Expected Limits on R-symmetric $\mu \to e$ Processes at Project X

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We investigate $\mu \to e$ processes in the Minimal R-symmetric Standard Model (MRSSM) with the expected limits from Project X. It is found that $\mu \to e$ conversion provides the tightest bound on the $\mu \to e$ mixing parameters at the order of $\lesssim O(10^{-3})$. Whereas $\mu \to eee$ only slightly improves the bound in the region where incoherence among different contributions to $\mu \to e$ is significant. No improvements on the bounds are obtained from $\mu \to e\gamma$.

I. INTRODUCTION

Lepton flavor violation (LFV) is predicted to occur at an unobservably small rate in the Standard Model (SM). In low energy supersymmetric theories, new sources of lepton flavor violation are generic in the soft breaking sector. The experimental non-observation of $\mu \to e$ processes is particularly restrictive, given the impressively small rate in the Standard Model (SM). In low energy supersymmetric theories, new sources of lepton flavor violation are generic in the soft breaking sector. The experimental non-observation of $\mu \to e$ processes is particularly restrictive, given the impressively small rate in the Standard Model (SM).

The sensitivities to $\mu \to e\gamma$ conversion on $\sim$ the flavor mixing in the MRSSM. The results will be organized as follow. Section II gives a discussion on sensitivities plots will be presented in this paper. It will be presented in section II. Finally, we will discuss the results in II.

II. $\mu \to e$ MIXING IN THE MRSSM

Consider $\tilde{\mu} - \tilde{e}$ mixing in the MRSSM, the mass eigenvalues of the two sleptons, $\tilde{l}_i$ are written as

$$\left(\begin{array}{c} \tilde{l}_1 \\ \tilde{l}_2 \end{array}\right)_{L,R} = \left(\begin{array}{cc} \cos \theta_{L,R} & \sin \theta_{L,R} \\ -\sin \theta_{L,R} & \cos \theta_{L,R} \end{array}\right)_{L,R} \left(\begin{array}{c} \tilde{e} \\ \tilde{\mu} \end{array}\right)_{L,R}.$$ (1)

To understand the dependence of $\mu \to e$ amplitudes on the mixing parameters, consider the $\tilde{e}\tilde{e}N$ vertex, where $l = (e, \mu)$ and $N$ is the neutralino. Dropping the subscripts $L$ and $R$ upon writing the slepton in the eigenbasis according to (1) one sees that the interaction is proportional to either $\cos \theta_L$ or $\sin \theta_L$. Now consider diagrams corresponding to $\mu \to e\gamma$ and $\mu \to e$ conversion where only one slepton runs in the loop. Because in all these diagrams the internal slepton line connects with both the external $\mu$ and $e$ line, the amplitude of all diagrams must be proportional to $\cos \theta_L \sin \theta_L$ for each slepton “chirality”. For $\mu \to eee$, the diagrams contain terms that are proportional to $\cos^3 \theta_L \sin \theta_L$ and others that are proportional to $\cos \theta_L \sin^3 \theta_L$ due to the two sleptons running in the loop. Because of the large intensity at Project X, the mixing angle $\theta_L$ can be assumed to be small and the diagrams proportional to $\cos \theta_L \sin^3 \theta_L$ drop out. In other words, for a set given masses, the branching fraction of $\mu \to e\gamma$, $\mu \to e$ conversion and $\mu \to eee$ are all proportional to $\sin^2 2\theta_L$. This fact is useful when one tries to estimate the bound on slepton mixing parameters during early runs of Project X.

Focusing on the first two generations of lepton mixing, the parameters sensitive to $\mu \to e$ processes are the mixing parameters $\sin 2\theta_{L,R}$, the bino mass, $M_B$, slepton masses, $m_{1,2}$, down type Higgsino mass $\mu_d$, and the slepton mixing angles $\sin 2\theta_{L,R}$. The following assumptions have been made...

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The exclusion plots of $\mu \to e$ conversion and $\mu \to eee$ with the expected limit at Project X are shown in Figures 1 and 2. The following assumptions have been made...
FIG. 1. $\mu \to e$ conversion exclusion plots with expected limit of $BR(\mu \to e) < 10^{-19}$ at Project X, where $m_1$ is the lightest slepton mass, and $M_B$ is the bino mass, with the slepton masses $m_2 = 1.5m_1$. The Higgsino mass is $\mu_d = 200$ GeV. The labeled contours are various values of $\sin^2 \theta_{L,R}$. Note that there is significant destructive interference among $\mu \to e$ conversion amplitudes a narrow region for the case of left-hand slepton mixing. In the production of these plots the chargino (with mass $\sim O(1 \text{ TeV})$) loops are omitted, and the results for left-handed mixing with bino mass up to only 500 GeV is presented for consistency.

FIG. 2. Same as Figure 1 but for the process $\mu \to eee$.

to simplify the parameter space. First, the slepton hierarchy is set to have order one splitting. In particular, $m_2/m_1 = 1.5$, so that the $\mu \to e$ amplitudes are not overly suppressed by the super-JIM mechanism. Second, we only allow either the left handed or right handed mixing to be nonzero, but not both. This is done so that the contribution from each of the left-right sector is manifest. Finally, we have set the down-type Higgsino mass $\mu_d = 200$ GeV and the squark masses $m_{\tilde{q}} = 1 \text{ TeV}$, where the squark masses appear only in the box diagram of
The sensitivities to $\mu \to e$ conversion and $\mu \to eee$ are expected to improve by $10^6$ and $10^3$ to $10^4$ respectively. In the scenario where no events from $\mu \to e$ processes are observed, then one would expect the bound on the mixing parameters to be more restricted by $10^{-3}$ for $\mu \to e$ conversion and $10^{-2}$ for $\mu \to eee$. This can be seen in Figures 1 and 2.

DISCUSSION

The results show that Project X will be able to constrain the parameter space of $\mu \to e$ mixing in the MRSSM by $\mu \to e$ conversion alone, giving bounds on the mixing parameters of $\sin 2\theta_{L,R} \lesssim O(10^{-3} - 10^{-4})$ for moderate slepton and bino masses. In the scenario where no $\mu \to e$ events are observed, the non-observation would motivate additional model building to explain the hierarchy between flavor conserving and flavor violating elements of the slepton mass matrix. The results presented here illustrate $BR(\mu \to e) \propto \sin^2 2\theta_{L,R}$. For example, the contours in Figure 2 are almost identical to the corresponding contours in [47], except that the values of $\sin 2\theta_{L,R}$ are scaled down by $10^{-2}$. Also, $\mu \to eee$ provides minimal improvement on the bound on left-handed $\mu \to e$ mixing - it merely excludes the bottom left tail of the incoherence region for $\mu \to e\gamma$ conversion. Finally, we checked the bound from $\mu \to e\gamma$ is weaker than the bound obtained in the other two processes in the region of parameter space of interest.

Note that only the masses used in this paper are expected to pass the collider bounds from the LHC. It was shown in [54] that the LHC bound on squark masses of the first and second generations in a model with $R$-symmetry is $m_{\tilde{q}} \lesssim 680 - 750$ GeV. Analysis for the bounds on slepton and neutralino masses have not been performed. However, using the squark pair production channels in [54] and translating it to slepton pair production, it is safe to expect that the LHC does not give stringent bounds on the slepton masses. The reason is that Drell-Yan is the only production process of the pair production of sleptons at the LHC. Whereas gluon fusion channels contribute to the squark pair production channel. Also, the amplitude of slepton pair production is down by a color factor of 3 and the ratio of electroweak to strong couplings $\alpha_{EW}/\alpha_s$ when compared to squark pair production.

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