



Higgs Searches in OPAL

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Standard Model (SM) Higgs

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(no final calibrations)

Extensions of the Standard Model

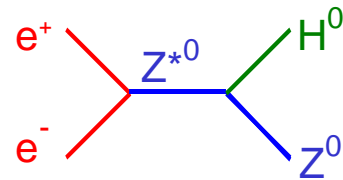
Preliminary results

6 March 2001

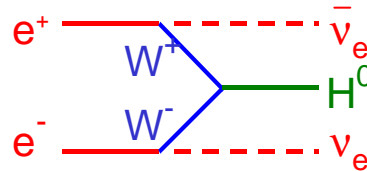


SM Higgs Production at LEP-2

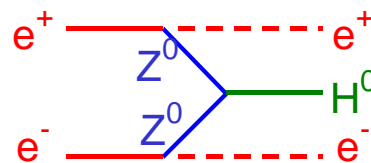
Higgs-strahlung



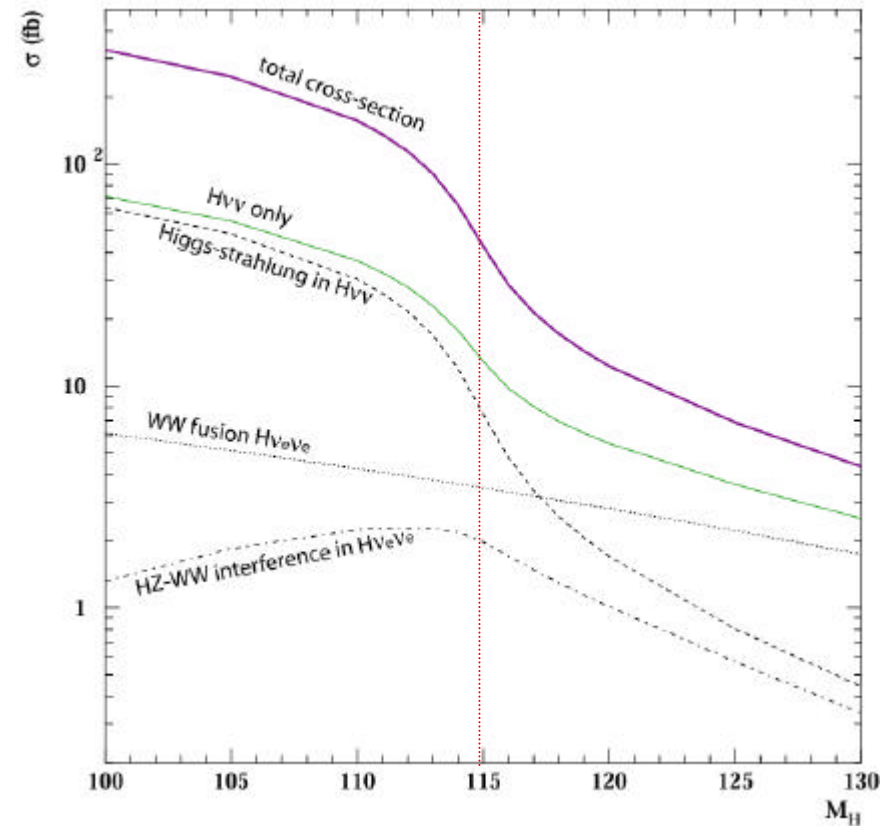
WW fusion



ZZ fusion

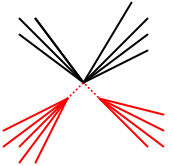
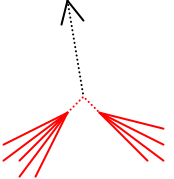
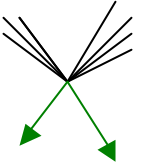
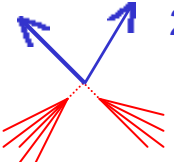


