Collider Signatures of Sneutrino Cold Dark Matter

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Abstract

Decays of sneutrinos are considered in the case that in the presence of lepton-number violation in the sneutrino sector the lighter τ-sneutrino is the Lightest Supersymmetric Particle and the Cold Dark Matter in the Universe. In such circumstances the signals from sparticle decays differ considerably from the "standard" case where the lightest neutralino is the Lightest Supersymmetric Particle and it is found that in a wide range of parameters compatible with the sneutrino Cold Dark Matter hypothesis signatures characteristic for such a scenario should be easily observable at for example a Next Linear Collider.

Recently there has been particular interest in sneutrinos, the scalar counterparts of the neutrinos appearing in supersymmetric (SUSY) extensions of the Standard Model (SM) [1], due to the fact that Lepton-number (L) violation present in the sneutrino sector of the low-energy SUSY Lagrangian [2, 3] has huge impacts both on sneutrino and neutrino phenomenology. The intimate connection between sneutrino and neutrino properties implies that if the sneutrino bears "Majorana" properties so does the neutrino, and vice versa. Sheding light on the as yet unresolved questions concerning the neutrino mass [4] is an unexpected feature of the SUSY version of the SM once L violation by sneutrinos exists. Further potentially observable consequences include L-violating processes such as neutrinoless double beta $0\nu\beta\beta$-decay (without the need of R-parity violation) [5], $e^- e^- \rightarrow \chi^- \chi^-$ and sneutrino oscillations [6, 3].

Particularly interesting is the impact of neutrino/sneutrino properties on Cosmology and the still unresolved questions of nature and origin of the dark matter in the universe. Whereas massive neutrinos are long known to be an interesting candidate for the hot component of dark matter in the universe, it emerged only recently that in the presence of L violation sneutrinos may well serve as cold component of dark matter [7]. The big experimental efforts (for a recent overview see

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e.g. [8]) that are being made to observe e.g. neutrino oscillations (LSND, GNO, Super Kamiokande etc.), $0\nu\beta\beta$-decay (Heidelberg-Moscow, Nemo, GENIUS among others), to establish SUSY (e.g. at the LHC, Next Linear Collider), to observe CDM (HDMS, CDMS, GENIUS among others) etc. will hopefully provide interesting insight into these questions soon.

One of the benefits of SUSY extensions of the SM is that under certain circumstances the LSP is stable and provides a candidate for the Cold Dark Matter in the Universe (CDM). This possibility has been ruled out for L-conserving sneutrinos: sneutrinos with masses of order $100GeV$ annihilate rapidly via s-channel Z^0-exchange so that no cosmologically interesting relic abundance is obtained. To reduce the annihilation rate it was proposed that sneutrinos should be either very light ($2GeV$ [9]) or very heavy (of order $1TeV$ [10]). The first case is excluded from Z^0-width measurements, the second case is excluded from direct nuclear recoil experiments like the Heidelberg-Moscow setup ([10] and ref. therein).

The situation changes if L is not conserved in the sneutrino sector. L violation for the $SU(2)_L$-doublet sneutrinos has been introduced in a model-independent way in [2] by means of an effective L-violating mass term $m_M^2 \tilde{\nu}_L \tilde{\nu}_L + h.c.$ which may be present below the electroweak symmetry breaking scale. In [3] L is violated by $SU(2)_L$-singlet sneutrinos which, below the electroweak symmetry breaking scale, mix with the $SU(2)_L$-doublet sneutrinos. The result of both approaches is that the light sneutrino states $\tilde{\nu}_i^{l,h}$ ("l" light, "h" heavy, i generation index) are no longer the interaction eigenstates, violate L and exhibit a mass difference.

L violation reopens the possibility that the CDM is made up of sneutrinos [7]: if the mass splitting of two sneutrino states (of the same generation) is bigger than about $5GeV$ the sneutrino may be a viable CDM candidate due to the fact that the coupling to the Z^0 is off-diagonal, i.e. $Z^0 \tilde{\nu}_i^l \tilde{\nu}_i^h$ for any generation i. This is a consequence of angular momentum conservation and Bose symmetry, thus suppressing both the annihilation of sneutrinos in the early universe and the elastic sneutrino scattering rates in counting experiments. Furthermore, sneutrino pair annihilation into gauge bosons and neutrinos has to be suppressed resulting in the additional conditions $m_{\tilde{\nu}LSP} < m_W$, $M_1 > 200GeV$ where M_1 is the mass of the $U(1)_Y$ gaugino.

