Status of the Light Singlino-Higgsino Scenario in the NMSSM

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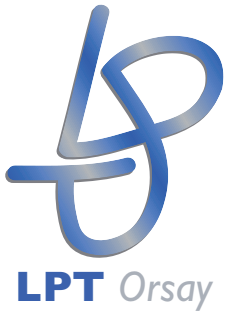


Light Higgsinos are natural:

Their mass is given by μ (MSSM) or $\mu \equiv \mu_{eff} \equiv \lambda \langle S \rangle$ (NMSSM)

The potential of scalar Higgs doublets includes mass terms $+\mu^2$, but must be unstable in order to trigger SU(2) $\times$ U(1) symmetry breaking

$\longrightarrow$ $+\mu^2$ must be cancelled by negative soft SUSY breaking terms

$\longrightarrow$ Requires fine tuning iff $|\mu| \gg M_Z$

Higgsinos are no good dark matter candidates:

Relic density too small (unless $|\mu| \gtrsim 1$ TeV)

Large direct detection rates (spin-dependent via Z-exchange)

MSSM:

Try bino LSP $\longrightarrow$ relic density too large

Try higgsino-bino mixing $\longrightarrow$ too large direct detection rates unless $M_{LSP} \gtrsim 1$ TeV

NMSSM:

The singlino is a good dark matter candidate:

Good relic density through annihilation via

- singlet-like CP-odd A_1 funnel (requires $M_{A_1} \sim 2 \times M_{LSP}$ for $M_{A_1} \lesssim 80$ GeV, but only $M_{A_1} \approx 2 \times M_{LSP}$ for $M_{A_1} \gtrsim 80$ GeV allowing for $A_1^* \to A_1 + H_1$, $A_1 \to t\bar{t}$ etc.)
- Z- or CP-even Higgs funnels
- charged higgsino in the t-channel

Note:

Singlino–A_1 coupling κ from $\frac{1}{3}\kappa S^3$ in the superpotential
$\longrightarrow$ no doublet component of the LSP is required for a good relic density

Still:

Unless the singlino-higgsino mass splitting is large, a singlino-like LSP aquires a higgsino component through mixing

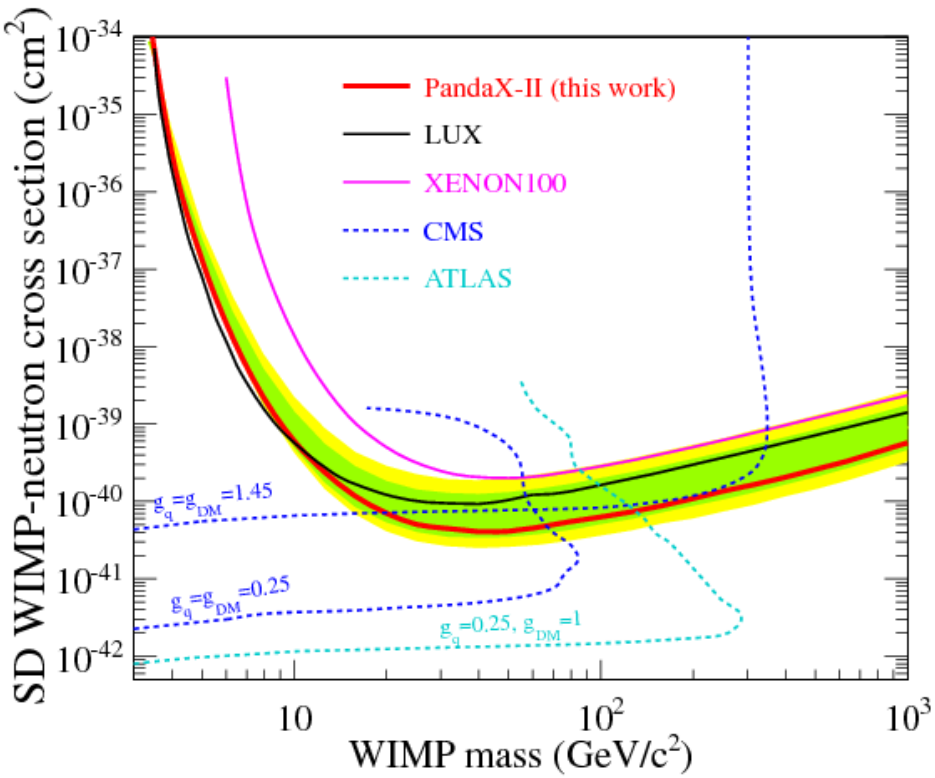
$\longrightarrow$ Constraints from direct detection:

