Higgs signals for SUSY Models Consistent with CoGeNT/DAMA

Jack Gunion
U.C. Davis

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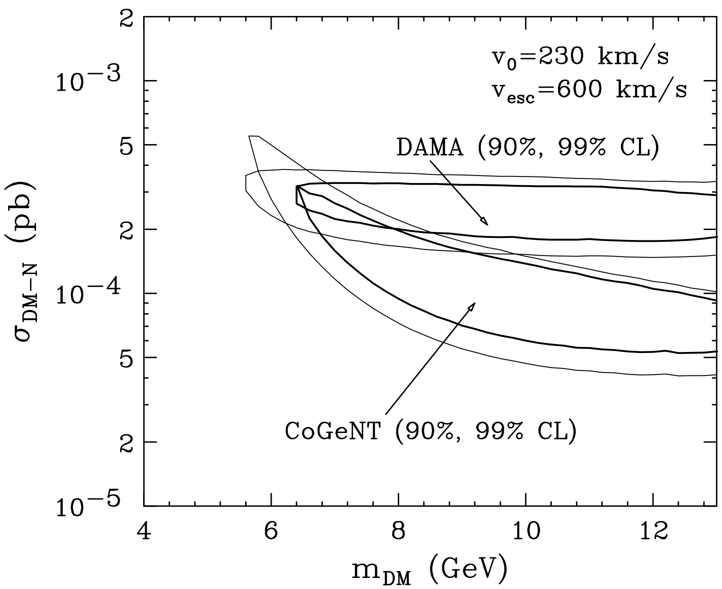
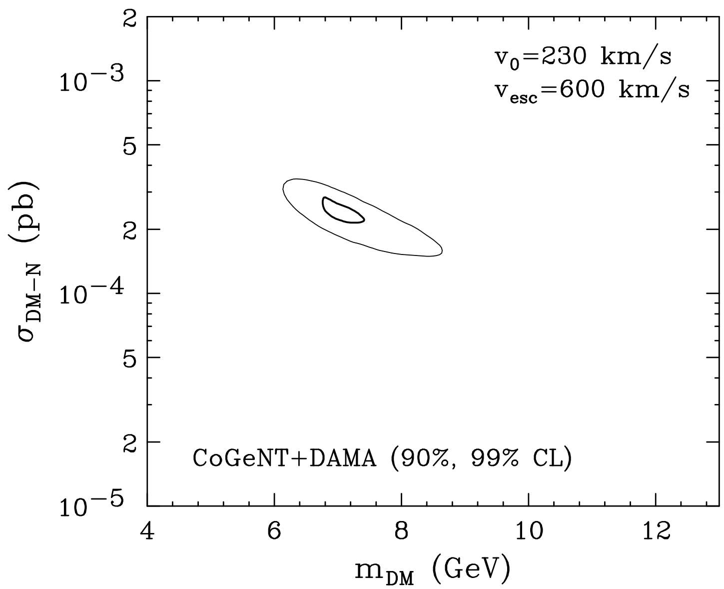
Papers/Collaborators

- *CoGeNT, DAMA, and Neutralino Dark Matter in the Next-To-Minimal Supersymmetric Standard Model*, John F. Gunion, Alexander V. Belikov, Dan Hooper, e-Print: arXiv:1009.2555 [hep-ph]

- *CoGeNT, DAMA, and Light Neutralino Dark Matter*, Alexander V. Belikov, John F. Gunion, Dan Hooper, Tim M.P. Tait, e-Print: arXiv:1009.0549 [hep-ph]

Introduction





- **CoGeNT and DAMA both have hints of dark matter detection corresponding to a very low mass particle with very large spin-independent cross section, $\sigma_{SI} \sim (1.4 - 3.5) \times 10^{-4}$ pb, for $m_{DM} = (9 - 6)$ GeV (see Hooper, *et al.*, e-Print: arXiv:1007.1005 [hep-ph]). Note: required σ_{SI} is reduced by $\sim 60\%$ if $\rho = 0.485$ GeV/cm^3 vs. usual 0.3 GeV/cm^3.**

- **One would hope that this scenario could be consistent with simple supersymmetric models.**

However, the MSSM fails. If one adjusts parameters so that Ωh^2 is ok (just barely possible to get small enough value at low $m_{\widetilde\chi_1^0}$) then σ_{SI} takes on its maximum possible value of $\sim 0.17 \times 10^{-4}~\mathrm{pb}$. The problem with Ωh^2 would be less severe if m_{A^0} could be smaller than allowed by LEP limits, but σ_{SI}, dominated by CP-even Higgs exchange, cannot be increased beyond the above.

$$\sigma_{SI} \approx 0.17 \times 10^{-4}~\mathrm{pb} \left(\frac{N_{13}^2}{0.1}\right)\left(\frac{\tan\beta}{50}\right)^2\left(\frac{100\mathrm{GeV}}{m_{H^0}}\right)^4 \cos^4\alpha\,, \quad (1)$$

where we have written $\widetilde\chi_1^0 = N_{11}\widetilde B + N_{12}\widetilde W^3 + N_{13}\widetilde H_d + N_{14}\widetilde H_u$. In the above, N_{13}^2 cannot be much larger than 0.1 because of limits on the Z invisible width.

And, this is before imposing the Tevatron limit, $B(B_s \to \mu^+\mu^-) \leq 5.8 \times 10^{-8}$. Once imposed, the largest σ_{SI} for scenarios with $\Omega h^2 \sim 0.1$ is $\sigma_{SI} \sim 0.017 \times 10^{-4}~\mathrm{pb}$ (Feldman, Liu, Nath, arXiv:1003.0437 [hep-ph]).

- What about the NMSSM?