Bounds on the sneutrino mass-splitting can be derived from the upper limits on neutrino masses, on $0\nu\beta\beta$-decay and from the Baryon Asymmetry in the Universe (BAU). The constraints from the neutrino mass [2, 3] allow the sneutrino mass-splitting being large enough for the third generation so that the lighter τ-sneutrino may be the CDM. On the other hand, the requirement that the BAU should not be erased by sneutrino-induced L-violating scatterings after the electroweak phase transition does not allow for sneutrino CDM [11].

However, this bound holds only in the case when sphaleron-mediated processes

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$$\tilde{\nu}_1^1 \quad 1,\bar{1} \qquad \tilde{\nu}_2^{1'} \quad \tilde{\nu}_1 \quad \bar{\nu},\nu \qquad \tilde{\nu}_2$$

$$\chi^{\pm} \qquad \bar{1},1 \qquad \chi^0 \qquad \bar{\nu},\nu$$

$$\tilde{\nu}_2$$

$$\tilde{\nu}_1 \qquad f$$
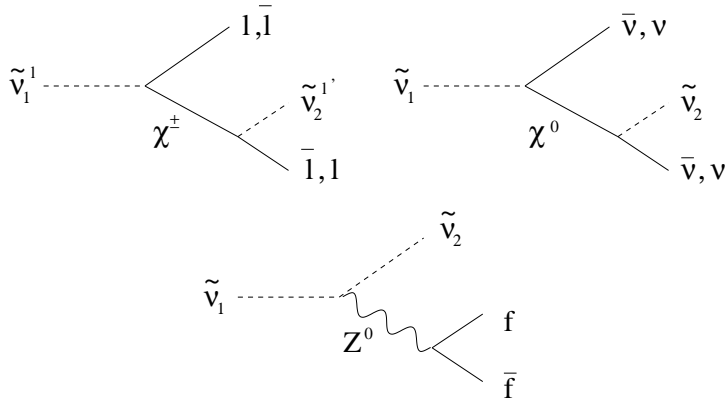
$$Z^0 \qquad \bar{f}$$

Figure 1: Three-body sneutrino decays into fermions and LSP-sneutrino.

are in equilibrium immediately after the electroweak phase transition. If *e.g.* the BAU is generated during the electroweak phase transition the lighter τ-sneutrino may be the CDM.

If the conditions mentioned before are not fulfilled the sneutrino abundance alone cannot account for the CDM in the universe, but still the lightest sneutrino could be the LSP. This is not true in the very special case of the mSUGRA model. Though there are ranges in the $M_1, \mu, \tan\beta, m_0, A_0$ parameter space where the sneutrino could be the LSP, the right-handed charged sleptons get too light to be compatible with the bounds on their masses [12].

The possibility of one sneutrino state being the LSP and in the case of conserved R-parity being a CDM candidate may have particularly interesting consequences for the sneutrino decay signatures to be expected at colliders. Usually the lightest neutralino is assumed to be the LSP and, if R-parity is conserved, *e.g.* the prevailing signature of a slepton pair produced at a Next Linear Collider (NLC) (see *e.g.* [14] and ref. therein) is simply an acoplanar lepton pair and missing momentum from the neutralino LSP. The situation is different for sneutrino LSP since the decay chains of the sparticles often contain heavy sneutrino states whose decays into the LSP sneutrino produce characteristic final states, see below. Therefore in case the lightest sneutrino being the LSP the expected SUSY signals differ considerably from the case the neutralino being the LSP.

In what follows we will assume that the lighter τ-sneutrino is the LSP with the sneutrinos of the first two generations being almost degenerate in mass, and that there is a substantial mass splitting (of order $10 GeV$) in the τ-sector since this possibility is the cosmologically interesting one. The characteristic feature of such a scenario should be that the decay chains of decaying sparticles contain copiously $\tau\tau$-pairs, $l\tau$-pairs ($l = e, \mu$) and jets since such pairs are produced by the decays of

sneutrinos not being the LSP into the LSP-sneutrino.