ECM = 206 GeV



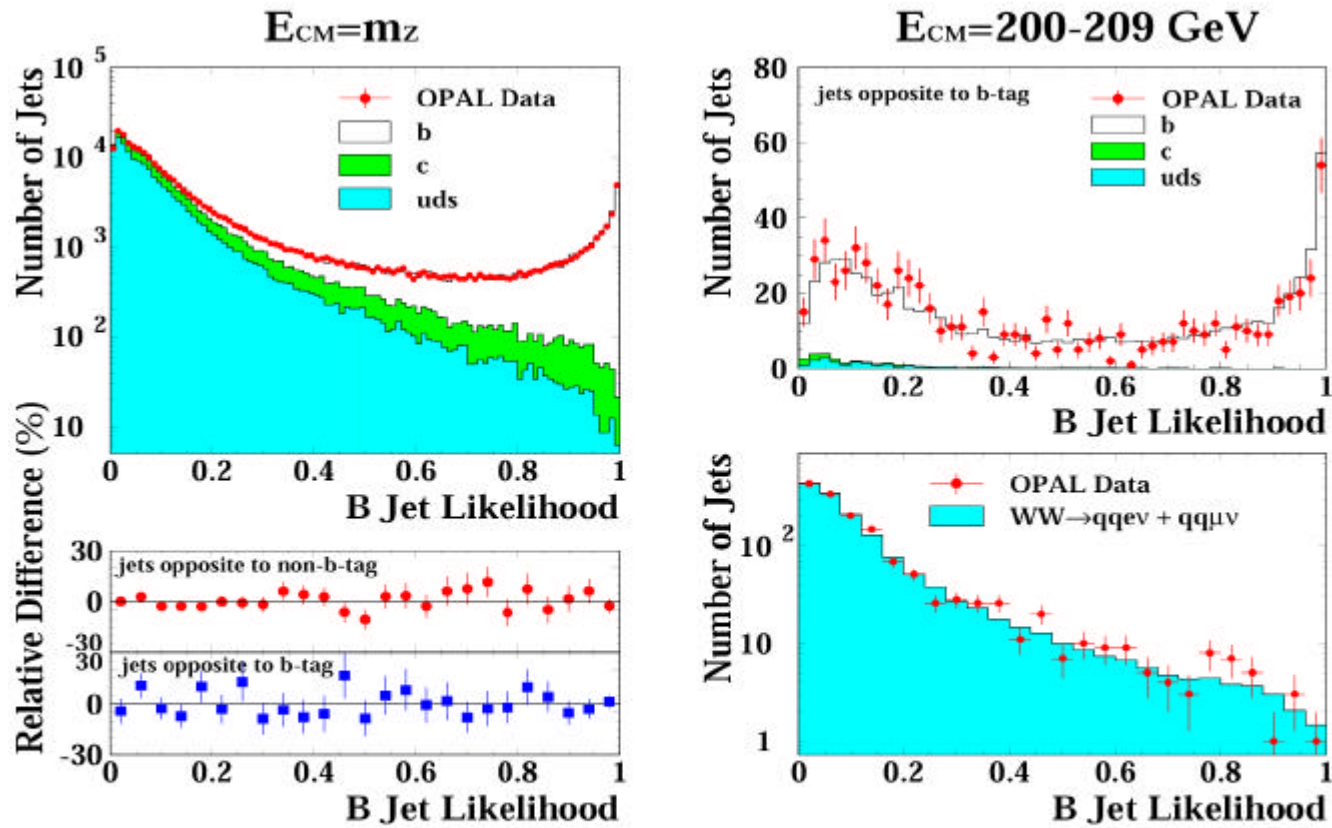


SM Higgs Search Channels

| Channel | B.R. | Process | Signature |
|-----------|------|--|--|
| Four-jet | 60% | $e^+e^- \rightarrow H^0 Z^0$ $Z^0 \rightarrow q\bar{q}, H^0 \rightarrow b\bar{b}$ |  4 jets 2 b-jets |
| Missing-E | 20% | $H^0 Z^0 : Z^0 \rightarrow \nu\bar{\nu}$ + W^+W^- fusion |  \cancel{E} + 2 b-jets |
| Tau | 9% | $H^0 \rightarrow b\bar{b}, Z^0 \rightarrow \tau^+\tau^-$ or $H^0 \rightarrow \tau^+\tau^-, Z^0 \rightarrow q\bar{q}$ |  2 (b-)jets + 2 tau s |
| Lepton | 7% | $H^0 Z^0 : Z^0 \rightarrow l^+l^- (l = e, \mu)$ + $Z^0 Z^0$ fusion |  2 leptons + 2 b-jets |



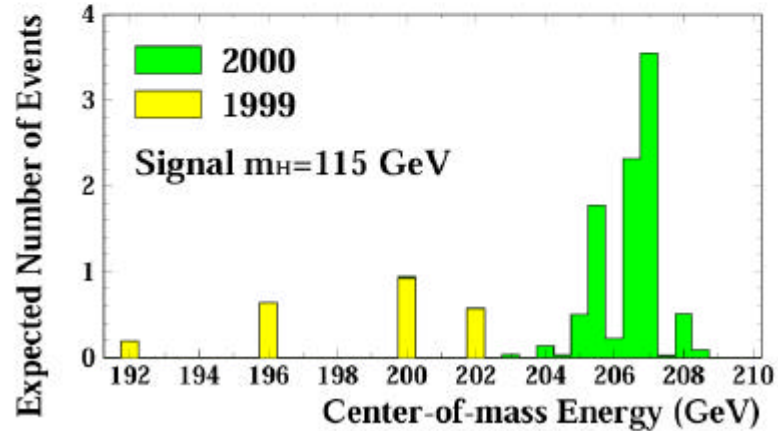
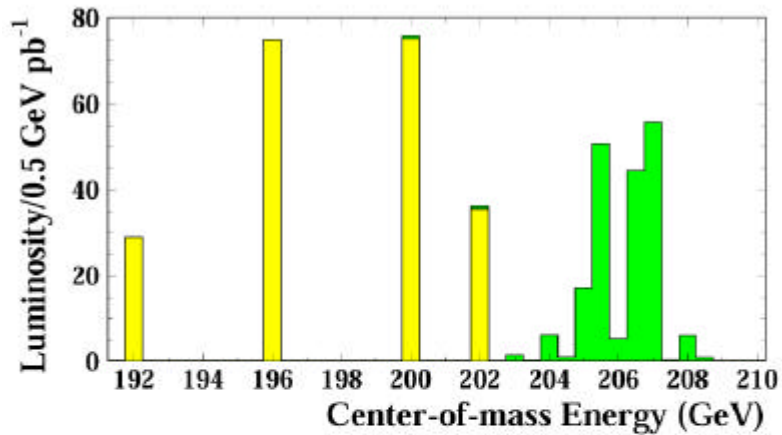
b-tagging in OPAL



