Flavour independent Searches for Higgs bosons at LEP2

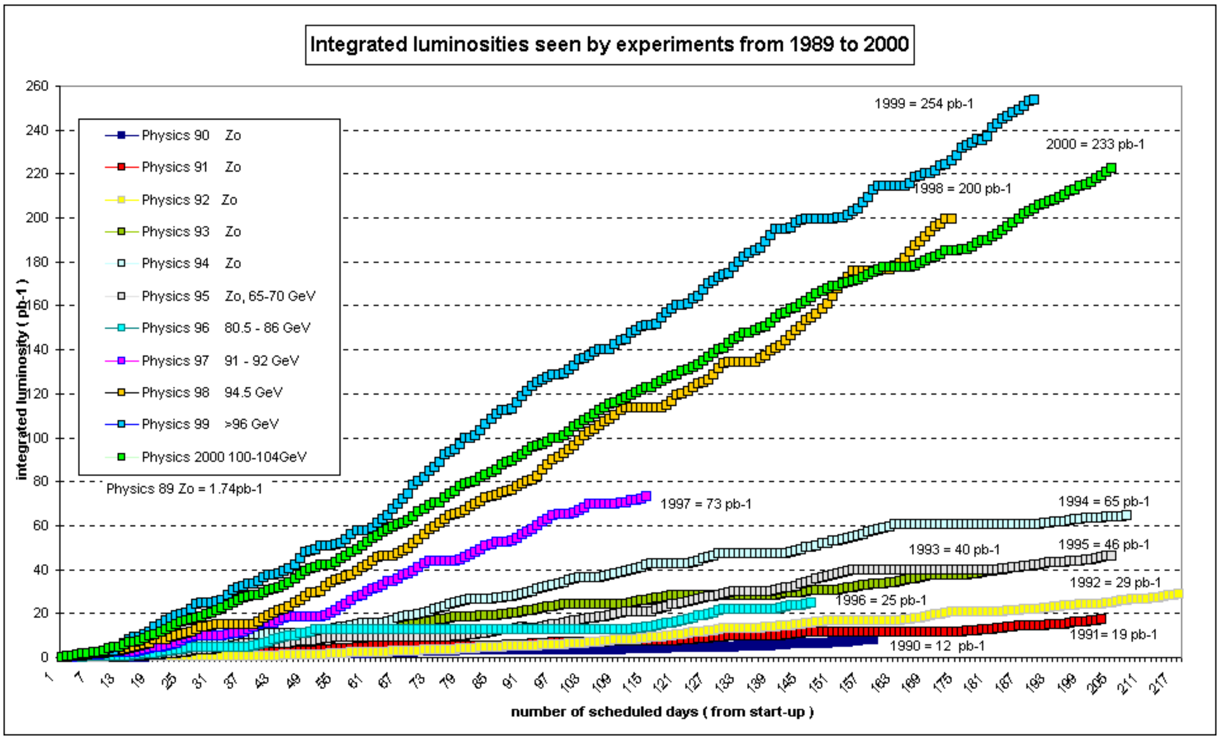
Thomas Trefzger
LMU Munich

May 2001
Higgs Workshop

- 2 Higgs Doublet Model
- Flavour-blind Analysis (ALEPH, L3, OPAL)
- non-b Analysis (DELPHI)
- Summary

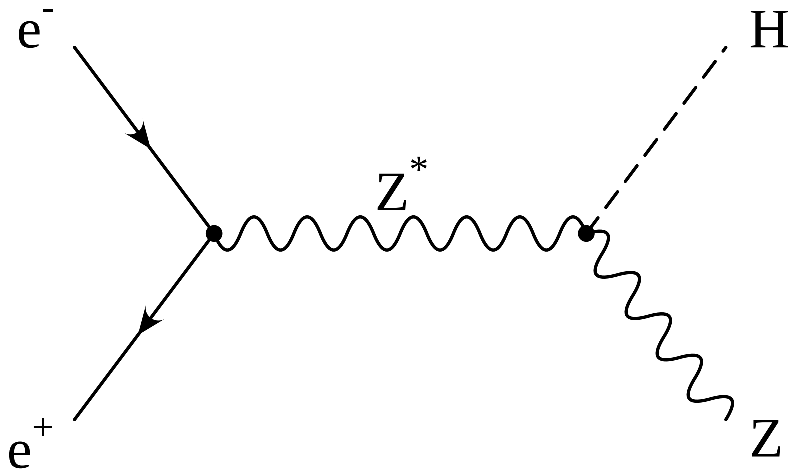
TWELVE YEARS OF LEP RUNNING

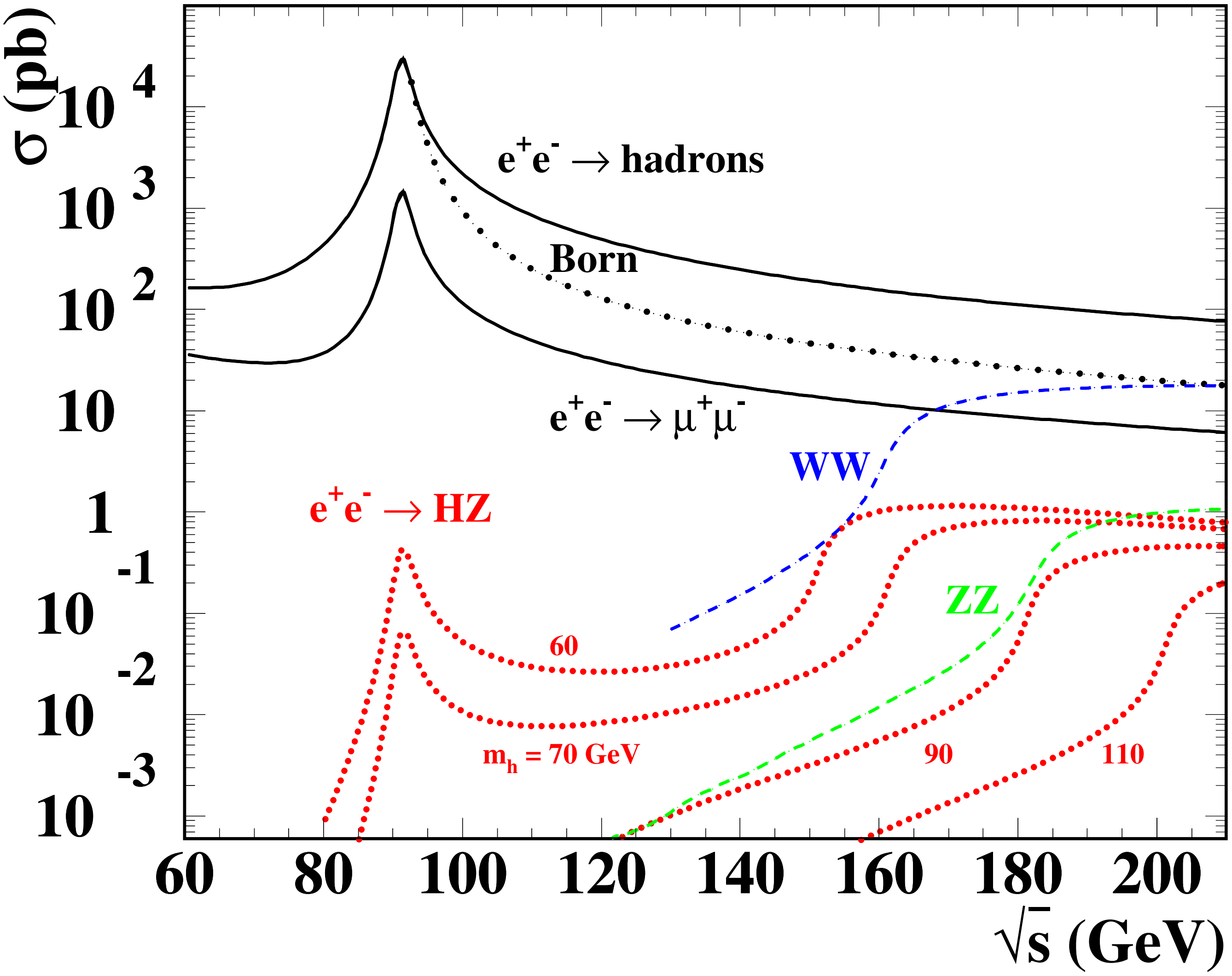
Stage	$\sqrt{s}$	Year	Luminosity
LEP1	$\approx M_{Z^0}$	1989–1995	175 pb^{-1}
LEP1.5	130–140 GeV	1995	5 pb^{-1}
LEP2	161 GeV	1996	10 pb^{-1}
LEP2	172 GeV	1996	10 pb^{-1}
LEP2	183 GeV	1997	55 pb^{-1}
LEP2	189 GeV	1998	180 pb^{-1}
LEP2	192-202 GeV	1999	230 pb^{-1}
LEP2	200-209 GeV	2000	220 pb^{-1}