On the other hand, if the lightest neutralino is the LSP τ-pairs and jets are produced by transitions from non-LSP neutralinos into LSP-neutralinos. However, the generation off-diagonal signature could be reproduced by such decays only if generation mixing in the neutralino-slepton-lepton vertex is sizeable. If a mixing matrix is introduced into the neutralino-slepton-lepton vertex the current bounds on the branching ratio BR of transitions $\tau \to l\gamma$ ($l=e, \mu$), $BR < \mathcal{O}(10^{-6})$ [12], set limits on its entries. Applying mass insertion on the external τ-line the relevant expression can be found in [13]. A rough estimate on the generation mixing may be obtained if one assumes that there are no cancelations between contributions from different neutralino and slepton mass-states entering the amplitude. For a common SUSY particle mass of $100 GeV$ and for a bino-dominated neutralino an upper bound on the mixing matrix elements connecting the third with the first and second generations $|U_{l\tau}|^2 < \mathcal{O}(10^{-2})$ can be deduced. The limit depends on the ratio $r = m_{\tilde{\chi}^0}^2/m_{\tilde{l}}^2$ and becomes slightly more restrictive for smaller values of r. In the limit where r becomes very large no constraint is obtained, but since it is assumed that one neutralino is the LSP this case is not of interest. Therefore it seems unlikely that generation off-diagonal lepton pairs are produced copiously by decaying heavy neutralinos. An additional possibility to distinguish between the two cases is provided by the different angular distributions of off-diagonal lepton pairs originating from decaying sneutrinos and neutralinos.

In the following the partial decay widths of sneutrinos are calculated for the first time under the assumption that there are no two-body decay channels kinematically accessible (*i.e.* the gauginos are heavier than all six sneutrino states). In the opposite case the final decay products are the same but the total decay width should be much bigger.

The parameters are chosen in accordance with the results of [7] in order to assure the viability of sneutrino CDM. Furthermore, it is assumed that the e- and μ-sneutrinos have masses between the values of the heavy and light τ-sneutrinos, if they are heavier additional decay channels into the heavier τ-sneutrino are present.

All sneutrinos but the LSP decay via neutralino, chargino and Z^0 three-body decays into the lighter τ-sneutrino plus fermions (note that there is no Higgs-mediated channel since the Higgs couples only either to two light or two heavy sneutrinos). These decay modes are depicted in figure 1. The decay width of the decay $\tilde{\nu}_m \to \tilde{\nu}_n + two\ fermions$ is

$$\Gamma_{\text{tot}} = \frac{1}{2m_m} \frac{1}{(2\pi)^5} \frac{\pi^2}{4m_m^2} g^4 (\Gamma'_{\tilde{\chi}^0} + \Gamma'_{\tilde{\chi}^+} + \Gamma'_{Z^0} + \Gamma'_{\tilde{\chi}^0 Z^0} + \Gamma'_{\tilde{\chi}^+ Z^0}) \,. \tag{1}$$

Note that there is no interference between chargino and neutralino contributions for any final state. The widths of the intermediate states have been neglected, propagator factors $1/(M^2 - X)$ are denoted as $P(M, X)$ and c_W is shorthand for $\cos \Theta_W$

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Leptonic:	$\tilde{\nu}_\tau^h$	$\rightarrow$	$\tau^\pm \tau^\mp \not{E}$		$\chi^\pm, Z^0$
	$\tilde{\nu}_\tau^h$	$\rightarrow$	$l^\pm l^\mp \not{E}$ $(l = e, \mu)$		Z^0
	$\tilde{\nu}_\tau^h$	$\rightarrow$	$\tau^\pm \tau^\pm l^\pm l^\pm \not{E}$ $(l = e, \mu)$		$\chi^\pm$
	$\tilde{\nu}_l$	$\rightarrow$	$\tau^\pm l^\mp \not{E}$ $(l = e, \mu)$		$\chi^\pm$
Hadronic:	$\tilde{\nu}_\tau^h$	$\rightarrow$	$q\bar{q} \not{E}$		Z^0

Table 1: Visible sneutrino decay channels into the LSP-sneutrino $\tilde{\nu}_\tau^l$ by exchange of $\chi^\pm$ and Z^0.

