Light neutralino dark matter in MSSM

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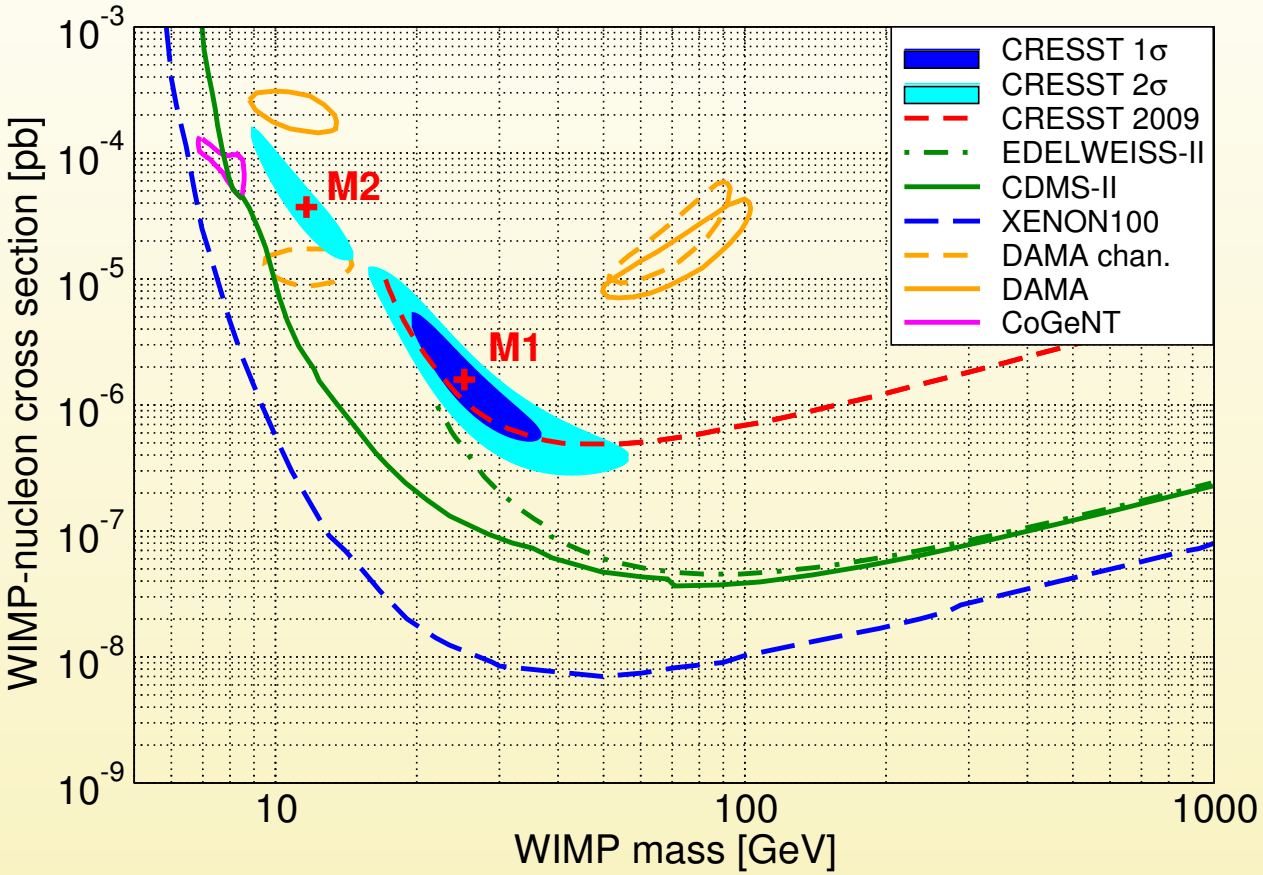
In collaboration with A. Arbey and M. Battaglia

Status of Dark Matter Direct Detection



CRESST, Eur.Phys.J. C72 (2012) 1971

The constrained MSSM scenarios provide no candidate "compatible" with DAMA, CoGeNT, CRESST and XENON data

Flat scans over the pMSSM 19 parameters.

Using many codes: `SuperIso Relic`, `SoftSusy`, `FeynHiggs`, `Hdecay`, `Sdecay`, `Higgsbounds`, `Micromegas`, `Prospino`, `Pythia and Delphes`, **with** `SuperIso` **as the central core.**

$2.16 \times 10^{-4} < \text{BR}(B \to X_s\gamma) < 4.93 \times 10^{-4}$
$\text{BR}(B_s \to \mu^+\mu^-) < 5.0 \times 10^{-9}$
$0.56 < \text{R}(B \to \tau\nu) < 2.70$
$4.7 \times 10^{-2} < \text{BR}(D_s \to \tau\nu) < 6.1 \times 10^{-2}$
$2.9 \times 10^{-3} < \text{BR}(B \to D^0\tau\nu) < 14.2 \times 10^{-3}$
$0.985 < \text{R}_{\mu 23}(K \to \mu\nu) < 1.013$
$-2.4 \times 10^{-9} < \delta a_\mu < 4.5 \times 10^{-9}$
+ sparticle mass lower bounds
+ Higgs search limits **122.5 GeV** $< M_h <$ **127.5 GeV**
+ neutralino LSP
Loose WMAP limits: $10^{-4} < \Omega_\chi h^2 < 0.155$
Tight WMAP limits: $0.068 < \Omega_\chi h^2 < 0.155$

Particle	Limits	Conditions
$\tilde{\chi}_2^0$	62.4	$\tan\beta < 40$
$\tilde{\chi}_3^0$	99.9	$\tan\beta < 40$
$\tilde{\chi}_4^0$	116	$\tan\beta < 40$
$\tilde{\chi}_1^\pm$	92.4	$m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} < 4$ GeV
	103.5	$m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} > 4$ GeV
$\tilde{e}_R$	73	
$\tilde{e}_L$	107	
$\tilde{\tau}_1$	81.9	$m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} > 15$ GeV
$\tilde{u}_R$	100	$m_{\tilde{u}_R} - m_{\tilde{\chi}_1^0} > 10$ GeV
$\tilde{u}_L$	100	$m_{\tilde{u}_L} - m_{\tilde{\chi}_1^0} > 10$ GeV
$\tilde{t}_1$	95.7	$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} > 10$ GeV
$\tilde{d}_R$	100	$m_{\tilde{d}_R} - m_{\tilde{\chi}_1^0} > 10$ GeV
$\tilde{d}_L$	100	$m_{\tilde{d}_L} - m_{\tilde{\chi}_1^0} > 10$ GeV
$\tilde{b}_1$	248	$m_{\tilde{\chi}_1^0} < 70$ GeV, $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 30$ GeV
	220	$m_{\tilde{\chi}_1^0} < 80$ GeV, $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 30$ GeV
	210	$m_{\tilde{\chi}_1^0} < 100$ GeV, $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 30$ GeV
	200	$m_{\tilde{\chi}_1^0} < 105$ GeV, $m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 30$ GeV
	100	$m_{\tilde{b}_1} - m_{\tilde{\chi}_1^0} > 5$ GeV
$\tilde{g}$	195	

