The existence of extra chiral generations is strongly disfavored by the precision electroweak data if all the extra fermions are heavier than \( m_Z \). However fits as good as the SM can be obtained if one allows the new neutral leptons to have masses close to 50 GeV. In the framework of SUSY models precision measurements cannot exclude one additional generation of heavy fermions if chargino and neutralino have masses around 60 GeV with \( \Delta m_{\tilde{\chi}^\pm,0} \simeq 1 \) GeV.

1 Introduction

The aim of this talk is to analyze to what extent precision measurements of IVB parameters allow to bound effectively the existence of extra chiral generations of heavy fermions, both quarks \((q = U, D)\) and leptons \((l = N, E)\). We will show that the case where all the extra particles are heavier than \( m_Z \) is now excluded by more than 2 standard deviations. However, if the masses of new neutrinos are assumed to be close to 50 GeV, then additional generations become allowed and up to three extra families can exist within 2.5\( \sigma \). Finally, inclusion of new generations in SUSY extension of Standard Model is briefly discussed.

For simplicity, we will assume that the extra neutrinos are just ordinary massive Dirac particles, and that their mass is larger than 45 GeV so to avoid contradiction with the experimental data on the invisible \( Z \) width. Also, we will neglect the possible mixing among new generations and the three existing ones, hence new fermions contribute to electroweak observables only through oblique corrections. On the other hand, we perform global fit of all precision data, studying both degenerate and non-degenerate extra generations on the equal footing. Taking the number of new generations \( N_g \) as a continuous parameter, just as it was done with the determination of the number of neutrinos from invisible \( Z \) width, we get a bound on it. The minimum \( \chi^2 \) corresponds to \( N_g \simeq -0.5 \), while the case \( N_g = 1 \) is excluded by more than 2 standard deviations.
2 Discussion

Heavy fermions. The comparison between theoretical predictions and experimental data is performed with the help of the computer code LEPTOP. To simplify the analysis we start from the “horizontally degenerate” case \(m_N = m_U\) and \(m_E = m_D = 130\) GeV (Tevatron bound). Regions show \(<1\sigma, <2\sigma\) etc. allowed domains.

Light neutrinos. For particles with masses close to \(m_Z/2\), oblique corrections drastically differ from what we have above \(m_Z\). If we assume that the mixing angle between \(N\) and the three known neutrinos is less than \(10^{-6}\), so to avoid the bound \(m_N > 70 \div 80\) GeV from LEP II searches of the de-
Figure 3. Exclusion plot in the $(N_g, m_b)$ plane. We assumed $m_{N,E,U,D} = 130$ GeV, $m_b = 200$ GeV and no $t_L - t_R$ mixing. Regions show $< 1\sigma$, $< 2\sigma$ etc. allowed domains.

Figure 4. Same as Fig. 3, but including the extra contributions from a 57 GeV almost degenerate chargino and neutralino in the higgsino-dominated scenario.

cays $N \to lW^*$, we have that extra neutrinos as light as 45 GeV are still allowed by direct search experiments. In this case, effects of $Z$-boson wave function renormalization become relevant, and the quality of the fit can be even better than the SM. Analyzing all the electroweak observables, we conclude that presently a light neutral lepton $N$ cannot be excluded by precision measurements as well. As an example, in Fig. 2 we assume $m_U = 220$ GeV, $m_D = 200$ GeV, $m_E = 100$ GeV and draw the exclusion plot in coordinates $(m_N, N_g)$: from this plot it is clear that for the case of extra generations with $m_N \approx 50$ GeV even two new generations are allowed within $1.5\sigma$.

The case of SUSY. Concerning bounds on extra generations which occur in SUSY extensions, when superpartners are heavy their contributions to electroweak observables become power suppressed, and the same Standard Model exclusion plots shown in Fig. 1 and Fig. 2 are valid. The present lower bounds on the sparticle masses from direct searches leave mainly this decoupled domain. One possible exception is a contribution of the third generation squark doublet, enhanced by large stop-sbottom splitting. To see whether this contribution affects the bounds on extra generations found in the previous section, in Fig. 3 we analyze the simplest case of the absence of $t_L - t_R$ mixing, setting the masses of all the extra fermions to the common value $m_{N,E,U,D} = 130$ GeV and showing the plot in coordinates $(N_g, m_b)$. It is clear that even in the con-
text of SUSY models new heavy generations are disfavored.

Situation qualitatively changes in the case of almost degenerate light chargino and neutralino. This possibility is yet not excluded – dedicated search at LEP II by DELPHI still allows the existence of such particles with masses as low as 45 GeV if their mass difference is $\approx 1$ GeV and even in this case radiative corrections are large. Fig. 4 demonstrates how the presence of a chargino-neutralino pair (dominated by higgsino) with mass 57 GeV relaxes the bounds shown on Fig. 1: we see that one extra generation of heavy fermions is now allowed within the $1.5\sigma$ domain.

3 Conclusions

Inclusion of new generations in Standard Model is not excluded by precision data if the new neutral leptons have masses close to $m_Z/2$ (see Fig. 3). In order to experimentally investigate this case a special search for the reaction $e^+e^- \rightarrow \gamma Z^* \rightarrow \gamma N\bar{N}$ with larger statistics and improved systematics is needed. Finally, further experimental search for light chargino and neutralino is of interest. These searches could close the existing windows of “light” extra particles, or open a door into a realm of New Physics.

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