Implications for NMSSM (of ∼125 GeV Higgs)

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NMSSM = MSSM + singlet

Higgs superpotential and soft-terms, most general case:

$$W_{Higgs} = (\mu + \lambda S) H_u H_d + \chi_F S + \tfrac{1}{2} M S^2 + \tfrac{1}{3} \kappa S^3$$

$$\mathcal{L} \supset m_S^2 |S|^2 + \lambda A_\lambda S H_u H_d + \tfrac{1}{3} A_\kappa \kappa S^3 + m_3^2 H_u H_d + \tfrac{1}{2} m_{S'}^2 S^2 + \chi_S S$$

Take full superpotential to be dimensionless (and $\mathbb{Z}^3$-invariant):

$$W_{Higgs} = \lambda S H_u H_d + \tfrac{1}{3} \kappa S^3$$

and set soft-terms $m_3^2, m_{S'}^2, \chi_S$ above to zero. Seven parameters, e.g.

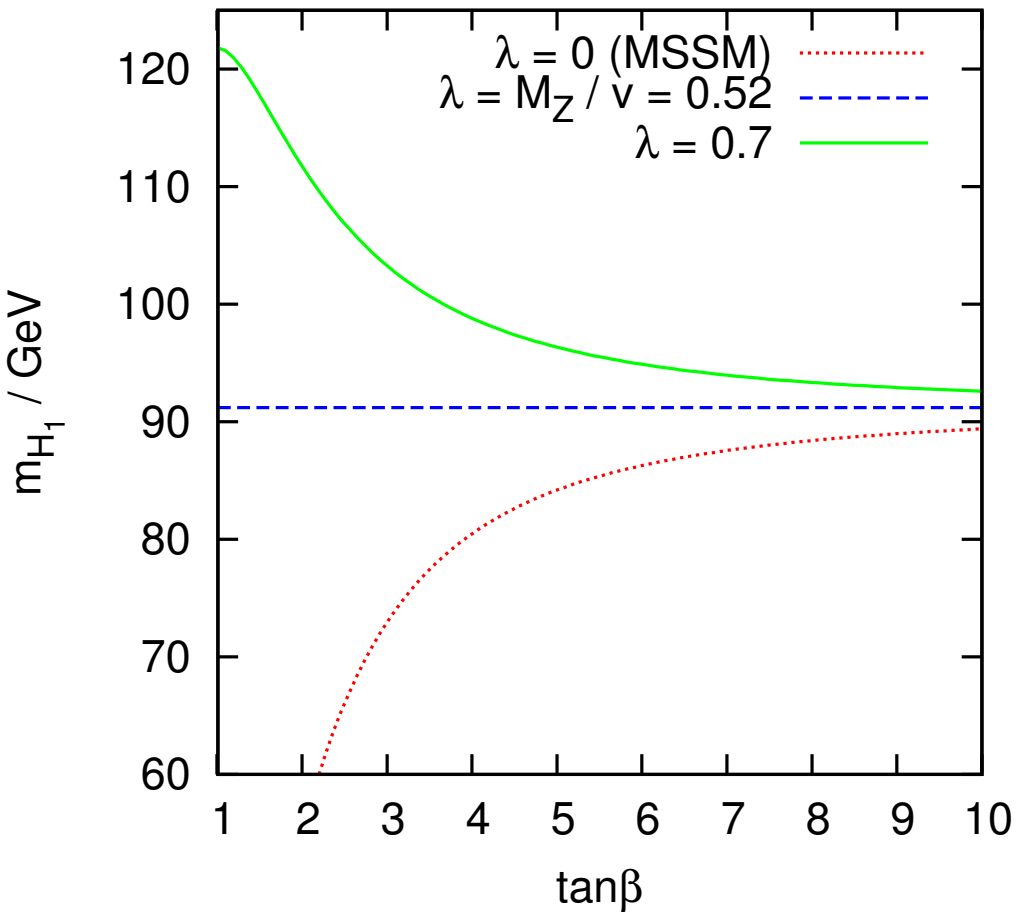
$$\mu \equiv \lambda \langle S \rangle, \ \tan\beta, \ \lambda, \ \kappa, \ A_\lambda, \ A_\kappa \quad \text{and } M_Z$$

