

Study of the Higgs Self-coupling at the ILC

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analysis with cheated jet clustering (qqHH)

strategy

pre-selection:

- ◆ same strategy as real analysis
- ◆ cheat jet clustering algorithm
- ◆ jets are paired using color singlet information
- ◆ use the real LCFIVertex for flavor tagging

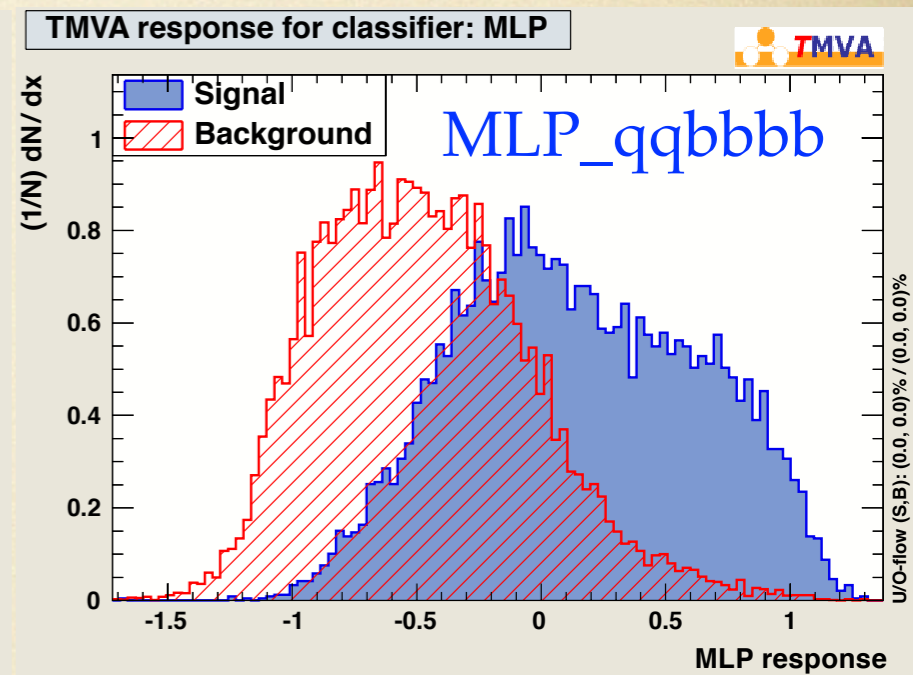
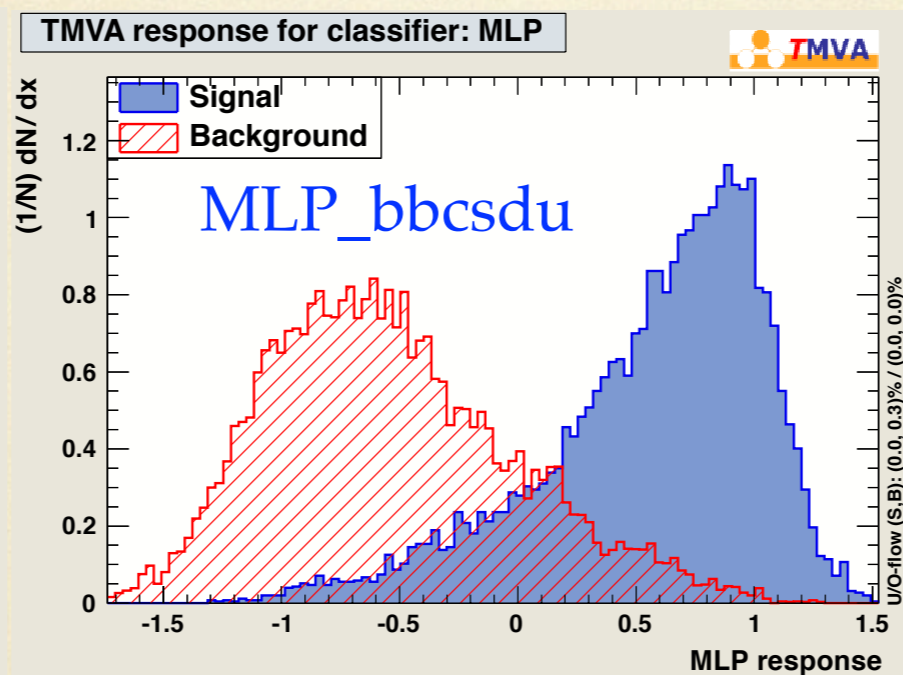
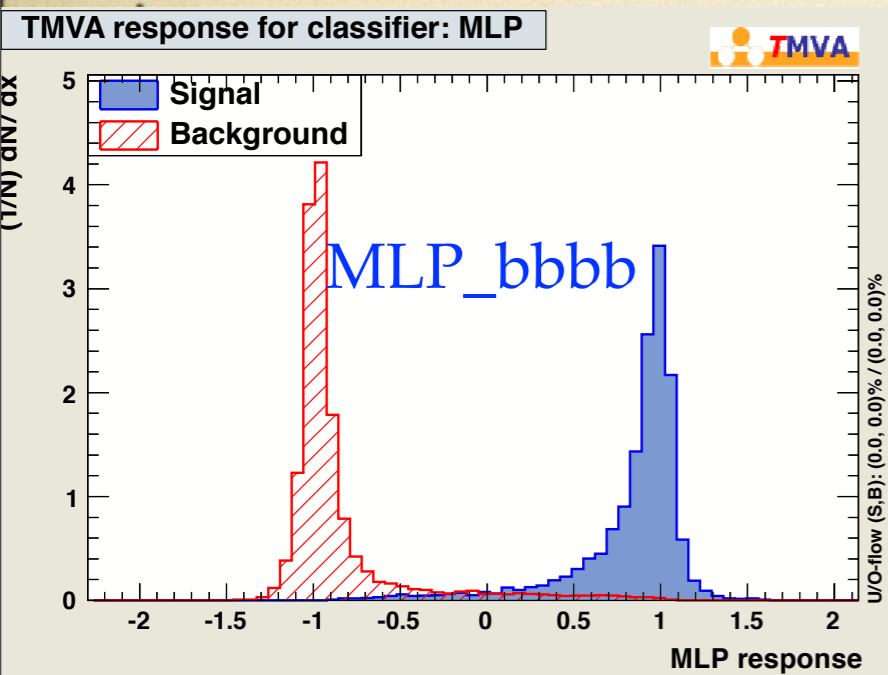
final selection:

- ◆ same strategy as previous analysis
- ◆ all the input variables of neural-net are the same
- ◆ slightly adjusted final cuts

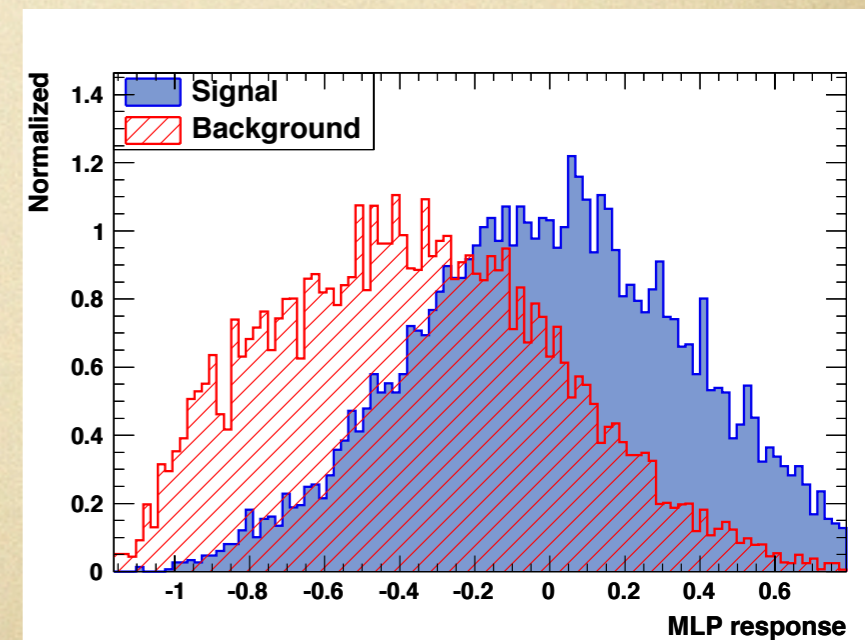
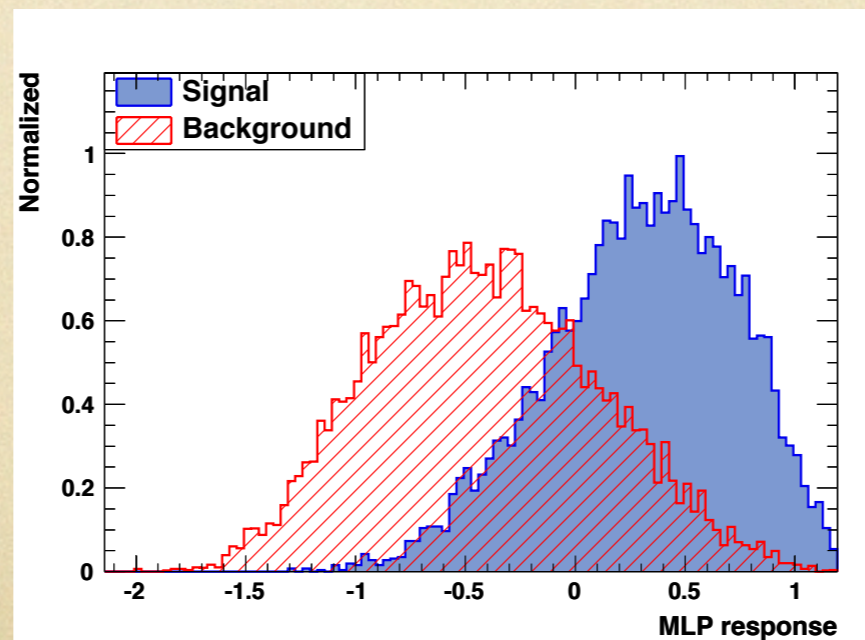
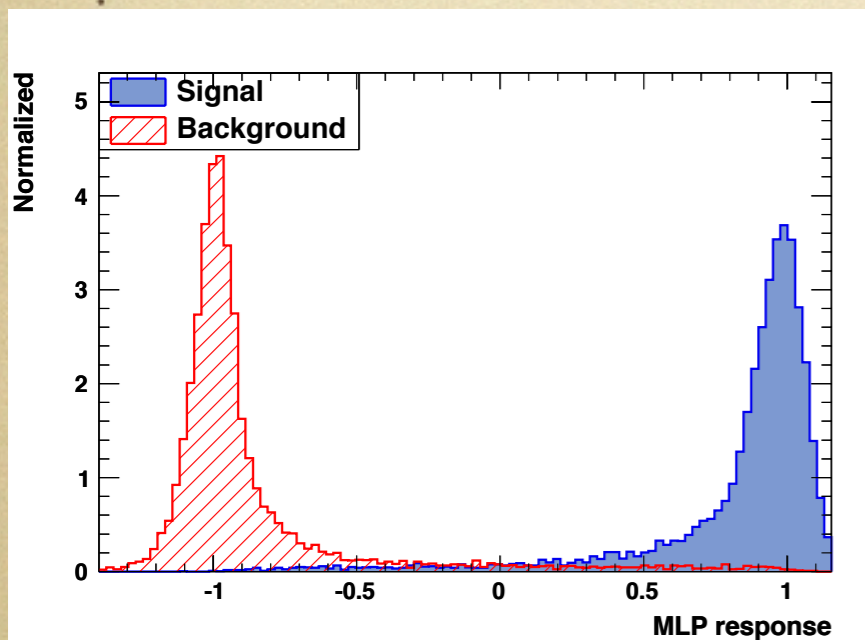
dominant backgrounds:

bbbb, lvbbqq, bbc sdu, bbuddu, bbcssc, qqbbbb, qqbbH

performance of the neural-net (cheated)



real



preliminary

reduction table (qqHH) cheated

(probZ1+probZ2 > 0.9)

