Dilaton domination in the MSSM and its singlet extensions

J.Louis,K.Schmidt-Hoberg and LZ [arXiv:1402.2977, t.a in Physics Letters B]

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Particles, Strings,
and the Early Universe
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Outline

Motivation

Minimal Supersymmetric Standard Model (MSSM)

- Signature of a UV completed theory: String Theory
- Gauge coupling unification
- Stabilizes the Higgs mass from radiative corrections (*hierarchy problem*)
- Dark matter candidate (neutralino)

Minimal Supersymmetric Standard Model+
Singlet extensions

- Now a *little hierarchy problem*
  MSSM models need large radiative corrections to achieve the 126GeV, this implies some fine tuning at the EW scale. At tree level:

$$m_h^{\text{tree}} \leq M_z$$

additional tree level mass term that could reduce the fine tuning

- Concerning DM
  Large susy scale can yield too large relic abundance

additional DM candidate, the *singlino*, that could relieve this tension

[U.Ellwanger,C.Hugonie,A.M.Texeira]
[M.Maniatis]

Motivation

String Theory

Embed the model in ST where our framework is a low energy limit.
String model building has two main steps

- Construct string background with additional singlet and its coupling.
- Define the susy breaking mechanism and vacua determine soft terms at high scale.

We start from $N = 1$ Supergravity effective theory (f , K , W)
with the spectrum of observable fields, and hidden fields.

Motivation

String Theory

Gravity mediated SUSY breaking

Observable sector
(MSSM, NMSSM..)

Hidden sector, breaks SUSY
(ex. dilaton , moduli..)

When the hidden field gets a vev and take the rigid limit → soft terms appear $\sim O(m_{\frac{3}{2}})$ [V.S.Klapunovsky,J.Louis '93]

SUSY is broken by the Dilaton (*dilaton domination*)

- Model independent (in heterotic strings)
- Universal soft terms (no flavor mixing terms)

We will study the pheno. implications of the Dilaton domination in MSSM and singlet extensions

Pheno constraints

Pheno constraints:

- Higgs mass $m_h = (125.6 \pm 3)$GeV [CMS,ATLAS '13]
- Dark Matter $0.1064 < \Omega h^2 < 0.01334$ [PLANCK '13] and SUSY searches

Numerical analysis:

- SPheno created by Sarah [W.Porod, F.Staub] (2 loop scalar Higgs masses)
- MicrOmegas [G.Belanger, F.Boujema,A.Pukhov,A.Semenov] (Dark Matter relic density)

Dilaton domination in the MSSM

$$\mathcal{W}_{\text{MSSM}} = \mu_h H_u H_d + \text{yukawa terms}$$

Dilaton domination fixes the soft parameters at GUT scale:

$$\mathbf{m_0}, \quad \mathbf{m_{1/2}} = \sqrt{\mathbf{3}}\mathbf{m_0}, \quad \mathbf{A_0} = -\sqrt{\mathbf{3}}\mathbf{m_0}$$

$\mathbf{B_h}$ **free** , $\mathsf{B_h} = 2\mu_h m_0$ [G.Giudice, A.Masiero]

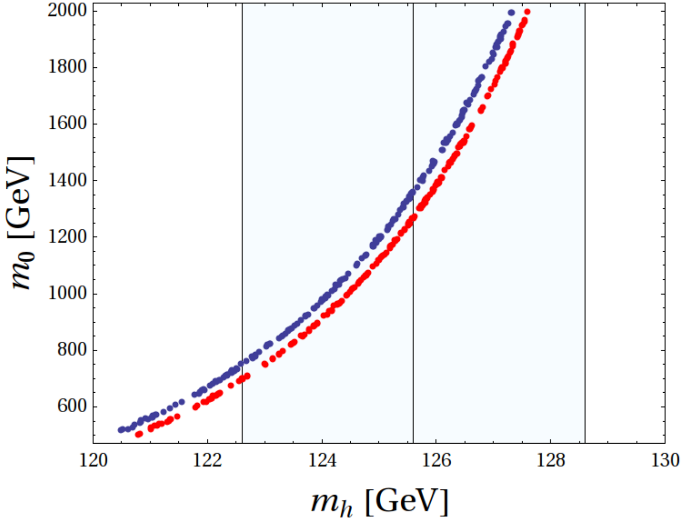
ruled out [R.Barbieri,J.Louis,R.Moretti]

