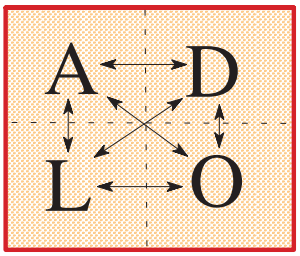
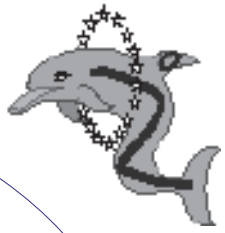
HWG report to LEPC





Status of searches for Higgs bosons at LEP with $\sqrt{s} \leq 210$ GeV

presented by

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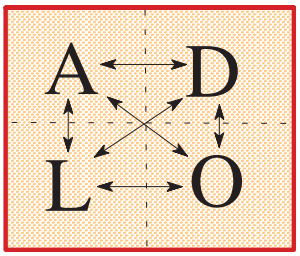
for the

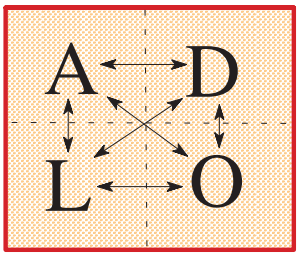
LEP working group for Higgs Boson searches:
S. Andringa, P. Bock, M. Carena, P. Colas, M. Felcini, I. Fisk, T. Fragat, P. Garcia-Abia, S. Heinemeyer, K. Hoffman, A. Holzner, D. Horváth, P. Janot, P. Igo-Kemenes, T. Junk, M. Kado, E. Locci, P. Lutz, C. Martinez-Rivero, P. McNamara, W. Murray, K. Nagai, A. N. Okpara, M. Oreglia, A. Quadt, A. Raspereza, A. Read, A. Rosca, V. Ruhlmann-Kleider, A. Sopczak, M. Stanitzki, P. Teixeira-Dias, A. Tilquin, C. Tully, C. Wagner, G. Weiglein, S. Yamashita

Outline



- Introduction
- SM Higgs
- MSSM neutral Higgs
- 2 HDM Charged Higgs
- Fermiophobic Higgs
- Invisible Higgs decays
- Summary

Introduction



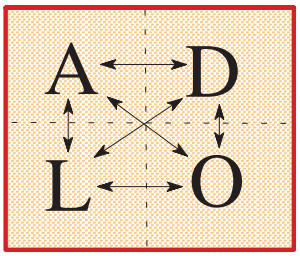
- Total luminosity in Y2K inputs delivered to HWG (last data update 10 July): ~360 pb^{-1}

- Combinations include (relevant) data taken ≤1999.

- Y2K data are placed in $\sqrt{s}$ bins (which vary from search to search and experiment to experiment) to prevent explosion in number of channels.

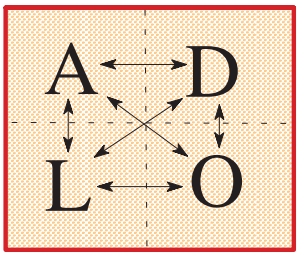
- Both the inputs to the HWG and the combination results are very fresh, and thus **preliminary,** but in most cases there has been time for satisfactory cross-checks.

SM Higgs search



- HZ, $H\upsilon_e\overline{\upsilon_e}$ (small) , He^+e^- (tiny) final states
- Only remaining freedom is Higgs mass
- H branches mainly to $b\bar{b}$ O(85%) and tau-pairs O(7%)
- Select SM Z decays, use Z mass constraint when relevant

Individual SM limits

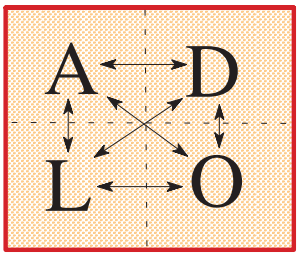


Expected (median, in presence of background-only) and observed SM Higgs mass exclusion limits (GeV).

Experiment	Expected at Moriond	Expected	Observed
ALEPH	107.2	111.0	110.6
DELPHI	106.3	109.2	109.0
L3	105.3	108.2	107.4
OPAL	105.2	109.8	110.0
LEP	109.1		

- Moriond individual expected limits computed by experiments.
- New results from combination procedure - consistent to ~0.2 GeV with experiments.
- Improvements of 3-5 GeV!
  - beam energy
  - analysis optimization

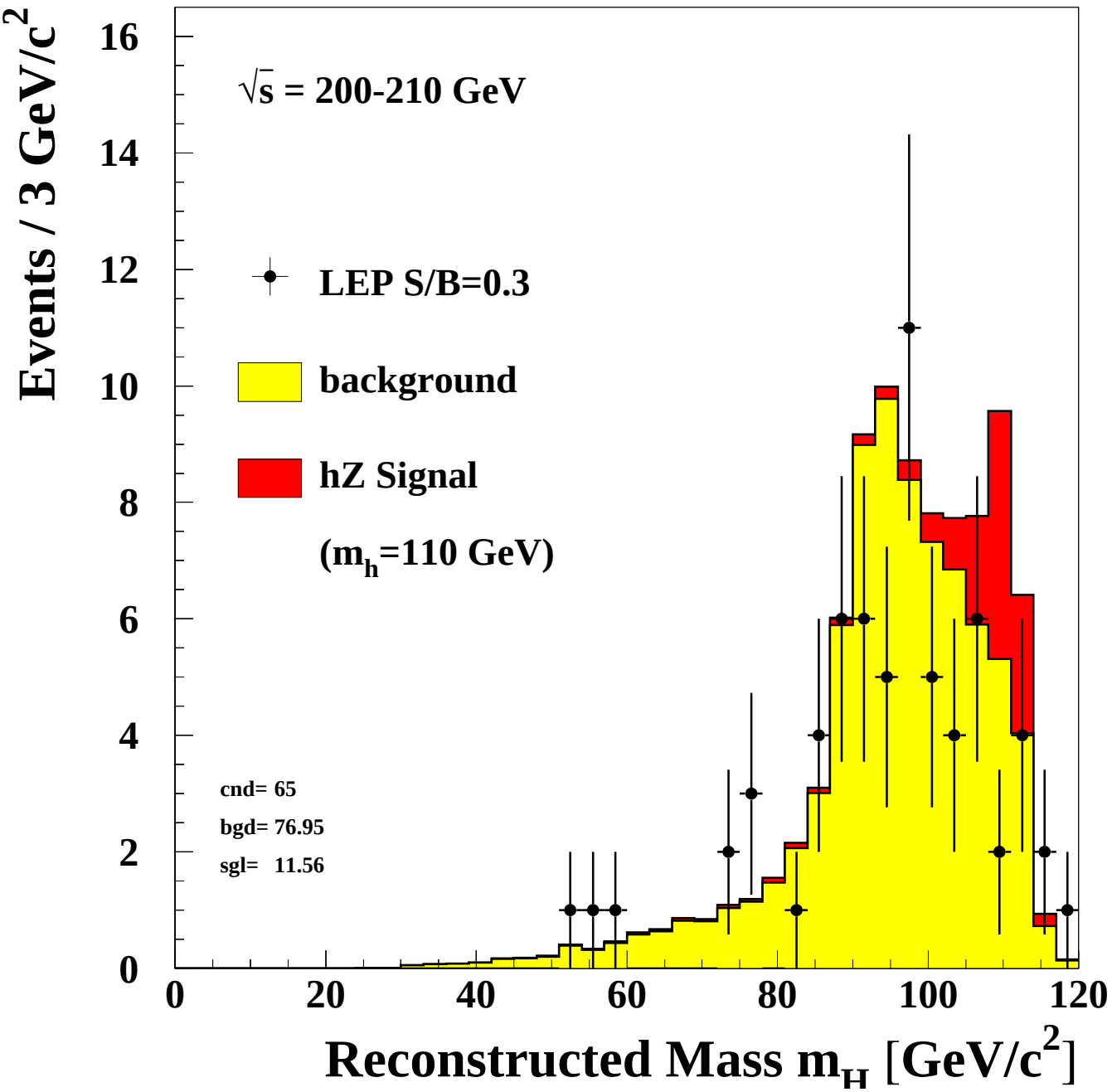
Mass plots



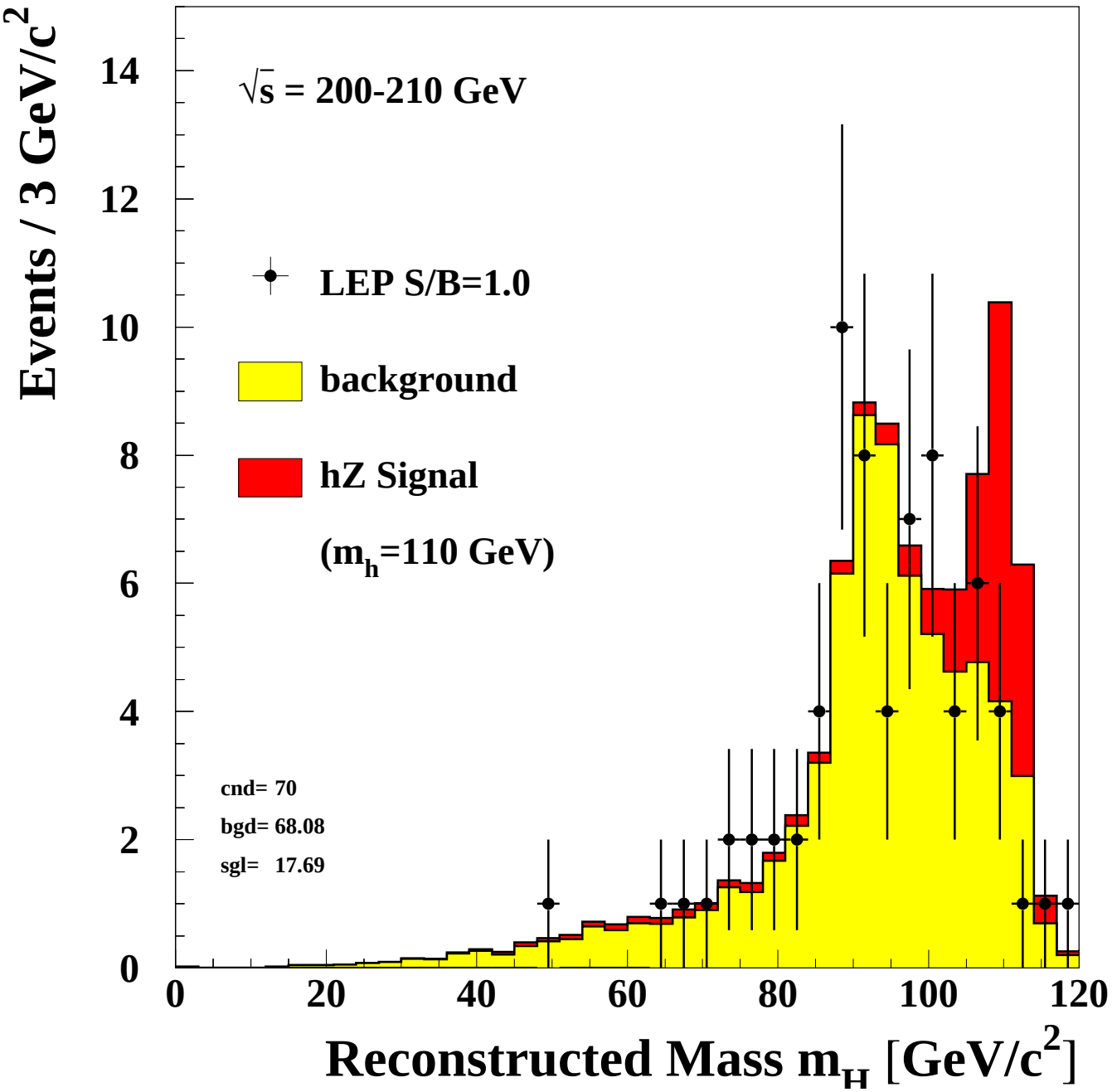
- "Significant" candidates only
- not used directly in limits and significance calculations
  - illustration
  - cross-check of calculations
- Produced versus:
  - center-of-mass energy
  - experiment
  - channel
  - 3 different S/B cuts
    - low = 0.3
    - medium = 1.0
    - high = 2.0