Y2000 results



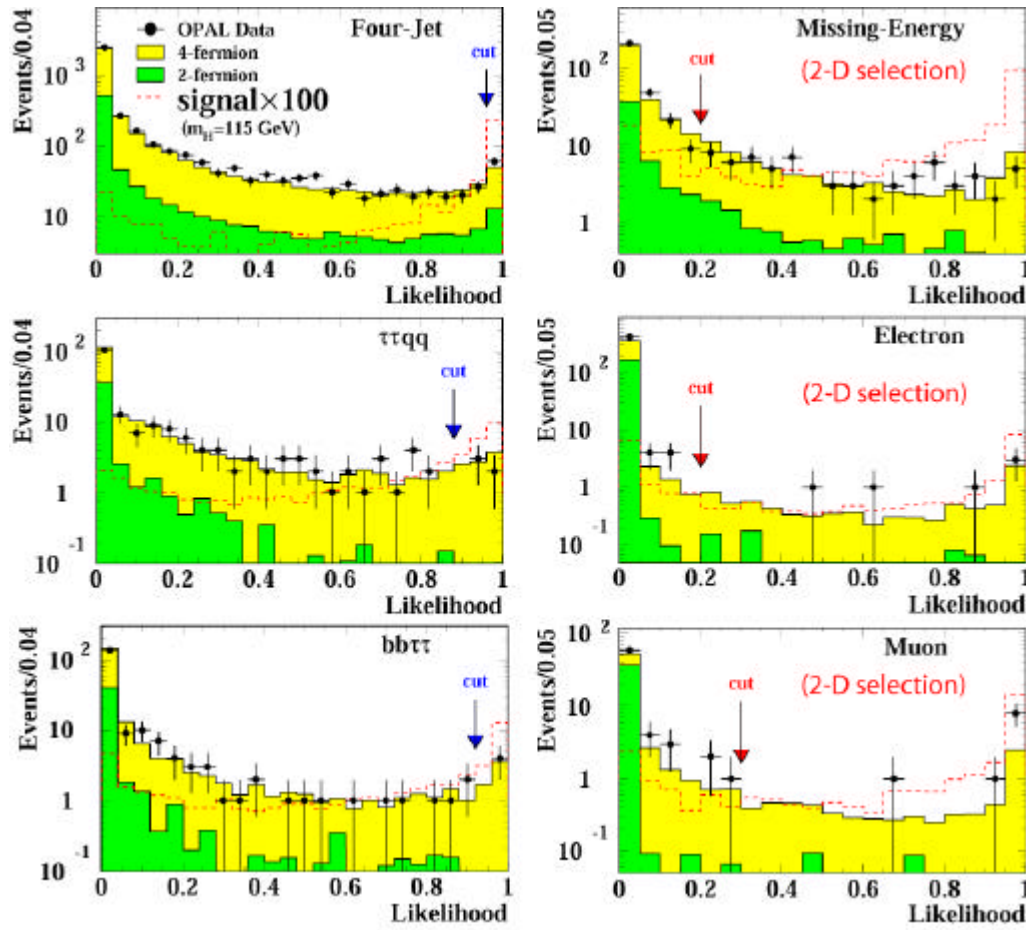
Data Collected by OPAL 1999-2000



| 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

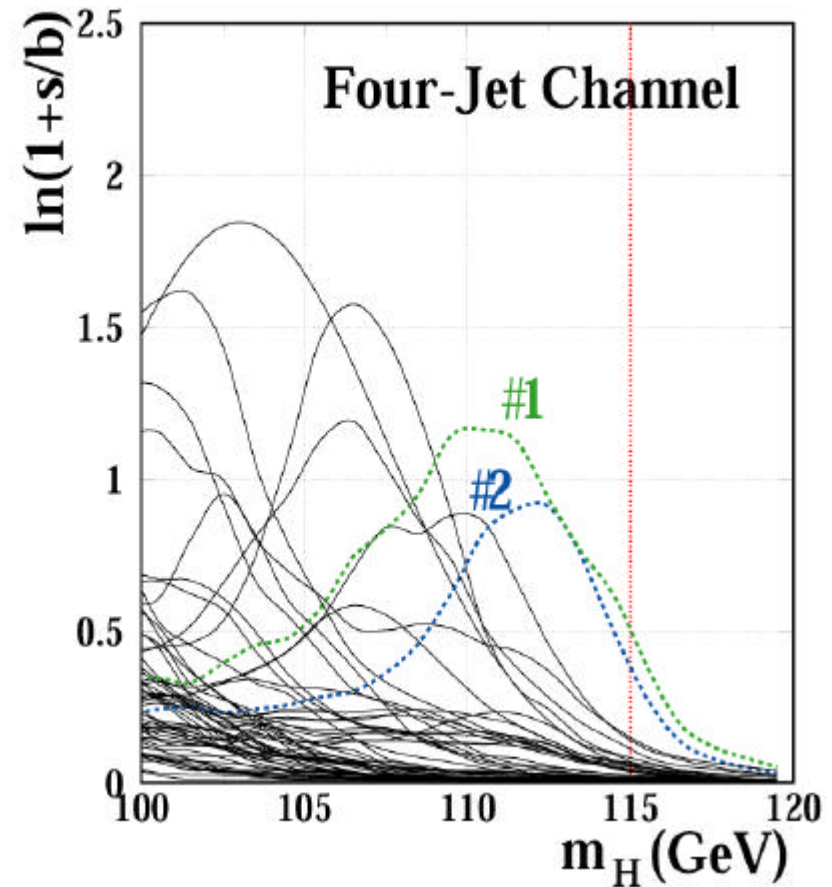
| Channel | Obs. Data | Exp. Bkg. | Signal (115 GeV) |
|--------------|------------|-----------------|------------------|
| 4-jet | 60 | 49.8±6.0 | 2.24±0.10 |
| \cancel{E} | 68 | 69.7±8.6 | 1.68±0.10 |
| Tau | 8 | 11.1±1.2 | 0.25±0.01 |
| Electron | 6 | 8.5 ±1.3 | 0.17±.004 |
| Muon | 10 | 7.0 ±1.0 | 0.23±.006 |
| All | 152 | 146 ± 11 | 4.57±0.14 |



SM Higgs Candidates

Significant Candidates by Channel

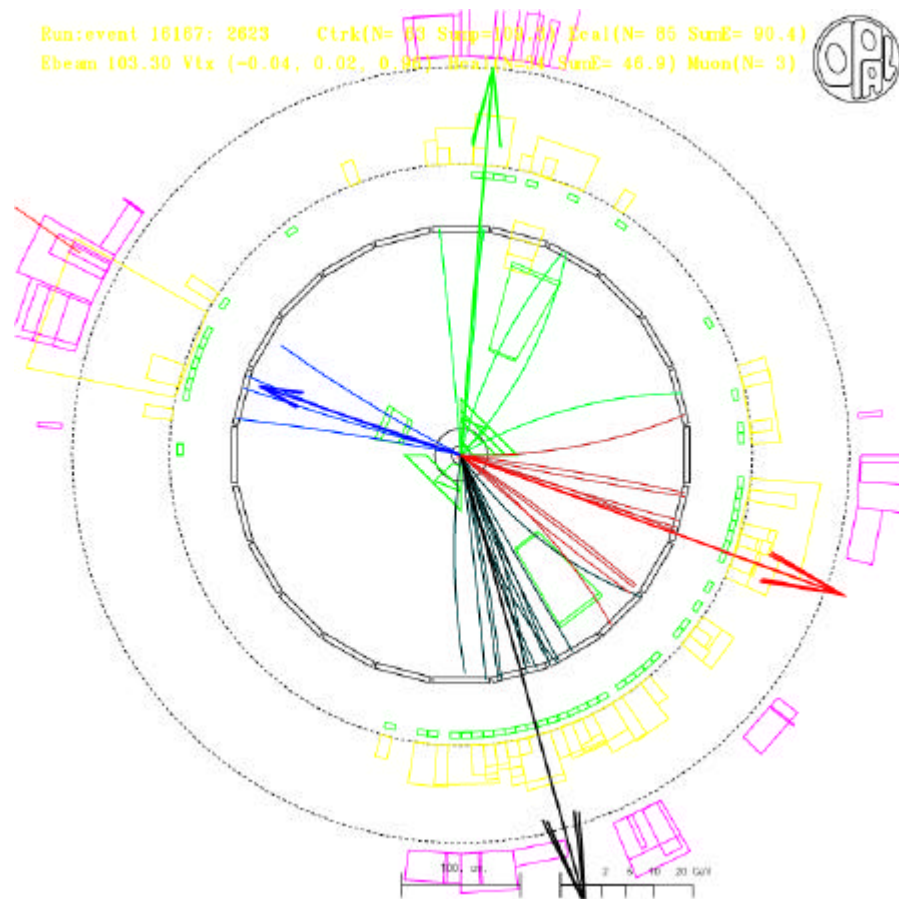
| # | Channel | m_{rec} | \mathcal{L}^{HZ} | s/b for 115 GeV |
|---|--------------|------------------|---------------------------|-----------------|
| 1 | 4-jet | 110.7 | .999 | 0.70 |
| 2 | 4-jet | 112.6 | .999 | 0.49 |
| 3 | \cancel{e} | 104.0 | .999 | 0.28 |
| 4 | \cancel{e} | 112.1 | .853 | 0.23 |
| 5 | Tau | 105.3 | .993 | 0.05 |
| 6 | Electron | 124.7 | .873 | 0.16 |
| 7 | Muon | 102.2 | .999 | 0.04 |



