BSM: Implications from/for Higgs searches

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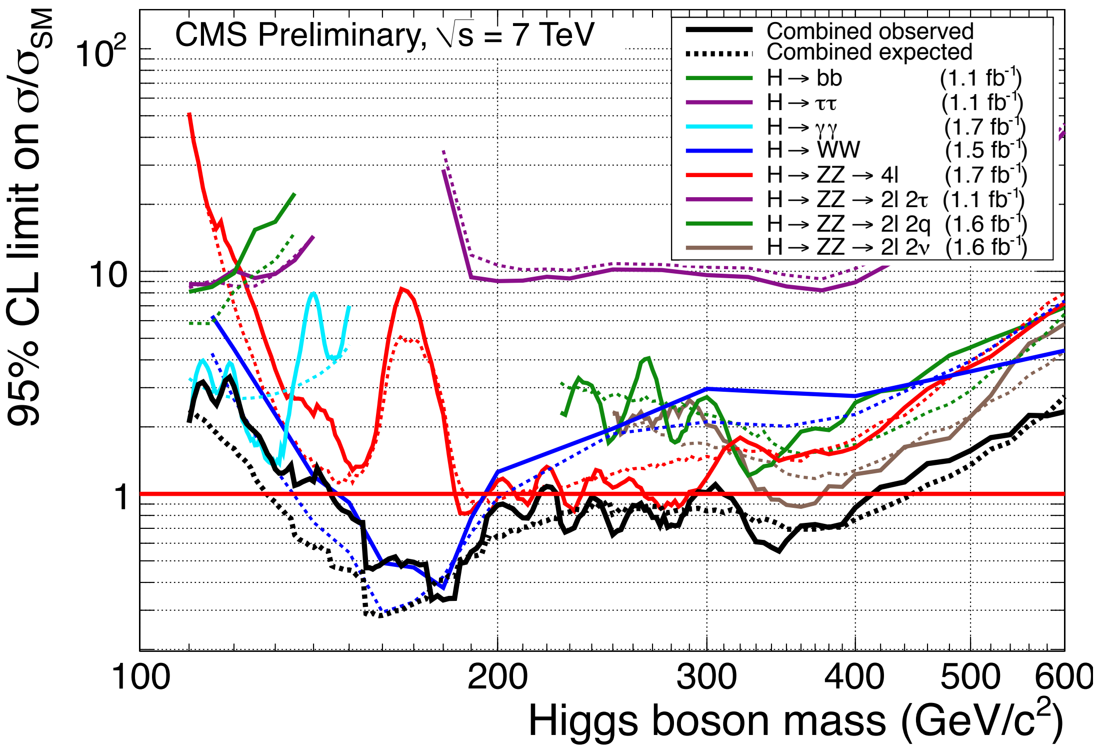
LAPTH

Contribution to Les Houches -
A .Albornoz-Vasquez, GB, A. Belyaev, M. Brown, F. Boudjema, G. DaSilva, G. Drieu La Rochelle, R. Godbole, F. Mahmoudi, F. Moortgat, A. Pukhov ...

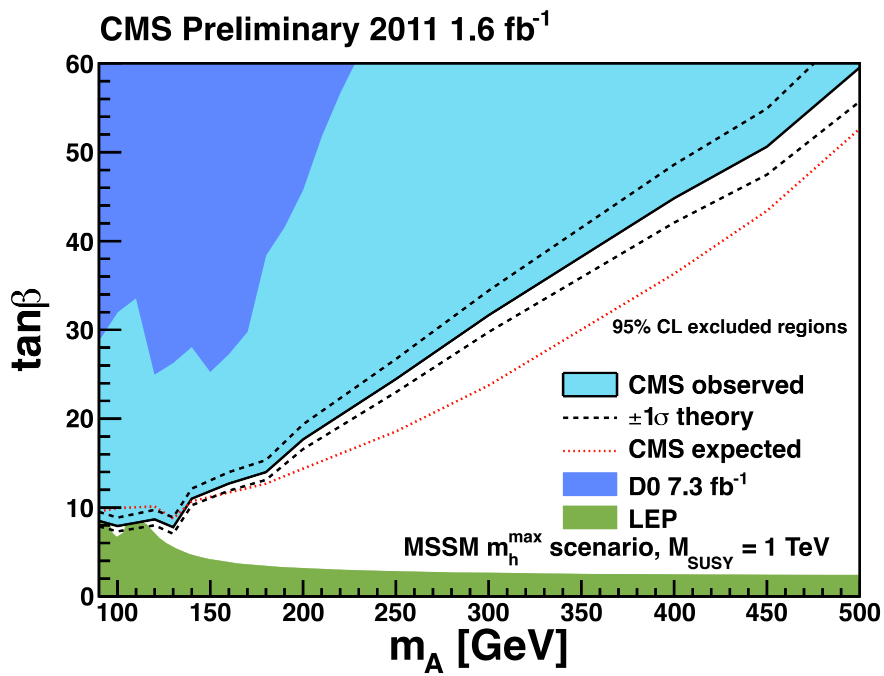
Introduction

- ATLAS and CMS have excluded a SM - Higgs in the range 144GeV<m_h< 440GeV with 1.7fb^{-1}

- With ~10fb^{-1} expect to close the range 114<m_h<144GeV



- In extensions of the SM, these limits cannot be applied directly, new physics can affect the Higgs couplings to WW,bb,tt,γγ,gg
- Higgs can decay invisibly thus reducing all signatures in SM particles
- Higgs can have new decay channels
- In some extensions of SM, Higgs searches in different channels are important, e.g. search for heavy Higgs doublet leads to constrain in the m_A-tanβ plane in SUSY



