Invisible Higgs and dark matter

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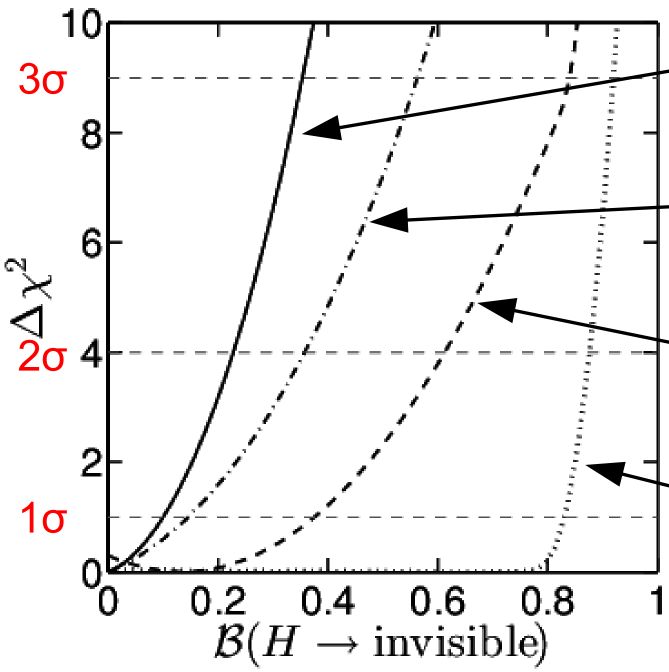
- Invisible Higgs decay constrain DM models with $M_{DM}<m_h/2$
- Strong link with direct detection
- Model independent: Scalar/fermion/vector
- Models : MSSM/NMSSM

Constraints on Br(H_{inv})

- From general fits (GB, Dumont, Elwanger, Gunion, Kraml,1302.5694)



SM+invisible
$\mathcal{B}(H \to \text{inv.}) < 0.23$ at 95% CL

SM+(C_U>0)+(C_D>0)+(C_V<1)+invisible
$\mathcal{B}(H \to \text{inv.}) < 0.36$ at 95% CL

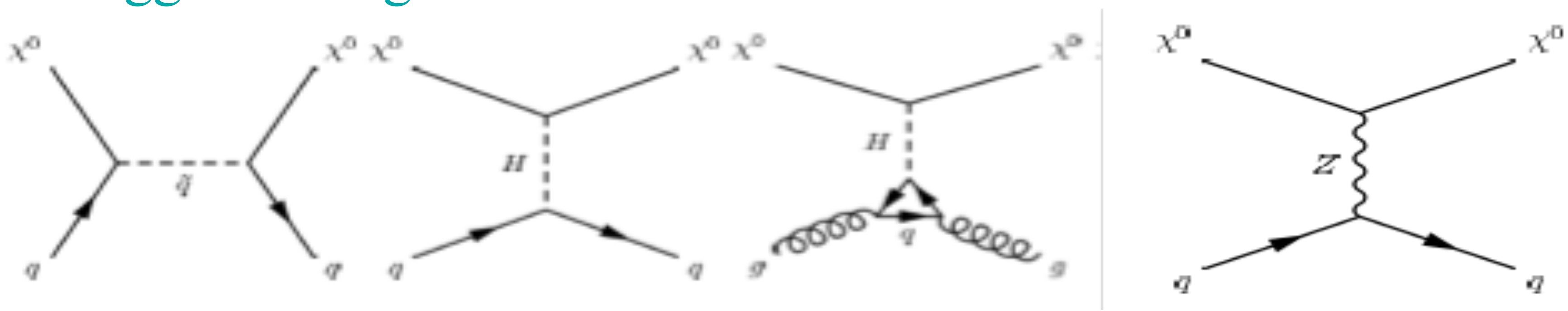
SM+ΔC_g+ΔC_γ+invisible
$\mathcal{B}(H \to \text{inv.}) < 0.61$ at 95% CL

SM+C_U+C_D+C_V+invisible
$\mathcal{B}(H \to \text{inv.}) < 0.88$ at 95% CL

- From direct searches (see Kirtimaan's)

Direct detection

- Higgs exchange often dominates



For Dirac fermions Z exchange contributes to SI and SD

- Both Invisible branching of Higgs and spin-independent cross -section depend on hχχ coupling squared