Notably from spin dependent direct detection via Z-exchange due to the "large" Z-nucleon coupling;

Constraints from spin independent direct detection via Higgs exchange can be avoided via negative interference of SM-like and singlet-like CP-even Higgs exchanges

Constraints on Spin-Dependent LSP-Neutron Xsection from PandaX-II:

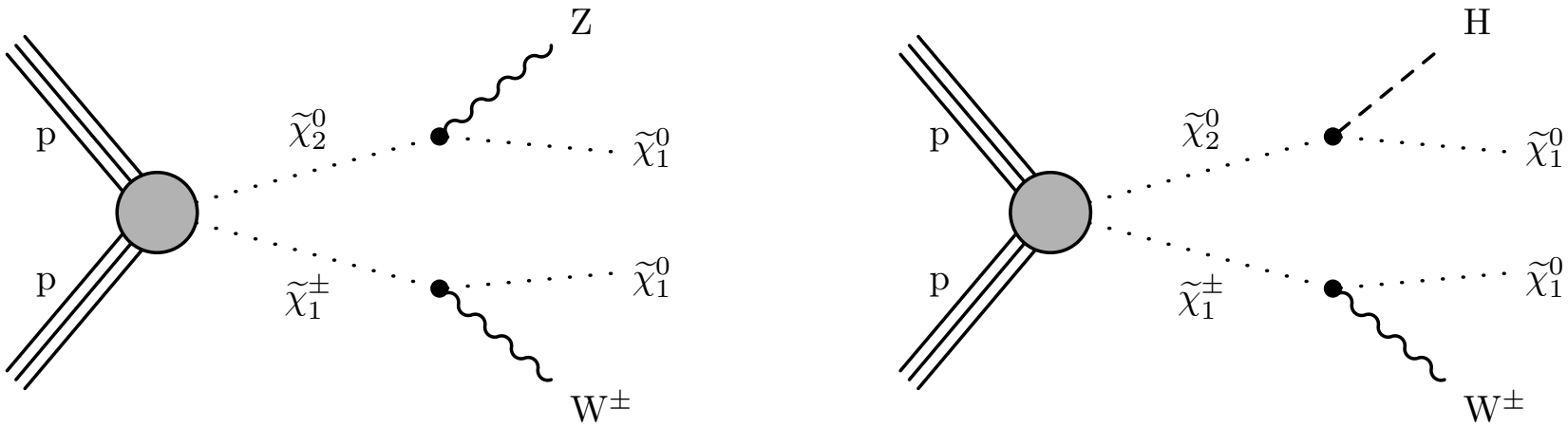
(from 1611.06553)



$\rightarrow$ Strong for $M_{LSP} \gtrsim 20$ GeV

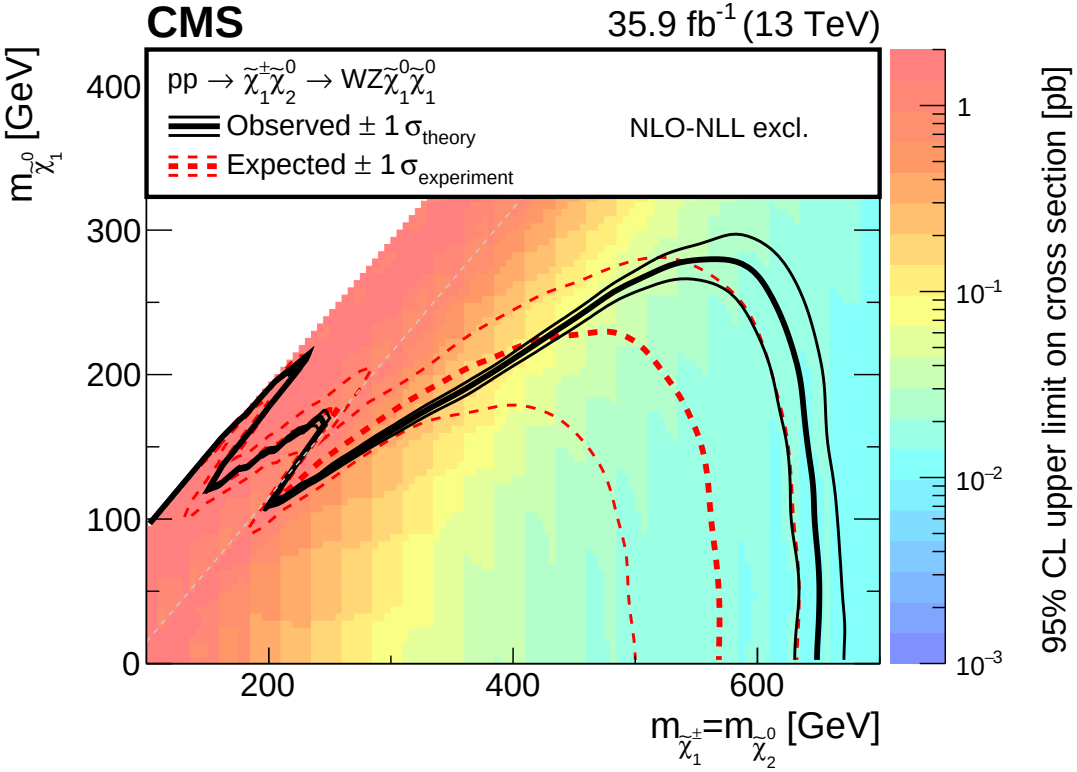
LHC Searches for Light Higgsinos:

Search for $W^* \to \chi_1^\pm + \chi_2^0$:



Most sensitive search: 3 leptons from $W^\pm$ and Z
Note: In the NMSSM one can have also $\chi_2^0 \to \chi_1^0 + H_1$ with H_1 singlet-like

95% CL upper limits on Xsection×BR in the plane $M_{\chi_1^\pm} - M_{\chi_1^0}$, assuming $M_{\chi_1^\pm} = M_{\chi_2^0}$, from CMS-SUS-17-004 (1801.03957):



→ Strong constraints on the Higgsino-Singlino scenario in the NMSSM?
Note: The black curve assumes wino-like $\chi_1^\pm$, χ_2^0 production Xsection

Recast the CMS Limits for the NMSSM Higgsino-Singlino Scenario:

Now:

— Higgsino-like $\chi_1^\pm$ with mass $\sim \mu_{eff}$

— Higgsino-like $\chi_{2,3}^0$ with masses $\sim \mu_{eff} \pm \Delta_\pm$ due to mixing (with $\Delta_\pm \sim 10$ GeV)

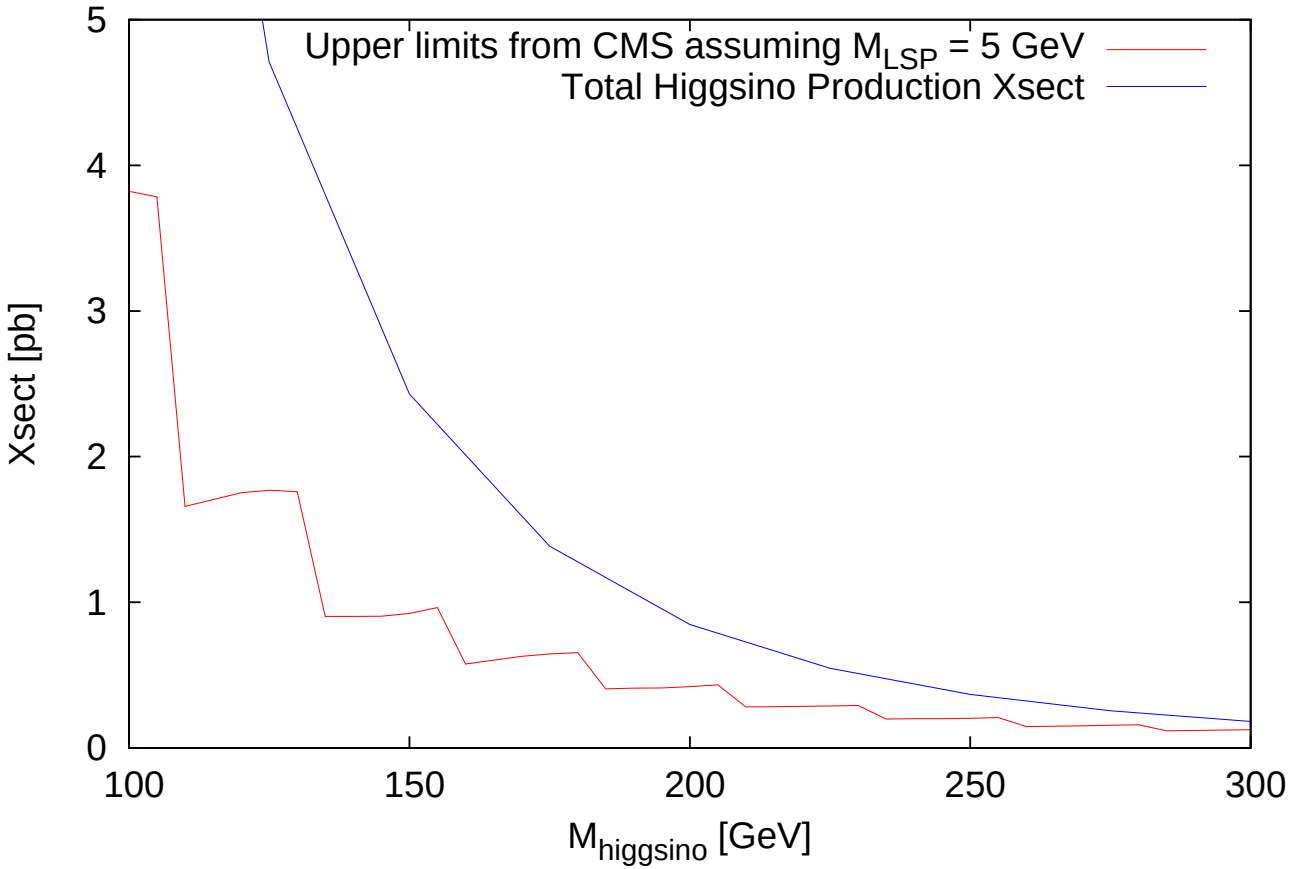
— Singlino-like χ_1^0

