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The Stealth Model at LEP2 [1]

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Abstract

The influence of massless scalar singlets on the Higgs signal at LEP2 is discussed. It is shown that for strong interactions between the Higgs boson and the singlet fields, detection of the Higgs signal can become impossible.

[1]Contribution to the Workshop on Physics at LEP2.

1 Introduction

The radiative corrections at LEP1 are not precise enough to determine the structure of the Higgs sector. It is therefore necessary to keep an open eye to the possibility that the Higgs sector is more complicated than in the standard model. Indeed there are some theoretical motivations to the idea that the Higgs sector of the standard model is not the final story. A motivation from cosmology is the fact that the standard model itself is unlikely to generate the baryon number of the universe, but extensions of the standard model probably can. A possibly deeper reason is the so-called naturalness problem, which basically says that it is unreasonable for the Higgs to be light, as its mass would receive radiative corrections that grow quadratically with the cut-off of the theory. A way out of this problem is supersymmetry which is discussed in a previous section. Another possibility is the presence of strong interactions. This has led to the idea of technicolor, which at least in its simplest form is ruled out by the LEP1 data.

However the idea of strong interactions is more general. In particular it is possible that strong interactions are present in the singlet sector of the theory. In general the choice of representations in a gauge theory is arbitrary and presumably a clue to a deeper underlying theory. Singlets do not have quantum numbers under the gauge group of the standard model. They therefore do not feel the strong or electro-weak forces, but can couple only to the Higgs particle. As a consequence radiative corrections to weak processes are not sensitive to the presence of singlets in the theory, because no Feynman graphs containing singlets appear at the one-loop level. Because effects at the two-loop level are below the experimental precision, the presence of a singlet sector is not ruled out by any of the LEP1 precision data.

It is therefore not unreasonable to assume that there exists a hidden sector, that affects Higgs physics only. Independent of the naturalness problem it is anyway useful to study simple extensions of the standard model in order to have a model for non-standard Higgs properties. Here we will study the coupling of a Higgs boson to an O(N) symmetric set of scalars, which is one of the simplest possibilities introducing only a few extra parameters in the theory. The effect of the extra scalars is practically the presence of a large invisible decay width of the Higgs particle. When the coupling is large enough the Higgs resonance can become wide even for a light Higgs. This has led to the conclusion that this Higgs becomes undetectable at the LHC [1], which justifies giving the model the name of Stealth model. As, at LEP one can measure missing energy more precisely than at a hadron machine, LEP2 can give important constraints on the parameters of the model. However it is clear that there will be a range of parameters, where this Higgs can be seen neither at LEP nor at the LHC. In the next section we will introduce the model together with presently known constraints and in the last section we will discuss discovery and exclusion limits at LEP2.

2 The model

The Higgs sector of the model is described by the following Lagrangian.

$$\mathcal{L} = -\partial_\mu \phi^+ \partial^\mu \phi - \lambda(\phi^+ \phi - v^2/2)^2 - 1/2\, \partial_\mu \vec{\varphi} \partial^\mu \vec{\varphi} - 1/2\, m^2\, \vec{\varphi}^2 - \kappa/(8N)\, (\vec{\varphi}^2)^2 - \omega/(2\sqrt{N})\ \vec{\varphi}^2\, \phi^+ \phi \tag{1}$$

where ϕ is the normal Higgs doublet and the vector $\vec{\varphi}$ is an N-component real vector of scalar fields, which we call phions . Couplings to fermions and vector bosons are as in the standard model. The ordinary Higgs field receives the vacuum expectation value $v/\sqrt{2}$. We assume that the $\vec{\varphi}$-field receives no vacuum expectation value, which can be assured by taking ω positive. After the spontaneous symmetry breaking one is left with the ordinary Higgs boson, coupled to the phions in which it decays. Also the phions receive an induced mass from the spontaneous symmetry breaking. The factor N is taken to be large, so that the model can be analysed in the $1/N$ expansion. By taking this limit the phion mass stays small, but because there are many phions the decay width of the Higgs boson can become large. Therefore the main effect of the presence of the phions is to give a large invisible decay rate of the Higgs boson. The formula for the invisible width is $m_H \Gamma_H = \frac{\omega^2 v^2}{32\pi}$ The model is different from Majoron models [2], since the width is not necessarily small. The model is similar to the technicolor-like model of [3].

