

Higgs searches with DELPHI



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DELPHI Collaboration

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All results are preliminary

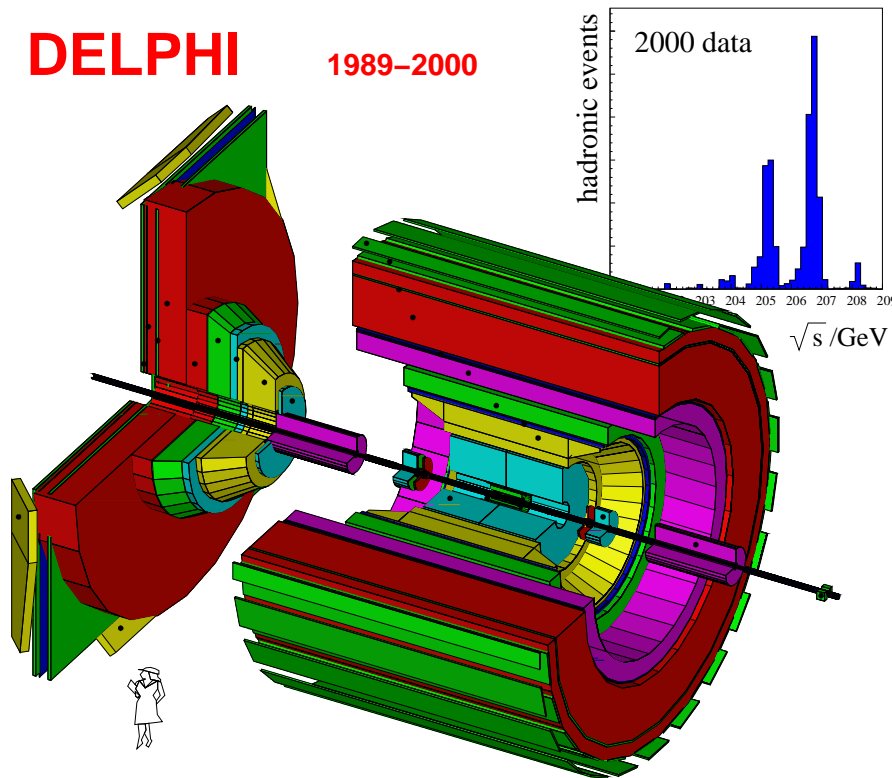


Outline

- Introduction
- SM Higgs boson searches
 - Hqq channel
 - $H\nu\nu$ channel
 - charged lepton channels
- Higgs bosons beyond the SM
 - hA searches
 - charged Higgs boson searches
 - invisible Higgs decays
- Prospects
- Conclusions



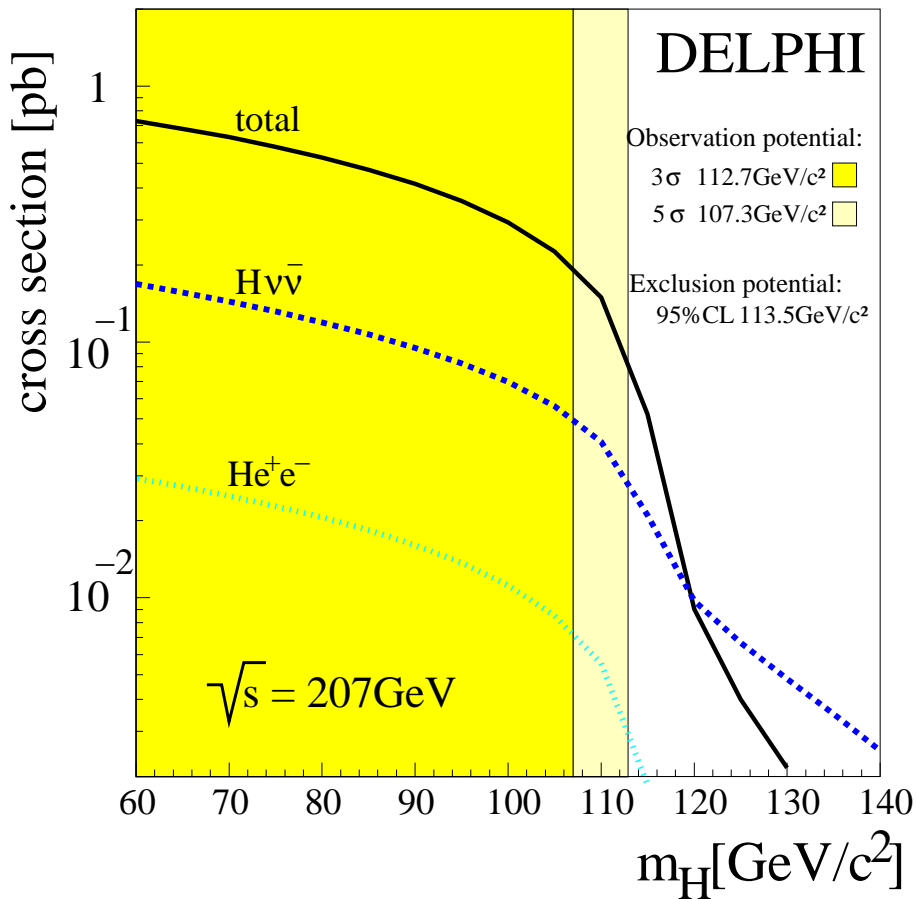
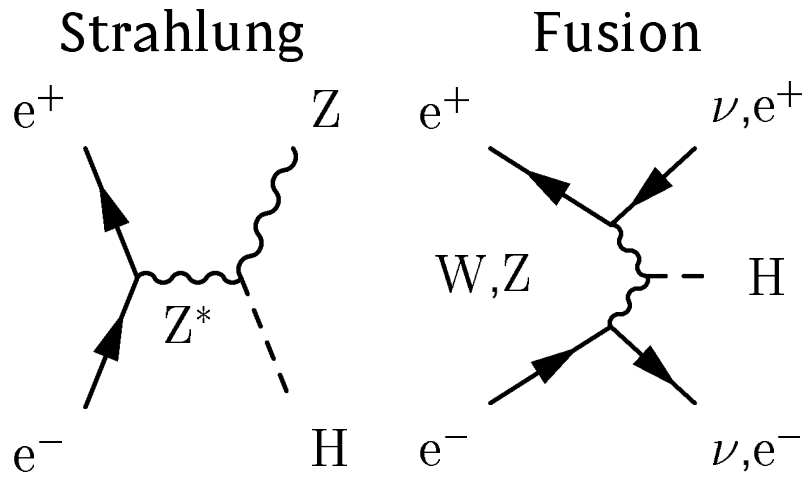
DELPHI data taking in the year 2000



