Dark Matter in the NMSSM
(Next-to-Minimal Supersymmetric Standard Model)

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WIMP Dark Matter

Vanilla thermal production:

$<\sigma v> \sim 3 \times 10^{-26}\ \mathrm{cm}^3/\mathrm{s}$

but direct detection limits are very strong

(see next talk by B.Pelssers)

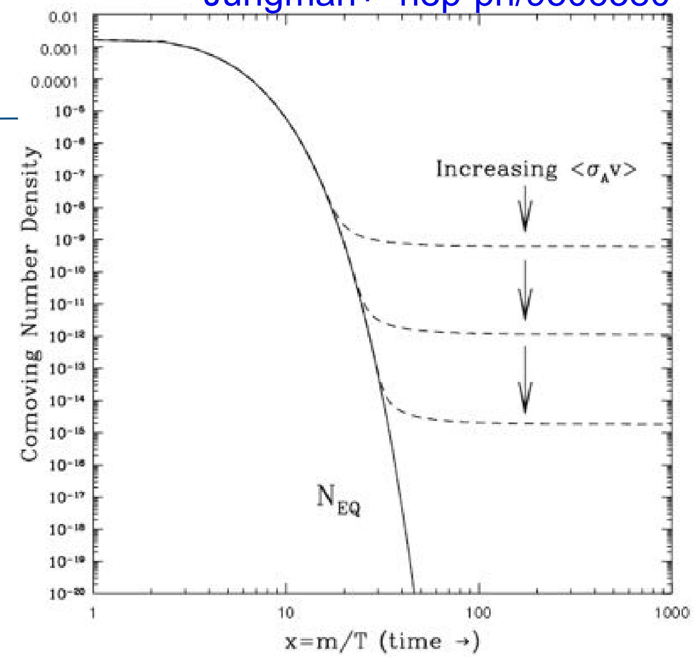
Production and direct detection cross-sections must be decoupled (unless $m_{DM} \gg 100$ GeV)

E.g., for interactions mediated by a scalar h with O(1) couplings to top quarks and $2m_\chi > m_h$ / $2m_t$:

$$\langle \sigma v \rangle \sim 10^{-27} \frac{\mathrm{cm}^3}{\mathrm{s}} \left(\frac{g_{h_\chi}}{0.1} \right)^2 \left(\frac{200\,\mathrm{GeV}}{m_\chi} \right)^2$$

$$\sigma^{\mathrm{SI}} \sim 10^{-8}\,\mathrm{pb} \left(\frac{g_{h\chi}}{0.1} \right)^2 \left(\frac{125\,\mathrm{GeV}}{m_h} \right)^4$$

Jungman+ hep-ph/9506380



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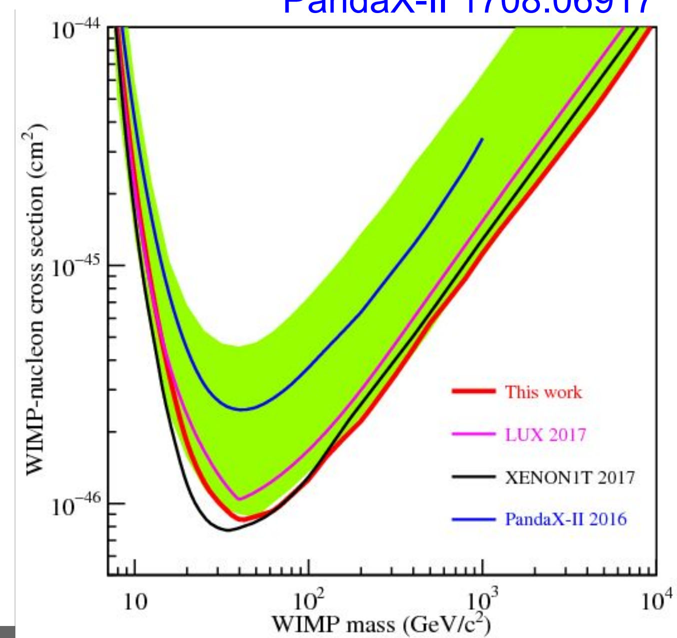

2 ways of decoupling <σv> and σ^{SI}/σ^{SD}

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Suppress coupling of DM candidate to all states which could mediate direct detection signals

Then, one needs to boost the annihilation cross-section:

- co-annihilation
- resonant annihilation

Griest&Seckel, PRD 43, 3197 (1991)

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Both options require extended BSM sectors to supply either

- co-annihilation partners,
- multiple mediators to allow for destructive interference

