The 125 GeV Higgs in the NMSSM in light of LHC results and astrophysics constraints

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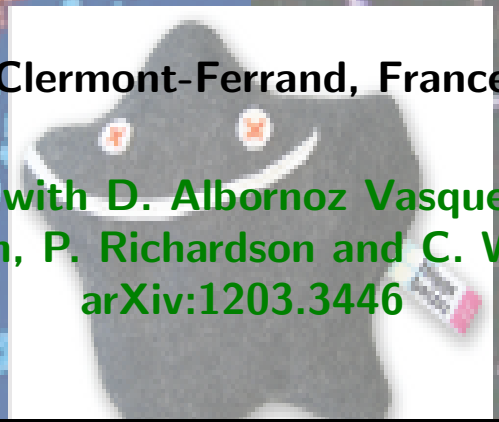
In collaboration with D. Albornoz Vasquez, G. Bélanger, C. Bœhm, P. Richardson and C. Wymant, arXiv:1203.3446



Outline

Motivations

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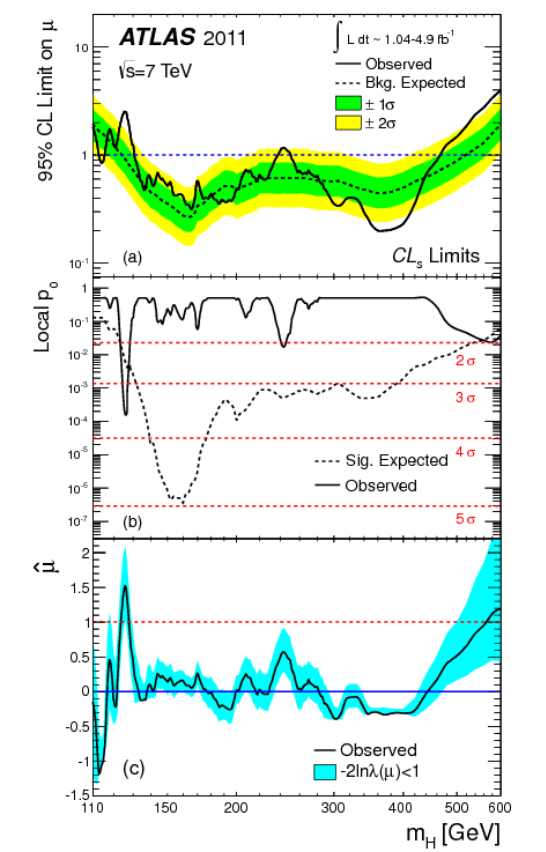
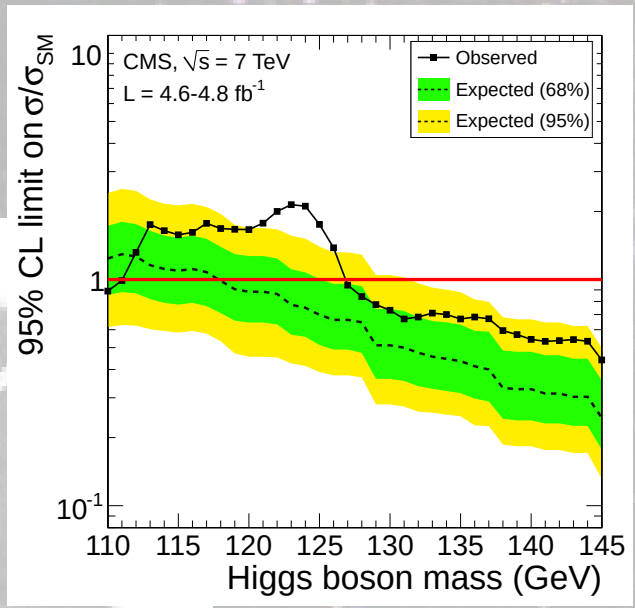
Higgs boson signal ?

