Triplet extension of the MSSM

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DESY
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Based on works done with
C. Arina, A. Delgado, V. Martin-Lozano, M. Quirós

Outline

1. Introduction
   - The model
2. Higgs Phenomenology
   - Features at small m_A
   - Features at large m_A
     - Without dark matter requests
     - With dark matter requests
3. Conclusion

Motivation

- No clear discrepancies between data and SM predictions with $m_h \simeq 126$ GeV
- If we do not give up with the (Planck/GUT - EW) hierarchy problem, SUSY is (one of) the favourite UV option
- In the MinimalSSM $m_h \simeq 126$ GeV requires "heavy" stop sector $\Rightarrow$ Little Hierarchy Problem, i.e. some fine-tuning
- Non-minimalSSM models can alleviate this problem as they can enhance the tree-level Higgs mass via

  D–terms: Extra gauge interactions

  F–terms: Extra chiral sector (singlets and/or triplets)

THE $Y = 0$ TRIPLET

Less free parameters than $Y = \pm 1$ extension, and extra charginos with collider and cosmological effects

The Y=0 Triplet Extension (Espinosa&Quiros'92,Di Chiara&Hsieh'08)

$$\Sigma = \begin{pmatrix} \xi^0/\sqrt{2} & -\xi_2^+ \\ \xi_1^- & -\xi^0/\sqrt{2} \end{pmatrix}, \quad \Delta W = \lambda H_1\cdot\Sigma H_2 + \frac{1}{2}\mu_\Sigma tr\Sigma^2 + \mu H_1\cdot H_2$$

- T parameter bound requires $\langle\xi^0\rangle \lesssim 4$ GeV which imposes (unless of fine-tuning)

$$|A_\lambda|,\, |\mu|\,,|\mu_\Sigma| \lesssim \frac{m_\Sigma^2 + \lambda^2 v^2/2}{10^2\ \lambda v}$$

- This hierarchy implies decoupling between ξ^0 and H_1, H_2

Mass boost: $V(H_1,H_2) \simeq V_{MSSM} + \lambda^2|H_1^0 H_2^0|^2$

(for $m_A \to \infty$: $m_h^2 = m_Z^2\cos^2 2\beta + \lambda^2 v^2 \sin^2 2\beta/2$)

(large λ and small $\tan\beta$ preferred)

(other tripl. extens. in E.J.Chun&al,1209.1303; Z.Kang&al,1301.2204)

The relevant spectrum

- Heavy scalar triplet [$\gtrsim 5$ TeV]

- Minimiz. conditions

$$m_3^2 = m_A^2 \sin\beta\cos\beta \ , \qquad m_Z^2 = \frac{m_2^2 - m_1^2}{\cos 2\beta} - m_A^2 + \frac{\lambda^2}{2} v^2$$

- CP-odd/charged Higgses [no preferences]

$$m_A^2 = m_1^2 + m_2^2 + 2|\mu|^2 + \frac{\lambda^2}{2} v^2 \ , \qquad m_{H^\pm}^2 = m_A^2 + m_W^2 + \frac{\lambda^2}{2} v^2$$

- Charginos [$\mathcal{O}(100\,\text{GeV})$ if $\gamma\gamma$ and $Z\gamma$ excesses]

$$\left(\tilde{W}^-, \tilde{H}_1^-, \tilde{\xi}_1^-\right) \mathcal{M}_{ch}^{\pm} \begin{pmatrix} \tilde{W}^+ \\ \tilde{H}_2^+ \\ \tilde{\xi}_2^+ \end{pmatrix} , \quad \mathcal{M}_{ch}^{\pm} = \begin{pmatrix} M_2 & g v_2 & 0 \\ g v_1 & \mu & -\lambda v_2 \\ 0 & \lambda v_1 & \mu_\Sigma \end{pmatrix}$$

The relevant spectrum

- CP-even Higgs masses (basis h_2, h_1)

$$\mathcal{M}_0^2 = \begin{pmatrix} m_A^2 \cos^2\beta + m_Z^2 \sin^2\beta & (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 \\ (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 & m_A^2 \sin^2\beta + m_Z^2 \cos^2\beta \end{pmatrix}$$

- After including radiative corrections $\Delta\mathcal{M}_{\tilde{t}}^2(h_t)$ and $\Delta\mathcal{M}_\Sigma^2(\lambda)$ (also in the min.condts) $[m_h = 126\,\mathrm{GeV}]$

$$\begin{pmatrix} h_2 \\ h_1 \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} h \\ H \end{pmatrix}$$

