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Search for Charged Higgs bosons: Preliminary Combined Results Using LEP data Collected at Energies up to 209 GeV

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The LEP working group for Higgs boson searches

Abstract

In the year 2000 the four LEP experiments have collected 870 pb^{-1} of data at energies between 200 and 209 GeV, with about 510 pb^{-1} above 206 GeV. These data have been combined with data sets collected earlier at lower energies. For charged Higgs bosons predicted by two-doublet extensions of the Standard Model and decaying only into the channels $\mathrm{H}^+ \to \mathrm{c\bar{s}}$ and $\tau^+\nu$, a lower mass bound of 78.6 GeV/c^2 is obtained, at the 95% confidence level.

ALL RESULTS QUOTED IN THIS NOTE ARE PRELIMINARY
(contributed paper for EPS'01 in Budapest and LP'01 in Rome)

1 Introduction

We present combined results from the ALEPH, DELPHI, L3 and OPAL Collaborations on searches for the charged Higgs boson predicted by extensions of the Standard Model with two Higgs field doublets. The results are obtained by combining the data collected in the year 2000 at centre-of-mass energies between 200 and 209 GeV with data collected earlier at energies of 189 GeV and larger [1]. The total luminosity used in this combination is 2500 pb^{-1}.The new data represent an integrated luminosity of approximately 870 pb^{-1} in total, with about 510 pb^{-1} above 206 GeV.

The cross-sections, branching ratios and other physics quantities used in this combination of data are calculated within the HZHA program package [2].

Each experiment has generated Monte Carlo event samples for the Higgs signal and the various background processes, typically at 202, 204, 206, 208 and 210 GeV energies. Cross-sections, branching ratios, distributions of the reconstructed mass and other discriminating variables relevant to the combination have been interpolated to the energies which correspond to the data sets. It has been checked that the interpolation procedures do not add significantly to the final systematic errors.

The statistical procedure adopted for the combination of the data and the precise definitions of the confidence levels CL_b, CL_{s+b}, CL_s by which the search results are expressed, have been previously described [1] [3]. The main sources of systematic error affecting the signal and background predictions are included. This is done using an extension of the method of Cousins and Highland [4] where the confidence levels are the averages of a large ensemble of Monte Carlo experiments. The correlations between search channels, LEP energies and individual experiments have not been taken into account, but these correlations are estimated to have only small effects to the final results.

2 Combined searches for the charged Higgs boson

Charged Higgs bosons are predicted by models with two Higgs field doublets (2HD models), of which the MSSM is a particular case with supersymmetry. At LEP2 energies charged Higgs bosons are expected to be produced mainly through the process $e^+e^-\to H^+H^-$. In the MSSM, at tree-level, the $H^\pm$ is constrained to be heavier than the $W^\pm$ bosons, but for specific choices of the MSSM parameters, loop corrections can drive the mass to lower values. Thus, any signal for H^+H^- would indicate either new physics beyond the MSSM or a rather extreme set of MSSM parameter values.

In 2HD models the $H^\pm$ mass is not predicted, and the tree-level cross-section is fully determined by the mass [5]. The searches are carried out under the assumption that the two decays $H^+\to c\bar{s}$ and $H^+\to\tau^+\nu$ exhaust the H^+ decay width, but the relative branching ratio is free. Thus, the searches encompass the following H^+H^- final states: $(c\bar{s})(\bar{c}s)$, $(\tau^+\nu)(\tau^-\bar{\nu})$ and the mixed mode $(c\bar{s})(\tau^-\bar{\nu})+(\bar{c}s)(\tau^+\nu)$. The combined search results are presented as a function of the branching ratio $B(H^+ \to \tau^+\nu)$.

