Signals at LHC and dark matter in a supersymmetric left-right model

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Outline:

Motivation

Supersymmetric left-right model (SUSYLR)

Dark matter in SUSYLR

Signals of SUSYLR DM at LHC

Summary

M. Frank, B. Fuks, KH, S.K. Rai, H. Waltari, arXiv:1702.02112
M. Frank, D. Ghosh, KH, S.K. Rai, I. Saha, H. Waltari, PRD 90 (2014) 115021, arXiv:1408.2423

Motivation

Dark matter remains well established but completely unknown.

Supersymmetric models have many candidates (neutralino, sneutrino, gravitino, axino). In some models constraints are strong.

In addition to the lightest *neutralino*, a *right-handed sneutrino* is a good possibility.

Note: left-handed sneutrino is excluded as DM:
due to the coupling to Z it annihilates too much in the early universe

Add right-handed neutrino superfields
→ generate neutrino masses

In **MSSM** or **NMSSM** singlet right-handed neutrino superfields can be added;
Right sneutrinos always present in left-right supersymmetric (**SUSYLR**) models: right-handed fermions are in doublets similarly than the left-handed fermions

Since the right-handed neutrino belongs to the same doublet than the right-handed charged lepton, always three right sneutrinos

Based on $SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L} \rightarrow SU(3)_c \times SU(2)_L \times U(1)_Y$

Many problems of MSSM can be solved in SUSYLR :
neutrinos massive, spontaneous parity violation, no explicit R-parity violation, strong CP-violation ok, SUSY CP phases ok, …

Mohapatra, Senjanovic PRL (1980);Kuchimanchi, Mohapatra PRD 48 (1993); Martin PRD 46 (1992); KH, Maalampi PLB (1995); Mohapatra, Rasin, PRL (1996), PRD (1996); Babu, Mohapatra PLB 668 (2008); Frank, Korutlu PRD 83 (2011); …

SUSYLR: $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$

-Gauge symmetry could originate from SO(10) or E_6 unified model

-B-L as gauge symmetry ➡ Lagrangian conserves $R_{parity}=(-1)^{3(B-L)+2s}$

New gauge bosons: W_R, W_L, Z', Z, γ

Matter:

$$(Q_L)^i = \begin{pmatrix} u_L^i \\ d_L^i \end{pmatrix} = (\mathbf{3}, \mathbf{2}, 1, \frac{1}{3}) , \qquad (Q_R)^i = \begin{pmatrix} d_R^i \\ -u_R^i \end{pmatrix} = (\bar{\mathbf{3}}, 1, \mathbf{2}^*, -\frac{1}{3})$$

$$(L_L)^i = \begin{pmatrix} \nu_L^i \\ \ell_L^i \end{pmatrix} = (1, \mathbf{2}, 1, -1) , \qquad (L_R)^i = \begin{pmatrix} \ell_R^i \\ -\nu_R^i \end{pmatrix} = (1, 1, \mathbf{2}^*, 1) ,$$

$$Q = I_{3L} + I_{3R} + \frac{B-L}{2}$$

Two step breaking $SU(2)_R \times U(1)_{B-L} \xrightarrow{M_R} U(1)_Y$, $SU(2)_L \times U(1)_Y \xrightarrow{M_W} U(1)_{em}$

Choose symmetry breaking scalars in such a way that R-parity conserving vacuum is the minimum

→ LSP is a dark matter candidate

$$\Phi_1 = \begin{pmatrix} \phi_1^+ & \phi_1^{0\prime} \\ \phi_1^0 & \phi_1^- \end{pmatrix} = (1, \mathbf{2}, \mathbf{2}^*, 0) , \qquad \Phi_2 = \begin{pmatrix} \varphi_2^+ & \varphi_2^0 \\ \varphi_2^{0\prime} & \varphi_2^- \end{pmatrix} = (1, \mathbf{2}, \mathbf{2}^*, 0) ,$$

$$\Delta_{1L} = \begin{pmatrix} \frac{\delta_{1L}^-}{\sqrt{2}} & \delta_{1L}^0 \\ \delta_{1L}^{--} & -\frac{\delta_{1L}^-}{\sqrt{2}} \end{pmatrix} = (1, \mathbf{3}, 1, -2) , \qquad \Delta_{2L} = \begin{pmatrix} \frac{\delta_{2L}^+}{\sqrt{2}} & \delta_{2L}^{++} \\ \delta_{2L}^0 & -\frac{\delta_{2L}^+}{\sqrt{2}} \end{pmatrix} = (1, \mathbf{3}, 1, 2) ,$$

$$\Delta_{1R} = \begin{pmatrix} \frac{\delta_{1R}^-}{\sqrt{2}} & \delta_{1R}^0 \\ \delta_{1R}^{--} & -\frac{\delta_{1R}^-}{\sqrt{2}} \end{pmatrix} = (1, 1, \mathbf{3}, -2) , \qquad \Delta_{2R} = \begin{pmatrix} \frac{\delta_{2R}^+}{\sqrt{2}} & \delta_{2R}^{++} \\ \delta_{2R}^0 & -\frac{\delta_{2R}^+}{\sqrt{2}} \end{pmatrix} = (1, 1, \mathbf{3}, 2)$$

$$S = (1, 1, 1, 0) .$$

Superpotential:

$$W = (Q_L)^T Y_Q^1 \Phi_1 (Q_R) + (Q_L)^T Y_Q^2 \Phi_2 (Q_R) + (L_L)^T Y_L^1 \Phi_1 (L_R) + (L_L)^T Y_L^2 \Phi_2 (L_R)$$
$$+ (L_L)^T Y_L^3 \Delta_{2L} (L_L) + (L_R)^T Y_L^4 \Delta_{1R} (L_R) + S[\lambda_L \mathrm{Tr}(\Delta_{1L} \cdot \Delta_{2L}) + \lambda_R \mathrm{Tr}(\Delta_{1R} \cdot \Delta_{2R})$$
$$+ \lambda_3 \mathrm{Tr}(\Phi_1^T \tau_2 \Phi_2 \tau_2) + \lambda_4 \mathrm{Tr}(\Phi_1^T \tau_2 \Phi_1 \tau_2) + \lambda_5 \mathrm{Tr}(\Phi_2^T \tau_2 \Phi_2 \tau_2) + \lambda_S S^2 + \xi_F] \ ,$$

An extra R-symmetry:

charges for [S]=+2, [L_L, L_R, Q_L, Q_R]=+1, and charge for all other particles=0

→ no bilinear supersymmetric Higgs mass terms

Neutrino masses can arise via seesaw with Y=2 triplets.

