

BMSSM Higgses at 125 GeV

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Based on F. Boudjema, G. DLR arXiv:1203.3141
see also F. Boudjema, G. DLR PhysRevD.85.035011



Outline

1 Model Description

- Motivations
- New operators

2 Analysis

- Parameter space
- Input from experiments

3 Results

- Signal features
- Expectations for other signals

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- MSSM limitations
 - fine-tuning problem
 - light Higgs constrained $m_h < 135$ GeV
- Natural extensions : NMSSM, U(1)'MSSM
- Effective Field Theory approach

$$M = 1.5 \text{ TeV}$$

$$K = K_{\text{MSSM}} + \frac{1}{M} K^{(1)} + \frac{1}{M^2} K^{(2)} + \dots$$

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F. Boudjema, GDLR arXiv:1203.3141

Brignole et al . arXiv:0301121

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Higher dimensionnal operators in the Higgs sector

- Include only operators involving Higgs superfields H_1, H_2
- Effective Field Theory expansion on K and W :

$$\begin{aligned} K \rightarrow & K + \frac{a_1}{M^2} \left(H_1^\dagger e^{V_1} H_1 \right)^2 + \frac{a_2}{M^2} \left(H_2^\dagger e^{V_2} H_1 \right)^2 \\ & + \frac{a_3}{M^2} \left(H_1^\dagger e^{V_1} H_1 \right) \left(H_2^\dagger e^{V_2} H_2 \right) + \frac{a_4}{M^2} (H_1 \cdot H_2)^\dagger (H_1 \cdot H_2) \\ & + \frac{a_5}{M^2} \left(H_1^\dagger e^{V_1} H_1 \right) (H_1 \cdot H_2 + h.c.) + \frac{a_6}{M^2} \left(H_2^\dagger e^{V_2} H_2 \right) (H_1 \cdot H_2 + h.c.) \\ W \rightarrow & W + \frac{\zeta_1}{M} (H_1 \cdot H_2)^2 \end{aligned}$$

- The effective coefficients can also have susy-breaking parts

$$a_i \rightarrow a_{i0} + \theta^2 m_s a_{i1} + \bar{\theta}^2 m_s a_{i1}^* + \theta^2 \bar{\theta}^2 m_s^2 a_{i2}$$

$$\zeta_1 \rightarrow \zeta_{10} + \theta^2 m_s^2 \zeta_{11}$$

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Change in the lagrangian

- M_Z, M_W : Weak boson masses modified

- Change in the oblique parameters ϵ_i

$$\Delta_\rho = \Delta_{\rho \text{ MSSM}} + \frac{1}{M^2} \Delta_{\rho \text{ eff}}$$

- Scalar Higgs potential

- $V_{\text{MSSM}} = \tilde{m}_1^2 |H_1|^2 + \tilde{m}_2^2 |H_2|^2 + \tilde{m}_{12}^2 (H_1 \cdot H_2 + h.c.) + \frac{1}{8} (g_1^2 + g_2^2)'' H^4$
- Only one non-trivial minimum possible
- Minimisation :
 - First v_1, v_2 determined from M_Z, t_β
 - Then $\tilde{m}_1, \tilde{m}_2, \tilde{m}_{12}$ can be fully determined from v_1, v_2, M_{A_0} using the tadpole condition.
 - Finally V_{BMSSM} is evaluated numerically to check that the point v_1, v_2 is a global minimum.

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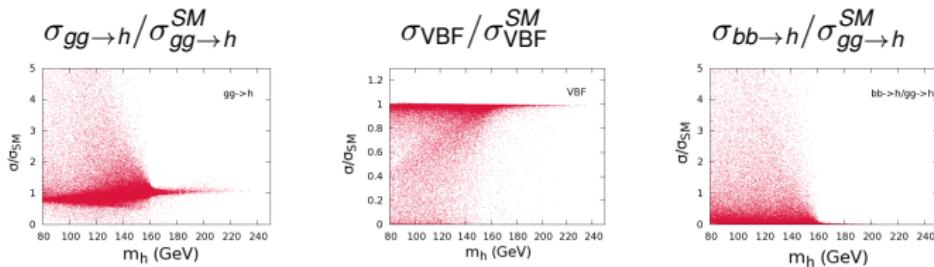


