Standard Higgs at LEP

Piotr Zalewski, SINS Warsaw

OUTLINE

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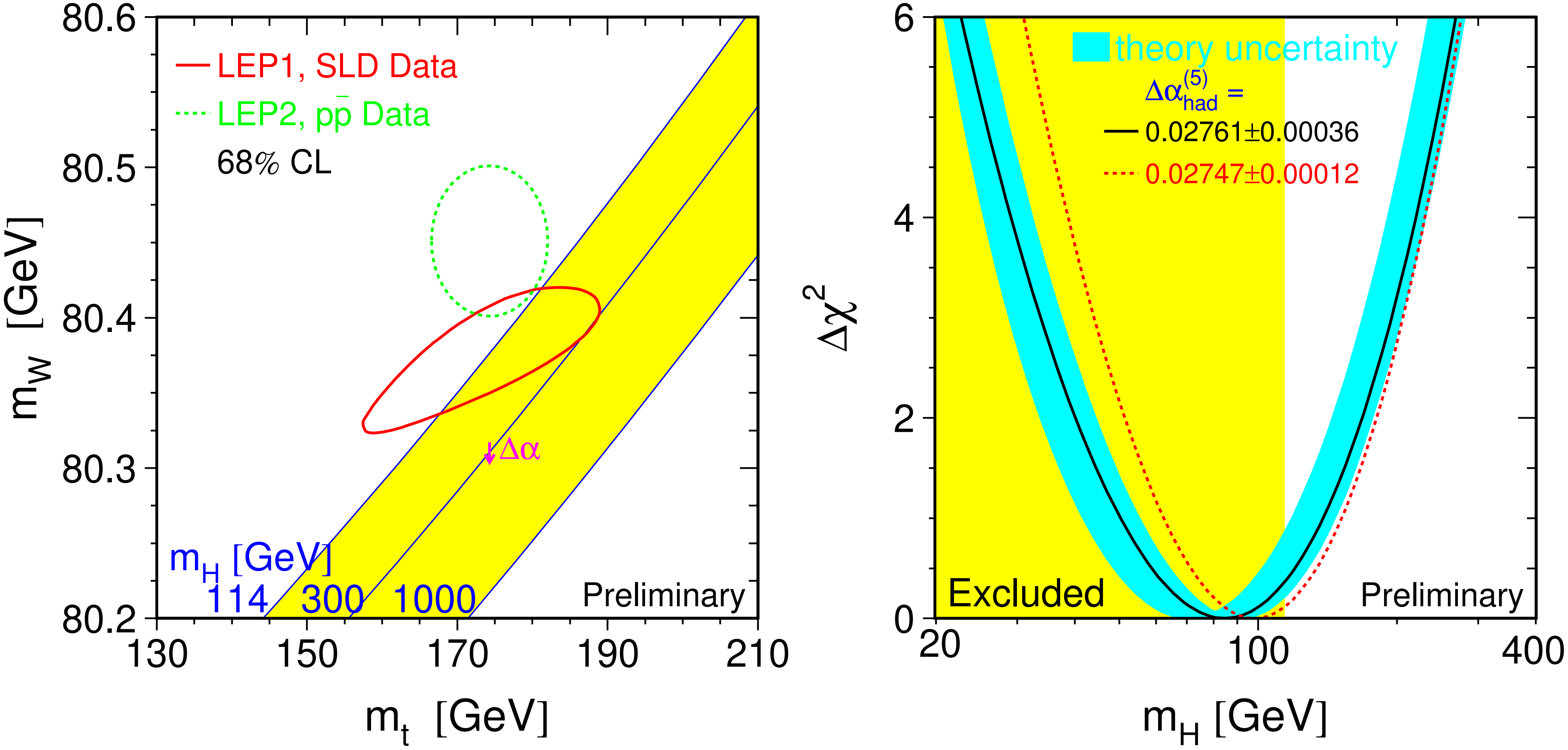
- Search for SM higgs at LEP
- The DELPHI example
- Statistical aspects
- Aleph excess
- The best LEP candidates
- The reconstructed Higgs boson mass
- The test statistics behaviour
- The final results
- What would have been?
- What is?
- Conclusions

What we know about the higgs?



(→ see Chiara Mariotti slide)

