Distinguishing between SUSY and Littlest Higgs Model using trileptons at the LHC (Pheno'09, Madison)

A. Datta, P. Dey, S.K. Gupta, B. Mukhopadhyaya, A. Nyffeler [Phys. Lett. B]

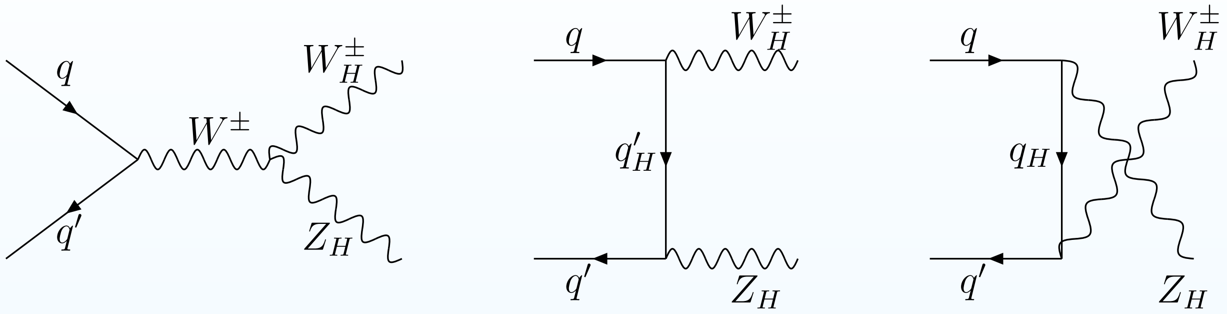
We will work with R-parity conserving MSSM and T-parity conserving Littlest Higgs Model (LHT).

- The idea of Littlest Higgs Model is based upon viewing Higgs Boson as a Goldstone Boson.
- The Littlest Higgs Model with T-parity and MSSM with R-parity shares the following common features:
  – Both have T/R-odd partners corresponding to each SM content.
  – Lightest T/R-odd particle is stable and hence a viable candidate for cold dark matter of the universe.
  – T/R-odd particles are pair produced and decays into LTP/LSP through cascades and therefore they carry huge amount of missing tranverse energy.

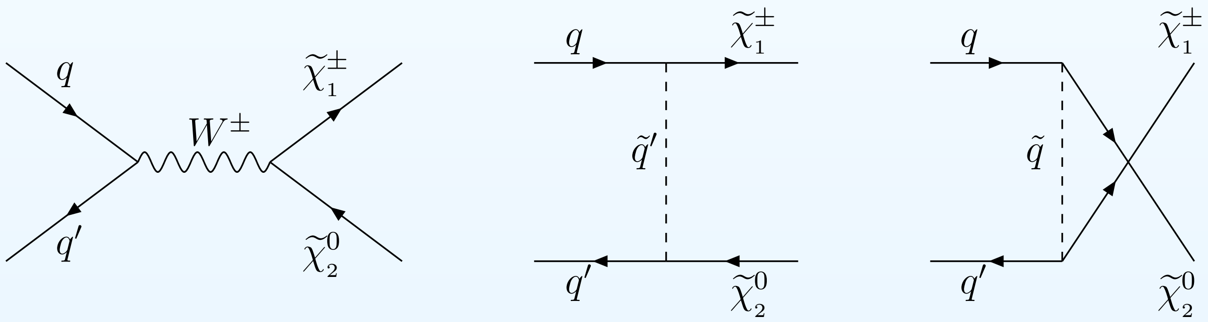
LHT differs with MSSM in the following:

– (T-odd) partners of Standard Model particles have the same spin unlike SUSY where the (R-odd) superpartners of the Standard Model differ by a spin 1/2. "Bosonic SUSY"
– Absence of T-odd partner of gluon and presence of extra (T-odd and -even) tops.