Bonus particles beyond MSSM: H, a, χ^0

Motivation

Tree-level Higgs mass in NMSSM with $W \supset \lambda S H_u H_d$

$$m_{H_1}{}^2 = (M_Z \cos 2\beta)^2 + (\lambda v \sin 2\beta)^2$$



MCMC Parameter Scans

Step through

$\mu,\ \tan\beta,\ \lambda,\ \kappa,\ A_\lambda,\ A_\kappa,\quad A_t,\ m_{\tilde{q}},\ m_{\tilde{l}},\ M_1,\ M_3 = 3M_2$

$$\text{weight} = \text{prior} \times \text{likelihood:}\ Q = P \times L$$

L contains B-physics, $(g-2)_\mu$, LEP limits on Higgs & SUSY,

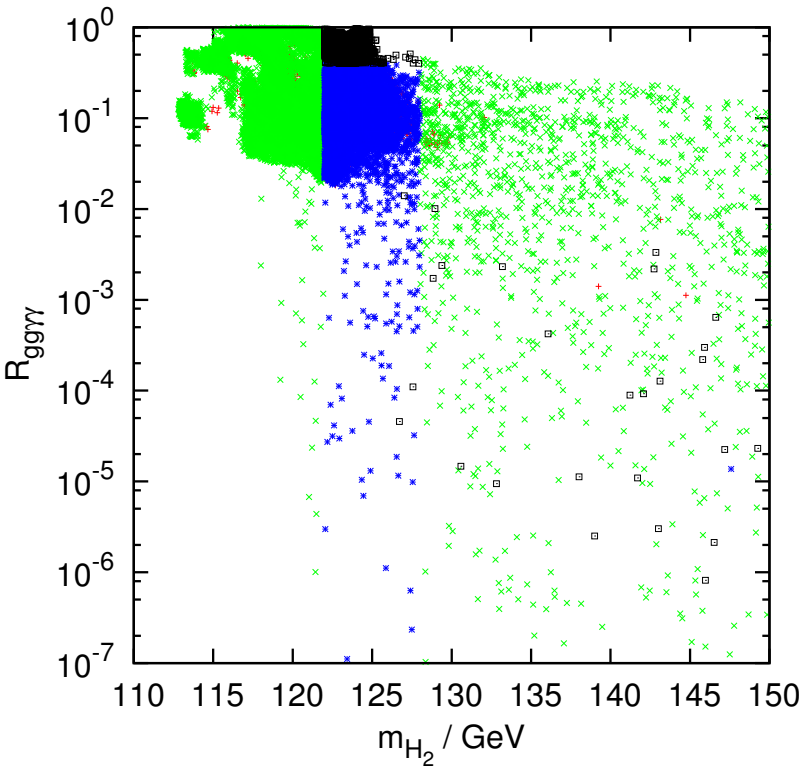
$$0.1 < \frac{\Omega h^2}{\Omega_{WMAP} h^2} < 1$$

"Light χ_1^0": $P \supset (m_{\chi_1^0} < 15\,\text{GeV})$. hep-ph/1009.4380:
D. Albornoz Vásquez, G. Bélanger, C. Boehm, A. Pukhov, J. Silk

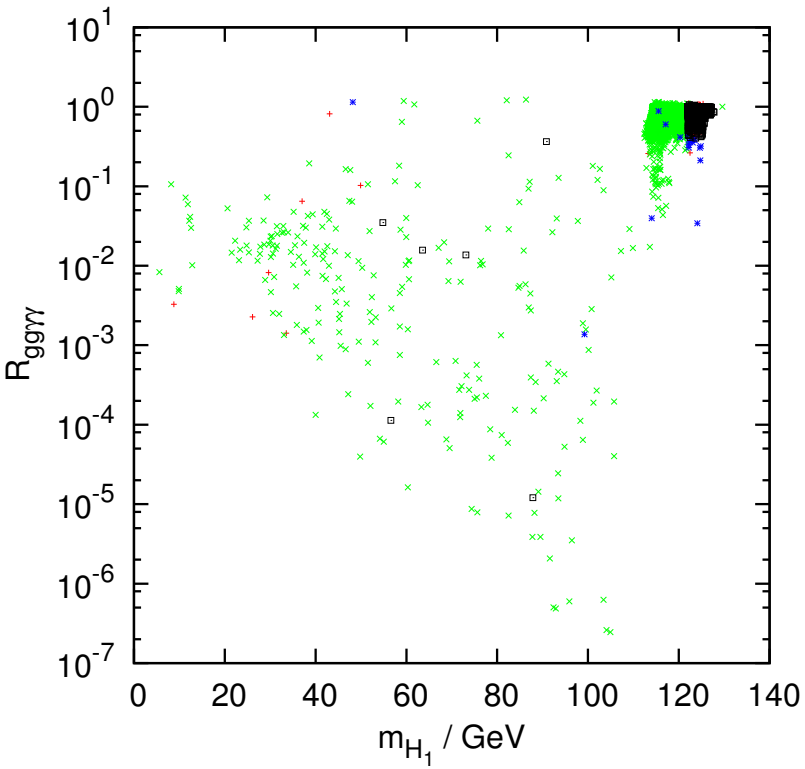
"Heavy χ_1^0": D. Albornoz Vásquez, G. Bélanger, J. Billard, F. Mayet (to appear on arXiv)