SM Mass plots low S/B

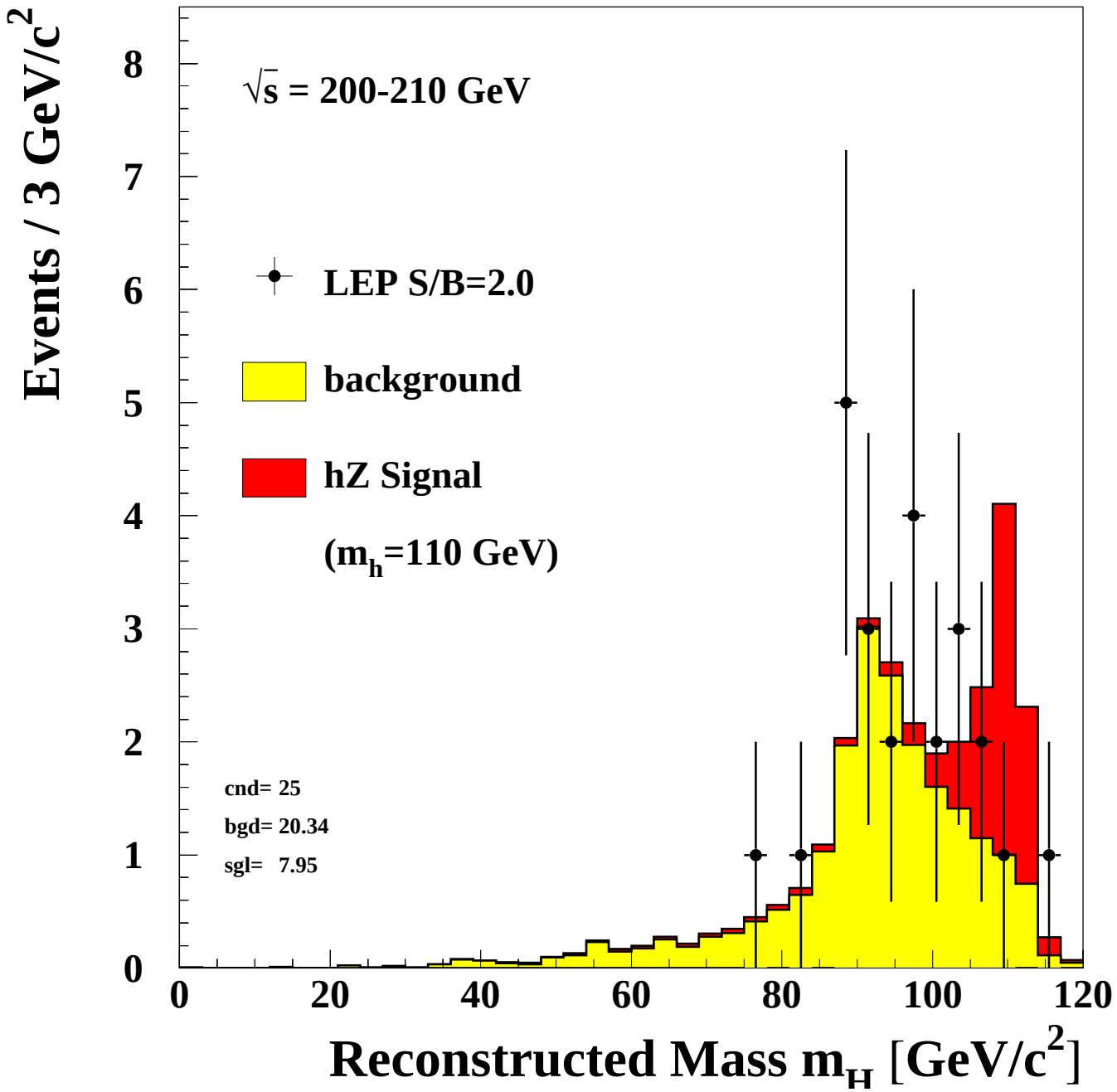
S/B computed for $m_{rec}>105$



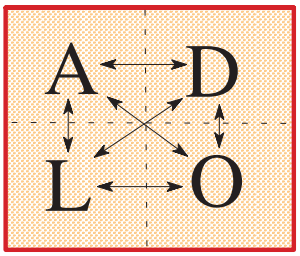
SM Mass plots medium S/B

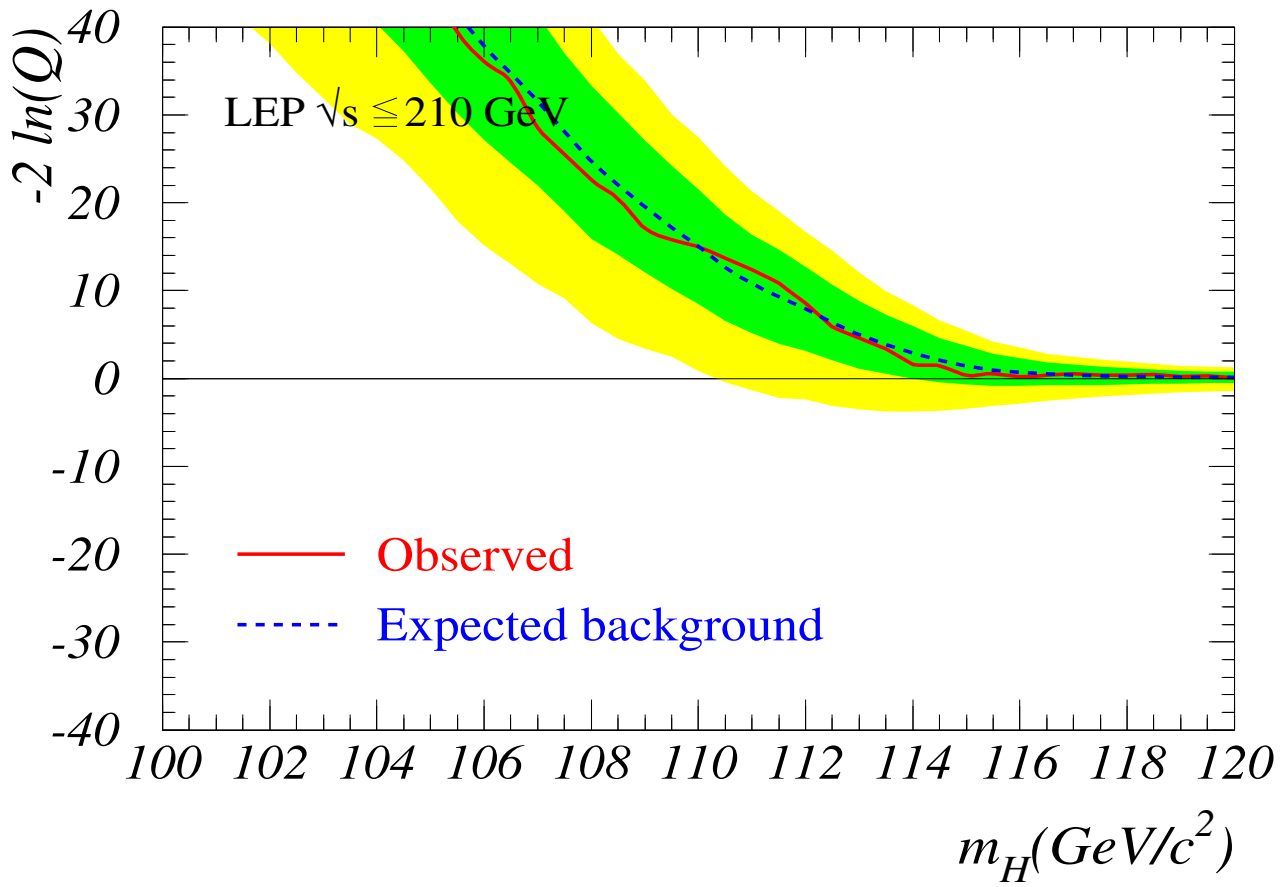


SM Mass plots high S /B



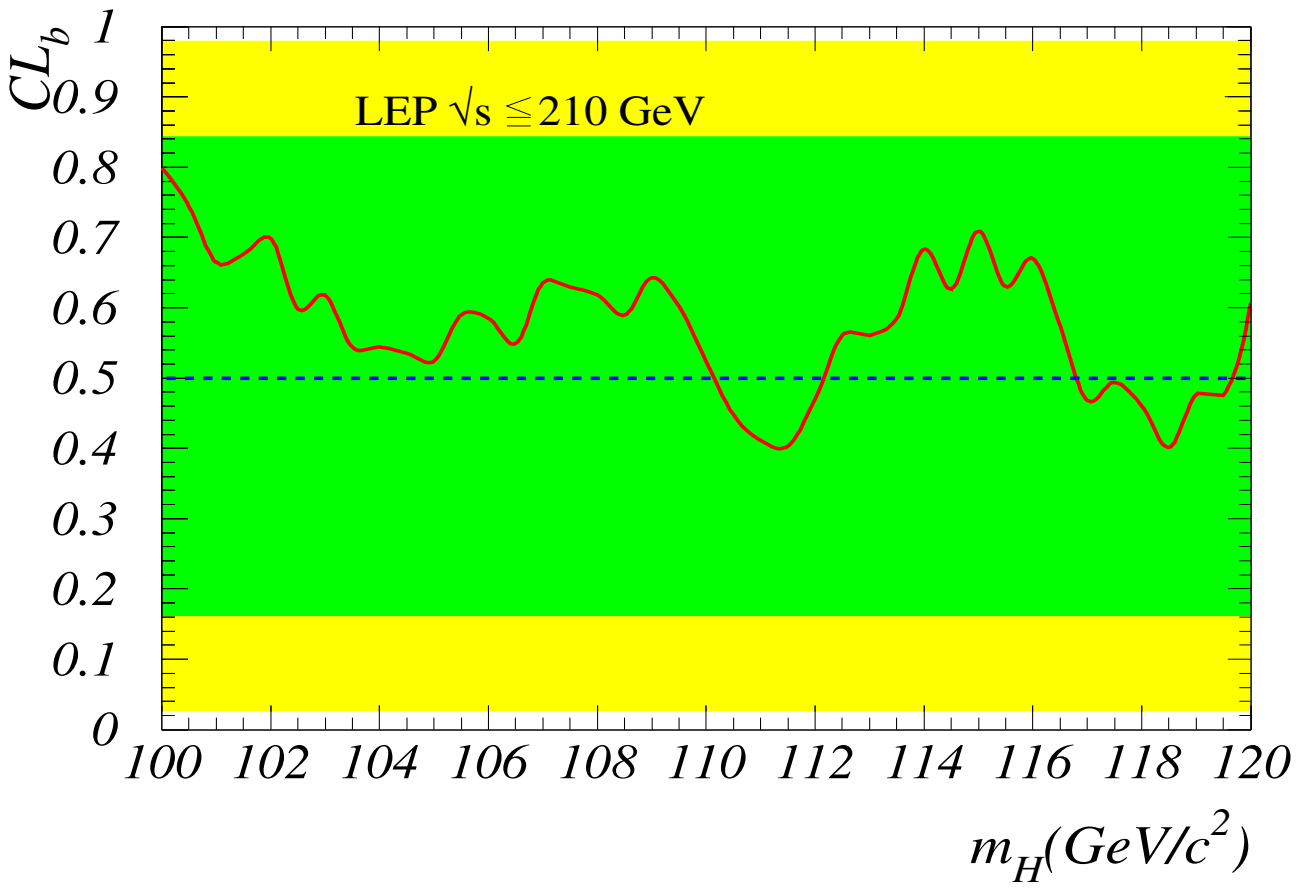
-2lnQ background expectations





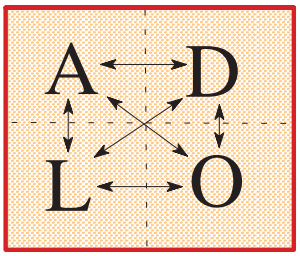
- In high-stats limit, -2lnQ $\rightarrow \Delta(\chi^2)$
  - but careful, we are not there yet!
- Anything below zero means signal favored

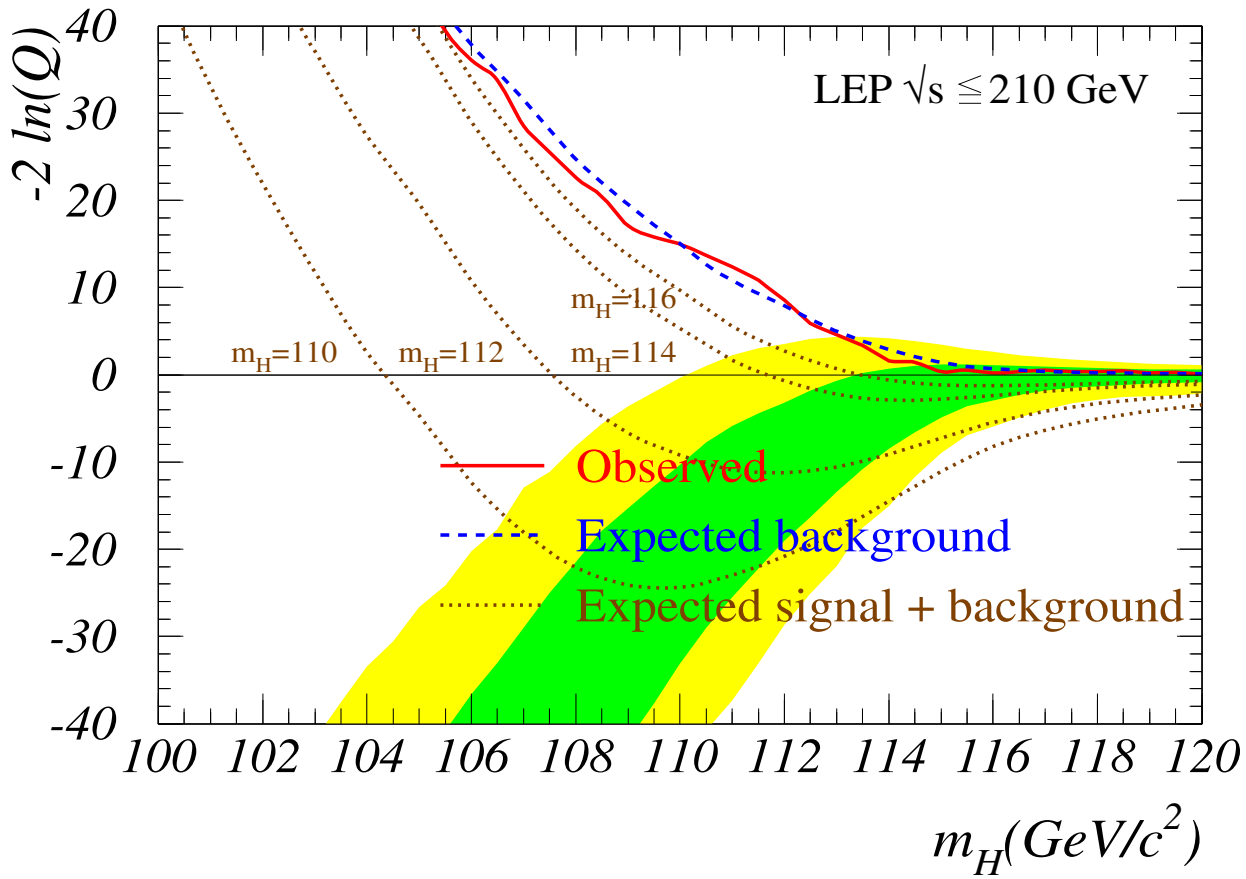
Background compatibility



- mean expected for background is 50%
- signal-like result would be > 1-5s =1-5.7x10^{-7}

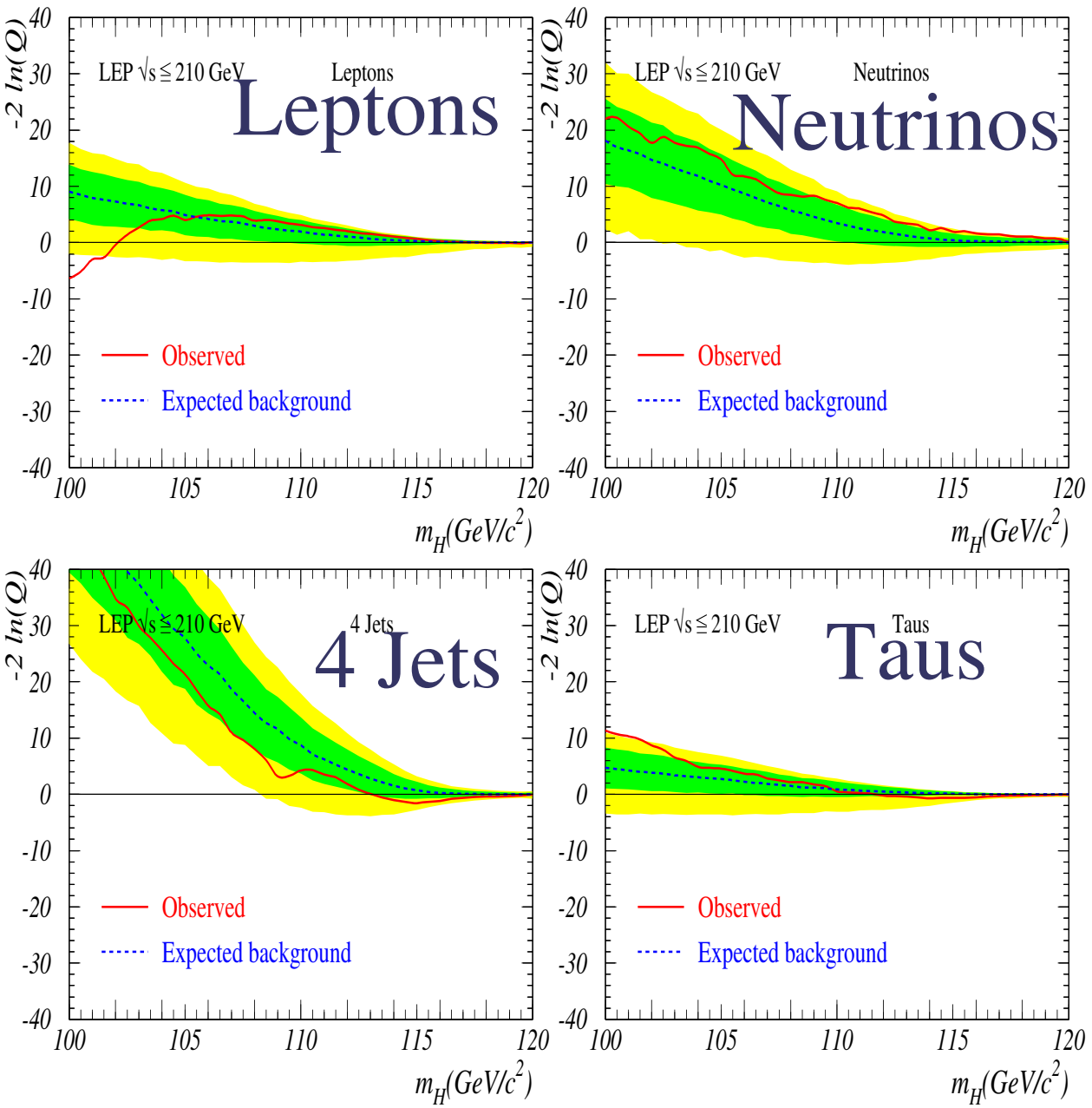
-2lnQ signal expectations



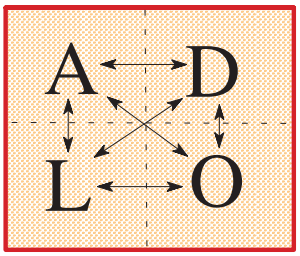


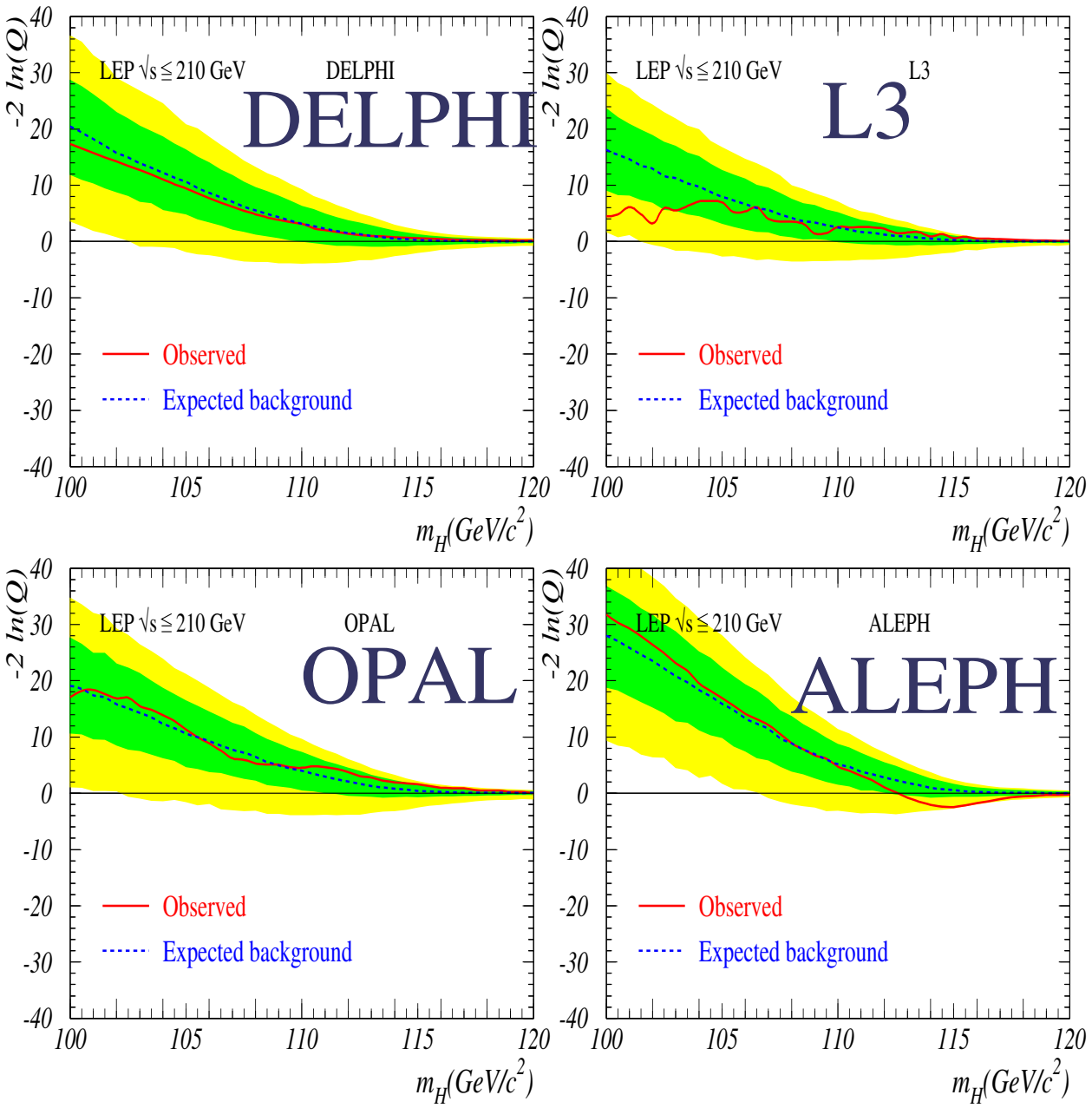
- Signal expectations for various m_H done for technical reasons with 4 times typical LEP experiment
- Significant minimum gives estimate of Higgs mass
- Note the overlap of signal band and background median at highest masses.

