Final status of L3 Standard Model Higgs searches and latest results from LEP wide combinations

Andre Holzner ETHZ / L3

Outline

- Higgs mechanism
- Signal processes
- L3 Detector
- Experimental signatures
- Data Samples
- Flow of a typical analysis
- L3 mass and final variable distributions
- Statistical Method
- L3 estimator evolution and confidence levels
- LEP combined results
- Conclusions

The Higgs mechanism

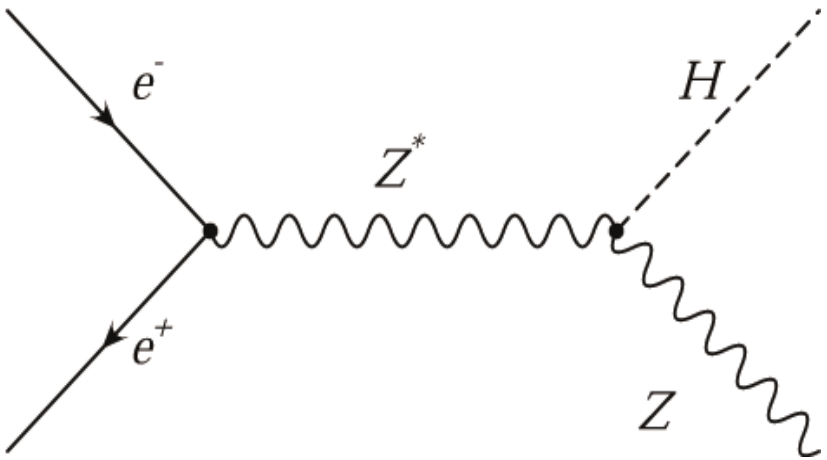
- Standard Model (SM) has massive gauge bosons and massive fermions (where left- and right-handed fermions behave differently)

  $\rightarrow$ mass terms in the Lagrangian which break the gauge symmetry

- The Higgs-Mechanism introduces a new complex doublet field with a non-zero vacuum expectation value which is interpreted as mass-terms.
- One of the four new degrees of freedom can not be associated with so far known particles, it is the field of a new scalar particle, the Higgs Boson

Signal processes

Higgs-Strahlung

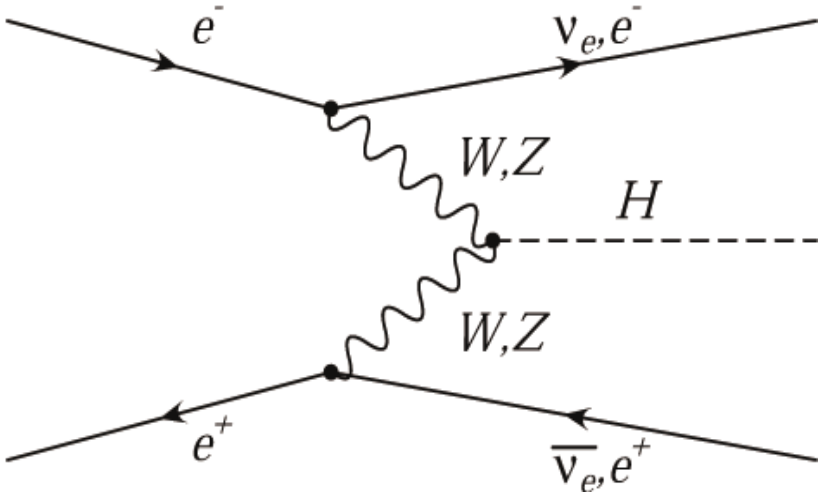


Cross section almost zero for

$m_H > \sqrt{s} - m_Z$

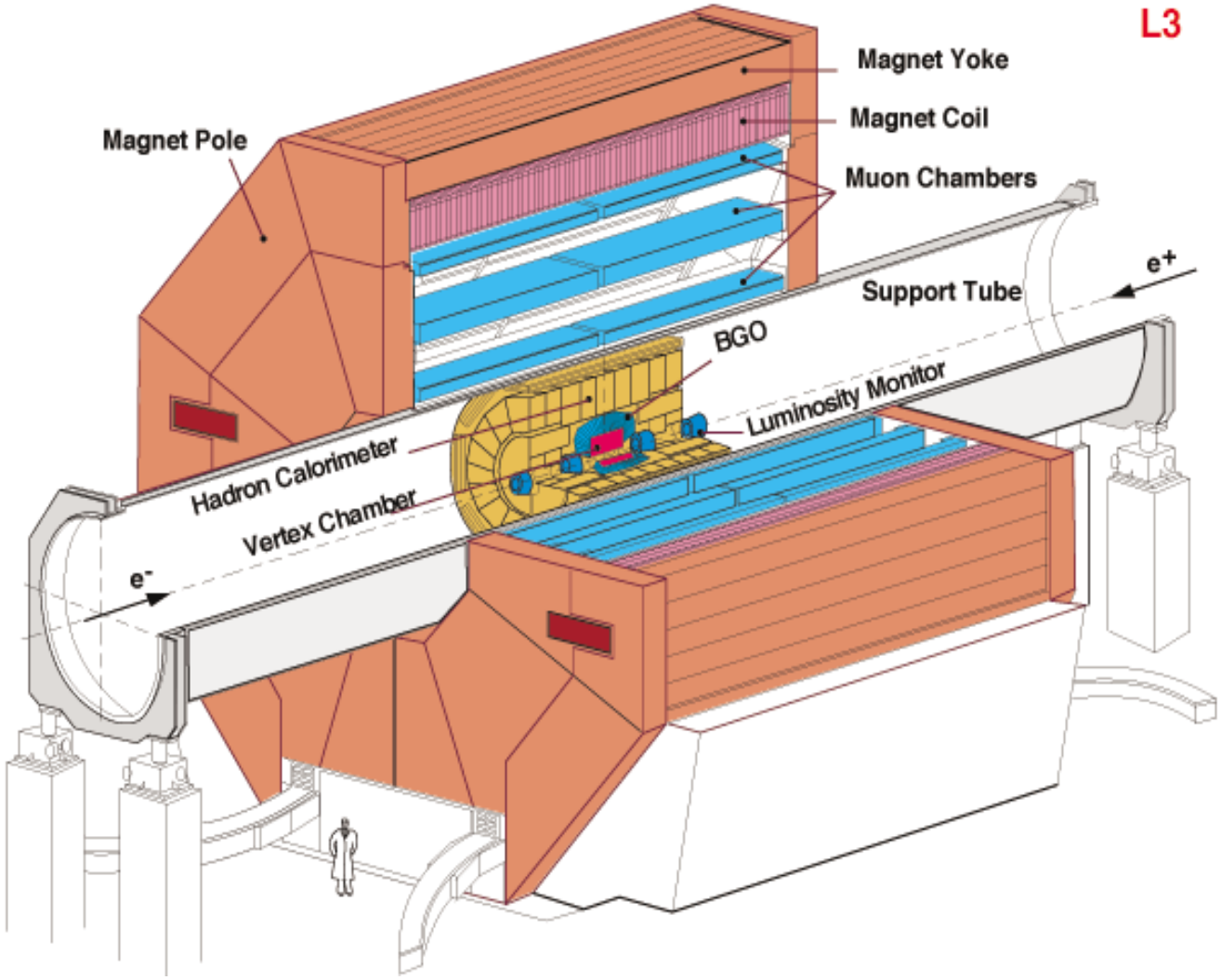
(kinematic limit)