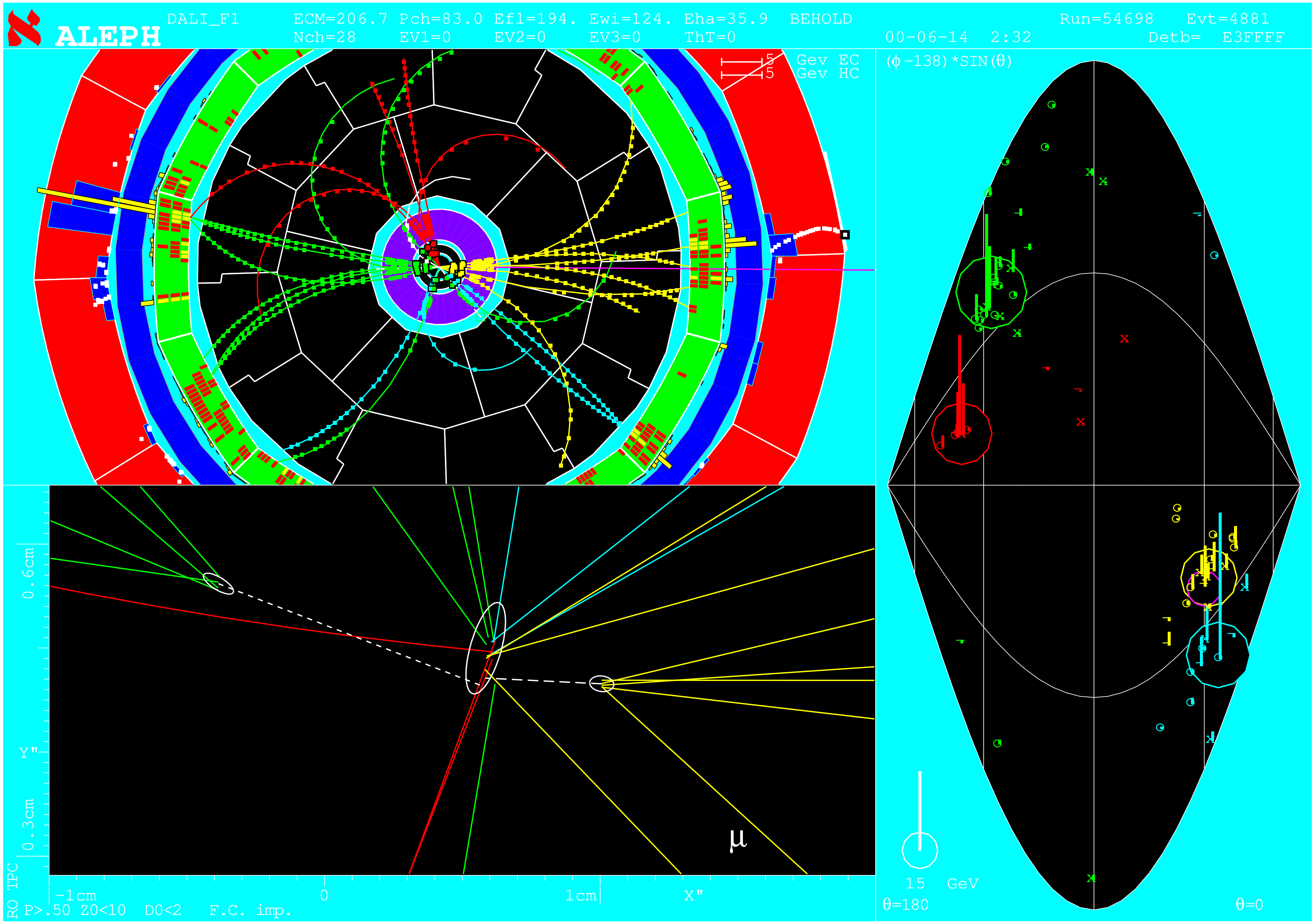
Search for SM higgs at LEP

- The higgs production is well determined within SM.
- The higgs decays mainly into $b\bar{b}$ (and into $\tau^+\tau^-$).
- The higgs is produced via higgs-stralung or vector boson fusion.
- Possible topologies are:

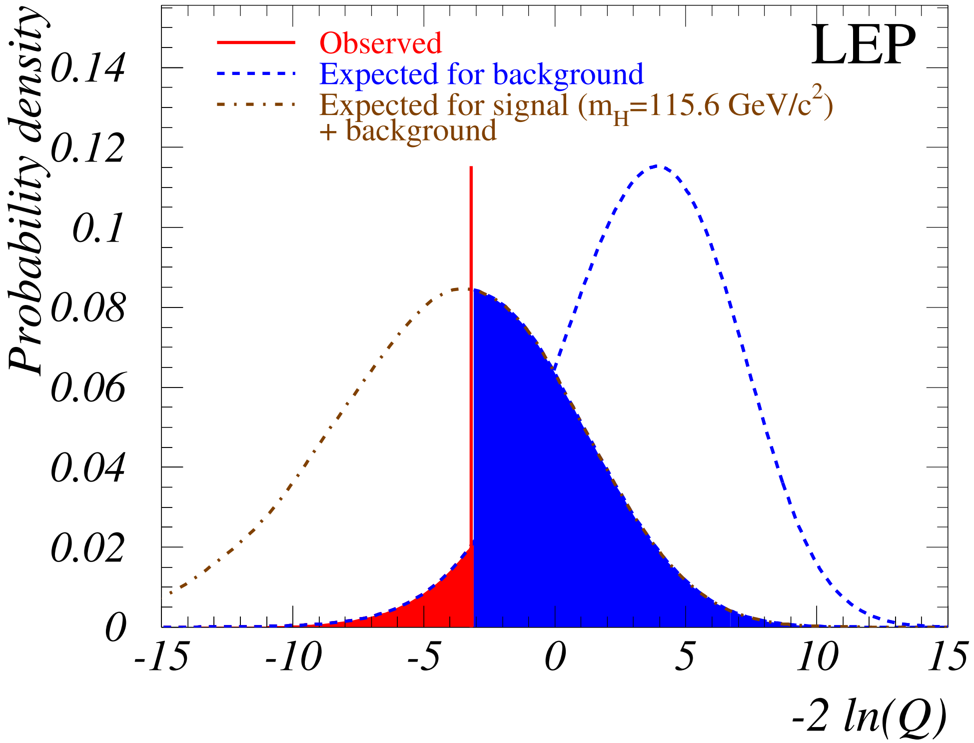
  1. fully hadronic: $b\bar{b}q\bar{q}$
  2. missing energy: $b\bar{b}\nu\bar{\nu}$
  3. semi-leptonic: $b\bar{b}\ell\bar{\ell}$
  4. tau channel: $b\bar{b}\tau^+\tau^-$, $\tau^+\tau^-q\bar{q}$

