at LEP are now able to rule out a significant range of Higgs masses.

If the Higgs mass is very large, the couplings of the Higgs to itself and to longitudinally polarized gauge bosons become large. Requiring that these couplings remain weak enough so that perturbation theory is applicable implies that $M_H \lesssim 1$ TeV [2]. While this is not an absolute bound, it is an indication of the mass scale at which one can no longer speak of an elementary Higgs boson. This fact is made more clear if one notes that the width of the Higgs boson is proportional to the cube of its mass and that a boson of mass 1 TeV has a width of 500 GeV.

It is believed that scalar field theories of the type used to describe Higgs self-interactions can only be effective theories valid over a limited range of energies if the Higgs self-coupling and hence Higgs mass is nonzero. A theory of this type that is valid at all energy scales must have zero coupling. The range of energies over which the interacting theory is valid is a function of the Higgs self-coupling and hence its mass. An upper bound on the Higgs mass can then be determined by requiring that the theory be valid (*i.e.*, have a nonzero value of the renormalized Higgs self-coupling) at all scales up to the Higgs mass [3]. Non-perturbative calculations using lattice [4] gauge theory that can be used to compute at arbitrary values of the Higgs mass indicate that $M_H \lesssim 750$ GeV.

If the Higgs mass were small, then the vacuum (ground) state with the correct value of M_W would cease to be the true ground state of the theory [5]. A theoretical constraint can then be obtained from the requirement that this is not the case, *i.e.*, that the our universe is in the true minimum of the Higgs potential. The constraint can be parametrized approximately as [6]

$$M_H > 1.85\,(m_{\rm top} - 85\ {\rm GeV})\ .$$

This constraint may be too restrictive. Strictly speaking we can only require that the predicted lifetime of our universe, if it is not at the true minimum of the Higgs potential, be longer than its observed age. This constraint can be approximated by [7,8]

$$M_H > 5.9\,(m_{\rm top} - 170\ {\rm GeV})\ .$$

Experiments at LEP are able to exclude a large range of Higgs masses. They search for the decay $Z \to HZ^*$. Here Z^* refers to a virtual Z boson that can appear in the detector as e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$, $\nu\overline{\nu}$ (*i.e.*, missing energy) or hadrons. The experimental searches have considered both $H \to$ hadrons and $H \to \tau^+\tau^-$. The best limits are shown in the listings below.

Precision measurement of electroweak parameters such as M_W and the various asymmetries at LEP and SLC are becoming sensitive enough that they can in principle constrain the Higgs mass through its effect in radiative corrections. Currently, the precision tests allow the entire range from the direct LEP limit ($M_H \gtrsim 60$ GeV) to 1 TeV [9]. However, a measurement of the top mass might enable a constraint on M_H to be extracted.

Extensions of the standard model, such as those based on supersymmetry [10], can have more complicated spectra of Higgs bosons. The simplest extension has two Higgs doublets whose neutral components have vacuum expectation values v_1 and v_2, both of which contribute to the W and Z masses. The physical particle spectrum contains one charged Higgs boson ($H^\pm$), two neutral scalars (H_1^0, H_2^0), and one pseudoscalar (A^0) if CP is conserved in the scalar sector [11]. In the simplest version of the supersymmetric model, there is an upper bound on the mass of one of these scalars. The bound depends upon the top quark mass; for $m_t = 150$ GeV, the bound is $M_{H_1^0} \lesssim 110$ GeV [12]. In models where all fermions of the same electric charge receive their masses from only one of the two doublets (v_2 gives mass to the charge 2/3 quarks, while v_1 gives mass to the charged leptons and the charge 1/3 quarks), there are, as in the standard model, no flavor-changing neutral currents at lowest order in perturbation theory. The H_i^0 and A^0 couplings to fermions depend on v_2/v_1 and are either enhanced or suppressed relative to the couplings in the standard model. Experiments at LEP are able to exclude ranges of masses for neutral Higgs particles in these models. These ranges depend on the values of v_2/v_1. See the listings below on H_1^0, Mass Limits in Supersymmetric Models.

Searches for charged Higgs bosons depend on the assumed branching fractions to $\nu\tau$, $c\overline{s}$, and $c\bar{b}$. See the listings for $H^\pm$ Mass Limit.

References

1. S. Weinberg, Phys. Rev. Lett. **19**, 1264 (1967);
A. Salam, in "Elementary Particle Theory," W. Svartholm, ed., Almquist and Wiksell, Stockholm (1968);
S.L. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. **D2**, 1285 (1970).
2. M. Veltman, Ann. Phys. (NY) **B8**, 475 (1977);
B.W. Lee, C. Quigg, and H. Thacker, Phys. Rev. **D16**, 1519 (1977).
3. L. Maiani, G. Parisi, and R. Petronzio, Nucl. Phys. **B136**, 115 (1978);
R. Dashen and H. Neuberger, Phys. Rev. Lett. **50**, 1897 (1983).
4. G. Bhanot and K. Bitar, Phys. Rev. Lett. **61**, 798 (1988);
J. Kuti, L. Lin, and Y. Shen, Phys. Rev. Lett. **61**, 678 (1988);
M. Gockeler, K. Jansen, and T. Neuhaus, Phys. Lett. **B273**, 450 (1991);
U.M. Heller, H. Neuberger, and P. Vranas, Phys. Lett. **B283**, 355 (1992).
5. A.D. Linde, JETP Lett. **23**, 64 (1976) [Pis'ma Zh. Eksp. Teor. Fiz. **23**, 73 (1976)];
S. Weinberg, Phys. Rev. Lett. **36**, 294 (1976).
6. M. Lindner, M. Sher, and H.W. Zaglauer, Phys. Lett. **B228**, 527 (1988);
M.J. Duncan, R. Phillipe, and M. Sher, Phys. Lett. **153B**, 165 (1985).
7. G. Anderson, Phys. Lett. **B243**, 265 (1990).
8. P.B. Arnold, Phys. Rev. **D40**, 613 (1989).
9. W. Hollik, presented at the *XVI International Symposium on Lepton-Photon Interactions*, (Cornell, Aug. 1993).