Higgs searches and BSM

- The SUSY case
  - Comparison with SM
  - gg-h-$\gamma\gamma$
  - Pseudoscalar and light DM
- Invisible Higgs (MSSM and extensions)
- BSM Higgs
- Conclusion

The SUSY case

- Modification of couplings
  - low M_A
  - stop sector
  - chargino sector
- Pseudoscalar Higgs search and the link to dark mattter

Higgs couplings in MSSM

- Non decoupling case - low mA
- Ignoring radiative corrections

$$\cos^2(\beta-\alpha) = \frac{M_h^2(M_Z^2 - M_h^2)}{M_A^2(M_H^2 - M_h^2)}$$

- Higgs coupling to SM particles`

$$\frac{g_{W^+W^-h}}{g_{SM}} = \sin(\beta-\alpha)\,, \qquad \frac{g_{\bar{t}th}}{g_{SM}} = \frac{\cos\alpha}{\sin\beta}\,, \qquad \frac{g_{\bar{b}bh}}{g_{SM}} = -\frac{\sin\alpha}{\cos\beta}\,.$$

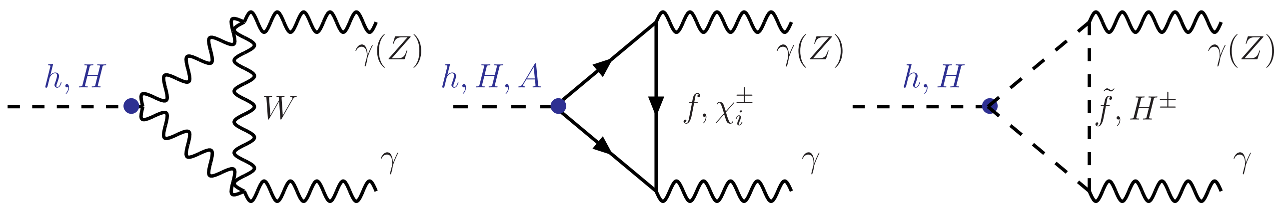
- Modification of couplings

$$\tan\alpha\tan\beta = -(1+r) \qquad r \simeq \frac{2M_Z^2}{M_A^2}\,\frac{\tan^2\beta - 1}{\tan^2\beta + 1} \geq 0$$

$$R_{VVh} \simeq 1 - \frac{r^2}{2}\frac{\tan^2\beta}{(1+\tan^2\beta)^2} \qquad R \simeq 1 - \frac{r}{1+\tan^2\beta} \qquad R_{bbh} \simeq 1 + r\frac{\tan^2\beta}{1+\tan^2\beta}$$

- Increase in bbh, more modest corrections (decrease) in tth,WWh

Loop-induced couplings



- hγγ: dominant contribution: W loop , top loop opposite sign
- If hWW coupling not modified, hγγ not much affected
- Total width dominated by bb, larger than in SM

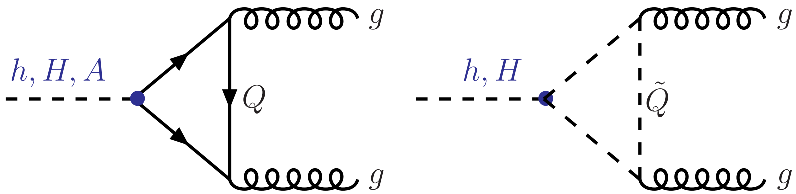
$$b - \frac{m_b/v}{1+\Delta m_b}\bar{b}\left[g_b^h\left(1-\frac{\Delta m_b}{\mathrm{tg}\alpha\ \mathrm{tg}\beta}\right)h\right.$$

- branching hγγ can drop

$$R_{\gamma\gamma} = \frac{BR^{SUSY}(h\to\gamma\gamma)}{BR^{SM}(h\to\gamma\gamma)}$$

- inNMSSM light Higgs an have large singlet component and much reduced coupling to b-quarks Br(γγ) increases up to factor 6
  - Ellwanger 1012.1201

ggH



- hgg dominant contribution top loop
- Expect small decrease at low m_A
- Stop contribution can be large
  - Djouadi, PLB345(98) 101

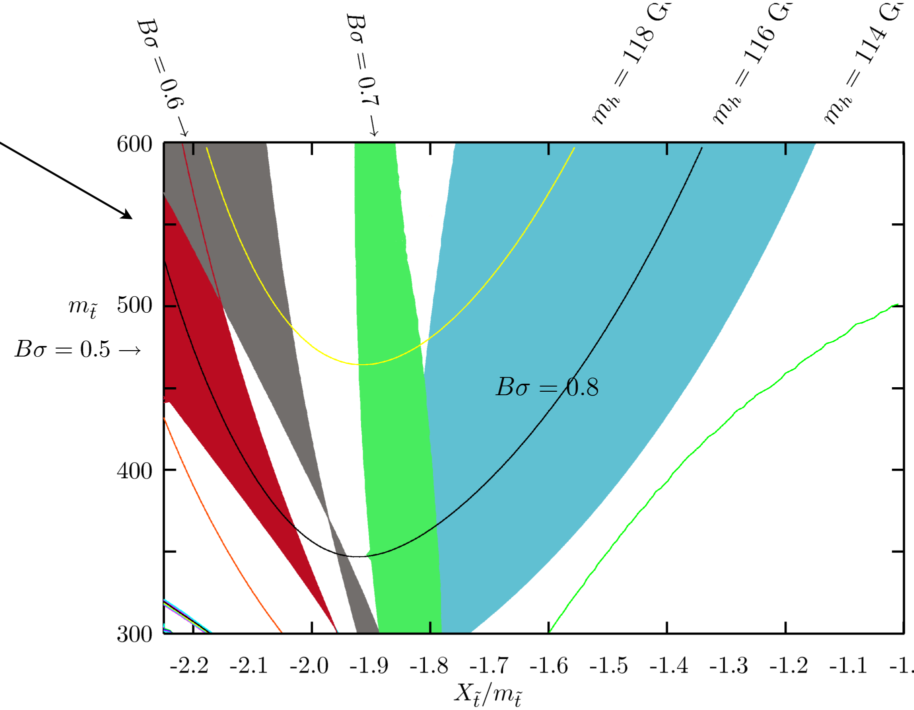
$$V_{\tilde{t}_1\tilde{t}_1 h} \simeq \frac{g}{M_W}\Bigg(\sin^2(2\theta_{\tilde{t}})\frac{(m^2_{\tilde{t}_1}-m^2_{\tilde{t}_2})}{4} + m_t^2 + M_Z^2\cos(2\beta)\left((\frac{1}{2}-\frac{2}{3}\sin^2\theta_W)\cos^2\theta_{\tilde{t}}+\frac{2}{3}\sin^2\theta_W\sin^2\theta_{\tilde{t}}\right)\Bigg)$$

