DELPHI 99-17 CONF 217

Search for $e^+e^- \longrightarrow H^+H^-$ with DELPHI

DELPHI collaboration

M. Battaglia[1], T. Ekelöf[2], M. Ellert[2], G. Gómez-Ceballos[3], A. Kiiskinen[1], P. Lutz[4], F. Matorras[3]

PRELIMINARY

1 Analysis

Data sample taken at 189 GeV (158 pb^{-1}) has been analysed and the results have been combined with those from previous runs at 161, 172 and 183 GeV.

The H^+H^- final state cscs is characterised by four jets, the cs$\tau\nu$ final state by three jets, one of which is slim, combined with missing momentum, and the $\tau\nu\tau\nu$ final state by two acollinear slim jets with large missing momentum.

In all three channels the decay of W^+W^- into the same final states constitute a major background. This W background grows rapidly when the reconstructed charged Higgs mass approaches that of the W, except for the $\tau\nu\tau\nu$ final state for which no boson mass can be reconstructed. Another important background channel in the cscs and cs$\tau\nu$ channels is quark pair production with gluon radiation (QCD), $q\bar{q}gg$ in the first channel and $q\bar{q}g$ in the second. In the $\tau\nu\tau\nu$ channel fermion pair production and $\gamma\gamma$ events constitute the additional important background.

A first data reduction has been made by imposing track quality criteria and cuts on event parameters against the various background channels. Most of the parameters and cuts used are described in appendix A.

In the cscs and cs$\tau\nu$ channels an additional cut was imposed on an "anti-QCD-likelihood" parameter. For the cscs channel this parameter was constructed from the product of the minimum jet energy and the minimum angle between two jets, the di-jet pair mass difference after a 4C energy-momentum

[1]Helsinki Institute of Physics, Helsinki, Finland
[2]Uppsala University, Uppsala, Sweden
[3]Universidad de Cantabria, Santander, Spain
[4]CEA, Saclay, France

fit, the reconstructed boson production polar angle, the acoplanarity, a variable reflecting the probability for that the pairing chosen of the four jets into two bosons is the correct one and a function of the probabilities for correctly identifying the quarks as cscs. For the cs$\tau\nu$ channel it was constructed from the polar angle of the total momentum, the logarithm of the clustering distance (y_{23} in the Durham algorithm), the product of the minimum jet energy and the minimum angle between two jets and a function of the probabilities for correctly identifying the quarks as cs.

In the $\tau\nu\tau\nu$ channel a first selection of all leptonic final states was made, followed by an identification of each slim jet (or single particle) as either an electron, a muon or a tau. A muon was defined as a single particle giving signal in the muon chambers or in the rear part of the hadron calorimeter and with less than 3 GeV (1 GeV if in barrel region) in a 30° cone around the particle. An electron was required to not be identified as a muon, to have a charged multiplicity less than 3 and to have a minimum energy deposition in the electromagnetic calorimeter. A tau decaying into hadrons was then identified as a lepton being neither a muon nor an electron. Electrons and muons coming from taus that are produced in H or W decays have lower momenta than electrons and muons being produced directly in W decays. A lepton with electromagnetic energy less than 15 GeV (for electron candidates) or momentum less than 20 GeV were considered to come from taus produced in H or W decay.

In table 1 is shown, for each of the three channels, the number of observed events, the expected number of background events, the efficiency for the detection of charged Higgs of 70 GeV/c^2 mass and the expected number of such Higgses. No significant H^+H^- signal can be seen in the data. For the determination of the lower charged Higgs mass limit the likelihood ratio method [1] has been used.

In each of the cscs and cs$\tau\nu$ channels two discriminating variables were used as input to the likelihood ratio algorithm, the reconstructed boson mass and an "anti-WW-likelihood", and in the $\tau\nu\tau\nu$ channel one discriminating variable was used. For the cscs channel the "anti-WW-likelihood" is based on the reconstructed boson production polar angle, the di-jet mass difference, a function of the probability for that the final state quark flavours are correctly identified as cscs and a variable reflecting the probability for that the pairing chosen of the four jets into two bosons is the correct one. The latter variable is based on the constraints that the two boson masses should be equal and that, for each of the two bosons, the sum of the particle momenta perpendicular to the boson decay axis should be minimal. For the cs$\tau\nu$ channel the "anti-WW-likelihood" is based on the reconstructed polar angle of the negatively charged particle (using the τ charge), the total τ energy, the angle between

channel	lumi (pb^{-1})	obs.	exp. bkg.	ϵ_{70}(%)	exp. sig_{70}
$\tau\nu\tau\nu$	152.9	15	16.0±1.0	33.0±0.7	17.1
cs$\tau\nu$	155.0	91	85.5±3.0	36.7±1.1	15.7
cscs	158.0	54	59.2±4.0	21.4±0.6	12.9
total	-	160	160.7±5.1	-	-

Table 1: The integrated luminosity, the number of observed events, the expected number of background events, the detection efficiency for 70 GeV/c^2 mass charged Higgs and the expected number of such Higgses in each of the three channels.

the two hadronic jets and the probability that the final state quark flavours are identified as cs. The single discriminating variable used in the $\tau\nu\tau\nu$ channel is based on the polar angles of the τ's and on variables sensitive to the polarisation of the τ.

2 Result

The resulting upper exclusion limit for the charged Higgs mass is plotted in figure 1 for different values of the H $\longrightarrow \tau\nu$ branching ratio (BR). For BR = 1 the observed 95% CL limit (black squares) is 78.1 GeV/c^2 and for BR = 0 it is 71.9 GeV/c^2. For intermediate BR values the observed limit is lower and charged Higgs of a mass below 65.1 GeV/c^2 can be excluded at all values of the BR. The expected limit (open circles) obtained from the simulation of a large number of “Monte Carlo experiments” agrees well with the observed limit at BR = 0 and reasonably well at BR = 1. At intermediate BR values the observed limit is up to 4 GeV/c^2 lower than the expected limit which can probably be attributed to two $H^+H^- \longrightarrow cs\tau\nu$ non-excluded candidate events at 183 GeV centre of mass energy, reconstructed with mass values 63.2 and 63.7 GeV/c^2.