EWSB fixes one parameter ($v \sim 246$GeV)
2 free parameters: (m_0, μ_h or)

$$\mathbf{m_0}, \ \mathbf{tan}\ \boldsymbol{\beta}, \ \textbf{sign}(\boldsymbol{\mu})$$

Higgs mass

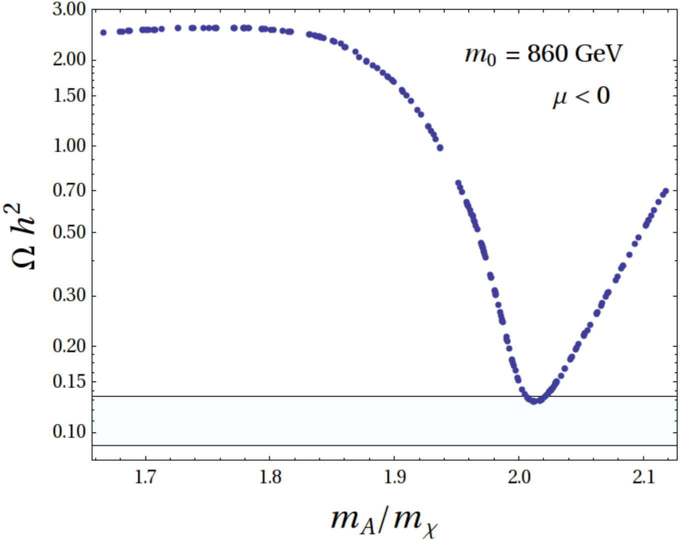
- Large $\tan\beta$
- Bound on m_0: m_0 >695GeV $(\mu_h > 0)$, m_0 >760GeV $(\mu_h < 0)$



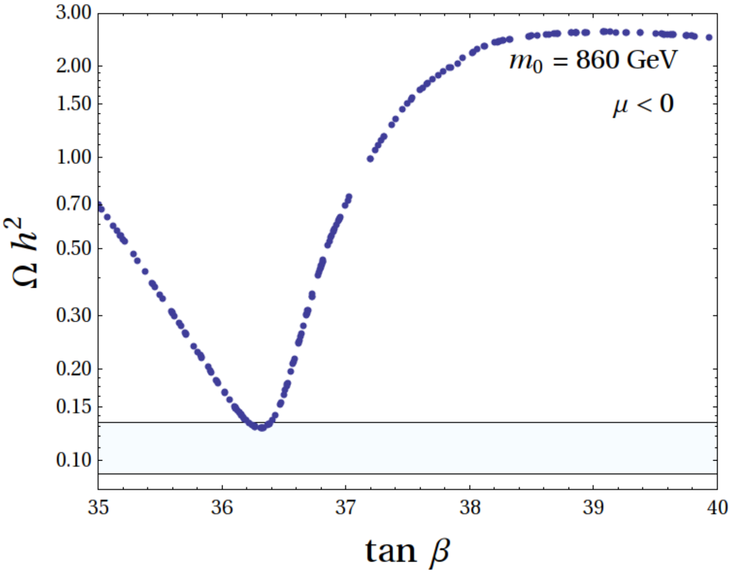
Dark Matter

Bino neutralino has very large RD, one can go to

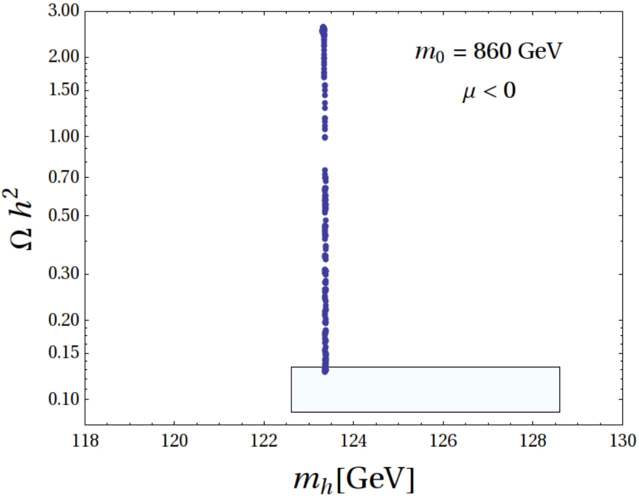
resonance in A channel: $m_A \sim 2m_\chi$