  - no-mixing case: stop interferes constructively with top -->increase in hgg, decrease(modest) in hγγ
  - large mixing : stop interferes destructively with top --> decrease in hgg

gg-H-γγ and SUSY

- Large corrections for light stop
  - GB, Boudjema, Sridhar, hep-ph/9904348
- Effect of top/stop on ggγγ
- Effect of chargino on hγγ less important
  - GB, Boudjema, Donato, Godbole, Rosier, hep-ph/0002039
- Decoupling limit (large mA) : hWW, htt, hbb SM-like (ignoring radiative correction effects which can lead to large modifications in hbb)

- m_A=400GeV, tanβ=30 Msusy=1TeV

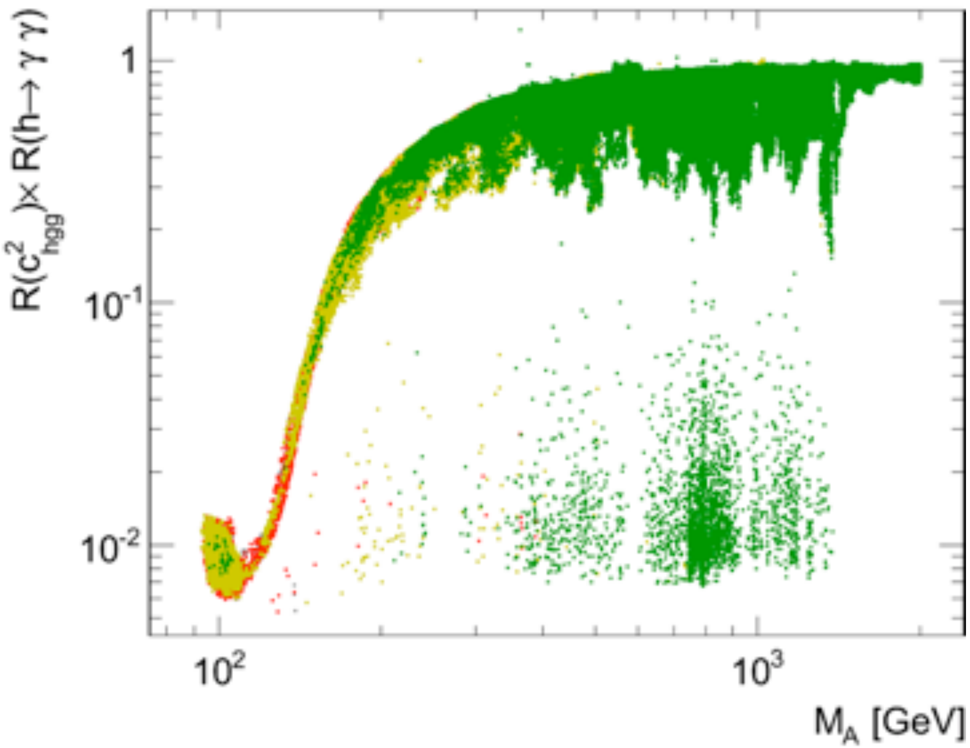


Low, Shalgar, 0901.0266

Higgs in MSSM

- Scan of MSSM with 11 free parameters
  - $M_1, M_2, M_3, \mu, \tan\beta, M_A, A_t, M_{lL}, M_{lR}, M_{q1}, M_{q3}$
  - MCMC approach
  - Higgs searches (HiggsBounds)
  - Flavour physics
  - DM observables
- LHC exclusion squarks not included
- Drop in gg-h-γγ signal at low M_A
  - partially excluded by DM constraints

