Higgs Coupling Measurements at a 1 TeV LC

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Higgs Branching Fractions from TESLA TDR

Channel	$M_H = 120\,\mathrm{GeV}$	$M_H = 140\,\mathrm{GeV}$	$M_H = 160\,\mathrm{GeV}$
$H^0/h^0 \to b\bar{b}$	$\pm\ 0.024$	$\pm\ 0.026$	$\pm\ 0.065$
$H^0/h^0 \to c\bar{c}$	$\pm\ 0.083$	$\pm\ 0.190$	
$H^0/h^0 \to gg$	$\pm\ 0.055$	$\pm\ 0.140$	
$H^0/h^0 \to \tau^+\tau^-$	$\pm\ 0.050$	$\pm\ 0.080$	

Table 2.2.5: *Relative accuracy in the determination of Higgs boson branching ratios for 500 fb*$^{-1}$ *at* $\sqrt{s} = 350$ *GeV.*

Channel	$M_H = 120\,\mathrm{GeV}$	$140\,\mathrm{GeV}$	$160\,\mathrm{GeV}$
$\sigma(e^+e^- \to H^0 Z)$	$\pm\ 0.025$	$\pm\ 0.027$	$\pm\ 0.030$
$H^0 \to WW^*$	$\pm\ 0.051$	$\pm\ 0.025$	$\pm\ 0.021$
$H^0 \to ZZ^*$			$\pm\ 0.169$

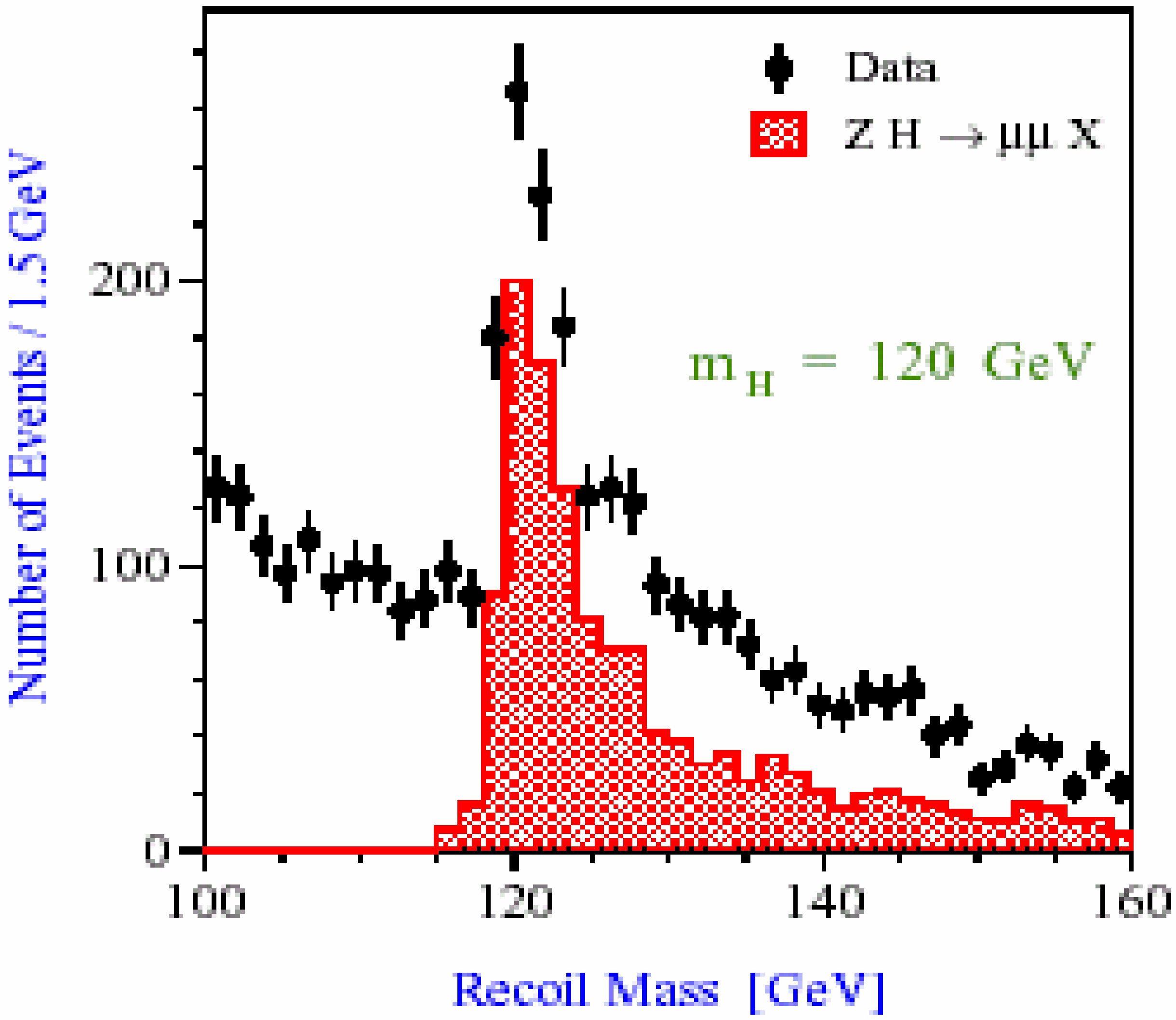
Table 2.2.3: *Relative accuracy in the determination of the SM Higgs boson production cross–sections and decay rates into gauge bosons for 500 fb*$^{-1}$ *at* $\sqrt{s} = 350$ *GeV and 500 GeV.*

