Higgs Self-Coupling Measurement at the ILC.

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Overview

- perform analysis for 125 GeV with and without overlay
- leptonic channel and neutrino channel presented in January
- today: give short overview of hadronic channel and preliminary results
- analysis strategy identical to Junping Tians LC-REP-2013-003
- complete analysis will be presented at AWLC2014 at FermiLab

Analysis strategy for hadronic channel

1. reject events with isolated leptons
2. remove low-p_T $\gamma\gamma \rightarrow$hadrons background
3. force the other reconstructed particles into six jets (Durham algorithm)
4. combine the six jets by choosing combination with smallest χ^2

$$\chi^2 = \frac{(M(j_i j_j) - M(H))^2}{\sigma_H^2} + \frac{(M(j_k j_l) - M(H))^2}{\sigma_H^2} + \frac{(M(j_m j_n) - M(Z))^2}{\sigma_Z^2}$$

5. require 3rd largest b-likeliness of 4 jets from the 2 Higgs to be bmax3 > 0.16
6. neural net analysis performed separately for signal and each background, output classifiers are used to suppress background

in final selection, separate all events into two categories according to the flavor tagging of the two jets from the Z boson

bbHH dominant and **light qqHH dominant**.

$\longrightarrow$ achieve separation with the sum of b-likeliness of the two jets from Z decay

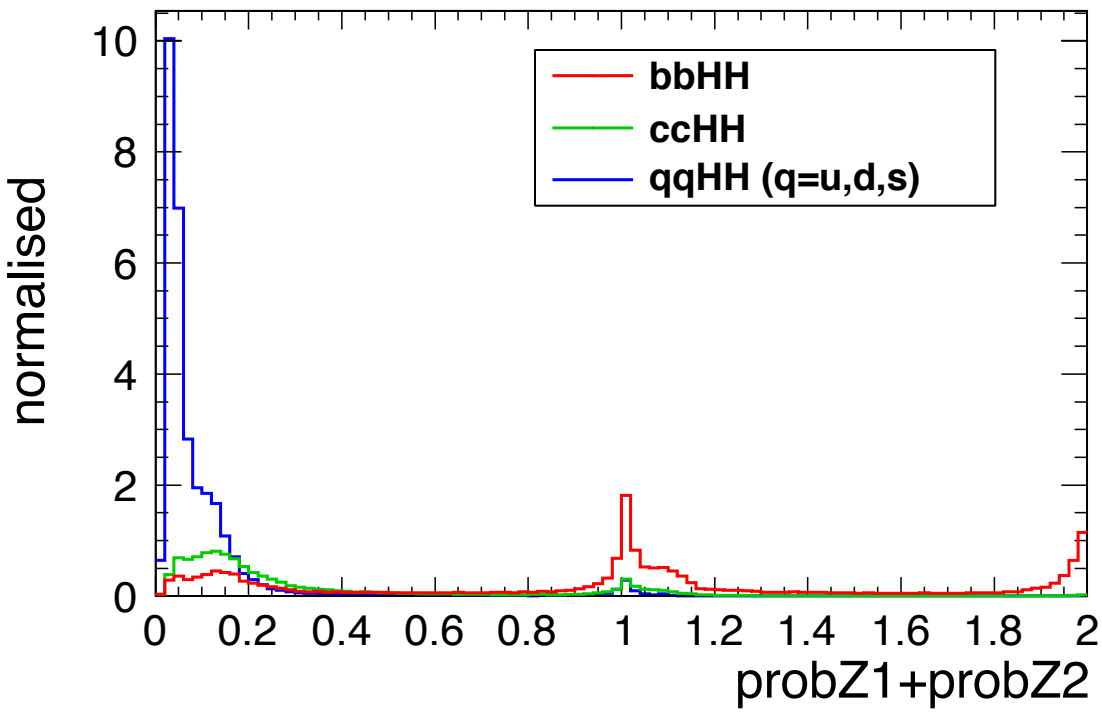

Figure : The b-likeliness of the two Z-bosons using samples with overlay.

Optimised cuts - dominant bbHH

optimise with overlay

- **cut1**: $\text{prop31} + \text{prob32} > 0.54$
- **cut2**:
  $P_{\text{t}}^{\text{miss}} < 77$ GeV,
  $\text{npfos} > 245$,
  $37\ \text{GeV} < \text{M(Z)} < 136\ \text{GeV}$,
  $83\ \text{GeV} < \text{M(H1)} < 159\ \text{GeV}$,
  $62\ \text{GeV} < \text{M(H1)} < 162\ \text{GeV}$
- **cut3**: $\text{MVAbbbb} > 0.83$
- **cut4**: $\text{MVAbbqqqq} > 0.51$
- **cut5**: $\text{MVAqqbbbb} > 0.16$
- **cut6**: $\text{bmax3} + \text{bmax4} > 1.21$