A charge and R-parity conserving vacuum, with Δ_{1L}, Δ_{2L} inert, is

$$\langle S\rangle = \frac{v_S}{\sqrt{2}}e^{i\alpha_S} \ , \quad \langle \Phi_1\rangle = \begin{pmatrix} 0 & \frac{v_1'}{\sqrt{2}}e^{i\alpha_1} \\ \frac{v_1}{\sqrt{2}} & 0 \end{pmatrix} \ , \quad \langle \Phi_2\rangle = \begin{pmatrix} 0 & \frac{v_2}{\sqrt{2}} \\ \frac{v_2'}{\sqrt{2}}e^{i\alpha_2} & 0 \end{pmatrix}$$

$$\langle \Delta_{1R}\rangle = \begin{pmatrix} 0 & \frac{v_{1R}}{\sqrt{2}} \\ 0 & 0 \end{pmatrix}, \quad \langle \Delta_{2R}\rangle = \begin{pmatrix} 0 & 0 \\ \frac{v_{2R}}{\sqrt{2}} & 0 \end{pmatrix} \ ,$$

Choose inert left triplet Higgses, since

1) For electroweak ρ-parameter at tree level

$$\rho \equiv \frac{m_W^2}{m_Z^2 \cos^2\theta_W}$$

Experimentally $\rho = 1.0004^{+0.0003}_{-0.0004}$

→ $<\Delta_{1L}>, <\Delta_{2L}>$ small

2) If not inert, the doubly charged mass should result from radiative corrections. Difficult with 1)

$K^0 - \bar{K}^0$ mixing constrains $W_L - W_R$ mixing which is proportional to $v_i v'_i e^{i\alpha}$

→ $v_S, v_{1R}, v_{2R} \gg v_2, v_1 \gg v'_1 = v'_2 \approx 0$, choose also $\alpha_1 = \alpha_2 = \alpha_S \approx 0$

Experimentally right-handed gauge bosons are heavy:
ATLAS and CMS: $m_{WR} > 2.7$ TeV

In LRSUSY could have new decay modes alleviating the bounds; in our benchmarks new branching ratios ~10-15%, SM BR~65-70%

We will choose two benchmarks with
m_{WR}=2.7 TeV (v_R=5.7 TeV, m_{ZR}=4.5 TeV) and other two with
m_{WR}=3.5 TeV (v_R=7.5 TeV, m_{ZR}=5.9 TeV)

At the tree-level the true vacuum is not the previous charge conserving one!

The charge conserving minimum is preferred to charge violating minimum after 1-loop corrections

Babu, Mohapatra PLB 668 (2008) 404

Need to consider

$$V_{\rm eff}^{1-{\rm loop}} = \frac{1}{64\pi^2}\sum_i (-1)^{2s}(2s+1)M_i^4\left[{\rm Log}(\frac{M_i^2}{\mu^2}) - \frac{3}{2}\right]$$

Constraints from the Higgs sector

When triplet VEV exists, $m_{H++}^2 < 0$ at tree-level

Need radiative corrections to find *doubly-charged Higgs* mass

→ lepton-slepton Babu, Mohapatra PLB 668 (2008) 404
gauge and Higgs sector corrections
Basso, Fuks,Krauss, Porod, JHEP 1507(2015)147

→ Decays $H^{++/--}$ to leptons nonnegligible;
least constraining bounds for ditaus
→ Fix benchmarks where decay to e/μ is < 10%
(nonzero couplings because of neutrino masses)

Experimental limits for $H^{++/--}$ with 12.9 fb^{-1} at $\sqrt{s}$=13 TeV :

CMS PAS HIG-16-036

*Search in: $pp \rightarrow Z^0/\gamma \rightarrow H_L^{++}H_L^{--} \rightarrow \tau^+\tau^+\tau^-\tau^-$ → m_{HL++}> 396 GeV

*Here only $H_R^{++/--}$ production → suppressed Z^0 mediation
→ smaller cross section and lower bound

For *singly charged Higgs*, constraints for mass from $b \to s\gamma$,
if no cancellations.
For the chosen parameters, all the MSSM-like Higgses heavy.