Invisible Higgs and direct detection

- For light DM particle, relation between invisible width and direct detection

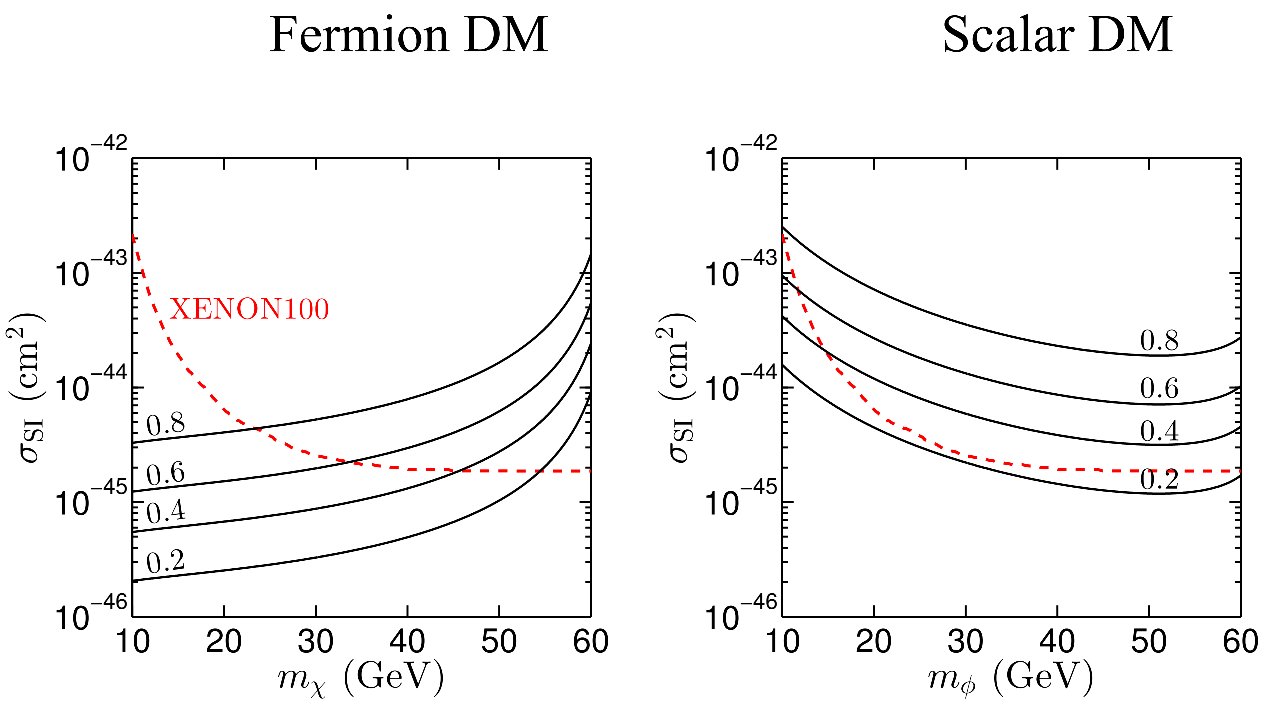
$$\sigma_{\rm SI} = \eta \mu_r^2 m_p^2 \frac{g^2}{M_W^2} \Gamma_{\rm inv} \left[C_U(f_u^N + f_c^N + f_t^N) + C_D(f_d^N + f_s^N + f_b^N) + \frac{\Delta C_g}{\widehat{C}_g} f_g^N \right]^2$$

- Majorana fermion

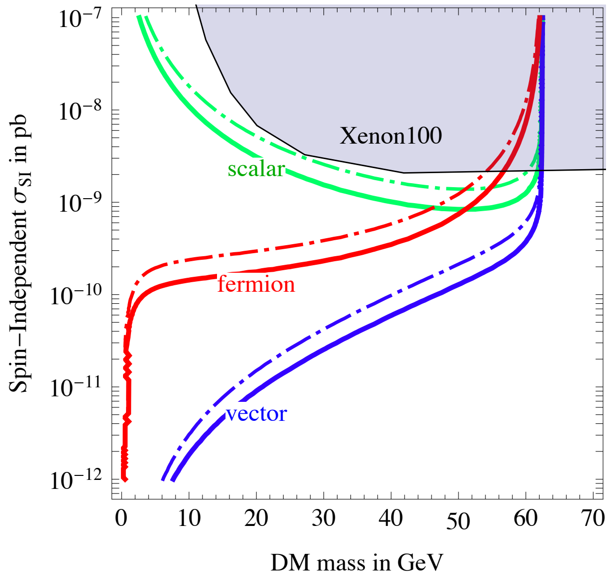
$$\eta = 4/(m_H^5 \beta^3)$$

- Real scalar

$$\eta = 2/(m_H^3 m_\phi^2 \beta)$$



- Fermions : for light DM - Higgs invisible much stronger constraint than DD
- Scalar - DD strong constraint on Br_{inv} except for very small masses



