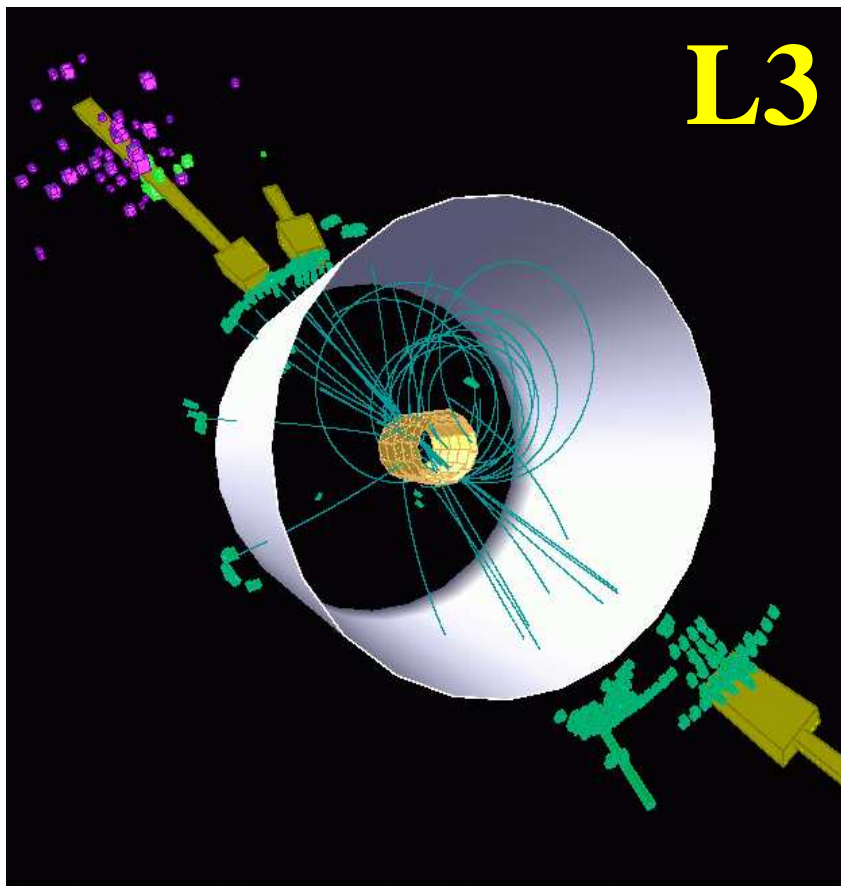# Search for Higgs Bosons at LEP

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On behalf of the L3 Collaboration

American Physical Society Meeting(APS03), Philadelphia

April 5-8, 2003

- Introduction

- Standard Model Higgs

- MSSM Neutral Higgs

- Charged Higgs

- Fermiophobic Higgs

- Invisible Higgs

- Flavour-blind Higgs

NO Higgs bosons are discovered at LEP

♠ LEP Higgs Working Group

http://lephiggs.web.cern.ch/LEPHIGGS/www/Welcome.html
http://alephwww.cern.ch/WWW/
http://delphiwww.cern.ch/Welcome.html
http://l3.web.cern.ch/l3/
http://opal.web.cern.ch/Opal/

♠ **Standard Model(SM) is a theory for massless particles**

♠ **But, gauge bosons(W, Z) and fermions do have masses**

♠ **The 'Higgs Mechanism': Particles acquire masses by interaction with the Higgs field**

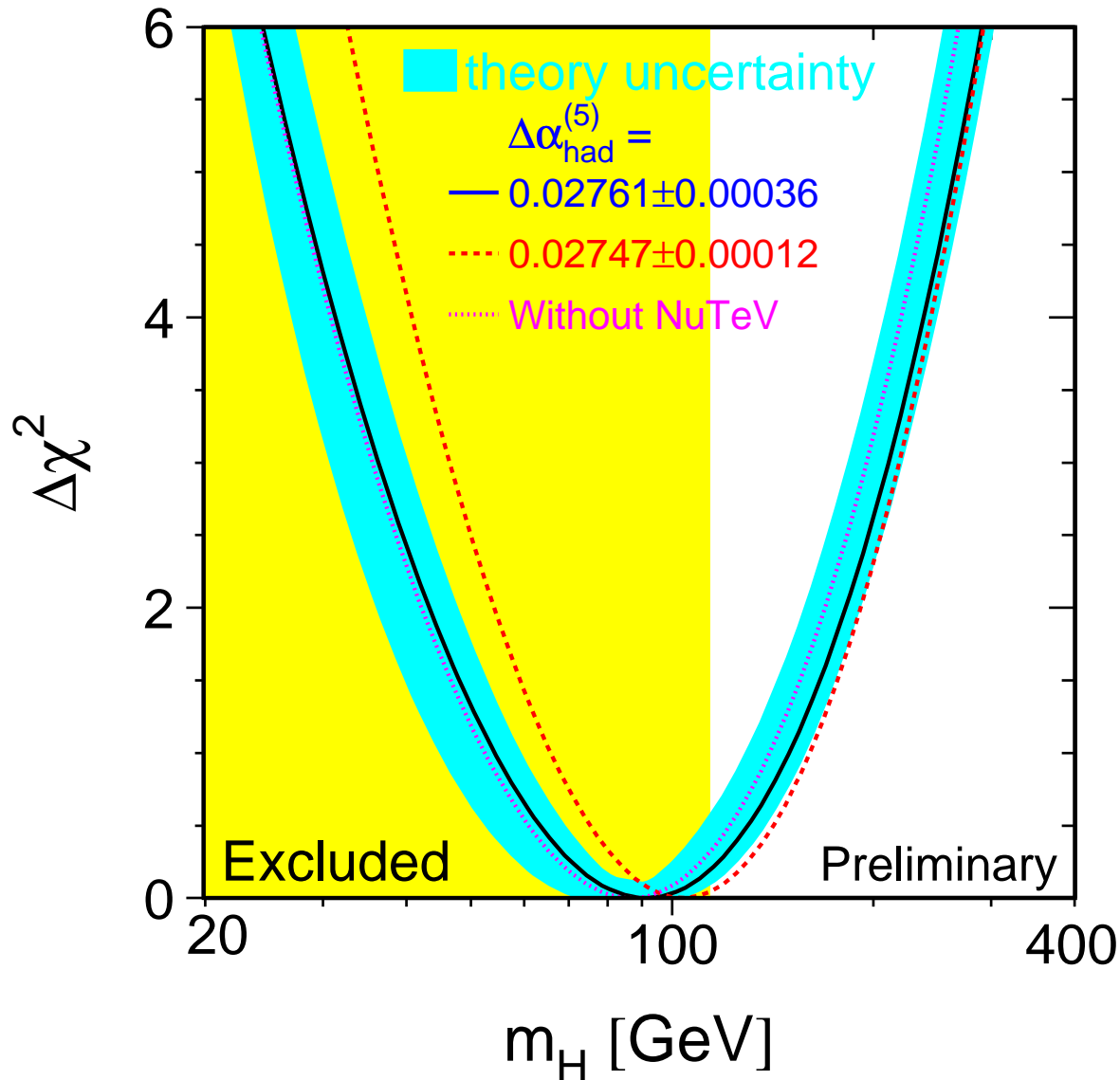♠ **The Higgs field has quanta - the Higgs bosons**