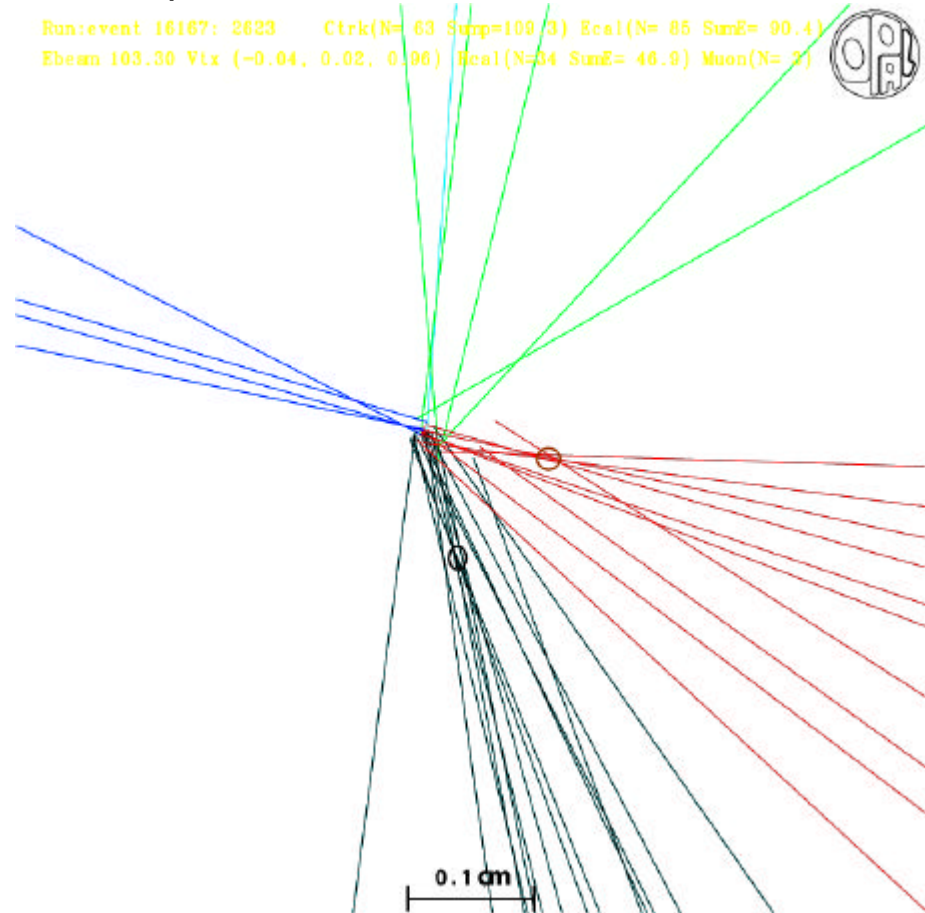


The Best (and last good) OPAL Candidate

General view:



Close-up view:

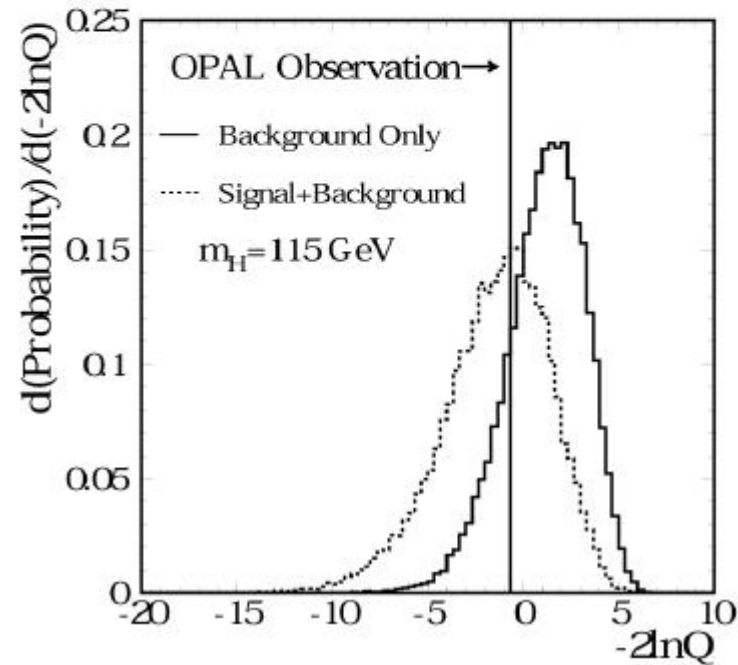
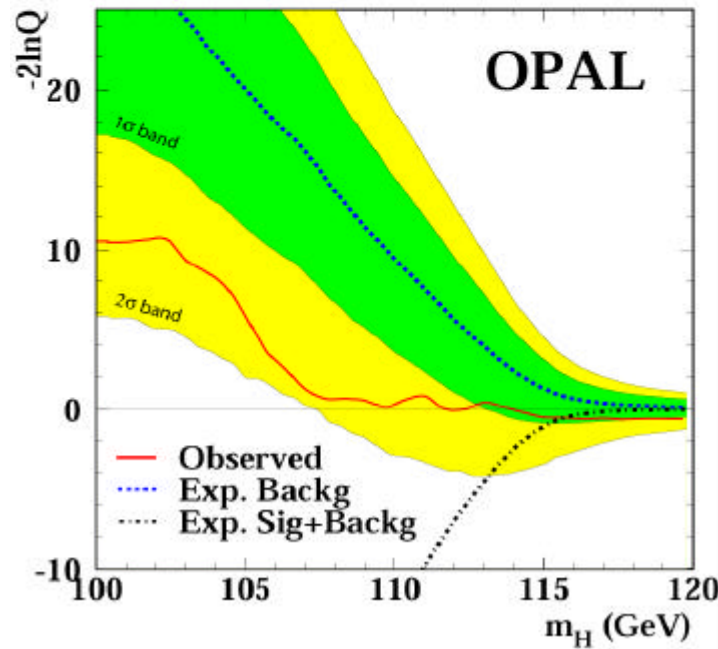




SM Higgs Observation in OPAL?