Details of the scans and results can be found in:

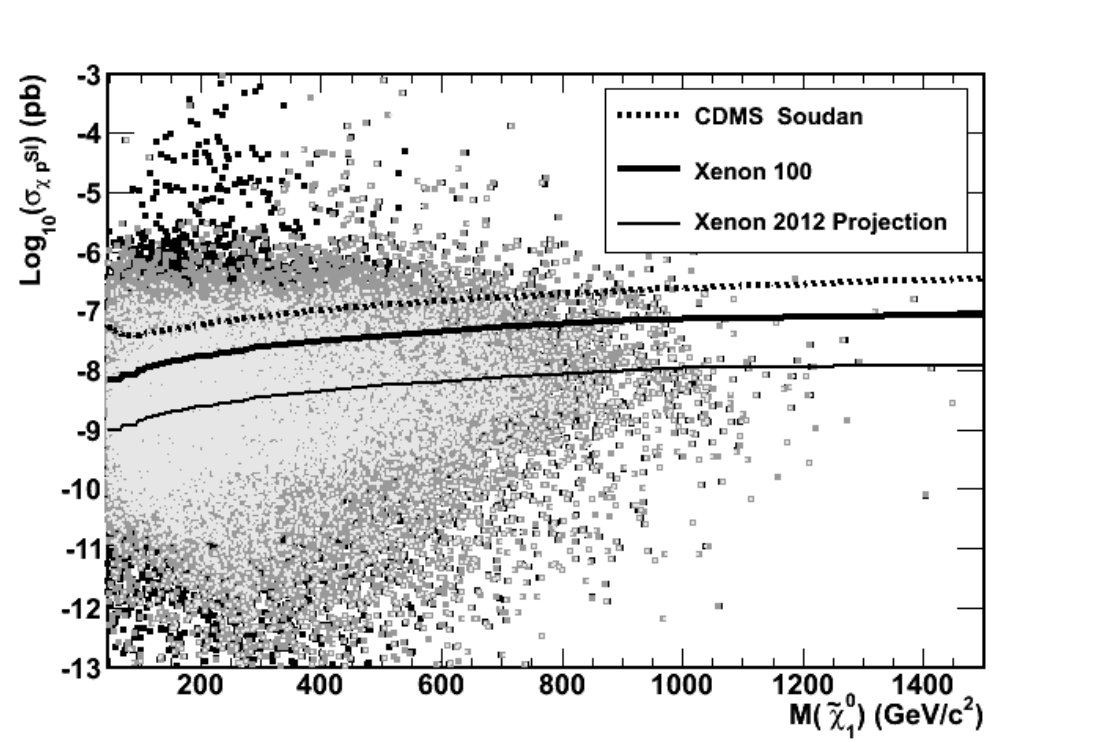
A. Arbey, M. Battaglia, F. Mahmoudi, Eur.Phys.J. C72 (2012) 1847

A. Arbey, M. Battaglia, F. Mahmoudi, Eur.Phys.J. C72 (2012) 1906

General scans in pMSSM: more than 60M generated points

Parameter	Range
$\tan\beta$	[1, 60]
M_A	[50, 2000]
M_1	[-2500, 2500]
M_2	[-2500, 2500]
M_3	[50, 2500]
$A_d = A_s = A_b$	[-10000, 10000]
$A_u = A_c = A_t$	[-10000, 10000]
$A_e = A_\mu = A_\tau$	[-10000, 10000]
μ	[-3000, 3000]
$M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$	[50, 2500]
$M_{\tilde{e}_R} = M_{\tilde{\mu}_R}$	[50, 2500]
$M_{\tilde{\tau}_L}$	[50, 2500]
$M_{\tilde{\tau}_R}$	[50, 2500]
$M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$	[50, 2500]
$M_{\tilde{q}_{3L}}$	[50, 2500]
$M_{\tilde{u}_R} = M_{\tilde{c}_R}$	[50, 2500]
$M_{\tilde{t}_R}$	[50, 2500]
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$	[50, 2500]
$M_{\tilde{b}_R}$	[50, 2500]

pMSSM points and XENON dark matter exclusion limit



A. Arbey, M. Battaglia, F. Mahmoudi, Eur.Phys.J. C72 (2012) 1847

About 20% of the points are excluded by XENON-100

Low-mass neutralino scans

Parameter	Range
$\tan\beta$	[1, 60]
M_A	[50, 2000]
M_1	[-300, 300]
M_2	[-650, 650]
M_3	[0, 2500]
$A_d = A_s = A_b$	[-10000, 10000]
$A_u = A_c = A_t$	[-10000, 10000]
$A_e = A_\mu = A_\tau$	[-10000, 10000]
μ	[-3000, 3000]
$M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$	[0, 2500]
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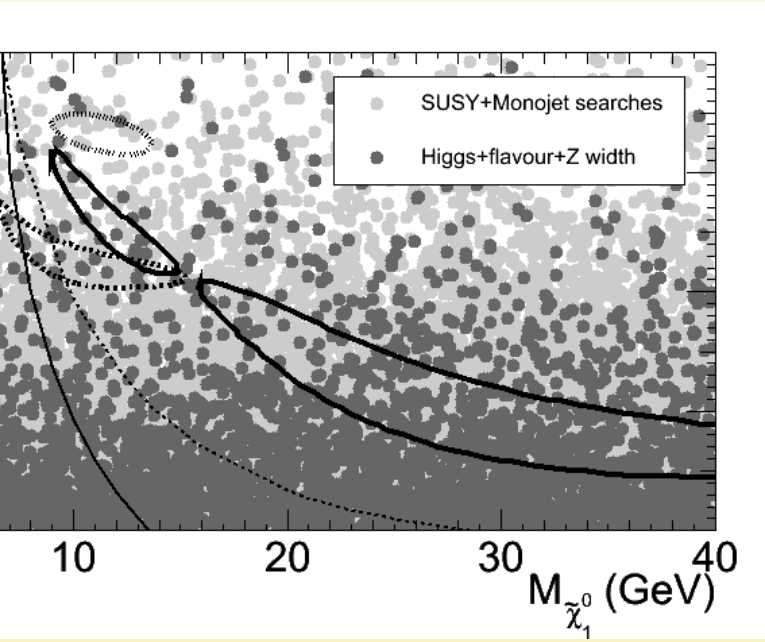
$M_{\tilde{t}_R}$	[0, 2500]
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$	[0, 2500]
$M_{\tilde{b}_R}$	[0, 2500]

Low mass neutralino scans: more than **one billion** generated points



Selection	pMSSM points
Valid points with light χ_1^0, large $\sigma(\chi - p)$	1 M

