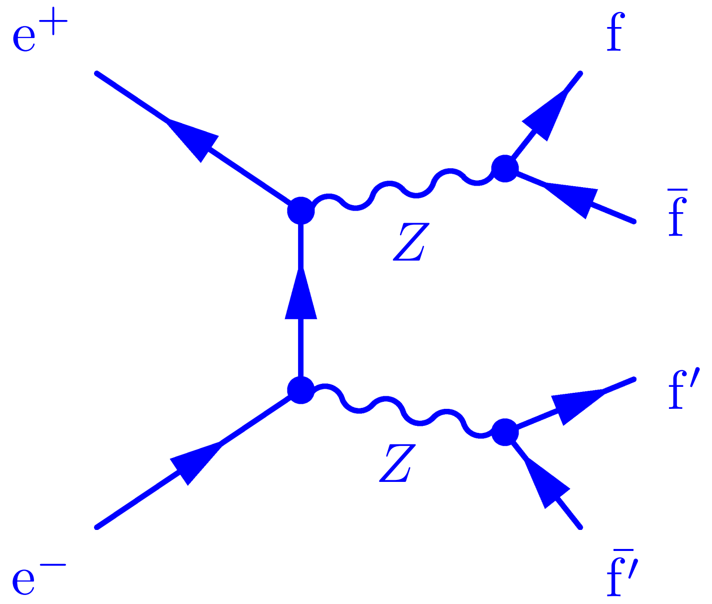
Study of pair-produced neutral heavy bosons at LEP using the L3 Detector

Serge Likhoded
DESY Zeuthen

Lake Louise Winter Institute, 17-23 February, 2002



▽ **Study** of the neutral gauge boson sector

▽ **Signal for a new physics** - probe the existence of the triple neutral gauge boson couplings, ZZZ and ZZγ.

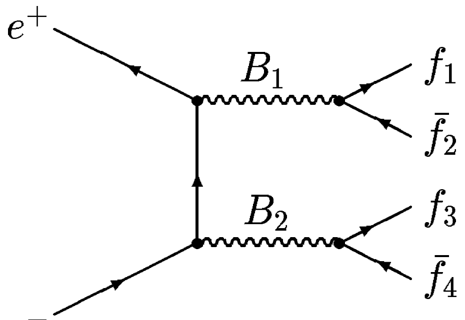
▽ **Irreducible background** for the Search of the Higgs bosons.

$\sqrt{s}$ (GeV)	205	207
$\int \mathcal{L}$dt, pb^{-1}	78	139
σ_{SM}, pb	1.07	1.08

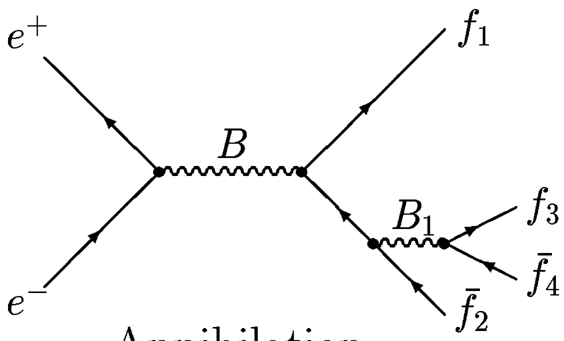
All results from year 2000 data are preliminary.

Life is a bit more complicated...

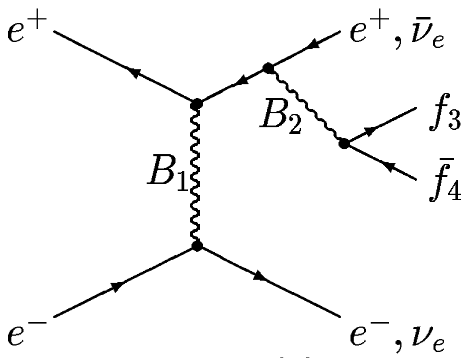
The four-fermion processes, accessible at LEP:



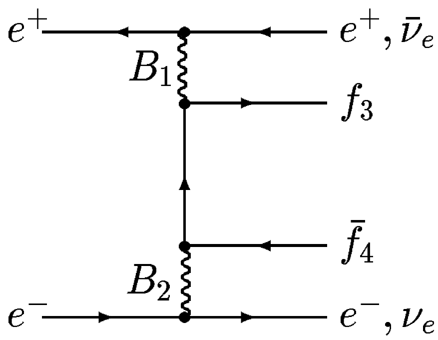
Conversion



Annihilation



Bremsstrahlung

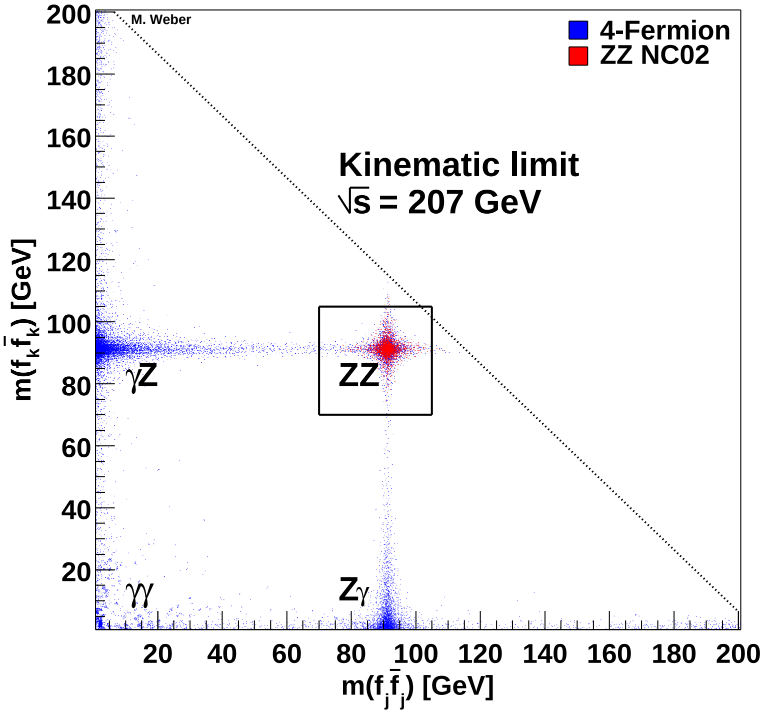


Multiperipheral

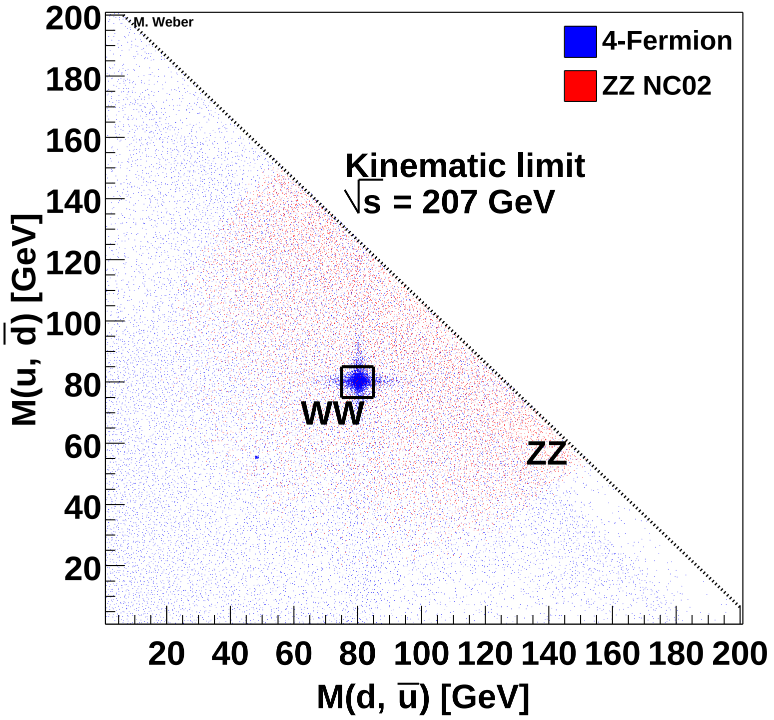
$(B = \gamma, Z^0, B_1, B_2 = Z^0, \gamma, W^\pm)$

We need a signal definition!