Extra contributions to the *lightest Higgs boson* mass:
at tree-level

$$m_h^2 \leq \left(1 + \frac{g_R^2}{g_L^2}\right) m_{W_L}^2 \cos^2 2\beta,$$

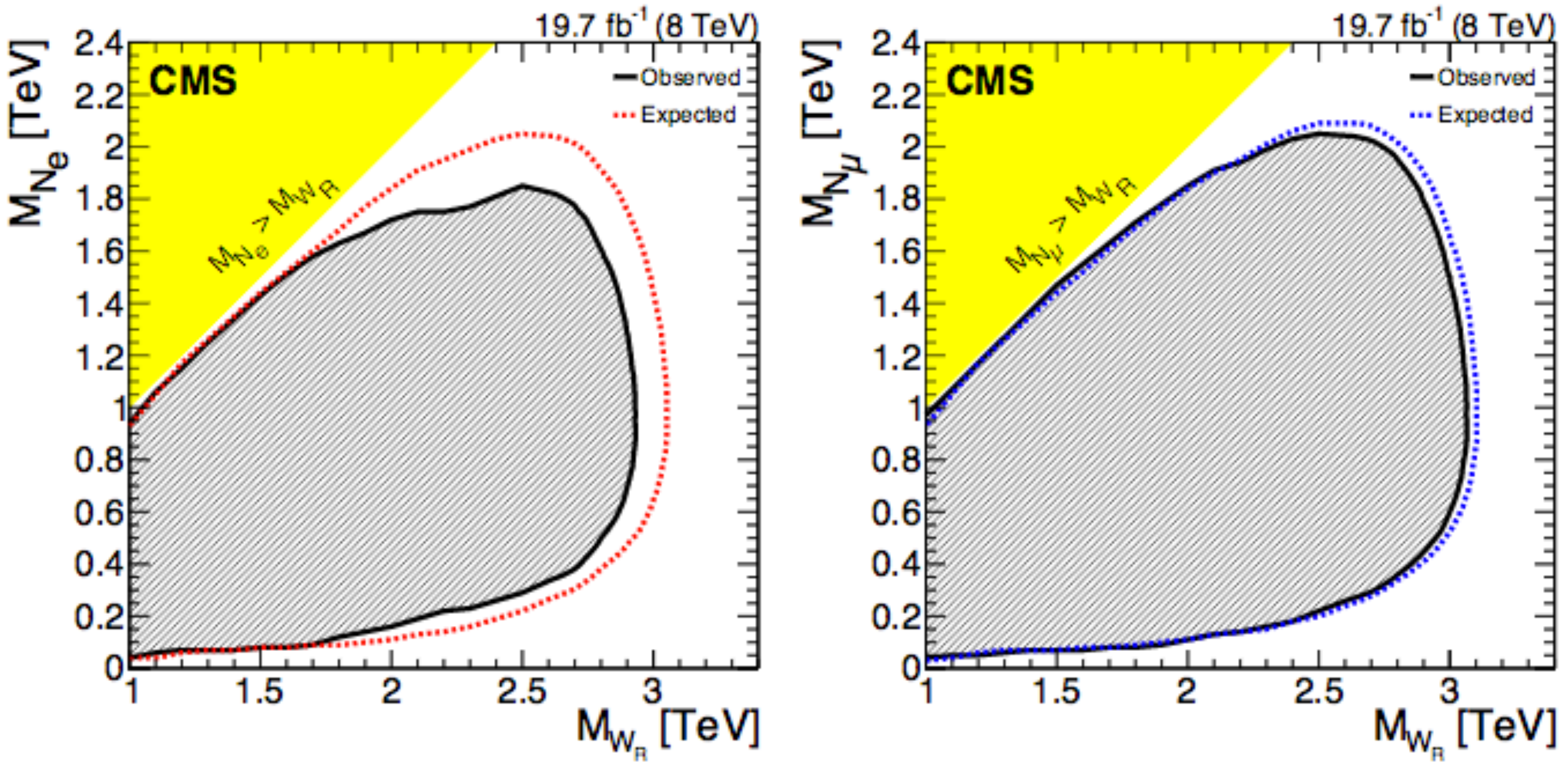
We assume $g_R = g_L$, $\tan\beta \equiv \frac{v_2}{v_1}$

$\Rightarrow$ $m_h < 113.7$ GeV

All *other Higgs* masses of the order v_R, v_S, or LH soft triplet masses

Constraints from neutrinos

Handle on right-handed neutrinos from pp→ l N_R→ l(l W_R*)→ l(ljj)
N_R Majorana ⇨ similar amounts of same sign and opposite sign dileptons Keung, Senjanovic, PRL 50 (1983) 1427



Eur.Phys.J C74(2014) 3149

For our benchmarks, m_N < 200 GeV (consistent with small triplet BR to e, μ)

Other than superpotential terms in the Lagrangian:

$$\mathcal{L}_{\rm soft} = -\frac{1}{2}\Big[M_1\tilde{B}\tilde{B} + M_{2L}\tilde{W}_L^a\tilde{W}_{La} + M_{2R}\tilde{W}_R^a\tilde{W}_{Ra} + M_3\tilde{g}^a\tilde{g}_a + h.c.\Big] - m^2_{\Delta 1L}{\rm Tr}(\Delta^\dagger_{1L}\Delta_{1L})$$
$$- m^2_{\Delta 2L}{\rm Tr}(\Delta^\dagger_{2L}\Delta_{2L}) - m^2_{\Delta 1R}{\rm Tr}(\Delta^\dagger_{1R}\Delta_{1R}) - m^2_{\Delta 2R}{\rm Tr}(\Delta^\dagger_{2R}\Delta_{2R}) - m^2_{\Phi 1}{\rm Tr}(\Phi^\dagger_1\Phi_1)$$
$$- m^2_{\Phi 2}{\rm Tr}(\Phi^\dagger_2\Phi_2) - m^2_S|S|^2 + m^2_{\tilde{Q}_L}\tilde{Q}^\dagger_L\tilde{Q}_L - m^2_{\tilde{Q}_R}\tilde{Q}^\dagger_R\tilde{Q}_R - m^2_{\tilde{L}_L}(\tilde{L}^\dagger_L\tilde{L}_L) - m^2_{\tilde{L}_R}(\tilde{L}^\dagger_R\tilde{L}_R)$$
$$- \{S[T_L{\rm Tr}(\Delta_{1L}\Delta_{2L}) + T_R{\rm Tr}(\Delta_{1R}\Delta_{2R}) + T_3{\rm Tr}(\Phi_1^T\tau_2\Phi_2\tau_2) + T_4{\rm Tr}(\Phi_1^T\tau_2\Phi_1\tau_2)$$
$$+ T_5{\rm Tr}(\Phi_2^T\tau_2\Phi_2\tau_2) + T_S S^2 + \xi_S] + h.c.\} + \{T^1_Q(\tilde{Q}_L)^T\Phi_1(\tilde{Q}_R) + T^2_Q(\tilde{Q}_L)^T\Phi_2(\tilde{Q}_R)$$
$$+ T^1_L(\tilde{L}_L)^T\Phi_1(\tilde{L}_R) + T^2_L(\tilde{L}_L)^T\Phi_2(\tilde{L}_R) + T^3_L(\tilde{L}_L)^T\Delta_{2L}(\tilde{L}_L) + T^4_L(\tilde{L}_R)^T\Delta_{1R}(\tilde{L}_R) + h.c.\}.$$

