SUSY and a 125 GeV scalar

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SUSY searches

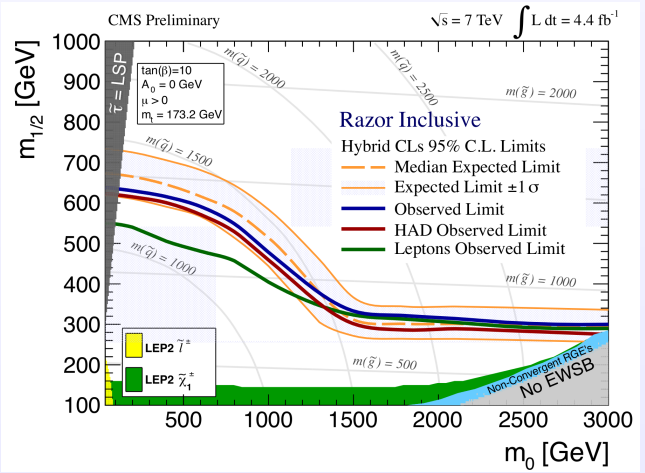
Main focus of BSM studies at the LHC!

Two categories of studies:

- Constrained SUSY scenarios: CMSSM, mSUGRA, AMSB, GMSB, CNMSSM,...
  handful number of free parameters, useful for benchmarking,...
- General SUSY scenarios: pMSSM
  much richer features, signatures and phenomenology!

Still a lot of solutions compatible with all present bounds!

→ Not possible to falsify MSSM!



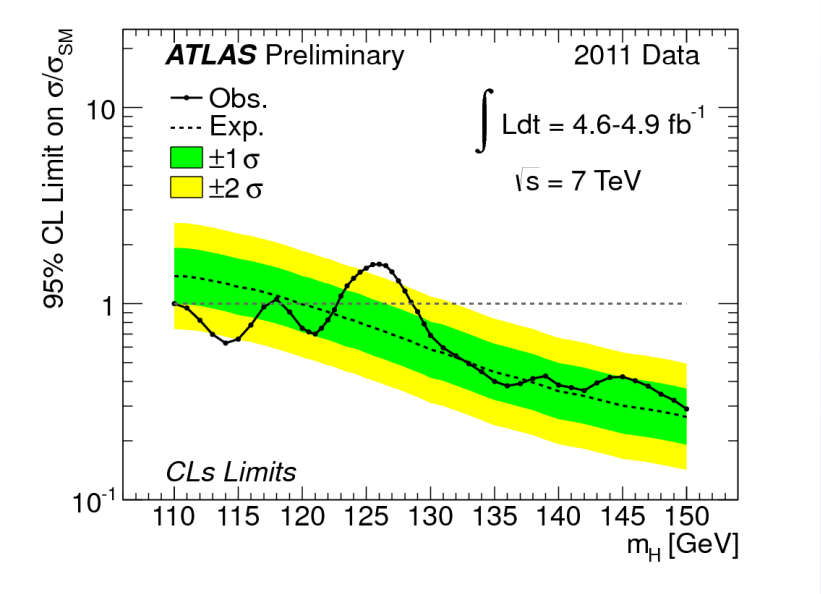
→ see talk by S. Kraml

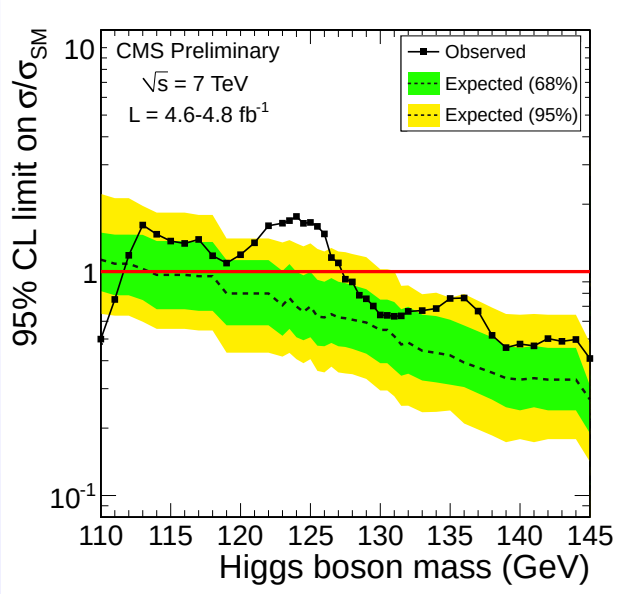
Alternative path to tightly constrain and test the MSSM at the LHC: through the Higgs sector!

Higgs ≡ Brout-Englert-Higgs scalar boson

Higgs searches

ATLAS and CMS excess around 125 GeV





ATLAS-CONF-2012-019, CMS-PAS-HIG-12-008

Excess around 125 GeV seen by both ATLAS and CMS in different channels
No evidence however...

ATLAS exclusion at 95% C.L.: 110–117.5 ; 118.5–122.5 ; 129–539 GeV
CMS exclusion at 95% C.L.: 127.5–600 GeV

Allowed range is roughly $117.5 < M_h < 118.5$ and $122.5 < M_h < 127.5$ GeV!

Consequences of a 125 GeV Higgs on constrained MSSM scenarios

If the excess will be confirmed by more data, what are the consequences?

- 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

$\rightarrow$ Calculation of M_h^{max} in different constrained scenarios

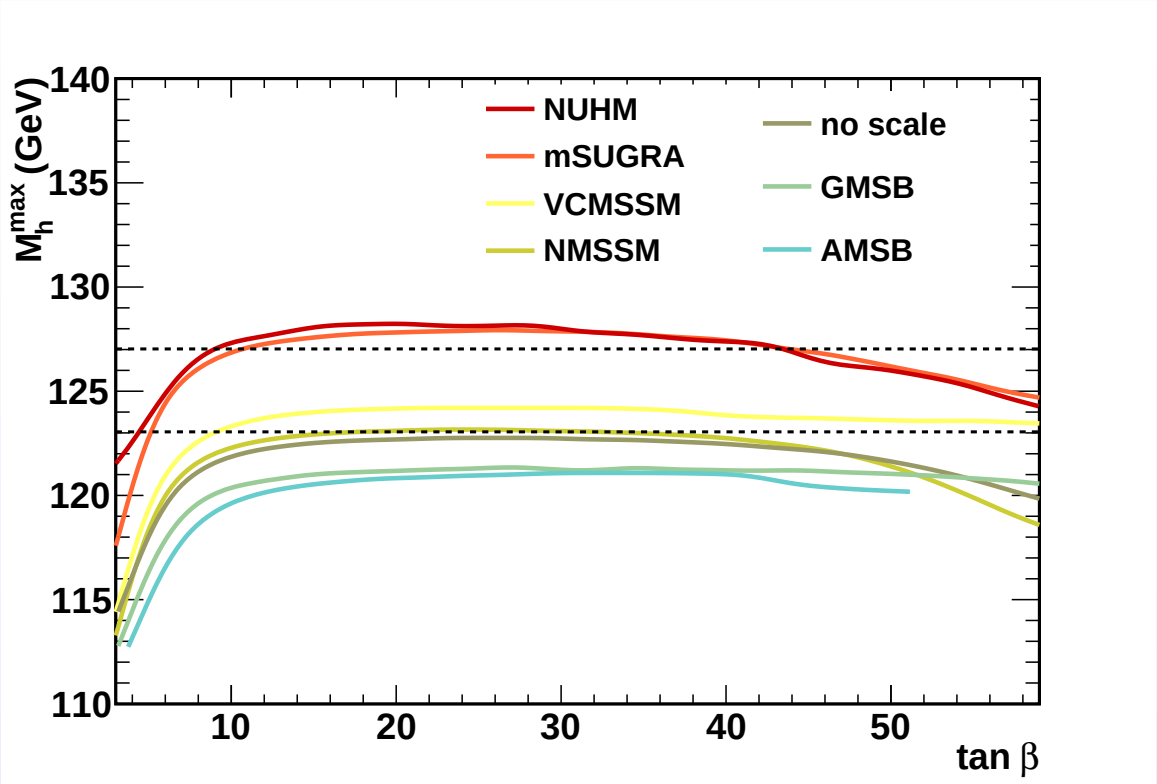
Consequences of a 125 GeV Higgs on constrained MSSM scenarios

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

- 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.* $X_t = \sqrt{6} M_S$
- In contrast, much smaller M_h^{max} values for the no-mixing scenario, *i.e.* $X_t \approx 0$.

