
LHC and Higgs Portal Dark Matter

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The Higgs key to the hidden sector

Motivation :

- ✓ $E_8 \times E_8$ strings
observable hidden
- ✓ dark matter
- ✓ ...

Special role of the Higgs :

Silveira, Zee '85
Foot, Lew, Volkas '91
...

$|H|^2$ = the only gauge and Lorentz-inv. dim-2 operator

$$L = a |H|^2 S^2 + b |H|^2 S$$

(S = "hidden" scalar)

$b=0$ (S has hidden charge):

$$L = a |H|^2 S^2$$

" S " is stable and couples weakly to SM --> **DARK MATTER (?)**

Vector Higgs portal:

OL, Lee, Mambrini '11

$$L = a |H|^2 V_\mu V^\mu + b (\bar{H} i D_\mu H V^\mu + \text{h.c.})$$

(V_μ = "hidden" vector)

$b=0$ ($V^\mu \leftrightarrow -V^\mu$ symmetry):

$$L = a |H|^2 V_\mu V^\mu$$

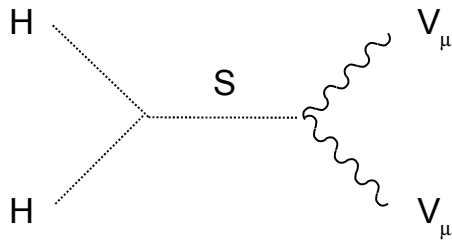
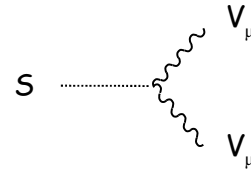
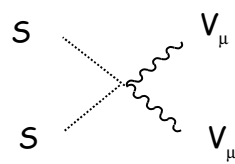


$$V^\mu = DM (?)$$

Higgs mechanism in the hidden sector :

$$L = -1/4 F_{\mu\nu} F^{\mu\nu} + D_{\mu} S^* D^{\mu} S - V(S) + \lambda/4 H^* H S^* S$$

$S \longrightarrow \text{VEV}$



$H^* H V_{\mu} V^{\mu}$ vertex

(Z_2 parity)

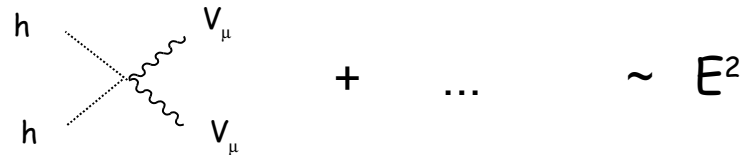
Unitarity:

$$L = \frac{1}{4} \lambda |H|^2 V_\mu V^\mu + \frac{1}{2} m^2 V_\mu V^\mu$$

Physical mass :

$$m_V^2 = m^2 + \frac{1}{2} \lambda v^2$$

Cutoff :