Dark Matter


3.00
2.00
1.50
1.00
0.70
0.50
0.30
0.20
0.15
0.10
Ωh^2
35
36
37
38
39
40
$\tan\beta$
m_0 = 860 GeV
$\mu < 0$

Dark Matter



Relic density increases rapidly with m_0

$$m_0 < 875\text{GeV}\ (\mu_h < 0)$$

which shows the tension with the Higgs mass!.

Prediction for LHC-14

To have a Higgs mass and DM relic density in the allowed range, we obtained

$$760\text{GeV} < m_0 < 875\text{GeV}\ ,\ \tan\beta \sim 36,\ \mu_h < 0$$

and found no available region for $\mu_h > 0$.

These yields

1. higgs mass $\sim$ lower bound
2. $2750\text{GeV} < m_{\tilde{g}} < 3150\text{GeV}$
3. $2450\text{GeV} < m_{\tilde{q}} < 2800\text{GeV}$

[J.Louis,K.Schmit.Hobert,LZ]

Dilaton domination in GNMSSM

$$\mathcal{W}_{\mathsf{GNMSSM}} = \mathcal{W}_{\mathsf{MSSM}} + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \mu_s S^2 + \xi S$$

Dilaton domination fixes the soft parameters at GUT scale:

$$\mathbf{m_0 = m_s}, \quad \mathbf{m_{1/2} = \sqrt{3} m_0}, \quad \mathbf{A_0 = A_\lambda = A_\kappa = -\sqrt{3} m_0}$$

general case	$\mathbf{B_s},\ \mathbf{B_h}$ **free**
constrained	$\mathbf{B_s = 2\boldsymbol{\mu}_s m_0},\ \mathbf{B_h = 2\boldsymbol{\mu}_h m_0}$

EWSB fixes one parameter ($v \sim 246$GeV)
7 free parameters: $(s \to v_s)$

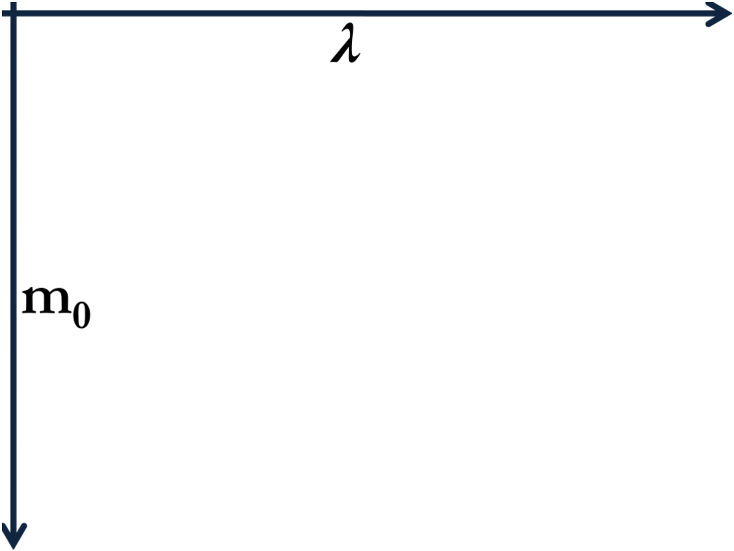
$$\mathbf{m_0},\ \mathbf{tan}\ \boldsymbol{\beta},\ \boldsymbol{\lambda},\ \boldsymbol{\kappa}, \boldsymbol{\mu}_\mathbf{s},\ \mathbf{B_s}, \mathbf{v_s}$$