♠ **One Higgs Doublet Model - SM Higgs boson**

♠ **Two Higgs Doublets Model, MSSM, ...**

♠ **The Higgs bosons masses are not predicted by theories**

Discovery of the Higgs boson(s) is one of the main goals at LEP, Tevatron and LHC

Global fit to all precision measurements
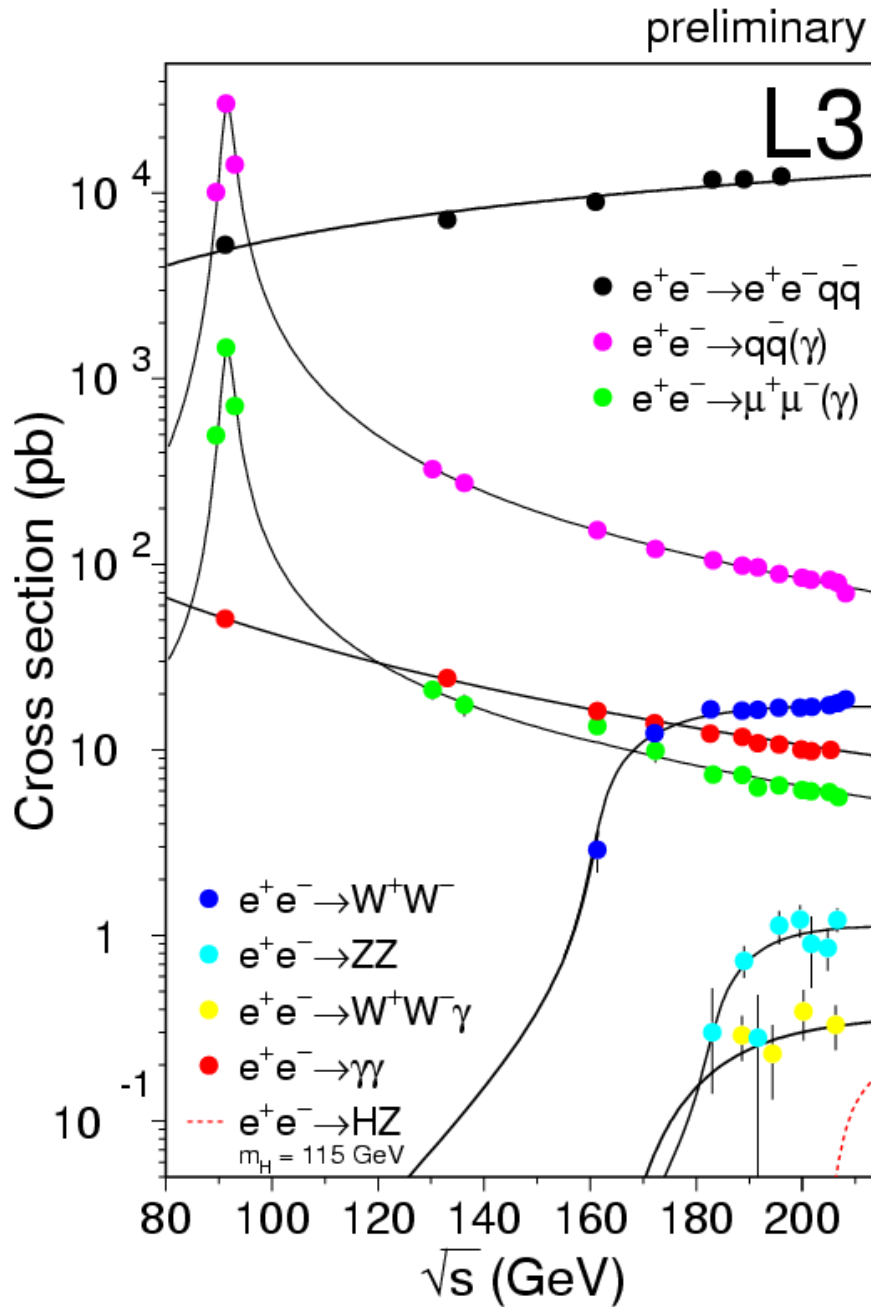### from LEP, SLC, Tevatron, ...

The fit prefers a low mass Higgs
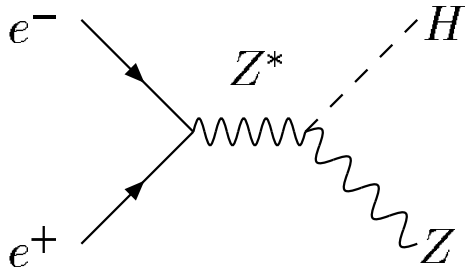
$$m_H < 211 \; GeV \text{ at 95\% C.L.}$$

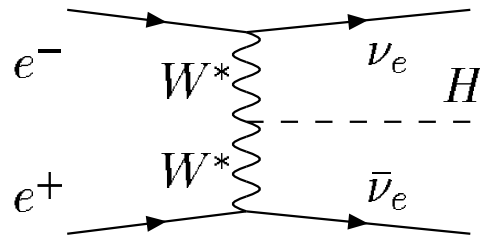**Total Integrated Luminosity: $887\ pb^{-1}$**

