Higgs Searches at OPAL

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Standard Model (SM) Higgs

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(no final calibrations)

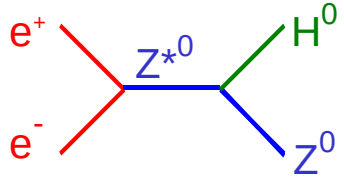
Extensions of the Standard Mode

Preliminary results

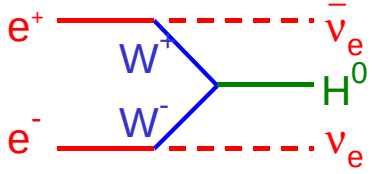
6 March 2001

SM Higgs Production at LEP

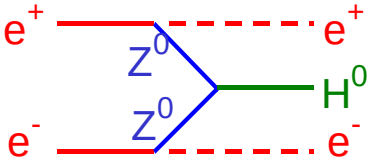
Higgs-strahlung

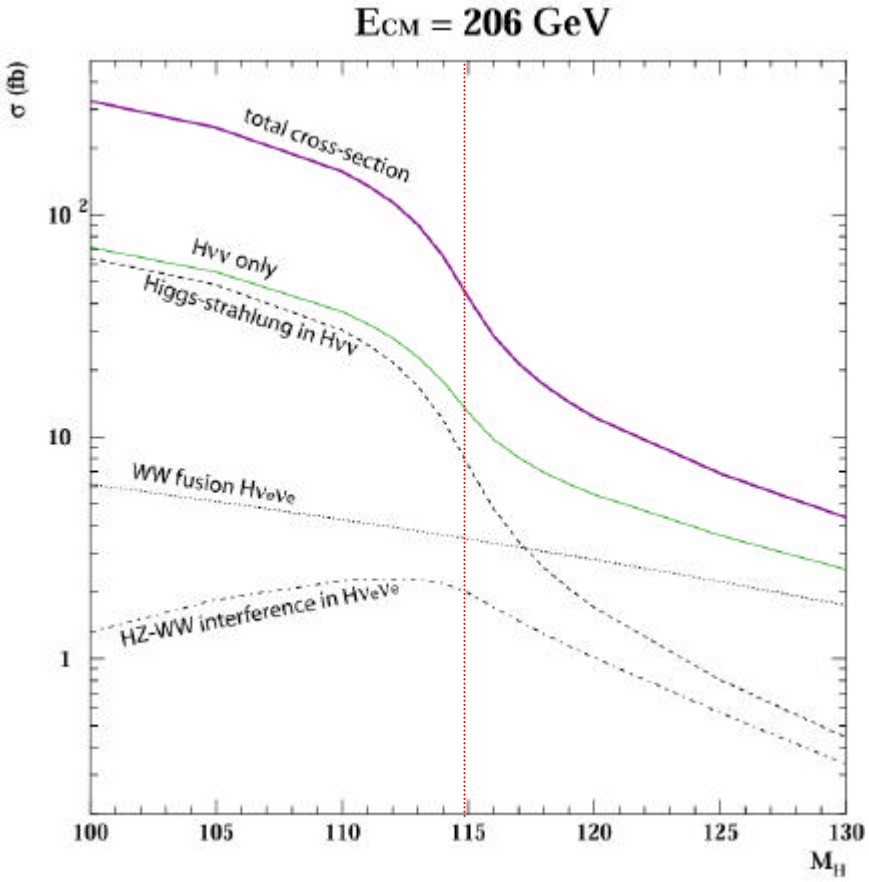


WW fusion

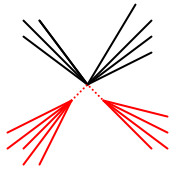
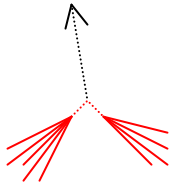
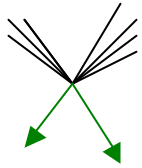
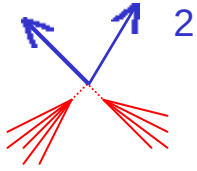