Details of the searches of the individual experiments can be found in [6][7]. These are summarised in Table 1, together with the 95% CL lower bounds, expected and observed. In the current combination, the OPAL search in the mixed channel is not included since it is still under scrutiny. In the table we quote the mass limits separately for $B(H^+ \to \tau^+\nu) = 0$, 1, and a limit independent of the branching ratio. It should be noted that L3 observes an excess of events in the pure hadronic and the semi-leptonic channels in the mass region around 68 GeV [7]. This behaviour is reproduced when the combination protocoll is applied to the L3 data only, but is not seen when applied to the ALEPH, DELPHI and OPAL data, see Figure 1. Indeed, ALEPH data show a clear deficit around that mass. The compatibiliy of the L3 and the three other experiments observations in the vicinity of 68 GeV is under investigation.

Assuming that a statistical combination is justified, Figure 2 shows the background confidence level $1-CL_b$ as a function of $m_{H^\pm}$, expected and observed, for $B(H^+ \to \tau^+\nu)$=1 and 0. The observed confidence level is everywhere within the light-shaded $\pm 2\sigma$ bands of the background prediction.

The mass limits expected and observed are shown in Figure 3. To obtain the limits, the branching ratio $B(H^+ \to \tau^+\nu)$ has been scanned in steps of 0.05, and the limit setting procedure repeated for each step. In the hadronic channel and for masses close to $m_{W^\pm}$, the sensitivity is suppressed by the large $e^+e^- \to W^+W^-$ background. There is a regain of sensitivity at higher masses, as signalled by the excluded "islands" above 84 GeV/c^2.

The combined 95% CL bounds are listed in Table 2 for $B(H^+ \to \tau^+\nu)$=0, 1, and for the weakest limit, valid for any value of $B(H^+ \to \tau^+\nu)$. Taking the lowest of the observed limits from Table 2, we quote a 95% CL lower bound of 78.6 GeV/c^2 for the mass of the charged Higgs boson. The inclusion of systematic errors has shifted the observed mass limits downwards by 600, 600, and 200 MeV/c^2 for $B(H^+ \to \tau^+\nu)$=0, 0.5 and 1, respectively. A major source of systematic error comes from the measurement of the W mass, since a shift of 50 MeV/c^2 in that value induces a shift of 200 MeV/c^2 in the limits when these limits are around the W mass.

As a cross-check of the confidence level calculation procedures, the expected and observed limits have been cross-checked using another test-statistic (Method C in [3]).

Figure 4 shows the 95% CL upper bound on the cross-section (with $\pm 1\sigma$ and $\pm 2\sigma$ bands) for the hadronic decay topology $H^+ \to c\bar{s}$. The dotted line corresponds to the 2HD model prediction at 206 GeV. Its intersections with the observed bound (full line) define the excluded regions in Figure 3 for $B(H^+ \to \tau^+\nu)$=0. The relation between the features of Figure 2(lower part) and Figure 4 is apparent.

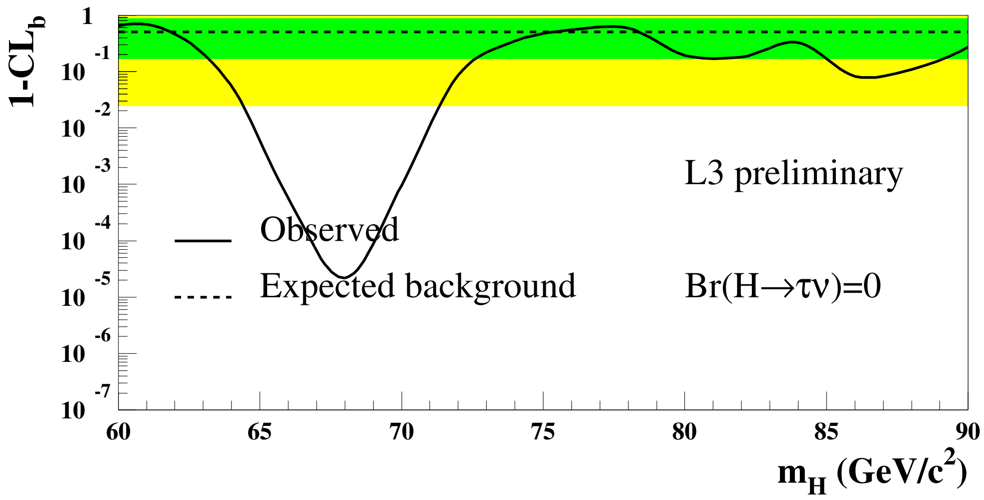
Experiment:	ALEPH	DELPHI	L3	OPAL
Total: Int. luminosity (pb^{-1}):	217.2	225.1	217.8	217.4
Backg. exp. / Events obs. (*)				
$(c\bar{s})(\bar{c}s)$:	997.7/968	412.8/387	883.3/961	424.2/439
$(c\bar{s})(\tau^+\nu)$:	118.0/127	190.8/173	171.8/171	203.5/224
$(\tau^+\nu)(\tau^-\bar{\nu})$:	22.0/17	23.8/ 25	49.8/44	331.7/315
Events in all channels:	1137.7/1112	627.4/585	1104.9/1176	959.4/978
Limit exp.(median)/ observed				
for B=0:	78.1/80.7	77.0/77.4	76.5/67.7	77.1/76.2
for B=1:	86.9/83.4	89.3/85.4	84.7/82.8	86.5/84.5
for any B:	76.9/78.0	75.4/73.8	75.1/65.6	74.5/72.2