Consequences of a 125 GeV Higgs on constrained MSSM scenarios

Maximal Higgs masses



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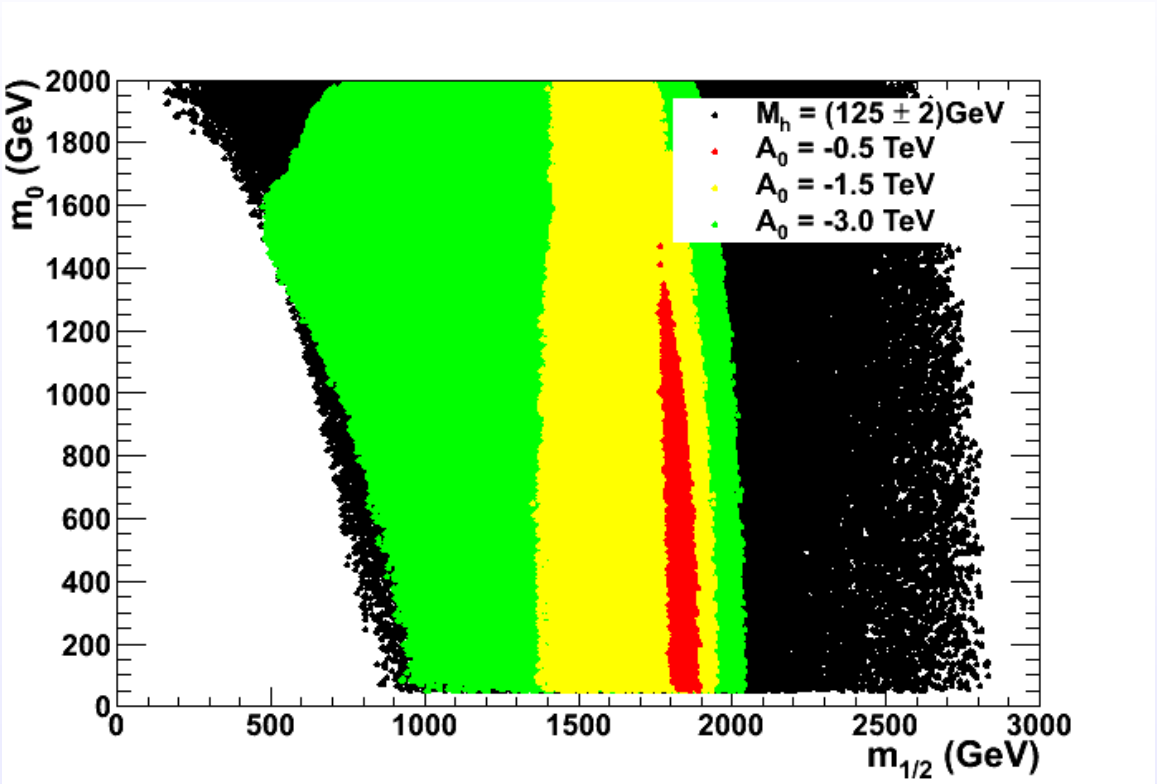
model	AMSB	GMSB	mSUGRA	no-scale	cNMSSM	VCMSSM	NUHM
$M_h^{\max}$	121.0	121.5	128.0	123.0	123.5	124.5	128.5

End of AMSB and GMSB in their minimal versions!

Consequences of a 125 GeV Higgs on constrained MSSM scenarios

Higgs mass between 123 and 127 GeV in the CMSSM



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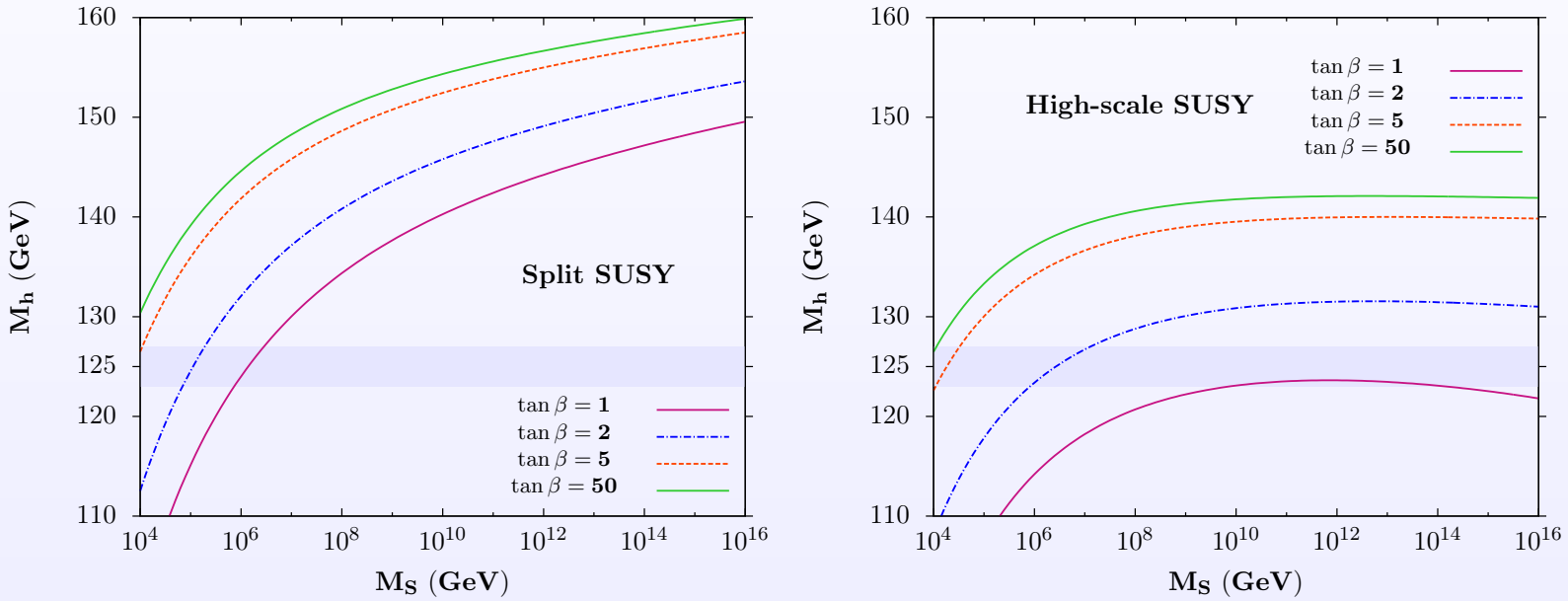
mSUGRA/CMSSM still survives, but only for negative values of A_0

