Implications of LHC Higgs and SUSY searches for MSSM

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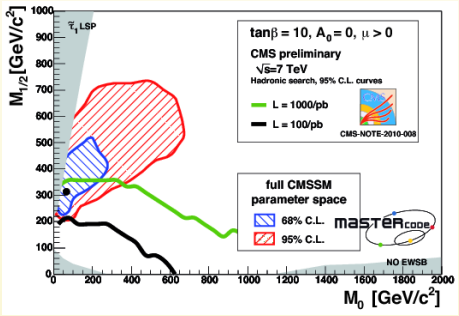
In collaboration with A. Arbey, M. Battaglia & A. Djouadi

SUSY searches

Search for SUSY is the main focus of BSM searches in both ATLAS and CMS!

Before the start of the LHC: high expectation for an early discovery of SUSY particles:



SUSY could be discovered even before the Higgs!

O. Buchmueller et al., JHEP 0809 (2008) 117

It appears not to be the case:

So far we have only limits which are pushing the masses to higher and higher values

Not enough to confirm/exclude SUSY

BUT:

- Supersymmetry is more than just the CMSSM!
- An alternative path to constrain SUSY efficiently is through the Higgs sector!

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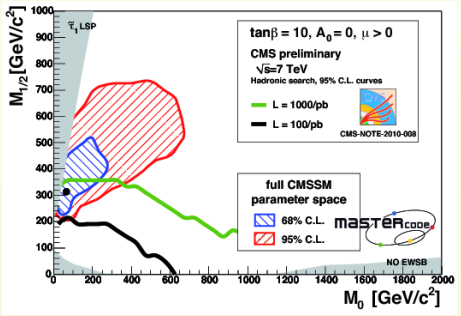

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phenomenological MSSM (pMSSM)

A nice framework to go beyond CMSSM is the phenomenological MSSM:
The most general CP/R parity-conserving MSSM, assuming Minimal Flavour Violation at the TeV scale and suppresed FCNC's at tree level, with 19 free parameters:
10 sfermion masses, 3 gaugino masses, 3 trilinear couplings, 3 Higgs/Higgsino

A. Djouadi et al., hep-ph/9901246

Flat scans over the pMSSM 19 parameters

Parameter	Range (in GeV)
$\tan\beta$	[1, 60]
M_A	[50, 2000]
M_1	[-2500, 2500]
M_2	[-2500, 2500]
M_3	[50, 2500]
$A_d = A_s = A_b$	[-10000, 10000]
$A_u = A_c = A_t$	[-10000, 10000]
$A_e = A_\mu = A_\tau$	[-10000, 10000]
μ	[-3000, 3000]
$M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$	[50, 3000]
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- Spectrum generation (SoftSusy, Suspect)
- Low energy observables (**SuperIso**)
- Dark matter (**SuperIso Relic**, Micromegas)
- SUSY and Higgs mass limits (SuperIso, HiggsBounds)
- Higgs and SUSY decays (HDECAY, Higlu, FeynHiggs, SDECAY)
- Event generation and cross sections (PYTHIA, Prospino)
- Fast detector simulation (Delphes)

Imposing constraints from:
Flavour physics (BR($B \to X_s\gamma$), BR($B_s \to \mu^+\mu^-$), R($B \to \tau\nu$), BR($D_s \to \tau\nu$), BR($B \to D^0\tau\nu$), $R_{\mu 23}(K \to \mu\nu)$), dark matter relic density, sparticle mass upper bounds and Higgs search limits.

