Experimental Precision at a Future LC

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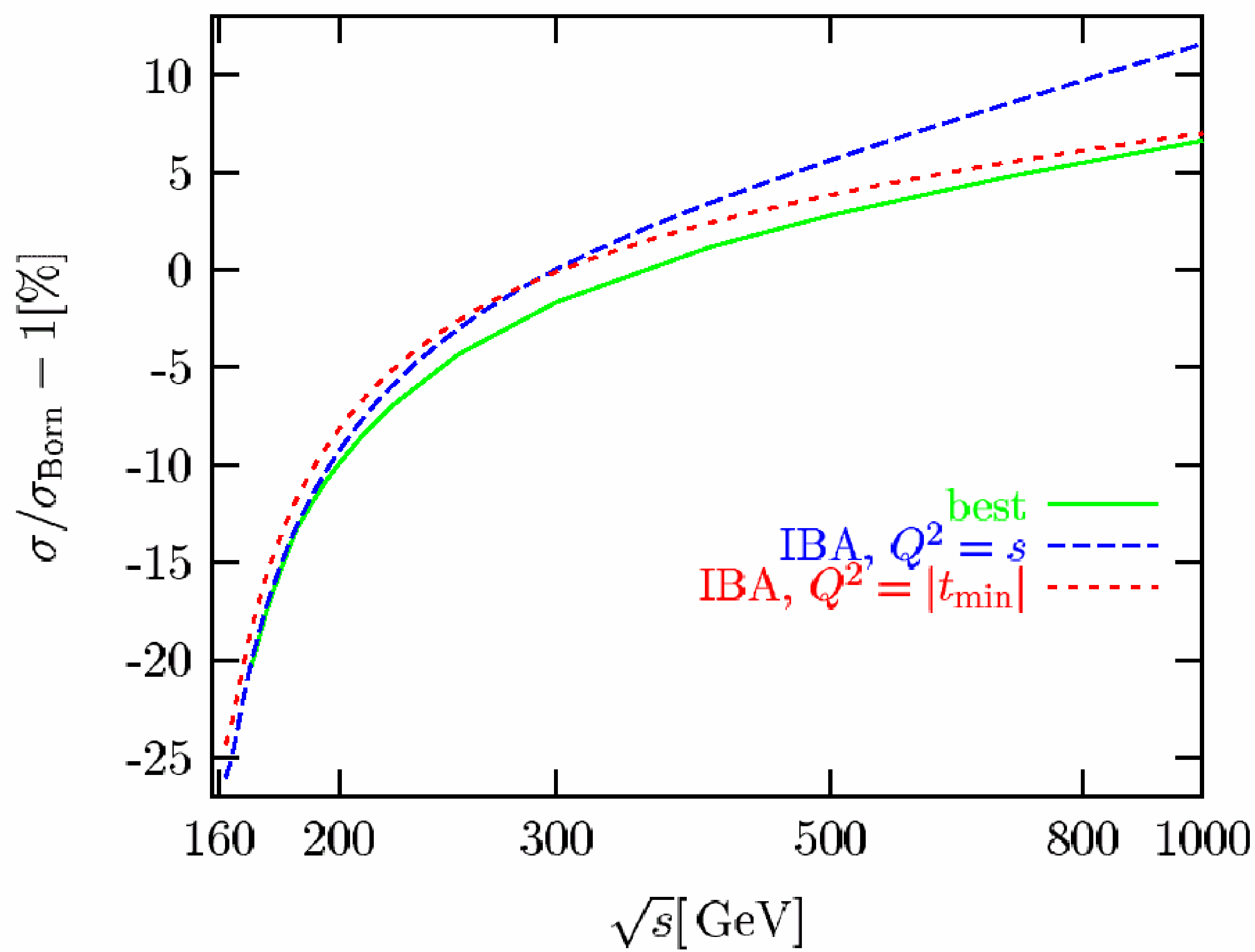
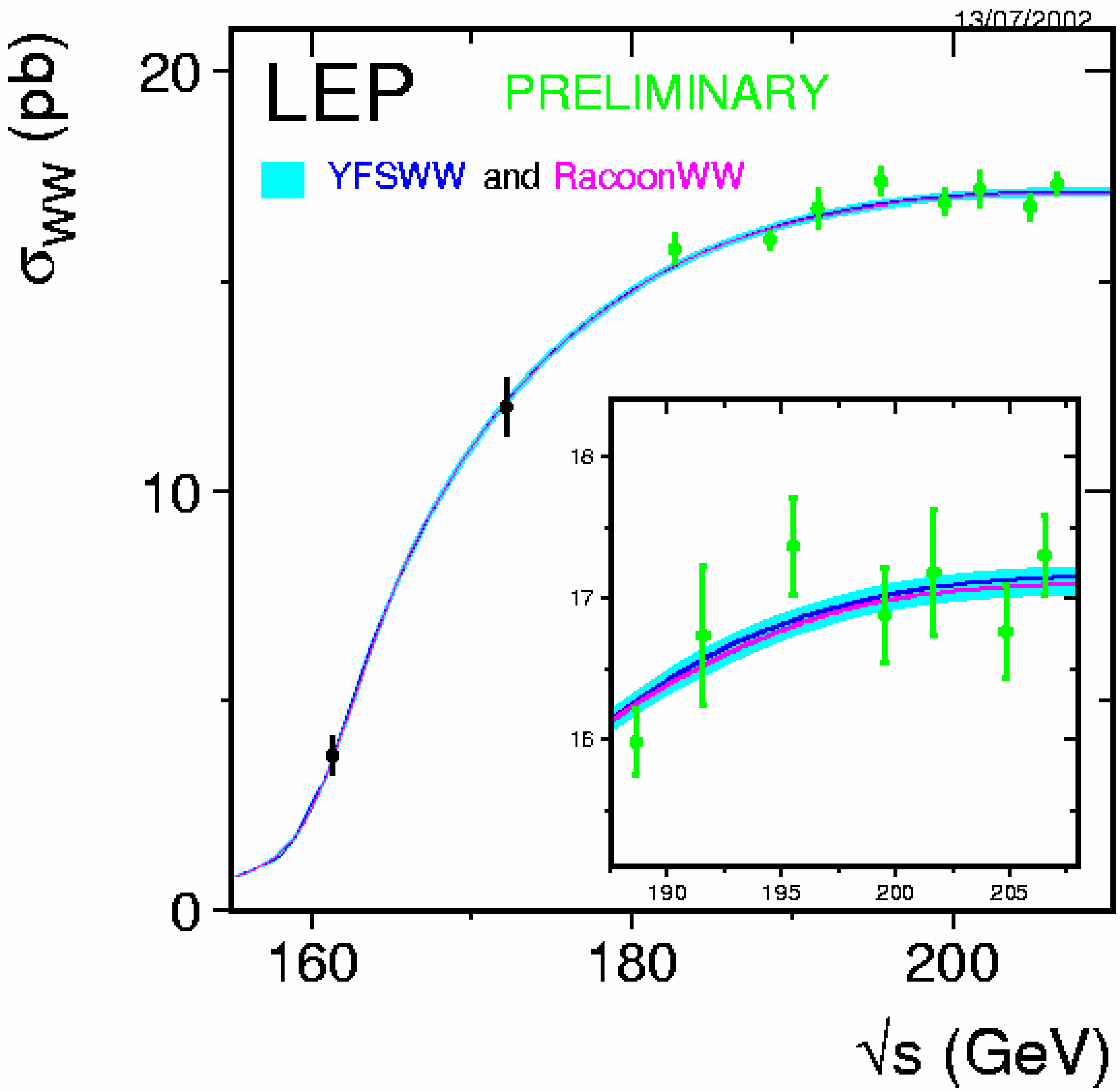
Outline