A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

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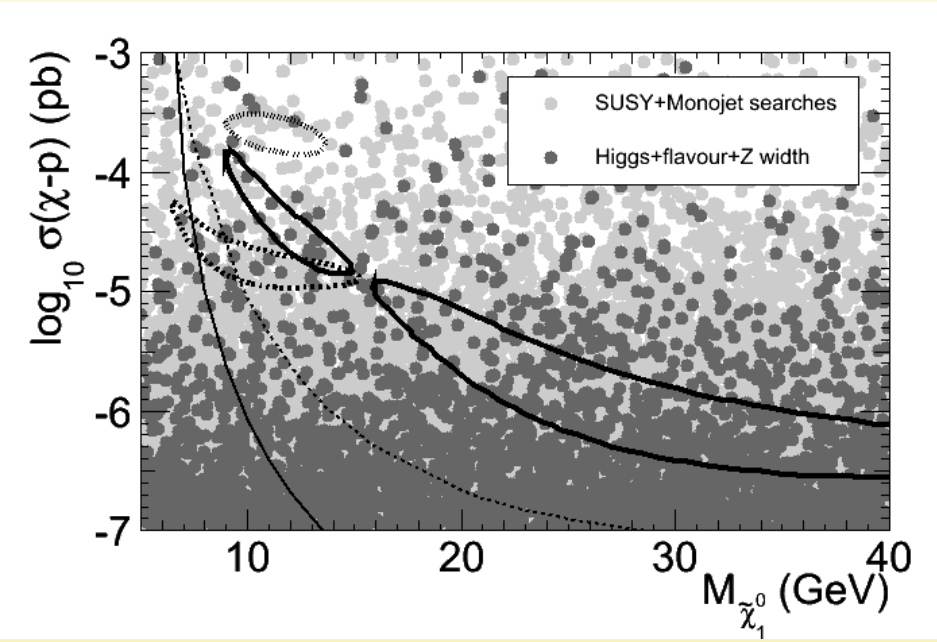

Selection	pMSSM points
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Monojet searches	280 k

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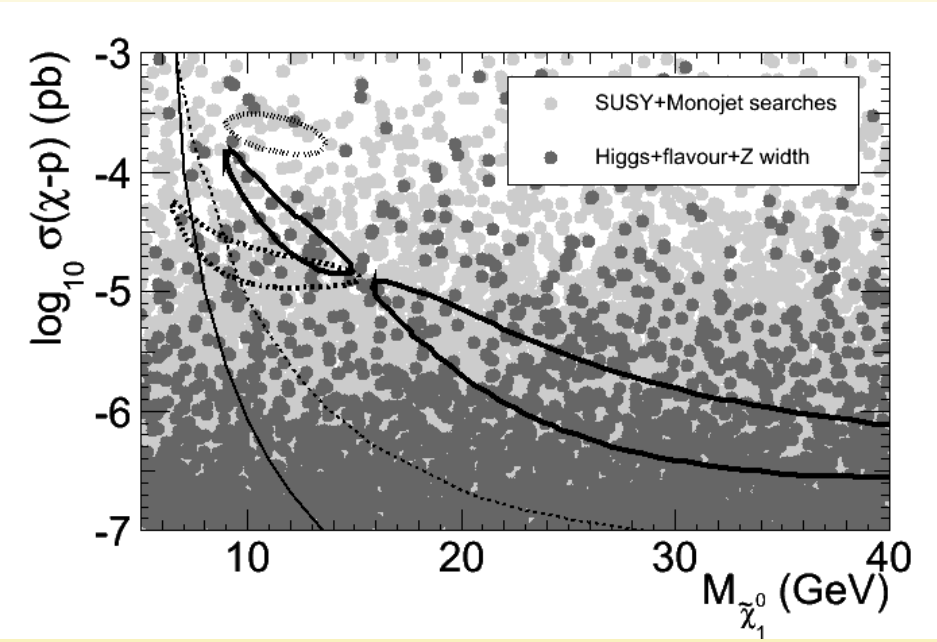

Selection	pMSSM points
Valid points with light χ_1^0, large $\sigma(\chi - p)$	1 M
Monojet searches	280 k
SUSY searches	90 k

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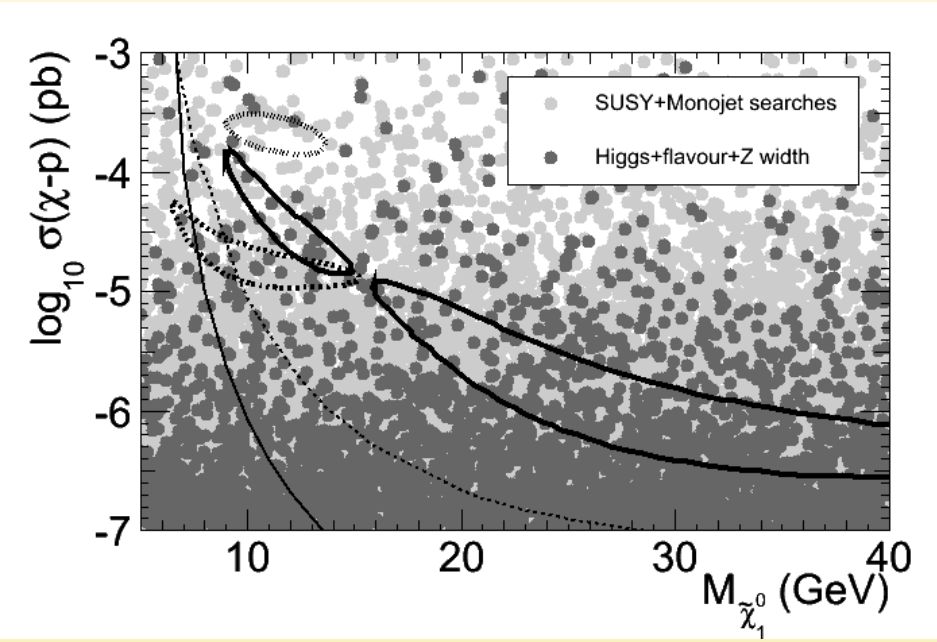

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Valid points with light χ_1^0, large $\sigma(\chi - p)$	1 M
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SUSY searches	90 k
LEP searches	50 k