Sources of trileptons in LHT and SUSY



(a)



(b)

followed by

$$W_H^\pm \rightarrow A_H W^\pm \rightarrow A_H l'^\pm \nu_{l'}, \quad Z_H \rightarrow A_H Z \rightarrow A_H l^\pm l^\mp,$$

$$\widetilde{\chi}_1^\pm \rightarrow \nu_{l'} \widetilde{l}'^\pm \rightarrow \widetilde{\chi}_1^0 l'^\pm \nu_{l'}, \qquad \widetilde{\chi}_2^0 \rightarrow l^\pm \widetilde{l}^\mp \rightarrow \widetilde{\chi}_1^0 l^\pm l^\mp.$$

Assumptions

- Assume the mass spectra of LHT and MSSM to be identical (not all states can be matched !)
- Assume that we have some information on these masses from the first phase of LHC.
- Assume that gluino is heavy $\longrightarrow$ no QCD-enhanced SUSY events $\Rightarrow$

  Hadronically quiet trilepton event rates could distinguish between the two models (at least in some region of the parameter space)

Matching SUSY spectrum with LHT

LHT spectrum can be essentially determined by 3 parameters: (f, κ_q, κ_l)

- $(\widetilde{l}, \widetilde{q})$ masses equated to (l_H, q_H) masses
- $(A_H, W_H^{\pm}, Z_H)$ masses aligned to $(\widetilde{\chi}_1^0, \widetilde{\chi}_1^{\pm}, \widetilde{\chi}_2^0)$ setting:
  - Bino mass M_1 set equal to m_{A_H}
  - $M_2 = m_{Z_H}$ and $\mu = 1.5$ TeV $\rightarrow$ pair $(\widetilde{\chi}_1^{\pm}, \widetilde{\chi}_2^0)$ is Wino dominated
    $\rightarrow$ SUSY scenario 1 (SS1)
  - $\mu = m_{Z_H}$ and $M_2 = 1.5$ TeV $\rightarrow$ pair $(\widetilde{\chi}_1^{\pm}, \widetilde{\chi}_2^0)$ is Higgsino dominated
    $\rightarrow$ SUSY scenario 2 (SS2)
  - Physical chargino and neutralino states obtained by diagonalization of respective mass matrices
- $M_3 = 5$ TeV to decouple gluinos
- Trilinear couplings set to zero (except A_t)
- Lighter CP-even Higgs mass set to $m_H = 120$ GeV
- $\tan\beta = 10$, $m_A = 850$ GeV

LHT versus SUSY spectrum

Masses and scale f in GeV:

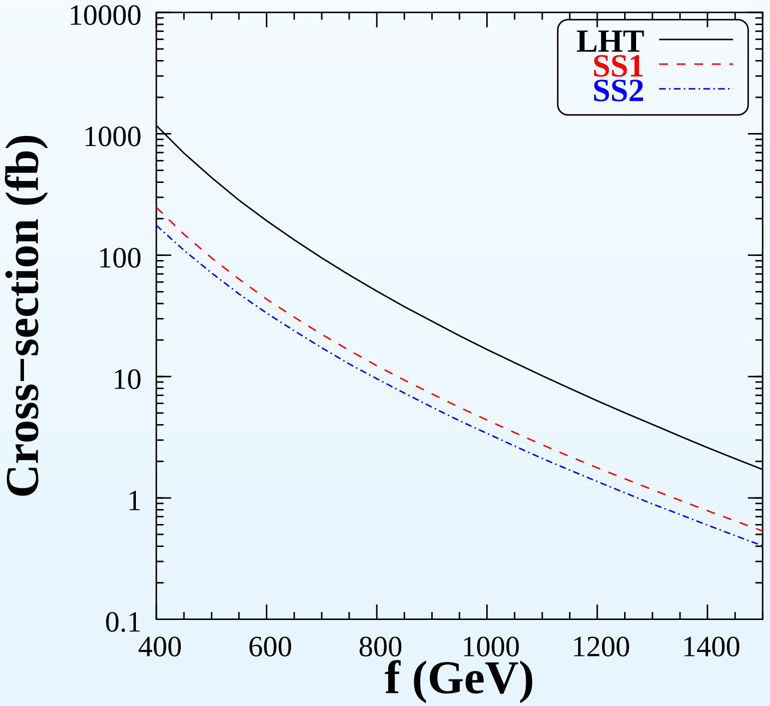
LHT							SUSY			
f	m_{A_H}	m_{Z_H}	m_{d_H}	m_{u_H}	m_{l_H}	m_{ν_H}	**Case**	$m_{\tilde{\chi}_1^0}$	$m_{\tilde{\chi}_2^0}$	$m_{\tilde{\chi}_1^\pm}$
$\kappa_l = \kappa_q = 1$										
500	66.2	316.7	707.1	685.7	707.1	685.7	**SS1**	65.9	314.9	314.9
							SS2	63.7	314.9	318.1
1000	150.2	648.3	1414.2	1403.5	1414.2	1403.5	**SS1**	149.8	645.0	645.0
							SS2	148.9	645.0	646.2
$\kappa_l = 0.4, \ \kappa_q = 1$										
500	66.2	316.7	707.1	685.7	282.8	274.2	**SS1**	65.9	314.9	314.9
							SS2	63.7	314.9	318.1
1000	150.2	648.3	1414.2	1403.5	565.7	561.4	**SS1**	149.8	645.0	645.0
							SS2	148.9	645.6	646.0