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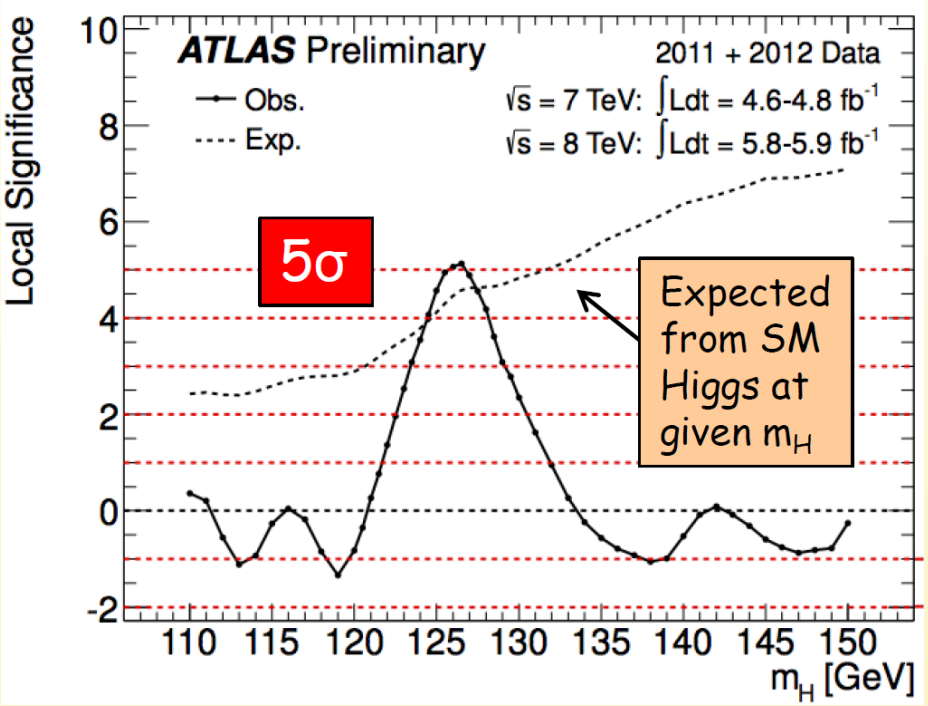
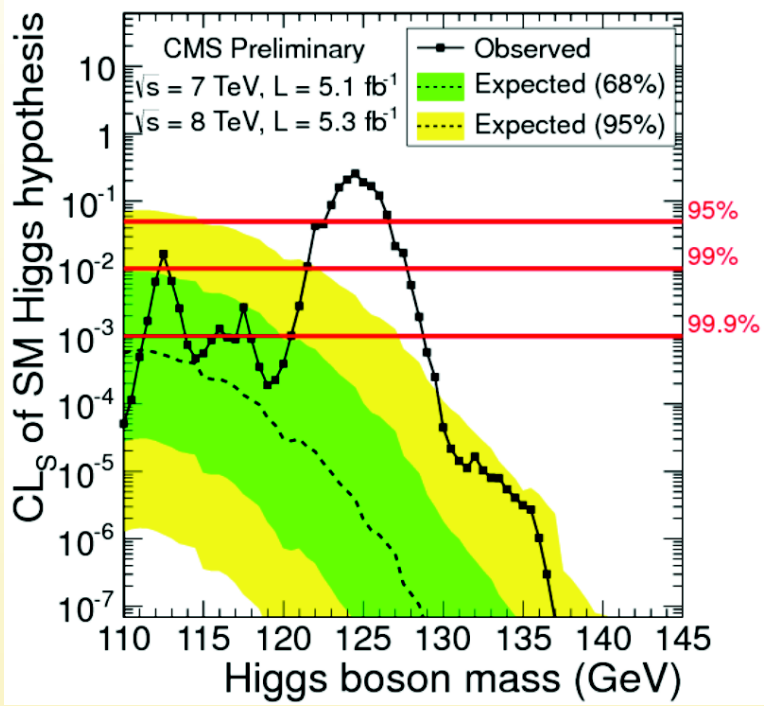
Higgs searches

Both ATLAS and CMS have confirmed the excess at $\sim$ 126 GeV!





Combining ATLAS and CMS results: $M_h = 125.9 \pm 2.1$ **GeV**

We consider the interval $123 < M_h < 129$ **GeV**

Higgs searches

- In the SM, the Higgs mass is essentially a free parameter
- In the MSSM, the lightest CP-even Higgs particle is bounded from above:
  $M_h^{max} \approx M_Z |\cos 2\beta| +$ radiative corrections $\lesssim 110 - 135$ GeV
- Imposing M_h places very strong constraints on the MSSM parameters through their contributions to the radiative corrections

$$M_h^2 \overset{M_A \gg M_Z}{\approx} M_Z^2 \cos^2 2\beta + \frac{3m_t^4}{2\pi^2 v^2}\left[\log\frac{M_S^2}{m_t^2} + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right]$$

- Important parameters for MSSM Higgs mass:
  - $\tan\beta$ and M_A
  - the SUSY breaking scale $M_S = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$
  - the mixing parameter in the stop sector $X_t = A_t - \mu \cot\beta$
- M_h^{max} is obtained for:
  - a decoupling regime with a heavy pseudoscalar Higgs boson, $M_A \sim \mathcal{O}(\text{TeV})$
  - large $\tan\beta$, *i.e.* $\tan\beta \gtrsim 10$
  - heavy stops, *i.e.* large M_S
  - maximal mixing scenario, *i.e.* $X_t = \sqrt{6} M_S$