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- Couplings also affected
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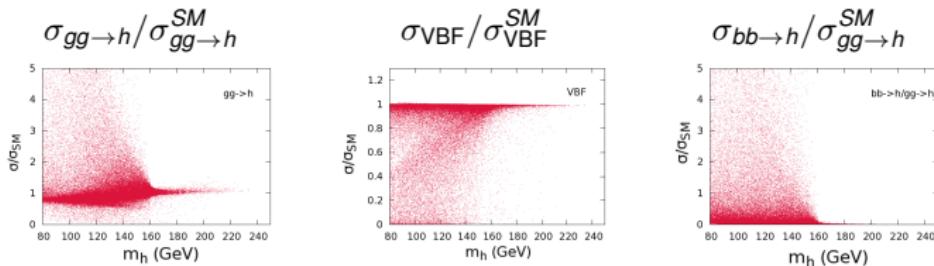
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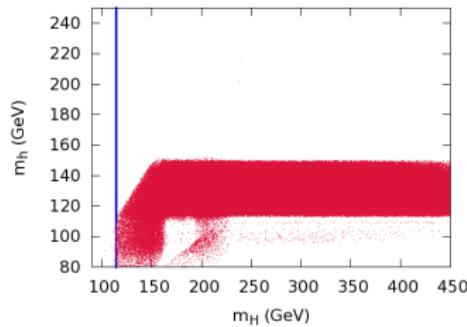
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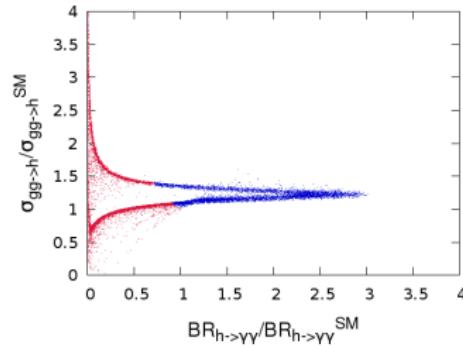


F. Boudjema, G. DLR
arXiv:1112.1434

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 - Enhance branching ratios in all over channels
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- Correlation with the gluon fusion

$$\frac{\sigma_{gg \rightarrow h}}{\sigma_{gg \rightarrow h}^{\text{SM}}} = \frac{|\mathcal{A}_t + x\mathcal{A}_b|^2}{|\mathcal{A}_t + \mathcal{A}_b|^2}$$

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Parameter Space

- MSSM free parameters $t_\beta \in [2, 40]$ and $M_{A_0} \in [50, 450]$
- Stop sector
- A) $M_{u3} = M_{d3} = M_{q3} = 400$ GeV, $A_t = 0$. \Rightarrow No mixing scenario
- B) $m_{\tilde{t}_1} = 200$ GeV, $m_{\tilde{t}_2} \in [300, 1000]$ GeV,
 $|\sin 2\theta_{\tilde{t}}| = 1$. \Rightarrow Maximal mixing
- All other superpartners are at $M_{\text{soft}} = 1$ TeV, $\mu = M_2 = 300$ GeV.
- Effective coefficients ζ, a taken in $[-1, 1]$.

Constraints

- Perturbativity check for $\frac{1}{M}$ expansion.
- Electroweak precision test
- Flavour constraints ($B_s \rightarrow \bar{\mu}\mu$ and $B \rightarrow X_s \gamma^*$)
- Dark Matter (Relic density by WMAP and direct detection by XENON 100)
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Input from LHC

- Neutral channels are

$VH \rightarrow V\bar{b}b$	$H \rightarrow \bar{\tau}\tau$	$H \rightarrow WW$
$H \rightarrow ZZ$	$H \rightarrow \gamma\gamma$	($H \rightarrow \gamma\gamma + 2$ jets)

- For neutral bosons Φ and each final state XX we define

$$R_{XX \Phi} = \frac{\sigma_{pp \rightarrow \Phi \rightarrow XX}}{\sigma_{pp \rightarrow \Phi \rightarrow XX}^{\text{SM}}} \quad \& \quad R_{XX \Phi}^{\text{Exclusion}} = \frac{\sigma_{pp \rightarrow \Phi \rightarrow XX}}{\sigma_{pp \rightarrow \Phi \rightarrow XX}^{\text{95% CL}}}$$

- Look for a signal (with $R_{XX \Phi}$) in [122, 128] GeV.
- Apply exclusion ($R_{XX \Phi}^{\text{Exclusion}} < 1$) on all other Higgses
- $R^{\text{Exclusion}}$ are added in quadrature among all channels to determine whether the point is excluded.
 - $R^{\text{Exclusion}}$ shows the sensitivity : e.g.
 $R^{\text{Exclusion}} = 0.5 \Rightarrow$ we need $\mathcal{L} \sim 4 \times 5 = 20 \text{ fb}^{-1}$.