The NMSSM is defined by adding a single SM-singlet superfield $\widehat{S}$ to the MSSM and imposing a Z_3 symmetry on the superpotential, implying

$$W = \lambda \, \widehat{S}\widehat{H}_u\widehat{H}_d + \frac{\kappa}{3} \, \widehat{S}^3 \tag{2}$$

The reason for imposing the Z_3 symmetry is that then only dimensionless couplings λ, κ enter. All dimensionful parameters will then be determined by the soft-SUSY-breaking parameters. In particular, the μ problem is solved via

$$\mu_{\rm eff} = \lambda \langle S \rangle \, . \tag{3}$$

$\mu_{\rm eff}$ is automatically of order a $\,\mathrm{TeV}$ (as required) since $\langle S \rangle$ is of order the SUSY-breaking scale, which will be below a $\,\mathrm{TeV}$.

- **The extra singlet field $\widehat{S}$ implies: 5 neutralinos, $\widetilde{\chi}^0_{1-5}$ with $\widetilde{\chi}^0_1 = N_{11}\widetilde{B} + N_{12}\widetilde{W}^3 + N_{13}\widetilde{H}_d + N_{14}\widetilde{H}_u + N_{15}\widetilde{S}$ being either singlet or bino, depending on M_1; 3 CP-even Higgs bosons, h_1, h_2, h_3; and 2 CP-odd Higgs bosons, a_1, a_2.**

- The soft-SUSY-breaking terms corresponding to the terms in W are:

$$\lambda A_\lambda S H_u H_d + \frac{\kappa}{3} A_\kappa S^3 \,. \tag{4}$$

When $A_\lambda, A_\kappa \to 0$, the NMSSM has an additional $U(1)_R$ symmetry, in which limit the a_1 is pure singlet and $m_{a_1} = 0$.

If, $A_\lambda, A_\kappa = 0$ at M_U, RGE's give $A_\lambda \sim 100 \text{ GeV}$ and $A_\kappa \sim 1 - 20 \text{ GeV}$, resulting in $m_{a_1} < 2m_B$ (see later) being quite natural and not fine-tuned.

- The NMSSM maintains all the attractive features (GUT unification, RGE EWSB) of the MSSM while avoiding important MSSM problems.

- In the simplest "ideal" Higgs scenarios (Dermisek and Gunion), it is the h_1 that has strong WW, ZZ couplings, with $m_{h_1} \lesssim 100 \text{ GeV}$ for perfect precision electroweak, baryogenesis, no finetuning, LEP excess, ..., escaping LEP limits via $h_1 \to a_1 a_1 \to 4\tau$ ($m_{a_1} < 2m_B$).

  But, it turns out that if you want to maximize σ_{SI} it should be the lightest Higgs, h_1, that has enhanced coupling to down-type quarks while it is the

h_2 that couples to WW, ZZ in SM-like fashion. Typical large σ_{SI} scenarios have $m_{h_1} < 90\ \mathrm{GeV}$ and $m_{h_2} \lesssim 110\ \mathrm{GeV}$, so still pretty ideal.

In some cases, h_1 and h_2 will share the WW, ZZ coupling.

One finds that there is then no problem (Gunion, Hooper, McElrath, e-Print: hep-ph/0509024) getting $\Omega h^2 \sim 0.1$ (using $\widetilde\chi_1^0 \widetilde\chi_1^0 \to a_1 \to X$ with m_{a_1} small). Further in paper 1) we show that if one pushes then $\sigma_{SI} \sim (0.1 - 0.2) \times 10^{-4}\ \mathrm{pb}$ is possible without violating the $B(B_s \to \mu^+\mu^-)$ bound, or any other bound.

But, to get σ_{SI} as large as 1×10^{-4} requires violating $(g-2)_\mu$ quite badly, and having some enhancement of the s-quark content of the nucleon.

- In paper 2), we explored the extended-NMSSM (ENMSSM) in which we only generalize the superpotential and soft-SUSY-breaking potential, keeping to just one singlet superfield.

$$v_0^2 \hat{S} + \frac{1}{2}\mu_S \hat{S}^2 + \mu \hat{H}_u \hat{H}_d + \lambda \hat{S} \hat{H}_u \hat{H}_d + \frac{1}{3}\kappa \hat{S}^3 \ , \tag{5}$$

and the soft Lagrangian

$$B_\mu H_u H_d + \frac{1}{2} m_S^2 |S|^2 + B_S S^2 + \lambda A_\lambda S H_u H_d + \kappa A_\kappa S^3 + H.c. \qquad (6)$$

Note the explicit μ and B_μ terms $\Rightarrow$ $\mu_{\rm eff} = \mu + \lambda \langle S \rangle$ and $B_\mu^{eff} = \lambda A_\lambda \langle S \rangle + B_\mu$. These reduce the appeal of the model somewhat, but there are string-theory-inspired sources for such explicit terms.

The ENMSSM appears to be the simplest SUSY model capable of describing the CoGeNT/DAMA events and getting $\Omega h^2 \sim 0.11$, while maintaining consistency with all known constraints.

To accomplish this, we find that the $\widetilde\chi_1^0$ should be singlino (vs. bino for maximal σ_{SI} in the NMSSM) and the h_1 should be largely singlet (rather than mainly H_d as needed for maximal σ_{SI} in the NMSSM).

To first approximation, Ωh^2 is controlled by $\widetilde\chi_1^0 \widetilde\chi_1^0 \to h_1 \to X$ and σ_{SI} is determined by h_1 exchange between the $\widetilde\chi_1^0$ and the down-type quarks in the nucleon, esp. s and b.

Dark Matter in the NMSSM and Higgs topologies

- There is a fairly clear strategy for maximising σ_{SI}.