Table 1: *Individual search results for the* $e^+e^-\to H^+H^-$ *final states. The luminosities and numbers of events correspond to the data sets taken at energies between 200 and 209 GeV (year 2000 data). (*) The OPAL selection is mass-dependent; the numbers are given here for* $m_{H^\pm} = 80$ GeV/c^2.

	Mass limit in GeV/c^2 (95% CL)
$B(H^+\to\tau^+\nu)=0$	
Limit expected (median) :	80.2 (*)
Limit observed :	81.0 (*)
$B(H^+\to\tau^+\nu)=1$	
Limit expected (median) :	92.1
Limit observed :	89.6
Any $B(H^+\to\tau^+\nu)$	
Limit expected (median):	78.8
Limit observed :	78.6

Table 2: *The combined 95% CL lower bounds for the mass of the charged Higgs boson, expected and observed, for fixed values of the branching ratio* $B(H^+\to\tau^+\nu)$ *and for the* $B(H^+\to\tau^+\nu)$ *giving the weakest limit. (*) These limits do not take into account the small regions excluded above 82 GeV.*

CHARGED HIGGS - PRELIMINARY



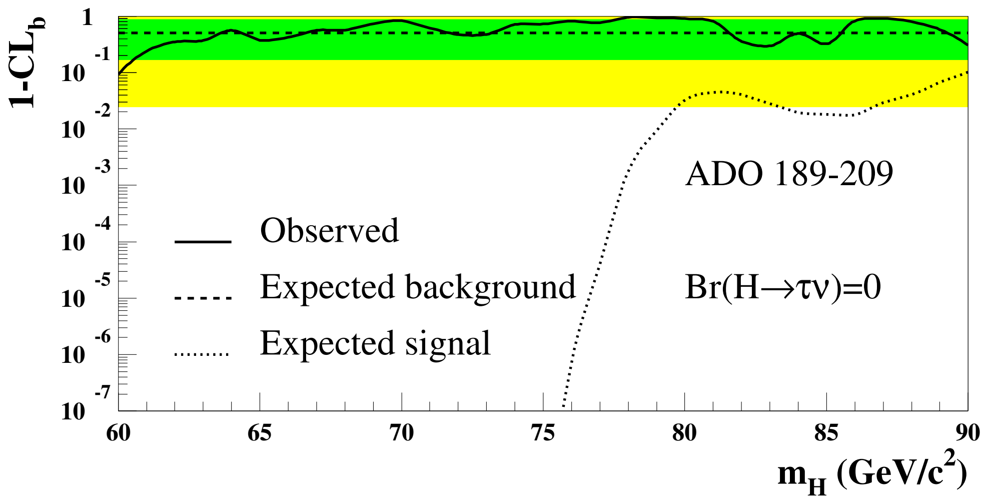


Figure 1: *The confidence level $1-CL_b$ as a function of $m_{\mathrm{H}^\pm}$, for the branching ratio $B(\mathrm{H}^+ \to \tau^+\nu)=0$ (top : L3 alone, bottom : ADO combination). The straight horizontal line at 50% and the shaded bands represent the mean result and the symmetric 1σ and 2σ probability bands expected in the absence of a signal. The solid curve is the observed result and the dotted curve shows the median result expected for a signal when tested at the "true" mass.*