Coupling ratios $\quad r_{\mathcal{H}XX} = g_{\mathcal{H}XX}/g_{hXX}^{\mathrm{SM}} \quad (\mathcal{H} = h, H)$

r^0_{hVV}	r^0_{HVV}	r^0_{htt}	r^0_{Htt}	r^0_{hdd}	r^0_{Hdd}
$\sin(\beta-\alpha)$	$\cos(\beta-\alpha)$	$\dfrac{\cos\alpha}{\sin\beta}$	$\dfrac{\sin\alpha}{\sin\beta}$	$-\dfrac{\sin\alpha}{\cos\beta}$	$\dfrac{\cos\alpha}{\cos\beta}$

The relevant spectrum

- CP-even Higgs masses (basis h_2, h_1)

$$\mathcal{M}_0^2 = \begin{pmatrix} m_A^2 \cos^2\beta + m_Z^2 \sin^2\beta & (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 \\ (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 & m_A^2 \sin^2\beta + m_Z^2 \cos^2\beta \end{pmatrix}$$

SM-LIKE INTERACTIONS WHEN $\alpha \simeq \beta - \pi/2$

Case 1: $\beta \simeq \beta_c = \pi/4, \ \lambda \simeq \lambda_c = \sqrt{2} m_h/2$ (relevant but accidental)

Case 2: $m_A \gg m_h$ (robust but obvious)

Coupling ratios $r_{\mathcal{H}XX} = g_{\mathcal{H}XX}/g_{hXX}^{\rm SM}$ $(\mathcal{H} = h, H)$

r_{hVV}^0	r_{HVV}^0	r_{htt}^0	r_{Htt}^0	r_{hdd}^0	r_{Hdd}^0
$\sin(\beta-\alpha)$	$\cos(\beta-\alpha)$	$\dfrac{\cos\alpha}{\sin\beta}$	$\dfrac{\sin\alpha}{\sin\beta}$	$-\dfrac{\sin\alpha}{\cos\beta}$	$\dfrac{\cos\alpha}{\cos\beta}$

Small m_A

Case 1

- Existence of the SM-like point beyond tree-level approx
- Quantifying the "$\simeq$"
- Some phenomenology

ArXiv:1303.0800

Small m_A (similar idea in Carena&al 1310:2248 for 2HDM)

- CP-even Higgs masses (basis h_2, h_1)

$$\mathcal{M}_0^2 = \begin{pmatrix} m_A^2 \cos^2\beta + m_Z^2 \sin^2\beta & (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 \\ (\lambda^2 v^2 - m_A^2 - m_Z^2)\sin 2\beta/2 & m_A^2 \sin^2\beta + m_Z^2 \cos^2\beta \end{pmatrix}$$

$$\begin{pmatrix} h_2 \\ h_1 \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} h \\ H \end{pmatrix}$$

- Tree-level h couplings are SM-like if $\alpha = \beta - \pi/2$. With $\mathcal{M}_0^2$:

$$\beta_c = \frac{\pi}{4}\,, \qquad \lambda_c = \sqrt{2}\frac{m_h}{v}$$

The lightest eigenvalue is INDEPENDENT of m_A

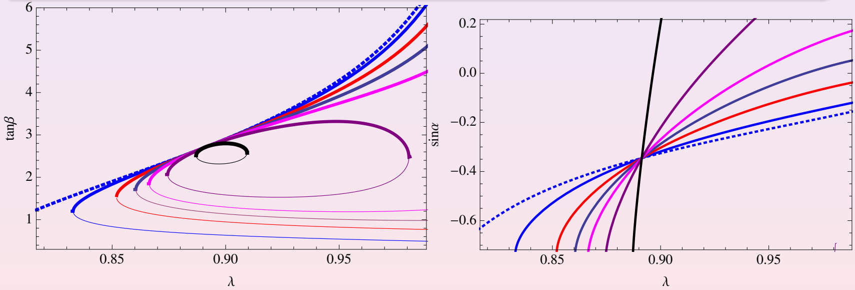
AND BEYOND TREE LEVEL ?

Small m_A

Radiative correction $\Delta\mathcal{M}^2_{\tilde{t}}(h_t)$ and $\Delta\mathcal{M}^2_{\Sigma}(\lambda)$ included ($m_Q = 700$ GeV, $A_t = 0$, $m_\Sigma = 5$ TeV).