Divide samples:

- Fails `HiggsBounds 3.6.1beta`
- No Higgs mass in $[122, 128]$ GeV
- H_1 and/or H_2 with mass $\in [122, 128]$ GeV but $R_{gg\gamma\gamma} < 0.4$
- H_1 and/or H_2 with mass $\in [122, 128]$ GeV and $R_{gg\gamma\gamma} > 0.4$



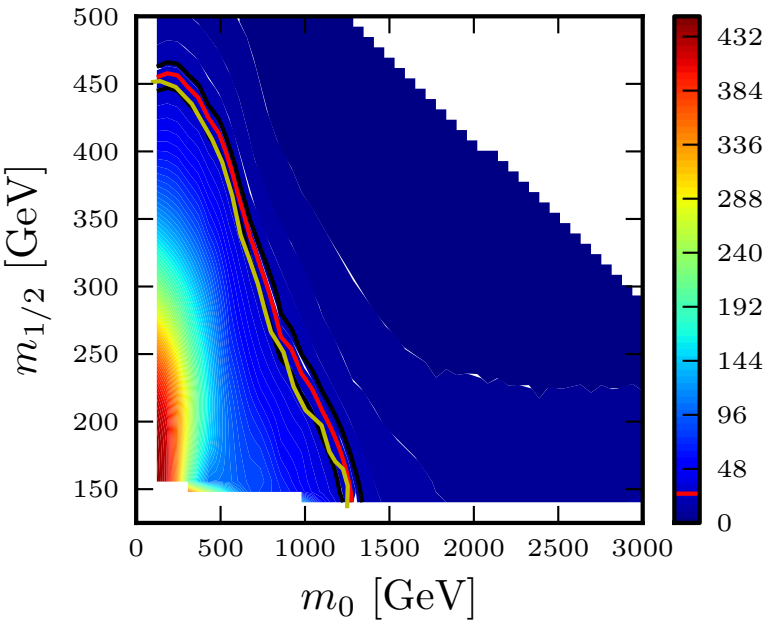
light neutralino scan



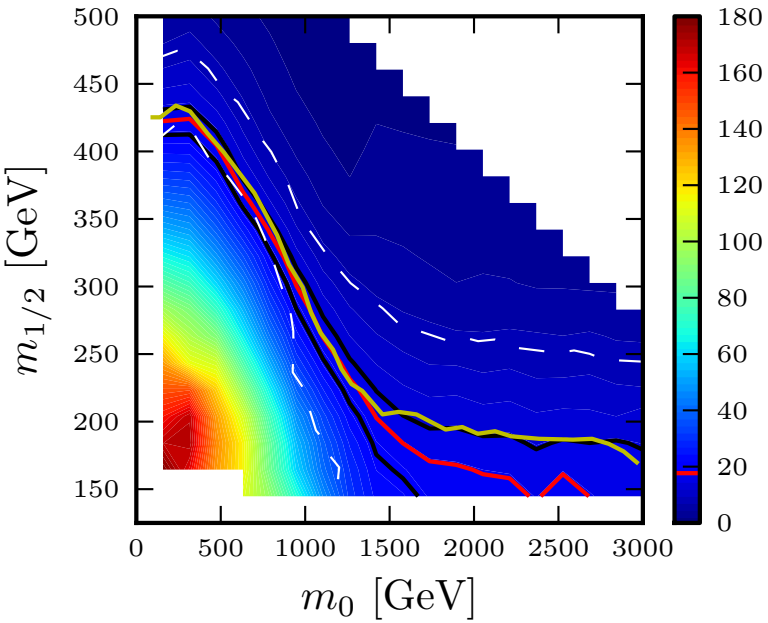
heavy neutralino scan

SUSY searches

ATLAS 1.04 fb^{-1} jets & missing E_T (hep-ex/1109.6572)
0 leptons, $E_T^{\text{miss}} > 130$ GeV, $\Delta\phi(jet, \mathbf{p}_T^{\text{miss}}) > 0.4$ ...