Center-of-Mass energies: $\sqrt{s} \simeq 90 - 209$ GeV

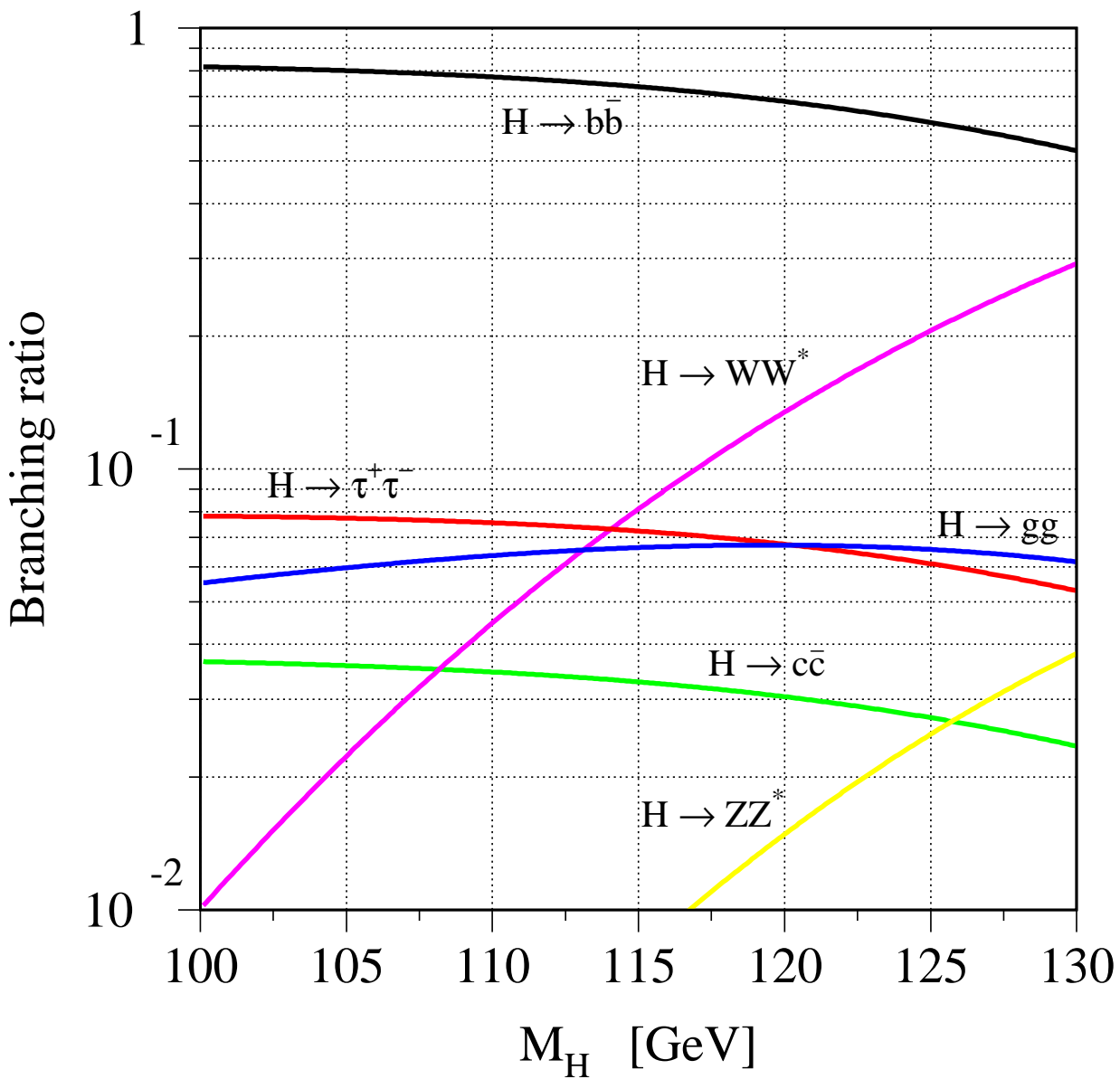**12 years operation: 1989 – 2000**

Higgs-strahlung Process

WW fusion process

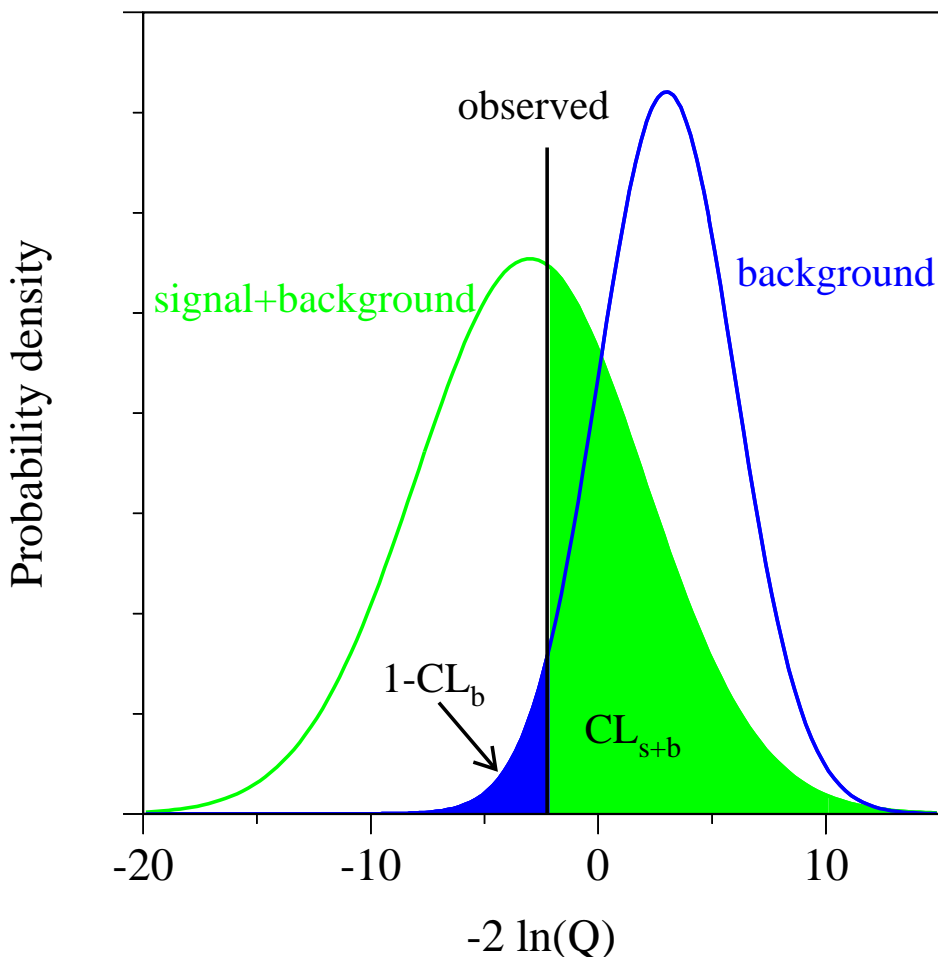**4 Channels: $Hq\bar{q}$, $H\nu\bar{\nu}$, $H\ell^{+}\ell^{-}$, $\tau^{+}\tau^{-}q\bar{q}$**