SM -2lnQ by channel

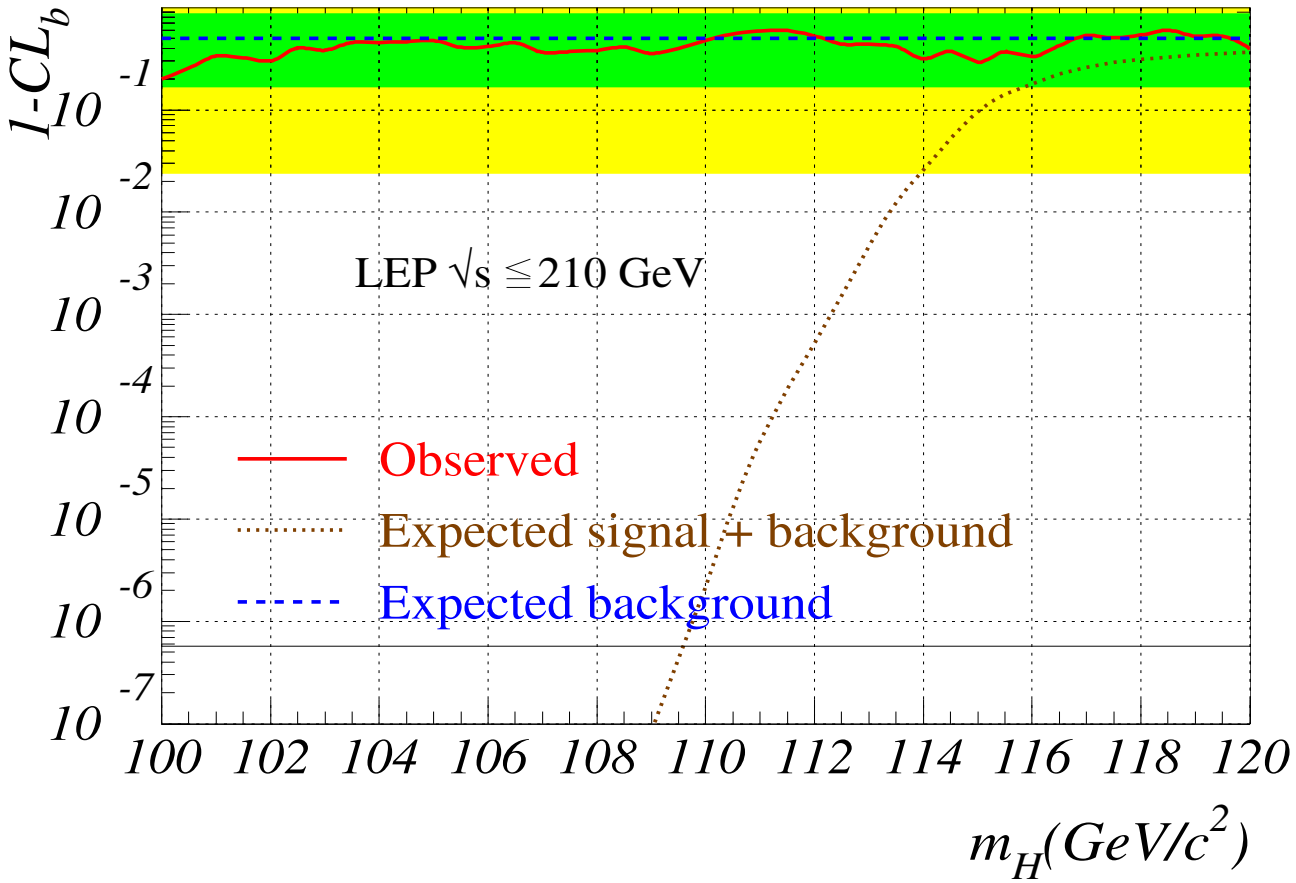


SM -2lnQ by experiment



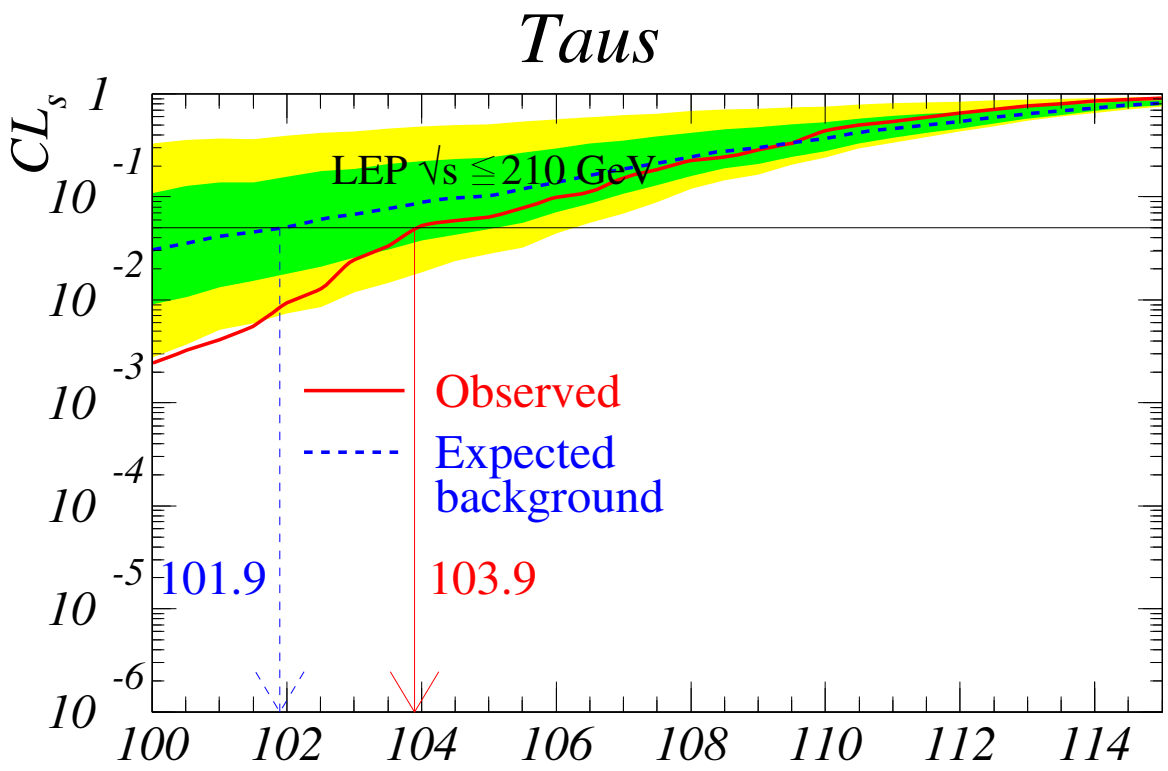


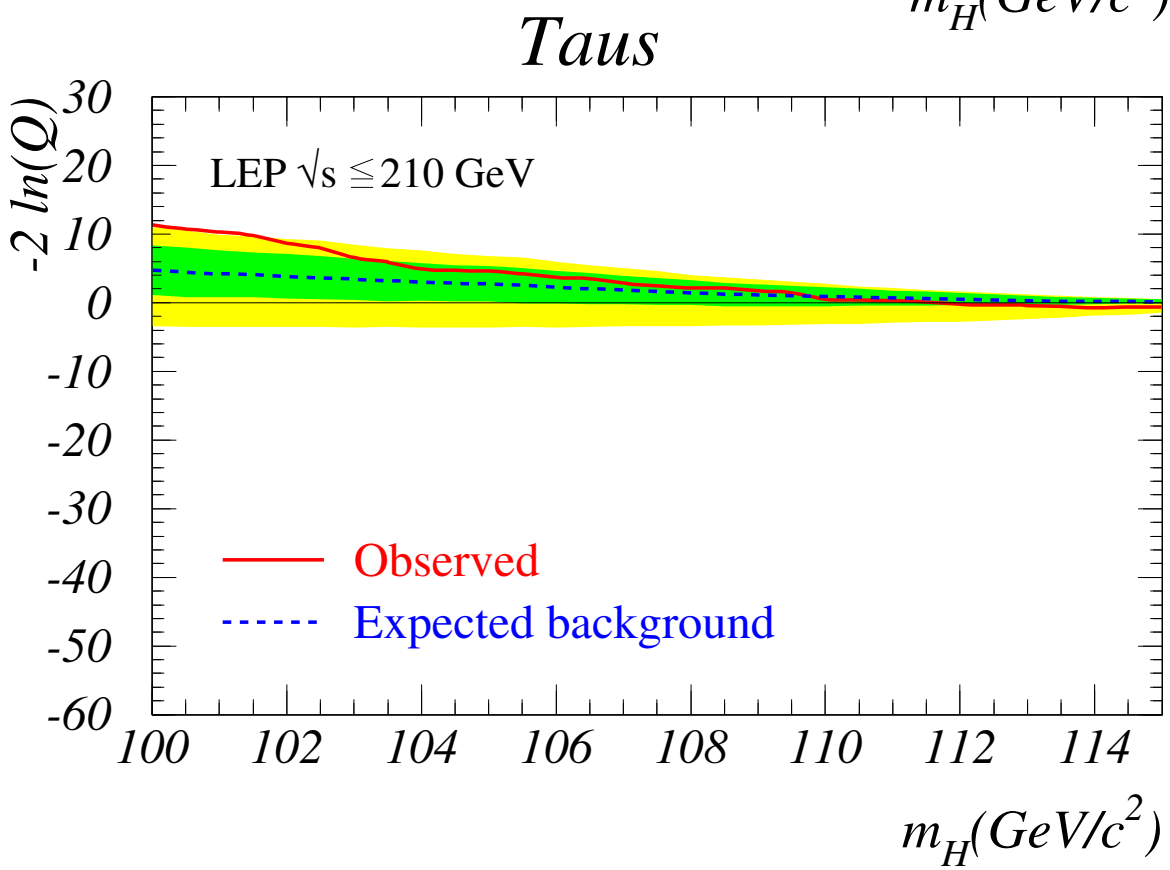
Signal significance (w.r.t backg.)



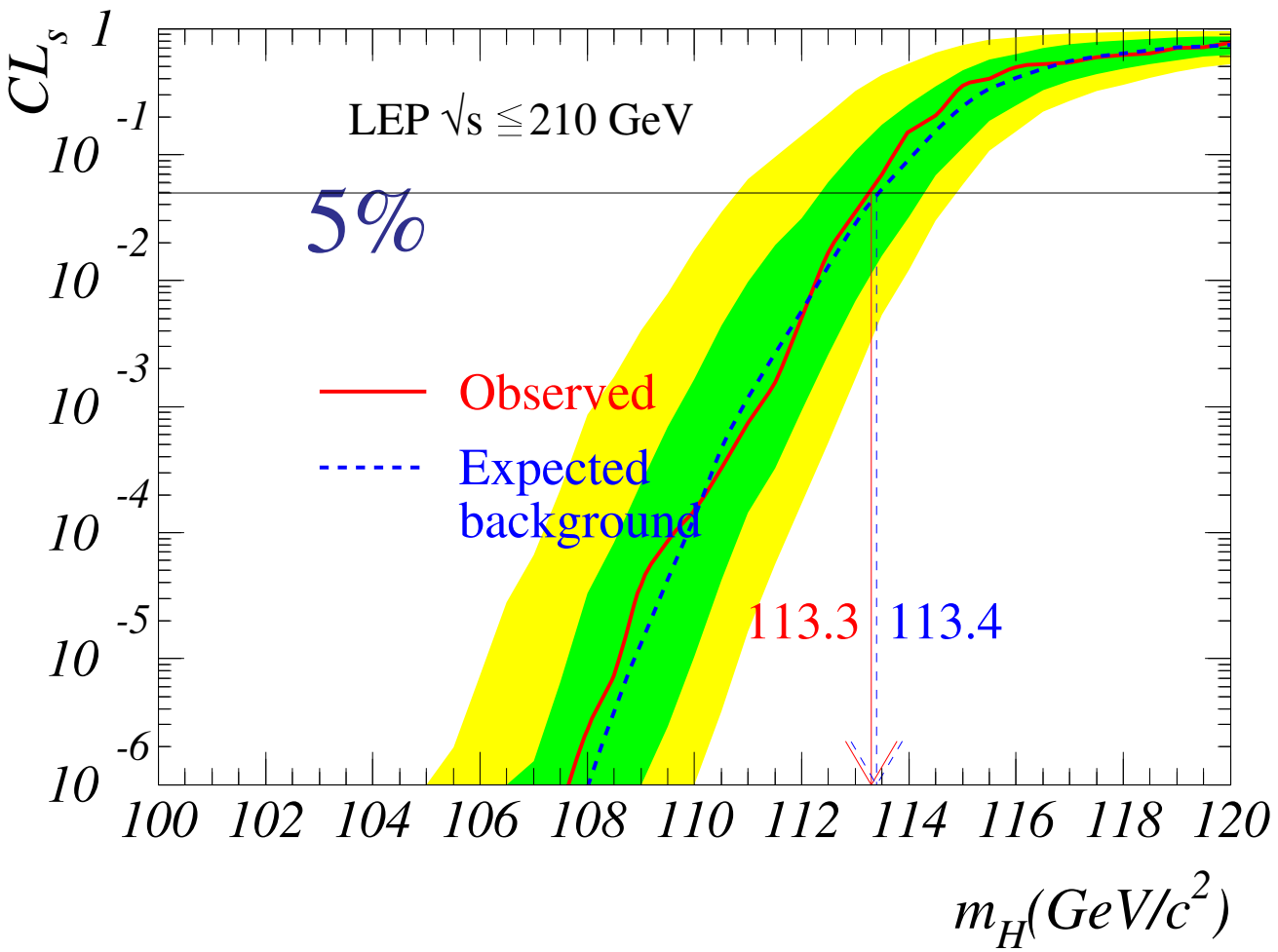
- mean expected for background is 50%
- signal-like result would be $<$ $5\sigma = 5.7 \cdot 10^{-7}$
- Dashed curve gives median expected 1-CL_b for Higgs signal.

Taus final state (Z or H decay)



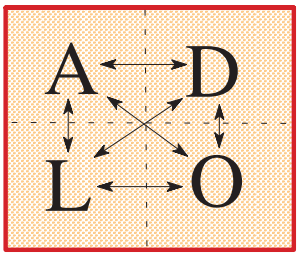


Exclusion limits



- 95% Confidence Limits where CL_S's cross 5%.
- Bands are 68% and 95% confidence intervals expected for background experiments

SM limits by channel



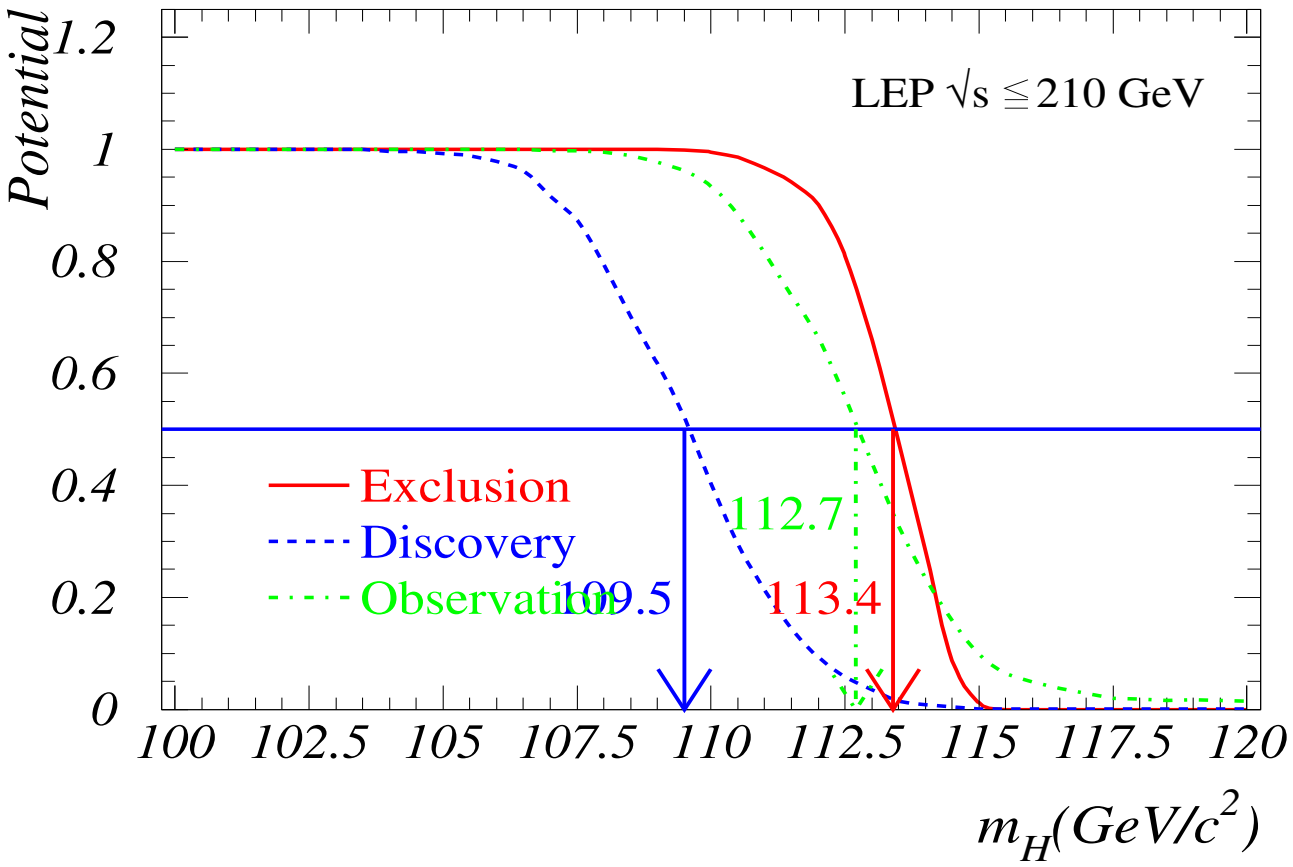
Experiment	Expected	Observed
Leptons	106.4	107.4 (*)
Neutrinos	109.6	111.5
Taus	101.9	103.9
4 Jets	112.2	111.3
LEP	113.4	113.3

(*) Unexcluded window below 102.8 GeV

Search potentials

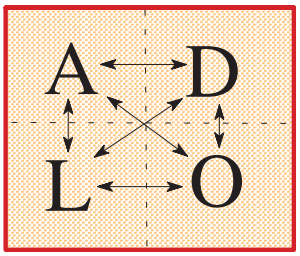
Search potentials for:

"Exclusion" - exclude signal at 95% CL in favor of background
"Observation" - exclude background at 3σ in favor of signal
"Discovery" - exclude background at 5 σ in favor of signal

