Multiphoton signatures of supersymmetry

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Based on:

G. Ferretti, A. Mariotti, K. Mawatari, C.P.
JHEP 1404 (2014) 126 (arXiv:1312.1698)

Motivations

- So far the LHC has not seen any clear signal of BSM physics

- However, so far the LHC has mainly probed minimal BSM scenarios

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This motivates:
- Non-minimal models
- Non-standard signatures at the LHC
- New LHC searches and strategies

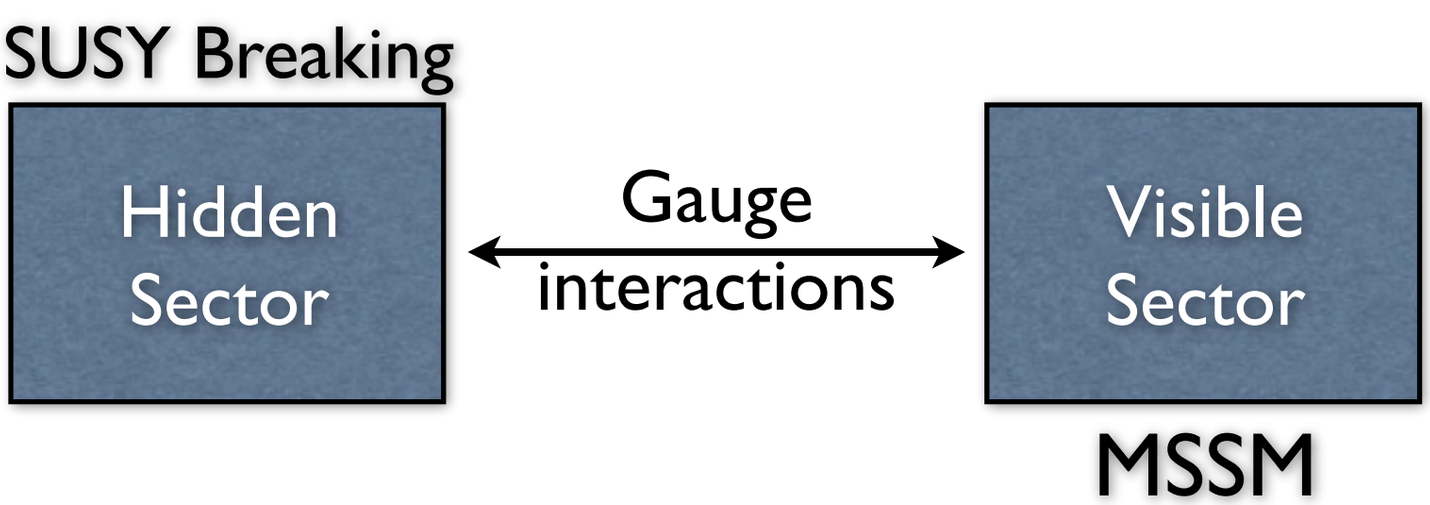
Plan of the talk and results

- General remarks on SUSY breaking and GMSB

- Exercise: Study how the standard phenomenology of GMSB is modified if SUSY is broken in more than one hidden sector.

- Results: - Softer final state spectrum
  - Existing LHC searches are poorly sensitive
  - Additional photons in the final states
  - These models can be probed with new, dedicated, searches

Standard case: One hidden sector

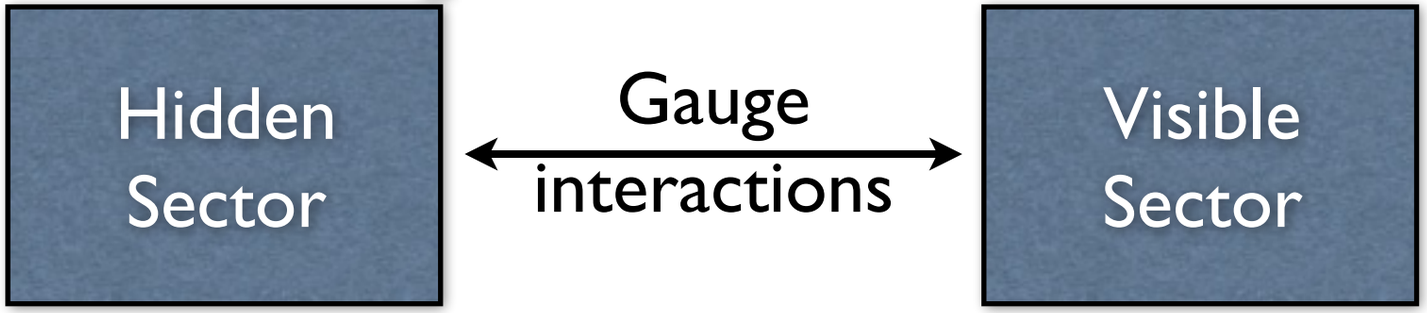


Standard case: One hidden sector

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

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

SUSY Breaking



MSSM

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, $m_W = (g/2)\, v$)

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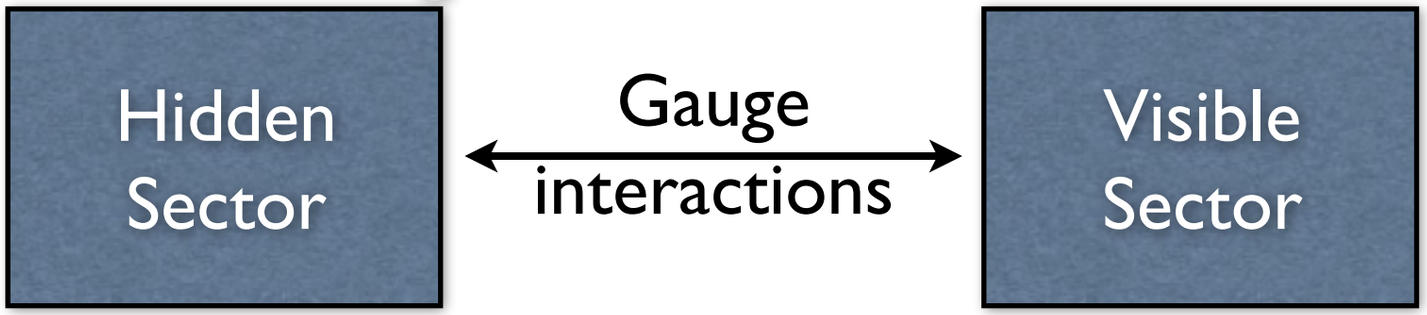
SUSY Breaking



