SUSY interpretations of the LHC Higgs Search Results

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LHC Physics Discussion

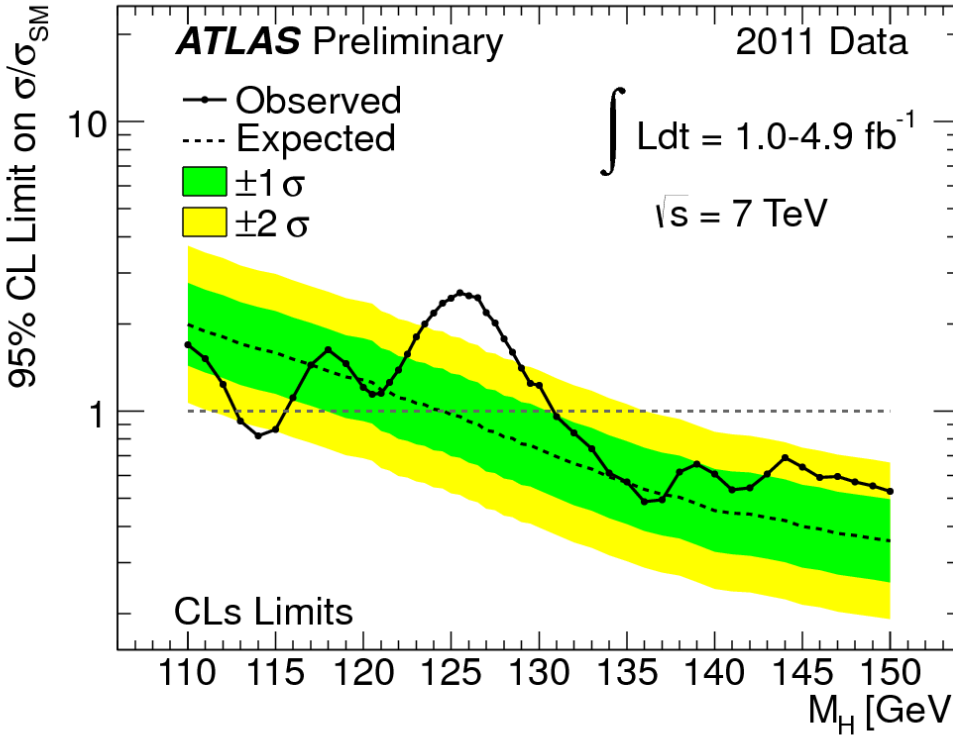
6.2 2012

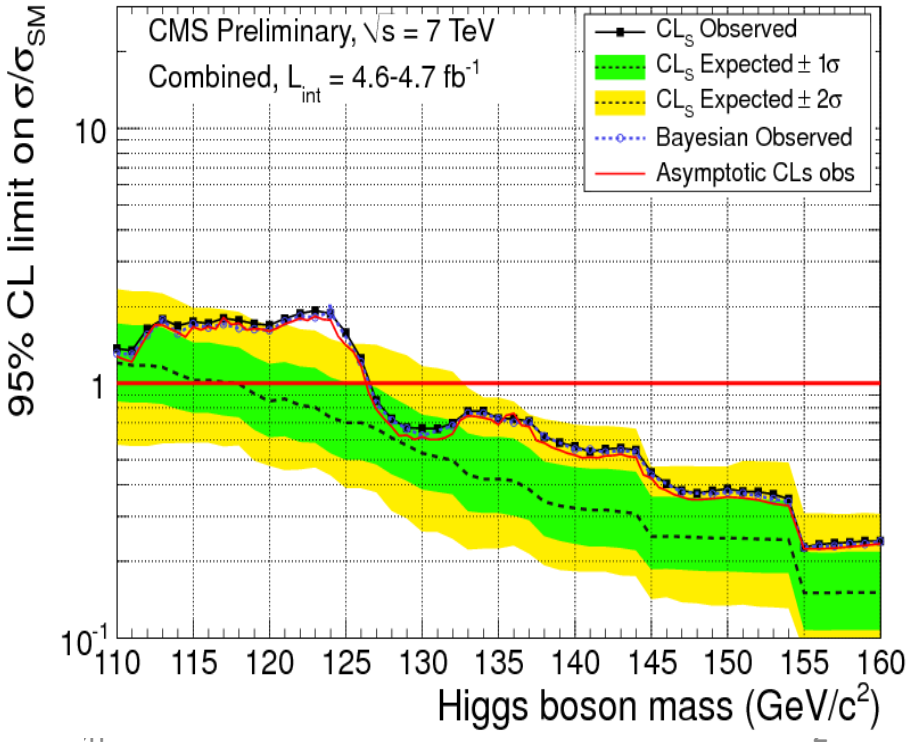
LHC Higgs Search Results

- Updated Higgs search results from ATLAS and CMS on Dec. 13 using 2011 dataset (close to 5 fb^{-1})

$$115.5\,\mathrm{GeV} < M_h < 127\,\mathrm{GeV}$$

- SM-like Higgs excluded for $M_H > 130$ GeV -> Good news for SUSY (heavy non-SM Higgses not excluded – model dependent bounds)





MSSM Higgs sector

- Two complex Higgs Doublets: H_u, H_d
  -> 8 degrees of freedom, 5 physical Higgs bosons

- CP conservation: h, H (CP-even), A (CP-odd), and $H^{\pm}$

$$m_H > m_h$$

- Higgs sector determined by two parameters at tree-level

$$M_A,\ \tan\beta = \frac{v_u}{v_d}$$

- Other Higgs masses can be *predicted*:

$$M_h^2 = M_{h,\mathrm{tree}}^2(M_A, \tan\beta)$$

$$M_{h,\mathrm{tree}}^2 \leq M_Z^2 \cos^2 2\beta$$

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- Other Higgs masses can be *predicted*:

$$M_h^2 = M_{h,\mathrm{tree}}^2(M_A, \tan\beta) + \Delta M_h^2\left(M_{\mathrm{SUSY}}, A_i, M_i, \ldots\right)$$