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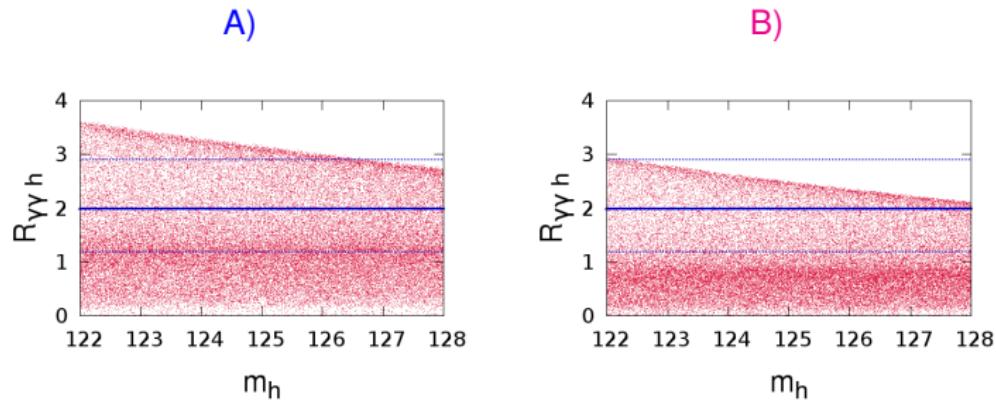
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Signal features : case of the light h (I)

- Enhancement in the $h \rightarrow \gamma\gamma$ channel



- Blue lines : 1σ error band on ATLAS best fit.
- Enhancement driven by the suppression of $g_{h\bar{b}b}$.

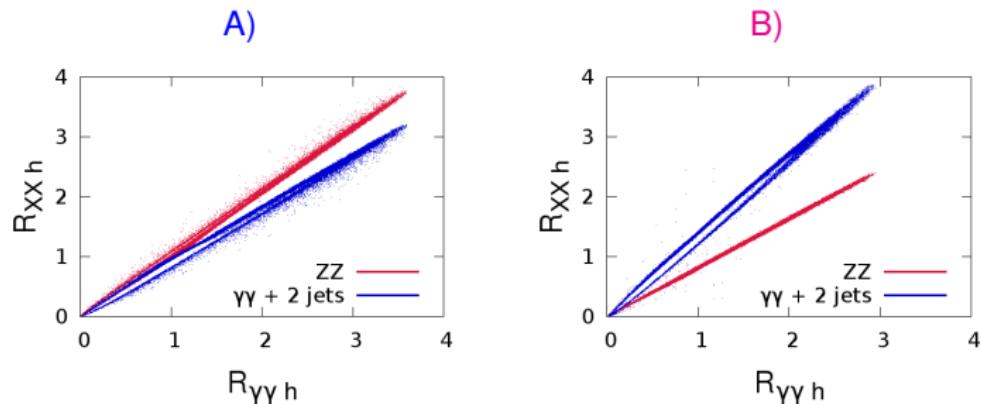
Signal features : case of the light h (II)

- Correlations between $ZZ, \gamma\gamma$ (inclusive) and $\gamma\gamma+2$ jets

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$$m_{\tilde{t}_1} \simeq m_{\tilde{t}_1} \simeq 400 \text{ GeV}$$

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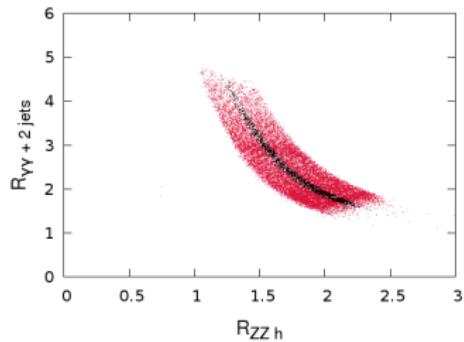
$$m_{\tilde{t}_2} = 600 \text{ GeV}$$

- Blue : R_{ZZ} , Red : $R_{\gamma\gamma + 2 \text{ jets}}$.