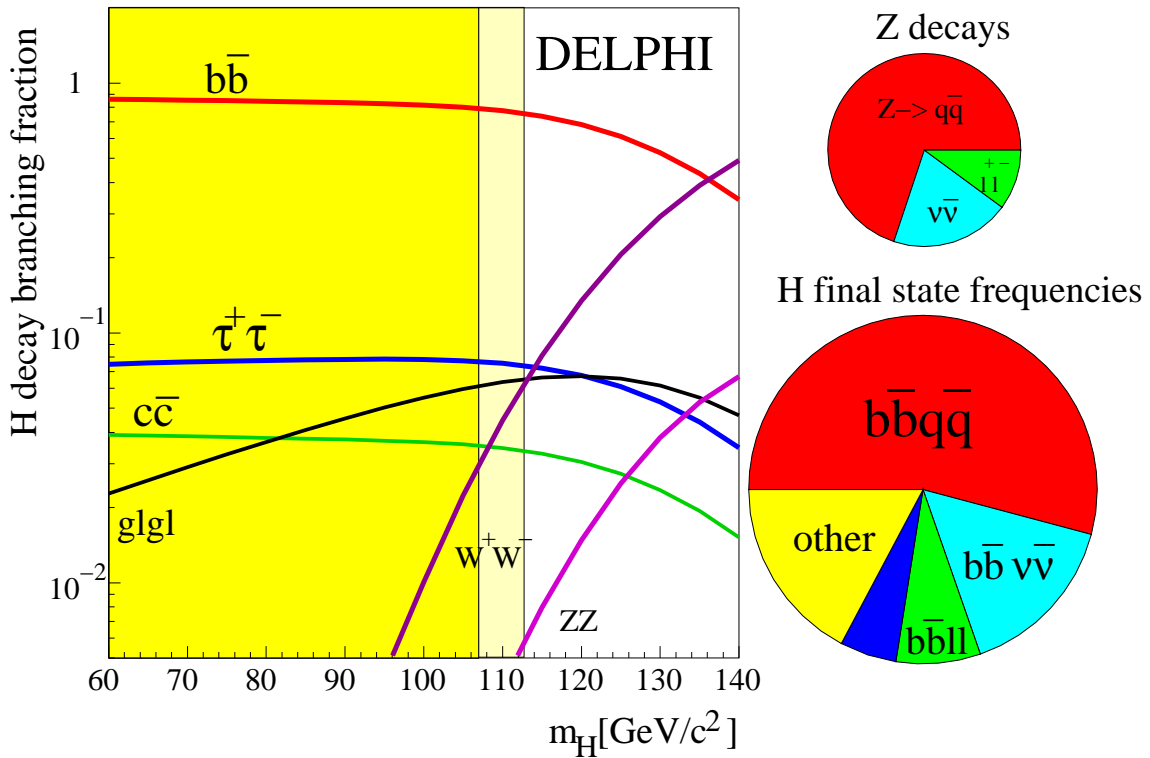
- about 225 pb^{-1} recorded data between 200 and 209 GeV
- about 688 pb^{-1} in total above WW threshold
- death of one TPC sector in September



Production of the SM Higgs at LEP



Decay properties of the SM Higgs at LEP

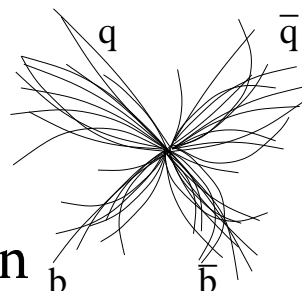


- analysis optimisation for $H \rightarrow b\bar{b}$
- quoted efficiencies include small fraction of other Higgs decay modes



4-jet channel

$H \rightarrow$ any but τ , $Z \rightarrow q\bar{q}$

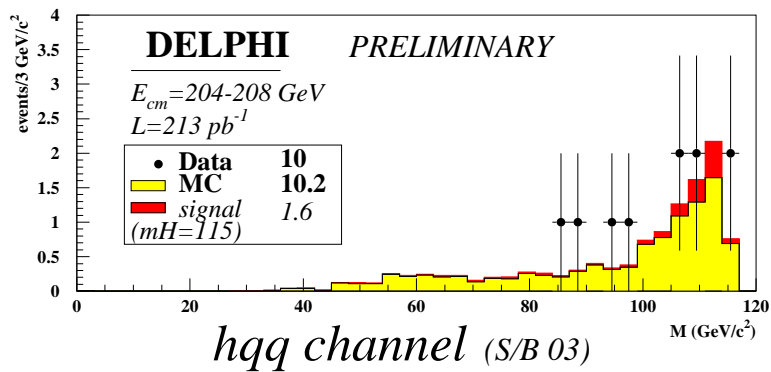
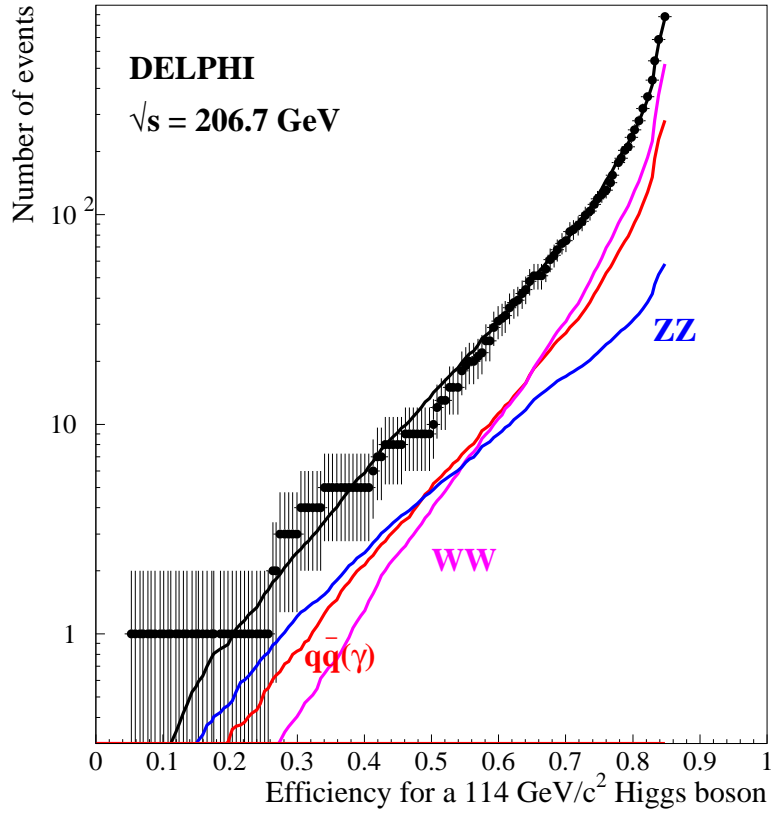


- cut based 4-jet preselection
- NNW with 13 input variables:
 - Anti-QCD (8)
 - WW and ZZ compatibility (4)
 - sum of the two largest jet btags in the event (1)
- likelihood based pairing strategy

Cut	data	background	eff. [%]
Presel.	2266	2342	85.0
intermed.	398	423.7	79.0
tight	8	7.4	36.0

