Latest Results on Standard Model Higgs Boson at LEP

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Abstract. In this talk, the search results on Standard Model Higgs boson using LEP data collected at energies up to 209 GeV are reported. An excess of 2.9 σ beyond the background expectation is found, consistent with the production of the Hoggs boson with a mass near 115 GeV/c^2.

INTRODUCTION

In 2000 the four LEP experiments (ALEPH, DELPHI, L3, OPAL) have collected data at various energies between 200 and 209 GeV, for aprroximately 850 pb^{-1} (about 210 $pb-1$ for each experiment), of which about 540 pb^{-1} above 206 GeV.

From combining the earlier data collected by the LEP experiments at center of mass energies up to 202 GeV, a 95% CL lower bound of 107.7 GeV/c^2 on the mass of Standard Model (SM) Higgs boson has been obtained [1]. In this talk, we present an update of the SM Higgs search which includes the new data collected at center-of-mass enrgies uo to 209 GeV

At LEP the SM Higgs boson is expected to be produced mainly via Higgs-strahlung process $e^+e^- \rightarrow HZ$, while contributions from the $WW \rightarrow H$ fusion channel, $e^+e^- \rightarrow H\nu\bar{\nu}$, are typically below 10%. The searches performed by the four LEP collaborations encompass the usual HZ final state topologies:

(1) Four-jet ($b\bar{b}q\bar{q}$) channel
(2) Missing energy ($b\bar{b}\nu\bar{\nu}$) channel
(3) Leptonic ($b\bar{b}e^+e^-$ and $b\bar{b}\mu^+\mu^-$) channel
(4) Tau ($b\bar{b}\tau^+\tau^-$ and $\tau^+\tau^-q\bar{q}$) channel

In the four jet and tau channels, the overlap between the SM Higgs and MSSM Higgs analyses needs to be treated carefully in order not to subtract background twice since the same SM Higgs analyses are combined in the MSSM Higgs searches.

The analysis procedures of the four LEP experiments are described in individual documents [2].

LIKELIHOOD RATIO AND CONFIDENCE LEVELS

Estimator (test-statistic):

An Estimator (or a test-statistic) X quantifies the "signal-ness" of an experiment. $X = -2lnQ$ where $Q = L(s+b)/L(b)$ is the likelihood ratio. Here the likelihood $L(s+b)$ assumes a signal process at Higgs mass m_H in addition to the background process, and the likelihood $L(b)$ assumes no Higgs signal but background process only.

Confidence Levels CL_{s+b} and CL_b:

Given an observed value of the estimator $X_{observed}$, the confidence level on the $signal+background$ and $background-only$ hypotheses are calculated as $CL_{s+b} = P_{s+b}(X \geq X_{observed})$ and $CL_b = P_b(X \geq X_{observed})$. The value P_b is the estimator probability function for experiments with background process only, while P_{s+b} is the estimator probability function for experiments with both background processes and a signal process of a given Higgs mass m_H with the Standard Model cross section.

Confidence Level CL_s:

The limit on m_H is obtained via the limit on the Higgs cross section (number of signal events). So the confidence level CL_s needs to be defined. Two methods are used in the CL_s calculation in the LEP experiments:

(A) Generalized Bayesian Method [3]:

$CL_s = CL_{s+b}/CL_b$.

This method are used in DELPHI, L3, OPAL and LEP combined results.

(B) Signal Estimator Method [4]:

$CL_s = CL_{s+b}$ - (1 - CL_b) $\cdot e^{-S}$, where S is the number of predicted signal events.

This method is used in the ALEPH results.

Both methods satisfy $CL_s = e^{-S}$ when zero event is observed, which is independent of background prediction. Method (B) gives typically about 0.5 GeV/c^2 better sensitivity for the exclusion on m_H than method (A).

