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RIGHT-HANDED LEPTONS AND SUPERSYMMETRIC DECAY OF HEAVY LEPTON

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Ильмар ОТС, Рихо ВИЛИ. ПРАВОВИНТОВЫЕ ЛЕПТОНЫ И СУПЕРСИММЕТРИЧНЫЙ РАСПАД ТЯЖЕЛОГО ЛЕПТОНА

(*Presented by G. Liidja*)

In papers [1–3] the supersymmetric decays

$$\mu \to e+\tilde{\nu}_\mu+\tilde{\bar{\nu}}_e, \tag{1}$$

$$\tau \to l+\tilde{\nu}_\tau+\tilde{\bar{\nu}}_l \tag{2}$$

mediated by spin 1/2 wino ($\tilde{w}$) with $\tilde{\nu}$ as zero spin *s*-neutrino have been investigated. At present there is experimental evidence that scalar neutrinos, if they exist, must have masses larger than that allowed by phase spaces of these decays [4]. Nevertheless, the investigation of lepton SUSY decays is not without interest. Firstly, leptons heavier than tau lepton may exist in nature and, secondly, the SUSY decays are in some cases more model-dependent than ordinary decays. The present paper serves to prove the latter statement.

The SUSY decay matrix elements used in papers [1–3] are straight supersummetric extensions of those used in the Standard Model. It is known that the Standard Models allows only left-handed leptons in weak decay processes. However, there exist models (e.g. the left-right symmetric model) with right-handed leptons. The possibility that right-handed leptons may participate in weak decay processes is not infinitesimally small [5].

Extending the models with right-handed leptons to SUSY decay of heavy lepton

$$L \to l+\tilde{\nu}_L+\tilde{\bar{\nu}}_l, \tag{3}$$

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one can take the decay matrix element as

$$M_s = \frac{g^2}{p^2_{\tilde{w}} - m^2_{\tilde{w}}} \bar{U}_l (P_R + \alpha P_L)(\hat{p}_{\tilde{w}} + m_{\tilde{w}})(P_L + \beta P_R) U_L \tag{4}$$

with $P_L = \frac{1}{2}(1-\gamma_5)$, $P_R = \frac{1}{2}(1+\gamma_5)$ and α, β as small parameters characterizing the right-handedness of leptons.***

Neglecting the term with product $\alpha\beta$ (it gives only a small correction to the SUSY extension of the Standard Model decay analyzed in [1–3]) and variation of the $\tilde{w}$ propagator with $p^2_{\tilde{w}}$, the squared matrix element has the form

$$|M_s|^2 = |M|^2 + \beta^2 |M_1|^2 + \alpha^2 |M_2|^2 + \beta (M M_1^* + M_1 M^*) \tag{5}$$

with

$$M = \frac{g^2}{2m^2_{\tilde{w}}} p^{\sigma}_{\tilde{w}} \bar{U}_l \gamma_\sigma (1-\gamma_5) U_L, \tag{6}$$

$$M_{1,2} = \frac{g^2}{2m_{\tilde{w}}} \bar{U}_l (1 \pm \gamma_5) U_L. \tag{7}$$

In (7) the upper sign belongs to M_1 and the lower one to M_2.

The squared matrix element (5) gives the following final charged lepton energy-angular distribution for the polarized initial heavy lepton:

$$d\Gamma_{\mathrm{SUSY}} = \frac{G^2 m_L^5}{8\pi^3} \varepsilon x J(x) \Big\{ x(1-x)[1+\eta(x)]^2 + \frac{1}{3} x^2 J^2(x) - 2 x x_l^2 + 2\beta\sigma x [1+\eta(x)] + 2\sigma^2(\alpha^2+\beta^2) x - x\cos\theta \Big[\frac{1}{3}(1-x) J^2(x) + x[1+\eta(x)]^2 + 2x^2 + 2\beta\sigma[1+\eta(x)] - 2\sigma^2(\alpha^2-\beta^2) \Big] \Big\} \, dx \, d\cos\theta, \tag{8}$$

where

$$J(x) = \Big[1 - 2\frac{x_l^2 + x_L^2}{1-2x} + \eta^2(x) \Big]^{1/2},$$

$$\eta(x) = \frac{x_l^2 - x_L^2}{1-2x}, \quad x = \frac{E_1}{m_L}, \quad x_l = \frac{m_{\tilde{\nu}_l}}{m_L},$$

$$x_L = \frac{m_{\tilde{\nu}_L}}{m_L}, \quad \varepsilon = \Big(\frac{m_W}{m_{\tilde{w}}} \Big)^4, \quad \sigma = \frac{m_{\tilde{w}}}{m_L}.$$