  The largest elastic scattering cross sections arise in the case of large $\tan\beta$, significant N_{13} (the Higgsino component of the $\widetilde{\chi}_1^0$), and relatively light m_{H_d}, where H_d is the Higgs with enhanced coupling to down quarks, $C_{H_d d\bar{d}} \sim \tan\beta$. In this limit, the relevant scattering amplitude is

$$\frac{a_d}{m_d} \approx \frac{-g_2 g_1 N_{13} N_{11} \tan\beta}{4 m_W m_{H_d}^2}, \tag{7}$$

  which in turn yields

$$\begin{aligned} \sigma_{\widetilde{\chi}_1^0 p,n} &\approx \frac{g_2^2\, g_1^2\, N_{13}^2 N_{11}^2\, \tan^2\beta\, m_{\widetilde{\chi}_1^0}^2\, m_{p,n}^4}{4\pi\, m_W^2 m_{H_d}^4\, (m_{\widetilde{\chi}_1^0} + m_{p,n})^2} \left[f_{T_s}^{(p,n)} + \frac{2}{27} f_{TG}^{(p,n)} \right]^2 \\ &\approx 1.7 \times 10^{-5}\ \mathrm{pb} \left(\frac{N_{13}^2}{0.10}\right) \left(\frac{\tan\beta}{50}\right)^2 \left(\frac{100\mathrm{GeV}}{m_{H_d}}\right)^4. \end{aligned} \tag{8}$$

- Constraints on the light $h_1 \sim H_d$ configuration are significant! We had to update NMHDECAY to include all the latest constraints and then linked to micrOMEGAs as in NMSSMTools.

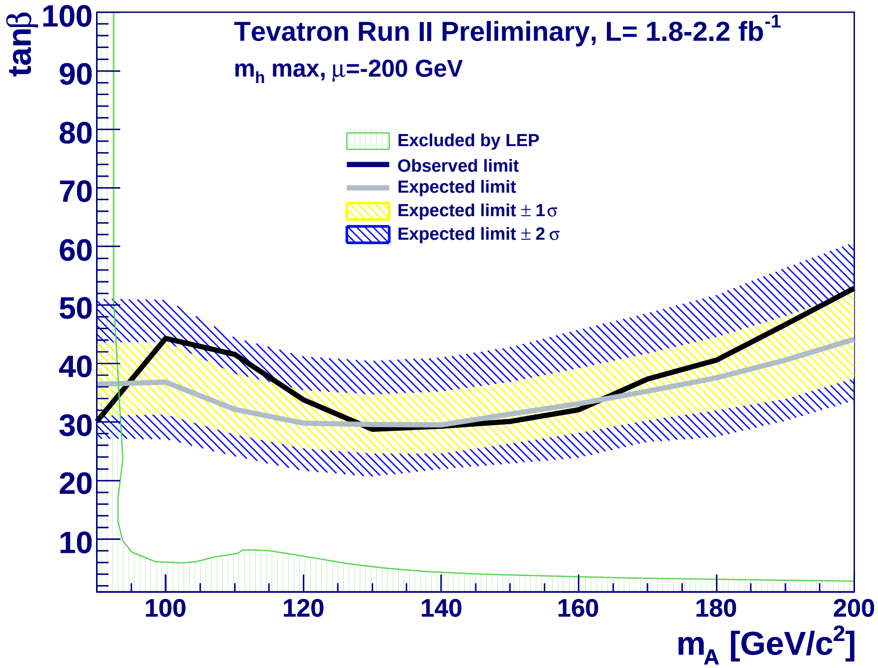
1. Constraints on the neutral Higgs sector from Zh_2 at LEP.
   These are important since we can minimize m_{h_1} for low $m_{\rm SUSY}$ and this keeps m_{h_2} low.
   In these cases the h_2 can be in the "ideal" zone and escapes LEP detection via $h_2 \to a_1 a_1$ decays with $m_{a_1} < 2m_B$ (but very close to avoid BaBar limits).
   Recall again that Dermisek and I have argued that the necessary "light-a_1" finetuning is not large due to the $U(1)_R$ symmetry limit of the NMSSM.
2. LEP constraints on $h_1 a_1$ and $h_1 a_2$.
   The $h_1 a_1$ cross section is $\propto maximal \times (\cos\theta_A)^2$. Thus, small $\cos\theta_A$ is desirable, which fits with the need for not having overly strong $\widetilde\chi_1^0 \widetilde\chi_1^0 \to a_1^* \to X$ annihilations, so as to achieve adequate Ωh^2.

3. Tevatron limits.

There are two especially relevant limits given focus on large $\tan\beta$:

(a) $b\bar{b}h_1$ associated production, which scales as $C^2_{h_1 b\bar{b}}$, the latter being something we want to maximize.

(b) And, since the h^+ tends to be quite light (e.g. $\sim 120-140~\mathrm{GeV}$) when the h_2 is SM-like, it is critical to include constraints from Tevatron limits on $t \to h^+ b$ with $h^+ \to \tau^+ \nu_\tau$ (dominant at large $\tan\beta$).



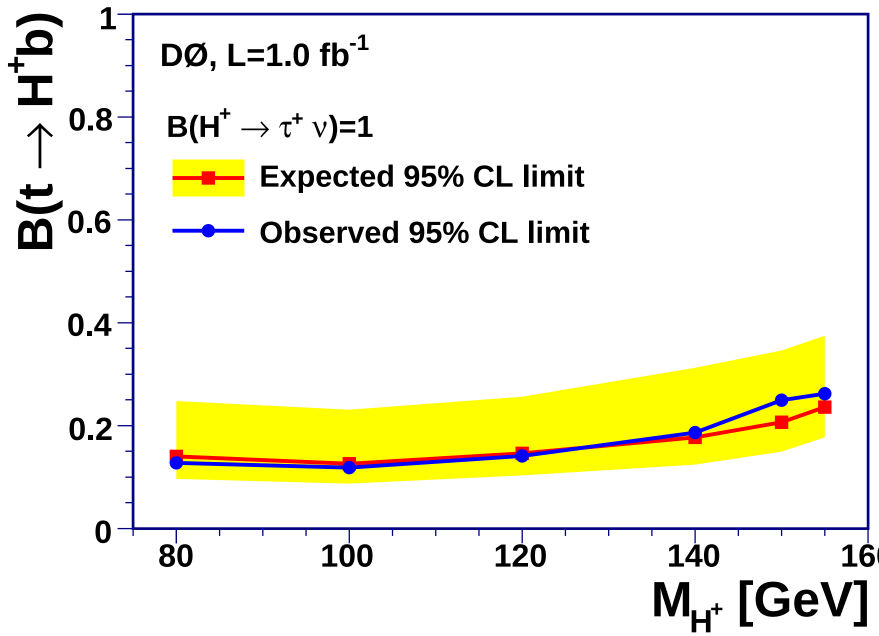


Figure 1: In left plot, must correct for fact that these curves assume $m_{H^0} \sim m_{A^0}$ which does not normally apply in our case.