Results GNMSSM

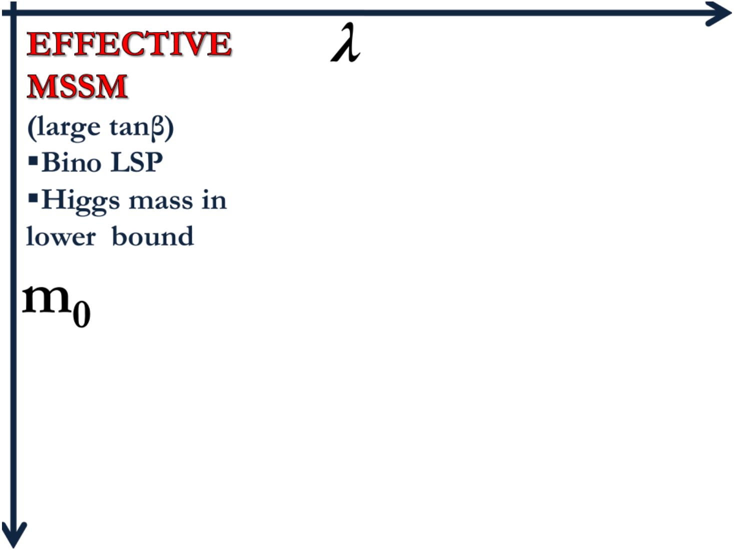
Singlet extensions could increase the tree level Higgs mass
in large λ and small $\tan\ \beta$ regime

$$m^2_{h(\text{tree})} < M_z^2 \cos^2\theta + \lambda^2 v^2 \sin^2\theta$$

For different singlet sectors of W_{GNMSSM}, depending on the regime of λ, we found examples of phenomenologically available regions in parameter space that relieve the tension found in the MSSM.


λ
m_0

$$\mathcal{W}_{\mathsf{GNMSSM}} = \mathcal{W}_{\mathsf{MSSM}}(\mu_h = 0) + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \mu_s S^2$$

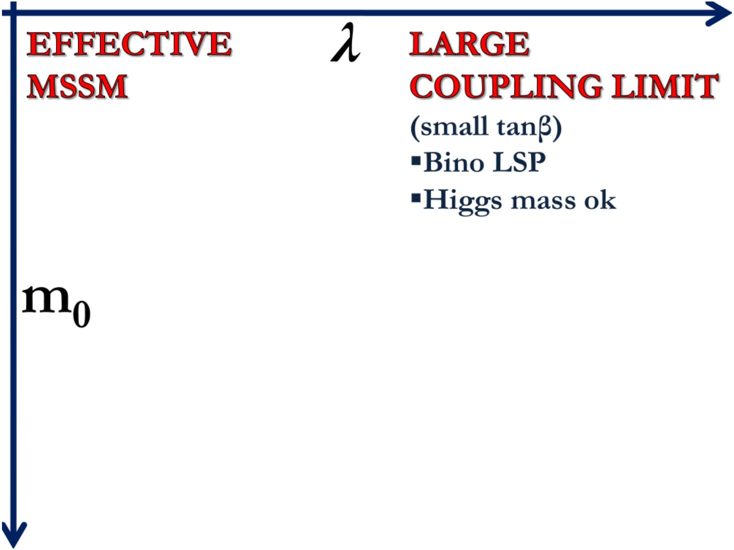


EFFECTIVE MSSM

(large tanβ)

- Bino LSP
- Higgs mass in lower bound

$$\mathcal{W}_{\text{GNMSSM}} = \mathcal{W}_{\text{MSSM}}(\mu_h \neq 0) + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \mu_s S^2$$



