  $105 < M_h < 140$  GeV

# Summary table of cuts

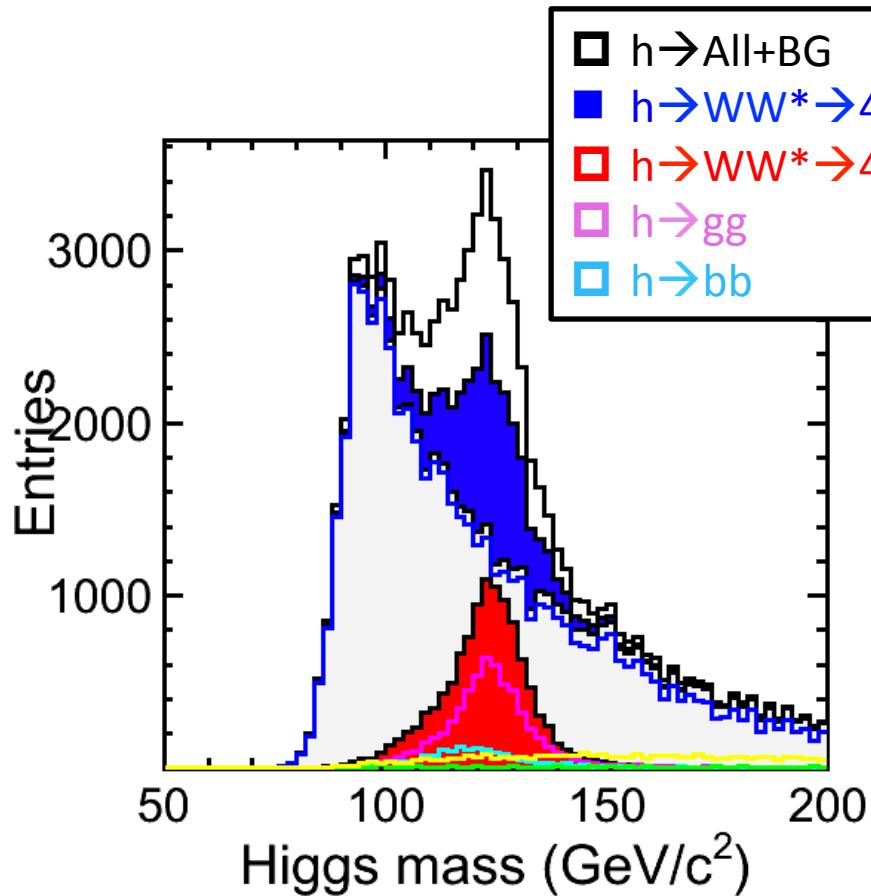
cuts	h->all	h->WW	h->WW->4j	h->gg	h->bb	2f	4f	6f	BG all
Gen	223,408	48,320	21,976	19,045	128,700	3,890,180	9,982,390	346,419	14,219,000
1	185,095	37,901	18,975	16,351	110,970	839,012	2,846,050	44,062	3,729,130
2	159,481	32,529	16,663	14,399	96,330	45,951	1,015,400	34,344	1,095,700
3	158,497	32,347	16,536	14,305	95,683	43,167	989,351	34,164	1,066,680
4	129,474	22,479	16,022	14,118	85,818	3,218	403,778	25,333	432,329
5	124,788	22,080	15,835	13,852	82,085	2,847	386,987	25,011	414,845
6	119,555	22,073	15,833	13,847	76,942	2,759	377,888	24,842	405,489
7	78,993	20,723	15,233	12,193	41,037	1,685	250,536	22,703	274,924
8	62,485	19,155	14,304	8,962	30,319	1,279	172,710	21,708	195,696
9	33,423	18,693	14,003	8,449	3,013	1,016	145,862	13,944	160,821
10	27,698	15,390	12,378	7,213	2,422	739	102,589	12,788	116,116
11	23,696	13,591	11,343	6,192	1,718	264	61,855	4,778	66,896
All cuts	19,722	11,288	10,061	5,395	1,277	61	23,140	1,079	24,280

# W1, W2 mass distribution

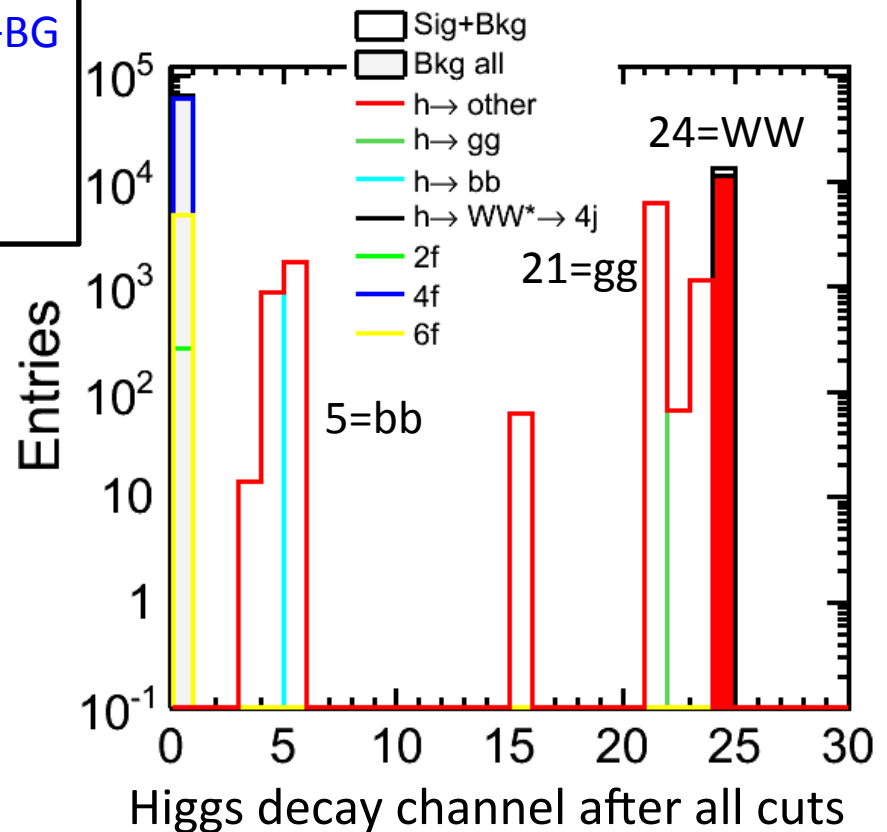


Re-checking jet chi2 and reconstruction for four jets

# Reconstructed mass distribution



Cut values are optimized  
 $h \rightarrow gg$  reduction is still updating



$$\Delta\sigma\text{BR}/\sigma\text{BR}(h \rightarrow \text{WW}^* \rightarrow 4j) = 2.5\%$$

# Summary

- $h \rightarrow bb, cc, gg$ 
  - Template fitting is applied for both polarization
- $h \rightarrow WW \rightarrow 4j$ 
  - Try to improve  $h \rightarrow gg$  BG reduction
  - Test TMVA for improvement
- Check  $aa$  BG but not well improved now