Weak Boson Fusion

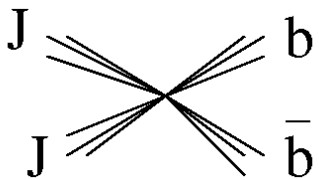
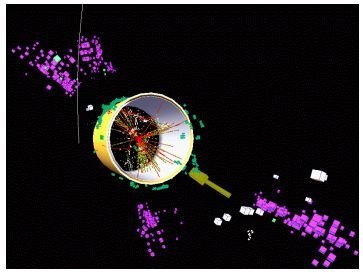
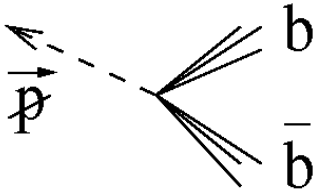
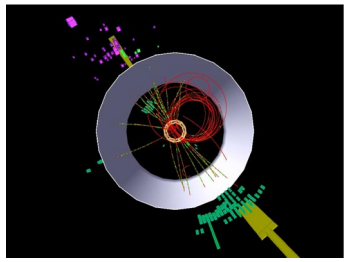
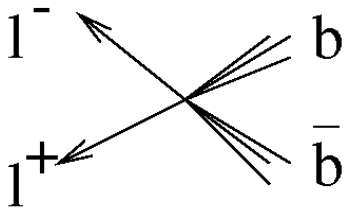
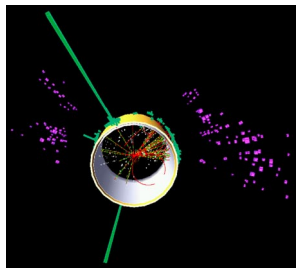


Small cross section but kinematic limit is $\sqrt{s}$

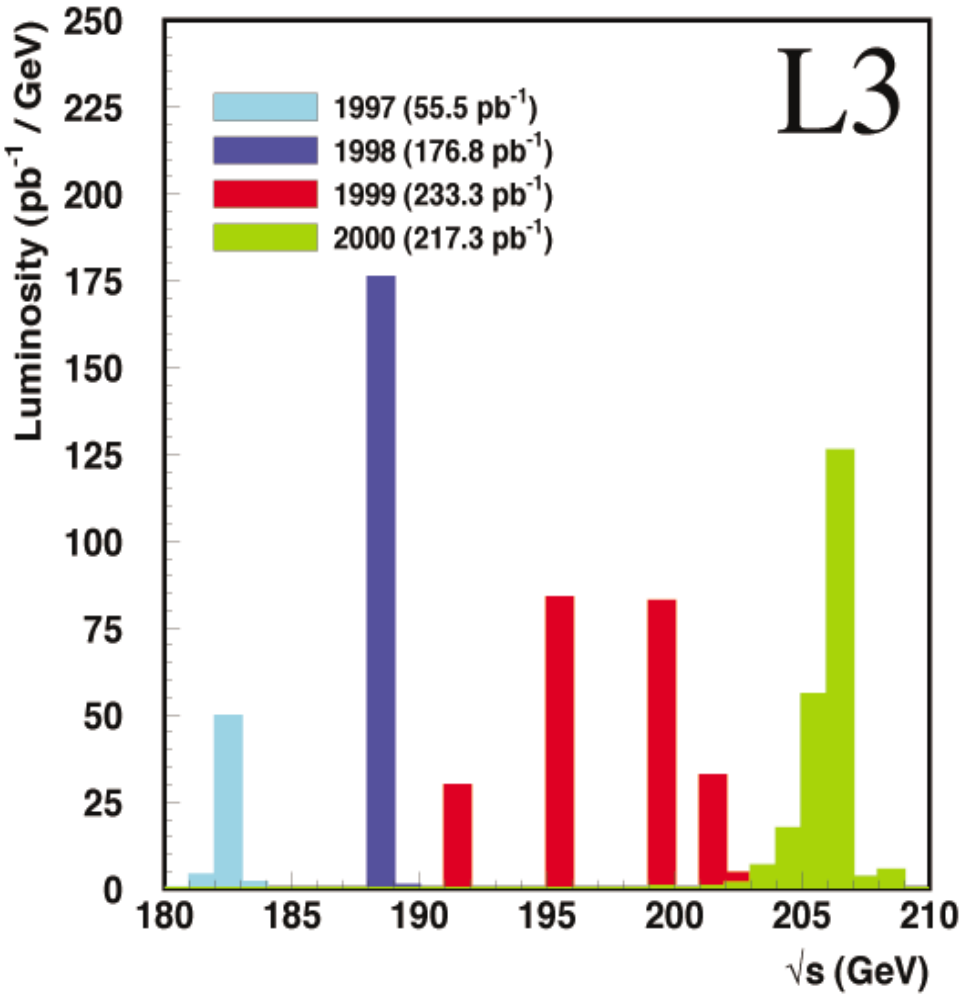
The L3 Detector at LEP



Experimental signatures

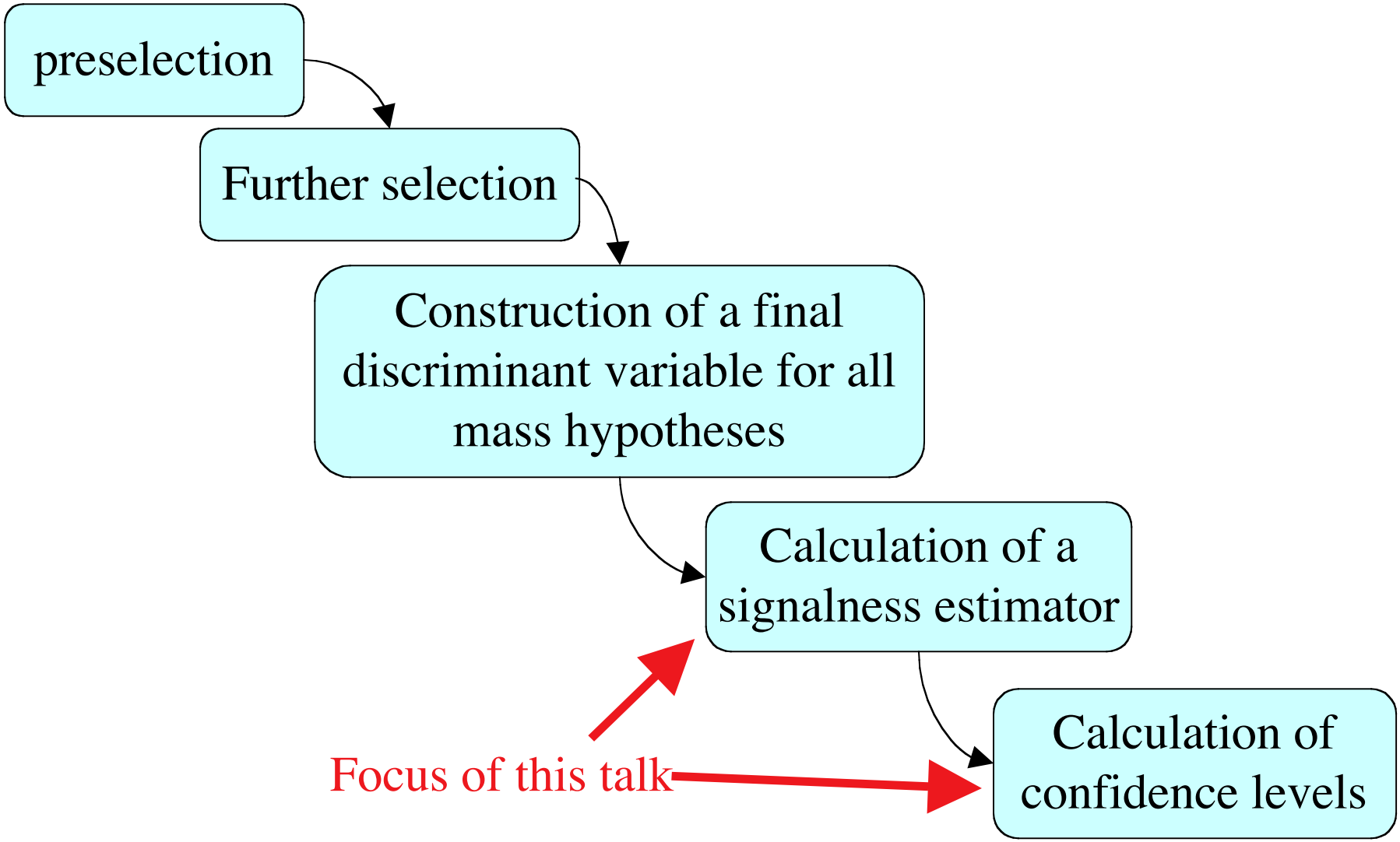
Channel	Topology	Br. ratio	example
four jets		≈ 64%	
two jets + missing momentum		≈ 18%	
two jets + lepton pair		≈ 9.3%	

