Linear Collider Workshop 2000 - LCWS 2000
Fermilab – October 24 - 28, 2000

Precision Measurements of Light Neutral Higgs at the LC

Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

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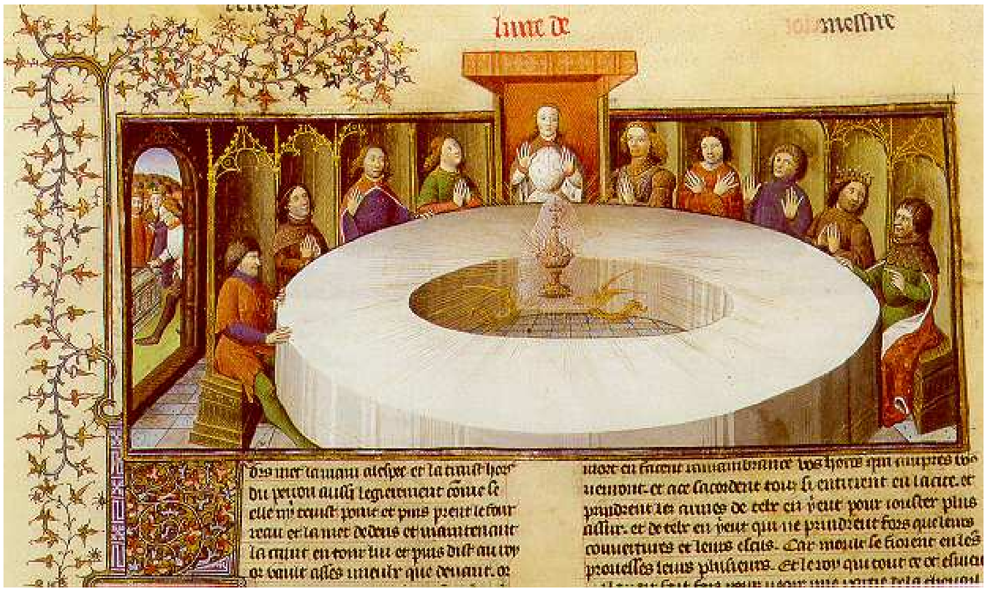

Contributions from:

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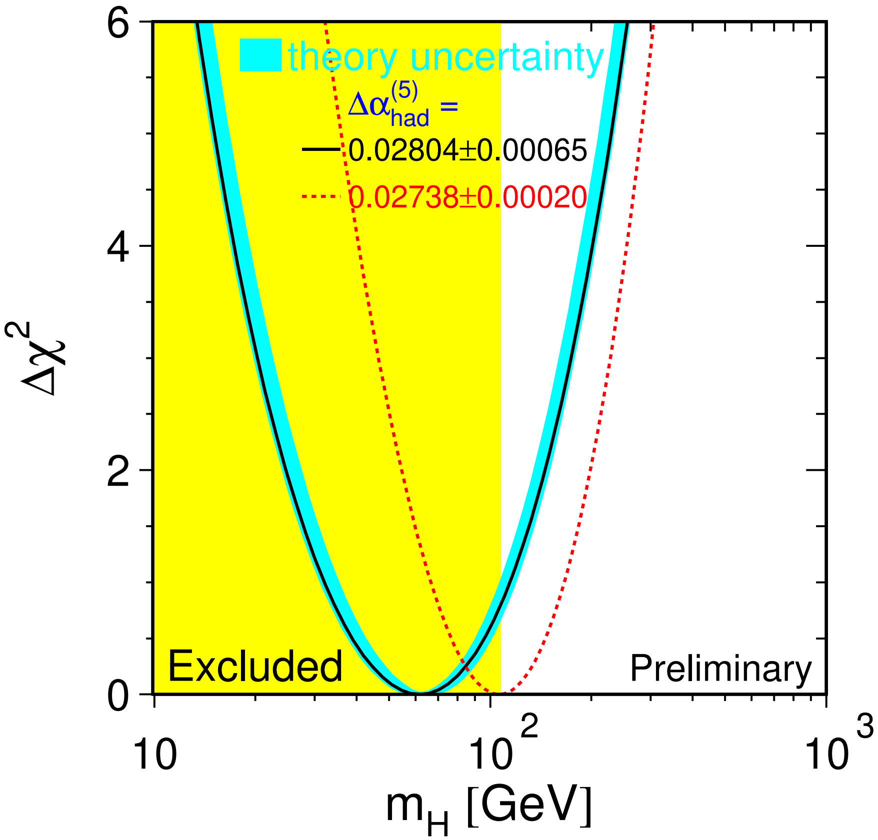
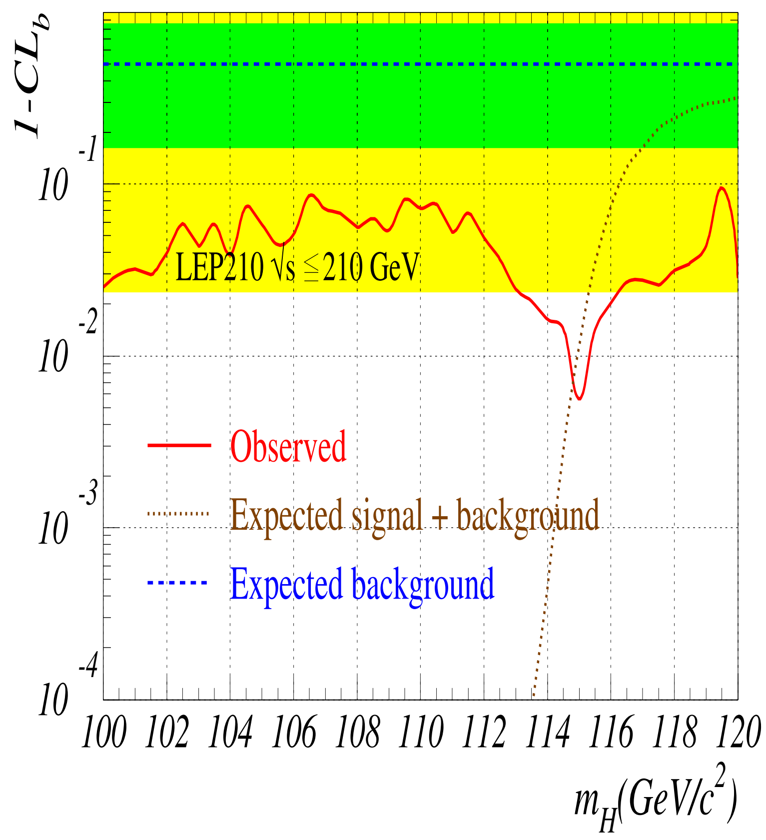
The Quest for the Higgs before the LC : LEP

Hints and Limits from LEP (+SLC+Tevatron)