SM HIGGS PRODUCTION AT LEP

Higgs-strahlung



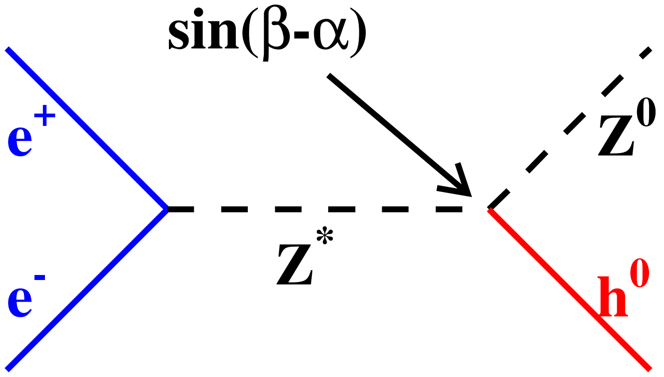


HIGGS BOSONS IN 2HDM

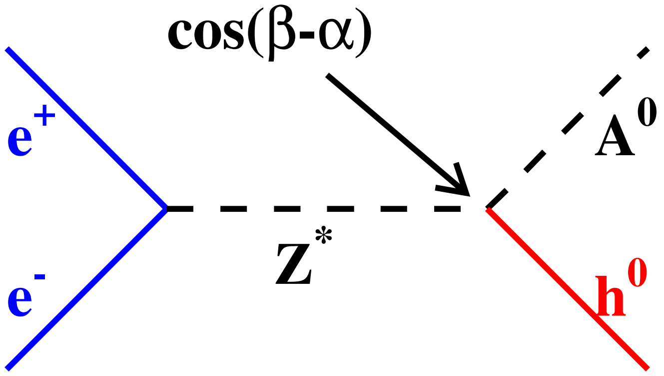
Most natural extension of the Standard Model.

h^0: neutral light Higgs Boson (CP-even)
H^0: neutral heavy Higgs boson (CP-even)
A^0: neutral Higgs boson (CP-odd)
H^+, H^-: charged Higgs bosons

$\tan\beta$: vacuum expectation value of the two dubletts
α: mixing angle of the CP-even Higgs bosons
6 free parameters.



Higgs-strahlung
$\sigma_{hZ} = \sin^2(\beta - \alpha) \cdot \sigma_{hZ}^{SM}$

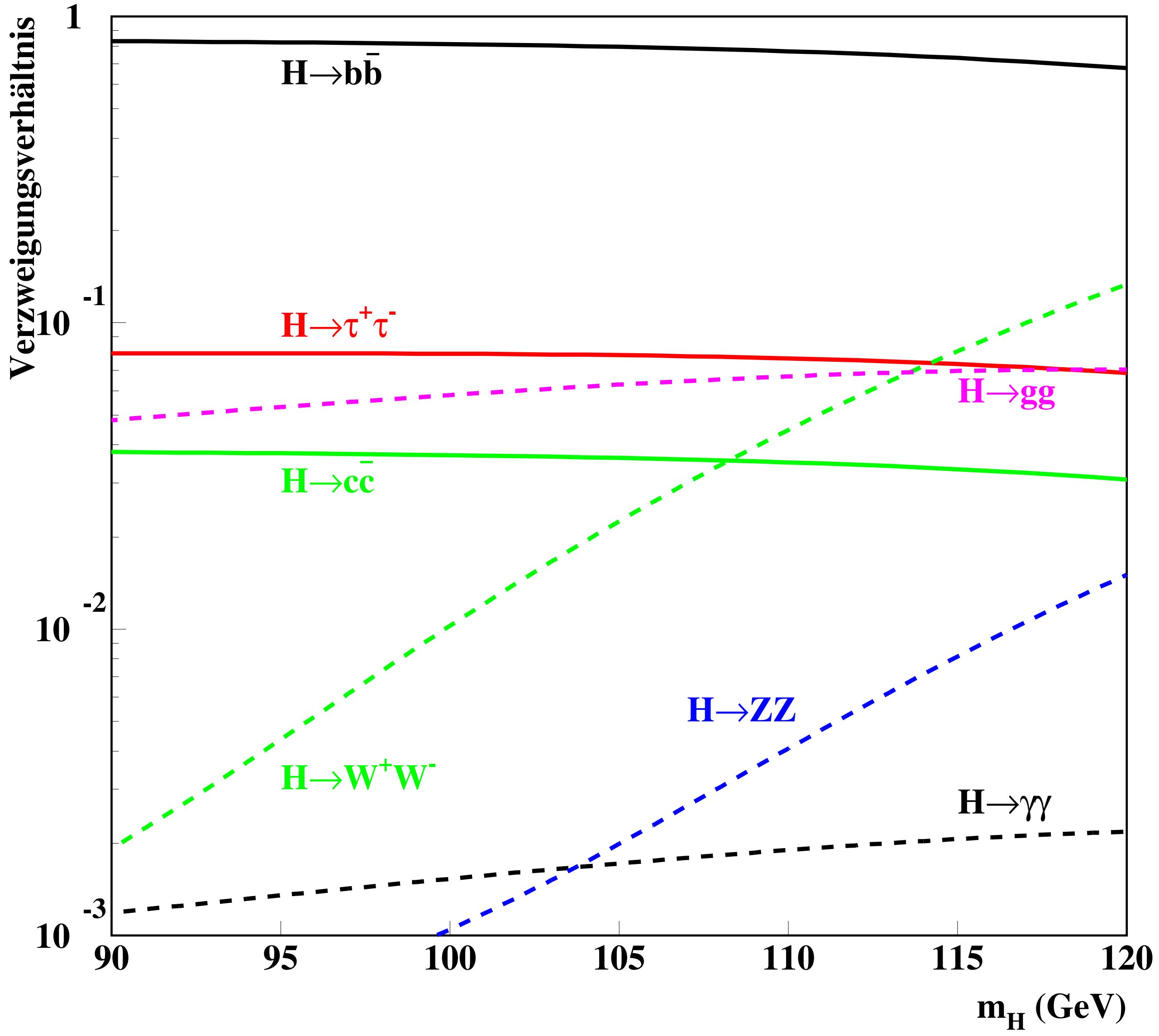


Associated production
$\sigma_{hA} = \cos^2(\beta - \alpha) \cdot \bar{\lambda}\sigma_{hZ}^{SM}$
$\bar{\lambda}$: kinematic factor $(m_h, m_A, \sqrt{s})$

SM HIGGS BOSON DECAYS AT LEP

- Coupling to fermions proportional to fermion masses
- Coupling to bosons proportional to boson masses squared

⇒ SM Branching ratio at LEP large for heavy quarks (b) and heavy leptons



2HDM

Couplings to fermion-antifermion pairs different in respect to the SM: $hu\bar{u} : \cos\alpha / \sin\beta$ and $hd\bar{d} : -\sin\alpha / \cos\beta$

The type of 2HDM is determined by the couplings of the Higgs doublets to fermions.