CHARGED HIGGS - PRELIMINARY

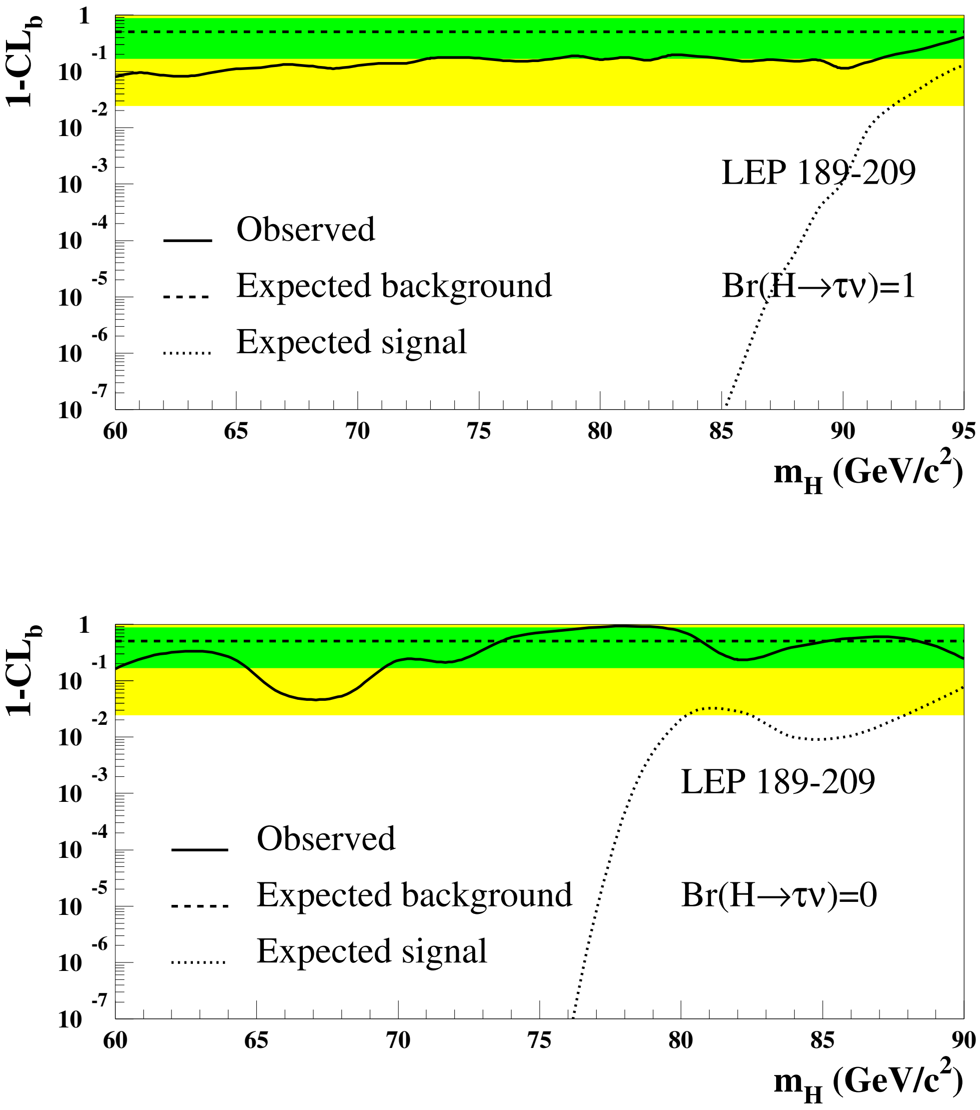


Figure 2: *The confidence level* $1-CL_b$ *as a function of* $m_{\mathrm{H}^{\pm}}$*, for the branching ratio* $B(\mathrm{H}^{+}\to\tau^{+}\nu)$*=0 and 1 (separate plots). The straight horizontal line at 50% and the shaded bands represent the mean result and the symmetric* 1σ *and* 2σ *probability bands expected in the absence of a signal. The solid curve is the observed result and the dotted curve shows the median result expected for a signal when tested at the "true" mass.*

