Phenomenology of light neutralinos in view of recent results at the CERN Large Hadron Collider

Stefano Scopel
Searching for susy dark matter is not for the faint of heart.
The logic connection between Weakly Interacting Massive Particles (WIMPs) relic density, their direct and indirect signals and accelerator physics

Thermal equilibrium in the Early Universe

The same class of interactions that kept WIMPS in thermal equilibrium in the early Universe could allow their detection today

is it possible to get correlations in a model independent way?
The LHC-direct-detection connection: three possible quantitative approaches:

1. Minimal SUGRA
2. Effective theory
3. Your (my) favorite model
The specific scenario of and effective MSSM
Effective MSSM scheme (effMSSM) - Independent parameters

- $M_1$ U(1) gaugino soft breaking term
- $M_2$ SU(2) gaugino soft breaking term
- $M_3$ SU(3) gaugino soft breaking term
- $\mu$ Higgs mixing mass parameter
- $\tan \beta$ ratio of two Higgs v.e.v.’s
- $m_A$ mass of CP odd neutral Higgs boson (the extended Higgs sector of MSSM includes also the neutral scalars $h, H,$ and the charged scalars $H^{\pm}$)
- $m_q$ soft mass for squarks of the first two families
- $m_{\tilde{t}}$ soft mass for squarks of 3rd family
- $m_{\tilde{l}}$ soft mass common to all sleptons
- $A$ common dimensionless trilinear parameter for the third family ($A_{\tilde{b}} = A_{\tilde{t}} \equiv A_{\tilde{q}}; A_{\tilde{\tau}} \equiv A_{\tilde{l}}$)
- $R \equiv M_1 / M_2$

SUGRA $\rightarrow R = 0.5$
Can the neutralino be *light*?

**Lower limits on the neutralino mass from accelerators**

- **Indirect limits from chargino production** \((e^+e^- \rightarrow \chi^+\chi^-)\):
  
  \[ m_{\chi^\pm} \gtrsim 100 \text{ GeV} \Rightarrow m_{\chi} \gtrsim 50 \text{ GeV} \quad \text{if} \quad R \equiv \frac{M_1}{M_2} = \frac{5}{3} \tan^2 \theta_W \]

- **Direct limits from** \(e^+e^- \rightarrow \chi^0_i\chi^0_j\) \((\chi^0_0 \equiv \chi, m_{\chi^0_1} < m_{\chi^0_2} < m_{\chi^0_3} < m_{\chi^0_4})\):
  
  ➤ Invisible width of the Z boson (upper limit on number \(N_{\nu}\) of neutrino families)
  ➤ Missing energy + photon(s) or \(f\bar{f}\) from \(\chi^0_i > 1 \rightarrow \chi^0_1\) decay

- **Direct limits from** \(\tilde{t} \rightarrow c\chi\) and \(\tilde{b} \rightarrow b\chi\) at Tevatron ‡
  
  † small production cross sections
  ‡ light squark masses \(\lesssim 100 \text{ GeV}\) required

**No absolute direct lower bounds on** \(m_{\chi}\)**
Constraint from the invisible width of the Z boson at LEP

\[ \Gamma(Z \rightarrow \chi\chi) = 166 \text{ MeV} \left[ 1 - \frac{(2m_\chi)^2}{M_Z^2} \right]^{3/2} a_3^4 \]

Assuming: \( \Gamma(Z \rightarrow \chi\chi) < 3 \text{ MeV} \)

\[ a_1^2 a_2^2 < 0.12 \]

Fornengo, Scopel, Bottino, PhysRevD.83.015001 (1011.4743)
In relic abundance:

\[ \chi - \chi \rightarrow f\bar{f} \text{ annihilation cross section - Diagrams (low } m_\chi) \]

\[ (m_\chi \leq M_W) \]
Approximate analytic expressions at small $m_\chi$

- The dominant terms in $\langle \sigma_{\text{ann}} v \rangle_{\text{int}}$ are the contributions due to Higgs-exchange in the $s$ channel and sfermion-exchange in the $t, u$ channels of the annihilation process $\chi + \chi \to \bar{f} + f$.