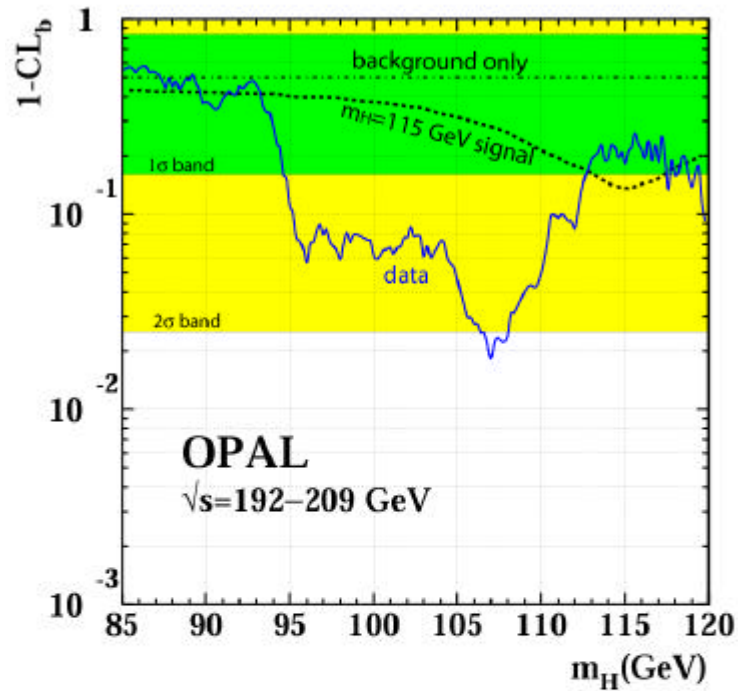
Likelihood ratio - Q

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

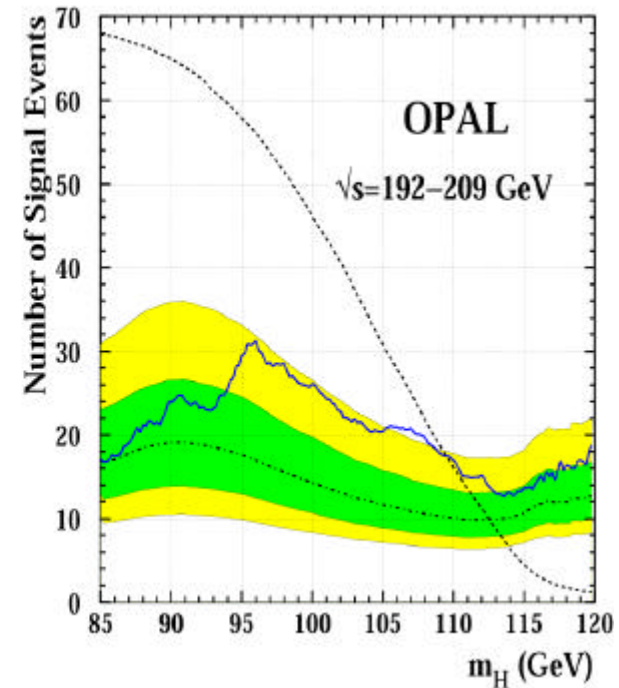




No SM Higgs Observation in OPAL?



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

$h^0 Z^0$ or $h^0 A^0$

Other exotics:

Charged Higgs

$H^+ H^-$

Flavor-Independent search

$h^0 \rightarrow$ (any) $q\bar{q}$ or gg

Invisible decay

e.g. $h^0 \rightarrow \chi_1^0 \chi_1^0$ (LSP)

Photonic decay

$h^0 \rightarrow \gamma\gamma$

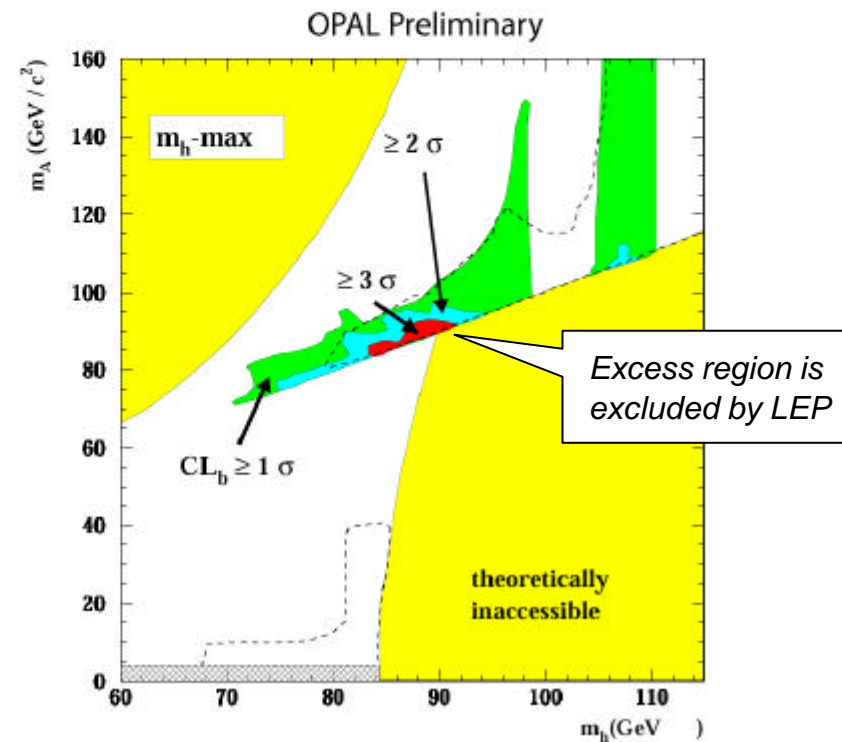


MSSM Higgs Searches

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

$$e+e- \rightarrow h^0 A^0 \rightarrow \begin{matrix} b\bar{b} b\bar{b} \\ \text{or} \\ b\bar{b} \tau^+ \tau^- \end{matrix}$$

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





MSSM Parameter Space Scan

Benchmark scans

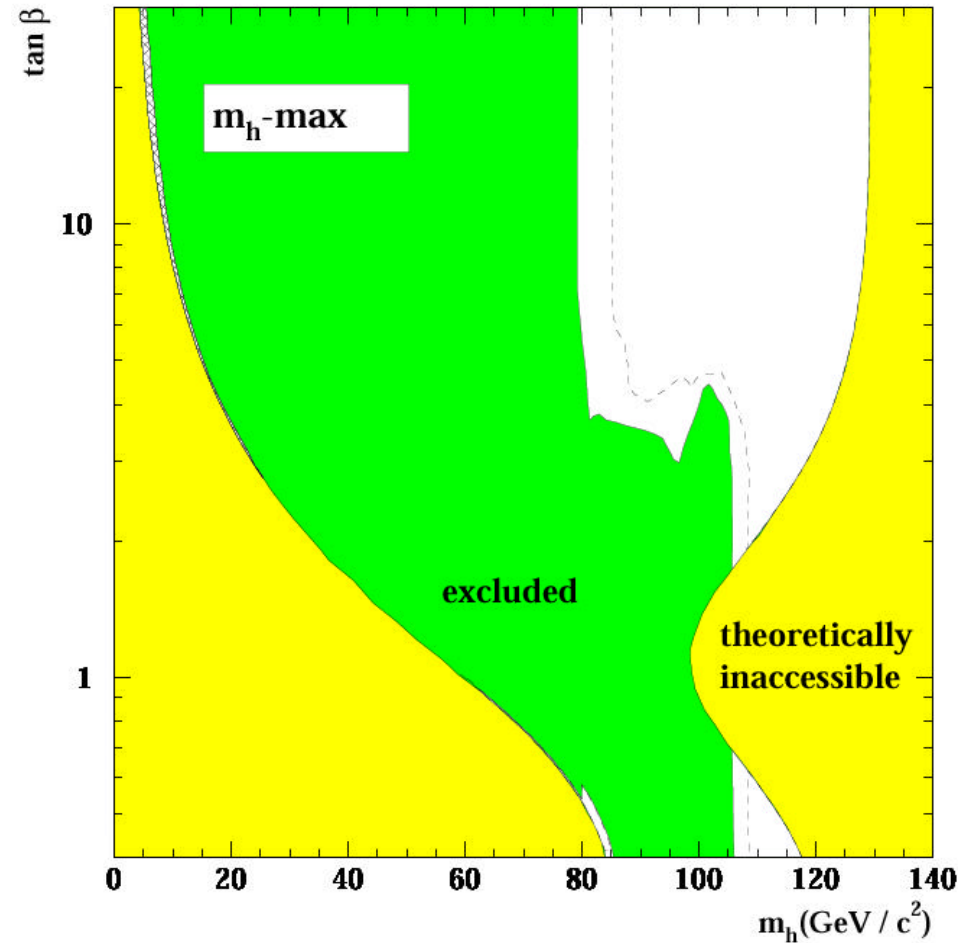
No mixing

Max. m_h conservative $\tan\beta$ limit

Large μ no $h^0 \rightarrow b\bar{b}$ decay

Max. m_h scan (m_h, m_A with $\tan\beta > 1.2$)

| | observed | expected |
|----------------------|----------|----------|
| m_h limit | 79.3 GeV | 85.1 GeV |
| m_A limit | 80.6 GeV | 86.9 GeV |
| Excluded $\tan\beta$ | 0.8-1.7 | 1.1-1.9 |