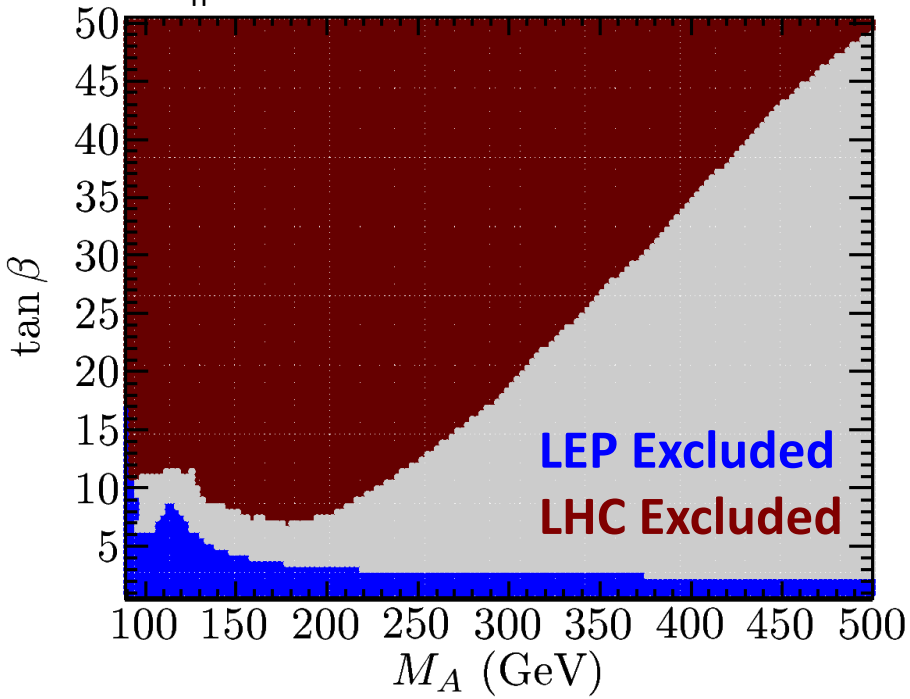
$$M_{h,\mathrm{tree}}^2 \leq M_Z^2 \cos^2 2\beta$$

MSSM exclusion limits

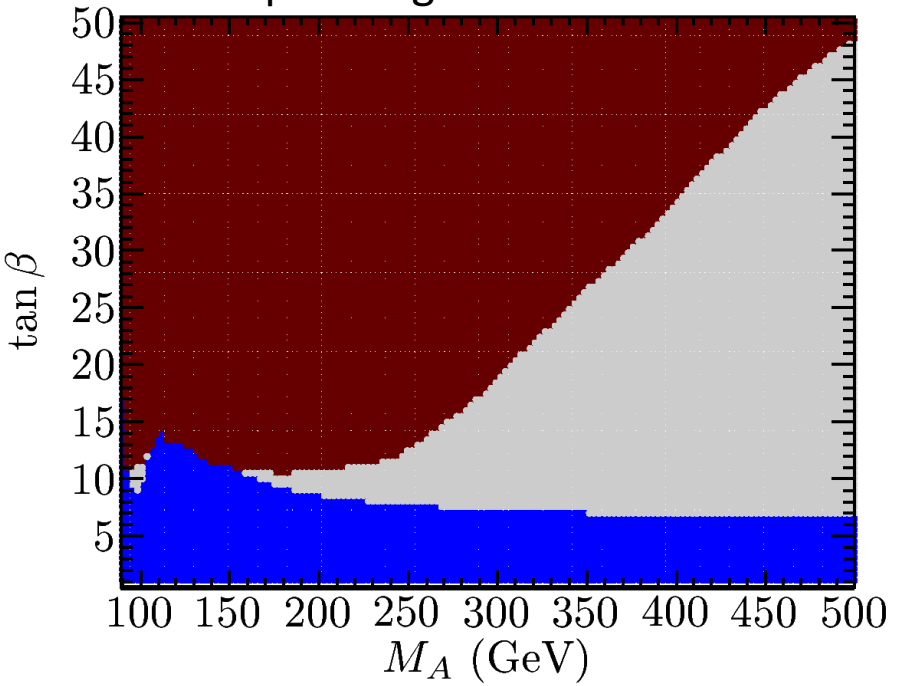
- In addition to the Dec. 13 results for a light SM-like h, include other searches for heavy MSSM Higgs, e.g. $H/A \to \tau\tau$

- Combined limits at 95% CL
  (no theory uncertainties on Higgs masses)

M_h-max scenario

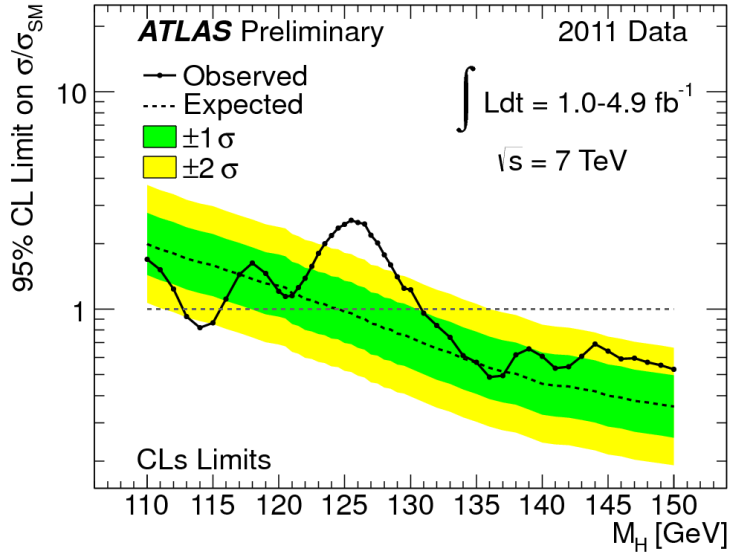


No stop mixing scenario



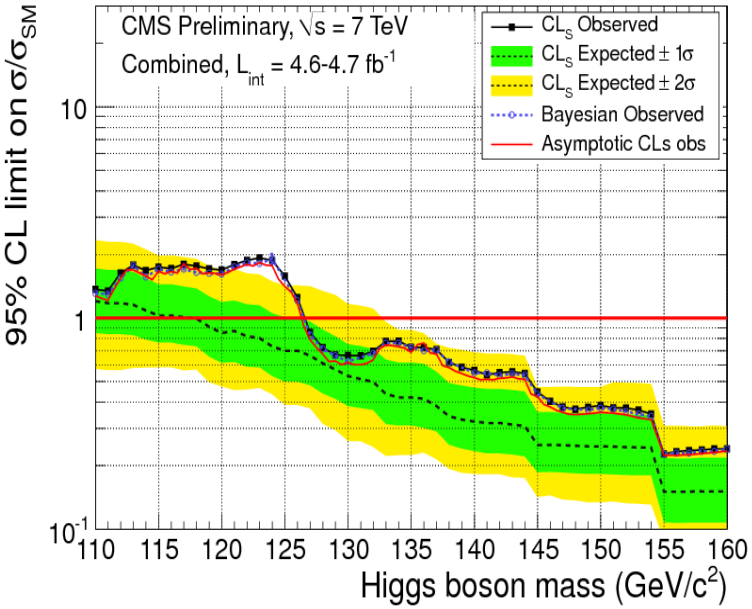
HiggsBounds: http://www.ippp.dur.ac.uk/HiggsBounds

First hint of a Higgs signal?



