SEARCH FOR NEUTRAL HIGGS BOSON PRODUCTION IN THE PROCESSES $e^+e^- \to Z^*H^0$ AND $e^+e^- \to H^0\gamma$ WITH L3

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A search for Higgs boson production in the processes $e^+e^- \to Z^*H^0$ and $e^+e^- \to H^0\gamma$ has been performed using three million hadronic Z decays collected by the L3 experiment at LEP from 1991 through 1994. No candidates have been found in the $H^0\nu\bar{\nu}$, $H^0e^+e^-$ and $H^0\mu^+\mu^-$ channels and a lower 95% C.L. mass limit of 60.2 GeV has been set. Final states with isolated photons have been analyzed and upper limits at 95% C.L. have been set on the production cross sections.

1 THE STANDARD MODEL HIGGS BOSON

At the Z peak, the Standard Model Higgs boson should be produced mainly in the bremsstrahlung process $e^+e^- \to Z \to Z^*H^0$. Another production mechanism, $e^+e^- \to Z \to H^0\gamma$ through an intermediate top quark or W boson loop, is expected to occur with a lower rate [1]. Up to now, the L3 experiment has analyzed three million hadronic Z decays, collected from 1991 through 1994. In this data sample, almost 30 events are expected to be produced for $M_H = 60$ GeV, but not all the final states can be distinguished from the background of the Z decaying into hadrons. Since a Higgs boson with mass $M_H \geq 50$ GeV should decay in $\sim 91\%$ of the time [2] into $q\bar{q}$ (95% of which into $b\bar{b}$) and in the remaining $\sim 9\%$ into $\tau^+\tau^-$, only the channels where the Z^*decays into electrons, muons or neutrinos, corresponding to 24% of the final states, are used. These channels, referred to as $H^0\nu\bar{\nu}$, $H^0e^+e^-$and $H^0\mu^+\mu^-$, have clear signatures: the ($H^0 \to hadrons$) ($Z^* \to \nu\bar{\nu}$) channel, with two acoplanar and acollinear jets accompanied by missing energy; the ($H^0 \to hadrons$) ($Z^* \to l^+l^-$) final state, with two energetic and isolated leptons (electrons or muons), well separated from the hadronic system. For a Higgs mass of 60 GeV, only ~ 3 events per million Z decays have such signature. About 0.4 events are expected from the $H^0\gamma$ channel.

2 THE L3 DETECTOR

The L3 detector [3] consists of a silicon microvertex detector, a central tracking chamber, a high resolution electromagnetic calorimeter of BGO crystals, a ring of scintillation counters, an uranium hadron calorimeter with proportional wire chamber readout and an accurate muon chamber system. These sub-detectors are installed in a 12 m diameter magnet which provides a solenoidal field of 0.5 T and a toroidal field of 1.2 T in the forward-backward region.

3 THE $H^0\nu\bar{\nu}$ CHANNEL

Due to the characteristics of the events, the main source of background is represented by $q\bar{q}\gamma$ events with an undetected photon and by events with missing momentum due to neutrinos from semileptonic decays of b quarks or to neutral long lived particles. Therefore, a good hermeticity of the detector and a good resolution for the jets energies and directions are crucial. The invariant mass resolution in L3 for Higgs masses around 60 GeV is about 8 GeV.
The selection is discussed in detail elsewhere [4]. Hadronic events with missing energy are selected by requiring a high multiplicity and a total visible energy below 80 GeV. Dead zones and small-angle regions of the detector are excluded. In order to reject two-photon events, the transverse momentum is required to be greater than 7 GeV and the visible energy greater than 40 GeV. Back-to-back hadronic events are rejected by requiring the acollinearity and acoplanarity angles to be smaller than 160° and 170° respectively, and the missing momentum to be isolated in a cone of 25° half opening angle. Hadronic three-jet events are rejected using the sum of the jet-jet angles. The final values of the cuts are chosen on the Monte Carlo samples through a statistical procedure that minimizes the average value of the 95% C.L. upper limit on the number of expected signal events. After this procedure has been applied on a final global variable, 0.25 background events are expected and the resulting selection efficiency for $M_H = 60$ GeV is equal to 26.6%.