A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

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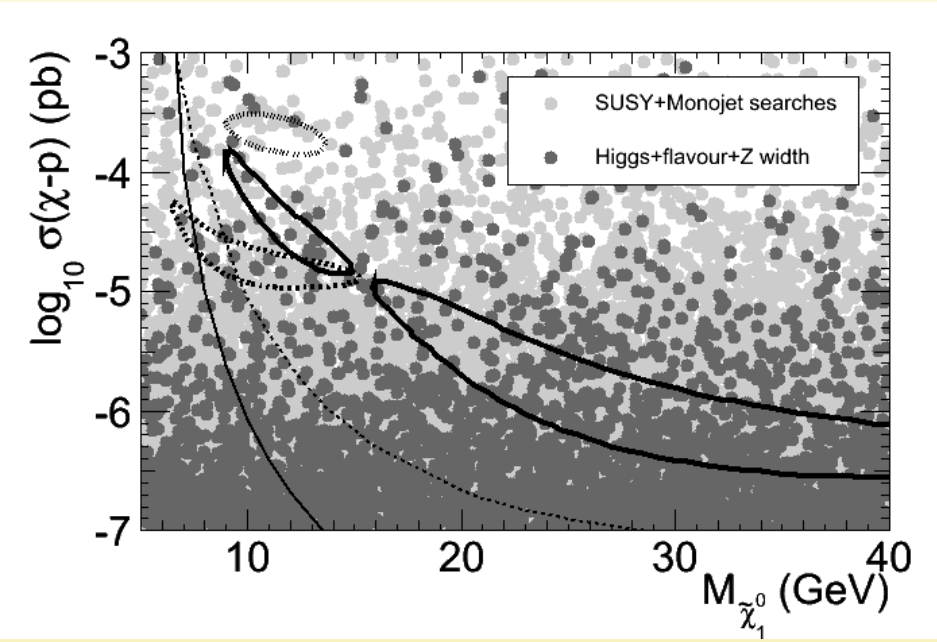

Selection	pMSSM points
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Monojet searches	280 k
SUSY searches	90 k
LEP searches	50 k
Flavour physics	20 k

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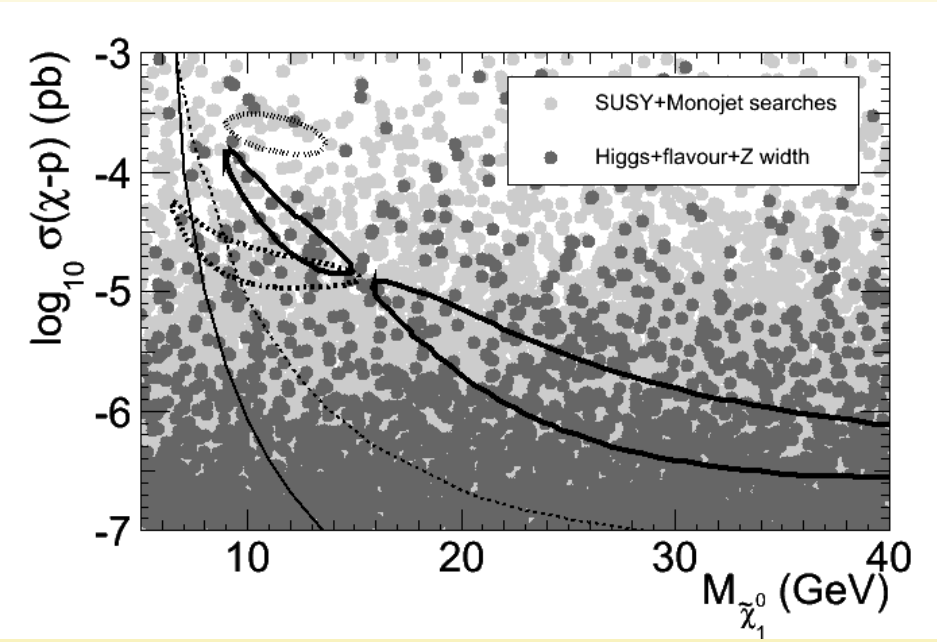
Low mass neutralino scans: more than **one billion** generated points



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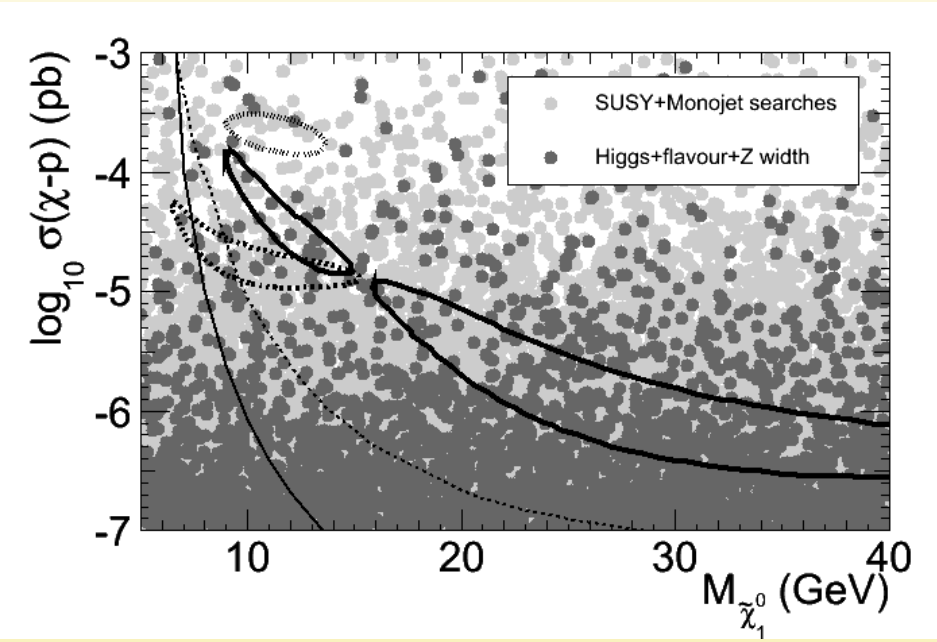

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LEP searches	50 k
Flavour physics	20 k
Higgs searches	10 k
Loose WMAP limit	20

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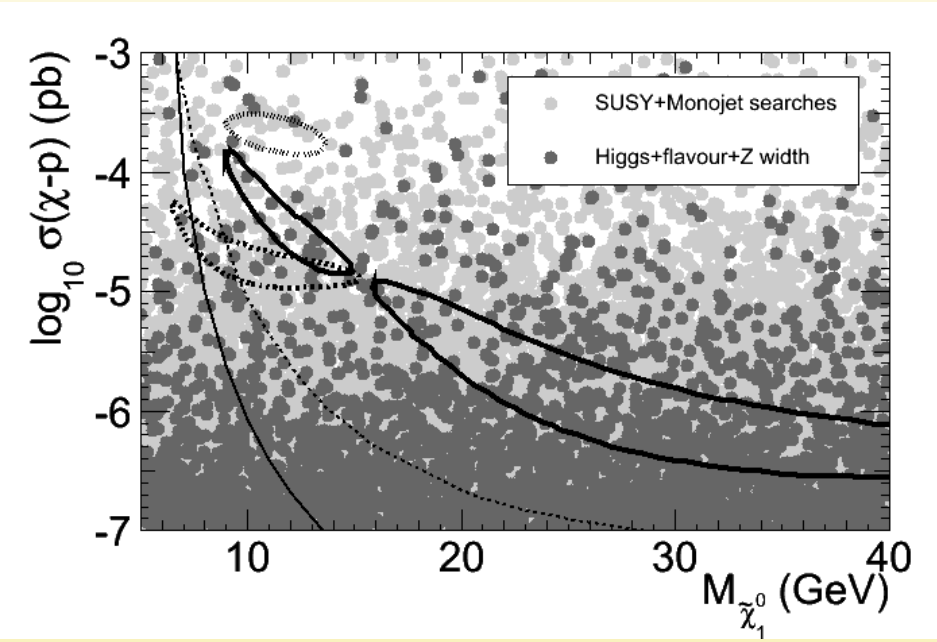
Low mass neutralino scans: more than **one billion** generated points