- Common Estimator used at LEP:

$$-2\ln Q \equiv 2\sum_i [s_i - n_i \ln(1 + s_i/b_i)]$$

Where n_i, s_i, b_i represent observed events, expected Higgs signal and SM background in the i-th bin, i indicates the i-th bin of final discriminant of each channel and at each $\sqrt{s}$.
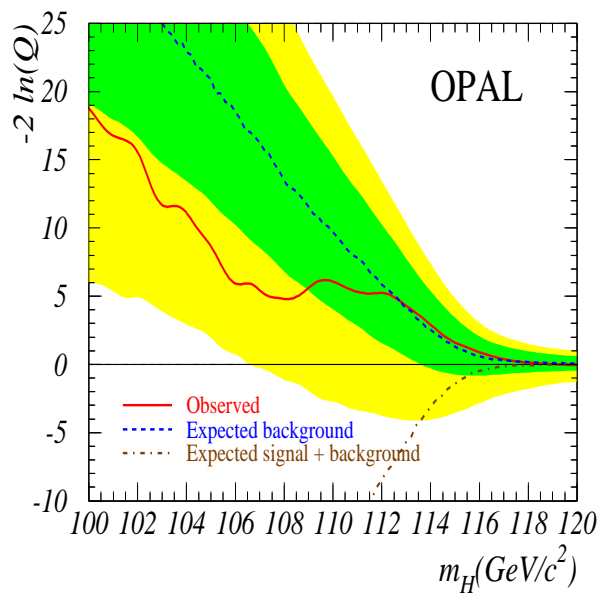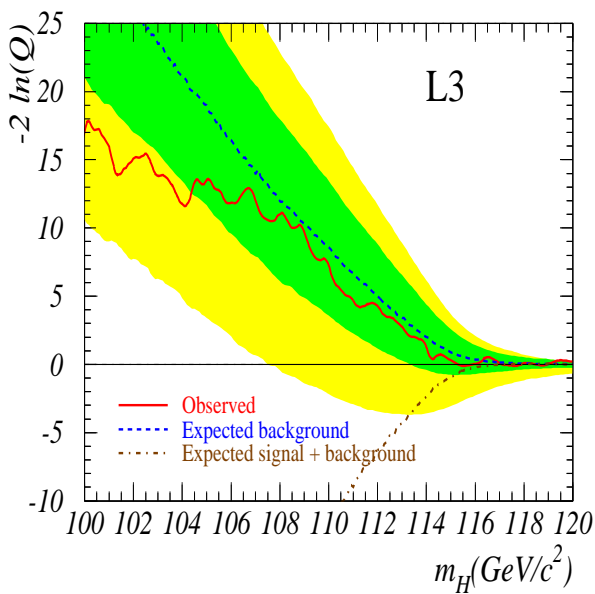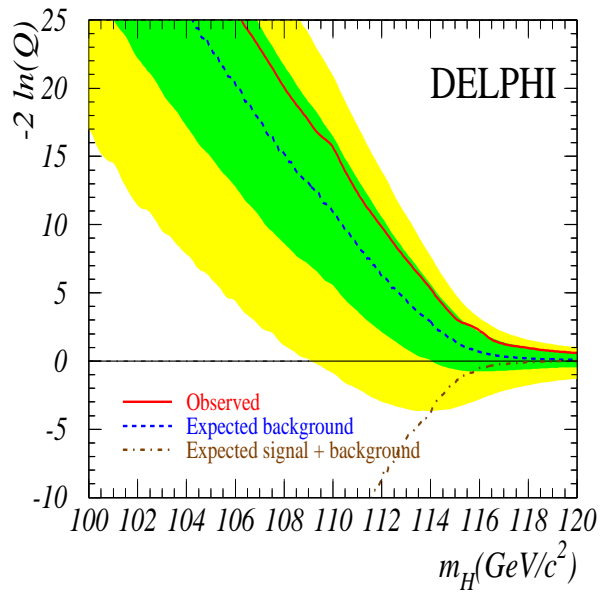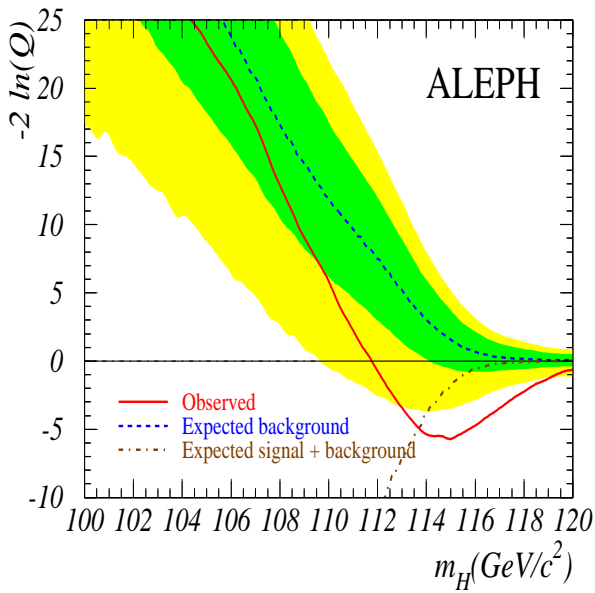
- MC experiments based on Poisson statistics.

$$\Rightarrow CL_s \equiv CL_{s+b} / CL_b$$

	Expected limit (GeV)	Observed limit (GeV)
LEP	115.3	114.4
ALEPH	113.5	111.5
DELPHI	113.3	114.3
L3	112.4	112.0
OPAL	112.7	112.8

	Expt	E_{cm}	Decay channel	m_H^{rec} (GeV)	$\ln(1+s/b)$ at 115 GeV
1	ALEPH	206.6	4-jet	114.1	1.76
2	ALEPH	206.6	4-jet	114.4	1.44
3	ALEPH	206.4	4-jet	109.9	0.59
4	L3	206.4	E-miss	115.0	0.53
5	ALEPH	205.1	Lept	117.3	0.49
6	ALEPH	206.5	Taus	115.2	0.45
7	OPAL	206.4	4-jet	108.2	0.43
8	ALEPH	206.4	4-jet	114.4	0.41
9	L3	206.4	4-jet	108.3	0.30
10	DELPHI	206.6	4-jet	110.7	0.28
11	ALEPH	207.4	4-jet	102.8	0.27
12	DELPHI	206.6	4-jet	97.4	0.23
13	OPAL	201.5	E-miss	111.2	0.22
14	L3	206.4	E-miss	110.1	0.21
15	ALEPH	206.5	4-jet	114.2	0.19
16	DELPHI	206.6	4-jet	108.2	0.19
17	L3	206.6	4-jet	109.6	0.18