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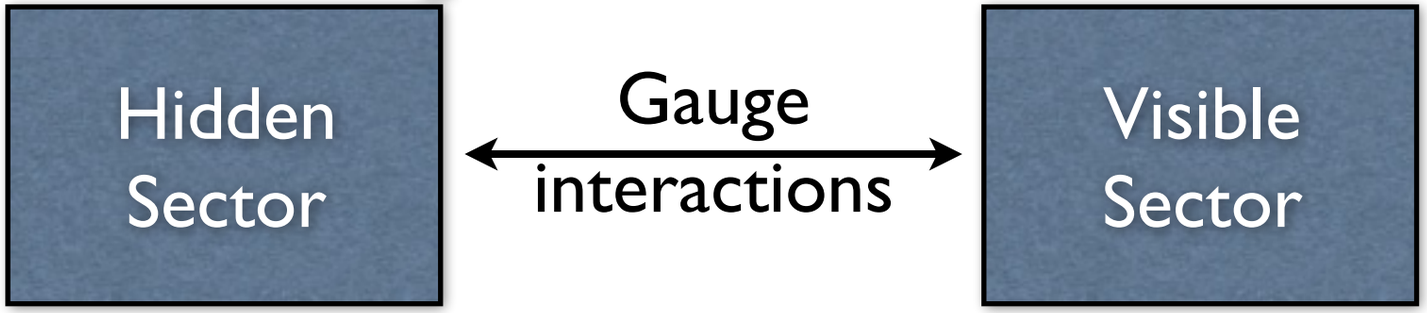
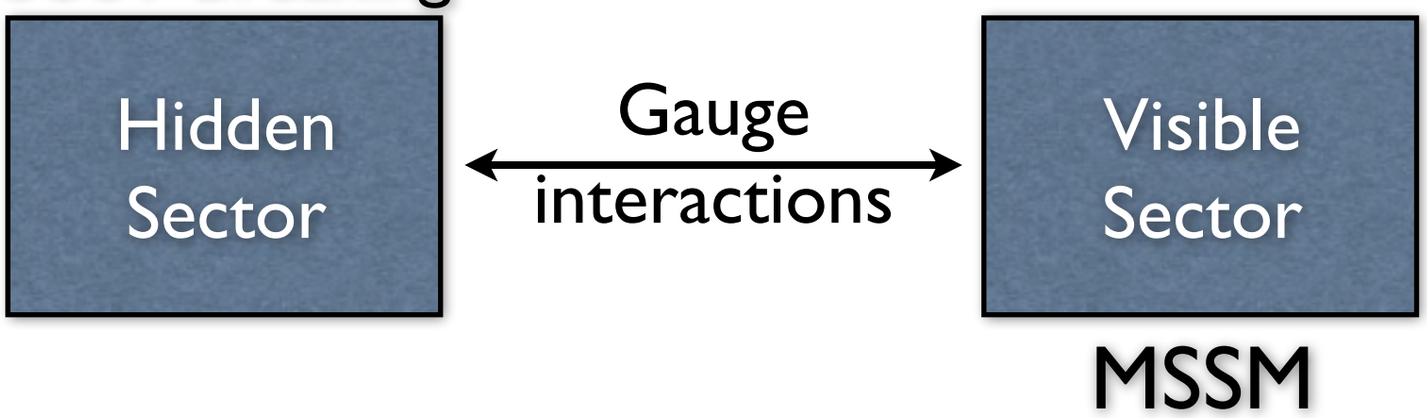


- In GMSB, the LSP is the nearly massless gravitino
- Assuming R-parity, the NLSP decays to its SM partner and the gravitino
- The Bino and the right-handed sleptons are often among the lightest SM superpartners

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)

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



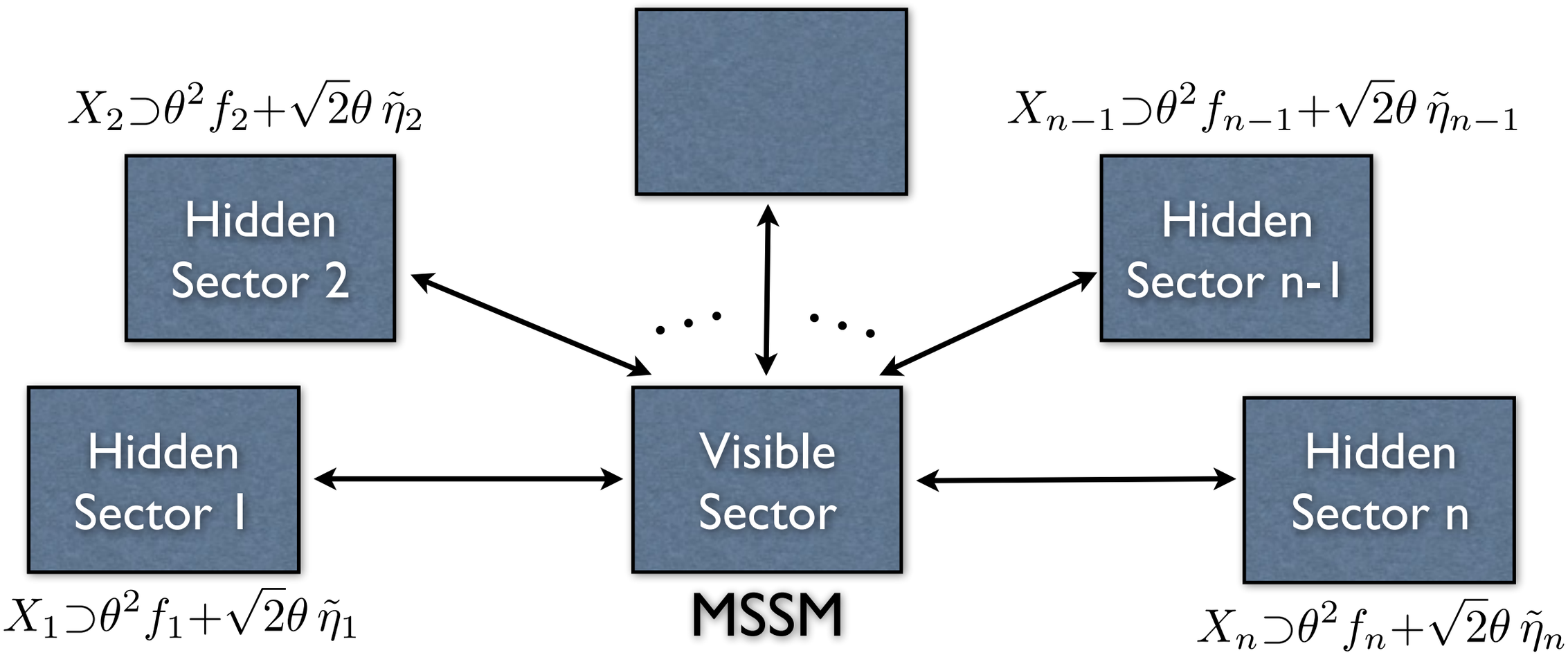
Previous studies of multiple hidden sector models in the context of gravity mediation:

[Benakli,Moura] [Cheung,Nomura,Thaler] [Craig,March-Russell,McCullough] [Izawa,Nakai,Shimomura] [Thaler,Thomas] [Cheung,D'Eramo,Thaler] [Cheng,Huang,Low,Menon][Bertolini,Rehermann,Thaler]

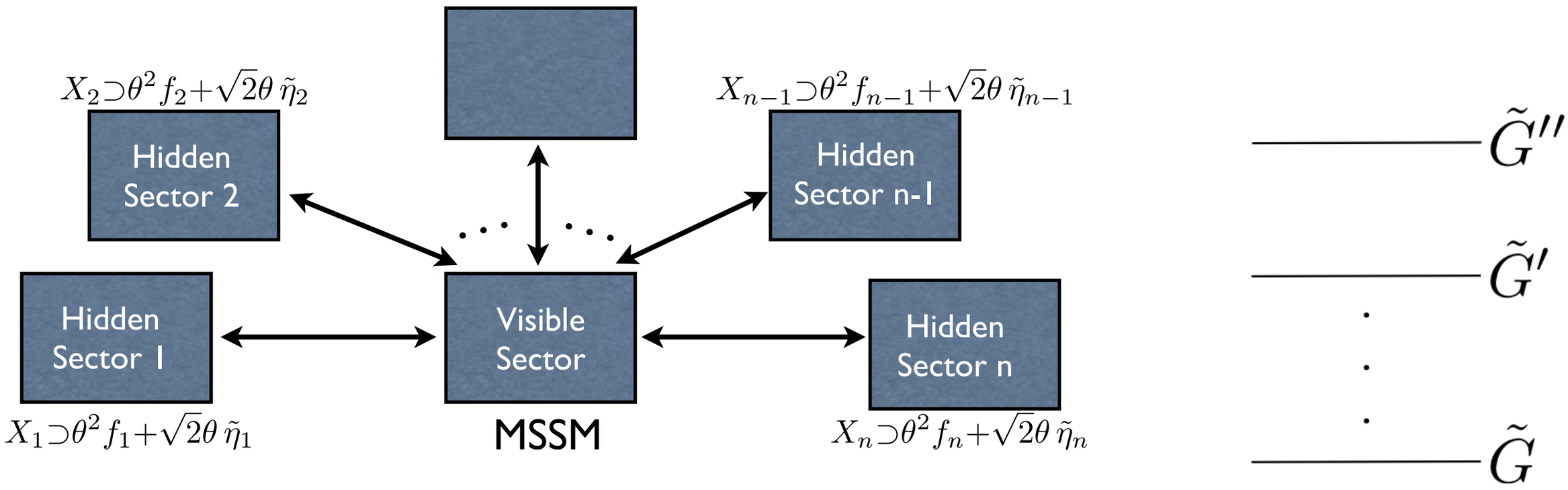
Multiple hidden sector models in the context of gauge mediation:

[Argurio,Komargodski,Mariotti] [Argurio,De Causmaecker,Ferretti,Mariotti,Mawatari,Takaesu] [Liu,Wang,Yang]