etc. The conventions for the gaugino mixing matrices follow [1]. The contribution of the Z^0-channel is

$$
\Gamma'_{Z^0} = \frac{2}{c_W^2} \int ds_2 |P(m_{Z^0}, s_2)|^2 B_{Z^0} \left((|O_L^f|^2 + |O_R^f|^2)\, F + \mathrm{Re}[O_L^f O_R^{f*}]\, G \right) \tag{2}
$$

$$
F = -\frac{1}{3}(3A_{Z^0}^2 + B_{Z^0}^2) + A_{Z^0}(m_m^2 + m_n^2 + 2m_f^2 - s_2) - m_f^2 \frac{(\Delta\tilde{m})^4}{m_{Z^0}^2}
$$
$$
+ \; (m_m^2 + m_f^2 - \frac{1}{2}s_2)(\frac{1}{2}s_2 - m_f^2 - m_n^2) - \frac{1}{4}(s_2 - m_f^2)(2m_m^2 + 2m_n^2 - s_2)
$$
$$
G = m_f^2 (2\frac{(\Delta\tilde{m})^4}{m_{Z^0}^2} - 2m_m^2 - 2m_n^2 + s_2)
$$

Here we have defined

$$
A_{Z^0} = m_f^2 + \frac{1}{2}(m_m^2 + m_n^2 - s_2); \quad B_{Z^0} = \frac{1}{2s_2}\lambda^{1/2}(s_2, m_m^2, m_n^2)\sqrt{s_2^2 - 4m_m^2 m_f^2}
$$

$$
(\Delta\tilde{m})^2 = m_m^2 - m_n^2; \quad O_f^L = T_{3f} - e_f s_W^2; \quad O_f^R = -e_f s_W^2
$$

and the integration range is $(s_2)_{min,max} = 4m_f^2, (m_m - m_n)^2$.

The contribution of the chargino-mediated channel is

$$
\Gamma'_{\tilde{\chi}^+} = \sum_{j,j'} |V_{j1}|^2 |V_{j'1}|^2
$$
$$
\times \; \int ds_2 P(m_j, s_2)[P(m_{j'}, s_2) 4 B_{f\bar{f}'}(s_2 - m_n^2 + m_f^2)(m_m^2 - s_2 - m_{\bar{f}'}^2)
$$
$$
- \; 2B_{f\bar{f}'} s_2 + (m_f^2 m_{\bar{f}'}^2 - m_m^2 m_n^2 + m_{j'}^2 s_2) \ln \frac{A_{f\bar{f}'} + B_{f\bar{f}'} + m_{j'}^2 - X}{A_{f\bar{f}'} - B_{f\bar{f}'} + m_{j'}^2 - X}]
$$
$$
+ \; (m_f \longleftrightarrow m_{\bar{f}'}) \tag{3}
$$

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Here we have defined

$$
\begin{aligned}
A_{f\bar{f}'} &= m_f^2 + m_{\bar{f}'}^2 - \frac{1}{2s_2}(s_2 + m_f^2 - m_n^2)(s_2 - m_m^2 + m_{\bar{f}'}^2) \\
B_{f\bar{f}'} &= \frac{1}{2s_2}\lambda^{1/2}(s_2, m_f^2, m_n^2)\lambda^{1/2}(s_2, m_{\bar{f}'}^2, m_m^2) \\
X &= m_m^2 + m_f^2 + m_{\bar{f}'}^2 + m_n^2 - s_2
\end{aligned}
\tag{4}
$$

The integration range is $(s_2)_{min,max} = (m_f + m_n)^2, (m_m - m_{\bar{f}'})^2$. Here and in the following λ is defined as usual as $\lambda(a, b, c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc$ and V is the chargino mixing matrix.