SS1: $M_2 < \mu$, SS2: $\mu < M_2$

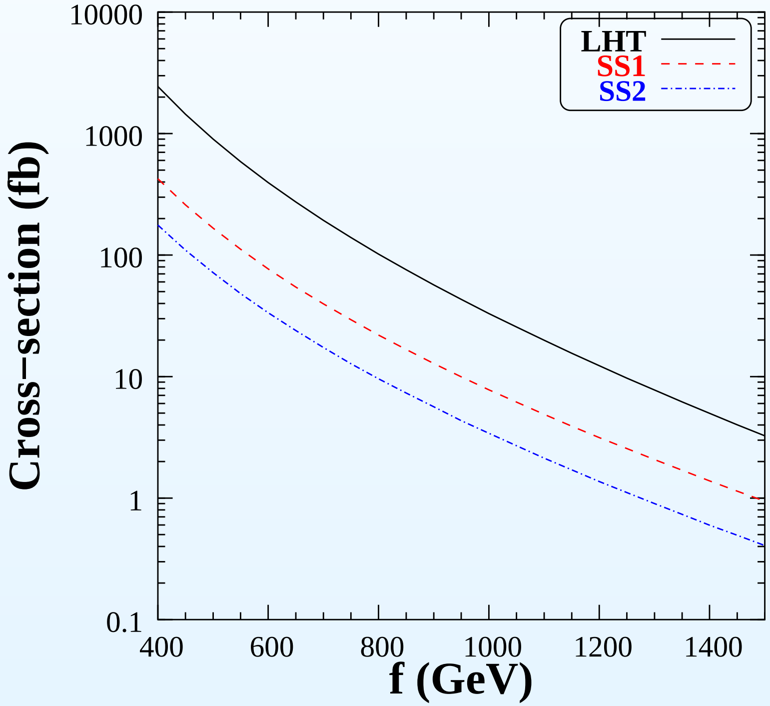
Production cross-sections

Pair production cross-sections at the LHC of $W_H^{\pm} Z_H$ (LHT) and $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ (SUSY)

