(N)MSSM Higgs near 125 GeV: implications for SUSY searches

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based on work with J. Gunion, Y. Jiang, S. Sekmen et al.
(1109.5119, 1201.0982 & more in prog.)

3rd Linear Collider Forum
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Motivation

- Both ATLAS and CMS report tantalizing excesses in the $\gamma\gamma$ channel hinting at a Higgs with mass of 123-127 GeV

  Talks by J. Schaarschmidt and M. Klute

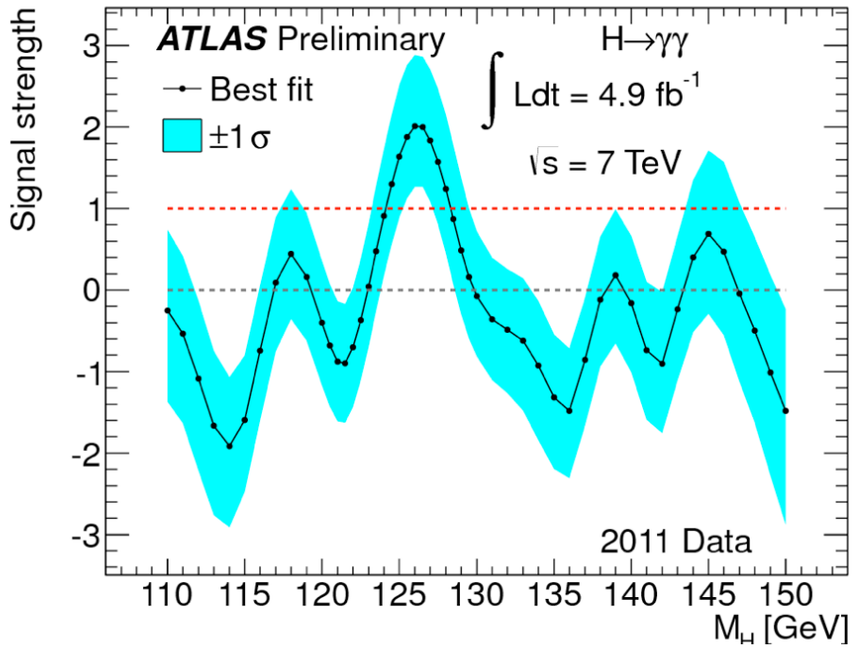
- Many studies of implications for MSSM, NMSSM and constrained versions thereof

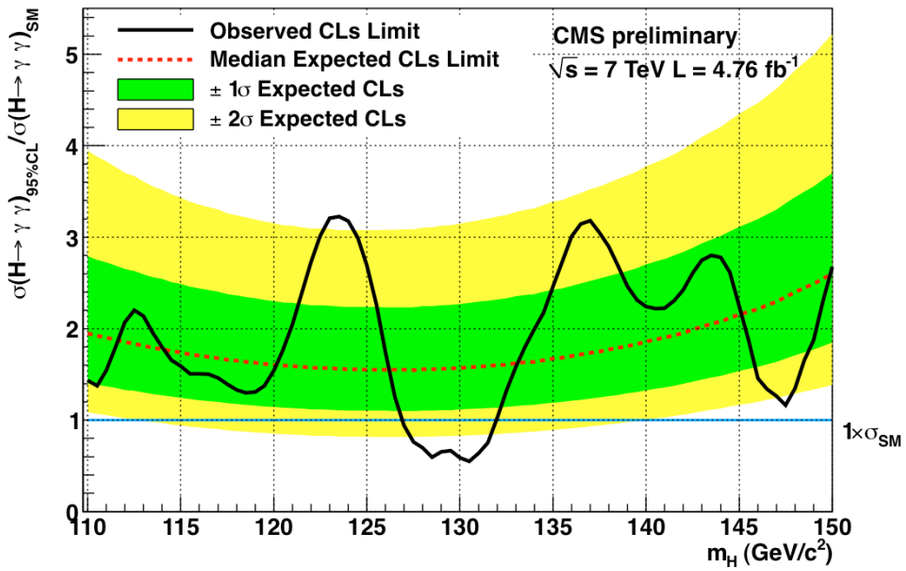
  c.f. talks by H. Baer, M. Battaglia, P. Bechtle

- Typically need heavy stops and maximal mixing – i.e. large A-terms!
  In constrained models this gives quite heavy spectra; GMSB, AMSB disfavored

- Howie: Should we be alarmed?
  → Effective SUSY, Yukawa-unified SO(10), etc

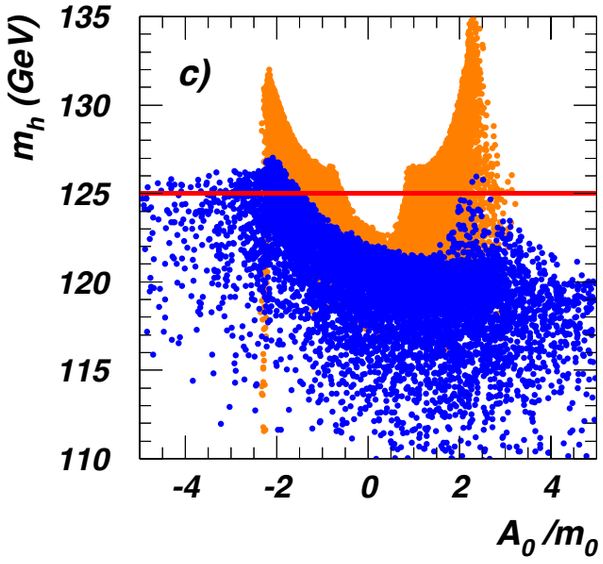
- Interpretation in RS: see talk by J. Gunion

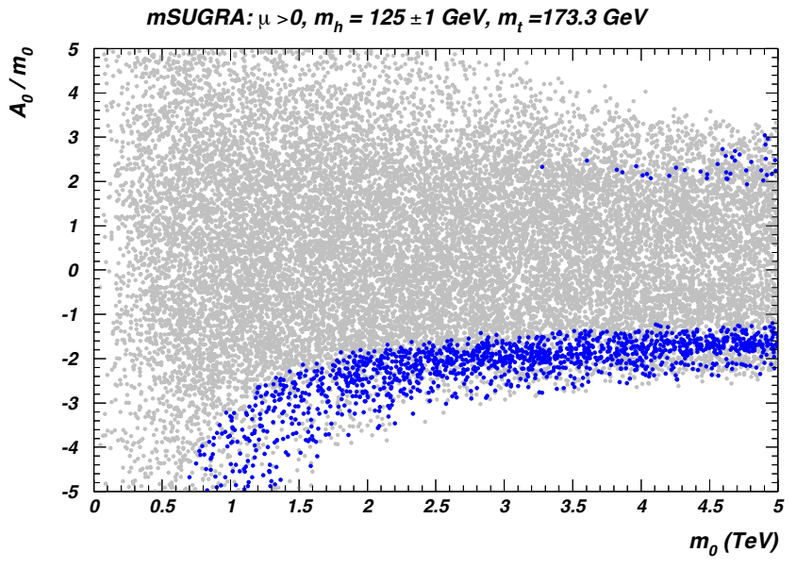




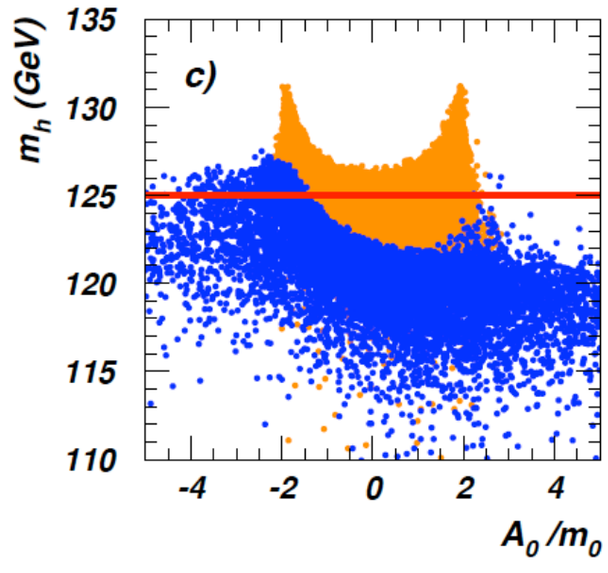
MSSM, CMSSM, NUHM, ...