ATLAS

Largest excess seen at M_H = 126 GeV
Significance: 3.6 σ local, 2.5 σ including LEE



CMS

Largest excess seen at M_H = 124 GeV
Significance: 2.6 σ local, 1.9 σ including LEE

First hint of a Higgs signal?

Since Dec. 13 many papers have appeared on this topic

[1112.2703], [1112.3017], [1112.3026], [1112.3028], [1112.3032], [1112.3336], [1112.3564], [1112.3645], [1112.3647], [1112.3548], [1112.4146], [1112.4391], [1112.4835], [1112.5099], [1112.5180], [1112.5666], [1201.2611], [1201.2671], [1201.2898], [1201.4338], [1201.5305], [1202.0054] …

Interpretations done in the framework of SM, pMSSM, cMSSM, NUHM, GMSB, AMSB, NMSSM, BMSSM, UMSSM, 2HDM, RS Radions,
(insert your favorite model here)

-> No time for a review. Not even of the MSSM results.

MSSM interpretation of M_h = 125 GeV

Based on S. Heinemeyer, OS, G. Weiglein [1112.3026]

- We *assume* a Higgs boson is present in LHC data

  Experimental result: $M_h = 125 \pm 1\,\mathrm{GeV}$

- MSSM Higgs spectrum is calculated with FeynHiggs.
  Theory uncertainty on M_h evaluation (from missing higher orders) of 2 GeV added linearly

$$122\,\mathrm{GeV} < M_h < 128\,\mathrm{GeV}$$

- SM top mass (1 σ interval) taken as parametric uncertainty

$$m_t = 173.2 \pm 0.9\,\mathrm{GeV}$$

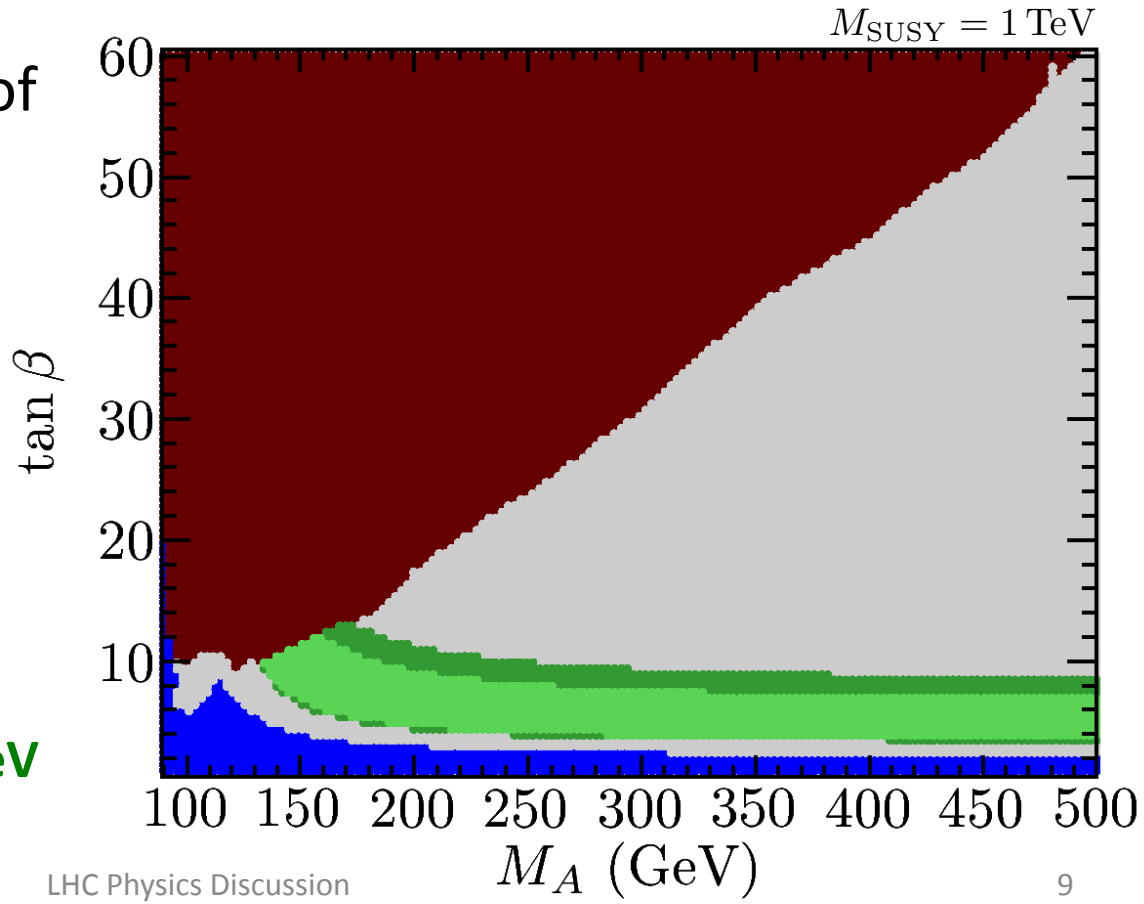
Limits on MSSM tree-level parameters

- For a given SUSY mass scale M_{SUSY}, maximize the contributions to M_h from radiative corrections. Maximal stop mixing