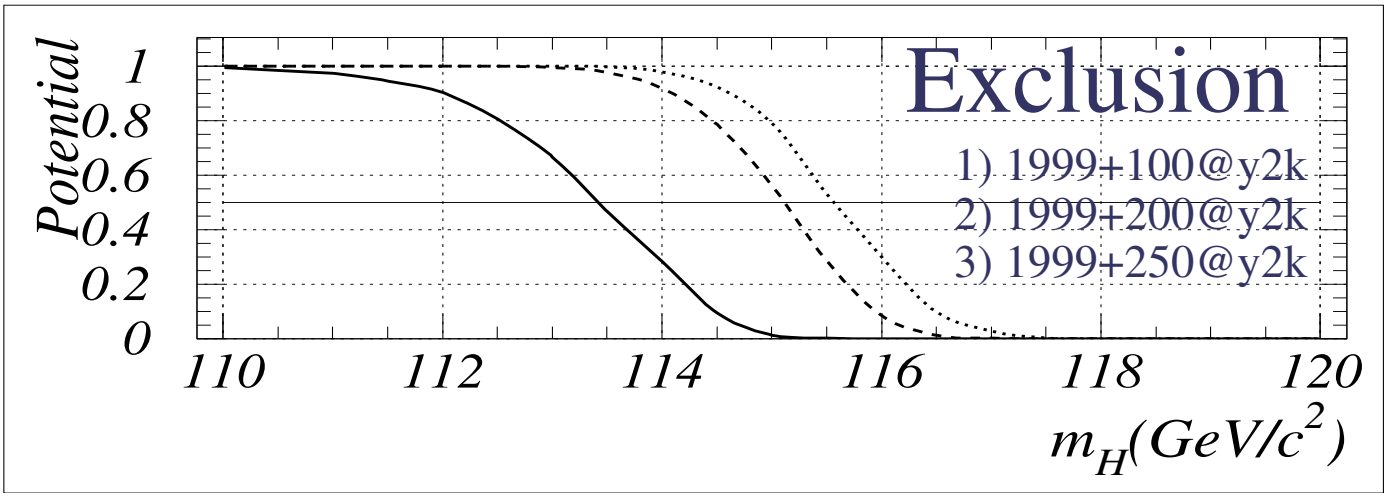


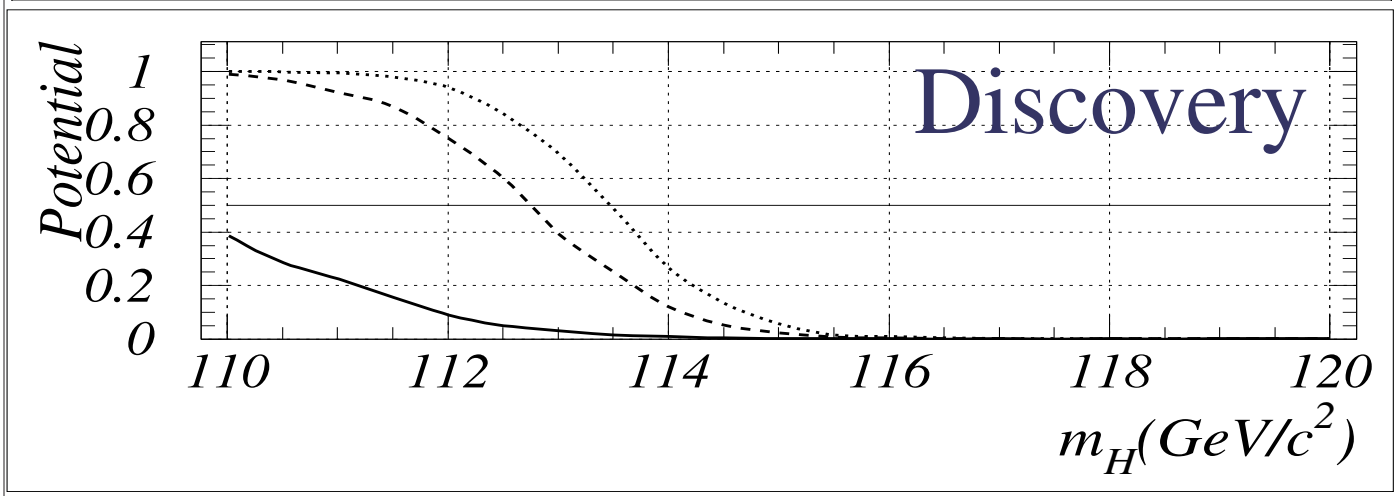
- Observation limit ~0.7 GeV below exclusion limit
- Warning: These potentials assume no previous results!

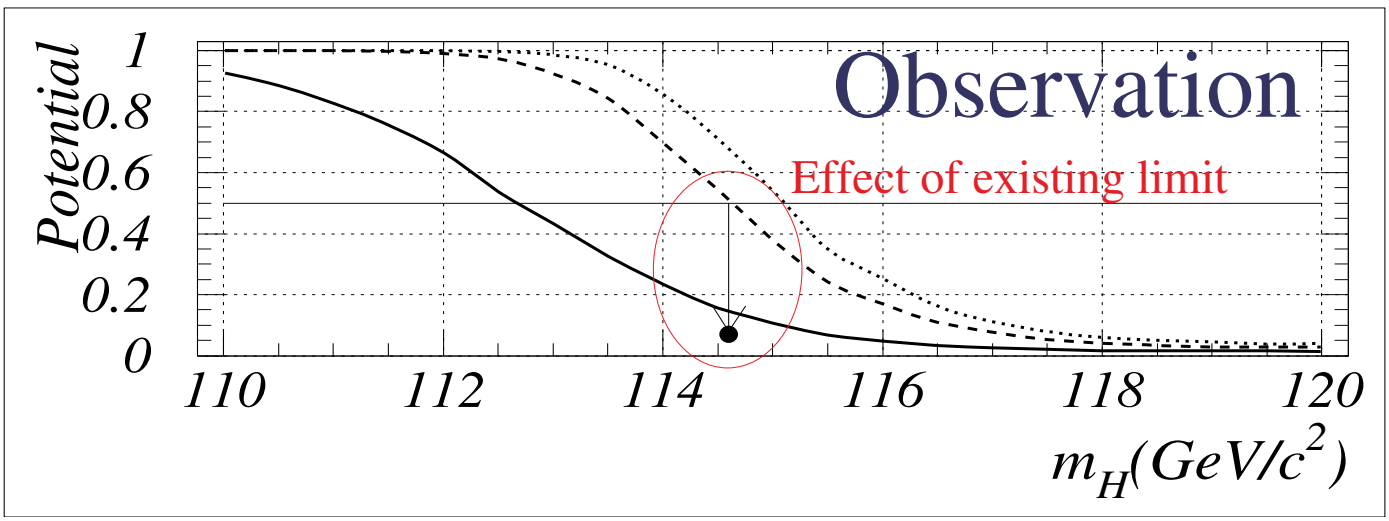
Prospects for rest of Y2K



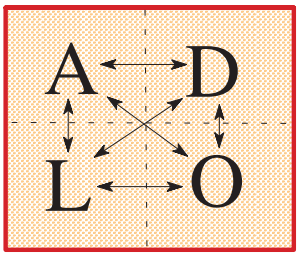
"y2k" ~same mixture of (√s, lumi)







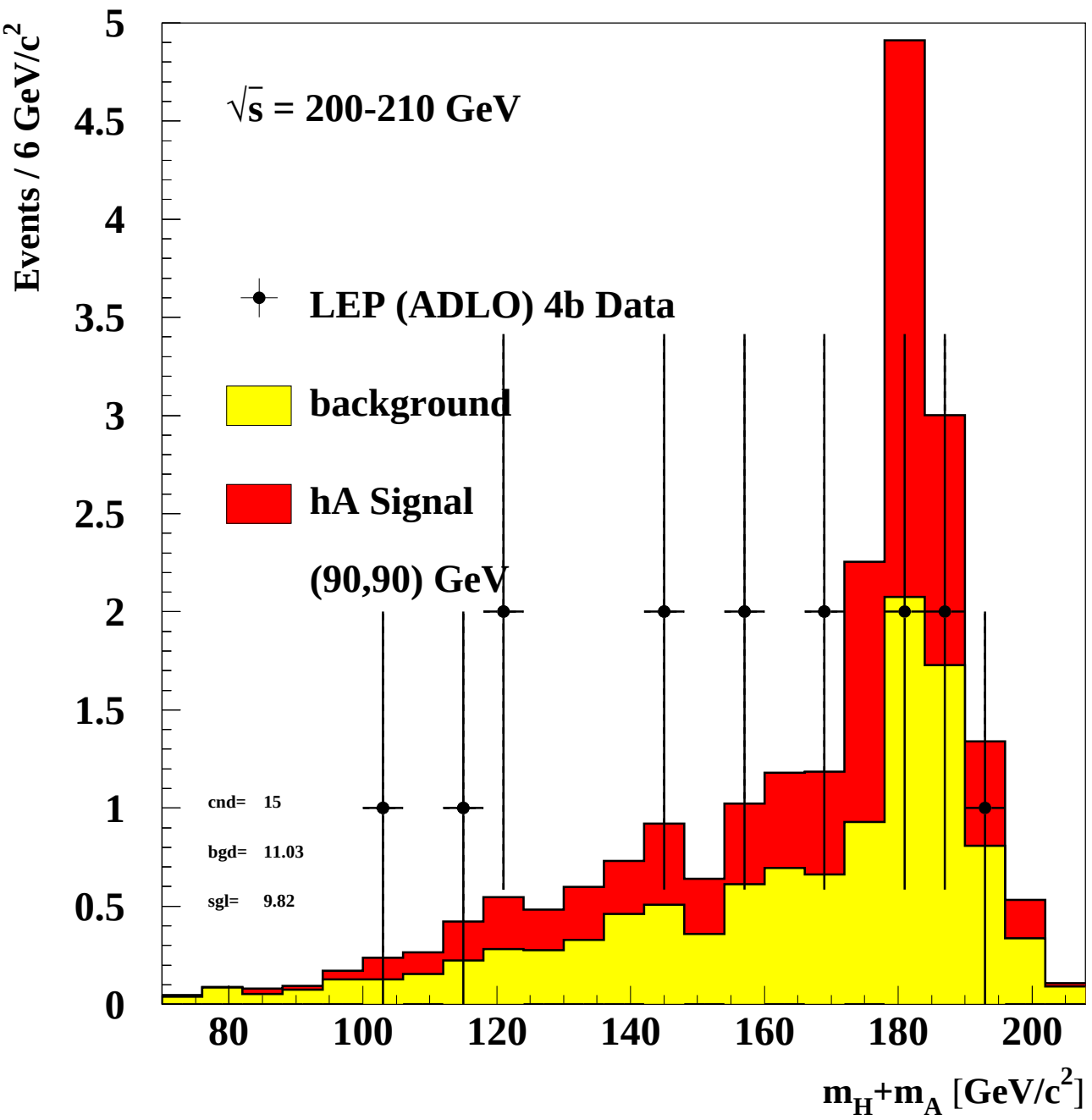
MSSM h,A searches



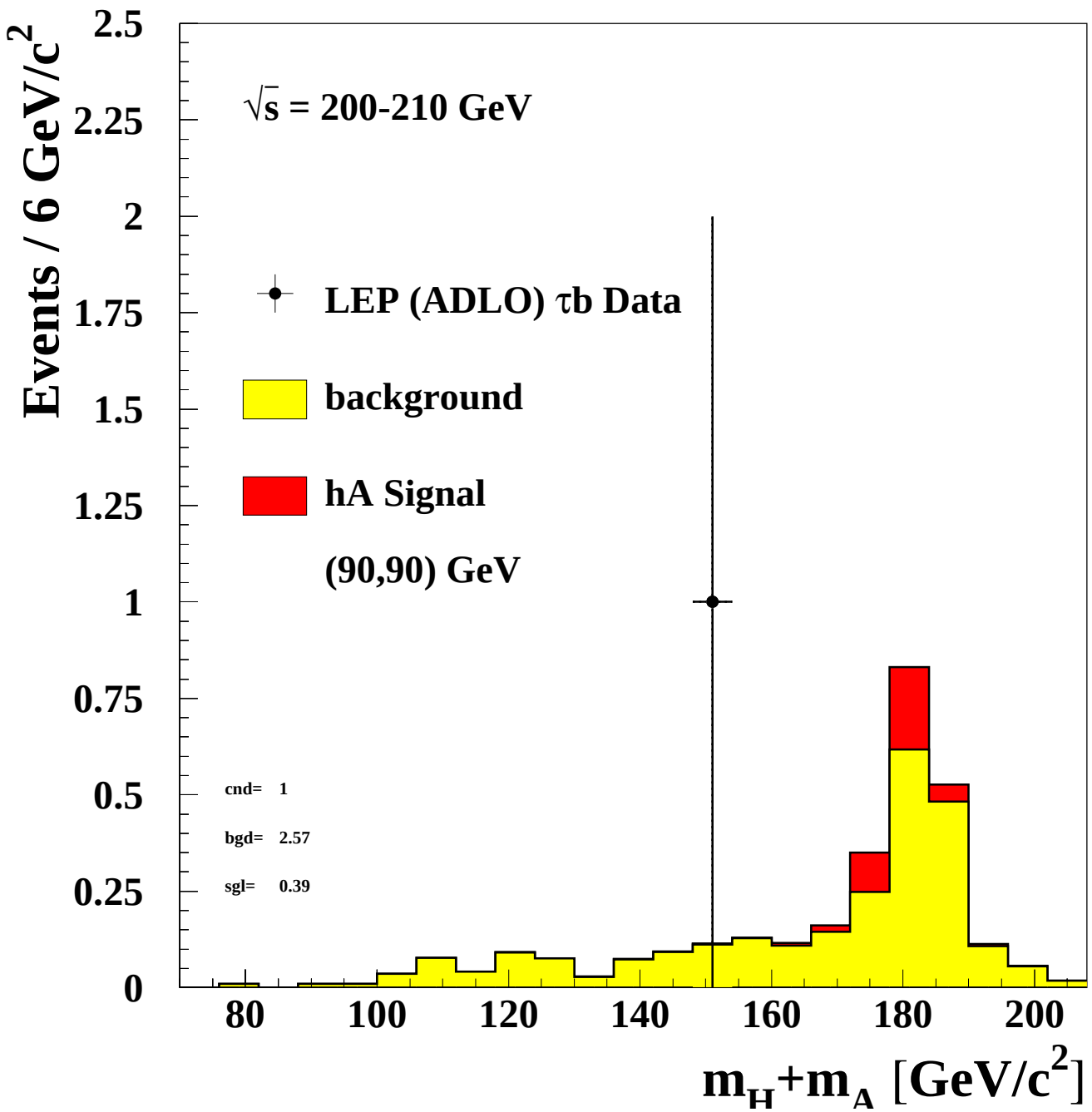
- 2 Higgs doublets
  - 2 charged
  - 2 neutral scalars h<H
  - 1 neutral pseudoscalar A
- two complementary processes
  - hZ (like SM HZ) - $\sin^2(\beta-\alpha)$
  - hA - $\cos^2(\beta-\alpha)$
    - 4 b's
    - bb$\tau\tau$
- three MSSM scenarios

Scenario:	No mixing	m_h-max	large μ
Approach	Diagramm.	Diagramm.	RGE
M_{SUSY}	1 TeV	1 TeV	400 GeV
M_2	200 GeV	200 GeV	400 GeV
μ	-200 GeV	-200 GeV	1 TeV
Xt	$2xM_{SUSY}$	$2xM_{SUSY}$	$\sqrt{6}xM_{SUSY}$
gluino mass	800 GeV	800 GeV	200 GeV
m_A	< 1 TeV	< 1 TeV	< 400 GeV