- For $m_A \lesssim 200$ GeV Higgs-exchange contribution due to S-wave annihilation into down-type fermions dominates:

$$
\langle \sigma_{\text{ann}} v \rangle^{\text{Higgs}}_f \approx \widetilde{a}^{\text{Higgs}}_f \approx \frac{2\pi \alpha_{\text{em}}^2 c_f}{\sin^2 \theta_W \cos^2 \theta_W} a_1^2 a_3^2 \tan^2 \beta (1 + \epsilon_f)^2 \frac{m_f^2 m_\chi^2 [1 - m_f^2/m_\chi^2]^{1/2}}{m_W^2 [(2m_\chi)^2 - m_A^2]^2}
$$

- $c_f = 3$ for quarks, $c_f = 1$ for leptons
- $m_f =$ fermion running mass evaluated at the energy scale $2m_\chi$
- $m_f =$ fermion pole mass
- $\epsilon_f =$ one-loop correction to the relationship between a down-type fermion running mass and the corresponding Yukawa coupling $(m = h \times v \times (1 + \epsilon))$
Cosmological lower bound on $m_\chi$ (low $m_A$ mass)

- $\Omega_\chi h^2 < 0.131$

- $< \sigma_{\text{ann}} v >$ is an increasing function of $m_\chi$

- The maximal value $(< \sigma_{\text{ann}} v >)_{max}$ at fixed $m_\chi$ is obtained by inserting into $< \sigma_{\text{ann}} v >$ the product $a_1^2 a_3^2 \tan^2 \beta$ for maximal bino–higgsino mixing:
  
  - $\frac{|a_3|}{|a_1|} \simeq 0.42 \sin \beta$
  - for $m_A \simeq 90$ GeV, $\tan \beta < 45$ (CDF)

- Keeping only the dominant contribution to $b\rightarrow \bar{b}$ final state:

  $$m_\chi [1 - m_\chi^2/m_b^2]^{1/4} \gtrsim 5.3 \text{ GeV } \left( \frac{m_A}{90 \text{ GeV}} \right)^2$$
Cosmological lower bound on $m_\chi$ (low $m_A$)


$m_\chi \left[1 - m_\chi^2/m_\chi^2\right]^{1/4} \gtrsim 5.3$ GeV $\left(\frac{m_A}{90 \text{ GeV}}\right)^2$

scatter plot: full calculation

curve: analytical approximation for minimal $\Omega_{CDM}h^2$

upper bound on $\Omega_{CDM}h^2$

à la Lee-Weinberg
Sfermion-exchange contribution

- Important if $m_A \gtrsim 200 \text{ GeV}$

- Both S-wave and P-wave contributions have to be taken into account in the expression:

\[
\langle \tilde{\sigma}_{\text{ann}} \, \tilde{u} \rangle_{s\text{fermion}} 
\simeq \tilde{a}_f \tilde{u}_{s\text{fermion}} + \frac{1}{2 x_f} \tilde{b}_f \tilde{u}_{s\text{fermion}}
\]

- Lowest $\Omega_{\chi} h^2$ obtained for $\tilde{\tau}$ exchange. Lightest $\tilde{\tau}$ ($m_{\tilde{\tau}} \simeq 87 \text{ GeV}$) if mixing is maximal