SS1: $M_2 < \mu$; SS2: $\mu < M_2$



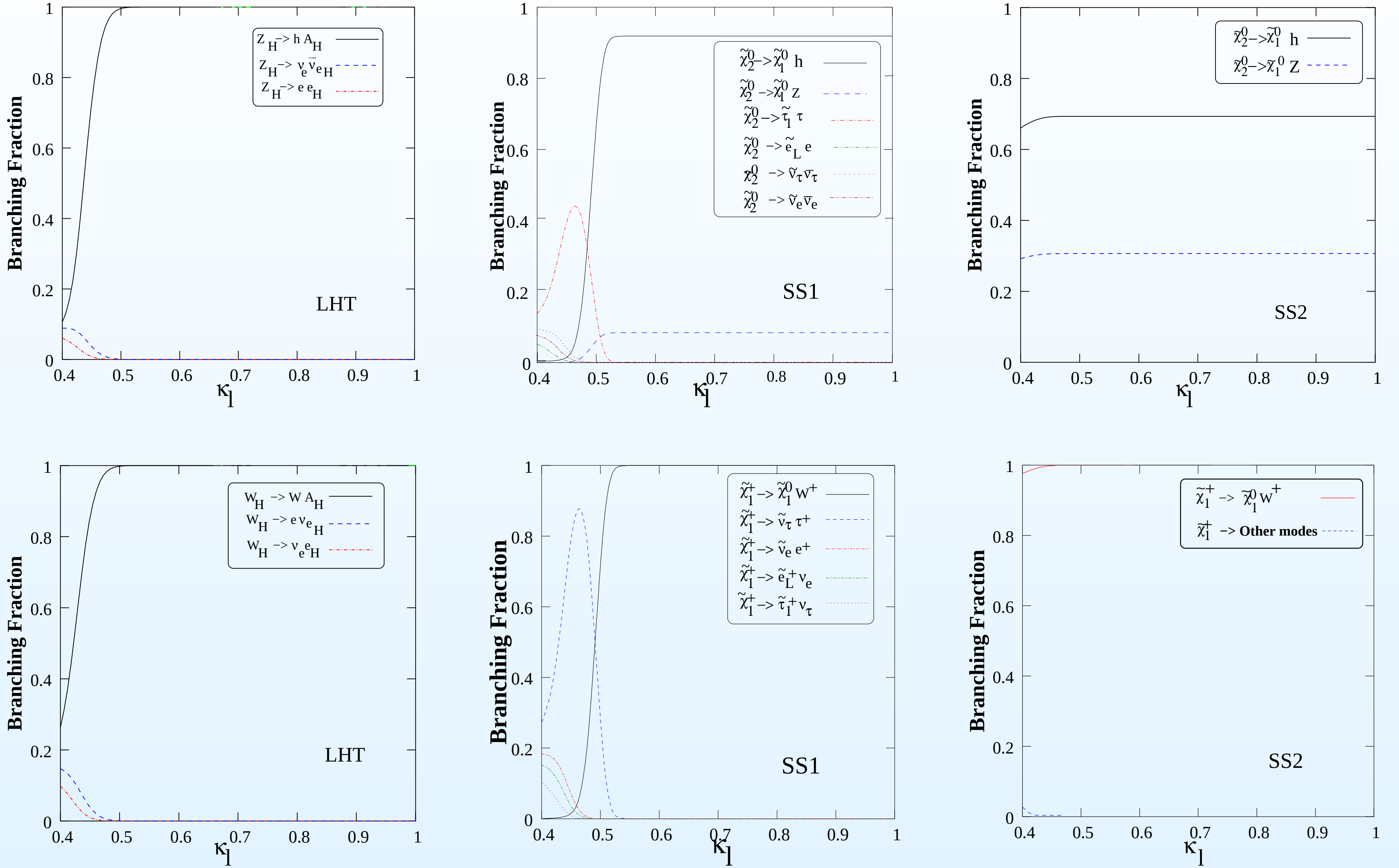
$\kappa_q = 1$



$\kappa_q = 1.5$

Branching fractions versus κ_l: LHT and SUSY

$f = 500$ GeV and $\kappa_q = 1$; SS1: $M_2 < \mu$ & SS2: $\mu < M_2$



Event selection

Basic Cuts

No jet with $p_{Tj} > 30$ GeV and $|\eta_j| < 2.7$,
$p_{T_l} > 25$ GeV, $|\eta_l| < 2.5$ and $\Delta R_{ll} > 0.2$
$\not{E}_T > 30$ GeV

Selection Cuts

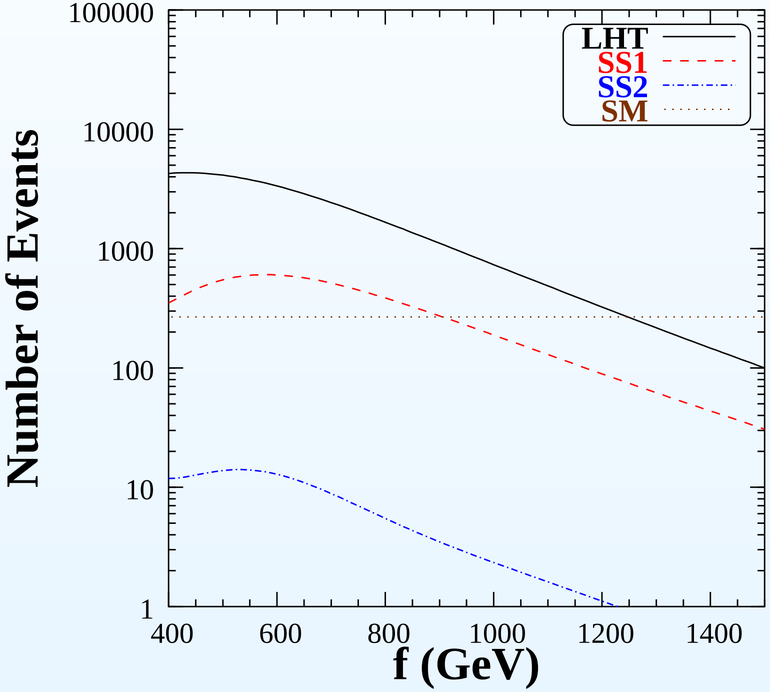
$\not{E}_T > 100$ GeV
$m_{l^+l^-} > 20$ GeV
$|m_{l^+l^-} - m_Z| > 15$ GeV
$|m_T(l\not{E}_T) - m_W| > 15$ GeV