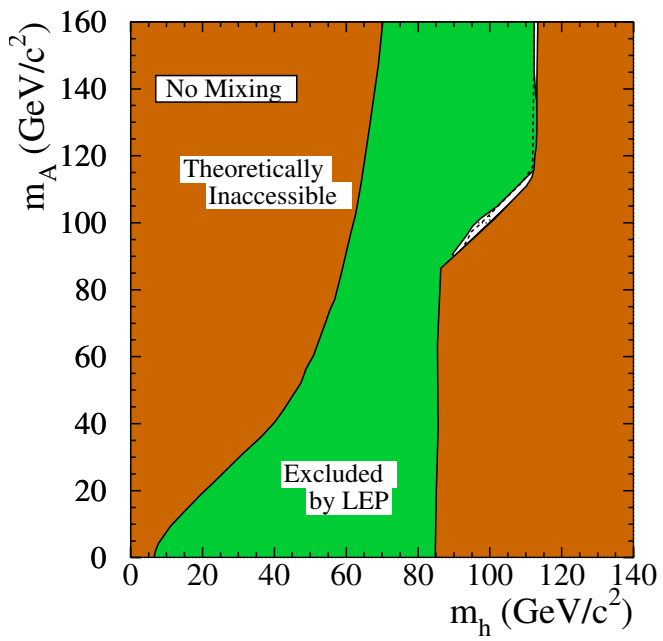
MSSM 4b mass plot

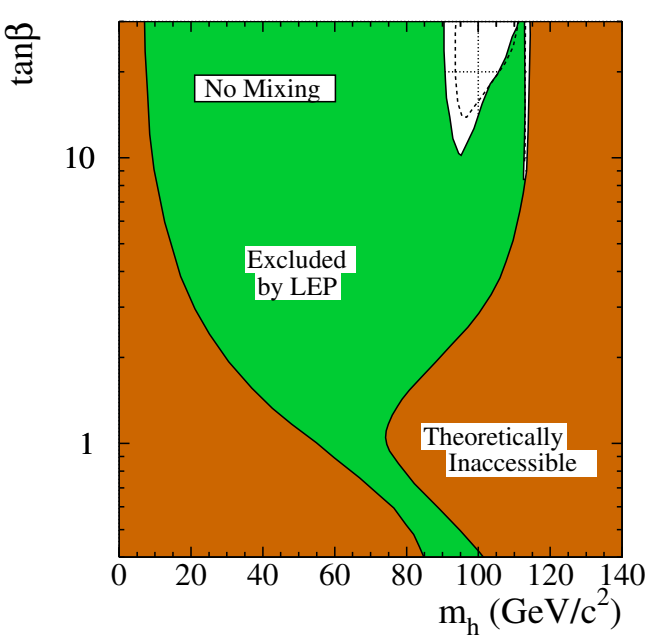


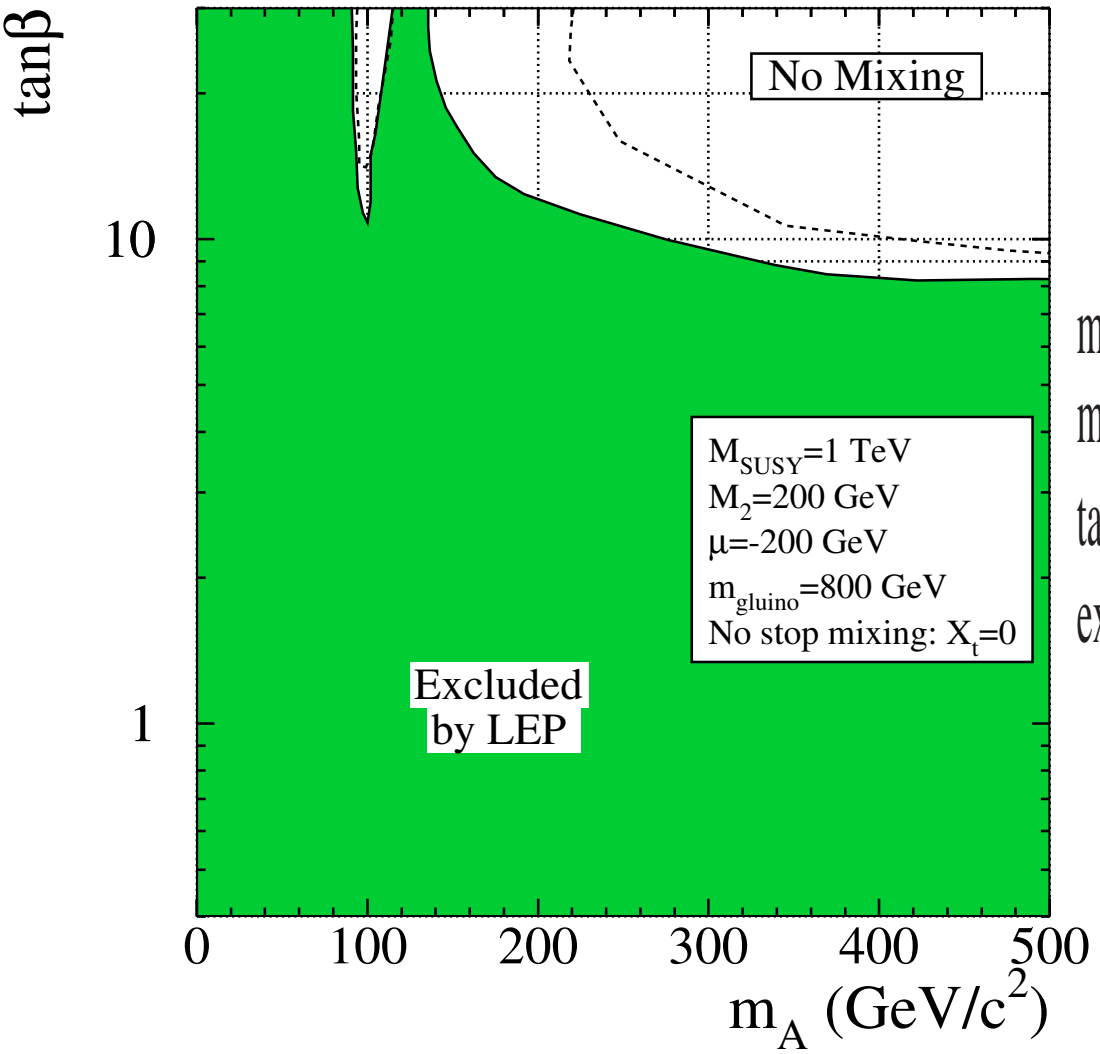
MSSM
bbττ mass plot



MSSM no mixing

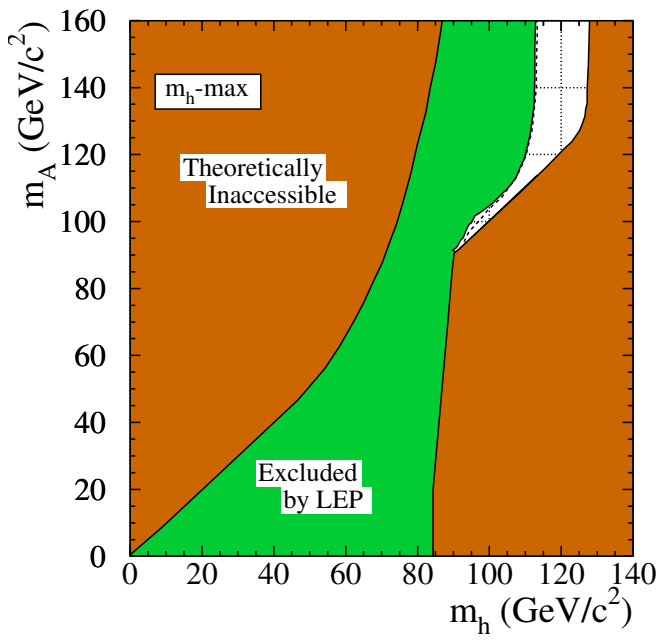


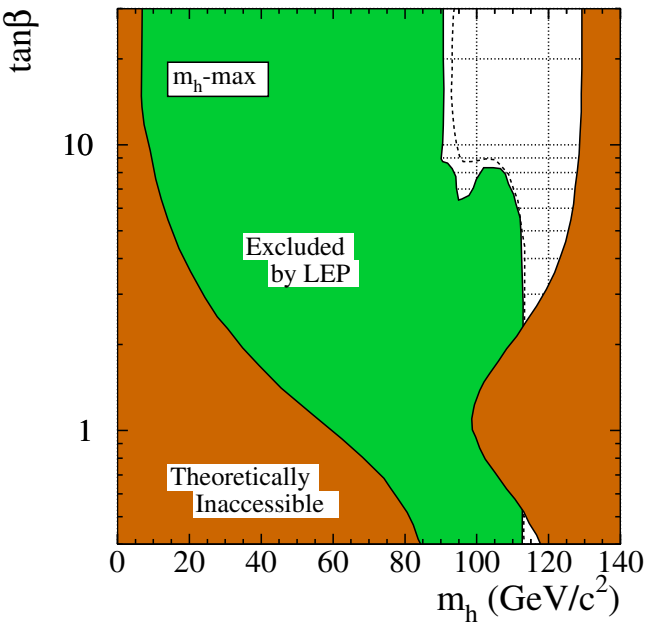


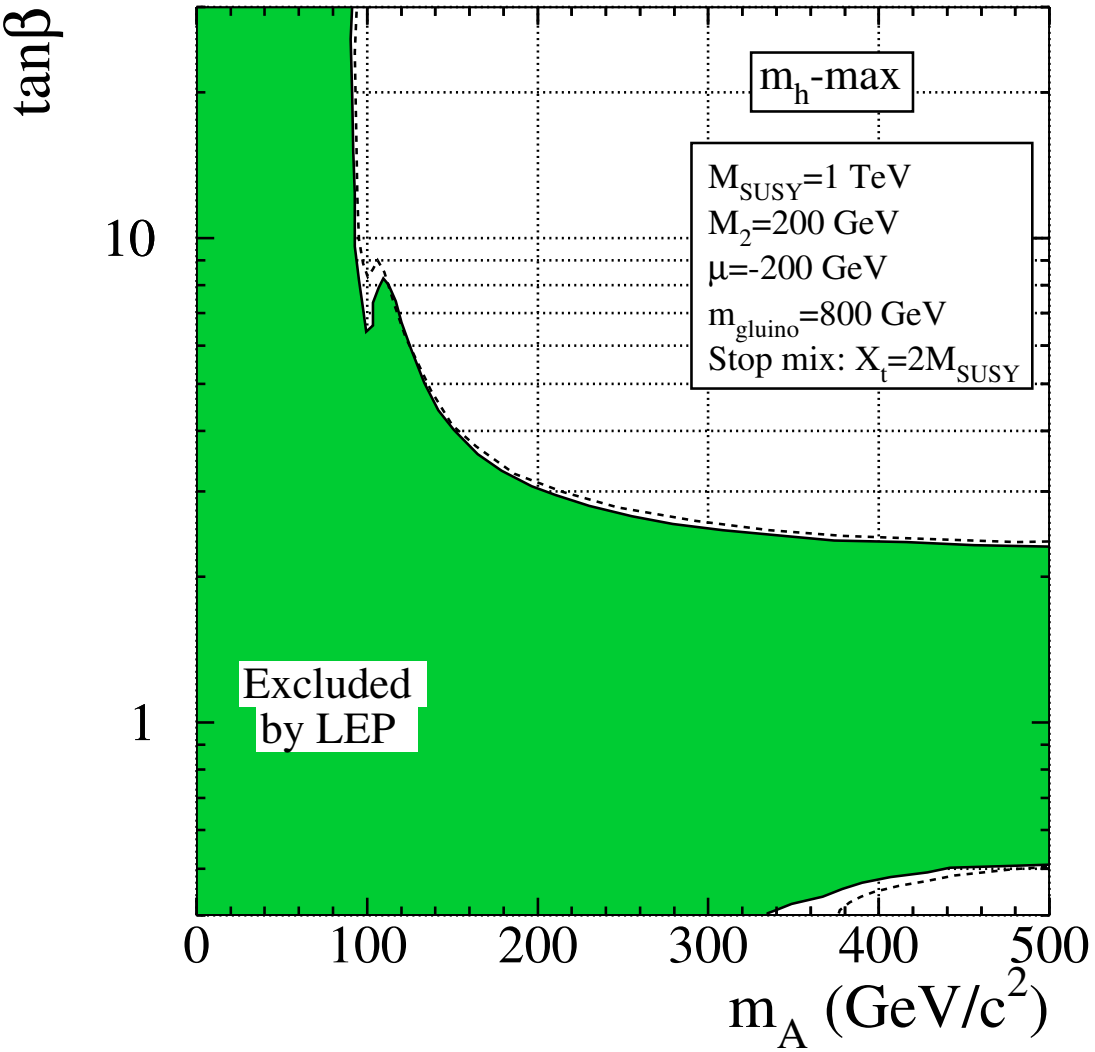


	obs.	exp.
$m_h >$	90.4	92.4
$m_A >$	90.5	92.9
tanβ	0.4-	0.4-
excl.	7.7	8.6

MSSM m_h-max

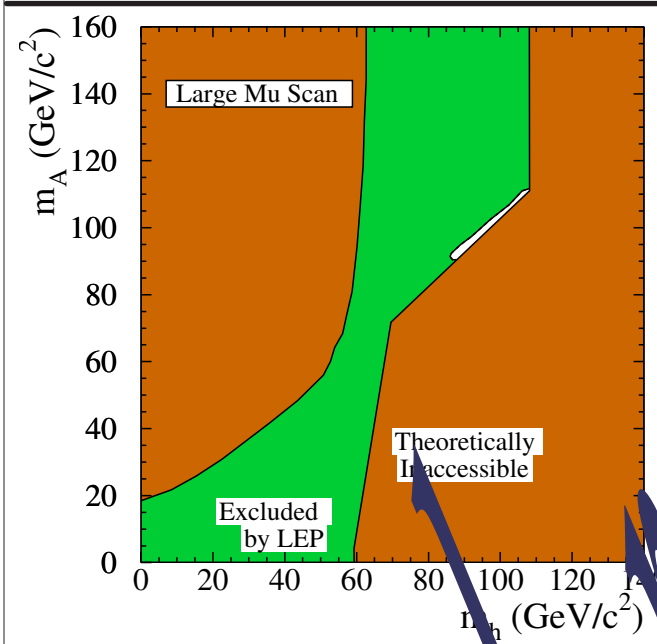


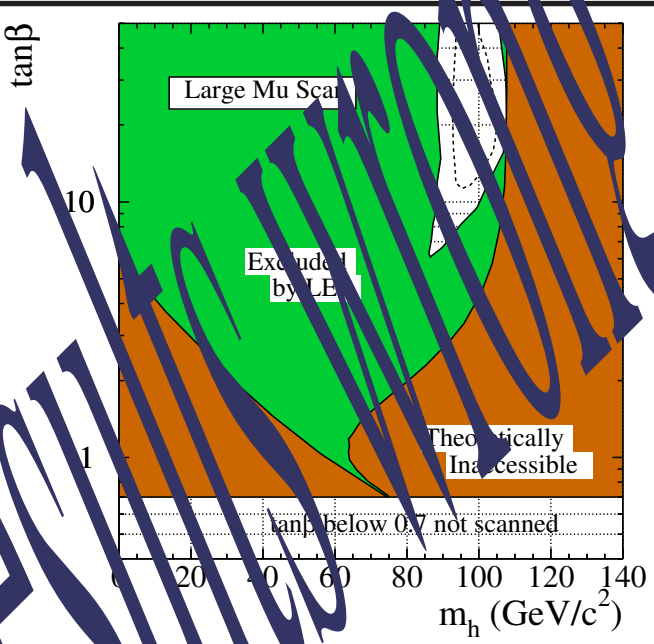


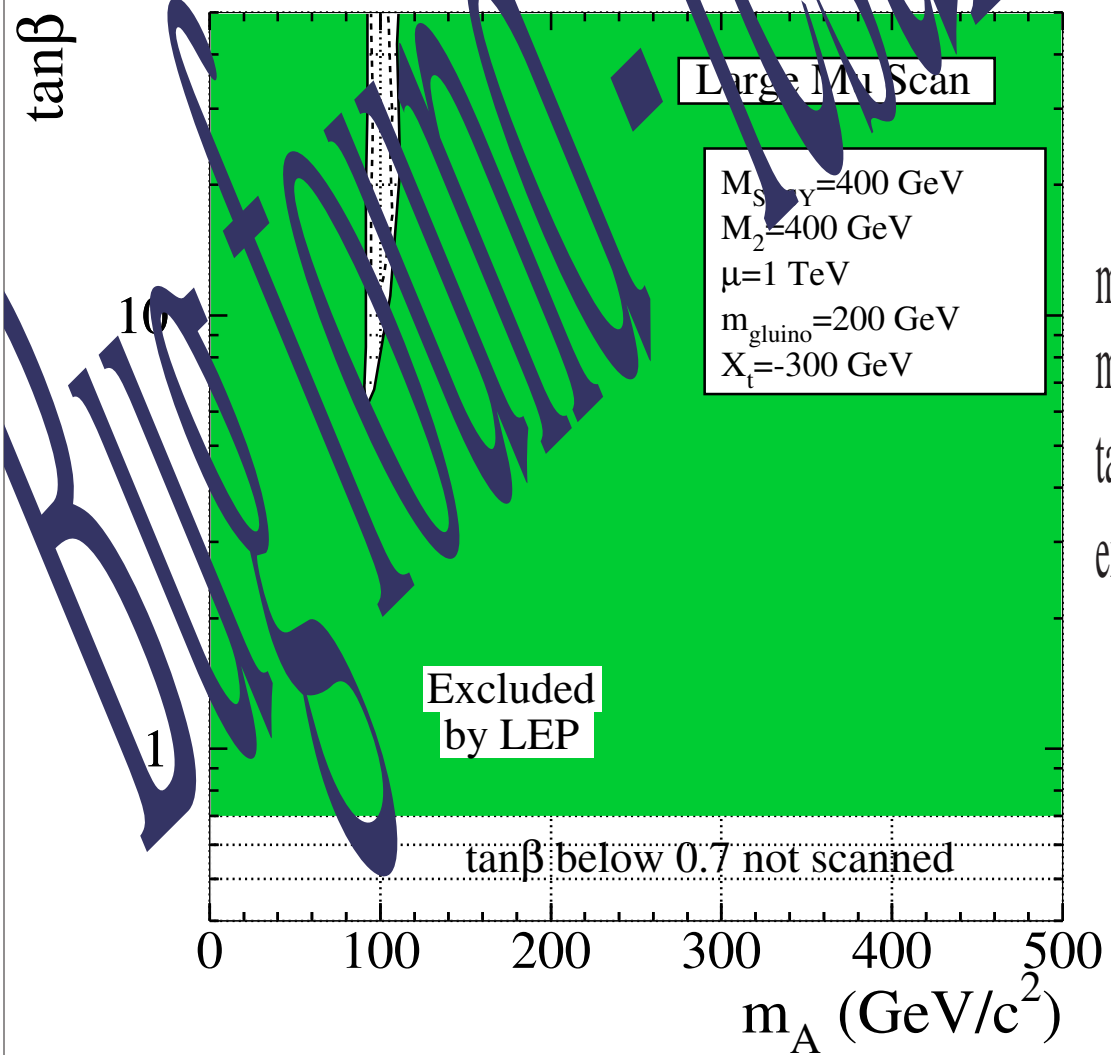


	obs.	exp.
m_h >	90.5	92.2
m_A >	90.5	92.8
tanβ excl.	0.5-2.3	0.5-2.3

MSSM large μ



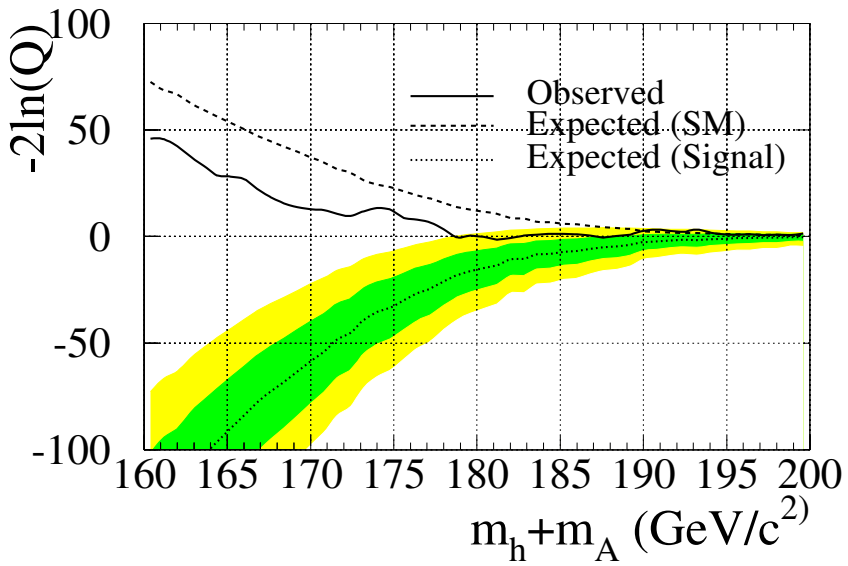




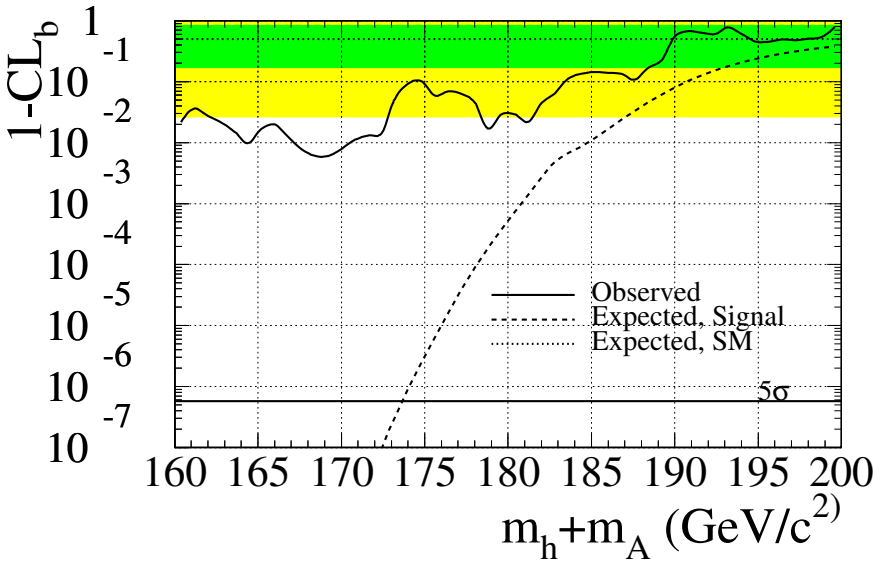
	obs.	exp.
$m_h >$	89.1	91.2
$m_A >$	91.1	93.2
tanβ	0.7-	0.7-
excl.	6.1	10.2