- $\langle \tilde{\sigma}_{\text{ann}} \, \tilde{u} \rangle_{s\text{fermion}} \simeq \langle \tilde{\sigma}_{\text{ann}} \, \tilde{u} \rangle_{\tau}$ maximized by:

\[
\left( \langle \tilde{\sigma}_{\text{ann}} \, \tilde{u} \rangle_{s\text{fermion}} \right)_{\text{max}} 
\simeq \frac{\pi \alpha_{e.m.}}{8 \cos^4 \theta_W} \frac{m^2_{\chi} [1- m^2_{\tilde{\tau}}/m^2_{\chi}]^{1/2}}{m^4_{\tilde{\tau}}} \left[ \left( 2 + \frac{5}{2} \frac{m_{\tilde{\tau}}}{m_{\chi}} \right)^2 + \frac{23}{2 x_f} \right]
\]
Cosmological lower bound on $m_\chi (m_A > 200 \text{ GeV})$


upper bound on $\Omega_{CDM} h^2$

curve: analytical approximation for minimal $\Omega_{CDM} h^2$

scatter plot: full calculation

$m_\chi [1 - m_\tau^2/m_\chi^2]^{1/4} \gtrsim 22 \text{ GeV} \left(\frac{m_\tau}{90 \text{ GeV}}\right)^2$

à la Lee-Weinberg
The bottom line: the cosmological lower bound on $m_x$ depends on the value of $m_A$:

- $m_x > 6$ GeV for light $m_A$
- $m_x > 22$ GeV for heavy $m_A$

$(\Omega_{CDM}h^2)_{max} = 0.3$

$(\Omega_{CDM}h^2)_{max} = 0.131$
Light neutralinos in eff-MSSM

Neutralino–quark cross section - Diagrams

at very low mass same diagrams, correlation between relic density and cross section for direct detection
Neutralino - nucleon cross section

(A.Bottino, F.Donato, N.Fornengo and S.Scopel, PRD69,037302 (2004) )

Tight correlation between relic abundance and $\chi$-nucleon cross section:

$$\Omega_{\chi} h^2 \leq (\Omega_{CDM} h^2)_{max}$$

$$\sigma_{(\text{nucleon})}^{(\text{scalar})} \geq \frac{10^{-46} \text{cm}^2}{(\Omega_{CDM} h^2)_{max}} \frac{\text{GeV}^2}{m_{\chi}^2 [1 - m_{\chi}^2/m_{\chi}^2]^{1/2}} \text{ for } m_{\chi} \lesssim 20 \text{ GeV}$$

The elastic cross section is bounded from below

→ “funnel” at low mass

DAMA/NaI modulation region, likelihood function values distant more than 4 $\sigma$ from the null result (absence on modulation) hypothesis, Riv. N. Cim. 26 n. 1 (2003) 1-73, astro-ph/0307403

Light relic neutralinos have (roughly) the right mass and cross section to explain DAMA/LIBRA, CoGeNT, CDMS II and CRESST II!
CRESST after DAMA and CoGeNT (+CDMS2): evidence for light Dark Matter piling up?

\[ m_{\text{WIMP}} \sim 10 \text{ GeV} \]
\[ \sigma_{\text{nucleon}} \sim 10^{-41} - 10^{-40} \text{ cm}^2 \]
However XENON100 and CDMS exclusion plots taken at face value rule out DAMA+CoGeNT

However, robustness of these constraint is questioned at low WIMP masses:
• Liquid Noble gases for Dark Matter searches: a synoptic survey, R. Bernabei et al., 0806.0011
• A Realistic Assessment of the Sensitivity of XENON10 and XENON100 to Light-Mass WIMPs, J. Collar, arXiv:1106.0653
• A comparison between the low-energy spectra from CoGeNT and CDMS, J. Collar, arXiv:1103.3481
XENON100 bound after 2012 data analysis

In the following I will not implement these bounds.

