

CONSTRAINTS ON R-PARITY VIOLATION FROM PRECISION ELECTROWEAK MEASUREMENTS

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We constrain the size of R-parity violating couplings using precision electroweak data.

1 Introduction

Precision electroweak measurements provide a window to physics beyond the Standard Model by constraining the size of radiative corrections from new particles and interactions. In this contribution, we summarize the constraints from the LEP and SLD data on an R-parity violating extension to the MSSM. Details are presented in Ref. 1.^a

We extend the MSSM with the addition of the the following terms to the superpotential:

$$\frac{1}{2}\lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}_k + \frac{1}{2}\lambda''_{ijk}\hat{U}_i\hat{D}_j\hat{D}_k, \quad (1)$$

where \hat{L}_i , \hat{E}_i , \hat{Q}_i , \hat{U}_i , and \hat{D}_i are the MSSM superfields defined in the usual fashion and the subscript $i = 1, 2, 3$ is the generation index. We focus our attention on these supersymmetric interactions only and ignore possible R-parity violating soft-breaking terms.³ This allows us to rotate away any bilinear terms that may be present.^{4b}

Since the couplings constants λ_{ijk} , λ'_{ijk} , and λ''_{ijk} are arbitrary and do not have any *a priori* flavor structure, they generically lead to flavor dependent processes and corrections to electroweak observables. In particular, they will give rise to flavor dependent corrections to the $Zf\bar{f}$ vertices which can be well constrained by the Z-pole data from LEP and

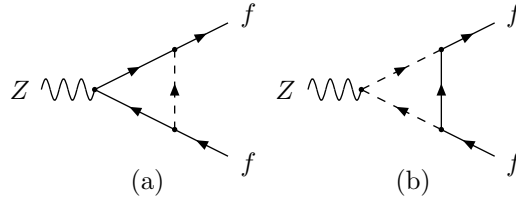


Figure 1. Corrections to the $Zf\bar{f}$ coupling from the R-parity violating interactions in Eq. (1). The sfermions are represented by the dashed lines. Wave-function renormalization corrections are not shown.

SLD. Previous works⁶ have already placed bounds on λ_{ijk} of $\mathcal{O}(10^{-2})$ from lepton universality in low energy charged current processes, and their effects on Z-pole observables are negligible. λ'_{ijk} and λ''_{ijk} have been less tightly constrained. However, the simultaneous presence of both terms leads to unacceptably fast proton decay so we will assume that only one of these terms is present at a time.

2 The Corrections

Corrections to the $Zf\bar{f}$ vertex from the interactions in Eq. (1) are shown schematically in Fig. 1. Of all the possible corrections, it can be shown that only those with the top quark in the internal fermion line are numerically significant. Therefore, we only need to consider the λ'_{i3k} (9 parameters) or the λ''_{3jk} (3 parameters)^c interactions. In this approximation, the λ'_{i3k} inter-

^aFor a discussion on the constraints on the MSSM itself, see Ref. 2.

^bAn extension of the MSSM with R-parity violation including bilinear and soft-breaking terms is discussed in Ref. 5.

^c λ''_{ijk} is antisymmetric in the latter two indices.

actions only affect the couplings of the left-handed charged leptons and the right-handed down-type quarks, while the λ''_{3jk} interactions only affect the couplings of the right-handed down-type quarks.

The actual sizes of these corrections depend on the masses of the internal sfermions. As a reference, we choose a common sfermion mass of 100 GeV. In this case, the shifts in the $Zf\bar{f}$ couplings due to the λ'_{i3k} interactions are found to be:^d

$$\begin{aligned}\delta h_{e_L}^R &= 0.0061 \sum_k |\lambda'_{i3k}|^2, \\ \delta h_{d_{kR}}^R &= -0.00215 \sum_i |\lambda'_{i3k}|^2.\end{aligned}$$

Similarly, the shifts due to the λ''_{3jk} interactions are:

$$\delta h_{d_{jR}}^R = -0.0043 \sum_k |\lambda''_{3jk}|^2.$$

In order to constrain the size of these shifts, all vertex and oblique corrections from within the MSSM must also be included and accounted for consistently. Here, we observe that the majority of the Z -pole observables are parity-violating asymmetries or ratios of partial widths which are all *ratios of coupling constants*.^e Oblique corrections enter the coupling constants through the ρ -parameter and the effective value of $\sin^2 \theta_W$.⁸ The dependence on the ρ -parameter cancels in the ratios, isolating the effects of oblique corrections in $\sin^2 \theta_W$. For the vertex corrections, we can apply the same approximation as above and neglect those without a heavy internal fermion. Of the corrections that remain, the simplifying assumption that all the sfermion masses are degenerate allows us to either cancel the correction in the ratios of coupling constants, or absorb them into a shift in $\sin^2 \theta_W$. The only vertex correction that must be considered inde-

pendently is the Higgs sector induced correction to the b_L coupling. These considerations allow us to parametrize all the corrections from both within and without the MSSM in terms of just a few parameters which can be fit to the differences of the Z -pole data⁹ and ZFITTER¹⁰ predictions.