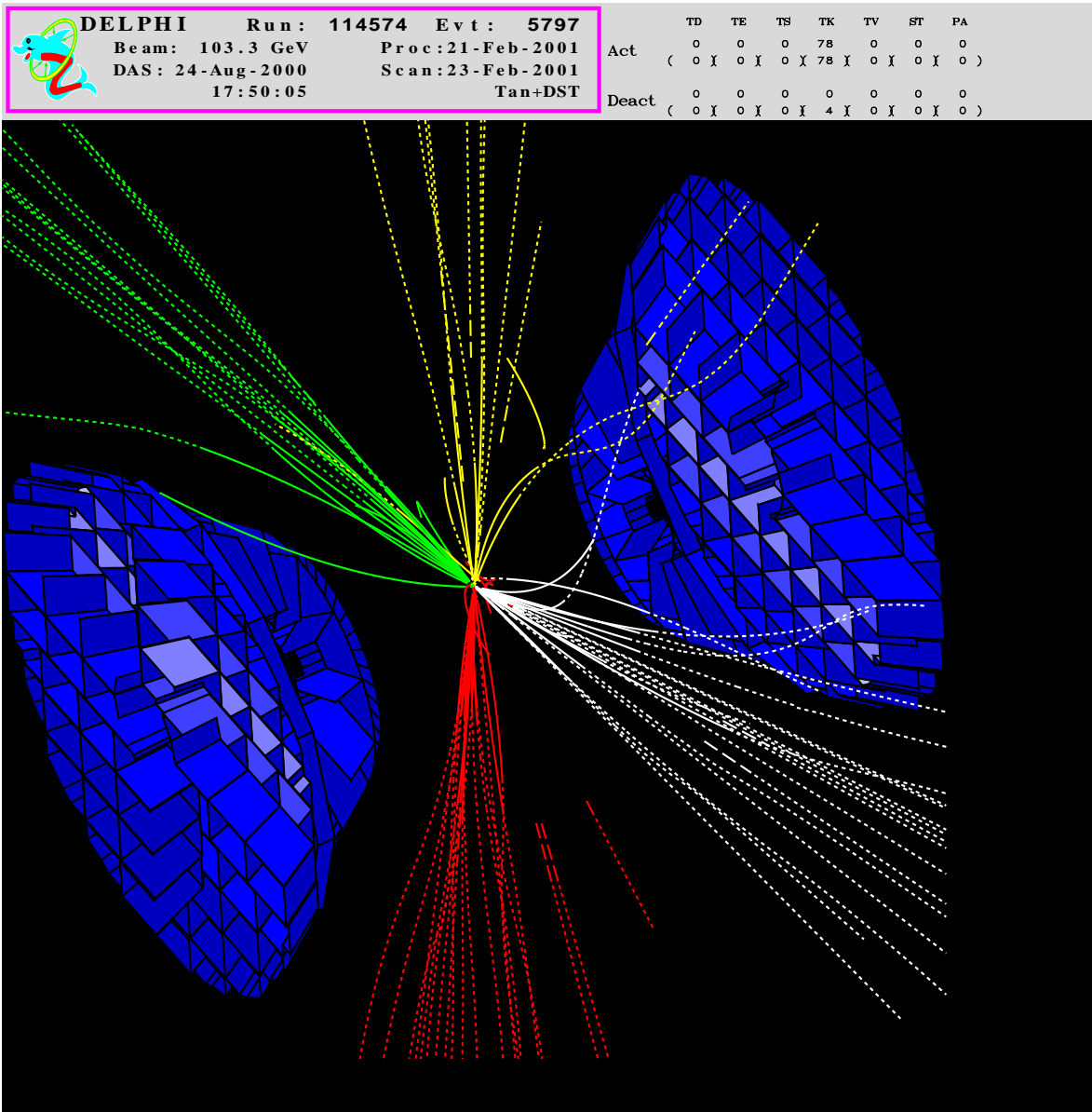


4-jet channel: results



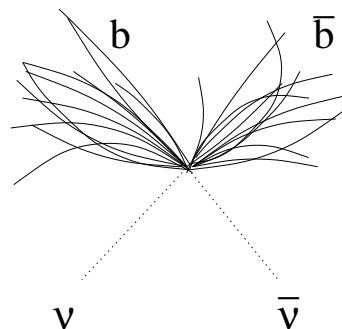
No indication for signal production





Missing energy channel

$$H \rightarrow \text{any}, Z \rightarrow \nu\bar{\nu}$$

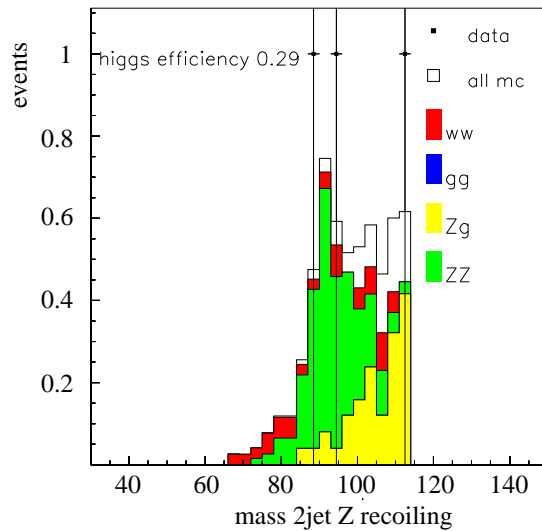
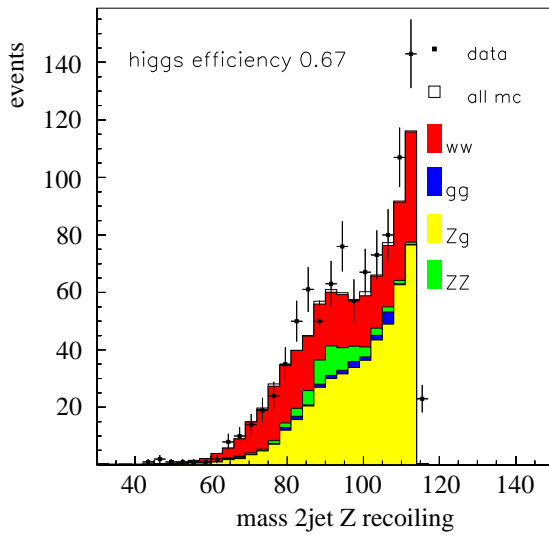
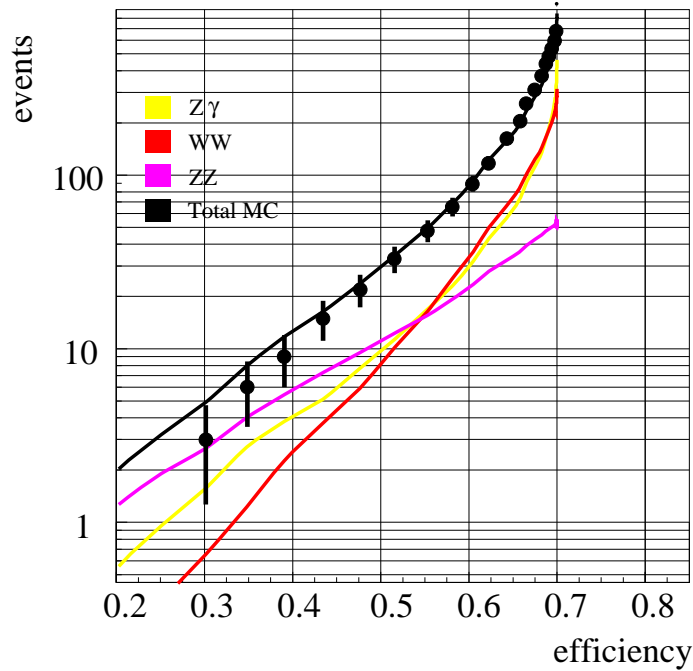


- four step sequential preselection
- final selection done by likelihood function

