Light neutralino dark matter in the MSSM

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“Implications of LHC results for TeV-scale physics” Workshop

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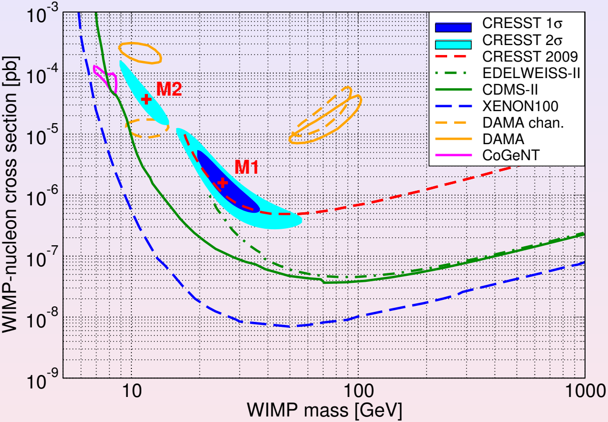
Status of Dark Matter Direct Detection



CRESST, arXiV:1109.0702

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

pMSSM scans

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.

$2.16 \times 10^{-4} < \mathrm{BR}(B \to X_s\gamma) < 4.93 \times 10^{-4}$
$\mathrm{BR}(B_s \to \mu^+\mu^-) < 5.0 \times 10^{-9}$
$0.56 < \mathrm{R}(B \to \tau\nu) < 2.70$
$4.7 \times 10^{-2} < \mathrm{BR}(D_s \to \tau\nu) < 6.1 \times 10^{-2}$
$2.9 \times 10^{-3} < \mathrm{BR}(B \to D^0\tau\nu) < 14.2 \times 10^{-3}$
$0.985 < \mathrm{R}_{\mu 23}(K \to \mu\nu) < 1.013$
$-2.4 \times 10^{-9} < \delta a_\mu < 4.5 \times 10^{-9}$
+ sparticle mass upper bounds
+ Higgs search limits $122.5\text{ GeV} < M_h < 127.5\text{ GeV}$

Particle	Limits	Conditions
$\tilde\chi^0_2$	62.4	$\tan\beta < 40$
$\tilde\chi^0_3$	99.9	$\tan\beta < 40$
$\tilde\chi^0_4$	116	$\tan\beta < 40$
$\tilde\chi^\pm_1$	94	$\tan\beta < 40$, $m_{\tilde\chi^\pm_1} - m_{\tilde\chi^0_1} > 5$ GeV
$\tilde e_R$	73	
$\tilde e_L$	107	
$\tilde\tau_1$	81.9	$m_{\tilde\tau_1} - m_{\tilde\chi^0_1} > 15$ GeV
$\tilde u_R$	100	$m_{\tilde u_R} - m_{\tilde\chi^0_1} > 10$ GeV
$\tilde u_L$	100	$m_{\tilde u_L} - m_{\tilde\chi^0_1} > 10$ GeV
$\tilde t_1$	95.7	$m_{\tilde t_1} - m_{\tilde\chi^0_1} > 10$ GeV
$\tilde d_R$	100	$m_{\tilde d_R} - m_{\tilde\chi^0_1} > 10$ GeV
$\tilde d_L$	100	$m_{\tilde d_L} - m_{\tilde\chi^0_1} > 10$ GeV
$\tilde b_1$	248	$m_{\tilde\chi^0_1} < 70$ GeV, $m_{\tilde b_1} - m_{\tilde\chi^0_1} > 30$ GeV
	220	$m_{\tilde\chi^0_1} < 80$ GeV, $m_{\tilde b_1} - m_{\tilde\chi^0_1} > 30$ GeV
	210	$m_{\tilde\chi^0_1} < 100$ GeV, $m_{\tilde b_1} - m_{\tilde\chi^0_1} > 30$ GeV
	200	$m_{\tilde\chi^0_1} < 105$ GeV, $m_{\tilde b_1} - m_{\tilde\chi^0_1} > 30$ GeV
	100	$m_{\tilde b_1} - m_{\tilde\chi^0_1} > 5$ 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

