Multiphoton signatures of supersymmetry

Christoffer Petersson

Université Libre de Bruxelles
International Solvay Institutes
Chalmers University of Technology

Email: christoffer.petersson@ulb.ac.be, christoffer.petersson@cern.ch
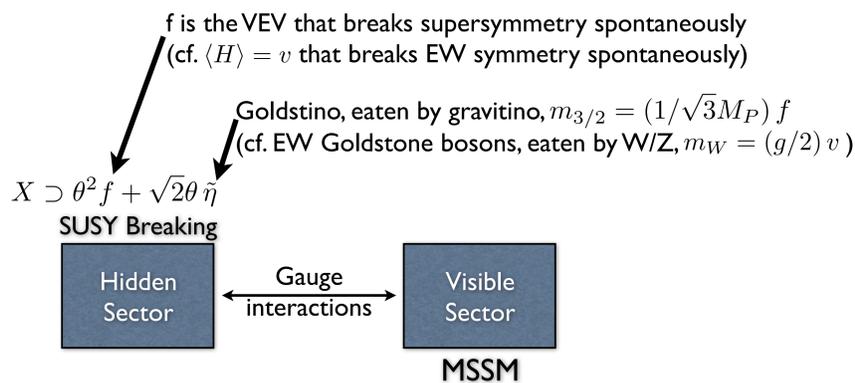
Abstract:

How is the usual phenomenology of gauge mediated supersymmetry breaking (GMSB) modified if one makes the non-minimal assumption that supersymmetry is broken in more than one hidden sector? Multiple hidden sector models give rise to light neutral fermions called pseudo-goldstini and due to the extra decay steps they give rise to, where soft photons are emitted, such models give rise to multiphoton plus missing energy signatures. The softness of these final state spectra make the existing LHC searches poorly sensitive. However, by performing a new LHC search, requiring the presence of additional (soft) photons in the final state, it would be possible to probe these models.

Based on a paper published in JHEP 1404 (2014) 126 (arXiv:1312.1698 [hep-ph]), done in collaboration with G. Ferretti, A. Mariotti and K. Mawatari.

---

1 Standard case: One hidden sector

f is the VEV that breaks supersymmetry spontaneously
(cf. $\langle H \rangle = v$ that breaks EW symmetry spontaneously)

Goldstino, eaten by gravitino, $m_{3/2} = (1/\sqrt{3}M_P) f$
(cf. EW Goldstone bosons, eaten by W/Z, $m_W = (g/2) v$)

$X \supset \theta^2 f + \sqrt{2}\theta\,\tilde{\eta}$

SUSY Breaking

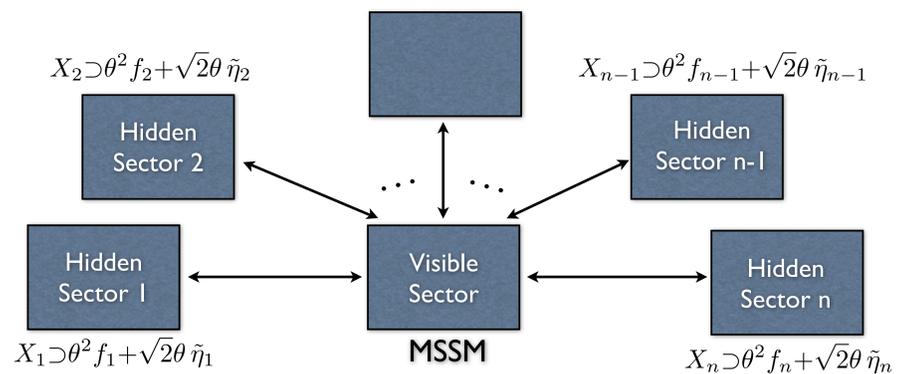Hidden Sector ←Gauge interactions→ Visible Sector

MSSM

- In GMSB, the LSP is the nearly massless gravitino

- Assuming R-parity, the NLSP decays to its SM partner and the gravitino

- The Bino and the right-handed sleptons are often among the lightest SM superpartners

Question: What if SUSY is broken in more than one hidden sector?
(cf. EW symmetry is broken both by the Higgs VEV and the QCD quark condensate)

2 Non-standard case: Multiple hidden sectors

$X_2 \supset \theta^2 f_2 + \sqrt{2}\theta\,\tilde{\eta}_2$ $X_{n-1} \supset \theta^2 f_{n-1} + \sqrt{2}\theta\,\tilde{\eta}_{n-1}$

Hidden Sector 2   · · · · · ·   Hidden Sector n-1

Hidden Sector 1   Visible Sector   Hidden Sector n

$X_1 \supset \theta^2 f_1 + \sqrt{2}\theta\,\tilde{\eta}_1$ MSSM $X_n \supset \theta^2 f_n + \sqrt{2}\theta\,\tilde{\eta}_n$

- The n additional neutral fermions $\tilde{\eta}_i$ extend the 4 by 4 MSSM neutralino mass matrix to an (4+n) by (4+n) matrix

- The true goldstino $\tilde{G}$ (i.e. the mode that is eaten by the gravitino) is given by one linear combination $\tilde{G} = (f_1\tilde{\eta}_1 + \cdots + f_n\tilde{\eta}_n)/f$

- The other n-1 linear combinations $\tilde{G}', \tilde{G}'', \ldots$ are pseudo-goldstini, they are not protected by the Goldstone theorem and hence they will acquire masses