$$V_D = \sum_i\Bigg[\frac{g_L^2}{8}\Big|{\rm Tr}(2\Delta^\dagger_{1L}\tau_i\Delta_{1L} + 2\Delta^\dagger_{2L}\tau_i\Delta_{2L} + \Phi_a\tau_i^T\Phi_b^\dagger) + \tilde{L}^\dagger_L\tau_i\tilde{L}_L\Big|^2$$
$$+\frac{g_R^2}{8}\Big|{\rm Tr}(2\Delta^\dagger_{1R}\tau_i\Delta_{1R} + 2\Delta^\dagger_{2R}\tau_i\Delta_{2R} + \Phi^\dagger_a\tau_i^T\Phi_b) + \tilde{L}^\dagger_R\tau_i\tilde{L}_R\Big|^2\Bigg]$$
$$+ \frac{g^2_{B-L}}{2}\Big[{\rm Tr}(-\Delta^\dagger_{1L}\Delta_{1L} + \Delta^\dagger_{2L}\Delta_{2L} - \Delta^\dagger_{1R}\Delta_{1R} + \Delta^\dagger_{2R}\Delta_{2R}) - \tilde{L}^\dagger_L\tilde{L}_L + \tilde{L}^\dagger_R\tilde{L}_R\Big]^2$$

$$\Rightarrow \lambda_{h\tilde{\nu}_{RI}\tilde{\nu}_{RI}} \simeq -\frac{1}{4}g_R^2 v\cos 2\beta$$

Aim

Study sneutrino dark matter and its collider signals via benchmarks in LRSUSY

Compare sneutrino and neutralino dark matter

Pseudoscalar sneutrino mass matrix

$$M^2_{\tilde{\nu}_L\tilde{\nu}_L} = m^2_{\tilde{L}_L} + D_{11}$$

$$M^2_{\tilde{\nu}_L\tilde{\nu}_R} = M^2_{\tilde{\nu}_R\tilde{\nu}_L} = (T^2_L v + Y^2_L Y^4_L v_{1R})\sin\beta + Y^2_L \mu_{\rm eff}\frac{v\cos\beta}{\sqrt{2}}$$

$$M^2_{\tilde{\nu}_R\tilde{\nu}_R} = m^2_{\tilde{L}_R} + D_{22} + 2(Y^4_L)^2 v^2_{1R} + \sqrt{2}T^4_L v_{1R} - Y^4_L \lambda_R v_S v_{2R}$$

For λ_R large, the last term is most important $(\mu_{eff} = \lambda_3 \upsilon_s / \sqrt{2})$

Neutralino sector (left-handed triplet 2x2 mass matrix and neutral bidoublet inert 2x2 –part are separate blocks)

$$M_{\tilde{\chi}^0} =$$

$$\begin{pmatrix} 0 & -\mu_{\rm eff} & 0 & 0 & -\mu_d & 0 & \frac{g_L v_u}{\sqrt{2}} & -\frac{g_R v_u}{\sqrt{2}} \\ -\mu_{\rm eff} & 0 & 0 & 0 & -\mu_u & 0 & -\frac{g_L v_d}{\sqrt{2}} & \frac{g_R v_d}{\sqrt{2}} \\ 0 & 0 & 0 & \mu_R & \frac{\lambda_R v_{2R}}{\sqrt{2}} & g' v_{1R} & 0 & -g_R v_{1R} \\ 0 & 0 & \mu_R & 0 & \frac{\lambda_R v_{1R}}{\sqrt{2}} & -g' v_{2R} & 0 & -g_R v_{2R} \\ -\mu_d & -\mu_u & \frac{\lambda_R v_{2R}}{\sqrt{2}} & \frac{\lambda_R v_{1R}}{\sqrt{2}} & \mu_S & 0 & 0 & 0 \\ 0 & 0 & g' v_R & -g' v_{2R} & 0 & M_1 & 0 & 0 \\ \frac{g_L v_u}{\sqrt{2}} & -\frac{g_L v_d}{\sqrt{2}} & 0 & 0 & 0 & 0 & M_{2L} & 0 \\ -\frac{g_R v_u}{\sqrt{2}} & \frac{g_R v_d}{\sqrt{2}} & -g_R v_{1R} & -g_R v_{2R} & 0 & 0 & 0 & M_{2R} \end{pmatrix}$$

Adjust to have neutralino DM benchmarks

Large for sneutrino DM benchmarks

$$\mu_S = \lambda_S \frac{v_s}{\sqrt{2}},\ \mu_{L,R} = \lambda_{L,R} \frac{v_s}{\sqrt{2}} \text{ and } \mu_{u,d} = \lambda_3 \frac{v_{u,d}}{\sqrt{2}}\,.$$

Higgsinos heavy due to large VEVs

Mass of singlino dominated state depends on λ_S

Benchmark parameter sets with Dark Matter in LRSUSY

To study possibilities for searches at the LHC, define

- two benchmarks with right sneutrino dark matter (BP1 and BP2)
- two with neutralino dark matter (BP3 and BP4)

Relic density requirement: $\Omega_{DM}h^2$=0.1199 ± 0.0027

Common parameters ($\lambda_4 = \lambda_5 = T_L = T_4 = T_5 = 0$)

Parameter	Value	Parameter	Value
λ_L	0.4	λ_R	0.9
λ_S	-0.5	T_R	-2 TeV
T_S	-2 TeV	T_3	1 TeV
$M^2_{\Delta 1L}, M^2_{\Delta 2L}$	2 TeV^2	M_3	3.5 TeV
$(Y^4_L)_{ii}$	$(0.019, 0.022, 0.10)$	ξ_F	-5000 GeV^2

Benchmark specific

$$\tan\beta_R \equiv \frac{v_{2R}}{v_{1R}}$$

Parameter	BP1	BP2	BP3	BP4
$\tan\beta$	6.5	8	7	7
$\tan\beta_R$	1.05	1.05	1.04	1.04
v_R (TeV)	5.7	7.5	5.7	7.5
v_S (TeV)	7	10	7	8
λ_3	0.15	0.10	0.10	0.08
$M_{2L,R}$ (GeV)	1200	900	700	700

