Sensitivity of the direct stop pair production analyses in phenomenological MSSM simplified models with the ATLAS detectors

Ian Snyder, on behalf of the ATLAS Collaboration

University of Oregon

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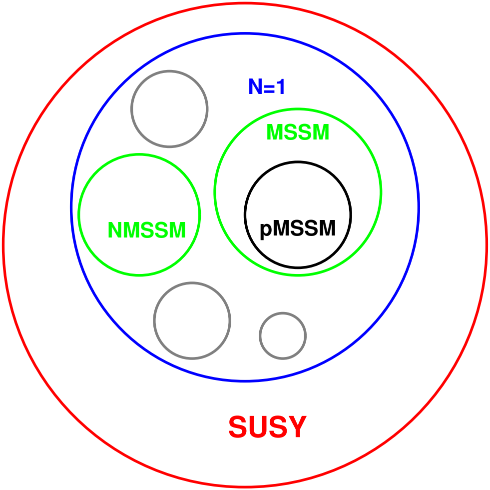
Introduction

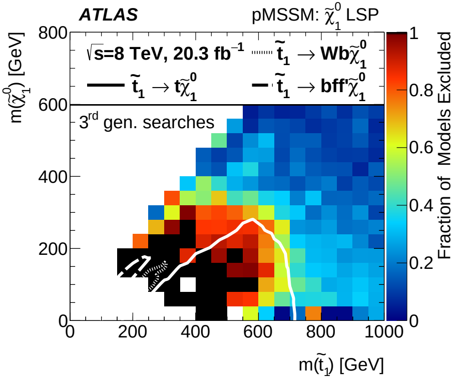
- Phenomenological Minimal Supersymmetric Model (pMSSM) uses assumptions from experimental constraints or other features
- Reduces MSSM parameters from 105 to 19
- A specific set of 19 values is one model point
- Sample grid randomly for each parameter
- In Run 1: 22 analyses, 310,327 model points considered



T. Rizzo, SLAC Summer Institute 2012

Run 1 Stop Results

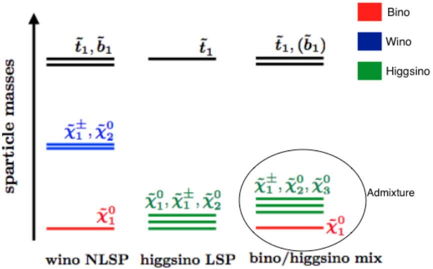
- Most easily visualized by projecting fraction of models excluded onto mass plane of particles
- Black points are (nearly) 100% excluded, dark blue is 0%
- Includes many analyses
- White line shows exclusion from simplified models
- Lower limits compared to simplified models - 100% branching fraction not assumed



Run 1 results, arXiv:1508.06608

Stop Interpretations

- See Sara's talk for full results of simplified models
  - 0-lepton: SUSY-2016-15
  - 1-lepton: SUSY-2016-16
  - 2-lepton: SUSY-2016-17
- 3 pMSSM scenarios in direct stop pair production searches
  - Wino next-to-lightest supersymmetric partner (NLSP)
  - Non-asymptotic higgsino, higgsino lightest supersymmetric partner (LSP)
  - Well-tempered neutralino, bino/higgsino mix
- Final states are consistent with simplified models with $t\bar{t} + E_T^{miss}$ (or $tb + E_T^{miss}$)
  - For models where the lightest third generation partners are mostly partners of left-handed SM particle, production of light $\tilde{b}$ with $m_{\tilde{b}} \approx m_{\tilde{t}}$ also considered



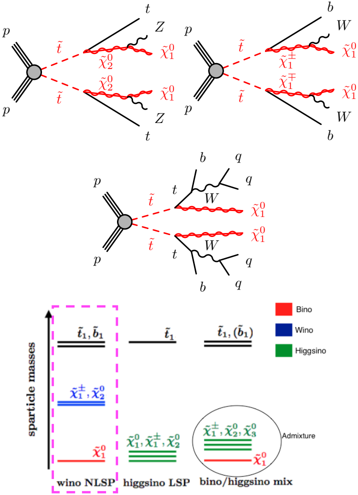
Parameter Values

- pMSSM-inspired simplified models: for each model vary 2 parameters out of 19, hold rest constant