4 THE $H^0 l^+ l^-$ CHANNELS

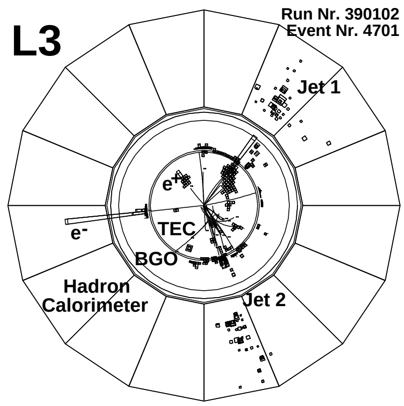

Fig. 1 The high mass Higgs candidate shown in the plane perpendicular to the beam line.

These final states have a clear signature because of the presence of the two energetic and isolated electrons or muons, and allow a good Higgs mass resolution, calculated as the recoil mass against the two leptons. In L3 the mass resolution, for a Higgs mass of 60 GeV, is equal to 0.7 GeV in the $H^0e^+e^-$ and 0.5 GeV in the $H^0\mu^+\mu^-$ channel. The background from four-fermion processes is irreducible: (3.0 ± 0.7) and (0.65 ± 0.11) events with a recoil mass greater than 30 GeV are expected in the electron and in the muon final state respectively, with a selection efficiency at $M_H = 60$ GeV of 42.2% and 32.3%. For Higgs masses above 30 GeV two candidates[4] are found in the $H^0e^+e^-$ channel with $M_H = (31.4 \pm 1.5)$ GeV and $M_H = (67.6 \pm 0.7)$ GeV (fig. 1), consistent with four-fermion background.

5 RESULTS

No candidates are found in the $H^0\nu\bar{\nu}$ and $H^0\mu^+\mu^-$ channels. The two $H^0e^+e^-$ candidates are not compatible with a Higgs boson of 60 GeV, taking into account the mass resolution. The resulting 95% C.L. lower limit on the Higgs mass is 60.2 GeV[4] (fig. 2).

6 FINAL STATES WITH ISOLATED PHOTONS

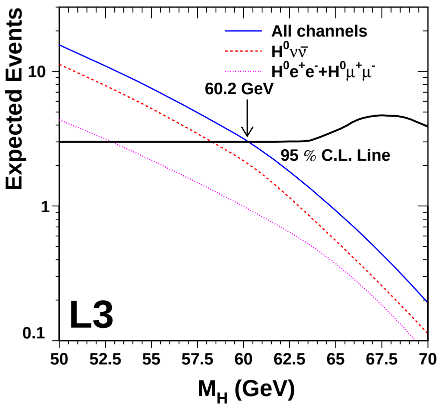

Fig. 2 The number of Higgs event expected in the different channels and the 95% C.L. line as a function of the Higgs mass. The 95% C.L. lower limit on the mass is indicated.

The final states $e^+e^- \to Z \to H^0\gamma$, $H^0 \to q\bar{q}$ and $e^+e^- \to Z \to H^0Z^*$, $H^0 \to \gamma\gamma$, $Z^* \to q\bar{q}$, occurring at one-loop level, have been analyzed searching for hadronic events with one or two isolated and energetic photons[5]. Irreducible background arises from initial and final state radiation and from neutral hadrons misidentified as a single photon. No signal has been seen in the distributions of the mass recoiling against the photon and of the $\gamma\gamma$ invariant mass. Upper limits at 95% C.L. have been set on the production cross sections for the two processes: $\sigma(e^+e^- \to H^0\gamma) \times BR(H^0 \to q\bar{q}) < 0.3 \div 1.0$ pb, for $M_H = 20 \div 80$ GeV, and $\sigma(e^+e^- \to H^0 + h\mathit{adrons}) \times BR(H^0 \to \gamma\gamma) < 0.1 \div 0.3$ pb, for $M_H = 20 \div 70$ GeV.

REFERENCES

1. S. Dawson, J.F. Gunion, H.E. Haber and G.L. Kane, Higgs Hunter's Guide, Addison Wesley, Menlo Park (1989)
2. E. Gross, B. Kniehl and G. Wolf, Z. Phys. **C 63** (1994) 417 and Erratum **C 66** (1995) 321
3. L3 Coll., B. Adeva et al., Nucl. Inst. Meth. **A 289** (1990) 35, L3 Coll., M. Acciarri et al., Nucl. Inst. Meth. **A 351** (1994) 300
4. L3 Coll., M. Acciarri et al., CERN-PPE/96-95, subm. Phys. Lett. B
5. L3 Coll., M. Acciarri et al., CERN-PPE/96-50, accep. Phys. Lett. B