E. Aprile, talk at DarkAttack2012, 18 July 2012
If $m_q$ (squark soft mass for the first two families) = $m_t$ (soft mass for the third family) the LHC constraints can be converted in a bound on the neutralino mass (S. Scopel, S. Choi, N. Fornengo and A. Bottino, Phys. Rev. D83 (2011) 095016)
$m_{\tilde{q}} = m_{\tilde{t}}$

Lower bound on $m_\chi$ depends on gluino mass:

$7.6 \text{ GeV} < m_{\chi_{\text{min}}} < 11.8 \text{ GeV}$
For light neutralinos $X=A$ (pseudoscalar Higgs boson)

- small $m_{\chi}$ requires small $m_A$ to boost $\sigma v$ and keep the relic density below the observational limit

$$m^2_{H^\pm} \simeq m^2_A + m^2_W$$

- masses of pseudoscalar Higgs boson $A$ and charged Higgs boson $H^+$ strictly correlated so also $H^+$ is light

- In $b \to s \gamma$ decay the loop with a top quark and a charged higgs must be canceled by the loop with a stop and a chargino (N.B.: in LNM also chargino is light)

**Lower bound on the stop mass proportional to the neutralino mass**
Estimate total efficiency $\varepsilon$ using ISAJET on a few selected benchmarks at the boundary of the allowed parameter space

$$0.07 < \varepsilon_{\text{CMS}} < 0.2$$

$$0.0002 < \varepsilon_{\text{ATLAS}} < 0.005$$

Upper bound on $m_{\text{squark}} = 800$ GeV from $b \to s \gamma$ decay if squark soft masses are universal

In the LNM scenario correlation among the squark mass and the lower bound of the neutralino mass → lower bound on $m_{\text{squark}}$ from LHC implies lower bound on $m_{\chi}$
N.B. when squark soft masses of the third family are allowed to float independently from those of the first two no upper bound on $m_{\text{squark}} \rightarrow$ no constraints on $m_\chi$

Tension between LHC and $b \rightarrow s \gamma$ disappears because:

- LHC $p + p$ cross section depends on $m_{\text{squark,12}}$
- $b \rightarrow s \gamma$ depends on stop soft mass

S. Scopel, S. Choi, N. Fornengo and A. Bottino, , Phys. Rev. D83 (2011) 095016
How to measure light neutralinos at the LHC?
Select a benchmark for sequential decay (LNM-seq) within the effMSSM:

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LNM-seq</td>
<td>14</td>
<td>500</td>
<td>2000</td>
<td>126</td>
<td>34</td>
<td>97</td>
<td>300</td>
<td>700</td>
<td>444</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

The LSP goes undetected, no complete kinematical reconstruction allowed in direct decay

however, kinematical endpoints in chain decays allow to reconstruct masses in a model-independent way (no charginos, otherwise neutrinos in final state)

<table>
<thead>
<tr>
<th>Related edge</th>
<th>Kinematic endpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l^+l^-$ edge</td>
<td>$(m_{ll}^{\text{max}})^2 = (\xi - l)(\tilde{l} - \chi)/l$</td>
</tr>
</tbody>
</table>
| $l^+l^-q$ edge | $(m_{llq}^{\text{max}})^2 = \begin{cases} \max \left( \frac{(q-\tilde{q})(\xi-\chi)}{\xi}, \frac{(q-\tilde{l})(\xi-\chi)}{\tilde{l}}, \frac{(q-\tilde{h})(\xi-\chi)}{\xi} \right) \\
\text{except for the special case in which } \tilde{l}^2 < \tilde{q} \chi < \xi^2 \text{ and } \chi^2 < \tilde{q} l^2 \text{ where one must use } (m_{\tilde{q}} - m_{\chi_1^0})^2 \\
Xq edge | $(m_{Xq}^{\text{max}})^2 = X + (\tilde{q} - \xi) \left[ \xi + X - \chi + \sqrt{(\xi - X - \chi)^2 - 4X\chi} \right]/(2\xi)$ |
| $l^+l^-q$ threshold | $(m_{llq}^{\text{min}})^2 = \begin{cases} \left[ 2l(q - \tilde{q})(\xi - \chi) + (\tilde{q} + \xi)(\xi - l)(\tilde{l} - \chi) \\
\text{and } \chi^2 < \tilde{q} l^2 \text{ where one must use } (m_{\tilde{q}} - m_{\chi_1^0})^2 \\
l_{\text{near}} q edge | $(m_{l_{\text{near}} q}^{\text{max}})^2 = (\tilde{q} - \tilde{l})(\xi - \tilde{l})/\tilde{l}$ |
| $l_{\text{far}} q edge | $(m_{l_{\text{far}} q}^{\text{max}})^2 = (\tilde{q} - \tilde{l})(\tilde{l} - \chi)/\tilde{l}$ |
| $t^{\pm}$ high-edge | $(m_{t^{\pm} q(\text{high})}^{\text{max}})^2 = \max \left( (m_{l_{\text{near}} q}^{\text{max}})^2, (m_{l_{\text{far}} q}^{\text{max}})^2 \right)$ |
| $t^{\pm} q$ low-edge | $(m_{t^{\pm} q(\text{low})}^{\text{max}})^2 = \min \left( (m_{l_{\text{near}} q}^{\text{max}})^2, (\tilde{q} - \tilde{l})(\tilde{l} - \chi)/(2\tilde{l} - \chi) \right)$ |
| $M_{T^2}$ edge | $\Delta M = m_{\tilde{q}} - m_{\chi_1^0}$ |