pMSSM scans

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]
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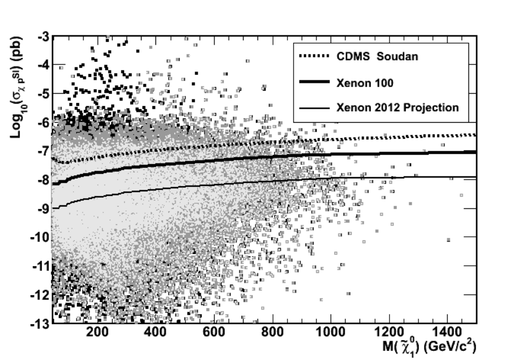
$M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$	[50, 2500]
$M_{\tilde{q}_{3L}}$	[50, 2500]
$M_{\tilde{u}_R} = M_{\tilde{c}_R}$	[50, 2500]
$M_{\tilde{t}_R}$	[50, 2500]
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$	[50, 2500]
$M_{\tilde{b}_R}$	[50, 2500]

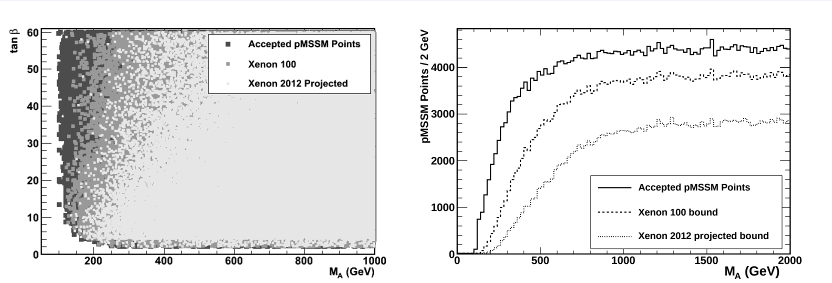
pMSSM points and XENON dark matter exclusion limit



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

Neutralinos and dark matter direct detection

pMSSM points and XENON dark matter exclusion limit



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pMSSM scans

General scans in pMSSM $\longrightarrow$ Low-mass neutralino scans

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$M_{\tilde{b}_R}$	[50, 2500]

$\longrightarrow$

Parameter	Range
$\tan\beta$	[1, 60]
M_A	[50, 2000]
M_1	[-300, 300]
M_2	[-650, 650]
M_3	[0, 2000]
$A_d = A_s = A_b$	[-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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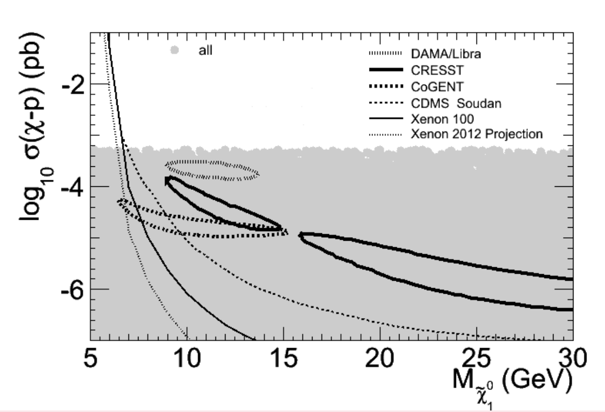
$M_{\tilde{b}_R}$	[0, 2500]