ZZ fusion

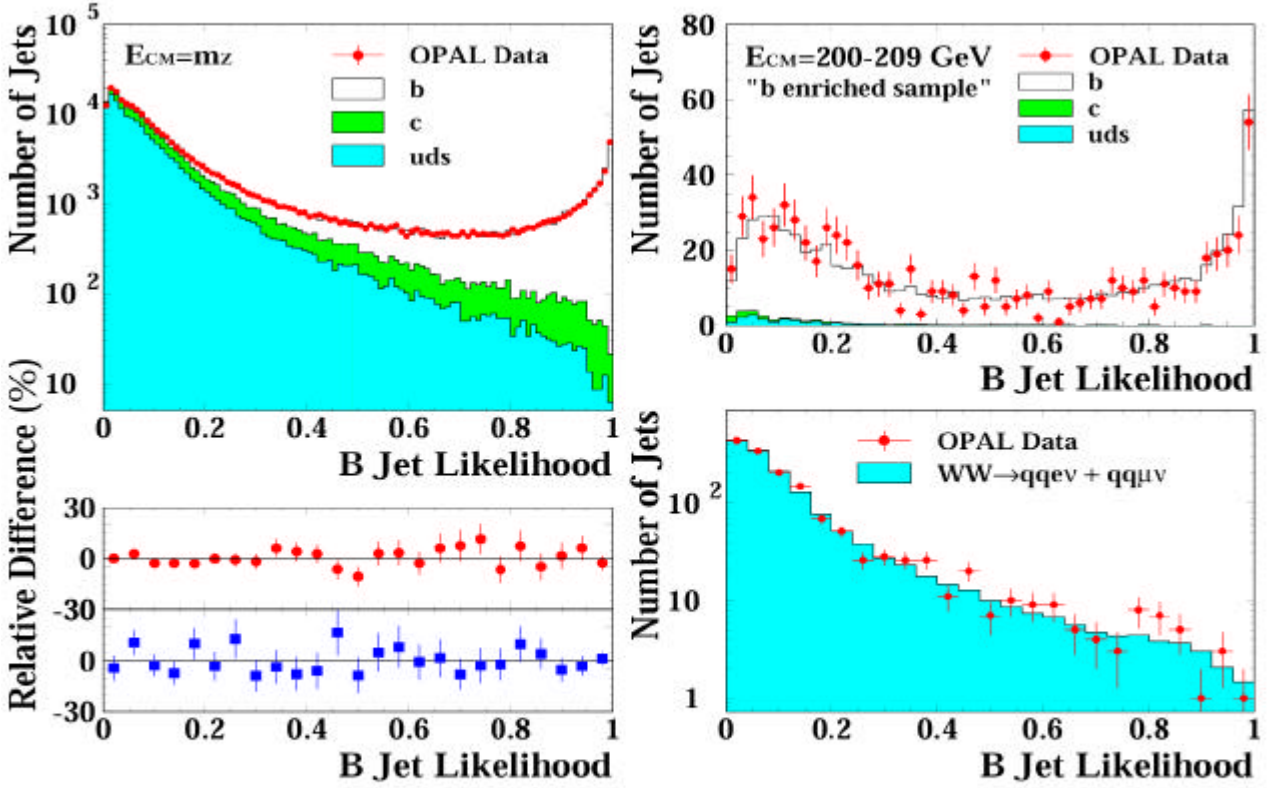




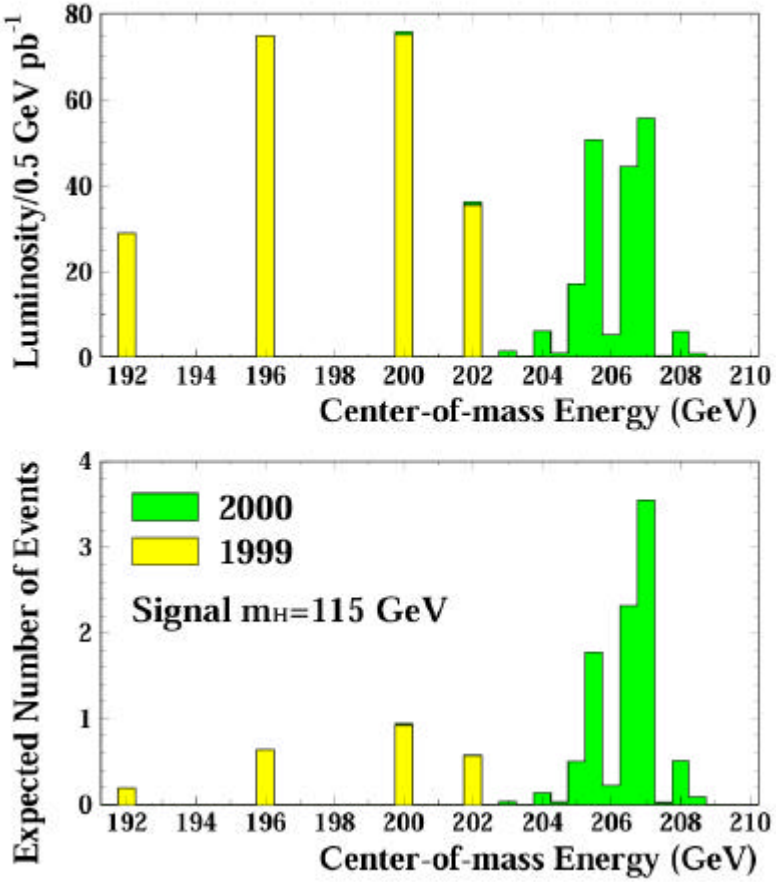
SM Higgs Search Channels

Channel	B.R.	Process	Signature
Four-jet	60%	$e^+e^- \to H^0Z^0$ $Z^0 \to q\bar{q},\ H^0 \to b\bar{b}$	 4 jets 2 b-jets
Missing-E	20%	$H^0Z^0 : Z^0 \to \nu\bar{\nu}$ $+ W^+W^-$ fusion	 $\not{E}$ + 2 b-jets
Tau	9%	$H^0 \to b\bar{b}, Z^0 \to \tau^+\tau^-$ or $H^0 \to \tau^+\tau^-, Z^0 \to q\bar{q}$	 2 (b-)jets + 2 tau s
Lepton	6%	$H^0Z^0 : Z^0 \to \ell^+\ell^-\ (\ell = e, \mu)$ $+ Z^0Z^0$ fusion	 2 leptons + 2 b-jets

b-tagging at OPAL

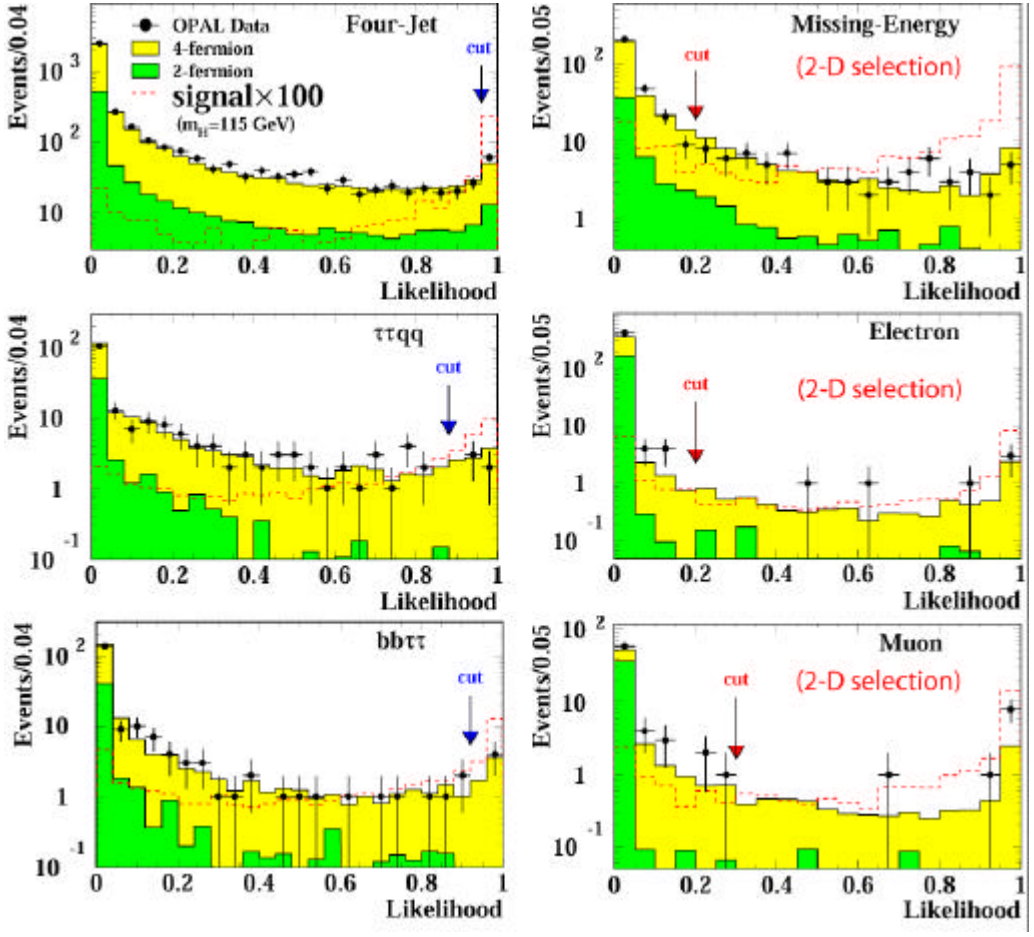


Data Collected by OPAL 1999-2000



Year	Luminosity (pb^{-1})	Exp. Signal m_H=115 GeV
1999	215	2.4
2000	210	9.1
Total	**425**	**11.5**