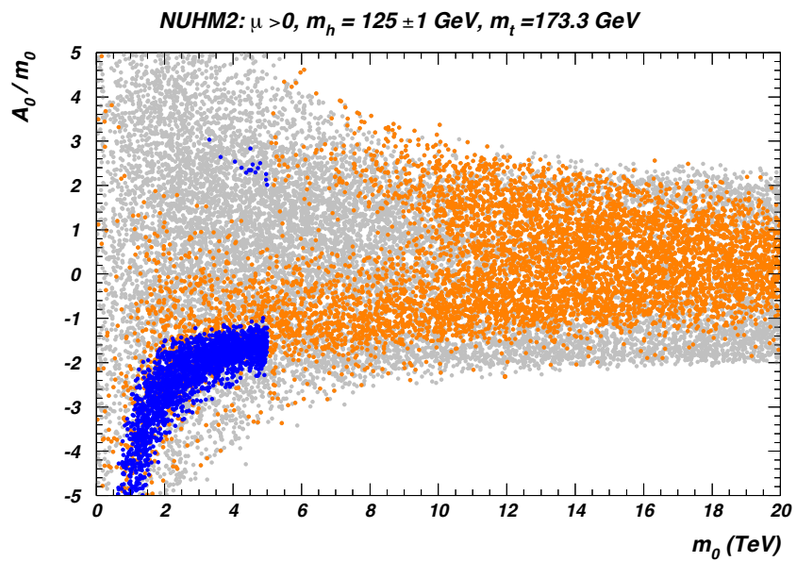
CMSSM





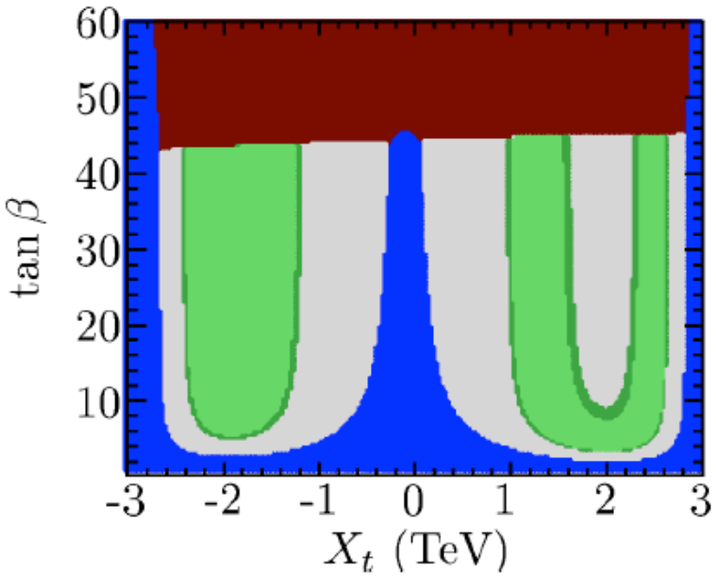
NUHM-MSSM





Baer, Barger, Mustafayev, 1112:3017

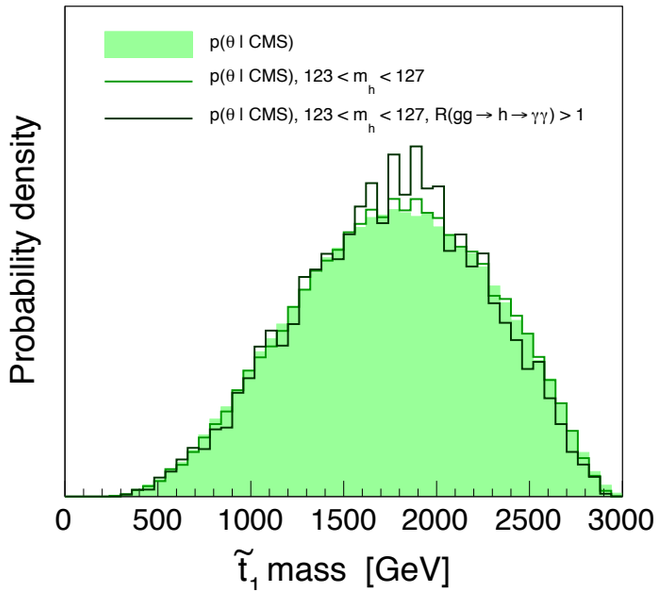
MSSM, M_{SUSY}= 1 TeV

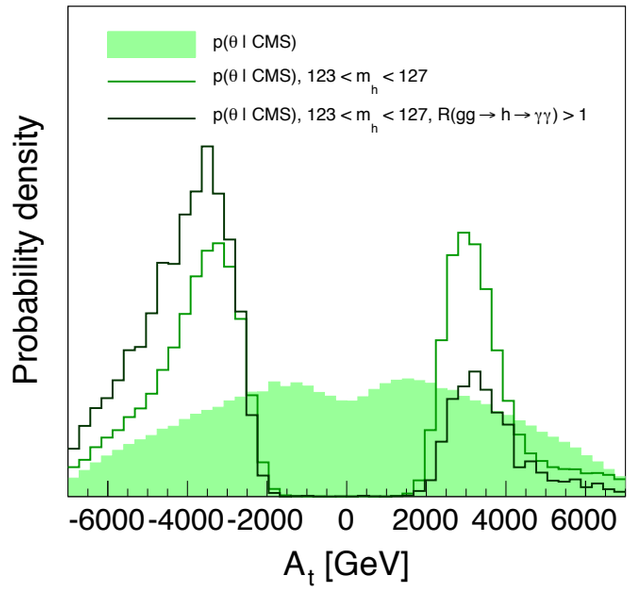


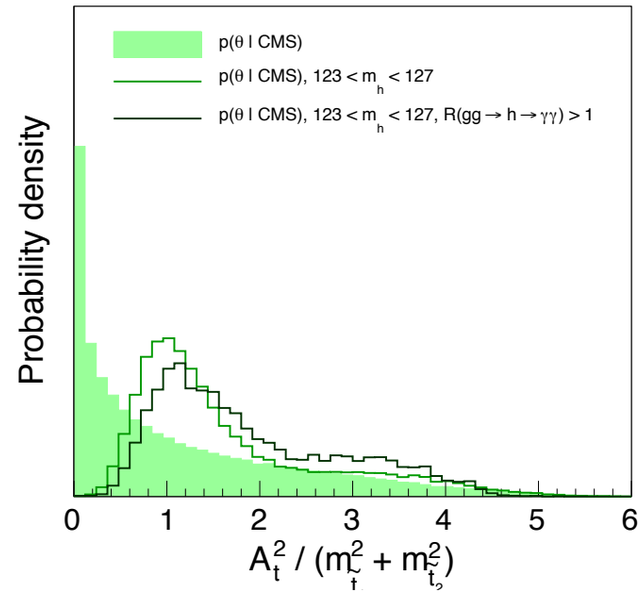
Heinemeyer, Stal, Weiglein, 1112:3026

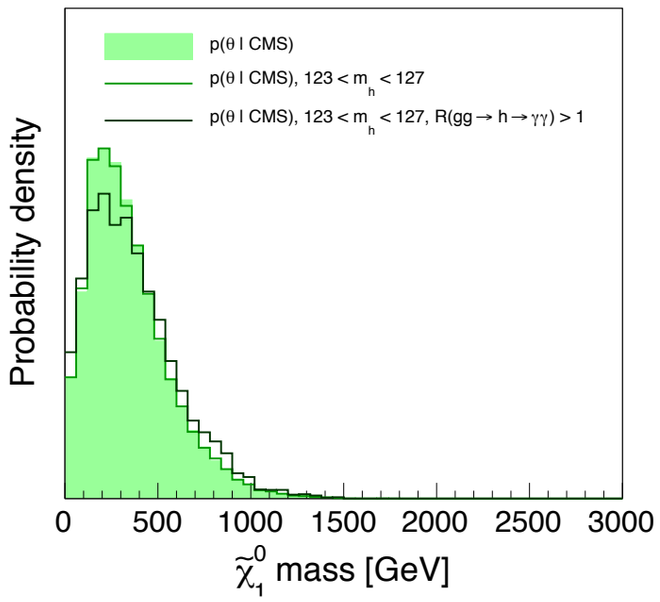
Phenomenological (weak-scale) MSSM

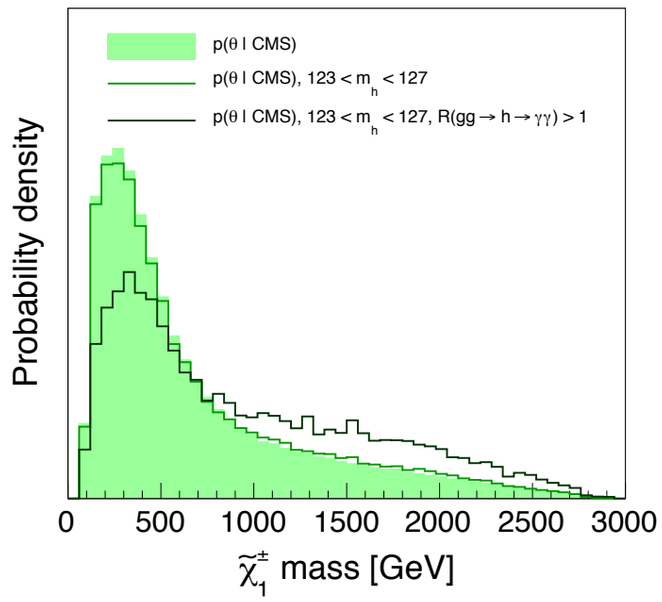
Probability distributions after 1fb^{-1} LHC SUSY searches