Charged Higgs Searches

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

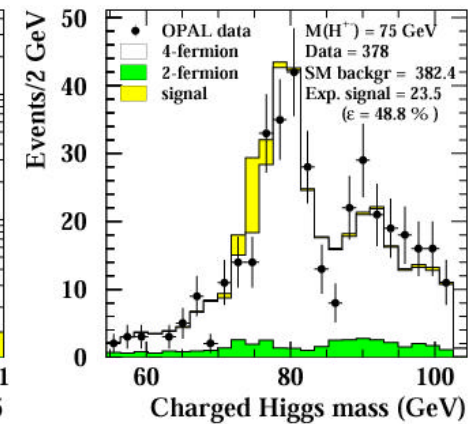
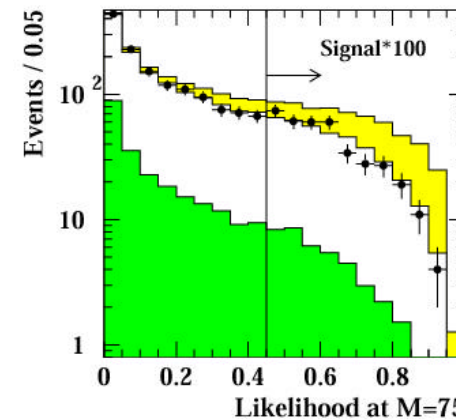
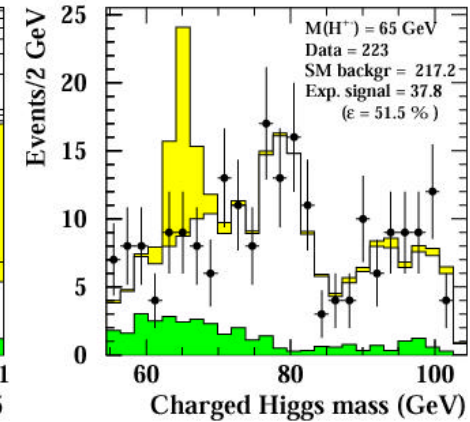
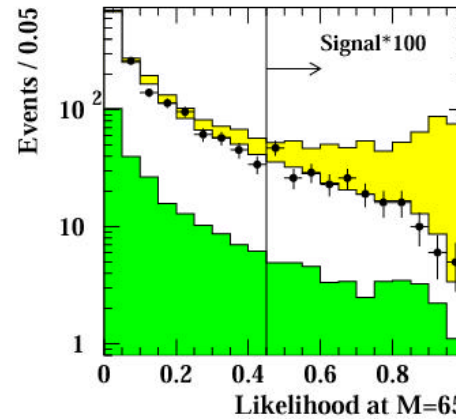
hadronic $H^\pm \rightarrow q\bar{q}$ 4 jets

Leptonic $H^\pm \rightarrow \tau\nu_\tau$ 2 τ s + \cancel{E}

Semi-leptonic (both) 2 jets +
+ τ + \cancel{E}

Very difficult to overcome the WW bkg.