SM Higgs Event Selection



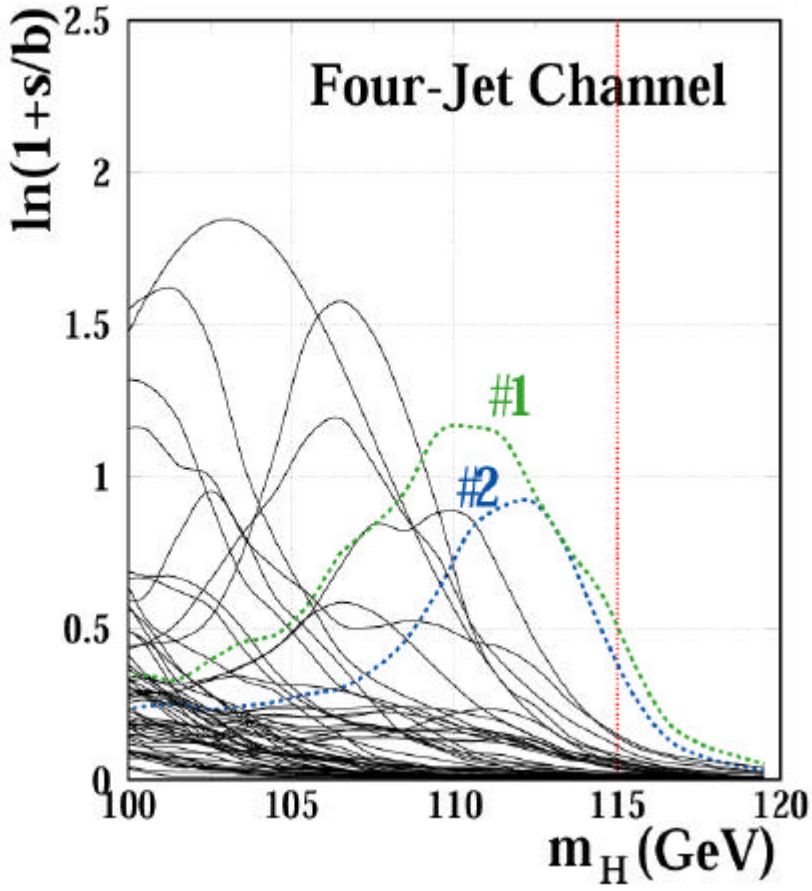
Y2000 selection results

Channel	Obs. Data	Exp. Bkg.	Signal (115 GeV)
4-jet	60	49.8 ±6.0	2.24±0.10
$\not{E}$	68	69.7 ±8.6	1.68 ±0.10
Tau	8	11.1 ±1.2	0.25 ±0.01
Electron	6	8.5 ±1.3	0.17 ±.004
Muon	10	7.0 ±1.0	0.23 ±.006
All	**152**	**146** ±11	**4.57** ±0.14

SM Higgs Candidates

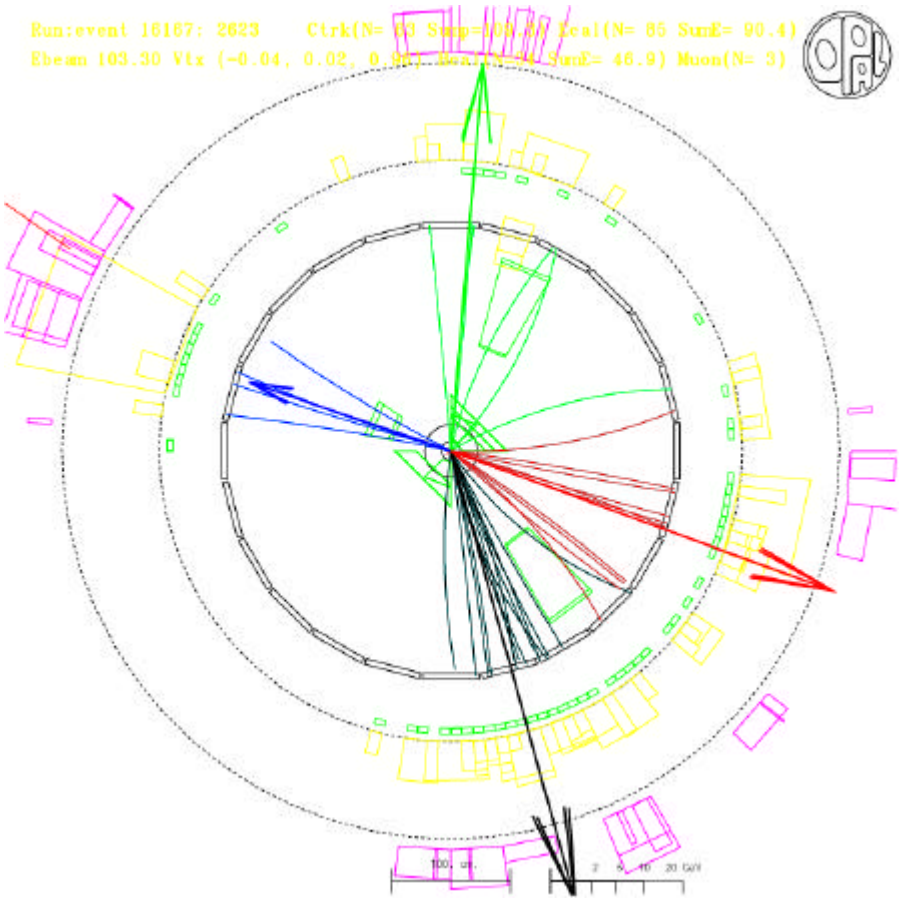
significant Candidates by channel

#	Channel	m_{rec}	L.H (HZ)	s/b for 115 GeV
1	4-jet	110.7	.995	0.70
2	4-jet	112.6	.999	0.49
3	$\not{E}$	104.0	.999	0.28
4	$\not{E}$	112.1	.853	0.23
5	Tau	105.3	.993	0.05
6	Electron	124.7	.873	0.16
7	Muon	102.2	.999	0.04