Multiple hidden sectors



Multiple hidden sectors

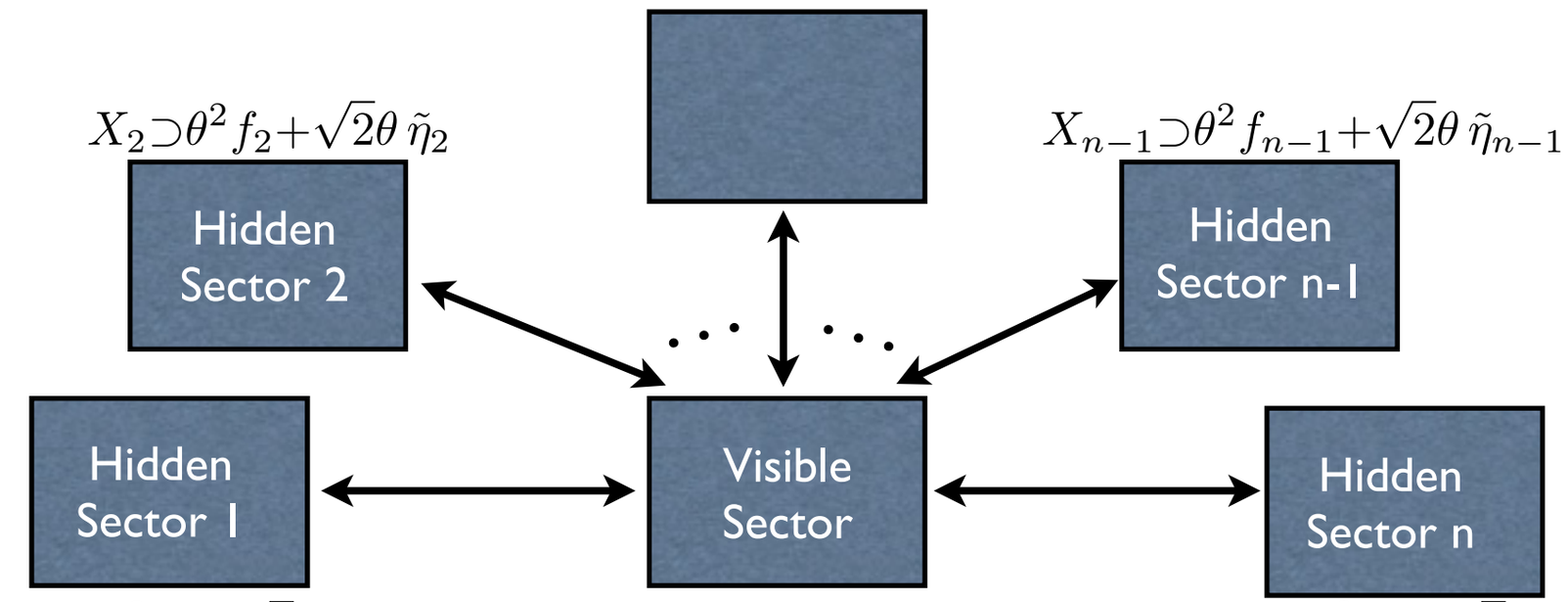


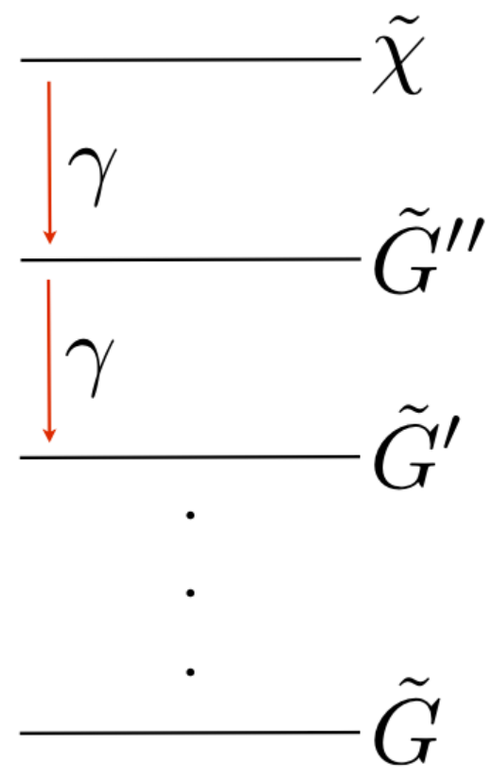
- The n additional neutral fermions $\tilde{\eta}_i$ extend the 4 by 4 MSSM neutralino mass matrix to an (4+n) by (4+n) matrix

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

- All the other n-1 linear combinations $\tilde{G}', \tilde{G}''$, ... are pseudo-goldstini, and they acquire masses at the tree and radiative level

Multiple hidden sectors





- If the Lightest MSSM SUSY Particle is a Bino-like neutralino, it dominantly decays to a photon and the heaviest pseudo-goldstini