$\tilde{G}''$ / $\tilde{G}'$ / · · · / $\tilde{G}$

3 Phenomenological consequences

$\tilde{\chi}$ / γ / $\tilde{G}''$ / γ / $\tilde{G}'$ / · / · / · / $\tilde{G}$
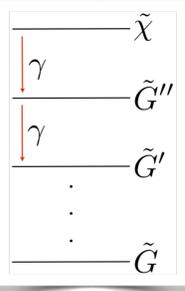
- If the lightest MSSM-particle is a Bino-like neutralino $\tilde{\chi}$, it turns out that it dominantly decays to a photon and the heaviest pseudo-goldstino $\tilde{G}''$

- In contrast to standard GMSB, where the neutralino decays to a photon and the nearly massless gravitino, due to the mass of $\tilde{G}''$, the photon will here be softer (also the amount of MET will here be smaller)

- If there are more than 2 hidden sectors, the heaviest pseudo-goldstino can decay promptly to a photon and a lighter pseudo-goldstino

Two main features of multiple hidden sector models:
- Softer final state spectrum than in standard GMSB
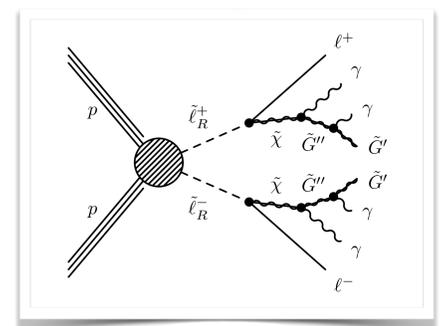- Additional (soft) photons in the final state

4 Simplified model with 3 hidden sectors

- We include the right-handed sleptons as one example of a SUSY production mode (one can consider other SUSY particles being light, and produced, and decaying to $\tilde{\chi}$)

$\tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R$ / e, μ, τ / $\tilde{\chi}$ / γ / $\tilde{G}''$ / γ / $\tilde{G}'$
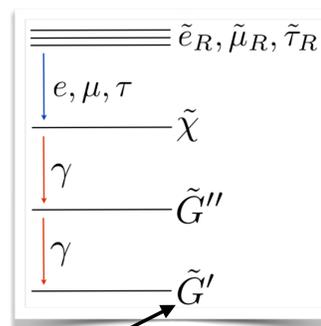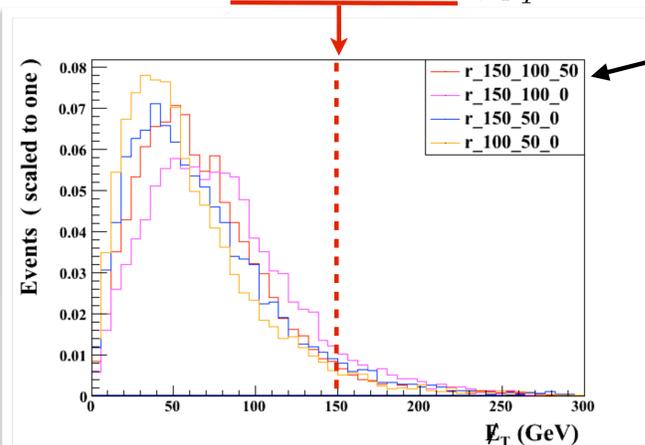
Stable on collider time scales

$2\ell + 4\gamma + \mathrm{MET}$
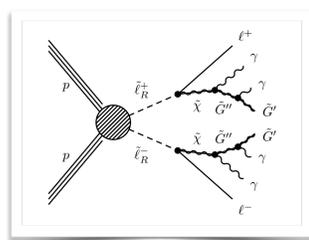
5 Comparison to existing LHC searches

- The most relevant one is the inclusive ATLAS diphoton+MET search [ATLAS-CONF-2014-001], in which the following cuts are employed:

$$\mathrm{MET} > 150\,\mathrm{GeV} \ , \ p_T^{\gamma_{1,2}} > 75\,\mathrm{GeV}$$

Benchmarks:

	r_150_100_50
	r_150_100_0
	r_150_50_0
	r_100_50_0

M_{ℓ_R}	M_χ	$M_{G''}$	$M_{G'}$
200	150	100	50
200	150	100	0
200	150	50	0
200	100	50	0

Events (scaled to one) vs $\not{E}_T$ (GeV)

Due to the small amount of MET, as well as the softness of the photons, current LHC searches are poorly sensitive to multiple hidden sector models.

6 Proposal for a new LHC search

- In order to be model-independent in terms of the SUSY production mode, we focus only on the last decay steps, from which the photons and the MET originate.

- From our simulations of this signal process we estimate that the following numbers of signal events are present already in the existing 8 TeV data set, i.e. with 20 fb⁻¹

final state	MET	150-100-50	150-100-0	150-50-0	100-50-0
3γ	(0-50)	32	25	39	43
	(50-100)	34	37	32	27
	(100-∞)	11	19	14	9
final state	MET	150-100-50	150-100-0	150-50-0	100-50-0
4γ	(0-50)	16	13	19	18
	(50-100)	15	19	13	9
	(100-∞)	3.4	8.3	5.6	3.0

- We have required each photon to have $p_T > 20\,\mathrm{GeV}$, $|\eta| < 2.5$, $\Delta R > 0.4$

- For example, a search in the final state with 4 photons and MET>50 GeV could lead to a discovery (or very strong bounds) already with the existing data set

We propose an inclusive search in the final state with $(3/4)\gamma + \mathrm{MET}$ (with minimal requirements on the photons)