p_T(jet1,2,3) > 40 GeV

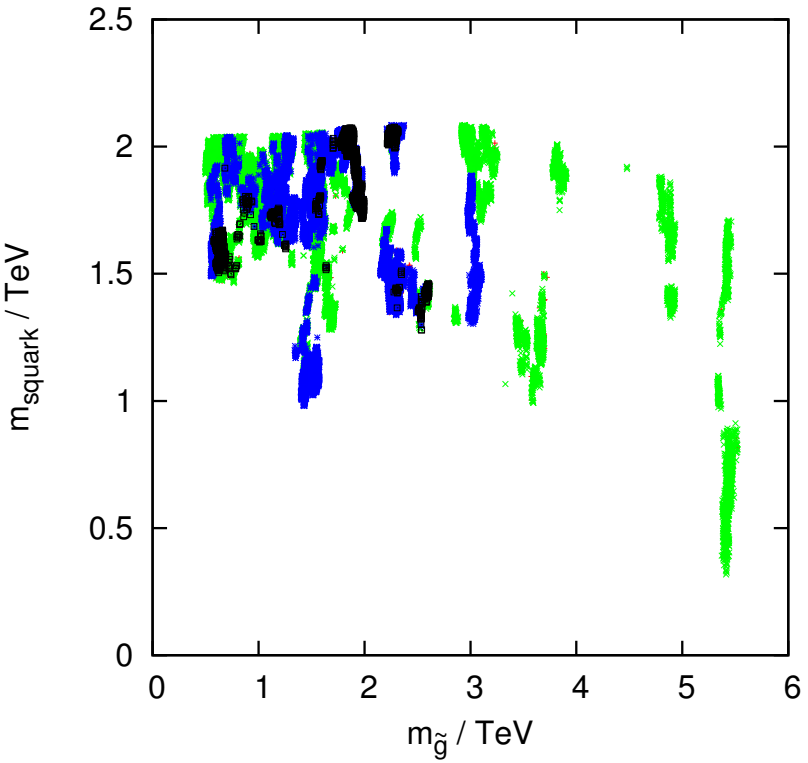


p_T(jet1,2,3,4) > 80 GeV

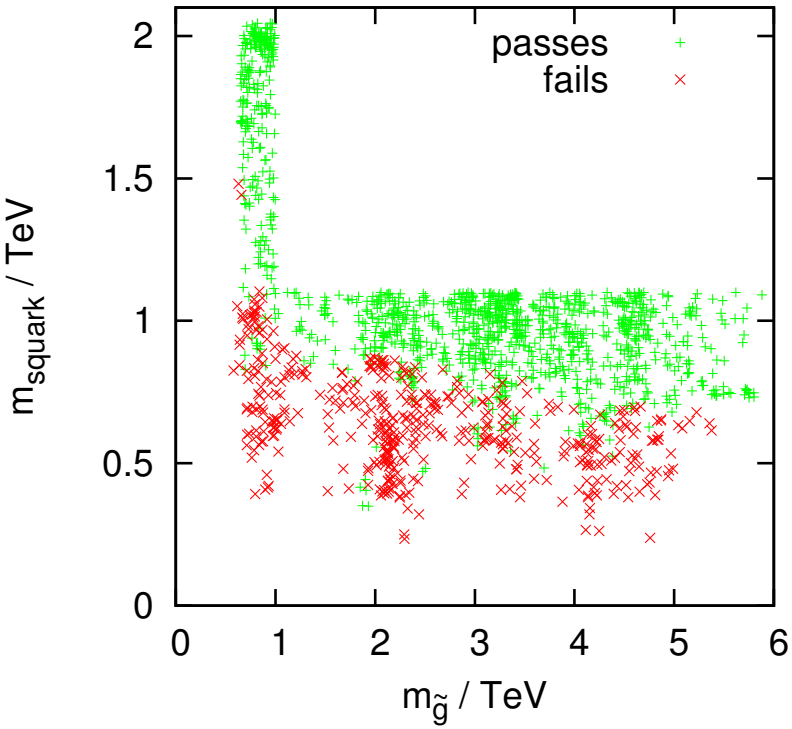
from hep-ph/1111.3365: D. Grellscheid, J. Jaeckel, V. V. Khoze, P. Richardson, CMW (to appear in JHEP)