Sneutrino benchmarks (BP1, BP2) Neutralino benchmarks (BP3, BP4)

Low energy Constraints	BP1	BP2	BP3	BP4
$\mathrm{BR}(b \to s\gamma)$	3.04×10^{-4}	3.10×10^{-4}	3.03×10^{-4}	3.08×10^{-4}
$\mathrm{BR}(B_s \to \mu\mu)$	2.74×10^{-9}	3.68×10^{-9}	3.44×10^{-9}	2.71×10^{-9}
Δa_μ	1.2×10^{-10}	1.5×10^{-10}	2.1×10^{-10}	1.9×10^{-10}

Resulting particle spectrum

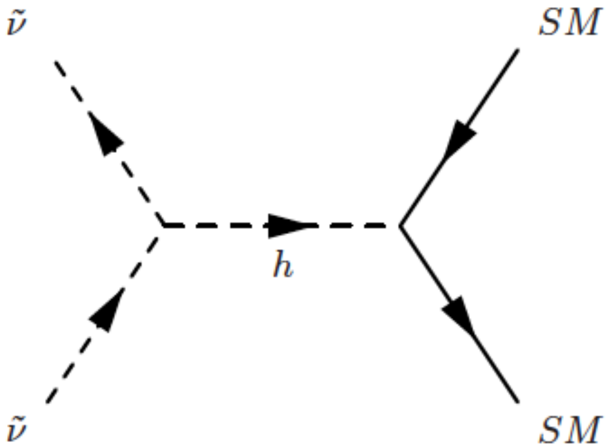
Particle	BP1	BP2	BP3	BP4
h	125.2	125.5	124.8	125.3
H_2	551.1	748.5	492.4	657.9
H_3	1958	2076	1949	2363
A_1	551.1	748.5	492.4	657.9
$H_1^{\pm}$	563.7	757.7	506.0	668.1
$H_1^{\pm\pm}$	339.1	494.6	431.7	509.8
$W_R^{\pm}$	2668	3510	2668	3510
Z'	4476	5889	4476	5889

	BP1	BP2	BP3	BP4
$\Omega_{DM}h^2 \sim$	0.119	0.116	0.107	0.124
ν_{Re}	104.2	136.8	104.7	137.6
$\nu_{R\mu}$	120.7	158.4	121.2	159.2
$\nu_{R\tau}$	548.5	719.6	550.8	724.1
$\tilde{\nu}_{I\tau}$	266.5	271.6	416.0	299.7
$\tilde{\nu}_{Ie}$	813.8	663.6	632.2	896.3
$\tilde{\nu}_{I\mu}$	856.9	716.2	792.0	947.3
$\tilde{\nu}_{Re}$	1301	1454	1159	1488
$\tilde{\nu}_{R\mu}$	1331	1566	1312	1590
$\tilde{\nu}_{R\tau}$	2262	2983	2269	2742
$\tilde{e}_R$	931.7	813.8	773.3	1011
$\tilde{\mu}_R$	931.7	928.2	947.3	1105
$\tilde{\tau}_R$	1399	1837	1449	1678
$\tilde{\chi}_1^0$	731.1	609.8	61.9	62.4
$\tilde{\chi}_2^0$	750.6	711.3	486.6	447.2
$\tilde{\chi}_3^0$	750.9	716.3	501.1	459.3
$\tilde{\chi}_1^\pm$	744.0	703.7	487.5	447.8

Bino

Right-handed sneutrino dark matter (BP1, BP2)

Leading annihilation channel when there are no significant coannihilations:



RH sneutrino

h from bidoublets

$$\lambda_{h\tilde{\nu}_{RI}\tilde{\nu}_{RI}} \simeq -\frac{1}{4} g_R^2 v \cos 2\beta$$

For $g_L = g_R$ and $\cos 2\beta \sim -1$, the only unknown is the right-sneutrino mass

Correct relic density can be found with nonresonant annihilation

250 GeV < m_{snu} < 290 GeV

DM-nucleon spin independent $\sigma < 2.5 \times 10^{-10}$ pb

Neutralino dark matter (BP3, BP4)

- Take M_1 as smallest soft gaugino mass

  ⇒ $U(1)_{B-L}$ –bino-dominated LSP

  (pure gaugino, higgsino DM studied in Demir, Frank, Turan, PRD 73 (2006) 115001)

- outside resonant annihilation channels relic density is too large

  ⇒ neutralino mass ~$m_h/2$

- Leads to $BR(h \rightarrow \chi^0 \chi^0) \sim 4 \times 10^{-4}$

- Spin-independent DM-nucleon $\sigma < 3 \times 10^{-11}$ pb,
  spin-dependent DM-nucleon $\sigma < 2 \times 10^{-6}$ pb

SUSYLR DM search at the LHC

Sneutrinos interact only weakly ⟹ challenge

Contrary to (N)MSSM, in LRSUSY right sneutrinos in doublets
⟹ gauge interactions exist also for right-handed superpartners

Main annihilation of sneutrino DM through Higgs
⟹ main pair-production through Higgs;
BUT non-resonant+small h coupling to partons → $\sigma \sim O(ab)$

⟹ Consider resonant production through heavy W_R :

$$pp \to \sum \tilde{\nu}\, \tilde{l}$$

Sum over all final state sneutrinos and sleptons; Bulk of σ from on-shell W_R

M_{WR} ~	2.7	3.5	2.7	3.5 TeV
	BP1	BP2	BP3	BP4
$\sigma(pp \to W_R)$ (fb)	245	38	245	38
$\mathrm{BR}(W_R \to \tilde{\nu}_{I\tau}\tilde{\ell}_\tau)$	0.52%	0.52%	0.38%	0.61%
$\mathrm{BR}(W_R \to \tilde{\nu}_{Ie}\tilde{\ell}_e)$	0.64%	1.06%	0.80%	0.82%
$\mathrm{BR}(W_R \to \tilde{\nu}_{I\mu}\tilde{\ell}_\mu)$	0.60%	0.98%	0.57%	0.74%
$\mathrm{BR}(W_R \to \tilde{\nu}_{Re}\tilde{\ell}_e)$	0.21%	0.60%	0.42%	0.47%
$\mathrm{BR}(W_R \to \tilde{\nu}_{R\mu}\tilde{\ell}_\mu)$	0.24%	0.47%	0.19%	0.36%
$\sigma \times \sum \mathrm{BR}(W_R \to \tilde{\nu}\tilde{\ell})$ (fb)	5.4	1.4	5.8	1.1