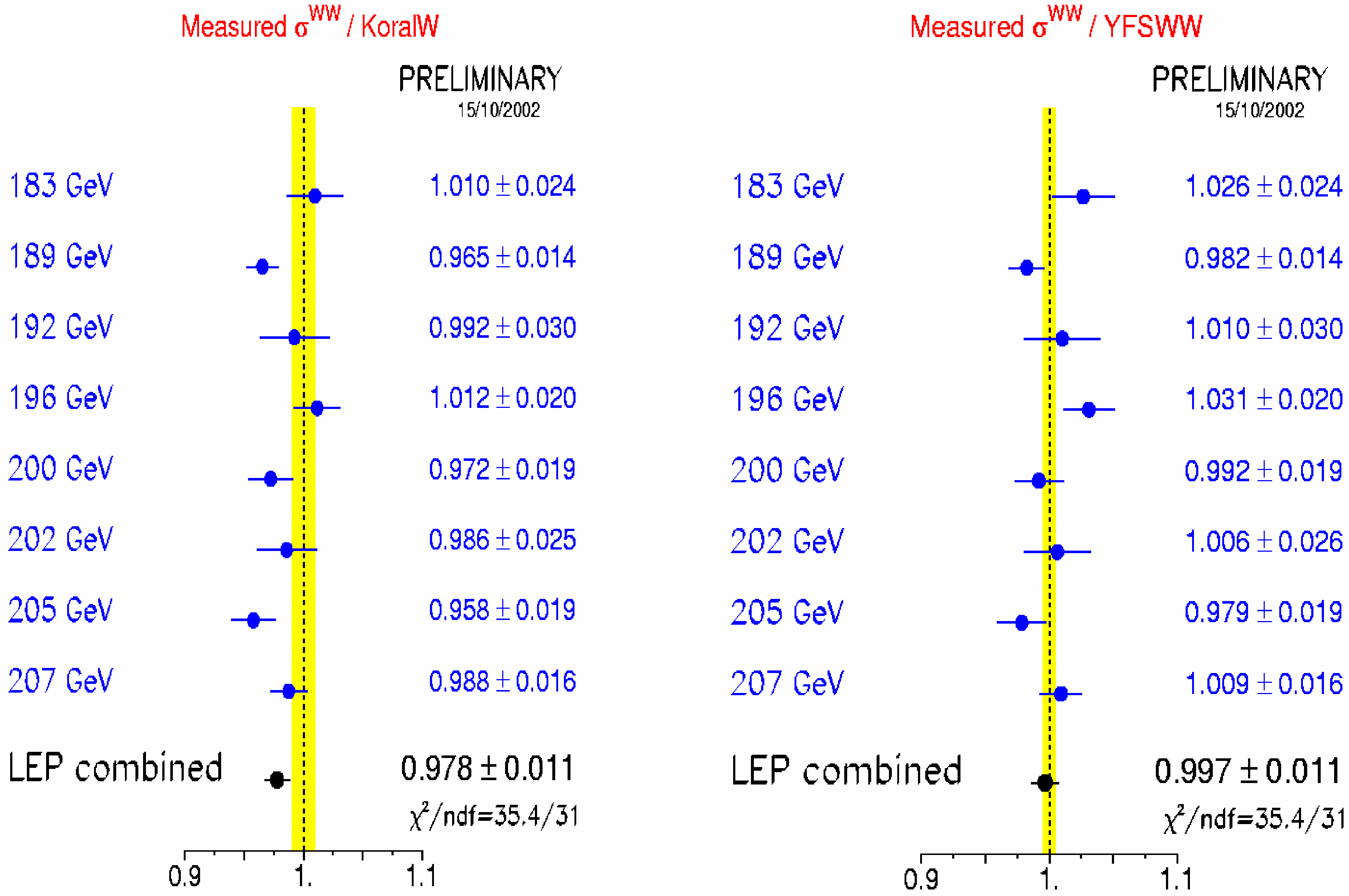
- W Cross-Sec, Mass & TGCs at LEP2
- TGCs at a LC
- SUSY
- Higgs Properties
- Summary