Higgs Branching Ratio B_x

$$B_x = \frac{N_x - L\sigma_b}{L\sigma_{Zh}\eta_x}$$

$$\frac{\Delta B_x}{B_x} = \left(1 - \frac{L\sigma_b}{N_x}\right)^{-1} \frac{\Delta N_x}{N_x} \oplus \frac{\Delta\sigma_{Zh}}{\sigma_{Zh}} \oplus \left(\frac{N_x}{L\sigma_b} - 1\right)^{-1} \frac{\Delta\sigma_b}{\sigma_b} \oplus \left(1 - \frac{L\sigma_b}{N_x}\right)^{-1} \frac{\Delta L}{L}$$

$\frac{\Delta B_x}{B_x}$ cannot be less than $\frac{\Delta\sigma_{Zh}}{\sigma_{Zh}} = 2.4\%$



Data
Z H → μμ X
m_H = 120 GeV
Number of Events / 1.5 GeV
0
100
200
100
120
140
160
Recoil Mass [GeV]

Higgs Γ_{tot}

$$\Gamma_{tot} = a \frac{(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})}{B_{b\bar{b}} B_{WW^*}}$$

$$\frac{\Delta\Gamma_{tot}}{\Gamma_{tot}} = \frac{\Delta(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})}{(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})} \oplus \frac{\Delta B_{b\bar{b}}}{B_{b\bar{b}}} \oplus \frac{\Delta B_{WW^*}}{B_{WW^*}}$$

$$\frac{\Delta(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})}{(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})} = 0.013 \quad \frac{\Delta B_{b\bar{b}}}{B_{b\bar{b}}} = 0.024 \quad \frac{\Delta B_{WW^*}}{B_{WW^*}} = 0.064 \Rightarrow \frac{\Delta\Gamma_{tot}}{\Gamma_{tot}} = 0.07$$

for $M_h = 115\ GeV$ assuming $500\, fb^{-1} @ \sqrt{s} = 350 - 500\ GeV$

Take cue from Battaglia & DeRoeck results for $B_{h\to\mu\mu}$ at CLIC and investigate branching fraction measurements in WW fusion at a 1 TeV LC.

Event rates assuming $m_h = 115\,GeV$

$\sqrt{s}\,(GeV)$	$L(fb^{-1})$	$e^-_{pol}(\%L)$	$e^+_{pol}(\%R)$			
				$L\sigma_{Zh}B_{h\to b\bar{b}}$	$L\sigma_{Zh}B_{h\to WW^*}$	$L\sigma_{Zh}B_{Z\to ee,\mu\mu}$
350	500	0	0	48720	5400	4443
				$L\sigma_{\nu\nu h}B_{h\to b\bar{b}}$	$L\sigma_{\nu\nu h}B_{h\to WW^*}$	$L\sigma_{eeh}$
500	500	80	0	50238	5562	
1000	1000	80	50	391149	43335	26159

Higgs Γ_{tot} using $(\sigma_{\nu\nu h} \bullet B_{WW^*})$

instead of B_{WW^*}

$$\Gamma_{tot} = a \frac{(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})^2}{B_{b\bar{b}}^{\;2} (\sigma_{\nu\nu h} \bullet B_{WW^*})}$$

$$\frac{\Delta\Gamma_{tot}}{\Gamma_{tot}} = 2\frac{\Delta(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})}{(\sigma_{\nu\nu h} \bullet B_{b\bar{b}})} \oplus 2\frac{\Delta B_{b\bar{b}}}{B_{b\bar{b}}} \oplus \frac{\Delta(\sigma_{\nu\nu h} \bullet B_{WW^*})}{(\sigma_{\nu\nu h} \bullet B_{WW^*})}$$

Optimize signal for $e^+e^- \rightarrow \nu_e \overline{\nu_e}\, h$ at 1 TeV
$\quad\quad\quad\quad\quad\quad\quad\quad \mapsto b\bar{b}$

Require:

$$|\cos\theta_{thrust}| < 0.95$$

$$PT_{vis} > 20 \text{ GeV}$$

$$100 < E_{vis} < 500 \text{ GeV}$$

$$N_{isolated\ leptons} = 0$$

$$N_{jets} < 9$$

$5 < N_{imp} < 20$ where N_{imp} is number of large impact parameter charged tracks

Use WHIZARD MC to Simulate All 0,2,4,6-Fermion Processes and Dominant 8-Fermion

SM Final States 0,2,4-Fermion

0-fermion

$e^+e^- \to$	$\gamma\gamma$	
	$\gamma\gamma\gamma$	
	$\gamma\gamma\gamma\gamma$	
	$\gamma\gamma\gamma\gamma\gamma$	

2-fermion

$e^+e^- \to$	ff	$f \neq \nu$
	$\nu\nu\gamma$	
	$\nu\nu\gamma\gamma$	
	$\nu\nu\gamma\gamma\gamma$	
$e^-\gamma \to$	$e^-\gamma$	
$\gamma e^+ \to$	$e^+\gamma$	