The L3 data samples



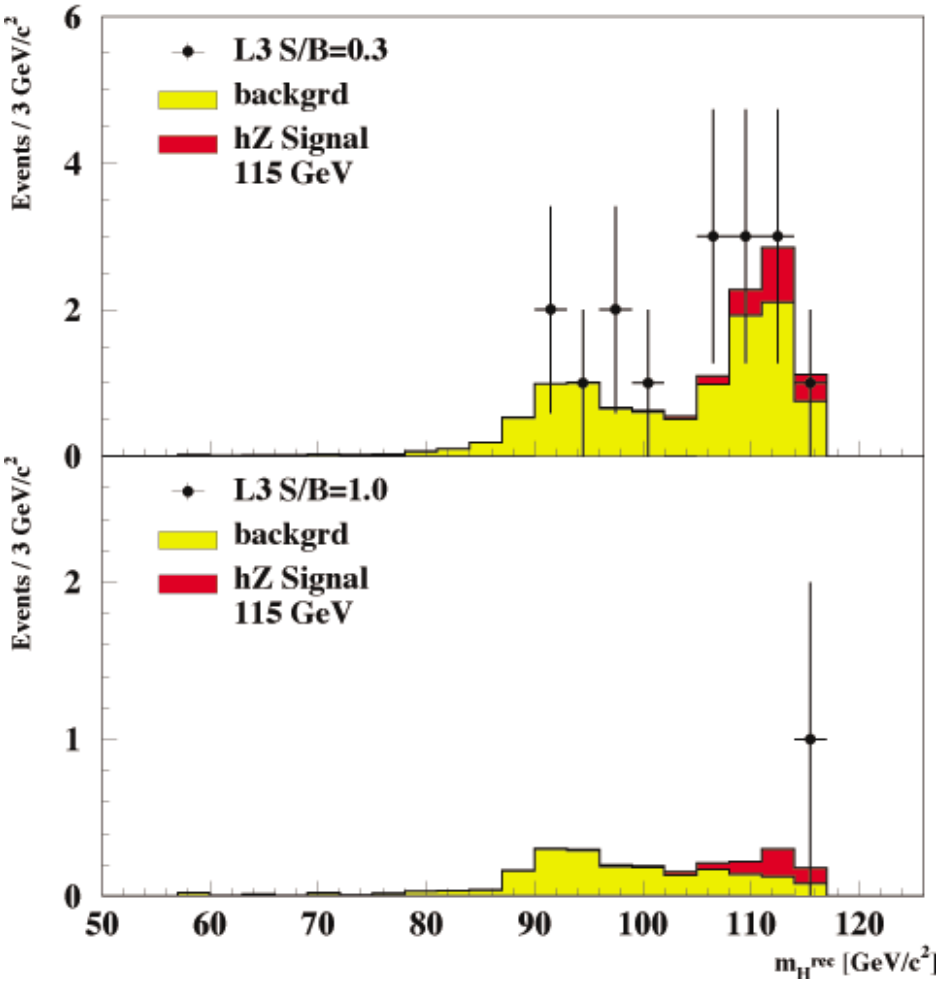
- Cross section is sharply falling above the kinematic limit
  → only the highest energy data are significant
- other LEP experiments collected similar data samples

Analysis flow



L3 combined mass distributions

Higgs candidate mass distributions after different cuts

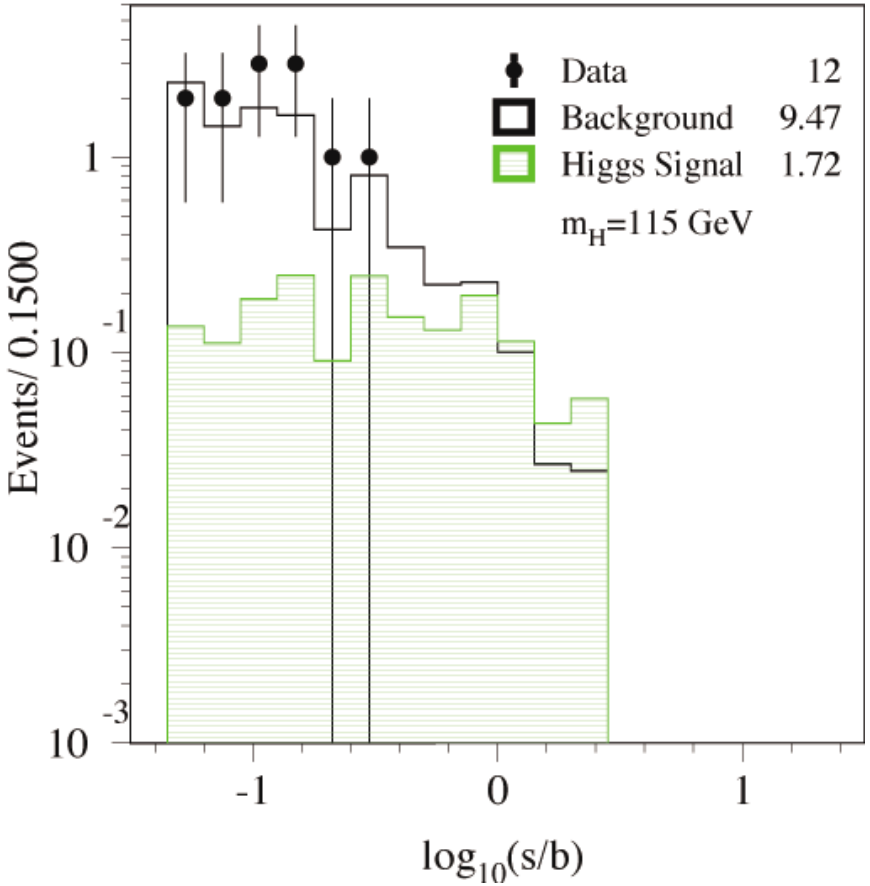


modest cuts

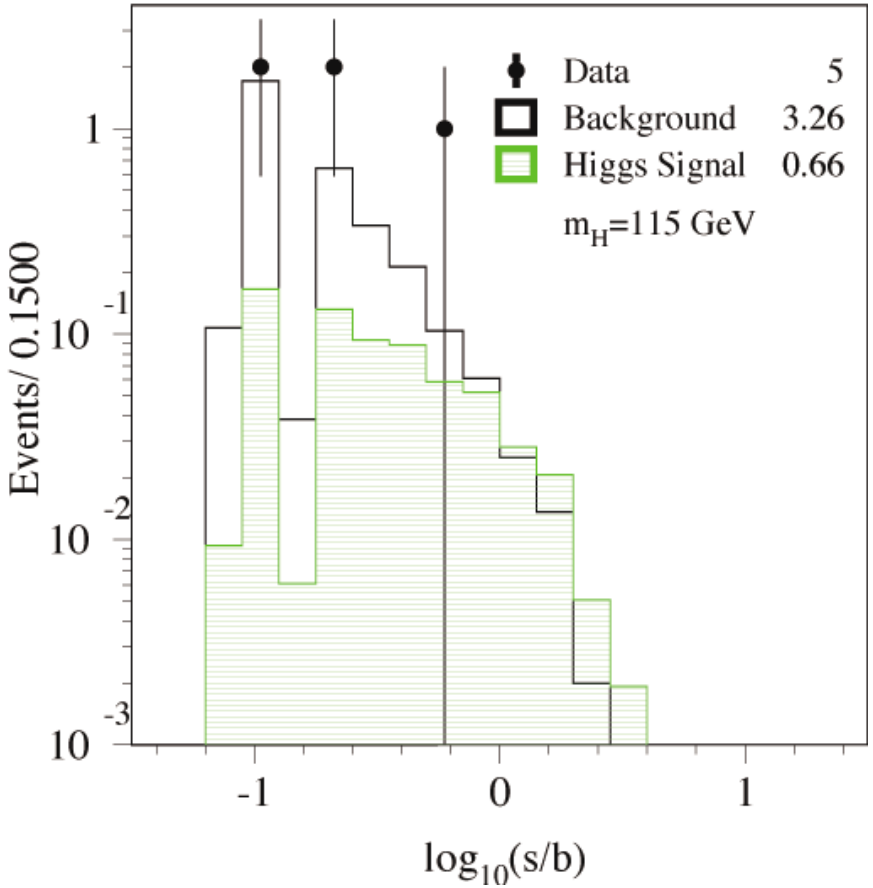
tight cuts

For testing the presence / absence of a signal, more information is used !!