$$X_t = A_t - \mu \cot\beta = 2M_{\mathrm{SUSY}}$$

- M_h is increasing function of tree-level parameters M_A, tan β

-> Lower bounds can be derived



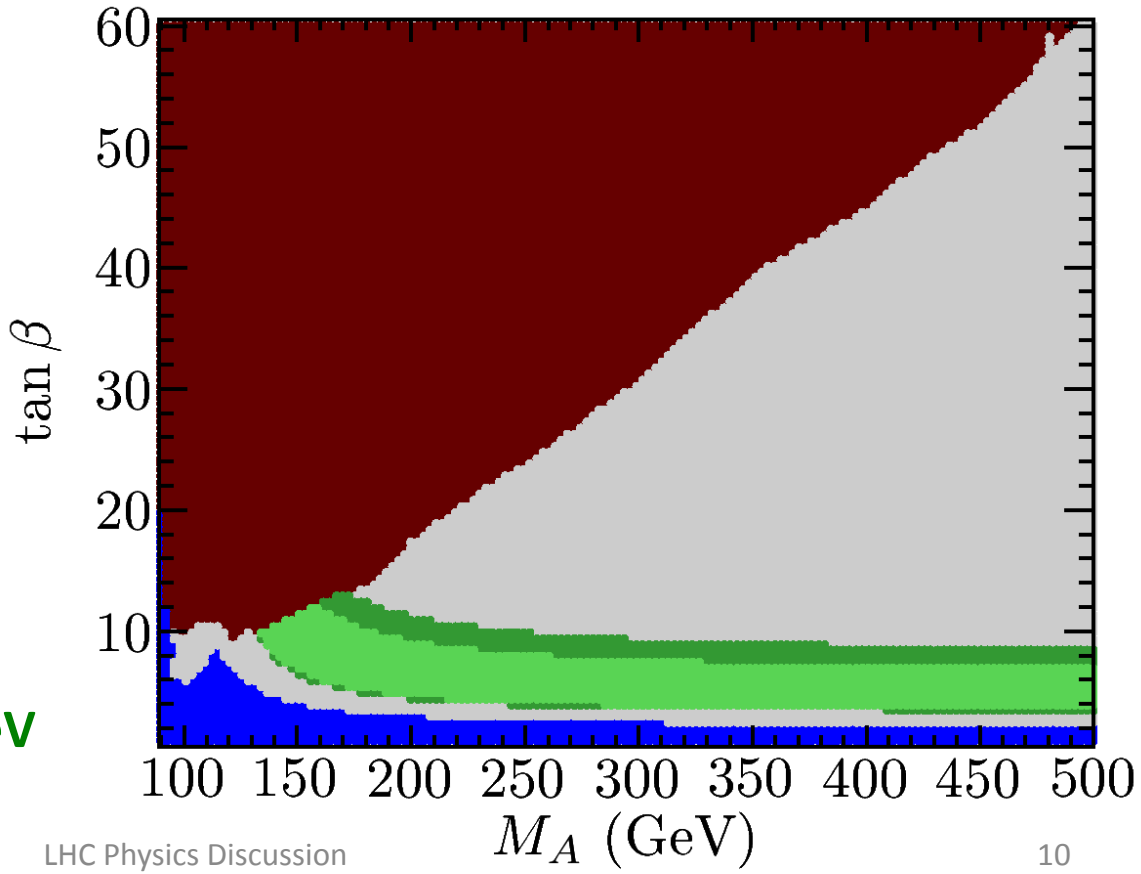
LEP Excluded

LHC Excluded

M_h = 125+-3 GeV

Limits on MSSM tree-level parameters

$M_{\rm SUSY}$ (GeV)	Limits without $M_h \sim 125$ GeV			Limits with $M_h \sim 125$ GeV		
	$\tan\beta$	M_A (GeV)	$M_{H^\pm}$ (GeV)	$\tan\beta$	M_A (GeV)	$M_{H^\pm}$ (GeV)
500	2.7	95	123	4.5	140	161
1000	2.2	95	123	3.2	133	155
2000	2.0	95	123	2.9	130	152



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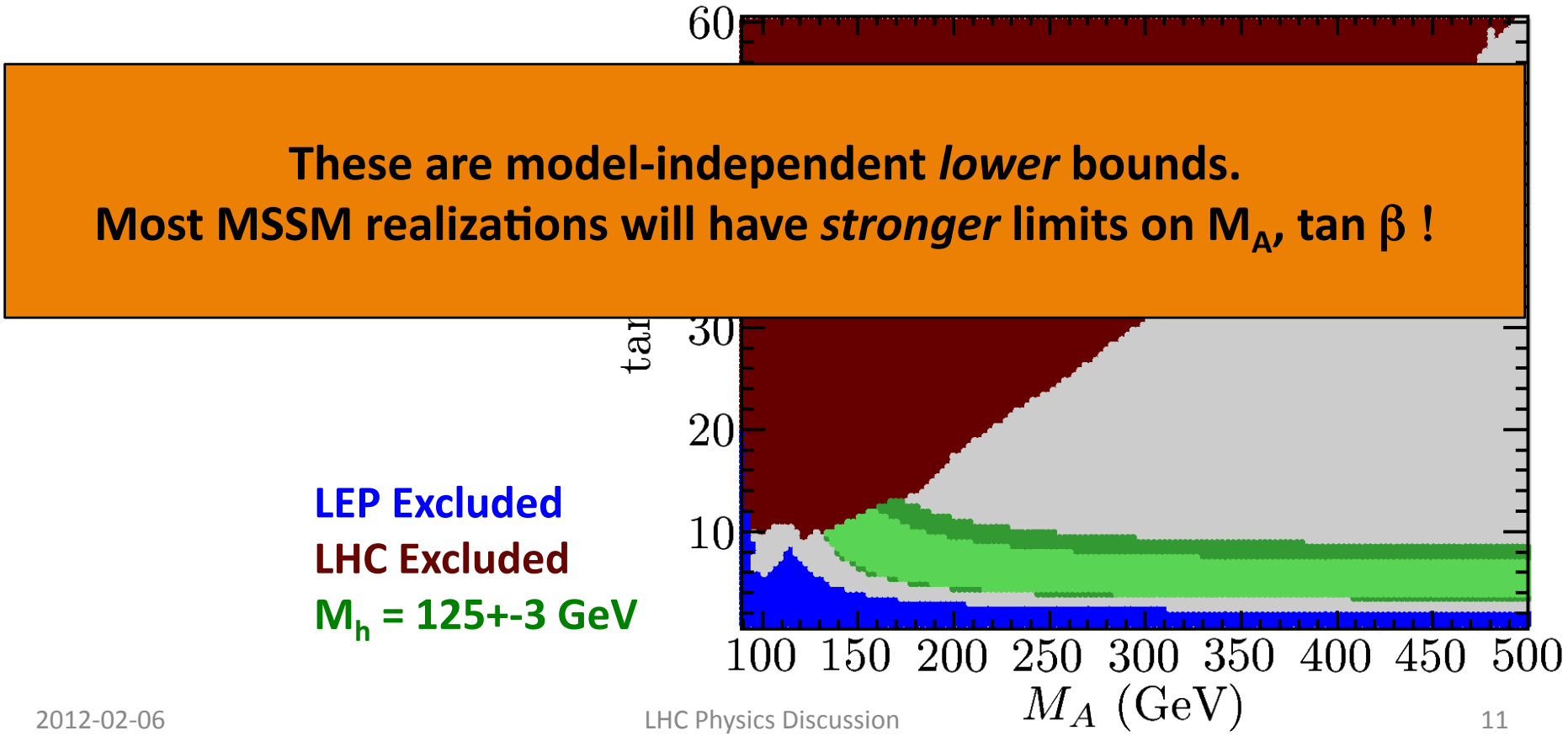
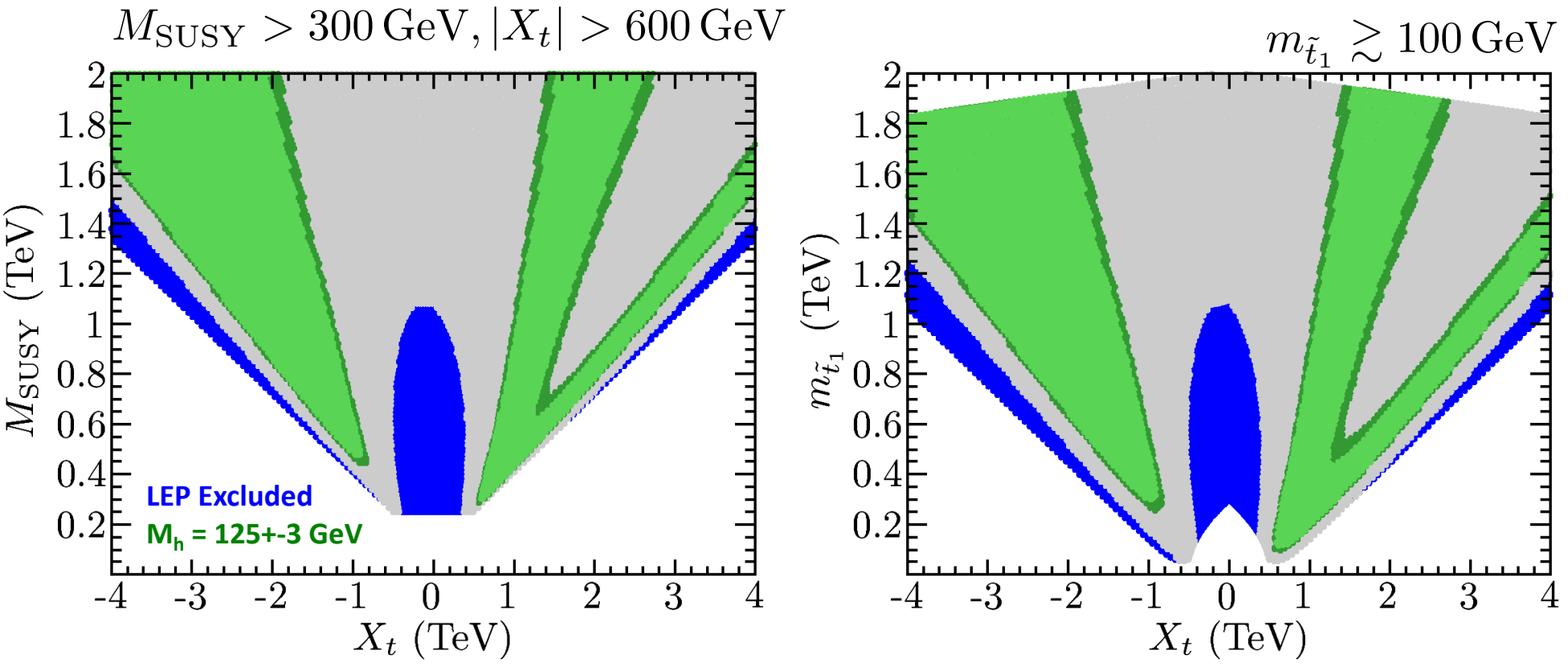
These are model-independent *lower* bounds.
Most MSSM realizations will have *stronger* limits on M_A, tan β !