4-fermion

$e^+e^- \to$	$\nu\nu\nu\nu\gamma$	6 total
	$u_j\overline{d}_j d_k\overline{u}_k$	25 total
		$\nu_e e^+ e^- \overline{\nu}_e$
		$\nu_e e^+ \mu^- \overline{\nu}_\mu$
		$\nu_e e^+ \tau^- \overline{\nu}_\tau$
		$\nu_e e^+ d\overline{u}$
		.
		.
		$c\overline{s}s\overline{c}$
	$u_j\overline{u}_j u_k\overline{u}_k$	9 total
	$u_j\overline{u}_j d_k\overline{d}_k$	25 total
	$d_j\overline{d}_j d_k\overline{d}_k$	21 total
$\gamma\gamma \to$	$f\overline{f}$	8 total
$e_L^-\gamma \to$	$\nu_e d_k\overline{u}_k$	5 total
$e^-\gamma \to$	$e^- f\overline{f}$	10 total
$\gamma e_R^+ \to$	$\overline{\nu}_e u_k\overline{d}_k$	5 total
$\gamma e^+ \to$	$e^+ f\overline{f}$	10 total

Initial state γ refers to both beamstrahlung and bremsstrahlung ↘

SM Final States 6-Fermion

6-fermion

$e^+e^- \to$	$u_i\overline{u}_i u_j\overline{d}_j d_k\overline{u}_k$	125 total
	$d_i\overline{d}_i u_j\overline{d}_j d_k\overline{u}_k$	150 total
	$u_i\overline{u}_i u_j\overline{u}_j u_k\overline{u}_k$	25 total
	$u_i\overline{u}_i u_j\overline{u}_j d_k\overline{d}_k$	65 total
	$u_i\overline{u}_i d_j\overline{d}_j d_k\overline{d}_k$	75 total
	$d_i\overline{d}_i d_j\overline{d}_j d_k\overline{d}_k$	56 total
$\gamma\gamma \to$	$u_j\overline{d}_j d_k\overline{u}_k$	25 total
	$u_j\overline{u}_j u_k\overline{u}_k$	9 total
	$u_j\overline{u}_j d_k\overline{d}_k$	25 total
	$d_j\overline{d}_j d_k\overline{d}_k$	21 total
$e^-_L\gamma \to$	$\nu_e u_j\overline{u}_j d_k\overline{u}_k$	25 total
	$\nu_e d_j\overline{d}_j d_k\overline{u}_k$	30 total
$e^-\gamma \to$	$e^- u_j\overline{d}_j d_k\overline{u}_k$	20 total
	$e^- u_j\overline{u}_j u_k\overline{u}_k$	10 total
	$e^- u_j\overline{u}_j d_k\overline{d}_k$	20 total
	$e^- d_j\overline{d}_j d_k\overline{d}_k$	21 total
$\gamma e^+_R \to$	$\overline{\nu}_e u_j\overline{d}_j u_k\overline{u}_k$	25 total
	$\overline{\nu}_e u_j\overline{d}_j d_k\overline{d}_k$	30 total
$\gamma e^+ \to$	$e^+ u_j\overline{d}_j d_k\overline{u}_k$	20 total
	$e^+ u_j\overline{u}_j u_k\overline{u}_k$	10 total
	$e^+ u_j\overline{u}_j d_k\overline{d}_k$	20 total
	$e^+ d_j\overline{d}_j d_k\overline{d}_k$	21 total

Initial state γ refers to both beamstrahlung and bremsstrahlung

SM Final States 8-Fermion

8-fermion

$$e^+e^- \to \quad f\overline{f}t\overline{t}$$

$$\gamma\gamma \to \quad t\overline{t}$$

$$e^-\gamma \to \quad e^-t\overline{t}$$

$$\nu_e b\overline{t}$$

$$\gamma e^+ \to \quad e^+t\overline{t}$$

$$\overline{\nu}_e t\overline{b}$$

$$e^+e^- \to \nu_e \bar{\nu}_e h$$
$$\qquad \qquad \mapsto b\bar{b}$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