Br_{inv}=0.19-0.28
Giardino et al, arXiv 1303.3570

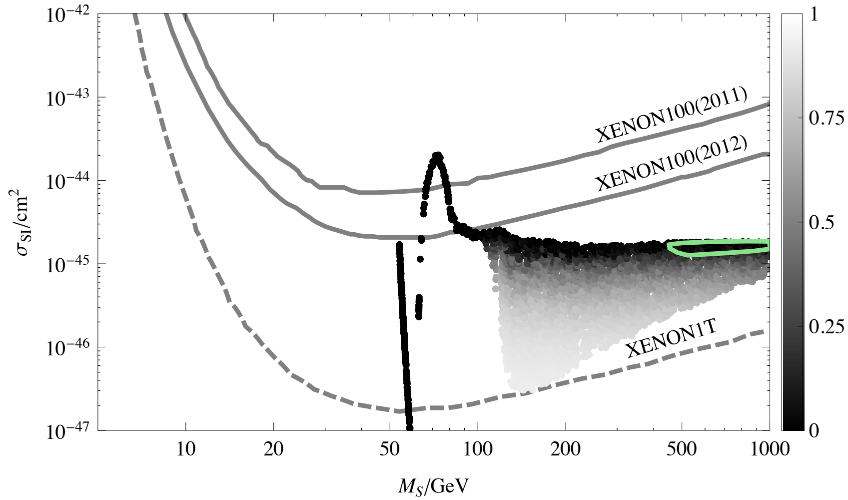
See also Djouadi et al, 1205.3169

$$\sigma_{\rm SI} = \eta \mu_r^2 m_p^2 \frac{g^2}{M_W^2}\,\Gamma_{\rm inv}\left[C_U(f_u^N + f_c^N + f_t^N) + C_D(f_d^N + f_s^N + f_b^N) + \frac{\Delta C_g}{\widehat{C}_g} f_g^N\right]^2$$

- Non-standard Higgs couplings
  - potential cancellation ($C_U<0$, $C_D>0$) - at first sight relax direct detection bound
  - however need to generate fermion mass - other Higgs should couple to fermion - give contribution to direct detection
- Direct detection can involve other particles
  - coloured particles (e.g. squarks in SUSY) contribution suppressed by mass scale
  - other Higgses

Specific models

- Take into account various constraints, in particular relic density
  - light DM need efficient annihilation mechanism
  - through Z, Higgs, new particles
  - Example: Scalar dark matter



SM+scalar singlet, Z_3
$Br_{inv}<0.4$
GB et al, 1211.1014

See also Djouadi et al , 1112.3299

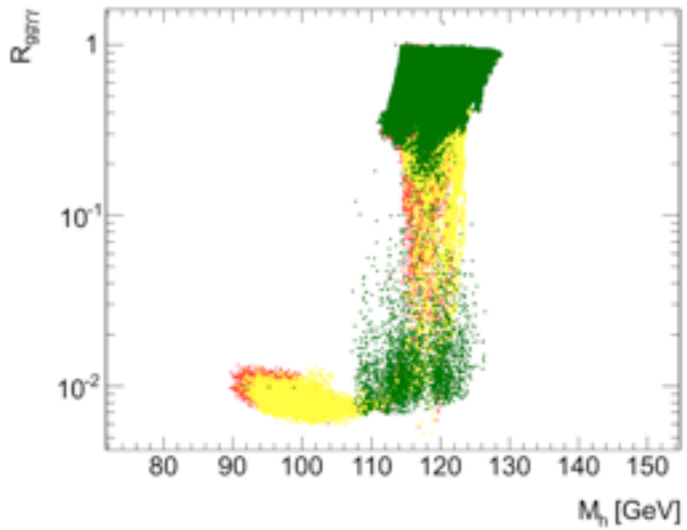
What about MSSM?

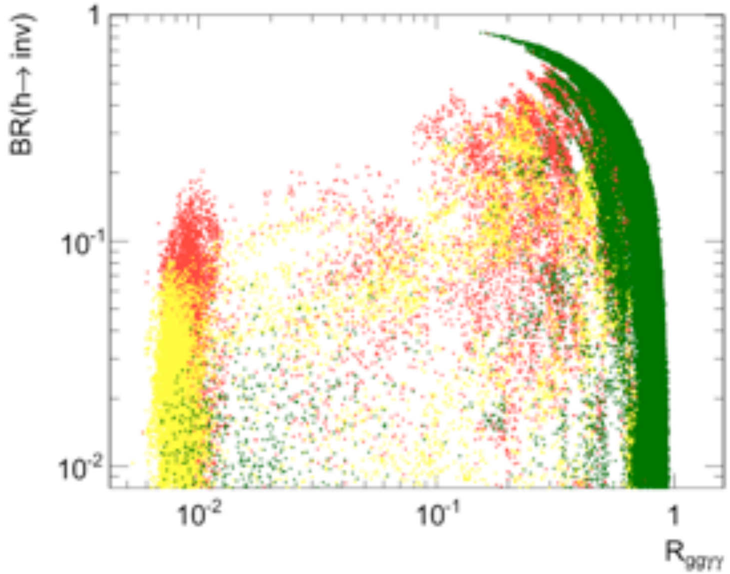
- Higgs coupling to neutralinos

$$C_{h\tilde{\chi}_1^0\tilde{\chi}_1^0} \quad = \quad (O_{12}^N - \tan\theta_W O_{11}^N)(\sin\alpha\, O_{13}^N \; + \; \cos\alpha\, O_{14}^N)$$