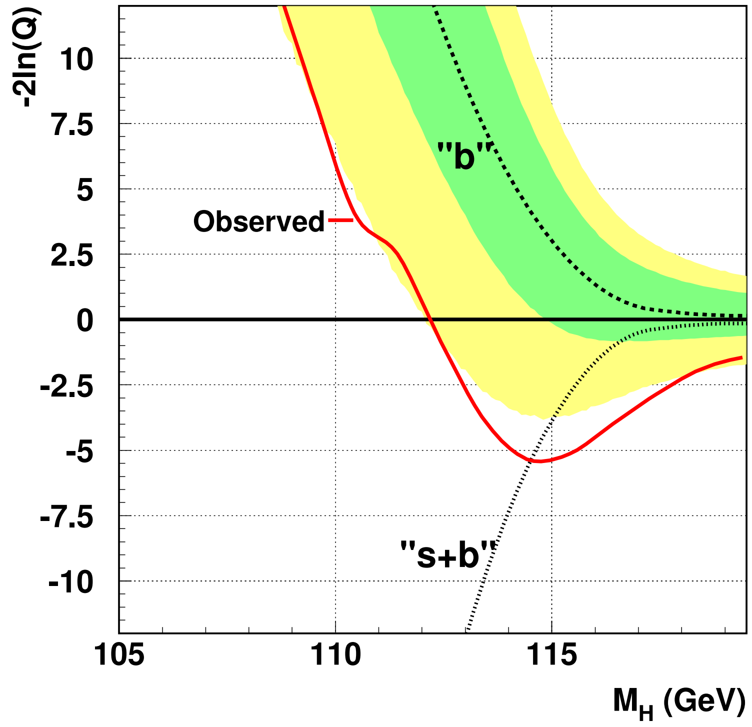
For the fully hadronic channel the performance is dominated by btag which prevails over huge background. Jet pairing ambiguities.
Mass resolution is the main challenge.
The only channel "to go beyond the kinematic limit" via vector boson fusion.
Excellent mass resolution but low X-section. Only Z^0Z^0 background is important.
Challenging reconstruction of τ decays.

→ see example – the DELPHI analysis


ALEPH
DALI_F1
ECM=206.7 Pch=83.0 Efl=194. Ewi=124. Eha=35.9 BEHOLD
Nch=28 EV1=0 EV2=0 EV3=0 ThT=0
00-06-14 2:32
Run=54698 Evt=4881
Detb= E3FFFF
5 Gev EC
5 Gev HC
(ϕ-138)*SIN(θ)
0.6cm
Y"
0.3cm
μ
-1cm
0
1cm
X"
RO TPC P>.50 Z0<10 D0<2 F.C. imp.
15 GeV
θ=180
θ=0