Table 4: The absolute kinematic endpoints of invariant mass quantities formed from decay chains of the types mentioned in the text for known particle masses. The following shorthand notation has been used: $\chi - m_{\chi_1^0}, \tilde{l} - m_{\tilde{l} R}, \xi - m_{\tilde{Q}_2}, \tilde{q} - m_{\tilde{q}}$ and $X$ is $m_{\tilde{h}}$ or $m_{\tilde{X}}^2$ depending on which particle participates in the “branched” decay.

C. Allanach et al., JHEP09(2000)004
In particular, define:

\[ m_{j\ell}(lo) \equiv \min(m_{j\ell n}, m_{j\ell f}) \]
\[ m_{j\ell}(hi) \equiv \max(m_{j\ell n}, m_{j\ell f}) \]

\[ \begin{array}{cccc}
\tilde{q} & \chi_i & \tilde{l} & \chi_i \\
q & l_n & l_f
\end{array} \]

(cannot distinguish far lepton \( l_f \) from near lepton \( l_n \))

In this way one gets a set of 4 measurable kinematic endpoints:

\[ (m_{\ell\ell}^{max}, m_{j\ell\ell}^{max}, m_{j\ell(lo)}^{max}, m_{j\ell(hi)}^{max}) \]

to measure the 4 unknown masses:

\[ (m_{\chi}, m_{\tilde{l}}, m_{\chi_i}, m_{\tilde{q}}) \]
Two problems in this procedure:

1) In the LNM the four endpoints are not independent. In particular, for $m_{\chi} < \frac{(m_i)^2}{m_q}$ (as in the LNM-seq benchmark) one has:

$$(m_{j\ell \ell}^{\text{max}})^2 = (m_{\ell \ell}^{\text{max}})^2 + (m_{j\ell (hi)}^{\text{max}})^2$$

Need another independent measurement. Take (Allanach et al., JHEP0009,004, 2000):

$$m_{j\ell \ell (\theta > \pi / 2)}^{\text{min}} = \text{lower bound of } m_{j\ell \ell} \text{ histogram with the additional constraint:}$$

$$\frac{(m_{\ell \ell}^{\text{max}})^2}{2} < (m_{\ell \ell}^{\text{max}})^2 < (m_{\ell \ell}^{\text{max}})^2$$

2) The solution of the inversion procedure has multiple solutions and in general is not unique
Duplicate solutions in the inversion procedure for the LNM-seq benchmark

