Dark Matter through the Higgs Portal

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Outline :

- Higgs key to the hidden sector
- Higgs portal DM
- LHC constraints
- Vacuum stabilization

The Higgs key to the hidden sector

Motivation :

✓ E_8 X 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

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

(V_μ = "hidden" vector)

b=0 (V^μ <--> $-V^\mu$ symmetry):

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

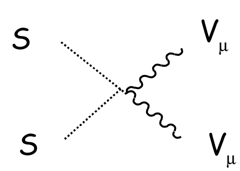
⇓

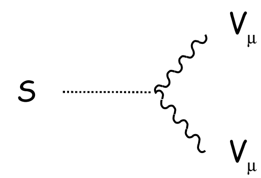
V^μ = DM (?)

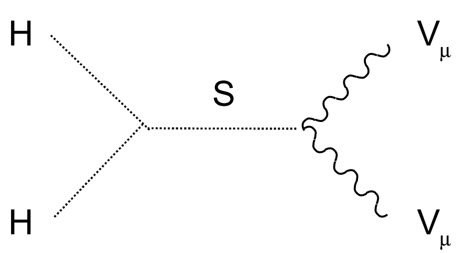
Higgs mechanism in the hidden sector :

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

$$S \longrightarrow VEV$$







$\Rightarrow$ $H^*H\, V_\mu V^\mu$ vertex

(Z_2 parity)

gauge invariance (+ minimal field content)

⇓

Z_2

OL, Lee, Mambrini '11

Stueckelberg DM :

$$L = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2} m^2 V_\mu V^\mu$$

Here : $V_\nu \equiv V'_\nu + 1/\mu \; \partial_\nu \phi$

Gauge transform:
$$\begin{cases} \delta V'_\nu = \partial_\nu \varepsilon \\ \delta \phi = -\mu \varepsilon \end{cases}$$

In general : $m^2 = \mu^2 (1 + c H^* H + \ldots)$

⇨ $H^* H V_\mu V^\mu$ coupling

OL, Lee, Mambrini '11

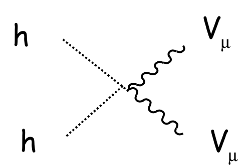
Unitarity:

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

Physical mass :

$$m^2_V = m^2 + \tfrac{1}{2}\lambda v^2$$

Cutoff :