Curves: $m_A = \infty, 200, 155, 145$,140,135,130 GeV

$\tan\beta(\lambda)$ and $\sin\alpha(\lambda)$ fixing $m_h = 126$ GeV



THE SM-LIKE CONDITION HAS MOVED TO THE CROSSING POINT

Small m_A (similar idea in Carena&al 1310:2248 for 2HDM)

- Given a spectrum and its dominant stop and triplet corrections ...

$$\mathcal{M}_1^2 = \begin{pmatrix} m_A^2 \cos^2\beta + m_{11}^2 \sin^2\beta & (-m_A^2 - m_{12}^2)\sin 2\beta/2 \\ (-m_A^2 - m_{12}^2)\sin 2\beta/2 & m_A^2 \sin^2\beta + m_{22}^2 \cos^2\beta \end{pmatrix}$$

- ...the lighest eigenvalue m_h is equal to $\overline{m}_h$ when

$$\mathcal{D} - \overline{m}_h^2 \mathcal{T} + \overline{m}_h^4 = 0$$
$$\Downarrow$$
$$A(\tan\beta, \lambda; \overline{m}_h^2) m_A^2 + B(\tan\beta, \lambda; \overline{m}_h^2) = 0 \qquad (\text{no } m_A^4!) \,,$$

- there exists a solution that is INDEPENDENT of m_A at

$$\begin{cases} A(\tan\beta_c, \lambda_c, \overline{m}_h^2) = 0 \\ B(\tan\beta_c, \lambda_c, \overline{m}_h^2) = 0 \end{cases}$$

- Moreover (analytically) when the lightest eigenvalue is independent of m_A , α is independent as well.
- Since independent of m_A, the particular case $m_A \to \infty$ is included, i.e. $\alpha = \beta - \pi/2$

Small m_A

Signal strengths $\mathcal{R}_{\mathcal{H}XX}$

$$\mathcal{R}_{\mathcal{H}XX} = \frac{\sigma(pp\to\mathcal{H})BR(\mathcal{H}\to XX)}{[\sigma(pp\to h)BR(h\to XX)]_{SM}}$$

$$\mathcal{R}^{(ggF)}_{\mathcal{H}XX} = \mathcal{R}^{(\mathcal{H}tt)}_{\mathcal{H}XX} = \frac{r^2_{\mathcal{H}tt}\ r^2_{\mathcal{H}XX}}{\mathcal{D}}\ , \quad \mathcal{R}^{(VBF)}_{\mathcal{H}XX} = \mathcal{R}^{(V\mathcal{H})}_{\mathcal{H}XX} = \frac{r^2_{\mathcal{H}WW}\ r^2_{\mathcal{H}XX}}{\mathcal{D}}$$

$$\begin{aligned}\mathcal{D} = &\ BR(h\to b\,b)_{SM}\ r^2_{\mathcal{H}bb} + BR(h\to gg,cc)_{SM}\ r^2_{\mathcal{H}tt}\\ &+ BR(h\to\tau\tau)_{SM}\ r^2_{\mathcal{H}\tau\tau} + BR(h\to WW,ZZ)_{SM}\ r^2_{\mathcal{H}WW}\end{aligned}$$

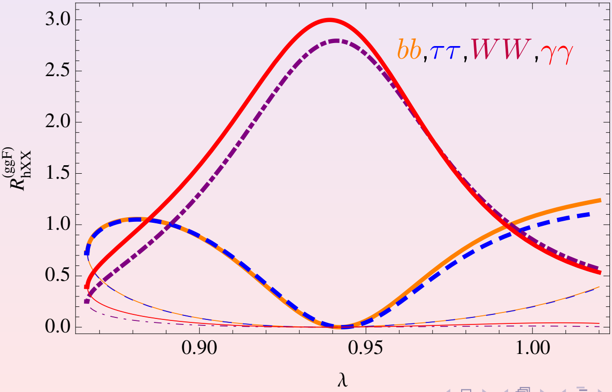
- No extra inv. width, i.e. $m_{\chi_0} \gtrsim m_{\mathcal{H}}/2$
- sbottom-gluino may correct r_{hbb} $(M_3 = 1$ TeV, $m_{\tilde{b}} = 700$ GeV$)$

Small m_A

$m_A = 140$ GeV, $\mu = \mu_\Sigma = 250$ GeV, $m_{\chi^\pm} = 104$ GeV

Signal strengths $\mathcal{R}_{hXX}$ from ggF and htt

$$\mathcal{R}_{\mathcal{H}XX} = \frac{\sigma(pp \to \mathcal{H})BR(\mathcal{H} \to XX)}{[\sigma(pp \to h)BR(h \to XX)]_{SM}}$$

