Is There A Higgs Boson With Mass Below 100 GeV/c^2
In The LEP Data?

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Abstract

There could be a Higgs boson with a mass less than 100 GeV/c^2 in the LEP data if its decay width and modes are not dominated by b quarks. At present, the quantum interference between signal and background processes has not been considered in flavour independent searches but when it is, the long-sought particle may appear.

1 Introduction

The search for a Higgs boson is arguably the top priority of particle physics today. It is also the most tantalizing. On the one hand, direct searches at LEP II have set lower limits of 114 GeV/c^2 for a Standard Model Higgs boson and 89.9 GeV/c^2 for the Minimal Supersymmetric Model Higgs [1]. On the other hand, indirect evidence from virtual Higgs effects in electroweak fits to LEP, SLC and Tevatron data suggest a Higgs exists with a mass significantly lower than these bounds. The fits to the Z data imply a mass of about 81 GeV/c^2 while the latest fit to the W data using the measured top quark mass gives a Higgs mass of just 26 GeV/c^2. Of course, the uncertainties are large (30-50 GeV/c^2) in both types of fit but nevertheless there is a growing feeling that these fits and the direct search result are an indication of a deviation from the Standard Model.

The assumption is that, for some reason, the Higgs mass is larger than the central value predicted by the fits. However this may not be so. In a companion paper [6] we have proposed a scenario with a universal Higgs-fermion coupling and its application to a Two Higgs Doublet Model (2HDM) of type II. With some reasonable parameters, a Higgs boson with a mass compatible with the fit values but a hadronic branching ratio of between 66% and 80% is predicted. These hadronic jet flavours are equally u and c (not b) with the remaining decays being to invisible neutrinos.

Although such a model sidesteps the limits imposed by the standard analyses quoted above, the LEP Higgs Working Group has combined flavour independent Higgs search results from the four LEP collaborations [7, 8, 9, 10] and produced a paper, with preliminary results [11], which appears to impose serious constraints. At face value, figure 2 from that paper suggests that, with a Z-Higgs production cross section roughly equal to the Standard Model rate and a hadronic branching ratio of about 80%, there can be no Higgs boson with a mass below about 110 GeV/c^2.

2 Flaws in the Flavour Independent Higgs Search

The flavour independent Higgs search has two significant flaws. Firstly the decay width of the Higgs boson in the Universal Higgs-Fermion Coupling model could be much larger than orthodox models and this needs to be taken into consideration.

Secondly, and more importantly, no account has been taken of any quantum interference between the signal and background. The signal process is e^+e^- → HZ → 4-jets while the background processes are e^+e^- → ZZ → 4-jets and e^+e^- → W^+W^- → 4-jets. The interference may be significant because

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the $H$ could have a similar mass to the $W$ and $Z$ and similar quark branching ratios. (Of course, the $Z$ and $W$ are spin one while the $H$ is spin zero.)

The result of such interference could be dips and rises in the production cross-section rather than a simple step. Whether this is what is seen in figure 2 of the LEP Higgs Working Group paper is impossible to tell but it is intriguing. Of course a careful simulation of the interference (if any) will be needed and we encourage the LEP Higgs Working Group to undertake this analysis as soon as possible. If a Higgs boson does hide in the LEP data, presumably charm tagging as a function of the electron-positron centre-of-mass energy will be required to dig it out.

3 Conclusion

The current flavour independent Higgs search result from LEP cannot currently exclude a low mass Higgs boson with properties similar to a $Z$ until quantum interference is simulated between $HZ$ and $ZZ$ production and the effect of broad Higgs decay widths are considered. Consequently the central result from the indirect (electroweak fit) Higgs searches is still viable.

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