L3 Final variable distribution by channel

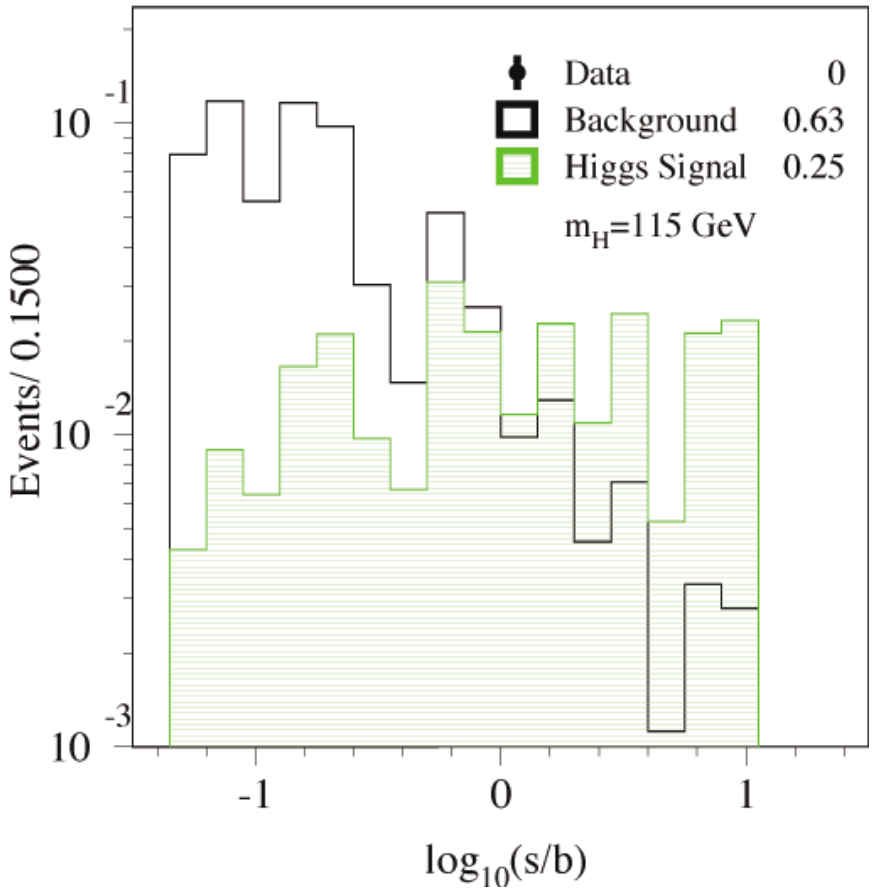


Four jets

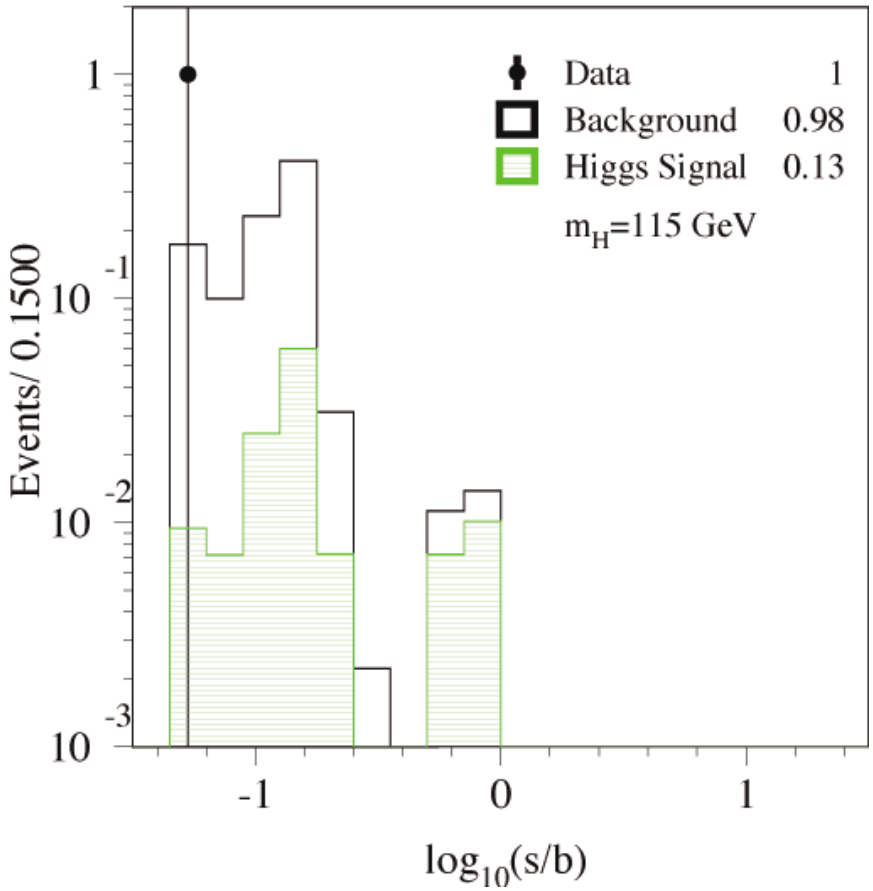


Missing energy

L3 Final variable distribution by channel



Electrons/muons + jets

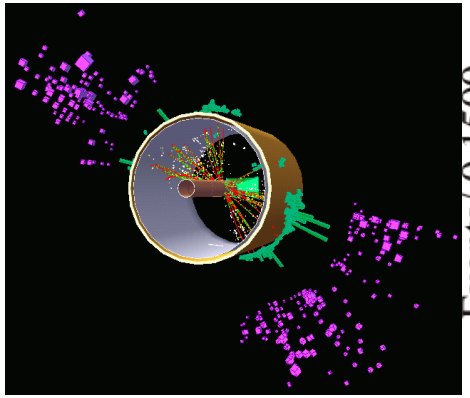


Tau channels

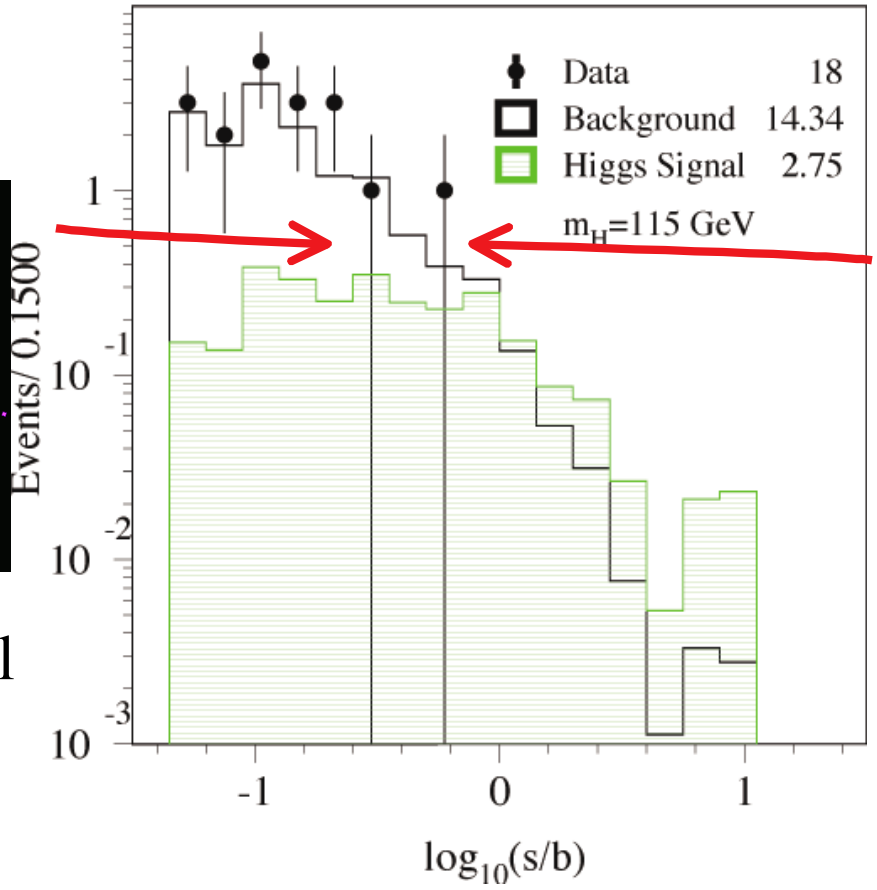
L3 combined final variable distribution

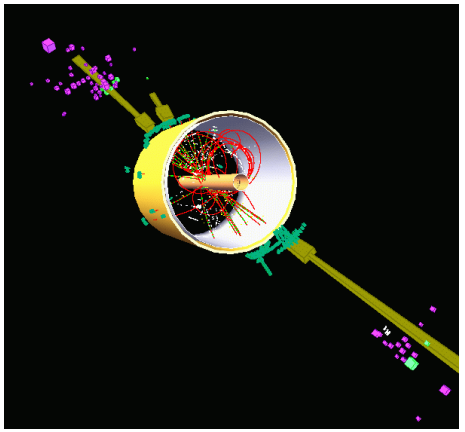
- Distribution of final discriminant for m_h= 115 GeV (all channels combined):

Missing energy channel



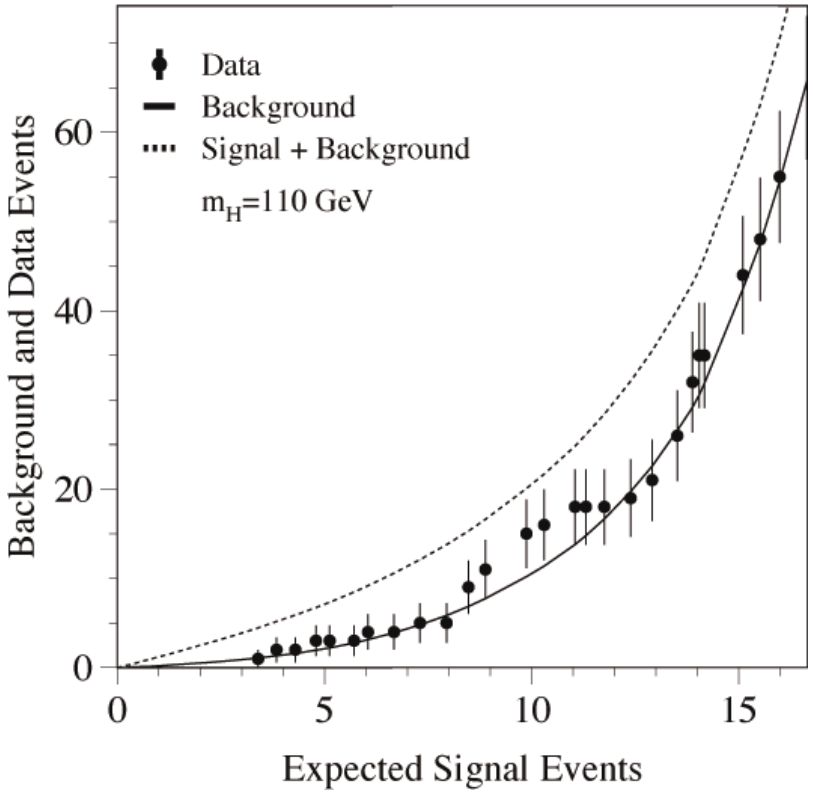
four jets channel



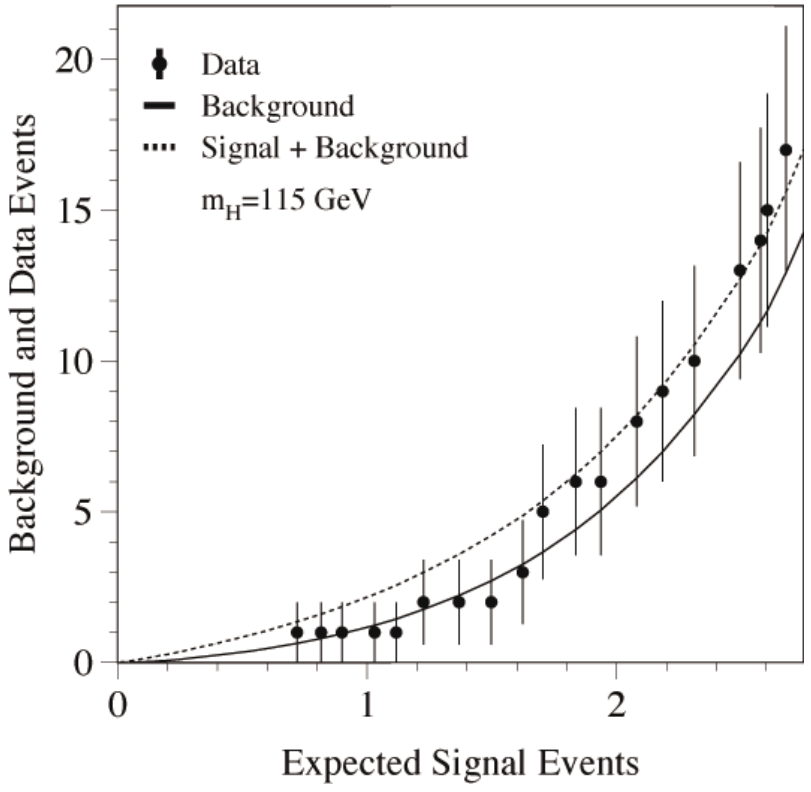


Going from high purity to high efficiency