- LHC $\Rightarrow$ excess in the Higgs decay channels into vector bosons around 125 GeV (interesting mass range : [122-128] GeV)
- Deviation from Standard Model (SM) expectation, most relevant : signal strength in the $\gamma\gamma$ channel : $\frac{\sigma^{\gamma\gamma}_{\text{osb}}}{\sigma^{\gamma\gamma}_{\text{SM}}} \sim 2$ for ATLAS and CMS (different m_h) $\Rightarrow$ Hints of new physics ?





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Higgs boson in Supersymmetry ?

- MSSM : some fine-tuning
  little corner in the parameter space with enhancement of $h \to \gamma\gamma$ M. Carena et al., 1112.3336
- NMSSM (see U. Ellwanger and D. Das talks) :
  new terms in the Higgs potential such as $A_\lambda \lambda S H_u H_d$
  $\Rightarrow$ easy to get $m_h \sim 125$ GeV
  doublet-singlet mixing (low $\tan\beta$, large λ) $\Rightarrow$ reduced $h \to b\bar{b}$,
  $Br(h \to \gamma\gamma)$ and then NMSSM signal strength $R_{gg\gamma\gamma}$ increased

$$R_{ggXX} = \frac{\sigma(gg\to h)_{\text{NMSSM}} BR(h\to XX)_{\text{NMSSM}}}{\sigma(gg\to h)_{\text{SM}} BR(h\to XX)_{\text{SM}}}$$

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Dark Matter (DM) constraints on the LSP (light/heavy, bino/higgsino/singlino, ...) ?

Scan of the model

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(see D. Albornoz Vasquez talk tomorrow on directional detection of neutralino in the (N)MSSM, more details in D. Albornoz Vasquez, et al., 1107.1614, 1201.6150)

- Scanning method : Markov Chain Monte Carlo with EW scale input parameters
  The one for $m_{\chi_1^0} < 15$ GeV (DAMA, CoGent signal), the other with $m_{\chi_1^0} > 15$ GeV

Parameter	Minimum	Maximum	Tolerance
M_1 (GeV)	1	1000	3
M_2 (GeV)	100	2000	30
M_3 (GeV)	500	6500	10
μ (GeV)	0.5	1000	0.1
$\tan\beta$	1	75	0.01
λ	0	0.75	0.1
κ	0	0.65	0.08
A_λ (GeV)	-5000	5000	100
A_κ (GeV)	-5000	5000	100
A_t (GeV)	-3000	3000	100
$M_{\tilde{l}_R}$ (GeV)	70	2000	15
$M_{\tilde{l}_L}$ (GeV)	70	2000	15
$M_{\tilde{q}_{1,2}}$ (GeV)	300	2000	14
$M_{\tilde{q}_3}$ (GeV)	300	2000	14

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- Scanning method : Markov Chain Monte Carlo with EW scale input parameters
- Constraints imposed on the scan

constraint	value/range	tolerance
$\Omega_{WMAP}h^2$	0.01131 - 0.1131	0.0034
$(g-2)_\mu$	$25.5\ 10^{-10}$	stat : $6.3\ 10^{-10}$ sys : $4.9\ 10^{-10}$
$b \to s\gamma$	$3.52\ 10^{-4}$	th : $0.24\ 10^{-4}$ exp : $0.23\ 10^{-4}$
$B_s \to \mu^+\mu^-$	$\leq 4.7\ 10^{-8}$	$4.7\ 10^{-10}$
$R(B^+ \to \tau\nu_\tau)$	1.28	0.38
$Z \to \chi_1^0\chi_1^0$	≤ 1.7 MeV	none
$e^+e^- \to \chi_1^0\chi_{2,3}^0$	≤ 0.1 pb	none
ΔM_s	$117.0\ 10^{-13}$ GeV	th : $21.1\ 10^{-13}$ GeV exp : $0.8\ 10^{-13}$ GeV
ΔM_d	$3.337\ 10^{-13}$ GeV	th : $1.251\ 10^{-13}$ GeV exp : $0.033\ 10^{-13}$ GeV