$3l + \not{E}_T$ event rates after cuts

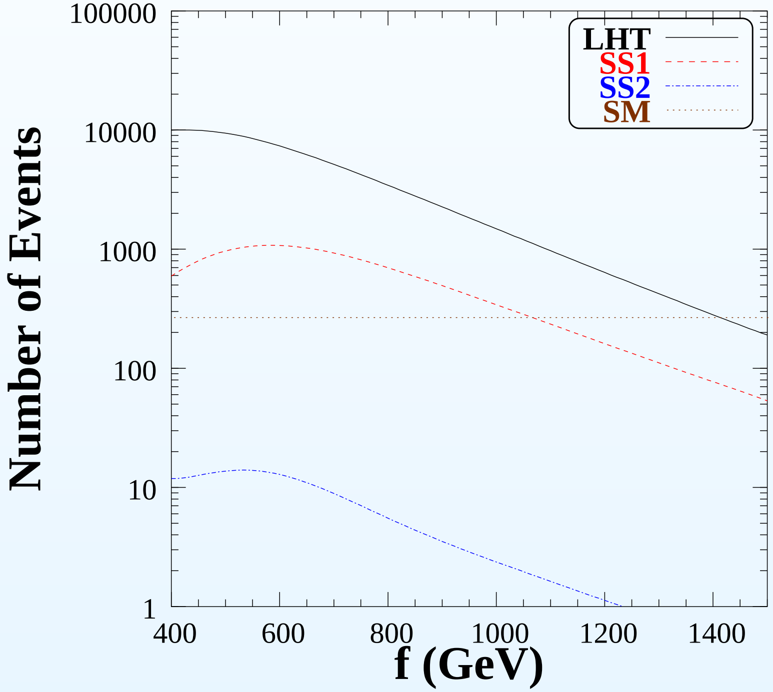
Number of trilepton events after cuts with integrated luminosity 300 fb^{-1},

$\kappa_l = 0.4$

SS1: $M_2 < \mu$; SS2: $\mu < M_2$



$\kappa_q = 1$



$\kappa_q = 1.5$

Trileptons at the LHC: cuts and their efficiency

$f = 500$ GeV, $\kappa_q = 1$, $\kappa_l = 0.4$

Integrated luminosity 300 fb^{-1}

Cuts	LHT	SS1	SS2	Background
No jet with $p_{Tj} > 30$ GeV and $\|\eta_j\| < 2.7$, $p_{Tl} > 25$ GeV, $\|\eta_l\| < 2.5$ and $\Delta R_{ll} > 0.2$ and $\not{E}_T > 30$ GeV	9292.7	1641.4	68.1	20232.5
$\not{E}_T > 100$ GeV	7281.2	1187.6	49.6	1599.9
$m_{l^\pm l^\mp} > 20$ GeV	7085.4	1137.5	48.1	1596.5
$\|m_{l^\pm l^\mp} - m_Z\| > 15$ GeV	4543.9	659.8	18.2	467.1
$\|m_T(l\not{E}_T) - m_W\| > 15$ GeV	4246.3	606.5	17.0	263.9

Summary

- LHT trilepton events can be distinguished, at least at the 6σ level, from either SUSY scenario (SS1 and SS2) even for matching mass spectra for $\kappa_l < .5$.
- For higher values of κ_l, with higher heavy mirror lepton / slepton masses, the trilepton rates in LHT and SUSY are too low compared to SM background.
- Though a LHT-SUSY discrimination is possible for an integrated luminosity of 30 fb^{-1}, the information on the mass spectrum might not be sufficient at that stage of the LHC.