Consistency conditions on the model come from two conditions. One condition is the absence of a Landau-pole below a certain scale Λ. The other follows from the stability of the vacuum up to a certain scale. An example of the limits one gets is given in figure 1, where $\kappa = 0$ was taken at the scale $2m_Z$, which allows for the widest range. For the model to be valid beyond a scale Λ one should be below the indicated upper lines in the figure, as otherwise there would appear a Landau pole before this scale. One should be to the right of the indicated lower lines to have stability of the vacuum.

For the search for the Higgs there are basically two channels, one is the standard decay, which is reduced in branching ratio, due to the decay into phions. The other is the invisible decay, which rapidly becomes dominant, eventually making the Higgs wide. Contrary to the case of the heavy Higgs boson, the widening does not mean that the coupling to the phions is extremely strong. The standard model light Higgs boson is in a sense anomalously narrow, because the couplings to the fermions is very small. In order to give the bounds we therefore neglect the coupling κ, as this is a small effect. We also neglect the phion mass. For other values of the phion mass the bounds can be found by rescaling the decay widths with the appropriate phase space factor. The present bounds, coming from the LEP1 visible and invisible search are given in figure 2.

3 LEP2 bounds

In the case of LEP2 the limits on the Higgs mass and couplings come essentially from the invisible decay, as the branching ratio into $\bar{b}b$ quarks drops rapidly with increasing φ-Higgs coupling. To define the signal we look at events around the Higgs resonance maximum, with an invariant mass $m_H \pm \Delta$, with $\Delta = 5GeV$,which corresponds to a typical mass resolution. Discovery and exclusion limits are determined by Poisson statistics as defined in the interim report [4]. The results are given in figure 3. One notices the somewhat reduced sensitivity for a Higgs mass near the Z boson mass. Also there is a somewhat better limit on the Higgs mass for moderate ω in comparison with the $\omega = 0$ case, which is due to events from the Higgs tail.

Finally we conclude from the analysis, that LEP2 can put significant limits on the parameter space of the model. However there is a range, where the Higgs will not be discovered, even if it is there. This holds also true, when one considers the search at the LHC. When one assumes a moderate to large value of ω, i.e. in the already difficult intermediate mass range, it is unlikely that sufficient signal is left at the LHC. In that case the only information can come directly from the NLC or indirectly from higher precision experiments at LEP1.

References

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[2] J. Valle et all. in this Report.

[3] R. S. Chivukula, M. Golden, Phys. Lett. B267, 233 (1991).

[4] LEP2 interim report, CERN-TH/95-151, CERN-PPE/95-78.

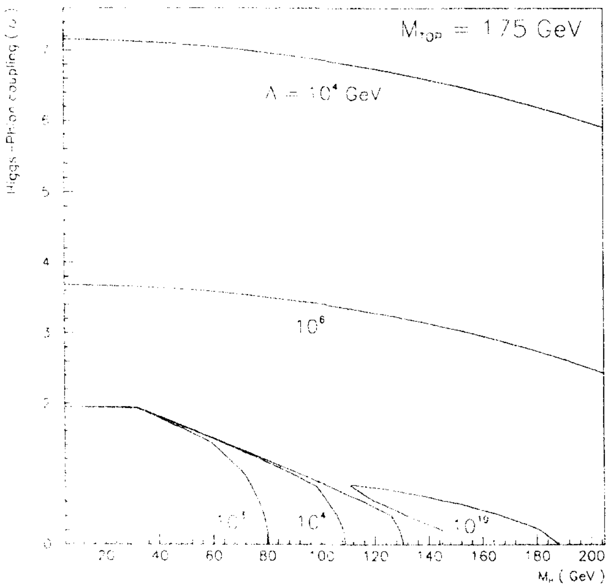

Figure 1: *Theoretical limits on the parameters of the model in the ω versus M_H plane. For consistency beyond a scale Λ one should be below the indicated upper lines and to the right of the lower lines.*