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- Scanning method : Markov Chain Monte Carlo with EW scale input parameters
- Constraints imposed on the scan
- Constraints imposed after the scan
  - DM direct detection limits (XENON100)
  - DM indirect detection limits (Fermi-LAT)
  - Latest Higgs search results from ATLAS and CMS seminar at CERN on 13th December 2011, with `HiggsBounds-3.6.1beta`
  - $\mathrm{Br}(B_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ (LHCb)
  - SUSY searches@LHC with ATLAS's 1.04 fb^{-1} 0-lepton jets + $\not{E_T}$ search using Herwig++ 2.5.1 and RIVET 1.5.2

Results

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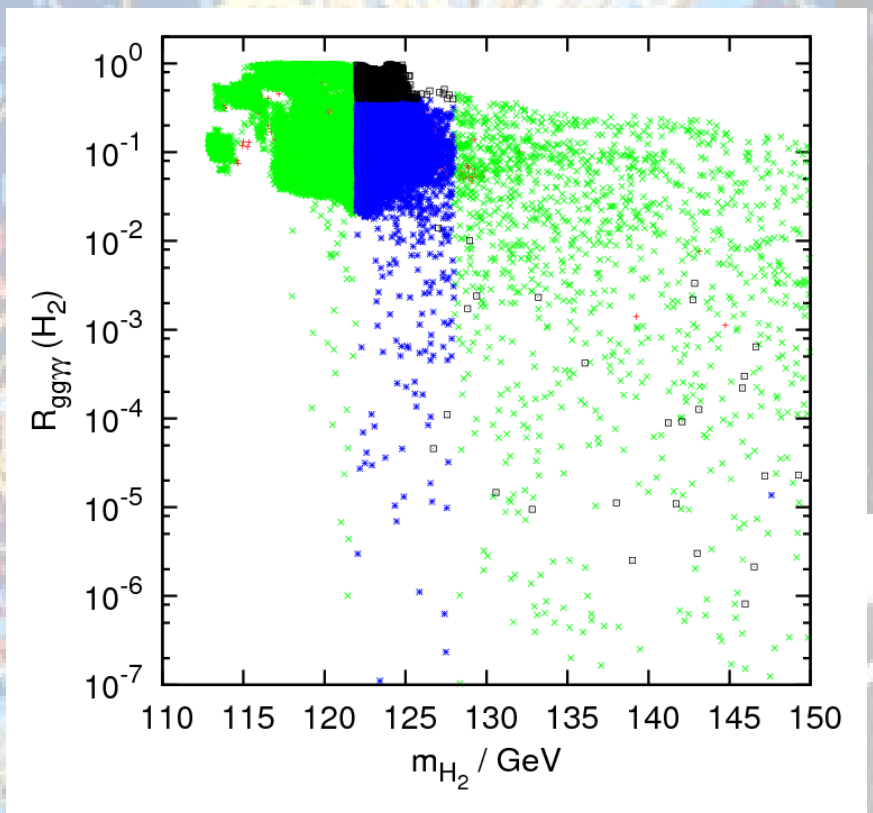
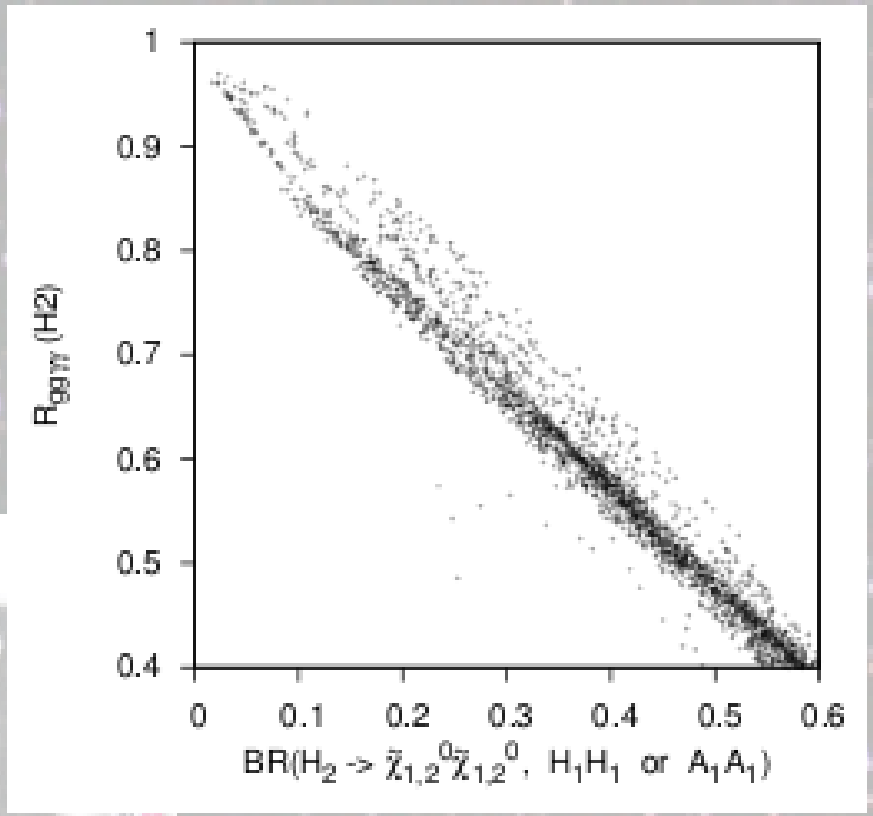
For light LSP (< 15 GeV)