EFFECTIVE MSSM

λ

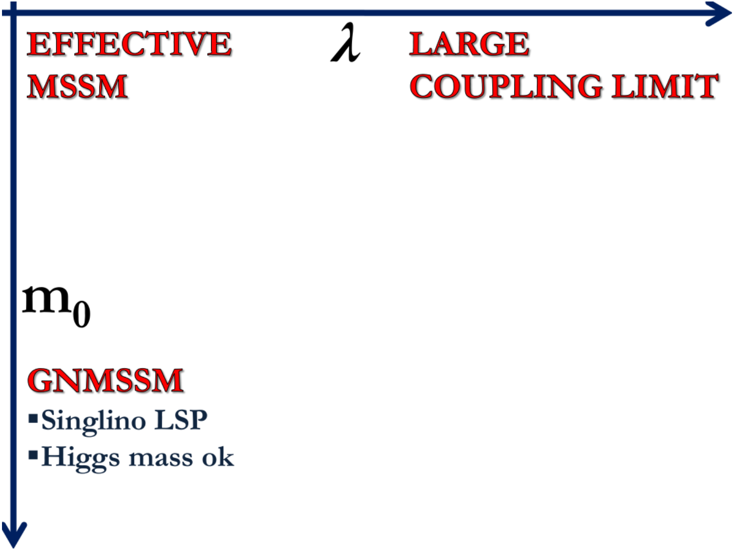
LARGE COUPLING LIMIT

(small tanβ)

- Bino LSP
- Higgs mass ok

m_0

$$\mathcal{W}_{\text{GNMSSM}} = \mathcal{W}_{\text{MSSM}}(\mu_h \neq 0) + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \mu_s S^2 + \xi S$$



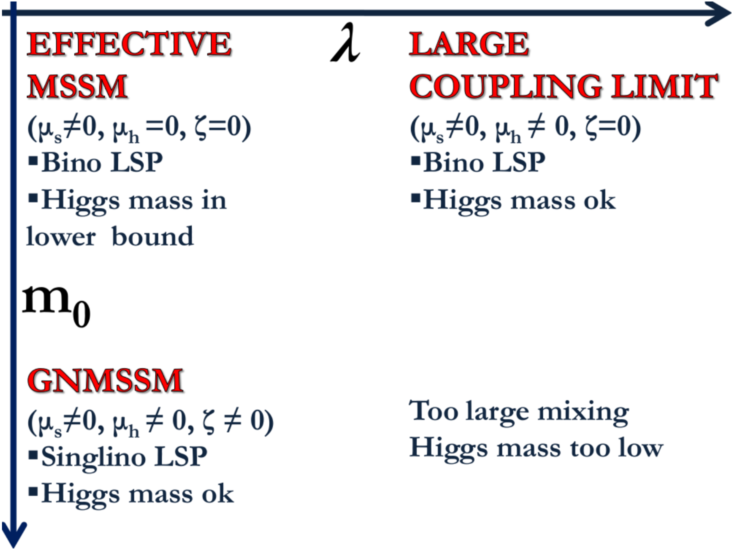
EFFECTIVE MSSM

LARGE COUPLING LIMIT

GNMSSM

- Singlino LSP
- Higgs mass ok

$$\mathcal{W}_{\mathsf{GNMSSM}} = \mathcal{W}_{\mathsf{MSSM}}(\mu_h \neq 0) + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \mu_s S^2 + \xi S$$



EFFECTIVE MSSM

($\mu_s \neq 0$, $\mu_h = 0$, $\zeta = 0$)

- Bino LSP
- Higgs mass in lower bound

LARGE COUPLING LIMIT

($\mu_s \neq 0$, $\mu_h \neq 0$, $\zeta = 0$)

- Bino LSP
- Higgs mass ok

GNMSSM

($\mu_s \neq 0$, $\mu_h \neq 0$, $\zeta \neq 0$)

- Singlino LSP
- Higgs mass ok

Too large mixing
Higgs mass too low

Conclusions

- The dilaton domination in both the MSSM and GNMSSM are phenomenologically viable scenarios.
- In the MSSM case we found a tension among the higgs mass and the DM relic density that yields predictions for the LHC-14:

$$2750\text{GeV} < m_{\tilde{g}} < 3150\text{GeV}$$
$$2450\text{GeV} < m_{\tilde{q}} < 2800\text{GeV}$$

with a higgs mass near the lower bound .

- In the GNMSSM we found regimes with the Higgs mass near its central value (large coupling limit) and the tension with DM relic abundance is relieved when DM candidate is a singlino (decoupling limit).

Thanks for your attention!