$$+ \dots \sim E^2$$

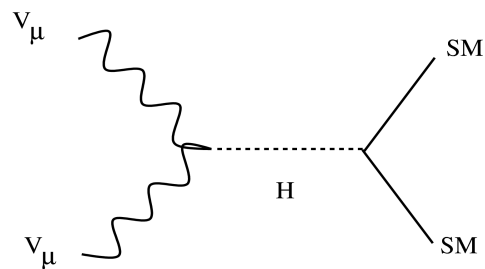
$$E \sim m_V^2 / m$$

$$(\cdot \sqrt{16\pi / \lambda})$$

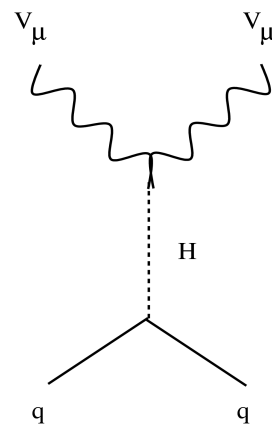
Dark matter constraints

DM-nucleon scattering

annihilation

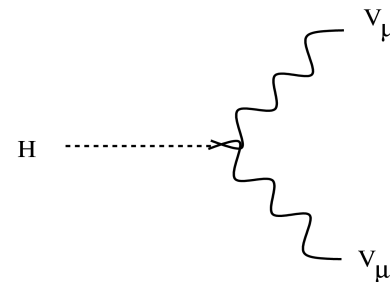


$$\langle \sigma v \rangle$$



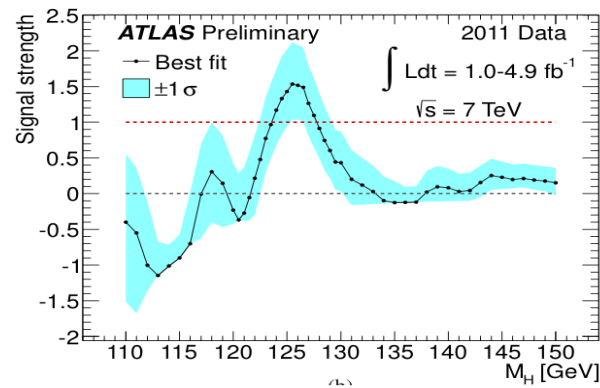
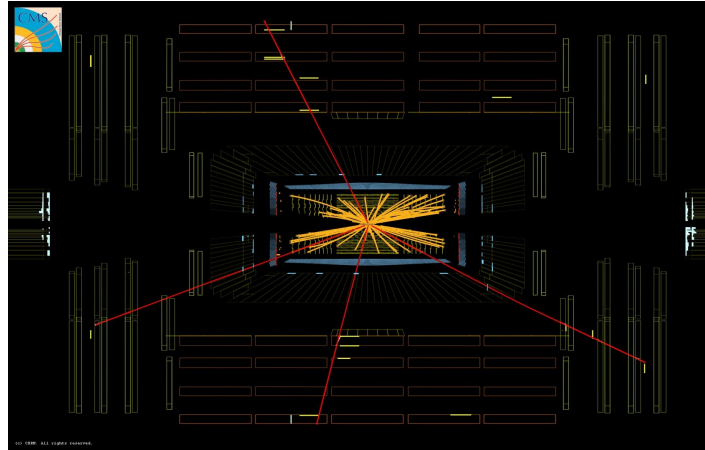
$$\sigma_{S-P}^{SI}$$

invisible Higgs decay



$$\Gamma_H^{inv}$$

First glimpse of the Higgs :