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Valid points with light χ_1^0, large $\sigma(\chi - p)$	1 M
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SUSY searches	90 k
LEP searches	50 k
Flavour physics	20 k
Higgs searches	10 k
Loose WMAP limit	20
Tight WMAP limit	5

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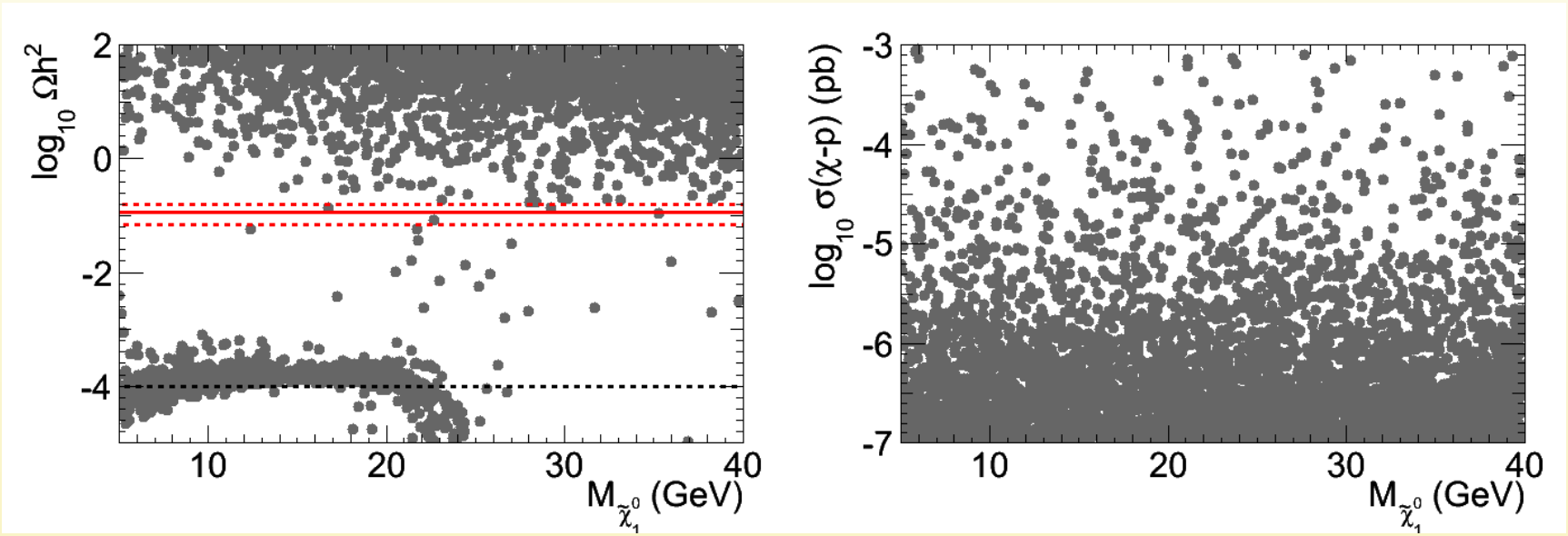
Difficult to have right amount of relic density and large scattering cross section!

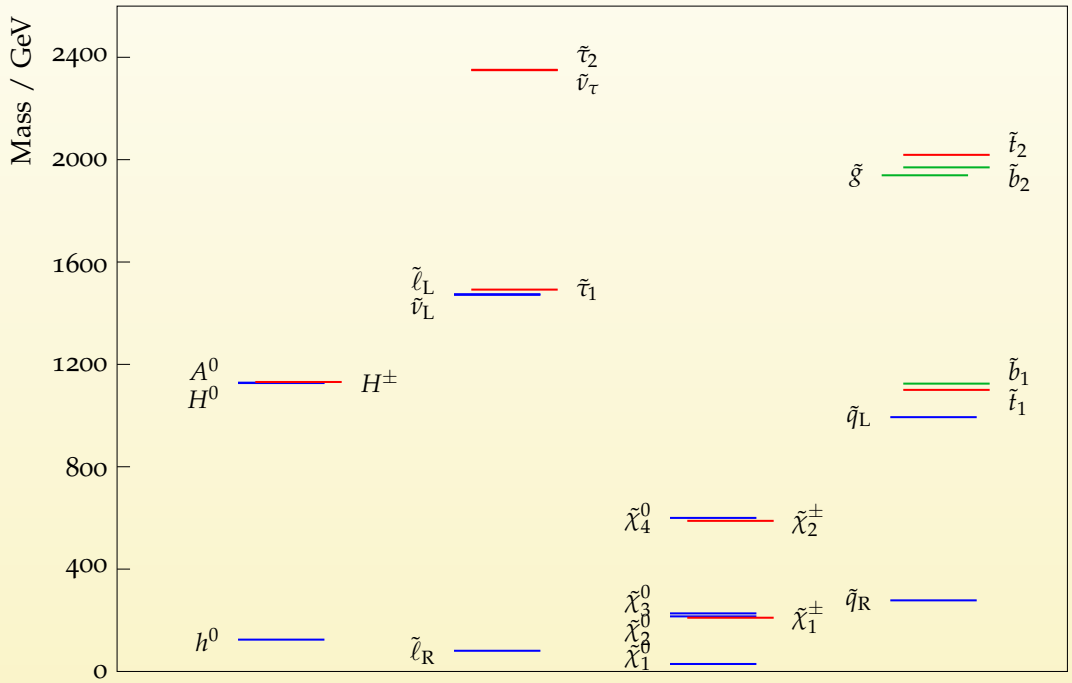


A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

Three main classes of surviving models:

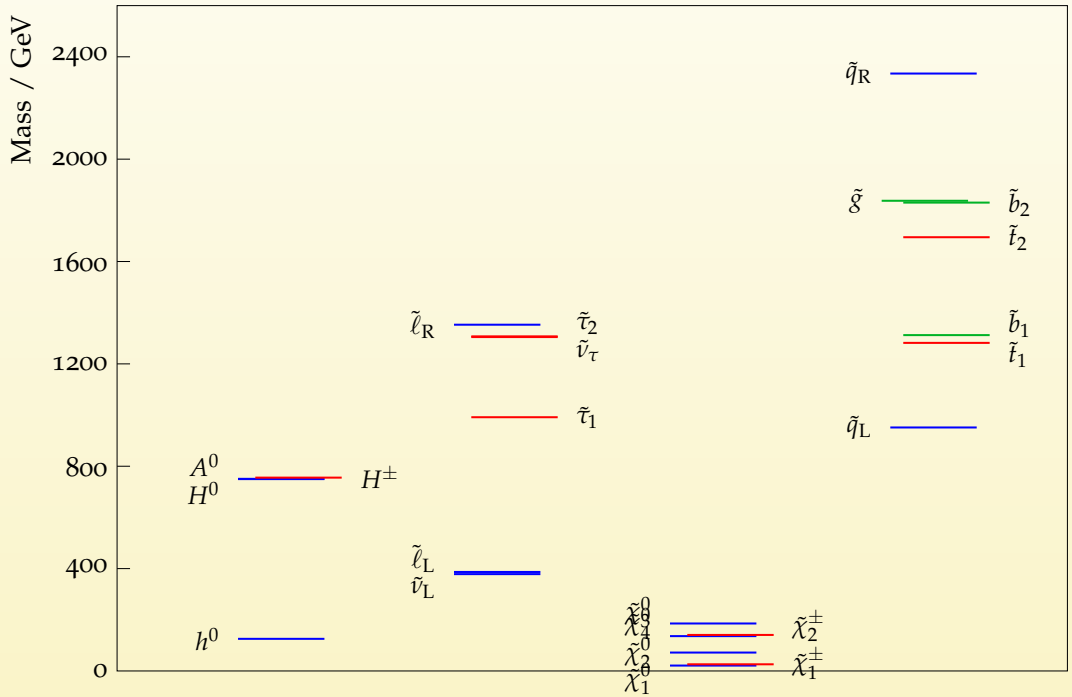
- sleptons with mass close to the LEP limit
  ($M_{\tilde{\chi}^0} \sim 20 - 40$ GeV)
- compressed spectra in the neutralino/chargino sector
  ($M_{\tilde{\chi}^0} \sim 10 - 40$ GeV, $\sigma \sim 10^{-6}$ pb)
- squarks quasi-degenerate with neutralino
  ($M_{\tilde{\chi}^0} \lesssim 10 - 20$ GeV, $\sigma \sim 10^{-4}$ pb)

Slepton with a mass at the LEP limit



A relatively standard scenario, but the neutralino mass has to be larger (around 30 GeV) to give a large scattering cross-section.

Compressed spectrum in the neutralino/chargino sector



This scenario may be very interesting...

Unfortunately $\sigma(e^+e^- \to \chi_1^0\chi_2^0)$ is in general too large and ruled out by the LEP limits!

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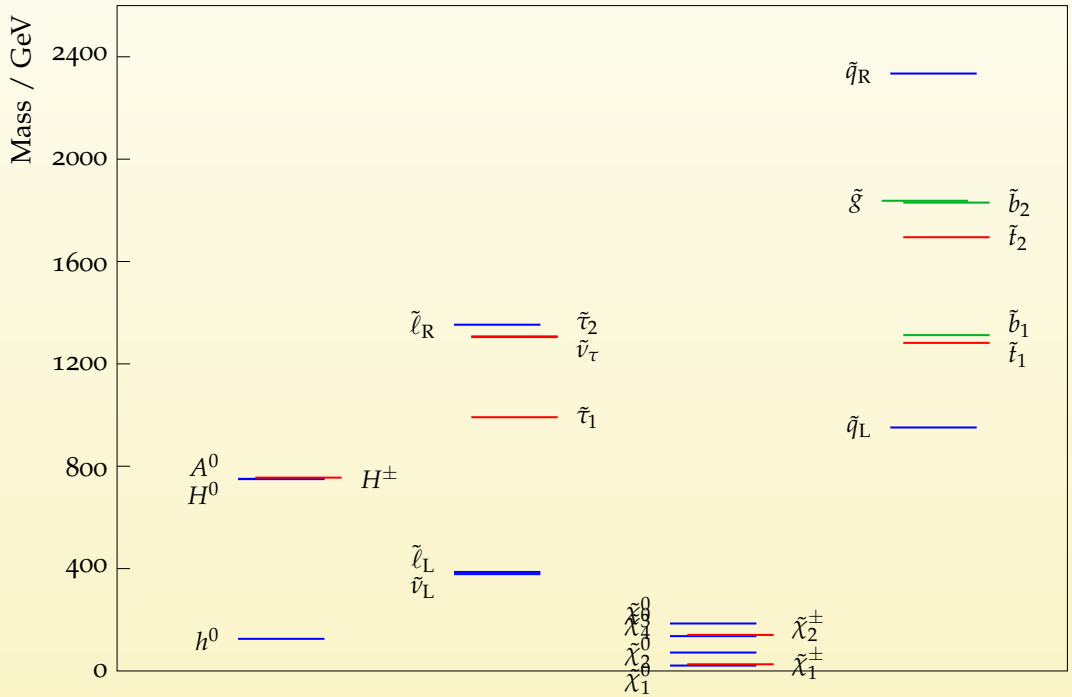

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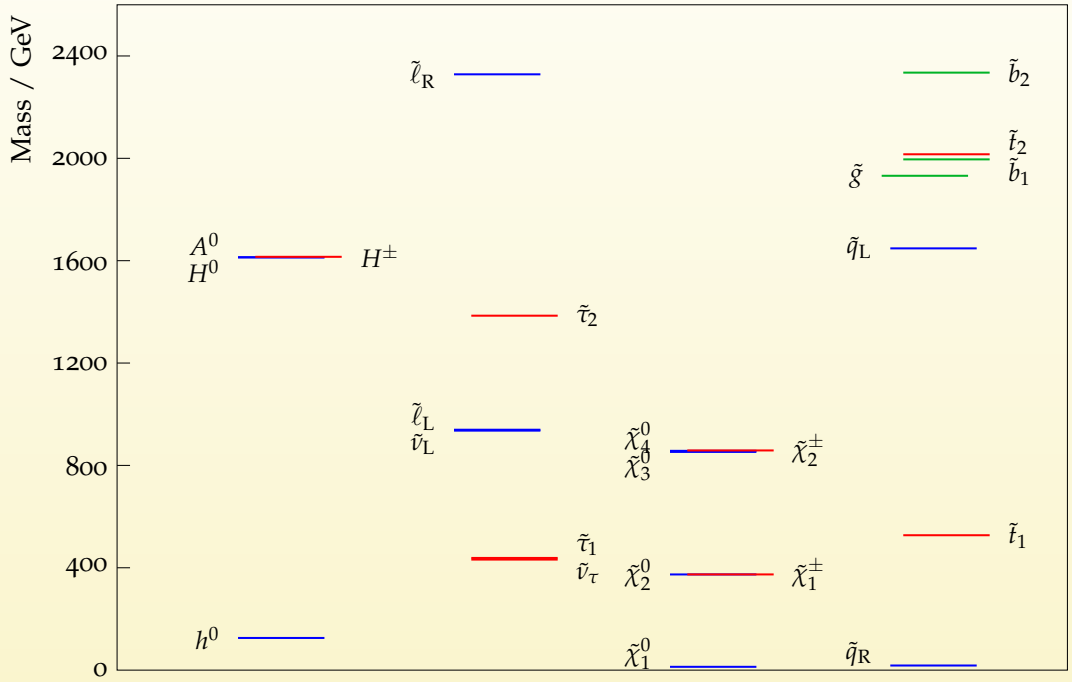
One squark quasi-degenerate with the neutralino



These spectra can fulfill all the constraints and have simultaneously a neutralino mass below 15 GeV and a large scattering cross-section!