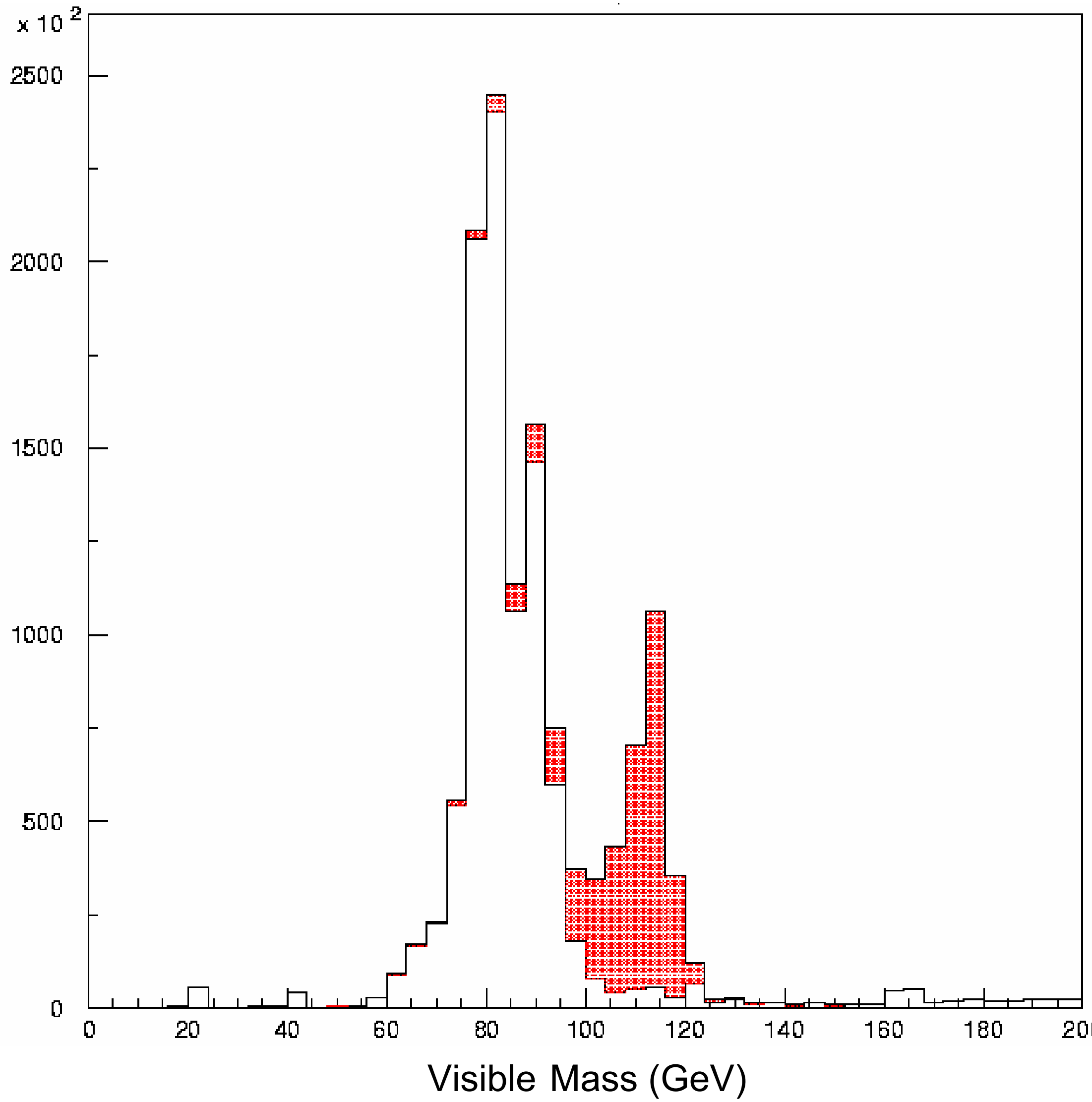
$L = 2\ ab^{-1}$

All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

Background passing cuts (white histogram) is mostly

$$e^+e^- \to e\nu W$$
$$eeZ$$
$$\nu\nu Z$$

Red histogram: $h \to b\bar{b}$



Optimize signal for $e^+e^- \to \nu_e \overline{\nu_e}\, h$ at 1 TeV
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad \mapsto WW^*$

Require:

$$|\cos\theta_{thrust}| < 0.95$$

$$20 \text{ GeV} < PT_{vis} < 500 \text{ GeV}$$

$$100 < E_{vis} < 400 \text{ GeV}$$

$$N_{isolated\ leptons} = 0$$

$$4 \leq N_{jets} \leq 5$$

$$16 \leq N_{chrg}$$

$N_{imp} \leq 6$ where N_{imp} is number of large impact parameter charged tracks

Perform Neural Net Analysis Using Above Variables and Dot Products of Jet 4-Vectors

$$e^+e^- \rightarrow \nu_e \overline{\nu}_e h$$
$$|\rightarrow WW^*$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