1. ZZ: $70 \text{ GeV} < M(f,\bar{f}), M(f',\bar{f}') < 105 \text{ GeV}$

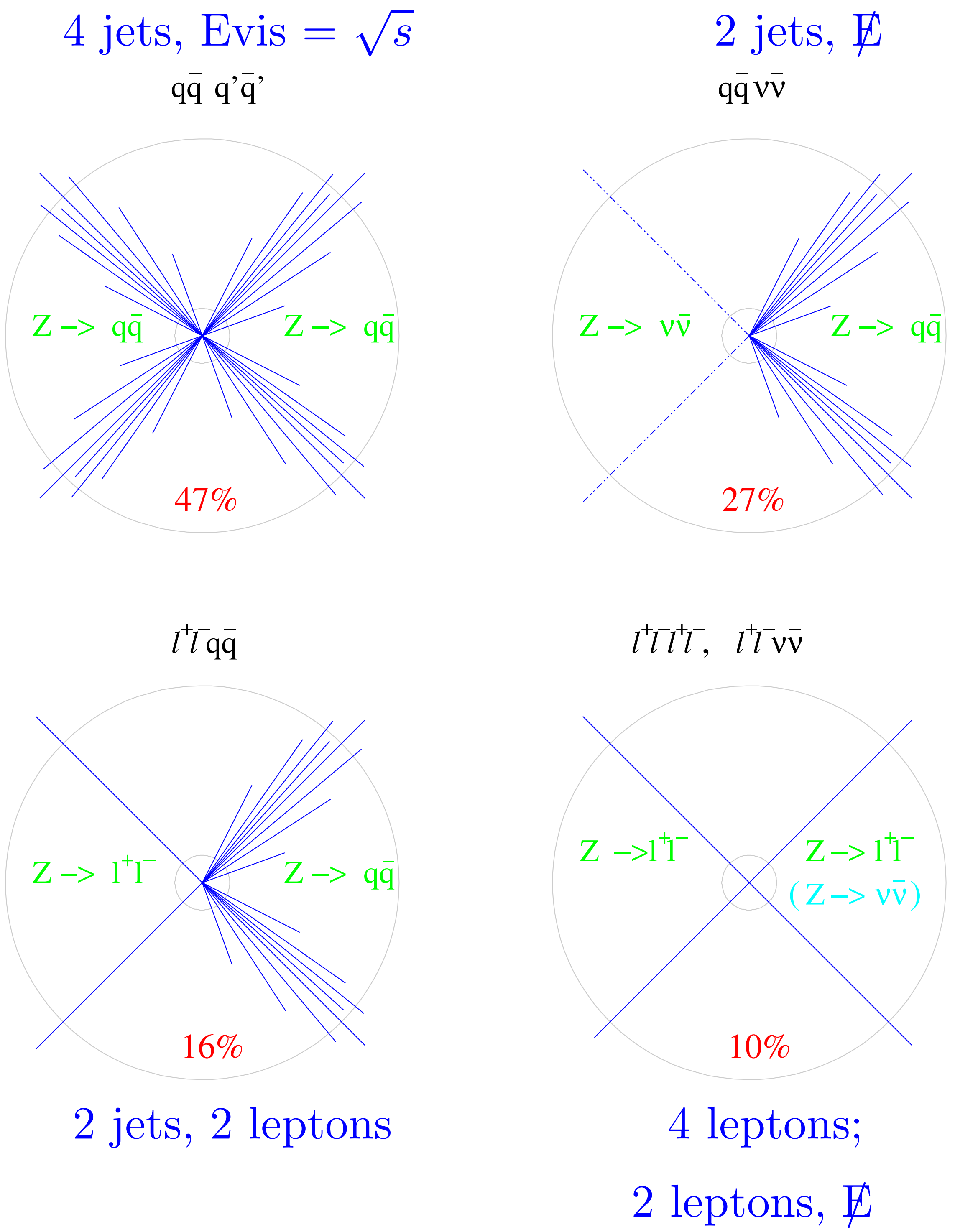


2. WW: $M(f,\bar{f}'), M(f',\bar{f}) \notin [75;85] \text{ GeV}$



Search Channels

All channels are covered!



Highest statistic channel

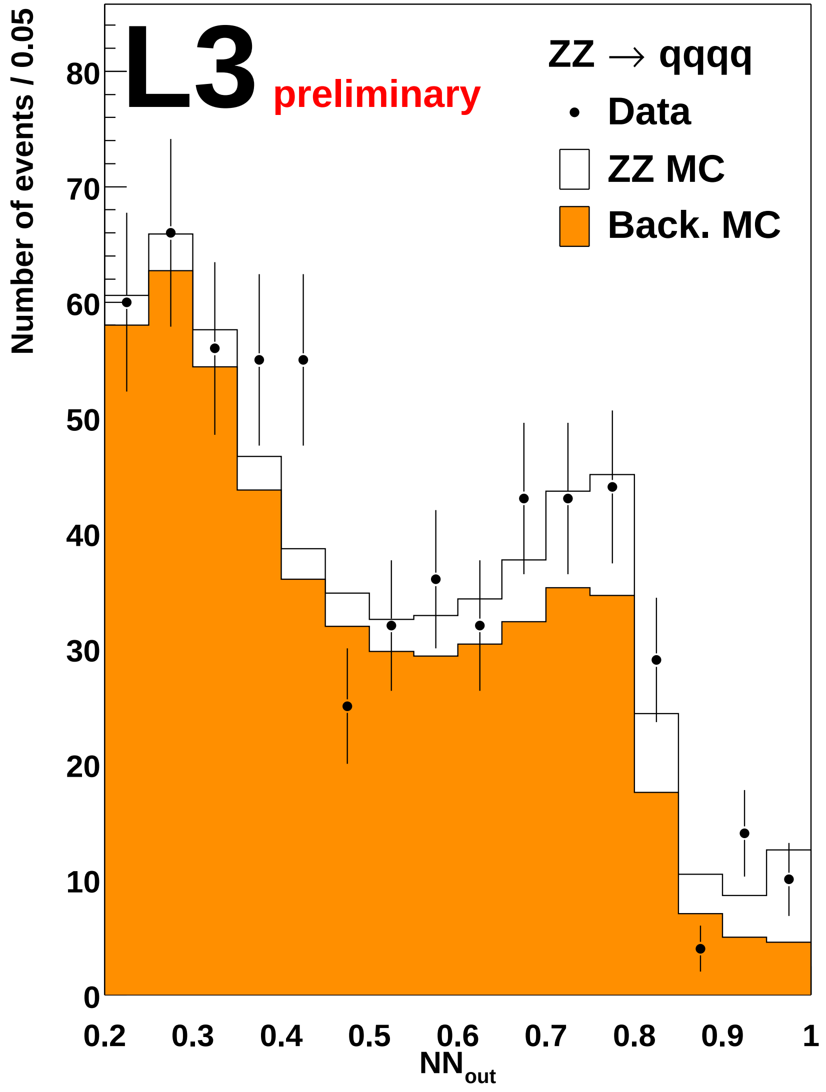
Most important (and highest) background:

$$e^+e^- \to Z^*/\gamma^* \to q\bar{q}(\gamma)$$

$$e^+e^- \to W^+W^-$$

Signature: 4 jets, high multiplicity, full energy in detector, balanced in momentum.

Analysis: Neural Network fed with the kinematic and topological event characteristics