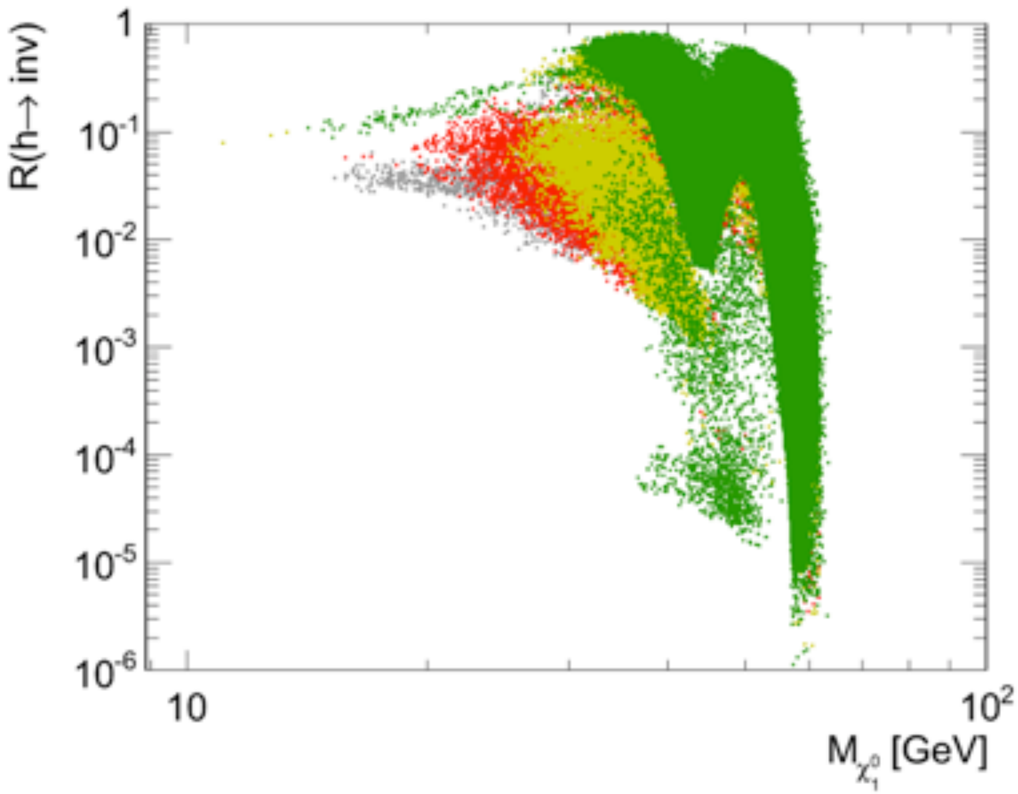
preliminary



D. Albornoz Vasquez

Higgs in MSSM

- Can have large invisible width -> reduction in all channels
- Possible modest enhancement of WW->h->$\tau\tau$

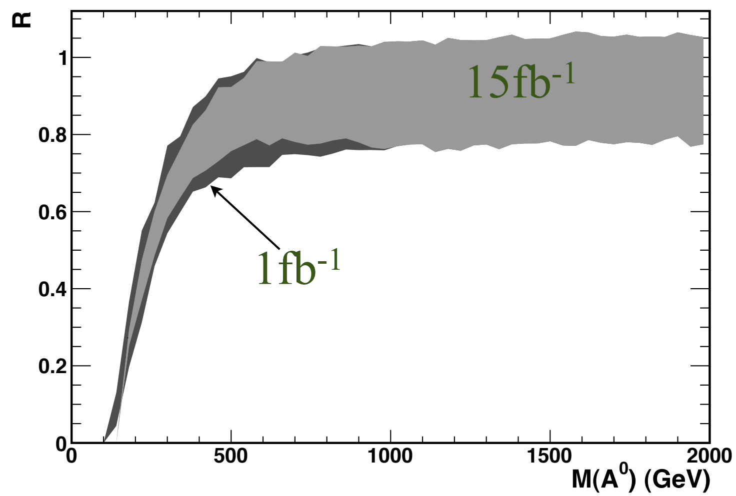


Yellow/red
Direct detection+
gamma-ray Fermi

Light Higgs in pMSSM

- Global scan in pMSSM
  - Mass limits (includes LHC 1fb^{-1})
  - Higgs searches (HiggsBounds)
  - Flavour physics
  - DM relic density
- If m_A>500 GeV, R>0.7
  - to rule out/explore large fraction of MSSM parameter space need slightly more luminosity than SM

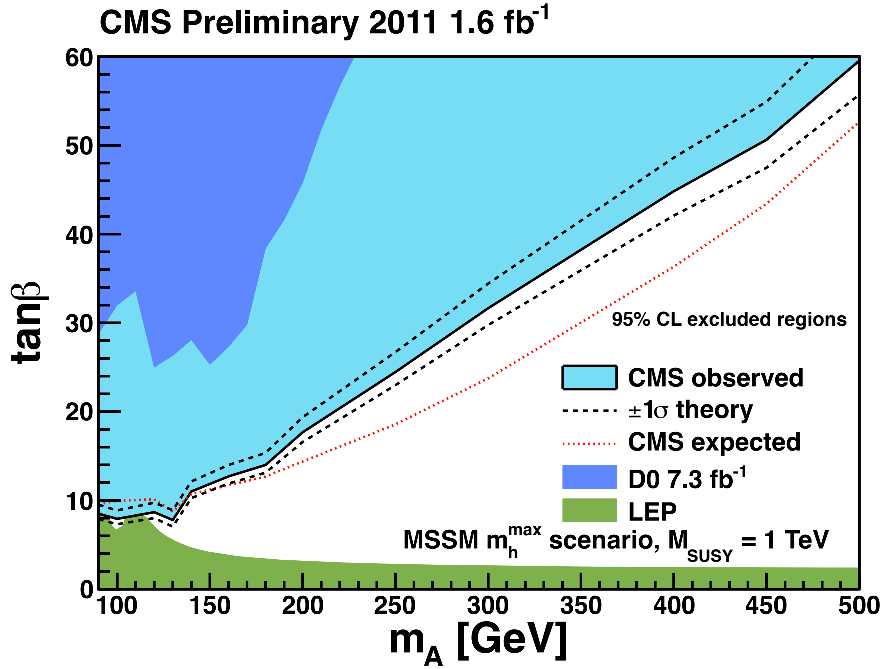
$R = gg\gamma\gamma_{MSSM}/gg\gamma\gamma_{SM}$