The contribution of neutralino-mediated decays into the final states $\nu\nu$, $\bar{\nu}\nu$, $\overline{\nu\nu}$ is

$$
\begin{aligned}
\Gamma'_{\tilde{\chi}^0} &= \Gamma'^{\nu\nu}_{\tilde{\chi}^0} + \Gamma'^{\bar{\nu}\,\bar{\nu}}_{\tilde{\chi}^0} + \Gamma'^{\bar{\nu}\nu}_{\tilde{\chi}^0} \tag{5} \\
\Gamma'^{\nu\nu}_{\tilde{\chi}^0} &= \frac{4}{2!}\sum_{i,j}(O_i^2 O_j^{*2} + O_i^{*2} O_j^2)\int \frac{ds_2}{(m_i^2 - s_2)(m_j^2 - s_2)}\frac{1}{2s_2}(m_m^2 - s_2)^2(s_2 - m_n^2)^2 \\
&= \Gamma'^{\bar{\nu}\,\bar{\nu}}_{\tilde{\chi}^0} \\
\Gamma'^{\bar{\nu}\nu}_{\tilde{\chi}^0} &= 8\sum_{i,j}|O_i|^2|O_j|^2\int ds_2 P(m_i, s_2)[\frac{1}{2s_2}P(m_j, s_2)(m_m^2 - s_2)^2(s_2 - m_n^2)^2 \\
&+ (m_n^2 - s_2)(m_m^2 - s_2) + (m_m^2 m_n^2 - m_j^2 s_2)\ln\frac{s_2 + m_j^2 - m_m^2 - m_n^2}{m_j^2 - m_m^2 m_n^2/s_2}]
\end{aligned}
$$

The integration limits are $(s_2)_{min,max} = m_n^2, m_m^2$ and we have defined (N is the neutralino mixing matrix) $O_i = \frac{1}{2}(N_{i1} - t_W N_{i2})$.

The interference between chargino- and Z^0-contributions is

$$
\begin{aligned}
\Gamma'_{\tilde{\chi}^+ Z^0} &= \frac{8}{c_W^2}\sum_j |V_{j1}|^2 \int ds_2 P(m_j, s_2)[O_L^f 2s_2 B_{ff} F + O_R^f \frac{m_f^2}{2}G] \tag{6} \\
F &= [s_2 m_Z^2 - s_2(m_m^2 - s_2) - \frac{m_n^2}{2}(m_f^2 - 2m_m^2 + 2s_2) - \frac{m_f^2}{2}(m_m^2 + 2s_2) \\
&+ \frac{1}{2}\frac{(\Delta\tilde{m})^2}{m_Z^2}m_f^2(m_m^2 - m_n^2)]\ln\frac{A_{ff} + B_{ff} - m_Z^2}{A_{ff} - B_{ff} - m_Z^2} \\
G &= \frac{1}{2}m_f^2[2s_2 - 2m_f^2 + m_m^2 + m_n^2 - \frac{(\Delta\tilde{m})^2}{m_Z^2}(m_m^2 - m_n^2)]\ln\frac{A_{ff} + B_{ff} - m_Z^2}{A_{ff} - B_{ff} - m_Z^2}.
\end{aligned}
$$

This term is only relevant for the transition $\tilde{\nu}_1^\tau \to \tilde{\nu}_2^\tau \tau\bar{\tau}$. The integration limits are $(s_2)_{min,max} = (m_f + m_n)^2, (m_m - m_f)^2$ and the functions A_{ff}, B_{ff} have been defined in (4).

	Γ_{χ^-}		Γ_{χ^0}	m_{χ^0}		Γ_{χ^0}	m_{χ^0}	
$M_2 = 400$	-		-	77.1		-	69.9	Ia
	0.133		1.217	86.9		23.20	82.5	Ib
	0.032		0.248	97.6		2.165	96.6	IIa
	0.114	A	0.943	88.2	B	14.29	84.1	IIb
$M_2 = 800$	0.009		0.094	89.5		1.036	86.5	Ia
	0.006		0.041	94.0		0.348	92.3	Ib
	0.003		0.021	98.9		0.152	98.5	IIa
	0.006		0.038	94.6		0.311	93.0	IIb
$M_2 = -400$	0.032		3.480	95.1		-	74.5	Ia
	0.114		2.354	93.5		185.2	82.1	Ib
	0.540		1.418	87.7		19.30	89.8	IIb
	0.133	C	2.227	92.8	D	126.1	83.4	IIb
$M_2 = -600$	0.008		0.411	99.2		10.09	89.3	Ia
	0.020		0.331	96.4		49.52	93.4	Ib
	0.039		0.250	93.1		2.334	94.9	IIa
	0.022		0.321	96.0		4.522	94.0	IIb