3 Lepton Universality

The shifts in the left-handed couplings of the charged leptons break lepton universality. Fitting to the leptonic data from LEP and SLD, we find:

$$\begin{aligned}\delta h_{\mu_L}^R - \delta h_{e_L}^R &= 0.00038 \pm 0.00056 \\ \delta h_{\tau_L}^R - \delta h_{e_L}^R &= -0.00013 \pm 0.00061\end{aligned}$$

The couplings contributing to $\delta h_{e_L}^R$ are already well constrained from other experiments, so if we neglect them we obtain the following 1σ (2σ) bounds:

$$\begin{aligned}|\lambda'_{23k}| &\leq 0.40 \quad (0.50) \\ |\lambda'_{33k}| &\leq 0.28 \quad (0.42)\end{aligned}$$

4 Hadronic Observables

The couplings of the right-handed down-type quarks are constrained by the hadronic observables from LEP and SLD. A global fit to all relevant observables yields:

$$\begin{aligned}\delta h_{d_R}^R &= 0.081 \pm 0.077 \\ \delta h_{s_R}^R &= 0.055 \pm 0.043 \\ \delta h_{b_R}^R &= 0.026 \pm 0.010\end{aligned}$$

Note that $\delta h_{d_R}^R$ and $\delta h_{s_R}^R$ are positive by more than 1σ , while $\delta h_{b_R}^R$ is positive by more than 2σ . Since both the λ'_{i3k} and λ''_{3jk} interactions lead to negative shifts, all these couplings are ruled out at the 1σ level. The (2σ) [3σ] bounds are:

$$\begin{aligned}|\lambda'_{i31}| &\leq (5.8) \quad [8.4] \\ |\lambda'_{i32}| &\leq (3.8) \quad [5.9] \\ |\lambda'_{i33}| &\leq () \quad [1.4]\end{aligned}$$

or

$$|\lambda''_{321}| \leq (2.7) \quad [4.1]$$

^dThe tree level coupling of fermion f to the Z is normalized to $h_f = I_{3f} - Q_f \sin^2 \theta_W$.

^eThe same observation has been used to constrain a variety of models in Ref. 7.

$$|\lambda''_{33i}| \leq () [0.96]$$

Stronger constraints on λ'_{i31} and λ'_{i32} are available from other experiments.

5 Bayesian Limits

If one makes the *a priori* assumption that the MSSM with R-parity violation is the correct underlying theory, one obtains the following 68% (95%) Bayesian confidence limits:

$$\begin{aligned} \delta h_{dR}^R &\geq -0.061 \quad (-0.123) \\ \delta h_{sR}^R &\geq -0.031 \quad (-0.064) \\ \delta h_{bR}^R &\geq -0.0046 \quad (-0.010) \end{aligned}$$

This translates into

$$\begin{aligned} |\lambda'_{i31}| &\leq 5.2 \quad (7.6) \\ |\lambda'_{i32}| &\leq 3.8 \quad (5.6) \\ |\lambda'_{i33}| &\leq 1.4 \quad (2.2) \end{aligned}$$

or

$$\begin{aligned} |\lambda''_{321}| &\leq 2.7 \quad (3.9) \\ |\lambda''_{33i}| &\leq 1.0 \quad (1.5) \end{aligned}$$

While these Bayesian bounds are considerably weaker, they are accompanied by large values of χ^2 .

6 The Common Sfermion Mass

To obtain bounds for a common sfermion mass other than the value of $m_{\tilde{f}} = 100$ GeV used in this analysis, the limits should be rescaled by $\sqrt{F(x_0)/F(x)}$, where

$$F(x) \equiv \frac{x}{1-x} \left(1 + \frac{1}{1-x} \ln x \right),$$

and

$$x \equiv \frac{m_t^2}{m_{\tilde{f}}^2}, \quad x_0 \equiv \frac{m_t^2}{(100 \text{ GeV})^2}.$$

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