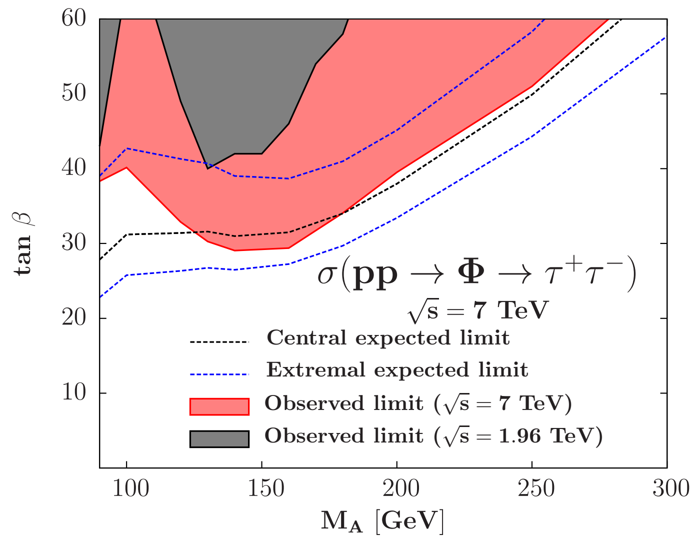
Arbey, Battaglia, Mahmoudi, arXiv:1110.3726

Impact of heavy Higgs search

- Search for pp-H-> ττ in CMS and ATLAS
- Production gg->H (through b loops) and bbH
- Strong enhancement for MSSM heavy doublet at large values of tanβ



- Theoretical uncertainties
  - Baglio, Djouadi, arXiv:1103.6247
  - At a given luminosity weakens the limit on tanβ

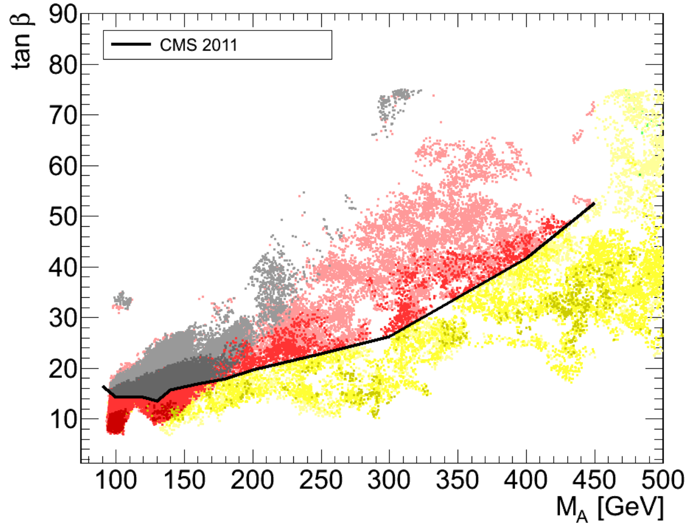


Impact of heavy Higgs search

- One example, MSSM with light neutralino DM (<30GeV)
- Possible only for non-universal gaugino mass
- Annihilation of LSP pairs:
  – through $\chi\chi \rightarrow A \rightarrow bb$
  – into fermion pairs through sfermion exchange (stau)
  – Both require particular conditions on spectrum.
- Consider Higgs case, for annihilation in early universe to be efficient m_A should be light and coupling large - $\tan\beta$ enhanced (not possible to have resonance effect)
- These scenarios constrained by heavy Higgs searches

Higgs in MSSM(2)

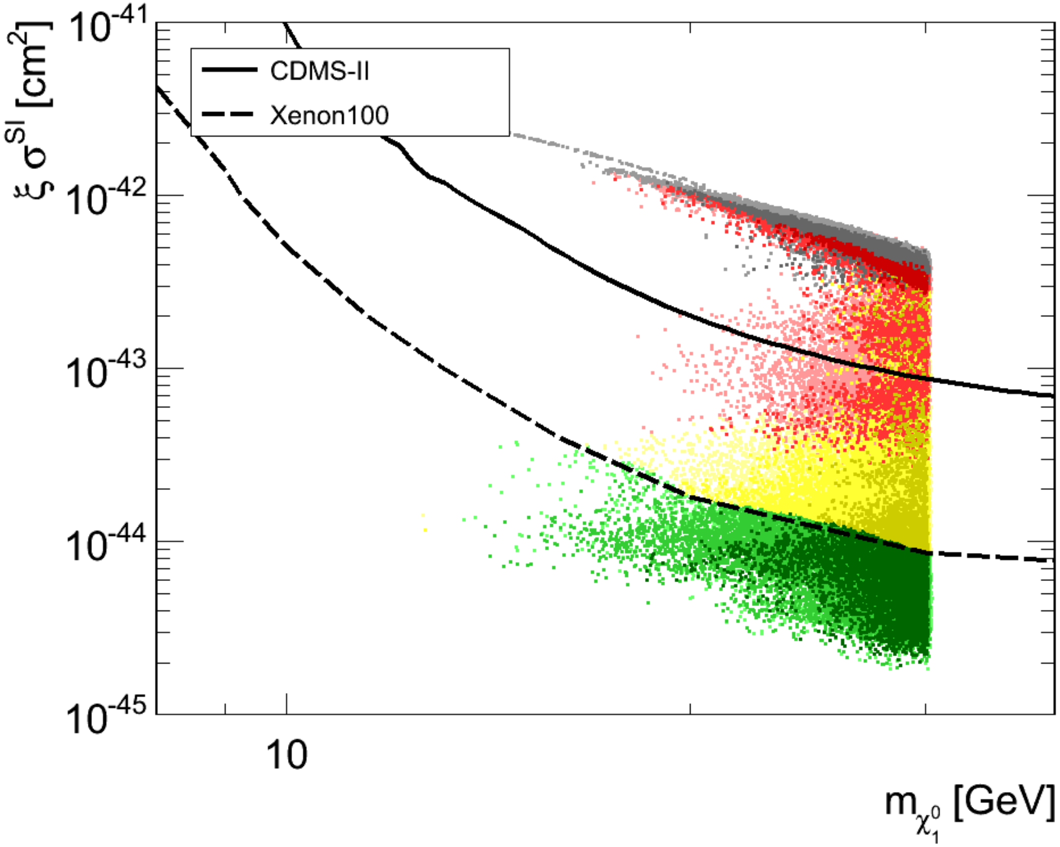
- Scan of MSSM focus on light neutralino (<30GeV)
  - 11 free parameters
  - $M_1, M_2, M_3, \mu, \tan\beta, M_A, A_t, M_{lL}, M_{lR}, M_{q1}, M_{q3}$
  - MCMC approach
  - Higgs searches ($36 pb^{-1}$) (HiggsBounds)
  - Flavour physics
  - DM observables
- Pseudoscalar search major impact on allowed points