4. **B-physics constraints.**

(a) The most restricting constraint arises from the very strong limit on $B(B_s \to \mu^+\mu^-)$.

Achieving a small enough value fixes A_t as a function of $m_{\rm SUSY}$.

(b) $b \to s\gamma$.

- The $\mu_{\rm eff} > 0$ scenarios have roughly 1σ discrepancy with the 2σ experimental window.
- The $\mu_{\rm eff} < 0$ scenarios only rarely have a $b \to s\gamma$ problem.

(c) $B^+ \to \tau^+\nu_\tau$.

- The $\mu_{\rm eff} > 0$ scenarios are mostly within the 2σ experimental window.
- The $\mu_{\rm eff} < 0$ scenarios with largest σ_{SI} typically have $1-2\sigma$ deviations from the experimental 2σ window.

5. $(g-2)_\mu$.

This is possibly crucial.

- For $\mu_{\rm eff} < 0$, the largest σ_{SI} values are achieved when $(g-2)_\mu$ is a few sigma outside the 2σ limits including theoretical uncertainties.

  If $(g-2)_\mu$ is strictly enforced, then it is not possible to get σ_{SI} as large as that suggested by the COGENT data.

– For $\mu_{\rm eff} > 0$, the largest σ_{SI} yield $(g-2)_\mu$ within the 2σ exp.+theor. window, but after including all other constraints the σ_{SI} values for $\mu_{\rm eff} > 0$ are not as large as those found with $\mu_{\rm eff} < 0$.

6. Ωh^2:

Of course, we require that any accepted scenario have correct relic density (~ 0.1) within the somewhat loose experimental limits encoded in NMSSMTools.

Results

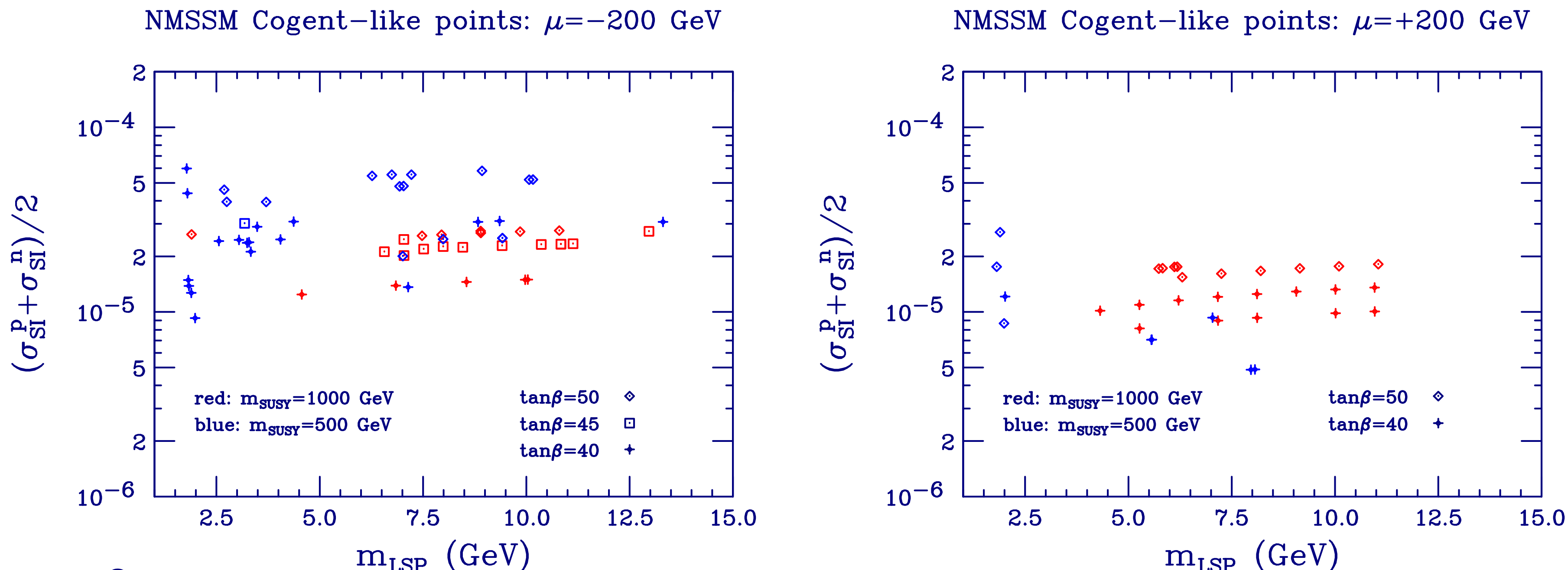
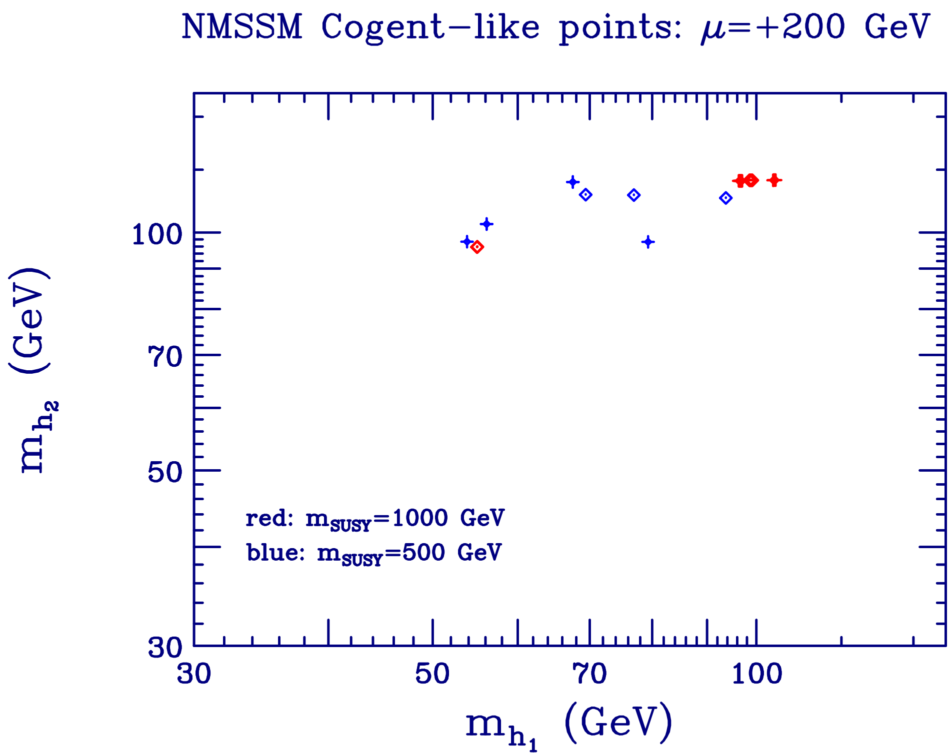