Signal features : stop effects

- Effect of the light stop loop

$$m_{\tilde{t}_2} \in [300 - 1000] \text{ GeV}$$



- Black :** $R_{\gamma\gamma} = 2.0 \pm 1\%$
- Red :** $R_{\gamma\gamma} = 2.0 \pm 10\%$

Flavour constraints

- $B_s \rightarrow \bar{\mu}\mu$ will cut on high t_β and low M_{A_0} . $\Rightarrow M_{A_0} > 200$ GeV
- Effective operators alter masses and mixing, but also new contribution
- $B \rightarrow X_s \gamma^*$ has important consequence in scenario B)
 - $S_{2\theta_L}(m_{\tilde{L}}^2 - m_{\tilde{L}}^2)$ also drives the chargino-stop contribution.
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- Conclusion :
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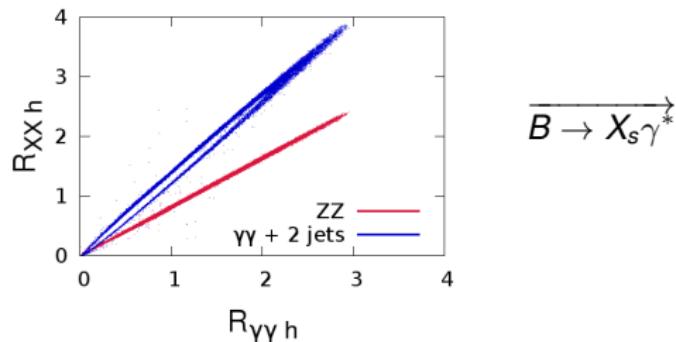
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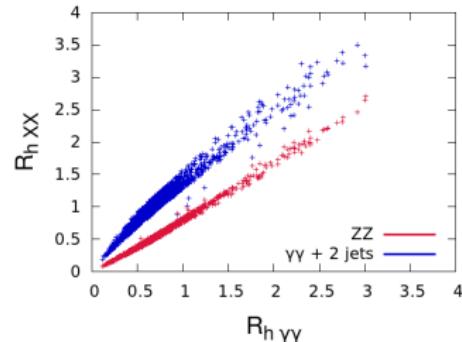
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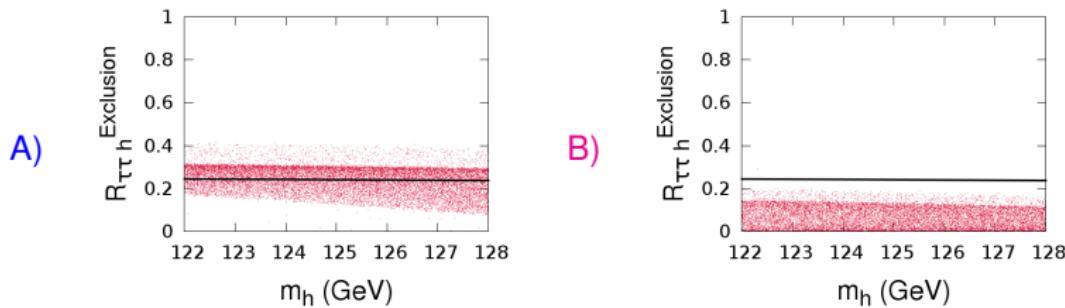


$B \rightarrow X_s \gamma^*$



Prospect for other signals (I)