Table 2: Partial decay widths in eV for the transitions $\tilde{\nu}_{e,\mu} \to \tilde{\nu}_\tau^{LSP}$ when two-body transitions are kinematically excluded. The mass splitting of the τ-sneutrinos is taken to be $10 GeV$, the mass of $\tilde{\nu}_\tau^{LSP}$ is $70 GeV$, the masses of the e- and μ-sneutrinos are $75 GeV$ and their mass-splitting has been neglected. The different ratios are $M_1 = M_2$ (A), $M_1 = (5\alpha_Y/3\alpha_W)M_2$ (B), $M_1 = -(5\alpha_Y/3\alpha_W)M_2$ (C) and $M_1 = -(\alpha_Y/\alpha_W)M_2$ (D). "I" ("II") stands for μ=100 (-100) GeV, "a" ("b") stands for $\tan\beta$=2 (40). M_2 is given in GeV. The parameters and in particular the ratios M_1/M_2 have been chosen in accordance with [7]: for these parameters $\tilde{\nu}_\tau^{LSP}$ has a relic abundance sufficient to account for the CDM. Γ_{χ^-} (Γ_{χ^0}) denotes the chargino- (neutralino-) mediated channel. If the e- and μ-sneutrinos are heavier than $\tilde{\nu}_\tau^h$ an additional decay channel of the former into the latter is open. The cases where the lightest neutralino is lighter than the decaying sneutrinos have been omitted.

Finally, the interference between neutralino and Z^0 contributions:

$$\Gamma'_{\tilde{\chi}^0 Z^0} = \frac{8}{c_W^2} \sum_i |O_i|^2 O_\nu^L \int ds_2 P(m_i, s_2)[(m_m^2 - s_2)(s_2 - m_n^2) \tag{7}$$

$$+ \ (s_2 m_{Z^0}^2 - m_n^2(s_2 - m_m^2) + s_2(s_2 - m_m^2))\ln(1 - \frac{(s_2 - m_m^2)(s_2 - m_n^2)}{m_{Z^0}^2 s_2})]$$

The integration limits are $(s_2)_{min,max} = m_n^2, m_m^2$ and this term is relevant only for the $\nu\bar{\nu}$ final state.

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	$\Gamma_{e\tau}$	$\Gamma_{\tau\tau}$		Γ_{tot}		Γ_{tot}	
$M_2 = 400$	-	-		-		-	Ia
	0.195	0.956		47.261		84.052	Ib
	0.037	0.166		42.748		48.603	IIa
	0.160	0.613	A	46.043	B	70.691	IIb
$M_2 = 800$	0.013	0.777		42.379		46.191	Ia
	0.009	0.955		42.083		43.952	Ib
	0.003	1.359		42.213		43.341	IIa
	0.008	9.931		42.0797		43.819	IIb
$M_2 = -400$	0.374	0.166		51.508		-	Ia
	0.160	0.613		49.738		280.64	Ib
	1.917	18.315		68.619		99.441	IIa
	0.195	0.956	C	49.853	D	212.69	IIb
$M_2 = -600$	0.009	0.895		44.163		64.086	Ia
	0.027	0.362		43.317		56.409	Ib
	0.068	0.078		42.728		48.970	IIa
	0.030	0.309		43.225		53.735	IIb

Table 3: Partial decay widths $\Gamma_{e\tau,\tau\tau}$ into final states containing τ's in eV for the transitions $\tilde{\nu}_\tau^h \to \tilde{\nu}_\tau^{LSP}$ for the parameters defined in table 2. $\Gamma_{e\tau}$ denotes the (chargino-mediated) width into a $e^\pm\tau^\mp$-pair ($\Gamma_{\mu\tau} \approx \Gamma_{e\tau}$), $\Gamma_{\tau\tau}$ is the (chargino- and Z^0-mediated) width containing $\tau^\pm\tau^\mp$-pairs in the final state and Γ_{tot} is the total width (when two-body transitions are kinematically excluded). The contribution of the Z^0-channel is constant and in particular the width into the remaining visible hadronic and fermionic states is $\Gamma_{other} = 21.850eV$. The total visible width is $\Gamma_{other} + \Gamma_{\tau\tau} + \Gamma_{e\tau} + \Gamma_{\mu\tau} \approx 22eV - 23eV$.