EW Precision Data

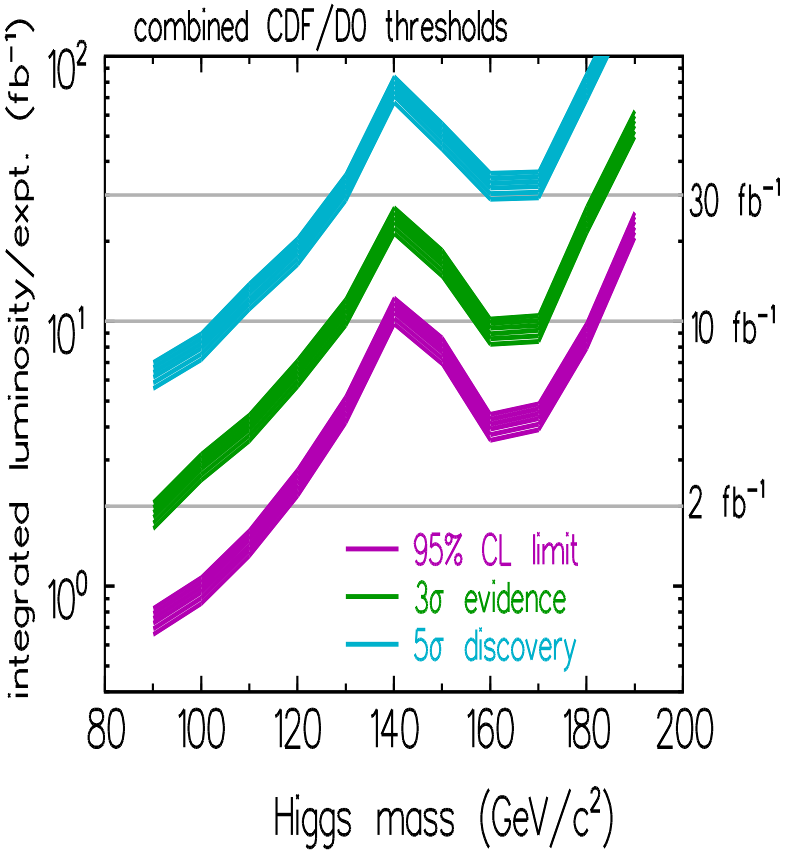


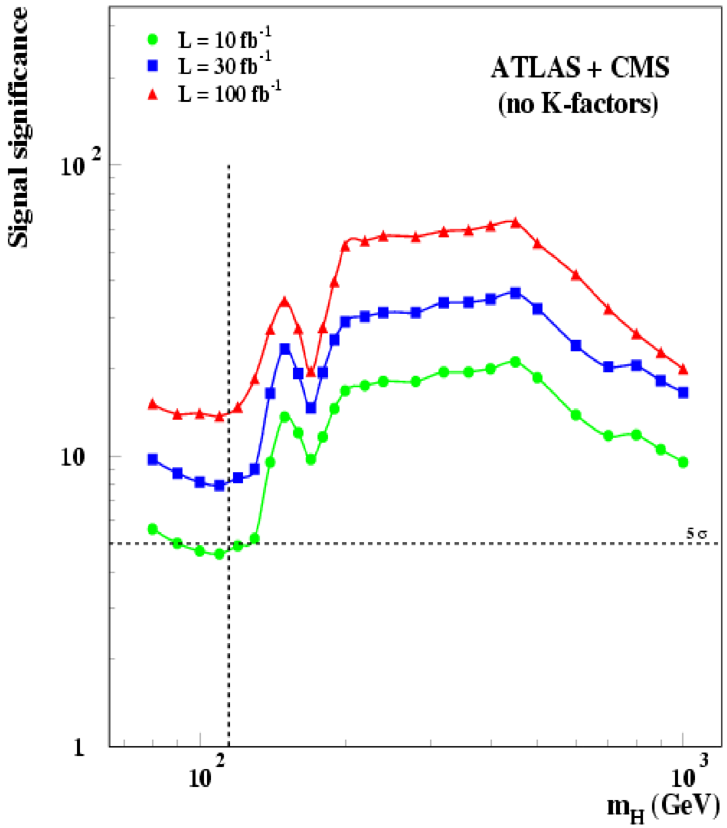
Direct LEP-2 Search



The Quest for the Higgs before the LC : Tevatron & LHC

Discovery Reach at Tevatron and LHC



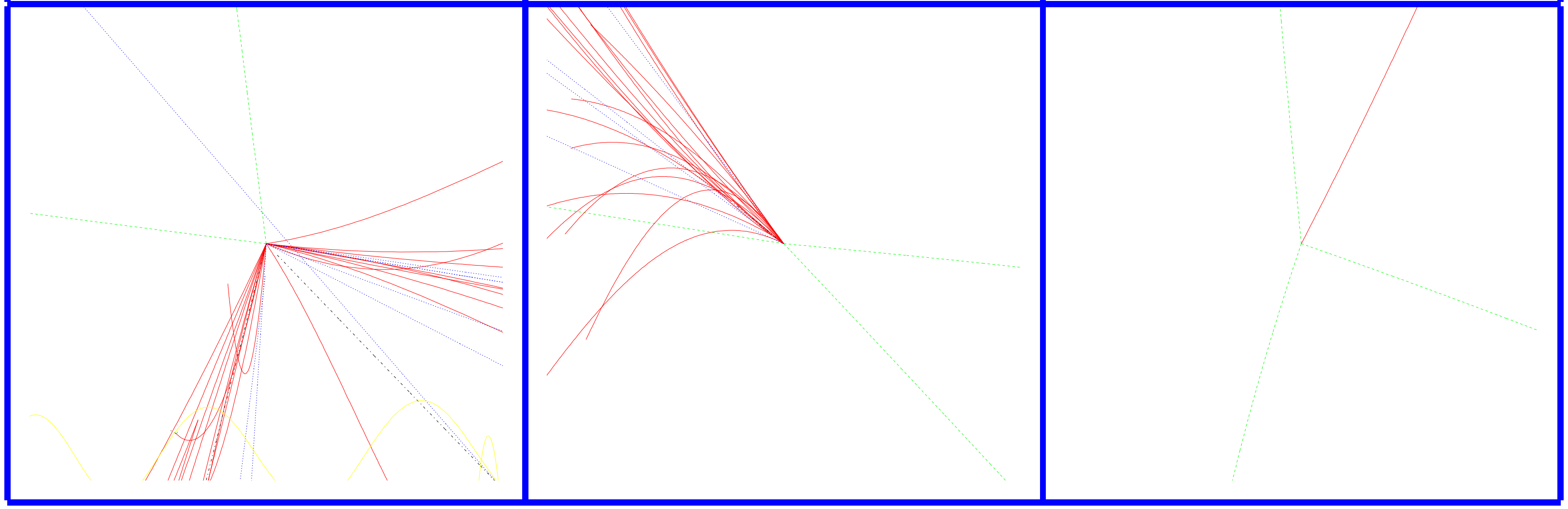


The Quest for the Higgs at the LC

Expected signal events $/500\ \text{fb}^{-1}$ for
$e^+e^- \rightarrow Z^0 H \rightarrow \ell^+\ell^- X,\ (\ell = e,\ \mu)$.

M_H (GeV/c^2)	X	$\sqrt{s} = 350$ GeV	500 GeV	800 GeV
120	$b\bar{b}$	3100	1500	575
140	$b\bar{b}$	1525	765	300
160	WW	2950	1650	670
180	WW/ZZ	2500	1650	700
200	WW/ZZ	2020	1500	680

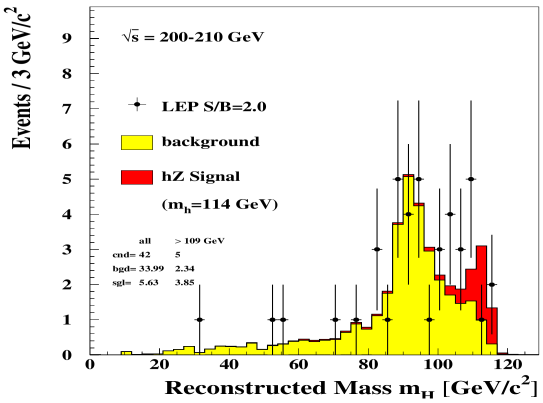
$HZ \rightarrow b\bar{b}\mu^+\mu^-$ | $HZ \rightarrow W^+W^-\mu^+\mu^-$ | $HZ \rightarrow Z^0Z^0\mu^+\mu^-$



The Higgs Boson Profile

Because, it is there ?

Which Peak is the correct one ?



Is It Really the Higgs ?

✥ Verify that the observed particle has the correct quantum numbers and gauge boson couplings.

✥ Verify that the fermionic couplings scale with m_f.

Which Higgs is It ?

✥ Tell a MSSM from a SM Higgs.

✥ Get informations on SUSY parameters and on the next mass scale.

Outlining the Higgs Profile at the LC

- **Determination of m_H, Γ_{tot} and Quantum Numbers.**

- **Accurate determination of Higgs couplings as fundamental test of the Higgs mechanism.**

  SM fermion Yukawa couplings to Higgs completely determined by m_f

  $$g_{Hff} = \frac{m_f}{v} \quad , \qquad v^2 = (\sqrt{2}G_F)^{-1}.$$

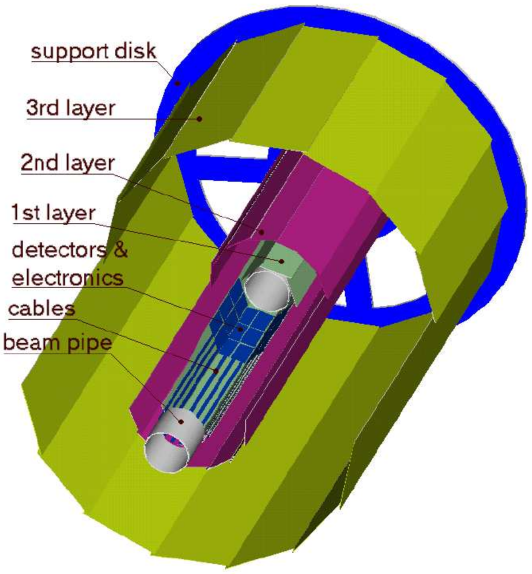
  Study $Hb\bar{b}$, $Hc\bar{c}$ and $H\tau^+\tau^-$ couplings through BRs, $Ht\bar{t}$ through BR$_{gg}$ and

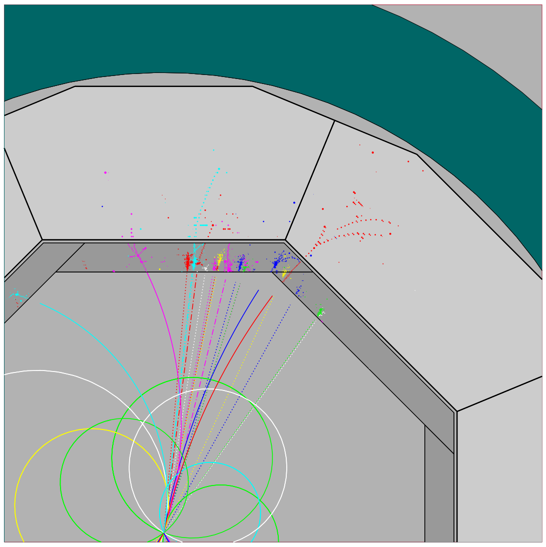
  $$\sigma(e^+e^- \to t\bar{t}H) \propto g^2_{Htt}/4\pi$$

- **Reconstruction of Higgs potential by determination of Higgs self-couplings ($e^+e^- \to HHZ$, $HH\nu_e\nu_e$).**

High resolution detectors (based on LEP/SLD and LHC R&D experience),

Advanced analysis techniques (developed from those adopted at LEP/SLC/LEP2)





Large data sets for different $\sqrt{s}$ and beam polarization schemes at the LC

to promote Higgs physics into the domain of precision measurements.

Higgs Production and Beam Polarization

Beam Polarization	σ_{HZ}	$\sigma_{H\nu\bar{\nu}}$	$\sigma_{W^+W^-}$	$\sigma_{Z^0Z^0}$
No Polarization	1	1	1	1
80% e^-_R	0.9	0.2	0.2	0.8
80% e^-_R + 60% e^+_L	1.3	0.1	0.1	1.1
80% e^-_L	1.1	1.8	1.8	1.3
80% e^-_L + 60% e^+_L	1.7	2.9	2.9	1.9

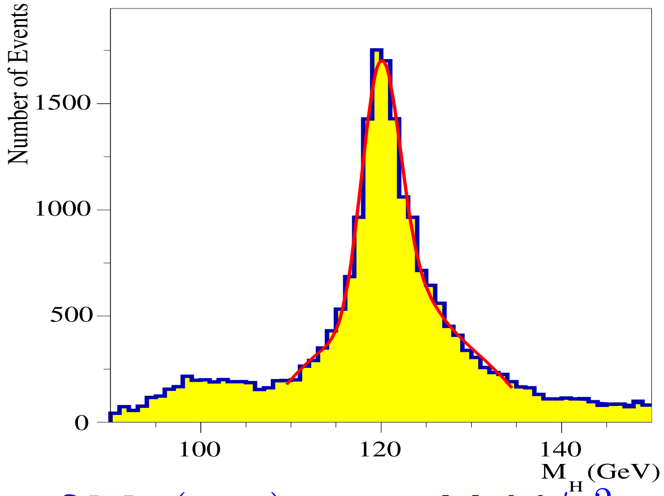
- With e^- polarization only S_{HZ} / B_{WW} improved $\times 5$ at the cost of suppressing WW-fusion production
- With e^- L-polarization WW-fusion can be enhanced w.r.t. HZ.
- Using different beam polarization schemes allows to estimate response of discriminating variables for signals and backgrounds directly from data, reducing systematic uncertainties.

Higgs Mass M_H

❖ Higgs mass M_H not predicted by theory: important to obtain its accurate experimental determination. **Once M_H is fixed, profile of the Higgs particle uniquely determined in SM.**

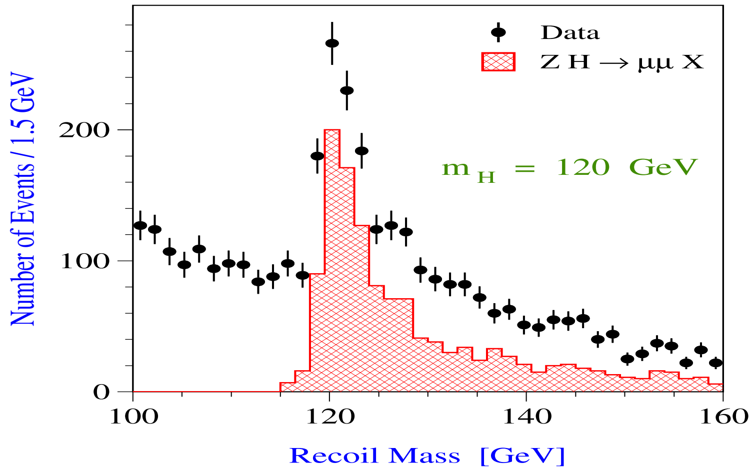
❖ At LC, M_H best measured by exploiting kinematics of Higgs-Strahlung process $e^+e^- \to Z^* \to HZ^0$:

❖ **Four jet channel $b\bar{b}q\bar{q}$**: Higgs reconstructed through $\to b\bar{b}$ and $Z^0 \to q\bar{q}$. M_H measurement relies on kinematical 5-C fit.