CHARGED HIGGS - PRELIMINARY

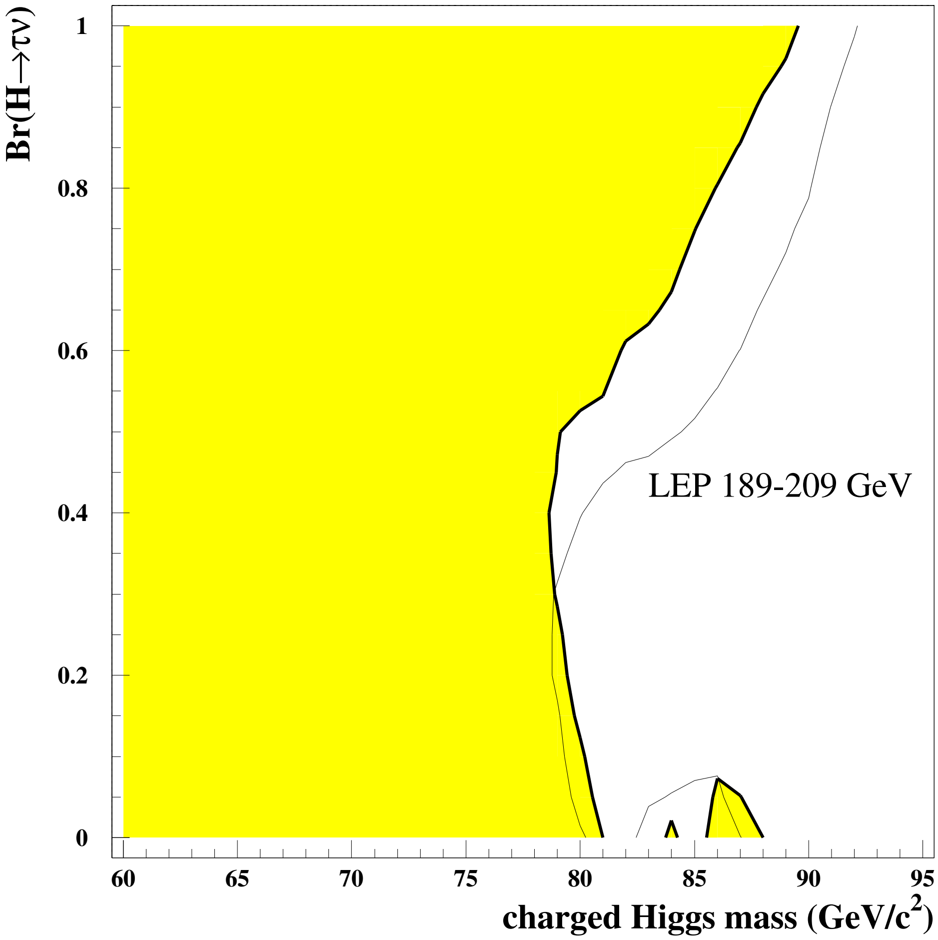


Figure 3: *The 95% CL bounds on $m_{\mathrm{H}^\pm}$ as a function of the branching ratio $B(\mathrm{H}^+ \to \tau^+\nu)$, combining the data collected by the four LEP experiments at energies from 189 to 209 GeV. The expected exclusion limits are indicated by the thin solid line and the observed limits by the thick solid one. The shaded area is excluded at the 95% CL.*