$L = 1\ ab^{-1}$

All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

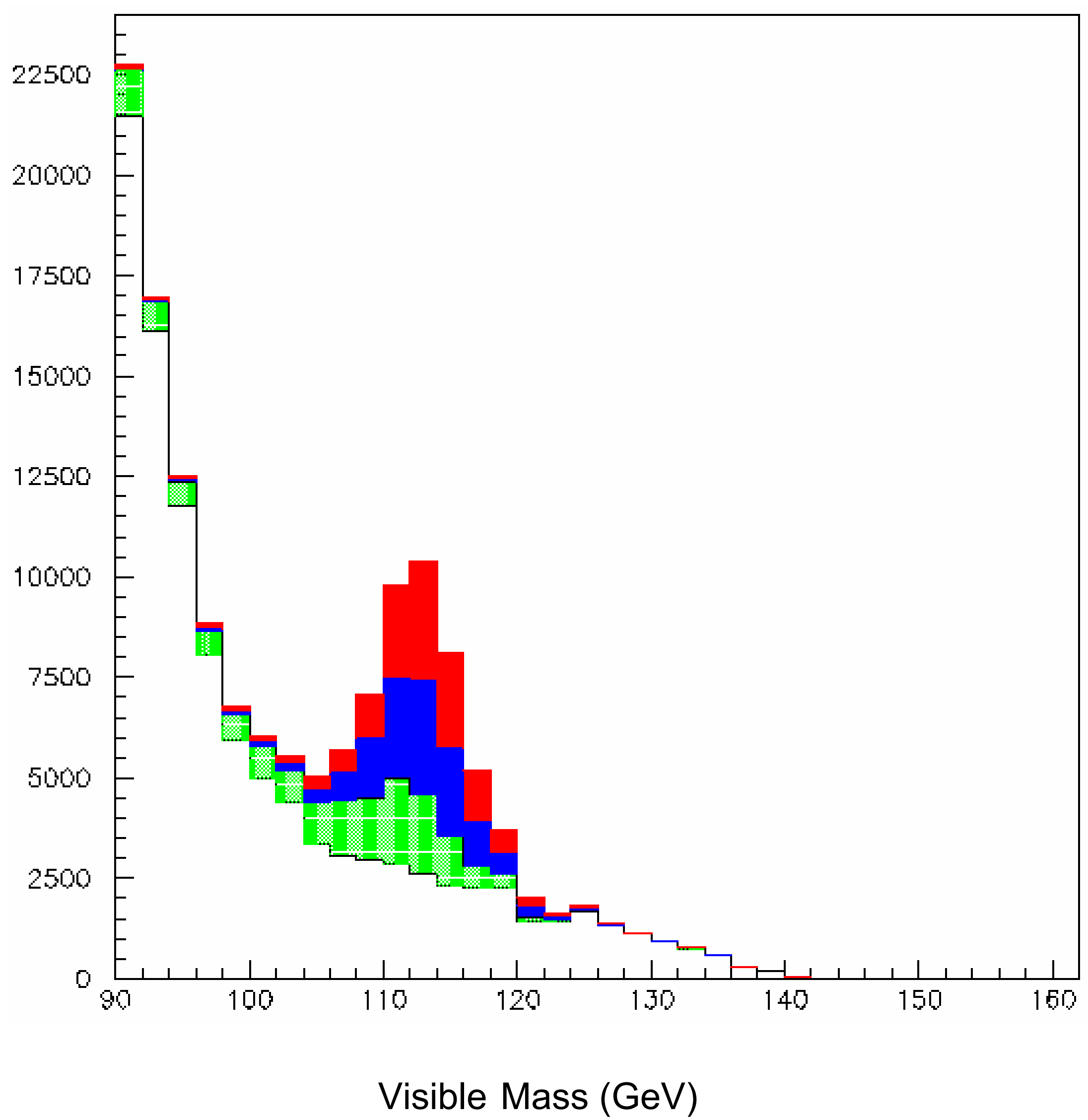
Non-Higgs background (white histogram) is mostly

$$e^+e^- \rightarrow e\nu W$$
$$(W\gamma \rightarrow ud)$$

Red histogram: $h \rightarrow WW^*$

Blue histogram: $h \rightarrow gg$

Green histogram: $h \rightarrow b\overline{b}$



$$e^+e^- \to \nu_e \overline{\nu}_e h$$
$$\quad\quad \mapsto WW^*$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

$L = 1\ ab^{-1}$

All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

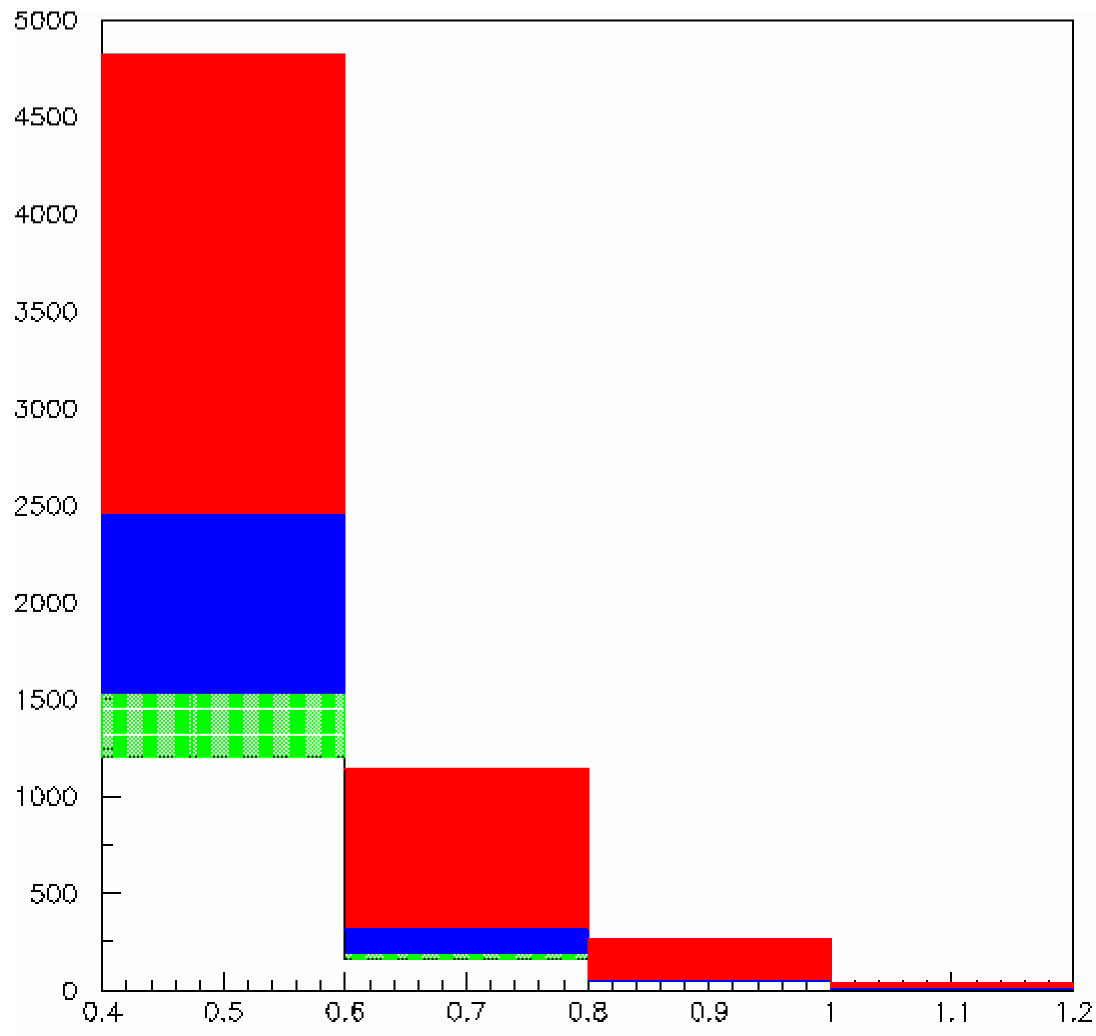
Non-Higgs background (white histogram) is mostly