♠ For $m_H = 115$ *GeV*

Data = 17, Signal = 8.42 & Background = 15.9

Large μ scenario: $m_{h^0} < 108\ GeV$:
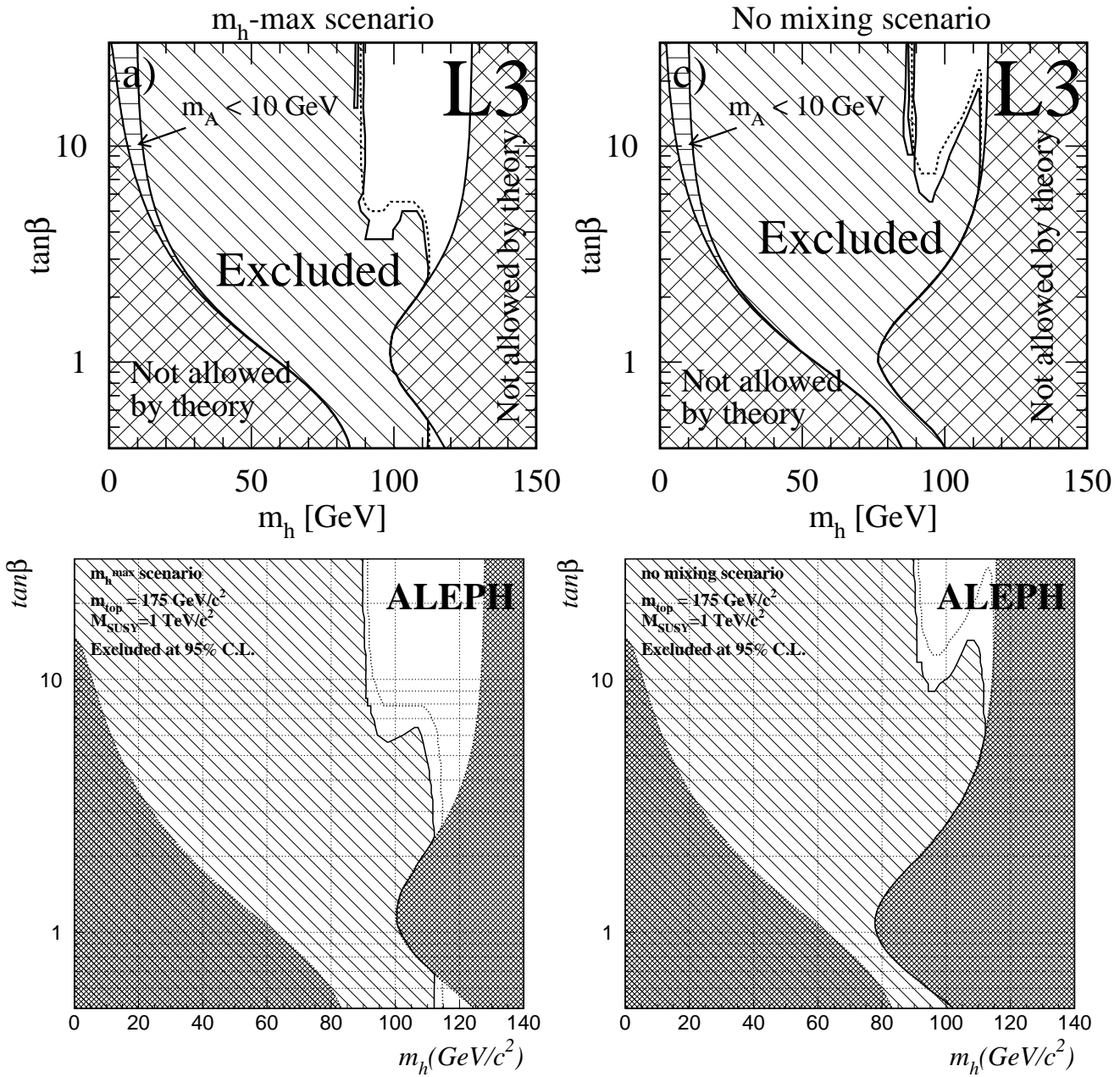
LEP 88-209 GeV Preliminary
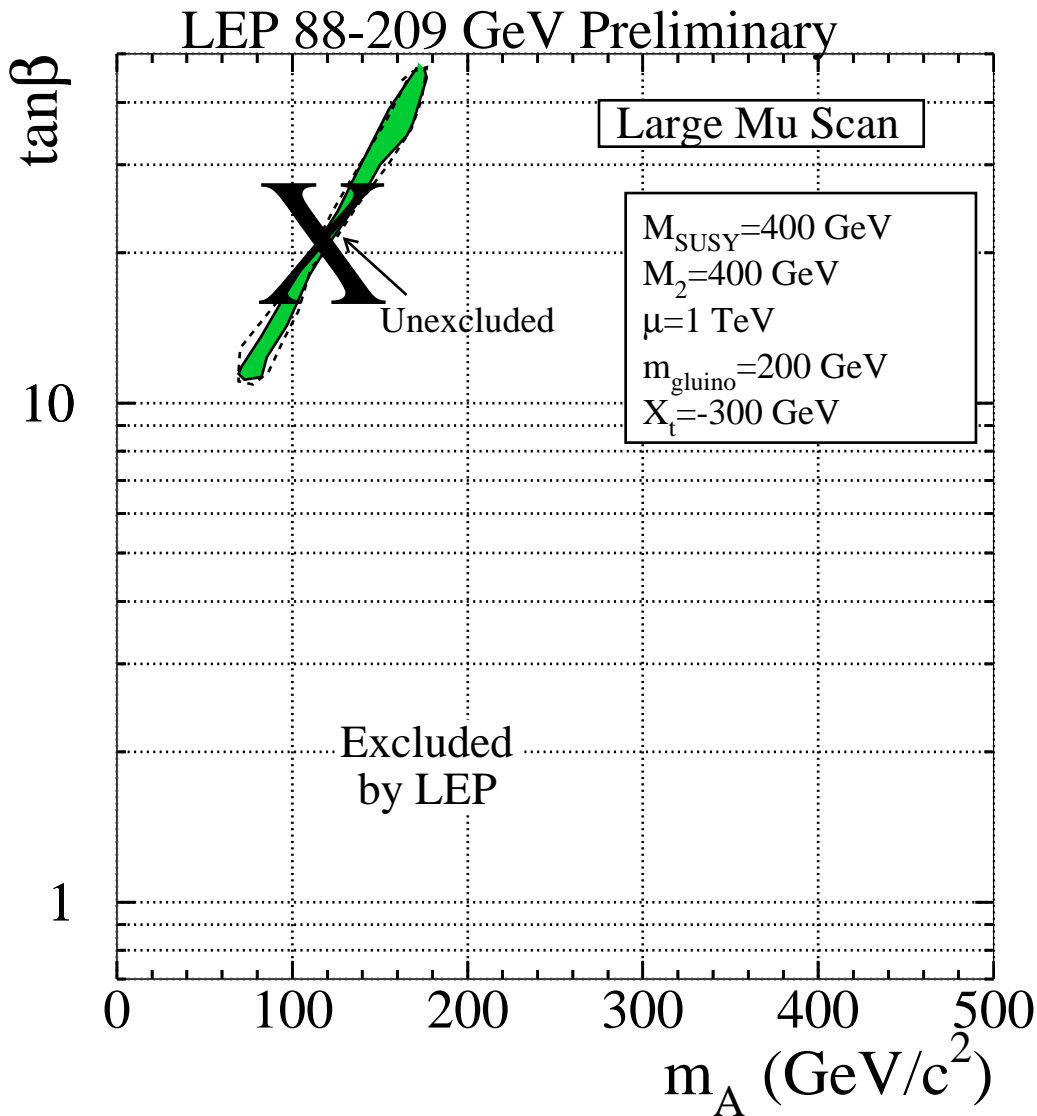
- Previous exclusion based only on
  $e^+e^- \rightarrow hZ, hA$ $h, A \rightarrow b\bar{b},\ \tau^+\tau^-$