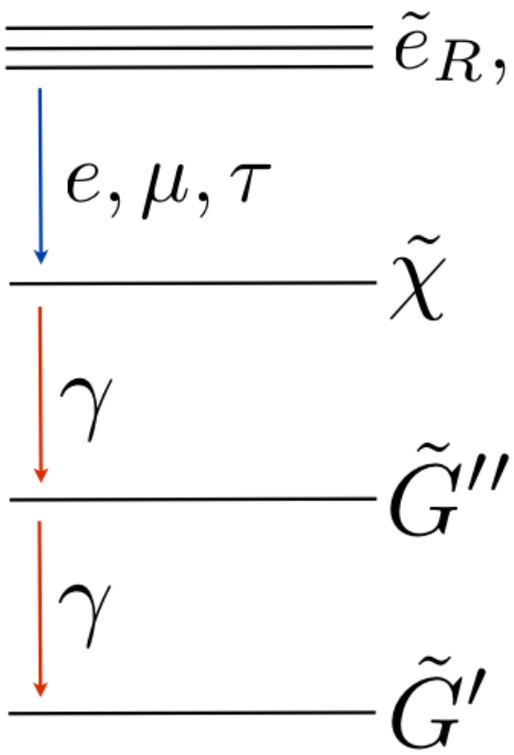
  → Softer final state spectrum

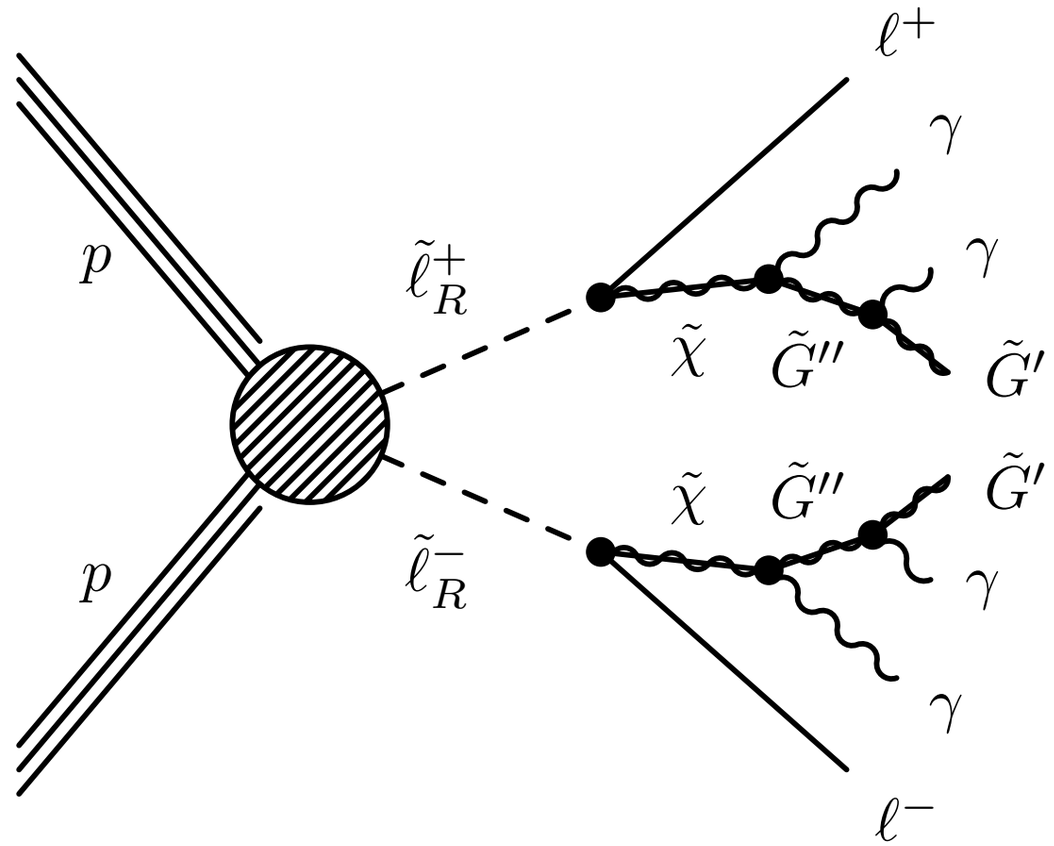
- If there are more than 2 hidden sectors, the pseudo-goldstino can decay to a photon and a lighter pseudo-goldstino

  → Additional (soft) photons in the final state

Simplified model of GMSB with goldstini

3 Hidden sectors

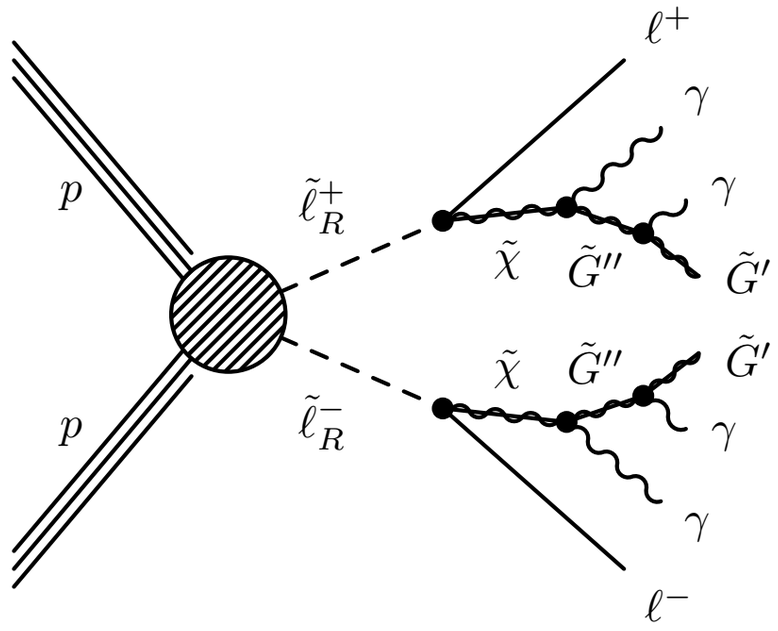




$$\ell^+\ell^- + 4\gamma + \mathrm{MET}$$

Comparing with existing LHC searches

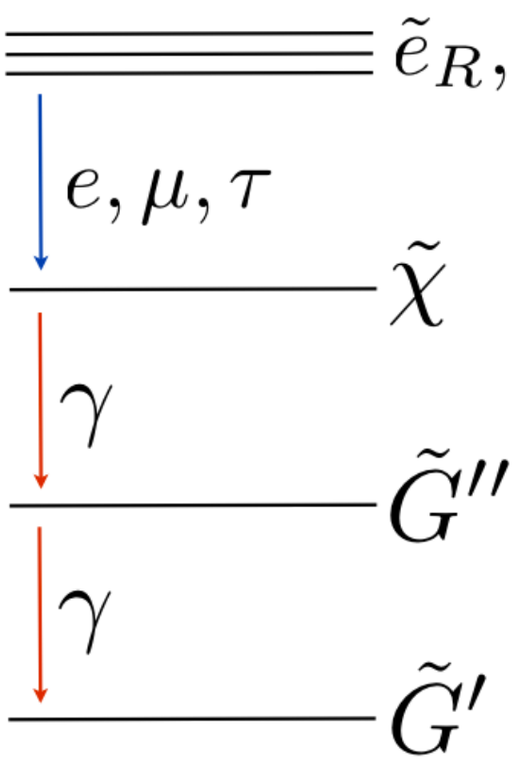
- CMS diphoton+MET search, CMS-PAS-SUS-12-018 (jet requirement)
- ATLAS lepton+photon+MET search, ATLAS-CONF-2012-144 (tight cuts)
- Dileptons+MET searches have too large backgrounds
- The most relevant search is the inclusive ATLAS diphoton+MET search, [arXiv:1209.0753 [hep-ex]]
- Updated diphoton+MET search in ATLAS-CONF-2014-001 (however, less sensitive due to tighter cuts)