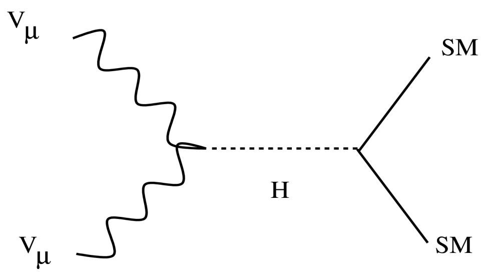
$$+ \quad \ldots \qquad \sim \; E^2$$

$$\boxed{E \sim m^2_V / m}$$

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

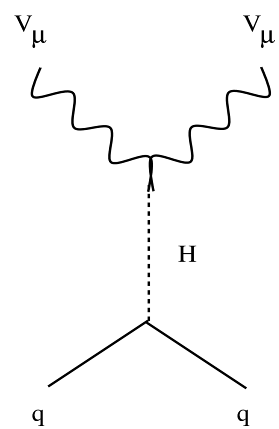
Dark matter constraints

annihilation



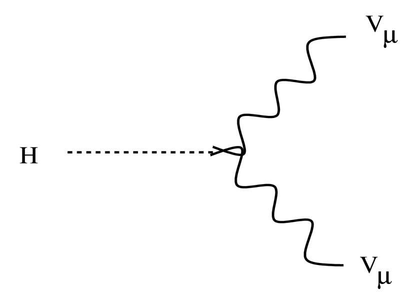
$< \sigma v >$

DM-nucleon scattering



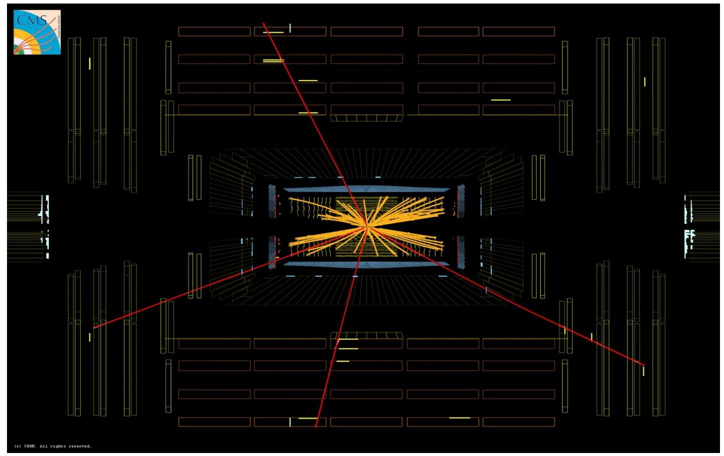
σ^{SI}_{S-P}

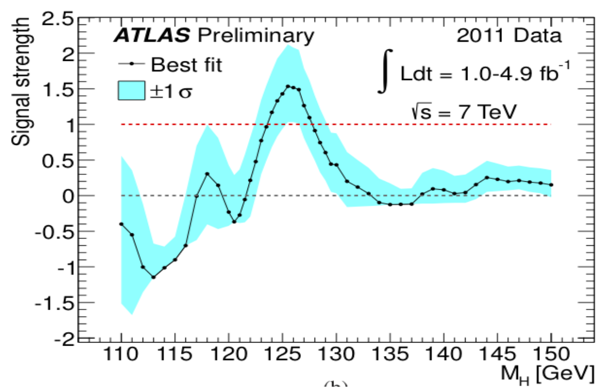
invisible Higgs decay



Γ_H^{inv}

First glimpse of the Higgs :