Statistical aspects

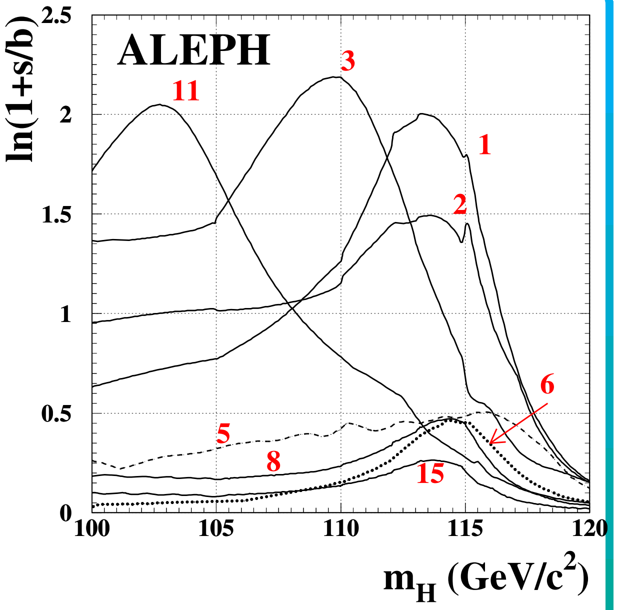


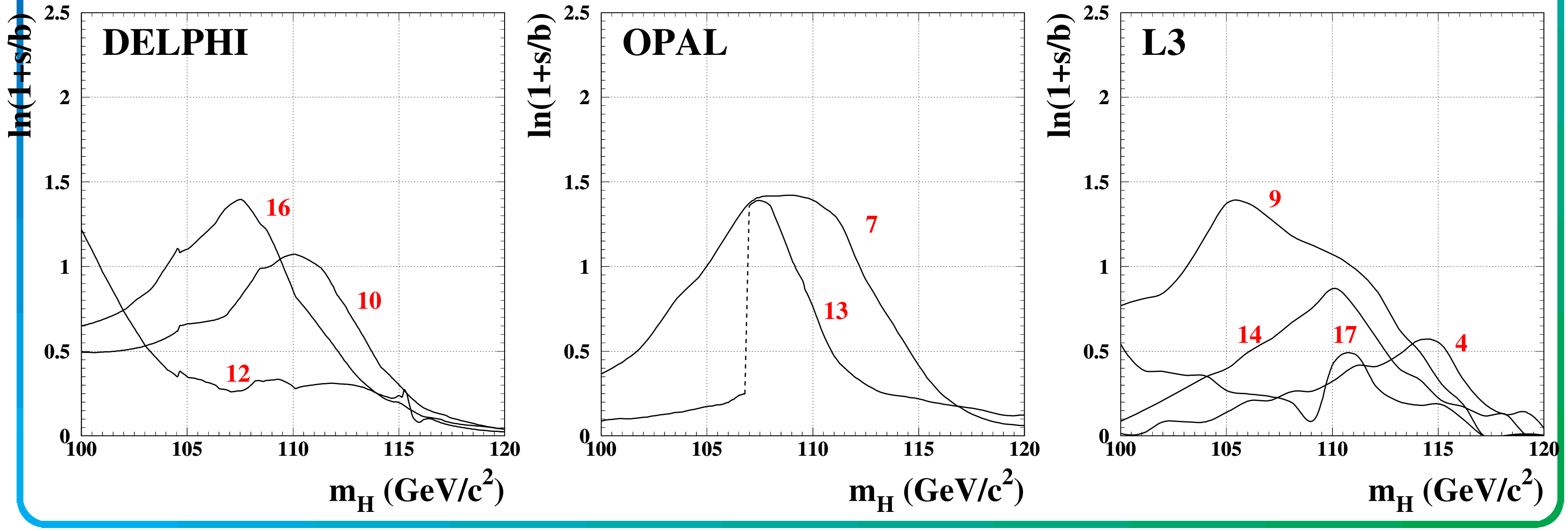


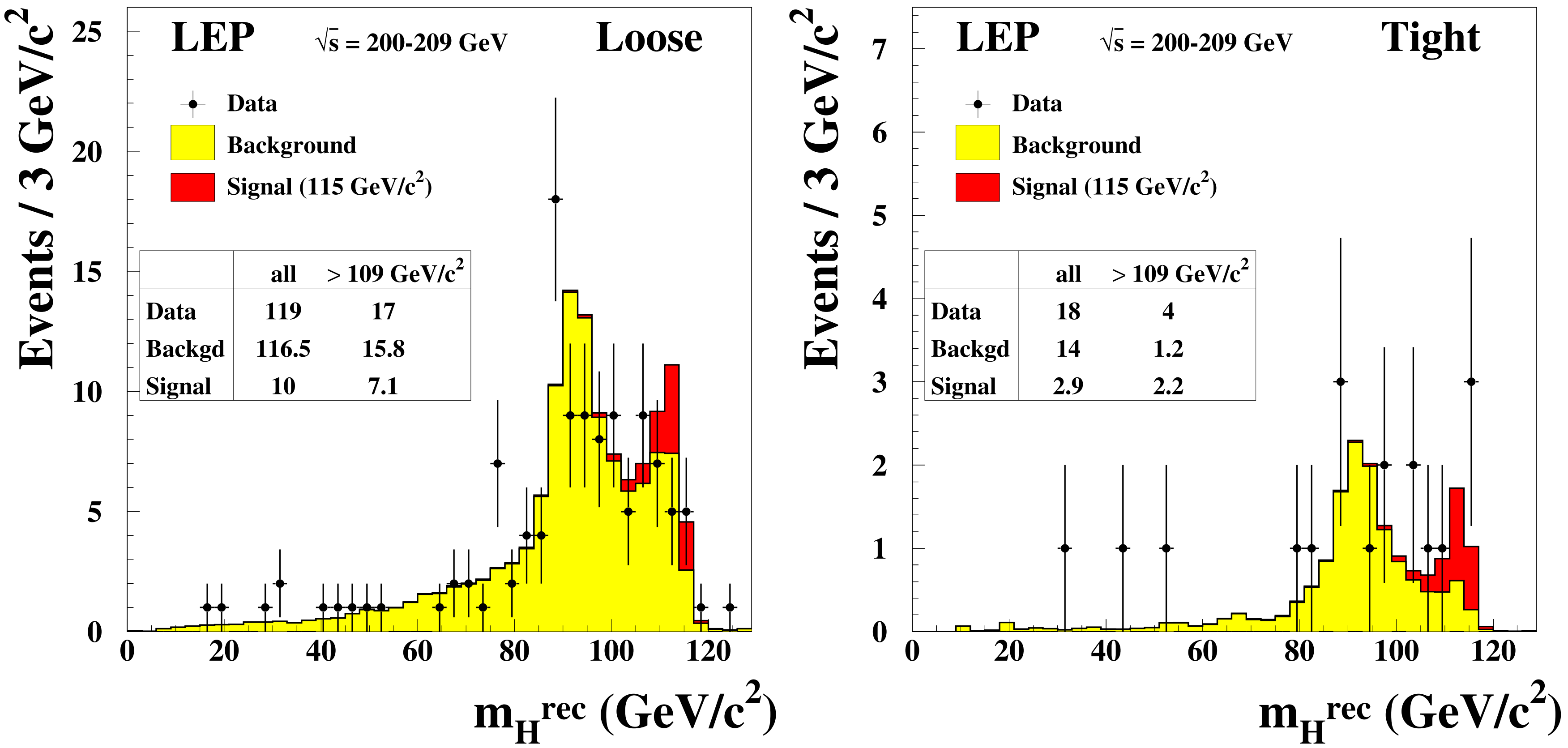
$1 - CL_b$ $\quad$ CL_{s+b} $\quad$ $Q(m_{\rm H}) = \mathcal{L}(s+b)/\mathcal{L}(b)$