<table>
<thead>
<tr>
<th>Variable</th>
<th>LNM-seq</th>
<th>LNM-seq'</th>
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<tr>
<td>$m_x$</td>
<td>11</td>
<td>263</td>
</tr>
<tr>
<td>$m_\tilde{t}$</td>
<td>305</td>
<td>383</td>
</tr>
<tr>
<td>$m_{\chi i}$</td>
<td>515</td>
<td>688</td>
</tr>
<tr>
<td>$m_\tilde{q}$</td>
<td>703</td>
<td>896</td>
</tr>
<tr>
<td>$m_{ll}^{max}$</td>
<td>415 (417.5 ± 3.5)</td>
<td></td>
</tr>
<tr>
<td>$m_{j_{ll}}^{max}$</td>
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<td></td>
</tr>
<tr>
<td>$m_{j_{ll}(lo)}^{max}$</td>
<td>338 (342.2 ± 4.3)</td>
<td></td>
</tr>
<tr>
<td>$m_{j_{ll}(hi)}^{max}$</td>
<td>477 (483 ± 14)</td>
<td></td>
</tr>
<tr>
<td>$m_{j_{ll}(θ&gt;\pi/2)}^{min}$</td>
<td>400 (399.3 ± 1.7)</td>
<td></td>
</tr>
<tr>
<td>$n', p'$</td>
<td>282,385</td>
<td>232,477</td>
</tr>
</tbody>
</table>

Inversion procedure from kinematic endpoints leads to correct solution plus a duplicate one with a completely different spectrum but **identical** endpoints!

Can break the degeneracy by using two-dimensional kinematic distributions

\[ R_{ij} \equiv \frac{m_i^2}{m_j^2} \]

Select 4 kinematic regions \( R_1, R_2, R_3, R_4 \) that lead to different shapes in two-dimensional distributions. LNM-seq belongs to region \( R_2 \)

(M. Burns, K. T. Matchev, M. Park, JHEP0905, 094 (2009)
In ideal situation (10000 data points in this example) can locate the position of the point $P'$ that allows to break the degeneracy and determine which is the correct solution.

Duplicate models: same kinematic endpoints but different mass spectra

(M. Burns, K. T. Matchev, M. Park, JHEP0905, 094 (2009))
Summary of edge-point determinations (in parenthesis) vs. expected values

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</tr>
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Final inversion from \( m_{\ell \ell}^{\text{max}}, m_{j l(hi)}^{\text{max}}, m_{j l(low)}^{\text{max}}, m_{j \ell \ell}^{\text{max}}, m_{j \ell \ell}^{\text{min}}(\theta < \pi/2) \) (only 4 are independent) to \( (m_{\chi}, m_\tilde{\nu}, m_{\chi_1}, m_{\tilde{q}}) \)

Do that by brutal force, just simulate a large number of random values of the 4 masses and plot the histogram of the mass combinations whose theoretical values of the endpoints fall within the measured ranges.

As expected find two solutions. However the correct one can be determined by imposing that the mass pattern has the correct shape in the \( m_{j l(lo)} - m_{j l(hi)} \) two-dimensional distribution (i.e. belongs to kinematic region \( R_2 \))

Final mass determination:

\[
\begin{align*}
    m_{\chi} &= (103 \pm 43) \text{ GeV} \\
    m_{\tilde{\chi}} &= (349 \pm 27) \text{ GeV} \\
    m_{\chi_i} &= (561 \pm 28) \text{ GeV} \\
    m_{\tilde{\chi}_i} &= (751 \pm 28) \text{ GeV}
\end{align*}
\]
The reconstructed mass of the light neutralino in the LNM-seq benchmark is ~103 GeV, and deviates remarkably from the input value ~10

This can be explained by the fact that the center-of-mass energy available in the sequential decay is set by the squark and is much larger than the neutralino mass → in the LNM the neutralino is produced in the relativistic regime and its kinematics is almost insensitive to $m_\chi$

This is actually quite intuitive. For the same reason LHC constraints in effective theories are almost flat for a low DM mass.