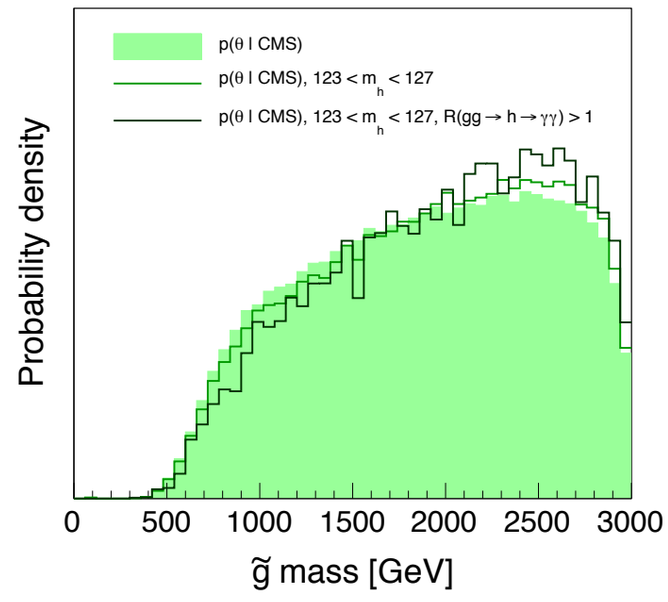












based on results from 1109.5119 & LH PhysTeV 2011 proceedings

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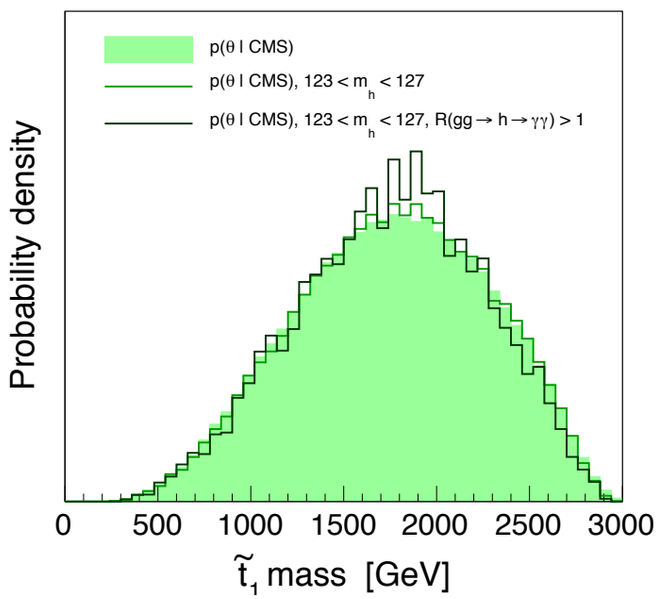