Two problems however: $\Gamma(Z \to \tilde{q}\bar{\tilde{q}})$ is very large and $BR(h^0 \to \tilde{q}\bar{\tilde{q}})$ is the dominant Higgs BR... for the first and second generations!

$\to$ Light **sbottoms** can pass all these constraints!

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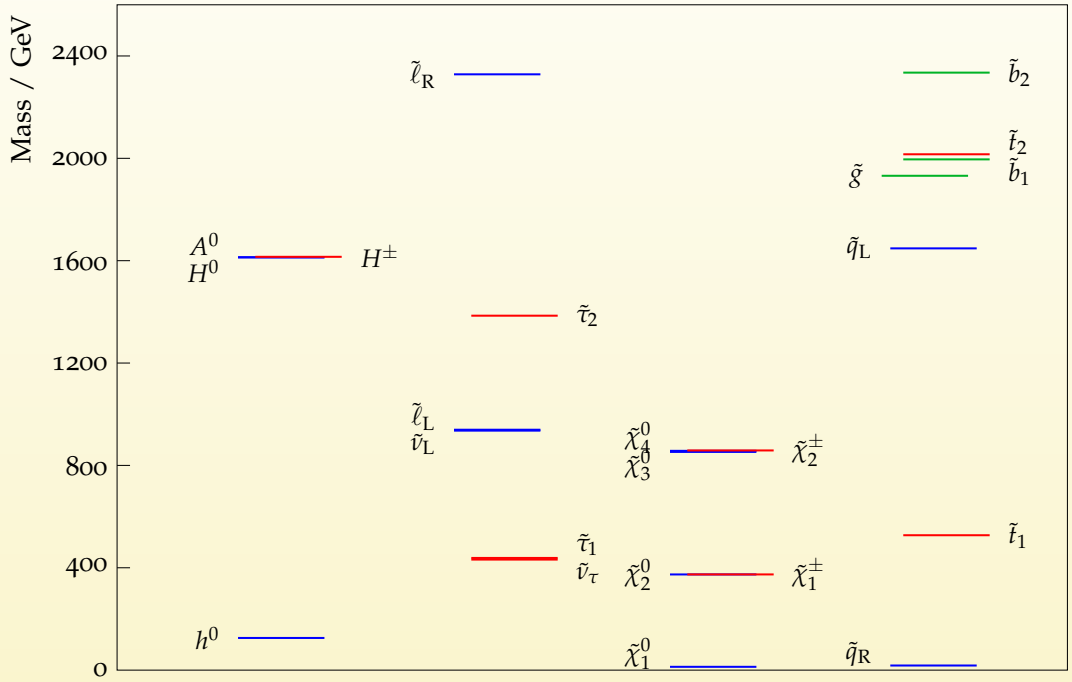

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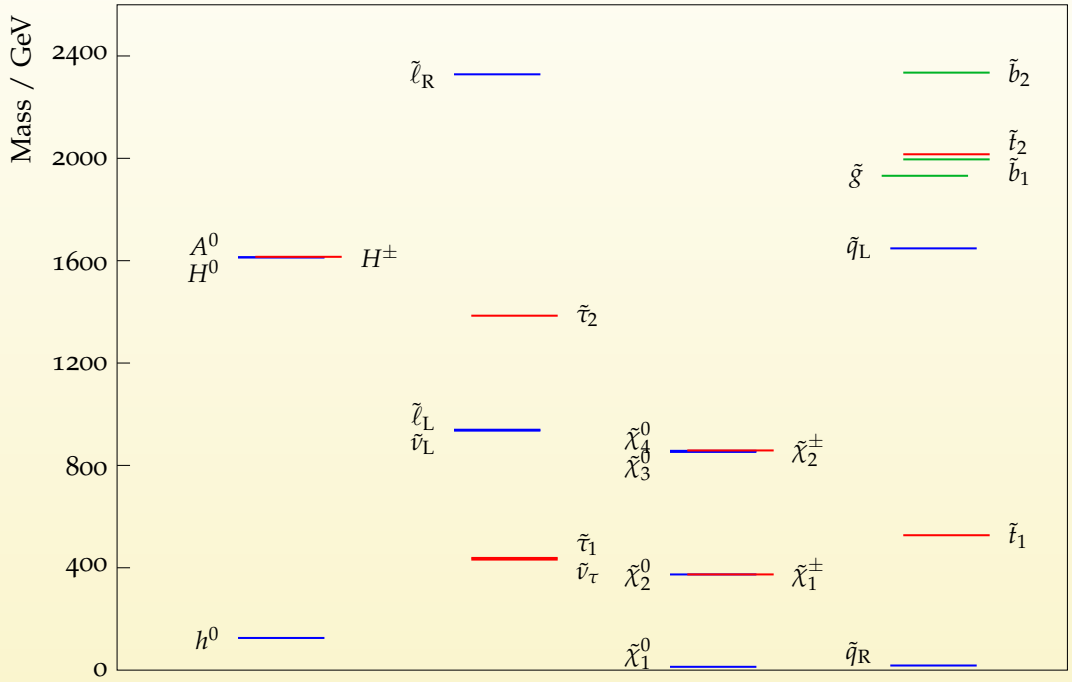