Scenario	Wino NLSP	Higgsino LSP	Bino/higgsino mix
Models	pMSSM	simplified	pMSSM
Mixing parameters		$X_t/M_S \sim \sqrt{6}$	
$\tan\beta$	20	20 or 60	20
M_S [TeV]	0.9–1.2	1.2	0.7–1.3
M_3 [TeV]	2.2	2.2	1.8
Scanned mass parameters	(M_1, m_{q3L})	$(\mu, m_{q3L}/m_{tR})$	$(M_1, m_{q3L}/m_{tR})$
Electroweakino masses [TeV]	$\mu = \pm 3.0$	$M_2 = M_1 = 1.5$	$M_2 = 2.0$
	$M_2 = 2M_1 \ll \lvert\mu\rvert$	$\mu \ll M_1 = M_2$	$M_1 \sim -\mu$, $M_1 < M_2$
Additional requirements	–	–	$0.10 < \Omega h^2 < 0.12$
	–	–	$\Delta < 100$
Sbottom pair production	considered	–	considered
$\tilde{t}_1$ decay modes and their BR [%]	$\tilde{t}_1 \sim \tilde{t}_{\mathrm{L}}$	(a) / (b) / (c)	(a) / (b)
$\tilde{t}_1 \to t\tilde{\chi}_1^0$	< 5	$\sim 25/\sim 45/\sim 33$	$< 10/< 10$
$\tilde{t}_1 \to b\tilde{\chi}_1^\pm$	~ 65	$\sim 50/\sim 10/\sim 33$	$\sim 50/\sim 10$
$\tilde{t}_1 \to t\tilde{\chi}_2^0$	~ 30	$\sim 25/\sim 45/\sim 33$	$\sim 20/\sim 40$
$\tilde{t}_1 \to t\tilde{\chi}_3^0$	–	–	$\sim 20/\sim 40$
$\tilde{b}_1$ decay modes and their BR [%]	$\tilde{b}_1 \sim \tilde{t}_{\mathrm{L}}$	–	$\tilde{b}_1 \sim \tilde{b}_{\mathrm{L}}$
$\tilde{b}_1 \to b\tilde{\chi}_1^0$	< 5	–	< 5
$\tilde{b}_1 \to t\tilde{\chi}_1^\pm$	~ 65	–	~ 85
$\tilde{b}_1 \to b\tilde{\chi}_2^0$	~ 30	–	< 5
$\tilde{b}_1 \to b\tilde{\chi}_3^0$	–	–	< 5

Wino-NLSP pMSSM Model

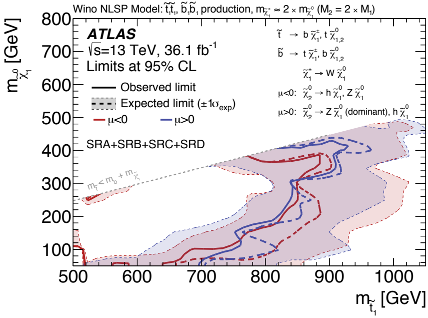
- Motivated by models with gauge unification at GUT scale (e.g. cMSSM and mSUGRA)
  - LSP is bino-like (mass=M_1)
  - NLSP is wino-like (mass=M_2)
  - Set $M_2 = 2M_1$, $m_{\tilde{t}_1} > M_1$
  - Scan M_1 and $m_{\tilde{q}3L}$
  - Allowed decays:
    - $\tilde{t}_1 \rightarrow t\tilde{\chi}_2^0 \rightarrow h/Z\tilde{\chi}_1^0$, maximum 33%, Z/h depends on sign of μ
    - $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$
    - $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ also considered where $m_{\tilde{t}} = m_b + m_{\tilde{\chi}_1^{\pm}}$



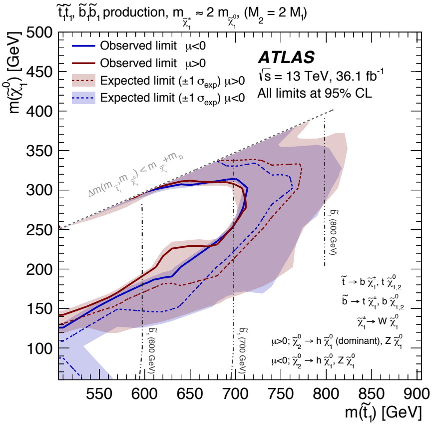
Wino-NLSP pMSSM Results

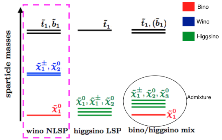
- Recall $M_2 = 2M_1$ and $m_{\tilde{t}_1} > M_1$
  - When $m_{\tilde{\chi}_1^0}$ is small, low sensitivity to $m_{\tilde{\chi}_1^\pm}$