OPAL Preliminary: $H^+H^- \rightarrow qqqq$, 200-209 GeV, 217.4 pb^{-1}

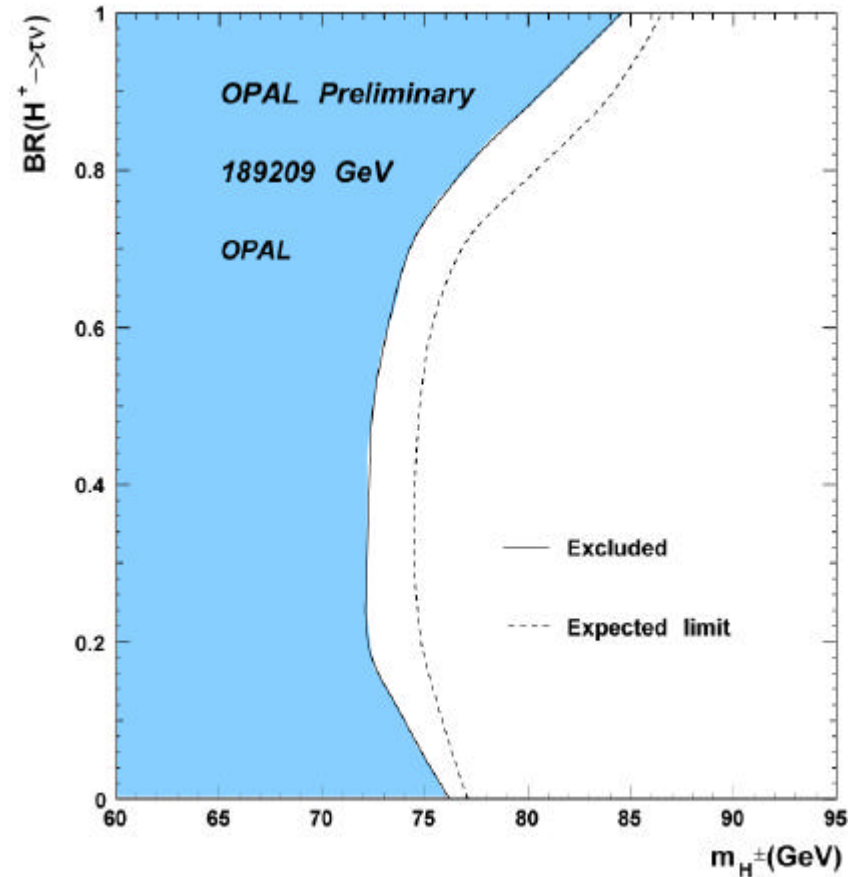




Charged Higgs Limits

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

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





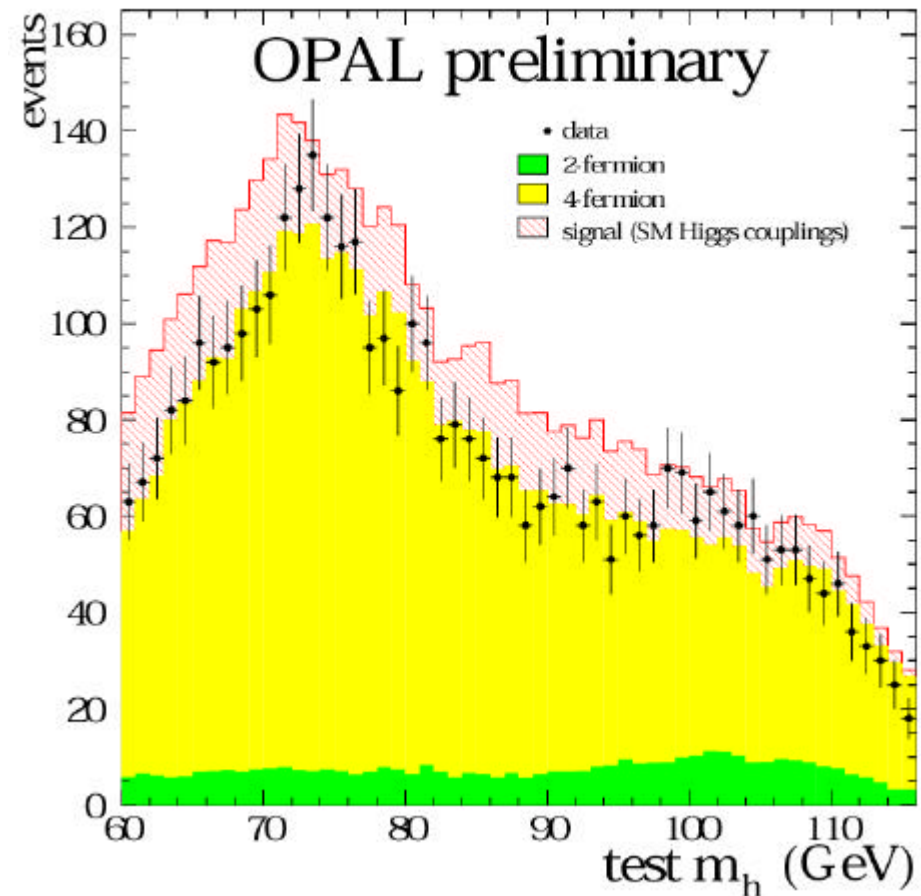
Flavor-Independent Decay Search

The process: $h^0 \rightarrow q\bar{q}$, 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