♠ New searches covered $h \rightarrow c\bar{c},\ gg$

All points excluded at 95% C.L.
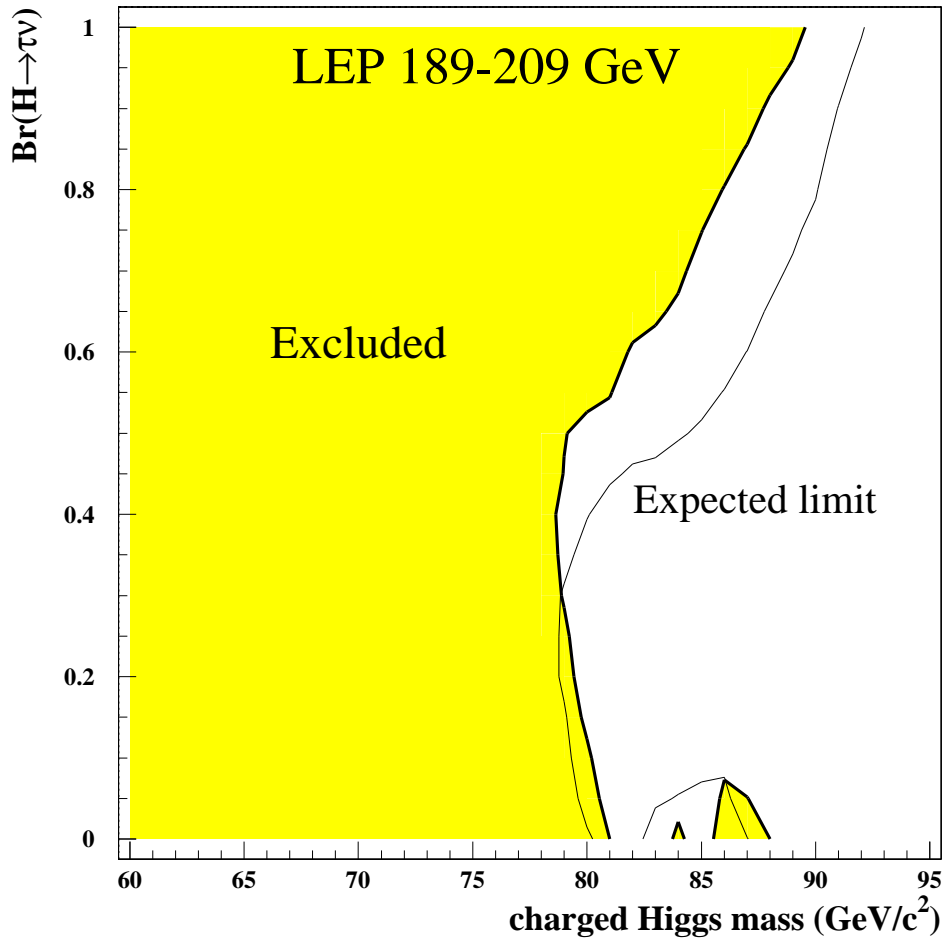
m_h-max scenario

No mixing scenario

95% C.L. Limits	ALEPH	DELPHI	L3	OPAL
obs (exp) - m_{h^0}	89.8 (91.3)	89.7 (88.8)	85.5 (88.5)	79.3 (85.1)
obs (exp) - m_A	90.1 (91.6)	90.7 (89.7)	86.3 (88.6)	80.6 (86.9)

Production: $e^+e^- \to H^+H^-$ **Decay:** $H^\pm \to cs,\ \tau\nu$

95% C.L. Limits	ALEPH	DELPHI	L3	OPAL
obs (exp)	79.3 (76.9)	73.8 (75.4)	66.9 (75.1)	72.2 (74.5)

$$e^+e^- \to Zh, \ h \to \gamma\gamma \text{ dominant for } m_h < 90 GeV$$
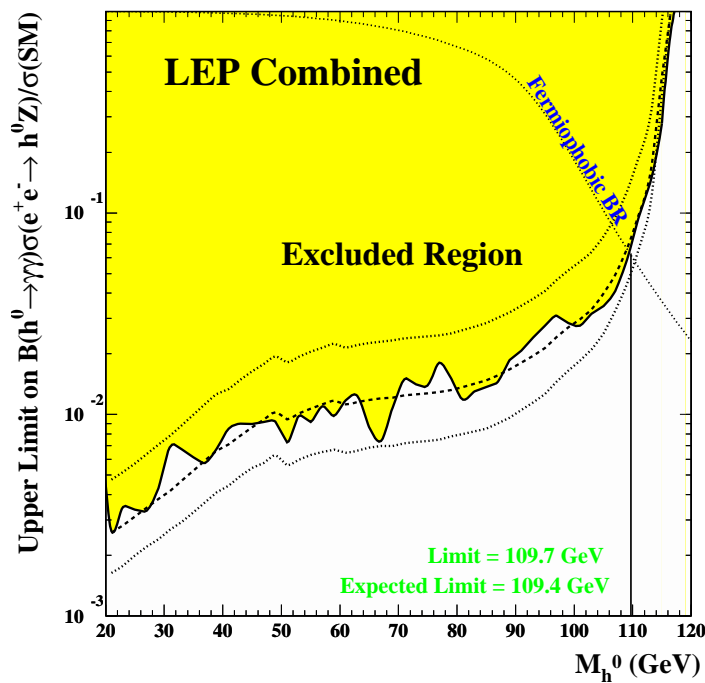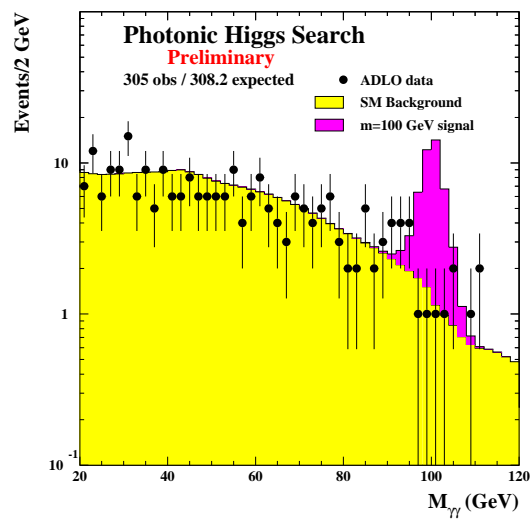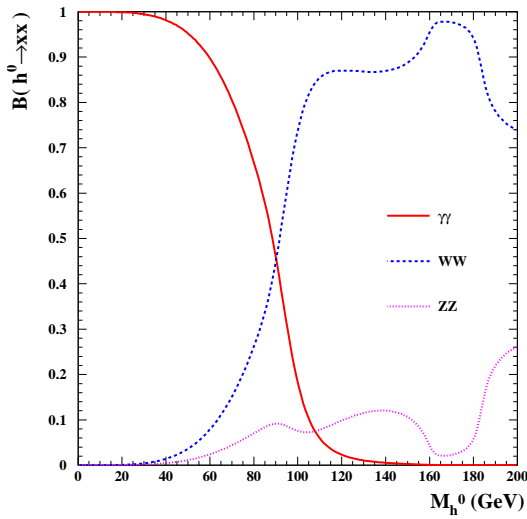
$$m_h > 109.7 \ GeV, BR(h \to \gamma\gamma) < 6\% \text{ at } 95\% \text{ C.L.}$$