Figure 2: All points obtained without imposing Tevatron and $(g-2)_\mu$ limits (only kills $\mu_{\rm eff} < 0$ points).



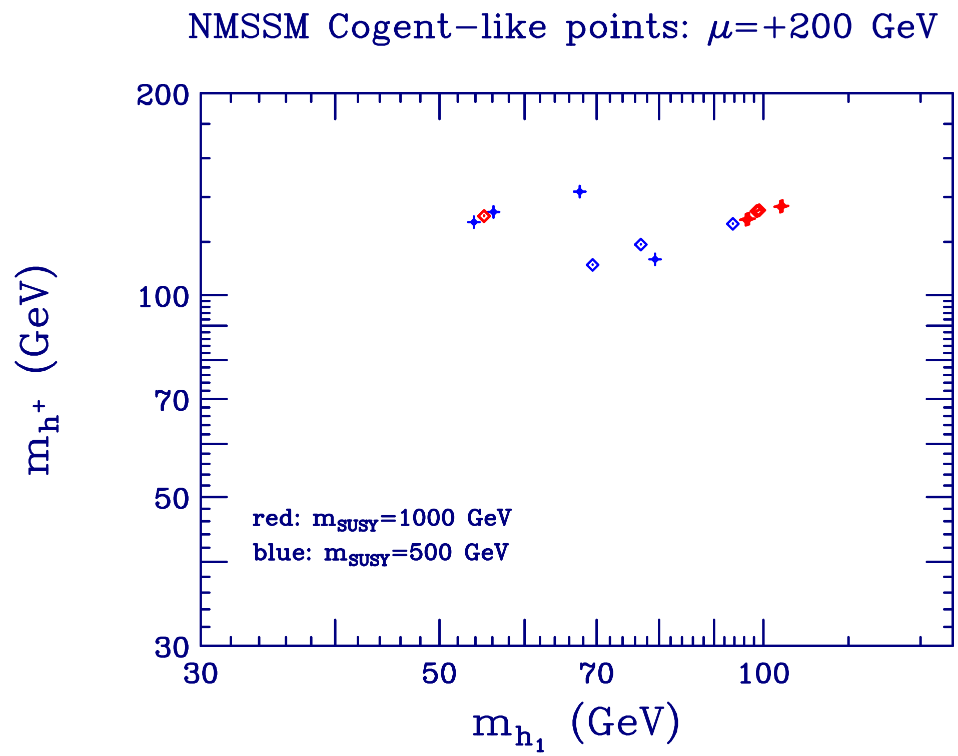


Figure 3: m_{h_2} **and** m_{h^+} **vs.** m_{h_1} **for** $\mu_{\rm eff} = +200~{\rm GeV}$ **points. Only level-I (LEP via NMHDECAY, BaBar,** Ωh^2**) constraints are imposed. There is a great amount of point overlap in this plot.**