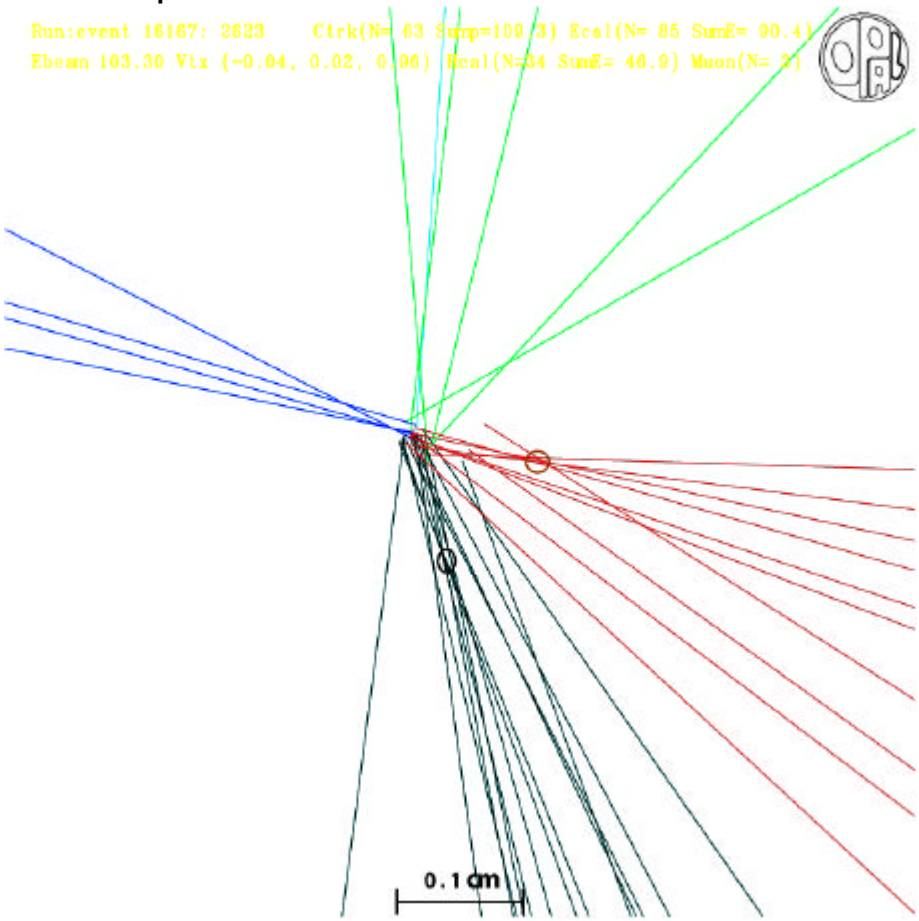


The Best (and last good) OPAL Candidate

General view:



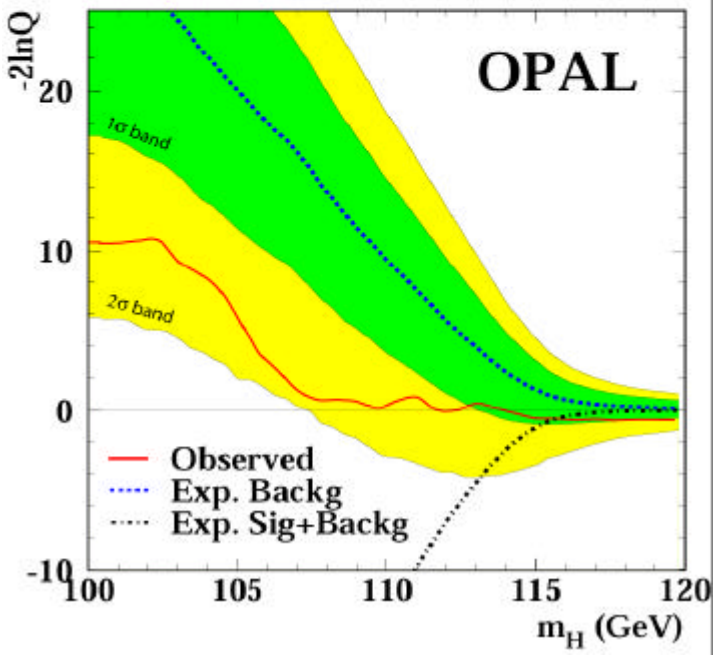
Close-up view:

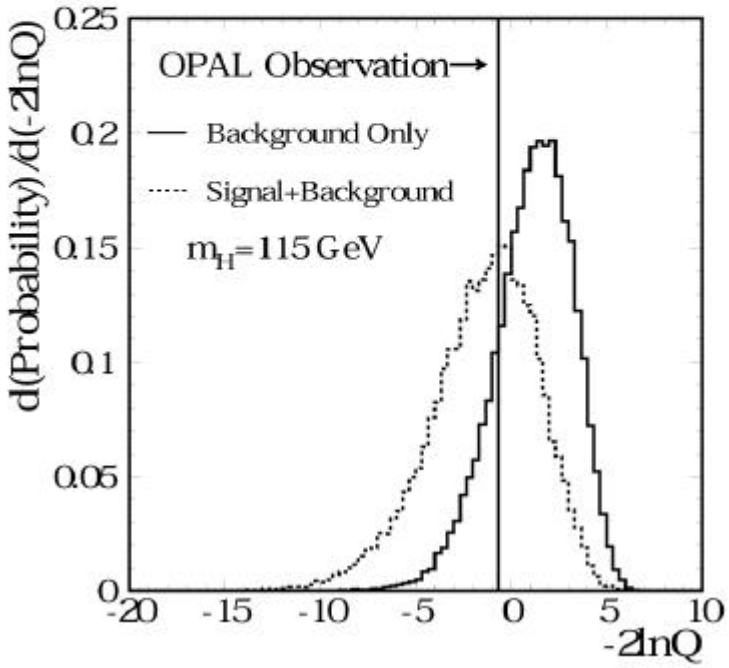


SM Higgs Observation at OPAL?

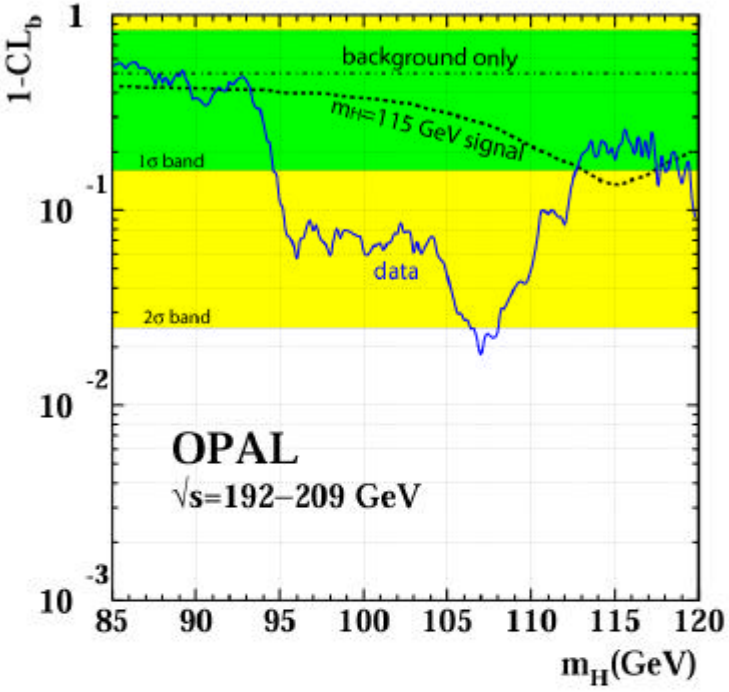
Likelihood ratio - Q

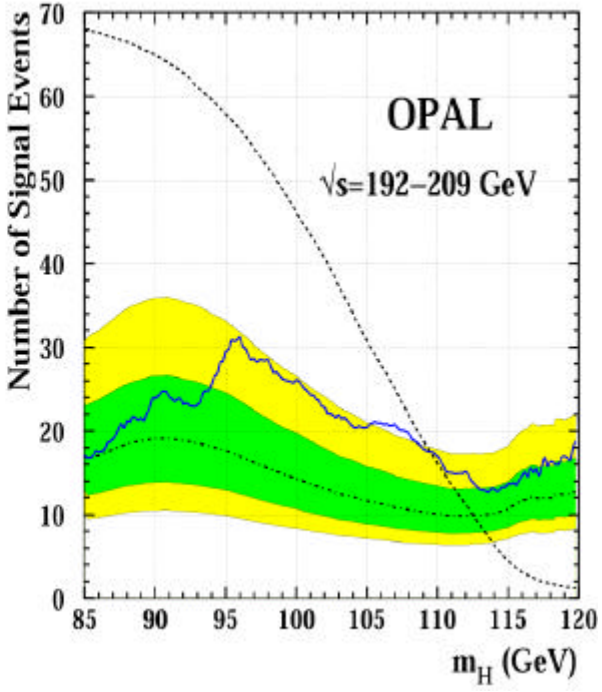
$$\ln Q = \sum_i s_i + \sum_i n_i \ln(1 + s_i/b_i)$$





No SM Higgs Observation at OPAL?