σ_{WW} : Improved Born Approx (IBA) vs $O(\alpha)$ EW NL corr from RACOONWW (best)

Total theory error of $\frac{\Delta\sigma_{WW}}{\sigma_{WW}} = 0.005$ for RACOONWW calcuation




13/07/2002
LEP
PRELIMINARY
YFSWW and RacoonWW
σ_{WW} (pb)
20
10
0
160
180
200
18
17
16
190
195
200
205
$\sqrt{s}$ (GeV)

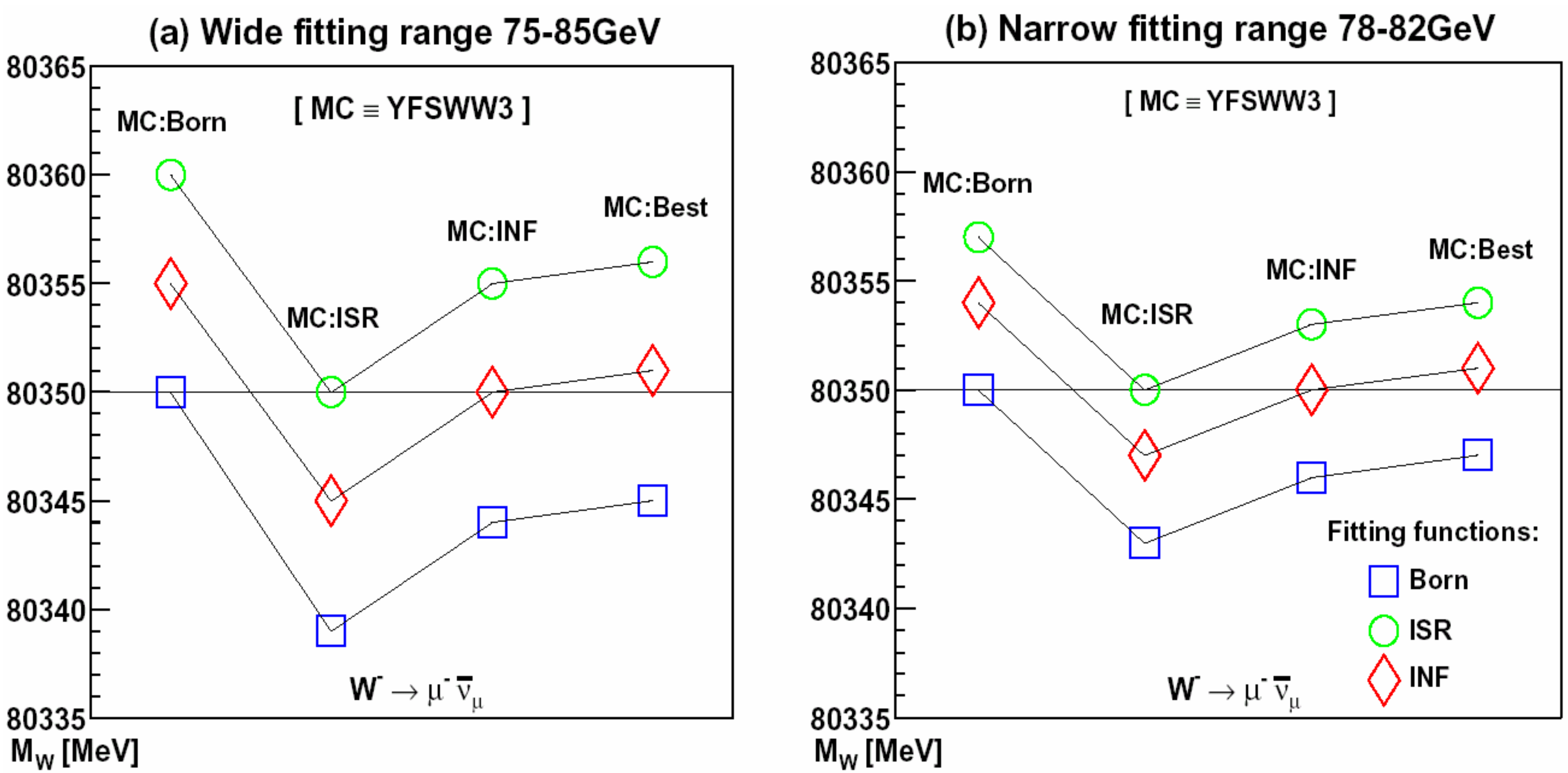


Measured σ^{WW} / KoralW
PRELIMINARY
15/10/2002
183 GeV 1.010 ± 0.024
189 GeV 0.965 ± 0.014
192 GeV 0.992 ± 0.030
196 GeV 1.012 ± 0.020
200 GeV 0.972 ± 0.019
202 GeV 0.986 ± 0.025
205 GeV 0.958 ± 0.019
207 GeV 0.988 ± 0.016
LEP combined 0.978 ± 0.011
$\chi^2/ndf=35.4/31$
0.9
1.
1.1
Measured σ^{WW} / YFSWW
PRELIMINARY
15/10/2002
183 GeV 1.026 ± 0.024
189 GeV 0.982 ± 0.014
192 GeV 1.010 ± 0.030
196 GeV 1.031 ± 0.020
200 GeV 0.992 ± 0.019
202 GeV 1.006 ± 0.026
205 GeV 0.979 ± 0.019
207 GeV 1.009 ± 0.016
LEP combined 0.997 ± 0.011
$\chi^2/ndf=35.4/31$
0.9
1.
1.1