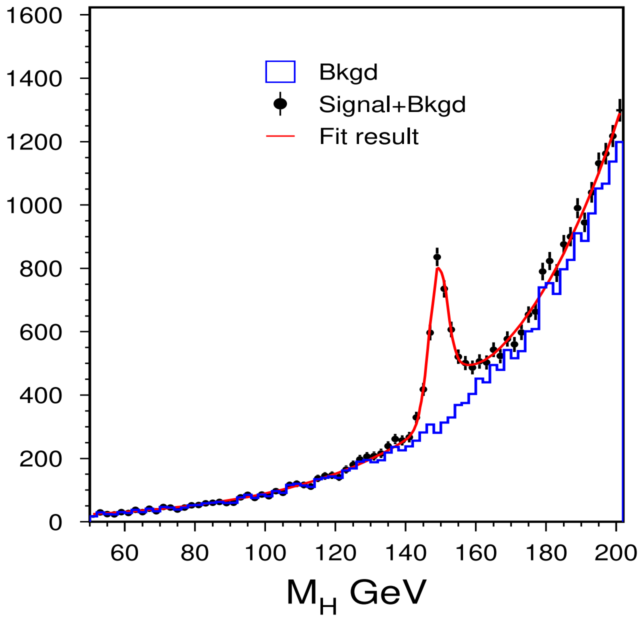
$\delta M_H(120) \simeq 50$ MeV$/c^2$

❖ **$b\bar{b}\ell^+\ell^-$ channel**: $Z^0 \to \ell^+\ell^-$ offers clean signature and p_ℓ accurately measured in large detector. Further improve $\delta p/p$ by Vtx. constraint to $\ell^\pm$ trajectories.



$\delta M_H(120) \simeq 70$ MeV$/c^2$

❖ **Six jet $W^+W^-q\bar{q}$ channel**: High multiplicity hadronic selection, discriminant analysis and 5- or 7-C fit. Needs to account for mis-reconstructed signal events.



$$\delta M_H(150) \simeq 130 \text{ MeV}/c^2$$

$$\delta M_H(180) \simeq 160 \text{ MeV}/c^2$$

Summary of Higgs Mass Determination Accuracies

M_H (GeV/c^2)	Technique	δM_H (MeV/c^2)
120	$\ell\ell qq$	70
120	$qqbb$	50
120	**Combined**	**40**
150	$\ell\ell$ Recoil	90
150	$qqWW$	130
150	**Combined**	70
180	$\ell\ell$ Recoil	110
180	$qqWW$	160
180	**Combined**	90

Couplings to Gauge Bosons
$\sigma_{e^+e^- \to Z^* \to HZ}$

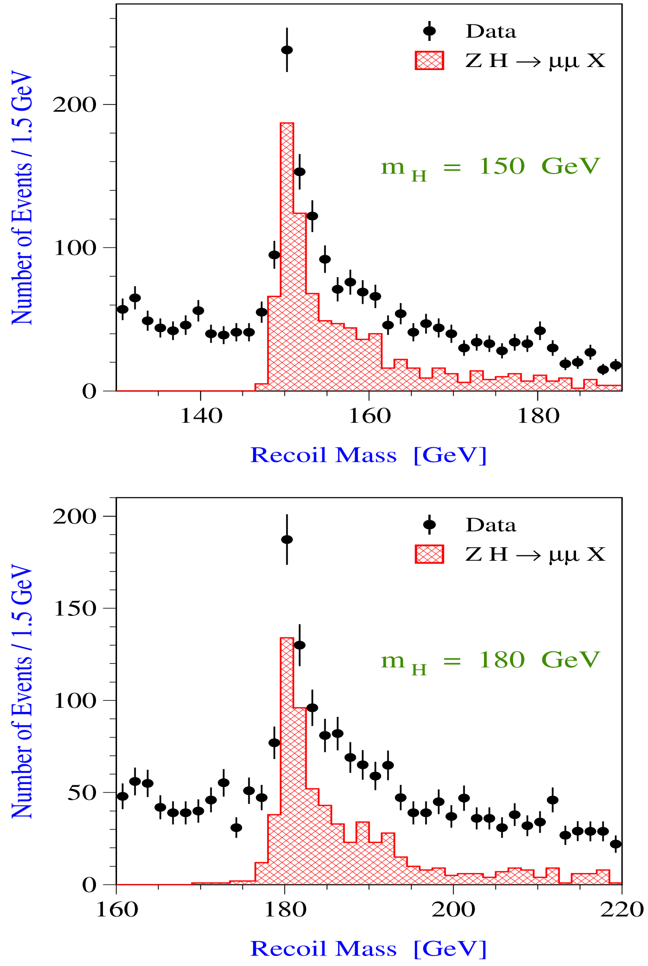
❖ Determination of Higgstrahlung cross-section to measure H coupling to Z and a key input to extract absolute BRs;

❖ use dilepton recoil mass from $Z^0 \to \ell^+\ell^-$ decay and impose beam-spot constraint to improve σ_p/p;

❖ analysis is flavour blind and sensitive to non-standard decay modes such as $H \to$ invisible.

M_H GeV/c^2	Fit $\sigma_{HZ\to\ell^+\ell^-}$ (fb) /500 fb^{-1}	δ_{stat} % /500 fb^{-1}
120	5.30±0.13(stat)±0.12(syst)	± 2.4
140	4.39± 0.12(stat)±0.10(syst)	± 2.7
160	3.60± 0.11(stat)±0.08(syst)	± 3.0

$\ell\ell$ Recoil Mass for $e^+e^- \to Z^0H^0 \to \ell^+\ell^- X$



Couplings to Gauge Bosons

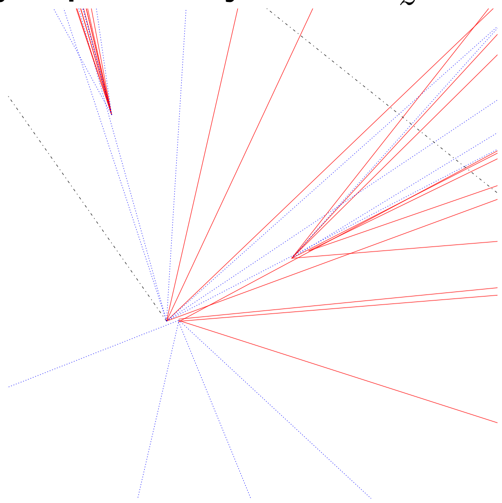
$\sigma_{e^+e^-\to WW\nu\bar{\nu}\to H\nu\nu}$

❖ Determination of WW-fusion reaction $\sigma_{e^+e^-\to WW\nu\bar{\nu}\to H\nu\bar{\nu}}$ to measure H coupling to W and a key input to extract Γ_{tot};

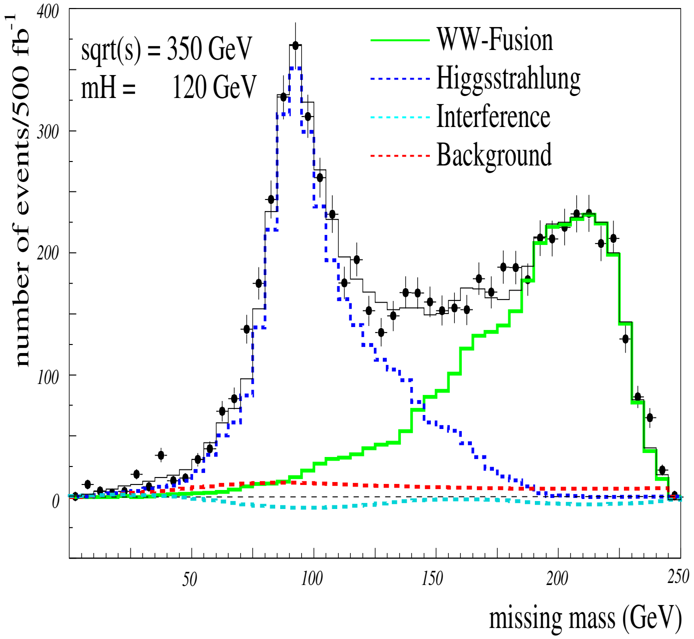
❖ Select b-tagged hadronic events with large E_{miss}, M_{miss} at $\sqrt{s} = 350$ GeV;

❖ Extract $\sigma_{H\nu\nu}$ from χ^2 fit to missing mass distribution:

❖ Overlapped $\gamma\gamma \to$ hadrons bkg. suppressed by i.p. analysis if $\sigma_z^{beam} >> \sigma_z^{ip}$



JET-JET MISSING MASS FOR $e^+e^- \to H^0\nu\bar{\nu} \to b\bar{b}\nu\bar{\nu}$

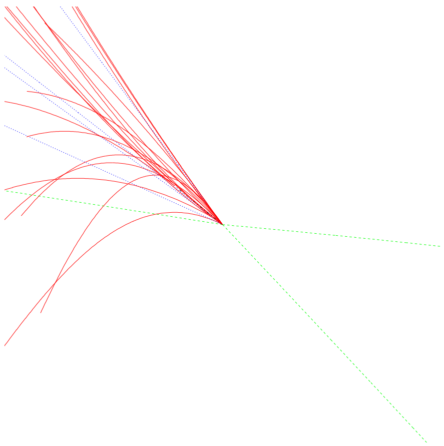


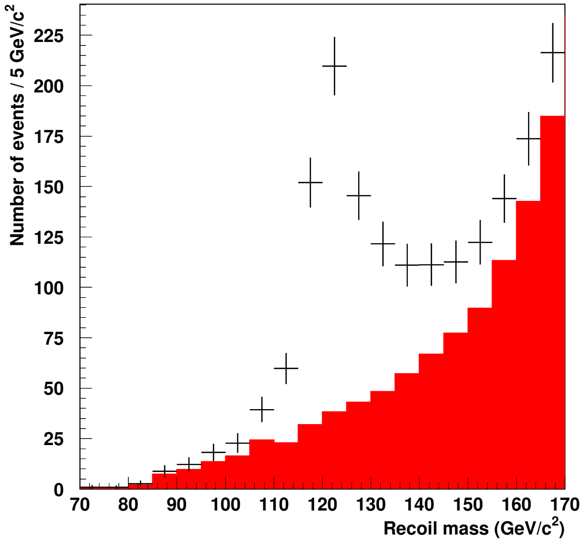
M_H GeV/c^2	Fitted Evts. / 500 fb^{-1}	$\frac{\delta(\sigma_{H\nu\nu})}{\sigma_{H\nu\nu}}$ / 500 fb^{-1}
120	3423 $\pm$ 83	$\pm$ 2.6 %
140	1330 $\pm$ 71	$\pm$ 5.3 %
150	663 $\pm$ 66	$\pm$ 10.3 %

Couplings to Gauge Bosons BR($H \to WW$)

❖ Accurate determination of BR($H \to WW^*$) analysing s.l. WW Higgs decay in HZ process $e^+e^- \to HZ \to \ell\bar{\nu}q\bar{q}q\bar{q}$.

❖ Large W^+W^- and $t\bar{t}$ backgrounds suppressed by $M_{JJ} = M_Z$ and $M_{recoil} = M_H$ constraints, anti-b tag and e_R polarization.





Accuracy on BR($H \to WW$)

M_H (GeV/c^2)	$\frac{\delta(BR_{WW})}{BR_{WW}}$ /500 fb^{-1}
120	5.1 %
130	3.2 %
140	2.5 %
160	2.1 %

Couplings to Photons $\sigma_{\gamma\gamma\rightarrow H}$ and BR($H \rightarrow \gamma\gamma$)

✥ Higgs production / decay to $\gamma\gamma$ proceed through loops dominated, in SM, by W contribution but sensitive to new particles directly coupled to H and γ.