SUSY searches continued

light neutralino scan

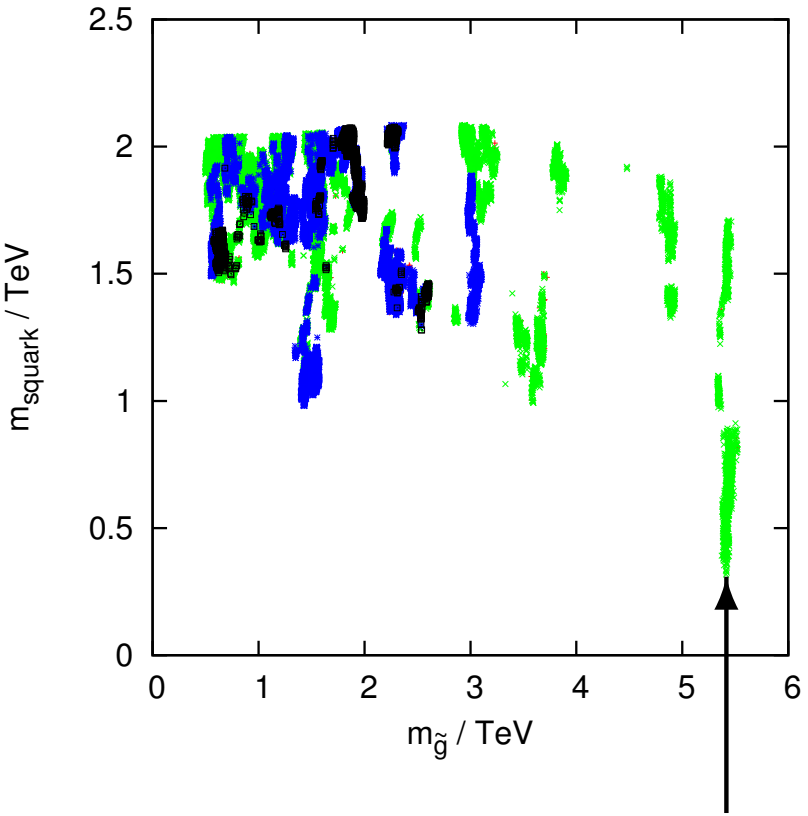


heavy neutralino scan

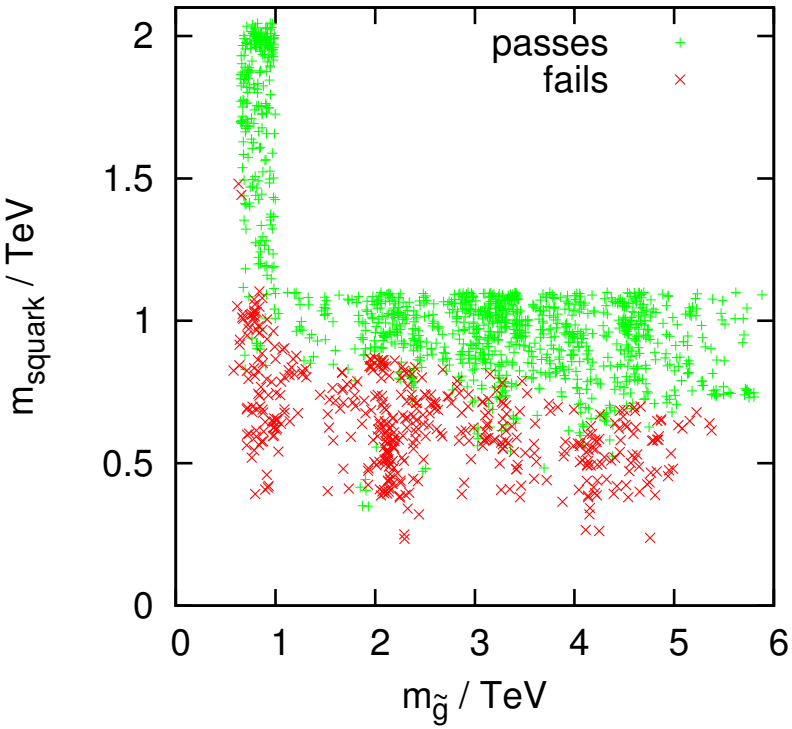


SUSY searches continued

light neutralino scan

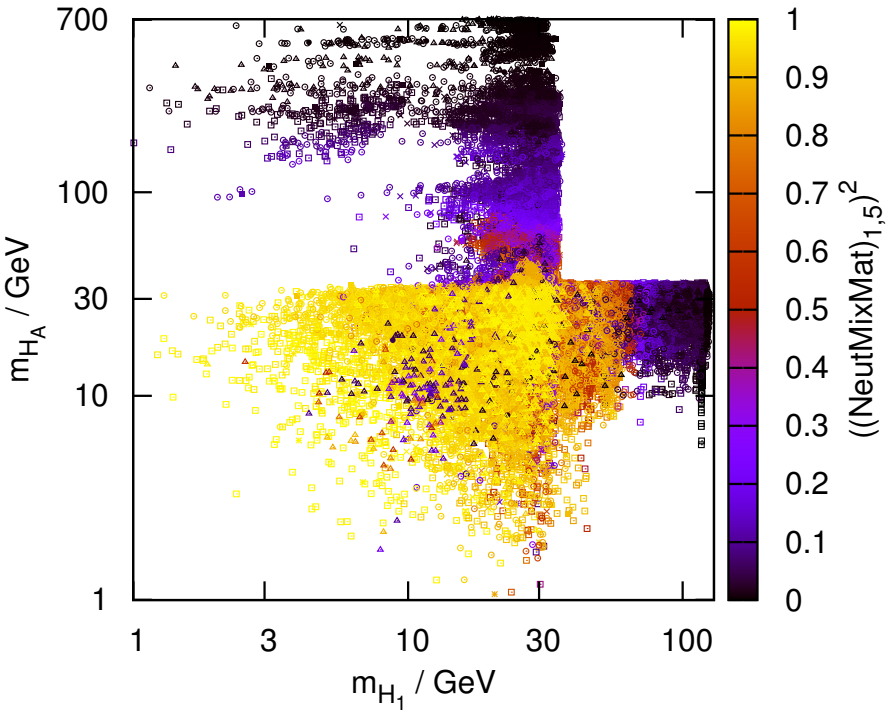