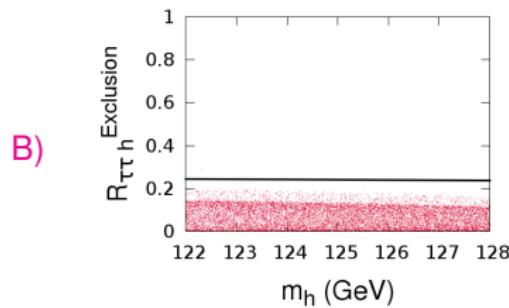
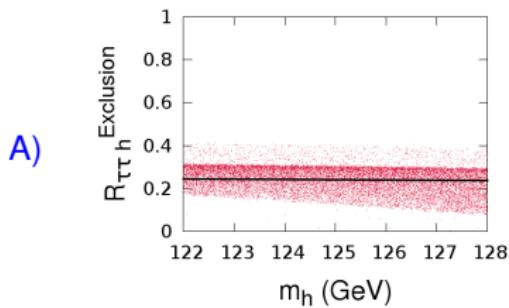
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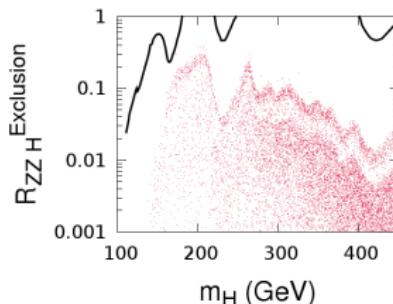
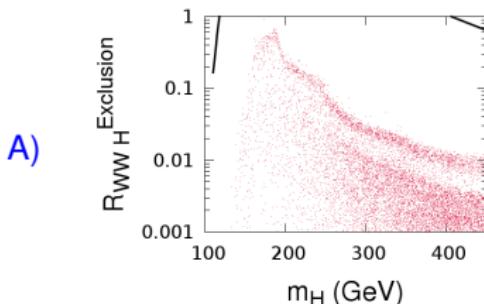
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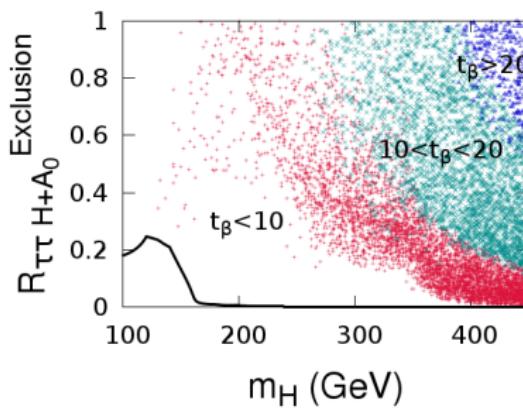


Prospect for other signals (I)

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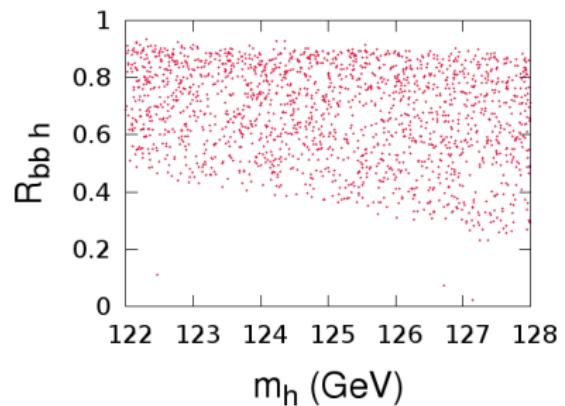
Summary

Summary

- The BMSSM framework can accommodate $R_{\gamma\gamma + 2 \text{ jets}} > R_{\gamma\gamma} > R_{ZZ}$.
- Correlations among channels will be the most constraining information, since it cannot be too flexible.
- Signal of other Higgses are possible within the next run.
- Consistent with flavour physics and coherent dark matter candidate.

Outlook

- Achieve a more precise use of LHC analyses on the SM Higgs.
- See to what extent this can be related to the direct searches for the stop particle.

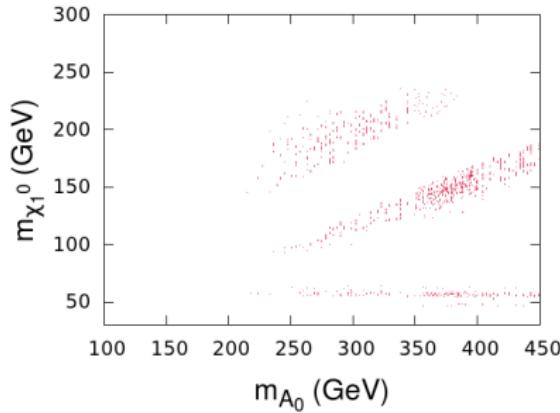


Dark Matter observables : Relic density

- Relic density with WMAP7 :

$$\Omega_h = 0.1126 \pm 15\%$$

- The LSP is $\tilde{\chi}_1^0$, which is a mixture of bino and higgsino.
- Mostly accounted for by $\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \bar{f}f$ by A_0 resonance



Dark Matter observables : Direct detection

- Spin-Independent bounds from XENON 100