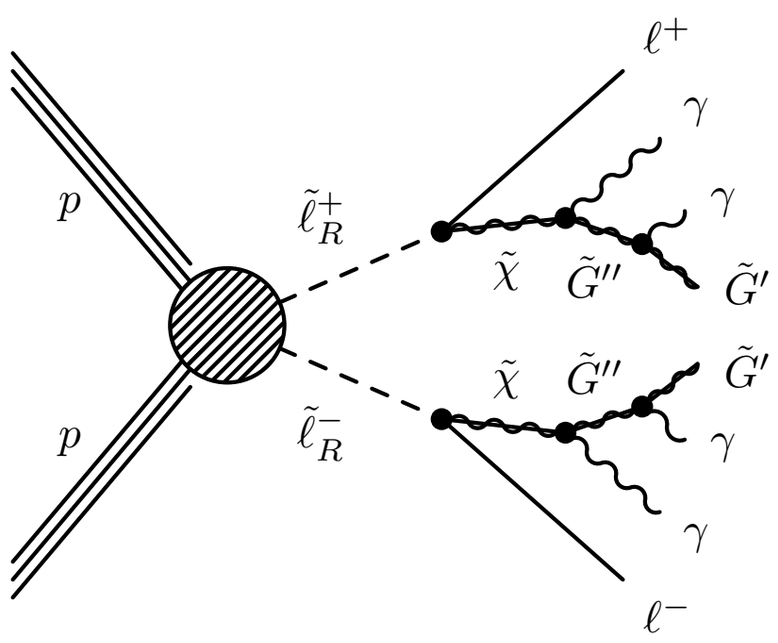


Comparing with existing LHC searches

- The most relevant search is the inclusive ATLAS diphoton+MET search [arXiv:1209.0753 [hep-ex]]

$$p_T^{\gamma_{1,2}} > 50\,\mathrm{GeV}\ ,\ \mathrm{MET} > 125\,\mathrm{GeV}$$





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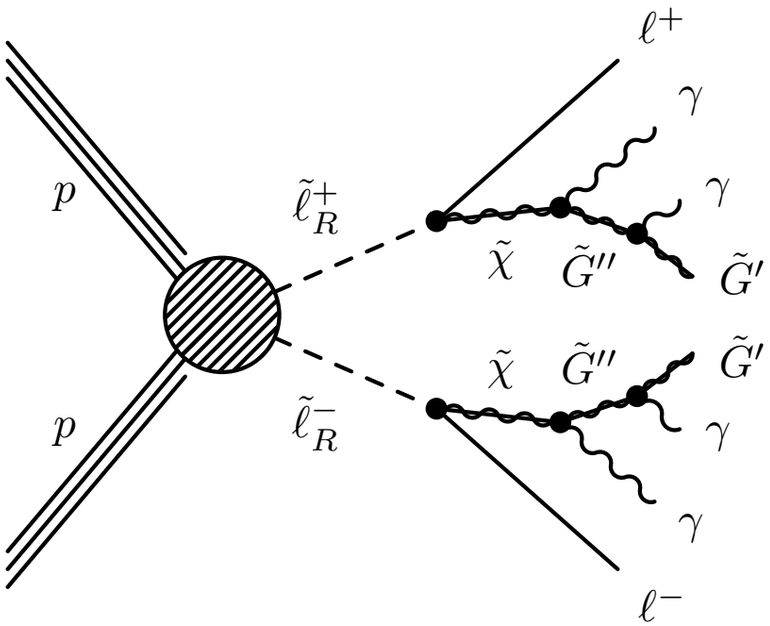
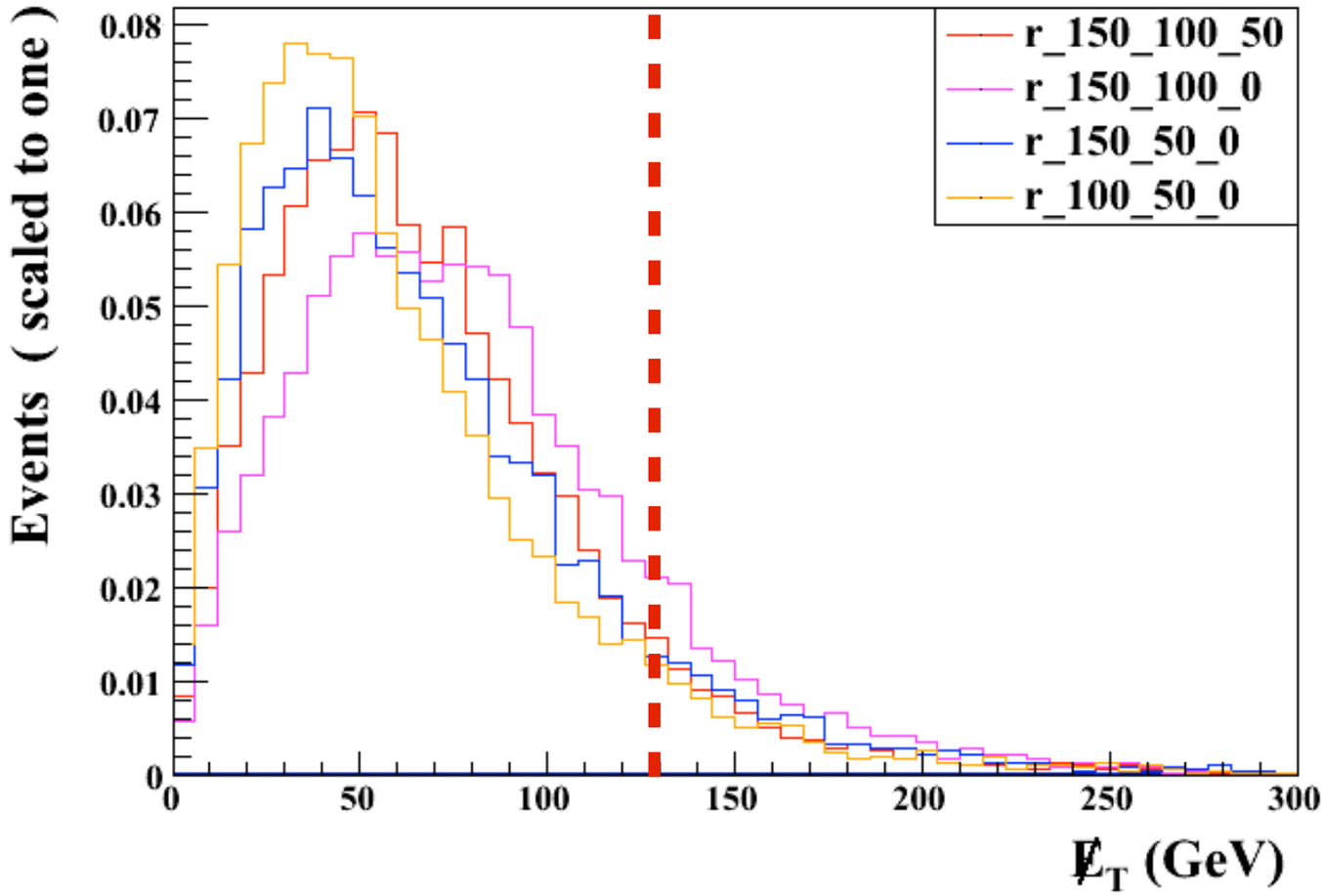