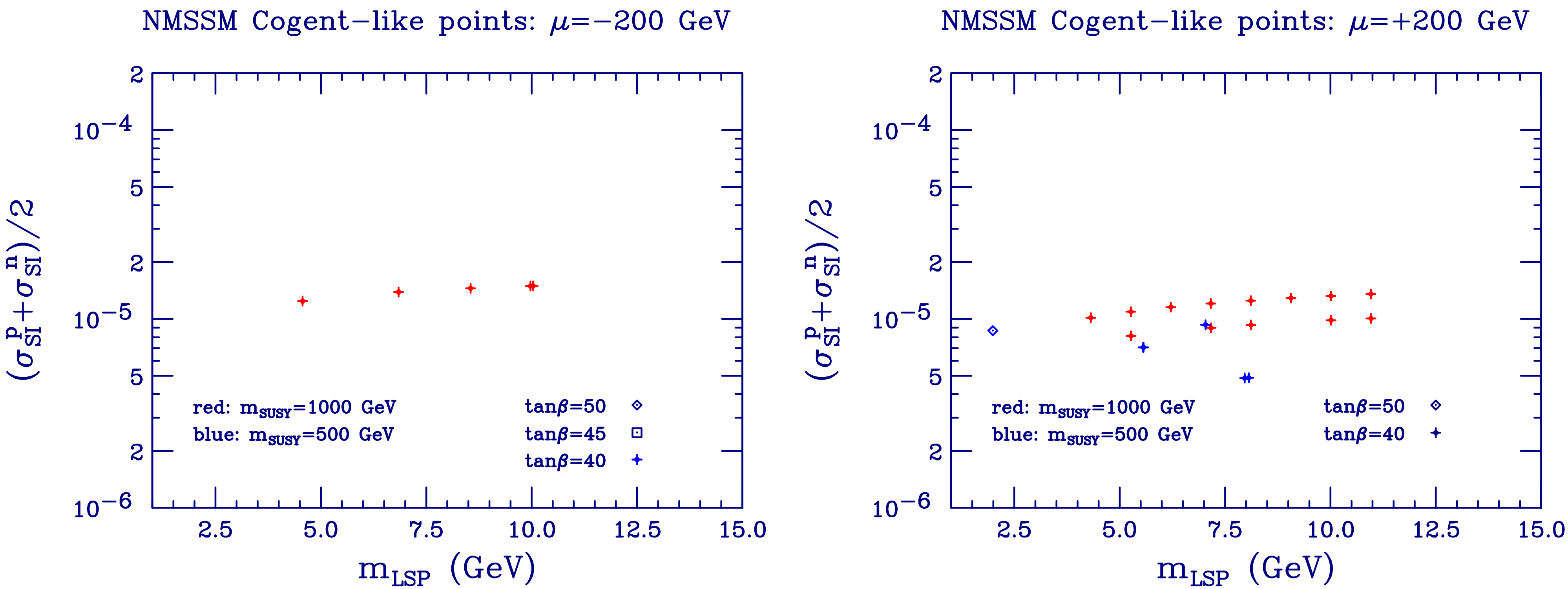


Figure 4: σ_{SI} **vs.** $m_{\widetilde{\chi}^0_1}$ **for points fully consistent with Tevatron limits on** $b\overline{b} + Higgs$ **and** $t \to h^+ b$**. Level-I constraints are imposed.** $(g-2)_\mu$ **still terrible (perfectly ok) for** $\mu_{\rm eff} < 0$ **(**$\mu_{\rm eff} > 0$**).**

Table 1: Properties of a particularly attractive but phenomenologically complex NMSSM point with $\mu_{\rm eff} = +200$ GeV, $\tan\beta = 40$ and $m_{\rm SUSY} = 500$ GeV. All Tevatron limits ok. h_3 is the most SM-like. In the last row, the brackets give the range of B-physics predictions for this point after including theoretical errors as employed in NMHDECAY.

λ	κ	A_λ	A_κ	M_1	M_2	M_3	A_{soft}
0.081	0.01605	-36 GeV	-3.25 GeV	8 GeV	200 GeV	300 GeV	479 GeV

m_{h_1}	m_{h_2}	m_{h_3}	m_{a_1}	m_{a_2}	m_{h^+}
53.8 GeV	97.3 GeV	126.2 GeV	10.5 GeV	98.9 GeV	128.4 GeV

$C_V(h_1)$	$C_V(h_2)$	$C_V(h_3)$	m_{eff}
-0.505	0.137	0.852	101 GeV

$C_{h_1 b\bar b}$	$C_{h_2 b\bar b}$	$C_{h_3 b\bar b}$	$C_{a_1 b\bar b}$	$C_{a_2 b\bar b}$
0.24	39.7	-5.1	6.7	39.4

$m_{\widetilde\chi_1^0}$	N_{11}	N_{13}	$m_{\widetilde\chi_2^0}$	$m_{\widetilde\chi_1^\pm}$	σ_{SI}	σ_{SD}	Ωh^2
7 GeV	-0.976	-0.212	79.1 GeV	153 GeV	0.93×10^{-5} pb	0.45×10^{-4} pb	0.12

$B(h_1\to a_1a_1)$	$B(h_2\to 2b,2\tau)$	$B(h_3\to 2h+2a)$	$B(h_3\to 2b,2\tau)$
0.96	$0.87, 0.12$	0.3	$0.58, 0.09$

$B(a_1\to jj)$	$B(a_1\to 2\tau)$	$B(a_1\to 2\mu)$	$B(a_2\to 2b,2\tau)$	$B(h^+\to\tau^+\nu)$
0.28	0.79	0.003	$0.87, 0.12$	0.97

$B(B_s\to\mu^+\mu^-)$	$B(b\to s\gamma)$	$B(h^+\to\tau^+\nu_\tau)$	$(g-2)_\mu$
$[1.7-6.0]\times10^{-9}$	$[5.8-12.5]\times10^{-4}$	$[0.91-4.22]\times10^{-4}$	$[4.42-5.53]\times10^{-9}$

Table 2: The $\pm2\sigma$ experimental ranges for the B physics observables tabulated in the last row of Table 1.

$B(B_s\to\mu^+\mu^-)$	$B(b\to s\gamma)$	$B(h^+\to\tau^+\nu_\tau)$	$(g-2)_\mu$
$<5.8\times10^{-8}$ (95% CL)	$[3.03-4.01]\times10^{-4}$	$[0.34-2.3]\times10^{-4}$	$[0.88-4.6]\times10^{-9}$

Table 3: LHC Neutral Higgs Discovery Channels ($b\bar b h_2, b\bar b a_2\to b\bar b 2\tau$ absent since $m_{h_2}\sim m_{a_2}<100$ GeV, the lower limit of the studies used — this should be a highly viable mode) (also $t\bar t\to b\bar t h^+\to\tau^+\nu X$ = excellent channel at LHC)

$L=30$ fb^{-1}	$L=300$ fb^{-1}			
$WW\to h_3\to 2\tau$	$b\bar b h_3\to b\bar b 2\tau$	$gg\to h_3\to 4\ell$	$gg\to h_3\to 2\ell 2\nu$	$WW\to h_3\to 2\tau$
3.8σ	2σ	1.4σ	1.1σ	14σ

- **Additional points.**

  1) Higgs decays to $\widetilde\chi_1^0\widetilde\chi_1^0$ are unimportant.

  2) $gg \to a_1 \to \mu^+\mu^-$ looks promising (Dermisek, Gunion, arXiv:0911.2460) because $C_{a_1 b\bar b} \sim 6$ and m_{a_1} is not directly under the Υ_{3S} peak.

- In a very recent paper by Das and Ellwanger (arXiv:1007.1151), cross sections as large as those found here are not achieved. They have $\sigma_{SI} \sim (1 - 1.5) \times 10^{-6}$ pb (without enhancing the s-quark content of the nucleon).