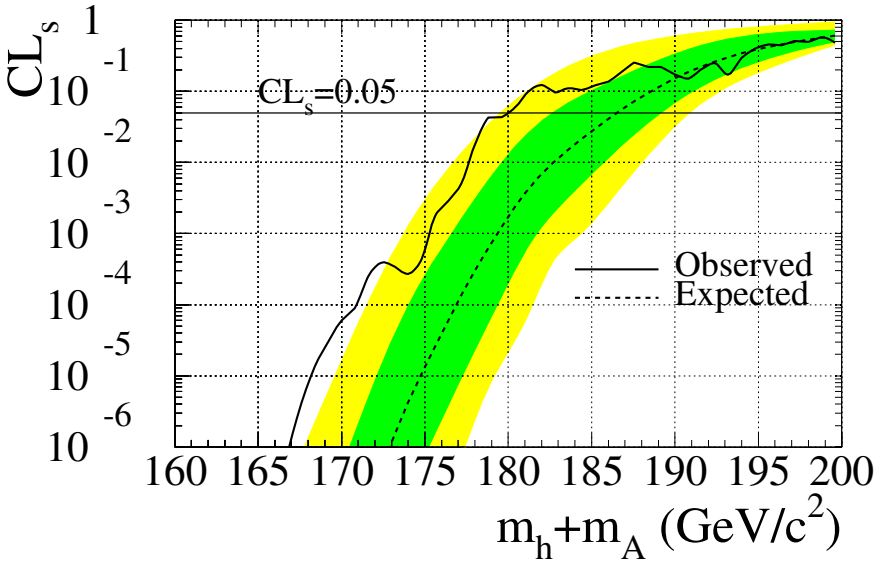
Preliminary

MSSM (m_h-max) $m_A=m_h$



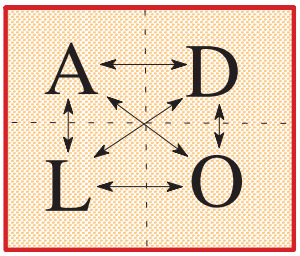
Excess either far from signal or in region of insensitivity

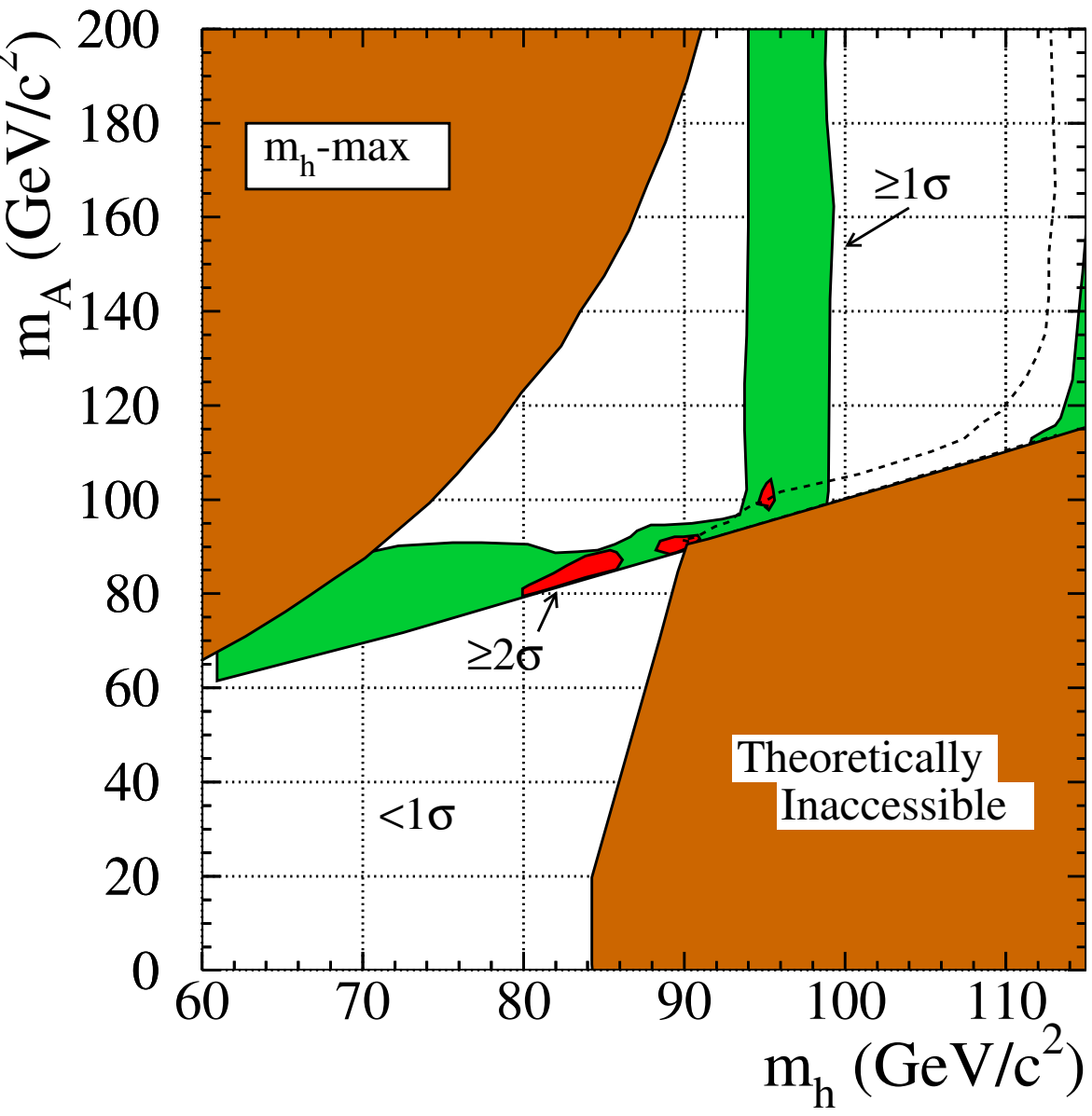




Expected limit increases by ~1.4 GeV with 2x"y2k" lumi (check!!)

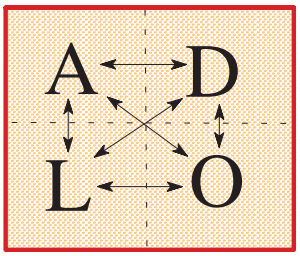
MSSM sig. test (m_h-max)





- "Hotspots" are either in excluded regions or regions of ~no sensitivity.
- Probability to get a 2σ hotspot in previously unexcluded region is ~40%
- No evidence of signal

MSSM limits



m_h max

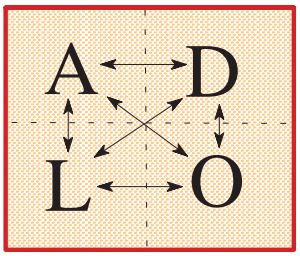
	observed	expected
$m_h >$	90.5	92.2
$m_A >$	90.5	92.8
$\tan\beta$ exclusion	0.5-2.3	0.5-2.3

no stop mixing

	observed	expected
$m_h >$	90.4	92.4
$m_A >$	90.5	92.9
$\tan\beta$ exclusion	0.4-7.7	0.4-8.6

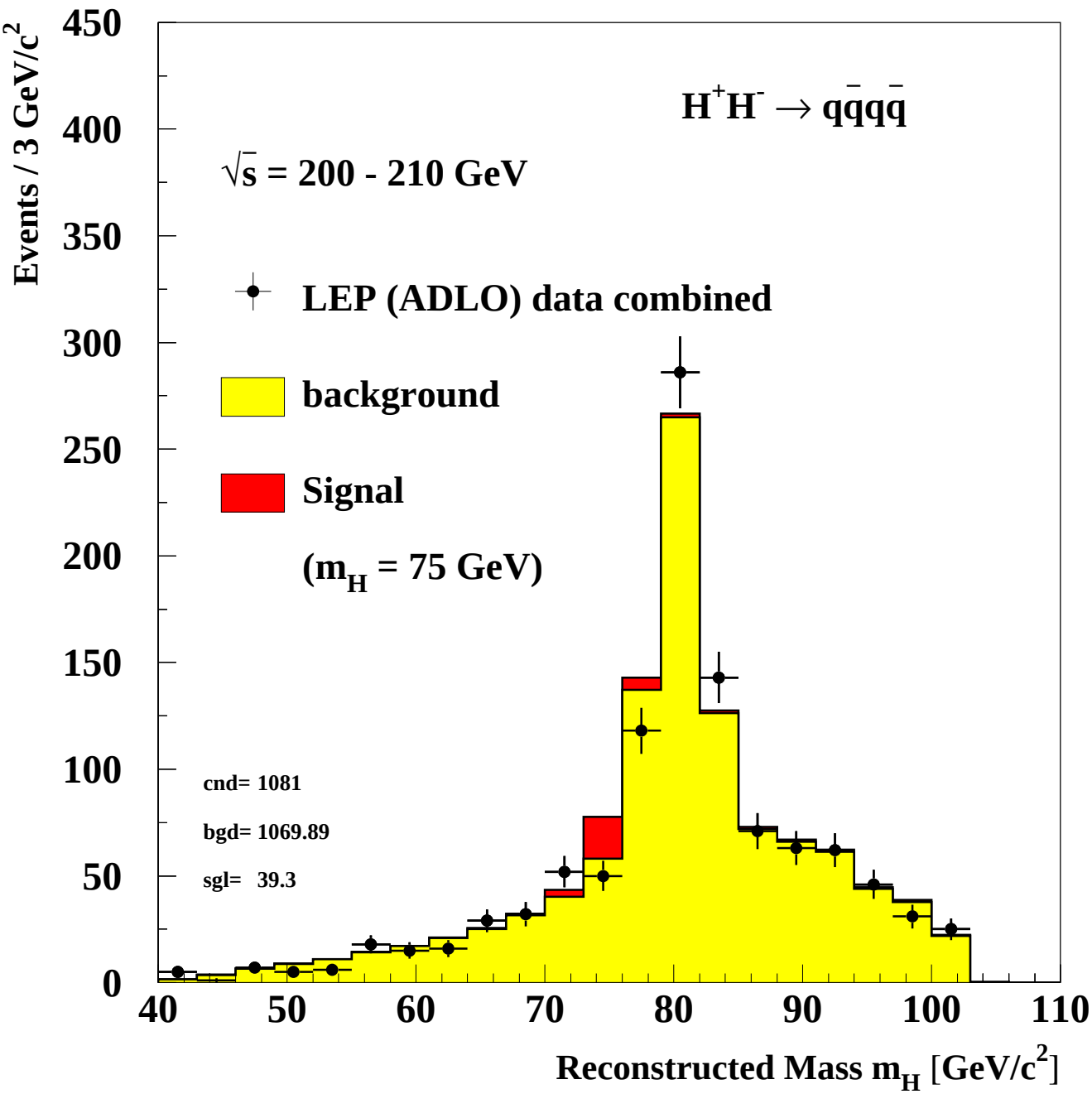
- Expect to exclude beyond Z, but existing candidates make it difficult.

H^+H^- search

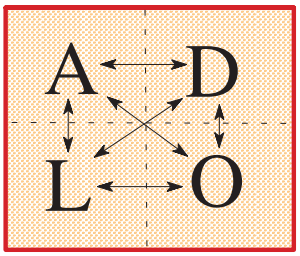


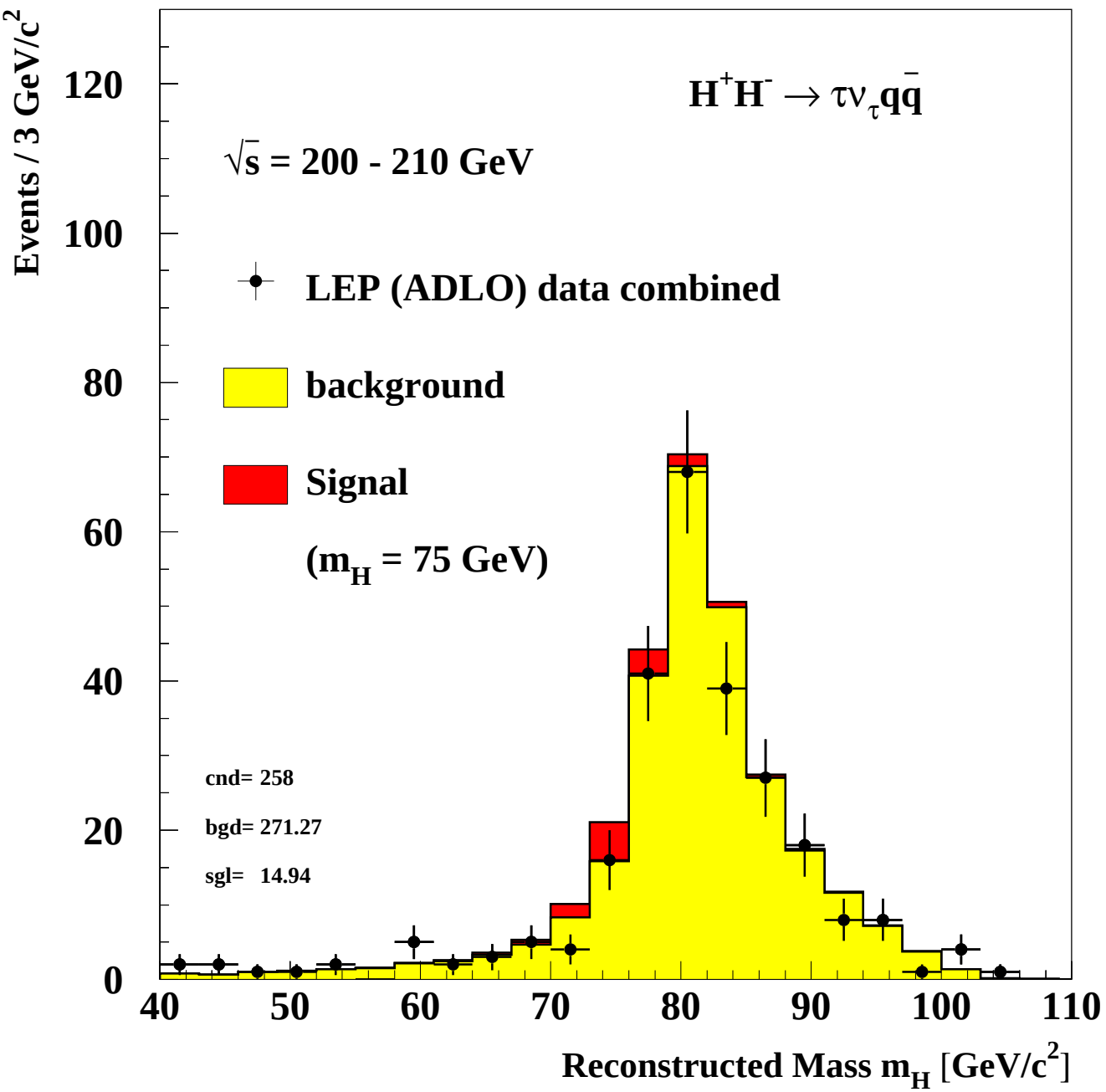
- In MSSM $m_H > m_W$
  - extreme parameters and radiative corrections can give $m_H < m_W$
- WW background is major obstacle
- search is carried out in context of more general 2HD models
  - $m_H > m_W$ constraint gone
  - cross-section determined by mass of H^{+-}
  - assume $c\bar{s}$ and $\tau\bar{\upsilon}_\tau$ exhaust decays
    - $c\bar{s}\,\bar{c}s$
    - $c\bar{s}\,\tau^-\upsilon_\tau$
    - $\tau^+\upsilon_\tau\tau^-\upsilon_\tau$ (no mass reconstruction)