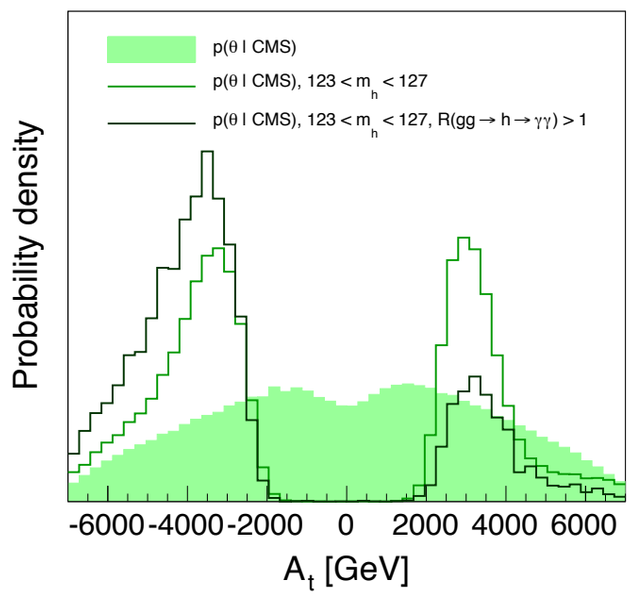

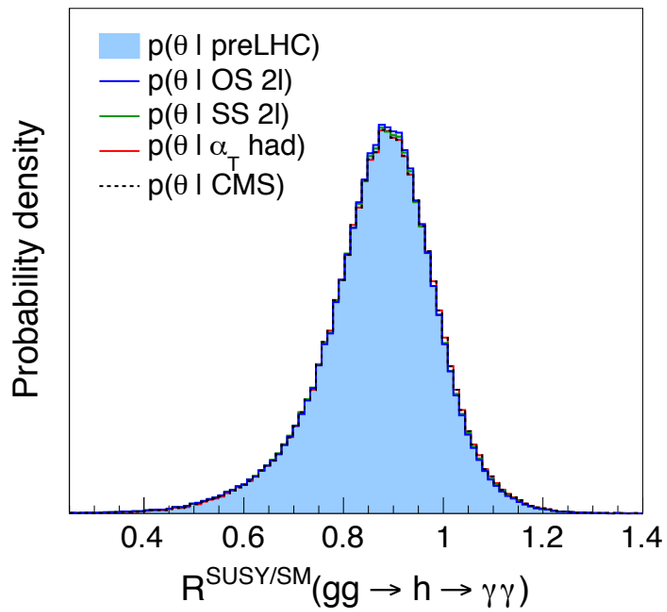

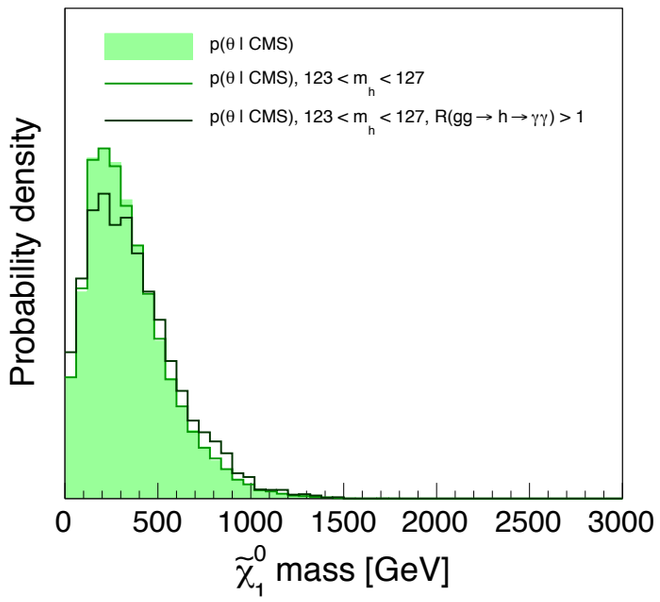

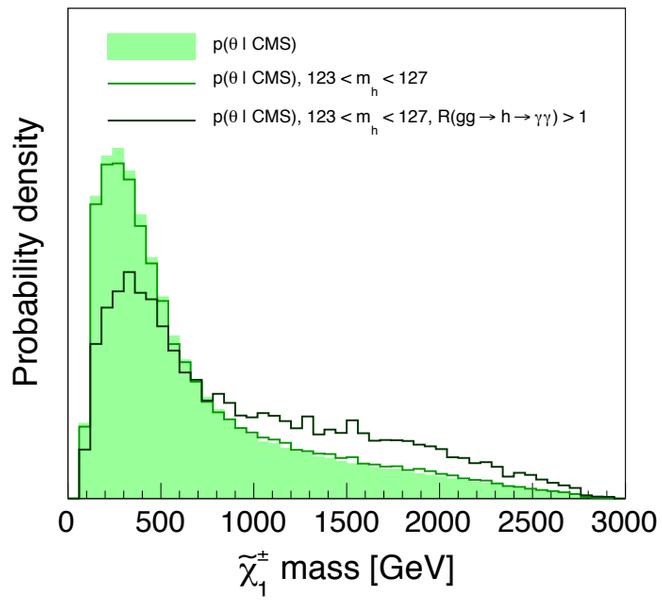

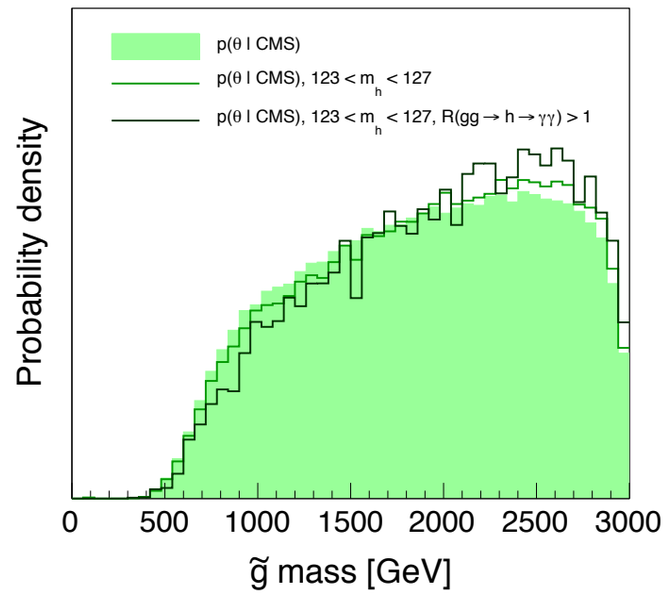

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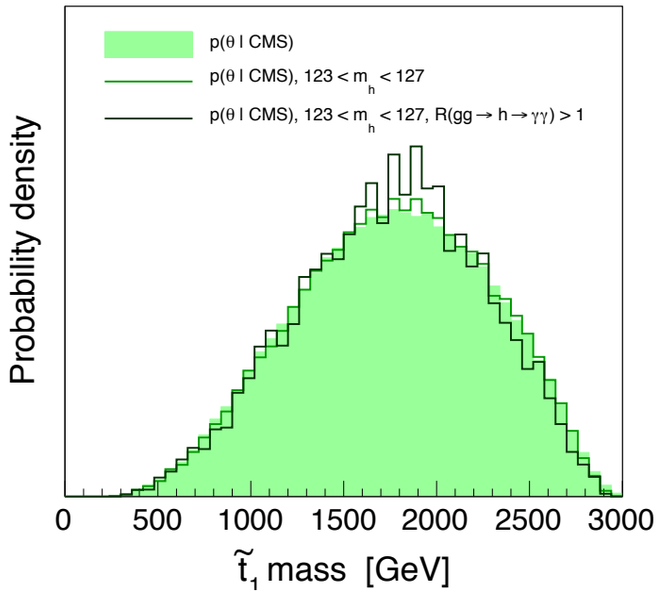

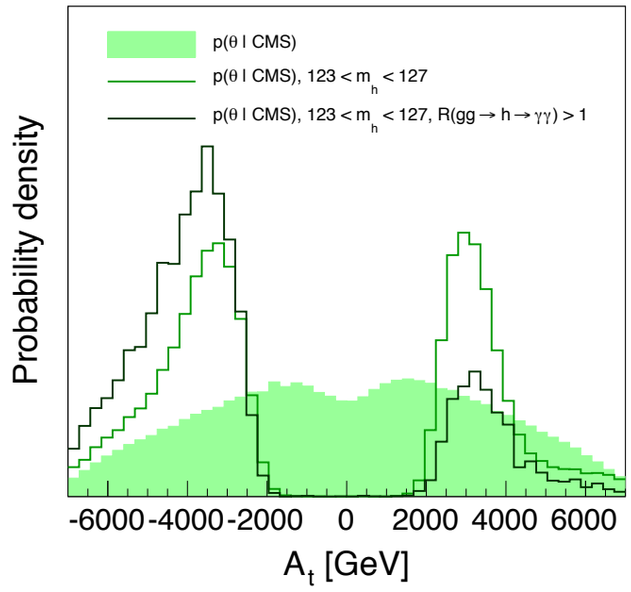

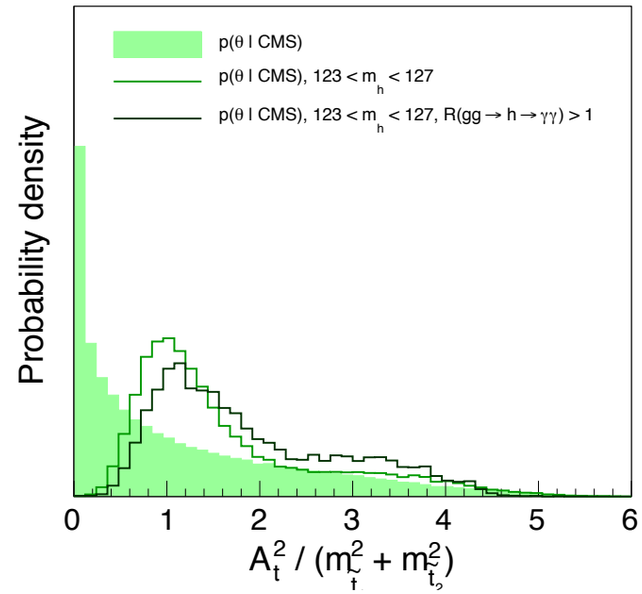

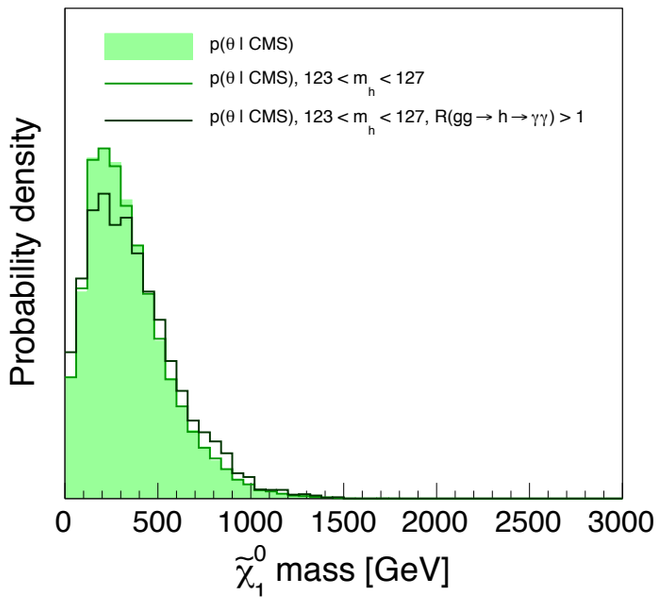

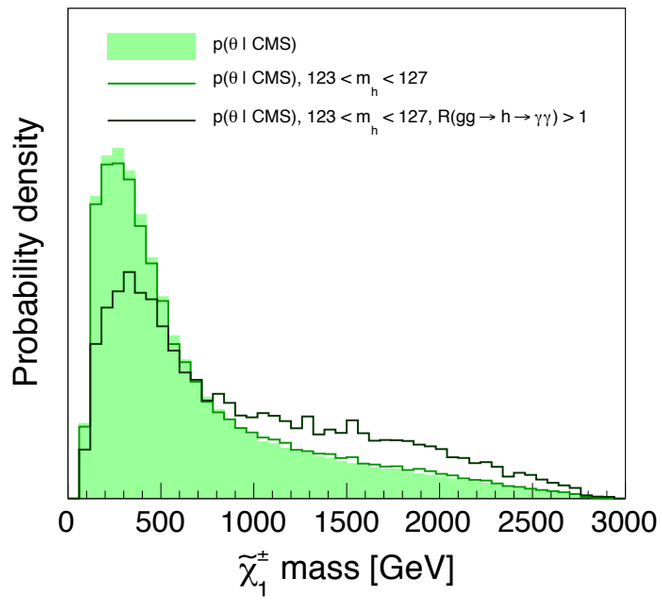

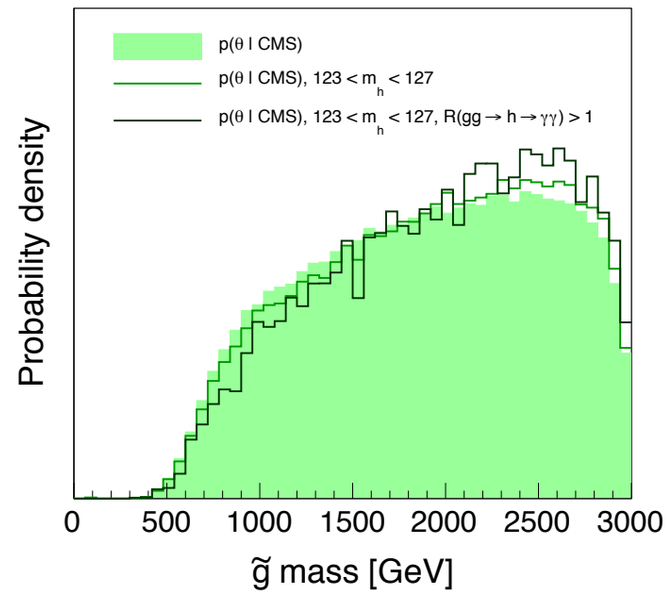

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Next-to-minimal MSSM

$$W_{\rm MSSM} = \mu H_u H_d + \ldots \;\rightarrow\; W_{\rm NMSSM} = \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + \ldots$$