M_W measurement does not depend on σ_{WW}

$O(\alpha)$ electroweak non-leading corrections shift M_W by 1 MeV

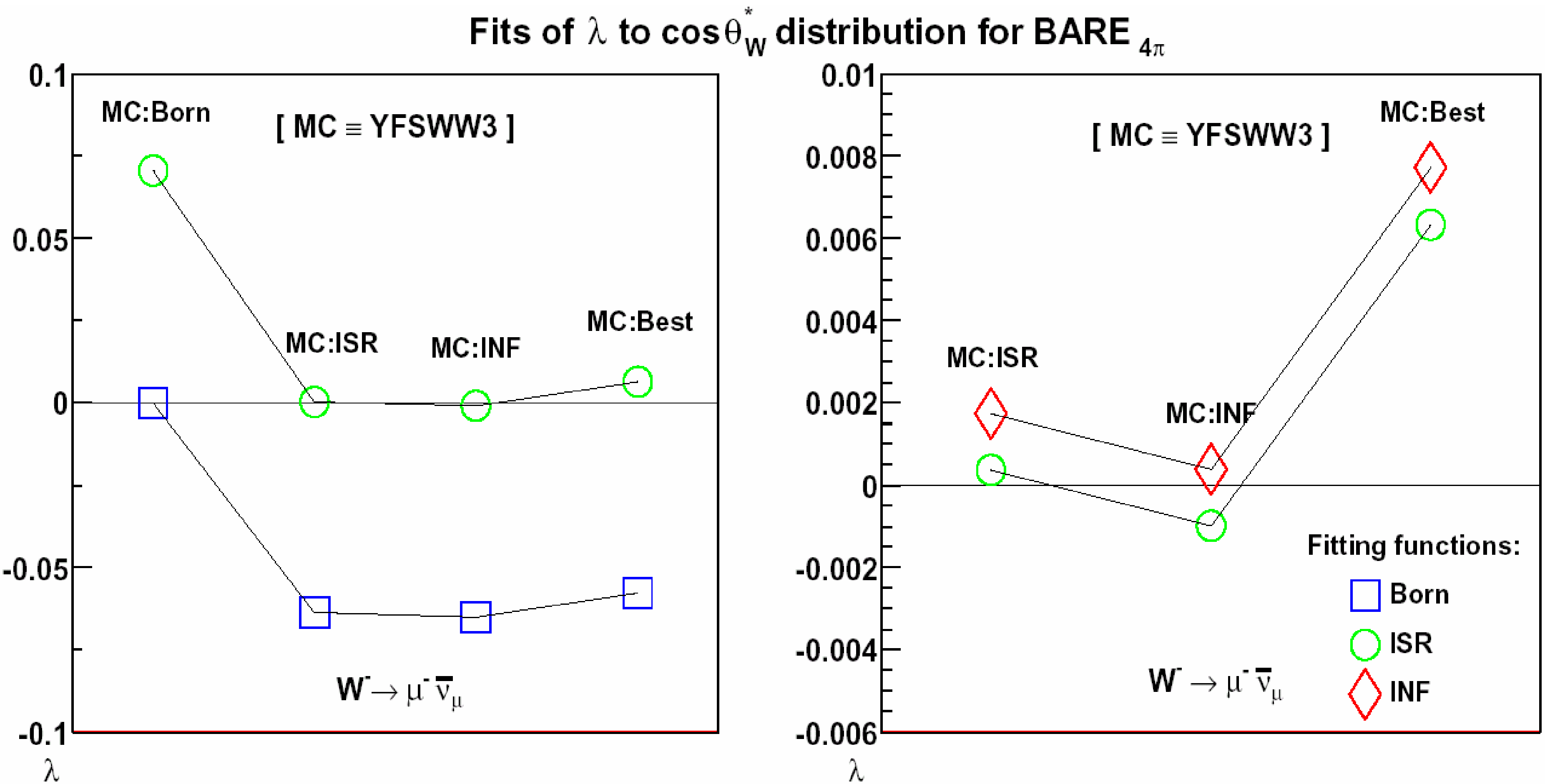
Total theory $\frac{\Delta M_W}{M_W} = 5$ MeV



TGC measurement depends on σ_{WW} and $\frac{1}{\sigma_{WW}} \frac{d\sigma_{WW}}{d\Omega}$

$O(\alpha)$ electroweak non-leading corrections shift λ by 0.008

Total theory $\Delta\lambda = 0.005$



TGC Measurements at a LC

Final LEP2 $\frac{\Delta g}{g} \approx 0.01 \approx \frac{1}{\sqrt{N}}$ Theory uncertainty at LEP2: $\frac{\Delta g}{g} \approx 0.005 = \frac{\Delta\sigma_{WW}}{\sigma_{WW}}$

	error $\times 10^{-4}$			
	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 1000$ GeV	
TGC	Re	Im	Re	Im
g_1^γ	15.5	18.9	12.8	12.5
κ_γ	3.5	9.8	1.2	4.9
λ_γ	5.4	4.1	2.0	1.4
g_1^Z	14.1	15.6	11.0	10.7
κ_Z	3.8	8.1	1.4	4.2
λ_Z	4.5	3.5	1.7	1.2

For κ & λ

$$\frac{\Delta g}{g} \approx 0.20\frac{1}{\sqrt{N}} \quad (0.5\,TeV)$$

$$0.05\frac{1}{\sqrt{N}} \quad (1.0\,TeV)$$

$$\frac{1}{\sqrt{N}} = 16.7\times 10^{-4} \qquad 24.5\times 10^{-4} \leftarrow$$

Twice the target theory error for 4-fermion differential cross-sec

SUSY - Masses

$0.25\, ab^{-1}$ at $\sqrt{s} = 0.5\, TeV$ or $0.1\, ab^{-1}$ at threshold

$\tilde{\ell}, \tilde{\nu}$	m [GeV]	δm_c [GeV]	δm_s [GeV]
$\tilde{\mu}_R$	132.0	0.3	0.09
$\tilde{\mu}_L$	176.0	0.3	0.4
$\tilde{\nu}_\mu$	160.6	0.2	0.8
$\tilde{e}_R$	132.0	0.2	0.05
$\tilde{e}_L$	176.0	0.2	0.18
$\tilde{\nu}_e$	160.6	0.1	0.07
$\tilde{\tau}_1$	131.0		0.6
$\tilde{\tau}_2$	177.0		0.6
$\tilde{\nu}_\tau$	160.6		0.6