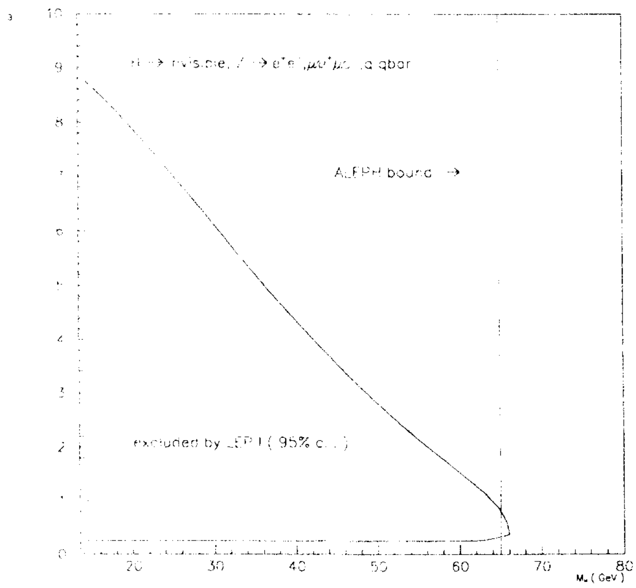

Figure 2: *Limits on the model from the LEP1 data. The area below the horizontal line can be excluded from visible decays.*

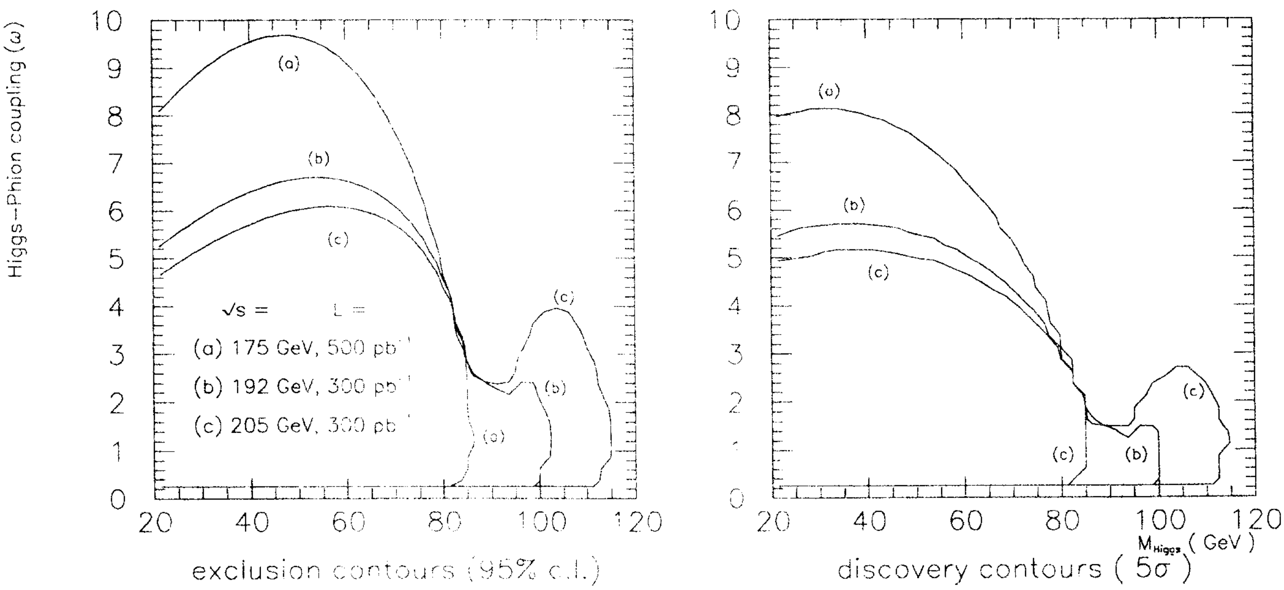

Figure 3: *Exclusion and discovery limits at LEP2.*

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