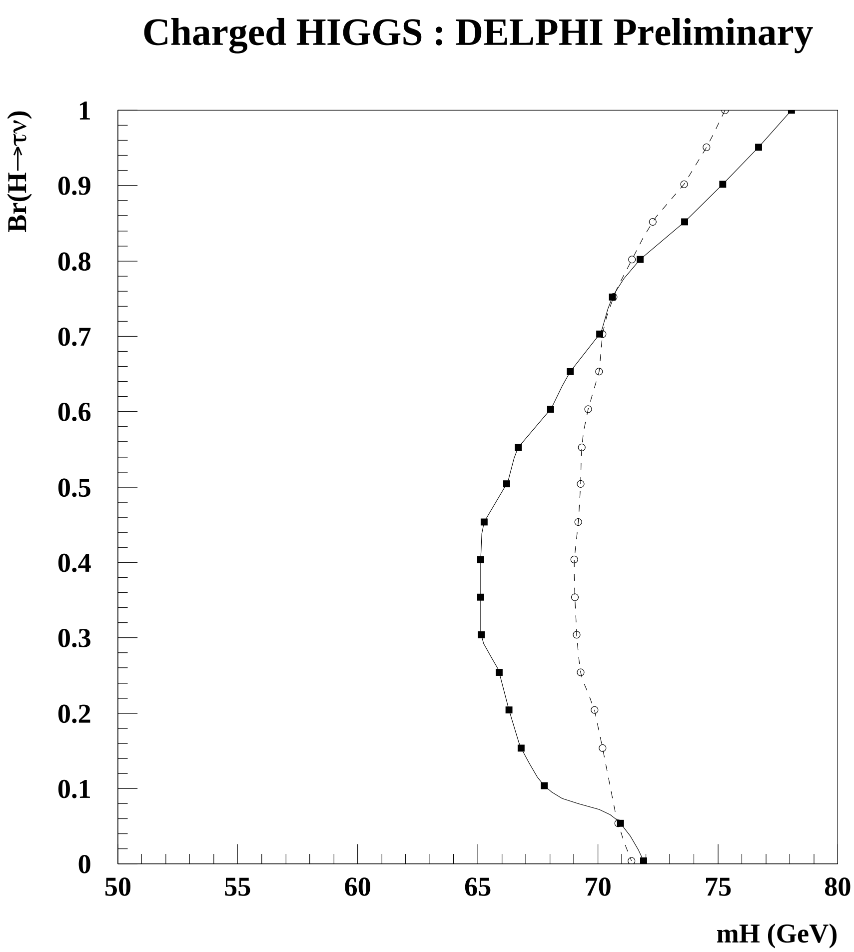

Figure 1: Observed (black squares) and expected (open circles) upper 95% CL exclusion limits for the mass of the charged Higgs boson for different values of the branching ratio of the decay H $\longrightarrow \tau\nu$.

A Cuts for the different channels

A.1 Hadronic channel

- 4-jet selection as in DELPHI Neutral Higgs searches [2]
- $H_2 + H_4 < 1.1$ (Fox-Wolfram moments)
- thrust value < 0.92

After clustering into 4 jets:

- $N_{ch}^{jet} \geq 1$
- $m_{inv}^{jet} > 1.5$ GeV/c^2
- $y_{34} > 0.005,\ y_{54} < 0.007$

A 4C and a 5C kinematical fit was performed and the jet combination with the lowest χ^2 in the 5C fit was chosen. The χ^2/d.o.f. was required to be smaller than 3. If the 4C fit for this combination had a difference in the di-jet masses above 8 GeV/c^2 the event was rejected.

A.2 Semileptonic channel

- $N_{ch} \geq 8$
- $E_{ch} > 0.15\sqrt{s}$
- $E_{seen} > 0.30\sqrt{s}$
- acollinearity $> 7^\circ$
- $20^\circ < \theta(p_{tot}) < 160^\circ$
- No neutral particle with energy above 30 GeV
- Energy within 20° (30°) of the beam axis $< 0.2\sqrt{s}$ ($0.3\sqrt{s}$)

After clustering into 3 jets the jet with the lowest charged multiplicity is chosen as a τ candidate. If there are several jets with the same charged multiplicity the least energetic one is chosen.

- $N_{ch}^{jet} \geq 1$
- $N_{ch}^{\tau-jet} \leq 3$
- $N_{tot}^{\tau-jet} \leq 7$
- $m_{inv}^{\tau-jet} < 2$ GeV/c^2

A.3 Leptonic channel

- $2 < N_{ch} < 5$
- $p_{\perp} > 0.04\sqrt{s}$
- Energy in a cone of 30° half-angle around the beam pipe $< 0.1\sqrt{s}$

Cluster into 2 jets

- $N_{ch}^{jet} = 1$ for at least 1 jet
- $m_{inv}^{jet} < 3$ GeV/c^2
- acollinearity $< 150°$
- acoplanarity $> 13°$ (25°)
- $E_{\perp} > 0.08\sqrt{s}$ $(0.10\sqrt{s})$

In the last two cuts the first value is applied if both jets are in the barrel and the second value otherwise.

References

[1] A. L. Read, DELPHI 97-158 PHYS 737

[2] P. Abreu et al. (DELPHI collaboration), to be published in *E. Phys. J.* **C** (1999).