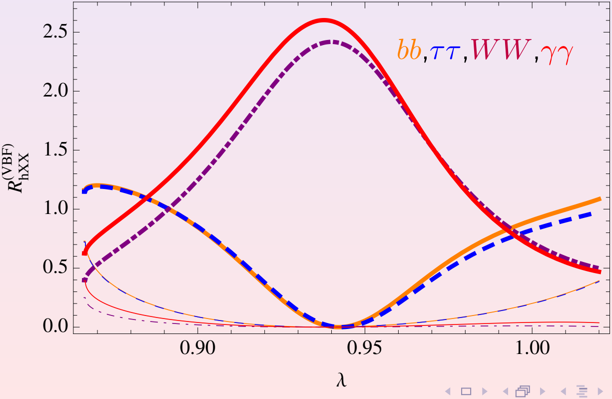


Small m_A

$m_A = 140$ GeV, $\mu = \mu_\Sigma = 250$ GeV, $m_{\chi^\pm} = 104$ GeV

Signal strengths $\mathcal{R}_{hXX}$ from VBF and Vh

$$\mathcal{R}_{\mathcal{H}XX} = \frac{\sigma(pp \to \mathcal{H})BR(\mathcal{H} \to XX)}{[\sigma(pp \to h)BR(h \to XX)]_{SM}}$$



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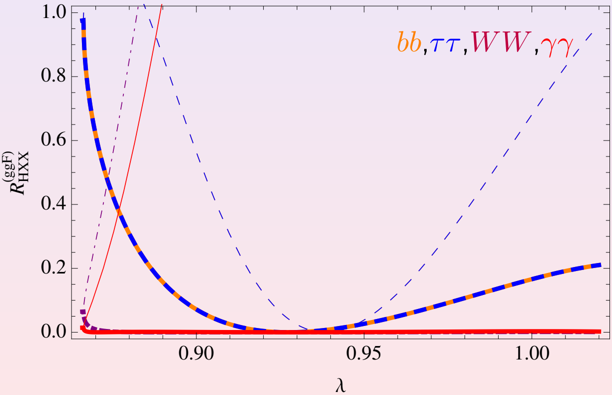

- Further reduction if $m_{\chi_0} \lesssim m_H/2$ $\quad$ ($m_H \sim$138 GeV)

Small m_A

Mini Summary

Exp. results on Higgs decays are hinting to SM-like values. If confirmed with much better accuracy, they still don't imply $m_A \gg m_h$ (as thought in the MSSM)

For instance in the TMSSM there exists a parameter region where

- we have both $m_h \approx 126\,\text{GeV}$ and SM-like h decay independently of m_A;
- H production is suppressed

To probe the scenario, present LHC studies on A and $H^\pm$ decays need to be improved (in the TMSSM these limits are $\lesssim$ MSSM or NMSSM ones).

In this direction:
Bandyopadhyay&Huitu&Sabanci'13, Bandyopadhyay&Di Chiara&al,'14(?)

Large m_A

Case 2

- Diphoton enhancement highlighted before
- Correlation with $h \to Z\gamma$
- Imposing DM

ArXiv:1207.6596
ArXiv:1403.6434

Enhancement in $h \to \gamma\gamma$

Signal strength $\mathcal{R}_{\gamma\gamma}$ $[= BR(h \to \gamma\gamma)/BR(h \to \gamma\gamma)_{\rm SM}]$

$$A^{\gamma\gamma}_{\widetilde{\chi}^{\pm}_{1,2,3}} = \left(-\frac{4}{3}\right) \frac{v^2(\lambda^2 M_2 + g^2 \mu_\Sigma)\sin 2\beta}{M_2 \mu \mu_\Sigma - \frac{1}{2}\lambda^2 v^2 (\lambda^2 M_2 + g^2 \mu_\Sigma)\sin 2\beta}$$

- ATLAS: 1.6 ± 0.3; CMS: $0.8 - 1.1 \pm 0.3$
- Loop-induced process which is sensitive to new charged particles
- New triplet charged fermion can enhance $R_{\gamma\gamma}$ ($\lesssim 1.2$ via MSSM charginos; e.g. Casas,Moreno,Rolbiecki,Zaldivar '13)
- As no (large) modifications in the Higgs production exist for $m_A \to \infty$, the diphoton enhancement is (easily implemented from the QED eff.pot. Ellis&al,79; Shifman&al,79; Carena&al,12)

$$R_{\gamma\gamma} = \left| 1 + \frac{A^{\gamma\gamma}_{\widetilde{\chi}^{\pm}_{1,2,3}}}{A^{\gamma\gamma}_W + A^{\gamma\gamma}_t} \right|^2$$