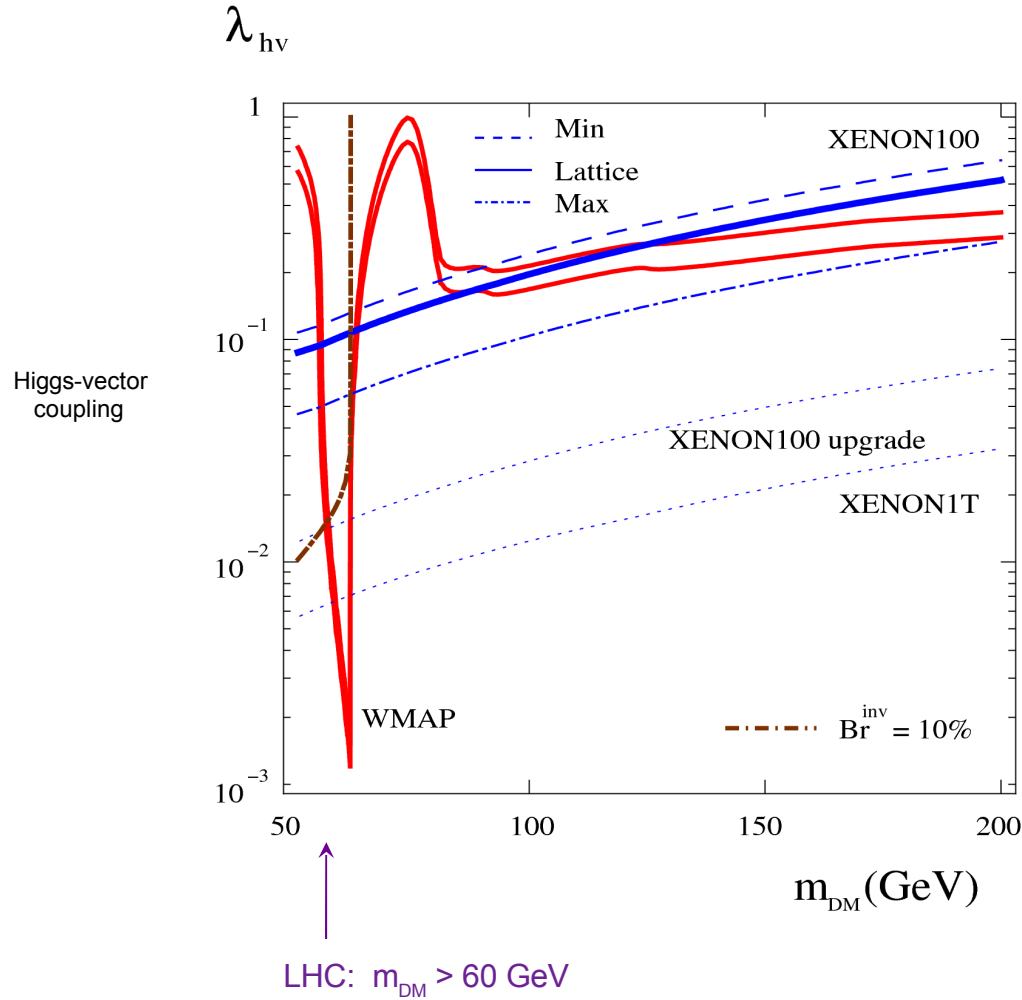


$m_h \sim 125 \text{ GeV} (?)$

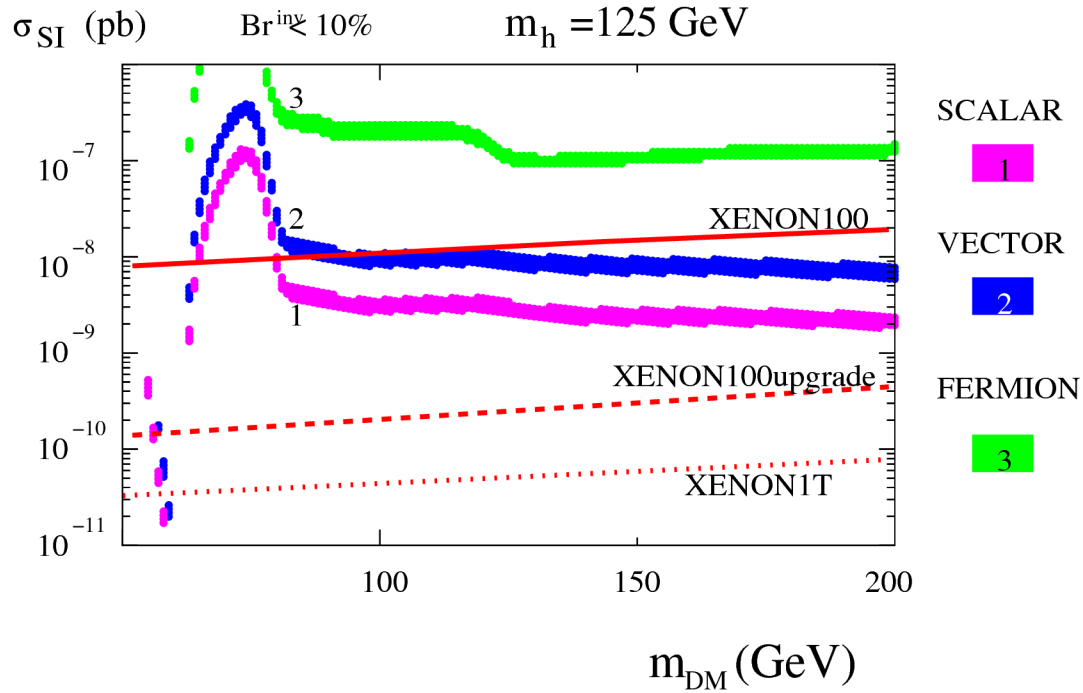
Constraints :

WMAP: annihilation cross section
XENON : DM-nucleon interaction
LHC : invisible Higgs decay

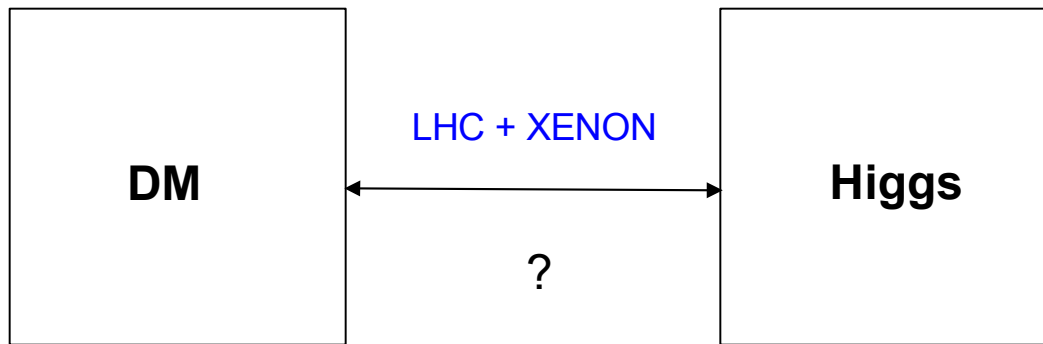
Djouadi, OL, Mambrini, Quevillon '11
OL , Lee , Mambrini '11



Prediction :



DM direct detection with $\sigma \sim 10^{-8} - 10^{-9}$ pb



More generally :

$$L = c |H|^2 S^2$$



(S has a VEV)

$$\left\{ \begin{array}{l} H_1 = H \cos \theta + S \sin \theta \\ H_2 = H \sin \theta - S \cos \theta \end{array} \right.$$

If $\langle S \rangle \gg 246 \text{ GeV}$,

$$\left\{ \begin{array}{l} \theta \rightarrow 0 \\ m_h^2 = 2 v^2 [\lambda_h - \lambda_{hs}^2 / (4\lambda_s)] \end{array} \right.$$

OL '12
Elias-Miro et al. '12

Need to measure the Higgs self-coupling !

Conclusion

- Higgs sector is special
- vector/scalar Higgs-portal DM
- constrained by LHC , $m_{DM} > 60 \text{ GeV}$
- need Γ_{inv} , λ_h , ...