For m_H=115 GeV,
signal is only 1.2σ from bkg.
(and data consistent with both)

OPAL lower limit on m_H (95% C.L.):
Observed 109.7 GeV
Expected 112.5 GeV

Extensions of the Standard Model

MSSM Higgs h^0Z^0 or h^0A^0

Other exotics:

Charged Higgs H^+H^-

Flavor-Independent search $h^0 \to (\text{any})q\bar{q}$ or gg

Invisible decay e.g. $h^0 \to \chi_1^0\chi_1^0$ (LSP)

Photonic decay $h^0 \to \gamma\gamma$

MSSM Higgs Searches

The standard search channels are used as well as the additional channels:

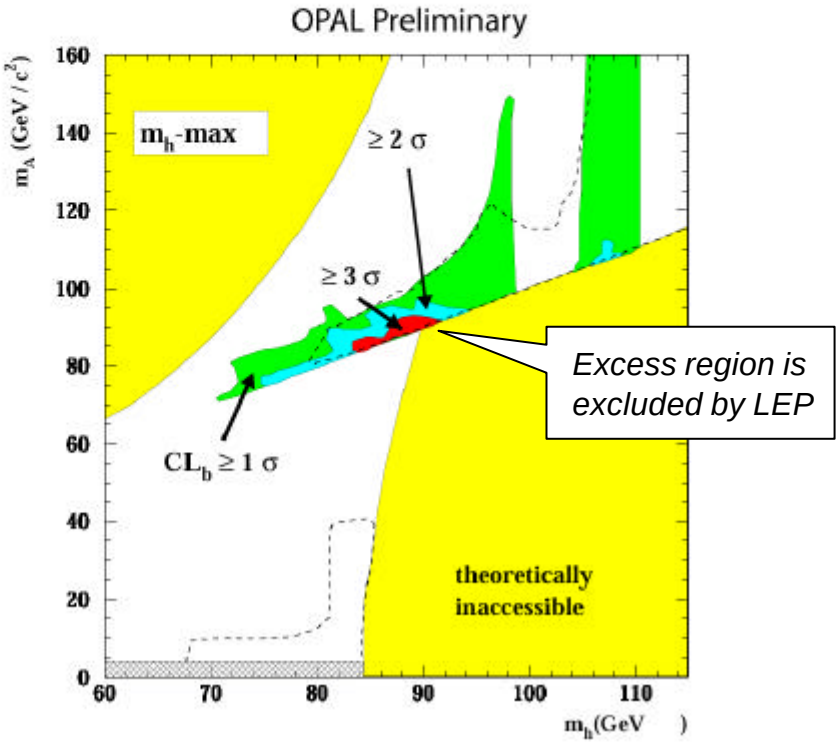
$e^+e^- \to h^0A^0 \to b\bar{b}\,b\bar{b}$

or

$b\bar{b}\tau^+\tau^-$

(no mass constraint on the tau pair)

hA Channels results Y2000:
Observed 16 events
Expected bkg.14.8±1.7 evts.



MSSM Parameter Space Scan

Benchmark scans

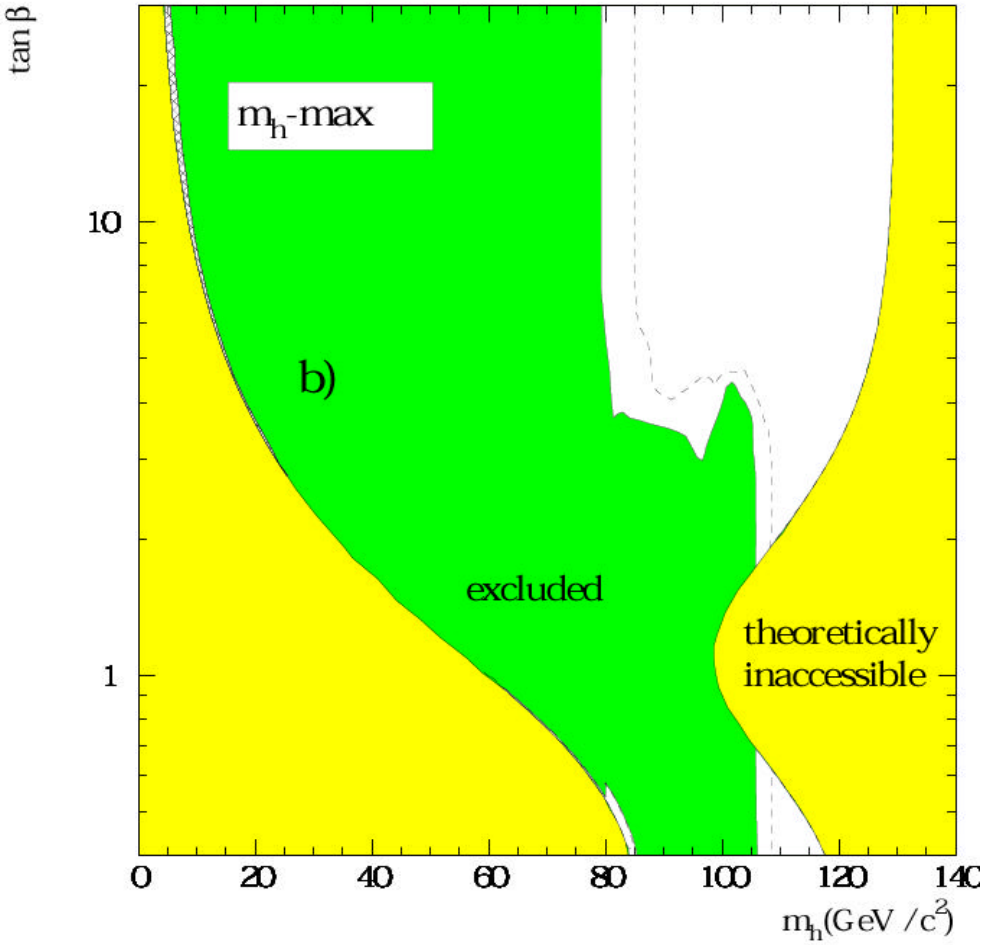
No mixing

Max. m_h conservative tanβ limit

Large μ no $h^0 \to b\bar{b}$ decay

Max. m_h scan (m_h,m_A with tanβ>1.2)

	observed	expected
m_h limit	79.3 GeV	85.1 GeV
m_A limit	80.6 GeV	86.9 GeV
Excluded tanβ	0.8-1.7	1.1-1.9