- WMAP satisfied for χ_1^0 near $m_{h_1,A_1}/2$, singlet-like Higgs
  $\Rightarrow$ large non standard decays widths + low doublet-singlet mixing
  $\Rightarrow$ difficult to reach $R_{gg\gamma\gamma} > 1$ (in black : $0.4 < R_{gg\gamma\gamma} < 3.6$) :

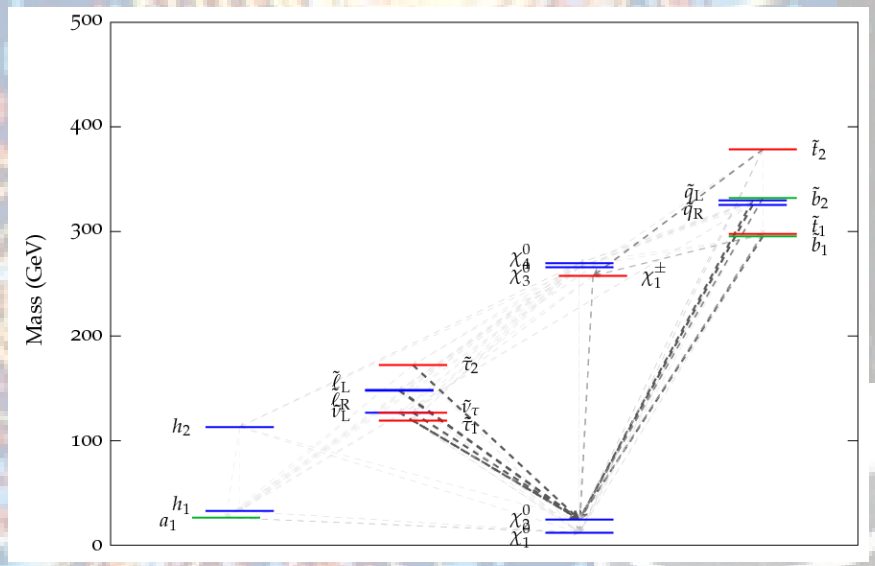


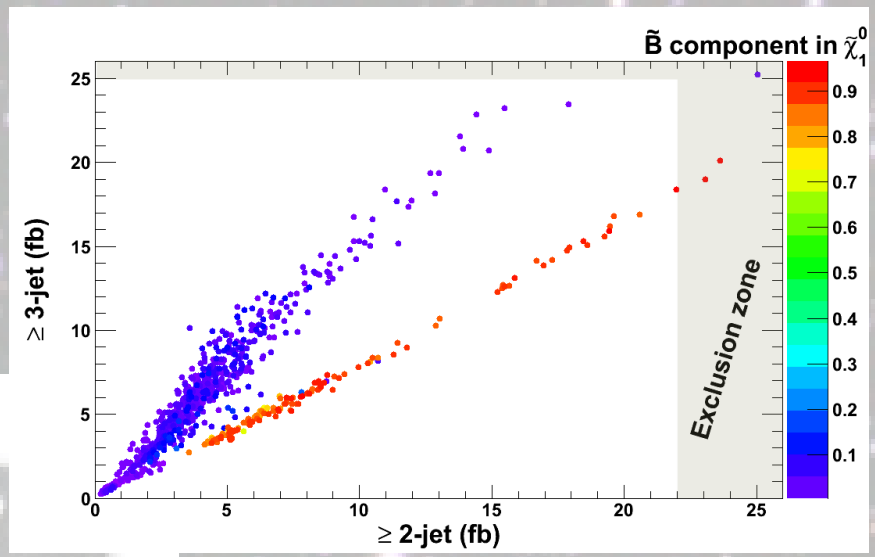


Results

For light LSP (< 15 GeV)