Consequences of a 125 GeV Higgs on high scale SUSY scenarios



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Very strong constraints on Split-SUSY and High-scale SUSY

pMSSM

MSSM with 19 parameters, CP and R-parity conservation

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, 2500]
$M_{\tilde{e}_R} = M_{\tilde{\mu}_R}$	[50, 2500]
$M_{\tilde{\tau}_L}$	[50, 2500]
$M_{\tilde{\tau}_R}$	[50, 2500]
$M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$	[50, 2500]
$M_{\tilde{q}_{3L}}$	[50, 2500]
$M_{\tilde{u}_R} = M_{\tilde{c}_R}$	[50, 2500]
$M_{\tilde{t}_R}$	[50, 2500]
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$	[50, 2500]
$M_{\tilde{b}_R}$	[50, 2500]

40M points generated with Softsusy/Suspect

Flavour constraints with SuperIso

Dark matter constraints with SuperIso Relic and Micromegas

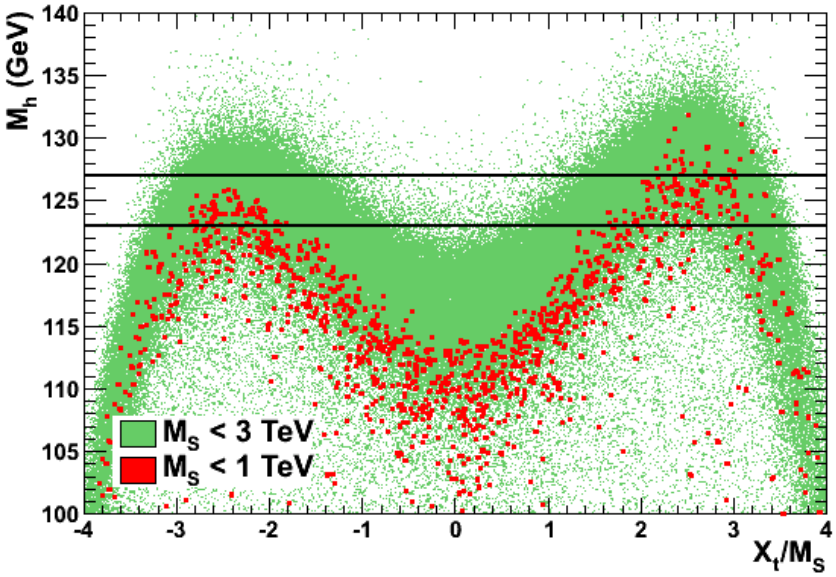
Higgs sector with HDECAY and HIGLU

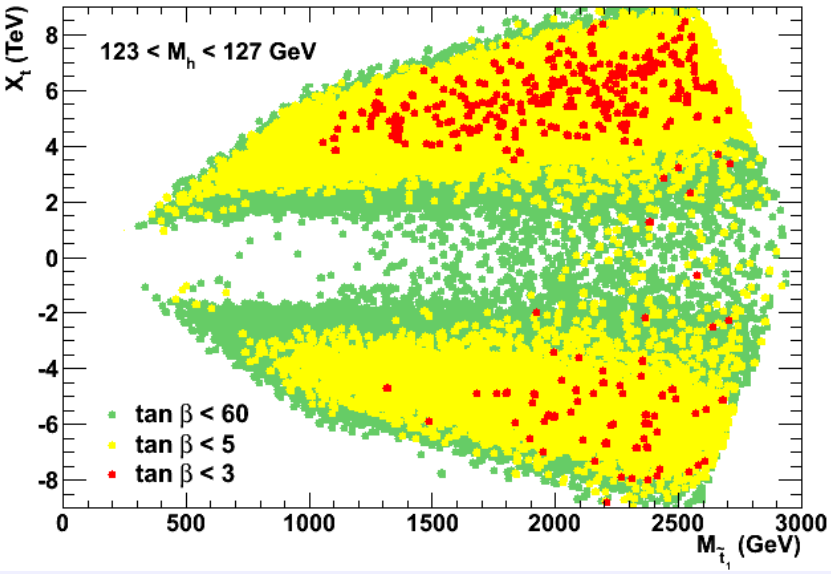
LHC constraints using Pythia/Delphes

20% of the points passing all constraints have a Higgs mass in the interval

$$123 < M_h < 127 \text{ GeV}$$

Consequences of a 125 GeV Higgs on pMSSM





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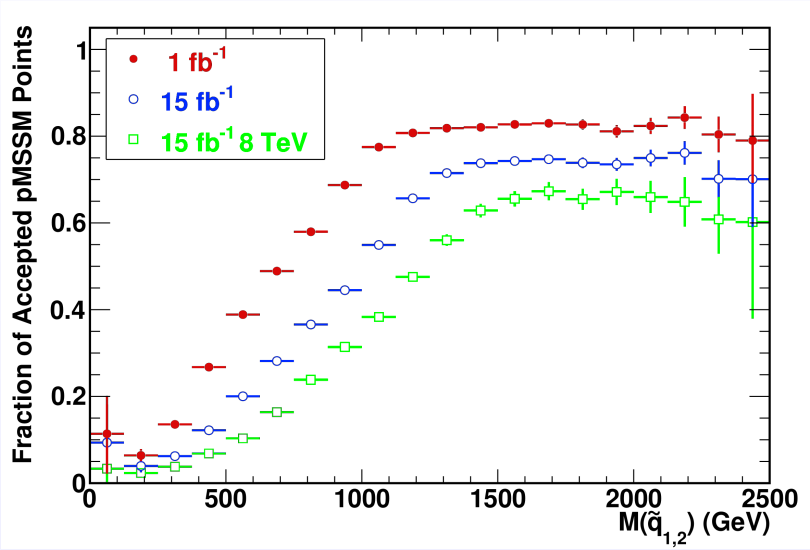
A large part of the pMSSM still survives

No mixing cases ($X_t \approx 0$) excluded for $M_S < 1$ TeV

Small stop masses still allowed

Consequences of a 125 GeV Higgs on pMSSM



With $M_h > 111$ GeV

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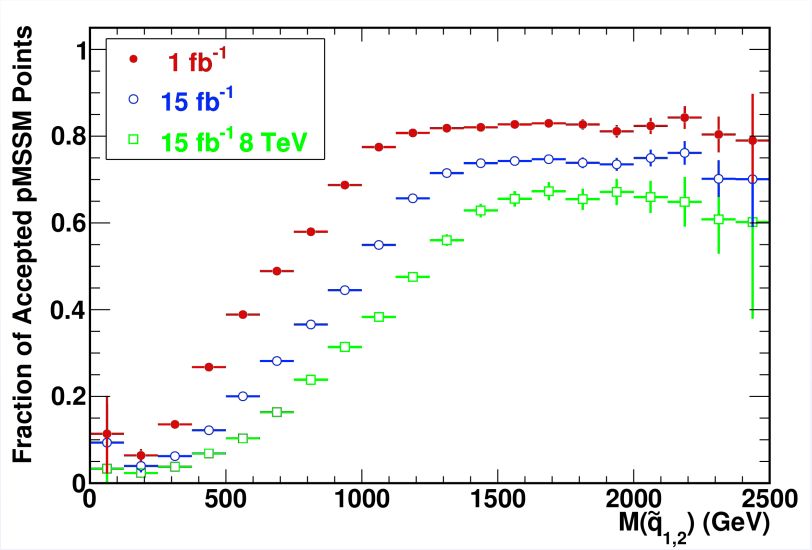