Cuts	data	background	eff. [%]
bhabha $\gamma\gamma$	17503	17753	86.1
$q\bar{q}(\gamma)$	1808	1681	78.3
W^+W^-	1357	1189	75.5
final presel.	970	851	66.9



Missing energy channel: results

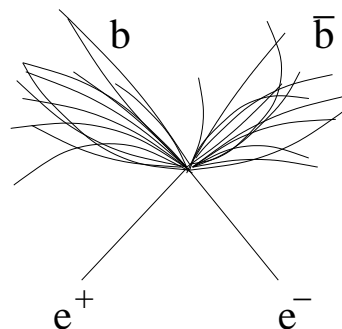


No indication for signal production



Hee channel

$H \rightarrow \text{any}, Z \rightarrow e^+e^-$



- sequential cut analysis
- final cut in btag

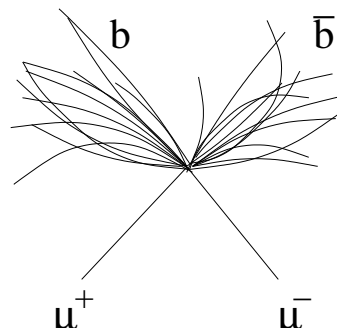
Cut	data	background	eff. [%]
Presel.	1242	1171.6	77.9
Ident.	168	195.9	65.6
El.ene.	68	78.7	63.3
Fit pr.	31	30.2	60.1
Jet Iso.	13	14.6	57.0
Mass sel.	7	11.6	56.7
btag	1	3.5	49.3

No indication for signal production



H $\mu\mu$ channel

$H \rightarrow \text{any}, Z \rightarrow \mu^+ \mu^-$




- sequential cut analysis
- final cut in btag

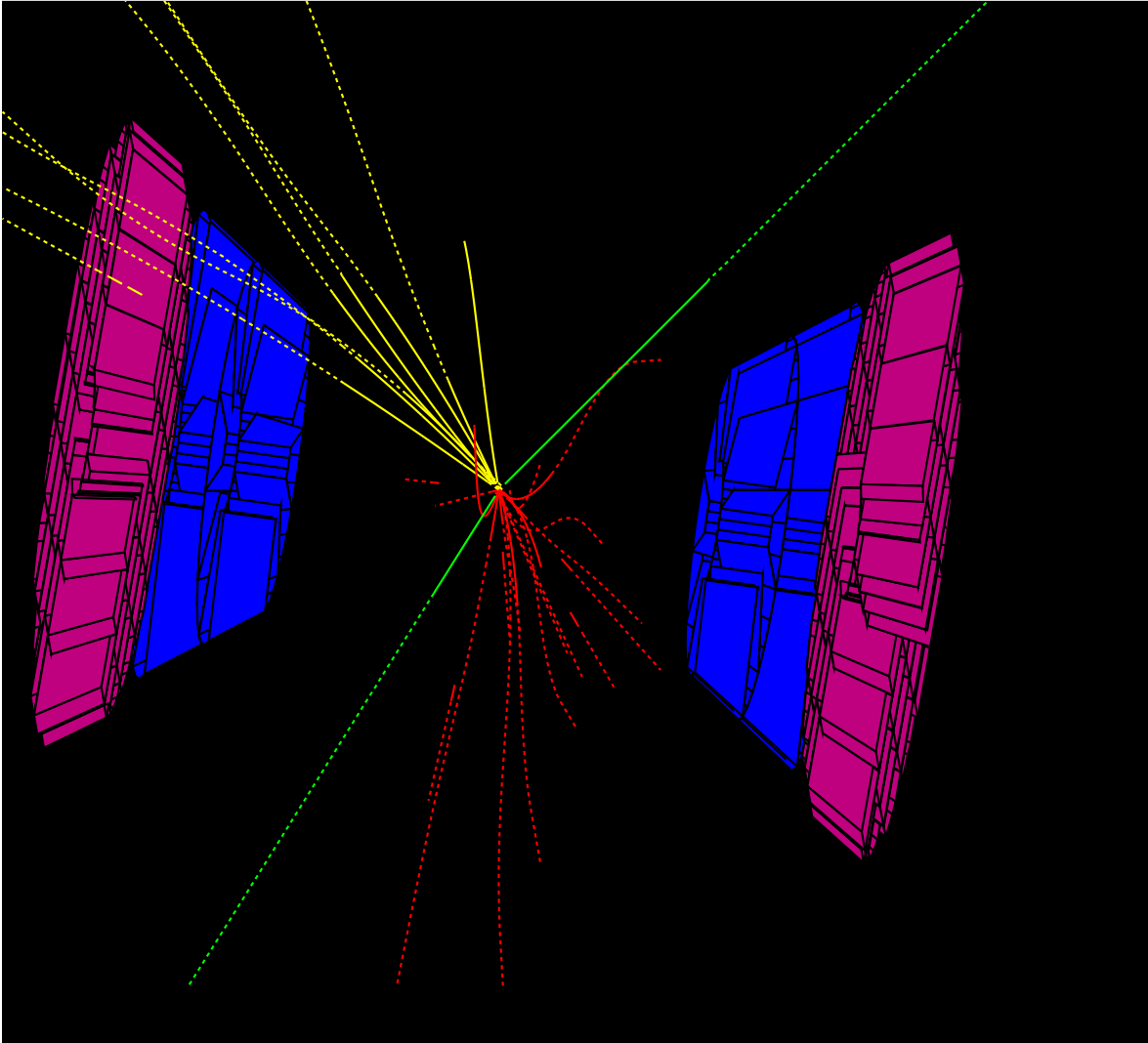
Cut	data	background	eff. [%]
PreSel	3780	3763.9	81.
Dil. ang. momentum	2858	2812.7	81.
Muon Id.	991	893.6	78.
Isolation	26	27.1	73.
5C - Fit	12	15.4	71.
B tag	7	10.6	68.
	3	5.8	61.

No indication for signal production



H $\mu\mu$ channel: candidate event

	DELPHI Run: 117588 Evt: 19267	TD TE TS TK TV ST PA Act (0 X 0 X 0 X 30 X 0 X 0 X 0) Deact (0 X 0 X 0 X 0 X 0 X 0 X 0)
	DAS: 27-Oct-2000	Tan+DST

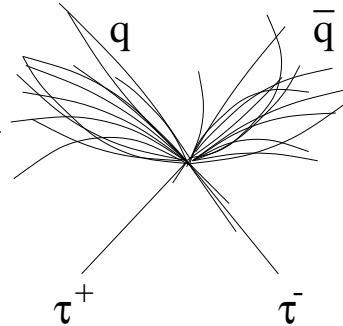


$$M_{qq} = 94 \text{ GeV}/c^2, M_{\mu\mu} = 85 \text{ GeV}/c^2, \text{large btag}$$



H_{ττ} and ττZ channel

$H \rightarrow \text{any but } \tau, Z \rightarrow \tau^+\tau^-$
 $H \rightarrow \tau^+\tau^-, Z \rightarrow q\bar{q}$