Constraints on MSSM stop sector parameters

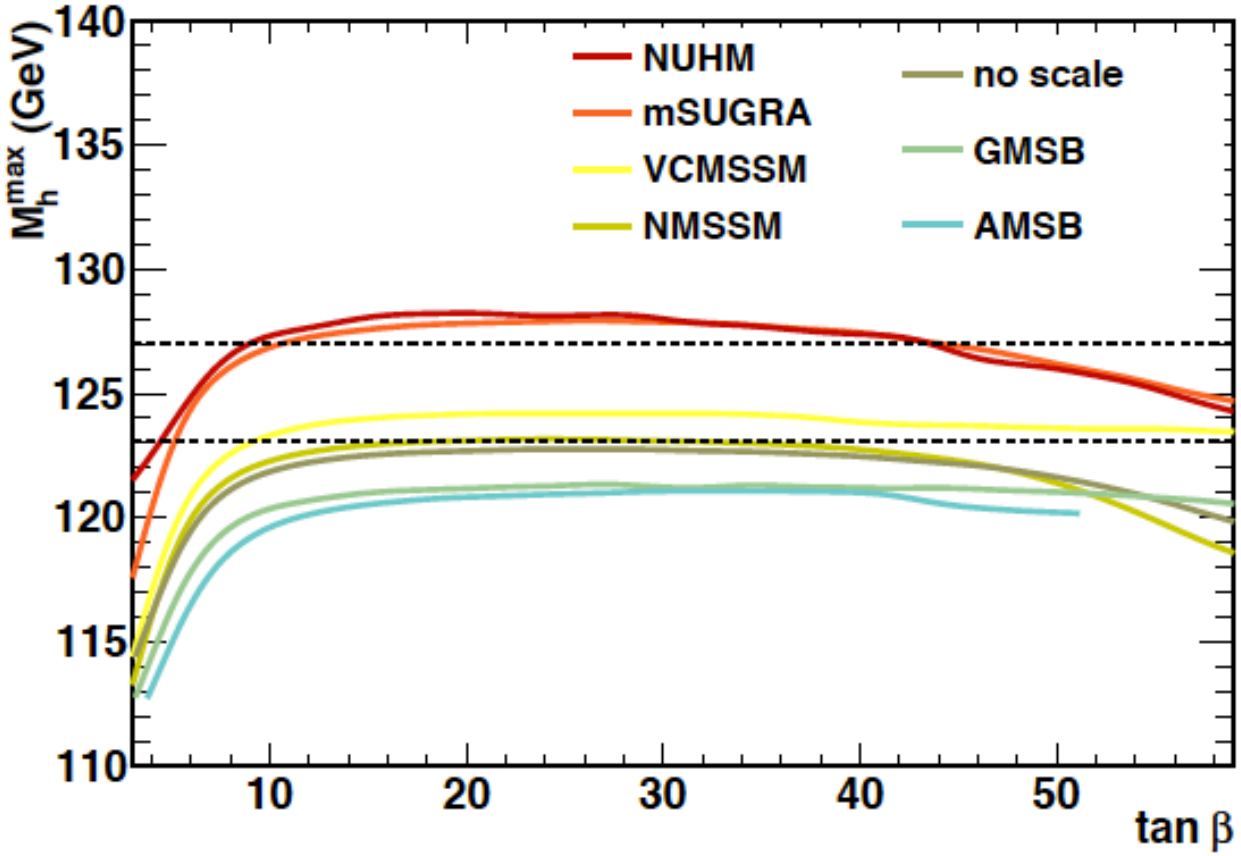
- We can also ask for a lower limit on the radiative corrections:
  $M_{h,\mathrm{tree}} \to M_Z$ (decoupling limit)

- High SUSY mass scale and/or large stop mixing required
  Can also be interpreted as a lower limit on the lightest stop mass



Constrained versions of the MSSM

- SUSY Higgs at M_h = 125 GeV in constrained scenarios



- Appears still OK with simple scenarios for gravity mediation (witgh large trilinear A_0). GMSB and ASMB under pressure.