Type I:
Only the second Higgs doublet couples to fermions
Type II:
The first Higgs doublet couples to down type fermions and the other couples to up type fermions

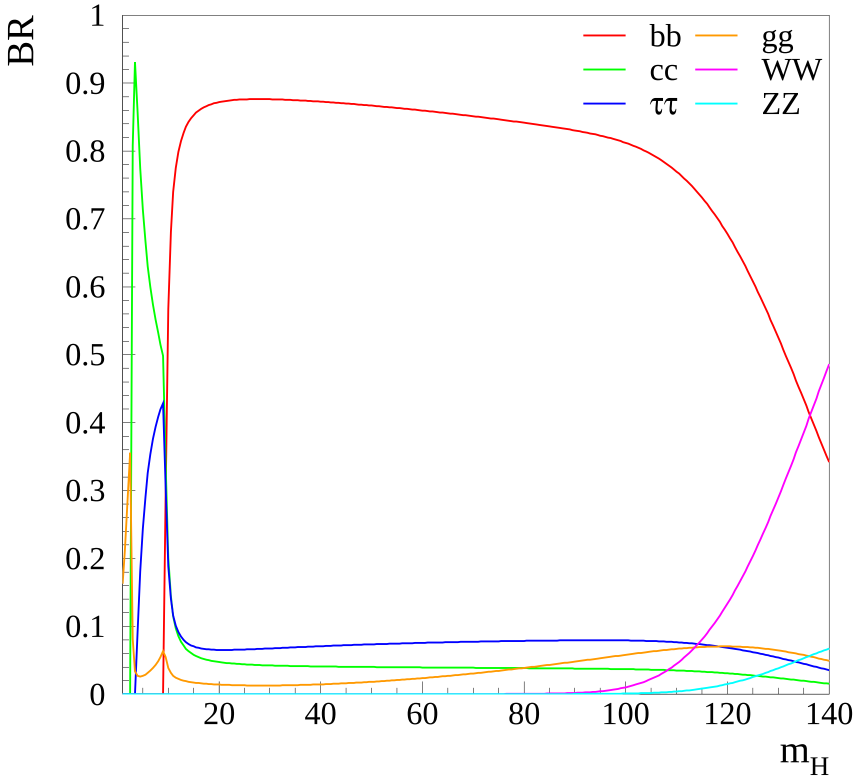
MSSM is a 2HDM(II)

Same tree level couplings to fermions and production cross sections of neutral Higgs bosons as in the MSSM
BUT since there are not the constraint derived from SUSY $h \to b\bar{b}$ is not anymore the dominant decay in large areas of the parameter space

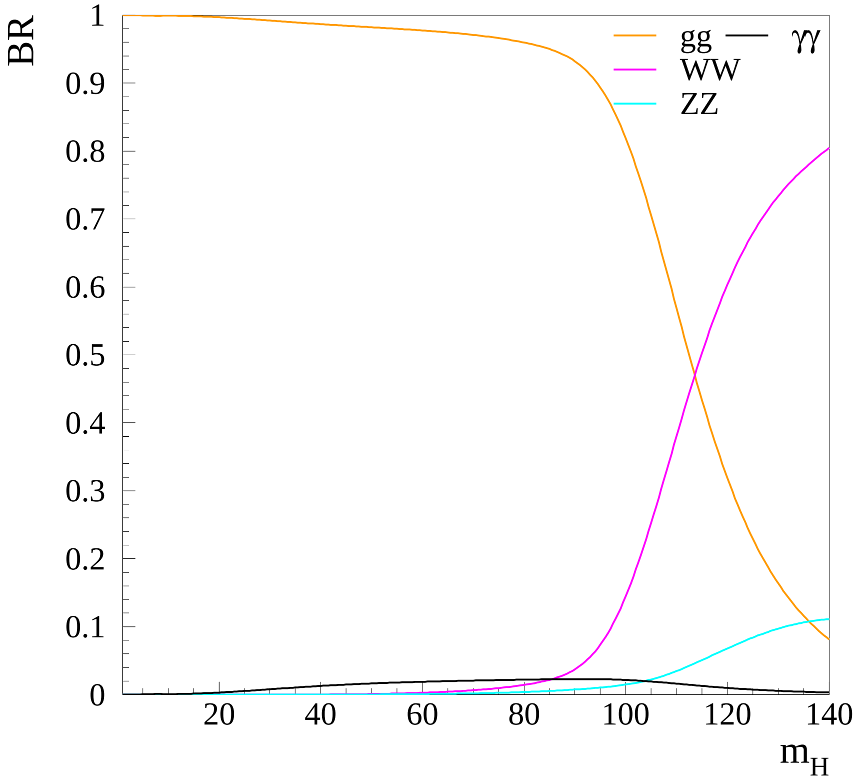
b-tag analyses can't provide exclusion where BR($h \to b\bar{b}$) is small.

NEW FLAVOUR INDEPENDENT ANALYSES WERE PERFORMED

MOTIVATION



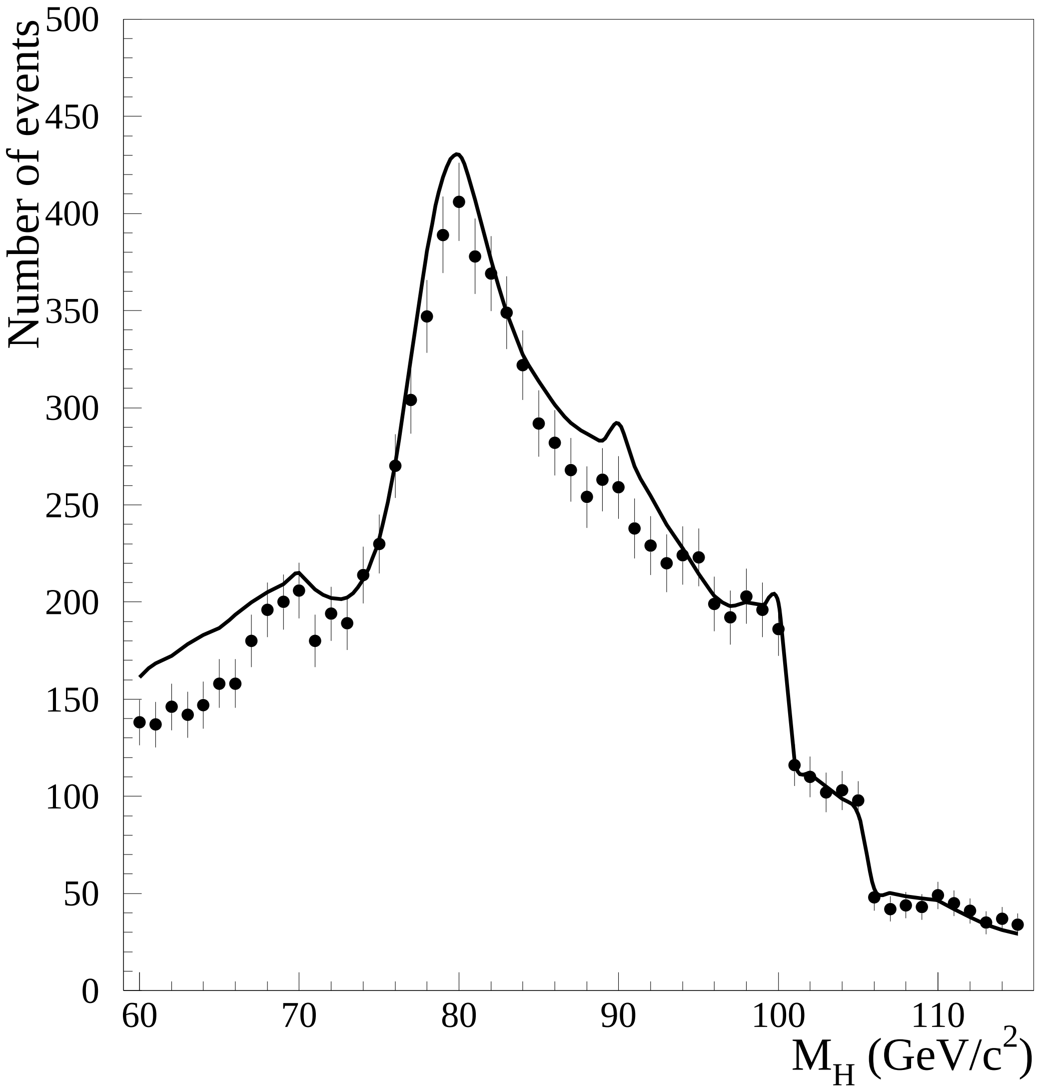
SM branching ratios



Fritzsch/Calmet Model (hep-ph-0008252)