$\tilde{\chi}$	m [GeV]	δm_c [GeV]	δm_s [GeV]
$\tilde{\chi}_1^\pm$	127.7	0.2	0.04
$\tilde{\chi}_2^\pm$	345.8		0.25
$\tilde{\chi}_1^0$	71.9	0.1	0.05
$\tilde{\chi}_2^0$	130.3	0.3	0.07
$\tilde{\chi}_3^0$	319.8		0.30
$\tilde{\chi}_4^0$	348.2		0.52

$\Delta m \approx \frac{\Delta E_{\exp}}{\sqrt{N}}$ or mass is related to cross-sec behavior at threshold

$\Rightarrow$ smaller lumi required for per mil accuracy

In many cases $\Delta m_{\tilde{x}} \leq \Gamma_{\tilde{x}}$

SUSY - Charginos

Measure polarized cross-sections for $\tilde{\chi}_1^+ \tilde{\chi}_1^-$, $\tilde{\chi}_1^+ \tilde{\chi}_2^-$, $\tilde{\chi}_2^+ \tilde{\chi}_2^-$

$0.5\ ab^{-1}\ e_L^-$ and $0.5\ ab^{-1}\ e_R^-$ at $\sqrt{s} = 0.8\ TeV$

Combine with measurements of chargino and electron sneutrino masses:

RR1

	theor. value	fit value	$\frac{\Delta x}{x}$
M_2	152 GeV	152 ± 1.75 GeV	0.012
μ	316 GeV	316 ± 0.87 GeV	0.003
$\tan\beta$	3	3 ± 0.69	0.233

RR2

	theor. value	fit value	$\frac{\Delta x}{x}$
M_2	150 GeV	150 ± 1.2 GeV	0.008
μ	263 GeV	263 ± 0.7 GeV	0.003
$\tan\beta$	30	> 20.2	> 0.667

Results can be improved by including chargino production and decay angle information

Higgs Branching Fraction

	$m_{h_{SM}} = 120$ GeV		$m_{h_{SM}} = 140$ GeV	
	BR	δBR/BR	BR	δBR/BR
$h_{SM} \rightarrow b\bar{b}$	$(69 \pm 2.0)\%$	2.9%	$(34 \pm 1.3)\%$	4.1%
$h_{SM} \rightarrow WW^*$	$(14 \pm 1.3)\%$	9.3%	$(51 \pm 1.8)\%$	3.7%
$h_{SM} \rightarrow c\bar{c}$	$(2.8 \pm 1.1)\%$	39%	$(1.4 \pm 0.64)\%$	45%
$h_{SM} \rightarrow gg$	$(5.2 \pm 0.93)\%$	18%	$(3.5 \pm 0.79)\%$	23%
$h_{SM} \rightarrow \tau^+\tau^-$	$(7.1 \pm 0.56)\%$	7.9%	$(3.6 \pm 0.38)\%$	10%

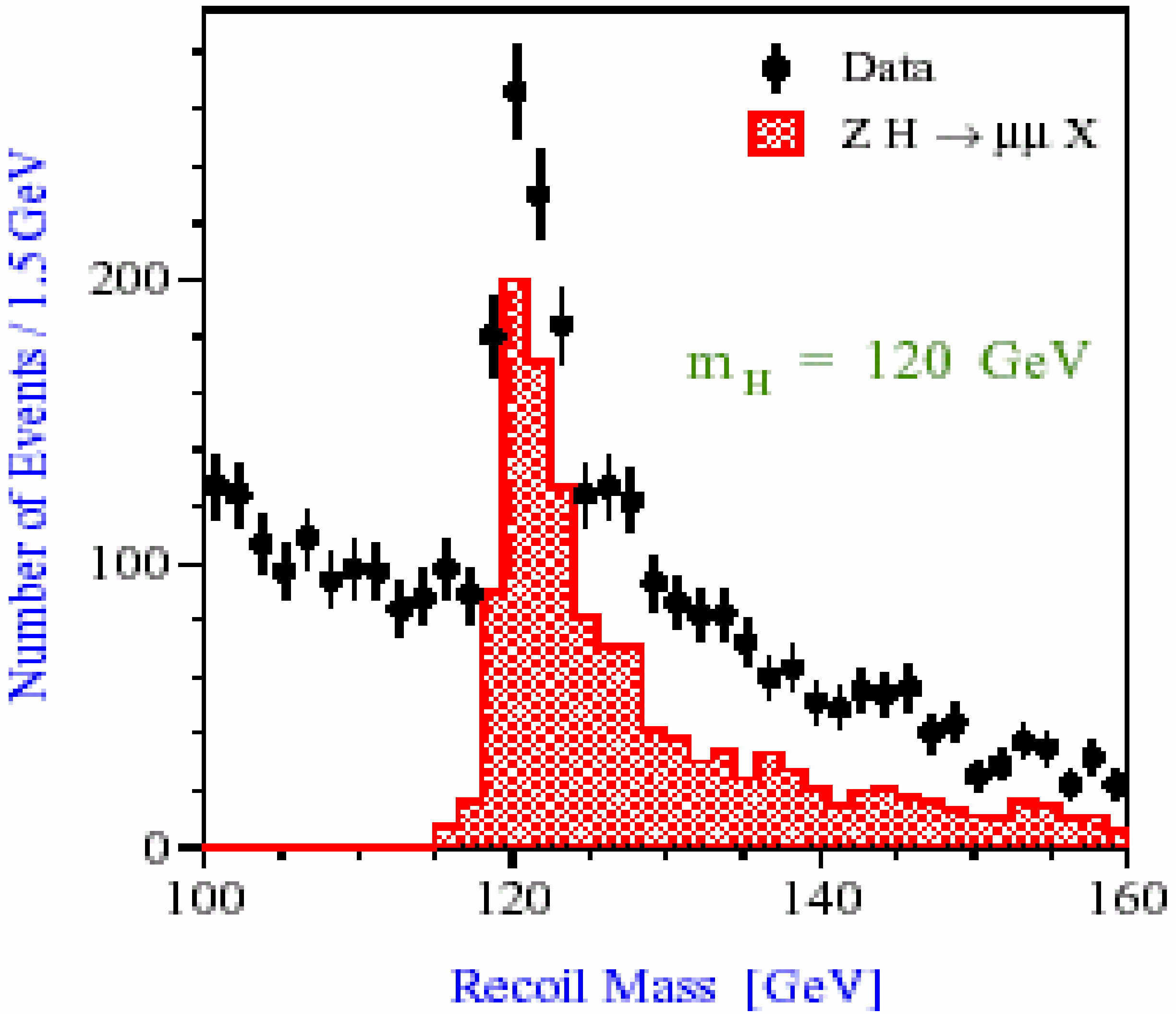
Table 3.1: Predicted branching ratio precisions in the L detector and typical vertex detector configuration for 500 fb^{-1} and $\sqrt{s} = 500$ GeV.