$\sqrt{s}$ = 13 TeV

BP2,4 : Smaller σ, larger BR;   Harder p_T expected

Relevant number of events with 100 fb^{-1}

→ may lead to useful final state

For the **lightest sneutrino,** we find:

BP2, 3, 4: $\tilde{l}_i \to l_i + \chi_1^0$ almost 100%; BP2 ($\tilde{\nu}$ LSP): χ_1^0 decays invisibly

BP1: $\tilde{l}_i \to l_i + \chi_1^0$ 30%; $\tilde{l}_i \to l_i + \chi_5^0$ 70%;

$$\chi_5^0 \to \chi_1^{\pm}\left(\to \mathrm{LSP} + \tau^{\pm}\right) + W^{\mp} \quad 100\%$$

higgsino dominated

Bino dominated

These decays lead to the following final states:

$$\text{BP2, 3, 4:}\ pp \to W_R \to \sum \tilde{l}\ \tilde{\nu} \to 1l + \not{E}_T$$

$$\text{BP1:}\ pp \to W_R \to \sum \tilde{l}\ \tilde{\nu} \to 1l + \not{E}_T \ \text{or}\ 1l + \tau + W + \not{E}_T$$

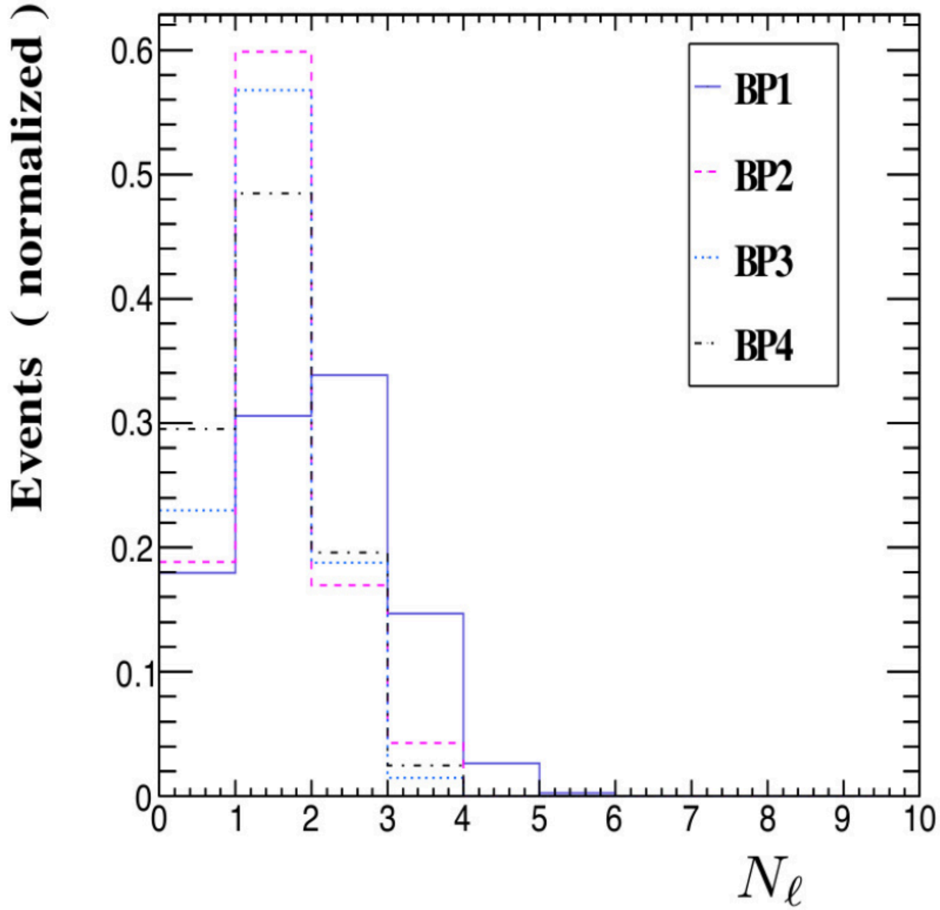
τ-events enriched

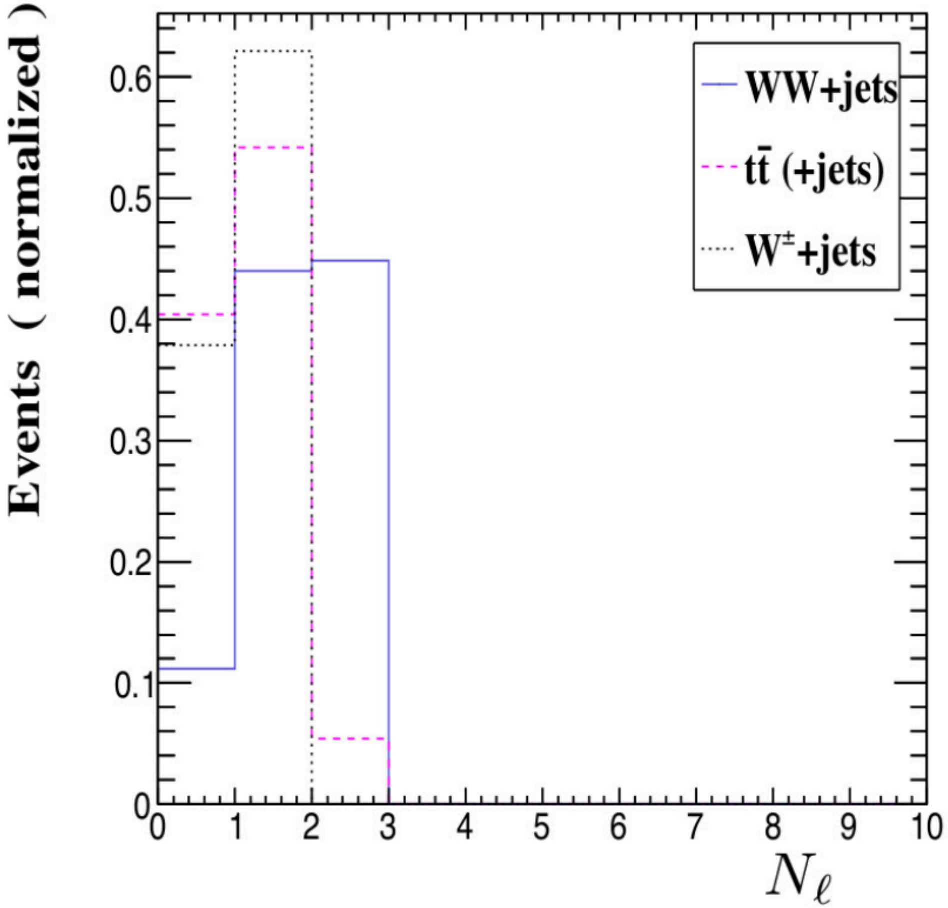
Heavier sneutrinos decay to chargino and e/μ around 50%

→ decays include energetic e or μ

In the analysis concentrate on electrons and muons

Charged lepton multiplicity:





$$(i) \quad \geq 1\ell + nj + \not{E}_T \quad \text{with} \quad n \leq 3$$

$$(ii) \quad \geq 2\ell + nj + \not{E}_T \quad \text{with} \quad n \leq 3$$

Initial requirements:

-Pseudorapidity < 2.5

-Delta(R) > 0.4 (> 0.5 for jets)

-Missing transverse energy > 200 GeV

-No isolated photons with p_T > 10 GeV

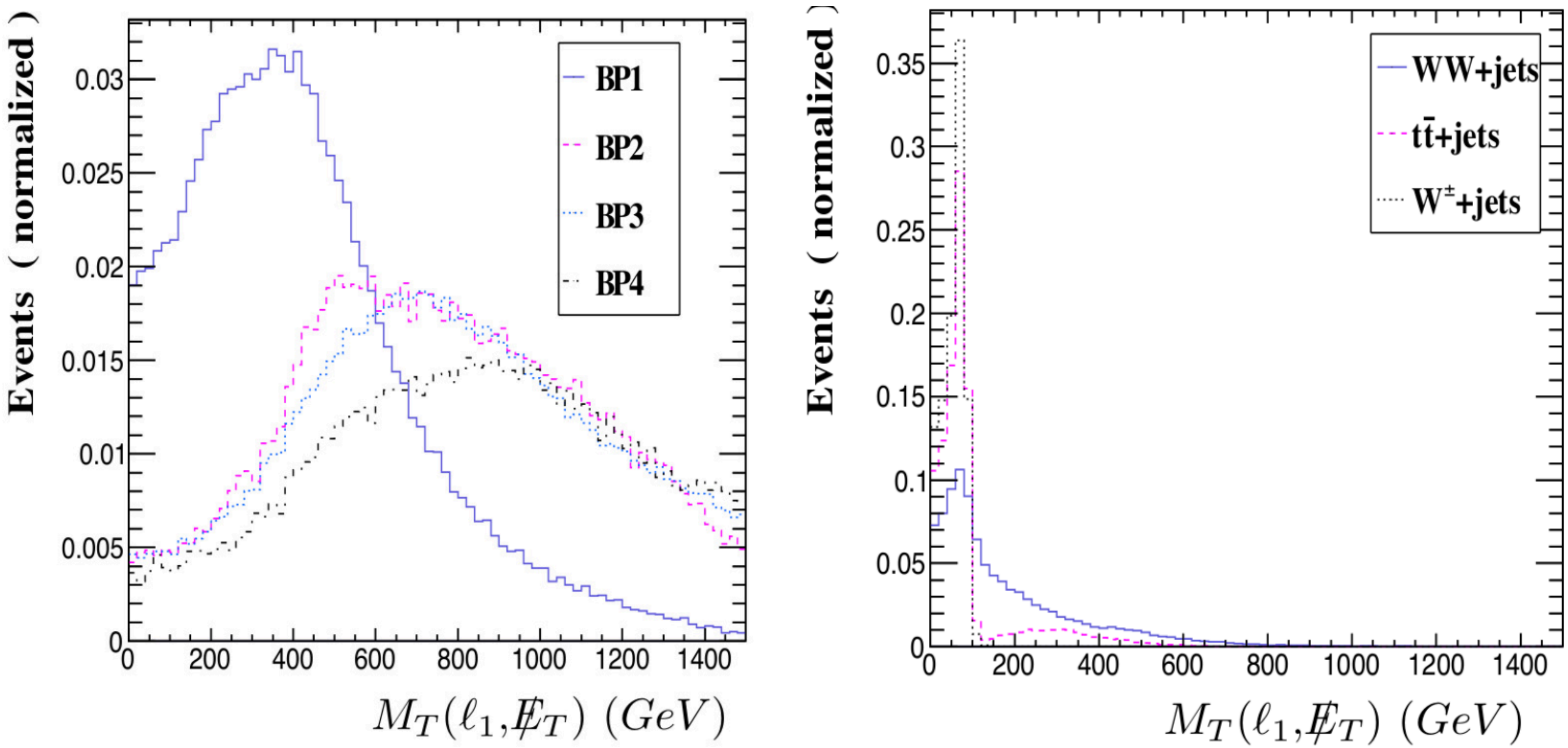
-No b-tagged jets (reduces number of top-events)