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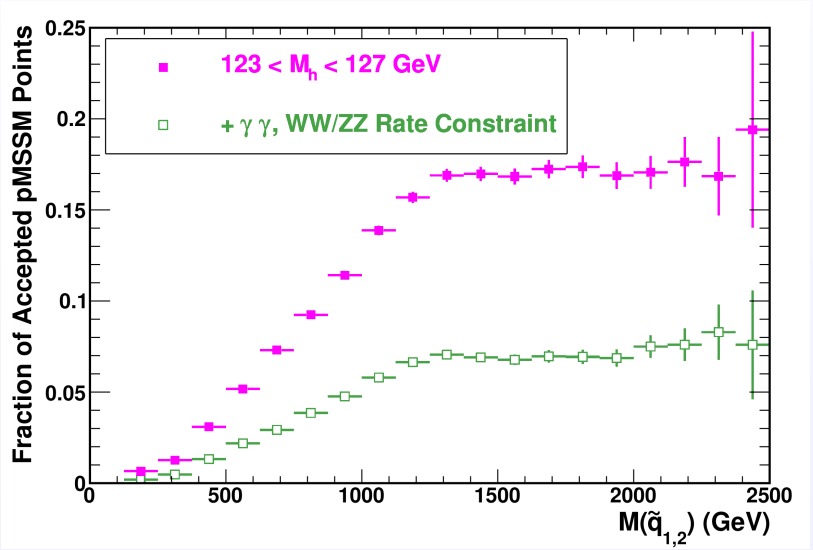

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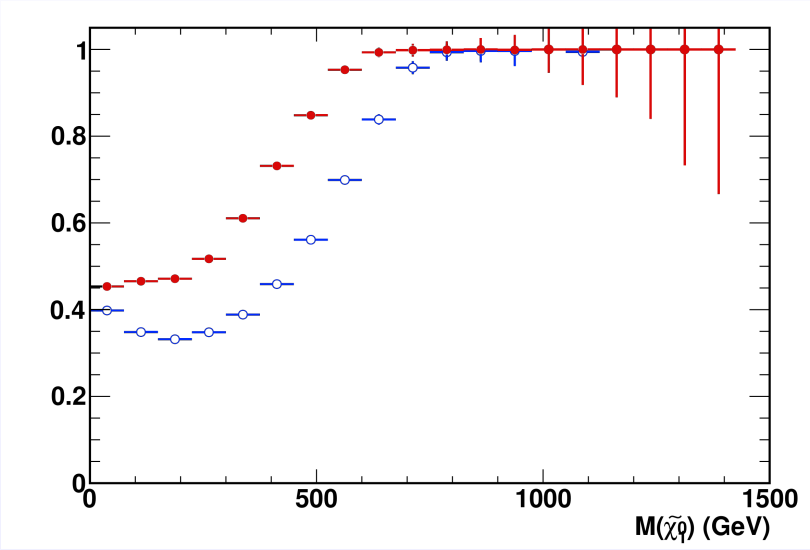

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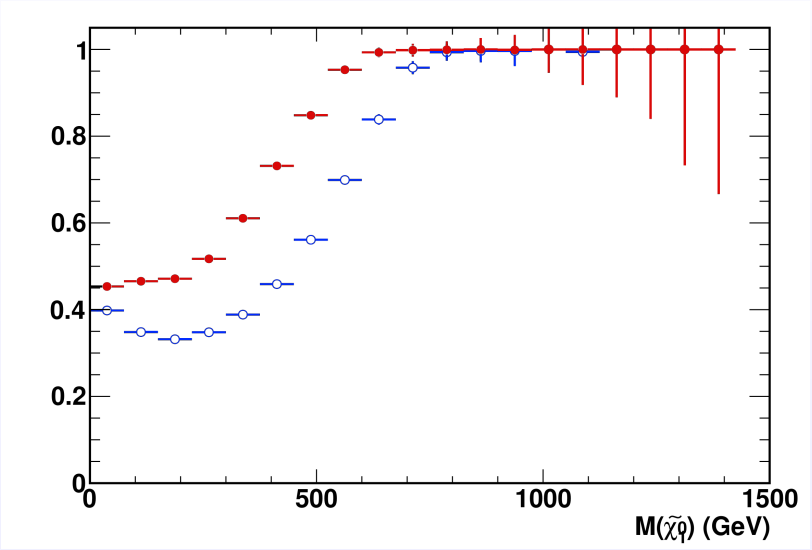

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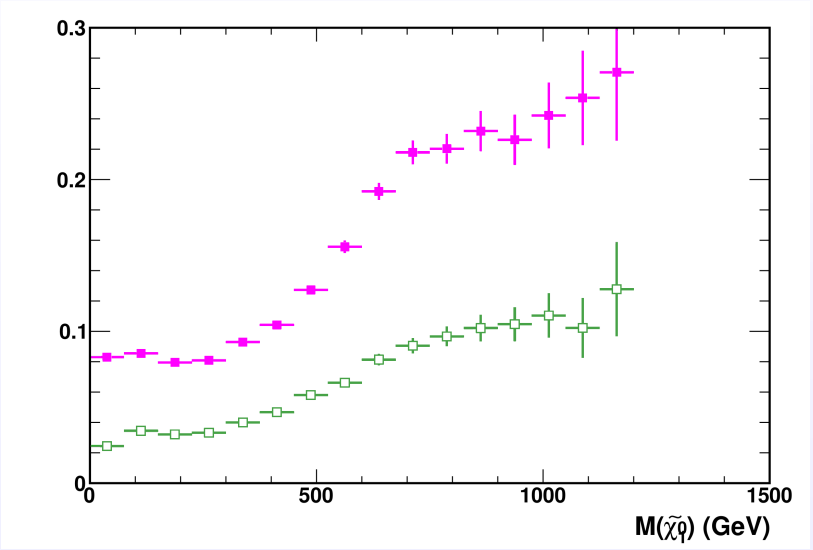

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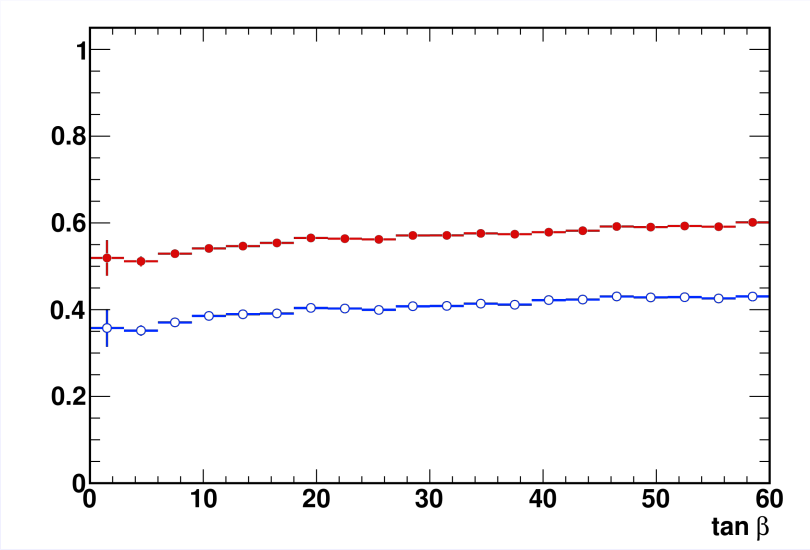