$$e^+e^- \to e\nu W$$
$$(W\gamma \to ud)$$

Red histogram: $h \to WW^*$

Blue histogram: $h \to gg$

Green histogram: $h \to b\overline{b}$



$$e^+e^- \rightarrow \nu_e \bar{\nu}_e h$$
$$\quad\quad\quad\quad\quad\quad\quad \mapsto gg$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

$L = 1\ ab^{-1}$

All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

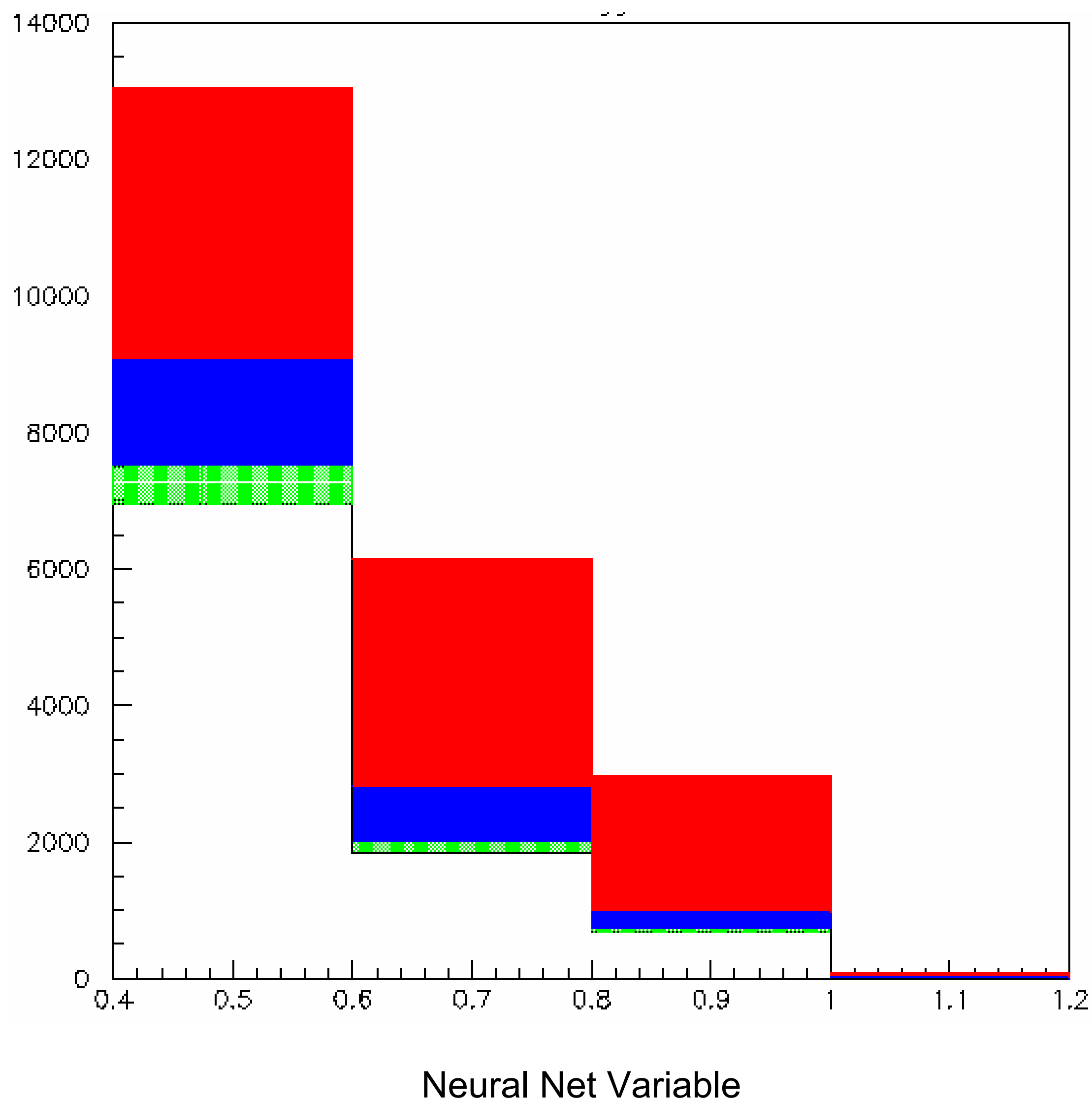
Non-Higgs background (white histogram) is mostly