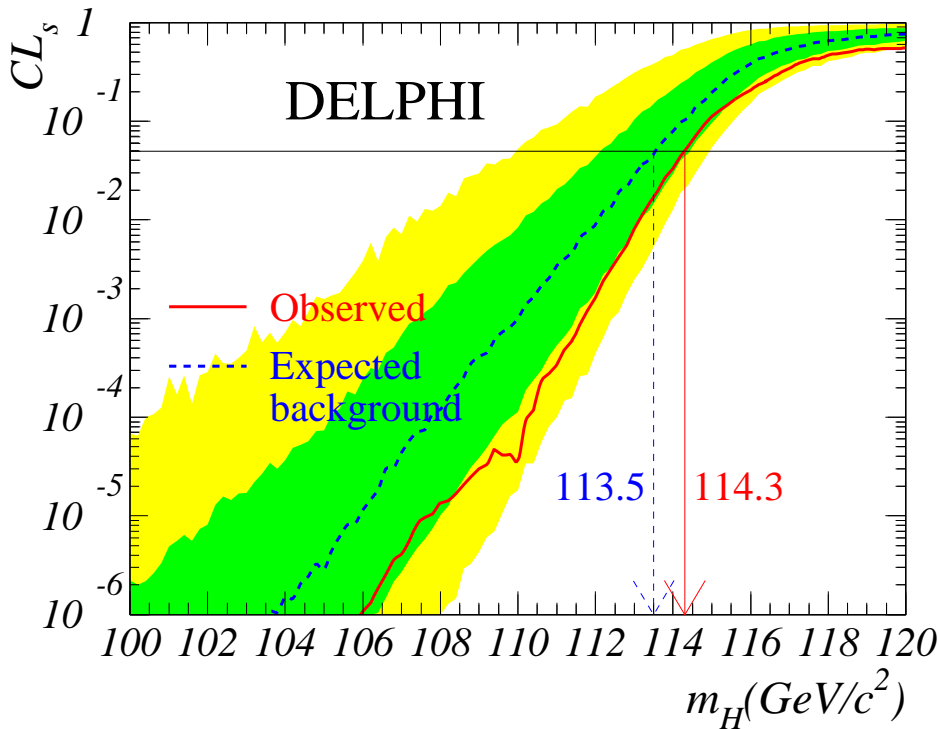
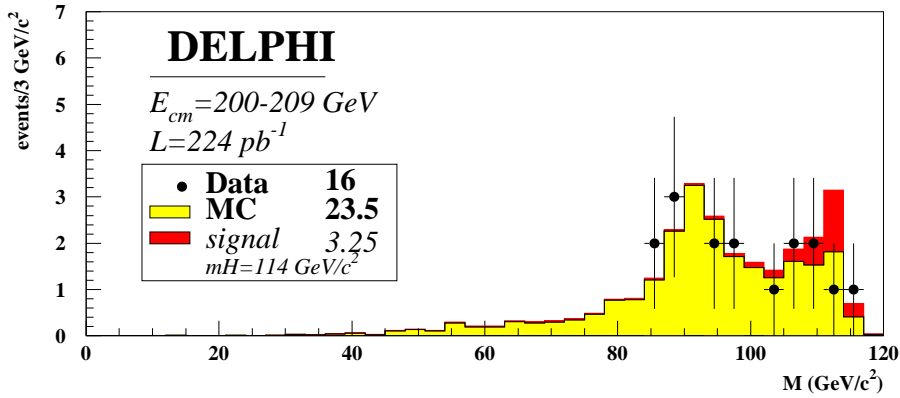
- covers also MSSM $h, A \rightarrow \tau^+\tau^-$ channels
- likelihood function to select τ candidates
- sequential cuts for final selection

Cut	data	background	eff. [%]
Presel.	9180	8876.0	98.1
final	5	7.15	15.9

No indication for Higgs production



SM results: DELPHI combined limits

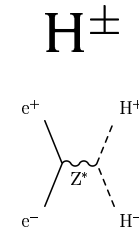
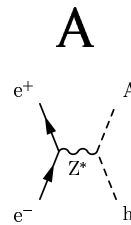
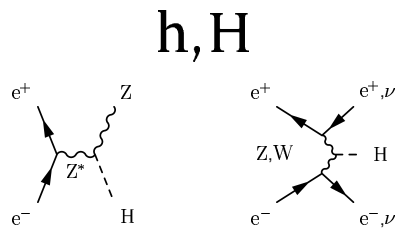


$M_H > 114.3 \text{ GeV}/c^2$ (113.5 GeV/c^2 exp.)



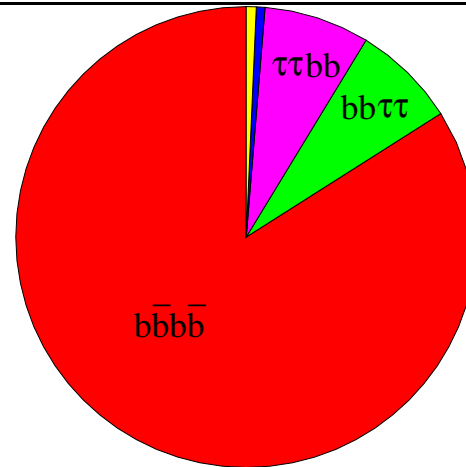
Beyond the SM: 2-doublet model, MSSM, ...

production



decays

$b\bar{b}$
 $\tau^+\tau^-$
 ...
 $\tilde{\chi}^0\tilde{\chi}^0$

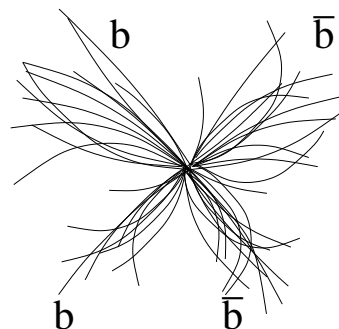


$c\bar{s}c\bar{s}$
 $c\bar{s}t\bar{v}$
 $\tau^+\nu\tau^-\bar{\nu}$
 ...