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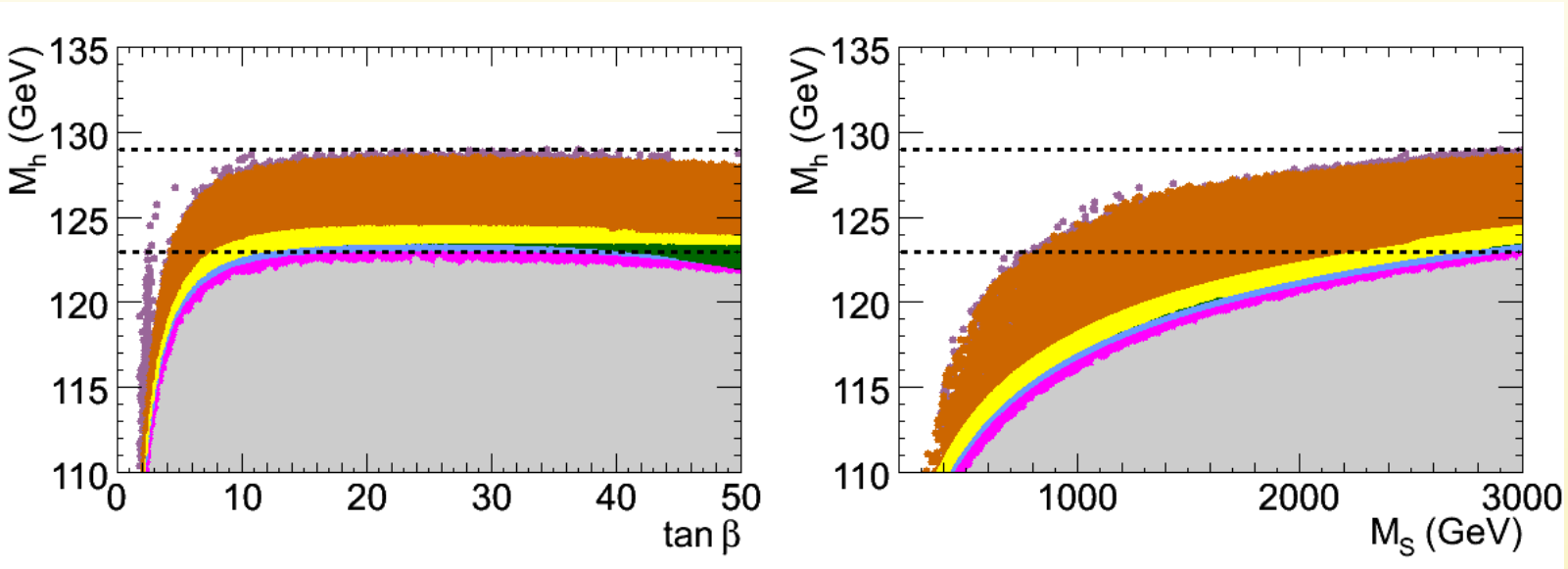
Consequences of a 126 GeV Higgs on constrained MSSM scenarios

Maximal Higgs mass

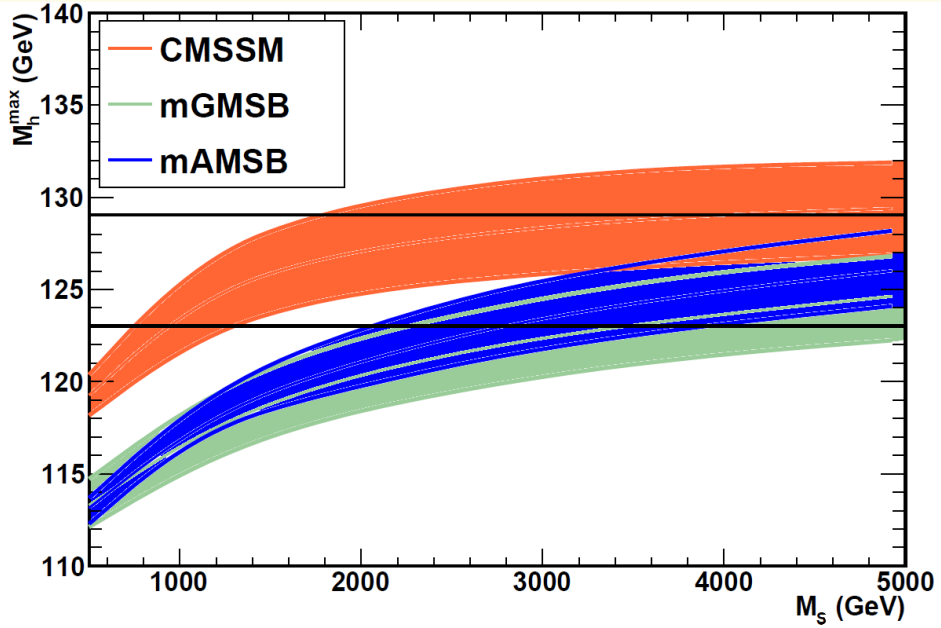


Several constrained models are excluded or about to be!

