PRELIMINARY RESULTS OF THE STANDARD MODEL
HIGGS BOSON SEARCH AT LEP2 IN 2000

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A search for the Standard Model Higgs boson is performed using the data collected
by the four LEP experiments at center-of-mass energies between 202 GeV and 209
GeV. An average luminosity of 140 $\,pb^{-1}$ per experiment has been analyzed. A
2.6 $\sigma$ excess is observed in the LEP-wide combination for a Higgs boson mass
hypothesis of around 114 GeV. All results are preliminary.

1 Introduction

The Standard Model has successfully described properties of interactions be-
tween fundamental particles up to the electroweak scale. There is still one
particle predicted by the theory yet to be discovered: the Higgs boson. Since
its mass cannot be predicted by the Standard Model alone, all possible masses
must be investigated. Consistency of the Standard Model parameters prefers
a low-mass Higgs with mass around 100 GeV. A Higgs mass below 107.9 GeV
has already been excluded at 95% confidence level by previous LEP-wide
analyses.

2 Higgs production and decay

At interaction energies available at LEP, the most dominant mechanism of
Higgs production is called “Higgs-strahlung” ($e^+e^- \rightarrow Z^* \rightarrow hZ$), where
the electron-positron annihilation produces an off-shell Z boson which then
radiates a Higgs boson.

The Higgs boson, once produced, immediately decays into other particles.
The main decay modes available to the Higgs at LEP energies are $b$-quark
decay ($h \rightarrow b\bar{b}$), $\sim 80\%$ of all decays, and $\tau$-lepton decay ($h \rightarrow \tau\bar{\tau}$), $\sim
12\%$ of all decays. With the combination of the Z boson decay modes, the
following four decay channels are analyzed, covering more than 90% of the
total branching ratio.

- four-jet channel, when the Z boson decays into quarks ($hZ \rightarrow b\bar{b}q\bar{q}$). The
  branching ratio is $\sim 60\%$.
- missing energy channel, when the Z boson decays into neutrino pairs
\[(hZ \rightarrow b\bar{b}w\bar{w}).\] The branching ratio is \(\sim 20\%\).

- lepton channel, when the Z boson decays into \(e^+e^-\) or \(\mu^+\mu^-\) pairs \((hZ \rightarrow b\bar{b}l^+l^-)\). The branching ratio is \(\sim 3\%\) respectively.

- \(\tau\) channel, with Z boson decays into \(\tau^+\tau^-\) pairs \((hZ \rightarrow b\bar{b}\tau^+\tau^-)\), the branching ratio is \(\sim 3\%\) or; because of the similar topology, the Higgs boson decays into \(\tau^+\tau^-\) pairs and while the Z boson decays into quark pairs \((hZ \rightarrow \tau^+\tau^-q\bar{q})\), the branching ratio is \(\sim 6\%).

3 Analysis

The main aim of the analysis is to reduce Higgs-like Standard Model backgrounds while retaining any possible Higgs signals. After neural network or cut based selections are performed, the most discriminating variables are combined to form the “final discriminant” which is a function of the Higgs mass hypothesis.

Figure 1 shows the LEP-wide (ALEPH, DELPHI, L3 and OPAL - “ADLO”) final discriminant variable constructed for the Higgs mass hypothesis of 115 GeV. In the upper plot, the white area is the background, the shaded area is the Higgs signal and the dots are the observed data. The horizontal scale is the logarithm base 10 of the signal to background ratio. Note the three right-most events with high signal over background ratios.

The lower two plots show the integral of the upper plot from right to left. The solid line is background only; the dashed line is signal plus background. Observed data, indicated by dots, is more consistent with the signal plus background line.

An alternate way of determining whether a set of data is more consistent with background rather than with signal plus background is to calculate the log likelihood ratio. The final variable is treated with Poisson statistics on a bin-by-bin basis. The log likelihood ratio is then given by:

\[
\ln Q = -S_{tot} + \sum_i n_i \ln(1 + \frac{S_i}{B_i})
\]  

(1)

where \(n_i\) is the number of observed events in the \(i\)-th bin with \(S_i\) expected signal events and \(B_i\) expected background events.

The log likelihood plot is shown in Figure 2. The upper dashed line is the background only hypothesis \((n_i\) is the background expectation\), the lower dotted line is the signal plus background hypothesis \((n_i\) is signal plus background expectation\). The solid line is the observed data. The shaded
Figure 1. The final discriminant variable for the Higgs mass hypothesis of 115 GeV.

region closest to the upper dashed line represents the area which is less than 1 sigma away from background. The wider shaded region is 2 sigma away.

The data stays roughly at the 2 sigma border until about 114.5 GeV when it dips to 2.6 sigma off the background expectation. This dip is due mostly to Higgs-like four-jet events seen by ALEPH and DELPHI.

4 Conclusion

With present statistics, Higgs observation cannot be confirmed or ruled out. The LEP running has been extended until November 2 which will increase
statistics. New data could possibly exclude Higgs mass up to 114 GeV at 95% confidence level or increase the LEP-wide excess to 3 sigma. The results will be updated after the end of 2000 LEP running. The results presented here are preliminary.

References

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3. Chris Tully, “Status LEP-wide Higgs Searches”, Special LEPC 5 September 2000.