$e^+e^- \rightarrow hA$ searches

$h \rightarrow b\bar{b}, A \rightarrow b\bar{b}$

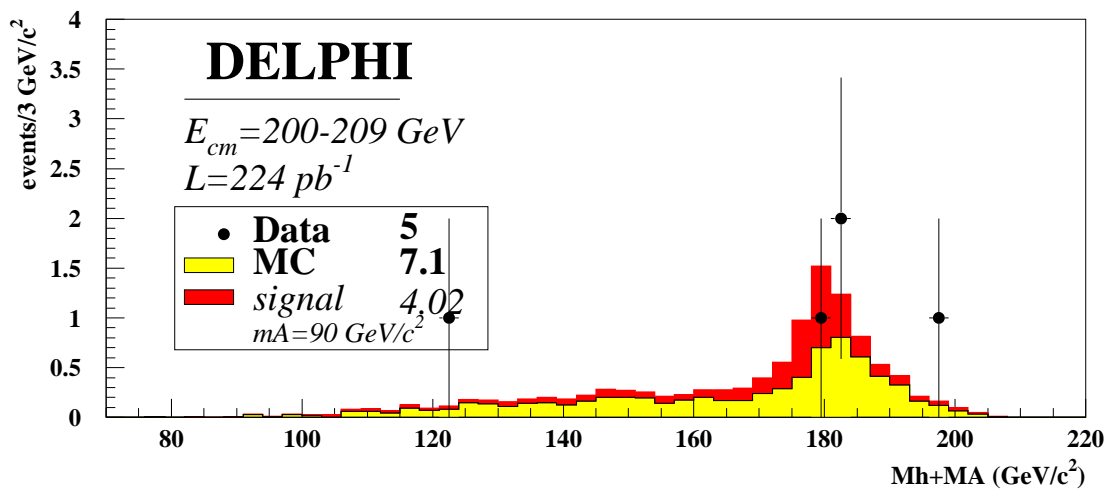
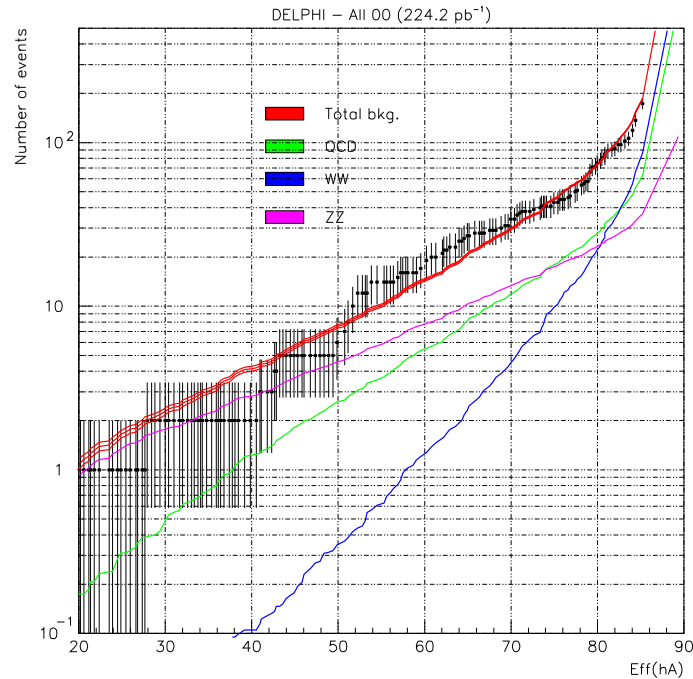


- sequential preselection as for SM $Hq\bar{q}$
- additional cuts against QCD
- likelihood for final selection

Cut	data	background	eff. [%]
presel.	1803	1933.5	89.2
intermed.	129	145.2	84.1
s/b=0.3	24	18.7	63.9
s/b=1	2	3.1	35.2



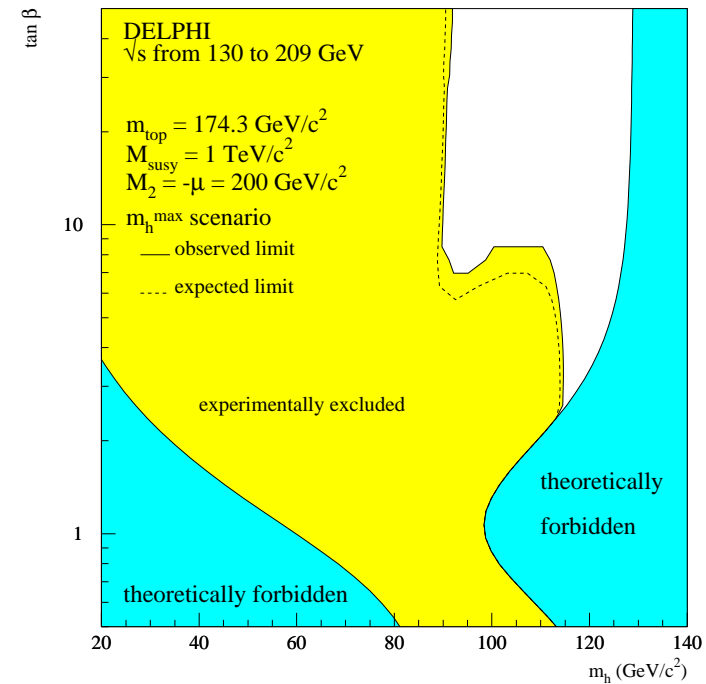
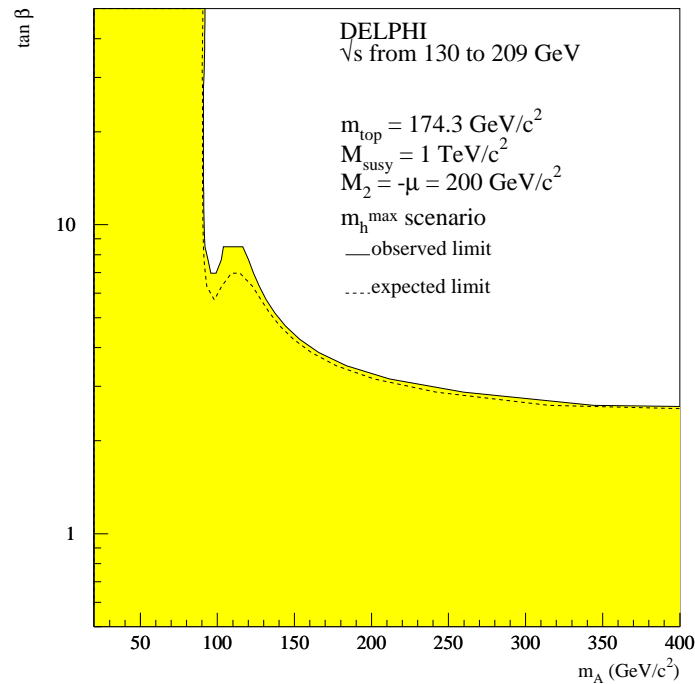
$e^+e^- \rightarrow hA$ searches



Compatible with background expectation



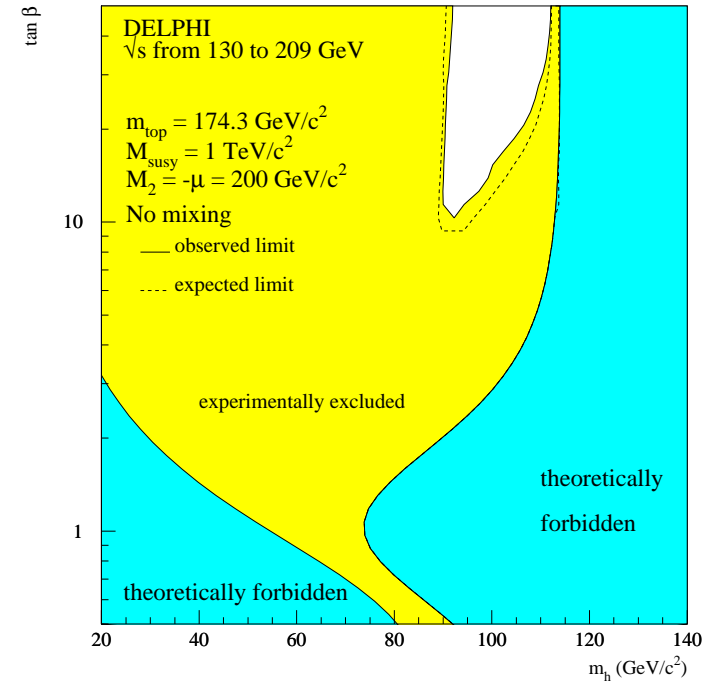
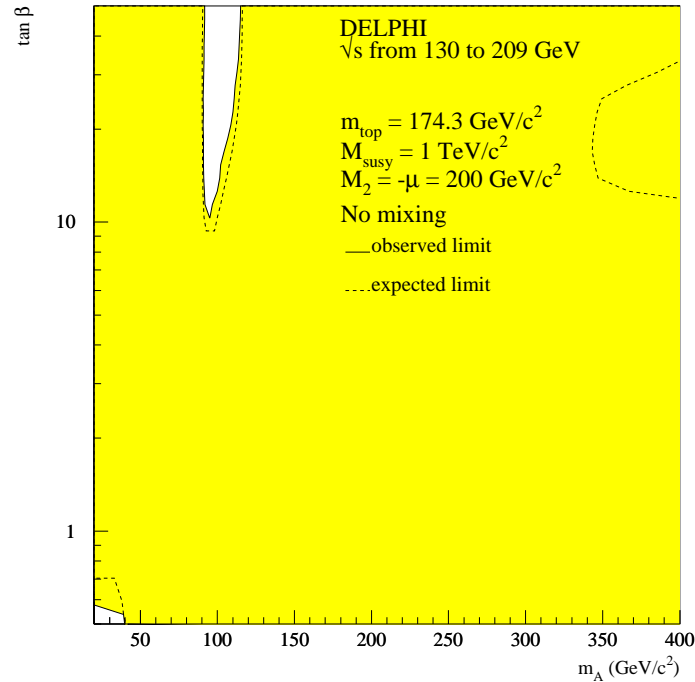
Interpretation in the MSSM: m_h^{max} scenario