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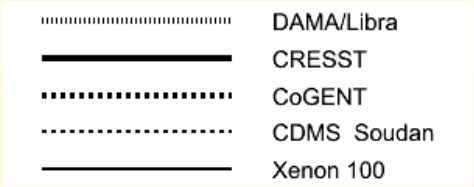
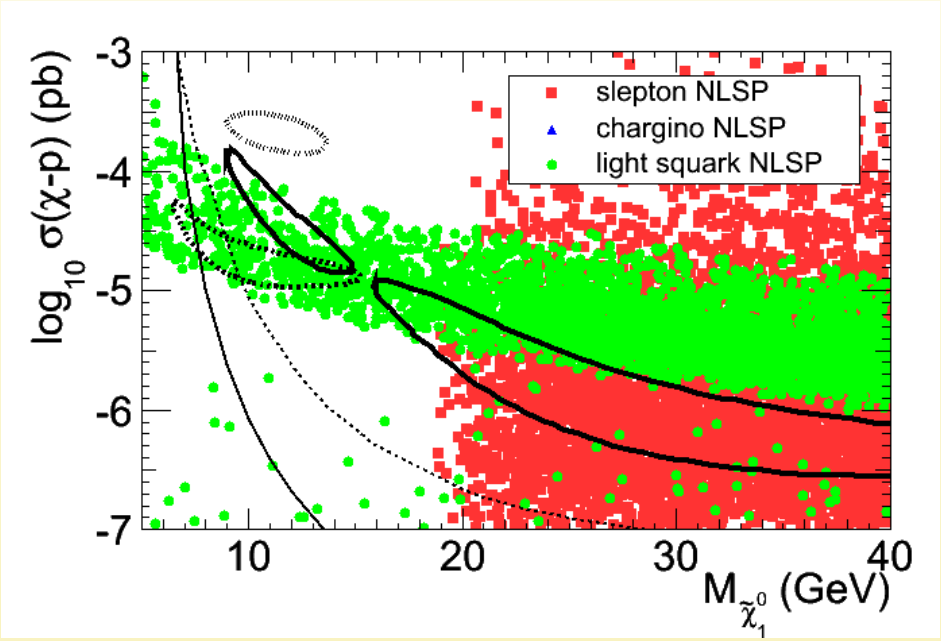
Using dedicated scans starting from our benchmark points:





Loose relic density constraint
$10^{-4} < \Omega_\chi h^2 < 0.155$

A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

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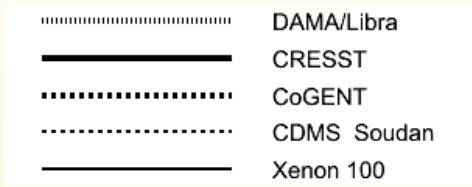

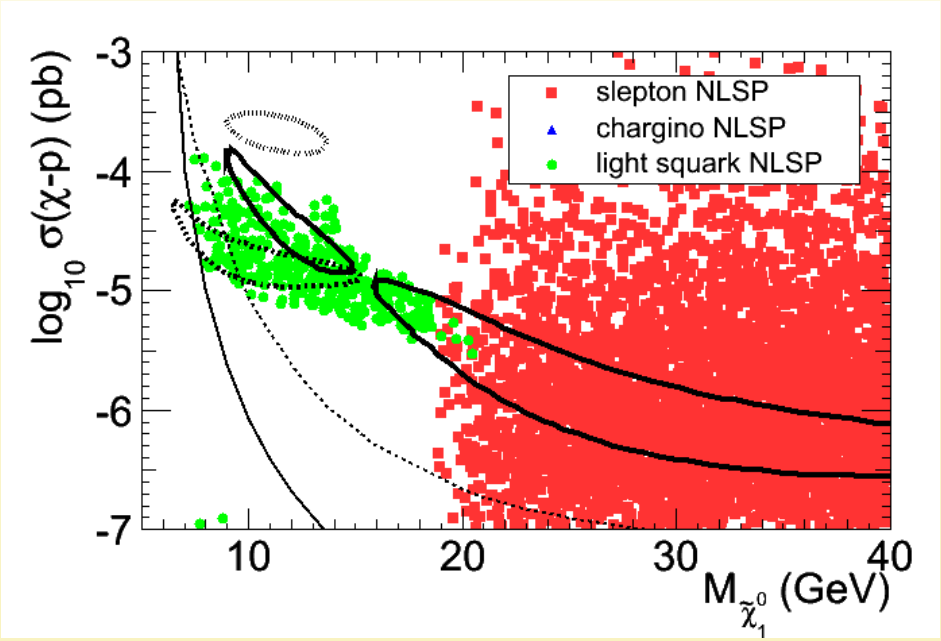

Tight relic density constraint
$0.068 < \Omega_\chi h^2 < 0.155$

The surviving models satisfy also the indirect dark matter constraint from Frmi-LAT!

A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

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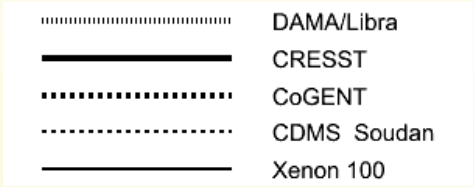

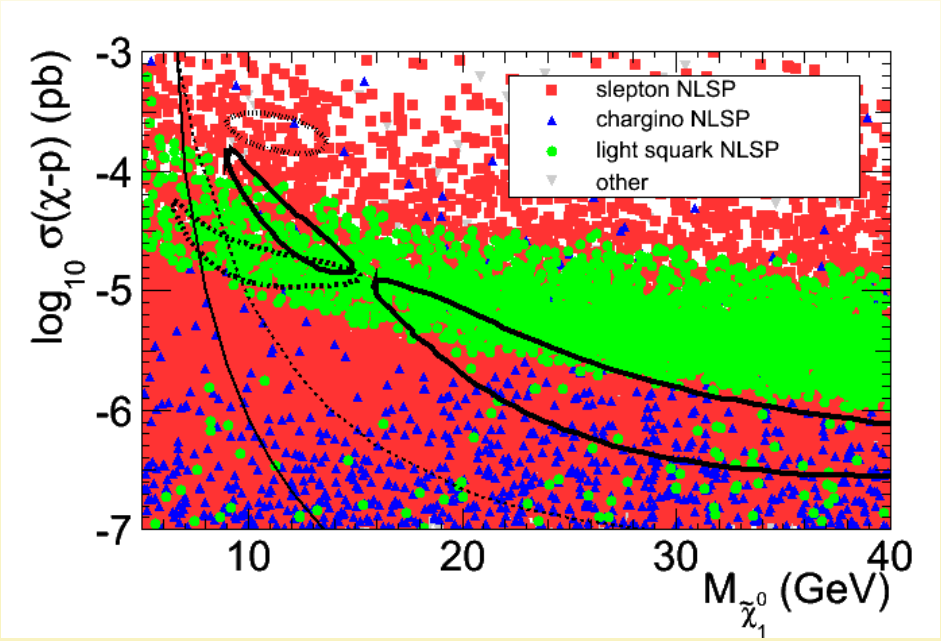

No relic density constraint

A. Arbey, M. Battaglia, F. Mahmoudi, arXiv:1205.2557 [hep-ph]

pMSSM light neutralino **CAN** be compatible with all constraints!

Three different scenarios

- Sbottoms quasi-degenerate with the neutralino
- Sleptons with a mass close to the LEP limit
- Compressed spectra in the gaugino sector

Next steps

- Characterise more these scenarios in terms of the ATLAS and CMS MET analyses
- Go to alternative scenarios (gravitino dark matter, beyond MSSM, ...)