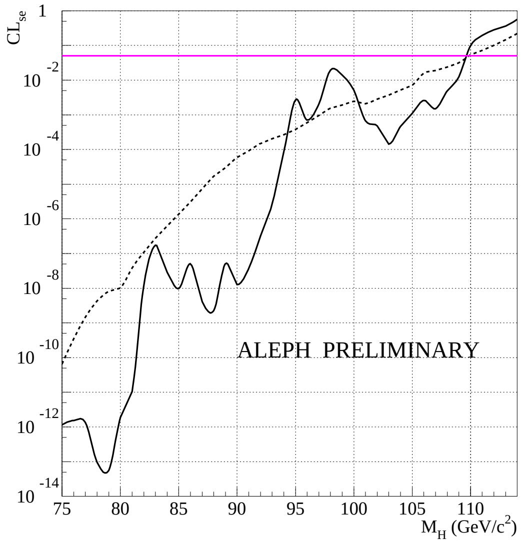
ALEPH

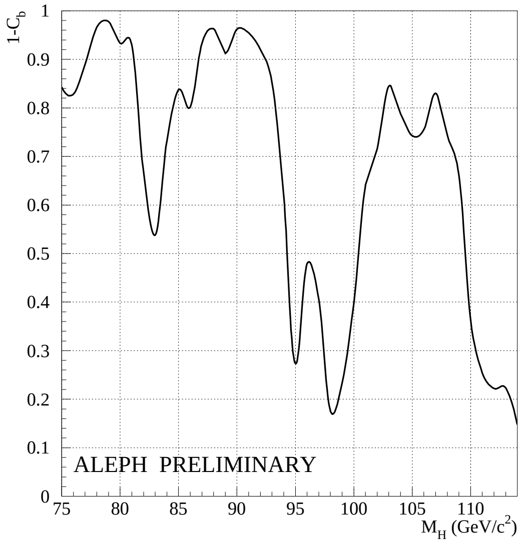
Flavour-independent searches in the process $e^+e^- \to hZ$ using 630 pb^{-1} of data at centre-of-mass energies from 189 to 209 GeV.
Four-jet, missing energy and leptonic final states are used.
New variables based on the di-jet mass are used.

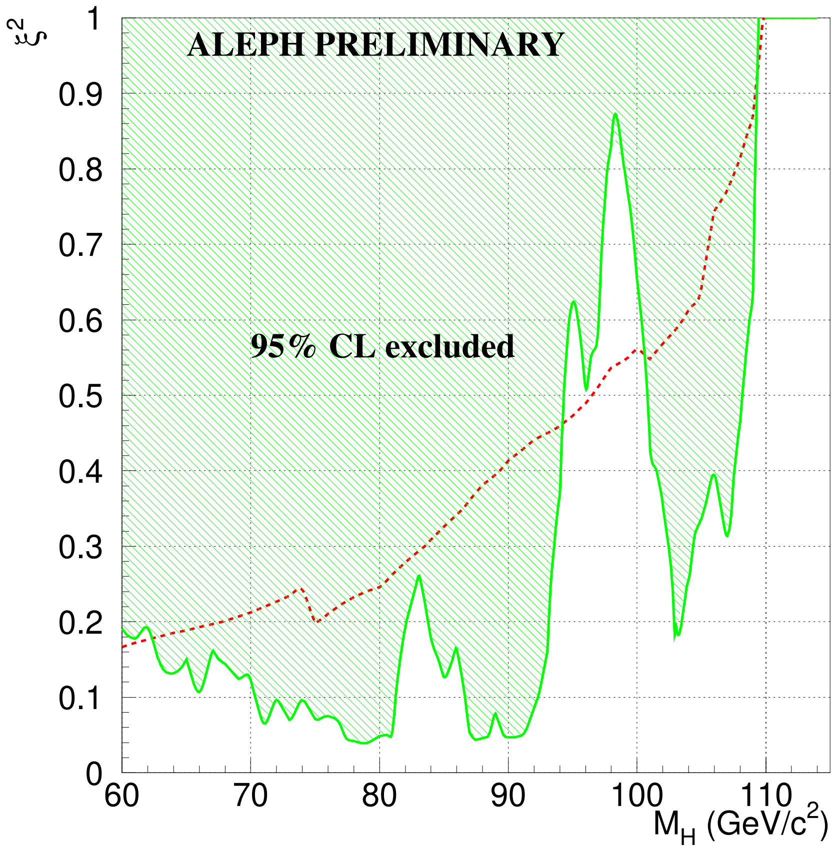


Expected background compared to collected data by the four-jet selection as function of the Higgs boson mass.

ALEPH







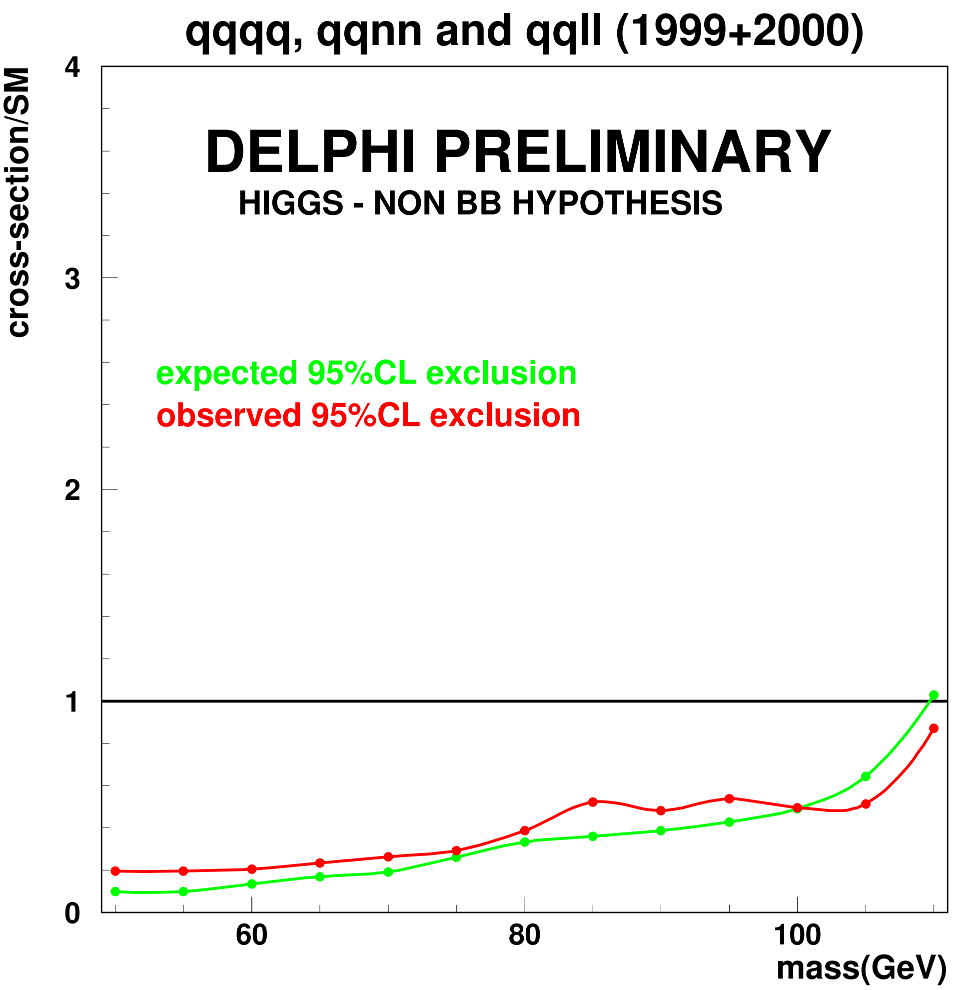
ξ^2: ratio of $e^+e^- \to HZ$ cross section to that of the SM times the branching fraction of the Higgs boson into hadrons.

observed limit: 109.4 GeV/c^2

expected limit: 109.8 GeV/c^2

DELPHI

Flavour-independent searches in the process $e^+e^- \to hZ$ using 630 pb^{-1} of data at centre-of-mass energies from 189 to 209 GeV.
Four-jet, missing energy and leptonic final states are used.
b-Veto is used.