Light neutralinos and dark matter direct detection

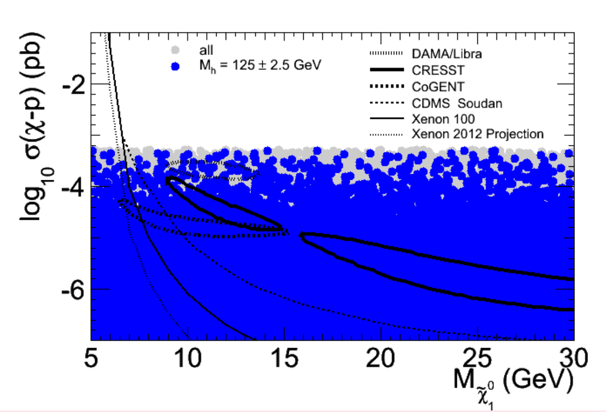
Low mass neutralino scans: more than 500M generated points



$\sim$ 1M points

A. Arbey, M. Battaglia, F. Mahmoudi, in preparation

Low mass neutralino scans: more than 500M generated points



$\sim$ 100k points (10%)

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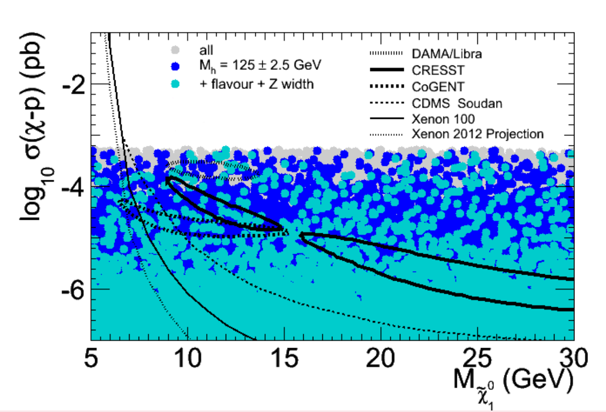

$\sim$ 10k points (1%)

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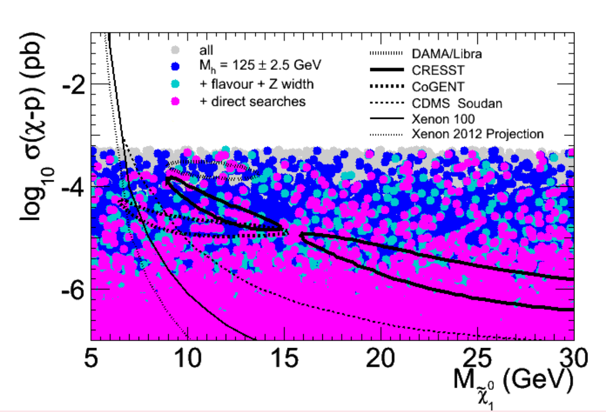

$\sim$ 5k points (0.5%)

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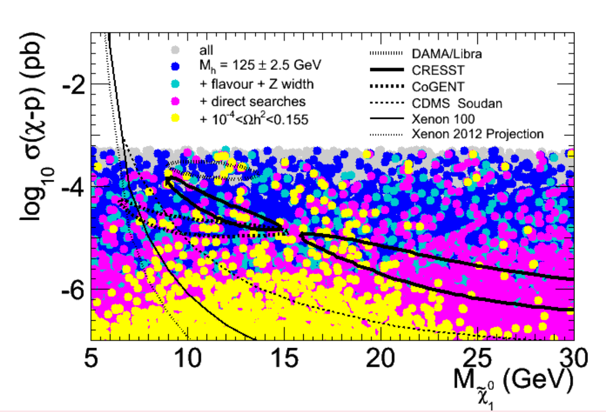
Low mass neutralino scans: more than 500M generated points



$\sim$ 1k points (0.1%)

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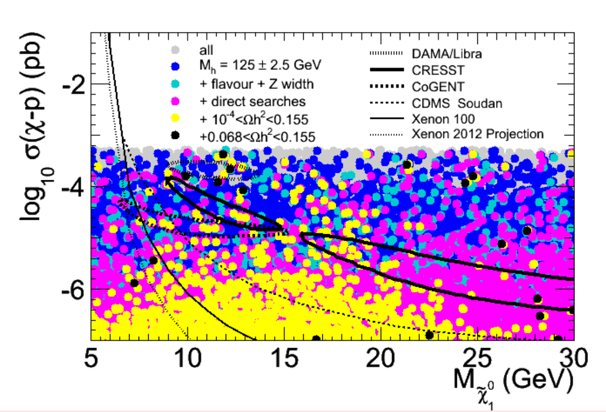
Low mass neutralino scans: more than 500M generated points