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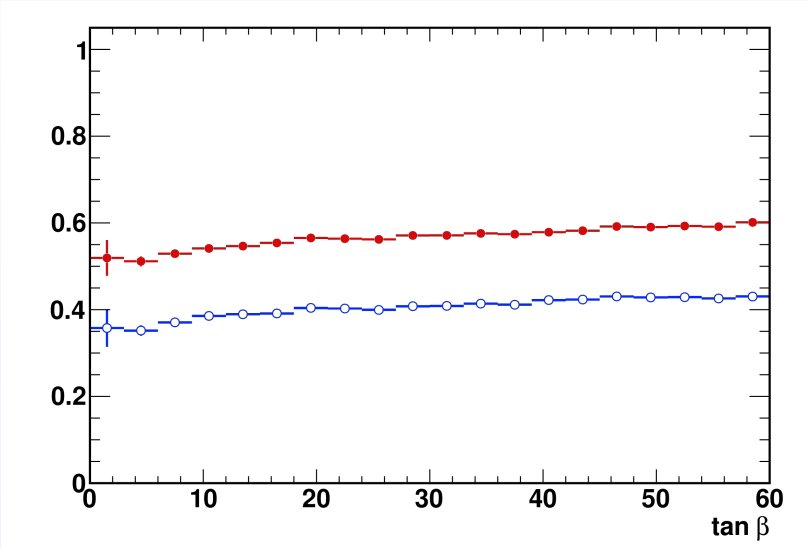

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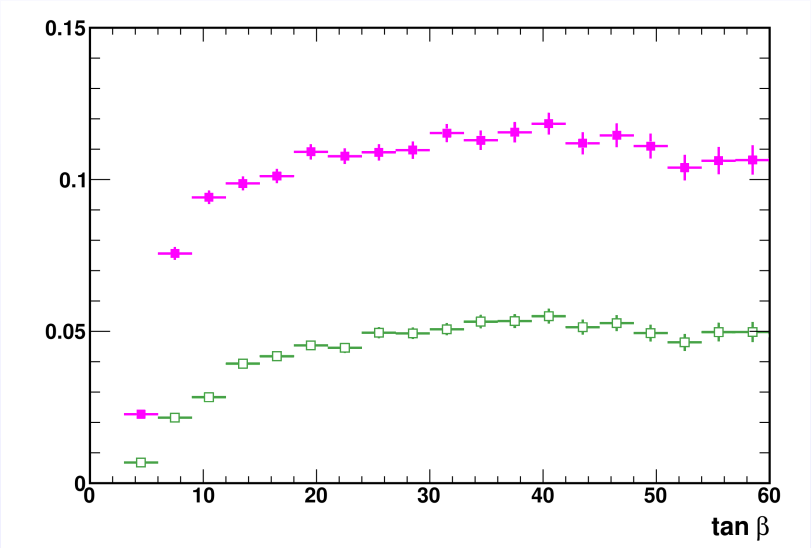

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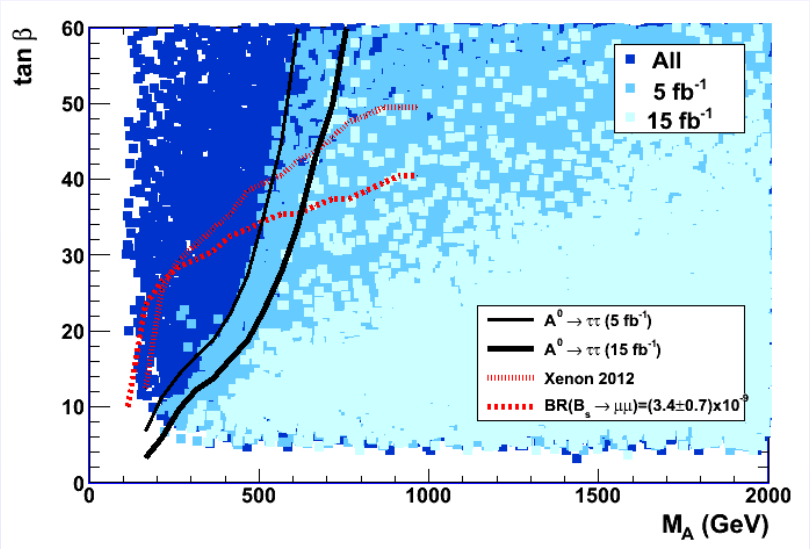
Consequences of a 125 GeV Higgs on pMSSM

Squeeze even more the parameter space by combining with:

- Direct $A \to \tau^+\tau^-$
- Constraints from BR($B_s \to \mu^+\mu^-$)
- Dark matter direct detection constraints (XENON)



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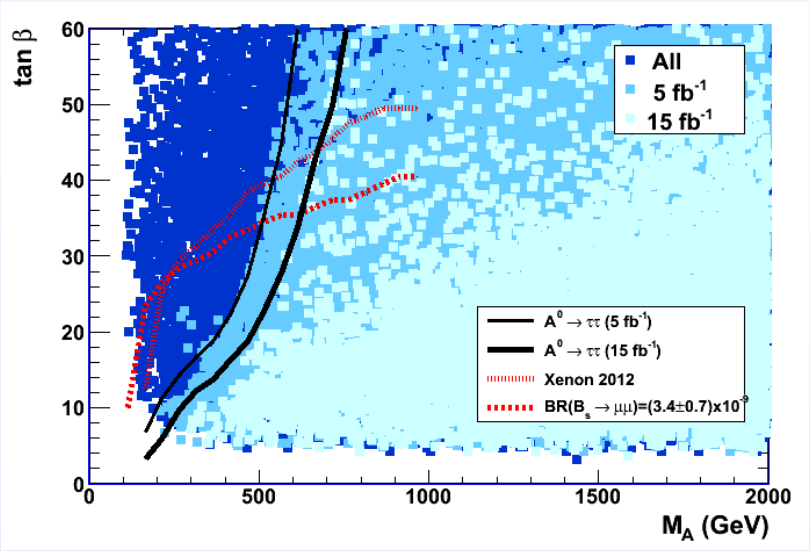

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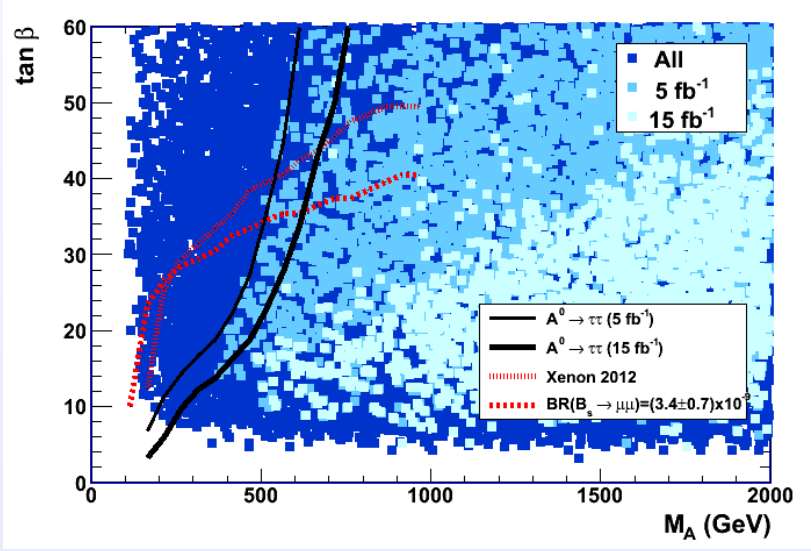