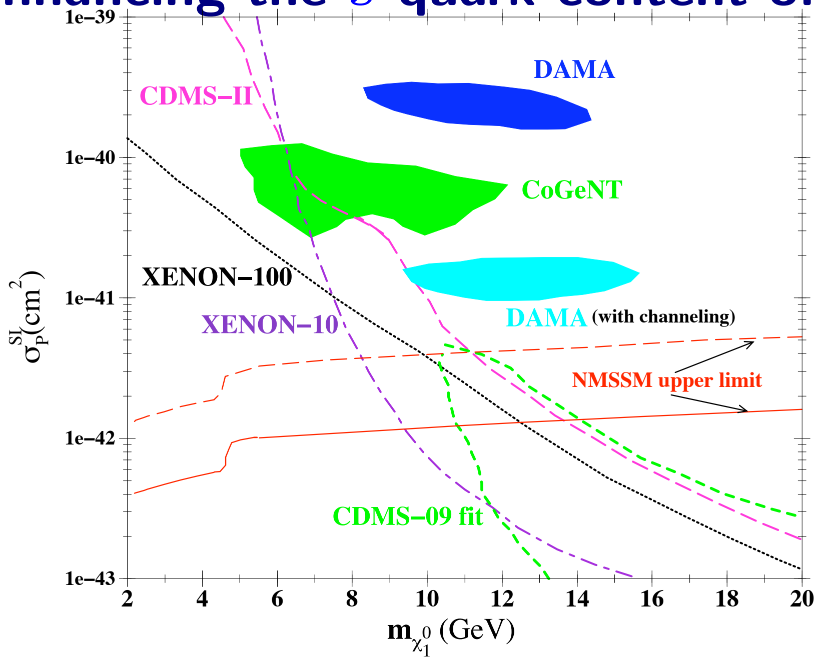


Figure 2: Upper bounds on the spin-independent cross section σ_p^{SI} in the NMSSM for default values of the strange quark content of nucleons as a full red line, and an enhanced strange quark content of nucleons as a dashed red line. Also shown are regions compatible with DAMA, CoGeNT and CDMS-II, and limits from Xenon10, Xenon100 and CDMS-II as explained in the text.

Their smaller σ_{SI} is largely because they did not seek scenarios with $h_1 \sim H_d$.

In addition, they did not take advantage of the $m_{a_1} \sim 10\ \mathrm{GeV}$ possibilities (they regard these as too finetuned).

Should we opt for enhanced s-quark nucleon content, our cross sections would go up by about the same factor of ~ 3 as in their plot.

Dark Matter in the ENMSSM and Higgs topologies

- **Given the 'failure' of the NMSSM, we realized that a qualitatively different and possibly promising alternative was to have a singlino LSP interacting with a singlet-like h_1. The NMSSM linking of parameter space to LEP and other limits was too constraining for such a scenario to have large σ_{SI}.**

  Thus, we moved to the ENMSSM and hoped to be able to realize the 'singlino-singlet' (SS) scenario.

  First, some background to see why this SS scenario has a 'miraculous' balance between the desired σ_{SI} and the observed $\Omega h^2 \sim 0.11$.

- **The singlino coupling to down-type quarks is given by:**

$$\frac{a_d}{m_d} = \frac{g_2 \kappa N_{15}^2 \tan\beta F_s(h_1) F_d(h_1)}{8 m_W m_{h_1}^2} \tag{9}$$

where $h_1 = F_d(h_1) H_d^0 + F_u(h_1) H_u^0 + F_s(h_1) H_S^0$. This leads to

$$\sigma_{\chi_1^0 p,n} \approx 2.2 \times 10^{-4}\,\mathrm{pb}\left(\frac{\kappa}{0.6}\right)^2 \left(\frac{\tan\beta}{50}\right)^2 \left(\frac{45\,\mathrm{GeV}}{m_{h_1}}\right)^4 \left(\frac{F_s^2(h_1)}{0.85}\right)\left(\frac{F_d^2(h_1)}{0.15}\right),$$

which is consistent with the value required by CoGeNT and DAMA/LIBRA. Furthermore, the mostly singlet nature ($F_s^2(h_1) = 0.85$) of the h_1 would hopefully allow it to evade the constraints from LEP II and the Tevatron.

Of course, one really sums coherently over all the CP-even Higgs bosons.

- The thermal relic density of neutralinos is determined by the annihilation cross section and mass. In the mass range we are considering here, the dominant annihilation channel is to $b\bar{b}$ (or, to a lesser extent, to $\tau^+\tau^-$) through the s-channel exchange of the same scalar Higgs, h_1, as employed for elastic scattering, yielding:

$$\sigma_{\chi_1^0\chi_1^0} v = \frac{N_c g_2^2 \kappa^2 m_b^2 F_s^2 F_d^2}{64\pi m_W^2 \cos^2\beta} \frac{m_{\chi_1^0}^2 (1 - m_b^2/m_{\chi_1^0}^2)^{3/2}\, v^2}{(4m_{\chi_1^0}^2 - m_{h_1}^2)^2 + m_{h_1}^2 \Gamma_{h_1}^2}, \quad (10)$$

where v is relative velocity between the annihilating neutralinos, $N_c = 3$ is a color factor and Γ_{h_1} is the width of the exchanged Higgs. The annihilation cross section into $\tau^+\tau^-$ is obtained by replacing $m_b \to m_\tau$ and $N_c \to 1$. This yields the thermal relic abundance of neutralinos: $\Omega_{\chi_1^0} h^2 \approx \frac{10^9}{M_{\rm Pl}} \frac{m_{\chi_1^0}}{T_{\rm FO}\sqrt{g_\star}} \frac{1}{\langle \sigma_{\chi_1^0\chi_1^0} v\rangle}$, where $g_\star$ is the number of relativistic degrees of freedom at freeze-out, $\langle \sigma_{\chi_1^0\chi_1^0} v\rangle$ is the thermally averaged annihilation cross section at freeze-out, and $T_{\rm FO}$ is the temperature at which freeze-out occurs.