$$-2\ln Q(m_{\rm H}) = 2\sum_{k=1}^{N}\left[s_k(m_{\rm H}) - \sum_{j=1}^{n_k}\ln\left(1 + \frac{s_k(m_{\rm H})S_k(\vec{x}_{jk};m_{\rm H})}{b_k B_k(\vec{x}_{jk})}\right)\right]$$

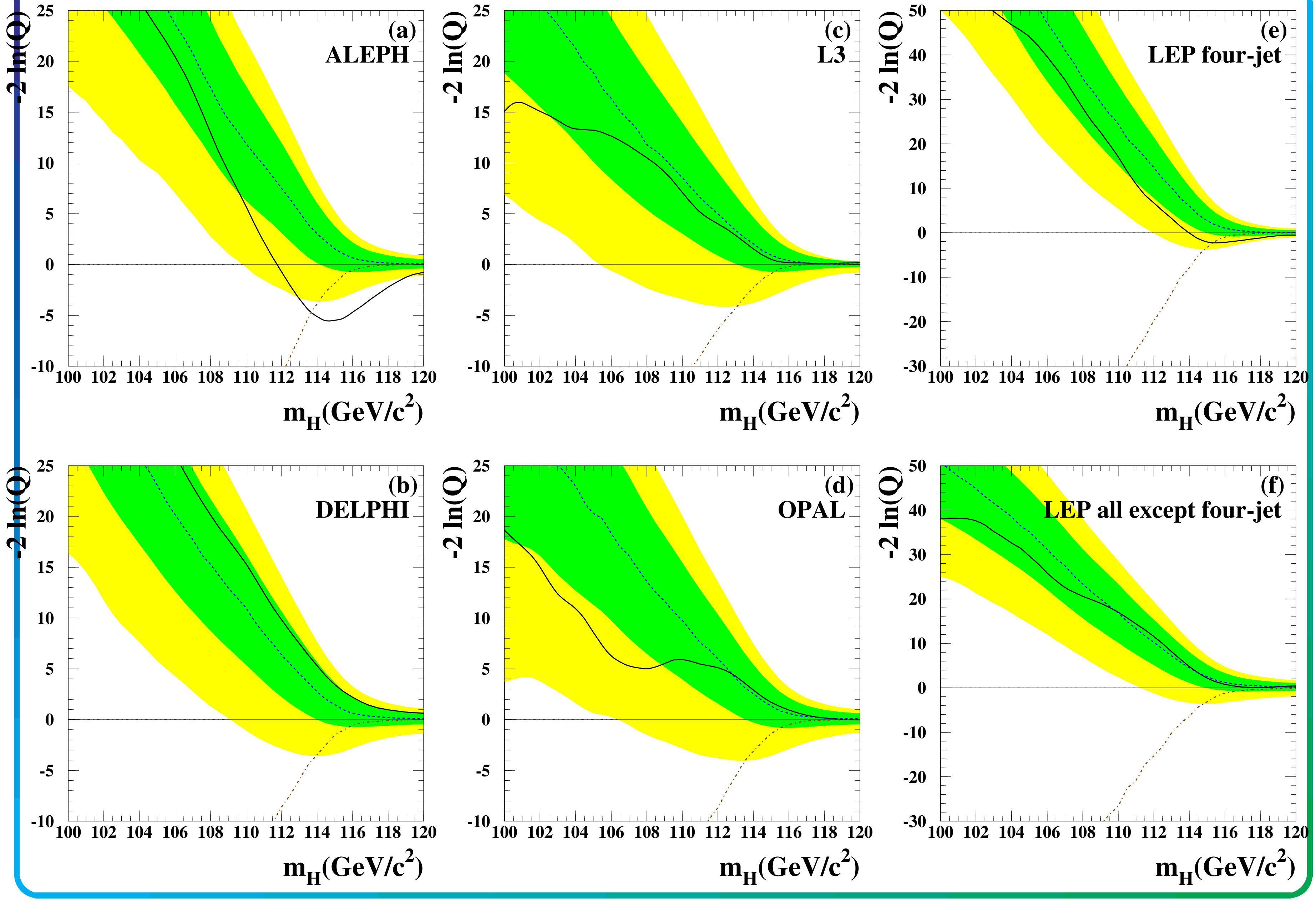
	Exp.	$\sqrt{s}$ (GeV)	Final state topology	$m_{\mathrm{H}}^{\mathrm{rec}}$ GeV/c^2	$\ln(1+s/b)$ at 115 GeV/c^2
1	ALEPH	206.6	Four-jet	114.1	1.76
2	ALEPH	206.6	Four-jet	114.4	1.44
3	ALEPH	206.4	Four-jet	109.9	0.59
4	L3	206.4	Miss. ene.	115.0	0.53
5	ALEPH	205.1	Leptonic	117.3	0.49
6	ALEPH	208.0	Tau	115.2	0.45
7	OPAL	206.4	Four-jet	111.2	0.43
8	ALEPH	206.4	Four-jet	114.4	0.41