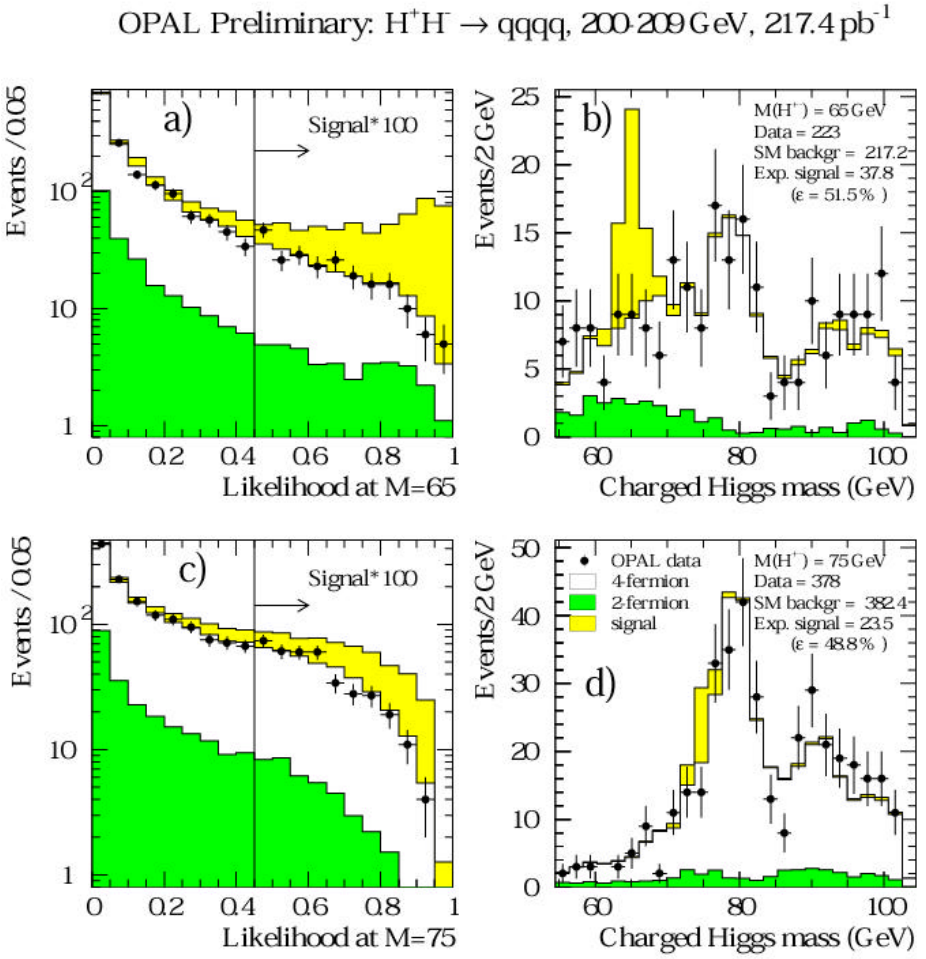


Charged Higgs Searches

3 channels in $e^+e^- \to H^+H^-$

hadronic	$H^\pm \to q\bar{q}$	4 jets
Leptonic	$H^\pm \to \tau\nu_\tau$	$2\tau s + \not{E}$
Semi-leptonic (both)		2 jets+ $+ \tau + \not{E}$

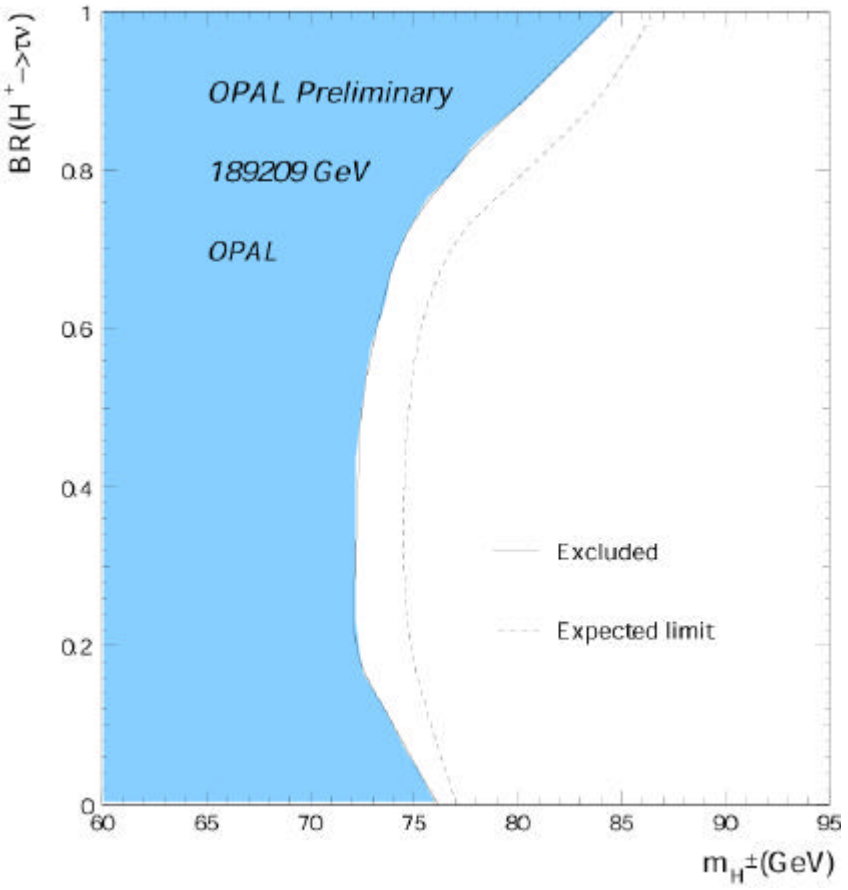
Very difficult to overcome the WW bkg.



Charged Higgs Limits

H^+H^- mass limits at 95% C.L.

$BR(H^+ \to \tau^+ \nu_\tau)$	Observed	Expected
0	76.2 GeV	77.1 GeV
1	84.5 GeV	86.5 GeV
Any	**72.2 GeV**	**74.5 GeV**