- Difficult to reach $R_{gg\gamma\gamma} > 1$
- Jets + $\not{E_T}$ constraint :
  In general exclude squarks lighter than 0.6 - 1 TeV and gluinos below 0.5 TeV
  $\Rightarrow$ Here reduced acceptance into Jets + $\not{E_T}$ search channels and more jets for singlino LSP



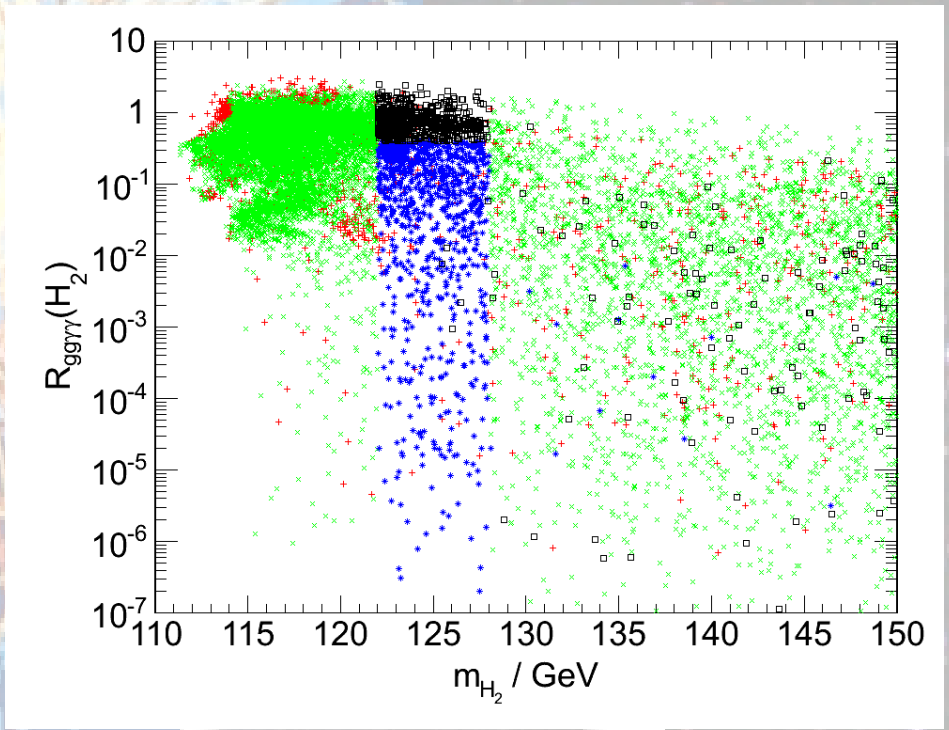


- $\tilde{q} \rightarrow q + (\chi_2^0 \rightarrow \chi_1^0 + (f\bar{f}$ for A_1 or $h_1))$