$\sim$ 18 points (0.002%)

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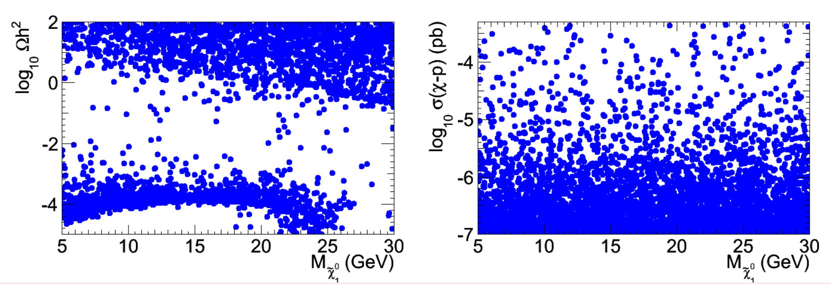
How to reconcile relic density and direct dark matter detection when $M_{\tilde{\chi}^0} < 30$ GeV?



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Light neutralinos and dark matter direct detection

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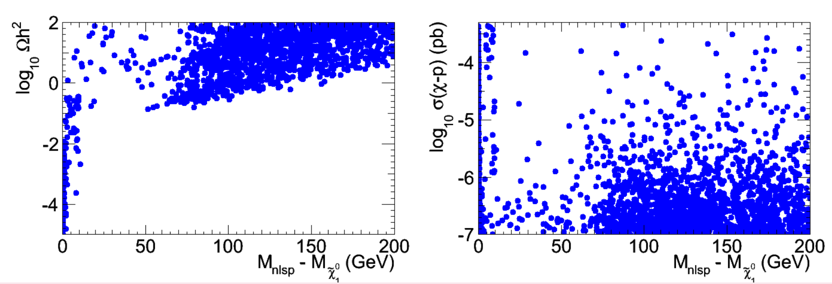

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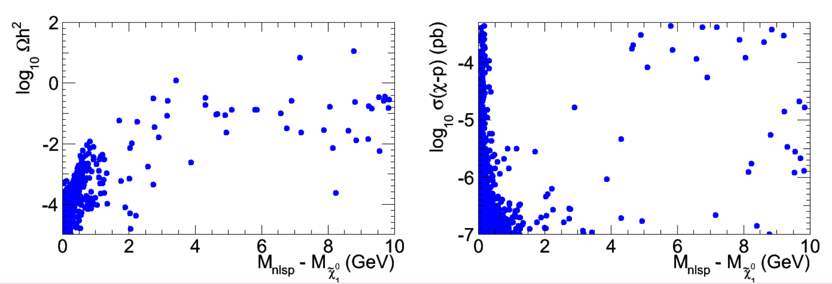

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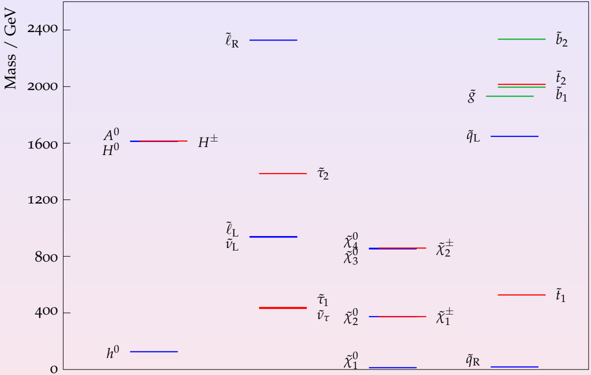
Light neutralinos and dark matter direct detection