H^+H^- 4 jet mass plot

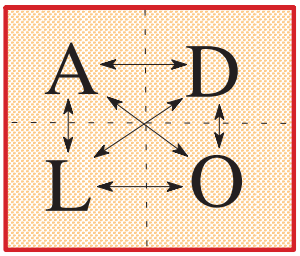


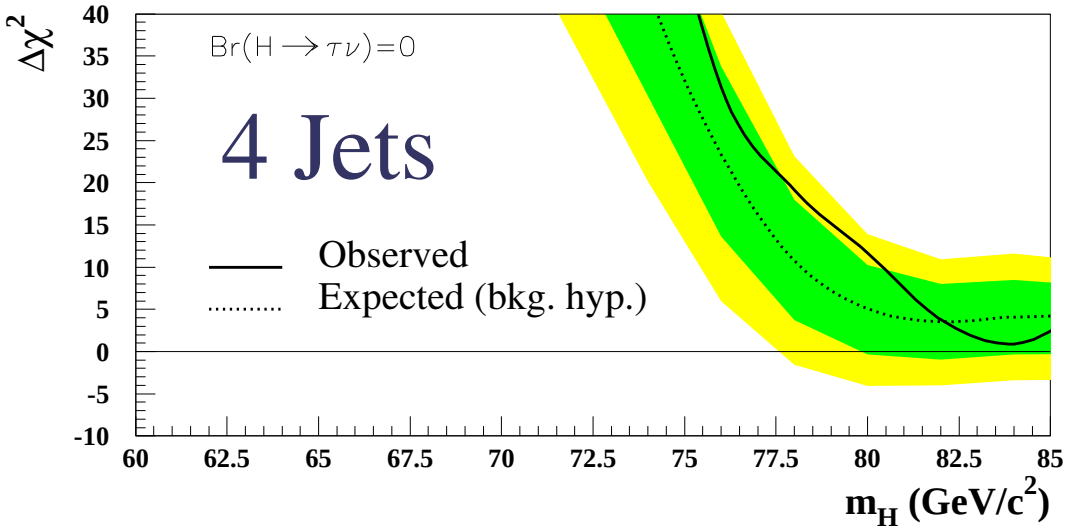
H+H- 2 jet+τ mass plot

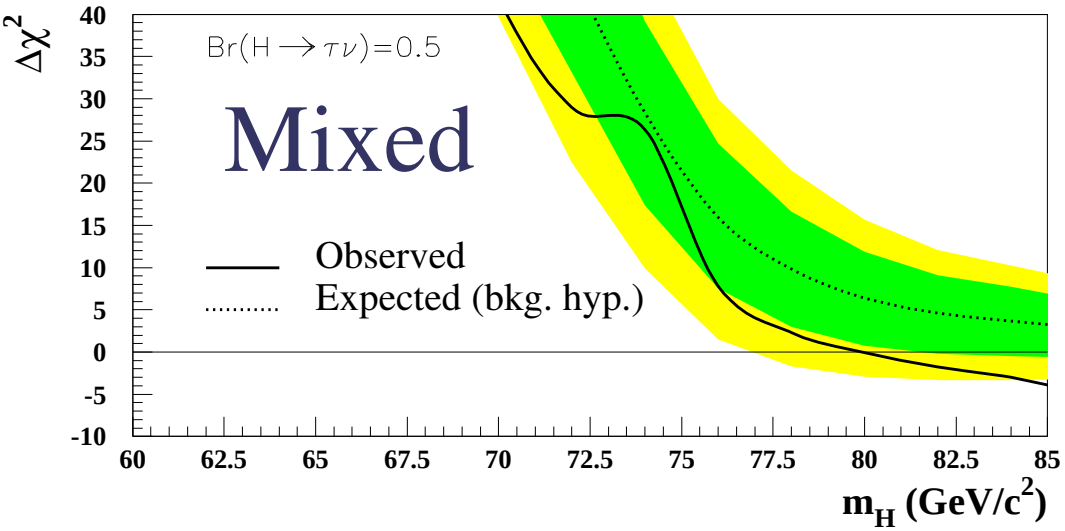


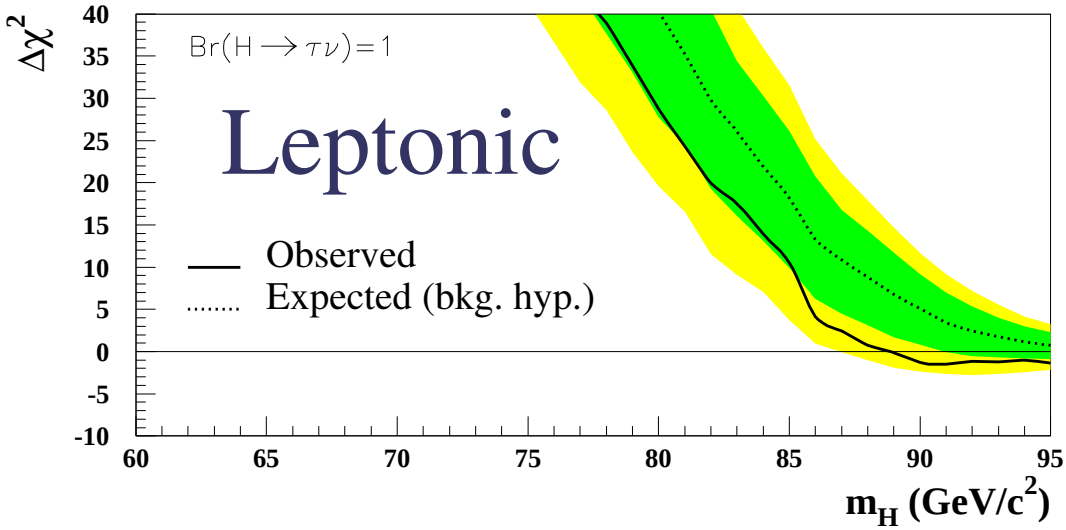


H+H- results

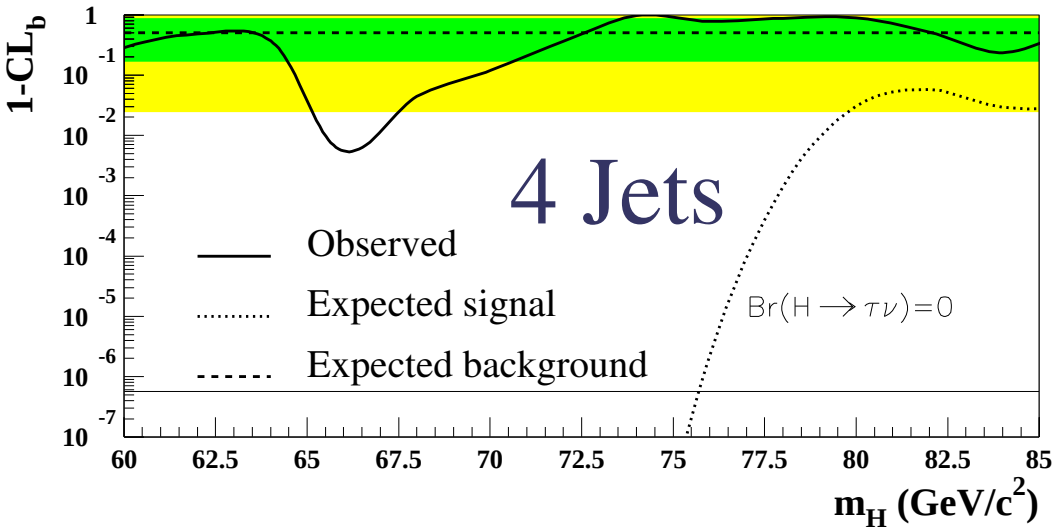

A
D
L
O

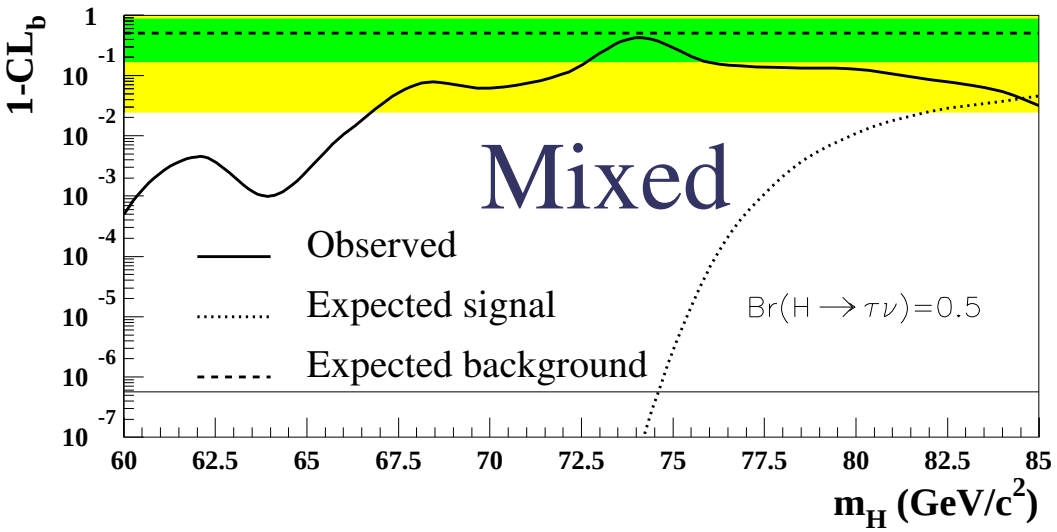

Br(H → τν)=0
4 Jets
Observed
Expected (bkg. hyp.)
Δχ²
m_H (GeV/c²)

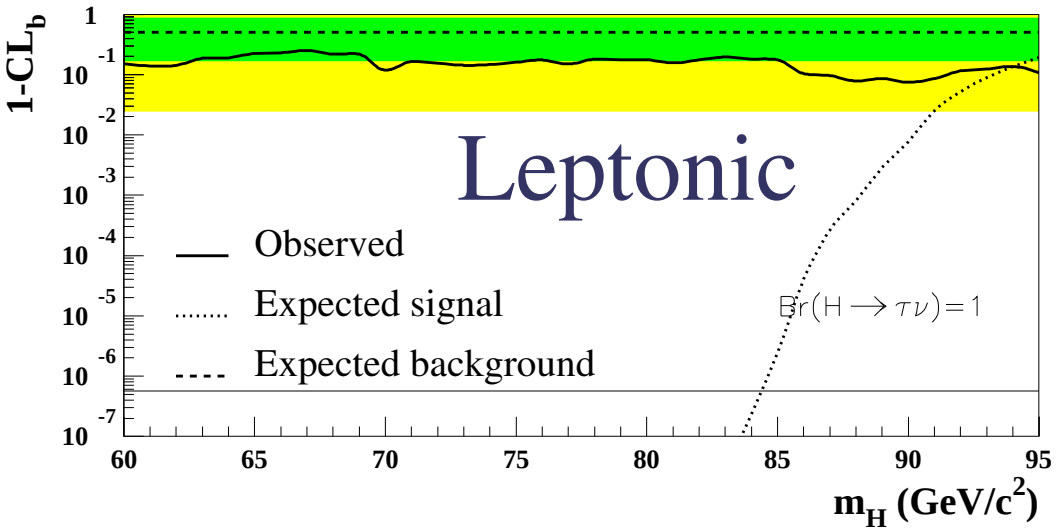

Br(H → τν)=0.5
Mixed
Observed
Expected (bkg. hyp.)
Δχ²
m_H (GeV/c²)


Br(H → τν)=1
Leptonic
Observed
Expected (bkg. hyp.)
Δχ²
m_H (GeV/c²)

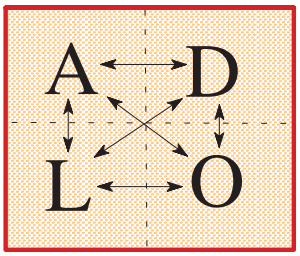
H+H- signal test

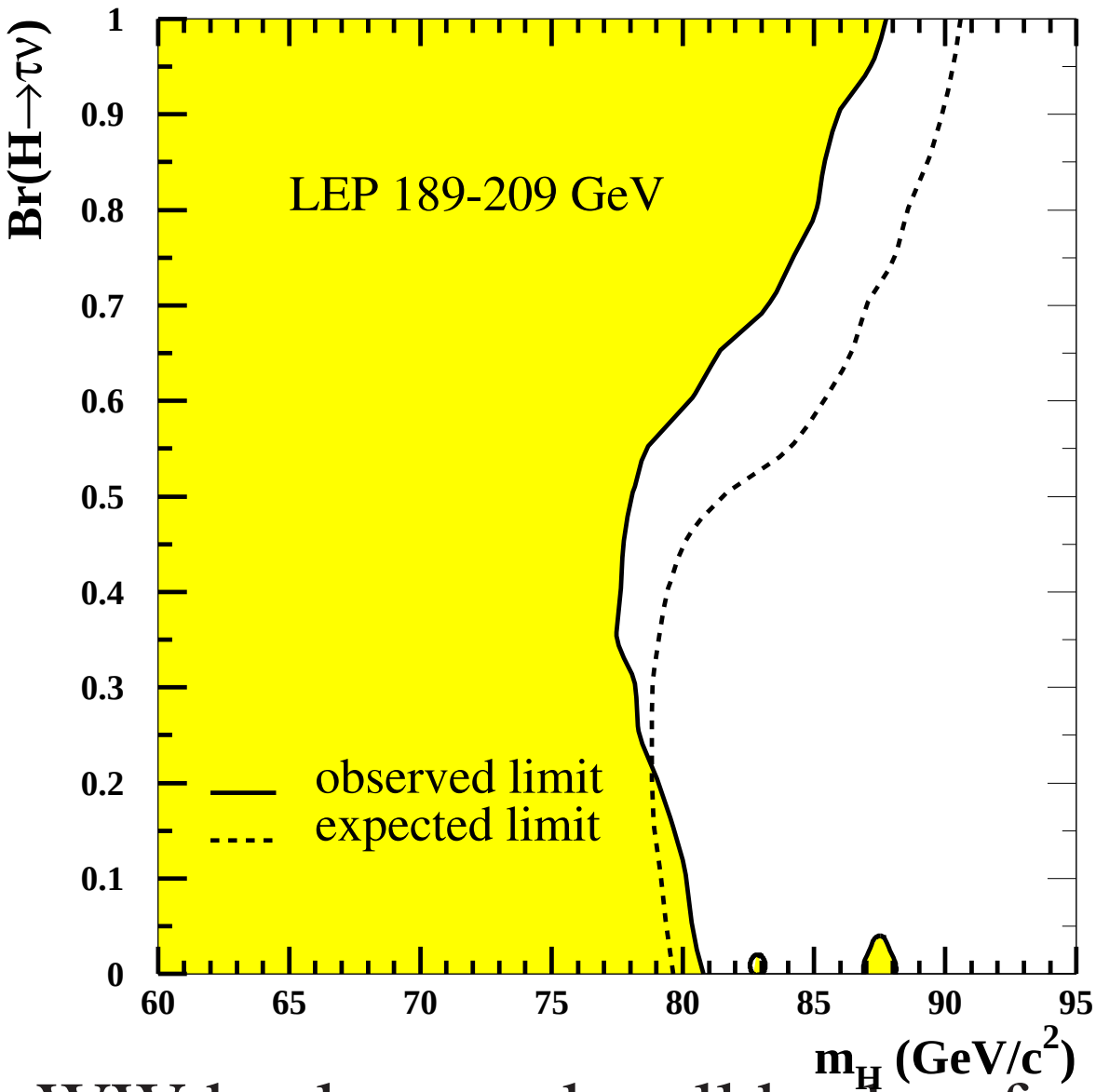






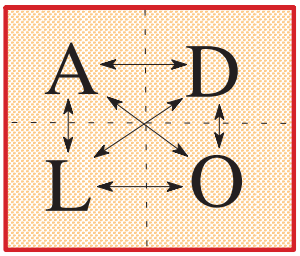
H+H- exclusion





- WW background wall broken for 100% leptonic decays
- Islands of exclusion cropping up above WW (also expected)
- Will be difficult to break WW wall independent of BR.

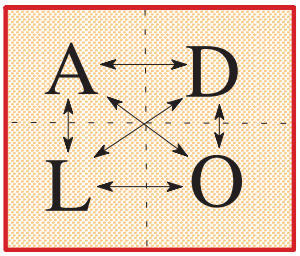
H^+H^- limits



Lower bounds on charged Higgs mass (GeV):

$B(H \to \tau \upsilon_\tau)$	Observed	Expected
0.0	80.8	79.6
0.5	78.1	81.7
1.0	87.7	90.5
Any	77.5	78.8

Fermiophobic Higgs



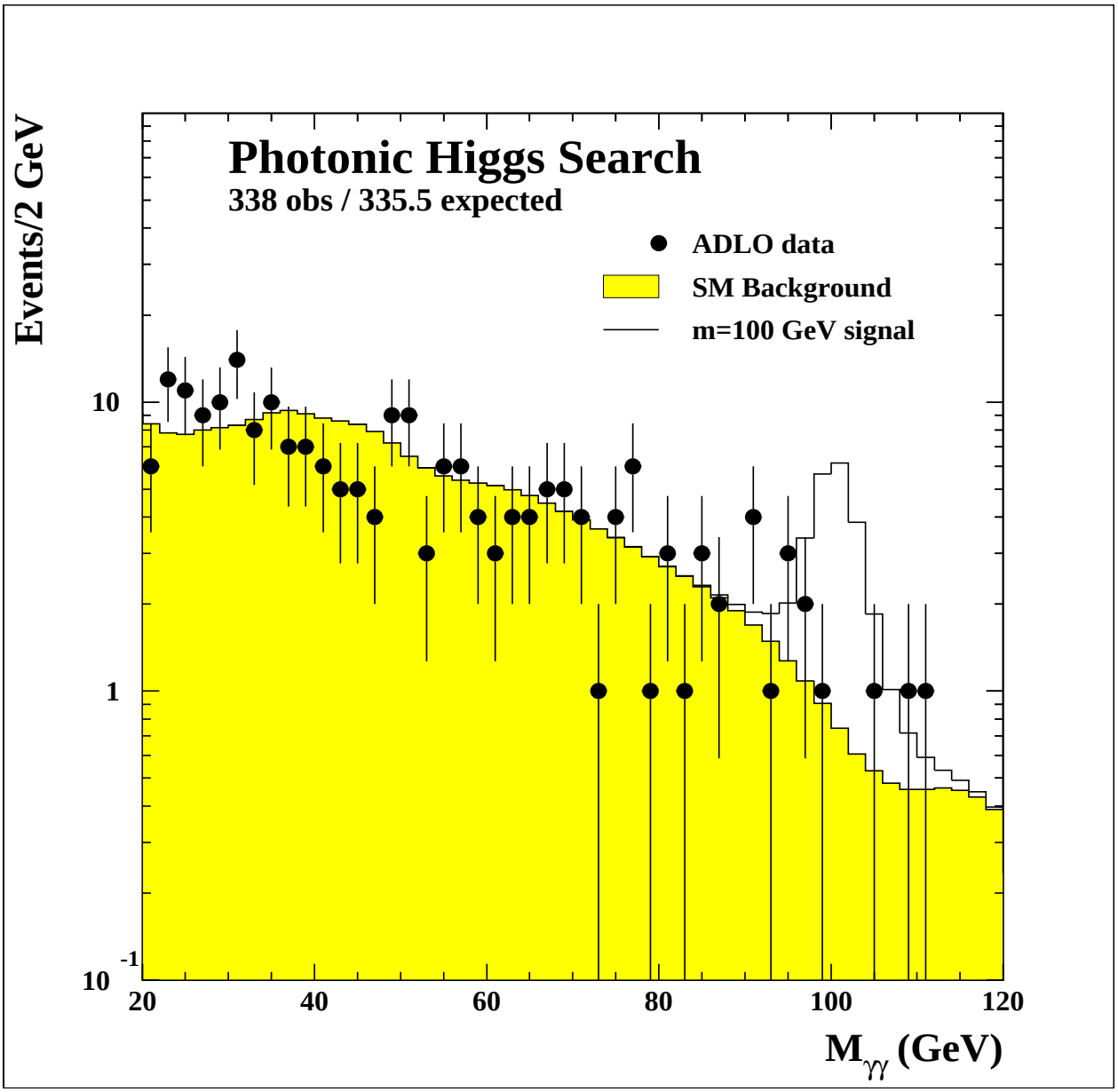
- 2 HDM of Type-I: fermion couplings of form SM*cosα/sinβ, so fermion couplings can be tuned off.
  - Higgs decays to bosons (and γγ for light Higgs)