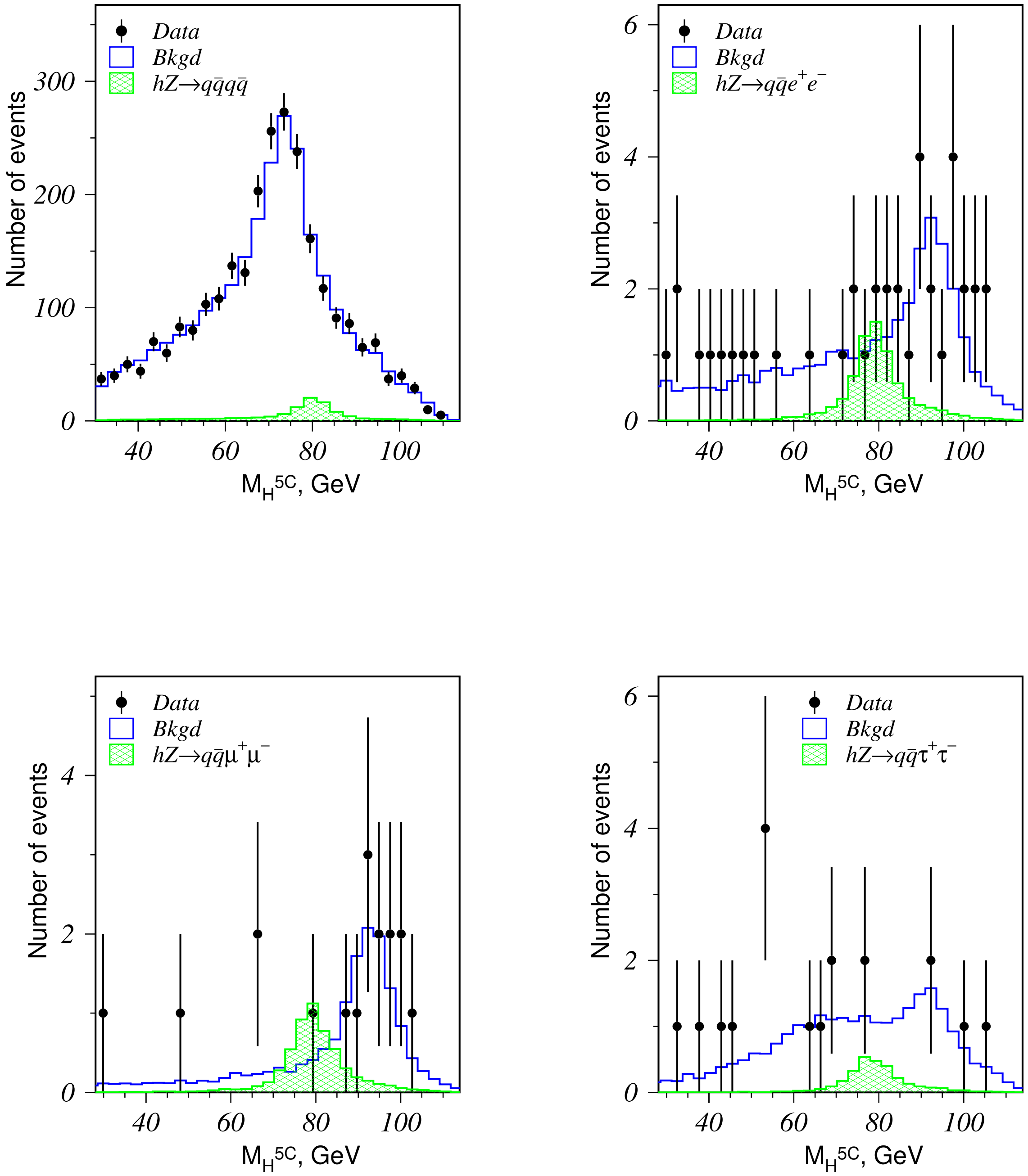
observed limit: 104.3 GeV/c^2
expected limit: 105.3 GeV/c^2
BR$\to$ non b = 100 %

L3

Flavour-independent searches in the process $e^+e^- \to hZ$ using 680 pb^{-1} of data at centre-of-mass energies from 183 to 209 GeV.

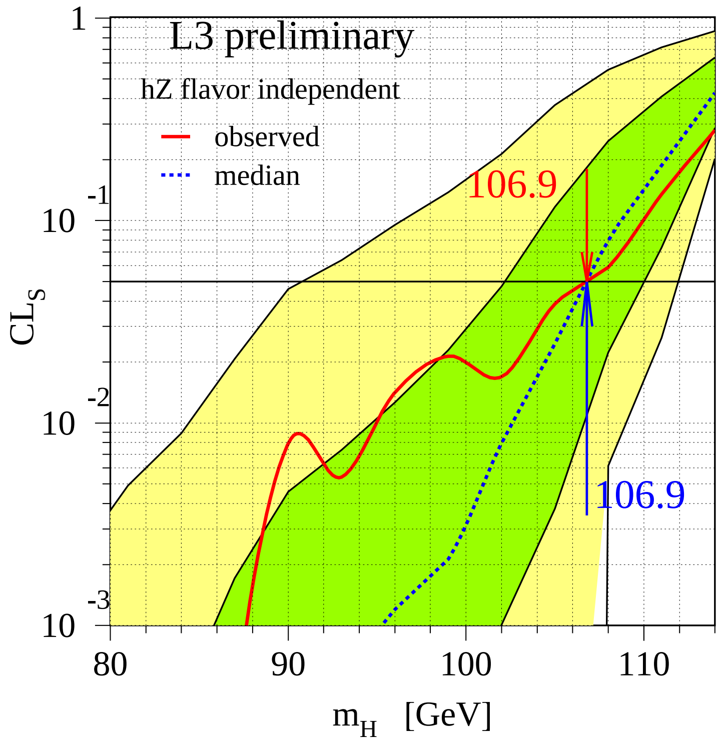
Four-jet, missing energy and leptonic final states are used.