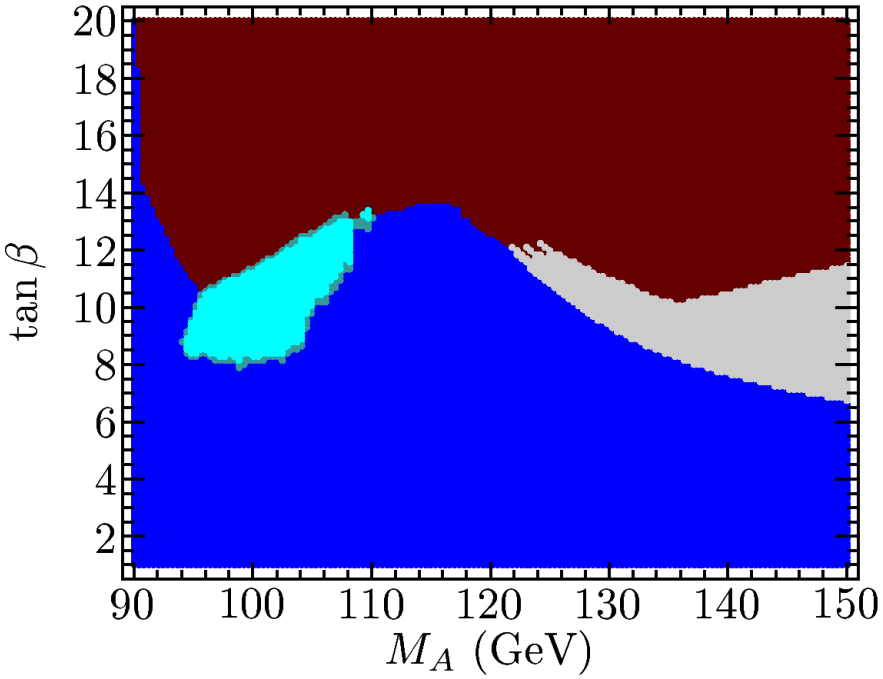
Arbey, Battaglia, Djouadi, Mahmoudi, Quevillon [1112.3028]

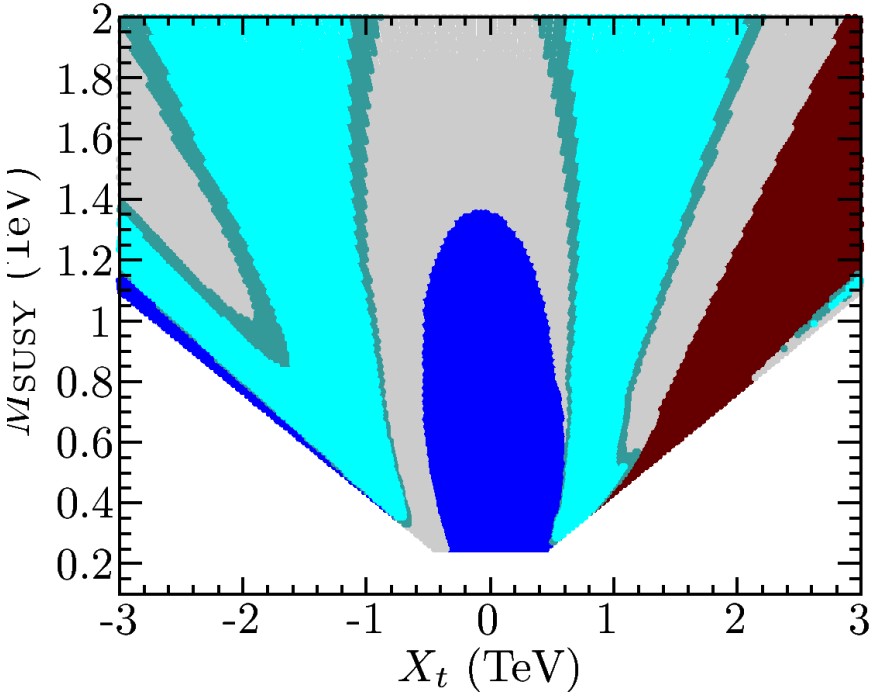
Alternative interpretation: M_H=125 GeV

- Viable to have the second lightest MSSM Higgs boson at 125 GeV? -> The answer is yes!

LEP Excluded
LHC Excluded
M_H =125+-3 GeV

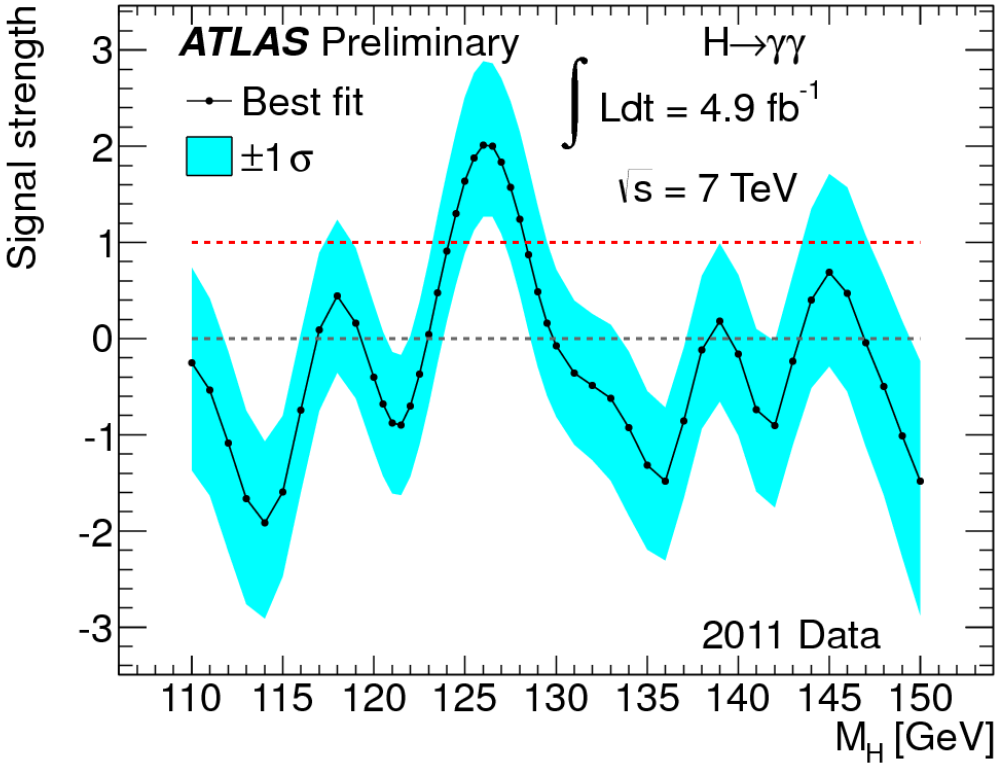
- Small corner of (M_A, tan β) where this is possible