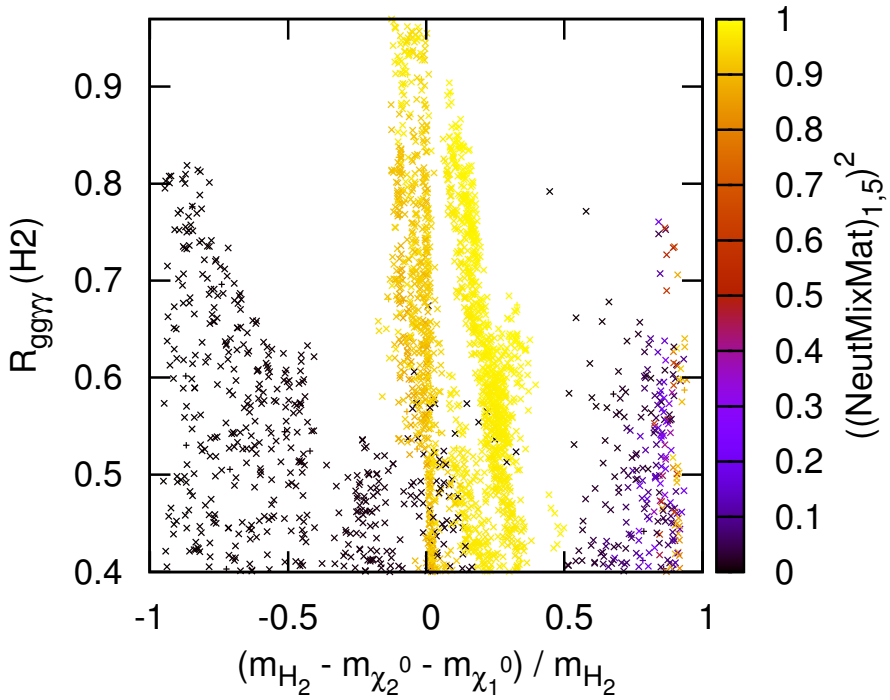
heavy neutralino scan



$\tilde{S}$-like χ_1^0, $\quad m_{\text{slepton}} < \frac{1}{2} m_{\text{squark}}$, $\quad \therefore \tilde{q} \to q + \chi^0_{i\geq 1} \to \text{jet} + \chi_1^0 + \textbf{leptons}$