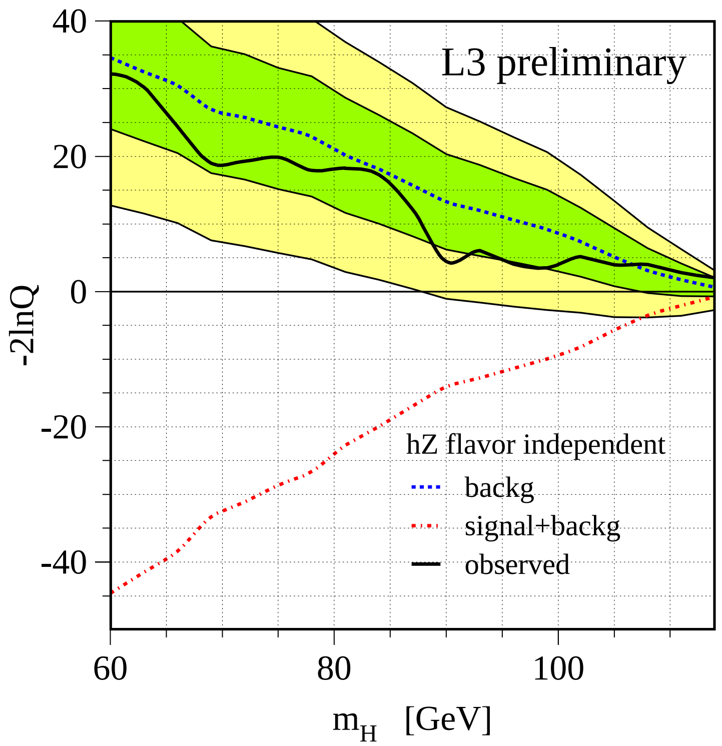
Recycling of SM Higgs search but without b-tag, final variable M_H^5C ($m_{qq,ll,\nu\nu} = m_Z$)