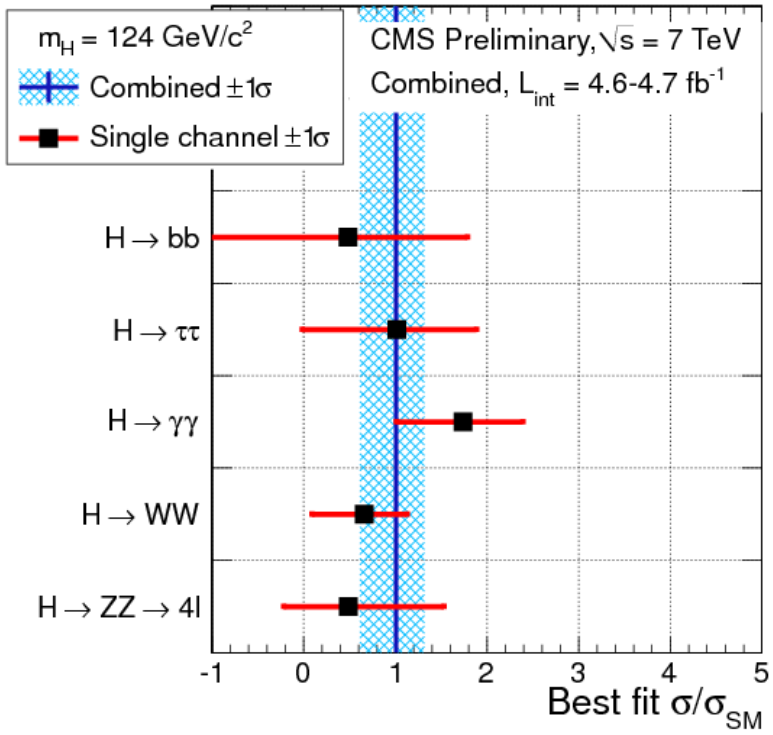




- In these scenarios the lightest Higgs is always below the LEP limit (with reduced couplings). ->LHC limits for lower M_H interesting

Including rate information





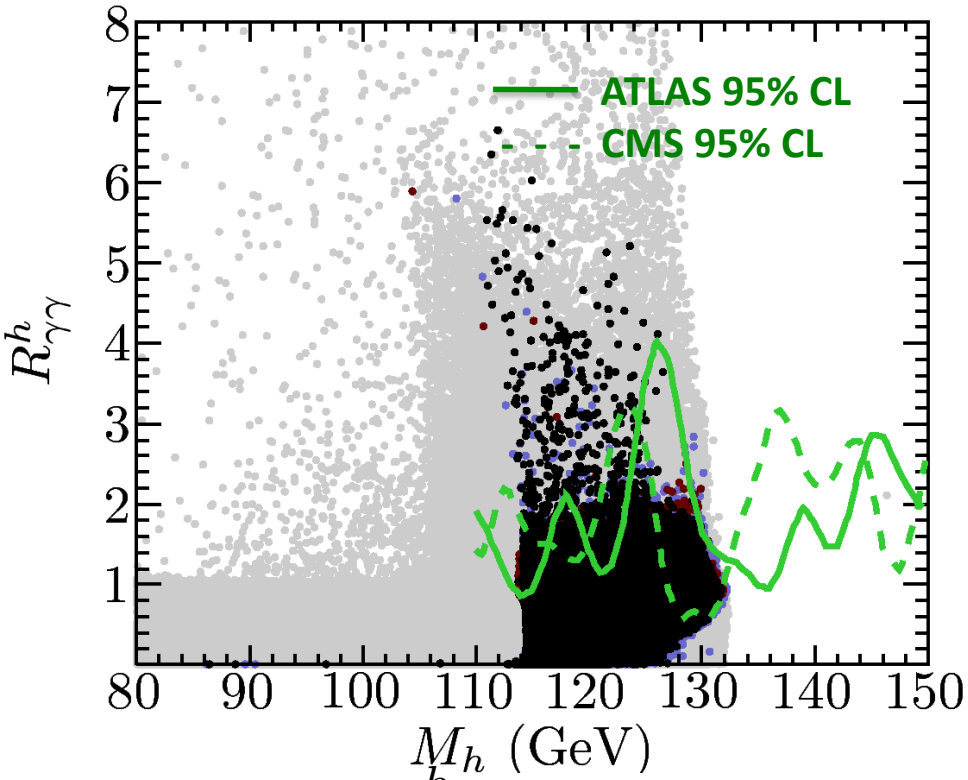
- Best fit signal strength is compatible with the SM, with room for an enhanced γγ rate

$$R_{\gamma\gamma}^{h_i} = \frac{\sigma(pp \to h_i) \times \mathrm{BR}(h_i \to \gamma\gamma)}{\sigma(pp \to h_i)_{\mathrm{SM}} \times \mathrm{BR}(h_i \to \gamma\gamma)_{\mathrm{SM}}} \gtrsim 1$$