Albornoz Vasquez, GB, Boehm, arXiv:1108.1338

Light neutralino and A/H

- All light neutralino scenarios with large direct detection cross section constrained from negative Higgs searches + other astrophysical constraints



Invisible Higgs in BSM

- Many BSM models have significant $Br_{inv,}$ in particular models with light DM
  - MSSM with non-universal gaugino masses (as shown previously)
  - NMSSM
  - MSSM+sneutrino with large L/R mixing
  - UMSSM
  - Extended scalar sector
  - Little Higgs model

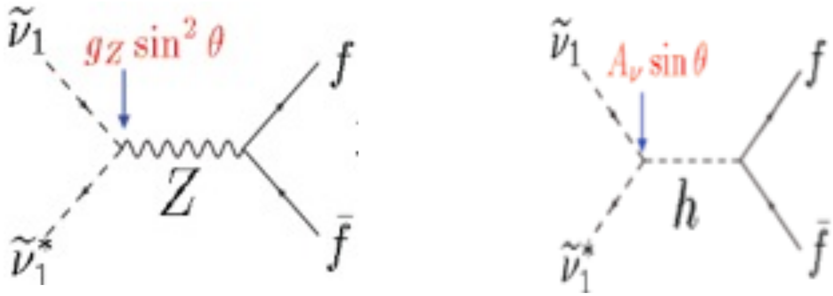
- In general invisible mode significant only in corner of parameter space due to kinematics
- DM 10GeV motivated by hints in direct detection experiments - whether or not these are confirmed, important to consider invisible mode
- Some models also have new decay modes for the Higgs, best example NMSSM with new singlet higgses, higgs to higss decays

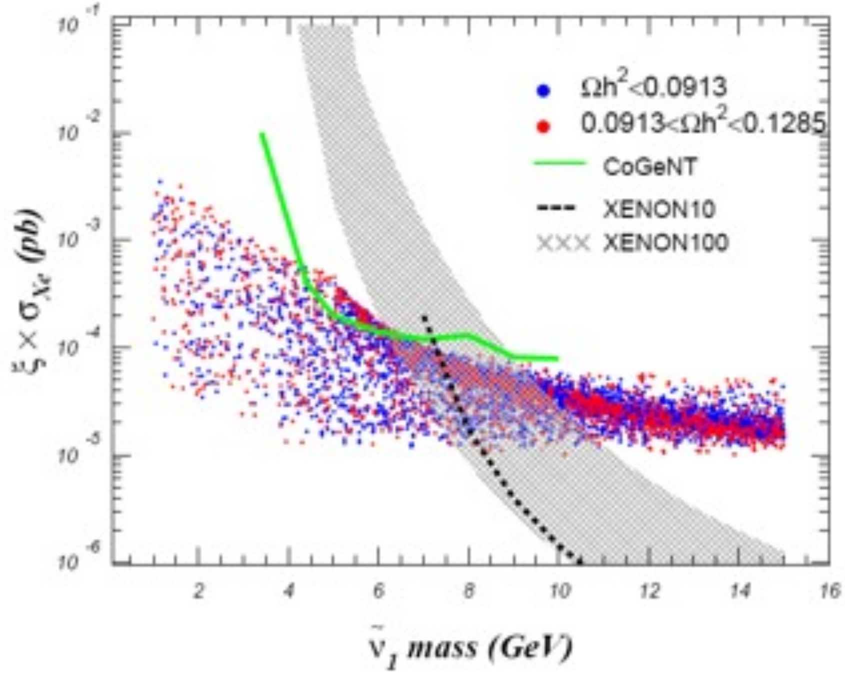
$$h \to A_1 A_1 \to 4\,\tau$$

  - Ellwanger et al, Phys. Rep. 486(2010)1

Example: sneutrino DM

- Extension of MSSM with RH neutrino+ sneutrino
    - Arkani-Hamed et al hep-ph/0006312
- Large L/R mixing makes sneutrino good DM candidate
- Annihilation