optimise without overlay

- **cut1**: $\text{prop31} + \text{prob32} > 0.54$
- **cut2**:
  $P_{\text{t}}^{\text{miss}} < 80$ GeV,
  $\text{npfos} > 246$,
  $34\ \text{GeV} < \text{M(Z)} < 136\ \text{GeV}$,
  $81\ \text{GeV} < \text{M(H1)} < 170\ \text{GeV}$,
  $73\ \text{GeV} < \text{M(H1)} < 167\ \text{GeV}$
- **cut3**: $\text{MVAbbbb} > 0.71$
- **cut4**: $\text{MVAbbqqqq} > 0.48$
- **cut5**: $\text{MVAqqbbbb} > 0.14$
- **cut6**: $\text{bmax3} + \text{bmax4} > 1.22$

Cutflow - dominant bbHH

light grey: without overlay
white: with overlay

	bbbb	lνbbqq	bbuddu	bbcsdu	bbcssc	qqbbbb	qqqqh	ttz	ttg	bgrd	signal (6b)
expected	40234.3	740098	156144	312013	155904	140.5	662.6	2197.2	2109.5	$1.4 \cdot 10^6$	273.13
preselection	23233.7	16136.2	570.0	6167.0	12588.5	83.6	114.7	166.4	428.9	59488.9	81.6 (59.7)
	23589.4	18813.7	952.9	8143.2	14255.2	83.5	116.2	175.1	434.6	66563.9	81.8 (59.4)
cut1	2294.9	318.2	11.4	90.4	261.4	14.2	15.4	16.9	45.3	3068.3	19.1 (16.1)
	2681.6	496.0	20.0	165.7	376.6	14.8	16.3	17.9	48.8	3837.9	19.6 (16.4)
cut2	673.8	109.0	11.3	82.2	246.1	12.9	14.5	14.8	31.9	1196.5	18.3 (15.6)
	796.2	185.7	18.2	148.9	341.6	12.9	14.9	15.1	33.0	1566.6	18.3 (15.7)
cut3	11.9	18.7	9.9	67.4	201.5	9.1	12.3	13.3	26.7	371.0	16.2 (14.3)
	11.5	21.2	12.7	109.0	242.8	7.4	10.9	12.7	24.8	453.1	14.9 (13.1)
cut4	10.0	14.8	7.3	48.6	130.9	8.1	11.4	12.7	24.8	268.7	15.6 (13.8)
	10.1	17.3	9.9	77.2	160.5	6.2	9.9	12.1	22.4	325.9	14.1 (12.4)
cut5	9.5	14.0	7.3	47.2	127.5	7.1	11.1	12.5	24.3	260.5	15.4 (13.7)
	9.6	17.0	9.7	74.5	157.1	5.6	9.7	12.2	22.3	317.8	13.9 (12.3)
cut6	3.8	0	0.7	0.7	3.0	3.2	5.0	2.3	2.7	21.3	9.1 (8.5)
	2.7	0	0.3	2.2	4.2	2.3	4.5	2.4	3.0	22.3	8.3 (7.8)

Optimised Cuts - dominant light qqHH

optimise with overlay

- **cut1**: $\text{prop31} + \text{prob32} < 0.54$
- **cut2**:
  $P_{\text{t}}^{\text{miss}} < 77$ GeV,
  npfos > 245,
  65 GeV $<$ M(Z) < 133 GeV,
  100 GeV $<$ M(H1) < 136 GeV,
  96 GeV $<$ M(H1) < 141 GeV
- **cut3**: $\text{MVAbbbb} > 0.73$
- **cut4**: $\text{MVAbbqqqq} > 0.52$
- **cut5**: $\text{MVAqqbbbb} > 0.11$
- **cut6**:
  $\text{bmax3} > 0.92$,
  $\text{bmax3} + \text{bmax4} > 1.37$

optimise without overlay

- **cut1**: $\text{prop31} + \text{prob32} < 0.54$
- **cut2**:
  $P_{\text{t}}^{\text{miss}} < 80$ GeV,
  npfos > 246,
  64 GeV $<$ M(Z) < 129 GeV,
  104 GeV $<$ M(H1) < 134 GeV,
  98 GeV $<$ M(H1) < 140 GeV
- **cut3**: $\text{MVAbbbb} > 0.59$
- **cut4**: $\text{MVAbbqqqq} > 0.43$
- **cut5**: $\text{MVAqqbbbb} > 0.15$
- **cut6**:
  $\text{bmax3} > 0.91$,
  $\text{bmax3} + \text{bmax4} > 1.38$