Enhancement in $h \to \gamma\gamma$

Signal strength $\mathcal{R}_{\gamma\gamma}$ $[= BR(h \to \gamma\gamma)/BR(h \to \gamma\gamma)_{\rm SM}]$

$$A^{\gamma\gamma}_{\tilde{\chi}^{\pm}_{1,2,3}} = \left(-\frac{4}{3}\right) \frac{\partial}{\partial \log v} \log(\det M^{tree}_{\tilde{\chi}^{\pm}})$$

$$\mathcal{M}^{tree}_{\tilde{\chi}^{\pm}} = \begin{pmatrix} M_2 & gv\sin\beta & 0 \\ gv\cos\beta & \mu & -\lambda v \sin\beta \\ 0 & \lambda v\cos\beta & \mu_\Sigma \end{pmatrix} \ , \quad U M_{\tilde{\chi}^{\pm}} V^{\dagger} = diag$$

- As no (large) modifications in the Higgs production exist for $m_A \to \infty$, the diphoton enhancement is (easily implemented from the QED eff.pot. Ellis&al,79; Shifman&al,79; Carena&al,12)

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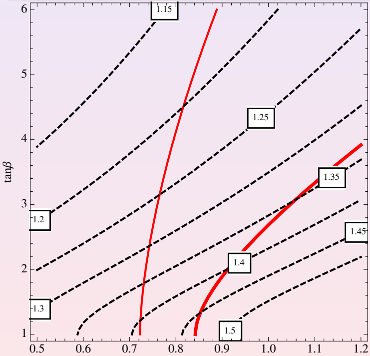
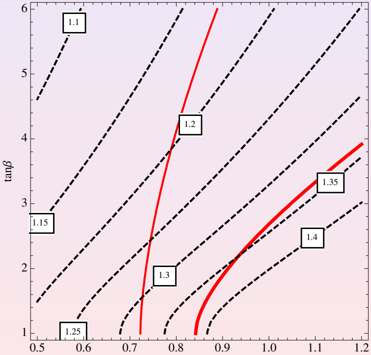
Enhancement in $h \to \gamma\gamma$

Signal strength $\mathcal{R}_{\gamma\gamma}$ $[= BR(h \to \gamma\gamma)/BR(h \to \gamma\gamma)_{\rm SM}]$

$$A^{\gamma\gamma}_{\widetilde{\chi}^{\pm}_{1,2,3}} = \left(-\frac{4}{3}\right) \frac{v^2(\lambda^2 M_2 + g^2 \mu_\Sigma)\sin 2\beta}{M_2 \mu \mu_\Sigma - \frac{1}{2}\lambda^2 v^2 (\lambda^2 M_2 + g^2\mu_\Sigma)\sin 2\beta}$$





$M_2 = 250$ GeV $\quad$ $X_t = 4$, **0**; $m_Q = 700$ GeV $\quad$ $M_2 = 750$ GeV

$\mu = \mu_\Sigma \to m_{\chi_1^\pm} \sim 105$ GeV

Correlation $h \to \gamma\gamma$ vs $h \to Z\gamma$

Signal strength $\mathcal{R}_{Z\gamma}$ $[= BR(h \to Z\gamma)/BR(h \to Z\gamma)_{\rm SM}]$

$$A^{Z\gamma}_{\widetilde{\chi}^{\pm}_{1,2,3}} = \sum_{j,k=1}^{3} \frac{g_2\, m_{\widetilde{\chi}^{\pm}_j}}{g_1\, m_Z} g_{Z\widetilde{\chi}^{+}_j\widetilde{\chi}^{-}_i}\; f\left(m_{\widetilde{\chi}^{\pm}_j}, m_{\widetilde{\chi}^{\pm}_k}, m_{\widetilde{\chi}^{\pm}_k}\right) g_{h\widetilde{\chi}^{+}_j\widetilde{\chi}^{-}_i}$$

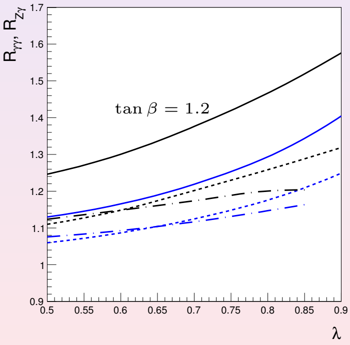
- Weak bounds by LHC but planned improvements
- Typically correlated to $h \to \gamma\gamma$
- TMSSM chargino sector should play a role (as for $R_{\gamma\gamma}$)
- Less transpartent expression because no applicable low-energy limit

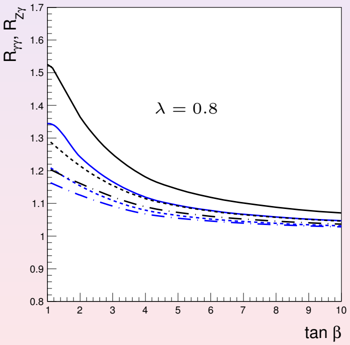
$$R_{\gamma\gamma} = \left| 1 + \frac{A^{Z\gamma}_{\widetilde{\chi}^{\pm}_{1,2,3}}}{A^{Z\gamma}_{W} + A^{Z\gamma}_{t}} \right|^2$$