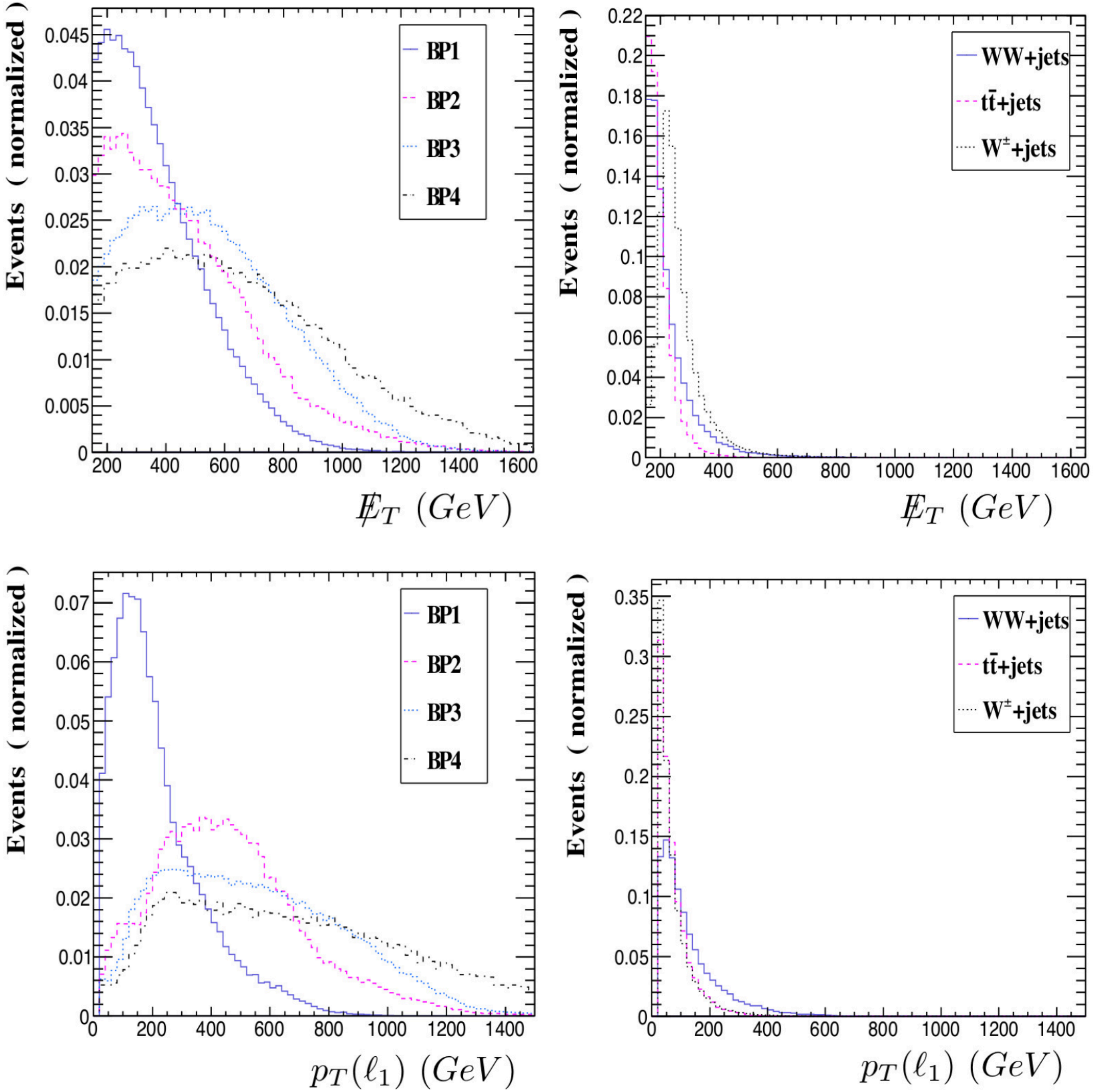
Signal consists of leptons and missing energy from heavy superpartners → expect

*tranverse mass
*missing transverse momentum
*transverse momentum of the leading lepton

to be much harder than in the background

BP3,4: mass gap between charged sleptons and LSP larger than in PB1,2




Events (normalized)
BP1
BP2
BP3
BP4
$\not{E}_T$ (GeV)
Events (normalized)
WW+jets
$t\bar{t}$+jets
$W^{\pm}$+jets
$\not{E}_T$ (GeV)
Events (normalized)
BP1
BP2
BP3
BP4
$p_T(\ell_1)$ (GeV)
Events (normalized)
WW+jets
$t\bar{t}$+jets
$W^{\pm}$+jets
$p_T(\ell_1)$ (GeV)

	BP1	BP2	BP3	BP4	diboson	top-antitop	Drell-Yan
Preselection	216	83	299	45	2065	7192	5.94×10^5
$M_T(\ell_1, \not{E}_T) > 250$ GeV	153	77	279	42	521	708	142
$p_T(\ell_1) > 100$ GeV	134	75	274	42	440	559	124
$\not{E}_T > 250$ GeV	113	67	258	40	229	149	69

Leads to sensitivities: 5σ 3σ 11σ 1.86σ with 100 fb^{-1}

LRSUSY sleptons accessible with 50 fb^{-1} upto 800 GeV if m_{W_R} ~3 TeV

	BP1	BP2	BP3	BP4	diboson	top-antitop
$n_\ell \geq 2$, $p_T(\ell_1) > 200$ GeV	55	21	77	14	94	590
$p_T(\ell_2) > 40$ GeV	50	18	66	13	72	38
$M_T(\ell_2, \not{E}_T) > 50$ GeV	46	17	63	13	41	21

Summary

For LRSUSY sneutrino DM no specific enhancement for annihilation is needed

In sneutrino DM leptonic events enriched – turns out that can be an efficient way to differentiate between neutralino and sneutrino DM only when luminosity >> 100 fb^{-1}

neutralino DM: in 10% of events more than 2 leptons

sneutrino DM: in 20-30% of events more than 2 leptons

Characteristics of SUSYLR DM sneutrino differ from singlet right sneutrino – e.g. mass of sneutrino << mass of stau

Production cross sections may be enhanced in LRSUSY if W_R is not heavier than around 3 TeV