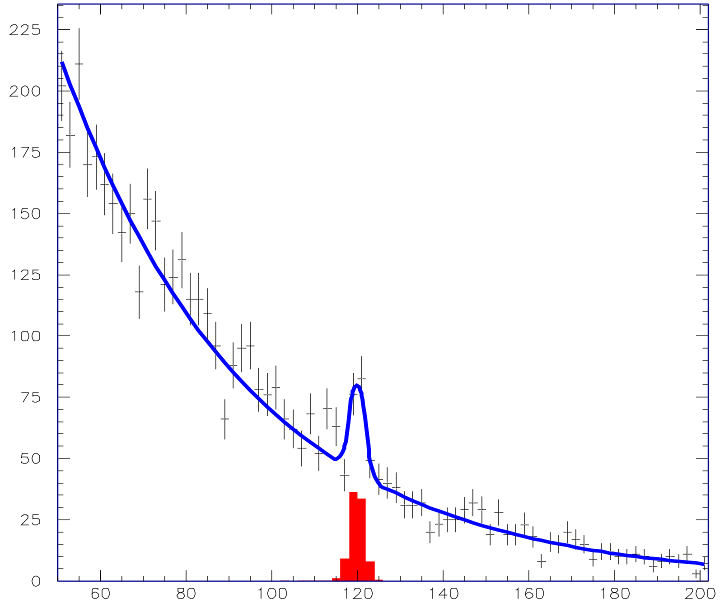
✥ $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ accessible at $\gamma\gamma$ collider;

✥ Severe $\gamma\gamma \rightarrow c\bar{c}(g)$ background (S/B $\simeq 15$ for $|\cos\theta| < 0.7$) rejected by efficient b-tagging;

✥ Assume $\int L(0 < z < z_{max}) =$ 150 fb^{-1}, 45 fb^{-1} on peak:

$$\delta\Gamma(\gamma\gamma \rightarrow H)/\Gamma(\gamma\gamma \rightarrow H) = 0.02$$

✥ $H \rightarrow \gamma\gamma$ decays analysed in both $\gamma\gamma\nu\bar{\nu}$ and $\gamma\gamma$ + jets final states.



$$\delta\mathrm{BR}(H \rightarrow \gamma\gamma)/\mathrm{BR}(H \rightarrow \gamma\gamma) = 0.14 \text{ for } 1000 \text{ fb}^{-1}$$

Higgs Total Width Γ_{tot}

❖ SM Higgs total width extremely narrow for light mass values and increases rapidly once the WW^* and ZZ^* decay channels become accessible to reach a value of 1 GeV at the ZZ threshold.

❖ At the LC, Γ_{tot} to be obtained **indirectly** from the **combination of measurements of a Higgs partial decay width with the corresponding decay branching fraction** for masses below 200 GeV/c^2:

$$\Gamma_{tot} = \frac{\Gamma_{H \to X}}{\mathrm{BR}(H \to X)}$$

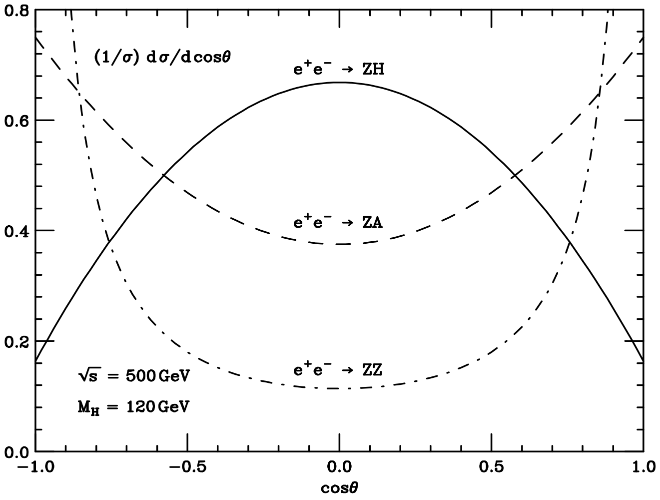
Accuracy $\delta\Gamma_{tot}/\Gamma_{tot}$ for $\sqrt{s} = 350$ GeV and 500 fb^{-1}

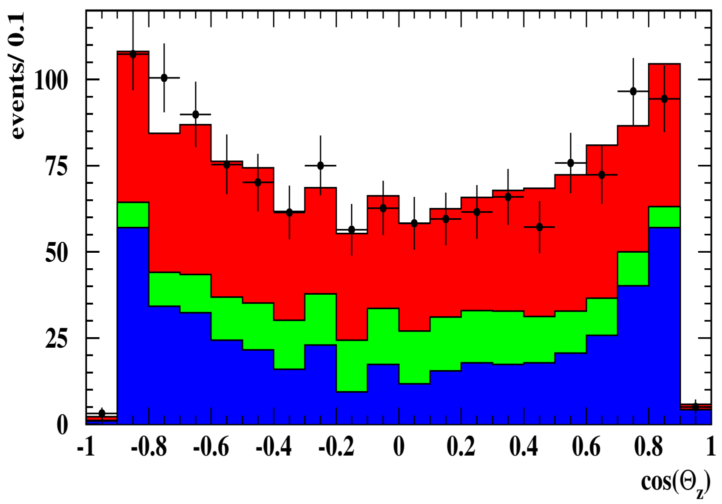
$\Gamma_{H\to X}$	BR($H \to X$)	$M_H = 120$	140	160
$WW = HZ$	$H \to WW$	0.056	0.037	0.036
$WW = WW\nu\nu$	$H \to WW$	0.057	0.058	0.200
$\gamma\gamma \to H$	$H \to \gamma\gamma$	0.19	-	-

Quantum Numbers of the Higgs Boson

✥ Spin, parity and charge-conjugation quantum numbers J^{PC} of Higgs bosons can be determined at LC in model-independent way.

- **Observation of production** $\gamma\gamma \rightarrow H$ or decay $H \rightarrow \gamma\gamma$ **decay** rules out $J = 1$ and sets C positive.
- **Angular dependence of** $\sigma_{e^+e^- \rightarrow ZH}$ **and of** $Z \rightarrow f\bar{f}$ decay products allows to determine J and P and distinguish SM H from CP-odd 0^{-+} state A, or CP-violating mixture of the two ($\Phi = xA + yH$).



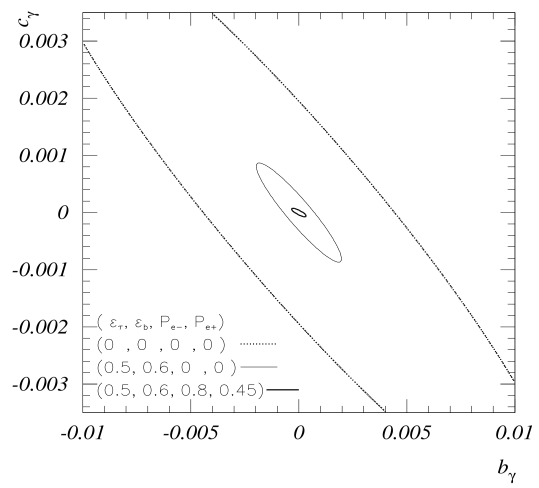


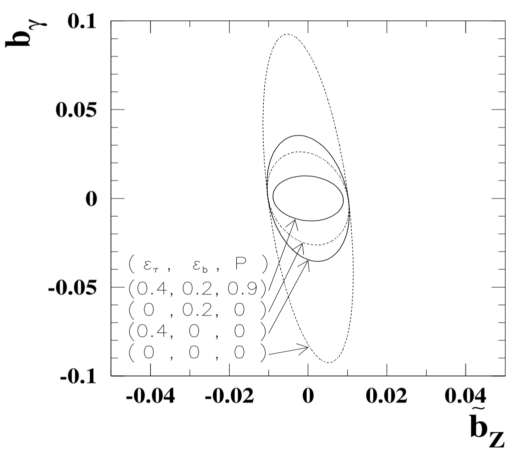
Sensitivity to A mixture: **0.13 (shape only)** and **0.03 (shape + σ)**

- Anomalous Higgs couplings: high $\int L$, efficient b and τ identification, $P(e^-)$ and $P(e^+)$ enable to determine deviations from standard couplings from the angular distribution of $e^+e^- \to Z\Phi \to \left(f\bar{f}\right)\Phi$.

Accuracy on general $ZZ\Phi$ and $Z\gamma\Phi$ couplings from optimal observable analysis.

$\lvert P_{e^-}\rvert$	—	0.8	0.8
$\lvert P_{e^+}\rvert$	—	0.6	0.6
ϵ_τ	—	—	0.5
ϵ_b	—	—	0.6
Re (b_Z)	0.00055	0.00023	0.00022
Re (c_Z)	0.00065	0.00011	0.00011
Re (b_γ)	0.01232	0.00036	0.00034
Re (c_γ)	0.00542	0.00008	0.00007
Re $(\tilde{b}_Z)$	0.00104	0.00078	0.00052
Re $(\tilde{b}_\gamma)$	0.00618	0.00101	0.00063

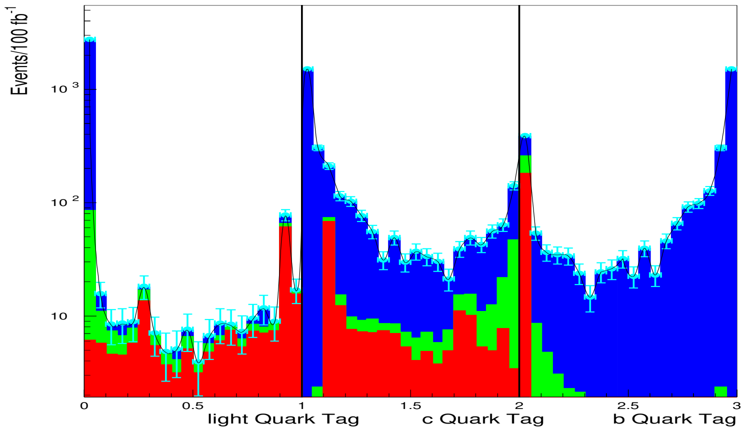




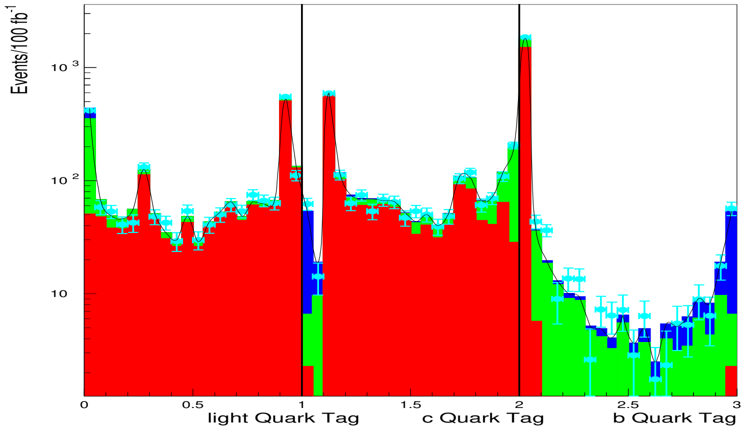
Couplings to Fermions
BR($H \to b\bar{b}$, $c\bar{c}$, $\tau^+\tau^-$)

- Compute $u\bar{u} + d\bar{d} + s\bar{s}$, $c\bar{c}$ and $b\bar{b}$ di-jet flavour tagging probs for $H \to q\bar{q}$ candidates;
- subtract bkg. from H sidebands;
- Fit hadronic branching fractions:
  - BR($H \to b\bar{b}$)/BR($H \to$ hadrons),
  - BR($H \to c\bar{c}$)/BR($H \to$ hadrons)
  - [BR($H \to gg$)/BR($H \to$had.)]
  - [BR($H \to WW$)/BR($H \to$had.)]
- binned likelihood fit to the background subtracted di-jet flavour tagging response:

M_H = 120 GeV/c^2, $\sqrt{s}$ = 350 GeV

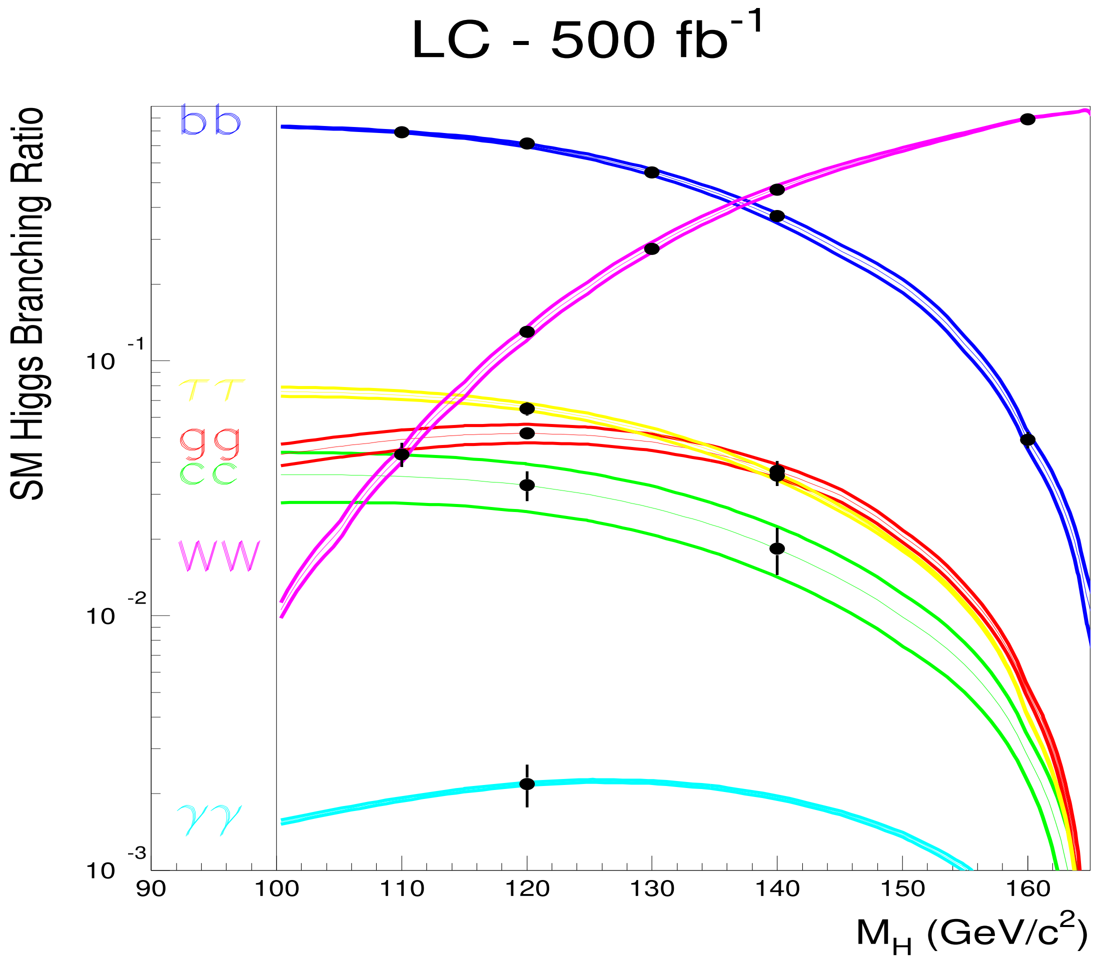


M_H = 160 GeV/c^2, $\sqrt{s}$ = 350 GeV

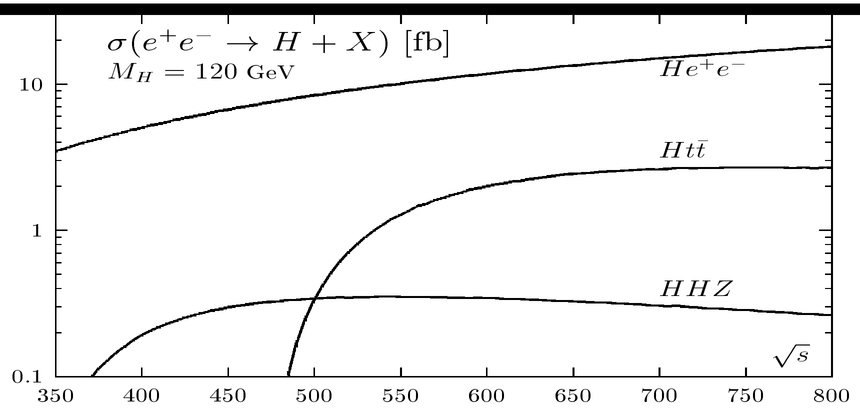


Accuracy on Higgs BRs for 500 fb^{-1}

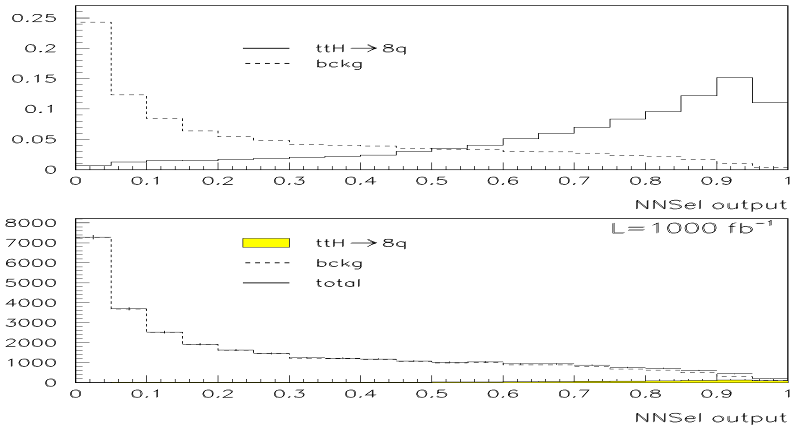
Channel	$\frac{\delta(BR(H\to X))}{BR}$ $M_H = 120$ GeV$/c^2$	$\frac{\delta(BR(H\to X))}{BR}$ $M_H = 160$ GeV$/c^2$
$H^0/h^0 \to b\bar{b}$	$\pm$ 0.024	$\pm$ 0.065
$H^0/h^0 \to c\bar{c}$	$\pm$ 0.083	
$H^0/h^0 \to gg$	$\pm$ 0.055	
$H \to \tau^+\tau^-$	$\pm$ 0.050	
$H \to WW^*$	$\pm$ 0.054	$\pm$ 0.030
$H \to ZZ^*$		$\pm$ 0.145
$H \to \gamma\gamma$	$\pm$ 0.190	



Couplings to Fermions
Higgs radiation off Top Quark $t\bar{t}H$



- Higgs Top Yukawa coupling, $g^2_{ttH} \simeq 0.5$ compared to $g^2_{bbH} \simeq 4 \times 10^{-4}$, accessible in $e^+e^- \to t\bar{t}H$ and indirectly in $H \to gg$.
- $t\bar{t}H$ experimental accuracy studied for $\sqrt{s} = 800$ GeV and $L = 1000$ fb^{-1} in both s.l. and fully hadronic channels.
- Efficiency loss from failures of the jet-clustering and of the b-tagging due to hard gluon radiation and large multiplicities.
- Adopt highly efficient pre-selection criteria and NN to separate signal from remaining backgrounds. Essential to ensure very good knowledge of σ_{bkg} and response to discriminating variable NNsel.



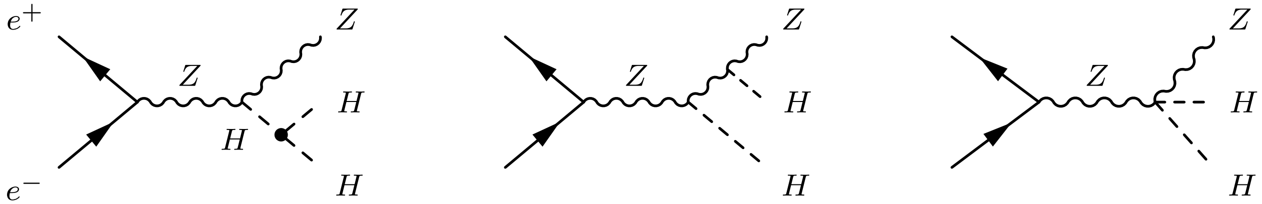
$\delta_{\text{stat.}}$ AND $\delta_{\text{syst.}}$ FOR $t\bar{t}H$ YUKAWA COUPLING AT 800 GEV WITH $L = 1000$ FB^{-1}.

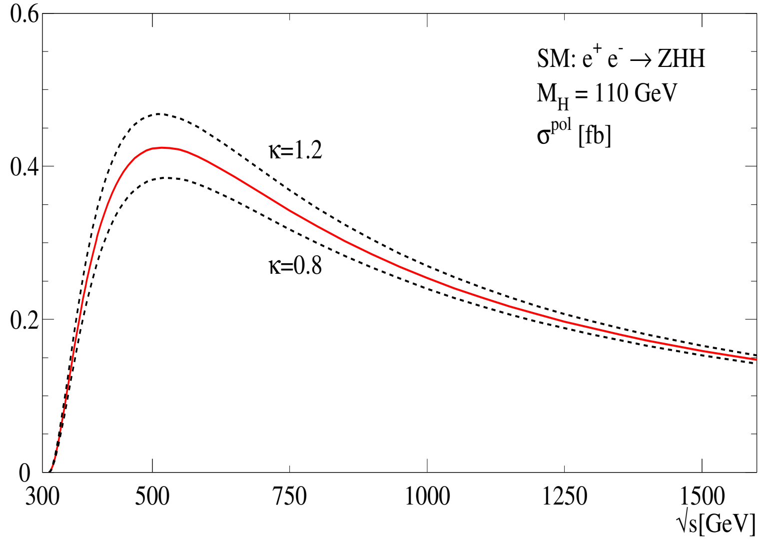
	ϵ (%)	S/B	$\delta_{\text{stat.}}$ (%)	$\delta_{\text{syst.}}$ (%)	$\delta_{\text{tot.}}$ (%)
Semileptonic					
After Preselection	54.1	0.03	11.5	63.1	64.1
NNSel>0.9 (optimal cut)	27.1	0.51	5.1	3.8	6.3
Hadronic					
After Preselection	77.1	0.03	9.8	83.5	83.5
NNSel>0.95 (optimal cut)	8.5	0.90	7.3	3.0	7.9
Combined			**4.2**	**3.5**	**5.5**

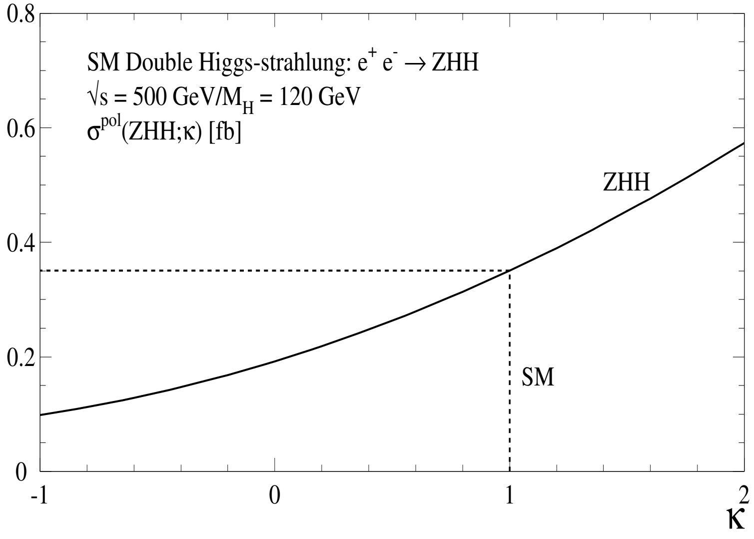
Higgs Self-Interaction Potential

❖ **Establish the Higgs mechanism** experimentally in an unambiguous way through the reconstruction of the Higgs self–energy potential.