Correlation $h \to \gamma\gamma$ vs $h \to Z\gamma$ $(m_{\chi_1^\pm} \gtrsim 100\text{ GeV})$

Signal strength $\mathcal{R}_{Z\gamma}$ $[= BR(h \to Z\gamma)/BR(h \to Z\gamma)_{\rm SM}]$

$$A^{Z\gamma}_{\widetilde{\chi}^\pm_{1,2,3}} = \sum_{j,k=1}^{3} \frac{g_2\, m_{\widetilde{\chi}^\pm_j}}{g_1\, m_Z} g_{Z\widetilde{\chi}^+_j\widetilde{\chi}^-_i}\; f\left(m_{\widetilde{\chi}^\pm_j}, m_{\widetilde{\chi}^\pm_k}, m_{\widetilde{\chi}^\pm_k}\right) g_{h\widetilde{\chi}^+_j\widetilde{\chi}^-_i}$$





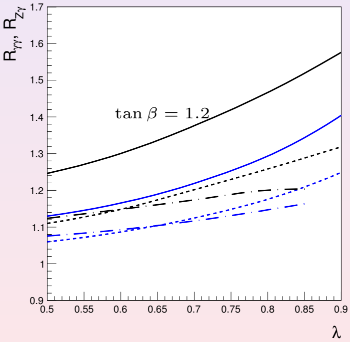
solid: $\mu_\Sigma = \mu = M_2 = 230$ GeV
dash: $\mu_\Sigma = \mu = 230$ GeV, $M_2 = 1$ TeV
dot-dash: $\mu_\Sigma = M_2 = 230$ GeV, $\mu = 400$ GeV

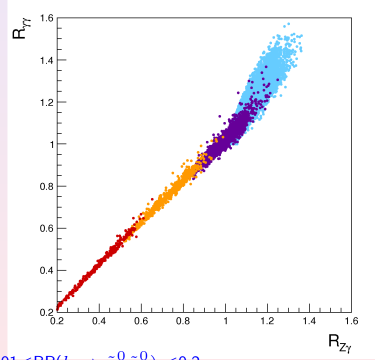
$A_t = 0$; $m_Q = m_U$ adjusted for $m_h = 126$ GeV

Correlation $h \to \gamma\gamma$ vs $h \to Z\gamma$ $\quad (m_{\chi_1^\pm} \gtrsim 100$ GeV$)$

Signal strength $\mathcal{R}_{Z\gamma}$ $\quad [= BR(h \to Z\gamma)/BR(h \to Z\gamma)_{\rm SM}]$

$$A^{Z\gamma}_{\tilde{\chi}^\pm_{1,2,3}} = \sum_{j,k=1}^{3} \frac{g_2\, m_{\tilde{\chi}^\pm_j}}{g_1\, m_Z} g_{Z\tilde{\chi}^+_j\tilde{\chi}^-_i} \; f\left(m_{\tilde{\chi}^\pm_j}, m_{\tilde{\chi}^\pm_k}, m_{\tilde{\chi}^\pm_k}\right) g_{h\tilde{\chi}^+_j\tilde{\chi}^-_i}$$





solid: $\mu_\Sigma = \mu = M_2 = 230$ GeV

dash: $\mu_\Sigma = \mu = 230$ GeV $, \quad M_2 = 1$ TeV

dot-dash: $\mu_\Sigma = M_2 = 230$ GeV $, \quad \mu = 400$ GeV

0.01 $<$ BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$ $<$ 0.2

0.2 $<$ BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$ $<$ 0.5

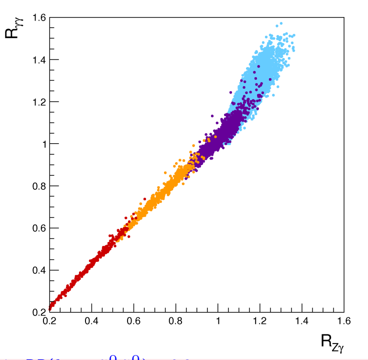
0.5 $<$ BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$

Correlation $h \to \gamma\gamma$ vs $h \to Z\gamma$ $(m_{\chi_1^\pm} \gtrsim 100$ GeV$)$

BR$(h \to \chi_1^0 \chi_1^0)$

$$\Gamma(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0) = \frac{G_F m_W^2}{2\sqrt{2}\pi} m_h \left(1 - \frac{4 m_{\tilde{\chi}_1^0}^2}{m_h^2}\right)^{3/2} g_{h11}^2$$