Sensivity to the top mass

Impact of m_t on the Higgs mass:

m_t =170, 173 and 176 GeV



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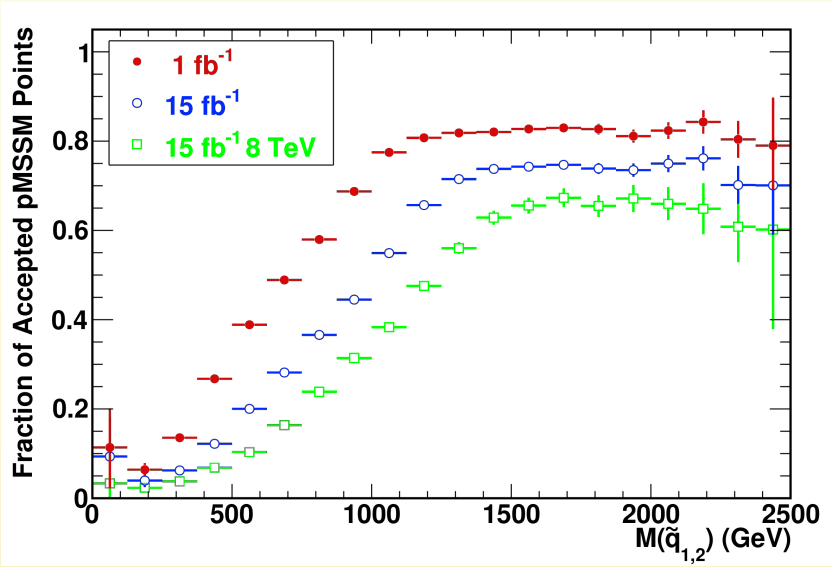
The variations in the top mass is directly transmitted to the Higgs mass!

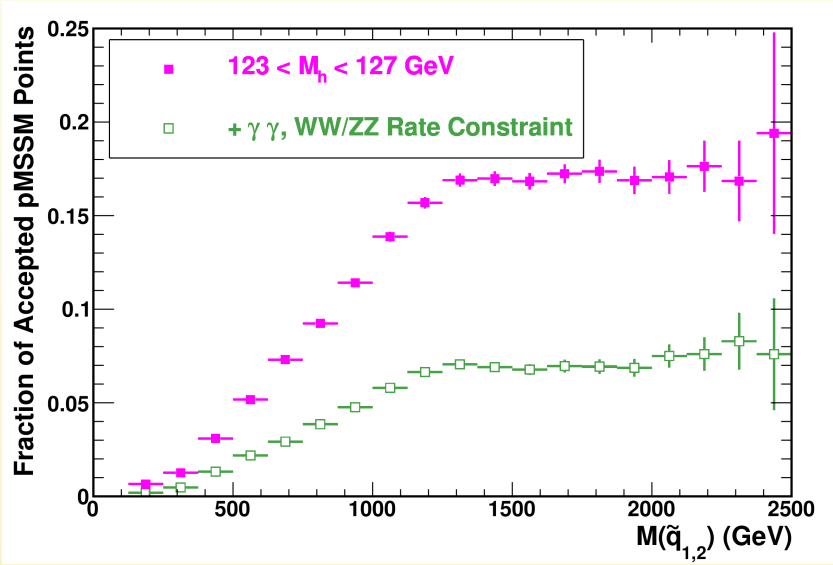
That can even resurrect mGMSB!