$$e^+e^- \rightarrow e\nu W$$
$$(W\gamma \rightarrow ud)$$

Red histogram: $h \rightarrow gg$

Blue histogram: $h \rightarrow WW^*$

Green histogram: $h \rightarrow b\bar{b}$



Use ZZ fusion to measure Γ_{ZZ}

Optimize signal for $e^+e^- \rightarrow e^+e^-h$ at 1 TeV

using only the final state e^+e^-

Take the largest mass e^+e^- pair in the event and require:

$$0.8 < \cos\theta_{e^-} < 0.9975$$

$$-0.9975 < \cos\theta_{e^+} < -0.8$$

$$|\cos\theta_{ee}| < 0.98$$

$$650 \text{ GeV} < M_{ee} < 870 \text{ GeV}$$

$$0.8 < acopl_{ee}$$

$e^+e^- \to e^+e^-h$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

$L = 1\ ab^{-1}$

All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

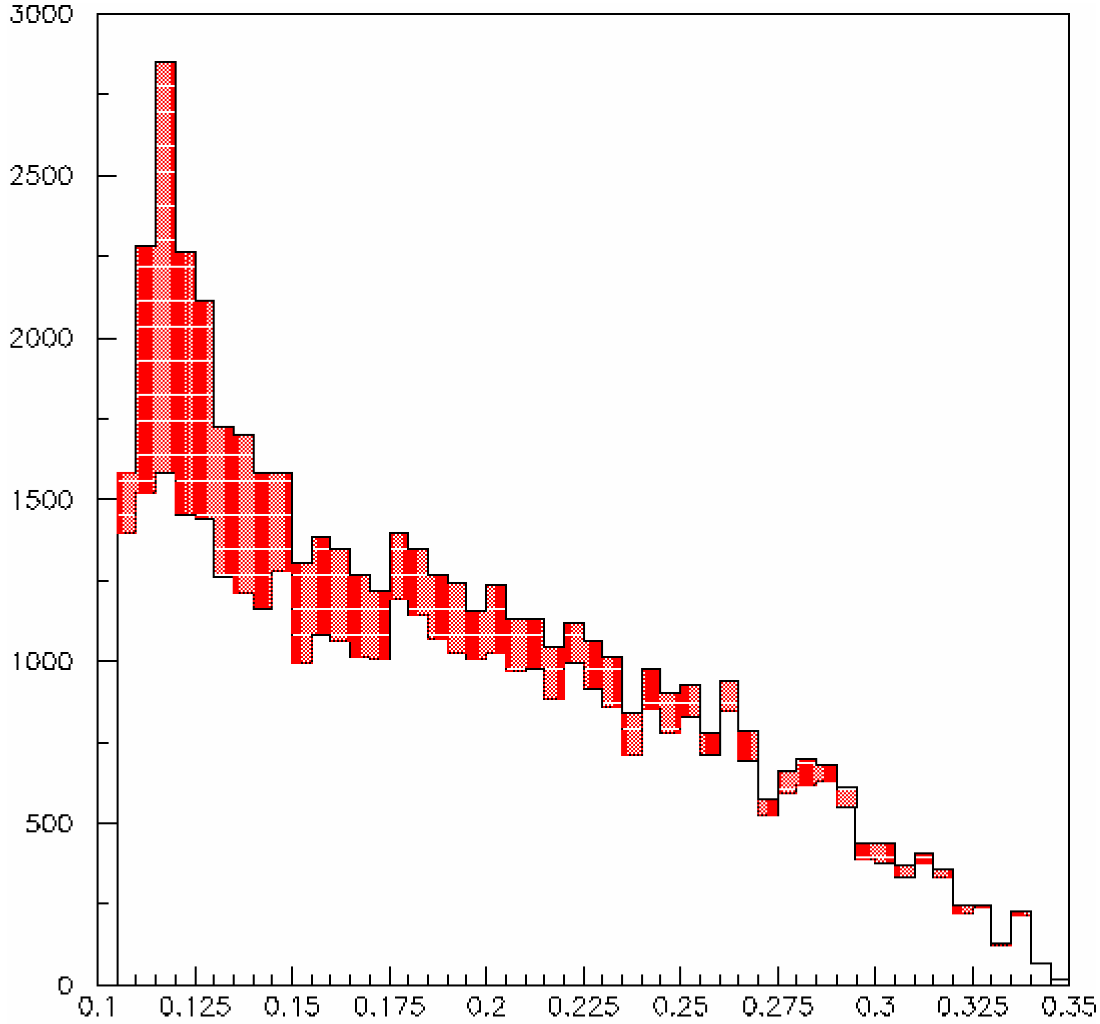
Non-Higgs background (white histogram) is mostly

$e^+e^- \to e^+e^-q\bar{q}$

$e^+e^- \to e^+e^-l^+l^-$

$e^+e^- \to e^+e^-W^+W^-$

Red histogram: $e^+e^- \to e^+e^-h$



Missing Mass Opposite e^+e^- (TeV)

$$\sqrt{s} = 1TeV \quad L = 1000\,fb^{-1} \quad m_h = 115\,GeV$$

$$\frac{\Delta\sigma_{\nu\nu h} \bullet B_{b\bar{b}}}{\sigma_{\nu\nu h} \bullet B_{b\bar{b}}} = 0.003 \qquad \frac{\Delta\sigma_{\nu\nu h} \bullet B_{WW^*}}{\sigma_{\nu\nu h} \bullet B_{WW^*}} = 0.023$$

$$\frac{\Delta\sigma_{\nu\nu h} \bullet B_{gg}}{\sigma_{\nu\nu h} \bullet B_{gg}} = 0.015 \qquad \frac{\Delta\sigma_{eeh}}{\sigma_{eeh}} = 0.029$$

x	$B_{h\to b\bar{b}}$	$B_{h\to WW^*}$	Γ_{tot}	$\Gamma_{h\to ZZ}$
$\Delta x / x$ without 1TeV	.024	.064	.070	.024
$\Delta x / x$ with 1TeV	.017	.027	.039	.018

$$e^+e^- \to \nu_e \bar{\nu}_e h$$
$$\hookrightarrow \gamma\gamma$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