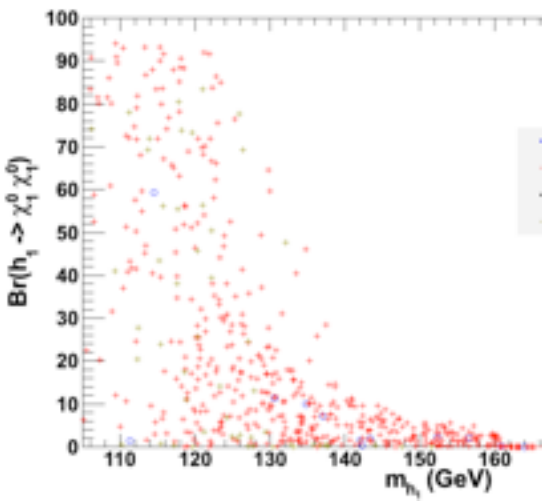


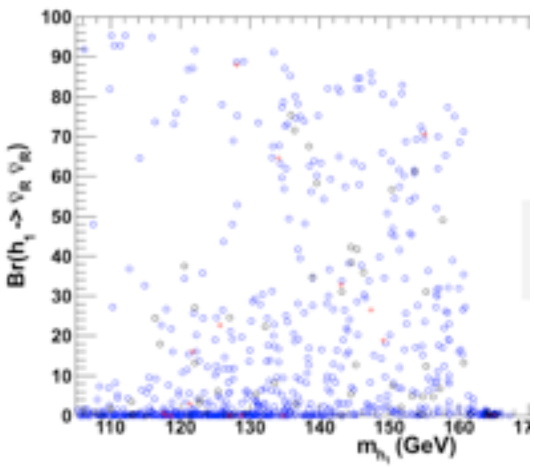
GB, Kakizaki, Kraml, Park,Pukhov JCAP 1011(2010)017

- Sneutrino couples to Higgs, if light nearly 100% Br_{inv}

Example 2: UMSSM

- MSSM with extended gauge symmetry U(1)
- Higgs sector h_1,h_2,h_3,A,H
- Scale of new gauge boson Z' >1.3-1.7TeV (depend on couplings)
- Light Higgs can be heavier than MSSM, SM-like WWh_1 coupling
- When LSP (neutralino or sneutrinoR) light , h-> inv





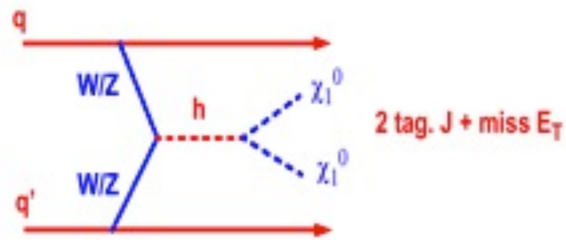
J. DaSilva, GB, in prep

Invisible Higgs at LHC

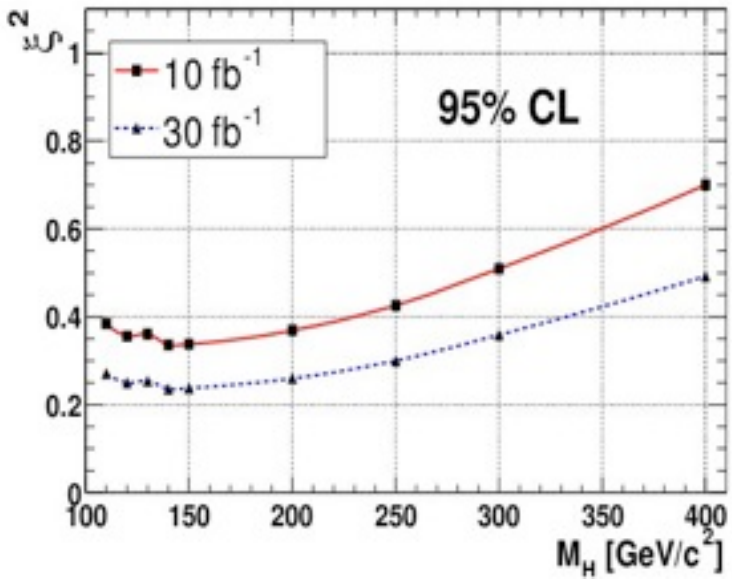
- Invisible decays --> reduction in all visible channels

- Search for invisible Higgs at LHC, important to complement visible channels and probe models with large invisible width
  - Vector boson fusion
    - Cavalli et al, Les Houches
    - hep-ph/ 0203056

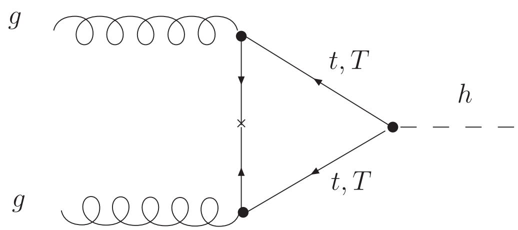
  - Associated production with t quarks
    - Gunion, PRL72(94)199
  - Assoc. production with gauge bosons
    - ZH-> dilepton + missing E_t
    - sensitive to Br_{inv}>.42 for m_h=120 at LHC14 ($100fb^{-1}$)
    - Godbole et al, hep-ph/030413



$$\xi^2 = \frac{\sigma(\mathrm{Hjj})}{\sigma(\mathrm{Hjj})_{SM}} \times \mathrm{Br}(\mathrm{H} \to \mathrm{inv})$$