Consequences of a 126 GeV Higgs on pMSSM

Influence on squark spectra



With $M_h > 111$ GeV



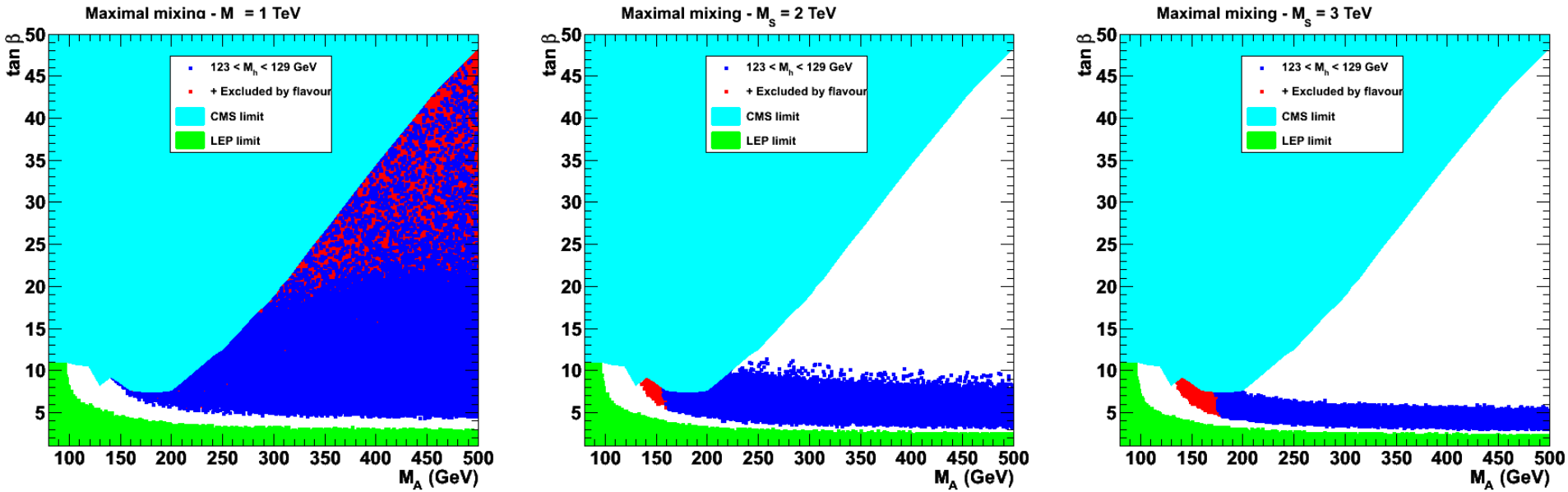
With $123 < M_h < 127$ GeV

A. Arbey, M. Battaglia, F.M., Eur.Phys.J. C72 (2012) 1847
A. Arbey, M. Battaglia, F.M., Eur.Phys.J. C72 (2012) 1906

Consequences of a 126 GeV Higgs

Particular benchmark scenarios

In the **maximal mixing** scenario ($X_t \approx \sqrt{6} M_S$):



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Cyan: CMS limit from $A^0 \to \tau\tau$ with 4.6/fb

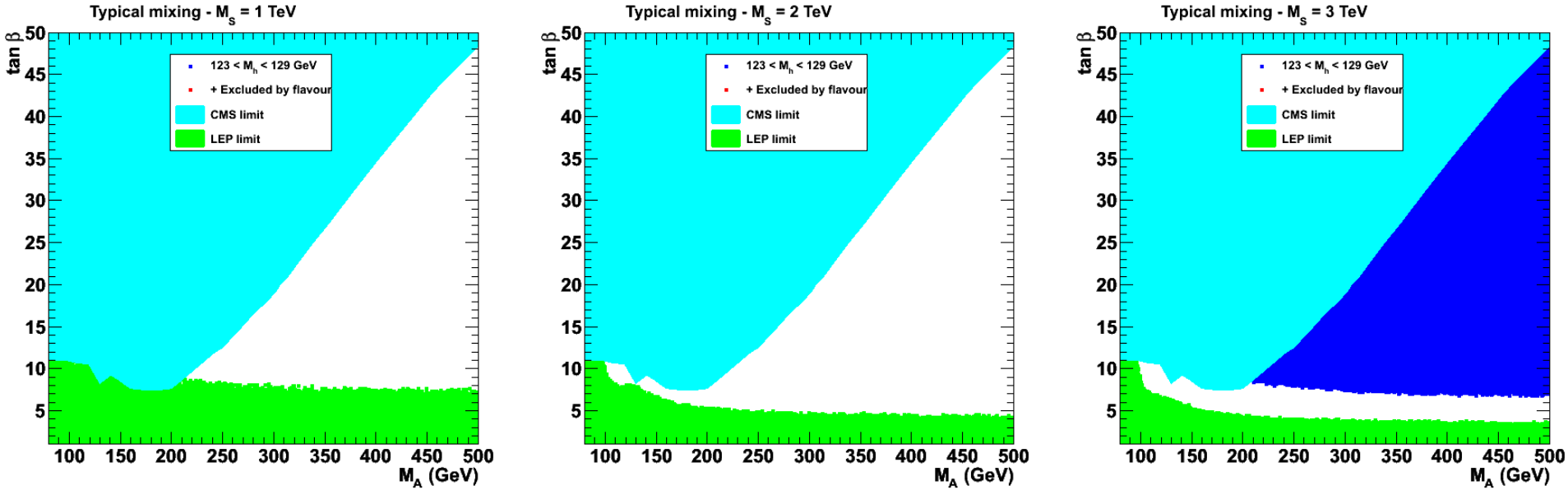
Red: flavour constraints: $b \to s\gamma$, $B \to \tau\nu$ and $B_s \to \mu\mu$

Very strong constraint from the neutral Higgs searches!

Consequences of a 126 GeV Higgs

Particular benchmark scenarios

In the **typical mixing** scenario ($X_t \approx M_S$):