95% CL exclusion limits, m_h^{max} scenario:
 $m_A > 90.9 \text{ GeV}/c^2$ ($90.1 \text{ GeV}/c^2$), $m_h > 89.8 \text{ GeV}/c^2$ ($89.0 \text{ GeV}/c^2$)
 $0.49 < \tan \beta < 2.36$ ($0.54 < \tan \beta < 2.36$)



Interpretation in the MSSM: No mixing scenario



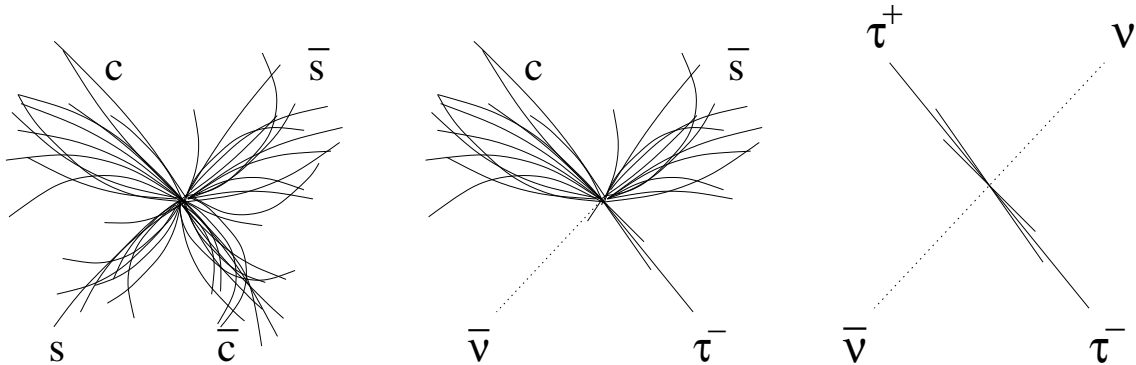
95% CL exclusion limits, no mixing scenario:

$m_A > 90.8 \text{ GeV}/c^2$ ($90.0 \text{ GeV}/c^2$), $m_h > 90.0 \text{ GeV}/c^2$
 ($89.1 \text{ GeV}/c^2$) $0.59 < \tan \beta < 9.36$ ($0.72 < \tan \beta < 9.36$)



Charged Higgs boson searches

$$H^+ H^- \rightarrow c\bar{s}c\bar{s}, c\bar{s}\tau\nu, \tau\nu\tau\nu$$



- sequential preselection
- likelihood analyses for all 3 channels
- limited by WW background

Channel	data	background	eff. [%]
$c\bar{s}c\bar{s}$	1040	1058.5	34
$c\bar{s}\tau\nu$	498	498.2	35
$\tau\nu\tau\nu$	64	63.7	34

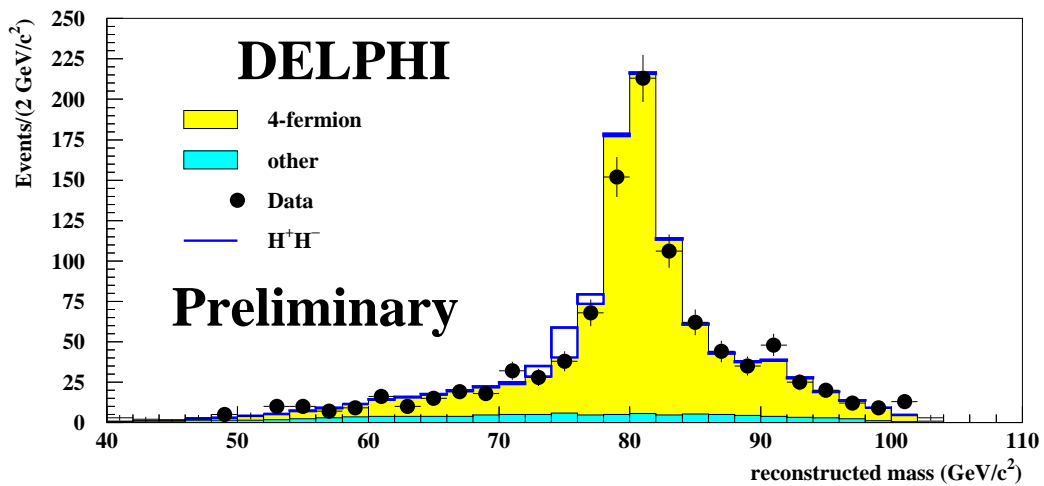
(efficiencies are given for a 70 GeV/c² signal)

(189 GeV < \sqrt{s} < 208 GeV)