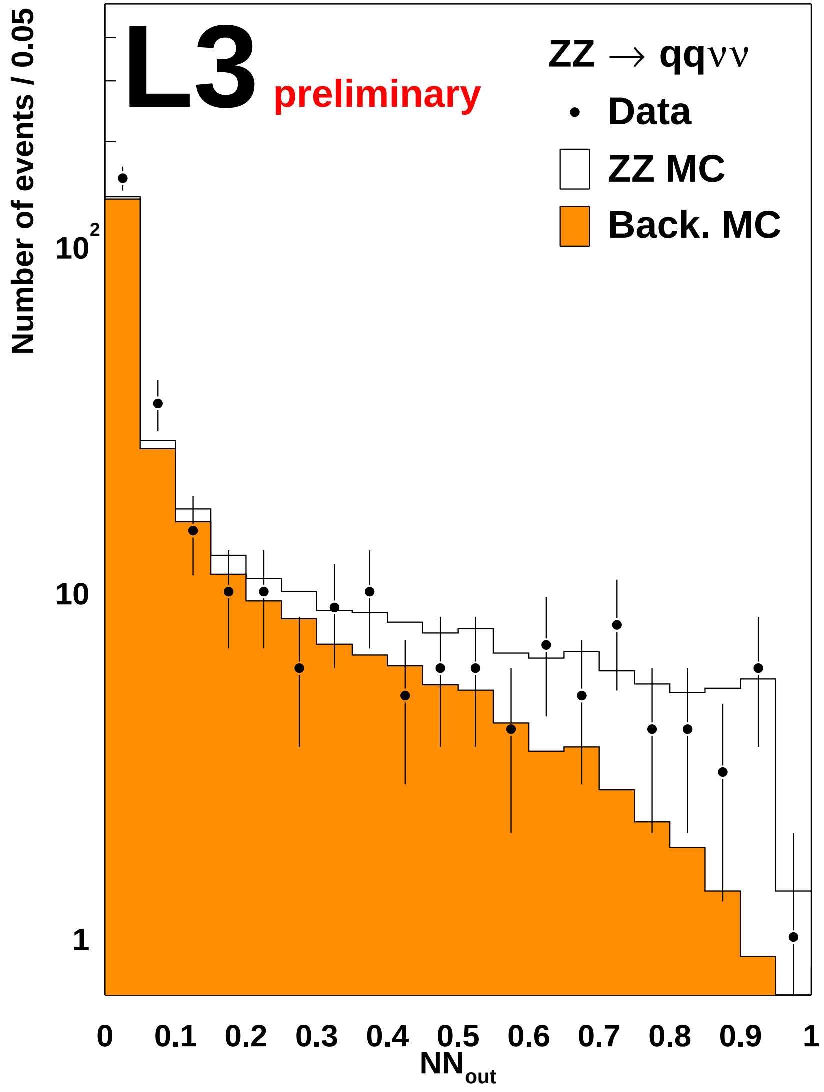
Moderate statistics

Most important background:

$$e^+e^- \to Z^*/\gamma^* \to q\bar{q}(\gamma)$$
$$e^+e^- \to q\bar{q}e\nu$$

Signature: 2 acoplanar jets, missing transverse momentum, high multiplicity

Analysis: Neural Network fed with the kinematic and topologic event characteristics



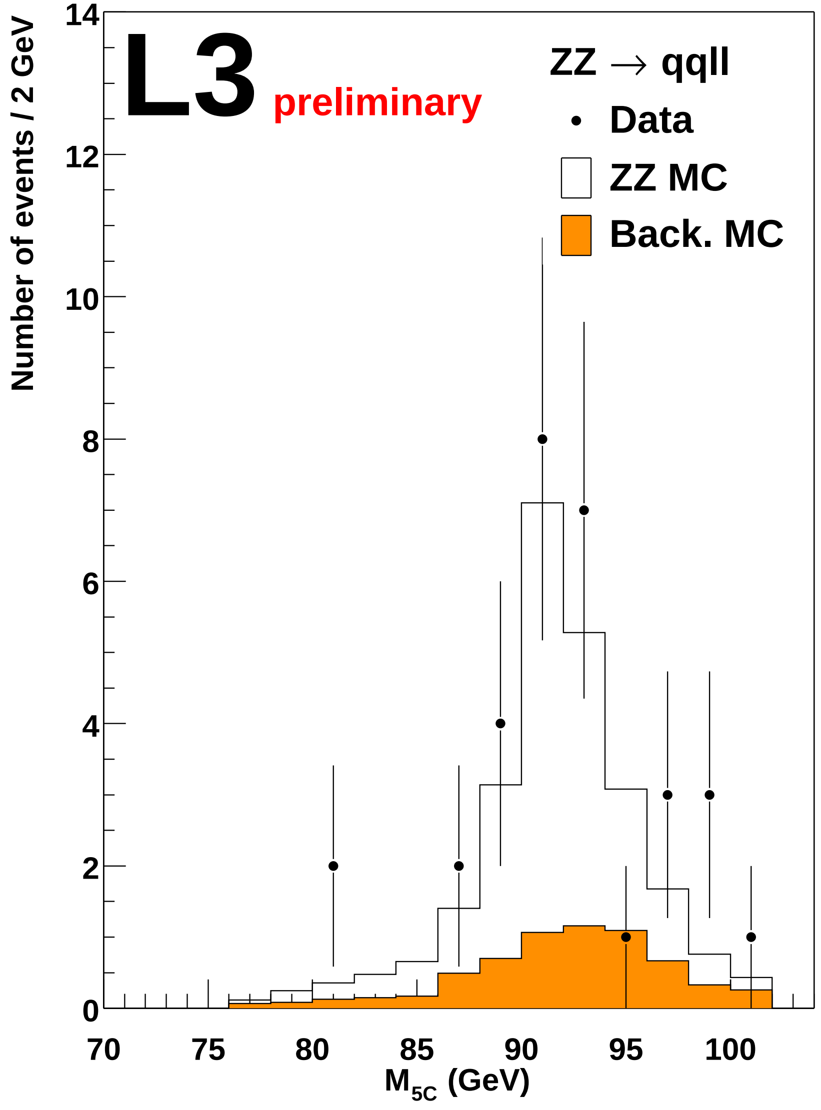
Lower statistics but cleanest channel

Most important background:

$$\mathrm{e^+e^-} \quad \to \quad \mathrm{Z^*/\gamma^* \to q\bar{q}(\gamma)}$$
$$\mathrm{e^+e^-} \quad \to \quad \mathrm{q\bar{q}e\nu}$$

Signature: 2 acoplanar jets, 2 isolated charged leptons, high multiplicity

Analysis: Cut based, lepton identification, 5C fit $M_{l^+l^-} = M_{q\bar{q}}$



$$l^+l^-l'^+l'^-,\ l^+l^-\nu\bar{\nu}$$

Small statistics channels

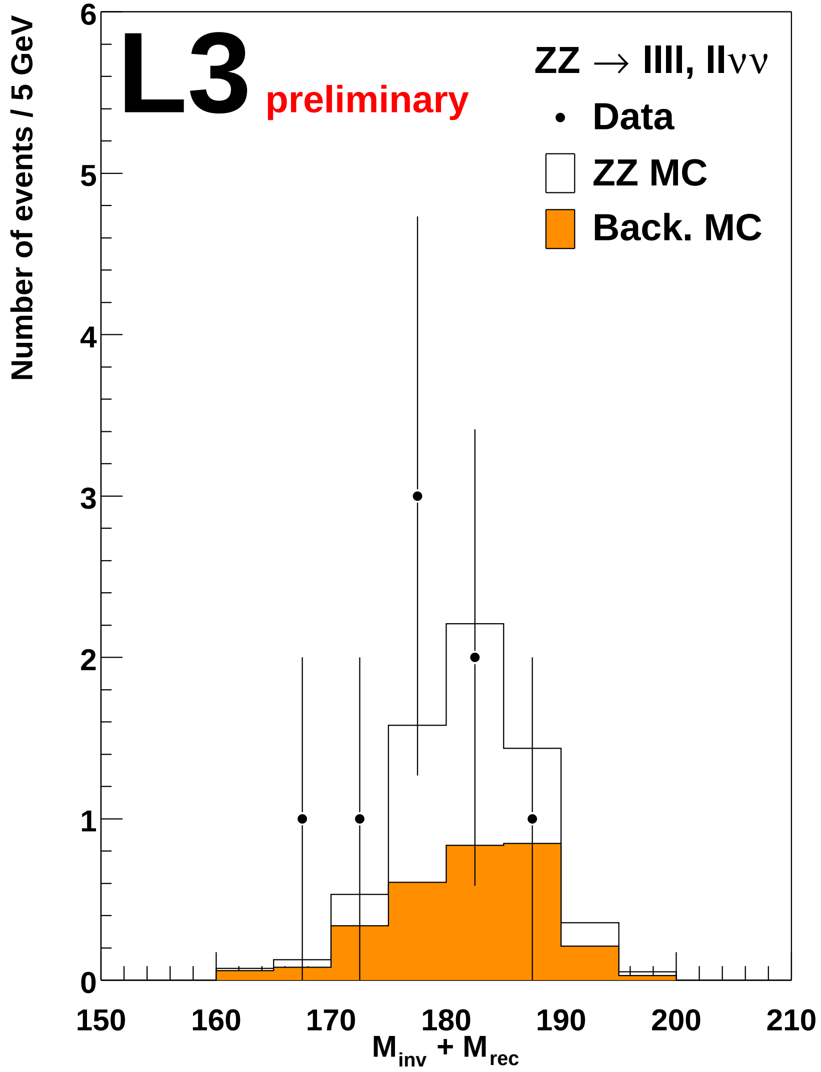
Most important background:

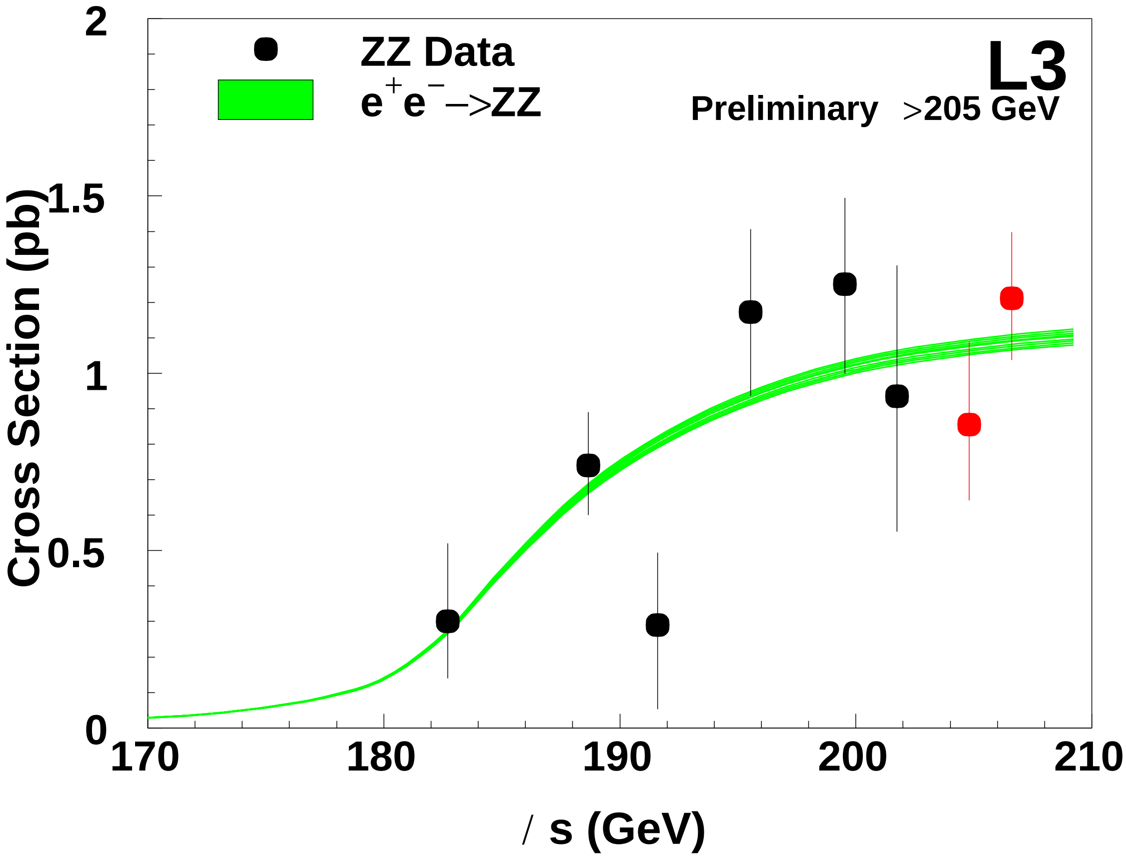
$$\mathrm{e^+e^-} \quad \rightarrow \quad \mathrm{l^+l^-}(\gamma)$$

Signature:

- 4 isolated charged leptons;
- 2 isolated charged leptons, missing energy;

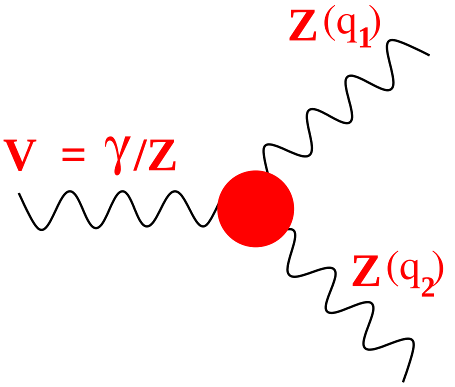
Analysis: Cut based, lepton identification





$\sqrt{s}$	σ_{ZZ}^{exp} (pb)	σ_{ZZ}^{SM} (pb)
205	$0.86^{+0.23}_{-0.21}(stat) \pm 0.07(syst)$	1.07
207	$1.21^{+0.19}_{-0.17}(stat) \pm 0.10(syst)$	1.08

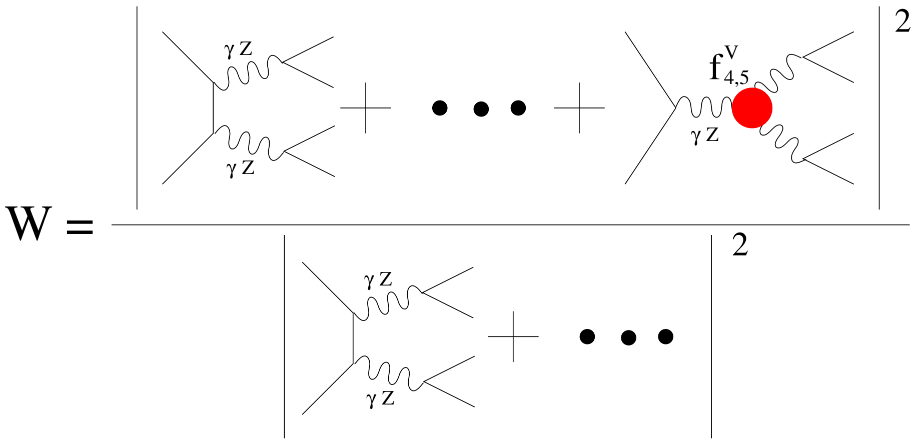
The most general ZZV vertex for on-shell Z bosons is:



$$ig_{ZZV}\Gamma^{\alpha\beta\mu}_{ZZV}(q_1, q_2, p)$$

$$\Gamma^{\alpha\beta\mu}_{ZZV} \sim f_4^{Z,\gamma}(\not{C}\mathrm{P},\ \mathrm{P}) \text{ and } f_5^{Z,\gamma}(\mathrm{CP},\ \not{\mathrm{P}})$$

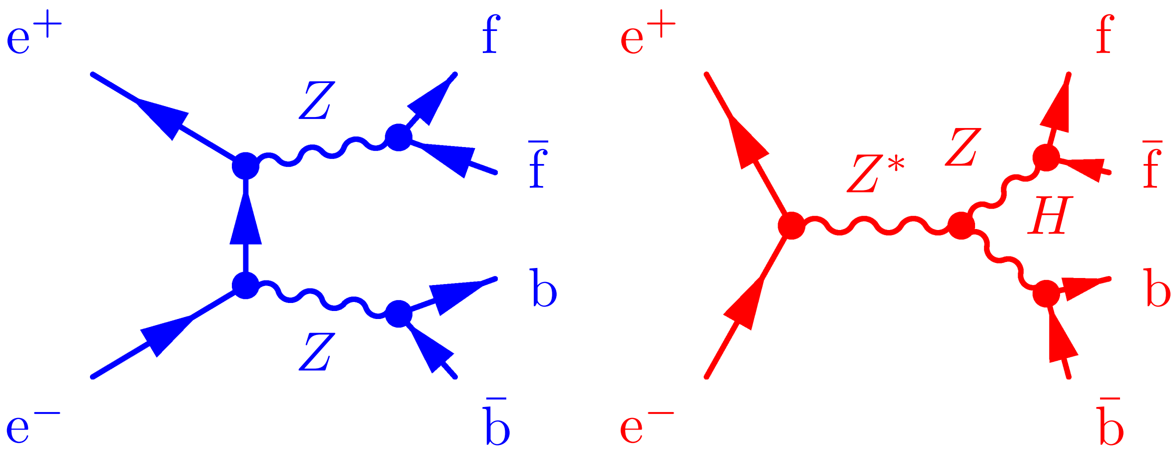
1. Re-weight MC sample including the A.C:



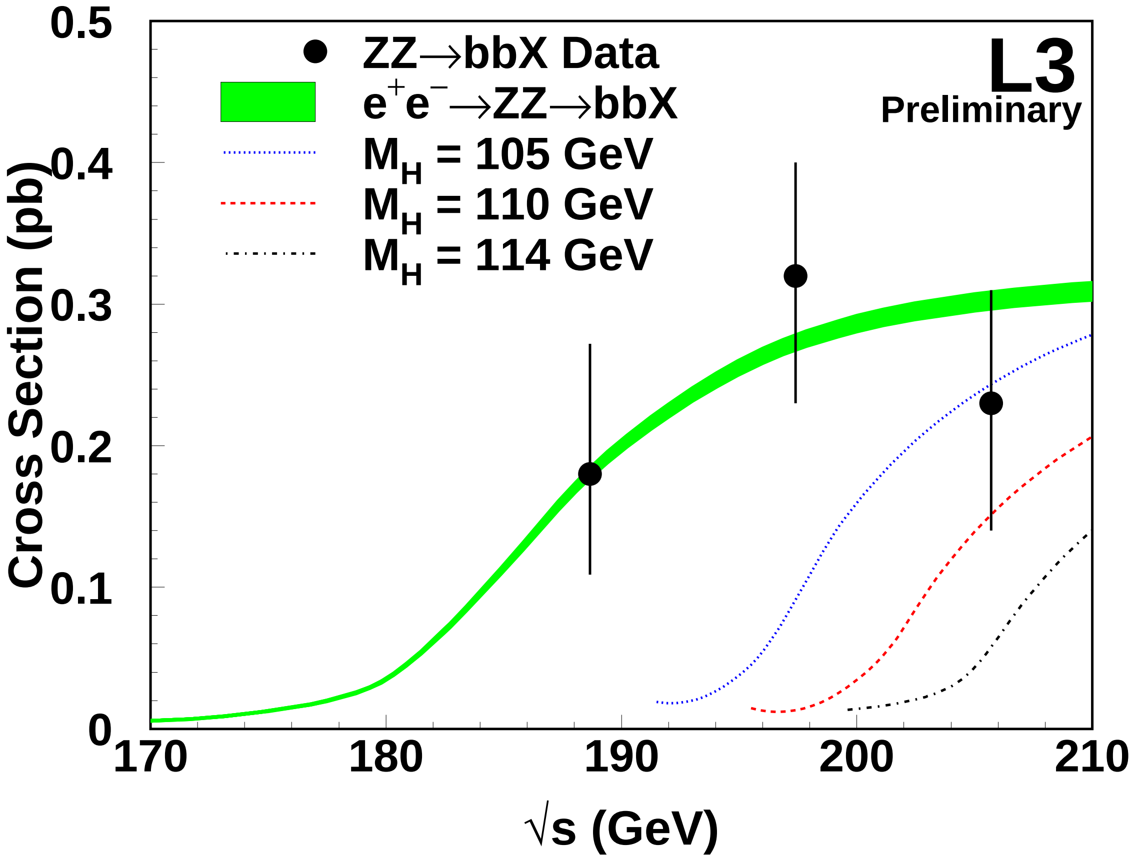
2. Perform binned maximum likelihood fits varying each of the $f^V_{4,5}$, fixing other three

$$\begin{aligned} -0.42 &\le f_4^Z \le 0.41 \\ -0.46 &\le f_5^Z \le 1.21 \\ -0.24 &\le f_4^\gamma \le 0.26 \\ -0.48 &\le f_5^\gamma \le 0.56 \end{aligned}$$

Similar topology:

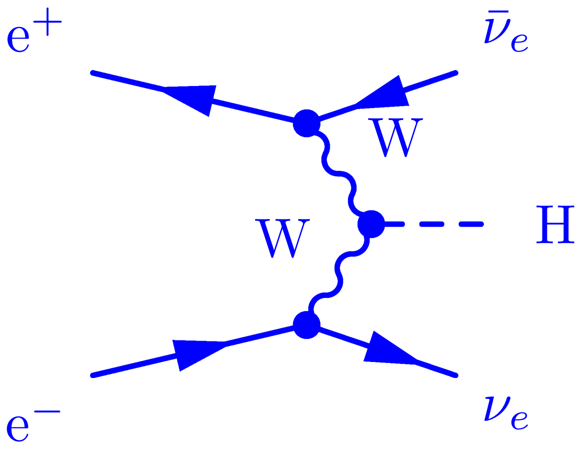


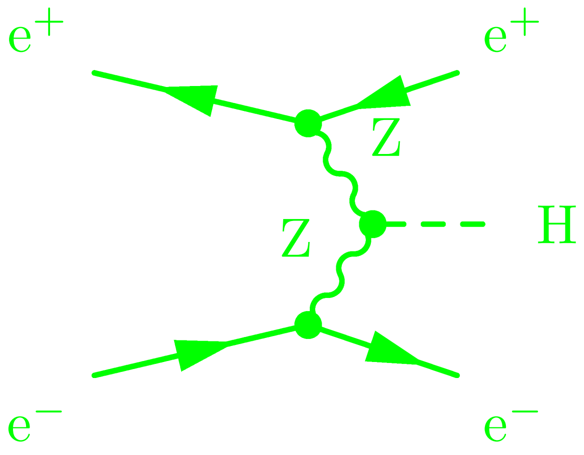
Comparable cross section:

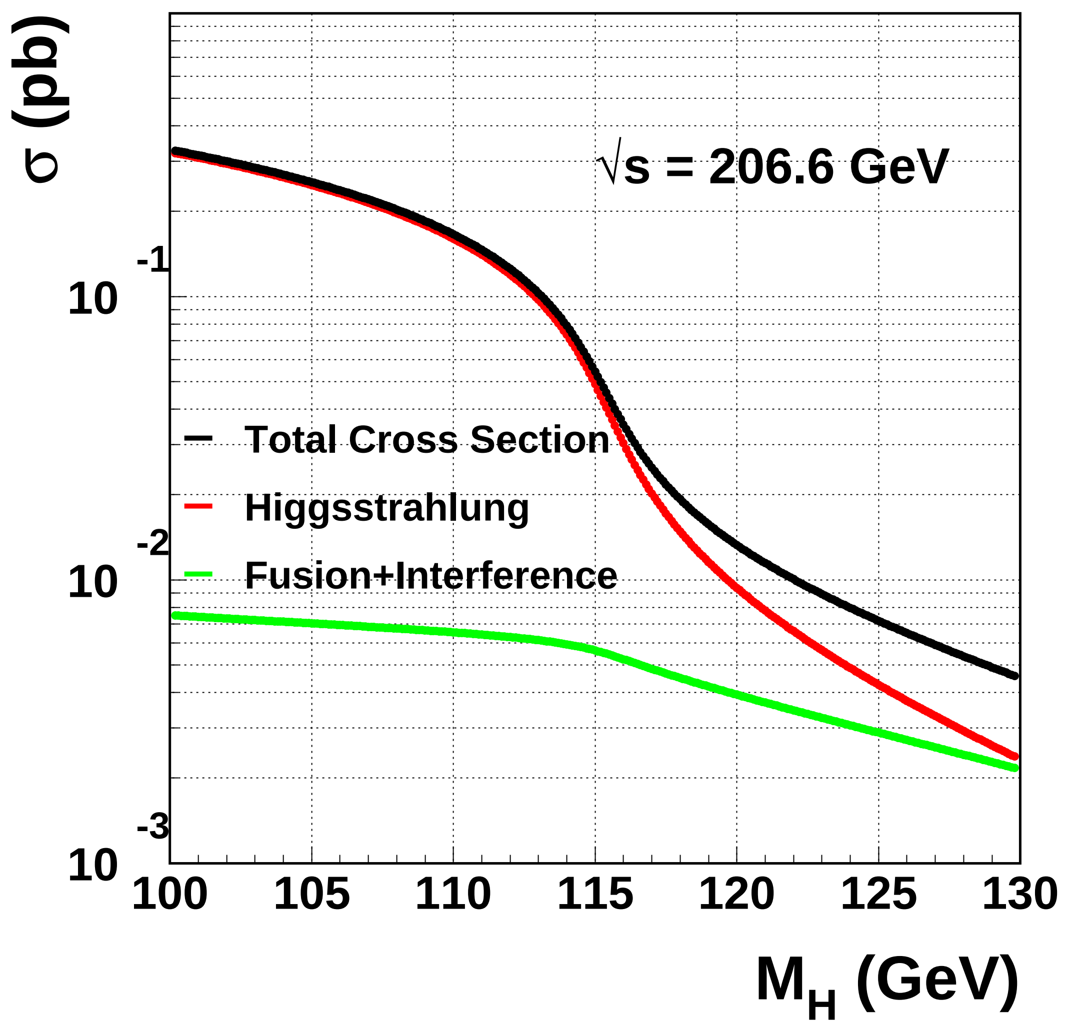


Sensitivity to $ZZ \to b\bar{b}X \Rightarrow$ Sensitivity to Higgs!