❖ Double Higgs-Strahlung $e^+e^- \rightarrow HHZ$ sensitive to trilinear Higgs coupling λ_{HHH} superimposed on other processes generated by the standard EW gauge interactions.



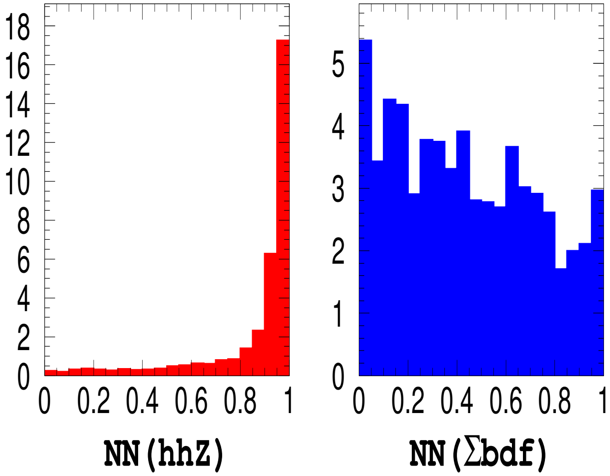




❖ 4- and 6-fermion bkg and tiny σ_{HHZ} make this analysis a genuine experimental challenge (S/B $\simeq 10^{-5}$).

❖ Profit of characteristics signature with 4-b jets and $Z^0 \rightarrow q\bar{q}$, $\ell^+\ell^-$ and of excellent tagging and reconstruction detector capabilities.

NN Analysis



$\delta\lambda_{HHH}/\lambda_{HHH} \simeq 0.22 - 0.18$
for 1000 fb^{-1} - 2000 fb^{-1}

Consecutive Cut Analysis

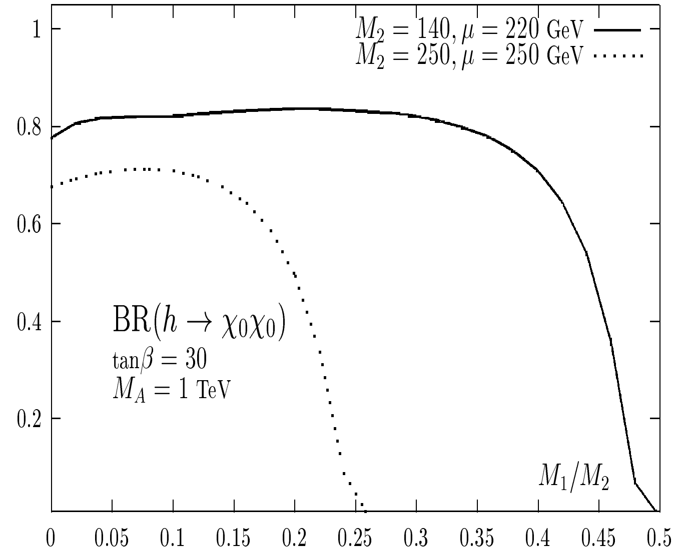
Nb. of Reconstructed Signal and Bkg. Evts.
for 1000 fb^{-1} at $\sqrt{s} = 500$ GeV.

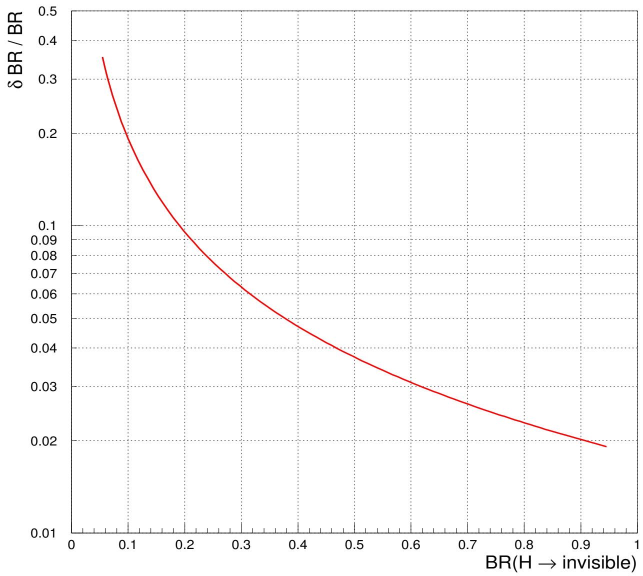
M_H (GeV/c^2)	120	130	140
σ_{HHZ} (fb)	0.186	0.149	0.115
Signal HHZ	186.	149.	115.
$\epsilon(HHZ)$ (%)	43.	43.	39.
$\delta\sigma_{HHZ}/\sigma_{HHZ}$	**0.17**	**0.19**	**0.23**

Non Standard Higgs Decays
$H \to \mathrm{invisible}$

✦ $\ell^+\ell^-$ Recoil analysis of $e^+e^- \to HZ \to X\ell^+\ell^-$ provides with flavour blind tag of H production;

✦ $H \to \mathrm{invisible}$ can be measured by comparing $N_{HZ\to\ell^+\ell^-}$ with BR$(Z \to \ell^+\ell^-) \times \sum_{i=b,c,\tau,...} N_{ZH\to f_i\bar{f}_i} + \sum_{j=W,Z,\gamma} N_{ZH\to B_j\bar{B}_j}$





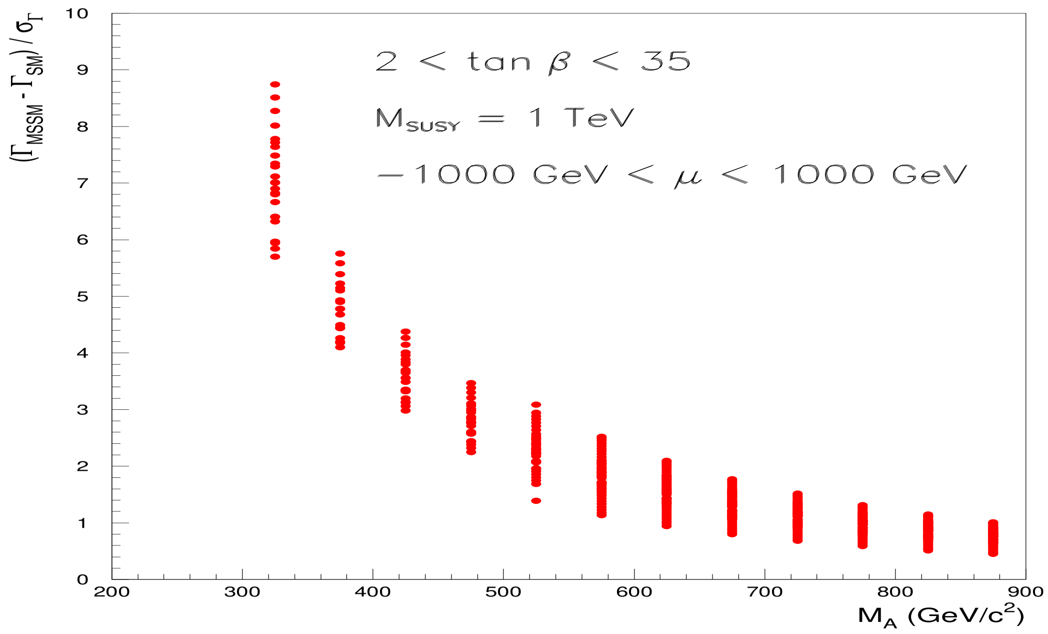
Telling the SM H^0 from the MSSM h^0

❖ If M_{SUSY} and M_A large, a neutral Higgs boson may be the only new particles observed by LEP-2, Tevatron, possibly LHC and the LC.

❖ Accurate determination of Higgs profile may reveal its SM / MSSM nature

❖ Γ_{tot} deviation from SM may provide with a mean of distinguishing the Higgs boson nature:

Higgs Total Width Γ_{tot} : MSSM/SM
An Exemplificative Scan



- Necessary to measure Higgs couplings to access information on MSSM parameters m_A and $\tan\beta$;

- In SUSY Higgs up-like and down-like fermion couplings originating from Yukawa couplings to different Higgs doublets gives deviations on BR_{uu}/BR_{dd} from SM:

$$\Gamma_{d\bar{d}}^{MSSM} \propto \Gamma_{d\bar{d}}^{SM} \frac{\sin^2\alpha}{\cos^2\beta}$$

$$\Gamma_{u\bar{u}}^{MSSM} \propto \Gamma_{u\bar{u}}^{SM} \frac{\cos^2\alpha}{\sin^2\beta} \qquad \Gamma_{WW}^{MSSM} \simeq \Gamma_{WW}^{SM}$$

$$\frac{BR(h\to c\bar{c})}{BR(h\to b\bar{b})} \propto \frac{1}{tan^2\alpha\tan^2\beta} \simeq \frac{(M_h^2-M_A^2)^2}{(M_Z^2+M_A^2)^2}$$

- If $M_{SUSY} \geq 1$ TeV and A^0 boson $M_A > 250$ GeV$/c^2$ SUSY not directly observable at $\sqrt{s} =$ 500 GeV LC and must be indirectly inferred from Higgs couplings.