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 $\frac{\Delta\sigma_{Zh}}{\sigma_{Zh}} \approx 2.5\%$



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

Higgs $\sigma \bullet B_x$

$$\sigma \bullet B_x = \frac{N_x - L\sigma_b}{L\eta_x}$$

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

$$\frac{\Delta\sigma_{\nu\nu h} \bullet B_{b\bar{b}}}{\sigma_{\nu\nu h} \bullet B_{b\bar{b}}} = 0.035$$ from $0.5\ ab^{-1}$ at $\sqrt{s} = 0.35 - 0.5\ TeV$

Measure X-Sec for $e^+e^- \to \nu_e \overline{\nu}_e h$, $h \to b\bar{b}$ at 1 TeV

Use the following cuts:

- Require $|\cos\theta_{\mathrm{thrust}}| < 0.8$
- Require $PT_{vis} > 20$ GeV
- Require $500 > E_{vis} > 100$ GeV
- Require that there be no isolated leptons
- Require that the number of jets is less than 9 with $d_{join} = 5$ GeV
- Require more than 5 and less than 20 charged tracks with momentum greater than 2 GeV and impact parameter greater than 3σ.

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

SM Final States 6-Fermion

6-fermion

$e^+e^- \longrightarrow$	$u_i\overline{u}_iu_j\overline{d}_jd_k\overline{u}_k$	125 total
	$d_i\overline{d}_iu_j\overline{d}_jd_k\overline{u}_k$	150 total
	$u_i\overline{u}_iu_j\overline{u}_ju_k\overline{u}_k$	25 total
	$u_i\overline{u}_iu_j\overline{u}_jd_k\overline{d}_k$	65 total
	$u_i\overline{u}_id_j\overline{d}_jd_k\overline{d}_k$	75 total
	$d_i\overline{d}_id_j\overline{d}_jd_k\overline{d}_k$	56 total
$\gamma\gamma \longrightarrow$	$u_j\overline{d}_jd_k\overline{u}_k$	25 total
	$u_j\overline{u}_ju_k\overline{u}_k$	9 total
	$u_j\overline{u}_jd_k\overline{d}_k$	25 total
	$d_j\overline{d}_jd_k\overline{d}_k$	21 total
$e^-_L\gamma \longrightarrow$	$\nu_eu_j\overline{u}_jd_k\overline{u}_k$	25 total
	$\nu_ed_j\overline{d}_jd_k\overline{u}_k$	30 total
$e^-\gamma \longrightarrow$	$e^-u_j\overline{d}_jd_k\overline{u}_k$	20 total
	$e^-u_j\overline{u}_ju_k\overline{u}_k$	10 total
	$e^-u_j\overline{u}_jd_k\overline{d}_k$	20 total
	$e^-d_j\overline{d}_jd_k\overline{d}_k$	21 total
$\gamma e^+_R \longrightarrow$	$\overline{\nu}_eu_j\overline{d}_ju_k\overline{u}_k$	25 total
	$\overline{\nu}_eu_j\overline{d}_jd_k\overline{d}_k$	30 total
$\gamma e^+ \longrightarrow$	$e^+u_j\overline{d}_jd_k\overline{u}_k$	20 total
	$e^+u_j\overline{u}_ju_k\overline{u}_k$	10 total
	$e^+u_j\overline{u}_jd_k\overline{d}_k$	20 total
	$e^+d_j\overline{d}_jd_k\overline{d}_k$	21 total