Assume efficiencies $\sim$ linear in the $\chi_1^\pm - \chi_{2,3}^0$ mass splitting $\pm\Delta_\pm$
($\rightarrow$ cancellations)

$\longrightarrow$ Use prospino to obtain the production cross section for a given nondegenerate $\chi_1^\pm - \chi_{2,3}^0$ system, rescale (by a few %) by the production cross section for higgsinos from the LHC SUSY Cross Section Working Group

$\longrightarrow$ Use prospino to find which degenerate $\chi_1^\pm - \chi_{2,3}^0$ system has the same production cross section as a given nondegenerate $\chi_1^\pm - \chi_{2,3}^0$ system; to be used for the limits from CMS

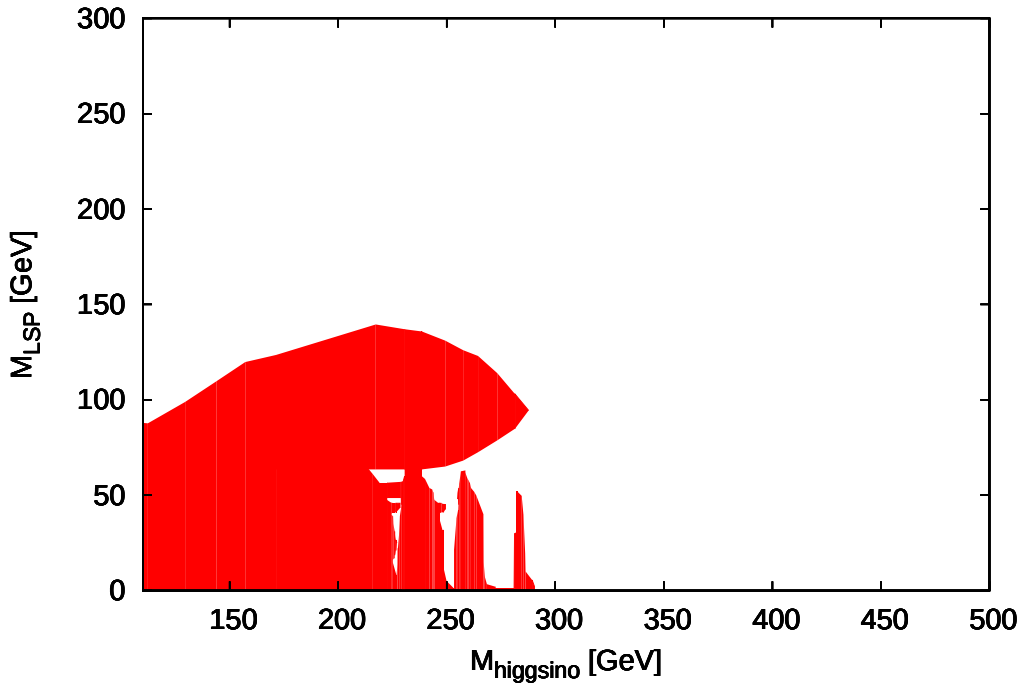
The CMS limits "wiggle" somewhat as function of $M_{\chi_1^\pm} = M_{higgsino}$, seemingly due to combinations of signal regions (not visible from the previous figure): For fixed $M_{\chi_1^0} = 5$ GeV, varying $M_{\chi_1^\pm}$:



$\rightarrow$ The bounds are satisfied only if the $BR(\chi_2^0 \rightarrow \chi_1^0 + Z)$ is small enough

After a scan of the pNMSSM parameter space (preliminary), imposing:

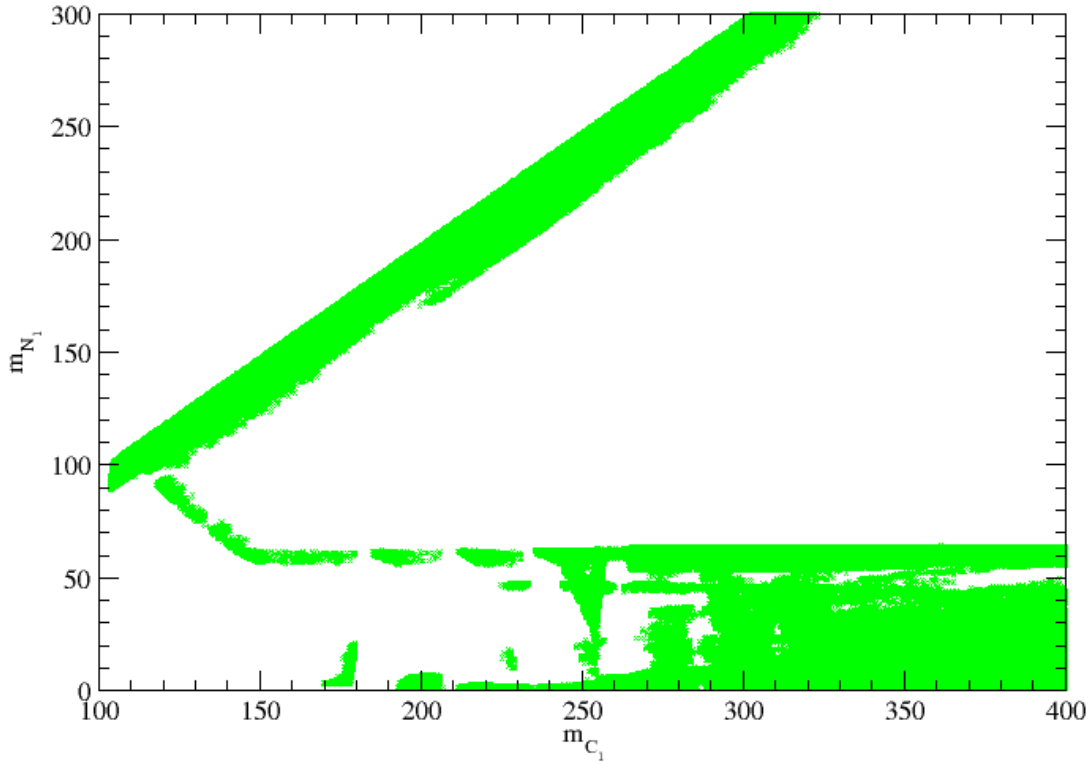
- Decoupled winos/other sparticles
- Good relic density
- Constraints from direct spin-dep. and spin-indep. DM detection expts.
- Constraints from SM Higgs properties and from BSM Higgs searches (as in NMSSMTools)
- Constraints from CMS:



At least one constraint is violated in the red region

After a scan of the NUH-NMSSM parameter space (preliminary), imposing:

- A not too large relic density
- Constraints from direct spin-dep. and spin-indep. DM detection expts.
- Constraints from SM Higgs properties and from BSM Higgs searches (as in NMSSMTools)
- Constraints from CMS:



Viable points exist at least in the green region (Here: winos are NOT decoupled)

Conclusions

The higgsino-singlino scenario in the NMSSM remains an attractive scenario for a light supersymmetric "WIMP" consistent with the dark matter relic density and constraints from direct detection

It is considerably less constrained by CMS searches than the pure wino scenario

BUT: The combination $M_{singlino} \lesssim 50$ GeV and $|\mu| \sim M_{higgsino} \lesssim 250$ GeV becomes difficult once all constraints are combined

...unless $\chi^0_{2,3} \to \tau + \tilde{\tau}$ dominates (if $M_{\tilde{\tau}}$ small enough; weak bounds at present! Disallowed for the present analysis): Then CMS constraints are avoided

Corresponding ATLAS searches would be highly welcome!