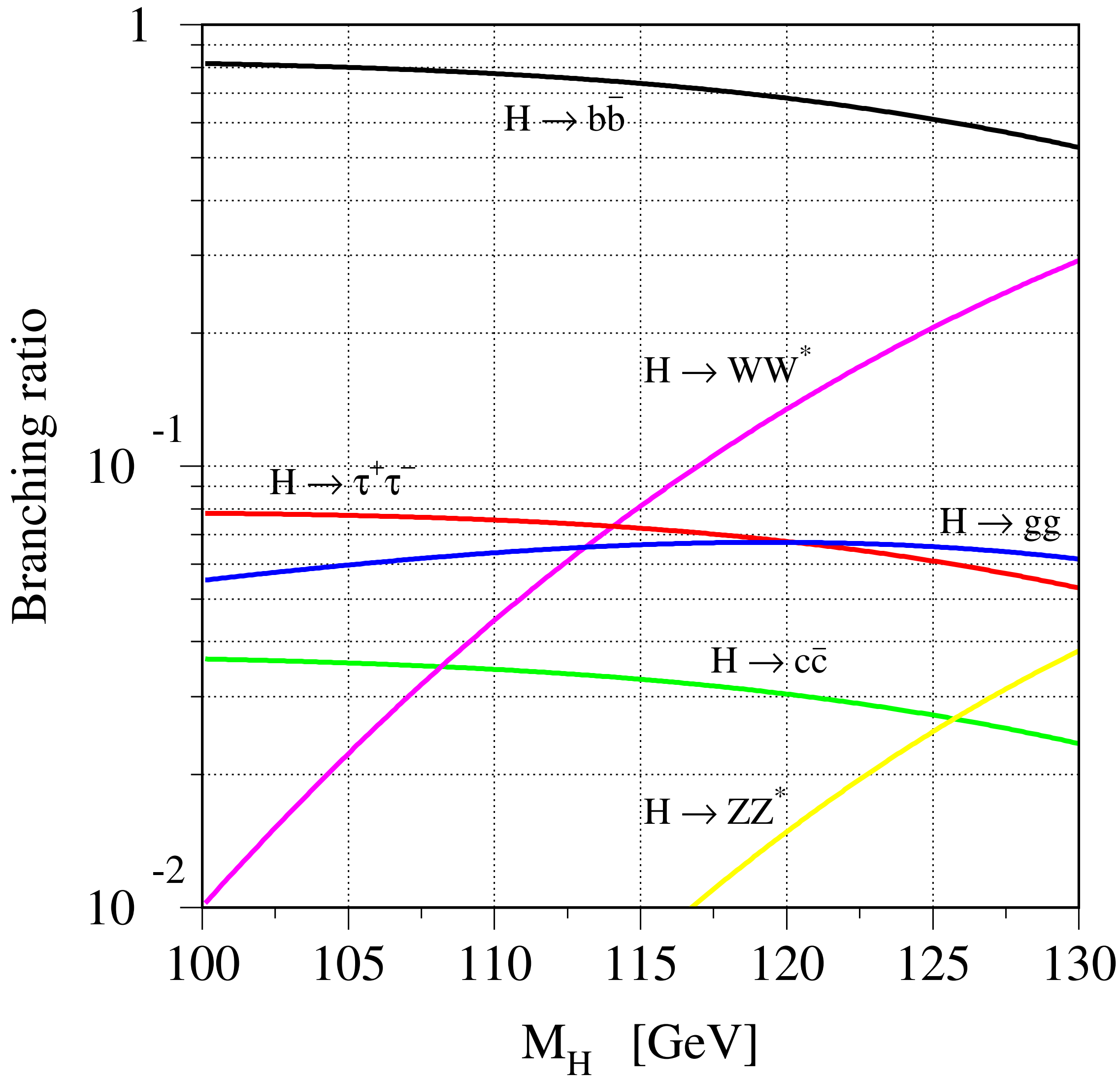
also via W/Z fusion:







Higgs decay branching ratios

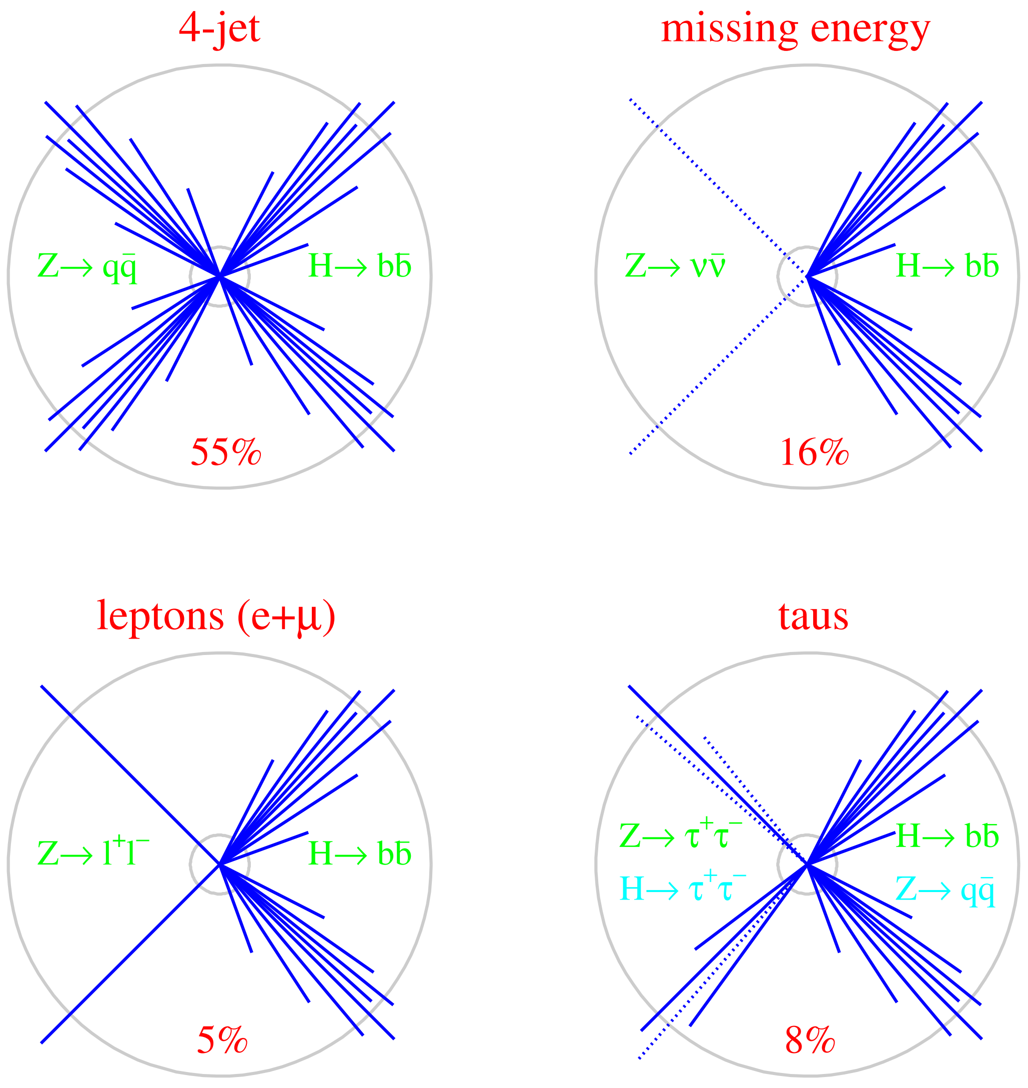


Dominant Higgs decay mode:

$\mathrm{BR}(H_{110} \to b\bar{b}) \simeq 78\%$, $\mathrm{BR}(Z \to b\bar{b}) \simeq 15\%$

B-tagging is essential!