Integrating the final variable from right to left:



m_h= 110 GeV



m_h= 115 GeV

Statistical Method

- A 'signalness' estimator is calculated from the final discriminant distribution to classify the experimental outcome
- By convention:
  - (more) positive for (more) background like
- Common Estimator used at LEP:

$$-2\ln Q = -2\ln \frac{\mathcal{L}(\text{data}\,|\,\text{sig}+\text{bg})}{\mathcal{L}(\text{data}\,|\,\text{bg})}$$

Where $\mathcal{L}$ = product of Poisson probabilities

Statistical Method

- ln Q can also be written as:

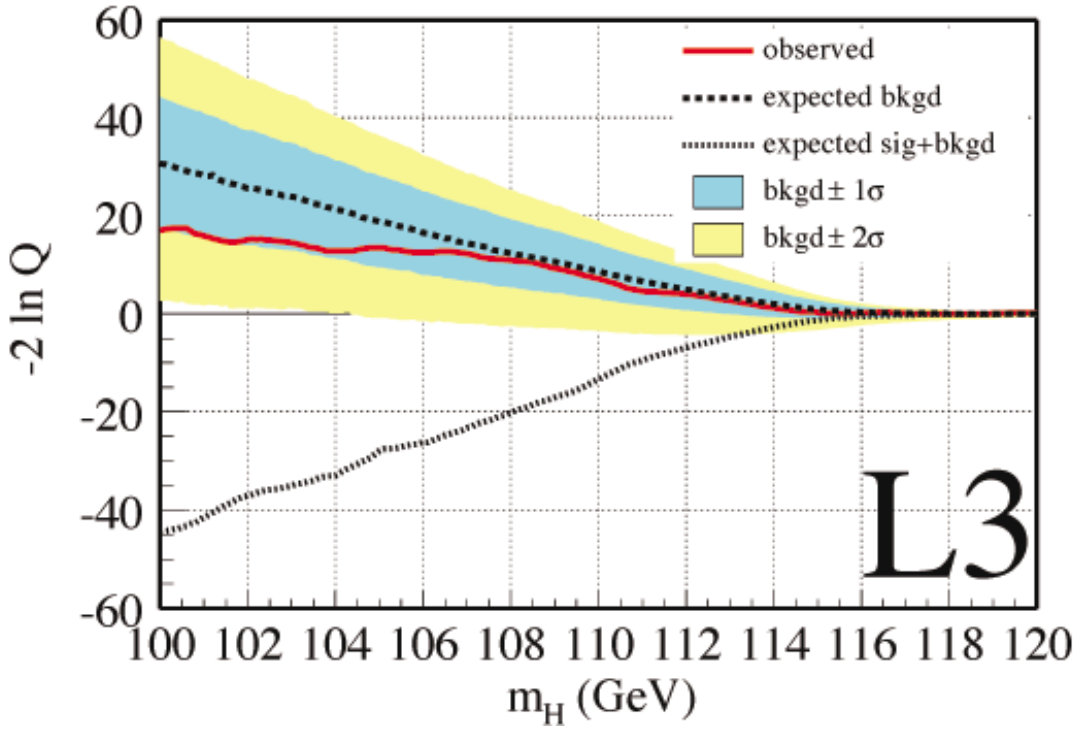
$$-s_{tot} + \sum_{i \in \text{ events}} \ln(1 + \frac{s_i}{b_i})$$