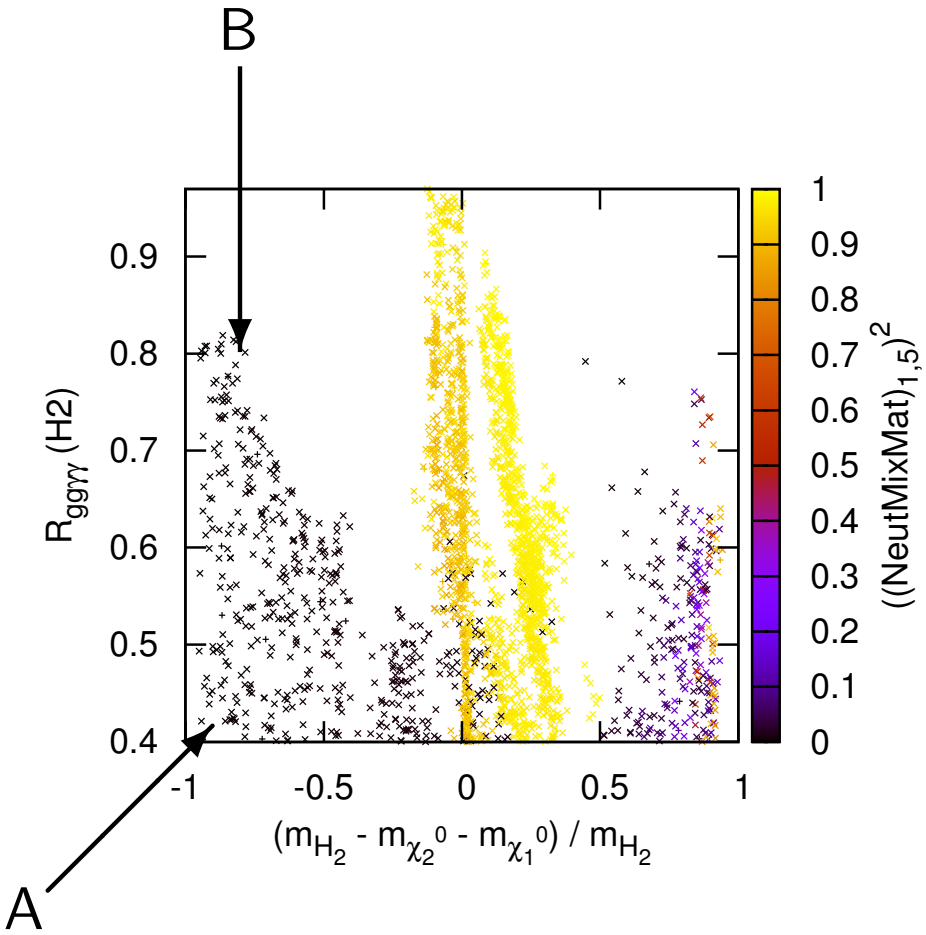
Higgs Results – Light χ_1^0 Scan





Higgs Results – Light χ_1^0 Scan – continued

	A	B
$\Gamma_{H_2 \to H_1 H_1}$/MeV	**4**	$\mathbf{10^{-6}}$
m_{H_1}/GeV	30.5	30.0
m_{H_2}/GeV	123	123
$S_{1,3}, S_{2,2}$	1,1	1,1
$\tan\beta$	17.2	17.8
λ	0.39	0.40
κ	0.32	0.33
A_λ/TeV	3.85	3.89
A_κ/GeV	-780	-788
μ/GeV	235	234