About 85% of the final states exploited

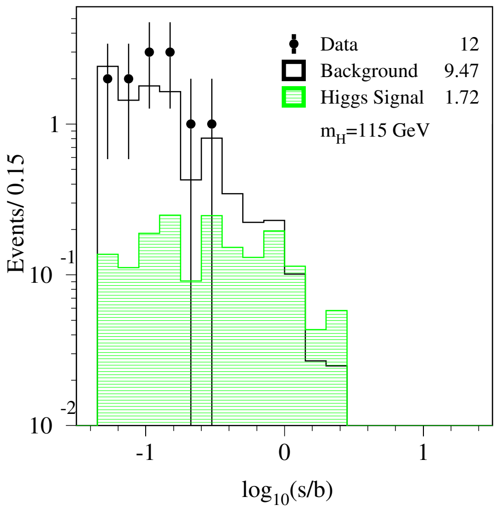


Analyses are almost the same as for ZZ, more use of b-tag and constraint to a Z boson and a heavy object.

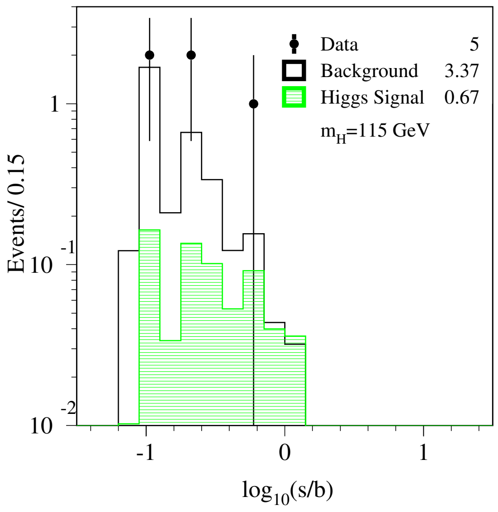
For each final state a final discriminant is built.

Distribution for the Final Discriminant for $M_{Higgs} = 115$ GeV for each channel:

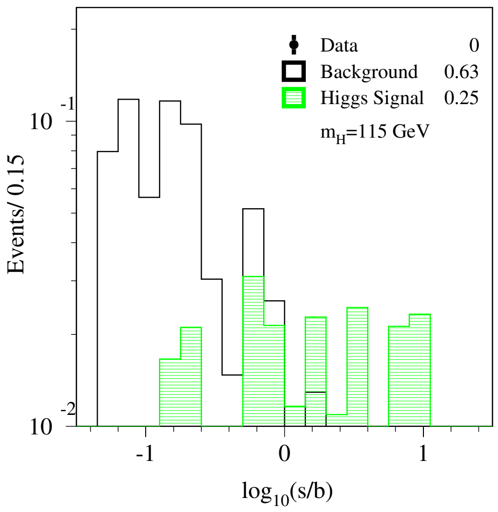
Four-jet channel



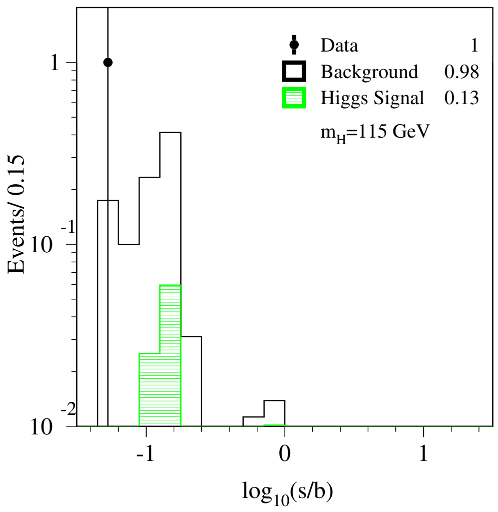
Missing energy



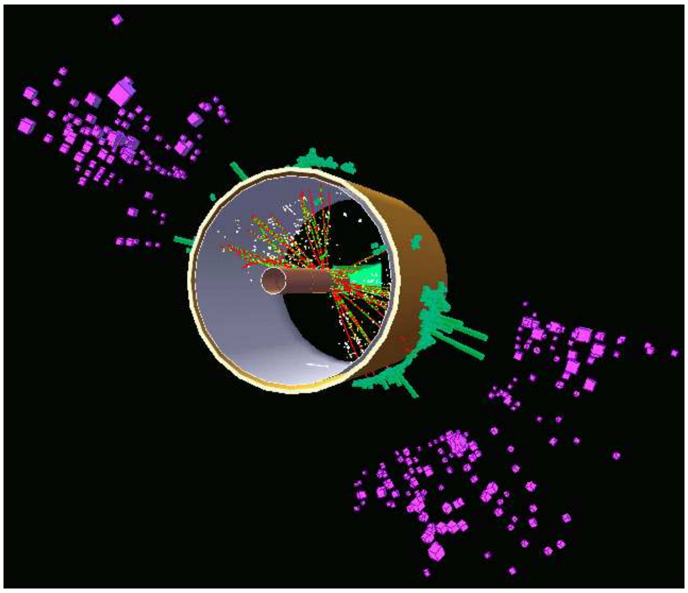
e/μ channels



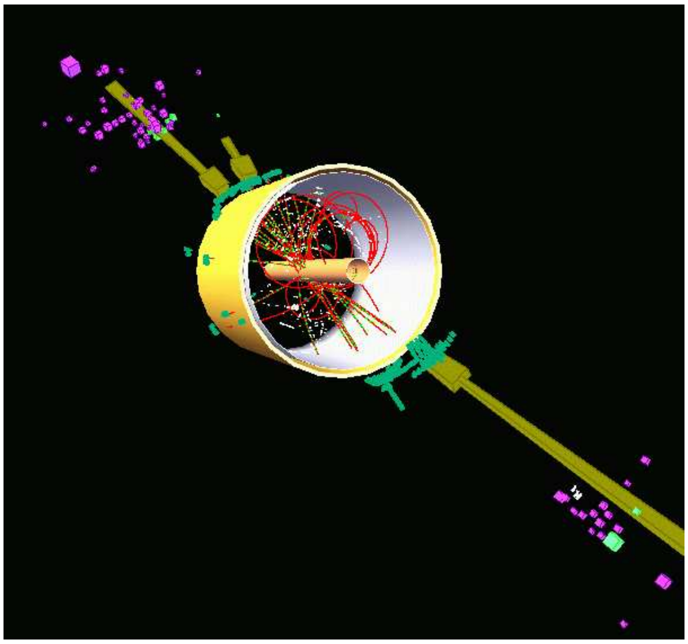
τ channels



The most significant candidates:
Four-jet channel candidate



Missing energy channel candidate

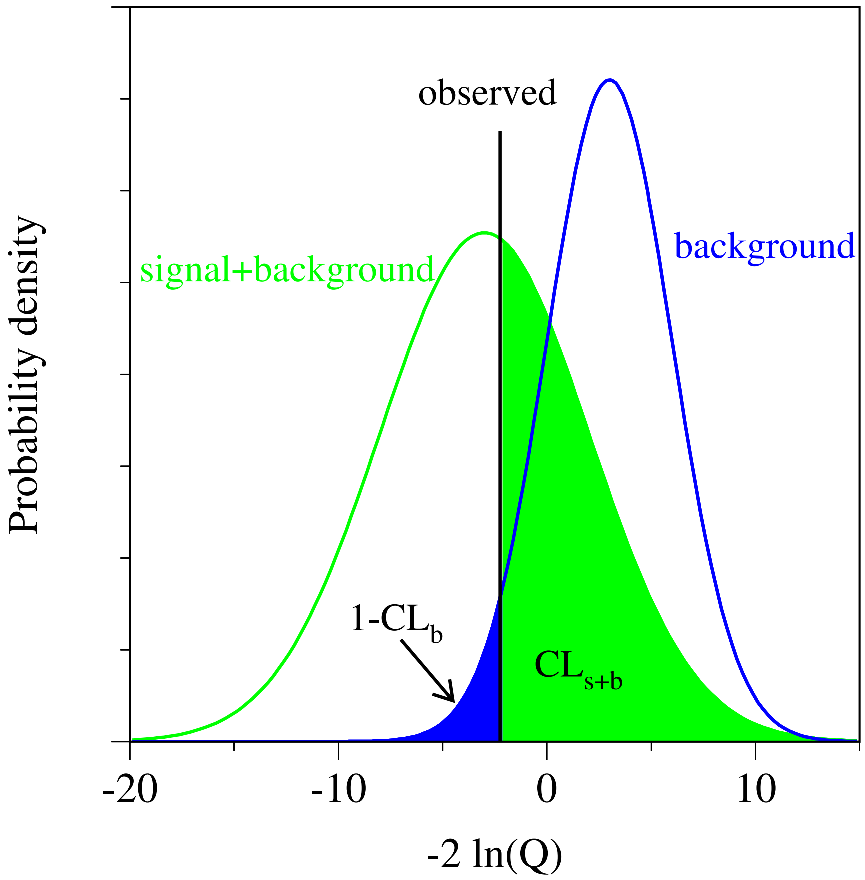


A "signalness" estimator is calculated from the final discriminant distribution for each Higgs mass hypothesis to classify the experimental outcome.