For the range of masses and cross sections considered here, we find $m_{\chi_1^0}/T_{\rm FO} \approx 20$, yielding a thermal relic abundance of

$$\Omega_{\chi_1^0} h^2 \approx 0.11 \left(\frac{0.6}{\kappa}\right)^2 \left(\frac{50}{\tan\beta}\right)^2 \left(\frac{m_{h_1}}{45\,{\rm GeV}}\right)^4 \left(\frac{7\,{\rm GeV}}{m_{\chi_1^0}}\right)^2 \left(\frac{0.85}{F_s^2(h_1)}\right) \left(\frac{0.15}{F_d^2(h_1)}\right), \quad (11)$$

i.e. naturally close to the measured dark matter density, $\Omega_{\rm CDM} h^2 = 0.1131 \pm 0.0042$.

- The only question is can we achieve the above situation without violating

LEP and other constraints. Basically, one wants a certain level of decoupling between the singlet sectors and the MSSM sectors, but not too much. We found some 'unusual' parameter choices that appeared to accomplish this at a 'naive' level.

We then performed parameter scans with an extended version of NMHDECAY and micrOMEGAs that includes both the non-NMSSM parameters of Eqs. (5) and (6) as well as the latest B-physics and Tevatron constraints. We find points for $15 < \tan\beta < 45$ that are consistent (within 2σ) with all collider and B-physics constraints (aside from $\sim 2.5\sigma$ excursions in $b \to s\gamma$ and $b\bar{b}h, h \to \tau^+\tau^-$) having the appropriate thermal relic density and $\sigma_{\chi_1^0 p,n}$ as large as $few \times 10^{-4}$ pb.

- **The complete framework has contributions to $\sigma_{\chi_1^0 p,n}$ and $\Omega_{\chi_1^0}$ beyond Eqs. (10) and (11) and high-$\sigma_{\chi_1^0 p,n}$ points typically have large contributions from the non-singlet Higgses.**

- **A 'Typical' Point**

Table 4: Properties of a typical ENMSSM point with $\tan\beta = 45$ and $m_{\rm SUSY} = 1000$ GeV.

λ	κ	λs	A_λ	A_κ	M_1	M_2	M_3	A_{soft}
0.011	0.596	−0.026 GeV	3943 GeV	17.3 GeV	150 GeV	300 GeV	900 GeV	679 GeV

B_S	μ_S	v_S^3	μ	B_μ	$\mu_{\rm eff}$	B_μ^{eff}
0	7.8 GeV	4.7 GeV	164 GeV	658 GeV	164 GeV	556 GeV

m_{h_1}	m_{h_2}	m_{h_3}	m_{a_1}	m_{a_2}	m_{h^+}
82 GeV	118 GeV	164 GeV	82 GeV	164 GeV	178 GeV

$F_S^2(h_1)$	$F_d^2(h_1)$	$F_S^2(h_2)$	$F_u^2(h_2)$	$F_S^2(h_3)$	$F_d^2(h_3)$	$F_S^2(a_1)$	$F_S^2(a_2)$
0.86	0.14	0.0	0.996	0.14	0.86	0.86	0.14

$C_V(h_1)$	$C_V(h_2)$	$C_V(h_3)$	$C_{h_1 b\bar b}$	$C_{h_2 b\bar b}$	$C_{h_3 b\bar b}$	$C_{a_1 b\bar b}$	$C_{a_2 b\bar b}$
−0.0096	0.999	−0.041	16.8	2.9	41.7	−16.9	41.7

$m_{\widetilde\chi_1^0}$	N_{11}^2	$N_{13}^2 + M_{14}^2$	N_{15}^2	σ_{SI}	Ωh^2
4.9 GeV	0.0	0.0	1.0	2.0×10^{-4} pb	0.105

$B(h_1\to\widetilde\chi_1^0\widetilde\chi_1^0)$	$B(h_1\to 2b, 2\tau)$	$B(h_2\to\widetilde\chi_1^0\widetilde\chi_1^0)$	$B(h_2\to 2b, 2\tau)$	$B(h^+\to\tau^+\nu)$
0.64	0.33, 0.03	0.003	0.88, 0.092	0.97

$B(a_1\to\widetilde\chi_1^0\widetilde\chi_1^0)$	$B(a_1\to 2b, 2\tau)$	$B(a_2, h_3\to\widetilde\chi_1^0\widetilde\chi_1^0)$	$B(a_2, h_3\to 2b, 2\tau)$
0.64	0.33, 0.03	0.05	0.85, 0.095

Notes

1. What you see is that the h_1, a_1 have separated off from something that is close to an MSSM-like doublet sector with $h_2 \sim h^0$ being SM-like and $h_3 \sim H^0$ and $a_2 \sim A^0$.

2. There are some $h_2, a_2 \to \widetilde{\chi}_1^0 \widetilde{\chi}_1^0$ decays, but at such a low branching ratio level that detection would be unlikely.
3. Decays to pairs of Higgs not of importance.
4. h_1 and a_1 decay primarily to $\widetilde{\chi}_1^0 \widetilde{\chi}_1^0$ but there also decays to $b\overline{b}$ and $\tau^+\tau^-$ with reduced branching ratios compared to 'normal'.
5. h_1 and a_1 do have somewhat enhanced couplings to $b\overline{b}$ (factor of 17) and so the rates for $gg \to b\overline{b}h_1$ and $gg \to b\overline{b}a_1$ will be large $\Rightarrow$ possibly detect in the $h_1, a_1 \to \tau^+\tau^-$ channel at very high L.
   Is there a hope for $gg \to b\overline{b} + (h_1, a_1) \to b\overline{b} + \not{E}_T$ at the predicted rate?
6. It is the very large value of A_λ and the very small λ that keep singlet and MSSM sectors fairly separate.

Conclusions

– Perhaps we have already seen the first sign of the Higgs sector in CoGeNT/DAMA data and dark matter relic abundance.

– If this scenario applies, the main observable Higgs will be MSSM-like.

So far, the parameter choices (large A_λ in particular) imply a relatively small mass separation between the h^0-like h_2 and the H^0, A^0-like h_3, a_2.

– Highly precise absolute determination of the h_2, h_3 and a_2 branching ratios would be needed to detect the slight 'bleed-in' to the singlet sector.

– With high L maybe could see the h_1, a_1 directly.

I'm $still$ waiting to see some sign of a Higgs!