imposing in addition the h rates

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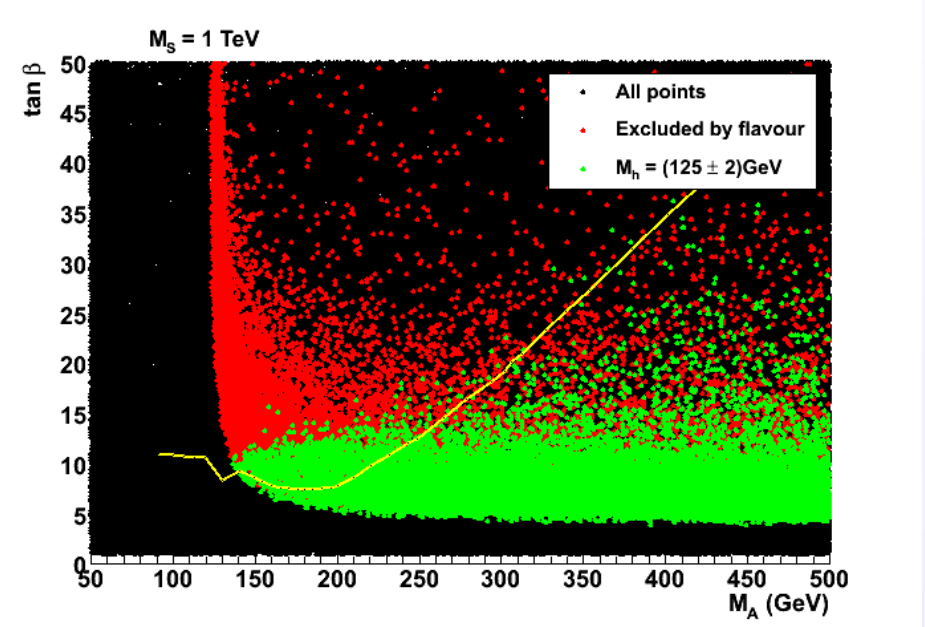
Consequences of a 125 GeV scalar on pMSSM

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

Preliminary



yellow line: CMS limit with 4.6/fb

Flavour constraints: $b \to s\gamma$, $B \to \tau\nu$ and the **new** LHCb limit on $B_s \to \mu\mu$

Very strong constraint from the neutral Higgs searches!

Consequences of a 125 GeV scalar on pMSSM

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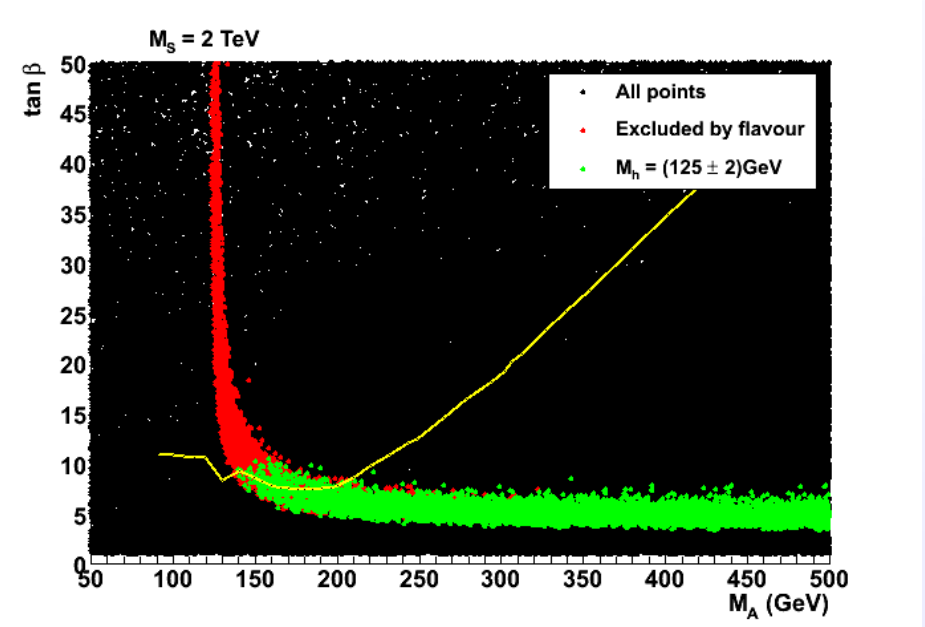

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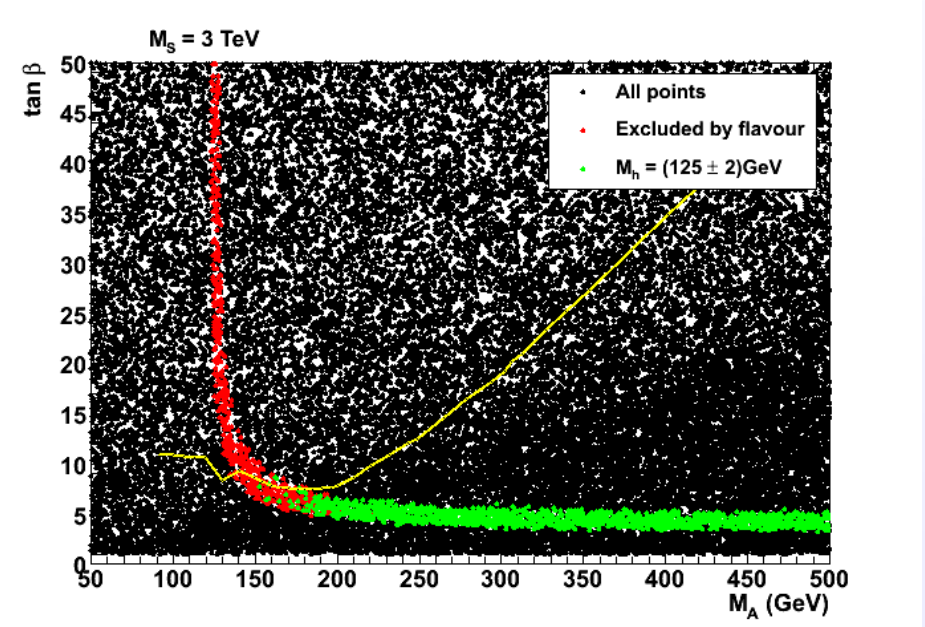

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Conclusion

- The Higgs sector can play an important role in constraining SUSY
- Several constrained MSSM scenarios can be ruled out by a Higgs discovery at 125 GeV
- The CMSSM still provides viable solutions with $A_0 < 0$
- General MSSM: A lot of viable model points survive, but combining with flavour and dark matter sector information, one can squeeze the parameter space

Backup

Constraints

$2.16 \times 10^{-4} < \mathrm{BR}(B \to X_s\gamma) < 4.93 \times 10^{-4}$
$\mathrm{BR}(B_s \to \mu^+\mu^-) < 1.26 \times 10^{-8}$
$0.56 < \mathrm{R}(B \to \tau\nu) < 2.70$
$4.7 \times 10^{-2} < \mathrm{BR}(D_s \to \tau\nu) < 6.1 \times 10^{-2}$
$2.9 \times 10^{-3} < \mathrm{BR}(B \to D^0\tau\nu) < 14.2 \times 10^{-3}$
$0.985 < \mathrm{R}_{\mu 23}(K \to \mu\nu) < 1.013$
$-2.4 \times 10^{-9} < \delta a_\mu < 4.5 \times 10^{-9}$
$10^{-4} < \Omega_\chi h^2 < 0.135$
+ sparticle mass upper bounds
+ Higgs search limits