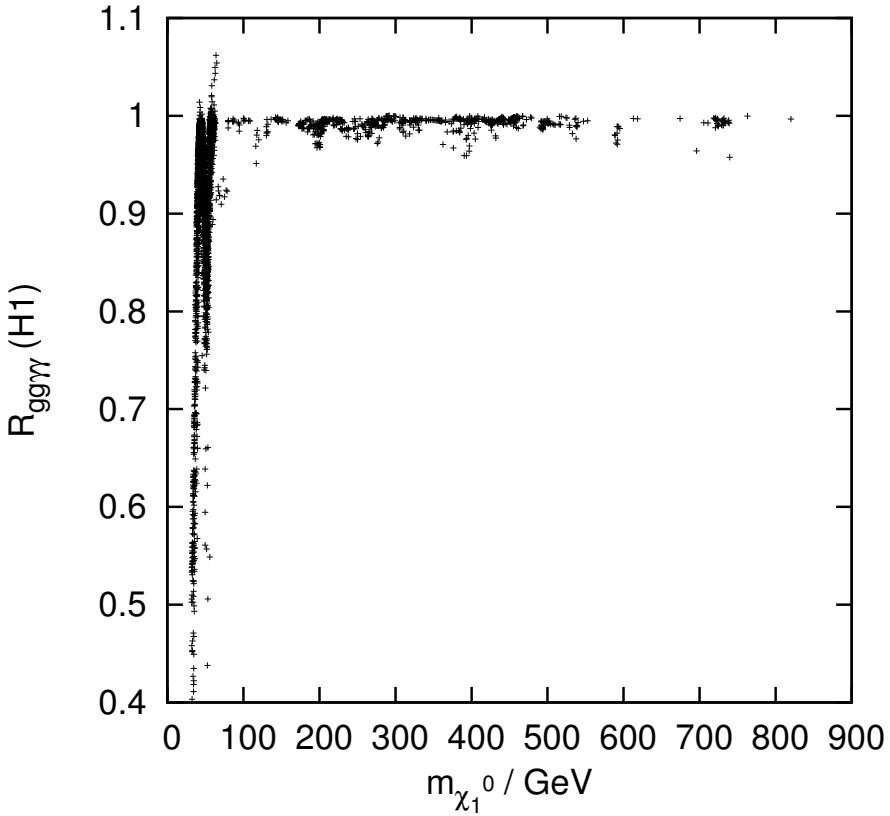


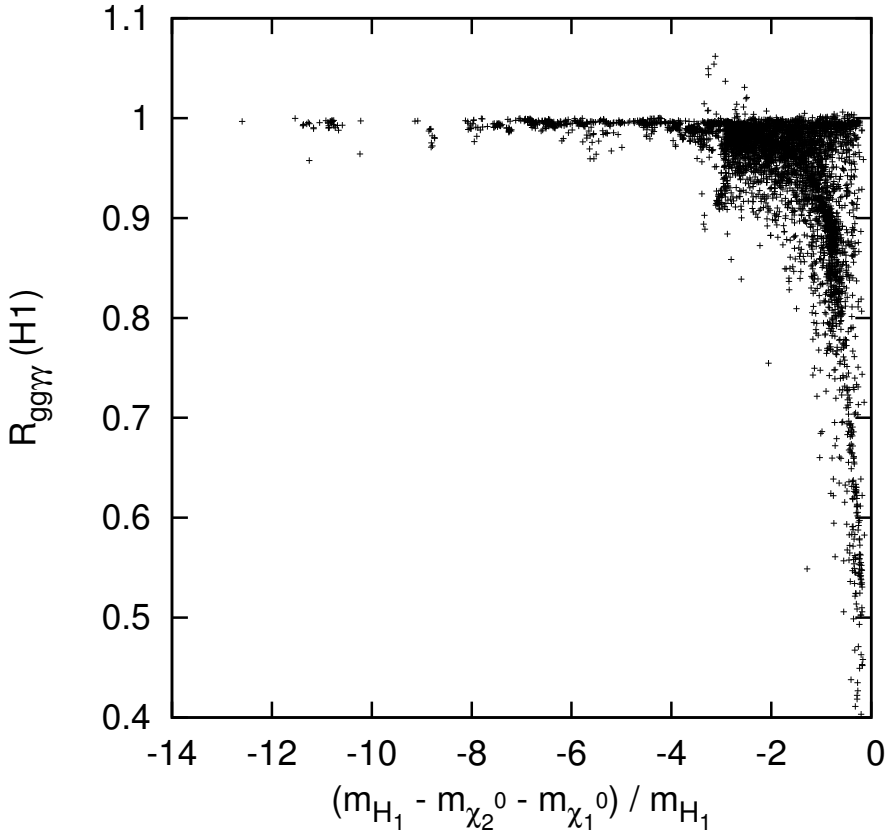
$$
\begin{aligned}
g_{H_a H_b H_c} = \quad & \frac{\lambda^2}{\sqrt{2}}\left(v_d(\Pi^{122}_{abc}+\Pi^{133}_{abc})+v_u(\Pi^{211}_{abc}+\Pi^{233}_{abc})+s(\Pi^{311}_{abc}+\Pi^{322}_{abc})\right) \\
& -\frac{\lambda\kappa}{\sqrt{2}}(v_d\Pi^{323}_{abc}+v_u\Pi^{313}_{abc}+2s\Pi^{123}_{abc})+\sqrt{2}\kappa^2 s\Pi^{333}_{abc} \\
& -\frac{\lambda A_\lambda}{\sqrt{2}}\Pi^{123}_{abc}+\frac{\kappa A_\kappa}{3\sqrt{2}}\Pi^{333}_{abc} \\
& +\frac{g_1^2+g_2^2}{4\sqrt{2}}\left(v_d(\Pi^{111}_{abc}-\Pi^{122}_{abc})-v_u(\Pi^{211}_{abc}-\Pi^{222}_{abc})\right) \\
& +\frac{\mu'}{\sqrt{2}}\left(\kappa\Pi^{333}_{abc}-\lambda\Pi^{123}_{abc}\right)
\end{aligned}
$$

where $5\Pi^{ijk}_{abc} = S_{ai}S_{bj}S_{ck}+S_{ai}S_{cj}S_{bk}+S_{bi}S_{aj}S_{ck}$
$+S_{bi}S_{cj}S_{ak}+S_{ci}S_{aj}S_{bk}+S_{ci}S_{bj}S_{ak}$

from hep-ph/0910.1785: U. Ellwanger, C. Hugonie, A. M. Teixeira (2009)

Higgs Results – Heavy χ_1^0 Scan





Conclusions

- Can see novel SUSY decay cascades at colliders
- 125 GeV Higgs easy for NMSSM (hard for MSSM)
- Observed excess can be H_1, mass boosted by singlet, or H_2, mass boosted by level-splitting
- If decays to $\chi^0_{1,2}, a_1, H_1$ are accessible, understand what suppresses them
- Can arrange $R_{gg\gamma\gamma} \sim 1$ (R_{ggVV} follows suit)
- $R_{gg\gamma\gamma} > 1$? Keep listening...