L3

$\rho = g_{hZZ}/g_{HZZ}^{SM} = 1$, BR($h \to q\bar{q}$)=100%





observed limit: 106.9 GeV/c^2

expected limit: 106.9 GeV/c^2

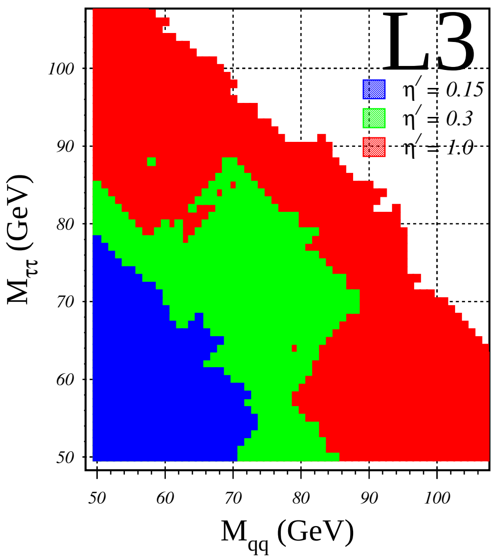
L3

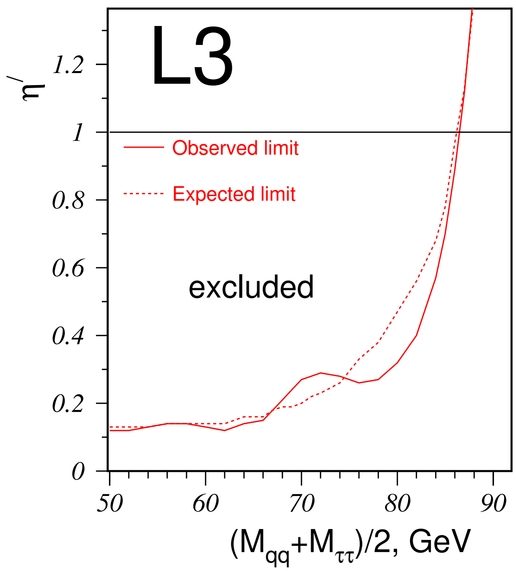
$hA \to q\bar{q}\tau^+\tau^-$

5C fit: $(M_{q\bar{q}} - M_{\tau\tau} = m_A - m_h)$

Final variable: $\frac{1}{2}(M^{5C}_{q\bar{q}} + M^{5C}_{\tau\tau})$

$\eta' = \cos^2(\beta - \alpha) \cdot BR(hA \to q\bar{q}\tau^+\tau^-)$



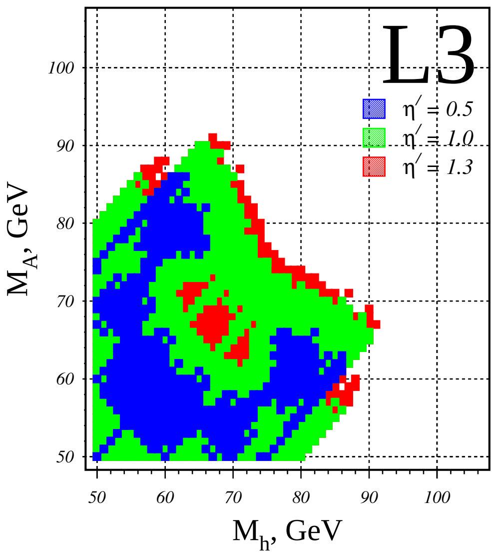


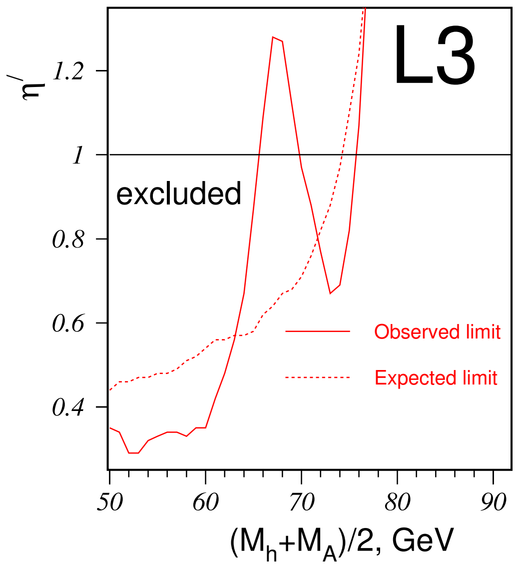
$hA \to q\bar{q}q\bar{q}$

5C fit: $(M_{q\bar{q}} - M_{q'\bar{q}'} = m_A - m_h)$

Final variable: $\frac{1}{2}(M^{5C}_{q\bar{q}} + M^{5C}_{q'\bar{q}'})$

$\eta' = \cos^2(\beta - \alpha) \cdot BR(hA \to q\bar{q}q\bar{q})$

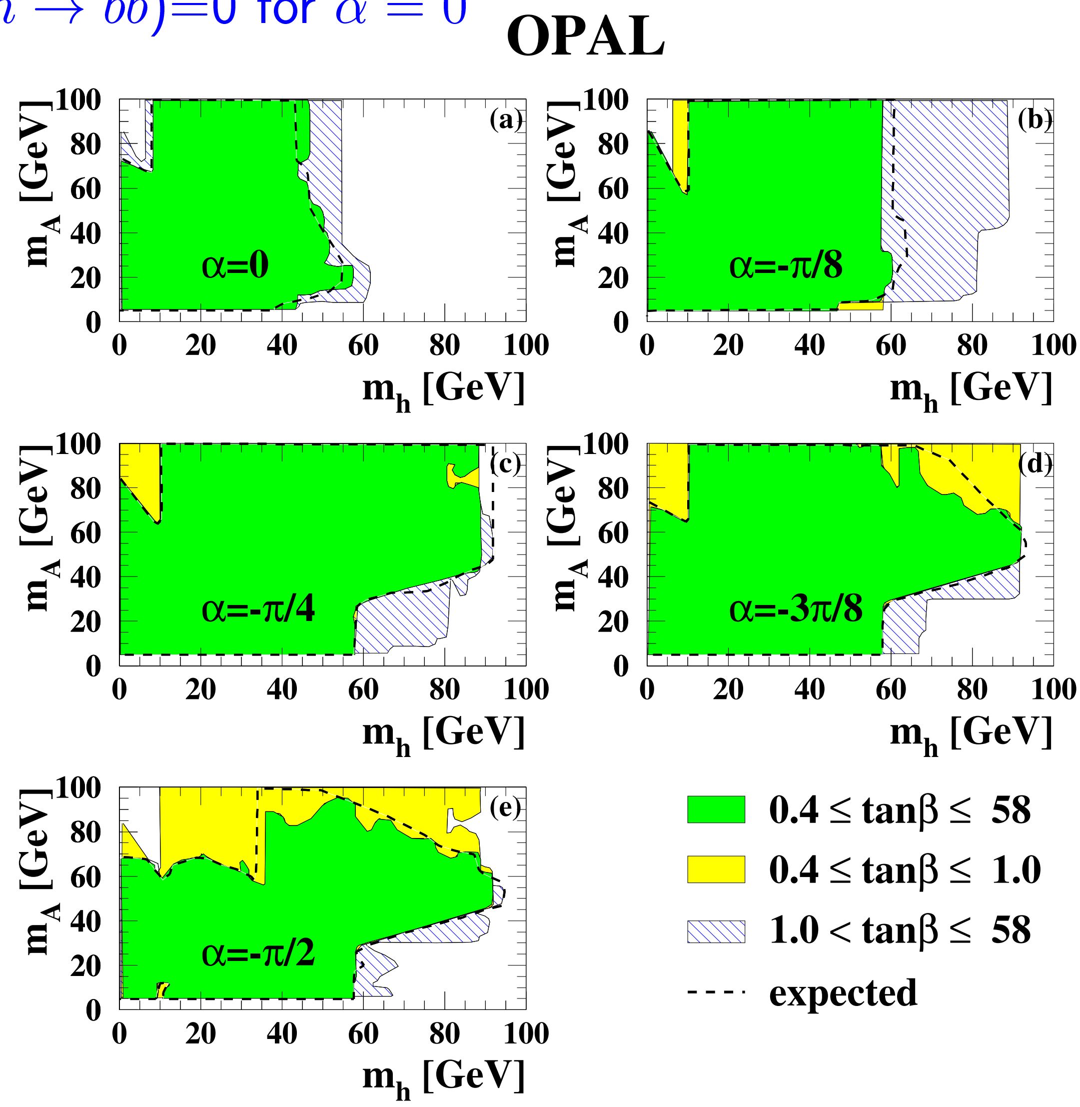




OPAL; 2HDM scan

Data taken at $\sqrt{s} \sim m_Z$, 183 and 189 GeV
flavour independent, mass dependent hA and hZ searches

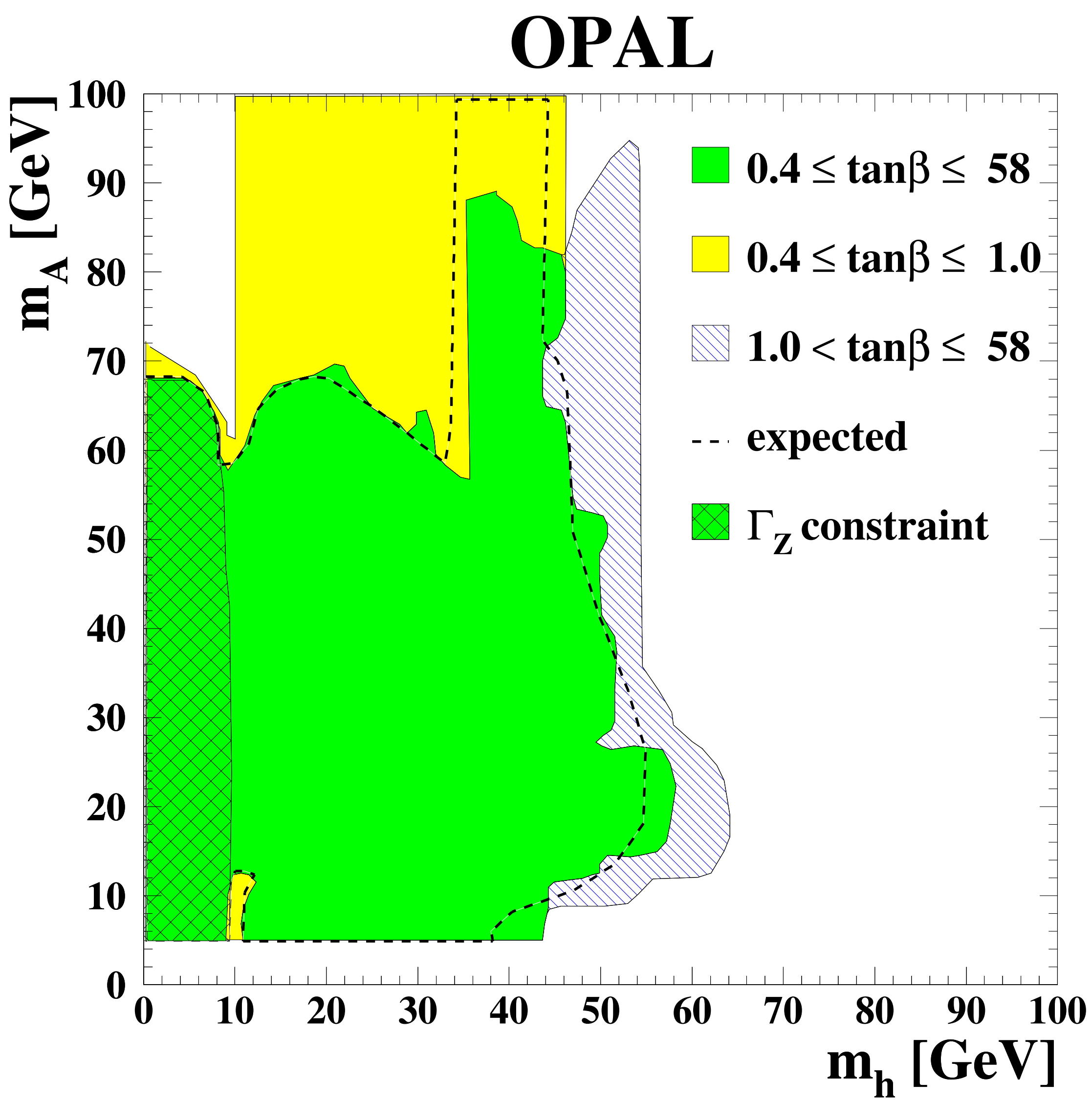
BR($h \to b\bar{b}$)=0 for $\alpha = 0$



BR($h \to c\bar{c}$)=0 for $\alpha = \pi/2$

OPAL, 2HDM scan

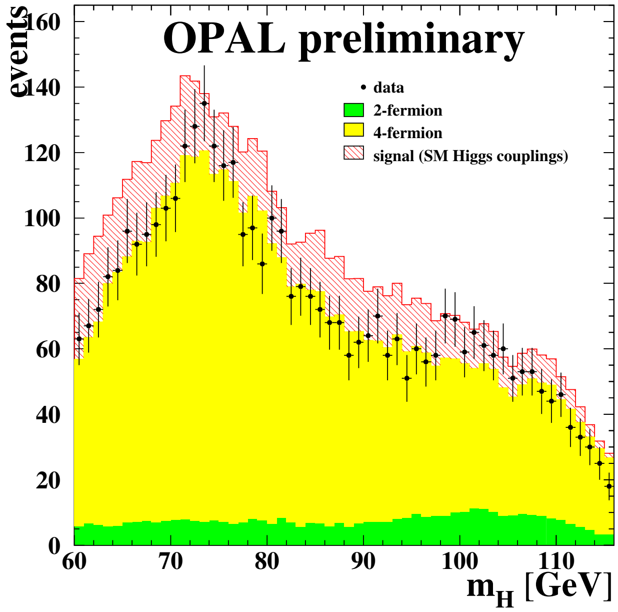
Data taken at $\sqrt{s} \sim m_Z$, 183 and 189 GeV
flavour independent, mass dependent hA and hZ searches