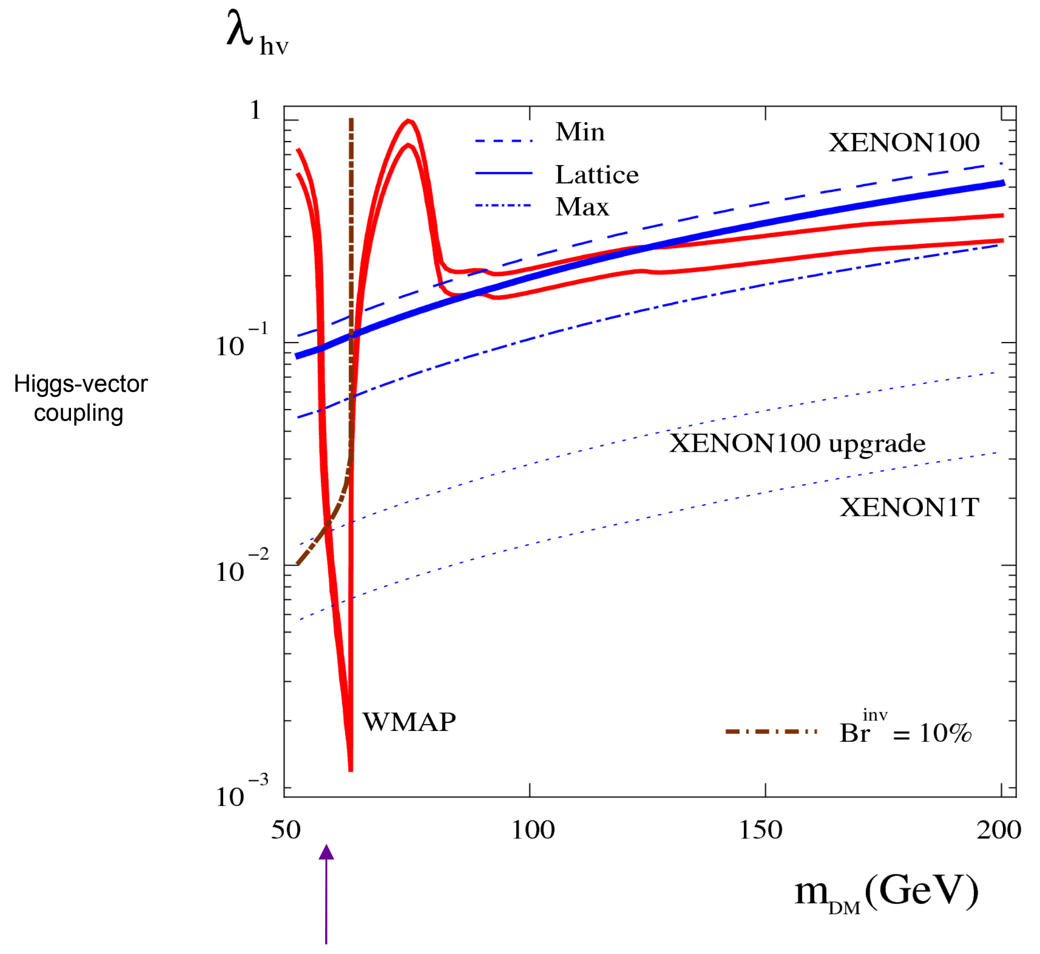




$m_h \sim 125$ GeV (?)

Constraints :

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



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

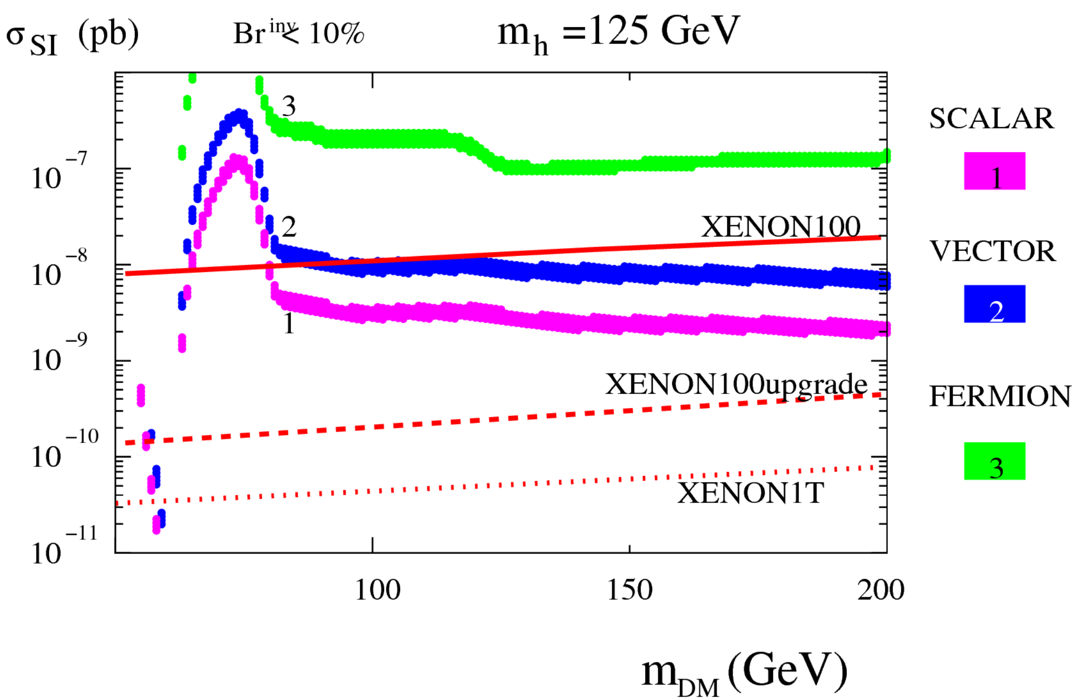
LHC: m_{DM} > 60 GeV

Scalar vs Vector DM :