0-lepton



2-lepton

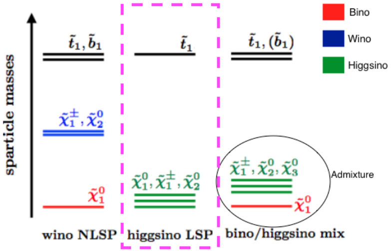




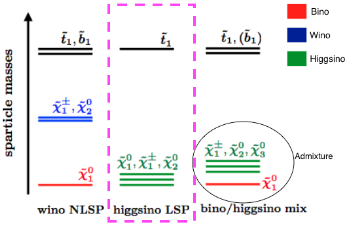
Non-Asymptotic Higgsino Model

- "Natural" model: low-mass stops and higgsino-like LSP
- Scan μ, $(m_{\tilde{q}3L}/m_{\tilde{t}R})$
- Assumes 3 sets of branching ratios
  - $\tilde{t}_1 \rightarrow t\tilde{\chi}_2^0$
  - $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$
  - $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$
- Branching ratio (33%, 33%, 33%)
  - pMSSM model with $\tilde{t}_1$ mostly consisting of $\tilde{t}_L$ and tanβ =60
- Branching ratio (45%, 10%, 45%)
  - pMSSM model with $m_{\tilde{q}L3} < m_{\tilde{t}R}$
- Branching ratio (25%, 50%, 25%)
  - pMSSM model with $m_{\tilde{t}R} < m_{\tilde{q}L3}$ and tanβ =20

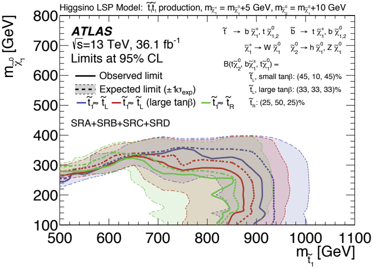
- Reconstructing soft lepton is important for right-handed scenario
  - Large BR to $b\tilde{\chi}_1^\pm$
  - Less useful for left-handed scenario



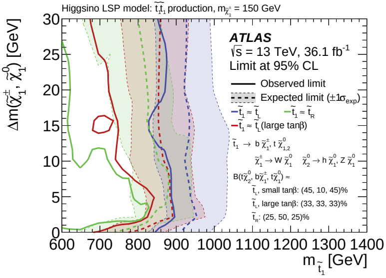
Non-Asymptotic Higgsino Results



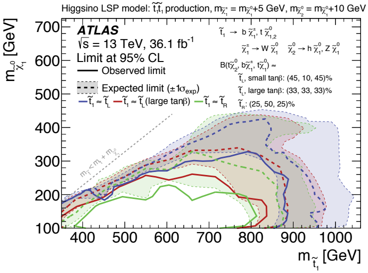
0-lepton



1-lepton, $\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ varied up to 30 GeV

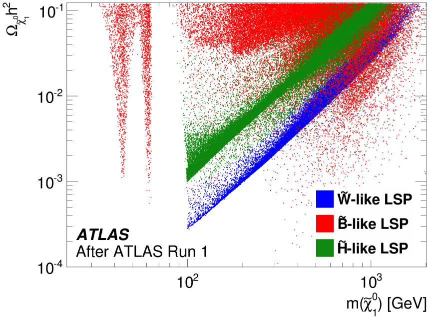


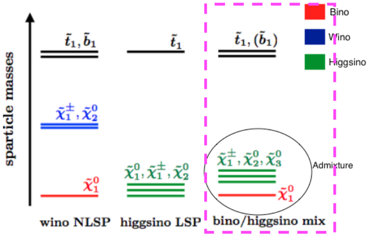
1-lepton



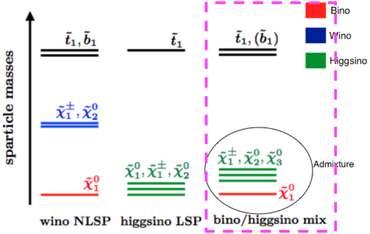
Well-tempered neutralino pMSSM Model

- Provides a viable dark-matter candidate
    - Neutralino annihilation rate consistent with dark-matter relic density ($0.10 < \Omega h^2 < 0.12$)
- LSP is a mix of bino and higgsino to address naturalness
- Electrowinos are compressed, 20-50 GeV of lightest state
- SM Higgs mass
- Scan M_1, ($m_{\tilde{q}3L}/m_{\tilde{t}R}$)

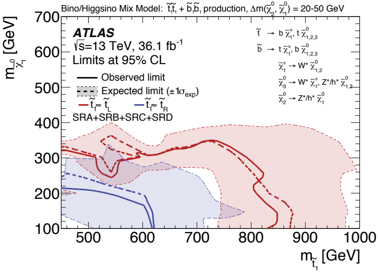




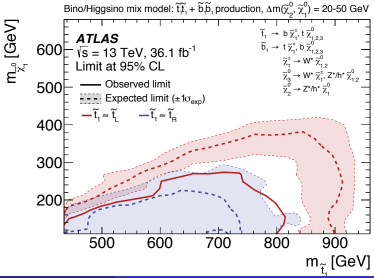
- Limits for right-handed and left-handed stops
  - Both stop and sbottom considered in $\tilde{t}_L$ scenario, doubles signal acceptance



0-lepton



1-lepton



Conclusions

- 3 interpretations from direct stop pair production with 0, 1, and 2 lepton final states
- pMSSM-inspired simplifed models were designed based on the Run-1 pMSSM and Run-2 simplifed models results
- New limits set for each of the models