SM Final States 8-Fermion

8-fermion

$$e^+e^- \rightarrow \quad f\bar{f}t\bar{t}$$

$$\gamma\gamma \rightarrow \quad t\bar{t}$$

$$e^-\gamma \rightarrow \quad e^-t\bar{t}$$

$$\nu_e b\bar{t}$$

$$\gamma e^+ \rightarrow \quad e^+t\bar{t}$$

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

$$e^+e^- \to \nu_e \bar{\nu}_e h$$
$$\quad\quad |\!\to b\bar{b}$$

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

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

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

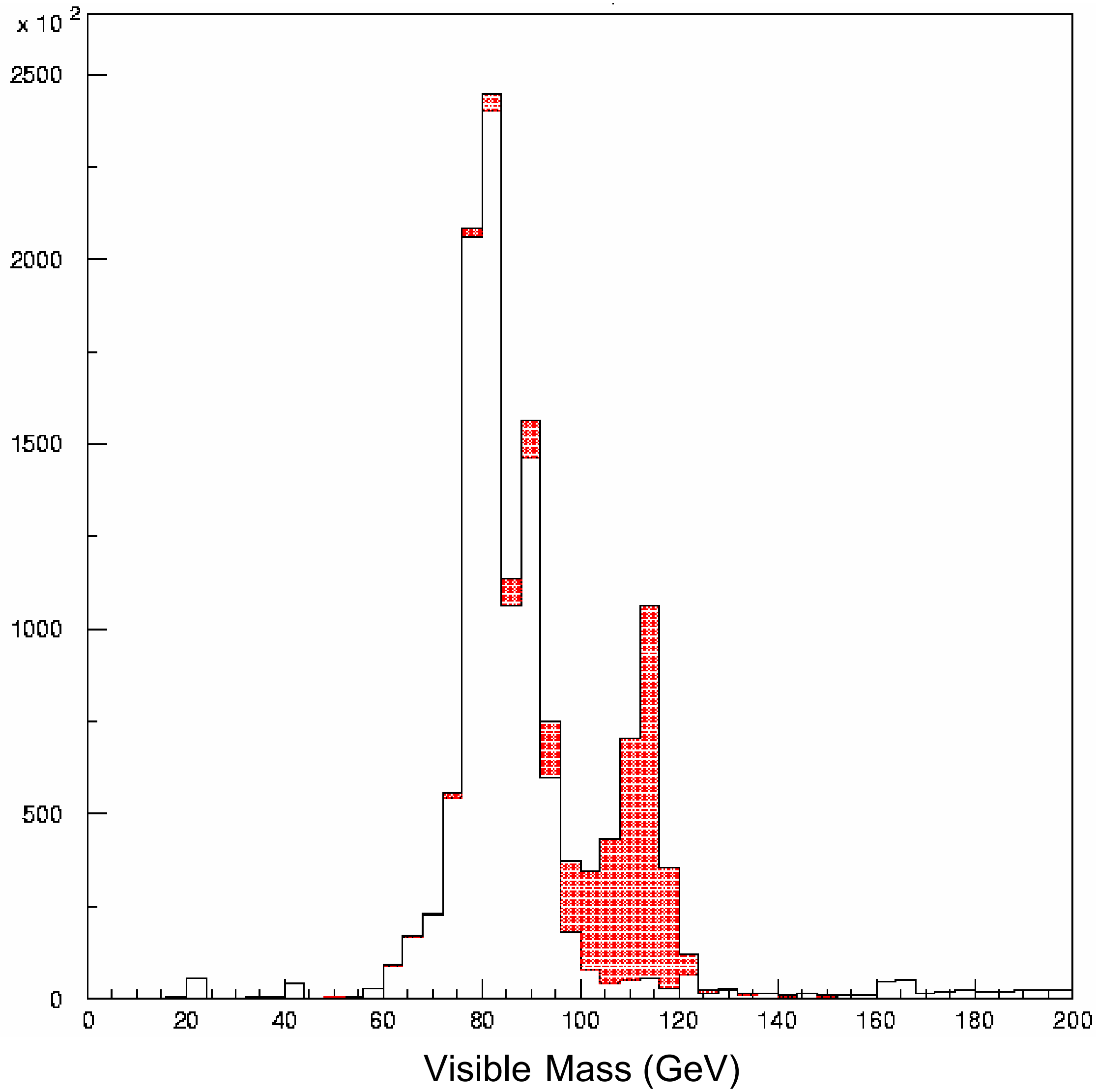
Background passing cuts (white histogram) is mostly