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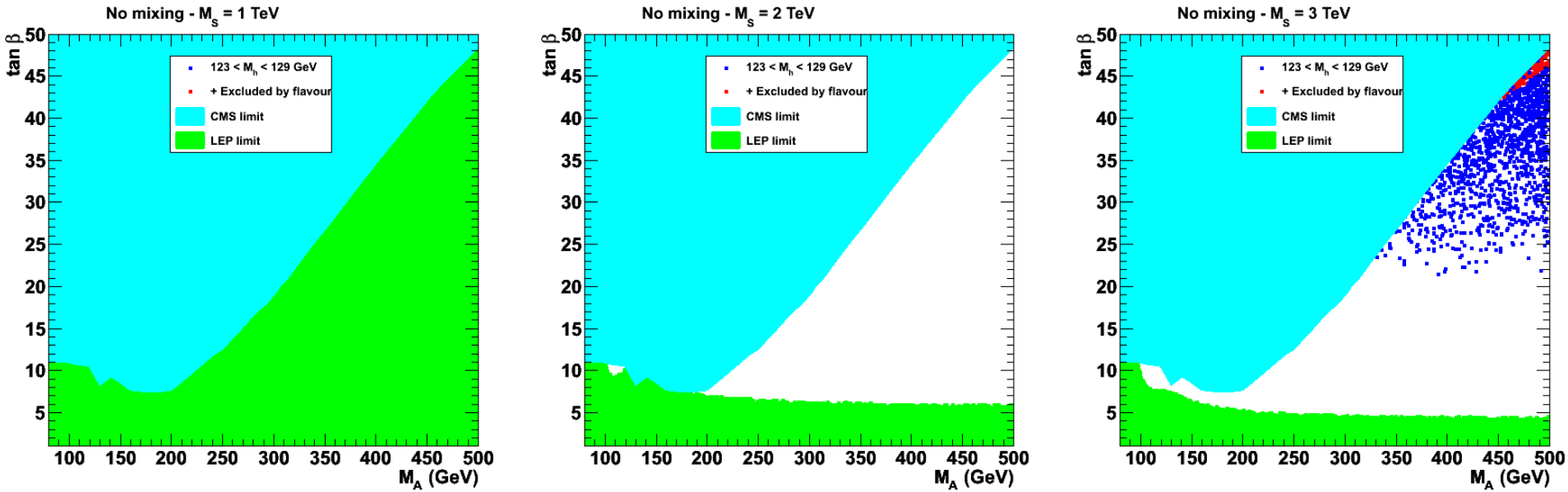
Particular benchmark scenarios

In the **no mixing** scenario ($X_t \approx 0$):



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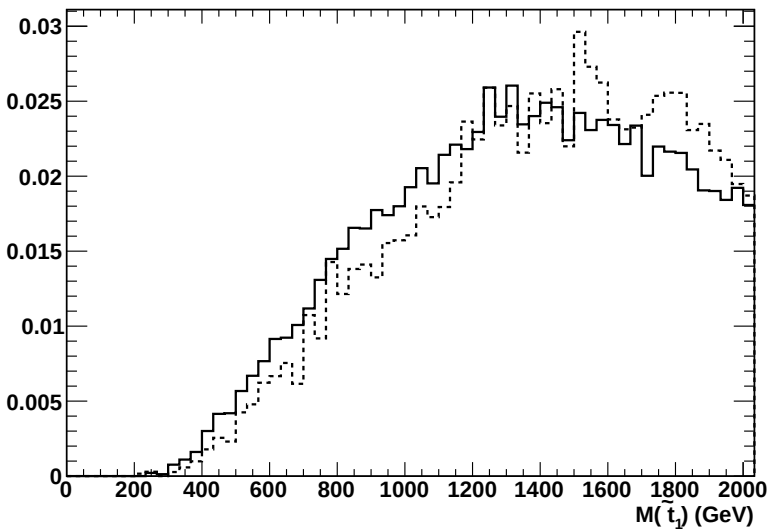
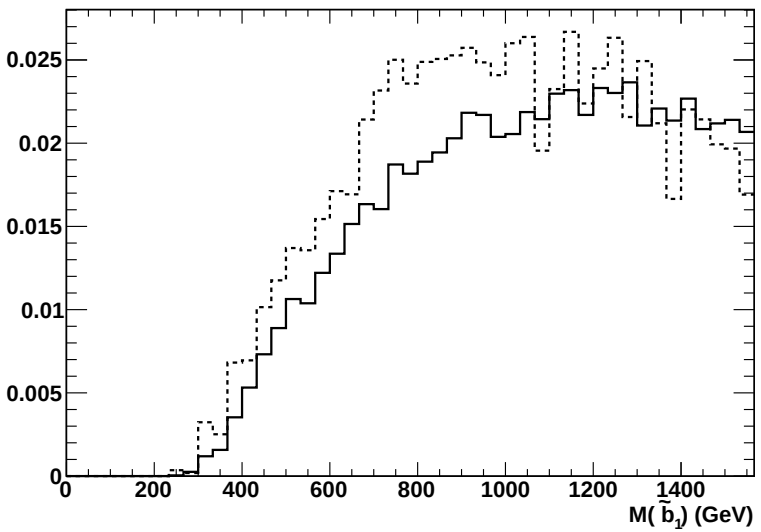
Consequences of a 126 GeV Higgs on pMSSM

Favoured region: χ^2 analysis and normalized distributions





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Solid lines: accepted pMSSM points with $123 < M_{h} < 129$ GeV

Dashed lines: points favoured at 90% C.L. by M_{h}, BR($h^0 \to \gamma\gamma$), BR($h^0 \to ZZ$) and BR($h^0 \to b\bar{b}$)

$R_{\gamma\gamma} = 1.71 \pm 0.33$, $R_{ZZ} = 0.95 \pm 0.40$ (ATLAS+CMS), $R_{b\bar{b}} = 1.06 \pm 0.50$ (CMS+Tevatron)

$\to$ Heavy stops and light sbottoms favoured by the new results!