$L = 1\ ab^{-1}$

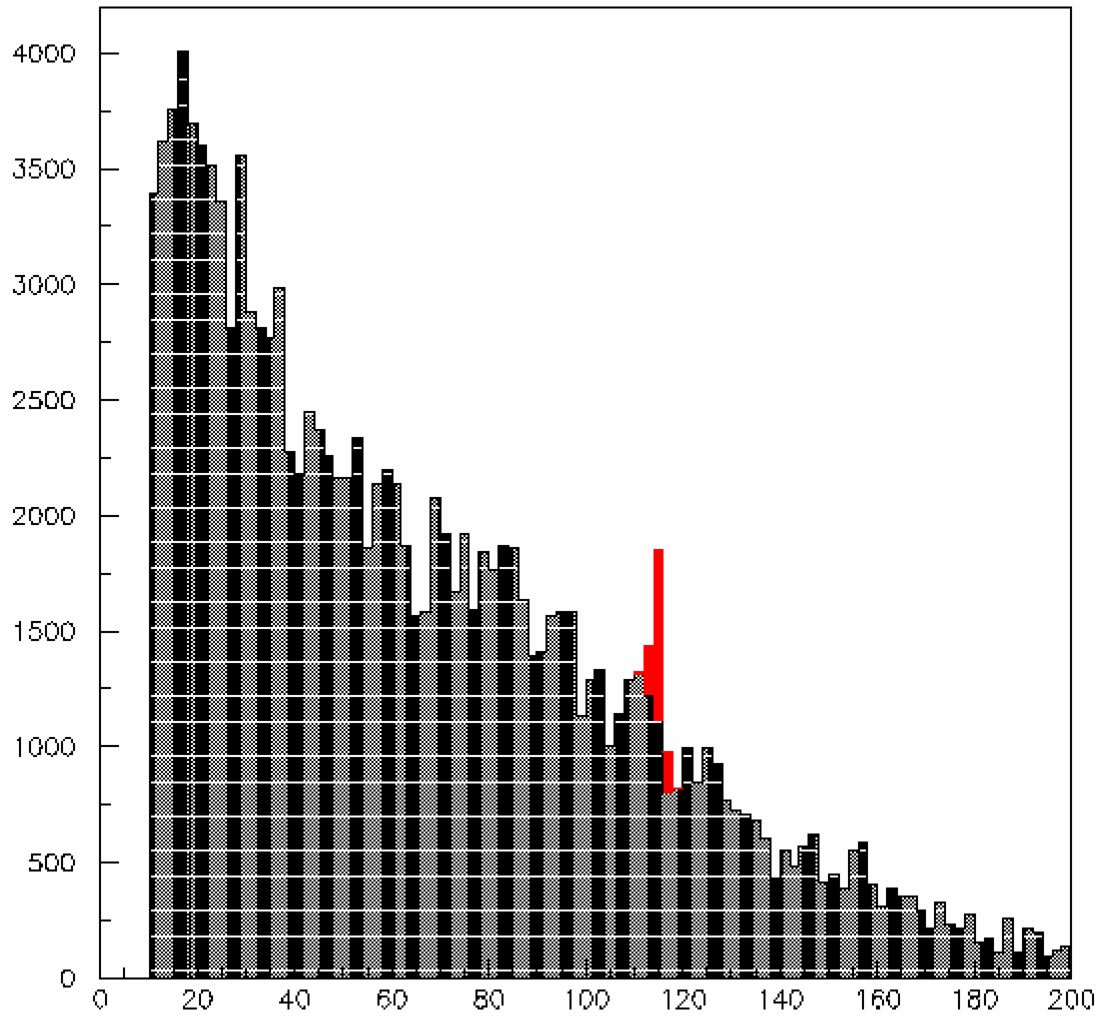
All 2,4,6-fermion and top-resonance 8-fermion backgrounds included

Non-Higgs background (white histogram) is mostly

$$e^+e^- \to \nu\nu\gamma\gamma$$

Red histogram: $h \to \gamma\gamma$

$$\frac{\Delta\sigma_{\nu\nu h} \bullet B_{\lambda\lambda}}{\sigma_{\nu\nu h} \bullet B_{\lambda\lambda}} = 0.06$$



Visible mass (GeV

SUMMARY

Meas of $\sigma_{\nu\nu h} \bullet B_{WW^*}$ and σ_{eeh} at 1 TeV improves resolution for B_{WW^*}, $B_{b\bar{b}}$, Γ_{ZZ}, Γ_{tot}

Further improvement in resolution for Γ_{tot} might be achieved with a measurement of $\sigma_{eeh} \bullet B_{WW^*}$ using WW semileptonic topology

6% measurement of $B_{\lambda\lambda}$ can be achieved.

Improvements in charm and gluon BR's are also possible.