Three different classes of points passing all the constraints:

- one squark quasi-degenerate with the neutralino ($M_{\tilde{\chi}^0} \lesssim 15$ GeV, $\sigma \sim 10^{-4}$ pb)
- a slepton with a mass at the LEP limit ($M_{\tilde{\chi}^0} \sim 30$ GeV, $\sigma \sim 10^{-6}$ pb)
- compressed spectrum in the neutralino/chargino sector ($M_{\tilde{\chi}^0} \sim 30$ GeV, $\sigma \sim 10^{-6}$ pb)

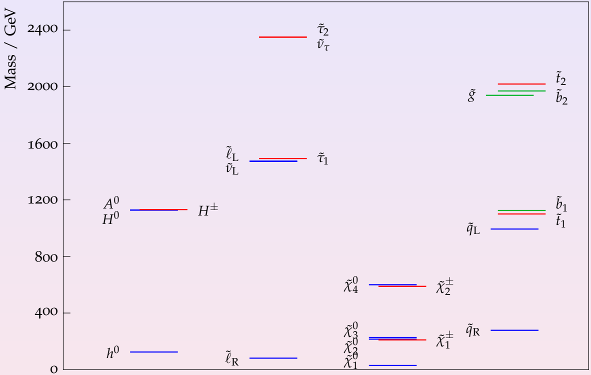
Most of the (yellow) points, i.e. for which the relic density is too small, and which have $M_{\tilde{\chi}^0} \lesssim 15$ GeV and $\sigma \sim 10^{-4}$, are of the third category.

One squark quasi-degenerate with the neutralino



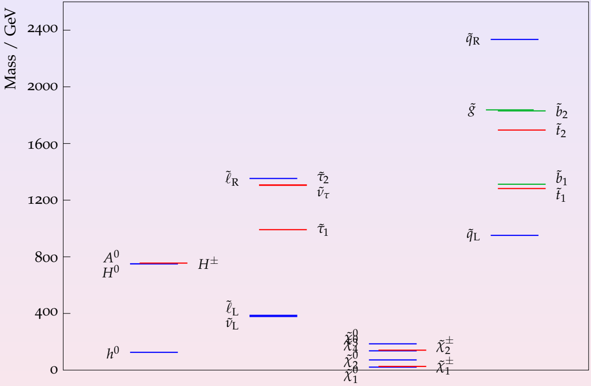
These spectra can fulfill all the constraints and have simultaneously a neutralino mass under 15 GeV and a large scattering cross-section!

Slepton with a mass at the LEP limit



A more 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 is very interesting. For neutralino masses of about 15 GeV, this kind of scenarios has a low relic density, but can fulfill all the other constraints.

Light neutralinos and dark matter direct detection

Compressed spectrum in the neutralino/chargino sector

The compressed spectrum scenario can become viable an interesting scenario even with a very light neutralino if e.g.:

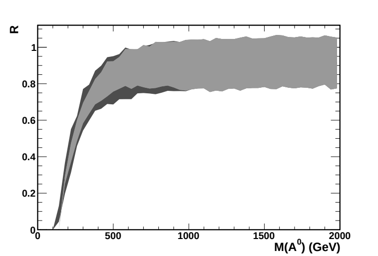
- the neutralino is not the only component of dark matter
- neutralinos can be produced non-thermally (e.g. by the decay of an inflaton)
- dark energy accelerated the expansion of the Universe before the freeze-out
- ...

Light neutralinos and Higgs rates

What about the Higgs rates?

A light neutralino/light spectrum opens up different possibilities for the Higgs decays:

- Higgs decays into light SUSY particles
- Higgs invisible decays



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Study in progress, some technical problems need to be solved...

Conclusions and perspectives

pMSSM light neutralino can be compatible with all constraints!

Three different scenarios

- One squark quasi-degenerate with the neutralino
- Slepton with a mass at the LEP limit
- Compressed spectrum in the gaugino sector

Next steps

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