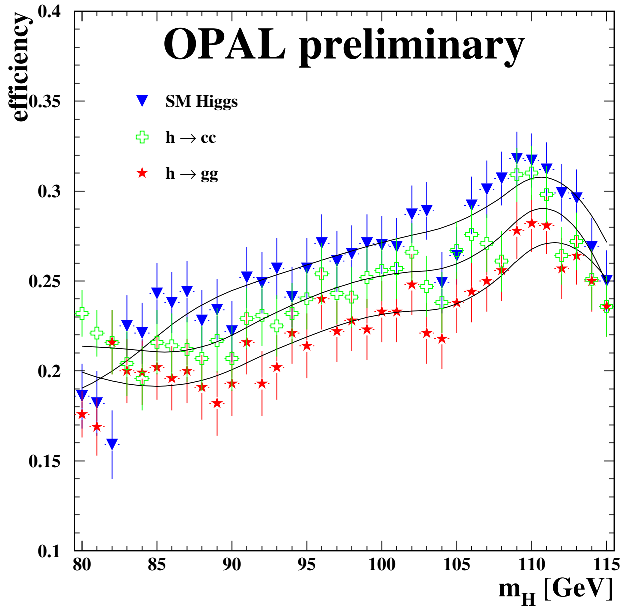


Independent of α

OPAL

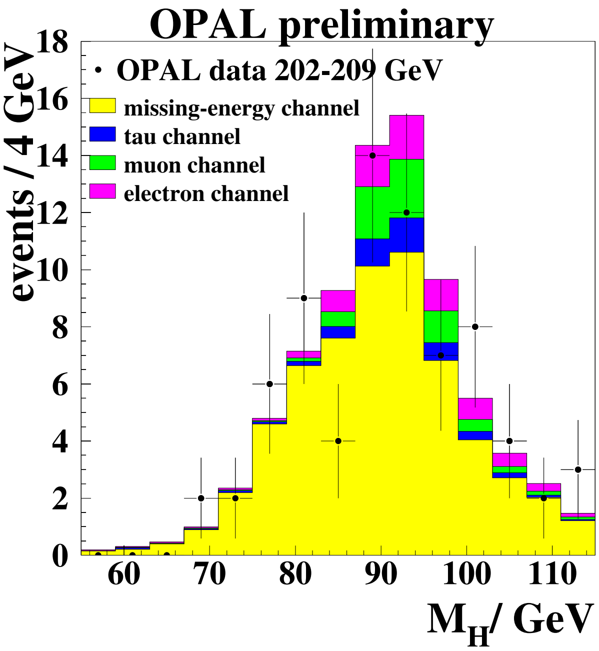
Flavour-independent searches in the process $e^+e^- \to hZ$ at centre-of-mass energies from 202 to 209 GeV.
Four-jet, missing energy and leptonic final states are used.
Test-mass dependent event selection
4 jet channel:



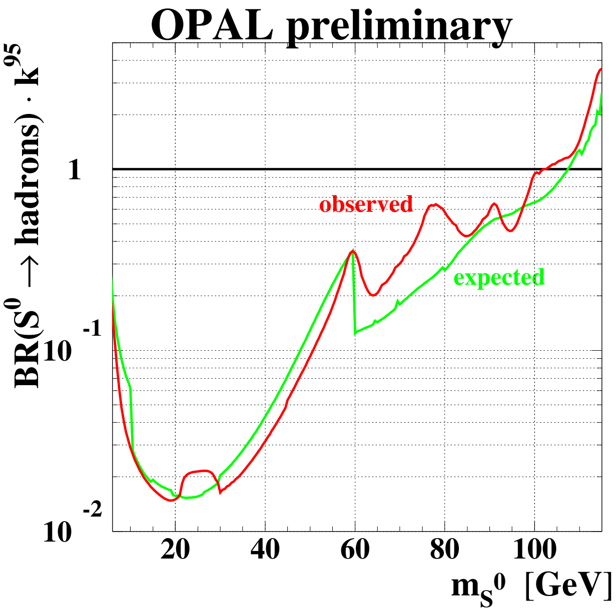


OPAL

missing energy and leptonic channels:



Limit on the cross section (all channels):

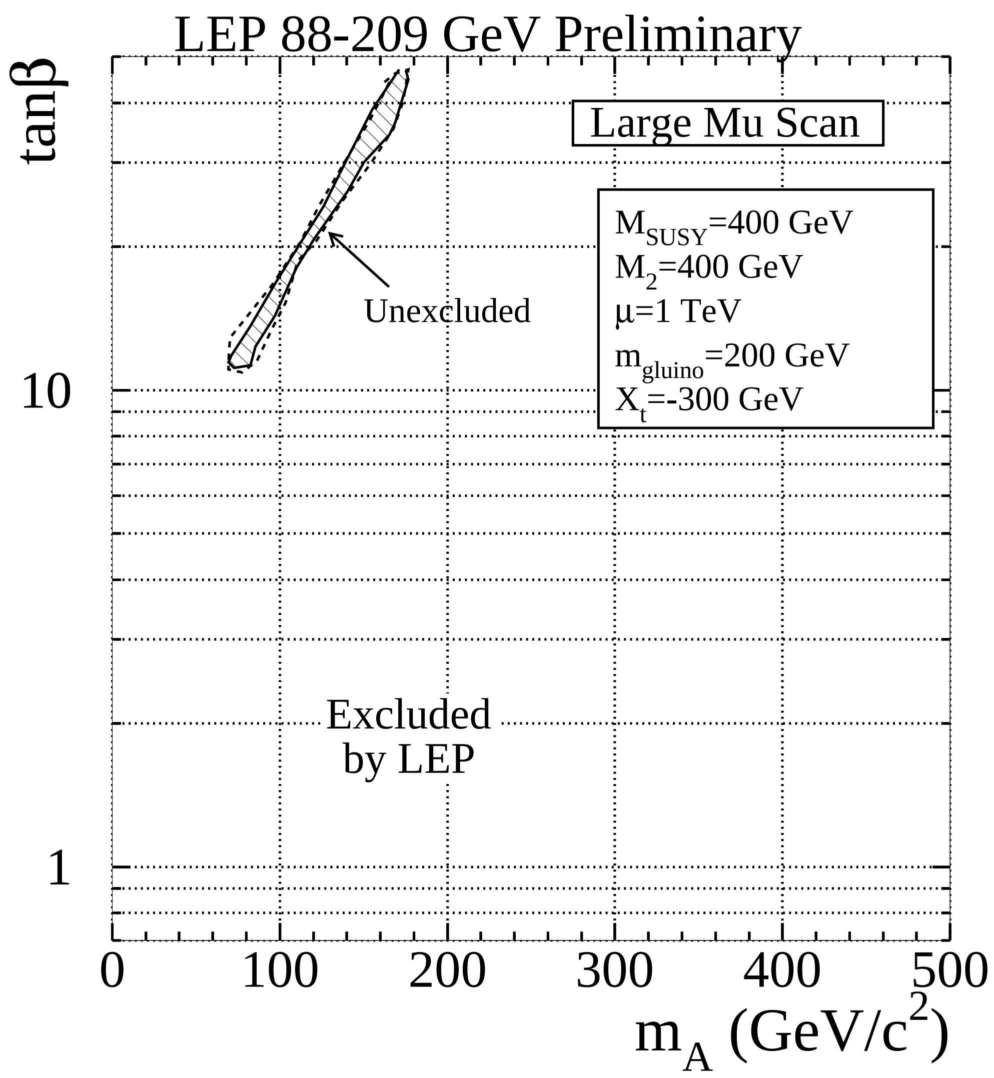


observed limit: 101.8 GeV/c^2

expected limit: 107.3 GeV/c^2

BR$\rightarrow$ hadronic = 100 %

MSSM



Large μ-scenario:

$m_h \approx$107 GeV
Non-excluded region where BR($h \to b\bar{b}$) is suppressed

$\Rightarrow$ Flavor independent analyses can help

Summary

- Flavour-blind Higgs boson searches have been performed by all LEP experiments.

- No evidence for signal has been found.

- Large amount of LEP2 data ($\sim$ 3000 pb^{-1}) allows to set stringent limits on Higgs masses:

	95%CL	expected	Experiment
Flav.blind	109.4 GeV/c^2	109.8 GeV/c^2	ALEPH
non-b	104.3 GeC/c^2	105.3 GeV/c^2	DELPHI
Flav.blind	106.9 GeV/c^2	106.9 GeV/c^2	L3
Flav.blind	101.8 GeV/c^2	107.3 GeC/c^2	OPAL

- ALL RESULTS ARE PRELIMINARY !!

- Next steps: Combine the four LEP experiments

- TeVatron and LHC are next in the line to discover the Higgs boson.