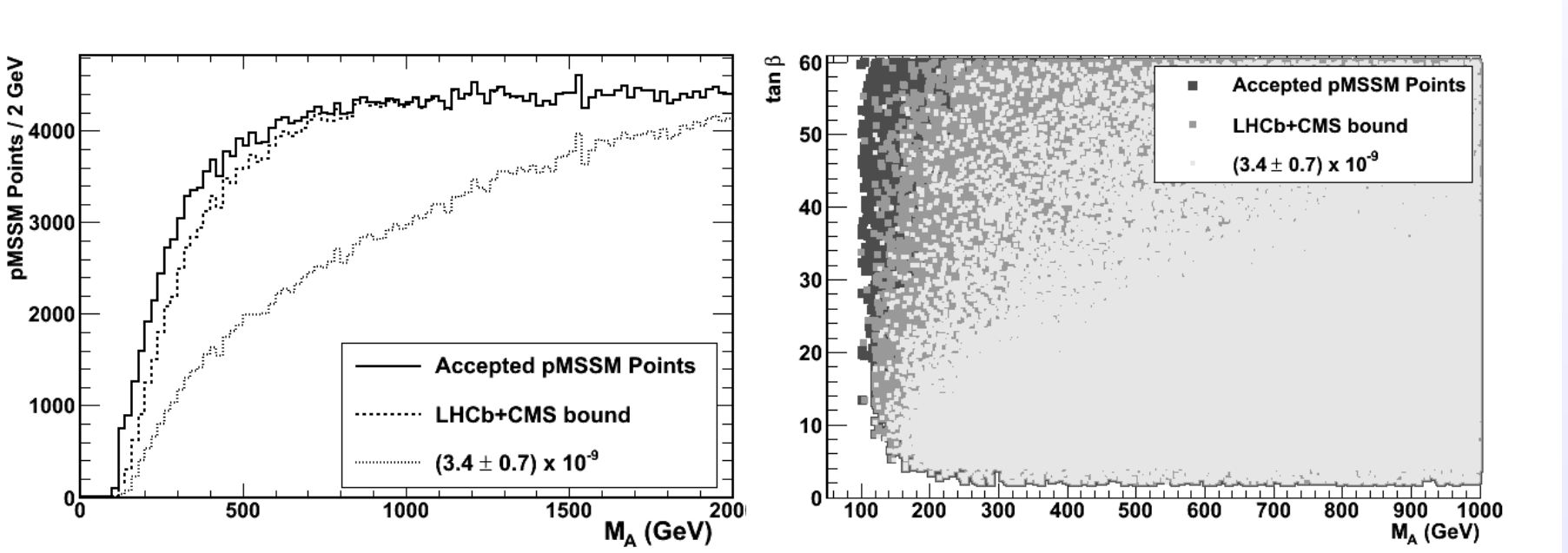
Sensitivity to M_A from BR($B_s \to \mu^+\mu^-$)

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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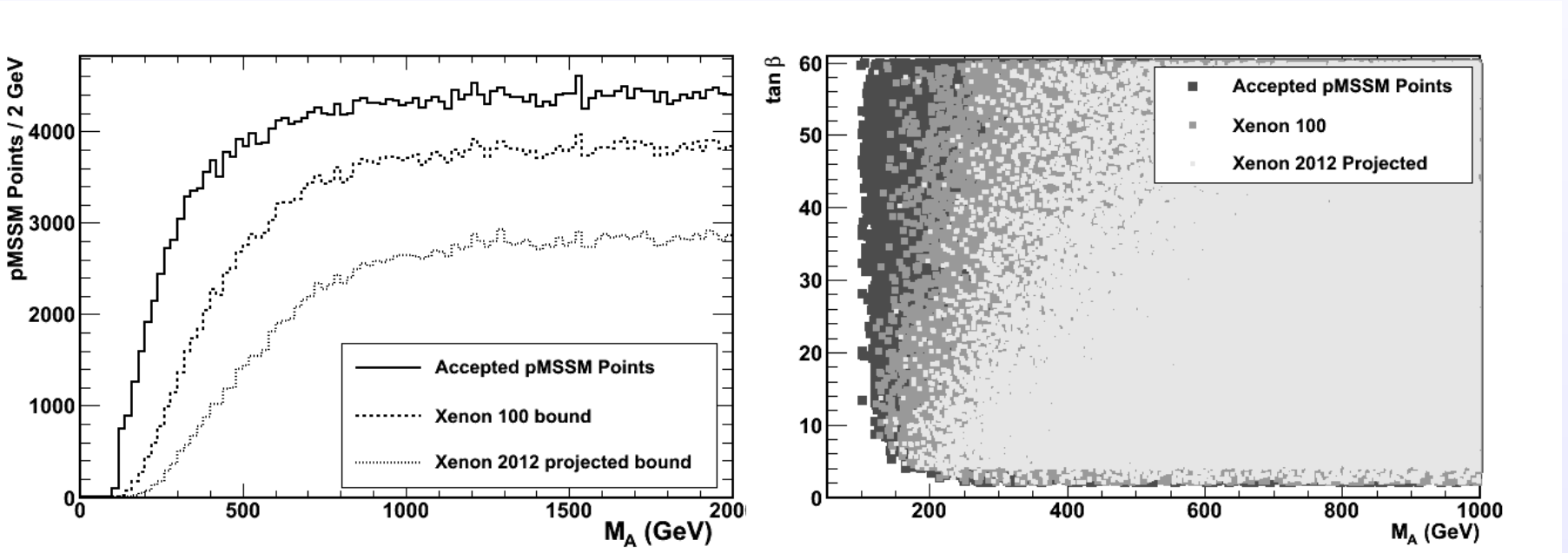
Light M_A strongly constrained!

Dark matter direct detection

Considering 2 scenarios:

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



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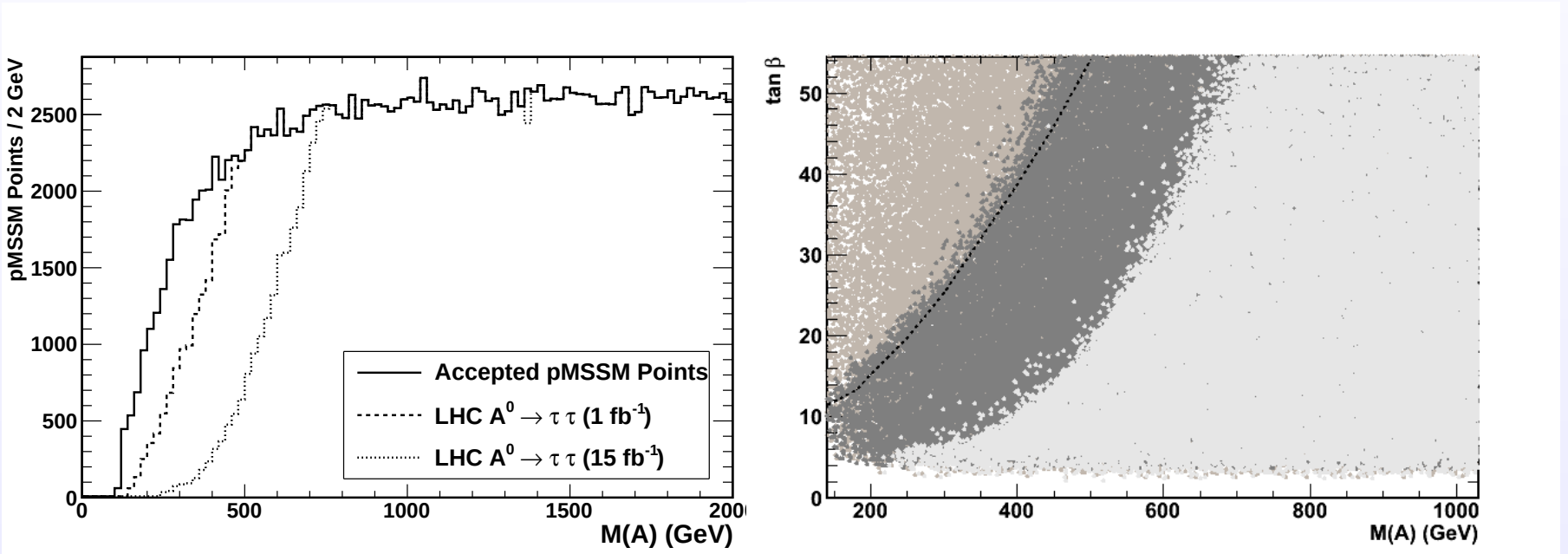
Again light M_A strongly constrained!

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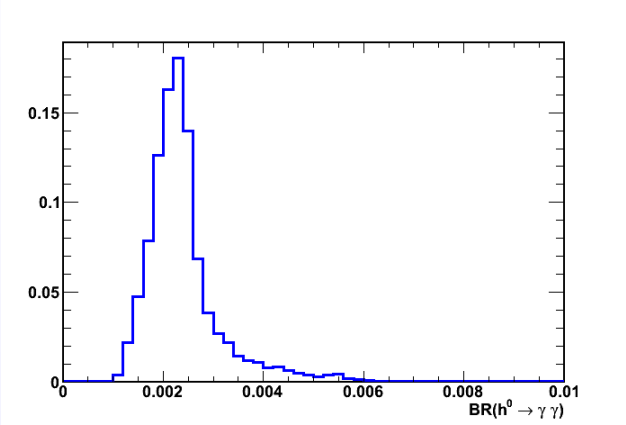
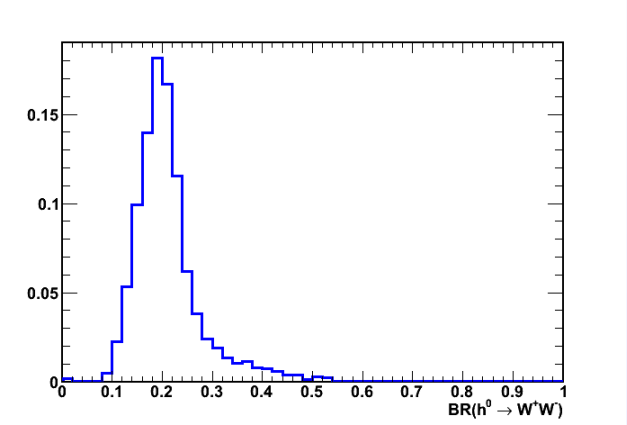
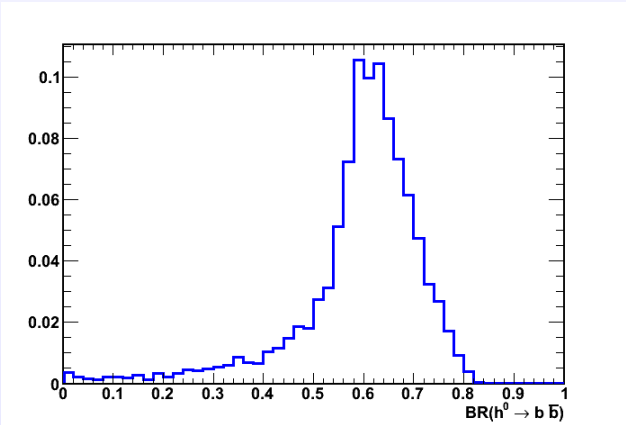
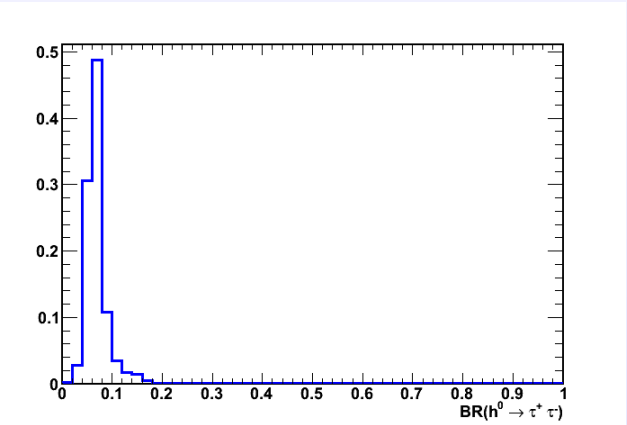
Low M_A region below 350 GeV can be explored and excluded if no signal except a narrow strip around $\tan\beta$ =5.

Higgs branching ratios









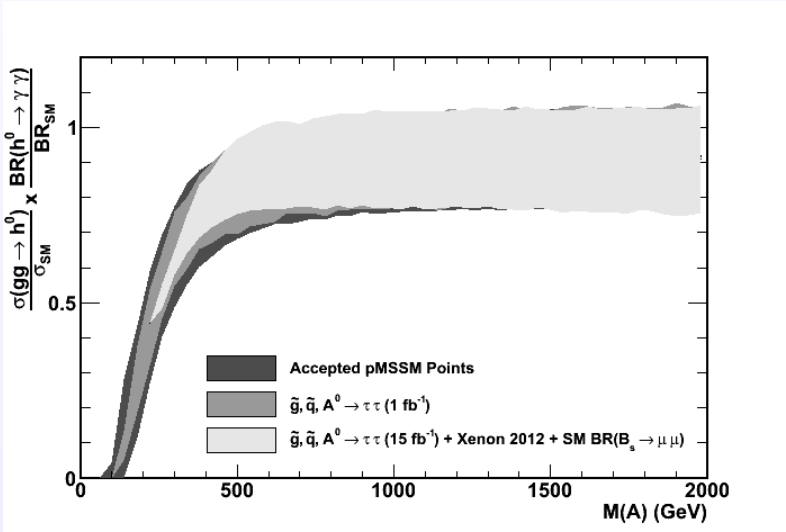
In the case of no Higgs discovery by the end of 2012

Higgs rates could be suppressed wrt the SM

- Study $\sigma\times$ BR suppression within pMSSM for $\gamma\gamma$ and WW final states assuming $M_{\chi_1^0} > 46$ GeV

- Look at suppression factor vs M_A for all accepted pMSSM points compatible with 1 fb^{-1} LHC data ($\tilde{g}, \tilde{q}$ and BR($B_s \to \mu^+\mu^-$)) and XENON 100 results

- projection for 2012 data assuming SM value for BR($B_s \to \mu^+\mu^-$).



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A suppression of a factor of 2 will be still possible!