Conclusion

- Impressive impact of the Higgs searches on SUSY scenarios
- Complementary to the direct SUSY searches
- Several constrained MSSM scenarios are about to be ruled out by the Higgs discovery
- It is now mandatory to go beyond CMSSM
- There is still plenty of room in general MSSM

Imagine what we can get by the end of the year with 3 times more data!

Backup

Backup

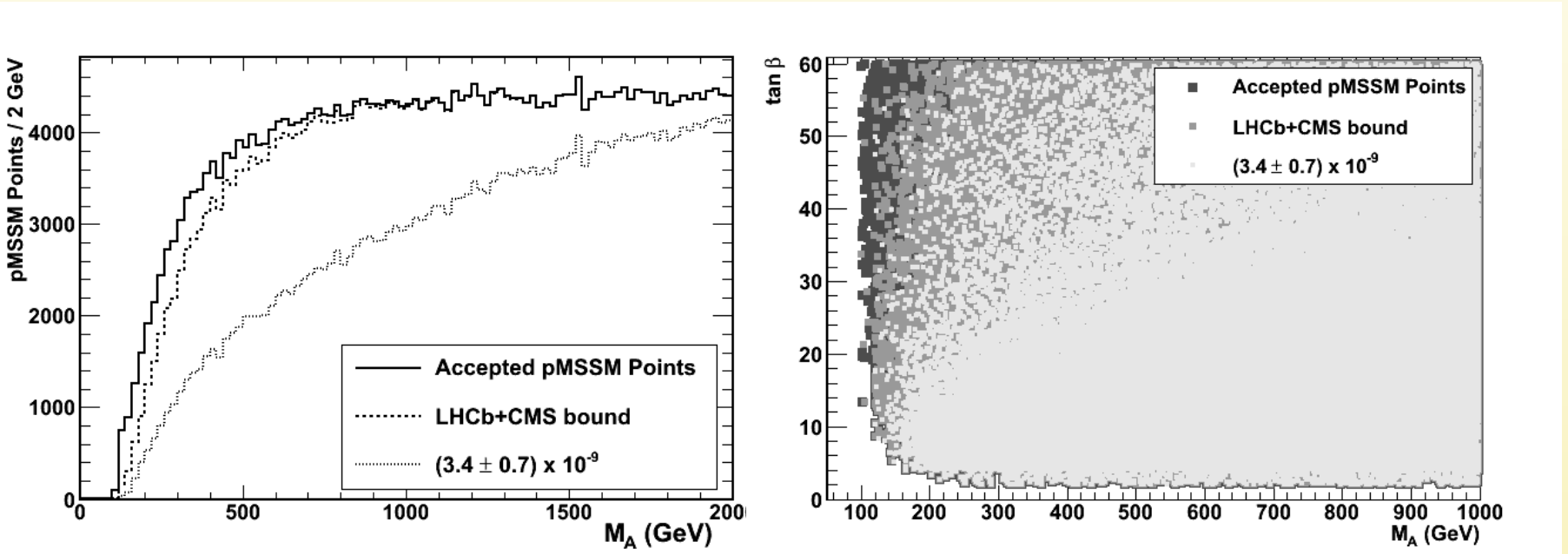
Sensitivity to M_A from BR($B_s \to \mu^+\mu^-$)

Considering 2 scenarios:

- Current bound from LHCb+CMS + estimated th syst:

$$\mathrm{BR}(B_s \to \mu^+\mu^-) < 1.26 \times 10^{-8}$$

- SM like branching ratio with estimated 20% total uncertainty



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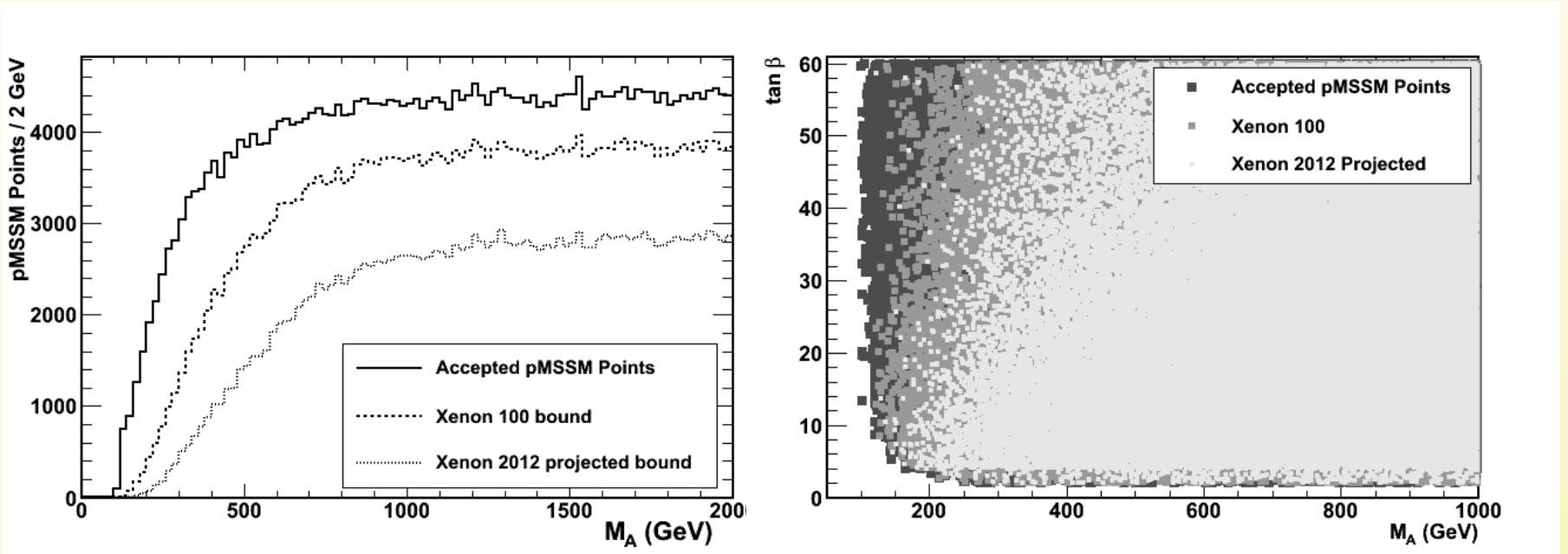
Light M_A strongly constrained!

Dark matter direct detection

Considering 2 scenarios:

- Current Xenon 100 limit
- Projected 2012 90% C.L. upper limit



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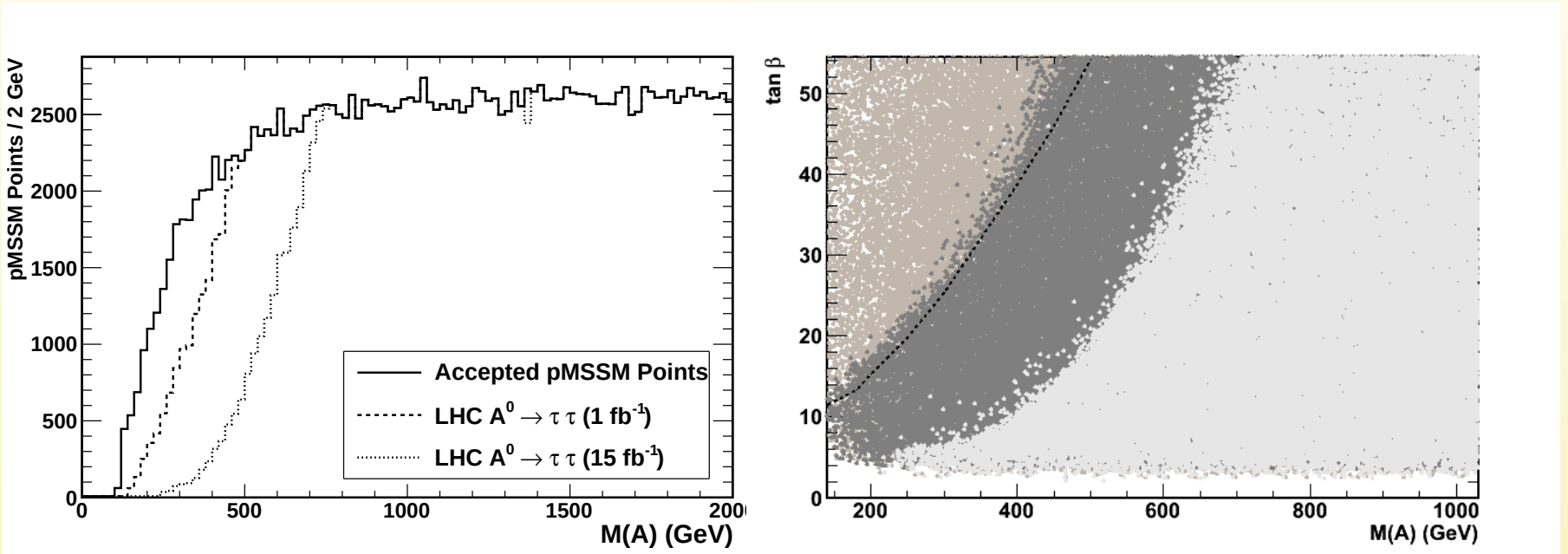
Again light M_A strongly constrained!

Higgs searches

Direct searches for $A \to \tau\tau$ CMS-PAS-HIG-11-009

Allowed region of $(M_A, \tan\beta)$ from full pMSSM scans for 1.1 and 15 fb^{-1} compared to published CMS expected limit



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Low M_A region below 350 GeV can be explored and excluded if no signal except a narrow strip around $\tan\beta$ =5.