Theory Uncertainties and SUSY Corrections

❖ Predictivity on SM Higgs couplings to quarks presently limited by m_q and α_s uncertainties:

❖ Use $\bar{M}S$ masses and evolve to $m_q(M_H^2)$.

$$\bar{m_Q}(M_Q) = \frac{M_Q}{1 + \frac{4}{3}\frac{\alpha_s(M_Q)}{\pi} + k_Q \frac{\alpha_s^2(M_Q)}{\pi^2}}$$

$$\bar{m_Q}(\mu) = \bar{m_Q}(M_Q) \frac{c(\alpha_s(\mu)/\pi)}{c(\alpha_s(M_Q)/\pi)}$$

	Today σ (GeV/c^2)	**After LC** σ (GeV/c^2)	Sources of Improvement
m_b	$\pm$ 0.080	$\pm$ 0.040	B-factories and Lattice from Υ
m_c	$\pm$ 0.110	$\pm$ 0.060	Lattice from J/Ψ
m_{top}	$\pm$ 5.0	$\pm$ 0.150	LC Threshold Scan
$\alpha_s(M_Z)$	$\pm$ 0.003	$\pm$ 0.001	Event Shape Variables at LC

QED Corrections

γ-echange and final state γ radiation

QCD Corrections

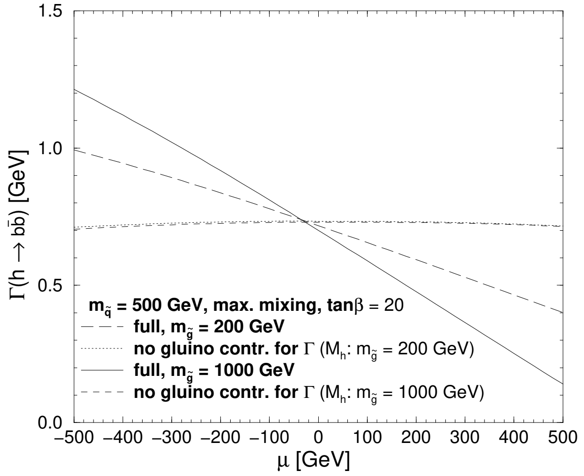
gluon-echange and final state gluon radiation

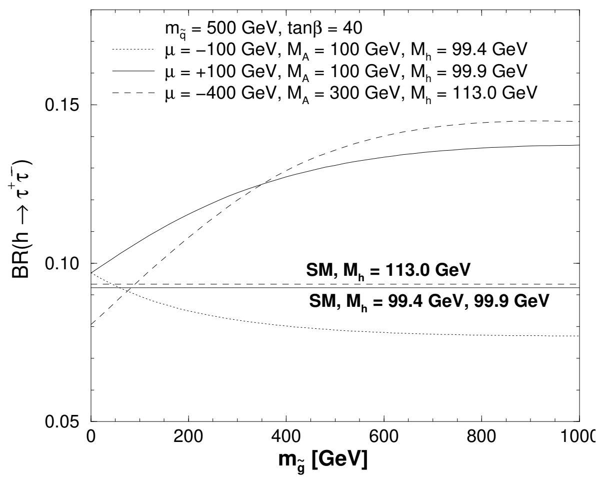
SUSY Corrections

Gluino loops induce shift

$$m_b = h_b v_1 \rightarrow m_b = v_1(h_b + \Delta h_b \tan\beta) = h_b v_1 (1 + \Delta m_b)$$

of the Yukawa coupling. $\Delta m_b \propto (\alpha_s/\pi)(\mu \tan\beta / M_{SUSY})$





✥ Predictivity on SUSY Higgs couplings to quarks may be limited by corrections to hqq from gluino loops.

Scan of MSSM Parameter Space

$$2 < \tan\beta < 35$$
$$150 \text{ GeV}/c^2 < M_A < 1000 \text{ GeV}/c^2$$
$$1000 \text{ GeV}/c^2 < M_{SUSY} < 1500 \text{ GeV}/c^2$$
$$-1000 \text{ GeV} < \mu < 1000 \text{ GeV}$$
$$0 < M^t_{LR}/M_{\tilde{q}} < \sqrt{6}$$
$$0.5 < M_{\tilde{g}}/M_{SUSY} < 1$$

- Find the MSSM parameters giving $M_{h^0} = (120 \pm 2)$ GeV/c^2 using the diagrammatic two-loop result for M_h
- Compute Higgs decay BRs, including QCD corrections
- Compute pulls of MSSM BRs from SM ones accounting for SM BR uncertainties:

$$\Delta(BR) = \frac{|BR^{MSSM} - BR^{SM}|}{\sqrt{\sigma^2_{th} + \sigma^2_{exp}}}$$

Discriminating Variables:

BR($h \to b\bar{b}$**)**

BR($h \to c\bar{c}$**)**

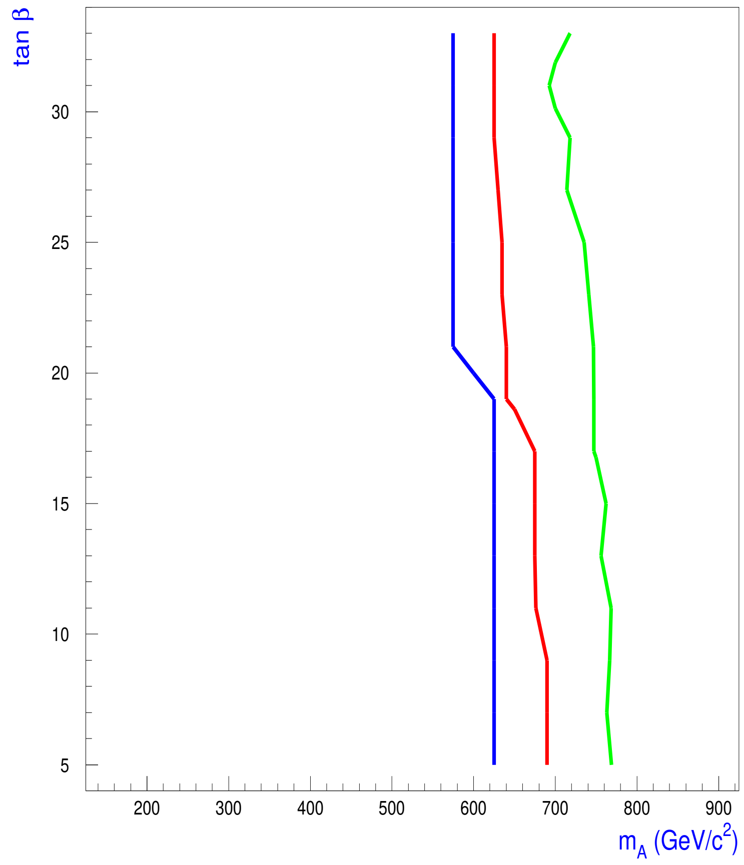
BR($h \to g\bar{g}$**)**

BR($h \to \tau^+\tau^-$**)**

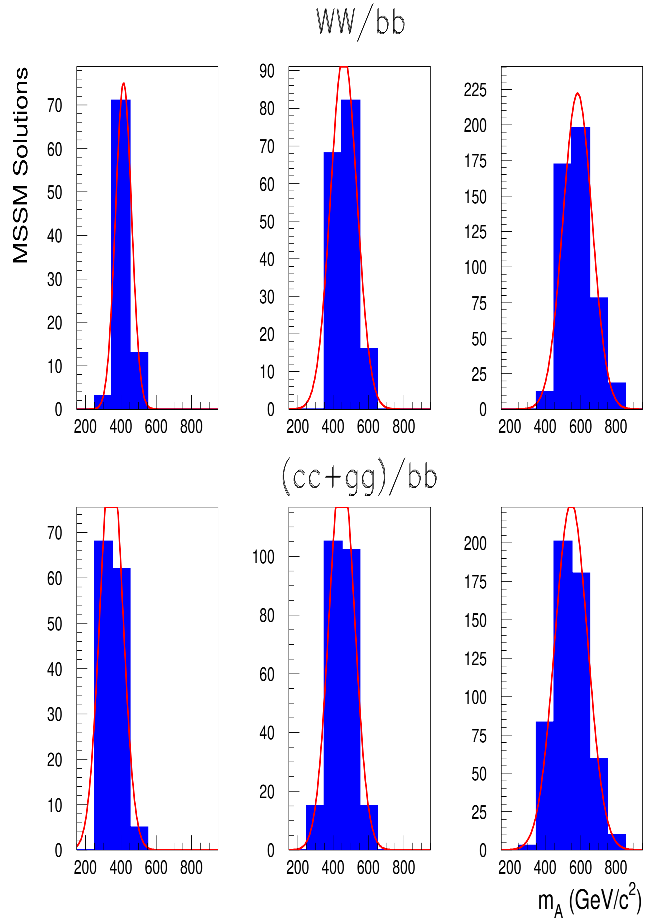
violet **BR(**$h \to WW^*$**)**

LC for $M_H = 120$ GeV/c^2 with L = 1000 fb^{-1}

$M_A - \tan\beta$ MSSM/SM Discrimination
95%, 90%, 68% Contours



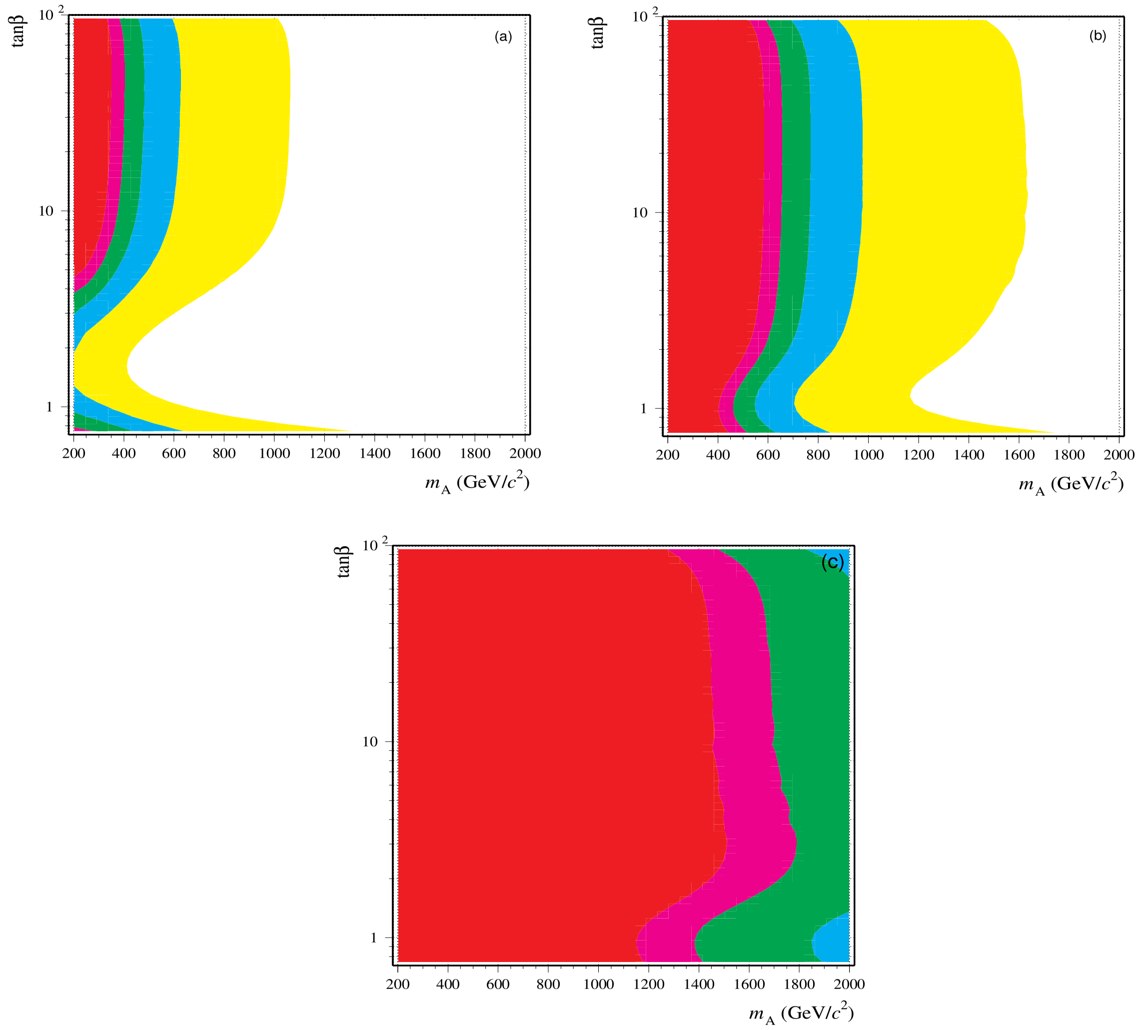
M_A for MSSM Solutions compatible with BRs at 68% C.L.