the more signal expected, the more candidates needed to have the same significance

the higher the (local) signal / background ratio of a candidate, the higher its weight

Estimator as function of mass

-2 ln Q as function of m_H
(all channels combined, Y2K + previous data):



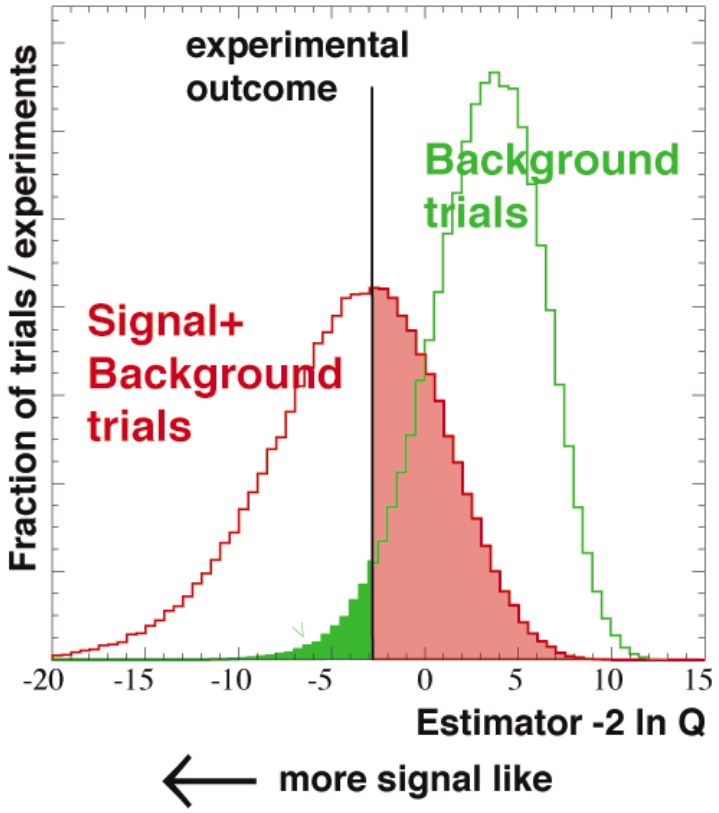
No deviation of more than one sigma from the background over the mass range 100-120 GeV

Confidence Levels

- To quantify the observation, Monte Carlo experiments are performed from the expected distributions

  One gets a distribution of the background-only and the signal+background-experiments:

  Systematic errors are taken into account by varying the background and signal expectations during the trials

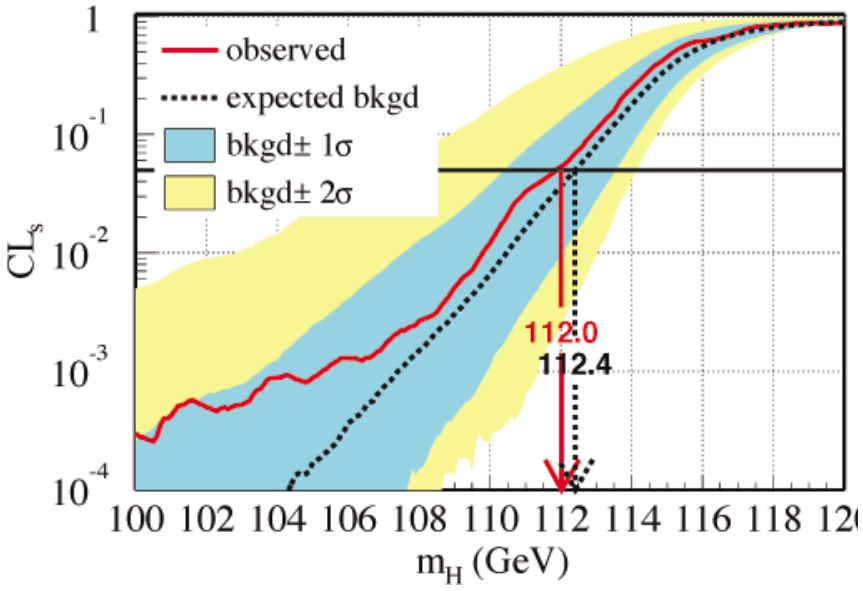


Confidence Levels

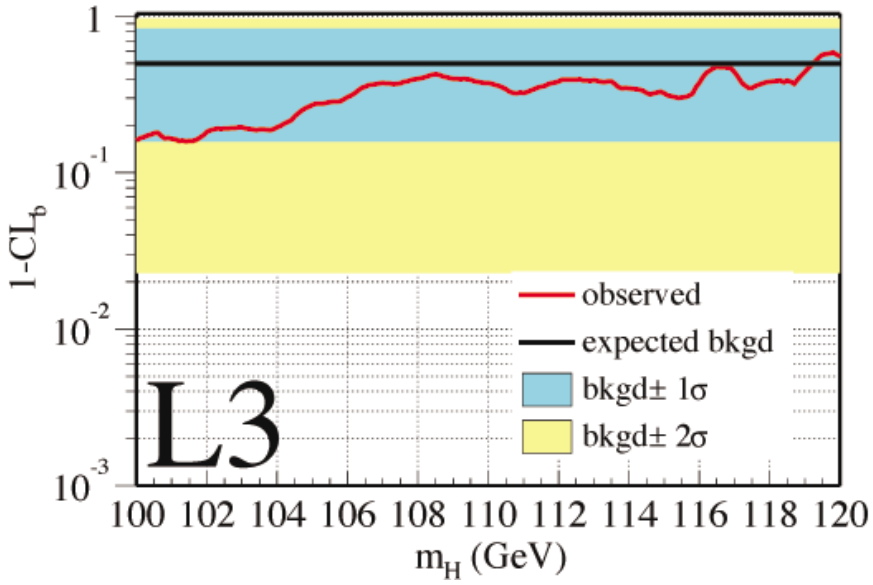
- Two confidence levels are calculated:
  - CL_s: fraction of sig+bg experiments which are more signal+background like than the data ('exclusion CL')
  - CL_b: fraction of bg experiments which are less background-like than the observation ('discovery CL')
- $CL_s < 5\%$: signal can be excluded at 95% CL
- $1\text{-}CL_b < 2.7 \cdot 10^{-3}$ ($5.7 \cdot 10^{-7}$) is a 3σ (5σ) deviation from the background

L3 Confidence Levels

Exclusion confidence level as function of m_h:



Discovery confidence level as function of m_h:



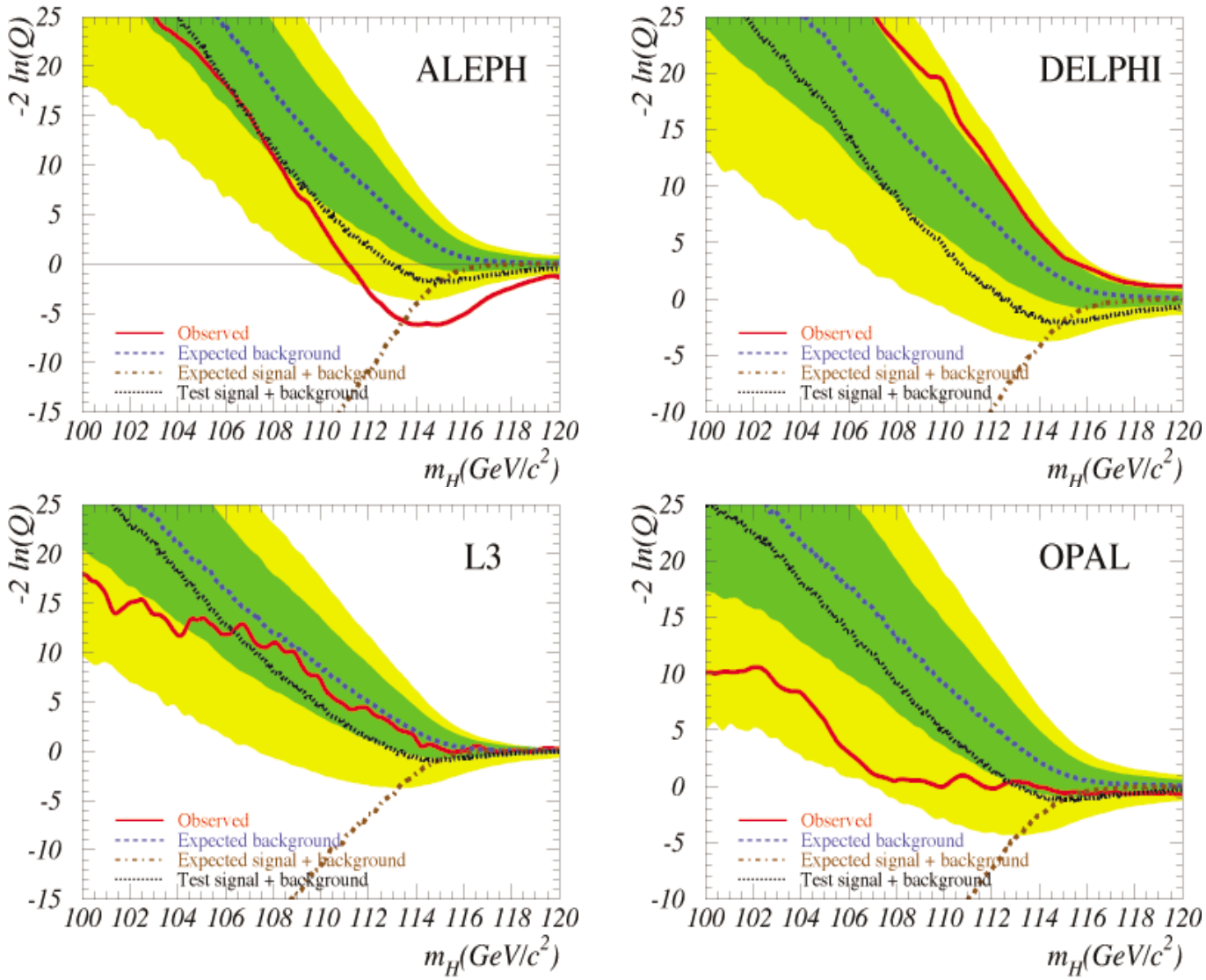
Observed (median expected) limit: $m_H >$ 112.0 (112.4) GeV

L3 Summary

- Higgs masses below 112.0 GeV are excluded at 95% confidence level (112.4 GeV expected)
- At m_h=115 GeV: observation is within 1σ from the background expectation (1-CL_b = 32%)
- These results have been accepted for publication (Phys.Lett. B517:319, 2001)

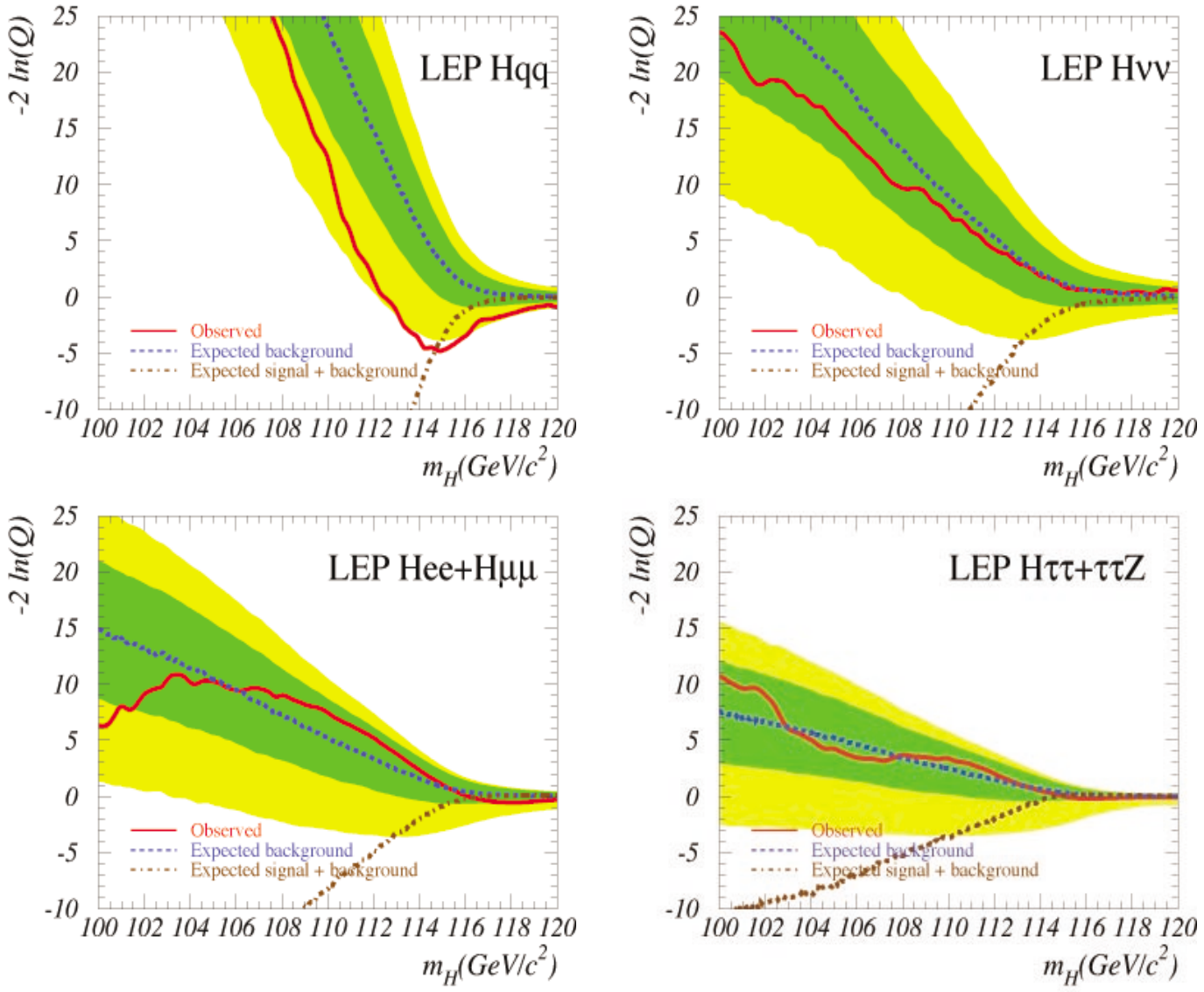
LEP wide Results by experiment

Estimator as function of m_h:



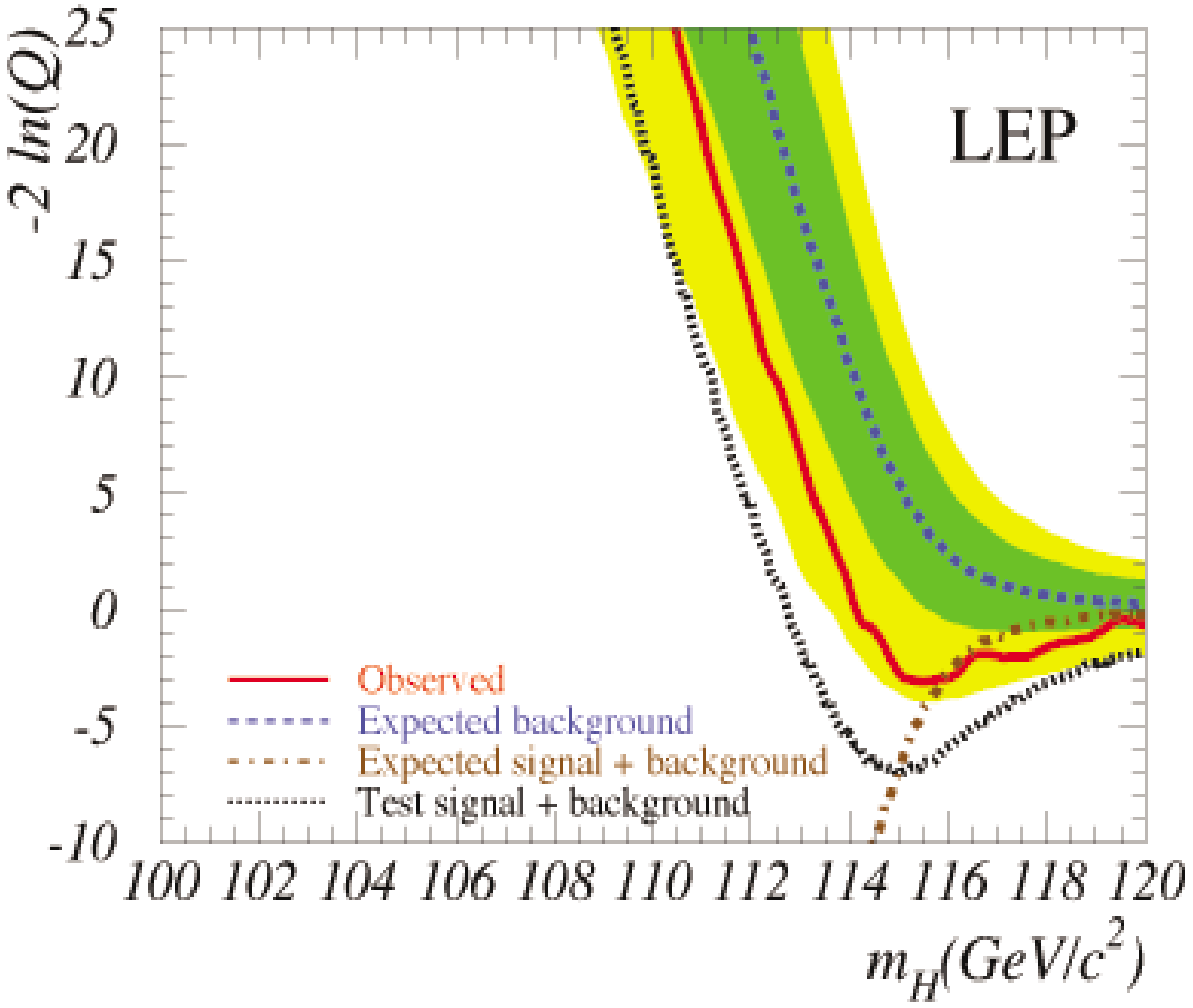
LEP wide Results by channel

Estimator as function of m_h:



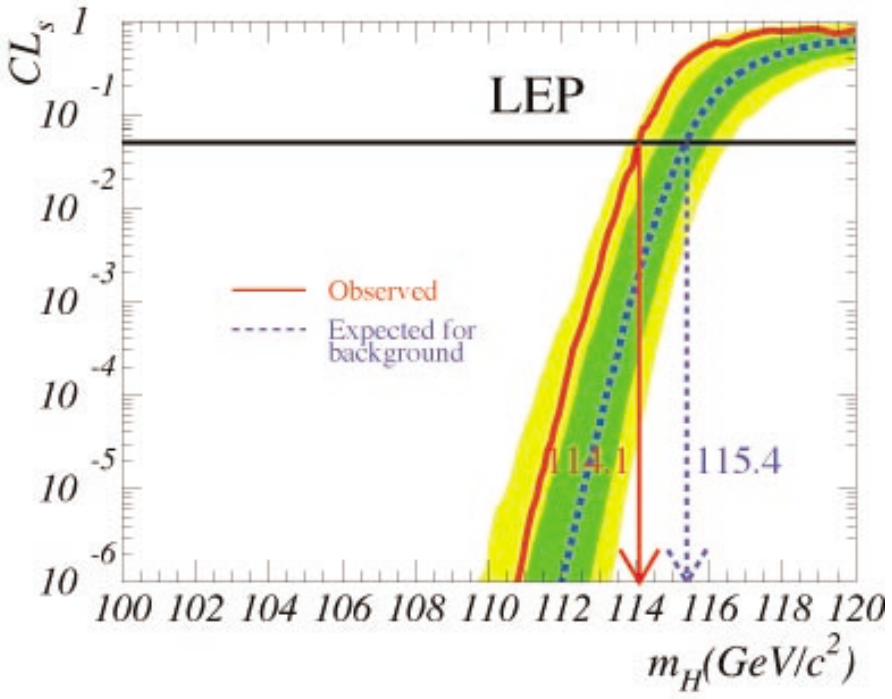
LEP combined: -2ln Q

Estimator as function of m_h:

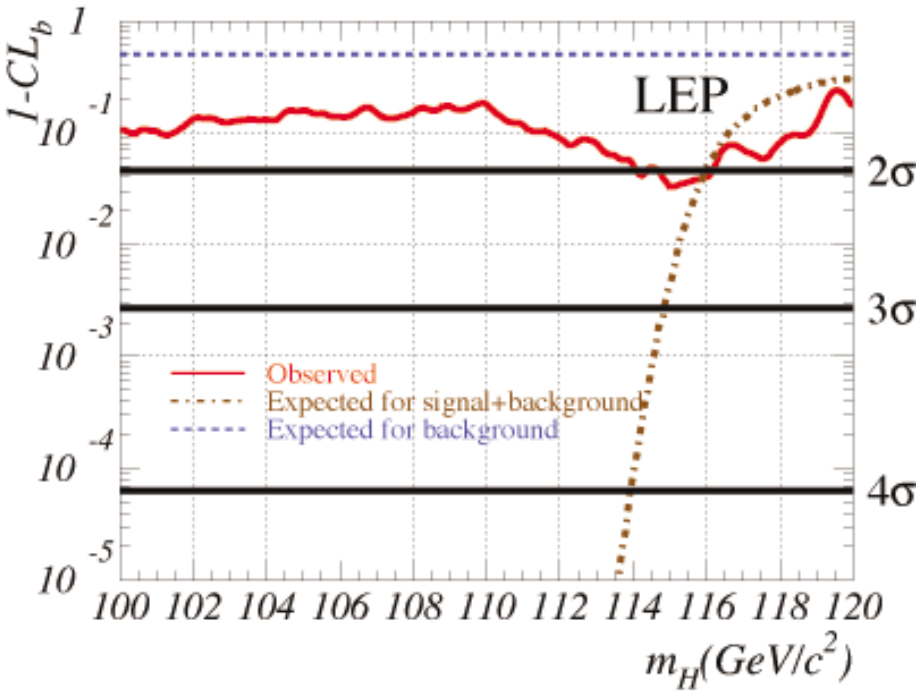


LEP combined: Confidence levels

Exclusion confidence level as function of m_h:



Background confidence level as function of m_h:



Observed limit is lower than expected limit because of presence of significant candidates

LEP wide Summary

- Almost 2.5 fb^{-1} of data were analysed
- An excess of signal like events is observed mainly by ALEPH in the four jets channel.
- LEP wide, this excess is most significant at m_H = 115.6 GeV, where the probability of a background fluctuation (1-CL_b) is 3.4 %
- Higgs masses below 114.1 GeV are excluded at 95% confidence level
- The LEP wide results are still preliminary, though no major changes are expected for the final publication