RESULTS

Figure 1 shows -2lnQ as a function of test Higgs mass. The solid line is the observation while the dashed / dash-dotted lines represent the median expected values for background / signal+background hypotheses. The dark- and light-shaded regions indicates the $\pm 1\sigma$ and $\pm 2\sigma$ bands around the background prediction. The expected curves and their spreads are obtained by replacing the observed data configuration by a large number of simulated event configuration.

A pronounced minimum at $m_H = 115 GeV/c^2$ (maximum of the likelihood ratio Q) is observed, indicating a significant deviation from the background hypothesis. The minimun coincides with the signal+background expectation for a test mass of 115 GeV. Taking into account the asymmetric shape of the minimum, the observation is compatible with the SM Higgs boson production rate over the mass range from 114.6 to 115.8 GeV/c^2 ($\pm 1\sigma$).

Figure 2 shows $1 - CL_b$ as a function of test Higgs mass, where the observation is given by the solid line while the expectations for the background and signal+background hypotheses are given by the dashed and dotted lines, respectively.

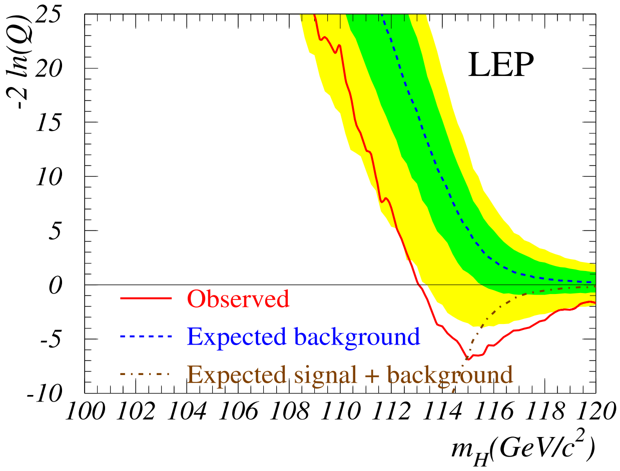

FIGURE 1. Likelihood Ratio -2lnQ as a function of test Higgs mass m_H.

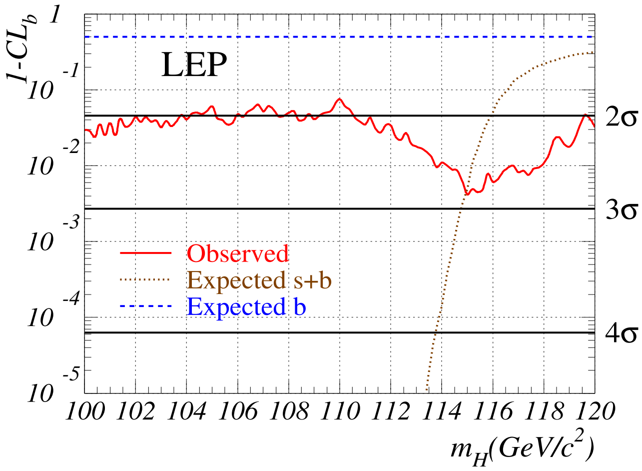

FIGURE 2. Probability 1-CL_b as a function of test Higgs mass m_H.The horizontal solid lines indicate deviations of 2- 3- and 4-σ from the background hypothesis

The minimum of $1 - CL_b$ is 4.2×10^{-3} at 115 GeV/c^2, which corresponds to an excess of 2.9 σ beyond the background expectation.

A 95 % confidence level lower limit on the SM Higgs mass may be set by identifying the mass region where $CL_s < 0.05$. The median limit expected in the absence of a signal is 115.3 GeV/c^2 and the limit observed by combining the LEP data is 113.5 GeV/c^2.

CONCLUSION

An excess of 2.9 σ beyond the background expectation is observed in the combined SM Higgs search of four experiments at LEP using the data up to 209 GeV. The excess is consistent with the production of the Higgs boson with a mass near 115 GeV/c^2. The measured lower bound for the mass of the SM Higgs boson is 113.5 GeV/c^2.

ACKNOWLEDGMENTS

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