The mass of the final charged particle is taken to be zero. Without σ terms Eq. (8) coincide with the one given in [3]. The σ terms with α, β are due to right-handed leptons in the decay process. Since the parameter σ may be quite large, the right-handed leptons may play a decisive role in the lepton SUSY decay. That can be seen more clearly in the zero mass limit of s-neutrinos. Then the spin-averaged distribution takes the form:

*** Other notations here and afterwards see [1, 3].

$$d\Gamma^0_{SUSY} = \frac{G^2 m_L^5}{4\pi^3} \varepsilon x^2 \left\{ 1 - \frac{2}{3} x + 2\sigma[\beta + \sigma(\alpha^2 + \beta^2)] \right\} dx. \tag{9}$$

From definitions of σ and ε, one can see that σ may be large enough to compensate for the suppressing influence of parameter ε. Therefore, the part with σ in (9) caused by right-handed leptons may be larger than that caused by ordinary (left-handed) leptons. Everything depends on comparative values of parameter ε and factors $\varepsilon\sigma\beta$, $\varepsilon\sigma^2\alpha^2$, $\varepsilon\sigma^2\beta^2$. Anyway, it is clear that all these factors must be quite small in the case of $L=\mu$ or τ in (3). Otherwise the deviations from the ordinary decay spectrum caused by the SUSY decay would contradict the experimental data. Since

$$\varepsilon\sigma = \left(\frac{m_w}{m_{\tilde{w}}}\right)^3 \frac{m_w}{m_L},$$

$$\varepsilon\sigma^2 = \left(\frac{m_w}{m_{\tilde{w}}}\right)^2 \left(\frac{m_w}{m_L}\right)^2,$$

parameters α and β must be very small, or the mass of the wino very large, in order to fulfill this requirement.

Let us illustrate the statement with an example.

Neglecting the effects of right-handed leptons in ordinary decay process, one may write out the Michel parameter characterizing the joint spectrum of ordinary and SUSY decays as

$$\varrho = \frac{3}{4} \left[1 + \frac{1}{2} \frac{\varepsilon(1+4\lambda)}{1 + \frac{3}{2}\varepsilon\left(1 + \frac{8}{3}\lambda\right)} \right] \tag{10}$$

with $\lambda = \sigma[\beta + \sigma(\alpha^2+\beta^2)]$.

In the case of $\lambda=0$, this expression coincides with the one given by Buchmüller and Scheck [2].

Let us now take $\alpha=\beta=0.01$. This value is much smaller than that allowed by experimental evidence. Taking into account this value, the expression (10) and experimental data [5] one can find that the lower limit of the wino mass must be somewhere in the region of 10^4 GeV in the case of μ-decay and in the region of some hundred GeV in the case of τ-decay. To stress the possible role of right-handed leptons in SUSY decays, let us point out that using Eq. (10) without λ-terms Buchmüller and Scheck have deduced the wino mass's lower limit $m_{\tilde{w}} > 4m_w$. Should the fourth generation of leptons exist in nature, the phase space of reaction (3) would permit the decay with *s*-neutrinos considerably more massive than those analyzed in [1–3]. If decay (3) is allowed, the considerations given above acquire some importance.

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REFERENCES

1. *Kane, G. L. and Rolnick, W. R.* Nucl. Phys. 1984, **B232**, 21—25.
2. *Buchmüller, W., Scheck, F.* Phys. Lett. 1984, **145B**, 421—424.
3. *Savage, M. J.* Phys. Rev. 1989, **D40**, 3116—3117.
4. *Krauss, L. M.* Phys. Rev. Lett. 1990, **64**, 999—1002.
5. *Fetscher, W.* Phys. Rev. 1990, **D42**, 1544—1567.

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