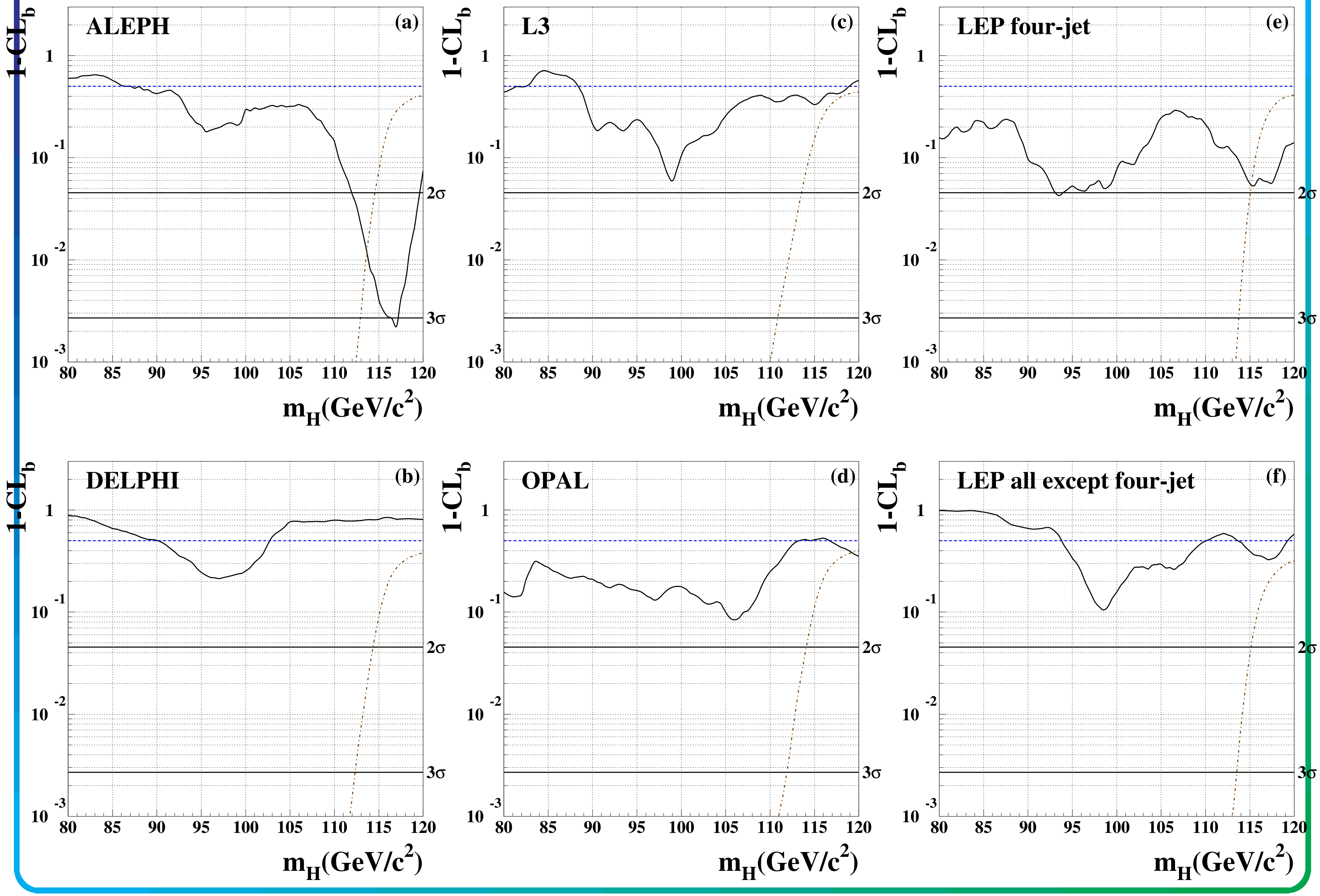


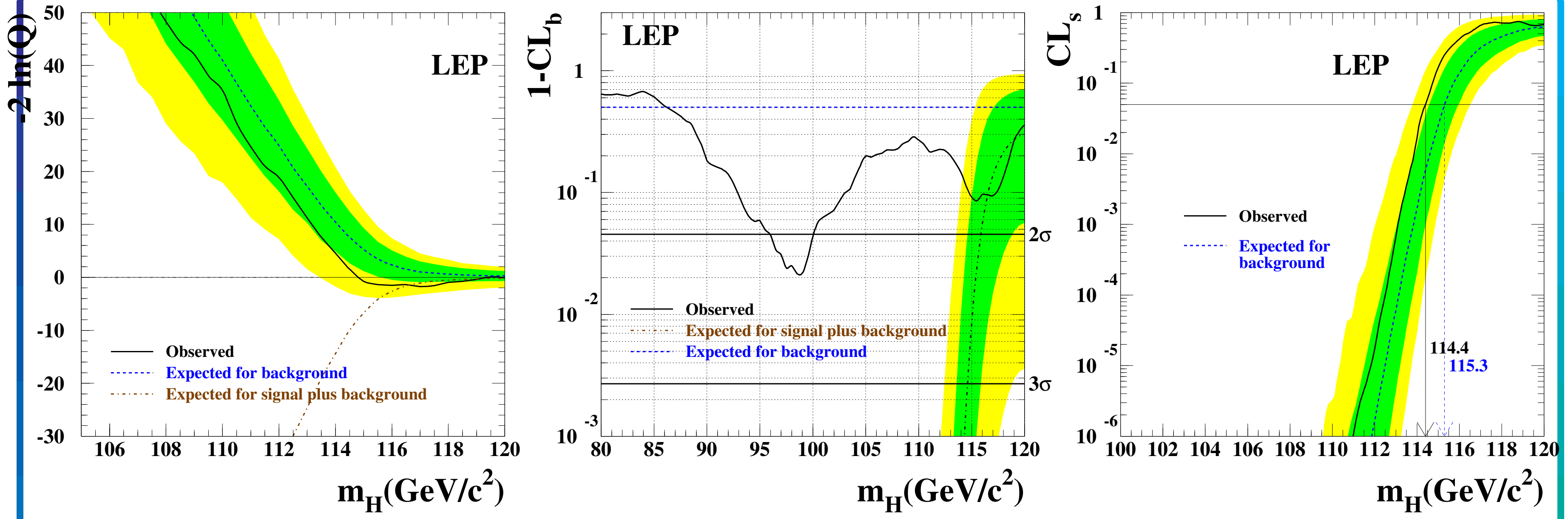




Distributions of the reconstructed Higgs boson mass, $m_{\mathrm{H}}^{\mathrm{rec}}$, obtained from two selections with different expected signal purities. The histograms show the Monte Carlo predictions, yellow for the background, red for an assumed Standard Model Higgs boson of mass 115 $\mathrm{GeV/c^2}$. The points with error bars show the data. In the loose and tight selections the cuts are adjusted in such a way as to obtain, for a Higgs boson of mass 115 $\mathrm{GeV/c^2}$, approximately 0.5 or 2 times more expected signal than background events when integrated over the region $m_{\mathrm{H}}^{\mathrm{rec}} > 109\ \mathrm{GeV/c^2}$.


(a)
ALEPH
(b)
DELPHI
(c)
L3
(d)
OPAL
(e)
LEP four-jet
(f)
LEP all except four-jet
-2 ln(Q)
m_H(GeV/c^2)


ALEPH (a)
DELPHI (b)
L3 (c)
OPAL (d)
LEP four-jet (e)
LEP all except four-jet (f)
1-CL_b
m_H(GeV/c^2)
2σ
3σ



Observed and expected behaviour of the test statistic $-2\ln Q$, the background confidence $1-\mathrm{CL_b}$ and the ratio $\mathrm{CL_s}=\mathrm{CL_{s+b}}/\mathrm{CL_b}$ as a function of the test mass m_H, obtained by combining the data of the four LEP experiments.

The full curve represents the observation.

The dashed blue curve shows the median background expectation.