$$e^+e^- \rightarrow Zh, \; h \rightarrow WW^*, \; ZZ^*$$
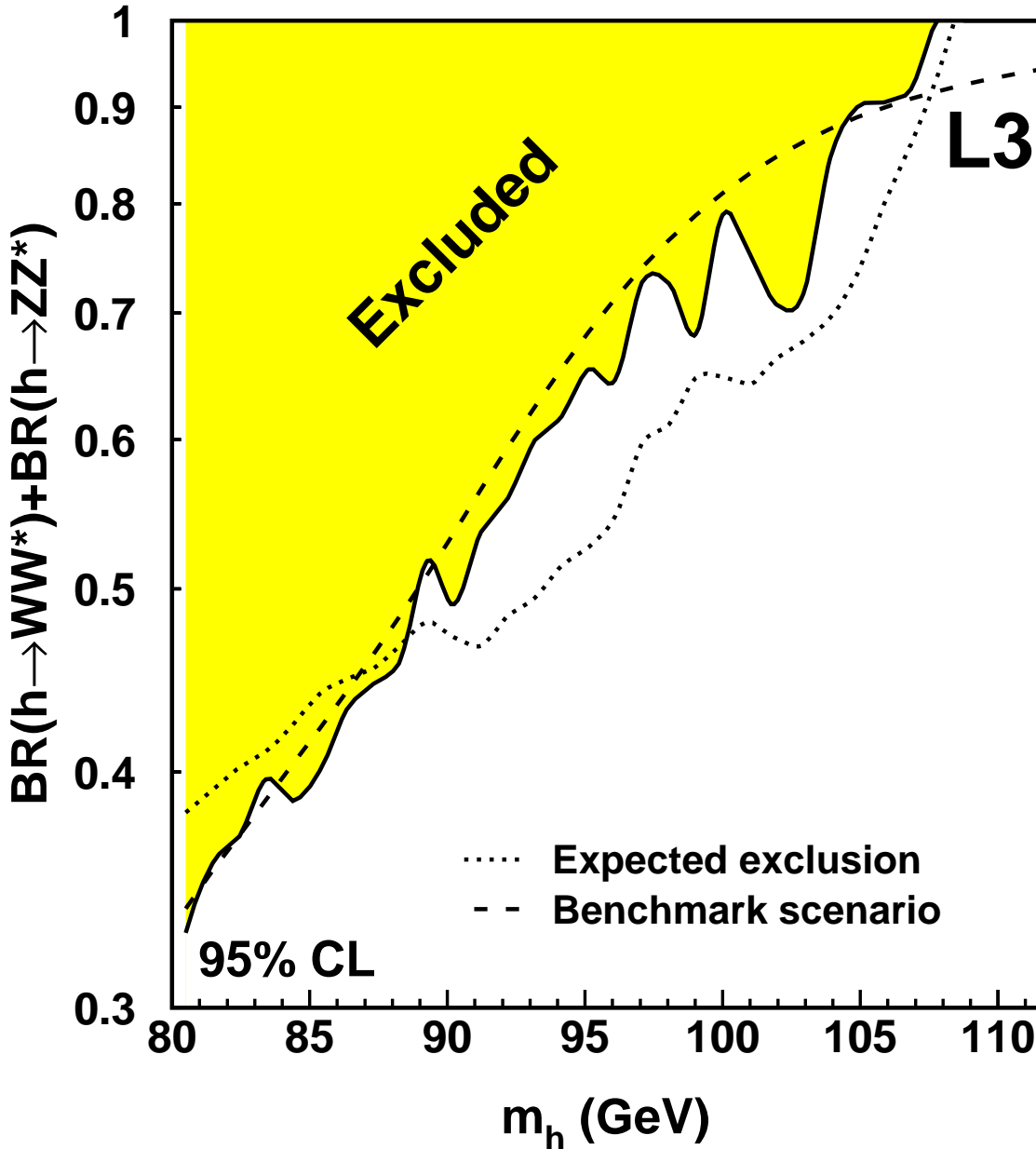
Six channels investigated($\sim 93\%$ BR):