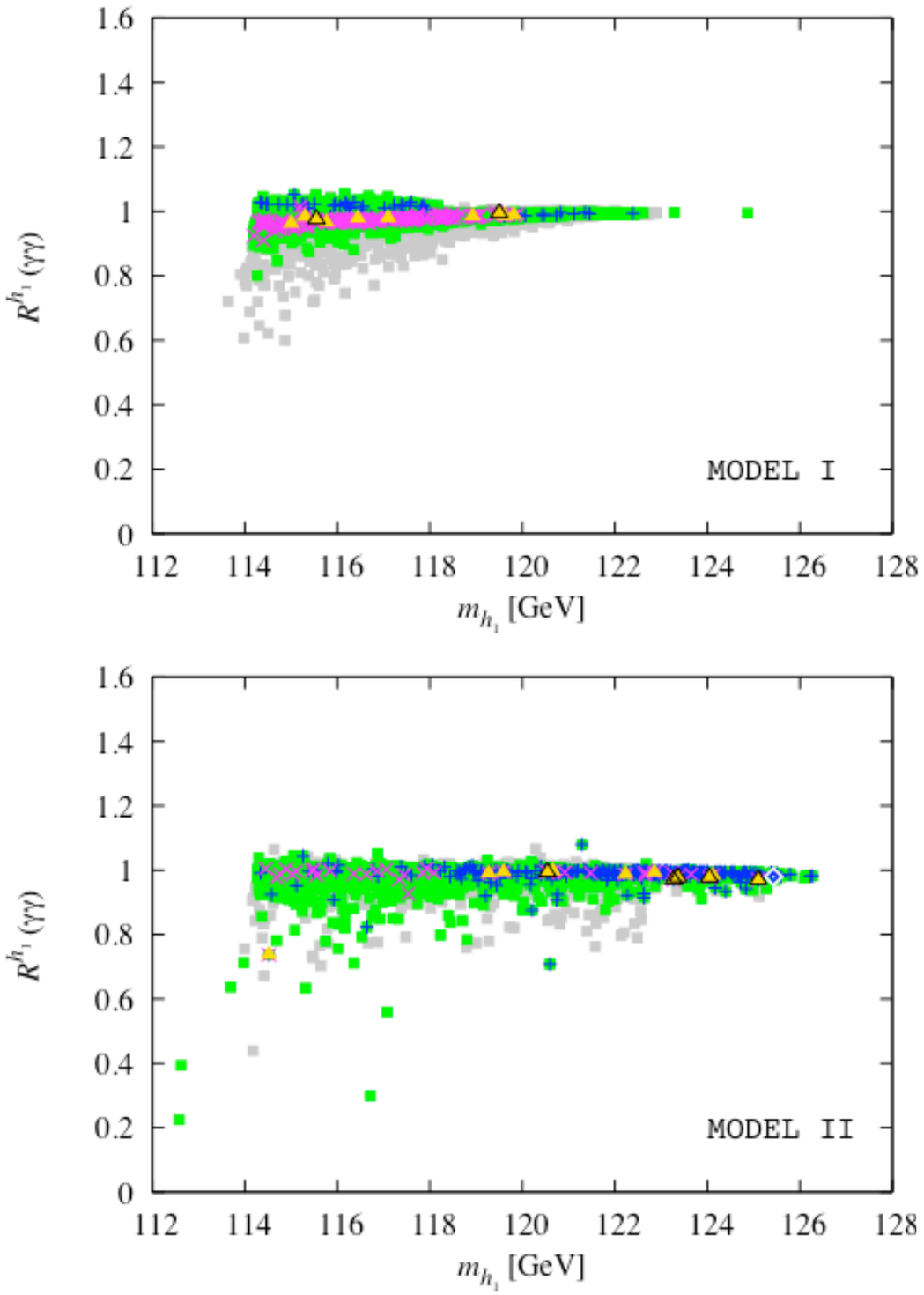
- NMSSM-specific couplings and mixing effects can give SM-like CP-even Higgs with mass near 125 GeV.
- U. Ellwanger, 1112.3548, finds m_{h_2}=124-127 GeV with enhanced $gg \rightarrow h_2 \rightarrow \gamma\gamma$ rate for λ~0.5–0.6 and tanβ<2 (unconstrained NMSSM with weak-scale parameters)
- We take GUT-scale parameters as inputs and study the following model variants, performing random and MCMC scans using NMSSMTools:
  - Model I: CNMSSM with $A_\lambda = A_\kappa = 0$
  - Model II: NUHM-relaxed CNMSSM with $A_\lambda = A_\kappa = 0$
  - Model III: NUHM-relaxed CNMSSM with general A_λ, A_κ

$$R^{h_i}(X) \equiv \frac{\Gamma(gg\rightarrow h_i)\ \mathrm{BR}(h_i\rightarrow X)}{\Gamma(gg\rightarrow h_{\rm SM})\ \mathrm{BR}(h_{\rm SM}\rightarrow X)}$$

Parameters: λ, tanβ, plus m_0, $m_{1/2}$, A_0, m_{Hu}, m_{Hd}, A_λ, A_κ at M_{GUT}

J. Gunion, Y. Jiang, SK

Constrained NMSSM variants



Green: B-physics OK

Blue: relic density < 0.136

Magenta: δa_μ >5.77e-10 but arbitratry Ωh^2

Golden: δa_μ >5.77e-10 and Ωh^2<0.136

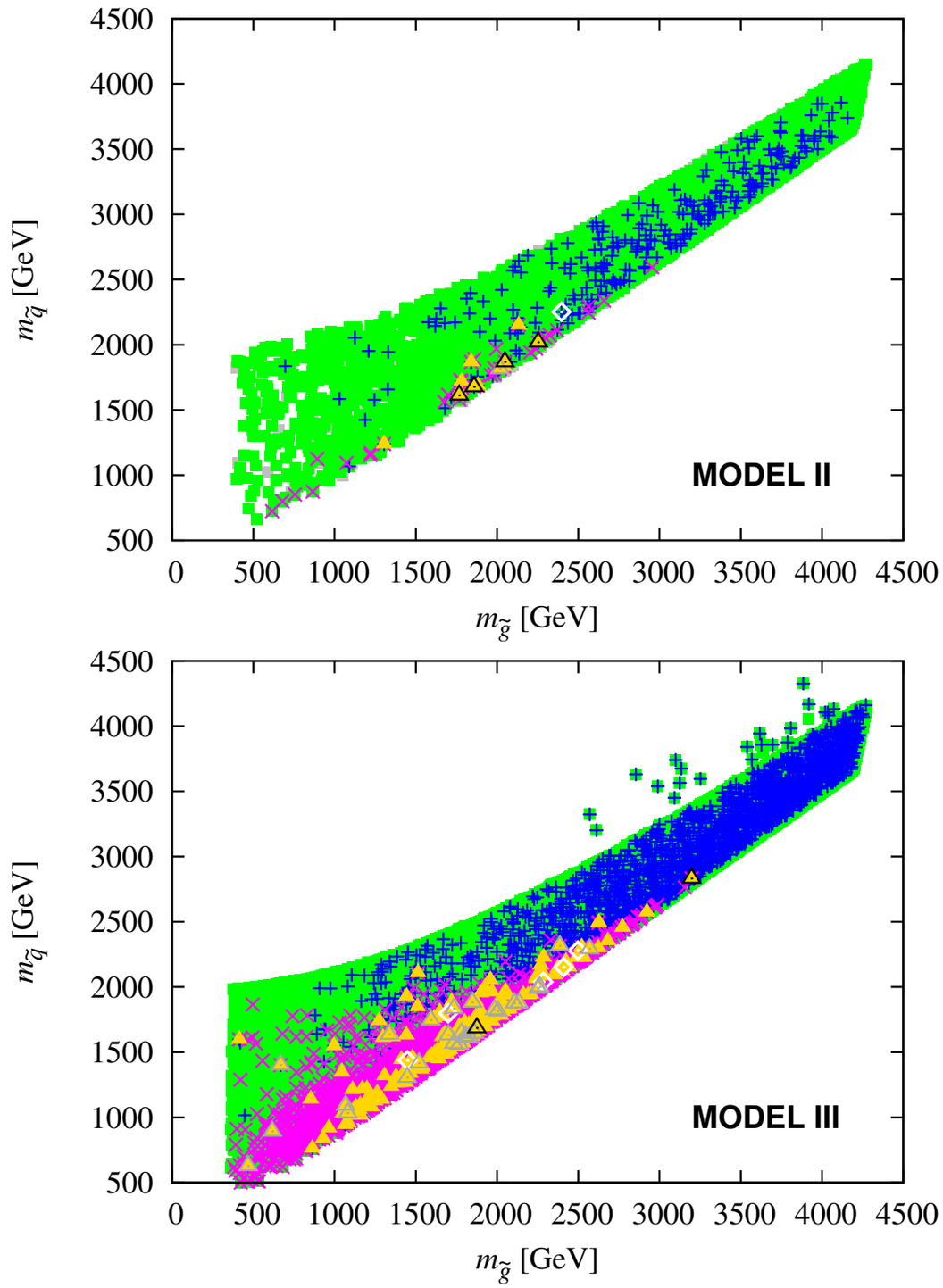
Open triangles: "perfect points", $0.094<\Omega h^2<0.136$ and δa_μ>5.77e-10