MSSM scenarios with SM rates

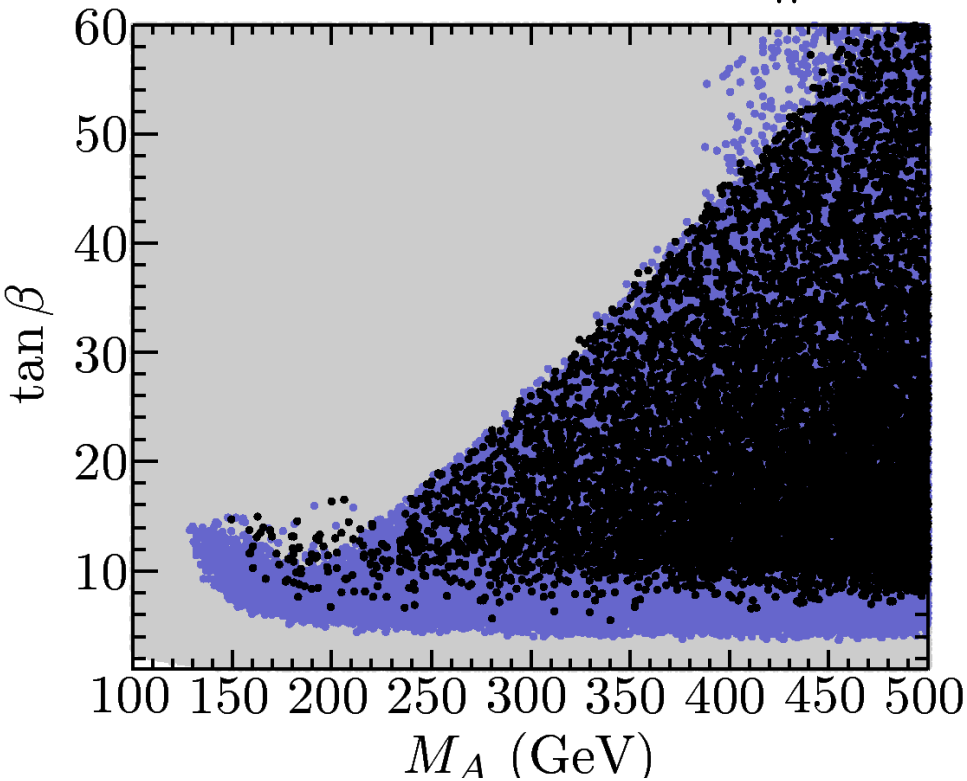
- Scan over (low-energy) MSSM parameters

Points fulfilling collider, g-2 and b->s γ constraints



All allowed points

$R_{\gamma\gamma}$ > 1



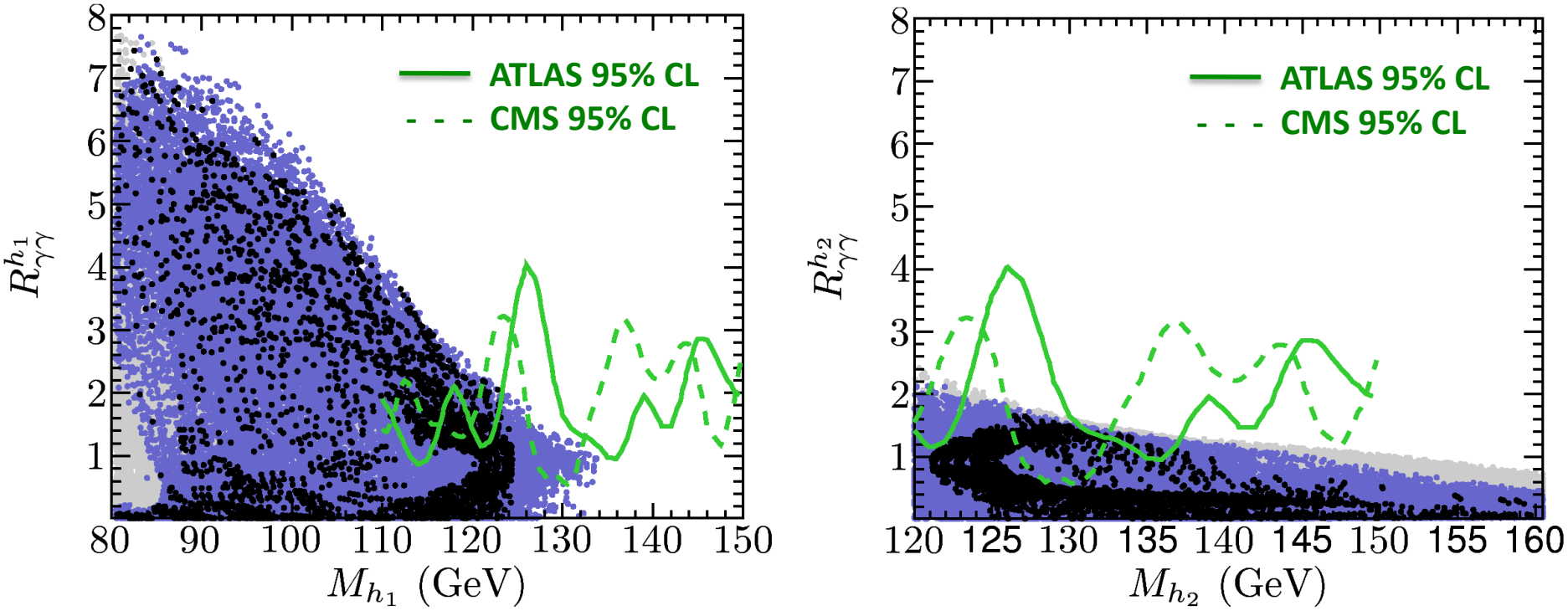
- Enhanced $R^h_{\gamma\gamma}$ from suppression of $h \to bb$ (by Higgs mixing) and increased $\mathrm{BR}(h \to \gamma\gamma)$ from light $\tilde{\tau}$ contributions [1112.3336]

Beyond the minimal model: the NMSSM

R. Benrik, S. Heinemeyer, M. Gomez, OS, G. Weiglein, L. Zeune (in preparation)
See also [1112.3548], [1201.2671]

$$m_h^2 = m_Z^2 \cos 2\beta + \lambda^2 v^2 \sin 2\beta + \Delta m_h^2 \qquad W_{(2)} = \lambda \hat{S} \hat{H}_u \cdot \hat{H}_d$$

- Suppression of $h_1 \to b\bar{b}$ by singlet mixing enhances $\gamma\gamma$



Conclusions

- LHC Higgs search results are starting to become really interesting as a probe of physics beyond the Standard Model.
  A large part of the MSSM (m_A, tan β) plane is already excluded

- Two possible MSSM interpretations of a 125 GeV excess:
  M_h = 125 GeV -> Lower limits on parameters
  M_H = 125 GeV -> Small parameter space still viable

- Constrained models (GMSB, AMSB) in trouble.

- M_h = 125 GeV with SM $\gamma\gamma$ rate can be fitted for allowed (M_A, tan β)

- NMSSM: M_{h1}/M_{h2} = 125 GeV with smaller need for radiative contributions than in MSSM. Additional mechanism for $R_{\gamma\gamma} > 1$ through singlet-doublet mixing.