CHARGED HIGGS -PRELIMINARY

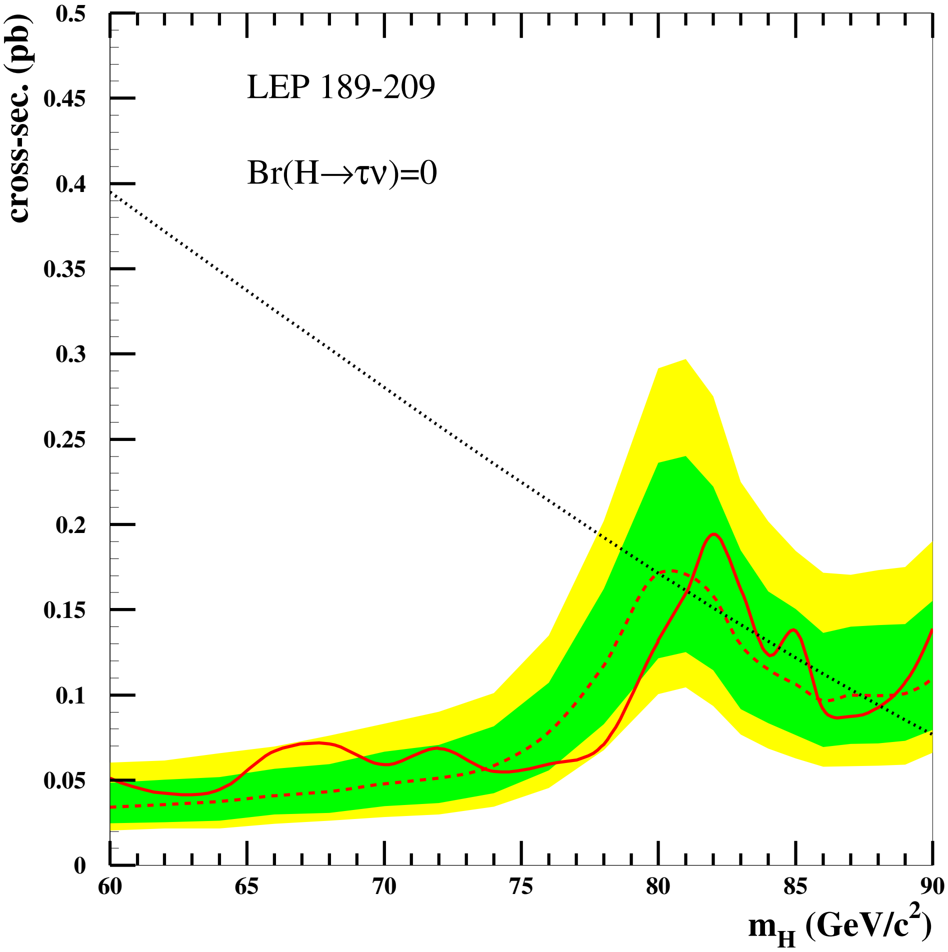


Figure 4: *The 95% CL bound on the production cross-section as a function of* $m_{\mathrm{H}^{\pm}}$ *for a branching ratio* $B(\mathrm{H}^{+}\to\tau^{+}\nu)=0$*, combining the data collected by the four LEP experiments at energies from 189 to 209 GeV. The expected exclusion limits are indicated by the dashed line and the shaded bands (1 and 2* σ*), the observed limit by the solid line. The dotted line represents the 2HD model computed charged Higgs cross-section at 206 GeV.*

3 Summary

The searches of the four LEP experiments for charged Higgs bosons predicted by models with two Higgs field doublets were combined. These assume that the two decays $H^+ \to c\bar{s}$ and $H^+ \to \tau^+\nu$ exhaust the H^+ decay width. In the absence of a signal, mass limits are obtained as a function of the branching ratio $B(H^+ \to \tau^+\nu)$. The most general lower limit, valid at the 95% confidence level for any value of the branching ratio, is 78.6 GeV/c^2.

ALL THE RESULTS QUOTED IN THIS NOTE ARE PRELIMINARY.

References

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