The dash-dotted brown curve indicates the expectation for signal plus background hypothesis, when the signal mass on the abscissa is tested.

The green and yellow bands represent the 68% and 95% probability bands about the median background expectation (signal plus background expectation in the middle plot).

For the expected behaviours, the medians of the simulated distributions are shown.

may 95 3

- **the time scale**

LEP can achieve the program in 2000 if extra cavities are ordered soon (and if they work well, see later)

LHC = if 1 "LHC year" ≃ 3 years
if one takes ~ 3 years to reach 10^{34}/14TeV

at best answer in 2004 + 6 years ~ 2010

→ one could gain a decade on that answer

- **the (non LHC) competition**

after 99 or so the upgraded Tevatron should provide 2TeV, ~ 15 pb^{-1}/week (55hr/"week" × L_{peak})

put 30 weeks/year, 4 years effective
→ 2000 pb^{-1} 4 fb^{-1} in the 2 exp^{ts}

if low mass objects exists obvious competition in the gaugino sector

What about Higgs sector? first, only "theorist MC" are known to me. second, one needs more L
30 fb^{-1} → 95 GeV

[Competition in gaugino sector already threatening: answer by running LEP 1.5 as soon as possible]

→ delaying by a decade is a dangerous policy

Also: should we ignore the possibility of a di Tevatron?