BSM Higgs



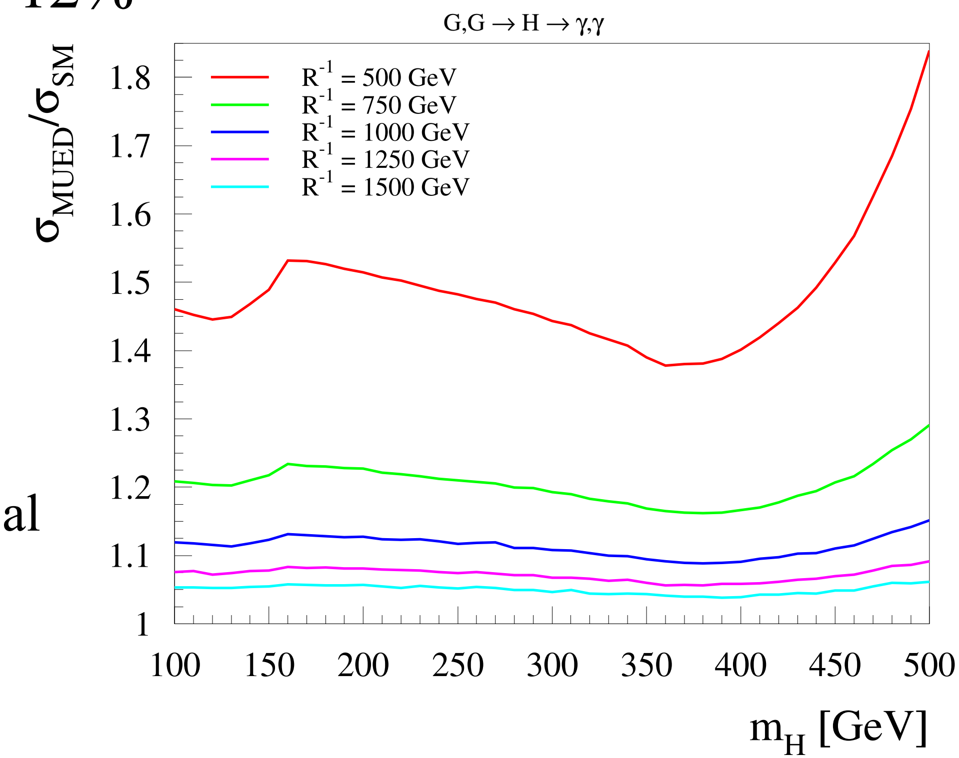
- New quark in the loop, contribution same sign as top, leads to increase in hgg
- Contribution also to hγγ, lead to small decrease (W contribution dominant)
- Found in many BSM
  - Warped extra dimension model
    - Djouadi, Moreau, hep-ph 0707.3800
  - UED models (5D and 6D)
  - ...... see G. Cacciapaglia et al 0901.0927
  - UED 6D - Nishiwaki et al, 1108.1764

Higgs in UED

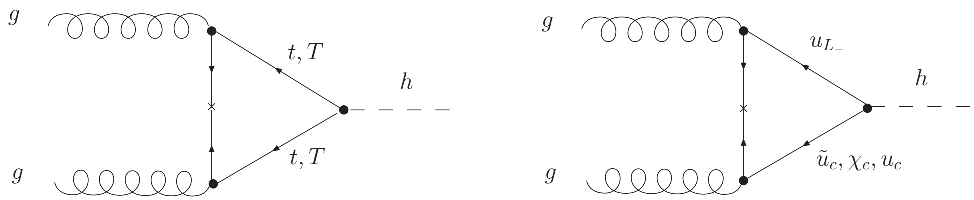
- KK top quarks contribution to ggh same sign as top -> increase in hgg width
- m_{KK}<500 GeV -> constrained by Higgs search with 1.7fb^{-1} if m_h~125GeV (similar to indirect limits)
- m_{KK}~1TeV -> γγ increase ~12%

mUED

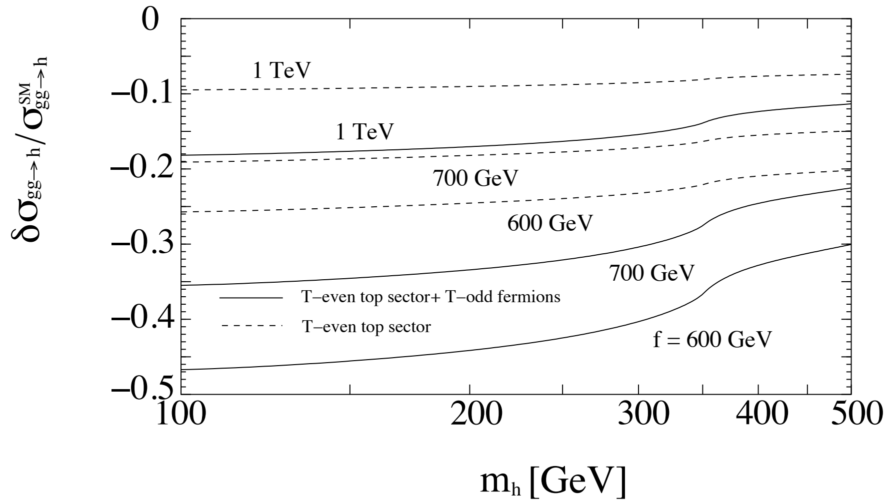
M. Brown, A. Belyaev et al



Little Higgs



- T-parity
- New T-even and T-odd fermions
- T-odd fermions: contribution opposite sign as top quark
- Significant decrease in ggh (20% for f=1TeV)
- Littlest Higgs model also allows for invisible width, H-> $A_H A_H$ significant only f~500GeV
  - Hundi et al hep-ph/0611116



Chen, Tobe, Yuan, hep-ph/0602211

Conclusion

- In BSM, Higgs signal can be enhanced or reduced relative to SM - channel dependent
- Need exclusion in each channel independently
- SUSY Higgs not probed with $1.7 fb^{-1}$ except in the $m_A/\tan\beta$ plane
- Search for Invisible Higgs important to cover all scenarios