White diamonds: "almost perfect points" with δa_μ relaxed to δa_μ>4.27e-10

J. Gunion, Y. Jiang, SK

Consequences for SUSY searches

- The regions of parameter space that are consistent with a Higgs of mass close to 125 GeV while observing other existing constraints have squark and gluino masses >1 TeV.
- Current limits from LHC are automatically evaded.
- LSP mass typically 300-450 GeV, (DM constraints)
- Scrutinizing SUSY particles may have to wait for 14 TeV LHC and/or CLIC



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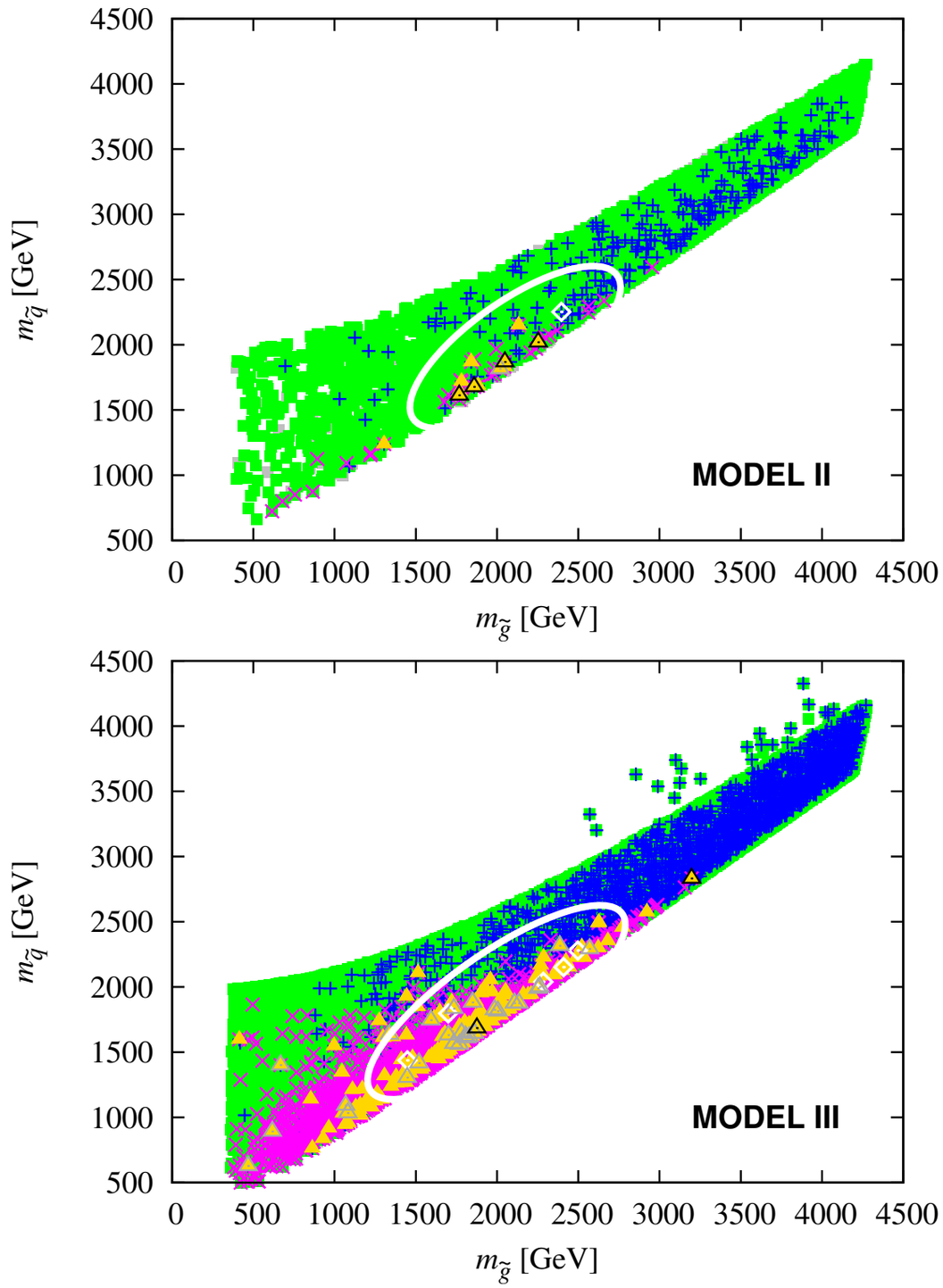


J. Gunion, Y. Jiang, SK

NMSSM sample points

	Model II			Model III			
Pt. #	1*	2*	3	4*	5	6	7
$\tan\beta(m_Z)$	17.9	17.8	21.4	15.1	26.2	17.9	24.2
λ	0.078	0.0096	0.023	0.084	0.028	0.027	0.064
κ	0.079	0.011	0.037	0.158	−0.045	0.020	0.343
$m_{1/2}$	923	1026	1087	842	738	1104	1143
m_0	447	297	809	244	1038	252	582
A_0	−1948	−2236	−2399	−1755	−2447	−2403	−2306
A_λ	0	0	0	−251	−385	−86.8	−2910
A_κ	0	0	0	−920	883	−199	−5292
$m^2_{H_d}$	$(2942)^2$	$(3365)^2$	$(4361)^2$	$(2481)^2$	$(935)^2$	$(3202)^2$	$(3253)^2$
$m^2_{H_u}$	$(1774)^2$	$(1922)^2$	$(2089)^2$	$(1612)^2$	$(1998)^2$	$(2073)^2$	$(2127)^2$

J. Gunion, Y. Jiang, SK

NMSSM sample points

	Model II			Model III			
Pt. #	1*	2*	3	4*	5	6	7
$\mu_{\rm eff}$	400	447	472	368	421	472	477
$m_{\tilde{g}}$	2048	2253	2397	1876	1699	2410	2497
$m_{\tilde{q}}$	1867	2020	2252	1685	1797	2151	2280
$m_{\tilde{b}_1}$	1462	1563	1715	1335	1217	1664	1754
$m_{\tilde{t}_1}$	727	691	775	658	498	784	1018
$m_{\tilde{e}_L}$	648	581	878	520	1716	653	856
$m_{\tilde{e}_R}$	771	785	1244	581	997	727	905
$m_{\tilde{\tau}_1}$	535	416	642	433	784	443	458
$m_{\tilde{\chi}_1^\pm}$	398	446	472	364	408	471	478
$m_{\tilde{\chi}_1^0}$	363	410	438	328	307	440	452
$f_{\tilde{B}}$	0.506	0.534	0.511	0.529	0.914	0.464	0.370
$f_{\tilde{W}}$	0.011	0.009	0.008	0.012	0.002	0.009	0.009
$f_{\tilde{H}}$	0.483	0.457	0.482	0.459	0.083	0.528	0.622
$f_{\tilde{S}}$	10^{-4}	10^{-6}	10^{-6}	10^{-4}	10^{-6}	10^{-4}	10^{-6}

← low μ

heavy squarks and gluinos

← fairly light stops

← ~light staus

← LSP ~300–450 GeV

sizable gaugino-higgsino mixing

Small neutralino-chargino mass splitting makes EW-ino detection at LHC difficult.
Interesting for a LC, but would want √s>1TeV

