Gravitino Lifetime and Neutrino Masses in Trilinear RpV

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1 Gravitino Lifetime

The full expressions for the gravitino decay width, considering trilinear R-Parity violation, are given in hep-ph/017286. For instance, from these expressions we can get an approximated formula for the leptonic decay $\Gamma(\tilde{G} \to \nu_i e_j \bar{e}_k)$ by assuming that the mass of the sleptons that mediate the three body decay are equal, such that $m_{\tilde{\nu}_{iL}} = m_{\tilde{e}_{jL}} = m_{\tilde{e}_{kR}} = \tilde{m}$, and expand in taylor series around the variable $m_G/\tilde{m}$ to obtain

$$\Gamma(\tilde{G} \to \nu_i e_j \bar{e}_k) \approx \frac{1}{96(2\pi)^3} \frac{\lambda_{ijk}^2}{8M_\star^2} \frac{m_G^7}{\tilde{m}^4}, \tag{1}$$

where $M_\star = (8\pi G_N)^{1/2} = 2.4 \times 10^{18}\,\text{GeV}$ is the reduced Planck mass. This result shows that the decay width (lifetime) decreases (increases) rapidly as we increase $\tilde{m}$, as expected. We expect that a similar behavior should be obtained even when the mass of sleptons are not equal.

Indeed, we have verified this expectation numerically, by evaluating the full expression given in hep-ph/017286 using the maximum numerical precission in Mathematica. For instance, in Fig. 1 we plot the gravitino lifetime as a function of $m_{\tilde{\nu}_{iL}}$ for $m_{\tilde{e}_{jL}} = m_{\tilde{\nu}_{iL}}/2$ and $m_{\tilde{e}_{kR}} = m_{\tilde{\nu}_{iL}}/5$. Also, in the same figure we plot the lifetime derived from Eq. 1 evaluated at $\tilde{m} = m_{\tilde{\nu}_{iL}}/2$ in order to check that both approaches, exact computation and approximated formula, behave quite similarly.

Therefore, we can confidently derive the following expression for the gravitino lifetime,

$$\tau_G \approx 7 \times 10^{28}\,\text{sec} \left(\frac{1}{\lambda_{ijk}\lambda_{ijk}}\right) \left(\frac{\tilde{m}}{10^8\,\text{GeV}}\right)^4 \left(\frac{1\,\text{TeV}}{m_G}\right)^7 \tag{2}$$

where we have normalized with respect to 10^{28} sec since this is the order of magnitude required by experiments such as AMS-02 and Fermi-LAT in order to fit the electron positron data in the first case or to avoid gamma ray constraints in the second.

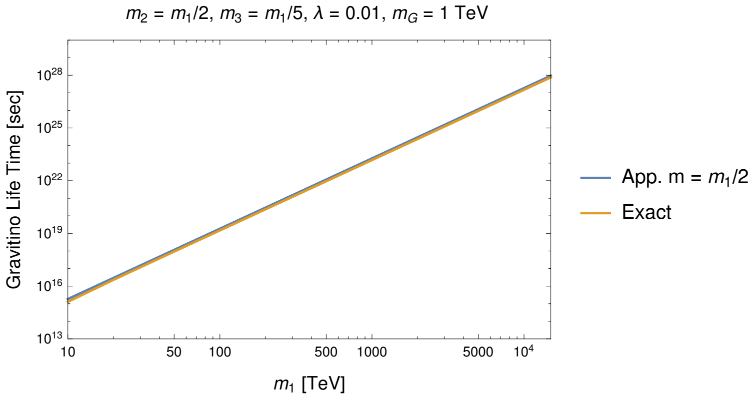

Figure 1: Gravitino life time in Trilinear RpV for $\lambda_{ijk} = 0.01$, $m_G = 1\,\text{TeV}$. For simplicity we use m_1, m_2, m_3 and m instead of $m_{\tilde{\nu}_{iL}}$, $m_{\tilde{e}_{jL}}$, $m_{\tilde{e}_{kR}}$ and $\tilde{m}$.

2 Neutrino Masses

In trilinear RpV the neutrino mass matrix receives contributions from 1-loop diagrams that contain both a charged lepton and the corresponding slepton. Indeed, we have derived the following (preliminary) expression

$$M^{\nu\,(1)}_{ij} \approx \frac{1}{16\pi^2}\sum_{gr} s_{\tilde{l}}c_{\tilde{l}}(\lambda_{igr}\lambda_{jrg}+\lambda_{jgr}\lambda_{irg})m_g \ln\frac{m^2_{\tilde{l}_{r2}}}{m^2_{\tilde{l}_{r1}}}$$

where i and j are neutrino generation indices that run from 1 to 3. g is a charged lepton index that also run from 1 to 3, as well as r which is a slepton index. Thus, it can be seen that for order one $s_{\tilde{l}}$, $c_{\tilde{l}}$ and $\ln(m^2_{\tilde{l}_{r2}}/m^2_{\tilde{l}_{r1}})$ we can get neutrino masses around the eV scale for $\lambda_{ijk} \approx 0.01$ even for $m_g \approx m_e$.

Indeed, by following the expressions given in hep-ph/0410242 for the contribution of λ' trilinear terms, we can get by analogy that the dominant term in the leptonic sector is

$$\begin{aligned} M^{\nu\,(1)}_{ij} &\approx \frac{1}{8\pi^2}\lambda_{i23}\lambda_{j32}\frac{m_\mu m_\tau A_\tau}{\tilde{m}^2} \\ &\approx 2\times10^{-2}\text{eV}\,\lambda_{i23}\lambda_{j32}\left(\frac{10^8\,\text{GeV}}{\tilde{m}}\right) \\ &\approx 2\times10^{-2}\text{eV}\,(\lambda_{i23}\lambda_{j32})^{5/4}\left(\frac{\tau_G}{7\times10^{28}\,\text{sec}}\right)^{1/4}\left(\frac{m_G}{1\,\text{TeV}}\right)^{7/4} \end{aligned}$$

where A_τ is a free parameter that can be considered of order $\tilde{m}$, as it is done in hep-ph/0410242. Thus, if we consider this formula together with Eq. 2 we see that we can have contributions to the neutrino mass matrix of order 10^{-2}eV for trilinear couplings and a scalar mass which are compatible with $\tau_G \approx 10^{28}$ sec.