Consider NMSSM with heavy sleptons/squarks

MSSM particle content + chiral superfield uncharged under SM

$$W \supset \lambda \widehat{S}\, \widehat{H}_u \cdot \widehat{H}_d + \frac{\kappa}{3} \widehat{S}^3$$

Higgs sector

- Three neutral CP-even Higgses
- Two neutral CP-odd Higgses
- 1 charged Higgs

$$H_u^R,\ H_d^R,\ H^S$$

$$A^{\text{NSM}},\ A^S$$

$$H^{\pm}$$

MSSM Higgs sector

New in NMSSM

Behavior controlled by $p_i = \{\lambda, \kappa, \tan\beta, \mu, A_\lambda, A_\kappa\}.$

Acceptable pheno of 125 GeV Higgs most easily obtained for λ~0.6
Carena+ 1510.09137
SB, Freese, Shakya, Shah 1703.07800

Neutralino sector

- Wino -- mass ~ M_2
- Bino -- mass ~ M_1
- 2 Higgsinos -- mass ~ -μ
- Singlino -- mass ~ 2κμ/λ

MSSM neutralino sector

New in NMSSM

NMSSM Dark Matter

Two singlet neutralinos present in NMSSM, which are good DM candidates:

- Bino with typical coupling strength g_1 ~ 0.2
- Singlino with typical couplings λ ~ 0.6

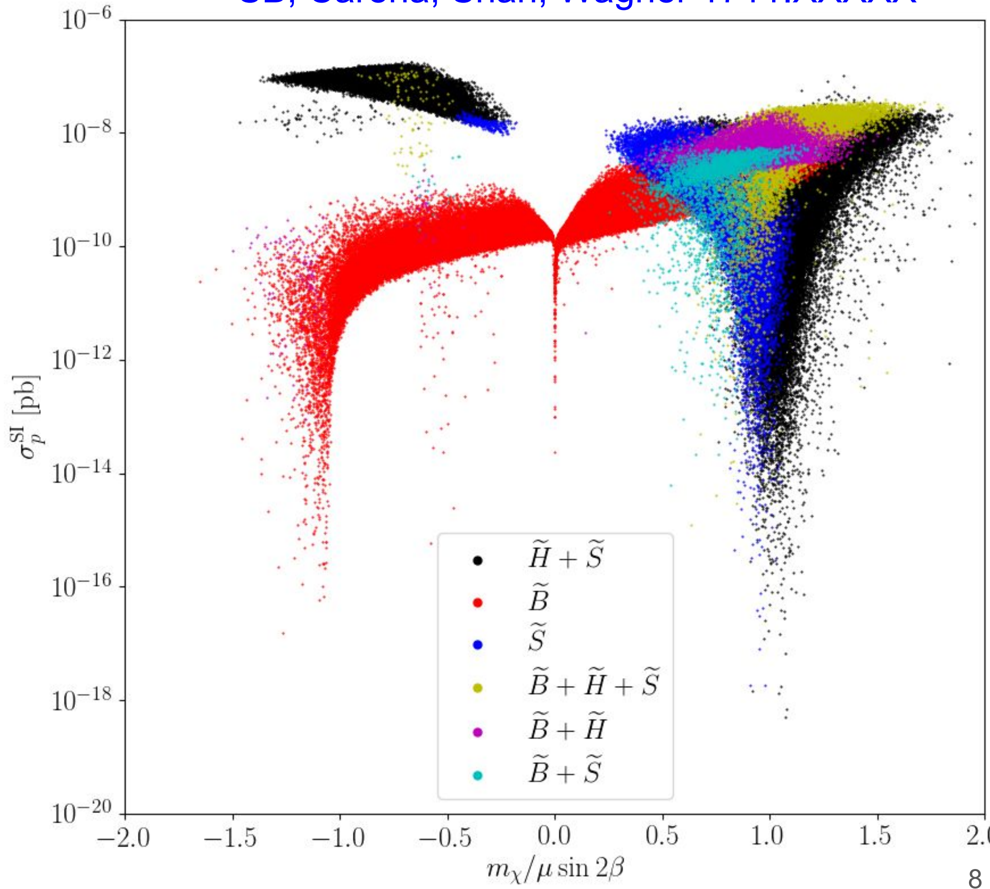
Induces large SI detection cross-section, one needs to cancel coupling to the SM-like Higgs:

Blind spot condition:

$m_\chi \simeq \pm\mu \sin 2\beta$

Cheung+ 1406.6372
Baziak+ 1512.02472

SB, Carena, Shah, Wagner 1711.XXXXX



New 'Well-tempered' Bino region

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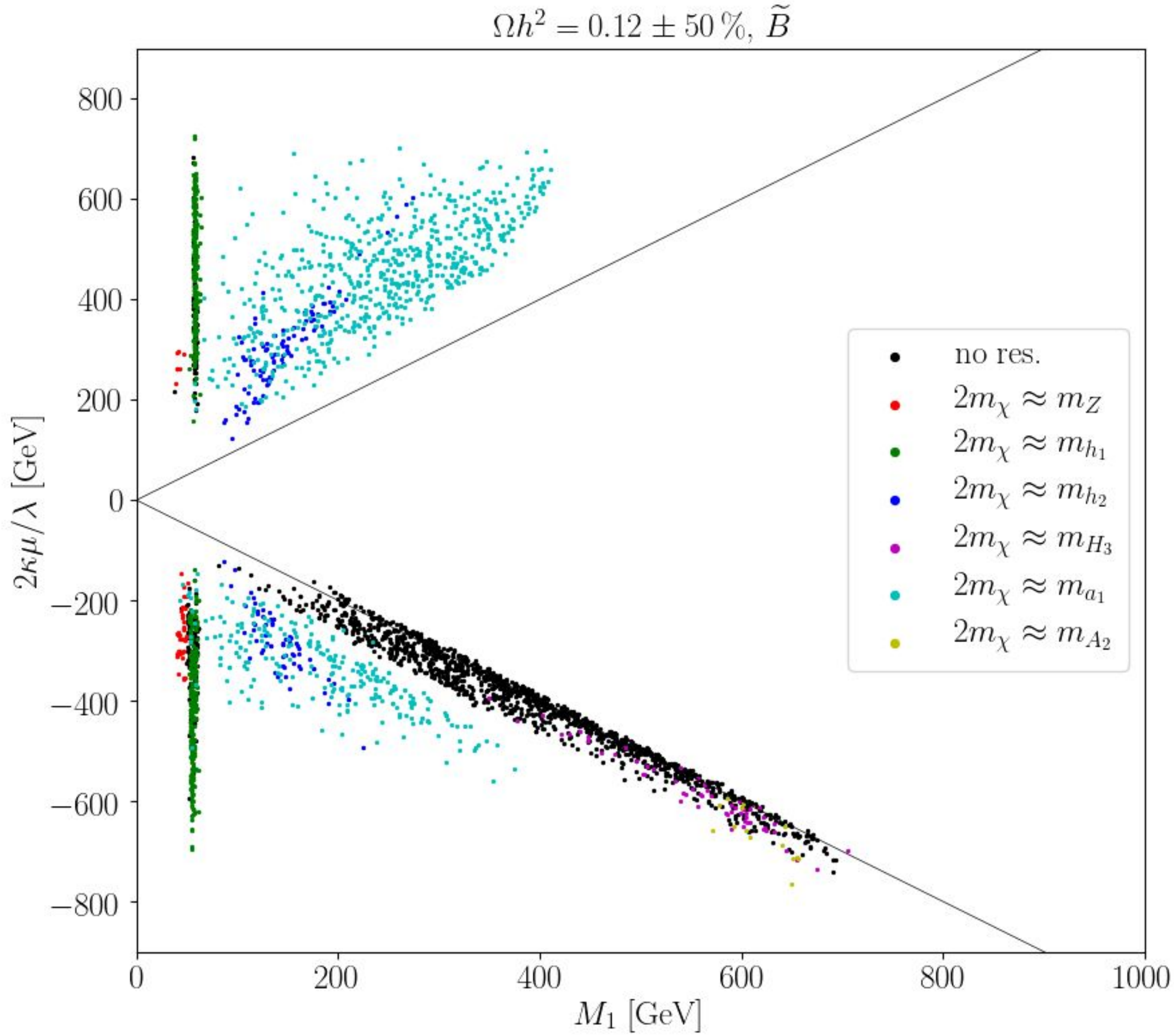
Correct relic density obtained by

- Resonant annihilation
- Co-annihilation with the singlino

SI direct detection cross-section sufficiently suppressed by blind spot condition $m_\chi \simeq -\mu \sin 2\beta$



Singlino Region

Relic density usually provided via $\chi\chi\to tt$ annihilation, dominantly mediated by longitudinal Z (Goldstone)

SI cross-section suppressed by:

- Blind spot , but not sufficient because of large coupling λ ~ 0.6,
- Additional suppression from destructive interference, mostly between the SM-like Higgs and (light) most-singlet state