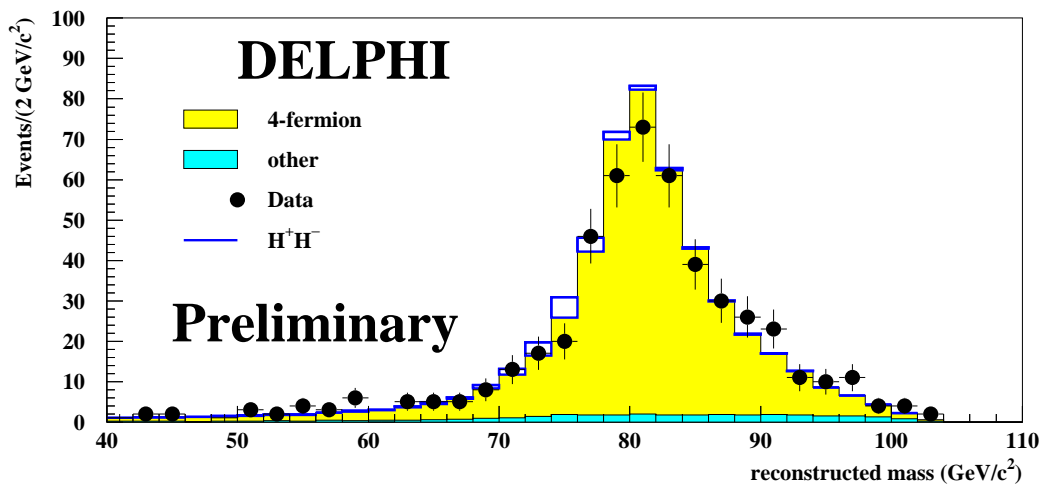


Charged Higgs bosons: mass distributions

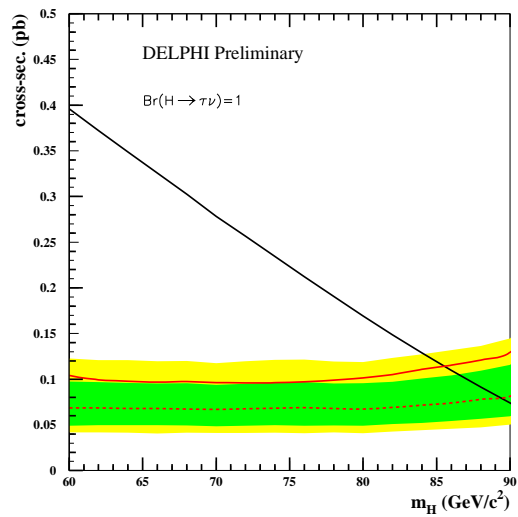
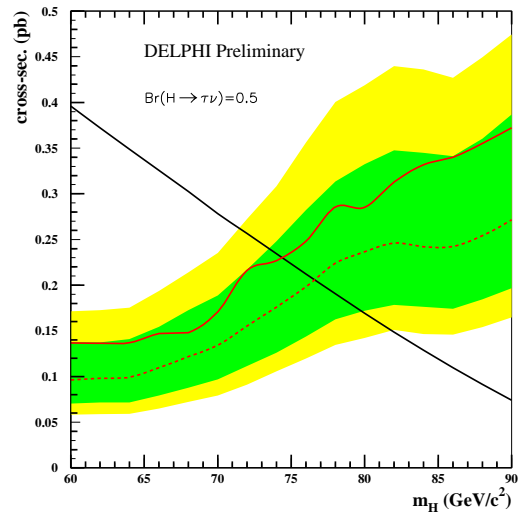
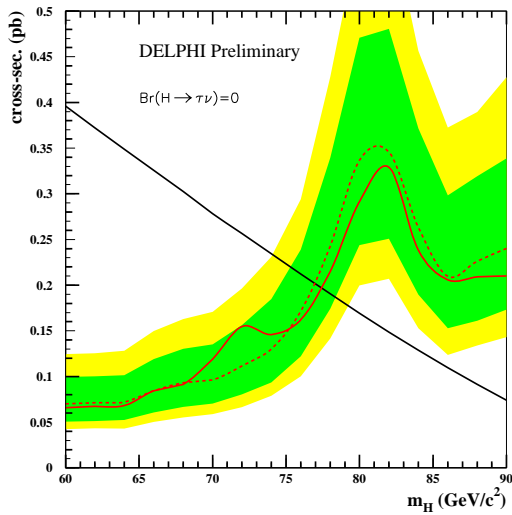
hadronic channel



semileptonic channel



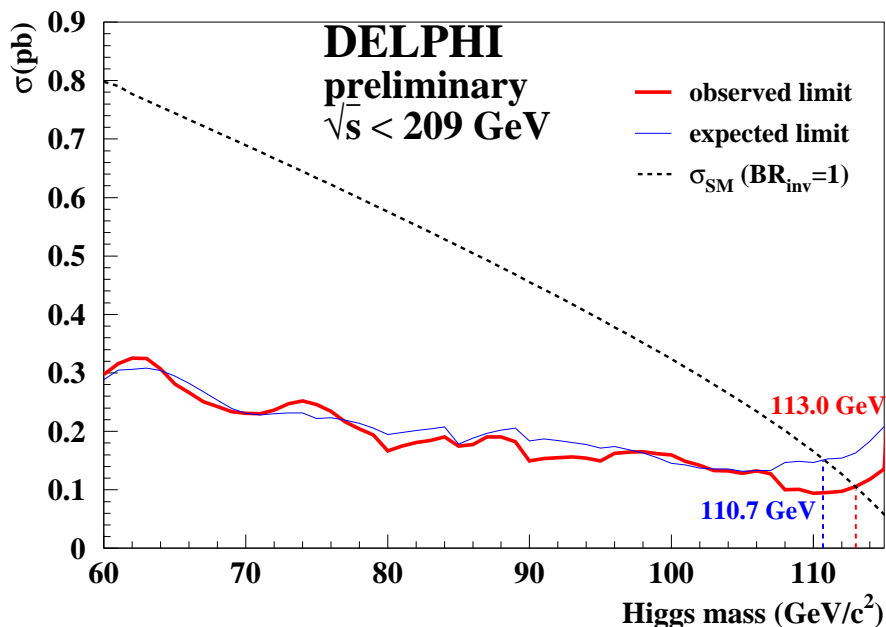
Charged Higgs bosons: cross section limits



Invisible Higgs decays

$$H \rightarrow inv, Z \rightarrow q\bar{q}, l^+l^-$$

- iterated discriminant analysis in hadronic channel
- sequential cuts for leptonic channels



BR 100% $m_H > 113.0 \text{ GeV}/c^2$ (110.7 GeV/c^2 exp.)
Any BR $m_H > 112.6 \text{ GeV}/c^2$ (109.8 GeV/c^2 exp.)



DELPHI Higgs Limits Summary

framework	observed	expected	remarks
SM	114.3 GeV/c ²	113.5 GeV/c ²	-
H^+H^-	73.8 GeV/c ²	75.4 GeV/c ²	any BR($H^\pm \rightarrow \tau\nu$)
H_{inv}	113.0 GeV/c ²	110.7 GeV/c ²	BR($H \rightarrow inv$)=1
$H_{inv} + H_{vis}$	112.6 GeV/c ²	109.8 GeV/c ²	any BR($H \rightarrow inv$)
MSSM m_A	90.9 GeV/c ²	90.1 GeV/c ²	m_h^{max} scenario
m_h	89.8 GeV/c ²	89.0 GeV/c ²	
$\tan \beta$	0.49 ... 2.36	0.54 ... 2.36	
MSSM m_A	90.8 GeV/c ²	90.0 GeV/c ²	no mixing
m_h	90.0 GeV/c ²	89.1 GeV/c ²	
$\tan \beta$	0.59 ... 9.36	0.72 ... 9.36	

All numbers are preliminary!



Prospects ...

Other Higgs-related analyses are on the way:

- general MSSM scan
- $h \rightarrow AA, A \rightarrow Zh$
- flavour blind/ non $b\bar{b}$ Higgs decays:
 - $h \rightarrow \gamma\gamma$
 - $h \rightarrow W^+W^-$
 - $h \rightarrow$ gluon gluon
 - $h \rightarrow s\bar{s}$



Conclusions

- We had a very successful data taking in 2000, the last year of LEP.
- During LEP2 DELPHI accumulated about 688 pb^{-1} above the WW threshold.
- Even after the end of LEP DELPHI is still a very active collaboration.
- No indication for a Higgs signal has been found.
- Many thanks to everybody who provided information to prepare this talk!