Results

For heavy LSP

- Singlet-like lightest Higgs boson not needed
  $\Rightarrow$ easier to get important doublet-singlet mixing
  $\Rightarrow$ Possibility to match LHC excess on $R_{gg\gamma\gamma}$ ...



... but it's mainly associated with neutralino being a fraction of DM

Conclusions

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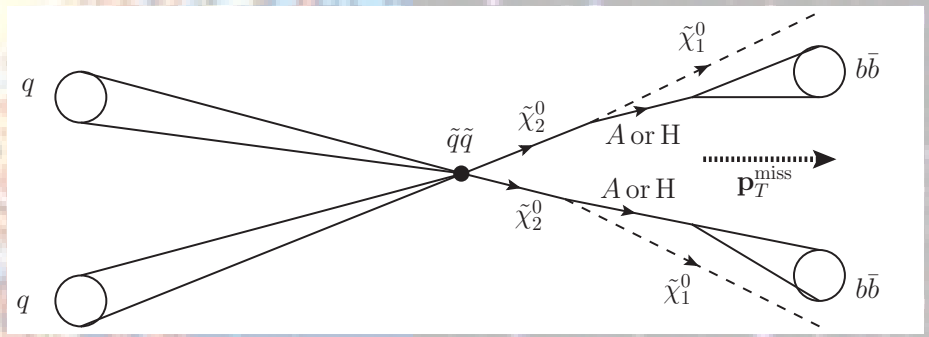
- **The NMSSM can explain both Higgs boson mass and excess in the $\gamma\gamma$ channel**
- **DM constraints powerful on the exclusion of some good candidates in the parameter space**
- **Interesting NMSSM signatures (very light Higgs, two Higgses in the preferred mass range, new jets + $\not{E}_T$ signal, ...)**



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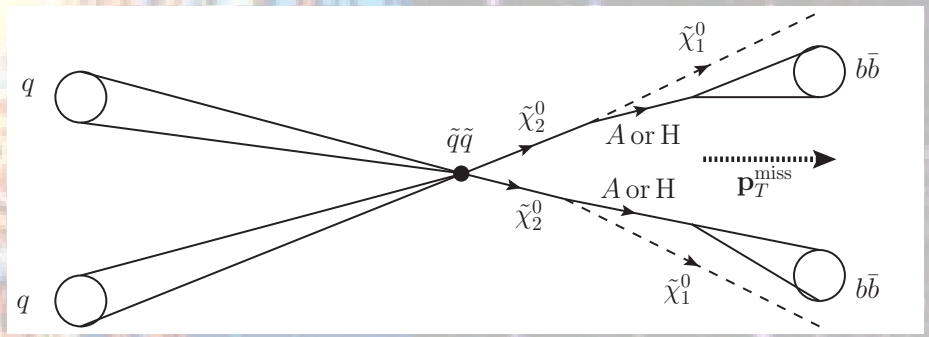

Thanks for your attention !

BACKUP

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- NMSSM superpotential :

$$W_{NMSSM} = W_{MSSM}(\mu = 0) + \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + ...$$

- 2 CP-odd, 5 CP-even Higgs
- Doublet-singlet mixing much more important than in the UMSSM for a Higgs $\sim$ 125 GeV (large λ)
- 5 neutralinos, lightest can be mostly singlino (especially if we want light DM)
- Input parameters at EW scale
- Light neutralino scan :