Cutflow - dominant light qqHH

light grey: without overlay

white: with overlay

	bbbb	lνbbqq	bbuddu	bbcsdu	bbcssc	qqbbbb	qqqqh	ttz	ttg	bgrd	signal (6b)
expected	40234.3	740098	156144	312013	155904	140.5	662.6	2197.2	2109.5	$1.41 \cdot 10^6$	273.13
preselection	23233.7	16136.2	570.0	6167.0	12588.5	83.6	114.7	166.4	428.9	59488.9	81.6 (59.7)
	23589.4	18813.7	952.9	8143.2	14255.2	83.5	116.2	175.1	434.6	66563.9	81.8 (59.4)
cut1 (probZ)	20938.8	15818.0	558.6	6076.6	12327.1	69.3	99.2	149.5	383.6	56420.7	62.5 (43.6)
	20907.8	18317.7	932.9	7977.5	13878.5	68.7	99.9	157.2	385.8	62726.0	62.1 (43.0)
cut2 (m,pfos,pt)	158.6	212.7	65.5	800.0	1552.1	5.2	13.3	21.8	41.5	2870.9	20.7 (17.7)
	196.2	338.7	141.1	1263.7	2132.6	6.8	17.2	27.2	49.6	4173.1	21.9 (18.4)
cut3 (mlp1)	12.3	81.8	62.4	741.1	1431.1	4.6	12.4	21.5	40.1	2407.3	19.5 (16.8)
	13.9	134.0	128.8	1116.5	1866.8	5.6	15.1	26.5	47.4	3354.6	19.8 (16.7)
cut4 (mlp2)	11.8	65.5	51.6	549.8	989.3	4.5	12.2	21.1	38.9	1744.8	19.2 (16.6)
	11.9	109.6	82.1	666.7	1034.3	5.1	14.1	25.2	42.7	1991.9	19.0 (16.1)
cut5 (mlp3)	11.3	64.7	50.3	541.7	973.4	4.1	12.1	21.1	38.7	1717.4	19.1 (16.5)
	11.8	109.6	81.2	661.7	1028.9	4.9	14.0	25.2	42.6	1979.9	18.9 (16.0)
cut6 (bmax3)	4.6	0.3	2.9	5.2	4.9	1.7	4.6	4.3	6.0	34.7	9.0 (8.2)
	5.6	0.5	2.4	6.2	5.1	2.0	5.8	5.0	6.6	39.3	8.7 (7.9)

Preliminary results of analysis for 125 GeV

- results extrapolated to m_H= 125 GeV give a precision of 53% on the Higgs self-coupling
- preliminary results for m_H= 125 GeV without overlay

modes	signal	background	significance	
			excess	measurement
$ZHH \to l^-l^+HH$	3.0	4.3	1.16σ	0.91σ
	3.3	6.0	1.12σ	0.91σ
$ZHH \to \nu\bar{\nu}HH$	5.4	7.0	1.72σ	1.45σ
$ZHH \to q\bar{q}HH$	9.1	21.3	1.78σ	1.61σ
	9.0	34.7	1.41σ	1.30σ

cross-section: $\frac{\delta\sigma_{ZHH}}{\sigma_{ZHH}} = 32\%$

Higgs self-coupling: $\frac{\delta\lambda}{\lambda} = 52\%$

We achieve a precision of 52% on the Higgs self-coupling for $m_H = 125$ GeV

Effect of $\gamma\gamma$-overlay ?

Preliminary results for $m_H = 125$ GeV with overlay

preliminary results for $m_H = 125$ GeV without overlay:

modes	signal	background	significance	
			excess	measurement
$ZHH \to l^- l^+ HH$	3.0	4.3	1.16σ	0.91σ
	3.3	6.0	1.12σ	0.91σ
$ZHH \to \nu\bar{\nu}HH$	5.4	7.0	1.72σ	1.45σ
$ZHH \to q\bar{q}HH$	9.1	21.3	1.78σ	1.61σ
	9.0	34.7	1.41σ	1.30σ

We achieve a combined signal significance of $s\sigma = 3.8\sigma$

preliminary results for $m_H = 125$ GeV with overlay:

modes	signal	background	significance	
			excess	measurement
$ZHH \to l^- l^+ HH$	2.4	4.0	0.94σ	0.72σ
	3.2	7.0	1.01σ	0.83σ
$ZHH \to \nu\bar{\nu}HH$	3.8	4.0	1.53σ	1.22σ
$ZHH \to q\bar{q}HH$	8.3	22.3	1.59σ	1.44σ
	8.7	39.3	1.29σ	1.19σ

Considering overlay, we achieve a combined signal significance of $s\sigma = 2.9\sigma$

Preliminary results of analysis for 125 GeV

- results without overlay for $m_H = 125$ GeV give a precision of 52% on the Higgs self-coupling
- preliminary results for $m_H = 125$ GeV with overlay

cross-section: $\frac{\delta\sigma_{ZHH}}{\sigma_{ZHH}} = 36.2\%$

Higgs self-coupling: $\frac{\delta\lambda}{\lambda} = 59.4\%$

Considering $\gamma\gamma$-overlay, we achieve a precision of 59% on the Higgs self-coupling

Next step: optimise analysis strategy