Provided the escaping fermions being not too soft to be detected the expected signatures are listed in table 1. The visible channels consist of one or more lepton pairs or jets and missing momentum. Each decaying sneutrino possesses individual characteristics. The transitions $\tilde{\nu}_{e,\mu}$ are background-free on tree-level, whereas the transition $\tilde{\nu}_\tau^h \to \tilde{\nu}_\tau^{LSP}\tau^\pm\tau^\mp + \not{E}$ is simulated by the decay of a heavier into a lighter neutralino which subsequently decays into $\tilde{\nu}_\tau^{LSP}\nu$. However, in this case the leptons possess another angular distribution. Hence, for $\tilde{\nu}_\tau^2$ being the LSP initially produced sneutrinos result in a signal which allows for each visible event to track the flavour of the decaying sneutrino, deduce its mass using missing momentum and therefore pin down their properties e.g. in $e^+e^- \to \tilde{\nu}_l^1\tilde{\nu}_l^2$. For the example parameters used in tables 2,3 in the case of decaying heavy τ-sneutrinos the branching ratio of the visible decay channels is about 50%, the rest being invisible neutrino final states from neutralino- and Z^0-exchange. The contribution of the Z^0-channel is constant

and in particular the width into the remaining visible hadronic and fermionic states is $\Gamma_{other} = 21.850eV$. The total visible width is ($\Gamma_{e\tau} \approx \Gamma_{\mu\tau}$)

$$\Gamma_{other} + \Gamma_{\tau\tau} + \cdot\Gamma_{e\tau} + \Gamma_{\mu\tau} \approx 22eV - 23eV .$$

Due to destructive interference of the chargino- and Z^0-mediated channels for the parameters chosen the $\tau\tau$-final state typically makes up only a few percent of the visible channels. An exception is the case C/D, $M_2 = -400$, IIa. The $l\tau$-channel accounts roughly for 0.1% to 1% of the visible events. About 10% of the $\tilde{\nu}^l$ decay themselves into the visible state (see table 2). Hence, for the projected NLC-luminosity of 50 $(fb \cdot y)^{-1}$ [14] and a sneutrino pair production cross-section of $\mathcal{O}(100fb)$ (for $m_{\tilde{\nu}} \sim \mathcal{O}(100GeV)$) at most a few events containing a single-sided two-acoplanar $l^\pm\tau^\mp$-pair is expected per year.

The situation is different for the decays of e- and μ-sneutrinos. The Z^0-channel does not contribute (in the absence of mixing in generation space) and $\Gamma_{vis}=\Gamma_{l\tau}$. For most of the parameters relevant for sneutrino CDM the visible partial decay width is of order 10% so that for the integrated luminositity 50 $(fb \cdot y)^{-1}$ and a sneutrino pair production cross-section of $\mathcal{O}(100fb)$ (for $m_{\tilde{\nu}} \sim \mathcal{O}(100GeV)$) several hundred visible sneutrino decay events containing a $\tau^\pm l^\mp$-pair are expected. Such a signal would be a clear hint for $\tilde{\nu}_\tau^{LSP}$. On the other hand, in the case $M_1 = M_2/2$ for high M_2 the visible width is negligible: $\Gamma_{vis} \approx 10^{-10}eV$, $\Gamma_{\chi^0} \approx 10^{-2}eV$.

In conclusion, the LSP being a sneutrino changes the signals expected for the decays of sparticles considerably in comparison with the case of a neutralino LSP. For the cosmologically interesting case of sneutrino CDM sneutrinos have to violate L and only the lighter τ-sneutrino can account for the CDM. In this case final sparticle-decay states are expected to frequently contain generation-diagonal fermion-pairs (which are present for a neutralino LSP as well) and in particular $\tau^\pm l^\mp$-pairs ($l=e$, μ) which would provide a clear signal for sneutrino-LSP. The latter ones are not present for a neutralino LSP. In the case that all sneutrino states are lighter than the neutralinos in most of the range of interest for sneutrino CDM the partial decay widths into the visible final states are of order 10% of the total decay width for decaying $\tilde{\nu}^{e,\mu}$ and 50% for decaying $\tilde{\nu}_\tau^h$ of the total decay width producing hundreds of events at *e.g.* the NLC. It therefore should be possible to settle the question of the sneutrino being CDM at such a facility.

Acknowledgements

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