$\mathcal{M}_{\chi^0}$

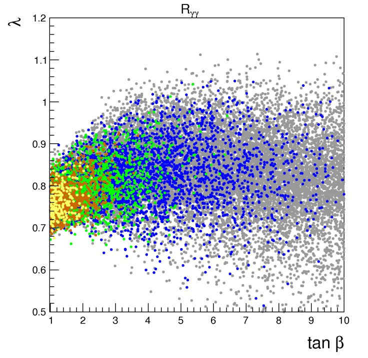


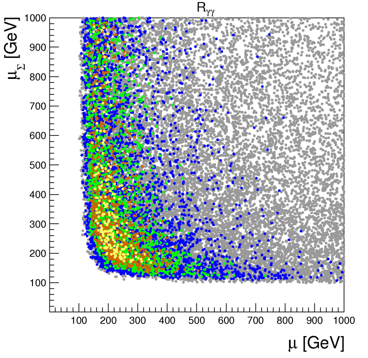
0.01< BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$ <0.2

0.2 < BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$ <0.5

0.5 < BR$(h \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$

Again $h \to \gamma\gamma$





$$R_{\gamma\gamma} < 1.1, 1.2, 1.3, 1.4 \quad R_{\gamma\gamma} > 1.4$$

If μ large, $R_{\gamma\gamma}$ small

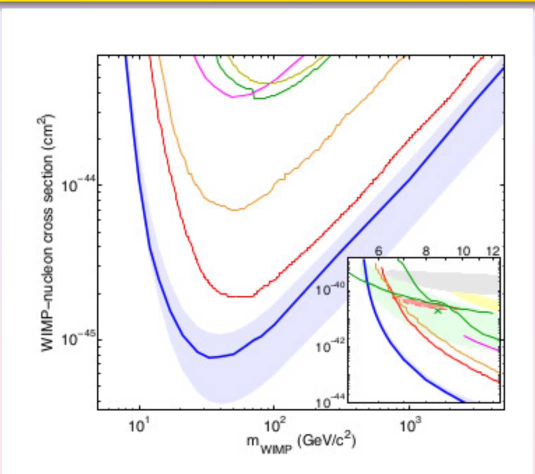
This seems to be strictly linked to Dark Matter!!!

If DM is the Bino-like neutralino

Framework is like well-tempered neutralino: Ω_{DM} relies on SM + ewkinos
If m_A or m_L are small, there are potential new channels.

Observable	Measured/Limit
σ^{SI}_{Xe}	LUX (90% CL)
$\Omega_{\rm DM}h^2$	0.1186 ± 0.0031 (exp) $\pm 20\%$ (theo)
m_h	125.85 ± 0.4 GeV (exp) ± 3 GeV (theo)
$\Gamma_Z^{\rm invisible}$	(166 ± 2) MeV
$m_{\tilde{t}_1}$	> 650 GeV (LHC 90% CL)
$m_{\tilde{\chi}_1^+}$	> 104 GeV (LEP 95% CL)

If DM is the Bino-like neutralino (LUX bound)

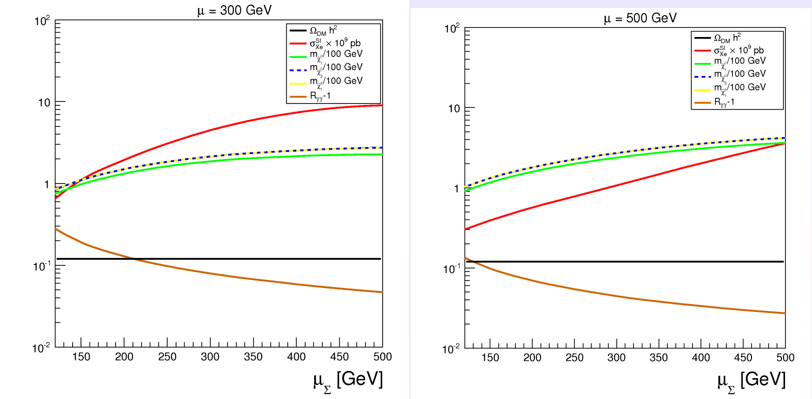


(dangerous) SI cross section is dominated by Higgs interchange ($g_{h\tilde{\chi}_1^0\chi_1^0}$)