A Comparison with the Muon Collider

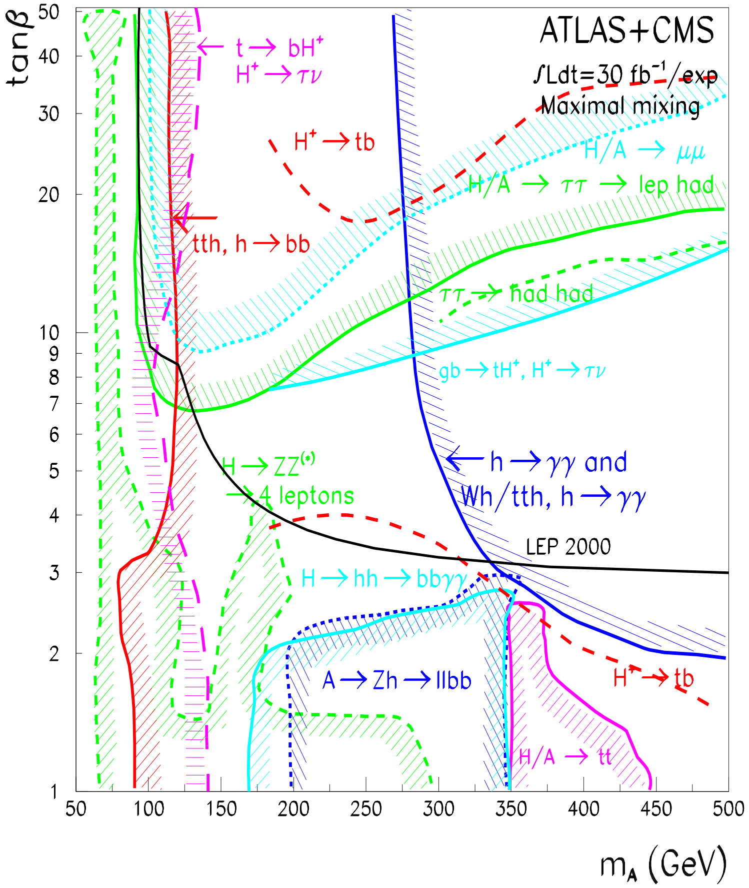
$M_H = 110$ GeV$/c^2$,
$M_{SUSY} = 1$ TeV, maximal stop mixing
$M_A - \tan\beta$ MSSM/SM DISCRIMINATION
(a) no Muon Coll., (b) 0.2 fb^{-1} at Muon Coll.,
(c) 10 fb^{-1} at Muon Coll.

$> 5\sigma$, 4 - 5 σ, 3 - 4 σ, 2 - 3 σ, 1 - 2 σ

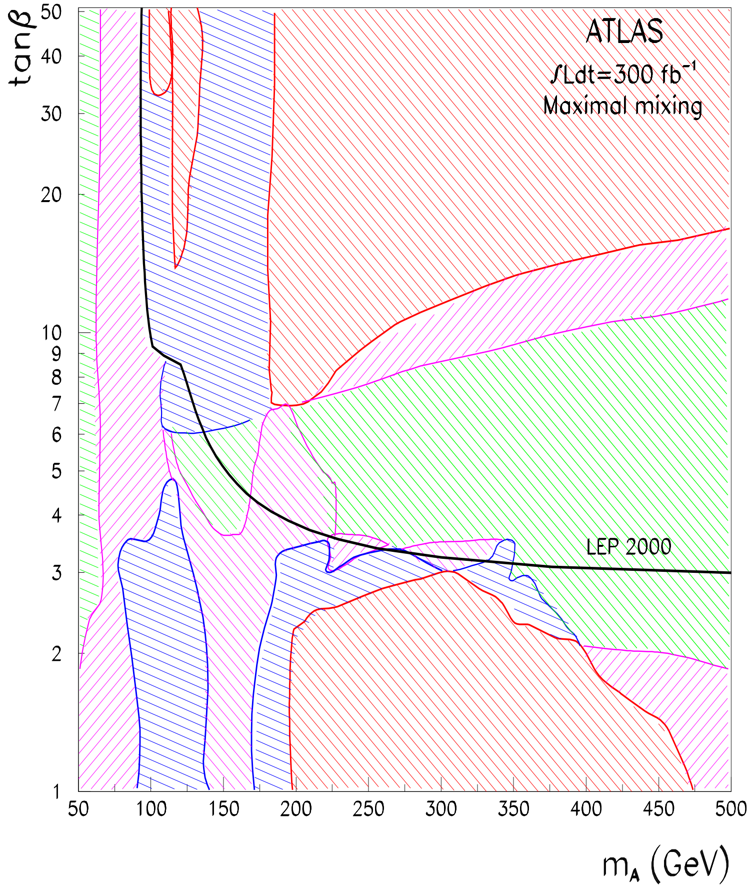


A Comparison with LHC

LHC Discovery Contours
ATLAS + CMS 30 fb^{-1}

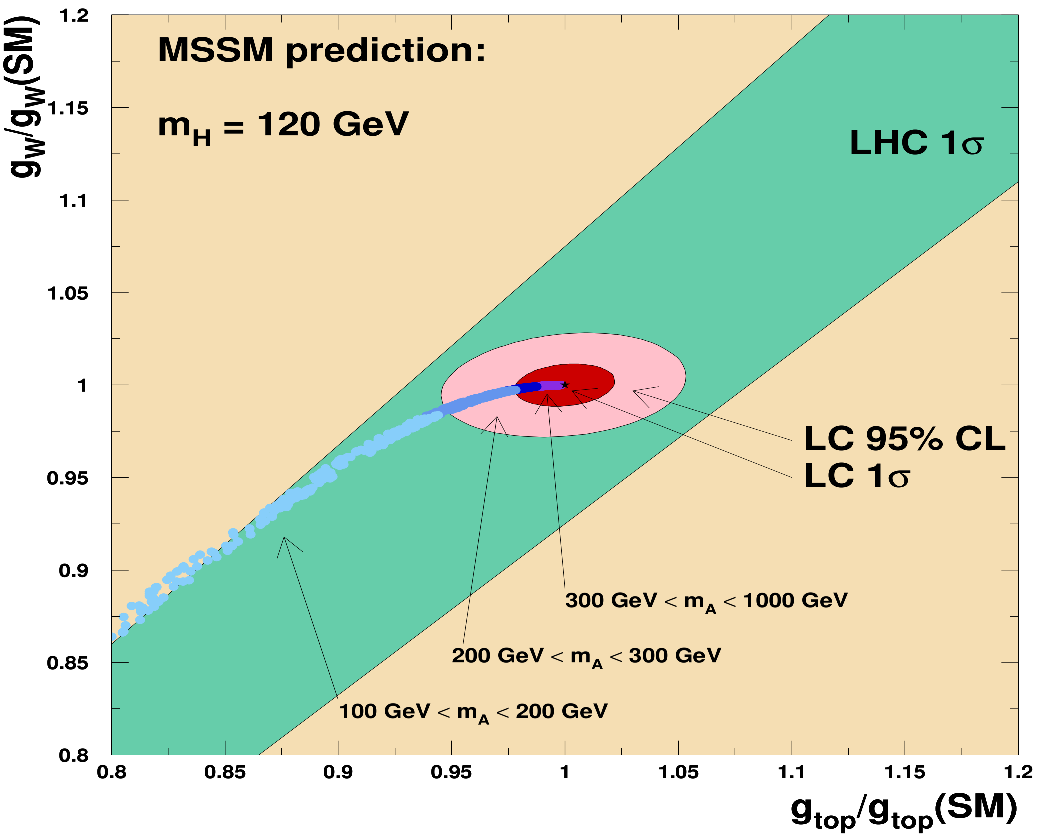


Nb. Of Higgs Bosons
Observable at LHC



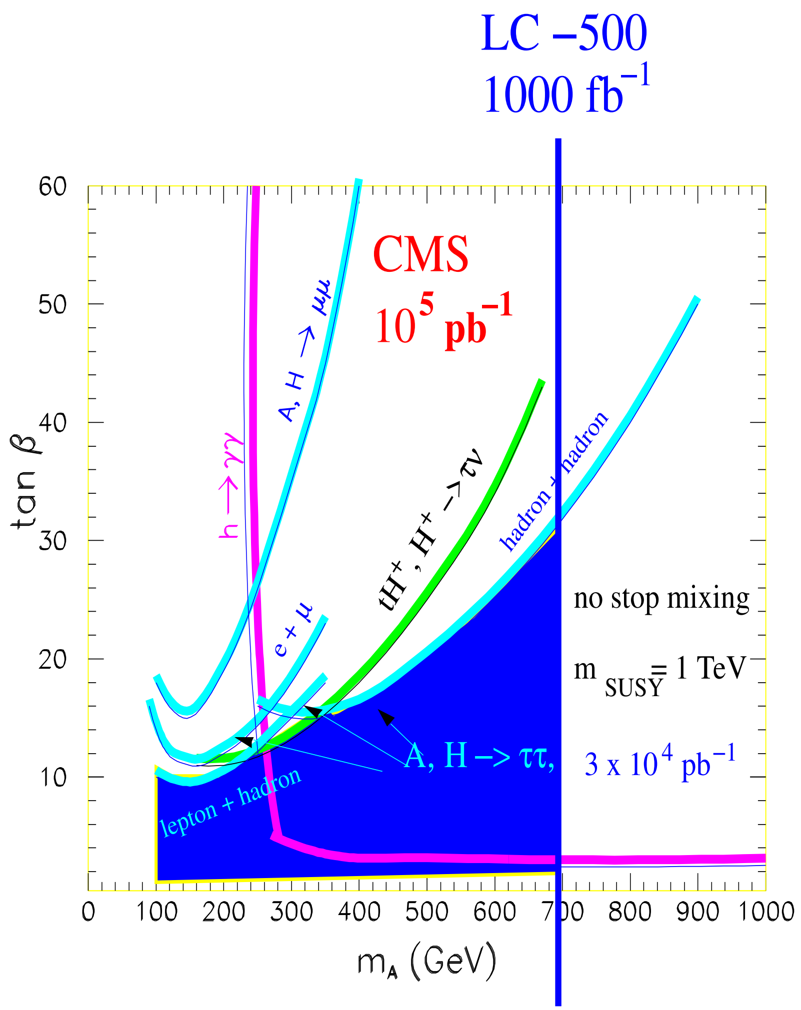
High $\int L$ LC to **improve accuracy of measurements performed also at LHC**

	M_H (GeV/c^2)	$\delta(X)/X$ LHC ATLAS+CMS 300 fb^{-1}	$\delta(X)/X$ **LC** 1 Exper. **500 fb^{-1}**
M_H	120	9×10^{-4}	3×10^{-4}
M_H	160	10×10^{-4}	4×10^{-4}
$\frac{g_{t\bar{t}H}}{g_{WWH}}$	120	0.075	0.030
$\frac{g_{ZZH}}{g_{WWH}}$	160	0.050	0.022



LC to extend test of Higgs mechanism and establish Higgs nature by **measurements not feasible at LHC**

Observable	$\delta(X)/X$ **LC** **500 fb**$^{-1}$
Γ_{tot}	0.04 - 0.06
g_{Huu}	0.02 - 0.04
g_{Hdd}	0.01 - 0.02
g_{HWW}	0.01 - 0.03
$\Phi = H + A$	0.03 - 0.13
λ_{HHH}	0.35



HFITTER - Extract Higgs Effective Couplings