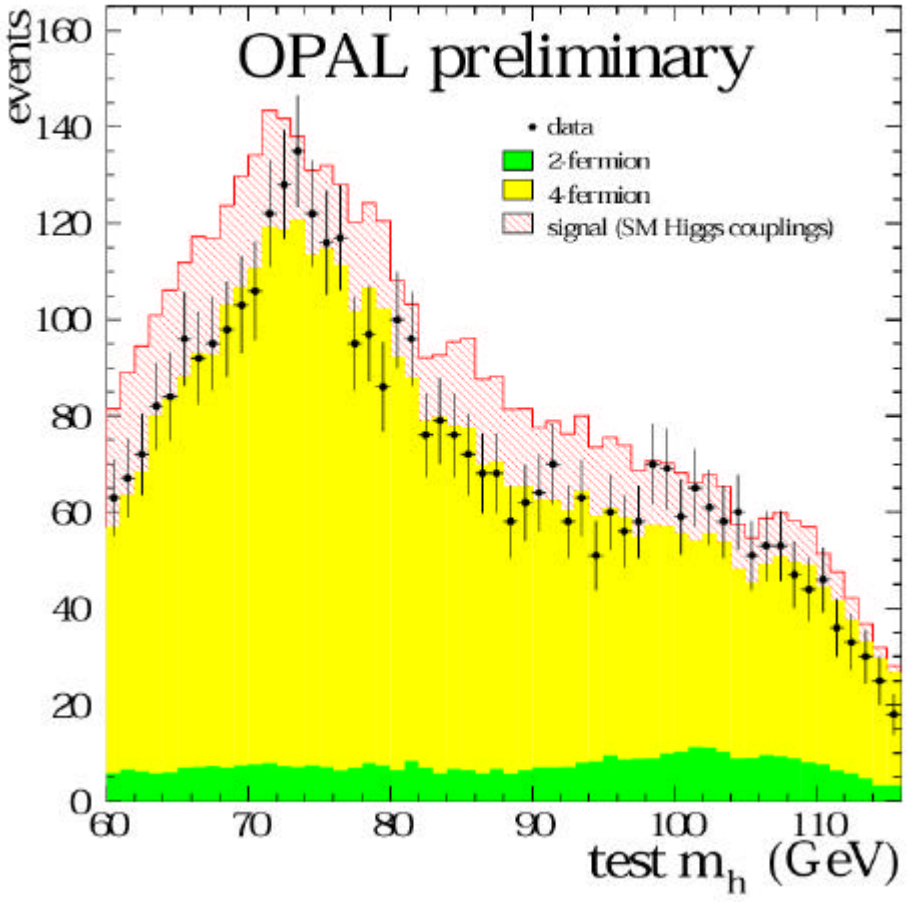
Flavor-Independent Decay Search

The process: $h^0 \to q\bar{q}, gg$ (hadronic decays) has the same search channels as the SM Higgs.

Similar analyses (**no b-tag**)