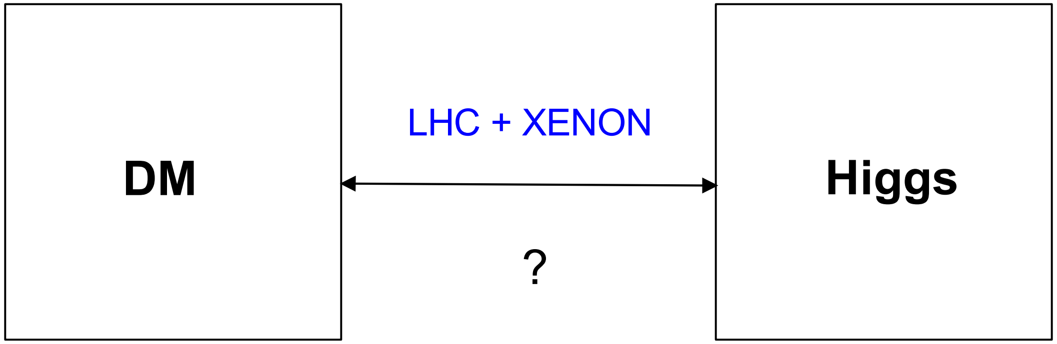
annihilation :	$g^2_{vector} = 3\, g^2_{scalar}$	(3 species)
direct detection :	same	(Higgs exchange)
Higgs decay :	$\Gamma_{vector} \sim \; m_h^4 / m_V^4 \;\; \Gamma_{scalar}$	(Goldstone production)

Prediction :

Djouadi, OL , Mambrini , Quevillon '11



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


DM
LHC + XENON
?
Higgs

A more general case :

Schabinger, Wells '05
Patt, Wilczek '06

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

⇓ (S has a VEV)

$$\begin{cases} H_1 = H\cos\theta + S\sin\theta \\ H_2 = H\sin\theta - S\cos\theta \end{cases}$$

two Higgs-like states , rate reduction

OL '12
Elias-Miro et al. '12

If $\langle S \rangle \gg$ 246 GeV ,

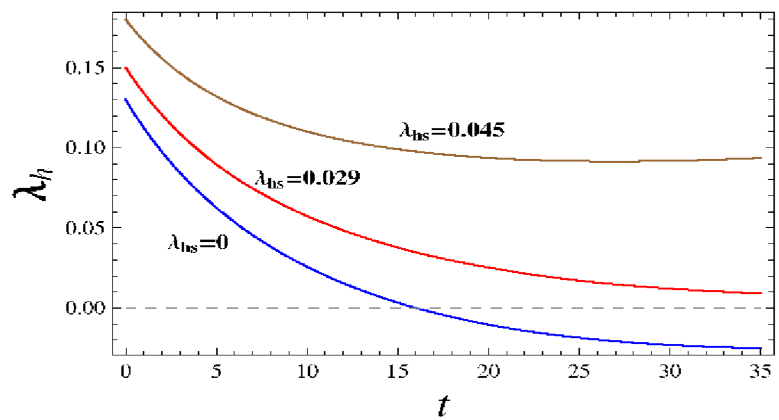
$\theta \to 0$ (SM—like Higgs)

$m_h^2 = 2 v^2 [\lambda_h - \lambda^2_{hs}/(4\lambda_s)]$

Degrassi et al.'12

Stability bound: $m_h >$ 126 GeV at 98% CL

Singlet tree level effect :

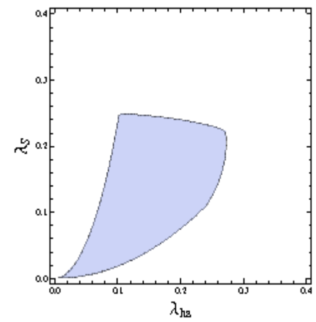


$t = \ln(\mu/m_t)$

a (very) weakly coupled singlet can make the EW vacuum stable

⇓

- favored by cosmology
- Higgs inflation
- ...



Conclusion

- Higgs sector is special
- vector/scalar Higgs-portal DM
- constrained by LHC , $m_{DM} > 60$ GeV
- vacuum stabilization