J. Gunion, Y. Jiang, SK

NMSSM sample points

Dark matter related quantities

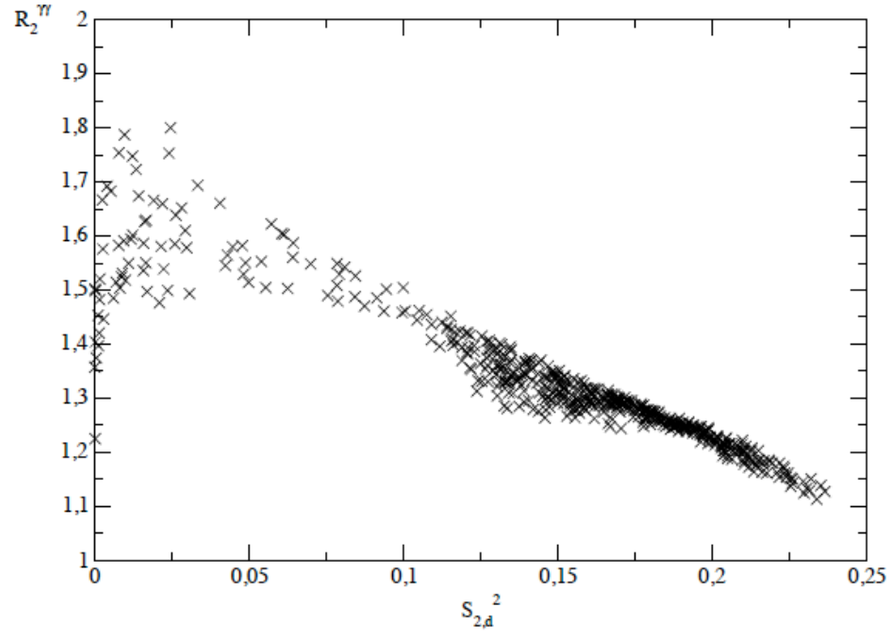
Pt. #	δa_μ	Ωh^2	Prim. Ann. Channels	$\sigma_{\rm SI}$ [pb]
1*	6.01	0.094	$\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to W^+W^-(31.5\%), ZZ(21.1\%)$	4.3×10^{-8}
2*	5.85	0.099	$\widetilde{\nu}_\tau\widetilde{\nu}_\tau \to \nu_\tau\nu_\tau(11.4\%), \widetilde{\nu}_\tau\overline{\widetilde{\nu}}_\tau \to W^+W^-(8.8\%)$	3.8×10^{-8}
3	4.48	0.114	$\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to W^+W^-(23.9\%), ZZ(17.1\%)$	3.7×10^{-8}
4*	6.87	0.097	$\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to W^+W^-(36.9\%), ZZ(23.5\%)$	4.5×10^{-8}
5	5.31	0.135	$\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to b\bar{b}(39.5\%), h_1a_1(20.3\%)$	5.8×10^{-8}
6	4.89	0.128	$\widetilde{\tau}_1\widetilde{\tau}_1 \to \tau\tau(17.4\%), \widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to W^+W^-(14.8\%)$	4.0×10^{-8}
7	4.96	0.101	$\widetilde{\chi}_1^0\widetilde{\chi}_1^0 \to W^+W^-(17.7\%), ZZ(12.9\%)$	4.0×10^{-8}

U. Ellwanger, 1112.3548

Weak-scale NMSSM and $R_{\gamma\gamma}>1$

- In the unconstrained NMSSM with weak-scale parameters, U. Ellwanger finds the 2nd CP-even scalar h_2 can give enhanced $\gamma\gamma$ signal in the124-127 GeV mass range if $\lambda\sim0.5–0.7$ and $\tan\beta<2$

- Fixes M_1=175 GeV, M_2=350 GeV and M_3=1000 GeV, squark masses 1200 GeV, (800 GeV for 3rd generation), slepton masses 300 GeV, $A_t = A_b = -1000$ GeV, μ_{eff}=140 GeV, m_A=300 GeV.

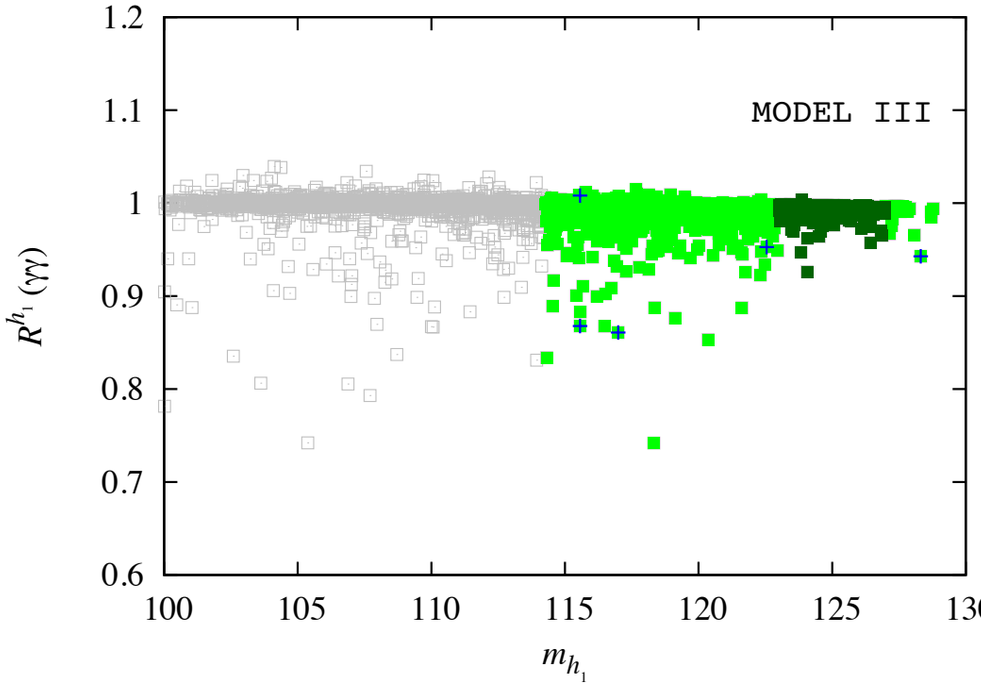


- "The density of viable points is particularly large for $\tan\beta\sim1.7-2$, $\lambda\sim0.5-0.6$, $\kappa\sim0.3-0.4$ and -250 GeV $< A_K < -200$ GeV."

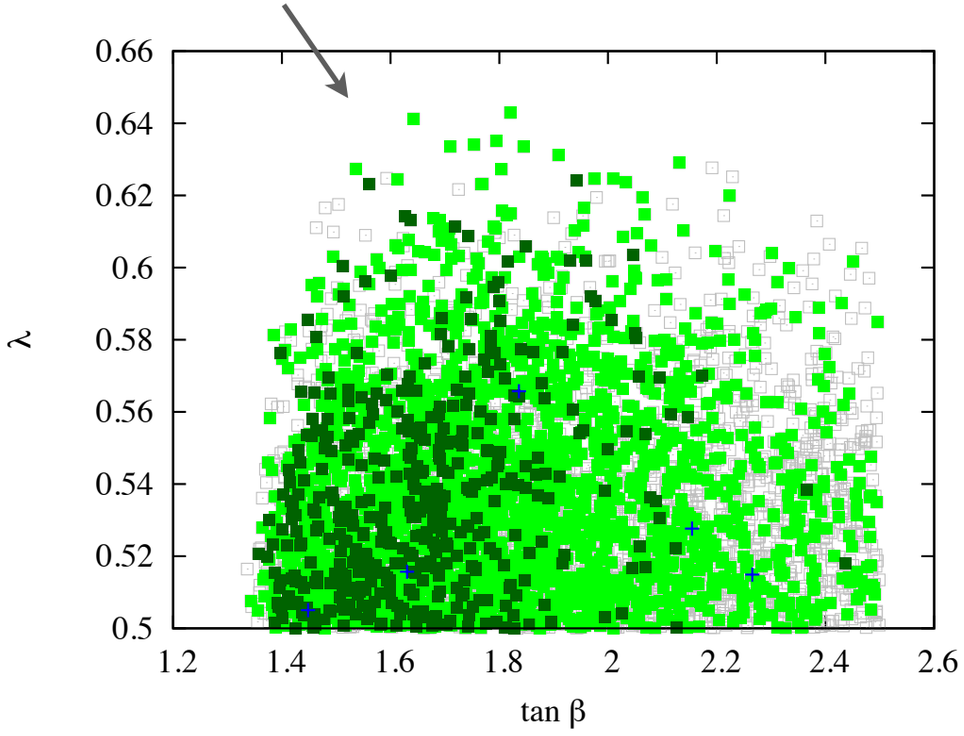
J. Gunion et al, in progress

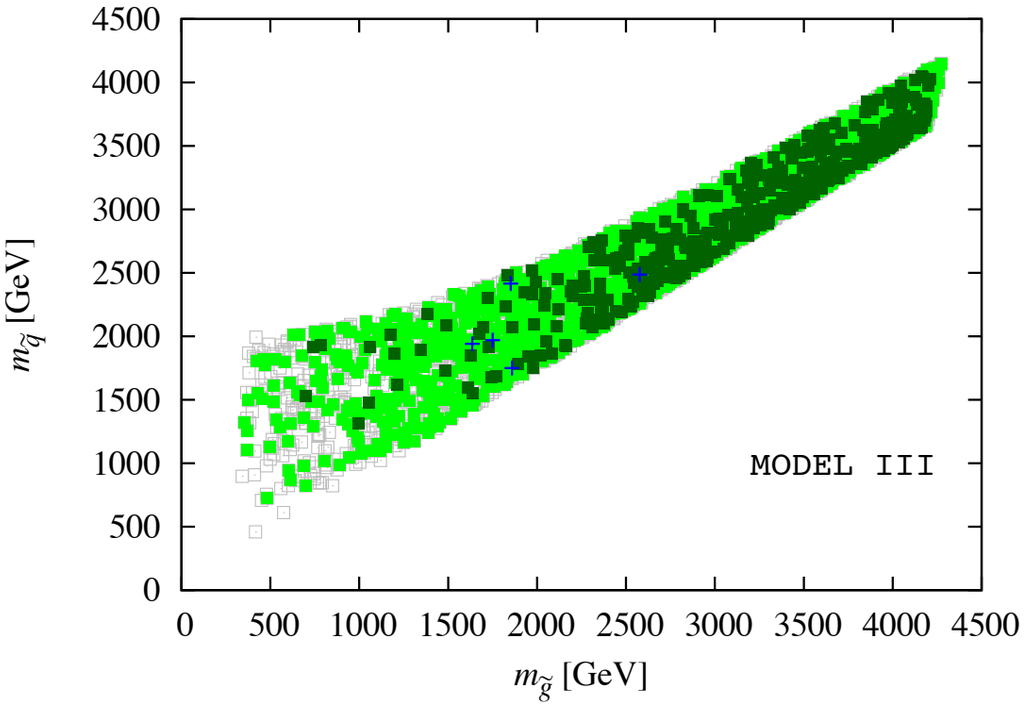
GUT-scale perspective of large λ, small tanβ scenarios