For a given parameter set, LUX ⇒ lower bound on μ

⇒ upper bound on $R_{\gamma\gamma}$ and $R_{Z\gamma}$

If DM is the Bino-like neutralino *(well-tempered)*

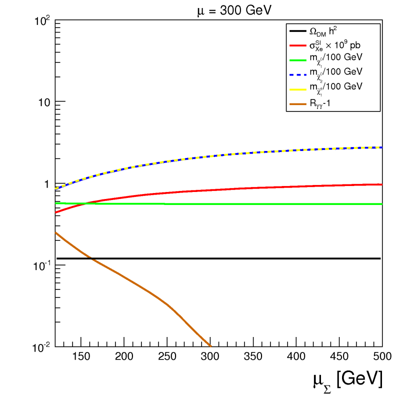


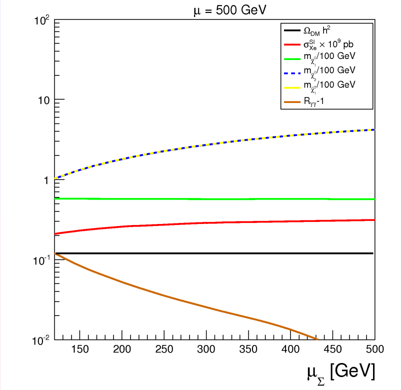
$M_2 = 1\,\text{TeV} \qquad \tan\beta = 2.8 \qquad \lambda = 0.85$

Good relic density if

Branch 1: Triplino-Bino coannihilation (driven by gauge interactions)
Branch 2: Higgs/Z resonance

If DM is the Bino-like neutralino (*resonance*)

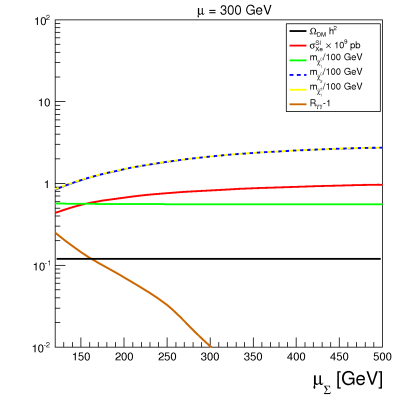


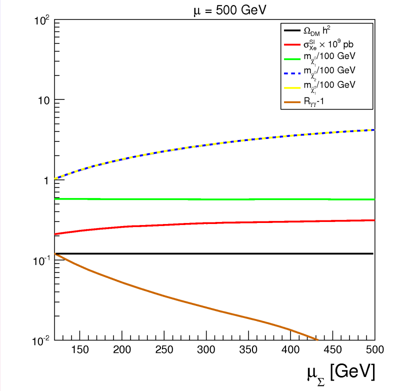


$M_2 = 1.5$ TeV $\qquad \tan\beta = 2.8 \qquad \lambda = 0.85$

LUX goes better when diphoton enhancement is smaller

If DM is the Bino-like neutralino *(resonance)*

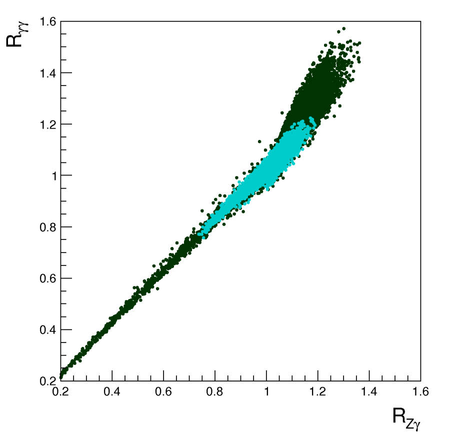




$M_2 = 1.5$ TeV $\qquad \tan\beta = 2.8 \qquad \lambda = 0.85$

Quantitatively, how much $R_{\gamma\gamma}$ (and $R_{Z\gamma}$) is allowed by LUX?

If DM is the Bino-like neutralino



$R_{\gamma\gamma} \lesssim 1.25 \qquad R_{Z\gamma} \lesssim 1.2 \qquad$ (correlated!)

Conclusion

1. Triplet extension alleviates the fine-tuninig with respect to the MSSM
2. SM-like Higgs signatures do NOT imply large m_A
3. If the dominant channels are SM-like, TMSSM chargino sector can provide $R_{\gamma\gamma}$ and $R_{Z\gamma}$ are large as
   - 1.6 and 1.4 (no DM)
   - 1.3 and 1.2 (with DM)
4. $R_{\gamma\gamma}$ and $R_{Z\gamma}$ are strongly correlated
5. Concerning well tempering, TMSSM DM easier than MSSM DM from top-down approach
6. Open issues: LHC bounds? EWino composition via ILC?
   De Blas,Delgado,Ostdiek,Quiros,'14 Moortgat-Pick,Porto,Rolbiecki,'14