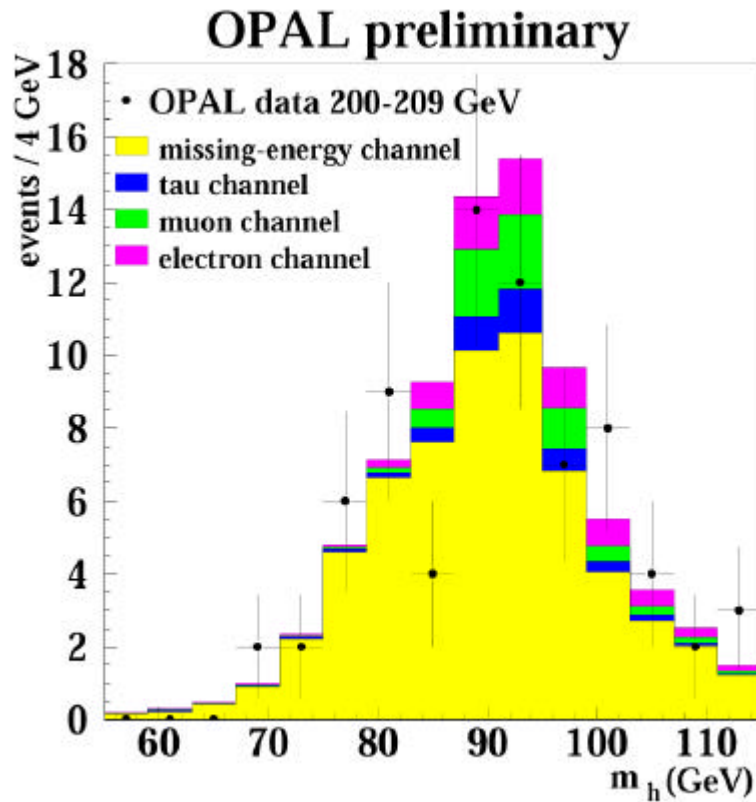
Four-jet channel



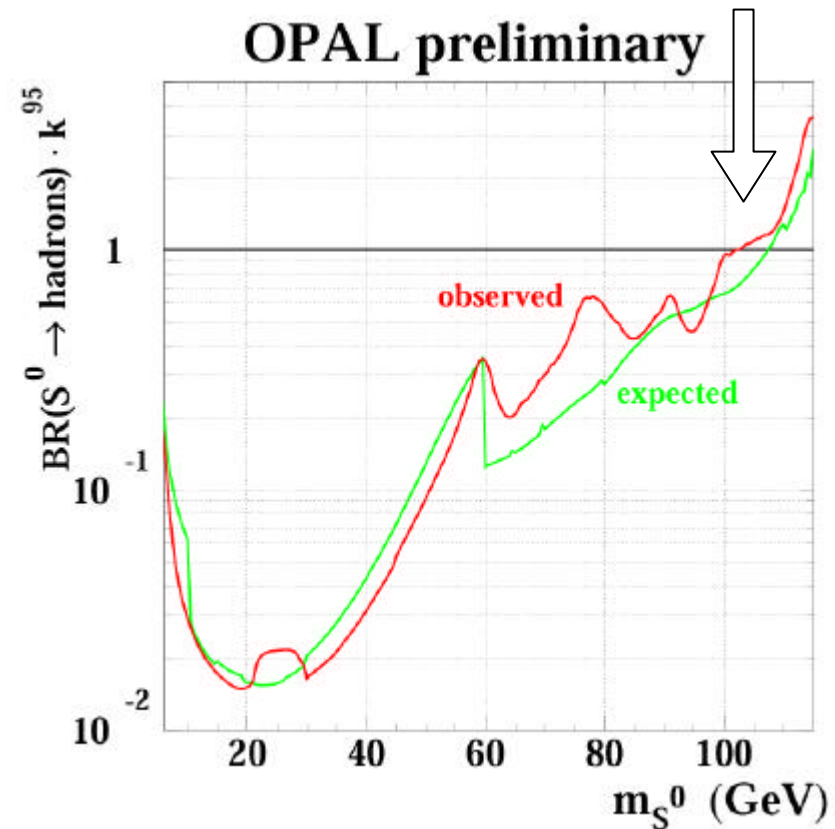


Flavor-Independent Search

The non-4-jet channels
mass distributions Y2000



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





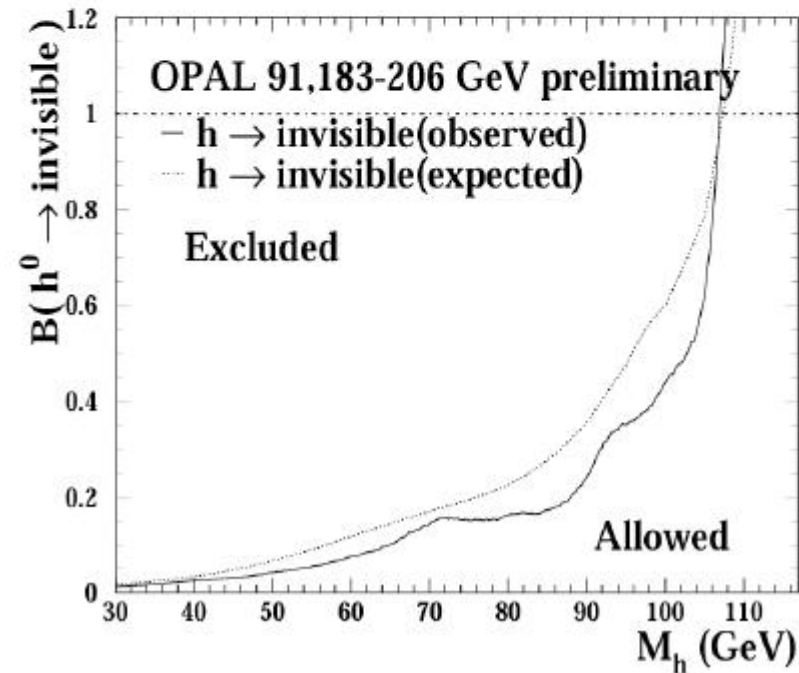
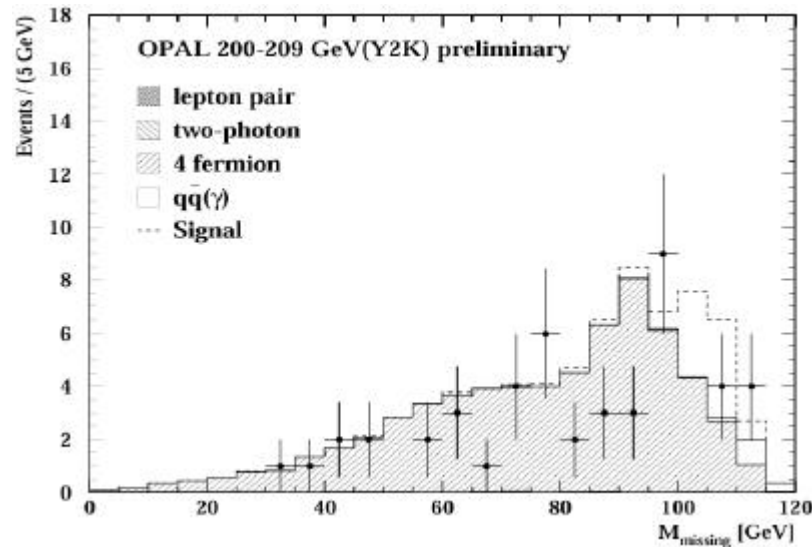
Invisibly Decaying Higgs Search

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

2 jets + \cancel{E}

$m_{\text{jets}} = m_Z$, $m_h = m_{\text{missing}}$

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





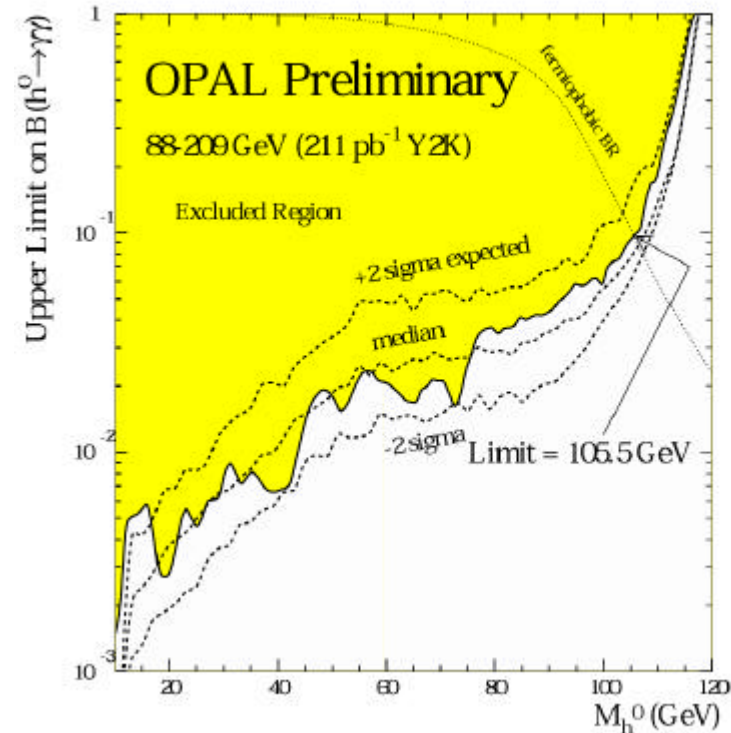
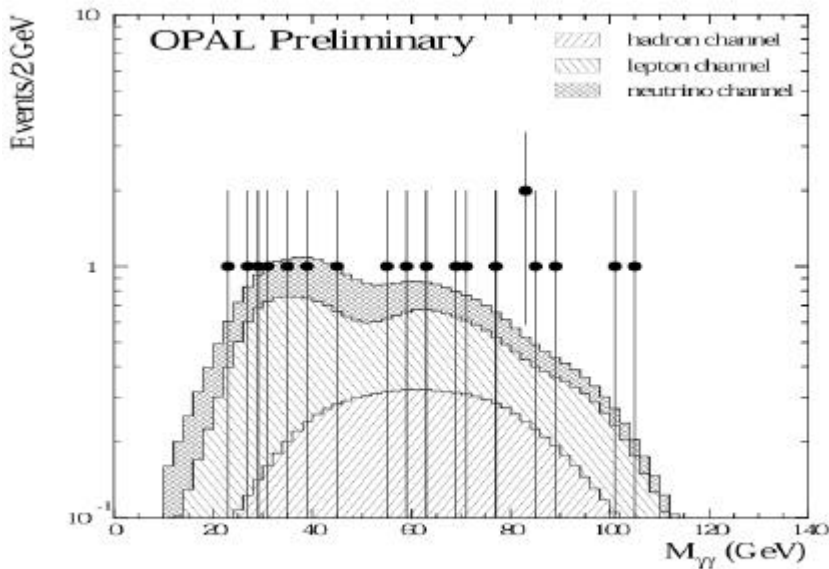
Search for Higgs decaying into Photons

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

| | |
|----------|-------------------------------|
| Hadron | $2\gamma + 2 \text{ jets}$ |
| Lepton | $2\gamma + 2 \text{ leptons}$ |
| Neutrino | $2\gamma + \cancel{E}$ |

$m_h = m_{\gamma\gamma}$

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





Higgs in 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 limits at 95% C.L.:

| | |
|--|---------------|
| Charged Higgs (conservative) | 72.2 GeV |
| MSSM neutral h^0, A^0 (conservative) | ~ 80 GeV |
| Other neutrals (assuming 100% exotic) | 102-107 GeV |