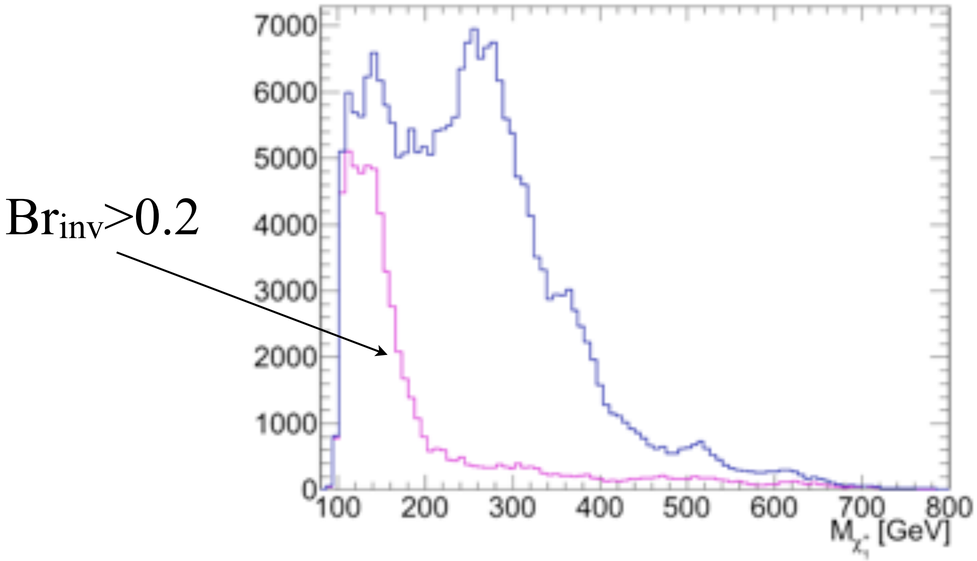
- Significant coupling for mixed bino/Higgsino LSP - μ small
- Light LSP must have sufficient annihilation for Ωh^2 ~0.1
  - through Higgs exchange --- mixed bino-higgsino
  - Z exchange -- higgsino component (O_{13}^2-O_{14}^2)
  - into fermions through stau exchange - bino

Results before LHC-Higgs discovery





- Scan in MSSM-11 (Albornoz Vasquez et al, 1112.2200)
- Taking into account m_h~125 + Higgs couplings, + Xenon limits + relic density, what are predictions for Br_{inv}?

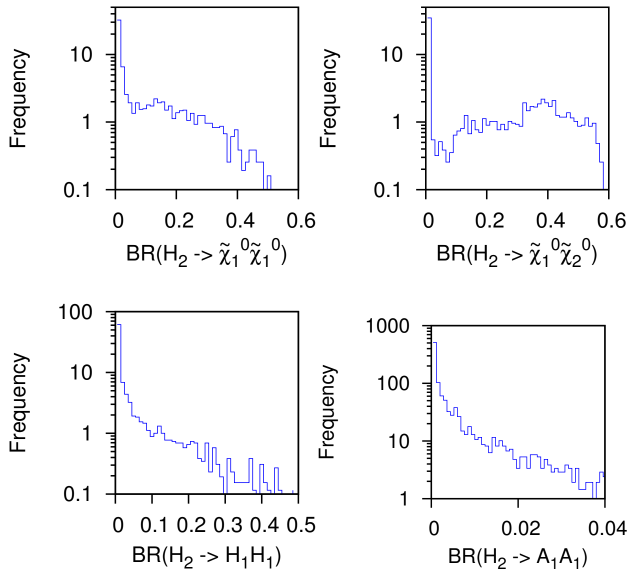


- Large Br_{inv} - associate with light chargino (small μ) - see also Dreiner, Kim, Lebedev, 1206.3096

NMSSM

- Additional light Higgses can contribute to annihilation of light neutralino, direct detection
- Both 'invisible and undetected' decays
- Destroy simple relation Br_{inv}--direct detection
- Important to search new Higgs decay channels AND H_{inv}

NMSSM with 14 parameters
with light neutralino
and DM constraints
arXiv:1203.3446



122<mh<128

Summary

- Constraints on invisible Higgs - limits on light DM
- Correlation invisible Higgs direct detection
- Remains to be seen : what is still allowed in specific models such as MSSM, NMSSM ...