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

eeZ

$\nu\nu Z$

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



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

$M_h = 115\ GeV$

$\sqrt{s} = 1\ TeV$

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

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

Background passing cuts (white histogram) is mostly

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

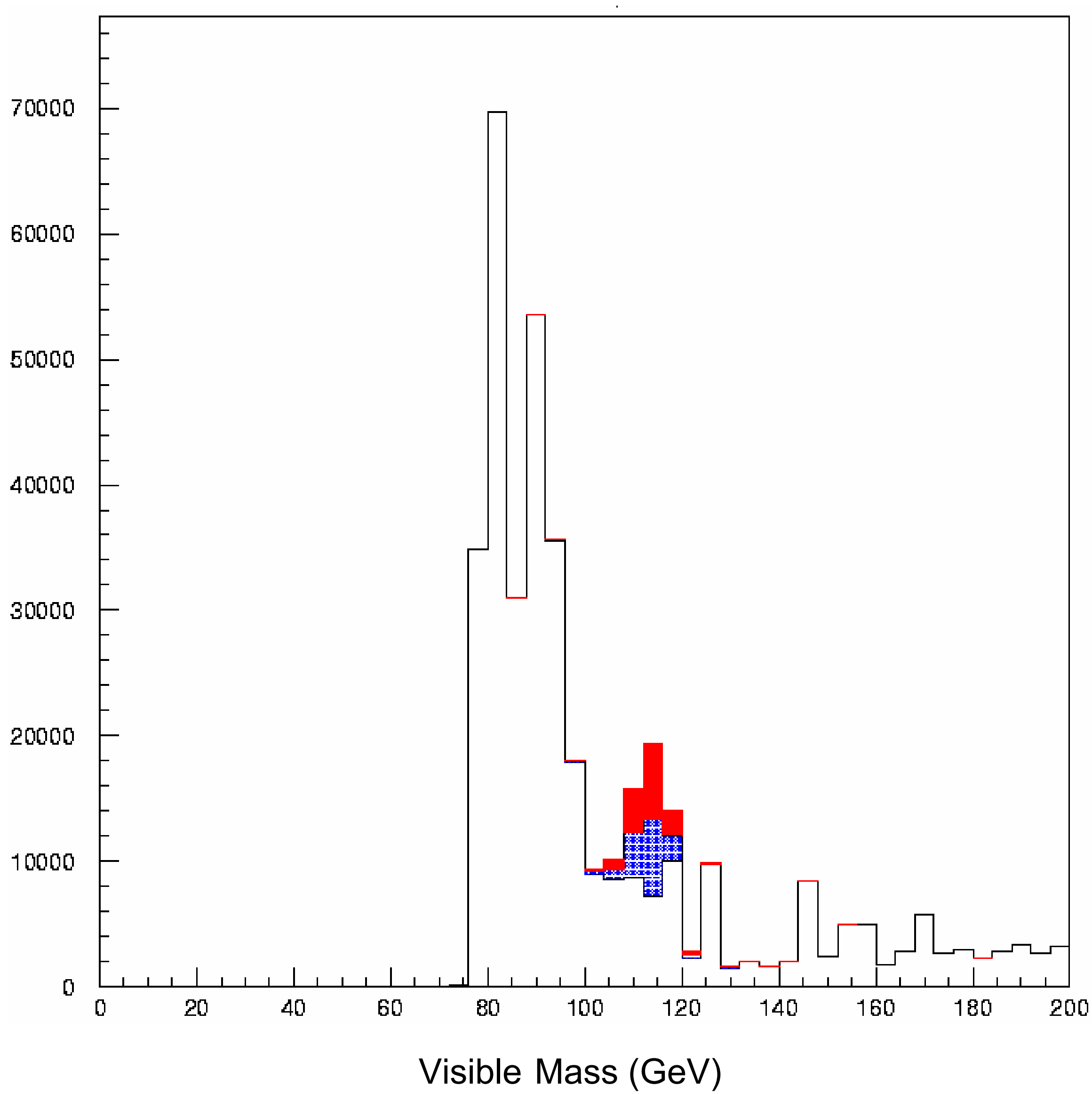
eeZ

$\nu\nu Z$

WW

Red histogram: $h \to WW^*$

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



Higgs $\sigma \bullet B_x$

$$\frac{\Delta\sigma_{\nu\nu h}\bullet B_{b\bar{b}}}{\sigma_{\nu\nu h}\bullet B_{b\bar{b}}} = 1.096\frac{\Delta N_x}{N_x} \oplus 0.096\frac{\Delta\sigma_b}{\sigma_b} \oplus \bullet\bullet\bullet$$

$$\frac{\Delta N_x}{N_x} = .0027$$

$$\Rightarrow \frac{\Delta\sigma_b}{\sigma_b} < 0.015$$

$\uparrow$

$1\,ab^{-1}$

$\downarrow$

$$\frac{\Delta\sigma_{\nu\nu h}\bullet B_{WW^*}}{\sigma_{\nu\nu h}\bullet B_{WW^*}} = 3.240\frac{\Delta N_x}{N_x} \oplus 2.240\frac{\Delta\sigma_b}{\sigma_b} \oplus \bullet\bullet\bullet$$

$$\frac{\Delta N_x}{N_x} = .0074$$

$$\Rightarrow \frac{\Delta\sigma_b}{\sigma_b} < 0.005$$

Extract $\frac{\Gamma_{WW}\Gamma_x}{\Gamma_{tot}}$ from $\sigma_{\nu\nu h} \bullet B_x$ and measure Γ_{tot}

$$\frac{\Delta\sigma_{\nu\nu h} \bullet B_{b\bar{b}}}{\sigma_{\nu\nu h} \bullet B_{b\bar{b}}} = 0.003 \qquad \frac{\Delta\sigma_{\nu\nu h} \bullet B_{WW^*}}{\sigma_{\nu\nu h} \bullet B_{WW^*}} = 0.024$$ from $1\, ab^{-1}$ at $\sqrt{s} = 1\, TeV$

$$\Rightarrow \frac{\Delta\sigma_{\nu\nu h}(theory)}{\sigma_{\nu\nu h}(theory)} < 0.0015$$ to achieve $$\Delta\frac{\Gamma_{WW}\Gamma_{b\bar{b}}}{\Gamma_{tot}}\left[\frac{\Gamma_{WW}\Gamma_{b\bar{b}}}{\Gamma_{tot}}\right]^{-1} = 0.003$$

$$\frac{\Delta B_{b\bar{b}}}{B_{b\bar{b}}} = 0.025 \qquad \frac{\Delta B_{WW^*}}{B_{WW^*}} = 0.100$$ from $0.5\, ab^{-1}$ at $\sqrt{s} = 0.35 - 0.5\, TeV$

$$\Rightarrow \frac{\Delta B_{b\bar{b}}}{B_{b\bar{b}}} = 0.024 \qquad \frac{\Delta B_{WW^*}}{B_{WW^*}} = 0.033 \qquad \frac{\Delta\Gamma_{tot}}{\Gamma_{tot}} = 0.053$$ from combined fit

SUMMARY

Rad Corr with TU of 0.5% needed at LEP2 for 1% meas of TGCs
and for proper interpretation of 1% meas of total WW cross-sec.

Rad Corr with diff x-sec TU of 0.1% needed at LC for 0.01% meas of TGCs

SUSY particle masses measured to 0.001 with a few 100 fb^{-1}

SUSY parameters such as μ , M_2 measured to 0.005 with 1000 fb^{-1}

Most Higgs measurements have a few percent uncertainty at $\sqrt{s} = 0.35 - 0.5\ TeV$

Example given of Higgs meas at 1 TeV requiring 0.5% SM background TU
and 0.15% TU in $\sigma_{\nu\nu h}$

A general statement regarding TU for 2,4,6,8-fermion SM background
processes can't be made until further studies are made.