Status of searches:

Experiment	√s (GeV)	Search channels
ALEPH	192-209	All Z decays (global)
DELPHI	189-202	qq, neutrinos
L3	189-202	qq, ll , neutrinos
OPAL	91-209	qq, ll, neutrinos

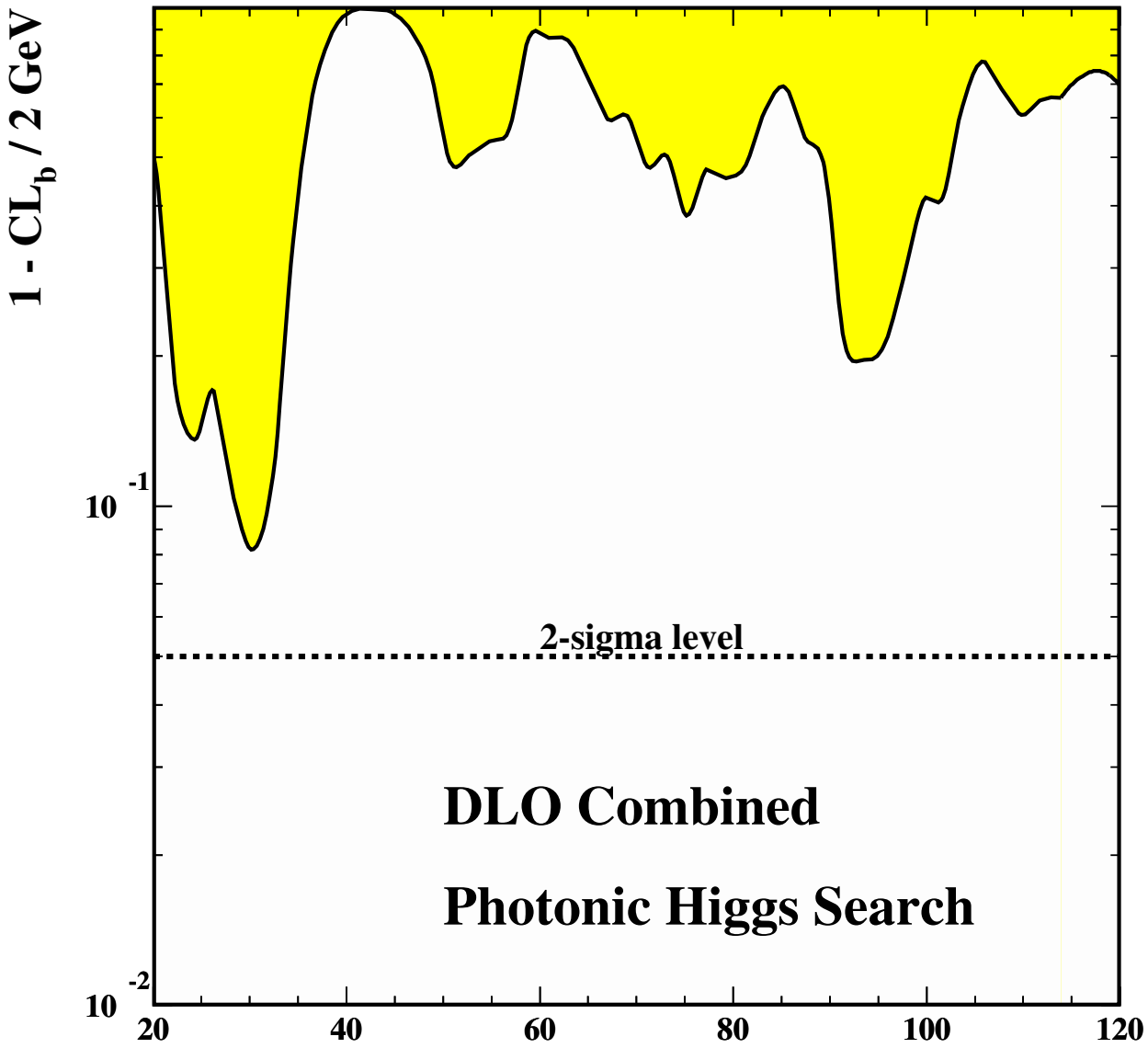
Fermiophobic mass plot

- $\gamma\gamma$ mass spectrum



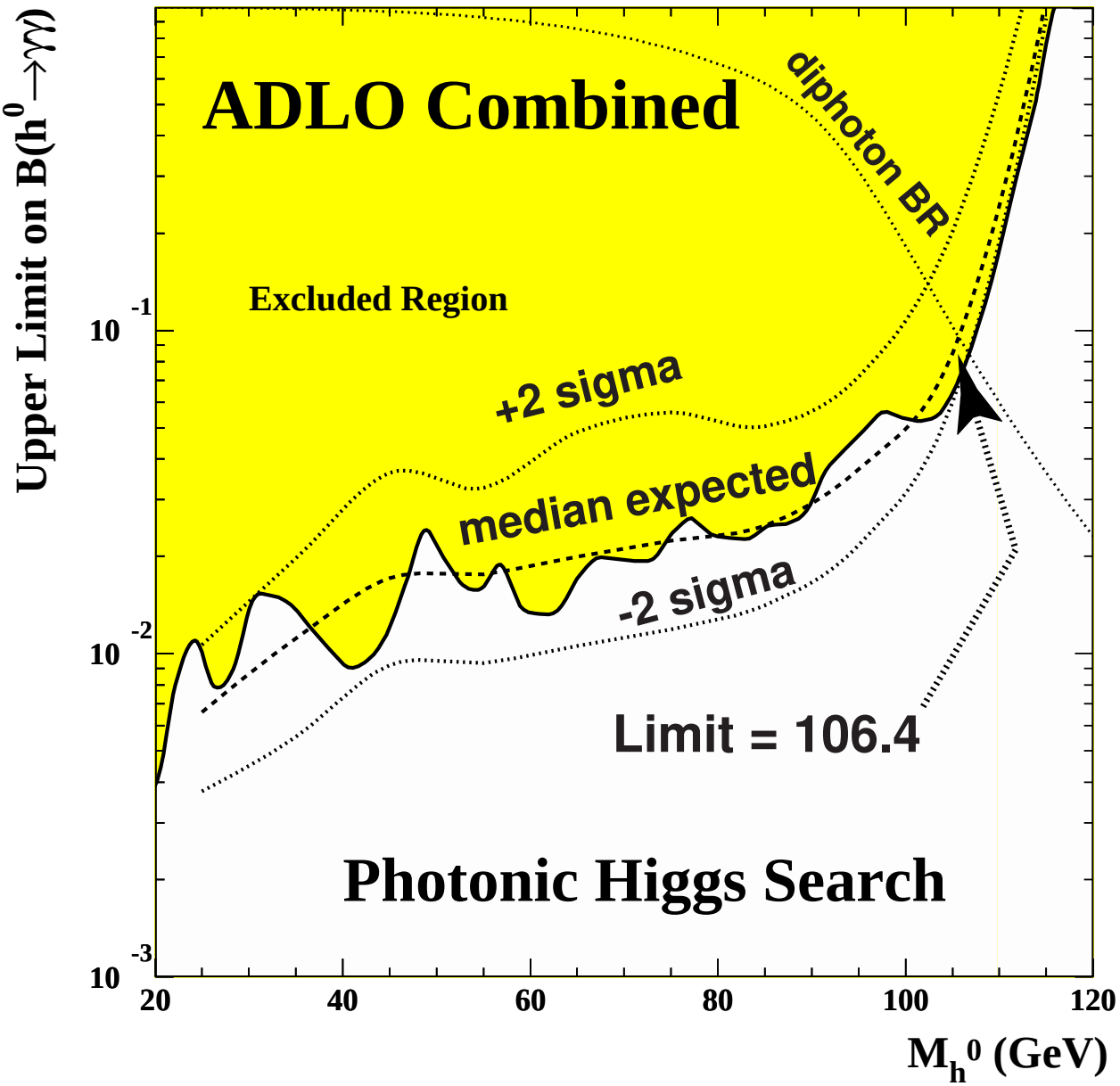
Fermiophobic significance

- 1-CL_b for DLO combination (no background subtraction from ALEPH)
- Signal comparison: SM except fermion couplings=0



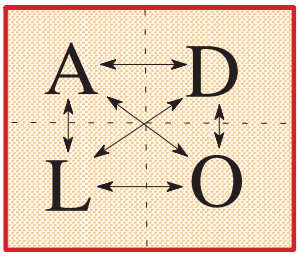
Fermiophobic BR limit

- 95% CL exclusion for B(h→γγ) from ADLO combination

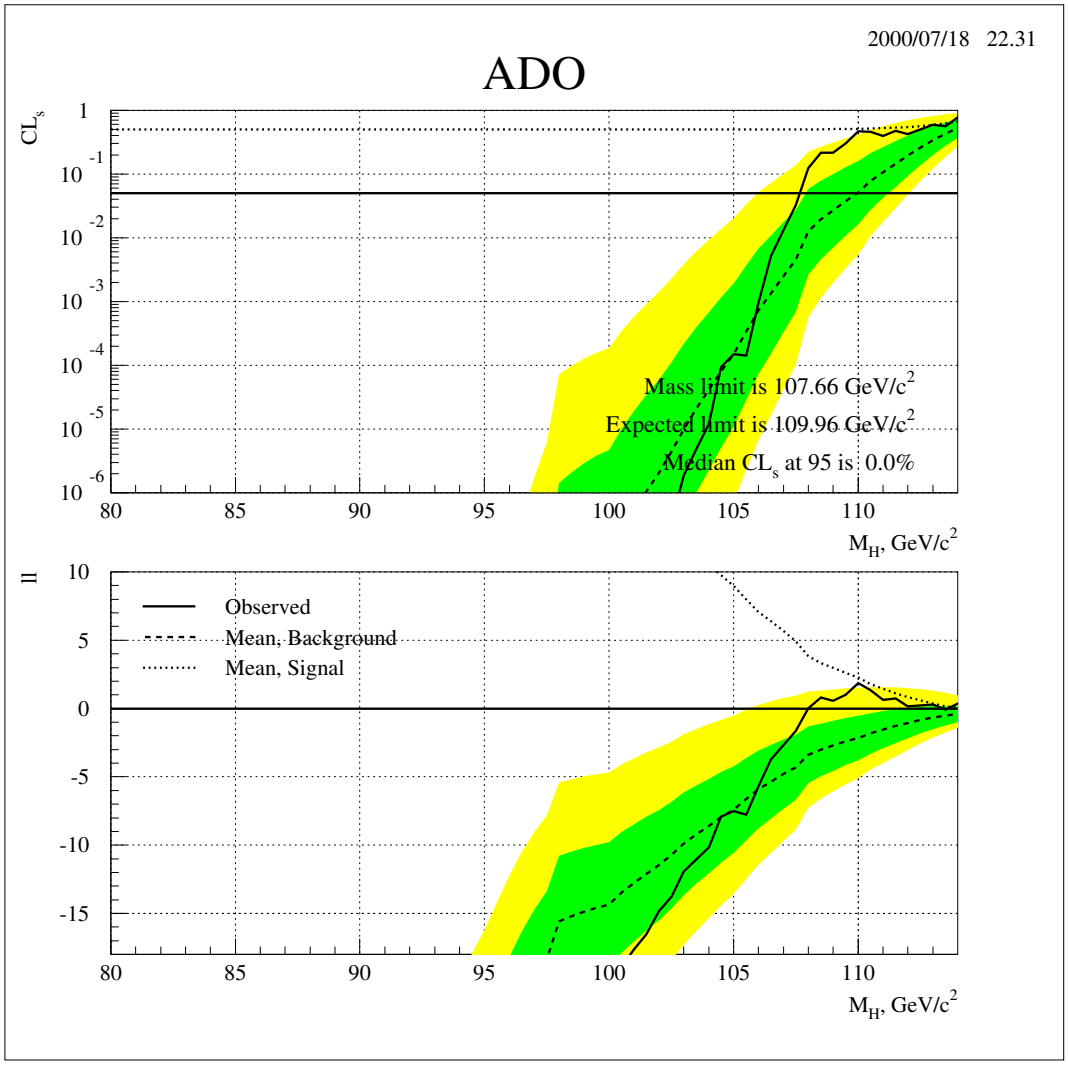


- median expected limit 105.6

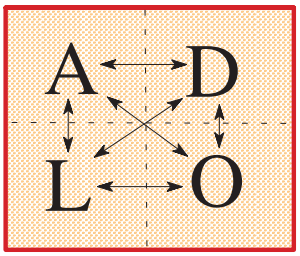
Invisible Higgs search

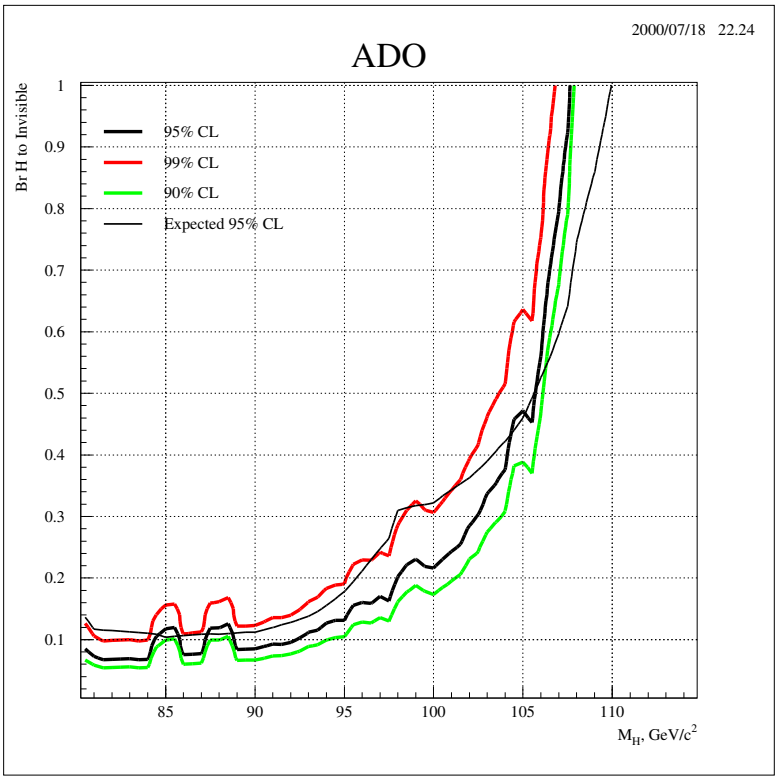


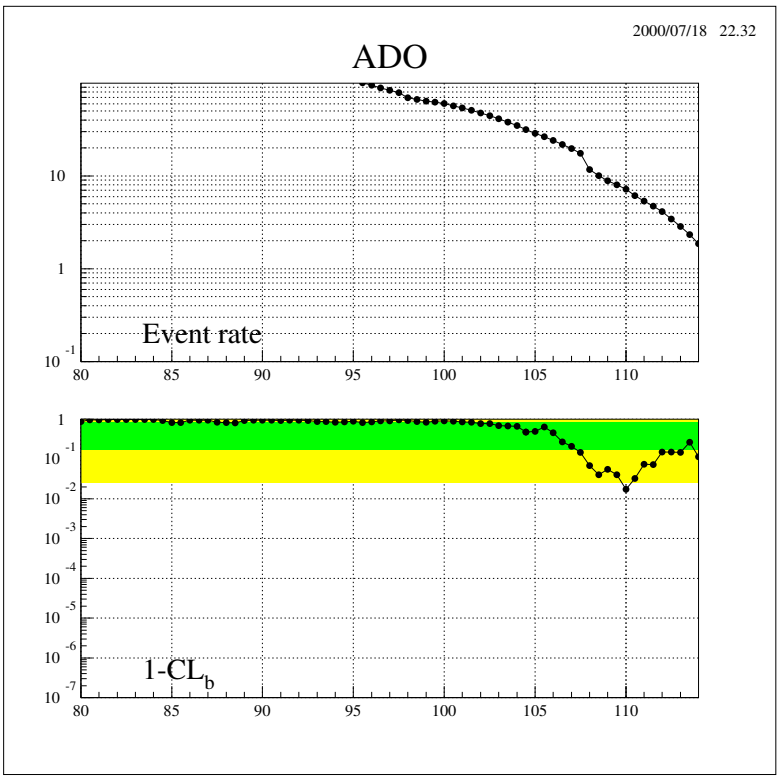
- production as SM/MSSM but decays into undetectable final state (neutralinos, Majorons)
- extremely preliminary!
- ADO with inputs
  - DELPHI up to 1999 inputs
  - ALEPH+OPAL $\sqrt{s} \leq 210$ GeV



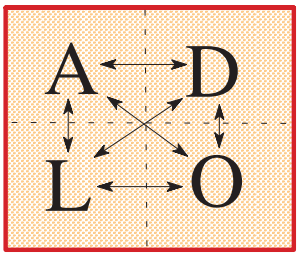
Invisible Higgs search







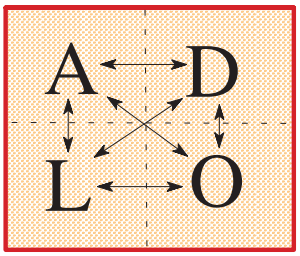
Invisible Higgs limits



Lower bounds (GeV) on invisible Higgs:

	Expected	Observed
ALEPH	108.6	106.9
DELPHI	103.5	102.9
OPAL	105.3	105.3
LEP (ADO)	109.9	107.7

Summary



Reminder: Results are preliminary

- First combined results for fermiophobic and invisible Higgs
- Fast analysis of y2k data in most searches
- No evidence of signal anywhere
- Exclusion limits obtained:

SM	$m_H > 113.3$ GeV
H^+H^-	$m_H > 77.5$ GeV
MSSM (m_h-max)	$m_h > 90.5$ $m_A > 90.5$ $\tan\beta < 0.5$ or $\tan\beta > 2.3$
Fermiophobic	$m_H > 106.4$ GeV
Invisible	$m_H > 107.7$ GeV

- Prospects for observing a signal with additional running at ~same ($\mathcal{L}$,$\sqrt{s}$) limited by present results
- O(1-2 GeV) improvements in exclusion limits are expected.