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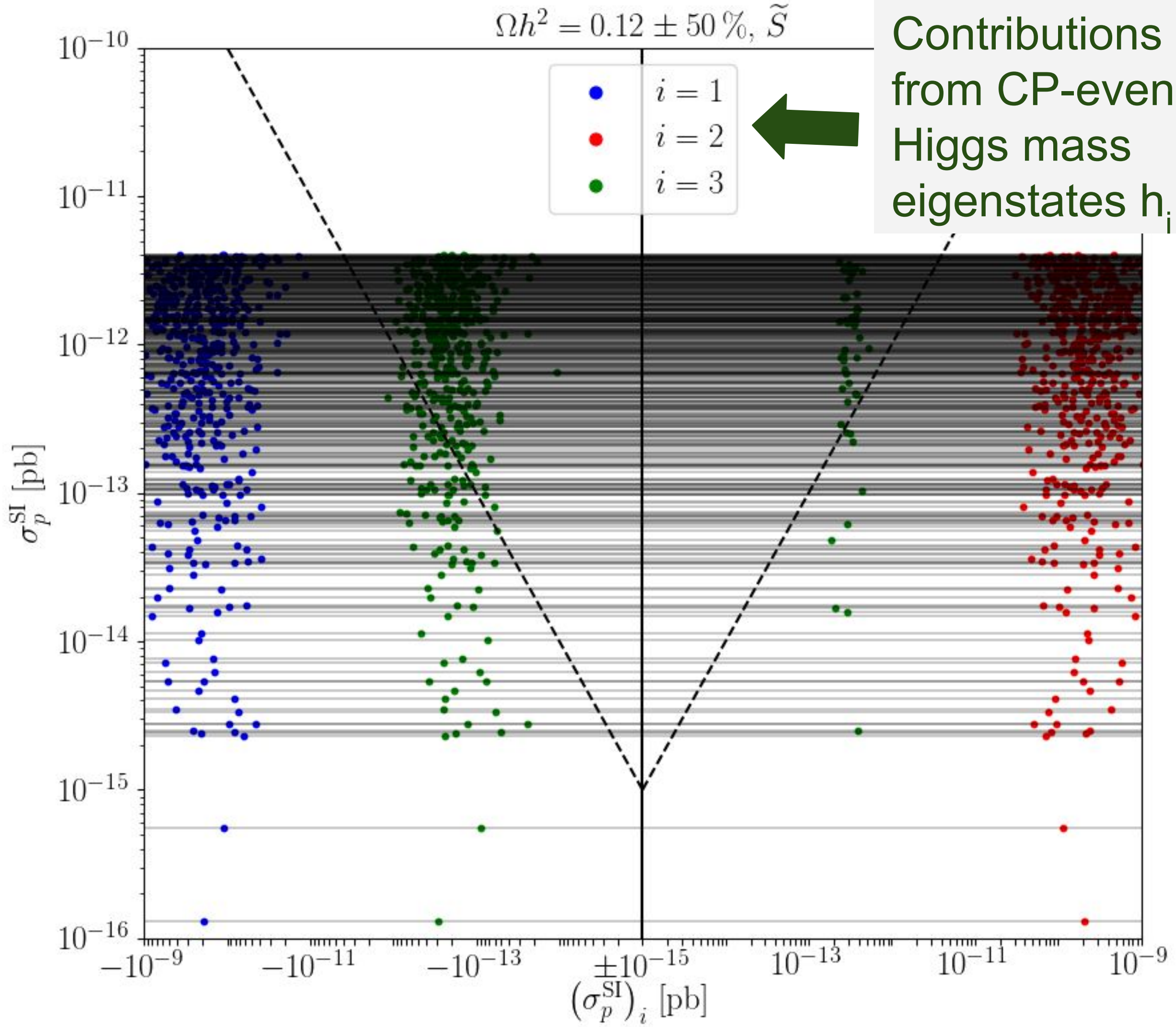

Contributions from CP-even Higgs mass eigenstates h_i

Conclusions

Stringent Direct Detection limits require decoupling of SI detection cross section and annihilation cross section

- Either, one enhances the production cross-section by resonant annihilation or co-annihilation,
- or, one suppresses the SI detection cross section by destructive interference

Both scenarios can be realized in the NMSSM:

- New ‘Well-tempered’ Bino-Higgsino region, co-annihilation with the singlino and blind-spot for SI detection
- Singlino region w/ vanilla thermal production via the Z boson (Goldstone) and blind-spot + destructive interference for SI detection