“Maverick DM”
The $B_s \rightarrow \mu \mu$ decay

Combined ATLAS+CMS+LHCb upper bound: $\text{BR}(B_s \rightarrow \mu \mu) < 4.2 \times 10^{-9}$

Important constraint whenever $m_A$ is light and $\tan \beta$ is large, as in the light neutralino model, since $\text{BR}(B_s \rightarrow \mu \mu) \propto \tan \beta^6 / m_A^4$

Dominant term:

$$BR^6(B_s \rightarrow \mu^+ \mu^-) \approx 5.8 \times 10^{-8} \left( \frac{14 A m_t m_{\tilde{q}}}{m_{\tilde{q}}^2 + m_t^2} \right)^2 \left( \frac{m_{\chi^\pm}}{90 \text{ GeV}} \right)^2 \left( \frac{90 \text{ GeV}}{m_A} \right)^4 \left( \frac{\tan \beta}{35} \right)^6$$

To pass the constraint need:

- chargino of higgsino type to be light $\rightarrow$ small $\mu$ (not true in SUGRA where $\mu$ is large due to EWSB)
- trilinear coupling $A$ to be small (leading to stop-quark degeneracy) and respecting the hierarchy:

$$\frac{|\mu|}{m_{\tilde{q}} \tan \beta} \ll |A| \ll \frac{m_{\tilde{q}}}{m_t}$$

easily verified, no fine tuning $\rightarrow$

Fornengo, Scopel, Bottino, PhysRevD.83.015001 (1011.4743)
In the light neutralino parameter space the mass of the HEAVY Higgs boson mass $m_H$ fall naturally in the range of the LHC excess. Also production rates are roughly OK! The light Higgs $h$ ($m_h<110$ GeV) goes undetected because it is in the decoupling limit.

A. Bottino, N. Fornengo, S. Scopel, PRD85(2012)095013
However, stringent bounds on this scenario from CMS constraints on $H \rightarrow \tau \tau$:

J. Incandela, talk at CERN, 4 July 2012

(no jets from taus)

little space from additional contribution from light higgs state → more stringent limits
Light neutralinos after the LHC

Lines at constant neutralino mass
The bound on light neutralinos moves now to \(~20\) GeV

Stronger bounds on \(\tan\beta\) (\(<15\)) from \(h\rightarrow\tau\tau\) searches @LHC (CMS, report CMS PAS HIG-11-029.)

(A. Bottino, N. Fornengo, S. Scopel, PRD85, 095013 (2012)}
Updated light neutralino funnel after LHC bounds on $h \rightarrow \tau\tau$

Red crosses: $115.5 \text{ GeV} < m_h < 131 \text{ GeV}$

(A. Bottino, N. Fornengo, S. Scopel, PRD85, 095013 (2012))
In the surviving parameter space of light neutralinos ($m_{\chi} > 20$ GeV) the annihilation cross section at decoupling that drives the relic abundance takes comparable contributions from $A$ exchange and stau exchange, the former still dominating at the lowest masses.

(A. Bottino, N. Fornengo, S. Scopel, PRD85, 095013 (2012))
Anyway, neutralino-nucleon cross section still dominated by exchange of lightest Higgs scalar $h$.

(A. Bottino, N. Fornengo, S. Scopel, PRD85, 095013 (2012)
Conclusions

• An effective MSSM scenario (effMSSM) with no unification of gaugino masses at the GUT scale allows neutralinos as light as \( \sim 20 \text{ GeV} \) taking into account the latest constraint from CMS on the \( \tan\beta \) parameter from \( h \rightarrow \tau\tau \).
• Could roughly explain some excesses in Dark Matter direct searches (DAMA, CRESST). Probably too heavy to explain CoGeNT.
• This scenario is compatible in a very natural way (no particular fine tuning required) to the heavy Higgs scalar being the particle measured at the LHC with a mass \( m_H \sim 125 \text{ GeV} \).
• In this case the lightest scalar \( h \) should be not far from discovery.
• This scenario is in tension with XENON100 and CDMS bounds, but the robustness of these constraints has been put into question.
• Difficult to pinpoint the mass of the neutralino if it is light from kinematic measurements at the LHC.