Polarization: (e-,e+)=(-0.8,+0.3) $E_{cm} = 500\text{GeV}$, $M_H = 120\text{GeV}$

$$\int Ldt = 2\text{ab}^{-1}$$

normalized	expected	MC	pre-selection	probZ1+probZ2>0.9	$E_{vis}>400$ MissPt<60 (P1max<20 Econe>10)	MLP_bbbb<0.2	MLP_bbqqq>0	MLP_qqbbb	Bmax3>0.6 Bmax4
qqhh(qqbbbb)	313(138)	117173	91.0(71.4)	17.0(15.9)	15.5(14.9)	14.8(14.2)	13.8(13.3)	13.8(13.3)	12.2(11.8)
qqbbbb	192	59994	65.2	7.75	7.12	5.16	2.31	2.31	2.02
qqqqH(ZZH)	381	49702	49.8	6.55	5.74	5.11	3.94	3.94	3.43
bbcsdu	394548	710285	2759	23.2	21.8	16.3	3.57	3.57	1.46
bbuddu	199165	109200	293	7.92	5.37	5.37	5.09	5.09	0
bbcsc	197790	359084	4696	53.8	48.6	34.2	7.90	7.90	2.66
ttqq	2169	9999	169	8.69	4.66	4.37	1.95	1.95	1.35
bbbb	40824	198431	5052	143	117	2.42	0.89	0.89	0.79
lvbbqq	821199	797027	8137	137	19.6	0.07	0.07	0.07	0.07
BG			21223	388	230	73.2	25.8	25.8	11.9

signal: 12.2 (8.5)
 backgrounds: 11.9 (11.7)
 significance: 3.0σ (2.2σ)

preliminary

reduction table (qqHH)

(probZ1+probZ2 < 0.9)

cheated

Polarization: (e-,e+)=(-0.8,+0.3) $E_{cm} = 500\text{GeV}$, $M_H = 120\text{GeV}$

$$\int Ldt = 2\text{ab}^{-1}$$

normalized	expected	MC	pre-selection	probZ1+probZ2<0.9	$E_{vis}>400$ MissPt<60 (P1max<20 Econe>10)	MLP_hbbb<0. 2	MLP_bbqqq> 0.6	Bmax3>0.8	Bmax4>0.52
qqhh(qqbbbb)	313(138)	117173	91.0(71.4)	74.0(5.5)	63.5(52.6)	60.3(51.0)	32.3(28.9)	23.3(21.0)	17.7(16.1)
qqbbbb	192	59994	65.2	57.4	53.5	41.5	3.97	2.76	1.97
qqqqH(ZZH)	381	49702	49.8	43.3	38.3	34.9	9.34	6.50	4.91
bbcsdu	394548	710285	2759	2736	2629	2259	79.0	22.6	8.07
bbuddu	199165	109200	293	285	280	241	15.7	5.52	2.69
bbcsc	197790	359084	4696	4642	4416	3747	105	19.7	7.25
ttqq	2169	9999	169	161	79.1	77.0	9.67	5.22	3.41
bbbb	40824	198431	5052	4909	3978	74.8	1.69	1.19	0.98
lvbbqq	821199	797027	8137	8000	1261	208	6.99	1.23	0.06
BG			21223	20835	12735	6684	232	64.9	29.5

signal: 17.7 (16.6)

backgrounds: 29.5 (129)

significance: 2.9σ (1.4σ)