- Focus scan on λ=0.5–0.7, tanβ=1–2, plus m_0, $m_{1/2}$, A_0, m_{Hu}, m_{Hd}, A_λ, A_K at M_{GUT} (model III)
- Lots of points with h_1 in interesting mass range but not h2
- No significant enhancement in $\gamma\gamma$ channel



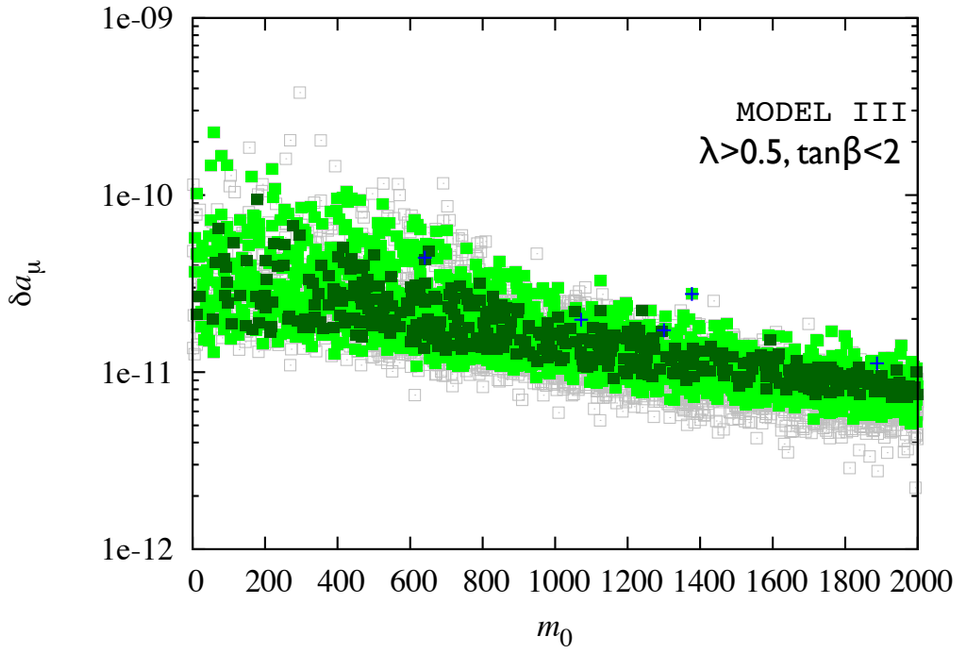
Landau pole or no global minimum

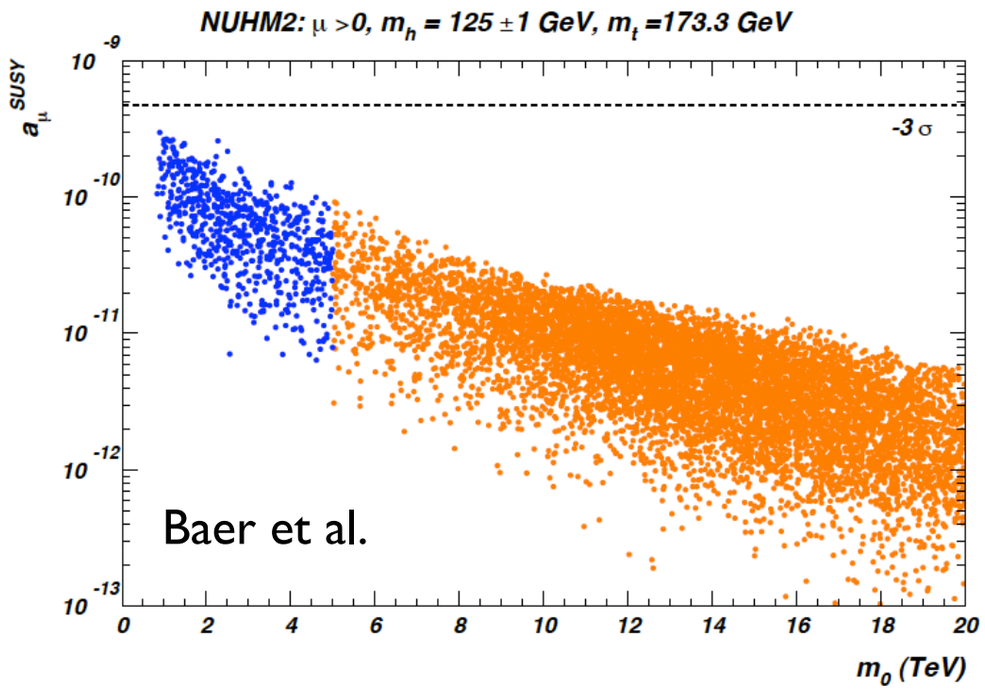


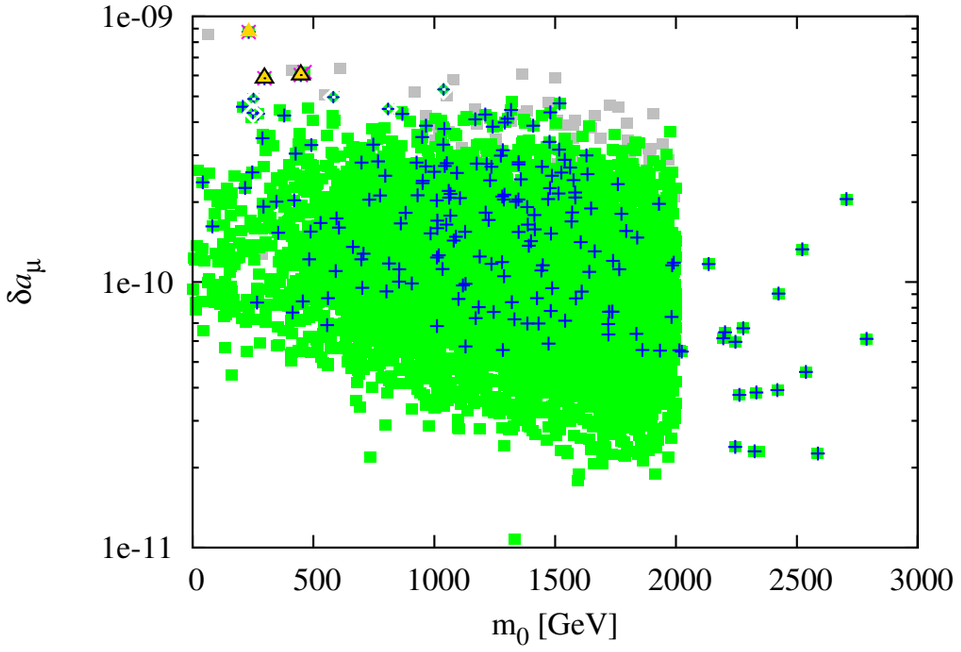


Tension with δa_μ

- Satisfying muon (g-2) constraint requires light charginos and smuons
  (c.f. talk by D. Stockinger)
- Higgs in the 123-127 GeV range prefers heavy sparticles
- Tension somewhat less severe in NMSSM than in MSSM ?







Conclusions

- A SM-like Higgs in the 123-127 GeV mass range poses a severe constraint on SUSY models.
- Typically points towards heavy SUSY → need 14 TeV LHC.
- Detailed measurements may be difficult at LHC because of large gaugino-higgsino mixing, at least in constrained NMSSM models. (Good prospects however for direct dark matter detection!)
- Consequences for linear collider: want $\sqrt{s}$ > 1 TeV for precision measurements of EW-inos, sleptons, stops, ...
- We still need to better understand regions of parameter space, in both MSSM & NMSSM, that can give enhanced $\gamma\gamma$ signal ($R_{\gamma\gamma}$>1)
  → work in progress
- Of course we want precise "profiling" of the Higgs(es) !

ps: interesting complementary work by King, Muhlleitner and Nevzorov, 1201:2671