- **higher E at LEP**

$P/_{turn} \sim E^4/R$ $N_{cav} \times E_{acc}$ → rely on 6 MV/m

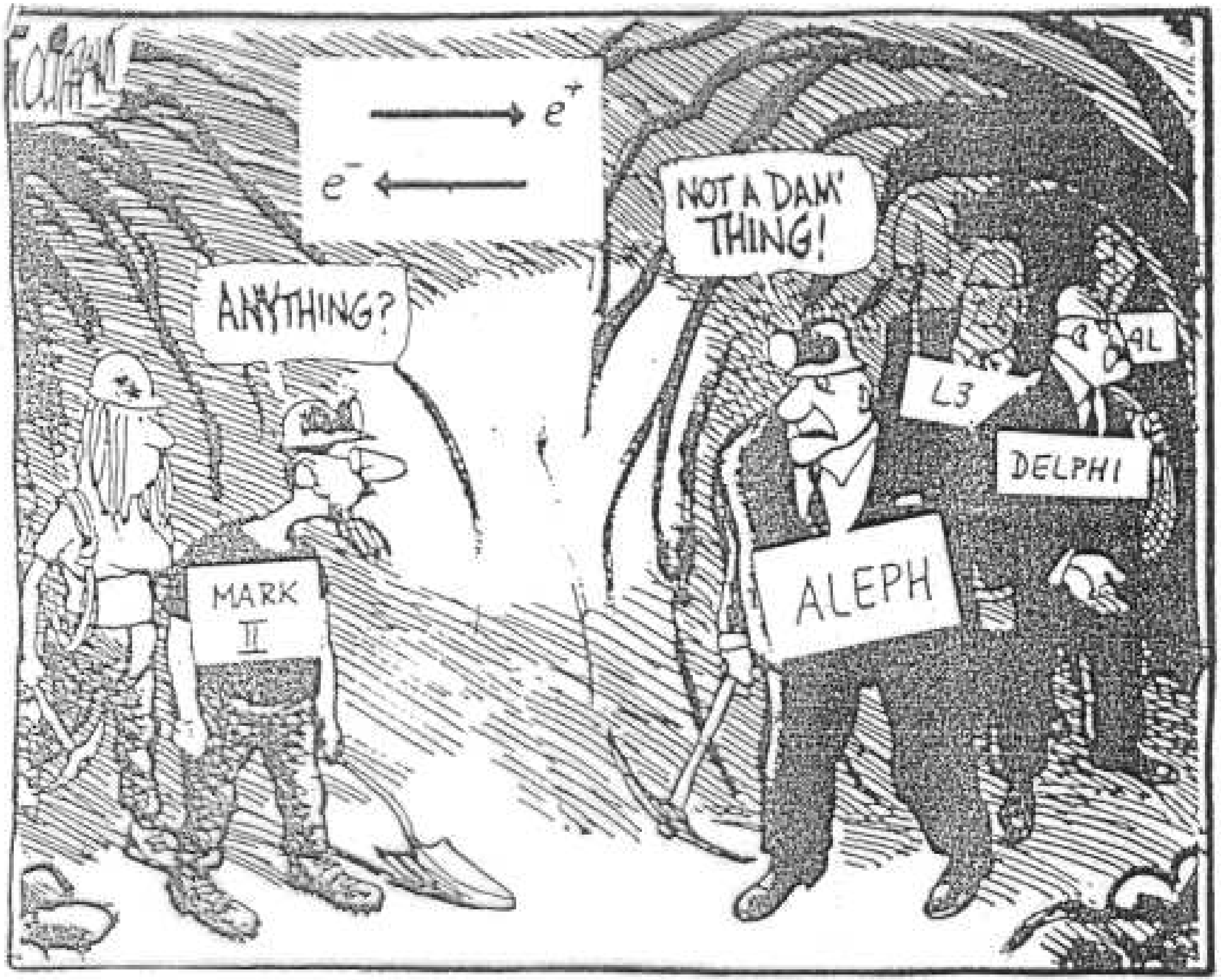
under discussion 272 SC + $\frac{1}{2}$ Cu → LEP195 | achievable ?
possible without further civil engin^g ~ 380 → LEP210 | improvable ?

then = ~ twice more per batch because of extra cryogeny
but NEEDED FOR LHC

Cost = next batch of 32 : 35-9=26 MSF

The final summary at ICHEP90:

("taken by Dydak from a Singapore newspaper and slightly adapted")



This summary is still valid...

Conclusions

- Despite excellent performance of LEP,
- sophisticated methods of statistical inference of data,
- searching all possible topologies,
- the higgs was not (yet) found at LEP.
- There are still ongoing analyzes.
- But when we will have...

higgs? $\longrightarrow$

TeVatron? $\longrightarrow$

LHC? $\longrightarrow$