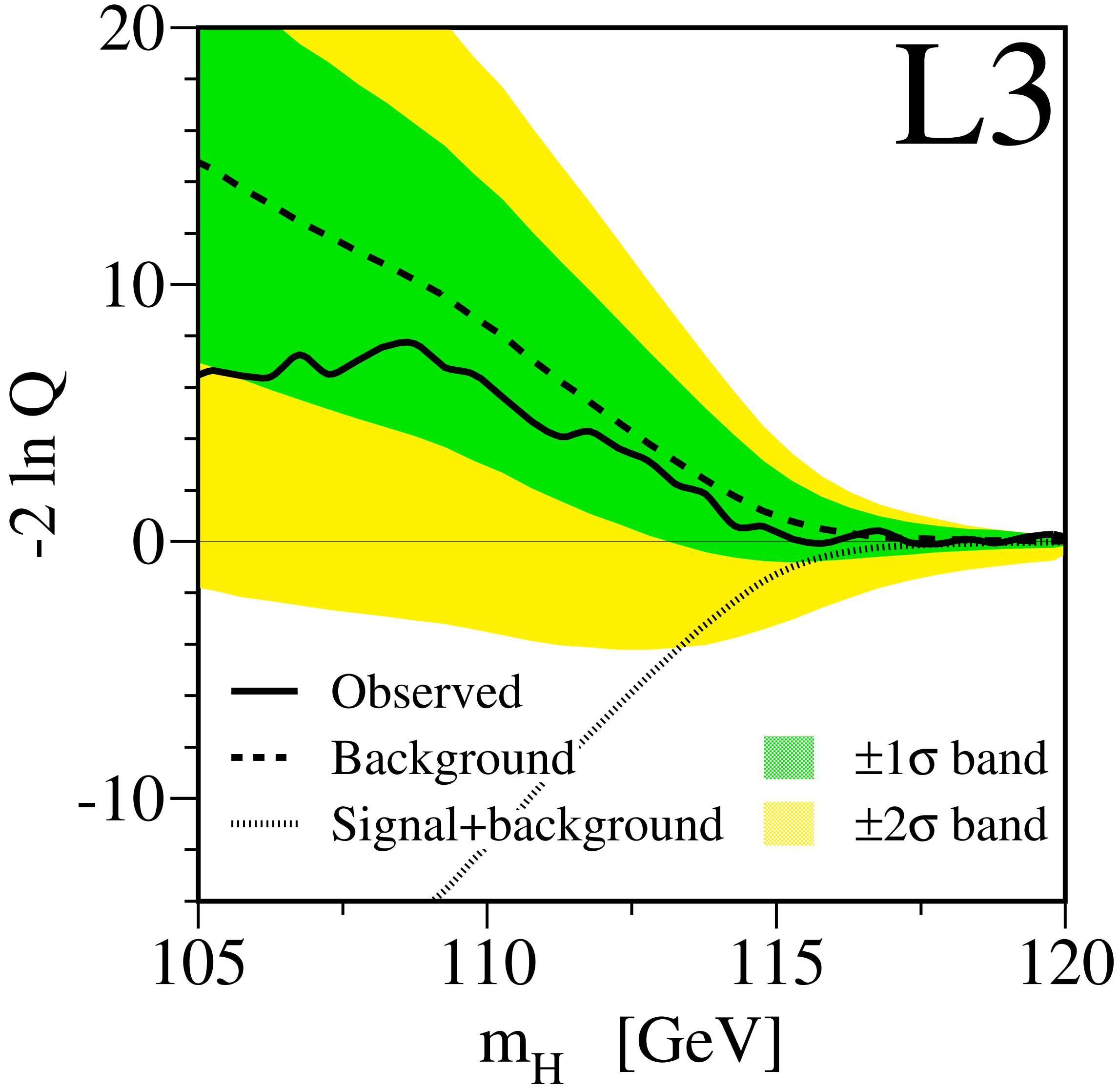
Each bin(i) in the Final Variable is treated as a Poisson counting experiment:

$$lnQ = -S_{tot} + \sum_{i=1}^{N} n_i ln(1 + \frac{s_i}{b_i})$$

Common Estimator (Likelihood Ratio) used at LEP (larger values for more background like events:)



Estimator (-2lnQ) as the function of Higgs mass; all channel combined:



No deviation of more than two sigmas from the background over the mass range 95-120 GeV.

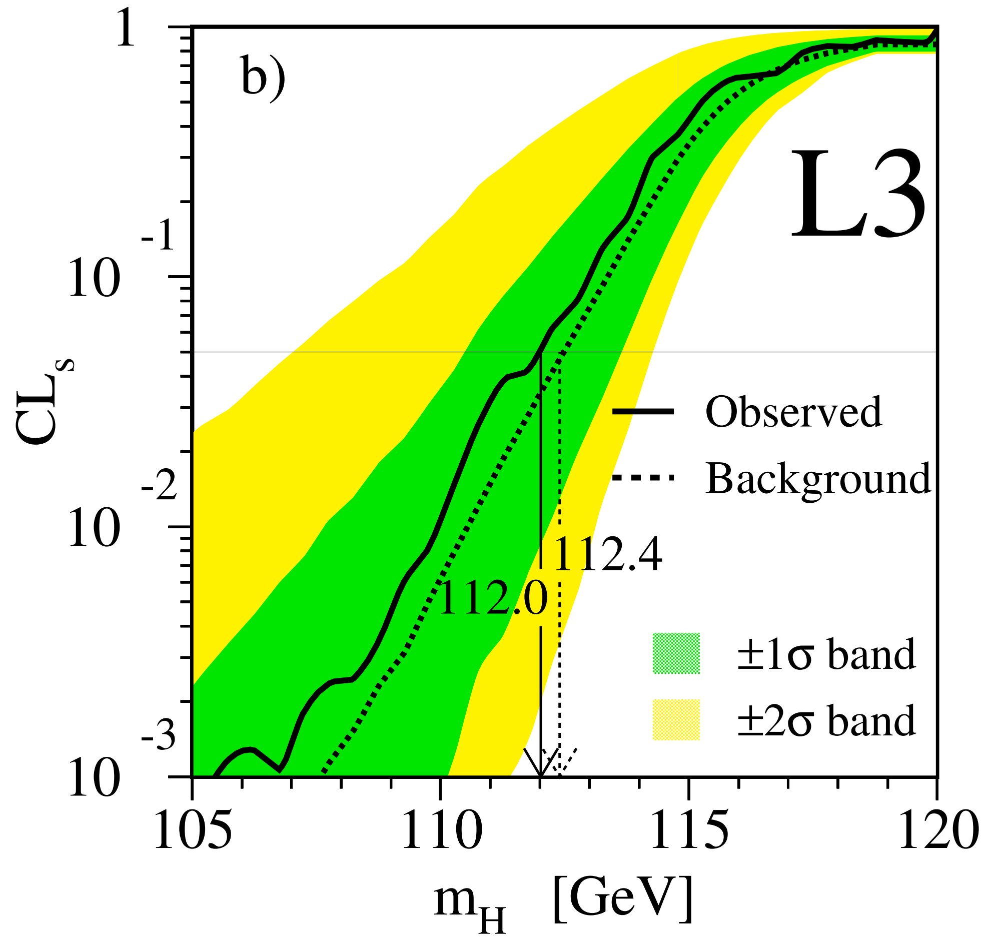
Two confidence levels are calculated:

CL_{s+b} – fraction of signal+background experiments which are more background like than the data

CL_b – fraction of background experiments which are more background-like than the observation

$$CL_S = \frac{CL_{s+b}}{CL_b} \quad (exclusion\ CL)$$

$CL_S < 5\%$ – signal can be excluded at 95% CL



Conclusions

- The cross section of the pair production of Z bosons is measured
- Final states containing b quarks investigated
- For the Higgs searches no deviation from the SM expectation found
- Limits on the SM Higgs boson mass are set: $M_{Higgs} = 112.0$ GeV at 95% CL