M_{ℓ_R}	M_χ	$M_{G''}$	$M_{G'}$
200	150	100	50
200	150	100	0
200	150	50	0
200	100	50	0



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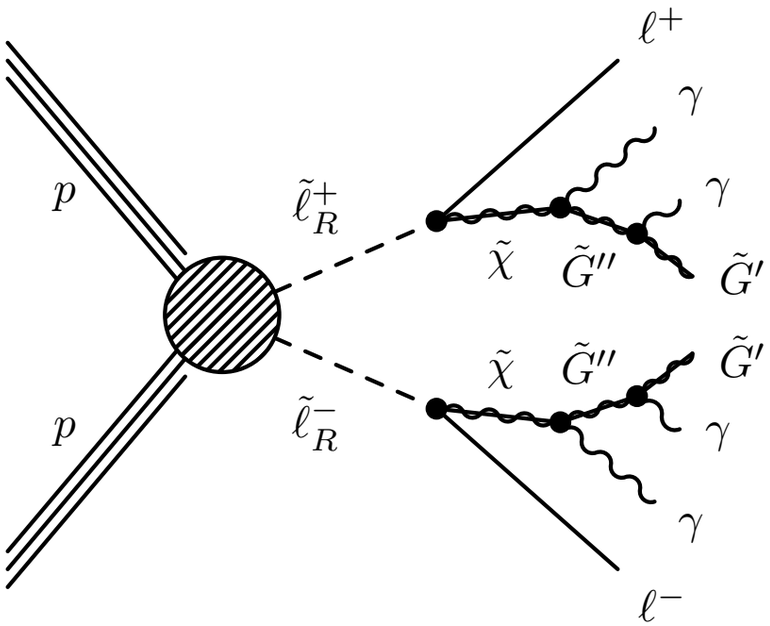

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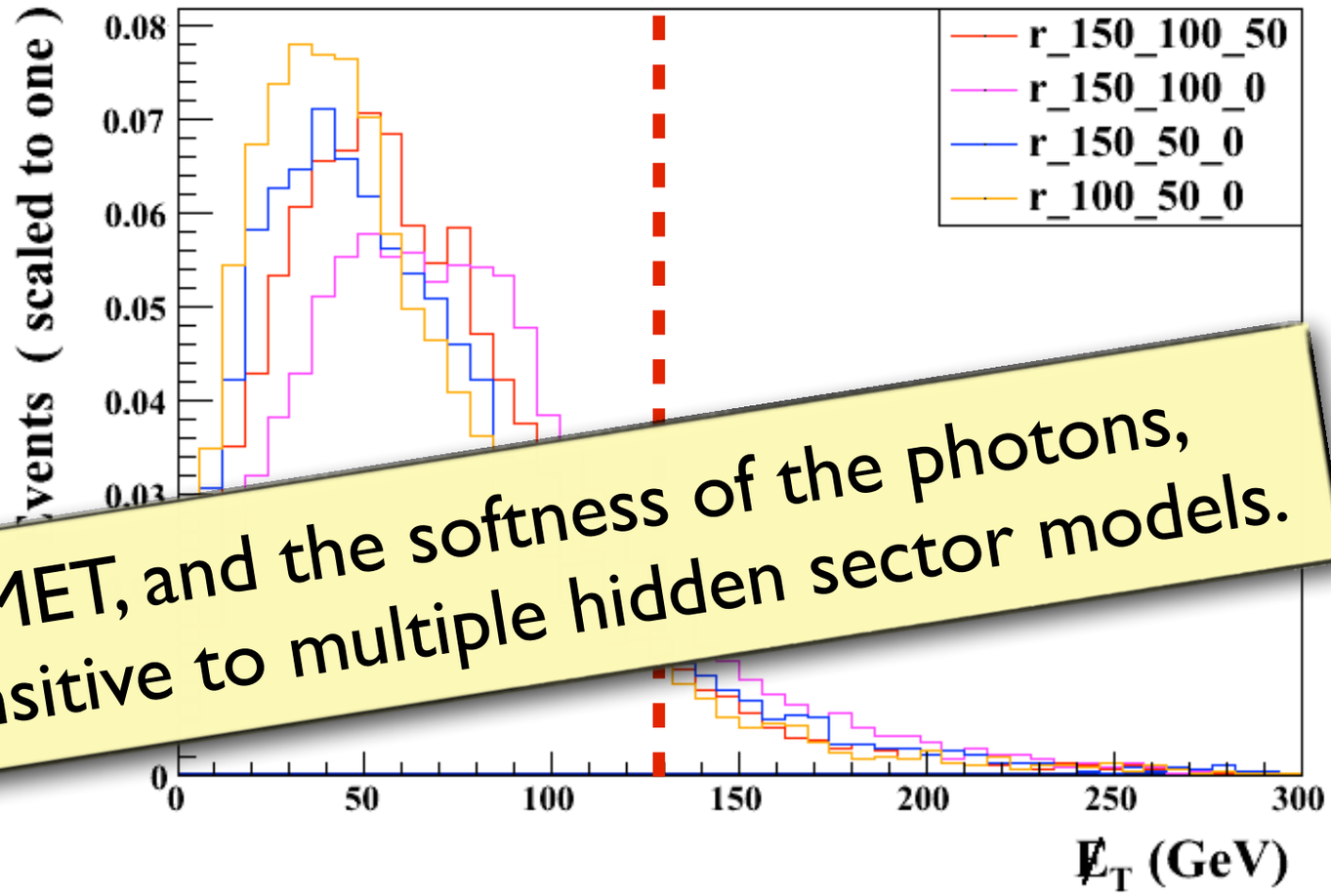
200			
			0