$Zh \rightarrow qqqqqq, \; qqqq\ell\nu, \; qq\ell\nu\ell\nu, \; \nu\nu qqqq, \; \nu\nu qq\ell\nu, \; \ell\ell qqqq$
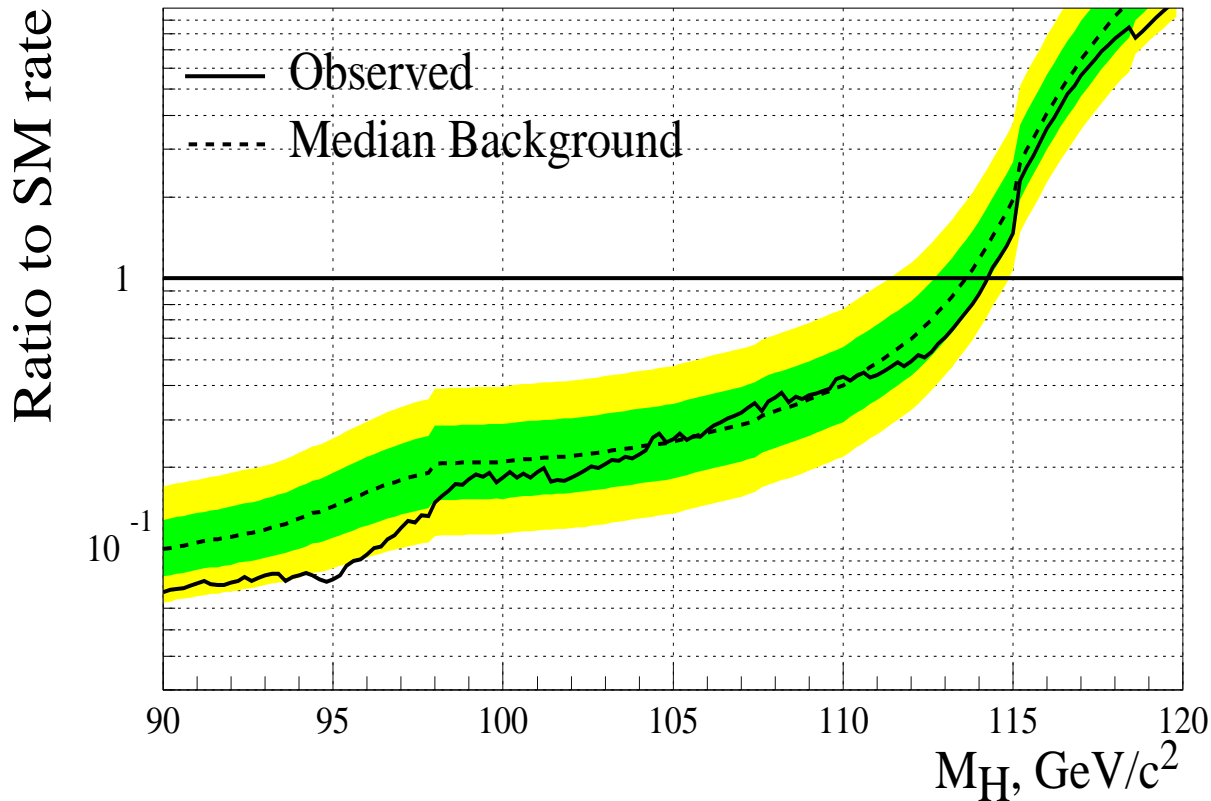
Assumption: $h \to inv.(\tilde{\chi}_1^0 \tilde{\chi}_1^0)$ might dominant
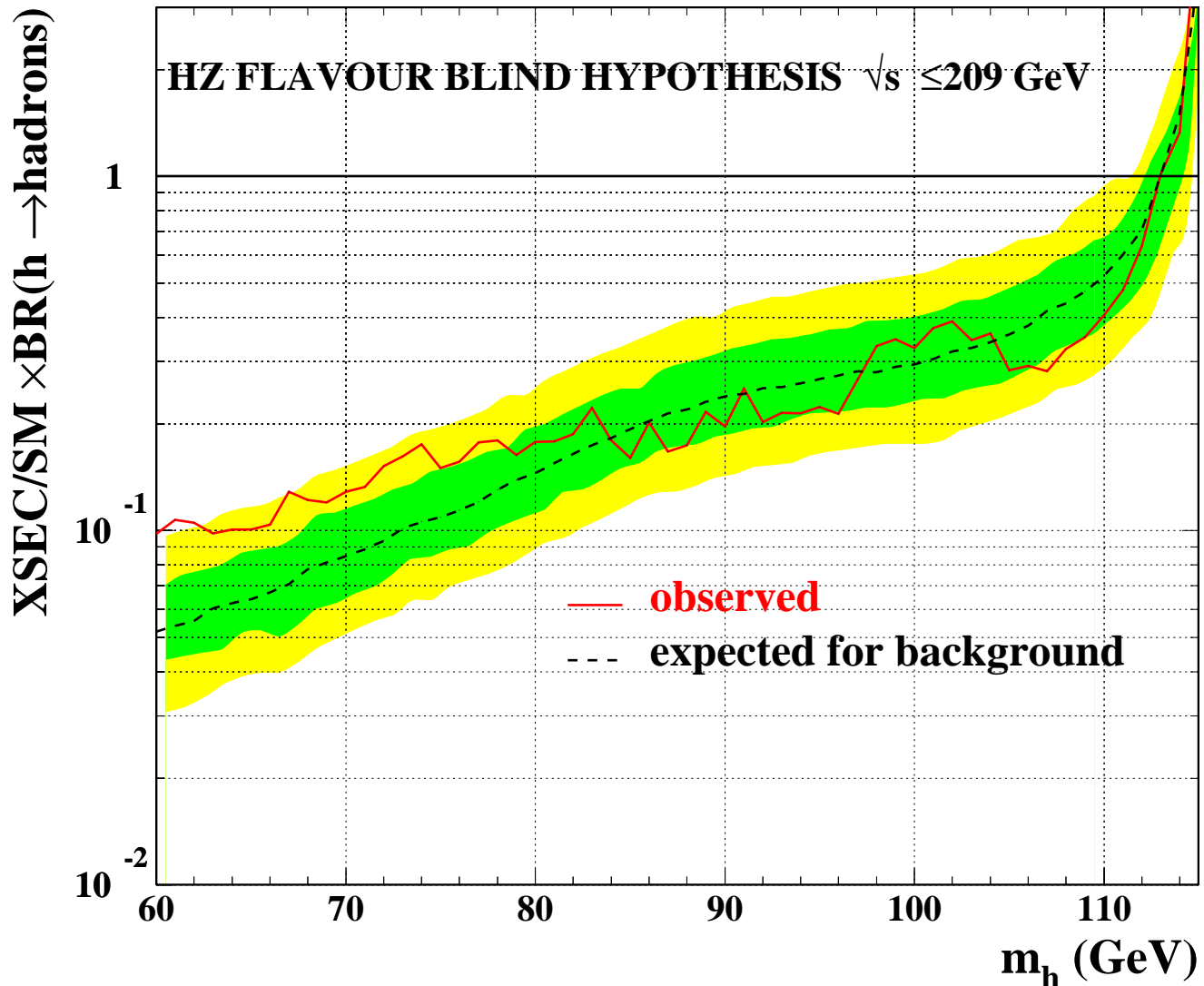
Signal: $h \to inv. + Z \to q\bar{q}, \ell^+\ell^-$

two acoplanar jets or leptons $\oplus$ missing energy

$m_h > 114.4(113.5\ exp.)\ GeV$ at 95% C.L. for $R_{inv} = 1$

Assumption: $h \to b\bar{b}$ **not necessarily dominant**

LEP PRELIMINARY

- **Searches not relying on b-tagging**
- **less model-dependent**

$m_h > 112.9(113\ exp.)\ GeV$ at 95% C.L.