preliminary

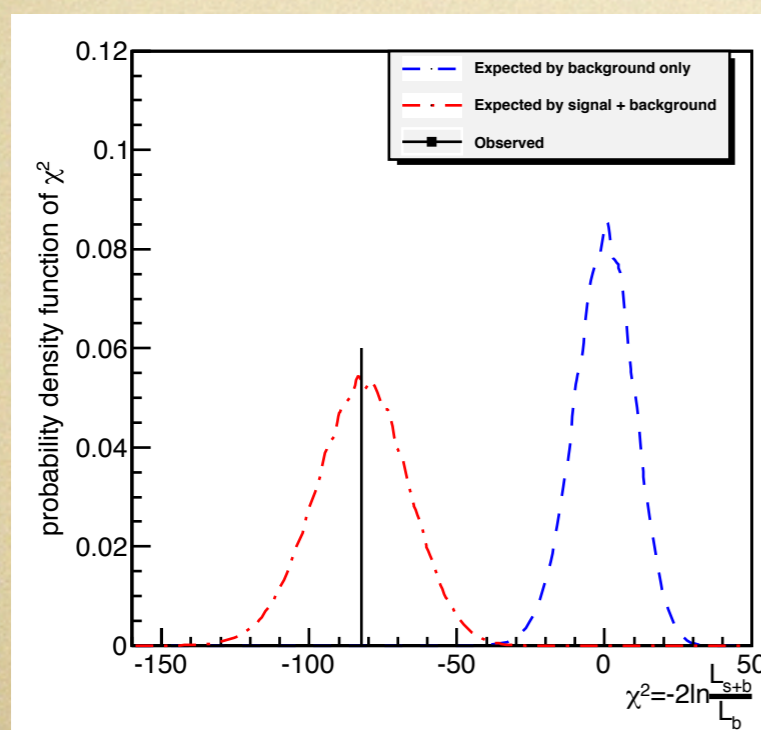
put all together

cheated analysis

Polarization: $(e^-, e^+) = (-0.8, 0.3)$

$$e^+ + e^- \rightarrow ZHH \quad M(H) = 120 \text{ GeV} \quad \int L dt = 2 \text{ ab}^{-1}$$

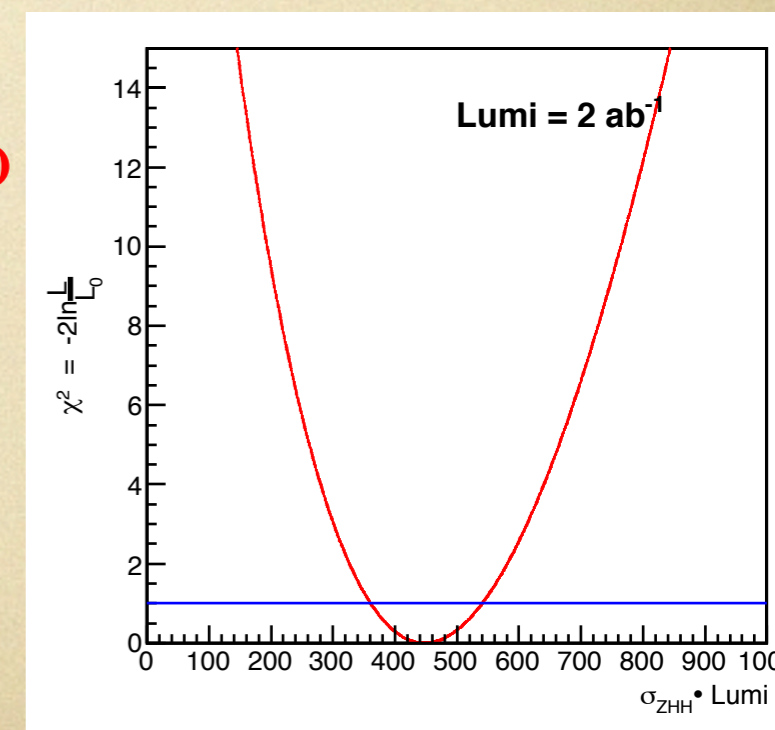
Energy (GeV)	Modes	signal	background	significance	
				excess (I)	measurement (II)
500	$ZHH \rightarrow (l\bar{l})(b\bar{b})(b\bar{b})$	9.8	3.9	3.7σ	2.8σ
500	$ZHH \rightarrow (\nu\bar{\nu})(b\bar{b})(b\bar{b})$	12.6	8.1	3.6σ	2.9σ
500	$ZHH \rightarrow (q\bar{q})(b\bar{b})(b\bar{b})$	12.2	11.9	3.0σ	2.6σ
		17.7	29.5	2.9σ	2.6σ
500	combined			8.1σ	5.2σ