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

Proposal for new LHC search

Number of signal events with 20 fb^{-1} of data at LHC-8TeV

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
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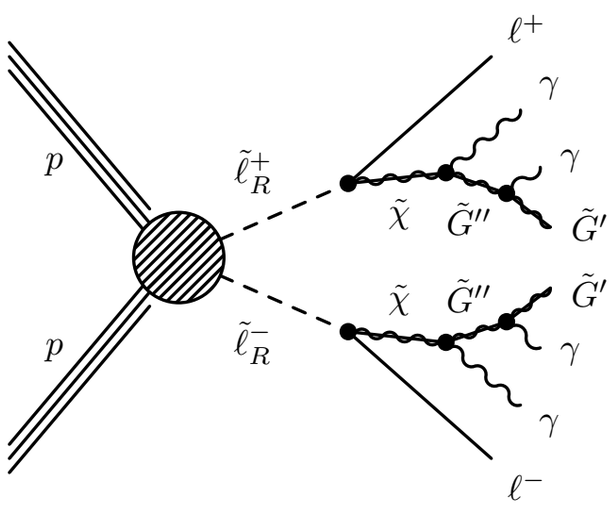
	(100-∞)	3.4	8.3	5.6	3.0



$$p_T > 20 \text{ GeV} \ , \ |\eta| < 2.5 \ , \ \Delta R > 0.4$$

M_{ℓ_R}	M_χ	$M_{G''}$	$M_{G'}$
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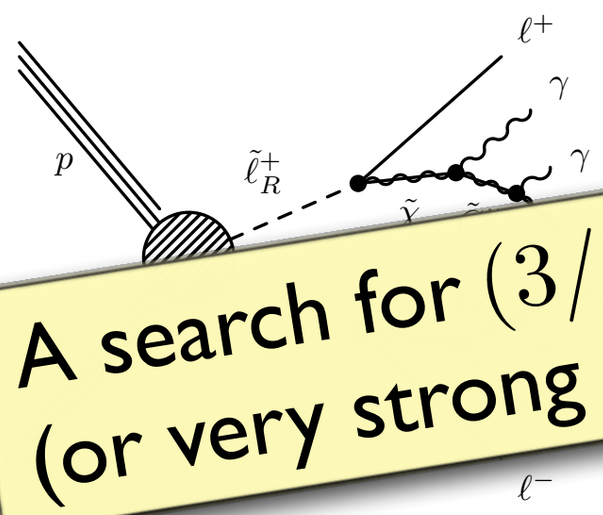


		100	50
200	150	100	0
200	150	50	0
200	100	50	0

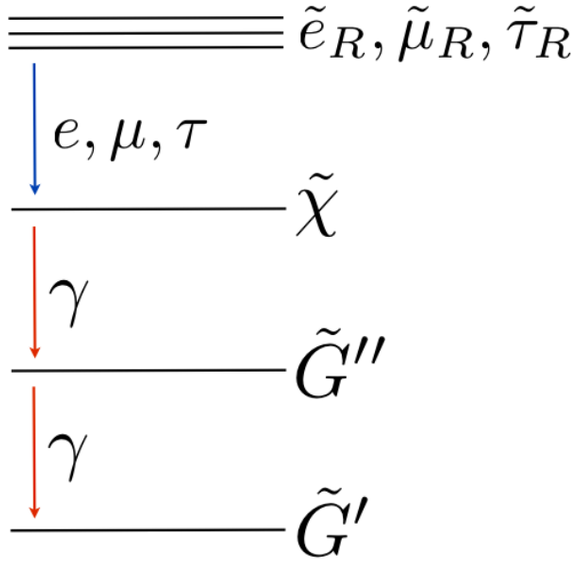
$\Delta R > 0.4$

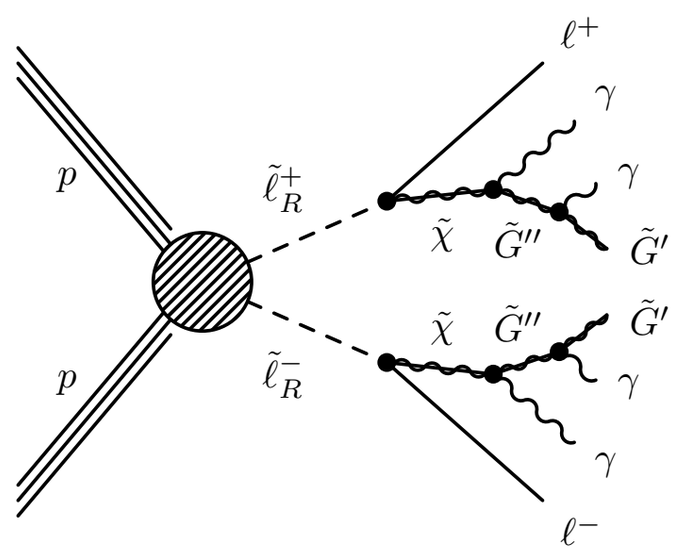
A search for $(3/4)\gamma + \mathrm{MET}$ could lead to a discovery (or very strong constraints) already with the existing LHC data set!

Conclusions

In GMSB models with multiple hidden sectors, the presence of pseudo-goldstini implies final state spectra which are soft but involve additional photons.

Focused on slepton pair production, one could consider other production modes





Proposed searches:

$$(3/4)\gamma + \mathrm{MET}$$

$$\ell^+\ell^- + (\geqslant 2)\gamma + \mathrm{MET}$$

Thank you!