Except 4-jet channel
Test-mass dependent event selection

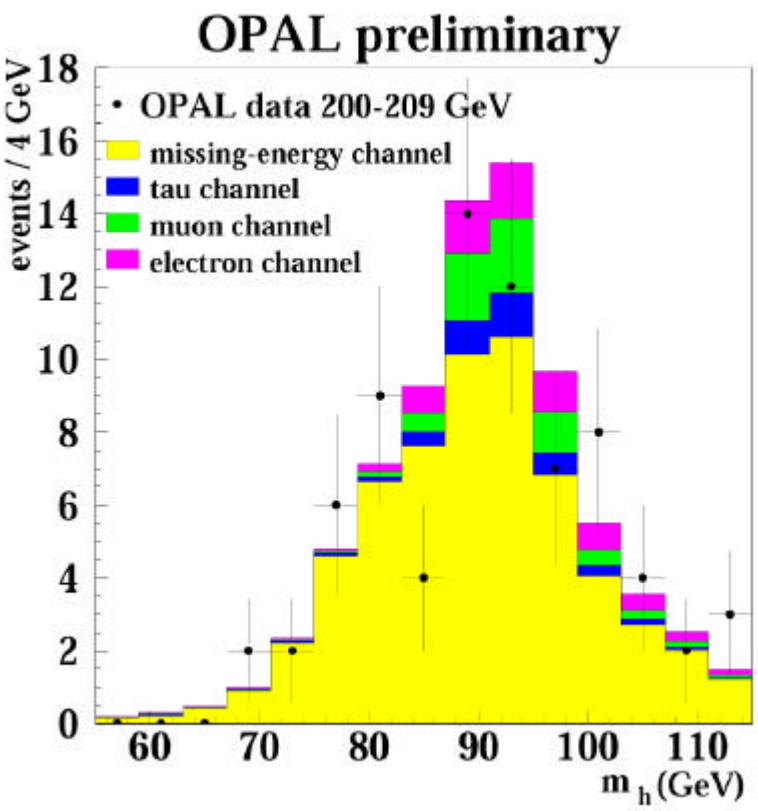
Four-jet channel

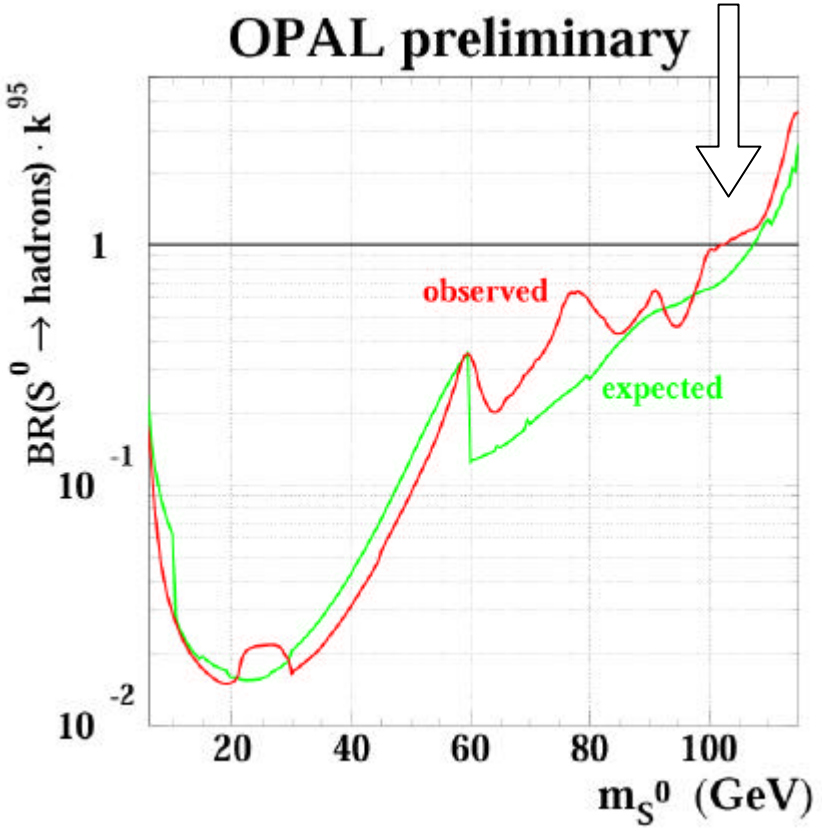


Flavor-Independent Search

The non-4-jet channels mass distributions Y2000

95% CL Mass limit for BR=100%
obs. 101.8 GeV exp. 107.3 GeV



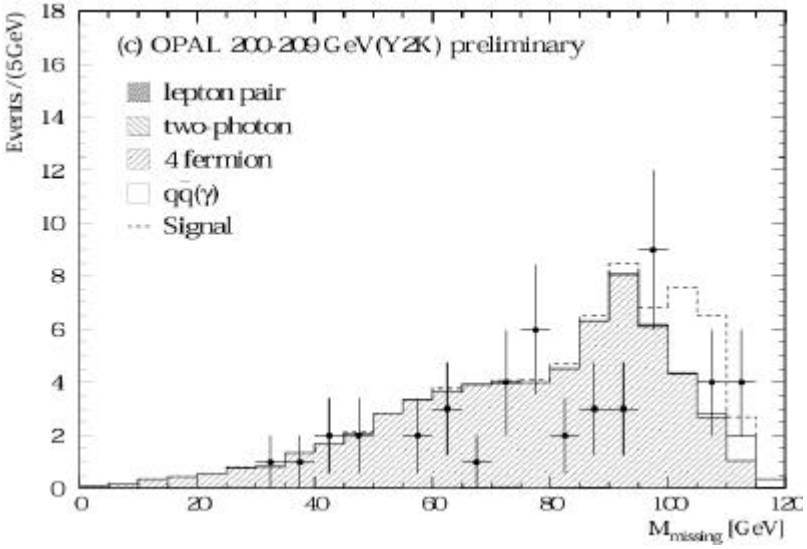


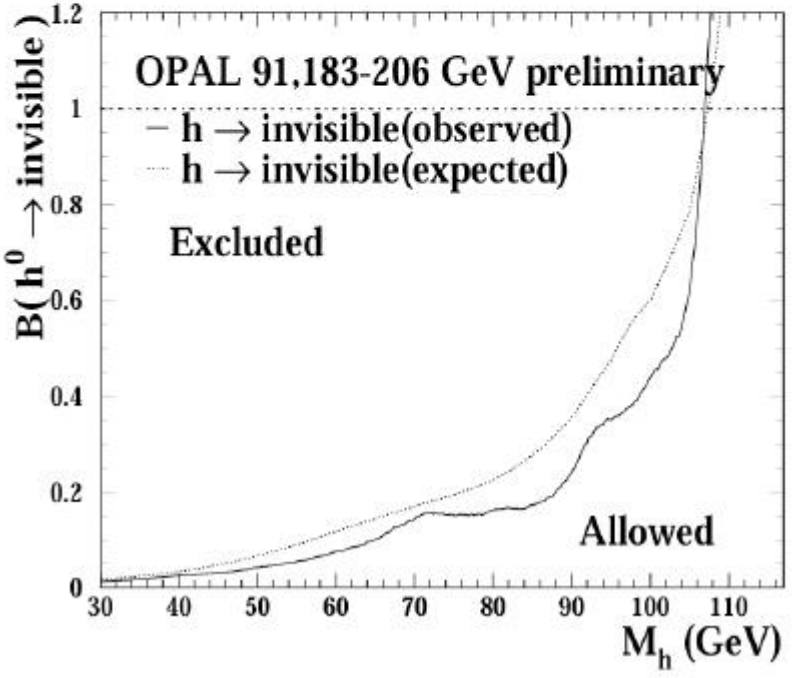
Invisibly Decaying Higgs Search

Process: $e^+e^- \to h^0Z^0$
$h^0 \to \chi_1^0\chi_1^0$(invisible), $Z^0 \to q\bar{q}$

2 jets + $\not{E}$
$m_{jets} = m_Z$, $m_h = m_{missing}$

95% CL Mass limit for BR=100%
Obs. 107.0 GeV , exp. 107.4 GeV





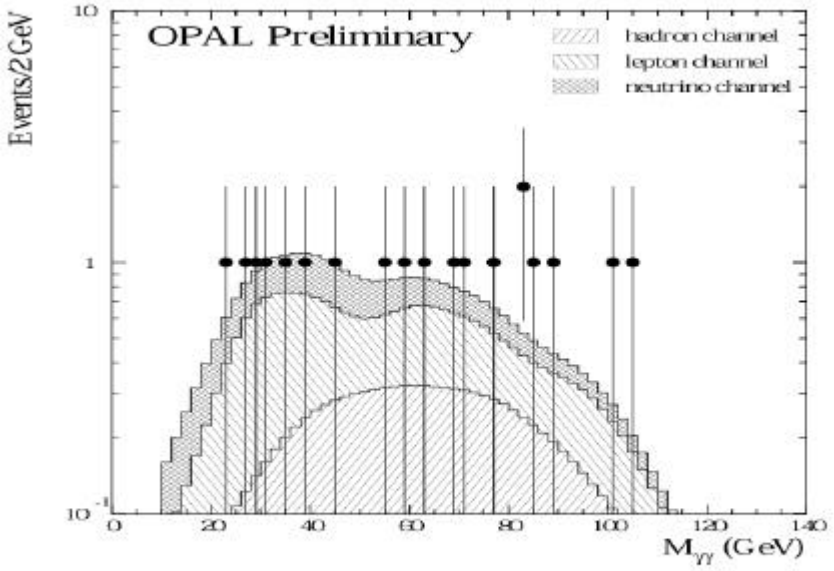
Search for Higgs decaying into Photons

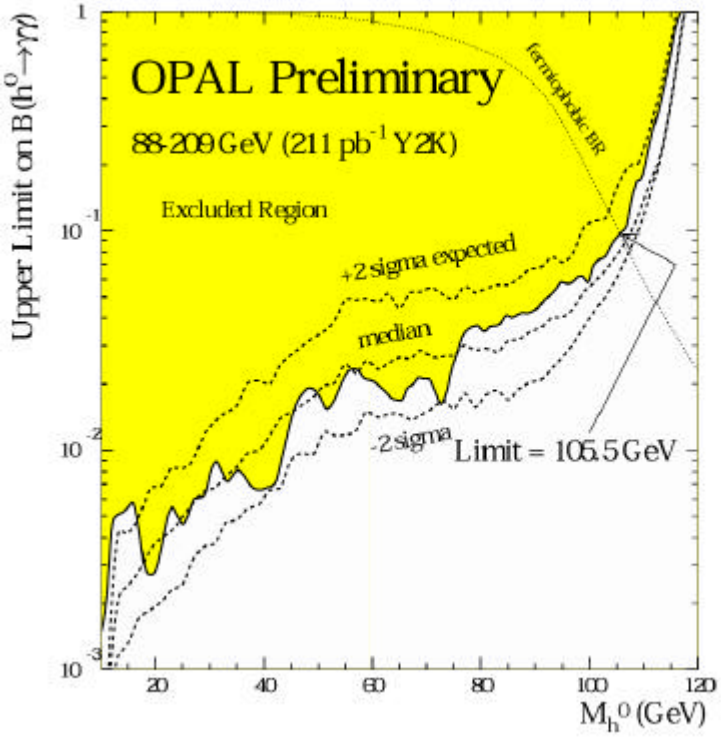
Process: $e^+e^- \to h^0Z^0$
$h^0 \to \gamma\gamma$, 3 channels:

Hadron	2γ + 2 jets
Lepton	2γ + 2 leptons
Neutrino	$2\gamma + \not{E}$

$m_h = m_{\gamma\gamma}$

95% CL Mass limit for fermiophobic Higgs
Obs. 105.5 GeV exp. 106.4 GeV





Higgs at OPAL Summary

Standard Model Higgs

Lower bound on Higgs mass at 95% C.L. = 109.7 GeV

At higher masses (~115 GeV), data are consistent with both background And background+signal hypotheses.

Extensions of the Standard Model

No significant deviations from SM background observed;

Lower mass bounds:

charged Higgs (conservative)	72.2 GeV
MSSM neutral h0, A0 (conservative)	~80 GeV
Other neutrals (assuming 100% exotic)	102-107 GeV