$$\sigma_{ZHH} = 0.22 \pm 0.04 \text{ fb} \quad (0.07)$$

$$\frac{\delta\sigma}{\sigma} = 20\% \quad (32\%)$$

$$\frac{\delta\lambda}{\lambda} = 36\% \quad (57\%)$$



summary

- ZHH analysis with cheated jet clustering algorithm is investigated. potentially a fact of 2 could be improved for the precision of x-section (considering that the cuts for cheated analysis are not optimized).
- the excess significance can be significantly improved, however the measurement significance is mainly limited by the selection efficiency ($\sim 20\%$) and the total number of signal events (~ 200). (even if without any background, only 6.3σ , corresponding to 16% measurement accuracy)
- next step: focus on the journal paper of previous analysis, meanwhile considering possible new strategy of improving the signal efficiency.

backup

reduction table

(probZ1+probZ2 > 0.9)

$P(e^-,e^+) = (-0.8, +0.3)$

$E_{cm} = 500\text{GeV}, M_H = 120\text{GeV}$

$\int Ldt = 2\text{ab}^{-1}$

normalized	expected	MC	pre-selection	probZ1+probZ2>0.9	Evis>400 MissPt<60 (Plmax<201) Econe>10)	MLP_bbbb>0.2	MLP_bbqqq>-0.3	MLP_qqbbbb>-0.6	Bmax3>0.76 Bmax4>0.33
qqhh(qqbbbb)	313(138)	117173	82.0(65.1)	15.5(13.8)	13.9(13.0)	13.1(12.3)	12.7(11.9)	12.1(11.4)	8.50(8.15)
qqbbbb	192	59994	50.9	3.17	2.97	2.01	1.75	1.28	0.55
qqqqH(ZZH)	381	49702	45.8	6.58	5.72	5.11	4.80	4.14	2.70
bbcsdu	394548	710285	3016	29.7	29.1	22.3	14.9	13.5	1.38
bbuddu	199165	109200	374	10.5	7.92	5.37	5.37	5.37	0.28
bbcssc	197790	359084	4904	58.4	53.8	47.9	39.2	36.5	2.01
ttqq	2169	9999	170	10.0	5.08	4.83	4.70	4.49	1.85
bbbb	40824	198431	4722	598	494	2.83	2.20	1.80	1.27
lvbbqq	821199	797027	12216	230	33.2	6.18	6.18	4.39	0.07
BG			25509	951	636	100	82.2	73.7	11.7

reduction table

(probZ1+probZ2 < 0.9)

$P(e^-,e^+) = (-0.8, +0.3)$

$E_{cm} = 500\text{GeV}, M_H = 120\text{GeV}$

$\int Ldt = 2\text{ab}^{-1}$

normalized	expected	pre-selection	probZ1+probZ2<0.9	Evis>400 MissPt<60 (Plmax<2011 Econe>10)	MLP_bbbb>0.2	MLP_bbqqqq>0.16	Bmax3>0.8 Bmax4>0.52
qqhh(qqbbbb)	313(138)	82.0(65.1)	66.4(51.3)	57.6(48.7)	54.9(47.1)	33.1(29.1)	16.6(15.1)
qqbbbb	192	50.9	47.7	44.9	36.2	11.7	6.00
qqqqH(ZZH)	381	45.8	39.2	35.0	32.3	15.5	7.65
bbcdu	394548	3016	2986	2869	2581	469	42.2
bbuddu	199165	374	364	356	324	67.3	5.37
bbcsc	197790	4904	4845	4616	4131	623	39.6
ttqq	2169	170	159	79.4	78.4	42.8	13.7
bbbb	40824	4722	4124	3368	70.1	18.2	9.12
lvbbqq	821199	12216	11986	1641	297	49.4	4.34
BG		25509	24557	13015	7555	1298	129

cheated jet clustering algorithm

three new processors are developed:

- ISRTaggerProcessor
identify the initial-state-radiated photons
- ColorSingletTaggerProcessor
find the originated color singlet for each PFO
find the B-hadron for each PFO if it is decayed from
- SatoruJetFinderWithCheatProcessor
combine the PFOs from a same color singlet
combine the PFOs from a same B-hadron